Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Sicopong River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of San Carlos

APRIL 2017

Published by the UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines – Diliman
Quezon City
1101 PHILIPPINES

This research project is supported by the Department of Science and Technology (DOST) as part of its Grants-in-Aid Program and is to be cited as:

E. C. Paringit and R. S. Otadoy (eds.) (2017), LiDAR Surveys and Flood Mapping of Sicopong River, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry-152pp.

For questions/queries regarding this report, contact:

Dr. Roland Emerito S. Otadoy
Project Leader, Phil-LiDAR 1 Program
University of San Carlos
Cebu City, Philippines 6000
E-mail: rolandotadoy2012@gmail.com

Enrico C. Paringit, Dr. Eng.
Program Leader, Phil-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

National Library of the Philippines
ISBN: 978-621-430-189-8

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]

IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
USC	University of San Carlos
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND SICOPONG RIVER

Enrico C. Paringit, Dr. Eng., Dr. Roland Otadoy, and Engr. Aure Flo Oraya

1.1 Background of the Phil-LIDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication entitled "FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et. al. 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the University of San Carlos (USC). USC is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 17 river basins in the Central Visayas Region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Sicopong River Basin

The Sicopong River Basin covers the municipalities of Pamplona, Santa Catalina, Tanjay City and Bayawan City Negros Oriental. The DENR River Basin Control Office identified the basin to have a drainage area of 308 km2 and an estimated 185 million cubic meter annual run-off (RBCO, 2015).

Its main stem, the Sicopong River, is located in the Province of Negros Oriental and passes along Bayawan City and the Municipality of Santa Catalina. Its head waters covers Tanjay City and Pamplona. The downstream part of the river acts as municipal boundary to Bayawan City and Sta Catalina. The Sicopong River is part of the seventeen (17) river systems in Central Visayas.

With regards to population, there is a total of 35,285 people residing within the immediate vicinity of the river, distributed among five (5) barangays in Bayawan City, namely: Narra, Cansumalig, San Isidro, Maninihon, and Villareal, and three (3) barangays in the Municipality of Santa Catalina, namely: Amio, Obat, and Caranoche (NSO, 2015). Sta Catalina is a 1st income class municipality with a population of 73,306 based on the 2010 census. Its topography is predominantly rolling hills, flat and steep terrain. Its industry is on agro-tourism and fishing. Bayawan City is a 2nd class component city with a population of 117,900 based on the 2015 census. The urban area is about 2.3% of the city's area and is the location of the main institutional, commercial and central business district. Industry in its sub-urban and rural areas are agricultural and agro-industrial. For the other communities within the river basin, as well as in the larger area of Negros Oriental, agriculture is the primary source of livelihood wherein sugarcane, corn, and coconut are the principal produce (Islands Web, 2015).

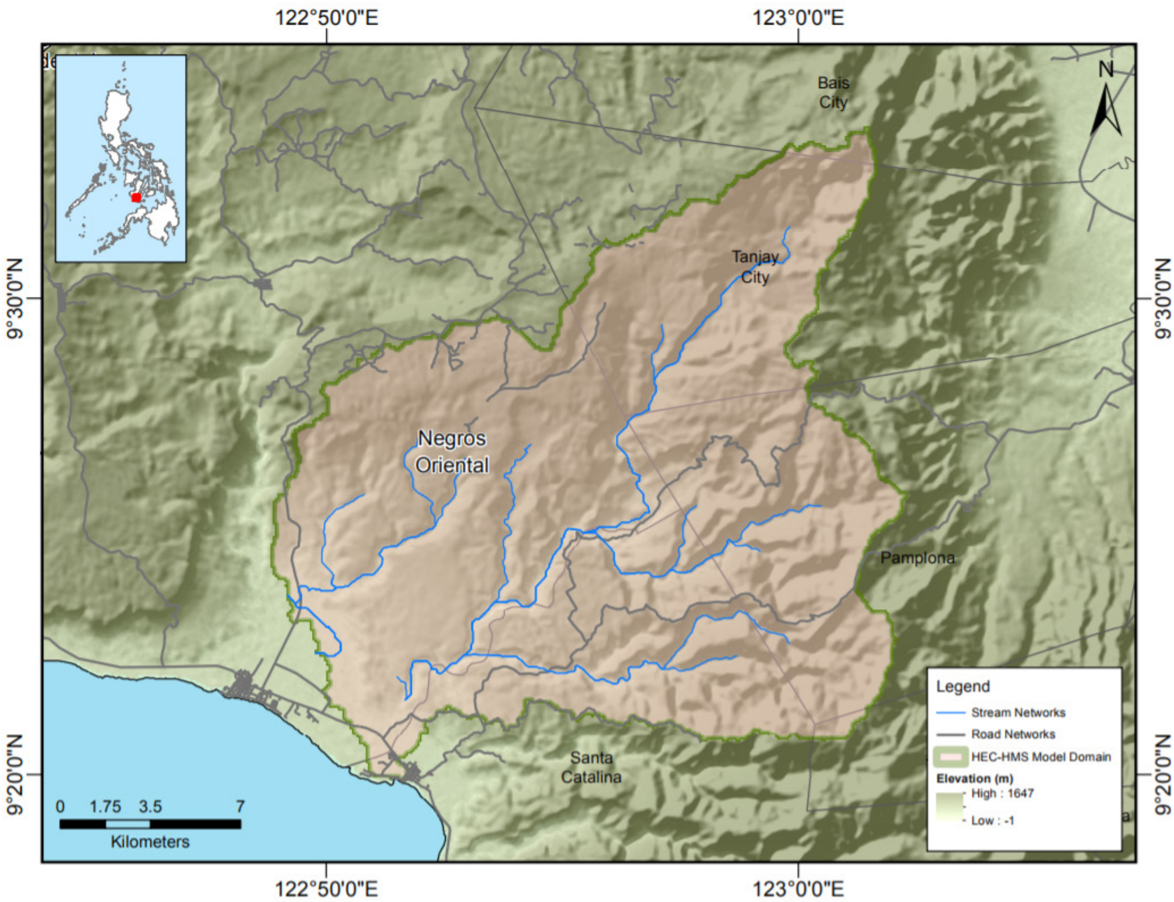


Figure 1. Map of Sicopong River Basin (in brown)

The weather in the area is classified under Type I weather in the Corona climate classification, wherein it has two pronounced seasons. It is dry from November to April and wet during the rest of the year. During the wet season, there is a large probability that typhoons pass through the Sicoping River Basin.

In fact, last December 2011, Typhoon Sendong internationally known as Washi brought massive property damages including 37 casualties and 200 injured. The Municipalities of Sibulan, Valencia, Pamplona, San Jose, Bacong, Amlan, Siaton, Dauin, San Jose and Tanjay City were the most affected during the event (The Negros Chronicle, 2011).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SICOPONG FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, For. Ma. Verlina Tonga, and Jasmine Alviar

The methods applied in this chapter were based on the DREAM methods manual (Sarmiento, et. al., 2014) and further enhanced and updated in Paringit, et. al. (2017).

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Sicopong Floodplain in Negros Oriental province. These missions were planned for 10 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are found in Table 1. Figure 2 shows the flight plans for Sicopong floodplain survey.

Table 1. Flight planning parameters for Gemini LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 53I	1000	30	40	100	50	130	5
BLK 53J	1000	30	40	100	50	130	5
BLK 53K	1000	30	40	100	50	130	5
BLK55A	1000	30	40	100	50	130	5

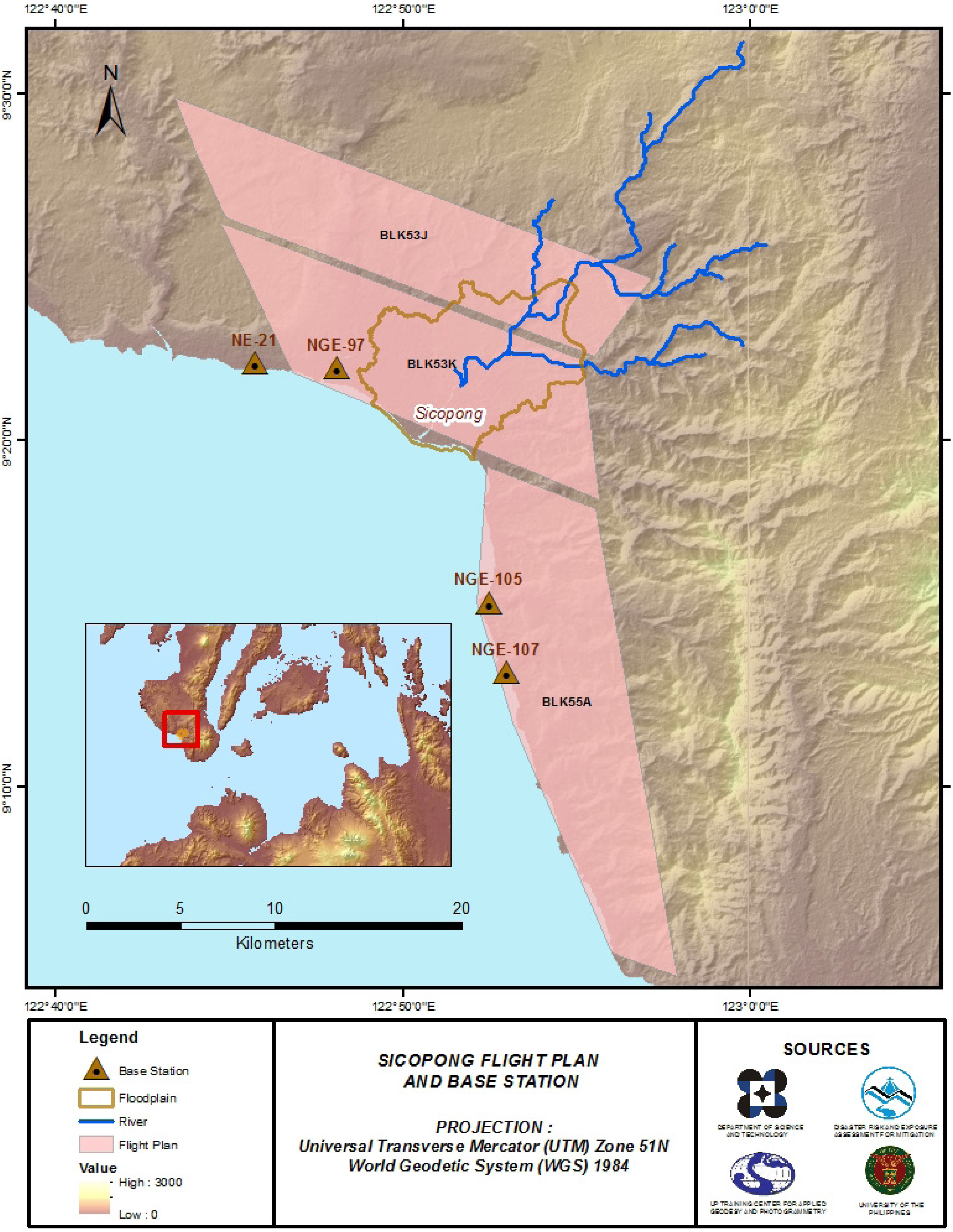
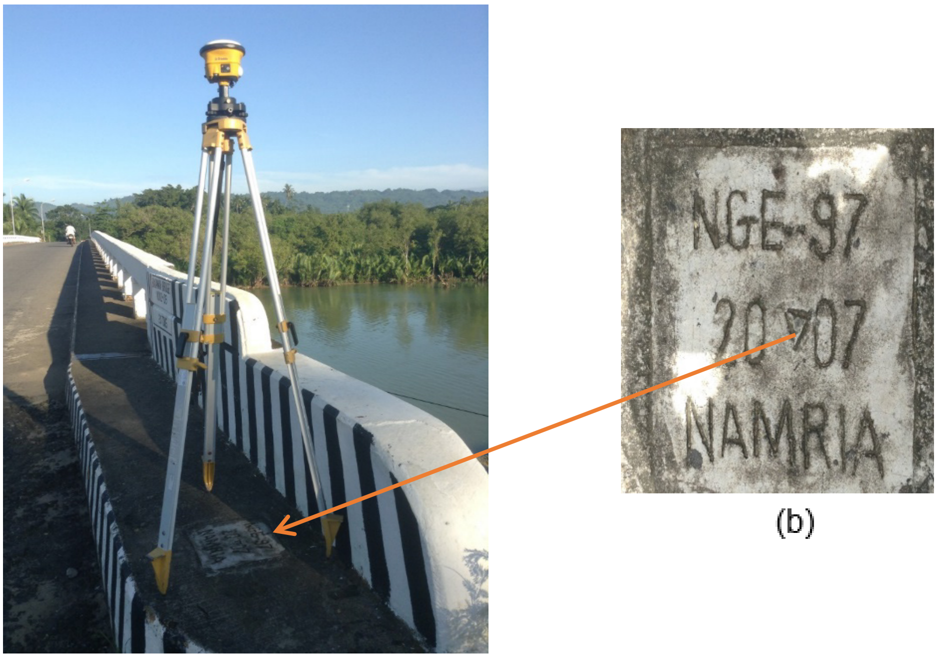


Figure 2. Flight plan and base stations used for Sicopong Floodplain.

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA horizontal ground control points of second (2nd) order accuracy, NGE-97, NGE-105 and NGE-107. One (1) NAMRIA benchmark was recovered, NE-21 which is of second (2nd) order accuracy. The benchmark was used as vertical reference point and was also established as ground control point. The certification for the base station is found in Annex 2 while the baseline processing reports for established ground control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (September 20 – October 15, 2014) especially on the days that flight missions were conducted. Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS 882 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Sicopong floodplain are shown in Figure 2. The list of LiDAR data acquisition team members are found in Annex 4.

Figure 3 to Figure 6 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 5 show the details about the following NAMRIA control stations and established points while Table 6 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.



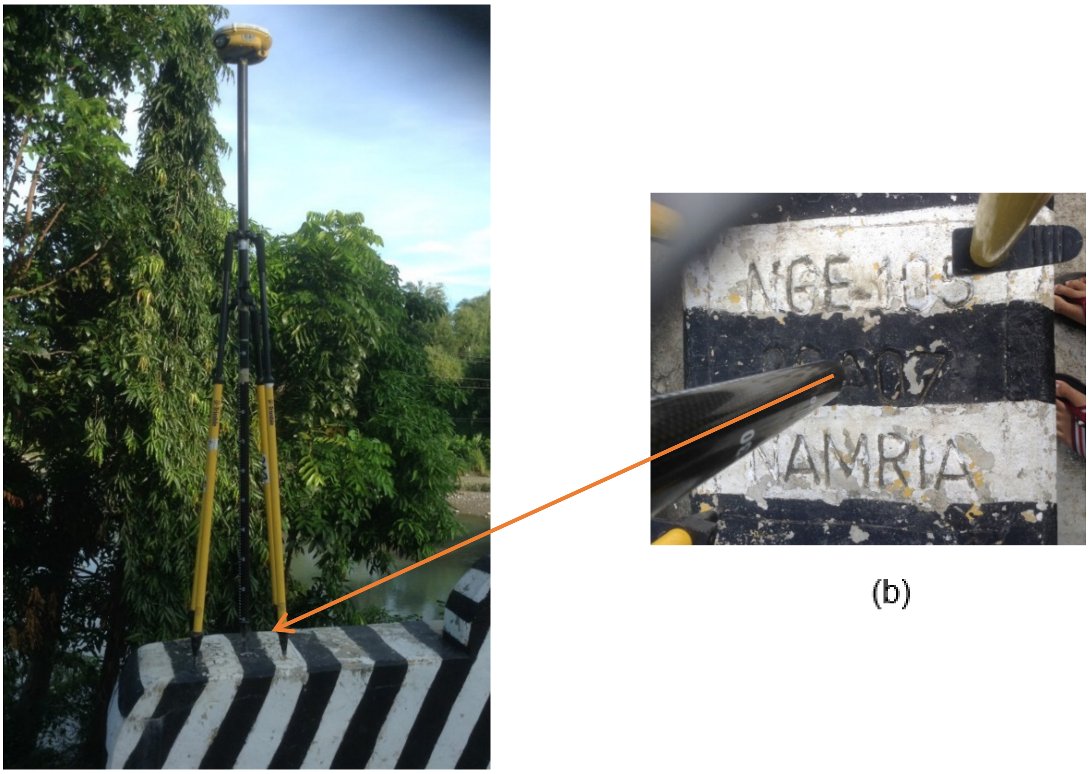
(a)

(b)

Figure 3. GPS set-up over NGE-97 on the SE corner concrete sidewalk of Sicopong Bridge in Barangay Suba under the municipality of Sicopong (a) and NAMRIA reference point NGE-97 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA reference point NGE-97 with processed coordinates used as base station for the LiDAR Acquisition.

Station Name	NGE-97	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°22'10.68255" North 122°48'1.35582" East 9.65300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	478073.348 meters 1035659.36 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°22'6.70304" North 122°48'6.69563" East 70.79700 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	478081.02 meters 1035659.36 meters



(a) (b)

Figure 4. GPS set-up over NGE-105 at top of the bridge wingwall SW of the Bridge main span on the left side of the 1st approach coming from Siaton on the way to Sta. Catalina. The station is located in Barangay Nagbalayen under the municipality of Sta. Catalina (a) and NAMRIA reference point NGE-105 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point NGE-105 used as base station for the LiDAR acquisition.

Station Name	NGE-105	
Order of Accuracy	3rd Order	
Relative Error (horizontal positioning)	1 in 20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°15'23.79985" 122°52'24.36983" 8.89200 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	486093.752 m 1023160.66 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°15'19.85595" 122°52'29.71925" 70.46200m
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	486098.62 m 1023160.66 m

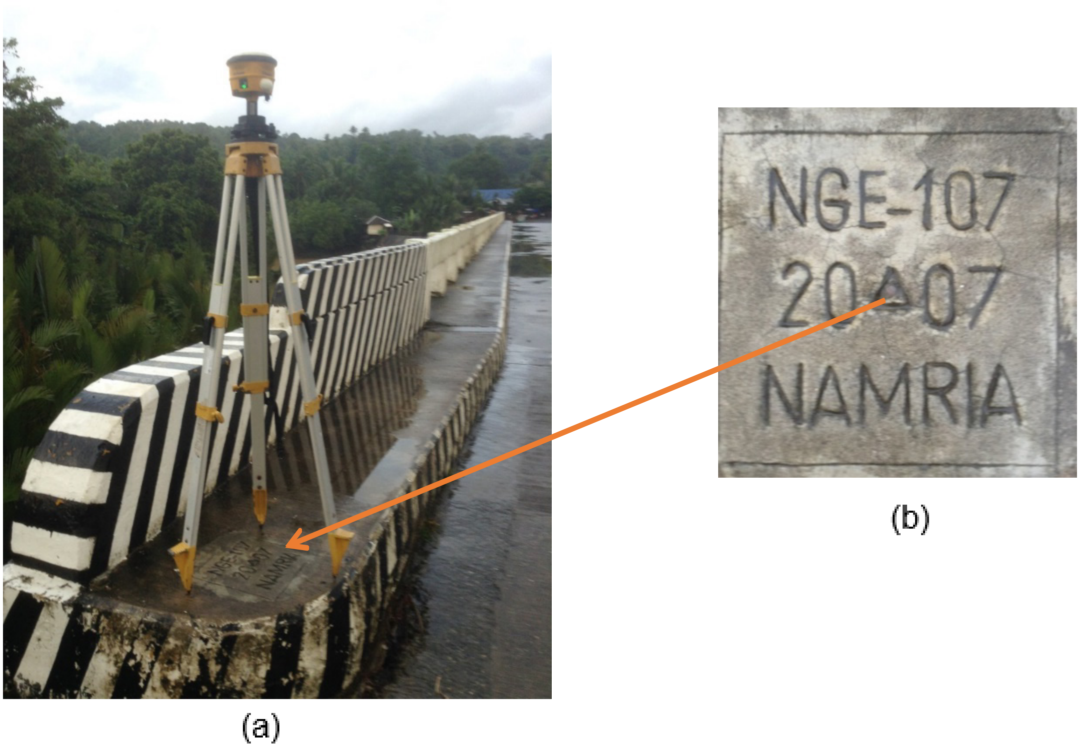
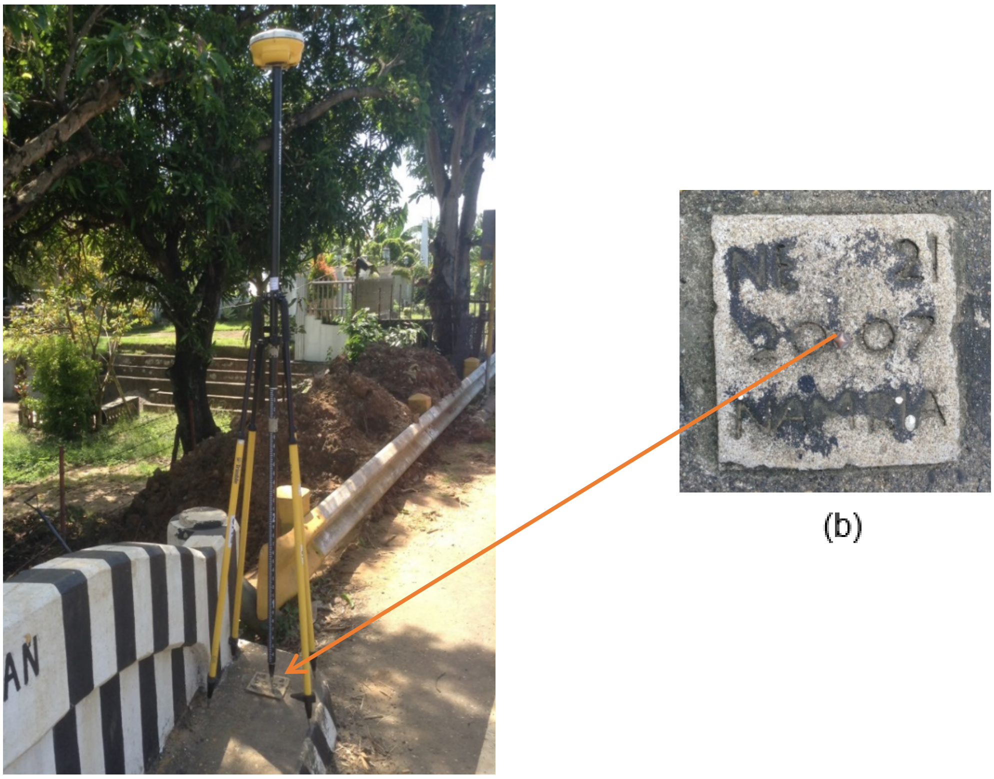


Figure 5. GPS set-up over NGE-107 on a concrete sidewalk on a bridge at KM. 80+569 over Manalongon River in Barangay Manalongon under the municipality of Sta. Catalina (a) and NAMRIA reference point NGE-107 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point NGE-107 used as base station for the LiDAR acquisition.

Station Name	NGE-107	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°13'23.69730" North 122°52'53.67884" East 8.08400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	486987.067 meters 1019829.085 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°13'19.76274" North 122°52'59.03119" East 69.74600 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	486991.62 meters 1019472.13 meters



(a)

(b)

Figure 6. GPS set-up over NE-21 on concrete sidewalk of Camaya-an Bridge about 0.30 meters above the ground and 4 meters from the road centerline. The station is located on barangay Malabogas under the municipality of Sicopong (a) and NAMRIA benchmark NE-21 (b) as recovered by the field team.

Table 5. Details of established ground control point NE-21 used as vertical reference point and established base station for the LiDAR acquisition.

Station Name	NE-21	
Order of Accuracy	2nd Order	
Elevation	5.4216	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°22’18.89002” North 122°45’39.02590” East 7.040 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°22’14.90643” North 122°45’44.36578” East 68.081 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	473740.044 meters 1035914.112 meters

Table 6. Ground Control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
30-Sep-14	7526G	2BLK53O55A273A	NGE-105, NGE-107
7-Oct-14	7540G	2BLK55AS53KS280A	NGE-105, NGE-107
17-Oct-14	7560G	2BLK55A290A	NGE-105, NGE-107
18-Oct-14	7562G	2BLK53I291A	NE-21, NGE-97
20-Oct-14	7566G	2BLK53JK293A	NE-21, NGE-97
21-Oct-14	7568G	2BLK53KS294A	NE-21, NGE-97

2.3 Flight Missions

Six (6) missions were conducted to complete the LiDAR data acquisition in Sicopong floodplain, for a total of twenty one hours and eight minutes (21+08) of flying time for RP-C9322. All missions were acquired using the Gemini LiDAR system. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for LiDAR data acquisition in Sicopong Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
30-Sep-14	7526G	263.24	65.53	17.94	47.59	-	2	35
7-Oct-14	7540G	381.81	107.06	29.36	77.70	-	3	29
17-Oct-14	7560G	143.39	164.21	0.00	164.21	-	3	47
18-Oct-14	7562G	125.11	162.44	1.62	160.82	-	4	11
20-Oct-14	7566G	238.42	156.75	11.39	145.36	-	3	35
21-Oct-14	7568G	381.81	171.88	59.76	112.12	-	4	11
TOTAL		1533.78	827.87	120.07	707.80	-	21	8

Table 8. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
7526G	1000	30	40	100	50	130	5
7540G	1100	30	40	100	50	130	5
7560G	1000	30	40	100	50	130	5
7562G	1000	30	40	100	50	130	5
7566G	1000	30	40	100	50	130	5
7568G	1100	30	40	100	50	130	5

2.4 Survey Coverage

Sicopong Floodplain is located in the province of Negros Oriental with majority of the floodplain situated within the city of Bayawan. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Sicopong floodplain is presented in Figure 7.

Table 9. List of municipalities and cities surveyed during Sicopong Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Negros Oriental	Bayawan City	683.21	335.85	49%
	Santa Catalina	542.62	186.27	34%
	Siaton	312.75	41.16	13%
	Pamplona	215.09	10.50	5%
Total		1753.67	573.78	32.72%

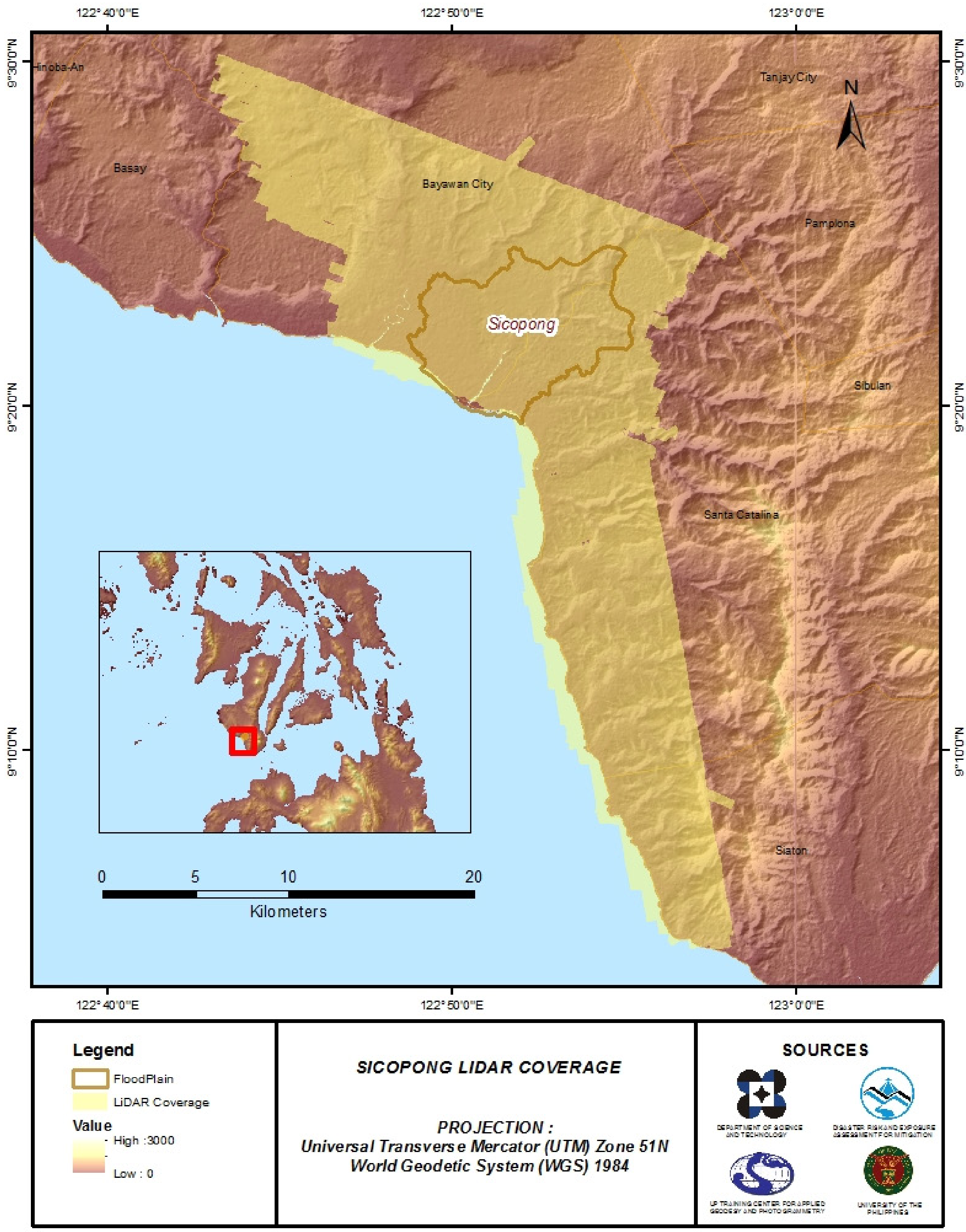


Figure 7. Actual LiDAR survey coverage for Sicopong Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE SICOPONG FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Joida F. Prieto , Ailyn G. Biñas , Engr. Jennifer B. Saguran, Engr. Monalyne C. Rabino, Engr. Justine Y. Francisco , Engr. Ma. Joanne I. Balaga, and Engr. Erica Erin E. Elazegui

The methods applied in this chapter were based on the DREAM methods manual (Ang, et. al., 2014) and further enhanced and updated in Paringit, et. al. (2017).

3.1 Overview of the LIDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component are checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory is done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification is performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

Using the elevation of points gathered in the field, the LiDAR-derived digital models are calibrated. Portions of the river that are barely penetrated by the LiDAR system are replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally are then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data is done through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in the flowchart shown in Figure 8.

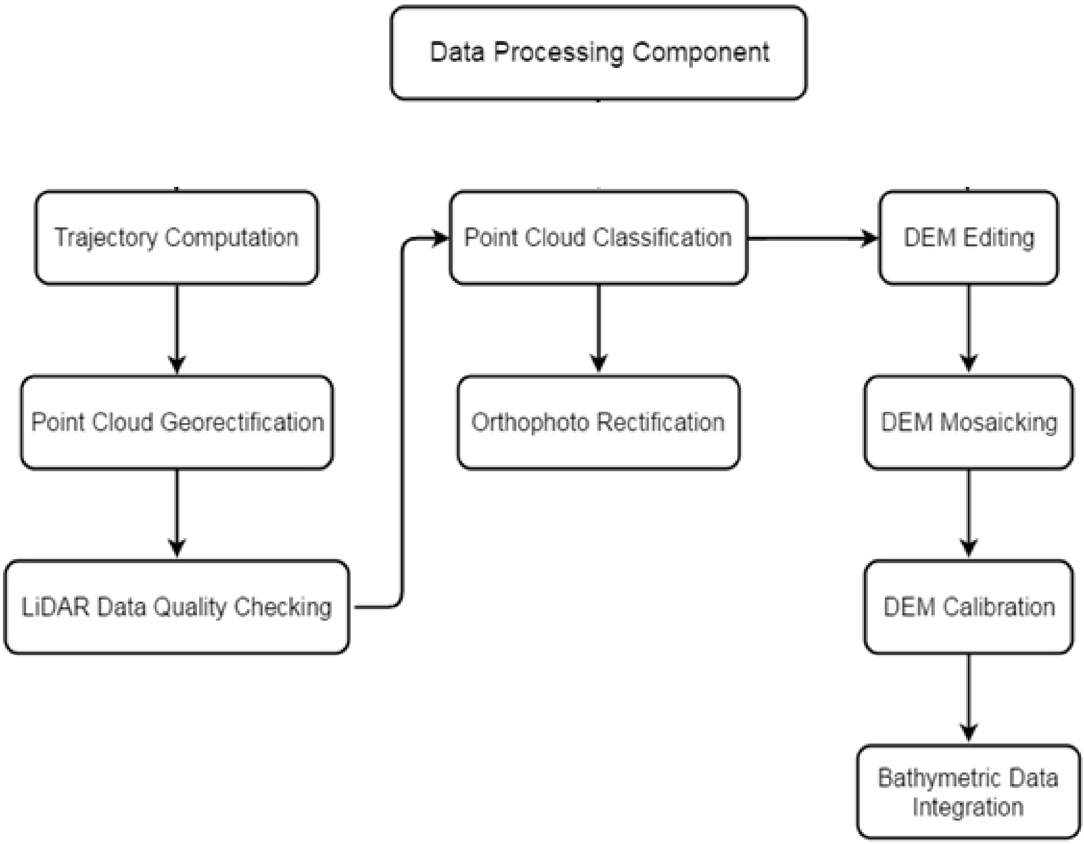


Figure 8. Schematic diagram for the data pre-processing.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Sicopong floodplain can be found in Annex 5. Missions flown during the survey conducted on September 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system over Sta. Catalina, Negros Oriental.

The Data Acquisition Component (DAC) transferred a total of 69.39 Gigabytes of Range data, 9.75 Gigabytes of POS data, 25.94 Megabytes of GPS base station data, and 91.5 Gigabytes of raw image data to the data server on November 06, 2014 for the survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Sicopong was fully transferred on November 06, 2014, as indicated on the Data Transfer Sheets for Sicopong floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 7540G, one of the Sicopong flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on October 7, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

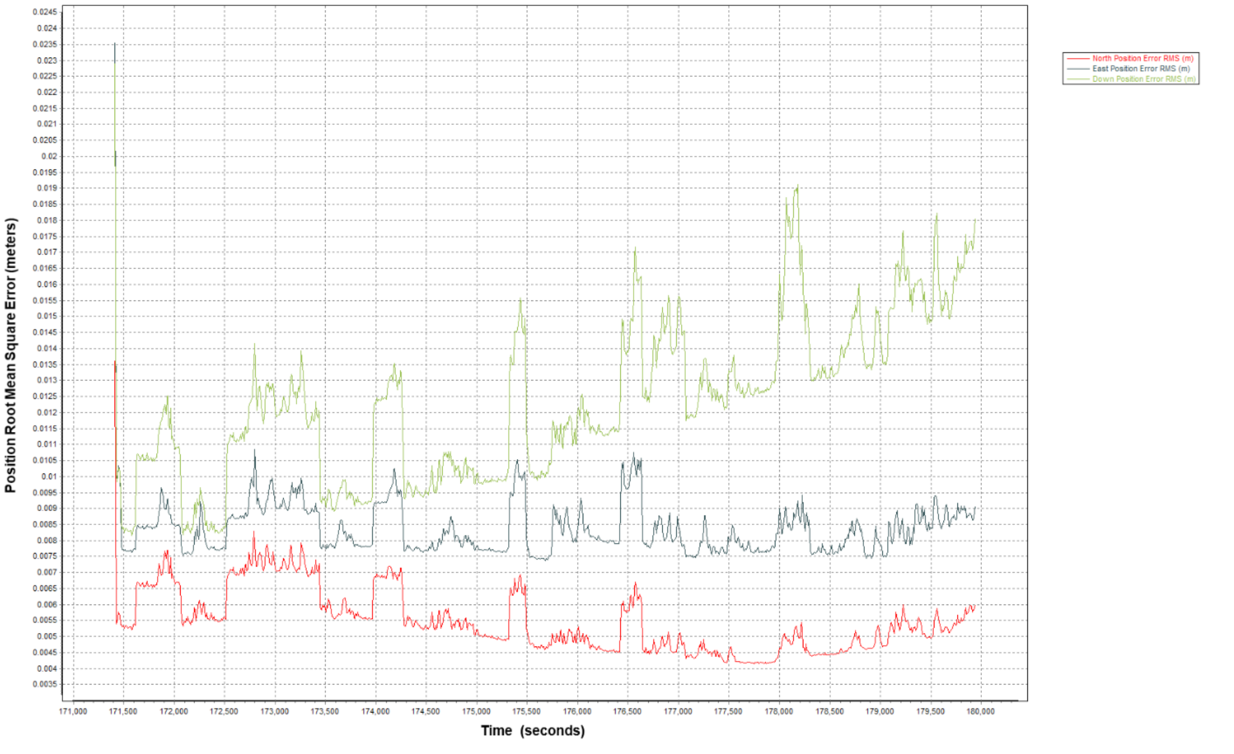


Figure 9. Smoothed Performance Metrics of Sicopong Flight 7540G.

The time of flight was from 171,400 seconds to 181,000 seconds, which corresponds to morning of October 07, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 shows that the North position RMSE peaks at 1.00 centimeter, the East position RMSE peaks at 1. 60 centimeters, and the Down position RMSE peaks at 3.20 centimeters, which are within the prescribed accuracies described in the methodology.

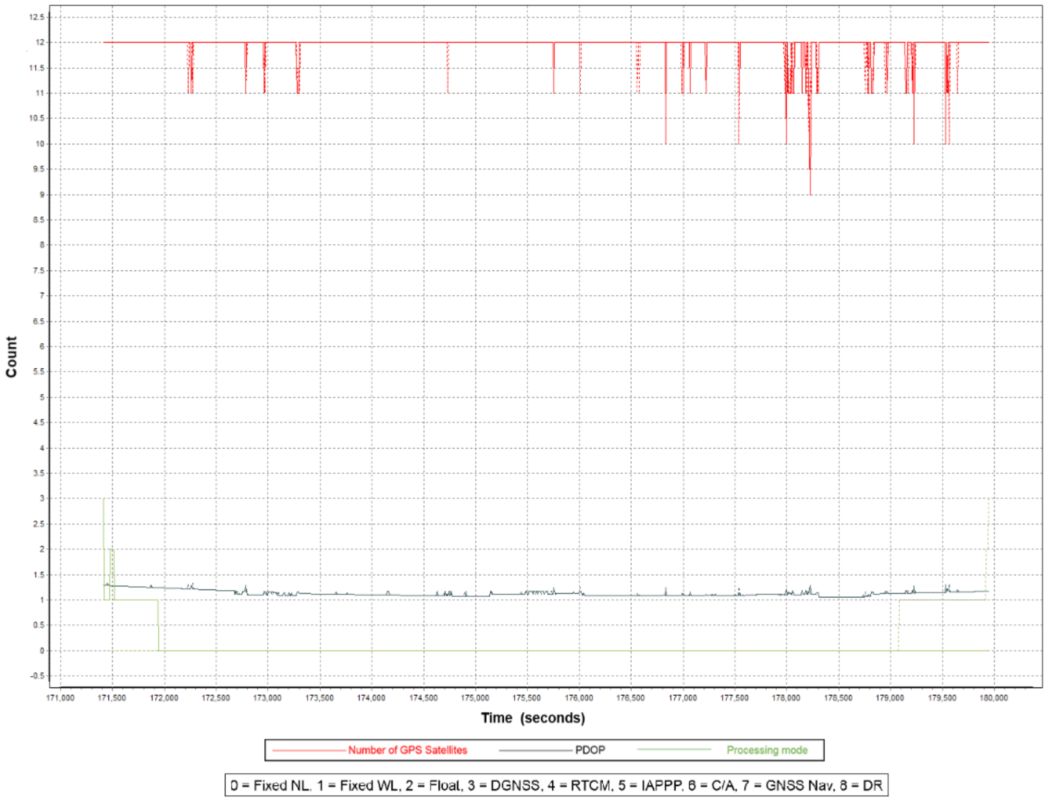


Figure 10. Solution Status Parameters of Sicopong Flight 7540G.

The Solution Status parameters of flight 7540G, one of the Sicopong flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 9. Majority of the time, the number of satellites tracked was between 9 and 12. The PDP value also did not go above the value of 1.5, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Sicopong flights is shown in Figure 11.

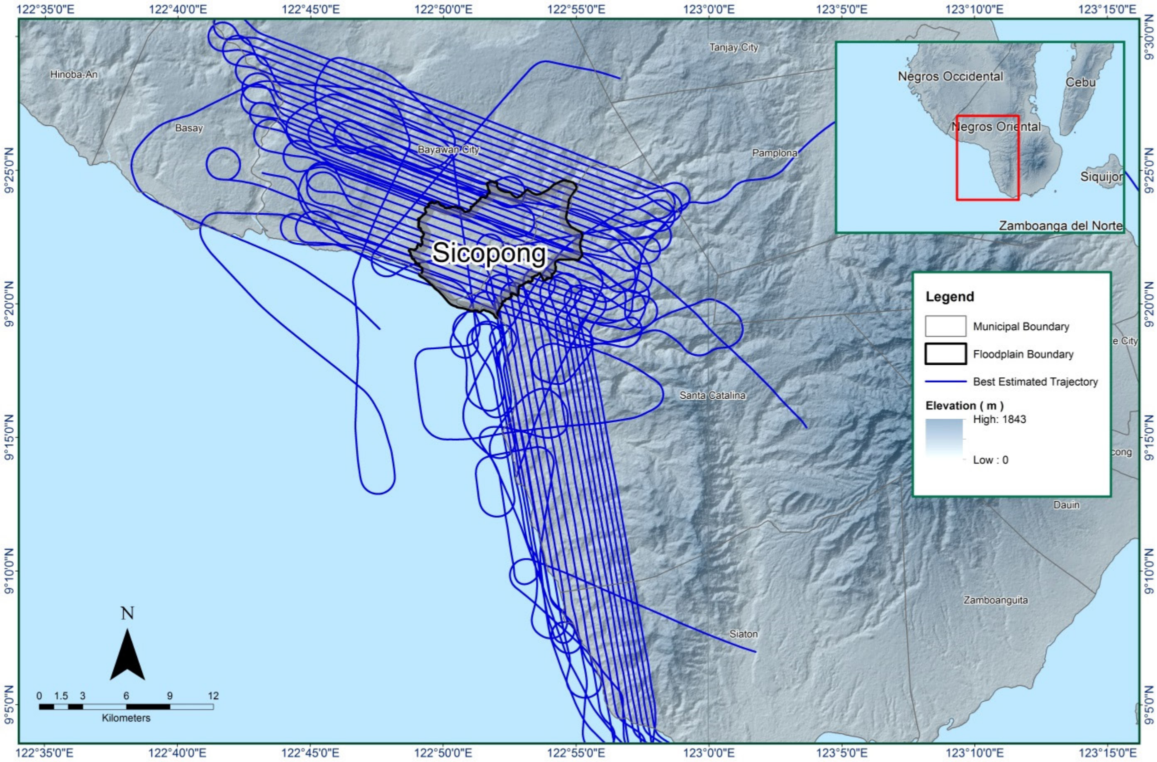


Figure 11. Best Estimated Trajectory for Sicopong FloodplainFloodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 67 flight lines, with each flight line containing one channel, since the Gemini system contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Sicopong floodplain are given in Table 10.

Table 10. Self-Calibration Results values for Sicopong flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000167
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.000941
GPS Position Z-correction stdev)	<0.01meters	0.0027

The optimum accuracy is obtained for all Sicopong flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in Annex 8: Mission Summary Reports.

3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Sicopong Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

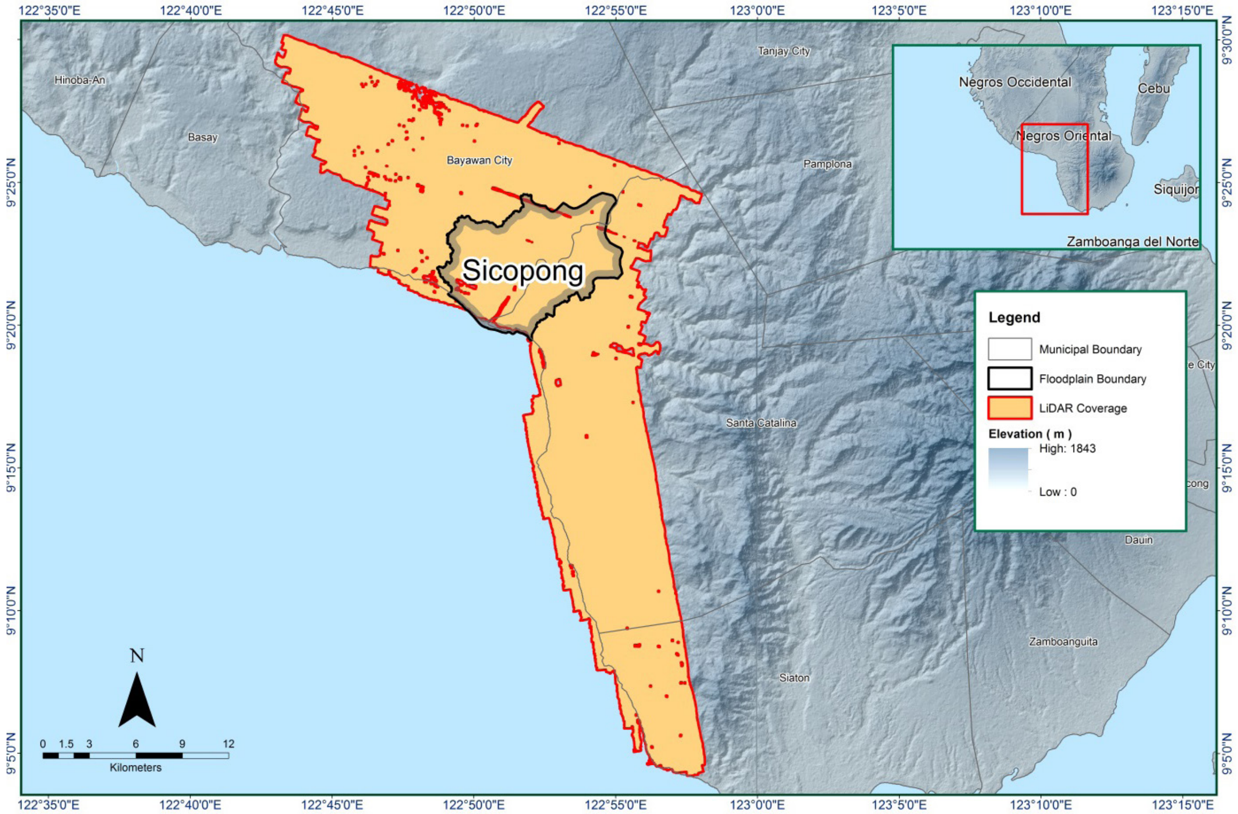


Figure 12. Boundary of the processed LiDAR data over Sicopong Floodplain.

The total area covered by the Sicopong missions is 493.63 sq.km that is comprised of five (5) flight acquisitions grouped and merged into four (4) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Sicopong Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq.km)
Dumaguete_Blk53J	7566G	153.17
Dumaguete_Blk53K	7540G	112.88
	7568G	
Dumaguete_Blk53K_supplement	7526G	52.62
Dumaguete_Blk55A	7560G	174.96
TOTAL		**493.63 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 13. Since the Gemini system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

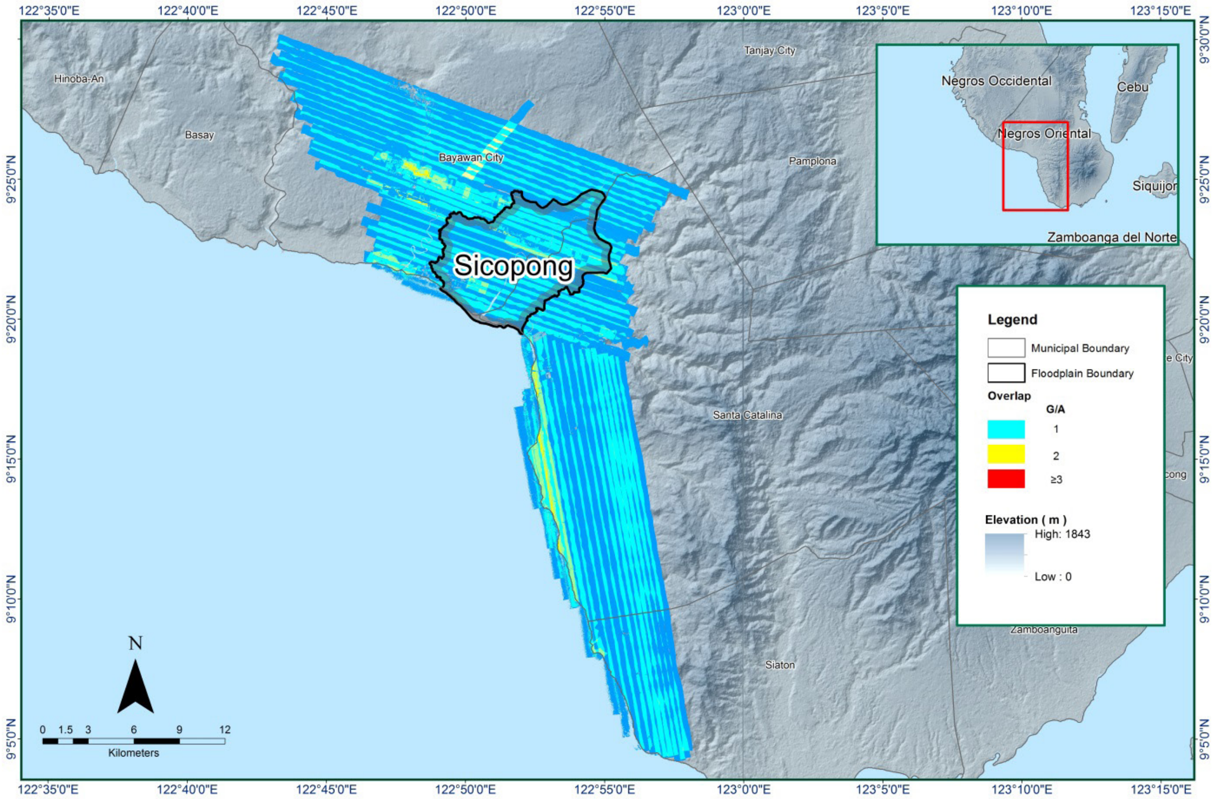


Figure 13. Image of data overlap for Sicopong Floodplain.

The overlap statistics per block for the Sicopong floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 30.01% and 47.63% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 14. It was determined that all LiDAR data for Sicopong floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.82 points per square meter.

