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

LiDAR Surveys and Flood Mapping of Labo River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Mapua Institute of Technology

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LIST OF ACRONYMS AND ABBREVIATIONS

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

Enrico C. Paringit, Dr. Eng., Dr. Francis Aldrine Uy, and Engr. Fibor Tan

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.

The program also aimed to produce an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication entitled "Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods" (Paringit et al., 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is MAPUA Institute of Technology (MIT). MIT 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 26 river basins in the Southern Tagalog Region. The university is located in Intramuros, Manila.

1.2 Overview of the Labo River Basin

The Labo River Basin is one of the major river basins in Camarines Norte, specifically located in the municipality of Labo (where it takes its name). It is also one of the biggest river basins in the Philippines. This river flows through six municipalities, which include Daet, Labo, Paracale, San Vicente, Talisay, and Vinzons. According to DENR - River Basin Control Office, it has a drainage area of 913 km2 and an estimated 1,235 million cubic meter (MCM) annual run-off of (RCBO, 2015).

Its main stem, Labo River is part of the twenty six (26) river systems in the Southern Tagalog Region. According to the 2015 national census of NSO, a total of 18,390 locals distributed among the five (5) barangays in Vinzons, and five (5) barangays in Labo are residing in the immediate vicinity of the river.
The river holds significant value to the nearby population of 100,000, as it serves as a source of livelihood. It has great economic significance for fisheries, irrigation, as well as transportation for tourism as it connects Mt. Labo and the Pacific Ocean.

However, the region was pathway of severe typhoons such as Anding in 1981, Unsang in 1988, Rosing in 1995, Loleng in 1998 and Ondoy in 2009, of which Rosing proved to be the most devastating. It caused intense flooding which damaged crop fields and submerged some barangays.

On November 30, 2008, the residents of the Municipalities of Labo and Vinzons were awakened by a flash flood. This was caused by a torrential rain due to the tail end of the cold front. It was reported that the incident washed out at least three (3) bridges along Labo River and caused to evacuate at least 1,200 families.

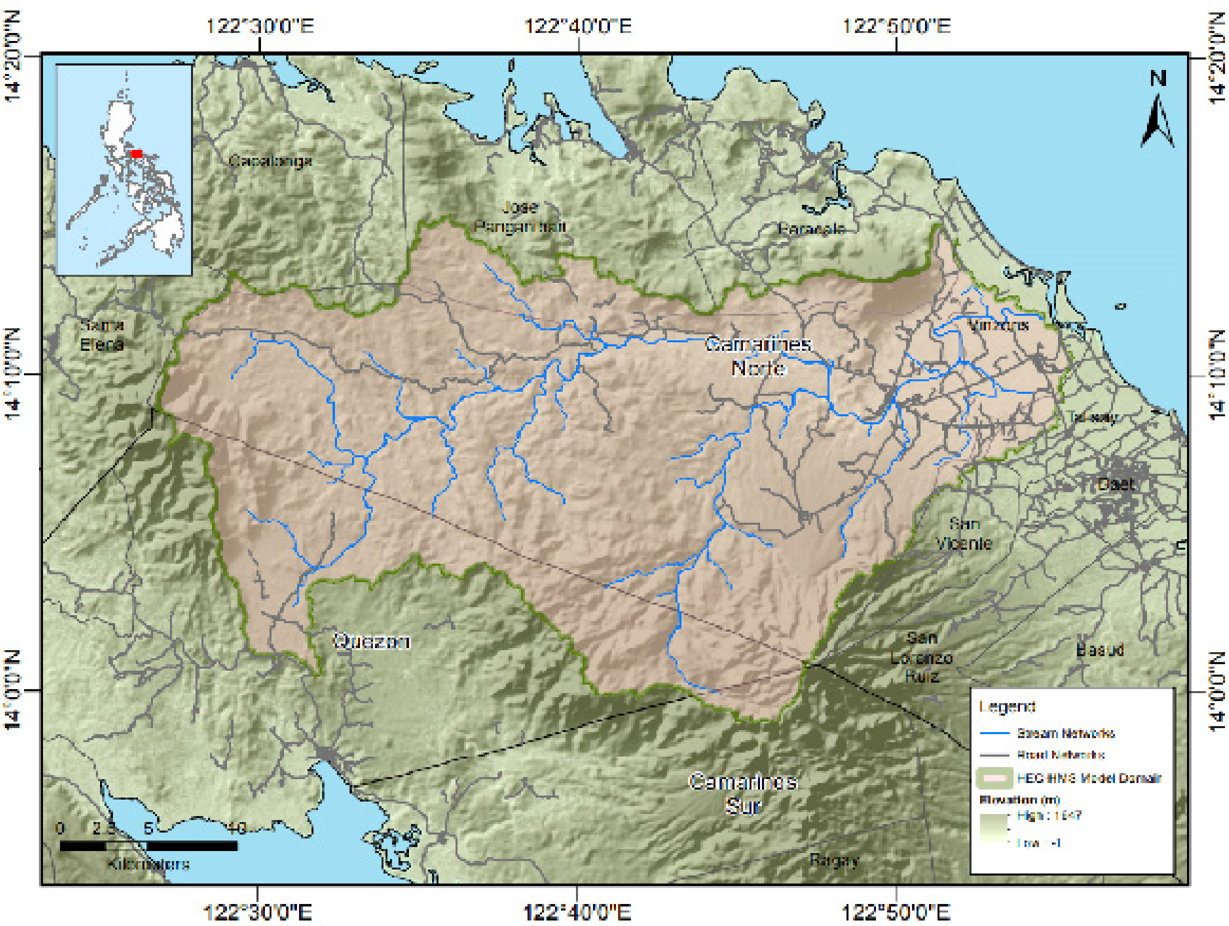

Figure 1. Map of Labo River Basin (in brown)

To prevent or at least minimize the effects of the flooding hazard to the people in the river basin, a combination of several technologies have been employed to produce a flood hazard map. The first is Light Detection and Ranging (LiDAR) data, which primarily contains elevation. From elevation values, one can infer the presence and behavior of waterbodies (such as rivers, streams, ponds, and lakes) and structures (such as roads, bridges, and buildings). Next, important data such as discharge and rainfall events gathered through fieldworks were used as input into hydrologic models to generate hydrographs. These generated outputs, along with LiDAR data, were then used as input for the river hydraulic model which would create 3D images of the river basins. The final output for these processes is a flood hazard map of the river basin. The flood hazard maps indicate the areas where flood might occur during heavy rainfall and typhoon events. With this, the community will be able to prepare for upcoming strong typhoons more efficiently. This will also help local government units (LGUs) draft evacuation plans for their barangay and pinpoint further developments needed to manage and minimize calamities brought about by flooding.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE LABO 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 Labo 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 2 shows the flight plan for Labo 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."

