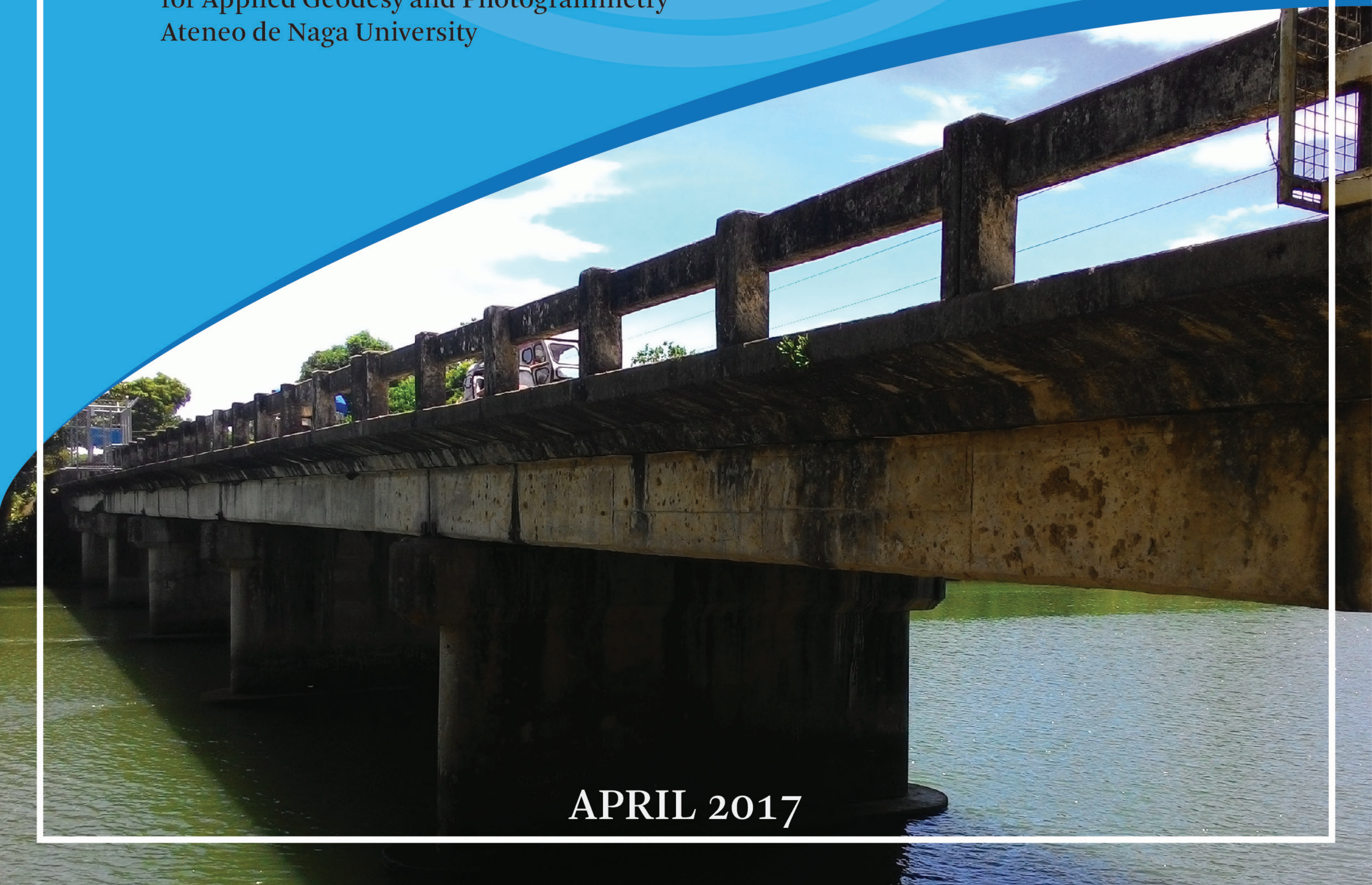
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Basud River

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



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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
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND DAET-BASUD RIVER

Enrico C. Paringit, Dr. Eng., Engr. Florentino F. Morales, Jr., and Engr. Omar P. Jayag

1.1 Background of the Phil-LIDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1 in 2014, supported by the Department of Science and Technology (DOST) Grant-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 method described 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 Basud River Basin

Basud River Basin covers nineteen (19) barangays in Municipality of Basud, and six (6) barangays in Municipality of San Lorenzo Ruiz in Camarines Norte. The DENR River Basin Control Office identified the basin to have a drainage area of 270 km2 and an estimated 365 million cubic meter (MCM) annual run-off (River Basin Control Office, 2017).

The main stream in the Basud River Basin is the Basud River with a length of 91.08 km. This area is hemmed to the south by the Bicol Natural Park and to the west by Mt. Labo, a potentially active volcano. The area of the river basin is under the jurisdiction of four (4) towns: Mercedes, Daet, Basud and San Lorenzo Ruiz. Daet is a first class municipality, Basud is third class and Mercedes and San Lorenzo Ruiz are both fifth class municipalities. The population of each municipalities are as follows: Daet has a total population of 104,799 distributed to 25 barangays as of 2015; Basud is populated with 41,017 based on the same census distributed in 29 barangays of the town; Mercedes has a total of 50,841 people in its 26 barangays while San Lorenzo Ruiz is populated with 14,063 in its 12 barangays. Meanwhile, according to the 2015 national census, a total of 28,182 persons are residing within the immediate vicinity of the river which is distributed among sixteen (16) barangays in the Municipalities of Daet, Basud and Mercedes in Camarines Norte (Philippine Statistics Authority, 2016).

This basin is drained by the Daet-Basud River that empties out to the Pacific Ocean to the east with the town of Mercedes at its floodplain. The municipalities of Basud, Mercedes and Daet are mostly agriculture and fishing based economy. Local government is encouraging the locals to production of deep-sea fishing fleets to broadened the industry up to food processing. The area is also agricultural in nature with three (3) major crops: rice, coconut and pineapple. Fisheries also thrive since there are coastal barangays in the area. Livestock and poultry production is limited to backyard farming. Other industries focus on diatomaceous earth or white clay and gravel and sand. Daet moreover is one of the most popular surfing spots I the Philippines (Geocities, 2009).

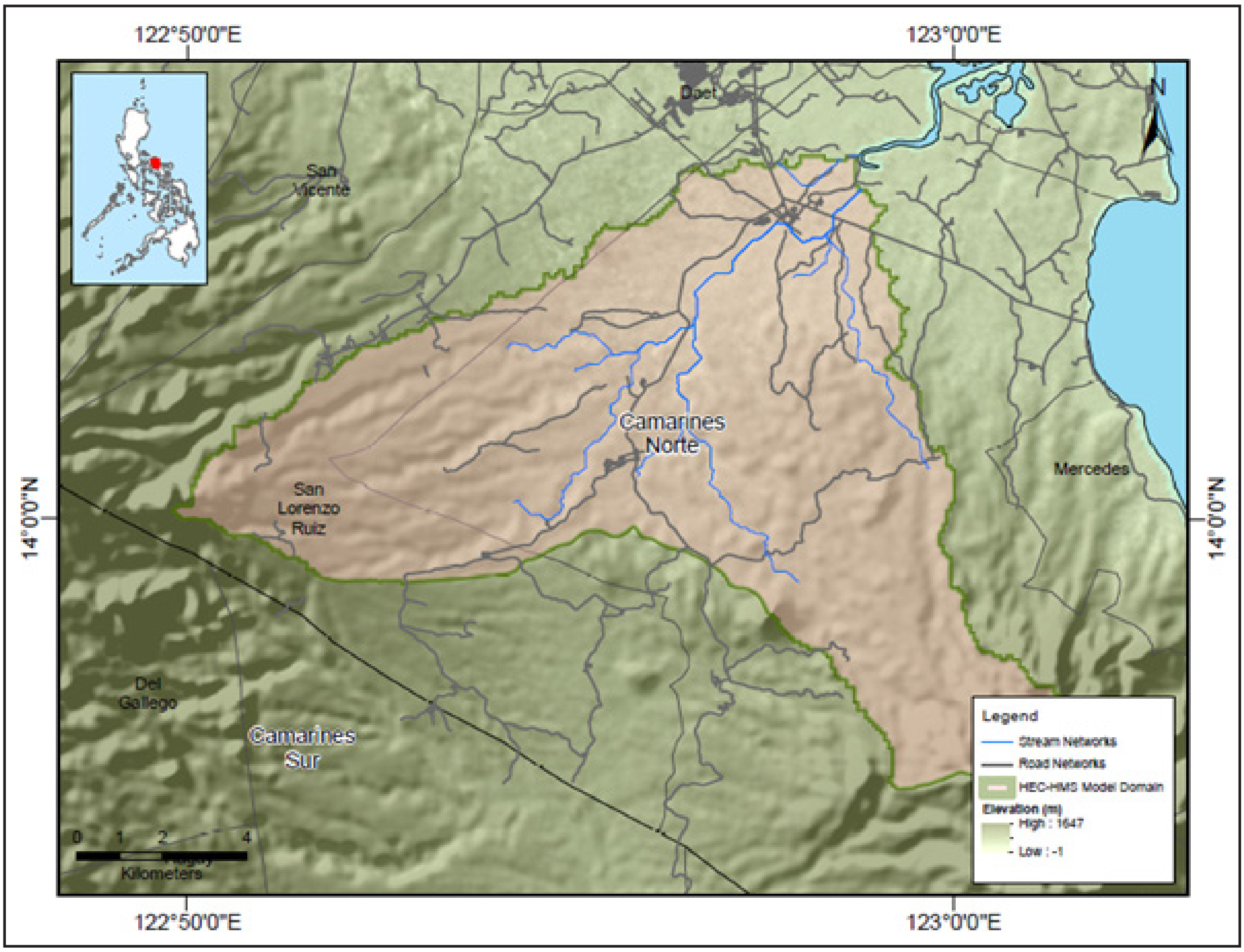

Figure 1. Location Map of the Daet-Basud River Basin (in brown)

In 1998, Typhoon Loleng devastated the town of Daet particularly its coastal area. Other typhoons that impacted Camarines Norte in general are TY Dante (Kuijira) and TY Ondoy (Ketsana) both in 2009 incurring damage in properties, livelihood and lives.

The most recent typhoon that struck the area was Typhoon Nona on December 2015. However the one that recently caused trees and electric poled to topple was Typhoon Glenda on July 2014 (Inquirer, 2014).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE DAET-BASUD FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Daet-Basud Floodplain in Camarines Norte Province. These missions were planned for 11 lines that run for at most three (3) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 1 shows the flight plan for Daet-Basud Floodplain survey.

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)
BLK 20A	1000, 600	30	50	150	30	130	5
BLK 20B	1100, 1000, 800, 600	30	50	150	30	130	5
BLK 20C	600	30	50	150	30	130	5
BLK 20D	1000, 800, 900, 700	15, 20	50	200	30	130	5
BLK 20E	800	15	50	200	30	130	5
BLK 20N	1100, 850	30	50	150	30	130	5
BLK 20S	1100	15	50	200	30	130	5

[1] The explanation of the parameters used are in the volume "LiDAR Surveys and Flood Mapping in the Philippines: Methods."

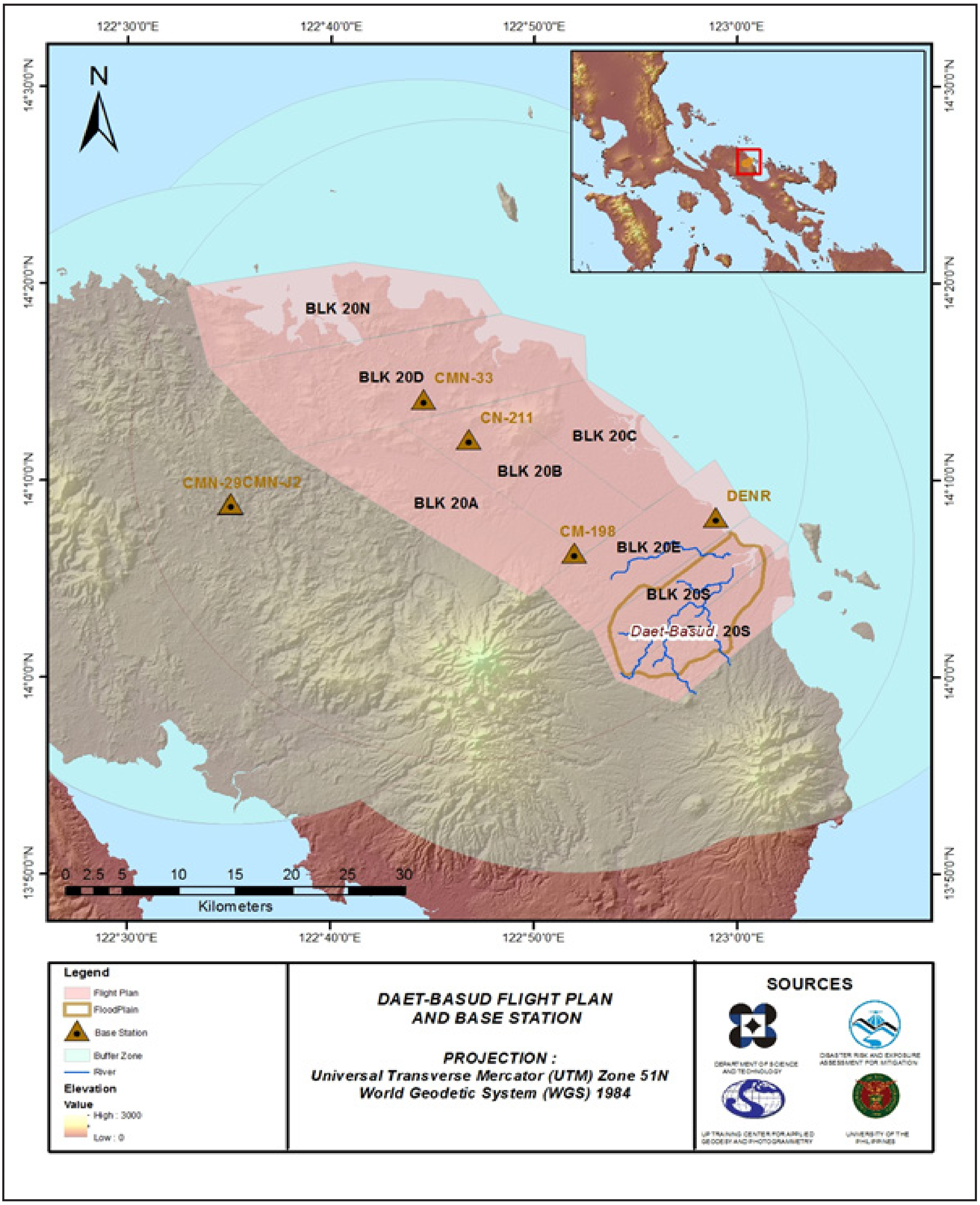
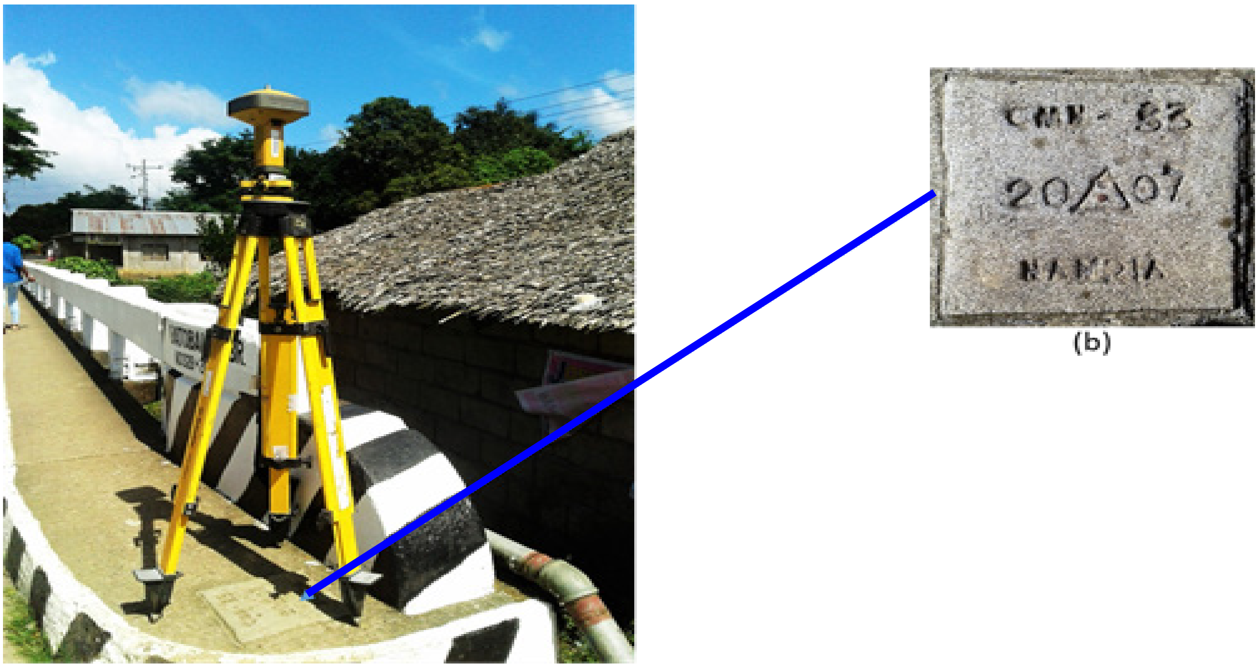


Figure 2. Flight plans and base stations for Daet-Basud floodplain.

2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA ground control points CMN-33 and CMN-29 which are of second (2nd) order accuracy. The project team established two (2) ground control point, CMN-J2 and DENR, and reprocessed two (2) benchmarks CM-198 and CN-211. The certification for the base stations are found in Annex 2 while the baseline processing report for the established ground control points and reprocessed benchmarks are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (March 9 - 17, 2016 and April 7 - 18, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 985, TRIMBLE SPS 852 and TOPCON GR-5. Flight plans and location of base stations used during aerial LiDAR acquisition in Daet-Basud floodplain are shown in Figure 2.

Figure 3 to Figure 6 show the recovered NAMRIA reference points and established ground control points within the area. In addition, Table 2 to 7 show the details about the NAMRIA reference point and established control point, while Table 8 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.



(a) (b)

Figure 3. GPS set-up over CMN-33 at Barangay Batobalani, Jose Panganiban, Camarines Norte (a) and NAMRIA reference point CMN-33 (b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point CMN-33 used as base station for the LiDAR acquisition

Station Name	CMN-33	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 14’ 11.70144” North 122° 44’ 31.91442” East 8.58900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	472178.341 meters 1574360.987 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 14’ 6.51050” North 122° 44’ 36.82890“ East 57.40600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1984)	Easting Northing	472188.08 meters 1573809.93 meters

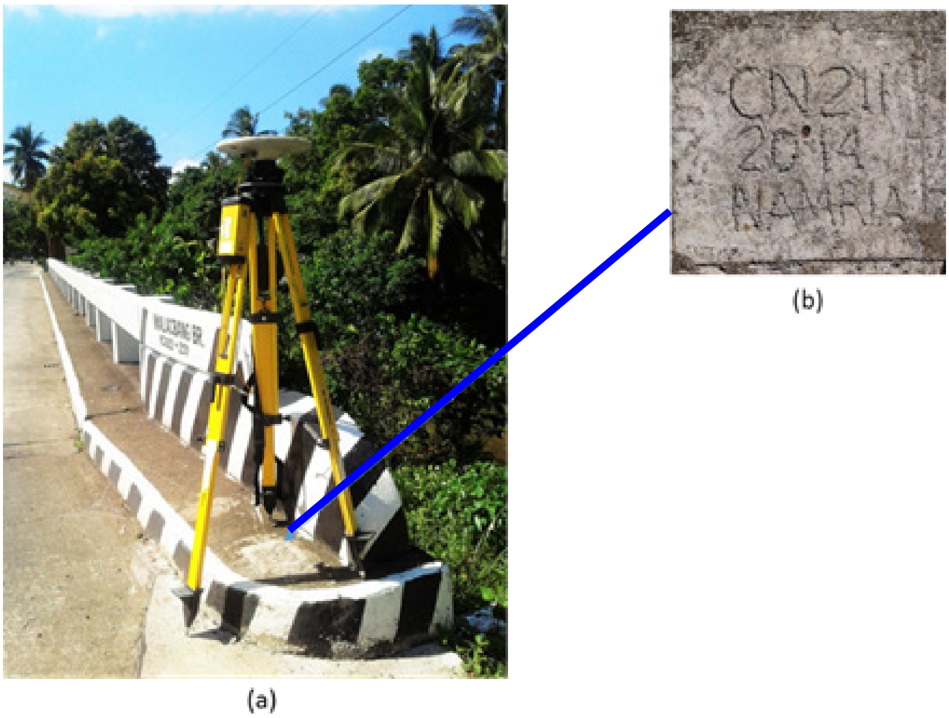


Figure 4. GPS set-up over CN-211 at Barangay Malacbang, Paracale, Camarines Norte (a) and NAMRIA reference point CN-211 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA Benchmark CN-211 with processed coordinates used as base station for the LiDAR acquisition

Station Name	**CN-211**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 :50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 12’ 10.35973” North 122° 46’ 45.33929” East 35.369 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 12’ 05.17982” North 122° 46’ 50.25638” East 84.372 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	476182.911 meters 1570078.228 meters

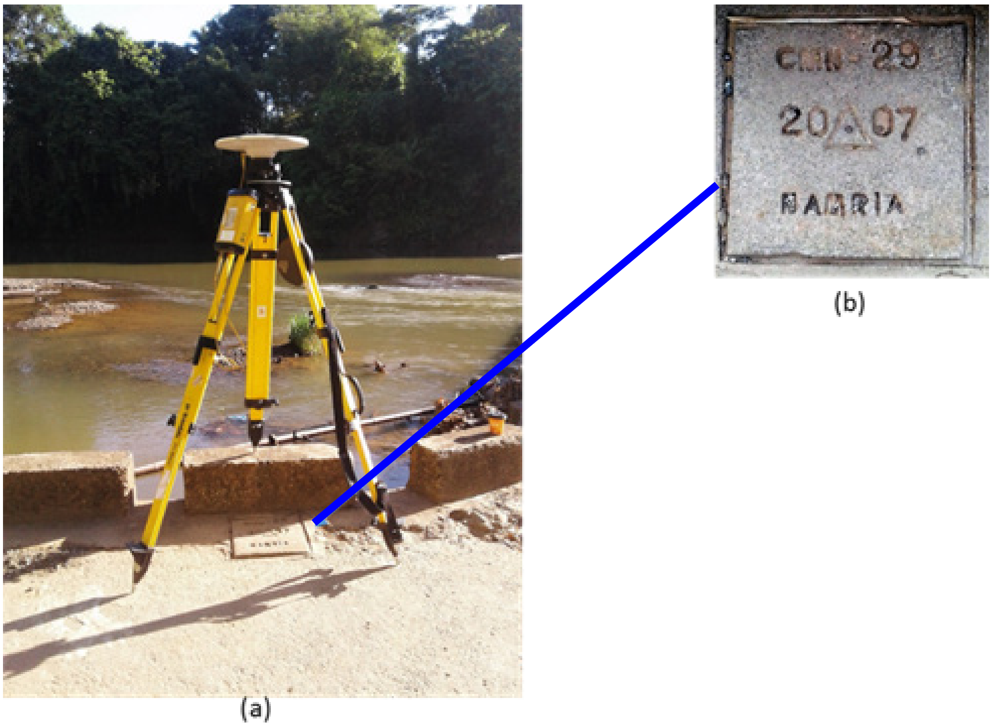
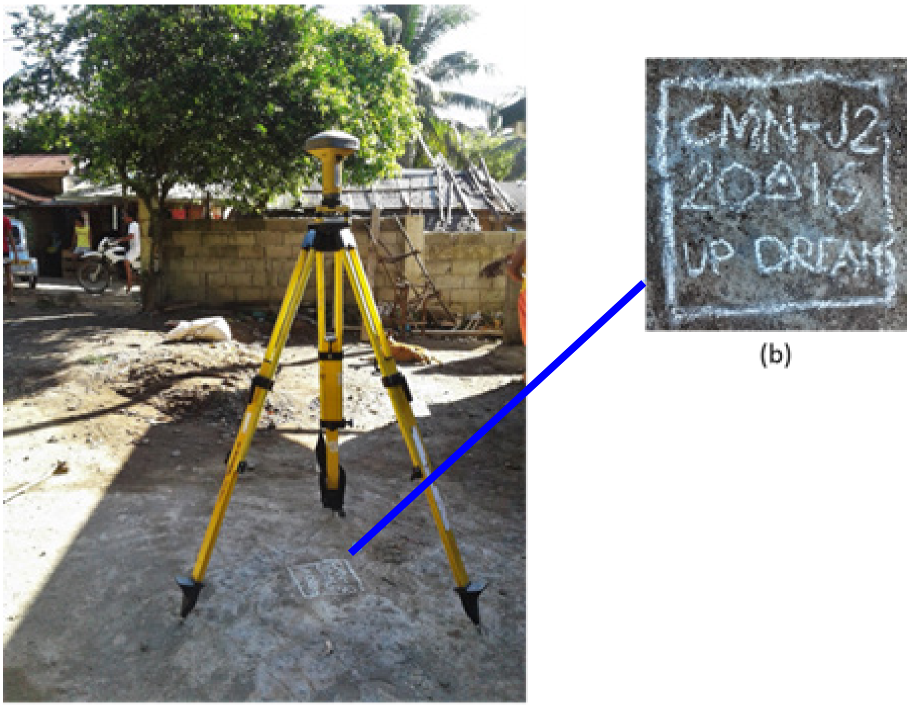


Figure 5. GPS set-up over CMN-29 at Barangay Malibago, Daet-Basud, Camarines Norte (a) and NAMRIA reference point CMN-29 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point CMN-29 used as base station for the LiDAR acquisition

Station Name	**CMN-29**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 08’ 52.17466” North 122° 34’ 59.83481” East 40.92600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Latitude Longitude Ellipsoidal Height	455011.114 meters 1564566.419 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 8’ 46.99182” North 122° 35’ 4.75796“ East 89.60600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1984)	Easting Northing	455026.86 meters 1564018.79 meters



(a)

Figure 6. GPS set-up over CMN-J2 at Barangay Malibago, Daet-Basud, Camarines Norte (a) and ground control point CMN-J2 (b) as established by the field team

Table 5. Details of the established control point CMN-J2 with processed coordinates used as base station for the LiDAR acquisition

Station Name	**CMN-J2**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 :50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 08’ 53.88940” North 122° 35’ 03.56309” East 51.531 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 08’ 48.48618” North 122° 35’ 08.48618” East 100.212 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	455138.726 meters 1564071.272 meters

Table 6. Details of the recovered NAMRIA Benchmark CM-198 with processed coordinates used as base station for the LiDAR acquisition

Station Name	CM-198	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 :50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 06' 23.36447" North 122° 51' 56.66504" East 16.891 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 06' 21.20640" North 122° 52' 03.55656" East 66.261 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	485569.809 meters 1563190.057 meters

Table 7. Details of the established control point DENR with processed coordinates used as base station for the LiDAR acquisition.

Station Name	DENR	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 :50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 08' 11.86920" North 122° 58' 54.64302" East 11.089 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 08' 06.72152" North 122° 58' 59.56437" East 60.772 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	498040.596 meters 1562740.733 meters

Table 8. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
10 March 2016	23170P	1BLK20DE69A	DENR and CM-198
12 March 2016	23182P	1BLK20ABCE72A	DENR and CMN-33
14 March 2016	23190P	1BLK20BS74A	DENR and CM-198
17 March 2016	23202P	1BLK20N77A	DENR and CM-198
7 April 2016	23226P	1BLK20A98A	CMN-29 and CMN-J2
9 April 2016	23234P	1BLK20D100A	CMN-33 and CN-211
17 April 2016	23266P	1BLK20D098A	CMN-33 and CN-211
17 April 2016	23268P	1BLK20S108	CMN-33 and CN-211
18 April 2016	23270P	1BLK20S109A	CMN-33 and CN-211

2.3 Flight Missions

Twelve (12) missions were conducted to complete the LiDAR Data Acquisition in Daet-Basud floodplain, for a total of twenty nine hours and six minutes (29+06) of flying time for RP-C9122. All missions were acquired using the Pegasus LiDAR system. Table 9 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 9. Flight missions for LiDAR data acquisition in Daet-Basud 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
9 March 2016	23170P	278.95	186.61	102.55	84.06	631	3	01
12 March 2016	23182P	316.23	94.23	26.30	67.93	326	4	15
14 March 2016	23190P	362.97	156.39	17.17	139.22	23	3	59
17 March 2016	23202P	407.26	237.25	0	237.25	766	4	28
7 April 2016	23226P	348.53	223.80	0	223.80	NA	4	17
9 April 2016	23234P	236.67	48.49	0	48.49	399	2	11
17 April 2016	23266P	233.4	171.41	0	171.41	456	3	11
17 April 2016	23268P	236.67	157.33	0.34	156.99	54	3	5
18 April 2016	23270P	234.1	31.51	0	31.51	NA	0	39
TOTAL		2654.78	1307.02	146.36	1160.66	2655	29	06

Table 10. 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)
23170P	1000	30	50	150	30	130	5
23182P	1000	30	50	150	30	130	5
23190P	1000	30	50	200	30	130	5
23202P	1100, 850	30	50	150	30	130	5
23226P	800	15	50	200	30	130	5
23234P	900	15	50	200	30	130	5
23266P	1000	30	50	200	30	130	5
23268P	1100	15	50	200	30	130	5
23270P	1100	15	50	200	30	130	5

2.4 Survey Coverage

Daet-Basud floodplain is situated within the municipalities of Camarines Norte. The municipality of Talisay is fully covered during the entire duration of the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 11. The actual coverage of the LiDAR acquisition for Daet-Basud floodplain is presented in Figure 7.

Table 11. List of Municipalities/Cities Surveyed during Daet-Basud floodplain LiDAR survey

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Camarines Norte	Daet	42.20	42.20	100%
	Jose Panganiban	211.71	196.51	92.82%
	Paracale	148.28	132.42	89.30%
	Talisay	37.90	27.32	72.09%
	Basud	251.71	116.88	46.43%
	San Vicente	47.17	20.81	44.11%
	San Lorenzo Ruiz	108.81	31.07	28.56%
	Vinzons	90.44	19.67	21.75%
	Mercedes	117.17	18.96	16.18%
	Labo	622.52	89.14	14.32%
	Capalonga	220.07	15.85	7.20%
TOTAL		1897.98	710.83	48%

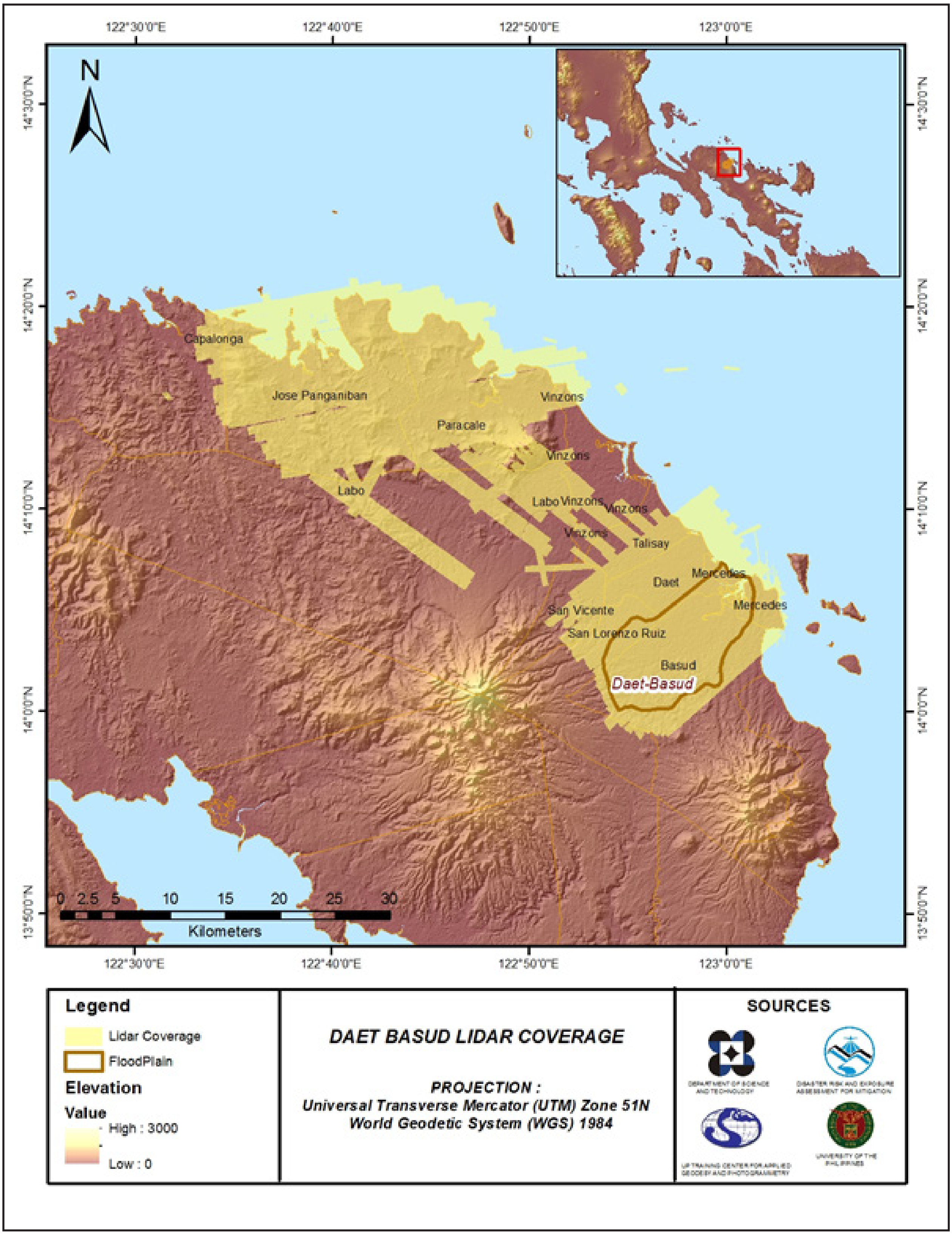


Figure 7. Actual LiDAR survey coverage for Daet-Basud floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE BASUD 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 8.

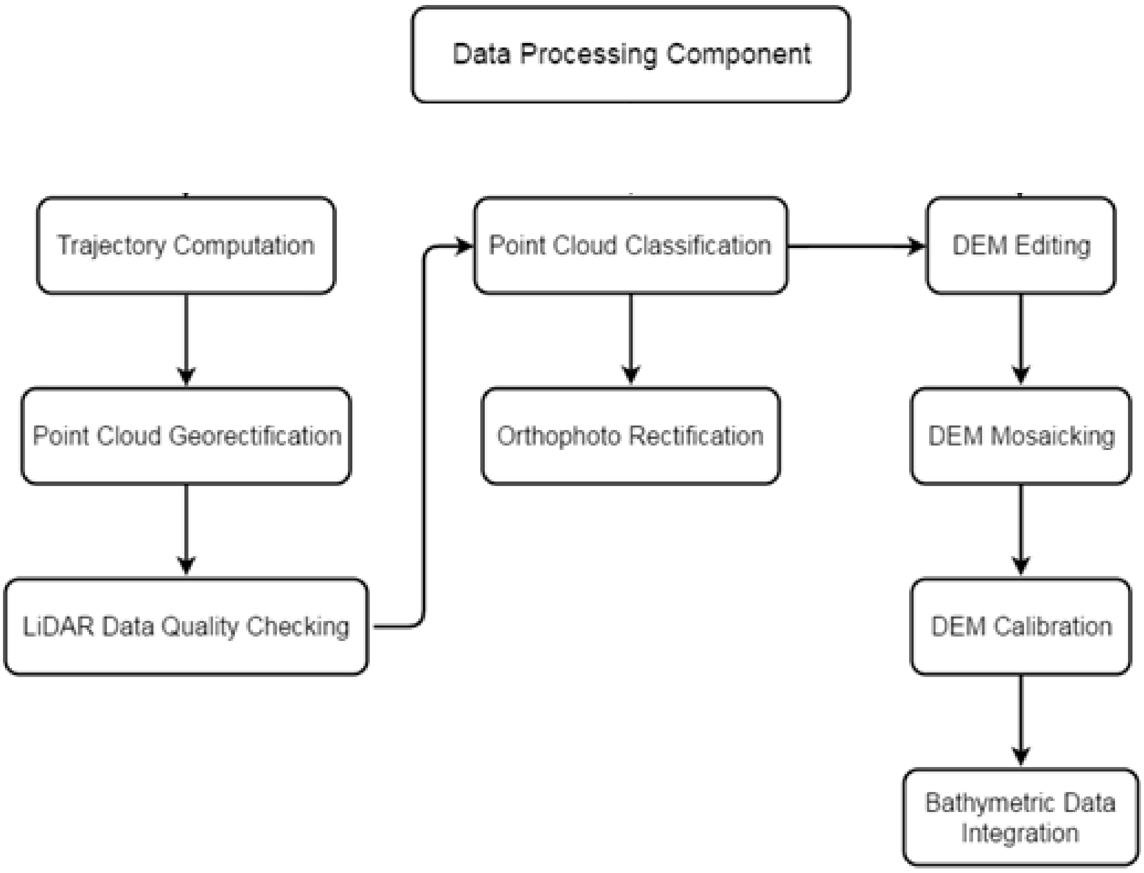


Figure 8. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Basud floodplain can be found in Annex 5. Missions flown during the first survey conducted on January 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions acquired during the second survey on May 2016 were flown using the same system over Basud, Camarines Norte.

The Data Acquisition Component (DAC) transferred a total of 135.72 Gigabytes of Range data, 1.72 Gigabytes of POS data, 826.22 Megabytes of GPS base station data, and 596.10 Gigabytes of raw image data to the data server on January 4, 2014 for the first survey and May 11, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Basud was fully transferred on May 18, 2016, as indicated on the Data Transfer Sheets for Basud floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 23182P, one of the Basud flights, which is the North, East, and Down position RMSE values are shown in Figure 9. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on March 12, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

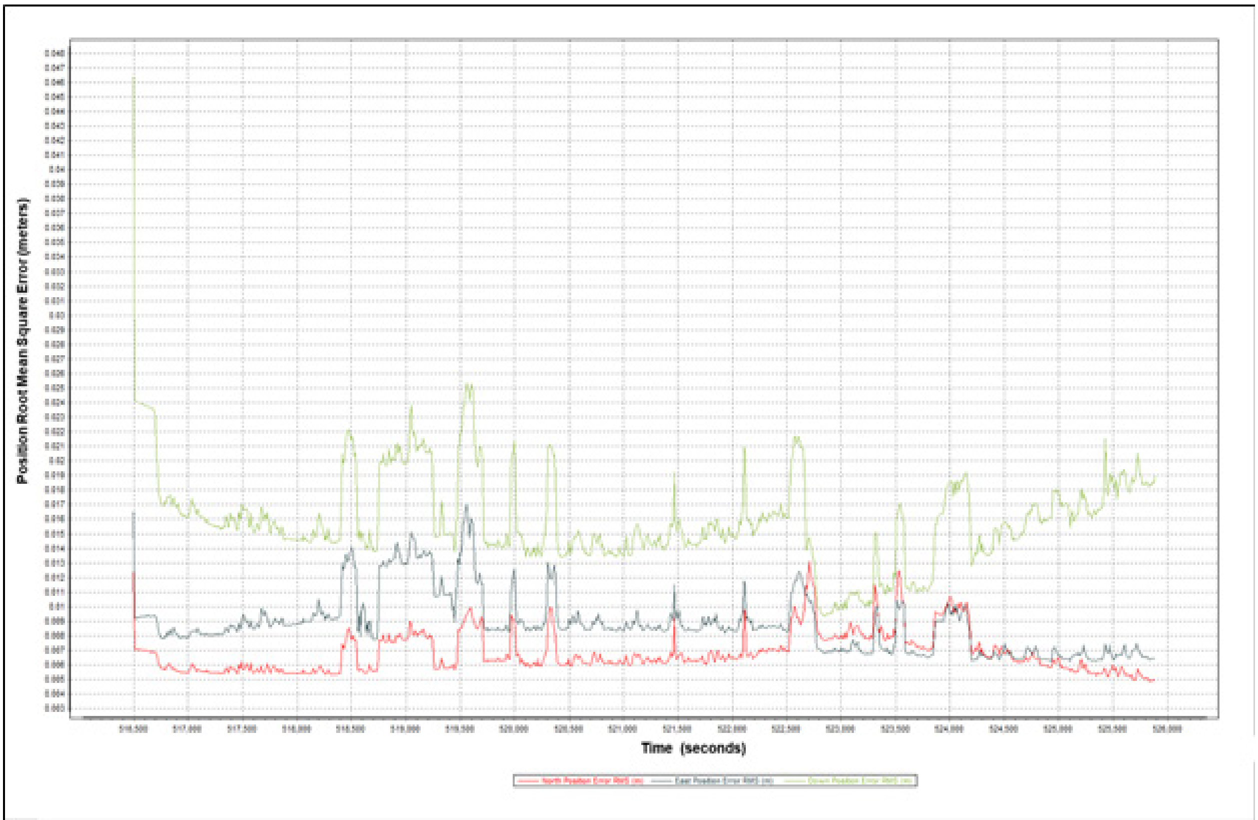


Figure 9. Smoothed Performance Metrics of a Basud Flight 23182P

The time of flight was from 516500 seconds to 526000 seconds, which corresponds to morning of March 12, 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 9 shows that the North position RMSE peaks at 1.30 centimeters, the East position RMSE peaks at 1. 70 centimeters, and the Down position RMSE peaks at 2.50 centimeters, which are within the prescribed accuracies described in the methodology.

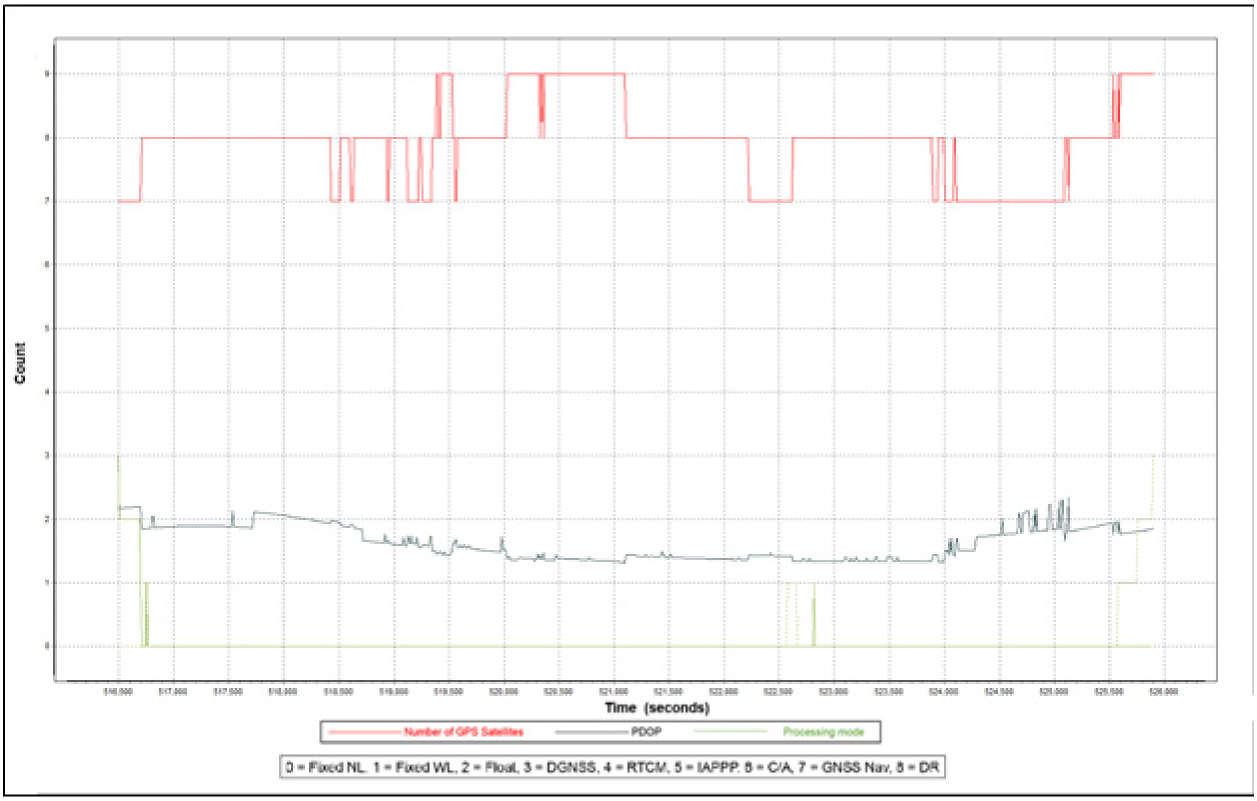


Figure 10. Solution Status Parameters of Basud Flight 23182P

The Solution Status parameters of flight 23182P, one of the Basud flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 7. Most of the time, the number of satellites tracked was between 7 and 9. The PDOP value also did not go above the value of 2.4, which indicates optimal GPS geometry. The processing mode remained at 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 Basud flights is shown in Figure 11.

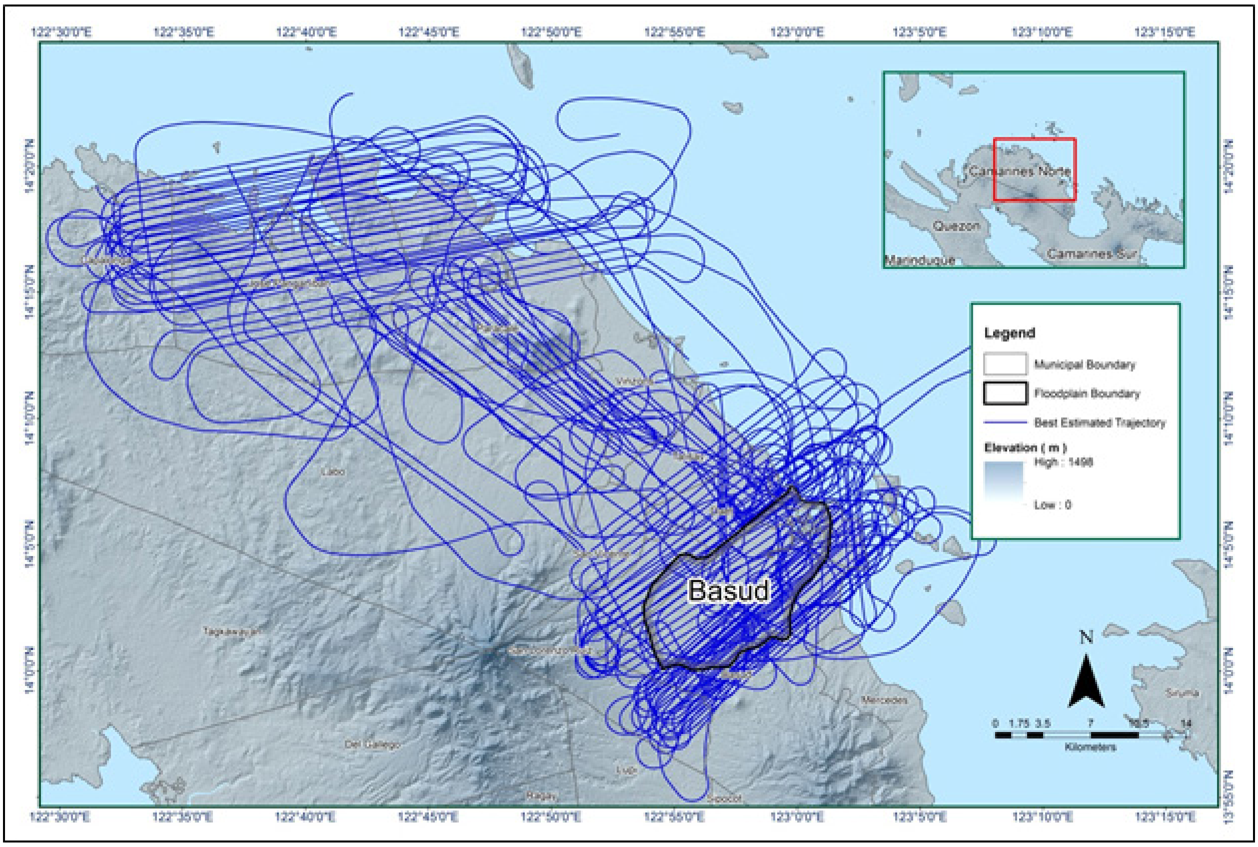


Figure 11. Best estimated trajectory for Basud floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 182 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Basud floodplain are given in Table 12.

Table 12. Self-Calibration Results values for Basud flights

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000368
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000811
GPS Position Z-correction stdev)	<0.01meters	0.0086

The optimum accuracy values for all Basud flights were calculated based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the ANNEX 8. Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

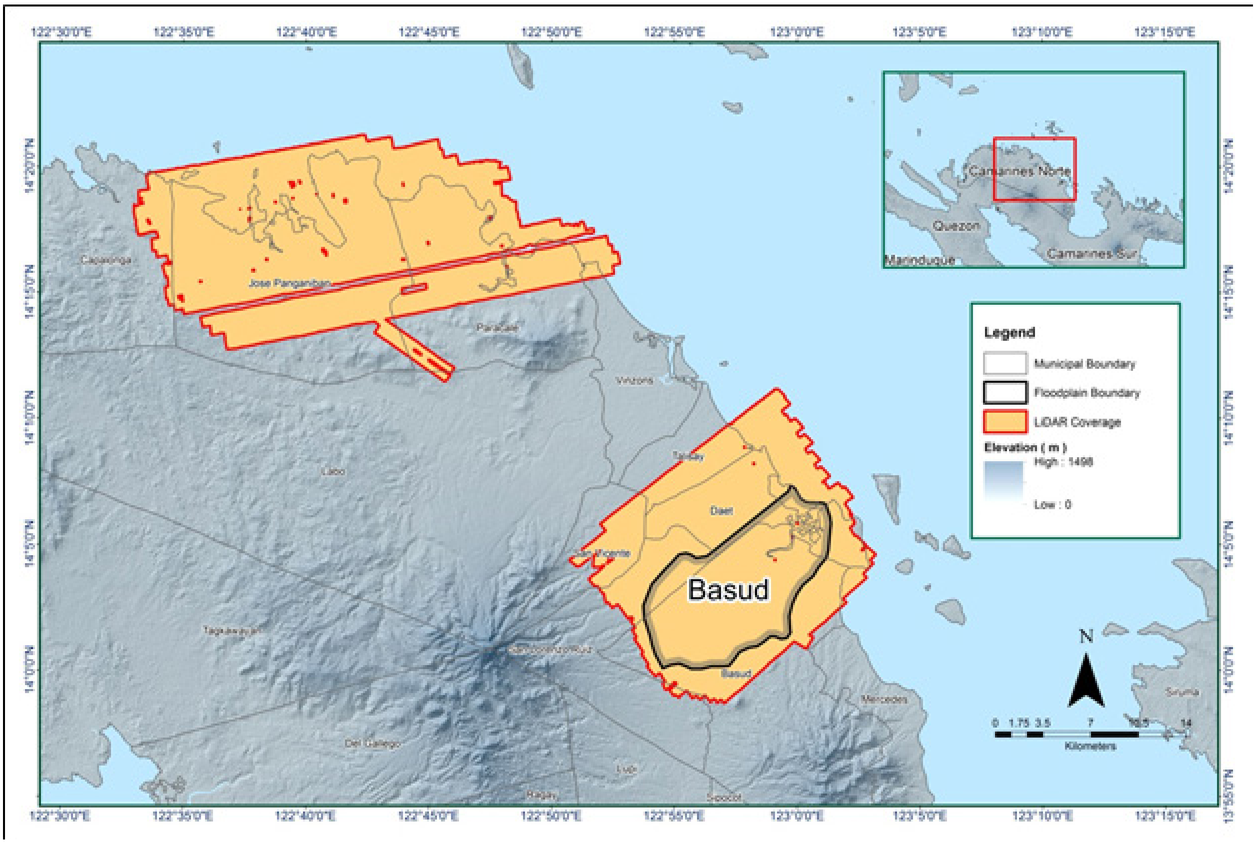


Figure 12. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Basud Floodplain.

The total area covered by the Basud missions is 824.71 sq.km that is comprised of eleven (11) flight acquisitions grouped and merged into nine (9) blocks as shown in Table 13.

Table 13. List of LiDAR blocks for Basud floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Bagasbas_Blk20E_suplement	23182P	37.87
	23190P	
Bagasbas_Blk20E_additional	23268P	25.85
Bagasbas_Blk20DE	23170P	185.93
Bagasbas_Blk20Q	23270P	10.01
Bagasbas_Blk20P	23226P	120.08
Bagasbas_Blk20O	23226P	127.35
	23234P	
Bagasbas_Blk20N	23202P	251.53
Bagasbas_Blk20N_supplement	23266P	62.05
Bagasbas_Blk20C_additional	23270P	8.03
TOTAL		808.70 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 13. Since the Pegasus system employs 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.

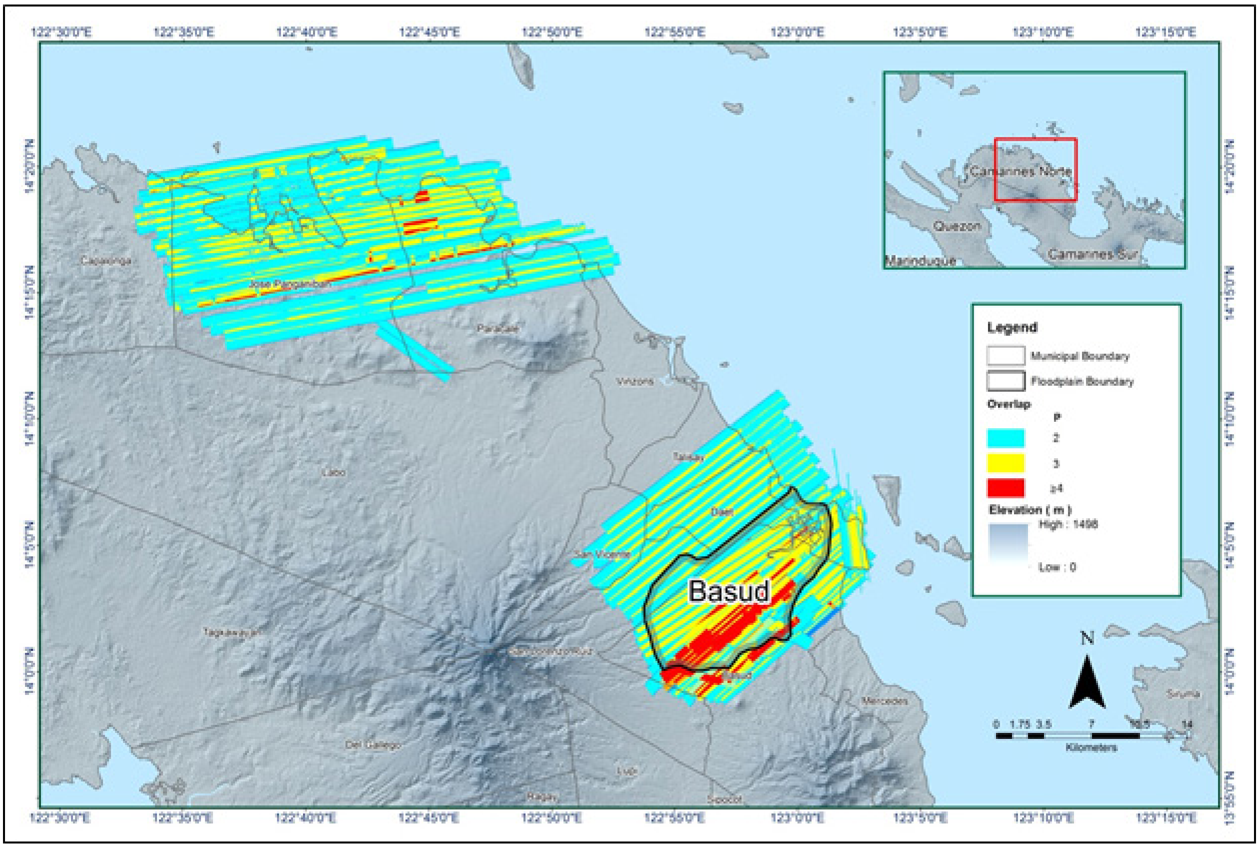


Figure 13. Image of data overlap for Basud floodplain

The overlap statistics per block for the Basud 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 31.21% and 83.93% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 14. It was determined that all LiDAR data for Basud floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.56 points per square meter.

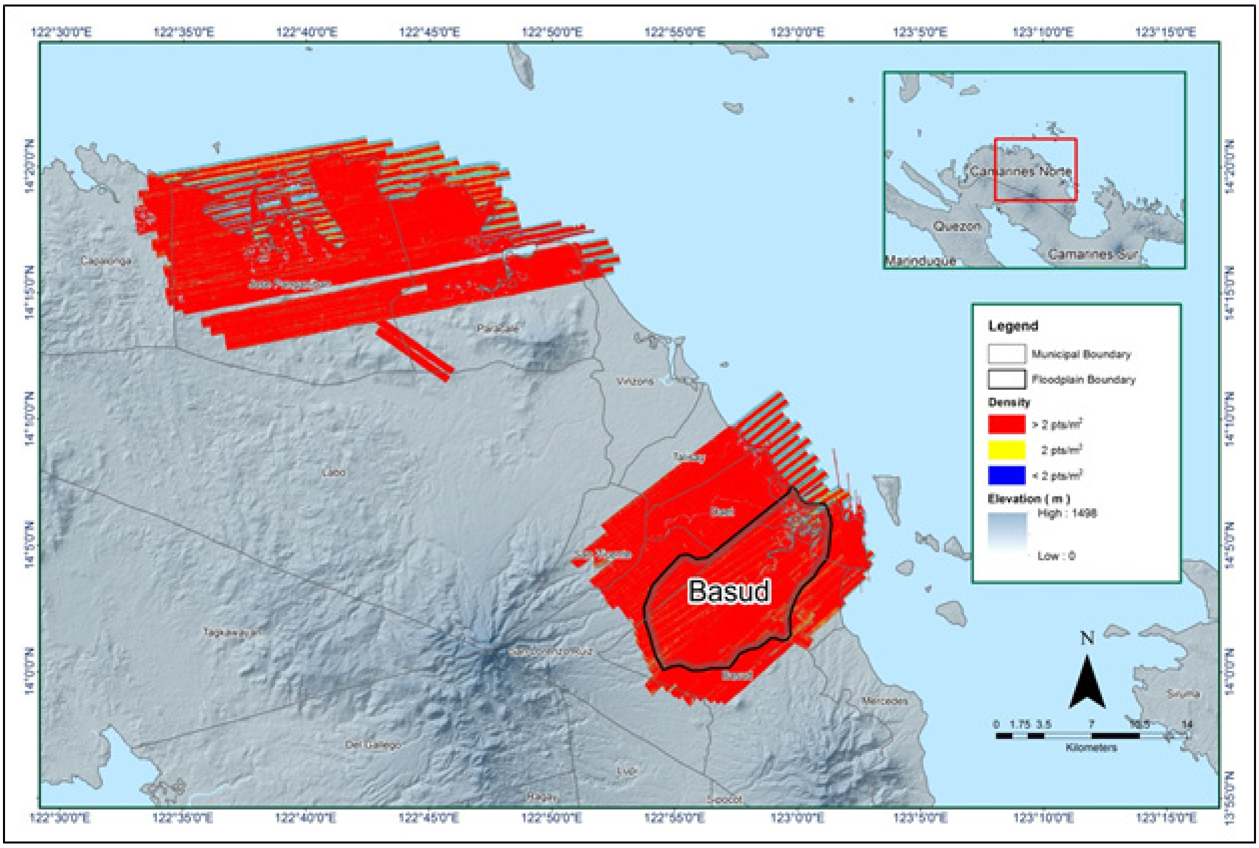


Figure 14. Pulse density map of merged LiDAR data for Basud floodplain

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

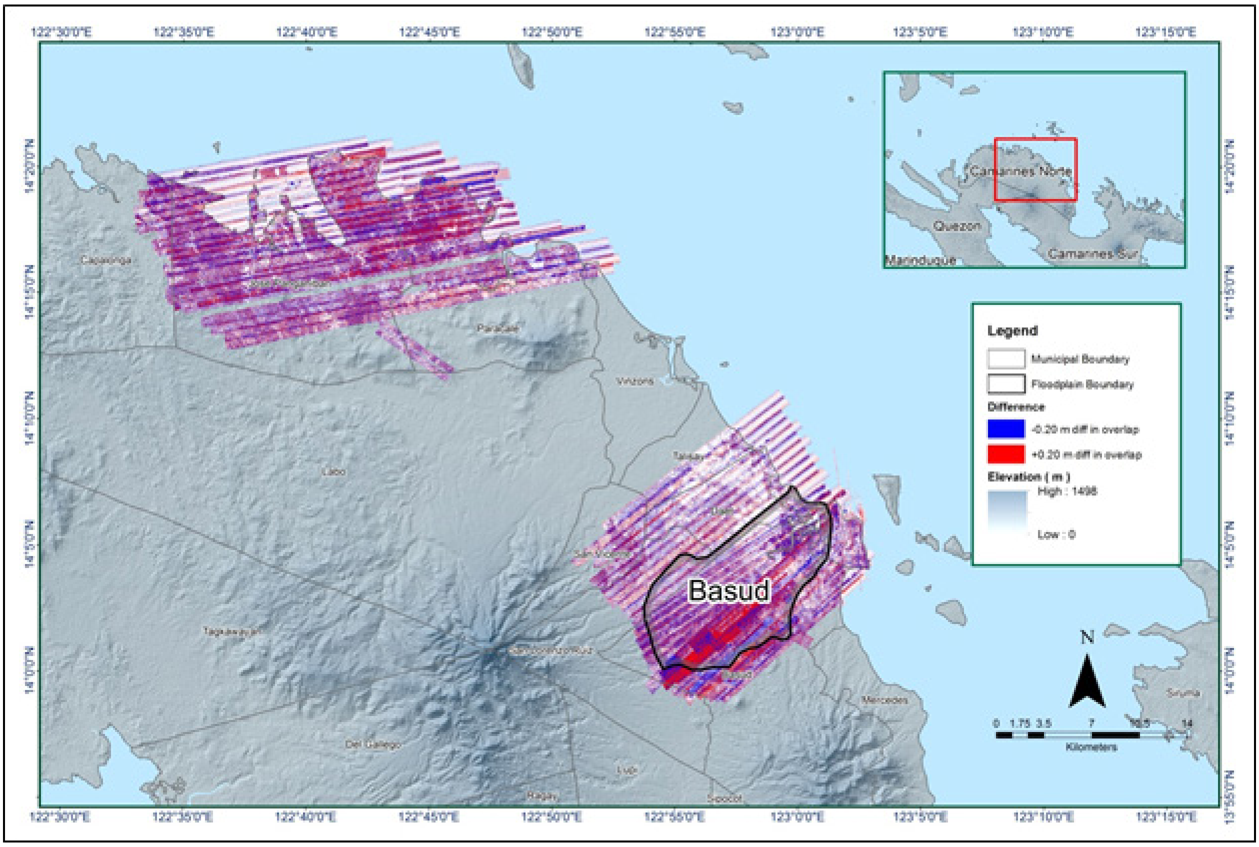


Figure 15. Elevation difference map between flight lines for Basud floodplain

A screen capture of the processed LAS data from a Basud flight 23182P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed 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.

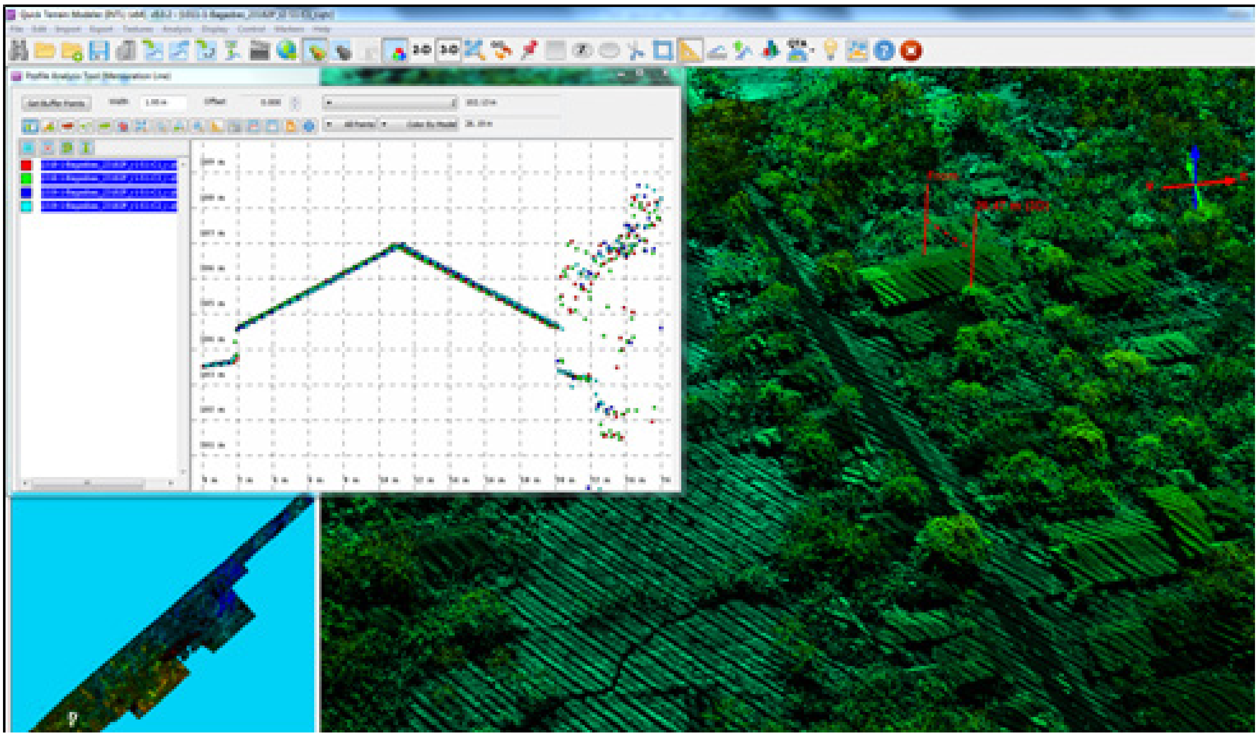


Figure 16. Quality checking for a Basud flight 23182P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Basud classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	695,673,949
Low Vegetation	508,813,813
Medium Vegetation	1,037,037,861
High Vegetation	2,491,646,331
Building	62,622,212

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Basud floodplain is shown in Figure 17. A total of 1,168 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 14. The point cloud has a maximum and minimum height of 813.35 meters and 9.37 meters respectively.

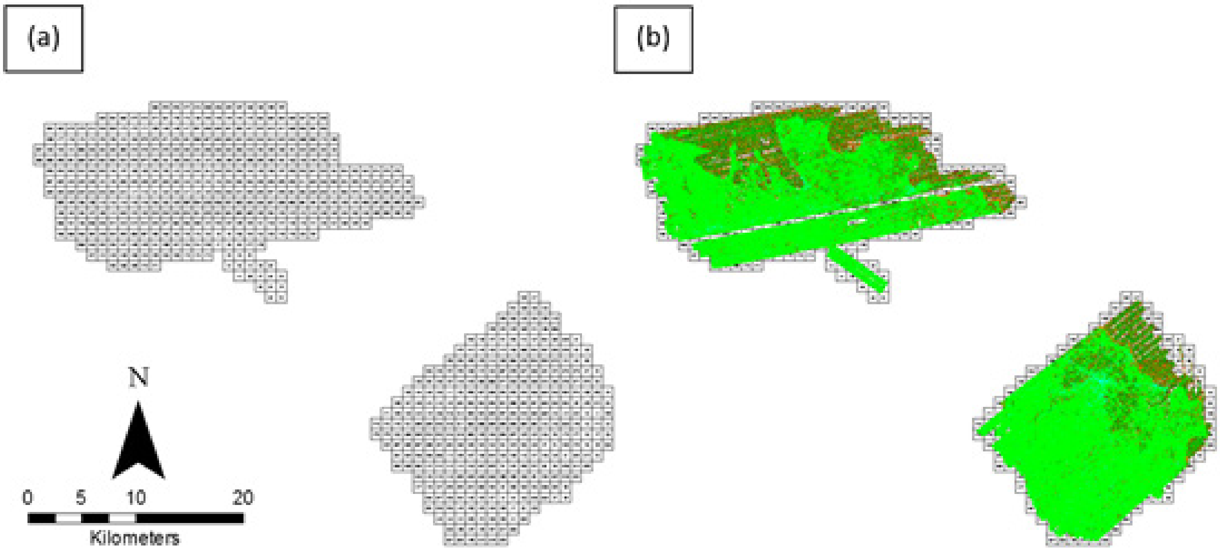


Figure 17. Tiles for Basud floodplain (a) and classification results (b) in TerraScan

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

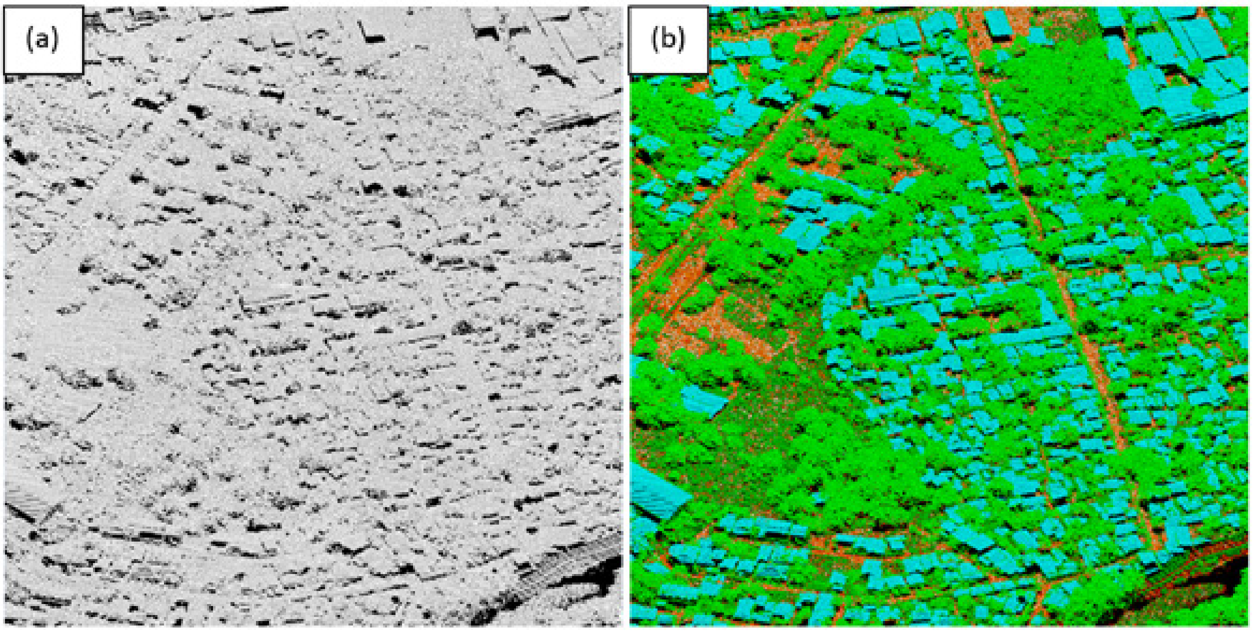


Figure 18. Point cloud before (a) and after (b) classification

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

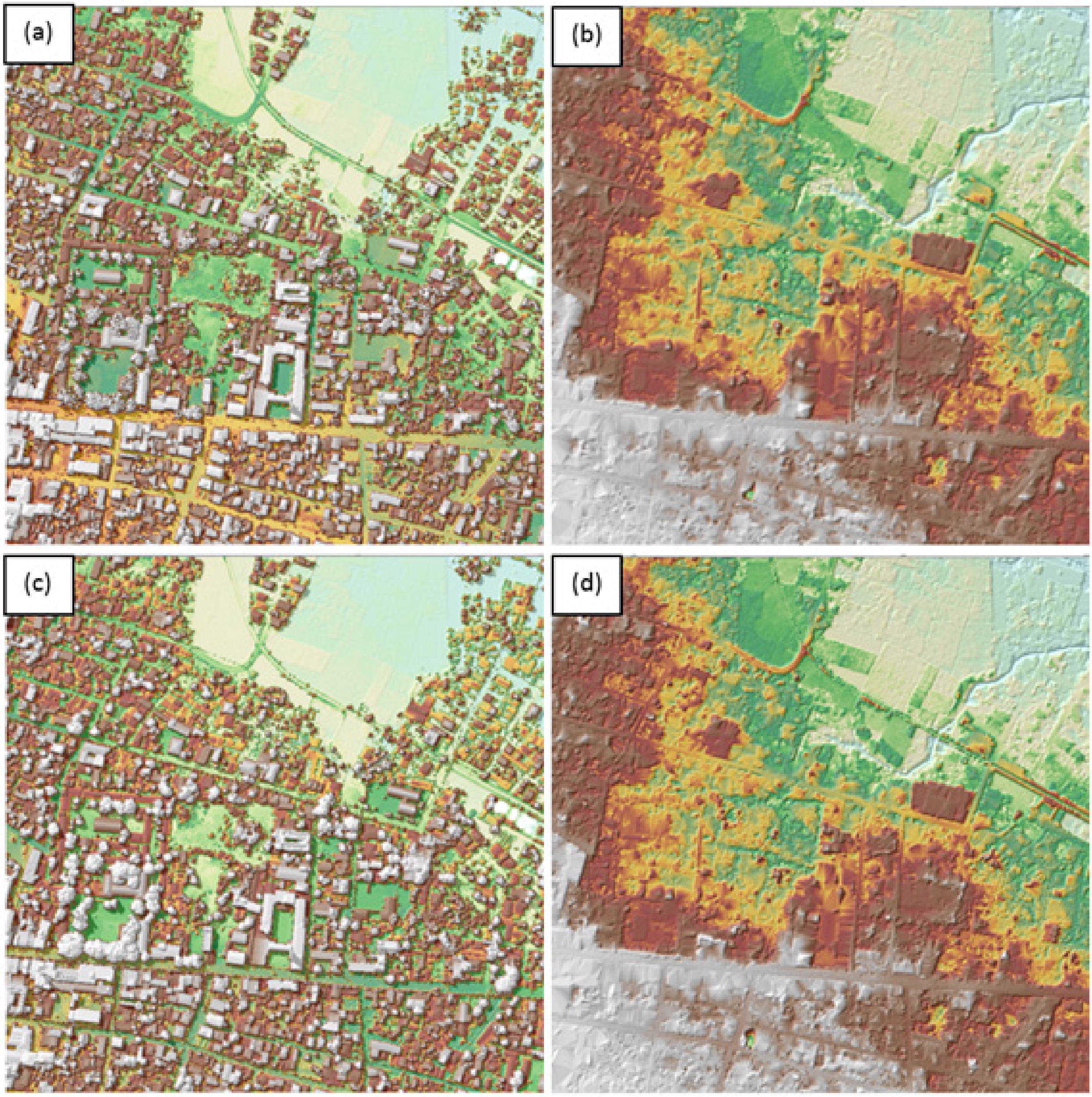


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Basud floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 624 1km by 1km tiles area covered by Basud floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Basud floodplain has a total of 443.31 sq.km orthophotogaph coverage comprised of 1733 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

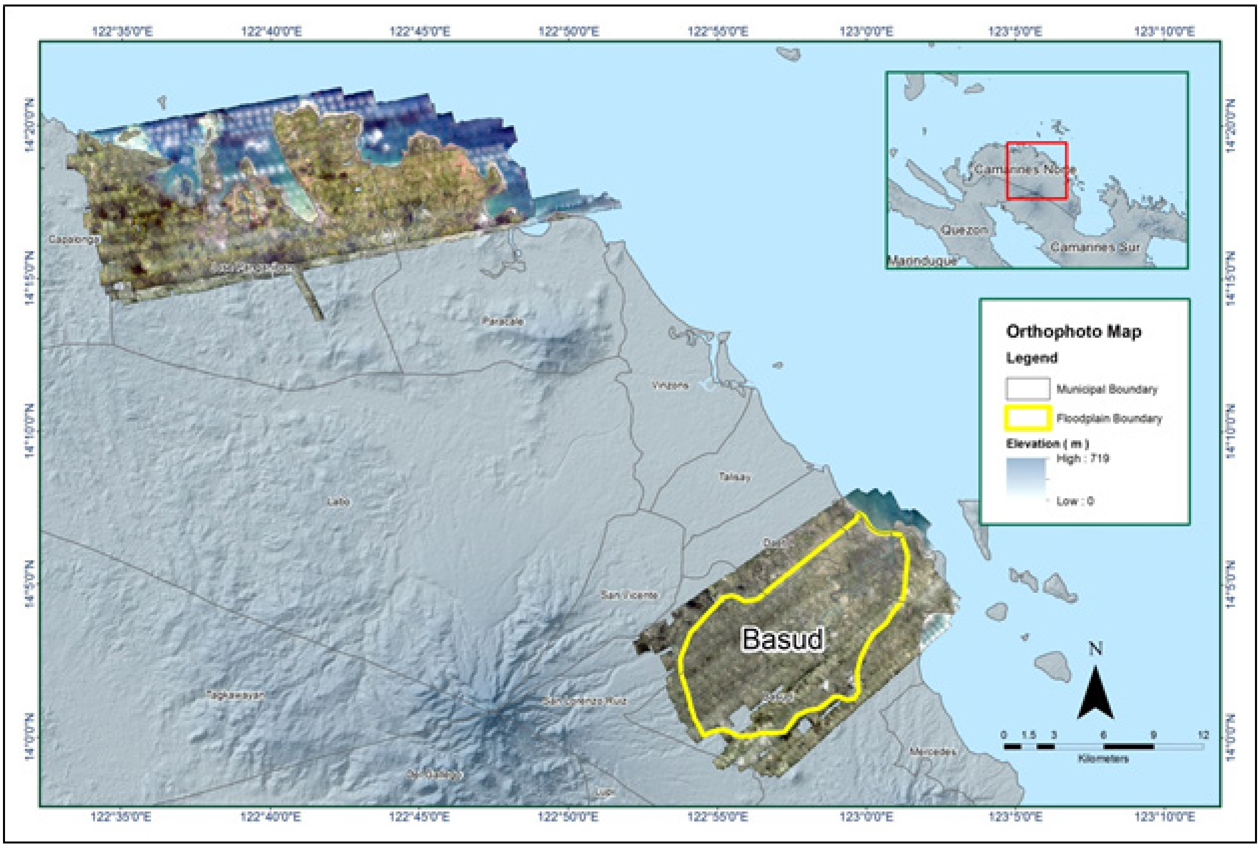


Figure 20. Basud floodplain with available orthophotographs

Figure 21. Sample orthophotograph tiles for Basud floodplain

3.8 DEM Editing and Hydro-Correction

Nine (9) mission blocks were processed for Basud flood plain. These blocks are composed of Bagasbas blocks with a total area of 808.70 square kilometers. Table 15 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
Bagasbas_Blk20E_supplement	37.87
Bagasbas_Blk20E_additional	25.85
Bagasbas_Blk20DE	185.93
Bagasbas_Blk20Q	10.01
Bagasbas_Blk20P	120.08
Bagasbas_Blk20O	127.35
Bagasbas_Blk20N	251.53
Bagasbas_Blk20N_supplement	62.05
Bagasbas_Blk20C_additional	8.03
TOTAL	808.70 sq.km

Portions of DTM before and after manual editing are shown in Figure 22. The mountain ridge (Figure 22a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 22b) to allow the correct flow of water. The bridge (Figure 22c) is also considered to be impedance to the flow of water along the river and has to be removed (Figure 22d) in order to hydrologically correct the river.