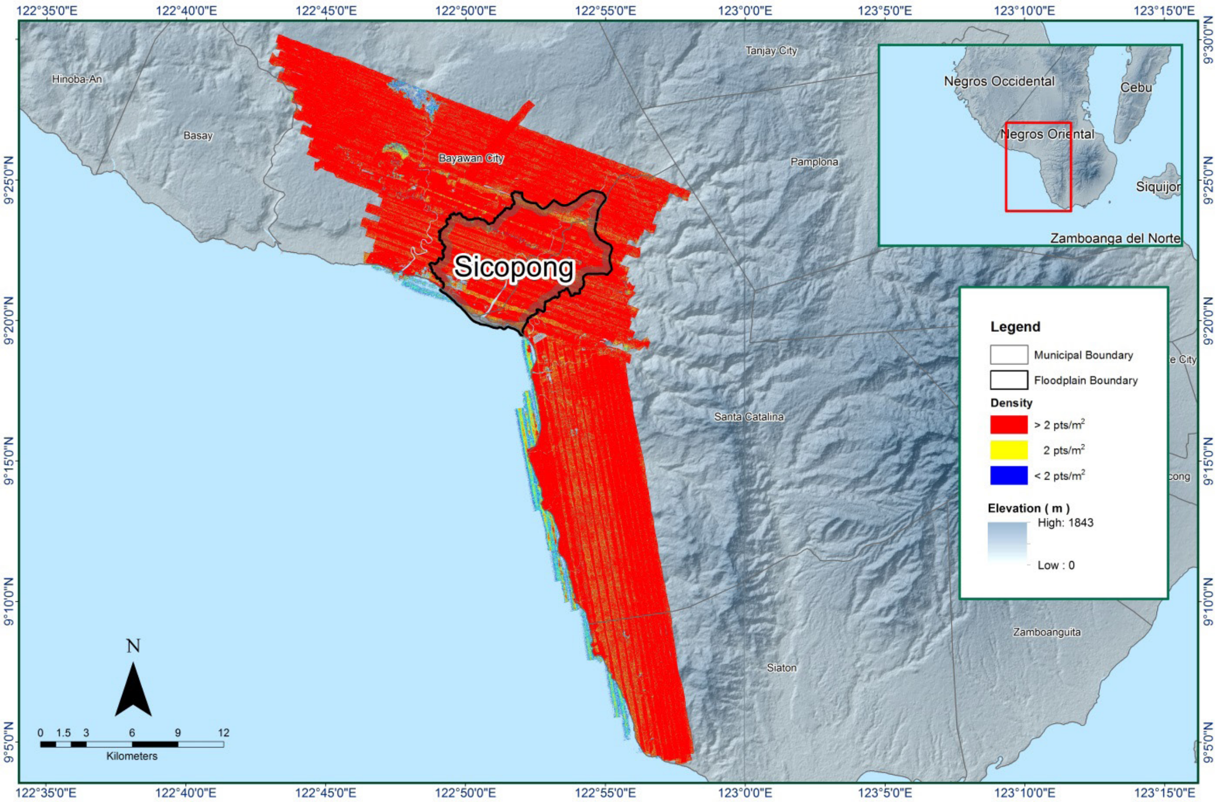


Figure 14. Pulse density map of merged LiDAR data for Sicopong Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

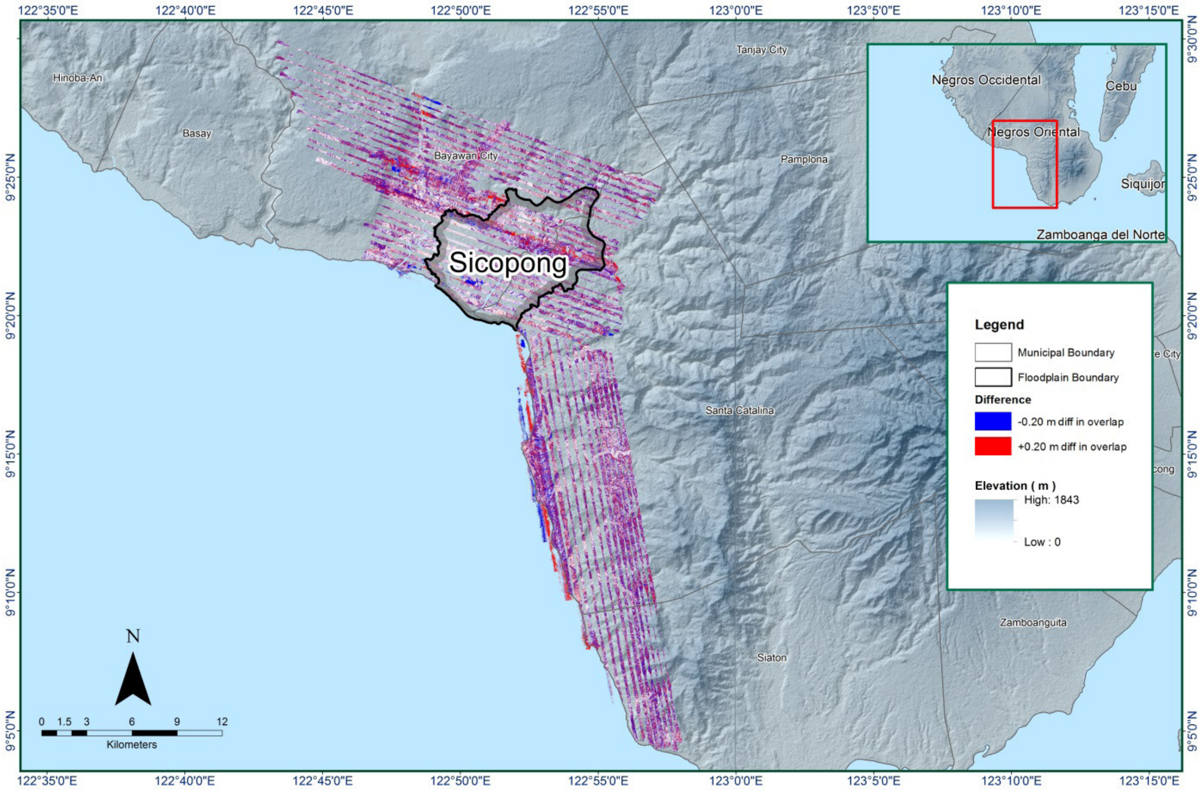


Figure 15. Elevation difference map between flight lines for Sicopong Floodplain.

A screen capture of the processed LAS data from a Sicopong flight 7540G loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

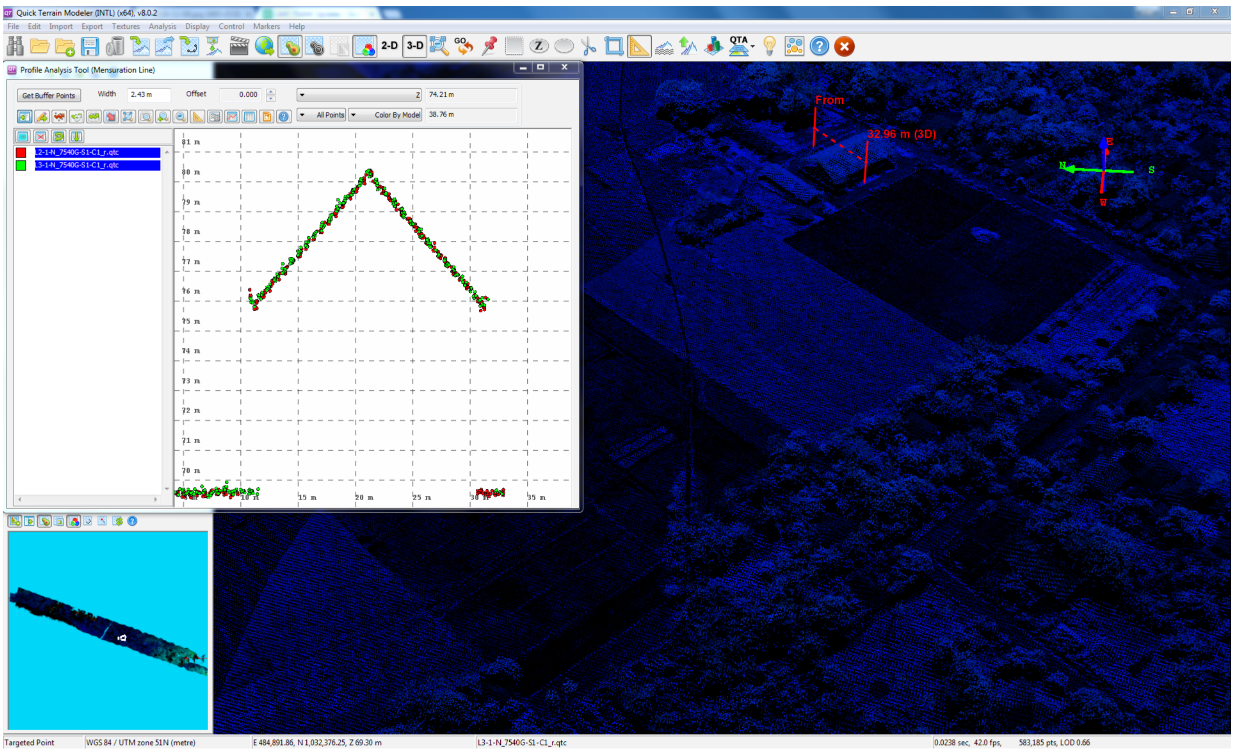


Figure 16. Quality checking for Sicopong Flight 7540G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Sicopong classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	229,210,704
Low Vegetation	229,410,290
Medium Vegetation	546,232,879
High Vegetation	678,374,394
Building	11,681,965

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Sicopong floodplain is shown in Figure 17. A total of 707 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 719.03 meters and 60.30 meters respectively.750.91 meters and 52.78 meters

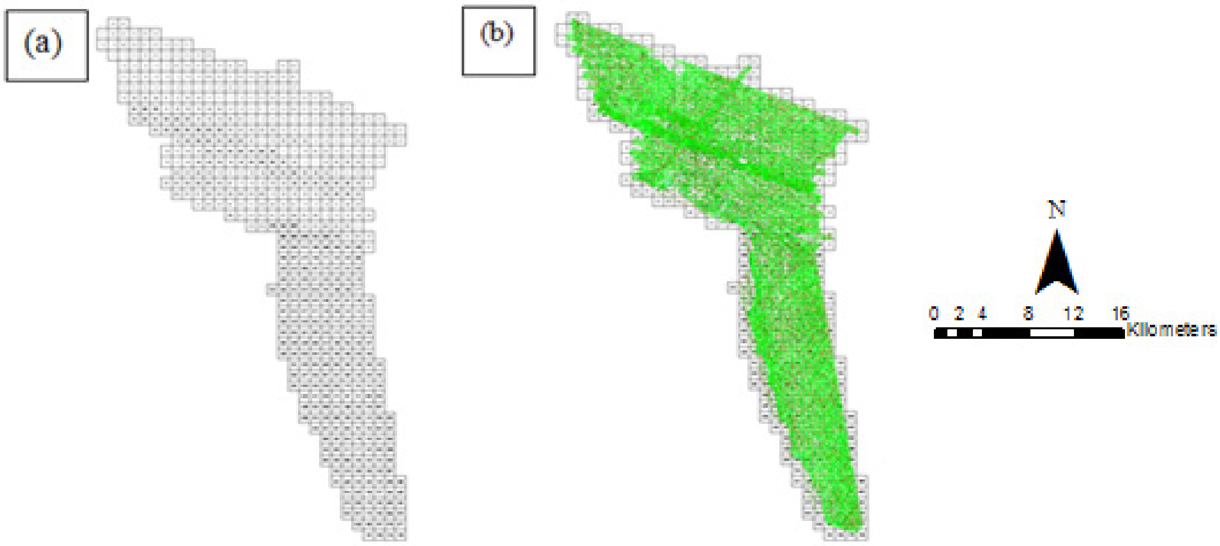


Figure 17. Tiles for Sicopong Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

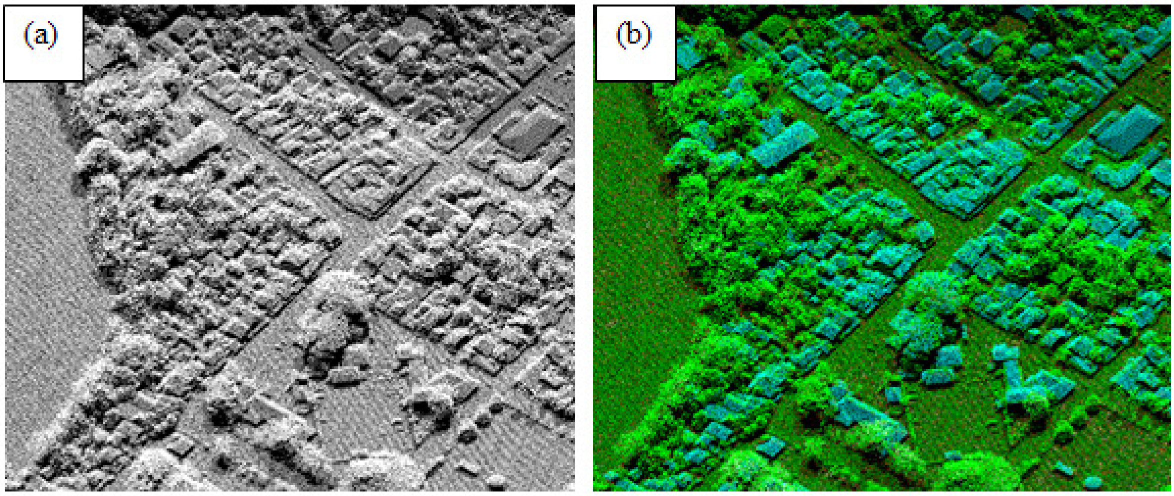


Figure 18. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 19. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

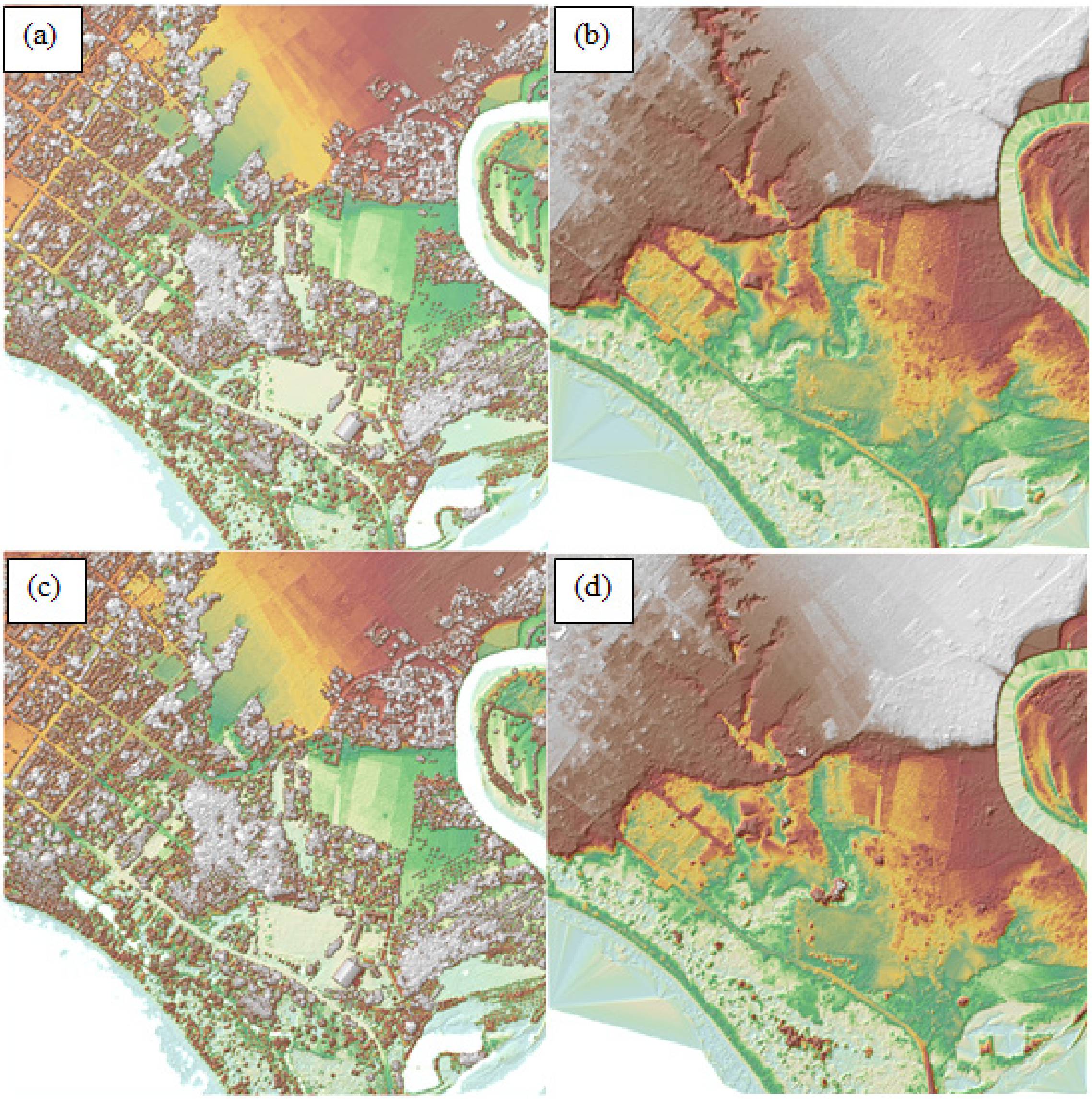


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Sicopong Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Sicopong floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Sicopong flood plain. These blocks are composed of Dumaguete blocks with a total area of 493.63 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq. km.)
Dumaguete_Blk53J	153.17
Dumaguete_Blk53K	112.88
Dumaguete_Blk53K_supplement	52.62
Dumaguete_Blk55A	174.96
TOTAL	493.63 sq.km

Portions of DTM before and after manual editing are shown in Figure 20. Lines along the DTM (Figure 20a) were removed (Figure 20b). Another is the bridge (Figure 20c) is also considered to be an impedance to the flow of water and has to be removed (Figure 20d) in order to hydrologically correct the river. These are shown in the figure below.

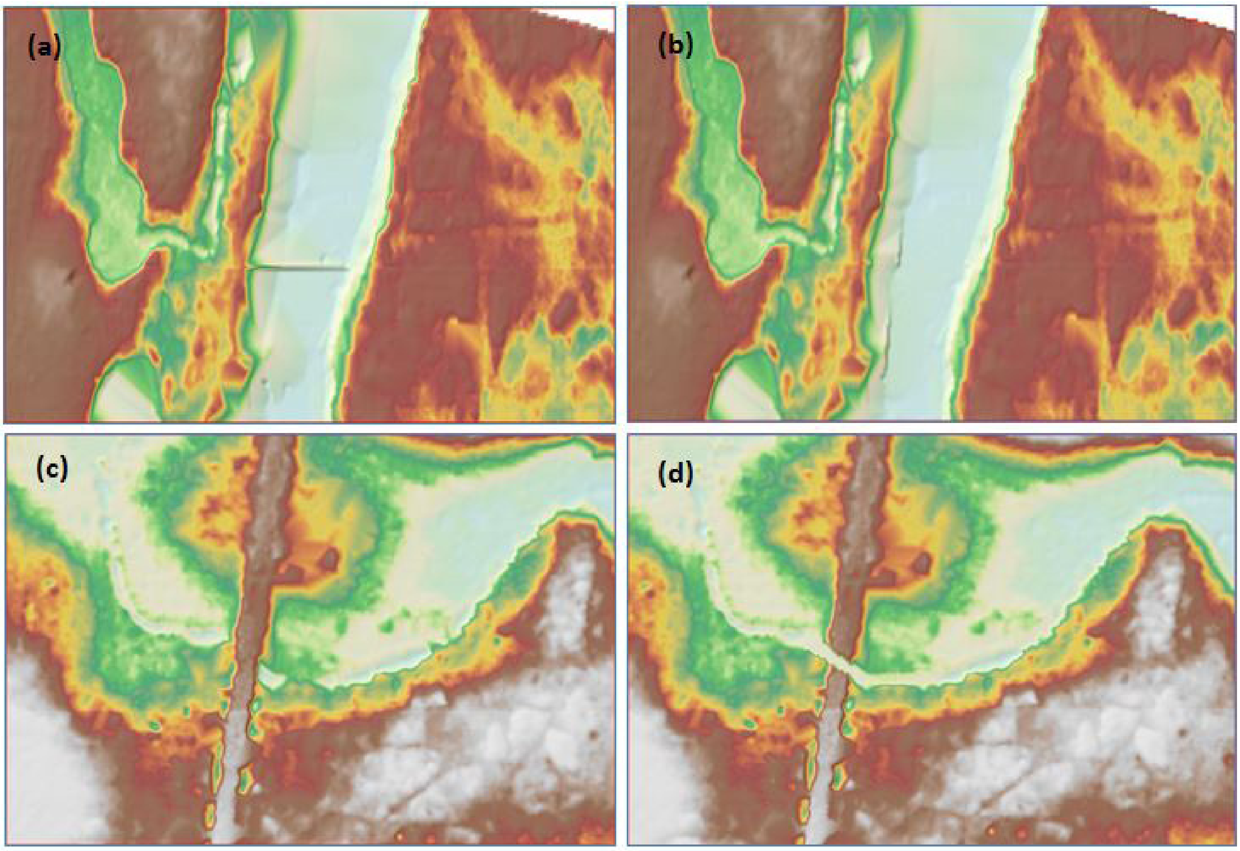


Figure 20. Portions in the DTM of Sicopong Floodplain – (a) before and (b) after editing; (c) before and (d) after bridge removal.

3.9 Mosaicking of Blocks

Dumaguete_Blk53H was used as the reference block at the start of mosaicking due to the presence of more fixed built-up areas like roads on the flight block compared to the other. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Sicopong floodplain shown in Figure 21. It can be seen that the entire Sicopong floodplain is 100% covered by LiDAR data.

Table 14. Shift Values of each LiDAR Block of Sicopong Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Dumaguete_Blk53J	0	0	0.20
Dumaguete_Blk53K	0	0	0.63
Dumaguete_Blk53K_supplement	0	0	0.15
Dumaguete_Blk55A	0	0	0.53

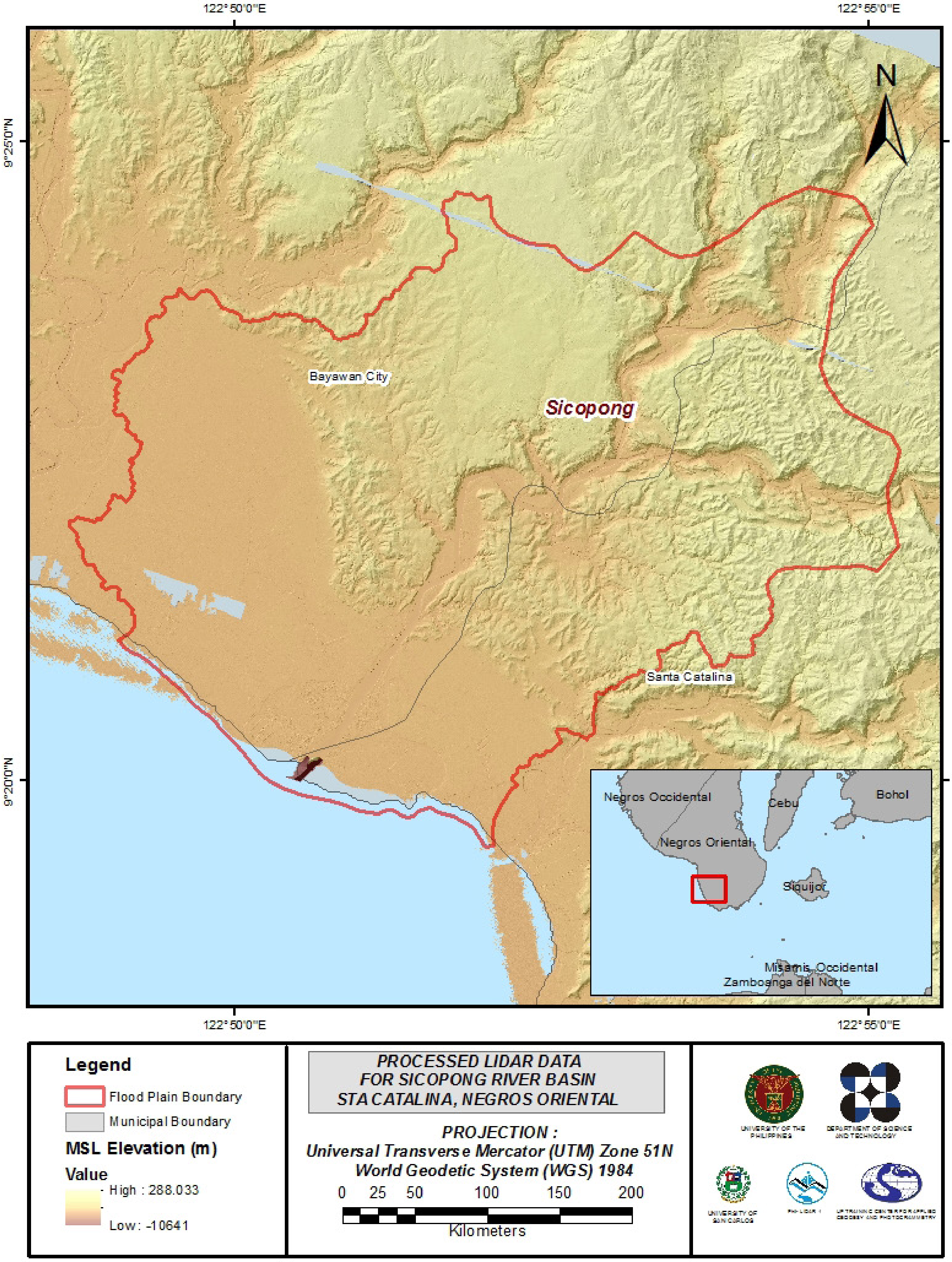


Figure 21. Map of Processed LiDAR Data for Sicopong Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Sicopong to collect points with which the LiDAR dataset is validated is shown in Figure 22. A total of 14,047 survey points were gathered for all the flood plains within the provinces of Negros Oriental and Negros Occidental wherein the Sicopong floodplain is located. Random selection of 80% of the survey points, resulting to 11,237 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 23. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 0.35 meters with a standard deviation of 0.18 meters. Calibration of the LiDAR data was done by subtracting the height difference value, 0.35 meters, to the mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

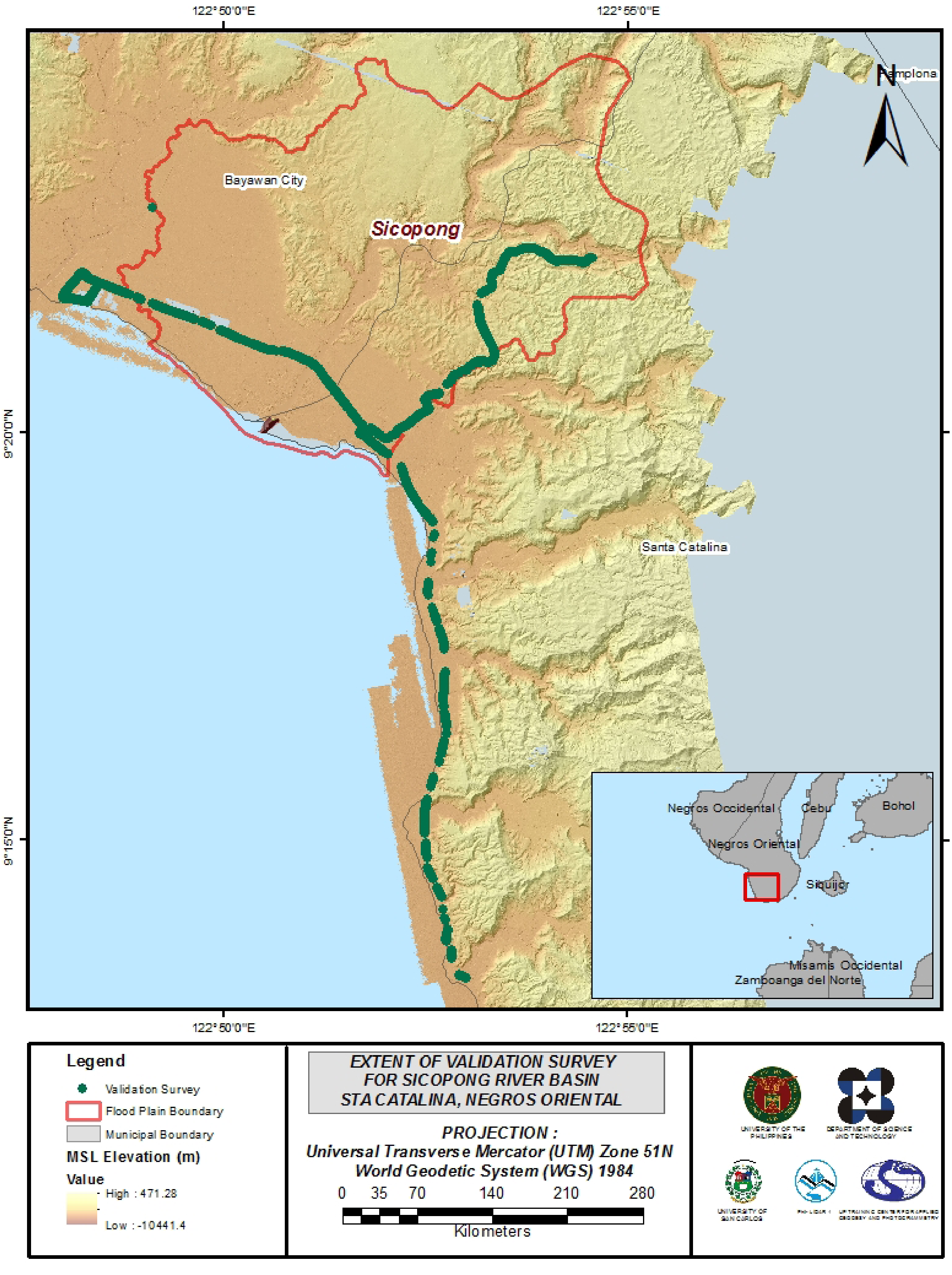


Figure 22. Map of Sicopong Floodplain with validation survey points in green.

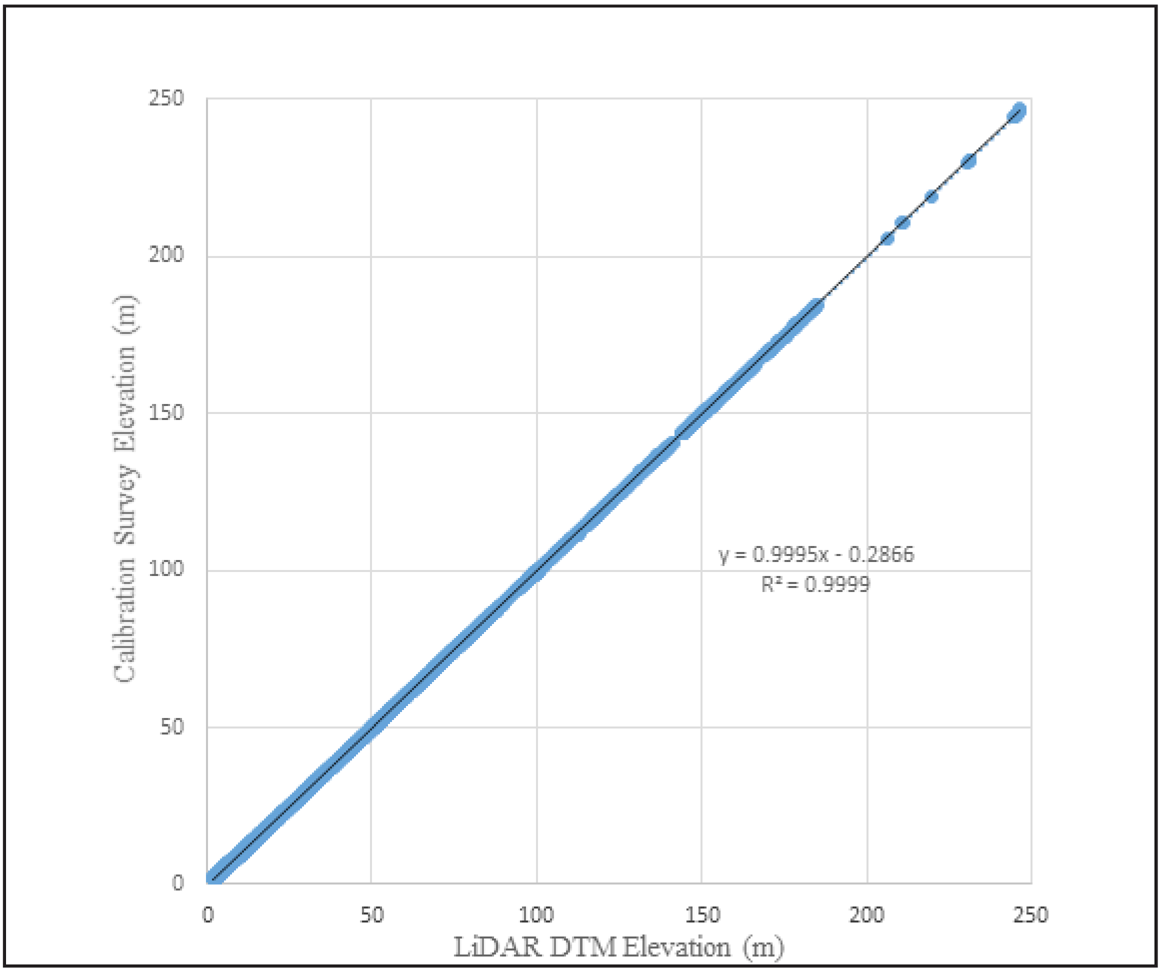


Figure 23. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	0.35
Standard Deviation	0.18
Average	-2.30
Minimum	-0.57
Maximum	0.30

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 343 points, were used for the validation of calibrated Sicopong DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM, is shown in Figure 24. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.19 meters with a standard deviation of 0.17 meters, as shown in Table 16.

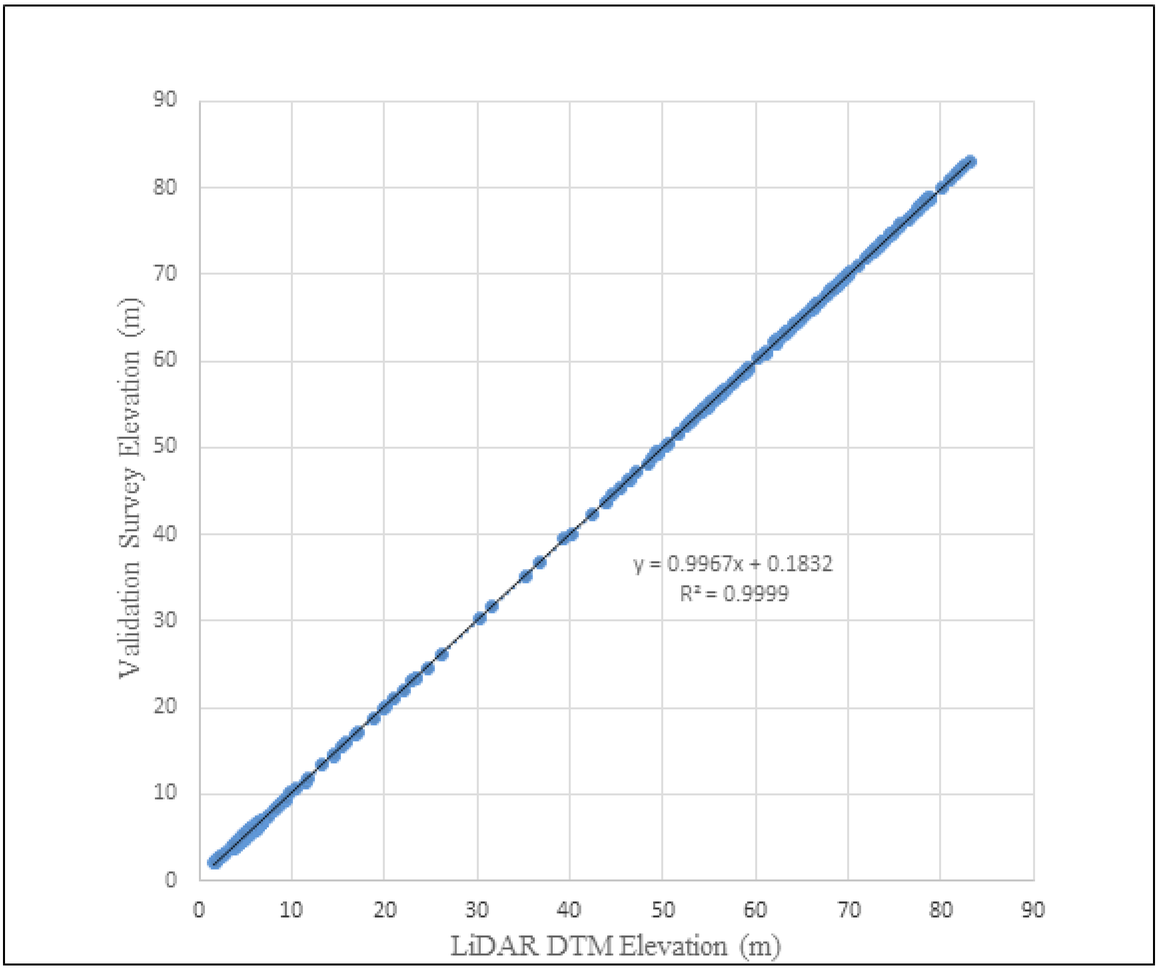


Figure 24. Correlation plot between validation survey points and LiDAR data.

Table 16. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.19
Standard Deviation	0.17
Average	0.07
Minimum	-0.21
Maximum	0.57

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Sicopong with 8,660 bathymetric survey points. The resulting raster surface produced was done Krigging interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.60 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Sicopong integrated with the processed LiDAR DEM is shown in Figure 25.

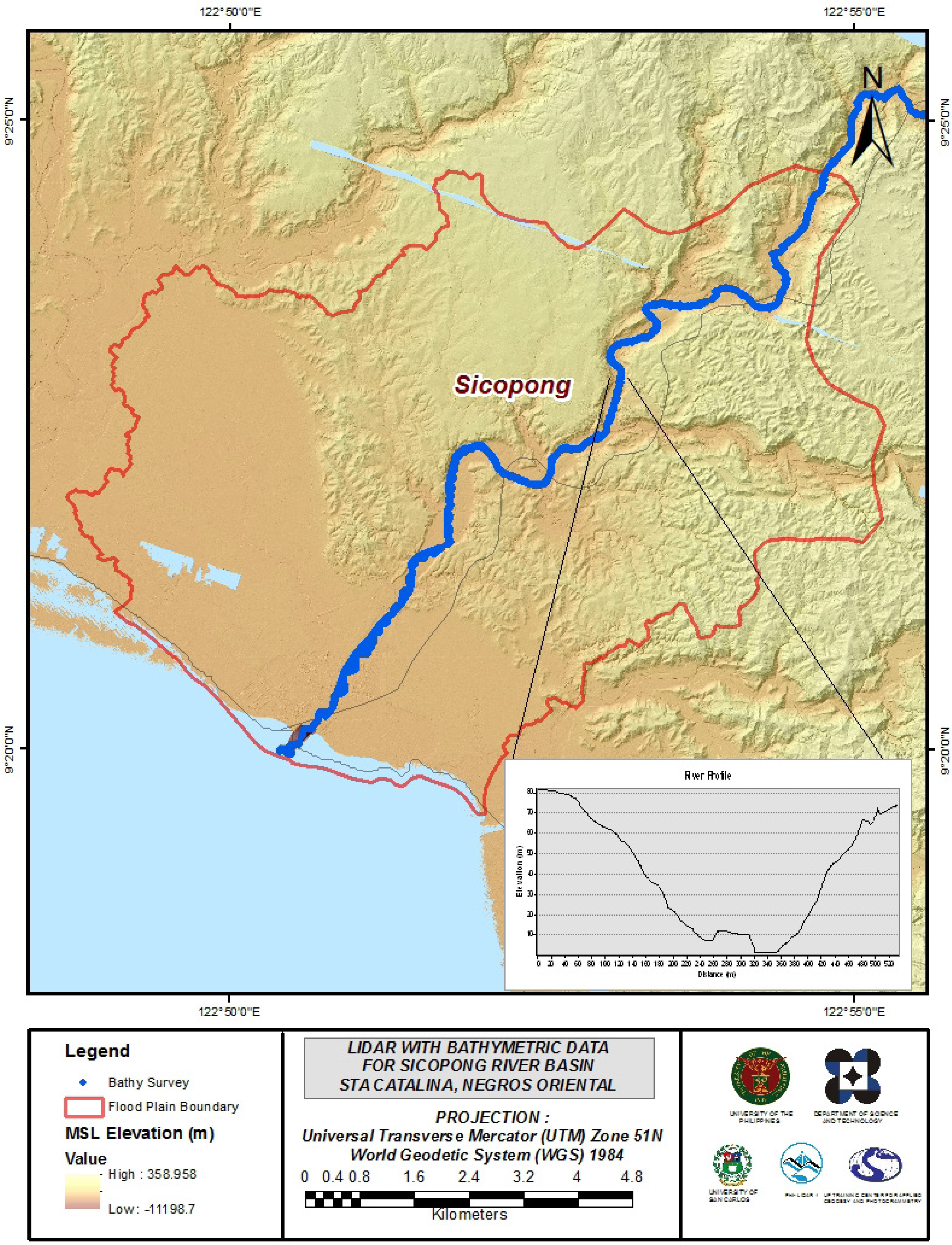


Figure 25. Map of Sicopong Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges and water bodies within the floodplain area with 200 m buffer zone. Mosaicked LiDAR DEM with 1 m resolution was used to delineate footprints of building features, which consist of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks comprise of main thoroughfares such as highways and municipal and barangay roads essential for routing of disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Sicopong floodplain, including its 200 m buffer, has a total area of 78.55 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 740 building features, are considered for QC. Figure 26 shows the QC blocks for Sicopong floodplain.

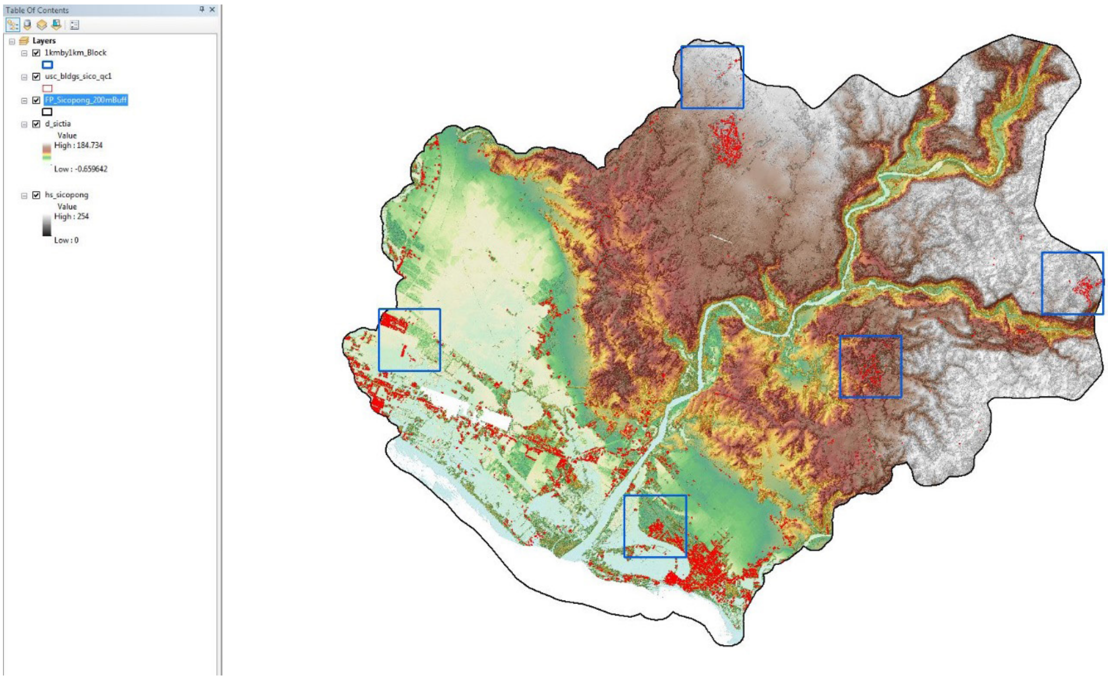


Figure 26. QC blocks for Sicopong building features.

Quality checking of Sicopong building features resulted in the ratings shown in Table 17.

Table 17. Quality Checking Ratings for Sicopong Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Sicopong	99.87	100.00	98.92	PASSED

3.12.2 Height Extraction

Height extraction was done for 5,770 building features in Sicopong floodplain. Of these building features, 60 were filtered out after height extraction, resulting to 5,710 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 13.5 m.

3.12.3 Feature Attribution

In attribution, combination of participatory mapping and actual field validation was done. Representatives from LGU were invited to assist in the determination of the features. The remaining unidentified features were then validated on the field.

Table 18 summarizes the number of building features per type. On the other hand, Table 19 shows the total length of each road type, while Table 20 shows the number of water features extracted per type.

Table 18. Building Features Extracted for Sicopong Floodplain.

Facility Type	No. of Features
Residential	5,377
School	134
Market	7
Agricultural/Agro-Industrial Facilities	2
Medical Institutions	35
Barangay Hall	8
Military Institution	0
Sports Center/Gymnasium/Covered Court	10
Telecommunication Facilities	0
Transport Terminal	2
Warehouse	14
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	1
Water Supply/Sewerage	0
Religious Institutions	16
Bank	1
Factory	0
Gas Station	1
Fire Station	0
Other Government Offices	11
Other Commercial Establishments	90
Total	**5,710**

Table 19. Total Length of Extracted Roads for Sicopong Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Sicopong	144.29	19.08	3.88	7.64	0	174.89

Table 20. Number of Extracted Water Bodies for Sicopong Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Sicopong	6	2	0	0	12	20

A total of 6 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were completely given the required attributes. All these output features comprise the flood hazard exposure database for the floodplain. This completes the feature extraction phase of the project.

Figure 27 shows the Digital Surface Model (DSM) of Sicopong floodplain overlaid with its ground features.

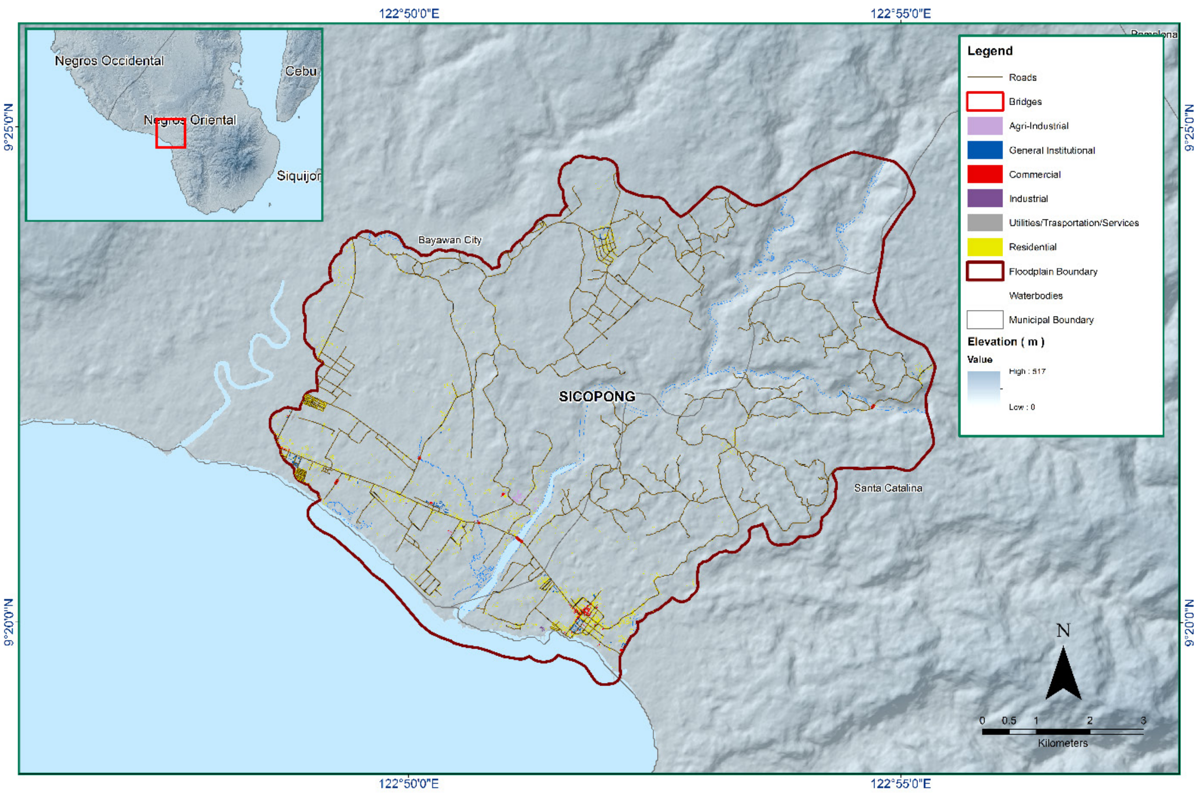


Figure 27. Extracted features for Sicopong Floodplain.

CHAPTER 4 LIDAR VALIDATION SURVEY AND MEASUREMENT OF THE SICOPONG RIVER BASIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, and For. Rodel C. Alberto

The methods applied in this chapter were based on the DREAM methods manual (Ang, et. al., 2014) and further enhanced and updated in Paringit, et. al. (2017).

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Sicopong River on March 9 – 23, 2016 with the following scope of work: reconnaissance; control survey; cross-section, bridge as-built survey and water level marking in MSL for Amio Bridge located in Brgy. Amio, Municipality of Santa Catalina, Inobangan Bridge in Brgy. Kabulacan, Municipality of Santa Catalina, and Amio Spillway in Brgy. Narra, Bayawan City; validation points data acquisition of about 30.14 km for the areas traversing the area of Sicopong River Basin; and bathymetric survey from Brgy. Narra, Bayawan City down to Brgy. Villareal, Bayawan City, with an estimated length of 21.145 km using OHMEX™ Sonarmite echo sounder and Trimble® SPS 882 GNSS PPK survey technique as shown in Figure 28.

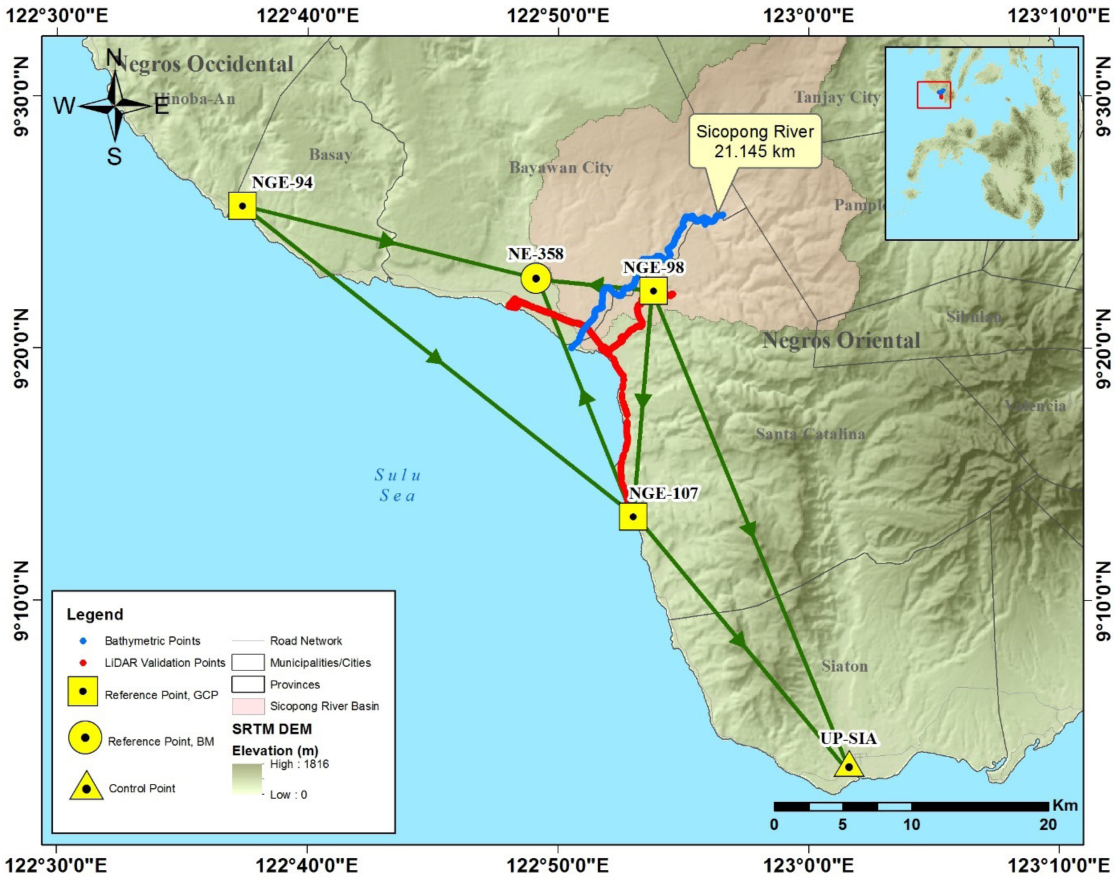


Figure 28. Sicopong River Survey Extent

4.2 Control Survey

The GNSS network used for Sicopong River Basin is composed of three (3) loops established on March 11, 2016 occupying the following reference points: NGE-98, a second-order GCP, in Brgy. Caranoche, Municipality of Santa Catalina; NGE-107, a second-order GCP, in Brgy. Manalongon, also in Municipality of Santa Catalina; and NE-358, a first-order BM, in Brgy. Ubos, Bayawan City.

A control point was established along the approach of Siaton Bridge, namely UP-SIA, at Brgy. Caticugan, Municiality of Siaton; and a NAMRIA established control point, NGE-94 located in Brgy. Bongalonan, Municipality of Basay which was used as a marker for the network.

The summary of reference and control points and its location is summarized in Table 21 while GNSS network established is illustrated in Figure 29.