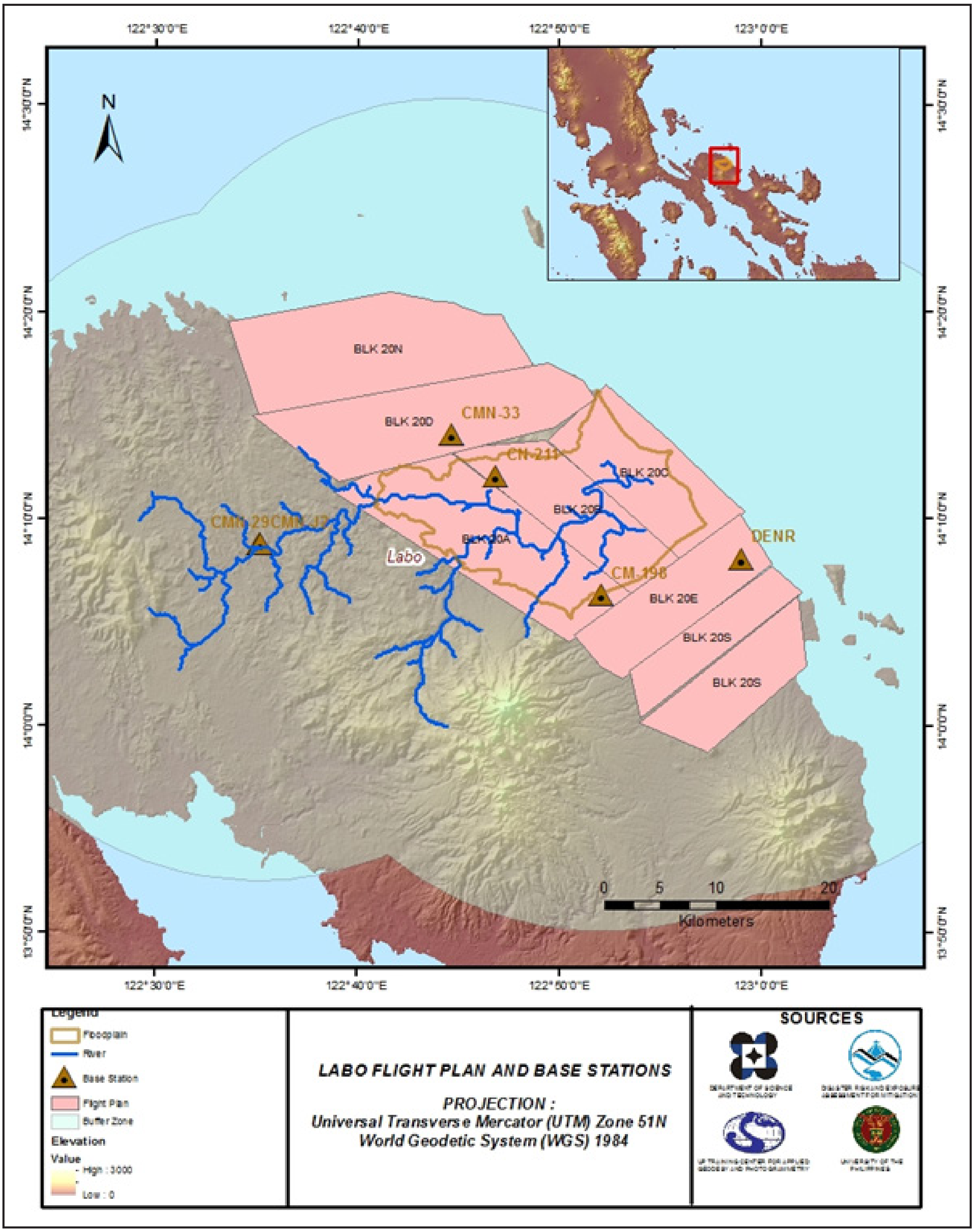


Figure 2. Flight plans for Pegasus System used for Labo Floodplain

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 A-2 while the baseline processing report for the established ground control points and reprocessed benchmarks are found in Annex A-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 Labo 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 Table 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.

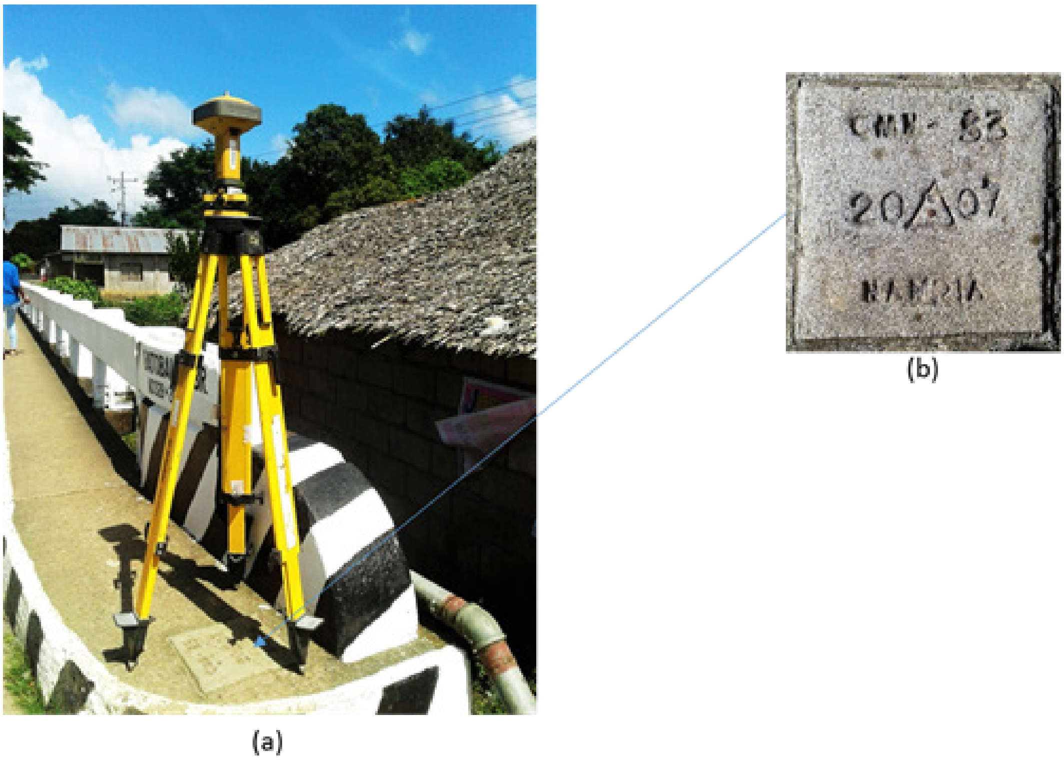


Figure 3. GPS set-up over CMN-33 at Barangay Batobalani, Jose Panganiban, Camarines Norte (a) and NAMRIA reference point CMN-33 (b) as recovered by the field team.

