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

LiDAR Surveys and Flood Mapping of Lagonoy River

University of the Philippines Training Center for Applied Geodesy and Photogrammetry
Ateneo de Naga University

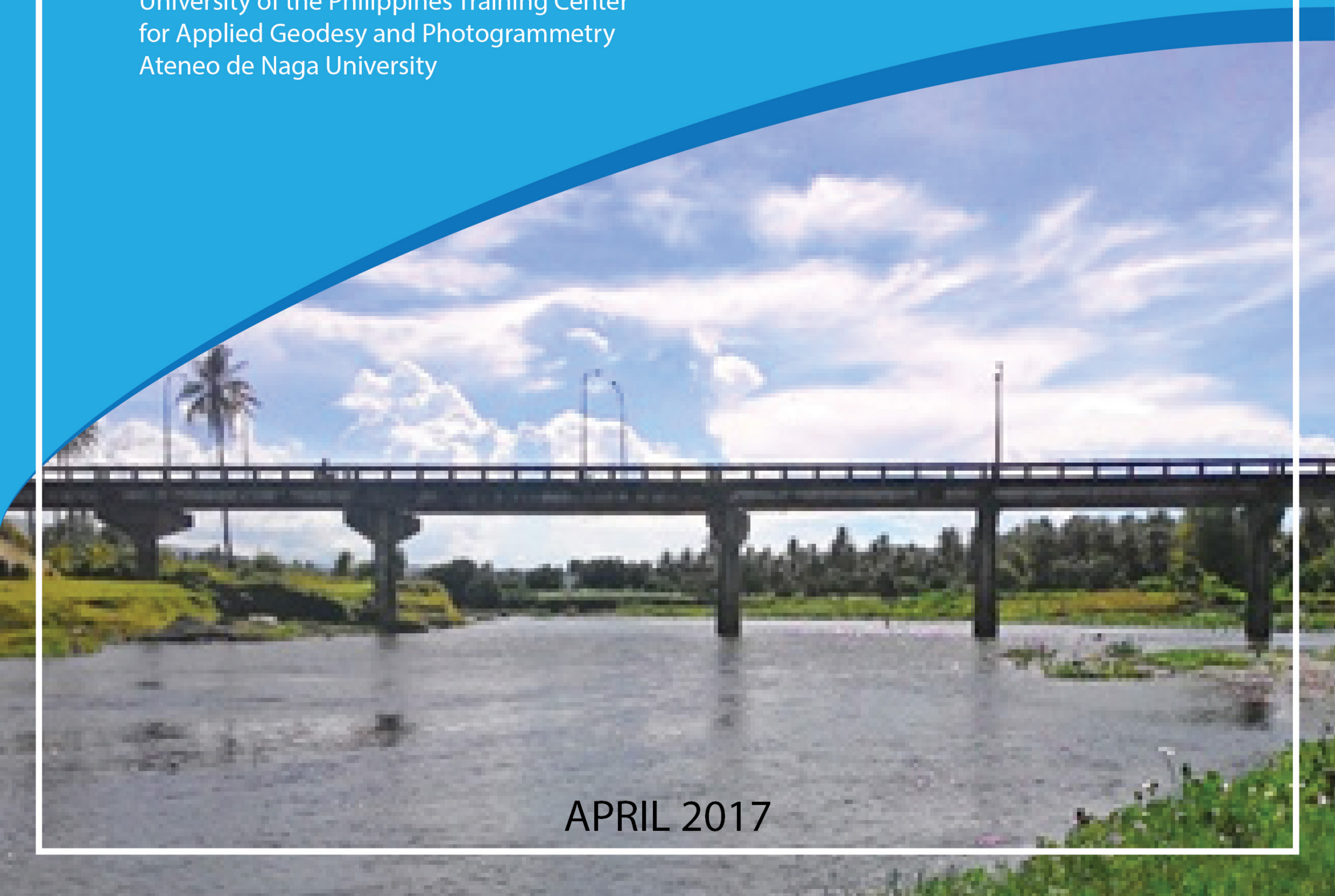

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ADNU	Ateneo de Naga University
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
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
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group

CHAPTER 1: OVERVIEW OF THE PROGRAM AND LAGONOY RIVER

Enrico C. Paringit, Dr. Eng., Ms. Joanaviva Plopenio, and Engr. Ferdinand Bien

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 in 2014 entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

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

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Naga (ADNU). ADNU 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 24 river basins in the Bicol Region. The university is located in Naga City in the Province of Camarines Sur.

1.2 Overview of the Lagonoy River Basin

Lagonoy River Basin (RB) is under the jurisdiction of five (5) municipalities in the Province of Camarines Sur. These are the towns of Lagonoy, Goa, Garchitorena, San Jose and Tinambac. These towns are in the eastern most area of Region V (Bicol Region) and thus experience very pronounced rainy months from November to January with no dry season. This is Type II of the modified Corona Classification of Climate in the Philippines.

Mt. Isarog Natural Park, a protected area and a potentially active stratovolcano reaching 1,966 meters above sea level (mASL) borders this river basin to the southwest. Some low-lying mountain ranges that constitute the Caramoan Peninsula borders the Lagonoy River Basin to the north. These areas, Mt. Isarog Natural Park and the low mountain range in the Caramoan Peninsula are categorized as extremely high and very high respectively, in terms of importance level for terrestrial and inland water areas of biological importance, according to the Philippine Biodiversity Conservation Priorities Report (Ong et al, 2002). These areas are also categorized as Extremely High Urgent and Extremely High Critical, respectively for terrestrial and inland waters conservation priority areas in the same report.

The town of Tinambac is a first class municipality, while Lagonoy and Goa are second class municipalities, according to the National Competitiveness Council of the Philippines. Garchitorena and San Jose however, are 4th class municipalities. Tinambac has a total population of 67,572 distributed across 44 barangays. Lagonoy is a municipality with 38 barangays, with a population of 55,465 as of the 2015 census. Goa, with 34 barangays, has a total of 63,308 residents. Garchitorena has 23 barangays with 27,010 population, while San Jose has a total population of 40,623 in 29 barangays.

These areas are agricultural in essence. Product ranges from rice to coconut, corn, and abaca. There is also a fish port in Tinambac for fish catch coming from San Miguel Bay.

The major stream that empties out the basin to Lagonoy Gulf in the east is the Lagonoy River. The river is usually used by those living near its banks for washing their clothes and ever bathing for some. In fact, some children use the Lagonoy Bridge as a place from which to jump into the river. This 26.71 km long river usually causes flooding especially in the town of Lagonoy during typhoons and sustained heavy rains.

The most recent and significant flooding in the area was in November 2006 caused by Typhoon Durian "Reming," resulting in damage to transmission lines and evacuation of 166 families among areas in Catanduanes including Virac (http://www.gmanetwork.com/news/story/22477/news/nation/reming-downgraded-to-typhoon, 2006).

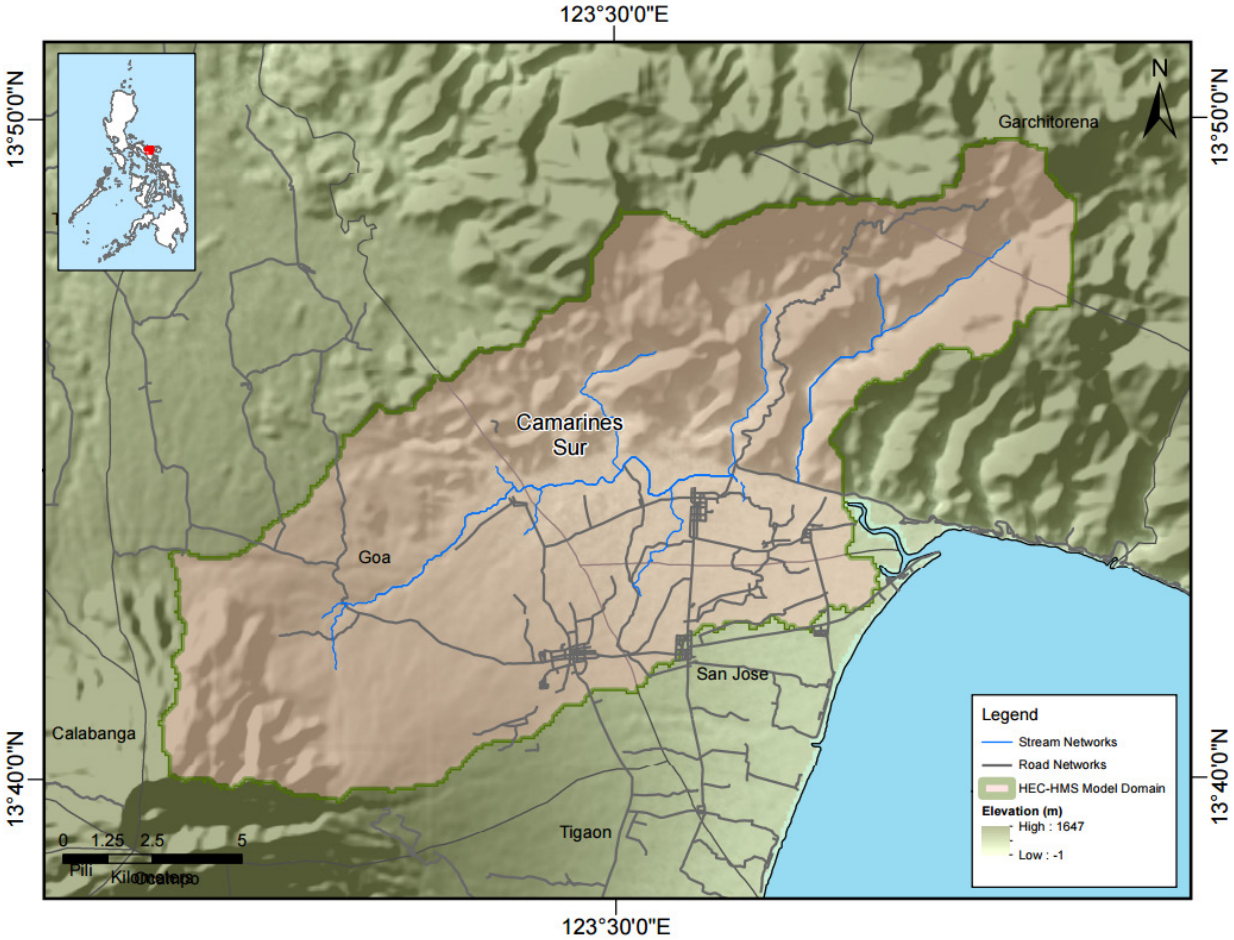


Figure 1. Map of the Lagonoy River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISTION OF THE LAGONOY FLOODPLAIN

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

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Lagonoy Floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Lagonoy Floodplain in Camarines Sur. These missions were planned for 16 lines and ran for at most four and a half (4.5) hours including take-off, landing, and turning time (See Annex 1 for sensor specifications). The flight planning parameters for the LiDAR system used in the LiDAR system are found in Table 1. Figure 2, on the other hand, shows the flight plan for Lagonoy Floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK24C	1000	30	50	200	30	130	5
BLK2B	1000	30	50	200	30	130	5
BLK24A	1000	30	50	200	30	130	5
BLK24E	1000	30	50	200	30	130	5
BLK24F	1000	30	50	200	30	130	5

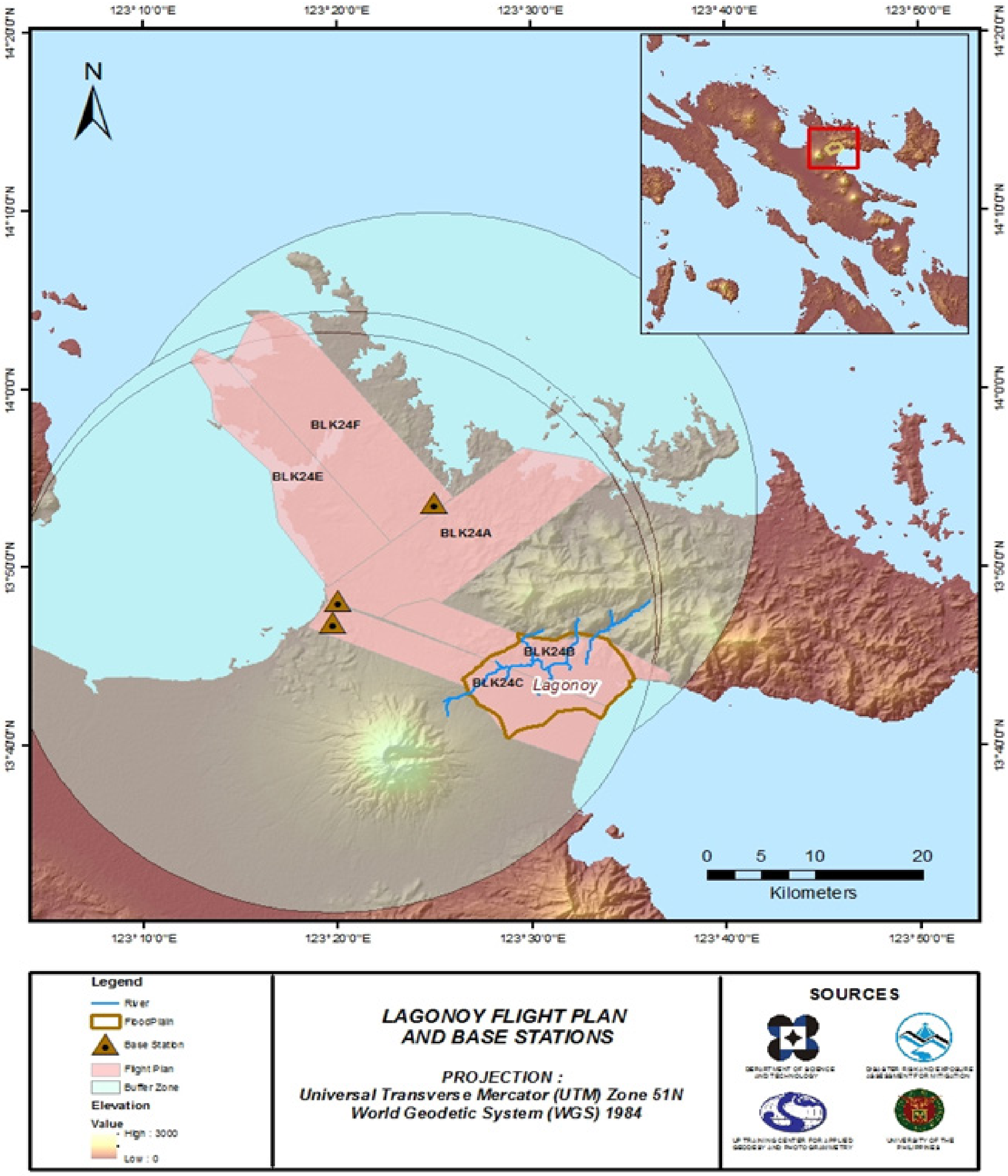
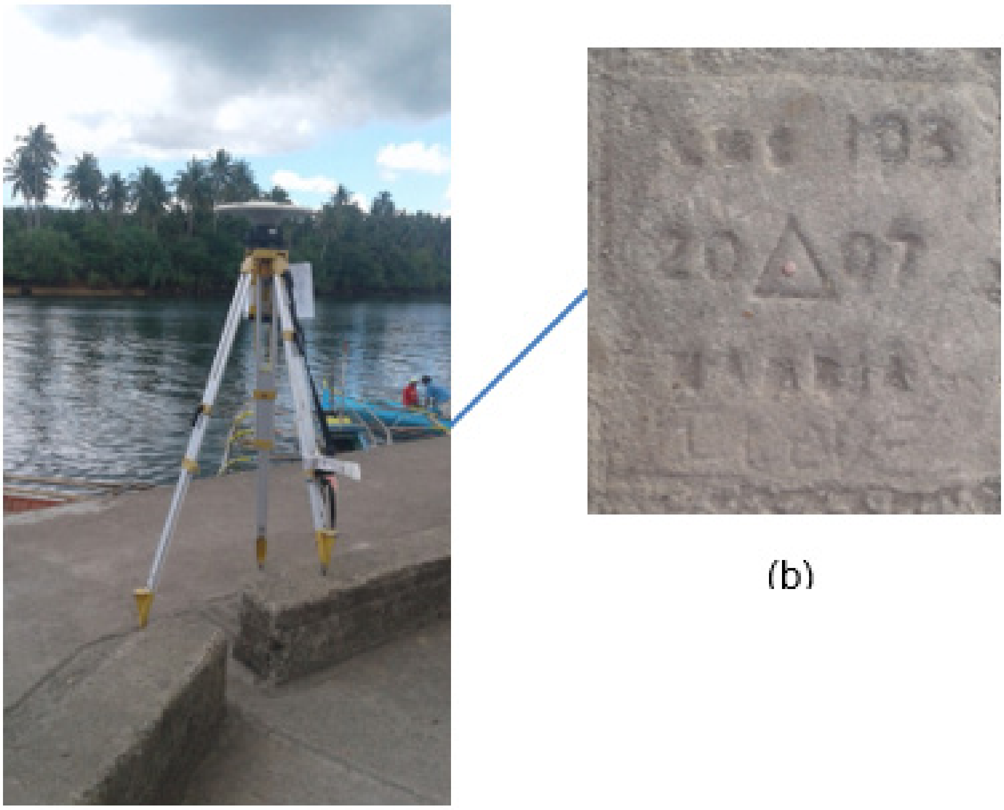


Figure 2. Flight plan and base stations used to for Lagonoy Floodplain

2.2 Ground Base Stations

The field team for this undertaking was able to recover one (1) NAMRIA ground control points: CMS-103 which is of second (2nd) order accuracy, and two (2) NAMRIA benchmarks, CS-464 and CS-461, which are of first (1st) order accuracy. These benchmarks were used as vertical reference points and were also established as ground control points. The certifications for the base stations and benchmarks points are found in Annex 2, while the baseline processing reports for the established ground control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (April 20 to May 4, 2016). Base stations were observed using dual frequency GPS receivers, Trimble SPS 852 and SPS 882. Flight plans and location of base stations used during the aerial LiDAR data acquisition in Lagonoy Floodplain are shown in Figure 2. For the list of team members, see Annex 4.

Figures 3 to 5 show the recovered NAMRIA reference points within the area. In addition, Tables 2 to 4 show the details about the following NAMRIA control points and established points while Table 5 shows the list of all ground control points occupied during the acquisition with the corresponding dates of survey.



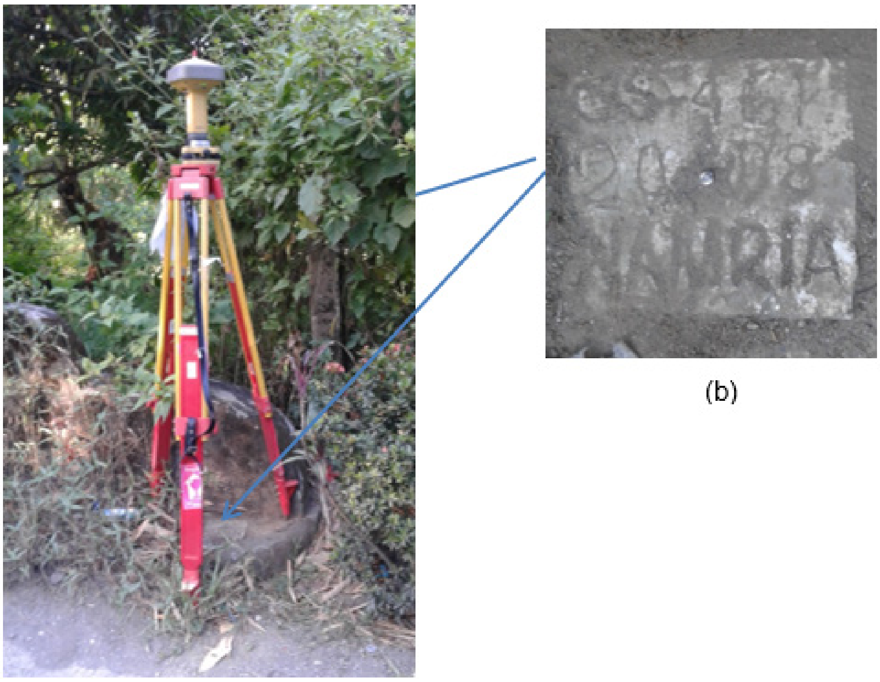
(b)

(a)

Figure 3. a) GPS set-up over CMS-103 located at Tamban port area on top of the seawall, and b) NAMRIA reference point CMS-103 as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point NGW-50 used as base station for the LiDAR acquisition.

Station Name	**CMS-103**	
Order of Accuracy	**2rd**	
Relative Error (Horizontal positioning)	**1 : 50,000**	
Geographic Coordinates, Philippine Reference Of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 53' 44.46082" North 123° 24' 52.41074" East 4.58100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	544805.234 meters 1536671.409 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 53' 39.40601" North 123° 24' 557.34955" East 55.99300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	544,789.55 meters 1,536,133.55 meters

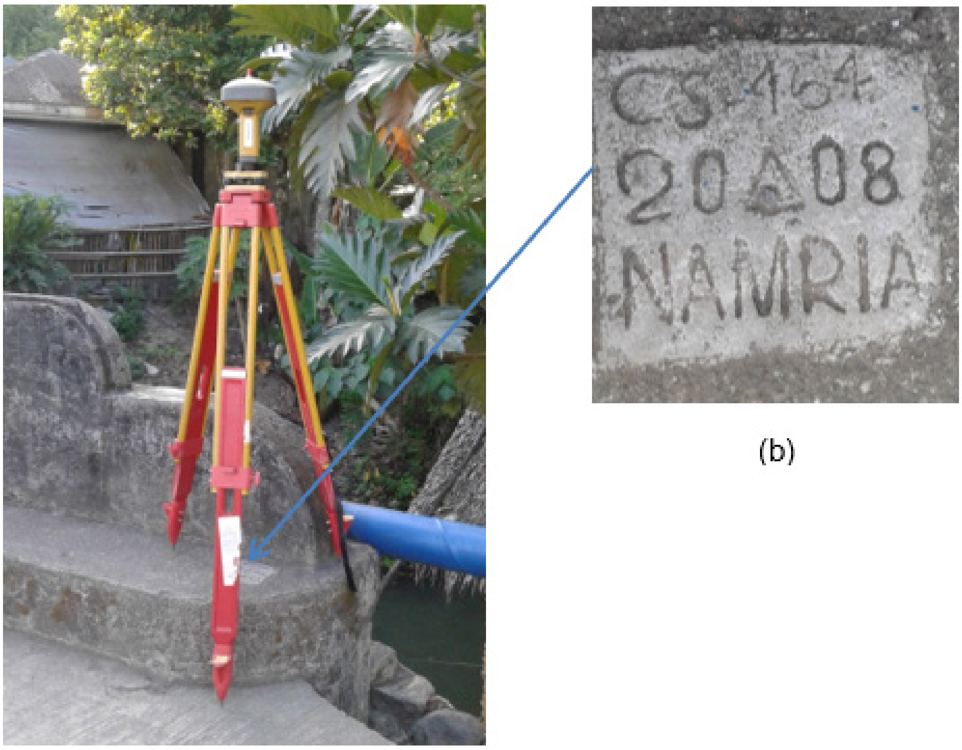


(a) (b)

Figure 4. a) GPS set-up over CS-461 located along Tinambac to Calabanga road in Barangay Bolaobalite, Municipality of Tinambac, Province of Camarines Sur, and b) NAMRIA reference point CS-461 as recovered by the field team.

Table 3. Details of the recovered NAMRIA vertical control point NGW-80 used as base station for the LiDAR data acquisition with established coordinates.

Station Name	CS-461	
Order of Accuracy	**2rd**	
Relative Error (Horizontal positioning)	**1 : 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 48’ 16.97629” North 123° 19’ 59.46340” East 8.314 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 48’ 11.93661” North 123° 20’ 04.41063” East 59.780 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	536011.654 meters 1526059.719 meters



(a)

(b)

Figure 5. a) GPS set-up over CS-464 located in the Municipality of Mananao, Province of Camarines Sur, and b) NAMRIA benchmark CS-464 as recovered by the field team.

Table 4. Details of the recovered NAMRIA vertical control point CS-464 used as base station for the LiDAR data acquisition with established coordinates.

Station Name	**CS-464**	
Order of Accuracy	**2rd**	
Relative Error (horizontal positioning)	**1 : 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 47' 06.64679" North 123° 19' 53.49615" East 8.046 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 47’ 01.61166” North 123° 19’ 58.44508” East 59.563 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	535835.478 meters 11523899.018 meters

Table 5. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
23 April 2016	23278P	1BLK24CAF114A	CMS-103 & CS-464
26 April 2016	23290P	1BLK24CSE117A	CMS-103 & CS-464
29 April 2016	23302P	1BLK24BES120A	CMS-103 & CS-464
2 May 2016	23314P	1BLK24ABCVOIDS123A	CMS-103 & CS-464
3 May 2016	23318P	1BLK24ACF124A	CMS-103 & CS-461

2.3 Flight Missions

Five (5) missions were conducted to complete LiDAR data acquisition in Lagonoy Floodplain, for a total of 21 hours and 55 minutes (21+55) of flying time for RP-C9122. All missions were acquired using the Pegasus LiDAR System. Table 6 shows the total area of actual coverage and the corresponding flight hours per mission, while Table 7 presents the actual parameters used during the LiDAR data acquisition.

Table 6. Flight missions for LiDAR data acquisition in Lagonoy Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
23-Apr-16	23278P	183.14	191.52	18.79	172.73	-	4	5
26-Apr-16	23290P	127.15	225.08	49.27	175.81	-	4	15
29-Apr-16	23302P	138.17	313.66	51.21	262.45	-	4	35
2-May-16	23314P	183.14	235.89	57.05	178.84	-	4	35
3-May-16	23318P	183.14	133.94	4.46	129.48	-	4	25
TOTAL		**738.16**	**768.26**	**103.92**	**664.34**	**-**	**21**	**55**

Table 7. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
23278P	600, 1000	30	50	200	30	130	5
23290P	850, 1000	30	50	200	30	130	5
23302P	800, 1000	30	50	200	30	130	5
23314P	600, 850	30	50	200	30	130	5
23318P	550, 600, 1000	30	50	200	30	130	5

2.4 Survey Coverage

Lagonoy Floodplain is located in the Province of Camarines Sur with majority of the floodplain situated within the Municipalities of Lagonoy, Goa, and San Jose. The Municipality of San Jose is mostly covered by the survey. 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 Lagonoy Floodplain is presented in Figure 6.

Table 8. List of municipalities and cities surveyed during Lagonoy Floodplain LiDAR survey

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Camarines Sur	San Jose	44.63	43.17	96.73%
	Goa	220.76	150.52	68.18%
	Tinambac	288.53	190	65.85%
	Siruma	137.36	60.71	44.20%
	Lagonoy	394.86	169.15	42.84%
	Calabanga	151.49	31.75	20.96%
	Bombon	40.64	3.63	8.93%
	Tigaon	79.34	2.61	3.29%
	Presentacion	160.13	4.45	2.78%
	Garchitorena	245.52	3	1.22%
TOTAL		1763.26	658.99	37.37%

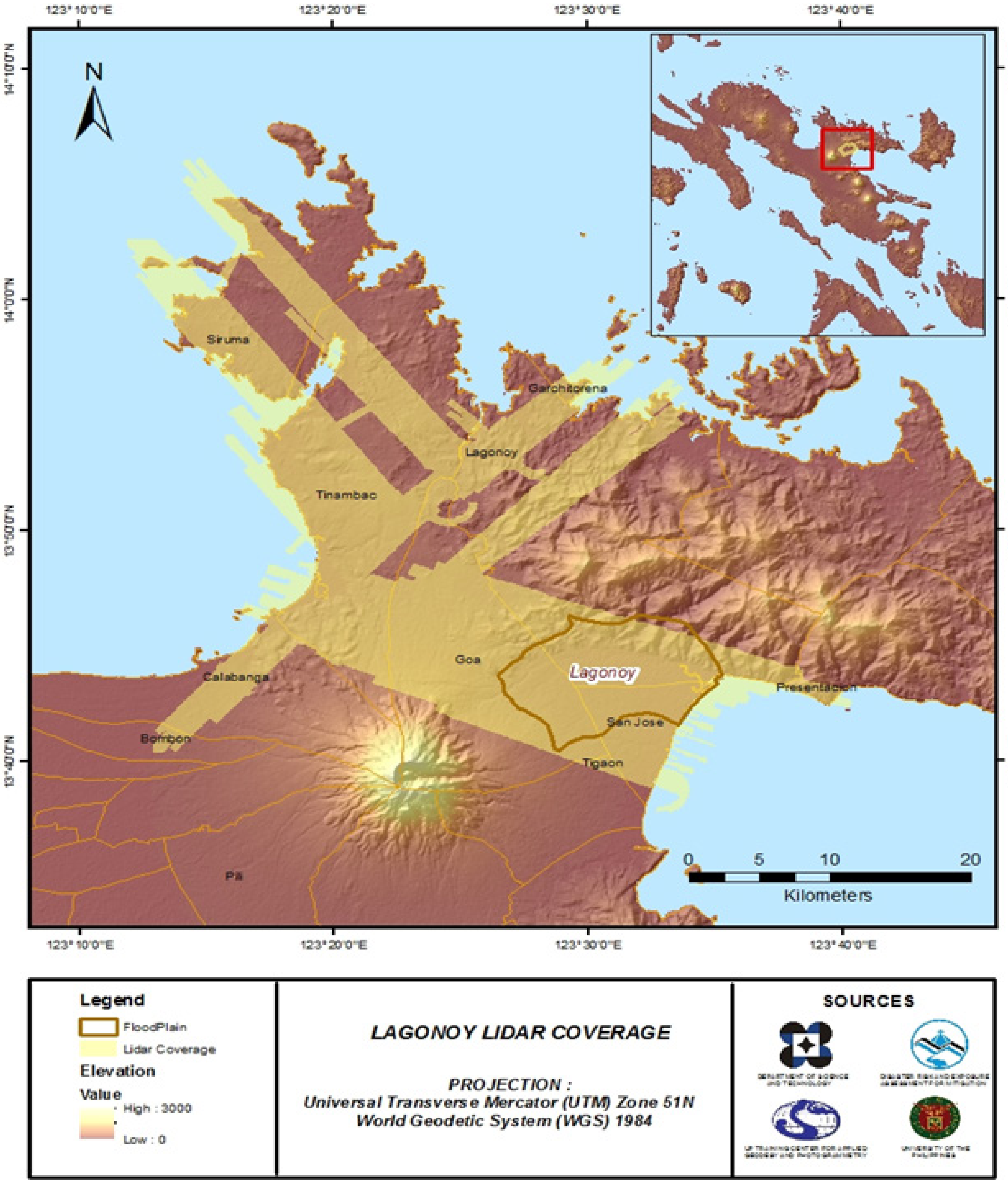


Figure 6. Actual LiDAR survey coverage for Lagonoy Floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE LAGONOY 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 Data Acquisition Component are checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory is done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification is performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds are subject for quality checking to ensure that the required accuracies of the program, which are the minimum point density, vertical and horizontal accuracies, are met. The point clouds are then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

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

These processes are summarized in the flowchart shown in Figure 7.

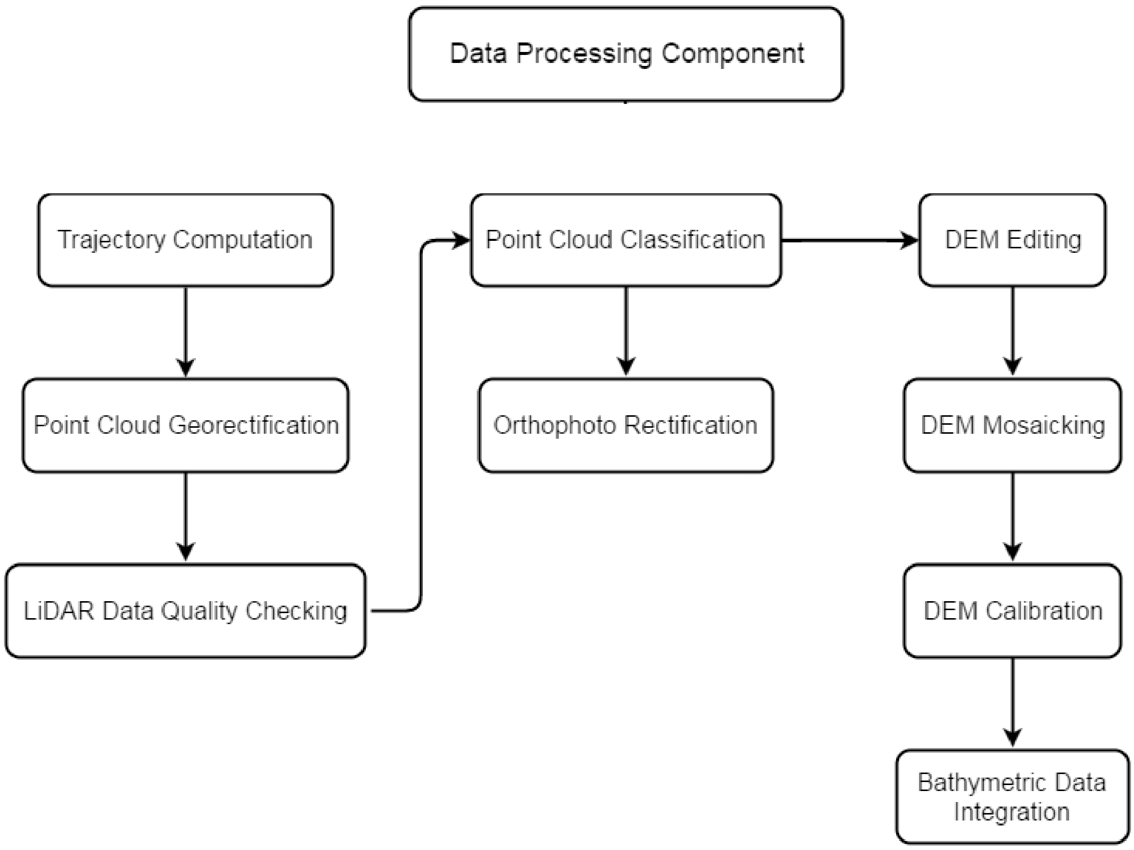


Figure 7. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Lagonoy Floodplain can be found in Annex 5. Missions flown during the survey conducted on April 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus sSstem over Naga. The Data Acquisition Component (DAC) transferred a total of 120.4 gigabytes of range data, 1.38 gigabytes of POS data, 525.5 megabytes of GPS base station data, and 0 gigabytes of raw image data to the data server on April 19, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Lagonoy was fully transferred on June 10, 2016, as indicated on the Data Transfer Sheets for Lagonoy Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for Flight 23290P, one of the Lagonoy flights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on April 26, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

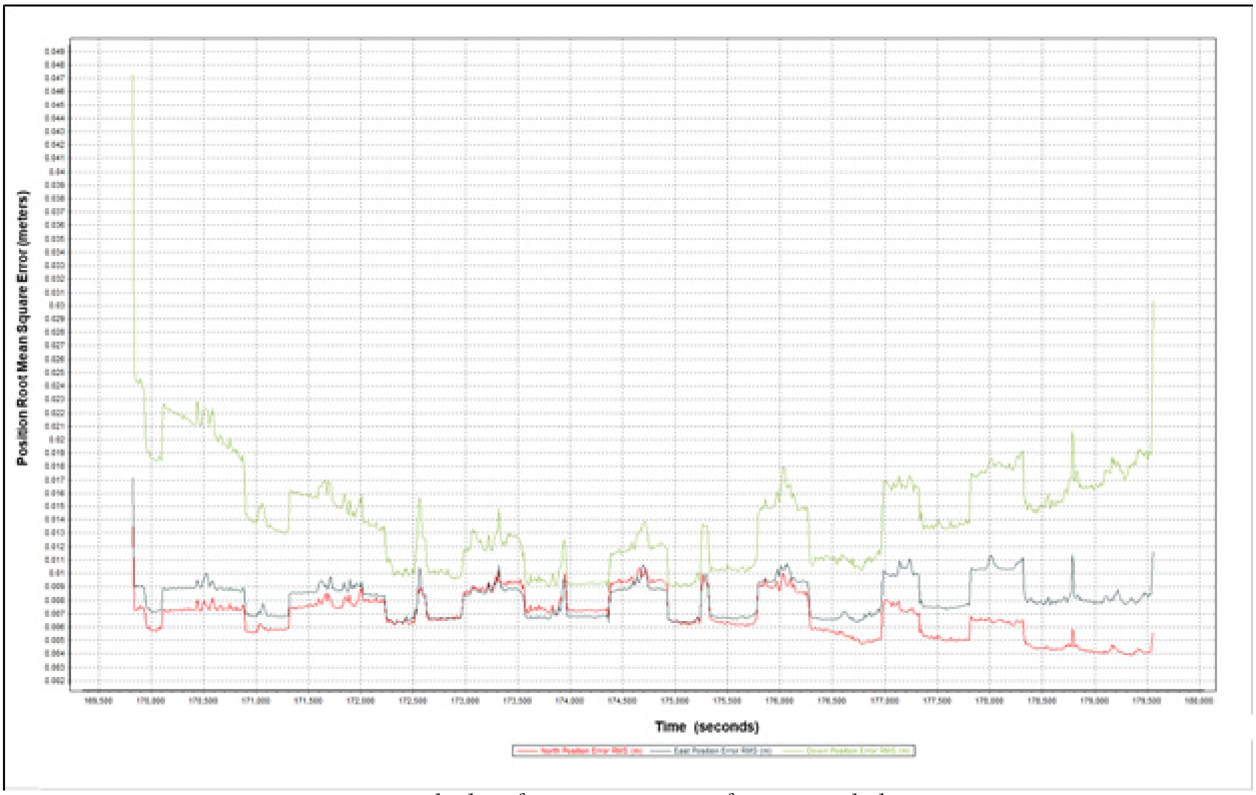


Figure 8. Smoothed Performance Metrics of Lagonoy Flight 23290P.

The time of flight was from 169500 seconds to 180000 seconds, which corresponds to the morning of April 26, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 1.0 centimeters, the East position RMSE peaks at 1.1 centimeters, and the Down position RMSE peaks at 2.3 centimeters, which are within the prescribed accuracies described in the methodology.

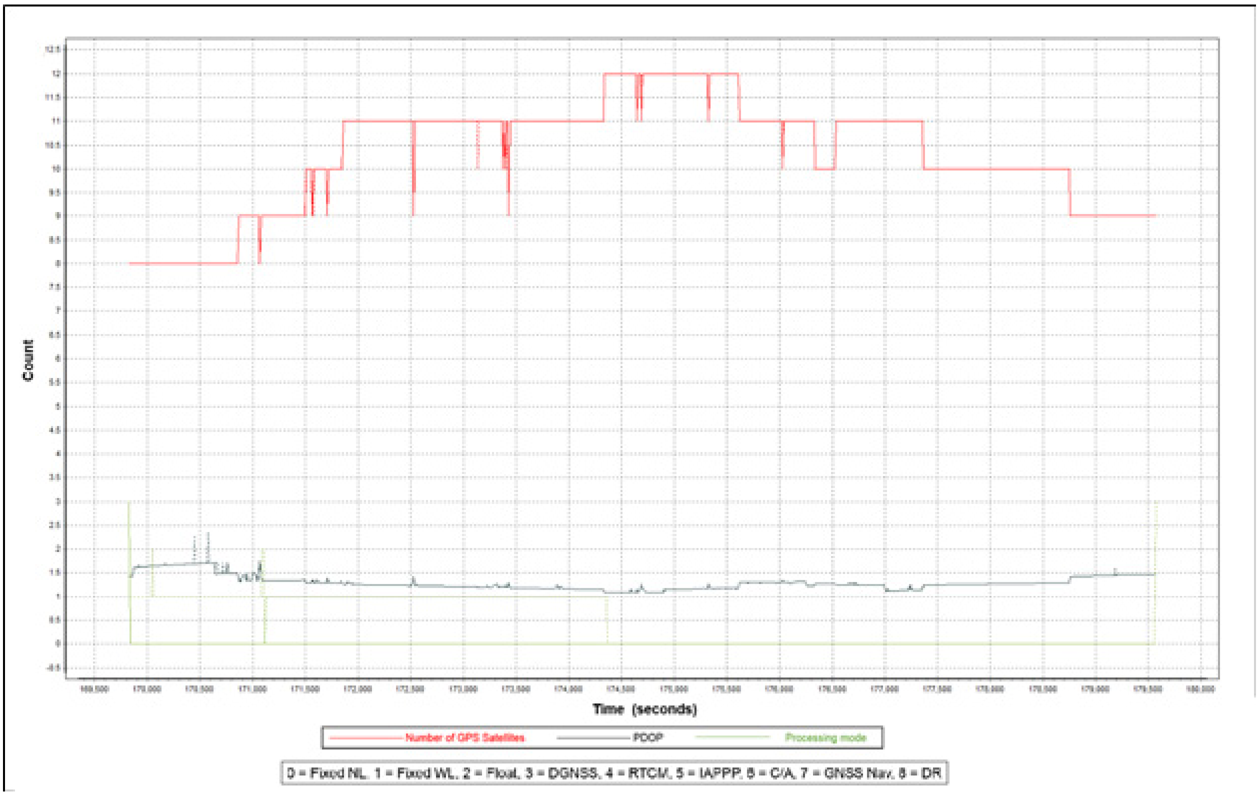


Figure 9. Solution Status Parameters of Lagonoy Flight 3028P.

The Solution Status parameters of Flight 23290P, one of the Lagonoy flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 8 and 12. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Lagonoy flights is shown in Figure 10.

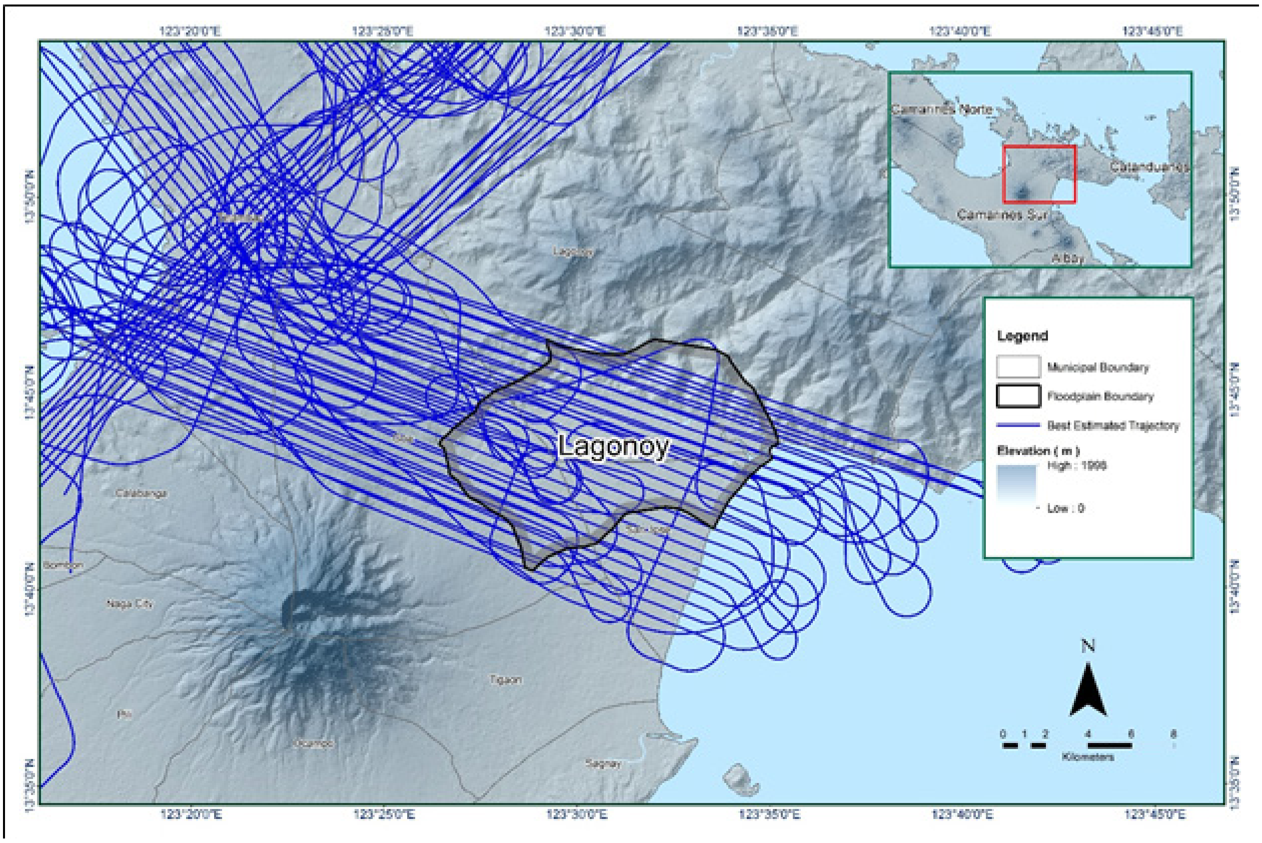


Figure 10. Best Estimated Trajectory of the LiDAR missions conducted over the Lagonoy Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 53 flight lines, with each flight line containing one channel, since the Pegasus System contain two channels only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Lagonoy Floodplain are given in Table 9.

Table 9. Self-Calibration Results values for Lagonoy flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev (<0.001degrees)	0.000462	0.000148
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000318	0.000385
GPS Position Z-correction stdev (<0.01meters)	0.0017	0.0058

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Lagonoy Floodplain is shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

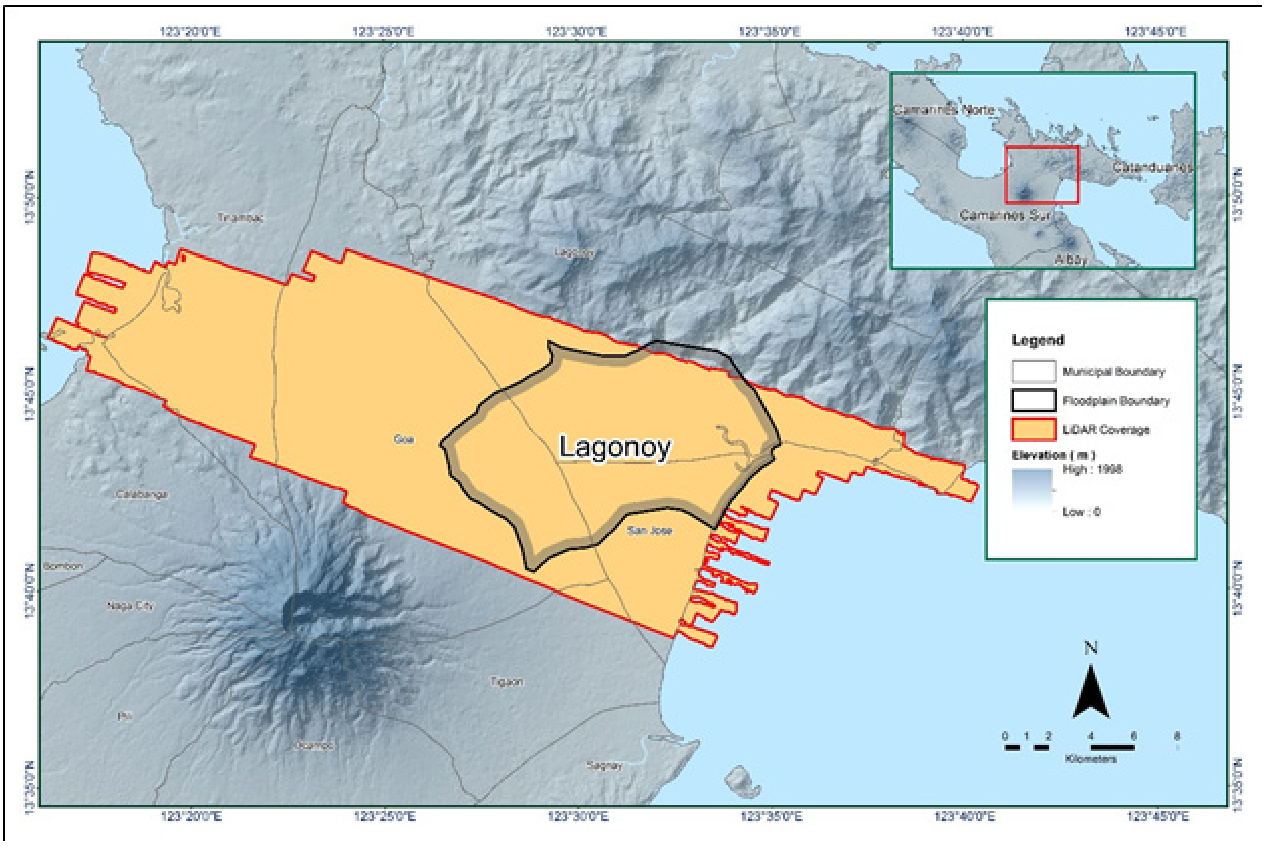


Figure 11. Boundary of the processed LiDAR data over Lagonoy Floodplain

The total area covered by the Lagonoy missions is 508.77 square kilometers that is comprised of five (5) flight acquisitions grouped and merged into four (4) blocks as shown in Table 10.

Table 10. List of LiDAR blocks for Lagonoy Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Naga_Blk24C	23278P	239.08
	23290P	
	23314P	
	23318P	
Naga_Blk24C_additional	23318P	31.09
Naga_Blk24C_supplement	23314P	99.62
	23318P	
Naga_Blk24B	23302P	138.98
	23314P	
TOTAL		**508.77 sq. km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 12. Since the Pegasus System employ two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

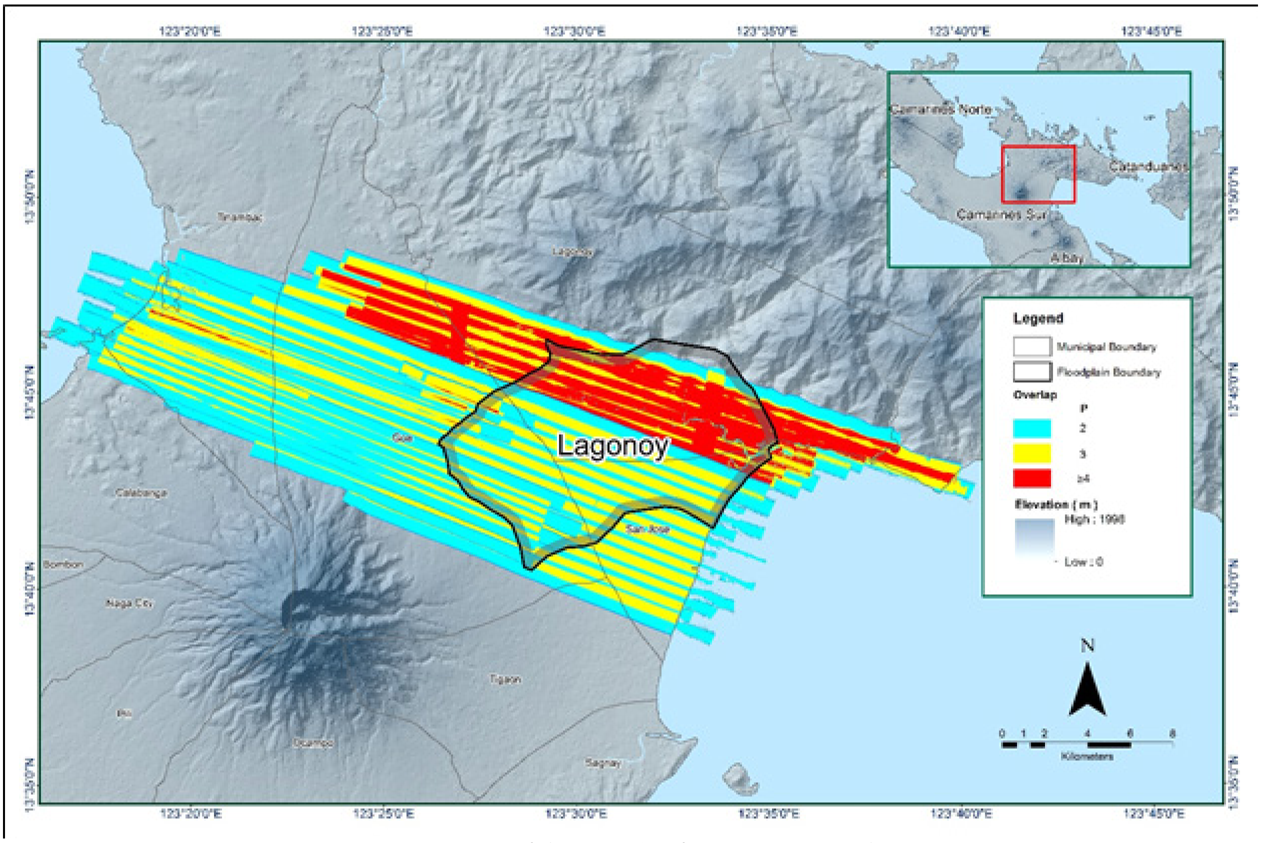


Figure 12. Image of data overlap for Lagonoy Floodplain.

The overlap statistics per block for the Lagonoy Floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 32.04% and 54.76% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Lagonoy Floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.36 points per square meter.

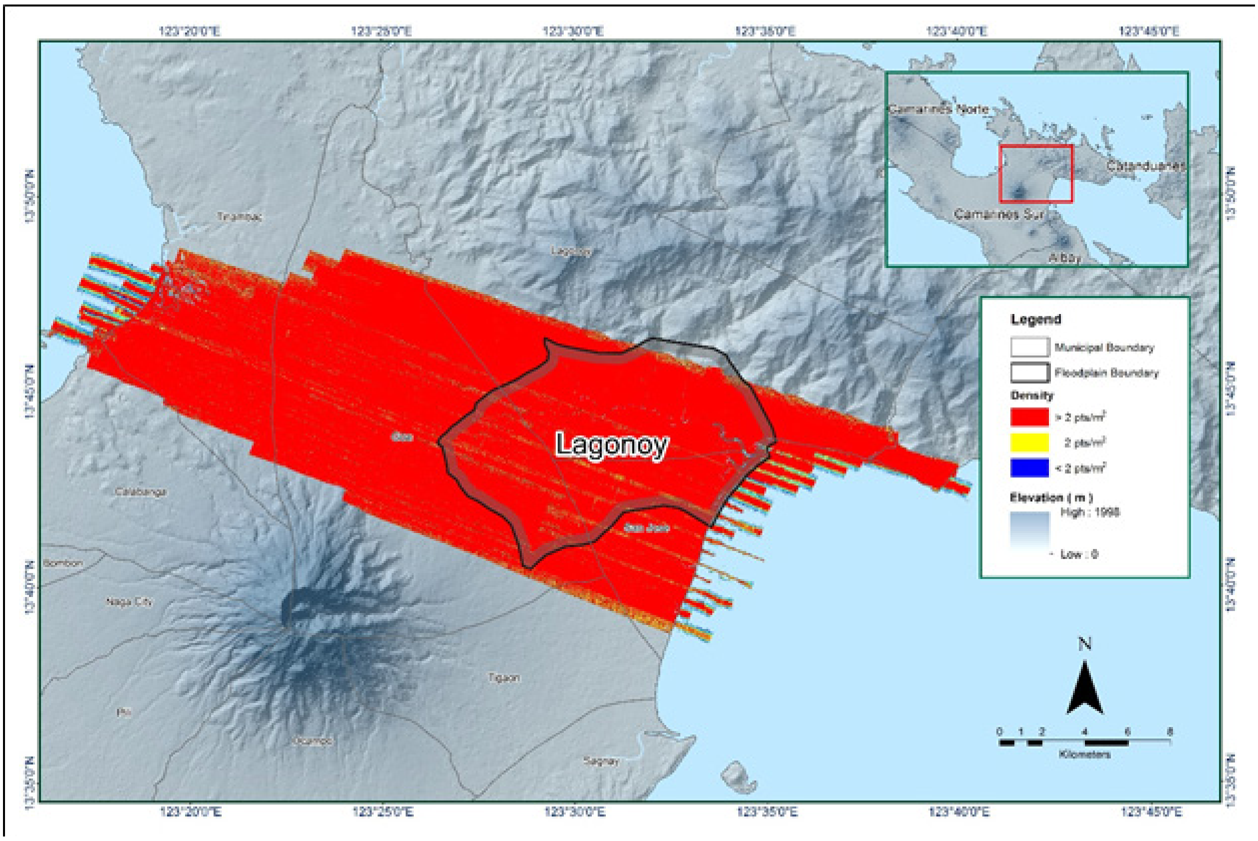


Figure 13. Pulse density map of merged LiDAR data for Lagonoy Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 m 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 m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

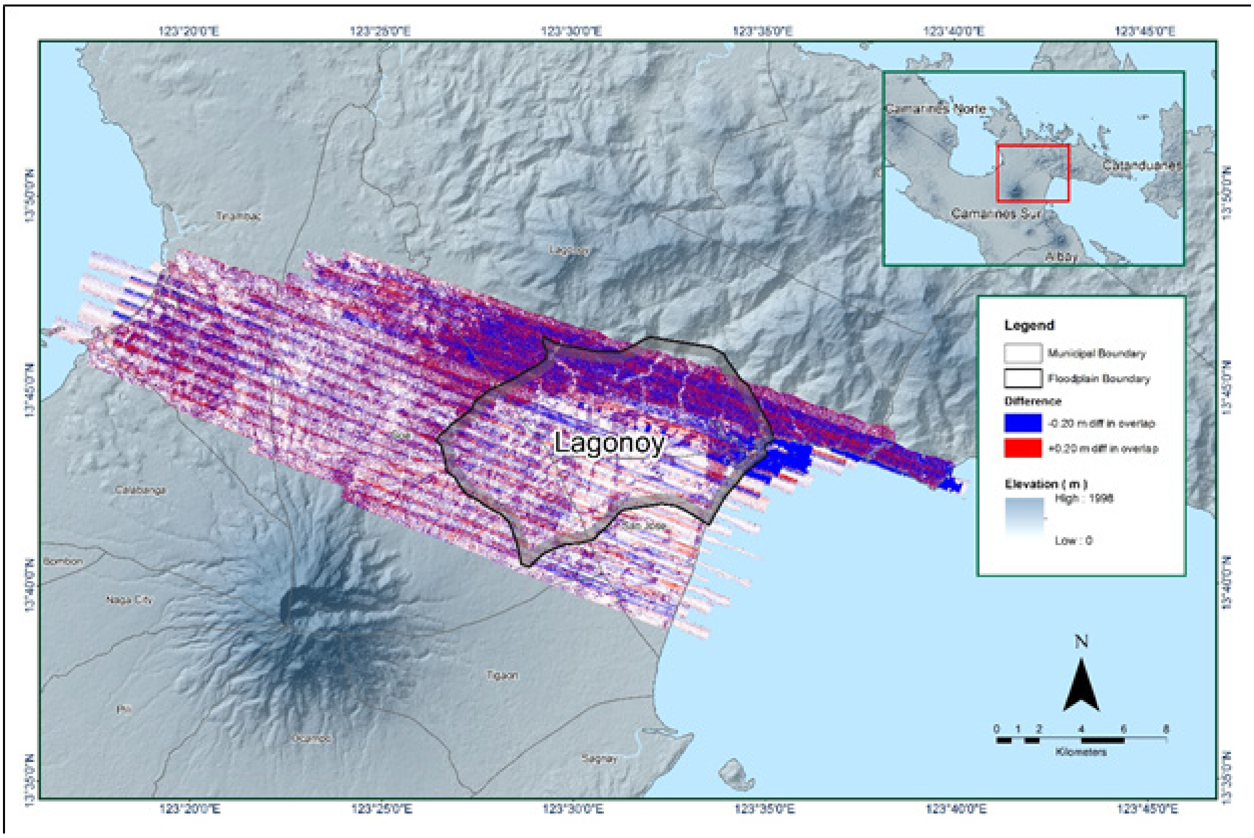


Figure 14. Elevation difference map between flight lines for Lagonoy Floodplain.