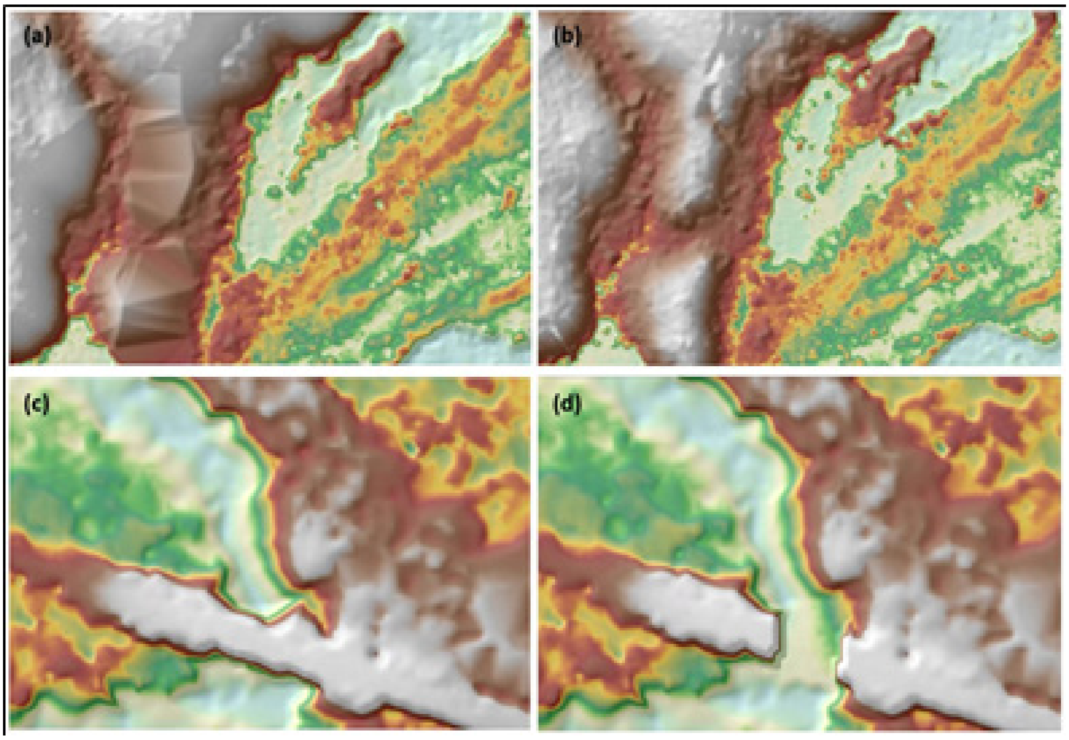


Figure 22. Portions in the DTM of Basud floodplain – a mountain ridge before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

Bagasbas Blk20DE was used as the reference block at the start of mosaicking because it is the located in the estuary of the river. Table 16 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Basud floodplain is shown in Figure 23. It can be seen that the entire Basud floodplain is 100% covered by LiDAR data.

Table 16. Shift Values of each LiDAR Block of Basud floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Bagasbas_Blk20E_supplement	1.00	-7.00	-7.21
Bagasbas_Blk20E_additional	0.00	1.00	-2.78
Bagasbas_Blk20DE	Reference Raster		
Bagasbas_Blk20Q	0.00	-10.00	0.06
Bagasbas_Blk20P	0.00	0.00	0.01
Bagasbas_Blk20O	-1.00	1.00	0.16
Bagasbas_Blk20N	0.00	0.00	0.00
Bagasbas_Blk20N_supplement	1.62	0.00	0.39
Bagasbas_Blk20C_additional	1.00	-8.00	2.80

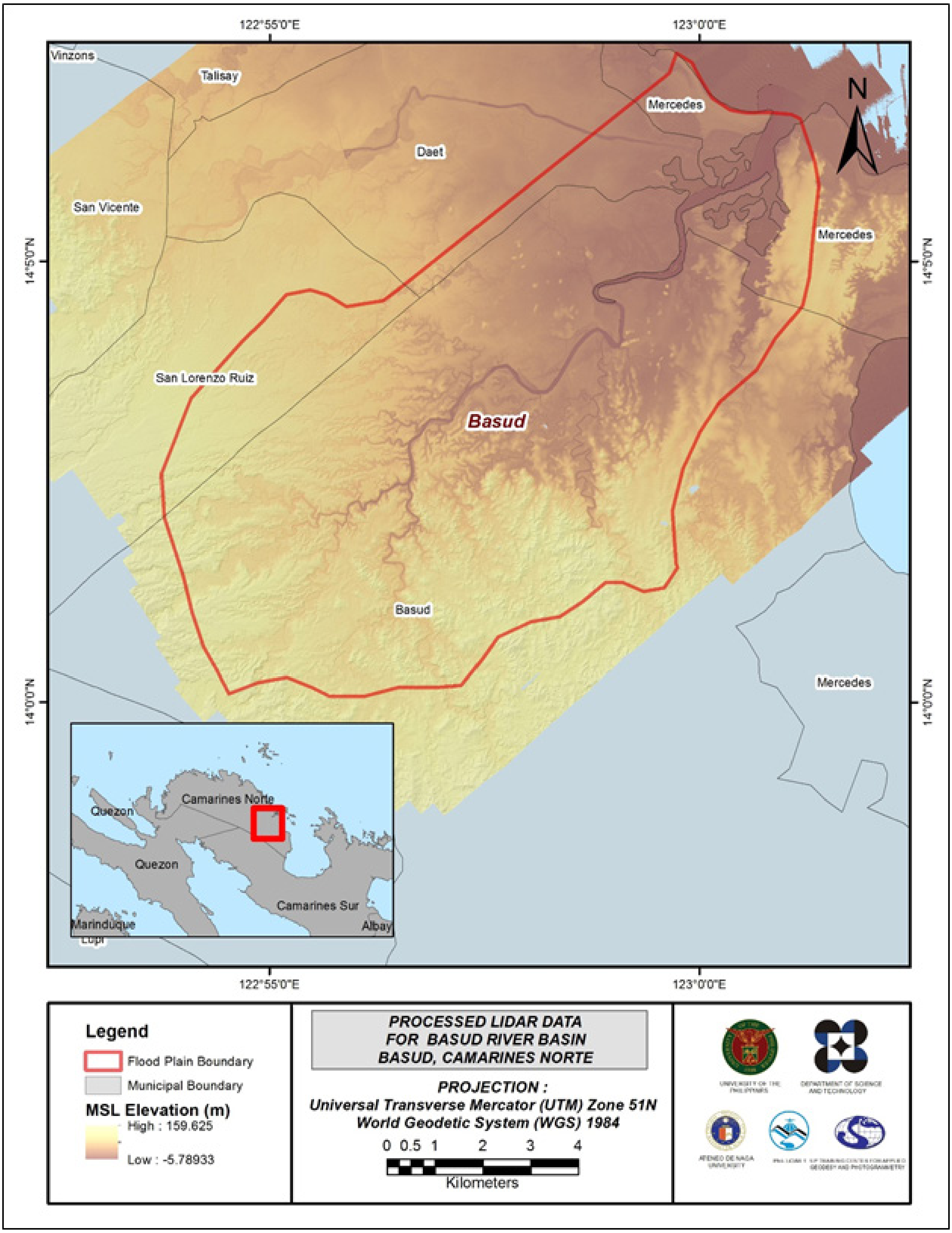


Figure 23. Map of Processed LiDAR Data for Basud Flood Plain

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 Basud to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 3652 survey points were used for calibration and validation of Basud LiDAR data. Random selection of 80% of the survey points, resulting to 3292 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 25. 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 2.80 meters with a standard deviation of 0.11 meters. Calibration of Basud LiDAR data was done by subtracting the height difference value, 2.80 meters, to Basud mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

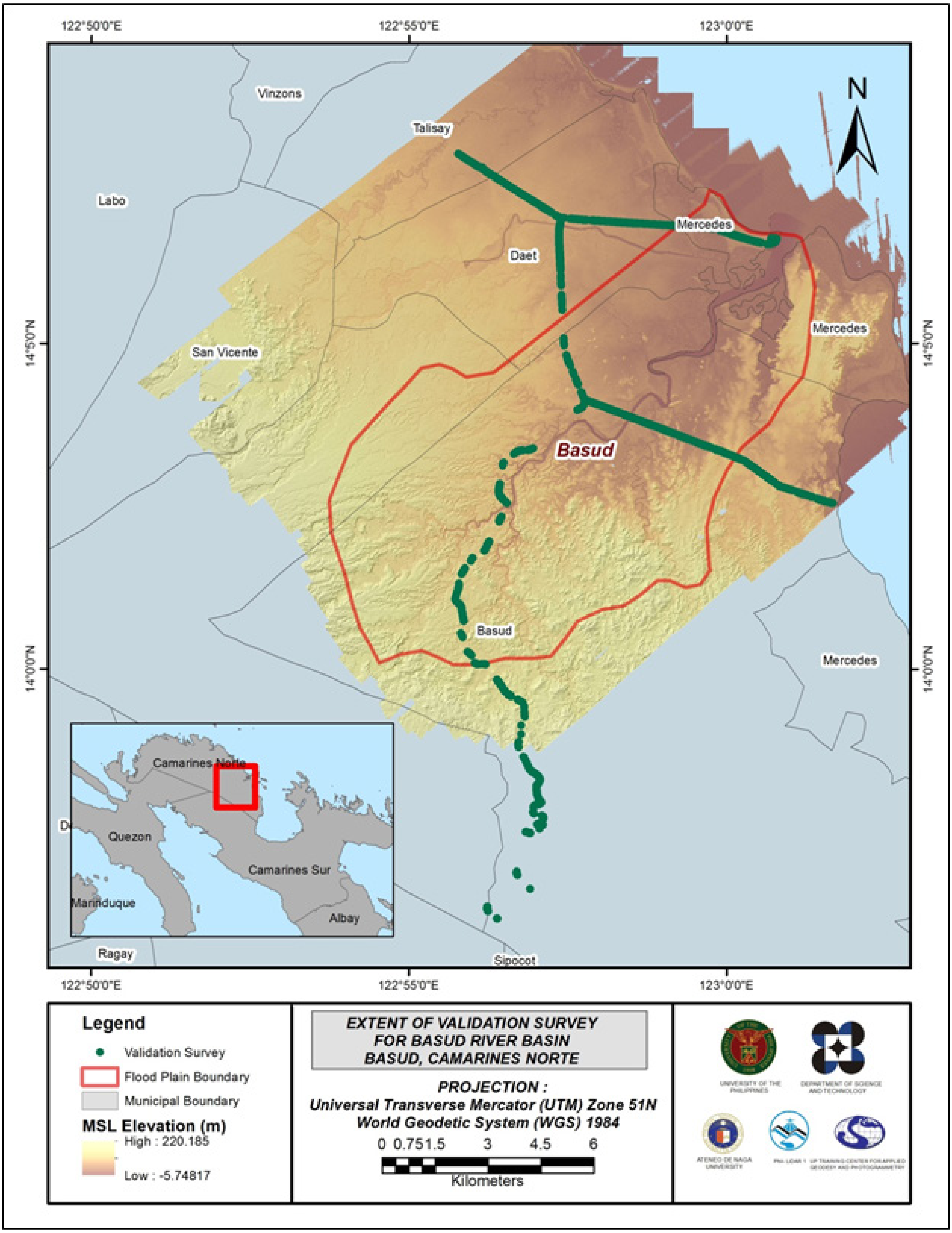


Figure 24. Map of Basud Flood Plain with validation survey points in green

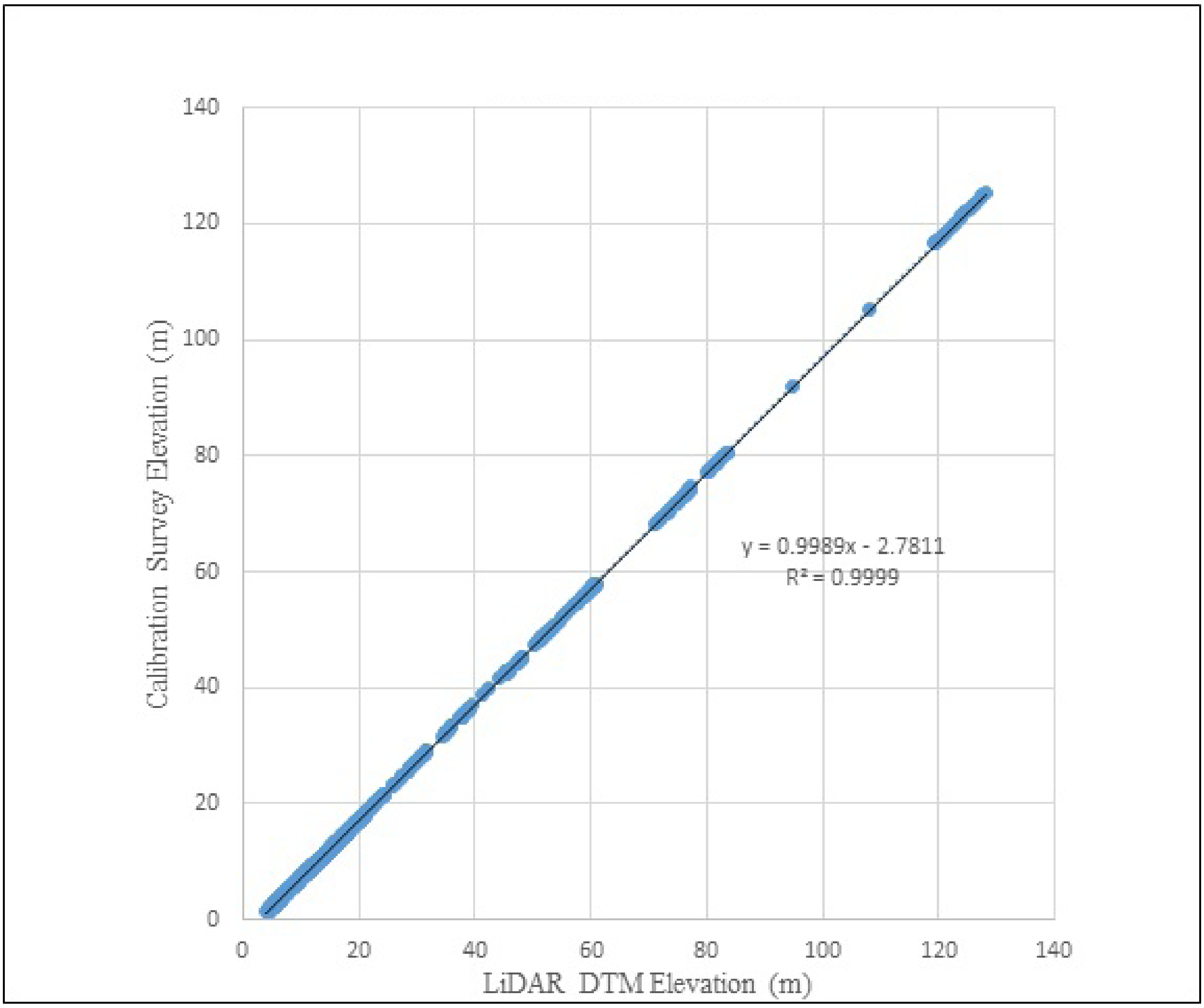


Figure 25. Correlation plot between calibration survey points and LiDAR data

Table 17. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	2.80
Standard Deviation	0.11
Average	-2.80
Minimum	-3.02
Maximum	-2.58

The remaining 20% of the total survey points, resulting to 731 points, were used for the validation of calibrated Basud 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 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.11 meters with a standard deviation of 0.11 meters, as shown in Table 18.

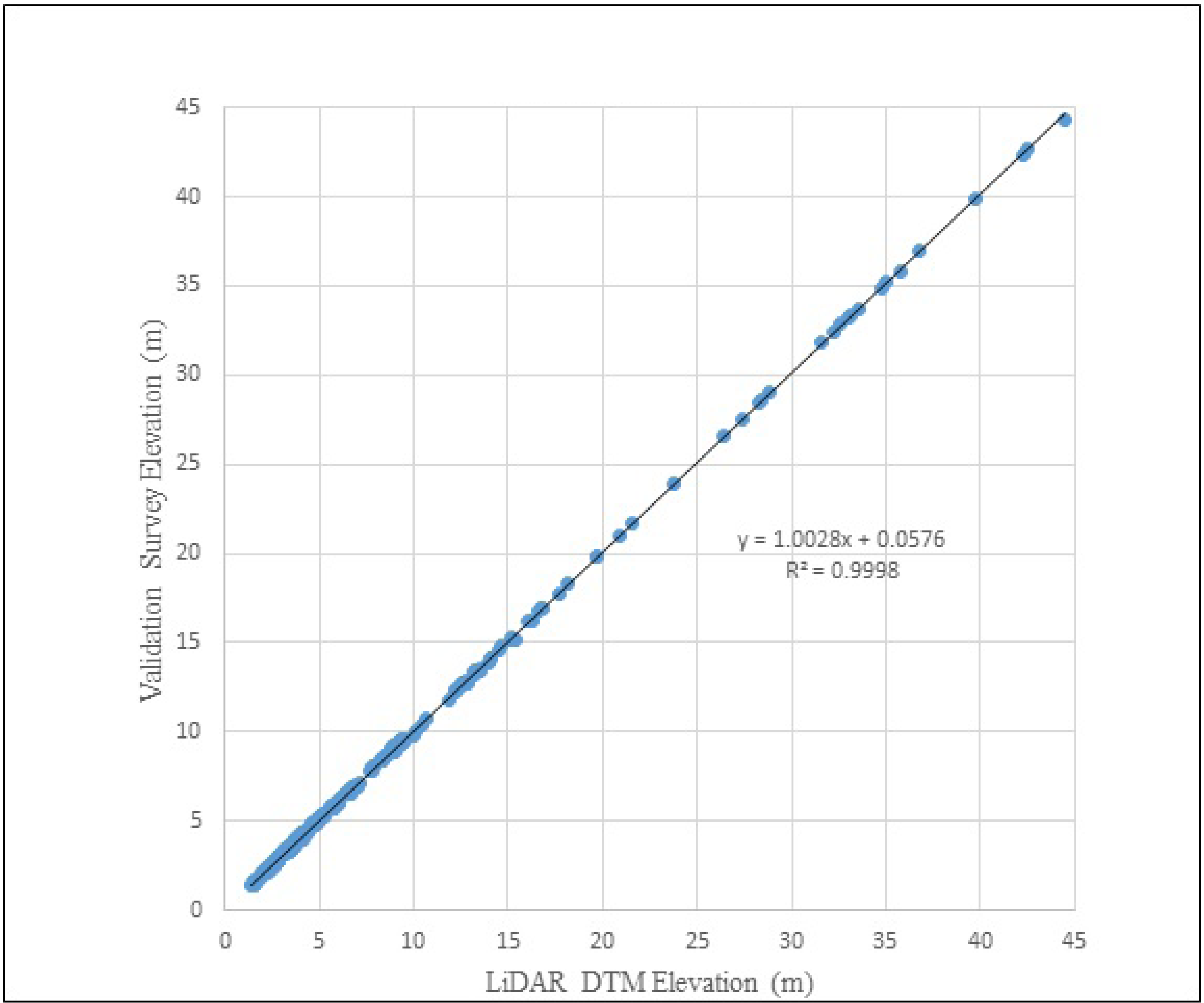


Figure 26. Correlation plot between validation survey points and LiDAR data

Table 18. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.11
Standard Deviation	0.11
Average	0.00
Minimum	-0.22
Maximum	0.23

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data was available for Basud with 17,380 bathymetric survey points. The resulting raster surface produced was done by Kernel interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.11 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Basud integrated with the processed LiDAR DEM is shown in Figure 27.

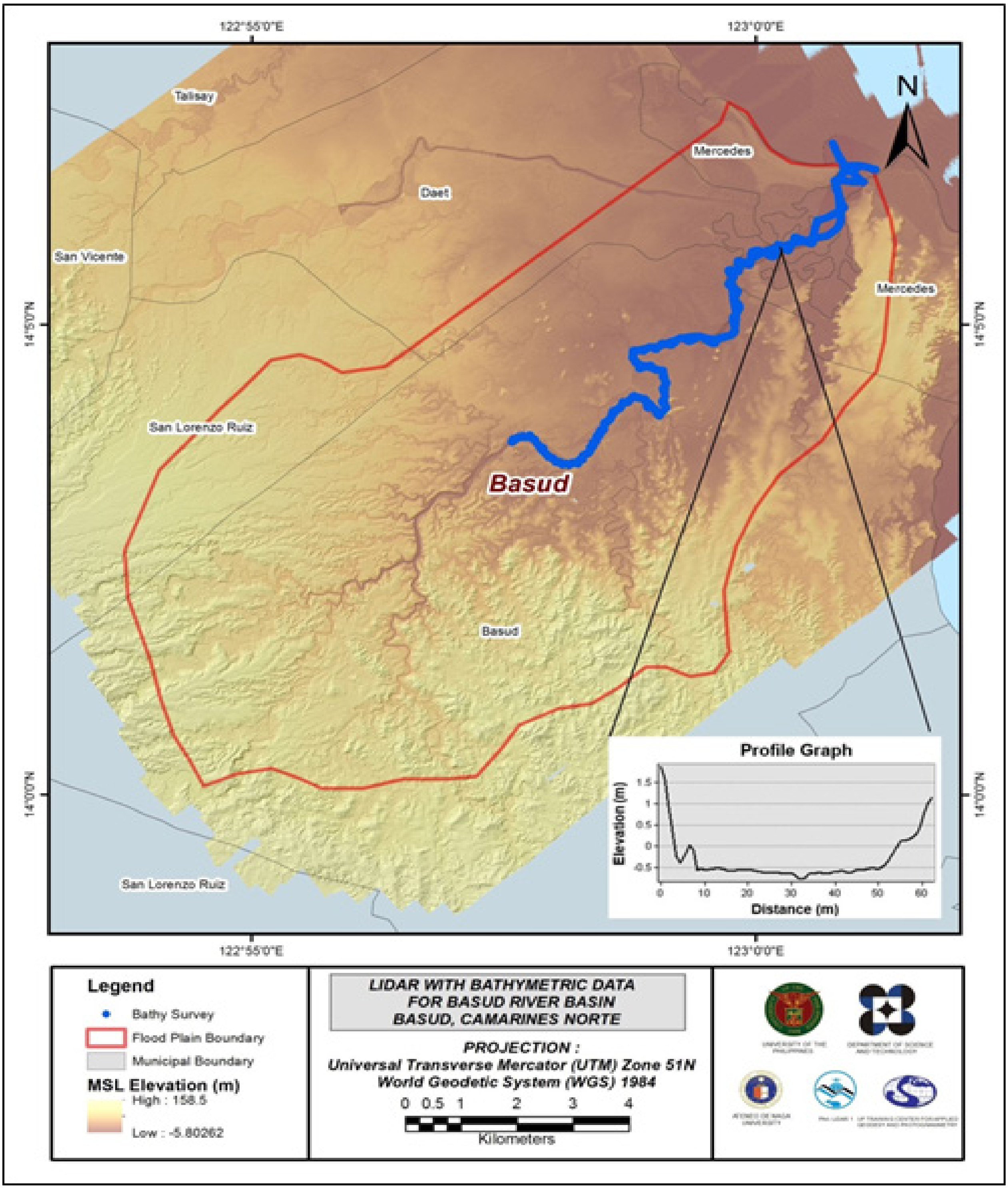


Figure 27. Map of Basud Flood Plain with bathymetric survey points shown in blue

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

Basud floodplain, including its 200 m buffer, has a total area of 105. 83 sq km. For this area, a total of 1.11 sq km, corresponding to a total of 16,005 building features, are considered for QC. Figure 28 shows the QC blocks for Basud floodplain.

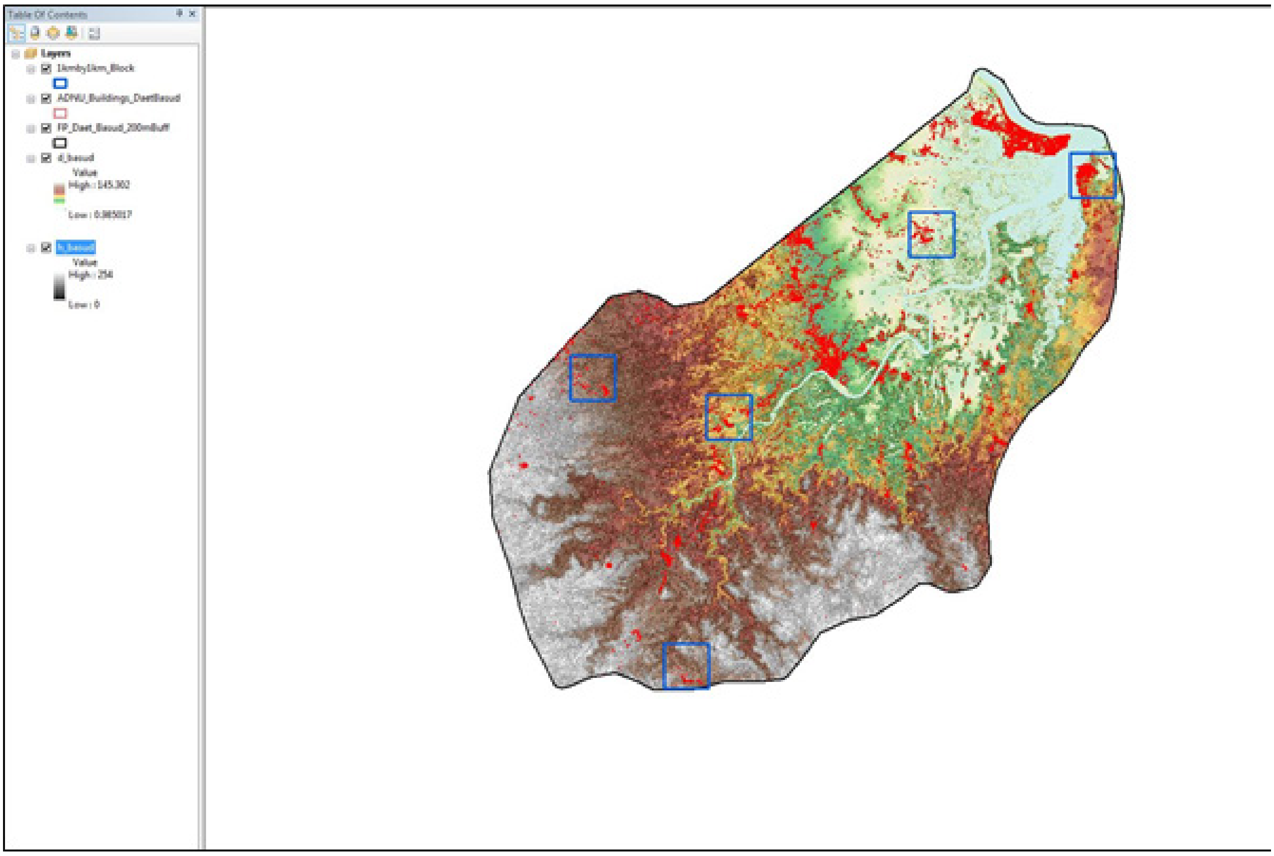


Figure 28. QC blocks for Basud building features

Quality checking of Basud building features resulted in the ratings shown in Table 19.

Table 19. Quality Checking Ratings for Basud Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Basud	96.09	98.83	83.45	PASSED

3.12.2 Height Extraction

Height extraction was done for 16, 519 building features in Basud floodplain. Of these building features, 514 were filtered out after height extraction, resulting to 16,005 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 7.97 m.

3.12.3 Feature Attribution

Feature Attribution was done for 16,005 building features in Basud 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 community with the premise that the local community in the area 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 23 summarizes the number of building features per type. On the other hand, Table 24 shows the total length of each road type, while Table 25 shows the number of water features extracted per type.

[1]Resource Extraction for Geographic Information System (reGIS), March 17,2015.

Table 20. Building Features Extracted for Basud Floodplain

Facility Type	No. of Features
Residential	15,567
School	246
Market	6
Agricultural/Agro-Industrial Facilities	23
Medical Institutions	11
Barangay Hall	29
Military Institution	0
Sports Center/Gymnasium/Covered Court	18
Telecommunication Facilities	0
Transport Terminal	1
Warehouse	4
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	2
Water Supply/Sewerage	6
Religious Institutions	31
Bank	0
Factory	0
Gas Station	4
Fire Station	1
Other Government Offices	38
Other Commercial Establishments	18
Total	16,005

Table 21. Total Length of Extracted Roads for Basud Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Basud	94.75641	20.89968	0	18.93541	0.00	134.5915

Table 22. Number of Extracted Water Bodies for Basud Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Basud	1	256	0	0	0	257

A total of 22 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 29 shows the Digital Surface Model (DSM) of Basud floodplain overlaid with its ground features.

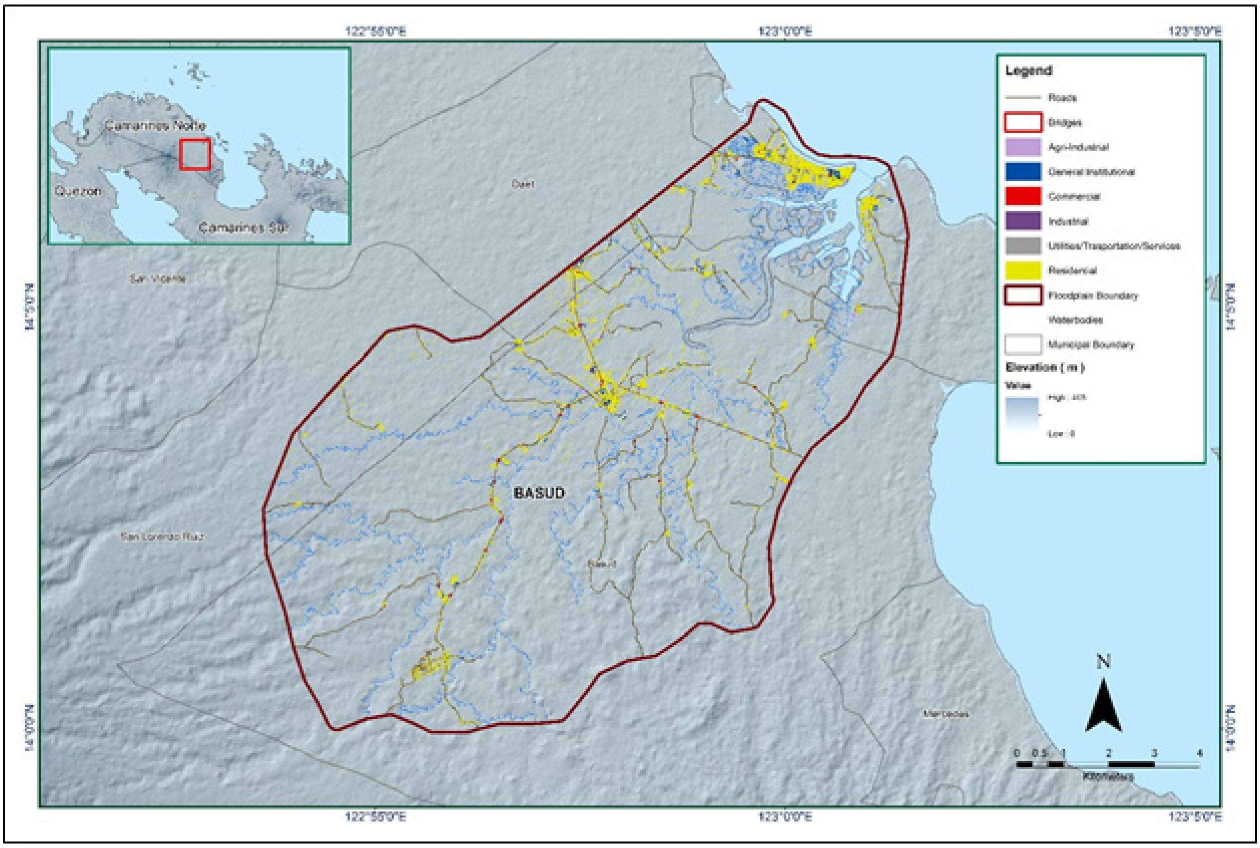


Figure 29. Extracted features for Basud floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE BASUD 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 Basud River on June 28 – July 12, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey at Mocong Bridge in Brgy. Mocong, Municipality of Basud; validation points acquisition of about 55 km covering the Basud River Basin area; and bathymetric survey from its upstream in Brgy. San Jose, Municipality of Basud to the mouth of the river located in Brgy. Maguisoc, in the Municipality of Mercedes, with an approximate length of 11.862 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (see Figure 30).

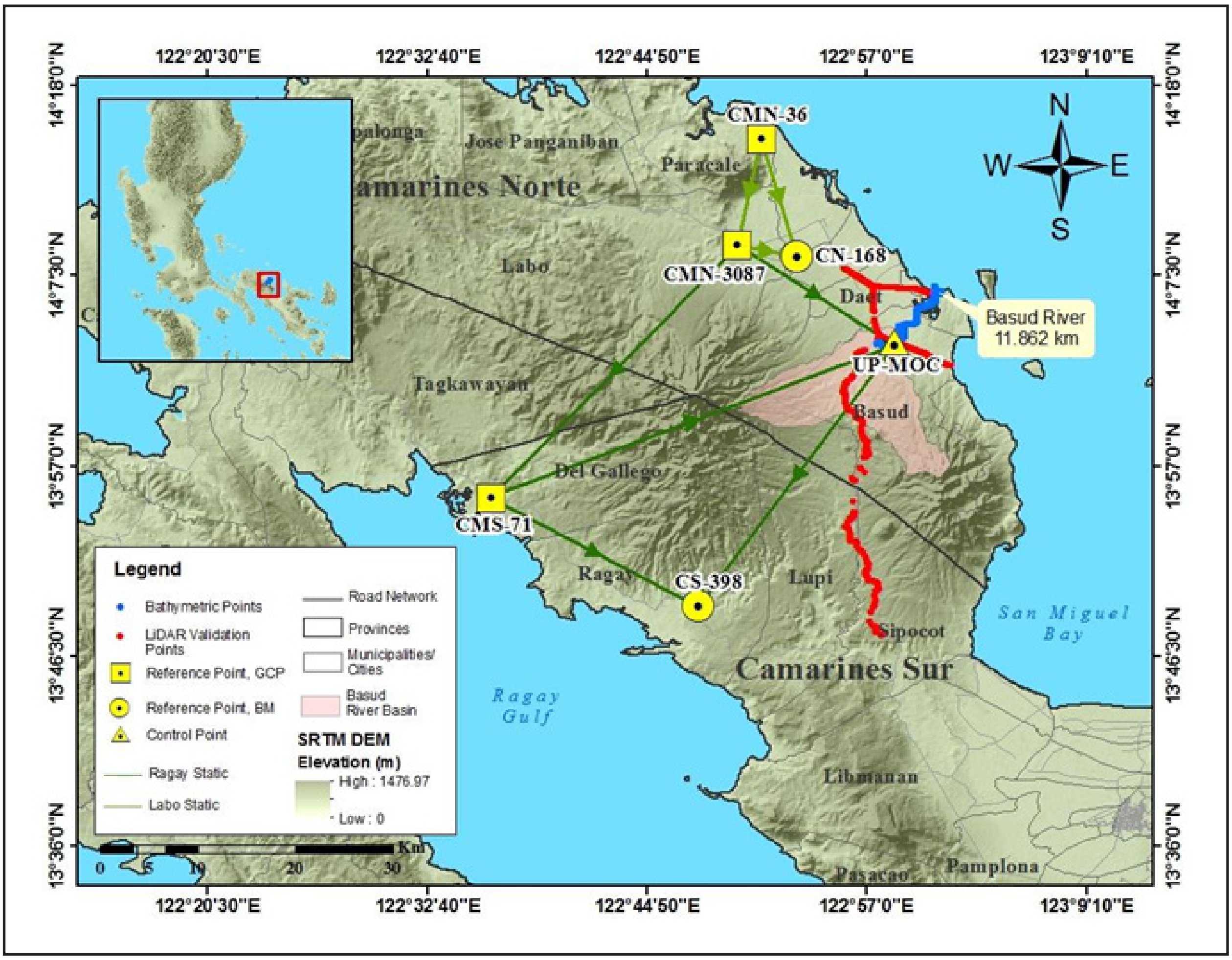


Figure 30. Basud River Survey Extent

4.2 Control Survey

A GNSS network from Labo River Survey was established on January 28, 2016 occupying the control points CMN-36, a second-order GCP, in Brgy. Mampungo, Municipality of Paracale; and CN-168, a first-order BM, in Brgy. Sant Domingo, Muncipality of Vinzonz; both in Camarines Norte.

The GNSS network used for Basud River Basin is composed of two (2) loops established on June 30, 2016 occupying the following reference points: CMS-71, a second-order GCP in Brgy. Cabasag, Municipality of Del Gallego; CS-398, a first order BM, in Brgy. Pangitayan, Municipality of Ragay; and CMN-3087, a fixed point from Labo Survey, located in Brgy. Bakiad, Municipality of Labo.

A control point was established along the approach of Mocong Bridge namely: UP-MOC, located in Brgy. Mocong, Municipality of Basud, Camarines Norte.

The summary of reference and control points and its location is summarized in Table 23 while the GNSS network established is illustrated in Figure 31.

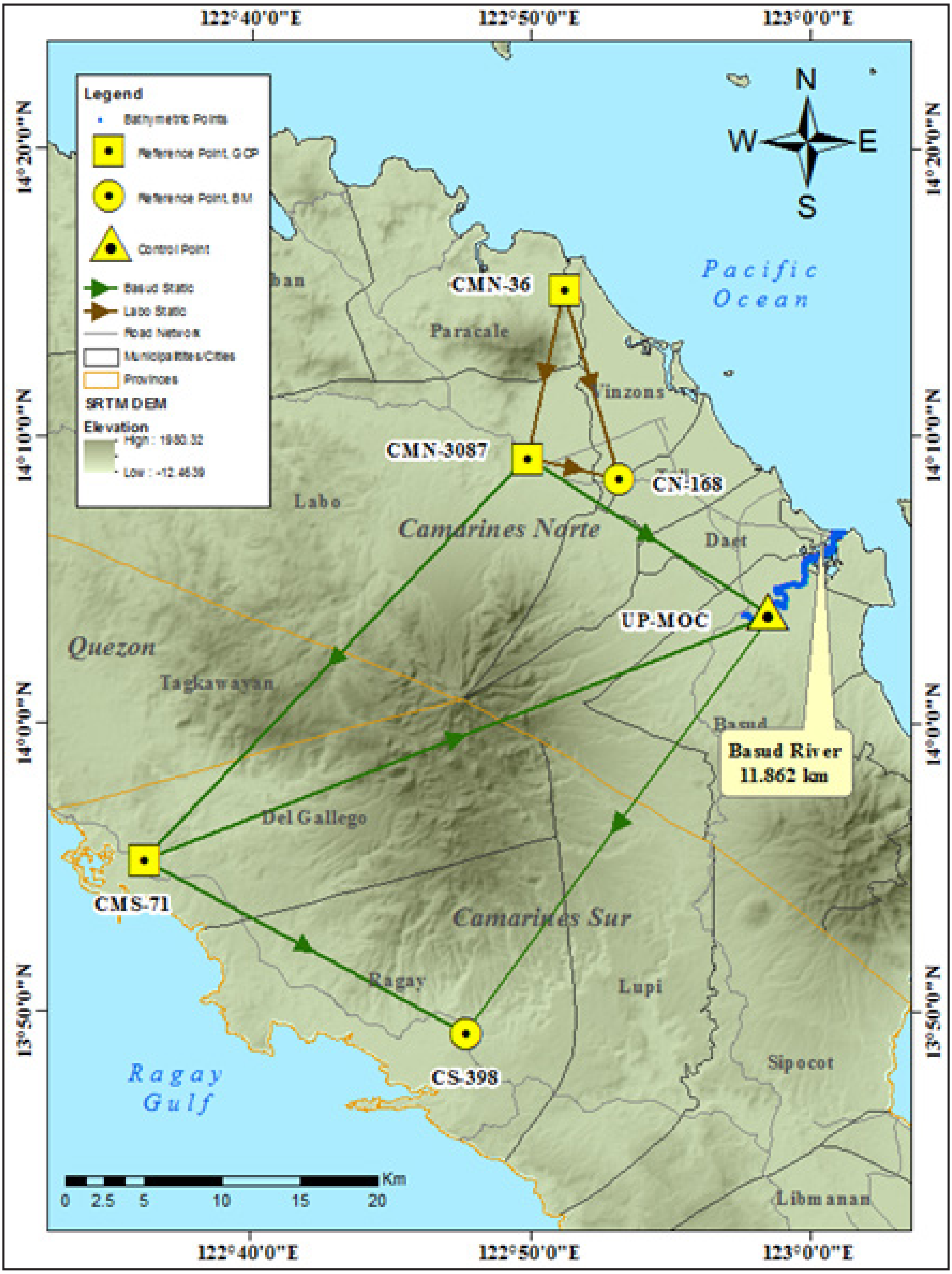


Figure 31. GNSS Network covering Basud River

Table 23. List of Reference and Control Points occupied for Basud River Survey

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
Control Survey on June 30, 2016						
CMN-36	2nd Order GCP	14°15'02.89999"N	122°51'10.48832"E	54.569	5.129	2007
CN-168	1st Order BM	14°08'31.19463"N	122°53'08.49490"E	62.569	12.721	2007
CMN-3087	Used as Marker	14°09'12.36125"N	122°49'52.53365"E	64.661	14.905	2007
Control Survey on June 28, 2016						
CMS-71	2nd order, GCP	13°55'14.18695"N	122°36'12.89833"E	59.636	-	2007
CS-398	1st order, BM	-	-	60.994	10.576	2008
CMN-3087	Fixed Control	14°09'12.36125"N	122°49'52.53365"E	64.661	14.905	2007
UP-MOC	UP Established	-	-	-	-	06-28-16

The GNSS set-ups on recovered reference points and established control points in Basud River are shown in Figure 32 to Figure 35.

Figure 32. GNSS base set up, Trimble® SPS 985, at CMS-71, situated at the approach of Kilbay Bridge in Brgy. Cabasag, Municipality of Del Gallego, Camarines Sur

Figure 33. GNSS receiver setup, Trimble® SPS 882, at CS-398, located at the approach of Ragay Bridge in Brgy. Pangitayan, Municipality of Ragay, Camarines Sur

Figure 34. GNSS receiver setup, Trimble® SPS 852, at CMN-3087, located at the approach of Labo Bridge in Brgy. Bakiad, Municipality of Labo, Camarines Norte

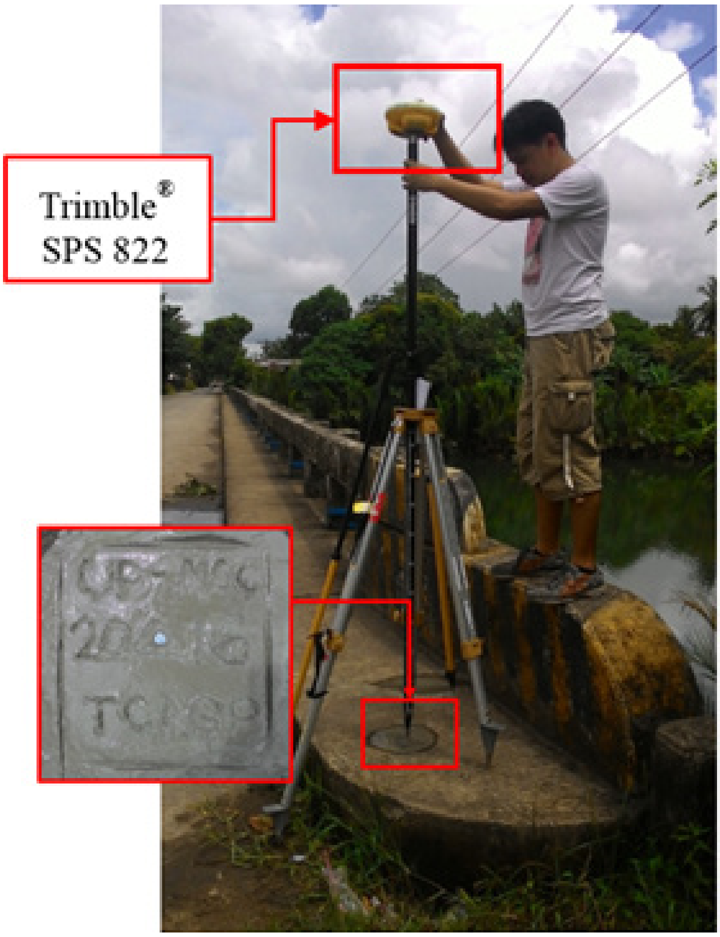


Figure 35. GNSS receiver setup, Trimble® SPS 822, at UP-MOC, located at the approach of Mocong Bridge in Brgy. Mocong, Municipality of Basud, Camarines Norte

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Basud River Basin is summarized in Table 24 generated by TBC software.

Table 24. Baseline Processing Summary Report for Basud River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CMS-71 --- CS-398	06-30-16	Fixed	0.003	0.014	118°07'06"	23448.013	1.313
CMS-71 --- UP-MOC	06-30-16	Fixed	0.004	0.014	68°18'41"	43178.316	-4.130
UP-MOC --- CS-398	06-30-16	Fixed	0.004	0.015	215°50'13"	33277.281	5.437
CMN-3087 --- UP-MOC	06-30-16	Fixed	0.003	0.015	122°19'44"	18380.742	-9.211
CMN-3087 --- CMS-71	06-30-16	Fixed	0.003	0.017	223°41'59"	35614.428	-5.115

As shown in Table 24, a total of five (5) baselines were processed with reference points CMS-71 and CS-398 held fixed for coordinate and elevation values, including CMS-3087 as fixed control from Labo Survey. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates Table C-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:

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

where:

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

for each control point. See the Network Adjustment Report shown in Table 25 to Table 28 for complete details.

The four (4) control points, CMS-71, CS-398, CMS-3087 and UP-MOC were occupied and observed simultaneously to form a GNSS loop. Coordinates of CMS-71 and CMN-3087; and elevation values of CS-398 and CMN-3087 were held fixed during the processing of the control points as presented in Table 25. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 25. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
CMS-71	Local	Fixed	Fixed		
CS-398	Grid				Fixed
CMN-3087	Local	Fixed	Fixed	Fixed	
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 26. The fixed control CMS-110 has no values for grid errors while CS-461 has no value for elevation errors.

Table 26. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
CMS-71	457175.646	?	1538981.558	?	10.059	0.046	LL
CS-398	477829.729	0.011	1527900.590	0.010	10.576	?	e
CMN-3087	481789.697	?	1564701.975	?	14.905	?	LLh
UP-MOC	497307.927	0.011	1554865.116	0.010	5.214	0.046	

With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)} < 20cm$ for horizontal and $z_e < 10\ cm$ for the vertical; the computation for the accuracy are as follows:

a. CMS-71
Horizontal Accuracy = Fixed
Vertical Accuracy = 4.6 < 10 cm

b. CS-398
Horizontal Accuracy = $\sqrt{((1.1)^2 + (1.0)^2}$
= $\sqrt{(1.21 + 1.0)}$
= 1.49 < 20 cm
Vertical Accuracy = Fixed

c. CMN-3087
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

d. UP-MOC
Horizontal Accuracy = $\sqrt{((1.1)^2 + (1.0)^2}$
= $\sqrt{(1.21 + 1.0)}$
= 1.49 < 20 cm
Vertical Accuracy = 4.6 < 10 cm

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

Table 27. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
CMS-71	N13°55'14.18695"	E122°36'12.89833"	59.636	0.046	LL
CS-398	N13°49'14.33596"	E122°47'41.49841"	60.994	?	e
CMN-3087	N14°09'12.36125"	E122°49'52.53365"	64.661	?	LLh
UP-MOC	N14°03'52.37147"	E122°58'30.23146"	55.501	0.046	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 27. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 28.

Table 28. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
CMS-71	2nd order, GCP	13°55'14.18695"	122°36'12.89833"	59.636	1538981.558	457175.646	10.059
CS-398	1st order, BM	13°49'14.33596"	122°47'41.49841"	60.994	1527900.59	477829.729	10.576
CMN-3087	Fixed Control	14°09'12.36125"	122°49'52.53365"	64.661	1564701.975	481789.697	14.905
UP-MOC	UP Established	14°03'52.37147"	122°58'30.23146"	55.501	1554865.116	497307.927	5.214

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

Cross-section and as-built survey were conducted on July 1 and 2, 2016 at the upstream side of Mocong Bridge in Brgy. Mocong, Municipality of Basud, Camarines Norte as shown in Figure 36. A total station through open traverse method was utilized for this survey as shown in Figure 37.

Figure 36. Mocong bridge facing downstream

Figure 37. Mocong bridge as-built survey

The cross-sectional line of Mocong Bridge is about 163 m with one hundred and twenty-two (122) cross-sectional points using the control point UP-MOC as the GNSS base station. The cross-section diagram, planimetric map, and the bridge data form, are shown in Figure 38 to Figure 40, respectively.

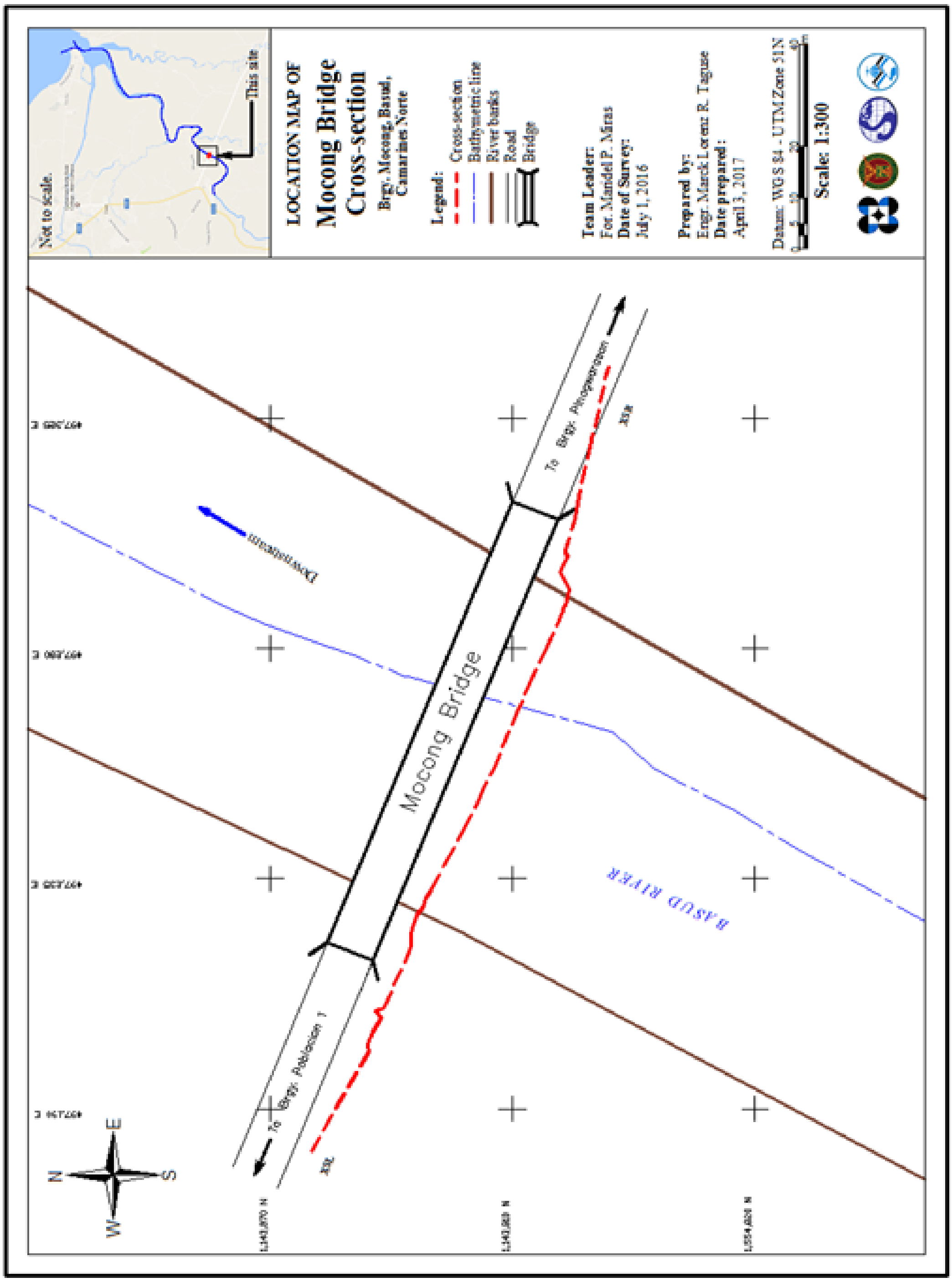


Figure 38. Mocong Bridge cross-section location map

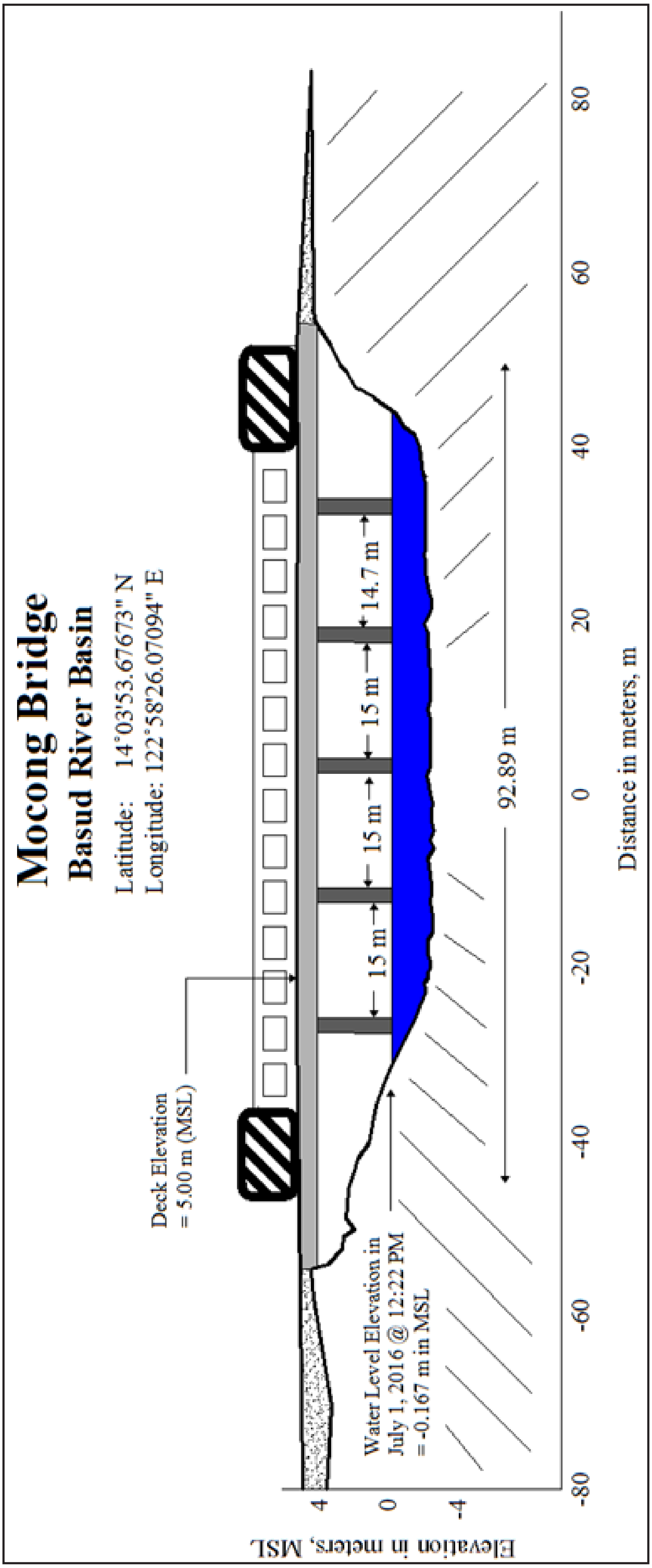


Figure 39. Mocong bridge cross-secction diagram

Bridge Data Form

Bridge Name: Mocong Bridge — Date: July 1, 2016

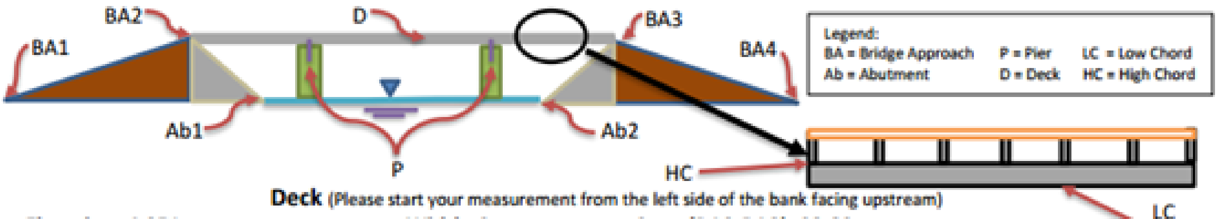
River Name: Basud River — Time: 12:22 PM

Location (Brgy, City,Region): Brgy. Mocong, Municipality of Basud, Camarines Norte

Survey Team: Maridel Miras, Caren Ordoña

Flow condition: normal — Weather Condition: fair

Latitude: 14˚03'53.67673" N — Longitude: 122˚58'26.07094" E



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

Elevation: 4.851 m — Width: 9 m — Span (BA3-BA2): 92.89 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	4.851 m	BA3	131.431 m	5.175 m
BA2	NA	NA	BA4	162.765 m	4.403 m

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

	Station (Distance from BA1)	Elevation
Ab1	Not available	Not available
Ab2	Not available	Not available

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	54.158 m	5.174 m	NA
Pier 2	69.155 m	5.211 m	NA
Pier 3	84.071 m	5.173 m	NA
Pier 4	99.098 m	5.224 m	NA
Pier 5	113.867 m	5.150 m	NA

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

Figure 40. Bridge as-built form of Mocong Bridge

Water surface elevation of Basud River was determined using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on July 1, 2016 at 12:22 PM with a value of -0.167 m in MSL as shown in Figure 39. This was translated into marking on the bridge's deck using the same technique. The making has a value of 3.254 m in MSL as shown in Figure 41. This will serve as reference for flow data gathering and depth gauge deployment of partner HEI responsible for Basud river, the Ateneo De Naga University.

Figure 41. Water-level markings on Mocong Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on July 1-3, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted in front of a vehicle as shown in Figure 42. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna heights were 1.71, 2.28, and 2.24 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 UP-MOC occupied as the GNSS base stations in the conduct of the survey.

Figure 49. The validation point acquisition survey setup using a GNSS receiver fixed in a van along the Silaga River Basin

TThe survey started from the Mocong Bridge in Brgy. Mocong, in the Municipality of Bansud; going north covering twenty-three (23) barangays in Municipalities of Basud, Daet, Mercedes and ended in Brgy. Itomang, Municipality of Talisay; and going south covering thirteen (13) more barangays in Municipalities of Basud and San Lorenzo Ruiz, Camarines Norte and nine (9) barangays in Municipalities of Sipocot and Lupi, ended in Brgy. Alteza, Municipality of Sipocot, Camarines Sur. The survey gathered a total of 5,800 points with approximate length of 55 km using UP-MOC as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 43.

Figure 43. Validation point acquisition survey of Basud River basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on July 2, 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 44. The survey started in Brgy. San Jose, Municipality of Basud, with coordinates 14°03'45.01207"N, 122°57'34.70089"E, and ended at the mouth of the river in Brgy. Manguisoc, in Municipality of Mercedes with coordinates 14°06'41.13753"N, 123°00'52.08692"E. The control point UP-MOC was used as the GNSS base station all throughout the entire survey.throughout the entire survey.

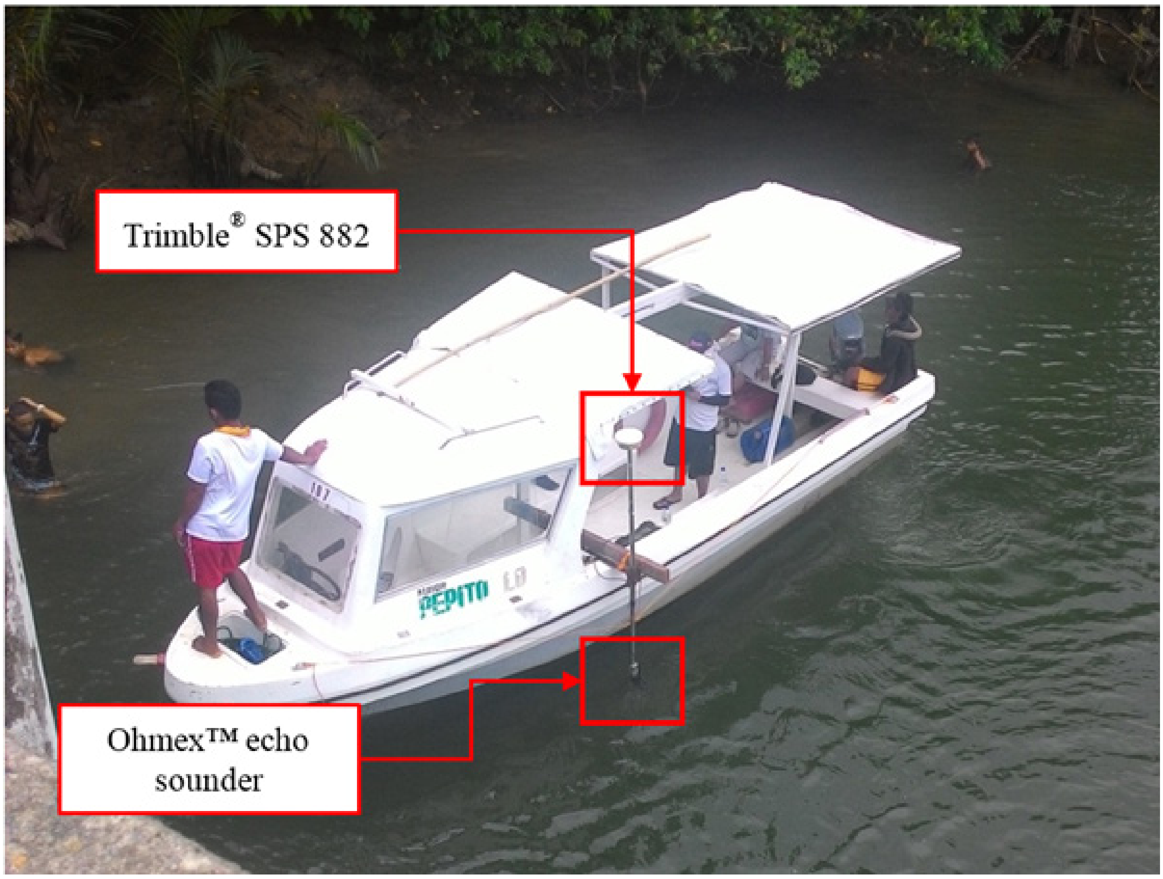


Figure 44. Bathymetric survey using Ohmex™ single beam echo sounder in Basud River

The bathymetric survey for Basud River gathered a total of 17,265 points covering 11,862 km of the river traversing sixteen (16) barangays in Municipalities of Basud, Daet and Mercedes. A CAD drawing was also produced to illustrate the riverbed profile of Basud River. As shown in Figure 46, the highest and lowest elevation has a 11-m difference. The highest elevation observed was 0.185 m in MSL located at Brgy. Mampili, Basud, while the lowest was -11.146 m below MSL located at the downstream portion of the river in Brgy. Poblacion VII, in Municipality of Mercedes. A 2-km bathymetric line was not surveyed because there is already an existing LiDAR survey data for it.

Figure 45. Bathymetric survey of Basud River

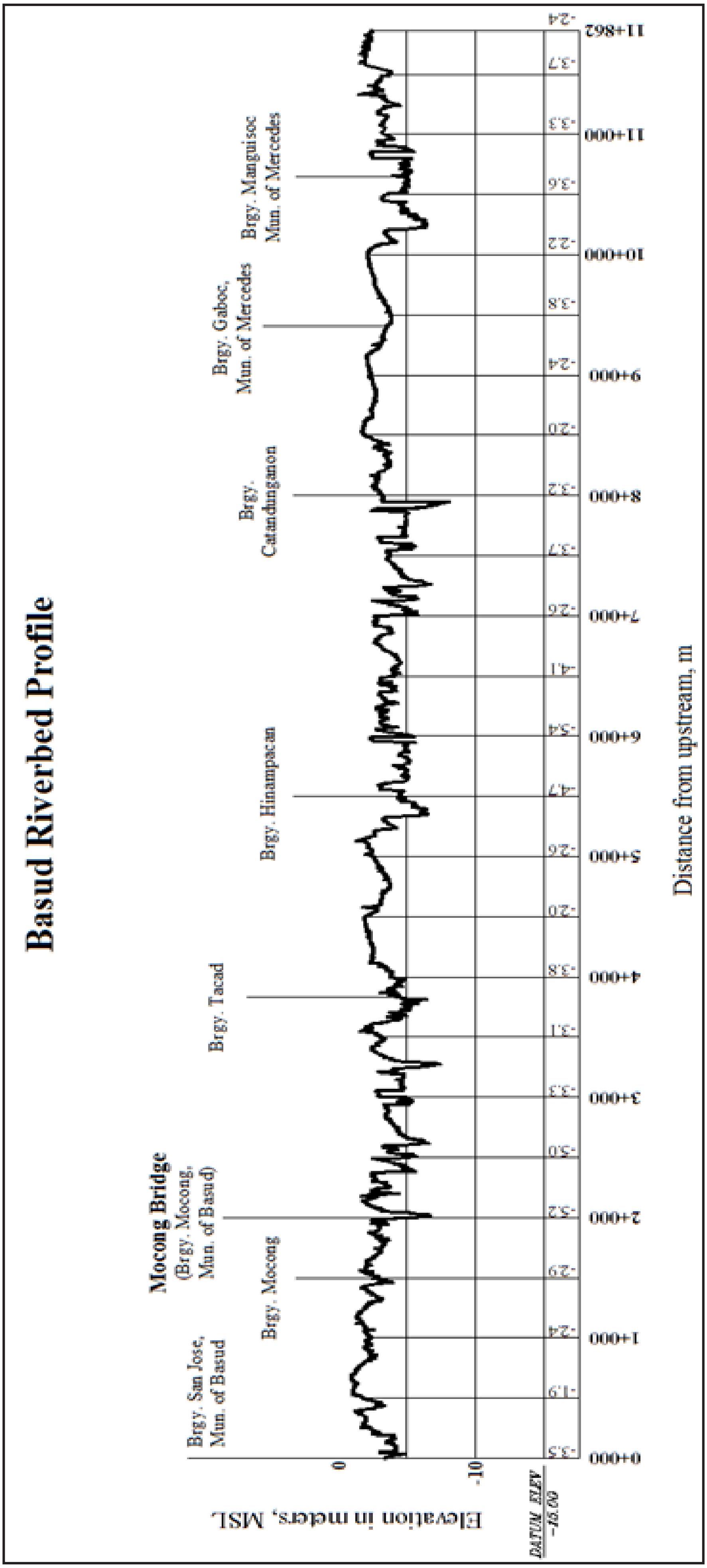


Figure 46. Basud Riverbed Profile

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, Christian Javier B. Arroyo, Daniel S. Baer, Jr., Mark D. Delloro, Julius Hector S. Manchete, John Paul B. Obina, Engr. Herminio Magpantay, Lech Fidel C. Pante, Aaron San Andres, and Engr. Ferdinand E. Bien

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data that affect the hydrologic cycle of the Basud 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 Basud River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from one automatic rain gauge (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The rain gauge was installed at San Lorenzo Ruiz (Figure 47). The precipitation data collection started from July 30, 2016 at 12:00 AM to July 31, 2016 at 2:00 AM with a 15-minute recording interval.

The total precipitation for this event in San Lorenzo Ruiz ARG is 28.6mm. It has a peak rainfall of 4.4mm on July 30, 2016 at 1:00 AM. The lag time between the peak rainfall and discharge is 17 hours and 40 minutes.

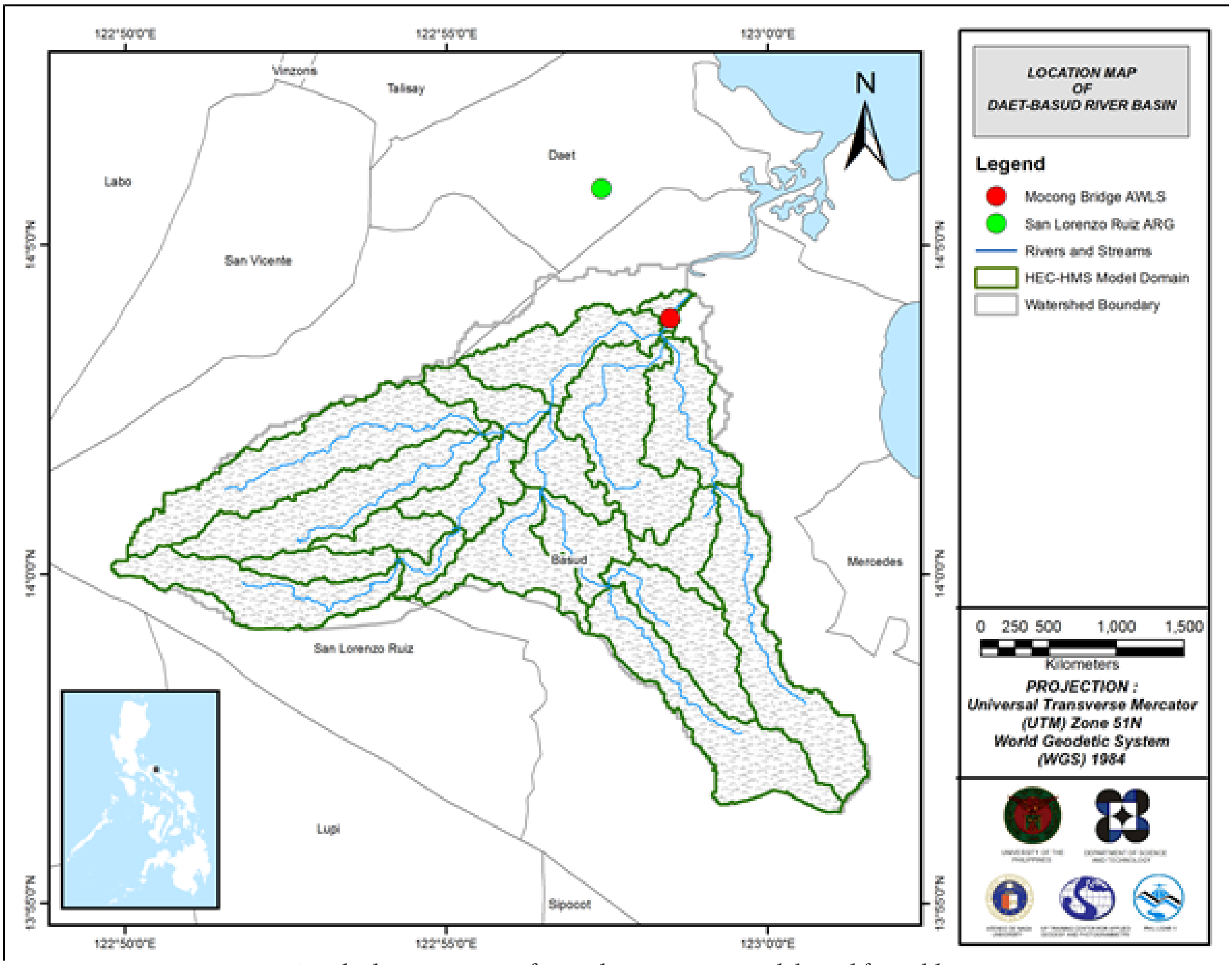


Figure 47. The location map of Basud HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Mocong Bridge, Basud, Camarines Norte (14°3'53.30"N, 122°58'28.67"E). It gives the relationship between the observed water levels at Mocong Bridge and outflow of the watershed at this location.

