HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Jibatang River

University of the Philippines Training Center for Applied Geodesy and Photogrammetry
Visayas State University

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
BSWM	Bureau of Soils and Water Management
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DA	Department of Agriculture
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
NAMRIA	National Mapping and Resource Information Authority
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
PSA	Philippine Statistics Authority
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RBCO	River Basin Control Office
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
UTM	Universal Transverse Mercator
VSU	Visayas State University
WGS	World Geodetic System
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND JIBATANG RIVER

Enrico C. Paringit, Dr. Eng., Dr. George Puno, and Eric Bruno

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 a 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.

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for a 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 the 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 Visayas State University (VSU). VSU 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 twenty-seven (27) river basins in the Eastern Visayas Region. The university is located in Baybay City in the province of Leyte.

1.2 Overview of the Jibatang River Basin

The Jibatang River Basin covers majority of Calbayog City, and minor portions of the Municipalities of Bobon and San Isidro, in the province of Samar. According to the Department of Environment and Natural Resources (DENR) River Basin Control Office (RBCO), it has a catchment area of 46 km², with an estimated 718 million cubic meters (MCM) annual run-off (RBCO, 2015).

The basin's main stem, the Jibatang River, is under the jurisdiction of the Phil-LiDAR 1 partner state university, VSU. The river's stream network traverses twenty-six (26) barangays in Calbayog City – from Jose A. Roño, down to the mouth of the river in Tomaliguez.

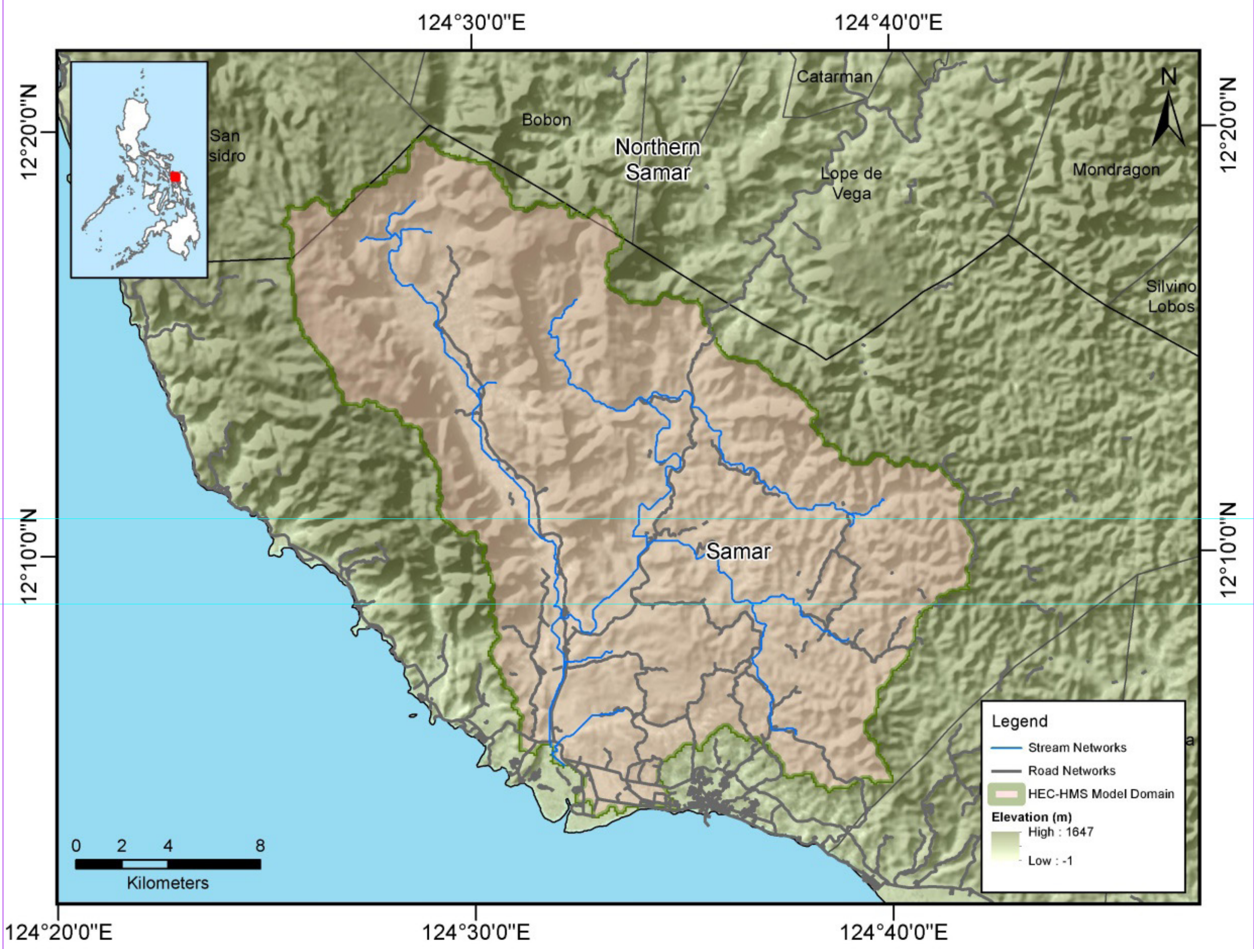

Figure 1. Location map of the Jibatang River Basin (in brown)

According to the Philippine Statistics Authority (PSA) 2010 census, the total population of residents of within the immediate vicinity of the Jibatang River is 21,927, distributed among seventeen (17) barangays.

Interviews with locals reveal that recent typhoons, such as Typhoon Ruby in December 2014 and Typhoon Amang in January 2015, have brought continuous torrential rains that caused flood waters to rise to up to two (2) meters or above.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE JIBATANG FLOODPLAIN

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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

To initiate the LiDAR acquisition survey of the Jibatang floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in Samar. These missions were planned for ten (10) lines that ran for at most four and a half (4.5) hours, including take-off, landing, and turning time. The ALS-80 LiDAR system was used for the missions (See ANNEX 1 for the sensor specifications). The flight planning parameters for the LiDAR system are found in Table 1. Figure 2 illustrates the flight plans for the Jibatang floodplain survey.

Table 1. Flight planning parameters for the ALS-80 LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse in Air	Average Speed (kts)	Average Turn Time (Minutes)
BLK33G	600	30	50	1	130	5
BLK33H	600	30	50	1	130	5

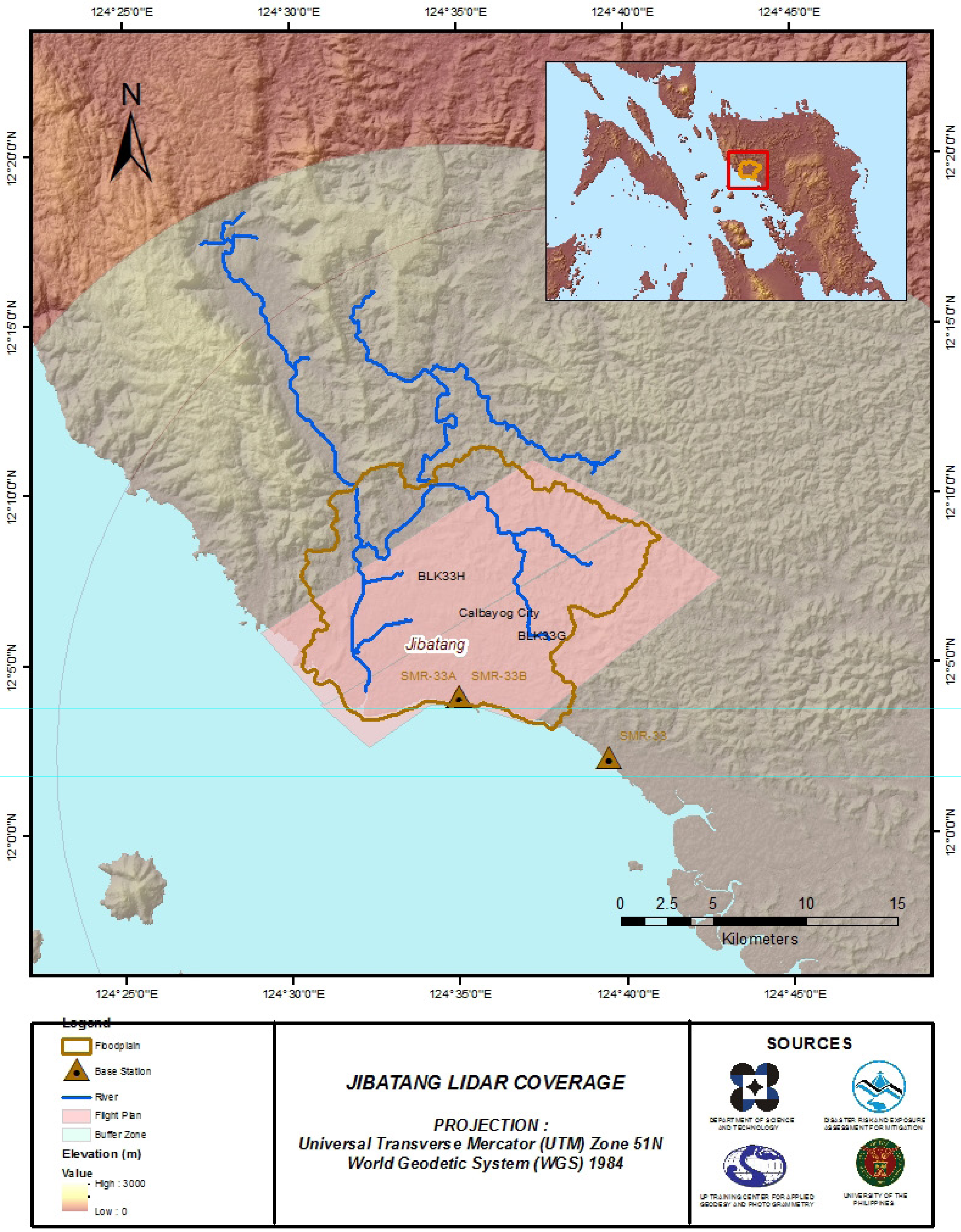

Figure 2. Flight plans and base stations used to cover the Jibatang floodplain survey

2.2 Ground Base Stations

The field team for this undertaking was able to recover one (1) NAMRIA reference point, SMR-33, which is of second (2nd) order accuracy. The team also established two (2) ground control points, SMR-33A and SMR-33B, which are of second (2nd) order accuracy. The NAMRIA certificate for SMR-33 is found in ANNEX 2. The baseline processing reports for the established ground control points are found in ANNEX 3. These were used as the base stations during the flight operations for the entire duration of the survey, held on November 14-16, 2016. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. The flight plans and locations of base stations used during the aerial LiDAR acquisition in the Jibatang floodplain are shown in Figure 2. The composition of the project team is shown in ANNEX 4.

Table 2 to Table 4 provide the details about the NAMRIA reference point and established points. Table 5 lists all of the ground control points occupied during the acquisition, together with the dates of utilization.

Table 2. Details of the recovered NAMRIA horizontal reference point SMR-33, used as a base station for the LiDAR acquisition

Station Name	SMR-33	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 2’ 19.48514” North 124° 39’ 22.13920” East 4.97358 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	462560.353 meters 1331244.592 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 2’ 14.98810” North 124° 39’ 27.22849” East 64.37800 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	680286.51 meters 1331298.78 meters

Table 3. Details of the established horizontal control point SMR-33A with processed coordinates, used as a base station for the LiDAR acquisition

Station Name	SMR-33A	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 04’ 06.98588” North 124° 34’ 54.39749” East 5.512 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	672169.393 meters 1334554.024 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 04’ 02.47512” North 124° 34’ 59.48472” East 64.658 meters

Table 4. Details of the established horizontal control point SMR-33B, used as a base station for the LiDAR acquisition

Station Name	SMR-33B	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 04' 07.12856" North 124° 34' 55.36866" East 5.717 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	672198.738 meters 1334558.577 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 04' 02.61782" North 124° 35' 00.45589" East 64.863 meters

Table 5. Ground control points used during the LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
NOV 14, 2016	10237L	4BLK33G319A	SMR-33, SMR-33A and SMR-33B
NOV 16, 2016	10241L	4BLK33H321A	SMR-33A and SMR-33B

2.3 Flight Missions

A total of two (2) flight missions were conducted to complete the LiDAR data acquisition in the Jibatang floodplain, for a total of nine hours and ten minutes (9+10) of flying time for RP-C9522. All missions were acquired using the ALS80 LiDAR system. The flight logs of the missions are provided in ANNEX 6. Table 6 indicates the total area of actual coverage and the corresponding flying hours per mission; while Table 7 presents the actual parameters used during the LiDAR data acquisition.

Table 6. Flight missions for the LiDAR data acquisition in the Jibatang floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
NOV 14, 2016	10237L	104.56	64.52	53.79	10.73	4	35	41
NOV 16, 2016	10241L	100.92	52.48	44.69	7.79	4	35	
TOTAL		**205.48**	**117**	**98.48**	**18.52**	**9**	**10**	

Table 7. Actual parameters used during the LiDAR data acquisition of the Jibatang floodplain

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	Pulse in Air	Average Speed (kts)	Average Turn Time (Minutes)
10237L	600	30	50	1	130	5
10241L	600	30	50	1	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Jibatang floodplain, which is located in the province of Samar, with majority of the floodplain situated within the City of Calbayog. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 8. The actual coverage of the LiDAR acquisition for the Jibatang floodplain is presented in Figure 3. The flight status report for the LiDAR survey of the Jibatang floodplain is found in ANNEX 7.

Table 8. List of municipalities and cities covered during the Jibatang floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Samar	Calbayog City	897.55	26.25	28.21%
Total		**897.55**	**26.25**	**28.21%**

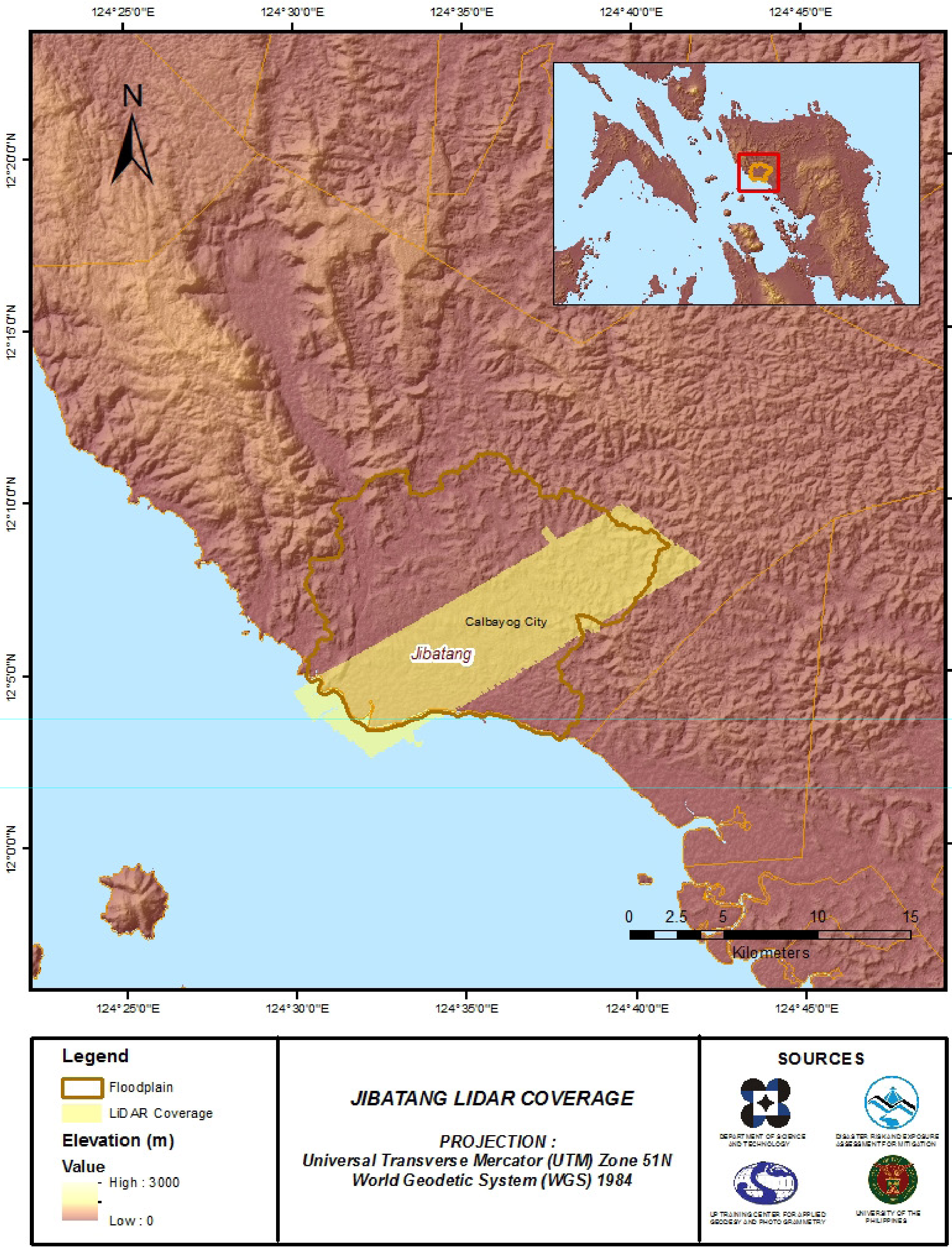

Figure 3. Actual LiDAR survey coverage of the Jibatang floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE JIBATANG FLOODPLAIN

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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 DAC were 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 was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate the correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality checking to ensure that the required accuracies of the program, which are the minimum point density, and vertical and horizontal accuracies, were met. The point clouds were then classified into various classes before generating Digital Elevation Models (DEMs), such as the Digital Terrain Model (DTM) and the Digital Surface Model (DSM).

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

These processes are summarized in the diagram in Figure 4.

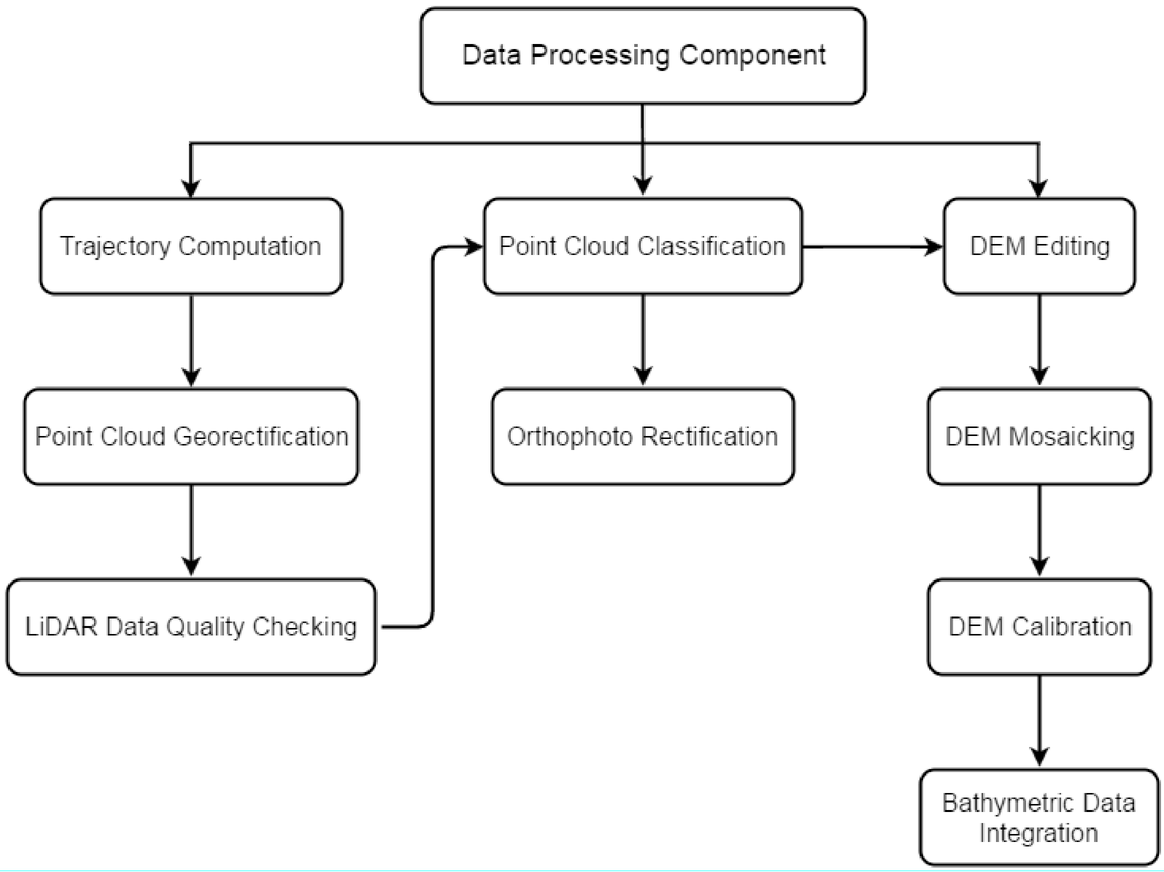

Figure 4. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Jibatang floodplain can be found in ANNEX 5. Missions flown for all the surveys conducted in November 2016 used the Airborne LiDAR Sensor ALS80-HP Leica Geosystems over the Province of Samar. The DAC transferred a total of 37.29 Gigabytes of RawLaser data, 1.25 Gigabytes of GNSSIMU data, 20.47 Megabytes of GPS base station data, and 151.1 Gigabytes of RCD30 raw image data to the data server on November 29, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Jibatang River survey was fully transferred on December 5, 2016, as indicated on the data transfer sheets for the Jibatang floodplain.

3.3 Trajectory Computation

The Estimated Position Accuracy parameters of the computed trajectory for flight 10225L, one of the Jibatang flights, which are the North, East, and Height position estimated standard deviations, are illustrated in Figure 5. The sum of these standard deviation values are indicated in the plot as the Trace values. 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 fell on November 8, 2016 at 00:00 hrs. on that week. The y-axis represents the estimated value of the standard deviation for that particular position.

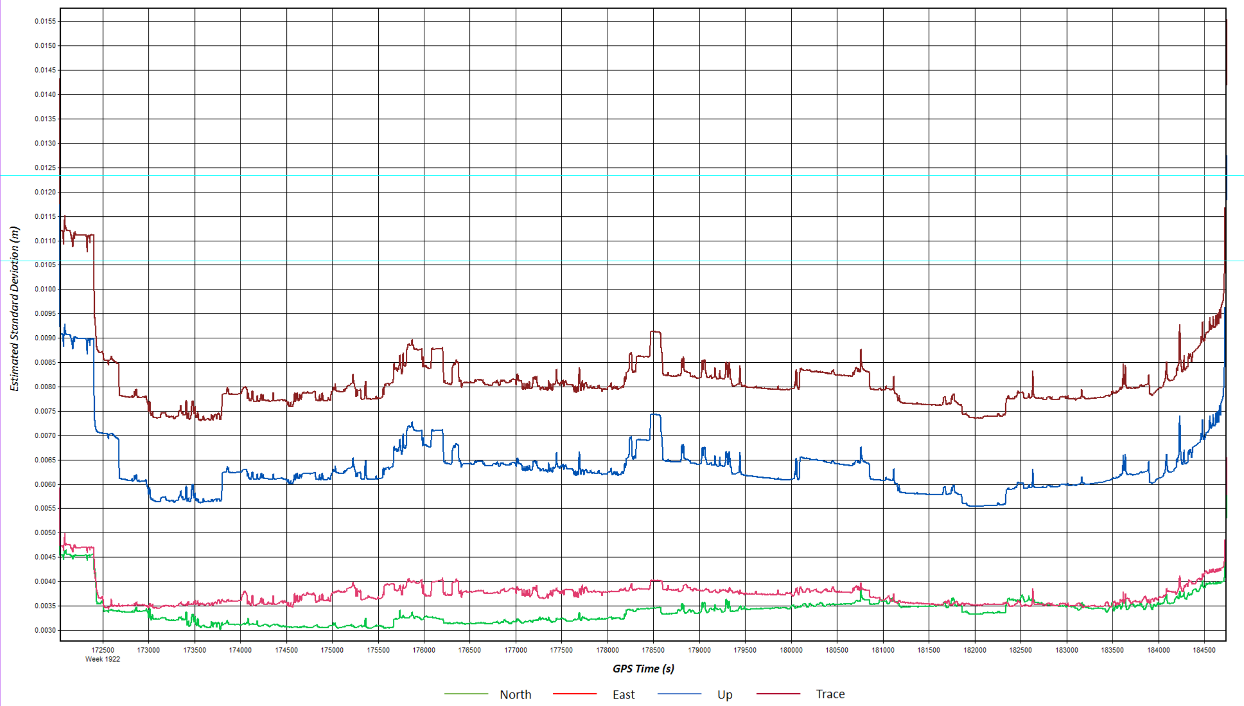

Figure 5. Estimated Position Accuracy of Jibatang Flight 10225L

The time of flight was from 172000 seconds to 184500 seconds, which corresponds to the afternoon of November 8, 2016. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the GNSS/IMU system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the GNSS/IMU system quickly minimized the standard deviation of the positions. The periodic increase in the standard deviation values from an otherwise smoothly curving set of standard deviation values corresponds to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 5 demonstrates that the North position standard deviation peaked at 0.40 centimeters, the East position standard deviation peaked at 0.40 centimeters, and the Height position standard deviation peaked at 0.75 centimeters, which are within the prescribed accuracies described in the methodology.

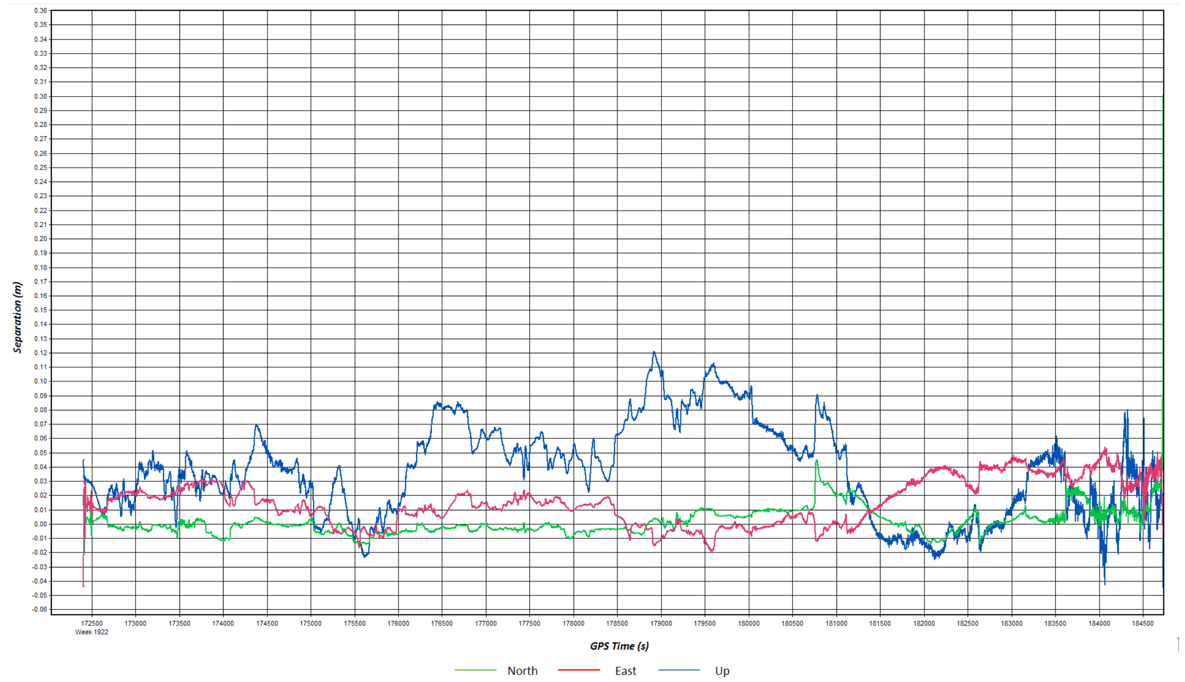

Figure 6. Combined Separation Plot of Jibatang Flight 10225L

The Combined Separation Plot of flight 10225L, one of the Jibatang flights, which displays the position difference between the forward and reverse processing results, is exhibited in Figure 6. The values for this plot should be within +/- 10 centimeters, in order to come up with an accurate trajectory solution. The figure reflects that the separation values were within -2 centimeters and 10 centimeters, except for some periods when the aircraft was turning. The number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. Additionally, the PDOP value did not go above 3, which indicates optimal GPS geometry. All of the parameters satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Jibatang flights is depicted in Figure 7.

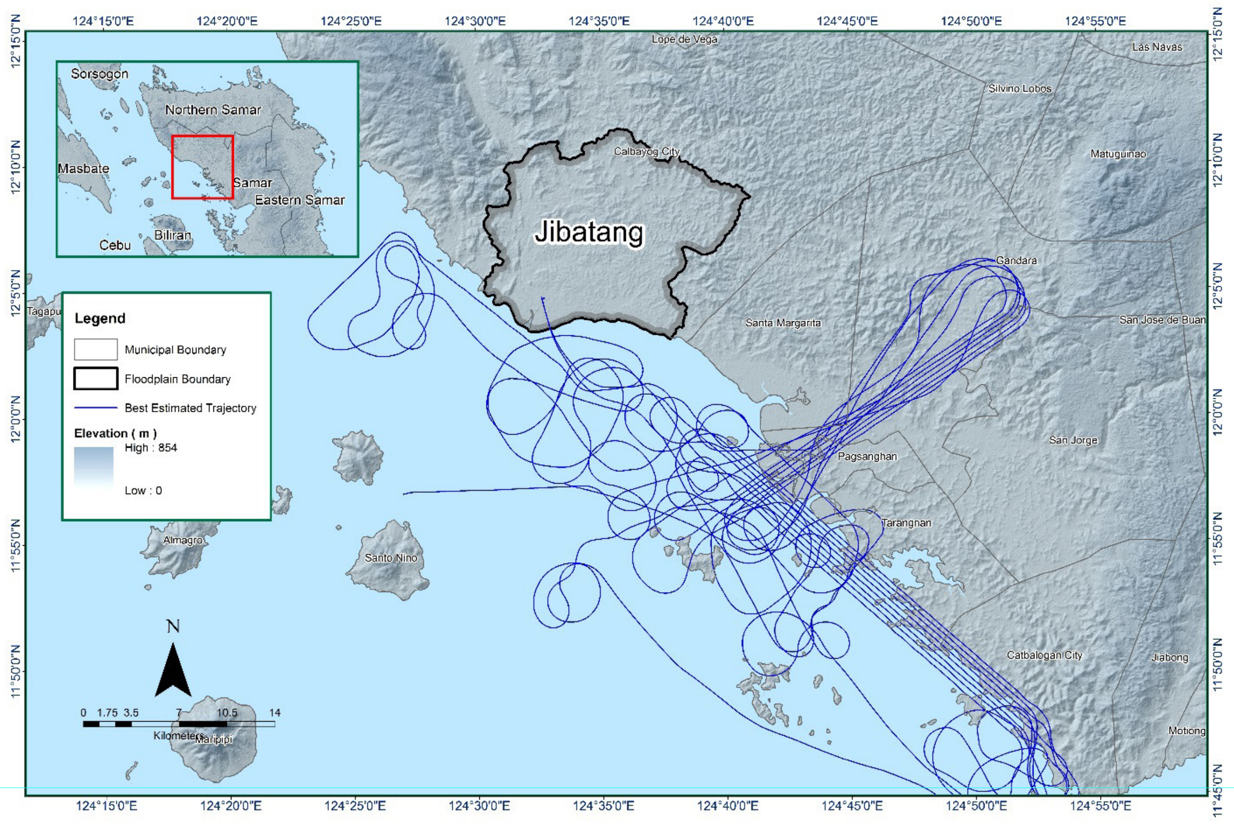

Figure 7. Best estimated trajectory conducted over the Jibatang floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains seventeen (17) flight lines, with each flight line containing two (2) channels, since the Leica ALS80-HP contains two (2) channels. The summary of the self-calibration results for all flights over the Jibatang floodplain, obtained through LiDAR processing in the Leica Geosystems' CloudPro software, is given in Table 9.

Table 9. Self-calibration results for the Jibatang flights

Boresight Parameters	Value	
	Channel A	Channel B
Roll Error	-0.00026404361	-0.0002590997
Pitch Error	0.0005049565	0.0006872629
Heading Error	-0.0021014205	-0.0020822516

The boresight parameter correction values in the table were derived from Terra Match, and were applied to compute for the LAS files of the Jibatang flights. The boresight parameter correction values for the individual blocks are available in ANNEX 8. Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of an SAR Elevation Data over the Jibatang floodplain are represented in Figure 8. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

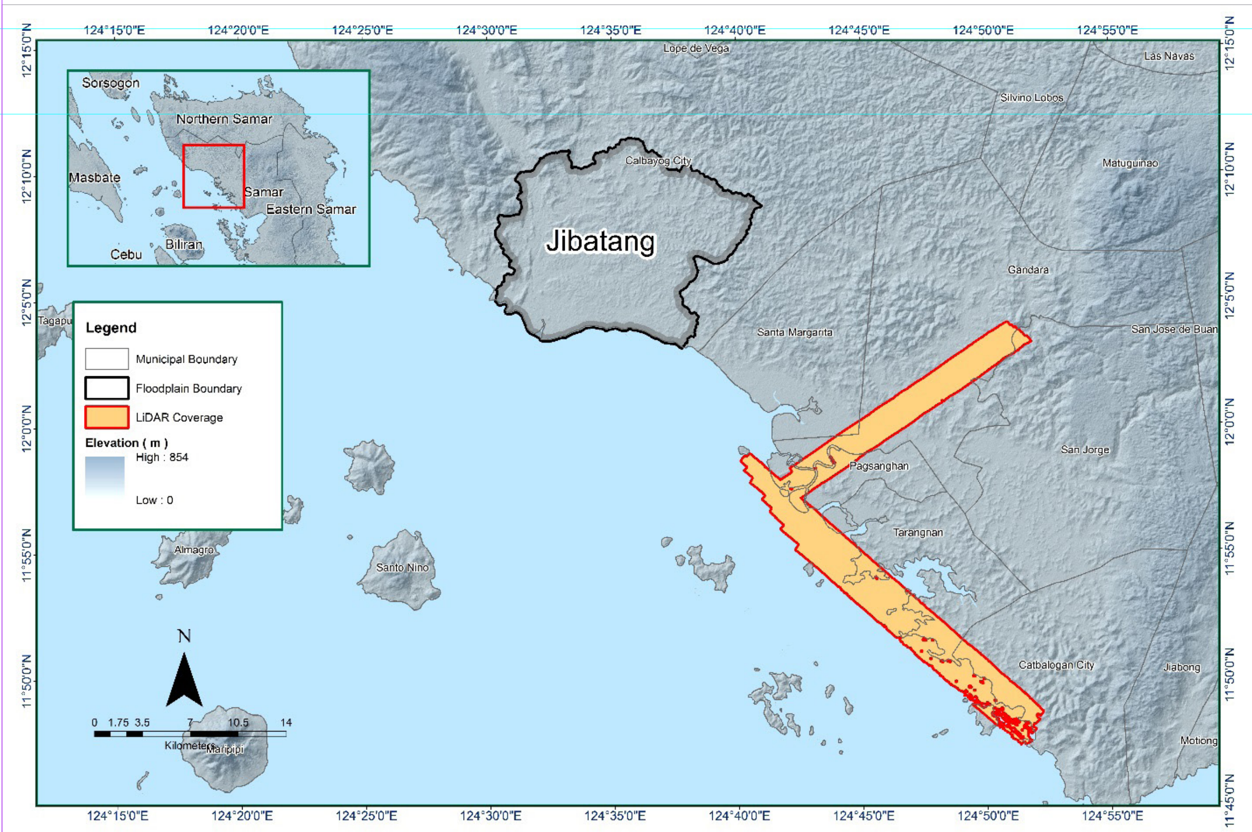

Figure 8. Boundaries of the processed LiDAR data over the Jibatang floodplain

The total area covered by the Jibatang missions is 123.01 square kilometers, comprised of two (2) flight acquisitions grouped and merged into two (2) blocks, as shown in Table 10.

Table 10. List of LiDAR blocks for the Jibatang floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Calbayog_Blk33D	10225L	46.22
Calbayog_Blk33C	10235L	76.79
TOTAL		123.01 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is illustrated in Figure 9. Since the Leica ALS80-HP contains two (2) channels, it is expected to have 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.

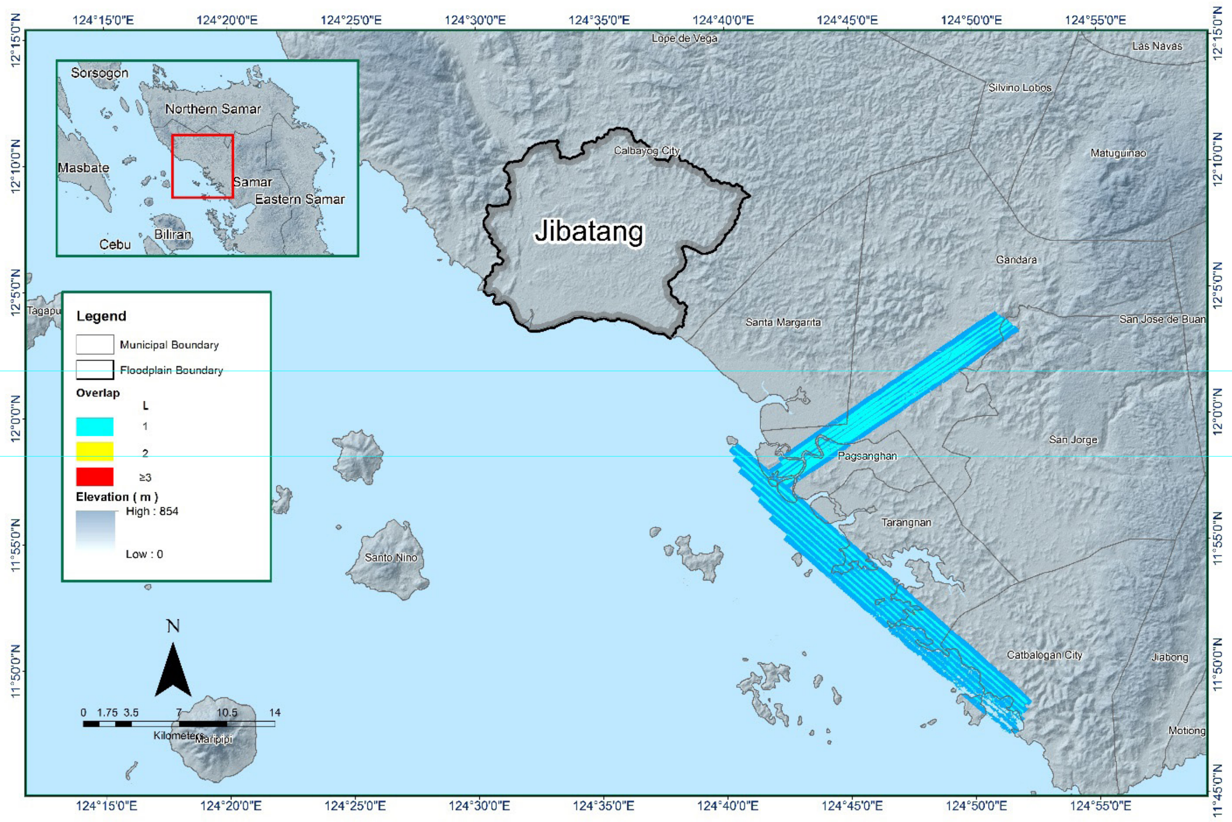

Figure 9. Image of data overlap for the Jibatang floodplain

The overlap statistics per block for the Jibatang floodplain can be found in ANNEX 8. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 28.35% and 52.90%, respectively, which satisfy 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 two (2) points per square meter criterion, is presented in Figure 10. It was determined that all LiDAR data for the Jibatang floodplain satisfy the point density requirement, and that the average density for the entire survey area is 6.96 points per square meter.

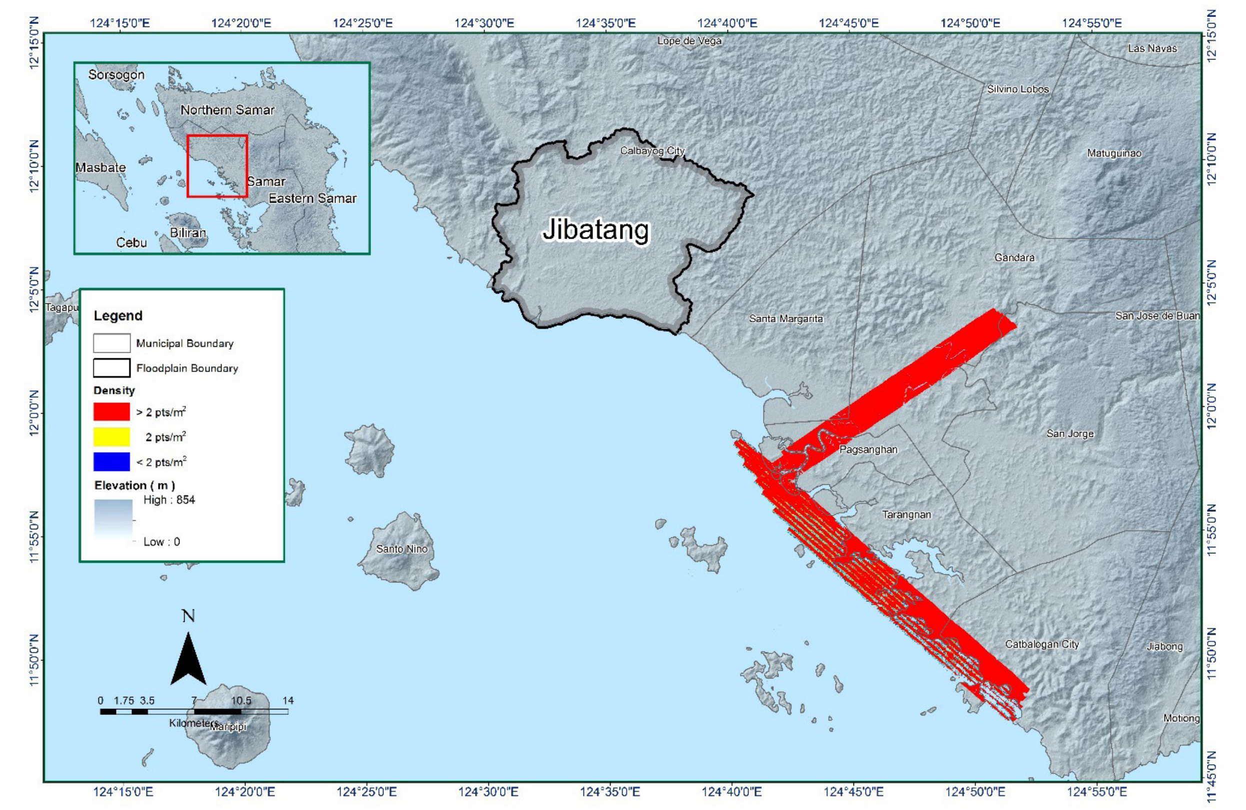

Figure 10. Pulse density map of merged LiDAR data for the Jibatang floodplain

The elevation difference between overlaps of adjacent flight lines is exhibited in Figure 11. The default color range is from blue to red. Bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 meters 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 0.20 meters relative to elevations of its adjacent flight line. Areas with bright red or bright blue were investigated further using the Quick Terrain (QT) Modeler software.

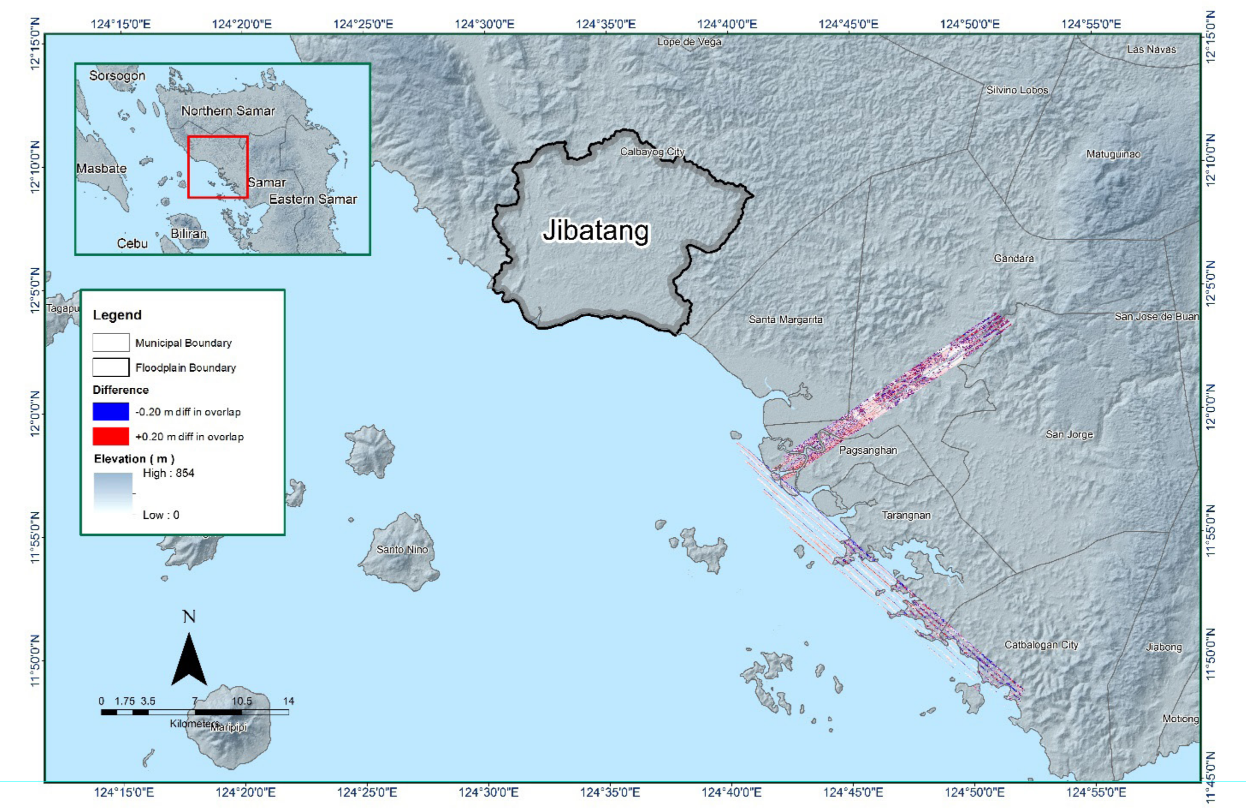

Figure 11. Elevation difference map between flight lines for the Jibatang floodplain

A screen capture of the processed LAS data from a Jibatang flight 10225L loaded in the QT Modeler is provided in Figure 12. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

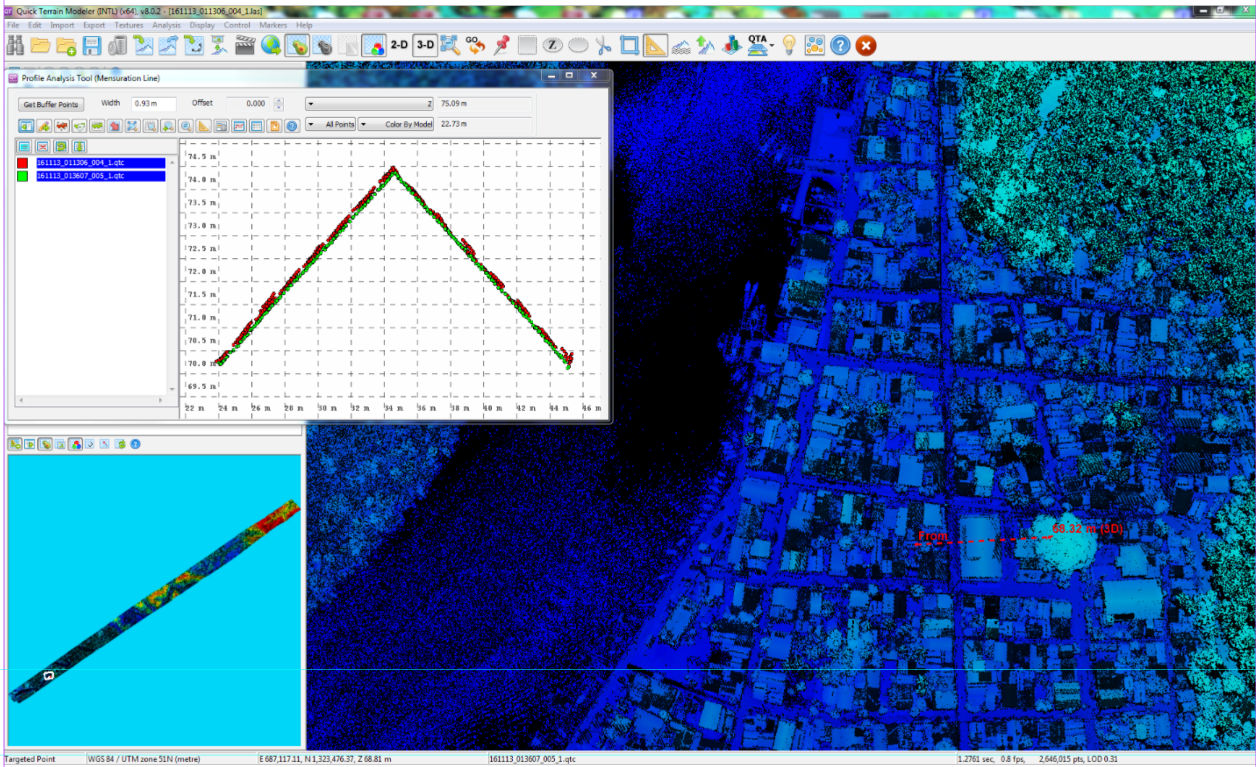

Figure 12. Quality checking for Jibatang flight 10225L using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 11. Jibatang classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	30,263,508
Low Vegetation	15,622,662
Medium Vegetation	50,739,555
High Vegetation	58,886,849
Building	1,567,659

The tile system that TerraScan employed for the LiDAR data, and the final classification image for a block near the Jibatang floodplain, are presented in Figure 13. A total of 409 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 11. The point cloud had a maximum and minimum height of 457.78 meters and 58.05 meters, respectively.

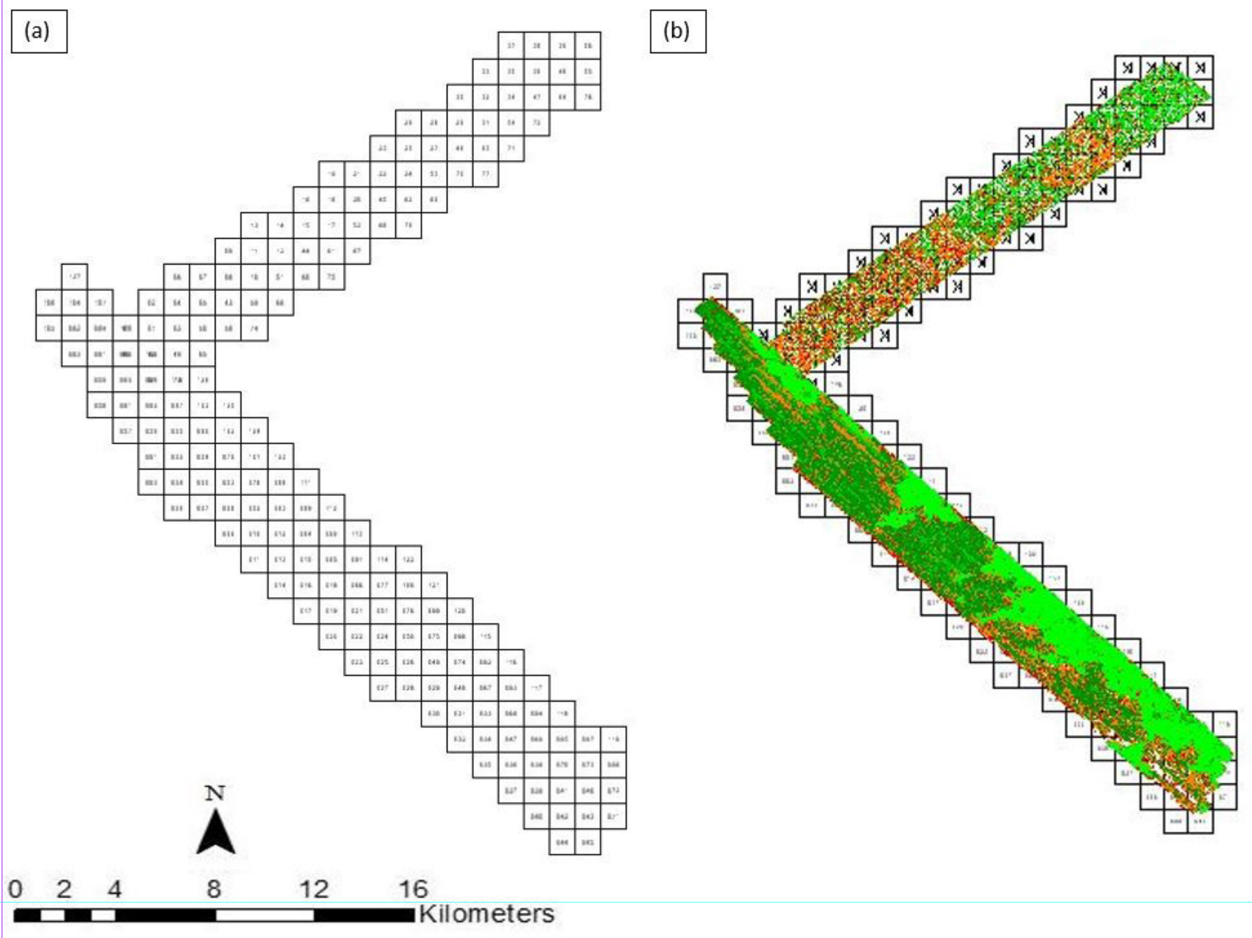

Figure 13. (a) Tiles for Jibatang floodplain; and (b) classification results in TerraScan

An isometric view of an area before and after running the classification routines is exhibited in Figure 14. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It is visible that residential structures adjacent or even below canopy were classified correctly, due to the density of the LiDAR data.

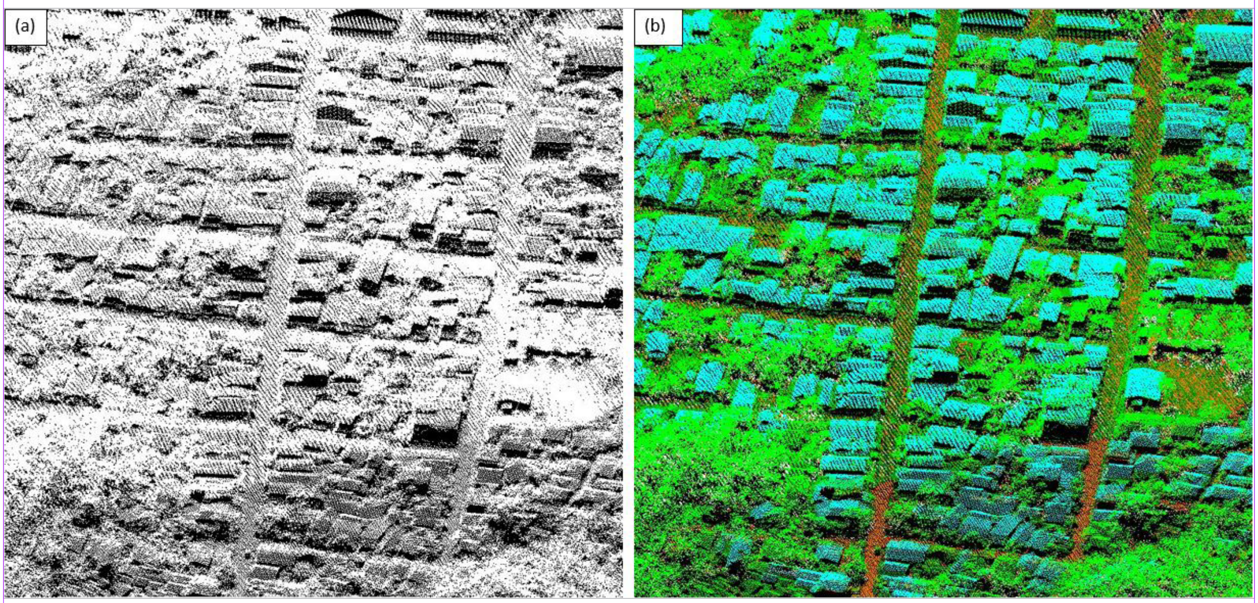

Figure 14. Point cloud (a) before and (b) after classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the area are presented in Figure 15, in top view display. The images show that DTMs are a representation of the bare earth; while the DSMs reflect all features that are present, such as buildings and vegetation.