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 of 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 Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	472188.08 meters 1573809.93 meters

(a) (b)

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 Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	476182.911 meters 1570078.228 meters

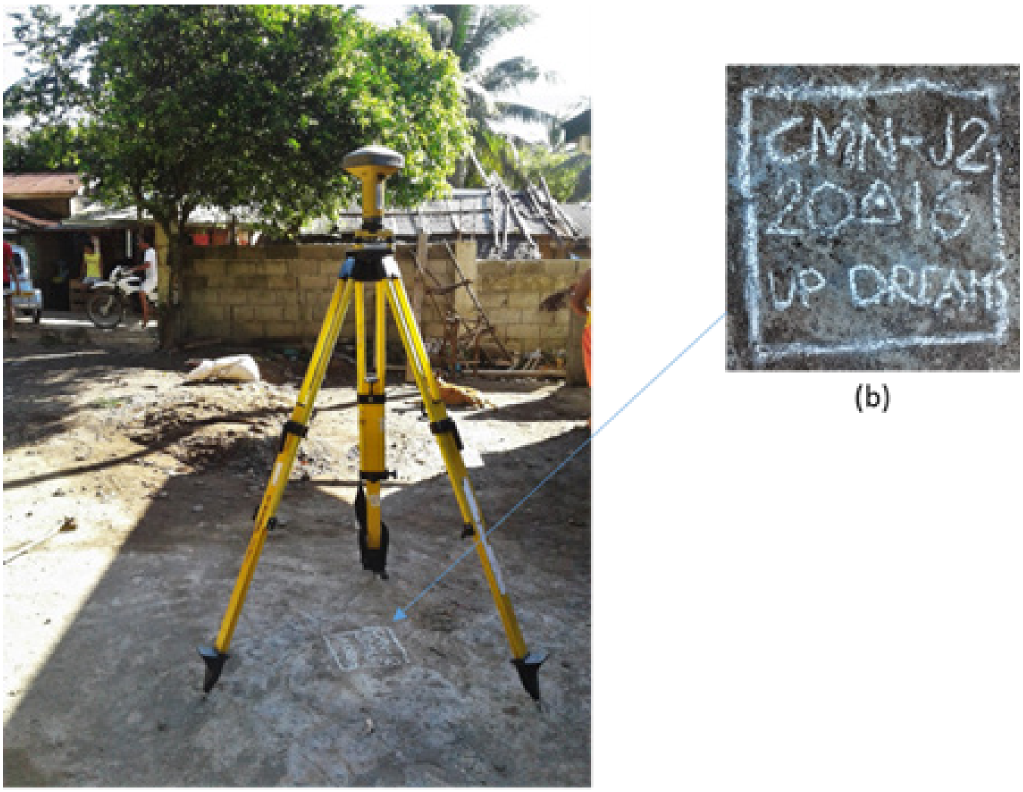
(b)

(a)

Figure 5. GPS set-up over CMN-29 at Barangay Malibago, Labo, 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 4 (PTM Zone 4 PRS 92)	Easting Northing	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 WGS 1984)	Easting Northing	455026.86 meters 1564018.79 meters



(b)

(a)

Figure 6. GPS set-up over CMN-J2 at Barangay Malibago, Labo, 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 PRS1992)	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
9 March 2016	23172P	1BLK20A69B	DENR and CMN-33
10 March 2016	23174P	1BLK20ASC70A	DENR and CMN-33
10 March 2016	23176P	1BLK20B70B	DENR and CMN-33
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
16 April 2016	23264P	1BLK20S107B	CMN-29 and CMN-J2
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 Labo Floodplain, for a total of thirty-seven hours and twenty-six minutes (37+26) 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 Labo 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	23172P	104.00	98.46	63.96	34.50	250	2	26
10 March 2016	23174P	382.3	261.04	152.88	108.16	608	4	10
10 March 2016	23176P	104.0	103.20	81.27	21.93	230	2	40
12 March 2016	23182P	285.5	94.23	39.31	54.92	326	4	15
14 March 2016	23190P	285.5	156.39	84.80	71.59	23	3	59
17 March 2016	23202P	235.45	237.25	NA	237.25	766	4	28
7 April 2016	23226P	510.3	223.80	2.28	221.52	NA	4	17
9 April 2016	23234P	510.3	48.49	NA	48.49	399	2	11
16 April 2016	23264P	510.3	113.85	0.92	112.93	269	2	5
17 April 2016	23266P	233.4	171.41	4.72	166.69	456	3	11
17 April 2016	23268P	234.1	157.33	NA	157.33	54	3	5
18 April 2016	23270P	234.1	31.51	9.74	21.77	NA	0	39
TOTAL		**3629.25**	**1696.96**	**439.88**	**1257.08**	**3381**	**37**	**26**

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)
23172P	1000	30	50	150	30	130	5
23174P	600	30	50	150	30	130	5
23176P	1100	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
23264P	700	20	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

Labo 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 Labo Floodplain is presented in Figure 7.

Table 15. List of municipalities/cities surveyed during the Labo floodplain LiDAR survey

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Camarines Norte	Talisay	37.90	37.90	100%
	Paracale	148.28	147.52	99.49%
	Jose Panganiban	211.71	204.84	96.75%
	Daet	42.20	40.73	96.51%
	San Vicente	47.17	33.88	71.84%
	Vinzons	90.44	63.41	70.11%
	Labo	622.52	198.61	31.90%
	San Lorenzo Ruiz	108.81	30.21	27.76%
	Basud	251.71	65..50	26.02%
	Mercedes	117.17	11.70	9.99%
TOTAL		**1677.91**	**768.8**	**63.04%**