Table 21. List of reference and control points used in Sicopong River Basin survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establishment
Control Survey on December 10, 2016						
NGE-98	2nd Order, GCP	9°22'16.41564"	122°53'48.54064"	132.087	-	2007
NGE-107	2nd Order, GCP	9°13'19.76274"	122°52'59.03199"	69.527	7.670	2007
NE-358	1st Order, BM	-	-	67.723	5.116	2008
NGE-94	Used as Marker	-	-	-	-	2007
UP-SIA	UP Established	-	-	-	-	March 2016

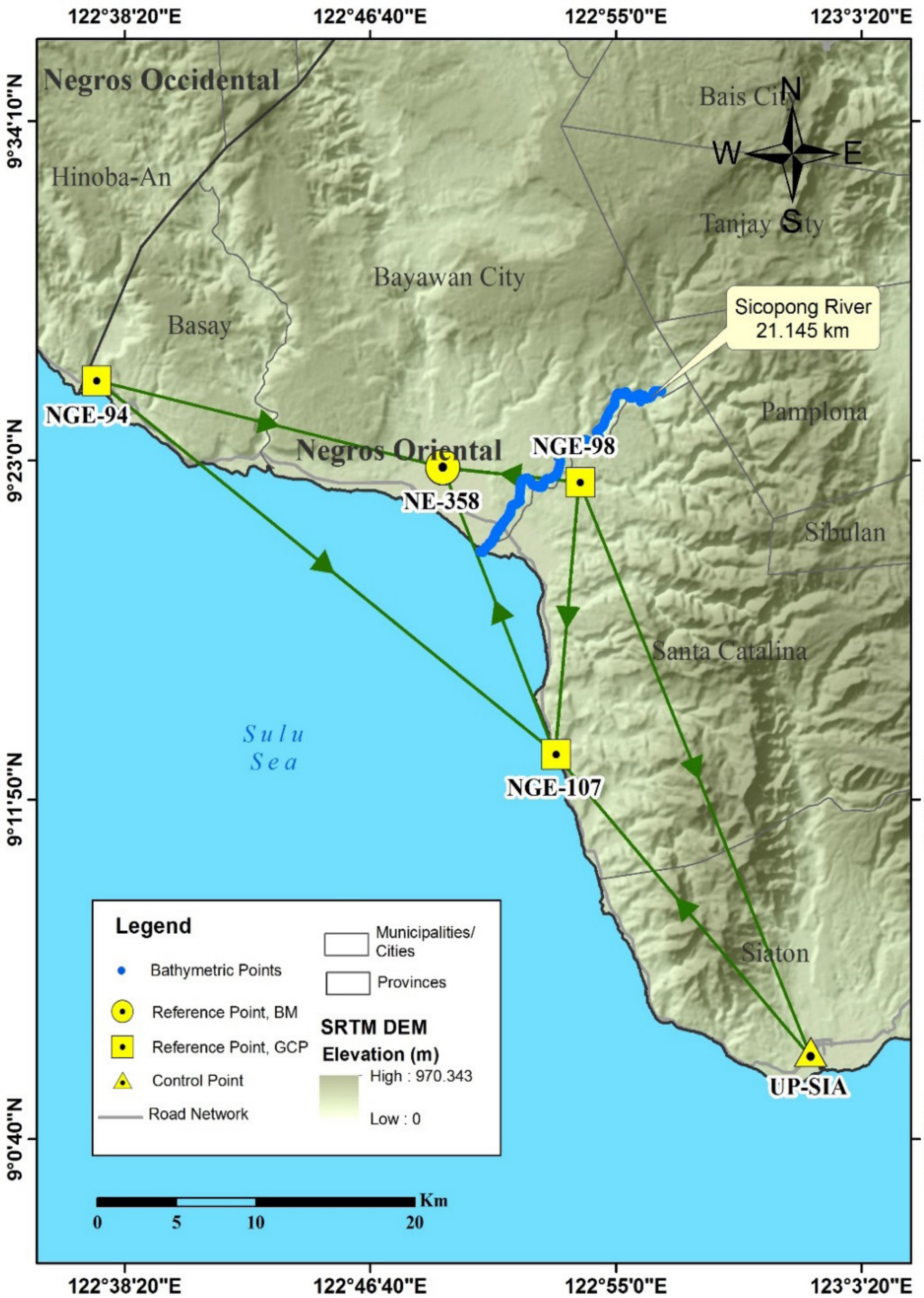


Figure 29. GNSS Network of Sicopong River field survey

The GNSS set up made in the location of the reference and control points are exhibited are shown in Figure 30 to Figure 34.

Figure 30. GNSS base set up, Trimble® SPS 852, at NGE-98 a second-order GCP located on top of a concrete block along Sta. Catalia-Pamplona Provincial Road in Brgy. Caranoche, Sta. Catalina, Negros Oriental

Figure 31. GNSS base set up, Trimble® SPS 882, at NE-107, a second-order GCP located at the approach of Manalongon Bridge in Brgy. Manalongon, Sta. Catalina, Negros Oriental

Figure 32. GNSS base set up, Trimble® SPS 855, at NE-358, a first-order BM, located on a culvert along Sta. Caalina-Bayawan Road in Brgy. Ubos, Bayawn City, Negros Oriental.

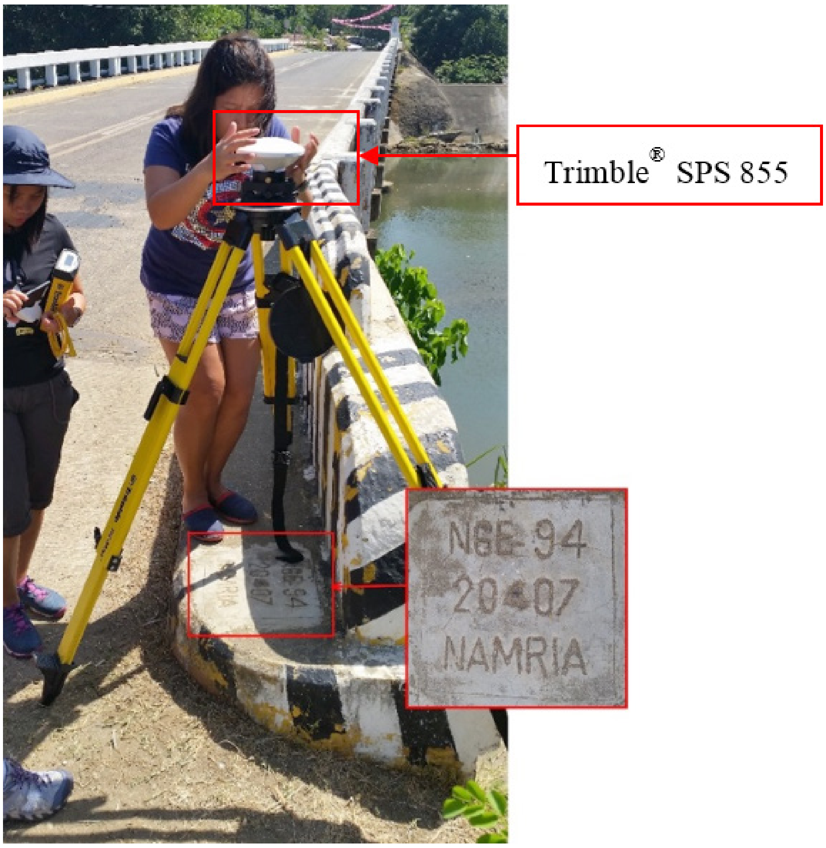


Figure 33. GNSS base set up, Trimble® SPS 855, at NGE-94, a GCP used as marker, located at the approach of Tiabanan Bridge in Brgy. Bongalonan, Basay, Negros Oriental

Figure 34. GNSS receiver set up, Trimble® SPS 882, at UP-SIA, an established control point, located at the approach of Siaton Bridge in Brgy. Caticugan, Siaton, Negros Oriental

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Sicopong River Basin is summarized in Table 22 generated by TBC software.

Table 22. Baseline Processing Report for Sicopong River Static Survey (Source: NAMRIA, UP-TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NE-358 --- NGE-98	03-11-2016	Fixed	0.004	0.020	276°04'18"	-64.370	-64.370
NGE-98 --- UP-SIA	03-11-2016	Fixed	0.003	0.019	157°29'24"	-61.895	-61.895
NGE-98 --- NGE-107	03-11-2016	Fixed	0.003	0.020	185°14'15"	-62.546	-62.546
NE-358 --- NGE-94	03-11-2016	Fixed	0.005	0.021	103°45'37"	-1.108	-1.108
NE-358 --- NGE-107	03-11-2016	Fixed	0.005	0.032	337°54'15"	-1.830	1.830
UP-SIA --- NGE-107	03-11-2016	Fixed	0.004	0.023	318°46'17"	-0.673	-0.673
NGE-94 --- NGE-107	03-11-2016	Fixed	0.003	0.029	128°25'03"	0.653	0.653

As shown in Table 22, a total of seven (7) baselines were processed with reference points NGE-98 and NGE 107 held fixed for grid values; and NE-358 fixed for elevation. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates table of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation form:

$$\sqrt{((x_e)^2 + (y_e)^2)} < 20\text{ cm and } z_e < 10\text{ cm}$$

where:

xe is the Easting Error,
ye is the Northing Error, and
ze is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 23 to Table 25 for the complete details.

The five (5) control points, NGE-98, NE-107, NE-358NGE-94 and UP-SIA were occupied and observed simultaneously to form a GNSS loop. Coordinates of points NGE-98 and NGE-107, and elevation value of NE-358, were held fixed during the processing of the control points as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 23. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
NGE-98	Global	Fixed	Fixed		
NGE-107	Global	Fixed	Fixed		
NE-358					Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 24. The fixed control points NGE-98 and NGE-107 have no values for grid errors; while NE-358 has no values for elevation error.

Table 24. Adjusted Grid Coordinates.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
NGE-98	488670.521	?	1035896.031	?	69.180	0.054	LL
NGE-107	487155.076	?	1019415.410	?	7.670	0.058	LL
NE-358	480099.830	0.009	1036810.192	0.008	5.116	?	e
NGE-94	458621.676	0.015	1042094.324	0.013	7.244	0.058	
UP-SIA	502963.760	0.013	1001378.367	0.011	8.267	0.070	

With the mentioned equation, $\sqrt{((x\_e)^2+(y\_e)^2)}<20cm$ for horizontal and $z^e<10$ cm for the vertical; the computation for the accuracy are as follows:

a. **NGE-98**
horizontal accuracy = Fixed
vertical accuracy = 5.40 < 10 cm

b. **NGE-107**
horizontal accuracy = Fixed
vertical accuracy = 5.80 cm < 10 cm

c. **NE-358**
horizontal accuracy = $\sqrt{((0.90)^2 + (0.80)^2}$
= $\sqrt{(0.81 + 0.64)}$
= 1.20 cm < 20 cm
vertical accuracy = Fixed

d. **NGE-94**
horizontal accuracy = $\sqrt{((1.50)^2 + (1.30)^2}$
= $\sqrt{(2.25 + 1.69)}$
= 1.98 cm < 20 cm
vertical accuracy = 5.80 cm < 10 cm

e. **UP-SIA**
horizontal accuracy = $\sqrt{((1.30)^2 + (1.10)^2}$
= $\sqrt{(1.69 + 1.21)}$
= 1.70 cm < 20 cm
vertical accuracy = 7.0 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the five (5) occupied control points are within the required precision.

Table 25. Adjusted Geodetic Coordinates.

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
NGE-98	N9°22'16.41564"	E122°53'48.54064"	132.087	0.054	LL
NGE-107	N9°13'19.76274"	E122°52'59.03199"	69.527	0.058	LL
NE-358	N9°22'46.06928"	E122°49'07.51892"	67.723	?	e
NGE-94	N9°25'37.57022"	E122°37'23.12090"	68.846	0.058	
UP-SIA	N9°03'32.50400"	E123°01'37.08746"	70.195	0.070	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 26.

Table 26. Reference and control points and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
NGE-98	2nd order, GCP	9°22'16.41564"N	122°53'48.54064"E	132.087	1035896.031	488670.521	69.180
NGE-107	Used as marker	9°13'19.76274"N	122°52'59.03199"E	69.527	1019415.410	487155.076	7.670
NE-358	1st order, BM	9°22'46.06928"N	122°49'07.51892"E	67.723	1036810.192	480099.830	5.116
NGE-94	UP Established	9°25'37.57022"N	122°37'23.12090"E	68.846	1042094.324	458621.676	7.244
UP-SIA	UP-Established	9°03'32.50400"N	123°01'37.08746"E	70.195	1001378.367	502963.760	8.267

4.5 Cross-section and Bridge As-Built survey and Water Level Marking

There are three bridges along Sicopong River namely, Sicopong Bridge, Amio Bridge, and Inobangan Bridge. Bridge as-built and cross-section survey was conducted on March 14, 2016 at the downstream side of Sicopong Bridge in Brgy. Villareal, Bayawan City using GNSS receiver Trimble® SPS 882 in PPK survey technique. Cross section survey was also conducted at the downstream side of Amio Bridge in Brgy. Amio, Municpality of Santa Catalina on March 15, 2016 using GNSS receiver Trimble® SPS 882 in PPK survey technique and a total station as shown in Figure 35. Cross section for the downstream side of Inobangan Bridge in Brgy. Kabucalan in the Municipality of Santa Catalina was conducted on March 19, 20 and 21, 2016 using GNSS receiver Trimble® SPS 882 in PPK survey technique and a total station as shown in Figure 36.

Figure 35. Cross-section survey conducted on Amio Bridge in Brgy. Amio, Municipality of Santa Catalina

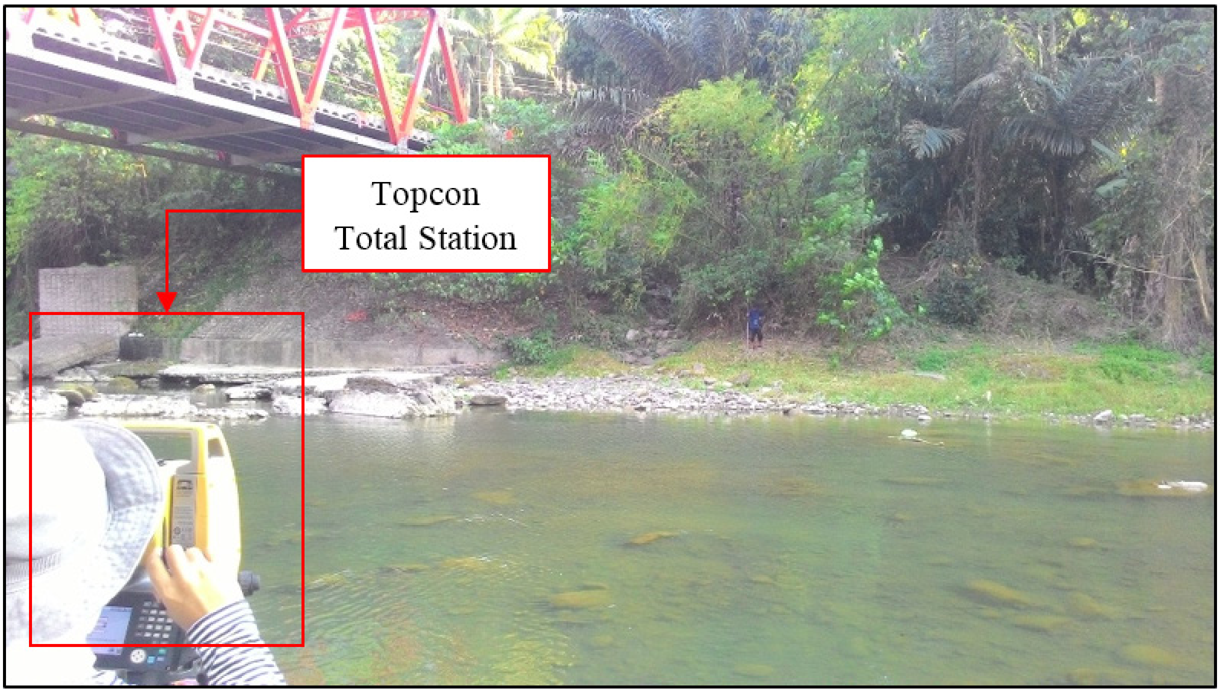


Figure 36. Cross-section survey conducted on Inobangan Bridge in Brgy. Kabulacan, Municipality of Santa Catalina

Figure 37. Cross-section survey conducted on Amio Spillway in Brgy. Narra, Bayawan City

The cross-sectional line length of Sicopong Bridge is about 164.37 m with 35 cross-sectional points acquired using NE-358 as the GNSS base station; 106.490 m with 41 points acquired for Amio Bridge using NGE-98 and NE-358; 82.039 m with 46 points acquired for Inobangan Bridge using NGE-98; and 62.754 m with 18 points for Amio Spillway using NGE-98 as base station. The location maps. cross-section diagrams, and the bridge data forms are shown in Figure 38 to Figure 48, respectively.

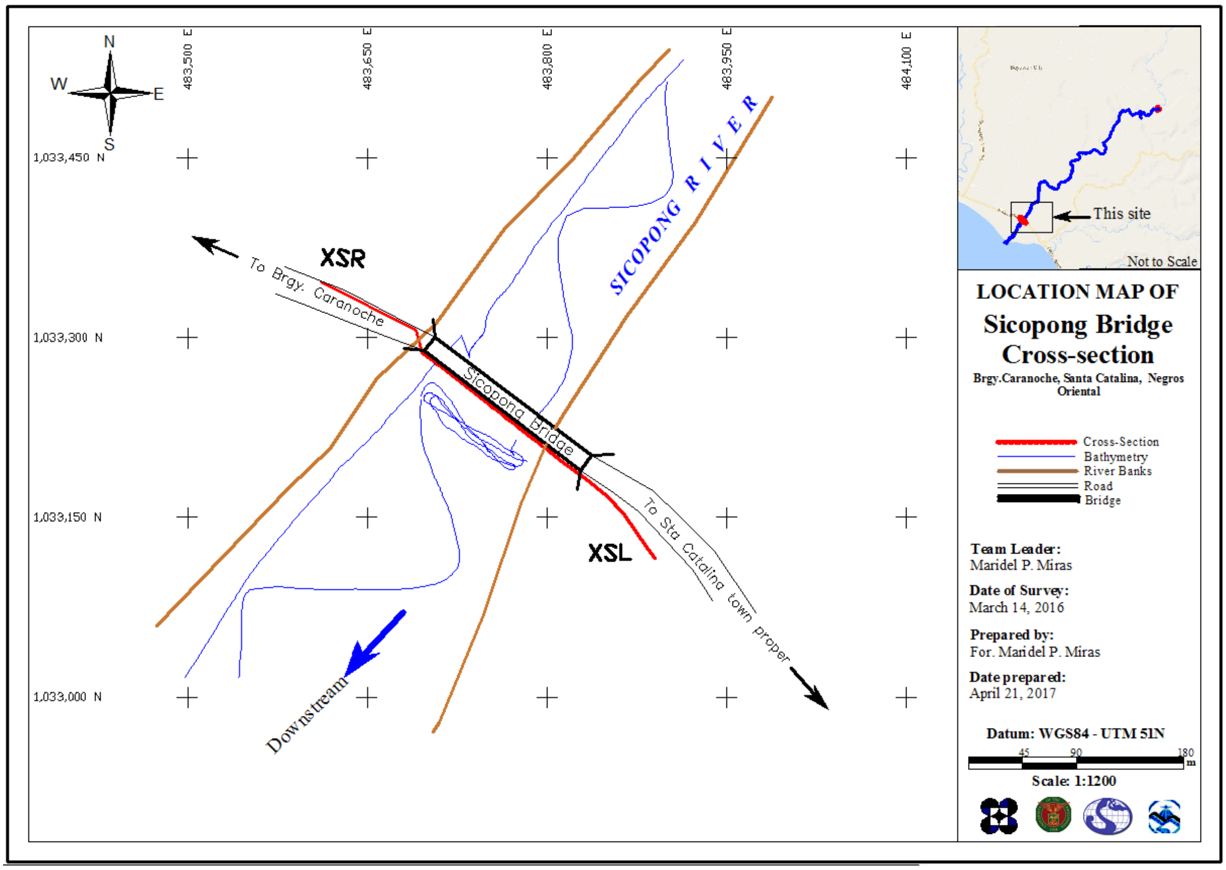


Figure 38. Location map of Sicopong River cross-section survey.

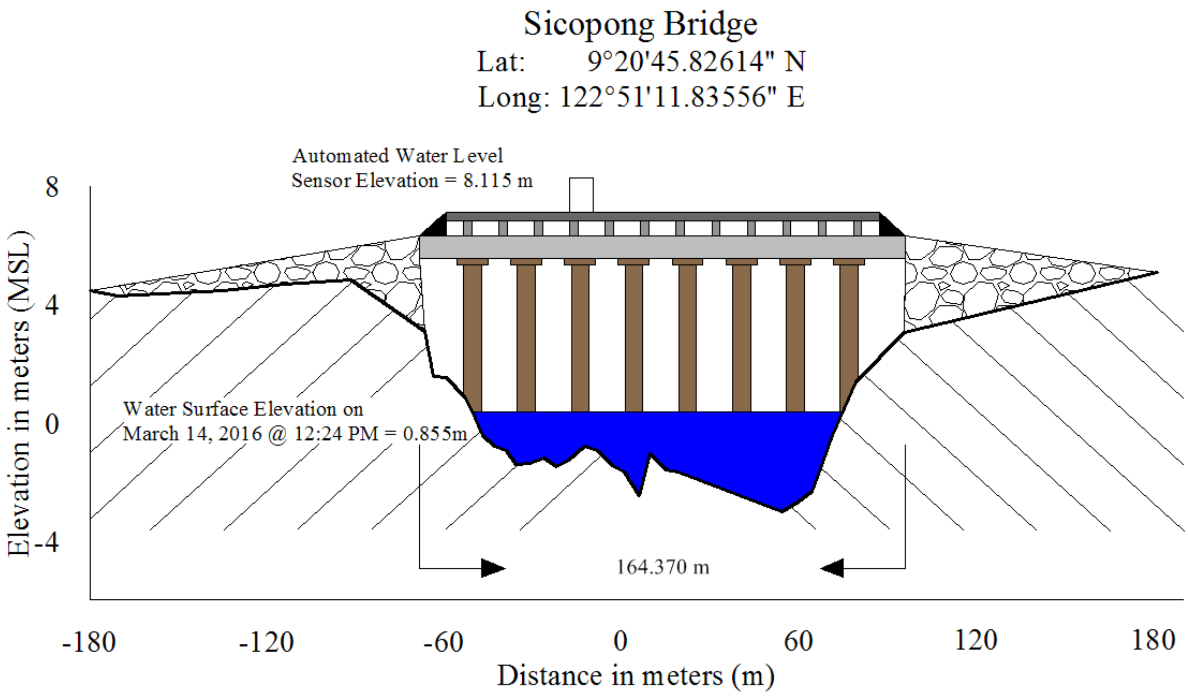


Figure 39. Sicopong River Cross-section Diagram.

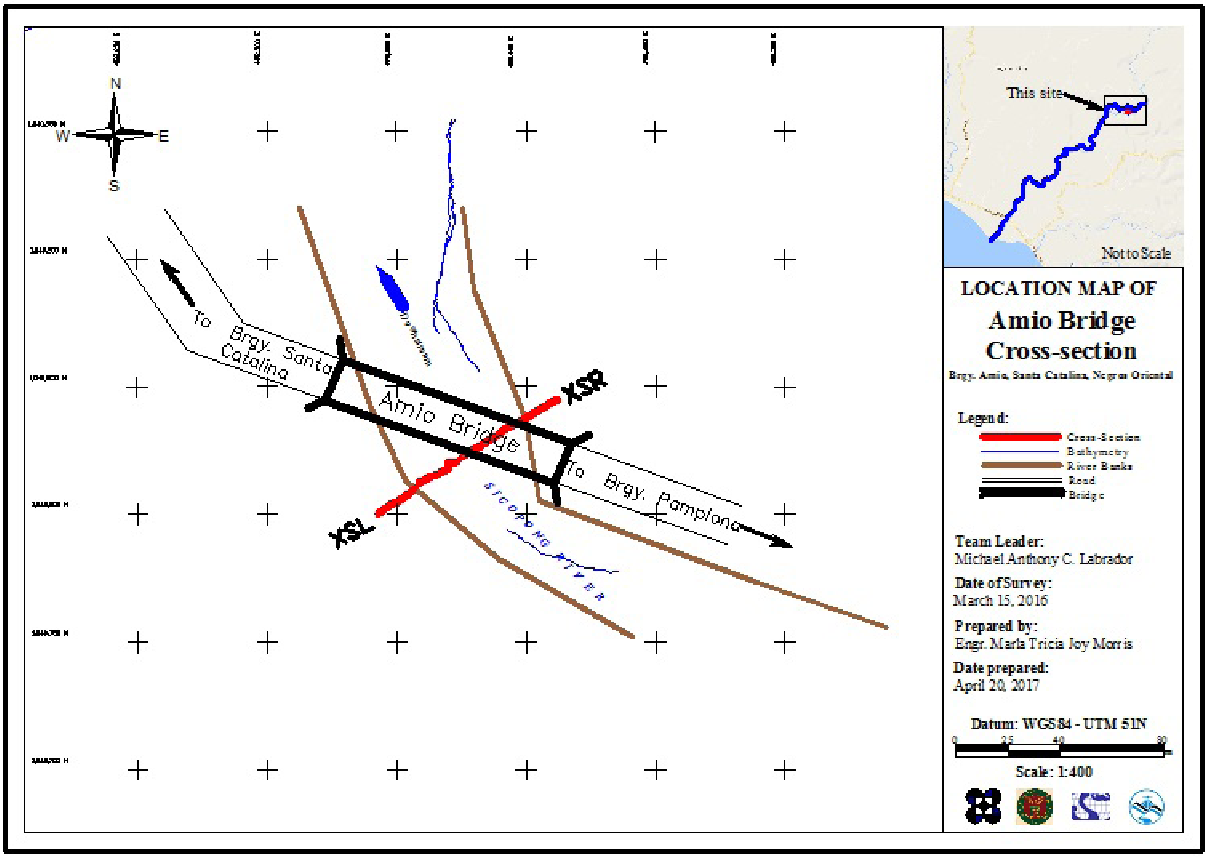


Figure 40. Amio bridge cross-section location map.

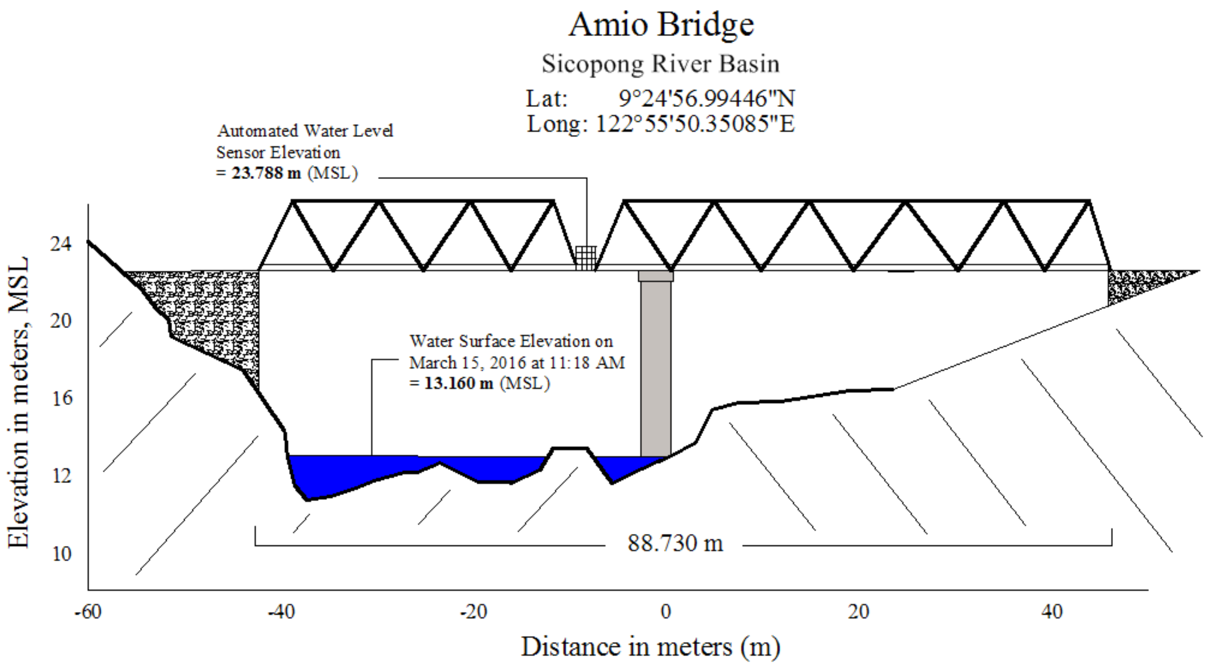


Figure 41. Amio cross-section diagram

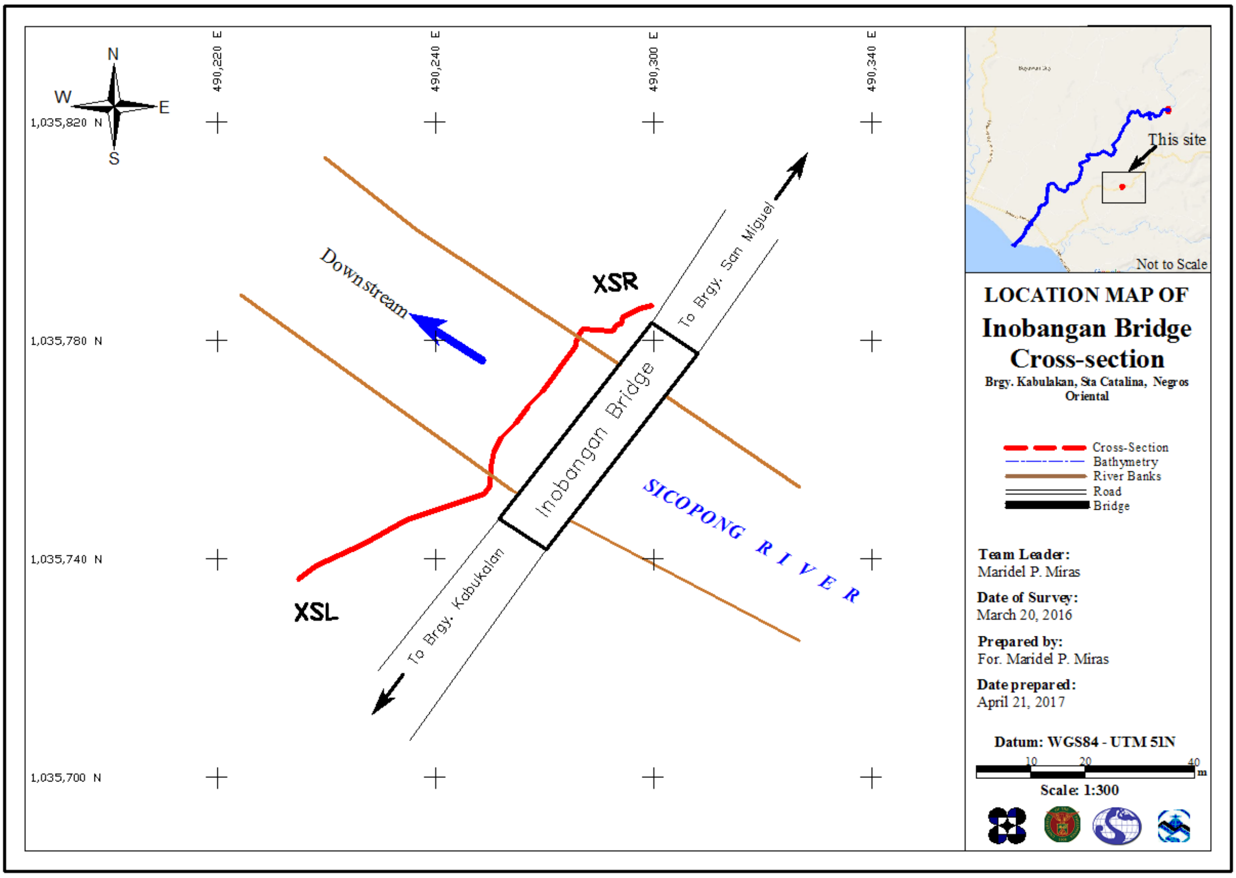


Figure 42. Inobangan bridge cross-section location map

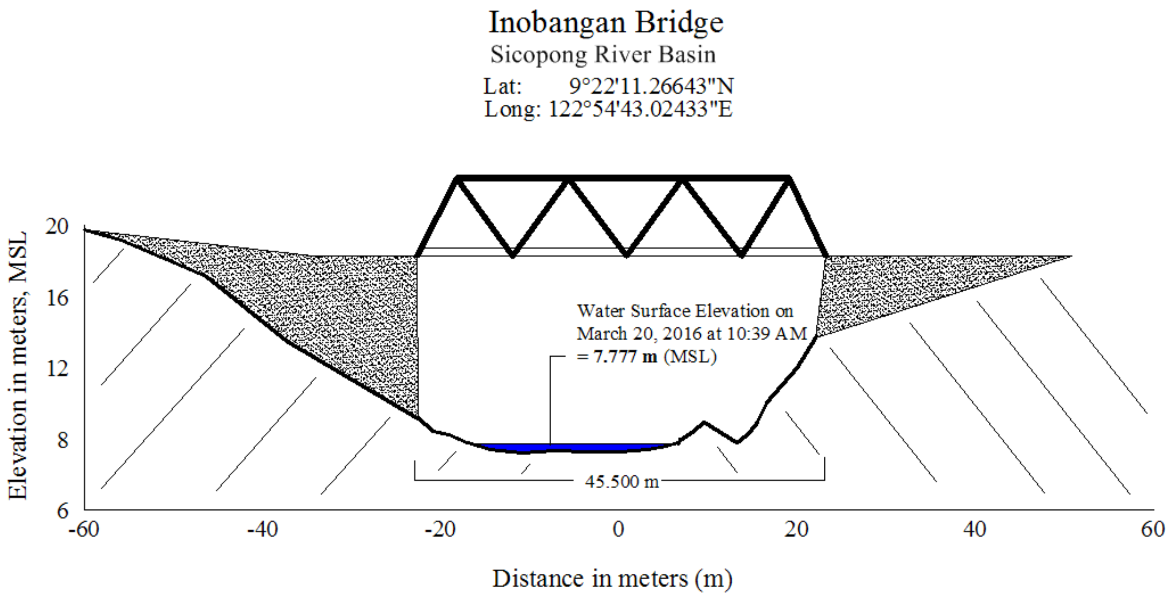


Figure 43. Inobangan cross-section diagram

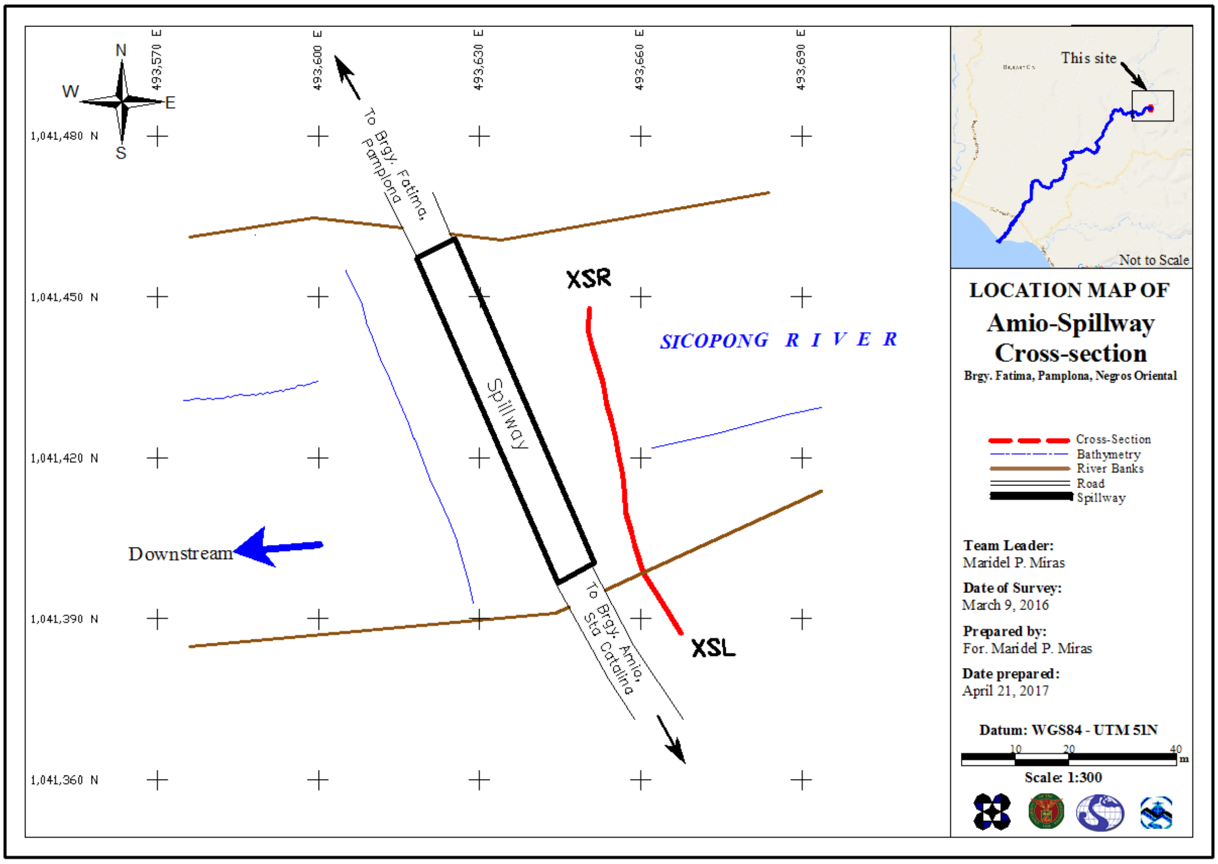


Figure 44. Amio spillway cross-section location map

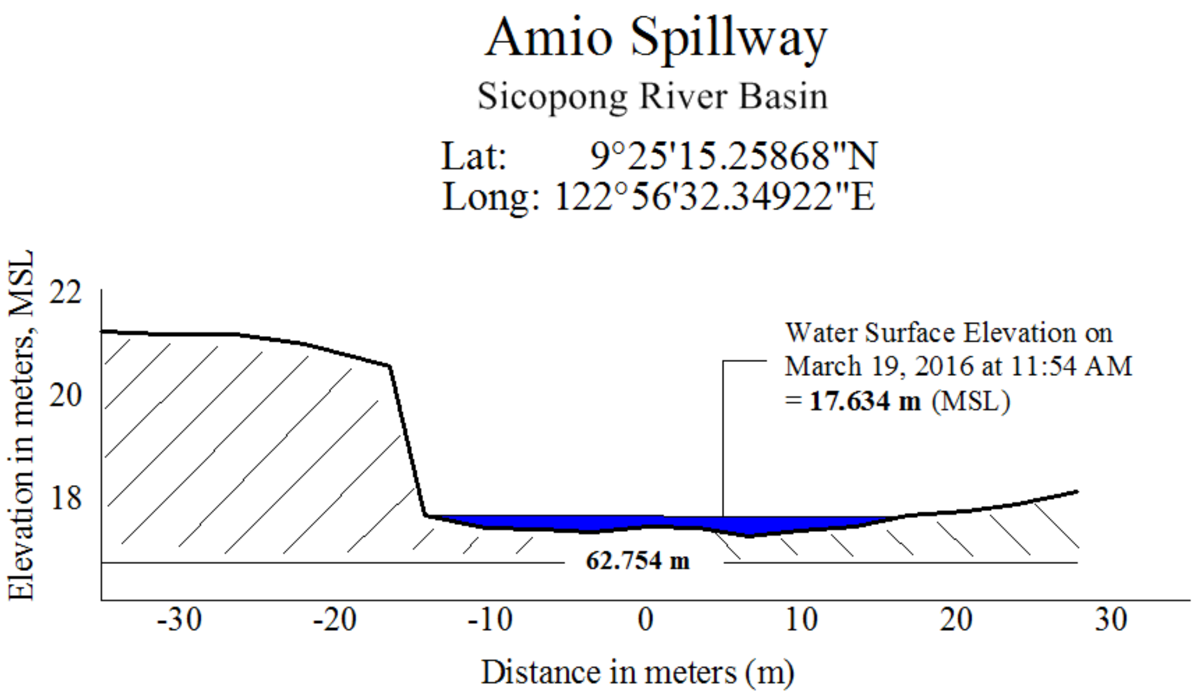


Figure 45. Amio Spillway Cross-section diagram

Bridge Data Form

Bridge Name: Sicopong Bridge **Date:** March 14, 2016

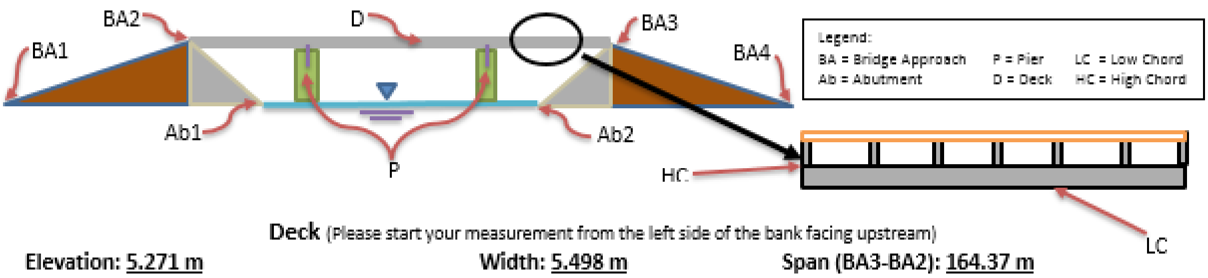
River Name: Sicopong River **Time:** 12:30 PM

Location (Brgy, City,Region): Brgy. Villareal, Bayawan City

Survey Team: Michael Labrador, Erlan Mendoza, Romalyn Boado, Maridel Miras, Rodel Alberto, Caren Ordona

Flow condition: normal **Weather Condition:** fair

Latitude: 9°20'45.82614" N **Longitude:** 122 ° 51'11.83556" E



Deck (Please start your measurement from the left side of the bank facing upstream)

Elevation: 5.271 m **Width:** 5.498 m **Span (BA3-BA2):** 164.37 m

	Station	High Chord Elevation	Low Chord Elevation
1	N/A		

Bridge Approach (Please start your measurement from the left side of the bank facing upstream)

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	4.471m	BA3	276.013m	5.544m
BA2	111.646m	5.271m	BA4	361.457m	5.069m

Abutment: Is the abutment sloping? **Yes** ; If yes, fill in the following information:

	Station (Distance from BA1)	Elevation
Ab1	116.210	1.560m
Ab2	N/A	

Pier (Please start your measurement from the left side of the bank facing upstream)

Shape: Cylinder Number of Piers: 8 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	129.607m	5.638m	8.77m
Pier 2	147.733m	5.796m	8.77m
Pier 3	165.926m	5.977m	8.77m
Pier 4	184.104m	6.199m	8.77m
Pier 5	202.310m	6.208m	8.77m
Pier 6	220.554m	6.069m	8.77m
Pier 7	238.809m	5.901m	8.77m
Pier 8	257.010m	5.749m	8.77m

NOTE: Use the center of the pier as reference to its station

Figure 46. Sicopong Bridge diagram data form

Bridge Data Form

Bridge Name: Amio Bridge — **Date:** March 15, 2016

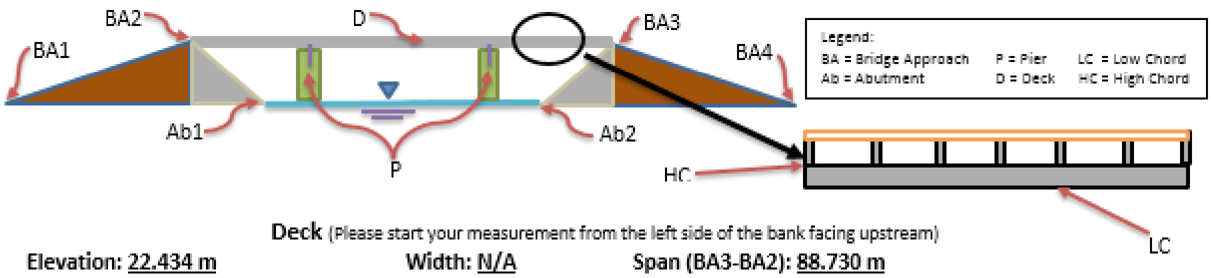
River Name: Sicopong River — **Time:** 11:18 AM

Location (Brgy, City,Region): Brgy. Amio, Municipality of Sta. Catalina

Survey Team: Michael Labrador, Erlan Mendoza, Romalyn Boado, Mady Miras, Rodel Alberto, Caren Ordona

Flow condition: normal — **Weather Condition:** fair

Latitude: 9°24'56.99446" N — **Longitude:** 122 °55'50.35085" E



Deck (Please start your measurement from the left side of the bank facing upstream)

Elevation: 22.434 m — **Width:** N/A — **Span (BA3-BA2):** 88.730 m

	Station	High Chord Elevation	Low Chord Elevation
1	N/A	NA	NA

Bridge Approach (Please start your measurement from the left side of the bank facing upstream)

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	22.434m	BA3	106.49m	22.511m
BA2	17.76m	22.545m	BA4	N/A	

Abutment: Is the abutment sloping? No; If yes, fill in the following information:

	Station (Distance from BA1)	Elevation
Ab1	N/A	NA
Ab2	N/A	NA

Pier (Please start your measurement from the left side of the bank facing upstream)

Shape: Oblong — Number of Piers: 1 — Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	58m	22.545m	1.5m

NOTE: Use the center of the pier as reference to its station

Figure 47. Amio Bridge diagram data form

Bridge Data Form

Bridge Name: Inobangan Bridge **Date:** March 20, 2016

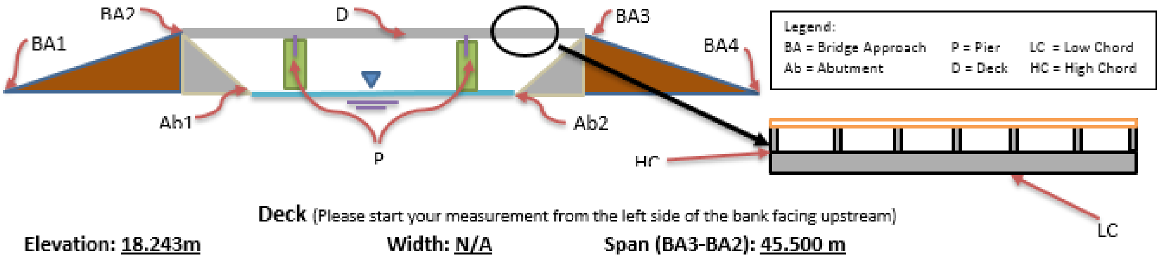
River Name: Sicopong River **Time:** 10:39 AM

Location (Brgy, City,Region): Brgy. Kabulacan, Municipality of Sta. Catalina

Survey Team: Michael Labrador, Erlan Mendoza, Romalyn Boado, Mady Miras, Rodel Alberto, Caren Ordona

Flow condition: normal **Weather Condition:** fair

Latitude: 9°22'11.26643" N **Longitude:** 122 °54'43.02433" E



Deck (Please start your measurement from the left side of the bank facing upstream)

Elevation: 18.243m **Width:** N/A **Span (BA3-BA2):** 45.500 m

	Station	High Chord Elevation	Low Chord Elevation
1	N/A		

Bridge Approach (Please start your measurement from the left side of the bank facing upstream)

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	18.243m	BA3	57m	18.243m
BA2	11.5m	18.243m	BA4	85m	18.243m

Abutment: Is the abutment sloping? **No** ; If yes, fill in the following information:

	Station (Distance from BA1)	Elevation
Ab1	N/A	NA
Ab2	N/A	NA

Pier (Please start your measurement from the left side of the bank facing upstream)

Shape: N/A Number of Piers: N/A Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
N/A			

NOTE: Use the center of the pier as reference to its station

Figure 48. Inobangan Bridge diagram data form

Water surface elevation in MSL of Sicopong River was determined on March 14, 2016 12:24 PM at Sicopong Bridge with a value of 0.855 m in MSL; on March 15, 2016 11:18 AM at Amio Bridge with a value of 13.160 m in MSL; on March 20, 2016 10:39 AM at Inobangan Bridge with a value of 7.777 m in MSL; and on March 19, 2016 11:54 AM at Amio Spillway m in MSL. The GNSS Trimble® SPS 882 in PPK mode technique was used all throughout the survey.

Water level values gathered for Inobangan and Amio Spillway were translated onto marking on the dikes along the river using a digital level as shown in Figure 49 and Figure 50, respectively. The markings with corresponding MSL values will serve as reference for flow data gathering and depth gauge deployment of USC for Sicopong river.

Figure 49. Water level marking on Inobangan Bridge abutment

Figure 50. Water level marking on Amio spillway

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on March 14, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached to the side of vehicle as shown in Figure 51. It was secured with cable ties to ensure that it was horizontally and vertically balanced. The antenna height was 2.265 m measured from the ground up to the bottom of notch of the GNSS rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with NE-358 occupied as the GNSS base station all throughout the conduct of the survey.

Figure 51. Validation points acquisition survey set-up

The validation points acquisition survey for the Sicopong River Basin traversed Bayawan City and the Municipality of Santa Catalina. The route of the survey aims to traverse LiDAR flight strips perpendicularly for the basin. A total of 43,714 points with an approximate length of 30.14 km was acquired for the validation point acquisition survey as shown in the map in Figure 52.

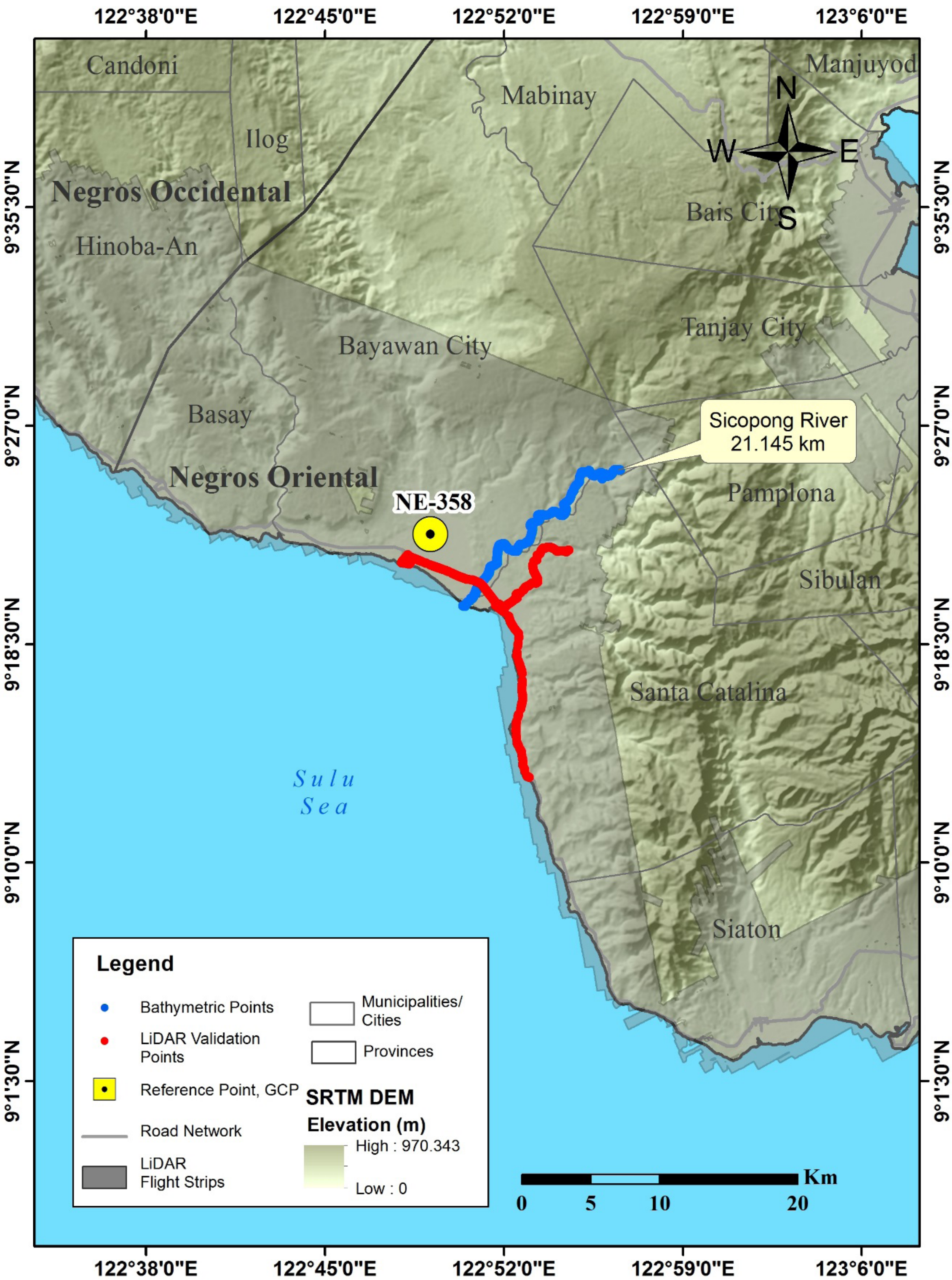


Figure 52. LiDAR Validation points acquisition survey for Sicopong River Basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on March 14, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique and Ohmex™ single beam echo sounder, as illustrated in Figure C-26. The extent of the survey is from Brgy. San Isidro, Bayawan City with coordinates 9d22'37.86971" N, 122d53'03.03631"E, down to the mouth of the river in Brgy. Villareal, Bayawan City with coordinates 9d19'58.38494"N, 122d50'24.08632"E, as shown in the map in Figure 53.