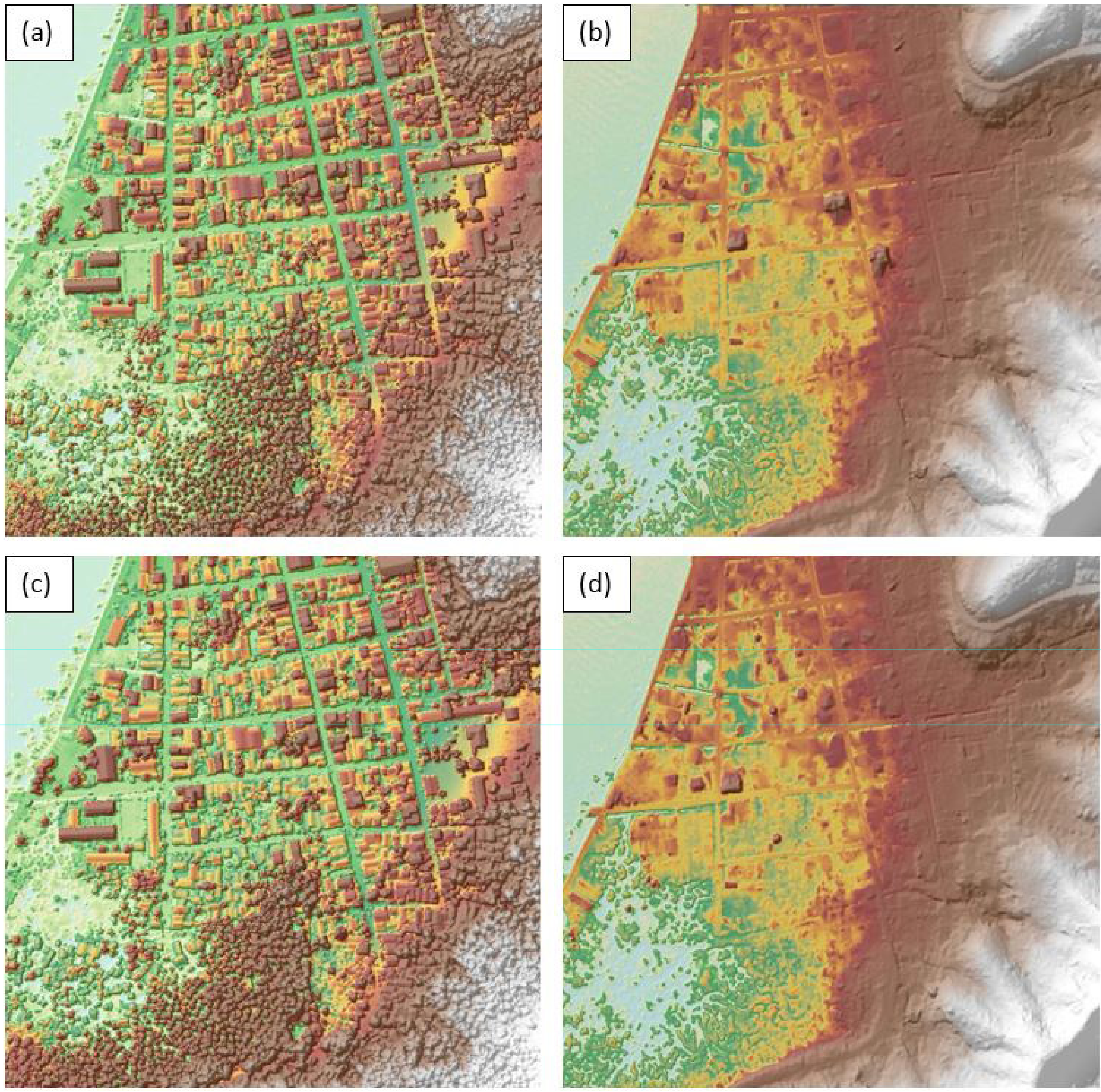

Figure 15. The production of last return (a) DSM and (b) DTM; and, (c) first return DSM and (d) secondary DTM in some portion near the Jibatang floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 202 1km by 1km tiles area covering the Jibatang floodplain is shown in Figure 16. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The survey of the block near the Jibatang floodplain attained a total of 127.87 square kilometers in orthophotographic coverage, comprised of 1,903 images. However, the block did not have a complete set of orthophotographs, and the orthophotographs were not able to cover the area of the Jibatang floodplain. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 17.

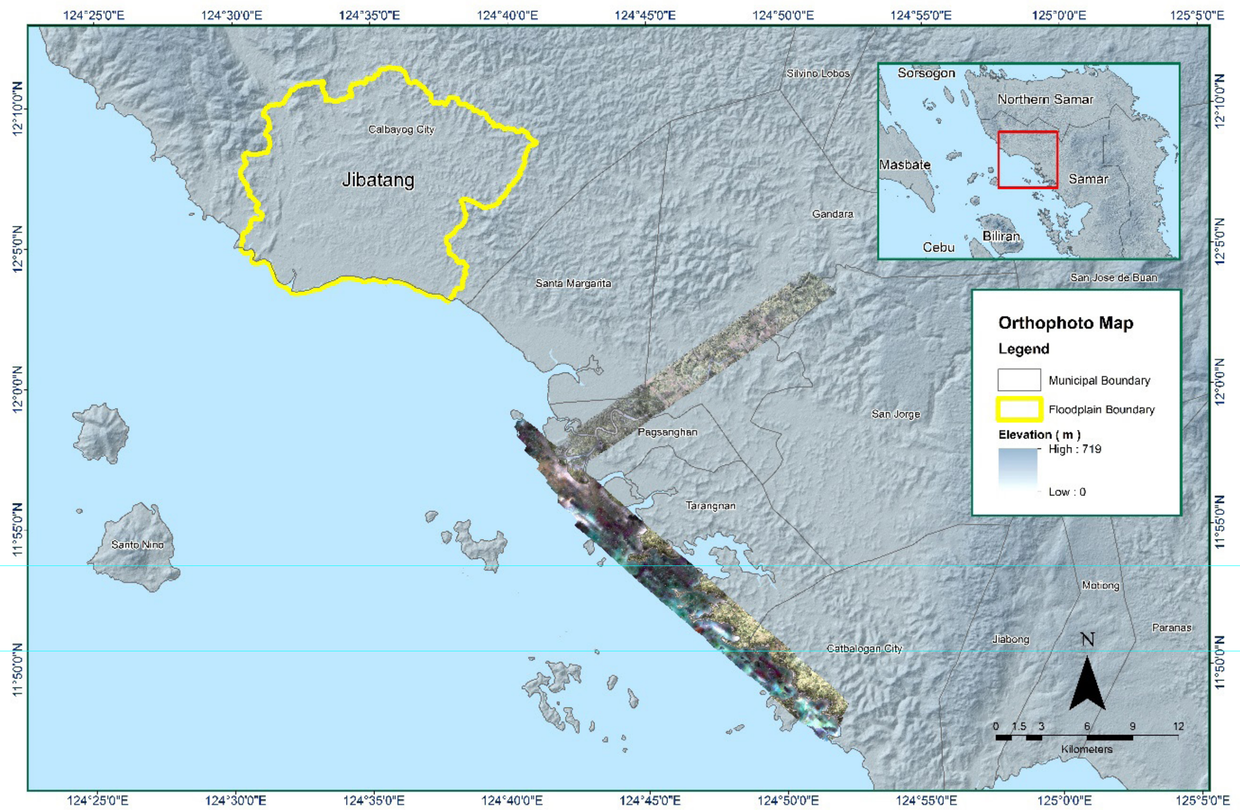

Figure 16. Available orthophotographs near the Jibatang floodplain

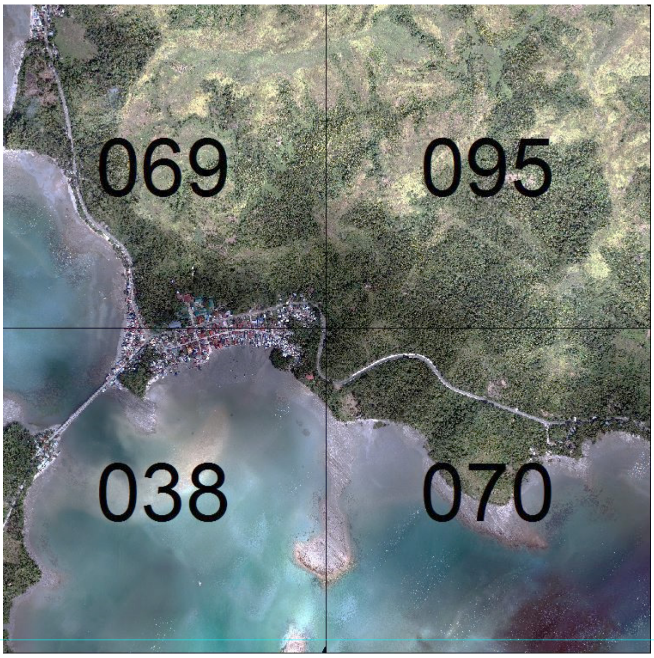

Figure 17. Sample orthophotograph tiles near the Jibatang floodplain

3.8 DEM Editing and Hydro-Correction

The Calbayog_Blk33C and Calbayog_Blk33D blocks are the blocks close to the Jibatang floodplain. The said blocks were processed in order to produce DEMs covering municipalities neighboring the Jibatang floodplain. The blocks have an area of 123.01 square kilometers. Table 12 enumerates the LiDAR blocks and their corresponding areas, in square kilometers.

Table 12. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
Calbayog_Blk33D	46.22
Calbayog_Blk33C	76.79
TOTAL	**123.01 sq.km**

Portions of the DTM before and after manual editing are exhibited in Figure 18. The bridge (Figure 18a) was considered to be an obstruction to the flow of water along the river and had to be removed (Figure 18b) in order to hydrologically correct the river. The river embankment (Figure 18c) was misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 18d), to allow for the correct flow of water.

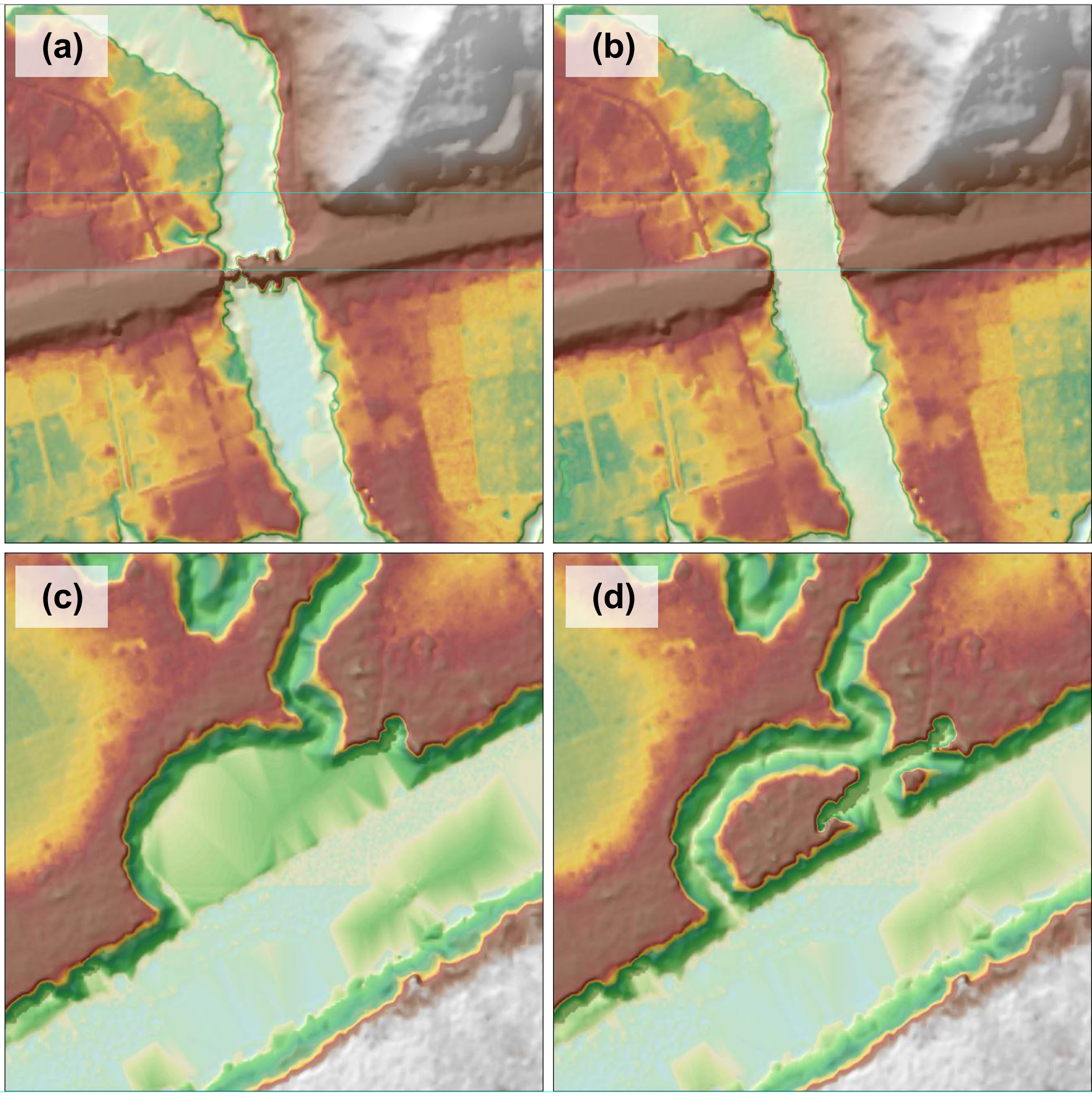

Figure 18. Portions in the DTM of blocks neighboring the Jibatang floodplain – a bridge (a) before and (b) after manual editing; and a river embankment (c) before and (d) after data retrieval

3.9 Mosaicking of Blocks

The IFSAR data covering the Jibatang and Gandara floodplains were mosaicked to the Calbayog blocks. Table 13 summarizes the shift values applied to the LiDAR blocks during mosaicking.

The IFSAR data for the Jibatang floodplain are illustrated in Figure 19.

Table 13. Shift values of each LiDAR block of the Jibatang floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
3924-I-1-3,6-9,12-14	0.00	0.00	3.5
3924-IV-4,5,10	0.00	0.00	4.5
3925-III-25	0.00	0.00	4.5
3925-II-21,22,23	0.00	0.00	4.5
Calbayog_Blk33D	0.00	0.00	0.00
Calbayog_Blk33C	0.00	1.00	0.85

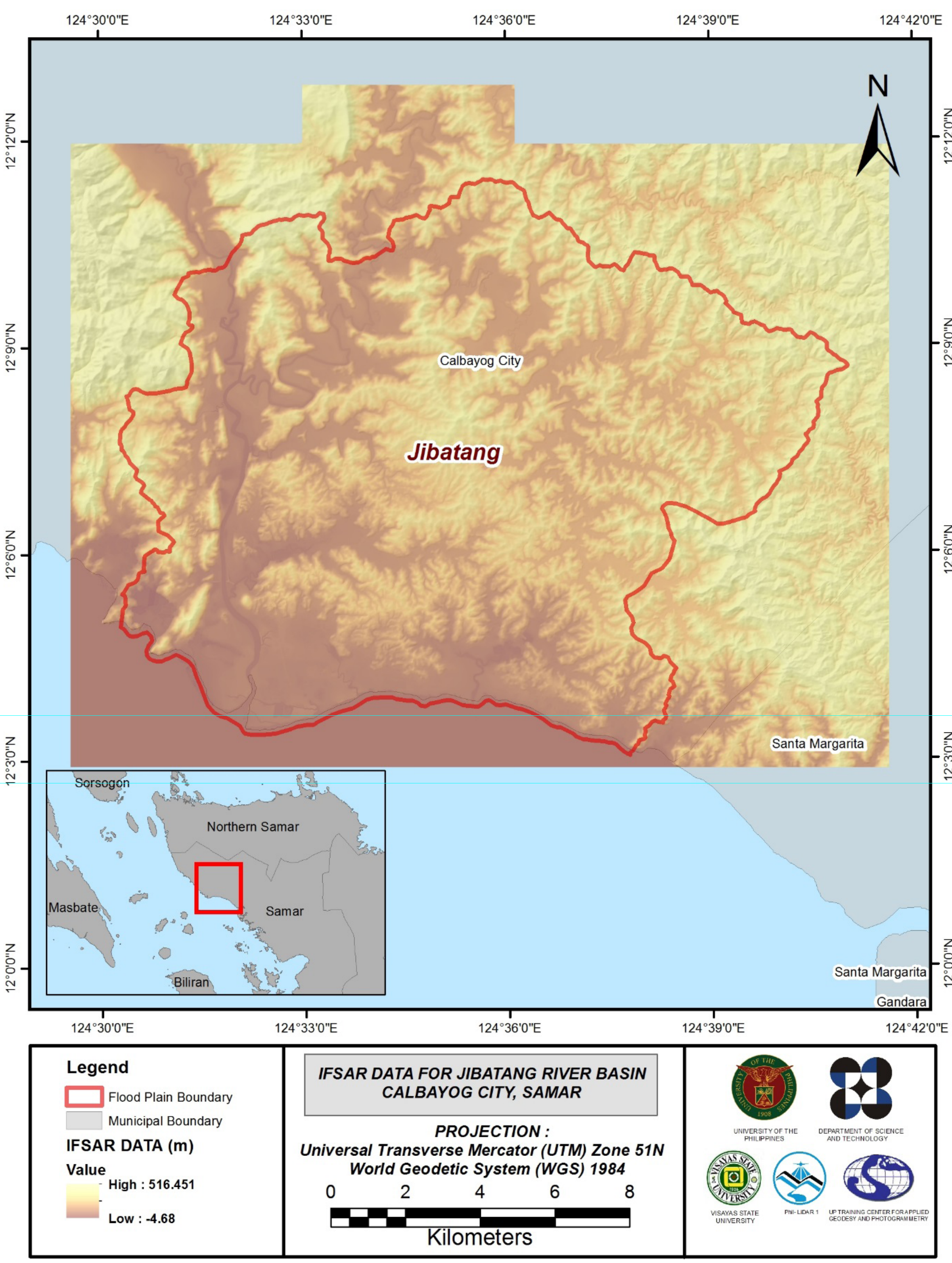

Figure 19. Map of the IFSAR data for the Jibatang floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

To undertake the data validation of the Mosaicked LiDAR DEMs, the DVBC conducted a validation survey along the Jibatang floodplain. The extent of the validation survey done in Jibatang to collect points with which the IFSAR dataset was validated is illustrated in Figure 20, with the validation survey points highlighted in green. A total of 17,140 survey points were gathered for the Jibatang floodplain.

The correlation between the uncalibrated IFSAR DTM and the ground survey elevation values is depicted in Figure 21. Statistical values were computed from extracted DTM values using the selected points, to assess the quality of the data and to obtain the values for vertical adjustment. The computed height difference between the DTM and the calibration points is 3.68 meters, with a standard deviation of 0.79 meters. The calibration of the Jibatang data was performed by subtracting the height difference value, 3.68 meters, from the Jibatang IFSAR data. Table 14 lists the statistical measurements of the compared elevation values between the Jibatang IFSAR data and the calibration data.

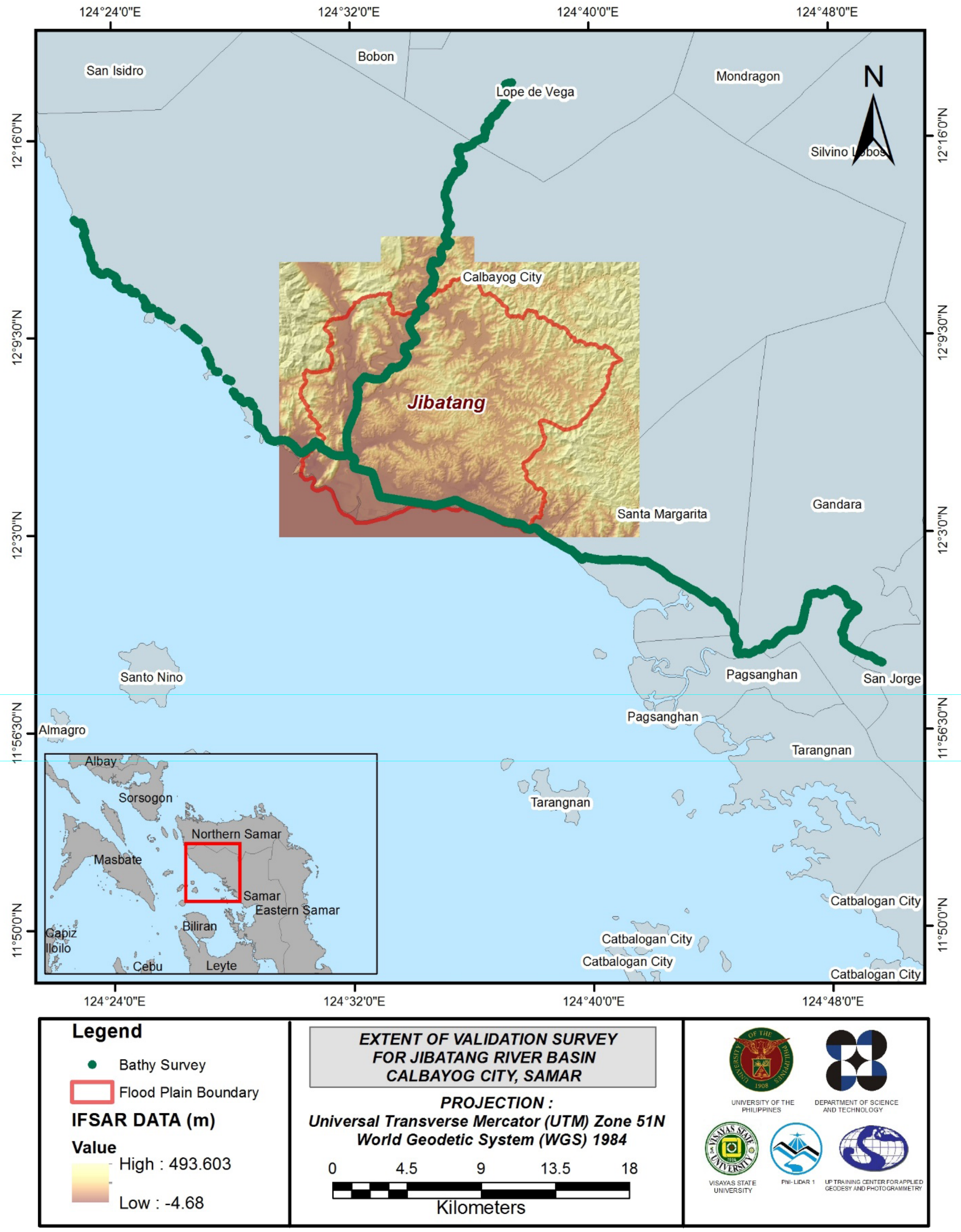

Figure 20. Map of the Jibatang floodplain, with validation survey points in green

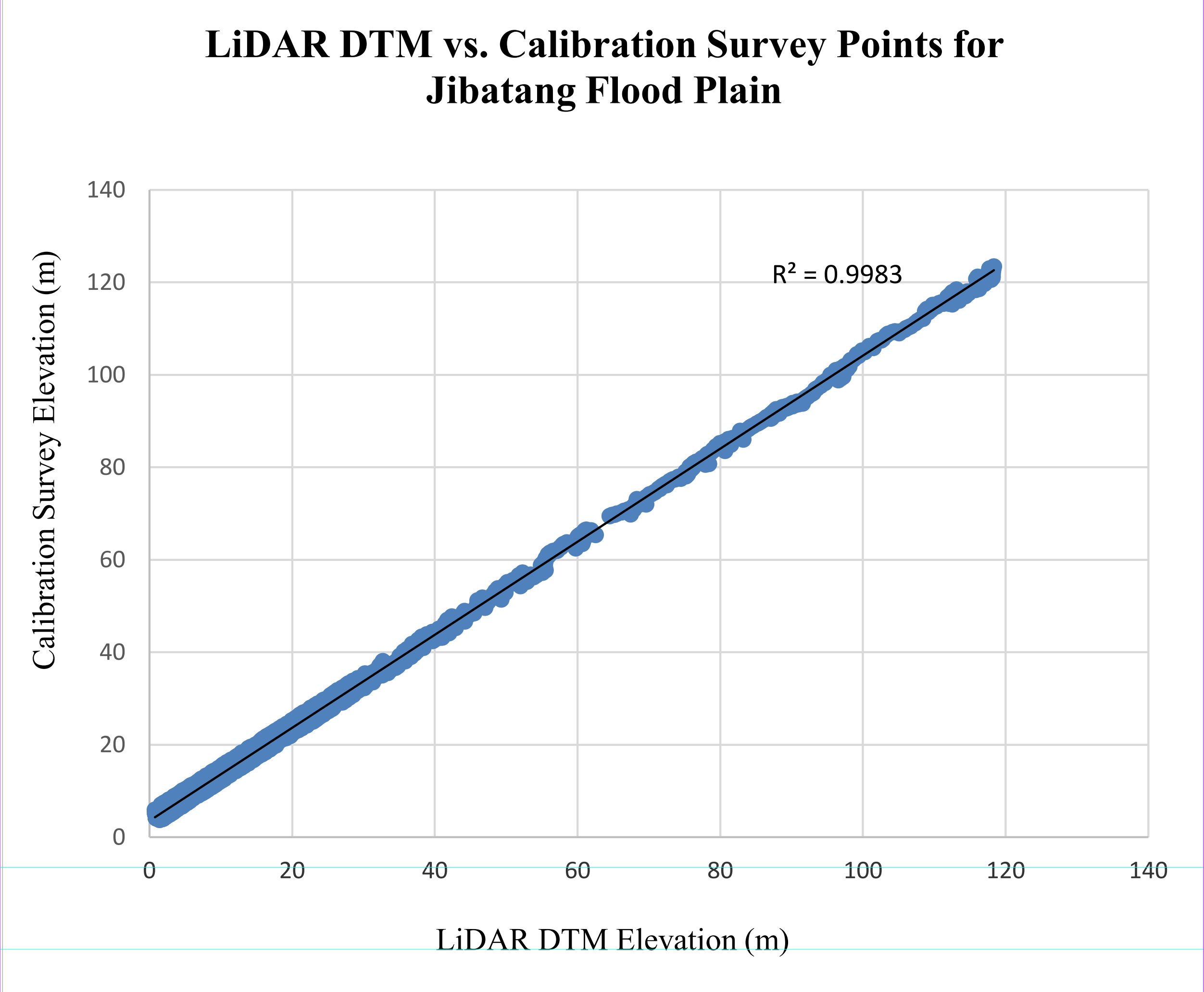

Figure 21. Correlation plot between the calibration survey points and the LiDAR data

Table 14. Table 14. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	3.68
Standard Deviation	0.79
Average	-3.60
Minimum	-5.31
Maximum	-2.07

Note: The calibration points lie within the IFSAR data; thus, the standard deviation value obtained is still acceptable.

A total of 4,997 survey points were used for the validation of the calibrated Jibatang 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 reflected in Figure 22. The computed RMSE between the calibrated LiDAR DTM and the validation elevation values is 4.17 meters, with a standard deviation of 1.59 meters, as indicated in Table 15.

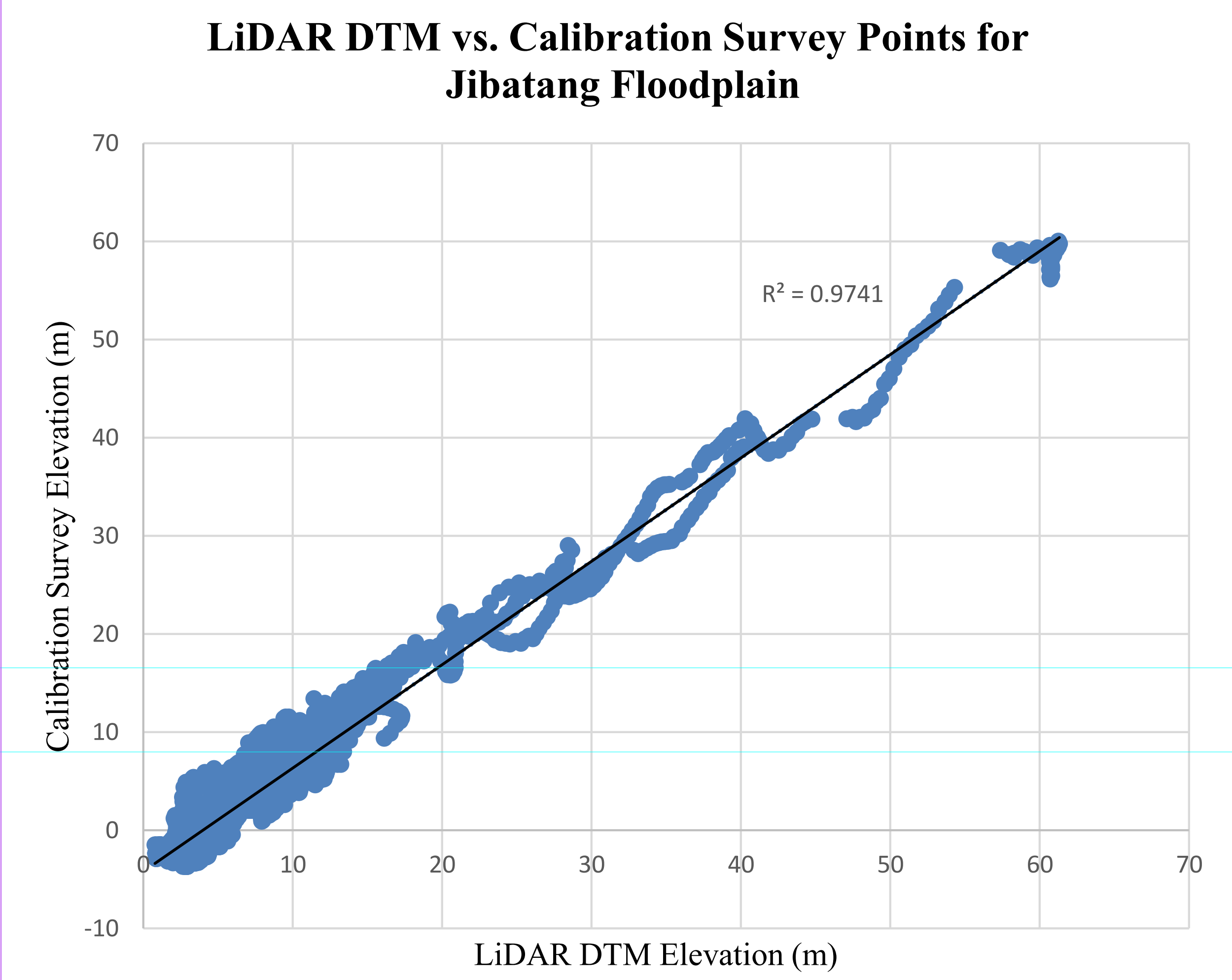

Figure 22. Correlation plot between the validation survey points and the LiDAR data

Table 15. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	4.17
Standard Deviation	1.59
Average	3.85
Minimum	0.67
Maximum	7.04

Note: The validation points lie within the IFSAR data; thus, the RMSE and standard deviation values obtained are still acceptable.

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Jibatang, with 24,901 bathymetric survey points. The resulting raster surface produced was obtained through the Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.52 meters. The extent of the bathymetric survey executed by the DVBC in the Jibatang River, integrated with the processed LiDAR DEM, is illustrated in Figure 23.

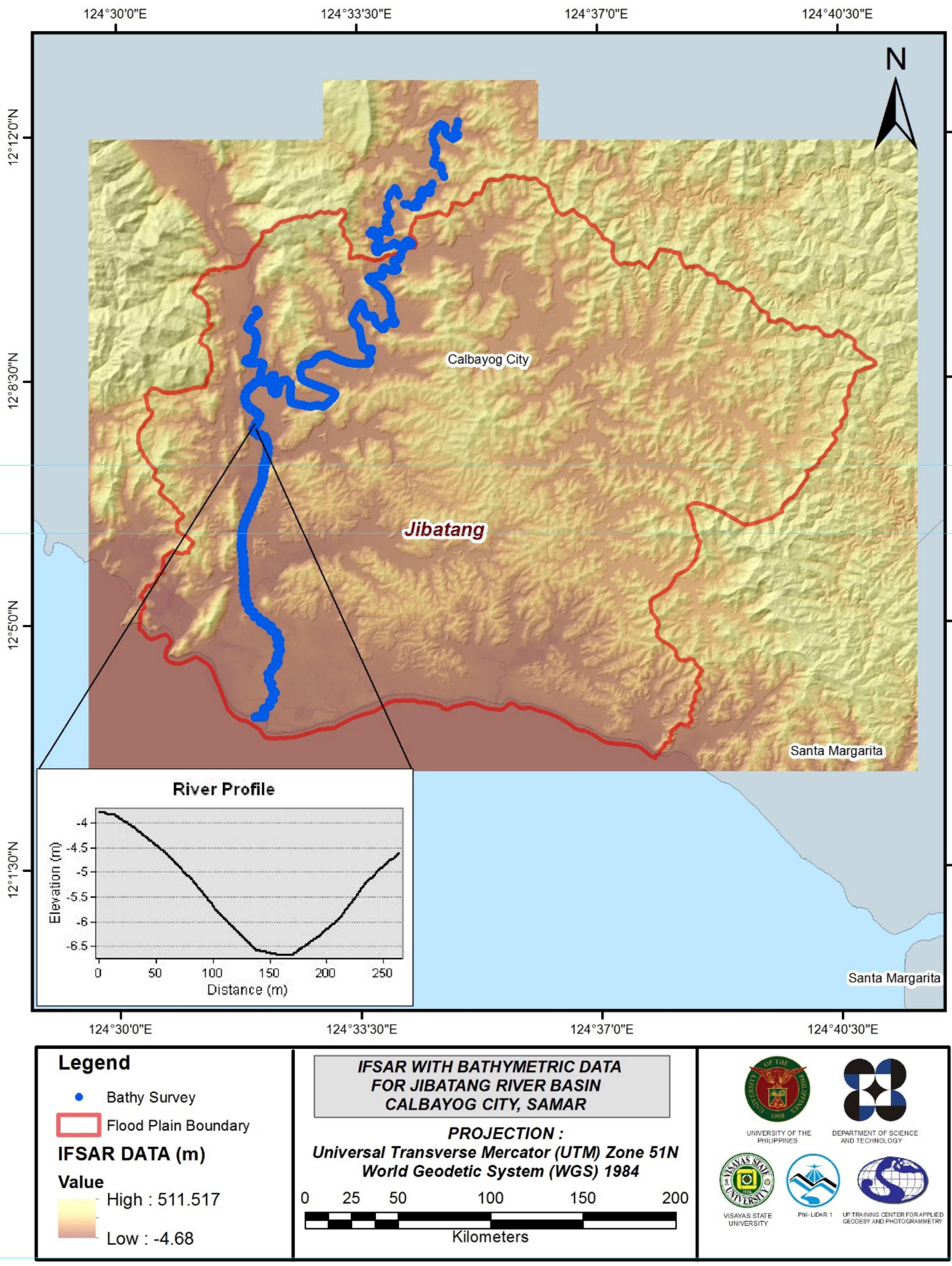

Figure 23. Map of the Jibatang floodplain, with bathymetric survey points in blue

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE JIBATANG RIVER BASIN

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

4.1 Summary of Activities

The DVBC conducted field surveys in two (2) river basins in the province of Samar, including the Jibatang River Basin, on December 3-14, 2015. The scope of work is as follows: (i.) initial reconnaissance; (ii.) control point survey; (iii.) cross-section survey and bridge as-built survey at the Cagbayang Bridge in Barangay Cagbayang, Oquendo, Calbayog City; (iv.) validation points acquisition of about 101.96 km. covering the Jibatang River Basin; and (v.) bathymetric survey from Barangay Jose A. Roño down to the mouth of the river in Barangays Tomaliguez and Basud, with an approximate distance of 34.13 km using Trimble® SPS 882 GNSS PPK survey technique and an OHMEX™ single beam echo sounder. The extent of the surveys are depicted in Figure 26.

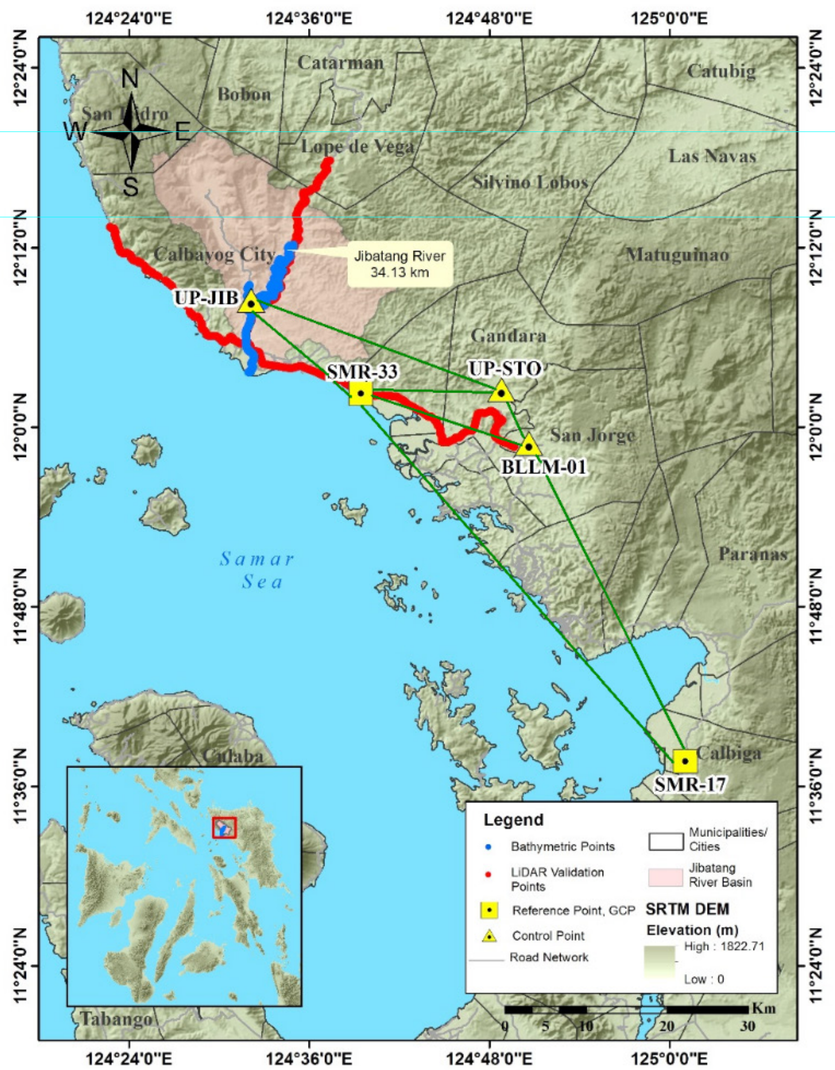


Figure 24. Extent of the bathymetric survey (in blue line) in the Jibatang River and the LiDAR data validation survey (in red)

4.2 Control Survey

A GNSS network was established by the VSU Phil-LiDAR 1 Team on September 7, 2015, occupying the following control points: SMR-17, UP-SLG, and BARVSU. The control point UP-SLG was used to supply the MSL value for this network. Its MSL value was derived from the benchmark SE-85 in Barangay Tabok in the Municipality of Llorente, from the network established in September 2014.

The GNSS network used for the Jibatang River Basin is composed of three (3) loops established on December 5-6, 2015, occupying the following reference points: (i.) SMR-17, a second (2nd) order GCP in Barangay Macaalan, Municipality of Calbiga; and (ii.) SMR-33, a second (2nd) order GCP in Barangay Monbon, Municipality of Sta. Margarita.

Two (2) control points were established along the approach of bridges, namely: (i.) UP-JIB, at the Jibatang Bridge in Barangay Oquando, Calbayog City; and (ii.) UP-STO, at the Sto. Niño Bridge in Barangay Sto. Niño, Municipality of Gandara. A NAMRIA-established control point, BLLM-01, located in Barangay Guindapunan in the Municipality of San Jorge, was also occupied to serve as a marker.

The summary of the reference and control points and their corresponding locations is provided in Table 20; while the established GNSS network is illustrated in Figure 27.

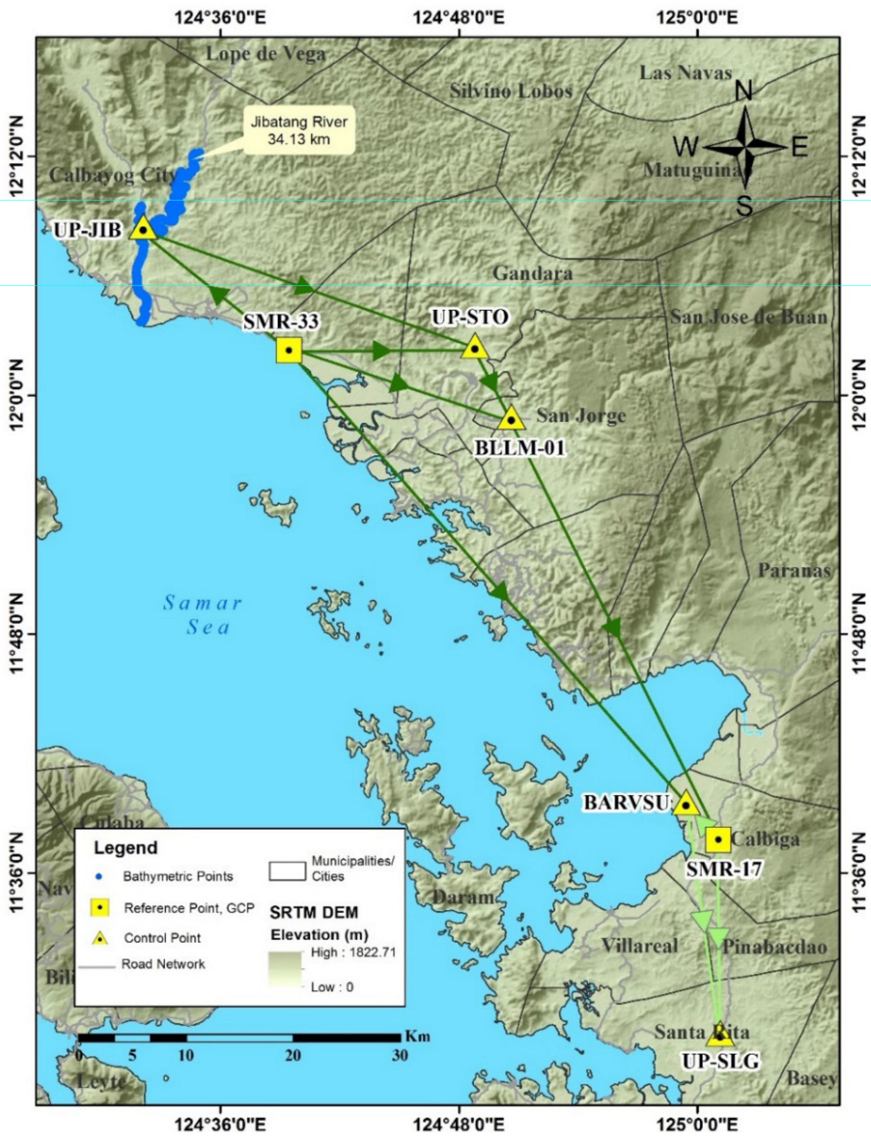


Figure 25. GNSS network established in the Jibatang River field survey

Table 16. List of reference and control points occupied in the Jibatang River survey (Source: NAMRIA; UP-TCAGP; VSU)

Control Point	Order of Accuracy	Geographic Coordinates (WGS UTM Zone 52N)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establish-ment
Control Survey on December 5 and 6, 2015						
SMR-17	2nd Order	11°37'39.96040"	125°01'03.14252"	72.836	10.153	2001
SMR-33	2nd Order	12°02'14.98810"	124°39'27.22840"	61.237	-	2007
BLLM-01	Used as Marker	-	-	-	-	2013
UP-JIB	UP established	-	-	-	-	Dec 5. 2015
UP-STO	UP established	-	-	-	-	Dec 6, 2015
Control Survey on September 7, 2015						
SMR-17	2nd Order	11°37'39.96040"	125°01'03.14252"	72.837	10.153	2001
UP-SLG	UP established	11°27'57.59924"	125°01'08.87429"	73.067	9.947	Sep 7, 2015
BARVSU	VSU established	11°39'35.28570"	124°59'25.89204"	64.121	1.636	2012

The GNSS set-ups of reference points and established control points in the Samar survey are exhibited in Figures 28 to 32.

Figure 26. GNSS receiver set-up, Trimble® SPS 985, at SMR-17, located at the Calbiga overpass Bridge approach in Barangay Macaalan, Municipality of Calbiga, Samar

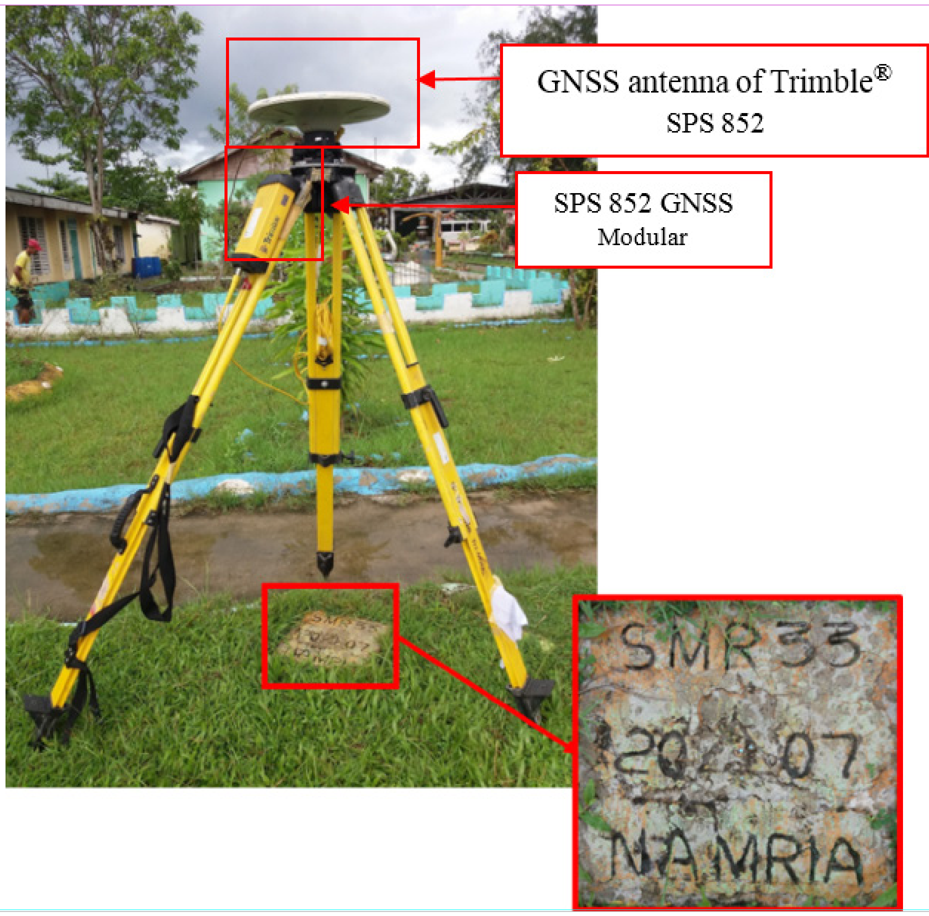


Figure 27. GNSS receiver set-up, Trimble® SPS 852, at SMR-33, inside the compound of Sta. Margarita Elementary School in Barangay Monbon, Municipality of Sta. Margarita, Samar

Figure 28. GNSS receiver set-up, Trimble® SPS 882, at BLLM-01, located beside the basketball court in Barangay Guindapunan, Municipality of San Jorge, Samar

Figure 29. GNSS receiver set-up, Trimble® SPS 985, at UP-JIB, at the Jibatang Bridge approach in Barangay Oquendo, Calbayog City, Samar

Figure 30. GNSS receiver set-up, Trimble® SPS 855, at UP-STO, at the Sto. Niño Bridge approach in Barangay Sto, Niño, Municipality of Gandara, Samar

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within the +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of 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, a re-survey is initiated. The baseline processing results of the control points in the Jibatang River Basin, as generated by TBC software, are summarized in Table 21.

Table 17. Baseline Processing Report for Jibatang River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
BLLM-01 --- SMR-17 (B1)	9-7-2015	Fixed	0.005	0.014	154°14'25"	43513.866
UP-STO --- BLLM-01 (B9)	9-7-2015	Fixed	0.003	0.015	153°23'51"	7419.683
UP-JIB --- UP-STO (B7)	9-7-2015	Fixed	0.003	0.015	109°54'58"	32215.774
SMR-33 --- SMR-17 (B3)	9-7-2015	Fixed	0.076	0.023	139°05'18"	59941.952
SMR-33 --- BLLM-01 (B4)	9-7-2015	Fixed	0.003	0.011	106°46'07"	21220.616
SMR-33 --- UP-JIB (B5)	9-7-2015	Fixed	0.004	0.014	310°51'34"	17574.856
SMR-33 --- UP-STO (B8)	9-7-2015	Fixed	0.004	0.014	88°16'51"	16999.634

As reflected in Table 21, a total of seven (7) baselines were processed, with the reference points SMR-17 and SMR-33 held fixed for grid values and elevation values, respectively. All of the baselines satisfied the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was 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 centimeters, and z less than 10 centimeters, or in equation form:

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

Where:

x_e is the Easting Error,
y_e is the Northing Error, and
z_e is the Elevation Error

for each control point. See the Network Adjustment Report presented in Table 22 to Table 24 for the complete details.

The five (5) control points – SMR-17, SMR-33, BLLM-01, UP-JIB, and UP-STO – were occupied and observed simultaneously to form a GNSS loop. The elevation value of SMR-17 and the coordinates of SMR-33 were held fixed during the processing of the control points, as indicated in Table 22. Through these reference points, the coordinates and elevation values of the unknown control points were computed.

Table 18. Constraints applied to the adjustments of the control points

Point ID	Type	North (Meter)	East (Meter)	Height (Meter)	Elevation (Meter)
SMR-17	Grid	Fixed	Fixed		Fixed
SMR-33	Local	Fixed	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 given in Table 23. The fixed control points SMR-17 and SMR-33 have no values for elevation errors and grid errors, respectively.

Table 19. Adjusted grid coordinates for the control points used in the Jibatang floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
SMR-17	719966.306	?	1286174.169	?	10.153	?	ENe
SMR-33	680439.007	?	1331244.394	?	1.419	0.055	LL
BLLM-01	700794.759	0.008	1325244.195	0.007	5.476	0.051	
UP-JIB	667077.807	0.012	1342660.924	0.008	4.825	0.071	
UP-STO	697428.302	0.009	1331856.947	0.008	12.485	0.064	

The network is was fixed at reference point SMR-17 with known elevation, and at SMR-33 with known coordinates. As shown demonstrated in Table 23C-4, the standard errors (xe and ye) of BLLM-01 are 0.80 cm centimeters and 0.70 cmcentimeters, respectively; those of UP-JIB with are 1.20 cm centimeters and 0.80 cmcentimeters; and those of UP-STO with are 0.90 cm centimeters and 0.80 cmcentimeters, respectively. With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)} < 20\ cm$ for horizontal accuracy, and $z_e < 10\ cm$ for the vertical accuracy,; the computations for the accuracy are as follows:

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

a. SMR-17

Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

b. SMR-33

Horizontal Accuracy = Fixed
Vertical Accuracy = 5.5 < 10 cm

c. BLLM-01

Horizontal Accuracy $= \sqrt{((0.8)^2 + (0.7)^2}$
$= \sqrt{(0.64 + 0.49)}$
$= 1.06\ cm < 20\ cm$
Vertical Accuracy = 5.1 < 10 cm

d. UP-JIB

Horizontal Accuracy $= \sqrt{((1.2)^2 + (0.8)^2}$
$= \sqrt{(1.44 + 0.64)}$
$= 1.44\ cm < 20\ cm$
Vertical Accuracy = 7.1 < 10 cm

e. UP-STO

Horizontal Accuracy $= \sqrt{((0.9)^2 + (0.8)^2}$
$= \sqrt{(0.81 + 0.64)}$
$= 1.20\ cm < 20\ cm$
Vertical Accuracy = 6.4 < 10 cm

Table 20. Adjusted geodetic coordinates for control points used in the Jibatang River floodplain validation

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
SMR-17	N11°37'39.96040"	E125°01'03.14252"	72.836	?	ENe
SMR-33	N12°02'14.98810"	E124°39'27.22840"	61.237	0.055	LL
BLLM-01	N11°58'55.52345"	E124°50'38.84504"	65.971	0.051	
UP-JIB	N12°08'29.05729"	E124°32'07.59990"	63.991	0.071	
UP-STO	N12°02'31.42690"	E124°48'49.02005"	72.560	0.064	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as shown in Table 24. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The computed coordinates of the reference and control points utilized in the Jibatang River GNSS Static Survey are indicated in Table 25.

Table 21. Reference and control points used in the Jibatang River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
Control Survey on December 5 and 6, 2015							
SMR-17	2nd Order, GCP	11d37'39.9604N"	125d01'03.1425"E	72.836	1286174.169	719966.306	10.153
SMR-33	2nd Order, GCP	12d02'14.9881"N	124d39'27.2284"E	61.237	1331244.394	680439.007	1.419
BLLM-01	Used as marker	11d58'55.5235"N	124d50'38.8450"E	65.971	1325244.195	700794.759	5.476
UP-JIB	UP Established	12d08'29.0573"N	124d32'07.5999"E	63.991	1342660.924	667077.807	4.825
UP-STO	UP Established	12d02'31.4269"N	124d48'49.0201"E	72.56	1331856.947	697428.302	12.485
Control Survey on September 7, 2015							
SMR-17	2nd Order, GCP	11d37'39.9604N"	125d01'03.1425"E	72.836	1286174.169	719966.306	10.153
UP-SLG	Up Established	11d27'57.59924"	125d01'08.87429"	73.067	1268277.803	720266.264	9.947
BARVSU	VSU Established	11d39'35.28570"	124d59'25.89204"	64.121	1289697.625	716995.082	1.636

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

The cross-section and bridge as-built surveys were conducted on December 12, 2015 along the downstream side of the Cagbayang Bridge located in Barangay Cagbayang, Oquendo, Calbayog City. A Total Station in open traverse method was used, as depicted in Figure 33.

Figure 31. Bridge as-built and cross-section survey on the downstream side of the Cagbayang Bridge in Barangay Cagbayag, Oquendo District, Calbayog City

The length of the cross-sectional line surveyed in the Cagbayang Bridge is 101.78 meters, gathering a total of forty-three (43) points. The location map, cross-section diagram, and bridge data form are presented in Figure 34 to Figure 36.