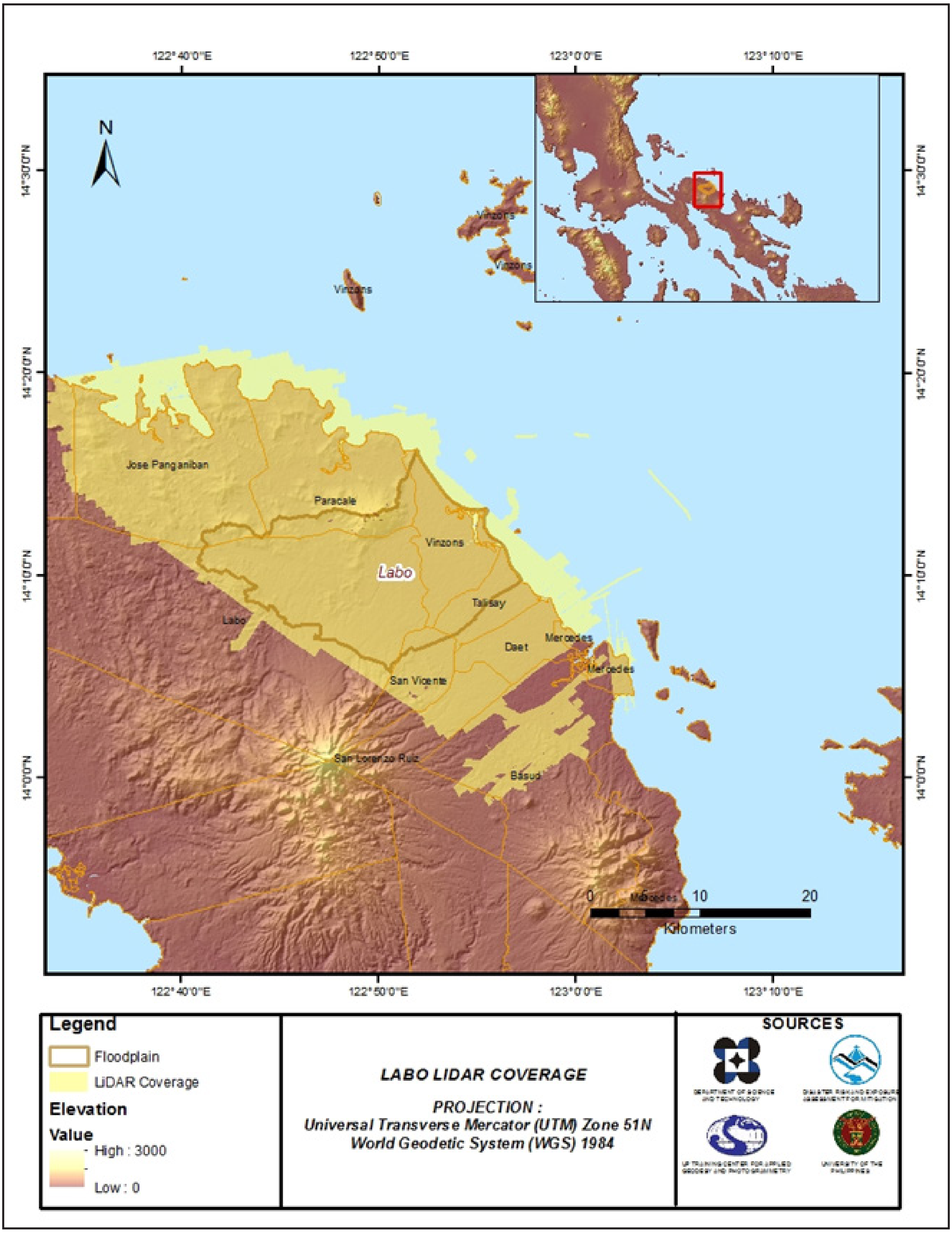


Figure 7. Actual LiDAR survey coverage for Labo Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE LABO FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Joida F. Prieto , Engr. Melissa F. Fernandez , Engr. Ma. Ailyn L. Olanda, Engr. Sheila-Maye F. Santillan, Engr. Mark Joshua A. Salvacion , Engr. Ezzo Marc C. Hibionada, and Ziarre Anne P. Mariposa

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 were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done to obtain the exact location of the LiDAR sensor when the laser was shot.

Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were 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 were 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 were calibrated. Portions of the river that are barely penetrated by the LiDAR system were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was 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.

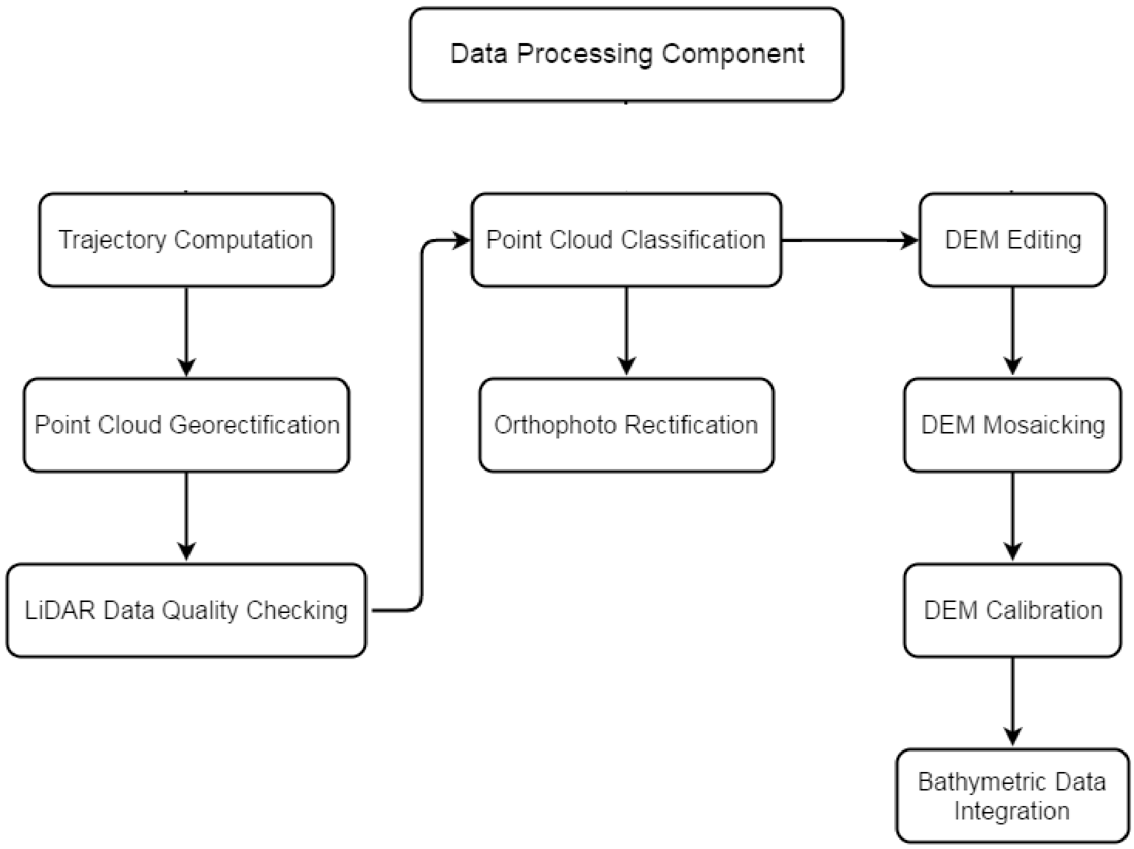


Figure 8. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Labo Floodplain can be found in Annex A-5. Data Transfer Sheets. Missions flown during the first survey conducted on March 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Municipality of Labo, Camarines Norte.

The Data Acquisition Component (DAC) transferred a total of 120.50 Gigabytes of Range data, 1.95 Gigabytes of POS data, 1,007.12 Megabytes of GPS base station data, and 149.00 Gigabytes of raw image data to the data server on May 17, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Labo was fully transferred on May 18, 2016 as indicated in the Data Transfer Sheets for Labo Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 23266P, one of the Labo 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 onApril16, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