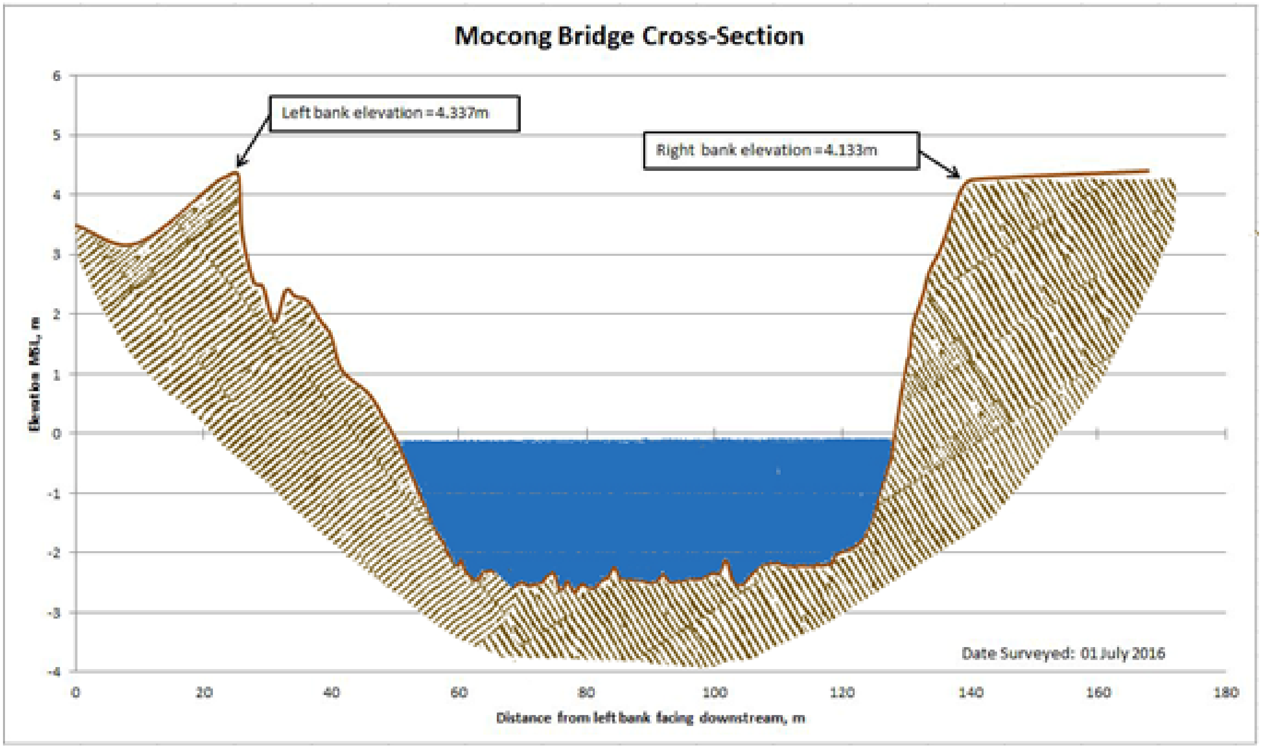


Figure 48. The cross-section plot of Mocong Bridge

For Mocong Bridge, the rating curve is expressed as Q = 40.159e0.4935h as shown in Figure 49.

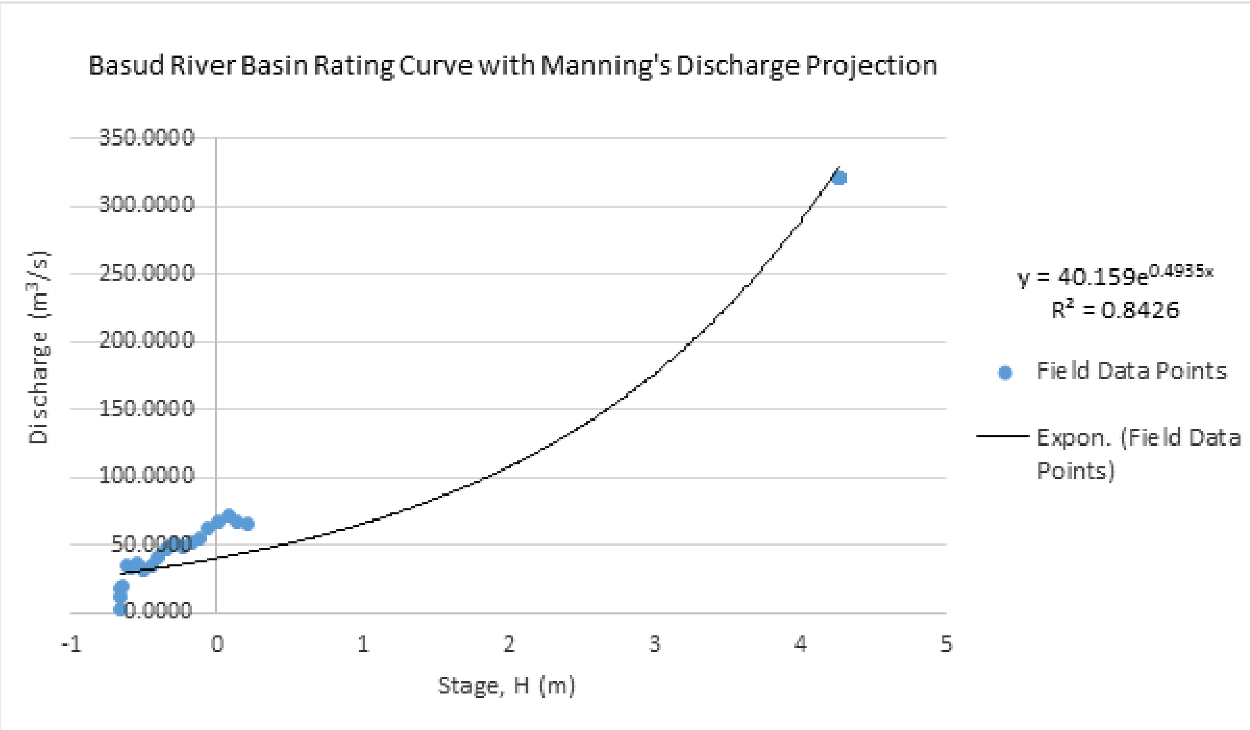


Figure 49. The rating curve of Mocong Bridge in Basud, Camarines Norte

This rating curve equation was used to compute the river outflow at Mocong Bridge for the calibration of the HEC-HMS model shown in Figure 50. The total rainfall for this event is 28.6mm and the peak discharge is 76.5 m3/s at 6:40 PM, July 30, 2016.

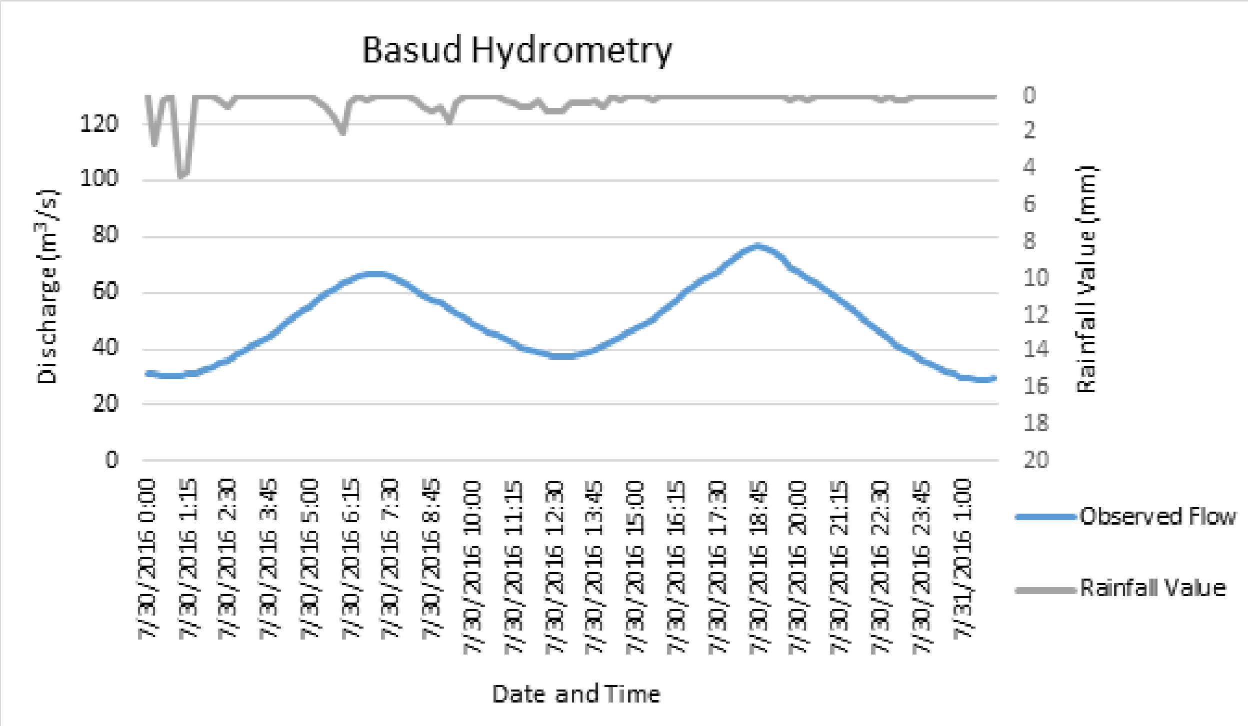


Figure 50. Rainfall and outflow data of the Basud River Basin, which was used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Daet RIDF. 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. This station was chosen based on its proximity to the Basud watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 29. RIDF values for Donsol Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	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	271.9	271.9	370.4	438.3	520.3

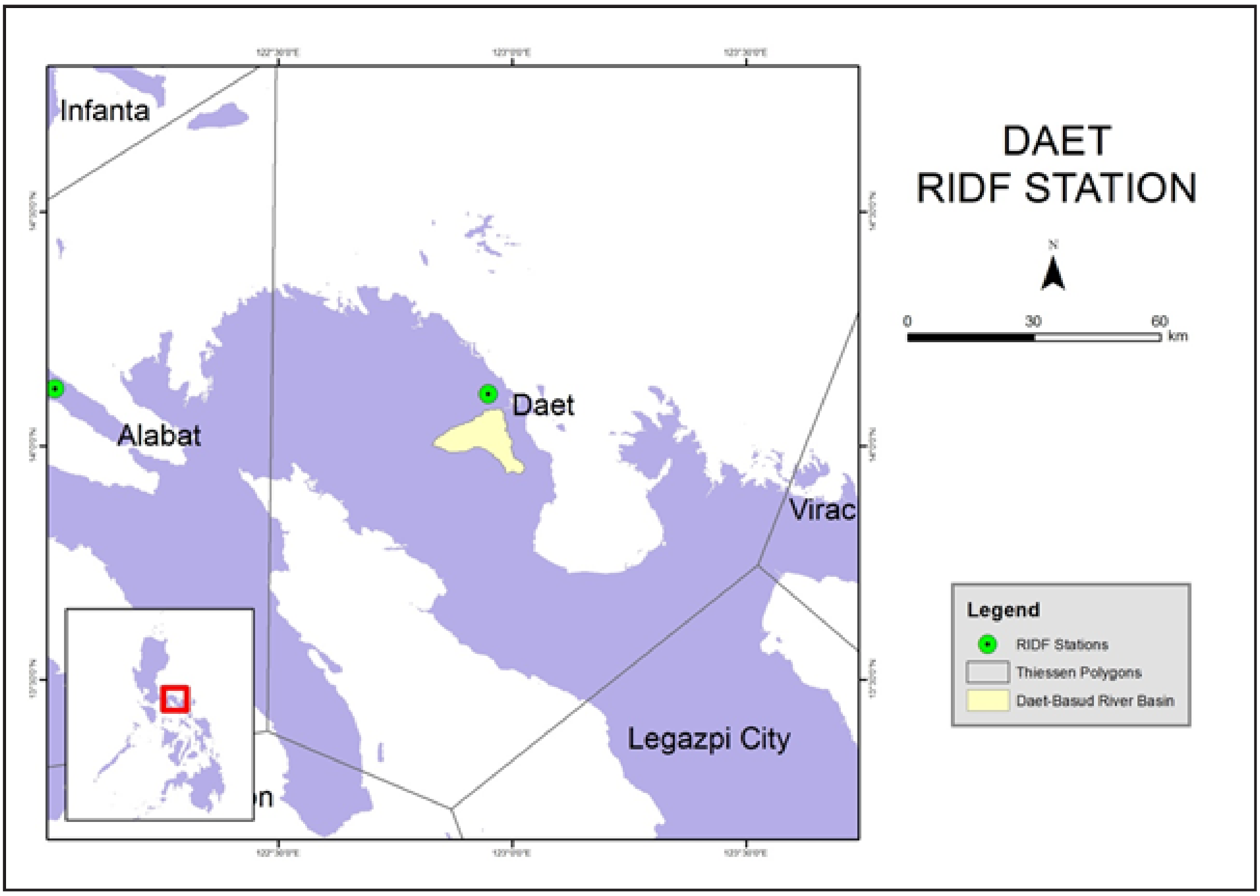


Figure 51. The location of the Daet RIDF station relative to the Basud River Basin

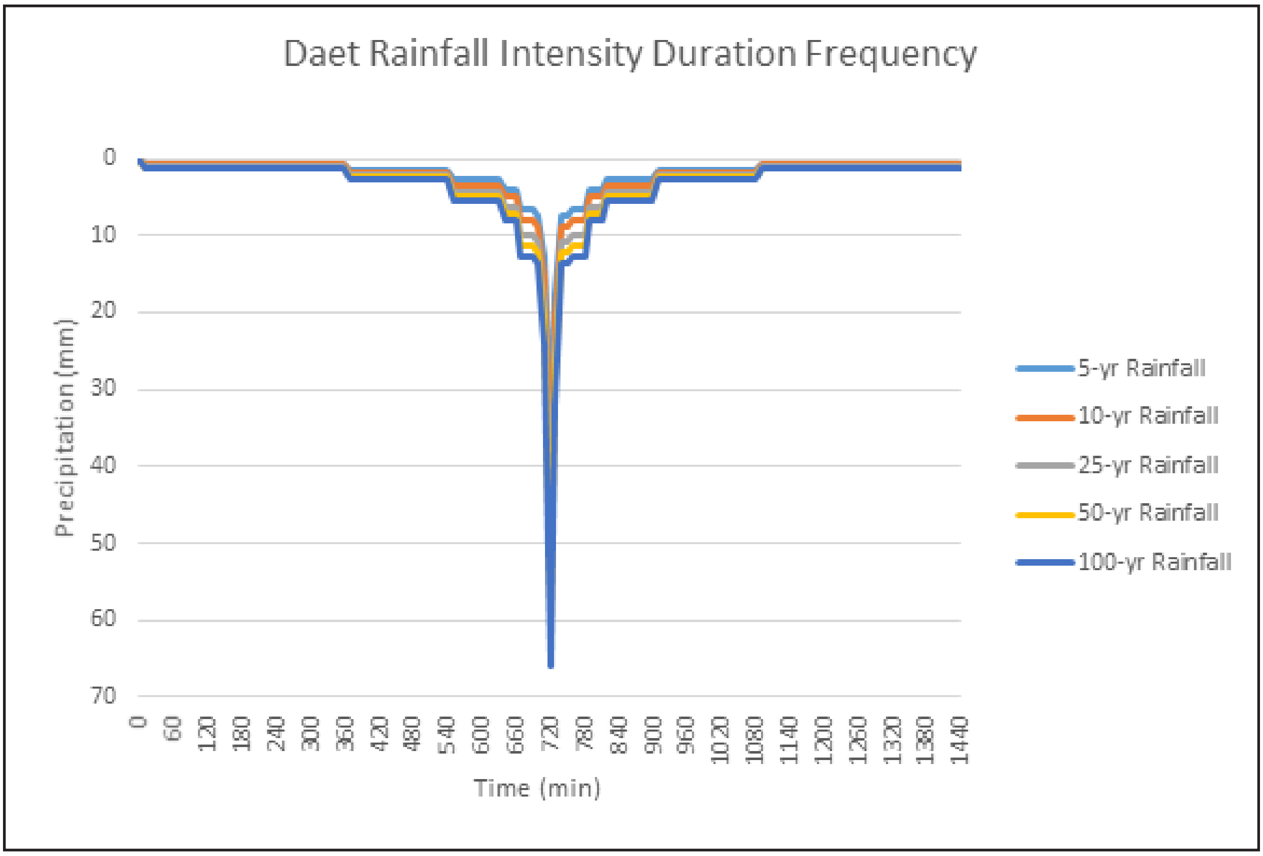


Figure 52. The synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil shapefile was generated before 2004 and borrowed from the Bureau of Soils and Water Management. It is under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Donsol River Basin are shown in Figures 53 and 54, respectively.

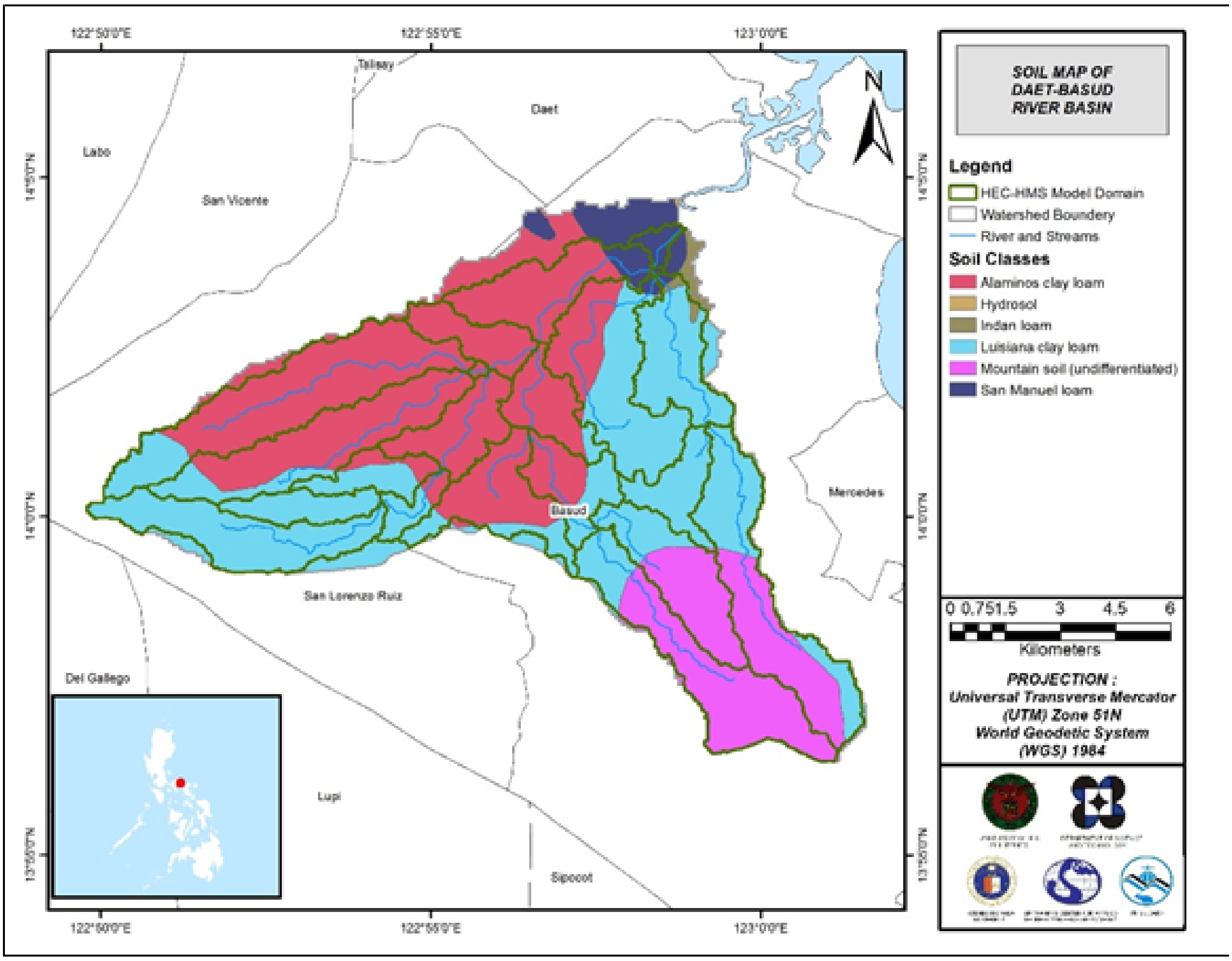


Figure 53. Soil map of Basud River Basin

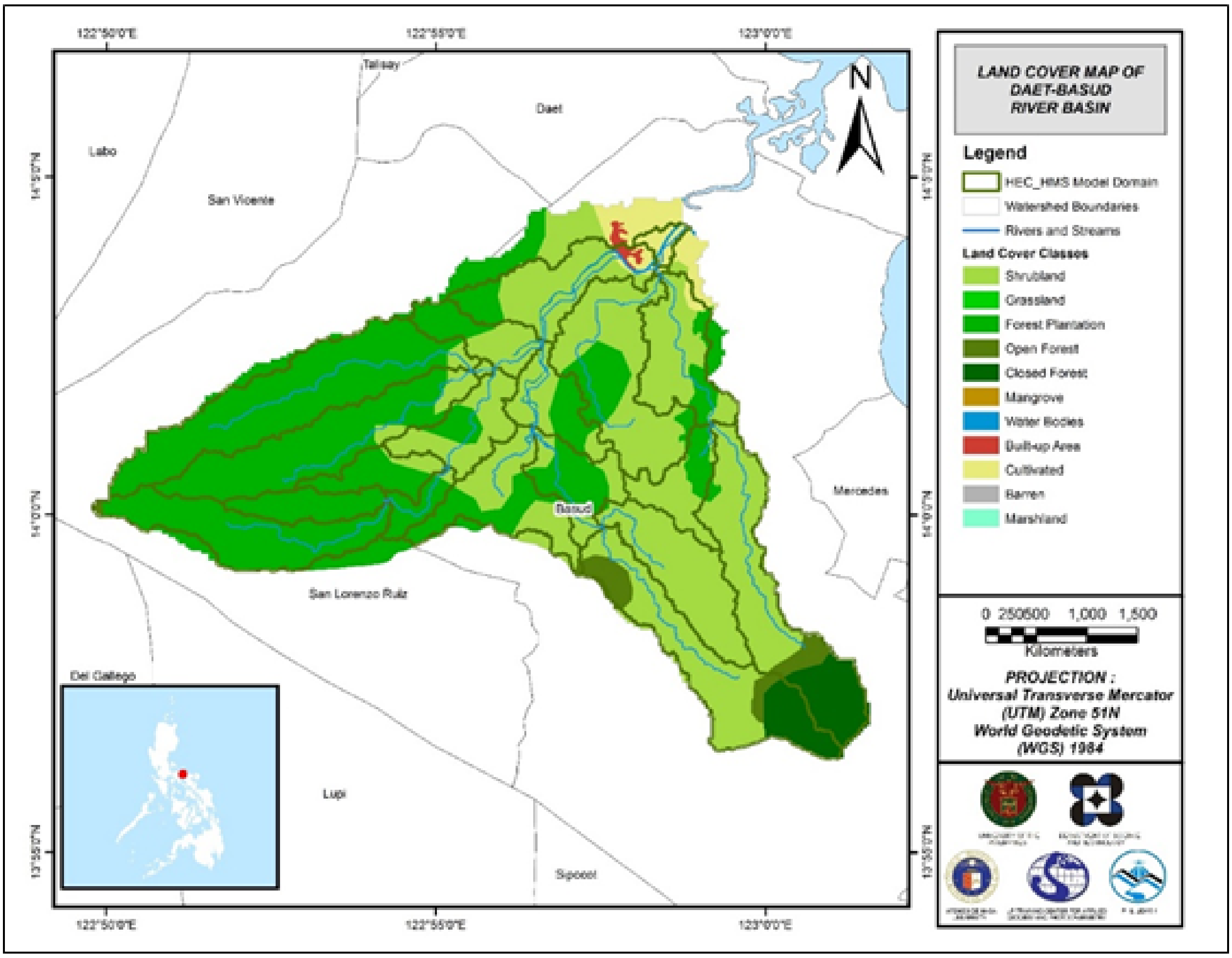


Figure 54. Land cover map of Basud River Basin (Source: NAMRIA)

For Basud, six soil classes were identified. These are Alaminos clay loam, Luisiana clay loam, Indan loam, San Manuel loam, hydrosol, and mountain soil. Moreover, six land cover classes were identified. These are shrubland, grassland, open and closed forests, cultivated, and built-up areas.

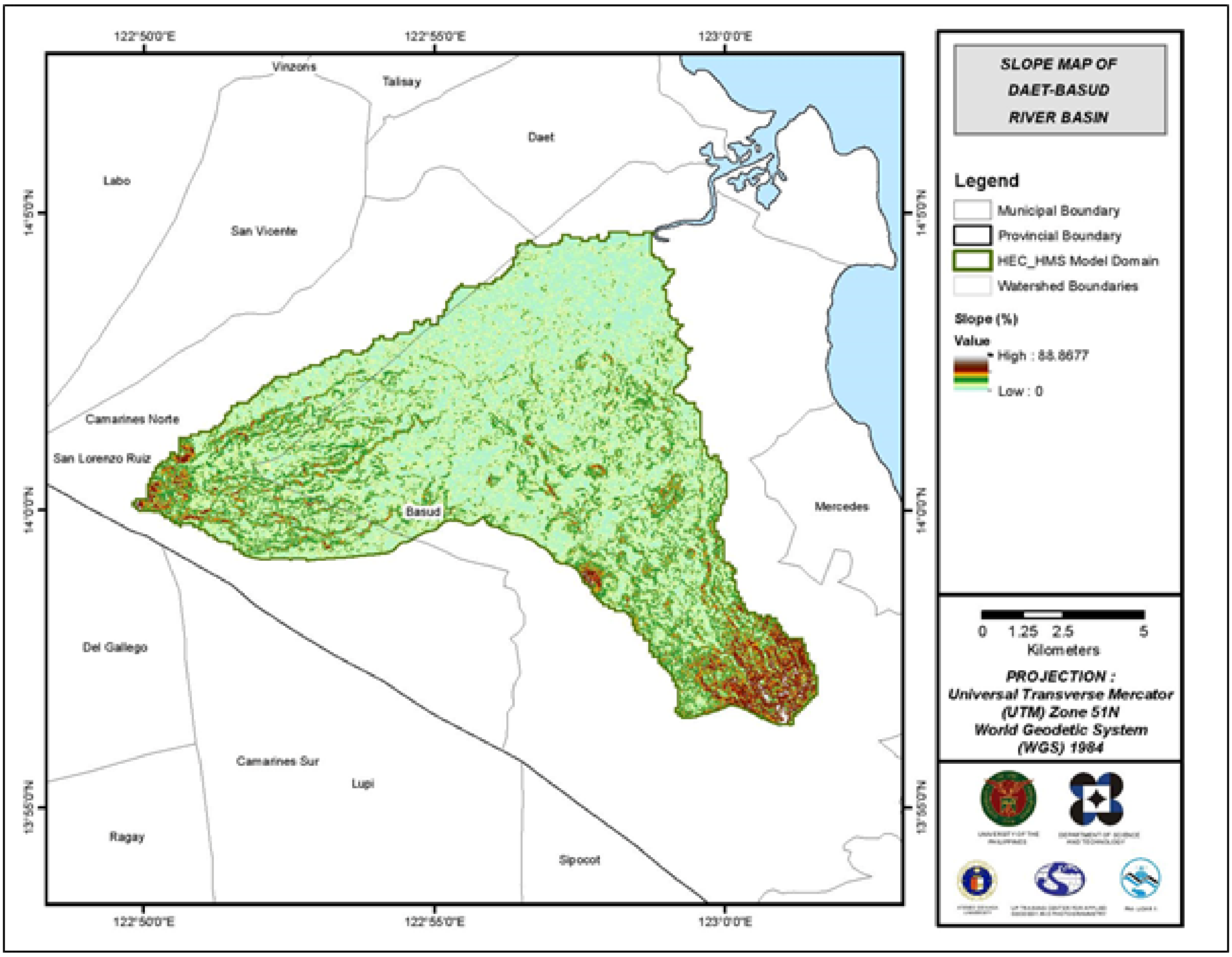


Figure 55. Slope map of Basud River Basin

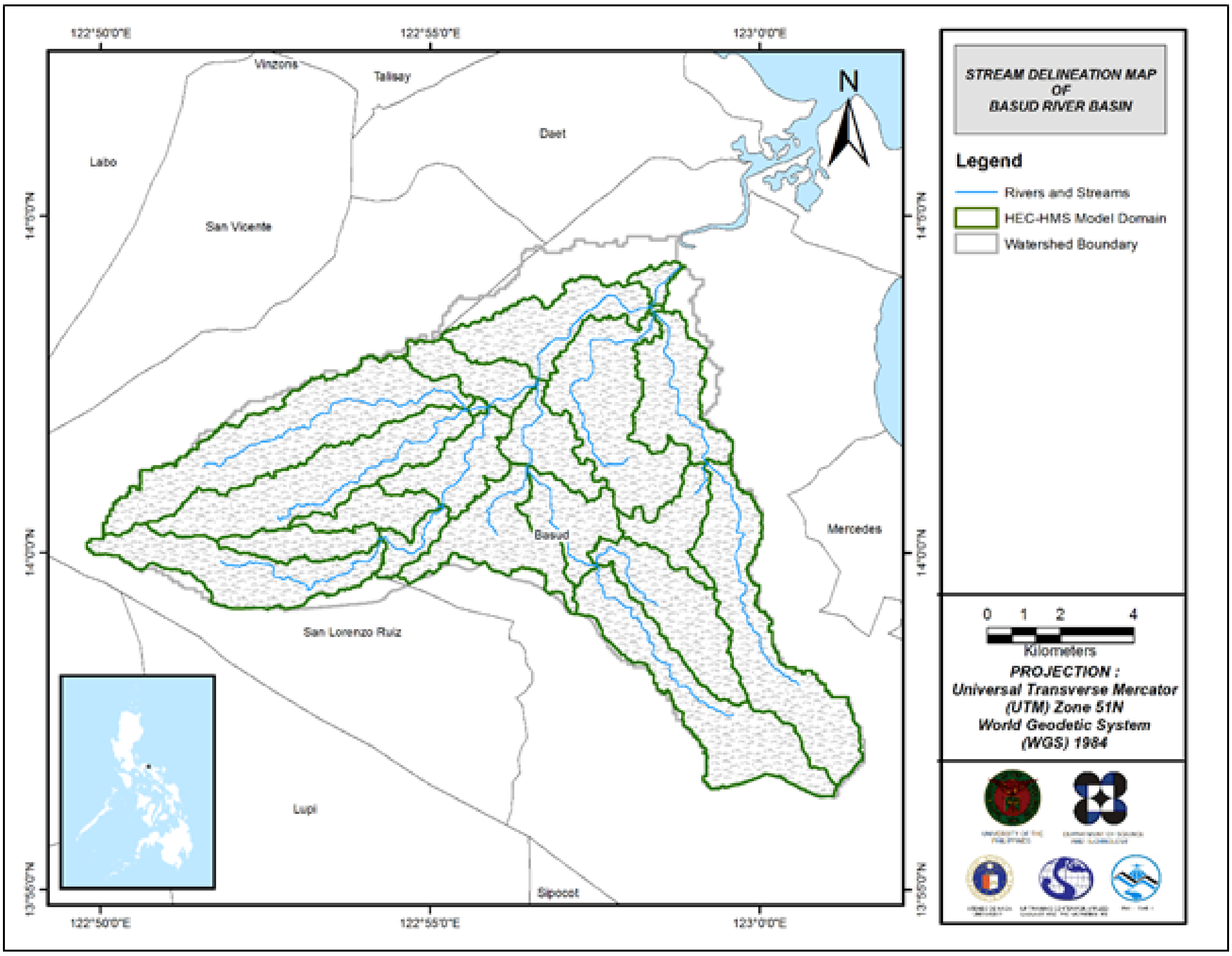


Figure 56. Stream delineation map of Basud River Basin

Using the SAR-based DEM, the Basud basin was delineated and further divided into subbasins. The model consists of 21 sub basins, 10 reaches, and 10 junctions, as shown in Figure 57. The main outlet is Mocong Bridge.

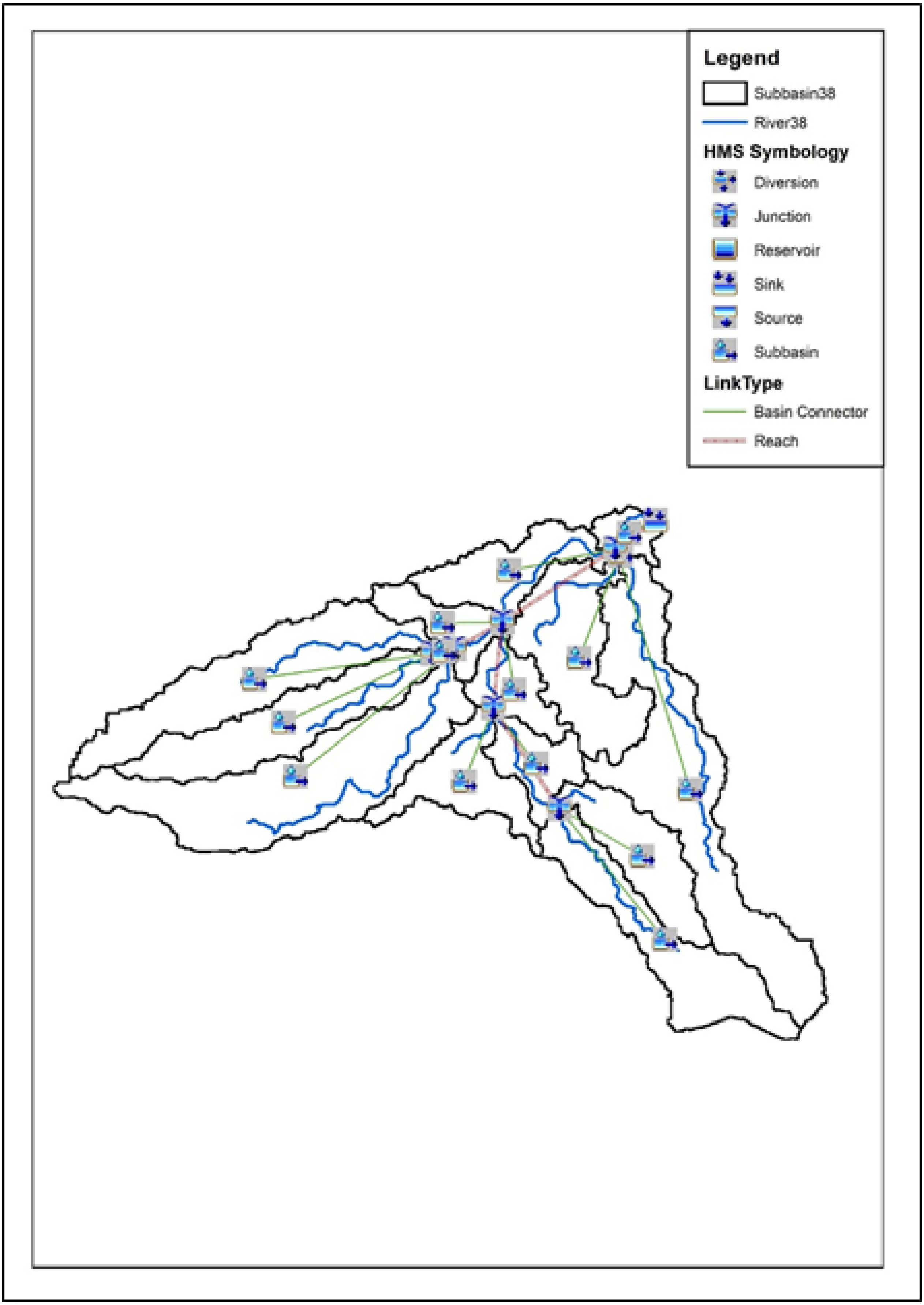


Figure 57. The Basud River Basin model generated in HEC-HMS

5.4 Cross-section Data

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

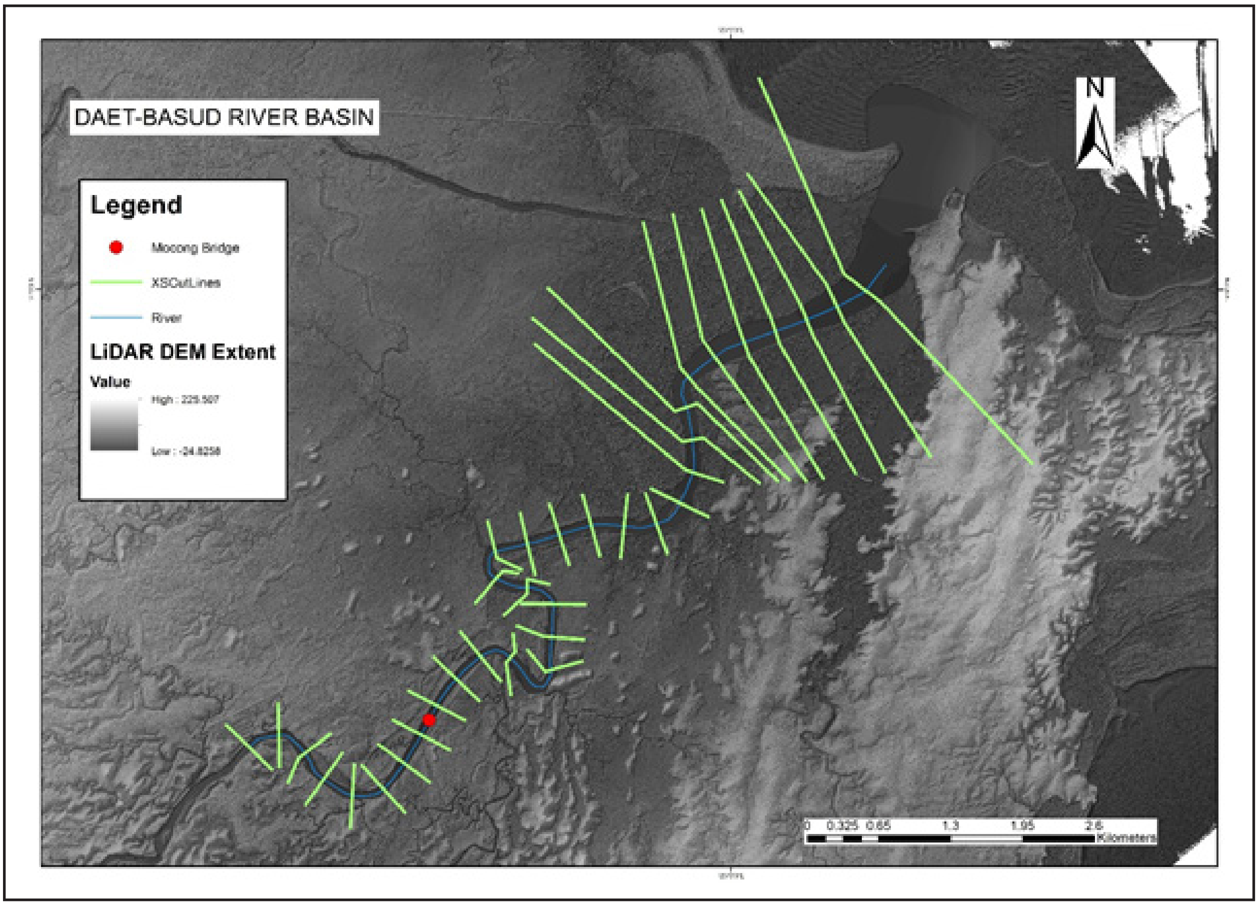


Figure 58. River cross-section of Basud River generated through Arcmap HEC GeoRAS tool

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 south and southwest of the model to the north, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

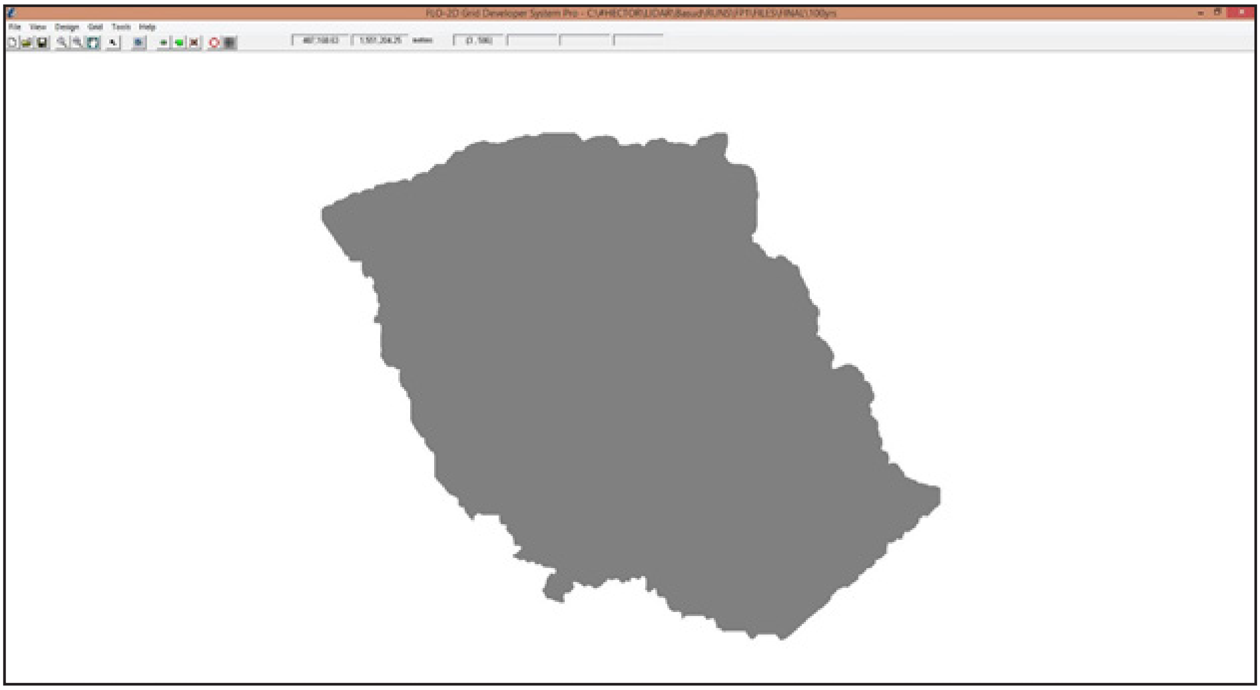


Figure 59. Screenshot of subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 66.00684 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 0.2m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0m2/s. The generated hazard maps for Basud are in Figures 63, 65, and 67.

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 51,474,100.00m2. The generated flood depth maps for Basud are in Figures 64, 66, and 68.

There is a total of 38,905,193.13m3 of water entering the model. Of this amount, 22,274,966.94m3 is due to rainfall while 16,630,226.19m3 is inflow from other areas outside the model. 4,918,806.50m3 of this water is lost to infiltration and interception, while 3,121,939.75m3 is stored by the flood plain. The rest, amounting up to 30,864,297.57m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Basud HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 60 shows the comparison between the two discharge data.

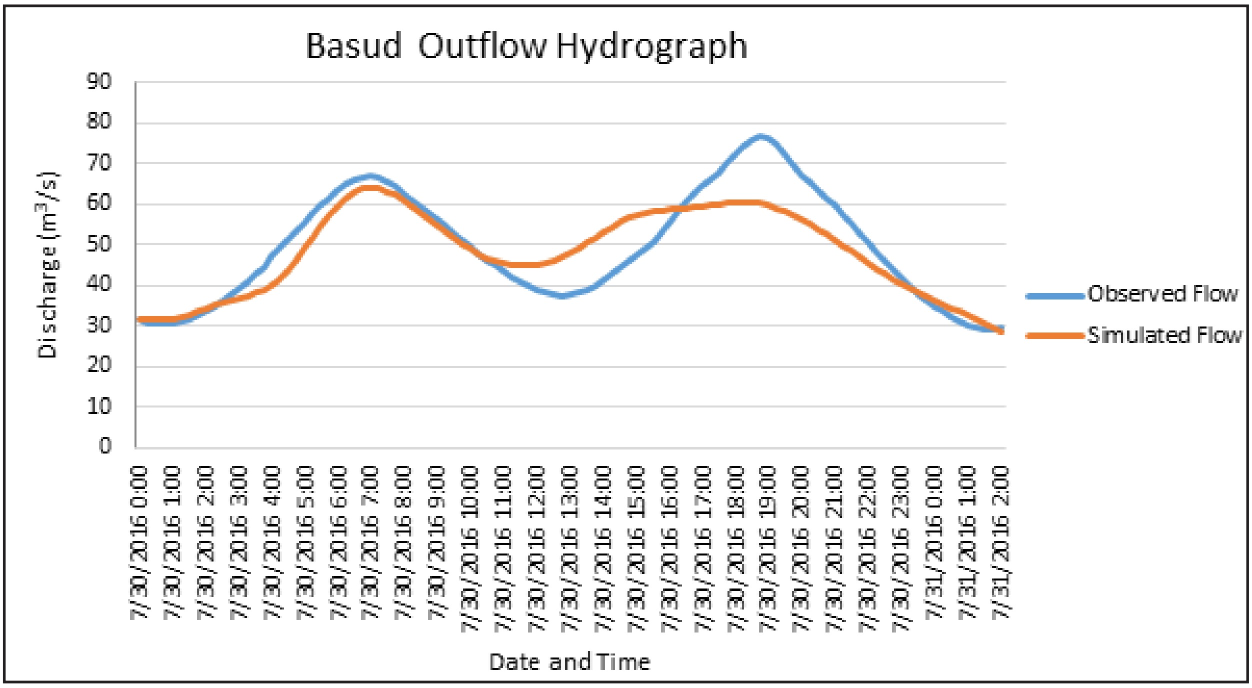


Figure 60. Outflow Hydrograph of Basud produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 30 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 30. Range of calibrated values for the Donsol River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.001-23
			Curve Number	94-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02-27
			Storage Coefficient (hr)	0.02-0.4
	Baseflow	Recession	Recession Constant	0.00001-0.00003
			Ratio to Peak	0.0008-1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0009-0.01

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 0.001mm to 23mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 94-99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Basud, the basin mostly consists of shrubland and the soil consists of Alaminos clay loam, Luisiana clay loam, and mountain soil.

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 27 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 and ratio to peak is the ratio of the baseflow discharge to the peak discharge. For Basud river basin, it will take at least 18 hours from the peak discharge to go back to the initial discharge.

Manning's roughness coefficient of 0.0001 corresponds to the common roughness in Basud watershed, which is determined to be built-up area that is concrete and float-finished (Brunner, 2010).

Table 31. Summary of the Efficiency Test of Basud HMS Model

Accuracy measure	Value
RMSE	6.70
r2	0.78
NSE	0.76
PBIAS	2.68
RSR	0.49

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 6.70 (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 0.78.

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 0.76.

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 2.68.

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 0.49.

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 61) shows the Basud 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 Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods from 1,310.4m3/s in a 5-year return period to 2,518.5m3/s in a 100-year return period.

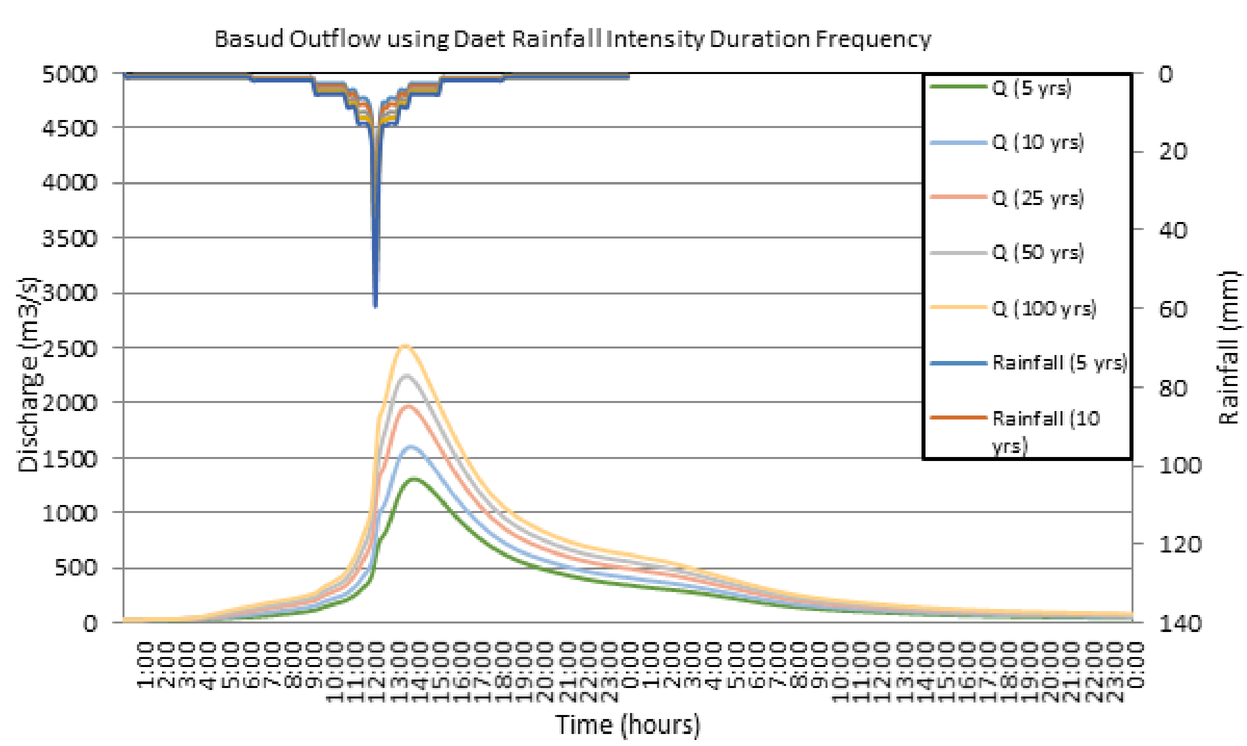


Figure 61. The outflow hydrograph at the Basud Basin, generated using the simulated rain events for 24-hour period for Daet station

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Basud discharge using the Daet Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 32.

Table 32. Peak values of the Basud 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	277.54	31.8	1310.4	1 hour, 50 minutes
10-Year	335.77	38.5	1602.3	1 hour, 40 minutes
25-Year	409.33	46.9	1971.7	1 hour, 30 minutes
50-Year	463.87	53.2	2245.7	1 hour, 30 minutes
100-Year	518.02	59.4	2518.5	1 hour, 20 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 62 shows a generated sample map of the Basud River using the calibrated HMS base flow.

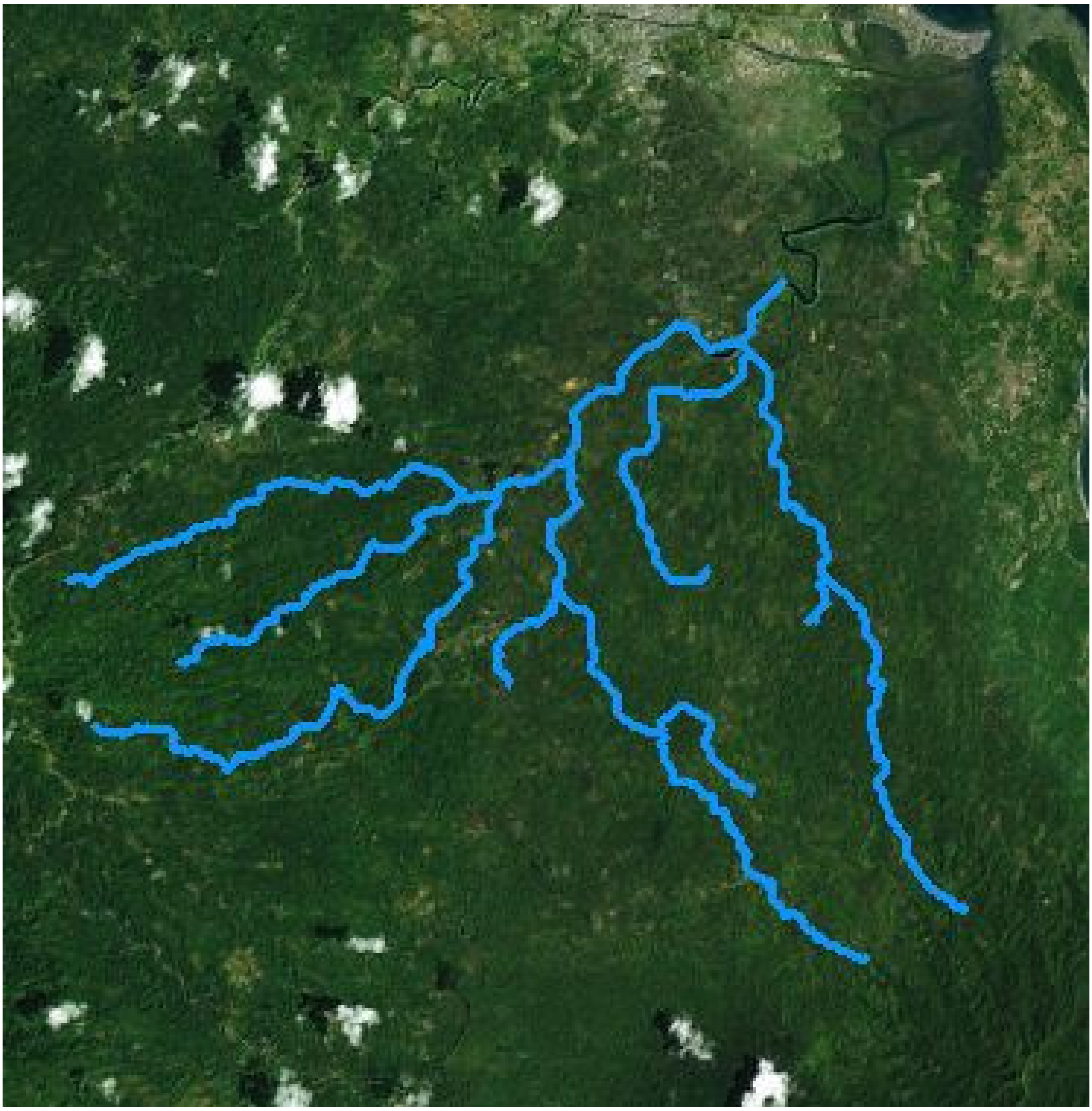


Figure 62. Sample output map of the Basud RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figures 63 to 68 show the 5-, 25-, and 100-year rain return scenarios of the Basud flood plain. The flood plain, with an area of 241.35km2, covers six (6) municipalities, namely Basud, Daet, Mercedes, San Lorenzo Ruiz, San Vicente, and Talisay. Table 33 shows the percentage of area affected by flooding per municipality.

Table 33. Municipalities affected in Donsol flood plain

Municipality	Total Area (km^2)	Area Flooded (km^2)	% Flooded
Basud	251.71	117.55	46.7
Daet	42.20	42.18	99.94
Mercedes	117.17	18.07	15.42
San Lorenzo Ruiz	108.81	28.76	26.43
San Vicente	47.17	15.36	32.56

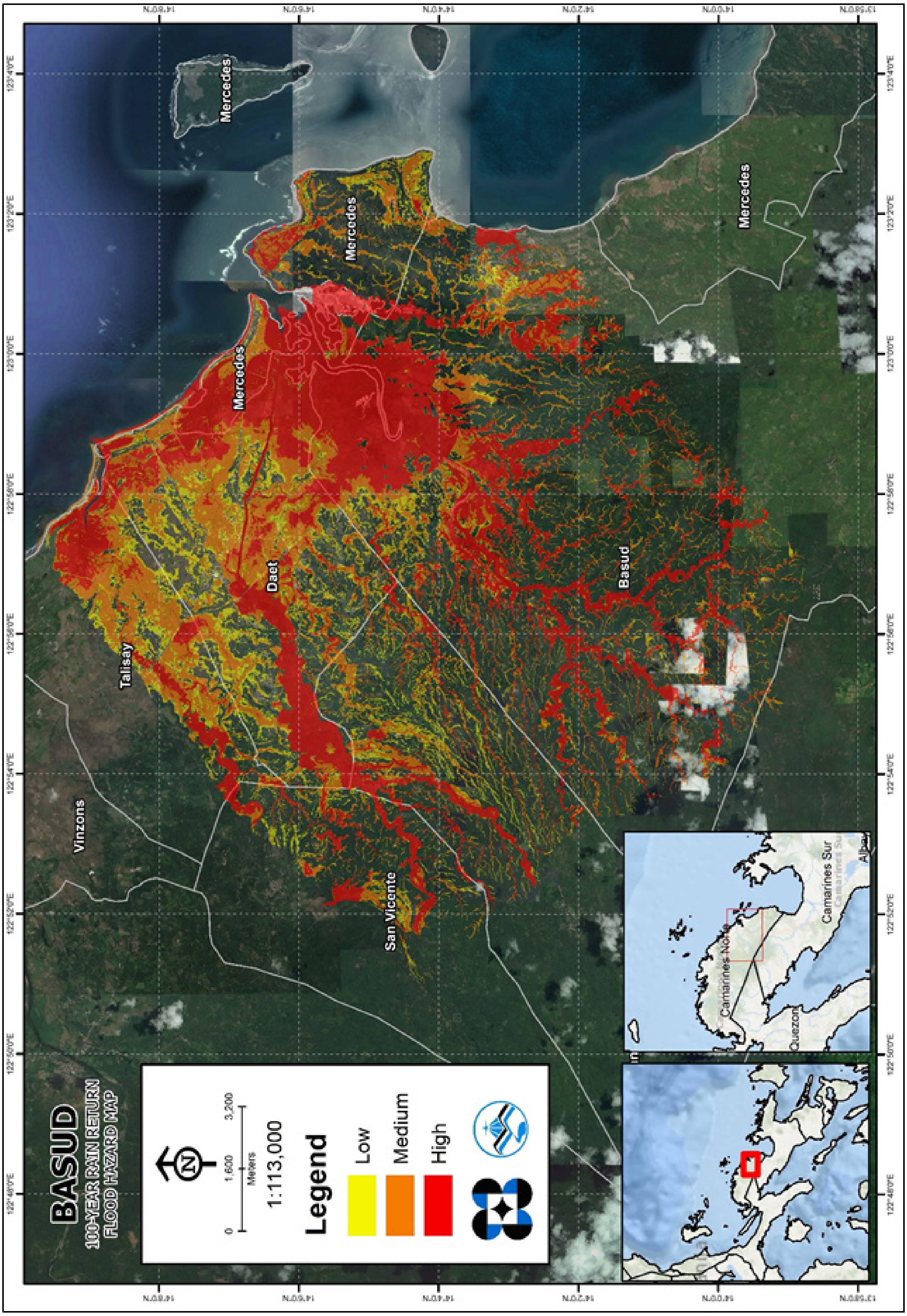


Figure 63. 100-year flood hazard map for the Basud flood plain overlaid on Google Earth imagery

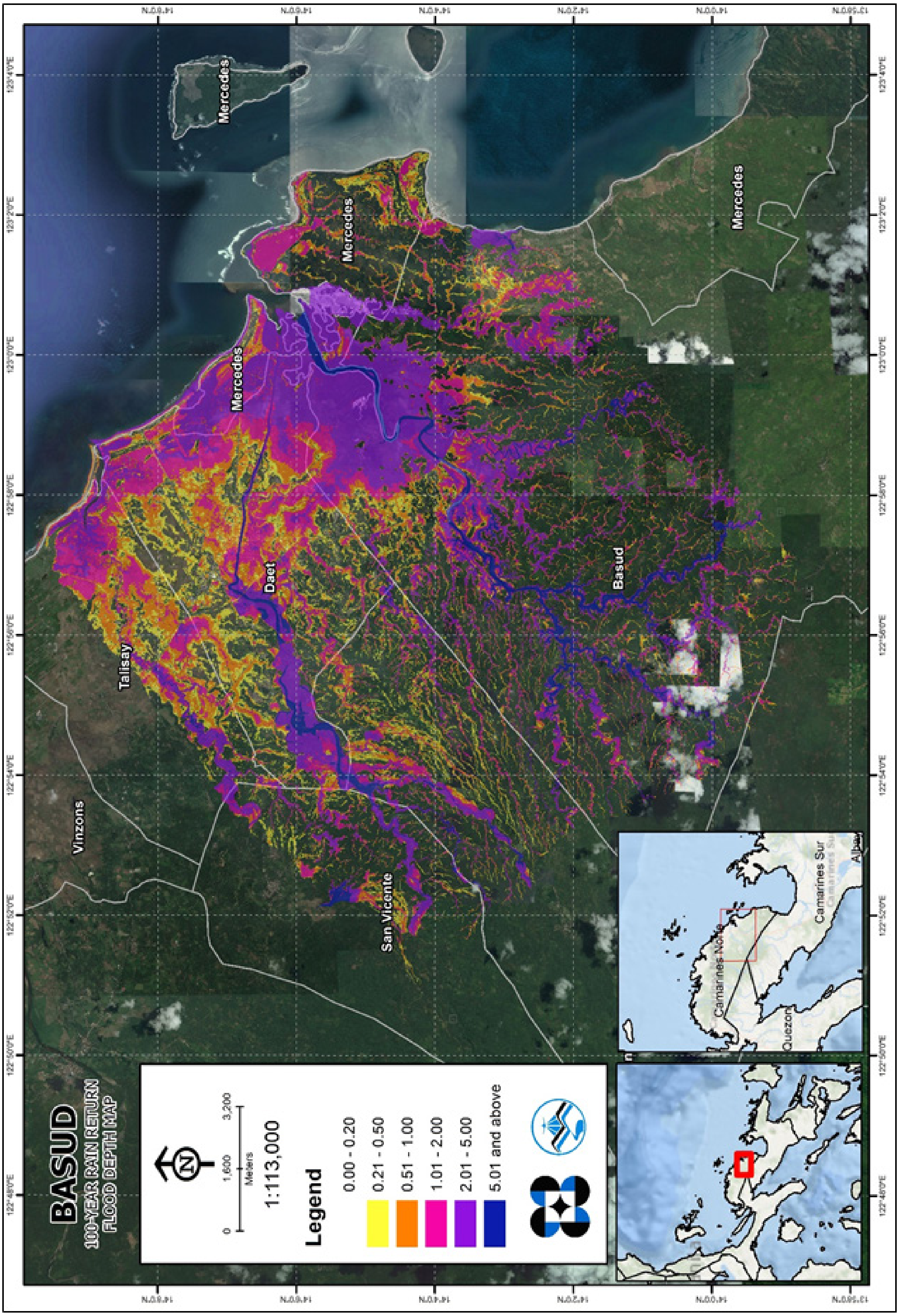


Figure 64. 100-year flow depth map for the Basud flood plain overlaid on Google Earth imagery

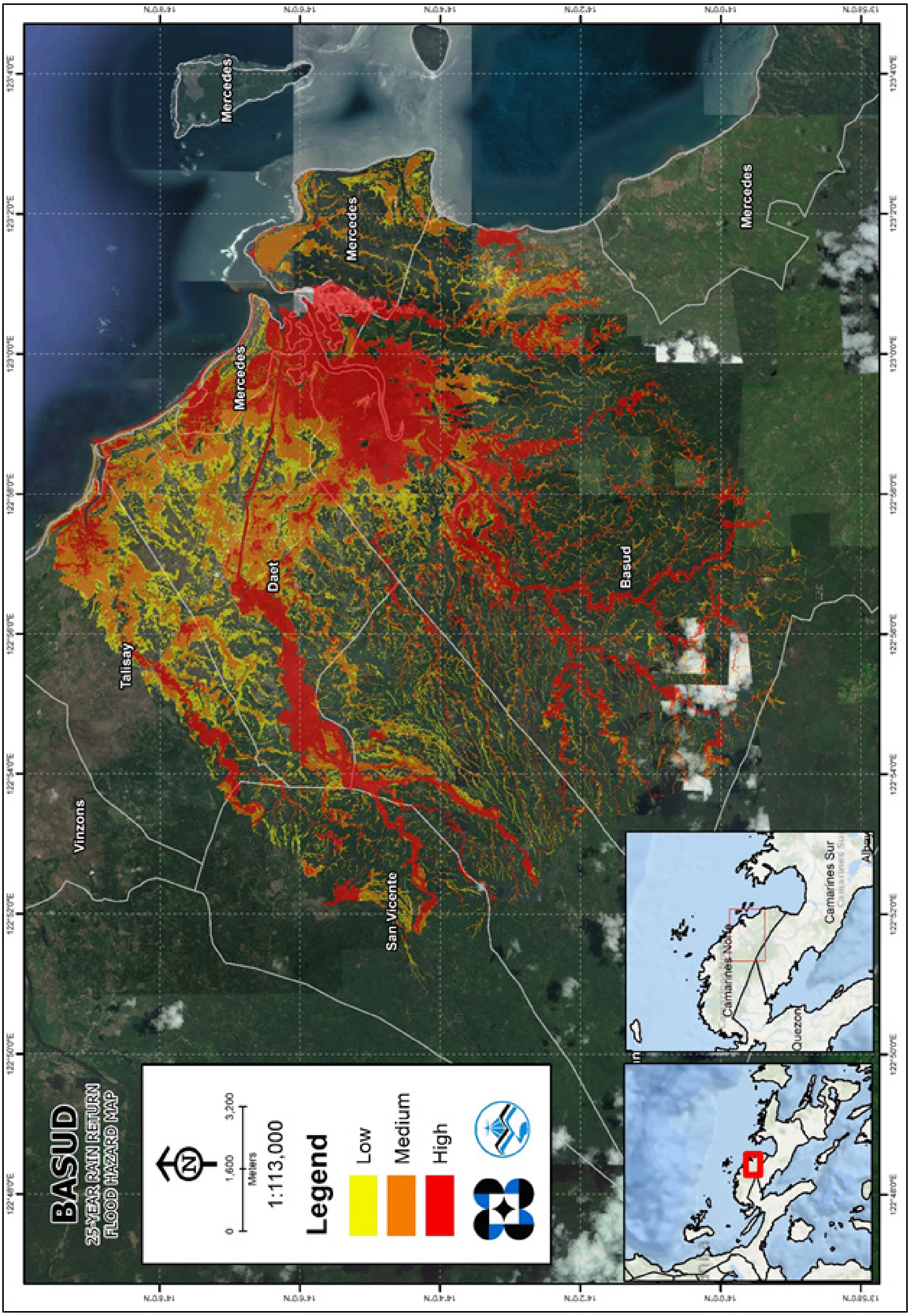


Figure 65. 25-year flood hazard map for the Basud flood plain overlaid on Google Earth imagery

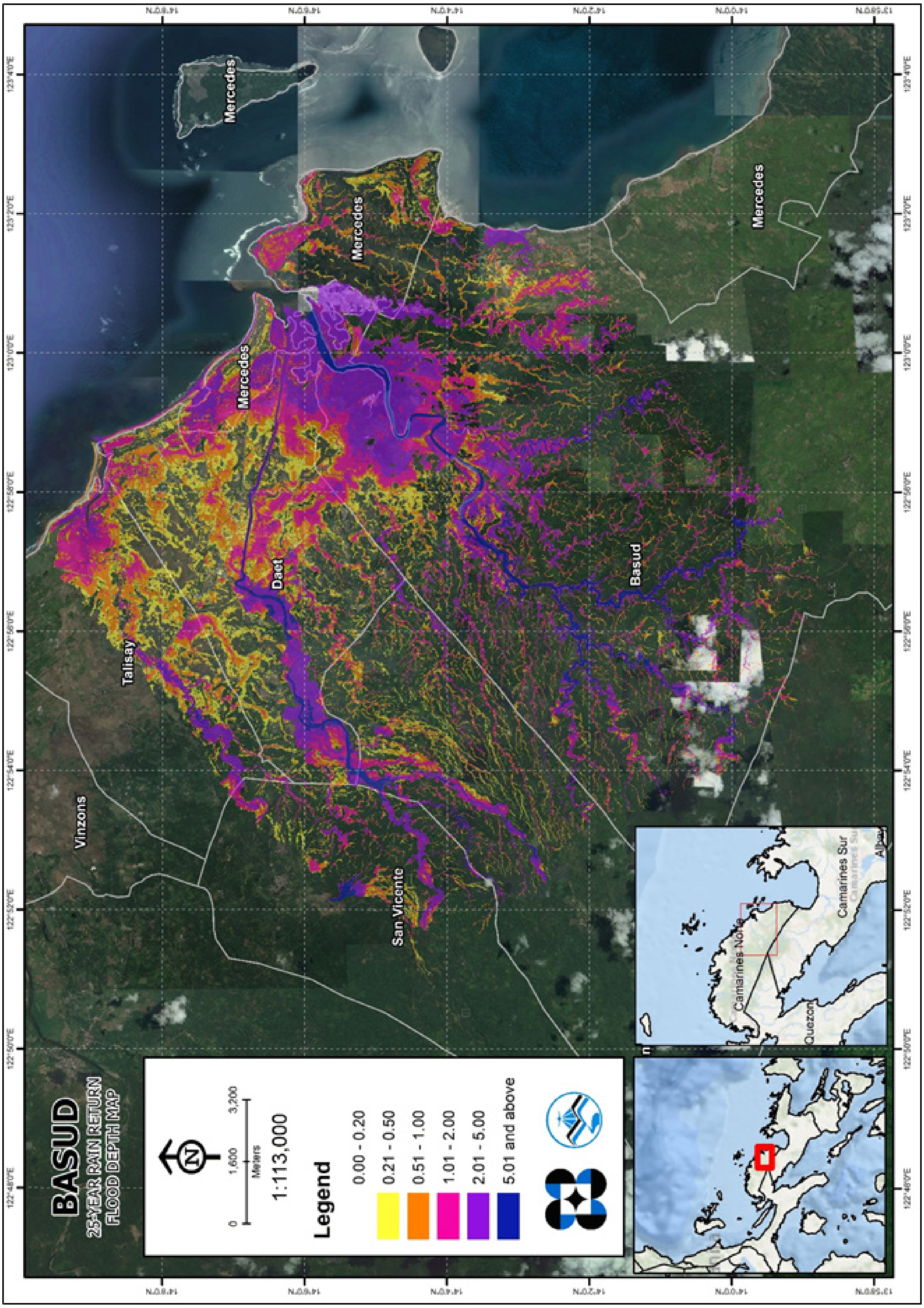


Figure 66. 25-year flow depth map for the Basud flood plain overlaid on Google Earth imagery

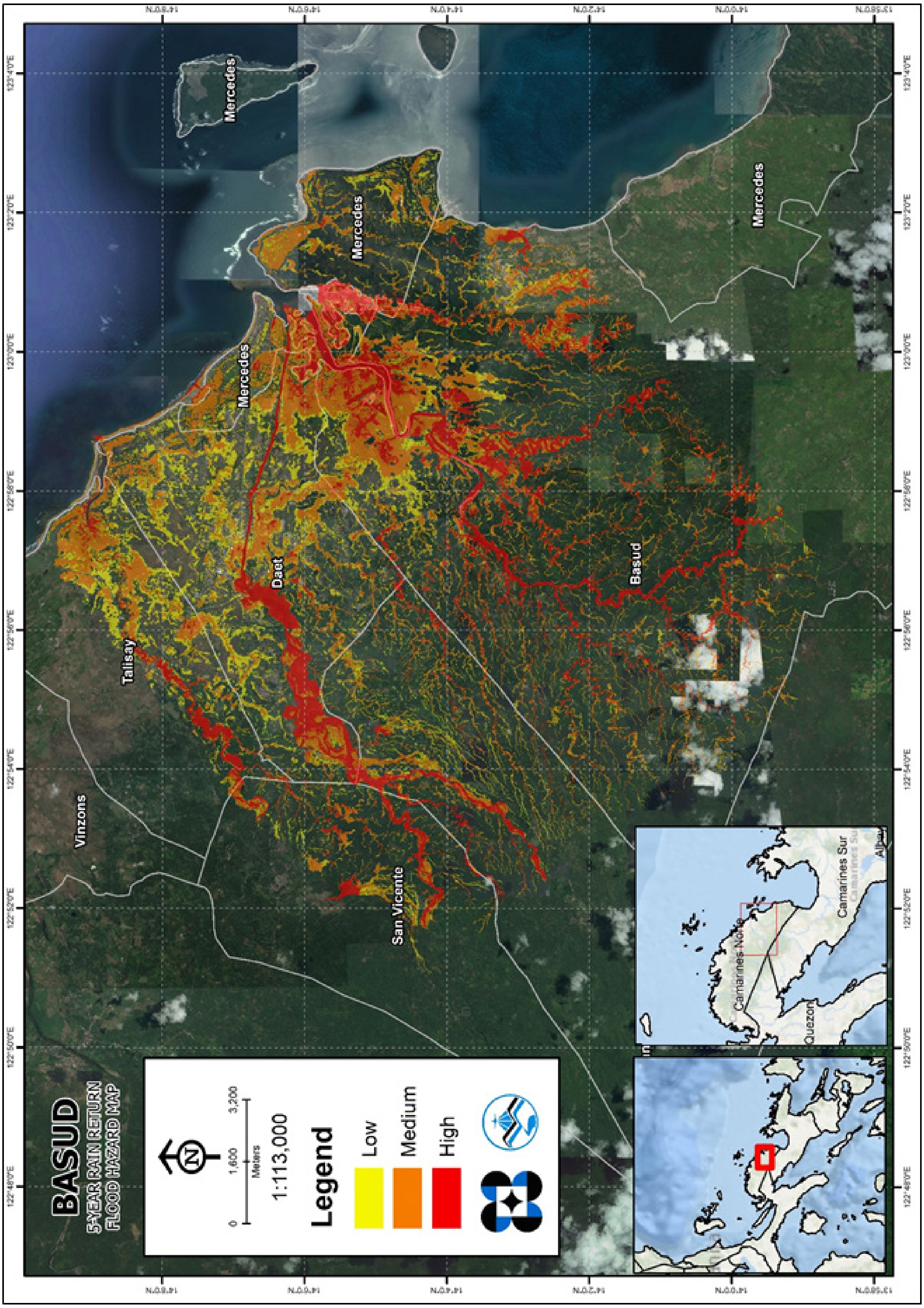


Figure 67. 5-year flood hazard map for the Basud flood plain overlaid on Google Earth imagery

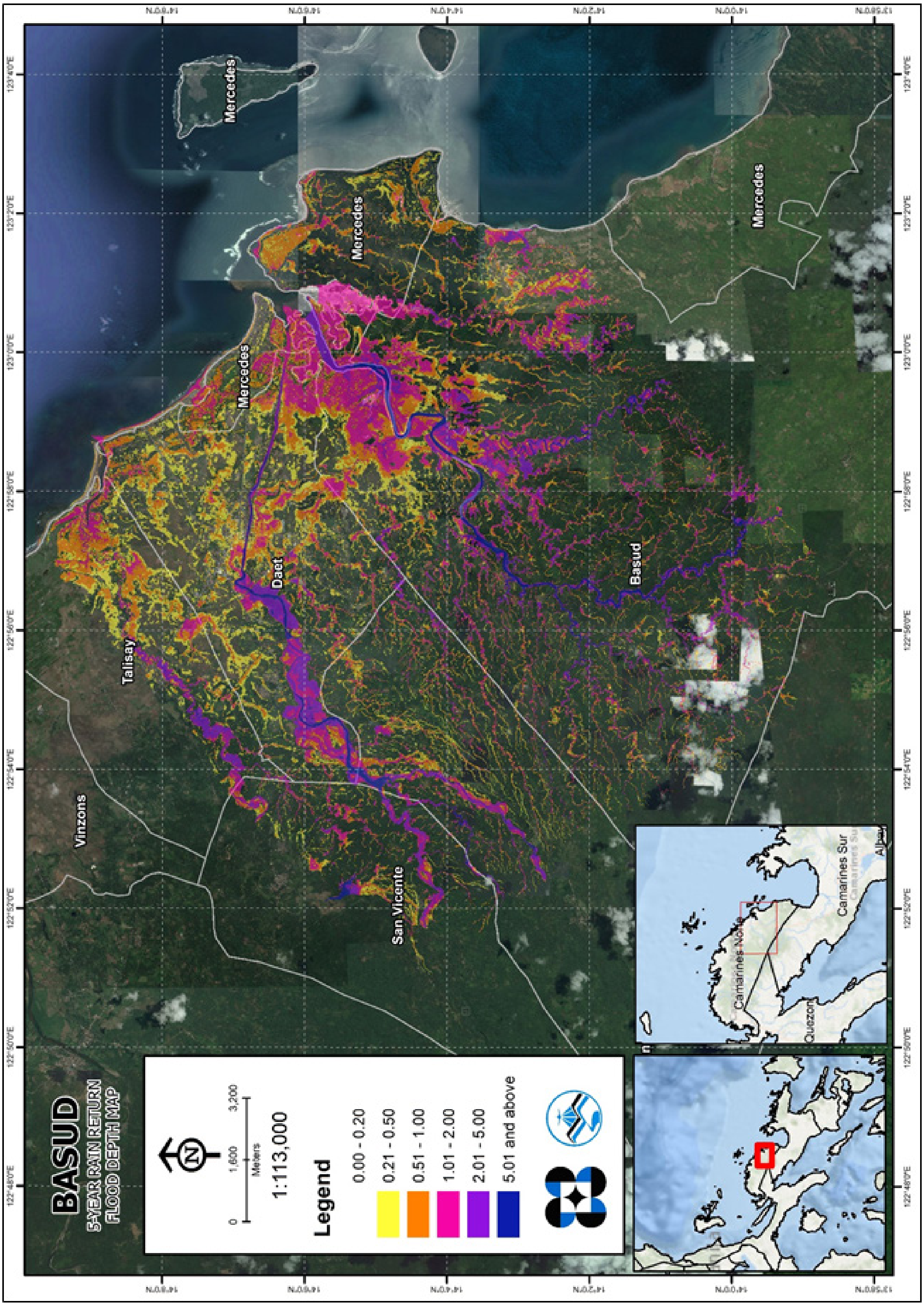


Figure 68. 5-year flow depth map for the Basud flood plain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the basud River Basin, grouped accordingly by municipality. For the said basin, six (6) municipalities consisting of 93 barangays are expected to experience flooding when subjected to the three rainfall return period scenarios.