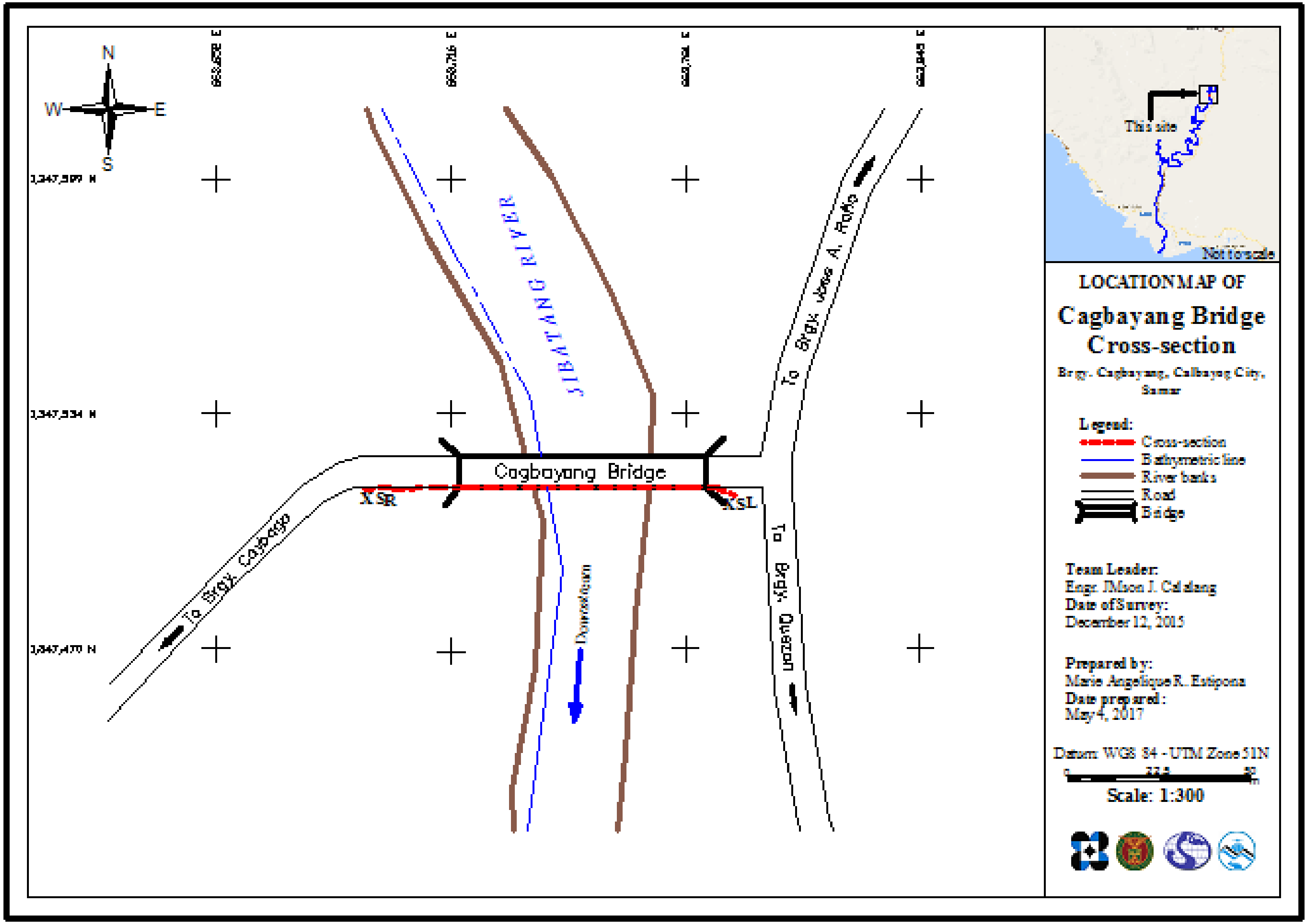


Figure 32. Cagbayang Bridge cross-section location map

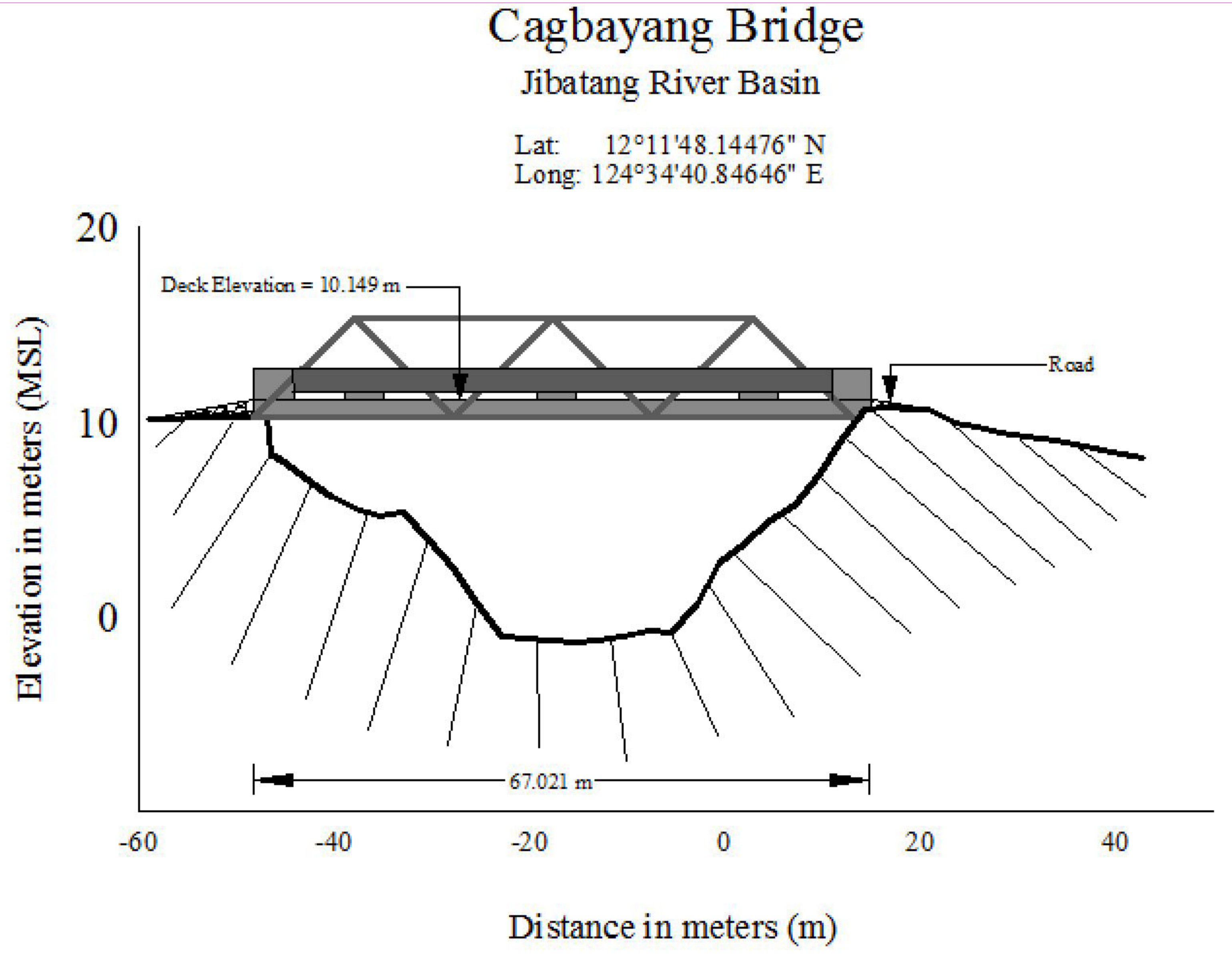


Figure 33. Cagbayang Bridge cross-section diagram

Bridge Data Form

Bridge Name: Cagbayang Bridge **Date: December 12, 2015**

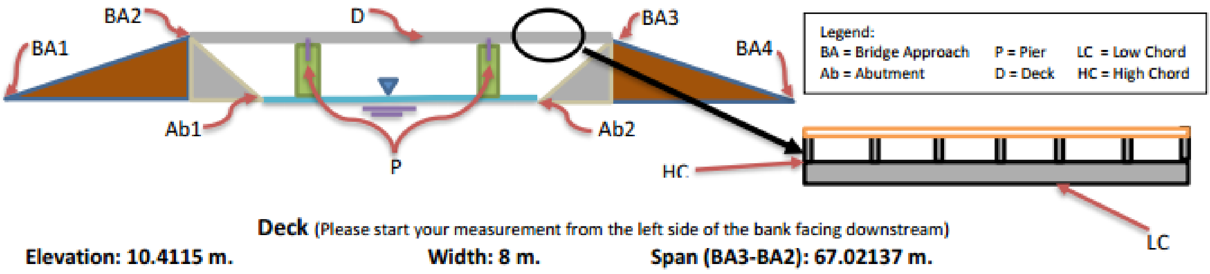
River Name: Gandara River **Time: 10:33 AM**

Location: Brgy. Cagbayang, Calbayog City, Samar

Survey Team: JMson Calalang, Marie Angelique Estipona, Caren Joy Ordoña

Flow condition: low ✓ normal high **Weather Condition:** ✓ fair rainy

Latitude: 12°11'48.16845"N **Longitude: 124°34'40.77429"E**



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

Elevation: 10.4115 m. **Width: 8 m.** **Span (BA3-BA2): 67.02137 m.**

	Station	High Chord Elevation	Low Chord Elevation
1			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	10.118	BA3	75.714	10.674
BA2	8.693	10.149	BA4	101.778	8.11

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: Cylindrical Number of Piers: 0 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1			
Pier 2			
Pier 3			
Pier 4			

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

Figure 34. Cagbayang Bridge Data Form

Insert text here re water surface elevation and water level markings.

Figure 35. Water level markings on the Cagbayang Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on December 6 and 12, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882. The receiver was mounted on a pole attached in front of the vehicle, as demonstrated in Figure 38. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.21 meters, 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 SMR-33 and UP-JIB occupied as the GNSS base stations all throughout the conduct of the survey.

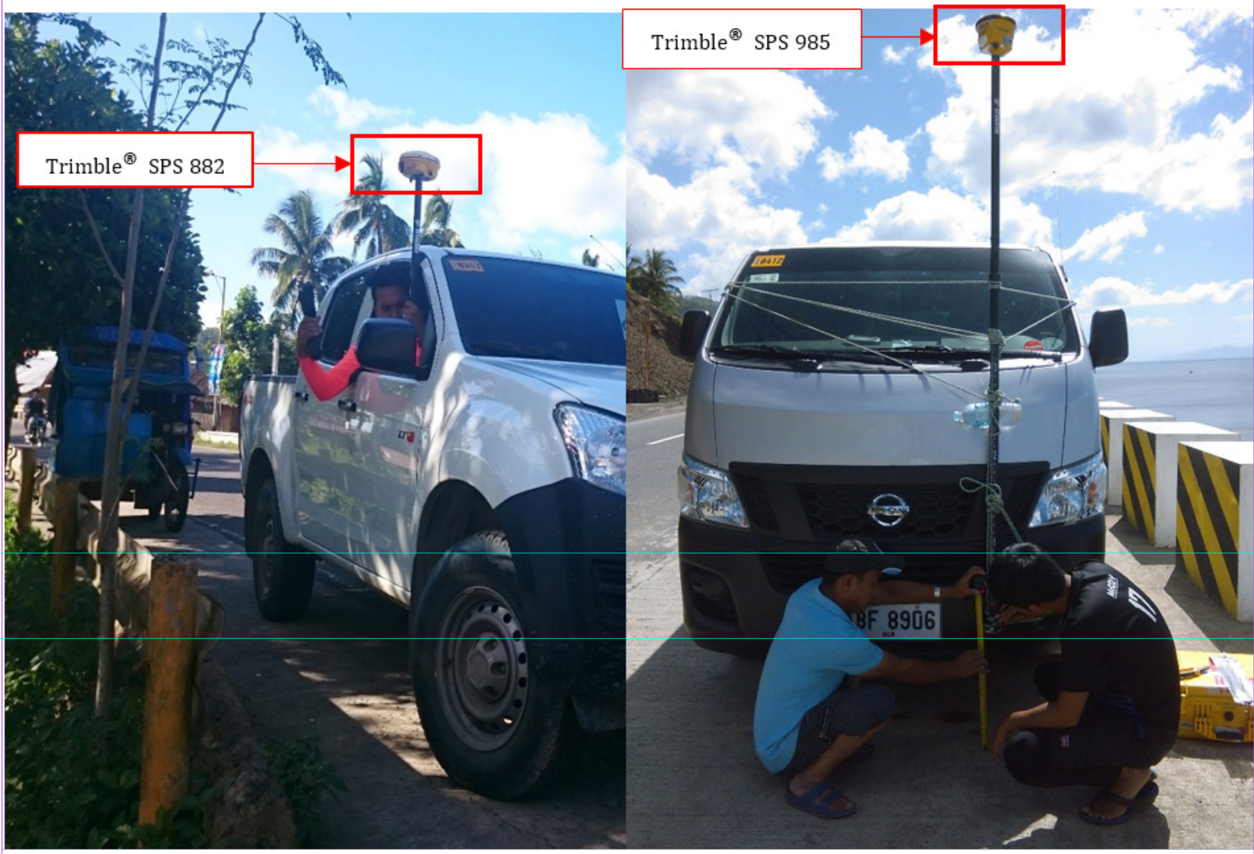


Figure 36. Validation points acquisition survey set-up

The validation points acquisition survey for the Jibatang River Basin traversed Calbayog City and the following municipalities of Samar: Lope de Vega, Santa Margarita, Gandara, and San Jorge. The route of the survey aimed to perpendicularly traverse the LiDAR flight strips for the basin. A total of 17,138 points with an approximate length of 101.96 kilometers were acquired for the validation points acquisition survey, as illustrated in the map in Figure 39.

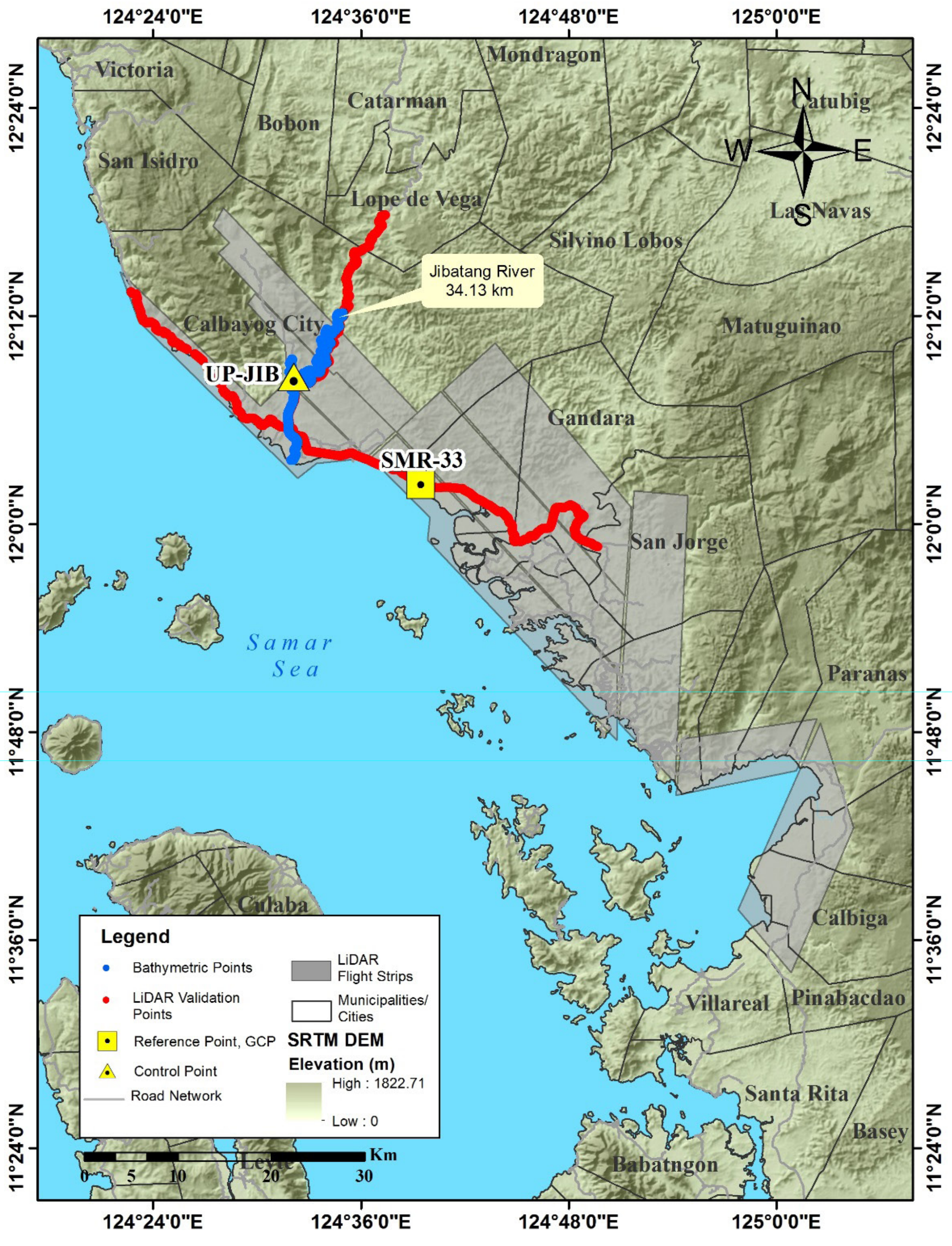


Figure 37. Extent of the LiDAR ground validation survey of the Jibatang River Basin

4.7 Bathymetric Survey

A bathymetric survey of the Jibatang River was conducted on December 10-11, 2015 using OHMEXTM and a Trimble® SPS 882 GNSS rover receiver attached to a pole on the side of the boat, as exhibited in Figure 40. The survey began in the upstream part of the river in Barangay Sinidman and Barangay Cagbilwang, with coordinates 12°09'20.2612"N 124°34'02.2192"E, and 12°09'30.7692"N 124°32'01.0910"E, respectively; and ended in Barangay Tomaliguez, with coordinates 12°03'40.7127"N 124°31'57.6420"E. All the traversed barangay are located in Calbayog City.

A manual bathymetric survey of the Jibatang River was executed on December 11, 2015 using Trimble® SPS 882 GNSS PPK technique, as shown in Figure 41. The survey began in the upstream portion of the river in Barangay Jose A. Roño, with coordinates 12°12'11.8118"N 124°34'57.9262"E; and ended at the endpoint of bathymetric survey by boat in Barangay Sinidman. The starting and end points are both in Calbayog City. The control point UP-JIB was used as the GNSS base station for the whole bathymetric survey.

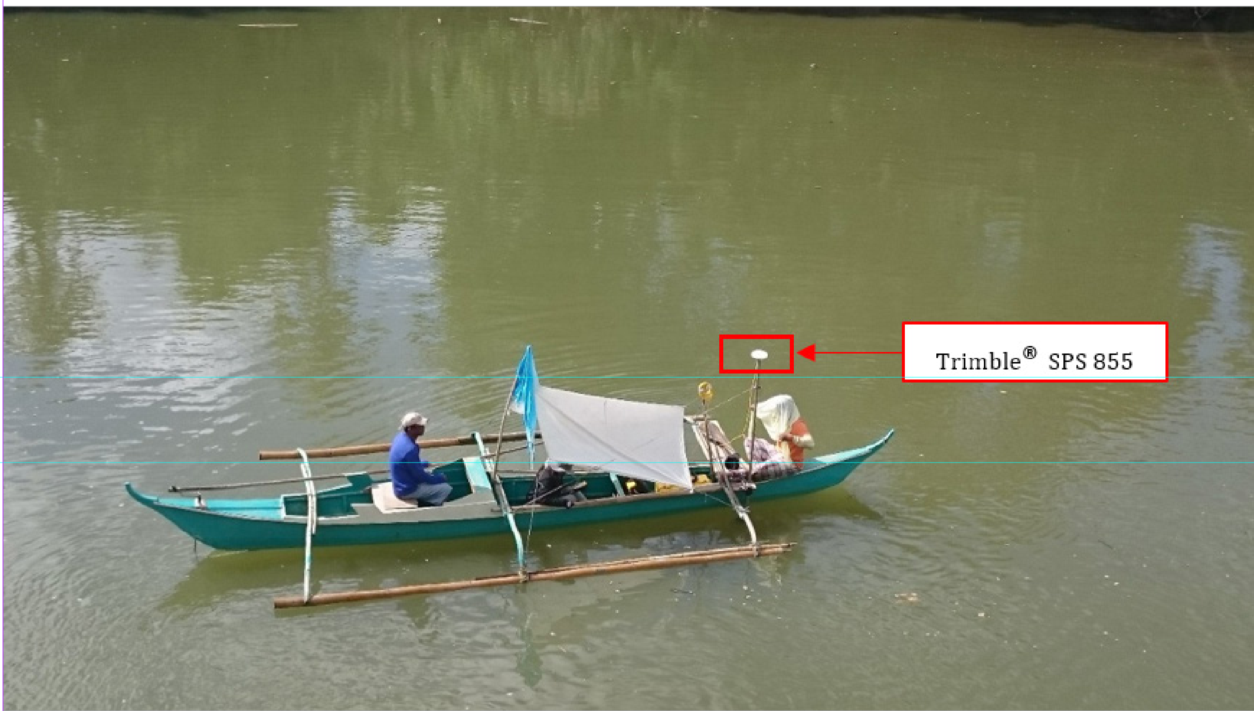


Figure 38. Bathymetric survey using OHMEX™ single beam Echo Sounder along the Jibatang River

Figure 39. Manual bathymetry along the Jibatang River

CAD drawings were produced to illustrate the riverbed profile of the Jibatang River, presented in Figure 43 to Figure 45. The profiles show that the highest and lowest elevation had a 15.11-meter difference. The highest elevation observed was 6.159 meters above MSL, located in Barangay Cagbayang. On the other hand, the lowest elevation was -8.954 meters below MSL, located at the intersection of the left and right tributaries in Barangay Oquendo. A total of 26,990 points were acquired during the survey covering 34.13 kilometers of the river, traversing the twenty-five (25) barangays in Calbayog City. The bathymetric survey was extended by 18 kilometers, as recommended by the VSU Phil-LiDAR 1 Team, to cover the upstream portion of the river and its surrounding communities. These areas are said to overflow during the rainy season, according to the locals. The gaps in the bathymetric survey were caused by the difficulties in acquiring satellites due to obstructions, such as dense canopies of trees and the presence of rapids along the river.

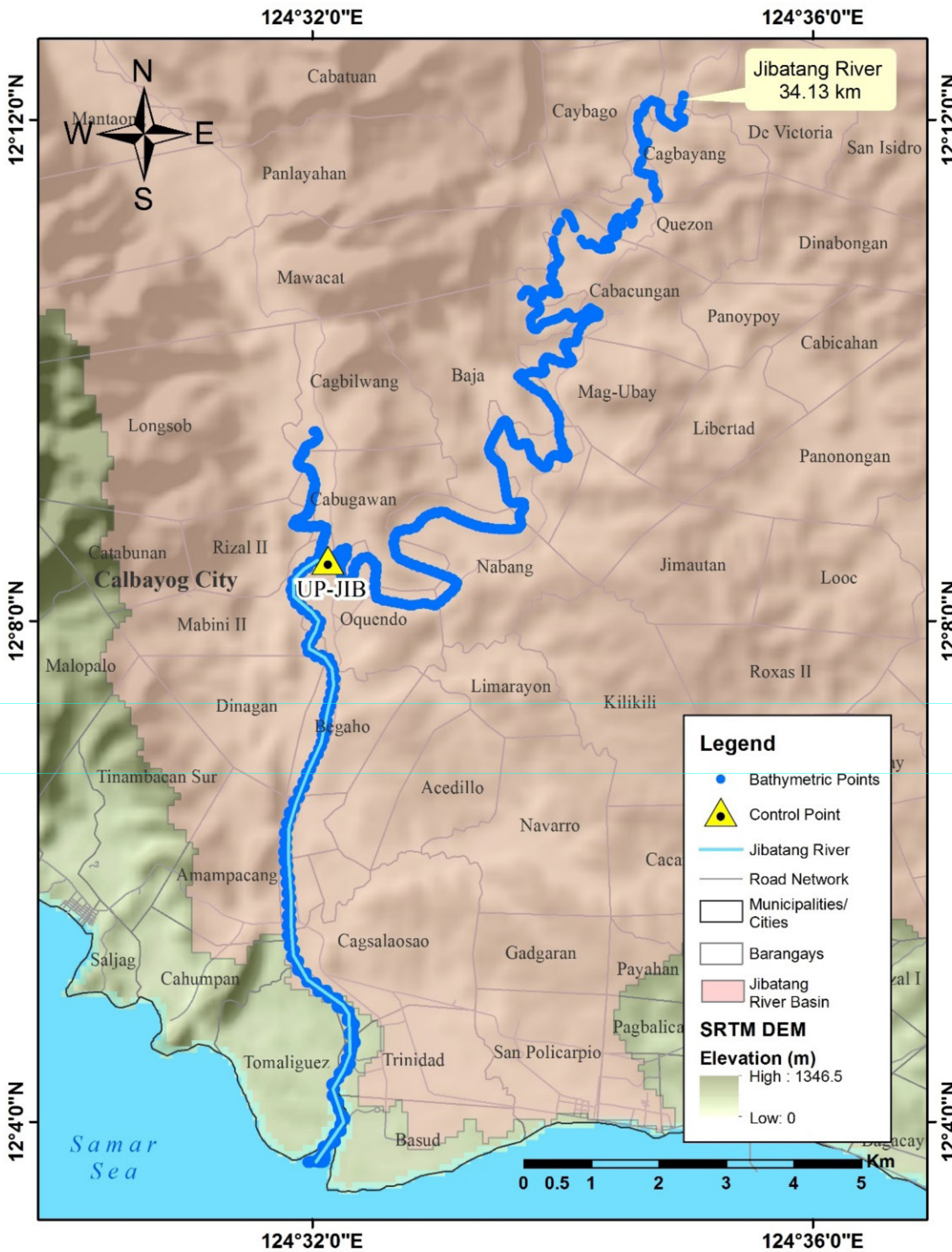


Figure 40. Extent of the bathymetric survey of the Jibatang River

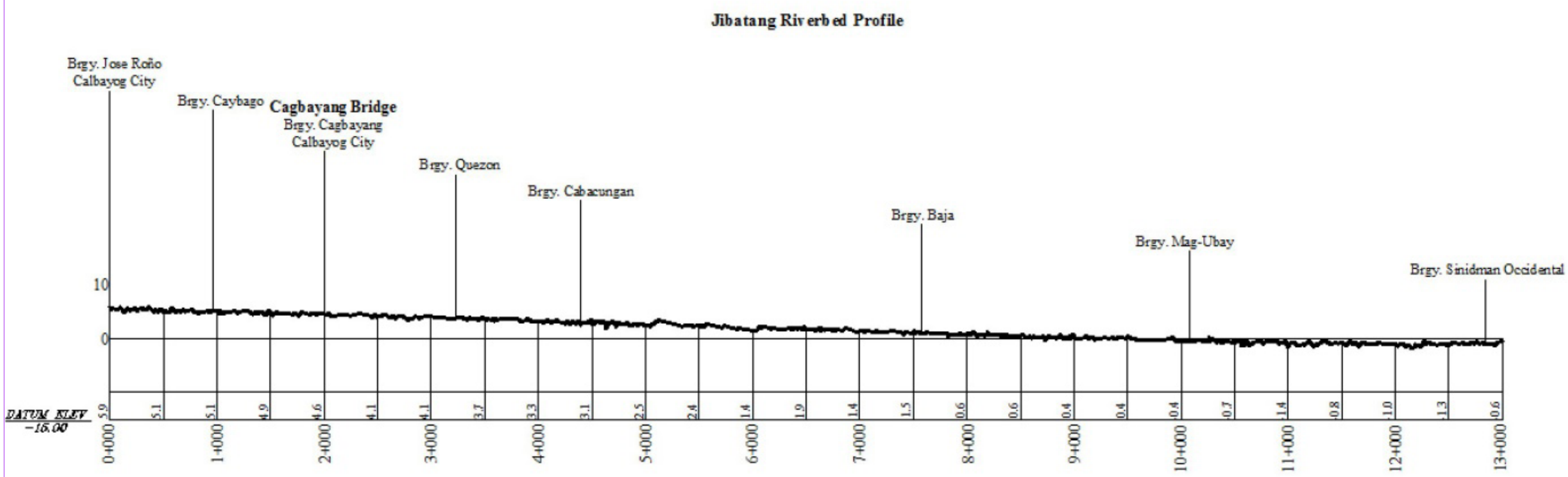


Figure 41. Cagbayang Bridge cross-section diagram

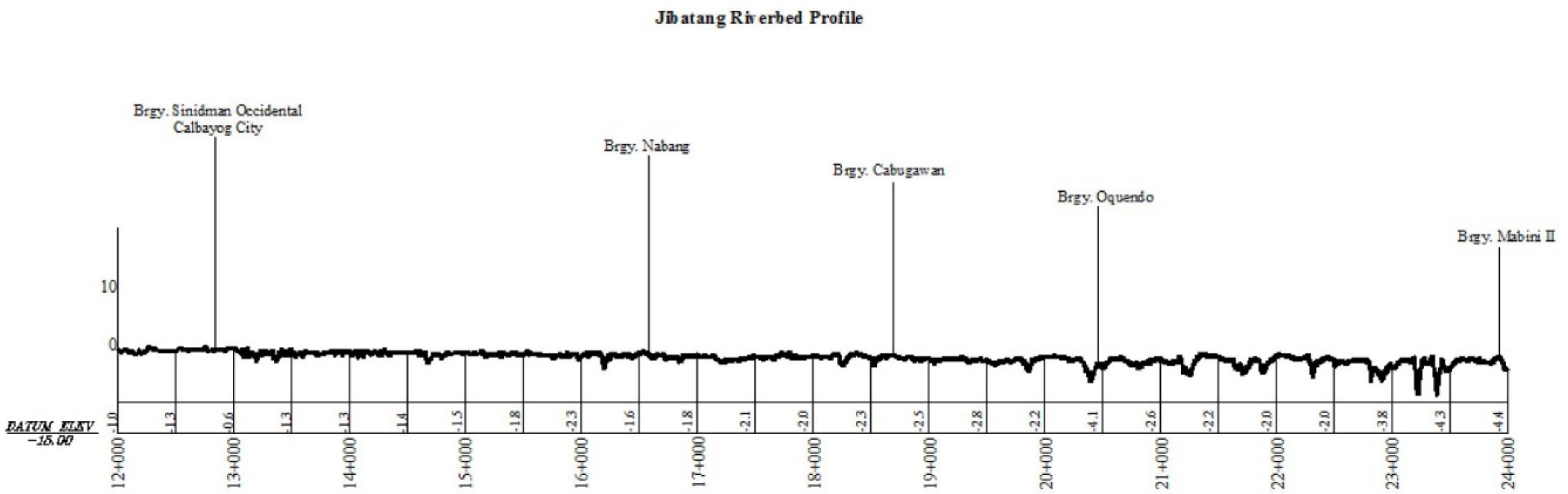


Figure 42. Riverbed profile of the middle portion of the Jibatang River

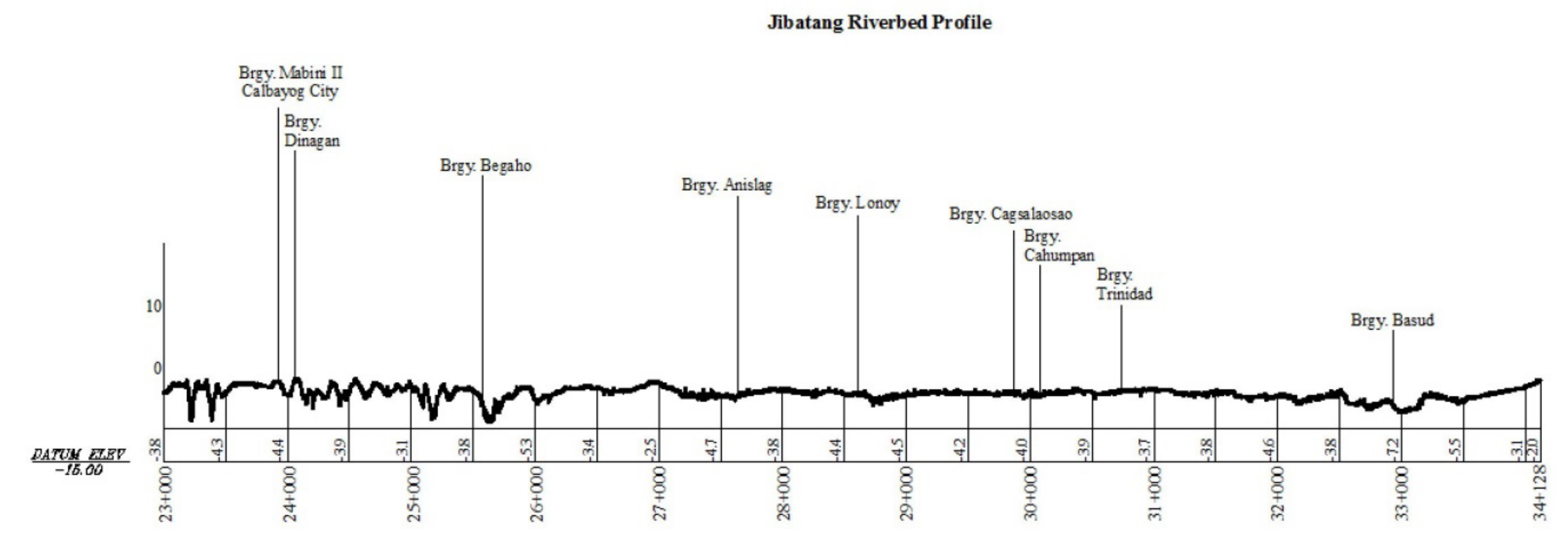


Figure 43. Riverbed profile of the downstream portion of the Jibatang River

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

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

5.1.2 Precipitation

Precipitation data was taken from one (1) automatic rain gauge (ARG) temporarily installed by the VSU Phil-LiDAR 1 Flood Modeling Component (FMC), which was the Sinidman Occidental ARG. The location of the rain gauge is seen in Figure 46.

Total rain from the Sinidman Occidental rain gauge was 58 mm. It peaked at 3.33 mm. on November 24, 2016 at 15:00 hrs. The lag time between the peak rainfall and discharge was twenty-nine (29) hours and fifty (50) minutes.

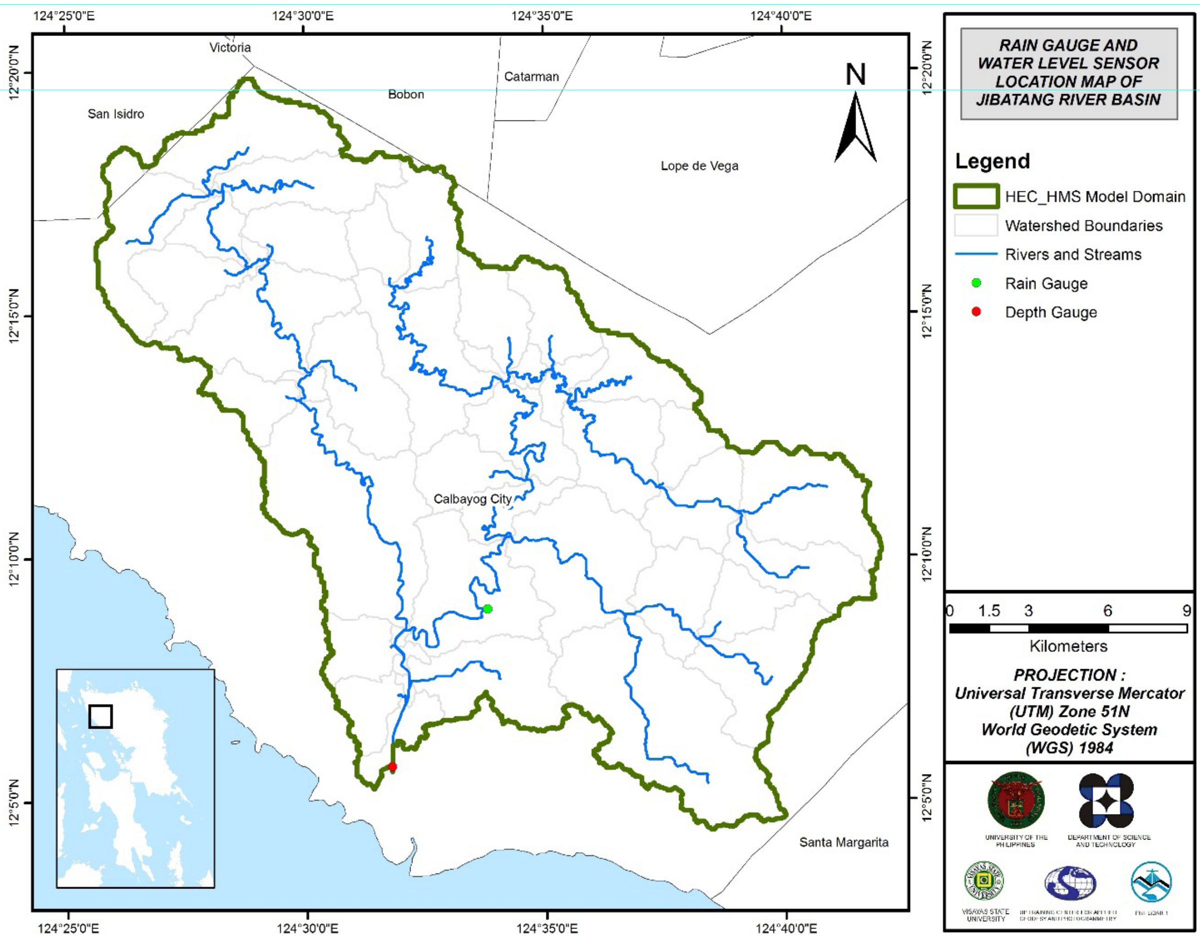


Figure 44. Location map of Jibatang HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 47) at the Cagbayang Bridge in Lonoy, Calbayog City, Samar (12° 5’35.83”N, 124°31’49.04”E) to establish the relationship between the observed water levels (H) at the bridge and the discharge (Q) of the watershed at this location.

For the Cagbayang Bridge, the rating curve is expressed as Q = 2.2973e0.751h, as illustrated in Figure48.

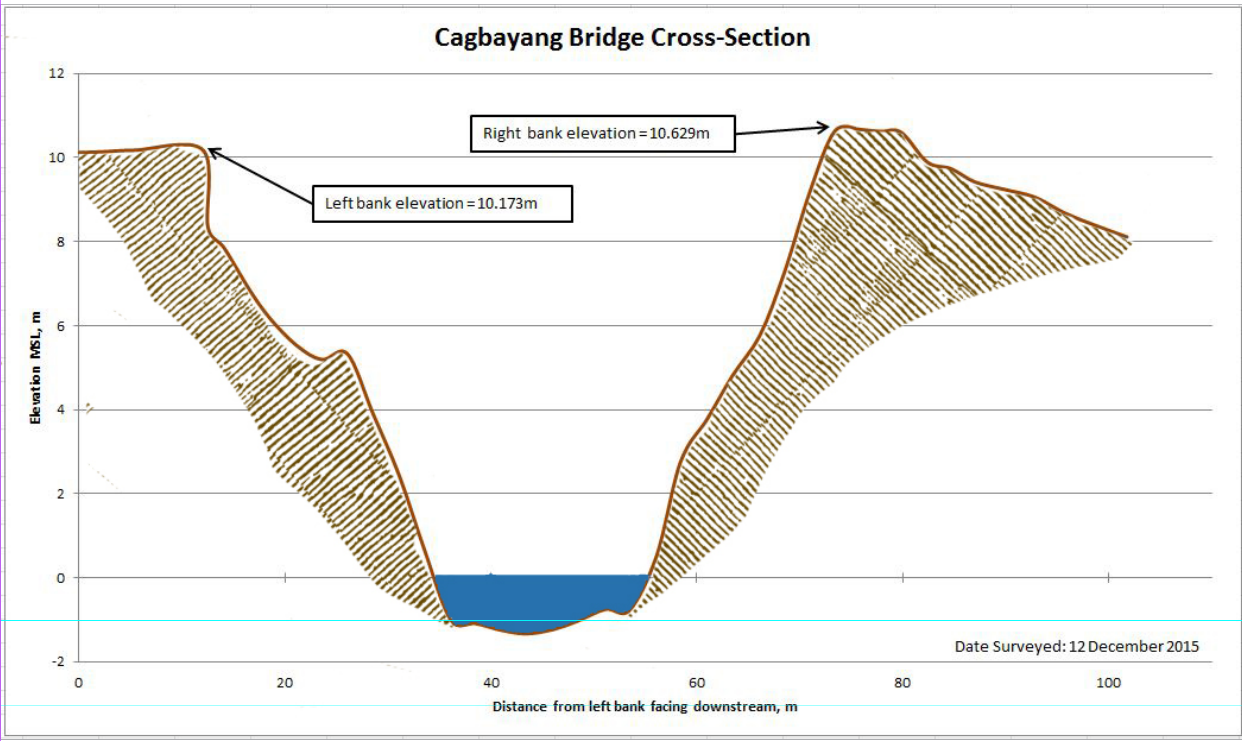


Figure 45. Cross-section plot of the Cagbayang Bridge

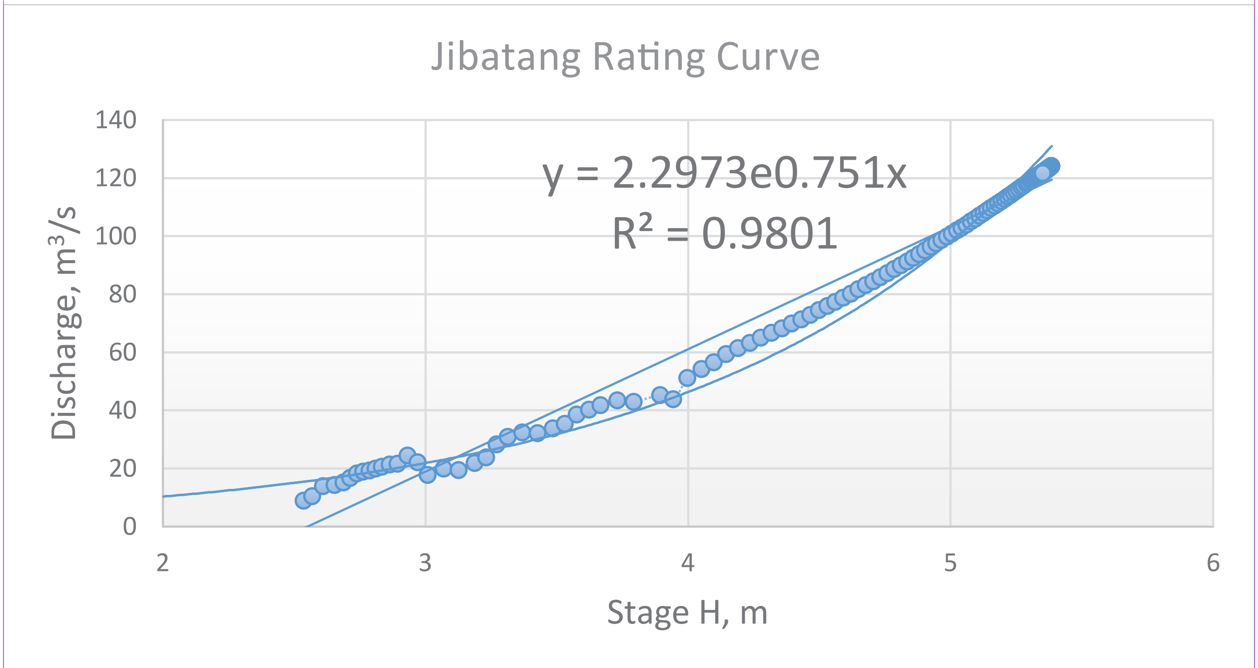


Figure 46. Rating curve of the Cagbayang Bridge

This rating curve equation was used to compute for the river outflow at the Cagbayang Bridge, for the calibration of the HEC-HMS model shown in Figure 49. Total rain from the Sinidman Occidental rain gauge was 58 mm. It peaked at 3.33 mm on November 24, 2016 at 15:00 hrs. The lag time between the peak rainfall and discharge was twenty-nine (29) hours and fifty (50) minutes.

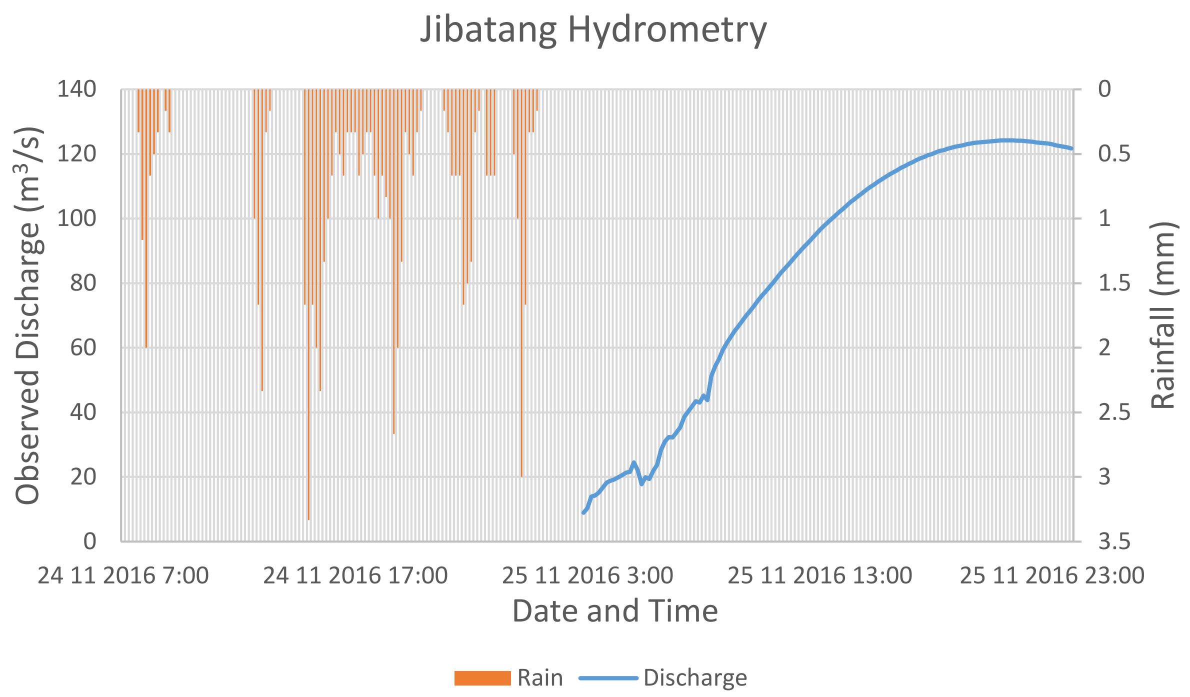


Figure 47. Rainfall and outflow data at the Cagbayang Bridge, used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Catarman Rain Gauge (Table 26). This station was selected based on its proximity to Jibatang watershed (Figure 50).The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values such that certain peak values were attained at a certain time. The extreme values for this watershed were computed based on a 52-year record.

Table 22. Table 26. RIDF values for the Catarman 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	22.5	34.2	42.4	57.5	80.9	96.4	125.2	156.6	180
5	29.9	45.4	56.2	77	110.3	135.9	183.5	229.5	255.4
10	34.7	52.8	65.4	90	129.7	162	222.1	277.8	305.4
15	37.5	57	70.5	97.3	140.7	176.7	243.9	305.1	333.6
20	39.4	60	74.2	102.4	148.4	187.1	259.1	324.1	353.3
25	40.9	62.2	76.9	106.3	154.3	195	270.9	338.8	368.5
50	45.5	69.2	85.5	118.4	172.6	219.5	307.1	384.1	415.3
100	50	76.1	94	130.5	190.7	243.8	343	429	461.8

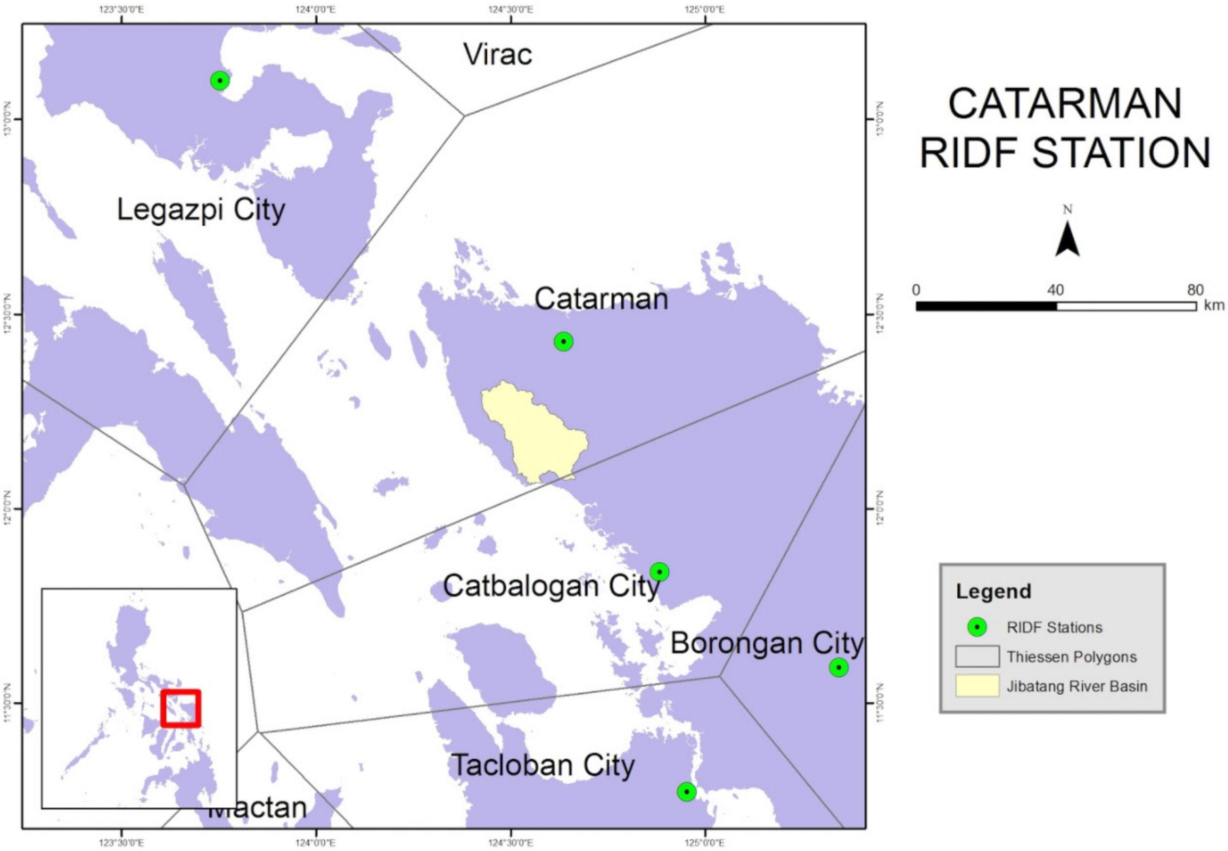


Figure 48. Location of the Catarman RIDF station relative to the Jibatang River Basin

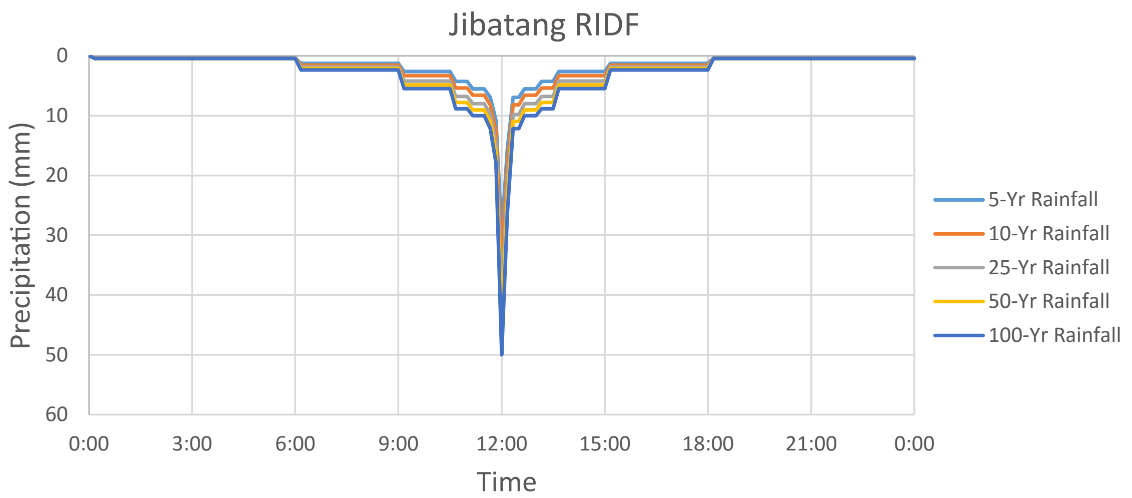


Figure 49. Synthetic storm generated from a 24-hr period rainfall, for various return periods

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004.The soil and land cover maps of the Jibatang River Basin are presented in Figures 52 and 53, respectively.

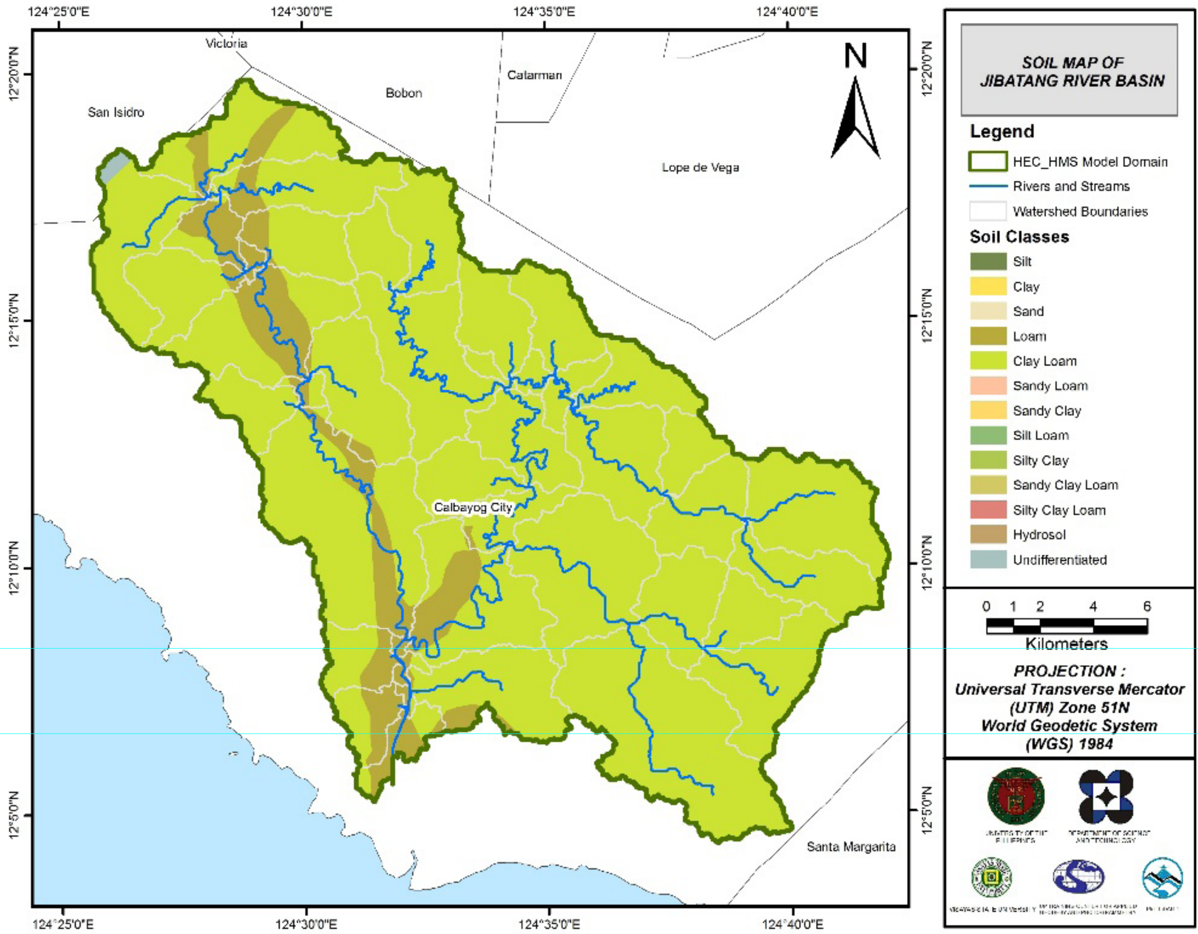


Figure 50. Soil map of the Jibatang River Basin (Source: DA)

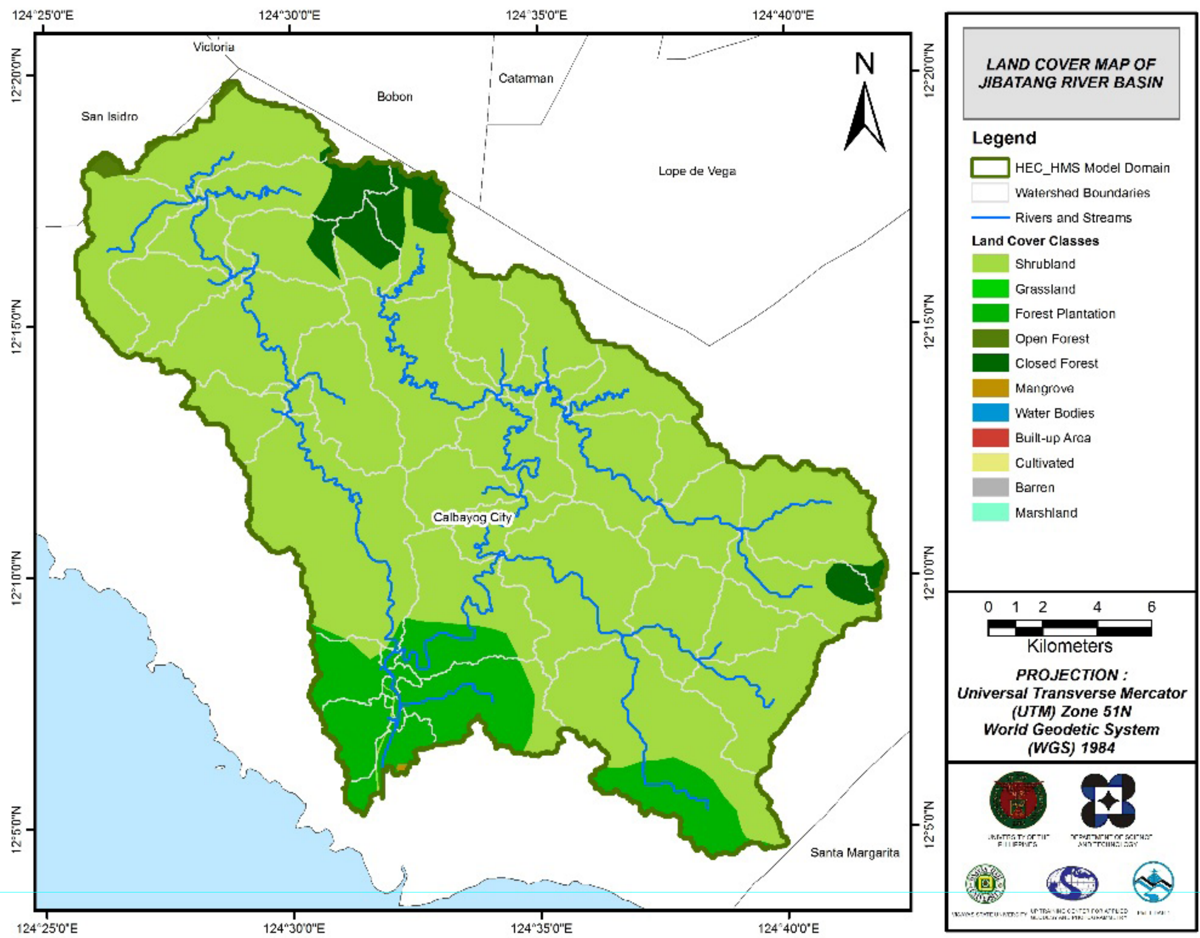


Figure 51. Land cover map of Jibatang River Basin (Source: NAMRIA)

The two (2) soil classes identified in the Jibatang River Basin were clay loam and loam. Moreover, the land cover types identified were shrublands, forest plantations, open forests, and closed forests.