Manual bathymetric survey was done on March 19, 2016 using a Trimble® SPS 882 GNSS PPK survey technique as shown in Figure 54. The survey began from the upstream portion of the river at Amio Spillway in Brgy. Narra, Bayawan City with coordinates 9d25'17.24892"N, 122d56'34.03185"E; traversed down by foot and ended at the starting point of the bathymetric survey using an echo sounder in the same barangay. The control points NGE-98 and NE-358 were occupied as the GNSS base stations all throughout the surveys.

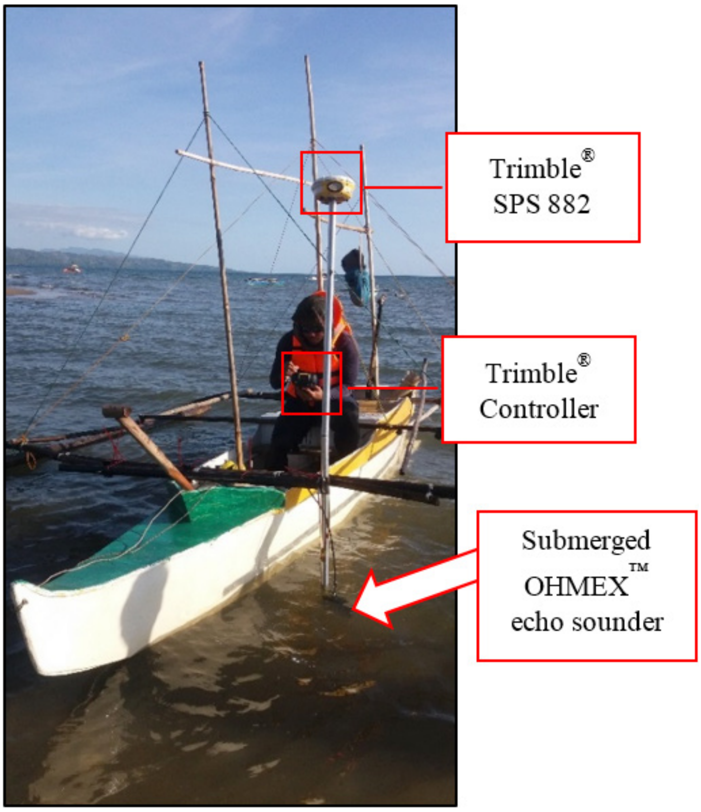


Figure 53. Bathymetric survey in Sicopong River

Figure 54. Manual bathymetric survey in Sicopong River.

The bathymetric survey gathered a total of 32,002 points covering 21.145 km of the river traversing a small portion of Brgy. Narra, Bayawan City, Negros Oriental, and Brgy. Villareal, Bayawan City, Negros Occidental (Figure 55).

Figure 55. Bathymetric survey of Sicopong River

A CAD drawing was also produced to illustrate the riverbed profile of Sicopong River. As shown in Figure 56 and Figure 57, the highest and lowest elevation has a 24.294-meter difference. The highest elevation observed was 21.205 m above MSL located at the upmost portion of the river while the lowest was -3.089 m below MSL located at the downstream portion of the river in Brgy. Villareal, Bayawan City.

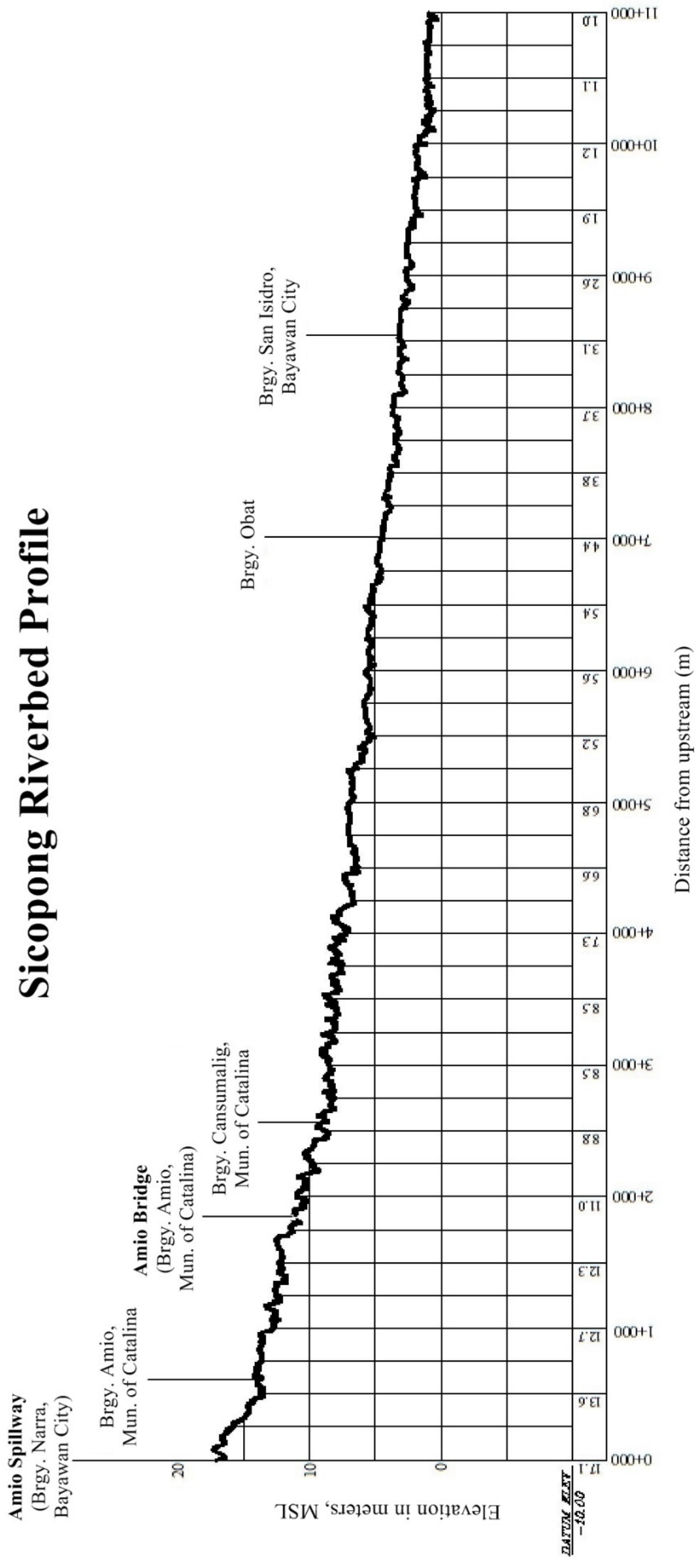


Figure 56. Sicopong riverbed profile

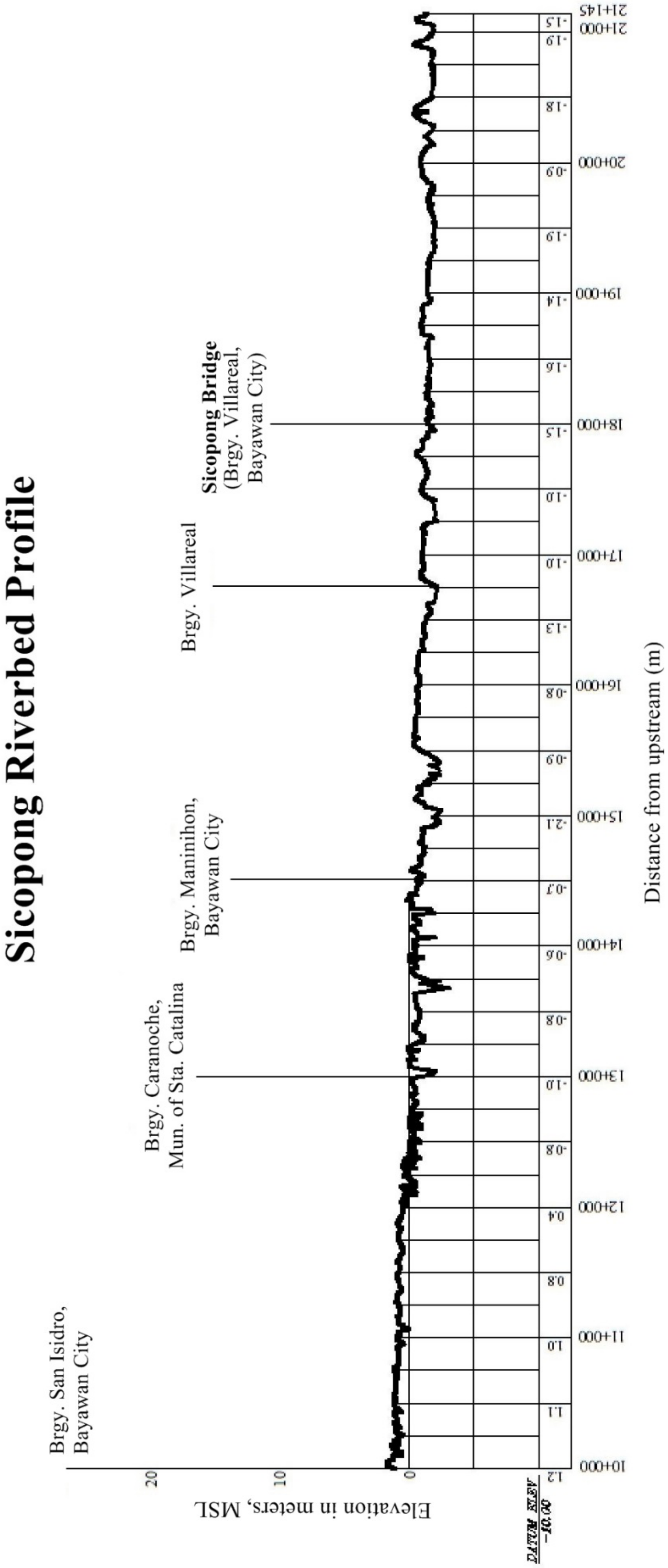


Figure 57. Sicopong riverbed profile

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, and Pauline Racoma

The methods applied in this chapter were based on the DREAM methods manual (Lagmay, et. al., 2014) and further enhanced and updated in Paringit, et. al. (2017).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All data that affect the hydrologic cycle of the Sicopong River Basin were monitored, collected, and analyzed. Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Sicopong River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from a data logging rain gauge installed by the University of San Carlos Phil LiDAR Project. The rain gauge was installed in the Brgy San Miguel, Sta Catalina with geographic coordinates of 9.35281°N and 122.943°E. The location of the rain gage in the watershed in presented in Figure 58. The total precipitation data used for calibration is 14.3 mm. The rainfall event was used started at 9:10 in the morning and ended at 11:30 in the morning on July 14, 2017.

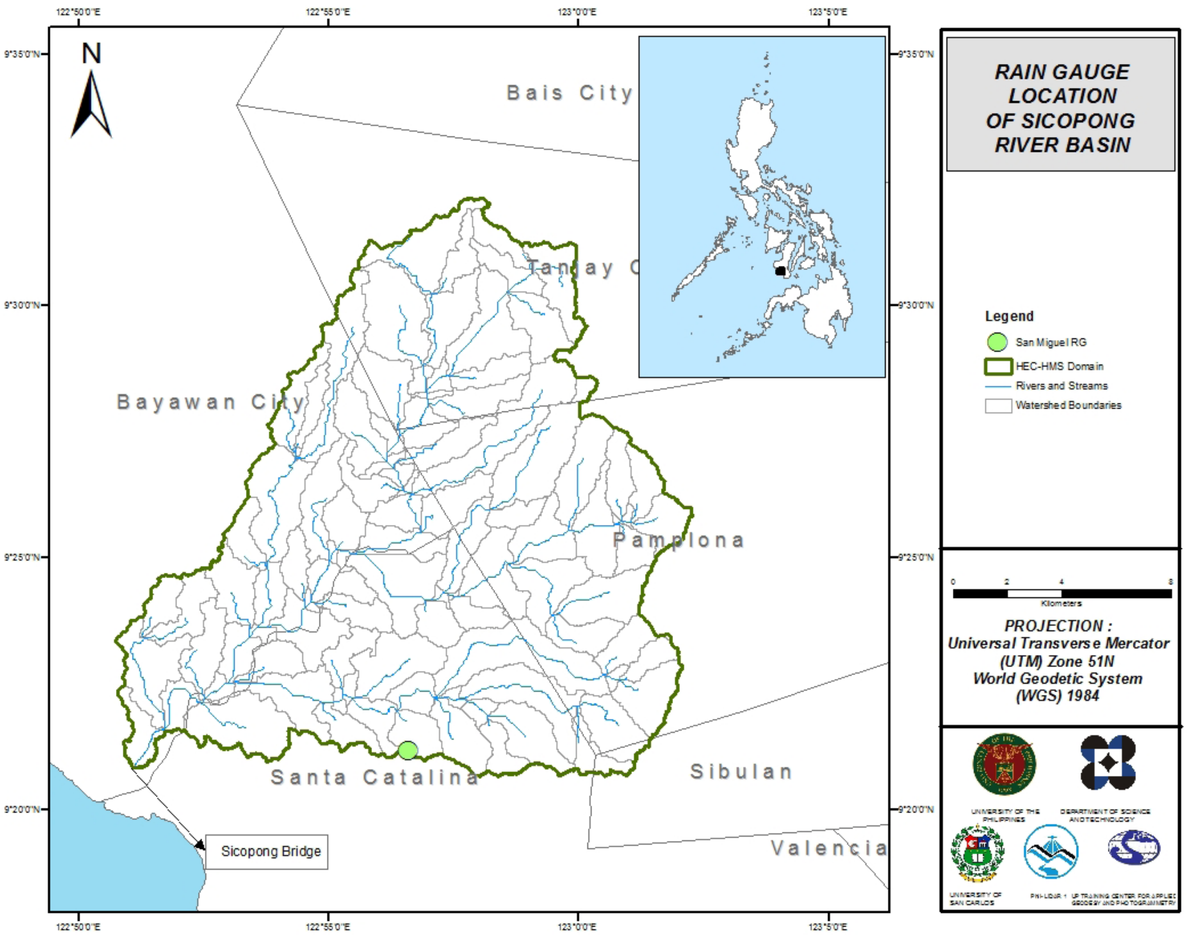


Figure 58. Location map of Sicopong HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Sicopong Bridge (9.347278° N and 122.852023°E). It gives the relationship between the observed water levels and outflow of the watershed at this location. It is expressed in the form of the following equation:

$$Q=a^{nh}$$

where, Q : Discharge (m3/s),
h : Gauge height (reading in Sicopong Bridge), and;
a and n : Constants.

For Sicopong Bridge the rating curve is expressed y=7.60316e^x as shown in Figure 60.

This image is not available for this river basin.

Figure 59. Cross-Section Plot of Sicopong Bridge

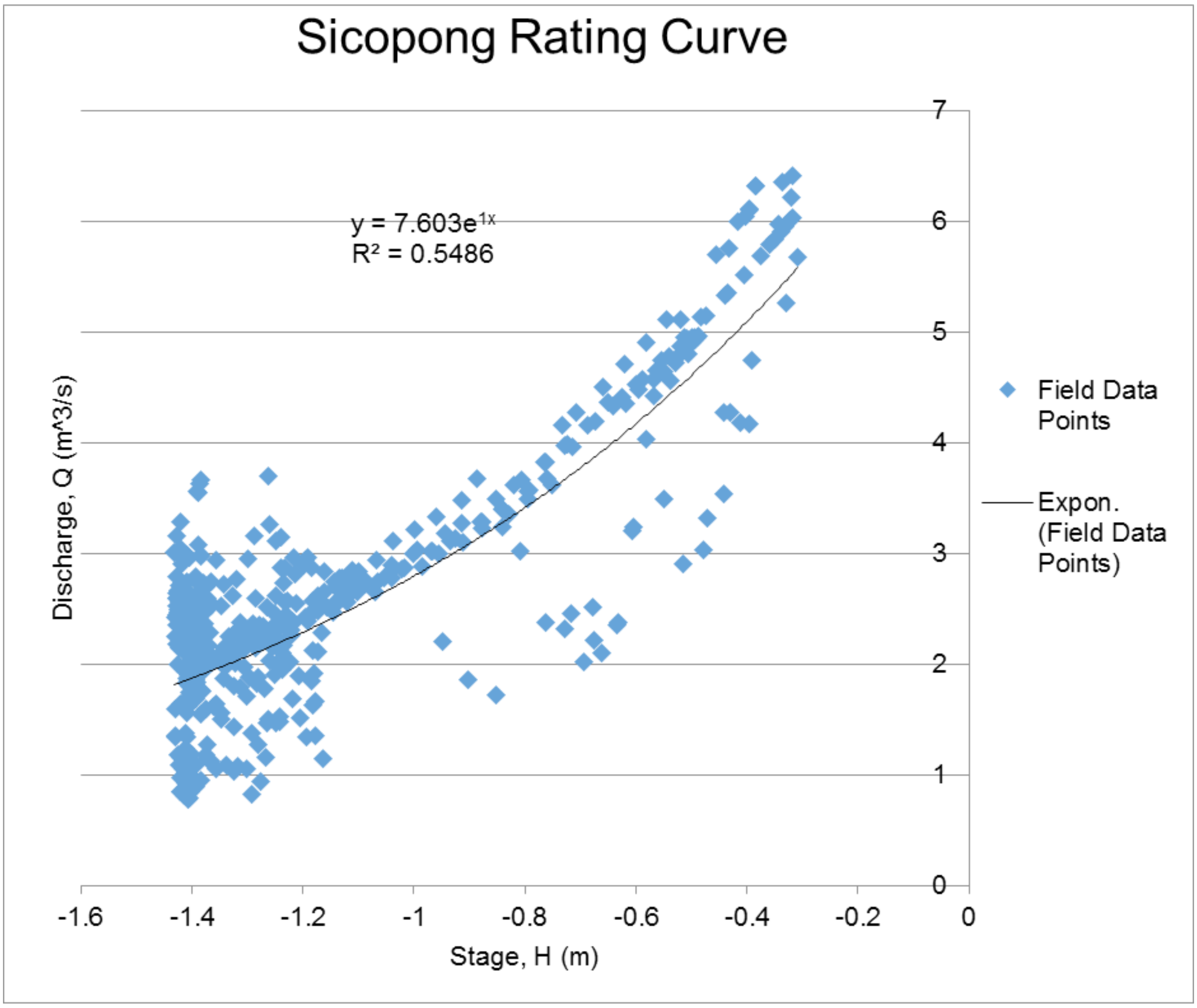


Figure 60. Rating curve at Sicopong Bridge in Sicopong River

This rain and outflow in Sicopong Bridge used for the calibration of the HMS Model of Sicopong is shown in Figure 61. Peak discharge is 67.67 m3/s at 15:30, July 14, 2017.

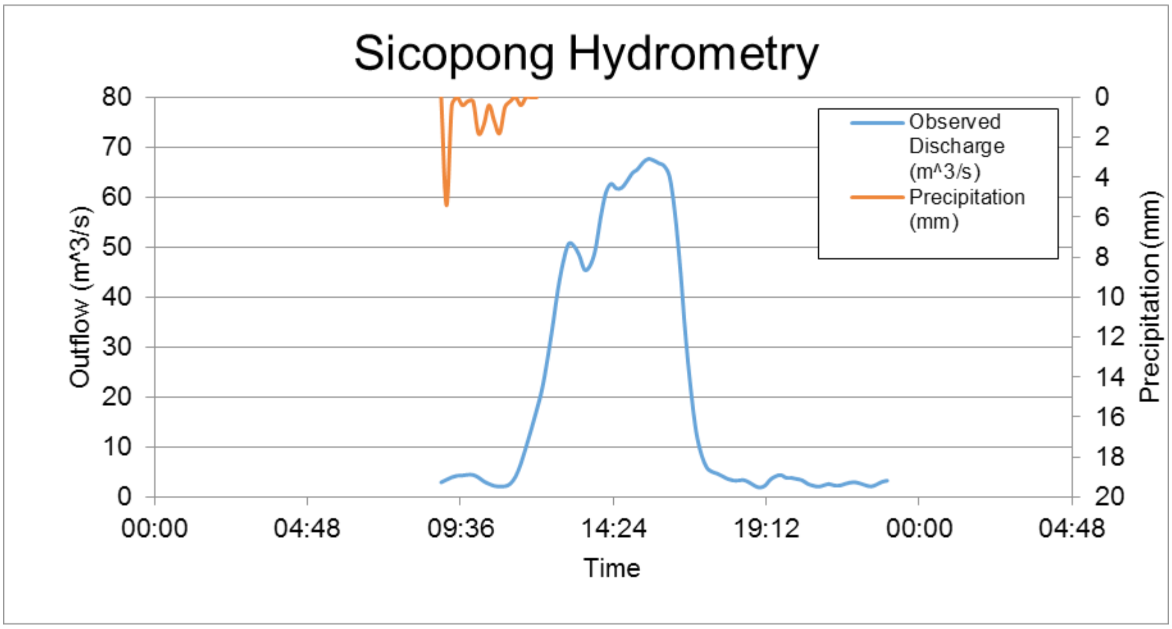


Figure 61. Rainfall and outflow data at Sicopong Bridge used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Dumaguete Point Gauge. This station chosen based on its proximity to the Sicopong watershed. Sicopong extreme values for this watershed were computed based on a 35-year record Table 27.

Table 27. RIDF values for Dumaguete Point Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	16.2	24.8	30.6	39.7	50	55.3	63.4	69.1	76
5	21.8	33.6	42.3	57.1	76.5	87.3	100	109.5	116.5
10	25.6	39.4	50	68.6	94	108.5	124.3	136.3	143.3
15	27.7	42.7	54.3	75.1	103.9	120.5	138	151.4	158.4
20	29.1	45	57.4	79.7	110.8	128.9	147.5	162	169
25	30.3	46.8	59.7	83.2	116.1	135.3	154.9	170.2	177.2
50	33.8	52.3	66.9	94	132.5	155.2	177.6	195.3	202.4
100	37.2	57.7	74.1	104.8	148.8	174.9	200.2	220.2	227.3

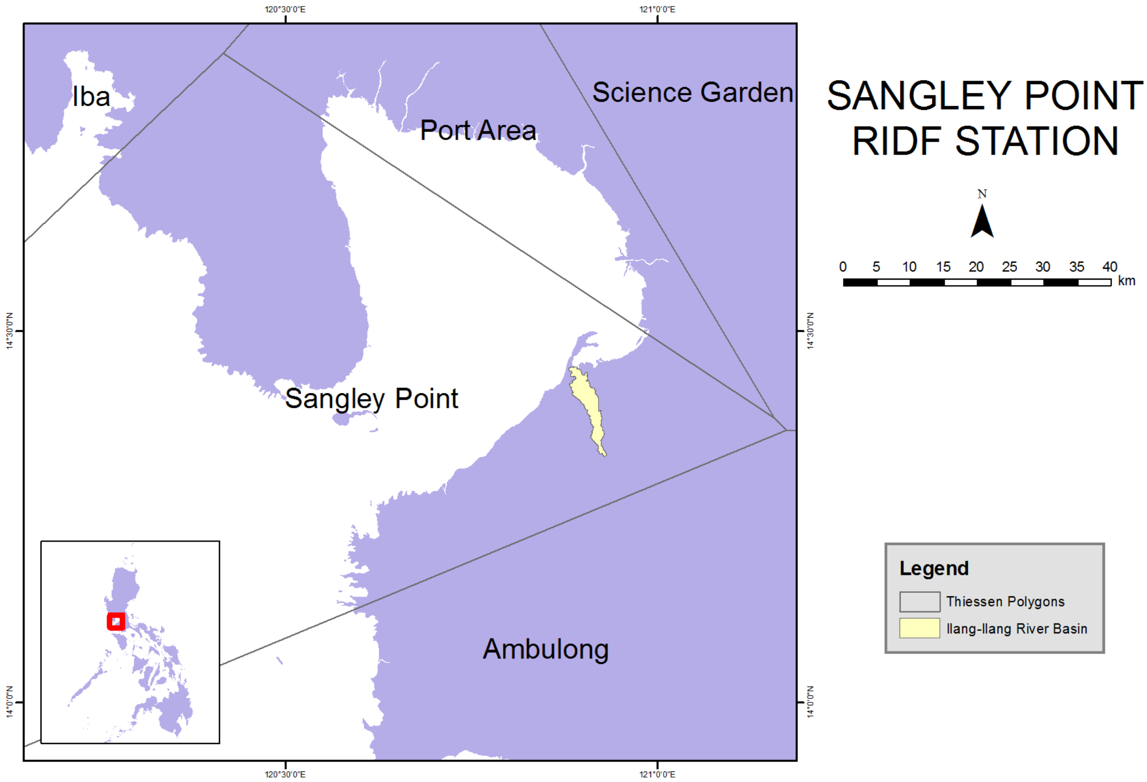


Figure 62.Location of Dumaguete RIDF Station relative to Sicopong River Basin

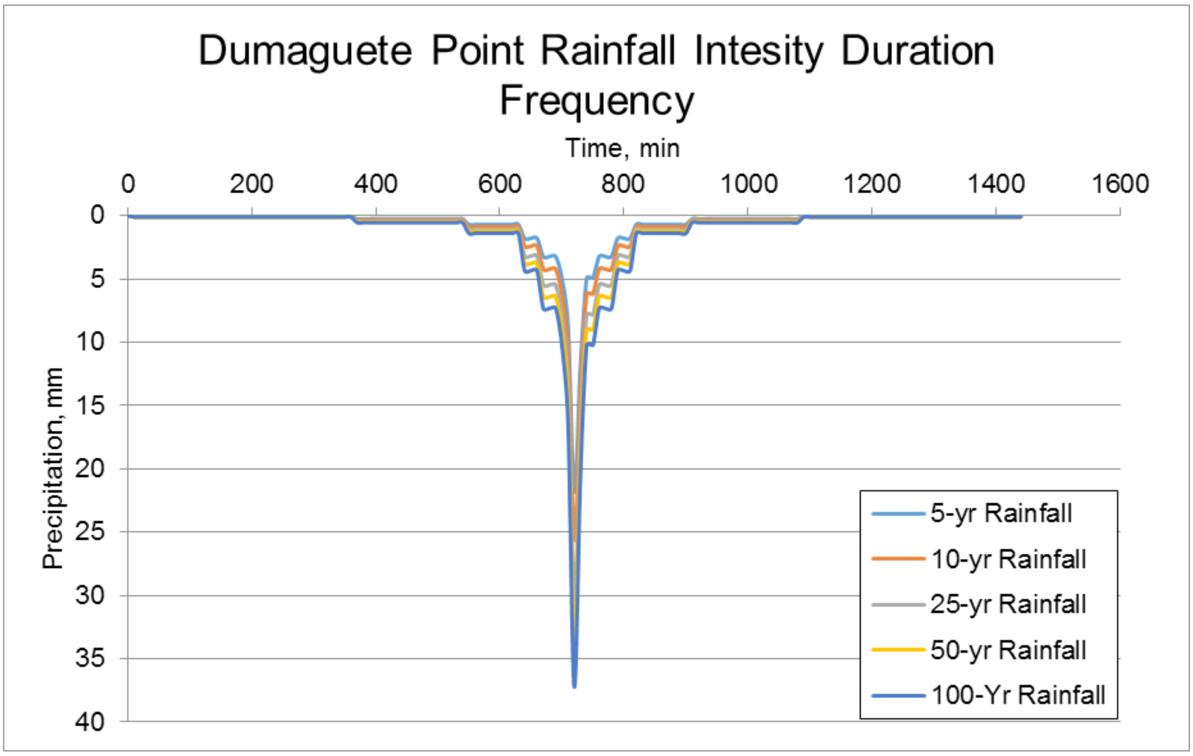


Figure 63. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management under the Department of Agriculture (DA-BSWM). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Sicopong River Basin are shown in Figure 64 and Figure 65, respectively.

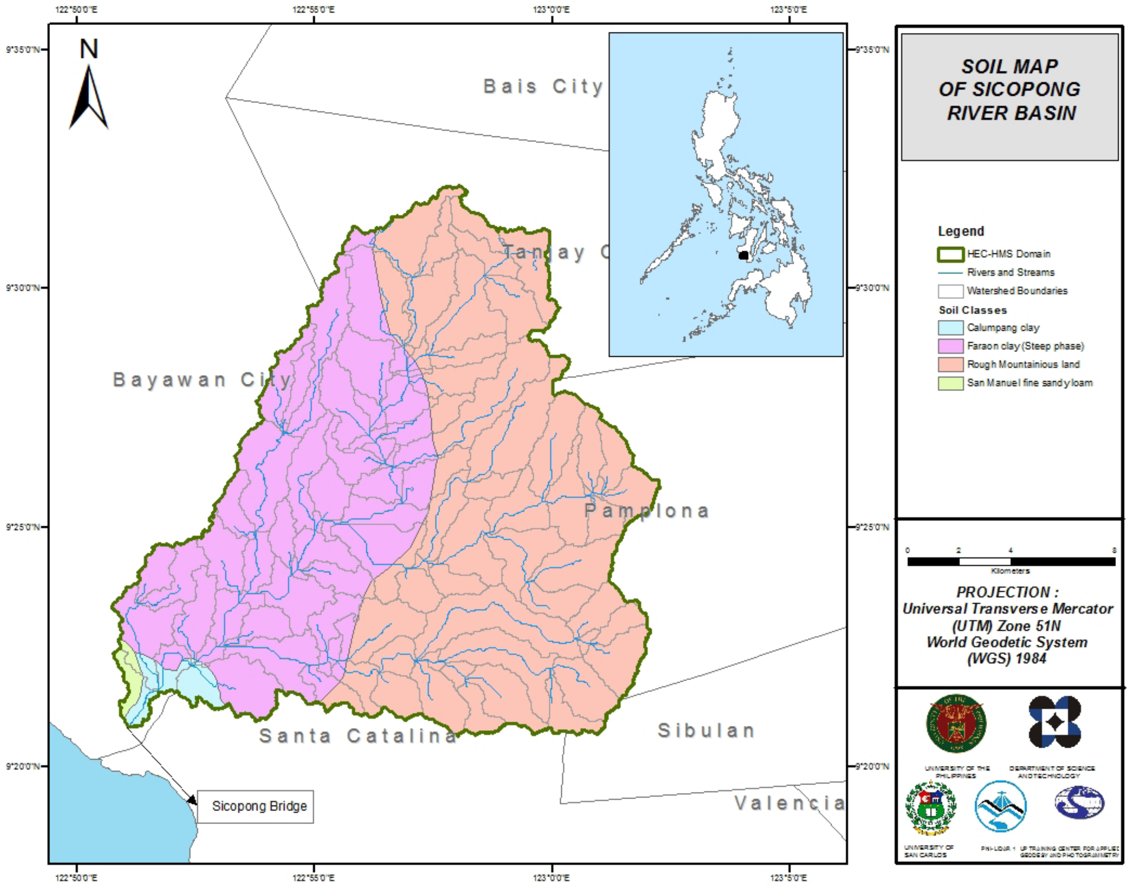


Figure 64. Soil map of the Sicopong River Basin used for the estimation of the CN parameter. (Source: DA)

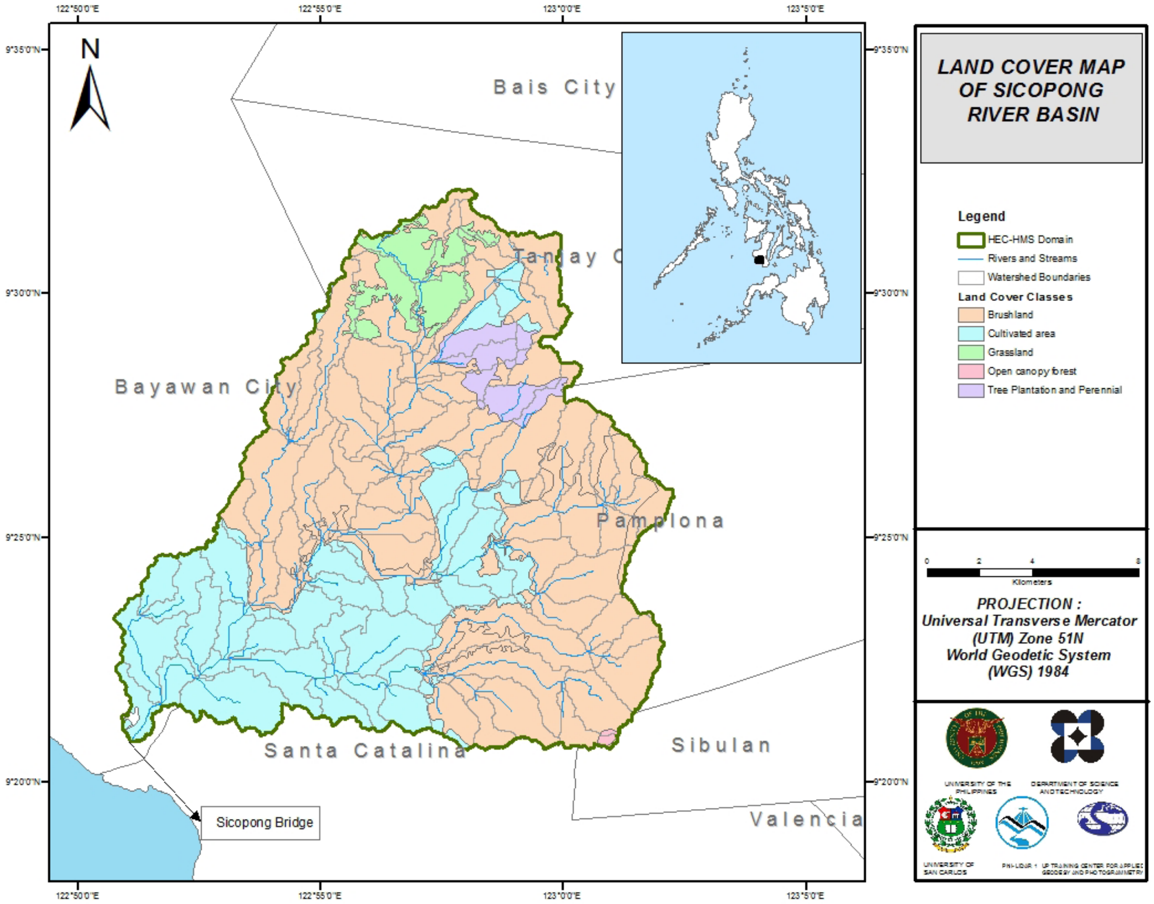


Figure 65. Land cover map of Tiabanan River Basin used for the estimation of the Curve Number (CN) and the watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For the Sicopong river basin, four (4) soil classes were identified. The Sicopong river basin is mostly rough mountainous land and Faraon clay (steep phase), with small portions of Calumpang clay and San Manuel fine sandy loam. Moreover, five (5) land cover classes were identified. Most of the Sicopong river basin is largely brushland and cultivated area, with small patches of grassland, tree plantation and perennial, and open canopy forest land cover.

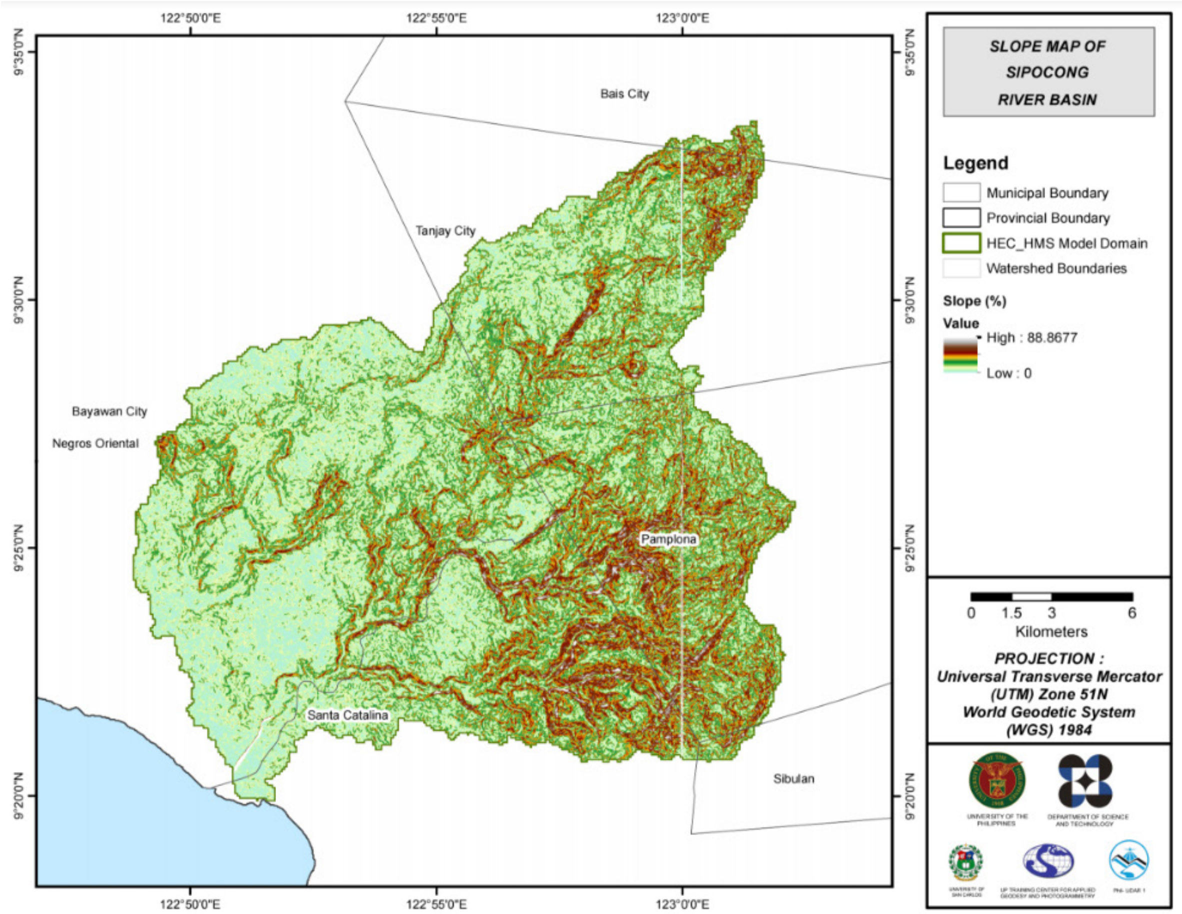


Figure 66. Slope map of Sicopong River Basin.

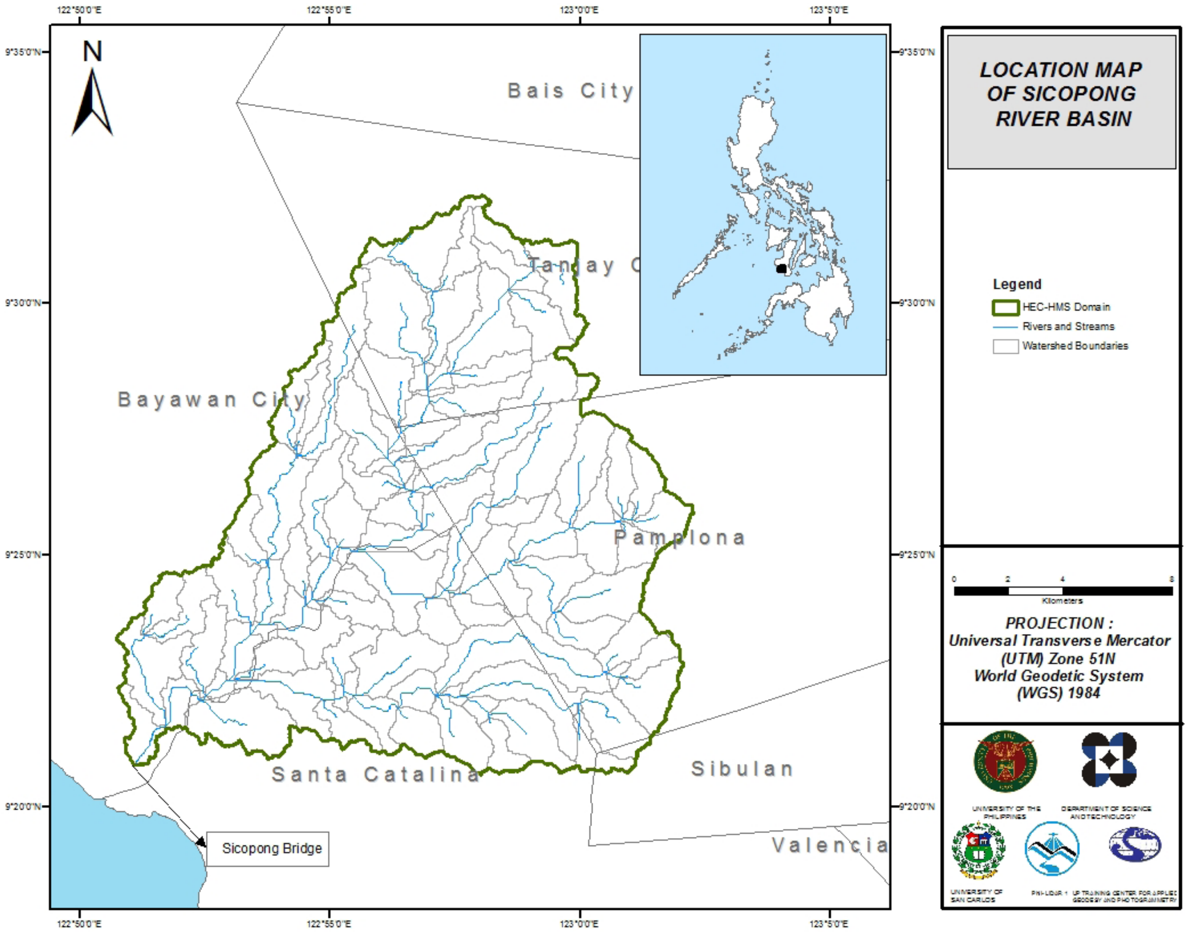


Figure 67. Stream delineation map of Sicopong River Basin

The Sicopong basin model comprises 101 sub basins, 50 reaches, and 50 junctions. The main outlet is outlet 1. This basin model is illustrated in Figure 68. The basins were identified based on soil and land cover characteristic of the area. Precipitation was taken from an installed rain gauge near and inside the river basin. Finally, it was calibrated using the data from actual discharge flow gathered in the Sicopong Bridge.

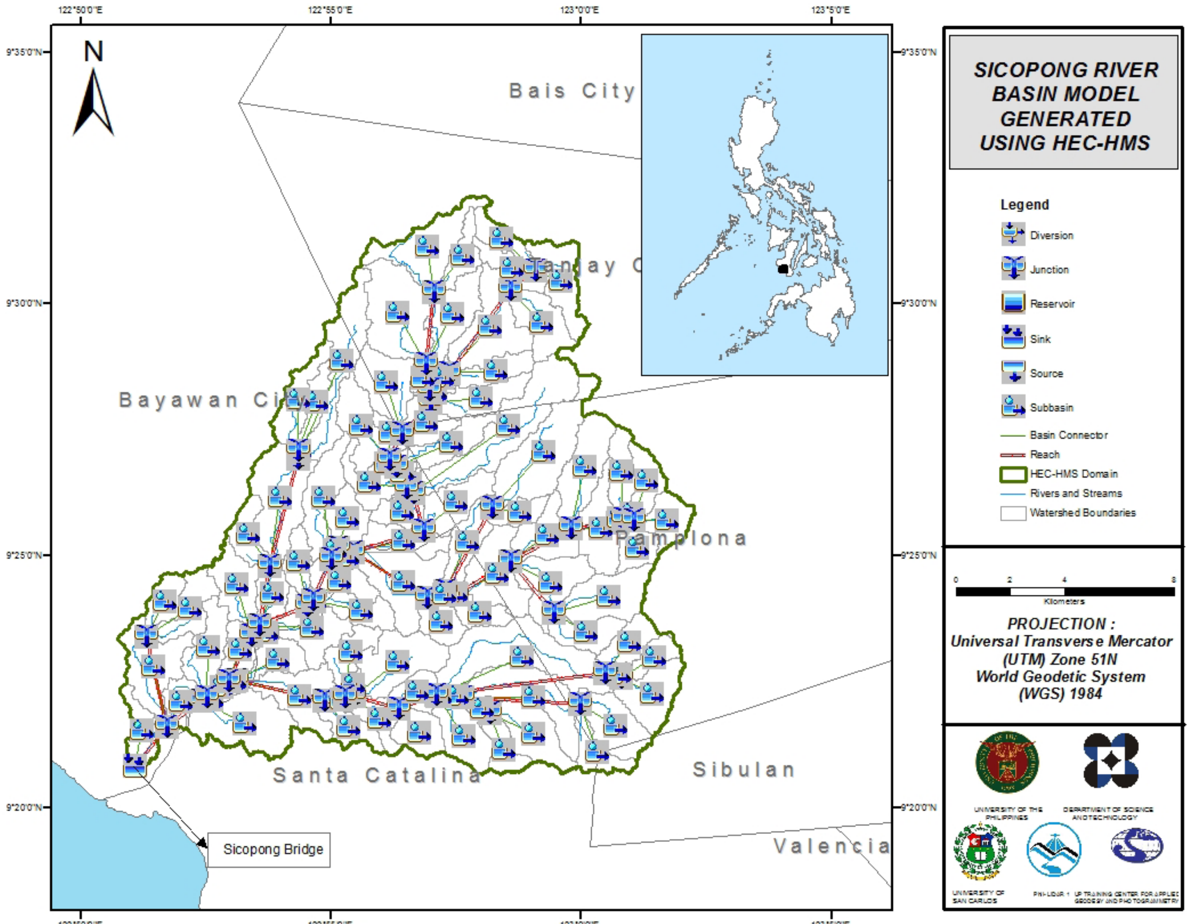


Figure 68. HEC-HMS generated Sicopong River Basin Model.

5.4 Cross-section Data

Riverbed cross-sections of the watershed are crucial in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived using the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS. This is illustrated in Figure 69.

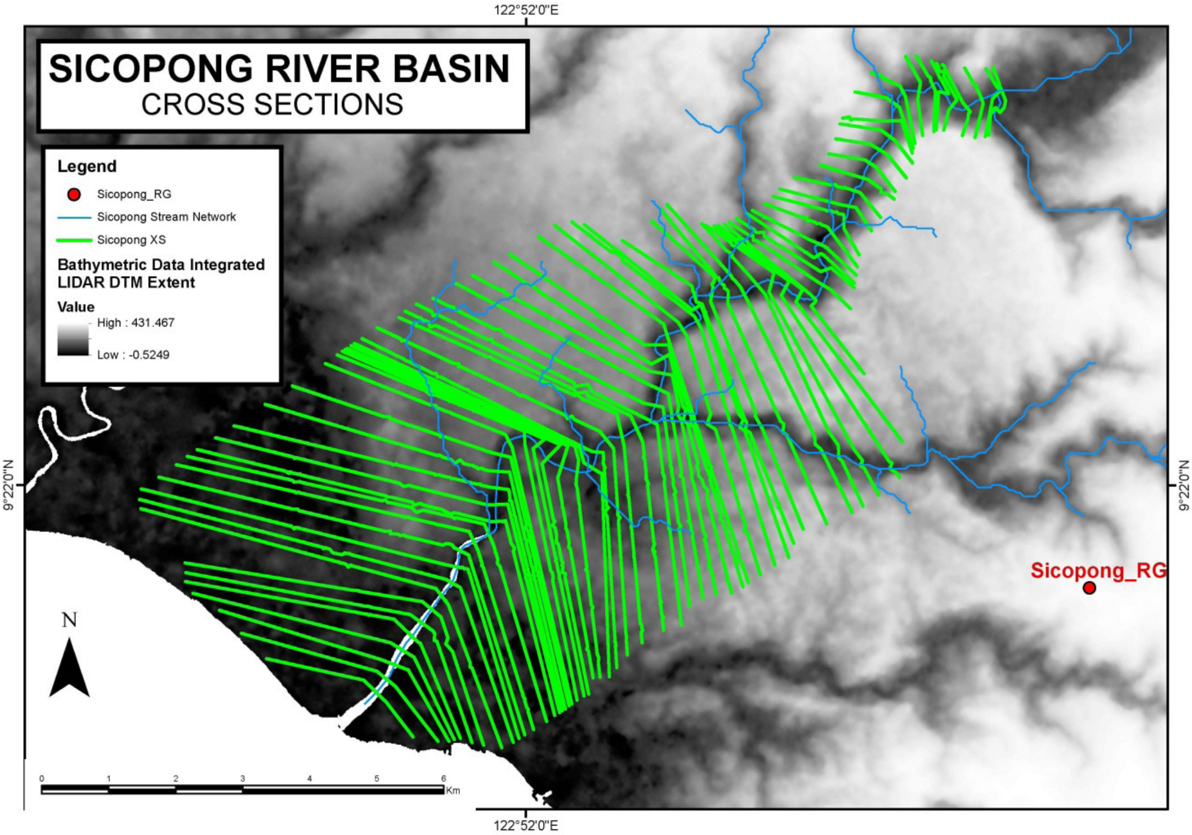


Figure 69. River cross-section of Sicopong River generated through Arcmap HEC GeoRAS tool.

5.5 Flo 2D Model

The automated modelling process allows for the creation of a model with boundaries that are almost exactly coincidental with that of the catchment area. As such, they have approximately the same land area and location. The entire area is divided into square grid elements, 10 meter by 10 meter in size. Each element is assigned a unique grid element number which serves as its identifier, then attributed with the parameters required for modelling such as x-and y-coordinate of centroid, names of adjacent grid elements, Manning coefficient of roughness, infiltration, and elevation value. The elements are arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements and in eight directions (north, south, east, west, northeast, northwest, southeast, southwest).

Based on the elevation and flow direction, it is seen that the water will generally flow from the northeast of the model to the southwest, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

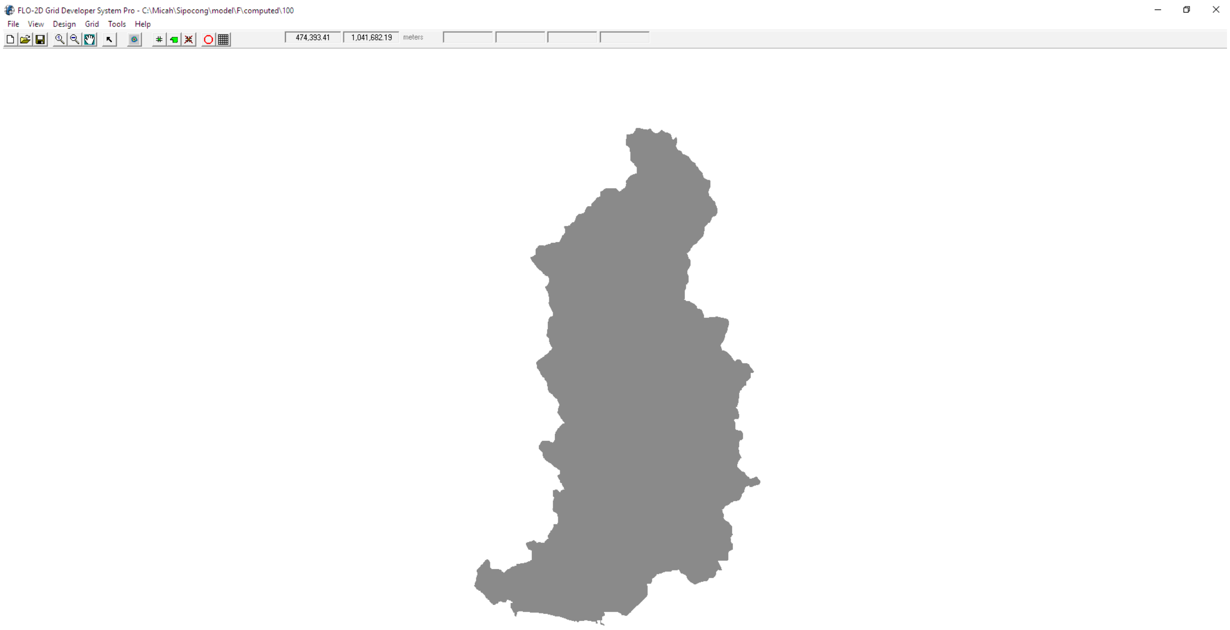


Figure 70. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 19.19775 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 24 523 300.00 m2.