A screen capture of the processed LAS data from Lagonoy Flight 23290P loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two 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 are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

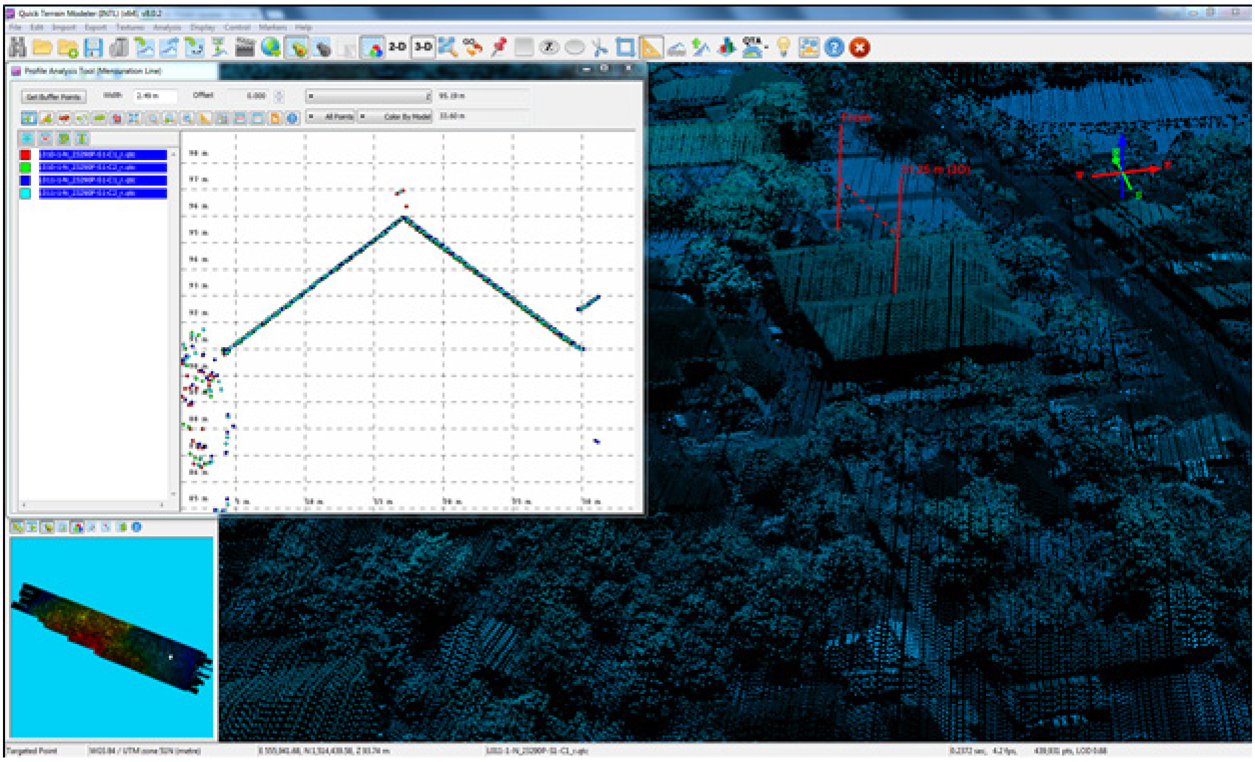


Figure 15. Quality checking for Lagonoy Flight 23290P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 11. Lagonoy classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	678,038,252
Low Vegetation	376,087,804
Medium Vegetation	734,089,650
High Vegetation	1,918,909,178
Building	36,442,996

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Lagonoy Floodplain is shown in Figure 16. A total of 730 1 km by 1 km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 11. The point cloud has a maximum and minimum height of 743.19meters and 21.36 meters respectively.

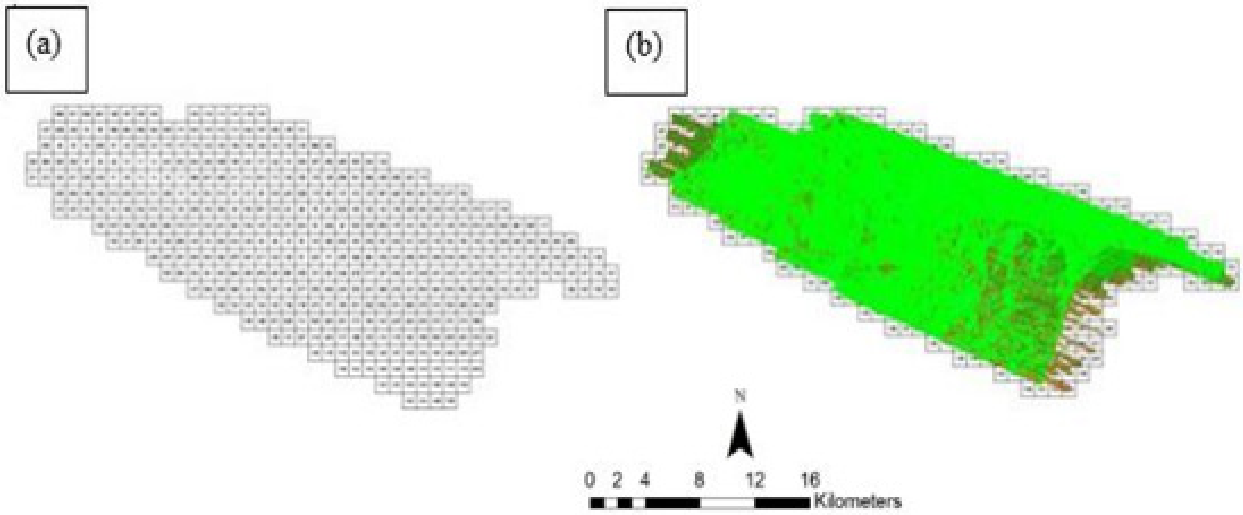


Figure 16. Tiles for Lagonoy Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 17. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

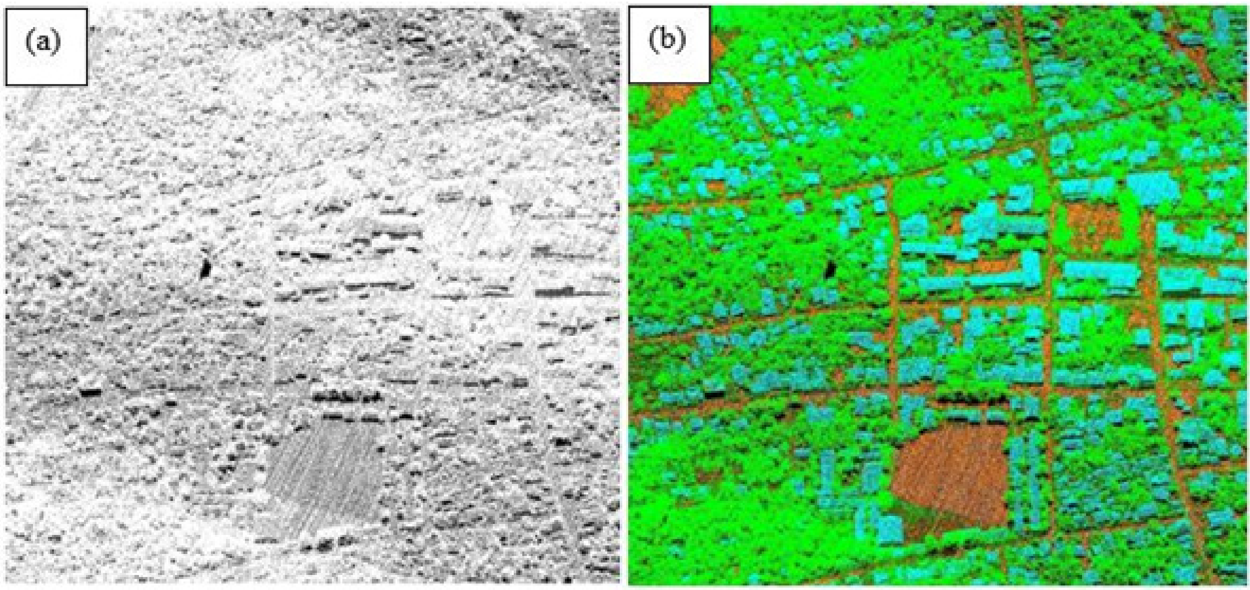


Figure 17. Point cloud before (a) and after (b) classification.

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 18. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

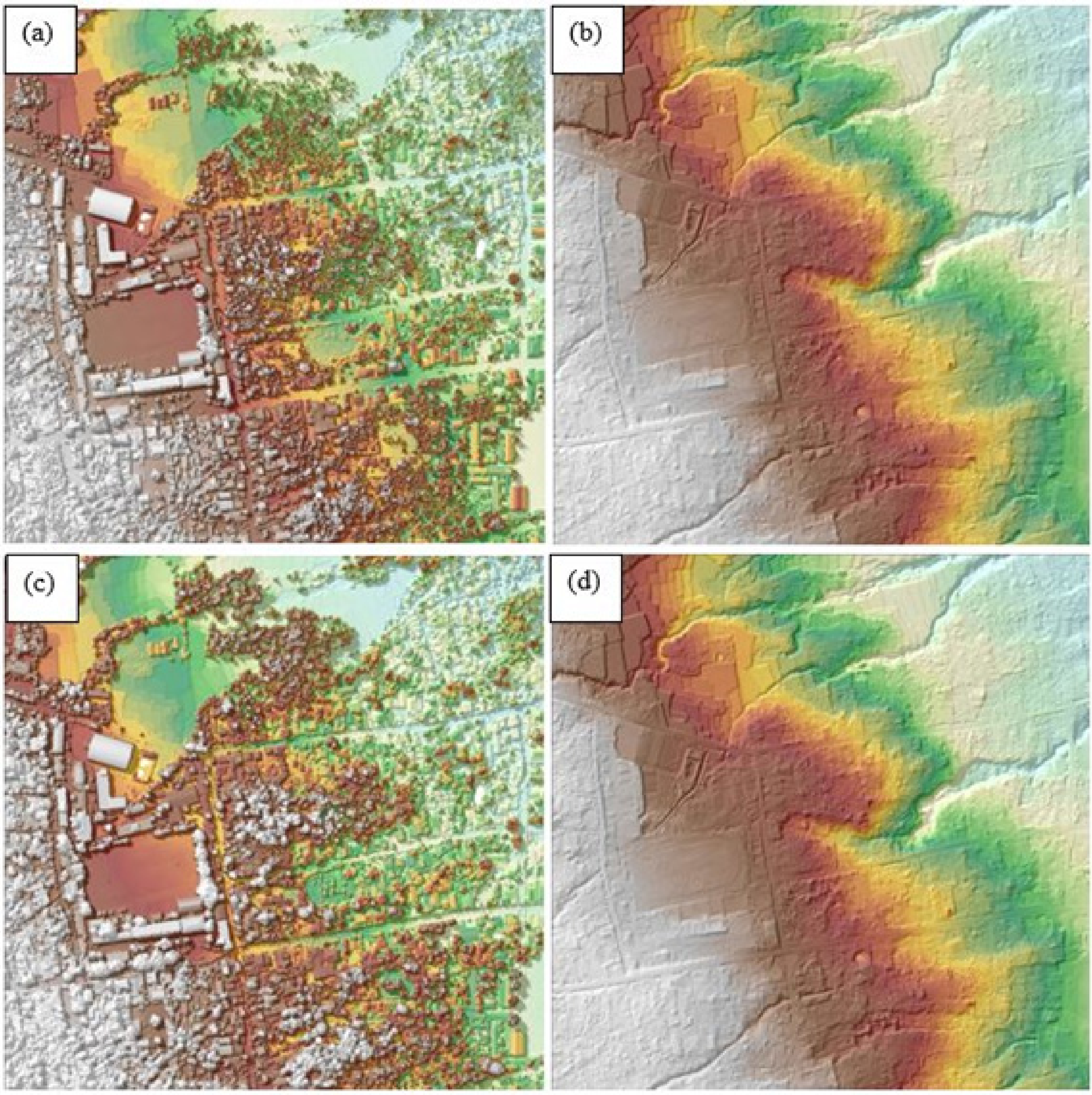


Figure 18. The Production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Lagonoy Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Lagonoy Floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Lagonoy Floodplain. These blocks are composed of Naga blocks with a total area of 508.77 square kilometers. Table 12 shows the name and corresponding area of each block in square kilometers.

Table 12. Shift Values of each LiDAR Block of Lagonoy Floodplain

LiDAR Blocks	Area (sq.km)
Naga_Blk24C	239.08
Naga_Blk24C_additional	31.09
Naga_Blk24C_supplement	99.62
Naga_Blk24B	138.98
TOTAL	508.77 sq.km

Figure 19 shows portions of DTM before and after manual editing. The paddy field (Figure 19a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 19b) to allow the correct flow of water. The bridge (Figure 19c) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 19d) in order to hydrologically correct the river.

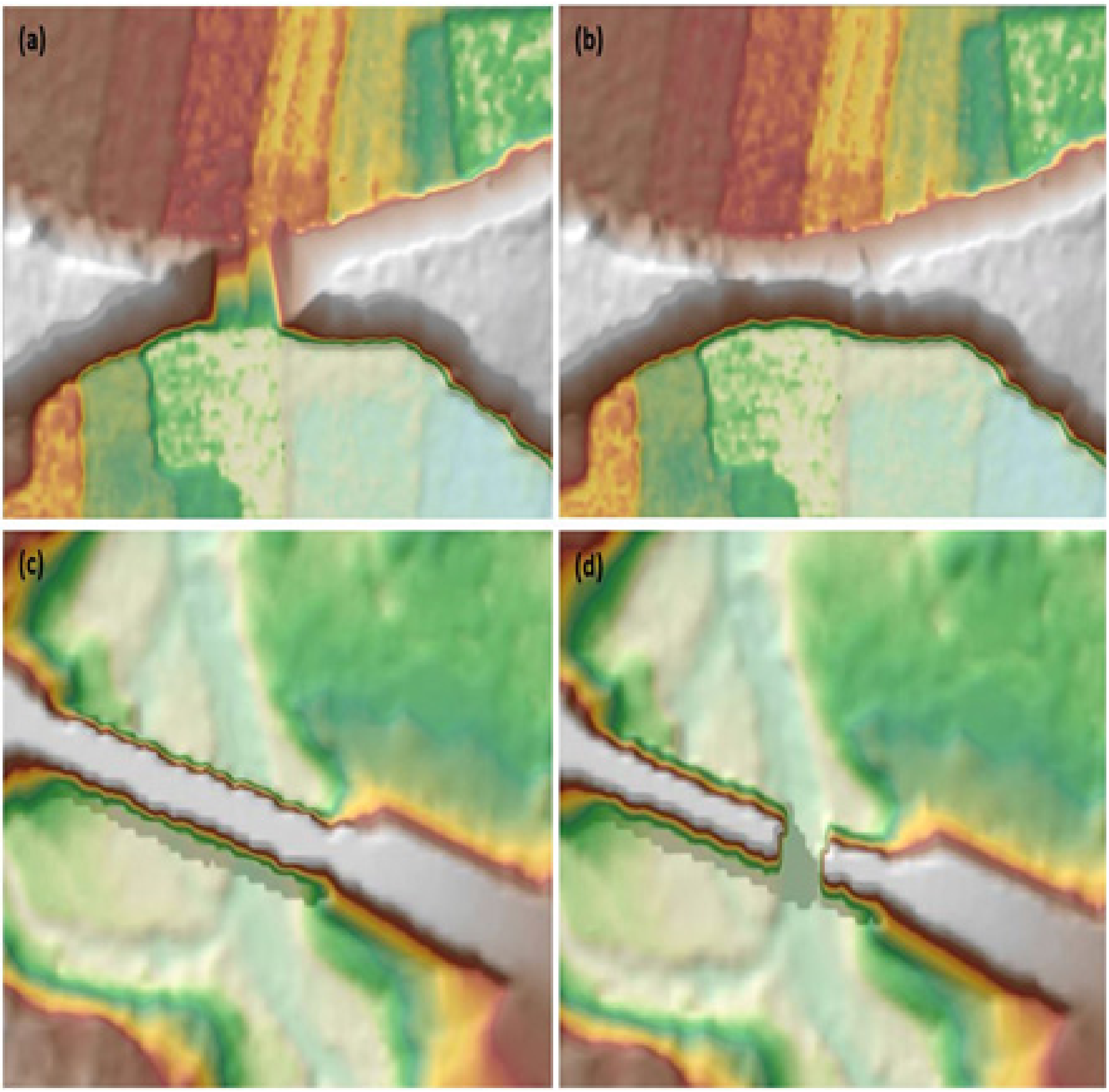


Figure 19. Portions in the DTM of Lagonoy Floodplain – a paddy field before (a) and after (b) data retrieval; and a bridge before (c) and after (d) manual editing.

3.9 Mosaicking of Blocks

Naga_Blk24C was used as the reference block at the start of mosaicking because it is located in the estuary of the river. Table 13 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Lagonoy Floodplain is shown in Figure 20. It can be seen that the entire Lagonoy Floodplain is 100% covered by LiDAR data.

Table 13. Shift Values of each LiDAR Block of Lagonoy Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Naga Blk24C	Reference raster		
Naga Blk24C_additional	0.00	0.00	0.30
Naga Blk24C_supplement	0.00	0.50	0.30
Naga Blk24B	-1.00	0.00	0.26

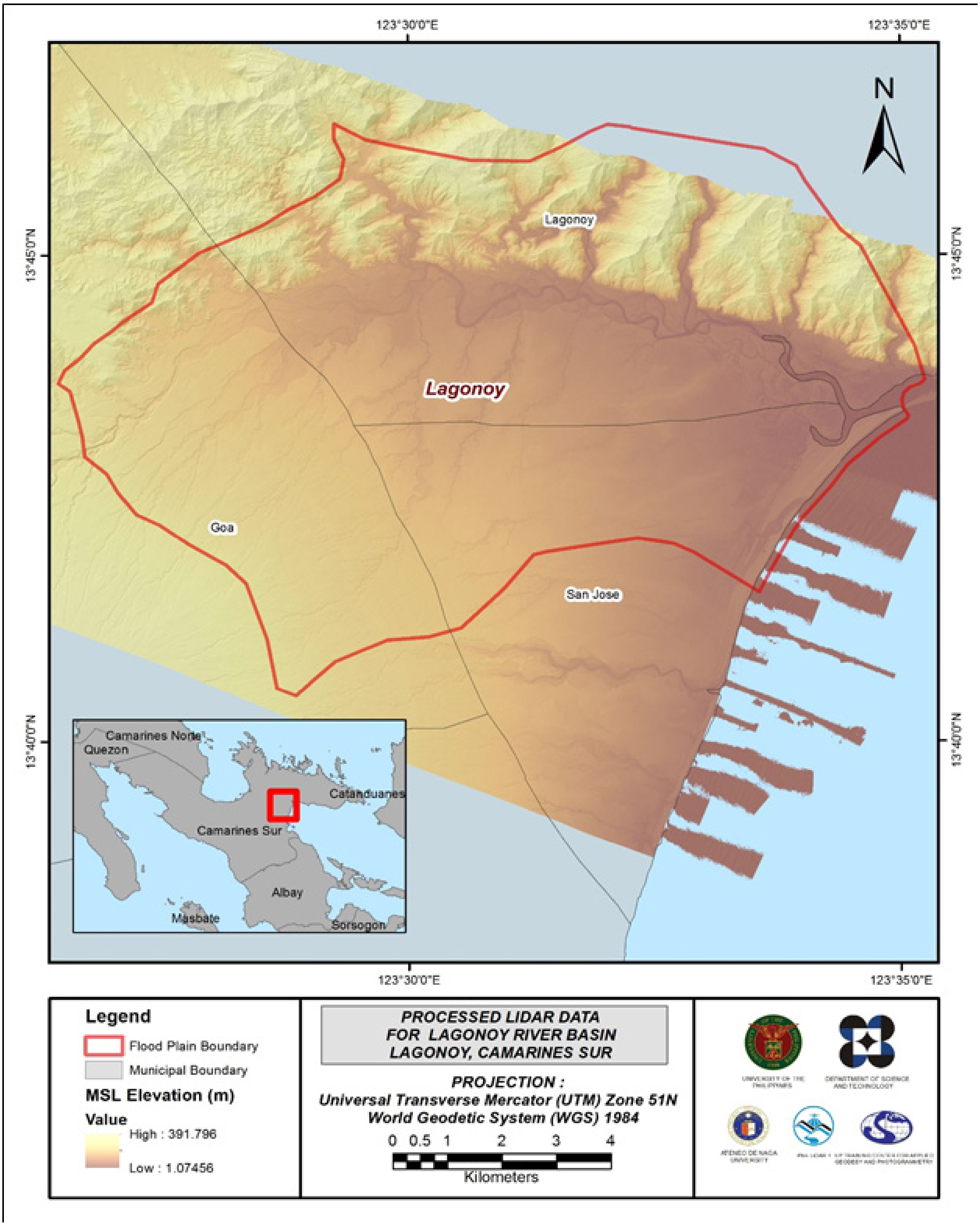


Figure 20. Map of Processed LiDAR Data for Lagonoy Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Lagonoy to collect points with which the LiDAR dataset is validated is shown in Figure 21. A total of 3,326 survey points were used for calibration and validation of Lagonoy LiDAR data. Random selection of 80% of the survey points, resulting to 3,082 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 22. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 2.88 meters with a standard deviation of 0.07 meters. Calibration of Lagonoy LiDAR data was done by subtracting the height difference value, 2.88 meters, to Lagonoy mosaicked LiDAR data. Table 14 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

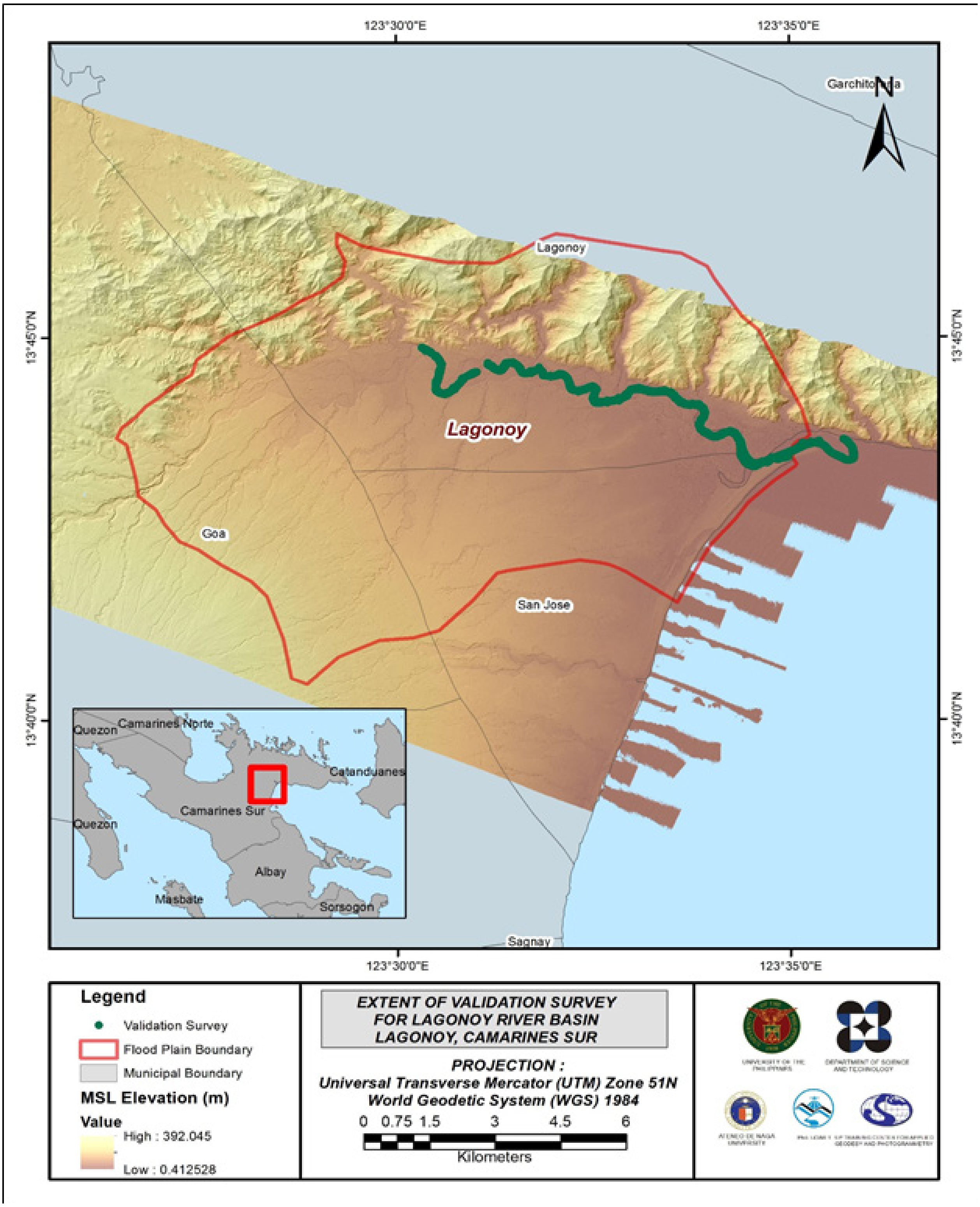


Figure 21. Map of Lagonoy Floodplain with validation survey points in green.

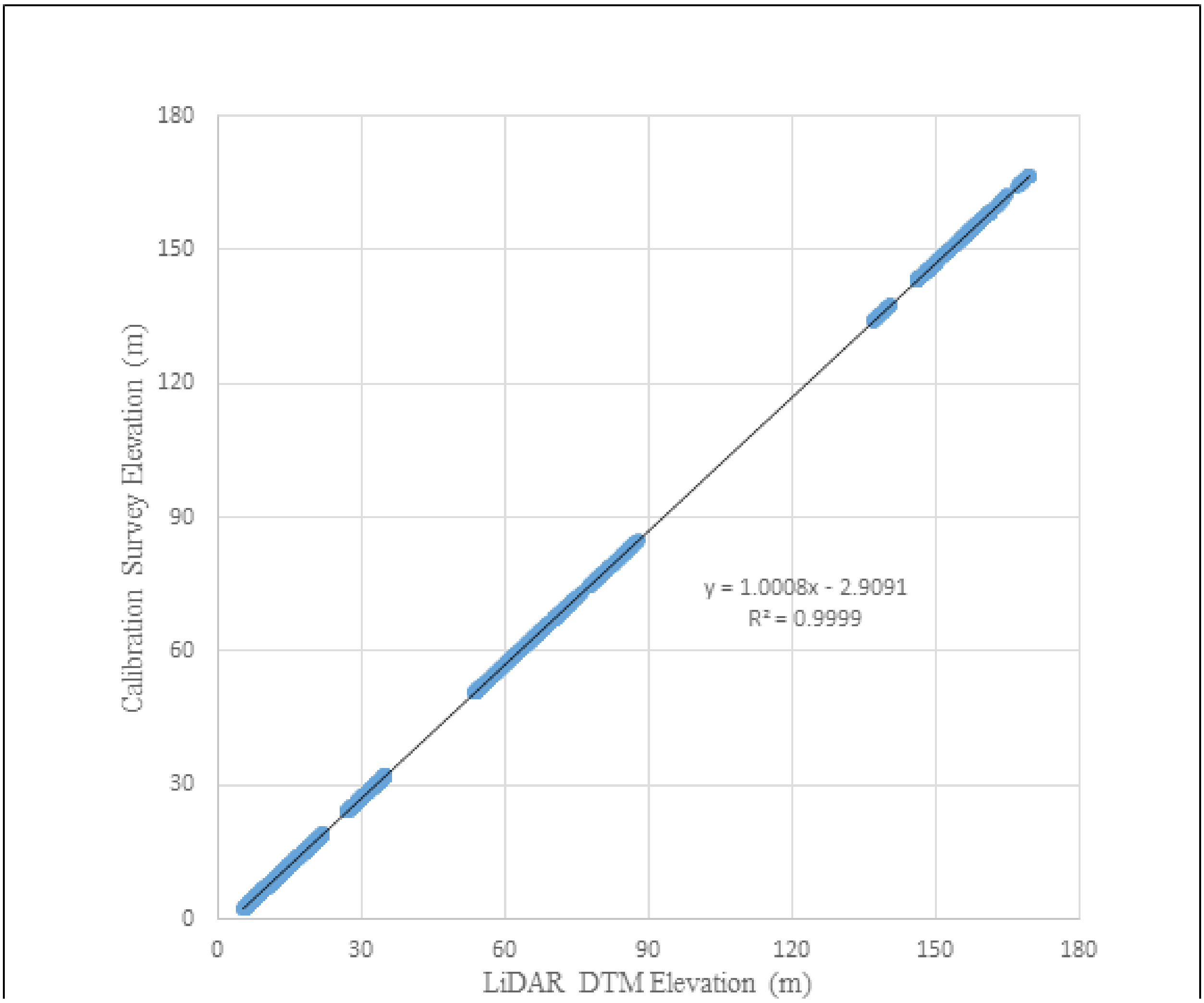


Figure 22. Correlation plot between calibration survey points and LiDAR data.

Table 14. Calibration Statistical Measure.

Calibration Statistical Measures	Value (meters)
Height Difference	2.88
Standard Deviation	0.07
Average	-2.88
Minimum	-3.01
Maximum	-2.74

The remaining 20% of the total survey points, resulting to 665 points, were used for the validation of calibrated Lagonoy DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 23. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.07 meters with a standard deviation of 0.07 meters, as shown in Table 15.

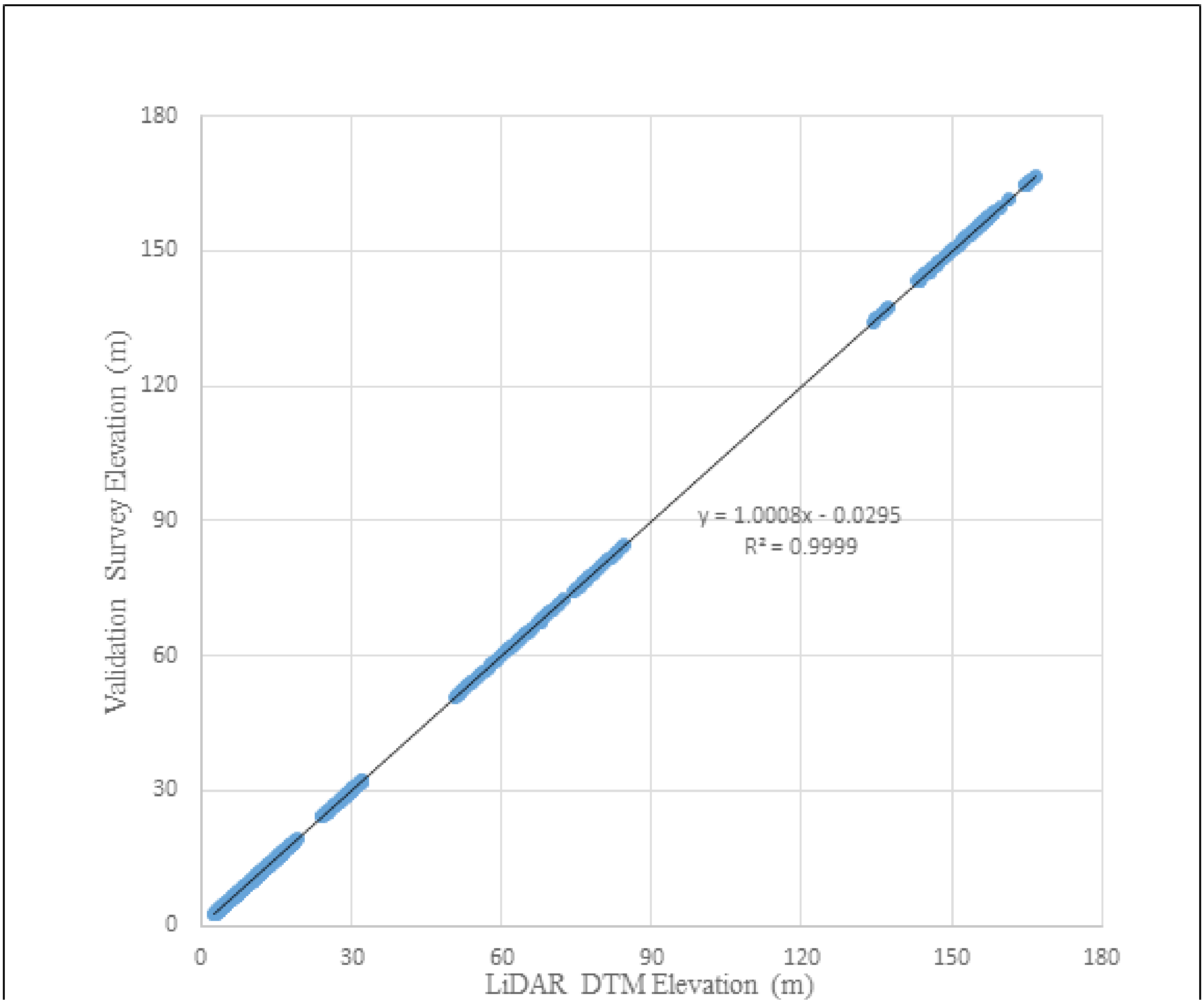


Figure 23. Correlation plot between validation survey points and LiDAR data.

Table 15. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.07
Standard Deviation	0.07
Average	-0.00
Minimum	-0.13
Maximum	0.13

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Lagonoy with 13,717 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.067 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Lagonoy integrated with the processed LiDAR DEM is shown in Figure 24.

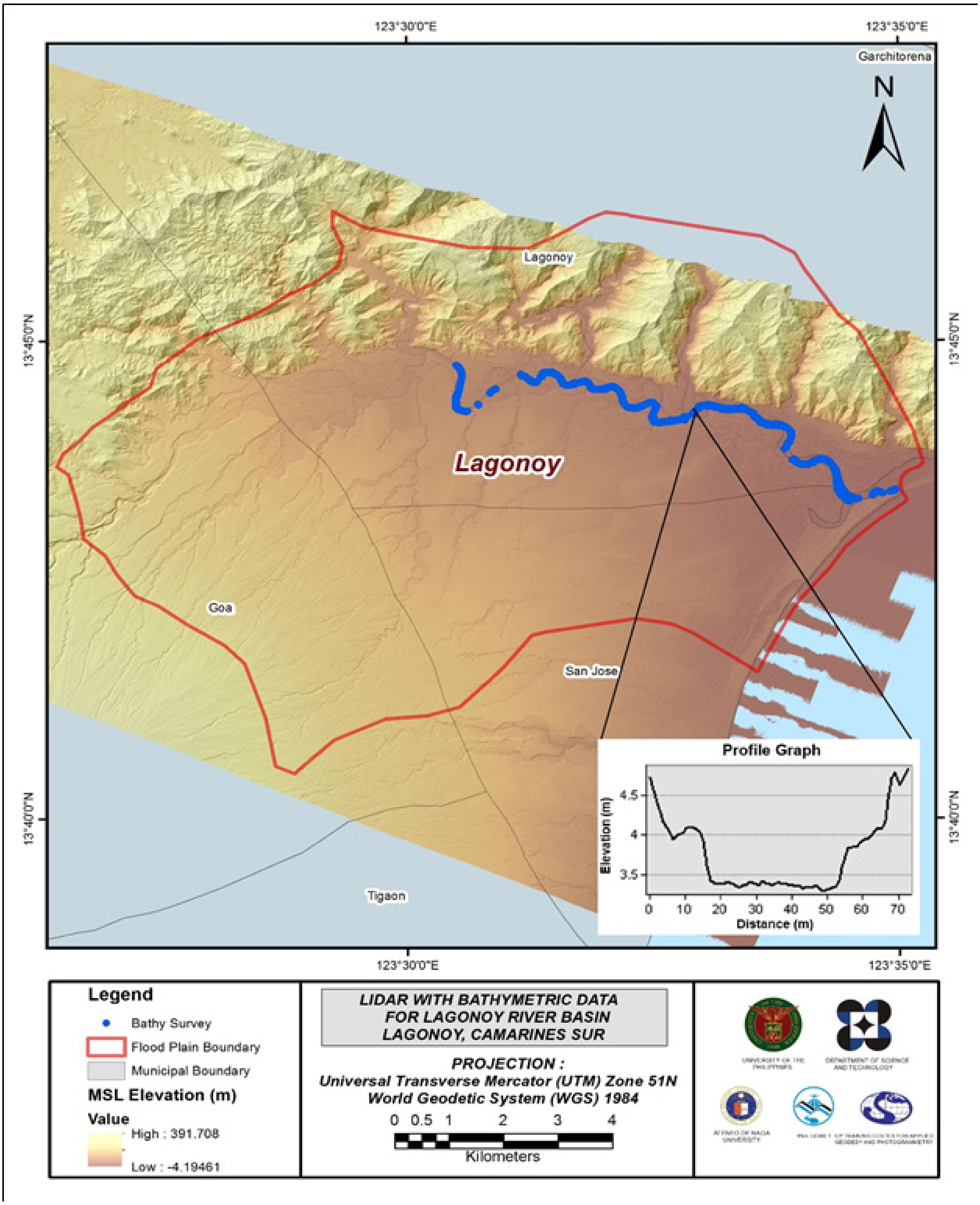


Figure 24. Map of Lagonoy Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Lagonoy Floodplain, including its 200 m buffer, has a total area of 115.78 sq km. For this area, a total of 5.00 square kilometers, corresponding to a total of 2,086 building features, are considered for QC. Figure 25 shows the QC blocks for Lagonoy Floodplain.

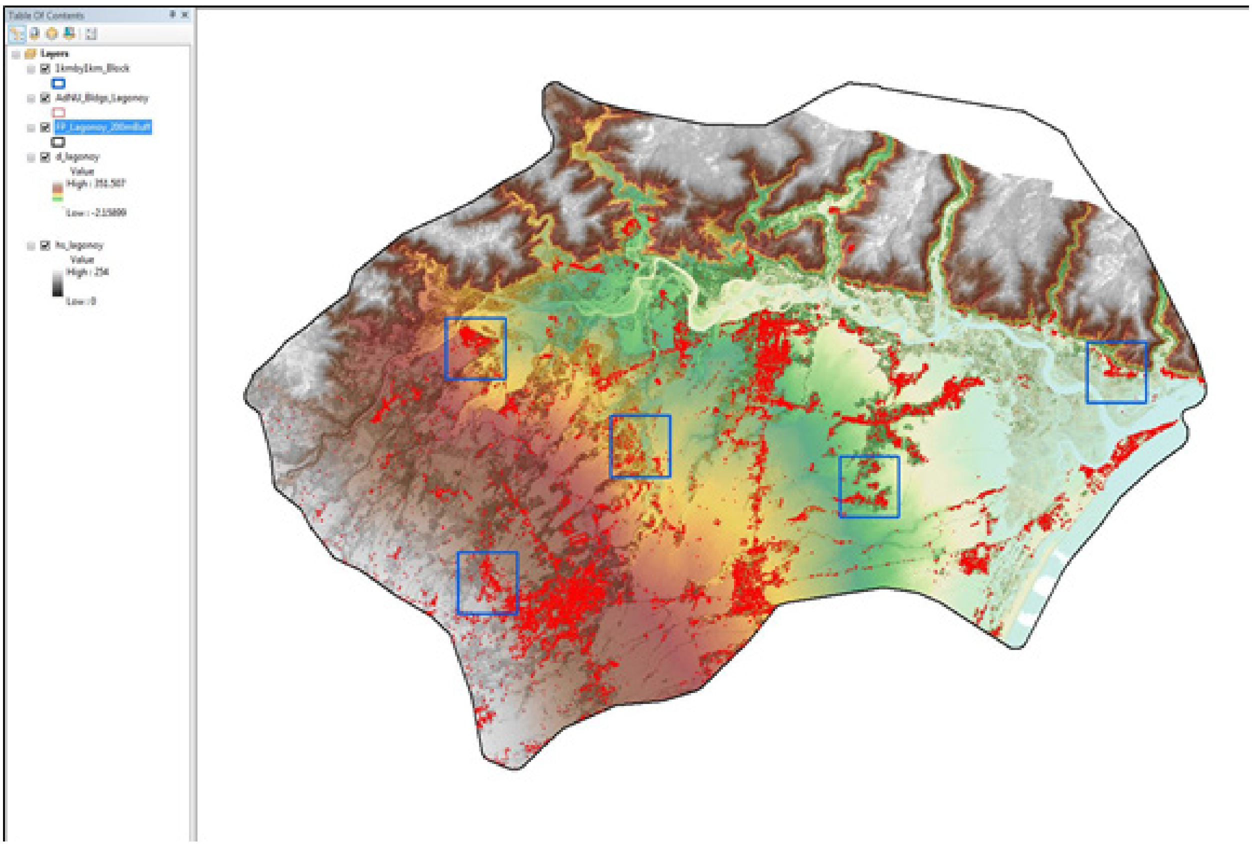


Figure 25. QC blocks for Lagonoy building features.

Quality checking of Lagonoy building features resulted in the ratings shown in Table 16.

Table 16. Quality Checking Ratings for Lagonoy Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Lagonoy	97.54	98.90	82.98	PASSED

3.12.2 Height Extraction

Height extraction was done for 24,106 building features in Lagonoy Floodplain. Of these building features, 239 were filtered out after height extraction, resulting to 23,867 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 8.47 m.

3.12.3 Feature Attribution

Feature Attribution was done for 23,867 building features in Lagonoy Floodplain with the use of participatory mapping and innovations. The approach used in participatory mapping undergoes the creation of feature extracted maps in the area and presenting spatial knowledge to the local community with the premise that they are considered experts in determining the correct attributes of the building features in the area.

The innovation used in this process is the creation of an Android application called reGIS. The Resource Extraction for Geographic Information System (reGIS)[1] app was developed to supplement and increase the field gathering procedures being done by the AdNU Phil-LiDAR 1. The Android application allows the user to automate some procedures in data gathering and feature attribution to further improve and accelerate the geotagging process. The app lets the user record the current GPS location together with its corresponding exposure features, code, timestamp, accuracy and additional remarks. This is all done by a few swipes with the help of the device's pre-defined list of exposure features. This effectively allows unified and standardized sets of data.

Table 17 summarizes the number of building features per type. On the other hand, Table 18 shows the total length of each road type, while Table 19 shows the number of water features extracted per type.

Table 17. Building Features Extracted for Lagonoy Floodplain.

Facility Type	No. of Features
Residential	22,851
School	511
Market	38
Agricultural/Agro-Industrial Facilities	24
Agro Center	1
Medical Institutions	39
Barangay Hall	66
Military Institution	0
Sports Center/Gymnasium/Covered Court	0
Telecommunication Facilities	6
Transport Terminal	4
Warehouse	14
Power Plant/Substation	1
NGO/CSO Offices	4
Police Station	11
Water Supply/Sewerage	2
Religious Institutions	92
Bank	11
Factory	0
Gas Station	17
Fire Station	2
Other Government Offices	36
Other Commercial Establishments	136
Demolished Building	0
New Building*	1
Total	23,867

Table 18. Total Length of Extracted Roads for Lagonoy Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Lagonoy	132.9515	36.9340	2.78298	18.0329	0	190.7014

Table 19. Number of Extracted Water Bodies for Lagonoy Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Lagonoy	1	24	1	0	0	26

A total of 104 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 26 shows the Digital Surface Model (DSM) of Lagonoy Floodplain overlaid with its ground features.

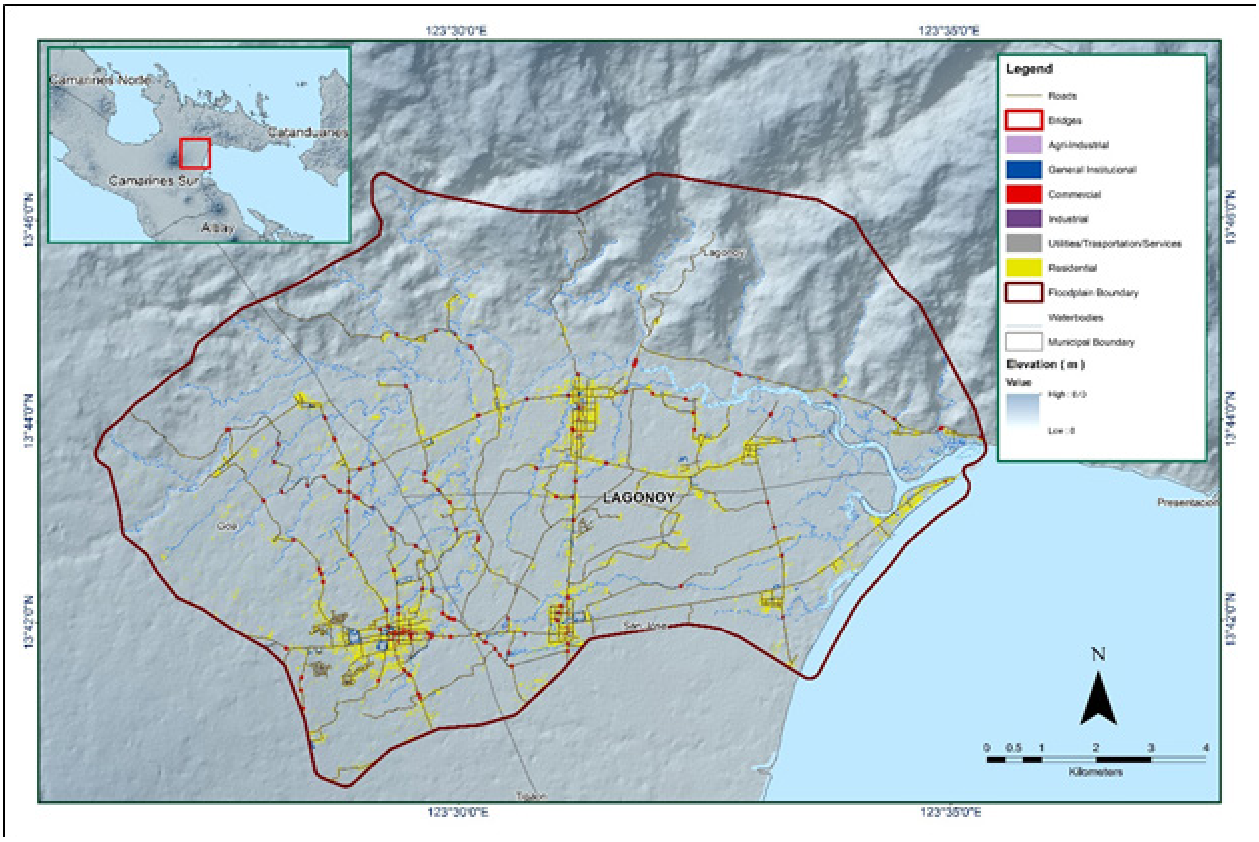


Figure 26. Extracted features for Lagonoy Floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, and For. Rodel C. Alberto

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Lagonoy River on June 22 – July 6, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey at Lagonoy Bridge in Brgy. Ginorangan, Municipality of Lagonoy; validation points acquisition of about 26 km covering the Lagonoy River Basin area; and bathymetric survey from its upstream in Brgy. Agosais to the mouth of the river located in Brgy. Sabang, both in the Municipality of Lagonoy, with an approximate length of 14.645 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 27).

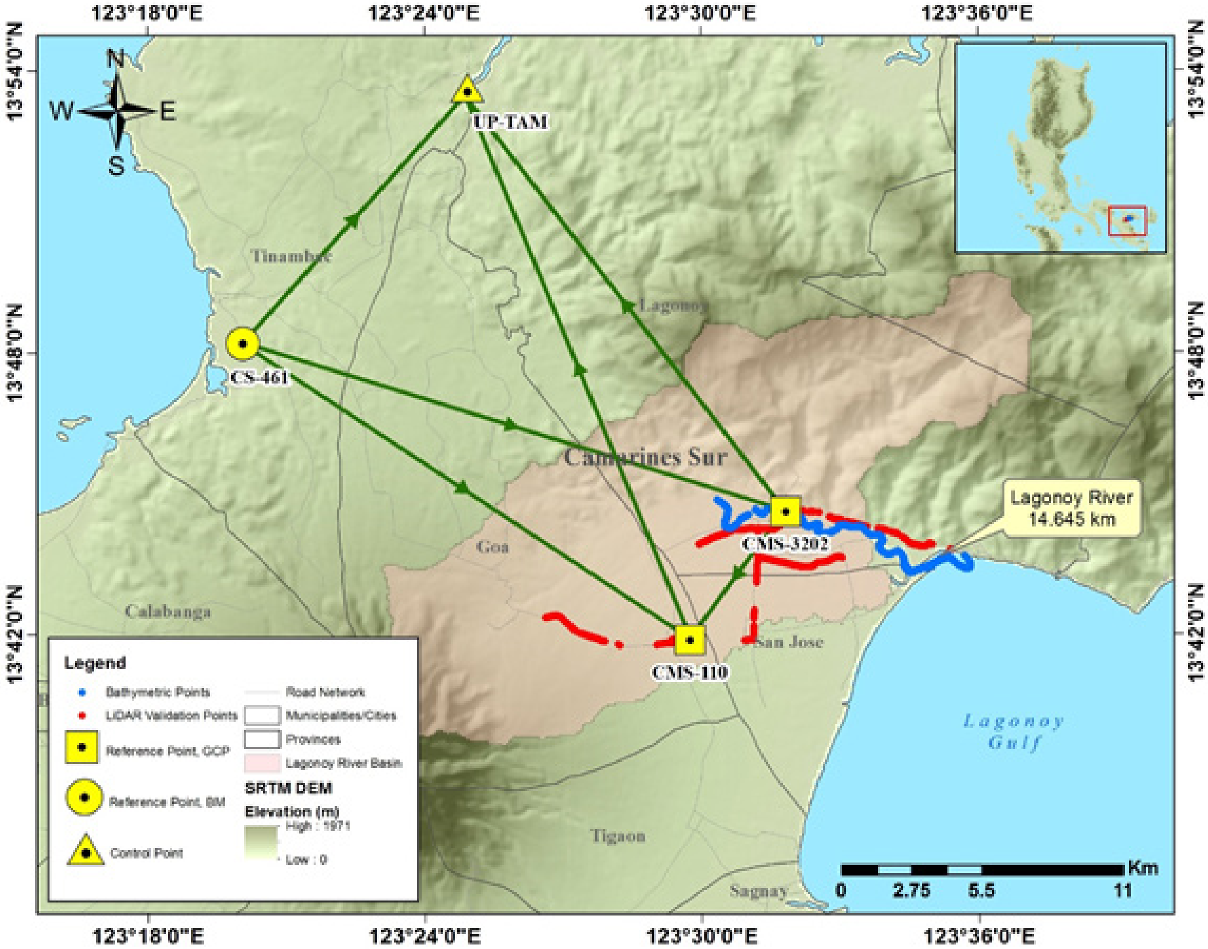


Figure 27. Extent of the bathymetric survey (in blue line) in Lagonoy River and the LiDAR data validation survey (red)

4.2 Control Survey

The GNSS network used for Lagonoy River Survey is composed of four (4) loops established on June 27, 2016 occupying the following reference points: CMS-110, a second-order GCP in Brgy. Taytay, Municipality of Goa; and CS-461, a first order BM, in Brgy. Balaobalite, Municipality of Timambac.

A control point was established namely UP-TAM, located at Tamban Port in Brgy. Tamban, Municipality of Tinambac. A NAMRIA established control point, CMS-3202 in Brgy. Ginotangan, Municipality of Lagonoy, was also occupied to use as marker.

The summary of reference and control points and its location is summarized in Table 20 while the GNSS network established is illustrated in Figure 28.

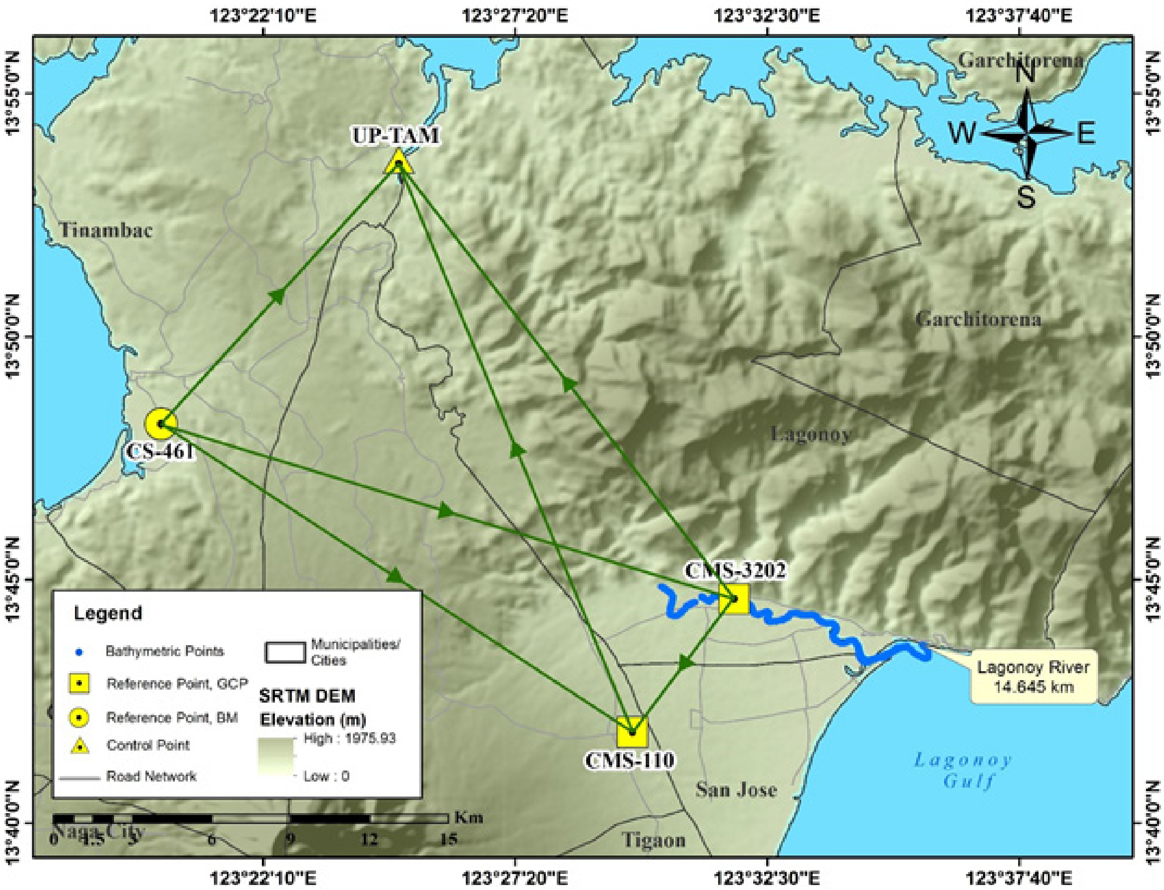


Figure 28. GNSS Network of Lagonoy River Basin Survey

Table 20. References used and control points established in the Lagonoy River Basin Survey

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
CMS-110	2nd order, GCP	13°41'52.12609"N	123°29'44.20763"E	104.205	-	06-27-16
CS-461	1st order, BM	-	-	57.480	5.428	06-27-16
CMS-3202	Used as Marker	-	-	-	-	06-27-16
UP-TAM	UP Established	-	-	-	-	06-27-16

The GNSS set-ups on recovered reference points and established control points in Lagonoy River are shown in Figures 29 to 32.

Figure 29. GNSS base set up, Trimble® SPS 882, at CMS-110, situated at the approach of Culasi Bridge in Brgy. Taytay, Municipality of Goa, Camarines Sur

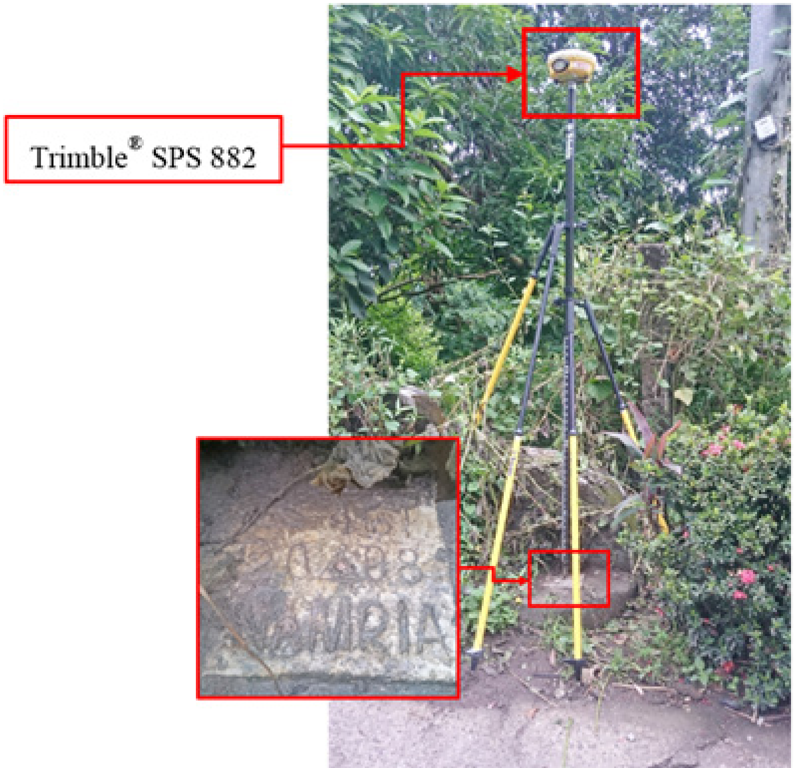


Figure 30. GNSS receiver setup, Trimble® SPS 882, at CS-461, located at the approach of a bridge in Brgy. Balaobalite, Municipality of Tinambac, Camarines Sur

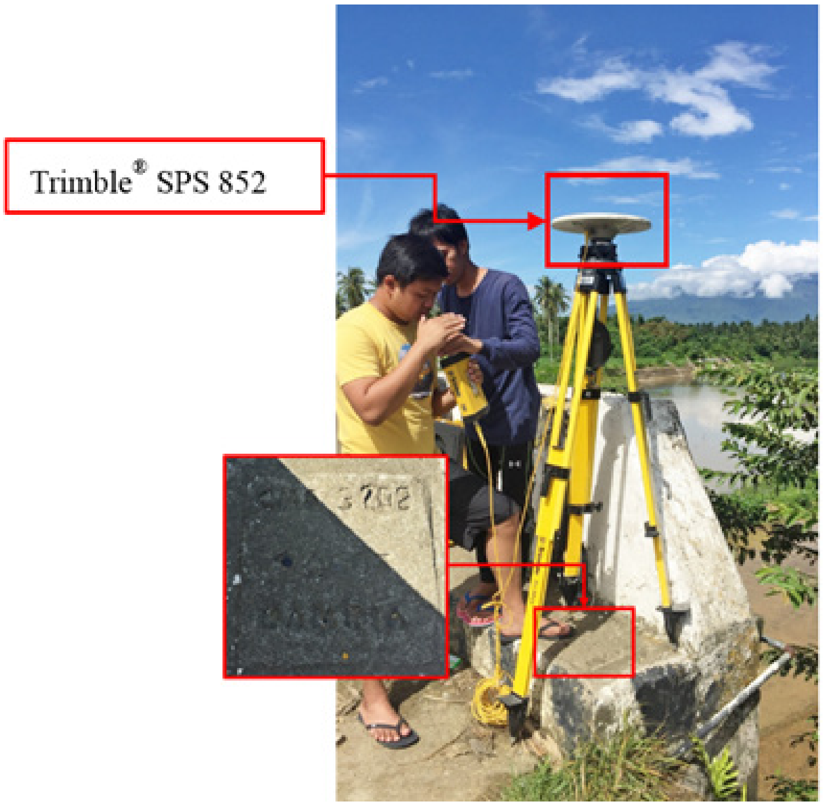


Figure 31. GNSS receiver setup, Trimble® SPS 852, at CMS-3202, located at the approach of Lagonoy Bridge in Brgy. Ginorangan, Municipality of Lagonoy, Camarines Sur

Figure 32. GNSS receiver setup, Trimble® SPS 822, at UP-TAM, located at Tamban Port, Brgy. Tamban, Municipality of Tinambac, Camarines Sur

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 ± 20 cm and ± 10 cm requirement, respectively. In cases when one or more baselines did not meet all of these criteria, masking is performed. Masking is the removal or covering portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 21 presents the baseline processing result of control points in Lagonoy River Basin, as generated by the TBC software.