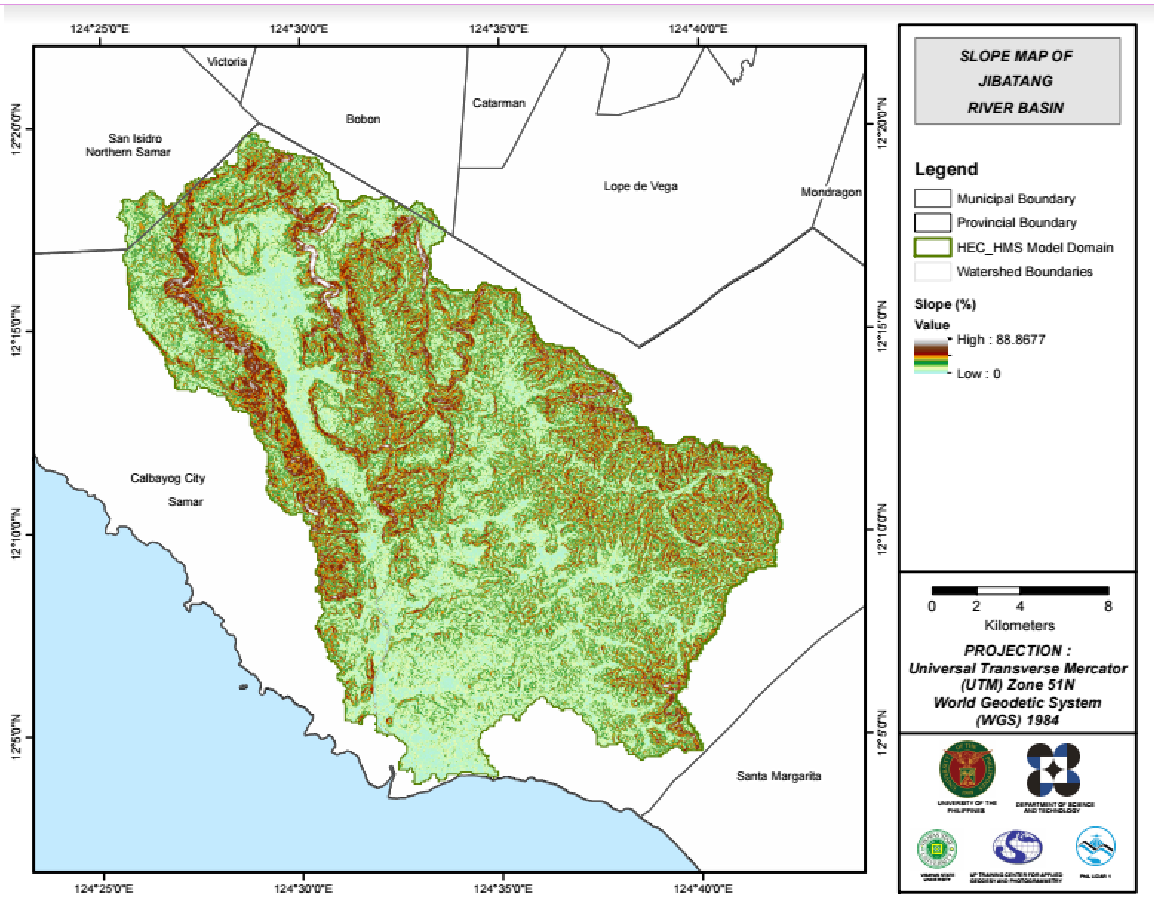


Figure 52. Slope map of the Jibatang River Basin

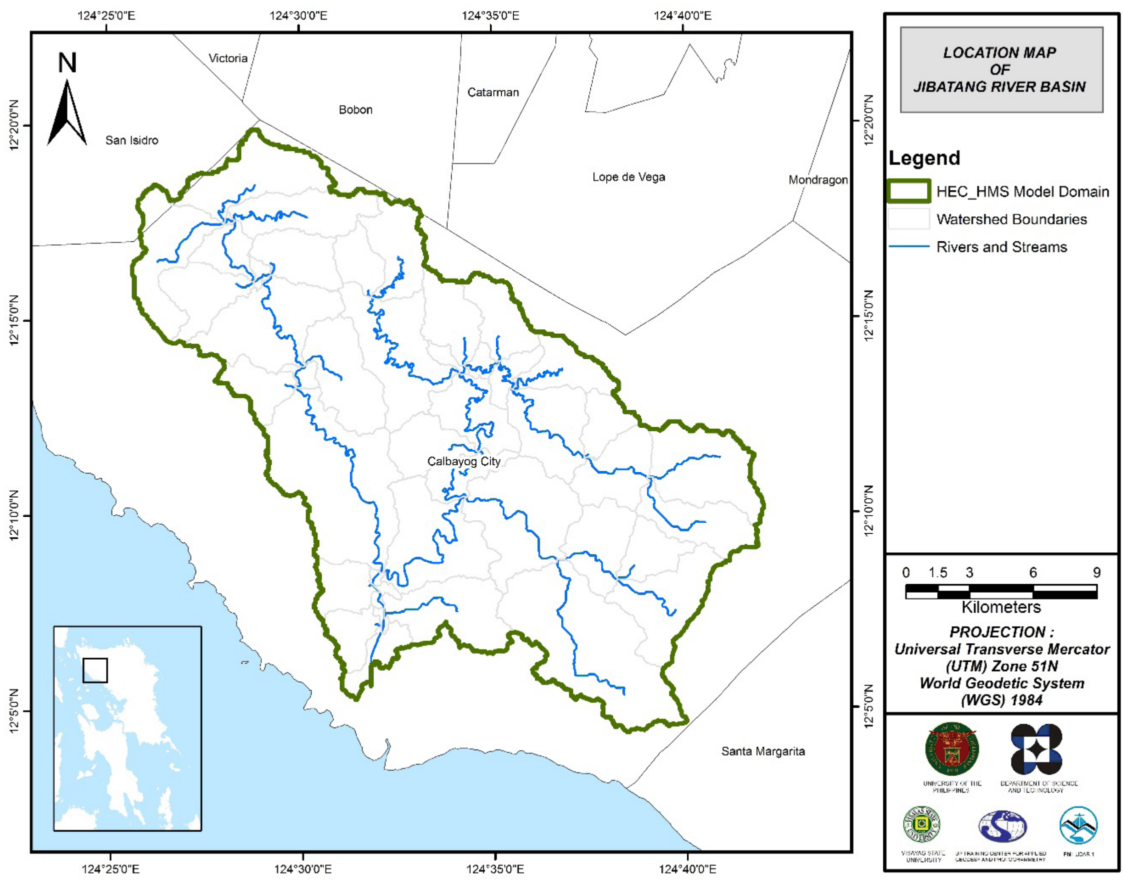


Figure 53. Stream delineation map of the Jibatang River Basin

Using the SAR-based DEM, the Jibatang basin was delineated and further subdivided into sub-basins. The model consists of forty-three (43) sub-basins, twenty-one (21) reaches, and twenty-one (21) junctions, as illustrated in Figure 56. The main outlet is at the Calbayang Bridge. The Jibatang Model Reach Parameters are available in ANNEX 10.

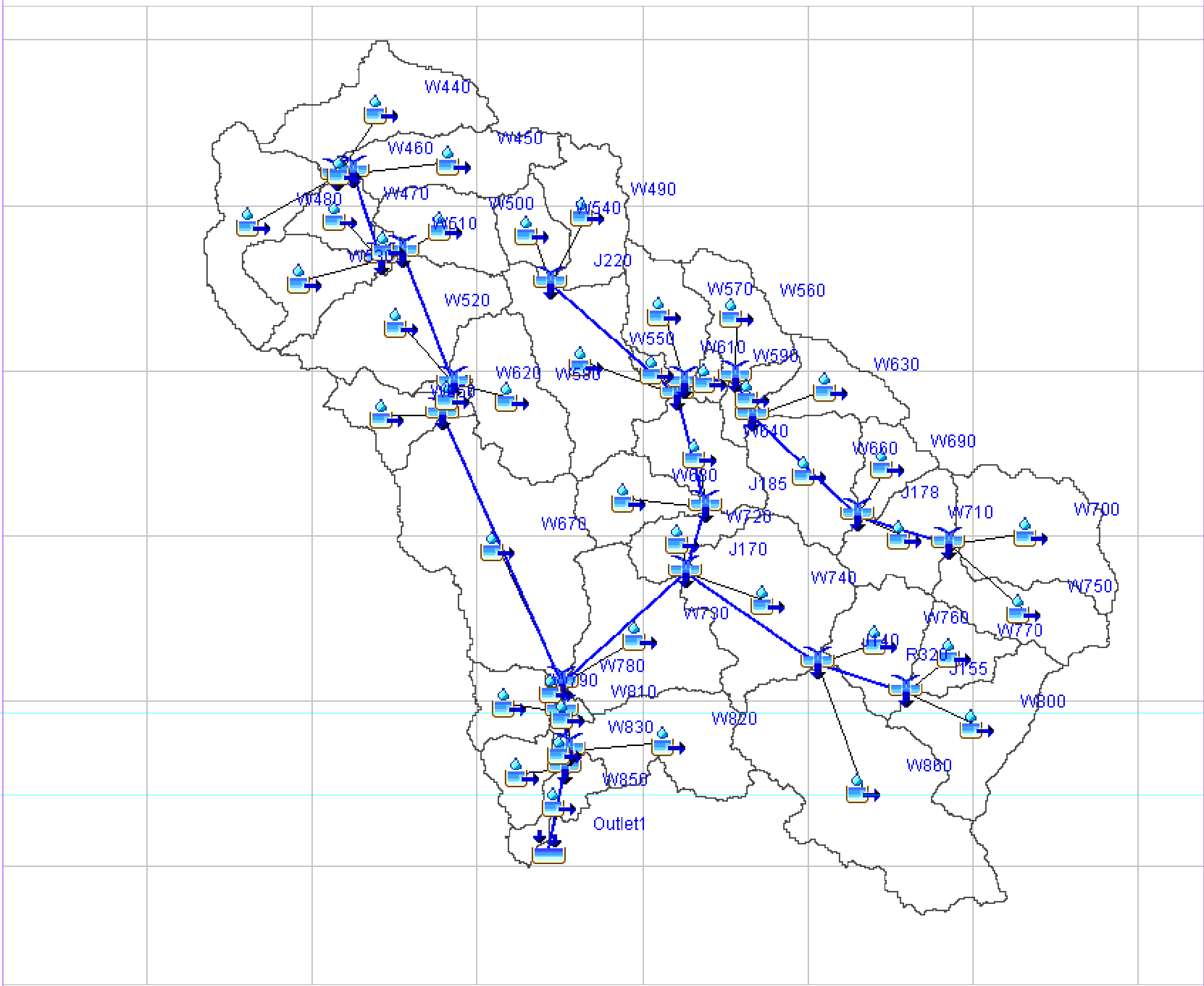


Figure 54. The Jibatang River Basin model generated in HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model were derived from the LiDAR DEM data. These were defined using the Arc GeoRAS tool, and post-processed in ArcGIS (Figure 57).

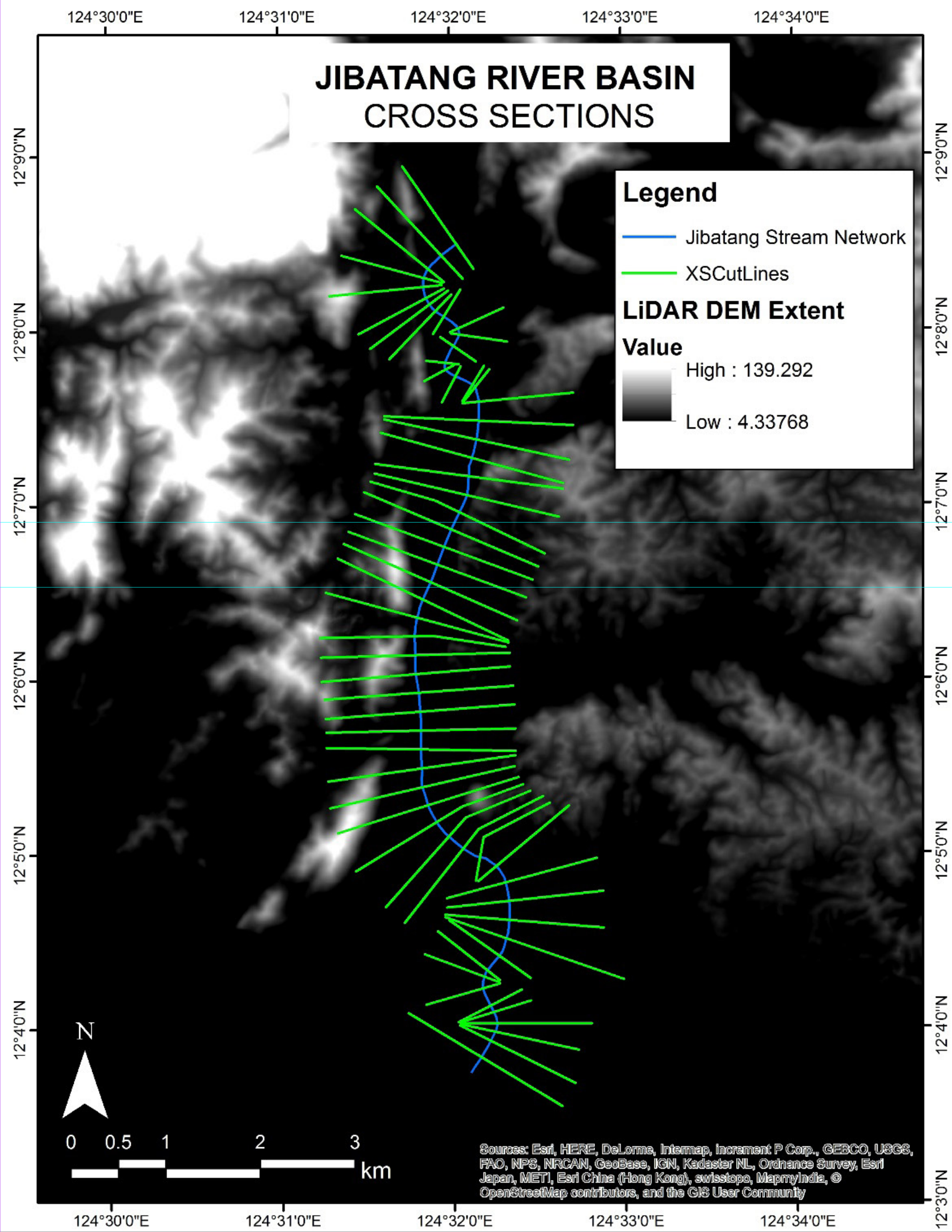


Figure 55. River cross-section of the Jibatang River generated through the ArcMap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modeling process allowed 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 was divided into square grid elements, 10 meters by 10 meters in size. Each element was assigned a unique grid element number, which served as its identifier. The elements were then attributed with the parameters required for modeling, such as x- and y-coordinates of centroid, names of adjacent grid elements, Manning's coefficient of roughness, infiltration, and elevation values. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements in eight directions (i.e., north, south, east, west, northeast, northwest, southeast, and southwest).

Based on the elevation and flow direction, it was observed that the water will generally flow from the northwest to the south, following the main channel. As such, boundary elements in those particular regions of the model were assigned as inflow and outflow elements, respectively.

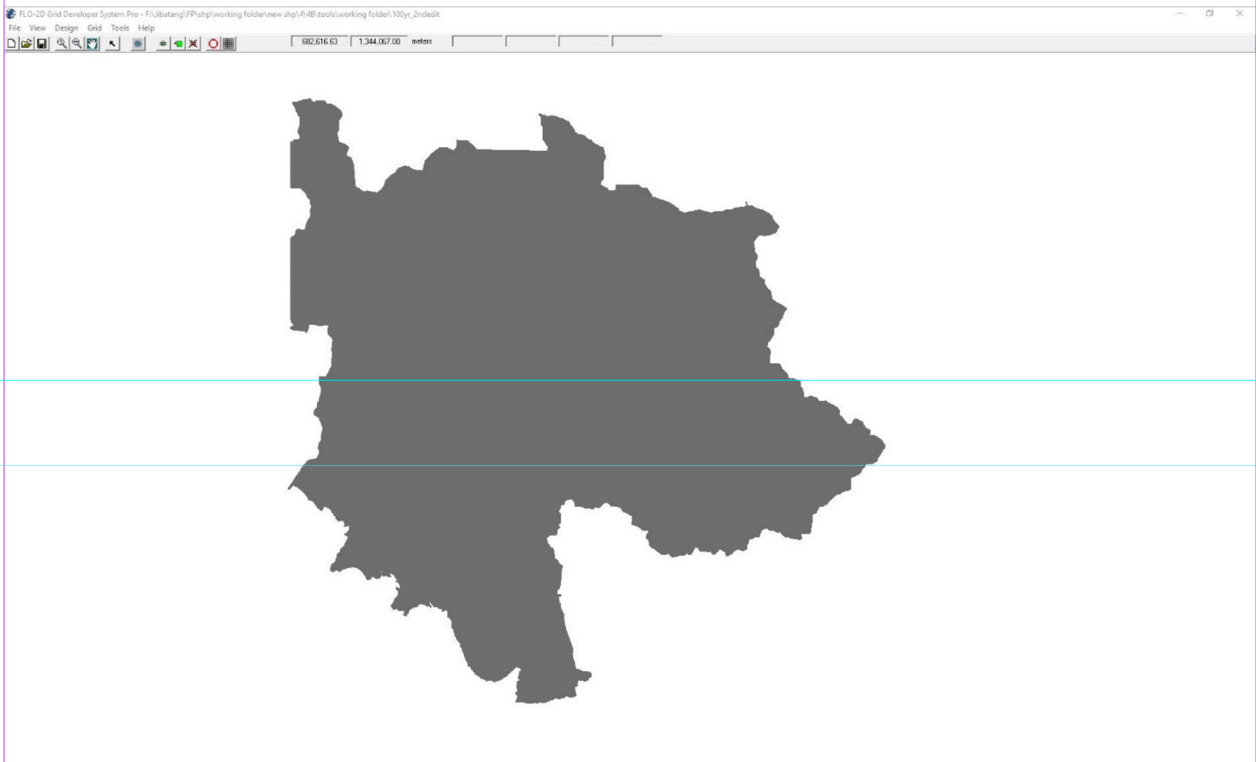


Figure 56. A screenshot of a sub-catchment, with the computational area to be modeled in FLO-2D GDS Pro

The simulation was then run through the FLO-2D GDS Pro. This particular model had a computer run time of 76.34570 hours. After the simulation, the FLO-2D Mapper Pro was 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 created the output flood hazard map. Most of the default values given by the FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) was set at 0.2 meters; while the minimum vh (Product of maximum velocity (v) and maximum depth (h)) was set at 0 m^2/s.

The creation of a flood hazard map from the model also automatically created a flow depth map, depicting the maximum amount of inundation for every grid element. The legend used by default in the Flo-2D Mapper was not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts covered a maximum land area of 59052900.00 m^2.

There was a total of 78347670.06 m^3 of water that entered the model. Of this amount, 24298021.46 m^3 was due to rainfall, while 54049648.60 m^3 was inflow from other areas outside the model. 6505293.00 m^3 of this water was lost to infiltration and interception, while 35990626.11 m^3 was stored by the floodplain. The rest, amounting to up to 35851563.43 m^3, was outflow.

5.6 Results of HMS Calibration

After calibrating the Jibatang HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 59 depicts the comparison between the two (2) discharge data. See ANNEX 9 for the Jibatang Model Basin Parameters.

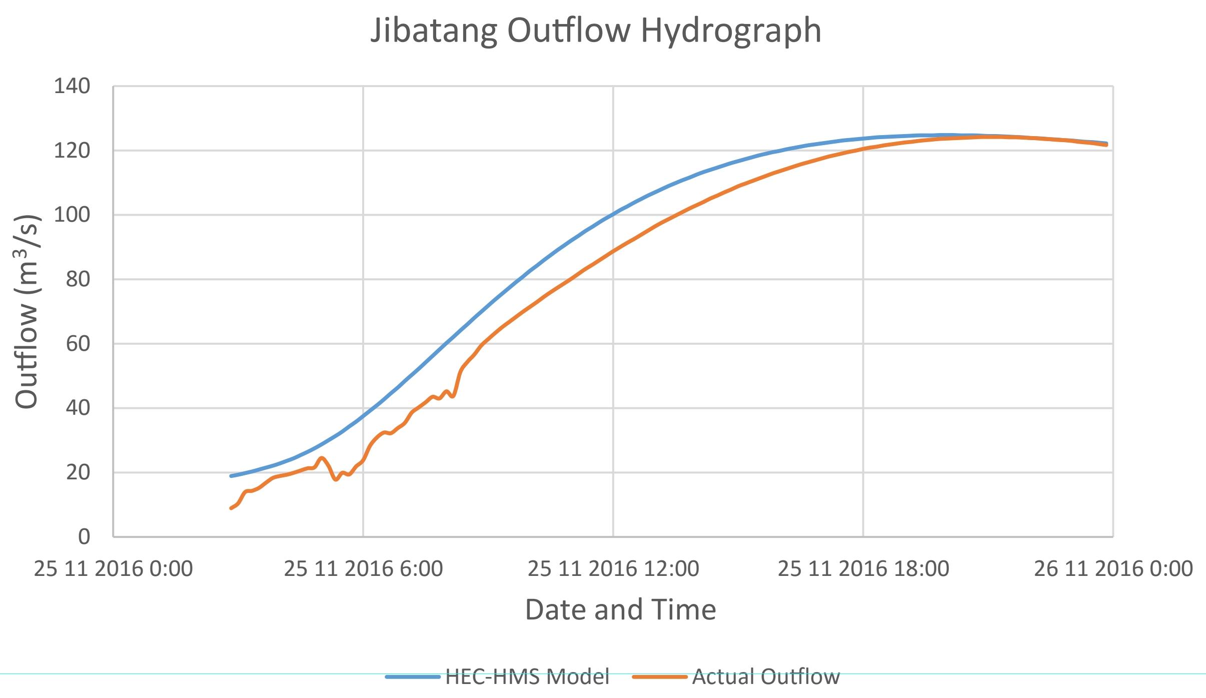


Figure 57. Outflow hydrograph of the Jibatang Bridge generated in HEC-HMS model, compared with observed outflow

Enumerated in Table 27 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 23. Range of calibrated values for the Jibatang River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	6 - 37
			Curve Number	68 - 88
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.2 - 12
			Storage Coefficient (hr)	0.3 - 19
	Baseflow	Recession	Recession Constant	0.4
			Ratio to Peak	0.48
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04

The initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. The range of values from 6mm to 37mm for initial abstraction signifies that there is a minimal to average amount of infiltration or rainfall interception by vegetation, per sub-basin.

The 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 the curve number increases. The range of 63 to 88 for the curve number is advisable for Philippine watersheds, depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

The time of concentration and the storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. The range of calibrated values from 0.2 to 19 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; and ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 0.4 indicates that the basin is unlikely to quickly return to its original discharge, and will be higher instead. A ratio to peak of 0.48 implies a steeper receding limb of the outflow hydrograph.

A Manning's roughness coefficient of 0.04 corresponds to the common roughness of the Jibatang watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 24. Efficiency Test of the Jibatang HMS Model

Accuracy measure	Value
RMSE	5.6
r^2	0.98
NSE	0.95
PBIAS	-8.29
RSR	0.21

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 5.6 (m^3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. A coefficient value close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it was measured as 0.98.

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 0.95.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is -8.29.

The Observation Standard Deviation Ratio (RSR) is an error index. A perfect model attains a value of 0 when the error units of the values are quantified. The model has an RSR value of 0.21.

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 60) illustrates the Jibatang outflow using the Catarman RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

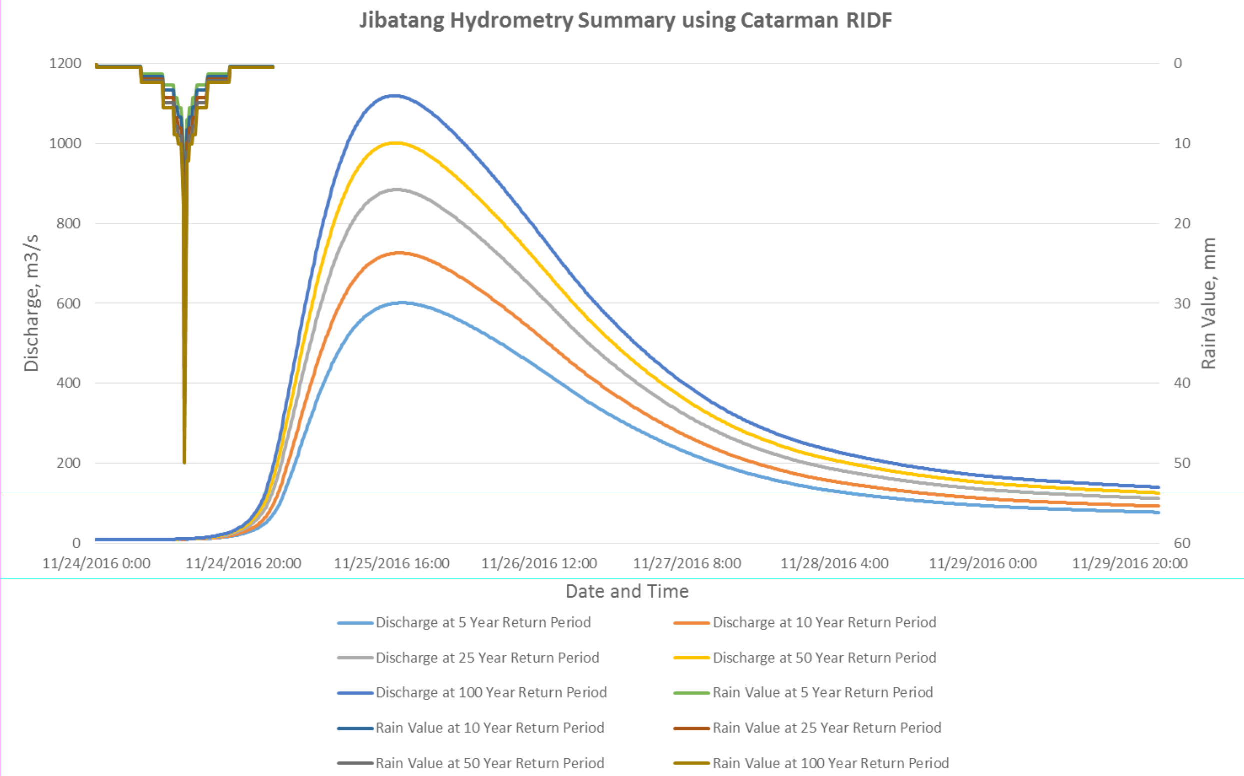


Figure 58. Outflow hydrograph at the Jibatang Station generated using the Catarman RIDF, simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Jibatang discharge using the Catarman RIDF curves in five (5) different return periods is given in Table 29.

Table 25. Peak values of the Jibatang HEC-HMS Model outflow, using the Catarman RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	255.4	29.9	505.6	21 hours, 40 minutes
10-Year	305.4	34.7	620	21 hours, 40 minutes
25-Year	368.5	40.9	778.4	21 hours, 40 minutes
50-Year	415.3	45.5	894.5	21 hours, 40 minutes
100-Year	461.8	50	1011.8	21 hours, 40 minutes

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 the extent of the real-time flood inundation of the river, after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map is presented, since only the VSU-FMC base flow was calibrated. The sample generated map of the Jibatang River using the calibrated HMS base flow is shown in Figure 61.

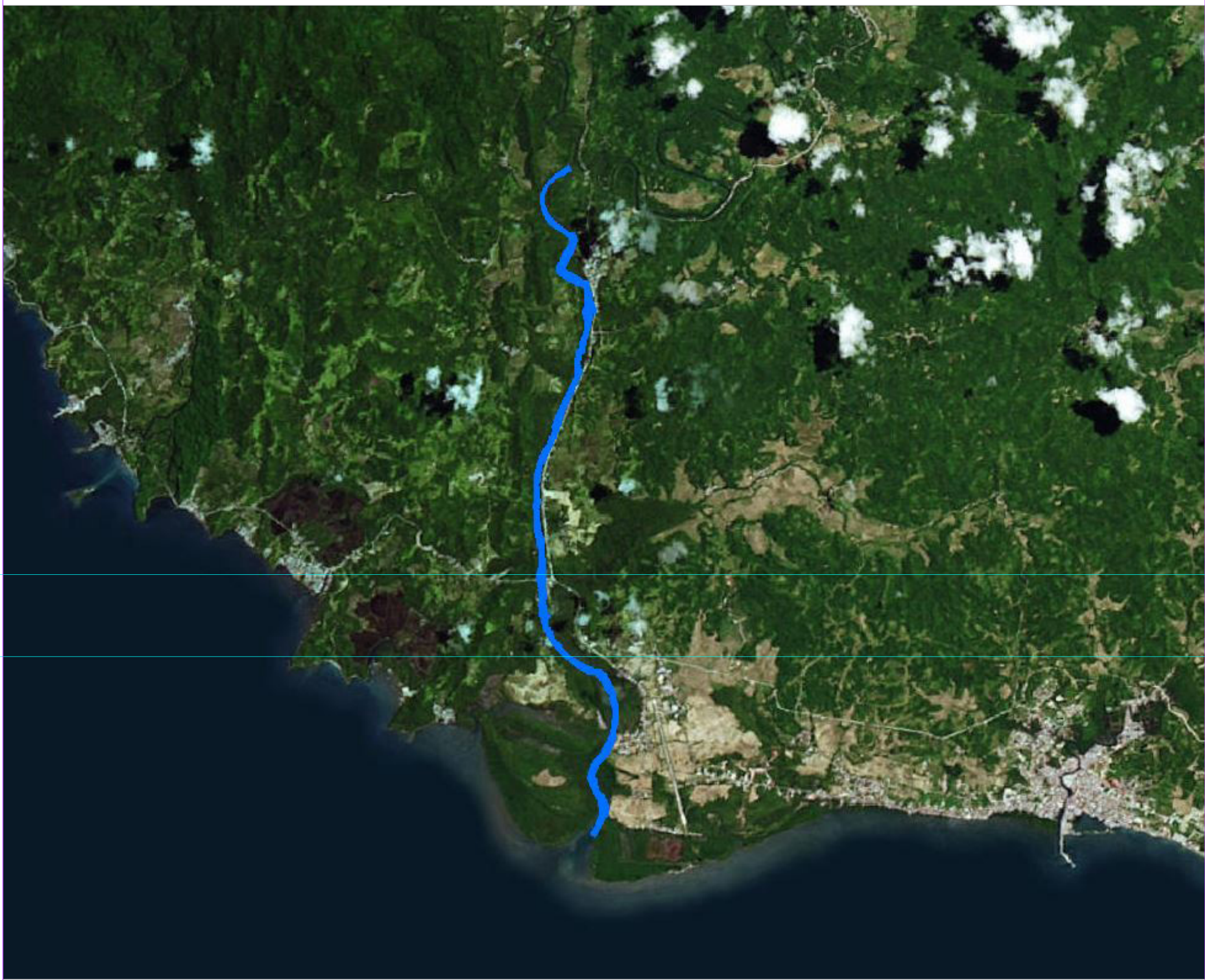


Figure 59. Sample output map of the Jibatang RAS Model

5.9 Flow Depth and Flood Hazard

The resulting flood hazard and flow depth maps have a 10-meter resolution. Figure 62 to Figure 67 exhibit the 5-year, 25-year, and 100-year rain return scenarios of the Jibatang floodplain.

The floodplain, with an area of 217.58 square kilometers, covers Calbayog City. Table 30 indicates the percentage of area affected by flooding in the city.

Table 26. Table 30. Municipalities affected in the Jibatang floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Calbayog City	897.55	215.23	23.98%

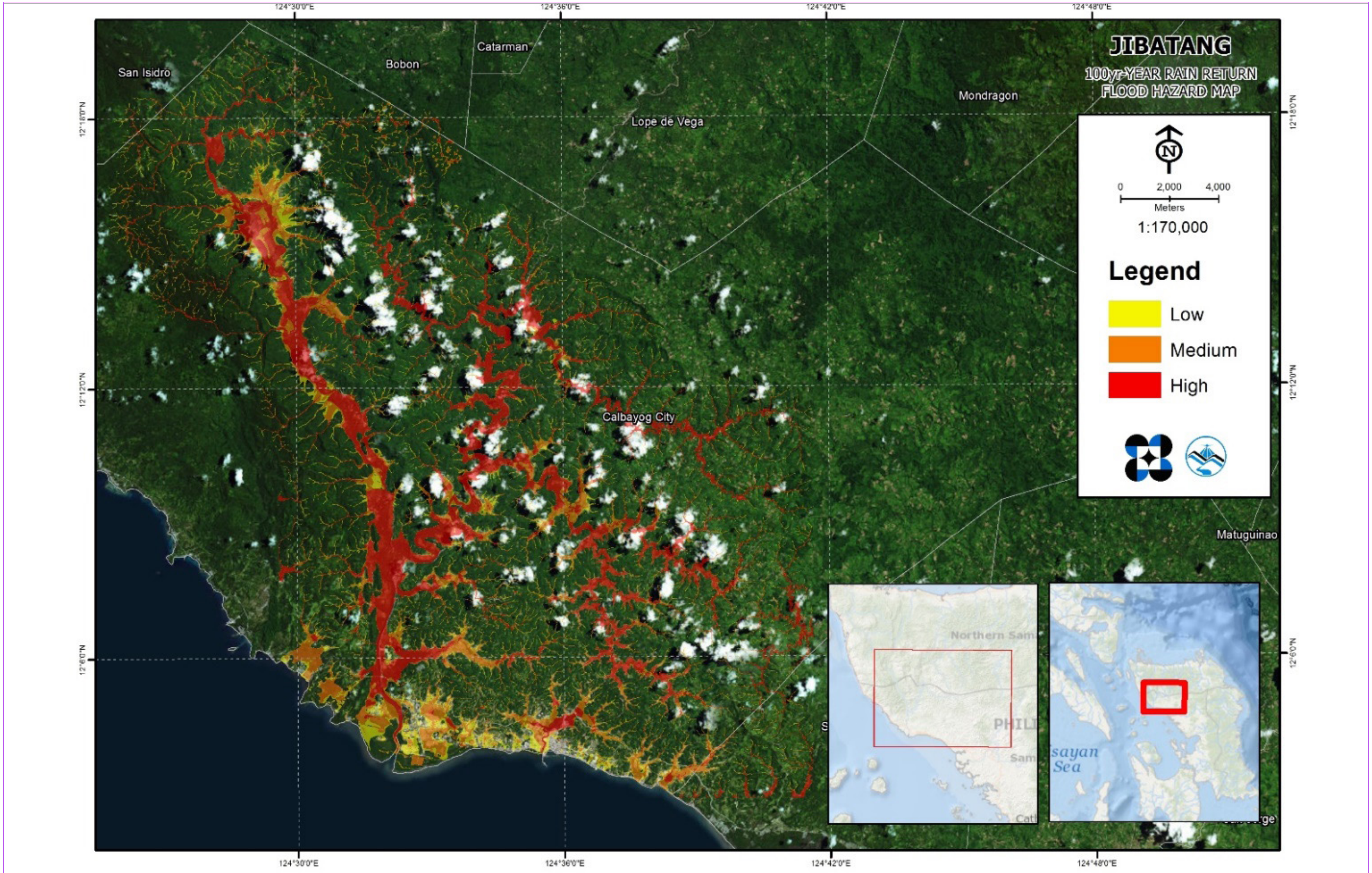


Figure 60. 100-year flood hazard map for the Jibatang floodplain

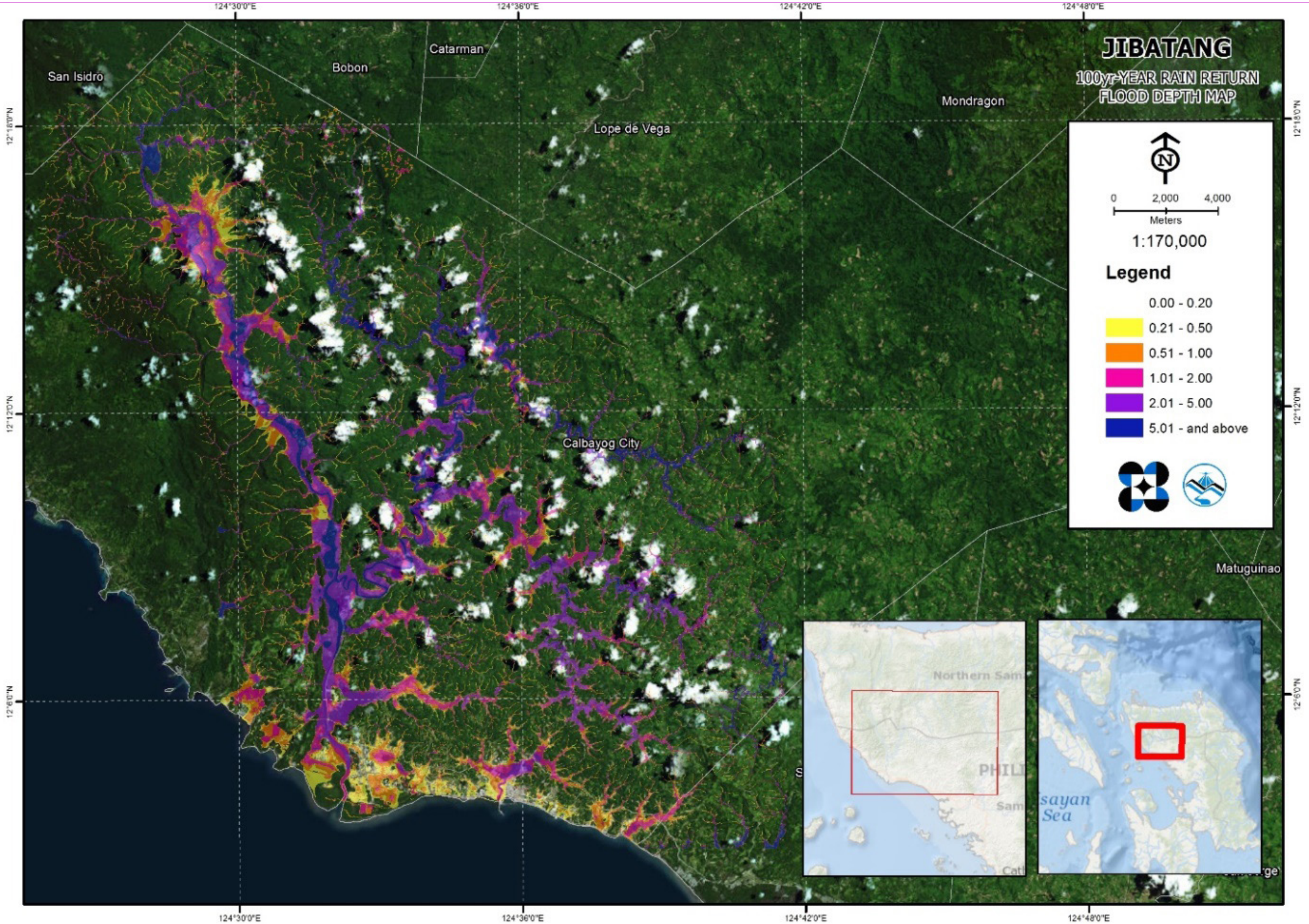


Figure 61. 100-year flow depth map for the Jibatang floodplain

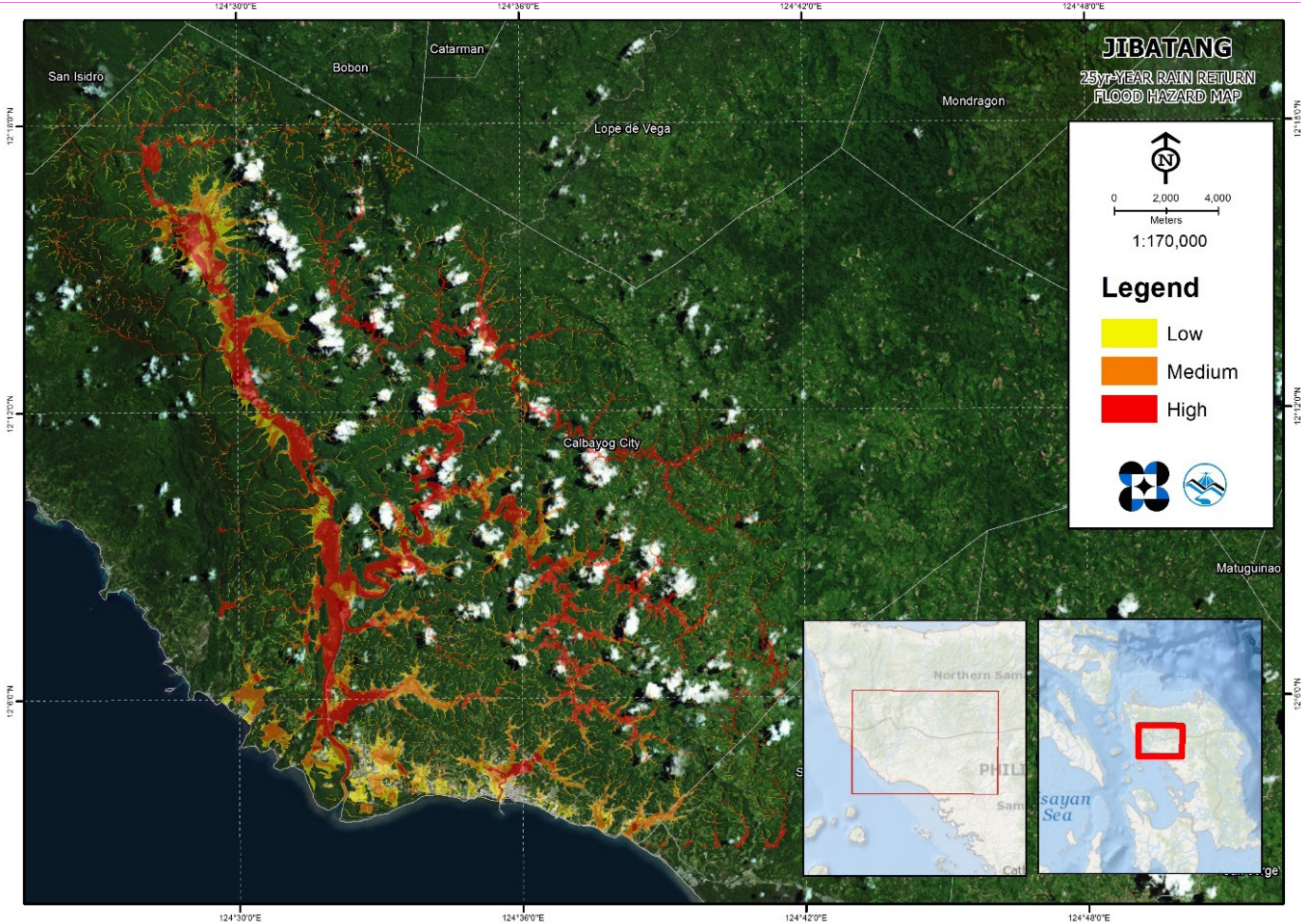


Figure 62. 25-year flood hazard map for the Jibatang floodplain

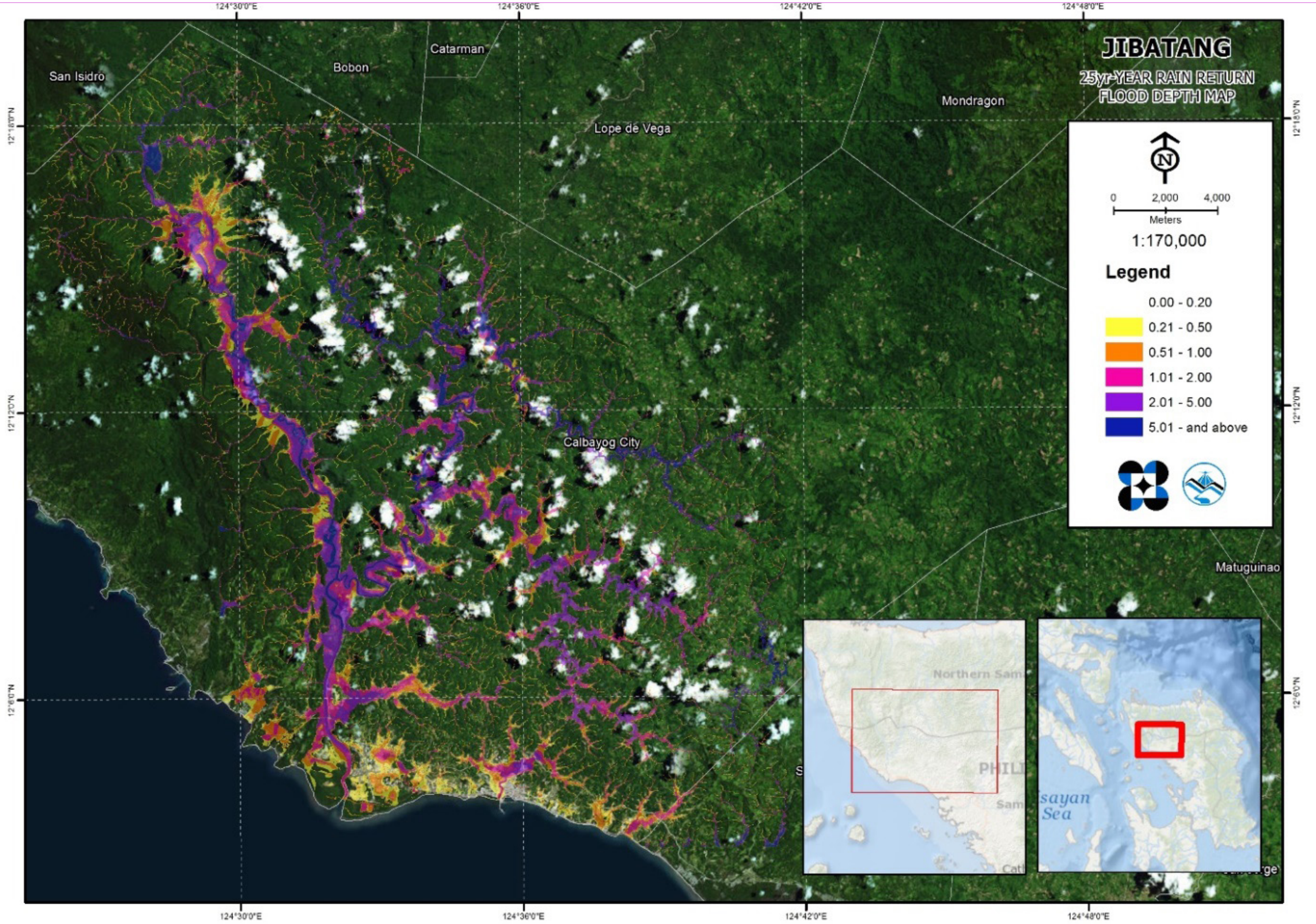


Figure 63. 25-year flow depth map for the Jibatang floodplain

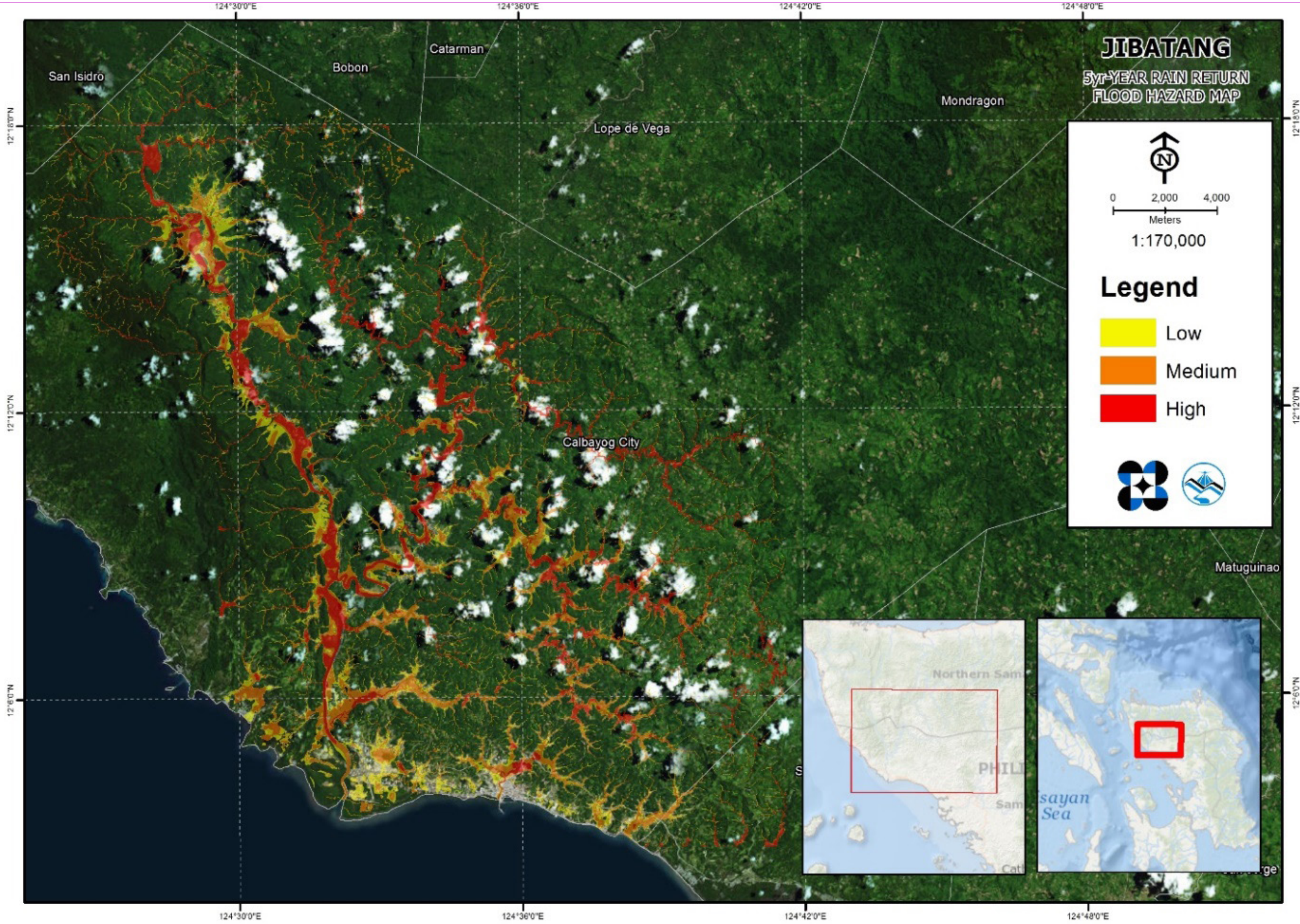


Figure 64. 5-year flood hazard map for the Jibatang floodplain

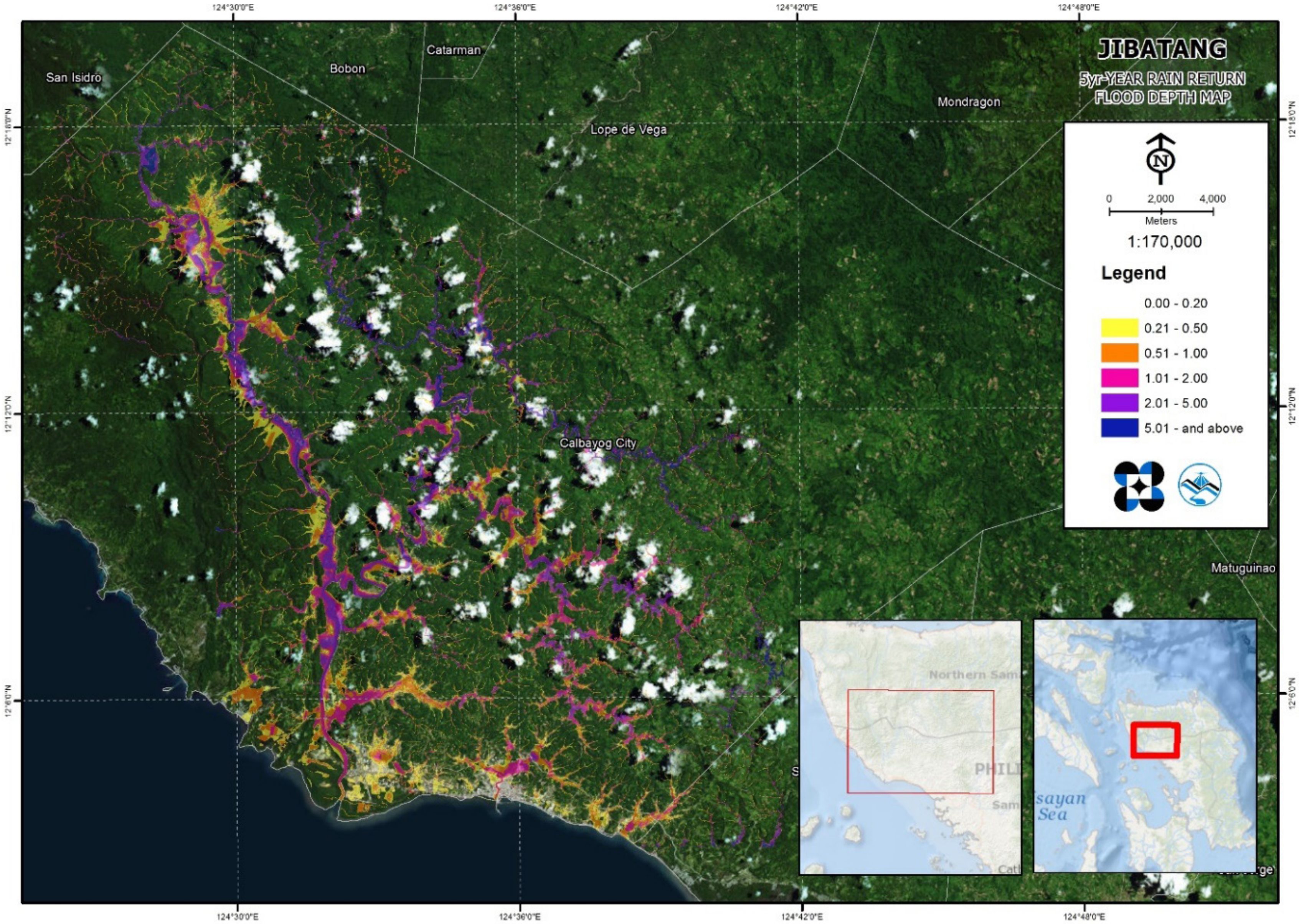


Figure 65. 5-year flow depth map for the Jibatang floodplain

5.10 Inventory of Areas Exposed to Flooding

The affected barangays in the Jibatang River Basin are listed below. For the said basin one (1) municipality, consisting of ninety (90) barangays, is expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 18.83% of the City of Calbayog, with an area of 897.55 sq. km., will experience flood levels of less than 0.20 meters. 1.4563% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile 1.5678%, 1.4368%, 0.6602%, and 0.0142% 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 Tables 31-40 are the affected areas, in square kilometers, by flood depth per barangay.