There is a total of 52 082 025.29 m3 of water entering the model. Of this amount, 5 608 006.37 m3 is due to rainfall while 46 474 018.91 m3 is inflow from other areas outside the model. 3 018 355.50 m3 of this water is lost to infiltration and interception, while 9 171 441.57 m3 is stored by the flood plain. The rest, amounting up to 39 892 229.24 m3, is outflow.
The rest, amounting up to 139 066 229.25 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Sicopong HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 71 shows the comparison between the two discharge data.

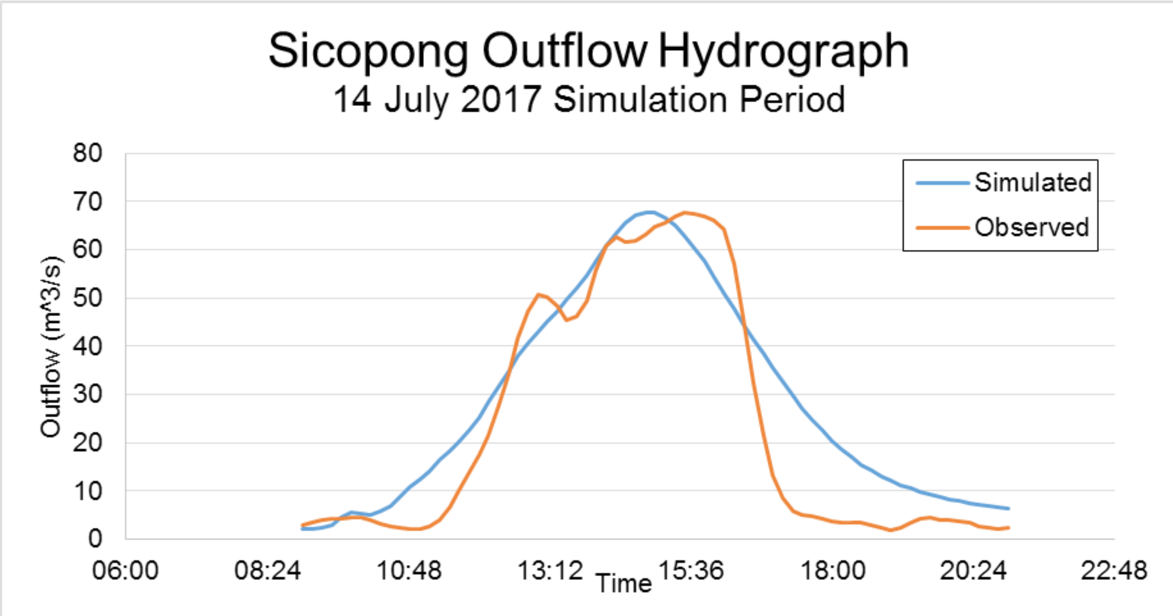


Figure 71. Outflow Hydrograph of Sicopong produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 28 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 28. Range of calibrated values for Tiabanan Watershed

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	0.57-13.76
			Curve Number	39.34-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0-100
			Storage Coefficient (hr)	0.02-199.99
	Baseflow	Recession	Recession Constant	0.02-23.14
			Ratio to Peak	0-0.01
Reach	Routing	Muskingum-Cunge	Manning’s Coefficient	0-0.03

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.57-13.76mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of curve numbers for Sicopong is 39.34-99 since it is consists mostly of grasslands and the soil consists of clay and mountainous land.

Time of Concentration is the travel time of runoff in a watershed. The range of calibrated values from 0.02-199.99 minutes determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant 0-0.01 indicates that the basin is unlikely to quickly return to its original discharge.

Manning's roughness coefficient of 0.014-0.8 corresponds to the landcover types in Sicopong riverbasin. These were identified as most brushland and cultivated areas (Brunner, 2010).

Table 29. Summary of the Efficiency Test of Sicopong HMS Model.

Accuracy measure	Value
RMSE	8.8913
r2	0.9535
NSE	0.8665
PBIAS	-23
RSR	0.3654

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 8.8913.

The Pearson correlation coefficient (assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9536.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.8665.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -23.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.3654.

5.7 Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 72) show the Sicopong outflow using the Dumaguete Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-, 10-, 25-, 50-, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a uniform duration of 24 hours and varying return periods.

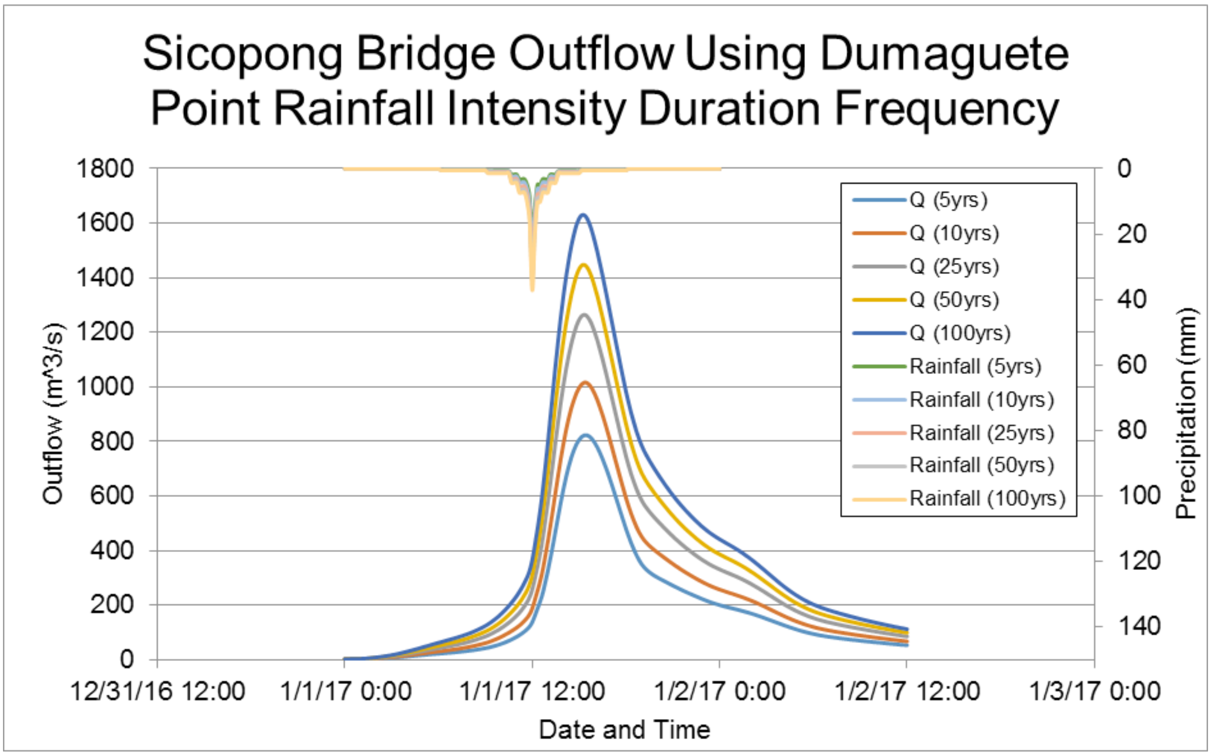


Figure 72. Outflow hydrograph at Sicopong Bridge, Sta. Catalina generated using Dumaguete Point RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Sicopong River discharge using the Dumaguete Point Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 30.

Table 30. Peak values of the Tiabanan HECHMS Model outflow using the Dumaguete RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-year RIDF	116.5	21.800	822.907	3 hours, 30 minutes
10-year RIDF	143.3	25.600	1,015.751	3 hours, 20 minutes
25-year RIDF	177.2	30.300	1,264.251	3 hours, 20 minutes
50-year RIDF	202.4	33.800	1,447.268	3 hours, 20 minutes
100-year RIDF	227.3	37.200	1,629.255	3 hours, 20 minutes

5.7.2 Discharge data using Dr. Horritt's recommended hydrologic method

The river discharge values for the river entering the floodplain are shown in and the peak values are summarized in Table 31.

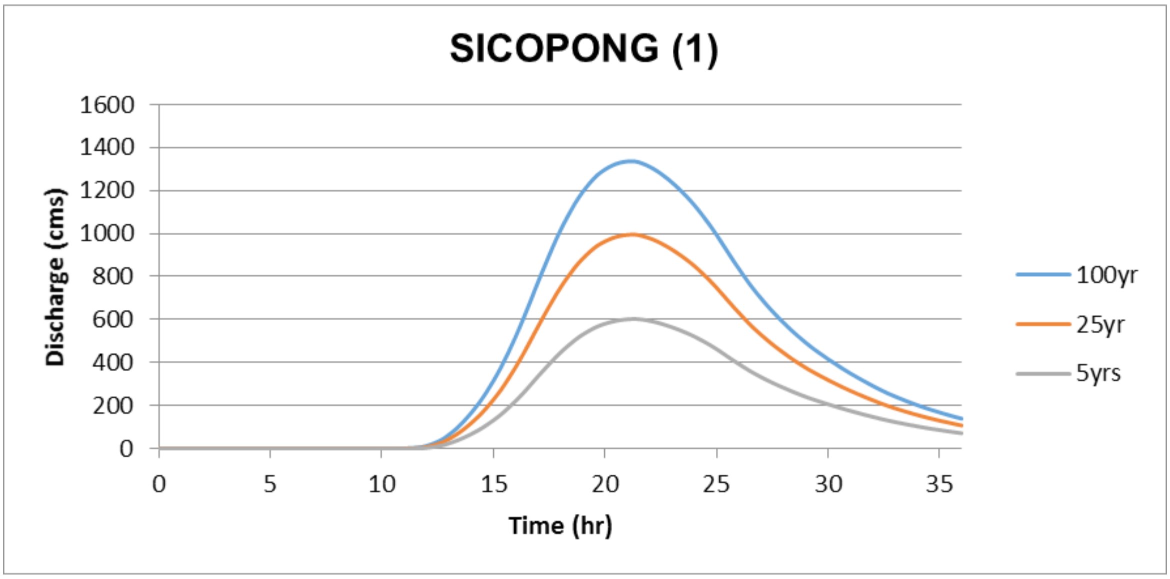


Figure 73. Sicopong river (1) generated discharge using 5-, 25-, and 100-year Dumaguete rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 31. Summary of Sicopong river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	2015.3	16 hours, 20 minutes
25-Year	1485.5	16 hours, 20 minutes
5-Year	873.3	16 hours, 20 minutes

Table 32. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Sicopong (1)	768.504	1088.954	456.556	Pass	Fail

The values from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful discharge method but it failed to satisfy the conditions for validation using the specific discharge method. The calculated values are based on theory but are supported using other discharge computation methods so they were good to use for flood modeling. However, these values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM/ Phil-LiDAR 1 website. For this publication, only a sample output map river was to be shown. The sample generated map of Sicopong River using the calibrated event flow is shown in Figure 74.

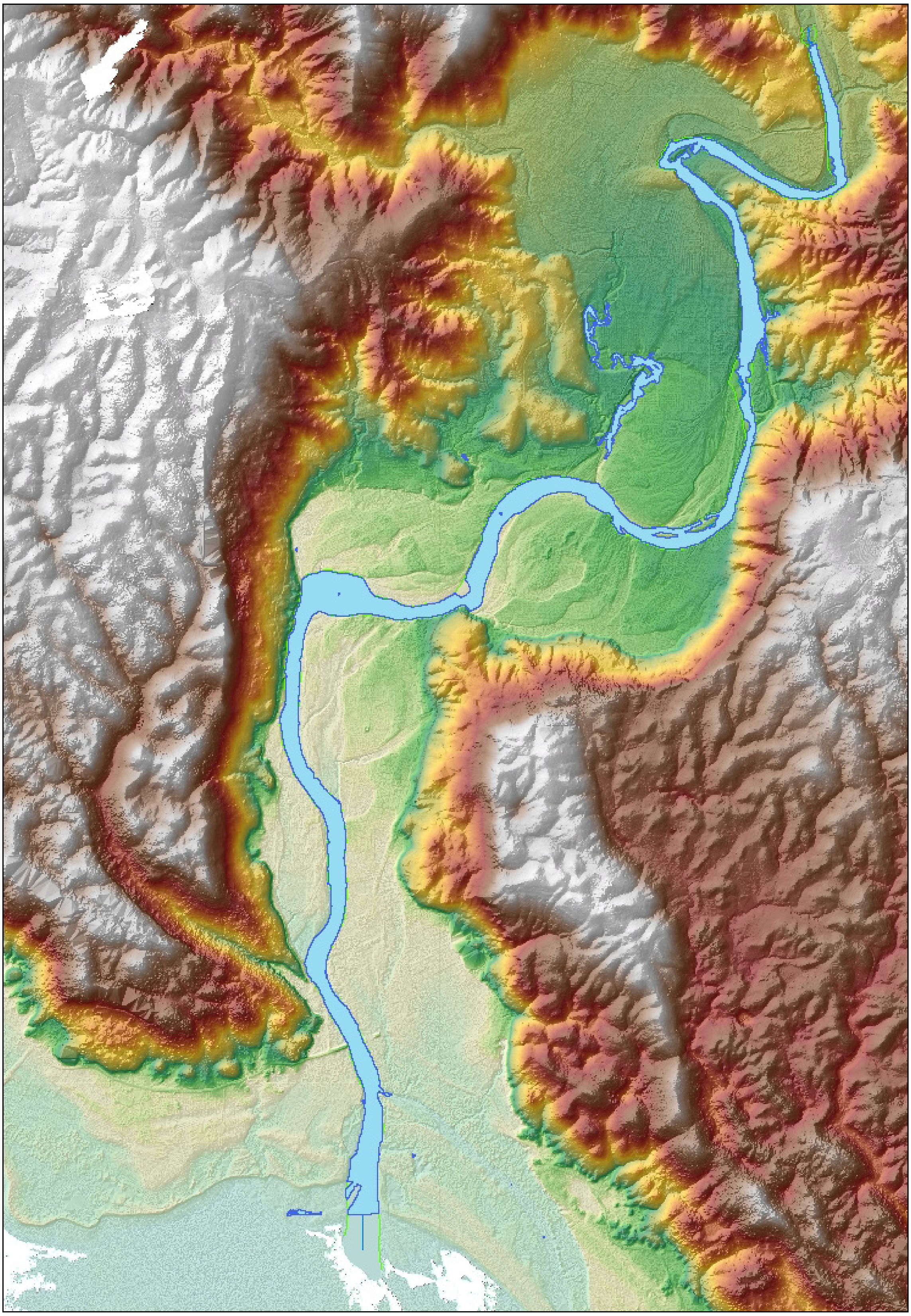


Figure 74. Sample output of Sicopong RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 75 to Figure 80 shows the 5-, 25-, and 100-year rain return scenarios of the Sicopong floodplain. The floodplain, with an area of ________ sq. km., covers one city and one municipality, namely Bayawan City and Santa Catalina, respectively. Table 31 shows the percentage of area affected by flooding per municipality.

Table 33. Municipalities affected in Sicopong Floodplain.

Province	Municipality	Total Area	Area Flooded	% Flooded
Bayawan City	699.09			
Santa Catalina	414.05			

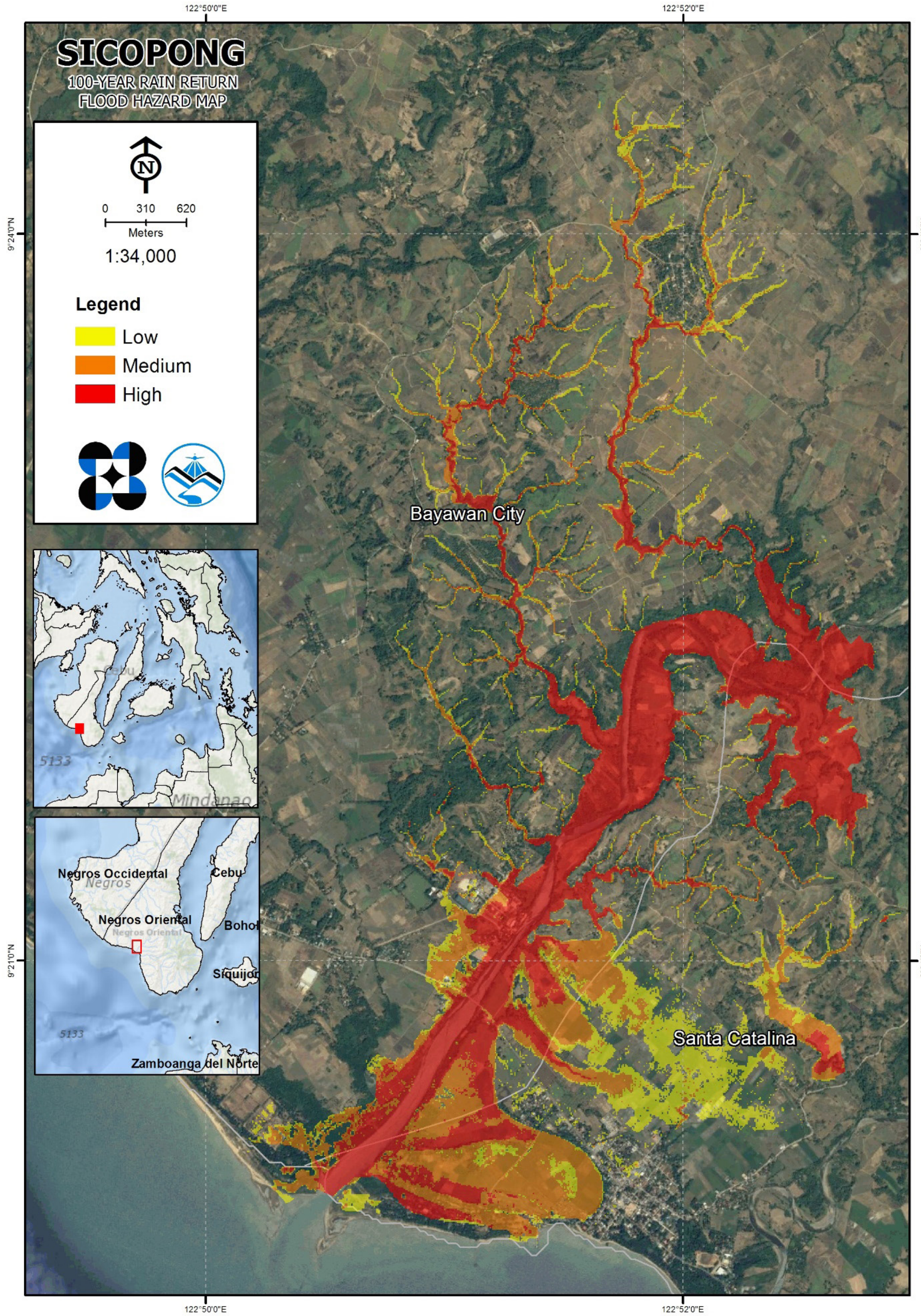


Figure 75. 100-year Flood Hazard Map for Sicopong Floodplain overlaid on Google Earth imagery.

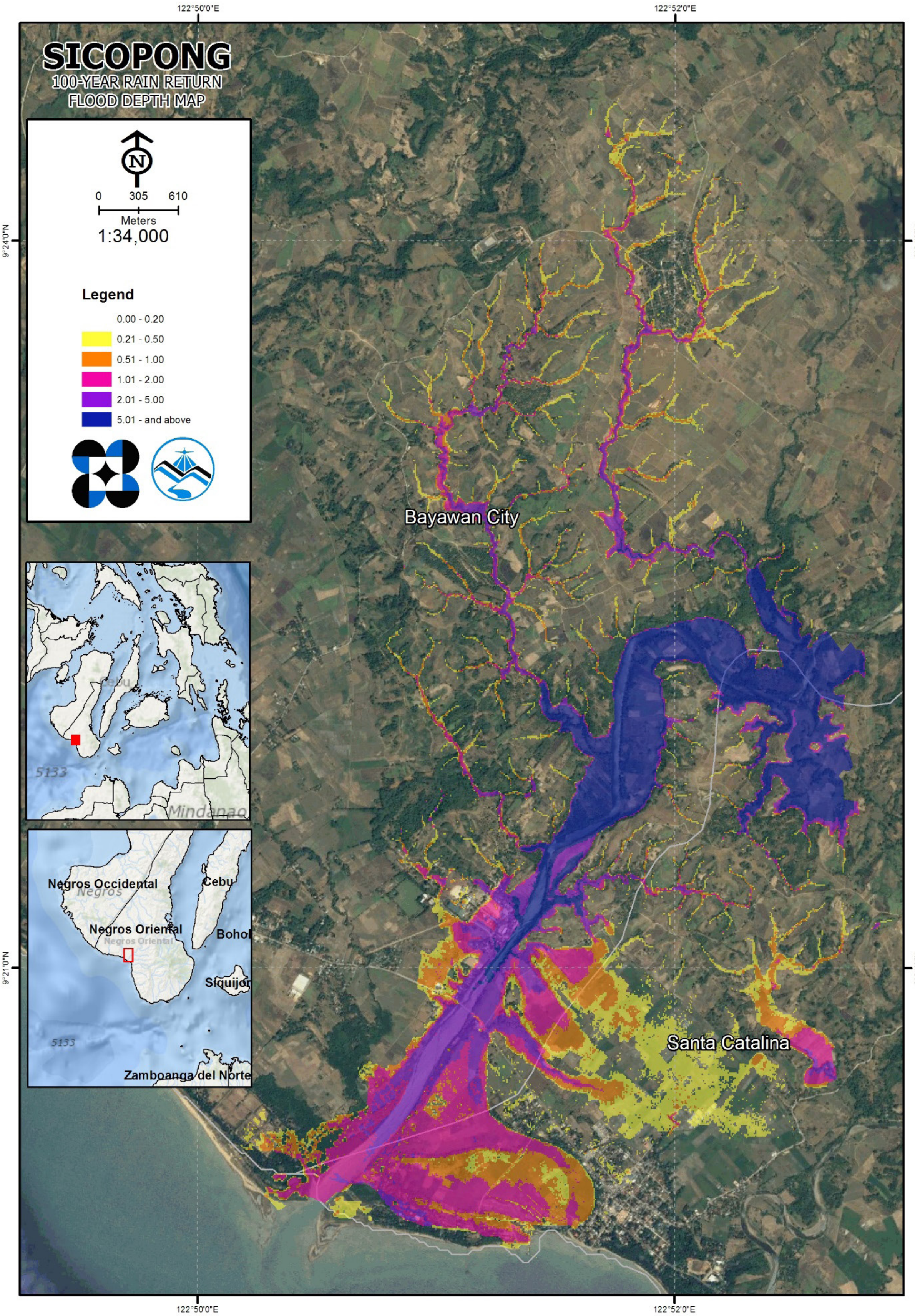


Figure 76. 100-year Flow Depth Map for Sicopong Floodplain overlaid on Google Earth imagery

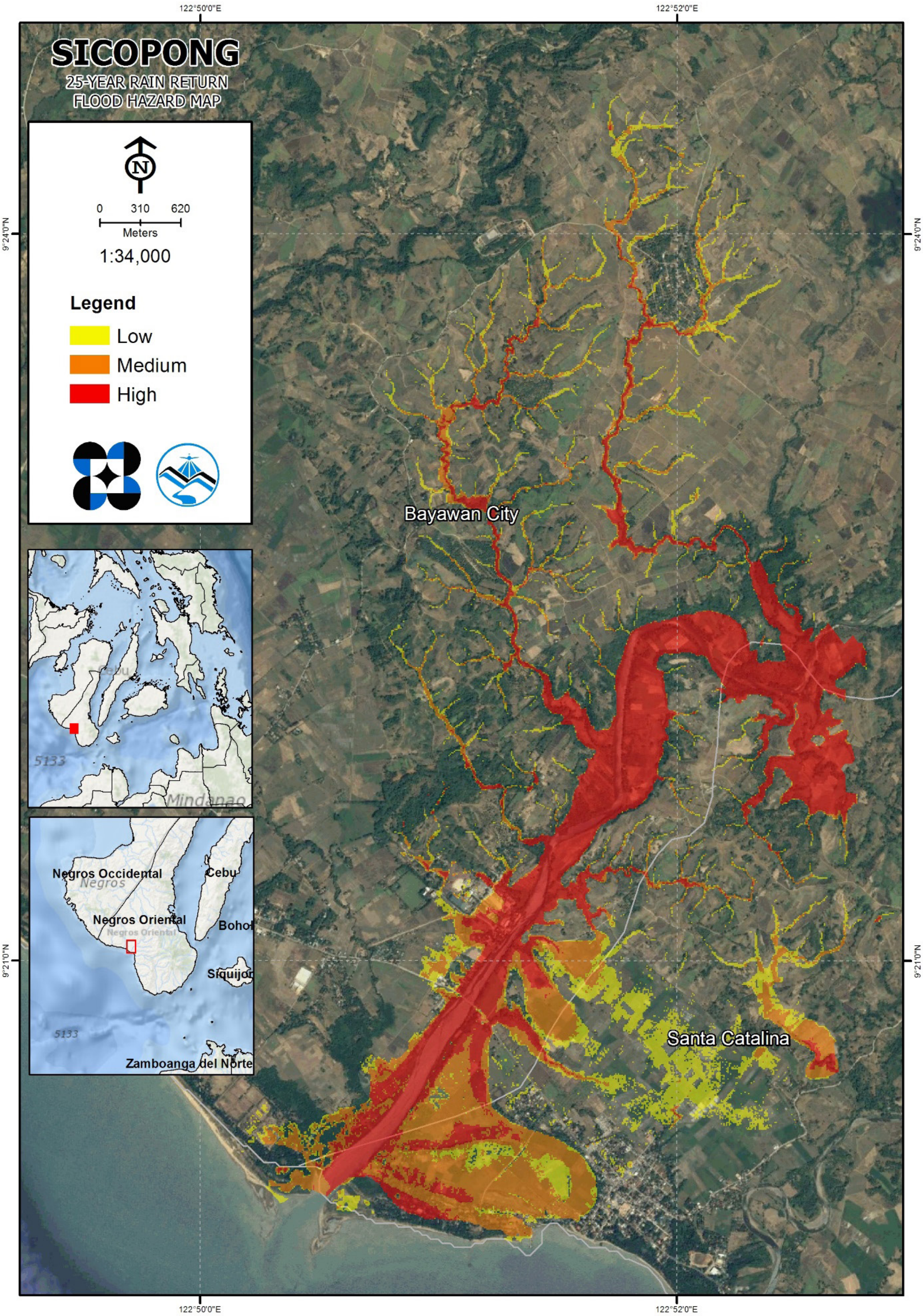


Figure 77. 25-year Flood Hazard Map for Sicopong Floodplain overlaid on Google Earth imagery

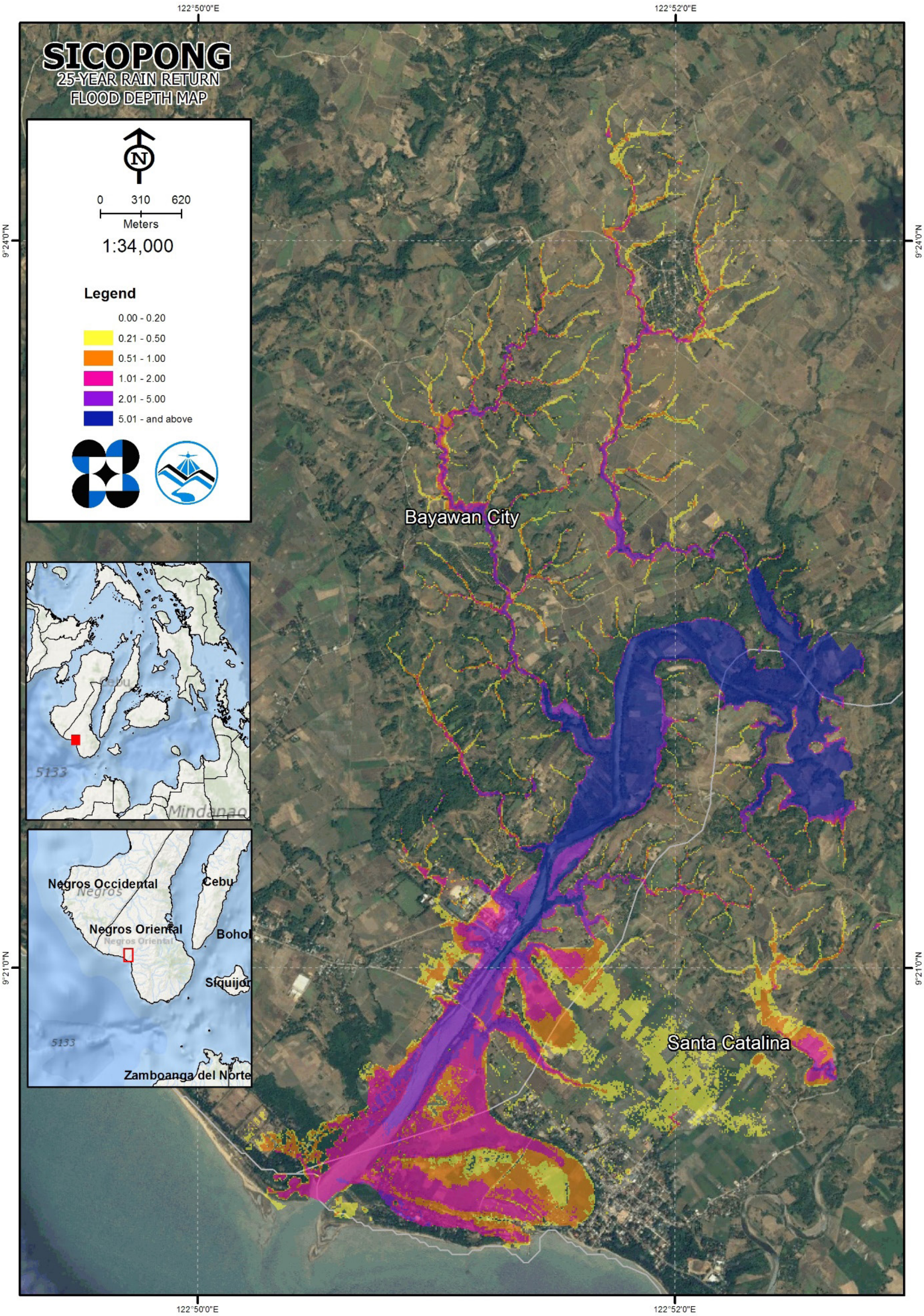


Figure 78. 25-year Flow Depth Map for Sicopong Floodplain overlaid on Google Earth imagery

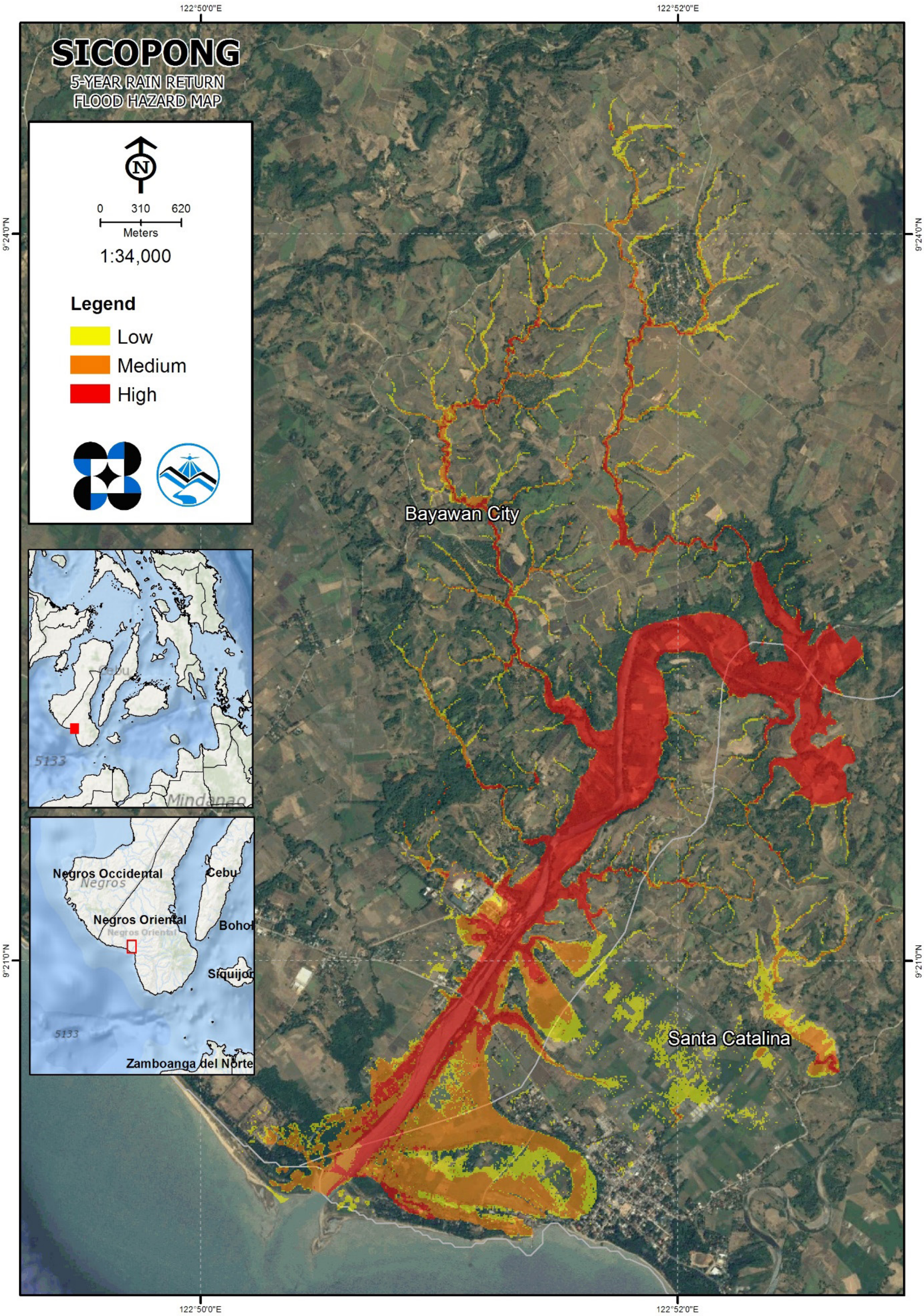


Figure 79. 5-year Flood Hazard Map for Sicopong Floodplain overlaid on Google Earth imagery

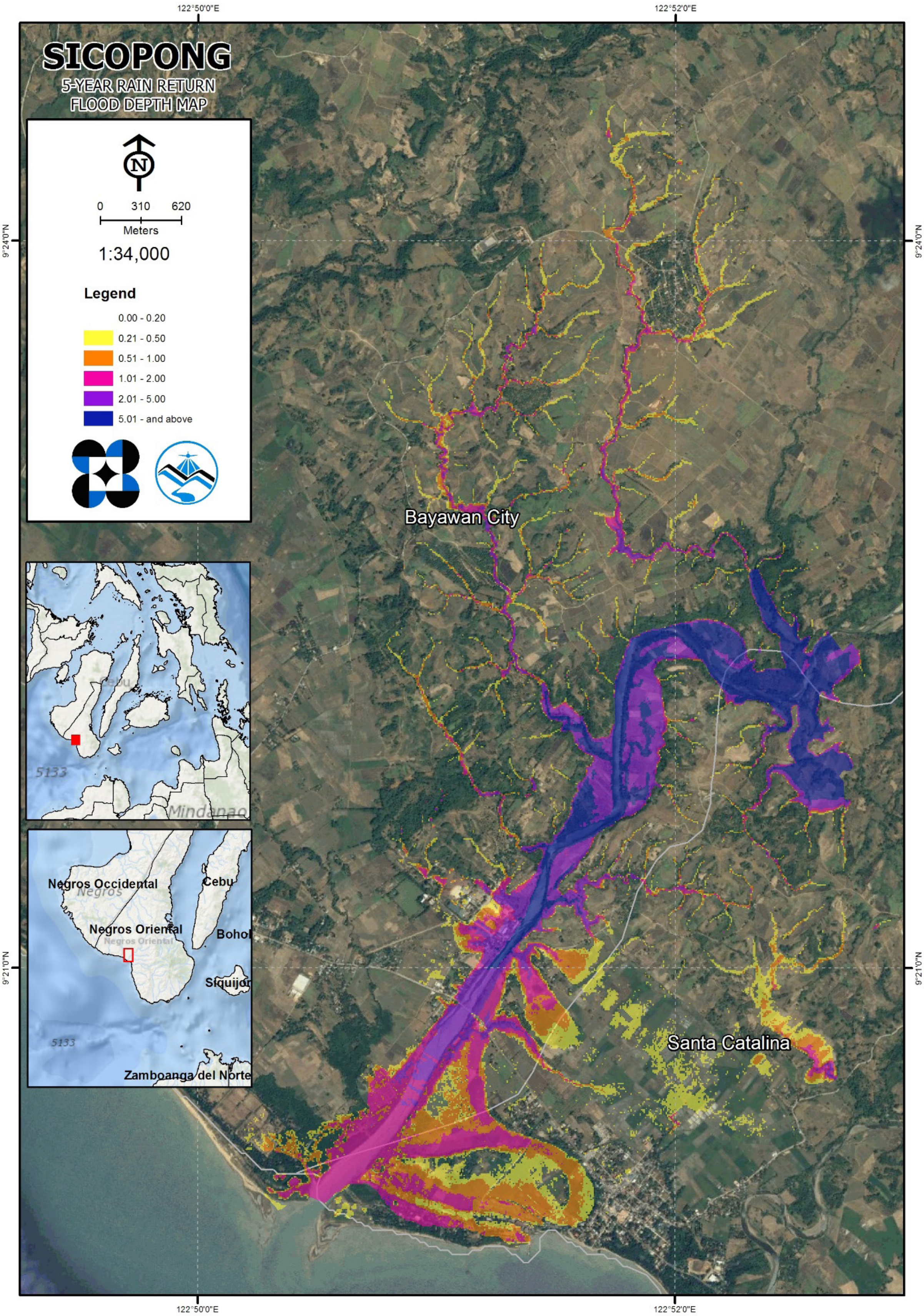


Figure 80. 5-year Flood Depth Map for Sicopong Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Sicopong river basin, grouped by municipality, are listed below. For the said basin, two (2) municipalities consisting of five (5) barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 1.74% of the city of Bayawan with an area of 699.09 sq. km. will experience flood levels of less 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters while 0.09%, 0.11%, 0.14%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in Table 34 and shown in Figure 81 are the affected areas in square kilometres by flood depth per barangay.

Table 34. Affected Areas in Bayawan City, Negros Oriental during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bayawan City (in sq. km.)		
	Maninihon	San Isidro	Villareal
0.03-0.20	7.89	3.17	1.11
0.21-0.50	0.4	0.14	0.23
0.51-1.00	0.24	0.053	0.36
1.01-2.00	0.2	0.047	0.56
2.01-5.00	0.4	0.18	0.4
> 5.00	0.37	0.37	0.083

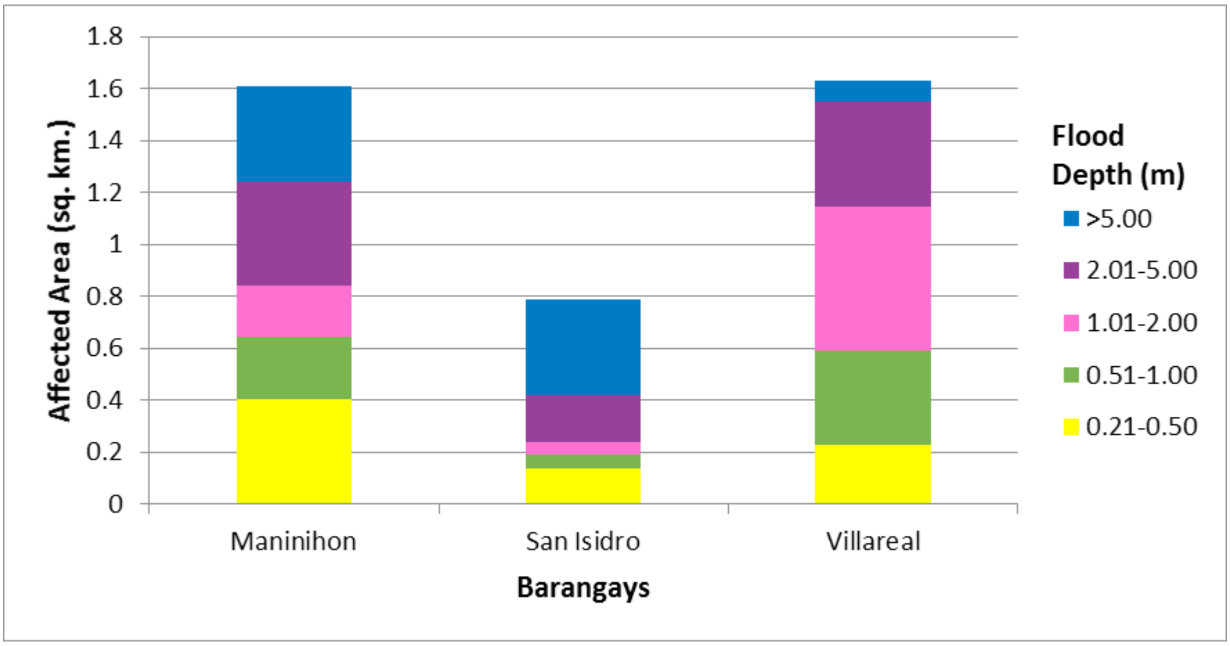


Figure 81. Affected Areas in Bayawan City, Negros Oriental during 5-Year Rainfall Return Period

For the municipality of Santa Catalina, with an area of 414.05 sq. km., 1.28% will experience flood levels of less 0.20 meters. 0.19% of the area will experience flood levels of 0.21 to 0.50 meters while 0.14%, 0.12%, 0.02%, and 0.1% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 35 and shown in Figure 82 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected Areas in Santa Catalina, Negros Oriental during 5-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Catalina (in sq. km.)	
	Caranoche	Poblacion
0.03-0.20	5.1	0.18
0.21-0.50	0.77	0.0089
0.51-1.00	0.58	0.0026
1.01-2.00	0.47	0.0019
2.01-5.00	0.09	0.0027
> 5.00	0.4	0

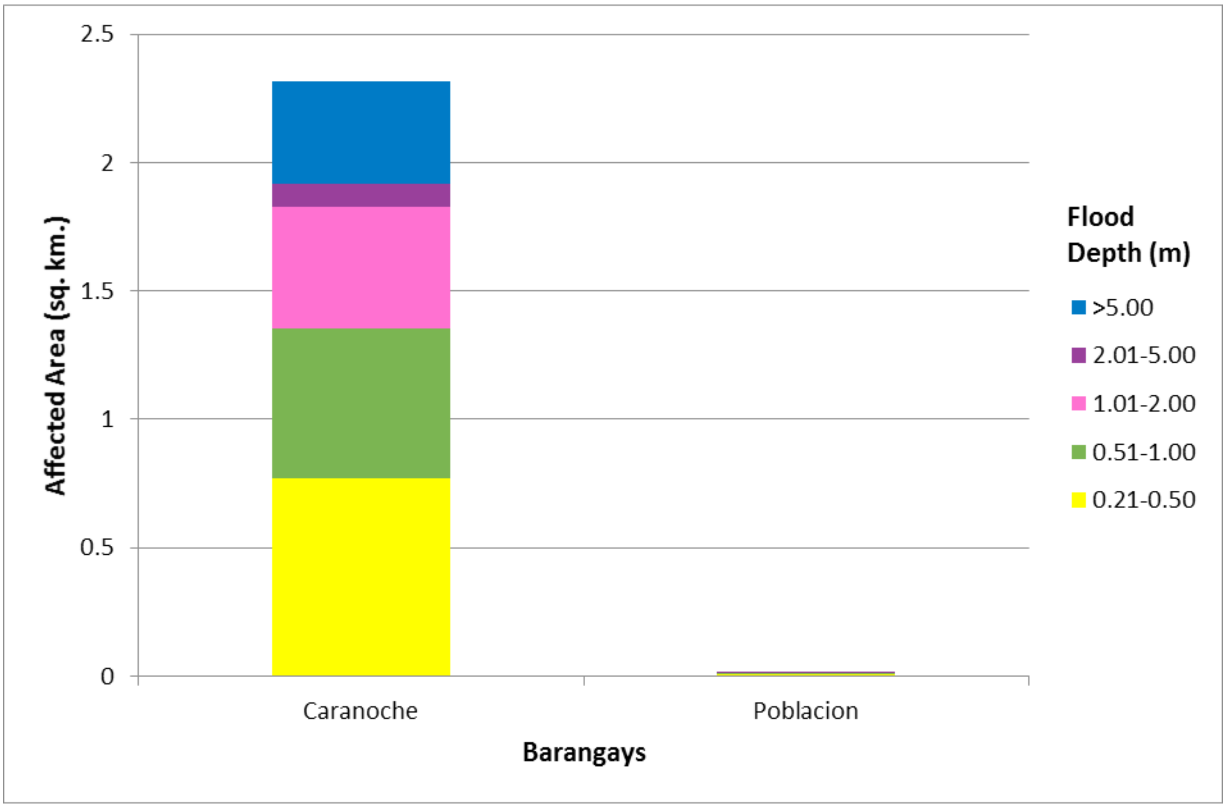


Figure 82. Affected Areas in Santa Catalina, Negros Oriental during 5-Year Rainfall Return Period.

For the 25-year return period, 1.66% of the city of Bayawan with an area of 699.09 sq. km. will experience flood levels of less 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters while 0.1%, 0.13%, 0.13%, and 0.18% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in Table 36 and shown in Figure 83 are the affected areas in square kilometres by flood depth per barangay.

Table 36. Affected Areas in Bayawan City, Negros Oriental during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bayawan City (in sq. km.)		
	Maninihon	San Isidro	Villareal
0.03-0.20	7.7	3.07	0.86
0.21-0.50	0.43	0.16	0.23
0.51-1.00	0.28	0.062	0.34
1.01-2.00	0.22	0.04	0.62
2.01-5.00	0.25	0.071	0.58
> 5.00	0.62	0.56	0.11

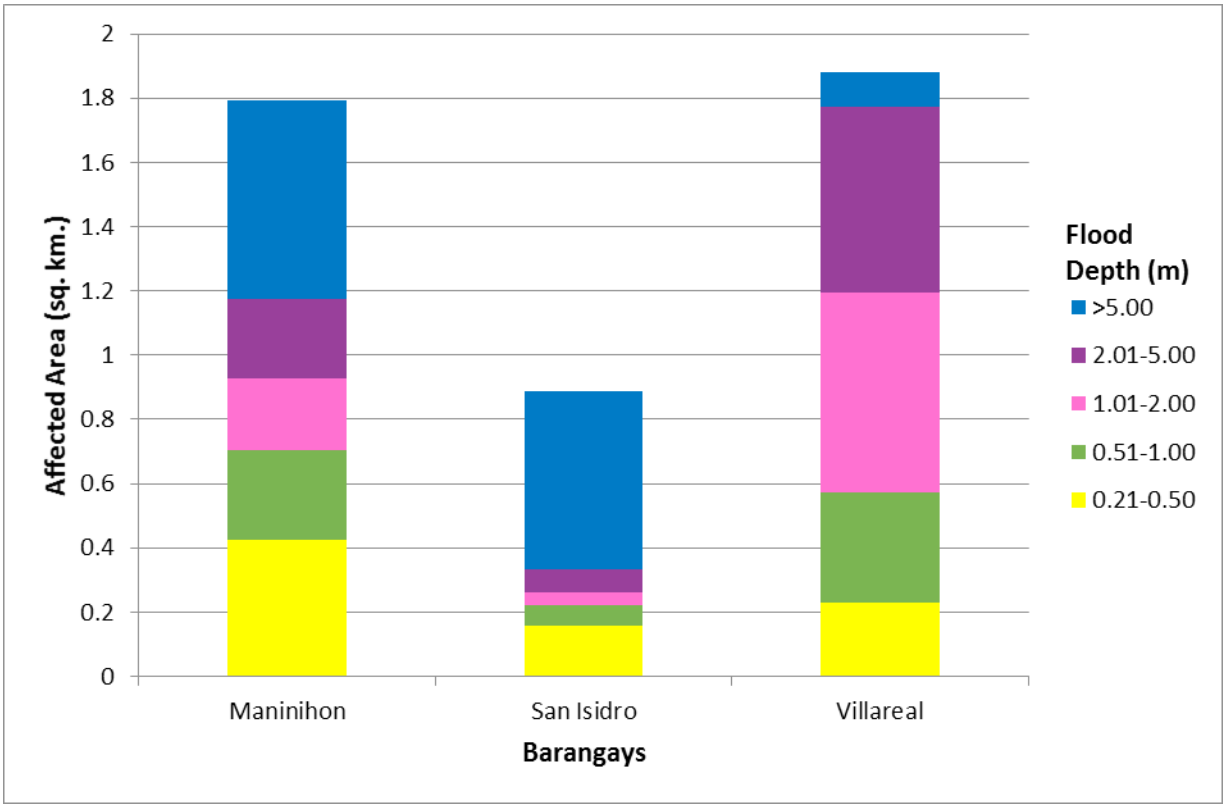


Figure 83. Affected Areas in Bayawan City, Negros Oriental during 25-Year Rainfall Return Period.

For the municipality of Santa Catalina, with an area of 414.05 sq. km., 1.11% will experience flood levels of less 0.20 meters. 0.23% of the area will experience flood levels of 0.21 to 0.50 meters while 0.15%, 0.19%, 0.03%, and 0.13% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 and shown in Figure 84 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Santa Catalina, Negros Oriental during 25-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Catalina (in sq. km.)	
	Caranoche	Poblacion
0.03-0.20	4.44	0.17
0.21-0.50	0.93	0.013
0.51-1.00	0.62	0.0062
1.01-2.00	0.77	0.0033
2.01-5.00	0.11	0.0035
> 5.00	0.55	0

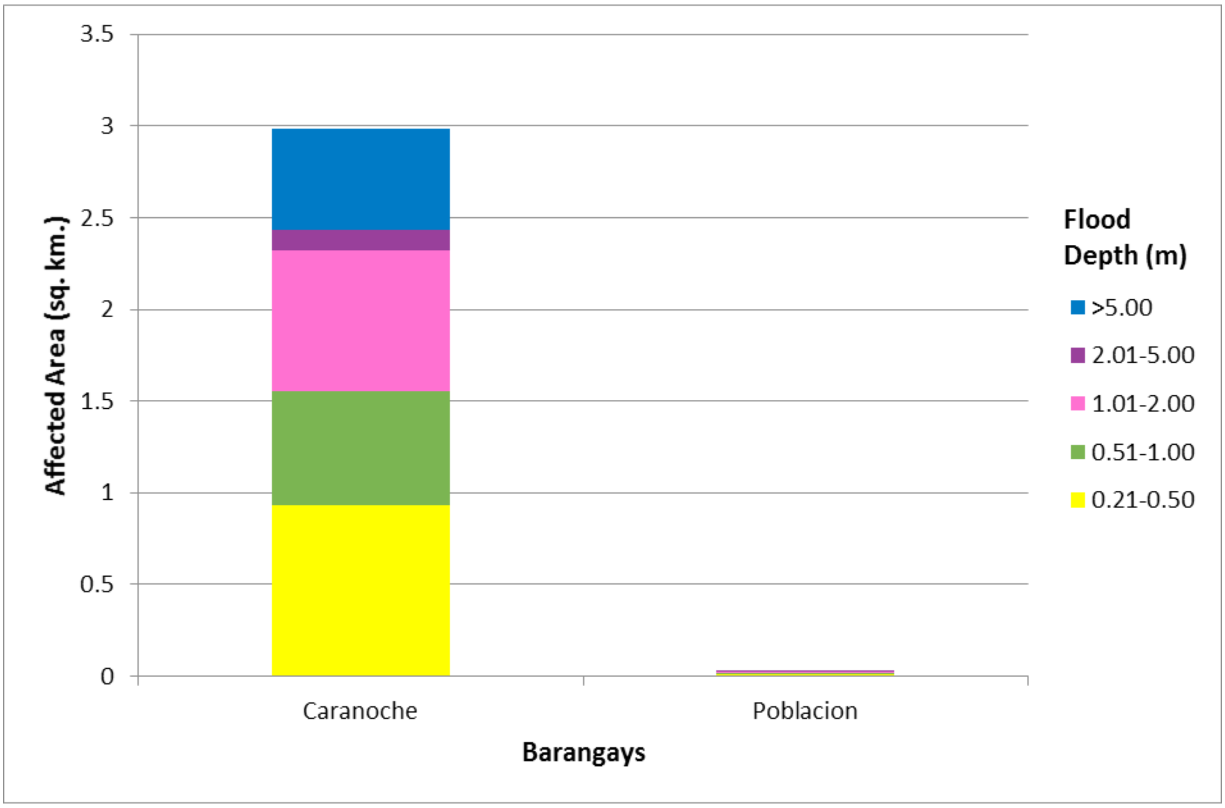


Figure 84. Affected Areas in Santa Catalina, Negros Oriental during 25-Year Rainfall Return Period.