Table 21. Baseline Processing Report for Lagonoy River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CS-461 --- UP-TAM	06-27-16	Fixed	0.006	0.026	41°09'23"	13328.475	-3.608
CS-461 --- UP-TAM	06-27-16	Fixed	0.005	0.042	41°09'22"	13328.449	-3.540
CS-461 --- CMS-3202	06-27-16	Fixed	0.003	0.019	107°21'48"	22178.246	4.270
CS-461 --- CMS-110	06-27-16	Fixed	0.003	0.019	123°48'32"	20967.545	46.722
CMS-3202 --- UP-TAM	06-27-16	Fixed	0.004	0.017	323°23'08"	20760.844	-7.812
CMS-3202 --- UP-TAM	06-27-16	Fixed	0.004	0.023	323°23'07"	20760.831	-7.801
CMS-3202 --- CMS-110	06-27-16	Fixed	0.003	0.011	216°37'18"	6285.971	42.467
CMS-110 --- UP-TAM	06-27-16	Fixed	0.005	0.021	338°18'24"	23362.491	-50.291
CMS-110 --- UP-TAM	06-27-16	Fixed	0.004	0.023	338°18'24"	23362.483	-50.264

As shown Table 21, a total of nine (9) baselines were processed with reference points CMS-110 and CS-461 held fixed for coordinate and elevation values. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

For complete details, see the Network Adjustment Report shown in Tables 22 to 25:

The four (4) control points, CMS-110, CS-461, CMS-3202 and UP-TAM were occupied and observed simultaneously to form a GNSS loop. Coordinates of CMS-110; and elevation values of CS-461 were held fixed during the processing of the control points as presented in Table 22. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 22. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
CMS-110	Global	Fixed	Fixed		
CS-461	Grid				Fixed
Fixed = 0.000001 (Meter)					

Likewise, the list of adjusted grid coordinates, (i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network) is indicated in Table 23. The fixed control CMS-110 has no values for grid errors while CS-461 has no value for elevation errors.

Table 23. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
CMS-110	553591.452	?	1514361.204	?	51.938	0.056	LL
CS-461	536159.891	0.008	1525999.493	0.007	5.428	?	e
CMS-3202	557328.793	0.007	1519412.663	0.006	9.384	0.055	
UP-TAM	544914.191	0.007	1536043.176	0.006	1.819	0.059	

The computation for the accuracy are as follows:

a. CMS-110

Horizontal accuracy	=	Fixed
Vertical accuracy	=	5.6 cm < 10 cm

b. CS-461

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

c. CMS-3202

Horizontal accuracy	=	$\sqrt{((0.7)^2 + (0.6)^2}$
	=	$\sqrt{(0.49 + 0.36)}$
	=	0.92 < 20 cm
Vertical accuracy	=	5.5 cm < 10 cm

d. UP-TAM

Horizontal accuracy	=	$\sqrt{((0.7)^2 + (0.6)^2}$
	=	$\sqrt{(0.49 + 0.36)}$
	=	0.92 < 20 cm
Vertical accuracy	=	5.9 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the two occupied control points are within the required precision.

Table 24. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
CMS-110	N13°41'52.12609"	E123°29'44.20763"	104.205	0.056	LL
CS-461	N13°48'11.94074"	E123°20'04.40925"	57.480	?	e
CMS-3202	N13°44'36.29589"	E123°31'48.99957"	61.737	0.055	
UP-TAM	N13°53'38.42492"	E123°24'56.57247"	53.908	0.059	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 24. Based on the result 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 used is indicated in Table 25.

Table 25. The reference and control points utilized in the Lagonoy River Survey with its corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
CMS-110	2nd order, GCP	13°41'52.12609"N	123°29'44.20763"E	104.205	1514361.204	553591.452	51.938
CS-461	1st order, BM	13°48'11.94074"N	123°20'04.40925"E	57.480	1525999.493	536159.891	5.428
CMS-3202	Used as Marker	13°44'36.29589"N	123°31'48.99957"E	61.737	1519412.663	557328.793	9.384
UP-TAM	UP Established	13°53'38.42492"N	123°24'56.57247"E	53.908	1536043.176	544914.191	1.819

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

The cross-section and as-built survey were conducted on June 25 and 28, 2016 along the downstream side of Lagonoy Bridge in Brgy. Ginorangan, Municipality of Lagonoy, Camarines Sur as shown in Figure 33. A survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique was utilized for this survey.

Figure 33. A) Lagonoy Bridge facing upstream, and B) its Bridge As-built survey

The cross-sectional line of Lagonoy Bridge is about 185 m with eighty-two (82) cross-sectional points using the control point CMS-3202 as the GNSS base station. The location map, cross-section diagram, and the bridge data form are shown in Figures 34 to 36, respectively.

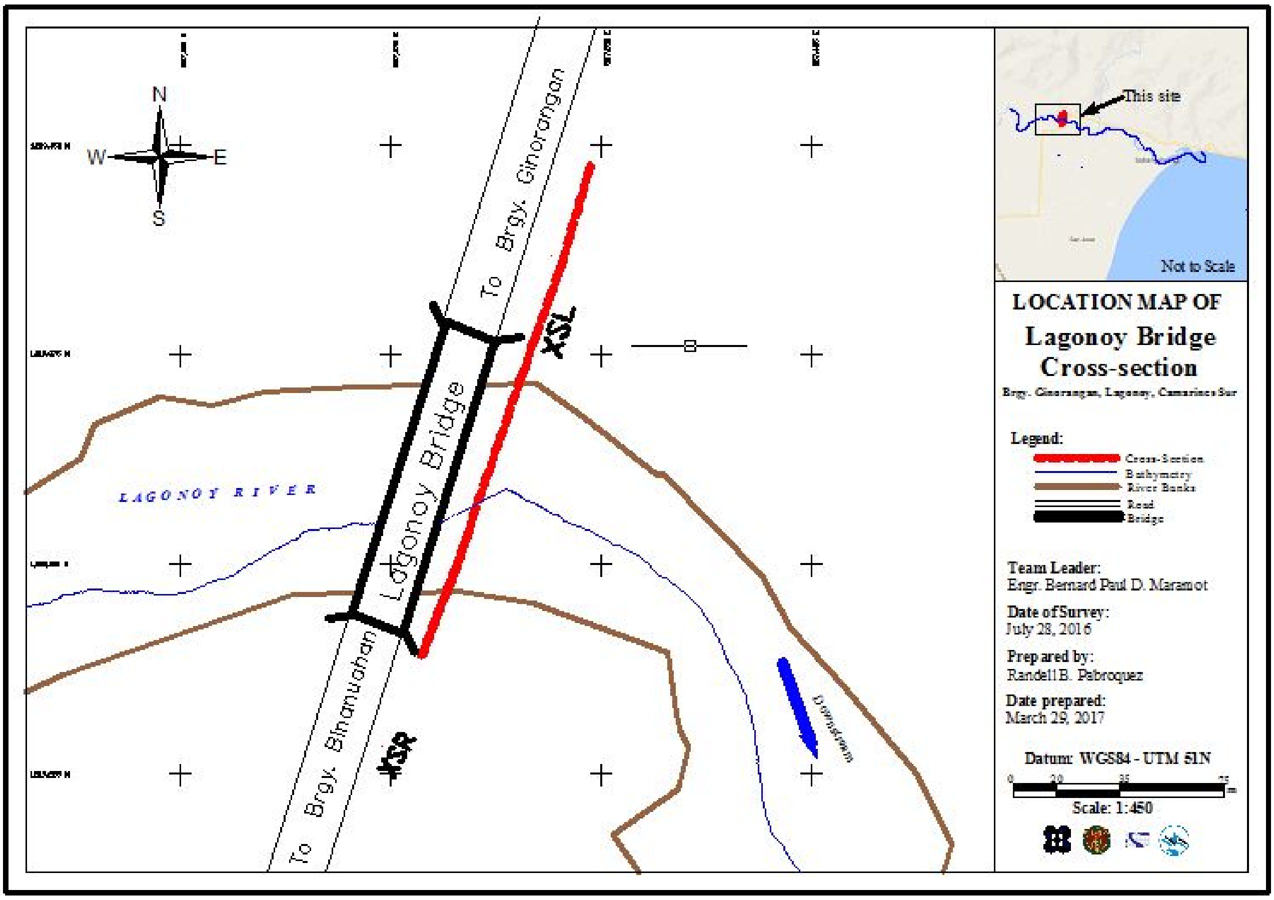


Figure 34. Lagonoy Bridge cross-section location map

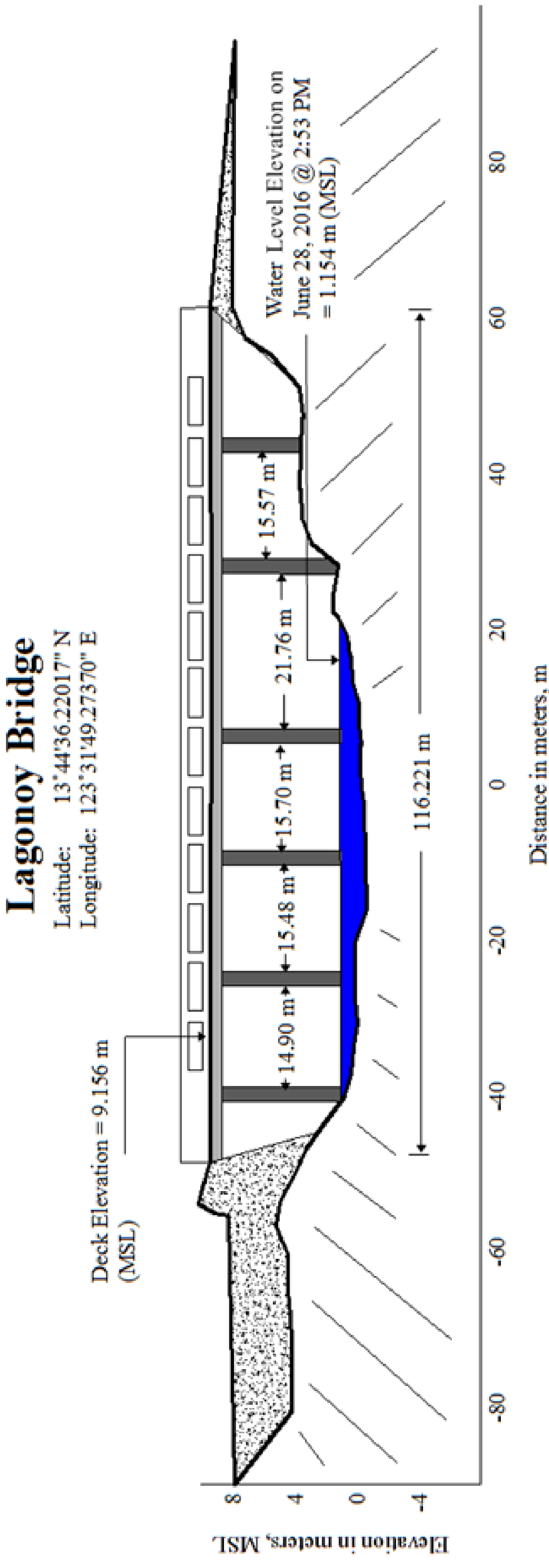


Figure 35. Cross section diagram at Lagonoy Bridge

Bridge Data Form

Bridge Name: Lagonoy Bridge | Date: June 25 and 28, 2016

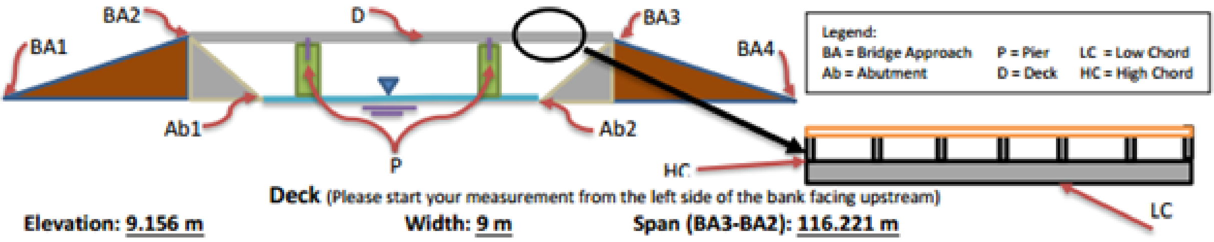
River Name: Lagonoy River | Time: 2:53 PM

Location (Brgy, City,Region): Brgy. Ginorangan, Municipality of Lagonoy, Camarines Sur

Survey Team: Rodel Alberto, Cybil Atacador, Russel Andrade

Flow condition: normal | Weather Condition: fair

Latitude: 13°44'36.22017" N | Longitude: 123°31'49.273704" E



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

Elevation: 9.156 m | Width: 9 m | Span (BA3-BA2): 116.221 m

	Station	High Chord Elevation	Low Chord Elevation
1	Not available	Not available	Not available

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	7.883 m	BA3	151.186 m	9.173 m
BA2	34.956 m	9.156 m	BA4	185.564 m	7.864 m

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

	Station (Distance from BA1)	Elevation
Ab1	43.175 m	3.982 m
Ab2	142.749 m	3.918 m

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

Shape: Flat oval | Number of Piers: 5 | Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	49.216 m	9.449 m	NA
Pier 2	64.114 m	9.408 m	NA
Pier 3	79.591 m	9.408 m	NA
Pier 4	95.291 m	9.370 m	NA
Pier 5	117.058 m	9.384 m	NA
Pier 6	132.631 m	9.446 m	

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

Figure 36. Bridge Data Form of Lagonoy Bridge

Water surface elevation of Lagonoy River was determined using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on June 28, 2016 at 2:53 PM with a value of 1.154 m in MSL as shown in Figure 36. This was translated into marking on the bridge's deck using the same technique. The marking has a value of 9.408 m in MSL as shown in Figure 37. This will serve as reference for flow data gathering and depth gauge deployment of partner HEI responsible for Lagonoy River, the Ateneo de Naga University.

Figure 37. Water-level markings on Lagonoy Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition was conducted on June 17 and 18, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on the roof of a vehicle as shown in Figure 38. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.255 m and 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 CMS-3202 occupied as the GNSS base stations in the conduct of the survey.

Figure 38. Validation points acquisition survey set up along Lagonoy River Basin

The survey started from the Lagonoy Bridge in Brgy. Ginorangan, in the Municipality of Lagonoy; going east covering Brgy. Manamoc and San Sebastian; going south covering ten more barangays in the Municipality of Lagonoy; down to seven (7) barangays in the Municipality of San Jose namely, Camagong, Santa Cruz, Del Carmen, San Vicente, San Juan, San Antonio and Soledan; and finally going west covering eight (8) barangays in the Municipality of Goa which ended in Brgy. Hiwacloy. The survey gathered a total of 3,325 points with approximate length of 26 km using CMS-3202 as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 39.

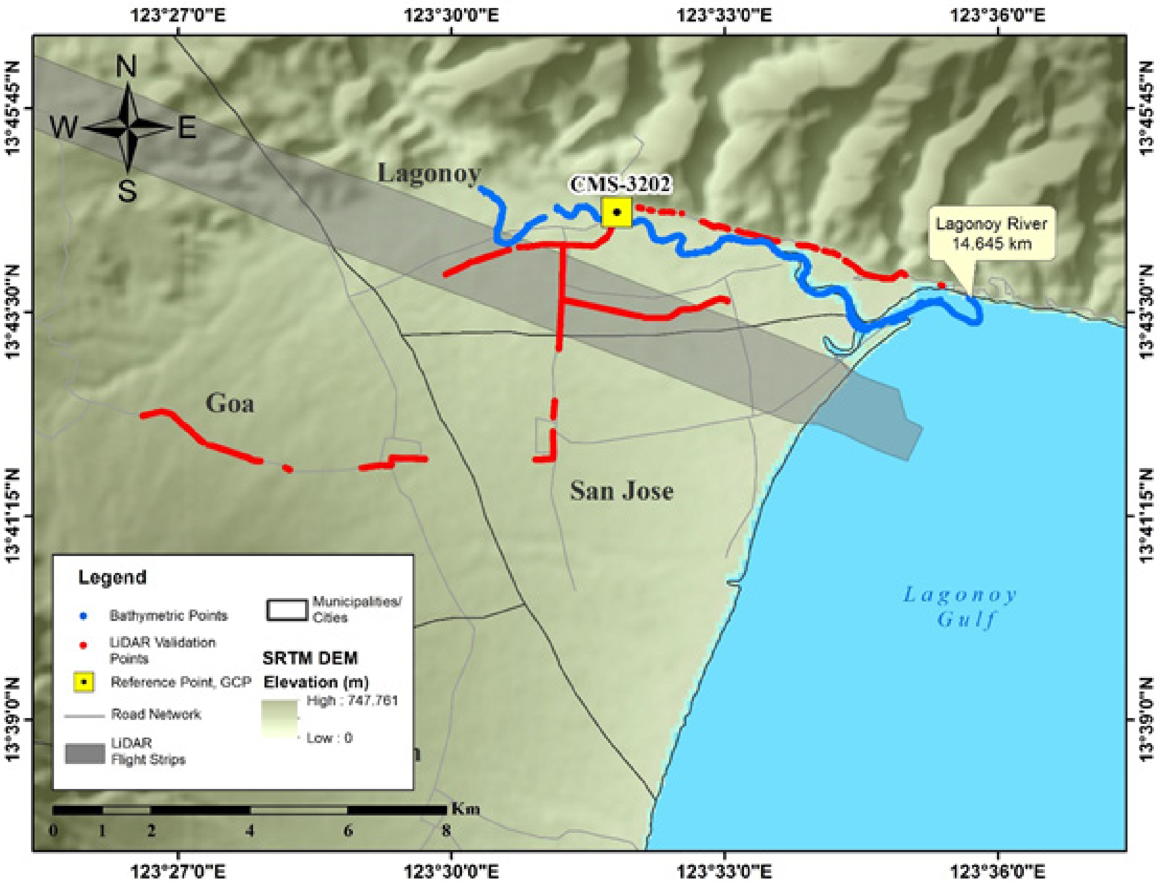


Figure 39. LiDAR Ground Validation survey along Lagonoy River Basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on June 25, 2016 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 40. The survey started in Brgy. Burabod, Municipality of Lagonoy, with coordinates 13°44'18.28661"N, 123°32'59.30757"E, and ended at the mouth of the river in Brgy. Sabang, in Municipality of San Jose with coordinates 13°43'24.89932"N, 123°35'48.11928"E.

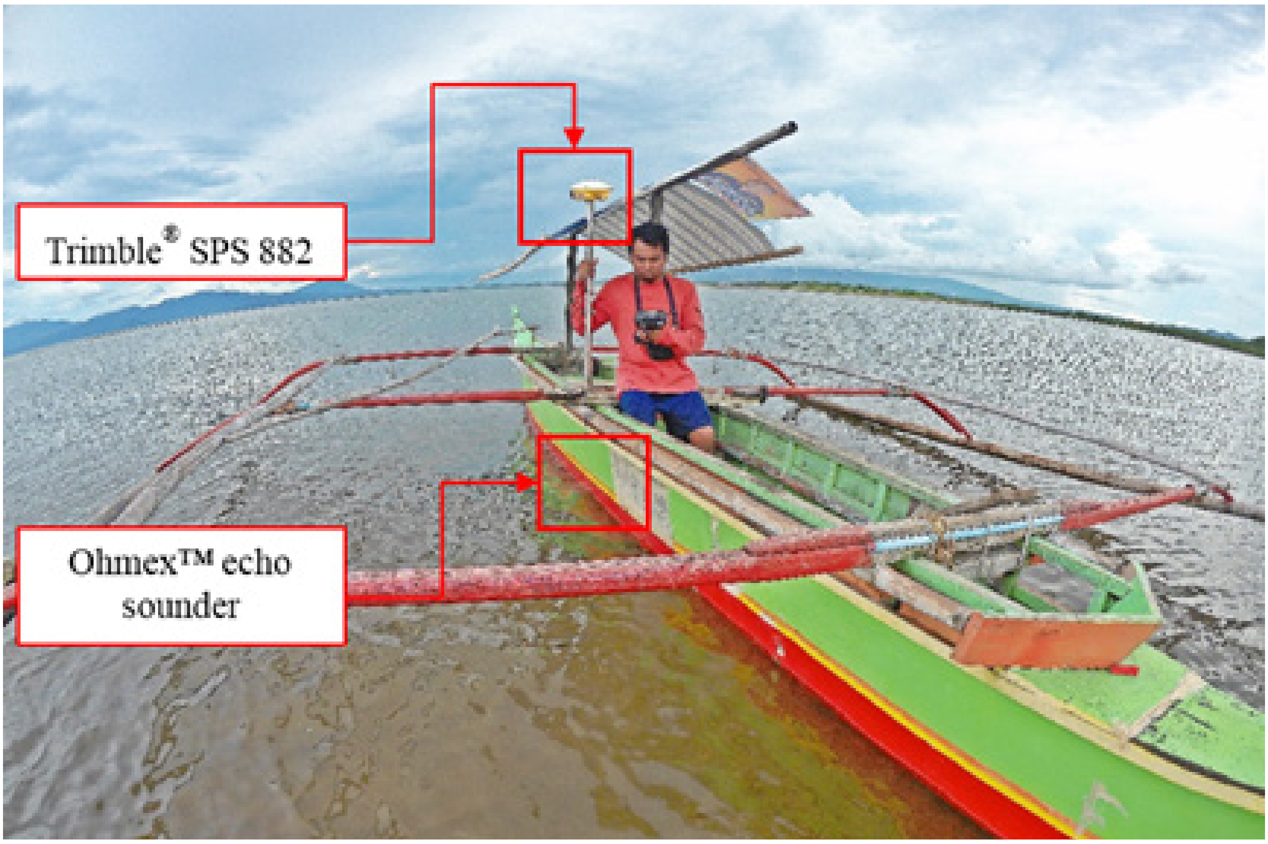


Figure 40. Bathymetric survey using Ohmex™ single beam echo sounder in Lagonoy River

Meanwhile, a manual bathymetric survey was executed on June 24 and 25, 2016 using Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 41. The survey started in Brgy. Agosais, Municipality of Lagonoy, with coordinates 13°44'51.89048"N, 123°30'19.35887"E, and ended at the starting point of bathymetric survey using boat. The control point CMS-3202 was used as the GNSS base station all throughout the entire survey.

Figure 41. Manual Bathymetric survey in Lagonoy River

The bathymetric survey for Lagonoy River gathered a total of 22,317 points covering 14.645 km of the river traversing ten (10) barangays in the Municipality of Lagonoy namely: Dahat, Agosais, Saripongpong, San Isidro Norte, Santa Maria, Ginorangan, Binanuahan, Loho, Burabod and Manamc; and Brgy. Sabang in Municipality of San Jose (Figure 42). A CAD drawing was also produced to illustrate the riverbed profile of Lagonoy River. As shown in Figure 43, the highest and lowest elevation has a 10 m-difference. The highest elevation observed was 4.929 m above MSL located at the upstream portion of the river in Brgy. Agsais, Municipality of Lagonoy, while the lowest was -5.988 m below MSL located at the downstream portion of the river in Brgy. Sabang, Municipality of San Jose.

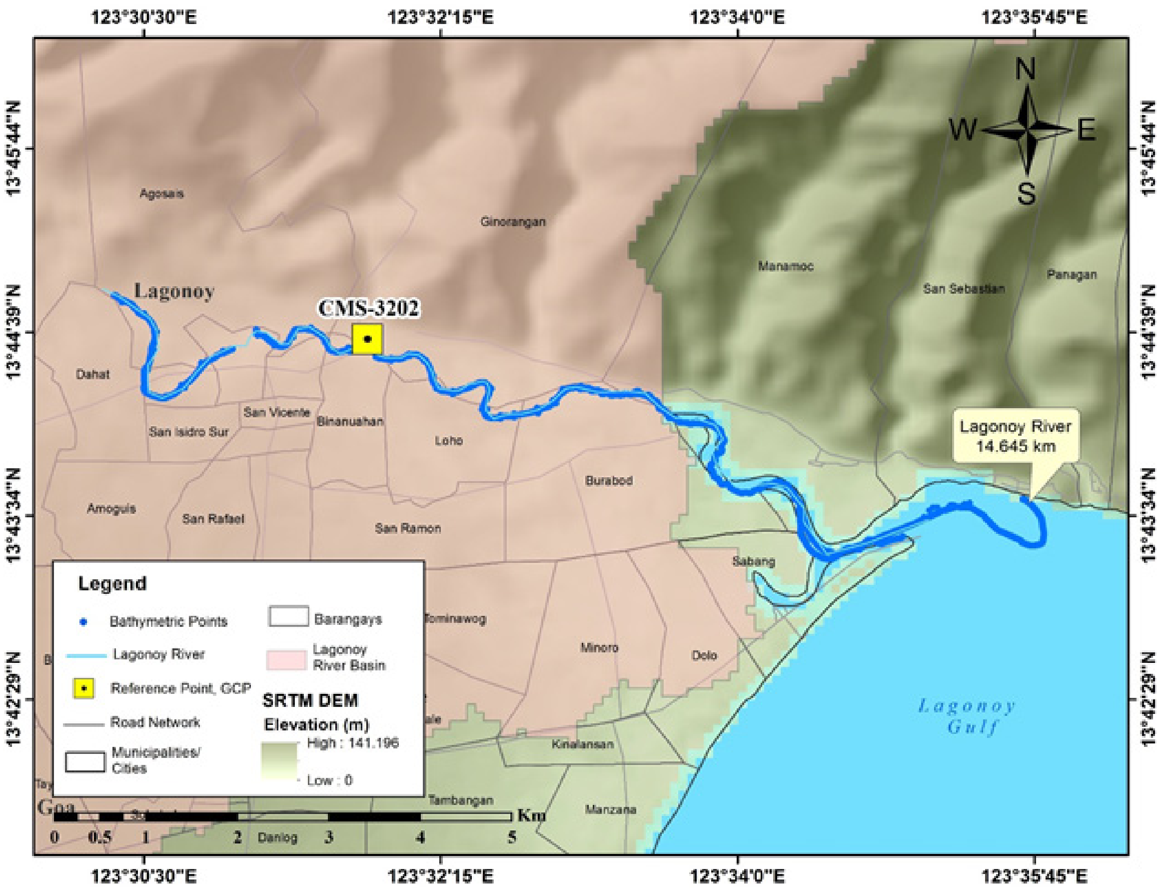


Figure 42. Bathymetric Survey of Lagonoy River

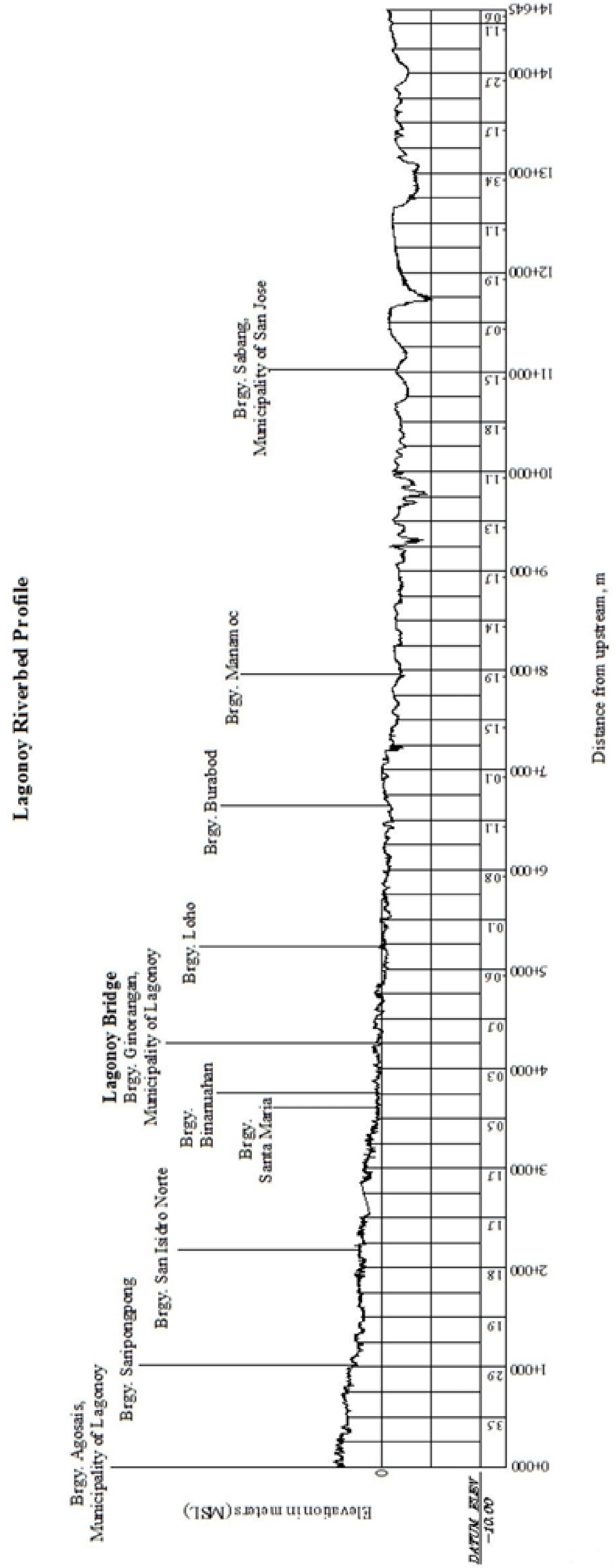


Figure 43. Lagonoy Riverbed Profile

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Gianni Sumajit, Engr. Ferdinand E. Bien, Christian Javier B. Arroyo, Daniel S. Baer Jr, Mark D. Delloro, Berlin Phil V. Garciano, Engr. Julius Hector S. Manchete, John Paul B. Obina, Engr. Lech Fidel C. Pante, Ernesto F. Razal Jr., Rox Harvey DP. Rosales, Aaron P. San Andres, Engr. Jayrik T. San Buenaventura, Sarah Mae F. Fulleros, and Engr. Julius Hector S. Manchete

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

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

5.1.2 Precipitation

Precipitation data was taken from one rain gauge deployed by the ADNU-FMC team. The rain gauge was deployed at Lagonoy Bridge (Figure 44). The precipitation data collection started from January 14, 2017 at 12:00 AM to January 15, 2017 at 12:00 AM with a 10-minute recording interval.

The total precipitation for this event in Lagonoy Bridge rain gauge is 60.8mm. It has a peak rainfall of 6mm on January 14, 2017 at 7:40 AM. The lag time between the peak rainfall and discharge is 3 hours and 50 minutes.

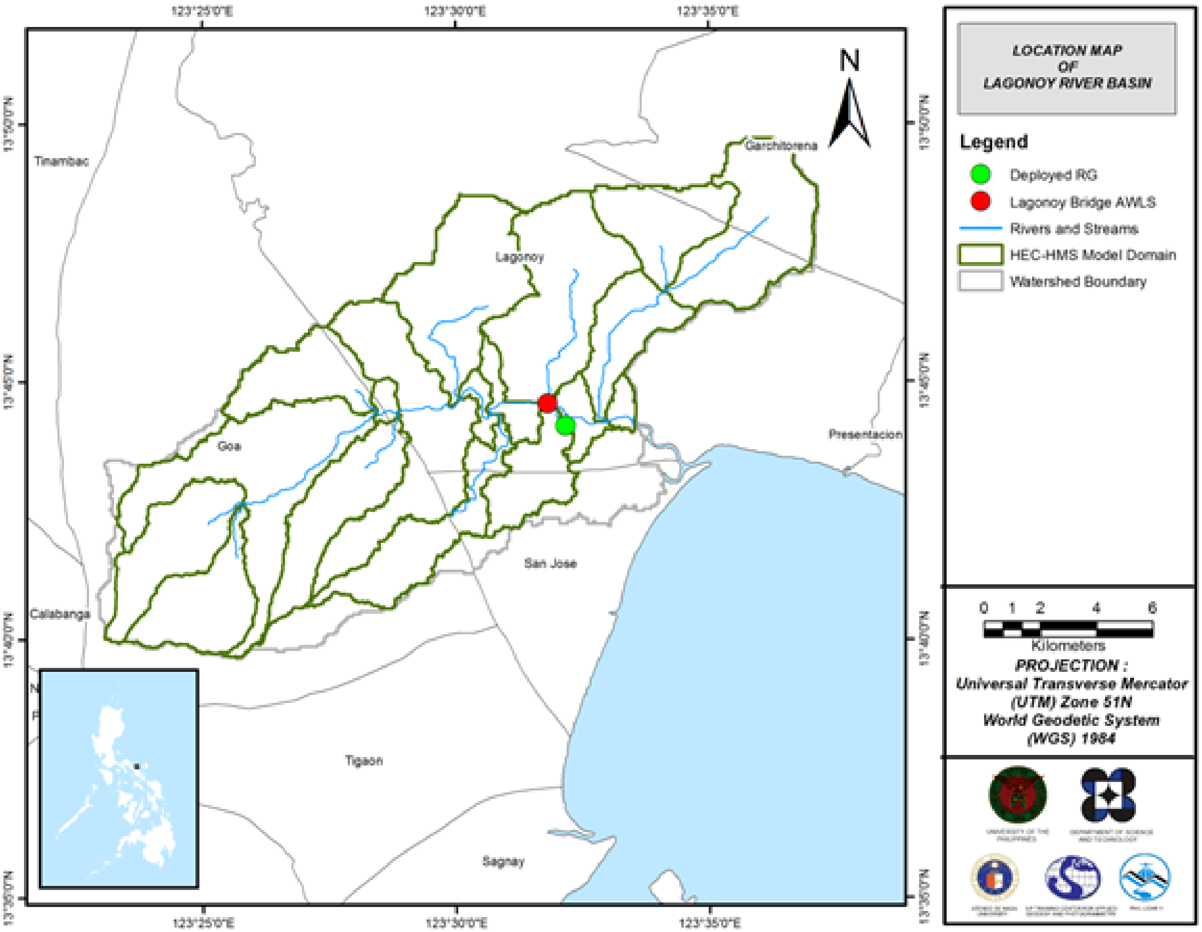


Figure 44. The location map of Lagonoy HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Lagonoy Bridge, Lagonoy, Camarines Sur (13°44’34.38"N, 123°31'49.09"E). It gives the relationship between the observed water levels at Lagonoy Bridge and outflow of the watershed at this location.

For Lagonoy Bridge, the rating curve is expressed as Q = 34.777e0.4365h as shown in Figure 46.

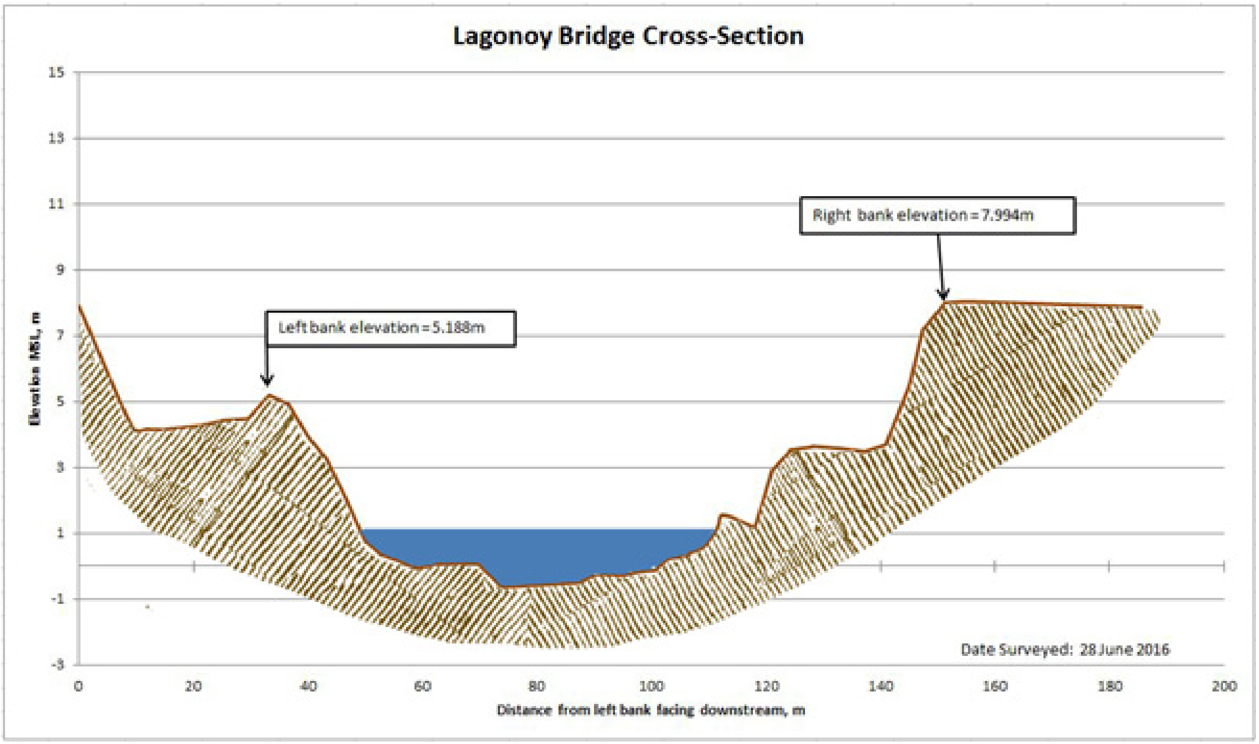


Figure 45. Cross-Section Plot of Lagonoy Bridge

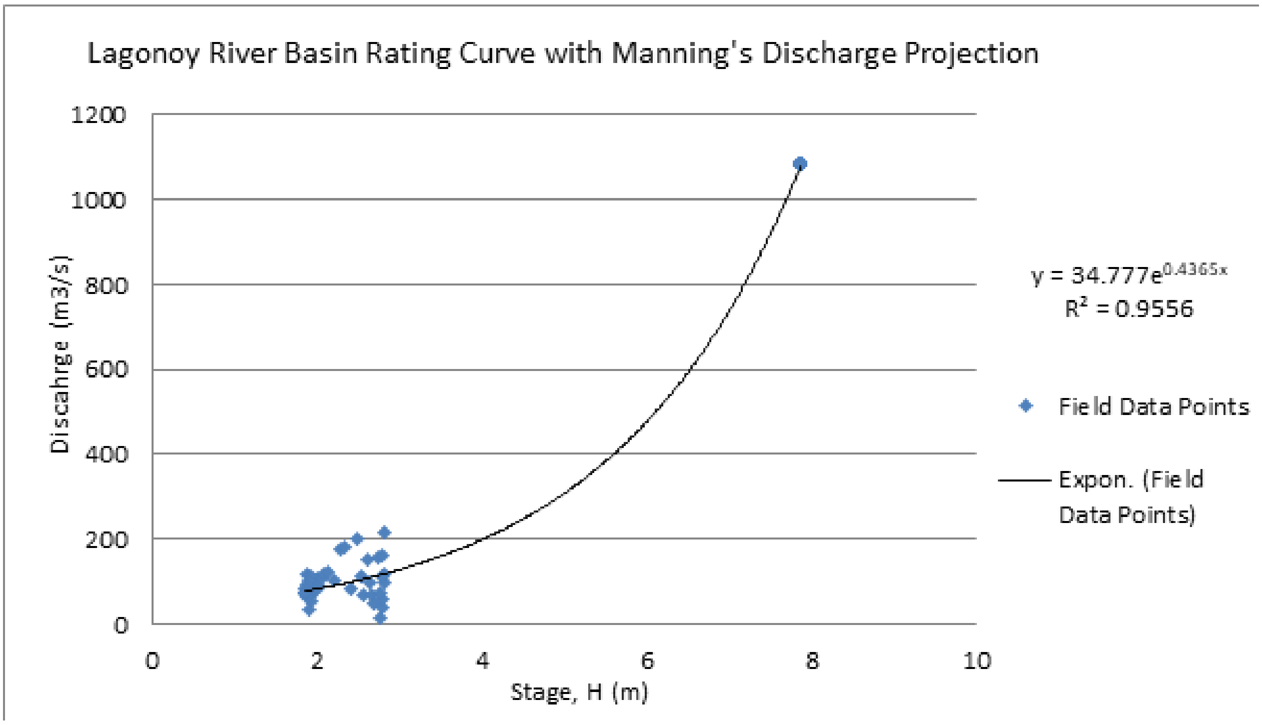


Figure 46. The rating curve of Lagonoy Bridge in Lagonoy, Camarines Sur

This rating curve equation was used to compute the river outflow at Lagonoy Bridge for the calibration of the HEC-HMS model shown in Figure 47. The total rainfall for this event is 60.8mm and the peak discharge is 119.1m3/s at 11:30 AM, January 14, 2017.

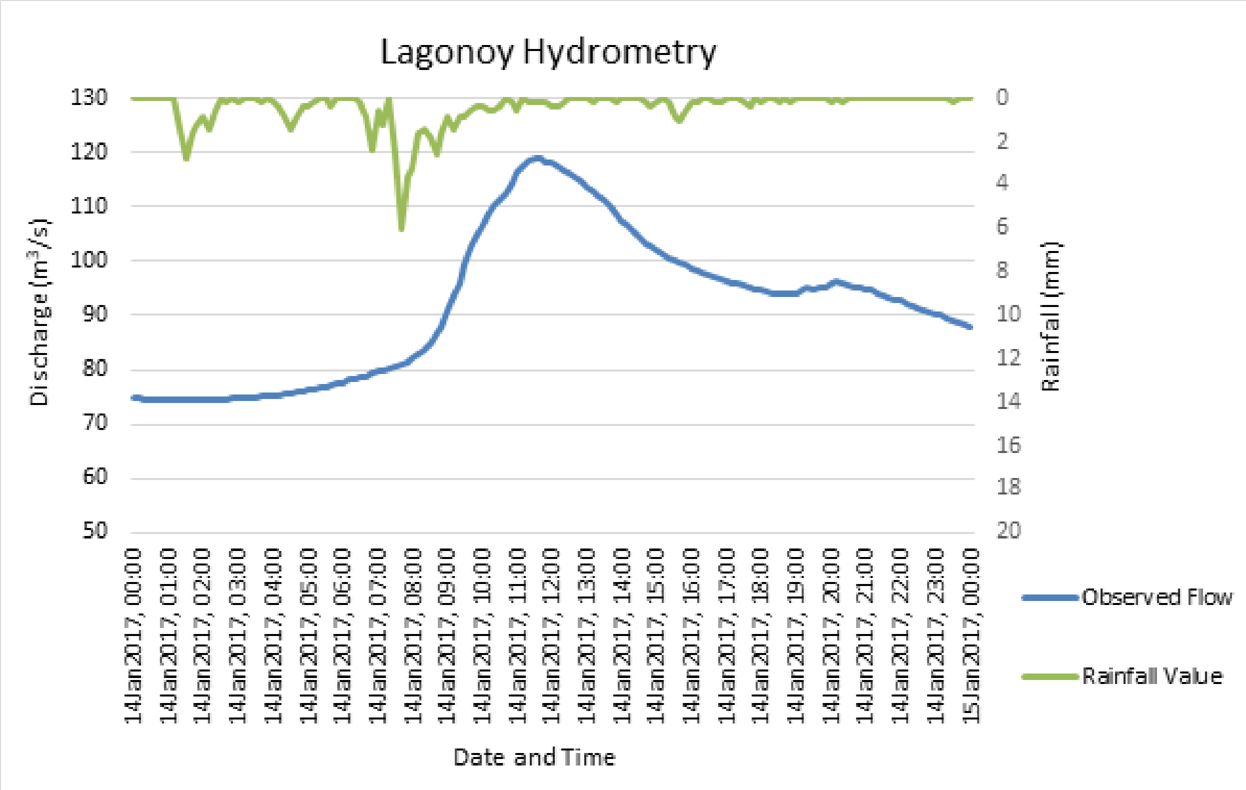


Figure 47. Rainfall and outflow data of the Lagonoy River Basin, which was used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Daet RIDF (Table 26). The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time (Figure 49). This station was selected based on its proximity to the Lagonoy watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 26. RIDF values for Lagonoy Rain Gauge computed by PAG-ASA

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	21.8	33.8	43.1	59.6	84	101	130.4	163.2	190.4
5	31.8	47.2	59.1	81.9	120.3	146.8	194.7	236.8	278.7
10	38.5	56.1	69.7	96.7	144.4	177.1	237.2	285.6	337.2
15	42.3	61.1	75.7	105	158	194.1	261.2	313.1	370.2
20	44.9	64.6	79.9	110.8	167.5	206.1	278	332.4	393.3
25	46.9	67.3	83.1	115.3	174.8	215.3	291	347.2	411.1
50	53.2	75.6	93	129.2	197.3	243.7	330.8	392.9	465.9
100	59.4	83.9	102.9	143	219.7	271.9	370.4	438.3	520.3

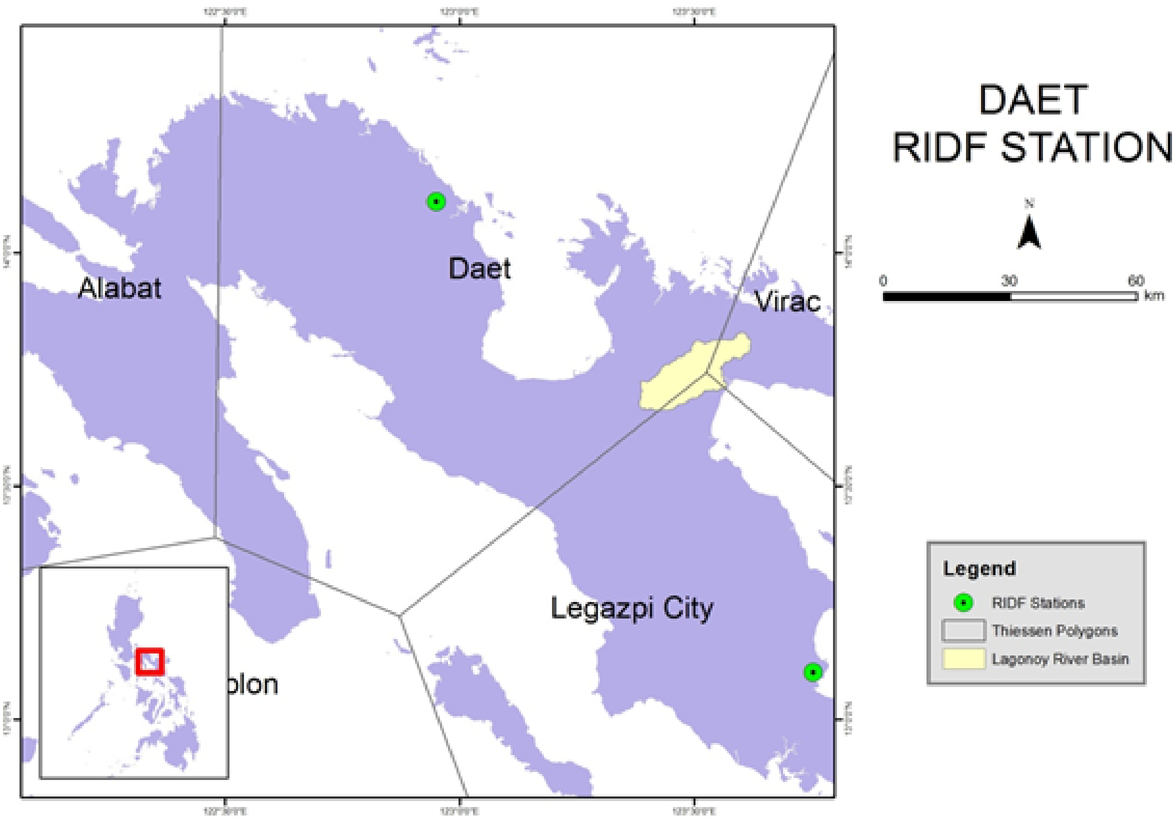


Figure 48. Location of the Daet RIDF station relative to the Lagonoy River Basin

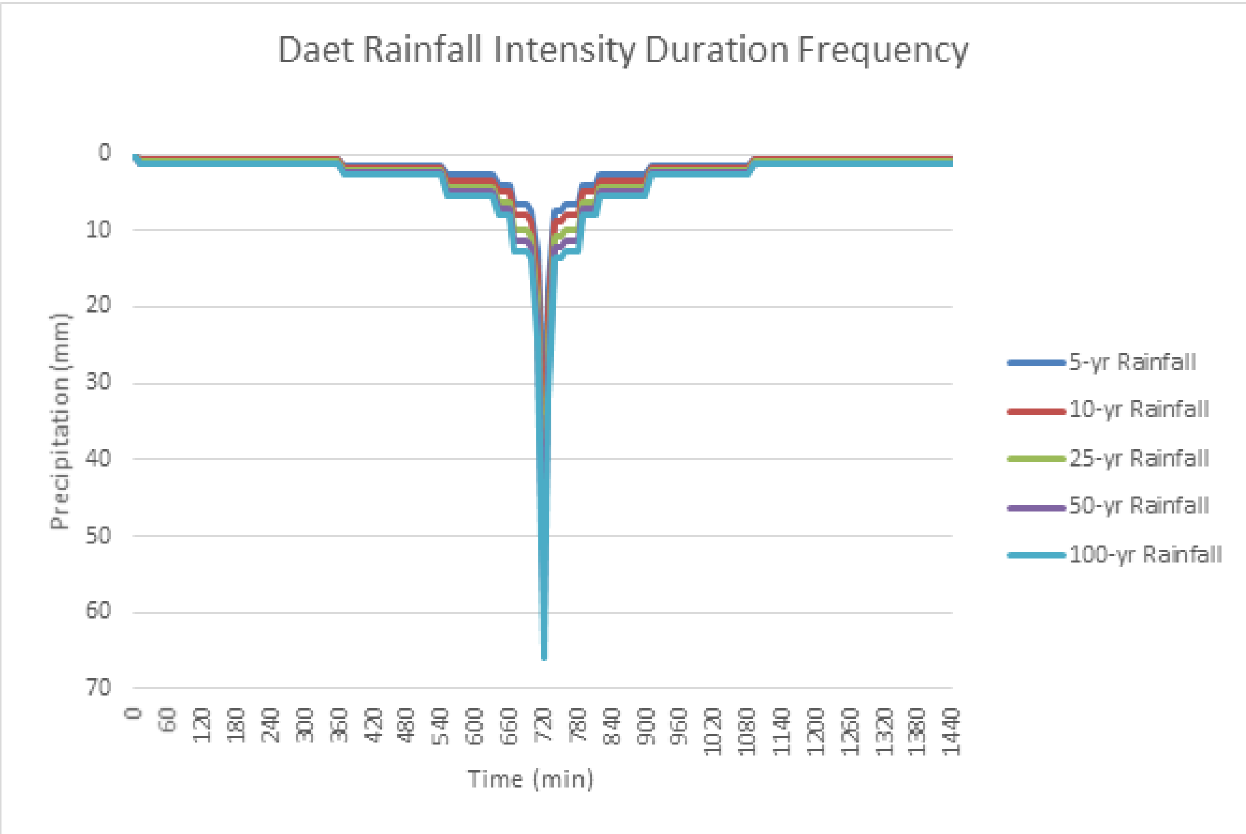


Figure 49. Synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated in 2004 by 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). The soil and land cover of the Lagonoy River Basin are shown in Figures 50 and 51, respectively.

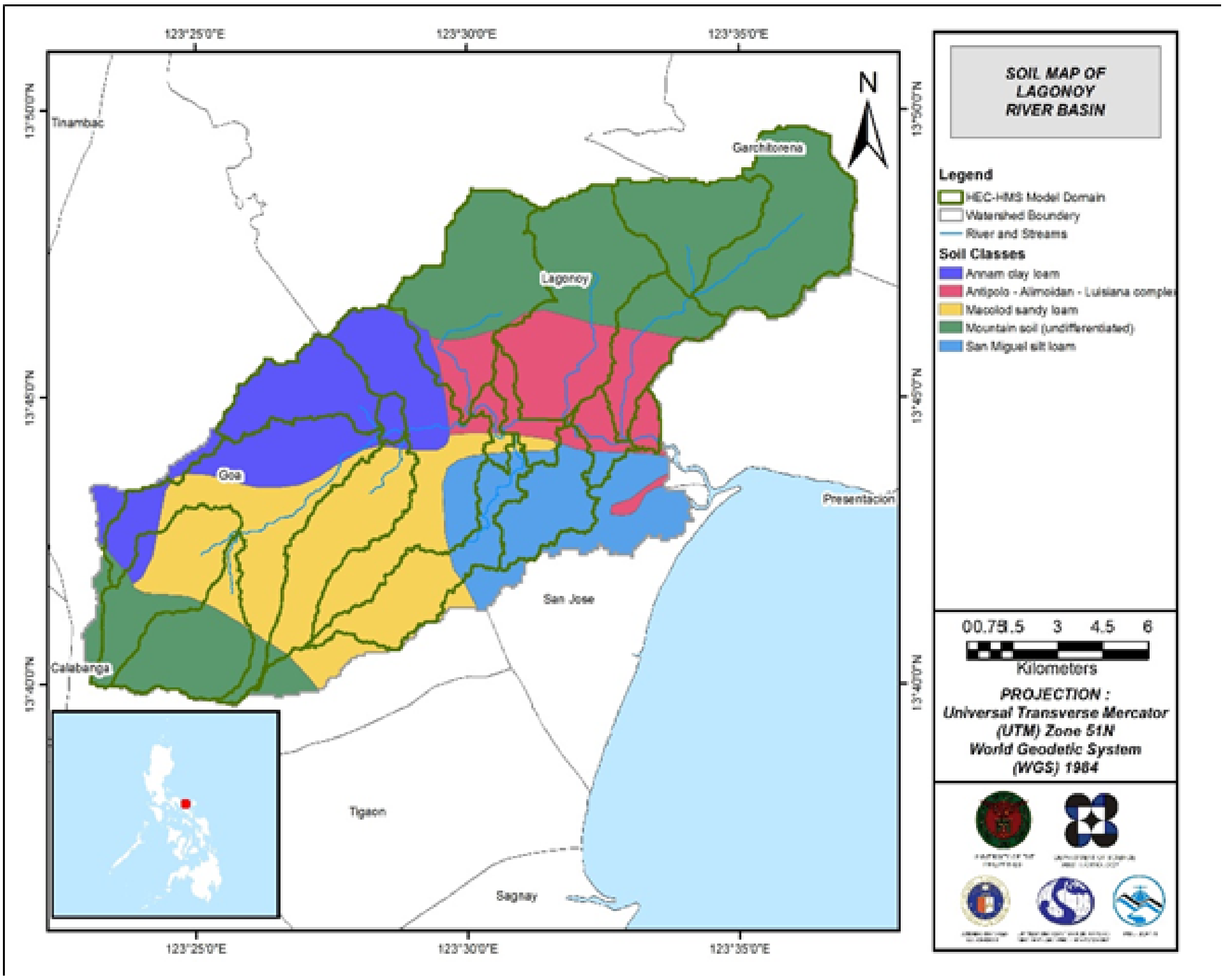


Figure 50. Soil Map of Lagonoy River Basin

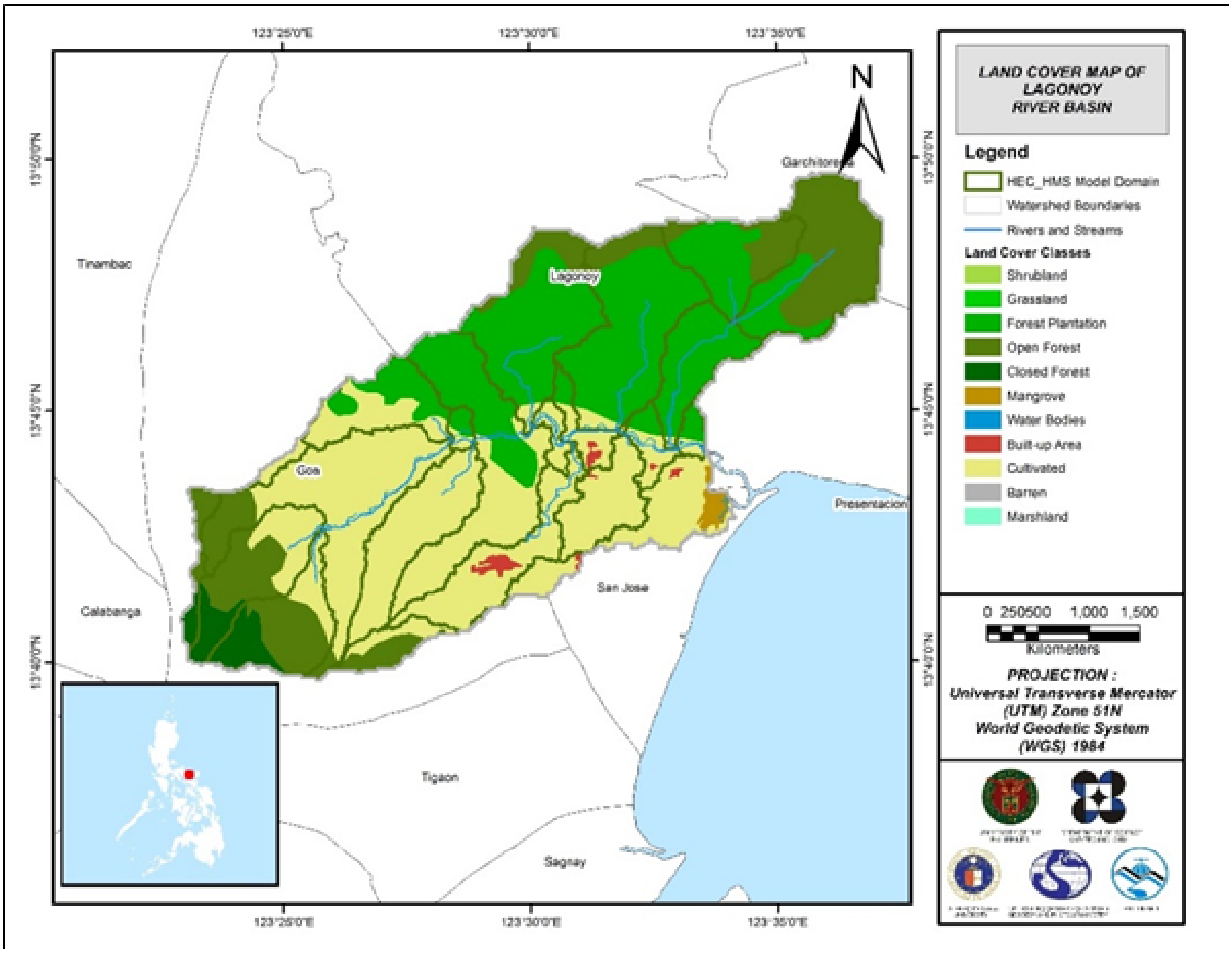


Figure 51. Land Cover Map of Lagonoy River Basin (Source: NAMRIA)

For Lagonoy, five soil classes were identified. These are Annam clay loam, Antipolo-Alimodian-Luisiana complex, Macolod sandy loam, San Miguel silt loam, and undifferentiated mountain soil. Moreover, six land cover classes were identified. These are grassland, open and closed forest, mangrove, cultivated, and built-up areas.