For the 5-year rainfall return period, 33.69% of the municipality of Basud with an area of 251.71 sq. km. will experience flood levels of less than 0.20 meters. 2.88% of the area will experience flood levels of 0.21 to 0.50 meters, while 3.38%, 4.19%, 2.01%, and 0.55% 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. Figures 69-71 depict the areas affected in Basud in square kilometers by flood depth per barangay.

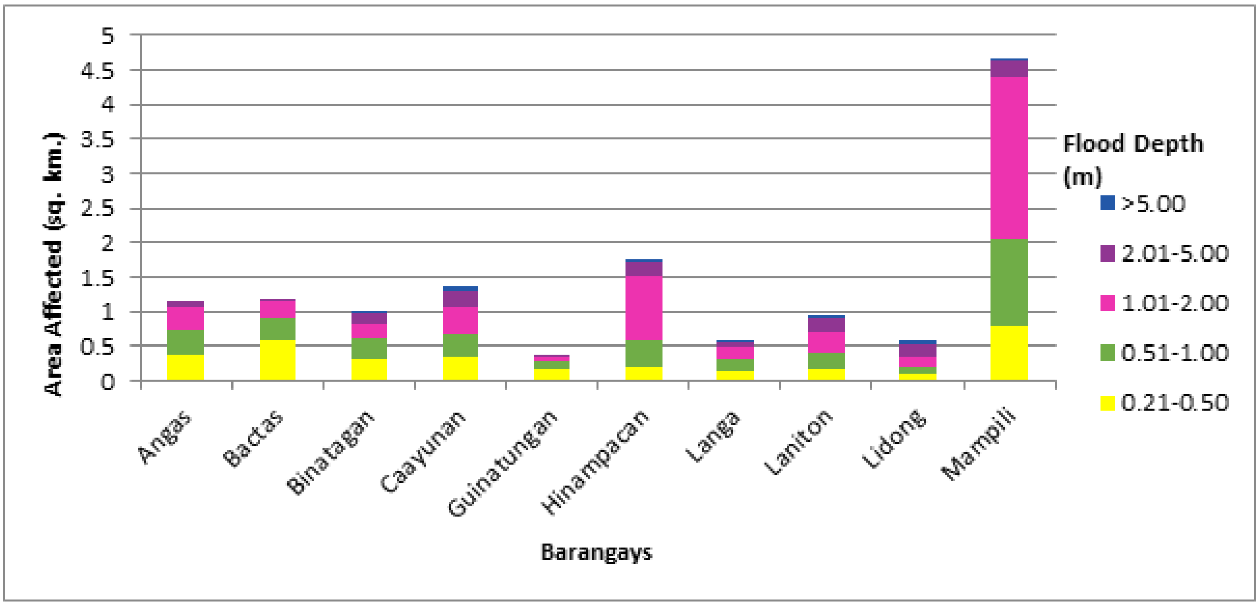


Figure 69. Affected Areas in Basud, Camarines Norte during the 5-Year Rainfall Return Period

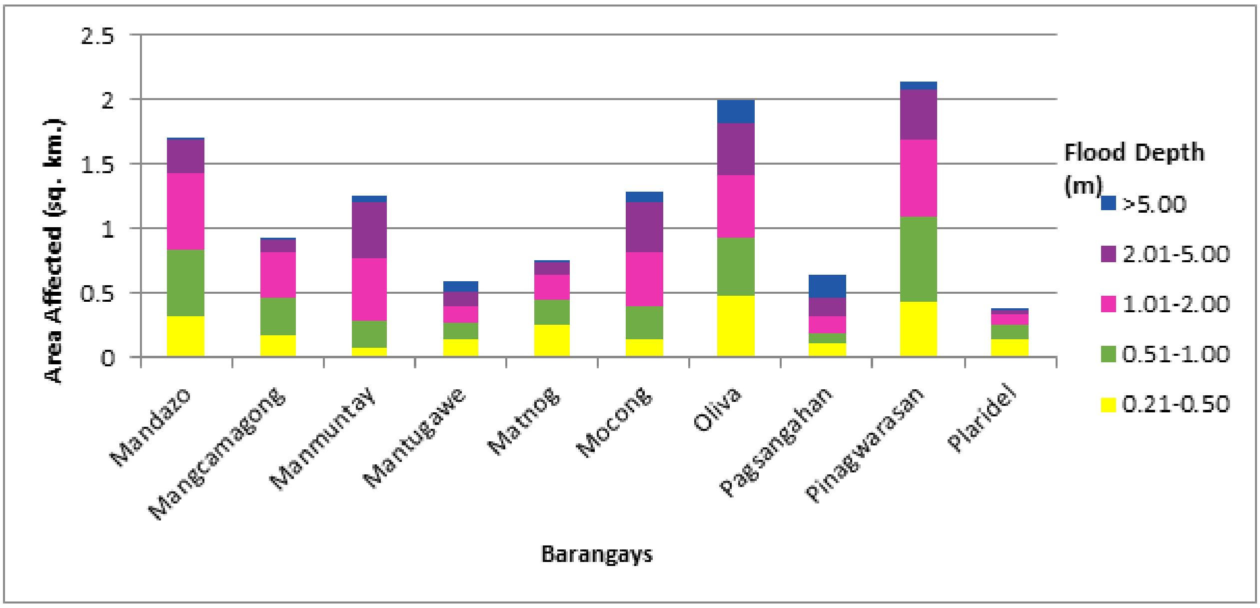


Figure 70. Affected Areas in Basud, Camarines Norte during the 5-Year Rainfall Return Period

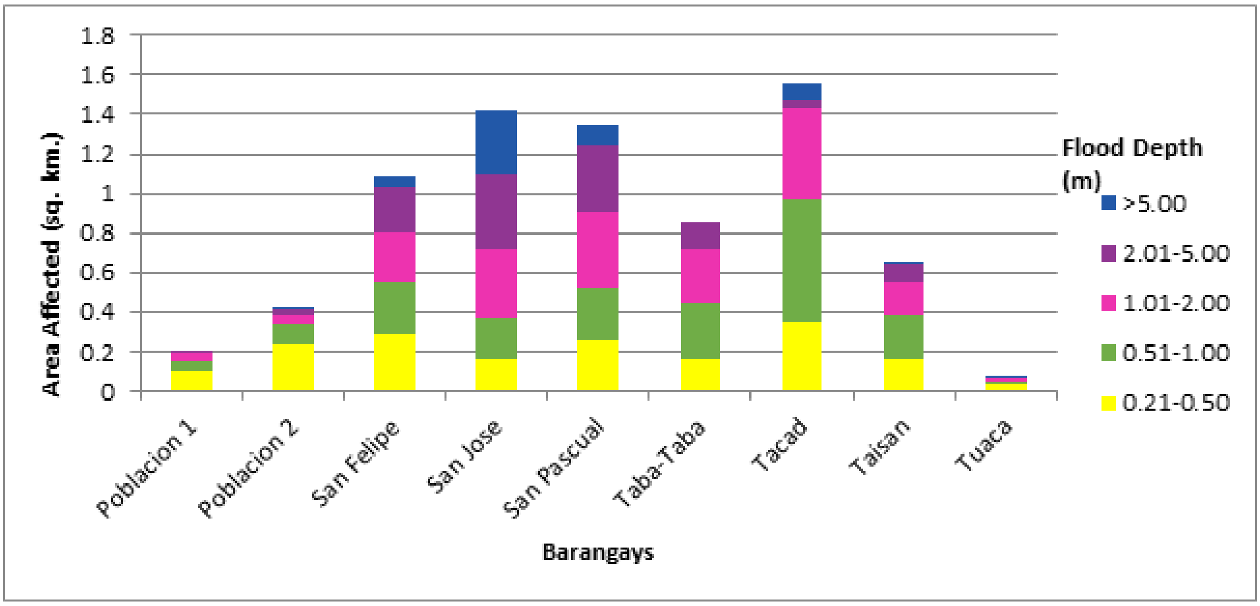


Figure 71. Affected Areas in Basud, Camarines Norte during the 5-Year Rainfall Return Period

Table 34. Affected Areas in Basud, Camarines Norte during the 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basud (in sq. km.)												
	Angas	Bactas	Binatagan	Caayunan	Guinatungan	Hinampacan	Langa	Laniton	Lidong	Mampili	Mandazo	Mangcamagong	Manmuntay
0.03-0.20	3.15	1.71	4.64	7.39	3.13	1.43	2.86	3.09	2.11	1.08	1.75	1.81	1.3
0.21-0.50	0.39	0.59	0.32	0.34	0.16	0.2	0.15	0.17	0.097	0.8	0.32	0.18	0.082
0.51-1.00	0.34	0.32	0.29	0.34	0.12	0.4	0.17	0.22	0.11	1.26	0.51	0.29	0.2
1.01-2.00	0.33	0.24	0.23	0.37	0.069	0.9	0.17	0.32	0.13	2.35	0.61	0.35	0.48
2.01-5.00	0.092	0.02	0.15	0.24	0.011	0.22	0.064	0.2	0.19	0.24	0.26	0.11	0.45
> 5.00	0	0	0.013	0.066	0	0.035	0.015	0.022	0.053	0.009	0.0002	0.0002	0.037

Table 35. Affected Areas in Basud, Camarines Norte during the 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basud (in sq. km.)										
	Mantugawe	Matnog	Mocong	Oliva	Pagsangahan	Pinagwarasan	Plaridel	Poblacion 1	Poblacion 2	San Felipe	San Jose
0.03-0.20	3.15	2.78	0.34	11.43	2.41	3.71	2.52	0.69	0.83	5.23	2.39
0.21-0.50	0.14	0.26	0.15	0.48	0.1	0.44	0.14	0.099	0.24	0.29	0.17
0.51-1.00	0.14	0.19	0.25	0.45	0.094	0.65	0.12	0.055	0.1	0.26	0.21
1.01-2.00	0.12	0.19	0.42	0.49	0.12	0.61	0.083	0.036	0.045	0.25	0.34
2.01-5.00	0.12	0.1	0.39	0.4	0.14	0.37	0.025	0.009	0.032	0.24	0.38
> 5.00	0.084	0.0001	0.072	0.17	0.18	0.068	0.0001	0	0.0017	0.052	0.32

Table 36. Affected Areas in Basud, Camarines Norte during the 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basud (in sq. km.)				
	San Pascual	Taba-Taba	Tacad	Taisan	Tuaca
0.03-0.20	7.16	1.59	1.53	2.93	0.63
0.21-0.50	0.25	0.16	0.35	0.16	0.036
0.51-1.00	0.27	0.28	0.62	0.22	0.016
1.01-2.00	0.39	0.28	0.47	0.17	0.011
2.01-5.00	0.33	0.14	0.042	0.1	0.0032
> 5.00	0.1	0	0.076	0.0015	0.000067

For the municipality of Daet with an area of 42.2 sq. km., 56.03% will experience flood levels of less than 0.20 meters. 17.48% of the area will experience flood levels of 0.21 to 0.50 meters, while 11.91%, 7.95%, 5.35%, and 1.23% 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. Figuress 72 and 73 depict the areas affected in Daet in square kilometers by flood depth per barangay.

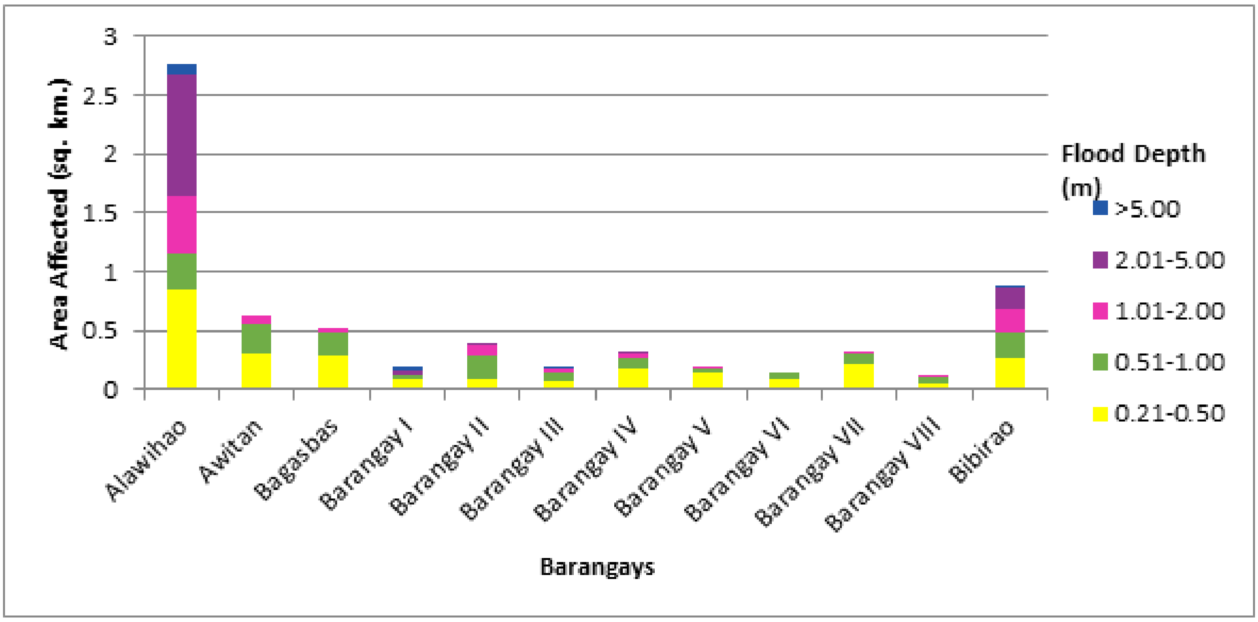


Figure 72. Affected Areas in Daet, Camarines Norte during the 5-Year Rainfall Return Period

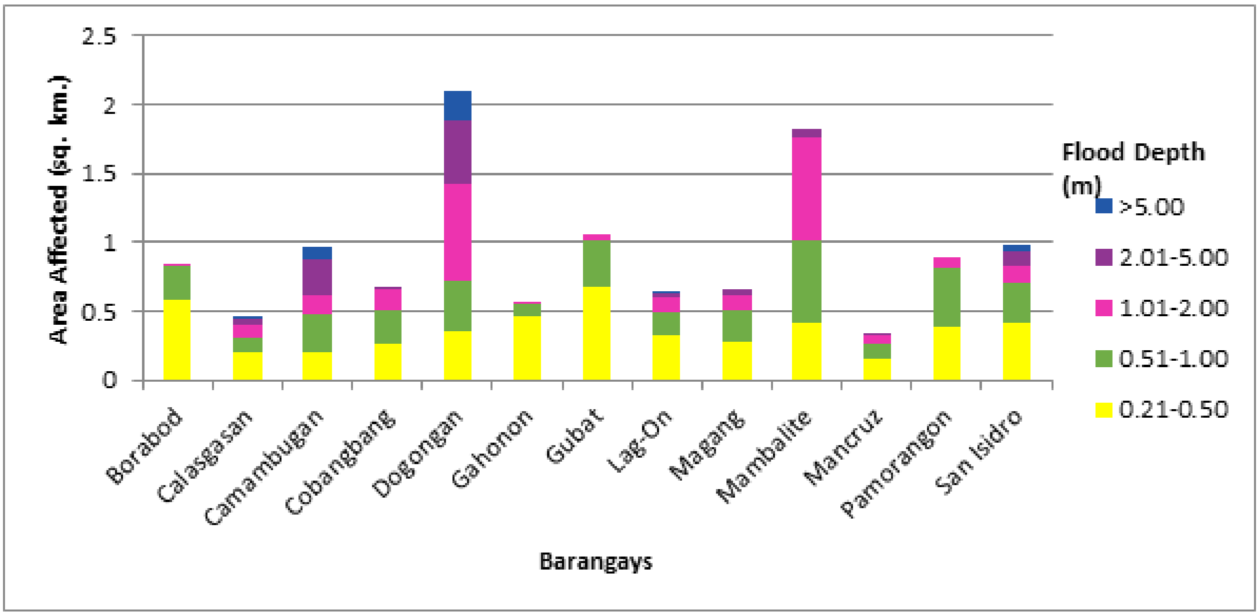


Figure 73. Affected Areas in Daet, Camarines Norte during the 5-Year Rainfall Return Period

Table 37. Affected Areas in Daet, Camarines Norte during the 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Daet (in sq. km.)													
	Alawihao	Awitan	Bagasbas	Barangay I	Barangay II	Barangay III	Barangay IV	Barangay V	Barangay VI	Barangay VII	Barangay VIII	Bibirao	Borabod	Calasgasan
0.03-0.20	3.26	0.7	0.95	0.28	0.14	0.042	0.37	0.59	0.12	0.18	0.14	1.7	1.36	1.79
0.21-0.50	0.84	0.31	0.29	0.093	0.093	0.061	0.17	0.14	0.097	0.21	0.06	0.27	0.59	0.2
0.51-1.00	0.31	0.26	0.2	0.025	0.19	0.075	0.089	0.027	0.044	0.087	0.037	0.21	0.25	0.11
1.01-2.00	0.49	0.061	0.033	0.014	0.085	0.034	0.039	0.0026	0	0.0096	0.00039	0.2	0.018	0.095
2.01-5.00	1.03	0	0	0.024	0.00096	0.014	0.0001	0	0	0	0	0.18	0	0.039
> 5.00	0.079	0	0	0.039	0	0.019	0	0	0	0	0	0.031	0	0.0001

Table 38. Affected Areas in Daet, Camarines Norte during the 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Daet (in sq. km.)										
	Camambugan	Cobangbang	Dogongan	Gahonon	Gubat	Lag-On	Magang	Mambalite	Mancruz	Pamorangon	San Isidro
0.03-0.20	0.38	0.58	2	1.41	1.74	1.12	1.05	0.68	1	0.98	1.1
0.21-0.50	0.2	0.27	0.36	0.45	0.68	0.33	0.28	0.41	0.16	0.39	0.42
0.51-1.00	0.27	0.24	0.37	0.11	0.33	0.16	0.22	0.6	0.1	0.42	0.29
1.01-2.00	0.14	0.15	0.69	0.0016	0.044	0.11	0.12	0.75	0.058	0.087	0.12
2.01-5.00	0.27	0.0022	0.47	0	0	0.025	0.032	0.056	0.0015	0	0.12
> 5.00	0.096	0	0.21	0	0	0.0056	0	0	0	0	0.038

For the municipality of Mercedes with an area of 117.17 sq. km., 9.49% will experience flood levels of less than 0.20 meters. 1.78% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.39%, 1.67%, 0.08%, and 0.01% 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. Figures 74 and 75 depict the areas affected in Mercedes in square kilometers by flood depth per barangay.

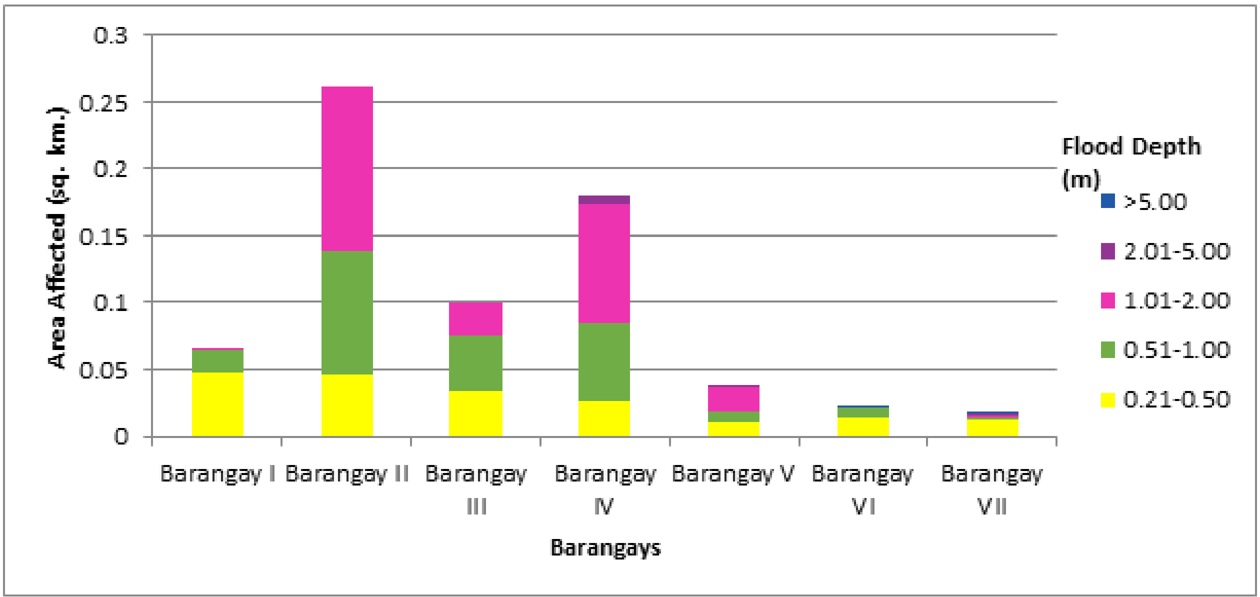


Figure 74. Affected Areas in Mercedes, Camarines Norte during the 5-Year Rainfall Return Period

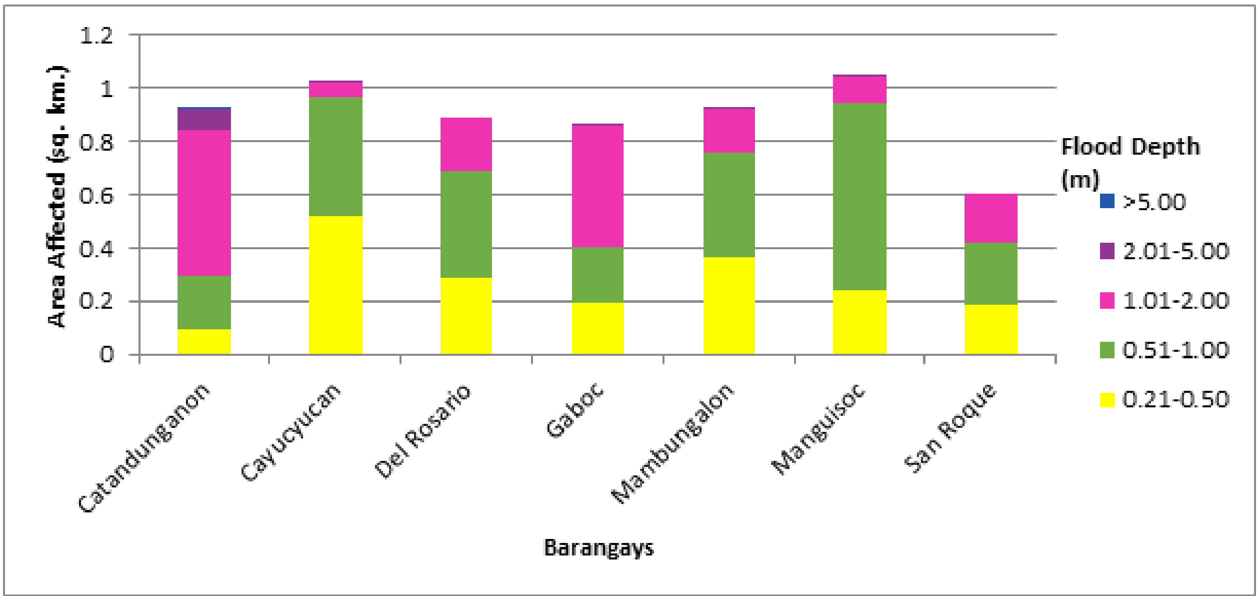


Figure 75. Affected Areas in Mercedes, Camarines Norte during the 5-Year Rainfall Return Period

Table 39. Affected Areas in Mercedes, Camarines Norte during the 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mercedes (in sq. km.)									
	Barangay I	Barangay II	Barangay III	Barangay IV	Barangay V	Barangay VI	Barangay VII	Catandunganon	Cayucyucan	Del Rosario
0.03-0.20	0.19	0.13	0.088	0.075	0.072	0.065	0.063	0.47	2.32	0.84
0.21-0.50	0.048	0.046	0.033	0.026	0.011	0.014	0.013	0.096	0.52	0.29
0.51-1.00	0.016	0.091	0.042	0.059	0.0074	0.0069	0.002	0.2	0.44	0.4
1.01-2.00	0.0009	0.12	0.024	0.088	0.019	0	0.00076	0.55	0.06	0.2
2.01-5.00	0	0	0	0.0072	0.000037	0.000057	0.0014	0.077	0.0003	0
> 5.00	0	0	0	0	0	0.00011	0.0012	0.0053	0	0

Table 40. Affected Areas in Mercedes, Camarines Norte during the 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Daraga			
	Gaboc	Mambungalon	Manguisoc	San Roque
0.03-0.20	3.03	2.06	0.92	0.79
0.21-0.50	0.2	0.36	0.24	0.19
0.51-1.00	0.2	0.39	0.7	0.23
1.01-2.00	0.46	0.16	0.096	0.18
2.01-5.00	0.0082	0.00078	0.0011	0
> 5.00	0	0	0	0

For the municipality of San Lorenzo Ruiz with an area of 108.81 sq. km., 20.77% will experience flood levels of less than 0.20 meters. 1.92% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.45%, 1.29%, 0.77%, and 0.23% 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. Figure 76 depicts the areas affected in San Lorenzo Ruiz in square kilometers by flood depth per barangay.

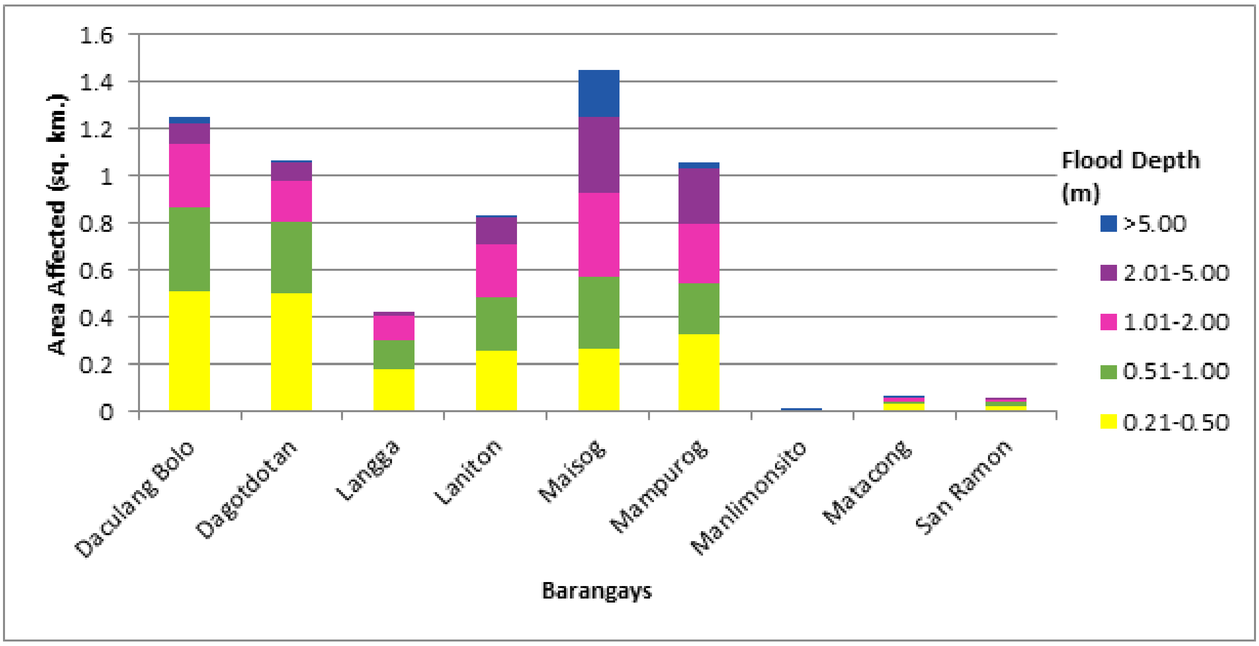


Figure 76. Affected Areas in San Lorenzo Ruiz, Camarines Norte during the 5-Year Rainfall Return Period

Table 41. Affected Areas in San Lorenzo Ruiz, Camarines Norte during the 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Lorenzo Ruiz (in sq. km.)								
	Daculang Bolo	Dagotdotan	Langga	Laniton	Maisog	Mampurog	Manlimonsito	Matacong	San Ramon
0.03-0.20	4.62	2.8	1.98	3.08	4.41	4.72	0.064	0.66	0.26
0.21-0.50	0.51	0.5	0.18	0.26	0.26	0.32	0.0027	0.028	0.019
0.51-1.00	0.36	0.31	0.12	0.22	0.31	0.22	0.0009	0.017	0.025
1.01-2.00	0.27	0.18	0.1	0.23	0.36	0.25	0.0015	0.012	0.0043
2.01-5.00	0.084	0.071	0.014	0.11	0.33	0.23	0.000029	0.003	0.0007
> 5.00	0.025	0.0008	0	0.0001	0.2	0.03	0.000082	0.0002	0

For the municipality of San Vicente with an area of 47.17 sq. km., 24.44% will experience flood levels of less than 0.20 meters. 2.34% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.83%, 2.25%, 1.47%, and 0.25% 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. Figure 77 depicts the areas affected in San Vicente in square kilometers by flood depth per barangay.

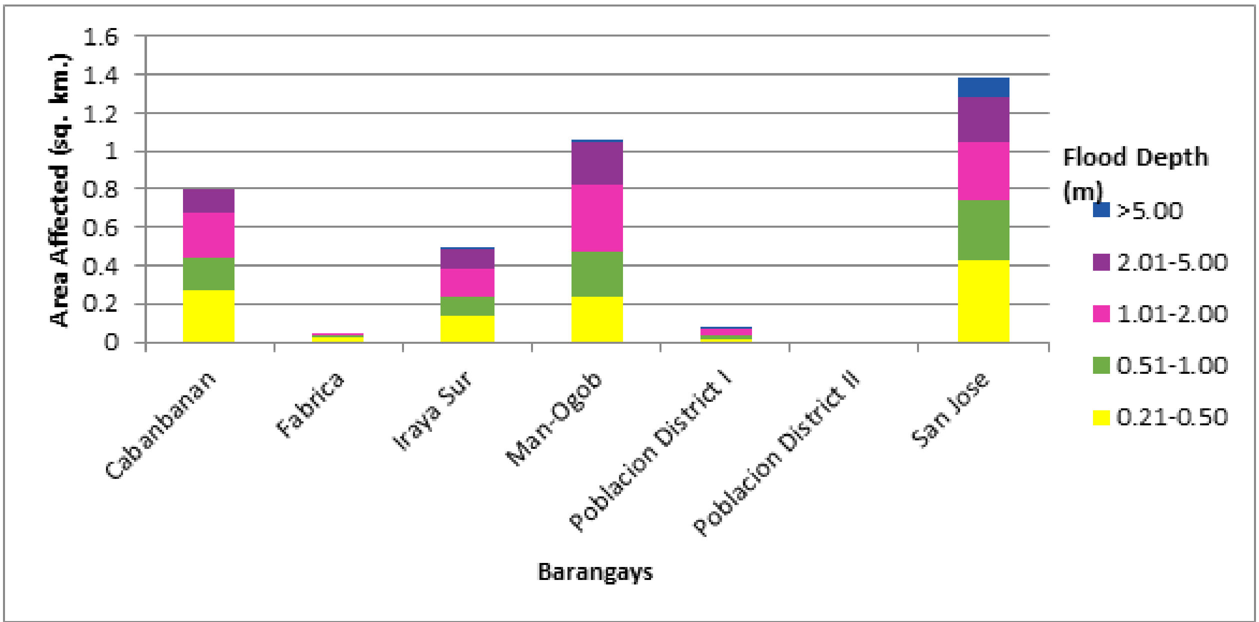


Figure 77. Affected Areas in San Vicente, Camarines Norte during the 5-Year Rainfall Return Period

Table 42. Affected Areas in San Vicente, Camarines Norte during the 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Vicente (in sq. km.)						
	Del Rosario	Florista	San Isidro	San Roque	Poblacion District I	Poblacion District II	San Jose
0.03-0.20	5.459	0.314079	0.749859	0.730638	0.17	0.000082	2.37
0.21-0.50	0.194233	0.004176	0.039221	0.029456	0.011	0	0.43
0.51-1.00	0.193042	0.0048	0.022222	0.024662	0.025	0	0.31
1.01-2.00	0.3305	0.009169	0.015202	0.031615	0.034	0	0.3
2.01-5.00	0.661169	0.026188	0.001041	0.014688	0	0	0.25
> 5.00	0.041644	0.012843	0	0	0.0029	0	0.095

For the municipality of Talisay with an area of 37.9 sq. km., 22.36% will experience flood levels of less than 0.20 meters. 7.89% of the area will experience flood levels of 0.21 to 0.50 meters, while 6.64%, 3.42%, 2.3%, and 0.07% 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. Figure 78 depicts the areas affected in Talisay in square kilometers by flood depth per barangay.

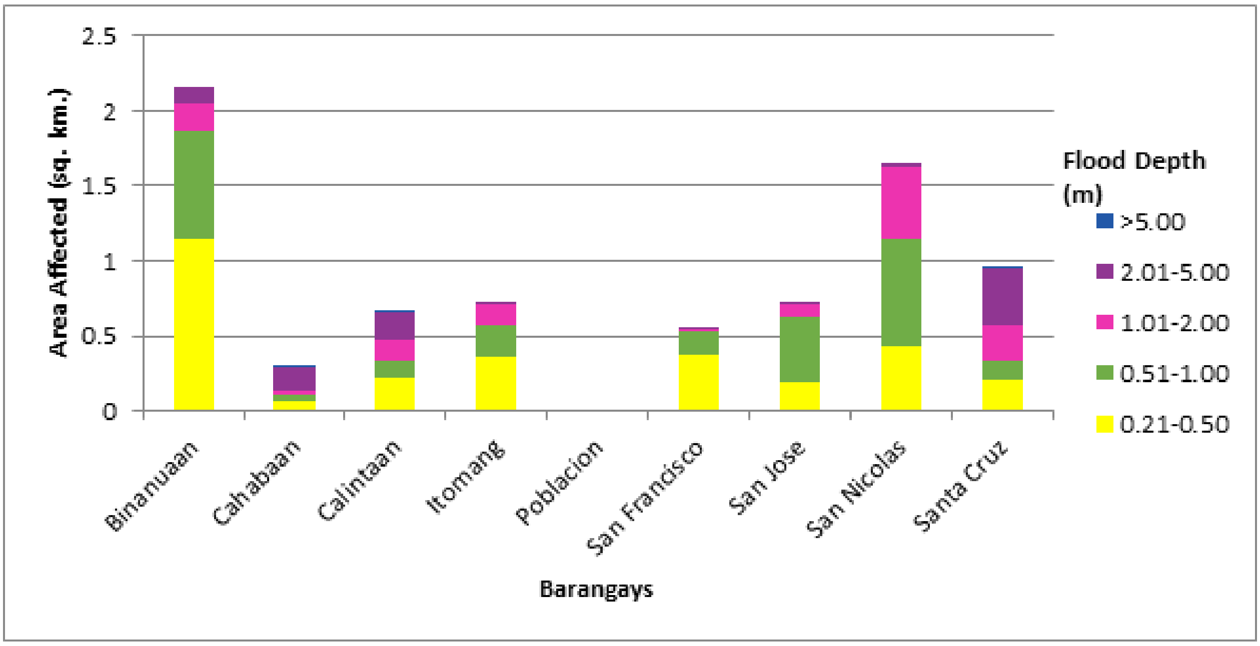


Figure 78. Affected Areas in Talisay, Camarines Norte during the 5-Year Rainfall Return Period

Table 43. Affected Areas in Talisay, Camarines Norte during the 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Daraga								
	Binanuaan	Cahabaan	Calintaan	Itomang	Poblacion	San Francisco	San Jose	San Nicolas	Santa Cruz
0.03-0.20	2.06	0.39	1.05	1.34	0.0044	0.65	0.35	0.88	1.76
0.21-0.50	1.15	0.064	0.22	0.35	0.00043	0.38	0.19	0.43	0.2
0.51-1.00	0.71	0.041	0.11	0.21	0	0.15	0.43	0.72	0.13
1.01-2.00	0.19	0.03	0.13	0.14	0	0.0064	0.088	0.47	0.24
2.01-5.00	0.11	0.16	0.18	0.0078	0	0.00052	0.003	0.032	0.37
> 5.00	0	0.017	0.0084	0	0	0	0	0	0.0015

For the 25-year rainfall return period, 30.36% of the municipality of Basud with an area of 251.71 sq. km. will experience flood levels of less than 0.20 meters. 2.46% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.79%, 4.3%, 5.67%, and 1.12% 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. Figures 79 to 81 depict the areas affected in Basud in square kilometers by flood depth per barangay.

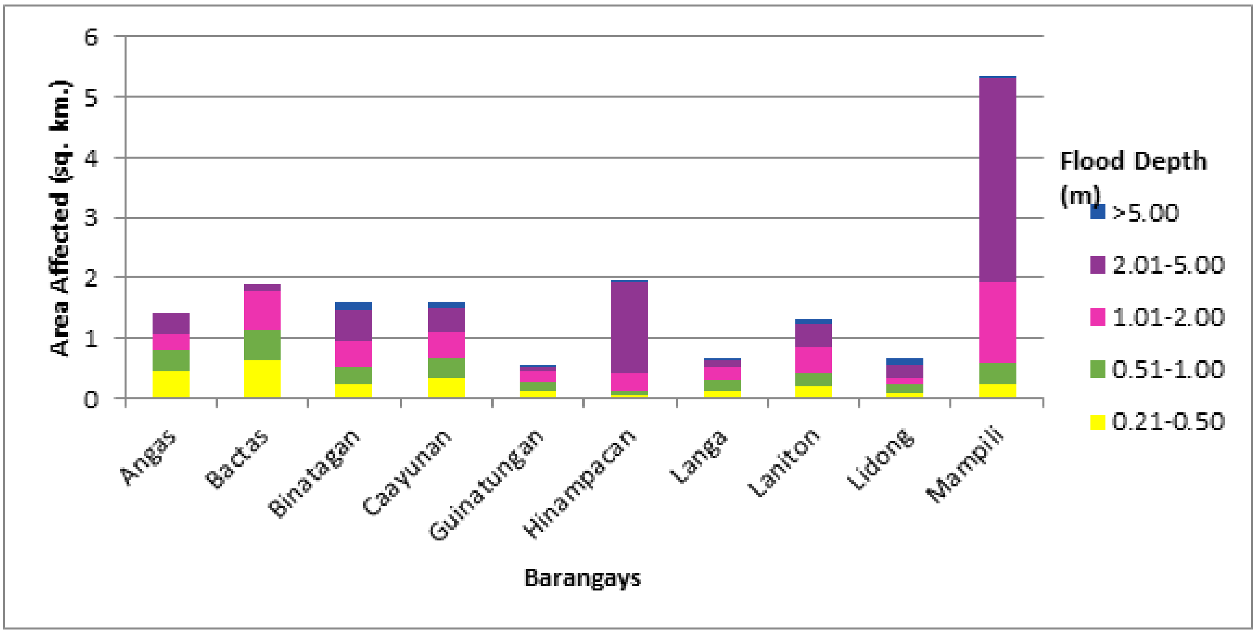


Figure 79. Affected Areas in Basud, Camarines Norte during the 25-Year Rainfall Return Period

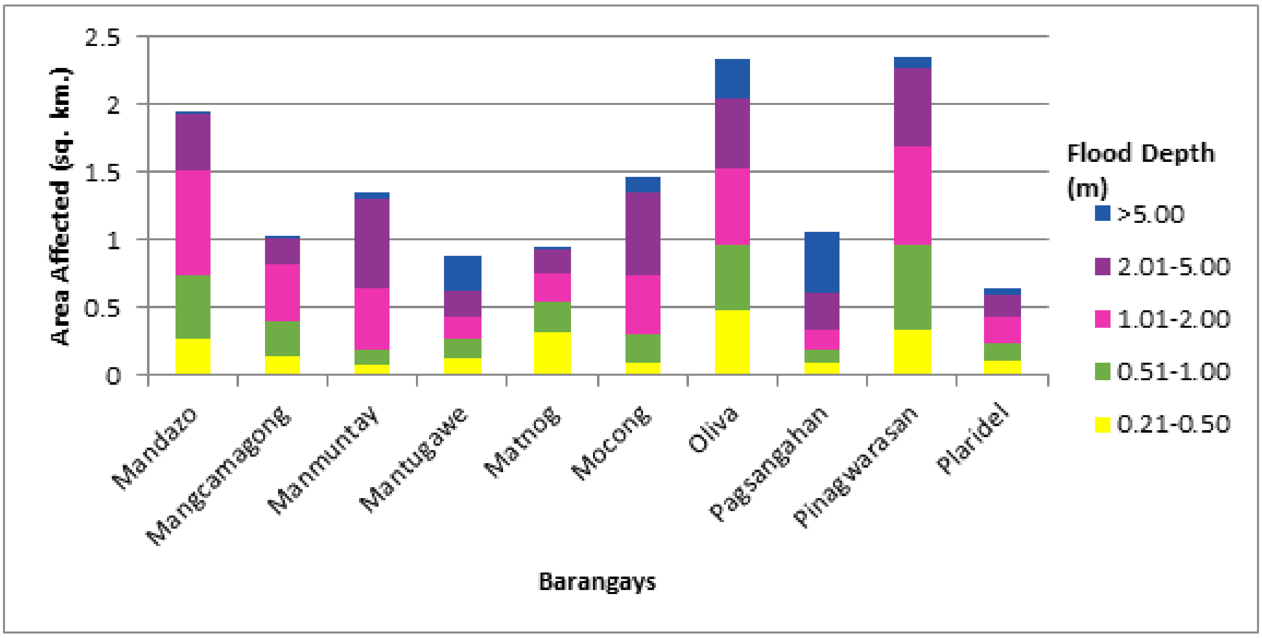


Figure 80. Affected Areas in Basud, Camarines Norte during the 25-Year Rainfall Return Period

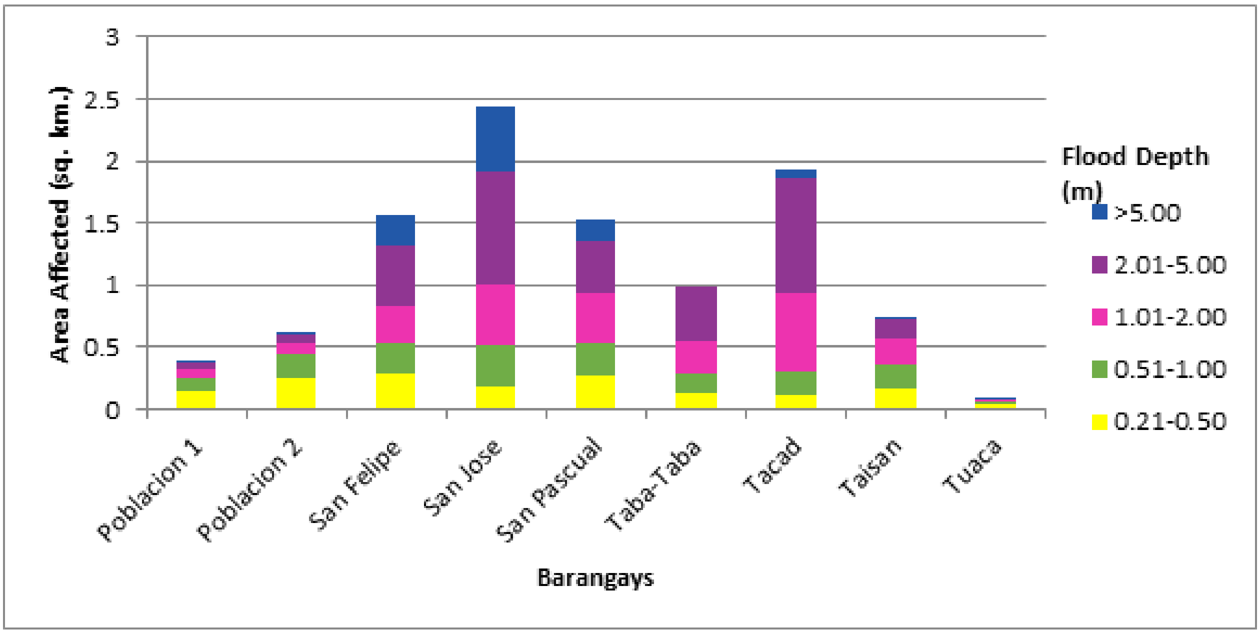


Figure 81. Affected Areas in Basud, Camarines Norte during the 25-Year Rainfall Return Period

Table 44. Affected Areas in Basud, Camarines Norte during the 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basud (in sq. km.)												
	Angas	Bactas	Binatagan	Caayunan	Guinatungan	Hinampacan	Langa	Laniton	Lidong	Mampili	Mandazo	Mangcamagong	Manmuntay
0.03-0.20	2.87	1	4.03	7.15	2.98	1.23	2.77	2.72	2.03	0.41	1.52	1.72	1.19
0.21-0.50	0.45	0.63	0.24	0.34	0.13	0.063	0.14	0.18	0.097	0.25	0.27	0.14	0.071
0.51-1.00	0.36	0.52	0.29	0.34	0.14	0.067	0.17	0.24	0.12	0.35	0.47	0.26	0.11
1.01-2.00	0.25	0.64	0.43	0.44	0.16	0.29	0.21	0.43	0.13	1.34	0.77	0.41	0.45
2.01-5.00	0.37	0.1	0.49	0.38	0.07	1.49	0.099	0.4	0.22	3.37	0.42	0.2	0.67
> 5.00	0	0	0.17	0.1	0.0037	0.039	0.029	0.06	0.088	0.015	0.0005	0.00082	0.049

Table 45. Affected Areas in Basud, Camarines Norte during the 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basud (in sq. km.)										
	Mantugawe	Matnog	Mocong	Oliva	Pagsangahan	Pinagwarasan	Plaridel	Poblacion 1	Poblacion 2	San Felipe	San Jose
0.03-0.20	2.87	2.6	0.16	11.1	2	3.49	2.25	0.52	0.64	4.75	1.37
0.21-0.50	0.13	0.32	0.096	0.49	0.099	0.34	0.12	0.14	0.25	0.28	0.19
0.51-1.00	0.14	0.23	0.21	0.47	0.09	0.62	0.13	0.1	0.19	0.26	0.32
1.01-2.00	0.16	0.21	0.42	0.57	0.14	0.72	0.19	0.082	0.098	0.3	0.49
2.01-5.00	0.2	0.17	0.62	0.51	0.28	0.59	0.16	0.045	0.06	0.48	0.92
> 5.00	0.26	0.0011	0.12	0.29	0.44	0.086	0.046	0.000015	0.0055	0.24	0.51

Table 46. Affected Areas in Basud, Camarines Norte during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basud (in sq. km.)				
	San Pascual	Taba-Taba	Tacad	Taisan	Tuaca
0.03-0.20	6.98	1.47	1.15	2.85	0.61
0.21-0.50	0.27	0.14	0.12	0.16	0.043
0.51-1.00	0.26	0.16	0.18	0.2	0.019
1.01-2.00	0.4	0.25	0.64	0.2	0.016
2.01-5.00	0.43	0.44	0.92	0.15	0.0038
> 5.00	0.16	0	0.08	0.0025	0.00026

For the municipality of Daet with an area of 42.2 sq. km., 39.91% will experience flood levels of less than 0.20 meters. 17.84% of the area will experience flood levels of 0.21 to 0.50 meters, while 16.15%, 14.39%, 9.6%, and 2.05% 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. Figures 82 and 83 depict the areas affected in Daet in square kilometers by flood depth per barangay.

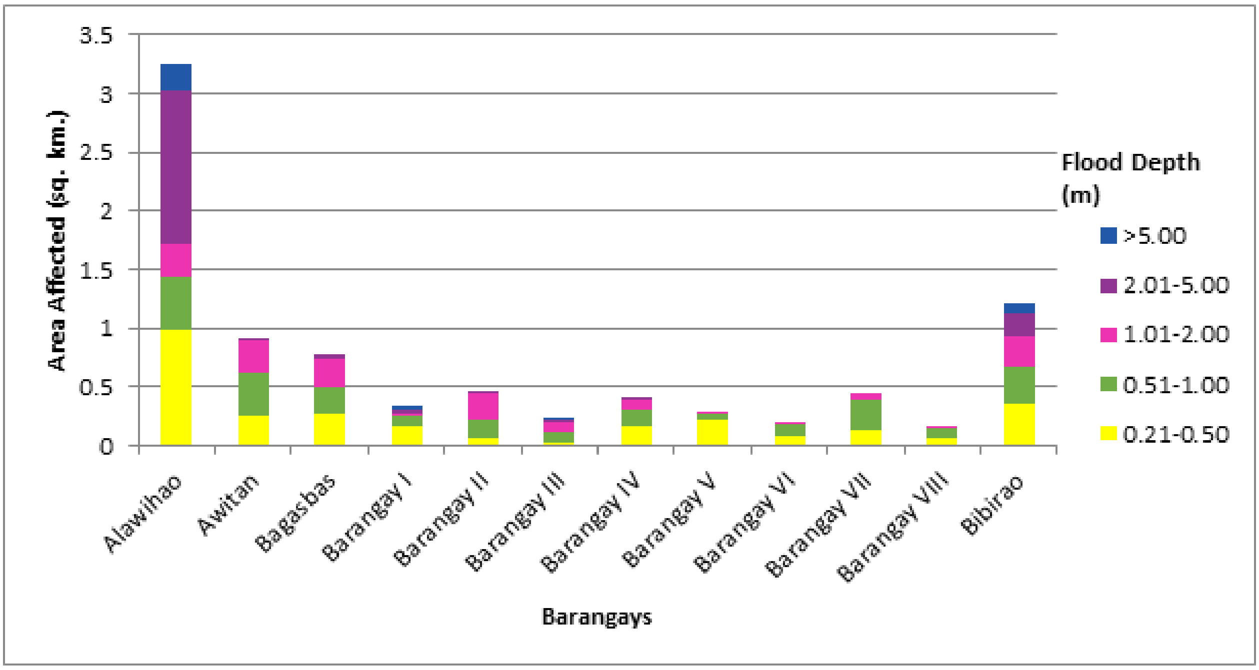


Figure 82. Affected Areas in Daet, Camarines Norte during the 25-Year Rainfall Return Period

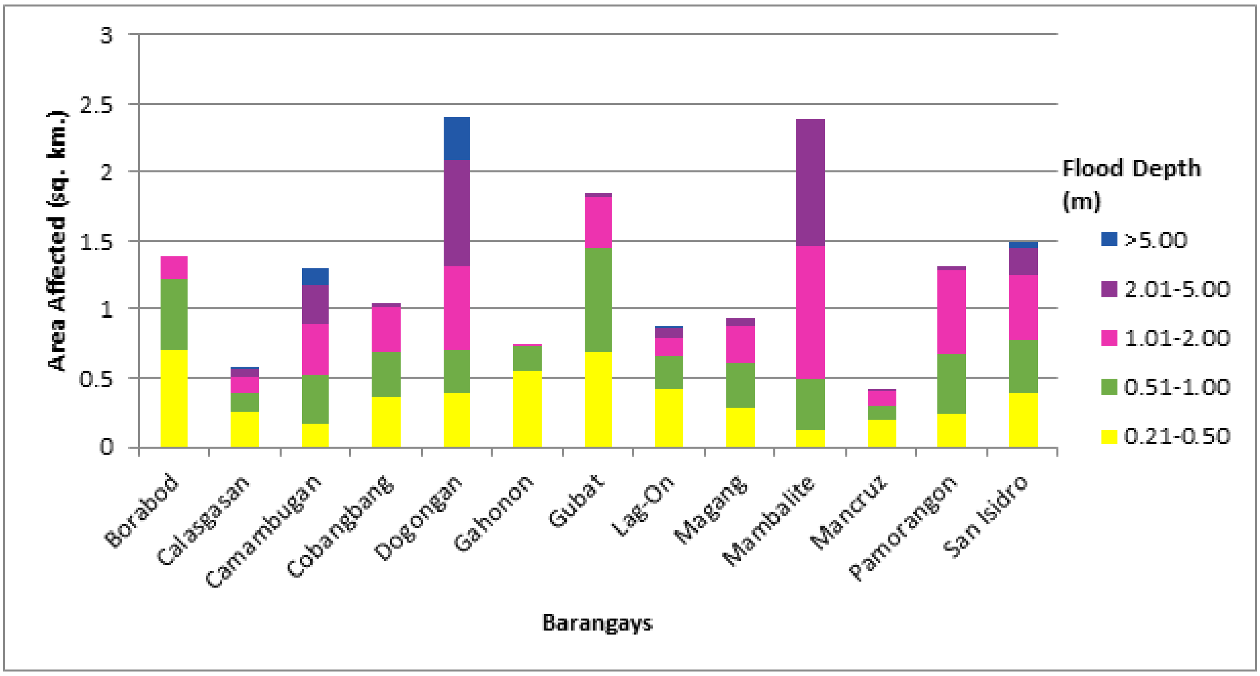


Figure 83. Affected Areas in Daet, Camarines Norte during the 25-Year Rainfall Return Period

Table 47. Affected Areas in Daet, Camarines Norte during the 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Daet (in sq. km.)													
	Alawihao	Awitan	Bagasbas	Barangay I	Barangay II	Barangay III	Barangay IV	Barangay V	Barangay VI	Barangay VII	Barangay VIII	Bibirao	Borabod	Calasgasan
0.03-0.20	2.77	0.42	0.71	0.14	0.042	0.014	0.28	0.48	0.076	0.046	0.09	1.38	0.81	1.66
0.21-0.50	0.98	0.25	0.27	0.16	0.062	0.023	0.17	0.22	0.077	0.13	0.065	0.36	0.71	0.26
0.51-1.00	0.46	0.38	0.23	0.093	0.15	0.091	0.14	0.059	0.1	0.27	0.075	0.3	0.52	0.13
1.01-2.00	0.27	0.27	0.25	0.021	0.24	0.079	0.08	0.0042	0.0075	0.043	0.0072	0.28	0.16	0.11
2.01-5.00	1.31	0.013	0.019	0.026	0.017	0.017	0.003	0	0	0	0	0.18	0	0.06
> 5.00	0.22	0	0	0.043	0	0.022	0	0	0	0	0	0.086	0	0.0037

Table 48. Affected Areas in Daet, Camarines Norte during the 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Daet (in sq. km.)										
	Camambugan	Cobangbang	Dogongan	Gahonon	Gubat	Lag-On	Magang	Mambalite	Mancruz	Pamorangon	San Isidro
0.03-0.20	0.055	0.2	1.69	1.23	0.94	0.88	0.75	0.11	0.92	0.56	0.59
0.21-0.50	0.17	0.36	0.39	0.56	0.69	0.42	0.28	0.13	0.19	0.24	0.38
0.51-1.00	0.36	0.33	0.31	0.18	0.75	0.24	0.33	0.37	0.11	0.43	0.39
1.01-2.00	0.36	0.33	0.61	0.0073	0.38	0.13	0.28	0.96	0.092	0.61	0.48
2.01-5.00	0.29	0.019	0.77	0	0.037	0.082	0.06	0.93	0.0036	0.027	0.19
> 5.00	0.12	0	0.32	0	0	0.0081	0	0	0	0	0.045

For the municipality of Mercedes with an area of 117.17 sq. km., 7.55% will experience flood levels of less than 0.20 meters. 1.48% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.72%, 2.41%, 2.19%, and 0.05% 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. Figures 84 and 85 depict the areas affected in Mercedes in square kilometers by flood depth per barangay.

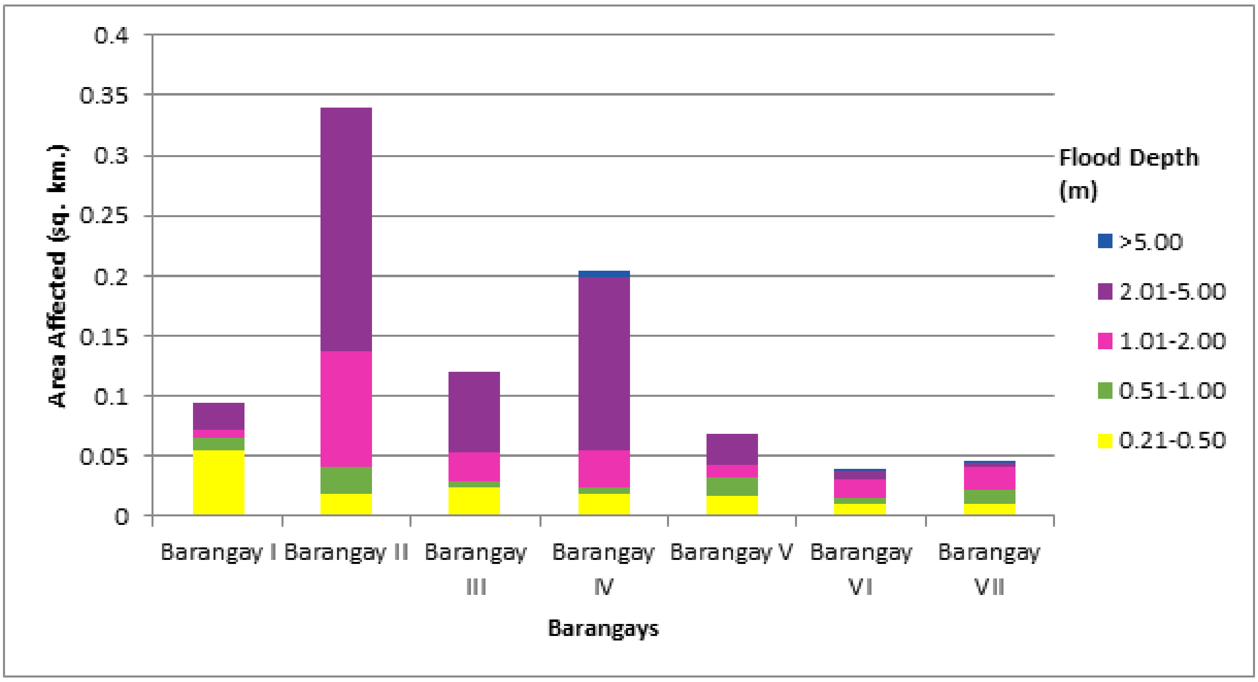


Figure 84. Affected Areas in Mercedes, Camarines Norte during the 25-Year Rainfall Return Period

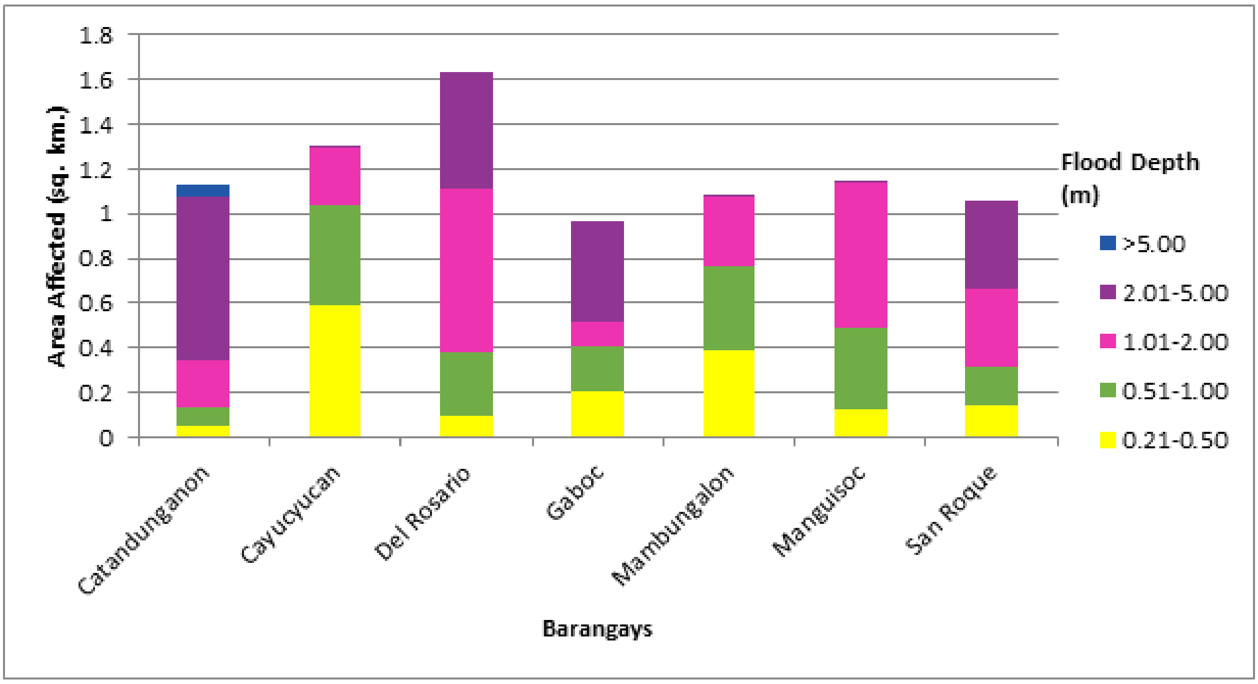


Figure 85. Affected Areas in Mercedes, Camarines Norte during the 25-Year Rainfall Return Period

Table 49. Affected Areas in Mercedes, Camarines Norte during the 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mercedes (in sq. km.)									
	Barangay I	Barangay II	Barangay III	Barangay IV	Barangay V	Barangay VI	Barangay VII	Catandunganon	Cayucyucan	Del Rosario
0.03-0.20	0.17	0.047	0.068	0.051	0.04	0.049	0.034	0.26	2.05	0.099
0.21-0.50	0.054	0.019	0.024	0.019	0.017	0.0095	0.01	0.049	0.59	0.095
0.51-1.00	0.011	0.022	0.0047	0.0058	0.016	0.0054	0.012	0.08	0.45	0.29
1.01-2.00	0.0076	0.097	0.025	0.03	0.011	0.016	0.018	0.22	0.26	0.73
2.01-5.00	0.021	0.2	0.066	0.15	0.026	0.0064	0.0046	0.73	0.0005	0.52
> 5.00	0	0	0	0.0048	0.000000003	0.00011	0.0016	0.058	0	0

Table 50. Affected Areas in Mercedes, Camarines Norte during the 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Daraga			
	Gaboc	Mambungalon	Manguisoc	San Roque
0.03-0.20	2.93	1.89	0.81	0.34
0.21-0.50	0.2	0.39	0.12	0.14
0.51-1.00	0.2	0.38	0.37	0.18
1.01-2.00	0.11	0.31	0.65	0.35
2.01-5.00	0.45	0.013	0.0043	0.39
> 5.00	0	0	0	0

For the municipality of San Lorenzo Ruiz with an area of 108.81 sq. km., 19.31% will experience flood levels of less than 0.20 meters. 2.29% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.6%, 1.63%, 1.26%, and 0.34% 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. Figure 86 depicts the areas affected in San Lorenzo Ruiz in square kilometers by flood depth per barangay.

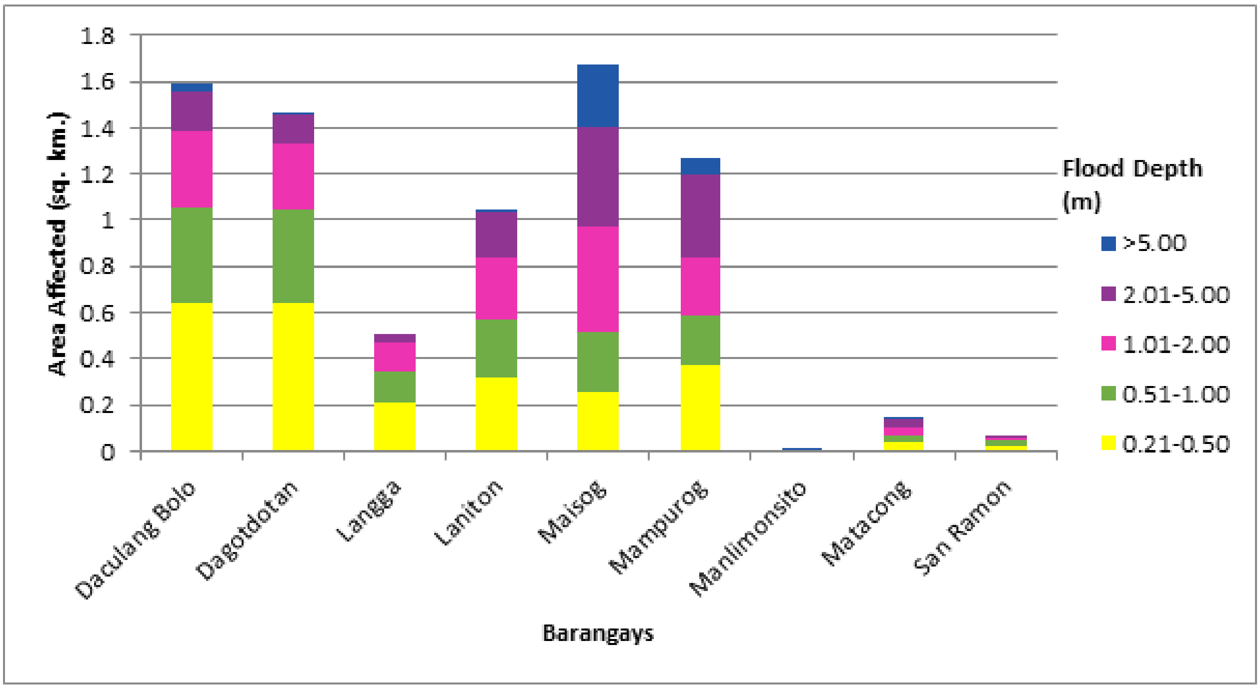


Figure 86. Affected Areas in San Lorenzo Ruiz, Camarines Norte during the 25-Year Rainfall Return Period

Table 51. Affected Areas in San Lorenzo Ruiz, Camarines Norte during the 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Lorenzo Ruiz (in sq. km.)								
	Daculang Bolo	Dagotdotan	Langga	Laniton	Maisog	Mampurog	Manlimonsito	Matacong	San Ramon
0.03-0.20	4.28	2.4	1.9	2.87	4.19	4.51	0.063	0.57	0.24
0.21-0.50	0.64	0.64	0.21	0.32	0.25	0.37	0.0028	0.036	0.021
0.51-1.00	0.42	0.41	0.14	0.25	0.26	0.22	0.00091	0.034	0.024
1.01-2.00	0.33	0.29	0.13	0.26	0.46	0.25	0.0019	0.03	0.017
2.01-5.00	0.17	0.13	0.031	0.2	0.43	0.36	0.00032	0.041	0.0016
> 5.00	0.029	0.0034	0	0.0013	0.26	0.068	0.00011	0.0018	0

For the municipality of San Vicente with an area of 47.17 sq. km., 23.17% will experience flood levels of less than 0.20 meters. 2.53% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.83%, 2.28%, 2.34%, and 0.42% 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. Figure 87 depicts the areas affected in San Vicente in square kilometers by flood depth per barangay.

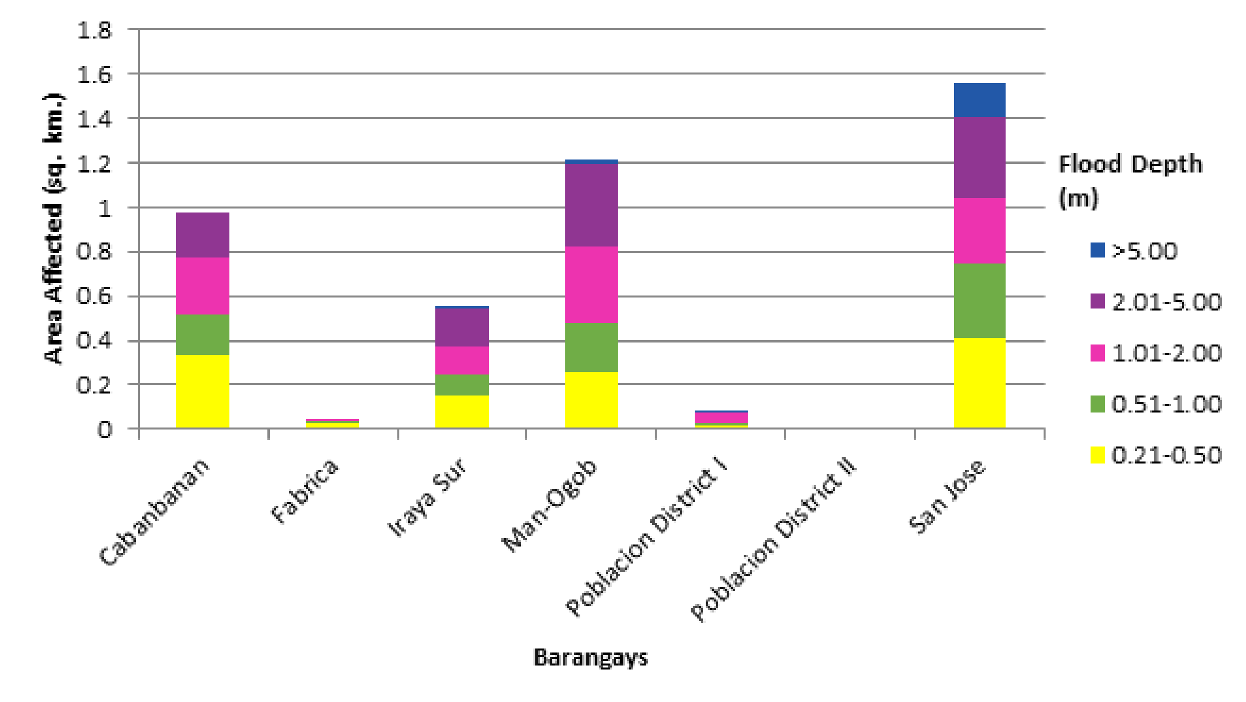


Figure 87. Affected Areas in San Vicente, Camarines Norte during the 25-Year Rainfall Return Period

Table 52. Affected Areas in San Vicente, Camarines Norte during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Vicente (in sq. km.)						
	Del Rosario	Florista	San Isidro	San Roque	Poblacion District I	Poblacion District II	San Jose
0.03-0.20	2.23	0.25	2.67	3.42	0.16	0.000082	2.19
0.21-0.50	0.33	0.031	0.15	0.26	0.013	0	0.41
0.51-1.00	0.19	0.01	0.099	0.21	0.015	0	0.34
1.01-2.00	0.26	0.00086	0.12	0.35	0.052	0	0.29
2.01-5.00	0.2	0	0.17	0.37	0	0	0.36
> 5.00	0	0	0.014	0.025	0.0029	0	0.16

For the municipality of Talisay with an area of 37.9 sq. km., 15.41% will experience flood levels of less than 0.20 meters. 8.2% of the area will experience flood levels of 0.21 to 0.50 meters, while 7.99%, 6.98%, 3.91%, and 0.18% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 88 depicts the areas affected in Talisay in square kilometers by flood depth per barangay.

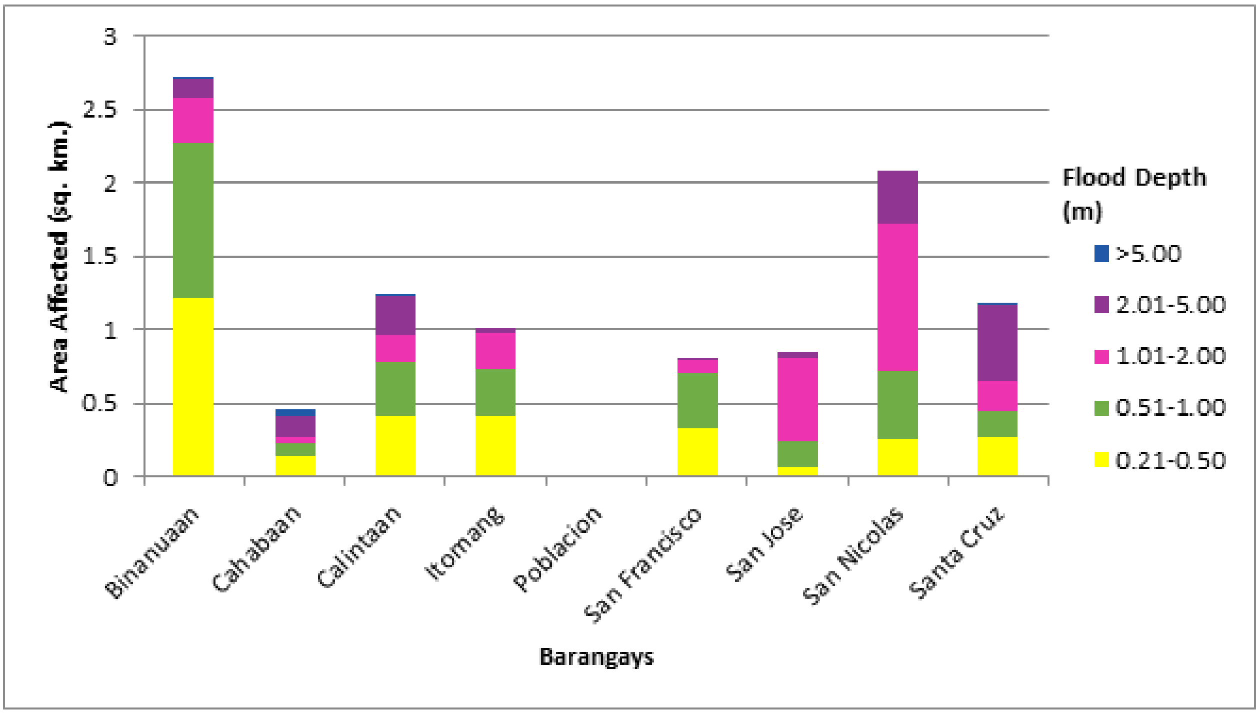


Figure 88. Affected Areas in Talisay, Camarines Norte during the 25-Year Rainfall Return Period

Table 53. Affected Areas in Talisay, Camarines Norte during the 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Daraga								
	Binanuaan	Cahabaan	Calintaan	Itomang	Poblacion	San Francisco	San Jose	San Nicolas	Santa Cruz
0.03-0.20	1.51	0.24	0.46	1.05	0.0038	0.39	0.21	0.44	1.52
0.21-0.50	1.22	0.14	0.41	0.41	0.00099	0.34	0.061	0.26	0.27
0.51-1.00	1.06	0.089	0.37	0.32	0	0.37	0.18	0.46	0.17
1.01-2.00	0.31	0.042	0.18	0.24	0	0.082	0.56	1.01	0.22
2.01-5.00	0.13	0.14	0.25	0.029	0	0.0014	0.041	0.37	0.52
> 5.00	0.0002	0.038	0.023	0	0	0	0	0	0.0085

For the 100-year rainfall return period, 28.85% of the municipality of Basud with an area of 251.71 sq. km. will experience flood levels of less than 0.20 meters. 2.3% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.67%, 3.98%, 7.42%, and 1.47% 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. Figures 89 to 91 depict the areas affected in Basud in square kilometers by flood depth per barangay.