For the 100-year return period, 1.62% of the city of Bayawan with an area of 699.09 sq. km. will experience flood levels of less 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters while 0.1%, 0.13%, 0.15%, and 0.2% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Listed in Table 38 and shown in Figure 85 are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Bayawan City, Negros Oriental during 100-Year Rainfall Return Period.

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Bayawan City (in sq. km.)		
	Maninihon	San Isidro	Villareal
0.03-0.20	7.58	2.99	0.72
0.21-0.50	0.44	0.17	0.2
0.51-1.00	0.29	0.071	0.32
1.01-2.00	0.25	0.041	0.65
2.01-5.00	0.27	0.069	0.72
> 5.00	0.66	0.6	0.13

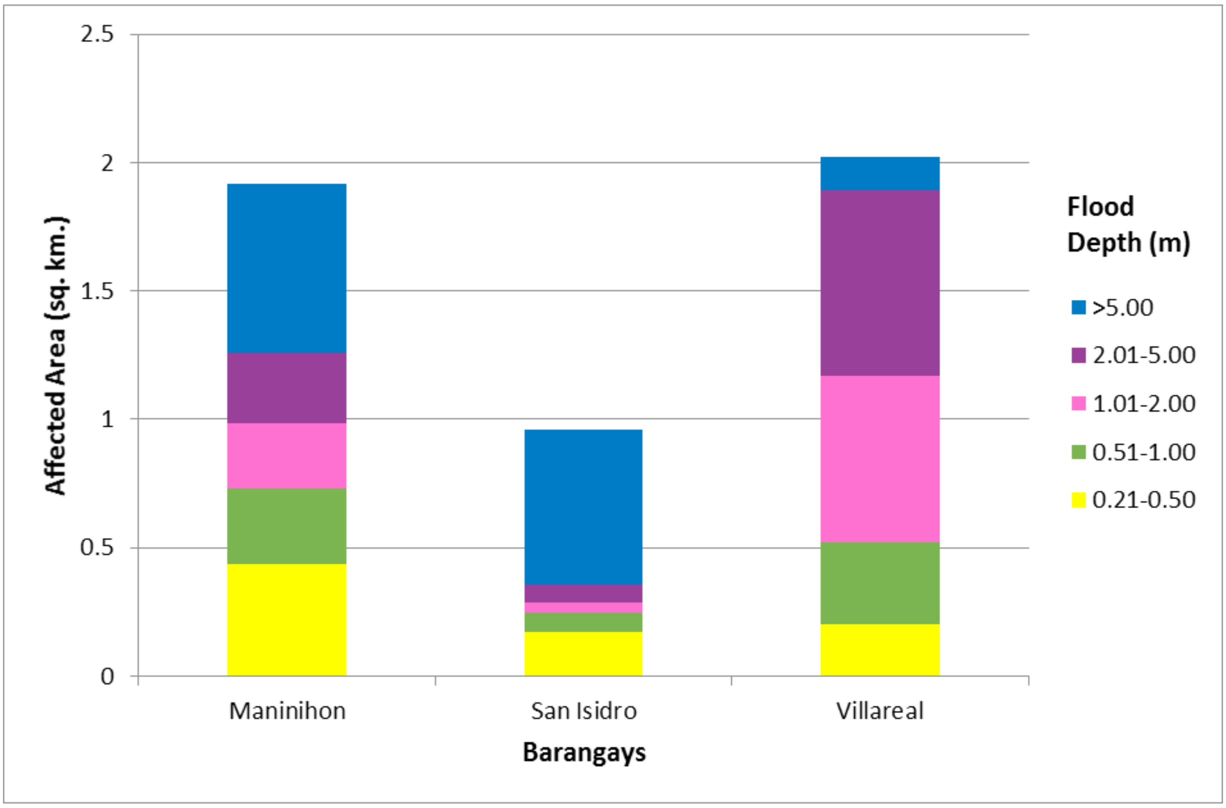


Figure 85. Affected Areas in Bayawan City, Negros Oriental during 100-Year Rainfall Return Period.

For the municipality of Santa Catalina, with an area of 414.05 sq. km., 0.98% will experience flood levels of less 0.20 meters. 0.26% of the area will experience flood levels of 0.21 to 0.50 meters while 0.18%, 0.22%, 0.04%, and 0.16% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 and shown in Figure 86 are the affected areas in square kilometres by flood depth per barangay.

Table 39. Affected Areas in Santa Catalina, Negros Oriental during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Catalina (in sq. km.)	
	Caranoche	Poblacion
0.03-0.20	3.91	0.16
0.21-0.50	1.06	0.017
0.51-1.00	0.72	0.0031
1.01-2.00	0.92	0.0077
2.01-5.00	0.17	0.0043
> 5.00	0.64	0

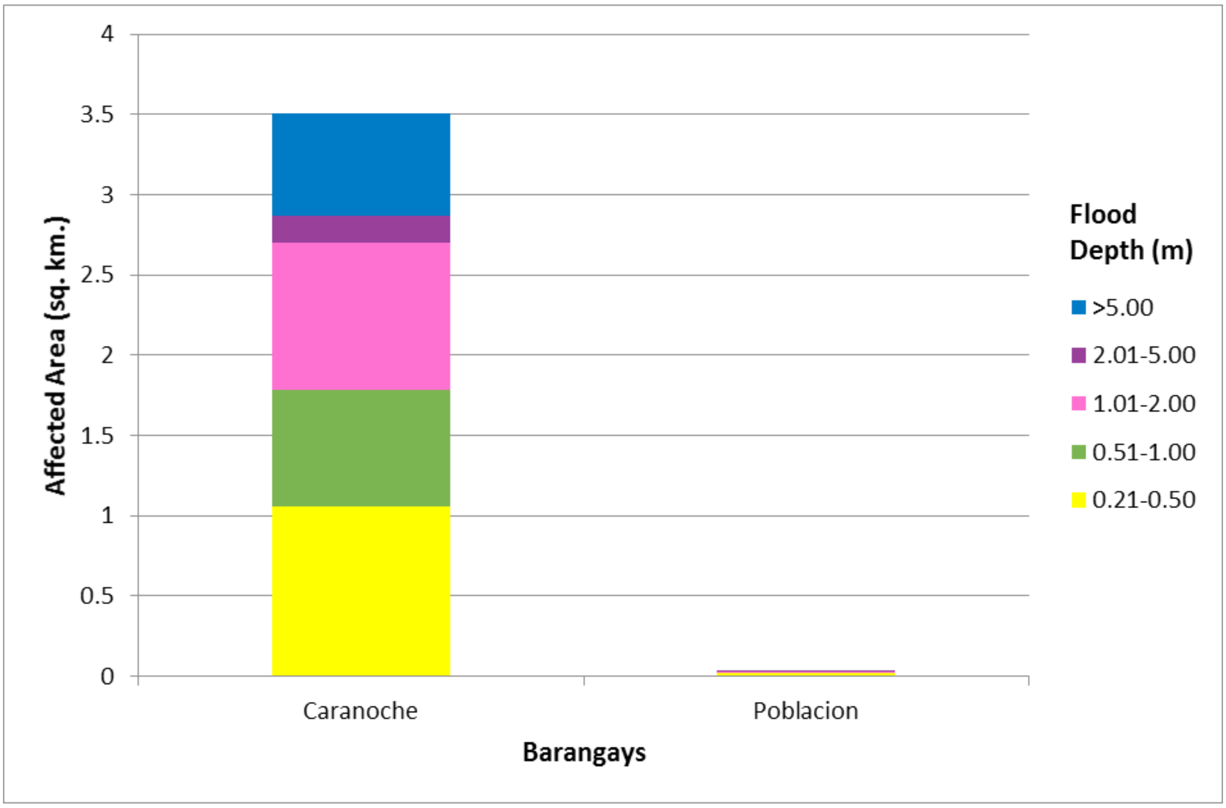


Figure 86. Affected Areas in Santa Catalina, Negros Oriental during 100-Year Rainfall Return Period

Among the barangays in the city of Bayawan, Maninihon is projected to have the highest percentage of area that will experience flood levels at 1.36%. Meanwhile, San Isidro posted the second highest percentage of area that may be affected by flood depths at 0.57%.

Among the barangays in the municipality of Santa Catalina, Caranoche is projected to have the highest percentage of area that will experience flood levels at 1.79%. Meanwhile, Poblacion posted the second highest percentage of area that may be affected by flood depths at 0.1%.

Moreover, the generated flood hazard maps for the Sicopong Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps - “Low”, “Medium”, and “High” - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr).

Table 40. Area covered by each warning level with respect to the rainfall scenario.

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	1.56	1.77	1.91
Medium	2.07	2.31	2.48
High	2.78	3.55	4.12
TOTAL	6.41	7.63	8.51

Of the six (6) identified Education Institutions in the Sicopong Flood plain, 1 school was assessed to be exposed to Low level flooding during the 5, and 25 year scenarios. The educational institutions affected by flooding in the Sicopong floodplain are found in Annex 12.

One (1) identified Medical Institution was identified in the Sicopong Flood Plain and it was not assessed to be exposed to any of the flooding scenarios. The medical or health institutions affected by flooding in the Sicopong floodplain are found in Annex 12.

5.11 Flood Validation

Survey was done along the floodplain of Sicopong River to validate the generated flood maps. The team gathered secondary data regarding flood occurrence in the area. Ground validation points were acquired as well as the other necessary details like date of occurrence, name of typhoon and actual flood depth.

During validation conducted last December 7, 2016, the team was assisted by the local Disaster Risk Reduction and Management representative from the Municipality of Sta Catalina. Residents along the floodplain were interviewed of the historical flood events they experiences.

Actual flood depth acquired from the ground validation were then computed and compared to the flood depth simulated by the model. An RMSE value of 0.05 was obtained (Figure 88).

This image is not available for this river basin.

Figure 87. Sicopong River Basin Flood Validation Points

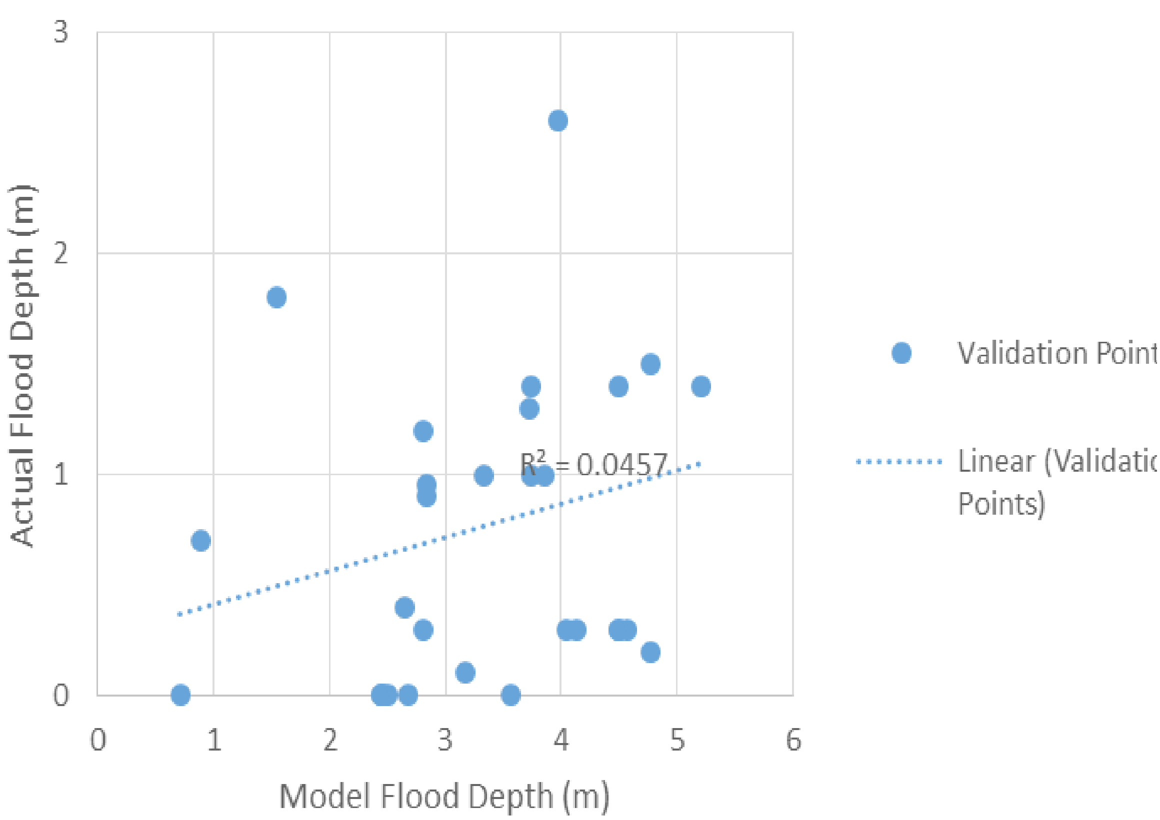


Figure 88. Flood map depth vs. actual flood depth

Table 41. Actual flood vs simulated flood depth of Sicopong River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	0	0	1	0	8	0	9
0.21-0.50	0	0	0	0	7	0	7
0.51-1.00	0	0	1	0	5	0	6
1.01-2.00	0	0	0	1	5	1	7
2.01-5.00	0	0	0	0	2	0	2
> 5.00	0	0	0	0	0	0	0
Total	0	0	2	1	27	1	31

The overall accuracy generated by the flood model is estimated at 12.90% with 4 points correctly matching the actual flood depths. In addition, there were 5 points estimated one level above and below the correct flood depths while there were 7 points and 15 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 0 points were underestimated in the modelled flood depths of Sicopong. The summary of the accuracy assessment is presented in Table 42.

Table 42. Summary of the Accuracy Assessment in the Sicopong River Basin Survey.

	No. of Points	%
Correct	4	12.90
Overestimated	27	87.10
Underestimated	0	0.00
Total	31	100.00

REFERENCES

Ang M.O., Paringit E.C., et al. 2014. DREAM Data Processing Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Balicanta L.P., Paringit E.C., et al. 2014. DREAM Data Validation Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Brunner, G. H. 2010a. HEC-RAS River Analysis System Hydraulic Reference Manual. Davis, CA: U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center.

Lagmay A.F., Paringit E.C., et al. 2014. DREAM Flood Modeling Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Paringit E.C, Balicanta L.P., Ang, M.O., Sarmiento, C. 2017. Flood Mapping of Rivers in the Philippines Using Airborne Lidar: Methods. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

Sarmiento C., Paringit E.C., et al. 2014. DREAM Data Acquisition Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

UP TCAGP 2016, Acceptance and Evaluation of Synthetic Aperture Radar Digital Surface Model (SAR DSM) and Ground Control Points (GCP). Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

ANNEXES

Annex 1. Optech Technical Specification of the Gemini Sensor

Figure A-1.1 Gemini Sensor

Table A-1.1 Parameters and Specifications of the Gemini Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

Annex 2. NAMRIA Certificate of Reference Points Used in the LiDAR Survey

1. NGE-97

Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

October 15, 2014

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

	Province: **NEGROS ORIENTAL**	
	Station Name: **NGE-97**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **SUBA**	
Municipality: **BAYAWAN**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **9° 22' 10.68255"**	Longitude: **122° 48' 1.35582"**	Ellipsoidal Hgt: **9.65300 m.**
	WGS84 Coordinates	
Latitude: **9° 22' 6.70304"**	Longitude: **122° 48' 6.69563"**	Ellipsoidal Hgt: **70.79700 m.**
	PTM / PRS92 Coordinates	
Northing: **1036021.986 m.**	Easting: **478073.348 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,035,659.36**	Easting: **478,081.02**	Zone: **51**

Location Description

NGE-97

The station is located on the SE corner of Bayawan Bridge which is at KM 102+198. Mark is the head of 4" copper nail flushed at the center of a 30cm x 30cm cement putty embedded on the bridge's concrete sidewalk with inscription "NGE-97 2007 NAMRIA."

Requesting Party: **Phil-LIDAR I**
Purpose: **Reference**
OR Number: **8075810 I**
T.N.: **2014-2468**

RUEL DM. BELEN, MNSA
Director, Mapping And Geodesy Branch

9 9 1 0 1 5 2 0 1 4 1 0 3 4 4 1

OP/4701/12/09/814

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph
ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 NGE-97

2. NGE-105

Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

October 15, 2014

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

Province: **NEGROS ORIENTAL**
Station Name: **NGE-105**
Order: **2nd**

Island: **VISAYAS**	Barangay: **NAGBALAYEN**	
Municipality: **STA CATALINA**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **9° 15' 23.79985"**	Longitude: **122° 52' 24.36983"**	Ellipsoidal Hgt: **8.89200 m.**
	WGS84 Coordinates	
Latitude: **9° 15' 19.85595"**	Longitude: **122° 52' 29.71925"**	Ellipsoidal Hgt: **70.46200 m.**
	PTM / PRS92 Coordinates	
Northing: **1023518.905 m.**	Easting: **486093.752 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,023,160.66**	Easting: **486,098.62**	Zone: **51**

Location Description

NGE-105
The station is located on top of the bridge wingwall SW of the Bridge main span. It is on the left side of the 1st approach coming from Siaton on the way to Sta Catalina. The height of the wingwall is about 1.00 m. from the road pavement. The bridge is at Km. 84+627. The station is along the Dumaguete-Bayawan national highway. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on concrete bridge's wingwall with inscriptions "NGE-105; 2007; NAMRIA".

Requesting Party: **Phil-LIDAR I**
Purpose: **Reference**
OR Number: **8075810 I**
T.N.: **2014-2462**

RUEL DM. BELEN, MNSA
Director, Mapping And Geodesy Branch

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2 NGE-105

3. NGE-107

Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

October 15, 2014

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

	Province: **NEGROS ORIENTAL**	
	Station Name: **NGE-107**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **MANALONGON**	
Municipality: **STA CATALINA**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **9° 13' 23.69730"**	Longitude: **122° 52' 53.67884"**	Ellipsoidal Hgt: **8.08400 m.**
	WGS84 Coordinates	
Latitude: **9° 13' 19.76274"**	Longitude: **122° 52' 59.03119"**	Ellipsoidal Hgt: **69.74600 m.**
	PTM / PRS92 Coordinates	
Northing: **1019829.085 m.**	Easting: **486987.067 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,019,472.13**	Easting: **486,991.62**	Zone: **51**

Location Description

NGE-107
The bridge is at Km.80+569 over Manalongon river. The barangay hall complex is on the NE of the bridge, about 60 m. from the station. The station is located on top of the sidewalk of Manalongon bridge, near the Manalongon barangay complex. It is located on the left approach of the bridge coming from Sta Catalina heading to Dumaguete City. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 03 cm. cement putty embedded on concrete bridge's sidewalk with inscriptions "NGE-107; 2007; NAMRIA".

Requesting Party: **Phil-LIDAR I**
Purpose: **Reference**
OR Number: **8075810 I**
T.N.: **2014-2464**

RUEL DM. BELEN, MNSA
Director, Mapping And Geodesy Branch

9 9 1 0 1 5 2 0 1 4 1 0 3 3 2 9

CERTIFICATION INTERNATIONAL ISO 9001:2008
ACCREDITED
CIP/4701/12/09/814

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph
ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3 NGE-107

4. NE-21

Republic of the Philippines
Department of Environment and Natural Resources
NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY

October 15, 2014

CERTIFICATION

To whom it may concern:

This is to certify that according to the records on file in this office, the requested survey information is as follows -

	Province: **NEGROS ORIENTAL**	
	Station Name: **NGE-107**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **MANALONGON**	
Municipality: **STA CATALINA**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **9° 13' 23.69730"**	Longitude: **122° 52' 53.67884"**	Ellipsoidal Hgt: **8.08400 m.**
	WGS84 Coordinates	
Latitude: **9° 13' 19.76274"**	Longitude: **122° 52' 59.03119"**	Ellipsoidal Hgt: **69.74600 m.**
	PTM / PRS92 Coordinates	
Northing: **1019829.085 m.**	Easting: **486987.067 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,019,472.13**	Easting: **486,991.62**	Zone: **51**

Location Description

NGE-107
The bridge is at Km.80+569 over Manalongon river. The barangay hall complex is on the NE of the bridge, about 60 m. from the station. The station is located on top of the sidewalk of Manalongon bridge, near the Manalongon barangay complex. It is located on the left approach of the bridge coming from Sta Catalina heading to Dumaguete City. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 03 cm. cement putty embedded on concrete bridge's sidewalk with inscriptions "NGE-107; 2007; NAMRIA".

Requesting Party: **Phil-LIDAR I**
Purpose: **Reference**
OR Number: **8075810 I**
T.N.: **2014-2464**

RUEL DM. BELEN, MNSA
Director, Mapping And Geodesy Branch

9 9 1 0 1 5 2 0 1 4 1 0 3 3 2 9

CERTIFICATION INTERNATIONAL ISO 9001:2008 | ACCREDITED
CIP/4701/12/09/814

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.4 NE-21

Annex 3. Baseline Processing Reports of Control Points used in the LiDAR Survey

1. NE-21

NGE-97 - NE-21 (6:29:33 AM-9:38:04 AM) (S1)

Baseline observation:	NGE-97 --- NE-21 (B1)
Processed:	11/3/2014 11:39:15 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.006 m
Vertical precision:	0.016 m
RMS:	0.019 m
Maximum PDOP:	1.766
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	10/20/2014 6:29:39 AM (Local: UTC+8hr)
Processing stop time:	10/20/2014 9:38:04 AM (Local: UTC+8hr)
Processing duration:	03:08:25
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	NGE-97				
Grid		**Local**		**Global**	
Easting	478081.022 m	**Latitude**	N9°22'10.68255"	**Latitude**	N9°22'06.70304"
Northing	1035659.360 m	**Longitude**	E122°48'01.35582"	**Longitude**	E122°48'06.69563"
Elevation	8.347 m	**Height**	9.653 m	**Height**	70.797 m

To:	NE-21				
Grid		**Local**		**Global**	
Easting	473740.044 m	**Latitude**	N9°22'18.89002"	**Latitude**	N9°22'14.90643"
Northing	1035914.112 m	**Longitude**	E122°45'39.02590"	**Longitude**	E122°45'44.36578"
Elevation	5.801 m	**Height**	7.040 m	**Height**	68.081 m

Vector					
ΔEasting	-4340.979 m	**NS Fwd Azimuth**	273°19'34"	**ΔX**	3674.857 m
ΔNorthing	254.752 m	**Ellipsoid Dist.**	4350.156 m	**ΔY**	2314.666 m
ΔElevation	-2.546 m	**ΔHeight**	-2.613 m	**ΔZ**	248.233 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	**σ NS fwd Azimuth**	0°00'00"	**σ ΔX**	0.005 m
σ ΔNorthing	0.002 m	**σ Ellipsoid Dist.**	0.002 m	**σ ΔY**	0.007 m
σ ΔElevation	0.008 m	**σ ΔHeight**	0.008 m	**σ ΔZ**	0.002 m

Figure A-2.1 NE-21

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	GEROME HIPOLITO	UP-TCAGP
LiDAR Operation	Research Associate (RA)	MA. VERLINA E. TONGA	
		MA. REMEDIOS VILLANUEVA	
Ground Survey, Data Download and Transfer		JONATHAN ALMALVEZ	
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINI	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. BRYAN DONGUINES	
		CAPT. NEIL ACHILLES AGAWIN	

Annex 5. Data Transfer Sheet for Sicopong Floodplain

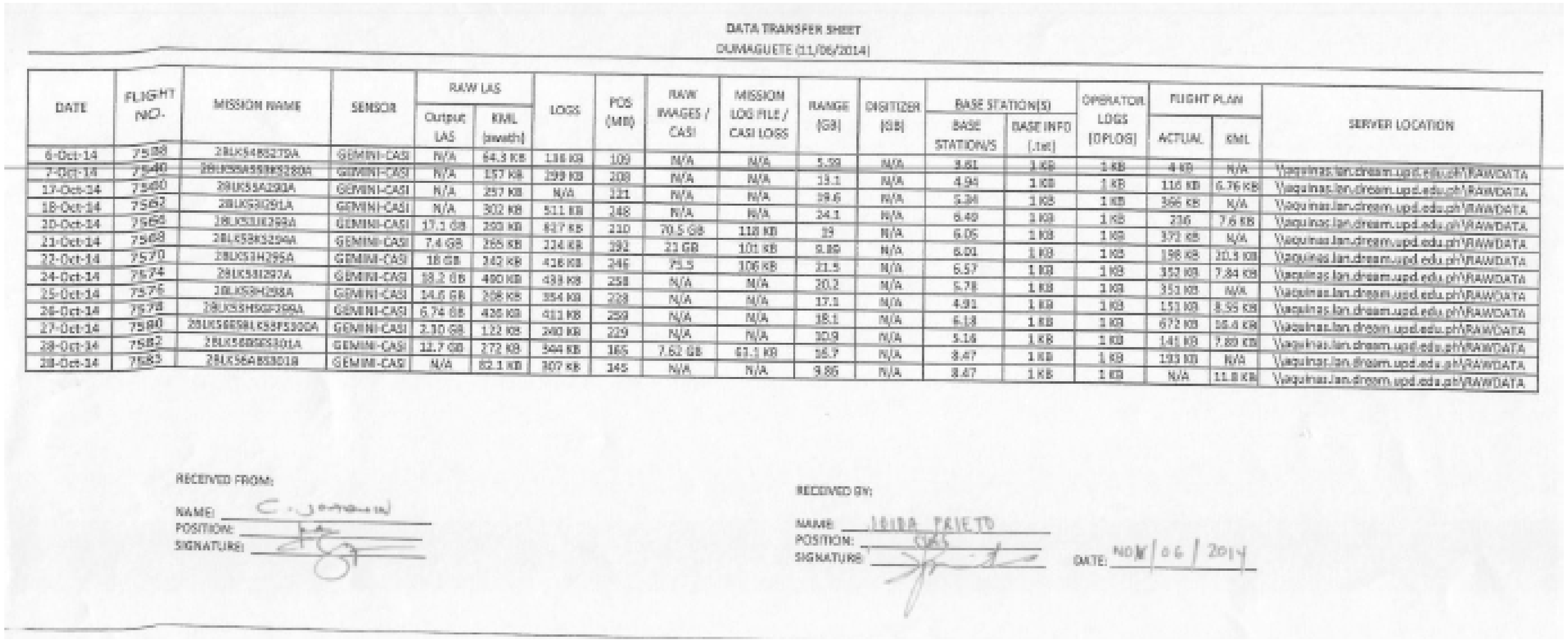
DATA TRANSFER SHEET
10/20/2014(Dumaguete ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base info (.txt)		Actual	KML	
24-Sep-14	7514	2BLK56F267A	GEMINI	14.1	198	450	228	NA	NA	20	NA	12	1KB	1KB	3	7/8	Z:\DAC\RAW DATA
24-Sep-14	7515	2BLK54C267B	GEMINI	9.1	119	264	162	NA	NA	12.7	NA	12	1KB	1KB	NA	11	Z:\DAC\RAW DATA
25-Sep-14	7516	2BLK56DC268A	GEMINI	18.2	285	630	236	NA	NA	26.6	NA	7.82	1KB	1KB	3	7	Z:\DAC\RAW DATA
26-Sep-14	7518	2BLK56B269A	GEMINI	14.1	193	173	72.5	NA	NA	15.3	NA	5.54	1KB	1KB	3	8	Z:\DAC\RAW DATA
29-Sep-14	7524	2BLK54C272A	GEMINI	16.8	303	535	248	NA	NA	27	NA	6.07	1KB	1KB	4	8/9	Z:\DAC\RAW DATA
30-Sep-14	7526	2BLK53O55A273A	GEMINI	5.37	91	173	144	NA	NA	7.8	NA	3.6	1KB	1KB	3/8	21	Z:\DAC\RAW DATA
1-Oct-14	7528	2BLK54B274A	GEMINI	7.91	115	219	122	NA	NA	9.25	NA	3.91	1KB	1KB	5/4	12	Z:\DAC\RAW DATA
2-Oct-14	7530	2BLK54BS56E275A	GEMINI	7.09	115	228	132	NA	NA	8.74	NA	3.7	1KB	1KB	3/4	12/7	Z:\DAC\RAW DATA

Received from
Name G. Sotelo
Position RA
Signature

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature 10/20/2014

Figure A-5.1 Data Transfer Sheet for Sicopong Floodplain Flight – A



DATA TRANSFER SHEET
DUMAGUETE (11/06/2014)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS (MB)	RAW IMAGES / CASI	MISSION LOG FILE / CASI LOGS	RANGE (GB)	DIGITIZER (GB)	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION/S	BASE INFO (.txt)		ACTUAL	KML	
6-Oct-14	7538	2BLK54BS279A	GEMINI-CASI	N/A	64.3 KB	138 KB	109	N/A	N/A	5.59	N/A	3.61	1 KB	1 KB	4 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
7-Oct-14	7540	2BLK55A55BK5280A	GEMINI-CASI	N/A	157 KB	299 KB	208	N/A	N/A	13.1	N/A	4.94	1 KB	1 KB	116 KB	6.76 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
17-Oct-14	7560	2BLK55A290A	GEMINI-CASI	N/A	257 KB	N/A	121	N/A	N/A	19.6	N/A	5.34	1 KB	1 KB	366 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
18-Oct-14	7562	2BLK53I291A	GEMINI-CASI	N/A	302 KB	511 KB	248	N/A	N/A	24.1	N/A	6.40	1 KB	1 KB	236	7.6 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
20-Oct-14	7566	2BLK53JK293A	GEMINI-CASI	17.1 GB	200 KB	617 KB	210	70.5 GB	118 KB	19	N/A	6.06	1 KB	1 KB	372 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
21-Oct-14	7568	2BLK53K3294A	GEMINI-CASI	7.4 GB	265 KB	224 KB	192	21 GB	101 KB	9.89	N/A	6.01	1 KB	1 KB	198 KB	20.3 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
22-Oct-14	7570	2BLK53H295A	GEMINI-CASI	18 GB	242 KB	416 KB	246	75.5	106 KB	21.5	N/A	6.57	1 KB	1 KB	352 KB	7.84 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
24-Oct-14	7574	2BLK53I297A	GEMINI-CASI	18.2 GB	490 KB	439 KB	258	N/A	N/A	20.2	N/A	5.78	1 KB	1 KB	351 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
25-Oct-14	7576	2BLK53H298A	GEMINI-CASI	14.6 GB	208 KB	354 KB	228	N/A	N/A	17.1	N/A	4.91	1 KB	1 KB	151 KB	8.55 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
26-Oct-14	7578	2BLK53H5GF299A	GEMINI-CASI	6.74 GB	426 KB	411 KB	259	N/A	N/A	18.1	N/A	6.18	1 KB	1 KB	672 KB	16.4 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
27-Oct-14	7580	2BLK56E5BLK53FS300A	GEMINI-CASI	2.10 GB	122 KB	240 KB	229	N/A	N/A	10.9	N/A	5.16	1 KB	1 KB	141 KB	7.89 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
28-Oct-14	7582	2BLK56BG5301A	GEMINI-CASI	12.7 GB	272 KB	544 KB	165	7.62 GB	61.1 KB	16.7	N/A	8.47	1 KB	1 KB	193 KB	N/A	\\aquinas.lan.dream.upd.edu.ph\RAWDATA
28-Oct-14	7583	2BLK56ABS301B	GEMINI-CASI	N/A	82.1 KB	307 KB	145	N/A	N/A	9.86	N/A	8.47	1 KB	1 KB	N/A	11.8 KB	\\aquinas.lan.dream.upd.edu.ph\RAWDATA

RECEIVED FROM:
NAME: C. Joaquin
POSITION:
SIGNATURE:

RECEIVED BY:
NAME: IDIDA PRIETO
POSITION: CSRS
SIGNATURE:
DATE: NOV/06/2014

Figure A-5.2 Data Transfer Sheet for Sicopong Floodplain Flight – B

Annex 6. Flight logs for the flight missions

1. Flight Log for 7526G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 7526

1 LIDAR Operator: MVE Tonga	2 ALTM Model: Gemini and Casi	3 Mission Name: 2BLK53O55A273A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: N. Aguin	9 Route:			
10 Date: Sept. 30, 2014	12 Airport of Departure (Airport, City/Province): Dumaguete City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0707	14 Engine Off: 0942	15 Total Engine Time: 02 35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Surveyed 3 lines of BLK53O and 4 lines of BLK 55A.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Lorelyn Aguinaldo	Raymund Dominic	R. Samar	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.1 Flight Log for 7526G Mission

2. Flight Log for 7540G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log Gemini + **Flight Log No.:** 7540

1 LIDAR Operator: MR Villanueva	2 ALTM Model: CAS1	3 Mission Name: 2BLK55AS57DS240A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-9322
7 Pilot: N. Agawin	8 Co-Pilot: F. De Ocampo	9 Route:			
10 Date: October 7, 2014	12 Airport of Departure (Airport, City/Province): Dumaguete City		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0657	14 Engine Off: 1026	15 Total Engine Time: 0329	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Cloudy				

20 Remarks:

Surveyed 11 lines.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Larry Acuña	Raymund Domini	Neil Agawin	MR Villanueva
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.2 Flight Log for 7540G Mission

3. Flight Log for 7560G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log — Gen +

Flight Log No.: 7560

1 LiDAR Operator: MVE Tonga	2 ALTM Model: CASI	3 Mission Name: 2BLK65A290A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9822
7 Pilot: R. Samar	8 Co-Pilot: N. Agawin	9 Route:			
10 Date: Oct 17, 2014	12 Airport of Departure (Airport, City/Province): Dumaguete		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 653	14 Engine Off: 1020	15 Total Engine Time: 3+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					
20 Remarks: Mission completed with minimal voids					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Lovely Acuña	Raymund Domine	D. Samar	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.3 Flight Log for 7560G Mission

4. Flight Log for 7562G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log   Gem t   2BLK 53Q 291 A   Flight Log No.: 7562

1 LIDAR Operator: MR Villanueva	2 ALTM Model: CASI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: R-Samar	8 Co-Pilot: N-Aguain	9 Route:			
10 Date: Oct 19, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 6:35	14 Engine Off: 10:46	15 Total Engine Time: 4+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					
20 Remarks: mission completed but voids were encountered during the survey					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Larry Acuna	Raymund Domini	R. Samar II	MR Villanueva
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.4 Flight Log for 7562G Mission

5. Flight Log for 7566G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log Gen + 2BLK53K 293A Flight Log No.: 7566

1 LiDAR Operator: MVE Tongo	2 ALTM Model: CASI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar	8 Co-Pilot: N. Agawin	9 Route:			
10 Date: Oct 30, 2014	12 Airport of Departure (Airport, City/Province): Dumaguete		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 6:33	14 Engine Off: 10:02	15 Total Engine Time: 3+05	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					
20 Remarks: Mission completed (with CASI)					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Lovely Acuña	Raymund Domino	R. Samar II	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.5 Flight Log for 7566G Mission

6. Flight Log for 7568G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log 6cm + CASI 2BLK5305 299 R **Flight Log No.:** 7568

1 LiDAR Operator: MR. Villanueva	2 ALTM Model:	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: R. Garay	8 Co-Pilot: O. Agawin	9 Route:			
10 Date: oct 21, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 6:33	14 Engine Off: 10:44	15 Total Engine Time: 4+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather fair					

20 Remarks:

Mission completed (with CASI -- first line)

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Lovely Acuña	Raymund Domino	R. Garay	MR. Villanueva
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.5 Flight Log for 7568G Mission

Annex 7. Flight status reports

Table A-7.1. Flight Status Report

NEGROS ORIENTAL
September 20 – October 15, 2014

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7526 G	BLK 53O & BLK 55A	2BLK53O55A273A	MVE Tonga	9/30/14	Surveyed 3 line of BLK53O and 4 lines of BLK55A
7540 G	BLK 55A & BLK 53K	2BLK55AS53KS280A	MR Villanueva	10/7/14	Surveyed 11 lines
7560 G	BLK 55A	2BLK55A290A	MVE Tonga	10/17/14	Mission completed with minimal voids
7562 G	BLK 53I	2BLK53I291A	MR Villanueva	10/18/14	Mission completed but there were voids encountered during the survey
7566 G	BLK 53K & BLK 53J	2BLK53JK293A	MVE Tonga	10/20/14	Mission completed with CASI
7568 G	BLK 53K	2BLK53KS294A	MR Villanueva	10/21/14	Mission completed

LAS BOUNDARIES PER FLIGHT

LAS

Flight No. : 7526G
Area: BLK53O & BLK55A
Mission Name: 2BLK53O55A273A (BLK53K)

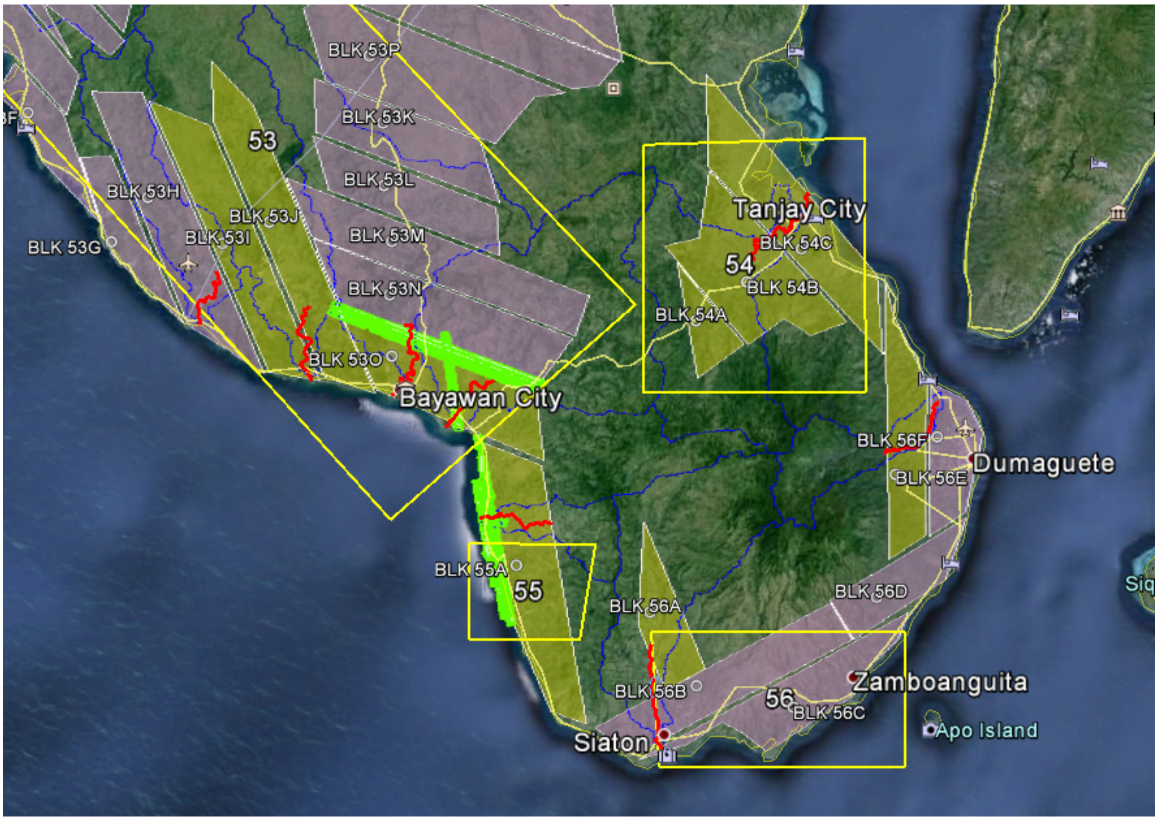


Figure A-7.1 Swath for Flight No. 7526G

Flight No. : 7540G
Area: BLK 55A and BLK 53K
Mission Name: 2BLK55AS53KS280A

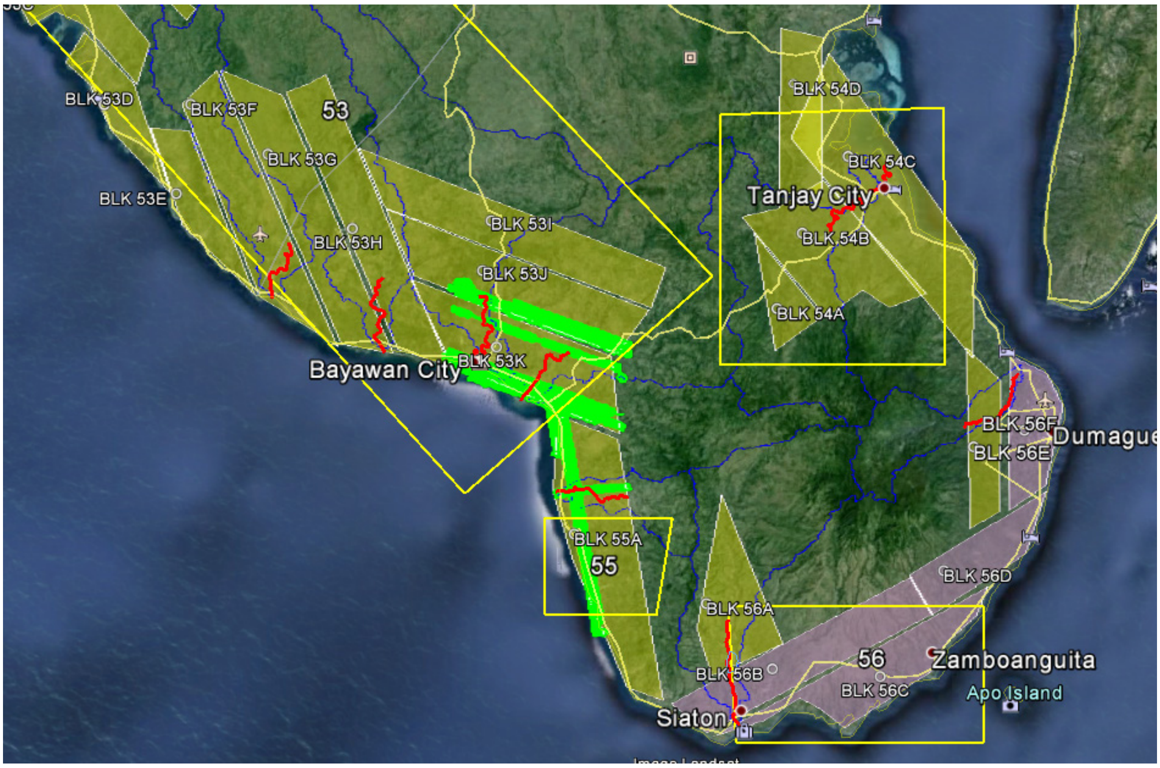


Figure A-7.2 Swath for Flight No. 7540G

Flight No. : 7560G
Area: BLK 55A
Mission Name: 2BLK55A290A

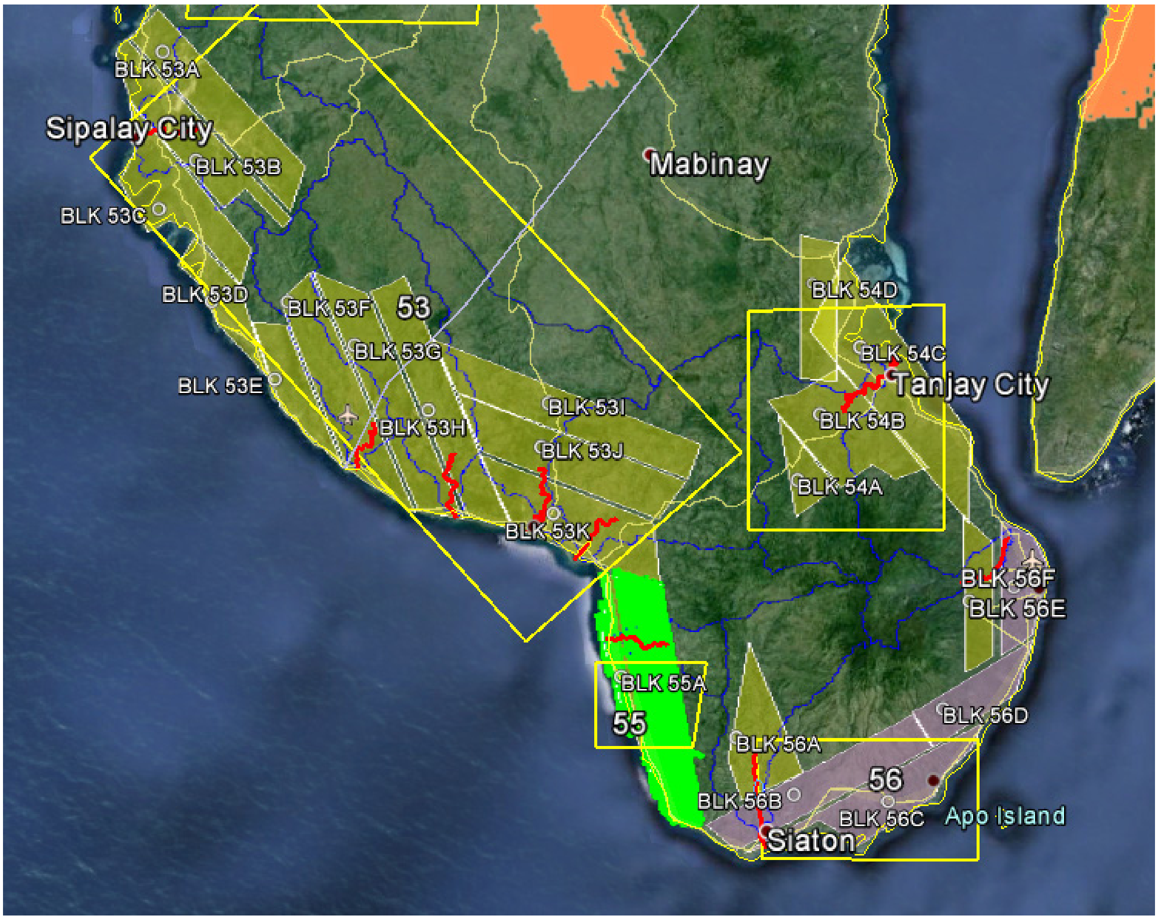


Figure A-7.3 Swath for Flight No. 7560G

Flight No. : 7562G
Area: BLK 53I
Mission Name: 2BLK53I291A

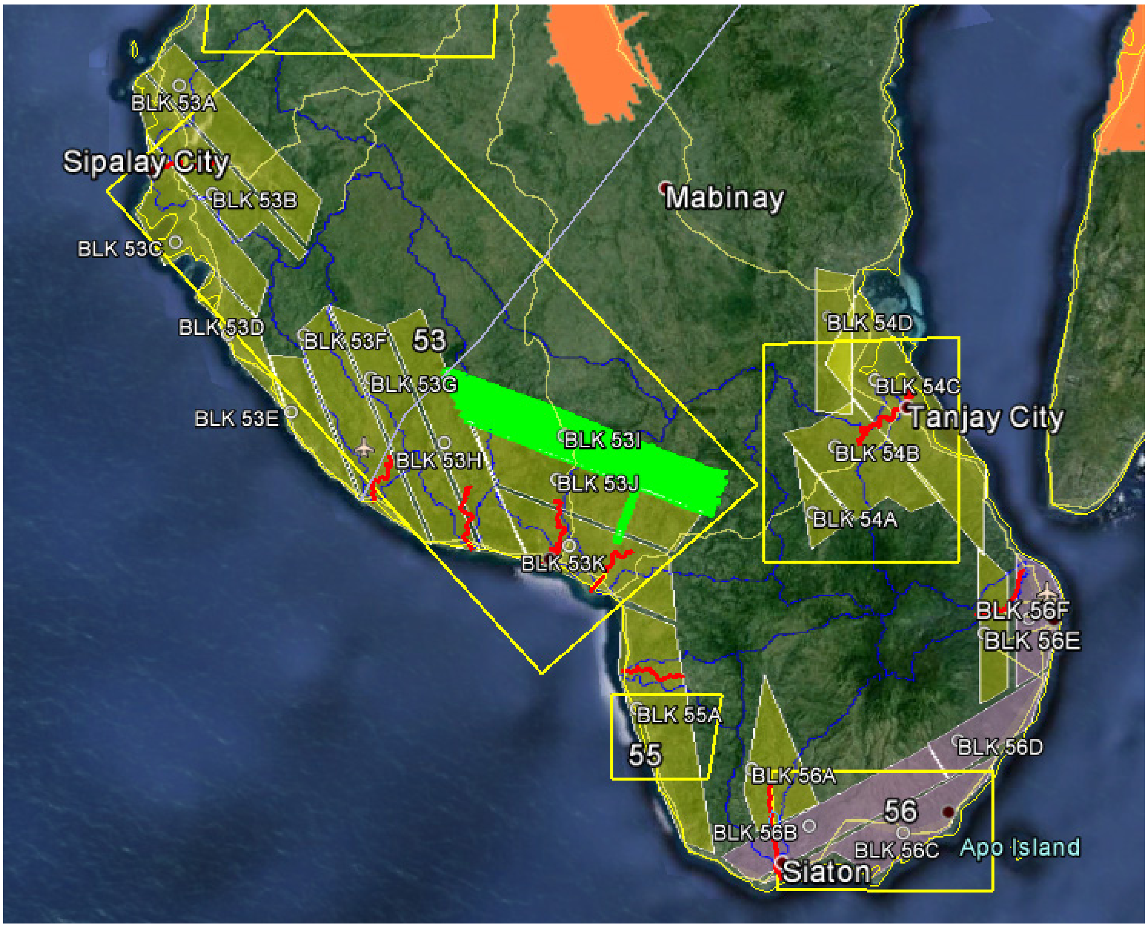


Figure A-7.4 Swath for Flight No. 7562G

Flight No: 566G
Area: BLK 53K & BLK 53J
Mission Name: 2BLK53JK293A

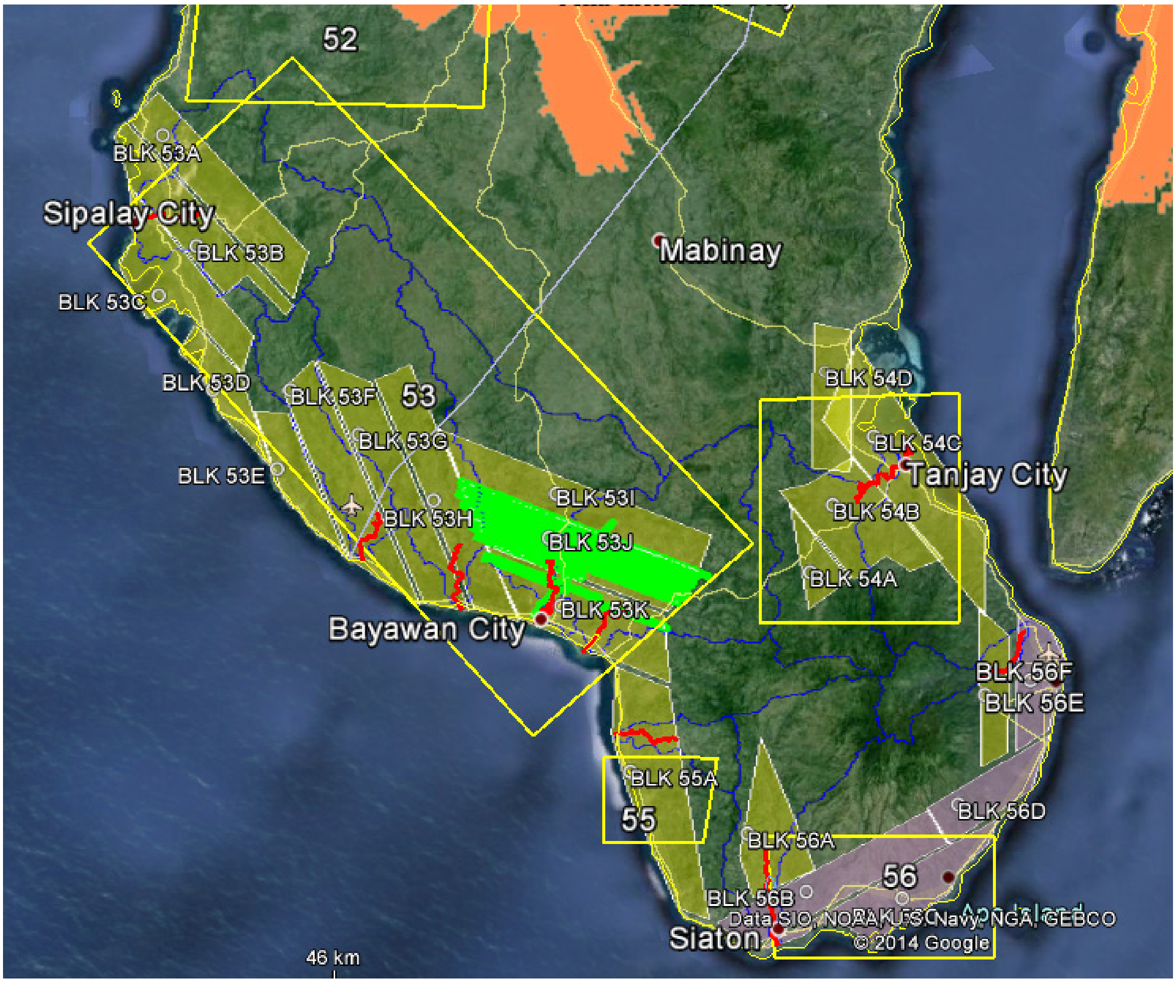


Figure A-7.4 Swath for Flight No. 7566G

Flight No. : 7568G
Area: BLK 53K
Mission Name: 2BLK53KS294A

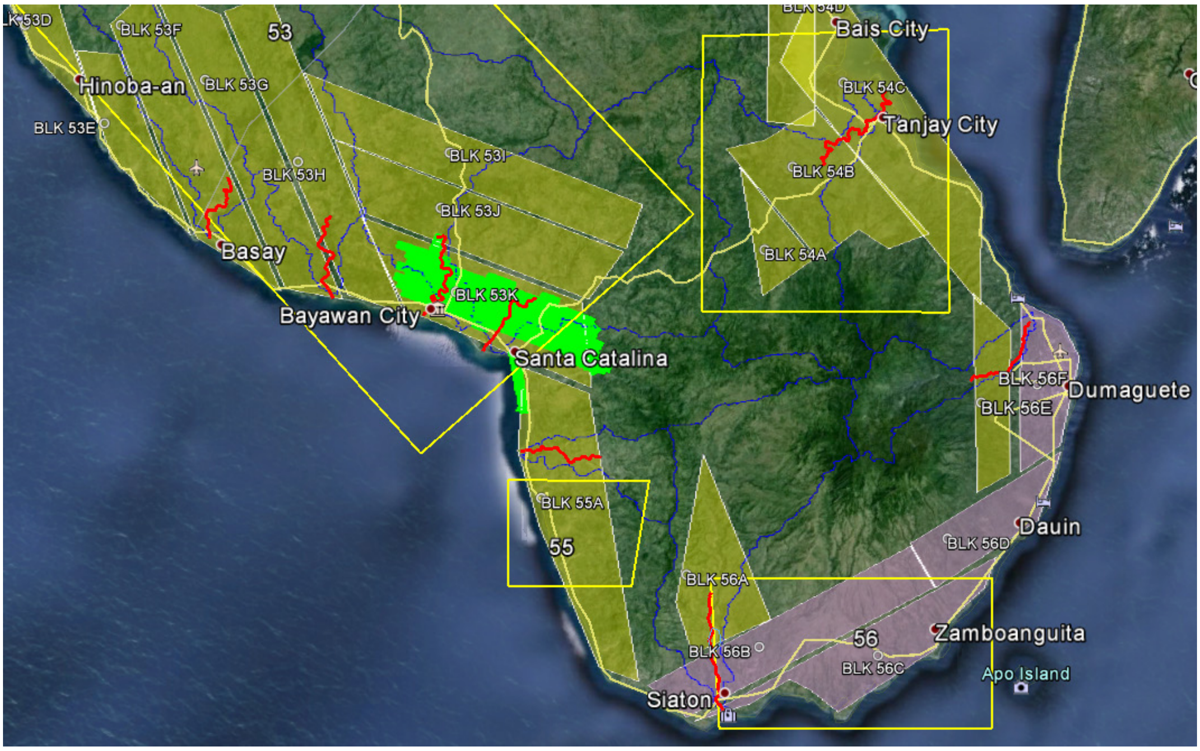


Figure A-7.4 Swath for Flight No. 7568G

ANNEX 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Mission Blk53J

Flight Area	Dumaguete
Mission Name	Blk53J
Inclusive Flights	7566G
Range data size	19.0 GB
Base data size	6.05 MB
POS	210 MB
Image	na
Transfer date	November 6, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.25
RMSE for East Position (<4.0 cm)	3.0
RMSE for Down Position (<8.0 cm)	5.0
Boresight correction stdev (<0.001deg)	0.000126
IMU attitude correction stdev (<0.001deg)	0.000301
GPS position stdev (<0.01m)	0.0012
Minimum % overlap (>25)	30.01%
Ave point cloud density per sq.m. (>2.0)	3.60
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	233
Maximum Height	440.16 m
Minimum Height	62.84 m
Classification (# of points)	
Ground	70,438,370
Low vegetation	63,300,697
Medium vegetation	166,611,886
High vegetation	213,423,896
Building	2,735,569
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Jeffrey Delica