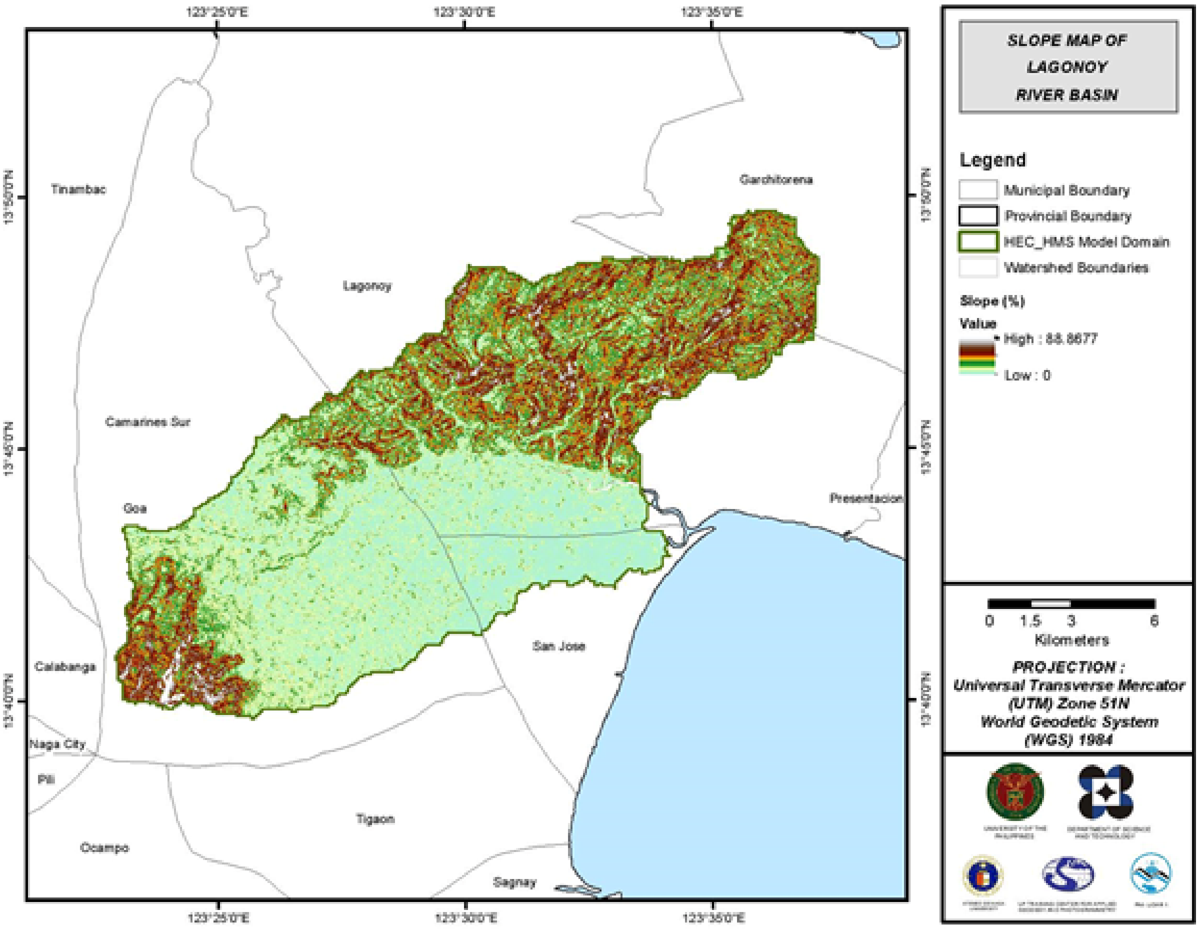


Figure 52. Slope Map of Lagonoy River Basin

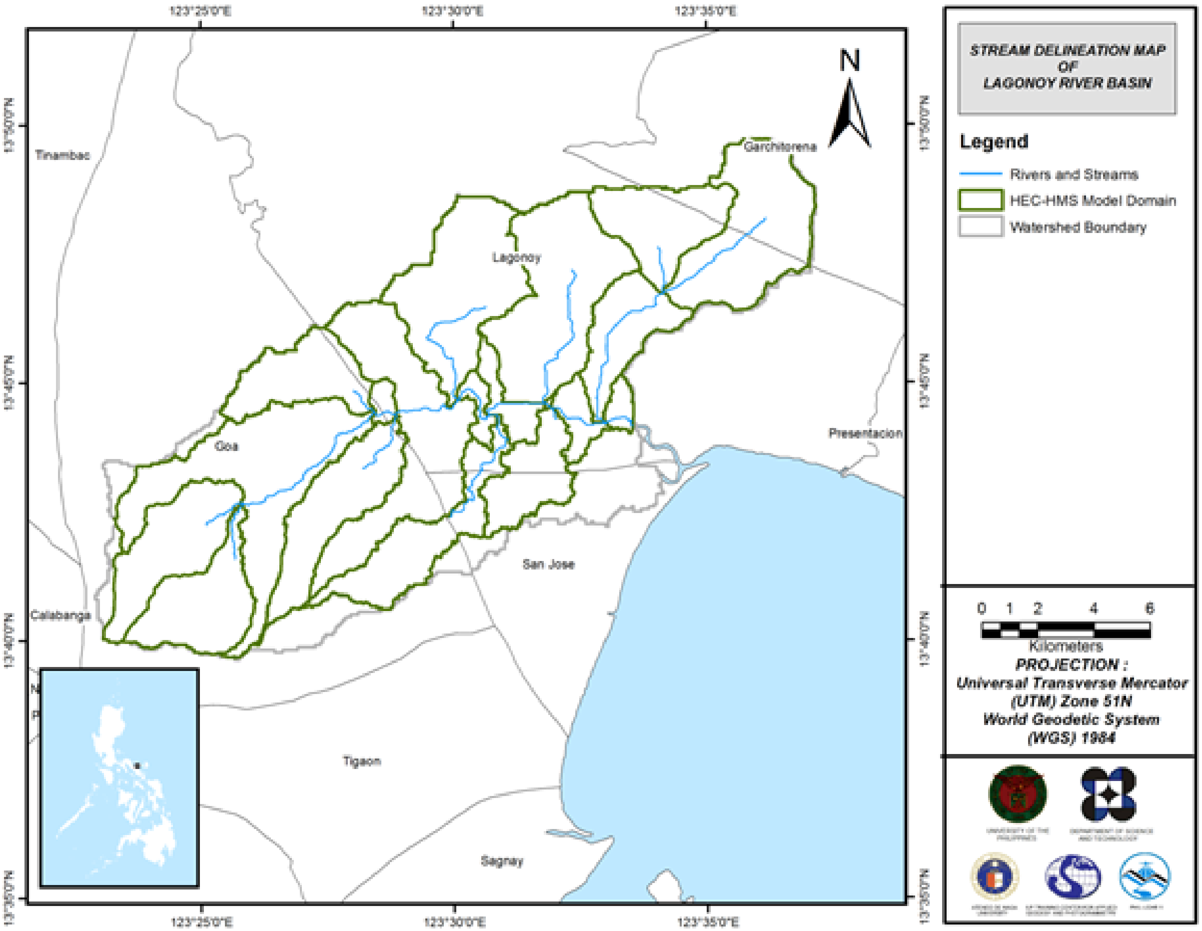


Figure 53. Stream delineation map of Lagonoy River Basin

Using the SAR-based DEM, the Lagonoy basin was delineated and further divided into subbasins. The model consists of 19 sub basins, 9 reaches, and 9 junctions, as shown in Figure 54 (See Annex 10). The main outlet is Lagonoy Bridge.

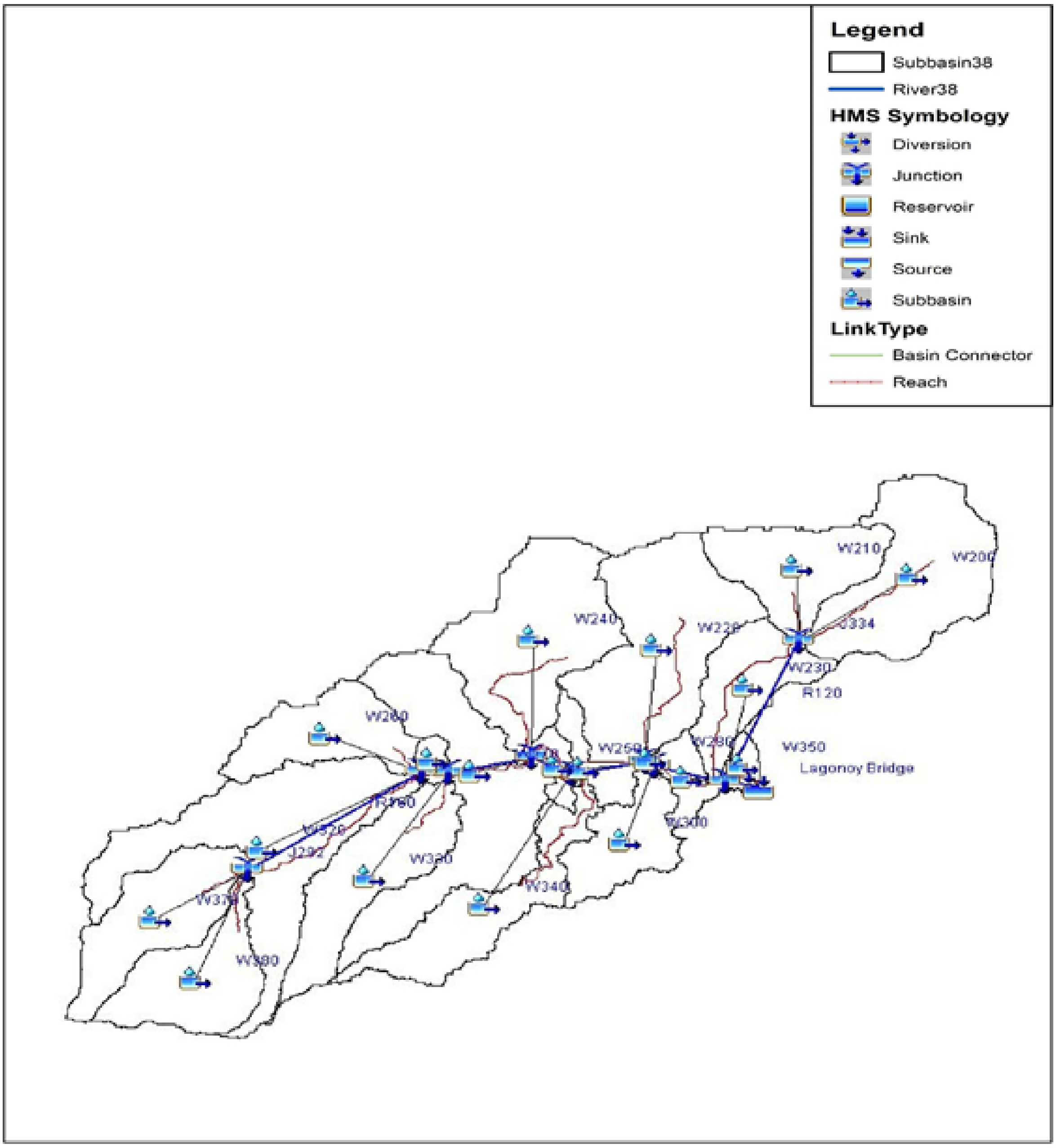


Figure 54. The Lagonoy River Basin model generated using HEC-HMS

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 55).

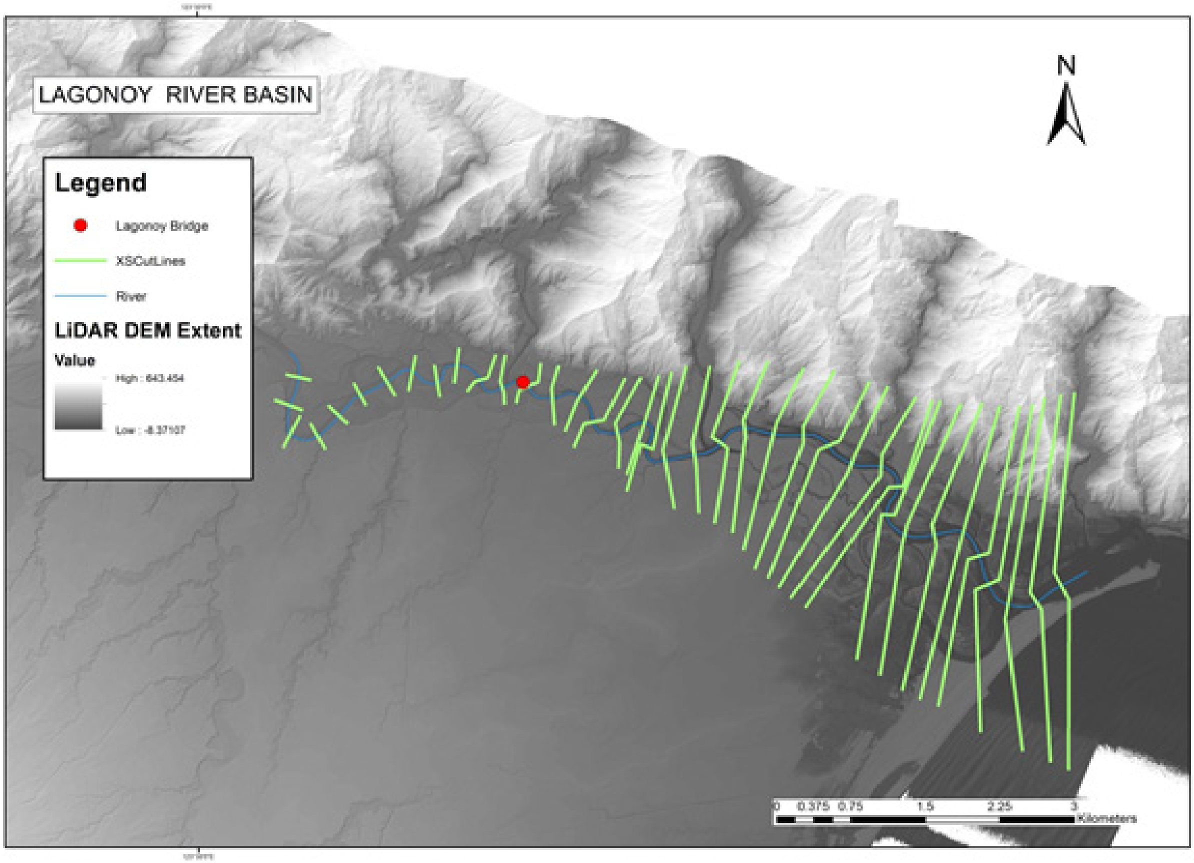


Figure 55. River cross-section of Lagonoy River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

Figure 56. A screenshot of ther river subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 73.06592 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0m2/s. The generated hazard maps for Lagonoy are in Figures 60, 62, and 64.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 70,962,528.00m2. The generated flood depth maps for Lagonoy are in Figures 61, 63, and 65.

There is a total of 93,583,611.65m3 of water entering the model. Of this amount, 30,627,999.76m3 is due to rainfall while 62,955,611.89m3 is inflow from other areas outside the model. 12,239,127.00m3 of this water is lost to infiltration and interception, while 21,750,395.18m3 is stored by the flood plain. The rest, amounting up to 59,594,103.34m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Lagonoy HEC-HMS river basin model (See Annex 9), its accuracy was measured against the observed values. Figure 57 shows the comparison between the two discharge data.

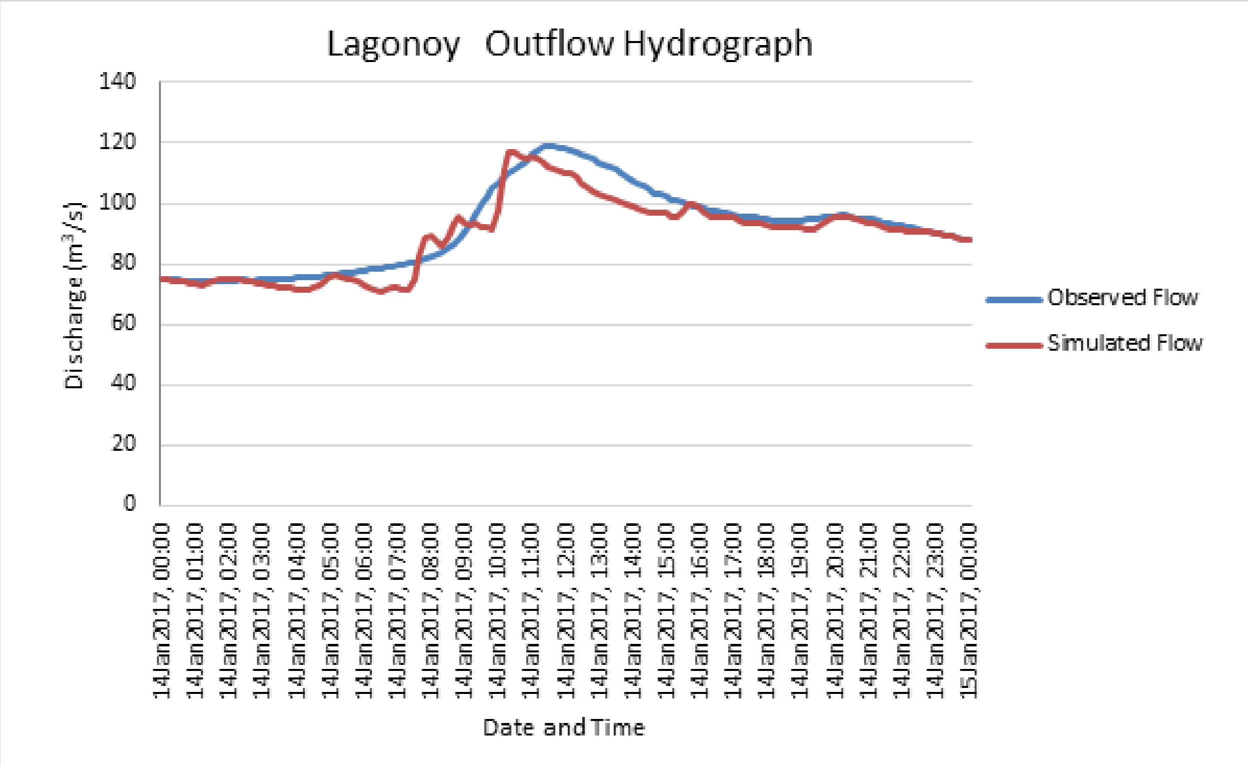


Figure 57. Outflow hydrograph of Lagonoy River Basin produced by the HEC-HMS model compared with observed outflow

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

Table 27. Range of Calibrated Values for the Lagonoy River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.001-29
			Curve Number	49-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02-0.2
			Storage Coefficient (hr)	0.02-0.1
	Baseflow	Recession	Recession Constant	0.00001-0.0001
			Ratio to Peak	0.01-0.9
Reach	Routing	Muskingum-Cunge	Slope	0.0007-0.02
			Manning's n	0.2-1

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.001 mm to 29 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

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 curve number increases. The range of 49-99 for curve number is wider than the advisable for Philippine watersheds (70-80), depending on the soil and land cover of the area. For Lagonoy, the basin mostly consists of grassland and the soil consists of ubay clay, Himayangan sandy clay loam, and hydrosol.

The time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.02 hours to 0.2 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. For Lagonoy, it will take 13 hours and 30 minutes from the peak discharge to go back to the initial discharge.

Manning's roughness coefficient of 1 corresponds to the common roughness in Lagonoy watershed, which is determined to be a mangrove forest with trees with heavy stand that flow into branches (Brunner, 2010).

Table 28. Summary of the Efficiency Test of Lagonoy HMS Model

Accuracy measure	Value
r2	0.92
NSE	4.74
PBIAS	0.92
RSR	0.88
RSR	0.35

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 4.74 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.92.

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 0.88.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 2.79.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.35.

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 58) shows the Lagonoy outflow using the synthetic storm events using the Daet Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAG-ASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods from 1429m3/s in a 5-year return period to 4313.5m3/s in a 100-year return period.

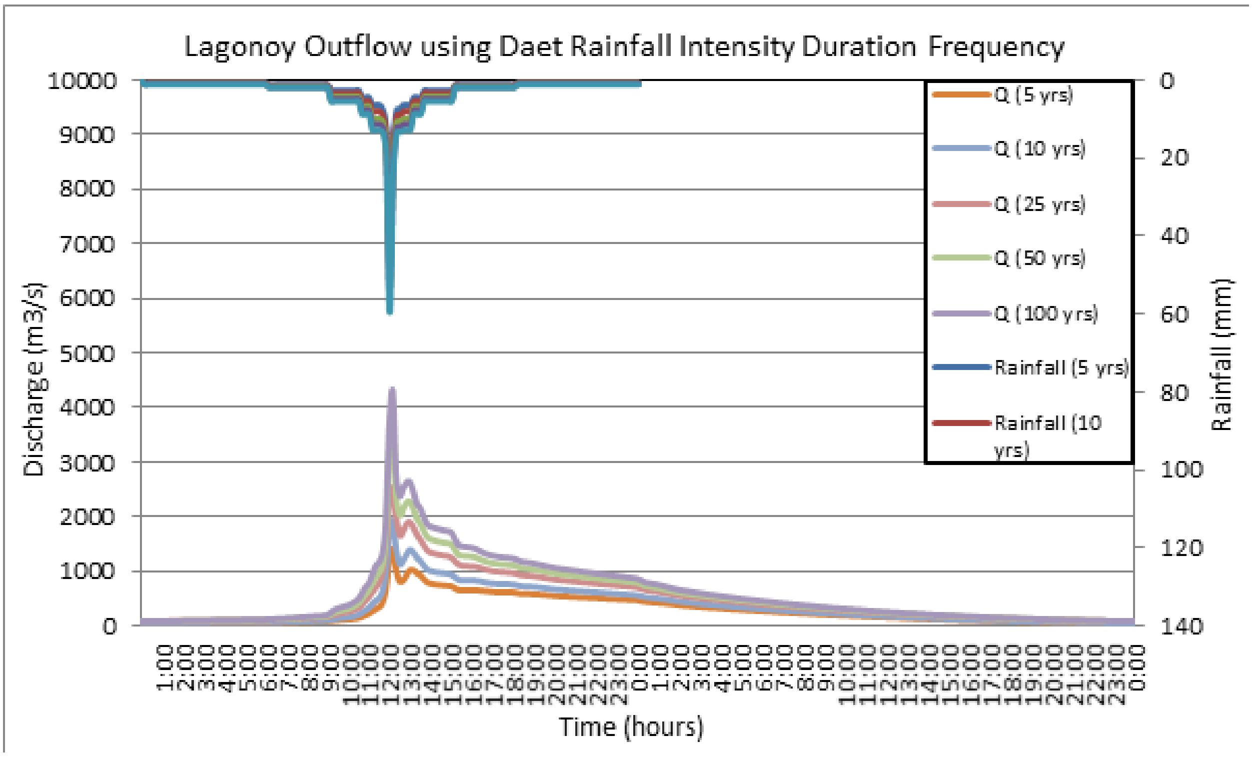


Figure 58. The Outflow hydrograph at the Lagonoy Basin, generated using the simulated rain events for 24-hour period for Daet station

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Lagonoy discharge using the Daet RIDF in five different return periods is shown in Table 29.

Table 29. Outlines the peak values of the Lagonoy HEC-HMS Model outflow using the Daet RIDF 24-hour values

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	297	35.2	286.2	1 hour, 30 minutes
10-Year	364.1	42.7	380.8	1 hour, 30 minutes
25-Year	449	52	520.5	1 hour, 20 minutes
50-Year	511.9	59	607	1 hour, 10 minutes
100-Year	574.4	65.9	713.3	hour, 10 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 real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown, since only the ADNU-DVC base flow was calibrated. Figure 59 shows a generated sample map of the Lagonoy River using the calibrated HMS base.

Figure 59. Sample output map of the Lagonoy RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10 m resolution. Figures 60 to 65 show the 5-, 25-, and 100-year rain return scenarios of the Lagonoy Floodplain. The flood plain, with an area of 140.67km^2, covers three (3) municipalities, namely Goa, Lagonoy, and San Jose. Table 30 shows the percentage of area affected by flooding per municipality.

Table 30. Municipalities affected in Lagonoy Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Goa	220.76	48.07	21.78
Lagonoy	394.86	61.62	15.61
San Jose	44.63	30.34	67.97

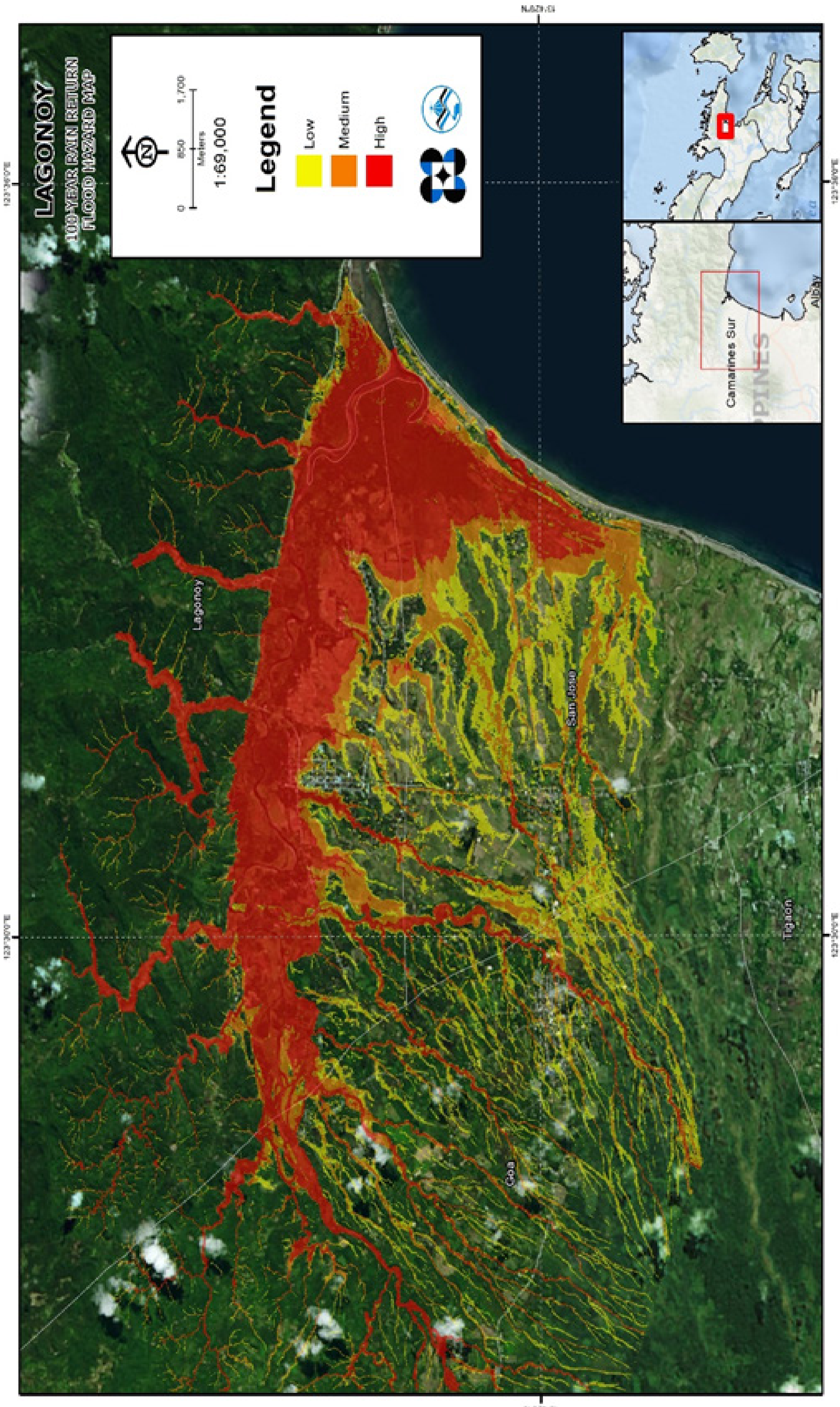


Figure 60. 100-year flood hazard map for the Lagonoy flood plain overlaid on Google Earth imagery

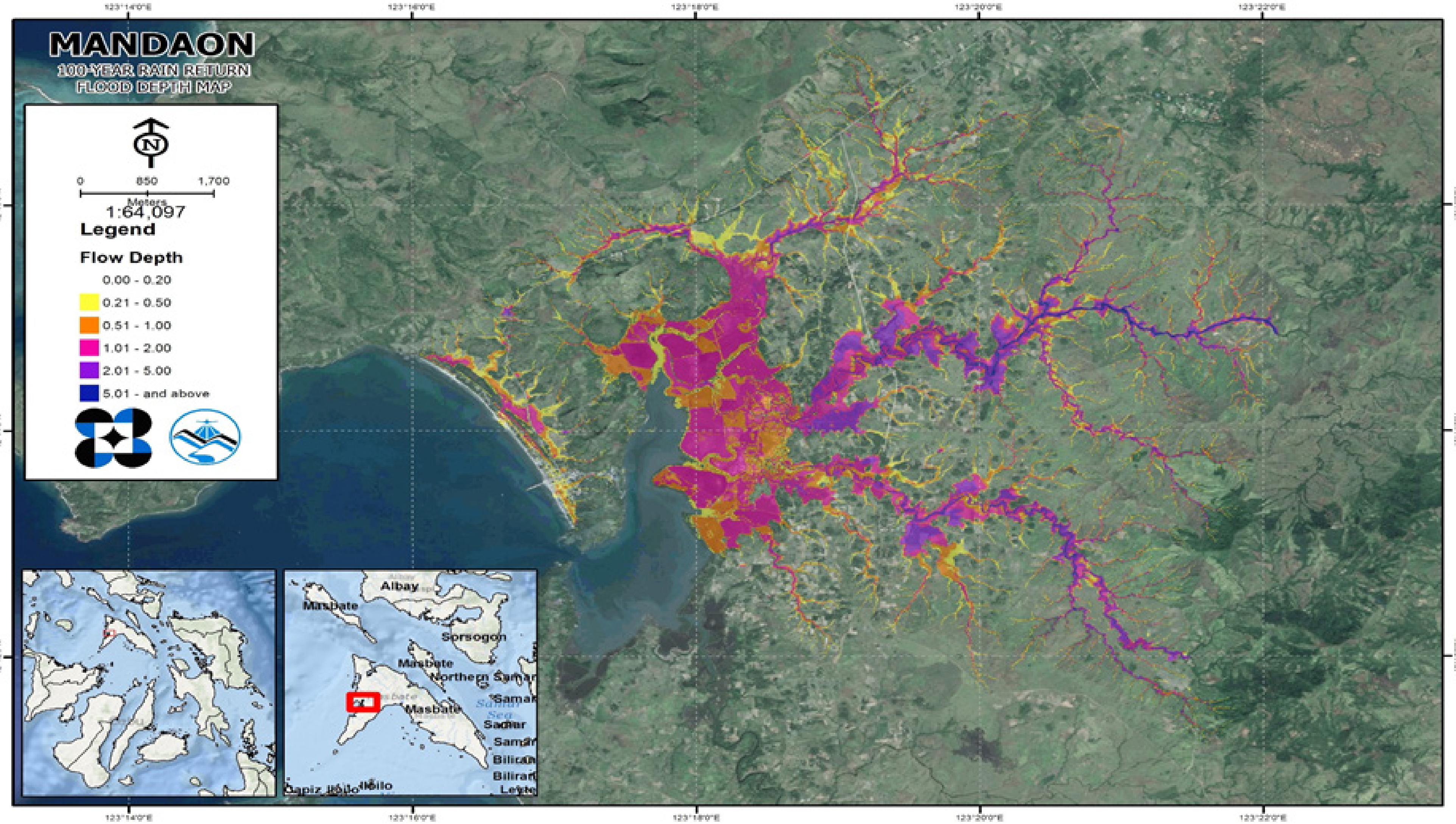


Figure 61. 100-year flow depth map for the Lagonoy flood plain overlaid on Google Earth imagery

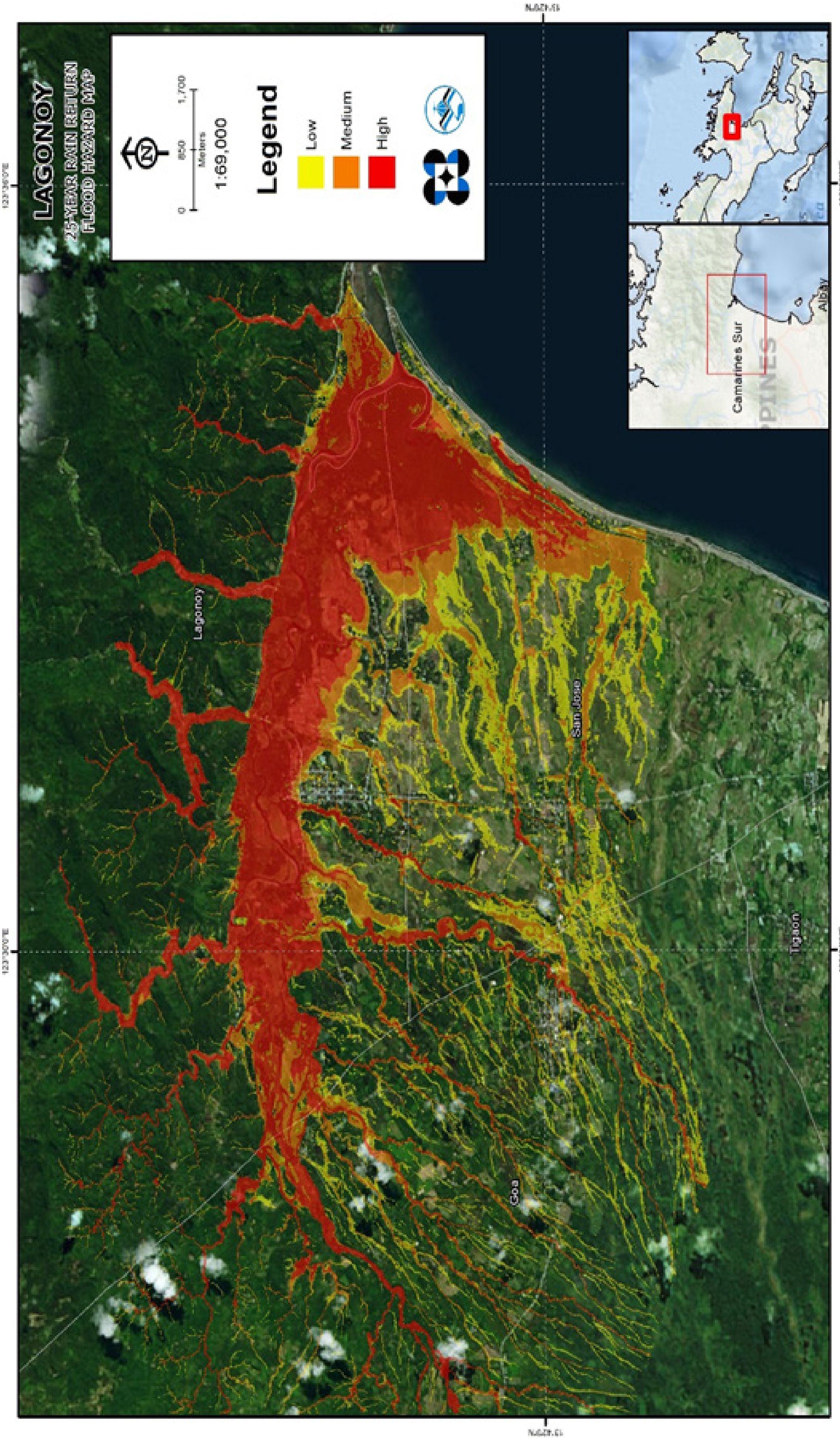


Figure 62. 25-year flood hazard map for the Lagonoy flood plain overlaid on Google Earth imagery

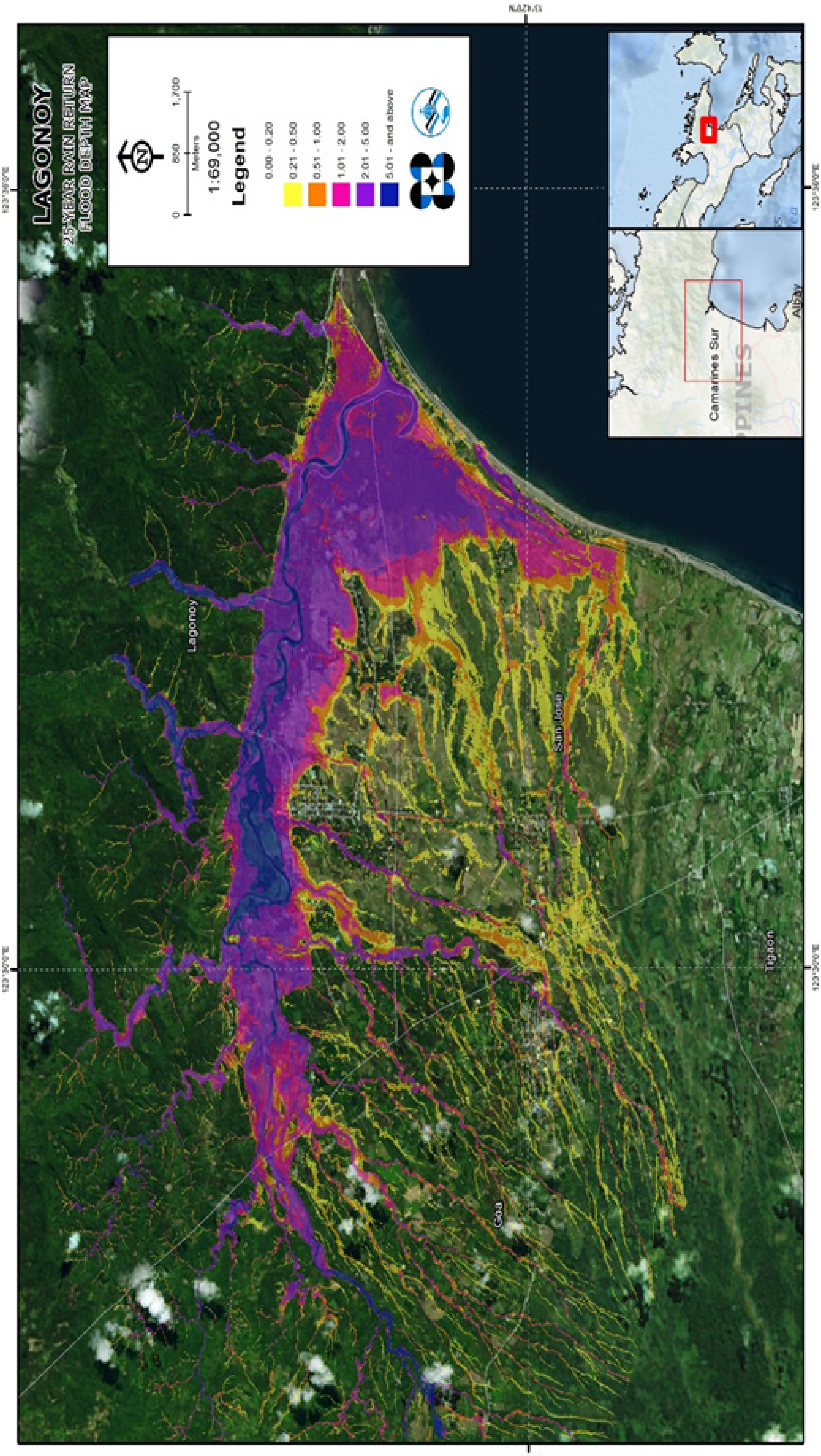


Figure 63. 25-year flow depth map for the Lagonoy flood plain overlaid on Google Earth imagery

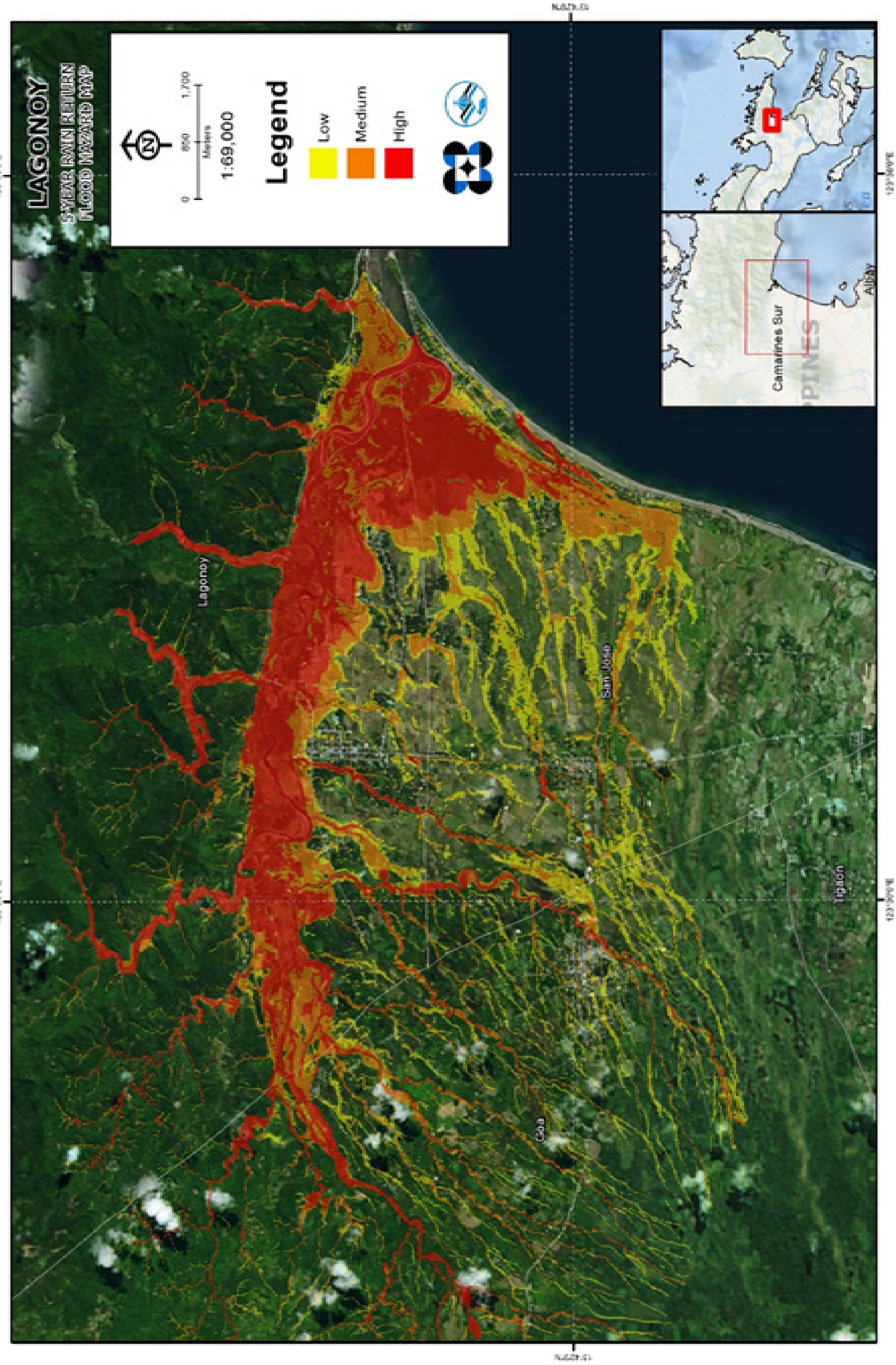


Figure 64. 5-year flood hazard map for the Lagonoy flood plain overlaid on Google Earth imagery

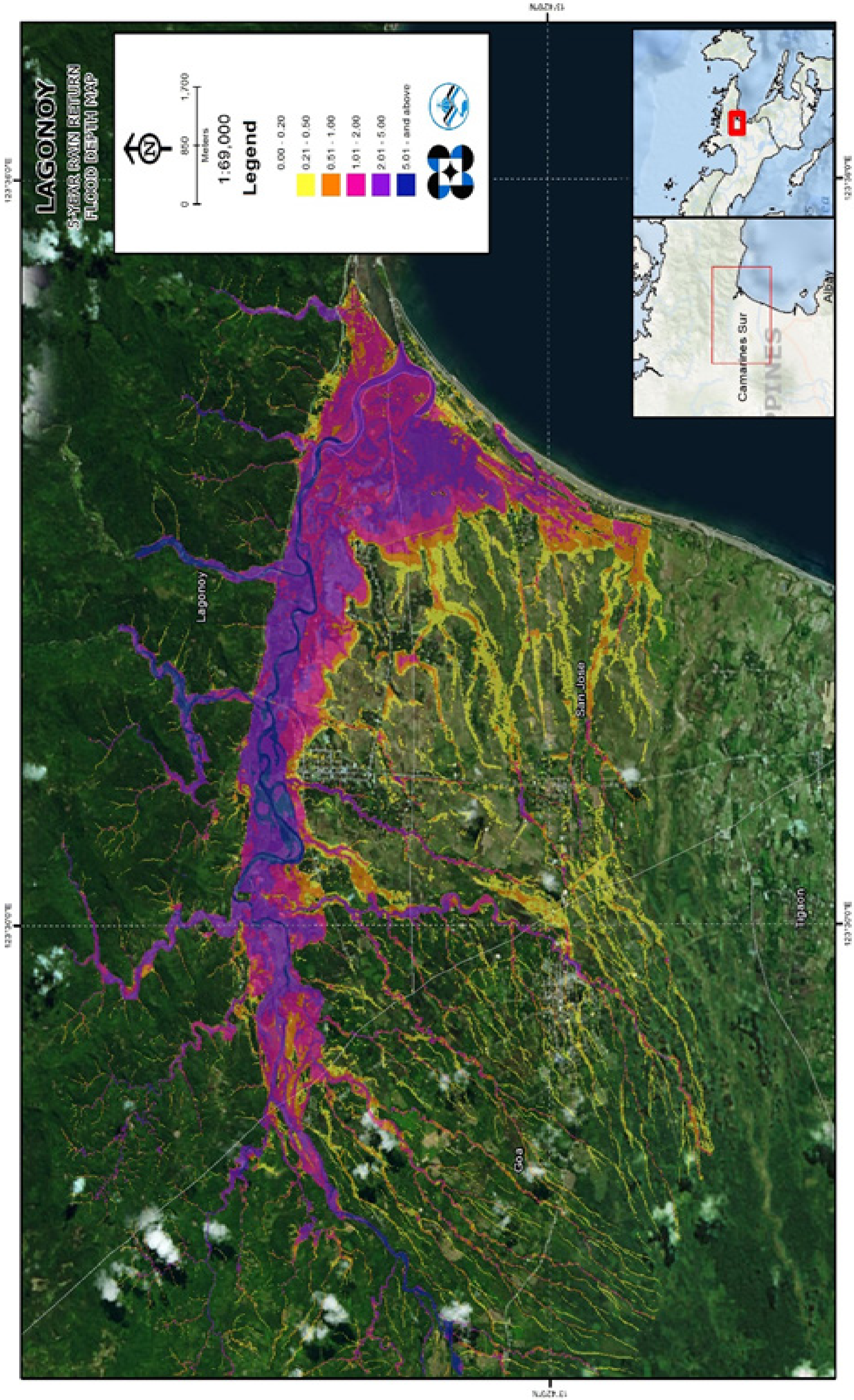


Figure 65. 5-year flow depth map for the Lagonoy flood plain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Lagonoy River Basin, grouped accordingly by municipality. For the said basin, three (3) municipalities consisting of 68 barangays are expected to experience flooding when subjected to the three rainfall return period scenarios.

For the 100-year rainfall return period, 16.92% of the Municipality of Goa with an area of 220.76 square kilometers will experience flood levels of less than 0.20 meters. 2.32% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.97%, 0.77%, 0.58%, and 0.21% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 31 to Table 33 depict the areas affected in Goa in square kilometers by flood depth per barangay.

Table 31. Affected Areas in Goa, Camarines Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Goa (in sq. km.)							
	Abucayan	Bagumbayan Grande	Bagumbayan Pequeño	Belen	Buyo	Cagaycay	Digdigon	Gimaga
0.03-0.20	2.04	0.12	0.46	0.25	0.97	4.37	0.14	1.07
0.21-0.50	0.23	0.033	0.09	0.041	0.31	0.37	0.0071	0.19
0.51-1.00	0.062	0.017	0.062	0.021	0.14	0.2	0.004	0.051
1.01-2.00	0.056	0.016	0.05	0.012	0.061	0.17	0.003	0.056
2.01-5.00	0.012	0.0082	0.024	0.0005	0.0098	0.18	0.0016	0.014
>5.00	0	0.00027	0	0	0	0.22	0.0018	0

Table 32. Affected Areas in Goa, Camarines Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Goa (in sq. km.)							
	Halawig-Gogon	Hiwacloy	La Purisima	Matacla	Maymatan	Napawon	Panday	Pinaglabanan
0.03-0.20	1.5	0.86	0.096	1.53	2.11	1.87	0.046	2.87
0.21-0.50	0.38	0.088	0.011	0.63	0.2	0.32	0.012	0.31
0.51-1.00	0.093	0.054	0.0035	0.18	0.1	0.12	0.0052	0.091
1.01-2.00	0.049	0.056	0.0003	0.016	0.13	0.12	0.0014	0.07
2.01-5.00	0.012	0.04	0	0.002	0.03	0.067	0.0031	0.018
>5.00	0	0.057	0	0	0	0	0.00038	0.00063

Table 33. Affected Areas in Goa, Camarines Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Goa (in sq. km.)								
	Salog	San Benito	San Isidro	San Jose	San Juan Bautista	San Juan Evangelista	San Pedro	Tagongtong	Taytay
0.03-0.20	10.43	0.099	0.041	0.022	0.24	0.086	0.046	5.55	0.52
0.21-0.50	0.72	0.013	0.0016	0.0083	0.1	0.0098	0.0039	0.82	0.23
0.51-1.00	0.58	0.0046	0.0000088	0.0054	0.021	0.0038	0.00031	0.2	0.12
1.01-2.00	0.68	0.0021	0.00003	0.0032	0.0005	0.0067	0	0.092	0.049
2.01-5.00	0.79	0.0017	0	0.0018	0	0.017	0	0.012	0.04
>5.00	0.18	0	0	0	0	0.00063	0	0	0.0062

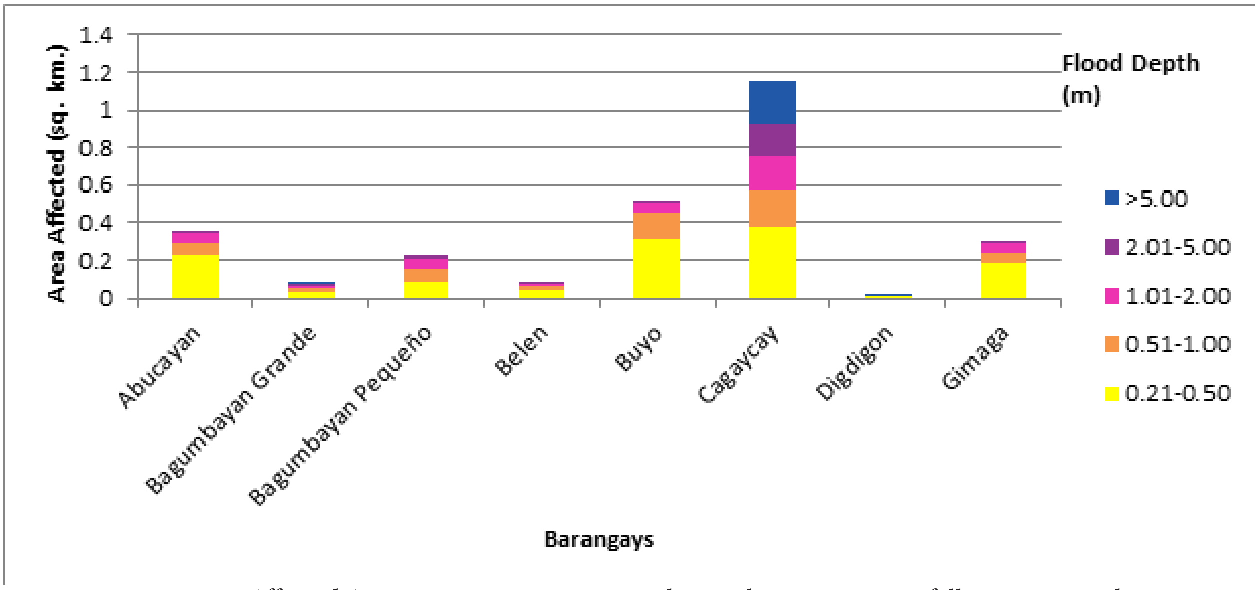


Figure 66. Affected Areas in Goa, Camarines Sur during the 100-Year Rainfall Return Period

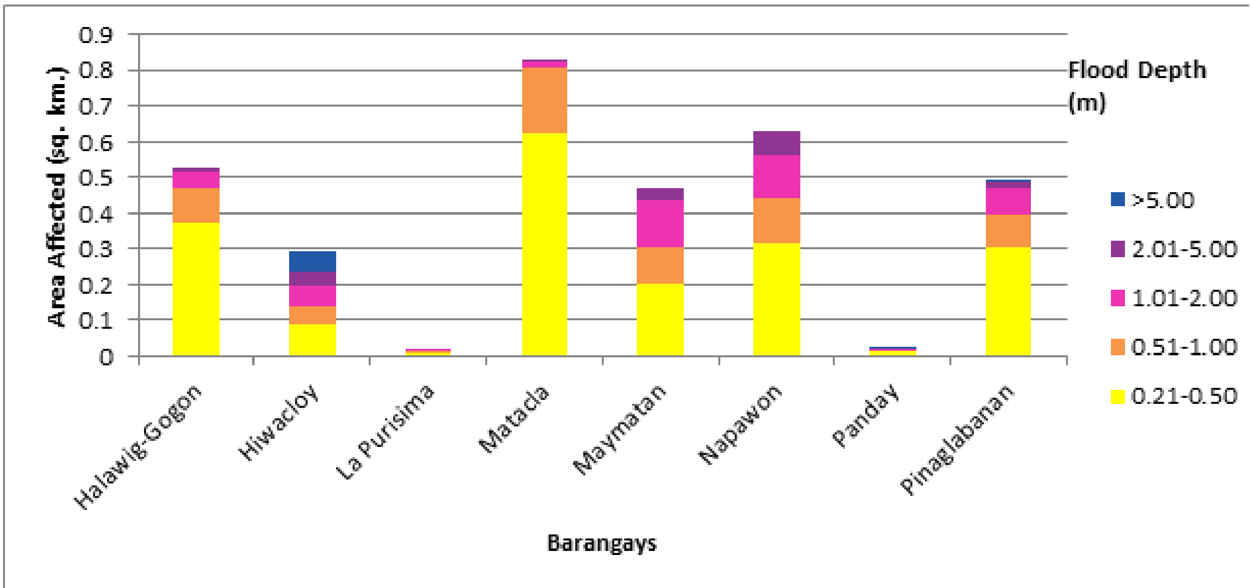


Figure 67. Affected Areas in Goa, Camarines Sur during the 100-Year Rainfall Return Period

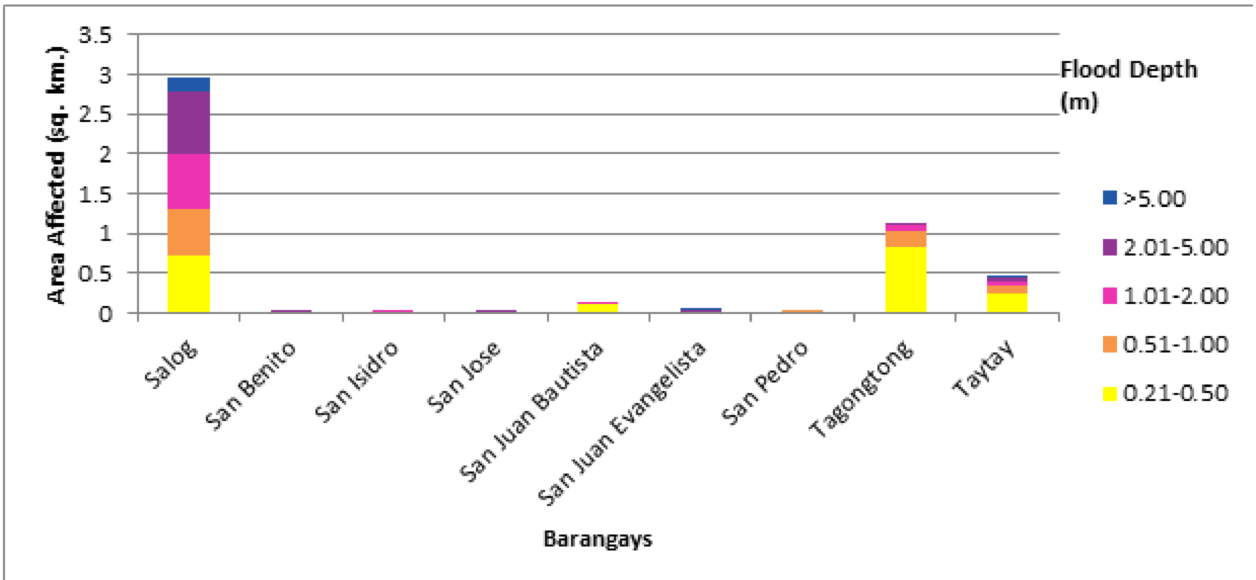


Figure 68. Affected Areas in Goa, Camarines Sur during the 100-Year Rainfall Return Period

For the Municipality of Lagonoy with an area of 394.86 square kilometers., 9.58% will experience flood levels of less than 0.20 meters. 0.65% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.5%, 0.93%, 2.95%, and 1% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Tables 34 to 35 depict the areas affected in Lagonoy in square kilometers by flood depth per barangay.