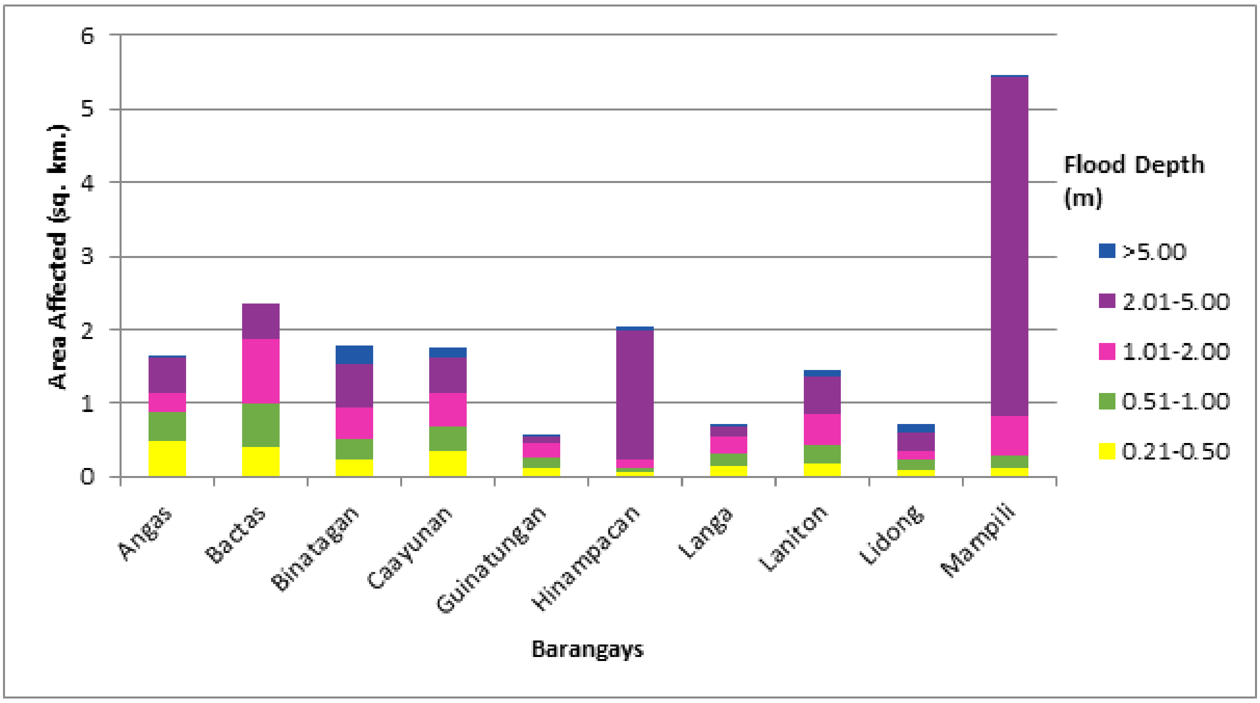


Figure 89. Affected Areas in Basud, Camarines Norte during the 100-Year Rainfall Return Period

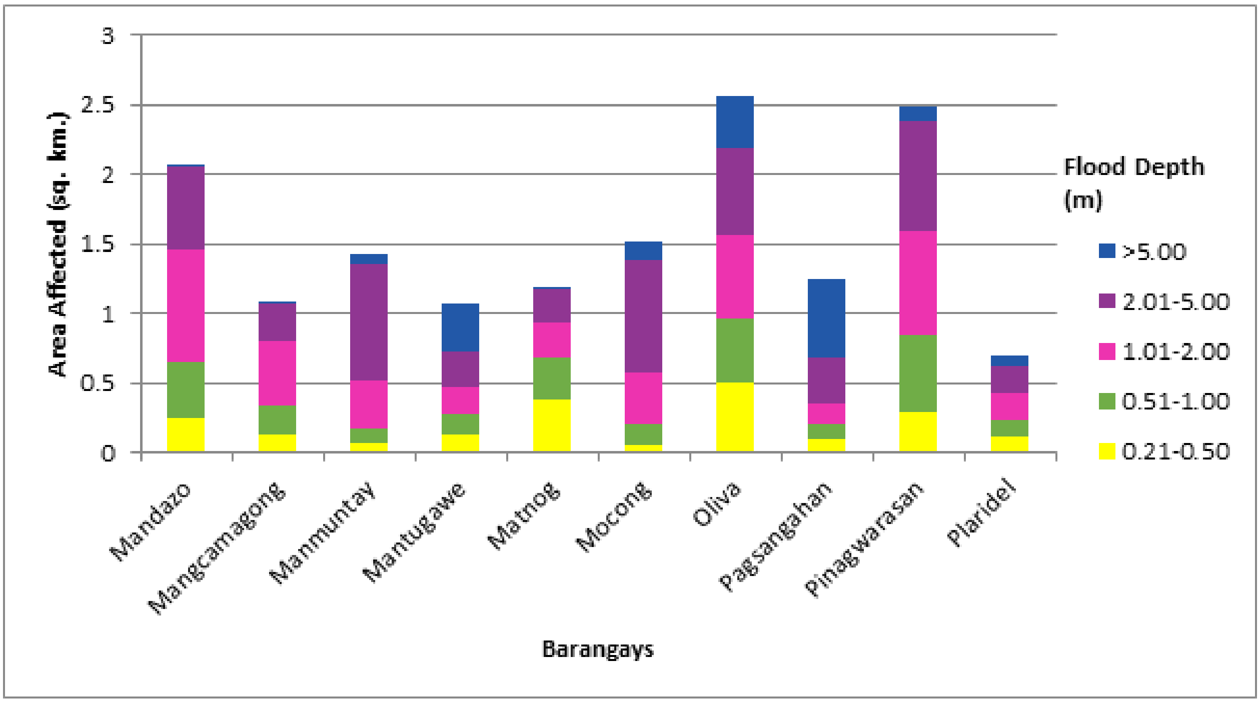


Figure 90. Affected Areas in Basud, Camarines Norte during the 100-Year Rainfall Return Period

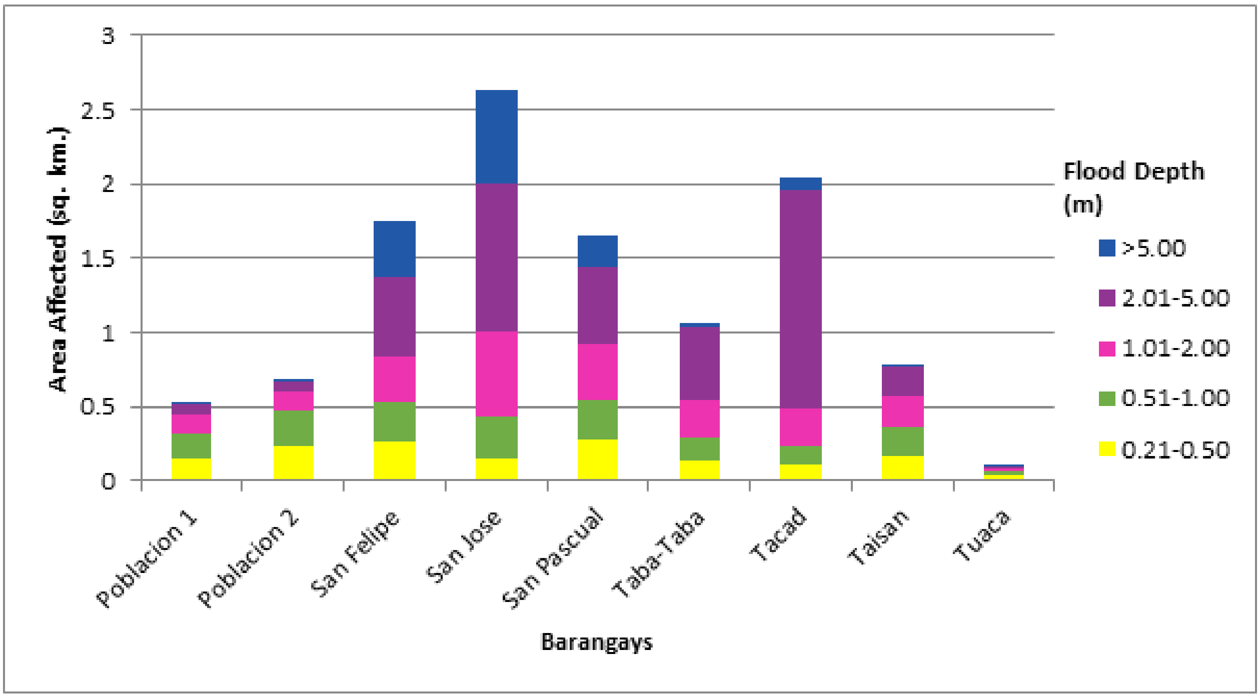


Figure 91. Affected Areas in Basud, Camarines Norte during the 100-Year Rainfall Return Period

Table 54. Affected Areas in Basud, Camarines Norte during the 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basud (in sq. km.)												
	Angas	Bactas	Binatagan	Caayunan	Guinatungan	Hinampacan	Langa	Laniton	Lidong	Mampili	Mandazo	Mangcamagong	Manmuntay
0.03-0.20	2.69	0.54	3.86	7	2.94	1.16	2.71	2.59	1.98	0.28	1.39	1.66	1.13
0.21-0.50	0.48	0.41	0.24	0.35	0.13	0.066	0.15	0.19	0.1	0.12	0.24	0.13	0.069
0.51-1.00	0.39	0.58	0.27	0.32	0.14	0.062	0.17	0.24	0.12	0.16	0.4	0.21	0.098
1.01-2.00	0.27	0.88	0.42	0.46	0.18	0.099	0.24	0.43	0.14	0.54	0.82	0.47	0.34
2.01-5.00	0.47	0.47	0.61	0.49	0.091	1.75	0.13	0.5	0.24	4.62	0.59	0.26	0.84
> 5.00	0.0014	0	0.25	0.13	0.0069	0.052	0.032	0.077	0.12	0.019	0.0007	0.0038	0.067

Table 55. Affected Areas in Basud, Camarines Norte during the 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basud (in sq. km.)										
	Mantugawe	Matnog	Mocong	Oliva	Pagsangahan	Pinagwarasan	Plaridel	Poblacion 1	Poblacion 2	San Felipe	San Jose
0.03-0.20	2.69	2.34	0.11	10.86	1.8	3.35	2.2	0.37	0.57	4.57	1.17
0.21-0.50	0.13	0.38	0.053	0.5	0.1	0.3	0.12	0.16	0.24	0.27	0.15
0.51-1.00	0.14	0.3	0.15	0.47	0.11	0.55	0.12	0.16	0.24	0.27	0.28
1.01-2.00	0.19	0.25	0.37	0.6	0.15	0.74	0.19	0.12	0.12	0.31	0.57
2.01-5.00	0.26	0.24	0.81	0.62	0.32	0.8	0.19	0.084	0.071	0.53	1
> 5.00	0.34	0.0053	0.14	0.38	0.57	0.11	0.069	0.00022	0.008	0.37	0.63

Table 56. Affected Areas in Basud, Camarines Norte during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Basud (in sq. km.)				
	San Pascual	Taba-Taba	Tacad	Taisan	Tuaca
0.03-0.20	6.85	1.38	1.04	2.8	0.61
0.21-0.50	0.28	0.14	0.1	0.16	0.046
0.51-1.00	0.26	0.15	0.13	0.2	0.022
1.01-2.00	0.38	0.25	0.26	0.21	0.018
2.01-5.00	0.52	0.49	1.47	0.19	0.0046
> 5.00	0.21	0.033	0.086	0.0033	0.00046

For the municipality of Daet with an area of 42.2 sq. km., 29.66% will experience flood levels of less than 0.20 meters. 15.01% of the area will experience flood levels of 0.21 to 0.50 meters, while 16.18%, 20.08%, 16.31%, and 2.7% 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. Figures 92 and 93 depict the areas affected in Daet in square kilometers by flood depth per barangay.

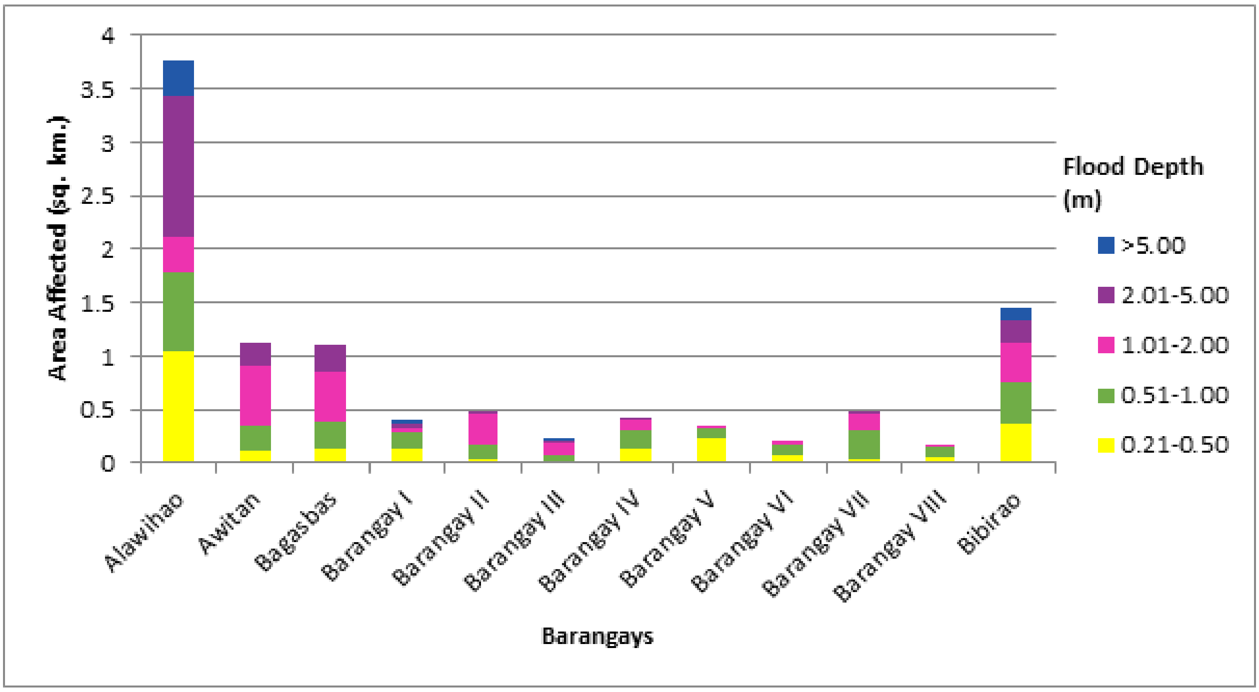


Figure 92. Affected Areas in Daet, Camarines Norte during the 100-Year Rainfall Return Period

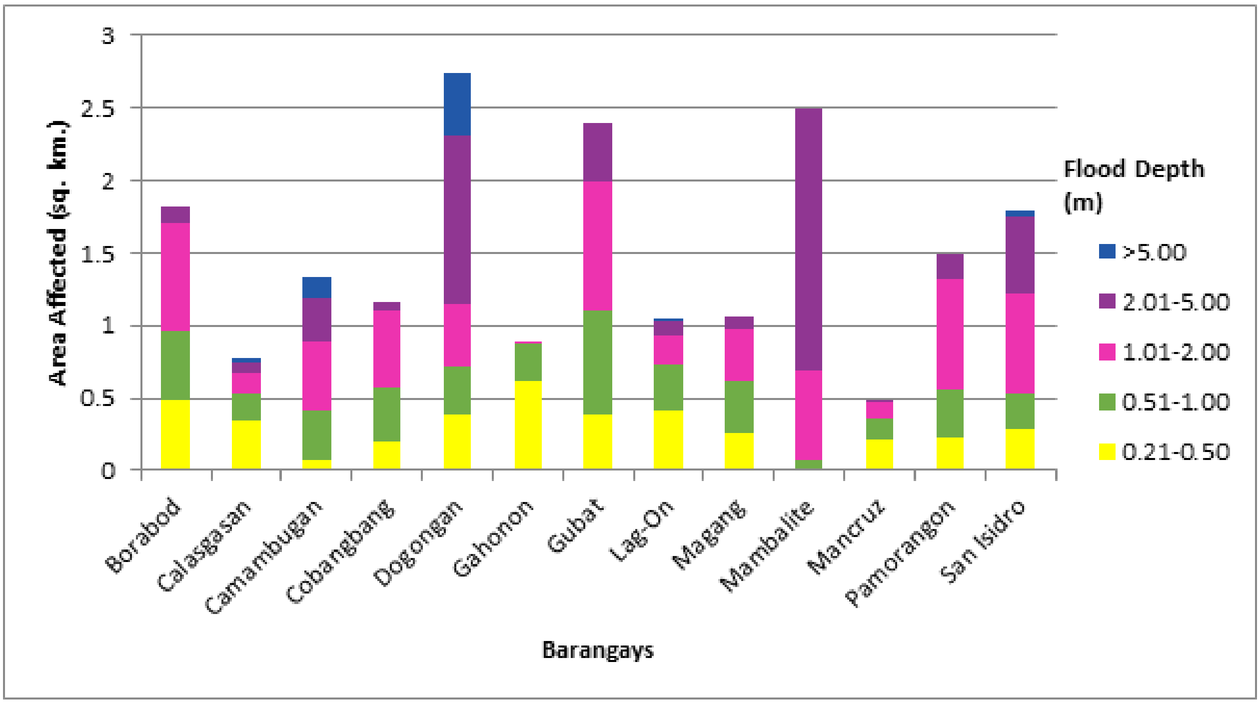


Figure 93. Affected Areas in Daet, Camarines Norte during the 100-Year Rainfall Return Period

Table 57. Affected Areas in Daet, Camarines Norte during the 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Daet (in sq. km.)													
	Alawihao	Awitan	Bagasbas	Barangay I	Barangay II	Barangay III	Barangay IV	Barangay V	Barangay VI	Barangay VII	Barangay VIII	Bibirao	Borabod	Calasgasan
0.03-0.20	2.26	0.2	0.36	0.073	0.022	0.0064	0.24	0.42	0.053	0.024	0.053	1.14	0.39	1.46
0.21-0.50	1.05	0.12	0.14	0.13	0.037	0.016	0.14	0.24	0.074	0.048	0.064	0.38	0.48	0.34
0.51-1.00	0.74	0.23	0.24	0.17	0.13	0.066	0.17	0.088	0.1	0.27	0.086	0.38	0.48	0.19
1.01-2.00	0.34	0.57	0.48	0.035	0.29	0.11	0.099	0.011	0.034	0.15	0.034	0.36	0.75	0.14
2.01-5.00	1.31	0.22	0.25	0.027	0.03	0.022	0.0098	0	0	0.0002	0	0.22	0.11	0.079
> 5.00	0.33	0	0	0.044	0	0.023	0	0	0	0	0	0.11	0	0.018

Table 58. Affected Areas in Daet, Camarines Norte during the 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Daet (in sq. km.)										
	Camambugan	Cobangbang	Dogongan	Gahonon	Gubat	Lag-On	Magang	Mambalite	Mancruz	Pamorangon	San Isidro
0.03-0.20	0.028	0.085	1.36	1.08	0.41	0.72	0.63	0.011	0.83	0.38	0.28
0.21-0.50	0.073	0.2	0.39	0.61	0.39	0.42	0.25	0.016	0.22	0.22	0.28
0.51-1.00	0.35	0.37	0.33	0.27	0.71	0.32	0.37	0.059	0.14	0.34	0.25
1.01-2.00	0.46	0.54	0.43	0.017	0.89	0.19	0.36	0.62	0.12	0.76	0.68
2.01-5.00	0.31	0.049	1.16	0	0.4	0.098	0.087	1.8	0.014	0.17	0.53
> 5.00	0.13	0	0.43	0	0	0.0092	0	0	0	0	0.049

For the municipality of Mercedes with an area of 117.17 sq. km., 6.49% will experience flood levels of less than 0.20 meters. 1.3% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.5%, 2.54%, 3.52%, and 0.06% 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. Figures 94 and 95 depict the areas affected in Mercedes in square kilometers by flood depth per barangay.

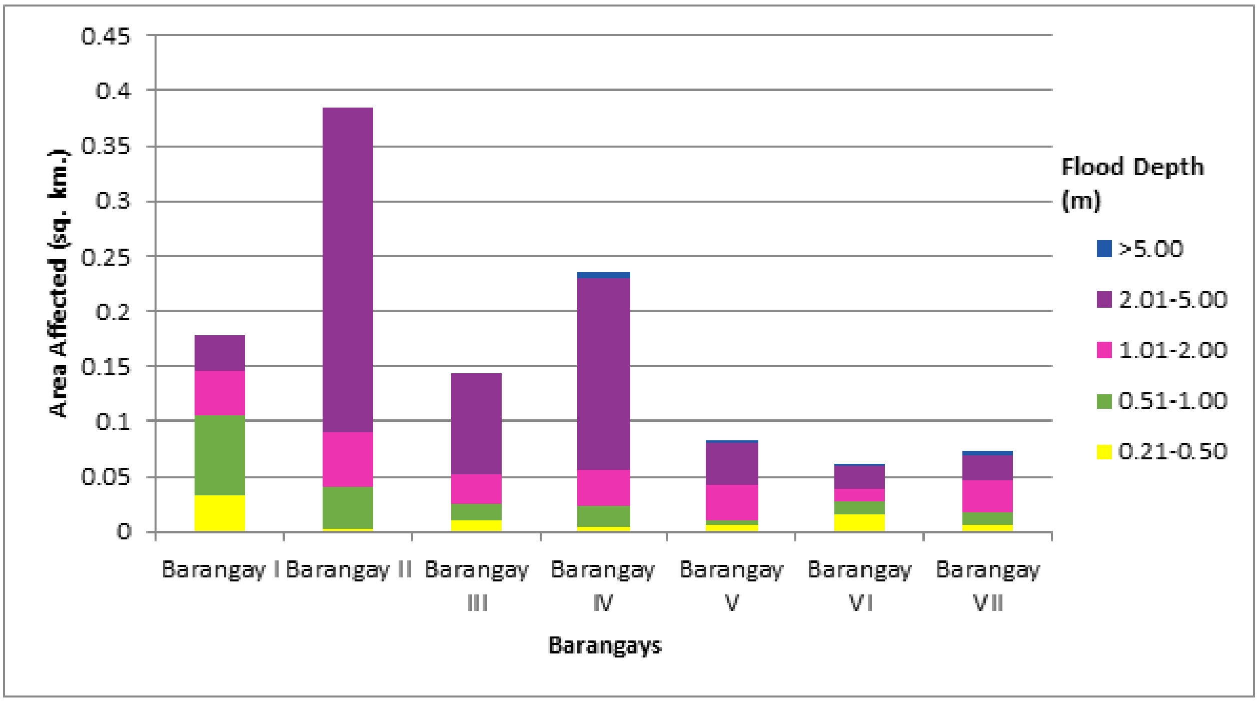


Figure 94. Affected Areas in Mercedes, Camarines Norte during the 100-Year Rainfall Return Period

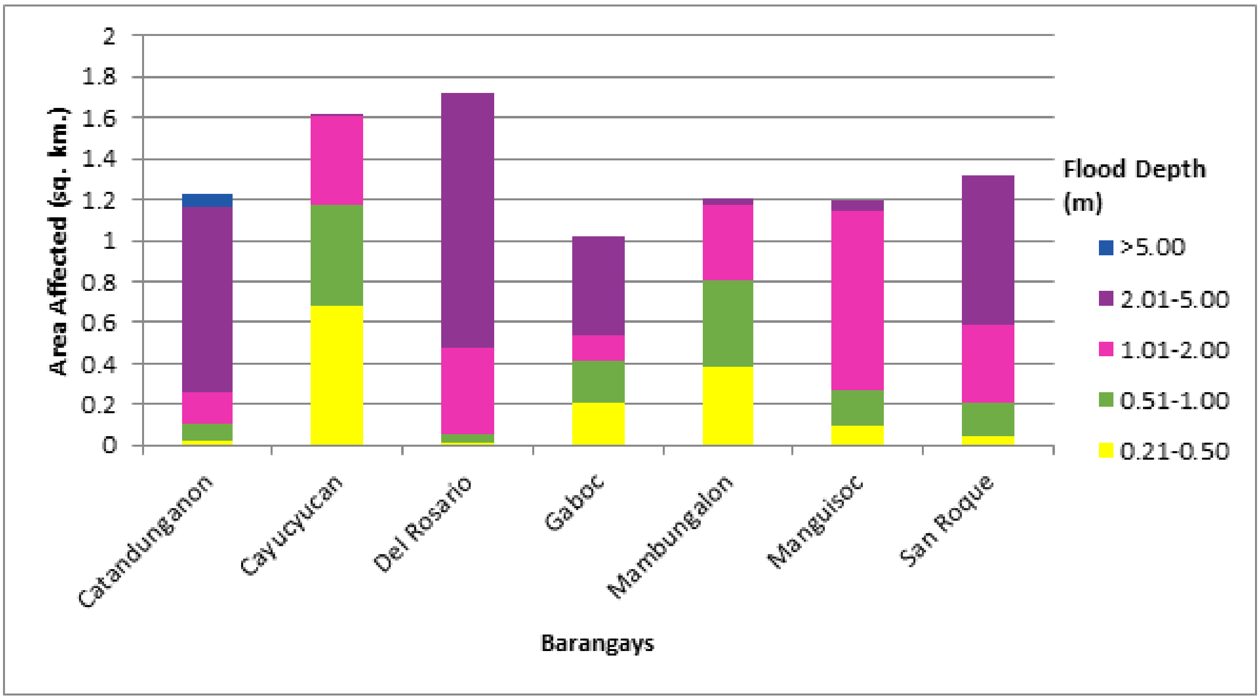


Figure 95. Affected Areas in Mercedes, Camarines Norte during the 100-Year Rainfall Return Period

Table 59. Affected Areas in Mercedes, Camarines Norte during the 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mercedes (in sq. km.)									
	Barangay I	Barangay II	Barangay III	Barangay IV	Barangay V	Barangay VI	Barangay VII	Catandunganon	Cayucyucan	Del Rosario
0.03-0.20	0.082	0.0013	0.045	0.019	0.03	0.025	0.0081	0.16	1.74	0.0075
0.21-0.50	0.032	0.0028	0.0099	0.0046	0.0068	0.015	0.0053	0.024	0.68	0.01
0.51-1.00	0.073	0.037	0.015	0.018	0.0035	0.012	0.012	0.08	0.49	0.048
1.01-2.00	0.042	0.051	0.027	0.033	0.032	0.011	0.029	0.16	0.44	0.42
2.01-5.00	0.031	0.29	0.091	0.17	0.037	0.023	0.022	0.9	0.0022	1.24
> 5.00	0	0	0	0.0065	0.000037	0.00017	0.0033	0.066	0	0

Table 60. Affected Areas in Mercedes, Camarines Norte during the 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Daraga			
	Gaboc	Mambungalon	Manguisoc	San Roque
0.03-0.20	2.88	1.77	0.76	0.078
0.21-0.50	0.21	0.38	0.096	0.041
0.51-1.00	0.21	0.42	0.18	0.17
1.01-2.00	0.12	0.38	0.87	0.38
2.01-5.00	0.48	0.028	0.056	0.74
> 5.00	0	0	0	0

For the municipality of San Lorenzo Ruiz with an area of 108.81 sq. km., 17.83% will experience flood levels of less than 0.20 meters. 2.68% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.95%, 1.87%, 1.67%, and 0.43% 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. Figure 96 depicts the areas affected in San Lorenzo Ruiz in square kilometers by flood depth per barangay.

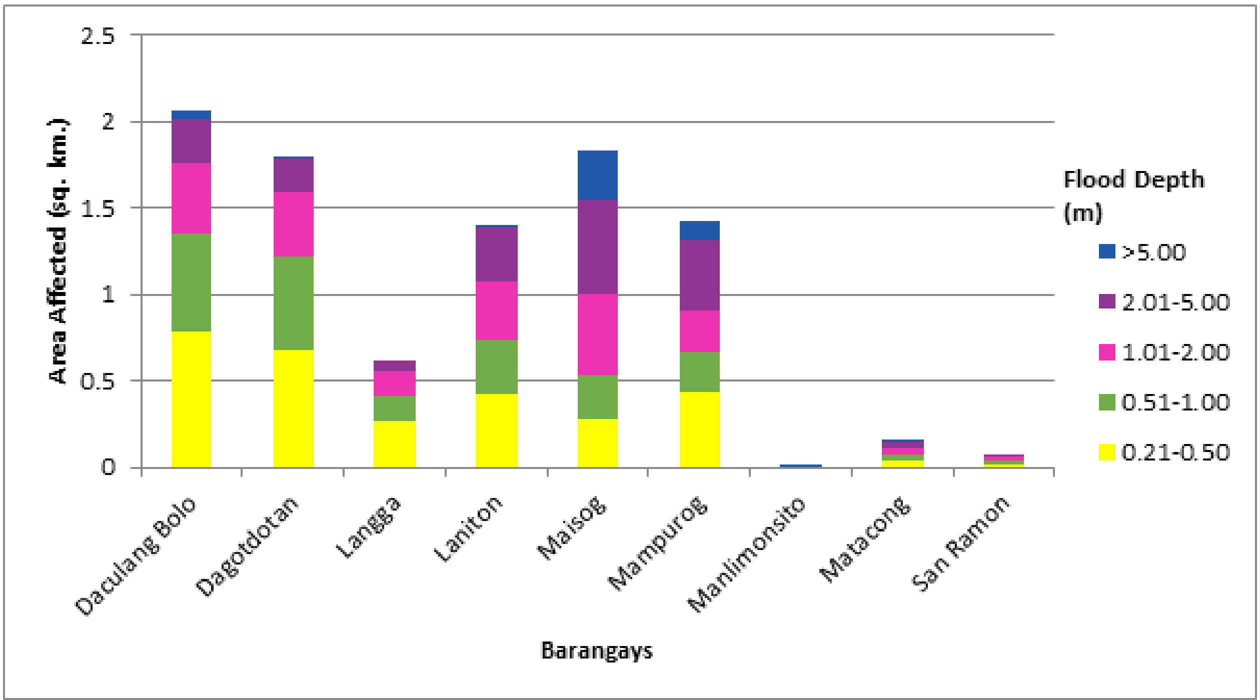


Figure 96. Affected Areas in San Lorenzo Ruiz, Camarines Norte during the 100-Year Rainfall Return Period

Table 61. Affected Areas in San Lorenzo Ruiz, Camarines Norte during the 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Lorenzo Ruiz (in sq. km.)								
	Daculang Bolo	Dagotdotan	Langga	Laniton	Maisog	Mampurog	Manlimonsito	Matacong	San Ramon
0.03-0.20	3.8	2.06	1.79	2.51	4.02	4.35	0.063	0.56	0.24
0.21-0.50	0.78	0.68	0.26	0.42	0.28	0.43	0.0029	0.035	0.019
0.51-1.00	0.56	0.54	0.15	0.32	0.25	0.23	0.001	0.036	0.024
1.01-2.00	0.42	0.38	0.14	0.33	0.46	0.24	0.0017	0.036	0.023
2.01-5.00	0.25	0.19	0.058	0.31	0.54	0.41	0.00068	0.044	0.0023
> 5.00	0.045	0.0078	0	0.0087	0.3	0.1	0.00011	0.0033	0

For the municipality of San Vicente with an area of 47.17 sq. km., 21.79% will experience flood levels of less than 0.20 meters. 2.75% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.99%, 2.27%, 3.15%, and 0.62% 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. Figure 97 depicts the areas affected in San Vicente in square kilometers by flood depth per barangay.

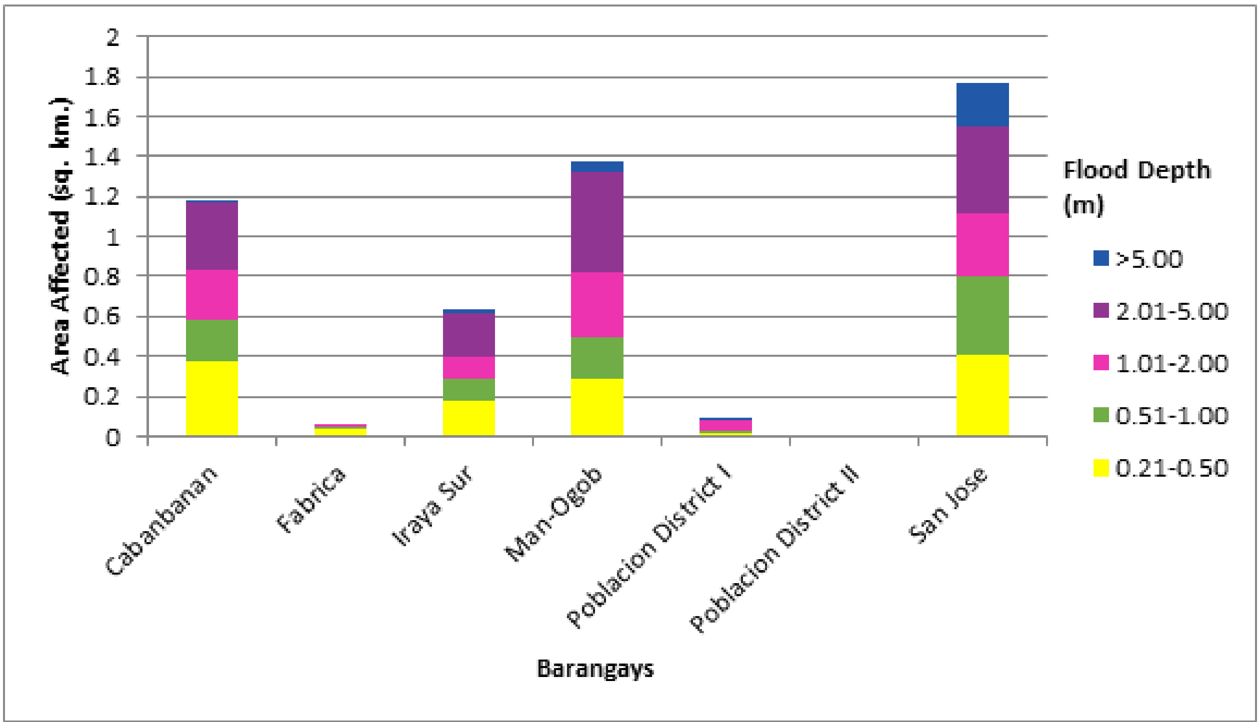


Figure 97. Affected Areas in San Lorenzo Ruiz, Camarines Norte during the 100-Year Rainfall Return Period

Table 62. Affected Areas in San Vicente, Camarines Norte during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Vicente (in sq. km.)						
	Del Rosario	Florista	San Isidro	San Roque	Poblacion District I	Poblacion District II	San Jose
0.03-0.20	2.04	0.24	2.59	3.26	0.16	0.000082	1.98
0.21-0.50	0.38	0.034	0.18	0.28	0.014	0	0.41
0.51-1.00	0.2	0.013	0.11	0.21	0.011	0	0.39
1.01-2.00	0.25	0.0016	0.11	0.32	0.058	0	0.32
2.01-5.00	0.33	0	0.22	0.5	0.0018	0	0.43
> 5.00	0.00019	0	0.02	0.049	0.0029	0	0.22

For the municipality of Talisay with an area of 37.9 sq. km., 9.86% will experience flood levels of less than 0.20 meters. 6.68% of the area will experience flood levels of 0.21 to 0.50 meters, while 9.82%, 9.81%, 6.23%, and 0.28% 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. Figure 98 depicts the areas affected in Talisay in square kilometers by flood depth per barangay.

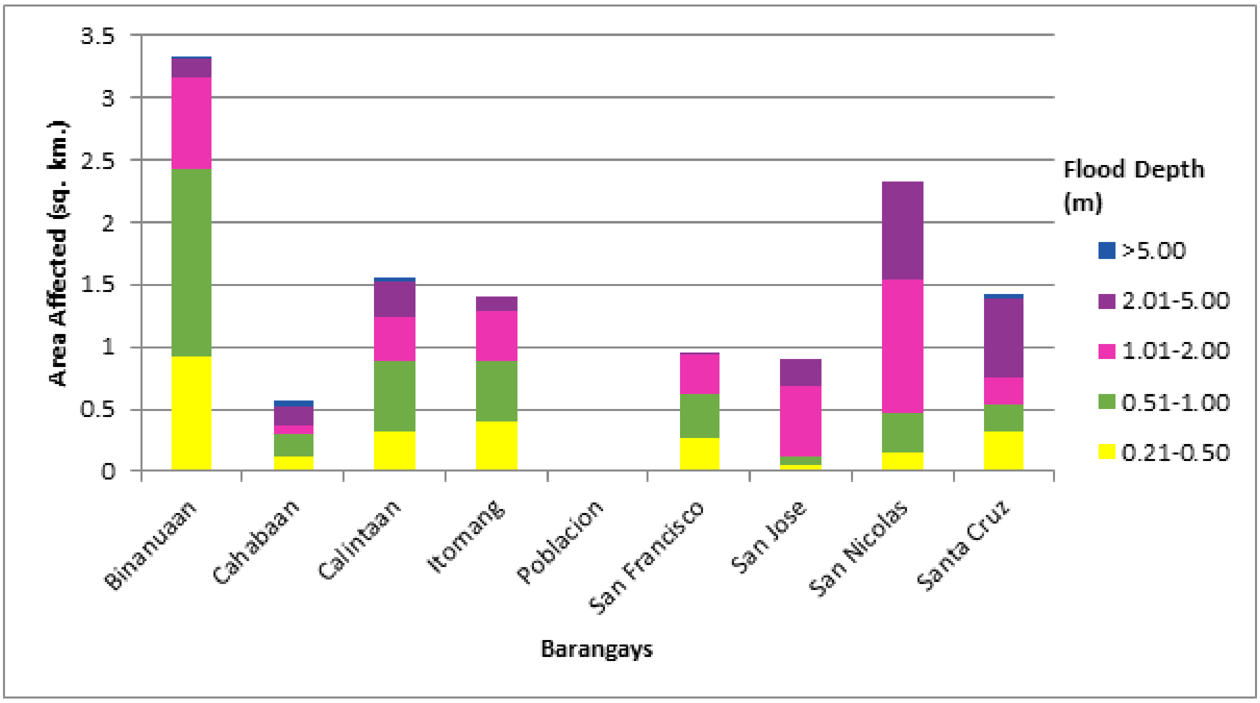


Figure 98. Affected Areas in Talisay, Camarines Norte during the 100-Year Rainfall Return Period

Table 63. Affected Areas in Talisay, Camarines Norte during the 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Affected Barangays in Daraga								
	Binanuaan	Cahabaan	Calintaan	Itomang	Poblacion	San Francisco	San Jose	San Nicolas	Santa Cruz
0.03-0.20	0.9	0.14	0.16	0.65	0.0014	0.24	0.15	0.2	1.29
0.21-0.50	0.93	0.11	0.32	0.4	0.003	0.27	0.04	0.15	0.31
0.51-1.00	1.51	0.19	0.57	0.49	0.00038	0.35	0.077	0.32	0.22
1.01-2.00	0.73	0.072	0.35	0.4	0	0.32	0.56	1.06	0.22
2.01-5.00	0.15	0.14	0.29	0.11	0	0.0051	0.23	0.79	0.64
> 5.00	0.0003	0.05	0.03	0	0	0	0	0	0.025

Among the barangays in the municipality of Basud, Oliva is projected to have the highest percentage of area that will experience flood levels at 5.33%. Meanwhile, Caayunan posted the second highest percentage of area that may be affected by flood depths at 3.48%.

Among the barangays in the municipality of Daet, Alawihao is projected to have the highest percentage of area that will experience flood levels at 14.26%. Meanwhile, Dogongan posted the second highest percentage of area that may be affected by flood depths at 9.71%.

Among the barangays in the municipality of Mercedes, Gaboc is projected to have the highest percentage of area that will experience flood levels of at 3.33%. Meanwhile, Cayucyucan posted the second highest percentage of area that may be affected by flood depths of at 2.86%.

Among the barangays in the municipality of San Lorenzo Ruiz, Daculang Bolo is projected to have the highest percentage of area that will experience flood levels of at 5.39%. Meanwhile, Mampurog posted the second highest percentage of area that may be affected by flood depths of at 5.31%.

Among the barangays in the municipality of San Vicente, Man-Ogob is projected to have the highest percentage of area that will experience flood levels of at 9.82%. Meanwhile, San Jose posted the second highest percentage of area that may be affected by flood depths of at 7.95%.

Among the barangays in the municipality of Talisay, Binanuaan is projected to have the highest percentage of area that will experience flood levels of at 11.14%. Meanwhile, Santa Cruz posted the second highest percentage of area that may be affected by flood depths of at 7.14%.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, performing a validation survey work is needed. Field personnel gathered secondary data regarding flood occurrence 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 are identified for validation.

The validation personnel then 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 or by interviewing some residents with knowledge of or have experienced flooding in a particular area.

After which, the actual data from the field was 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 201 points randomly selected all over the Basud flood plain. It has an RMSE value of 0.863404408.

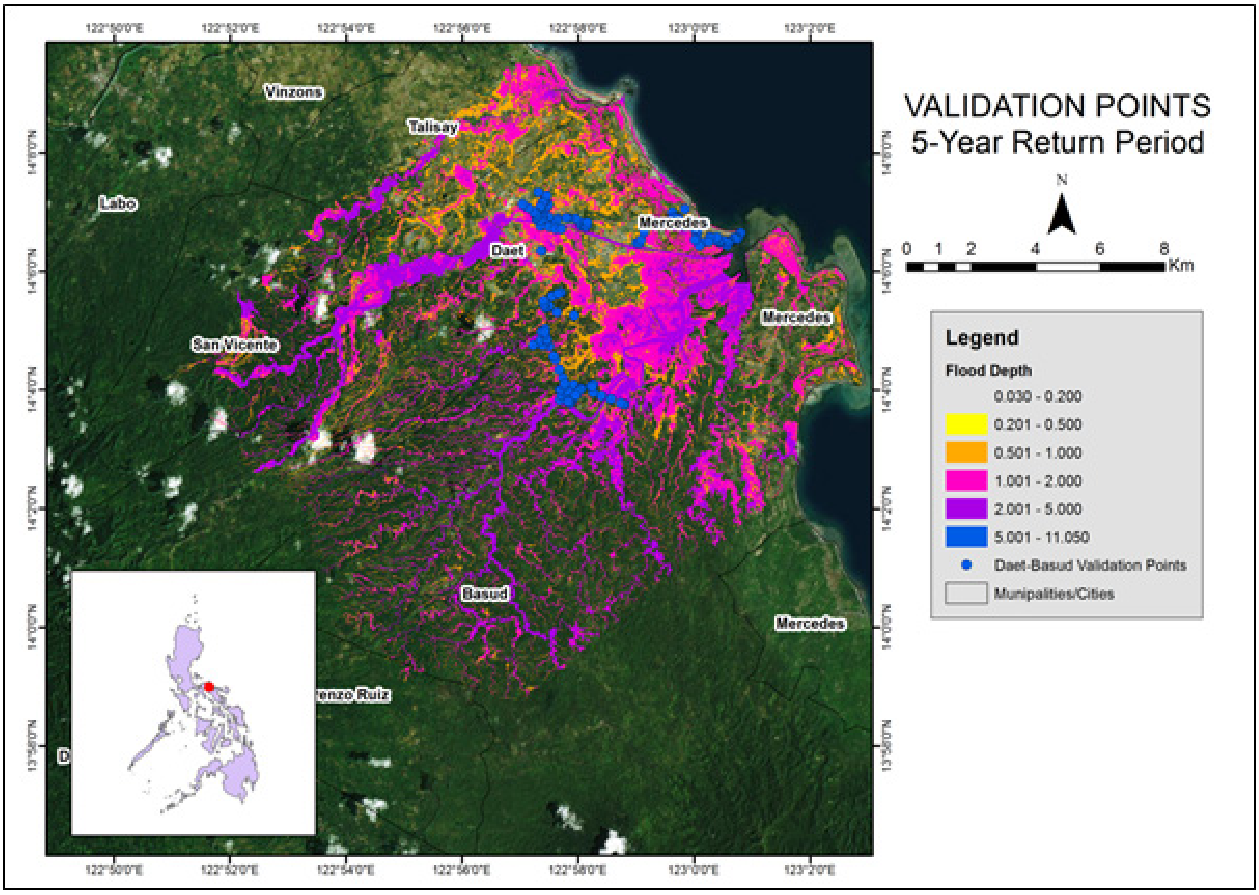


Figure 99. The validation points for the 5-Year flood depth map of the Basud flood plain

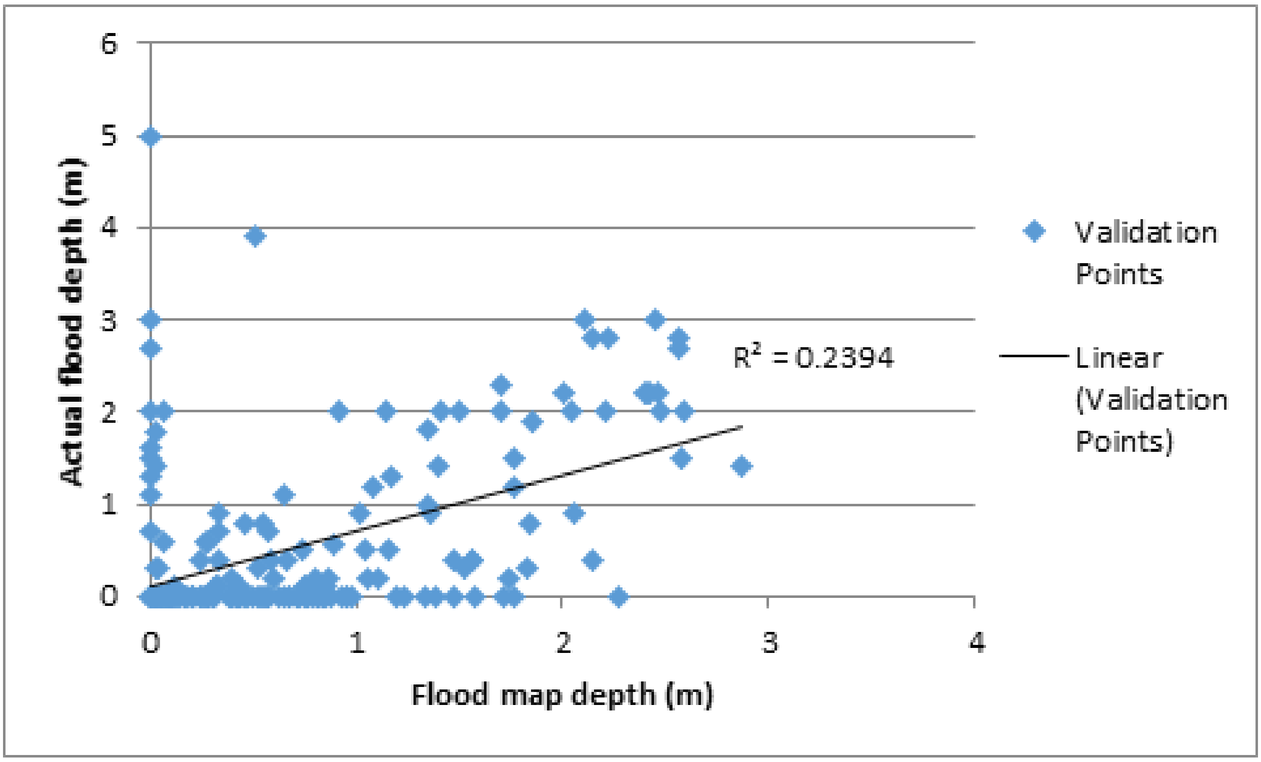


Figure 100. Flood map depth vs. Actual flood depth

Table 64. Actual flood vs simulated flood depth at differnent levels in the Basud 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	48	31	34	11	1	0	125
0.21-0.50	2	2	4	7	1	0	16
0.51-1.00	2	5	3	4	1	0	15
1.01-2.00	8	0	2	11	6	0	27
2.01-5.00	3	0	1	1	11	0	16
> 5.00	0	0	0	0	0	0	0
Total	63	38	44	34	20	0	199

The overall accuracy generated by the flood model is estimated at 37.69%, with 75 points correctly matching the actual flood depths. In addition, there were 55 points estimated one level above and below the correct flood depths, 45 points estimated two levels above and below, and 24 points estimated three or more levels above and below the correct flood depths. A total of 100 points were overestimated while a total of 24 points were underestimated in the modelled flood depths of Basud. Table 65 depicts the summary of the accuracy assessment in the Basud River Basin survey.

Table 65. Summary of the Accuracy Assessment in the Basud River Basin Survey

BASUD	No. of Points	%
Correct	75	37.69
Overestimated	100	50.25
Underestimated	24	12.06
Total	199	100

REFERENCES

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

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

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

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

Paringit, E.C., Balicanta, L.P., Ang, M.C., Lagmay, A.F., 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.J.S., Paringit E.C., et al. 2014. DREAM Data Aquisition Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

ANNEXES

ANNEX 1. Optech Technical Specification of the Pegasus Sensor

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 Certification of Reference Points Used in the LIDAR Survey

1. CMN-33

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

March 11, 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 NORTE**
Station Name: **CMN-33**
Order: **2nd**

Island: **LUZON**		Barangay: **BATOBALANI**	
Municipality: **JOSE PANGANIBAN**		MSL Elevation:	

PRS92 Coordinates

Latitude:	**14° 14' 11.70144"**	Longitude:	**122° 44' 31.91442"**	Ellipsoidal Hgt:	**8.58900 m.**

WGS84 Coordinates

Latitude:	**14° 14' 6.51050"**	Longitude:	**122° 44' 36.82890"**	Ellipsoidal Hgt:	**57.40600 m.**

PTM / PRS92 Coordinates

Northing:	**1574360.987 m.**	Easting:	**472178.341 m.**	Zone:	**4**

UTM / PRS92 Coordinates

Northing:	**1,573,809.93**	Easting:	**472,188.08**	Zone:	**51**

Location Description

CMN-33

From Mun. of Labo, travel NW along Maharlika Highway for about 5.5 Km. up to Brgy. Talobatib, upon reaching Brgy. Talobatib turn right at road junction, then travel for about 7 Km. up to Brgy. Batobalani. Station is located at Brgy. Batobalani. It was established NW wing of Malaquit Bridge, 100 m S of road junction going to Paracale. Mark is the head of a 3 in. copper nail centered on a drilled hole with 30 cm x 30 cm cement putty, embedded at concrete bridge, with inscriptions, "CMN-33, 2007, NAMRIA".

Requesting Party:	**PHIL-LIDAR 1**
Purpose:	**Reference**
OR Number:	**8090013 I**
T.N.:	**2016-0613**

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. CMN-29

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

April 14, 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 NORTE**
Station Name: **CMN-29**
Order: **2nd**

Island: **LUZON**	Barangay: **TANAWAN**	
Municipality: **BAGONG SILANG**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **14° 8' 52.17466"**	Longitude: **122° 34' 59.83481"**	Ellipsoidal Hgt: **40.92600 m.**
	WGS84 Coordinates	
Latitude: **14° 8' 46.99182"**	Longitude: **122° 35' 4.75796"**	Ellipsoidal Hgt: **89.60600 m.**
	PTM / PRS92 Coordinates	
Northing: **1564566.419 m.**	Easting: **455011.114 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,564,018.79**	Easting: **455,026.86**	Zone: **51**

Location Description

CMN-29

From Mun. of Labo, travel W along Maharlika highway for approx. 30 Km. then turn left to a road going to Brgy. Malaya, passing through Malibago Elem. School for about 3 Km. Station is located at Brgy. Malibago. It was established at Basigan, NW of spillway. Mark is the head of a 4 in. copper nail centered on a drilled hole with cement putty, embedded at concrete pavement with inscriptions, "CMN-29, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8084228 I**
T.N.: **2016-0910**

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

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

1. DENR

Vector Components (Mark to Mark)

From:	CMN-33				
Grid		Local		Global	
Easting	472188.079 m	Latitude	N14°14'11.70144"	Latitude	N14°14'06.51050"
Northing	1573809.933 m	Longitude	E122°44'31.91442"	Longitude	E122°44'36.82890"
Elevation	8.054 m	Height	8.589 m	Height	57.406 m

To:	DENR				
Grid		Local		Global	
Easting	498040.596 m	Latitude	N14°08'11.86920"	Latitude	N14°08'06.72152"
Northing	1562740.733 m	Longitude	E122°58'54.64302"	Longitude	E122°58'59.56437"
Elevation	10.763 m	Height	11.089 m	Height	60.772 m

Vector					
ΔEasting	25852.517 m	NS Fwd Azimuth	113°06'57"	ΔX	-23201.756 m
ΔNorthing	-11069.200 m	Ellipsoid Dist.	28133.743 m	ΔY	-11758.951 m
ΔElevation	2.709 m	ΔHeight	2.501 m	ΔZ	-10719.727 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.008 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000239070		
Y	-0.0000322289	0.0000585638	
Z	-0.0000143603	0.0000201237	0.0000119954

2

2. CM-198

DENR - CM-198 (7:15:40 AM-11:29:59 AM) (S3)

Baseline observation:	DENR --- CM-198 (B3)
Processed:	4/22/2016 2:41:05 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.019 m
RMS:	0.003 m
Maximum PDOP:	2.457
Ephemeris used:	Broadcast
Antenna model:	No phase table corrections applied.
Processing start time:	3/14/2016 7:15:40 AM (Local: UTC+8hr)
Processing stop time:	3/14/2016 11:29:59 AM (Local: UTC+8hr)
Processing duration:	04:14:19
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	DENR				
Grid		Local		Global	
Easting	496040.590 m	Latitude	N14°08'11.66904"	Latitude	N14°08'06.72136"
Northing	1562740.728 m	Longitude	E122°58'54.64282"	Longitude	E122°58'59.56417"
Elevation	10.717 m	Height	11.043 m	Height	60.726 m

To:	CM-198				
Grid		Local		Global	
Easting	483569.809 m	Latitude	N14°08'26.36447"	Latitude	N14°08'21.20640"
Northing	1563190.057 m	Longitude	E122°51'58.66504"	Longitude	E122°52'03.58686"
Elevation	16.441 m	Height	16.891 m	Height	66.281 m

Vector					
ΔEasting	-12470.782 m	NS Fwd Azimuth	272°03'33"	ΔX	10528.200 m
ΔNorthing	449.329 m	Ellipsoid Dist.	12483.855 m	ΔY	6694.508 m
ΔElevation	5.724 m	ΔHeight	5.848 m	ΔZ	433.054 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.008 m
σ ΔElevation	0.010 m	σ ΔHeight	0.010 m	σ ΔZ	0.003 m

2

3. CN-211

CMN-33 - CN-211 (2:32:11 PM-3:47:13 PM) (S1)

Baseline observation:	CMN-33 --- CN-211 (B1)
Processed:	6/13/2016 3:39:11 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.006 m
Vertical precision:	0.019 m
RMS:	0.004 m
Maximum PDOP:	2.989
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	4/6/2016 2:32:11 PM (Local: UTC+8hr)
Processing stop time:	4/6/2016 3:47:13 PM (Local: UTC+8hr)
Processing duration:	01:15:02
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	CMN-33				
Grid		**Local**		**Global**	
Easting	472188.079 m	**Latitude**	N14°14'11.70144"	**Latitude**	N14°14'06.51050"
Northing	1573809.933 m	**Longitude**	E122°44'31.91442"	**Longitude**	E122°44'36.82890"
Elevation	8.054 m	**Height**	8.589 m	**Height**	57.406 m

To:	CN-211				
Grid		**Local**		**Global**	
Easting	476182.911 m	**Latitude**	N14°12'10.35973"	**Latitude**	N14°12'05.17982"
Northing	1570078.228 m	**Longitude**	E122°46'45.33929"	**Longitude**	E122°46'50.25638"
Elevation	34.838 m	**Height**	35.369 m	**Height**	84.372 m

Vector					
ΔEasting	3994.832 m	**NS Fwd Azimuth**	132°59'10"	**ΔX**	-3873.755 m
ΔNorthing	-3731.705 m	**Ellipsoid Dist.**	5468.796 m	**ΔY**	-1372.596 m
ΔElevation	26.784 m	**ΔHeight**	26.780 m	**ΔZ**	-3608.128 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	**σ NS fwd Azimuth**	0°00'00"	**σ ΔX**	0.006 m
σ ΔNorthing	0.002 m	**σ Ellipsoid Dist.**	0.002 m	**σ ΔY**	0.008 m
σ ΔElevation	0.010 m	**σ ΔHeight**	0.010 m	**σ ΔZ**	0.003 m

2

4. CMN-J2

Vector Components (Mark to Mark)

From:	CMN-33				
Grid		Local		Global	
Easting	472188.079 m	Latitude	N14°14'11.70144"	Latitude	N14°14'06.51050"
Northing	1573809.933 m	Longitude	E122°44'31.91442"	Longitude	E122°44'36.82890"
Elevation	8.054 m	Height	8.589 m	Height	57.406 m

To:	CMN-J2				
Grid		Local		Global	
Easting	455138.726 m	Latitude	N14°08'53.88940"	Latitude	N14°08'48.70654"
Northing	1564071.272 m	Longitude	E122°35'03.56309"	Longitude	E122°35'08.48618"
Elevation	51.090 m	Height	51.531 m	Height	100.212 m

Vector					
ΔEasting	-17049.354 m	NS Fwd Azimuth	240°12'06"	ΔX	13031.656 m
ΔNorthing	-9738.661 m	Ellipsoid Dist.	19642.244 m	ΔY	11248.492 m
ΔElevation	43.036 m	ΔHeight	42.942 m	ΔZ	-9458.830 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.007 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.011 m
σ ΔElevation	0.014 m	σ ΔHeight	0.014 m	σ ΔZ	0.004 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000516438		
Y	-0.0000773807	0.0001288439	
Z	-0.0000233071	0.0000375098	0.0000122595

Occupations

	From	To
Point ID:	CMN-33	CMN-J2
Data file:	C:\Users\Windows User\Documents \Business Center - HCE\Unnamed(1)\CMN-33 (Topcon) 1.403M [04-08-16].16O	C:\Users\Windows User\Documents \Business Center - HCE\Unnamed(1)\CMN-J2 (Modular) 1.500M [04-08-16].T02
Receiver type:	Unknown	SPS852
Receiver serial number:	U034ESOECQW	5217K84538
Antenna type:	CR.G5	Zephyr Geodetic 2 RoHS
Antenna serial number:	-Unknown-	--------
Antenna height (measured):	1.403 m	1.500 m
Antenna method:	Bottom of antenna mount	Bottom of notch

Tracking Summary

ANNEX 4. The LIDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	UP TCAGP
		LOVELYN ASUNCION	UP TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
		PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	KRISTINE JOY ANDAYA	UP-TCAGP
		MILLIE SHANE REYES	UP-TCAGP
		JONATHAN ALMALVEZ	UP-TCAGP
		JERIEL PAUL ALAMBAN	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JASMIN DOMINGO	UP-TCAGP
		GEF SORIANO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. ERWIN DELOS SANTOS	PHILIPPINE AIR FORCE (PAF)
		SSG JAYCO MANZANO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. CESAR ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. MARK TANGONAN	AAC
		CAPT. RANDY LAGCO	AAC
		CAPT. KHALIL ANTHONY CHI	AAC

ANNEX 5. Data Transfer Sheet for Daet-Basud Floodplain Flights

DATA TRANSFER SHEET

01/04/2016 BAGASBAS

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	
3/9/2016	23170P	1BLK20DE69A	PEGASUS	1.77	1245	11.5	253	40.6	309	18.2	NA	171	1KB	1KB	1.41	NA	Z:\DAC\RAWDATA
3/9/2016	23172P	1BLK20A69B	PEGASUS	815	552	6.27	149	14.9	123	8.3	NA	171	1KB	1KB	5.05	NA	Z:\DAC\RAWDATA
3/10/2016	23174P	1BLK20ASC70A	PEGASUS	2.12	1484	12.5	266	41.4	NA	22.5	NA	186	1KB	1KB	7.17	NA	Z:\DAC\RAWDATA
3/10/2016	23176P	1BLK20B70B	PEGASUS	903	490	5.53	159	15.7	NA	8.7	NA	186	1KB	1KB	NA	NA	Z:\DAC\RAWDATA
3/12/2016	23182P	1BLK20ABCE72A	PEGASUS	1.04	686	8.96	265	20.8	NA	10.8	NA	3.82	1KB	1KB	NA	NA	Z:\DAC\RAWDATA
3/13/2016	23186P	1BLK20K73A	PEGASUS	1.26	630	6.63	190	17.7	NA	12.8	NA	1.9	1KB	1KB	377	NA	Z:\DAC\RAWDATA
3/14/2016	23190P	1BLK20BS74A	PEGASUS	1.66	869	9.89	254	1.52	NA	17.4	NA	69.3	1KB	1KB	448	NA	Z:\DAC\RAWDATA
3/15/2016	23194P	1BLK20JKL75A	PEGASUS	2.15	1241	10.8	267	35.6	263	22.4	NA	81.5	1KB	1KB	103	NA	Z:\DAC\RAWDATA
3/16/2016	23198P	1BLK20IM76A	PEGASUS	1.96	1241	11	279	33.8	NA	22	NA	84	1KB	1KB	1.52	NA	Z:\DAC\RAWDATA
3/17/2016	23202P	1BLK20N77A	PEGASUS	2.29	1664	12.5	287	50.5	NA	25.9	NA	131	1KB	1KB	60.6	NA	Z:\DAC\RAWDATA

Name KI ANDAYA
Position RA
Signature

Name Irish Cortez 4/11/16
Position RA
Signature

16-1

DATA TRANSFER SHEET
BAGASBAS 5/17/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	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	
April 16,2016	23262P	1BLK20S107A	PEGASUS	NA	296	9.26	222	36.3	277	15.8	NA	83	1KB	NA	NA	NA	Z:\DAC\RAW DATA
April 16,2016	23264P	1BLK20DS107B	PEGASUS	NA	295	6.01	456	18.5	1KB	16	NA	83	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 17,2016	23266P	1BLK20S108A	PEGASUS	NA	352	8.08	198	32.5	229	18.1	NA	154	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 17,2016	23268P	1BLK20S108B	PEGASUS	NA	359	8.74	203	3.68	65	18.7	NA	154	1KB	NA	NA	NA	Z:\DAC\RAW DATA
April 18,2016	23270P	1BLK20S109A	PEGASUS	NA	112	3.36	99	455	7.2	5.52	NA	29.1	1KB	NA	NA	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 5/18/16

16-31

DATA TRANSFER SHEET
BAGASBAS 5/17/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	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	
April 16,2016	23262P	1BLK20S107A	PEGASUS	NA	296	9.26	222	36.3	277	15.8	NA	83	1KB	NA	NA	NA	Z:\DAC\RAW DATA
April 16,2016	23264P	1BLK20DS107B	PEGASUS	NA	295	6.01	456	18.5	1KB	16	NA	83	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 17,2016	23266P	1BLK20S108A	PEGASUS	NA	352	8.08	198	32.5	229	18.1	NA	154	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 17,2016	23268P	1BLK20S108B	PEGASUS	NA	359	8.74	203	3.68	65	18.7	NA	154	1KB	NA	NA	NA	Z:\DAC\RAW DATA
April 18,2016	23270P	1BLK20S109A	PEGASUS	NA	112	3.36	99	455	7.2	5.52	NA	29.1	1KB	NA	NA	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 5/18/16

16-31

ANNEX 6. Flight logs for the flight missions

1. Flight Log for 23170P Mission

Data Acquisition Flight Log

Flight Log No.: 23170P

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20DEL94	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: M. Tangonan	8 Co-Pilot: K. Lagco	9 Route:			
10 Date: 7-9-16	12 Airport of Departure (Airport, City/Province): Bagasbas		12 Airport of Arrival (Airport, City/Province): Bagasbas		
13 Engine On: 7:44 AM	14 Engine Off: 11:54 AM	15 Total Engine Time: 4+10	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

Successful Flight. Complete BLK 20D and surveyed 10 lines at BLK 20E.

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
P. Arceo	A1C Jaylo [illegible] PAF	M. Tangonan	J. Almalvez	
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 23182P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23182P

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Pegasus	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: M. Tangonan	8 Co-Pilot: R. Lagco	9 Route:			
10 Date: 3-Mar-14	12 Airport of Departure (Airport, City/Province): Bagasbas		12 Airport of Arrival (Airport, City/Province): Bagasbas		
13 Engine On: 7:16	14 Engine Off: 11:31	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

Successful flight. Covered voids at Blk A, B, C, and E.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
P. Arceo	[illegible] PAF	M. Tangonan	J. Almalvez	
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 23190P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23190P

1 LiDAR Operator: MJ Reyes	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20BS	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: M. Tangonan	8 Co-Pilot: R. Lagro	9 Route:			
10 Date: 3-14-16	12 Airport of Departure (Airport, City/Province): Bagasbas		12 Airport of Arrival (Airport, City/Province): Bagasbas		
13 Engine On: 7:09	14 Engine Off: 11:08	15 Total Engine Time: 3+59	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

Successful flight. Covered voids NW BLK 20Bs

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
P. Arceo	A1C Jaboo C Mantano PAF	M. Tangonan	MJ Reyes	
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 23202P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23202P

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Pegasus	3 Mission Name: 1BLK30I7A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: M. Tangonan	8 Co-Pilot: R. Gaylo	9 Route:			
10 Date: 3-17-16	12 Airport of Departure (Airport, City/Province): Bagasbas		12 Airport of Arrival (Airport, City/Province): Bagasbas		
13 Engine On: 7:17	14 Engine Off: 11:45	15 Total Engine Time: 4+28	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

Successful flight over BLK30N with voids.