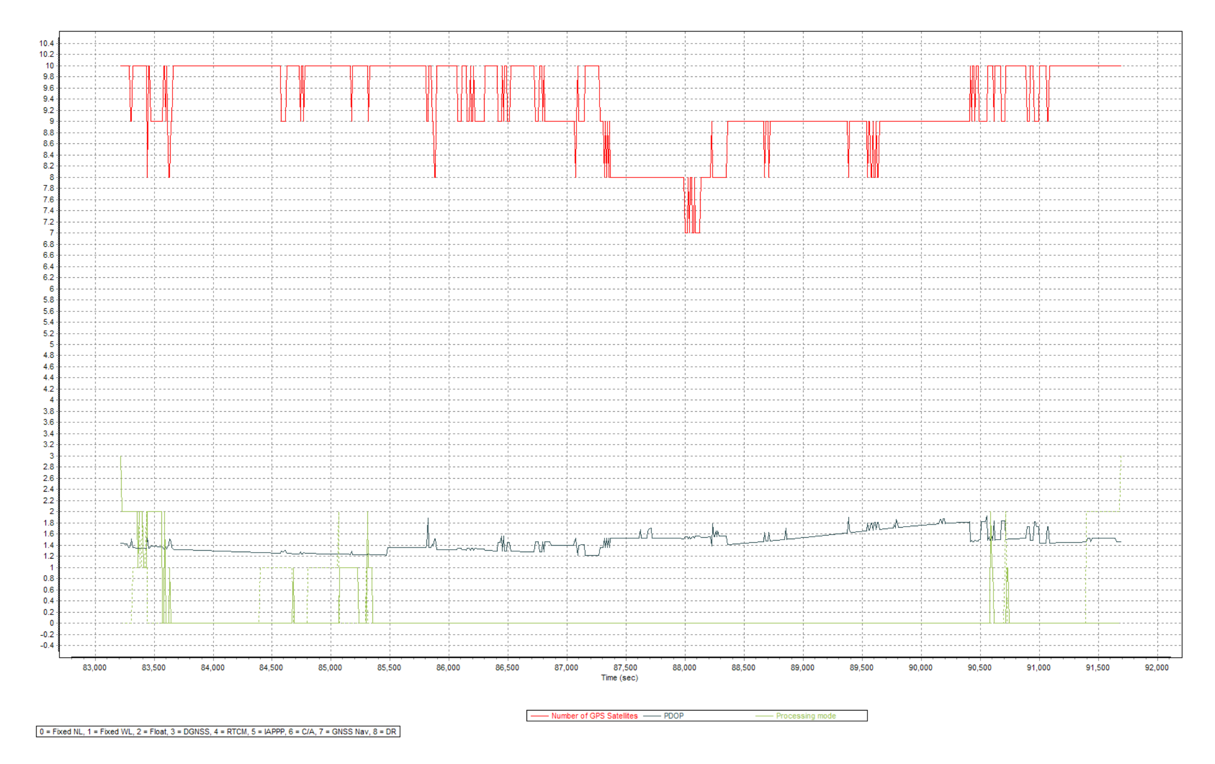


Figure A-8.1 Solution Status

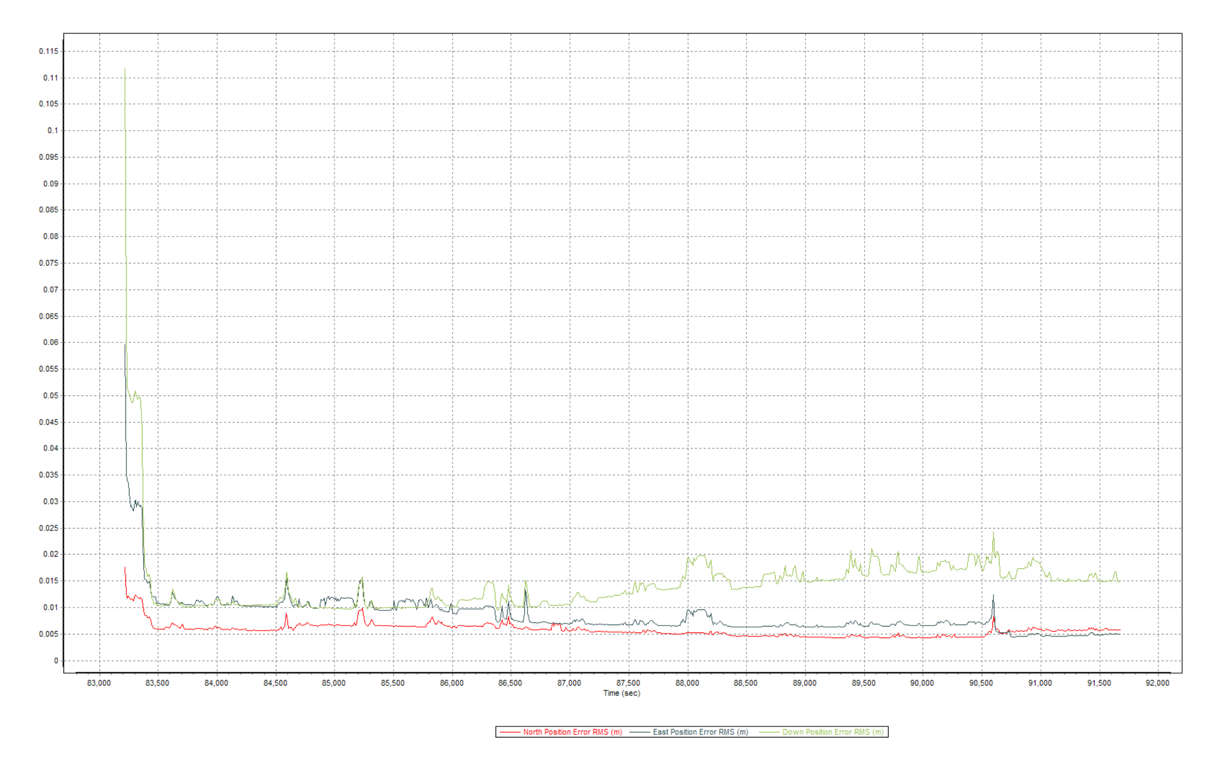


Figure A-8.2. Smoothed Performance Metric Parameters

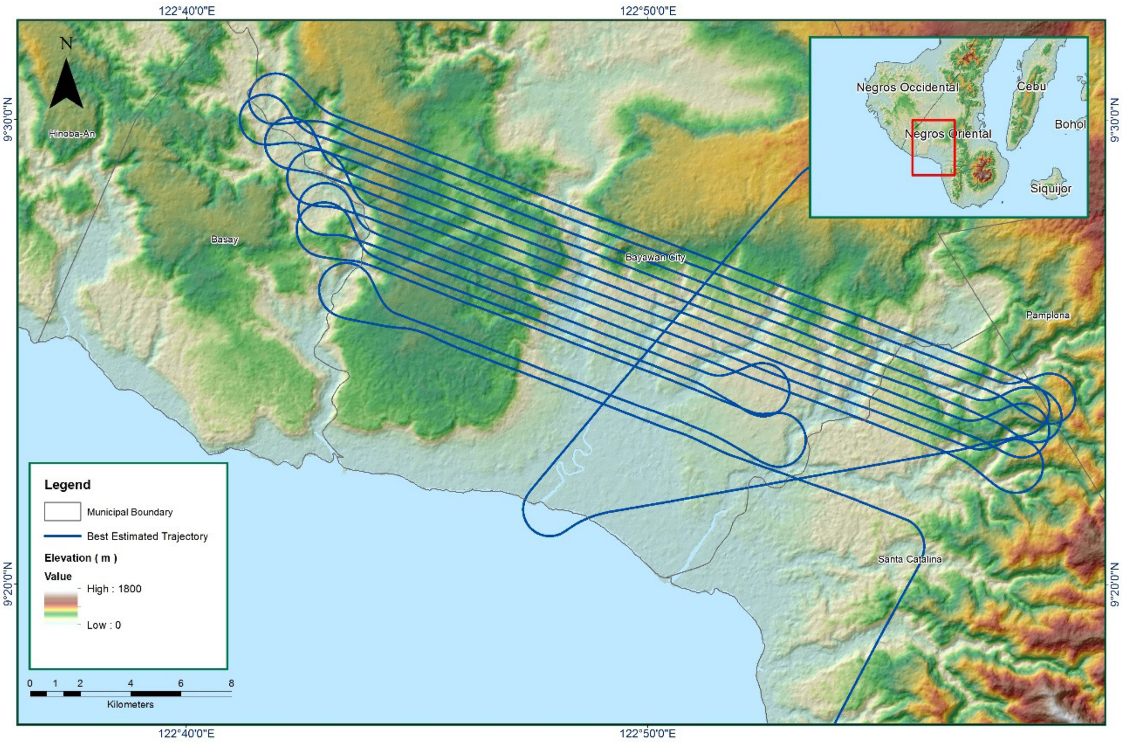


Figure A-8.3. Best Estimated Trajectory

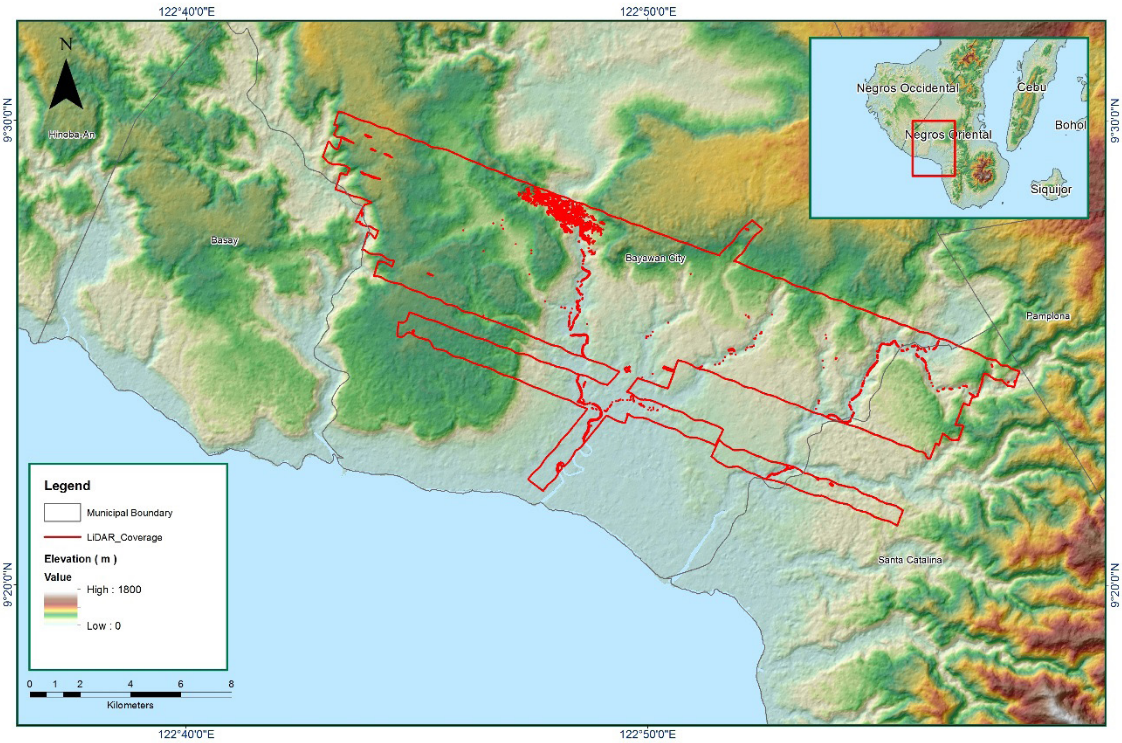


Figure A-8.4. Coverage of LiDAR data

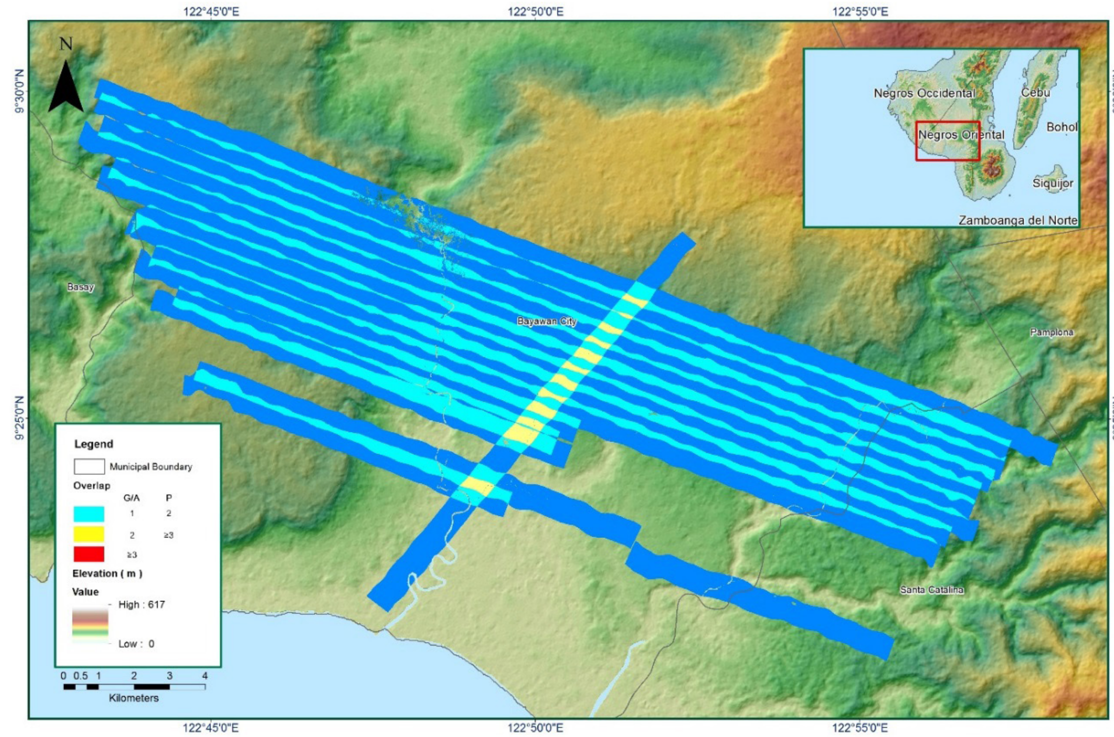


Figure A-8.5. Image of data overlap

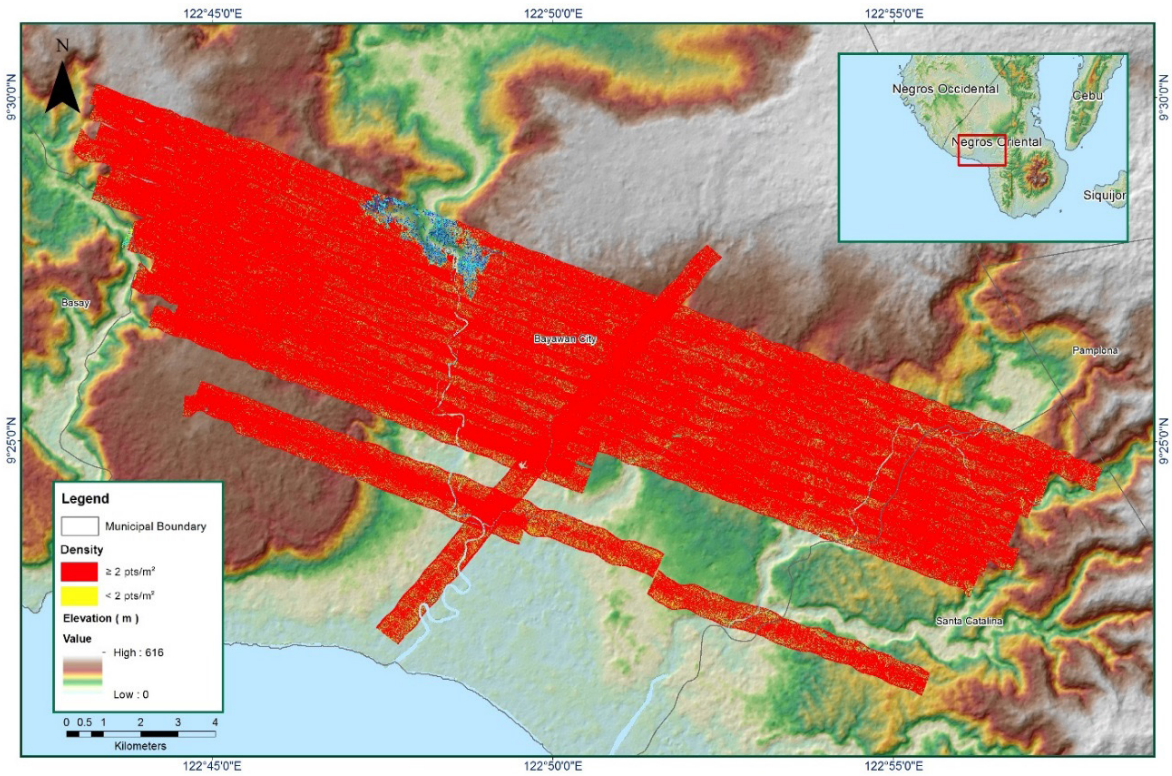


Figure A-8.6. Density map of merged LiDAR data

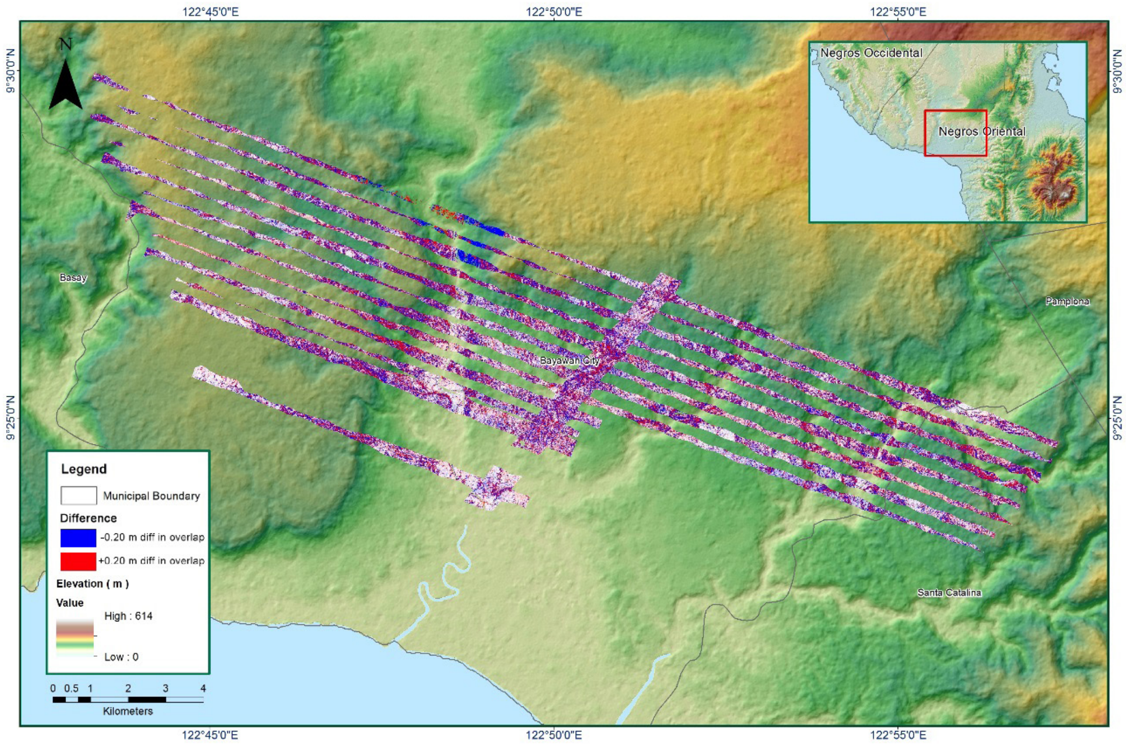


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk53K

Flight Area	Dumaguete
Mission Name	Blk53K
Inclusive Flights	7540G, 7566G, 7568G
Range data size	41.99 GB
Base data size	17.00 MB
POS	610 MB
Image	na
Transfer date	November 6, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000194
IMU attitude correction stdev (<0.001deg)	0.157208
GPS position stdev (<0.01m)	0.0132
Minimum % overlap (>25)	46.62%
Ave point cloud density per sq.m. (>2.0)	3.78
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	156
Maximum Height	442.28 m
Minimum Height	62.23 m
Classification (# of points)	
Ground	52,875,981
Low vegetation	63,446,538
Medium vegetation	142,908,519
High vegetation	123,701,134
Building	3,086,316
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Christy Lubiano, Jovy Narisma

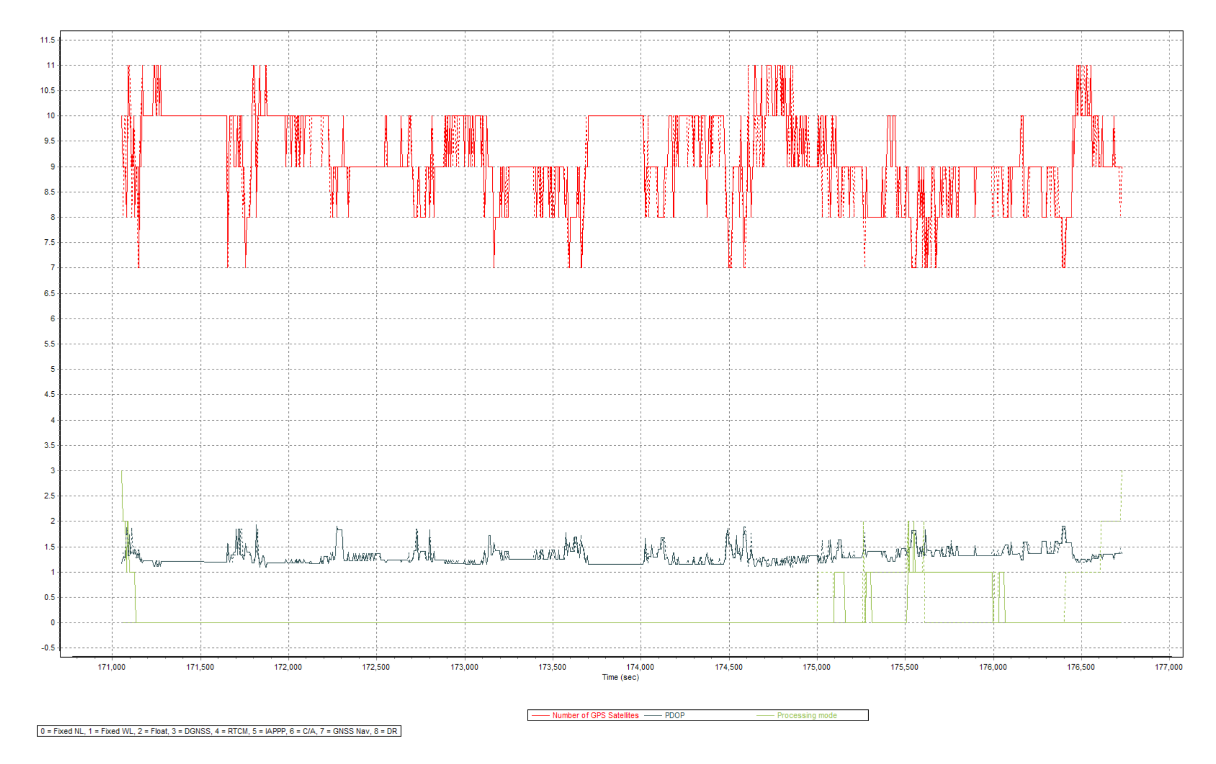


Figure A-8.8. Solution Status

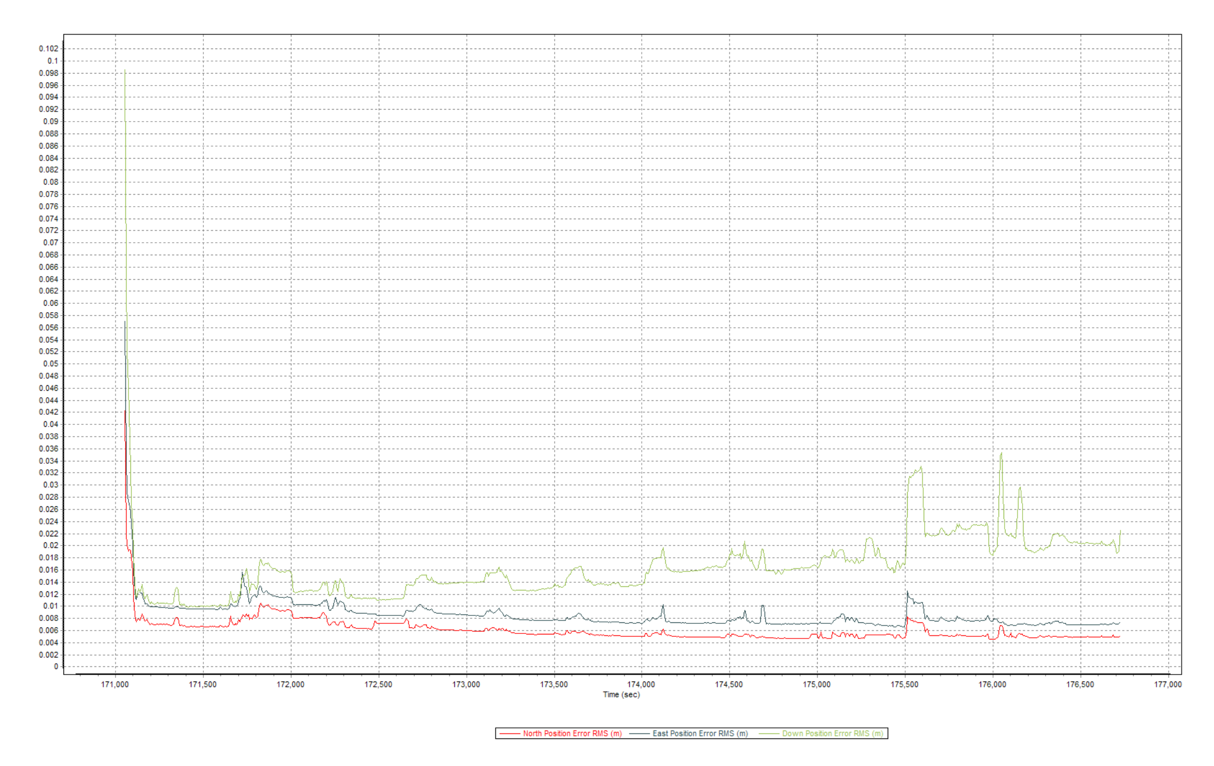


Figure A-8.9. Smoothed Performance Metric Parameters

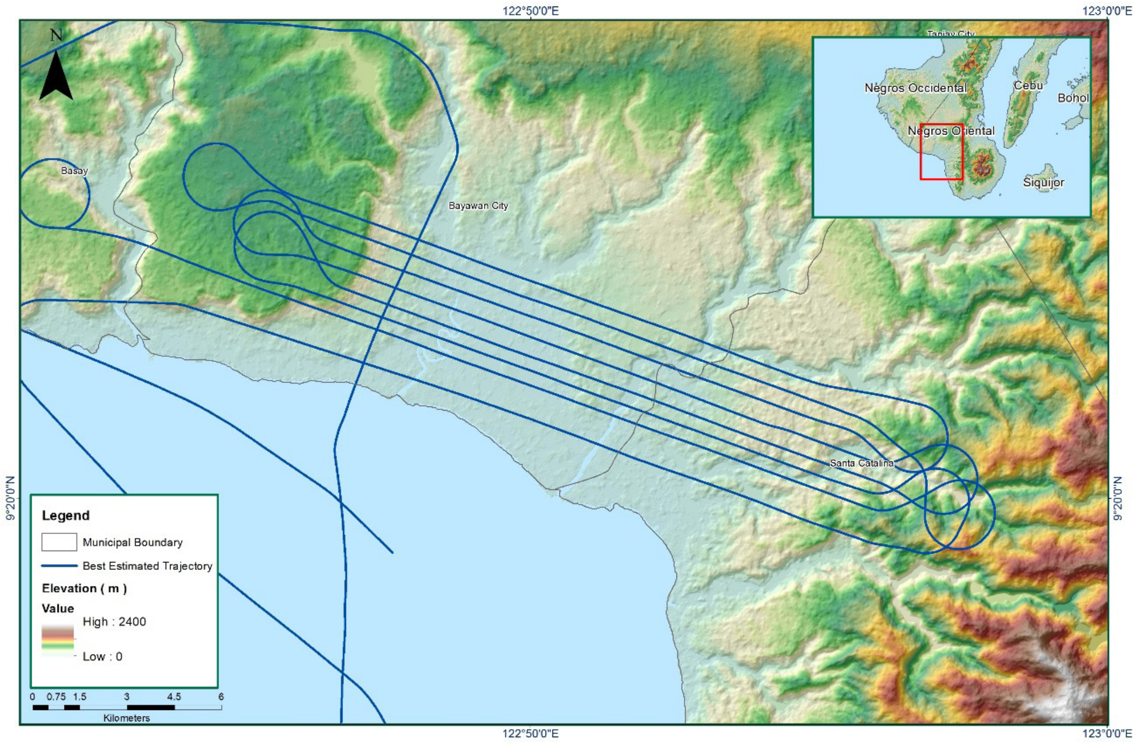


Figure A-8.10. Best Estimated Trajectory

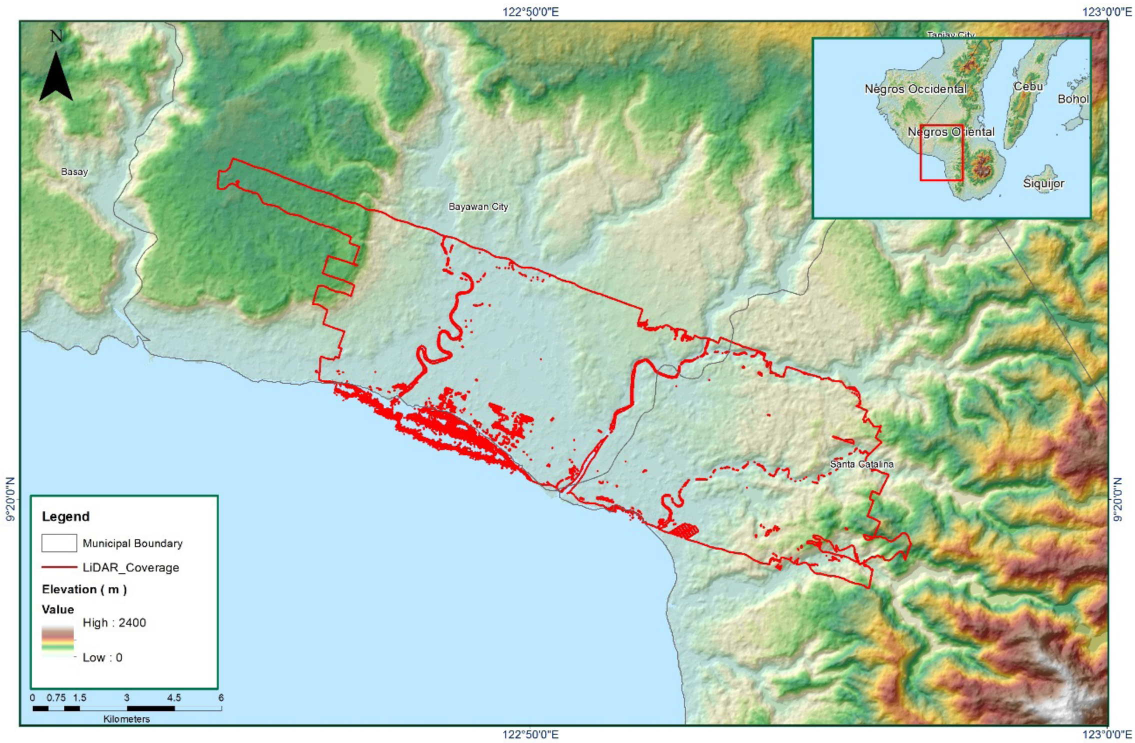


Figure A-8.11. Coverage of LiDAR data

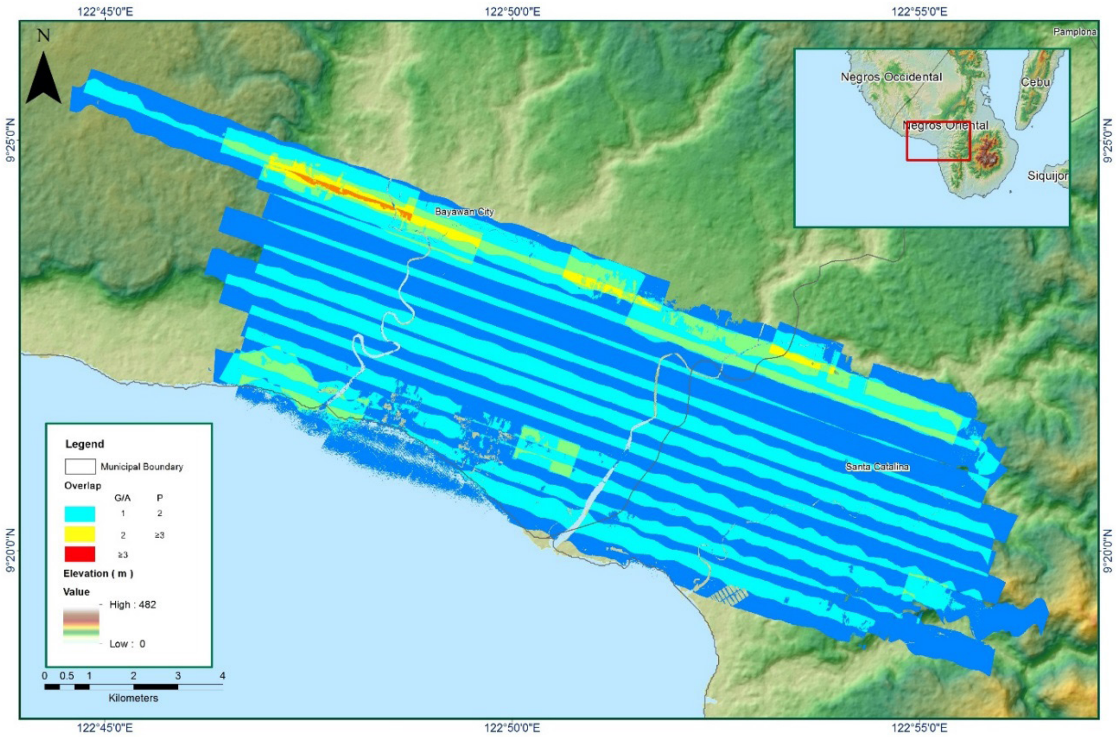


Figure A-8.12. Image of data overlap

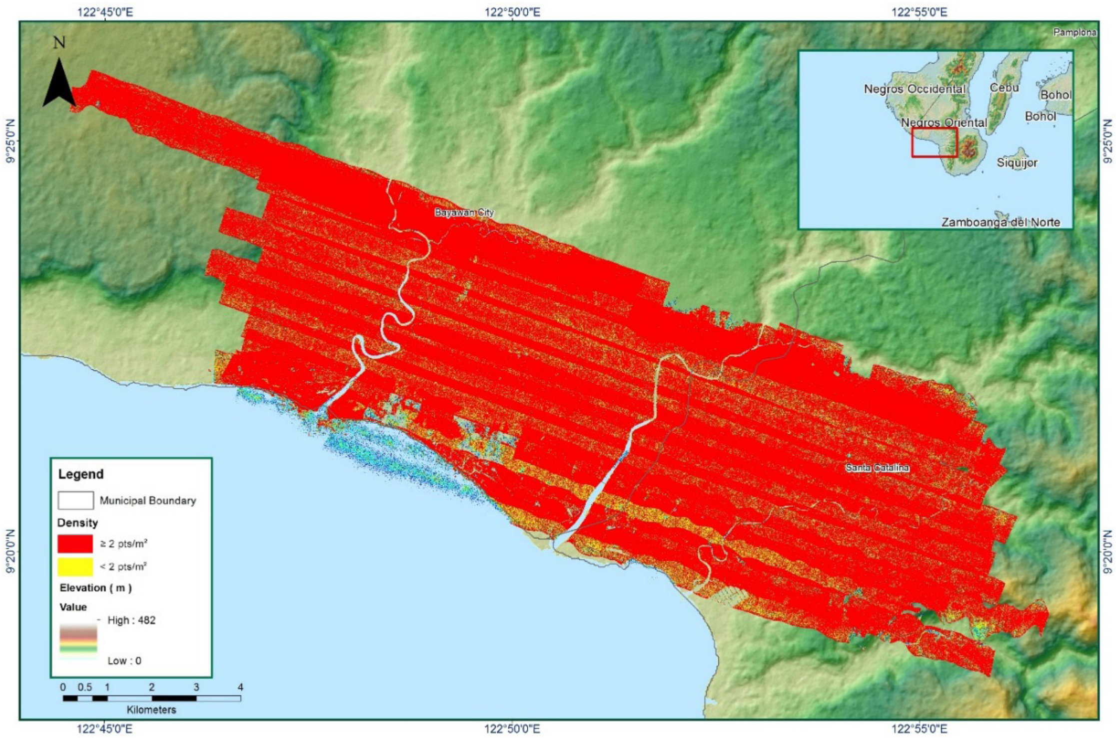


Figure A-8.13. Density map of merged LiDAR data

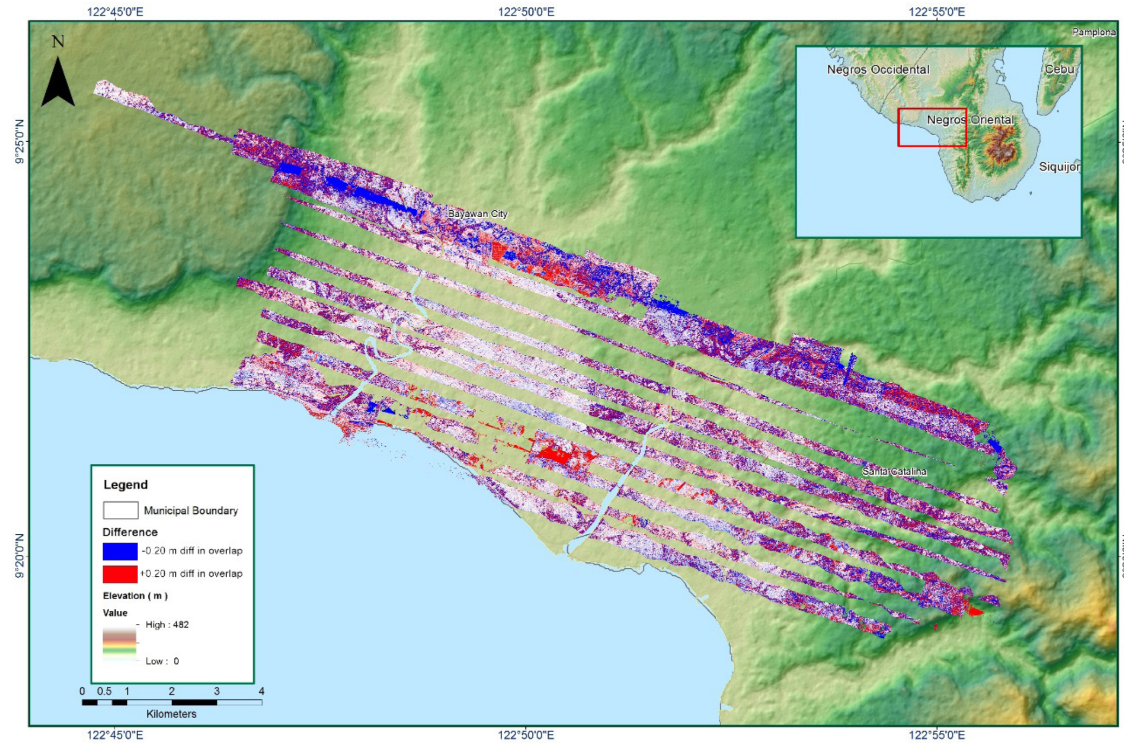


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk53K_supplement

Flight Area	Dumaguete
Mission Name	Blk53K_supplement
Inclusive Flights	7526G,7540G
Range data size	20.9 GB
Base data size	8.54 MB
POS	352 MB
Image	na
Transfer date	Oct. 20 and Nov. 6, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.082
RMSE for East Position (<4.0 cm)	1.05
RMSE for Down Position (<8.0 cm)	1.9
Boresight correction stdev (<0.001deg)	0.000571
IMU attitude correction stdev (<0.001deg)	0.001794
GPS position stdev (<0.01m)	0.0102
Minimum % overlap (>25)	47.63%
Ave point cloud density per sq.m. (>2.0)	4.08
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	93
Maximum Height	383.29 m
Minimum Height	64.07 m
Classification (# of points)	
Ground	21,234,446
Low vegetation	22,518,129
Medium vegetation	75,022,634
High vegetation	65,449,423
Building	801,385
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Mark Joshua Salvacion, Engr. Ma. Ailyn Olanda