Table 34. Affected Areas in Lagonoy, Camarines Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lagonoy (in sq. km.)										
	Agosais	Agpo-Camagong-Tabog	Amoguis	Binanuahan	Burabod	Dahat	Gimagtocon	Ginorangan	Gubat	Loho(	Manamoc
0.03-0.20	5.9	0.56	0.68	0.066	0.18	0.12	6.39	7.58	2.68	0.033	5.48
0.21-0.50	0.17	0.15	0.16	0.064	0.056	0.078	0.19	0.2	0.1	0.044	0.27
0.51-1.00	0.11	0.036	0.24	0.11	0.076	0.13	0.16	0.094	0.1	0.051	0.2
1.01-2.00	0.13	0.025	0.26	0.17	0.22	0.18	0.27	0.11	0.12	0.19	0.61
2.01-5.00	0.5	0.0049	0.13	0.57	3.06	0.88	0.94	1.04	0.13	1.09	0.98
>5.00	0.93	0	0.0029	0.18	0.16	0.25	0.15	1.16	0.0089	0.088	0.13

Table 35. Affected Areas in Lagonoy, Camarines Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lagonoy (in sq. km.)										
	Pinamihagan	San Francisco	San Isidro Norte	San Isidro Sur	San Rafael	San Ramon	San Roque	San Sebastian	San Vicente	Santa Maria	Saripongpong
0.03-0.20	2.89	0.15	0	0.12	0.63	1	1.97	1.31	0.065	0	0
0.21-0.50	0.095	0.037	0	0.056	0.11	0.35	0.32	0.073	0.029	0	0
0.51-1.00	0.057	0.023	0.0012	0.073	0.044	0.19	0.16	0.073	0.043	0.0012	0
1.01-2.00	0.05	0.02	0.018	0.16	0.053	0.17	0.74	0.11	0.057	0.015	0.00045
2.01-5.00	0.059	0.024	0.13	0.13	0.1	0.042	1.28	0.19	0.055	0.19	0.12
>5.00	0.012	0.0068	0.39	0.0036	0.00028	0	0.084	0.03	0.0065	0.14	0.23

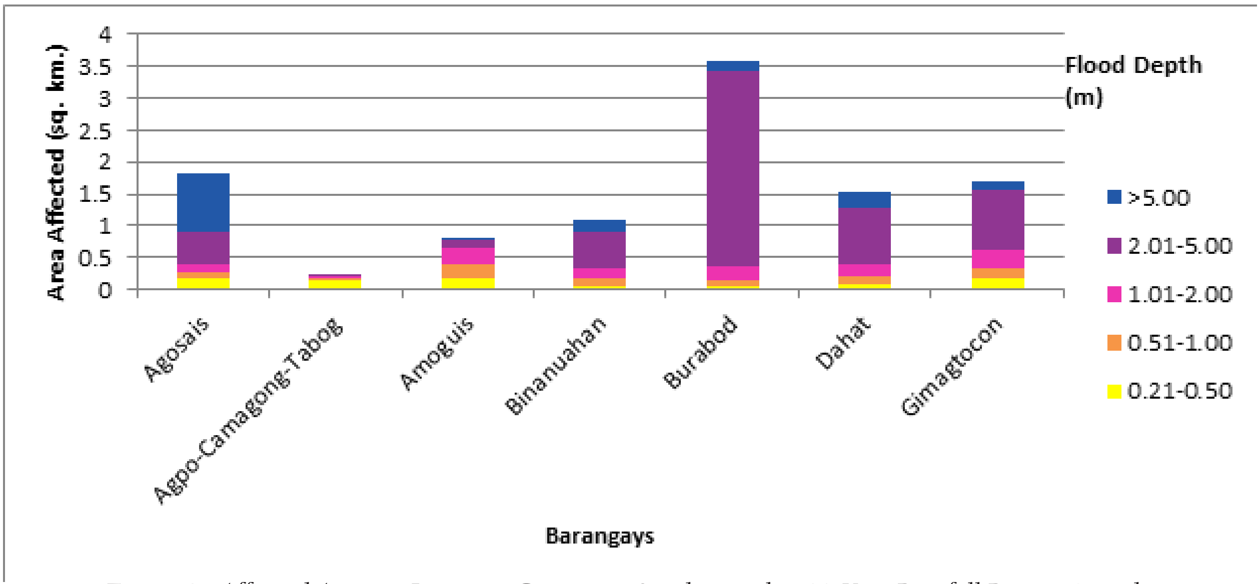


Figure 69. Affected Areas in Lagonoy, Camarines Sur during the 100-Year Rainfall Return Period

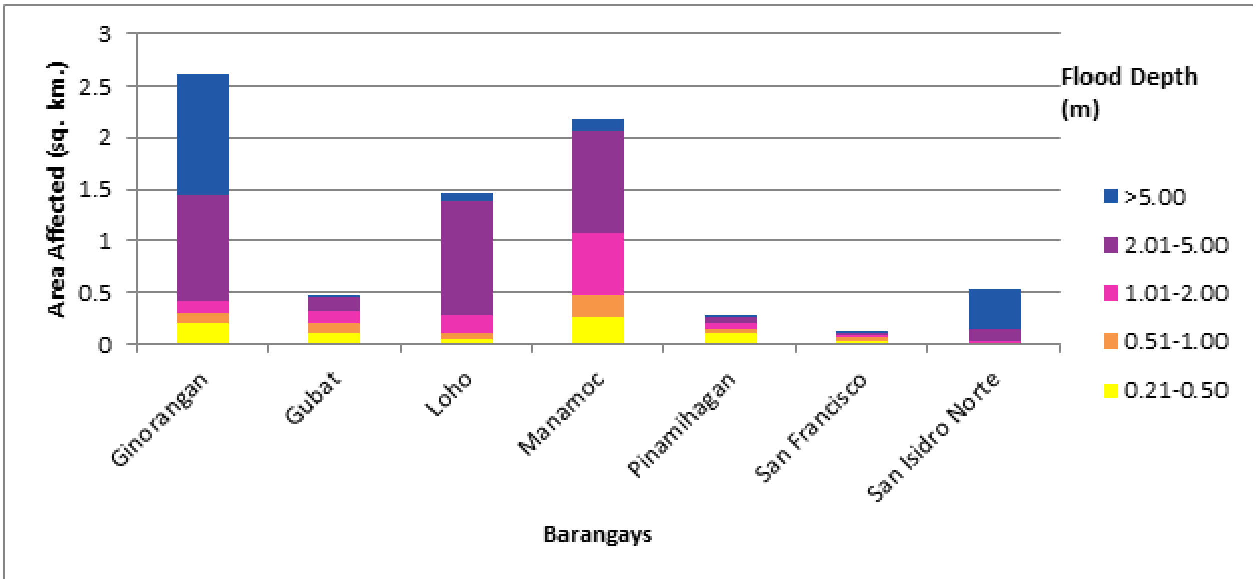


Figure 70. Affected Areas in Lagonoy, Camarines Sur during the 100-Year Rainfall Return Period

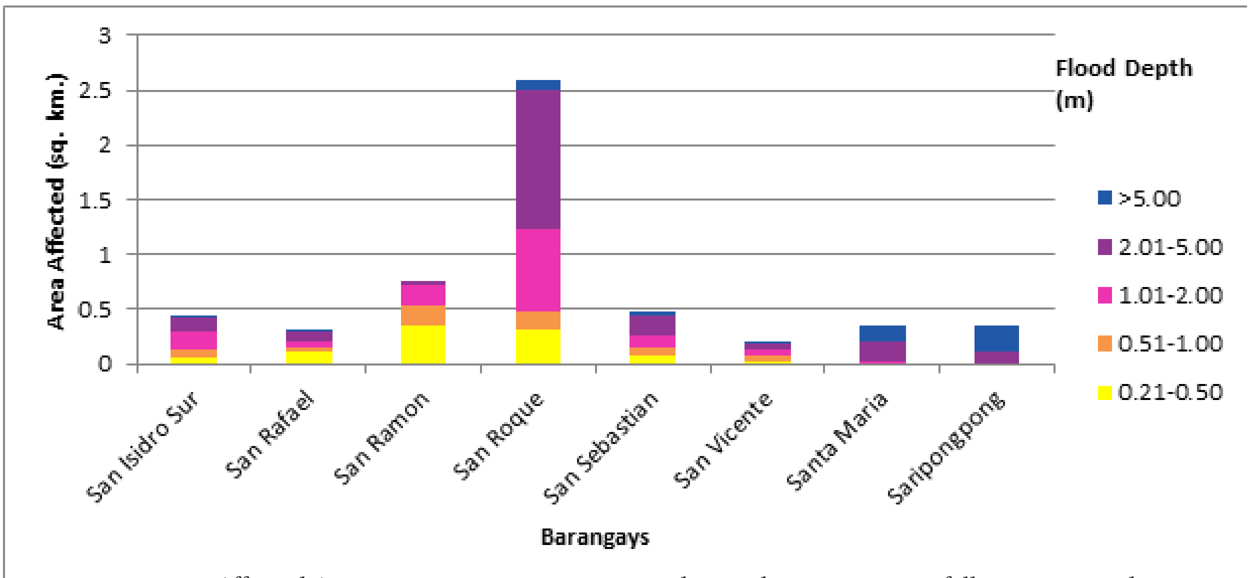


Figure 71. Affected Areas in Lagonoy, Camarines Sur during the 100-Year Rainfall Return Period

For the Municipality of San Jose with an area of 44.63 square kilometers., 32.72% will experience flood levels of less than 0.20 meters. 14.17% of the area will experience flood levels of 0.21 to 0.50 meters, while 6.39%, 5.7%, 8.97%, and 0.02% 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. Tables 36 to 37 depict the areas affected in San Jose in square kilometers by flood depth per barangay.

Table 36. Affected Areas in San Jose, Camarines Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)										
	Bahay	Boclod	Calalahan	Camagong	Danlog	Del Carmen	Dolo	Kinalansan	Manzana	Minoro	Palale
0.03-0.20	0.99	1.56	0.00067	2.01	1.3	0.33	0.2	0.26	0.27	0.44	0.94
0.21-0.50	0.2	0.53	0	0.59	0.59	0.056	0.051	0.11	0.066	0.29	0.71
0.51-1.00	0.089	0.22	0	0.11	0.15	0.0081	0.09	0.099	0.099	0.2	0.24
1.01-2.00	0.11	0.085	0	0.05	0.12	0.0000014	0.23	0.12	0.61	0.42	0.0063
2.01-5.00	0.19	0.059	0	0.046	0.033	0	1.24	0.16	0.39	0.97	0
>5.00	0.0033	0	0	0.00011	0	0	0	0	0	0	0

Table 37. Affected Areas in San Jose, Camarines Sur during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)									
	Pugay	Sabang	San Antonio	San Juan	San Vicente	Santa Cruz	Soledad	Tambangan	Telegrafo	Tominawog
0.03-0.20	1	0.39	0.11	0.4	0.19	0.58	0.24	2.21	0.17	1.03
0.21-0.50	0.17	0.092	0.03	0.13	0.021	0.21	0.12	1.74	0.081	0.55
0.51-1.00	0.014	0.075	0.0051	0.037	0.0057	0.12	0.034	0.65	0.18	0.44
1.01-2.00	0.0054	0.17	0.003	0.0025	0.0048	0.044	0.016	0.13	0.27	0.14
2.01-5.00	0	0.86	0.0044	0.00043	0.0005	0.038	0.0093	0.001	0	0.0022
>5.00	0	0.0042	0	0	0	0	0	0	0	0

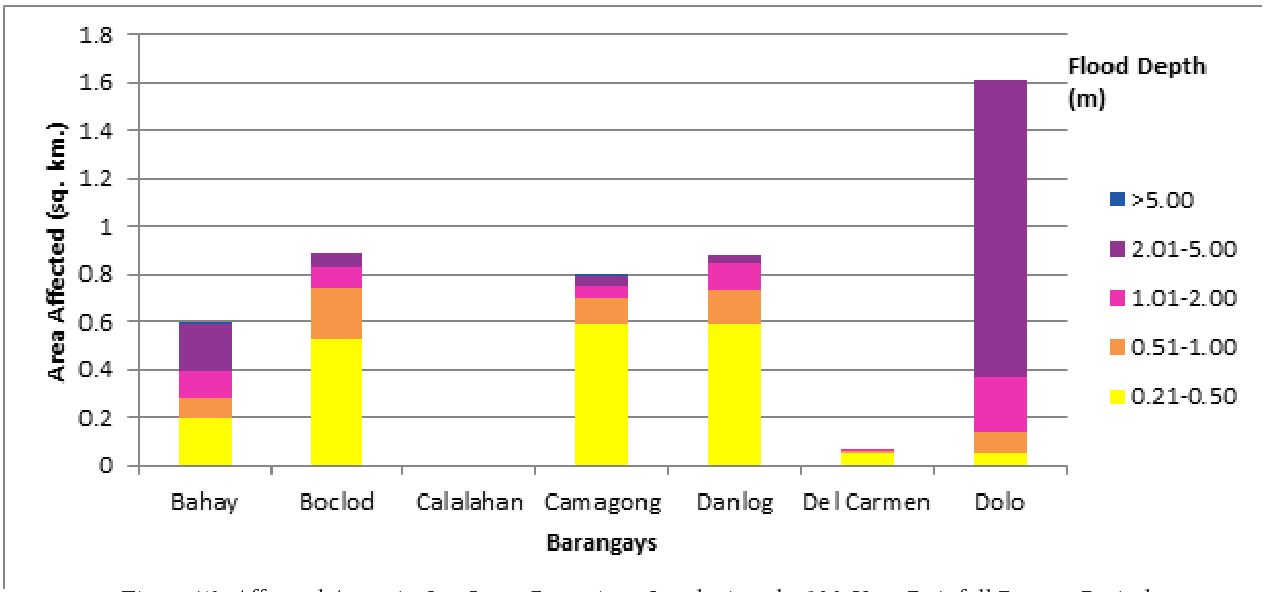


Figure 72. Affected Areas in San Jose, Camarines Sur during the 100-Year Rainfall Return Period

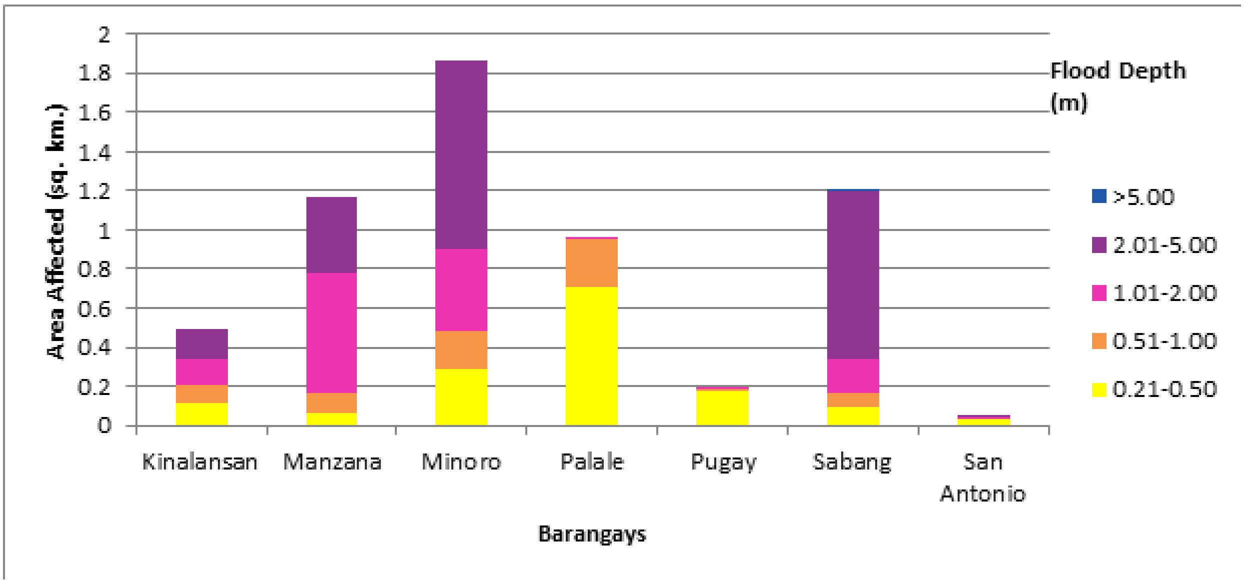


Figure 73. Affected Areas in San Jose, Camarines Sur during the 100-Year Rainfall Return Period

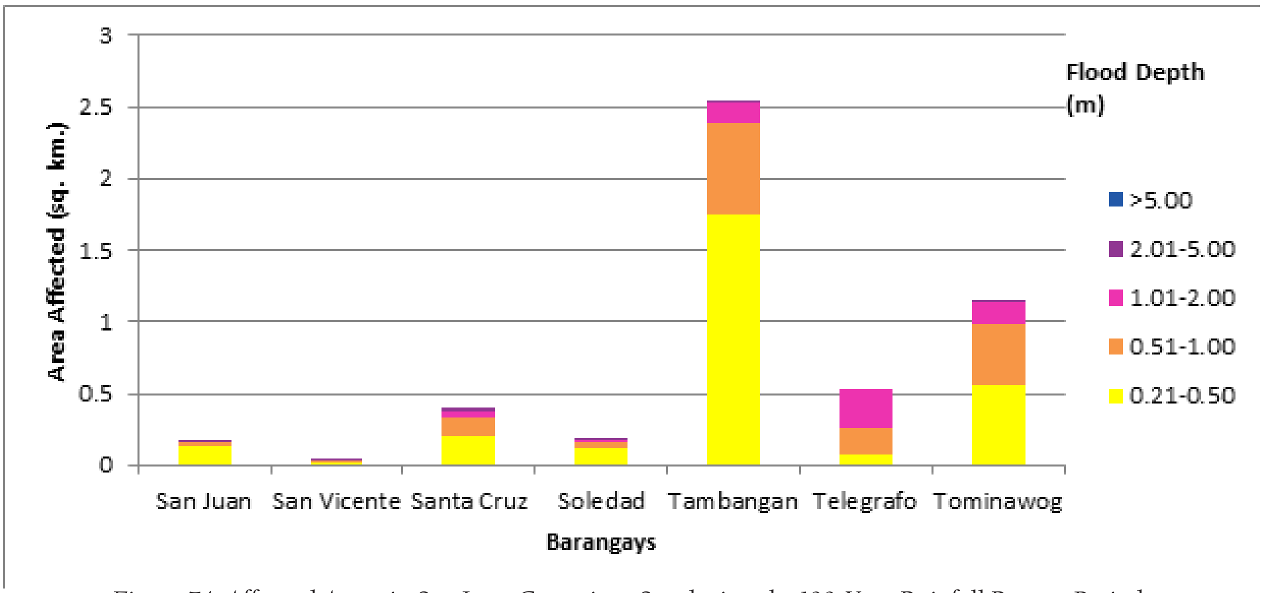


Figure 74. Affected Areas in San Jose, Camarines Sur during the 100-Year Rainfall Return Period

For the 25-year rainfall return period, 17.61% of the Municipality of Goa with an area of 220.76 square kilometers will experience flood levels of less than 0.20 meters. 1.98% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.86%, 0.68%, 0.49%, and 0.16% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Tables 38 to 40 depict the areas affected in Goa in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Goa, Camarines Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Goa (in sq. km.)							
	Abucayan	Bagumbayan Grande	Bagumbayan Pequeño	Belen	Buyo	Cagaycay	Digdigon	Gimaga
0.03-0.20	2.11	0.12	0.5	0.26	1.07	4.51	0.14	1.13
0.21-0.50	0.19	0.032	0.077	0.035	0.26	0.33	0.006	0.15
0.51-1.00	0.057	0.016	0.051	0.019	0.11	0.18	0.0035	0.053
1.01-2.00	0.046	0.011	0.043	0.0095	0.047	0.16	0.0022	0.045
2.01-5.00	0.0053	0.0063	0.017	0.0003	0.0057	0.15	0.0012	0.0061
>5.00	0	0	0	0	0	0.2	0.0015	0

Table 39. Affected Areas in Goa, Camarines Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Goa (in sq. km.)							
	Halawig-Gogon	Hiwacloy	La Purisima	Matacla	Maymatan	Napawon	Panday	Pinaglabanan
0.03-0.20	1.61	0.9	0.099	1.68	2.18	1.97	0.05	2.96
0.21-0.50	0.29	0.076	0.0084	0.53	0.17	0.27	0.01	0.25
0.51-1.00	0.082	0.053	0.0027	0.13	0.11	0.1	0.0035	0.083
1.01-2.00	0.042	0.051	0.0002	0.01	0.11	0.11	0.0011	0.058
2.01-5.00	0.0074	0.029	0	0.0012	0.015	0.046	0.0031	0.012
>5.00	0	0.044	0	0	0	0	0.0003	0

Table 40. Affected Areas in Goa, Camarines Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Goa (in sq. km.)								
	Salog	San Benito	San Isidro	San Jose	San Juan Bautista	San Juan Evangelista	San Pedro	Tagongtong	Taytay
0.03-0.20	10.69	0.1	0.042	0.025	0.26	0.09	0.048	5.77	0.57
0.21-0.50	0.7	0.0093	0.00065	0.0076	0.09	0.0076	0.0023	0.66	0.21
0.51-1.00	0.56	0.0035	0	0.0042	0.013	0.004	0.00031	0.16	0.098
1.01-2.00	0.62	0.0021	0.00003	0.0032	0.0002	0.0072	0	0.071	0.045
2.01-5.00	0.72	0.0014	0	0.0015	0	0.015	0	0.0066	0.034
>5.00	0.11	0	0	0	0	0.0004	0	0	0.0043

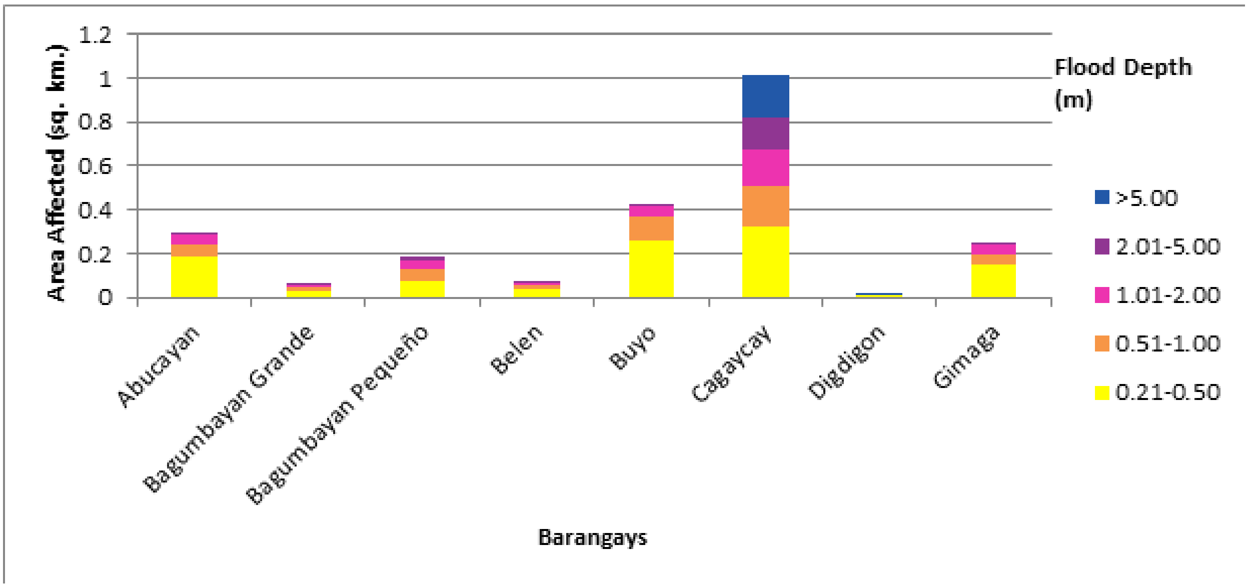


Figure 75. Affected Areas in Goa, Camarines Sur during the 25-Year Rainfall Return Period

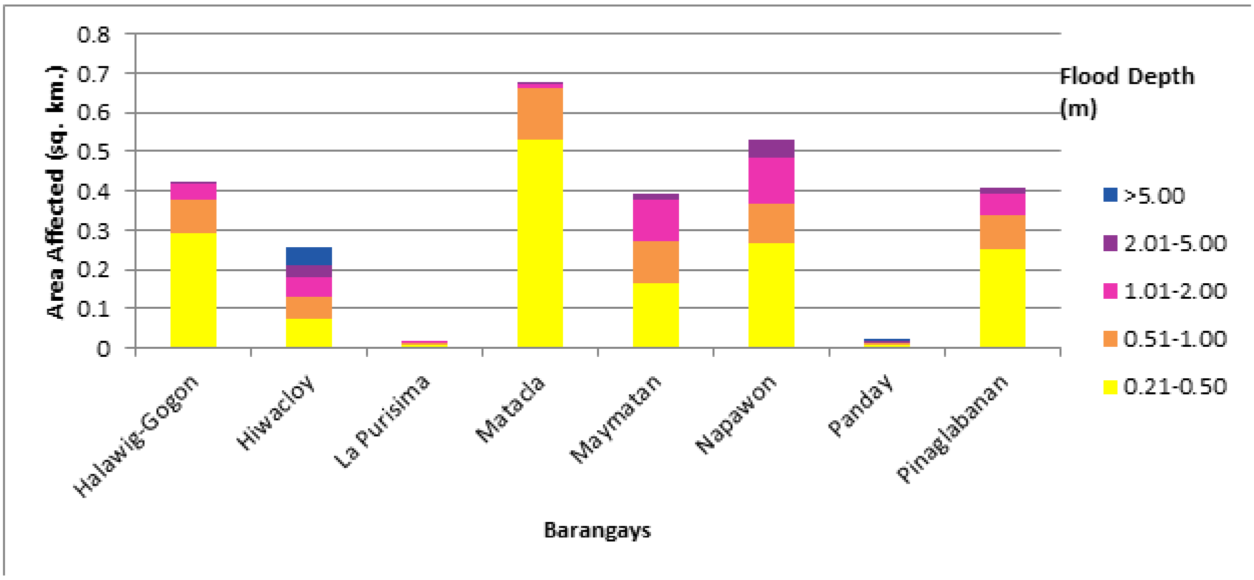


Figure 76. Affected Areas in Goa, Camarines Sur during the 25-Year Rainfall Return Period

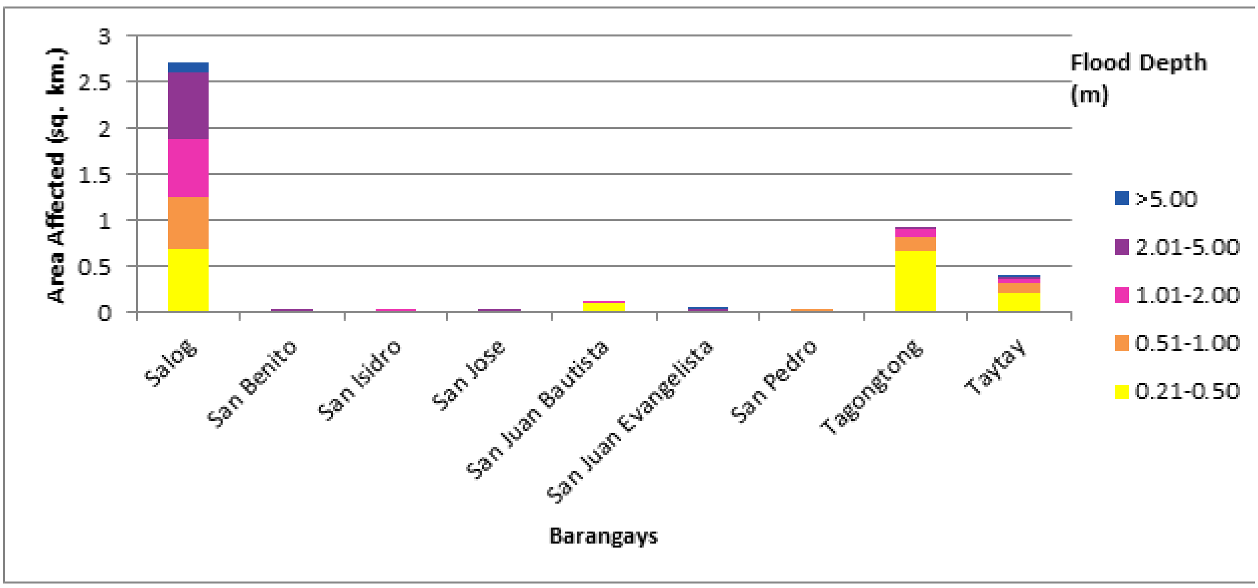


Figure 77. Affected Areas in Goa, Camarines Sur during the 25-Year Rainfall Return Period

For the Municipality of Lagonoy with an area of 394.86 sq. km., 10.03% will experience flood levels of less than 0.20 meters. 0.62% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.54%, 1.12%, 2.62%, and 0.68% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Tables 41 to 42 depict the areas affected in Lagonoy in square kilometers by flood depth per barangay.

Table 41. Affected Areas in Lagonoy, Camarines Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lagonoy (in sq. km.)										
	Agosais	Agpo-Camagong-Tabog	Amoguis	Binanuahan	Burabod	Dahat	Gimagtocon	Ginorangan	Gubat	Loho(	Manamoc
0.03-0.20	0.79	0.23	0.27	0.21	6.5	7.7	2.73	0.14	5.58	0.033	5.48
0.21-0.50	0.17	0.094	0.083	0.1	0.19	0.18	0.1	0.076	0.27	0.044	0.27
0.51-1.00	0.25	0.085	0.11	0.12	0.16	0.093	0.11	0.11	0.23	0.051	0.2
1.01-2.00	0.15	0.17	0.46	0.24	0.36	0.13	0.098	0.26	0.83	0.19	0.61
2.01-5.00	0.11	0.49	2.71	0.86	0.82	1.31	0.1	0.85	0.65	1.09	0.98
>5.00	0.0007	0.084	0.12	0.11	0.07	0.78	0.0063	0.065	0.11	0.088	0.13

Table 42. Affected Areas in Lagonoy, Camarines Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lagonoy (in sq. km.)										
	Pinamihagan	San Francisco	San Isidro Norte	San Isidro Sur	San Rafael	San Ramon	San Roque	San Sebastian	San Vicente	Santa Maria	Saripongpong
0.03-0.20	2.91	0.2	0.0046	0.28	0.69	1.19	2.09	1.33	0.15	0.0024	0
0.21-0.50	0.088	0.026	0.0053	0.069	0.089	0.27	0.27	0.072	0.025	0.005	0
0.51-1.00	0.054	0.0075	0.011	0.091	0.036	0.18	0.23	0.07	0.027	0.0083	0.0018
1.01-2.00	0.045	0.0077	0.048	0.078	0.035	0.1	0.91	0.1	0.038	0.091	0.028
2.01-5.00	0.054	0.024	0.12	0.031	0.084	0.0027	1	0.19	0.018	0.13	0.099
>5.00	0.0075	0	0.35	0	0	0	0.052	0.013	0	0.12	0.23

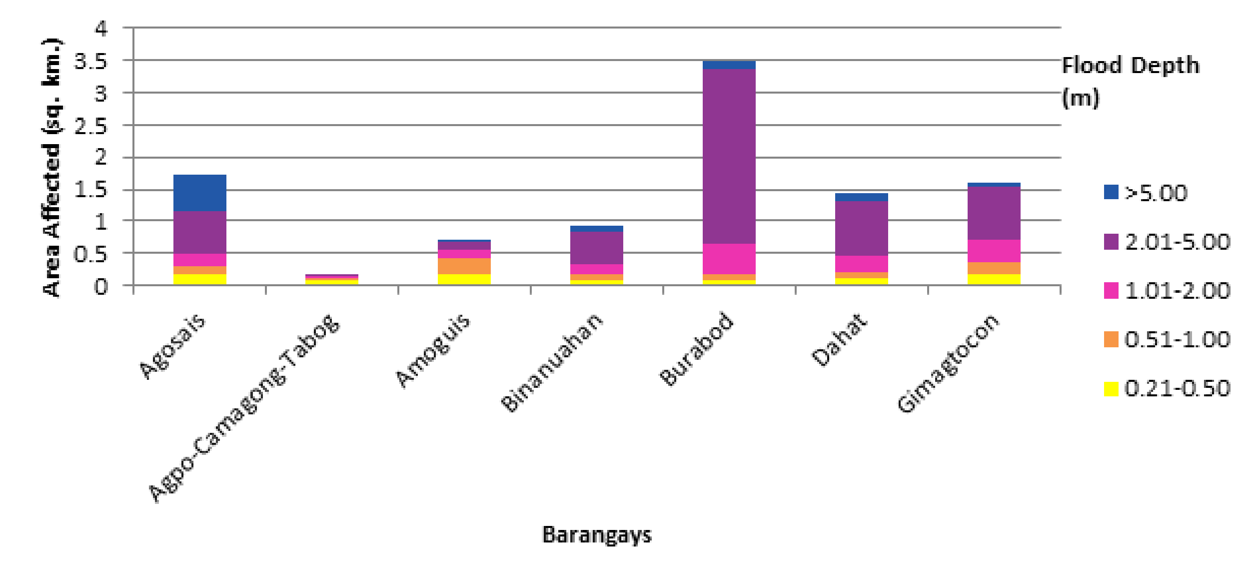


Figure 78. Affected Areas in Lagonoy, Camarines Sur during the 25-Year Rainfall Return Period

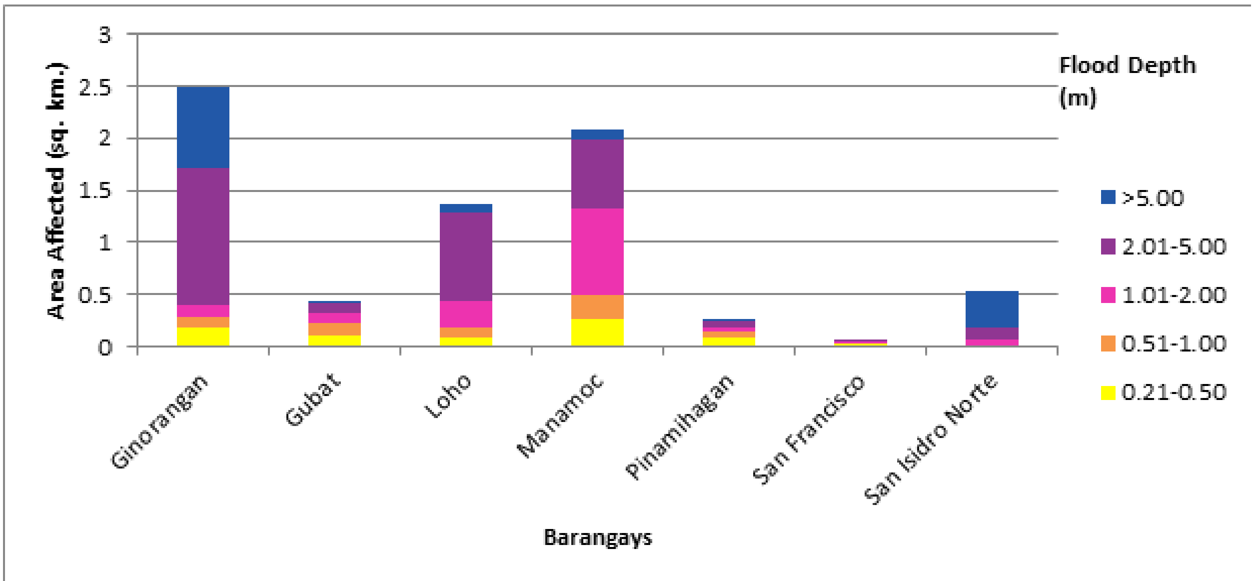


Figure 79. Affected Areas in Lagonoy, Camarines Sur during the 25-Year Rainfall Return Period

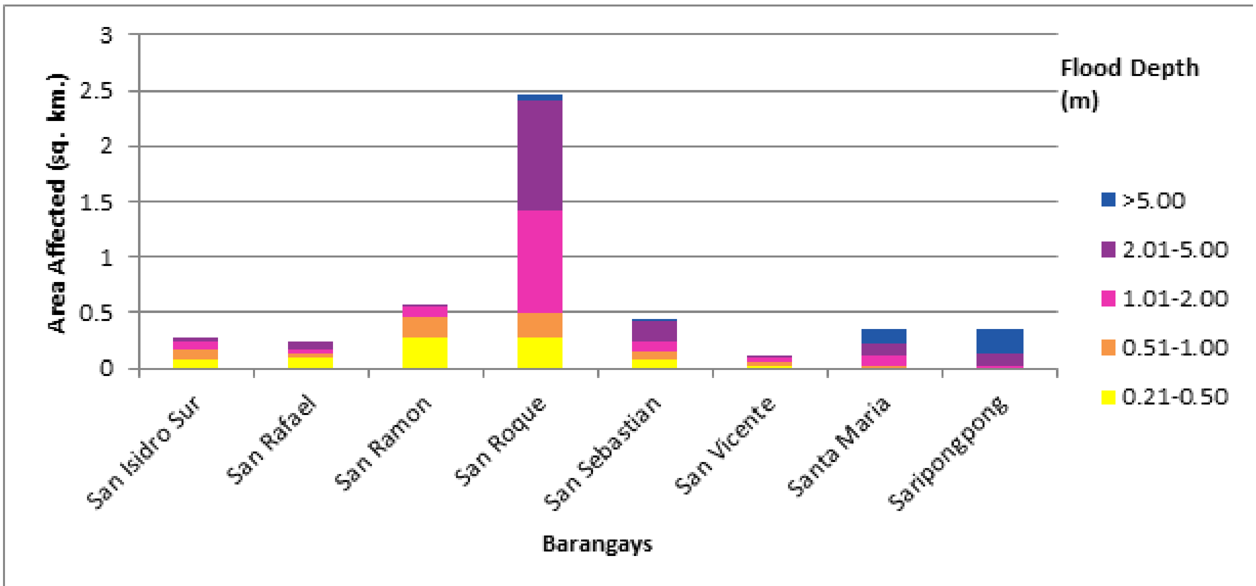


Figure 80. Affected Areas in Lagonoy, Camarines Sur during the 25-Year Rainfall Return Period

For the Municipality of San Jose with an area of 44.63 square kilometers., 37.55% will experience flood levels of less than 0.20 meters. 12.61% of the area will experience flood levels of 0.21 to 0.50 meters, while 5.6%, 5.29%, 6.92%, and 0.004% 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. Tables 43 to 44 depict the areas affected in San Jose in square kilometers by flood depth per barangay.

Table 43. Affected Areas in San Jose, Camarines Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)										
	Bahay	Boclod	Calalahan	Camagong	Danlog	Del Carmen	Dolo	Kinalansan	Manzana	Minoro	Palale
0.03-0.20	1.07	1.7	0.00067	2.21	1.47	0.35	0.26	0.34	0.33	0.59	1.11
0.21-0.50	0.16	0.46	0	0.43	0.47	0.033	0.073	0.1	0.099	0.36	0.66
0.51-1.00	0.08	0.17	0	0.079	0.12	0.0055	0.12	0.094	0.21	0.23	0.12
1.01-2.00	0.12	0.081	0	0.046	0.098	0	0.25	0.1	0.64	0.45	0.003
2.01-5.00	0.15	0.038	0	0.038	0.019	0	1.11	0.12	0.15	0.67	0
>5.00	0.0017	0	0	0	0	0	0	0	0	0	0

Table 44. Affected Areas in San Jose, Camarines Sur during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)									
	Pugay	Sabang	San Antonio	San Juan	San Vicente	Santa Cruz	Soledad	Tambangan	Telegrafo	Tominawog
0.03-0.20	1.04	0.44	0.11	0.43	0.19	0.63	0.27	2.76	0.21	1.23
0.21-0.50	0.13	0.095	0.023	0.098	0.018	0.2	0.11	1.47	0.09	0.55
0.51-1.00	0.012	0.12	0.0041	0.031	0.0043	0.083	0.03	0.46	0.21	0.32
1.01-2.00	0.0034	0.19	0.0025	0.0022	0.0044	0.036	0.014	0.061	0.19	0.06
2.01-5.00	0	0.76	0.0038	0.00017	0.0004	0.034	0.0077	0.0001	0	0
>5.00	0	0	0	0	0	0	0	0	0	0

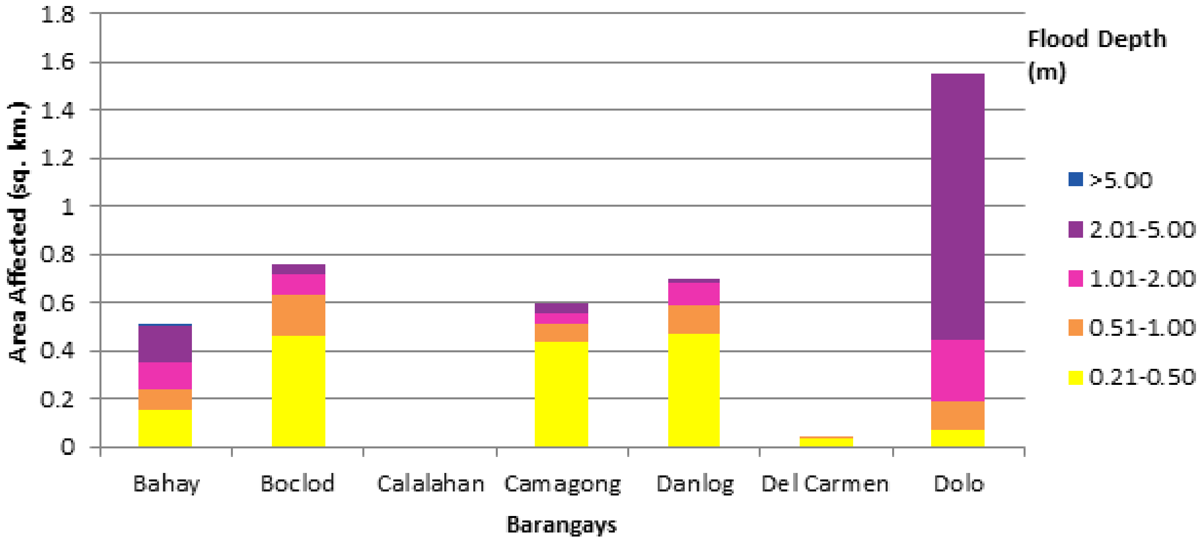


Figure 81. Affected Areas in San Jose, Camarines Sur during the 25-Year Rainfall Return Period

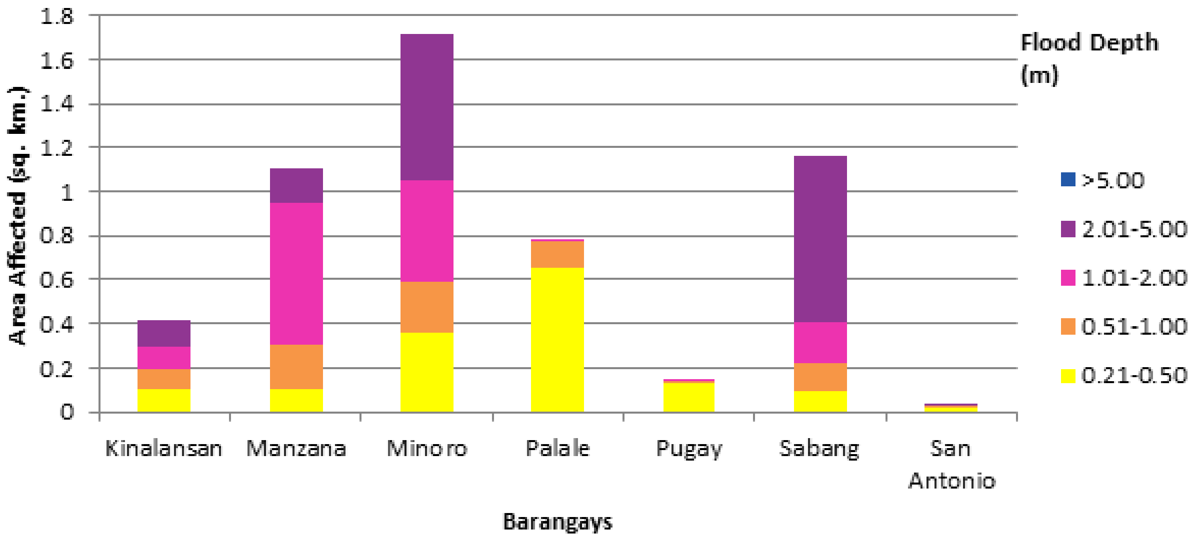


Figure 82. Affected Areas in San Jose, Camarines Sur during the 25-Year Rainfall Return Period

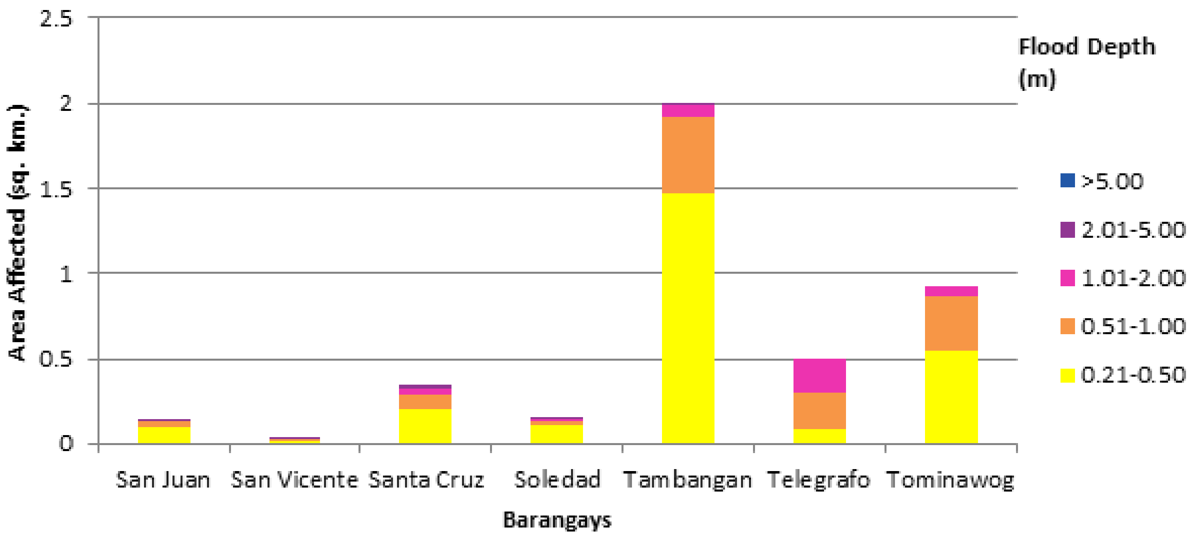


Figure 83. Affected Areas in San Jose, Camarines Sur during the 25-Year Rainfall Return Period

FFor the 5-year rainfall return period, 18.25% of the municipality of Goa with an area of 220.76 square kilometers will experience flood levels of less than 0.20 meters. 1.66% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.76%, 0.6%, 0.39%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Tables 45 to 47 depict the areas affected in Goa in square kilometers by flood depth per barangay.

Table 45. Affected Areas in Goa, Camarines Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Goa (in sq. km.)							
	Abucayan	Bagumbayan Grande	Bagumbayan Pequeño	Belen	Buyo	Cagaycay	Digdigon	Gimaga
0.03-0.20	2.16	0.13	0.53	0.27	1.14	4.64	0.15	1.18
0.21-0.50	0.15	0.031	0.066	0.028	0.22	0.29	0.0057	0.11
0.51-1.00	0.054	0.015	0.041	0.016	0.086	0.17	0.0038	0.051
1.01-2.00	0.037	0.007	0.037	0.0079	0.037	0.15	0.0016	0.037
2.01-5.00	0.0035	0.005	0.013	0.0001	0.0035	0.13	0.0013	0.0033
>5.00	0	0	0	0	0	0.16	0.0012	0

Table 46. Affected Areas in Goa, Camarines Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Goa (in sq. km.)							
	Halawig-Gogon	Hiwacloy	La Purisima	Matacla	Maymatan	Napawon	Panday	Pinaglabanan
0.03-0.20	1.7	0.93	0.1	1.83	2.24	2.06	0.053	3.03
0.21-0.50	0.22	0.065	0.0068	0.44	0.14	0.21	0.0084	0.21
0.51-1.00	0.071	0.048	0.0021	0.078	0.11	0.091	0.0026	0.074
1.01-2.00	0.035	0.047	0.0001	0.0077	0.083	0.1	0.00068	0.047
2.01-5.00	0.004	0.027	0	0.0012	0.0086	0.033	0.0031	0.008
>5.00	0	0.037	0	0	0	0	0.0003	0

Table 47. Affected Areas in Goa, Camarines Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Goa (in sq. km.)								
	Salog	San Benito	San Isidro	San Jose	San Juan Bautista	San Juan Evangelista	San Pedro	Tagongtong	Taytay
0.03-0.20	10.95	0.11	0.043	0.027	0.28	0.093	0.049	5.96	0.64
0.21-0.50	0.67	0.006	0.00011	0.0065	0.074	0.0056	0.0014	0.53	0.18
0.51-1.00	0.55	0.0026	0	0.0036	0.0093	0.0036	0.00031	0.13	0.07
1.01-2.00	0.58	0.0026	0.00003	0.0027	0	0.0079	0	0.055	0.038
2.01-5.00	0.57	0.0007	0	0.0014	0	0.014	0	0.0045	0.029
>5.00	0.062	0	0	0	0	0.0002	0	0	0.0027

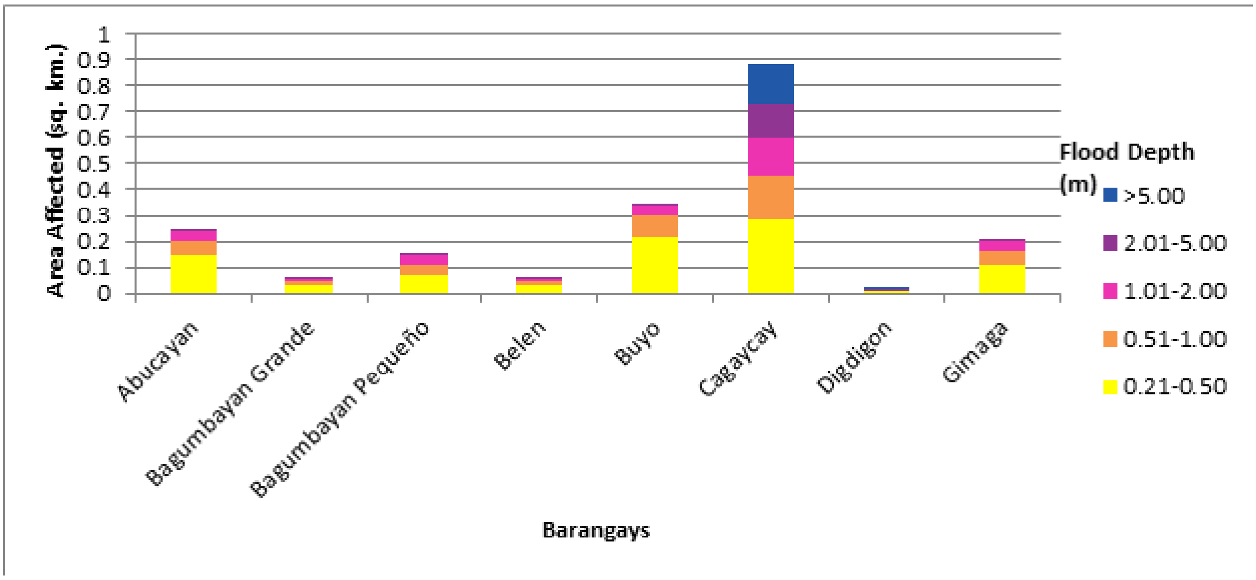


Figure 84. Affected Areas in Goa, Camarines Sur during the 5-Year Rainfall Return Period

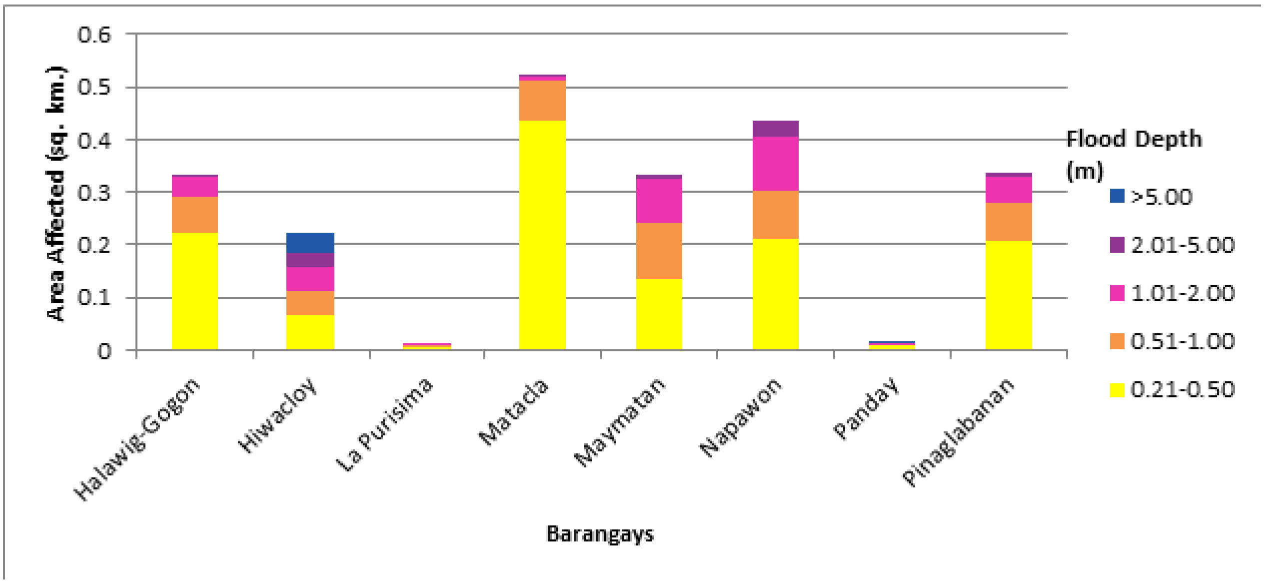


Figure 85. Affected Areas in Goa, Camarines Sur during the 5-Year Rainfall Return Period

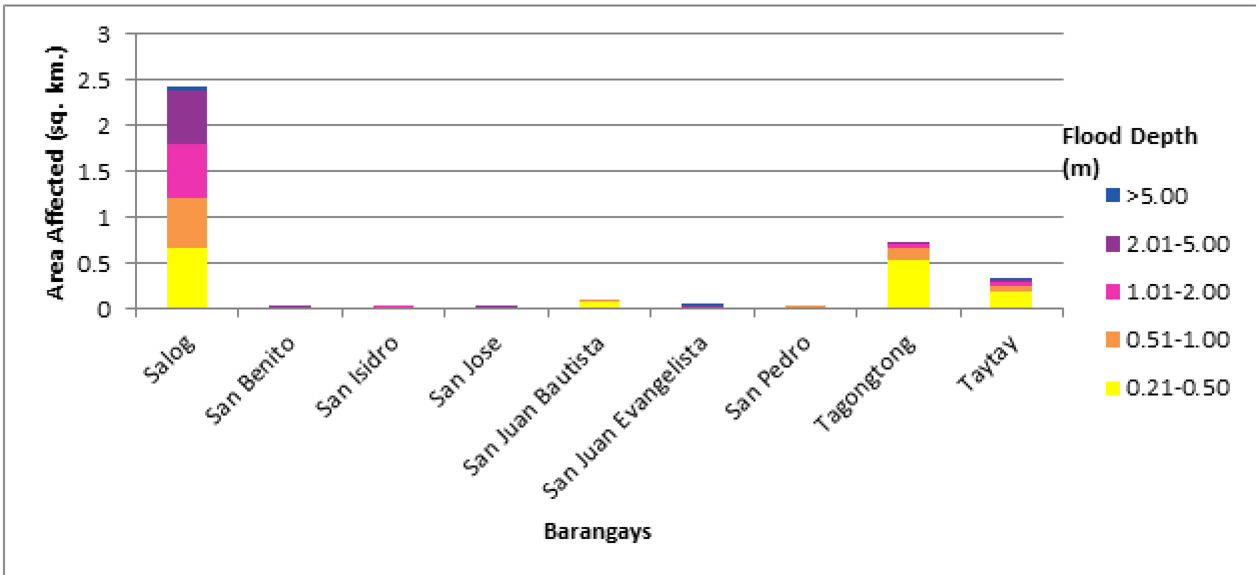


Figure 86. Affected Areas in Goa, Camarines Sur during the 5-Year Rainfall Return Period

For the municipality of Lagonoy with an area of 394.86 square kilometers., 10.5% will experience flood levels of less than 0.20 meters. 0.62% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.65%, 1.56%, 1.88%, and 0.4% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Tables 48 to 49 depict the areas affected in Lagonoy in square kilometers by flood depth per barangay.