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ____________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
J. Arfeto	A1C Joseph Cabañas PAF	M. Tangonan	J. Almalvez	
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 23226P (renamed from 3072P) Mission

Flight Log No.: 3072

Data Acquisition Flight Log

1 LiDAR Operator: G. Quisado	2 ALTM Model: Peg	3 Mission Name: 1BLK29A098A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 912-C
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Daet - Daet			
10 Date: April 7, 2014	12 Airport of Departure (Airport, City/Province): Daet		12 Airport of Arrival (Airport, City/Province): Daet		
13 Engine On: —	14 Engine Off: —	15 Total Engine Time: —	16 Take off: —	17 Landing: —	18 Total Flight Time:
19 Weather: Fair					

20 Flight Classification

20.a Billable
- o 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

Cancelled due to transition error (Rx shutters)

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

Acquisition Flight Approved by: J. Alviar — Signature over Printed Name (End User Representative)

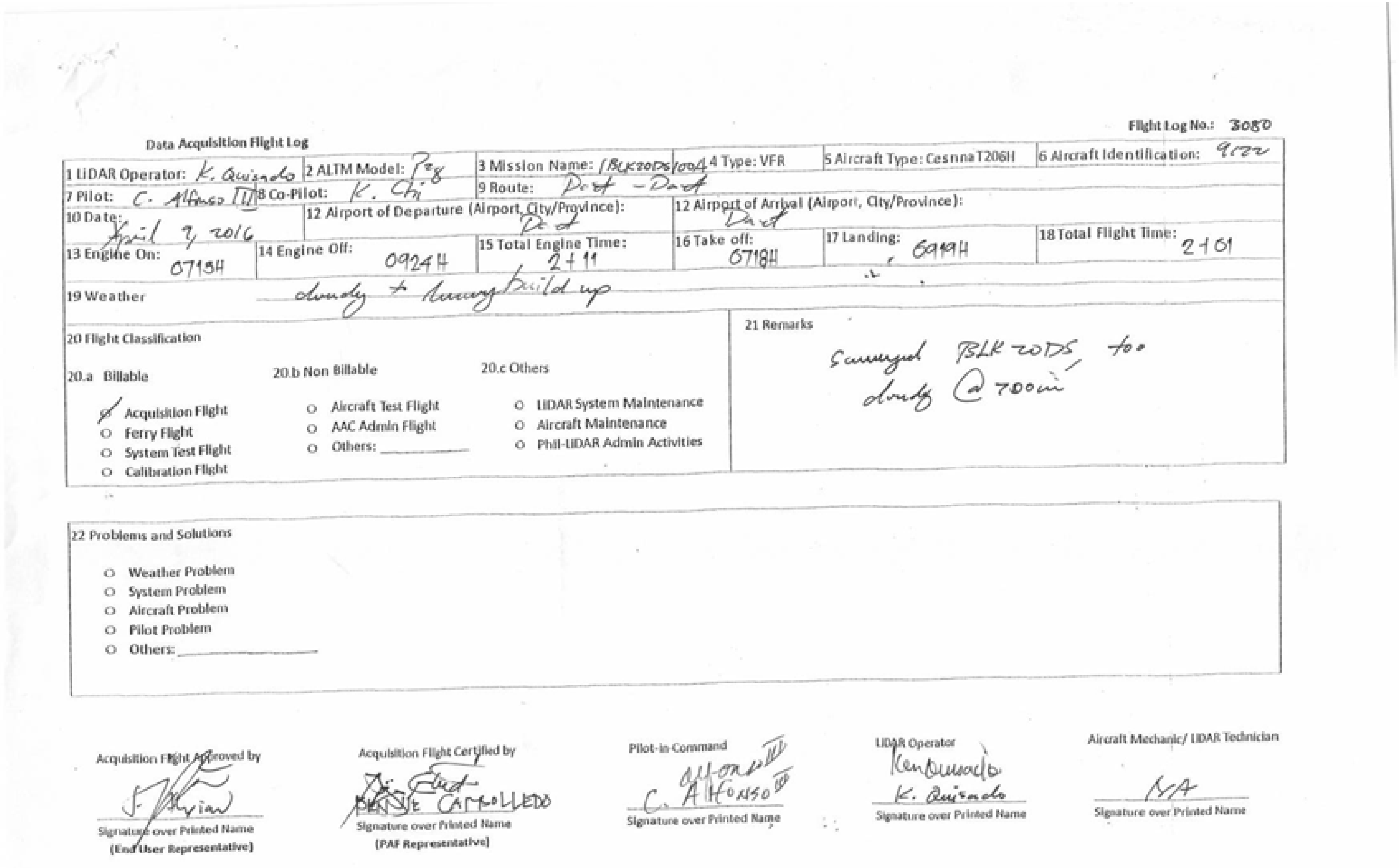
Acquisition Flight Certified by: [signature] — Signature over Printed Name (PAF Representative)

Pilot-in-Command: C. Alfonso III — Signature over Printed Name

LiDAR Operator: R. Quisado — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: MA — Signature over Printed Name

6. Flight log for 23234P (renamed from 3080P) Mission



Data Acquisition Flight Log

Flight Log No.: 3080

1 LIDAR Operator: K. Quisado	2 ALTM Model: Peg	3 Mission Name: 1BLK20DS1004	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Dvt - Dvt			
10 Date: April 9, 2016	12 Airport of Departure (Airport, City/Province): Dvt		12 Airport of Arrival (Airport, City/Province): Dvt		
13 Engine On: 0713H	14 Engine Off: 0924H	15 Total Engine Time: 2+11	16 Take off: 0718H	17 Landing: 0919H	18 Total Flight Time: 2+01
19 Weather: cloudy + heavy build up					

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 BLK 20DS, too cloudy @ 700m

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

Acquisition Flight Approved by — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — C. Alfonso III — Signature over Printed Name

LIDAR Operator — K. Quisado — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician — N/A — Signature over Printed Name

7. Flight log for 23266P(3112P) Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3112

1 LiDAR Operator: JP Alambar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20G084	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Daet - Daet			
10 Date: April 17, 2016	12 Airport of Departure (Airport, City/Province): Daet		12 Airport of Arrival (Airport, City/Province): Daet		
13 Engine On: 0746H	14 Engine Off: 1057H	15 Total Engine Time: 3+11	16 Take off: 0751H	17 Landing: 1052H	18 Total Flight Time: 3+01
19 Weather: partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 20S

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
[signature]	[signature] Benjie Carbolledo	[signature] C. Alfonso III	[signature] JP Alambar	N/A
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

8. Flight log for 23268P (renamed from 3114P) Mission

Flight Log No.: 3114

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: K. Quisado	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20S108B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Daet - Daet			
10 Date: April 17, 2016	12 Airport of Departure (Airport, City/Province): Daet		12 Airport of Arrival (Airport, City/Province): Daet		
13 Engine On: 1254H	14 Engine Off: 1559H	15 Total Engine Time: 3+05	16 Take off: 1259H	17 Landing: 1554H	18 Total Flight Time: 2+55
19 Weather: Partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed gaps in BLK 20

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

Cam calib - cam overrun

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
J. Arrian	[illegible] Carbolledo	C. Alfonso III	Kenneth Quisado	
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

9. Flight log for 23270P (renamed from 3116P) Mission

PHIL-LIDAR 1 Data Acquisition Flight Log — Flight Log No.: 3116

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20S109A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Ori	9 Route: Daet - Daet			
10 Date:	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0538 April 18, 2016	14 Engine Off:	15 Total Engine Time: 1437	16 Take off:	17 Landing:	18 Total Flight Time: 1?22
19 Weather: partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Gap-filling

22 Problems and Solutions

- ○ Weather Problem
- ○ System Problem
- ○ Aircraft Problem
- ○ Pilot Problem
- ○ Others: ____________

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
J. Alviar	[illegible] CABALLERO	C. Alfonso III	[illegible]	N/A
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

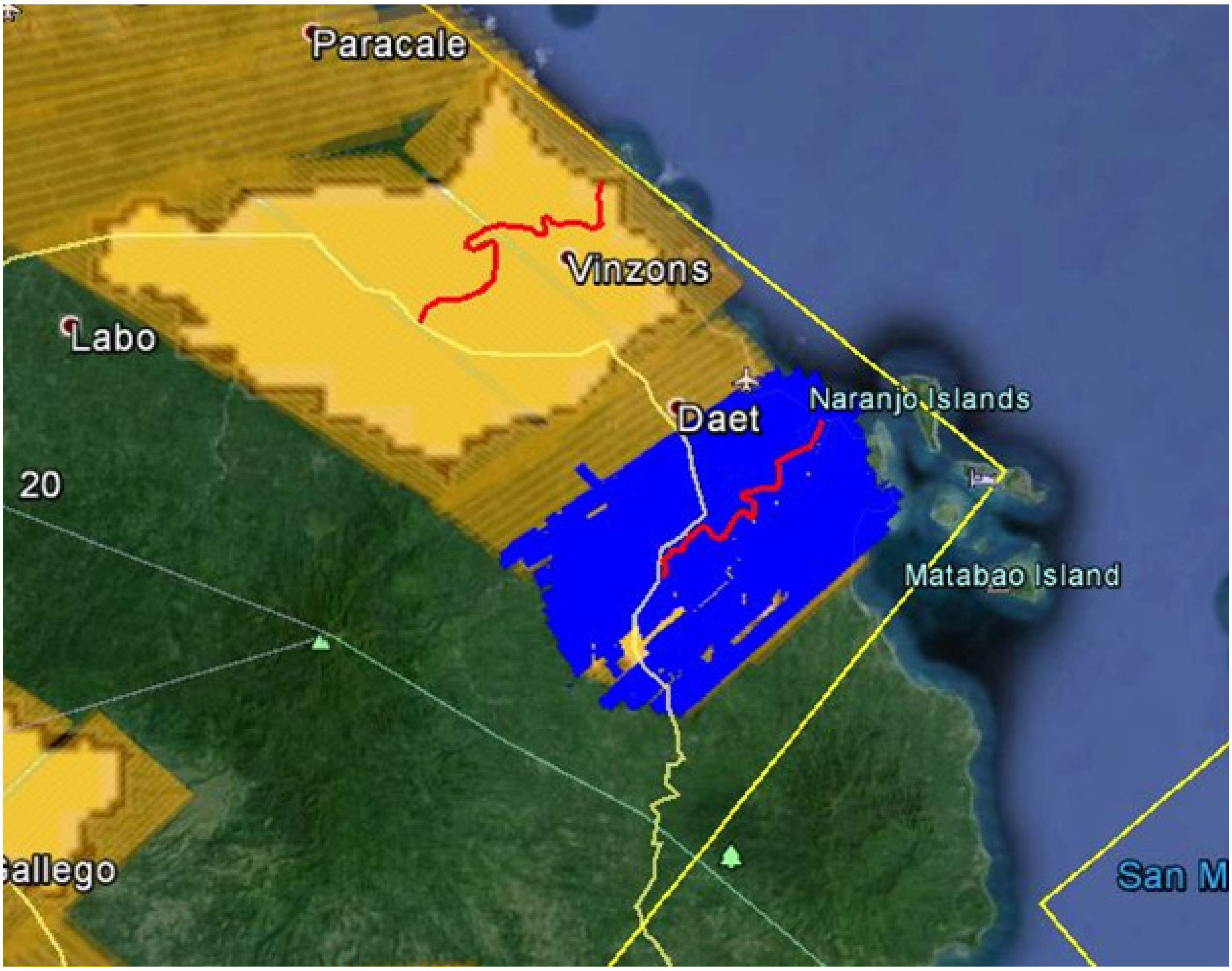
ANNEX 7. Flight status reports

CAMARINES SUR & QUEZON
(March 7-21, 2016 and May 10-17, 2016)

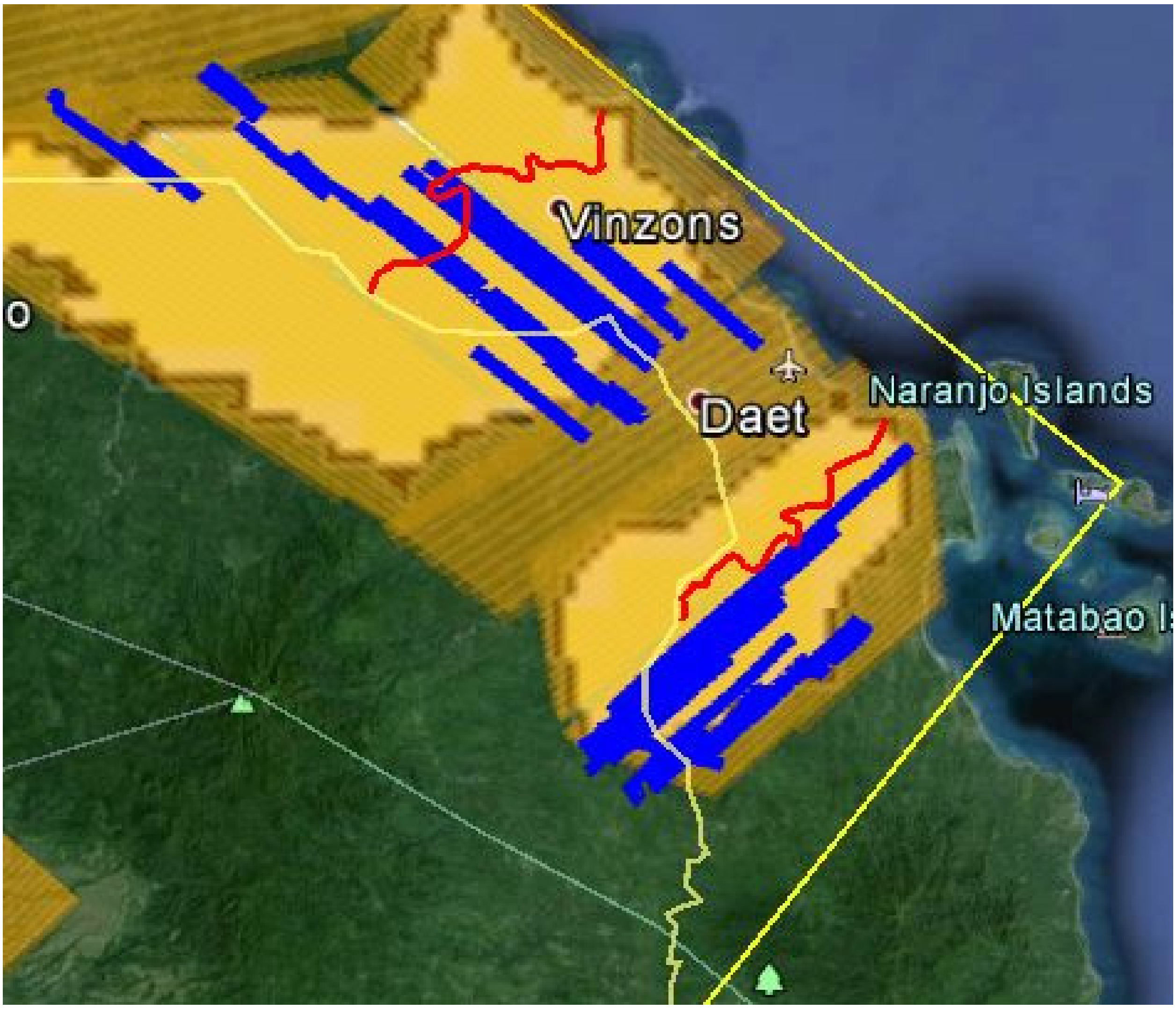
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23170P	BAGASBAS	1BLK20DE69A	J. ALMALVEZ	9 March 2016	COMPLETED BLK 20D AND SURVEYED 10 LINES AT BLK 20E.
23182P	BAGASBAS	1BLK20ABCE72A	J. ALMALVEZ	12 March 2016	COVERED VOIDS AT BLK 20A, 20B, 20C, AND 20E.
23190P	BAGASBAS	1BLK20BS74A	M.S. REYES	14 March 2016	COVERED VOIDS AT BLK20B
23202P	BAGASBAS	1BLK20N77A	J. ALMALVEZ	17 March 2016	SUCCESSFUL FLIGHT OVER BLK20N WITH VOIDS
23226P	BLK 20DE DAET, PARACALE	1BLK20D098A	K. QUISADO	APRIL 7	SURVEYED BLK 20D,E 224.61 SQ.KM
23234P	PARACALE	1BLK20D100A	J. ALAMBAN	APRIL 9	SURVEYED BLK PARACALE; HEAVY BUILD UP 45.78 SQ.KM
23266P	BLK 20DS, JOSE PANGANIBAN GAPS BLK 20DS, JOSE PANGANIBAN GAPS	1BLK20S108A	J. ALAMBAN	APRIL 17	SURVEYED GAPS IN BLK20D 183.08 SQ.KM
23268P	BLK 20DES	1BLK20S108	K. QUISADO	APRIL 17	SURVEYED BLK20DES 161.62 SQ.KM
23270P	BLK 20S	1BLK20S109A	J. ALVIAR	APRIL 18	SURVEYED REMAINING GAPS IN BLK 20 31.02 SQ.KM

LAS BOUNDARIES PER FLIGHT

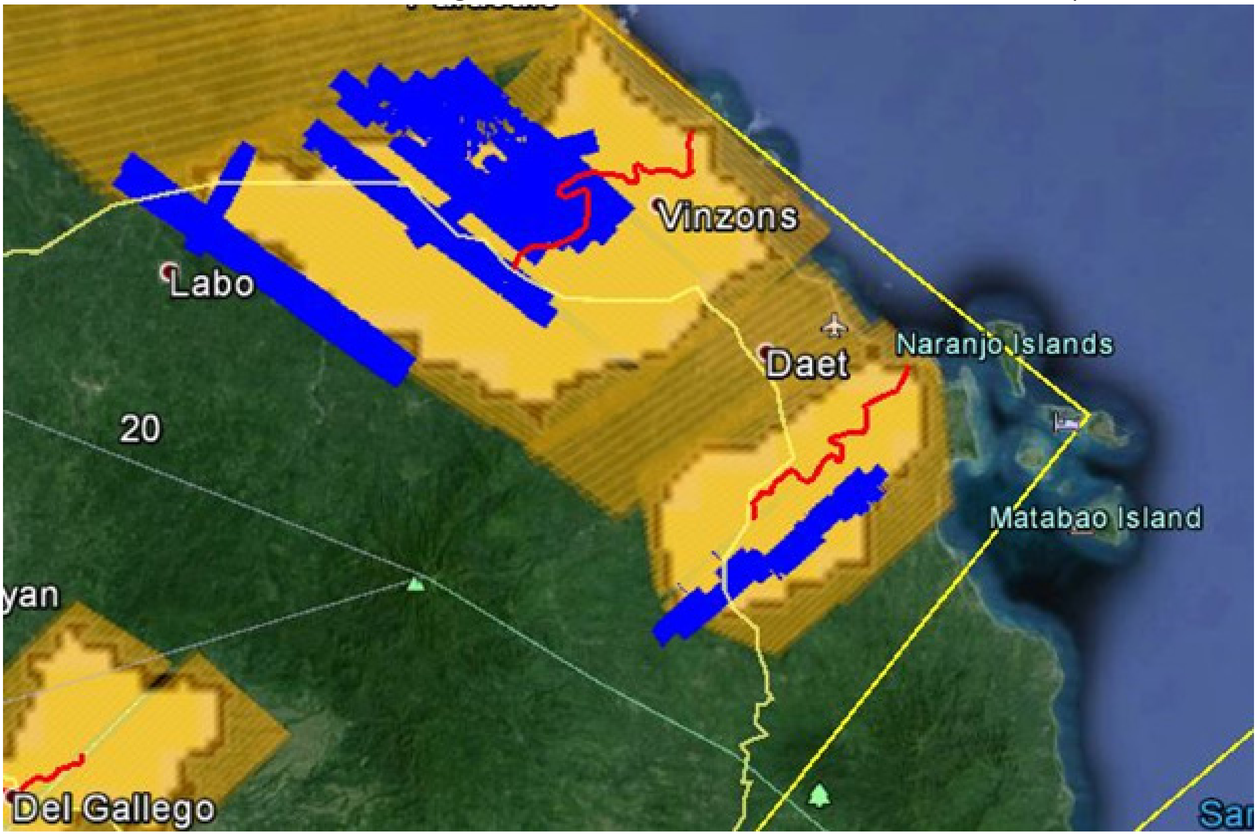
FLIGHT NO.:	23170P		
AREA:	Bagasbas		
MISSION NAME:	1BLK20DE69A		
ALT:	600-1100m	SCAN FREQ:	30Hz
SCAN ANGLE:	50 deg	SURVEYED AREA:	162.13 sq.km.



FLIGHT NO.:	23182P		
AREA:	Bagasbas		
MISSION NAME:	1BLK20ABCE72A		
ALT:	600-1100m	SCAN FREQ:	30Hz
SCAN ANGLE:	50 deg	SURVEYED AREA:	77.2 sq.km.

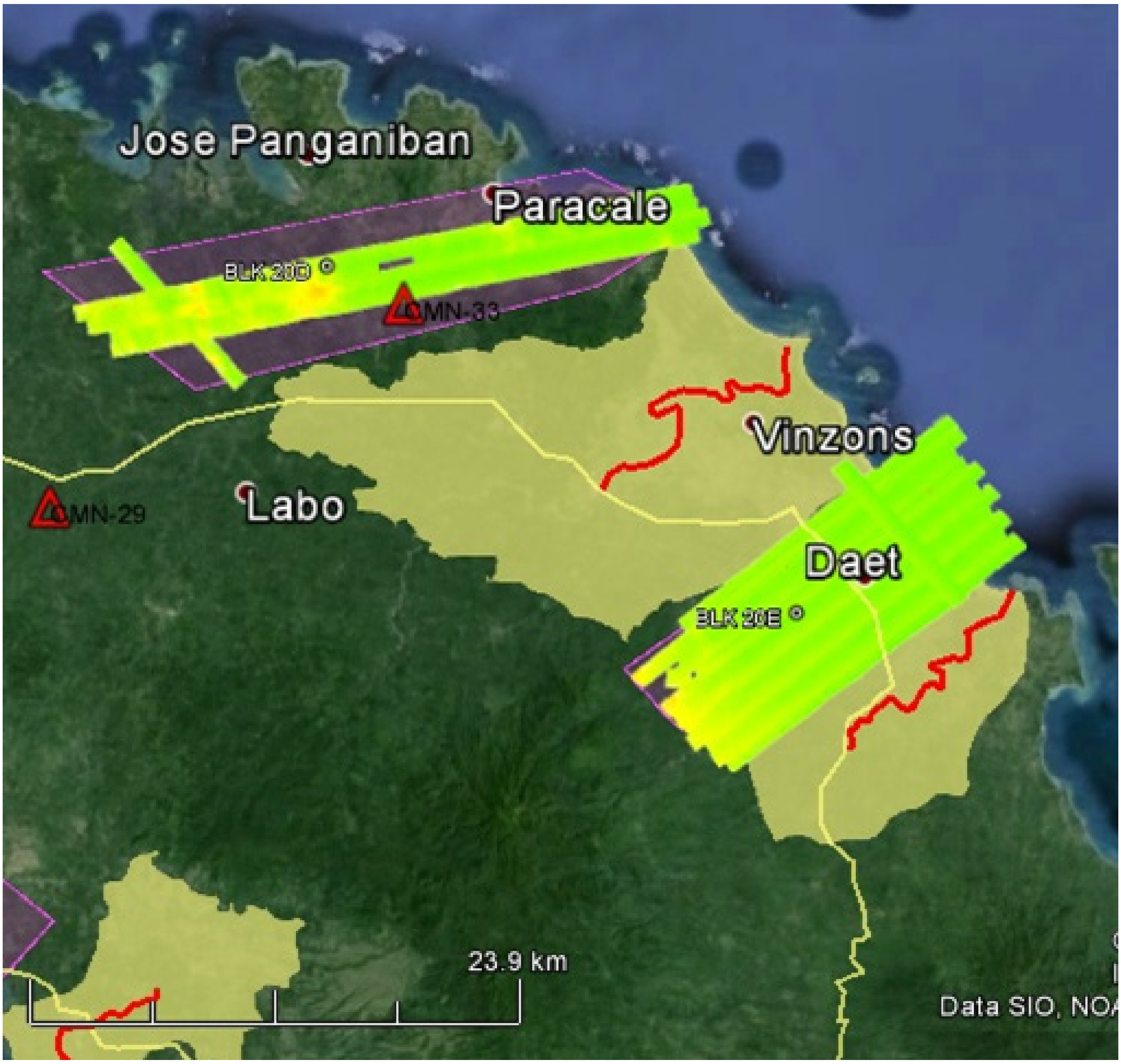


FLIGHT NO.:	23190P		
AREA:	Bagasbas		
MISSION NAME:	1BLK20BS74A		
ALT:	600-1100m	SCAN FREQ:	30Hz
SCAN ANGLE:	50 deg	SURVEYED AREA:	151.12 sq.km.

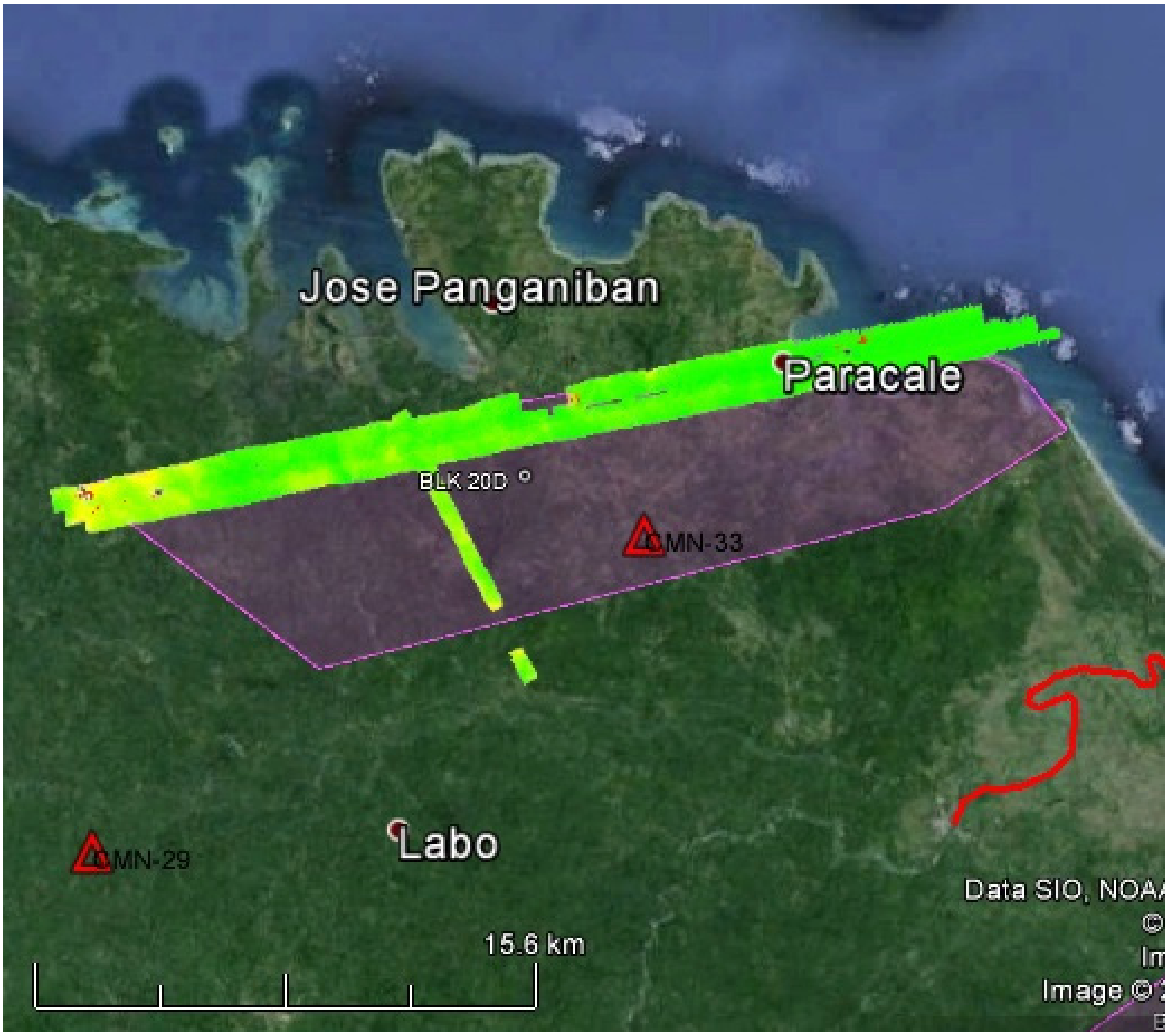


FLIGHT NO.:	23202P		
AREA:	Bagasbas		
MISSION NAME:	1BLK20N77A		
ALT:	600-1100m	SCAN FREQ:	30Hz
SCAN ANGLE:	50 deg	SURVEYED AREA:	232.46 sq.km.

Flight No. :	23226P		
Area:	Bagasbas		
PRF:	200 kHz	SCF:	30 Hz
Lidar FOV:	50 deg		

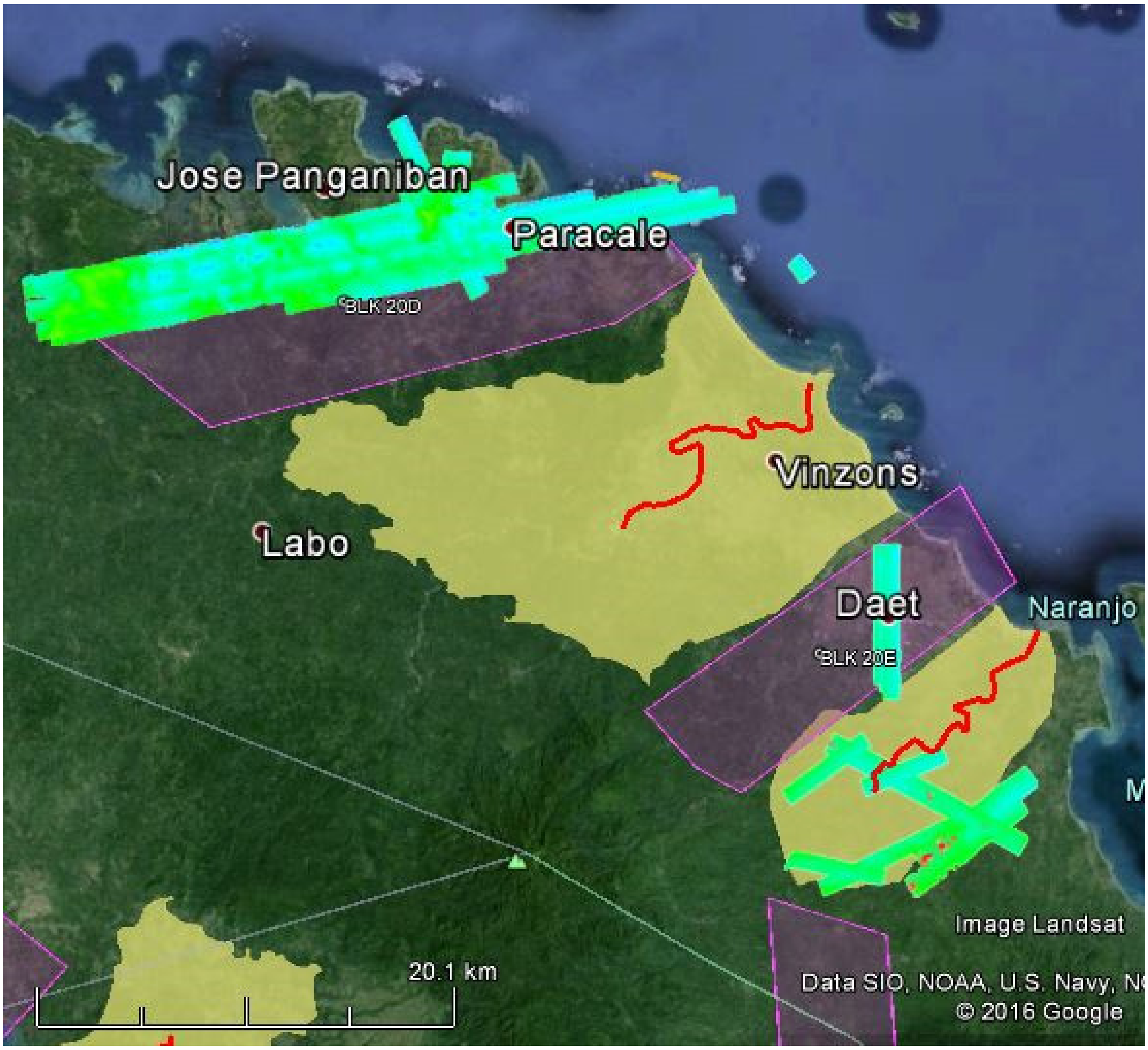


Flight No. :	23234P		
Area:	Bagasbas		
PRF:	200 kHz	SCF:	30 Hz
Lidar FOV:	50 deg		



Flight No. :	23266P		
Area:	Bagasbas		
PRF:	200 kHz	SCF:	30 Hz
Lidar FOV:	50 deg		

Flight No. :	23268P		
Area:	Bagasbas		
PRF:	200 kHz	SCF:	30 Hz
Lidar FOV:	50 deg		



Flight No. :	23270P		
Area:	Bagasbas		
PRF:	200 kHz	SCF:	30 Hz
Lidar FOV:	50 deg		

ANNEX 8. Mission Summary Reports

Table A-8.1 Mission Summary Report of Mission Blk20E_supplement

Flight Area	Bagasbas
Mission Name	Bagasbas_Blk20E_supplement
Inclusive Flights	23182P,23190P
Range data size	10.8 GB
POS	265 MB
Base data size	3.82 MB
Image	n/a
Transfer date	April 11,2016
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)	1.3
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	2.5
Boresight correction stdev (<0.001deg)	0.000368
IMU attitude correction stdev (<0.001deg)	0.000584
GPS position stdev (<0.01m)	0.0086
Minimum % overlap (>25)	83.93%
Ave point cloud density per sq.m. (>2.0)	8.52
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	77
Maximum Height	219.96
Minimum Height	0.09
Classification (# of points)	
Ground	38077996
Low vegetation	23521084
Medium vegetation	75376526
High vegetation	190498019
Building	3343819
Orthophoto	
Processed by	Engr. Jennifer Saguran, Aljon Rie Araneta, Maria Tamsyn Malabanan

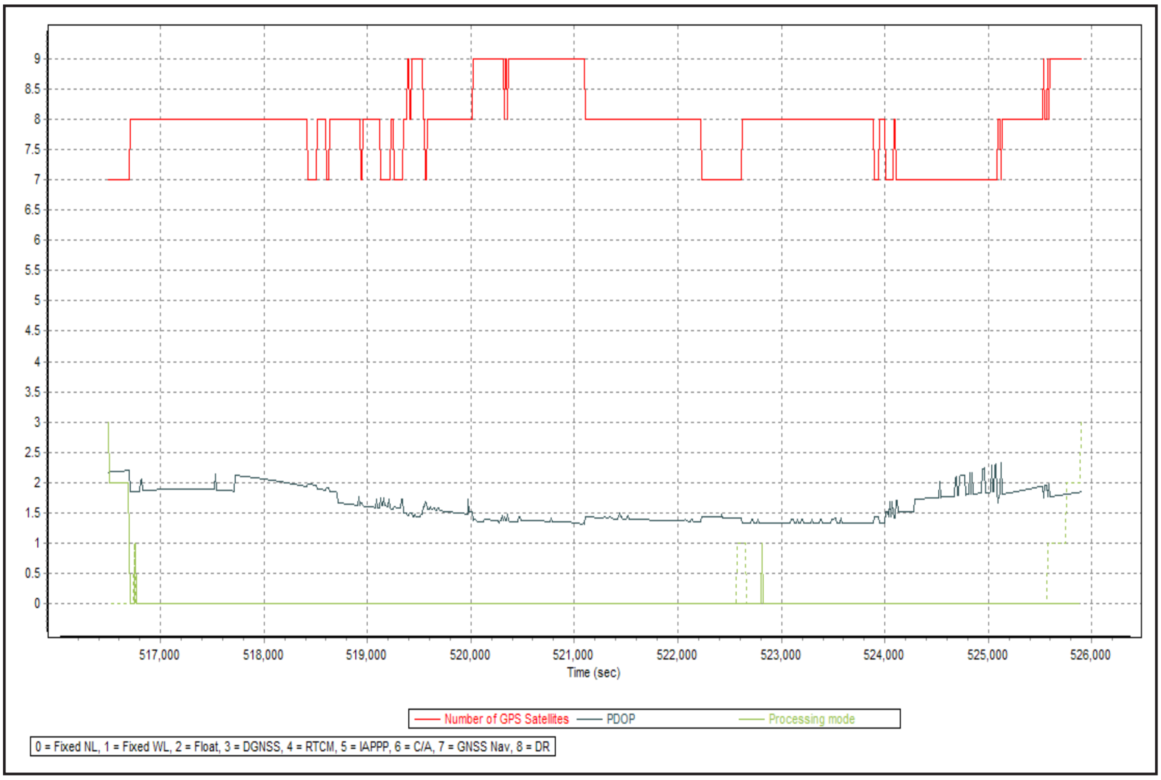


Figure 1.1.1. Solution Status

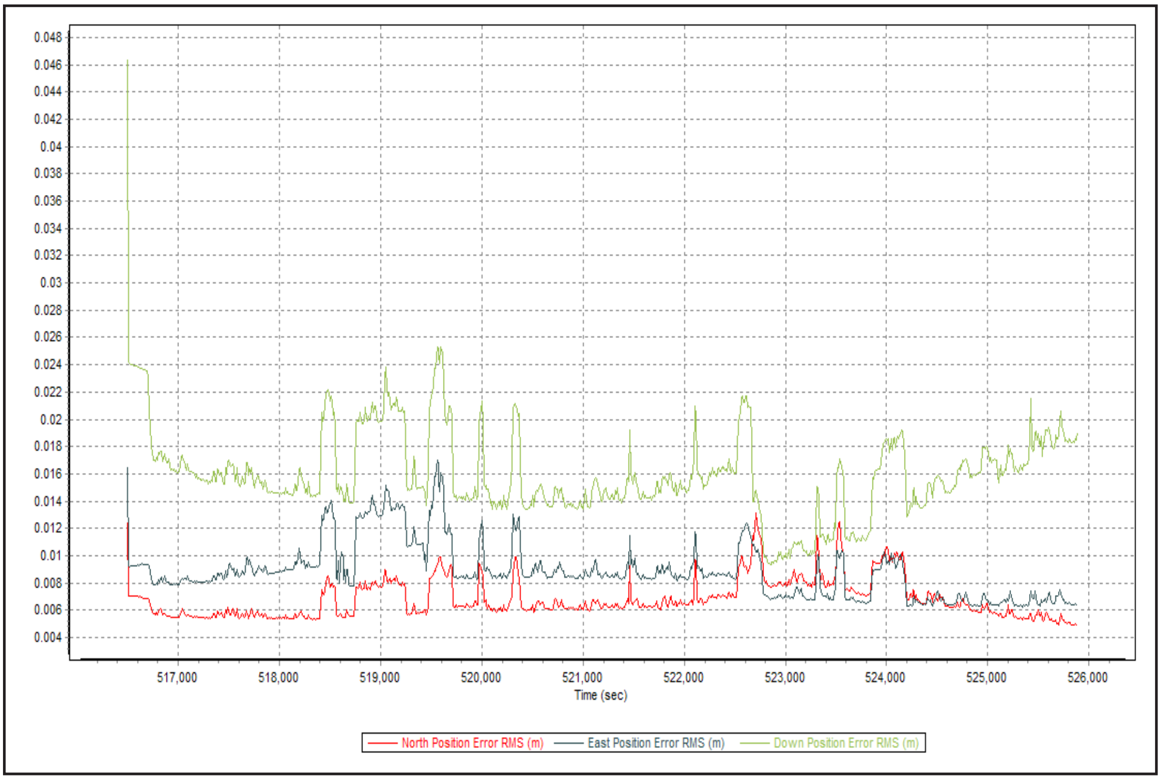


Figure 1.1.2. Smoothed Performance Metric Parameters

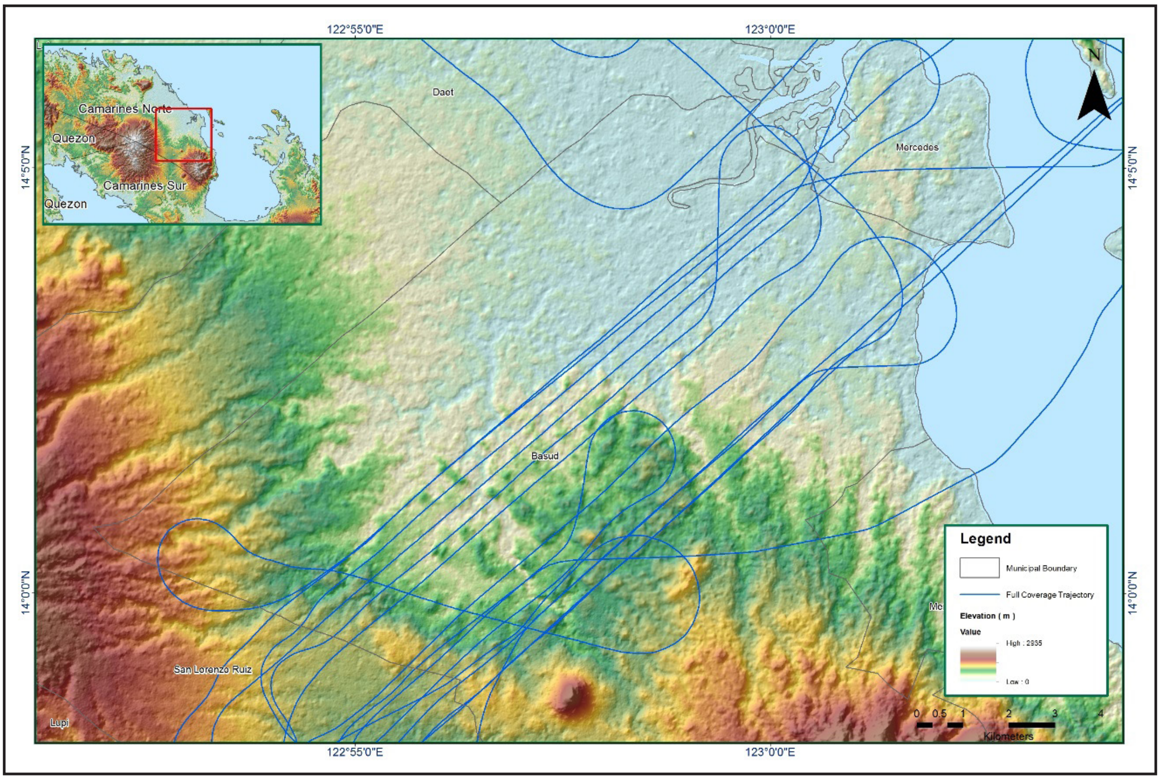


Figure 1.1.3. Best Estimated Trajectory

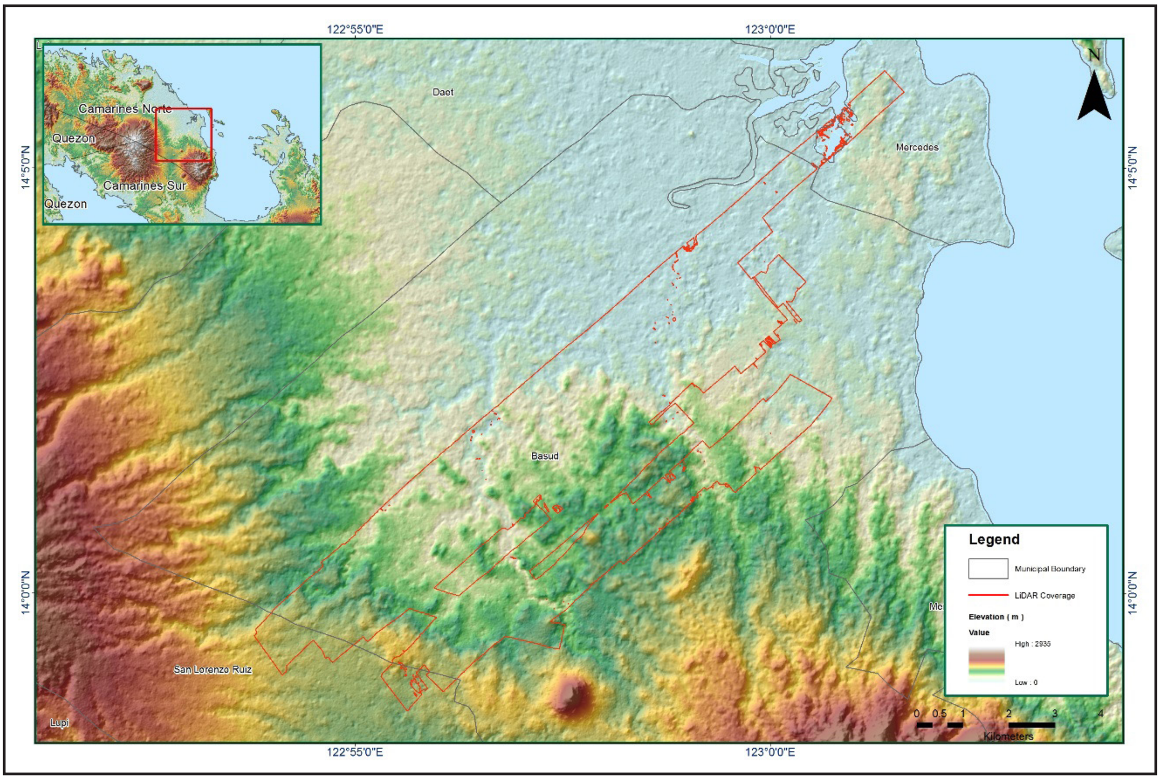


Figure 1.1.4. Coverage of LiDAR Data

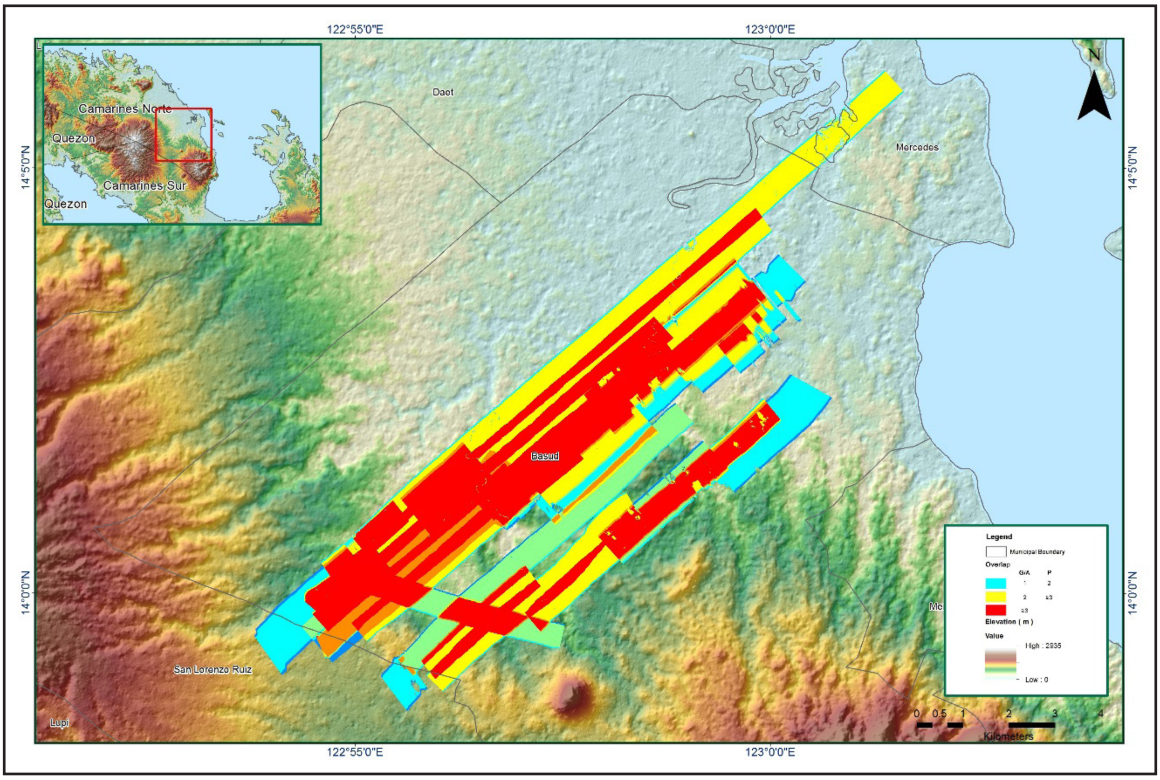


Figure 1.1.5. Image of data overlap

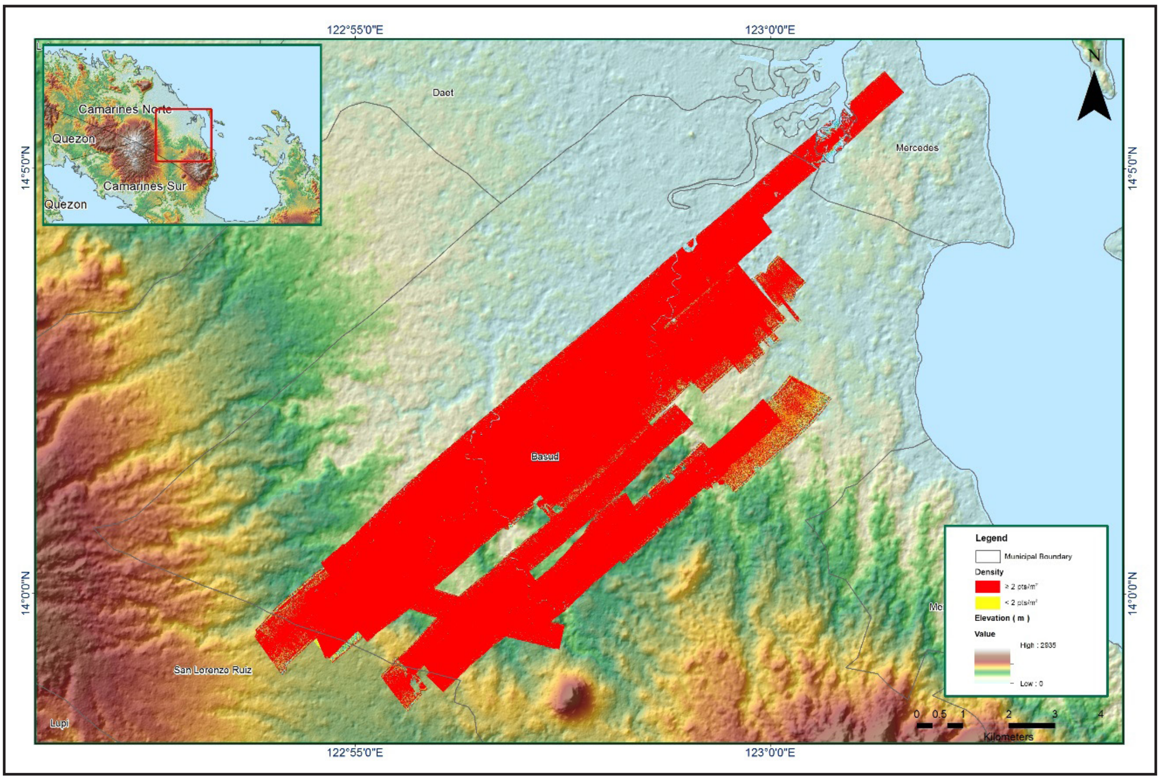


Figure 1.1.6. Density map of merged LiDAR data

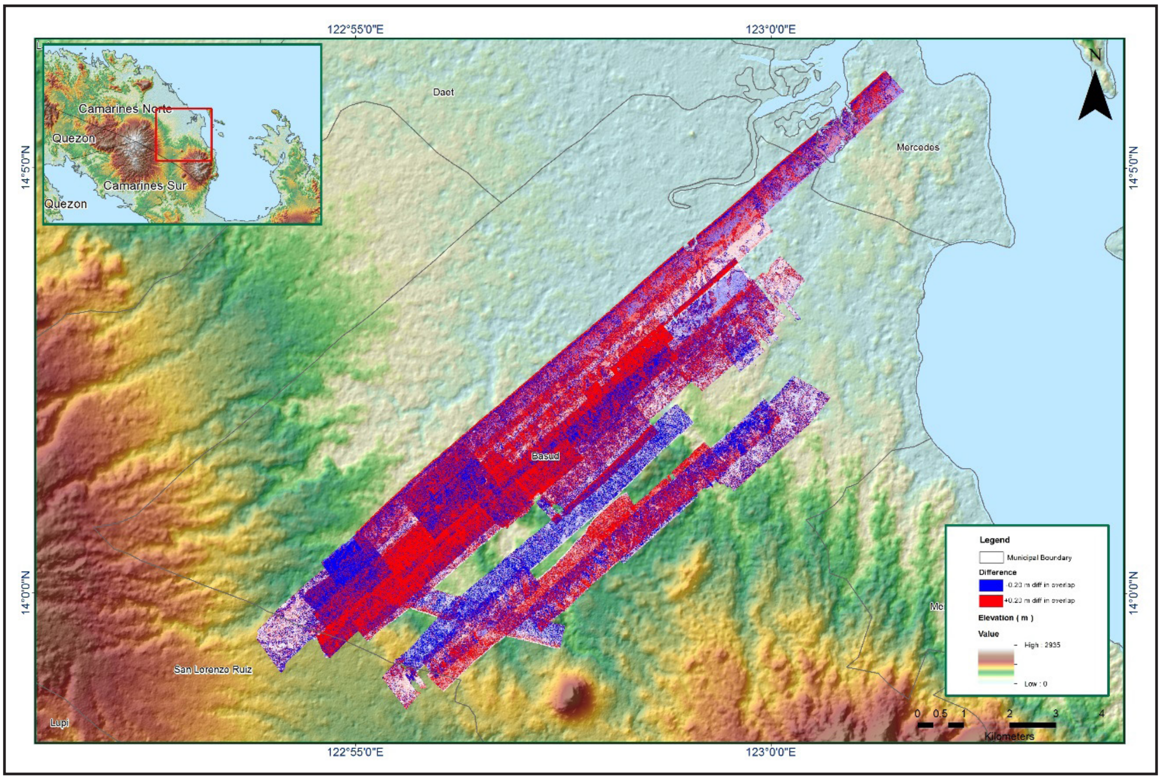


Figure 1.1.7. Elevation difference between flight line

Table A-8.2 Mission Summary Report of Mission Blk20E_additional

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20E_additional
Inclusive Flights	23268P
Range data size	18.7 GB
POS	203 MB
Base data size	154 MB
Image	n/a
Transfer date	May 18,2016
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)	1.2
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	1.9
Boresight correction stdev (<0.001deg)	0.000481
IMU attitude correction stdev (<0.001deg)	0.002637
GPS position stdev (<0.01m)	0.0118
Minimum % overlap (>25)	41.03%
Ave point cloud density per sq.m. (>2.0)	3.97
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	52
Maximum Height	204.61
Minimum Height	53.28
Classification (# of points)	
Ground	17373866
Low vegetation	13805955
Medium vegetation	39791743
High vegetation	102541924
Building	1710622
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Aljon Rie Araneta, Maria Tamsyn Malabanan

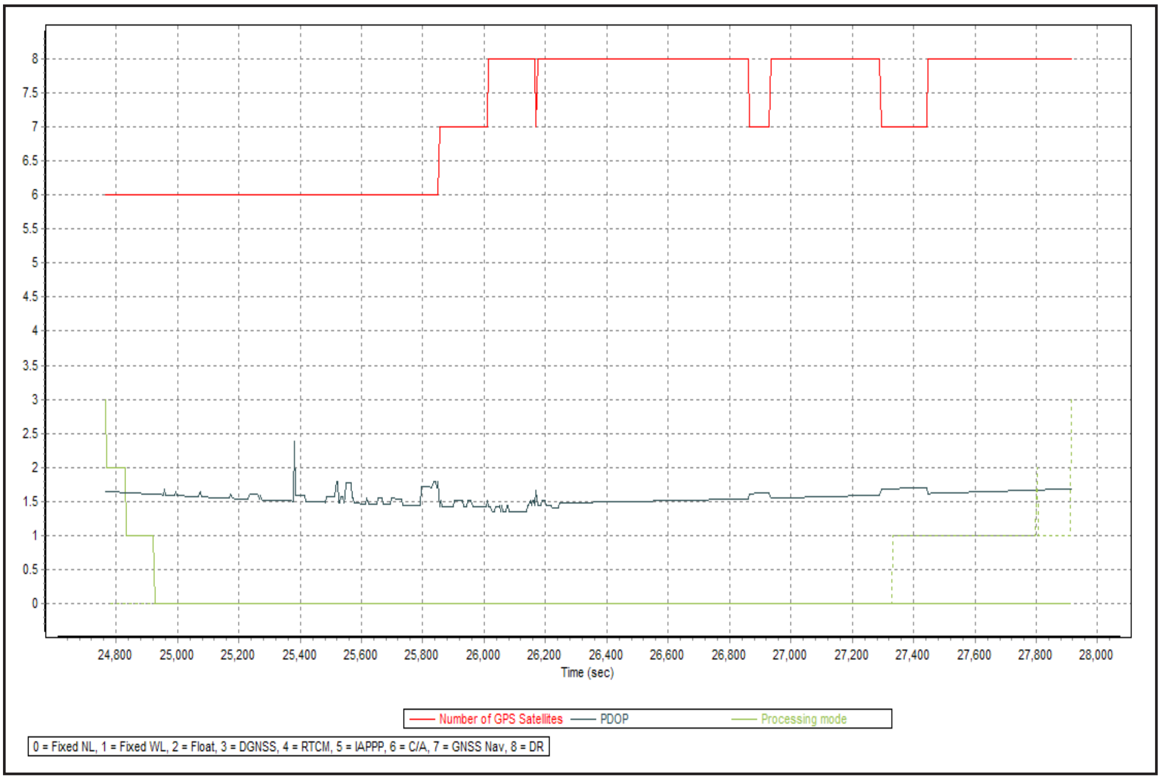


Figure 1.2.1. Solution Status

Figure 1.2.2. Smoothed Performance Metric Parameters

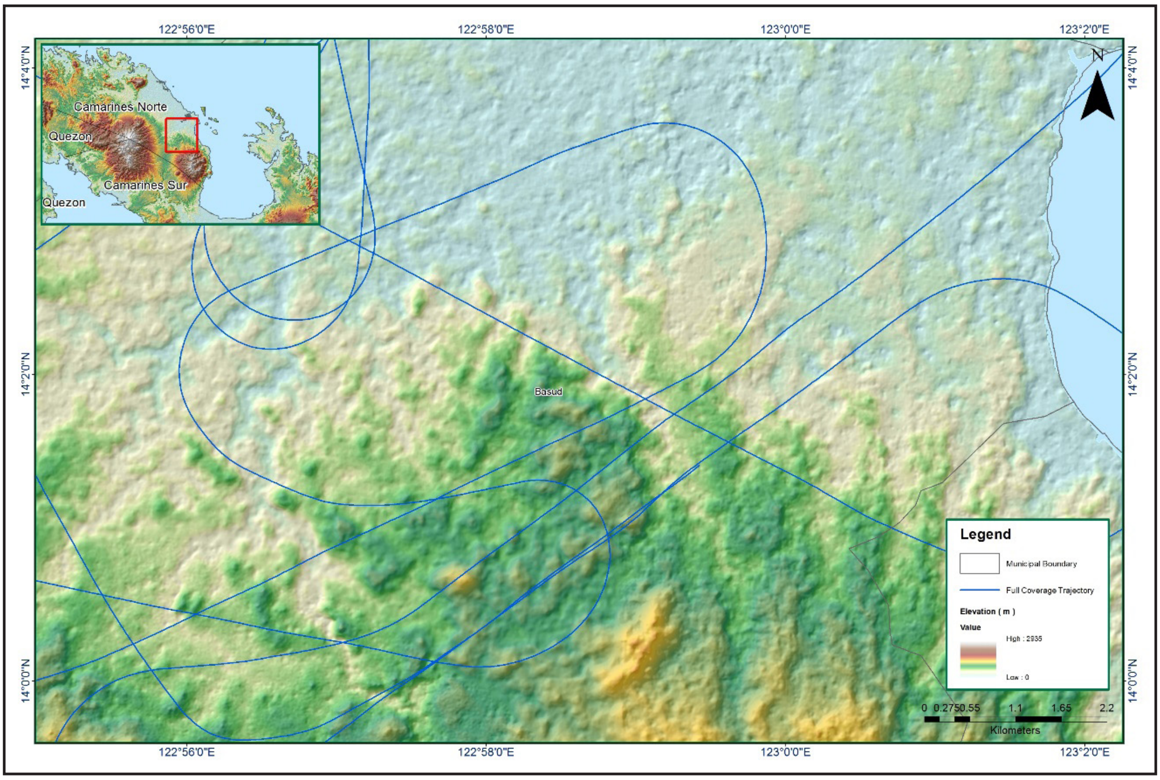


Figure 1.2.3. Best Estimated Trajectory

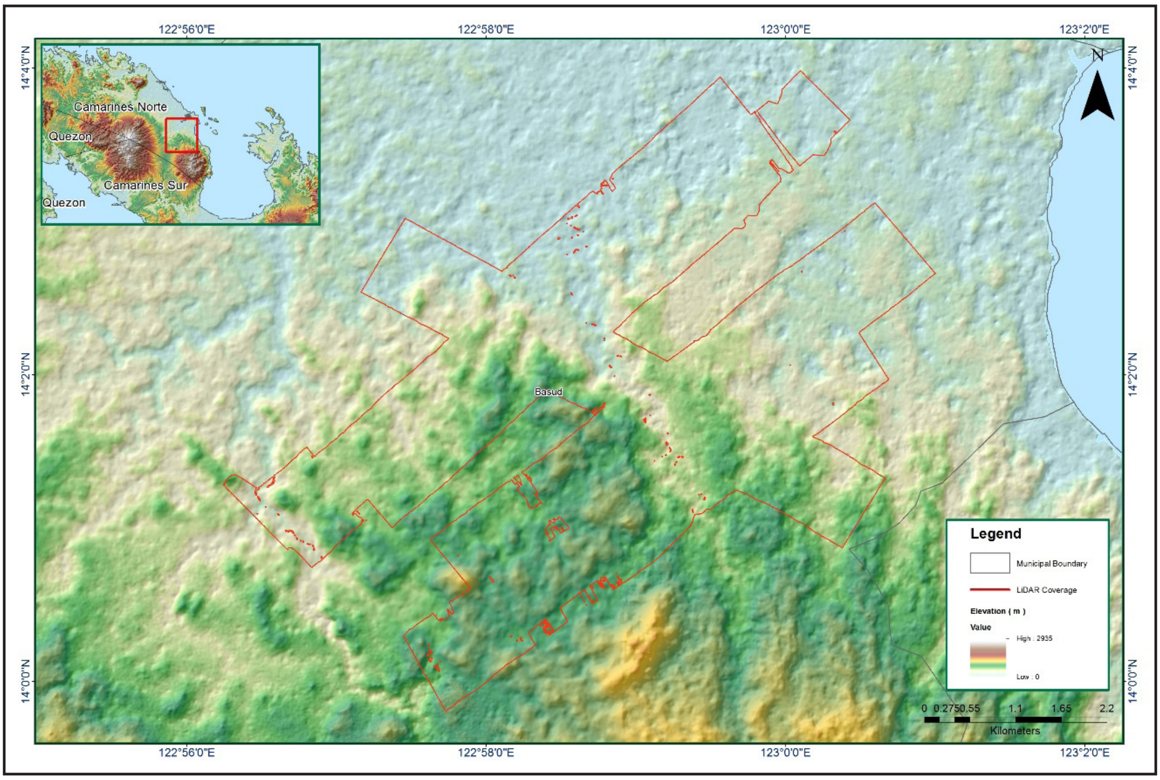


Figure 1.2.4. Coverage of LiDAR Data

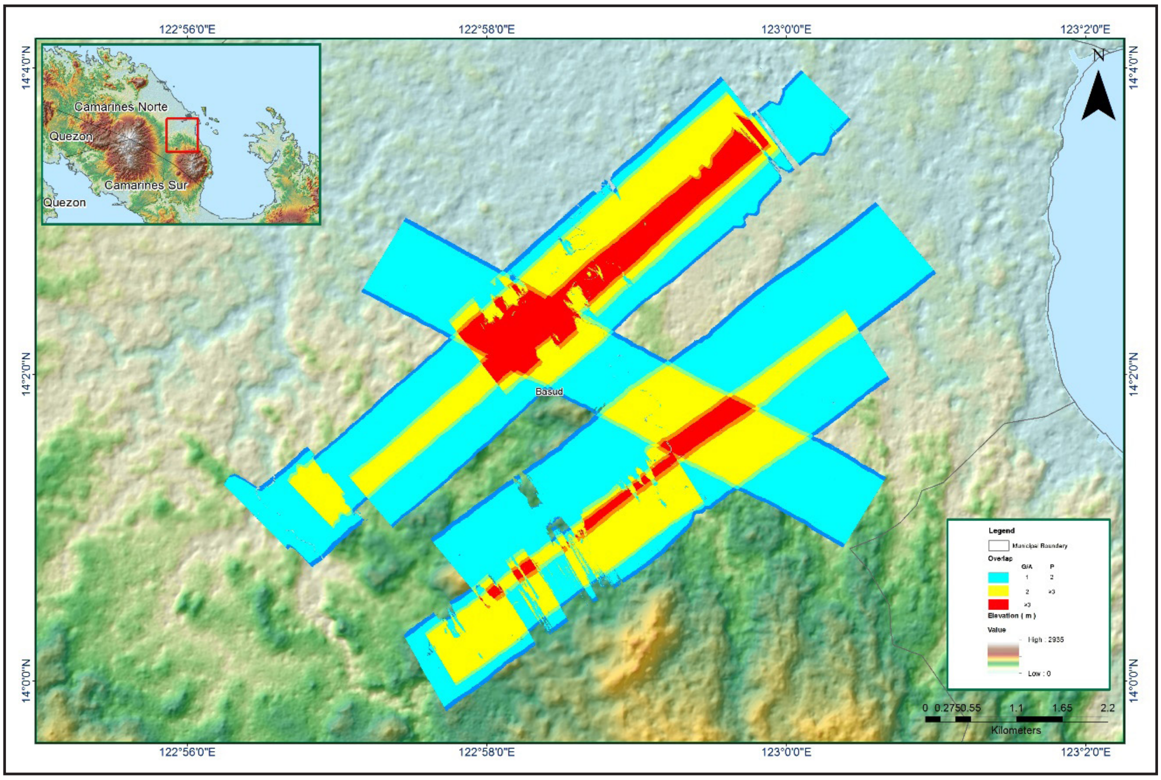


Figure 1.2.5. Image of data overlap

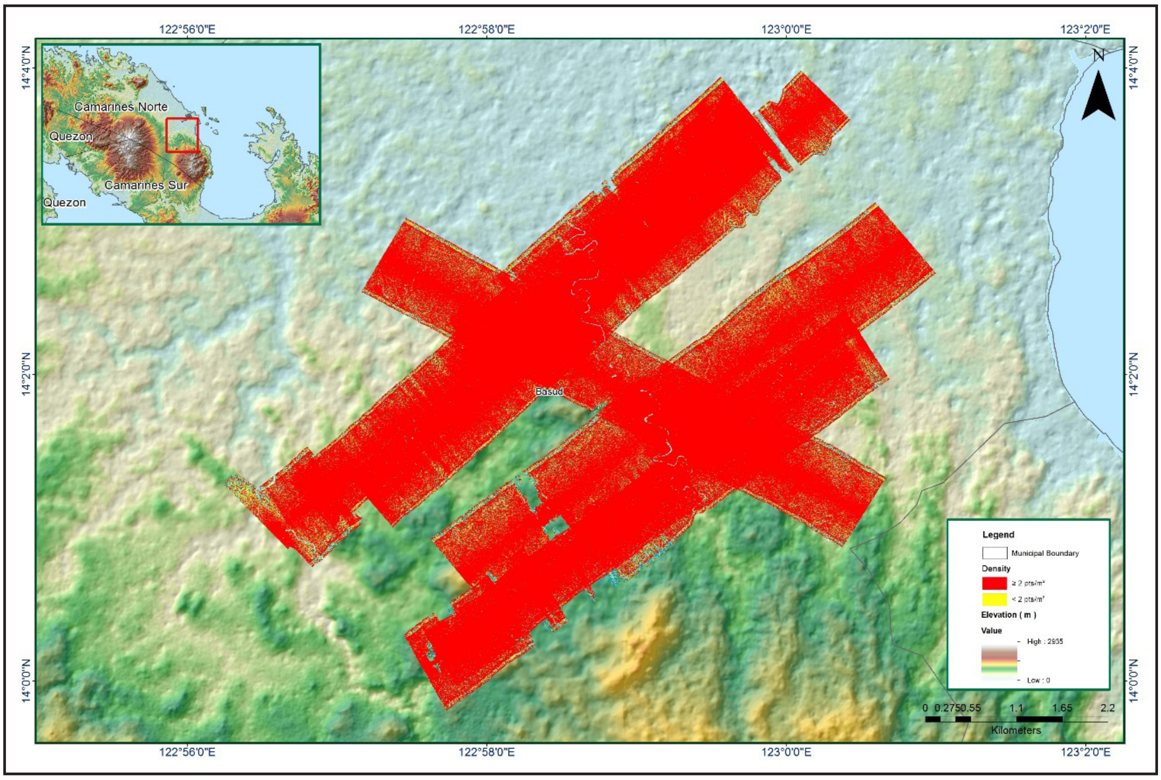


Figure 1.2.6. Density map of merged LiDAR data

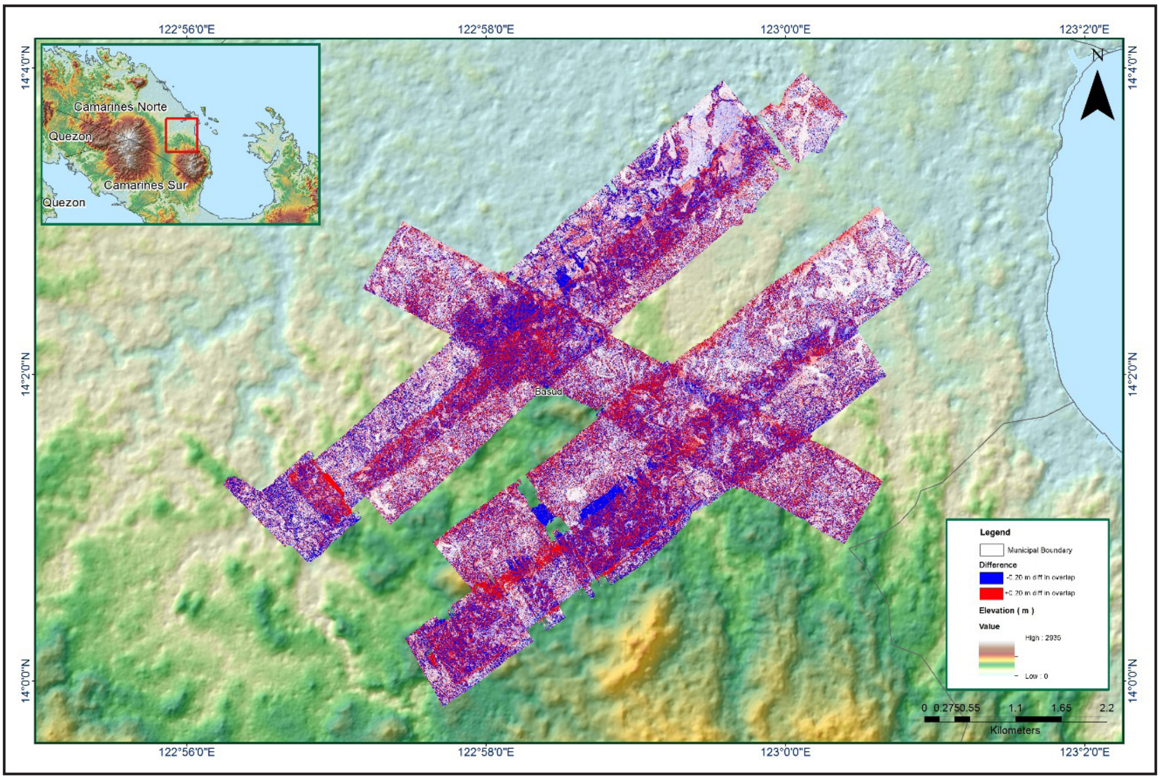


Figure 1.2.7. Elevation difference between flight line

Table A-8.3 Mission Summary Report of Mission Blk20DE

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20DE
Inclusive Flights	23170P
Range data size	18.2 GB
POS	253 MB
Base data size	171 MB
Image	n/a
Transfer date	April 11,2016
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)	1.2
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000394
IMU attitude correction stdev (<0.001deg)	0.004139
GPS position stdev (<0.01m)	0.0265
Minimum % overlap (>25)	54.01%
Ave point cloud density per sq.m. (>2.0)	3.10
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	233
Maximum Height	238.71
Minimum Height	9.81
Classification (# of points)	
Ground	132618782
Low vegetation	120066956
Medium vegetation	232832451
High vegetation	517053547
Building	11330479
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga Jr., Jovy Narisma

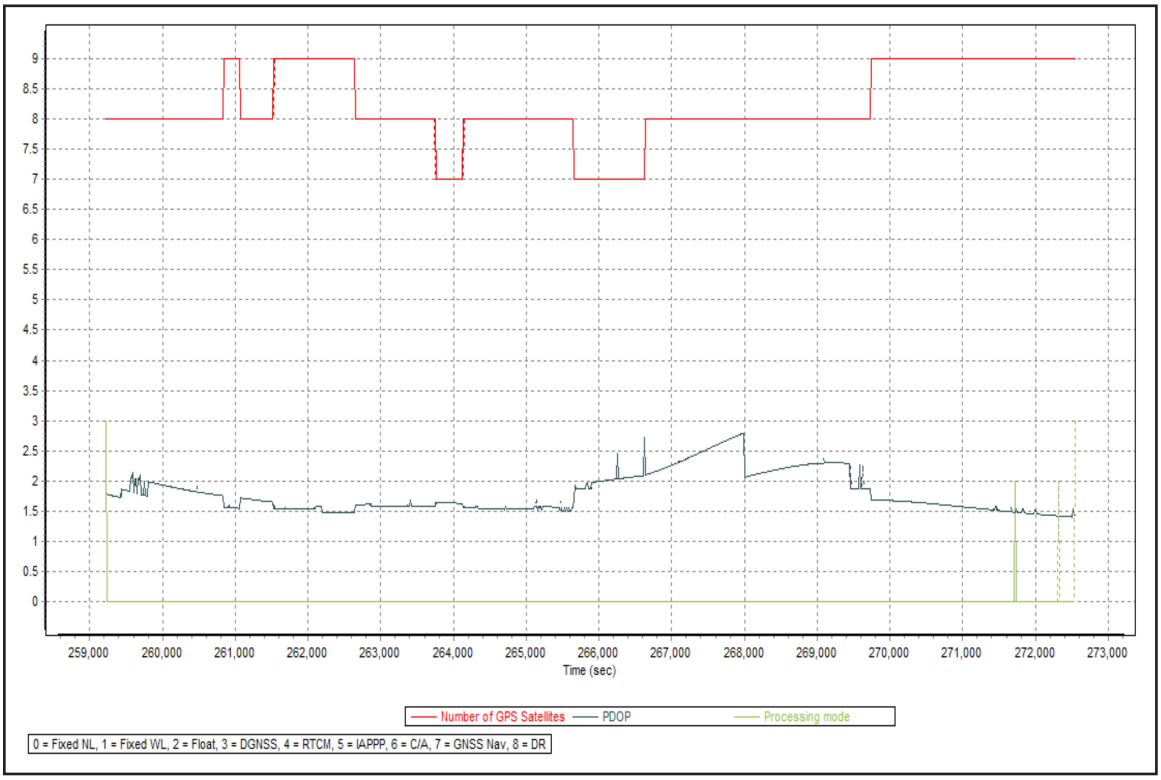


Figure 1.3.1. Solution Status

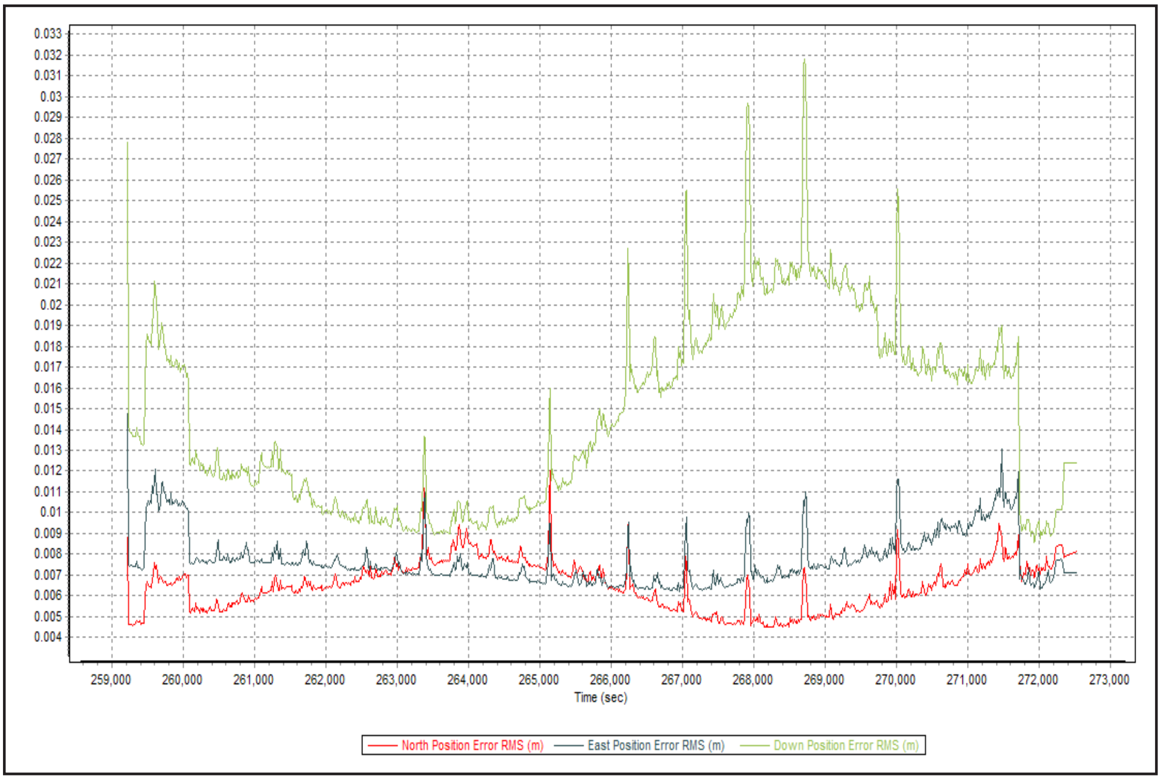


Figure 1.3.2. Smoothed Performance Metric Parameters

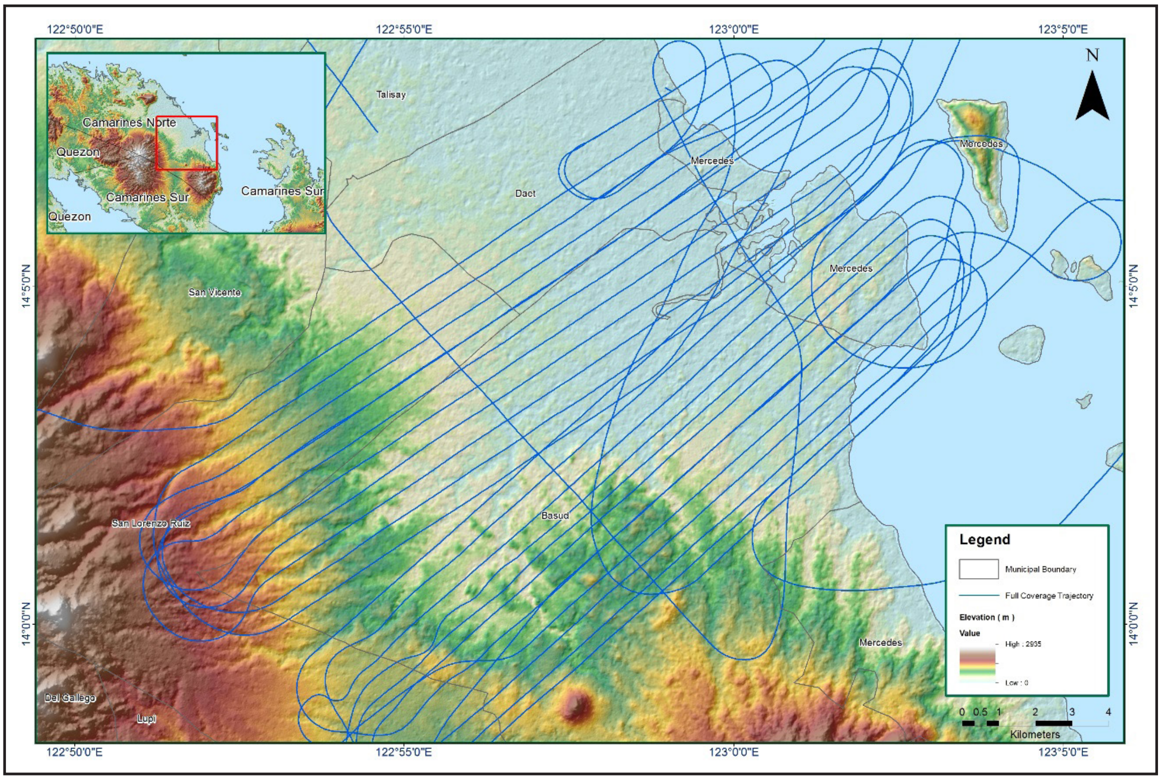


Figure 1.3.3. Best Estimated Trajectory

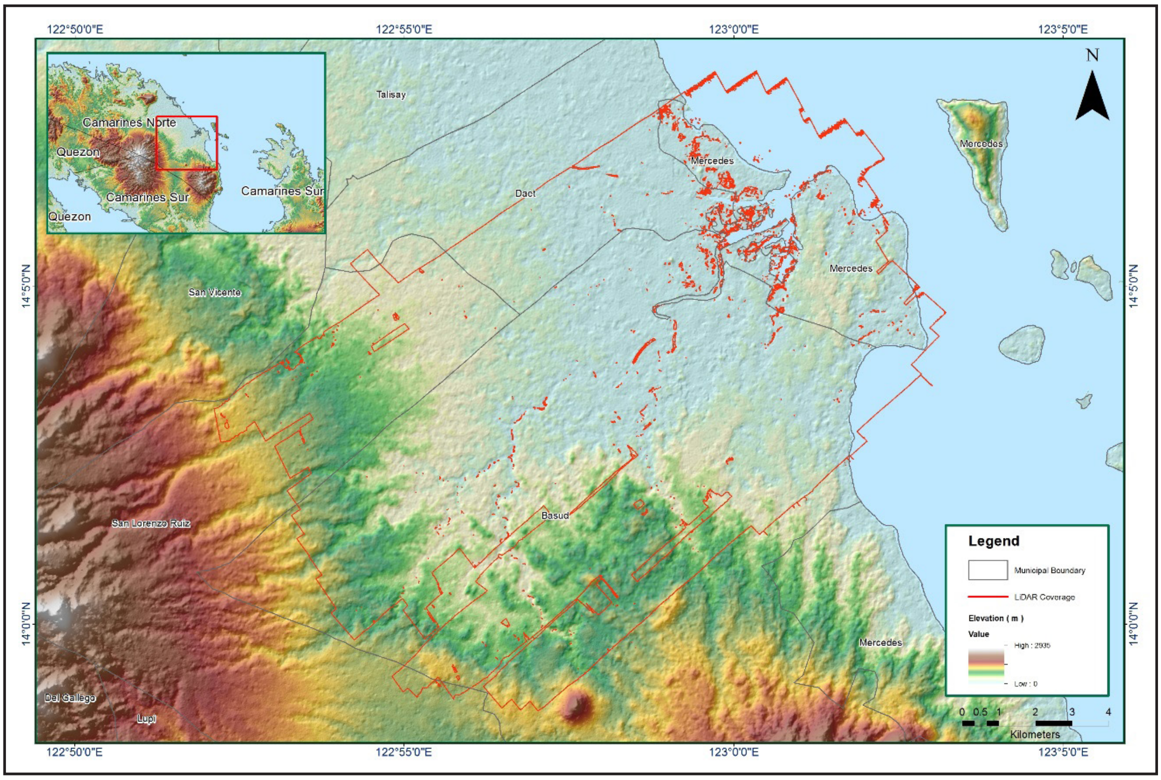


Figure 1.3.4. Coverage of LiDAR Data

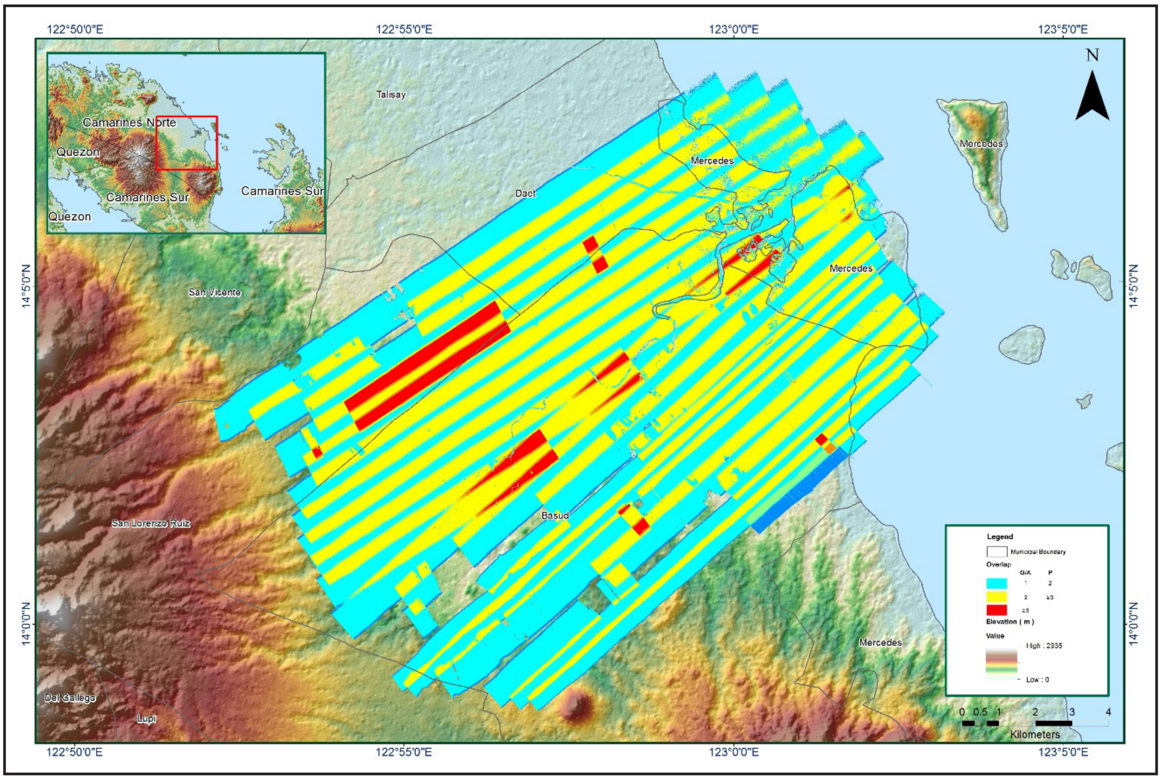


Figure 1.3.5. Image of data overlap

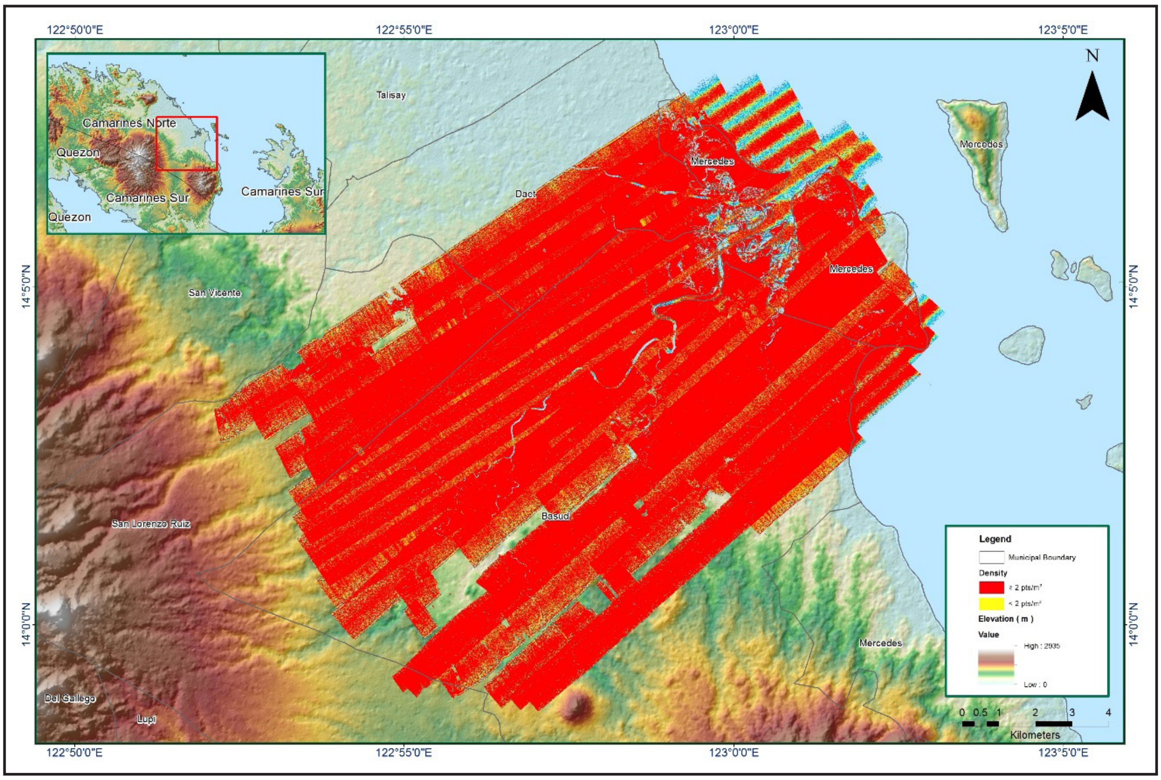


Figure 1.3.6. Density map of merged LiDAR data

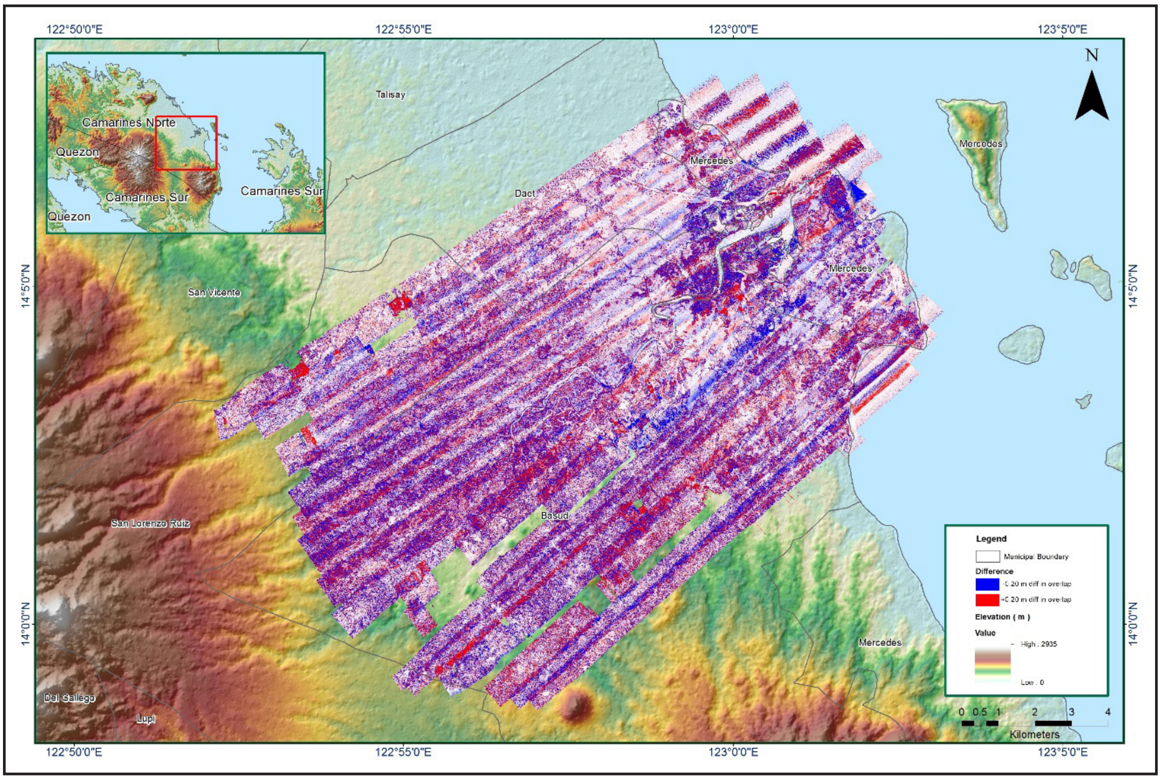


Figure 1.3.7. Elevation difference between flight line

Table A-8.4 Mission Summary Report of Mission Blk20Q

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20Q
Inclusive Flights	23270P
Range data size	5.52 GB
POS	99 MB
Base data size	29.1 MB
Image	n/a
Transfer date	May 18 ,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)	1.1
RMSE for East Position (<4.0 cm)	1.0
RMSE for Down Position (<8.0 cm)	2.1
Boresight correction stdev (<0.001deg)	0.000277
IMU attitude correction stdev (<0.001deg)	0.000421
GPS position stdev (<0.01m)	0.0090
Minimum % overlap (>25)	43.68%
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	32
Maximum Height	507.17
Minimum Height	9.37
Classification (# of points)	
Ground	24019582
Low vegetation	8662706
Medium vegetation	11182538
High vegetation	3058599
Building	0
Orthophoto	
Processed by	Engr. Jommer Medina, Aljon Rie Araneta, Engr. Elainne Lopez