Table 27. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Acedillo	Aguit-Itan	Alibaba	Amampacang	Anislag	Awang East	Awang West	Bagacay	Baja
0.03-0.20	2.06	0.16	1.37	2.8	0.25	0.2	0.25	1.6	3.23
0.21-0.50	0.13	0.017	0.037	0.15	0.085	0.014	0.0097	0.22	0.18
0.51-1.00	0.11	0.032	0.079	0.19	0.17	0.015	0.00044	0.11	0.19
1.01-2.00	0.055	0.02	0.21	0.11	0.1	0.11	0	0.026	0.34
2.01-5.00	0	0	0.34	0.015	0.082	0.0094	0	0.0002	0.16
> 5.00	0	0	0	0	0	0	0	0	0.041

Table 28. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Balud	Bante	Basud	Begaho	Bontay	Burabod	Cabacungan	Cabicahan	Cabugawan
0.03-0.20	0.03	0.12	1.9	1.16	1.54	0	1.26	1.79	2.09
0.21-0.50	0.0087	0.038	0.49	0.097	0.16	0	0.13	0.089	0.15
0.51-1.00	0.019	0	0.2	0.16	0.23	0	0.17	0.25	0.17
1.01-2.00	0.13	0	0.001	0.3	0.081	0	0.17	0.28	0.3
2.01-5.00	0	0	0	0.48	0.003	0	0.12	0.073	0.4
> 5.00	0	0	0	0	0	0	0.0064	0.0031	0.00063

Table 29. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City City (in sq. km.)								
	Cacaransan	Cagbanayacao	Cagbilwang	Cagboborac	Cagsalaosao	Cahumpan	Capoocan	Carayman	Carmen
0.03-0.20	3.02	0.34	2.13	1.04	3.42	1.87	0.7	1.6	0.83
0.21-0.50	0.15	0.0053	0.14	0.041	0.49	0.42	0.1	0.35	0.14
0.51-1.00	0.2	0.00039	0.11	0.15	0.32	0.3	0.012	0.32	0.15
1.01-2.00	0.26	0	0.072	0.31	0.77	0.085	0.0031	0.062	0.035
2.01-5.00	0.041	0	0.18	0.15	0.023	0	0	0	0
> 5.00	0	0	0.0079	0	0	0	0	0	0

Table 30. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Catabunan	Central	Cogon	Dagum	Dinabongan	Dinagan	Gabay	Gadgaran	Gajo
0.03-0.20	1.27	0.086	4.98	1.57	1.98	2.18	1.2	2.02	0
0.21-0.50	0.037	0.019	0.16	0.057	0.084	0.21	0.037	0.099	0
0.51-1.00	0.023	0.067	0.17	0.051	0.15	0.21	0.075	0.064	0
1.01-2.00	0.014	0.14	0.12	0.024	0.056	0.29	0.17	0.02	0
2.01-5.00	0.0024	0	0.011	0	0.003	0.19	0.16	0.0012	0
> 5.00	0	0	0	0	0	0	0	0	0

Table 31. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Geraga-an	Guimbaoyan Norte	Guimbaoyan Sur	Guin-On	Hamorawon	Jimautan	Kilikili	La Paz	Langoyon
0.03-0.20	3.6	1.5	2.13	3.23	0.13	2.96	4.93	3.21	4.91
0.21-0.50	0.11	0.088	0.1	0.14	0.019	0.13	0.23	0.15	0.14
0.51-1.00	0.18	0.19	0.21	0.14	0.046	0.075	0.2	0.31	0.18
1.01-2.00	0.22	0.32	0.32	0.071	0.056	0.058	0.24	0.51	0.34
2.01-5.00	0.038	0.037	0.12	0.0055	0.0089	0.002	0.067	0.45	0.11
> 5.00	0	0	0	0	0	0	0	0	0

Table 32. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Libertad	Limarayon	Longsob	Lonoy	Looc	Mabini II	Mag-Ubay	Malopalo	Matobato
0.03-0.20	2.01	1.39	2.82	0.14	2.73	1.66	2.52	1.02	0.82
0.21-0.50	0.1	0.09	0.32	0.072	0.11	0.13	0.18	0.025	0.13
0.51-1.00	0.18	0.31	0.23	0.15	0.22	0.11	0.12	0.018	0.013
1.01-2.00	0.21	0.21	0.086	0.16	0.17	0.28	0.097	0.0086	0.000035
2.01-5.00	0.12	0.0019	0.066	0.028	0.2	0.24	0.17	0.0015	0
> 5.00	0.0039	0	0.0034	0	0.0007	0	0.036	0	0

Table 33. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Mawacat	Maybog	Maysalong	Migara	Nabang	Naga	Navarro	Nijaga	Obrero
0.03-0.20	0.89	2.09	0.91	4.59	2.53	4.44	3.32	1.32	0.43
0.21-0.50	0.026	0.077	0.025	0.14	0.22	0.27	0.48	0.11	0.14
0.51-1.00	0.0062	0.043	0.057	0.17	0.27	0.48	0.78	0.13	0.052
1.01-2.00	0.0007	0.036	0.13	0.36	0.25	0.21	0.18	0.1	0.055
2.01-5.00	0	0.0026	0.056	0.046	0.22	0.0032	0.011	0	0
> 5.00	0	0	0	0	0.007	0	0	0	0

Table 34. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Oquendo	Osmeña	Pagbalican	Palanas	Panonongan	Panoypoy	Payahan	Quezon	Rawis
0.03-0.20	1.7	0	0.88	0.16	5.01	1.27	1.03	0.77	1.69
0.21-0.50	0.12	0	0.11	0.037	0.58	0.17	0.036	0.02	0.14
0.51-1.00	0.16	0	0.1	0.11	0.68	0.26	0.022	0.019	0.25
1.01-2.00	0.49	0	0.045	0.21	0.37	0.15	0.0064	0.0092	0.14
2.01-5.00	0.46	0	0	0	0.17	0.016	0.0004	0.0074	0.043
> 5.00	0	0	0	0	0.0045	0	0	0	0

Table 35. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Rizal I	Rizal II	Roxas II	Saljag	San Jose	San Policarpio	Saputan	Sinantan	Sinidman Occidental
0.03-0.20	4.36	1.58	3.3	0.76	0.75	2.29	1.15	3.82	0.84
0.21-0.50	0.27	0.12	0.18	0.14	0.014	0.55	0.042	0.13	0.15
0.51-1.00	0.31	0.083	0.22	0.087	0.013	0.18	0.084	0.14	0.18
1.01-2.00	0.086	0.13	0.13	0	0.015	0.1	0.34	0.25	0.25
2.01-5.00	0.0011	0.13	0.0062	0	0.0068	0.003	0.11	0.19	0.2
> 5.00	0	0	0	0	0	0	0	0	0.013

Table 36. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Sinidman Oriental	Tabawan	Tapa-e	Tinambacan Norte	Tinambacan Sur	Tomaliguez	Trinidad	Victory	Villahermosa
0.03-0.20	1.52	1.25	2.67	1.02	4.24	2.83	1.69	4.13	3.99
0.21-0.50	0.14	0.049	0.061	0.29	0.26	0.39	0.56	0.12	0.084
0.51-1.00	0.18	0.057	0.052	0.3	0.45	0.19	0.34	0.17	0.068
1.01-2.00	0.056	0.042	0.046	0.029	0.094	0.11	0.19	0.17	0.083
2.01-5.00	0.0068	0.0055	0.0023	0.000046	0.012	0	0	0.025	0.083
> 5.00	0	0	0	0	0	0	0	0	0

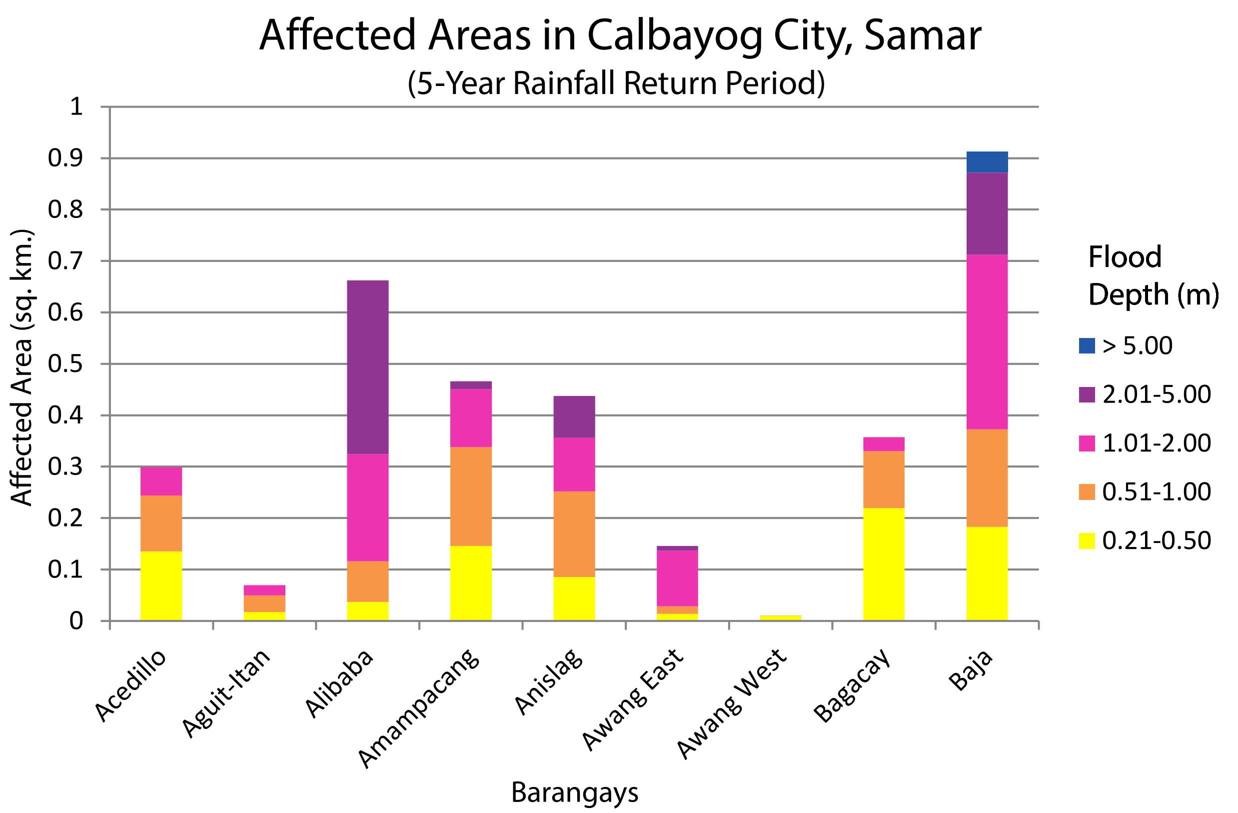


Figure 66. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

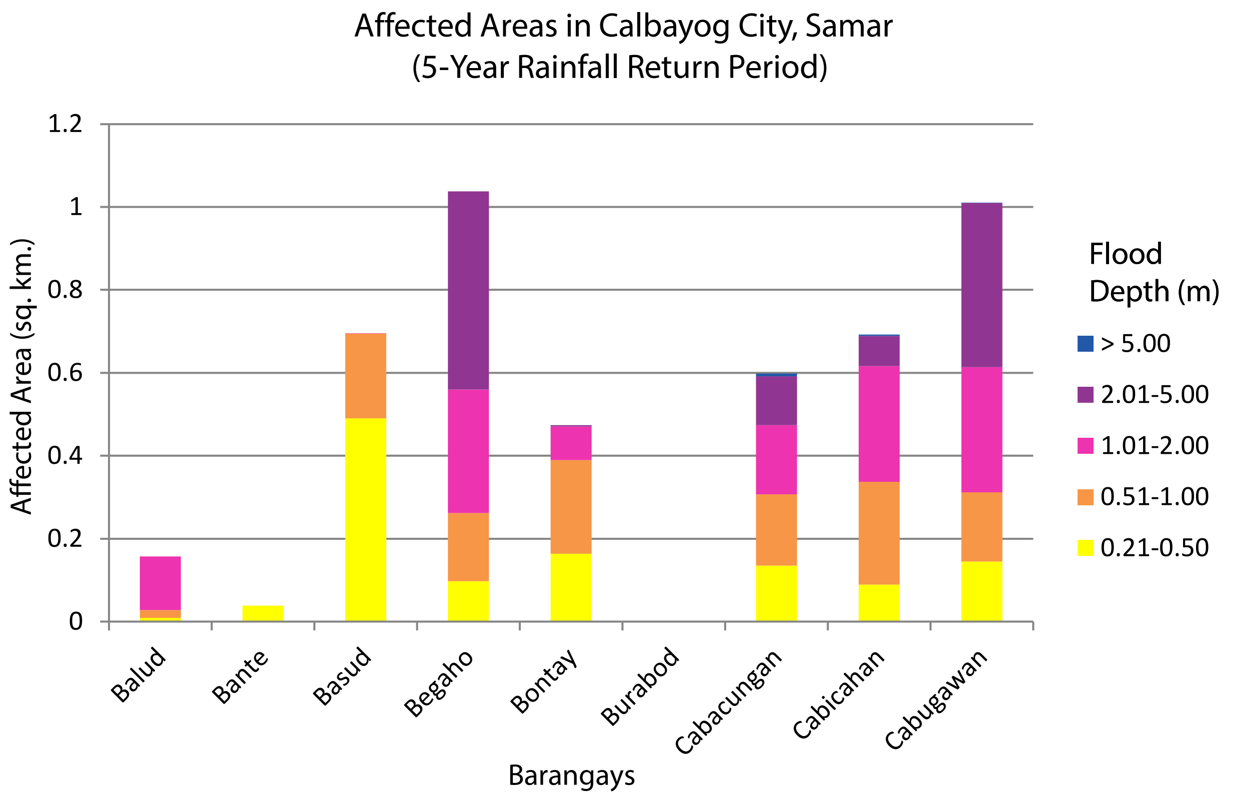


Figure 67. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

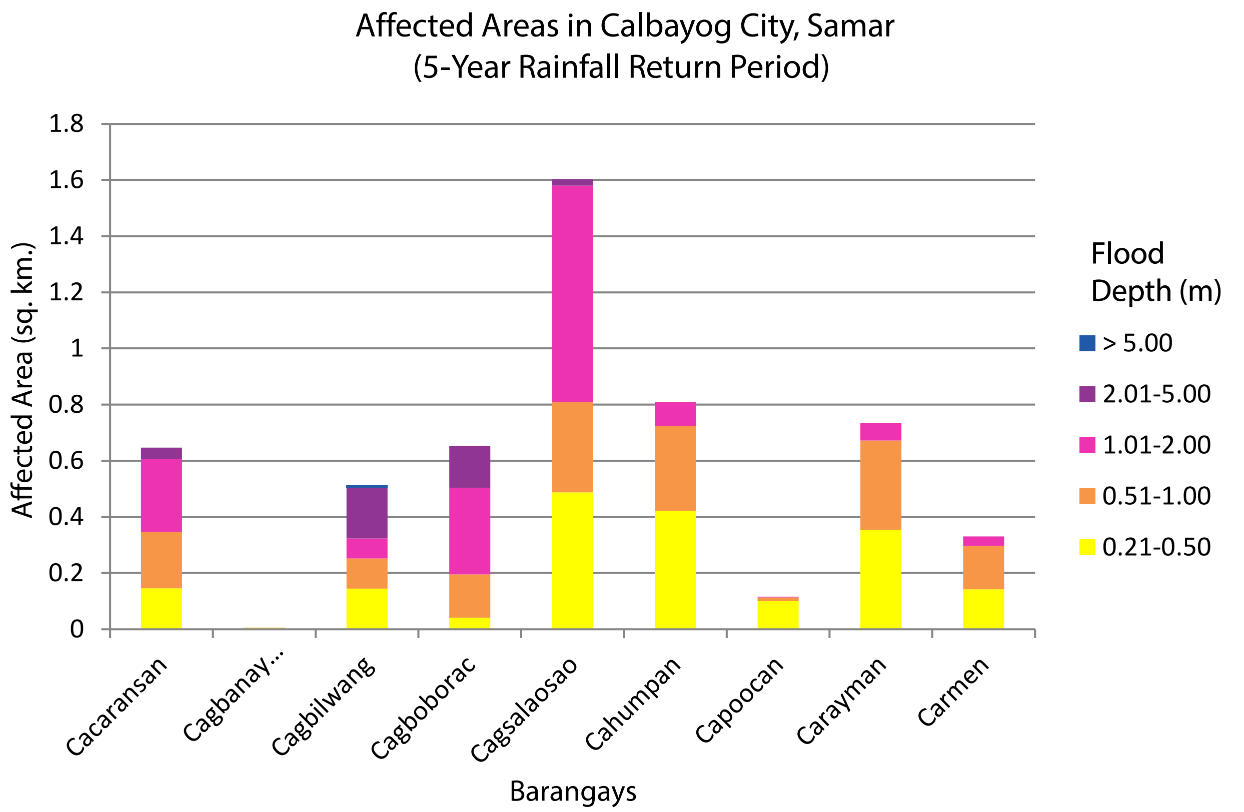


Figure 68. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

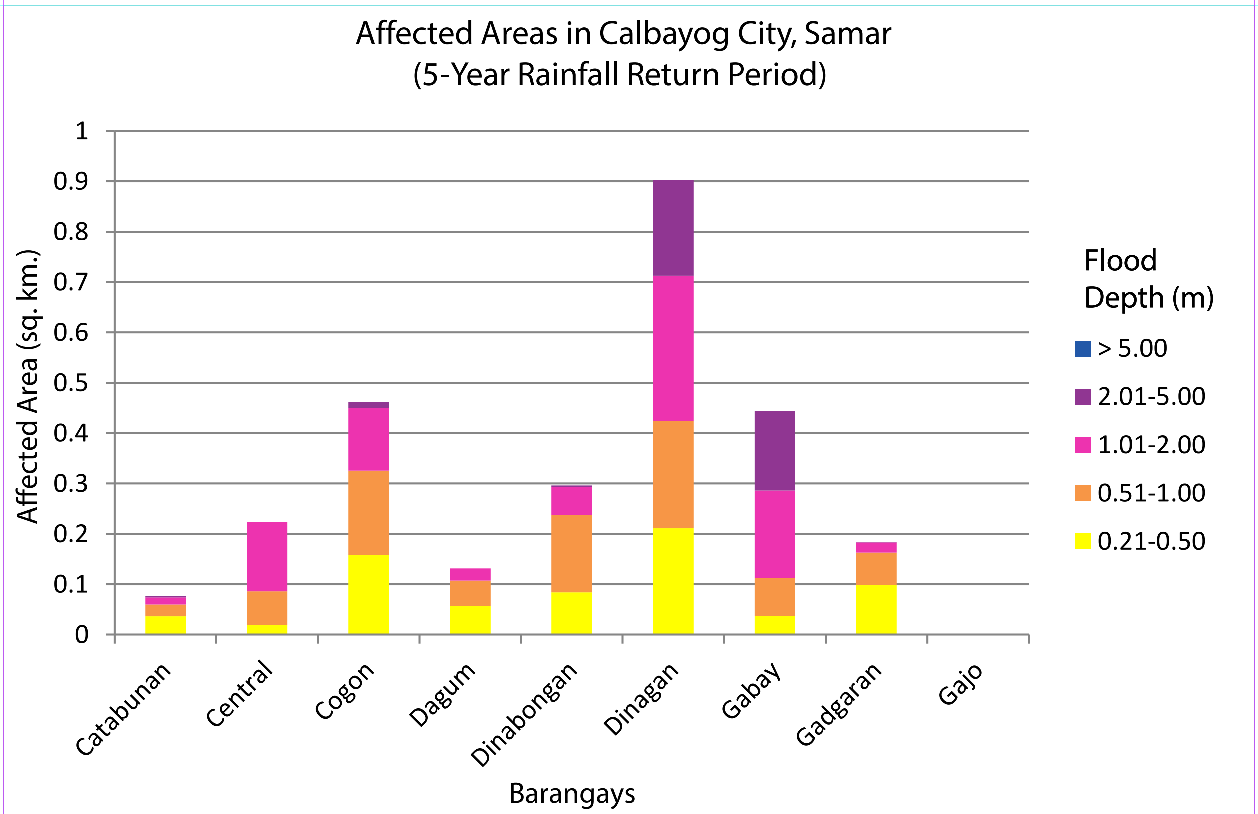


Figure 69. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

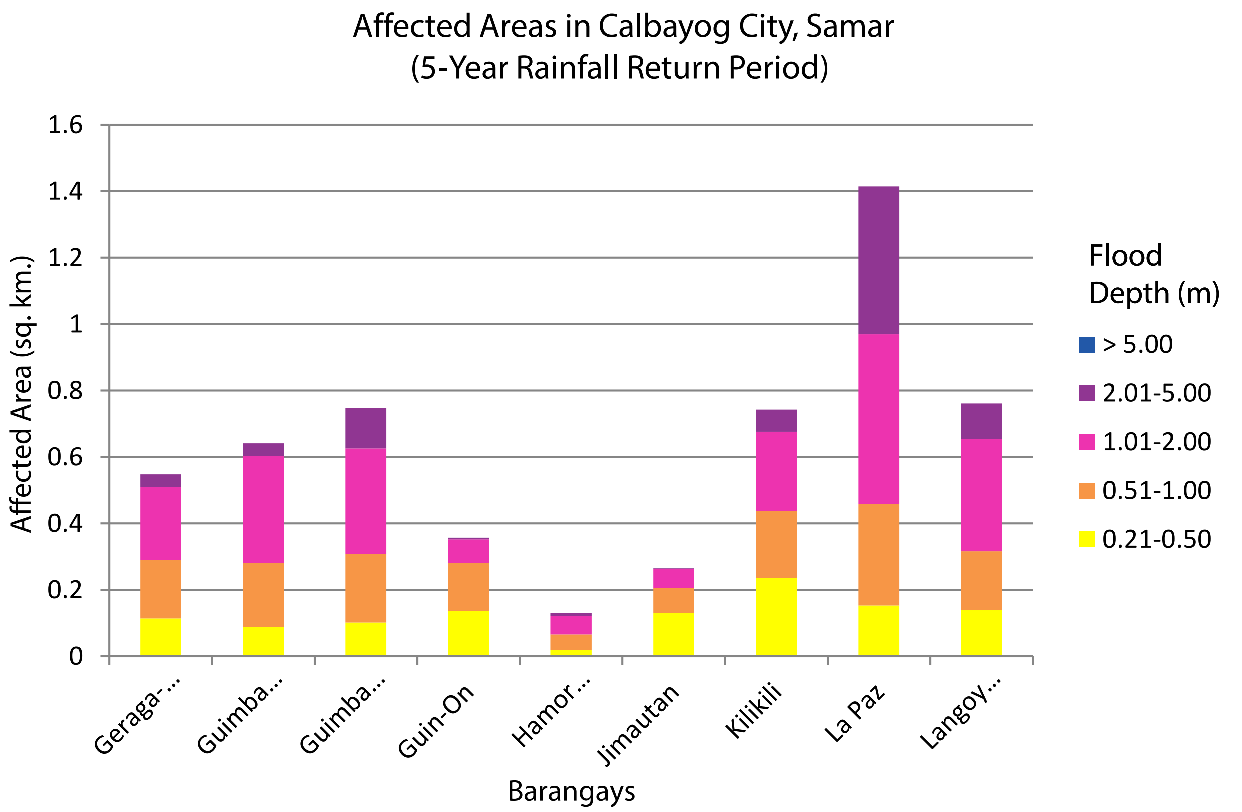


Figure 70. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

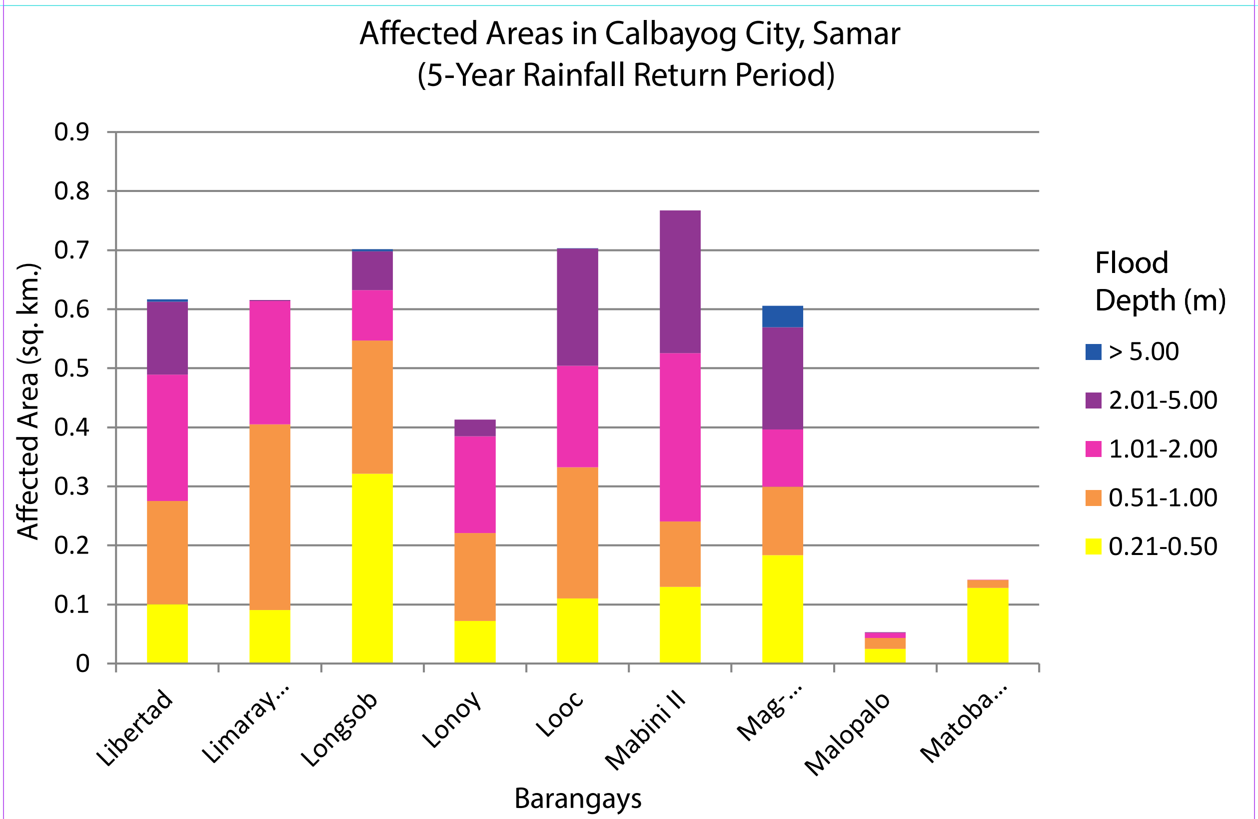


Figure 71. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

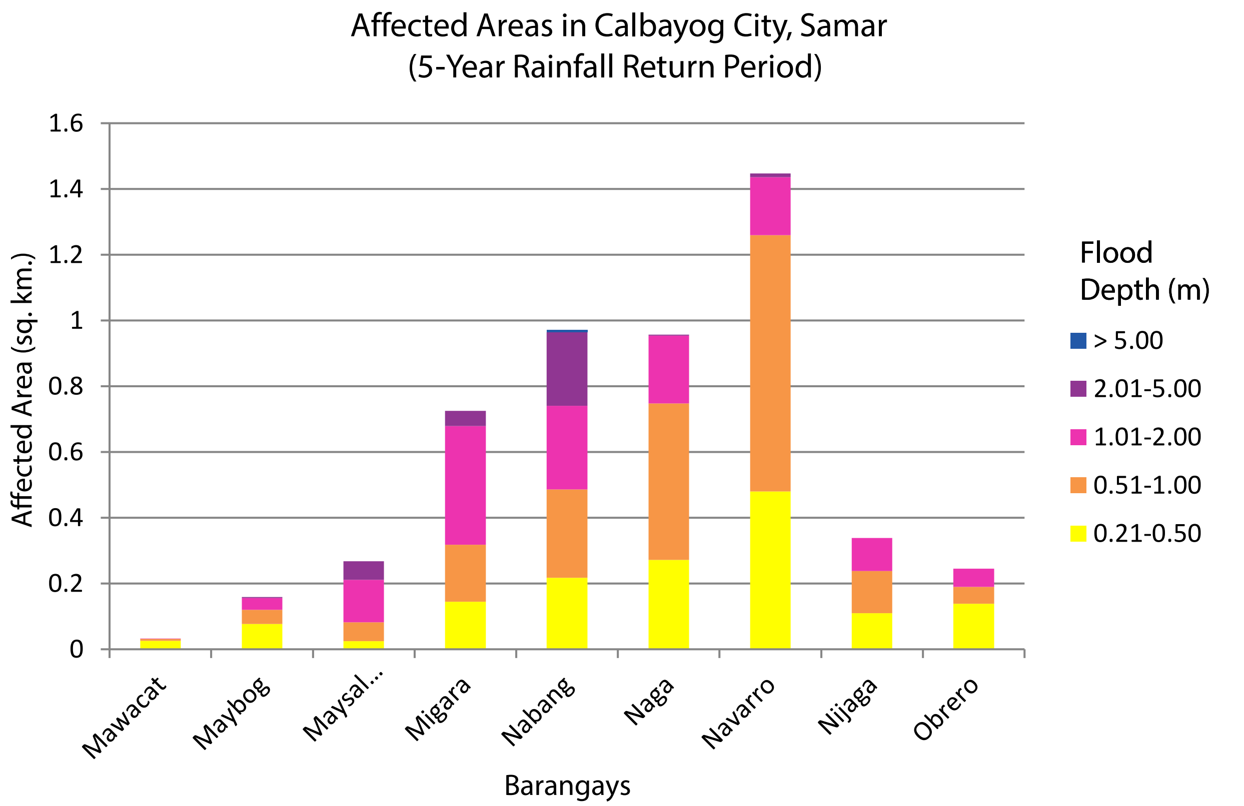


Figure 72. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

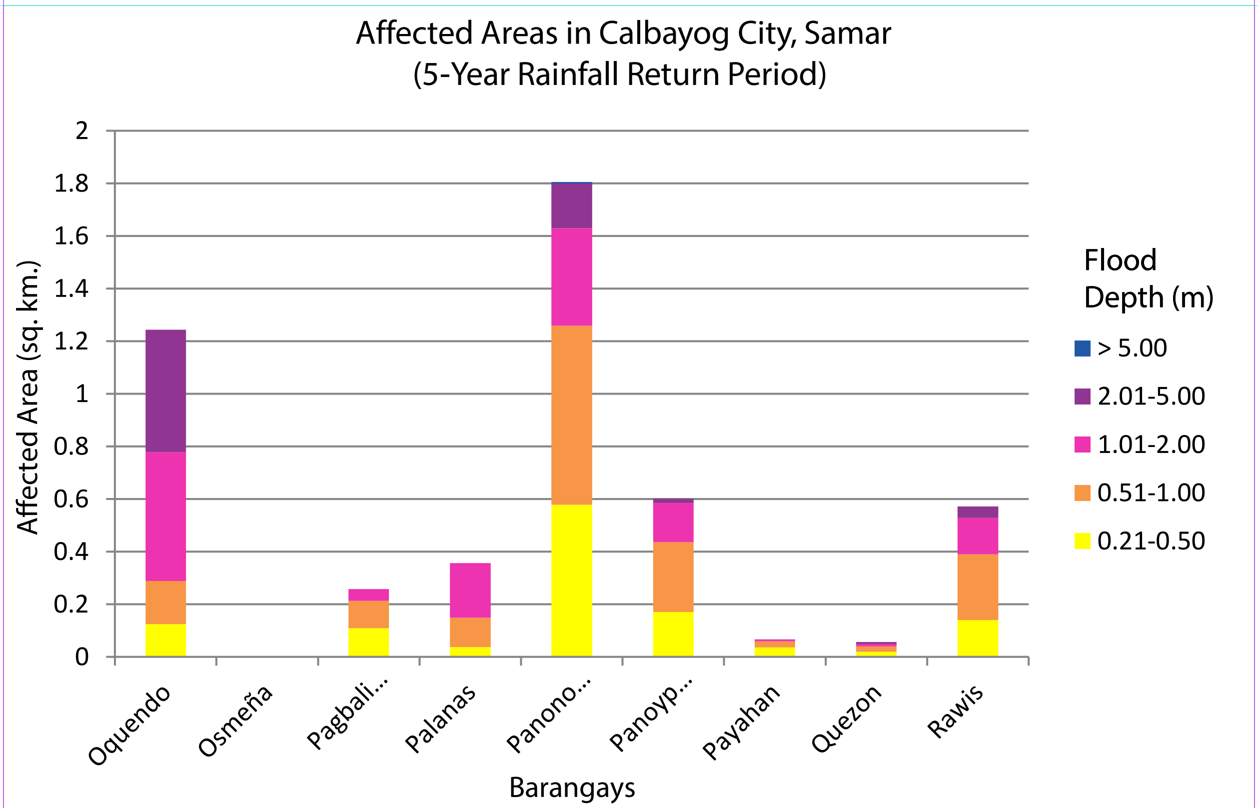


Figure 73. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

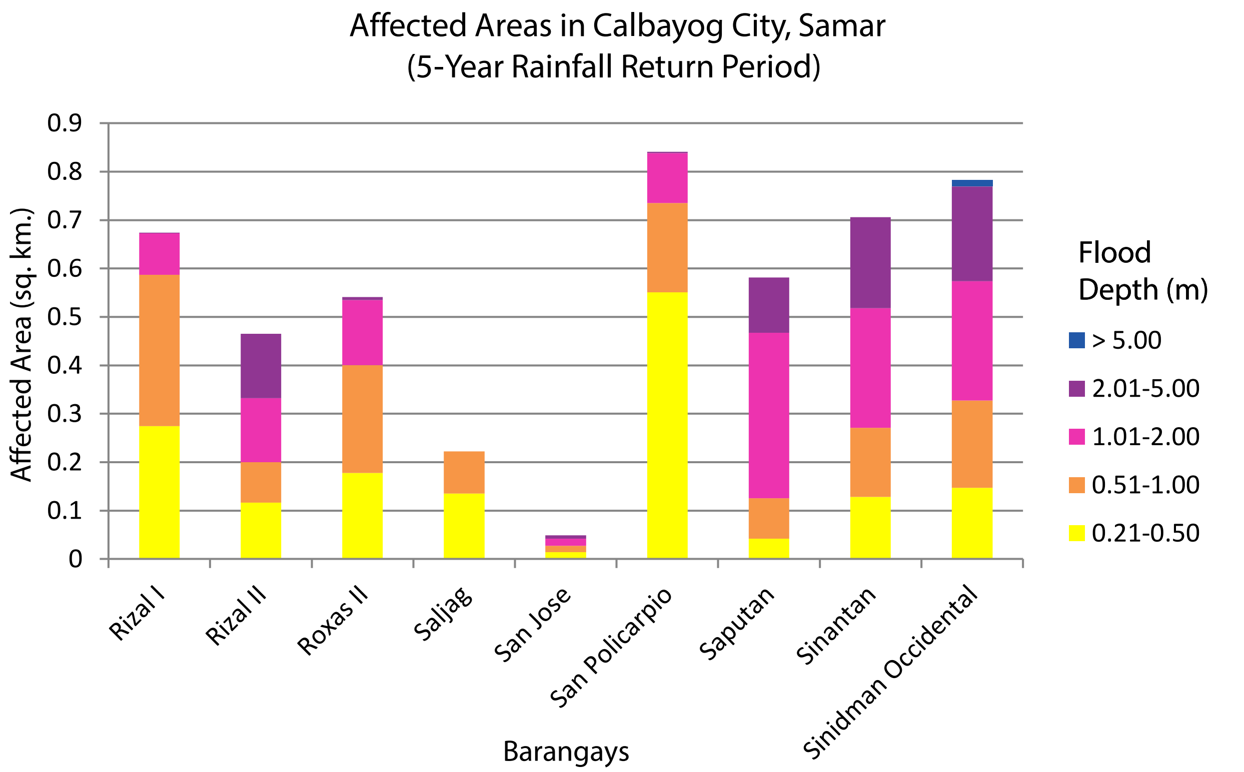


Figure 74. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

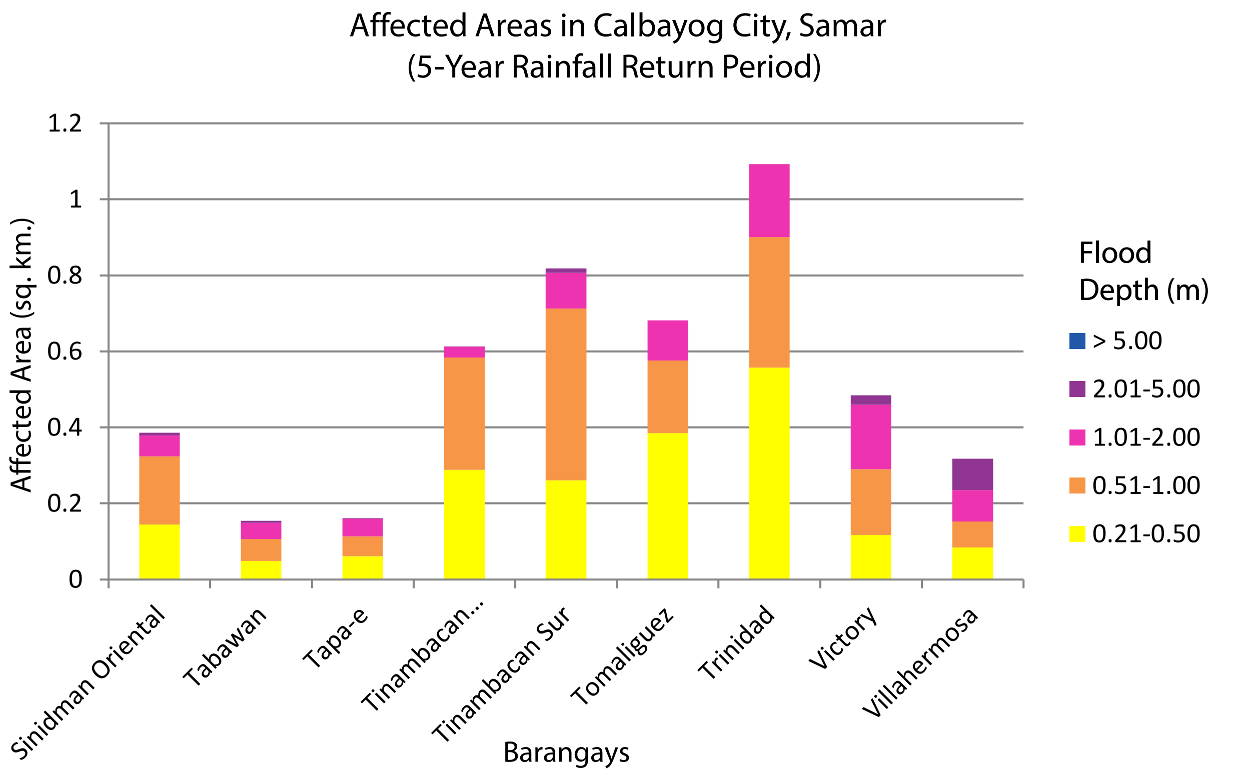


Figure 75. Affected areas in Calbayog City, Samar during a 5-year rainfall return period

For the 25-year return period, 17.866% of the City of Calbayog, with an area of 897.55 sq. km., will experience flood levels of less than 0.20 meters. 1.3062% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.4471%, 1.6953%, 1.4987%, and 0.1526% 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 Tables 41-50 are the affected areas, in square kilometers, by flood depth per barangay.

Table 37. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Acedillo	Aguit-Itan	Alibaba	Amampacang	Anislag	Awang East	Awang West	Bagacay	Baja
0.03-0.20	2.01	0.094	1.3	2.72	0.17	0.19	0.24	1.49	2.99
0.21-0.50	0.11	0.062	0.029	0.12	0.038	0.011	0.015	0.28	0.15
0.51-1.00	0.091	0.028	0.045	0.11	0.072	0.015	0.0025	0.12	0.18
1.01-2.00	0.12	0.043	0.14	0.25	0.22	0.043	0	0.053	0.45
2.01-5.00	0.025	0	0.51	0.061	0.19	0.087	0	0.0005	0.29
> 5.00	0	0	0.0079	0	0	0	0	0	0.094

Table 38. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Balud	Bante	Basud	Begaho	Bontay	Burabod	Cabacungan	Cabicahan	Cabugawan
0.03-0.20	0.025	0.074	1.52	1.08	1.46	0	1.19	1.71	1.87
0.21-0.50	0.0056	0.071	0.63	0.071	0.11	0	0.058	0.072	0.08
0.51-1.00	0.0094	0.011	0.36	0.083	0.15	0	0.099	0.13	0.075
1.01-2.00	0.037	0	0.086	0.18	0.23	0	0.28	0.29	0.23
2.01-5.00	0.11	0	0	0.74	0.06	0	0.22	0.26	0.62
> 5.00	0	0	0	0.039	0	0	0.013	0.016	0.22

Table 39. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Cacaransan	Cagbanayacao	Cagbilwang	Cagboborac	Cagsalaosao	Cahumpan	Capoocan	Carayman	Carmen
0.03-0.20	2.95	0.34	2.05	1	3.19	1.71	0.63	1.51	0.77
0.21-0.50	0.14	0.0058	0.13	0.028	0.46	0.27	0.15	0.29	0.11
0.51-1.00	0.15	0.0015	0.083	0.055	0.36	0.41	0.026	0.42	0.15
1.01-2.00	0.32	0	0.065	0.28	0.4	0.27	0.0042	0.12	0.14
2.01-5.00	0.11	0	0.18	0.33	0.62	0.024	0	0	0
> 5.00	0	0	0.14	0	0	0	0	0	0

Table 40. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Catabunan	Central	Cogon	Dagum	Dinabongan	Dinagan	Gabay	Gadgaran	Gajo
0.03-0.20	1.26	0.056	4.93	1.55	1.95	2.03	1.15	1.99	0
0.21-0.50	0.041	0.026	0.15	0.06	0.073	0.14	0.033	0.1	0
0.51-1.00	0.029	0.028	0.17	0.055	0.16	0.17	0.044	0.075	0
1.01-2.00	0.017	0.14	0.17	0.039	0.085	0.21	0.099	0.036	0
2.01-5.00	0.0068	0.058	0.023	0.0007	0.0069	0.53	0.32	0.0023	0
> 5.00	0	0	0	0	0	0.011	0.004	0	0

Table 41. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Geraga-an	Guimbaoyan Norte	Guimbaoyan Sur	Guin-On	Hamorawon	Jimautan	Kilikili	La Paz	Langoyon
0.03-0.20	3.53	1.41	2.07	3.18	0.11	2.91	4.8	3.09	4.82
0.21-0.50	0.11	0.052	0.078	0.14	0.012	0.13	0.25	0.095	0.14
0.51-1.00	0.13	0.077	0.14	0.13	0.024	0.089	0.22	0.19	0.14
1.01-2.00	0.22	0.27	0.32	0.12	0.076	0.087	0.26	0.39	0.36
2.01-5.00	0.15	0.32	0.26	0.019	0.033	0.0027	0.15	0.83	0.2
> 5.00	0.0004	0	0	0	0	0	0	0.036	0.0023

Table 42. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Libertad	Limarayon	Longsob	Lonoy	Looc	Mabini II	Mag-Ubay	Malopalo	Matobato
0.03-0.20	1.96	1.35	2.67	0.052	2.67	1.57	2.37	1.01	0.77
0.21-0.50	0.065	0.067	0.16	0.012	0.089	0.062	0.19	0.025	0.16
0.51-1.00	0.1	0.16	0.13	0.028	0.19	0.1	0.1	0.022	0.031
1.01-2.00	0.25	0.41	0.21	0.28	0.15	0.17	0.13	0.014	0.000035
2.01-5.00	0.23	0.014	0.29	0.17	0.33	0.42	0.24	0.0028	0
> 5.00	0.017	0	0.055	0	0.0032	0.11	0.093	0	0

Table 43. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Mawacat	Maybog	Maysalong	Migara	Nabang	Naga	Navarro	Nijaga	Obrero
0.03-0.20	0.88	2.06	0.87	4.5	2.23	4.34	3.17	1.29	0.23
0.21-0.50	0.035	0.086	0.021	0.14	0.15	0.24	0.35	0.089	0.17
0.51-1.00	0.0075	0.056	0.018	0.16	0.17	0.44	0.64	0.13	0.18
1.01-2.00	0.0024	0.04	0.05	0.28	0.3	0.37	0.57	0.15	0.08
2.01-5.00	0	0.0088	0.22	0.22	0.53	0.0067	0.037	0.0035	0.0079
> 5.00	0	0	0.0012	0	0.13	0	0	0	0

Table 44. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Oquendo	Osmeña	Pagbalican	Palanas	Panonongan	Panoypoy	Payahan	Quezon	Rawis
0.03-0.20	1.01	0	0.85	0.14	4.8	1.21	1.02	0.77	1.64
0.21-0.50	0.063	0	0.094	0.018	0.42	0.087	0.039	0.019	0.12
0.51-1.00	0.16	0	0.12	0.016	0.77	0.21	0.029	0.022	0.21
1.01-2.00	0.59	0	0.076	0.12	0.59	0.32	0.0083	0.013	0.23
2.01-5.00	0.89	0	0	0.22	0.23	0.04	0.0009	0.0083	0.059
> 5.00	0.23	0	0	0	0.014	0	0	0	0

Table 45. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Rizal I	Rizal II	Roxas II	Saljag	San Jose	San Policarpio	Saputan	Sinantan	Sinidman Occidental
0.03-0.20	4.29	1.49	3.24	0.7	0.75	2.03	1.08	3.74	0.63
0.21-0.50	0.24	0.091	0.15	0.11	0.018	0.66	0.029	0.12	0.12
0.51-1.00	0.35	0.073	0.18	0.13	0.012	0.3	0.036	0.12	0.14
1.01-2.00	0.15	0.079	0.21	0.043	0.016	0.12	0.088	0.23	0.25
2.01-5.00	0.012	0.24	0.06	0	0.011	0.02	0.5	0.31	0.42
> 5.00	0	0.067	0	0	0	0	0.0001	0.011	0.051

Table 46. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Sinidman Oriental	Tabawan	Tapa-e	Tinambacan Norte	Tinambacan Sur	Tomaliguez	Trinidad	Victory	Villahermosa
0.03-0.20	1.47	1.23	2.65	0.92	4.13	2.13	1.28	4.09	3.94
0.21-0.50	0.12	0.041	0.069	0.19	0.24	0.63	0.59	0.1	0.094
0.51-1.00	0.17	0.062	0.052	0.37	0.46	0.42	0.56	0.16	0.063
1.01-2.00	0.12	0.056	0.054	0.16	0.21	0.26	0.34	0.19	0.083
2.01-5.00	0.02	0.013	0.011	0.0015	0.025	0.075	0.0089	0.067	0.12
> 5.00	0	0	0	0	0	0	0	0	0.0026