Table 48. Affected Areas in Lagonoy, Camarines Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lagonoy (in sq. km.)										
	Agosais	Agpo-Camagong-Tabog	Amoguis	Binanuahan	Burabod	Dahat	Gimagtocon	Ginorangan	Gubat	Loho(	Manamoc
0.03-0.20	6.15	0.66	0.9	0.35	0.4	0.36	6.6	7.8	2.78	0.32	5.69
0.21-0.50	0.19	0.06	0.19	0.094	0.12	0.13	0.19	0.16	0.11	0.089	0.29
0.51-1.00	0.13	0.028	0.21	0.097	0.16	0.2	0.22	0.092	0.091	0.14	0.35
1.01-2.00	0.21	0.017	0.078	0.33	1.48	0.32	0.42	0.26	0.092	0.57	0.96
2.01-5.00	0.8	0.0037	0.095	0.23	1.51	0.57	0.65	1.36	0.076	0.34	0.3
>5.00	0.25	0	0.0007	0.053	0.088	0.056	0.029	0.51	0.0043	0.035	0.085

Table 49. Affected Areas in Lagonoy, Camarines Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lagonoy (in sq. km.)										
	Pinamihagan	San Francisco	San Isidro Norte	San Isidro Sur	San Rafael	San Ramon	San Roque	San Sebastian	San Vicente	Santa Maria	Saripongpong
0.03-0.20	2.94	0.21	0.025	0.4	0.74	1.35	2.2	1.36	0.18	0.02	0.022
0.21-0.50	0.078	0.016	0.017	0.055	0.069	0.22	0.24	0.072	0.028	0.018	0.0076
0.51-1.00	0.05	0.0055	0.034	0.048	0.027	0.15	0.37	0.063	0.021	0.05	0.028
1.01-2.00	0.043	0.0069	0.06	0.028	0.034	0.042	0.94	0.1	0.01	0.11	0.06
2.01-5.00	0.047	0.021	0.17	0.016	0.071	0	0.77	0.18	0.013	0.099	0.085
>5.00	0.005	0	0.23	0	0	0	0.031	0.0072	0	0.052	0.15

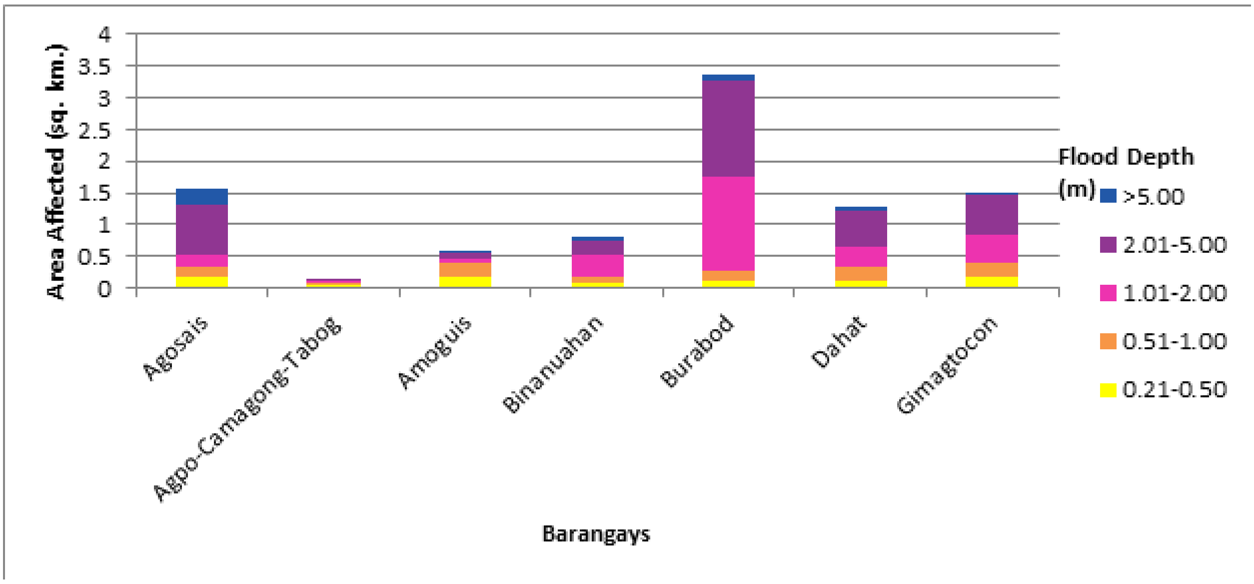


Figure 87. Affected Areas in Lagonoy, Camarines Sur during the 5-Year Rainfall Return Period

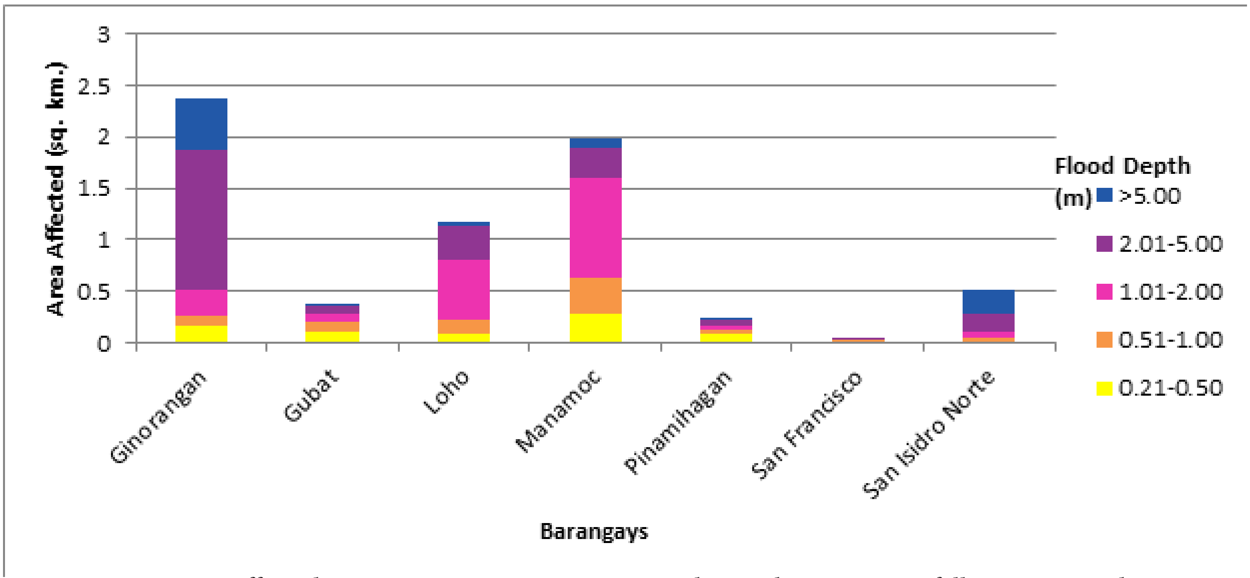


Figure 88. Affected Areas in Lagonoy, Camarines Sur during the 5-Year Rainfall Return Period

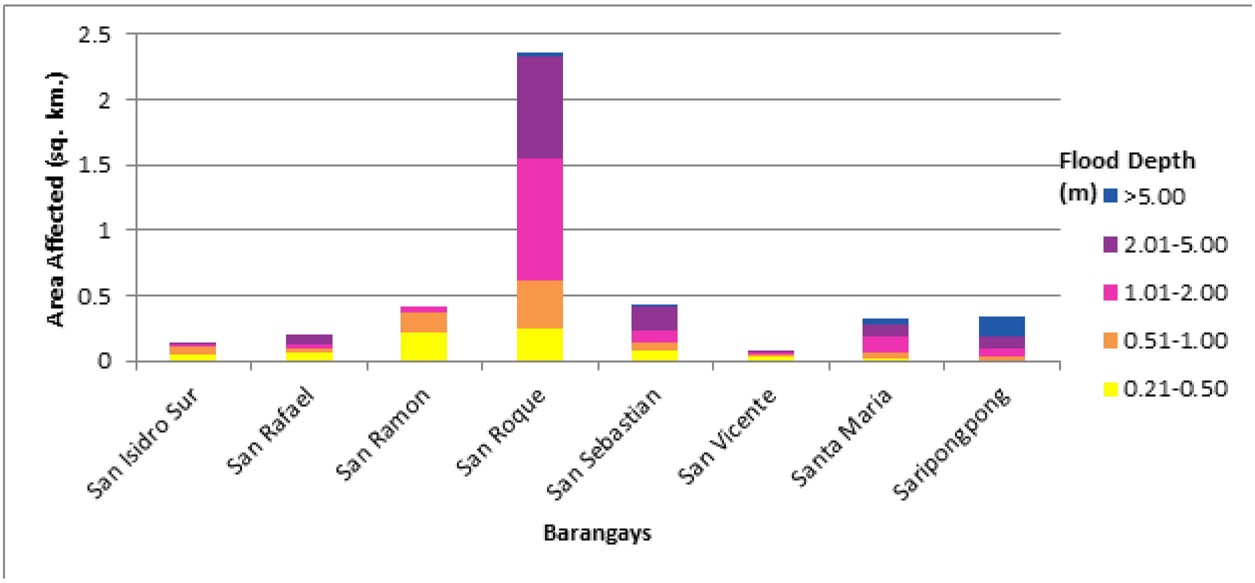


Figure 89. Affected Areas in Lagonoy, Camarines Sur during the 5-Year Rainfall Return Period

For the Municipality of San Jose with an area of 44.63 square kilometers, 42.58% will experience flood levels of less than 0.20 meters. 10.91% of the area will experience flood levels of 0.21 to 0.50 meters, while 5.02%, 5.33%, 4.13%, and 0.4% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Tables 50 to 51 depict the areas affected in San Jose in square kilometers by flood depth per barangay.

Table 50. Affected Areas in San Jose, Camarines Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)										
	Bahay	Boclod	Calalahan	Camagong	Danlog	Del Carmen	Dolo	Kinalansan	Manzana	Minoro	Palale
0.03-0.20	1.15	1.84	0.00067	2.38	1.63	0.36	0.35	0.42	0.45	0.78	1.32
0.21-0.50	0.12	0.39	0	0.29	0.35	0.024	0.096	0.09	0.18	0.43	0.52
0.51-1.00	0.075	0.13	0	0.064	0.1	0.0028	0.12	0.081	0.4	0.28	0.049
1.01-2.00	0.12	0.074	0	0.047	0.08	0	0.42	0.12	0.36	0.47	0.0017
2.01-5.00	0.11	0.022	0	0.027	0.011	0	0.82	0.046	0.04	0.34	0
>5.00	0	0	0	0	0	0	0	0	0	0	0

Table 51. Affected Areas in San Jose, Camarines Sur during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)									
	Pugay	Sabang	San Antonio	San Juan	San Vicente	Santa Cruz	Soledad	Tambangan	Telegrafo	Tominawog
0.03-0.20	1.08	0.52	0.12	0.47	0.2	0.69	0.3	3.22	0.25	1.47
0.21-0.50	0.094	0.14	0.018	0.072	0.014	0.17	0.084	1.18	0.1	0.5
0.51-1.00	0.011	0.075	0.0036	0.022	0.0039	0.064	0.024	0.31	0.24	0.18
1.01-2.00	0.0026	0.49	0.0022	0.0022	0.0042	0.029	0.011	0.027	0.11	0.016
2.01-5.00	0	0.38	0.0034	0	0.0003	0.03	0.0059	0	0	0
>5.00	0	0	0	0	0	0	0	0	0	0

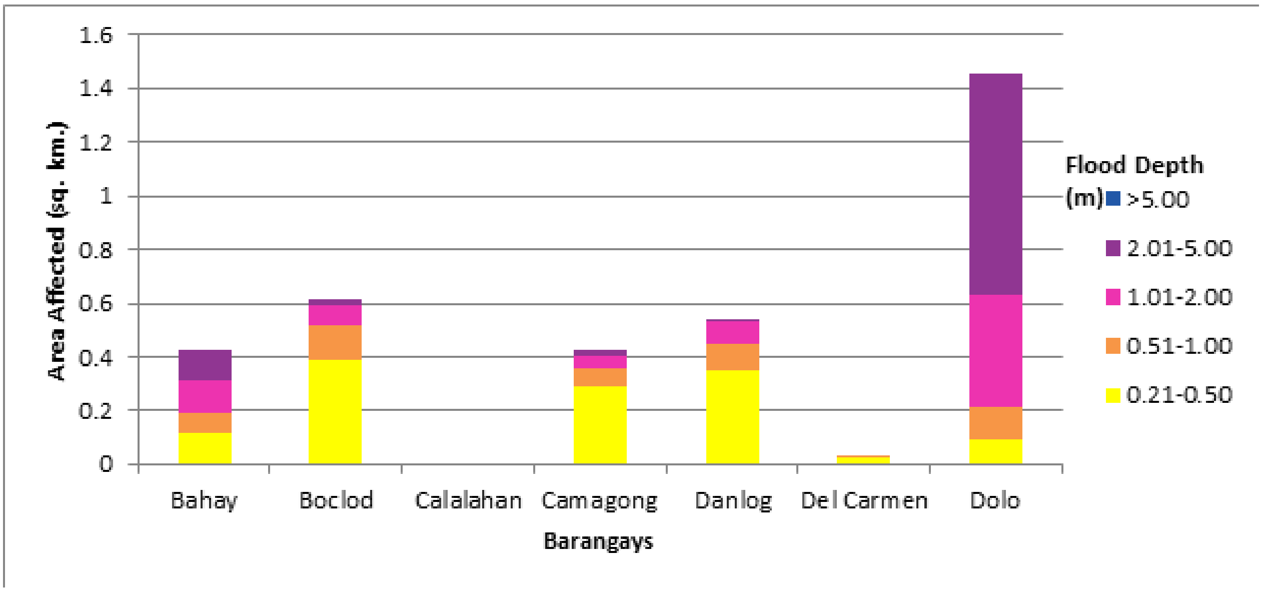


Figure 90. Affected Areas in San Jose, Camarines Sur during the 5-Year Rainfall Return Period

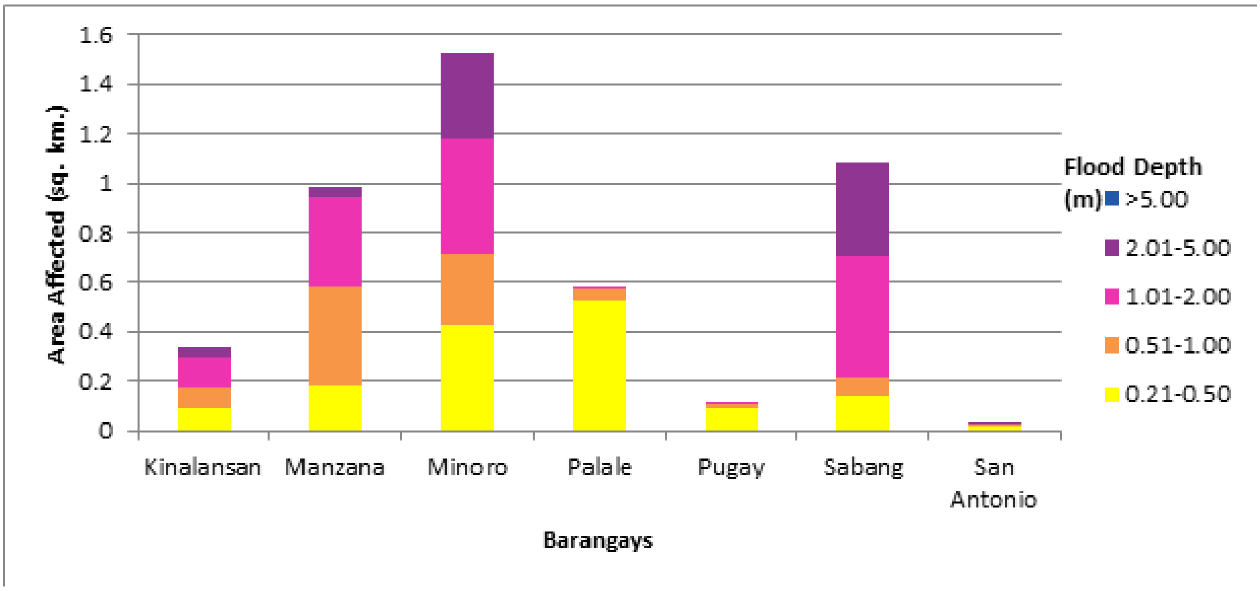


Figure 91. Affected Areas in San Jose, Camarines Sur during the 5-Year Rainfall Return Period

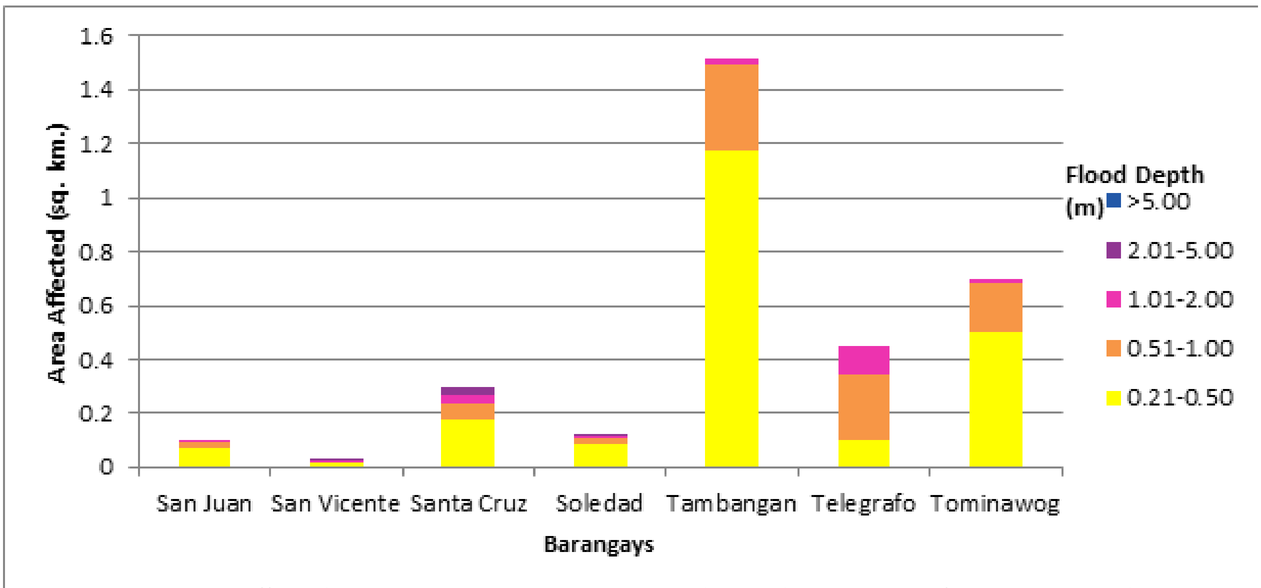


Figure 92. Affected Areas in San Jose, Camarines Sur during the 5-Year Rainfall Return Period

Among the barangays in the Municipality of Goa, Salog is projected to have the highest percentage of area that will experience flood levels at 6.07%. Meanwhile, Tagongtong posted the second highest percentage of area that may be affected by flood depths at 3.02%.

Among the barangays in the Municipality of Lagonoy, Ginorangan is projected to have the highest percentage of area that will experience flood levels at 2.58%. Meanwhile, Gimagtocon posted the second highest percentage of area that may be affected by flood depths at 2.05%.

Among the barangays in the Municipality of San Jose, Tambangan is projected to have the highest percentage of area that will experience flood levels of at 10.62%. Meanwhile, Camagong posted the second highest percentage of area that may be affected by flood depths of at 6.29%.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there is a need to perform validation survey work. Field personnel gathered secondary data regarding flood occurrences in the area within the major river system in the Philippines.

From the Flood Depth Maps produced by 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 and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events and interview of some residents with knowledge of or have had experienced flooding in a particular area.

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation consists of 155 points randomly selected all over the Lagonoy Flood plain. It has an RMSE value of 1.432894882.

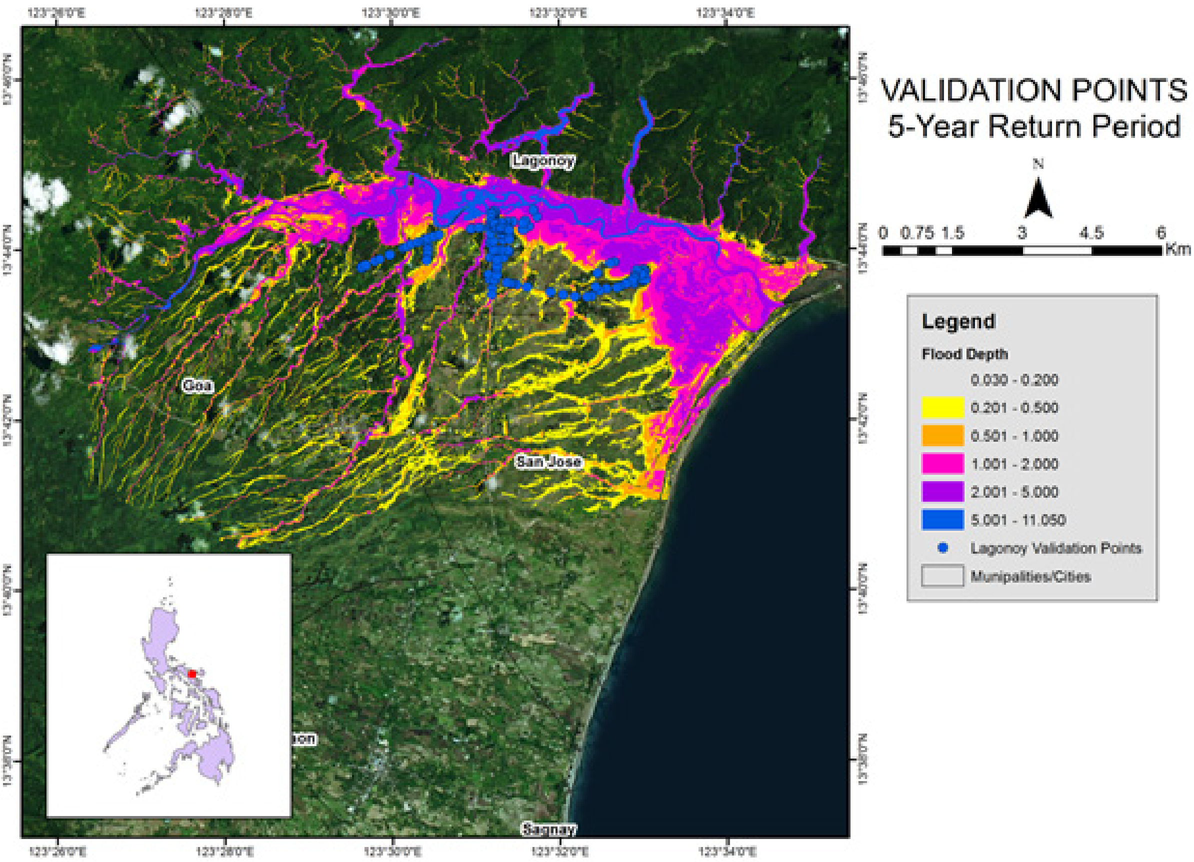


Figure 93. Flood validation points for Lagonoy Floodplain

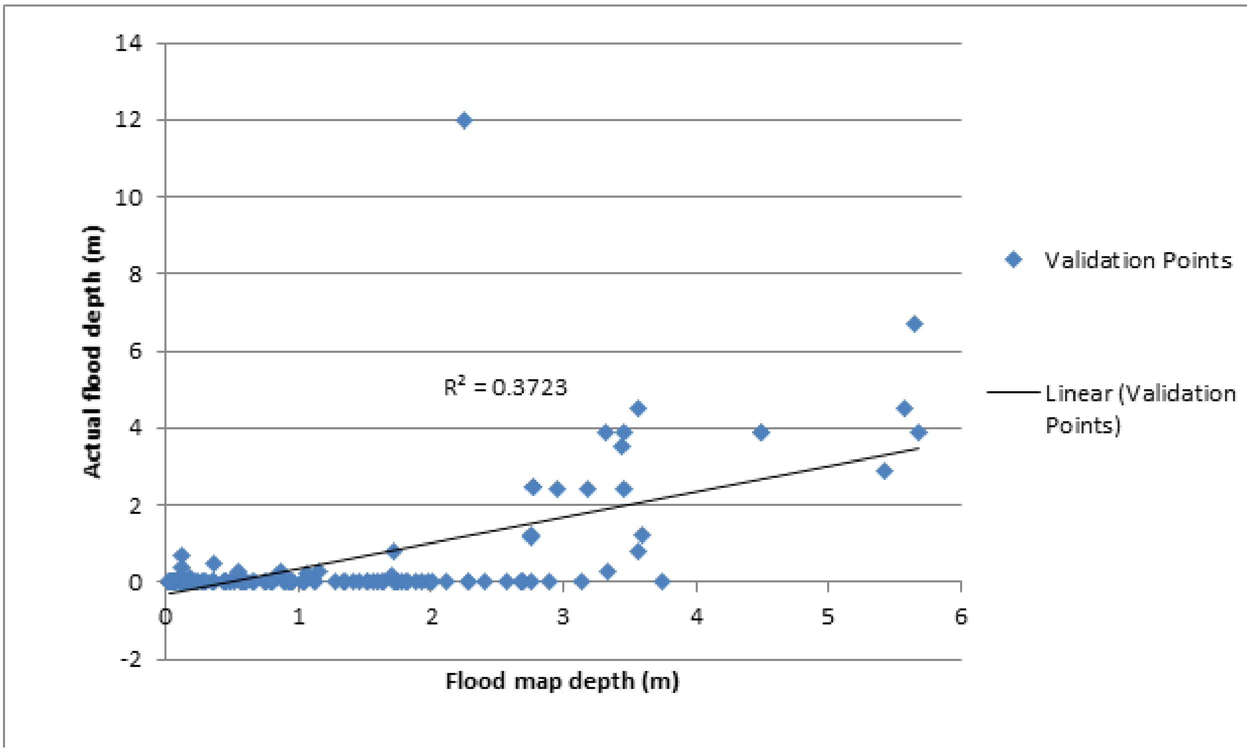


Figure 94. Flood map depth vs. Actual flood depth

Table 52. Actual flood vs. simulated flood depth in the Lagonoy River Basin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	47	16	22	28	13	0	126
0.21-0.50	1	1	2	2	1	0	7
0.51-1.00	1	0	0	1	1	0	3
1.01-2.00	0	0	0	0	3	0	3
2.01-5.00	0	0	0	0	11	3	14
> 5.00		0	0	0	1	1	2
	49	17	24	31	30	4	155

On the whole, the overall accuracy generated by the flood model is estimated at 38.71%, with 60 points correctly matching the actual flood depths. In addition, there were 27 points estimated one level above and below the correct flood depths, while there were 29 points estimated two levels above and below, and 7 points estimated three or more levels above and below the correct flood depths. A total of 92 points were overestimated while a total of 3 points were underestimated in the modelled flood depths of Lagonoy. Table 53 depicts the summary of the accuracy assessment in the Lagonoy River Basin survey.

Table 53. Summary of Accuracy Assessment in the Lagonoy River Basin Survey

	No. of Points	%
Correct	60	38.71
Overestimated	92	59.35
Underestimated	3	1.94
Total	155	100

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.

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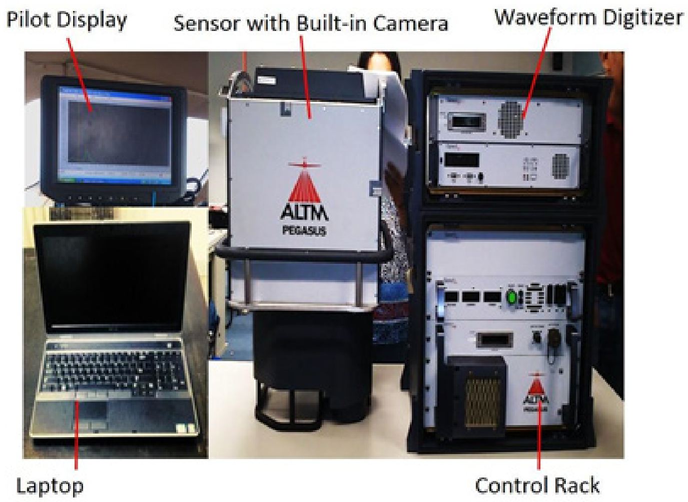
Paringit E.C, Balicanta L.P., Ang, M.O., Sarmiento, C. 2017. Flood Mapping of Rivers in the Philippines Using Airborne Lidar: Methods. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

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

ANNEXES

Annex 1. Technical Specifications of the Pegasus Sensor used in the Lagonoy Floodplain Survey



Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Vertical target separation distance	<0.7 m
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

Annex 2. NAMRIA Certificates of Reference Points Used

1. CMS-103

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

May 02, 2016

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: **CAMARINES SUR**
Station Name: **CMS-103**
Order: **2nd**

Island: **LUZON**
Municipality: **TAMBAN**
Barangay: **POBLACION**
MSL Elevation:

		PRS92 Coordinates			
Latitude:	**13° 53' 44.46082"**	Longitude:	**123° 24' 52.41074"**	Ellipsoidal Hgt:	**4.58100 m.**
		WGS84 Coordinates			
Latitude:	**13° 53' 39.40601"**	Longitude:	**123° 24' 57.34955"**	Ellipsoidal Hgt:	**55.99300 m.**
		PTM / PRS92 Coordinates			
Northing:	**1536671.409 m.**	Easting:	**544805.234 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**1,536,133.55**	Easting:	**544,789.55**	Zone:	**51**

Location Description

CMS-103

Station is located at Tamban port area, it was established at the top edge of seawall. Mark is the head of a 4 in. copper nail centered on a drilled hole with cement putty, embedded at concrete pavement, with inscriptions, "CMS-103, 2007, NAMRIA".

Requesting Party: **Merlin Fernando**
Purpose: **Reference**
OR Number: **3943035 I**
T.N.: **2016-1021**

For

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. CS-461

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

June 28, 2016

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: CAMARINES SUR
Station Name: CS-461

Island: Luzon	Municipality: TINAMBAC	Barangay: BOLAOBALITE
Elevation: 5.4281 +/- 0.0818 m.	Accuracy Class at 95% C.L.: 5 CM	Datum: Mean Sea Level
Latitude:	Longitude:	

The accuracy standards reported herein (FGDC-STD-007-1998) supersedes and replace the previous accuracy standards found in FGCC 1984 and FGCC 1989. Classified control points are verified as being consistent w/ all other points in the network, not merely those within that particular survey.

Location Description

CS-461 is in the Province of Camarines Sur, Municipality of Tinambac, Brgy. Balaobalite, along the Tinambac to Calabanga road. The station is located on a bridge.

A copper nail is embedded and cemented in the middle of a 6 in. x 6 in cement putty with inscription "CS-461, 2008 NAMRIA".

Requesting Party: PHIL-LIDAR 1
Purpose: Reference
OR Number: 8084826 I
T.N.: 2016-1311

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

www.namria.gov.ph

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

Vector Components (Mark to Mark)

From:	CMS-103				
Grid		Local		Global	
Easting	544789.551 m	Latitude	N13°53'44.46082"	Latitude	N13°53'39.40601"
Northing	1536133.547 m	Longitude	E123°24'52.41074"	Longitude	E123°24'57.34955"
Elevation	3.904 m	Height	4.581 m	Height	55.993 m

To:	CS-461				
Grid		Local		Global	
Easting	536011.654 m	Latitude	N13°48'16.97629"	Latitude	N13°48'11.93661"
Northing	1526059.719 m	Longitude	E123°19'59.46340"	Longitude	E123°20'04.41063"
Elevation	7.728 m	Height	8.314 m	Height	59.780 m

Vector					
ΔEasting	-8777.897 m	NS Fwd Azimuth	221°10'00"	ΔX	6018.784 m
ΔNorthing	-10073.828 m	Ellipsoid Dist.	13366.718 m	ΔY	6854.008 m
ΔElevation	3.824 m	ΔHeight	3.732 m	ΔZ	-9770.665 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.009 m
σ ΔElevation	0.011 m	σ ΔHeight	0.011 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000320941		
Y	-0.0000473036	0.0000756414	
Z	-0.0000144523	0.0000223329	0.0000079814

Occupations

	From	To
Point ID:	CMS-103	CS-461
Data file:	C:\Users\Windows User\Documents \Business Center - HCE\Unnamed(3)\CMS-103 (Modular) 1.552M [05-03-16].T02	C:\Users\Windows User\Documents \Business Center - HCE\Unnamed (3)\RINEX CS-461 1.490M [05-03-16].16D
Receiver type:	SPS852	Unknown
Receiver serial number:	5203K81512	U1K7M3544CO
Antenna type:	Zephyr Geodetic	CR.G5
Antenna serial number:	--------	-Unknown-
Antenna height (measured):	1.552 m	1.490 m
Antenna method:	Bottom of notch	Bottom of antenna mount

Tracking Summary

Vector Components (Mark to Mark)

From:	CMS-103				
Grid		Local		Global	
Easting	544789.551 m	Latitude	N13°53'44.46082"	Latitude	N13°53'39.40601"
Northing	1536133.547 m	Longitude	E123°24'52.41074"	Longitude	E123°24'57.34955"
Elevation	3.904 m	Height	4.581 m	Height	55.993 m

To:	CS-464				
Grid		Local		Global	
Easting	535835.478 m	Latitude	N13°47'06.64679"	Latitude	N13°47'01.61166"
Northing	1523899.018 m	Longitude	E123°19'53.49615"	Longitude	E123°19'58.44508"
Elevation	7.478 m	Height	8.046 m	Height	59.563 m

Vector					
ΔEasting	-8954.073 m	NS Fwd Azimuth	216°17'54"	ΔX	5885.438 m
ΔNorthing	-12234.530 m	Ellipsoid Dist.	15166.867 m	ΔY	7382.824 m
ΔElevation	3.574 m	ΔHeight	3.465 m	ΔZ	-11869.678 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000186593		
Y	-0.0000199574	0.0000353943	
Z	-0.0000064437	0.0000096572	0.0000033881

Annex 4. The LIDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
		LOVELY GRACIA ACUÑA	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELYN ASUNCION	UP-TCAGP

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
		ENGR. GEF SORIANO	UP-TCAGP
Ground Survey / Data Download and Transfer	Research Associate (RA)	JASMIN DOMINGO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. BENJIE CARBOLLEDO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. KAHLIL CHI	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. DEXTER CABUDOL	AAC

Annex 5. Data Transfer Sheets for Lagonoy Floodplain

DATA TRANSFER SHEET
5/5/2014(Bacolod [illegible]) Brady

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Apr 21, 2014	1371P	1BLK45DE110A	PEGASUS	1.83GB	300KB	7.87MB	165MB	43.7GB	336KB	16.9GB	N/A	14.8MB	1KB	0B	53.3KB/48.8KB/39.9KB/53.3KB/	1.67KB	Z:\Airborne_Raw\1371P
Apr 21, 2014	1373P	1BLK45B110B	PEGASUS	1.93GB	1.42MB	7.76MB	149MB	23.2GB	221KB	17.2GB	N/A	14.8MB	1KB	230B	39.9KB	1.67KB	Z:\Airborne_Raw\1373P
Apr 22, 2014	1375P	1BLK45B111A	PEGASUS	3.72GB	1.65MB	13.9MB	264MB	46.0GB	366KB	34.9GB	N/A	13.6MB	1KB	527B	28.3KB/37.8KB/41.0KB	1.67KB	Z:\Airborne_Raw\1375P
Apr 22, 2014	1377P	1BLK45C111B	PEGASUS	1.73GB	1.06MB	7.10MB	154MB	17.5GB	4.19KB/164KB	15.6GB	N/A	13.6MB	1KB	250B	3.44KB/49.6KB	1.67KB	Z:\Airborne_Raw\1377P
Apr 25, 2014	1387P	1BLK45AC114A	PEGASUS	2.59GB	672KB	13.2MB	275MB	44.2GB	350KB	27.3GB	N/A	7.15MB	1KB	457B	73.5KB/62.3KB/57.8KB	1.67KB	Z:\Airborne_Raw\1387P
Apr 26, 2014	1391P	1BLK44CB115A	PEGASUS	3.40GB	1.51MB	12.6MB	257MB	52.0GB	159KB/188KB	30.7GB	N/A	12.3MB	152B	460B	51KB/48.8KB/725KB/53.8KB/3	2.01KB	Z:\Airborne_Raw\1391P
Apr 27, 2014	1393P	1BLK44AB115B	PEGASUS	2.82GB	2.91MB	13.3MB	264MB	45.0GB	356KB	30.8GB	N/A	12.3MB	152B	668B	61.3KB/49.1KB	2.01KB	Z:\Airborne_Raw\1393P

Received from

Name GRACE B. SINADJAN
Position RA
Signature

Received by

Name Benjamin Magallon
Position
Signature
5/26/2014

DATA TRANSFER SHEET
Bacolod Reflights 10/22/15

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
02-Oct-15	10007P	1BLK44LMSCALIB275A	PEGASUS	1.07	828/720	9.21	263	30/14.2/9.26	128/237/1/76	10.6	NA	8.71	1KB	1KB	36/51/27/32	NA	Z:\DAC\RAW DATA
2-Oct-15	10008P	1BLK45BLK46276A	PEGASUS	206	258	2.5	95.1	5.7	48	36	NA	9.98	1KB	1KB	108/92/83	NA	Z:\DAC\RAW DATA
3-Oct-15	10009P	1BLK45BLK46276B	PEGASUS	858	1.04	6.29	193	2.2/6.2/10.3	18/70/1/7	11.7	NA	10	1KB	1KB	108/92/80	NA	Z:\DAC\RAW DATA

Received from

Name C JOSON H
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SUPSRS
Signature 11/03/15

Annex 6. Flight Logs

1. Flight log for 23278P mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 23278P

1 LiDAR Operator: Soriano	2 ALTM Model: Pegasus	3 Mission Name: 1BLK14ACF11A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-9122
7 Pilot: S. Alfonso	8 Co-Pilot: K. Chi	9 Route:			
10 Date: 09/27/16	12 Airport of Departure (Airport, City/Province): NAGA		12 Airport of Arrival (Airport, City/Province): NAGA		
13 Engine On: 0647	14 Engine Off: 1054	15 Total Engine Time: 4+05	16 Take off: 0652	17 Landing: 1047	18 Total Flight Time: 3+55
19 Weather					

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 2 lines in BLK C, 4 lines in BLK A and 6 lines in BLK F.

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/ Technician
LOVELYN ASUNCION	BENDITE CABALLERO	C. ALFONSO III	GEF SORIANO	
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

2. Flight log for 23290P mission

DREAM Program's Data Acquisition Flight Log | **Flight Log No.:** 23290P

1 LiDAR Operator: Soriano	2 ALTM Model: Pegasus	3 Mission Name: 1BLK24CE17A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso	8 Co-Pilot: K. Chi	9 Route:			
10 Date: 09/26/16	12 Airport of Departure (Airport, City/Province): NAGA		12 Airport of Arrival (Airport, City/Province): NAGA		
13 Engine On: 0620	14 Engine Off: 1035	15 Total Engine Time: 4+15	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

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

Completed BLK 24C and surveyed 2 lines at BLK 24E

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/ Technician
LOVELYN ASUNCION	BENNIE CARSOLLEDO	C. ALFONSO III	GEF SORIANO	
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

3. Flight log for 23302P mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 23302P

1 LiDAR Operator: MCE Baligans	2 ALTM Model: Pegasus	3 Mission Name: 2BLK 29BES 140A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: S Alfonso	8 Co-Pilot: K Chi	9 Route:			
10 Date: 09/29/16	12 Airport of Departure (Airport, City/Province): Naga		12 Airport of Arrival (Airport, City/Province): Naga		
13 Engine On: 0600	14 Engine Off: 1035	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

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

Completed BLK 29B and 24E

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/ Technician
LOVELYN ASUNCION	BESSIE CAMBALLEDO	C. ALFONSO III	MCE BALIGUAS	
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

4. Flight log for 23314P mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 23314P

1 LIDAR Operator: MCE BALIGUAS	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK24ABC123A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: C. ALFONSO III	8 Co-Pilot: R. CHI	9 Route:			
10 Date: May 2, 2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0645	14 Engine Off: 1120	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

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

Covered voids over BLK24A, B, C

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/ Technician
LOVELYN ASUNCION	RENNIE CARBALLEDO	C. ALFONSO III	MCE BALIGUAS	
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

5. Flight log for 23318P mission

DREAM Program's Data Acquisition Flight Log — Flight Log No.: 23318P

1 LiDAR Operator: G. SORIANO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK24ABC voids (24A)	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: S. Alfonso	8 Co-Pilot: K. Chi	9 Route:			
10 Date: May 8, 2016	12 Airport of Departure (Airport, City/Province): Naga		12 Airport of Arrival (Airport, City/Province): Naga		
13 Engine On: 0622	14 Engine Off: 1047	15 Total Engine Time: 4+25	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 voids in BLK 24A, B, C

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/Technician
LOVELYN ASUNCION	[illegible] CAMBALLERO	C. Alfonso III	GEF SORIANO	G. ANTONIO
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

Annex 7. Flight status reports

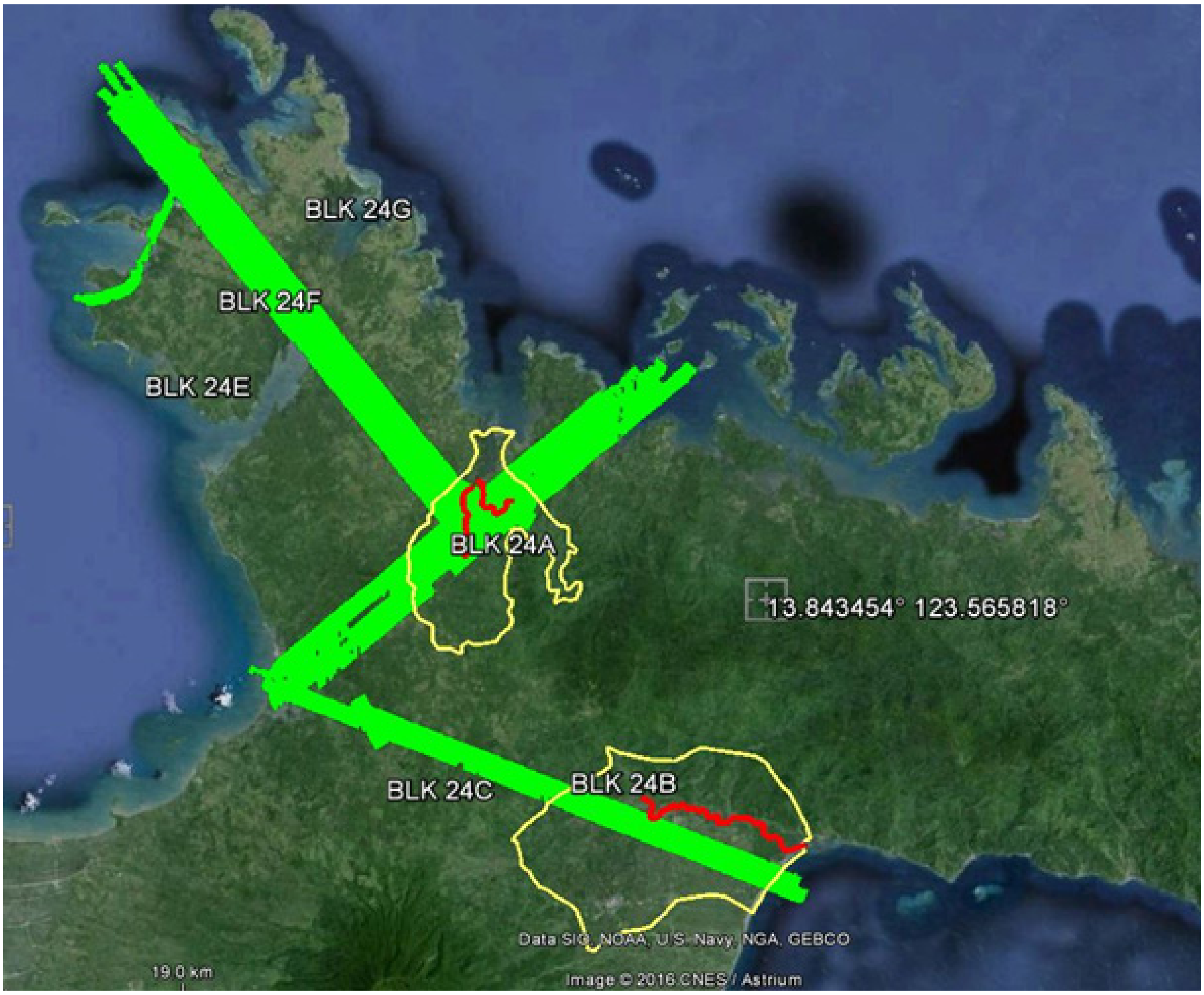
FLIGHT STATUS REPORT
NAGA A (PEGASUS SENSOR WITHOUT CAMERA & DIGITIZER)
APRIL 23 – MAY 4, 2016

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23278	169.14	1BLK24CAF114A	G SORIANO	23 APRIL 16	Surveyed 2 lines over BLK24C, 4 lines over BLK24A and 6 lines over BLK24F. Laser shut off due to clouds.
23290	202.07	1BLK24CSE117A	G SORIANO	26 APRIL 16	Surveyed 11 lines over BLK24C and 2 lines at BLK24E.
23302	283.94	1BLK24BES120A	MCE BALIGUAS	29 APRIL 16	Surveyed 7 lines over BLK24B, 2 lines at A and 12 lines at E. Surveyed at different altitudes due to clouds.
23314	208.44	1BLK24ABCVOIDS123A	MCE BALIGUAS	02 MAY 16	Covered voids over BLKs 24 A, B and C at different altitudes because of high terrain and heavy buildup of clouds.
23318	120.98	1BLK24ACFVOIDS124A	G SORIANO	03 MAY 16	Covered voids over BLKs24 A, C,F. Cloudy most of the area.

LAS BOUNDARIES PER FLIGHT

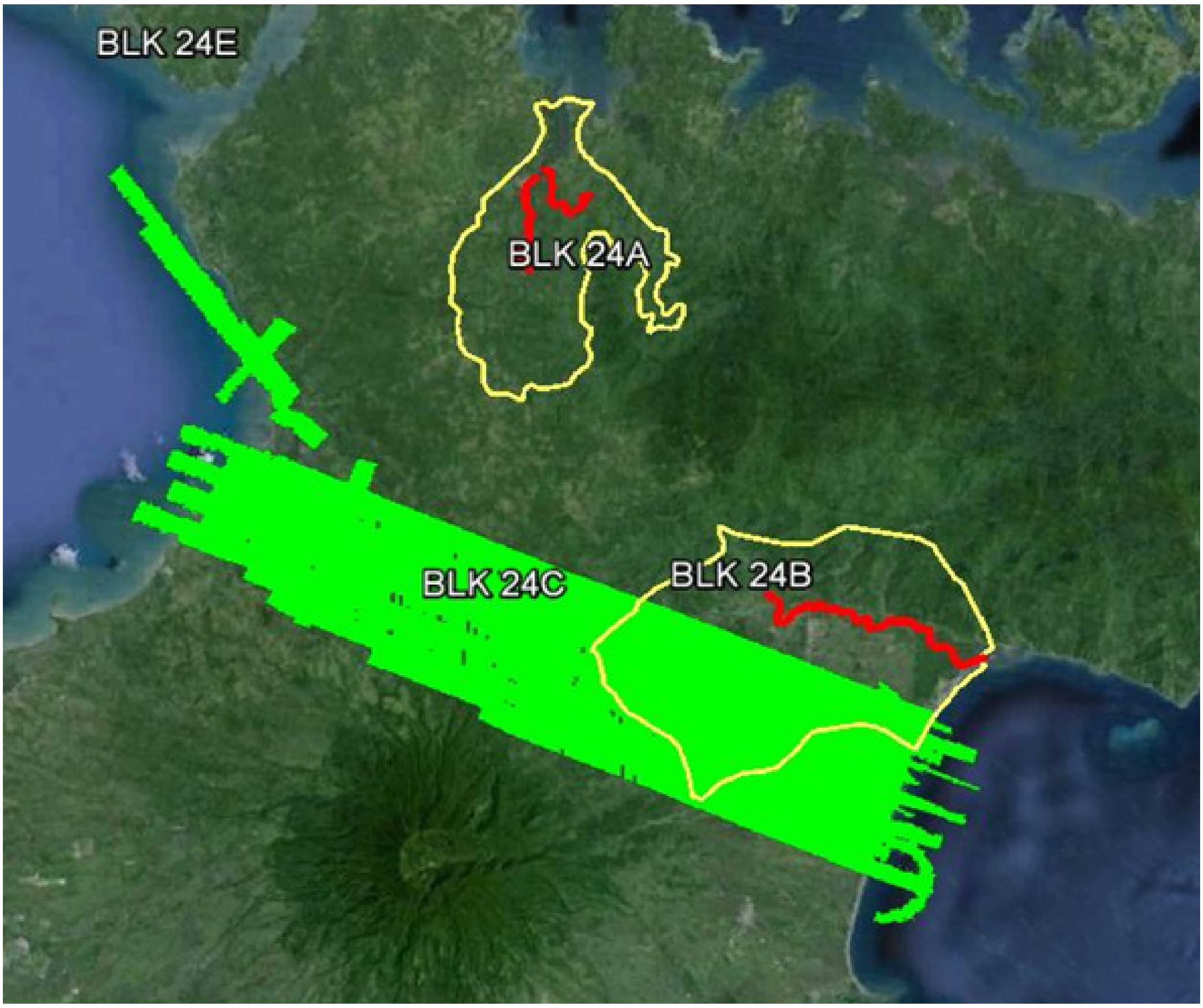
Flight No. : 23278

Area: BLK24 C, A & F
Mission Name: 1BLK24CAF114A
Parameters: Altitude: 600 and 1000m PRF: 150 & 200
Total Area Surveyed: 169.14 sq km



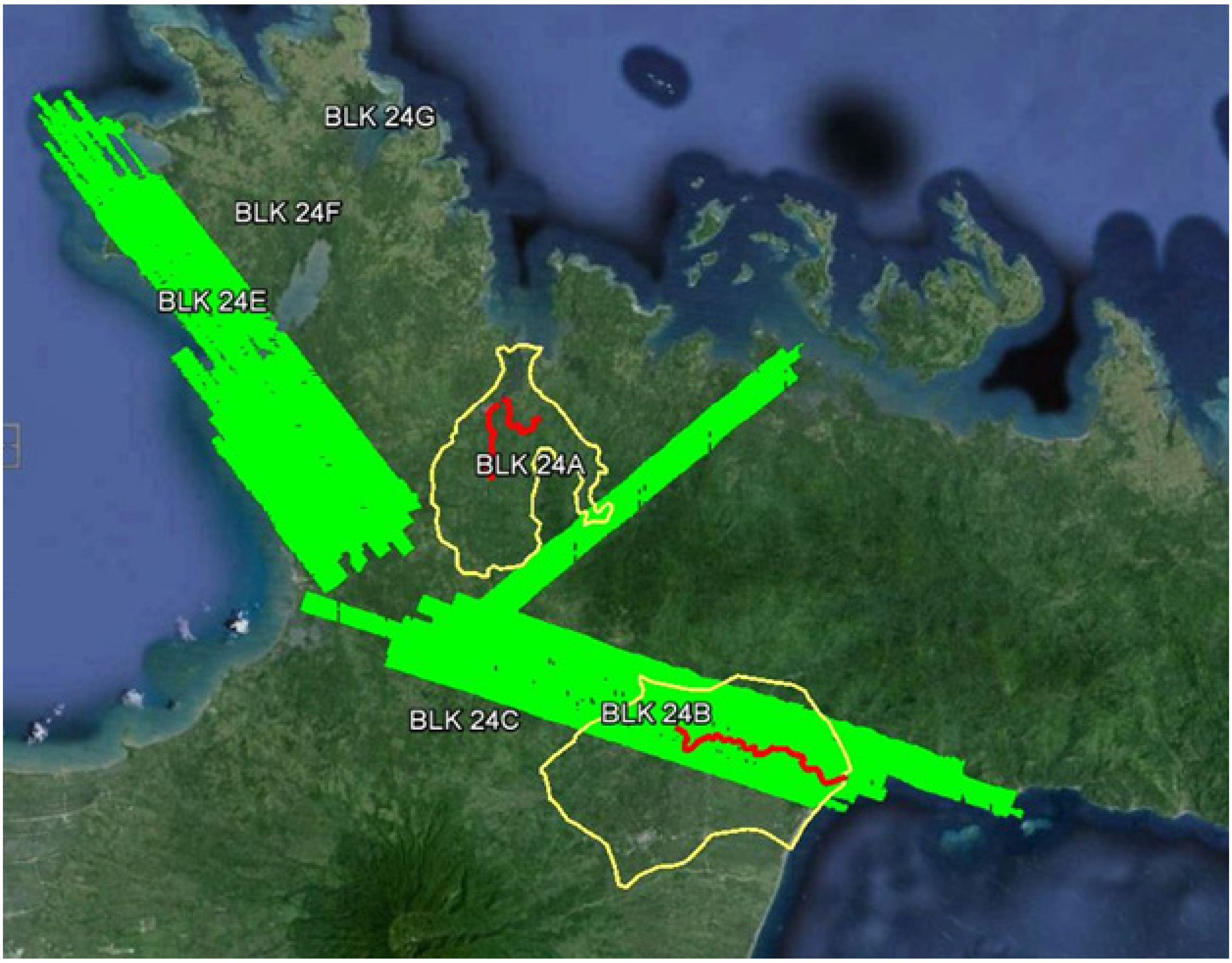
Flight No. : 23290P

Area: BLK24 C and E
Mission Name: 1BLK24CSE117A
Parameters: Altitude: 850 and 1000m PRF: 200
Total Area Surveyed: 202.07 sq km



Flight No. : 23302P

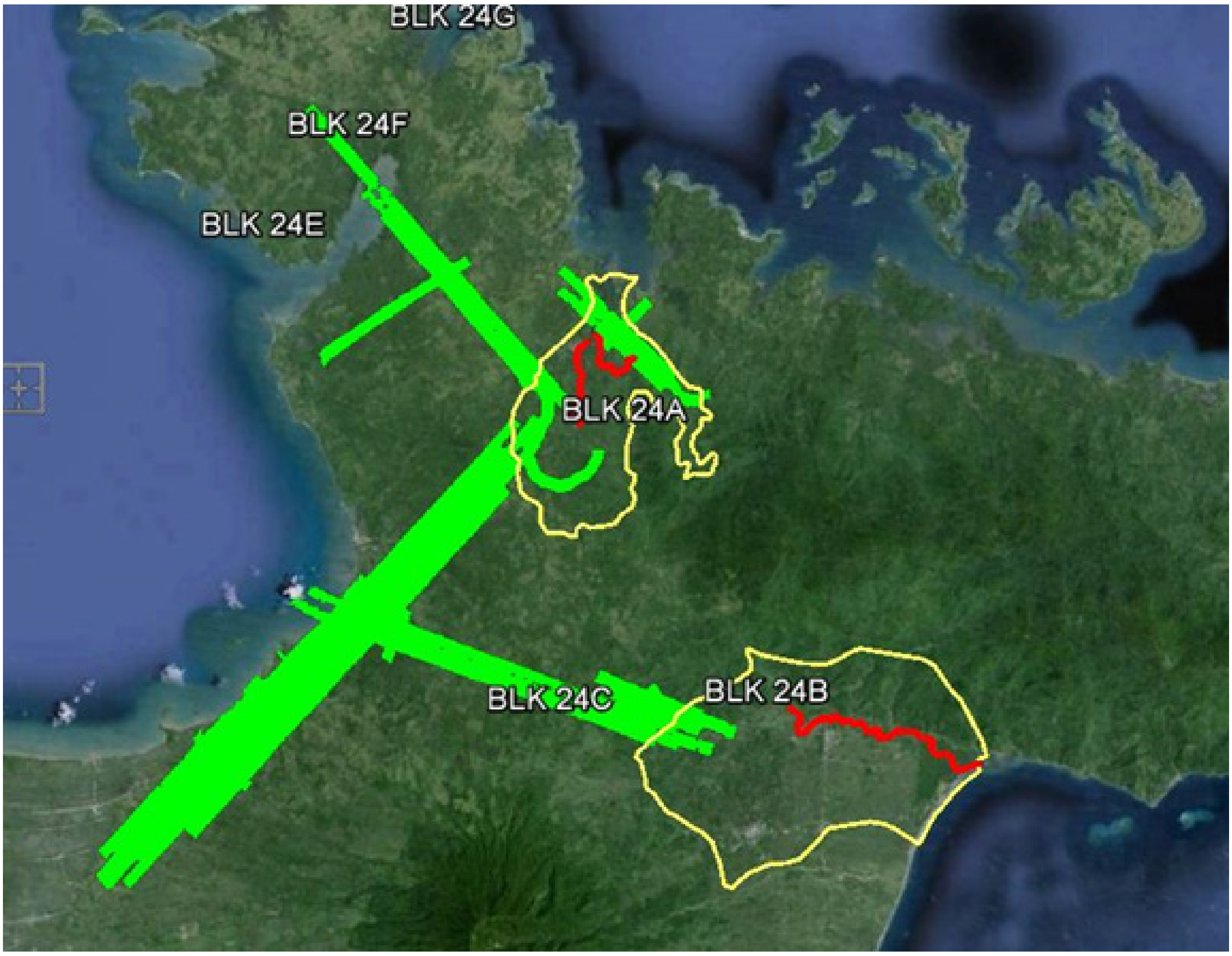
Area: BLK24B, A and E
Mission Name: 1BLK24BES120A
Parameters: Altitude: 800 and 1000m PRF: 200
Total Area Surveyed: 283.94 sq km



Flight No. : 23304P

Area: BLK24 G and E
Mission Name: 1BLK24ESGS120B
Parameters: Altitude: 1000m PRF: 200
Total Area Surveyed: 108.44 sq km

Flight No: 23318P
Area: BLK24 A, C and F
Mission Name: 1BLK24ACFVOIDS124A
Parameters: Altitude: 550 to 600 and 1000m PRF: 150 and 200
Total Area Surveyed: 120.98 sq km



Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk 24C

Flight Area	Naga
Mission Name	Blk 24C
Inclusive Flights	23278P, 23290P, 23314P, 23318P
Range data size	90.9 GB
POS data size	1089 MB
Base data size	412.5 MB
Image	NA
Transfer date	June 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.039
RMSE for East Position (<4.0 cm)	1.136
RMSE for Down Position (<8.0 cm)	2.288
Boresight correction stdev (<0.001deg)	0.000148
IMU attitude correction stdev (<0.001deg)	0.000253
GPS position stdev (<0.01m)	0.0058
Minimum % overlap (>25)	44.75%
Ave point cloud density per sq.m. (>2.0)	2.65
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	308
Maximum Height	743.19 m
Minimum Height	21.36 m
Classification (# of points)	
Ground	334,822,156
Low vegetation	142,016,025
Medium vegetation	208,533,539
High vegetation	522,318,599
Building	9,214,165
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Analyn Naldo, Engr. Edgardo Gubatanga, Jr., Engr. Czarina Jean Añonuevo