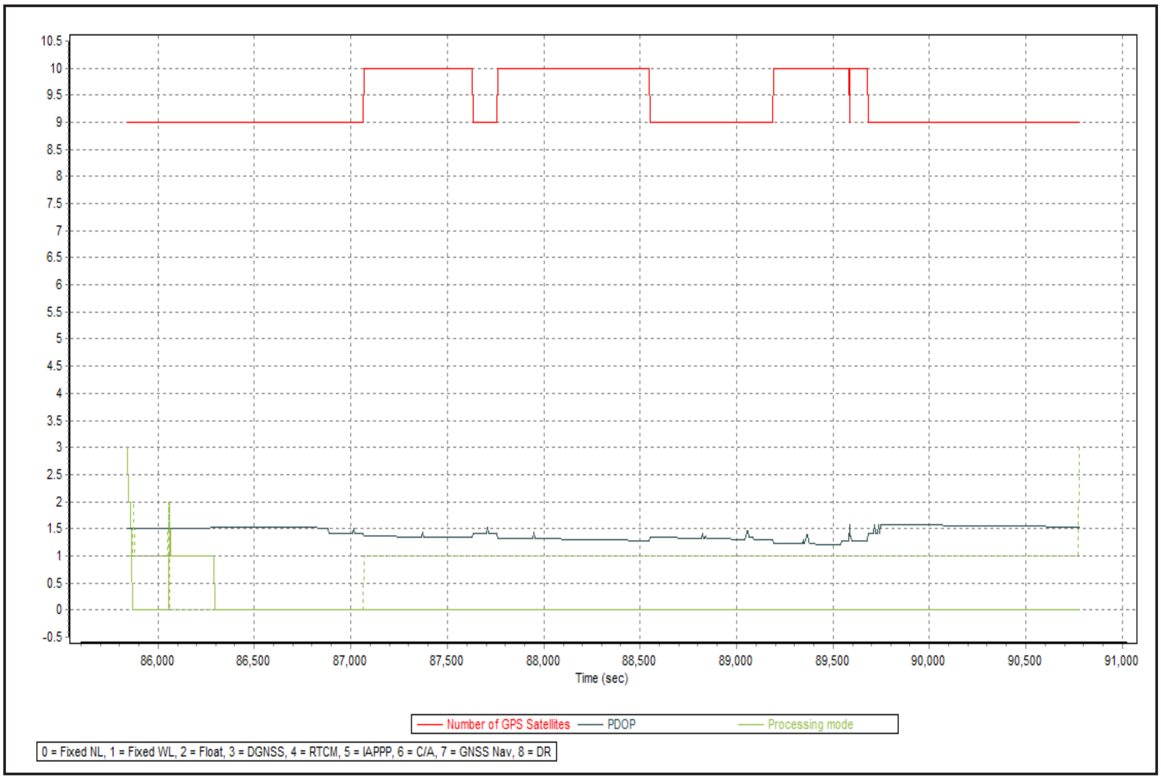


Figure 1.4.1. Solution Status

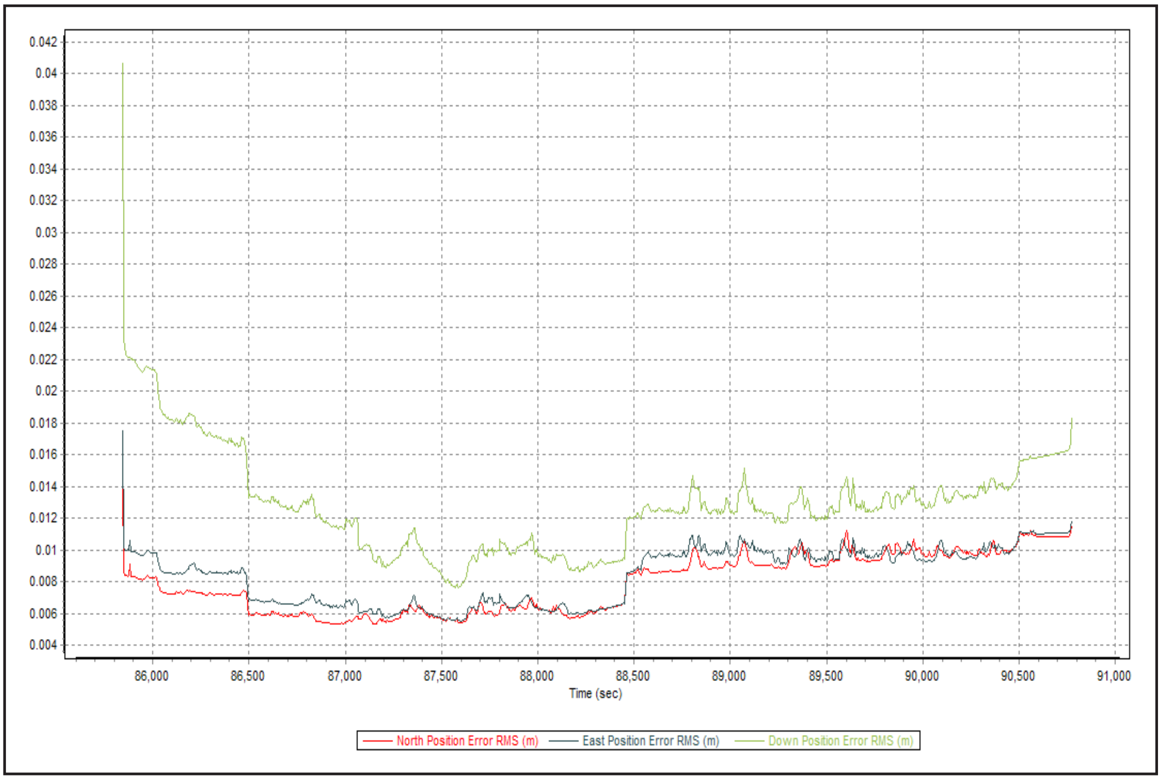


Figure 1.4.2. Smoothed Performance Metric Parameters

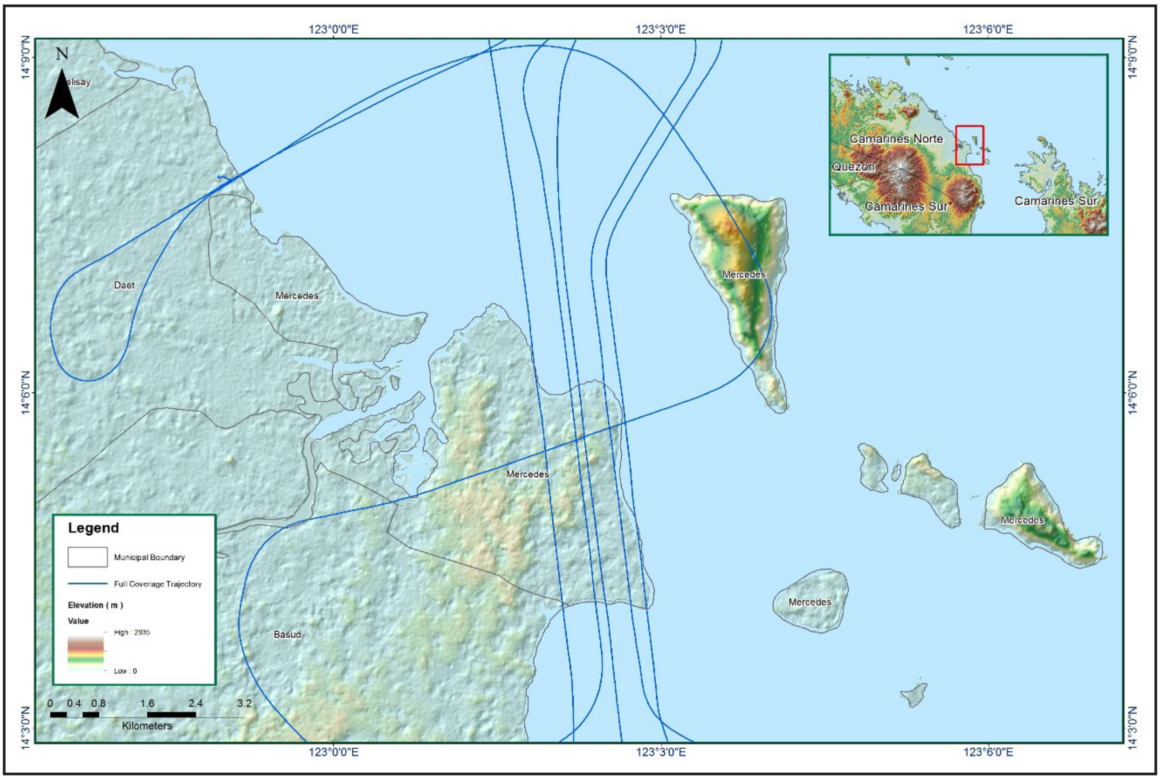


Figure 1.4.3. Best Estimated Trajectory

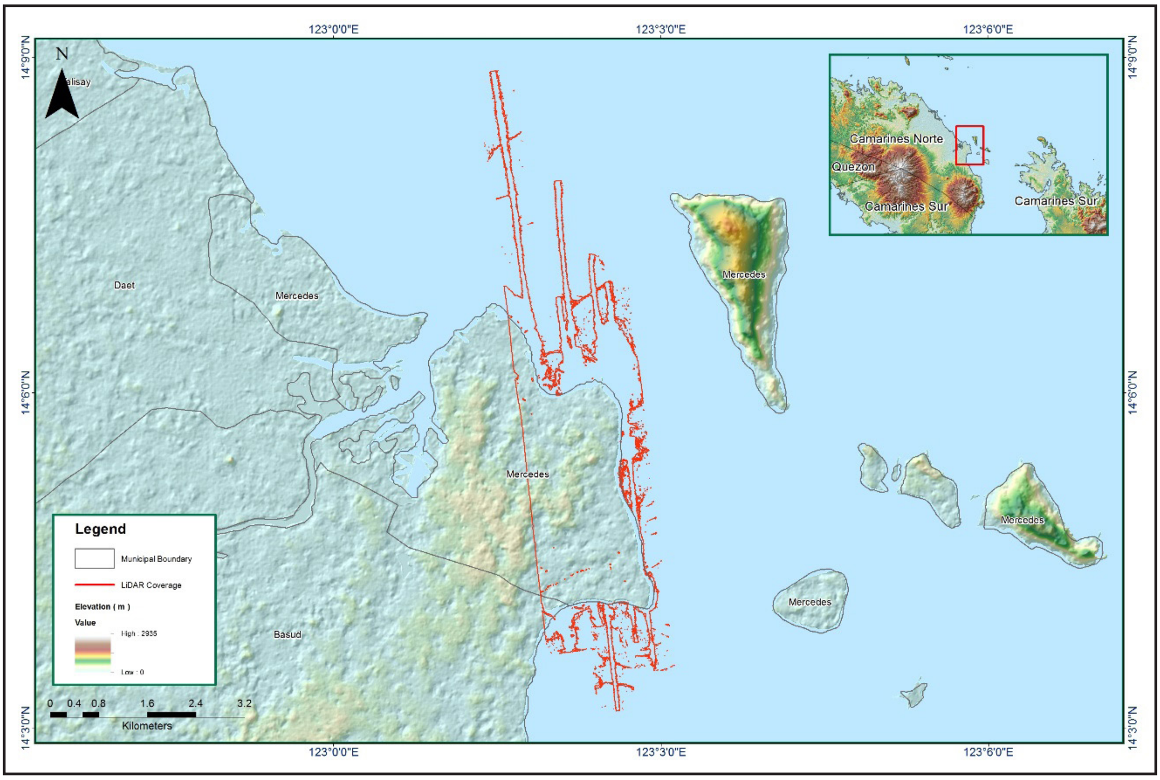


Figure 1.4.4. Coverage of LiDAR Data

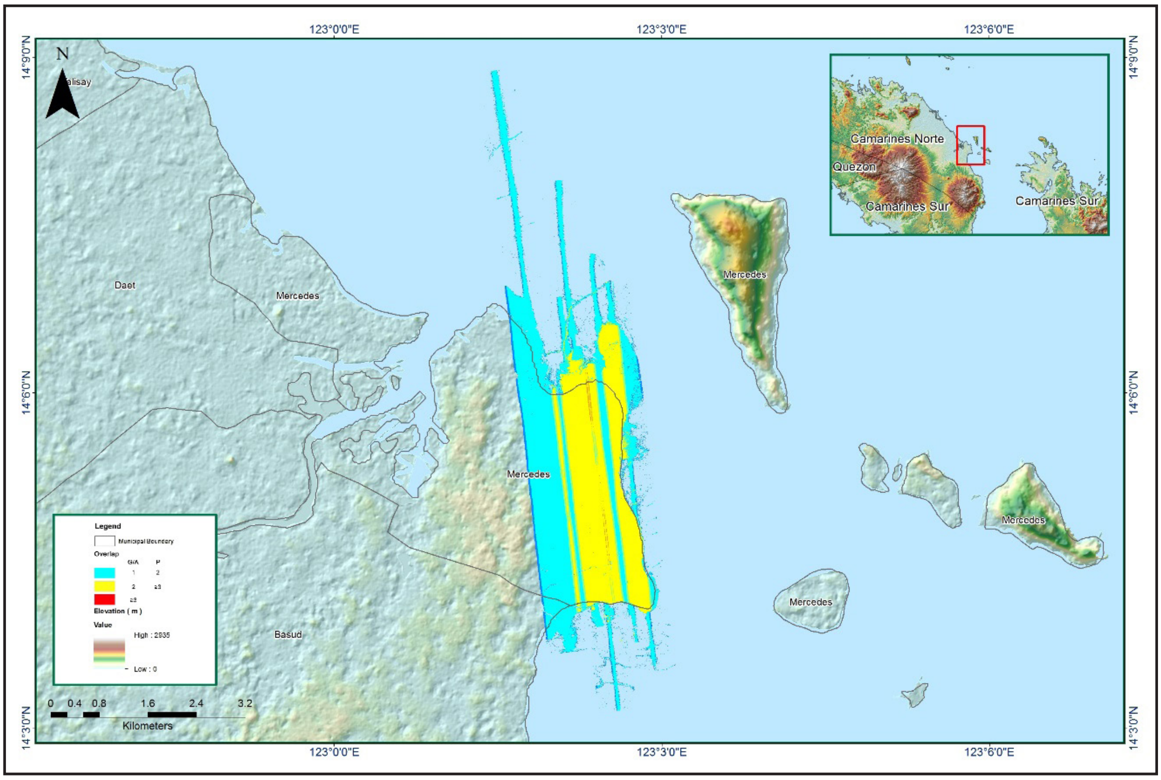


Figure 1.4.5. Image of data overlap

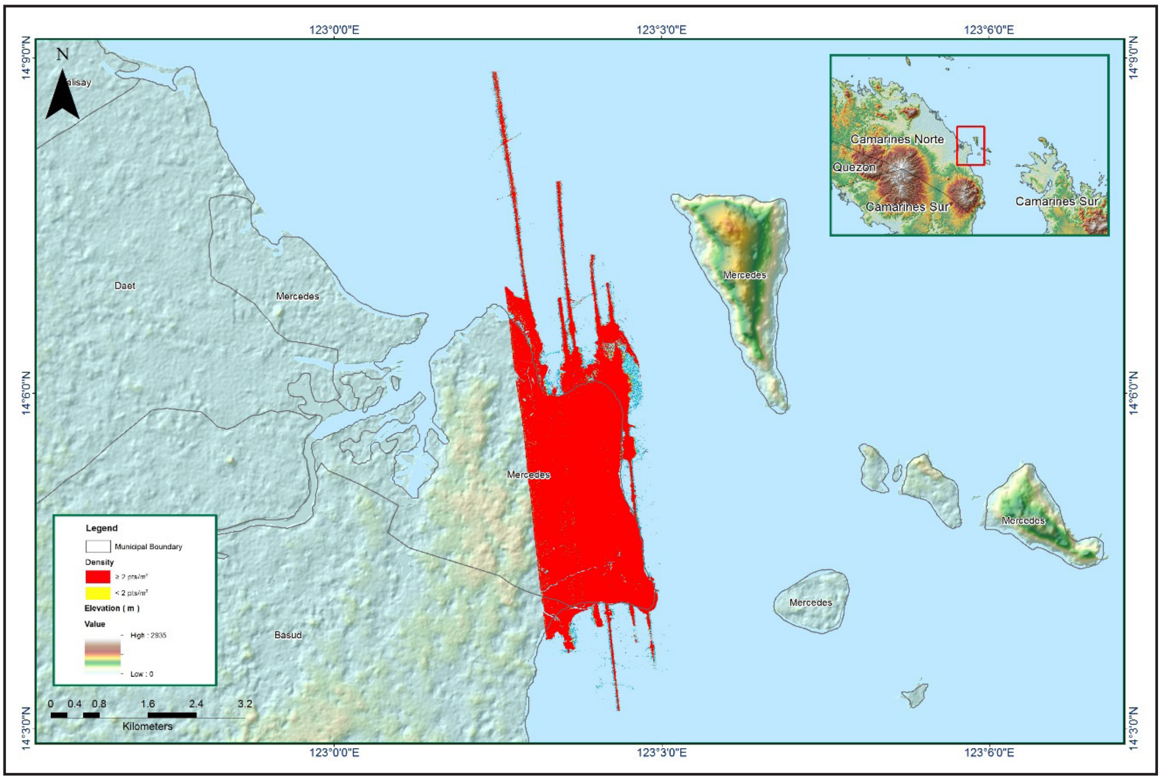


Figure 1.4.6. Density map of merged LiDAR data

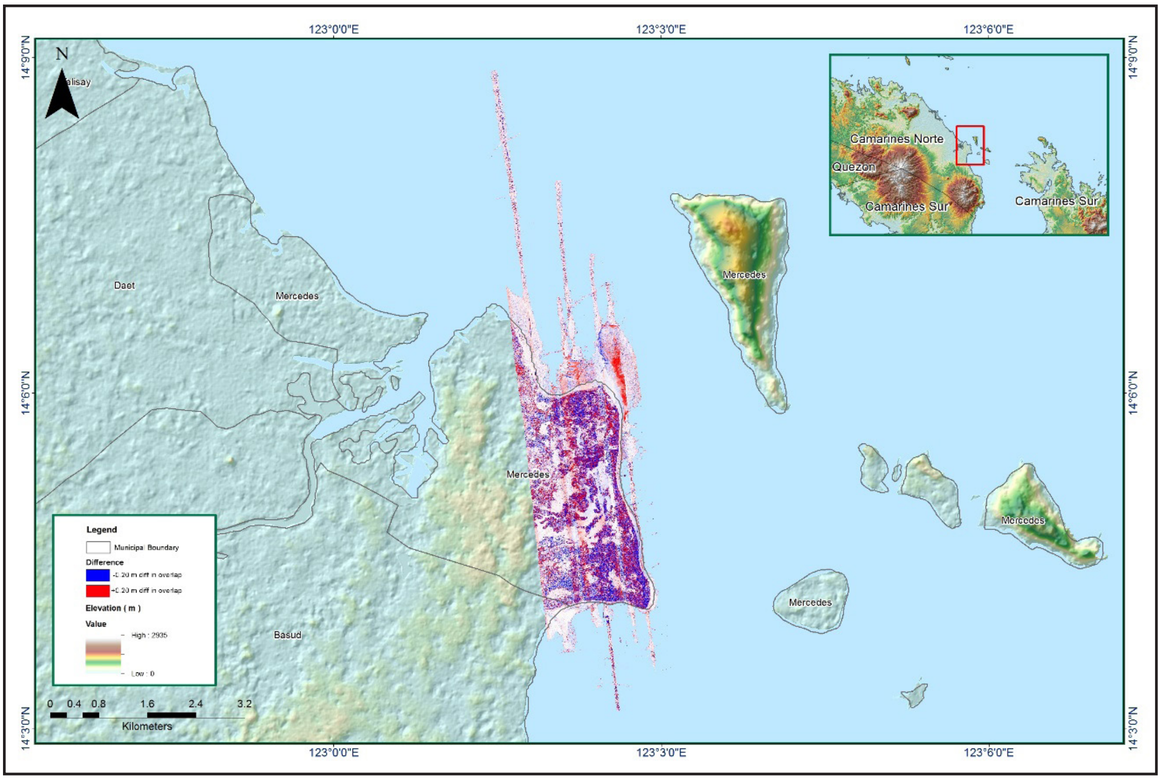


Figure 1.4.7. Elevation difference between flight line

Table A-8.5 Mission Summary Report of Mission Blk20P

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20P
Inclusive Flights	23226P
Range data size	26.6 GB
POS	226 MB
Base data size	130 MB
Image	n/a
Transfer date	May 16 ,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	2.2
Boresight correction stdev (<0.001deg)	0.000184
IMU attitude correction stdev (<0.001deg)	0.000400
GPS position stdev (<0.01m)	0.0062
Minimum % overlap (>25)	31.21%
Ave point cloud density per sq.m. (>2.0)	2.92
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	175
Maximum Height	294.35
Minimum Height	43.31
Classification (# of points)	
Ground	138409998
Low vegetation	119886032
Medium vegetation	140219976
High vegetation	316314086
Building	16548491
Orthophoto	
Processed by	Engr. Jommer Medina, Engr. Christy Lubiano, Alex John Escobido

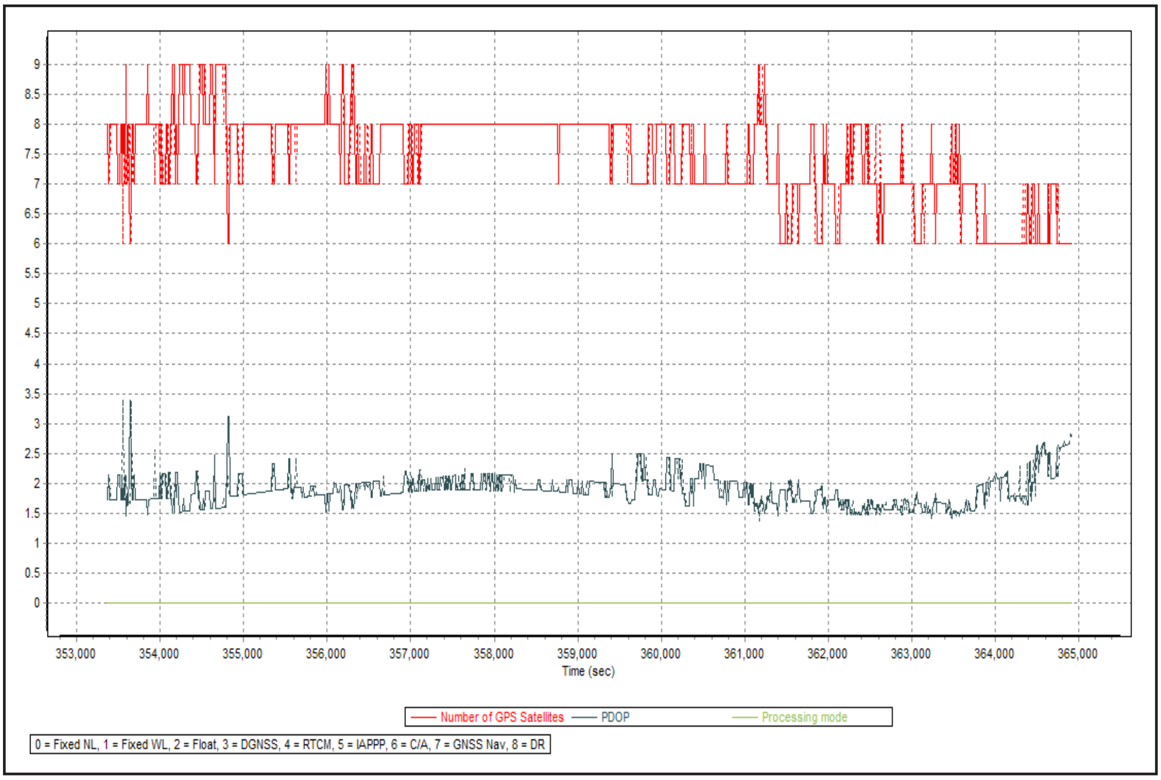


Figure 1.5.1. Solution Status

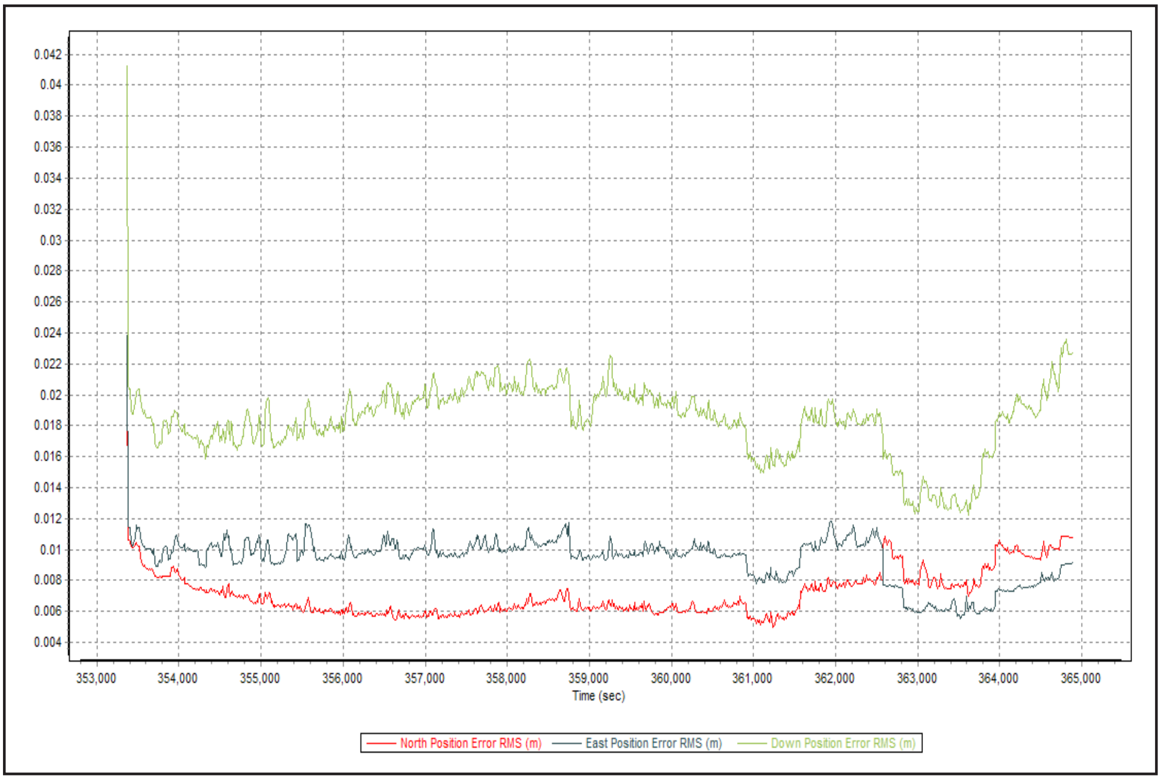


Figure 1.5.2. Smoothed Performance Metric Parameters

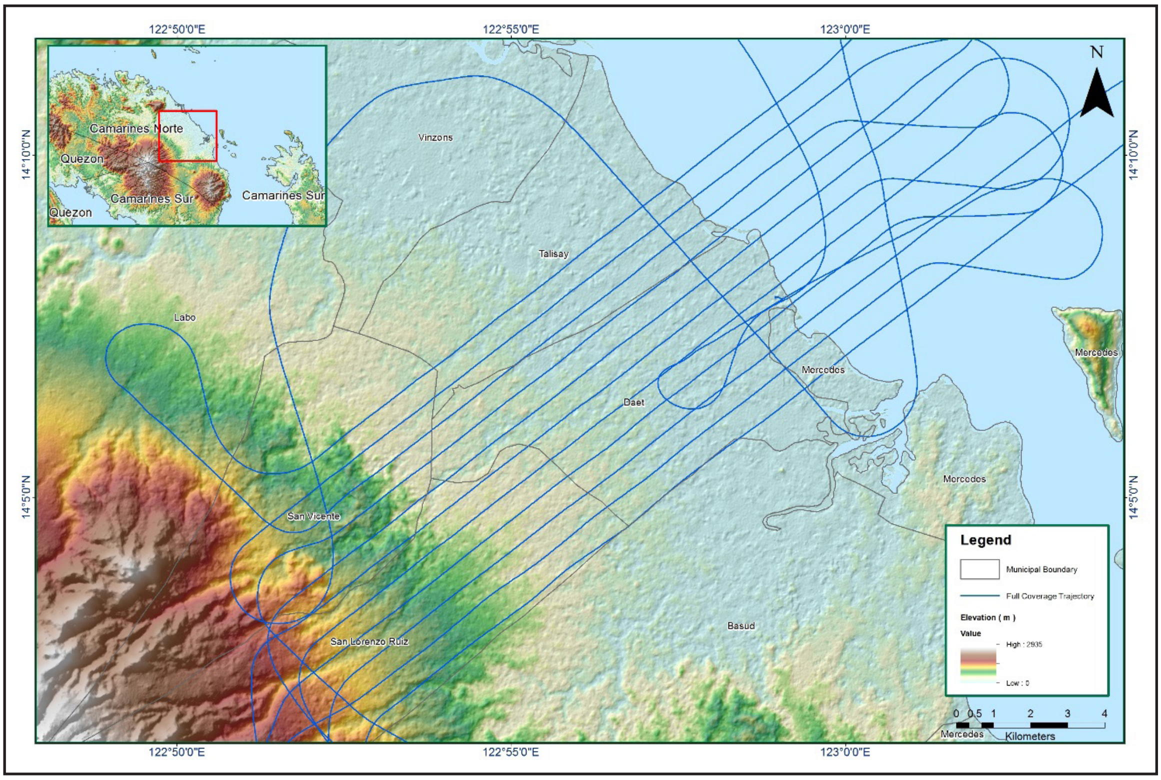


Figure 1.5.3. Best Estimated Trajectory

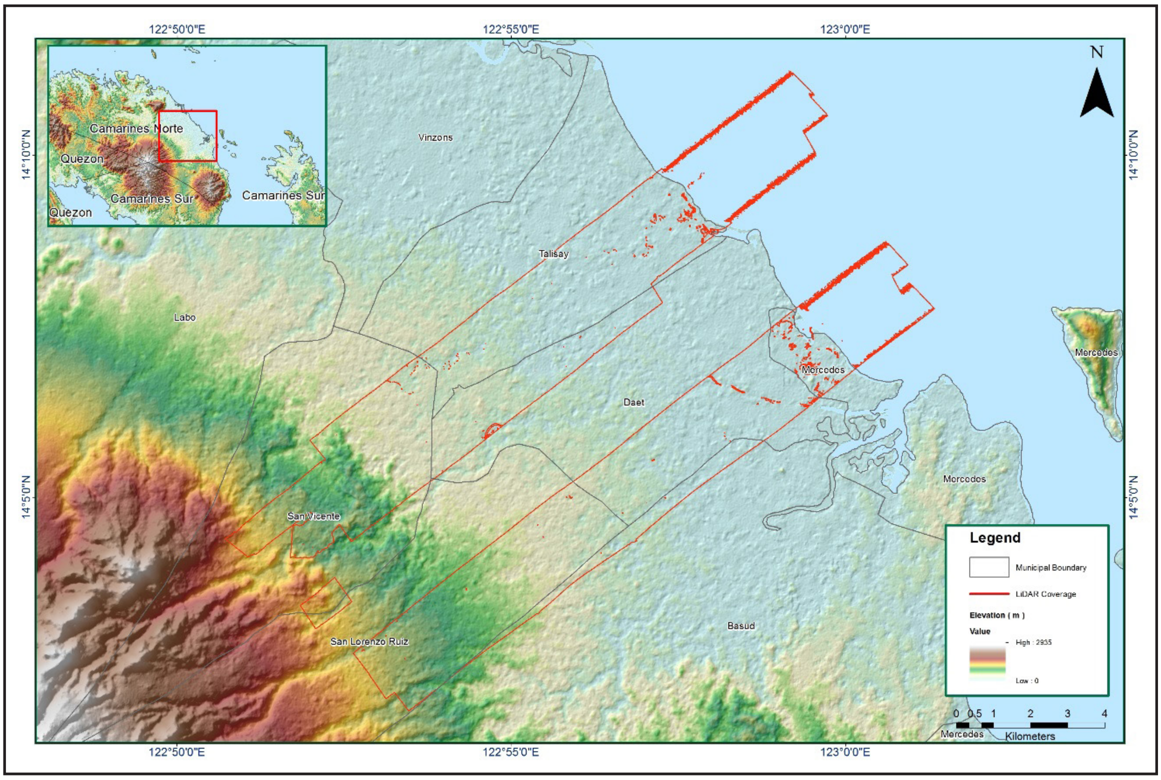


Figure 1.5.4. Coverage of LiDAR Data

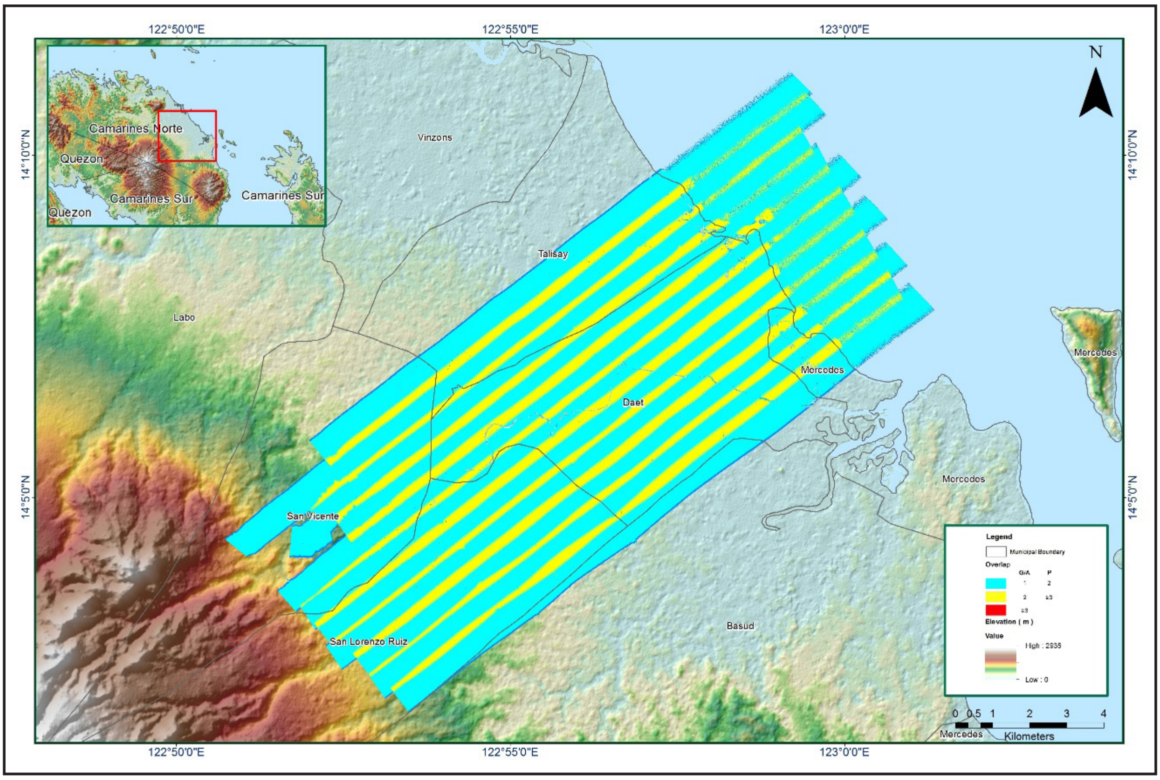


Figure 1.5.5. Image of data overlap

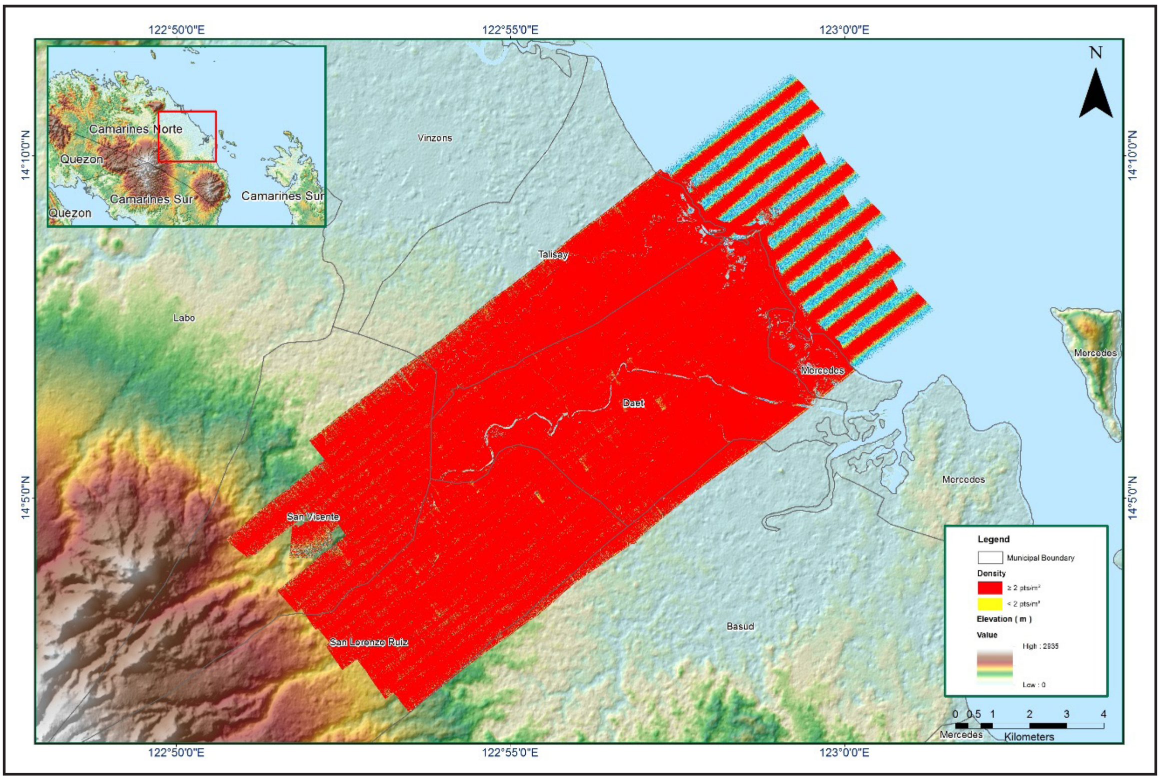


Figure 1.5.6. Density map of merged LiDAR data

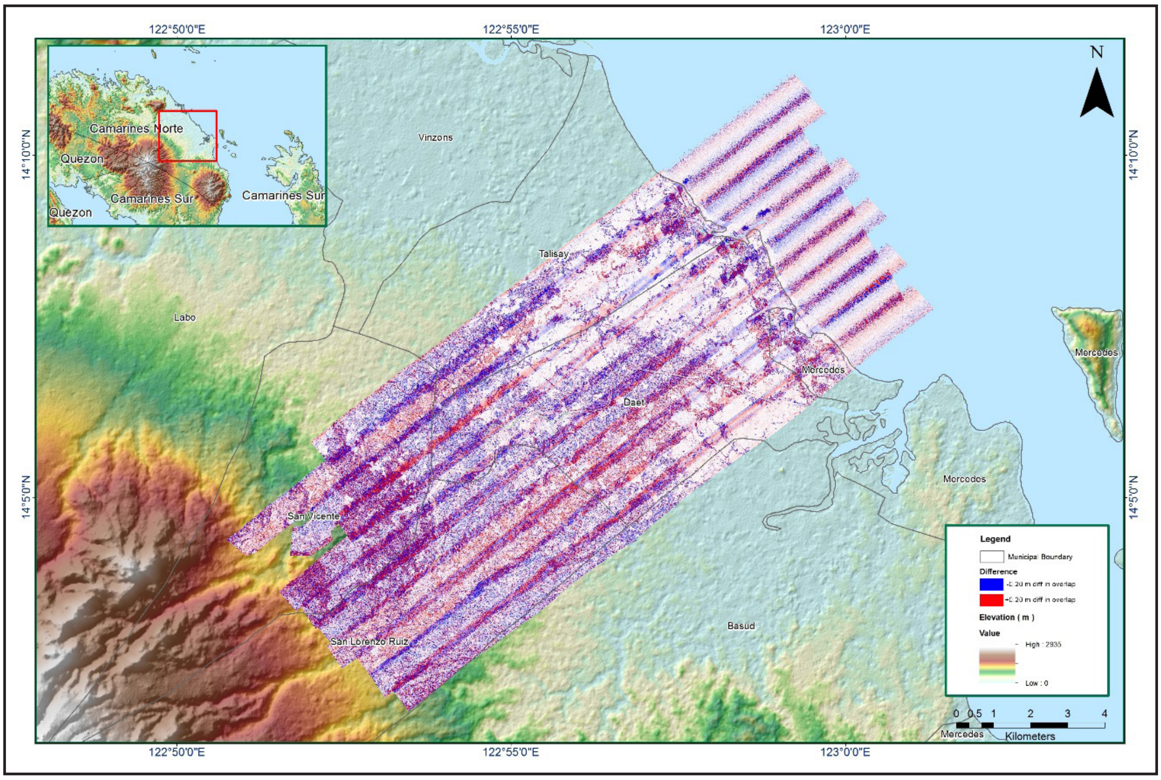


Figure 1.5.7. Elevation difference between flight lines

Table A-8.6 Mission Summary Report of Mission Blk20O

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20O
Inclusive Flights	23234P,23226P
Range data size	12.6 GB
POS	132 MB
Base data size	138 MB
Image	n/a
Transfer date	May 16 ,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)	0.9
RMSE for East Position (<4.0 cm)	1.0
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	0.000255
IMU attitude correction stdev (<0.001deg)	0.000622
GPS position stdev (<0.01m)	0.0077
Minimum % overlap (>25)	24.21%
Ave point cloud density per sq.m. (>2.0)	4.19
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	186
Maximum Height	813.35 m
Minimum Height	39.97 m
Classification (# of points)	
Ground	142,285,660
Low vegetation	72,465,031
Medium vegetation	215,191,412
High vegetation	568,979,873
Building	16,300,515
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Edgardo Gubatanga, Maria Tamsyn Malabanan

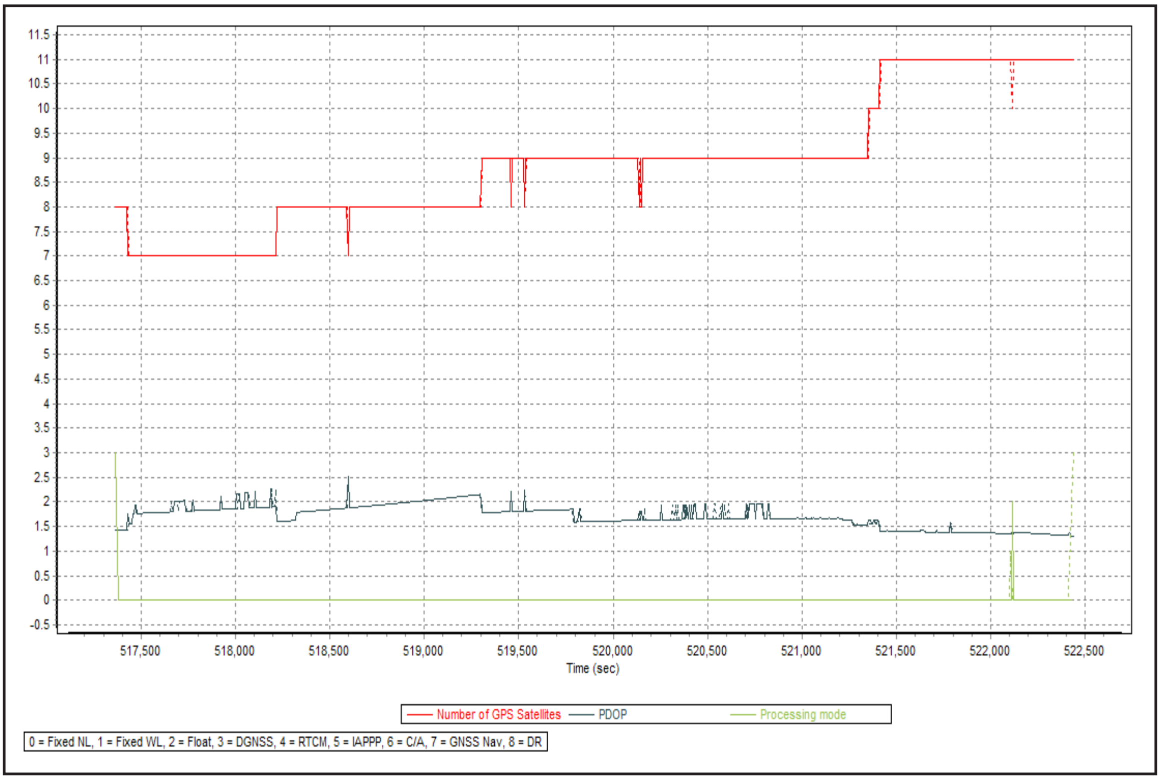


Figure 1.6.1. Solution Status

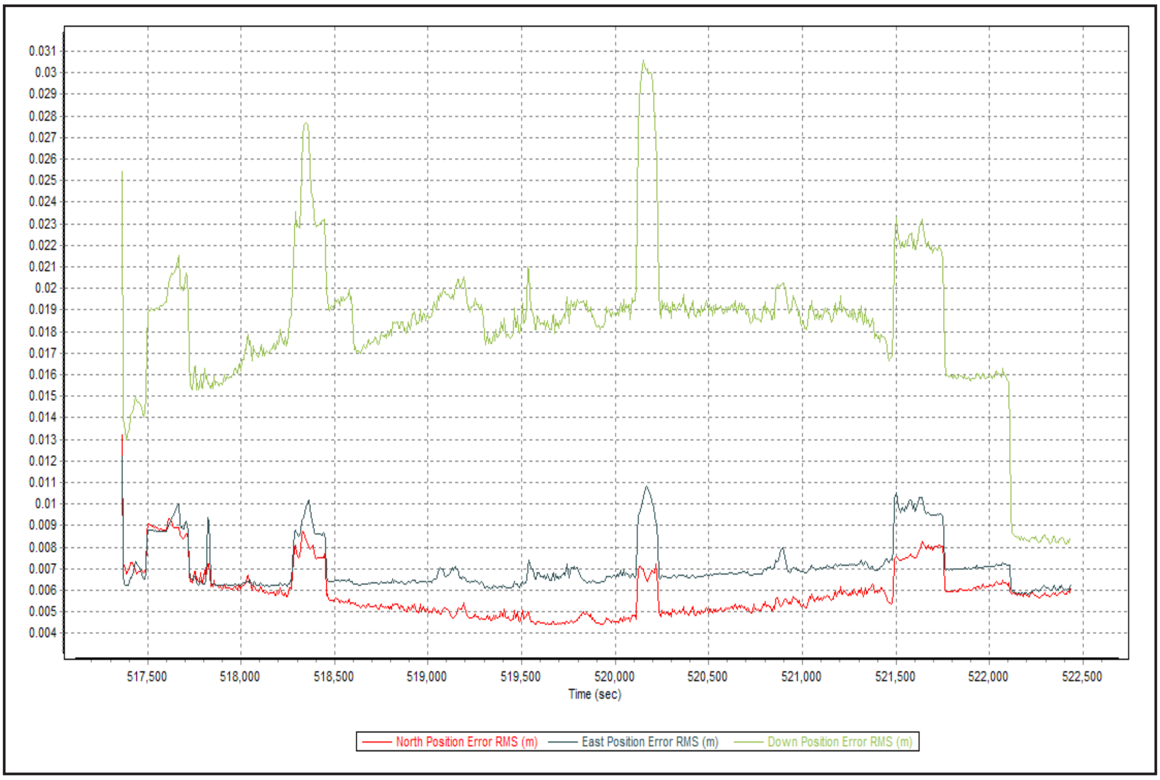


Figure 1.6.2. Smoothed Performance Metric Parameters

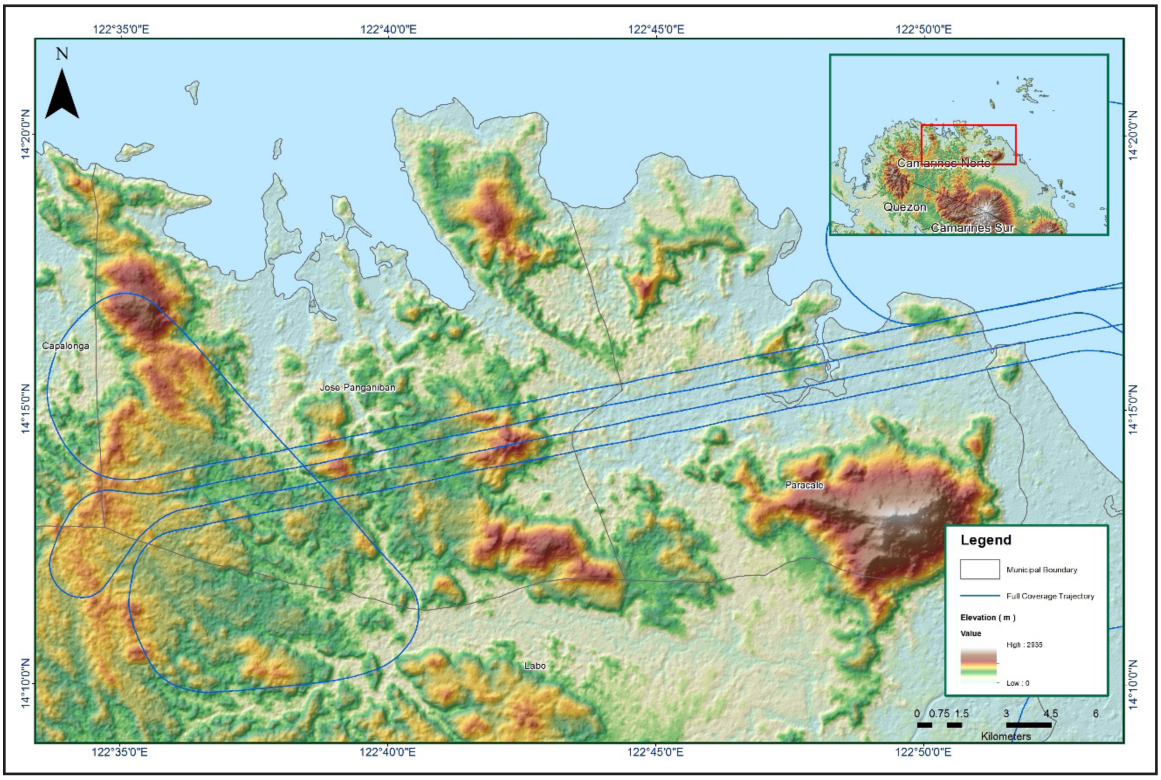


Figure 1.6.3. Best Estimated Trajectory

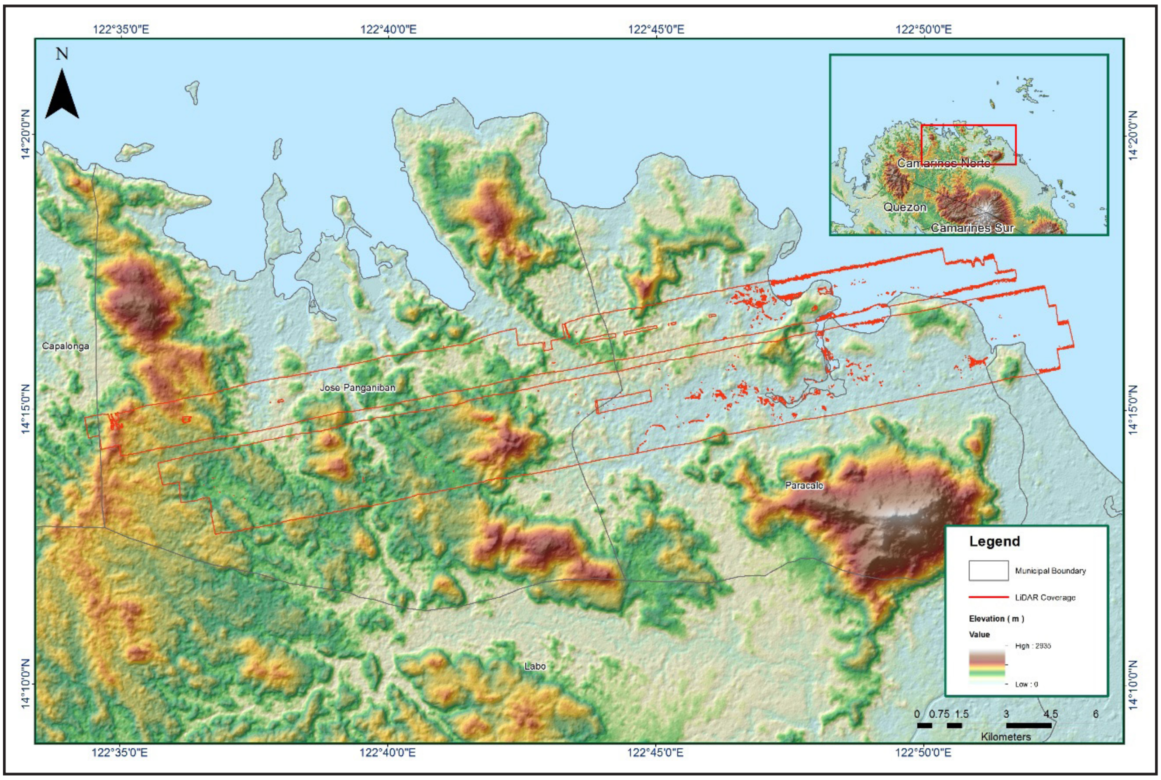


Figure 1.6.4. Coverage of LiDAR Data

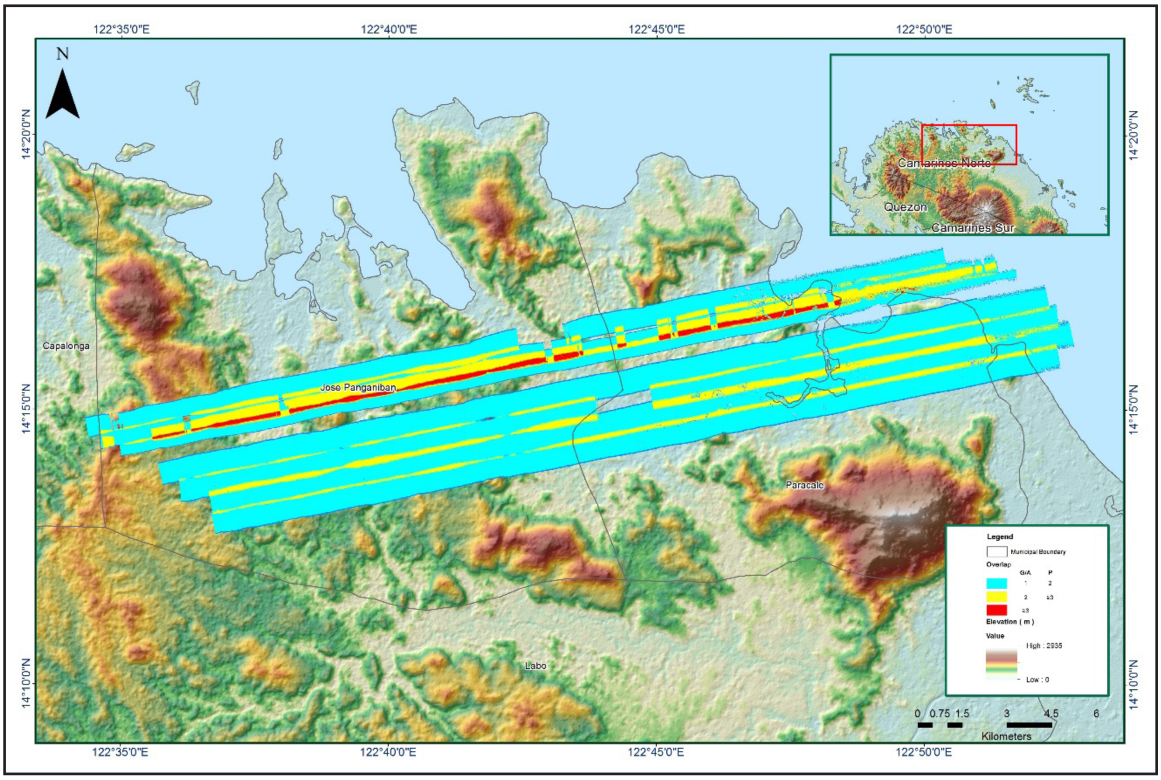


Figure 1.6.5. Image of data overlap

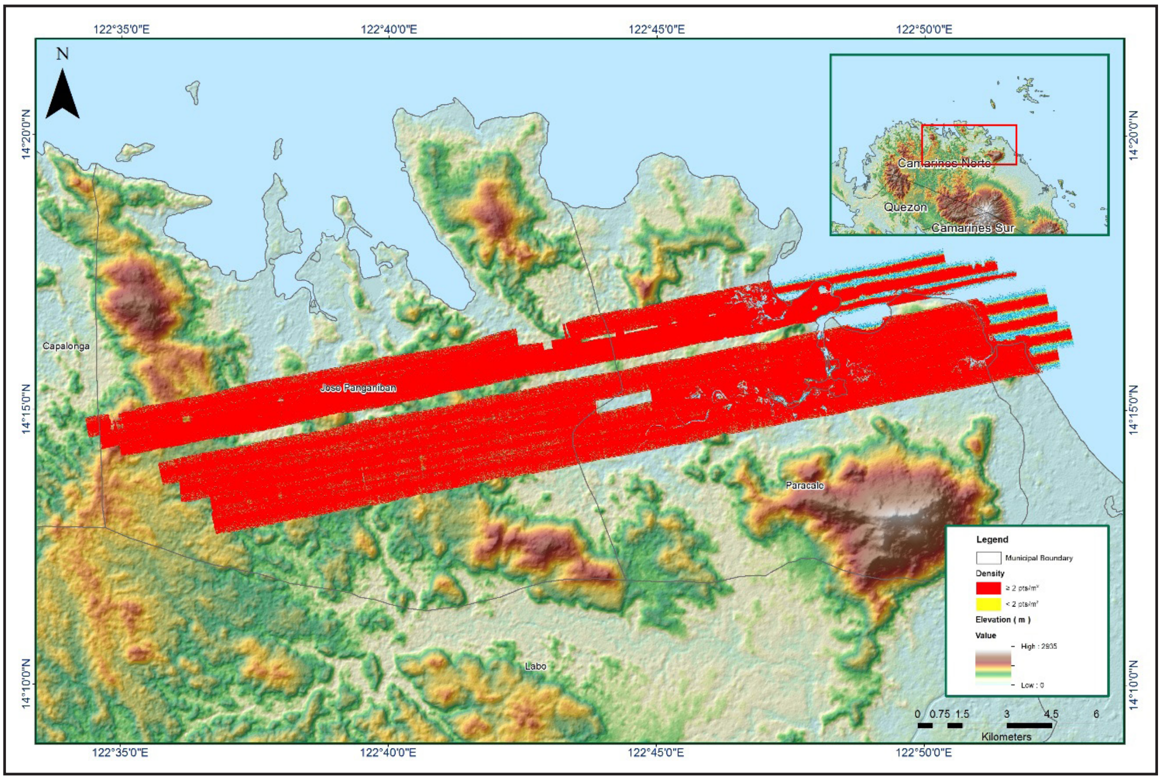


Figure 1.6.6. Density map of merged LiDAR data

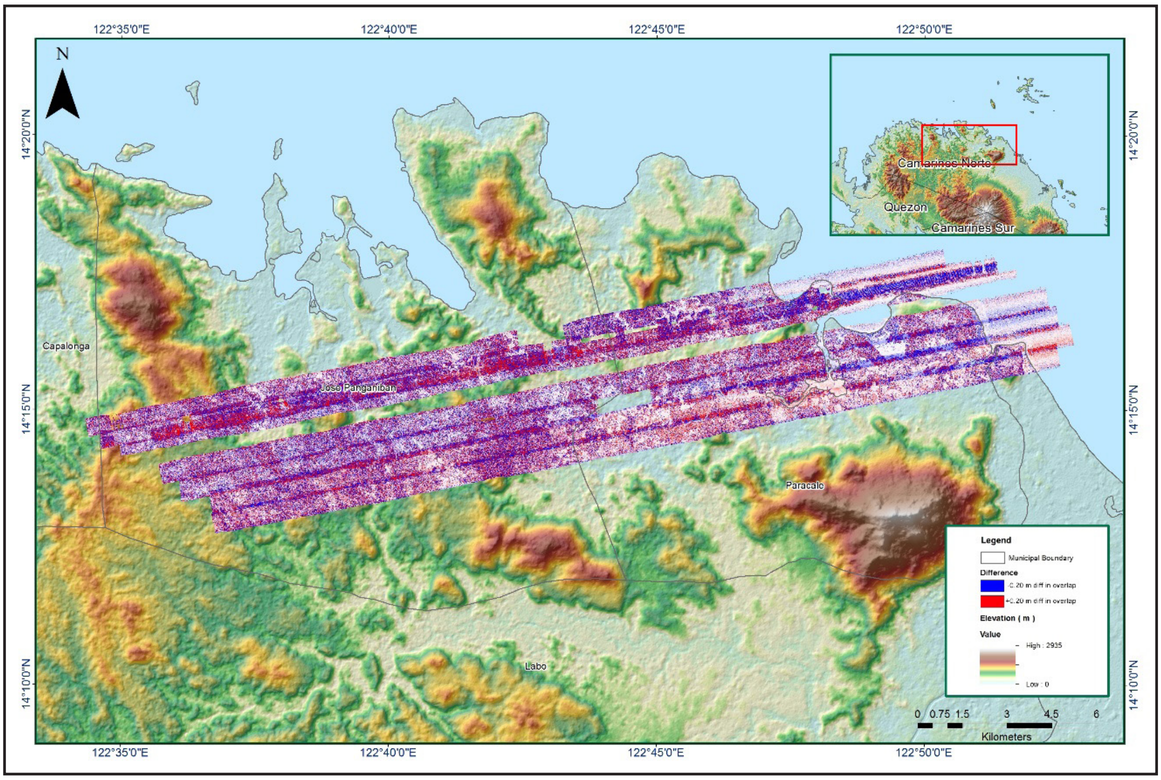


Figure 1.6.7. Elevation difference between flight lines

Table A-8.7 Mission Summary Report of Mission Blk20N

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20N
Inclusive Flights	23202P
Range data size	25.9 GB
POS	287 MB
Base data size	131 MB
Image	n/a
Transfer date	April 11,2016
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)	1.3
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	2.3
Boresight correction stdev (<0.001deg)	0.000285
IMU attitude correction stdev (<0.001deg)	0.007923
GPS position stdev (<0.01m)	0.0091
Minimum % overlap (>25)	45.27%
Ave point cloud density per sq.m. (>2.0)	2.77
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	286
Maximum Height	480.35 m
Minimum Height	49.55 m
Classification (# of points)	
Ground	154,031,800
Low vegetation	108,265,331
Medium vegetation	239,655,059
High vegetation	563,215,524
Building	9,269,645
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Velina Angelina Bemida, Engr. Monalyne Rabino