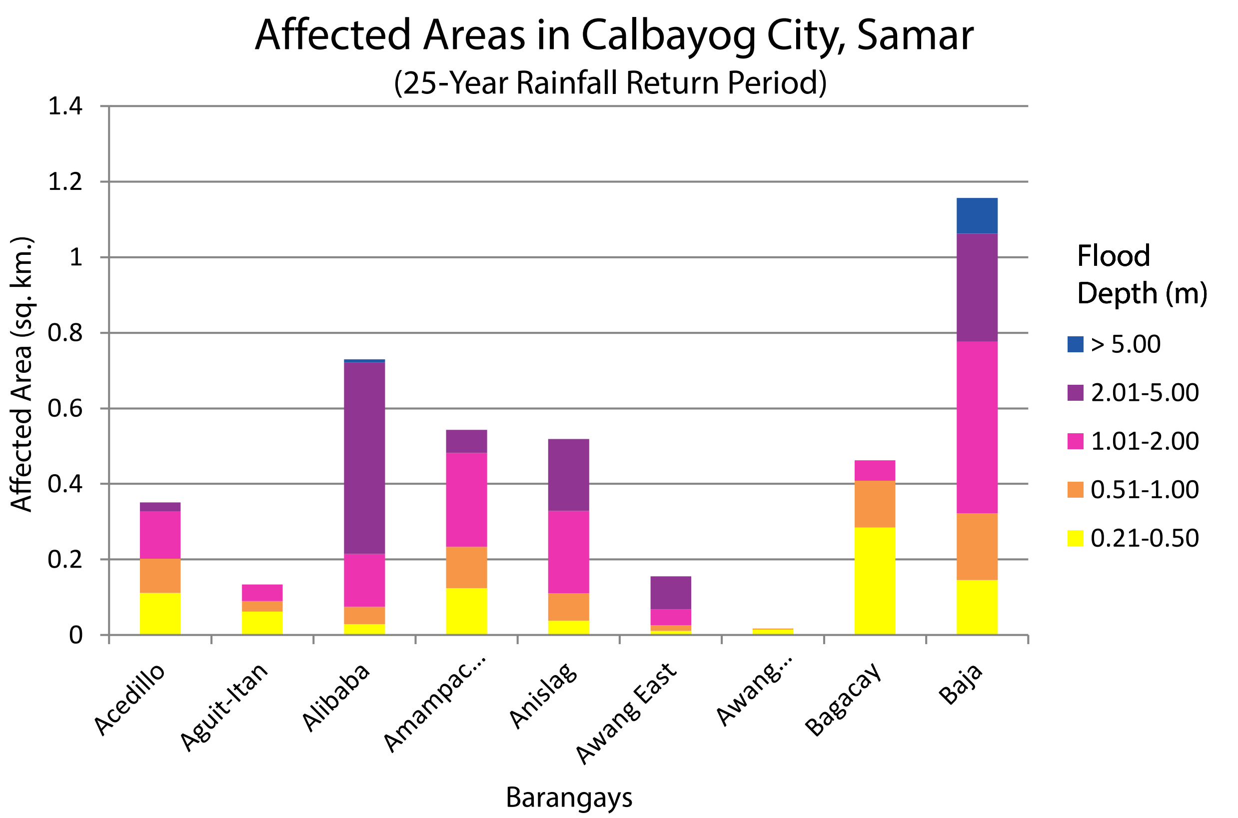


Figure 76. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

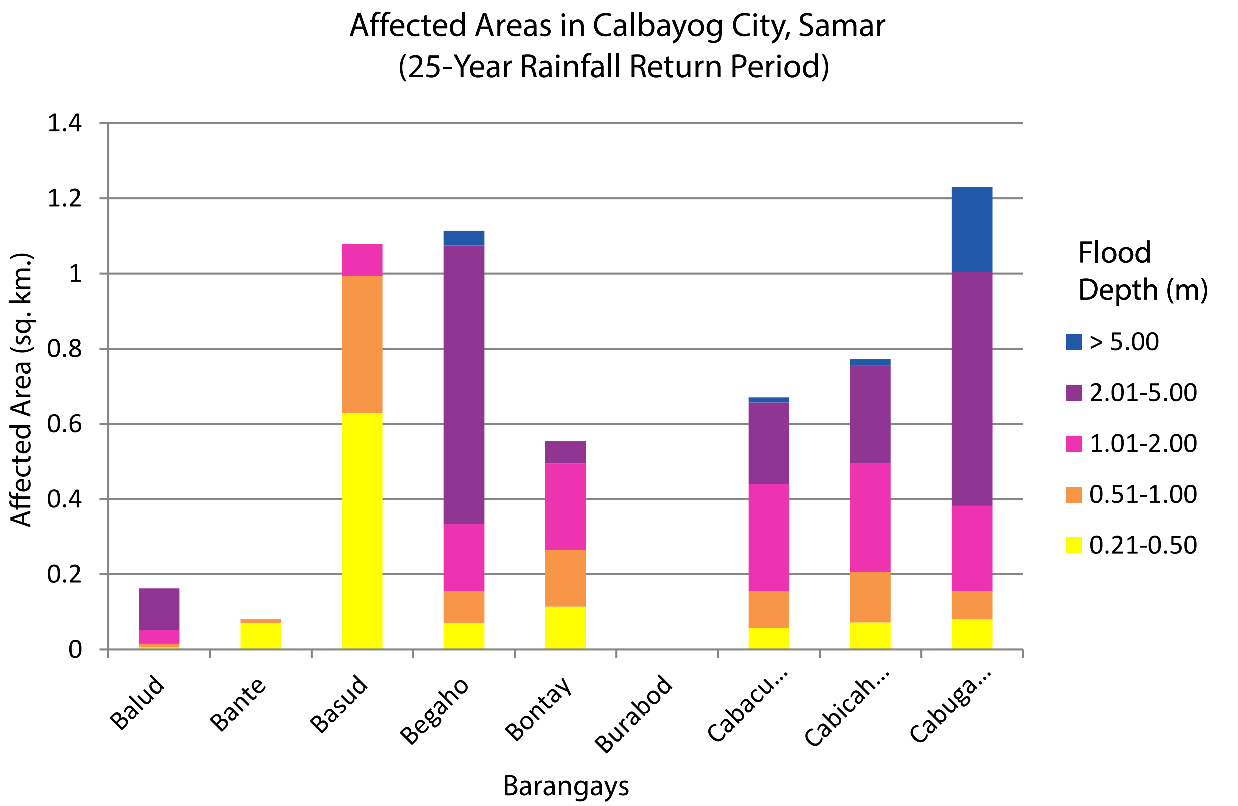


Figure 77. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

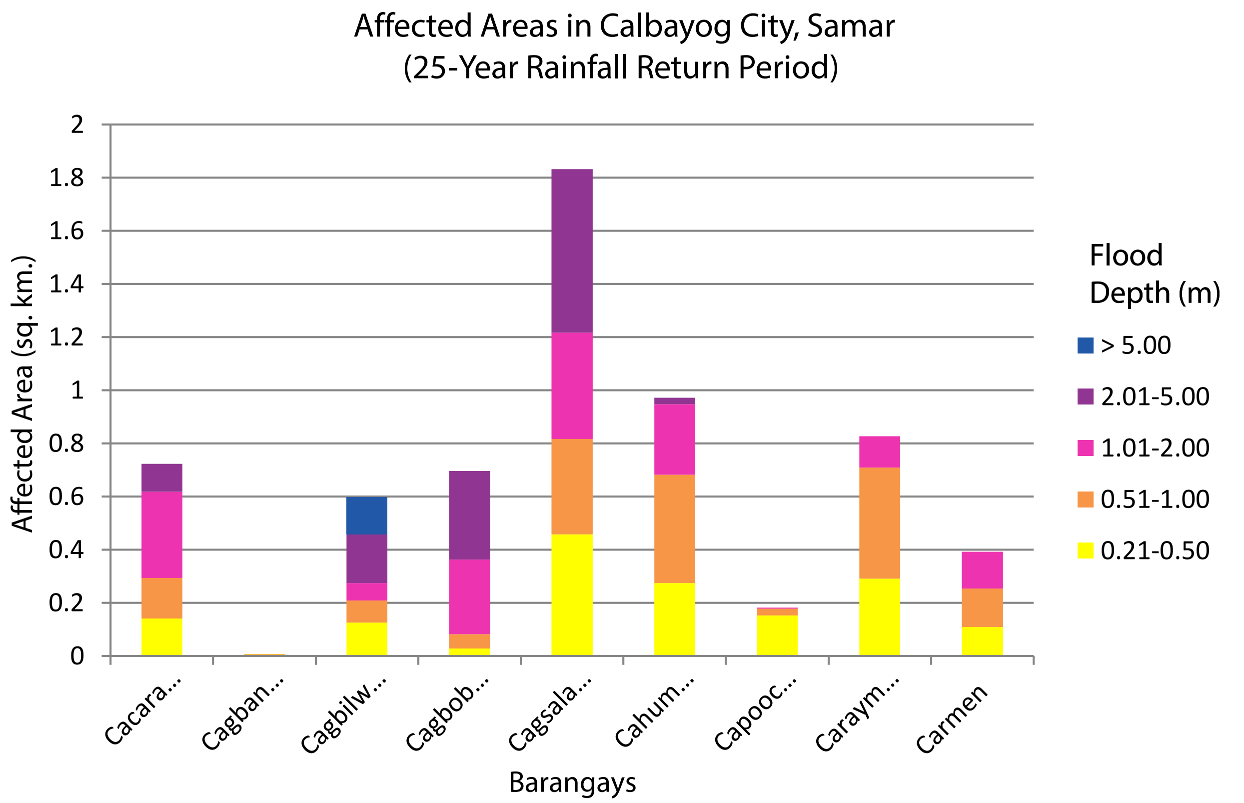


Figure 78. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

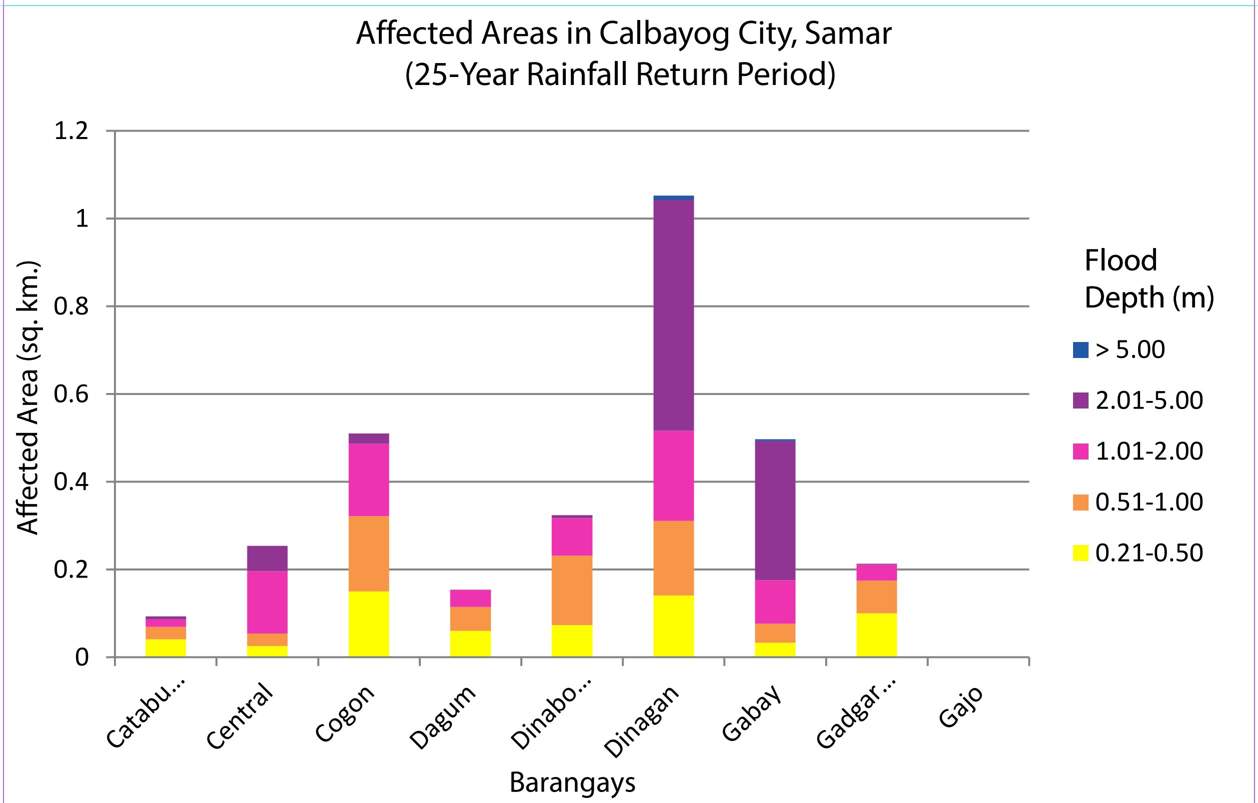


Figure 79. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

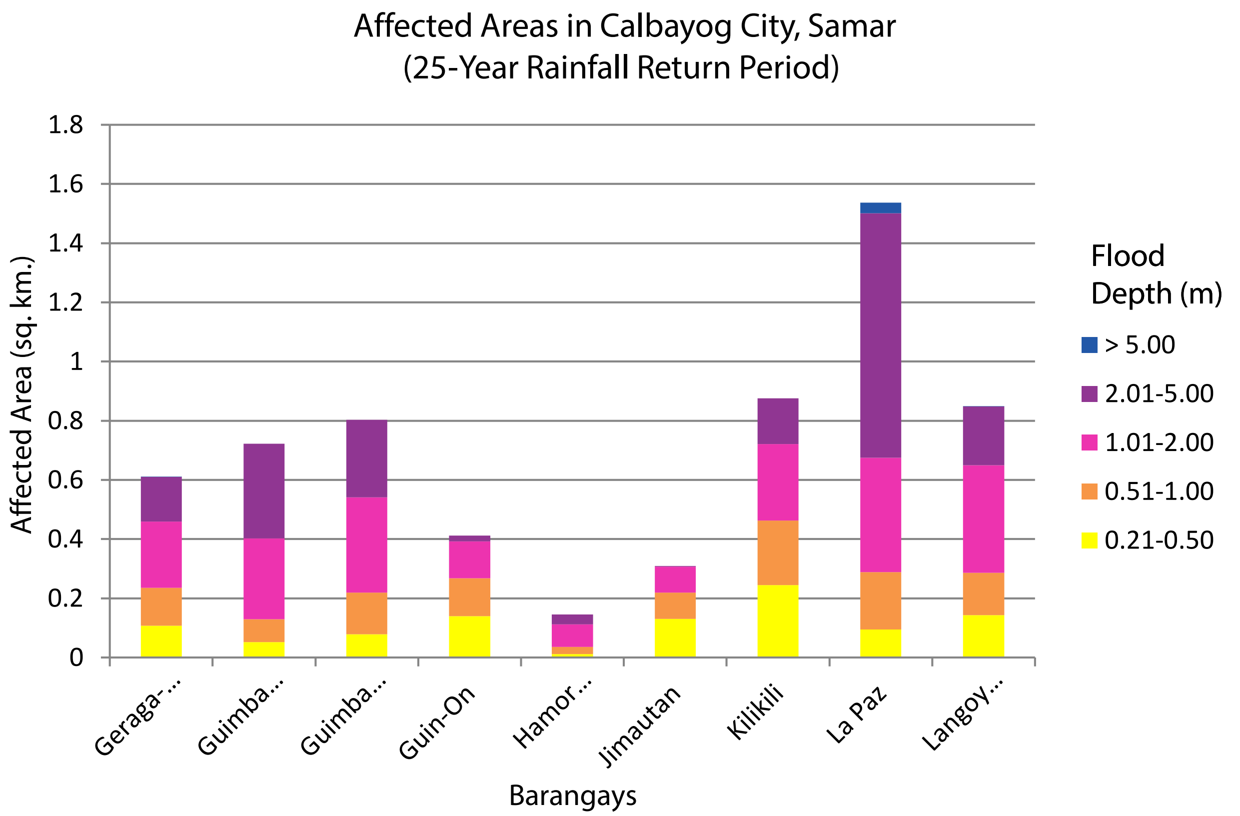


Figure 80. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

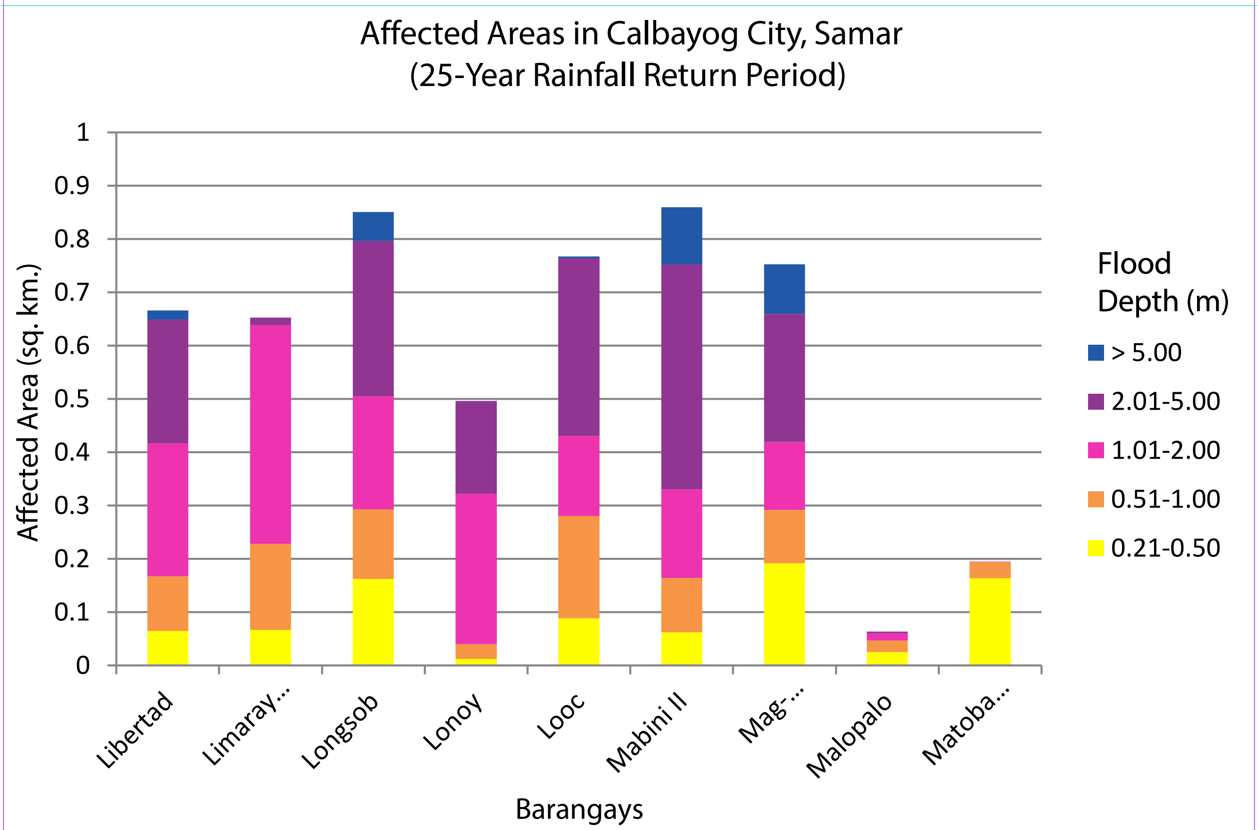


Figure 81. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

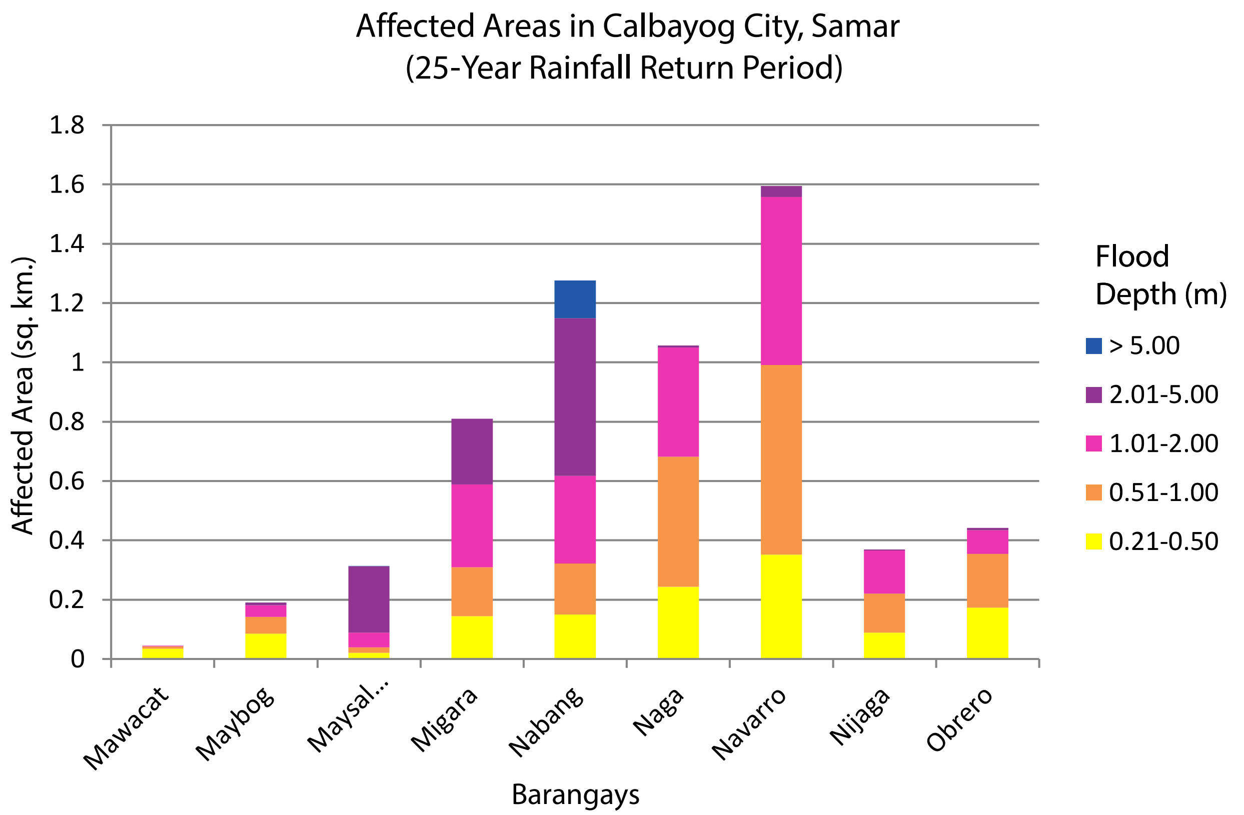


Figure 82. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

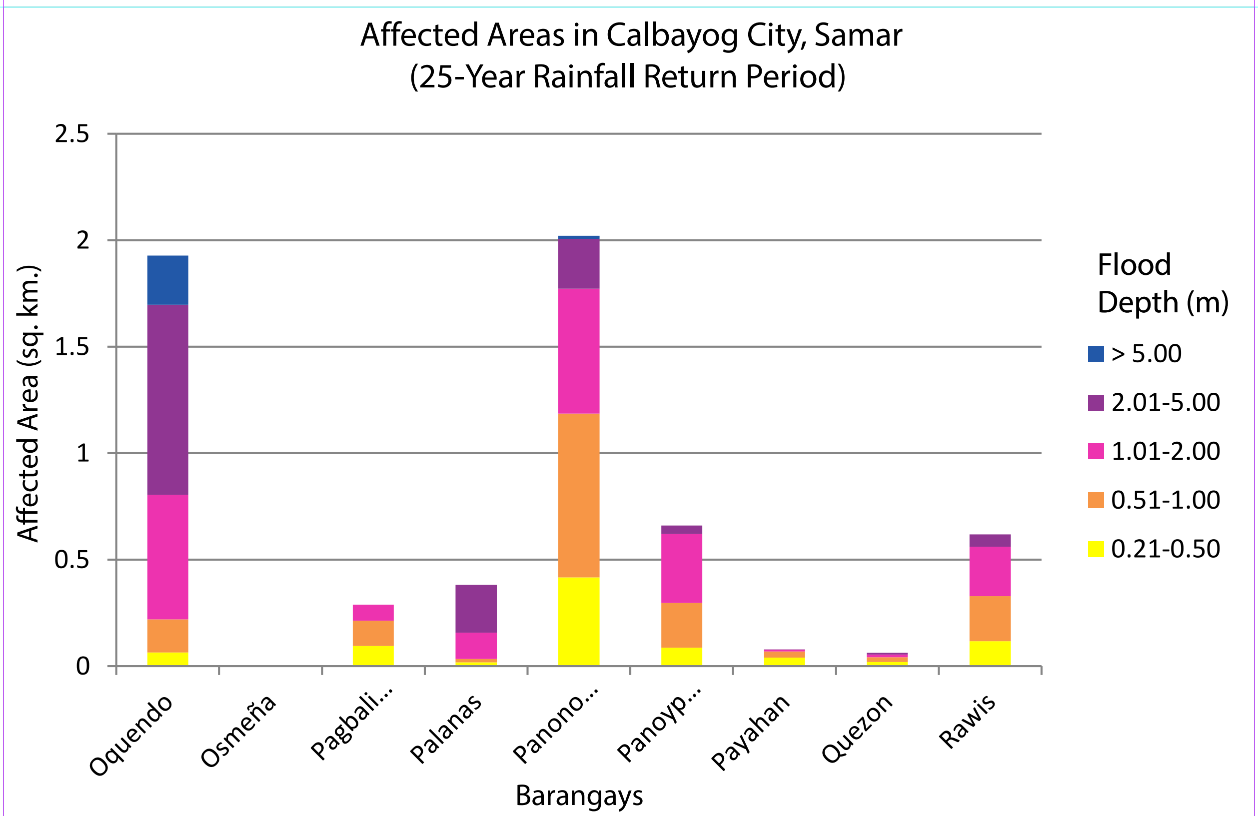


Figure 83. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

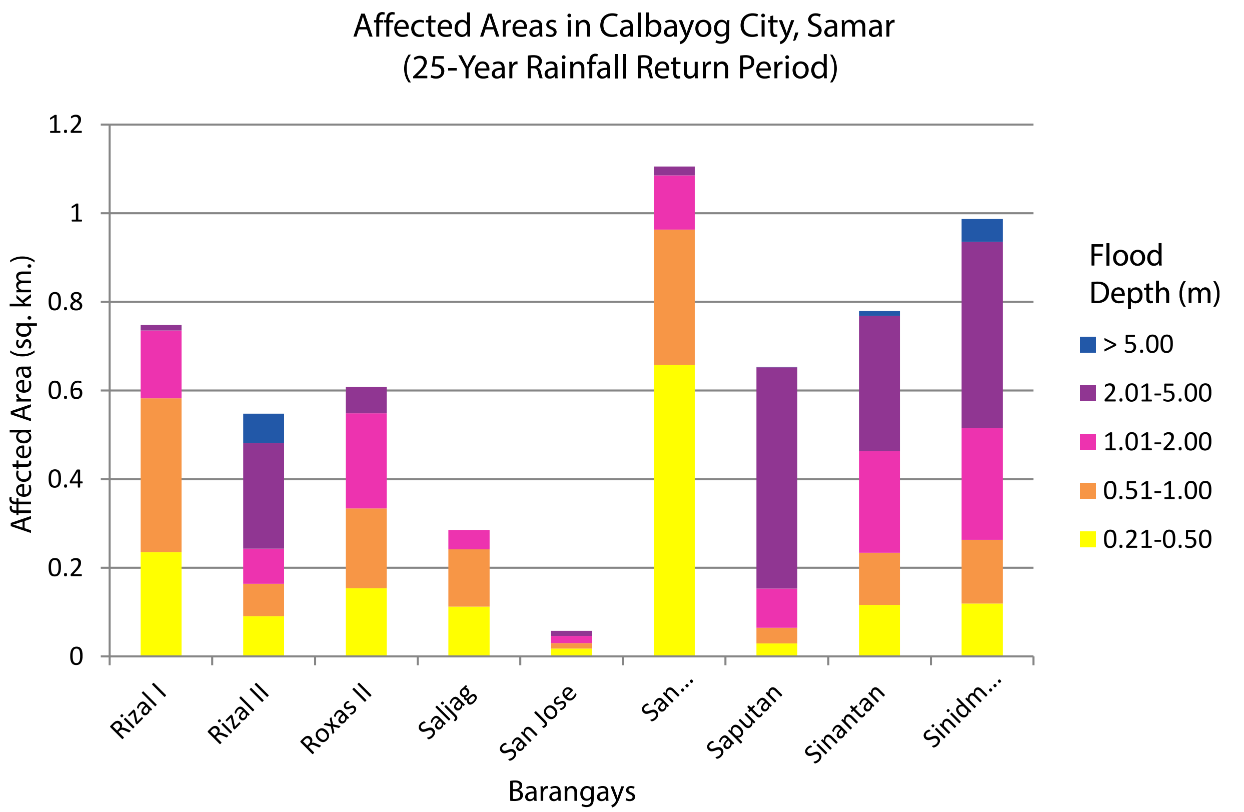


Figure 84. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

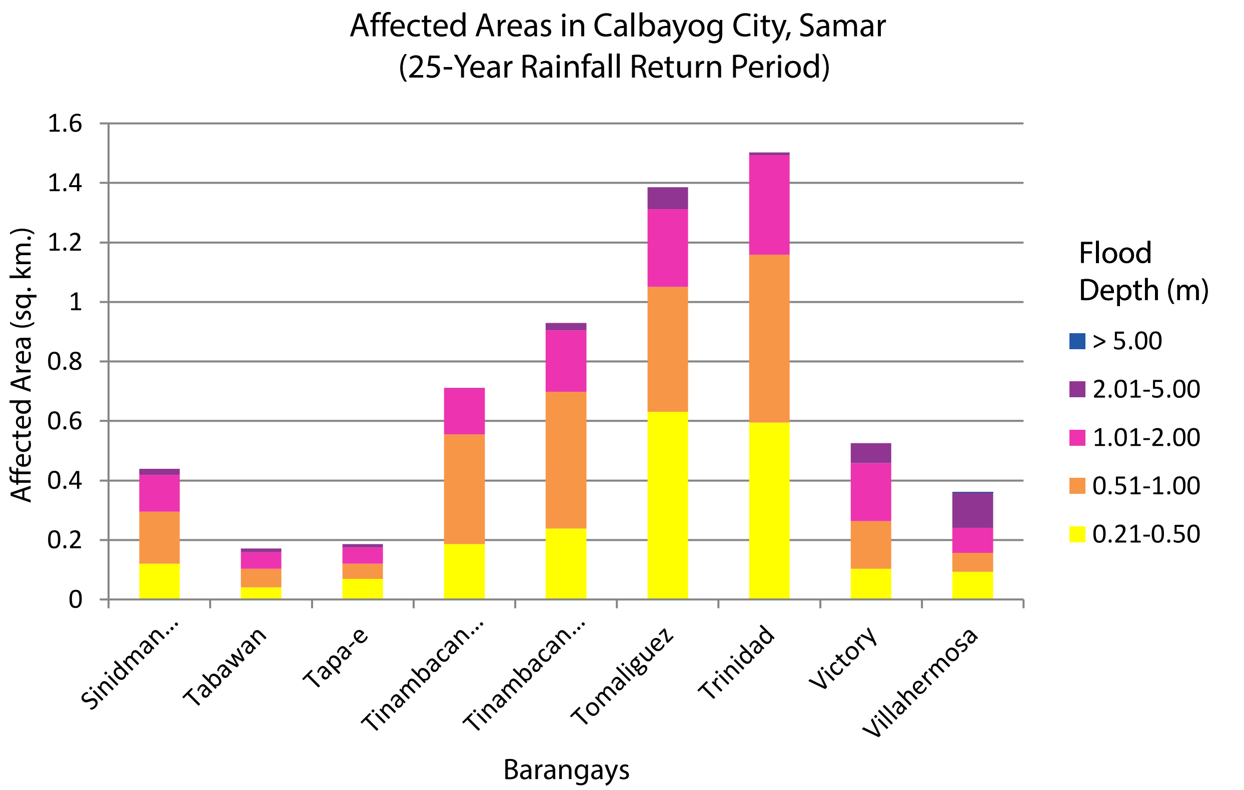


Figure 85. Affected areas in Calbayog City, Samar during a 25-year rainfall return period

For the 100-year return period, 17.373% of the City of Calbayog, with an area of 897.55 sq. km., will experience flood levels of less than 0.20 meters. 1.2583% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.3533%, 1.6258%, 2.0329%, and 0.323% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Tables 51-60 are the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Acedillo	Aguit-Itan	Alibaba	Amampacang	Anislag	Awang East	Awang West	Bagacay	Baja
0.03-0.20	1.98	0.043	1.26	2.68	0.15	0.18	0.24	1.43	2.87
0.21-0.50	0.1	0.087	0.031	0.12	0.022	0.0096	0.018	0.32	0.14
0.51-1.00	0.09	0.045	0.036	0.11	0.044	0.014	0.0035	0.13	0.14
1.01-2.00	0.1	0.052	0.082	0.14	0.1	0.024	0	0.076	0.38
2.01-5.00	0.085	0.0011	0.53	0.21	0.37	0.11	0	0.0014	0.5
> 5.00	0	0	0.096	0	0	0	0	0	0.12

Table 48. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Balud	Bante	Basud	Begaho	Bontay	Burabod	Cabacungan	Cabicahan	Cabugawan
0.03-0.20	0.022	0.07	1.37	1.04	1.43	0	1.16	1.68	1.8
0.21-0.50	0.0044	0.055	0.57	0.068	0.09	0	0.054	0.068	0.072
0.51-1.00	0.0078	0.031	0.5	0.075	0.12	0	0.039	0.074	0.051
1.01-2.00	0.031	0	0.16	0.091	0.17	0	0.16	0.2	0.11
2.01-5.00	0.12	0	0	0.67	0.2	0	0.42	0.44	0.64
> 5.00	0	0	0	0.25	0	0	0.024	0.022	0.44

Table 49. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Cacaransan	Cagbanayacao	Cagbilwang	Cagboborac	Cagsalaosao	Cahumpan	Capoocan	Carayman	Carmen
0.03-0.20	2.9	0.34	2	0.97	3.07	1.65	0.59	1.46	0.74
0.21-0.50	0.13	0.0061	0.12	0.023	0.41	0.28	0.18	0.26	0.075
0.51-1.00	0.15	0.0021	0.081	0.035	0.42	0.36	0.038	0.45	0.14
1.01-2.00	0.32	0	0.065	0.18	0.28	0.31	0.0052	0.17	0.19
2.01-5.00	0.17	0	0.15	0.48	0.85	0.081	0	0.0062	0.0085
> 5.00	0	0	0.23	0.0002	0	0	0	0	0

Table 50. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Catabunan	Central	Cogon	Dagum	Dinabongan	Dinagan	Gabay	Gadgaran	Gajo
0.03-0.20	1.25	0.043	4.9	1.54	1.93	1.96	1.11	1.97	0
0.21-0.50	0.044	0.027	0.15	0.062	0.077	0.11	0.031	0.1	0
0.51-1.00	0.03	0.029	0.17	0.057	0.15	0.15	0.038	0.08	0
1.01-2.00	0.02	0.11	0.19	0.048	0.11	0.2	0.076	0.049	0
2.01-5.00	0.011	0.099	0.043	0.002	0.014	0.58	0.36	0.0037	0
> 5.00	0	0	0	0	0	0.076	0.032	0	0

Table 51. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Geraga-an	Guimbaoyan Norte	Guimbaoyan Sur	Guin-On	Hamorawon	Jimautan	Kilikili	La Paz	Langoyon
0.03-0.20	3.49	1.37	2.03	3.14	0.1	2.89	4.71	3.02	4.77
0.21-0.50	0.11	0.045	0.071	0.14	0.0096	0.13	0.26	0.084	0.14
0.51-1.00	0.11	0.062	0.11	0.12	0.02	0.1	0.23	0.11	0.13
1.01-2.00	0.21	0.14	0.31	0.13	0.07	0.096	0.27	0.39	0.3
2.01-5.00	0.22	0.52	0.35	0.063	0.053	0.0092	0.21	0.87	0.33
> 5.00	0.0038	0	0	0	0	0	0.0025	0.14	0.0084

Table 52. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Libertad	Limarayon	Longsob	Lonoy	Looc	Mabini II	Mag-Ubay	Malopalo	Matobato
0.03-0.20	1.93	1.33	2.61	0.035	2.63	1.53	2.28	0.99	0.74
0.21-0.50	0.072	0.065	0.12	0.01	0.087	0.049	0.2	0.031	0.18
0.51-1.00	0.053	0.085	0.072	0.018	0.15	0.068	0.11	0.023	0.048
1.01-2.00	0.19	0.47	0.14	0.15	0.17	0.14	0.13	0.017	0.00025
2.01-5.00	0.35	0.056	0.5	0.34	0.38	0.42	0.26	0.0037	0
> 5.00	0.026	0	0.074	0	0.0083	0.22	0.14	0	0

Table 53. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Mawacat	Maybog	Maysalong	Migara	Nabang	Naga	Navarro	Nijaga	Obrero
0.03-0.20	0.87	2.04	0.85	4.45	2.15	4.28	3.1	1.27	0.096
0.21-0.50	0.042	0.091	0.019	0.15	0.11	0.23	0.3	0.074	0.22
0.51-1.00	0.0086	0.063	0.016	0.16	0.1	0.39	0.51	0.13	0.23
1.01-2.00	0.0034	0.041	0.035	0.26	0.21	0.48	0.73	0.16	0.1
2.01-5.00	0	0.016	0.25	0.3	0.75	0.016	0.12	0.016	0.027
> 5.00	0	0	0.015	0	0.19	0	0	0	0

Table 54. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Oquendo	Osmeña	Pagbalican	Palanas	Panonongan	Panoypoy	Payahan	Quezon	Rawis
0.03-0.20	0.97	0	0.84	0.13	4.69	1.18	1.01	0.76	1.61
0.21-0.50	0.035	0	0.07	0.016	0.34	0.067	0.043	0.021	0.12
0.51-1.00	0.032	0	0.13	0.01	0.63	0.12	0.031	0.022	0.15
1.01-2.00	0.16	0	0.097	0.033	0.82	0.36	0.012	0.017	0.31
2.01-5.00	1.28	0	0	0.33	0.32	0.14	0.001	0.0087	0.077
> 5.00	0.46	0	0	0	0.019	0	0	0	0

Table 55. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Rizal I	Rizal II	Roxas II	Saljag	San Jose	San Policarpio	Saputan	Sinantan	Sinidman Occidental
0.03-0.20	4.24	1.45	3.19	0.69	0.74	1.87	1.05	3.7	0.56
0.21-0.50	0.22	0.075	0.15	0.067	0.019	0.67	0.025	0.11	0.074
0.51-1.00	0.33	0.033	0.17	0.18	0.013	0.42	0.033	0.11	0.12
1.01-2.00	0.21	0.088	0.21	0.048	0.017	0.14	0.069	0.17	0.23
2.01-5.00	0.031	0.24	0.12	0	0.014	0.033	0.56	0.4	0.55
> 5.00	0	0.16	0	0	0	0	0.0004	0.03	0.09

Table 56. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Calbayog City (in sq. km.)								
	Sinidman Oriental	Tabawan	Tapa-e	Tinambacan Norte	Tinambacan Sur	Tomaliguez	Trinidad	Victory	Villahermosa
0.03-0.20	1.43	1.22	2.63	0.88	4.09	1.5	1.01	4.06	3.91
0.21-0.50	0.1	0.039	0.077	0.14	0.2	0.78	0.65	0.1	0.1
0.51-1.00	0.15	0.059	0.052	0.35	0.36	0.67	0.66	0.14	0.063
1.01-2.00	0.14	0.068	0.057	0.25	0.38	0.46	0.41	0.21	0.075
2.01-5.00	0.087	0.017	0.018	0.0073	0.037	0.1	0.044	0.1	0.13
> 5.00	0	0	0	0	0	0	0	0	0.025

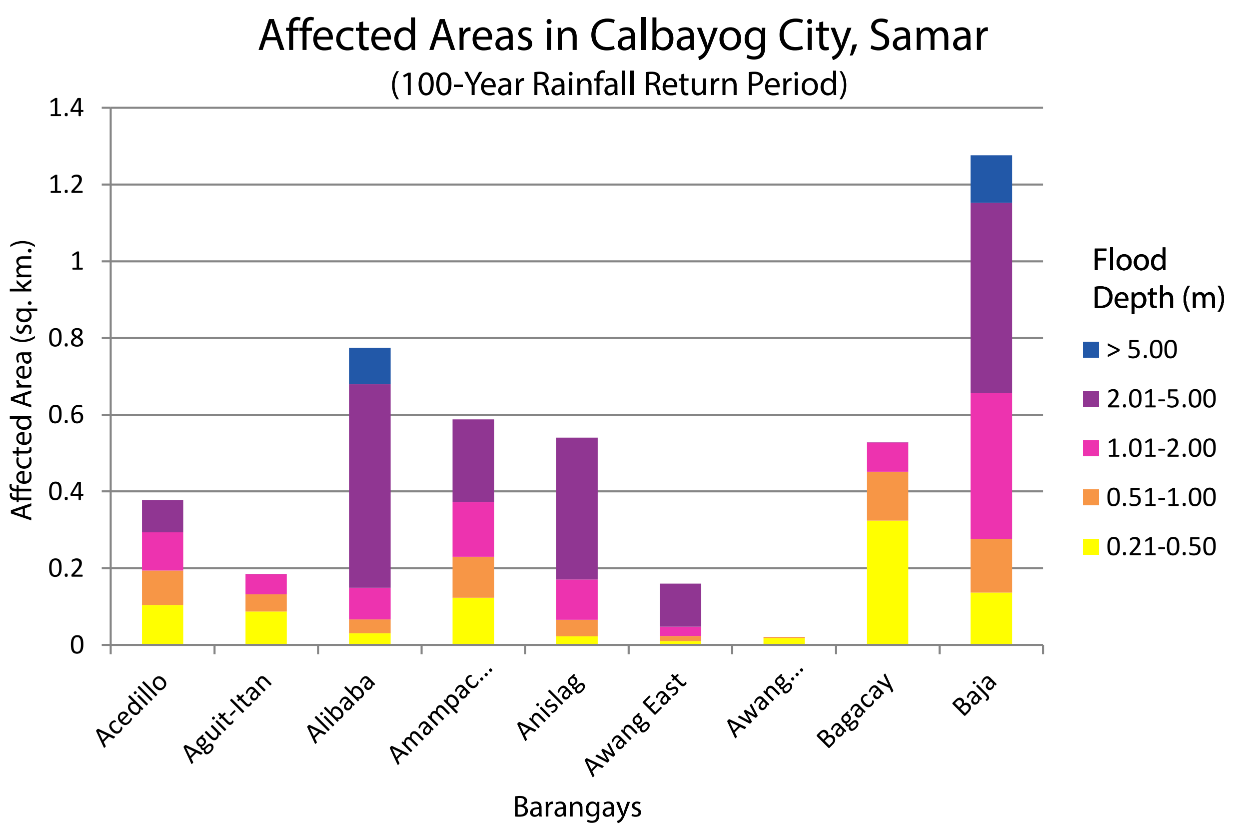


Figure 86. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

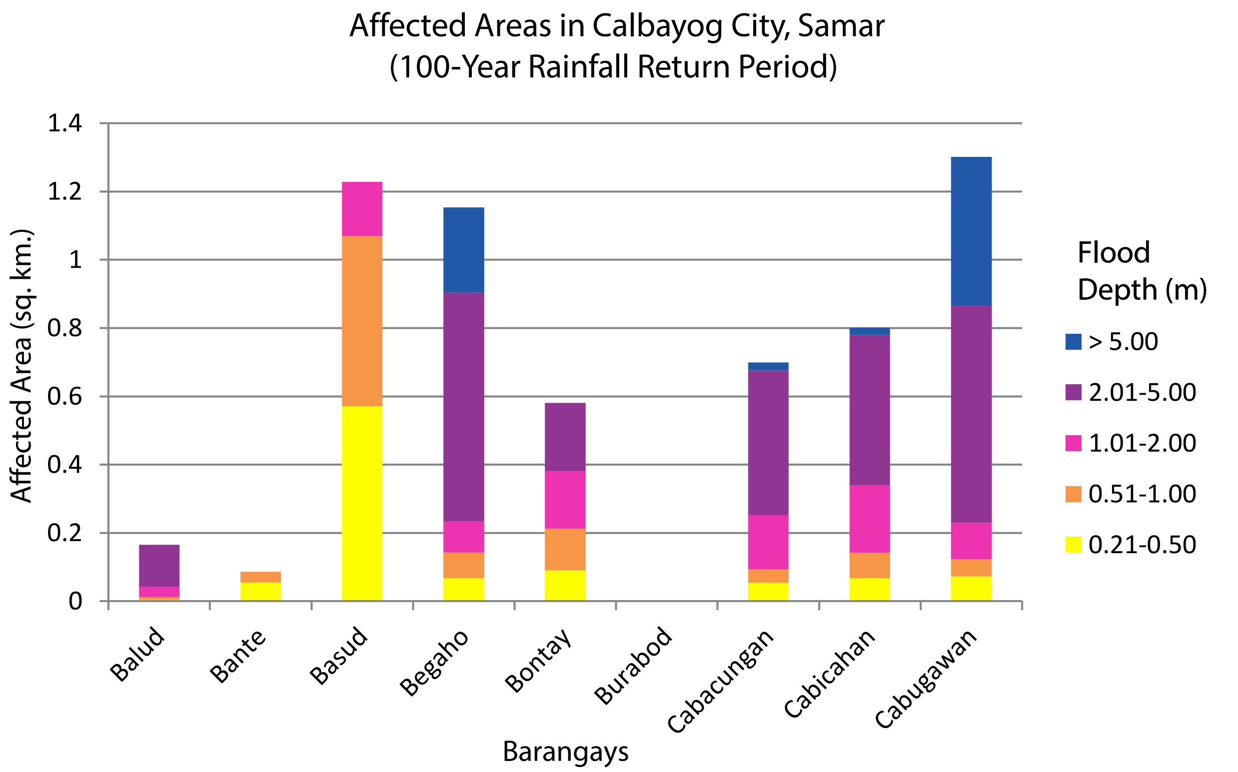


Figure 87. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

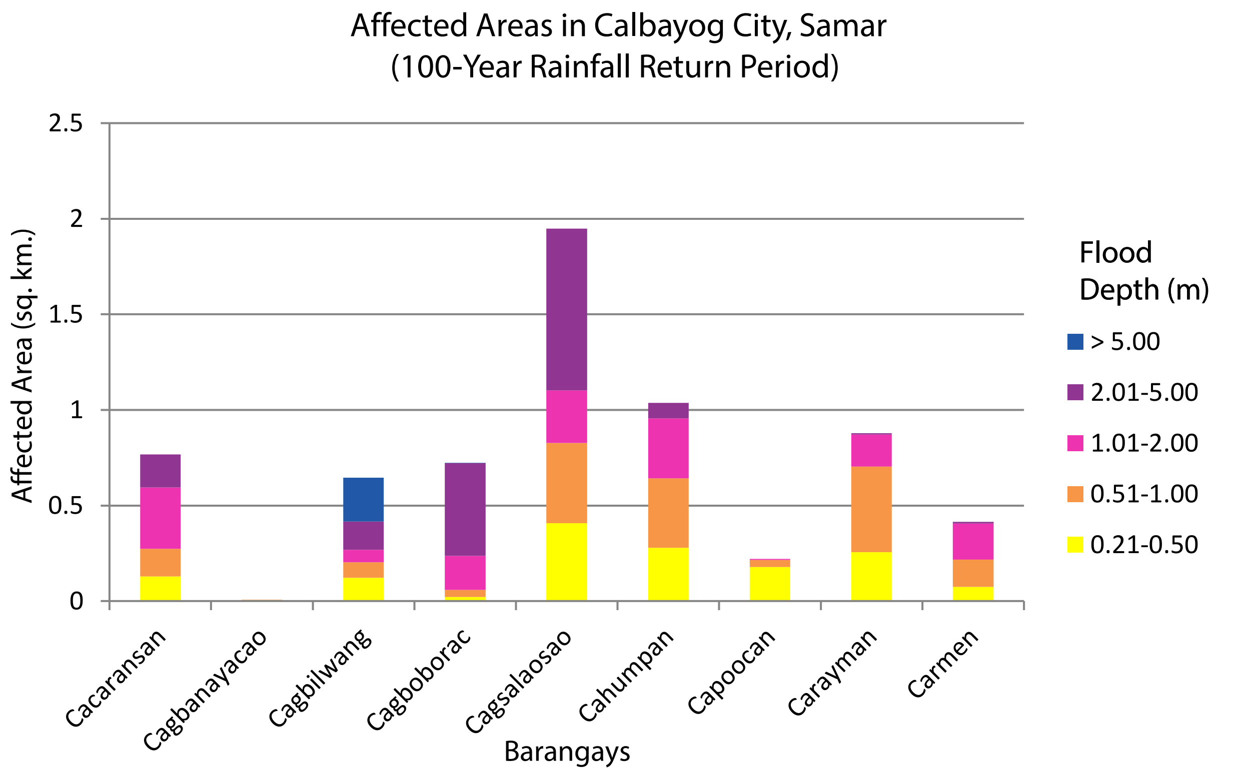


Figure 88. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

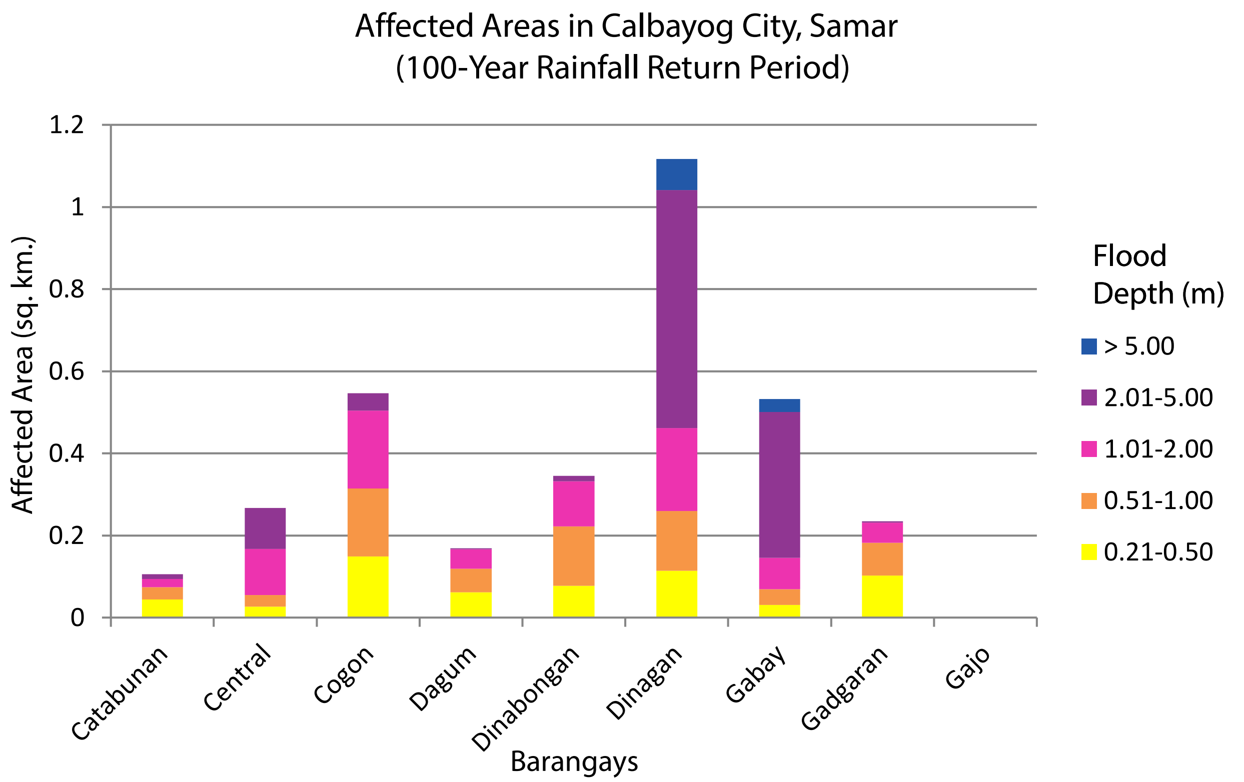


Figure 89. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

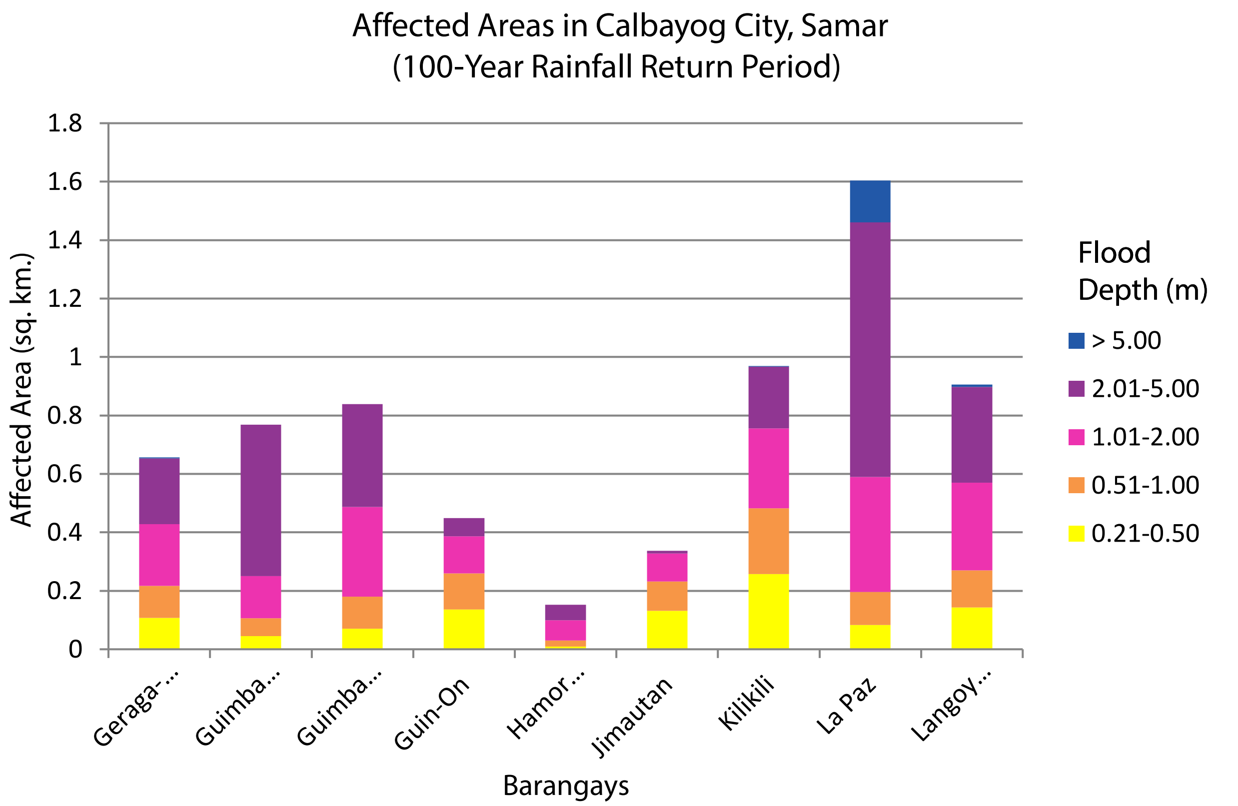


Figure 90. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

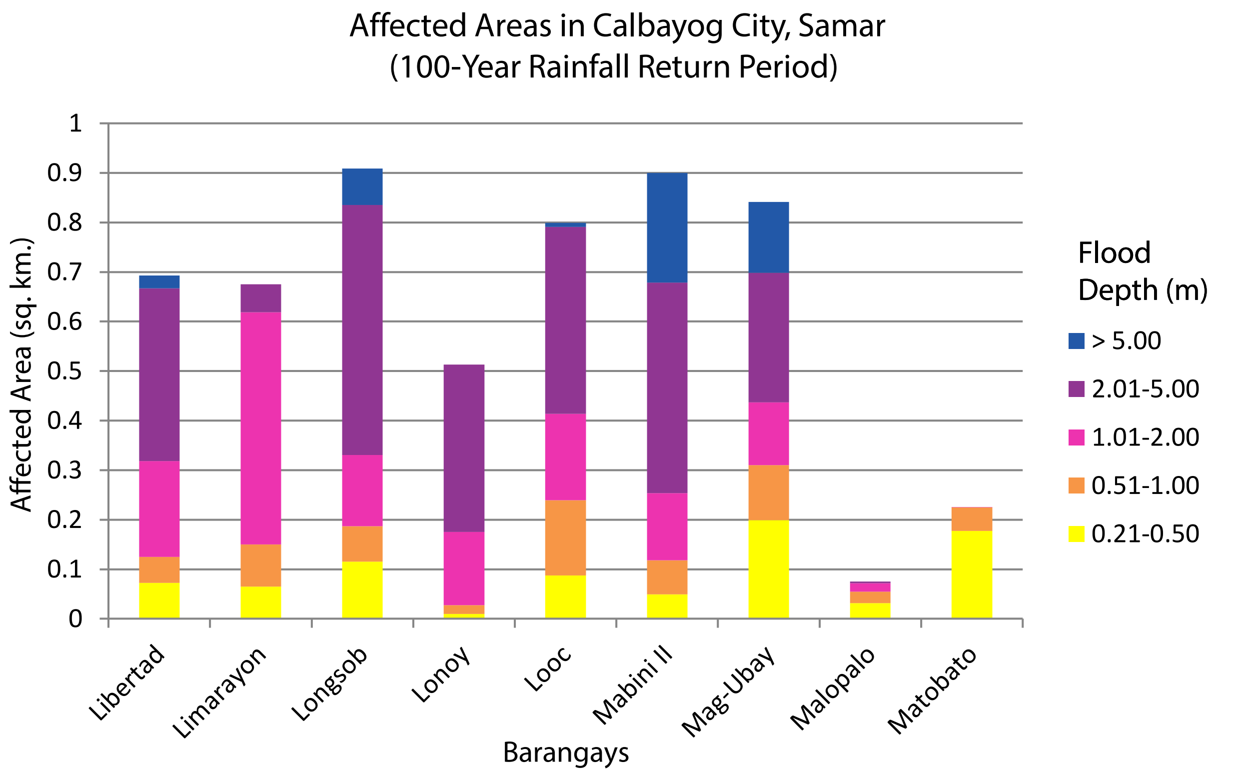


Figure 91. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

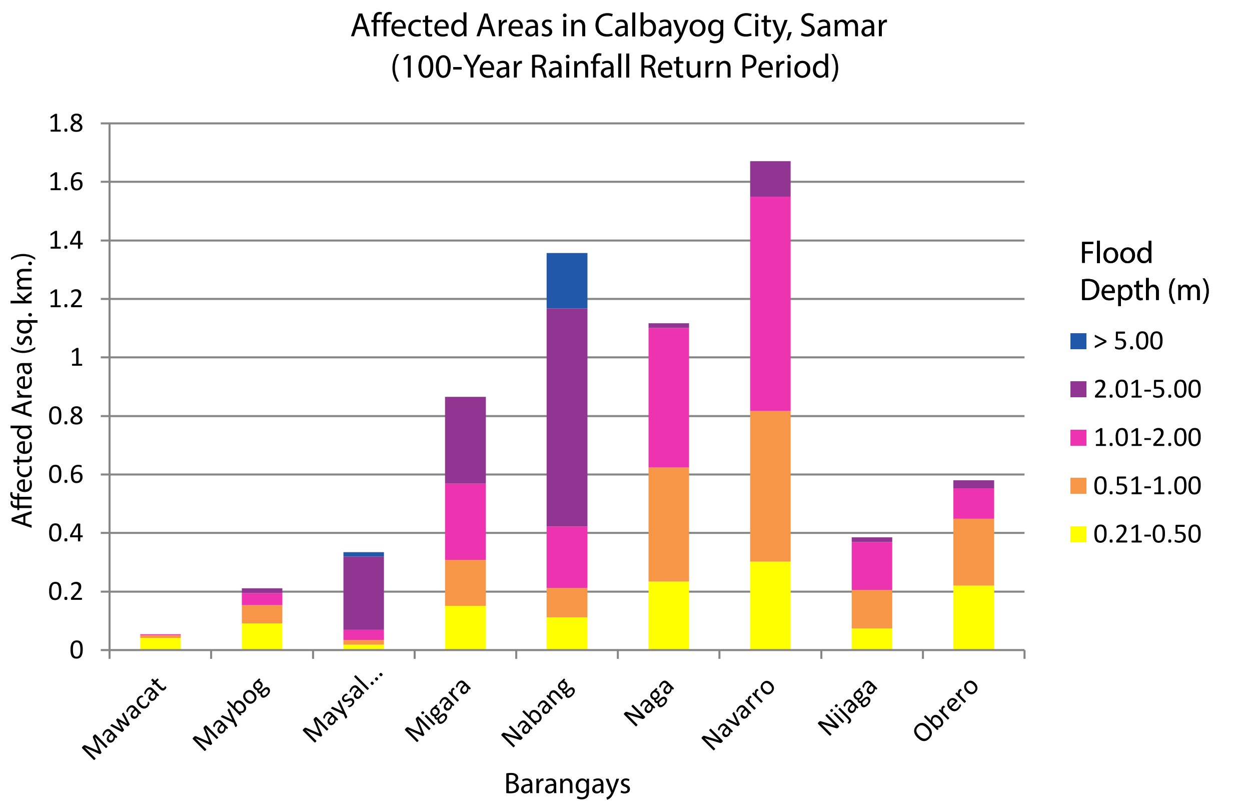


Figure 92. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

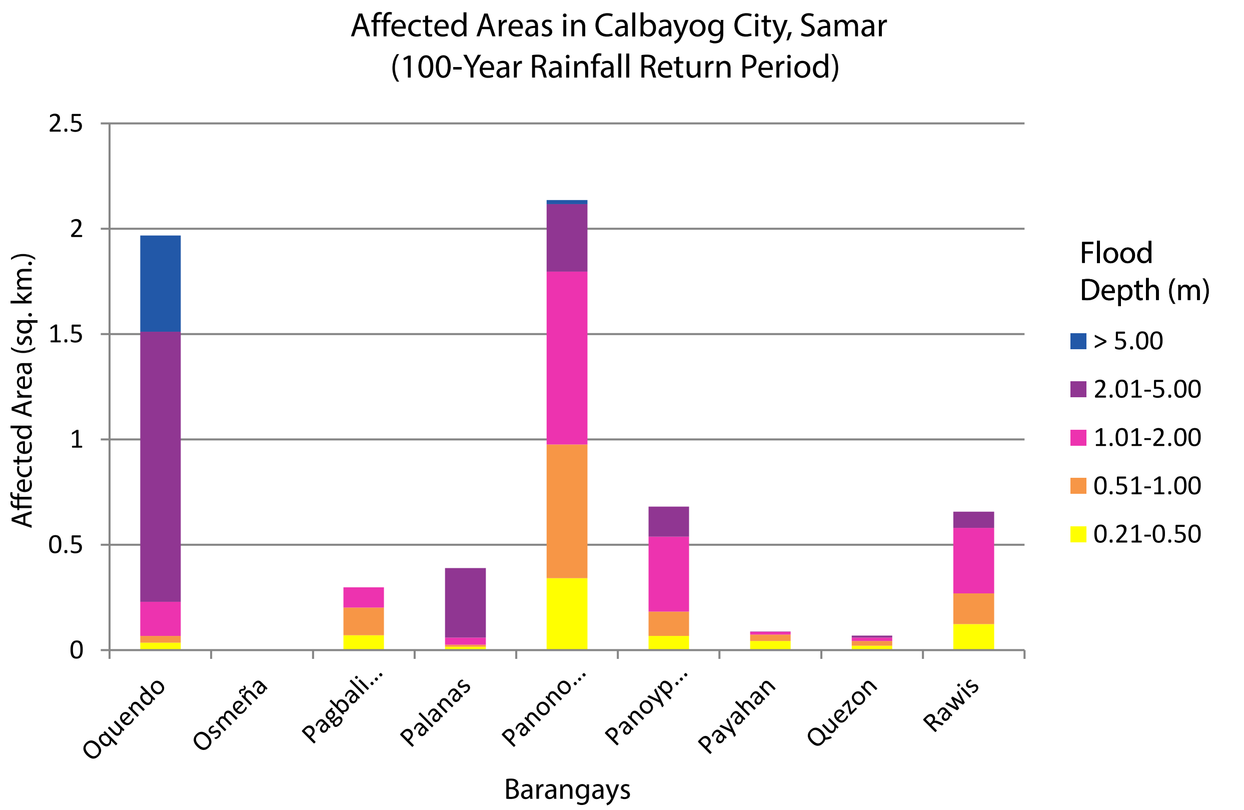


Figure 93. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

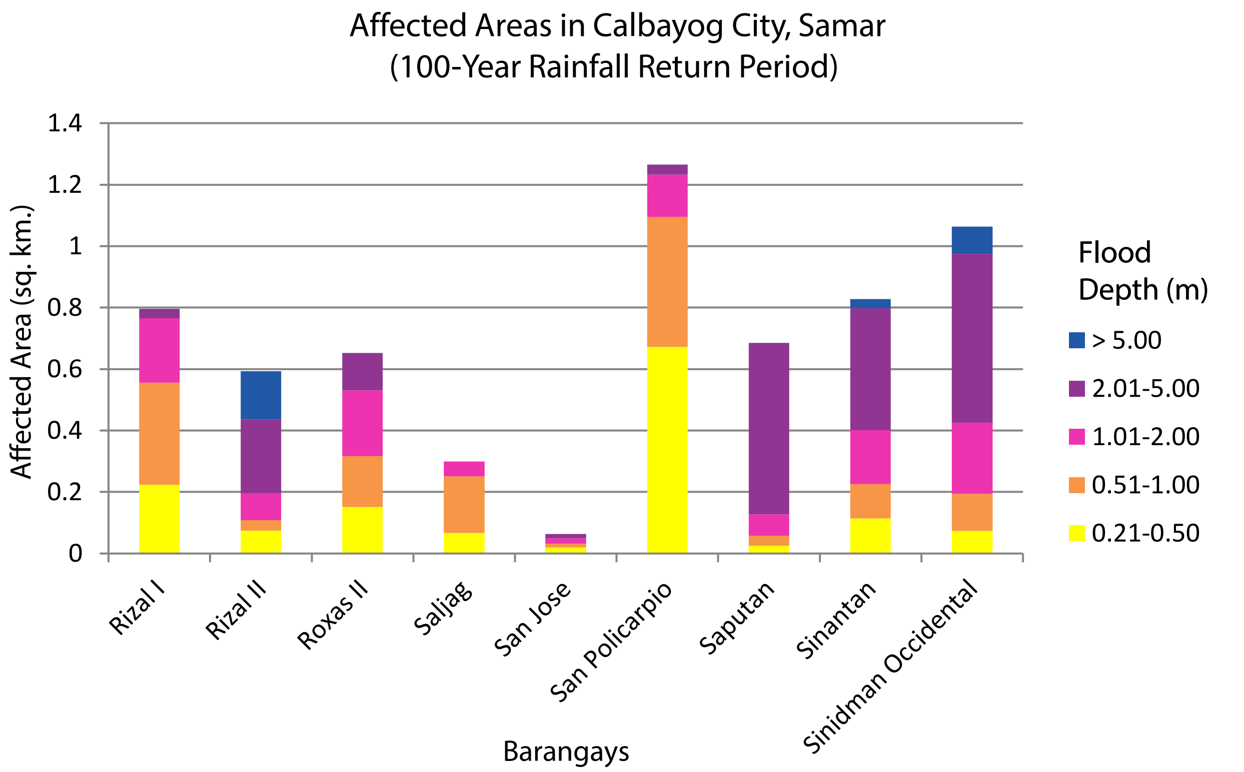


Figure 94. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

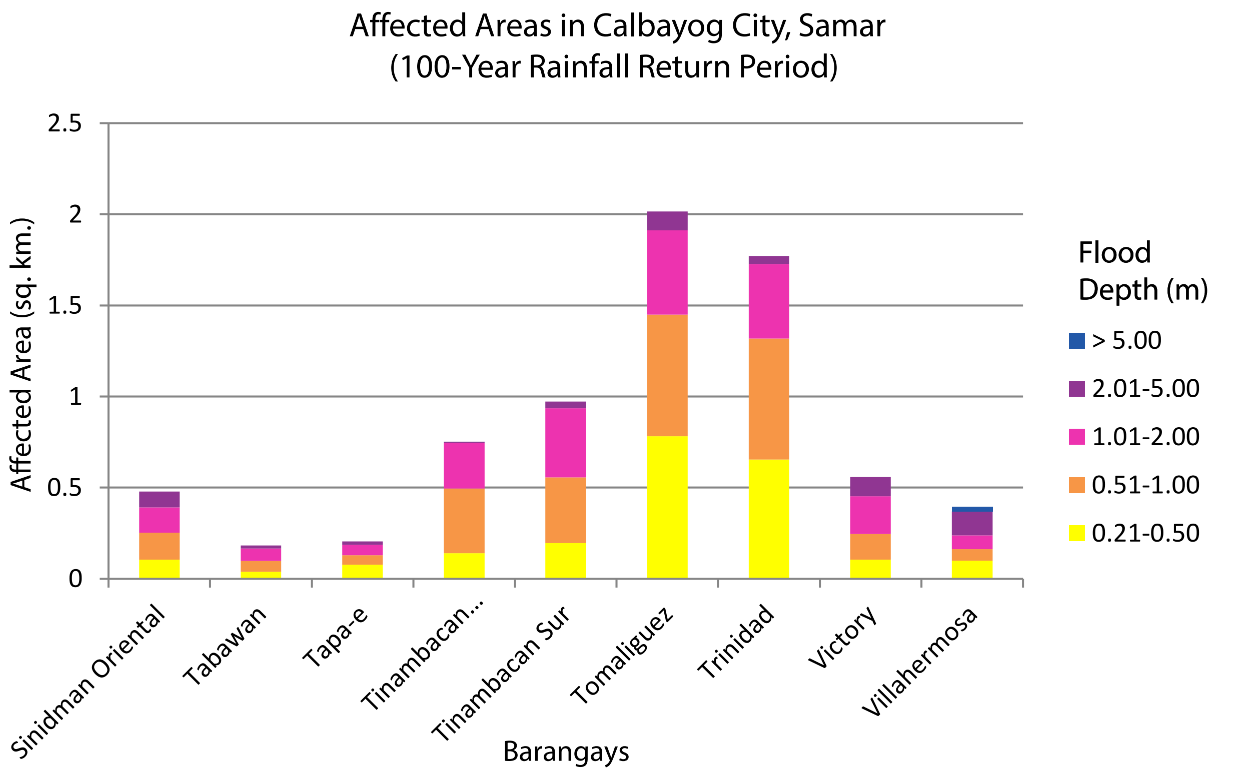


Figure 95. Affected areas in Calbayog City, Samar during a 100-year rainfall return period

Among the barangays in the City of Calbayog, Panonongan is projected to have the highest percentage of area that will experience flood levels, at 0.7594%. Meanwhile, Cagsalaosao posted the second highest percentage of area that may be affected by flood depths, at 0.5596%.