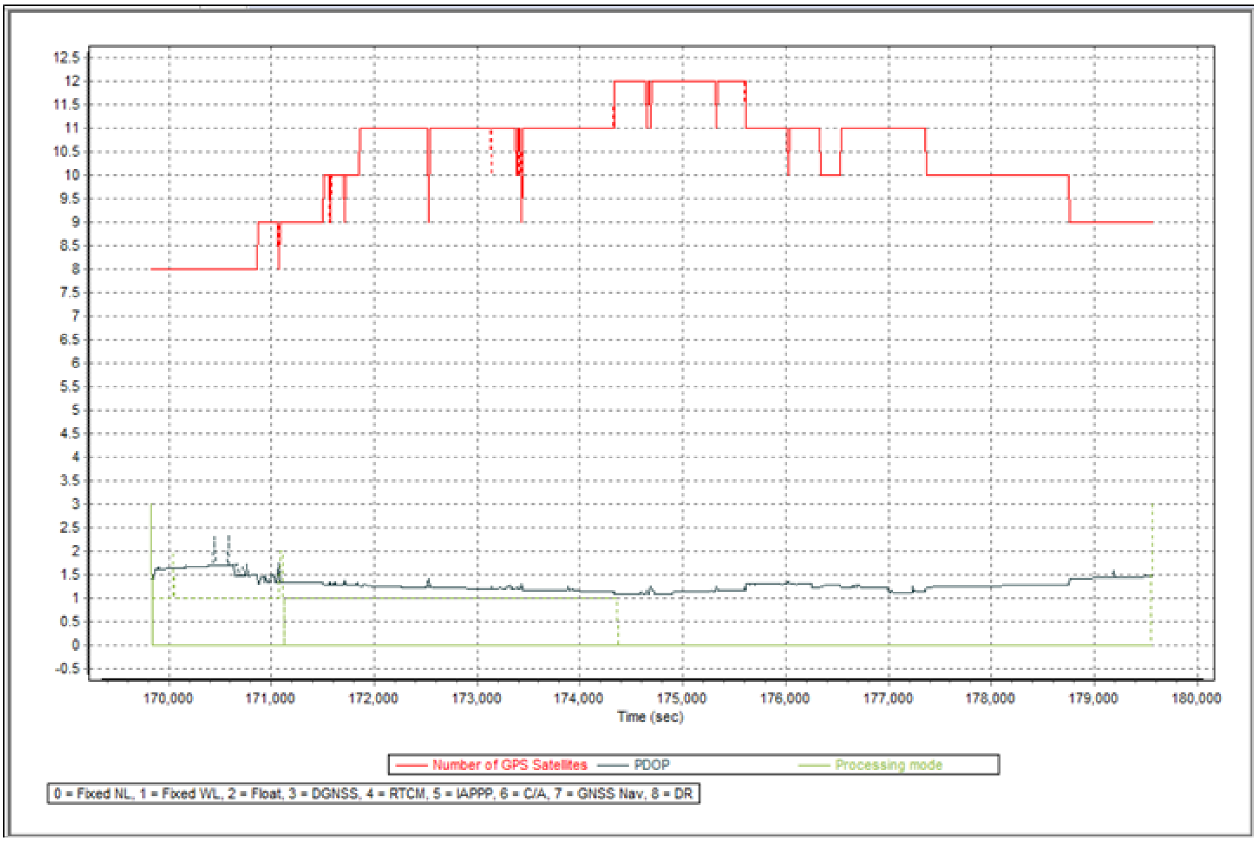


Figure A-8.1. Solution Status

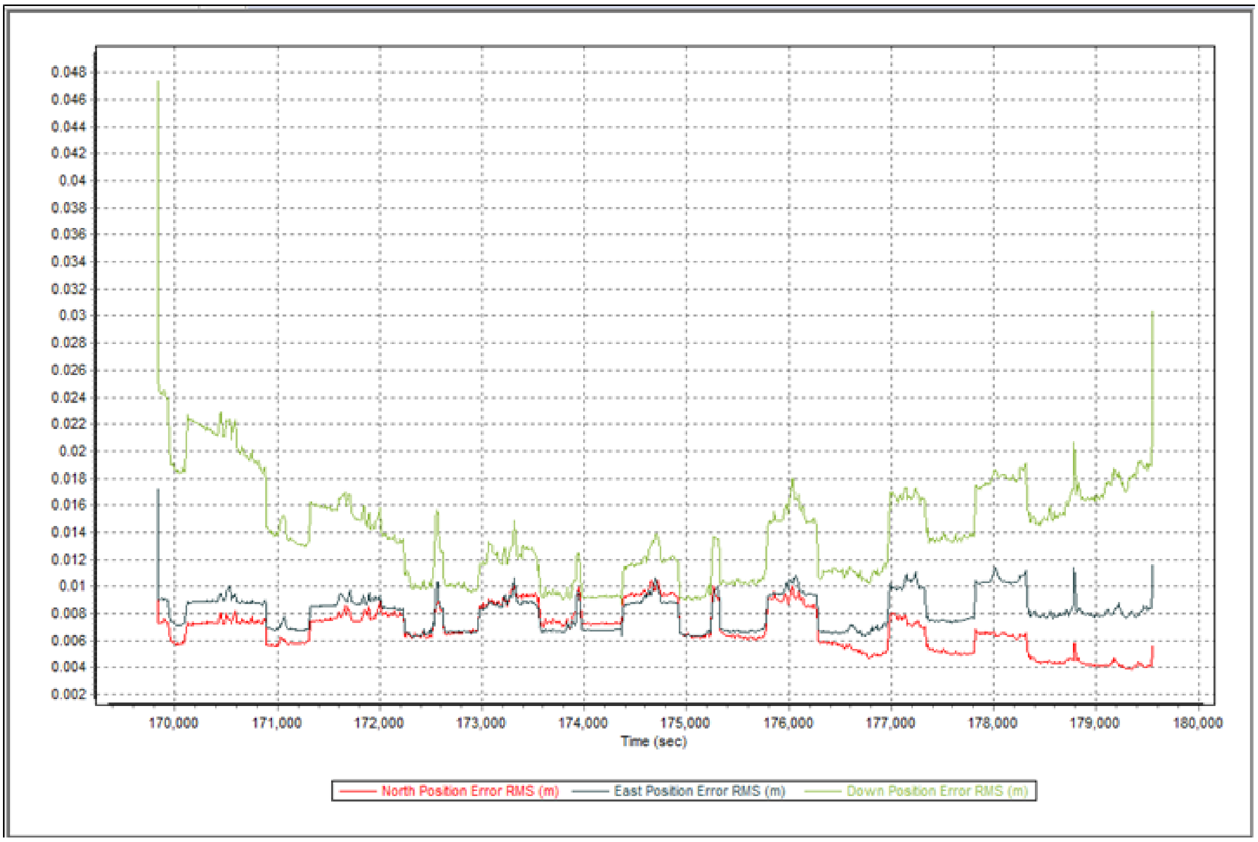


Figure A-8.2. Smoothed Performance Metrics Parameters

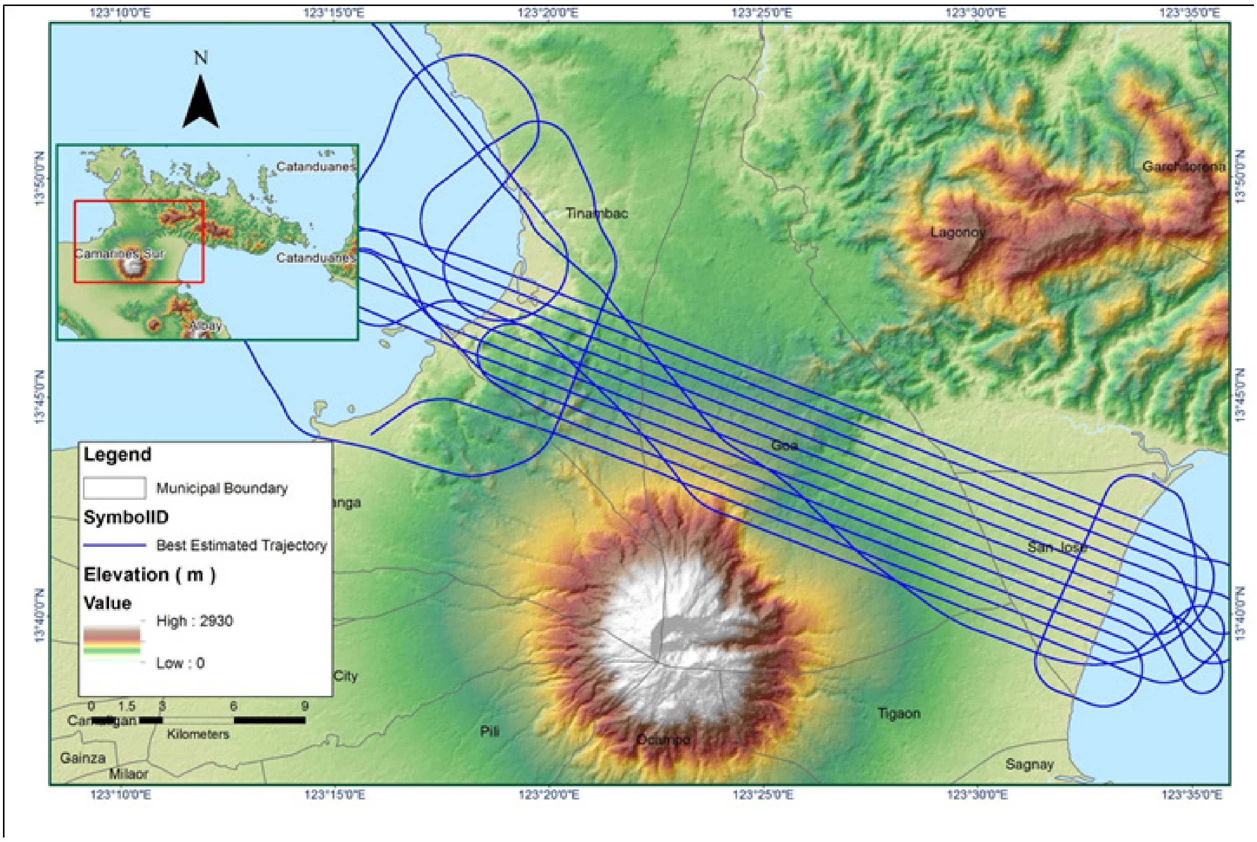


Figure A-8.3. Best Estimated Trajectory

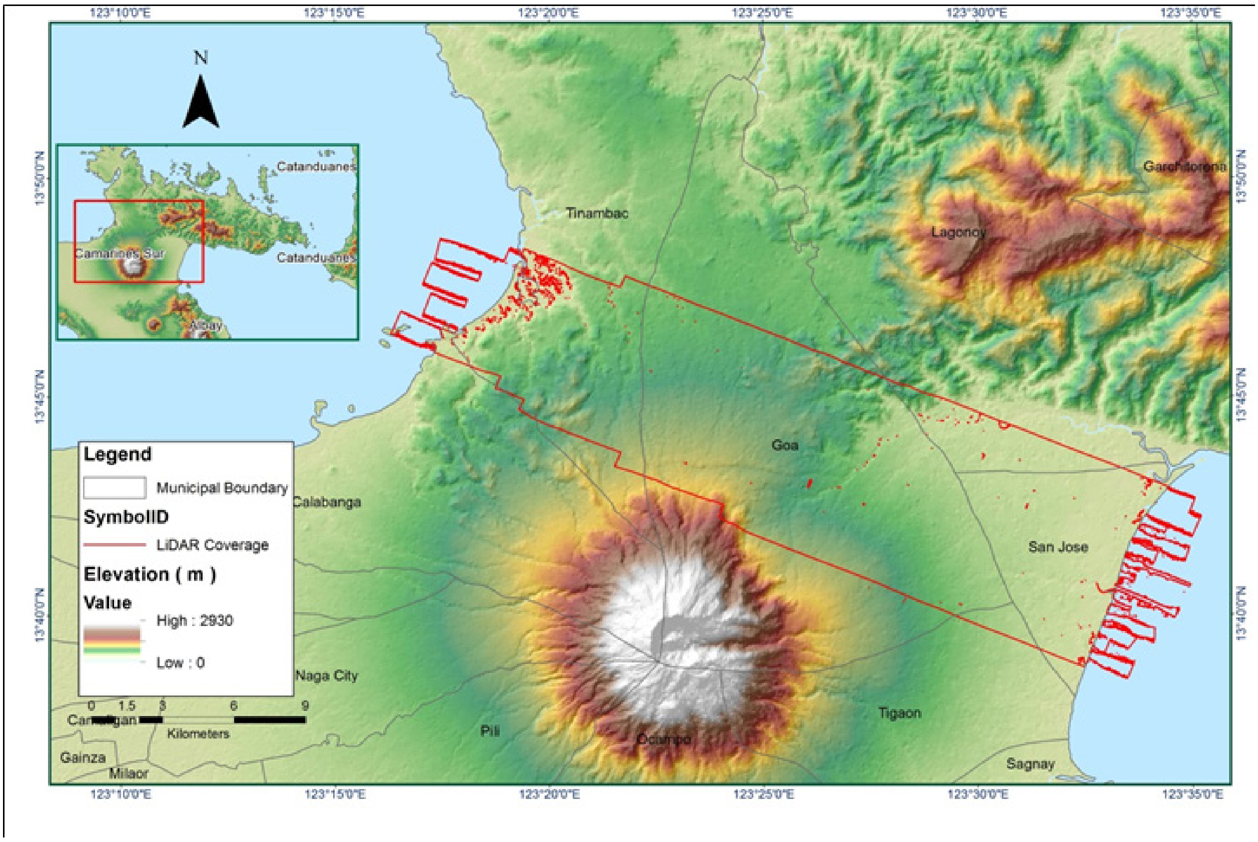


Figure A-8.4. Coverage of LiDAR data

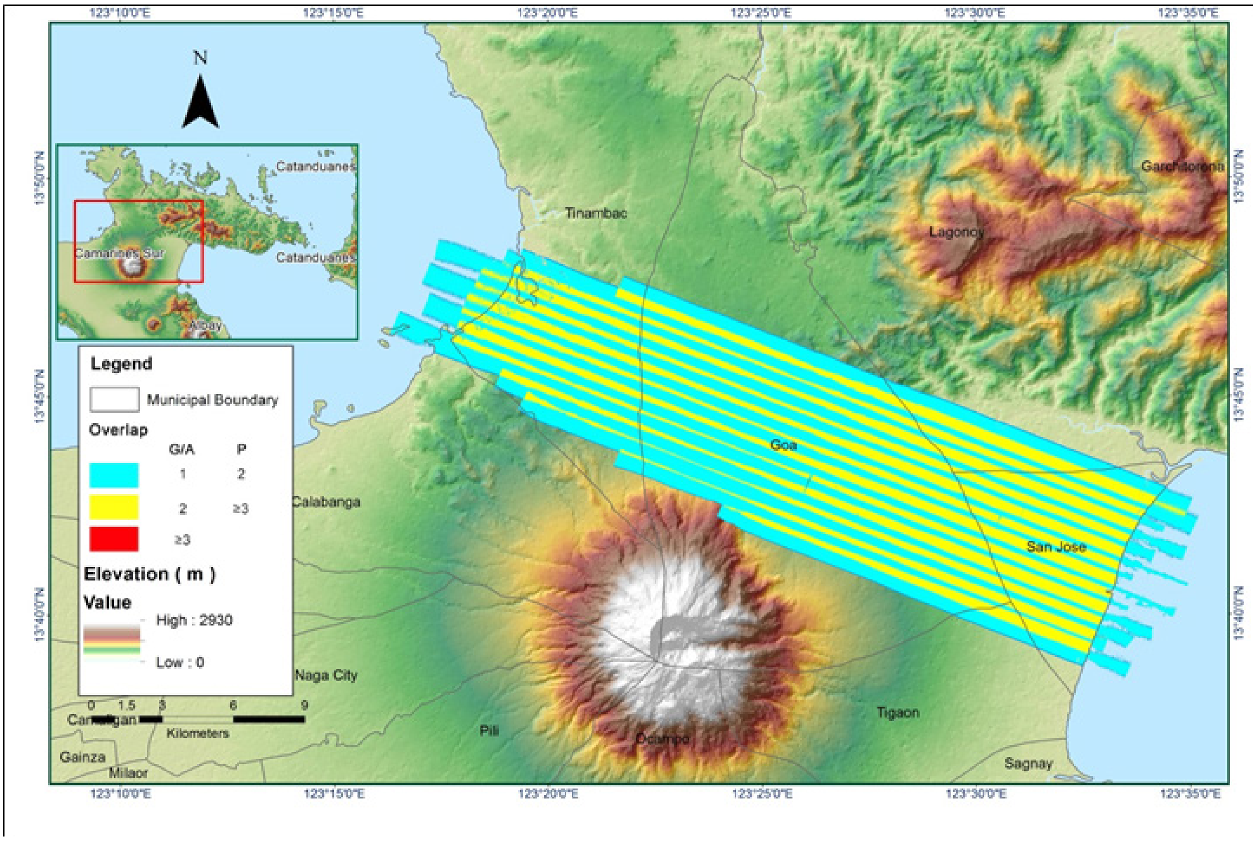


Figure A-8.5. Image of Data Overlap

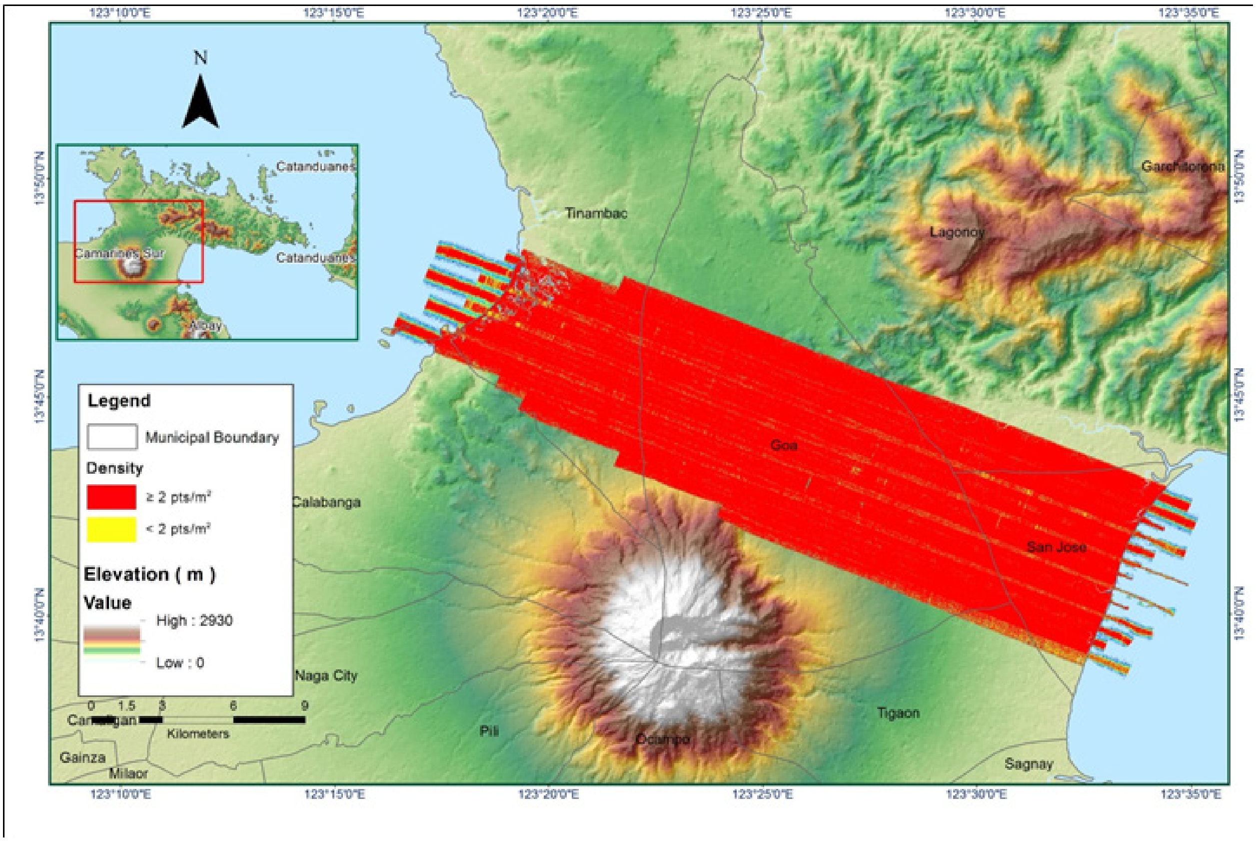


Figure A-8.6. Density map of merged LiDAR data

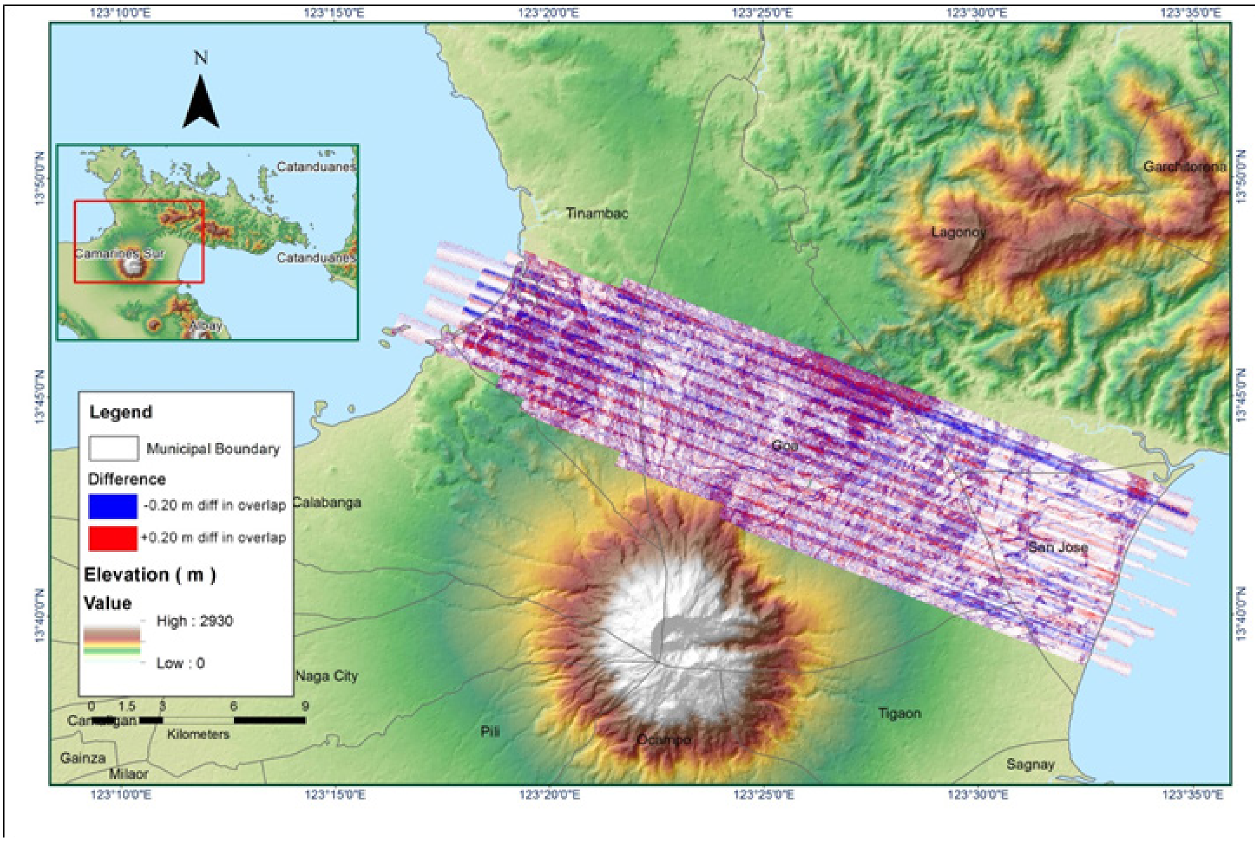


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk 24C_additional

Flight Area	Naga
Mission Name	Blk 24C_additional
Inclusive Flights	23318P
Range data size	19.5 GB
POS data size	261 MB
Base data size	101 MB
Image	NA
Transfer date	June 10, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.453
RMSE for East Position (<4.0 cm)	1.915
RMSE for Down Position (<8.0 cm)	7.629
Boresight correction stdev (<0.001deg)	0.000249
IMU attitude correction stdev (<0.001deg)	0.000673
GPS position stdev (<0.01m)	0.0013
Minimum % overlap (>25)	5.26
Ave point cloud density per sq.m. (>2.0)	45.44%
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	67
Maximum Height	338.01 m
Minimum Height	53.10 m
Classification (# of points)	
Ground	40,009,192
Low vegetation	33,328,464
Medium vegetation	73,665,640
High vegetation	165,857,759
Building	2,698,051
Orthophoto	No
Processed by	Engr. Regis Guhiting, Aljon Rie Araneta, Engr. Melissa Fernandez

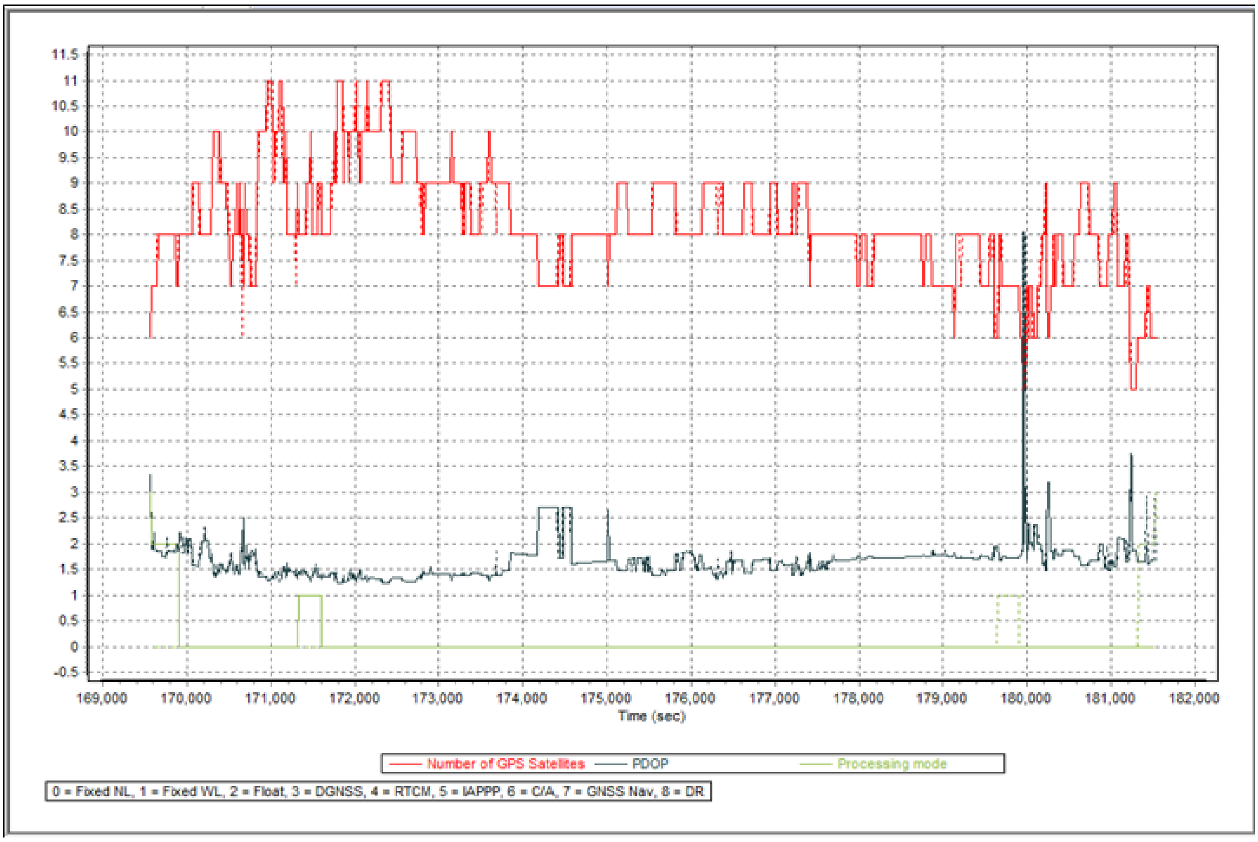


Figure A-8.8. Solution Status Parameters

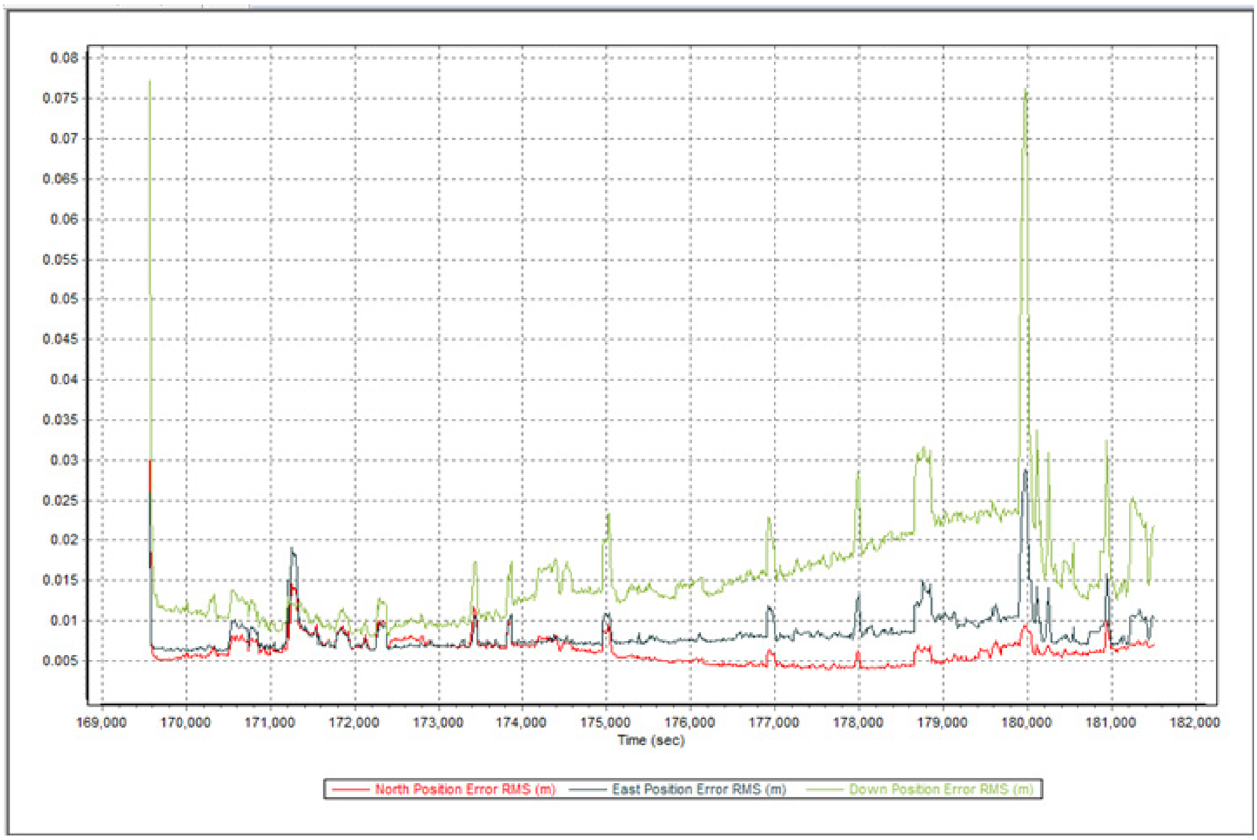


Figure A-8.9. Smoothed Performance Metrics Parameters

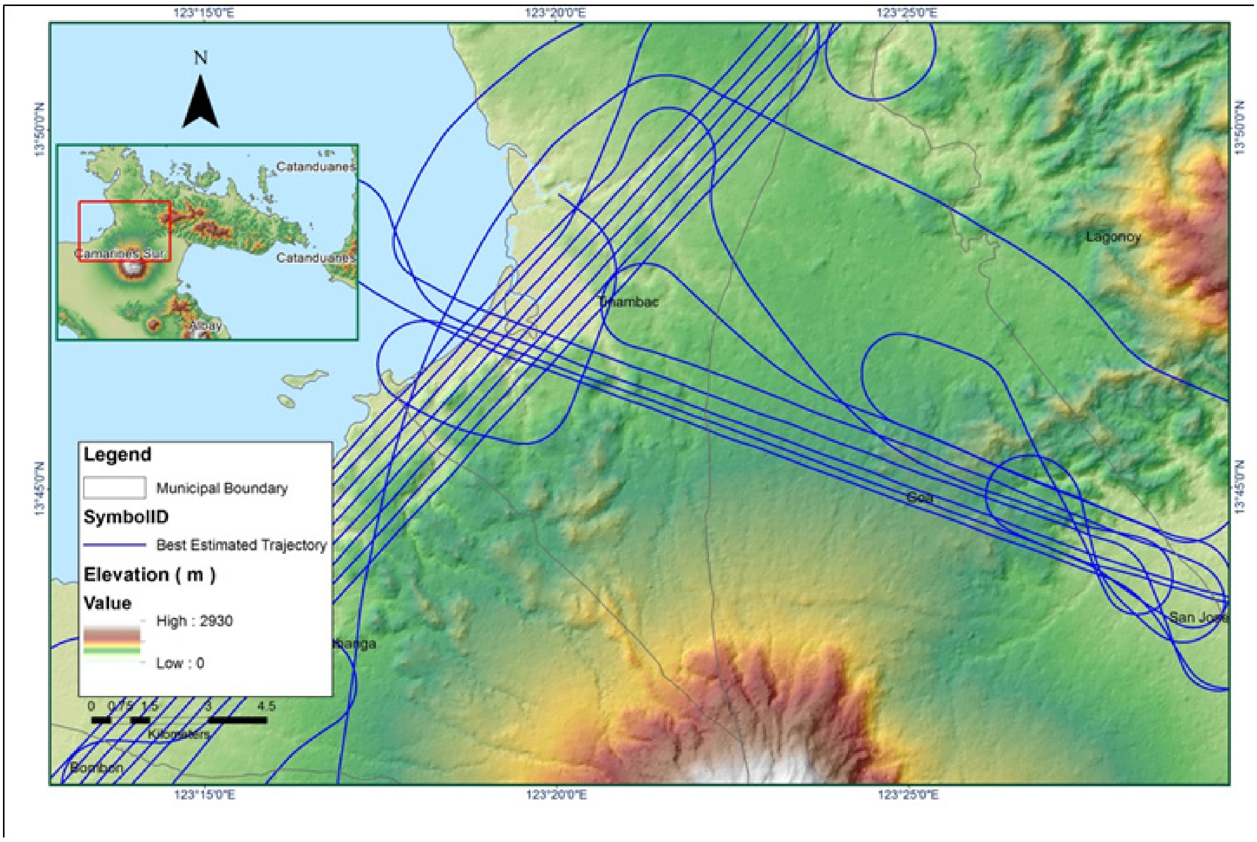


Figure A-8.10. Best Estimated Trajectory

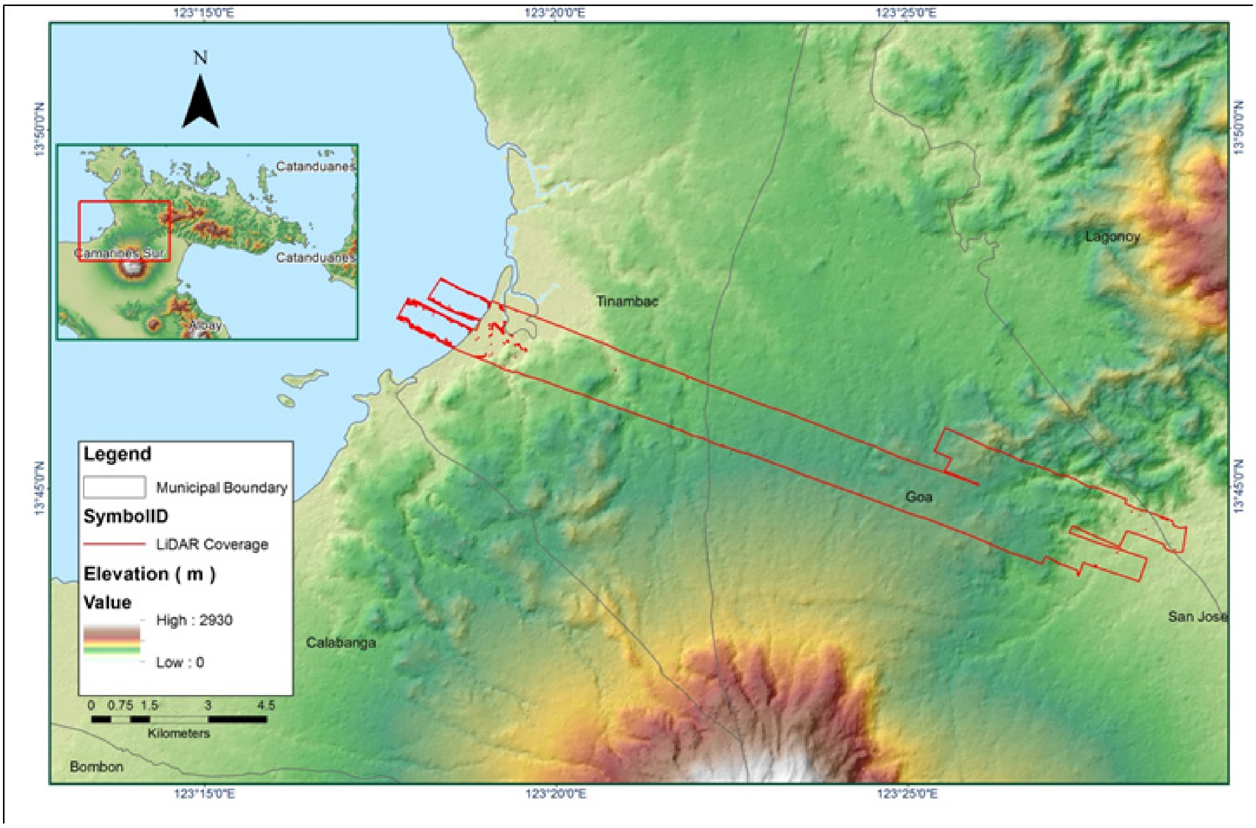


Figure A-8.11. Coverage of LiDAR data

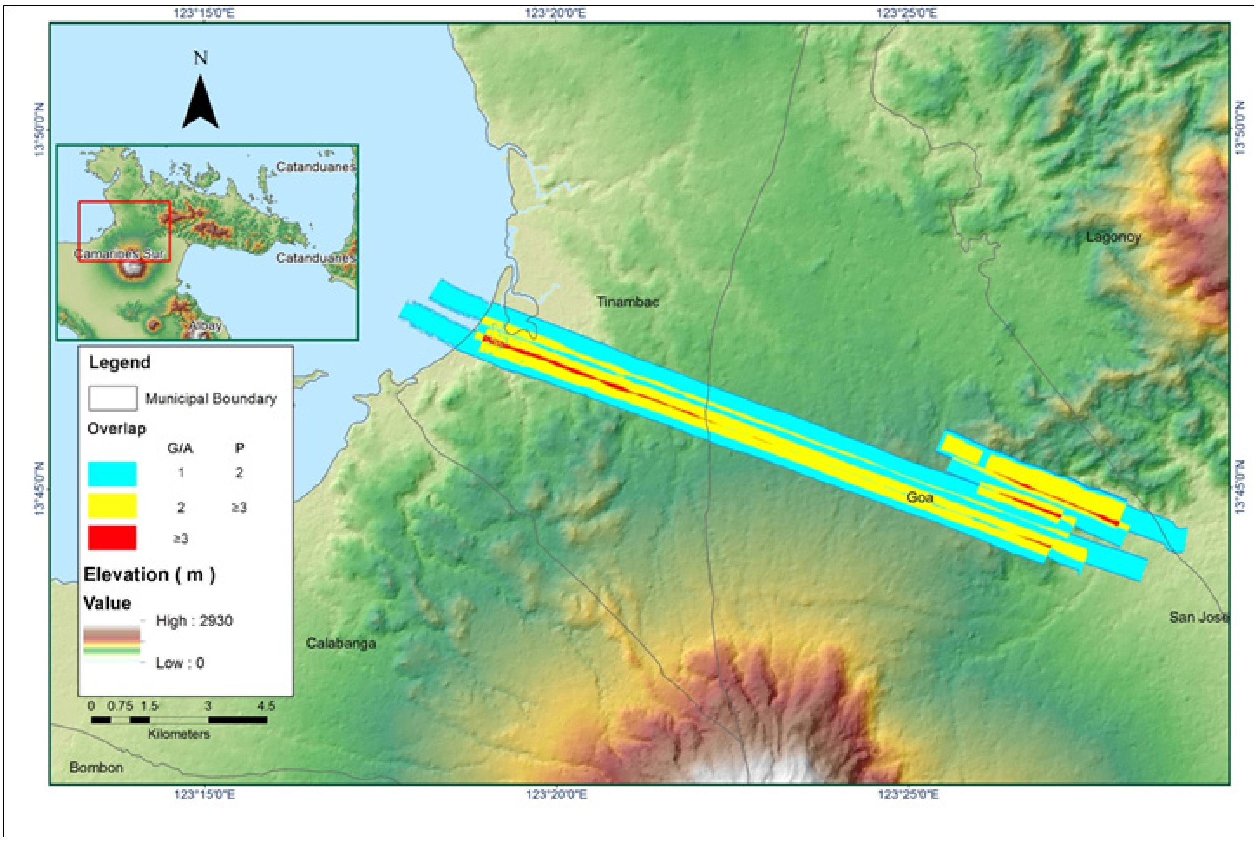


Figure A-8.12. Image of Data Overlap

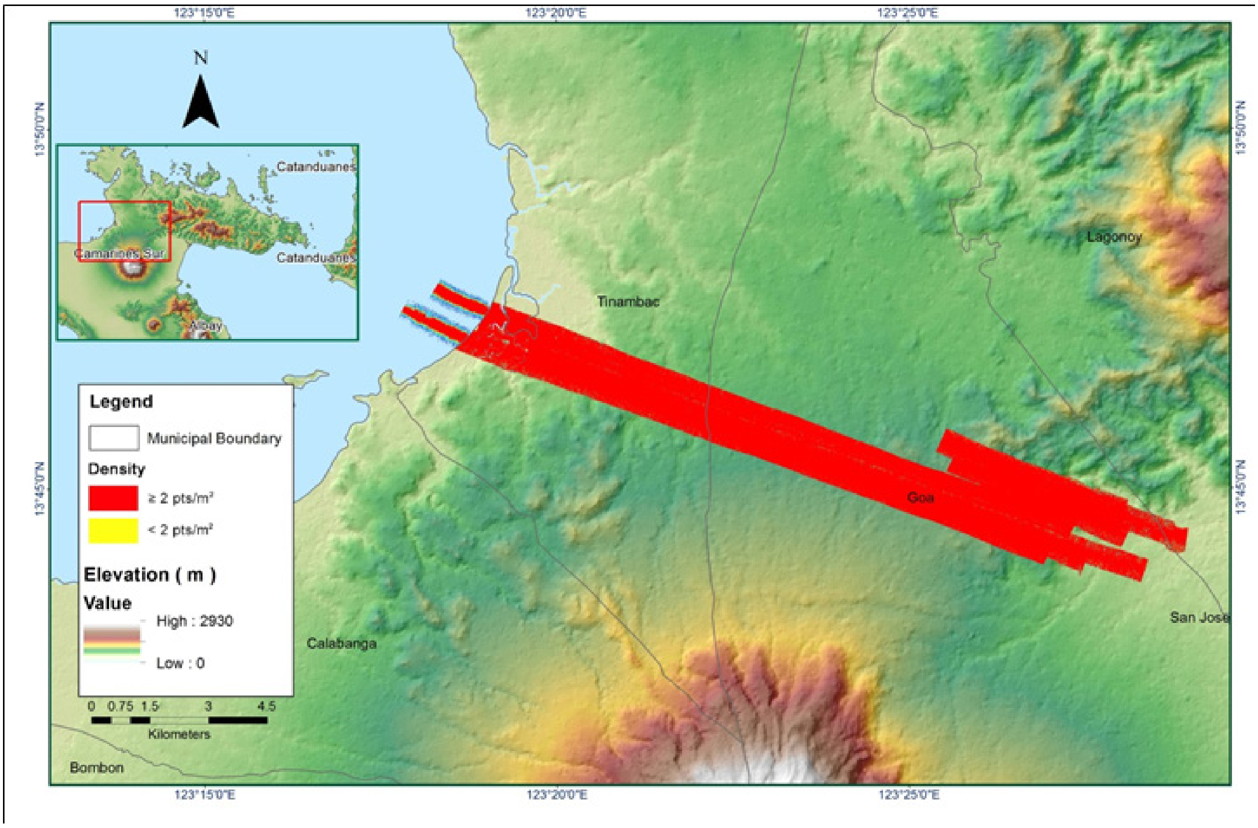


Figure A-8.13. Density map of merged LiDAR data

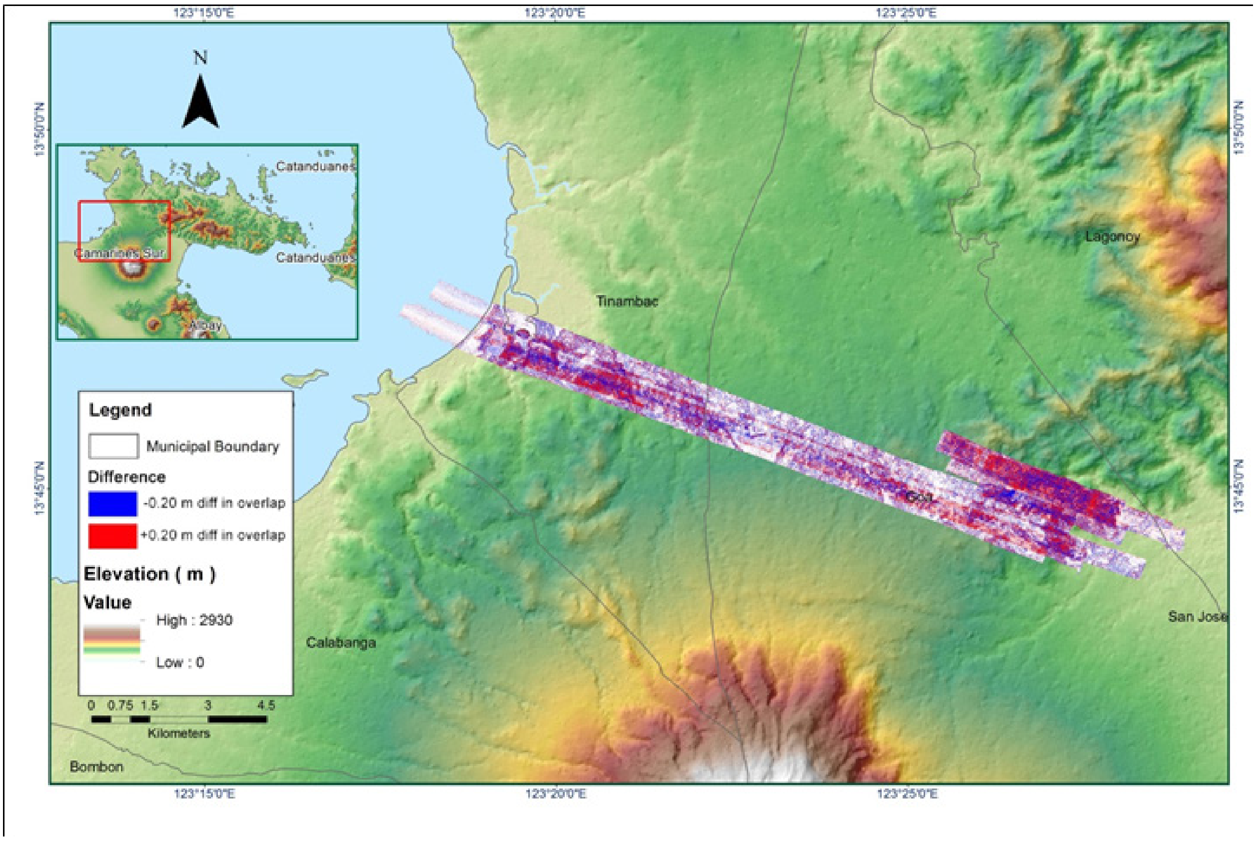


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk 24C_supplement

Flight Area	Naga
Mission Name	Blk 24C_supplement
Inclusive Flights	23314P, 23318P
Range data size	48.4 GB
POS data size	578 MB
Base data size	211 MB
Image	NA
Transfer date	June 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.215
RMSE for East Position (<4.0 cm)	1.810
RMSE for Down Position (<8.0 cm)	3.612
Boresight correction stdev (<0.001deg)	0.000223
IMU attitude correction stdev (<0.001deg)	0.000050
GPS position stdev (<0.01m)	0.0342
Minimum % overlap (>25)	32.04%
Ave point cloud density per sq.m. (>2.0)	4.28
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	162
Maximum Height	485.06
Minimum Height	43.61
Classification (# of points)	
Ground	134,081,704
Low vegetation	95,689,556
Medium vegetation	176,957,262
High vegetation	382,970,765
Building	8,622,938
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Sheila-Maye Santillan, Engr. Chelou Prado, Engr. Monalyne Rabino