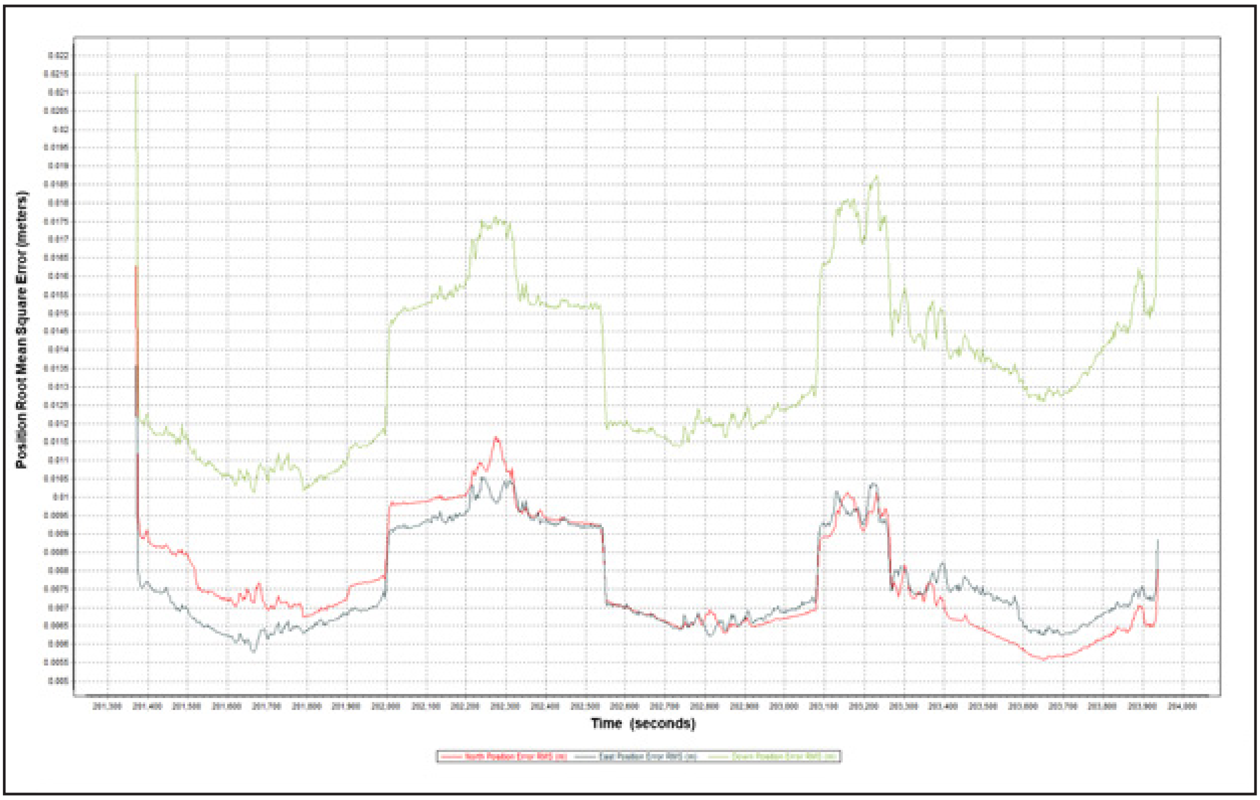


Figure 9. Smoothed Performance Metrics of a Labo Flight 23266P.

The time of flight was from 605,500 seconds to 614,000 seconds, which corresponds to morning of April 17, 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 minimize 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 1.03 centimeters, the East position RMSE peaks at 1.17 centimeters, and the Down position RMSE peaks at 2.32 centimeters, which are within the prescribed accuracies described in the methodology.

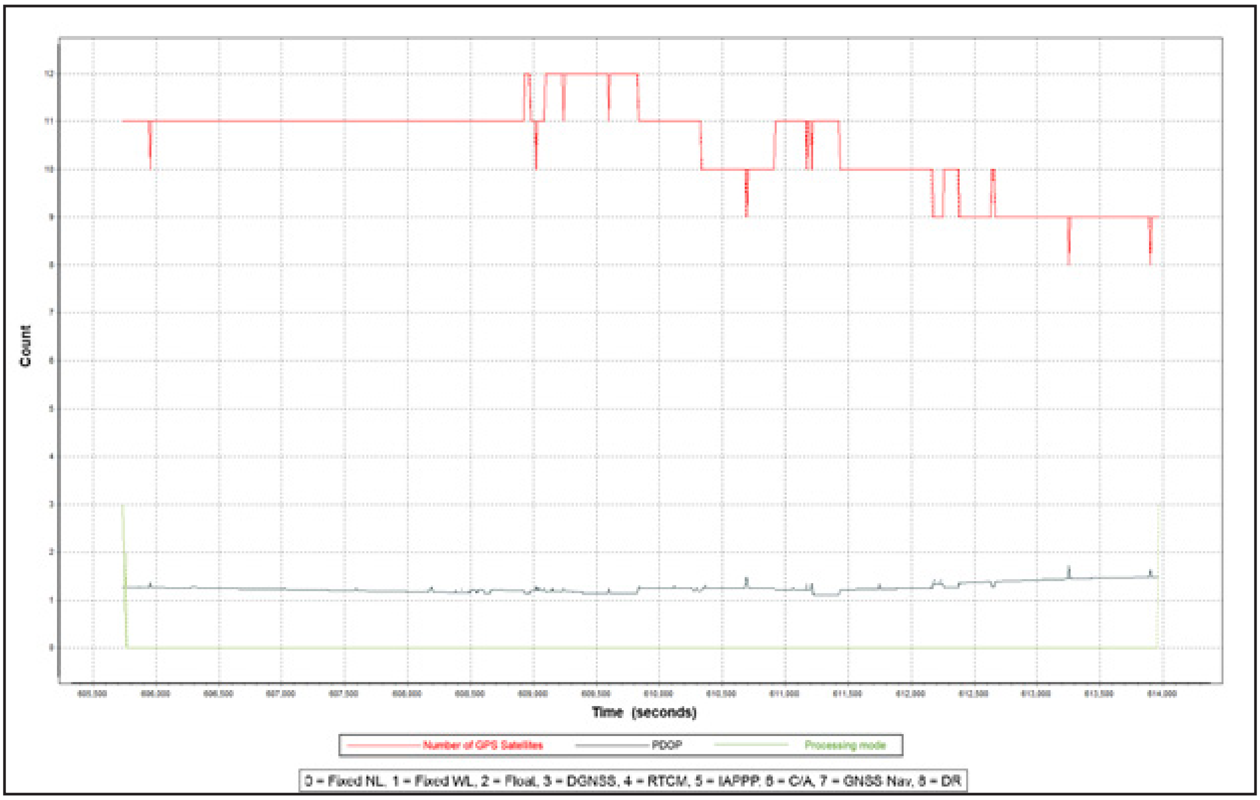


Figure 10. Solution Status Parameters of Labo Flight 23266P.

The Solution Status parameters of flight 23266P, one of the Laboflights, which indicate the number of GPS satellites, Positional Dilution of Precision, 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 below 8. Most of the time, the number of satellites tracked was between 9 and12. The PDOP value also did not go above the value of 3, which still indicates optimal GPS geometry. The processing mode remained at 0 for almost the entire survey time with some parts go to 1 attributed to the turn 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 Labo flights is shown in Figure 11.