The generated flood hazard maps for the Jibatang floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for the flood hazard maps – "Low", "Medium", and "High" – the affected institutions were given an individual assessment for each flood hazard scenario (i.e., 5-year, 25-year, and 100-year). ANNEX 12 and ANNEX 13 present the educational and health institutions exposed to flooding, respectively.

Table 57. 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	13.39	12.02	11.55
Medium	22.50	22.22	21.21
High	11.25	21.54	27.44
Total	**47.14**	**55.78**	**60.2**

Insert text re: assessment of educational and medical institutions here.

5.11 Flood Validation

In order to check and validate the extent of flooding in the different river systems, there is a need to perform validation survey work. For this purpose, field personnel gathered secondary data regarding flood occurrences in the respective areas within the major river systems in the Philippines.

From the flood depth maps produced by the Phil-LiDAR 1 Program, multiple points representing the different flood depths for different scenarios were identified for validation.

The validation personnel went to the specified points identified in a river basin to gather data regarding the actual flood levels in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents with knowledge or experience of flooding in a particular area.

After which, the actual data from the field were compared with the simulated data to assess the accuracy of the flood depth maps produced, and to improve on the results of the flood map. The points in the flood map versus the corresponding validation depths are illustrated in Figure 99.

The flood validation consists of 229 points, randomly selected all over the Jibatang floodplain. It has an RMSE value of 0.34. Table 62 shows a contingency matrix of the comparison. The field validation points are found in ANNEX 11.

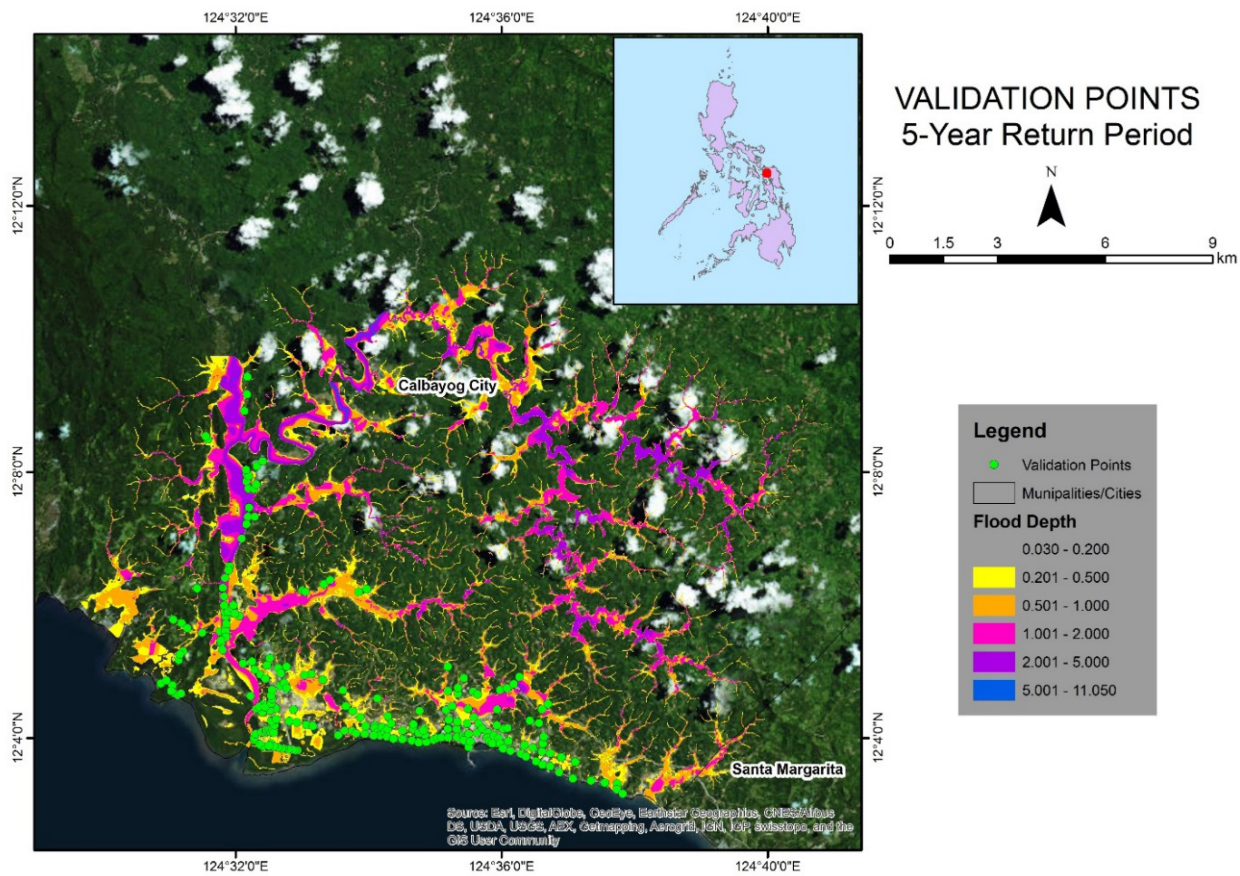


Figure 96. Validation points for the 5-year flood depth map of the Jibatang floodplain

Figure 97. Flood map depth vs. actual flood depth

Table 58. Actual flood depth vs. simulated flood depth in the Jibatang River Basin

JIBATANG BASIN		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
Actual Flood Depth (m)	0-0.20	135	26	10	0	0	0	**171**
	0.21-0.50	24	1	1	3	0	0	**29**
	0.51-1.00	5	3	8	13	0	0	**29**
	1.01-2.00	0	0	0	0	0	0	**0**
	2.01-5.00	0	0	0	0	0	0	**0**
	> 5.00	0	0	0	0	0	0	**0**
	Total	**164**	**30**	**19**	**16**	**0**	**0**	**229**

The overall accuracy generated by the flood model is estimated at 62.88%, with one hundred and forty-four (144) points correctly matching the actual flood depths. In addition, there were sixty-four (64) points estimated one (1) level above and below the correct flood depths; while there were eighteen (18) points estimated two levels above and below the correct flood depths. There were zero (0) points, estimated three (3) or more levels above and below the correct flood levels. A total of four (4) points were overestimated, while a total of thirty-two (32) points were underestimated in the modeled flood depths of the Jibatang floodplain.

Table 59. Summary of the Accuracy Assessment in the Jibatang River Basin survey

	No. of Points	%
Correct	144	62.88
Overestimated	53	23.14
Underestimated	32	13.97
Total	**229**	**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 Anaylysis System Hydraulic Reference Manuel. Davis, CA: U.S. Corps of Engineers, Institue 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.

ANNEX

ANNEX 1. Technical Specifications of the LiDAR Sensors used in the Jibatang Floodplain Survey

Figure A-1.1. ALS-80 Sensor

Table A-1.1. Technical specifications of the Aquarius sensor

Parameter	Specification
Operational altitude	100 to 3500 m max AGL
Maximum measurement rate	1000 kHz
Maximum scan rate	200 Hz for sine; 158 for triangle;120 for raster
Field of view (degrees, full angle, user-adjustable)	0 to 72
Roll Stabilization (automatic adaptive, degrees)	72 – active FOV
Number of returns	unlimited
Number of intensity measurements	3(first, second and third)
Data Storage	ALS80: removable SSD hard disk (800GB each volume)
Power Consumption	922 W @ 22.0 -30.3 VDC
Dimensions and weight	Scanner:37 W x 68 L x 26 H cm; 47 kg; Control Electronics: 45 W x 47 D x 25 H cm; 33 kg
Operating temperature	0-40˚C
Data Storage	Ruggedized removable SSD hard disk (SATA III)
Power	28 V, 900 W, 35 A
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Dimensions and weight	Sensor:250 x 430 x 320 mm; 30 kg; Control rack: 591 x 485 x 578 mm; 53 kg
Operating temperature	0-35˚C
Relative humidity	0-95% no-condensing

ANNEX 2. NAMRIA Certification of Reference Points used in the LiDAR Survey

1. SMR-33

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

December 11, 2015

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: **SAMAR (WESTERN SAMAR)**
Station Name: **SMR-33**
Order: **2nd**

Island: **VISAYAS**	Barangay:		
Municipality: **SANTA MARGARITA**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **12° 2' 19.48514"**	Longitude: **124° 39' 22.13920"**	Ellipsoidal Hgt:	**4.97358 m.**
	WGS84 Coordinates		
Latitude: **12° 2' 14.98810"**	Longitude: **124° 39' 27.22840"**	Ellipsoidal Hgt:	**64.37800 m.**
	PTM / PRS92 Coordinates		
Northing: **1331244.592 m.**	Easting: **462560.353 m.**	Zone:	**5**
	UTM / PRS92 Coordinates		
Northing: **1,331,298.78**	Easting: **680,286.51**	Zone:	**51**

Location Description

SMR-33
From Calbayog City proper, travel about 10 km. south going to proper of Brgy. Sta. Margarita Western Samar. From the national road, turn about 100 m. east, then turn about 60 m. west going to the elementary school of Brgy. Sta.Margarita, from the entrance gate about 150 m. west, and in front of the School building about 10 m. north, where the monument was located. Mark is the head of a 4" copper nail flushed in a 30X30 cm. cement block embedded in the ground protruding about 20 cm., with inscriptions "SMR-33; 2007; NAMRIA."

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8088859 I**
T.N.: **2015-4107**

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

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

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-2.1. SMR-33

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

1. Established 1/SMR-33A

Table A-3.1. SMR-33A

Vector Components (Mark to Mark)

From:	SMR-33				
Grid		Local		Global	
Easting	680286.501 m	Latitude	N12°02'19.48512"	Latitude	N12°02'14.98810"
Northing	1331298.782 m	Longitude	E124°39'22.13923"	Longitude	E124°39'27.22840"
Elevation	4.559 m	Height	4.974 m	Height	64.378 m

To:	Established-1				
Grid		Local		Global	
Easting	672169.393 m	Latitude	N12°04'06.98588"	Latitude	N12°04'02.47512"
Northing	1334554.024 m	Longitude	E124°34'54.39749"	Longitude	E124°34'59.48472"
Elevation	5.112 m	Height	5.512 m	Height	64.658 m

Vector					
ΔEasting	-8117.107 m	NS Fwd Azimuth	292°11'54"	ΔX	7055.762 m
ΔNorthing	3255.242 m	Ellipsoid Dist.	8745.652 m	ΔY	4033.409 m
ΔElevation	0.552 m	ΔHeight	0.538 m	ΔZ	3230.203 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.008 m
σ ΔNorthing	0.003 m	σ Ellipsoid Dist.	0.004 m	σ ΔY	0.014 m
σ ΔElevation	0.017 m	σ ΔHeight	0.017 m	σ ΔZ	0.006 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000678489		
Y	-0.0001087526	0.0002021737	
Z	-0.0000413164	0.0000775710	0.0000377481

2. Established 2/SMR-33B

Table A-3.2. SMR-33B

Vector Components (Mark to Mark)

From:	SMR-33				
Grid		Local		Global	
Easting	680286.501 m	Latitude	N12°02'19.48512"	Latitude	N12°02'14.98810"
Northing	1331298.782 m	Longitude	E124°39'22.13923"	Longitude	E124°39'27.22840"
Elevation	4.559 m	Height	4.974 m	Height	64.378 m

To:	Established-2				
Grid		Local		Global	
Easting	672198.738 m	Latitude	N12°04'07.12856"	Latitude	N12°04'02.61782"
Northing	1334558.577 m	Longitude	E124°34'55.36866"	Longitude	E124°35'00.45589"
Elevation	5.317 m	Height	5.717 m	Height	64.863 m

Vector					
ΔEasting	-8087.762 m	NS Fwd Azimuth	292°17'53"	ΔX	7031.987 m
ΔNorthing	3259.796 m	Ellipsoid Dist.	8720.123 m	ΔY	4016.149 m
ΔElevation	0.758 m	ΔHeight	0.743 m	ΔZ	3234.534 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.007 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000217539		
Y	-0.0000322317	0.0000554524	
Z	-0.0000095804	0.0000159517	0.0000058465

ANNEX 4. The LiDAR Survey Team Composition

Table A-4.1. 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 ACUNA	UP-TCAGP
		ENGR. GEROME HIPOLITO	UP-TCAGP
FIELD TEAM			
	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	JASMIN DOMINGO	UP-TCAGP
		SANDRA POBLETE	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JONATHAN ALMALVEZ	UP-TCAGP
LiDAR Operation	Airborne Security	TSG. SANDY UY	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JACKSON JAVIER	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. KHALIL ANTONY CHI	AAC
		CAPT. GEO VILLACASTIN	AAC

ANNEX 5. Data Transfer Sheets for the Jibatang Floodplain Flights

DATA TRANSFER SHEET
CALBAYOG 11/25/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	KML (swath)	GnssImu	LogFiles	TestData	RawLaser	RawTDC	RawWFD	WebCam	RCD30 RAW IMAGES	BASE STATION(S)		SERVER LOCATION
													BASE STATION(S)	Base Info (.txt)	
8-Nov-16	10225L	4BLK33AC313A	ALS 80	413	547	167	39.5	653/19.2	155/8.36	NA	7.52/177	8.48	6.19	1KB	Z:\DAC\RAW DATA
11-Nov-16	10231L	4BLK33D316A	ALS 80	35	568	151	21.7	4.35/1.8/4.35/229	647/1.37/3.23/183	NA	62.1/21.5/80.2/2.45	26.6	9.33	1KB	Z:\DAC\RAW DATA
13-Nov-16	10235L	4BLK33D318A	ALS 80	NA	650	176	19	10.6/918	7.96/703	NA	149/12	49.5	8.53	1KB	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature [signature]

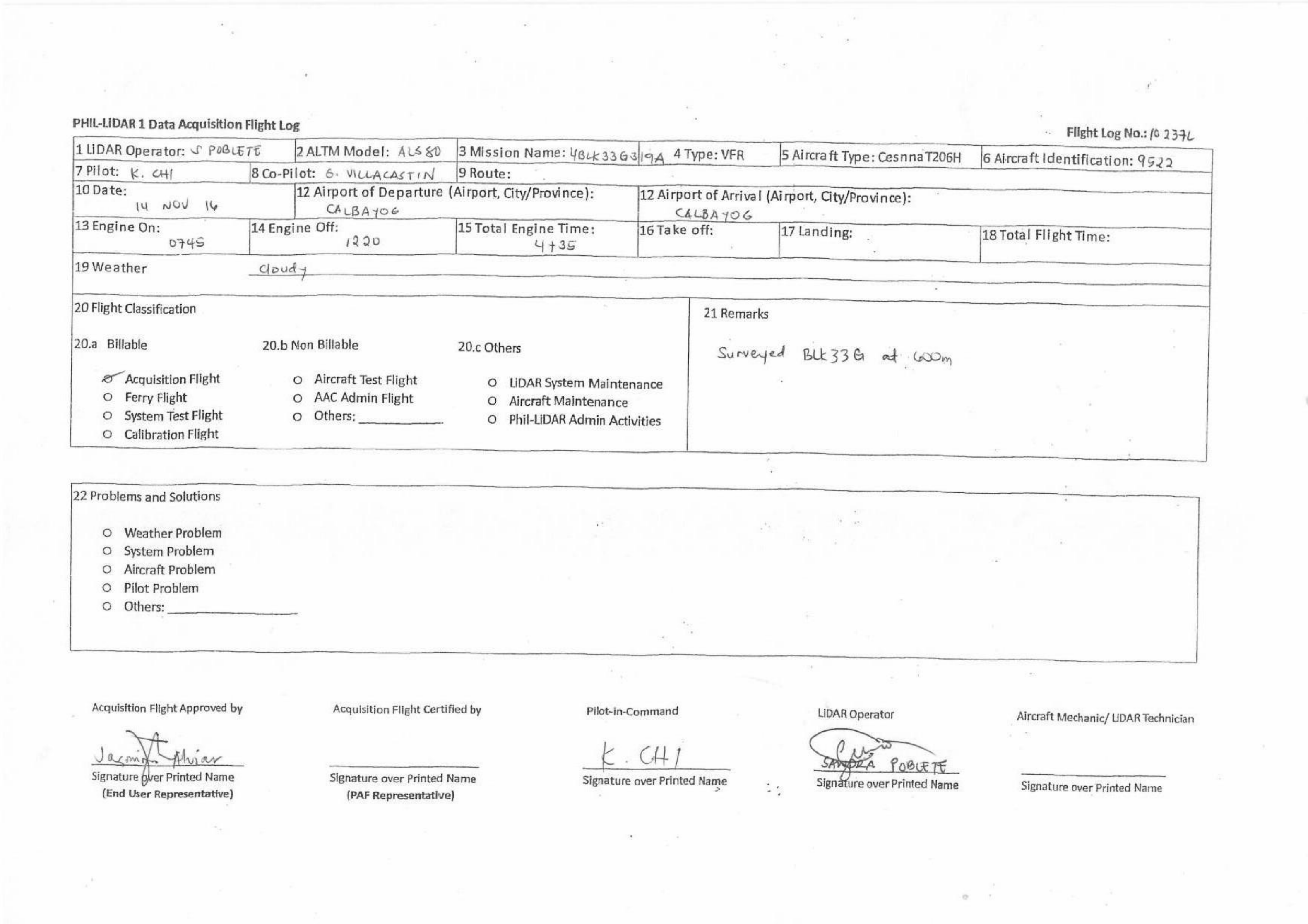
Received by

Name ACBongat
Position SSRS
Signature [signature] 11/29/16

Figure A-5.1. Data Transfer Sheet for Jibatang Floodplain – A

ANNEX 6. Flight Logs for the Flight Missions

1. Flight Log for 10237L Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 10237L

1 LiDAR Operator: S POBLETE	2 ALTM Model: ALS 80	3 Mission Name: 4BLK33G319A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9522
7 Pilot: K. CHI	8 Co-Pilot: G. VILLACASTIN	9 Route:			
10 Date: 14 NOV 16	12 Airport of Departure (Airport, City/Province): CALBAYOG		12 Airport of Arrival (Airport, City/Province): CALBAYOG		
13 Engine On: 0745	14 Engine Off: 1220	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	cloudy				

20 Flight Classification

20.a Billable
- ☑ Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight

20.b Non Billable
- ○ Aircraft Test Flight
- ○ AAC Admin Flight
- ○ Others: ___________

20.c Others
- ○ LIDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil-LIDAR Admin Activities

21 Remarks

Surveyed BLK33G at 600m

22 Problems and Solutions
- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ___________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
Jasmin Alviar		K. CHI	SANDRA POBLETE	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.1. Flight Log for Mission 10237L

2. Flight Log for 10241L Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: J. DOMINGO	2 ALTM Model: ALS80	3 Mission Name: 4BLK33GS321A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9522
7 Pilot: K. CHI	8 Co-Pilot: G. VILLACASTIN	9 Route:			
10 Date: 16 NOV 16	12 Airport of Departure (Airport, City/Province): CALBAYOG		12 Airport of Arrival (Airport, City/Province): CALBAYOG		
13 Engine On: 0715	14 Engine Off: 1150	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Flight Classification

20.a Billable
- ✓ Acquisition Flight
- o Ferry Flight
- o System Test Flight
- o Calibration Flight

20.b Non Billable
- o Aircraft Test Flight
- o AAC Admin Flight
- o Others: ____________

20.c Others
- o LiDAR System Maintenance
- o Aircraft Maintenance
- o Phil-LiDAR Admin Activities

21 Remarks

surveyed BLK 33H

22 Problems and Solutions
- o Weather Problem
- o System Problem
- o Aircraft Problem
- o Pilot Problem
- o Others: ____________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
Jasmine Alviar		K. CHI	JASMINE DOMINGO	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for Mission 10241L

ANNEX 7. Flight Status Reports

Table A-7.1. Flight Status Report

CALBAYOG
(NOVEMBER 7-21, 2016)

Flight No	Area	Mission	Operator	Date Flown	Remarks
10237L	JIBATANG FP BLK 33G	4BLK33G319A	S POBLETE	NOV 14	SURVEYED BLK 33G AT 600M 62.4 SQ.KM
10241l	JIBATANG FP BLK 33H	4BLK33H321A	J DOMINGO	NOV 16	SURVEYED BLK 33H AT 600M 42.7 SQ.KM

SWATH PER FLIGHT MISSION

Flight No. : 10237L
Area: BLK 33G
Mission Name: 4BLK33G319A
Parameters: FOV 50 SIDELAP 30 FLYING HT. 600M

Figure A-7.1. Swath for Flight No. 10237L

Flight No. : 10241L
Area: BLK 33H
Mission Name: 4BLK33H321A
Parameters: FOV 50 SIDELAP 30 FLYING HT. 600M

Figure A-7.2. Swath for Flight No. 10241L

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk33C

Flight Area	Calbayog
Mission Name	Blk33C
Inclusive Flights	10225L
RawLaser	19.76 GB
GnssImu	547 MB
Image	8.848
Transfer date	11/29/2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Combined Separation (-0.1 up to 0.1)	Yes
Estimated Position Accuracy (in cm)	
Estimated Standard Devation for North Position (<4.0 cm)	0.35
Estimated Standard Devation for East Position (<4.0 cm)	0.40
Estimated Standard Devation for Height Position (<8.0 cm)	0.75
Minimum % overlap (>25)	28.35
Ave point cloud density per sq.m. (>2.0)	10.14
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	127
Maximum Height	210.54 m
Minimum Height	53.42 m
Classification (# of points)	
Ground	191,265,570
Low vegetation	93,129,601
Medium vegetation	132,826,641
High vegetation	255,754,880
Building	11,852,181
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Harmond Santos, Engr. Gladys Mae Apat

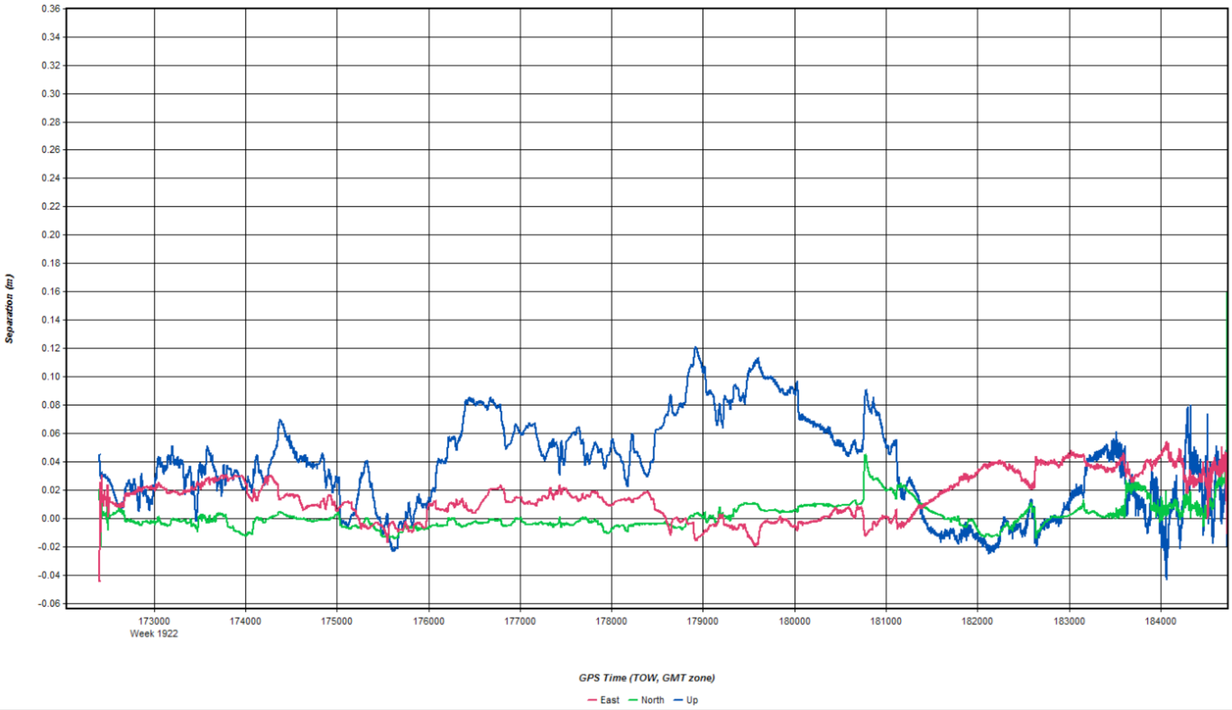


Figure A-8.1. Combined Separation

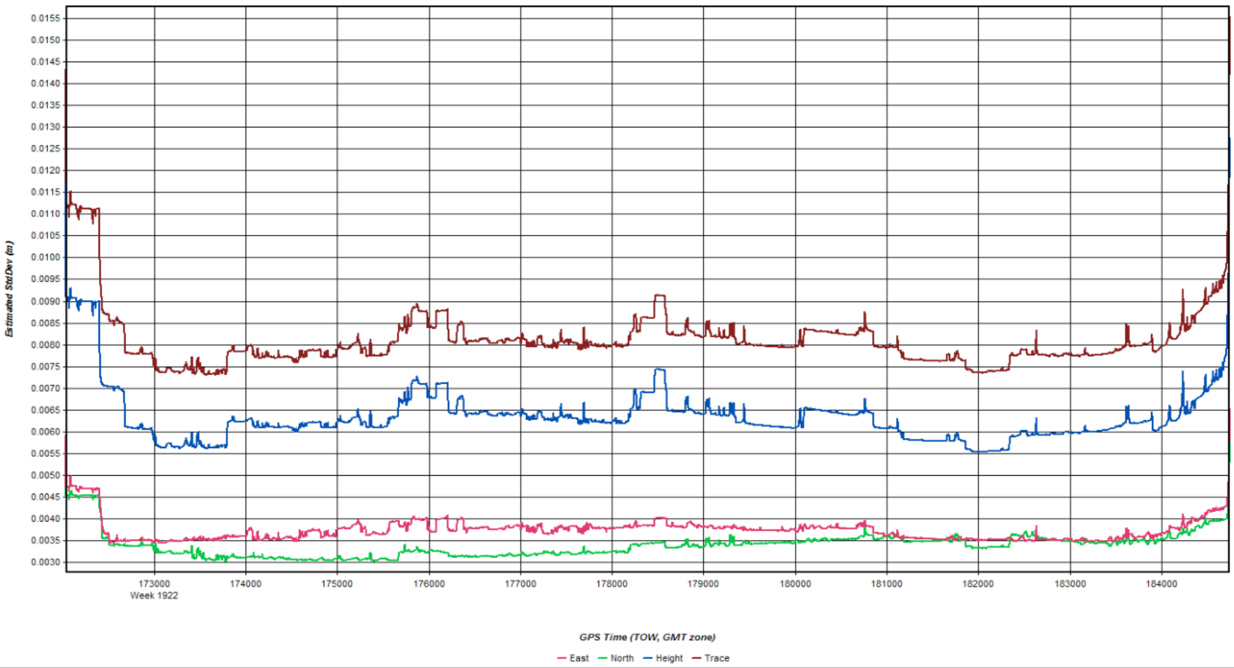


Figure A-8.2. Estimated Position of Accuracy

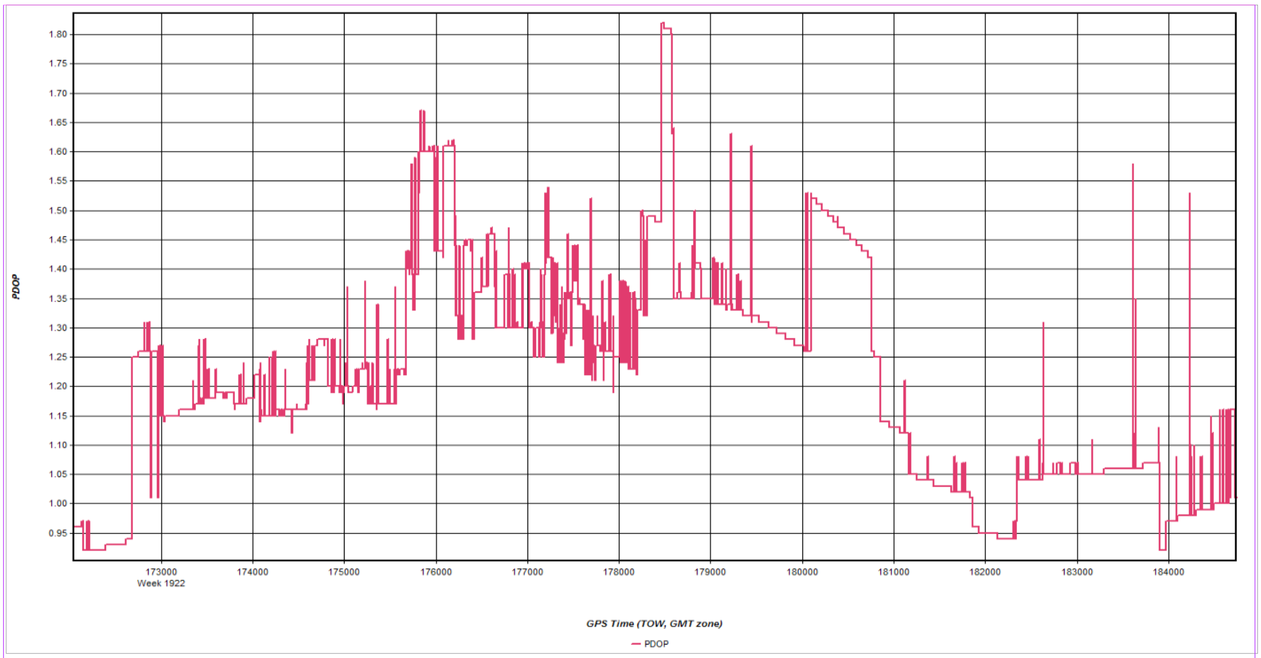


Figure A-8.3. PDOP

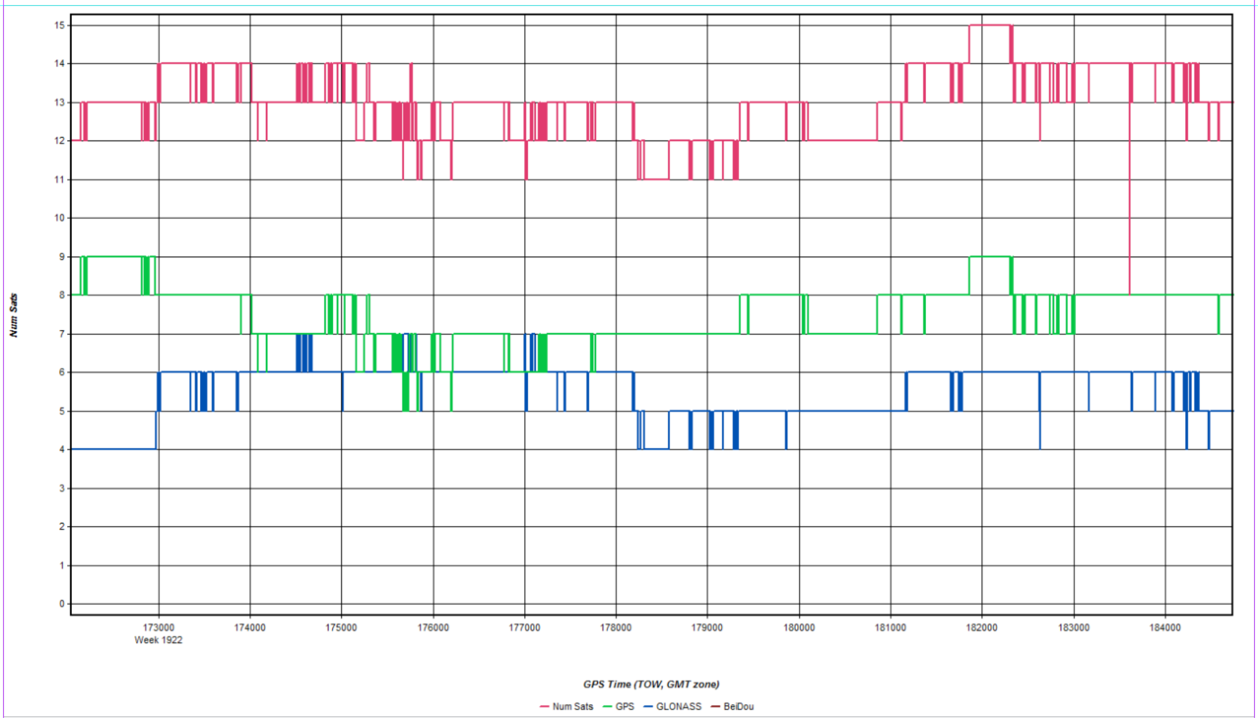


Figure A-8.4. Number of Satellites

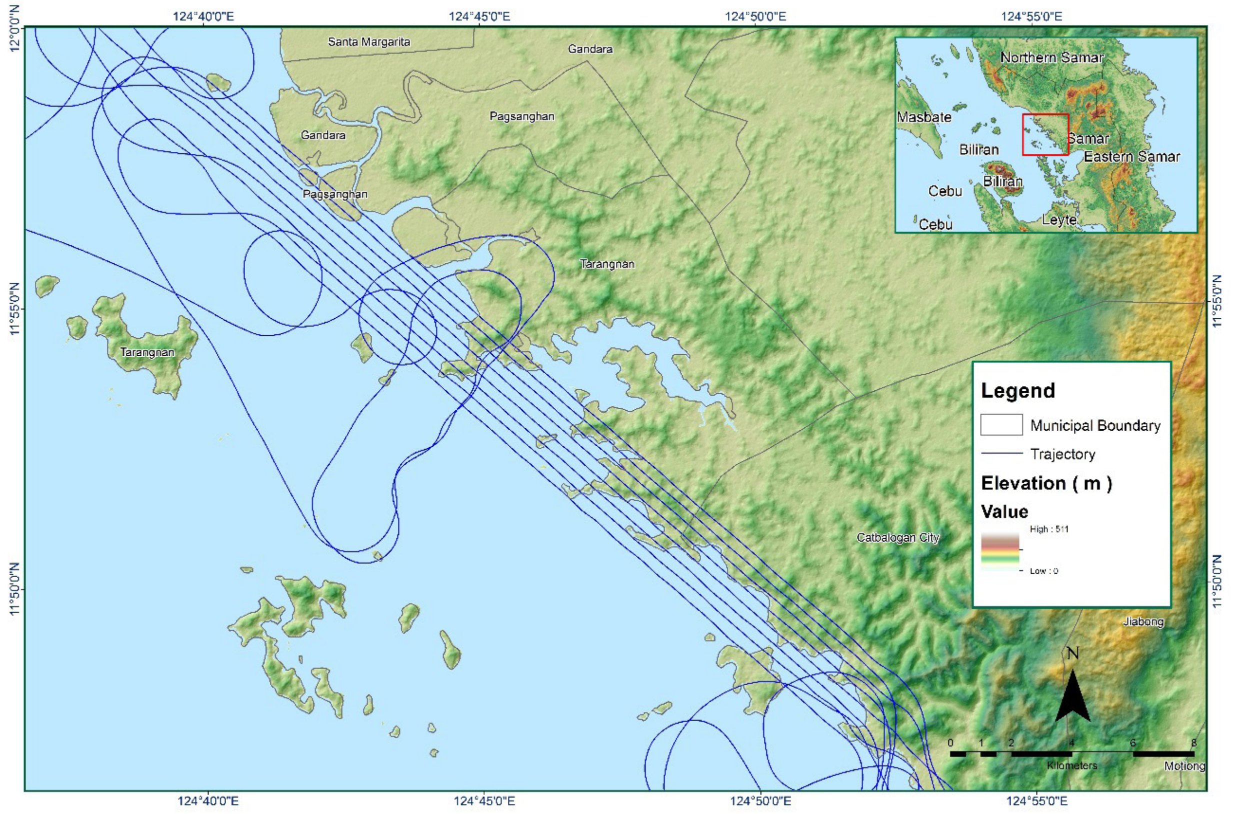


Figure A-8.5. Best Estimated Trajectory

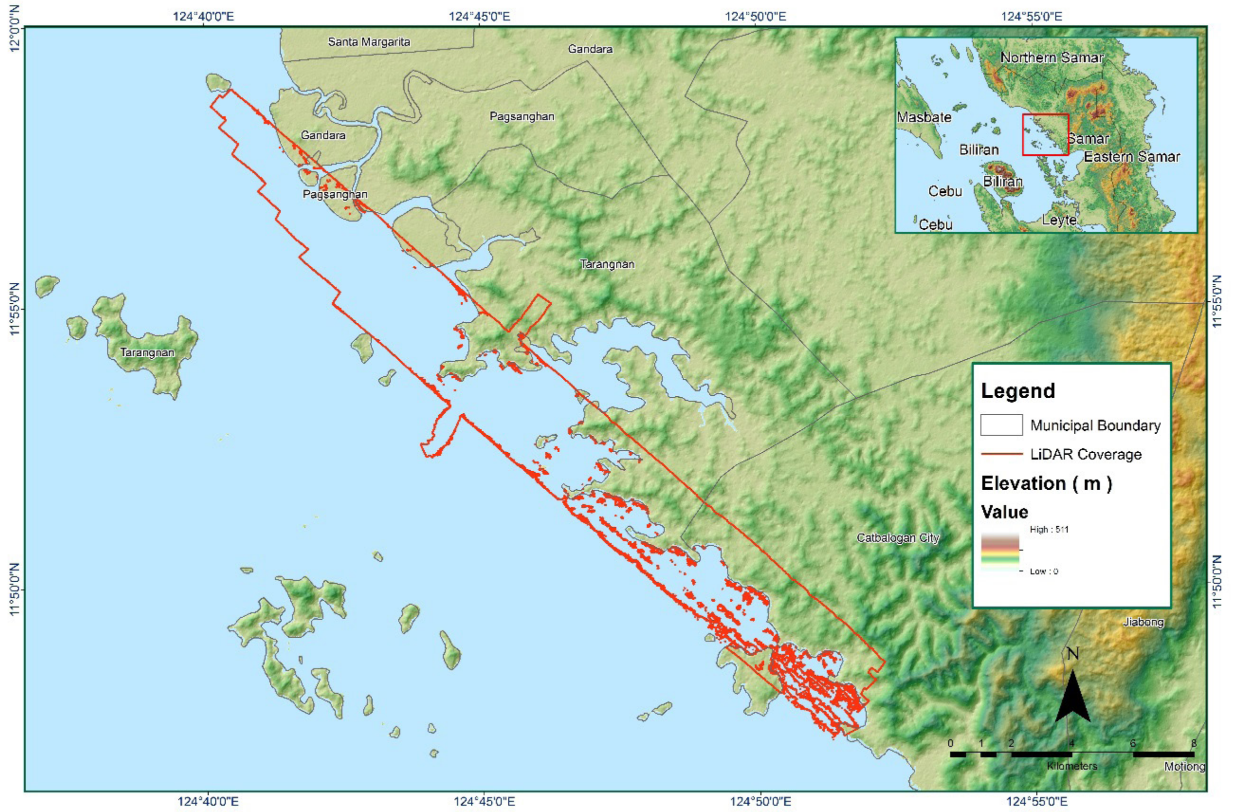


Figure A-8.6. Coverage of LiDAR data

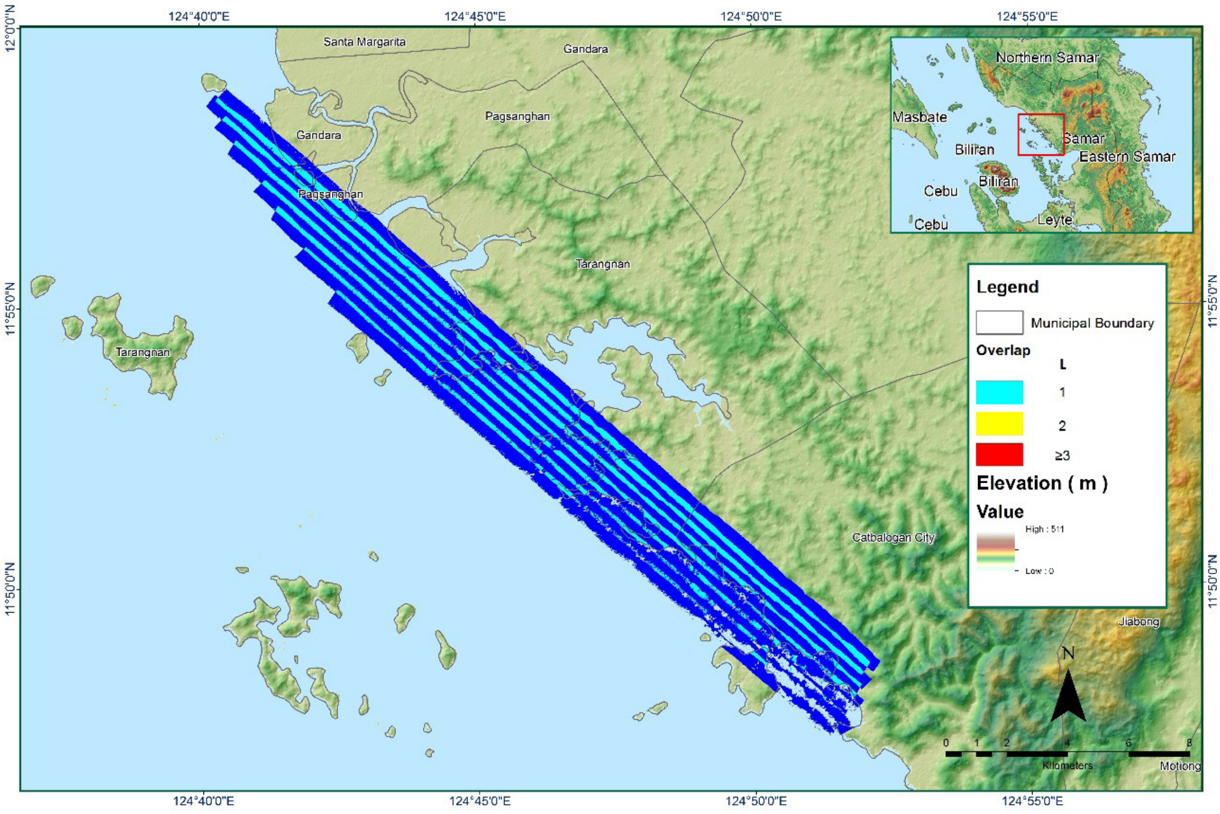


Figure A-8.7. Image of data overlap

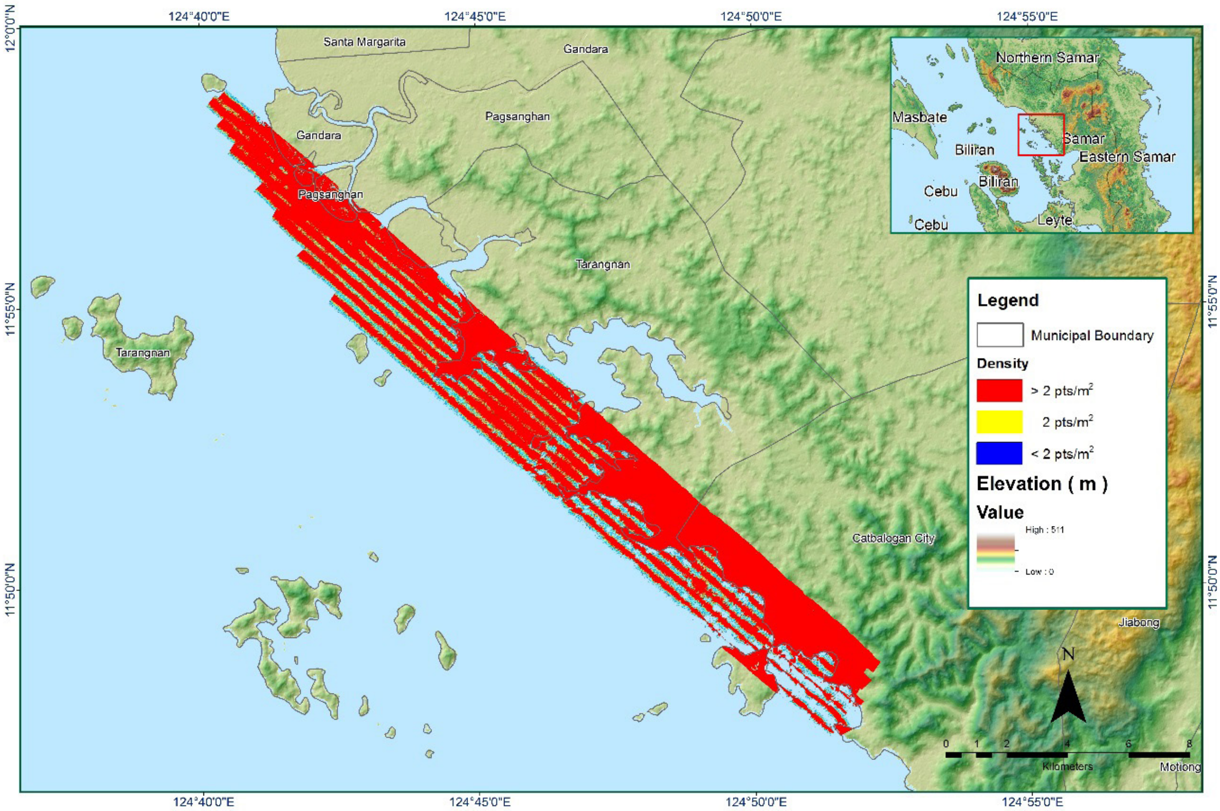


Figure A-8.8. Density map of merged LiDAR data

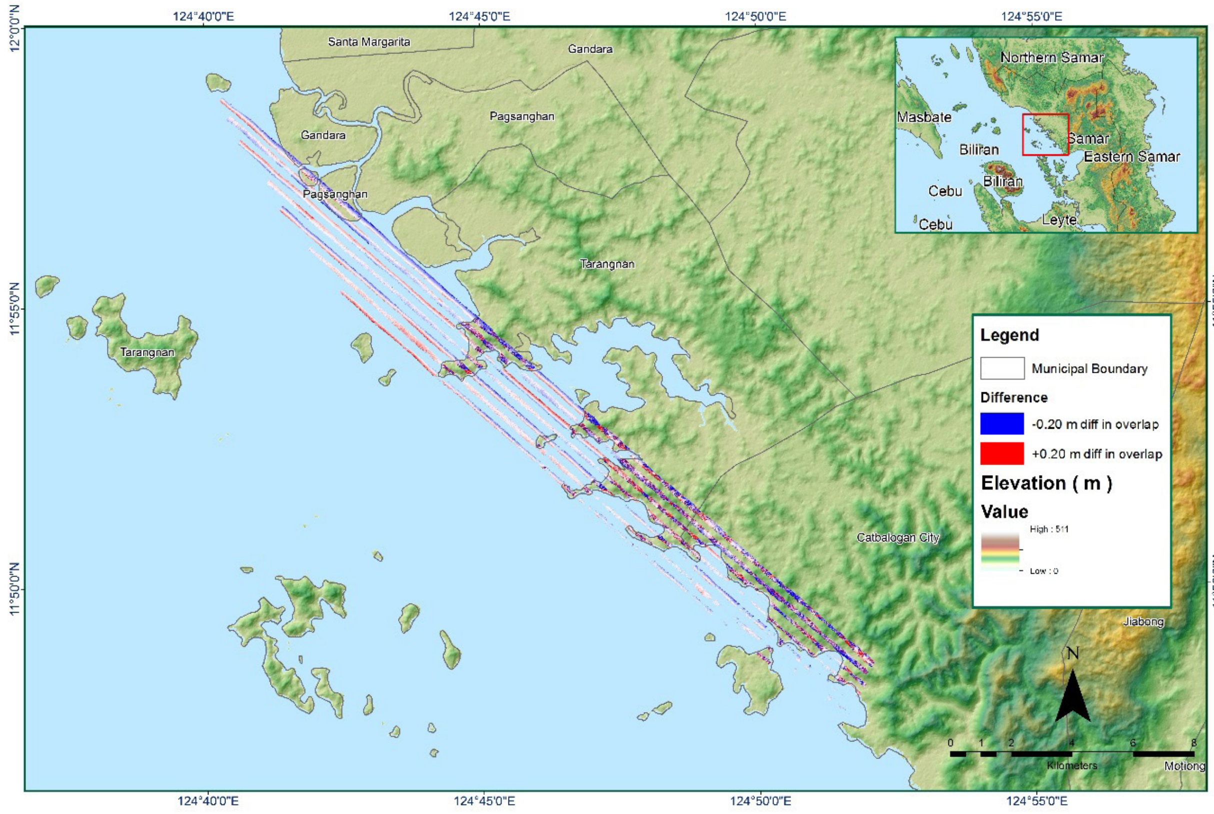


Figure A-8.9. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk33D

Flight Area	Calbayog
Mission Name	Blk33D
Inclusive Flights	10235L
RawLaser	11.52 GB
GnssImu	650 MB
Image	49.5 GB
Transfer date	11/29/2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Combined Separation (-0.1 up to 0.1)	Yes
Estimated Position Accuracy (in cm)	
Estimated Standard Devation for North Position (<4.0 cm)	0.70
Estimated Standard Devation for East Position (<4.0 cm)	0.70
Estimated Standard Devation for Height Position (<8.0 cm)	1.15
Minimum % overlap (>25)	52.90
Ave point cloud density per sq.m. (>2.0)	17.72
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	78
Maximum Height	336.44 m
Minimum Height	54.61 m
Classification (# of points)	
Ground	84,549,091
Low vegetation	72,774,213
Medium vegetation	184,192,909
High vegetation	389,527,929
Building	34,689,199
Orthophoto	Yes
Processed by	Engr. James Kevin Dimaculangan, Engr. Harmond Santos, Engr. Gladys Mae Apat