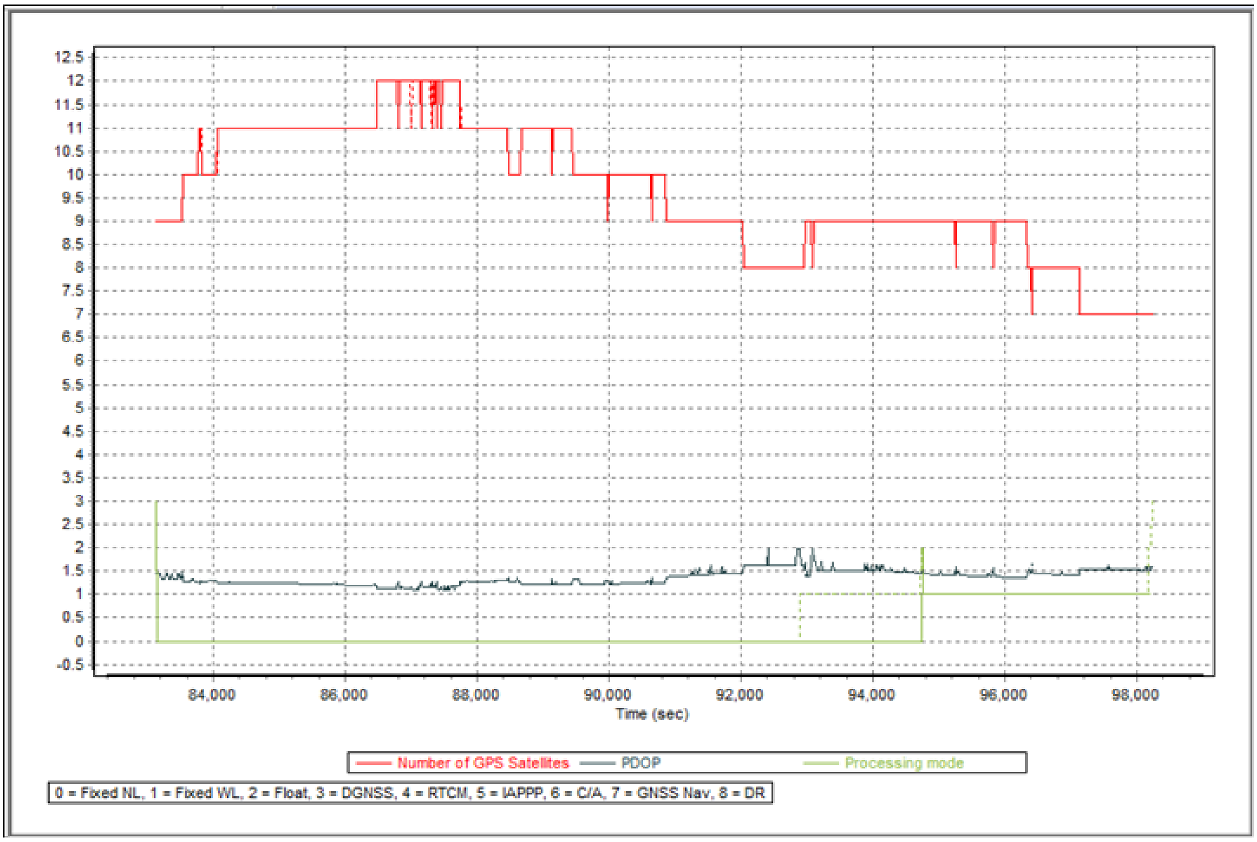


Figure A-8.15. Solution Status

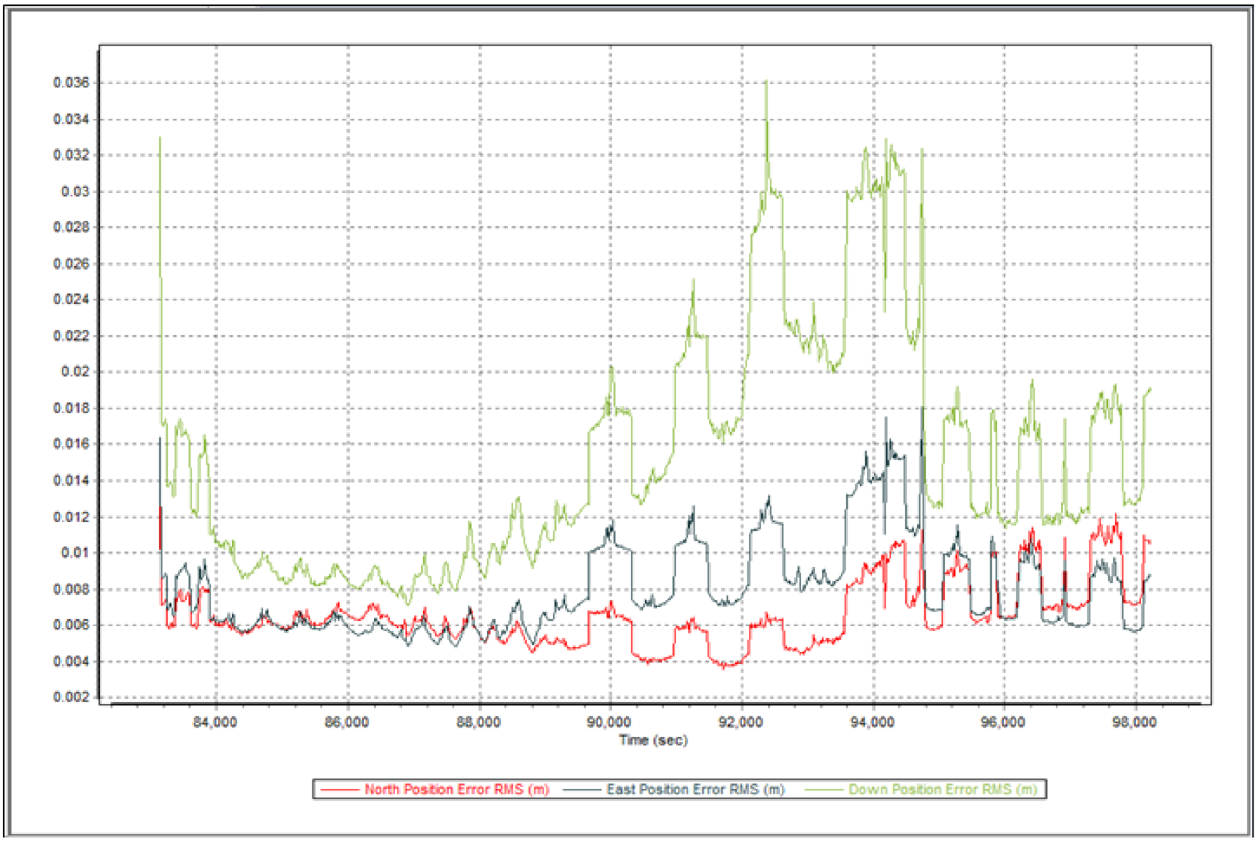


Figure A-8.16. Smoothed Performance Metric Parameters

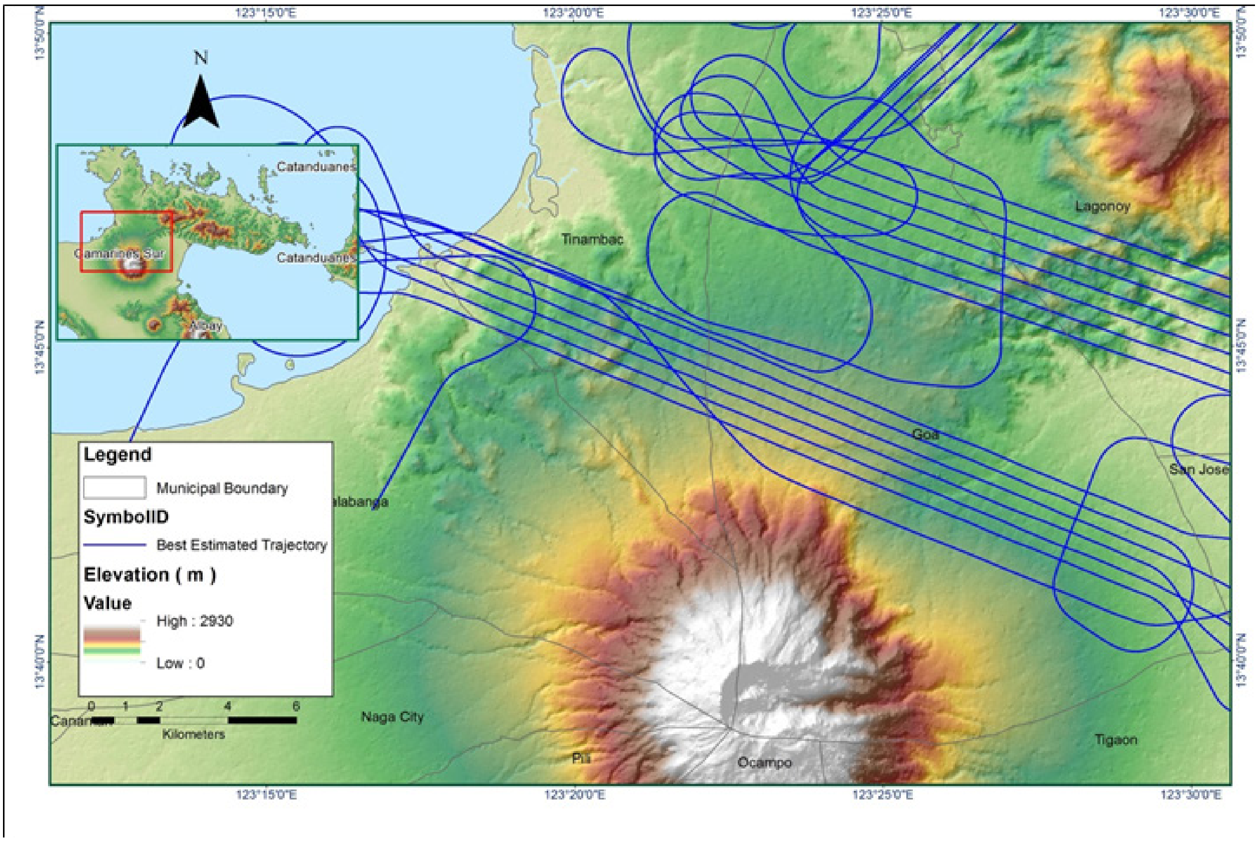


Figure A-8.17. Best Estimated Trajectory

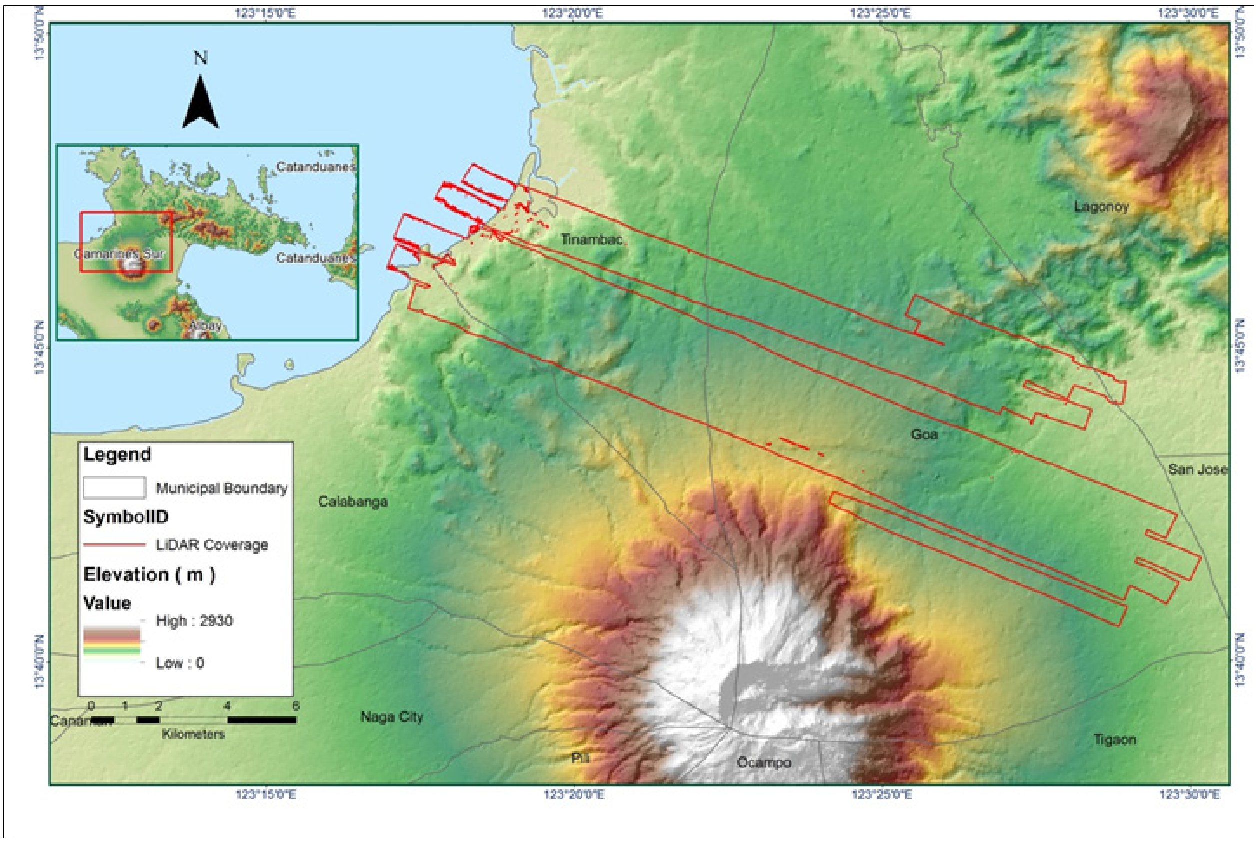


Figure A-8.18. Coverage of LiDAR data

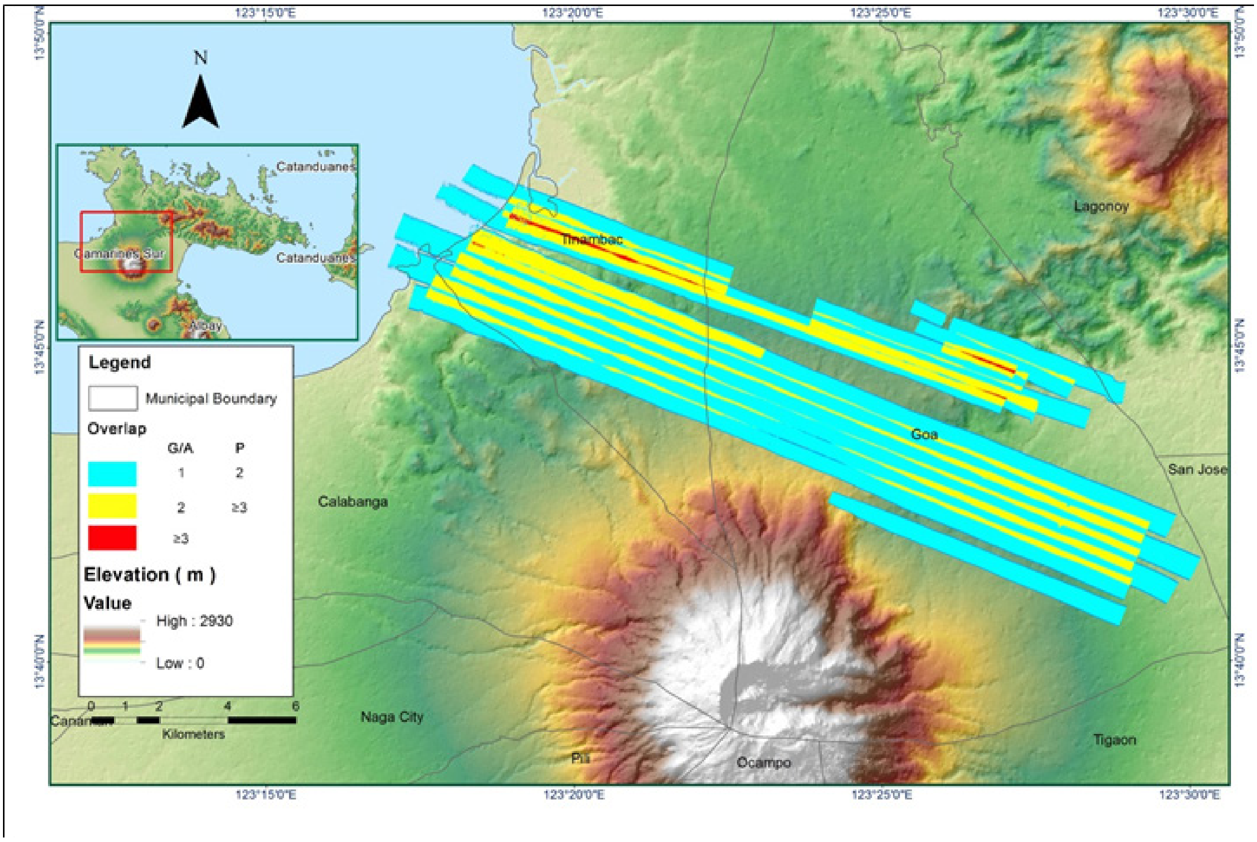


Figure A-8.19. Image of Data Overlap

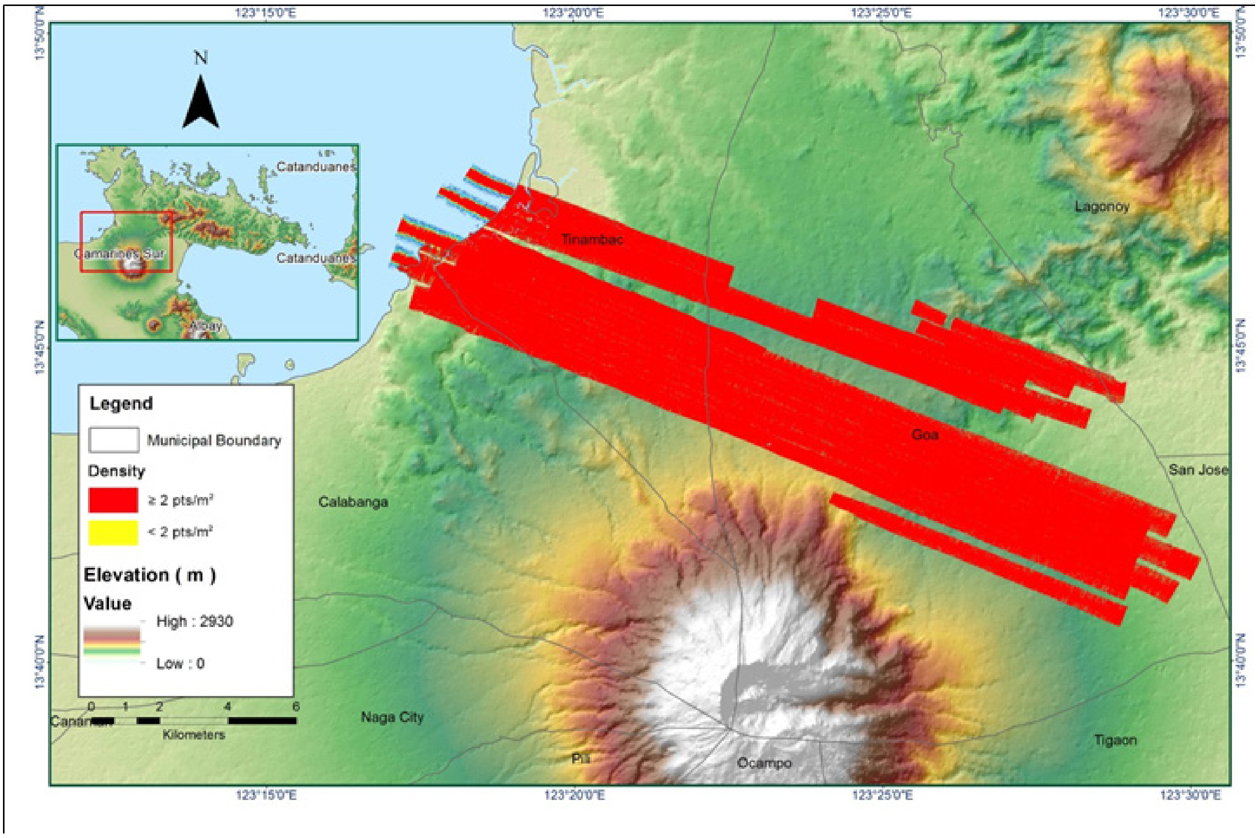


Figure A-8.20. Density map of merged LiDAR data

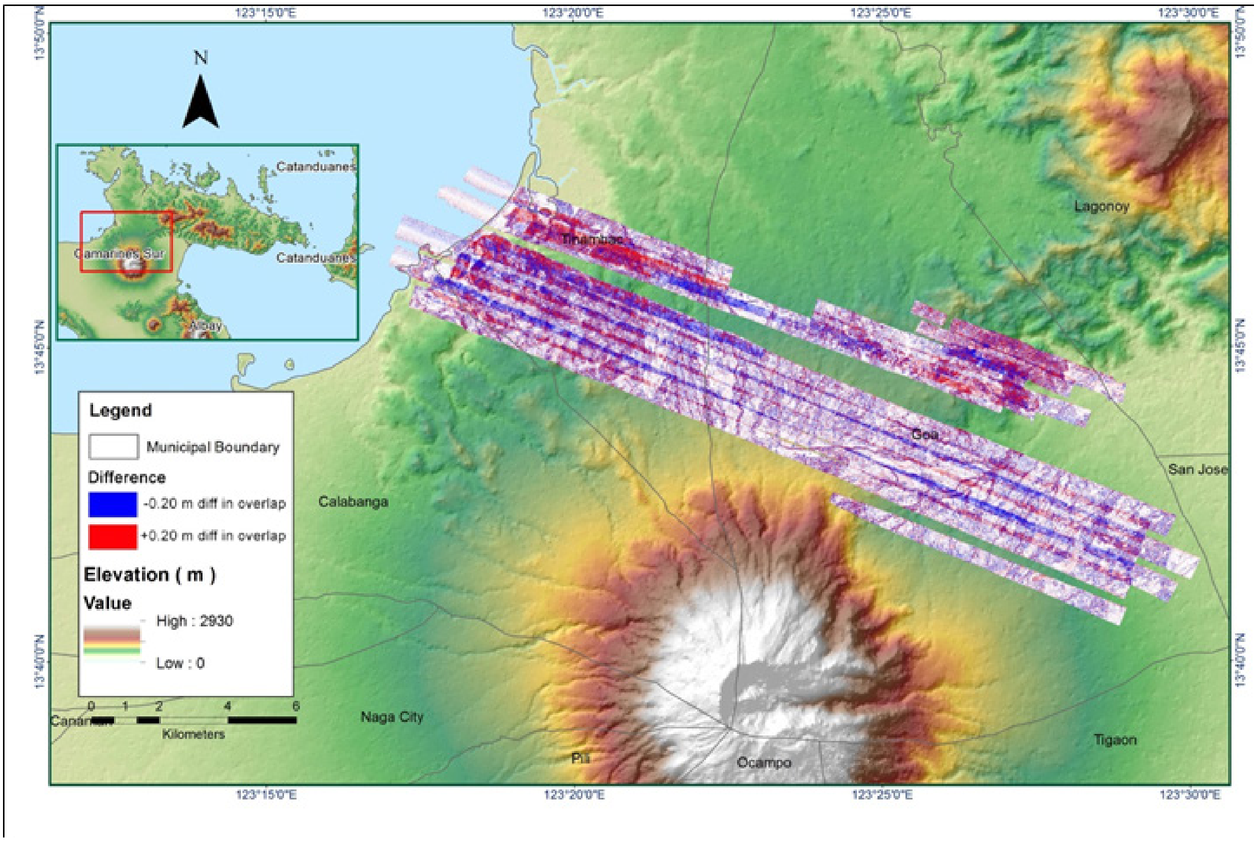


Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk 24B

Flight Area	Naga
Mission Name	Blk 24B
Inclusive Flights	23302P, 23314P
Range data size	58.4 GB
POS data size	610 MB
Base data size	223 MB
Image	NA
Transfer date	June 10, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.215
RMSE for East Position (<4.0 cm)	1.810
RMSE for Down Position (<8.0 cm)	3.612
Boresight correction stdev (<0.001deg)	0.000234
IMU attitude correction stdev (<0.001deg)	0.000636
GPS position stdev (<0.01m)	0.0009
Minimum % overlap (>25)	54.76%
Ave point cloud density per sq.m. (>2.0)	5.26
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	193
Maximum Height	462.86 m
Minimum Height	43.04 m
Classification (# of points)	
Ground	169,125,200
Low vegetation	105,053,759
Medium vegetation	274,933,209
High vegetation	847,762,055
Building	15,907,842
Orthophoto	No
Processed by	Engr. Don Matthew Banatin, Engr. Sheila-Maye Santillan, Engr. Edgardo Gubatanga, Jr., Maria Tamsyn Malabanan

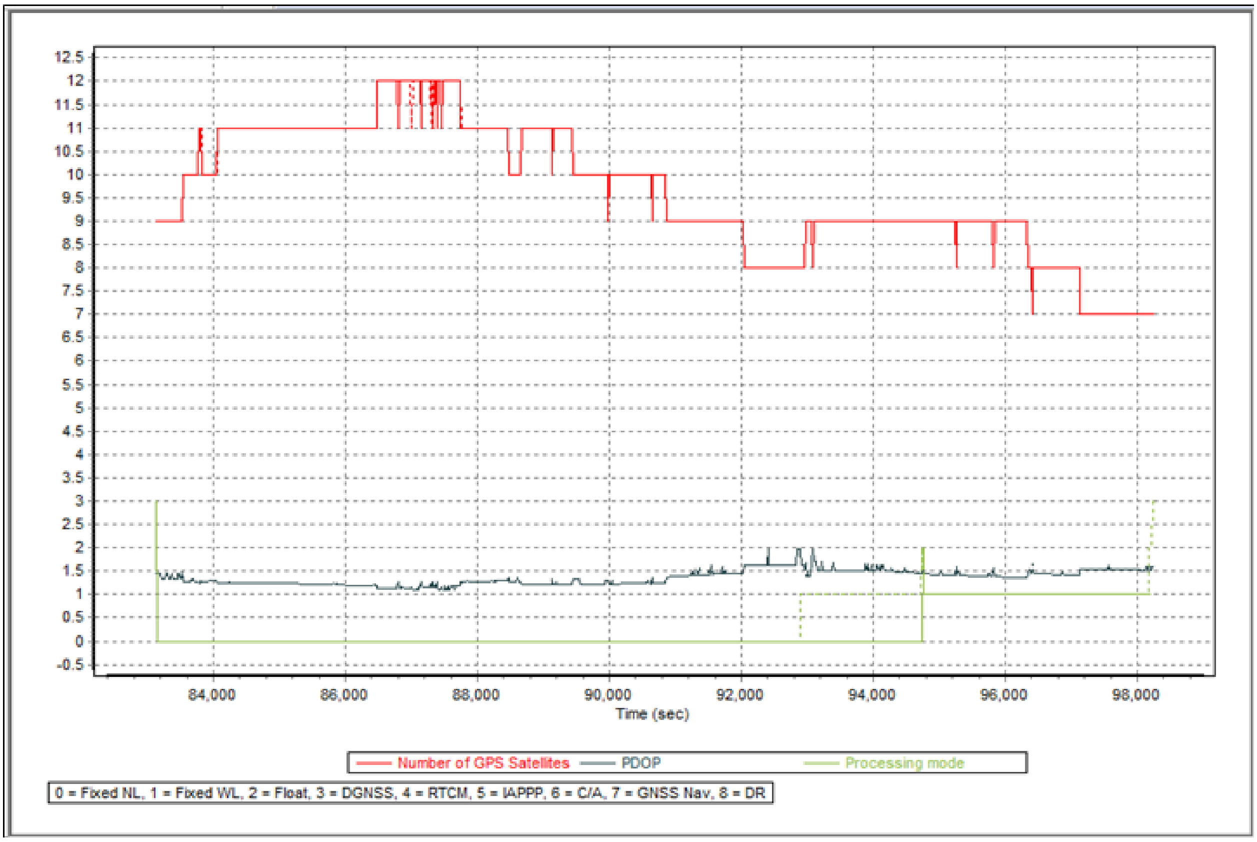


Figure A-8.22 Solution Status

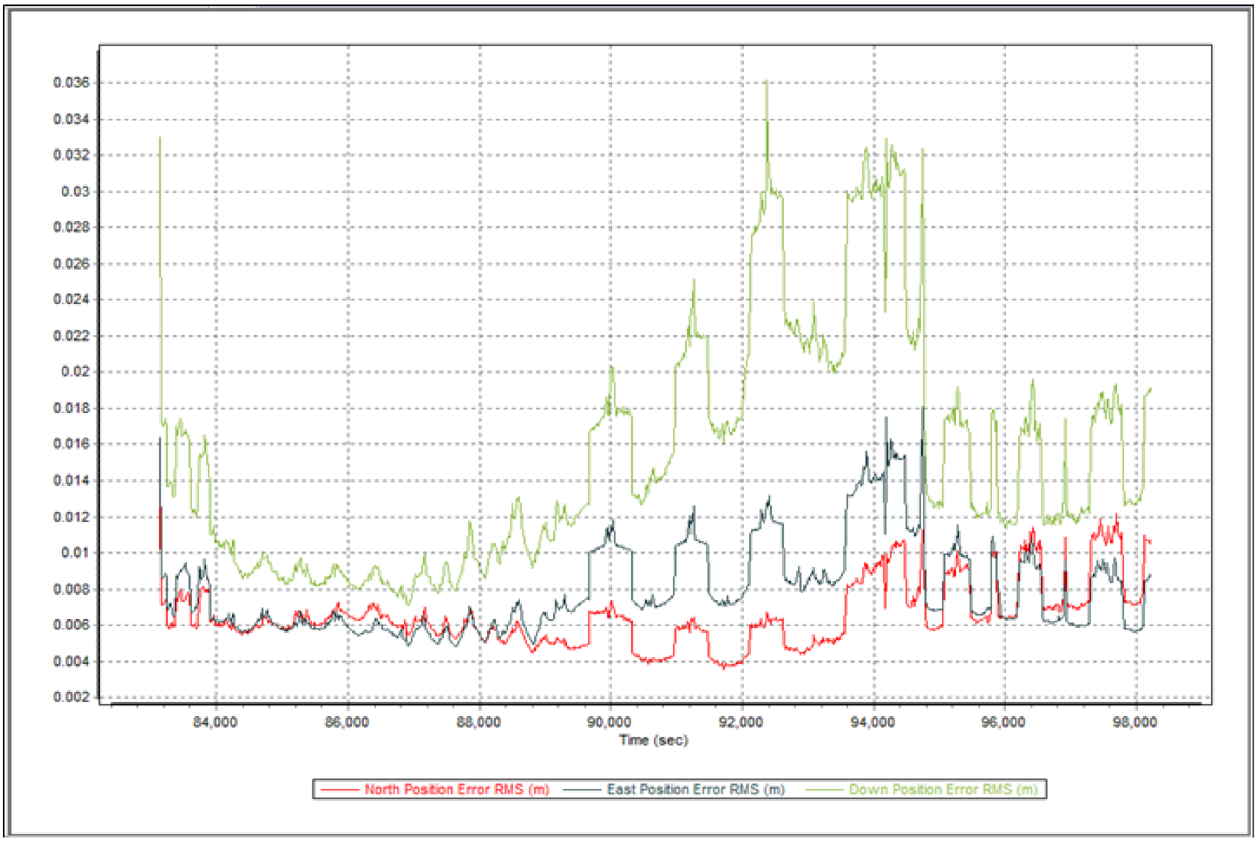


Figure A-8.23 Smoothed Performance Metric Parameters

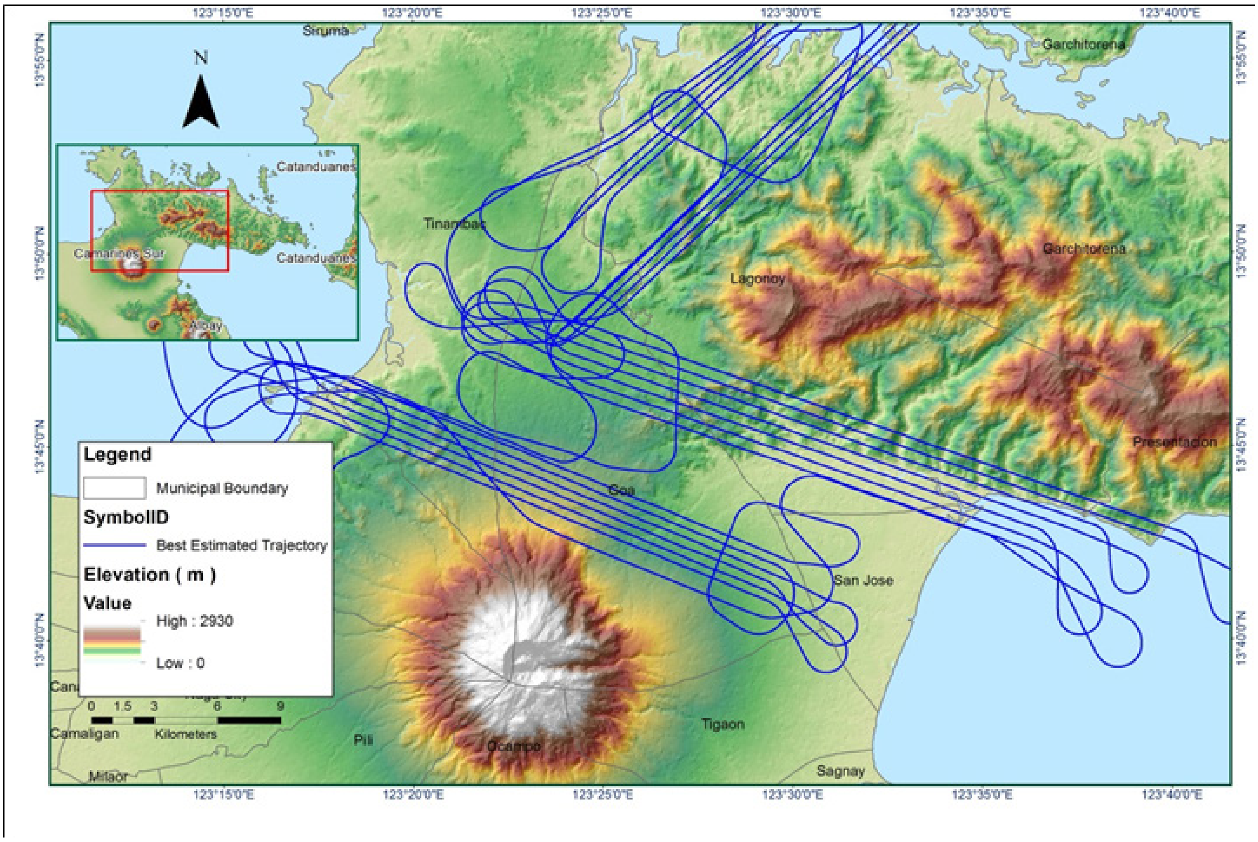


Figure A-8.24 Best Estimated Trajectory

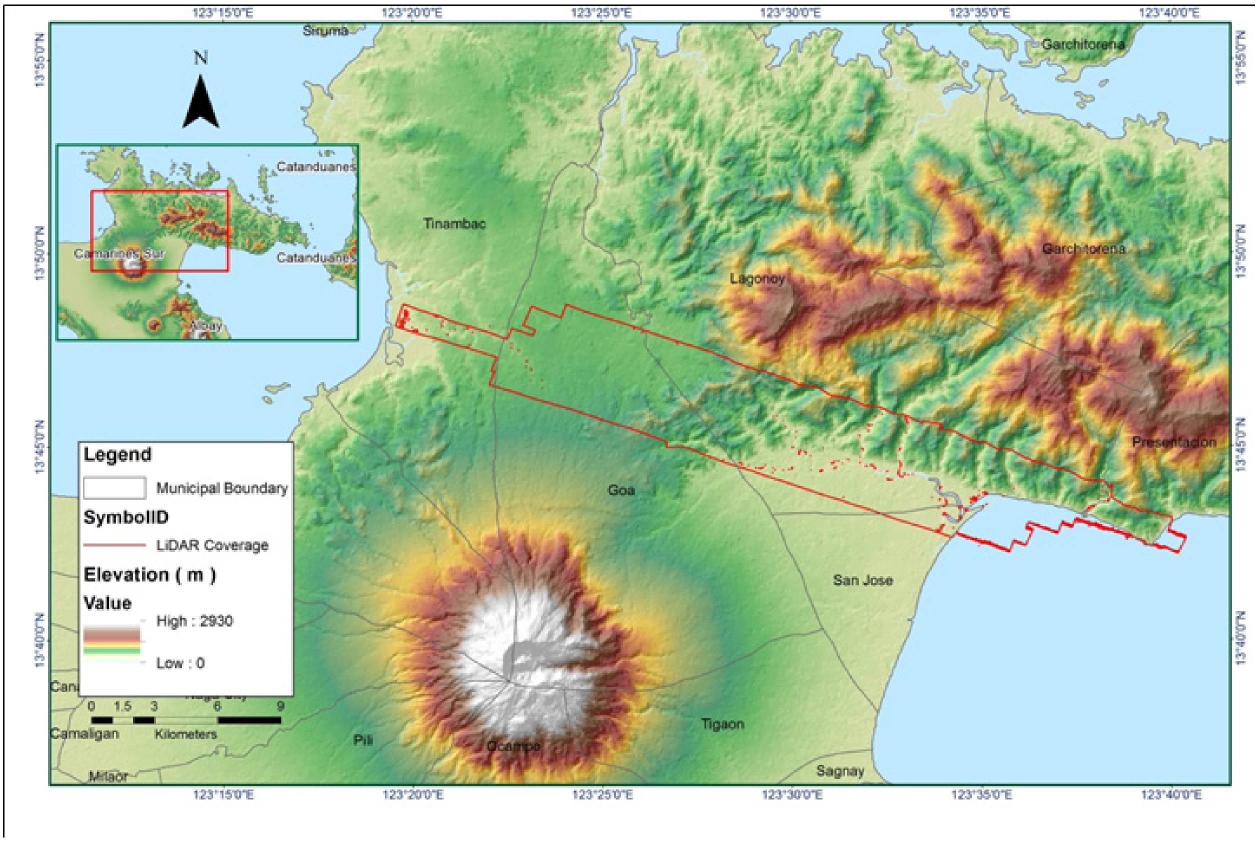


Figure A-8.25 Coverage of LiDAR data

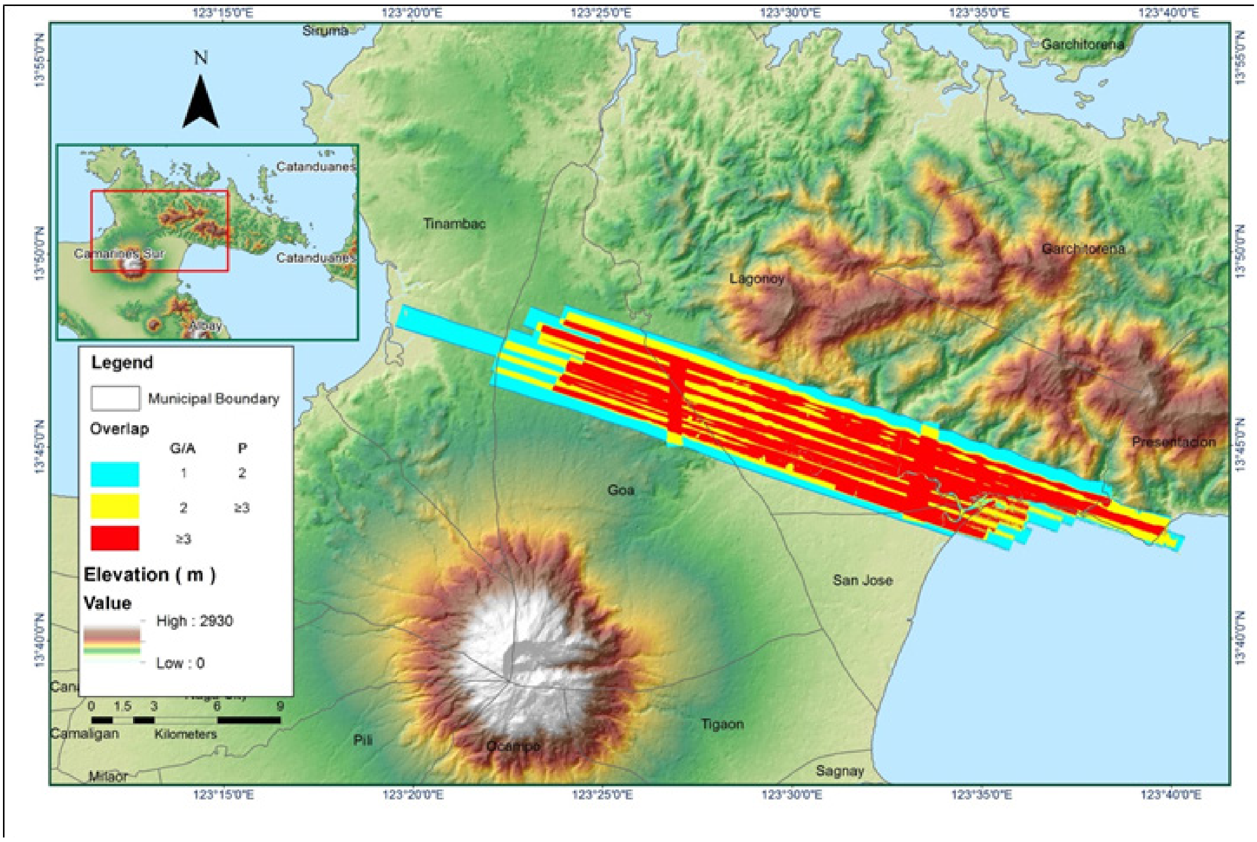


Figure A-8.26 Image of Data Overlap

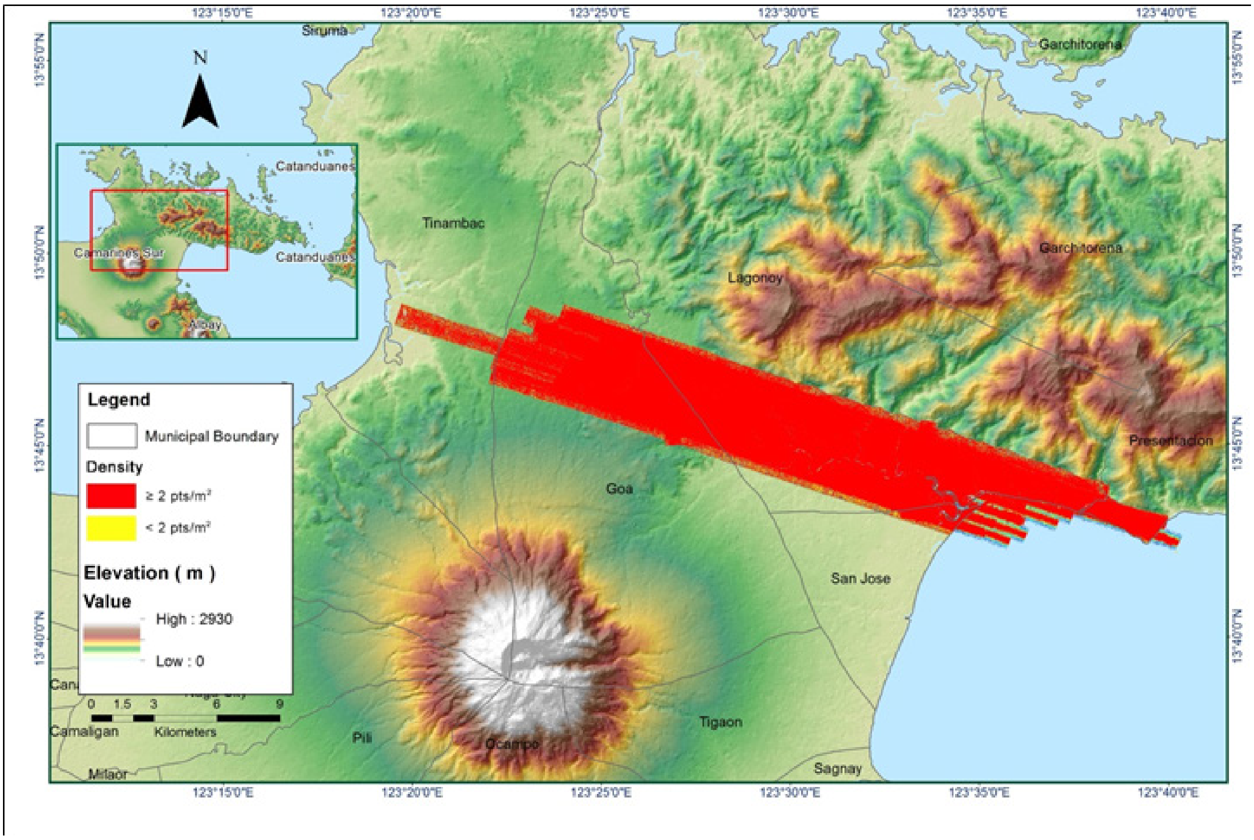


Figure A-8.27 Density map of merged LiDAR data

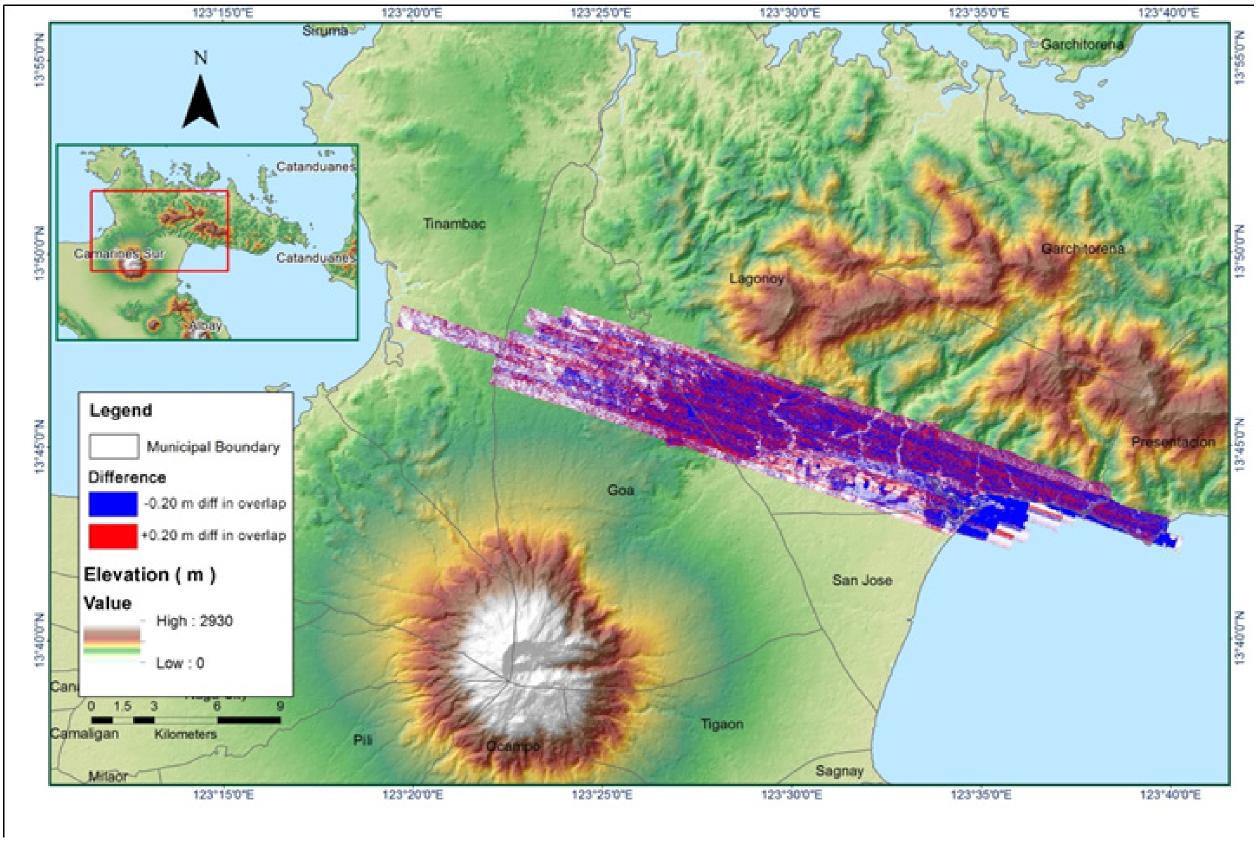


Figure A-8.28 Elevation difference between flight lines

Annex 9. Lagonoy 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 (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W200	5.424	48.848	0	0.017	0.05956	Discharge	6.8234	0.00001	Ratio to Peak	0.01807
W210	0.191	99.000	0	0.017	0.06925	Discharge	4.0551	0.00001	Ratio to Peak	0.01495
W220	1.496	64.812	0	0.017	0.08323	Discharge	8.1136	0.00001	Ratio to Peak	0.01996
W230	25.571	54.405	0	0.167	0.07488	Discharge	3.2604	0.00001	Ratio to Peak	0.01565
W240	70.774	99.000	0	0.143	0.08055	Discharge	7.2300	0.00001	Ratio to Peak	0.61996
W250	0.001	96.732	0	0.017	0.08102	Discharge	0.6556	0.00001	Ratio to Peak	0.01691
W260	5.080	98.592	0	0.126	0.13558	Discharge	3.5696	0.00001	Ratio to Peak	0.86128
W270	29.179	97.951	0	0.165	0.07983	Discharge	8.0066	0.00001	Ratio to Peak	0.01843
W280	0.001	99.000	0	0.146	0.01667	Discharge	0.0354	0.00001	Ratio to Peak	0.01714
W290	18.538	99.000	0	0.146	0.01667	Discharge	1.2011	0.00001	Ratio to Peak	0.09082
W300	0.021	99.000	0	0.147	0.01667	Discharge	2.9413	0.00001	Ratio to Peak	0.01987
W310	0.002	96.172	0	0.017	0.01667	Discharge	0.4409	0.00001	Ratio to Peak	0.01852
W320	6.283	98.919	0	0.017	0.08214	Discharge	9.0656	0.00001	Ratio to Peak	0.10634
W330	0.004	74.009	0	0.155	0.08321	Discharge	4.7673	0.00001	Ratio to Peak	0.02671
W340	0.291	96.584	0	0.149	0.01667	Discharge	4.3385	0.00001	Ratio to Peak	0.06106
W350	0.327	99.000	0	0.017	11.10300	Discharge	0.5448	0.00005	Ratio to Peak	0.54735
W360	0.614	73.116	0	0.165	0.01667	Discharge	1.0866	0.00001	Ratio to Peak	0.02294
W370	2.252	99.000	0	0.017	0.05956	Discharge	4.4956	0.00001	Ratio to Peak	0.50855
W380	0.007	99.000	0	0.017	0.06925	Discharge	4.1685	0.00014	Ratio to Peak	0.24581

Annex 10. Lagonoy Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing							
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope	
1	R50	Automatic Fixed Interval	311.7	0.00293	0.99238	Trapezoid	66.295	1
2	R70	Automatic Fixed Interval	3276.9	0.00293	1.00000	Trapezoid	66.295	1
3	R80	Automatic Fixed Interval	2615.0	0.00065	0.56536	Trapezoid	66.295	1
4	R90	Automatic Fixed Interval	1022.7	0.01012	1.00000	Trapezoid	66.295	1
5	R110	Automatic Fixed Interval	3064.7	0.00141	1.00000	Trapezoid	66.295	1
6	R120	Automatic Fixed Interval	6708.0	0.00514	0.17633	Trapezoid	66.295	1
7	R130	Automatic Fixed Interval	2298.8	0.00160	1.00000	Trapezoid	66.295	1
8	R140	Automatic Fixed Interval	1332.5	0.00160	0.99406	Trapezoid	66.295	1
9	R160	Automatic Fixed Interval	8092.4	0.01613	1.00000	Trapezoid	66.295	1

Annex 11. Lagonoy Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	13.72839167	123.5494617	0.59	0	0.59		5-Year
2	13.728395	123.549525	0.76	0	0.76		5-Year
3	13.72837167	123.549625	0.89	0	0.89		5-Year
4	13.72837833	123.54978	0.93	0	0.93		5-Year
5	13.73743833	123.5159417	1.52	0	1.52		5-Year
6	13.73743667	123.5161117	1.41	0	1.41		5-Year
7	13.73735333	123.51583	1.71	0.2	1.51	STY Reming 2006	5-Year
8	13.73758167	123.5177567	1.64	0	1.64		5-Year
9	13.72742833	123.5201967	0.07	0	0.07		5-Year
10	13.73515	123.52227	0.03	0	0.03		5-Year
0	13.72715833	123.5502417	0.34	0	0.34		5-Year
0	13.72725667	123.550245	0.57	0	0.57		5-Year
0	13.72724	123.55021	0.48	0	0.48		5-Year
0	13.72730667	123.550045	0.28	0	0.28		5-Year
0	13.72739	123.5506433	1.06	0.25	0.81	STY Reming 2006	5-Year
0	13.72853167	123.550435	1.05	0	1.05		5-Year
0	13.72915167	123.55038	0.96	0	0.96		5-Year
0	13.72935167	123.5501	1.12	0	1.12		5-Year
0	13.72931833	123.5498617	0.9	0	0.9		5-Year
0	13.7292	123.5493783	0.74	0	0.74		5-Year
0	13.728905	123.5493367	0.51	0	0.51		5-Year
0	13.728605	123.5493017	0.45	0	0.45		5-Year
0	13.72845167	123.54919	0.44	0	0.44		5-Year
0	13.72850167	123.5489517	0.45	0	0.45		5-Year
0	13.72841667	123.5498317	0.93	0	0.93		5-Year
0	13.72921667	123.548675	1.73	0	1.73		5-Year
0	13.7282	123.54842	0.89	0	0.89		5-Year
0	13.72788667	123.548335	0.24	0	0.24		5-Year
0	13.72757	123.5482717	0.03	0	0.03		5-Year
0	13.72666667	123.5481383	0.05	0	0.05		5-Year
0	13.72713	123.547935	0.03	0	0.03		5-Year
0	13.72659	123.546675	0.03	0	0.03		5-Year
0	13.72600833	123.54546	0.03	0	0.03		5-Year
0	13.725825	123.544875	0.03	0	0.03		5-Year
0	13.725635	123.54283	0.03	0	0.03		5-Year
0	13.72521667	123.5414633	0.03	0	0.03		5-Year
0	13.72593667	123.5406933	0.05	0	0.05		5-Year
0	13.72864333	123.5410567	1.03	0	1.03		5-Year
0	13.73080333	123.54435	2.75	1.17	1.58	STY Rosing	5-Year
0	13.73080333	123.54435	2.75	1.2	1.55	STY Rosing	5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
0	13.73062167	123.54355	1.72	0.8	0.92	STY Rosing	5-Year
0	13.72417333	123.5398367	0.03	0	0.03		5-Year
0	13.72404333	123.53887	0.04	0	0.04		5-Year
0	13.72409833	123.536535	0.05	0	0.05		5-Year
0	13.72441167	123.5341683	0.03	0	0.03		5-Year
0	13.72494	123.53163	0.12	0.4	-0.28	STY Rosing	5-Year
0	13.72597833	123.527	0.03	0	0.03		5-Year
0	13.72640333	123.5250133	0.12	0.7	-0.58	STY Rosing	5-Year
0	13.7266	123.5240367	0.12	0	0.12		5-Year
0	13.72664167	123.5238167	0.07	0	0.07		5-Year
0	13.726715	123.523495	0.12	0	0.12		5-Year
0	13.726825	123.522955	0.07	0	0.07		5-Year
0	13.72574333	123.5201067	0.1	0	0.1		5-Year
0	13.72455333	123.5200333	0.17	0	0.17		5-Year
0	13.7297	123.4940783	0.1	0.1	0	STY Reming 2006	5-Year
0	13.73003	123.494185	0.36	0.5	-0.14	STY Reming 2006	5-Year
0	13.730315	123.4948717	0.18	0.1	0.08	STY Reming 2006	5-Year
0	13.73101333	123.4967017	0.14	0	0.14		5-Year
0	13.73144333	123.4976517	0.19	0	0.19		5-Year
0	13.73230833	123.499685	0.08	0	0.08		5-Year
0	13.73358667	123.5024	0.19	0	0.19		5-Year
0	13.73375833	123.5027967	0.48	0	0.48		5-Year
0	13.73387167	123.503005	0.54	0.3	0.24	STY Reming 2006	5-Year
0	13.73433833	123.5039517	1.52	0	1.52		5-Year
0	13.73475667	123.50527	1.63	0	1.63		5-Year
0	13.73508667	123.5061817	1.57	0	1.57		5-Year
0	13.735255	123.5067033	1.82	0	1.82		5-Year
0	13.73473833	123.5071783	1.34	0	1.34		5-Year
0	13.734	123.5072317	1.27	0	1.27		5-Year
0	13.73343833	123.5071683	0.79	0	0.79		5-Year
0	13.733245	123.50718	0.58	0	0.58		5-Year
0	13.73240667	123.5071567	0.19	0	0.19		5-Year
0	13.73151167	123.50705	0.56	0	0.56		5-Year
0	13.731145	123.5069983	0.28	0	0.28		5-Year
0	13.73555333	123.5072583	1.98	0	1.98		5-Year
0	13.73584833	123.5084367	1.72	0	1.72		5-Year
0	13.73619833	123.5095133	1.93	0	1.93		5-Year
0	13.73756667	123.517355	1.35	0	1.35		5-Year
0	13.72742	123.5200467	0.15	0	0.15		5-Year
0	13.72754333	123.5195533	0.14	0	0.14		5-Year
0	13.7284	123.51931	0.03	0	0.03		5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
0	13.73174667	123.5196117	0.36	0	0.36		5-Year
0	13.73172167	123.5206733	0.07	0	0.07		5-Year
0	13.731705	123.5214017	0.06	0	0.06		5-Year
0	13.731685	123.5222067	0.05	0	0.05		5-Year
0	13.73277333	123.5233783	0.12	0	0.12		5-Year
0	13.73308667	123.5233683	0.1	0	0.1		5-Year
0	13.73317167	123.5231917	0.06	0	0.06		5-Year
0	13.73324167	123.5217667	0.06	0	0.06		5-Year
0	13.73327	123.52086	0.04	0	0.04		5-Year
0	13.733305	123.5203467	0.06	0	0.06		5-Year
0	13.734595	123.5196	0.36	0	0.36		5-Year
0	13.73514667	123.5197633	0.13	0	0.13		5-Year
0	13.73498167	123.5203617	0.03	0	0.03		5-Year
0	13.72729833	123.5204983	0.03	0	0.03		5-Year
0	13.72831167	123.52095	0.23	0	0.23		5-Year
0	13.72970333	123.5210283	0.06	0	0.06		5-Year
0	13.730145	123.5210467	0.06	0	0.06		5-Year
0	13.73128667	123.5210583	0.04	0	0.04		5-Year
0	13.73634333	123.5218983	0.45	0	0.45		5-Year
0	13.73630333	123.522315	0.67	0	0.67		5-Year
0	13.736165	123.5234483	0.94	0	0.94		5-Year
0	13.73629167	123.523435	1.04	0	1.04		5-Year
0	13.735655	123.523455	0.65	0	0.65		5-Year
0	13.73529	123.52343	0.27	0	0.27		5-Year
0	13.7373133	123.5219099	0.86	0.3	0.56	STY Nina 2016	5-Year
0	13.73724161	123.5220564	1.46	0	1.46		5-Year
0	13.7373996	123.5220714	1.15	0.3	0.85		5-Year
0	13.73974332	123.528929	3.56	4.5	-0.94	STY Rosing	5-Year
0	13.73791818	123.5268149	3.46	2.4	1.06	STY Rosing	5-Year
0	13.73782489	123.5272944	3.44	3.5	-0.06	TY Loleng	5-Year
0	13.73720816	123.5260833	3.13	0	3.13		5-Year
0	13.73715647	123.5262084	3.74	0	3.74		5-Year
0	13.74103361	123.5281933	3.56	0.8	2.76	TY Loleng	5-Year
0	13.73898743	123.5265841	2.95	2.4	0.55	TY Loleng	5-Year
0	13.73847582	123.5262202	3.6	1.2	2.4	TY Loleng	5-Year
0	13.73877996	123.5241517	3.19	2.4	0.79	TY Loleng	5-Year
0	13.73868602	123.5230152	2.68	0	2.68		5-Year
0	13.73874379	123.522982	2.69	0	2.69		5-Year
0	13.7379722	123.5227959	2.25	12	-9.75	STY Nina 2016	5-Year
0	13.73868407	123.5219329	2.28	0	2.28		5-Year
0	13.73863305	123.5218384	2.29	0	2.29		5-Year
0	13.73870413	123.520468	2.11	0	2.11		5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
0	13.73908529	123.5204455	2.69	0	2.69		5-Year
0	13.73964781	123.5205143	3.33	0.3	3.03	STY Nina 2016	5-Year
0	13.74022349	123.5205834	3.46	3.9	-0.44	STY Rosing	5-Year
0	13.74027741	123.5205332	3.32	3.9	-0.58	STY Rosing	5-Year
0	13.74039379	123.5205331	4.5	3.9	0.6	STY Rosing	5-Year
0	13.74041501	123.5205587	4.5	3.9	0.6	STY Rosing	5-Year
0	13.74050298	123.5205454	5.68	3.9	1.78		5-Year
0	13.74094199	123.520511	5.42	2.9	2.52	STY Rosing	5-Year
0	13.74053003	123.5201891	5.58	4.5	1.08	STY Rosing, TY Loleng	5-Year
0	13.74052121	123.5199607	5.65	6.7	-1.05	STY Rosing	5-Year
0	13.73878307	123.5197724	2.77	2.5	0.27	STY Rosing	5-Year
0	13.73879412	123.5197868	2.77	2.5	0.27	STY Rosing	5-Year
0	13.74023649	123.5198726	2.57	0	2.57		5-Year
0	13.73942569	123.519798	2.9	0	2.9		5-Year
0	13.73835592	123.5196828	2.76	0	2.76		5-Year
0	13.7386116	123.5199631	2.4	0	2.4		5-Year
0	13.7377157	123.5196384	1.75	0	1.75		5-Year
0	13.73754672	123.519662	1.59	0	1.59		5-Year
0	13.73749849	123.5196381	1.52	0	1.52		5-Year
0	13.73696646	123.5196422	0.81	0	0.81		5-Year
0	13.73637713	123.519772	0.3	0	0.3		5-Year
0	13.73761171	123.5204842	0.8	0	0.8		5-Year
0	13.73759321	123.5205773	0.9	0	0.9		5-Year
0	13.7382001	123.5204835	1.75	0	1.75		5-Year
0	13.73829652	123.5205312	1.78	0	1.78		5-Year
0	13.73737552	123.5210905	0.44	0	0.44		5-Year
0	13.73740312	123.5215817	0.61	0	0.61		5-Year
0	13.73741362	123.5218607	0.94	0	0.94		5-Year
0	13.73752574	123.5219424	1.13	0	1.13		5-Year
0	13.73742471	123.5227131	1.88	0	1.88		5-Year
0	13.73733661	123.5233481	2.01	0	2.01		5-Year
0	13.73710963	123.5234703	1.81	0	1.81		5-Year

Annex 12. Educational Institutions Affected by flooding in Lagonoy Floodplain

Camarines Sur				
Goa				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Goa science highschool	Belen			
st. paul academy 7bldgs.	Belen			
juan l. filipino national high school	Buyo	Low	Medium	Medium
cagaycay elem school	Cagaycay			Low
day care center gimaga	Gimaga			
gimaga elem school	Gimaga			
halawig-gogon elem school	Halawig-Gogon			
taytay highschool	Halawig-Gogon		Low	Low
Goa science highschool	La Purisima			
Sports Center/Gymnasium/Covered Court	La Purisima			
matacla elem. school	Matacla			
maymatan elem school	Maymatan			
napawon day care center	Napawon			
napawon elem school	Napawon			
bicol for Christ mission academy	Panday			
WRI colleges	Panday			
salog elem school	Salog			
visita de salog hs	Salog	Low	Low	Medium
Fatima school of school and tech inc	San Isidro			
arborvitae plains Montessori inc	San Jose			
Fatima school of school and tech inc	San Jose			
goa central school	San Juan Bautista		Low	Low
bagumbayan grande day care	San Juan Evangelista	Medium	High	High
belen day care center	Tagongtong			
montesori children's learning center	Tagongtong			
partido state university goa	Tagongtong	Low	Low	Low
philippine science high school	Tagongtong			
tagongtong elementary school	Tagongtong			

Camarines Sur				
Lagonoy				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
agosais elem school	Agosais	Low	High	High
arborvitae plains Montessori inc	Agpo-Camagong-Tabog			Low
glorious Adonai learning academy	Agpo-Camagong-Tabog	Low	Low	Low
little lamb child dev center	Agpo-Camagong-Tabog			
San Rafael daycare cntr	Agpo-Camagong-Tabog	Low	Low	Low
partido state university/kalahi bldg.	Binanuahan	High	High	High
burabod elem school	Burabod	Medium	High	High
daycare burabod	Burabod			
dahat elem school	Dahat	Low	High	High
dahat highschool	Dahat	Low	Low	Medium
gimagtocon elem school	Gimagtocon			
gubat community school	Gimagtocon			
seventh day adventist multigrade school	Gimagtocon	Medium	Medium	High
bgy binanuahan elem. school	Loho	High	High	High
loho daycare	Loho	Medium	Medium	High
loho elem school	Loho	Medium	High	High
bgy. manamoc day care	Manamoc	Medium	Medium	Medium
manamoc elem. school	Manamoc	Low	Low	Medium
dahat highschool	San Isidro Sur			Medium
kalahi cidss	San Rafael			
San Rafael -agpo elem school	San Rafael			
San Ramon daycare NB	San Ramon			
san ramon elem. school	San Ramon		Low	Low
San Ramon pilot Nat. high school	San Ramon			Medium
amoguis day care	San Roque			
san roque elem school	San Roque			
quinayangan san sebastian day care center	San Sebastian		Low	Low
lagonoy high school	San Vicente			Medium
san isidro high school	San Vicente			Low
yellow ribbon san francisco lagonoy cam. sur	San Vicente			
lagonoy high school	Santa Maria		Low	Medium
st. mary day care center lagonoy	Santa Maria	Medium	High	High

Camarines Sur				
San Jose				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
amoguis elem school	Bahay			
taytay elem school	Bahay			
bahay elem school	Boclod	Low	Low	Low
camagong elem school	Camagong			
San Jose PSU	Del Carmen	Low	Low	Low
kinalansan elem school	Dolo	Medium	Medium	High
solo elem school	Dolo		Medium	Medium
kinalansan elem school	Kinalansan	Medium	High	High
kinalansan high school	Kinalansan	Low	Low	Medium
kinalansan high school	Minoro	Low	Low	Medium
minor community school	Minoro			
Gk day care center	Sabang			
sabang elem school	Sabang			
glorious Adonai learning school	San Antonio			
glorious Adonai learning school	San Vicente	Low	Low	Low
holy rosary preparatory seminary	San Vicente			
soledad day care center	San Vicente			
connecting point Christian academy	Santa Cruz			
San Jose nat. hs	Soledad		Low	Low
tominawog elem. school	Tominawog			

Annex 13. Health Institutions affected by flooding in Lagonoy Floodplain

Camarines Sur				
Goa				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
st. Vincent de Ferrer hospital	Bagumbayan Grande			
Thelma magsombol clinic	Bagumbayan Grande	Low	Low	Low
partido medical diagnostic center	Belen			
gogon brgy health center	Halawig-Gogon	Low	Low	Low
Goa municipal infirmary	La Purisima			
st Louise diagnostic co-operative center	La Purisima			
health center maymatan	Maymatan			
brgy health center napawon	Napawon			
Dr. Evelyn Reyes clinic	Panday			
st. Therese medical clinic	Panday			Low
San Benito health center	San Benito			
dental clinic	San Isidro			Low
generika drugstore	San Isidro			
pinoy botika generiks	San Jose	Medium	Medium	Medium
dental clinic	San Juan Bautista			
maternity & gynecologic clinic	San Juan Bautista	Low	Low	Low
partido medical diagnostic center	San Juan Bautista			
bagumbayan grande health center	San Juan Evangelista	Medium	High	High
Dr. Evelyn Reyes clinic	San Juan Evangelista			
Thelma magsombol clinic	San Juan Evangelista			
maternity clinic	Tagongtong		Low	Low
tagongtong health center	Tagongtong			

Camarines Sur				
Lagonoy				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
dental clinic	Agpo-Camagong-Tabog			
main health center	Agpo-Camagong-Tabog			
sta maria soledad health center	Dahat		Medium	High
gimagtocon health station	Gimagtocon	High	High	High
brgy gubat health center	Gubat			Low
bgy. manamoc health center	Manamoc	Low	Low	Low
sta maria soledad health center	San Isidro Sur		Low	Medium

Camarines Sur				
San Jose				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
boclod health center	Boclod	Low	Low	Medium
San Jose Medicare community hospital	Del Carmen			
kinalansan day care	Kinalansan			
bgy. palale health center..	Palale			
boclod health center	Soledad	Low	Low	Medium