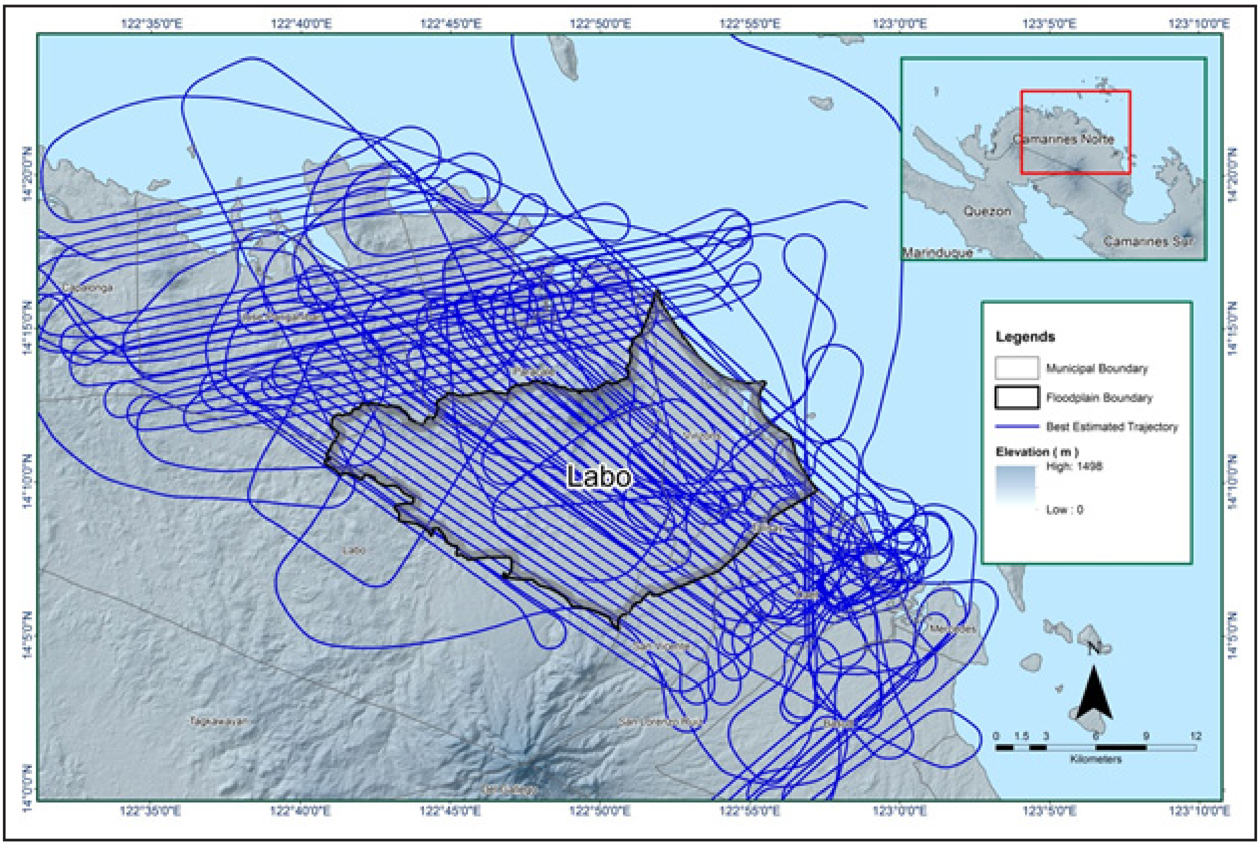


Figure 11. Best estimated trajectory for Labo Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 95flight lines, with each flight line containing two (2) 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 Labo Floodplain are indicated in Table 12.

Table 12. Self-Calibration Results values for Labo flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000255
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000622
GPS Position Z-correction stdev)	<0.01meters	0.0077

The optimum accuracy is obtained for all Labo flights 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.

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.

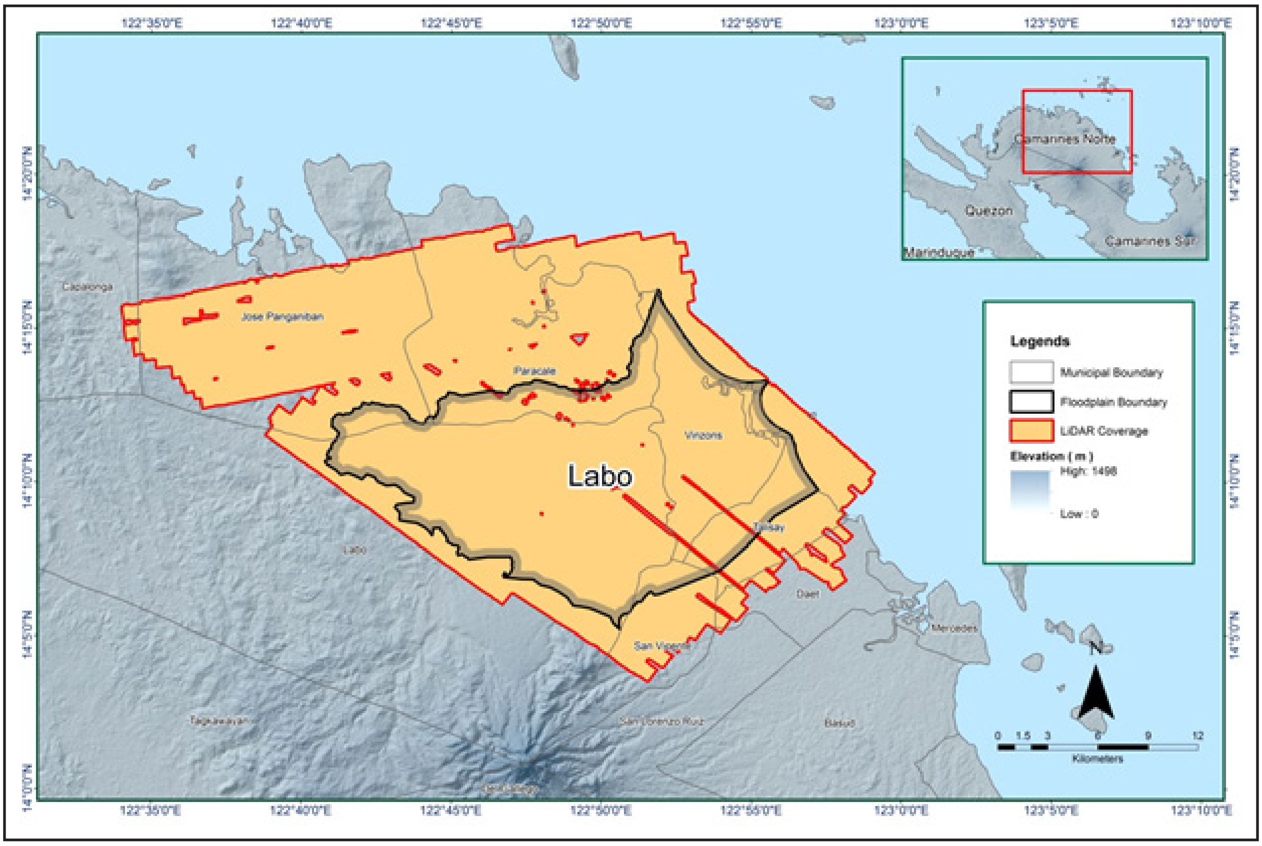


Figure 12. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Labo Floodplain.

The total area covered by the Labo missions is 750.00 sq.km comprised of eight (8) flight acquisitions grouped and merged into five (5) blocks as shown in Table 13.

Table 13. List of LiDAR blocks for Labo Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Bagasbas_Blk20A	23172P	140.08
	23174P	
	23182P	
Bagasbas_Blk20B	23176P	168.45
	23182P	
	23190P	
Bagasbas_Blk20C	23174P	216.97
	23182P	
	23190P	
Bagasbas_Blk20O_supplement1	23264P	175.26
	23268P	
Bagasbas_Blk20O_supplement2	23266P	49.24
TOTAL		**750.00 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.