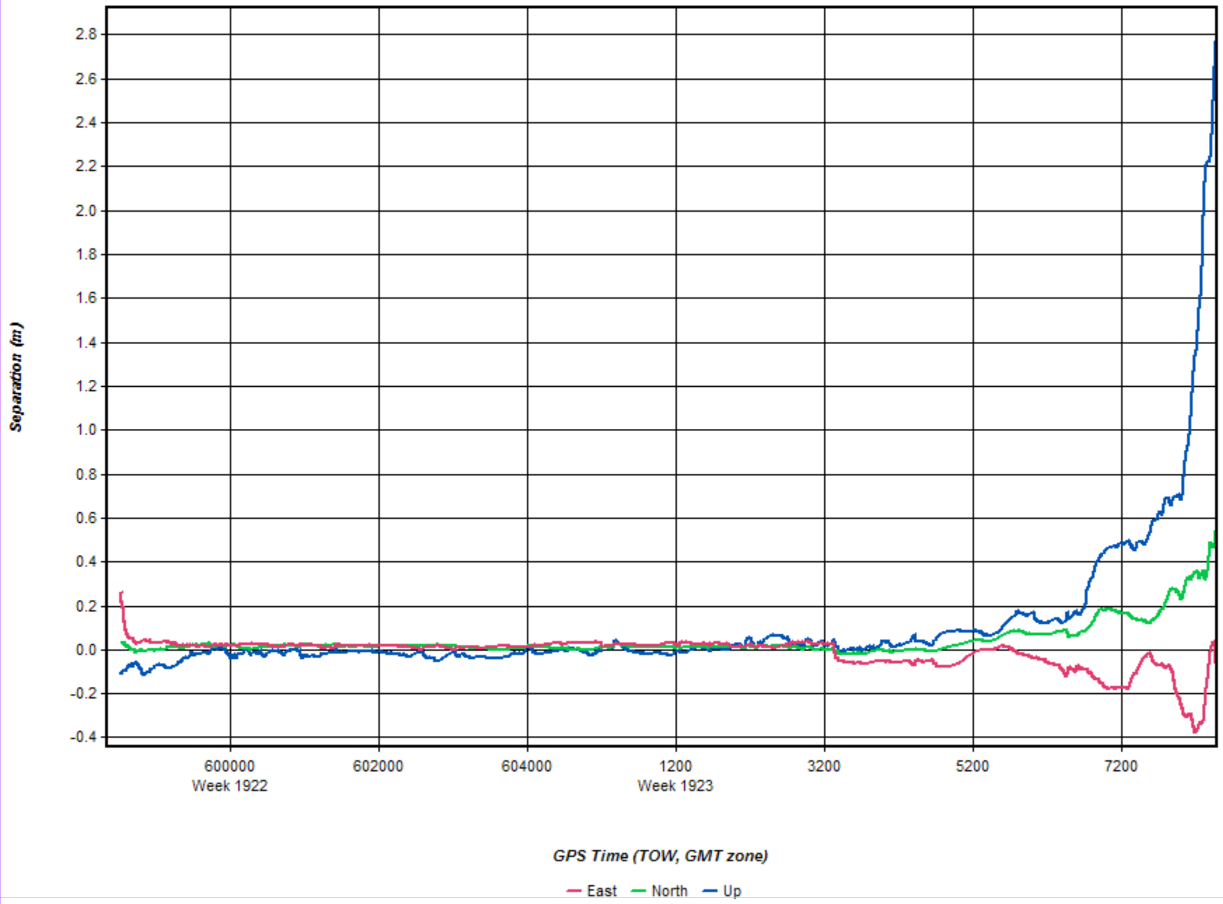


Figure A-8.10. Combined Separation

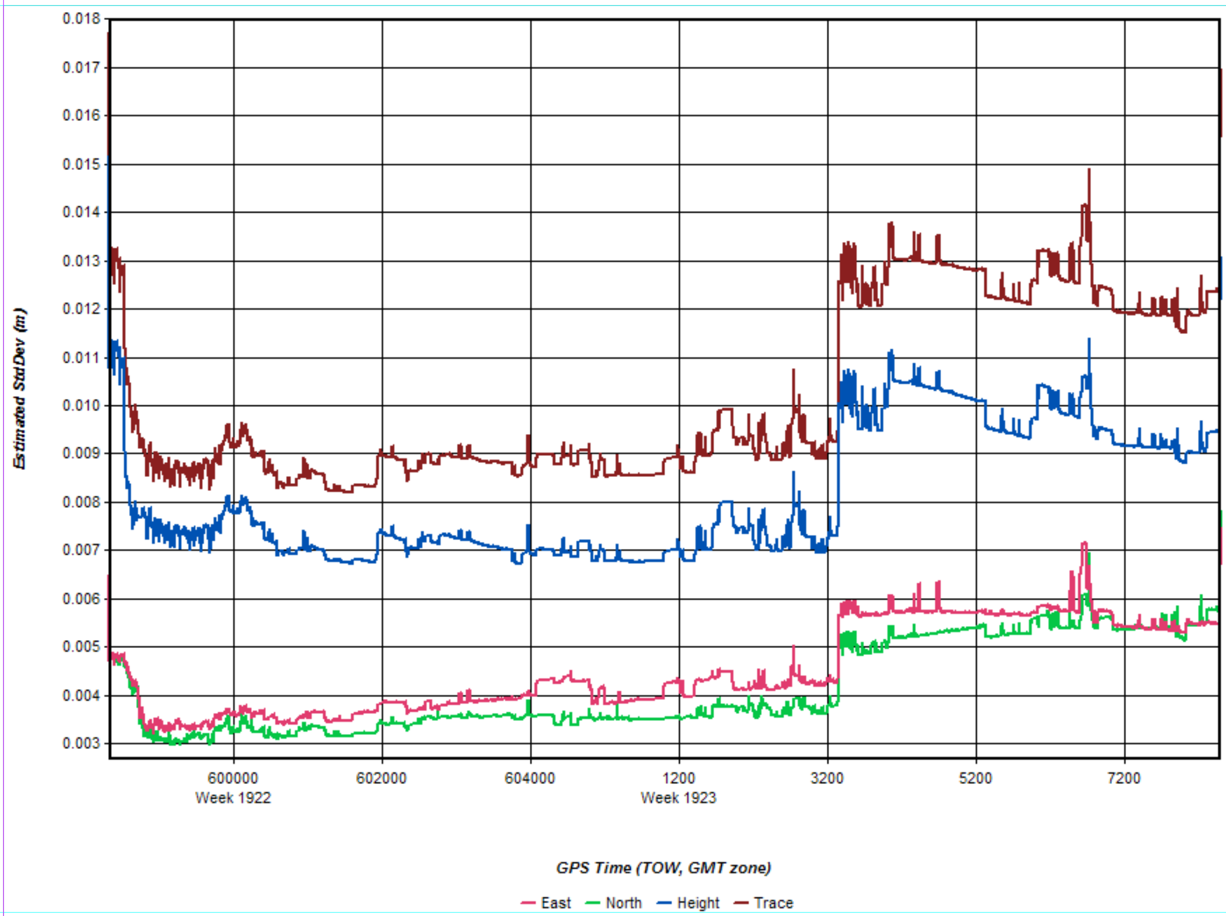


Figure A-8.11. Estimated Position of Accuracy

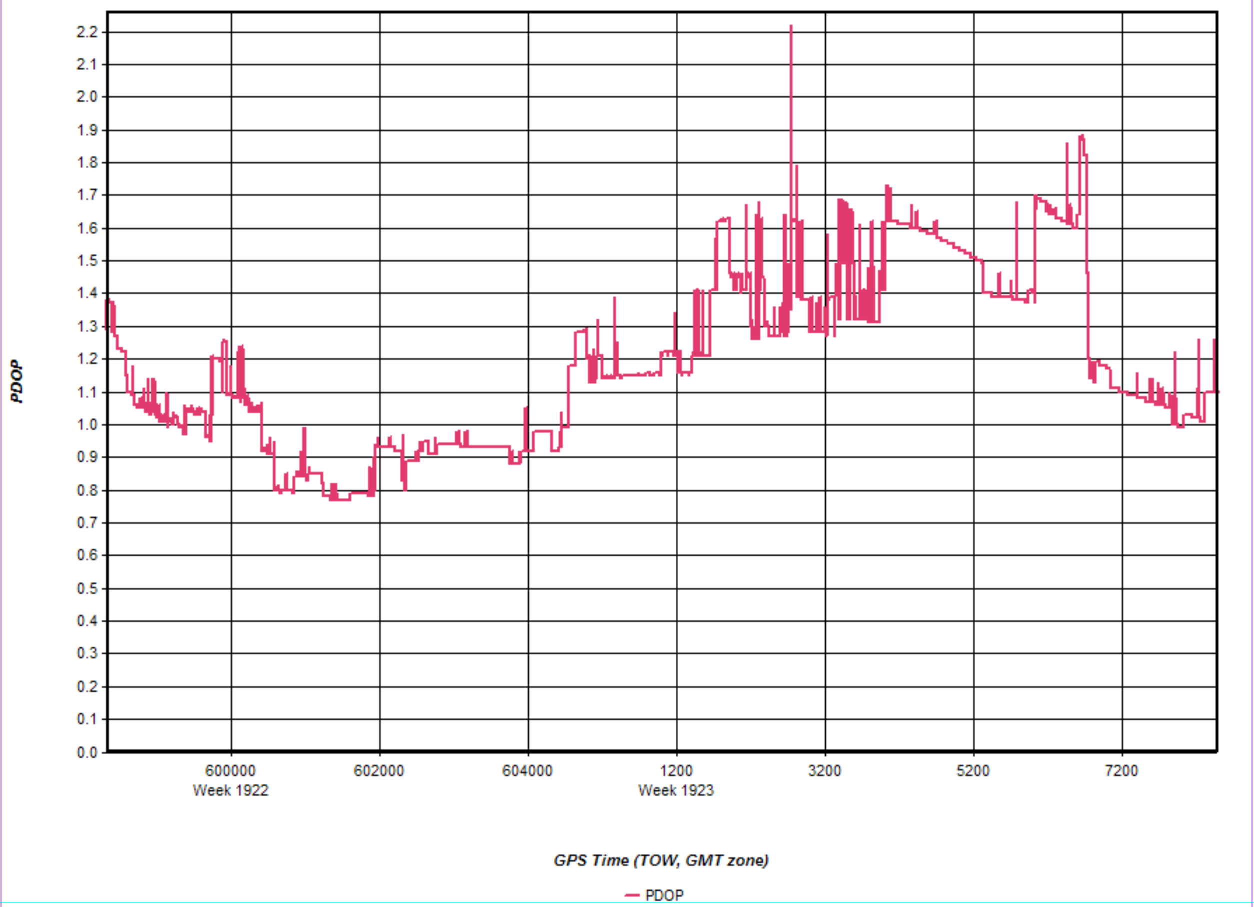


Figure A-8.12. PDOP

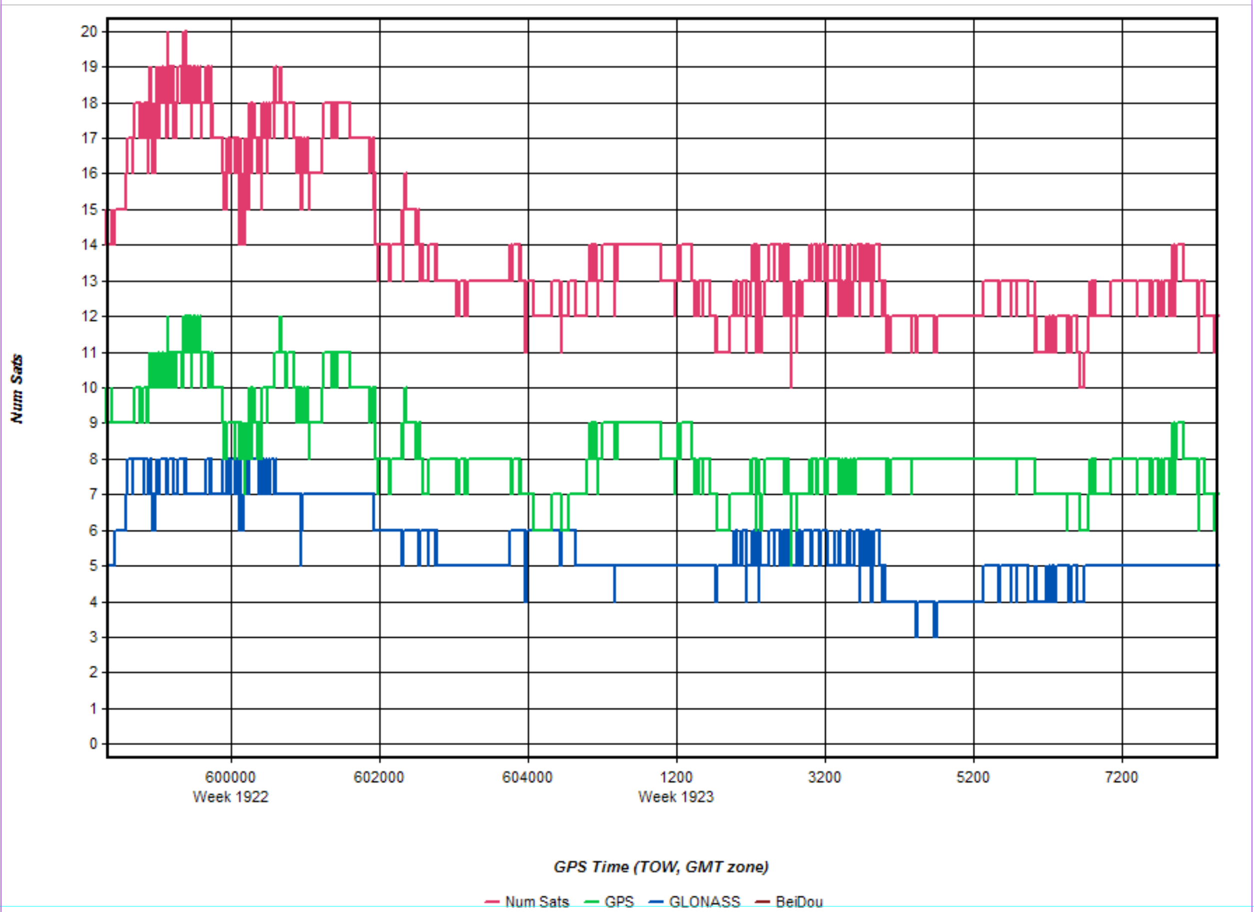


Figure A-8.13. Number of Satellites

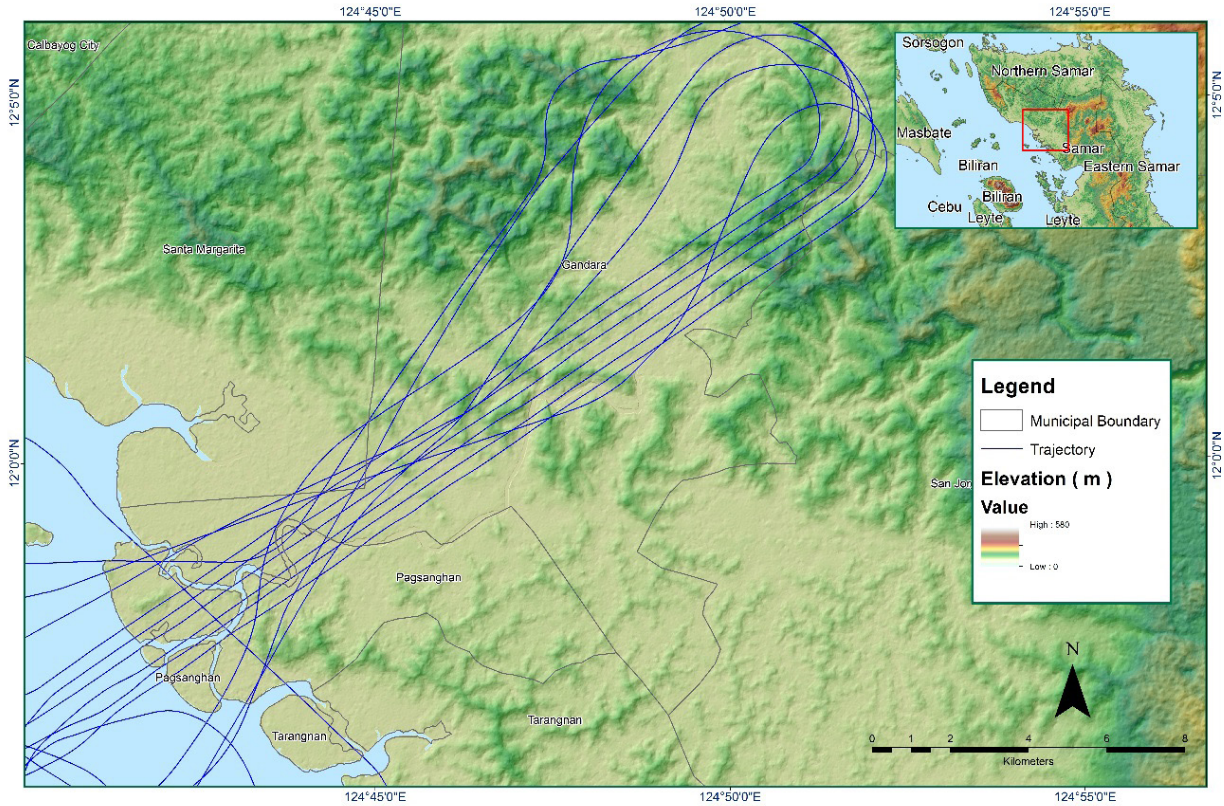


Figure A-8.14. Best Estimated Trajectory

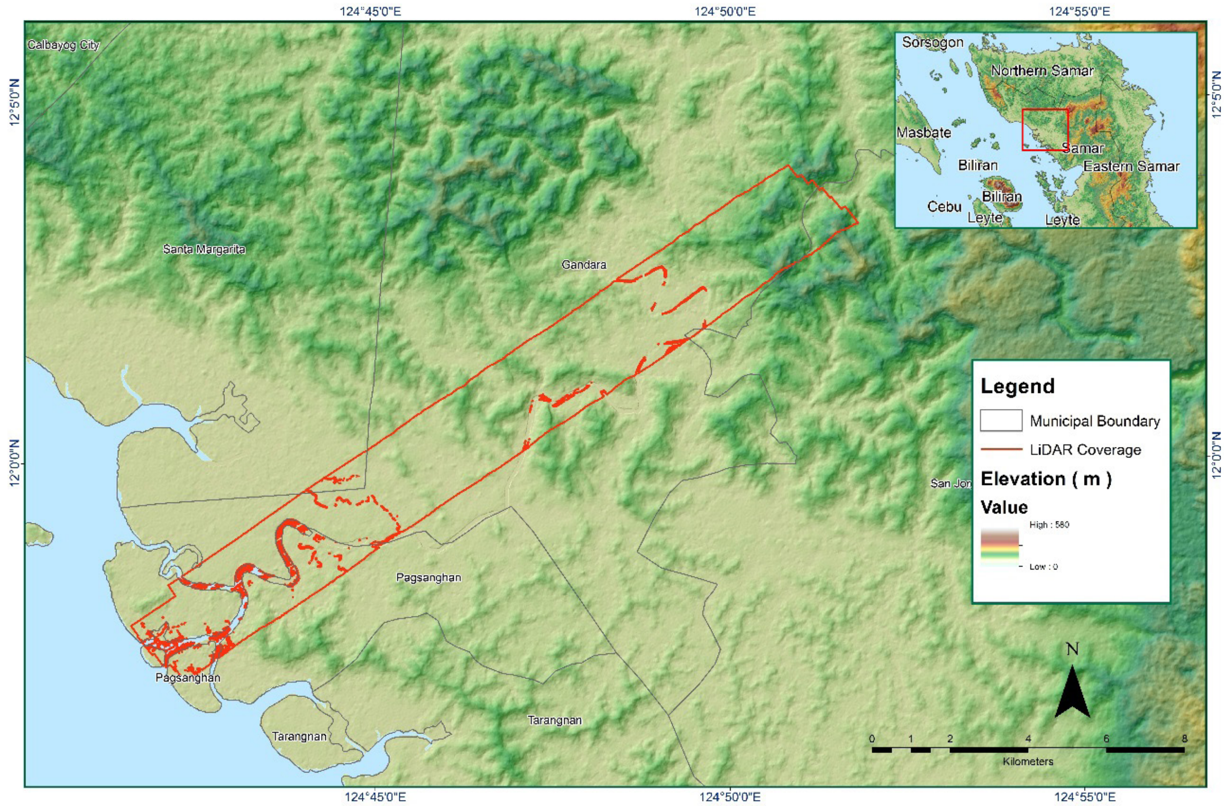


Figure A-8.15. Coverage of LiDAR data

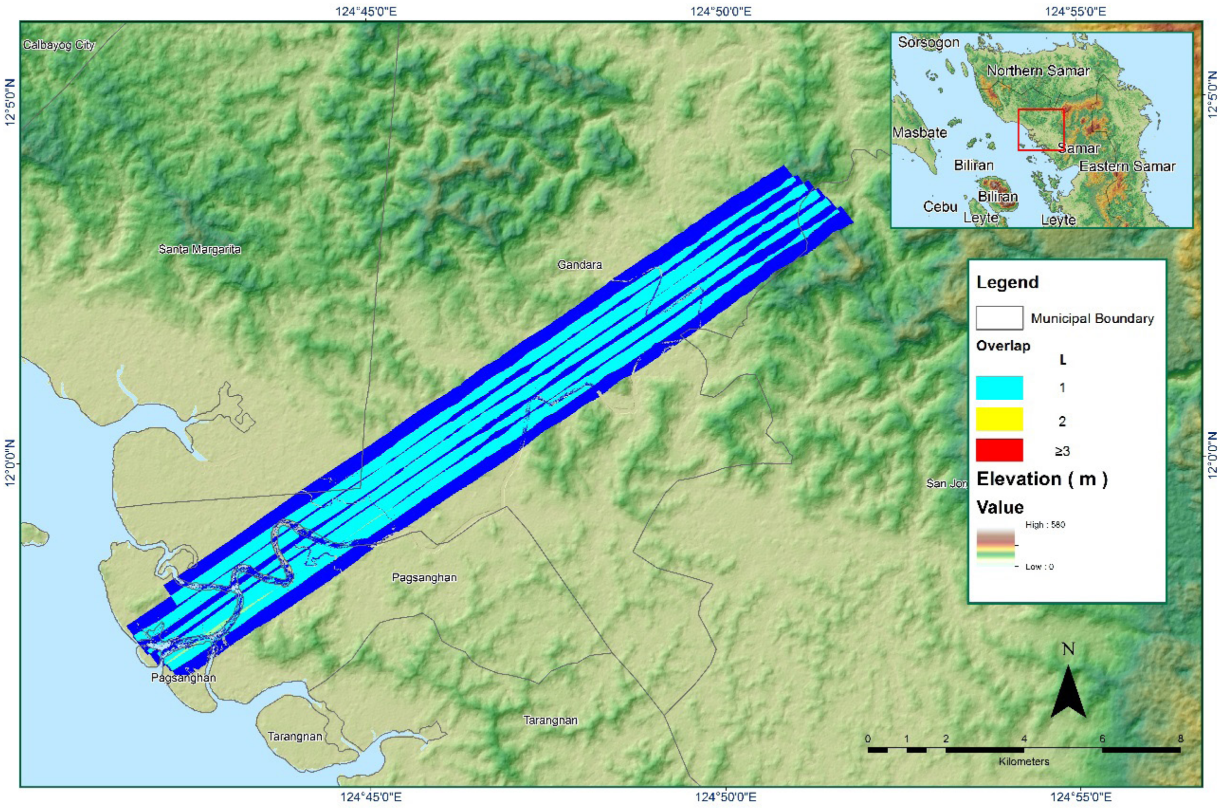


Figure A-8.16. Image of data overlap

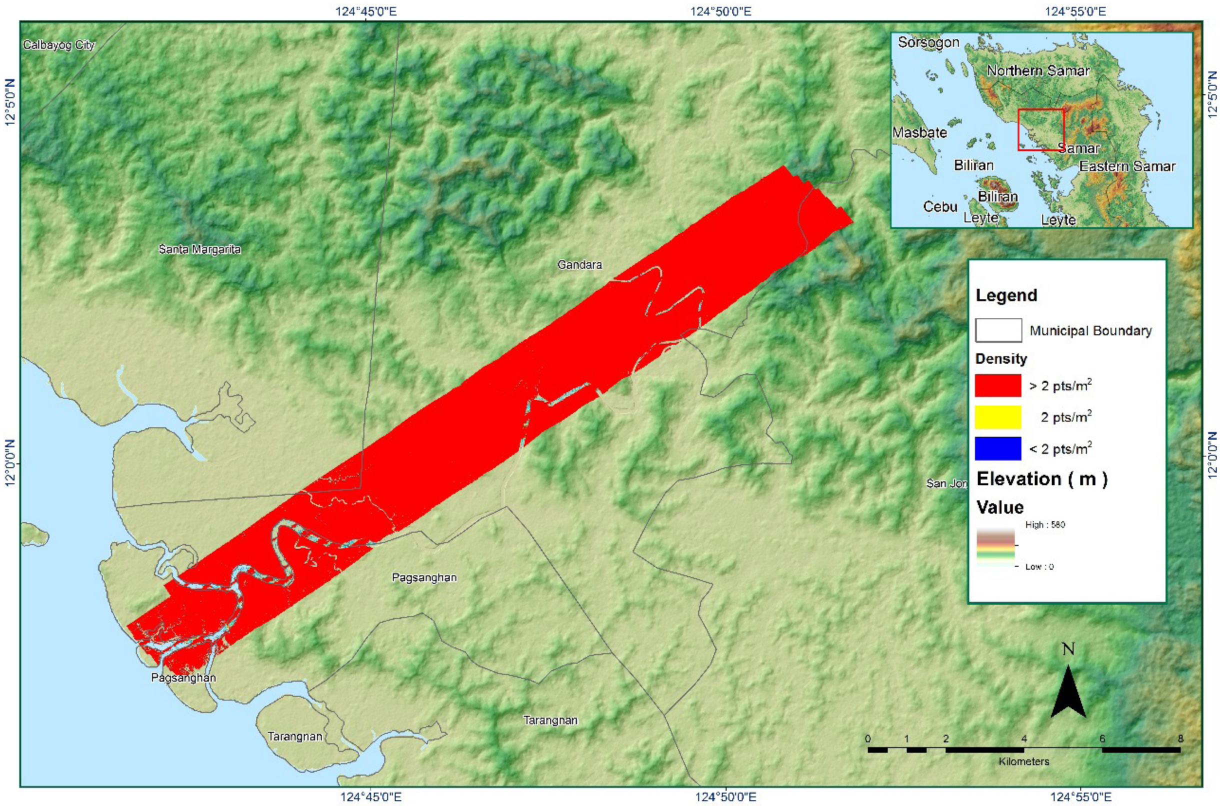


Figure A-8.17. Density map of merged LiDAR data

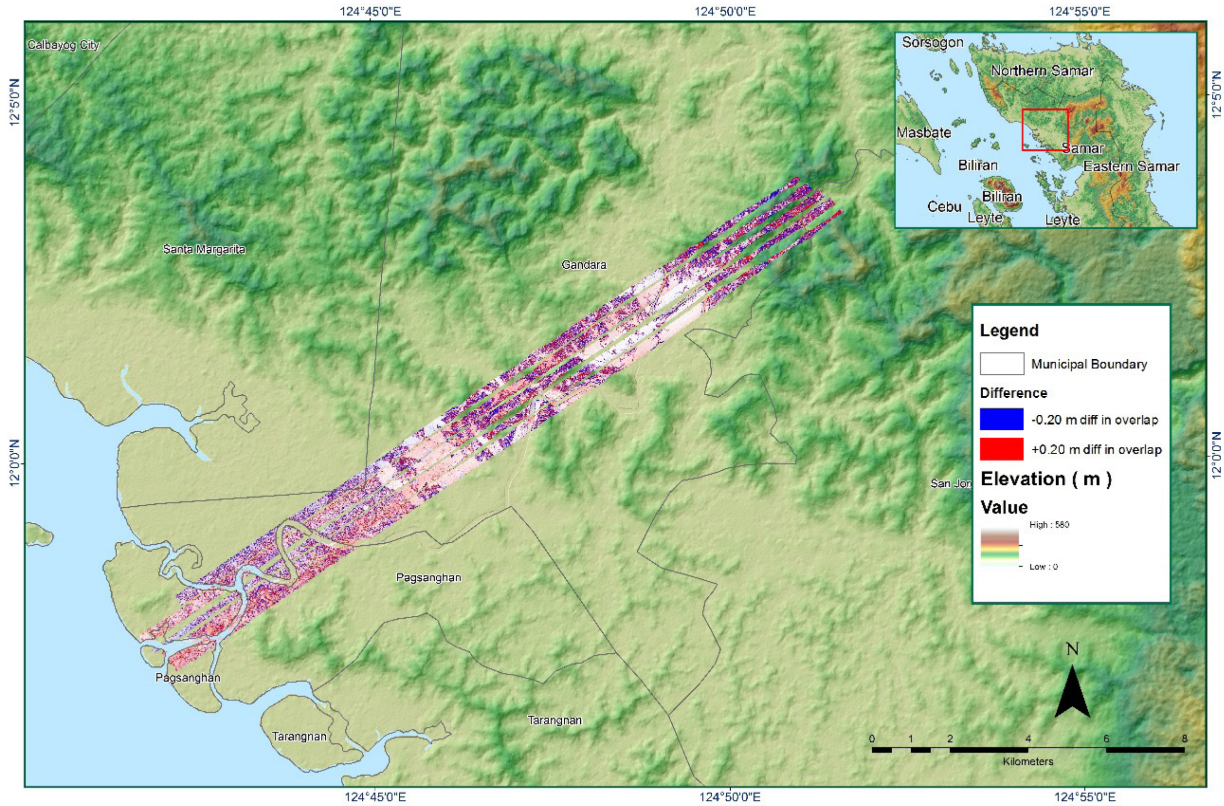


Figure A-8.18. Elevation difference between flight lines

ANNEX 9. Jibatang Model Basin Parameters

Table A-9.1. Jibatang Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W260	6.2787	78	0	2.636	1.0755	Discharge	4.112	0.4	Ratio to Peak	0.48
W270	7.7403	78	0	4.1778	1.70453	Discharge	6.3953	0.4	Ratio to Peak	0.48
W280	11.887	78	0	2.2006	0.89786	Discharge	6.6183	0.4	Ratio to Peak	0.48
W290	12.375	78	0	1.8043	0.73616	Discharge	6.9127	0.4	Ratio to Peak	0.48
W300	10.492	78	0	4.9132	1.8504	Discharge	6.5381	0.4	Ratio to Peak	0.48
W310	10.547	78	0	0.21171	0.34551	Discharge	4.4583	0.4	Ratio to Peak	0.48
W320	13.68	78	0	0.7278	1.1877	Discharge	10.703	0.4	Ratio to Peak	0.48
W330	23.357132	78	0	1.1113	1.81362	Discharge	2.8297	0.4	Ratio to Peak	0.48
W340	21.521	78	0	1.3396	2.18622	Discharge	8.2853	0.4	Ratio to Peak	0.48
W350	33.867	78	0	3.664	5.98	Discharge	4.7879	0.4	Ratio to Peak	0.48
W360	17	78	0	0.8947	1.46017	Discharge	4.2985	0.4	Ratio to Peak	0.48
W370	34.068	68	0	1.3587	2.21748	Discharge	19.462	0.4	Ratio to Peak	0.48
W380	36.876	68	0	1.7271	2.8187	Discharge	7.3825	0.4	Ratio to Peak	0.48
W390	27.705	68	0	9.7093	15.8456	Discharge	5.1267	0.4	Ratio to Peak	0.48
W400	35.102983	68	0	5.8087	9.47979	Discharge	4.4743	0.4	Ratio to Peak	0.48
W410	35.982	68	0	6.9182	11.29046	Discharge	19.784822	0.4	Ratio to Peak	0.48
W420	33.867	68	0	5.7064	9.31	Discharge	10.15	0.4	Ratio to Peak	0.48
W430	33.867	68	0	2.4417	3.98	Discharge	4.9814	0.4	Ratio to Peak	0.48

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (cms)	Recession Constant	Threshold Type	Ratio to Peak
W440	33.867	68	0	5.9523	9.71	Discharge	6.7648	0.4	Ratio to Peak	0.48
W450	33.867	72	0	6.9728	11.38	Discharge	1.6348	0.4	Ratio to Peak	0.48
W460	33.867	88	0	3.5146	5.74	Discharge	5.3884	0.4	Ratio to Peak	0.48
W470	33.867	88	0	4.8772	7.96	Discharge	2.191	0.4	Ratio to Peak	0.48
W480	33.867	88	0	11.6931	19.08	Discharge	4.1498	0.4	Ratio to Peak	0.48
W490	33.867	88	0	5.9603	9.73	Discharge	8.4089	0.4	Ratio to Peak	0.48
W500	33.867	88	0	5.3355	8.71	Discharge	0.46105	0.4	Ratio to Peak	0.48

ANNEX 10. Jibatang Model Reach Parameters

Table A-10.1. Jibatang Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	704.47	0.010608	0.04	Trapezoid	70.932	45
R30	Automatic Fixed Interval	5827.4	0.000250275	0.04	Trapezoid	54.488	45
R50	Automatic Fixed Interval	2562.2	0.0016713	0.04	Trapezoid	43.846	45
R60	Automatic Fixed Interval	1495.9	0.000250275	0.04	Trapezoid	41.234	45
R100	Automatic Fixed Interval	6910.8	0.0027958	0.04	Trapezoid	39.58	45
R110	Automatic Fixed Interval	5093.2	0.0019849	0.04	Trapezoid	26.052	45
R120	Automatic Fixed Interval	4839.7	0.000250275	0.04	Trapezoid	18.146	45
R130	Automatic Fixed Interval	7307.2	0.0091268	0.04	Trapezoid	20.342	45
R140	Automatic Fixed Interval	16426	0.0043083	0.04	Trapezoid	10.06	45
R160	Automatic Fixed Interval	2330.7	0.0734835	0.04	Trapezoid	10.06	45
R170	Automatic Fixed Interval	4644.2	0.0178226	0.04	Trapezoid	7.628	45
R200	Automatic Fixed Interval	6818.5	0.0194253	0.04	Trapezoid	17.376	45

ANNEX 11. Jibatang Field Validation Points

Table A-11.1. Jibatang Field Validation Points for the 5-Year Flood Depth Map

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	12.06358499	124.5489406	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
10	12.06457565	124.5403181	0.15	0	-0.15	Heavy Rainfall/ December 16-17, 2016	5 Year
100	12.06736883	124.5591135	0.07	0	-0.07	Heavy Rainfall/ December 16-17, 2016	5 Year
101	12.06847893	124.5607393	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
102	12.06836712	124.5626319	0.05	0	-0.05	Heavy Rainfall/ December 16-17, 2016	5 Year
103	12.06782372	124.5636084	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
104	12.06768014	124.5657178	0.26	0	-0.26	Heavy Rainfall/ December 16-17, 2016	5 Year
105	12.0696586	124.5659708	0.17	0	-0.17	Heavy Rainfall/ December 16-17, 2016	5 Year
106	12.07179724	124.5646559	0.44	0	-0.44	Heavy Rainfall/ December 16-17, 2016	5 Year
107	12.07466528	124.5610599	1.00	0	-1.00	Heavy Rainfall/ December 16-17, 2016	5 Year
108	12.07860586	124.5602753	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
109	12.06982599	124.5682762	0.16	0	-0.16	Heavy Rainfall/ December 16-17, 2016	5 Year
11	12.06511779	124.5393918	0.14	1	0.86	Heavy Rainfall/ December 16-17, 2016	5 Year
110	12.06911478	124.56828	0.16	0	-0.16	Heavy Rainfall/ December 16-17, 2016	5 Year
111	12.06813594	124.5689836	0.10	0	-0.10	Heavy Rainfall/ December 16-17, 2016	5 Year
112	12.06728141	124.5695362	0.30	0	-0.30	Heavy Rainfall/ December 16-17, 2016	5 Year
113	12.06936389	124.5700463	0.35	0	-0.35	Heavy Rainfall/ December 16-17, 2016	5 Year
114	12.06730991	124.5679437	0.09	0	-0.09	Heavy Rainfall/ December 16-17, 2016	5 Year
115	12.06808599	124.5707975	0.09	0	-0.09	Heavy Rainfall/ December 16-17, 2016	5 Year
116	12.06890289	124.5715696	0.09	0	-0.09	Heavy Rainfall/ December 16-17, 2016	5 Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
117	12.06882351	124.5778544	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
118	12.06856753	124.5752217	0.20	0	-0.20	Heavy Rainfall/ December 16-17, 2016	5 Year
119	12.06695267	124.5713012	0.06	0	-0.06	Heavy Rainfall/ December 16-17, 2016	5 Year
12	12.06606846	124.5380592	0.66	1	0.34	Heavy Rainfall/ December 16-17, 2016	5 Year
120	12.06646023	124.5729869	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
121	12.06635336	124.5751647	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
122	12.06605547	124.5775896	0.14	0	-0.14	Heavy Rainfall/ December 16-17, 2016	5 Year
123	12.06546237	124.5792887	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
124	12.06568172	124.5812004	0.08	0	-0.08	Heavy Rainfall/ December 16-17, 2016	5 Year
125	12.0674244	124.5808303	0.17	0	-0.17	Heavy Rainfall/ December 16-17, 2016	5 Year
126	12.06784819	124.579286	0.06	0	-0.06	Heavy Rainfall/ December 16-17, 2016	5 Year
127	12.06900816	124.580632	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
128	12.07346558	124.5795078	0.06	0	-0.06	Heavy Rainfall/ December 16-17, 2016	5 Year
129	12.10357572	124.5501616	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
13	12.06658814	124.5380738	0.84	1	0.16	Heavy Rainfall/ December 16-17, 2016	5 Year
130	12.10330716	124.5508746	0.59	0	-0.59	Heavy Rainfall/ December 16-17, 2016	5 Year
131	12.10518647	124.5555586	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
132	12.10618735	124.5571086	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
133	12.1032158	124.5642142	0.68	0	-0.68	Heavy Rainfall/ December 16-17, 2016	5 Year
134	12.10394184	124.566235	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
135	12.06626376	124.5830552	0.11	0	-0.11	Heavy Rainfall/ December 16-17, 2016	5 Year
136	12.06671043	124.5840003	0.05	0	-0.05	Heavy Rainfall/ December 16-17, 2016	5 Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
137	12.06674497	124.5849194	0.07	0	-0.07	Heavy Rainfall/ December 16-17, 2016	5 Year
138	12.06677439	124.586623	0.08	0	-0.08	Heavy Rainfall/ December 16-17, 2016	5 Year
139	12.06681026	124.5888971	0.07	0	-0.07	Heavy Rainfall/ December 16-17, 2016	5 Year
14	12.06763068	124.5384159	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
140	12.06719331	124.5904683	0.08	0	-0.08	Heavy Rainfall/ December 16-17, 2016	5 Year
141	12.06679836	124.5910594	0.08	0	-0.08	Heavy Rainfall/ December 16-17, 2016	5 Year
142	12.0677508	124.5918031	0.08	0	-0.08	Heavy Rainfall/ December 16-17, 2016	5 Year
143	12.06895209	124.5865521	0.09	0	-0.09	Heavy Rainfall/ December 16-17, 2016	5 Year
144	12.06603209	124.5905611	0.05	0	-0.05	Heavy Rainfall/ December 16-17, 2016	5 Year
145	12.06893549	124.5887845	0.09	0	-0.09	Heavy Rainfall/ December 16-17, 2016	5 Year
146	12.07112409	124.5867892	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
147	12.07069972	124.5889923	0.10	0	-0.10	Heavy Rainfall/ December 16-17, 2016	5 Year
148	12.07366062	124.5861124	0.09	0	-0.09	Heavy Rainfall/ December 16-17, 2016	5 Year
149	12.07461549	124.5876635	0.41	0	-0.41	Heavy Rainfall/ December 16-17, 2016	5 Year
15	12.06807777	124.5398898	0.14	0	-0.14	Heavy Rainfall/ December 16-17, 2016	5 Year
151	12.07773079	124.5890723	0.06	0	-0.06	Heavy Rainfall/ December 16-17, 2016	5 Year
152	12.07826237	124.5928703	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
153	12.07752242	124.5940411	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
154	12.07927818	124.5891233	0.45	0	-0.45	Heavy Rainfall/ December 16-17, 2016	5 Year
155	12.08168244	124.5906153	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
156	12.08451418	124.5865614	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
157	12.07843822	124.586561	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
158	12.07658214	124.5689295	0.85	0	-0.85	Heavy Rainfall/ December 16-17, 2016	5 Year
159	12.07401761	124.5916212	0.93	0	-0.93	Heavy Rainfall/ December 16-17, 2016	5 Year
16	12.06791927	124.5407791	0.22	0	-0.22	Heavy Rainfall/ December 16-17, 2016	5 Year
160	12.07187276	124.5930984	0.64	0	-0.64	Heavy Rainfall/ December 16-17, 2016	5 Year
162	12.06438672	124.5917929	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
163	12.06581684	124.5922505	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
164	12.06794668	124.5938588	0.10	0	-0.10	Heavy Rainfall/ December 16-17, 2016	5 Year
165	12.07028867	124.5942182	0.05	0	-0.05	Heavy Rainfall/ December 16-17, 2016	5 Year
168	12.07383388	124.5989135	0.86	0	-0.86	Heavy Rainfall/ December 16-17, 2016	5 Year
17	12.06822312	124.5411585	0.26	0	-0.26	Heavy Rainfall/ December 16-17, 2016	5 Year
170	12.07868993	124.5996928	0.42	0	-0.42	Heavy Rainfall/ December 16-17, 2016	5 Year
171	12.07909964	124.6014044	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
172	12.08013757	124.6030686	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
173	12.08195661	124.6044945	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
174	12.06896047	124.595218	0.06	0	-0.06	Heavy Rainfall/ December 16-17, 2016	5 Year
175	12.0679652	124.5967256	0.05	0	-0.05	Heavy Rainfall/ December 16-17, 2016	5 Year
176	12.06668663	124.5964114	0.07	0	-0.07	Heavy Rainfall/ December 16-17, 2016	5 Year
177	12.06588582	124.5970164	0.07	0	-0.07	Heavy Rainfall/ December 16-17, 2016	5 Year
178	12.0672519	124.5981163	0.05	0	-0.05	Heavy Rainfall/ December 16-17, 2016	5 Year
179	12.06525073	124.5977386	0.08	0	-0.08	Heavy Rainfall/ December 16-17, 2016	5 Year
18	12.06868571	124.5411823	0.26	0	-0.26	Heavy Rainfall/ December 16-17, 2016	5 Year
180	12.06657398	124.5992808	0.09	0	-0.09	Heavy Rainfall/ December 16-17, 2016	5 Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
181	12.06893306	124.6004451	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
182	12.06982045	124.5988622	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
183	12.06528375	124.5996537	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
184	12.06403208	124.6004355	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
185	12.06911478	124.6015017	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
186	12.07100934	124.6070917	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
187	12.07041205	124.6094259	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
188	12.07381259	124.6101516	0.20	0	-0.20	Heavy Rainfall/ December 16-17, 2016	5 Year
189	12.07519711	124.611623	0.29	0	-0.29	Heavy Rainfall/ December 16-17, 2016	5 Year
19	12.06867004	124.5418156	0.37	0	-0.37	Heavy Rainfall/ December 16-17, 2016	5 Year
190	12.06588917	124.6017433	0.19	0	-0.19	Heavy Rainfall/ December 16-17, 2016	5 Year
191	12.06339472	124.6022573	0.07	0	-0.07	Heavy Rainfall/ December 16-17, 2016	5 Year
192	12.06270816	124.6049091	0.10	0	-0.10	Heavy Rainfall/ December 16-17, 2016	5 Year
193	12.06489818	124.605791	0.40	0	-0.40	Heavy Rainfall/ December 16-17, 2016	5 Year
194	12.06421397	124.6078302	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
195	12.06531099	124.610362	0.05	0	-0.05	Heavy Rainfall/ December 16-17, 2016	5 Year
196	12.06699726	124.6105915	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
197	12.06320336	124.6101613	0.27	0	-0.27	Heavy Rainfall/ December 16-17, 2016	5 Year
198	12.06282525	124.6122805	0.17	0	-0.17	Heavy Rainfall/ December 16-17, 2016	5 Year
199	12.06203098	124.606177	0.11	0	-0.11	Heavy Rainfall/ December 16-17, 2016	5 Year
2	12.0635725	124.5483334	0.12	0	-0.12	Heavy Rainfall/ December 16-17, 2016	5 Year
20	12.06809143	124.5423317	0.34	0	-0.34	Heavy Rainfall/ December 16-17, 2016	5 Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
200	12.06082977	124.6086889	0.13	0	-0.13	Heavy Rainfall/ December 16-17, 2016	5 Year
201	12.06002385	124.6103054	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
202	12.05954734	124.6121847	0.08	0	-0.08	Heavy Rainfall/ December 16-17, 2016	5 Year
203	12.0618641	124.6150298	0.37	0	-0.37	Heavy Rainfall/ December 16-17, 2016	5 Year
204	12.05802276	124.6145184	0.14	0	-0.14	Heavy Rainfall/ December 16-17, 2016	5 Year
205	12.0565063	124.6179061	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
206	12.06062618	124.6185346	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
207	12.05597573	124.6224208	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
208	12.05543233	124.6258443	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
209	12.0552579	124.6289843	0.19	0	-0.19	Heavy Rainfall/ December 16-17, 2016	5 Year
21	12.06870834	124.5426369	0.34	0	-0.34	Heavy Rainfall/ December 16-17, 2016	5 Year
210	12.0537127	124.6288998	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
211	12.05268122	124.6303878	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
212	12.0777841	124.5181586	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
213	12.07739216	124.5189199	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
214	12.07986005	124.5176119	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
215	12.08838729	124.5202685	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
216	12.09539532	124.5198597	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
217	12.09335575	124.5294864	0.64	1	0.36	Heavy Rainfall/ December 16-17, 2016	5 Year
218	12.09039945	124.5298249	0.88	1	0.12	Heavy Rainfall/ December 16-17, 2016	5 Year
219	12.08869114	124.5301818	1.67	1	-0.67	Heavy Rainfall/ December 16-17, 2016	5 Year
22	12.06796219	124.5429725	0.39	0	-0.39	Heavy Rainfall/ December 16-17, 2016	5 Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
220	12.09262954	124.5308039	0.83	1	0.17	Heavy Rainfall/ December 16-17, 2016	5 Year
221	12.09421816	124.5308983	1.13	1	-0.13	Heavy Rainfall/ December 16-17, 2016	5 Year
222	12.09348818	124.5308801	0.74	1	0.26	Heavy Rainfall/ December 16-17, 2016	5 Year
223	12.09703775	124.5308029	0.73	1	0.27	Heavy Rainfall/ December 16-17, 2016	5 Year
224	12.09836955	124.5306838	0.45	1	0.55	Heavy Rainfall/ December 16-17, 2016	5 Year
225	12.09829026	124.5315162	0.18	1	0.82	Heavy Rainfall/ December 16-17, 2016	5 Year
226	12.09722056	124.5343163	0.36	1	0.64	Heavy Rainfall/ December 16-17, 2016	5 Year
227	12.09892737	124.5327192	0.03	0.5	0.47	Heavy Rainfall/ December 16-17, 2016	5 Year
228	12.10669999	124.5307362	1.24	1	-0.24	Heavy Rainfall/ December 16-17, 2016	5 Year
229	12.10964656	124.5318757	1.09	1	-0.09	Heavy Rainfall/ December 16-17, 2016	5 Year
23	12.06527679	124.542309	0.16	0	-0.16	Heavy Rainfall/ December 16-17, 2016	5 Year
231	12.11662266	124.5349571	0.03	1	0.97	Heavy Rainfall/ December 16-17, 2016	5 Year
232	12.12202555	124.5364856	0.03	1	0.97	Heavy Rainfall/ December 16-17, 2016	5 Year
234	12.12916257	124.5366171	1.49	1	-0.49	Heavy Rainfall/ December 16-17, 2016	5 Year
236	12.1317768	124.5363473	1.58	1	-0.58	Heavy Rainfall/ December 16-17, 2016	5 Year
237	12.13092294	124.5361166	1.58	1	-0.58	Heavy Rainfall/ December 16-17, 2016	5 Year
238	12.13281674	124.5361909	1.38	0.5	-0.88	Heavy Rainfall/ December 16-17, 2016	5 Year
239	12.13470678	124.5387191	0.08	0.5	0.42	Heavy Rainfall/ December 16-17, 2016	5 Year
24	12.06987645	124.5432015	0.07	0	-0.07	Heavy Rainfall/ December 16-17, 2016	5 Year
240	12.13598217	124.5402126	0.04	0.5	0.46	Heavy Rainfall/ December 16-17, 2016	5 Year
241	12.08255039	124.5395801	0.03	0.5	0.47	Heavy Rainfall/ December 16-17, 2016	5 Year
242	12.07979274	124.5445859	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
243	12.07510441	124.5403645	0.14	0.5	0.36	Heavy Rainfall/ December 16-17, 2016	5 Year
244	12.08270436	124.5523776	0.18	0	-0.18	Heavy Rainfall/ December 16-17, 2016	5 Year
245	12.07334965	124.5627289	0.45	0	-0.45	Heavy Rainfall/ December 16-17, 2016	5 Year
246	12.07209748	124.5715331	0.12	0	-0.12	Heavy Rainfall/ December 16-17, 2016	5 Year
247	12.07014626	124.5779448	0.25	0	-0.25	Heavy Rainfall/ December 16-17, 2016	5 Year
248	12.07026822	124.572348	0.21	0	-0.21	Heavy Rainfall/ December 16-17, 2016	5 Year
249	12.06853886	124.5803889	0.05	0	-0.05	Heavy Rainfall/ December 16-17, 2016	5 Year
25	12.07085964	124.542356	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
250	12.07025589	124.5913875	0.57	0	-0.57	Heavy Rainfall/ December 16-17, 2016	5 Year
26	12.07139215	124.5435844	0.13	0	-0.13	Heavy Rainfall/ December 16-17, 2016	5 Year
27	12.07083467	124.5468659	0.34	0	-0.34	Heavy Rainfall/ December 16-17, 2016	5 Year
28	12.07404309	124.5434901	0.07	0	-0.07	Heavy Rainfall/ December 16-17, 2016	5 Year
29	12.07349969	124.5419893	0.14	0.5	0.36	Heavy Rainfall/ December 16-17, 2016	5 Year
3	12.06371474	124.5477372	0.05	0	-0.05	Heavy Rainfall/ December 16-17, 2016	5 Year
30	12.07310641	124.5401473	0.05	0.5	0.45	Heavy Rainfall/ December 16-17, 2016	5 Year
31	12.07396866	124.5386686	0.04	0.5	0.46	Heavy Rainfall/ December 16-17, 2016	5 Year
32	12.07446948	124.539301	0.07	0.5	0.43	Heavy Rainfall/ December 16-17, 2016	5 Year
33	12.07440896	124.5408135	0.08	0.5	0.42	Heavy Rainfall/ December 16-17, 2016	5 Year
34	12.07532049	124.5423211	0.06	0.5	0.44	Heavy Rainfall/ December 16-17, 2016	5 Year
35	12.07647376	124.5424887	0.03	0.5	0.47	Heavy Rainfall/ December 16-17, 2016	5 Year
36	12.07731388	124.5422805	0.03	0.5	0.47	Heavy Rainfall/ December 16-17, 2016	5 Year
37	12.07873017	124.5424982	0.04	0.5	0.46	Heavy Rainfall/ December 16-17, 2016	5 Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
38	12.08147624	124.5408907	0.04	0.5	0.46	Heavy Rainfall/ December 16-17, 2016	5 Year
39	12.08381739	124.5382221	0.19	0.5	0.31	Heavy Rainfall/ December 16-17, 2016	5 Year
4	12.06378574	124.5466172	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
40	12.08531876	124.5352243	0.08	0.5	0.42	Heavy Rainfall/ December 16-17, 2016	5 Year
41	12.0918983	124.5310133	0.92	1	0.08	Heavy Rainfall/ December 16-17, 2016	5 Year
42	12.09529582	124.5310852	1.04	1	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
43	12.07720893	124.5371783	0.03	0.5	0.47	Heavy Rainfall/ December 16-17, 2016	5 Year
44	12.07778603	124.5197199	0.06	0	-0.06	Heavy Rainfall/ December 16-17, 2016	5 Year
45	12.07836606	124.5172946	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
46	12.08030907	124.5146494	0.08	0	-0.08	Heavy Rainfall/ December 16-17, 2016	5 Year
47	12.08106168	124.5161281	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
49	12.08621822	124.5191176	0.06	0	-0.06	Heavy Rainfall/ December 16-17, 2016	5 Year
5	12.06406728	124.5454499	0.06	0	-0.06	Heavy Rainfall/ December 16-17, 2016	5 Year
50	12.08762395	124.5194132	0.25	0	-0.25	Heavy Rainfall/ December 16-17, 2016	5 Year
51	12.09110722	124.5297244	1.20	1	-0.20	Heavy Rainfall/ December 16-17, 2016	5 Year
52	12.09303388	124.5250086	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
53	12.09413141	124.5213357	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
54	12.09633652	124.5178401	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
55	12.10415231	124.5237293	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
58	12.14138028	124.5264732	0.36	0	-0.36	Heavy Rainfall/ December 16-17, 2016	5 Year
59	12.14221713	124.5258978	0.72	0	-0.72	Heavy Rainfall/ December 16-17, 2016	5 Year
6	12.06402144	124.5449723	0.06	0	-0.06	Heavy Rainfall/ December 16-17, 2016	5 Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
60	12.09778927	124.5332147	0.03	0.5	0.47	Heavy Rainfall/ December 16-17, 2016	5 Year
61	12.09987243	124.5328639	0.58	0.5	-0.08	Heavy Rainfall/ December 16-17, 2016	5 Year
62	12.09990889	124.5305465	1.86	1	-0.86	Heavy Rainfall/ December 16-17, 2016	5 Year
63	12.10211283	124.5305197	1.27	1	-0.27	Heavy Rainfall/ December 16-17, 2016	5 Year
64	12.104256	124.5302549	1.88	1	-0.88	Heavy Rainfall/ December 16-17, 2016	5 Year
65	12.10868265	124.5316398	1.64	1	-0.64	Heavy Rainfall/ December 16-17, 2016	5 Year
67	12.12022101	124.5360819	0.03	1	0.97	Heavy Rainfall/ December 16-17, 2016	5 Year
68	12.12439704	124.5367575	0.21	1	0.79	Heavy Rainfall/ December 16-17, 2016	5 Year
69	12.12205094	124.5382071	0.03	0.5	0.47	Heavy Rainfall/ December 16-17, 2016	5 Year
7	12.06430114	124.5440854	0.15	0	-0.15	Heavy Rainfall/ December 16-17, 2016	5 Year
76	12.12896065	124.537965	1.16	0.5	-0.66	Heavy Rainfall/ December 16-17, 2016	5 Year
77	12.13017904	124.5385844	0.20	0	-0.20	Heavy Rainfall/ December 16-17, 2016	5 Year
78	12.13228273	124.5367375	1.23	0.5	-0.73	Heavy Rainfall/ December 16-17, 2016	5 Year
79	12.13379164	124.5360306	0.29	0.5	0.21	Heavy Rainfall/ December 16-17, 2016	5 Year
8	12.06456559	124.5430357	0.07	0	-0.07	Heavy Rainfall/ December 16-17, 2016	5 Year
81	12.14855377	124.5355636	0.03	0.5	0.47	Heavy Rainfall/ December 16-17, 2016	5 Year
82	12.15713298	124.5363622	0.19	0.5	0.31	Heavy Rainfall/ December 16-17, 2016	5 Year
84	12.15275553	124.5362667	0.03	0.5	0.47	Heavy Rainfall/ December 16-17, 2016	5 Year
85	12.08580717	124.5375592	0.03	0.5	0.47	Heavy Rainfall/ December 16-17, 2016	5 Year
86	12.08489053	124.541228	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
87	12.08660421	124.5420158	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
88	12.08417832	124.5440804	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event/Date	Rain Return/ Scenario
	Lat	Long					
89	12.08281718	124.544722	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
9	12.06467489	124.5417477	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
90	12.08036481	124.5455922	0.06	0	-0.06	Heavy Rainfall/ December 16-17, 2016	5 Year
91	12.07913753	124.5462	0.18	0	-0.18	Heavy Rainfall/ December 16-17, 2016	5 Year
92	12.07386665	124.5478913	0.05	0	-0.05	Heavy Rainfall/ December 16-17, 2016	5 Year
93	12.07058614	124.5487115	0.43	0	-0.43	Heavy Rainfall/ December 16-17, 2016	5 Year
94	12.06992833	124.5511831	0.05	0	-0.05	Heavy Rainfall/ December 16-17, 2016	5 Year
95	12.06969322	124.5527803	0.04	0	-0.04	Heavy Rainfall/ December 16-17, 2016	5 Year
96	12.08238719	124.5506028	0.82	0	-0.82	Heavy Rainfall/ December 16-17, 2016	5 Year
97	12.08457872	124.5461635	0.03	0	-0.03	Heavy Rainfall/ December 16-17, 2016	5 Year
98	12.08121448	124.5552302	0.46	0	-0.46	Heavy Rainfall/ December 16-17, 2016	5 Year

ANNEX 12. Educational Institutions Affected by Flooding in JibatanFloodplain

Table A-12.1. Educational Institutions Affected by Flooding in the Jibatan Floodplain

Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year

ANNEX 13. Medical Institutions Affected by Flooding in Jibatang Floodplain

Table A-13.1. Medical Institutions Affected by Flooding in the Jibatang Floodplain

Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year

UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
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