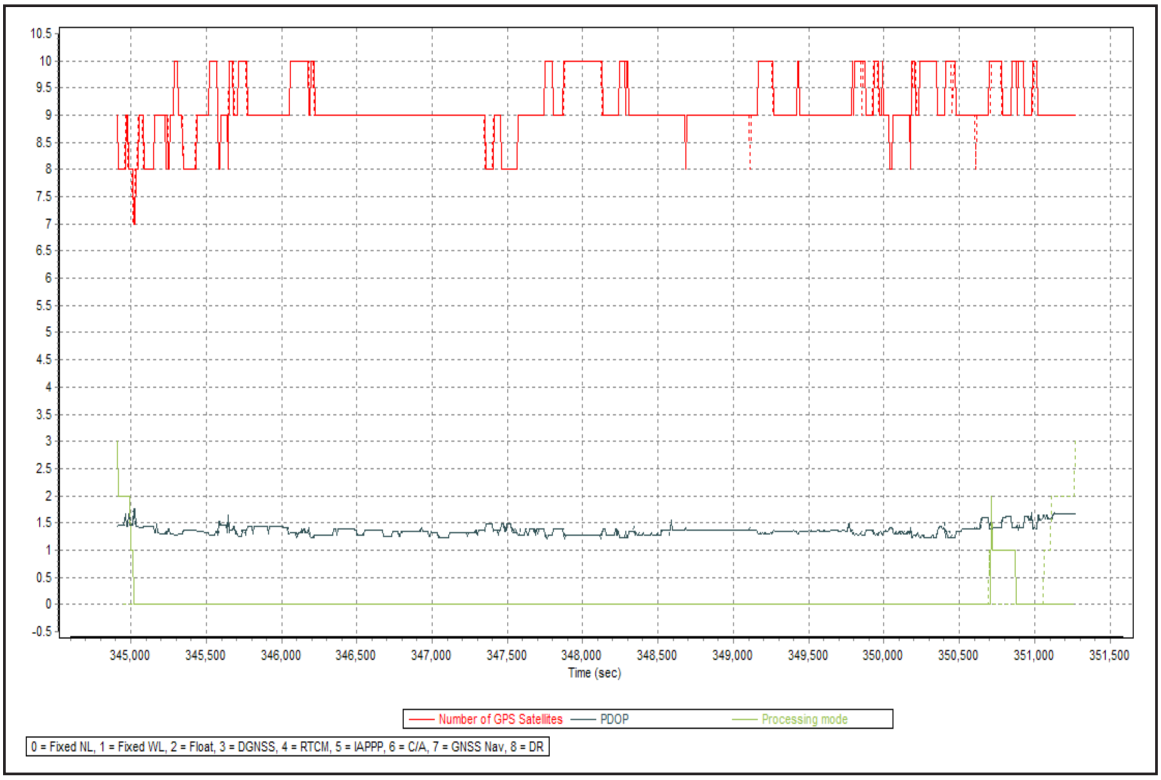


Figure 1.7.1. Solution Status

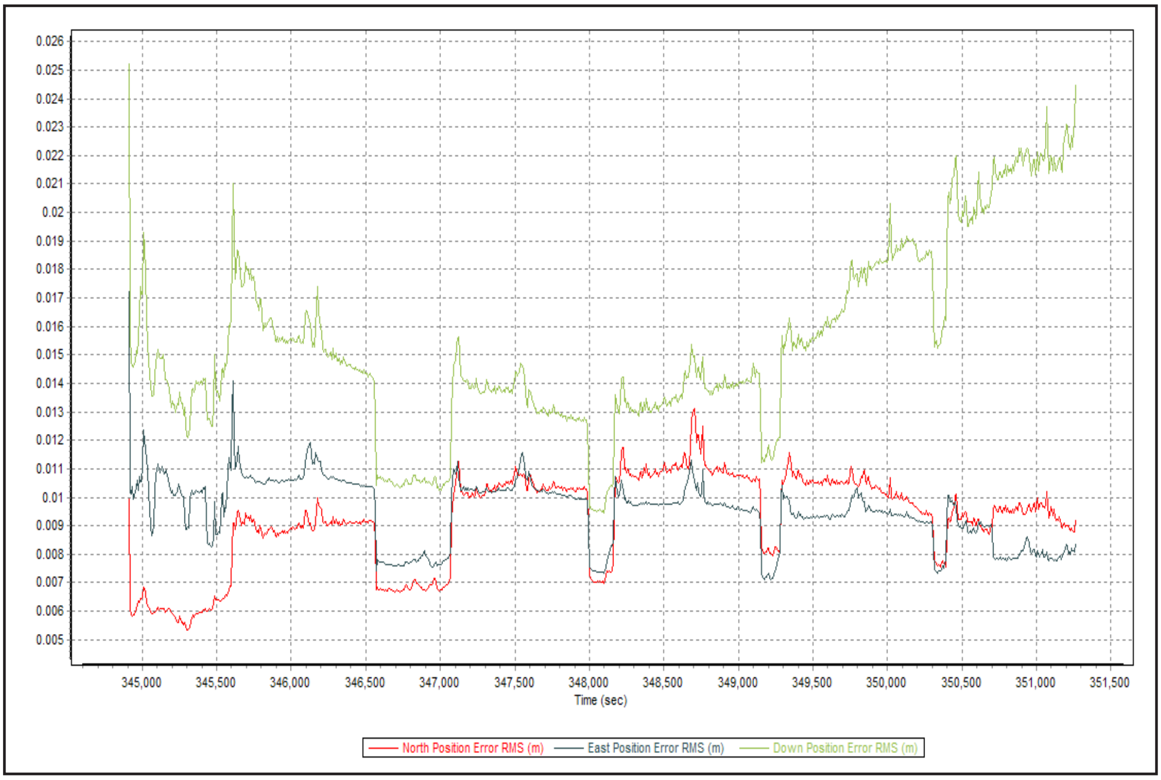


Figure 1.7.2. Smoothed Performance Metric Parameters

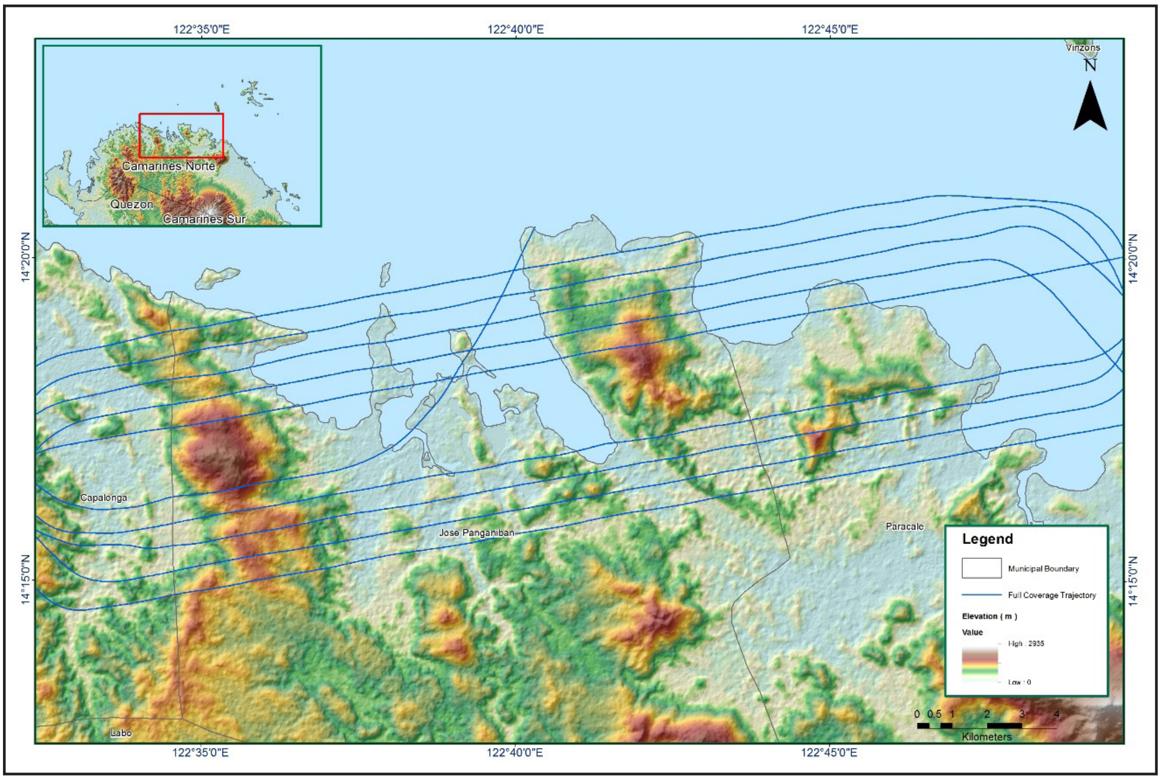


Figure 1.7.3. Best Estimated Trajectory

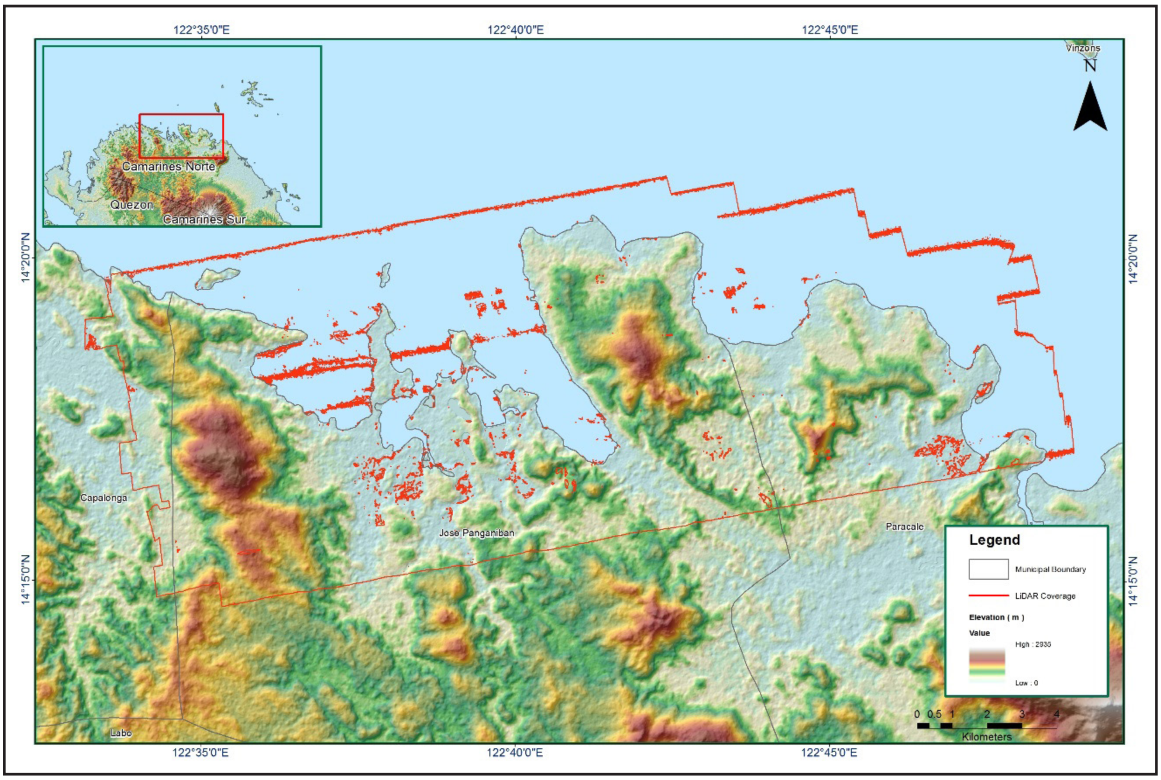


Figure 1.7.4. Coverage of LiDAR Data

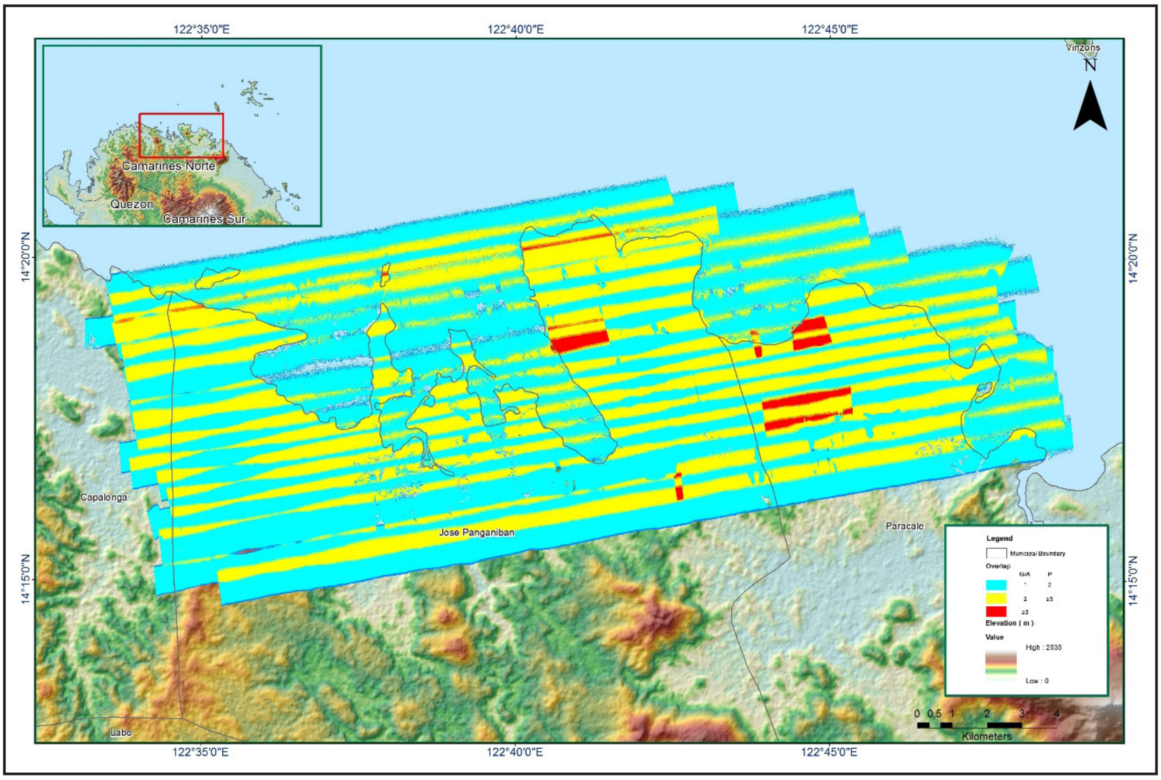


Figure 1.7.5. Image of data overlap

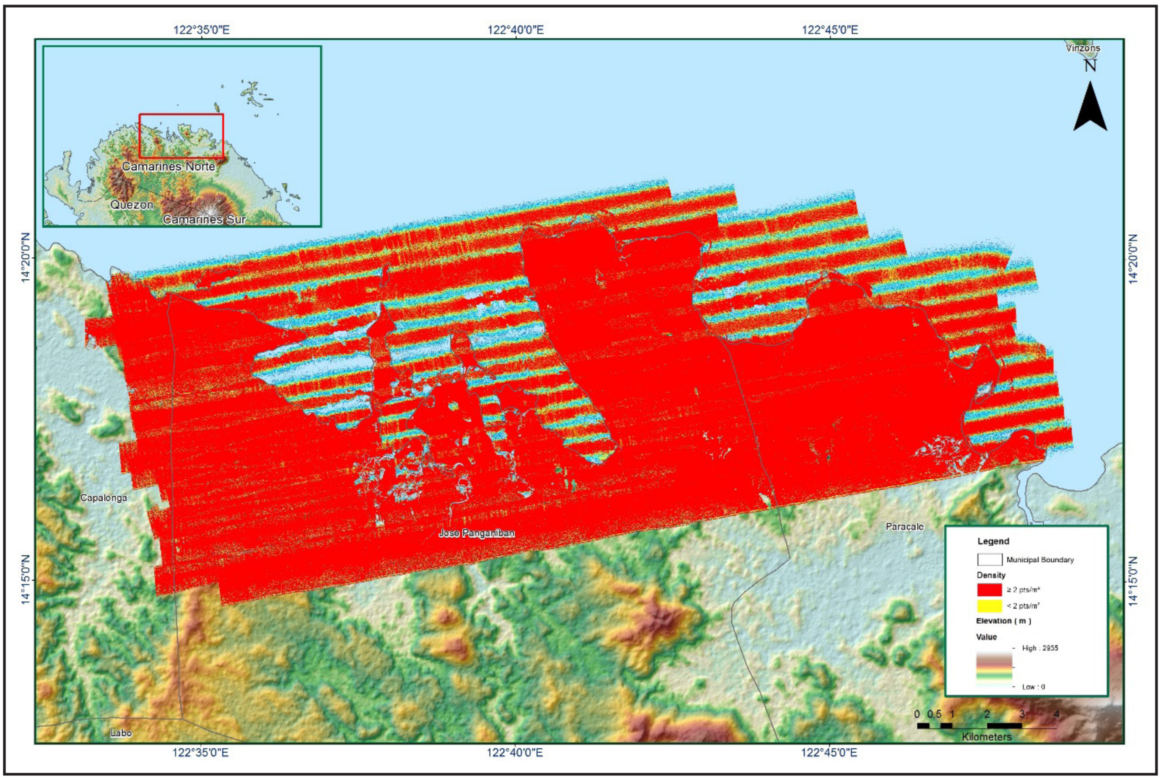


Figure 1.7.6. Density map of merged LiDAR data

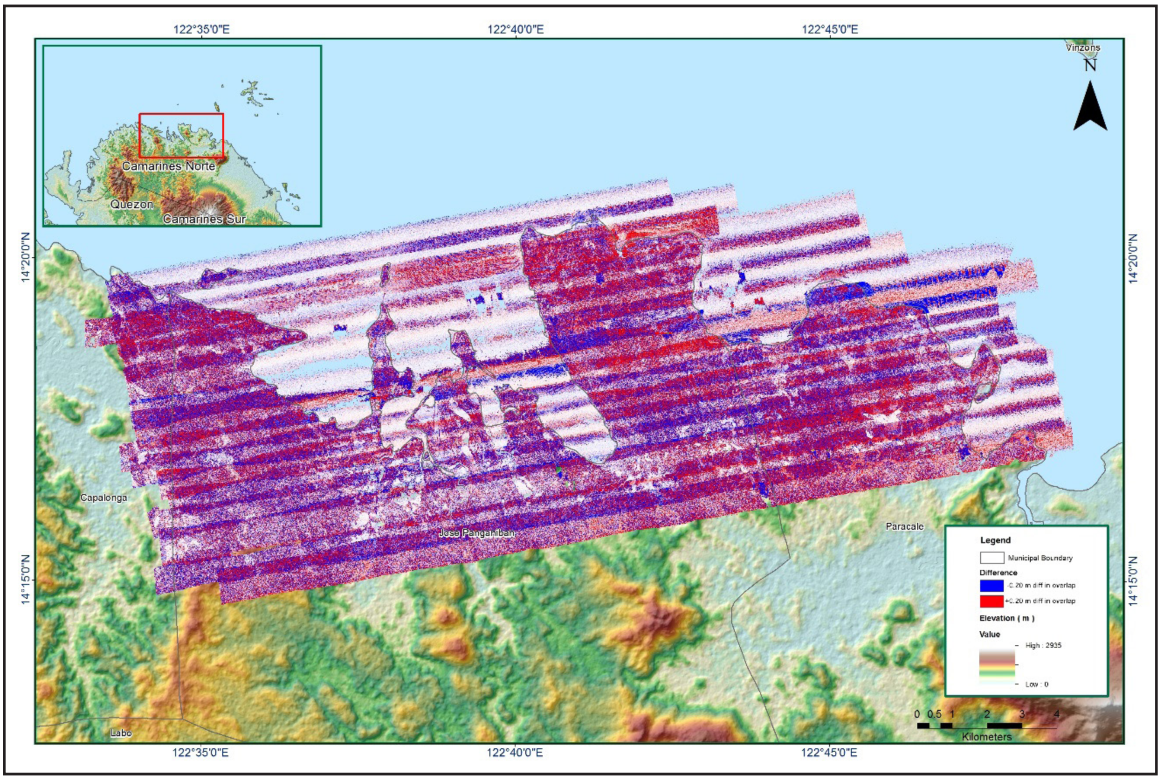


Figure 1.7.7. Elevation difference between flight line

Table A-8.8 Mission Summary Report of Mission Blk20N_supplement

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20N_supplement
Inclusive Flights	23266P
Range data size	26.6 GB
POS	226 MB
Base data size	130 MB
Image	n/a
Transfer date	May 16 ,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)	0.9
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	2.3
Boresight correction stdev (<0.001deg)	0.000346
IMU attitude correction stdev (<0.001deg)	0.000497
GPS position stdev (<0.01m)	0.0123
Minimum % overlap (>25)	22.68%
Ave point cloud density per sq.m. (>2.0)	2.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	104
Maximum Height	383.83 m
Minimum Height	49.47 m
Classification (# of points)	
Ground	43,027,089
Low vegetation	35,835,777
Medium vegetation	63,920,261
High vegetation	165,063,417
Building	3,275,730
Orthophoto	Yes

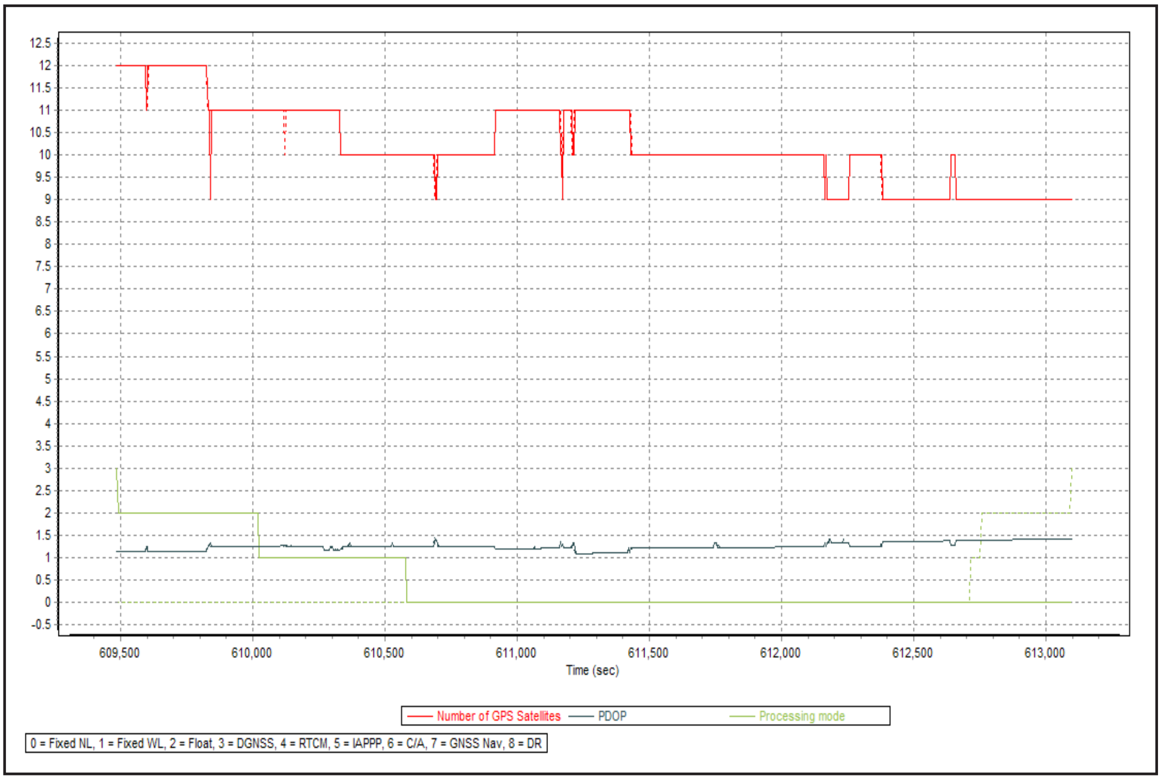


Figure 1.8.1. Solution Status

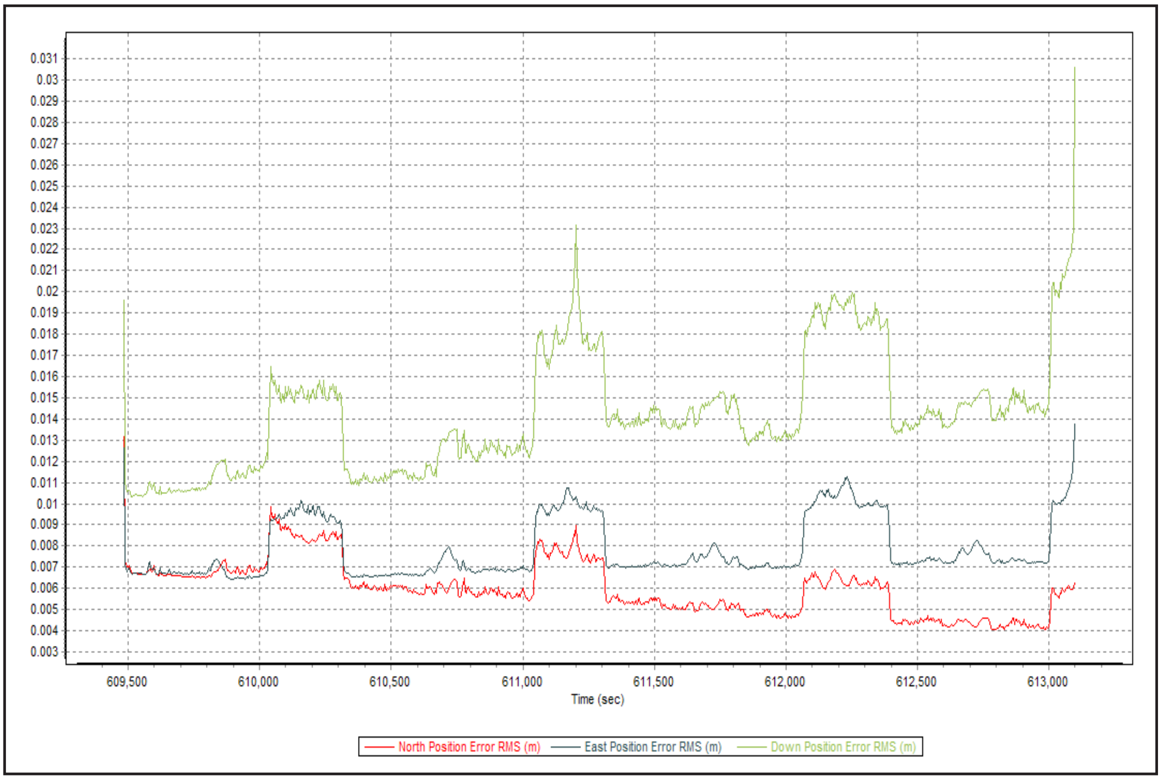


Figure 1.8.2. Smoothed Performance Metric Parameters

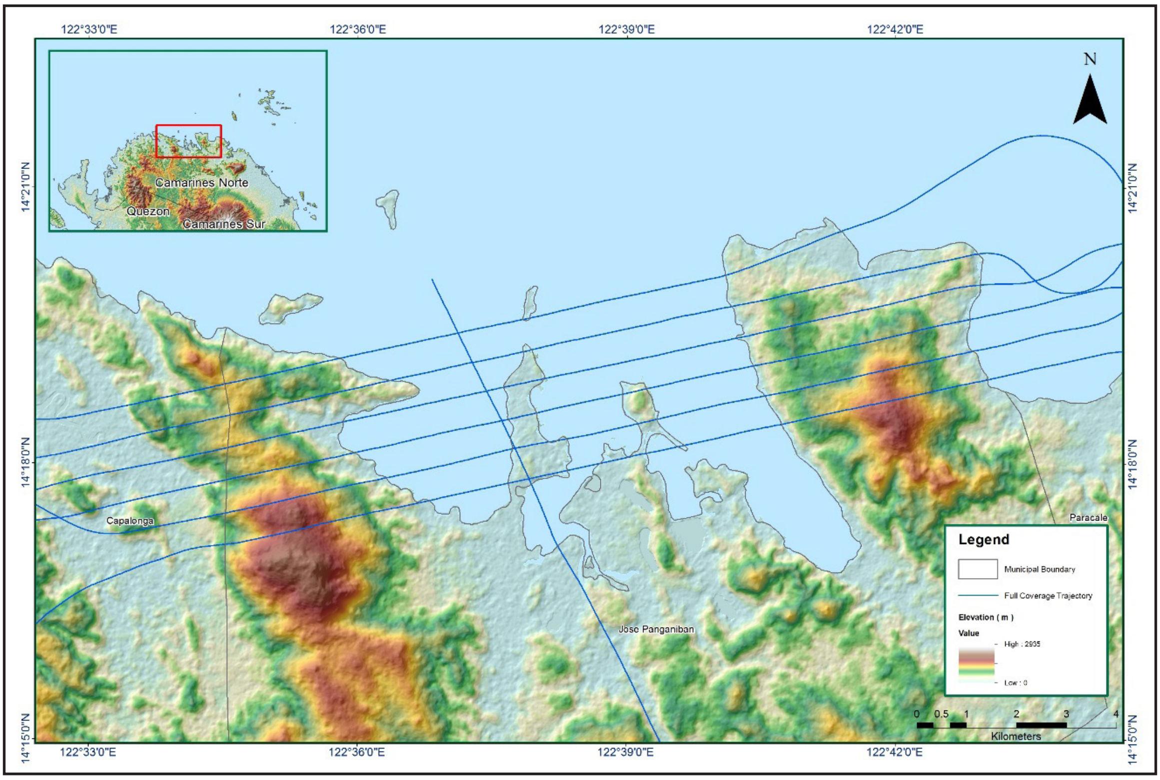


Figure 1.8.3. Best Estimated Trajectory

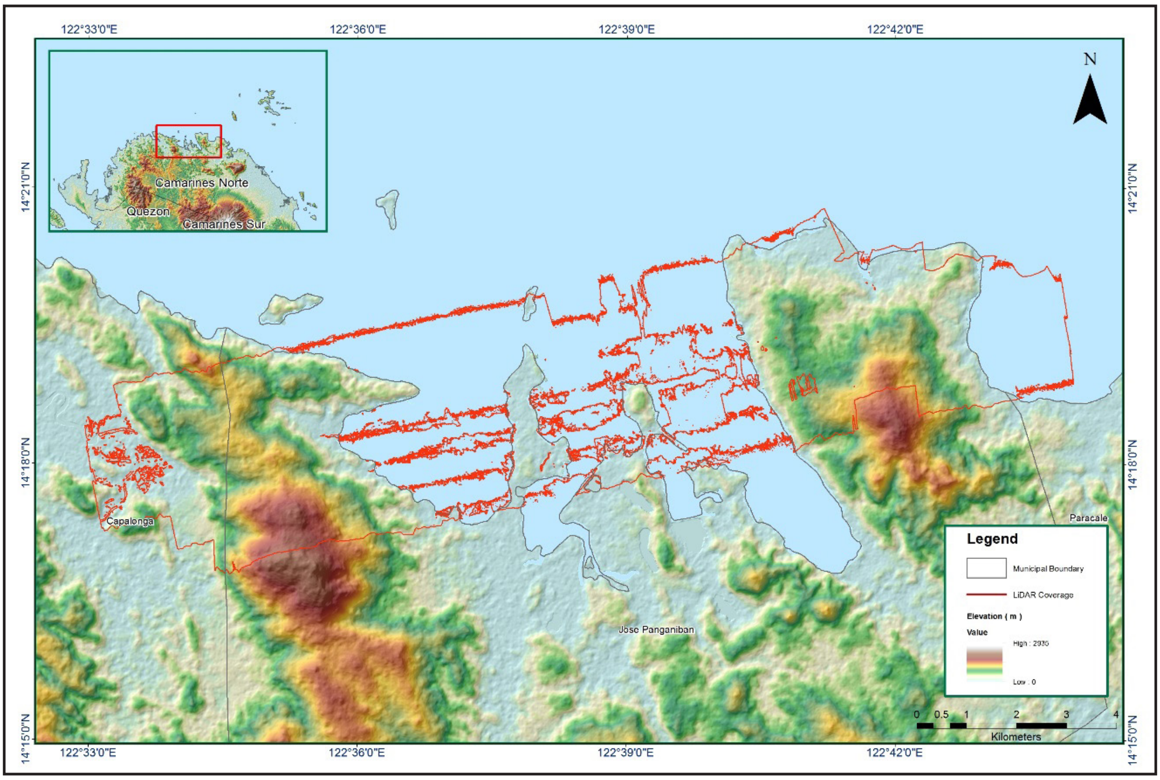


Figure 1.8.4. Coverage of LiDAR Data

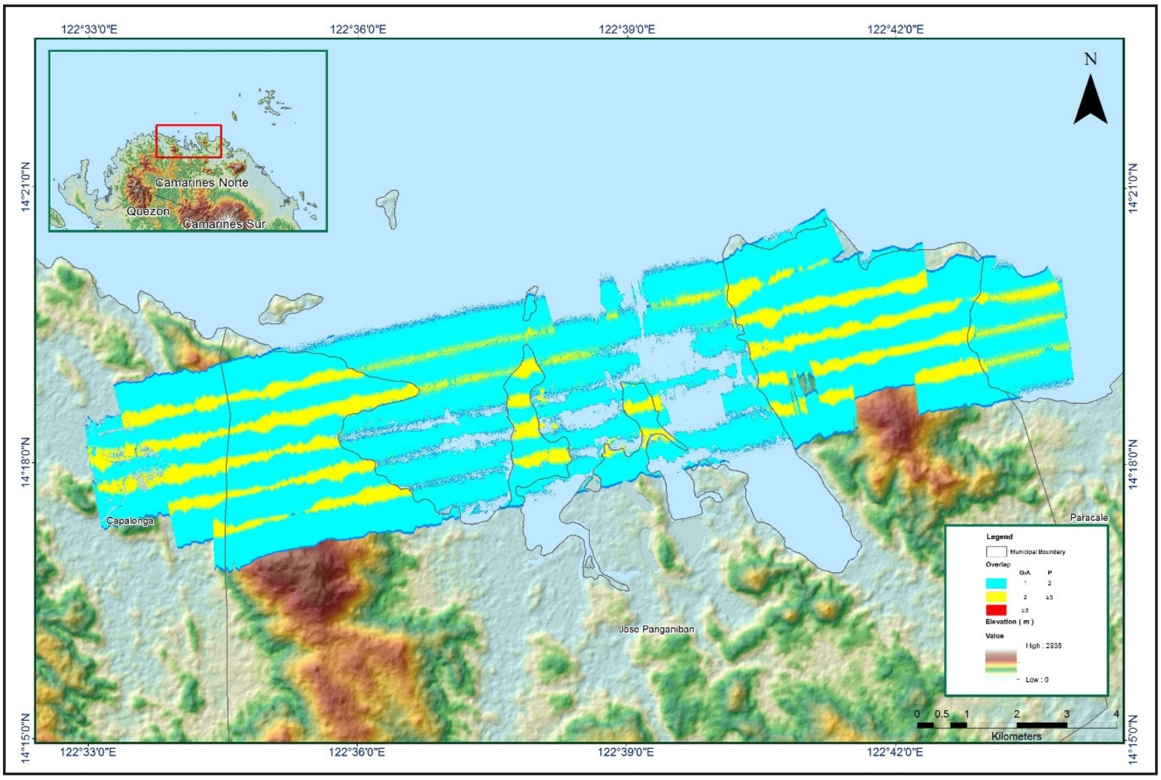


Figure 1.8.5. Image of data overlap

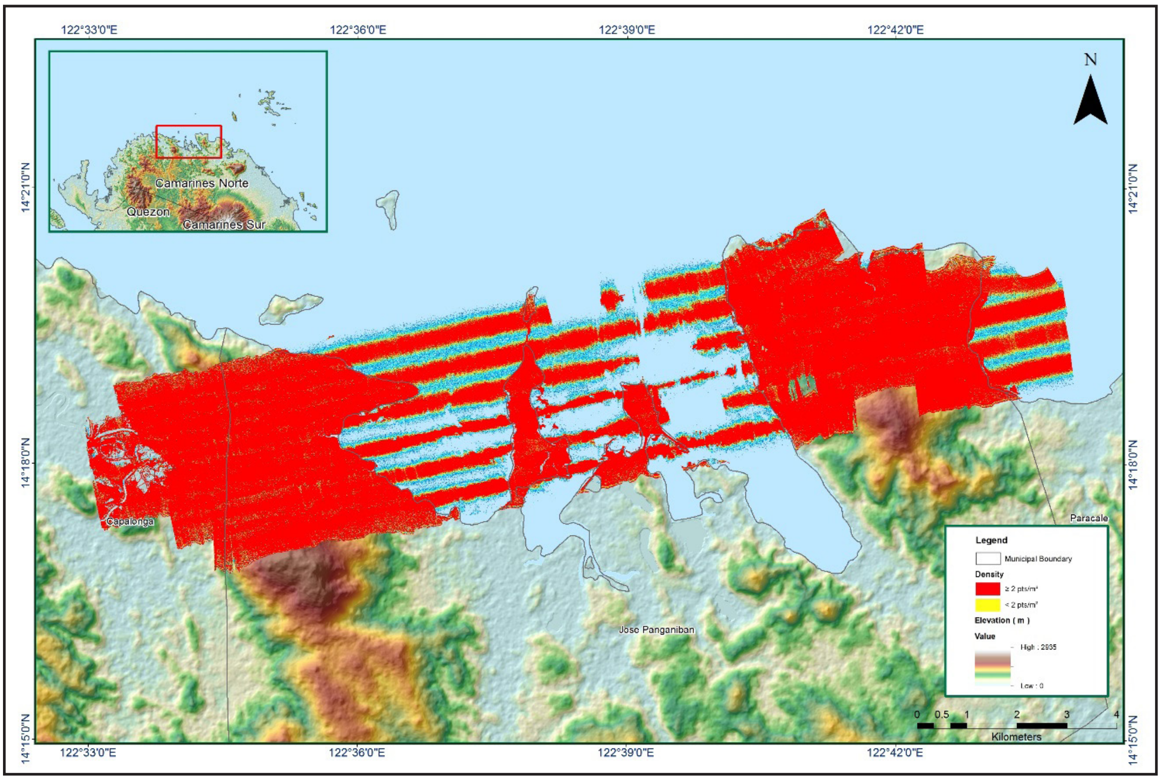


Figure 1.8.6. Density map of merged LiDAR data

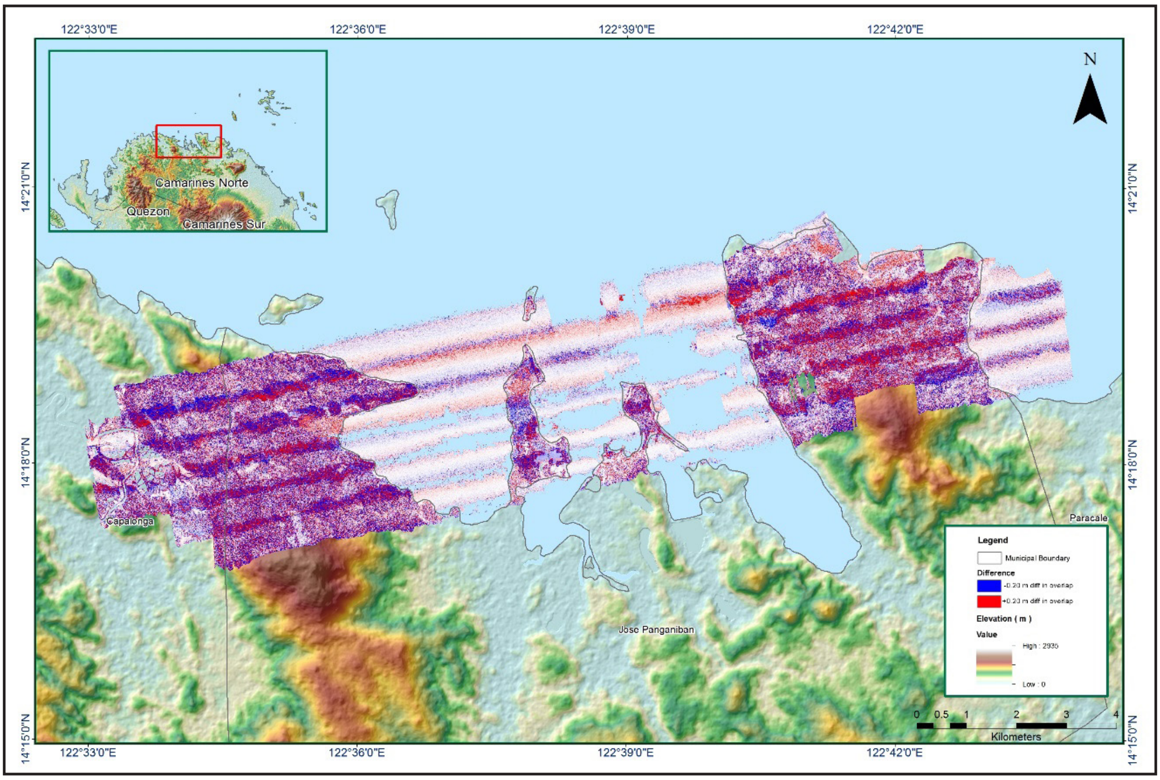


Figure 1.8.7. Elevation difference between flight line

Table A-8.9 Mission Summary Report of Mission Blk20C_additional

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20C_additional
Inclusive Flights	23270P
Range data size	5.52 GB
POS data size	99 MB
Base data size	29.1 MB
Image	n/a
Transfer date	May 18,2016
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)	1.1
RMSE for East Position (<4.0 cm)	1.0
RMSE for Down Position (<8.0 cm)	1.7
Boresight correction stdev (<0.001deg)	0.003619
IMU attitude correction stdev (<0.001deg)	0.006918
GPS position stdev (<0.01m)	0.0262
Minimum % overlap (>25)	0%
Ave point cloud density per sq.m. (>2.0)	5.0
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	23
Maximum Height	179.88 m
Minimum Height	9.63 m
Classification (# of points)	
Ground	5,256,105
Low vegetation	5,553,072
Medium vegetation	16,064,438
High vegetation	20,58,1604
Building	36,980
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Merven Matthew Natino, Engr. Monalyne Rabino

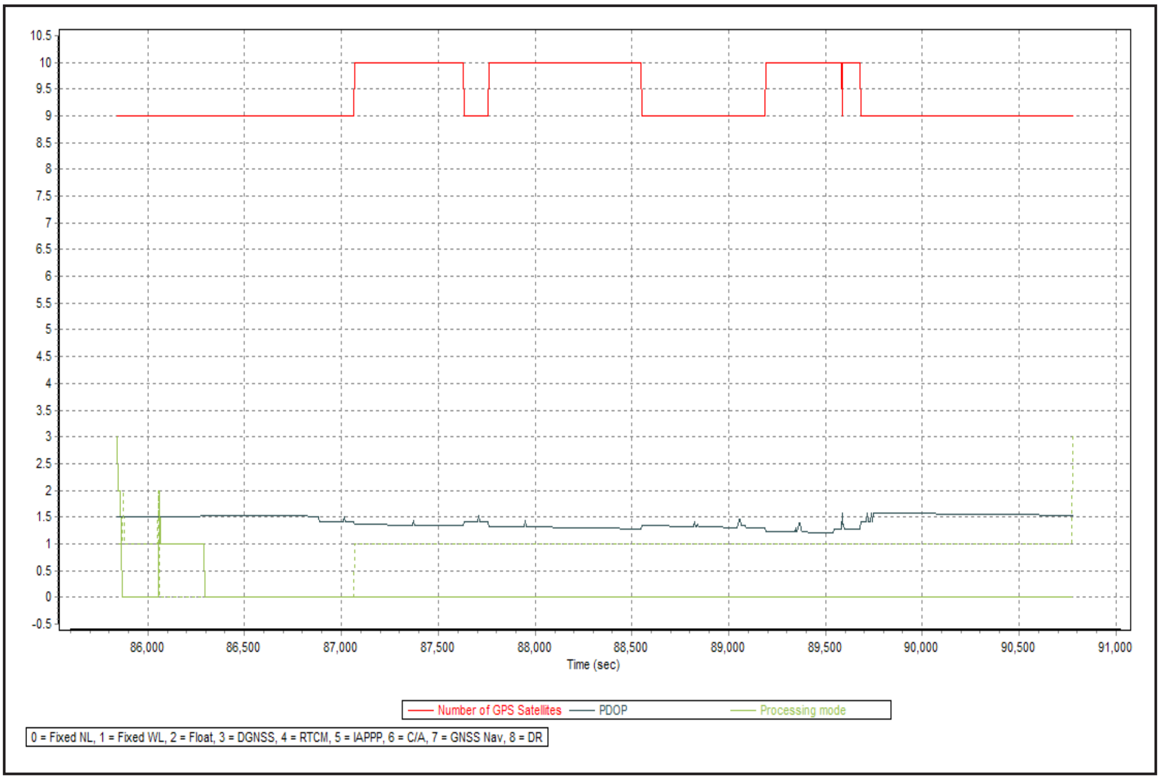


Figure 1.9.1. Solution Status

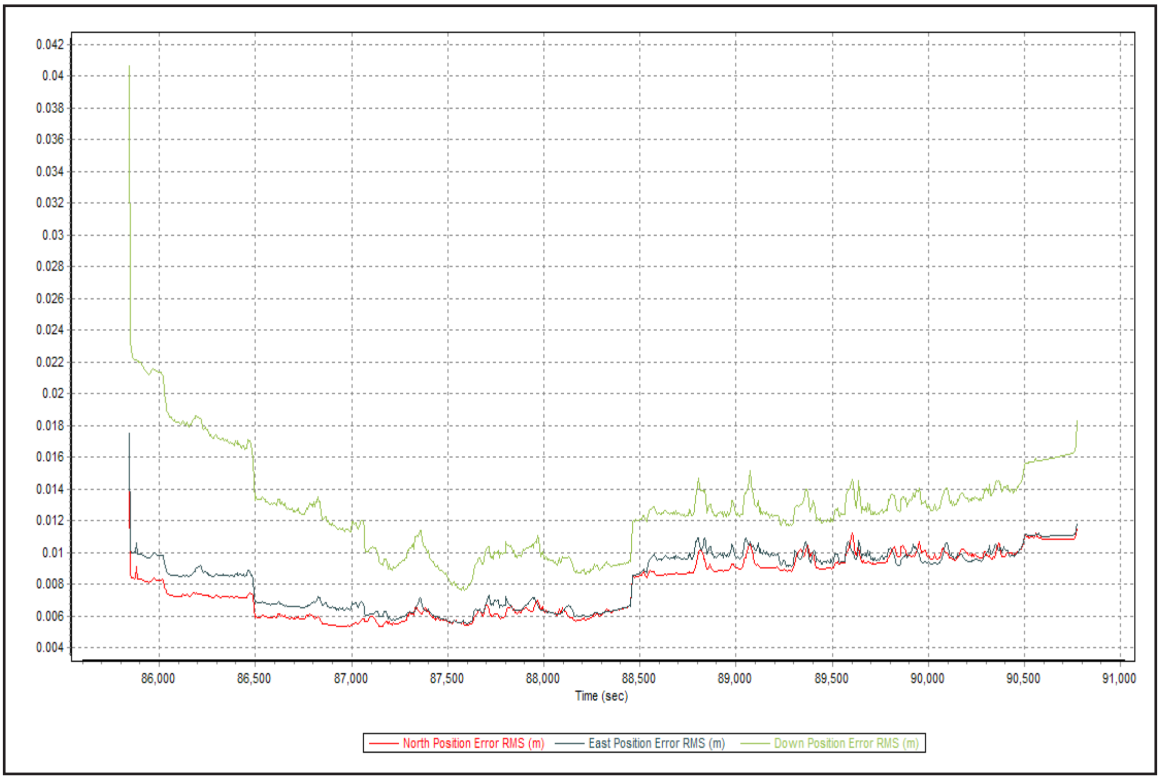


Figure 1.9.2. Smoothed Performance Metric Parameters

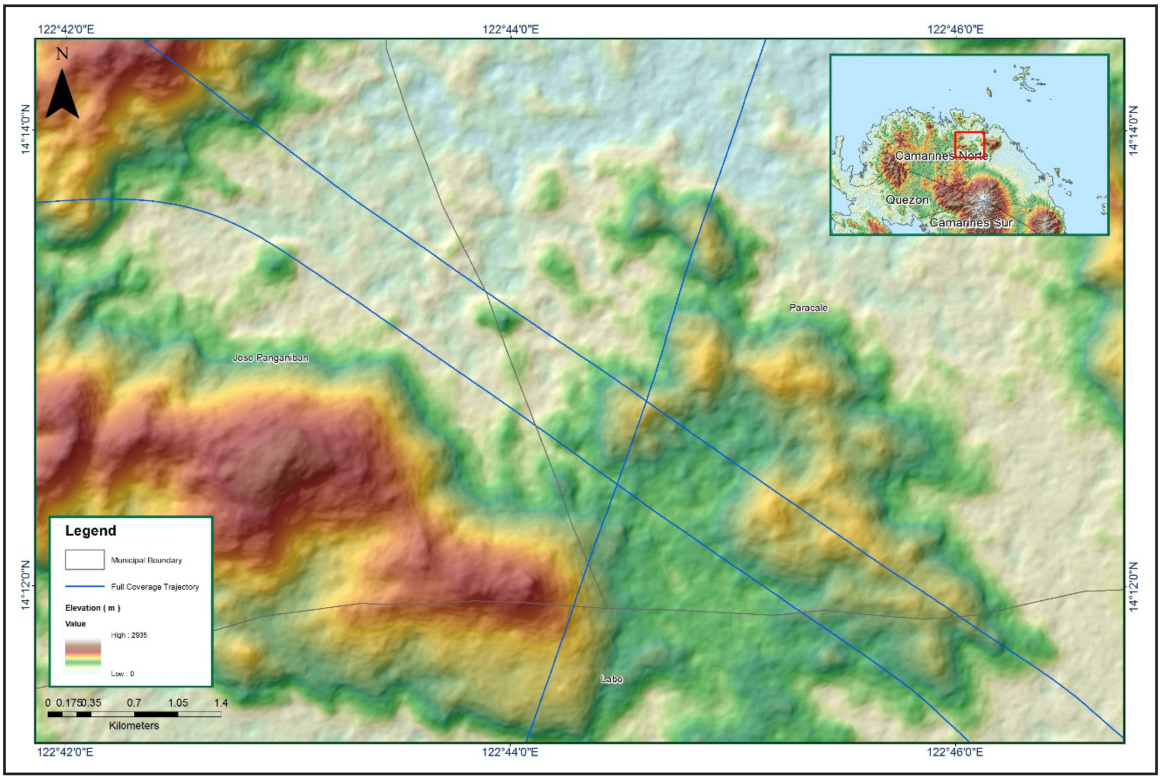


Figure 1.9.3. Best Estimated Trajectory

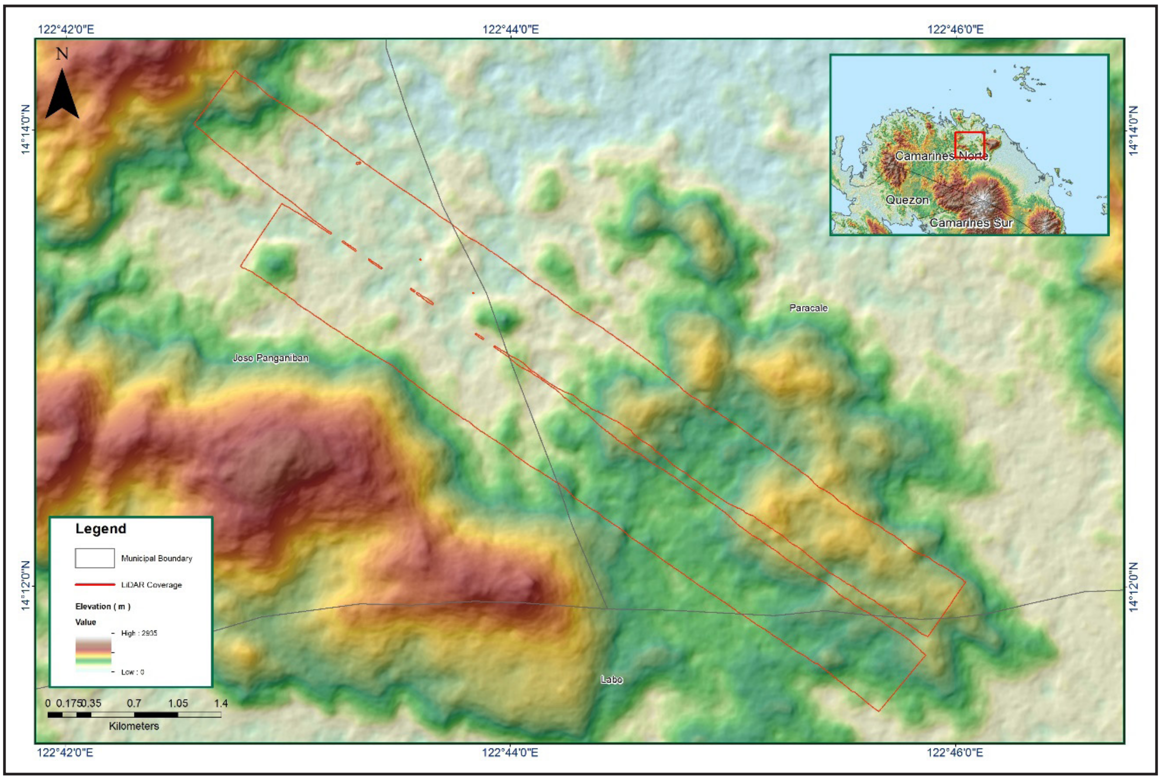


Figure 1.9.4. Coverage of LiDAR Data

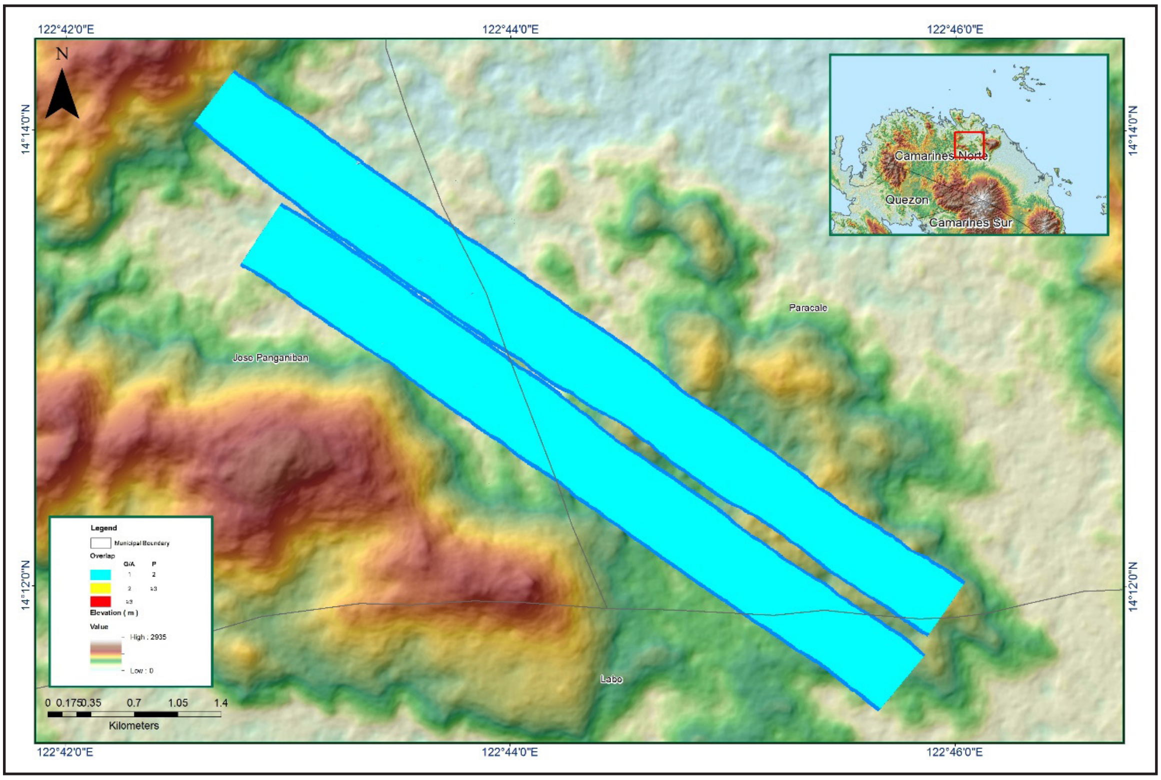


Figure 1.9.5. Image of data overlap

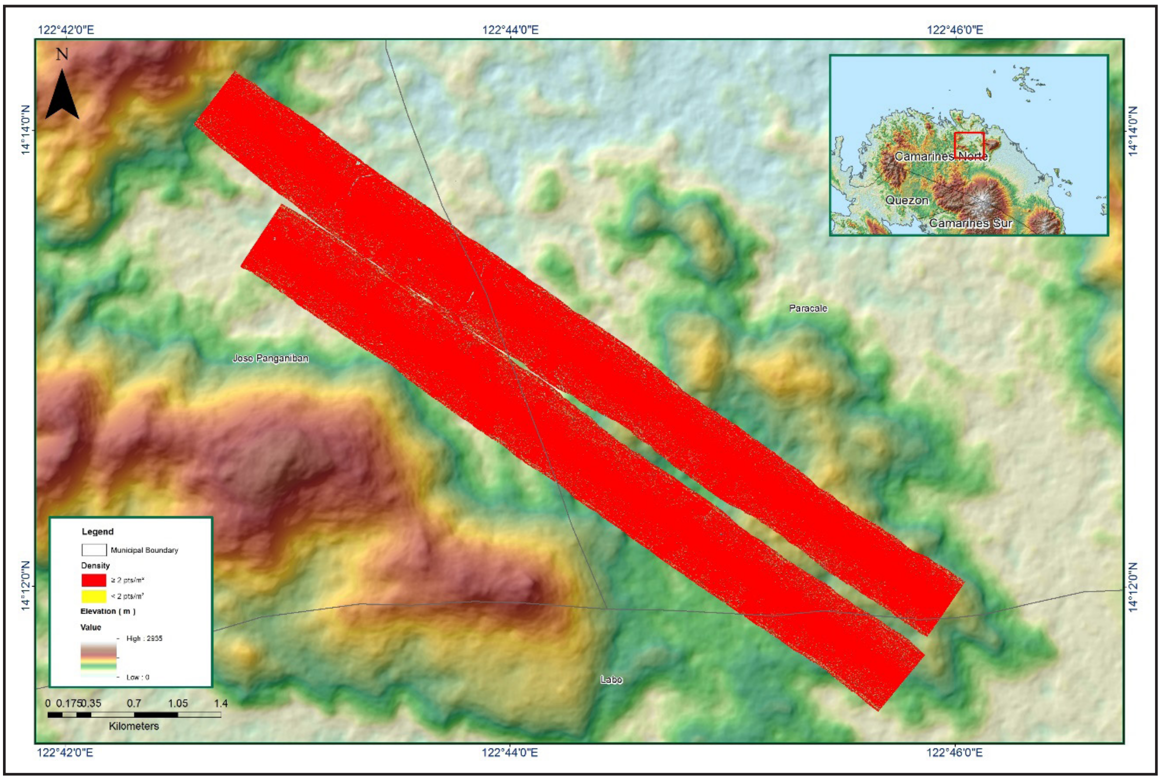


Figure 1.9.6. Density map of merged LiDAR data

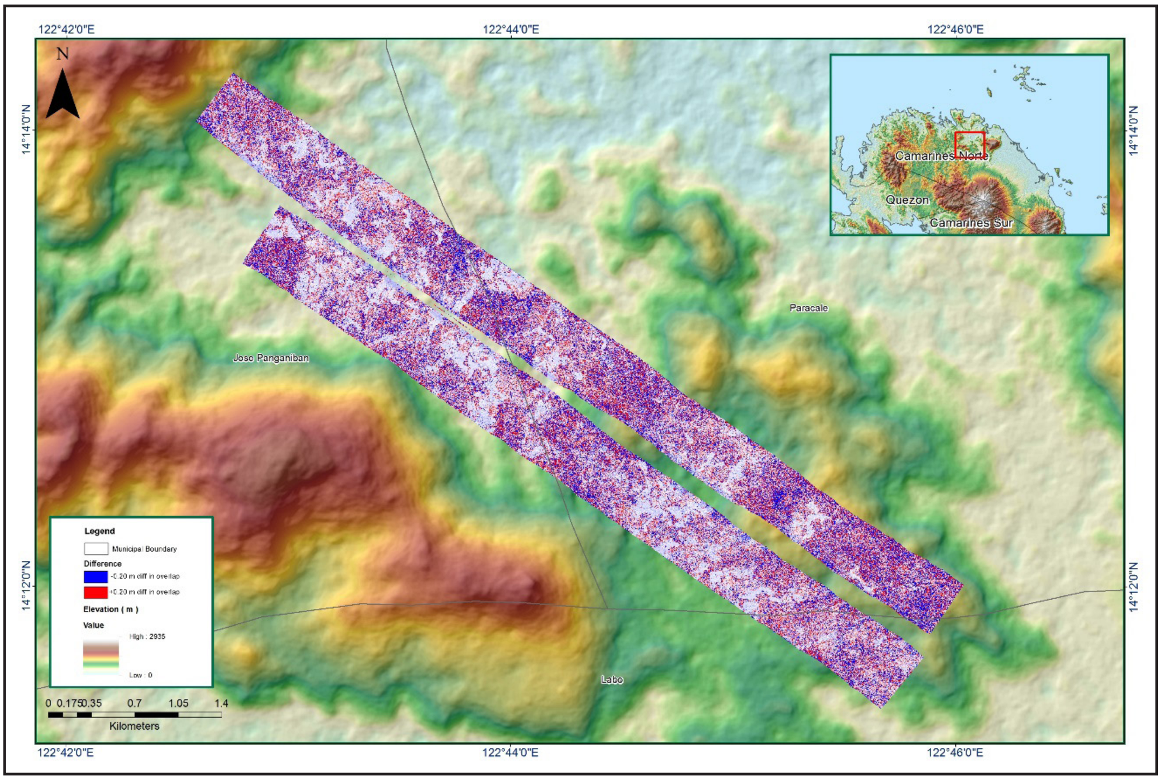


Figure 1.9.7. Elevation difference between flight line

ANNEX 9. Basud Model Basin Parameters

Table A-9.1 Basud 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 (CU.M/S)	Recession Constant	Threshold Type	Ratio to Peak
W220	0.117	99.000	0	26.701	0.10215	Discharge	0.2075	0.00001	Ratio to Peak	0.01167
W230	0.001	99.000	0	25.200	0.10483	Discharge	1.7547	0.00001	Ratio to Peak	0.06195
W240	0.001	99.000	0	0.215	0.10818	Discharge	0.0172	0.00001	Ratio to Peak	0.04712
W250	0.001	94.156	0	18.550	0.09101	Discharge	2.8292	0.00001	Ratio to Peak	0.17249
W260	0.003	99.000	0	0.194	9.26220	Discharge	0.8790	0.00001	Ratio to Peak	0.00083
W270	0.001	99.000	0	0.017	0.12047	Discharge	1.0304	0.00001	Ratio to Peak	0.04782
W280	0.008	99.000	0	2.351	0.11045	Discharge	3.6937	0.00002	Ratio to Peak	0.12917
W290	0.001	99.000	0	0.219	0.10616	Discharge	0.0457	0.00001	Ratio to Peak	0.06482
W300	0.001	99.000	0	0.206	0.11177	Discharge	1.1933	0.00001	Ratio to Peak	0.01067
W310	0.001	99.000	0	0.248	0.12439	Discharge	2.7623	0.00001	Ratio to Peak	0.01161
W320	6.850	99.000	0	18.950	0.39931	Discharge	1.6225	0.00003	Ratio to Peak	0.08645
W330	0.001	99.000	0	0.017	0.08595	Discharge	0.9181	0.43930	Ratio to Peak	0.96633
W340	0.001	99.000	0	0.017	0.10108	Discharge	1.6944	0.00001	Ratio to Peak	0.05183
W350	0.001	99.000	0	0.208	0.01667	Discharge	1.0911	0.00001	Ratio to Peak	0.00349
W360	14.941	98.736	0	0.250	0.11171	Discharge	0.7559	0.00001	Ratio to Peak	0.00483
W370	16.937	99.000	0	0.183	0.08671	Discharge	0.4217	0.00001	Ratio to Peak	0.00441
W380	23.004	99.000	0	0.017	0.01667	Discharge	3.0867	0.00001	Ratio to Peak	0.40702
W390	16.011	99.000	0	0.191	0.01667	Discharge	0.7488	0.00001	Ratio to Peak	0.08041
W400	0.001	99.000	0	0.017	0.10651	Discharge	2.1217	0.00001	Ratio to Peak	0.01565
W410	15.917	99.000	0	0.017	0.10965	Discharge	1.8369	0.00001	Ratio to Peak	0.11487
W420	0.011	94.642	0	0.218	0.11365	Discharge	2.8221	0.00001	Ratio to Peak	0.61697

ANNEX 10. Basud Model Reach Parameters

Table A-10.1 Basud Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (M)	Slope(M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R10	Automatic Fixed Interval	1427.7	0.00142	0.40720	Trapezoid	115.102	1
R20	Automatic Fixed Interval	241.4	0.01188	0.99300	Trapezoid	115.102	1
R30	Automatic Fixed Interval	4914.0	0.00086	0.07196	Trapezoid	115.102	1
R40	Automatic Fixed Interval	1750.7	0.00329	0.44252	Trapezoid	115.102	1
R50	Automatic Fixed Interval	625.6	0.01216	0.00010	Trapezoid	115.102	1
R60	Automatic Fixed Interval	5408.4	0.00678	0.00010	Trapezoid	115.102	1
R70	Automatic Fixed Interval	2974.2	0.00569	0.35856	Trapezoid	115.102	1
R110	Automatic Fixed Interval	3614.3	0.00713	0.05524	Trapezoid	115.102	1
R160	Automatic Fixed Interval	2985.3	0.01152	0.00010	Trapezoid	115.102	1
R170	Automatic Fixed Interval	4006.5	0.00603	0.04730	Trapezoid	115.102	1

Annex 11. Basud Floodplain Field Validation Points

BASUD				
ID	Latitude	Longitude	Depth	Accuracy (m)
1	13.8223031	122.7581565	0	3
2	13.82088941	122.7566752	0	3
3	13.82219565	122.7583349	0	3
4	13.82190355	122.7586748	0	3
5	13.82152239	122.7589239	0	3
6	13.82126875	122.7591099	0	3
7	13.81884317	122.7637424	0	3
8	13.81698964	122.765904	1.1	3
9	13.81494363	122.7659222	2.7	9
10	13.82006045	122.7713142	5	3
11	13.81837518	122.7929818	1.5	3
12	13.81868754	122.7930126	2	3
13	13.82061222	122.7907707		3
14	13.82051119	122.7905127	0.7	11
15	13.82009012	122.7925951	1.3	3
16	13.82029517	122.7937957	3	3
17	13.82097373	122.7926957	1.6	3
18	14.10976769	123.0045858	1.2	4
19	14.10898533	123.0044965	0.55	3
20	14.06818953	122.9654192	0	3
21	14.06821675	122.9710386	0.6	3
22	14.06719436	122.9675665	0.8	3
23	14.06690165	122.9674384	0.3	3
24	14.06617795	122.9667594	0.2	3
25	14.0652009	122.9660419	0.1	3
26	14.06469943	122.9656285	0.3	3
27	14.06386141	122.9651124	0.3	3
28	14.06348497	122.96476	0	3
29	14.06310409	122.9644409	0	3
30	14.06292455	122.964285	2	4
31	14.0633835	122.9638931	0	3
32	14.06416236	122.9629141	0.7	3
33	14.06394787	122.961471	0	3
34	14.06526168	122.9617979	2.3	3
35	14.0652727	122.9636386	0.5	3
36	14.06579177	122.964599	0	3
37	14.06631012	122.9637864	0	3
38	14.08053989	122.9578885	0.8	3
39	14.08106	122.9577428	0	3
40	14.08229588	122.9573812	0	3
41	14.08324867	122.9572973	0	3

BASUD				
ID	Latitude	Longitude	Depth	Accuracy (m)
42	14.08392842	122.9572683	0	3
43	14.08983056	122.957211	0	3
44	14.09030316	122.9570354	0	3
45	14.09079644	122.9569241	0	3
46	14.09179997	122.956846	0	3
47	14.09386392	122.9610062	0	3
48	14.11280008	122.9678472	0	3
49	14.11291966	122.967609	0	3
50	14.11399632	122.9672842	0	3
51	14.11281803	122.9686454	0	3
52	14.11248486	122.968869	0	3
53	14.11293167	122.9691818	0.1	3
54	14.11382115	122.9692732	0.1	3
55	14.11495171	122.9660258	0	3
56	14.11580481	122.9559196	0	3
57	14.11687173	122.9567652	0.1	5
58	14.11826947	122.9578041	0.2	3
59	14.11887258	122.9581388	0	3
60	14.11996531	122.9573347	0.1	3
61	14.1201257	122.9570079	0.2	3
62	14.11928142	122.9564024	0	4
63	14.118016	122.9557617	0	3
64	14.11638402	122.9546404	0	9
65	14.10583381	122.9562549	0	3
66	14.11078667	123.013485	2	4.099999905
67	14.11023833	123.0131017	0.2	2.799999952
68	14.109435	123.0127033	1.9	1.5
69	14.10916667	123.0124217	2	2.599999905
70	14.10918833	123.0117733		2
71	14.10952167	123.0117	0.9	2.299999952
72	14.10927	123.0117617	1.8	2.200000048
73	14.10856167	123.010465	1.3	1
74	14.108155	123.0101733	2.2	1.799999952
75	14.10825167	123.00994	2	2.099999905
76	14.10728167	123.0095	2.2	1
77	14.10772333	123.0090583	1.5	2.799999952
78	14.108465	123.0094417	1.2	1
79	14.10867333	123.0085067	2	1.5
80	14.10813667	123.0073583	0	1.5
81	14.10840167	123.0073983	0	2.099999905
82	14.10856333	123.0073733	0	2.099999905
83	14.10872667	123.006655	0.5	2.5
84	14.10902667	123.0061833	0.9	2.900000095

BASUD				
ID	Latitude	Longitude	Depth	Accuracy (m)
85	14.10959667	123.006545	0	2.799999952
86	14.10960833	123.00463	0.5	3.900000095
87	14.1084	123.004345	1.1	3.400000095
88	14.10799667	122.9836117	2	1
89	14.10799333	122.9843817	2	2.200000048
90	14.10881	122.9847933	0	1.700000048
91	14.11112833	122.985695	0.3	1
92	14.11347167	122.9857383	1.4	1.200000048
93	14.11285167	122.987635	1.4	1.100000024
94	14.11280833	122.9874517	1.5	1.899999976
95	14.11349667	122.98861	0.9	1
96	14.06779167	122.97036	0	0.899999976
97	14.067645	122.9707833	0.1	0.800000012
98	14.065205	122.966055	0.4	1.100000024
99	14.06341333	122.9638917	0	2.200000048
100	14.066785	122.9616183	0	1.200000048
101	14.06788167	122.9628117	0	3
102	14.06854667	122.9628133	0	1.899999976
103	14.113745	122.9684967	0	0.800000012
104	14.11332167	122.9679433	0	1
105	14.11282667	122.9679317	0	1.299999952
106	14.11289167	122.9676317	0	0.899999976
107	14.11398667	122.9672983	0	0.899999976
108	14.11280667	122.9685883	0	0.899999976
109	14.11248333	122.968845	0	1.100000024
110	14.112905	122.9691933	0.1	1.399999976
111	14.11379167	122.9692817	0	1.100000024
112	14.114925	122.9660767	0	1.200000048
113	14.11992167	122.957285	0.1	1.399999976
114	14.12004167	122.9570017	0.2	0.899999976
115	14.12128333	122.9577867	0.7	1.799999952
116	14.12234167	122.9552983	0	1.799999952
117	14.11931167	122.9564783	0	0.899999976
118	14.11807	122.9557933	0	1.100000024
119	14.11637833	122.954625	0	2.200000048
120	14.08301333	122.9562167	0	1
121	14.08303	122.9570883	0	1
122	14.11501333	122.96419	0	1.100000024
123	14.11500833	122.9635617	0.6	1.100000024
124	14.11508833	122.963325	0.6	1.799999952
125	14.11494833	122.9606617	3.9	1.299999952
126	14.11433333	122.9605467	0.4	2.700000048
127	14.11358167	122.9592517	0	1.299999952

BASUD				
ID	Latitude	Longitude	Depth	Accuracy (m)
128	14.11386	122.9576867	0	2.5
129	14.11470167	122.9579167	0	2.099999905
130	14.11537833	122.958295	0	1.200000048
131	14.11546167	122.9566533	0	1.799999952
132	14.11482333	122.956555	0	2.700000048
133	14.11402	122.9567367	0	1.799999952
134	14.11280667	122.95613	0.9	1.700000048
135	14.11280667	122.9558417	0	1.100000024
136	14.11248167	122.95843	0	1.100000024
137	14.11204833	122.9602383	0	1.200000048
138	14.11192333	122.96184	0	2.200000048
139	14.11452167	122.954815	0	1.399999976
140	14.11430833	122.9556683	0	1.899999976
141	14.11511	122.9547717	0	2.900000095
142	14.11572167	122.9548633	0	3.299999952
143	14.11636167	122.9545967	0	2.200000048
144	14.11693833	122.9538583	0	1.600000024
145	14.11798833	122.952205	0	2.400000095
146	14.11793333	122.9524167	0	1
147	14.11888167	122.9507467	0	1.100000024
148	14.10586333	122.9561483	0	1
149	14.10857431	123.0092533	0.4	9979.568359
150	14.10857431	123.0092533	0.4	9979.568359
151	14.10826179	123.0028749	0.3	3
152	14.10723168	123.0015989	1	3
153	14.11020798	123.0008742	0.4	3
154	14.10888076	123.000285	0.8	4
155	14.11153615	123.0011165	0	3
156	14.1118902	123.0002099	0.4	3
157	14.11298675	123.000291	0.2	3
158	14.11270559	122.9979086	0.2	3
159	14.11265194	122.9975009	0	3
160	14.11287725	122.9967552	0	3
161	14.11374503	122.9958255	0.4	3
162	14.113065	122.9951674	0	3
163	14.11511421	122.9956502	0	3
164	14.11504447	122.9956341	0	3
165	14.11761279	122.9974402	0	3
166	14.11669941	122.9937733	2.8	3
167	14.11316886	122.9949326	2	3.790225744
168	14.11377311	122.9939979	2.7	3
169	14.11423981	122.9940999	3	3
170	14.11456704	122.9936063	3	3

BASUD				
ID	Latitude	Longitude	Depth	Accuracy (m)
171	14.11535561	122.9941535	2.2	3
172	14.11492442	122.9947912	2.2	9
173	14.11392868	122.9949421	2	3
174	14.0626649	122.9800372	2.2	3
175	14.06279829	122.9797978	2.8	4
176	14.06308956	122.9789597	2.8	3
177	14.06412853	122.9761182	2	3
178	14.06510379	122.9734532	1.77	3
179	14.06598346	122.9710944	1.4	3
180	14.06725169	122.9675495	0.4	5
181	14.06819337	122.9653808	0	4
182	14.06671583	122.9614497	0	3
183	14.06737498	122.9625075	0	3
184	14.06862317	122.9628804	0	3
185	14.06861504	122.9628828	0	3
186	14.07019022	122.9623596	0	3
187	14.07241177	122.9613586	0	3
188	14.07515039	122.9601787	0	3
189	14.07629496	122.95968	0	3
190	14.07935129	122.9537013	0	4
191	14.07902718	122.9584162	0	3
192	14.07929594	122.9572752	0	3
193	14.07935946	122.9564661	0	3
194	14.08076206	122.9559985	0	3
195	14.08767797	122.965581	0	3
196	14.08851156	122.9606345	0	3
197	14.09080223	122.9579631	0	3
198	14.08989358	122.9581737	0	3
199	14.09031624	122.9583058	0	3
200	14.09317003	122.9593255	0	3
201	14.09414723	122.9616922	0	3

ANNEX 12. Educational Institutions affected by flooding in Basud Floodplain

Table A-12.1. Educational Institutions affected by flooding in Basud Floodplain

Camarines Norte				
Basud				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Don Juan Pimentel Elem. School	Bactas			Low
Hinampacan Elem. School	Hinampacan			
Langga Elem. School	Langa			
PR Samonte Elementary School	Laniton		Medium	Medium
Goito Pimentel Elem. School	Mampili		Medium	High
Kalahi Prince Arnold Child Development Center	Mampili	Low	Medium	High
Mampili Elem. School	Mampili	Low	Medium	High
Porforio R. Ponayo HighSchool	Mampili		Medium	High
Porforio R. Ponayo HighSchool;	Mampili		Medium	High
Manmuntay Elem. Chapel	Manmuntay			
San Jose Elem. School	Manmuntay		Low	Medium
Brgy. Mantugawe Day Care	Mantugawe			
Pinagsangahan Elem. School	Mantugawe			
Matnog Elem. School	Matnog			
Mampili Elem. School	Mocong	Medium	Medium	High
Mocong Elem. School	Mocong	Medium	High	High
Daycare	Oliva			
Langga Daycare	Pagsangahan			Low
Dominador Narido HS	Pinagwarasan			
Pinagwarasan Elem. School	Pinagwarasan			
Tacad Elem. School	Pinagwarasan			
Basud Natioal HighSchool	Poblacion 1	Low	Medium	Medium
Basud National HS annex1	Poblacion 1			Low
Christian Foundation Learning Center	Poblacion 1			
Basud Elementary School	Poblacion 2	Low	Medium	Medium
Poblacion 2 Daycare	Poblacion 2	Medium	High	Medium
Tacad Elem. School	Tacad			
Briñas Elem. School	Taisan			

Daet				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Gregorio Pimentel Memorial School	Mancruz			
Mercedes National Highschool	San Isidro		Medium	High
San Roque National Highschool	San Isidro	Medium	High	High
Mercedes				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Our Lady of the Holy Bible Learning Center	Barangay I	Low	Low	Medium
Daycare	Barangay II			Medium
Brgy. 3 Daycare center	Barangay IV			
Brgy. 5 Daycare	Barangay VI			Medium
Mercedes Elementary School	Barangay VI	Low	Low	Low
Mercedes National Highschool	Del Rosario		Medium	High
Manguisoc Daycare	Manguisoc	Low	Low	Low
Manguisoc Elementary School	Manguisoc			
Manguisoc Highschool	Manguisoc			
Manguisoc Kindergarten	Manguisoc			
Camarines Sur State College	San Roque	Low	High	High
San Roque Daycare	San Roque		Medium	High
San Roque Daycare Center	San Roque	Low	High	High
San Roque Elementary School	San Roque	Low	Medium	High
San Lorenzo Ruiz				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Matnog Elem. School	Laniton			

Annex 13. Health Institutions affected by flooding in Basud Floodplain

Table A-13.1. Health Institutions affected by flooding in Basud Floodplain

Camarines Norte				
Basud				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Health and Nutrition Post	Bactas			Medium
Health Center/ Day Care	Bactas	Medium	Medium	Medium
Brgy. Mantugawe Health Center	Mantugawe			
Health Center/ Daycare	Matnog			
Health Center/ Covered Court	Pinagwarasan			
Taisan Health Center	Pinagwarasan			
Basud Municipal Health Office and Maternity Clinic	Poblacion 2	Medium	High	Medium
Daet				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Health Nutrition Post	Pamorangon			Low
Philhealth	Pamorangon			
Mercedes				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Manguisoc Health Center	Manguisoc			
San Roque Health	San Roque		Medium	High