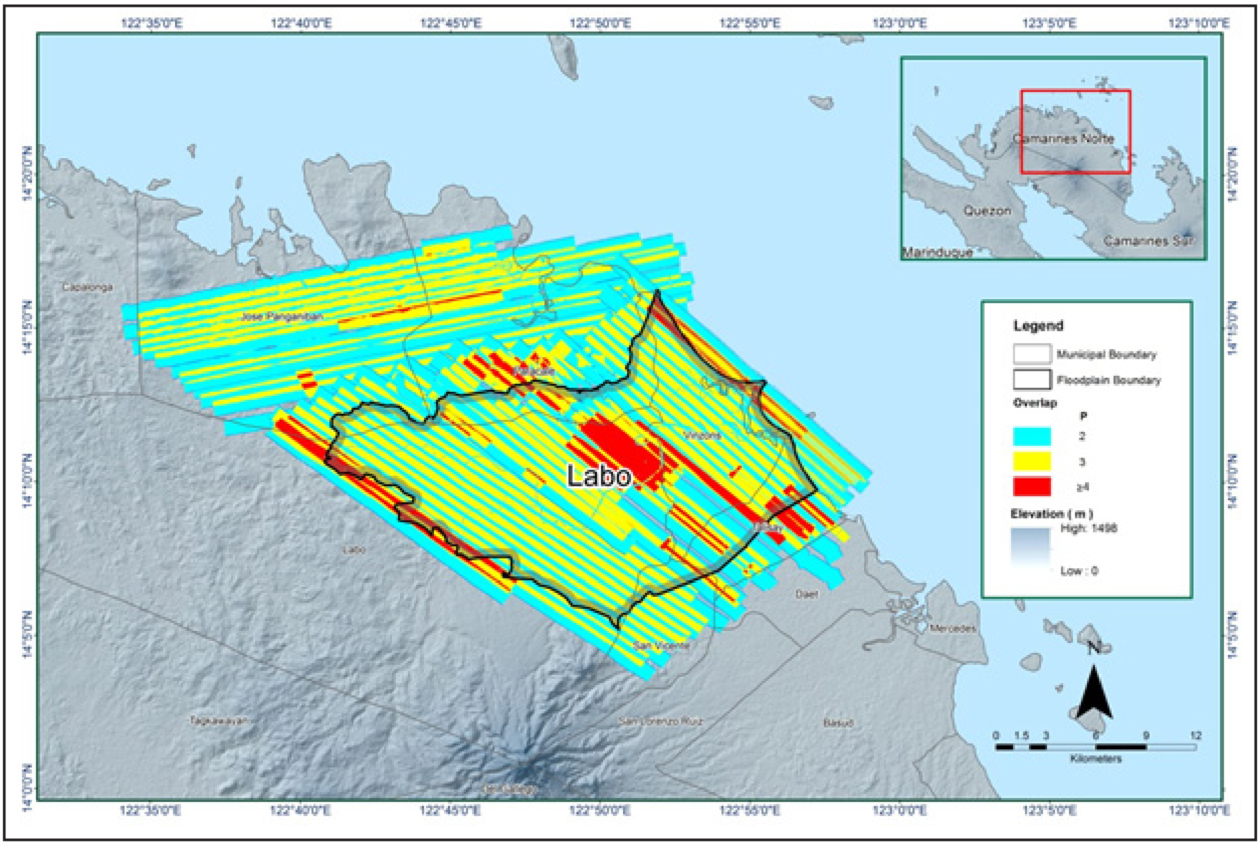


Figure 13. Image of data overlap for Labo Floodplain.

The overlap statistics per block for the Labo Floodplain can be found in Annex B-1. Mission Summary Reports. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.55% and 62.25% 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 Labo Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.56 points per square meter.

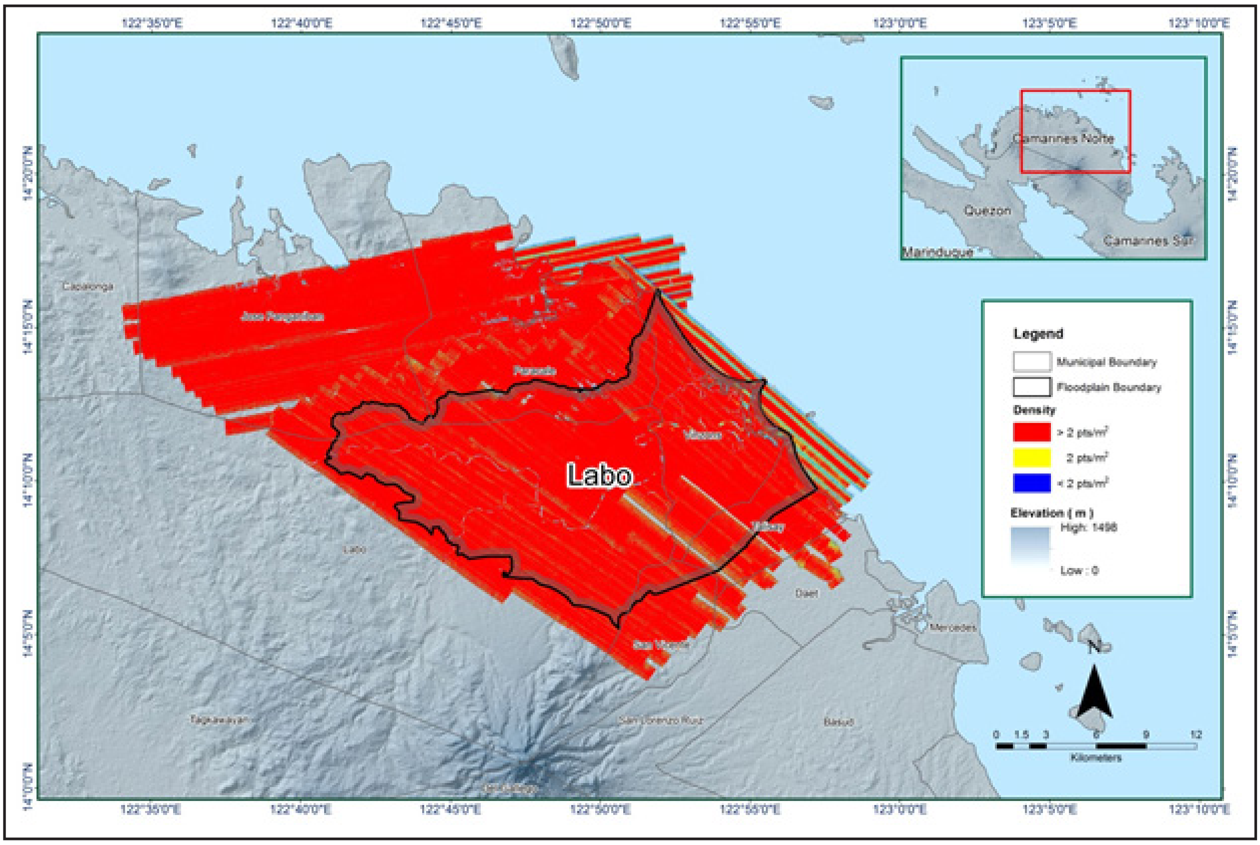


Figure 14. Pulse density map of merged LiDAR data for Labo Floodplain.

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.