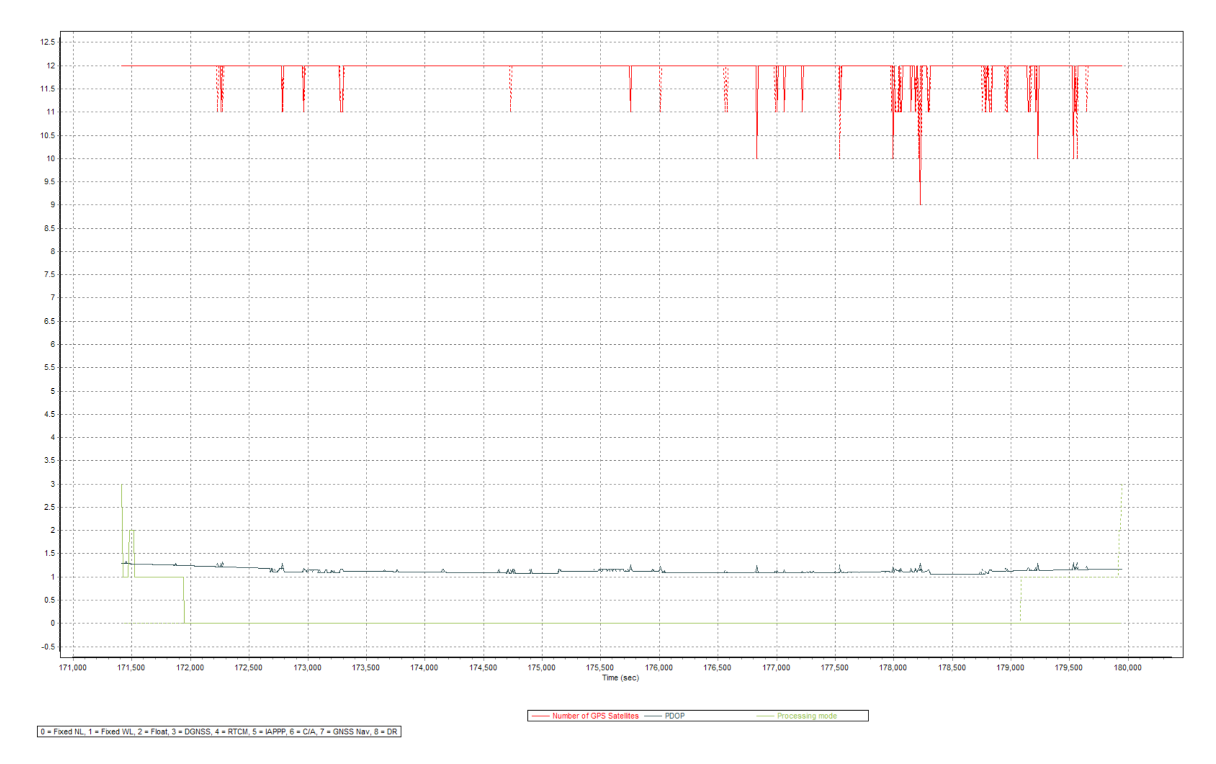


Figure A-8.15. Solution Status

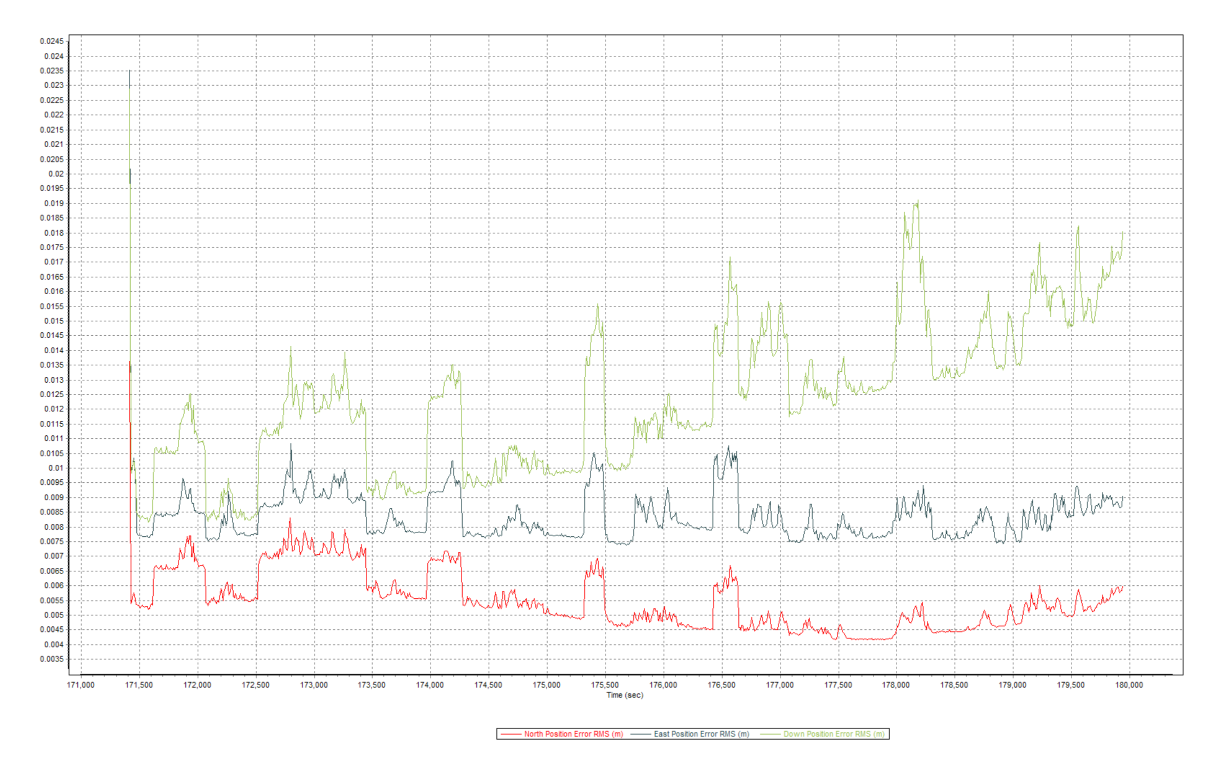


Figure A-8.16. Smoothed Performance Metrics Parameters

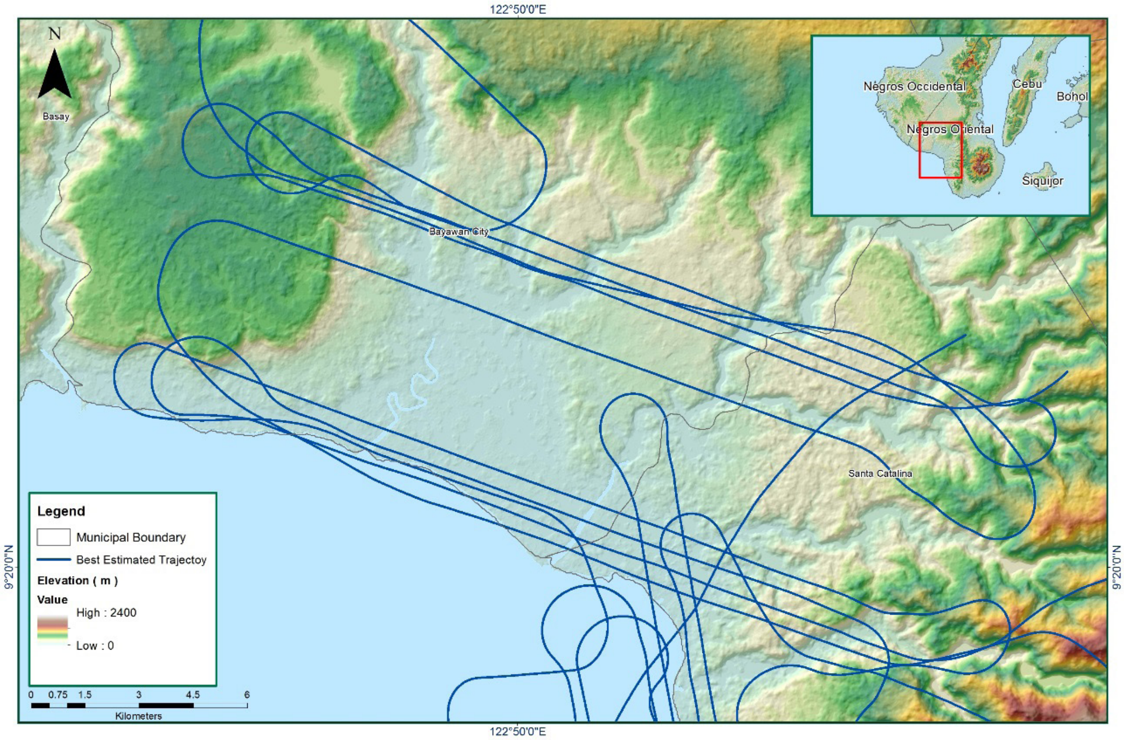


Figure A-8.17. Best Estimated Trajectory

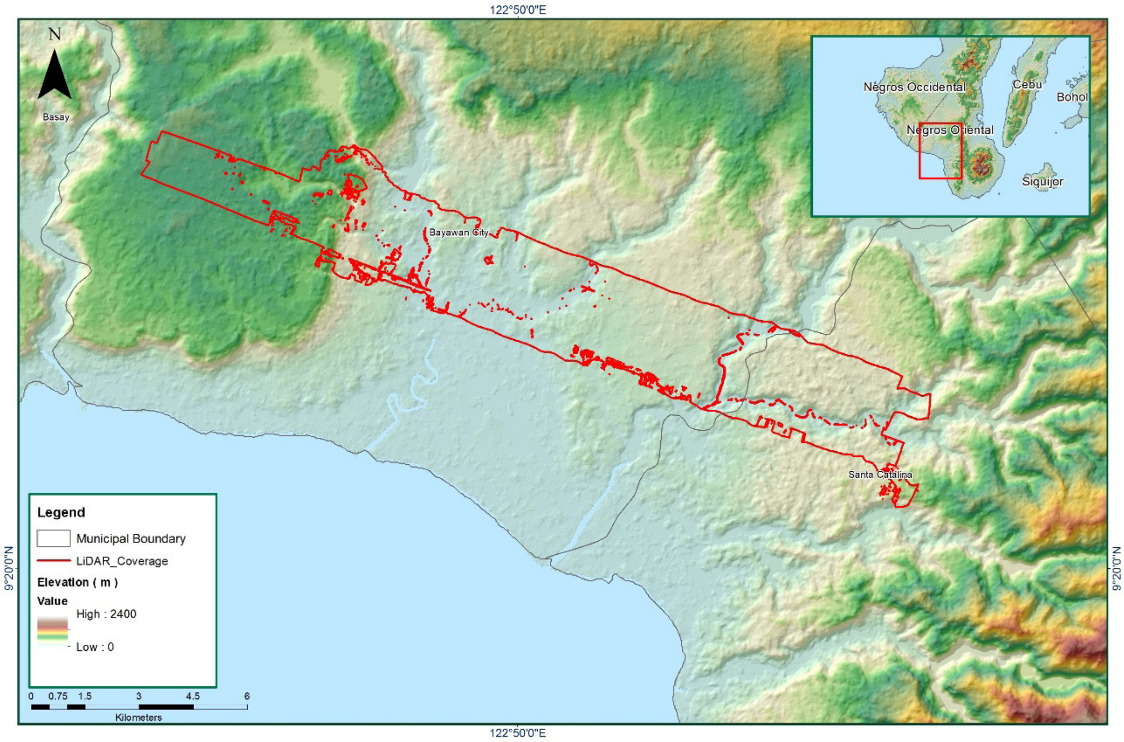


Figure A-8.18. Coverage of LiDAR data

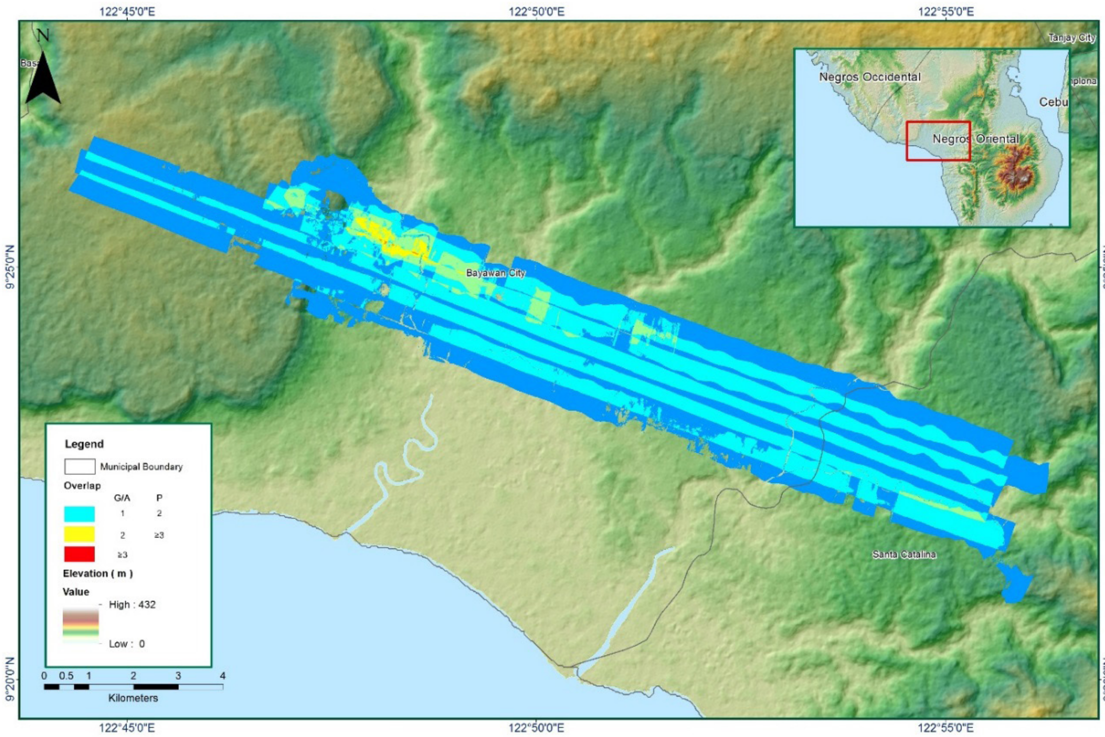


Figure A-8.19. Image of data overlap

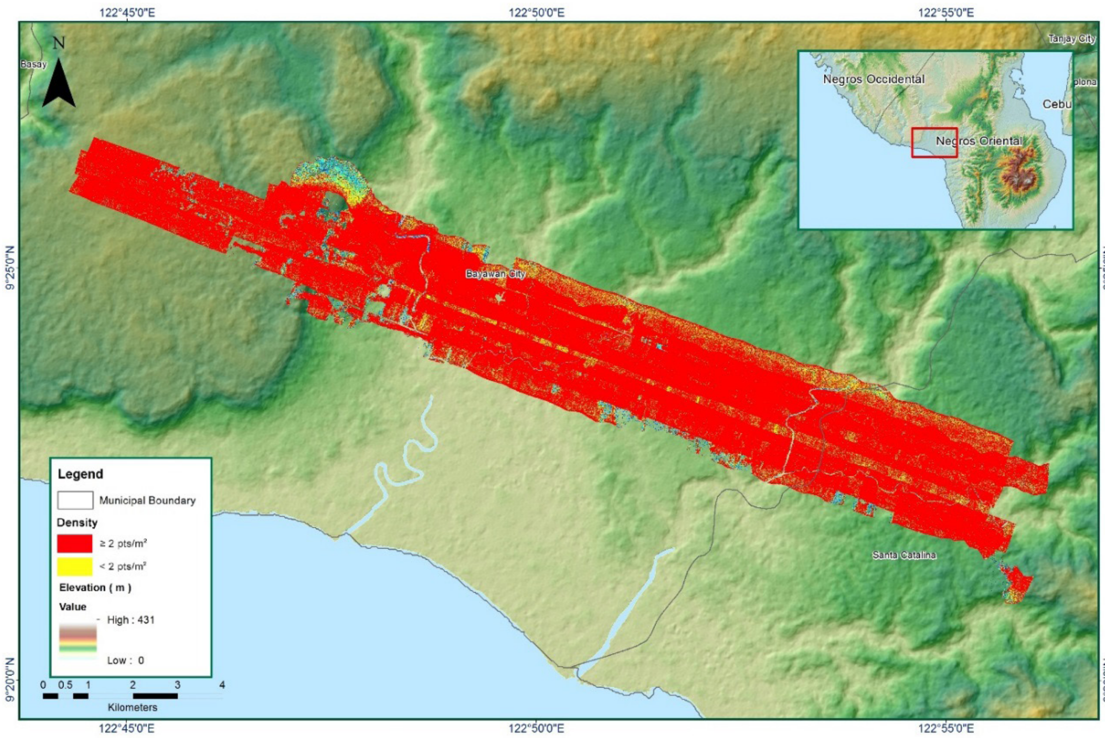


Figure A-8.20. Density of merged LiDAR data

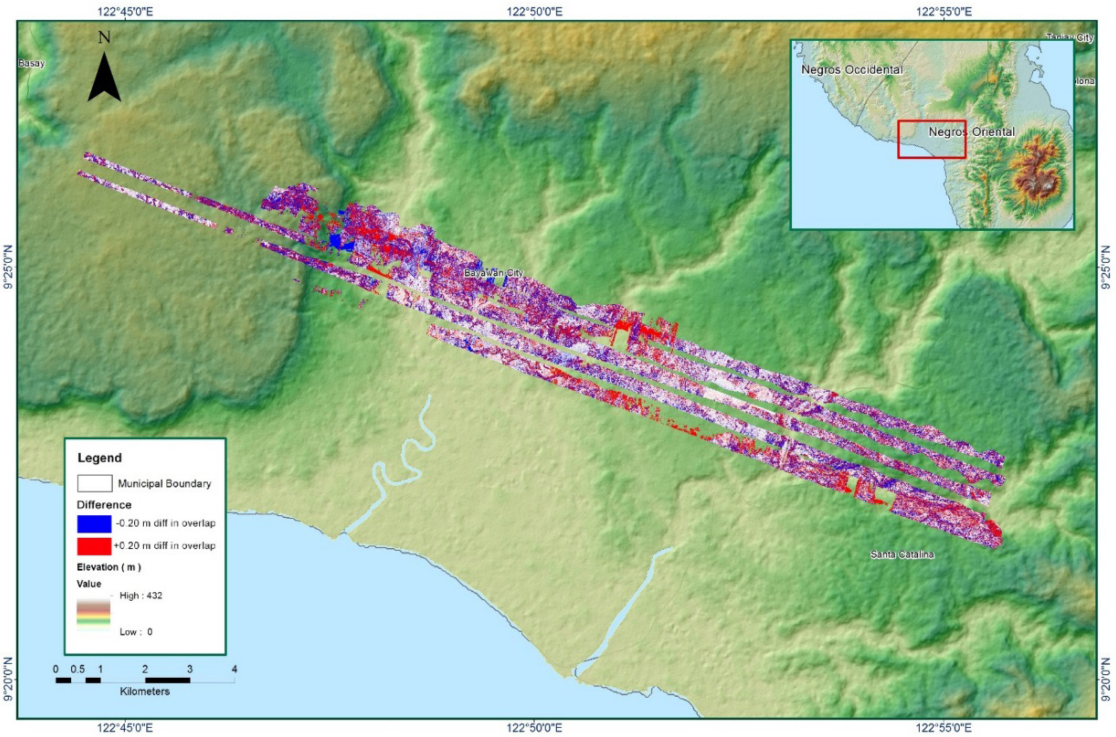


Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk55A

Flight Area	Dumaguete
Mission Name	Blk55A
Inclusive Flights	7526G, 7540G, 7560G
Range data size	59.7 GB
Base data size	13.88 MB
POS	667 MB
Image	na
Transfer date	Oct. 20 and Nov. 6, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.088
RMSE for East Position (<4.0 cm)	1.32
RMSE for Down Position (<8.0 cm)	2.2
Boresight correction stdev (<0.001deg)	0.000170
IMU attitude correction stdev (<0.001deg)	0.001080
GPS position stdev (<0.01m)	0.0066
Minimum % overlap (>25)	47.00%
Ave point cloud density per sq.m. (>2.0)	3.83
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	225
Maximum Height	719.03 m
Minimum Height	60.3 m
Classification (# of points)	
Ground	84661907
Low vegetation	80144926
Medium vegetation	161689840
High vegetation	275799941
Building	5058695
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Edgardo Gubatanga Jr., Engr. Elainne Lopez

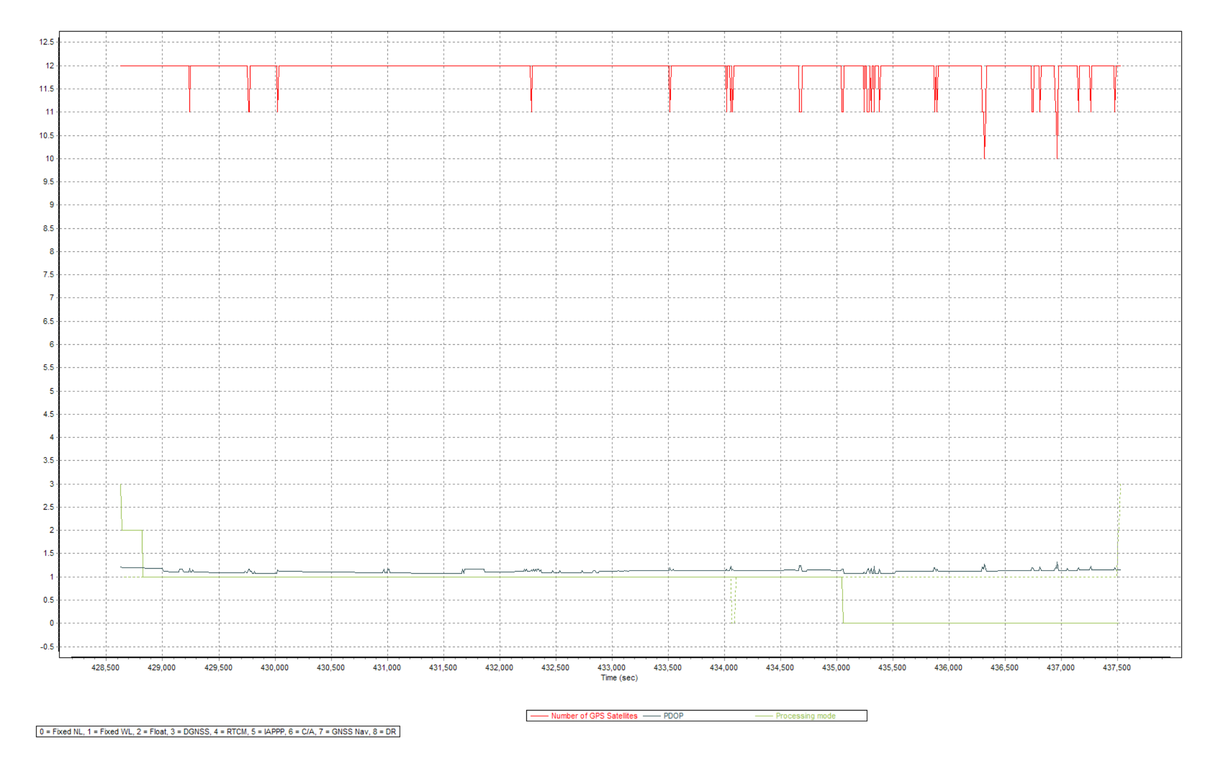


Figure A-8.22. Solution Status

Figure A-8.23. Smoothed Performance Metrics Parameters

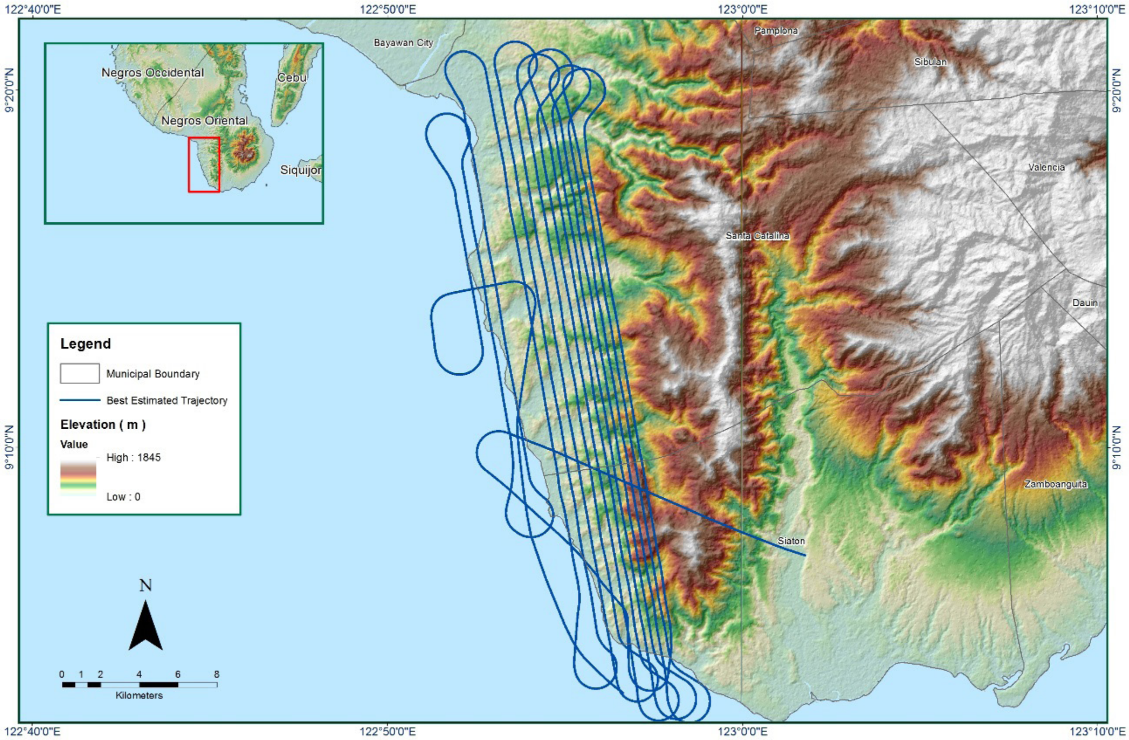


Figure A-8.24. Best Estimated Trajectory

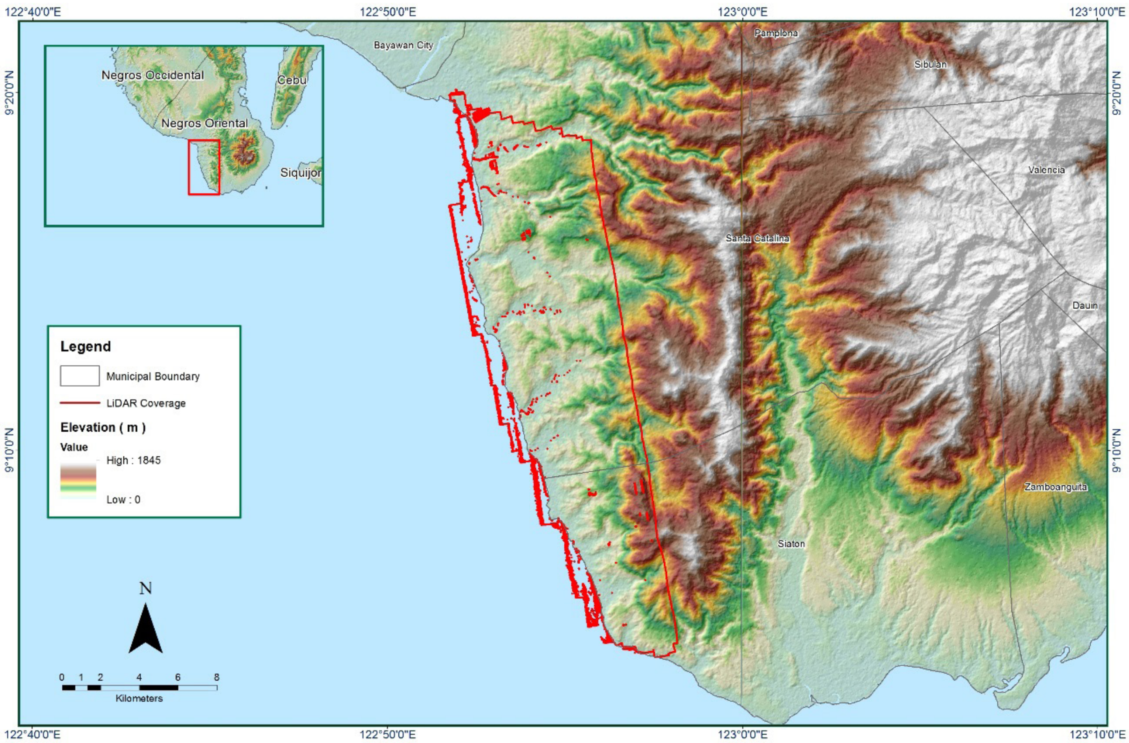


Figure A-8.25. Coverage of LiDAR data

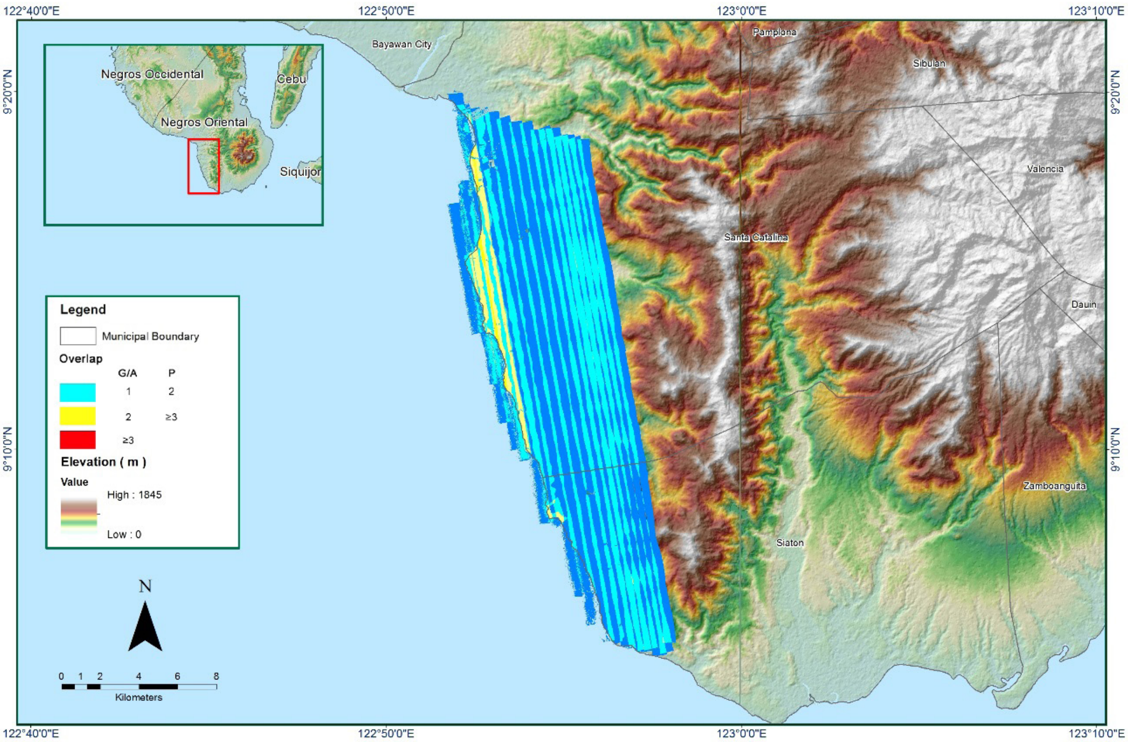


Figure A-8.26. Image of data overlap

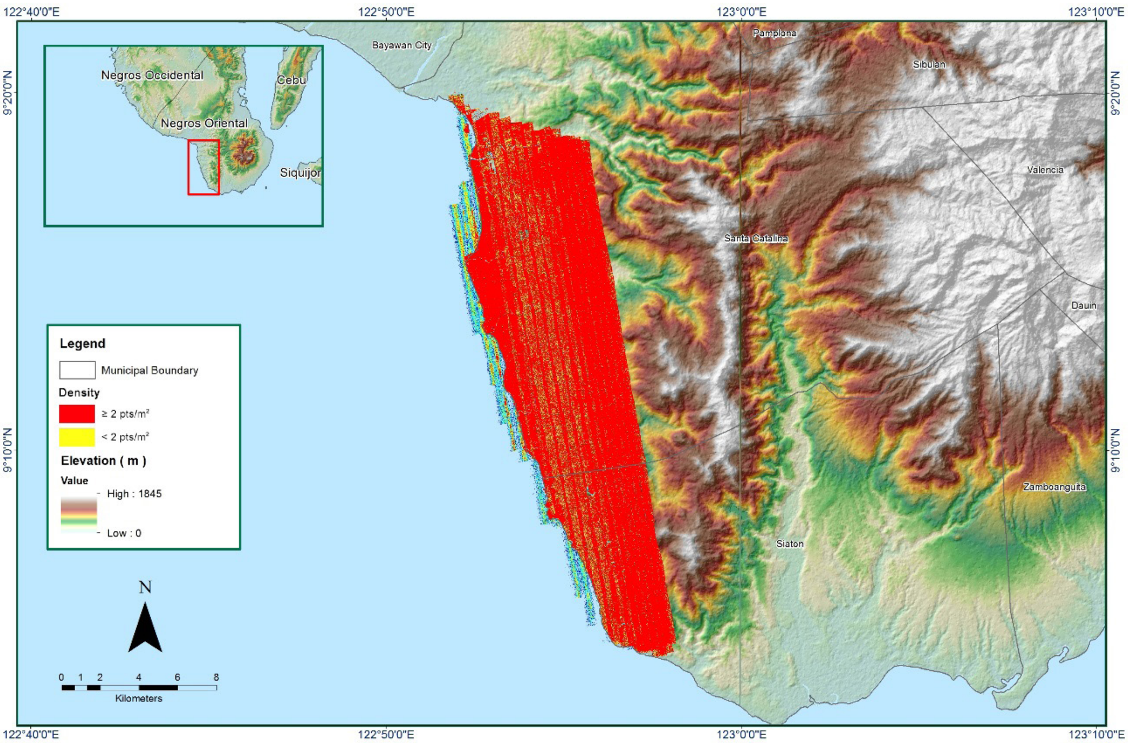


Figure A-8.27. Density of merged LiDAR data

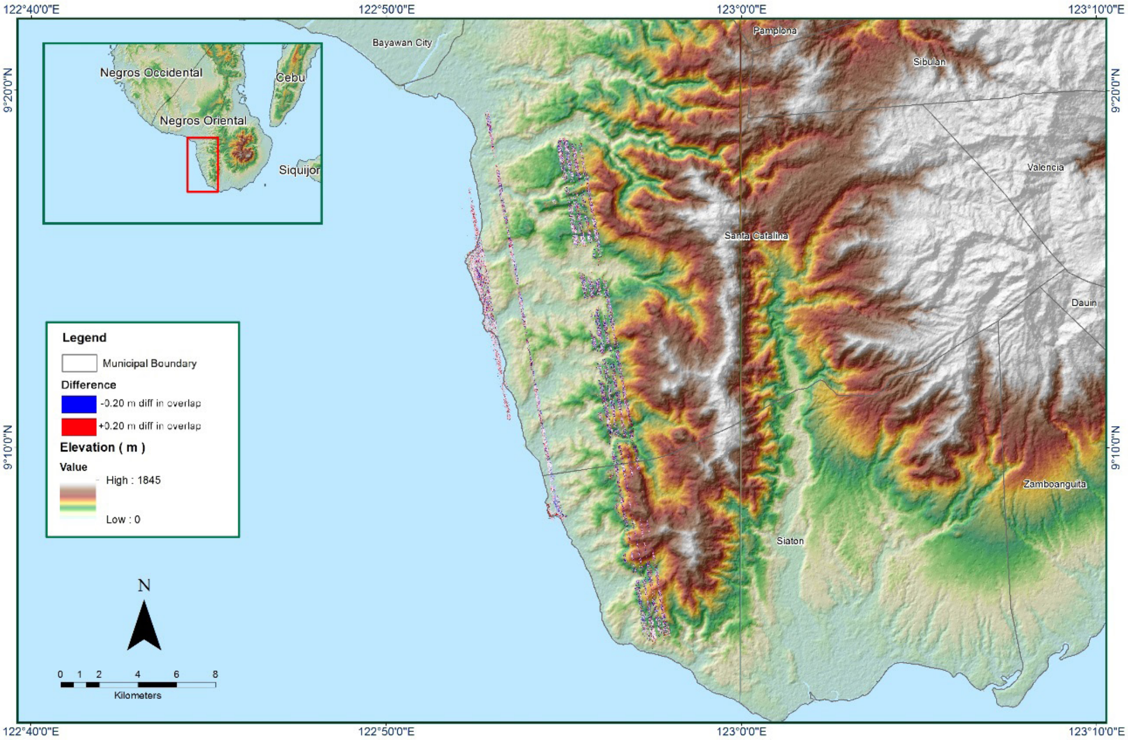


Figure A-8.28. Elevation difference between flight lines

Annex 9. Sicopong Model Basin Parameters

Table A-9.1 Sicopong Model Basin Parameters

Basin Number	SCS Curve Number Loss Model			Clark Transform Model		Recession Constant Baseflow Model				
	Initial Abstraction	Curve Number	Impervious	Time of Concentration	Storage Coefficient	Initial Type	Initial Dis-charge	Recession Constant	Threshold Type	Ratio to Peak
W1020	9.7538	43.496	0	14.734	3.3062	Discharge	0.0433534	0.0043018	Ratio to Peak	0.001
W1030	12.986	55.944	0	16.405	0.74476	Discharge	0.0147593	0.0029264	Ratio to Peak	0.001
W1040	13.507	58.153	0	20.953	1.3263	Discharge	0.031531	0.0029264	Ratio to Peak	0.001
W1050	10.118	39.337	0	1.155	0.049856	Discharge	0.0163445	0.0029264	Ratio to Peak	0.001
W1060	11.137	60.249	0	17.871	1.2059	Discharge	0.0155759	0.0029264	Ratio to Peak	0.001
W1070	8.7142	67.242	0	63.36	1.2617	Discharge	0.0476415	0.0043018	Ratio to Peak	0.001
W1080	10.044	63.323	0	40.005	1.1978	Discharge	0.0319675	0.0029264	Ratio to Peak	0.001
W1090	7.1089	72.512	0	1.5283	0.13334	Discharge	0.0282665	0.0029264	Ratio to Peak	0.001
W1100	4.1184	87.584	0	7.0548	10.322	Discharge	0.047426	0.0145185	Ratio to Peak	0.001
W1110	6.4711	51.065	0	199.99	1.2003	Discharge	0.056047	0.0029264	Ratio to Peak	0.001
W1120	5.8982	99	0	3.3974	0.041846	Discharge	0.0050228	0.0029264	Ratio to Peak	0.00276
W1130	10.862	99	0	2.8992	0.057841	Discharge	0.0055767	0.0029264	Ratio to Peak	0.00667

W1140	10.514	99	0	2.8669	0.035562	Discharge	0.0173835	0.0029264	Ratio to Peak	0.00667
W1150	4.6939	99	0	3.4575	0.28914	Discharge	0.0324032	0.0029264	Ratio to Peak	0.0029778
W1160	8.4585	65.903	0	31.474	1.4027	Discharge	0.0679041	0.0043896	Ratio to Peak	0.001
W1170	6.5388	81.945	0	2.4449	1.1973	Discharge	0.0022781	0.0039506	Ratio to Peak	0.001
W1180	4.9632	97.02	0	3.5265	0.0931871	Discharge	0.0192321	0.0059259	Ratio to Peak	0.00298
W1190	4.522	99	0	4.1003	0.064265	Discharge	0.0246025	0.0145185	Ratio to Peak	0.00287
W1200	9.7197	63.979	0	2.906	0.068004	Discharge	0.0247331	0.0059259	Ratio to Peak	0.001
W1210	11.689	58.97	0	11.877	1.7937	Discharge	0.0591185	0.0065844	Ratio to Peak	0.001
W1220	4.7385	99	0	4.1276	0.0893606	Discharge	0.029745	0.0065504	Ratio to Peak	0.009
W1230	4.72	56.087	0	9.5802	1.8516	Discharge	0.0074384	0.0065512	Ratio to Peak	0.001
W1240	7.046	99	0	3.2353	0.04827	Discharge	0.0125284	0.0146661	Ratio to Peak	0.00447
W1250	8.3186	68.399	0	8.0227	5.7549	Discharge	0.0227176	0.0065844	Ratio to Peak	0.0067
W1260	4.7434	82.448	0	0.28479	0.02	Discharge	0.000611046	0.0112943	Ratio to Peak	0.0067
W1270	13.721	57.682	0	8.6016	0.54423	Discharge	0.0368327	0.0065844	Ratio to Peak	0.001
W1280	4.7425	82.448	0	4.8409	0.052092	Discharge	0.0508636	0.0065843	Ratio to Peak	0.001
W1290	4.7432	82.448	0	3.6726	0.069912	Discharge	0.0045137	0.0065513	Ratio to Peak	0.001

W1300	4.743	82.448	0	6.6178	2.9764	Discharge	0.0053271	0.0065844	Ratio to Peak	0.001
W1310	7.046	99	0	9.9136	0.33656	Discharge	0.0176972	0.0065844	Ratio to Peak	0.0067
W1320	4.7431	82.448	0	3.2806	0.044585	Discharge	0.0021707	0.0065514	Ratio to Peak	0.001
W1330	7.0803	93.645	0	3.1102	0.055309	Discharge	0.0154932	0.0065844	Ratio to Peak	0.001
W1340	4.7424	82.448	0	9.9507	0.073236	Discharge	0.031565	0.0019509	Ratio to Peak	0.00667
W1350	13.758	57.6	0	8.4909	0.80183	Discharge	0.019331	0.0088889	Ratio to Peak	0.001
W1360	13.758	57.6	0	6.5646	0.61977	Discharge	0.0174585	0.0142281	Ratio to Peak	0.001
W1370	5.8121	77.713	0	4.0399	3.7023	Discharge	0.0248095	0.0065844	Ratio to Peak	0.001
W1380	5.6794	99	0	2.4898	0.9162	Discharge	0.0124372	0.009679	Ratio to Peak	0.0098
W1390	4.4291	85.662	0	2.5695	1.9176	Discharge	0.02655	0.0065844	Ratio to Peak	0.001
W1400	13.758	57.6	0	4.0266	1.7908	Discharge	0.0207014	0.0088889	Ratio to Peak	0.001
W1410	13.758	57.6	0	4.4988	1.2101	Discharge	0.0017729	0.0087998	Ratio to Peak	0.001
W1420	13.758	57.6	10	5.2286	0.020099	Discharge	0.000707608	0.0065186	Ratio to Peak	0.001
W1430	13.758	57.6	10	4.4232	0.72315	Discharge	0.0319636	0.0098765	Ratio to Peak	0.001
W1440	13.758	57.6	10	4.1365	0.033645	Discharge	0.0152198	0.0098765	Ratio to Peak	0.001
W1450	10.296	62.376	10	4.2556	4.6809	Discharge	0.0279073	0.0098765	Ratio to Peak	0.001

W1460	4.7842	91.526	10	11.242	2.2876	Discharge	0.0229022	0.0065844	Ratio to Peak	0.00447
W1470	7.0798	82.448	10	7.4181	0.068157	Discharge	0.0200494	0.0043896	Ratio to Peak	0.00445
W1480	4.7426	82.448	10	0.14871	0.030036	Discharge	0.0018061	0.0019509	Ratio to Peak	0.00467
W1490	4.3993	84.098	10	0.23476	0.025245	Discharge	0.0028111	0.0043896	Ratio to Peak	0.004
W1500	2.8208	92.583	10	4.351	0.36095	Discharge	0.020156	0.0019509	Ratio to Peak	0.0044
W1510	6.4707	92.921	10	0.0166667	0.21727	Discharge	0.0389432	0.0065844	Ratio to Peak	0.0029
W1520	3.9827	91.352	10	4.4912	0.52638	Discharge	0.0169617	0.009679	Ratio to Peak	0.00447
W1530	8.2905	72.604	10	4.7808	6.1862	Discharge	0.0346434	0.0098765	Ratio to Peak	0.001
W1540	3.6834	93.022	10	5.3581	0.0293777	Discharge	0.017015	0.0019509	Ratio to Peak	0.00196
W1550	4.6973	87.6	25	4.7147	0.25591	Discharge	0.0145477	0.0019509	Ratio to Peak	0.0029
W1560	13.752	57.614	25	4.3804	12.684	Discharge	0.0370173	0.0148148	Ratio to Peak	0.001
W1570	1.5896	99	25	4.9068	0.69873	Discharge	0.0275133	0.0019509	Ratio to Peak	0.00133
W1580	13.758	57.6	25	2.1739	3.724	Discharge	0.00201	0.0043896	Ratio to Peak	0.001
W1590	6.4511	79.578	25	0.14313	0.02	Discharge	0.000618771	0.0043458	Ratio to Peak	0.001
W1600	5.145	85.402	25	5.2305	0.057009	Discharge	0.0464441	0.0043896	Ratio to Peak	0.0029
W1610	3.7941	92.396	25	4.8134	0.076668	Discharge	0.0133101	0.0043896	Ratio to Peak	0.00193

W1620	1.8235	99	25	5.3968	0.055572	Discharge	0.0185554	0.0019509	Ratio to Peak	0.00133
W1630	4.7325	87.422	25	5.6481	0.046818	Discharge	0.0168289	0.0059259	Ratio to Peak	0.00291
W1640	4.6876	87.649	25	0.15229	0.057863	Discharge	0.0021244	0.0019509	Ratio to Peak	0.02572
W1650	2.8548	97.976	25	14.36	3.3103	Discharge	0.032292	0.0019509	Ratio to Peak	0.00133
W1660	1.5794	99	25	5.6672	0.076319	Discharge	0.0161661	0.0019509	Ratio to Peak	0.00133
W1670	1.5697	99	25	6.1634	0.056293	Discharge	0.0235573	0.0019509	Ratio to Peak	0.00223
W1680	2.7401	98.705	25	0.31055	0.14342	Discharge	0.0036825	0.0019509	Ratio to Peak	0.00058
W1690	10.19	66.578	25	51.994	0.69206	Discharge	0.0723692	0.0043896	Ratio to Peak	0.01
W1700	1.5697	99	25	6.2426	0.068848	Discharge	0.0171487	0.0019509	Ratio to Peak	0.00133
W1710	1.9077	99	25	6.5805	0.50503	Discharge	0.041256	0.0019509	Ratio to Peak	0.00198
W1720	13.203	58.834	50	4.4407	1.4264	Discharge	0.0207107	0.009679	Ratio to Peak	0.01
W1730	1.5697	99	50	6.7033	0.052825	Discharge	0.0268312	0.0019509	Ratio to Peak	0.00131
W1740	13.758	57.6	50	3.9619	0.0836671	Discharge	0.0190459	0.0043896	Ratio to Peak	0.003
W1750	3.2274	95.684	50	5.5861	0.070529	Discharge	0.0417211	0.0043896	Ratio to Peak	0.00193
W1760	1.5798	99	50	5.5808	0.052278	Discharge	0.0175349	0.0059259	Ratio to Peak	0.002
W1770	1.5697	99	50	6.4863	0.19197	Discharge	0.0178478	0.0019509	Ratio to Peak	0.00133

W1780	13.758	57.6	50	11.539	0.37405	Discharge	0.0032005	0.0043018	Ratio to Peak	0.00293
W1790	13.758	57.6	50	3.7577	0.056137	Discharge	0.0126535	0.0043896	Ratio to Peak	0.01
W1800	1.5697	99	50	0.14673	0.02	Discharge	4.87E-05	0.0019509	Ratio to Peak	0.002
W1810	13.758	57.6	50	6.7241	0.05805	Discharge	0.0368914	0.0019509	Ratio to Peak	0.001
W1820	1.5697	99	50	0.14614	0.02	Discharge	0.0055828	0.0019509	Ratio to Peak	0.001
W1830	13.758	57.6	50	22.794	3.4137	Discharge	0.0486759	0.0043896	Ratio to Peak	0.002
W1840	3.5843	99	50	6.8629	0.060053	Discharge	0.0142541	0.0019509	Ratio to Peak	0.00191
W1850	1.5697	57.6	50	4.3935	0.079347	Discharge	0.030482	0.0043896	Ratio to Peak	0.00196
W1860	4.1883	93.587	50	6.0394	0.048004	Discharge	0.0149509	0.0043896	Ratio to Peak	0.00296
W1870	11.403	99	50	0.27609	0.02	Discharge	0.0036825	0.0043675	Ratio to Peak	0.0067
W1880	13.583	90.24	50	0.15799	0.02	Discharge	0.000115875	0.0035556	Ratio to Peak	0.00131
W1890	1.5697	63.228	50	5.6802	0.0926833	Discharge	0.0031672	0.0043676	Ratio to Peak	0.00133
W1900	1.5697	57.985	50	5.47	0.0882592	Discharge	0.0065716	0.0043896	Ratio to Peak	0.00444
W1910	2.5193	99	100	0.28541	0.02	Discharge	0.0027934	0.0043896	Ratio to Peak	0.0045
W1920	13.758	99	100	0.19028	0.02	Discharge	0.000666666	0.0019509	Ratio to Peak	0.001
W1930	13.408	99	100	5.0266	0.79255	Discharge	0.0168968	0.0043896	Ratio to Peak	0.001

W1940	3.2525	57.6	100	5.0491	3.6499	Discharge	0.0307647	0.0064527	Ratio to Peak	0.002
W1950	3.5821	58.373	100	5.2032	0.067171	Discharge	0.016163	0.0087111	Ratio to Peak	0.001
W1960	9.0355	95.533	100	0.15127	0.99288	Discharge	0.0168806	0.0065505	Ratio to Peak	0.001
W1970	13.758	93.6	100	4.925	1.0371	Discharge	0.0195867	0.0065504	Ratio to Peak	0.002
W1980	13.758	70.116	100	5.5072	0.046984	Discharge	0.0278841	0.0065844	Ratio to Peak	0.00193
W1990	1.5697	57.6	100	5.1463	0.082491	Discharge	0.0138872	0.0065844	Ratio to Peak	0.001
W2000	6.1078	57.6	100	5.607	23.143	Discharge	0.0322896	0.0065844	Ratio to Peak	0.001
W2010	1.5697	99	100	5.7262	0.17766	Discharge	0.0518601	0.0019509	Ratio to Peak	0.00133
W2020	0.5697	91.03	100	7.0229	0.0177371	Discharge	0.0180989	0.00019509	Ratio to Peak	0.0000133

Annex 10. Sicopong Model Reach Parameters

Reach Number	Muskingum Cunge Routing Model						
	Time Step Method	Length	Slope	Manning's n	Shape	Width	Side Slope
R1010	Automatic Fixed Interval	2196.8	0.12898	0.1028	Trapezoid	30	1
R110	Automatic Fixed Interval	1011.4	0.0076348	0.0001	Trapezoid	30	1
R120	Automatic Fixed Interval	1059.5	0.0113428	0.0001	Trapezoid	30	1
R130	Automatic Fixed Interval	488.99	0.0323817	0.0001	Trapezoid	30	1
R160	Automatic Fixed Interval	1780.7	0.031455	0.0001	Trapezoid	30	1
R190	Automatic Fixed Interval	296.57	0.0321708	0.000298872	Trapezoid	30	1
R220	Automatic Fixed Interval	1130.5	0.0018656	0.0001	Trapezoid	30	1
R230	Automatic Fixed Interval	381.84	0.001	0.0001	Trapezoid	30	1
R260	Automatic Fixed Interval	931.54	0.0960995	0.0001	Trapezoid	30	1
R270	Automatic Fixed Interval	419.71	0.0268924	0.000207996	Trapezoid	30	1
R30	Automatic Fixed Interval	1195.8	0.001	0.0001	Trapezoid	30	1
R330	Automatic Fixed Interval	413.14	0.12219	0.0001	Trapezoid	30	1
R350	Automatic Fixed Interval	245.56	0.0188967	0.0001	Trapezoid	30	1
R370	Automatic Fixed Interval	2004.7	0.0509529	0.0244429	Trapezoid	30	1
R380	Automatic Fixed Interval	1715.8	0.0100022	0.000125856	Trapezoid	30	1
R420	Automatic Fixed Interval	622.13	0.001	0.0649963	Trapezoid	30	1
R430	Automatic Fixed Interval	2923.1	0.001	0.001762	Trapezoid	30	1
R450	Automatic Fixed Interval	499.41	0.001	0.0360312	Trapezoid	30	1
R460	Automatic Fixed Interval	2946.3	0.0238535	0.22938	Trapezoid	30	1
R480	Automatic Fixed Interval	5615.3	0.0314977	0.0466044	Trapezoid	30	1
R490	Automatic Fixed Interval	4555.5	0.0281237	0.022266	Trapezoid	30	1
R500	Automatic Fixed Interval	445.56	0.013661	1	Trapezoid	30	1

R510	Automatic Fixed Interval	2713.9	0.007662	0.5079	Trapezoid	30	1
R530	Automatic Fixed Interval	3798.8	0.0115925	1	Trapezoid	30	1
R540	Automatic Fixed Interval	777.7	0.001	0.95558	Trapezoid	30	1
R550	Automatic Fixed Interval	1791.7	0.0059356	0.0498469	Trapezoid	30	1
R570	Automatic Fixed Interval	296.98	0.001	0.0440906	Trapezoid	30	1
R600	Automatic Fixed Interval	3270.5	0.0409344	0.0921516	Trapezoid	30	1
R620	Automatic Fixed Interval	2585.5	0.0152759	0.0248704	Trapezoid	30	1
R630	Automatic Fixed Interval	2554.1	0.0012882	0.0455436	Trapezoid	30	1
R650	Automatic Fixed Interval	502.55	0.001	0.0489809	Trapezoid	30	1
R700	Automatic Fixed Interval	682.84	0.0454288	0.0499526	Trapezoid	30	1
R730	Automatic Fixed Interval	2118.2		0.0433442	Trapezoid	30	1
R740	Automatic Fixed Interval	288.28	0.0035135	0.24762	Trapezoid	30	1
R760	Automatic Fixed Interval	8525.2	0.0255741	0.0784149	Trapezoid	30	1
R770	Automatic Fixed Interval	28.284	0.001	0.18322	Trapezoid	30	1
R80	Automatic Fixed Interval	3284.2	0.0632947	0.0001	Trapezoid	30	1
R800	Automatic Fixed Interval	518.7	0.0041365	0.16561	Trapezoid	30	1
R820	Automatic Fixed Interval	1061	0.0018221	0.0565404	Trapezoid	30	1
R830	Automatic Fixed Interval	1007	0.0114739	0.0451094	Trapezoid	30	1
R840	Automatic Fixed Interval	3542.4	0.0019207	0.0160964	Trapezoid	30	1
R850	Automatic Fixed Interval	785.56	0.0083455	0.13076	Trapezoid	30	1
R860	Automatic Fixed Interval	255.56	0.001	0.0010885	Trapezoid	30	1
R870	Automatic Fixed Interval	2169.9	0.0133495	0.0078649	Trapezoid	30	1
R880	Automatic Fixed Interval	5252.9	0.0403591	0.0035488	Trapezoid	30	1
R890	Automatic Fixed Interval	2138.7	0.0037704	0.0001	Trapezoid	30	1
R90	Automatic Fixed Interval	4130.9	0.0255131	0.0138838	Trapezoid	30	1
R900	Automatic Fixed Interval	1280.2	0.0515484	0.0500794	Trapezoid	30	1
R960	Automatic Fixed Interval	4347.5	0.0088696	0.0191434	Trapezoid	30	1
R970	Automatic Fixed Interval	2881	0.0014989	0.012402	Trapezoid	30	1

Annex 11. Sicopong Flood Validation Data

Table A-11.1 Sicopong Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event / Date	Return Period of Event
	Longitude	Latitude					
1	122.852908	9.346479	0.893	0.7	0.03725	Ruping	100-Year
2	122.852701	9.346389	2.682	0	7.19312	Ramil	5-Year
3	122.852674	9.346266	2.842	0.9	3.77136	Ruping	100-Year
4	122.852542	9.346032	2.507	0	6.28505	Ramil	5-Year
5	122.852481	9.345921	2.463	0	6.06637	Ondoy	100-Year
6	122.852754	9.346505	2.44	0	5.9536	Ramil	5-Year
7	122.852706	9.346449	2.44	0	5.9536	Quennie	100-Year
8	122.852647	9.346425	2.807	1.2	2.58245	Ramil	5-Year
9	122.85261	9.346439	2.807	0.3	6.28505	Quennie	100-Year
10	122.852462	9.346817	1.543	1.8	0.06605	Ramil	5-Year
11	122.852559	9.346957	3.978	2.6	1.89888	Ruping	100-Year
12	122.851576	9.348236	2.834	0.95	3.54946	Ramil	5-Year
13	122.851605	9.348245	3.179	0.1	9.48024	Quennie	100-Year
14	122.851593	9.348035	3.738	1.4	5.46624	Ramil	5-Year
15	122.851592	9.348042	3.738	1	7.49664	Quennie	100-Year
16	122.851542	9.347736	3.506	3.1	0.16484	Ruping	5-Year
17	122.85151	9.347801	3.571	0	12.752	Ramil	5-Year
18	122.851539	9.34778	4.04	0.3	13.9876	Quennie	100-Year
19	122.851353	9.349	0.717	0	0.51409	Ruping	100-Year
20	122.854153	9.351129	5.203	1.4	14.4628	Ramil	5-Year
21	122.854154	9.351105	4.768	1.5	10.6798	Ruping	100-Year
22	122.854169	9.351091	4.768	0.2	20.8666	Sendong	100-Year
23	122.853931	9.351722	4.128	0.3	14.6536	Ramil	5-Year
24	122.853974	9.351761	4.574	0.3	18.2671	Ruping	100-Year
25	122.854564	9.351835	4.5	0.3	17.64	Ramil	5-Year
26	122.854565	9.351804	4.5	0.3	17.64	Quedan	100-Year
27	122.854234	9.351773	4.502	1.4	9.6224	Ruping	100-Year
28	122.854269	9.351731	3.851	1	8.1282	Ramil	5-Year
29	122.85539	9.353198	3.336	1	5.4569	Ruping	100-Year
30	122.854356	9.355223	2.654	0.4	5.08052	Ramil	5-Year
31	122.853844	9.352102	3.732	1.3	5.91462	Ramil	5-Year

Annex 12. Educational Institutions Affected in Sicopong Floodplain

Table A-12.1 Educational Institutions in Bayawan City, Negros Oriental Affected by Flooding in Sicopong Floodplain

Negros Oriental				
Bayawan City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
OMOD HIGH SCHOOL	Maninihon			
AW-A ELEMENTARY SCHOOL	San Isidro			
OMOD ELEMENTARY SCHOOL	San Isidro			

Table A-12.2 Educational Institutions in Santa Catalina, Negros Oriental Affected by Flooding in Sicopong Floodplain

Negros Oriental				
Santa Catalina				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BAPTIST LEARNING CENTER	Caranoche			
SCIENCE ELEMENTARY SCHOOL	Caranoche		Low	Low
STA. CATALINA ACADEMY	Caranoche			

Annex 13. Health Institutions Affected in Sicopong Floodplain

Table A-13.1 Health Institutions in Santa Catalina, Negros Oriental Affected by Flooding in Sicopong Floodplain

Negros Oriental				
Santa Catalina				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
STA. CATALINA HEALTH CENTER	Caranoche			