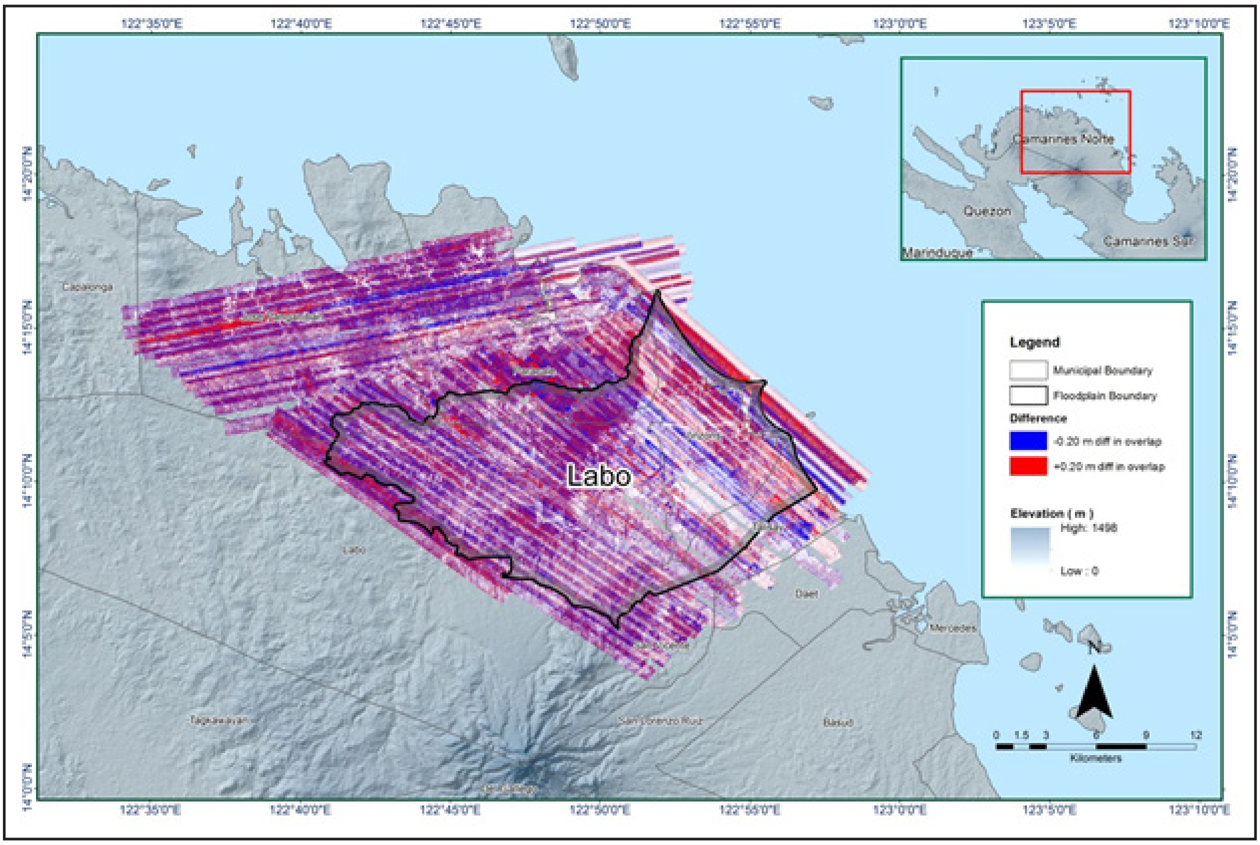


Figure 15. Elevation difference map between flight lines for Labo Floodplain.

A screen capture of the processed LAS data from a Labo flight 23266P 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.

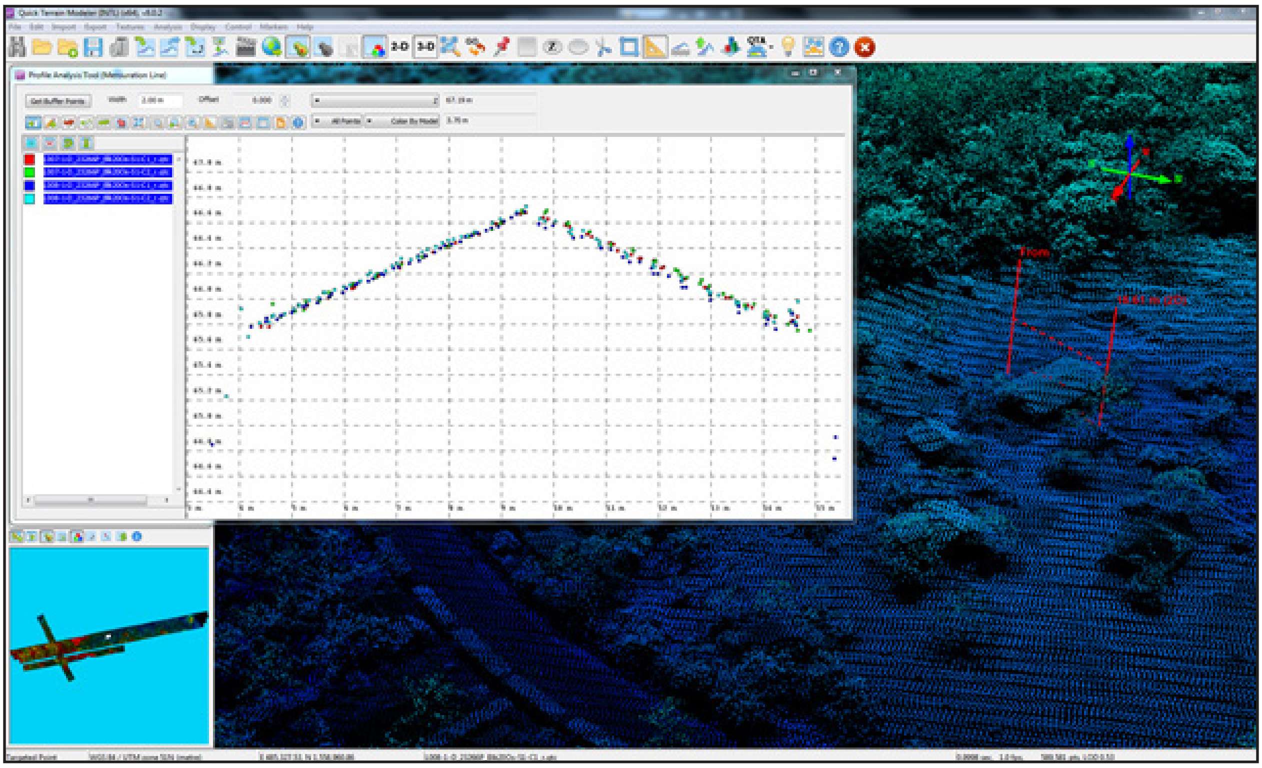


Figure 16. Quality checking for a Labo flight 23266P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Labo classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	585,605,657
Low Vegetation	523,942,808
Medium Vegetation	1,022,924,922
High Vegetation	2,758,133,823
Building	39,283,193

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Labo Floodplain is shown in Figure 17. A total of 995 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 840.48 meters and 40.94 meters respectively.

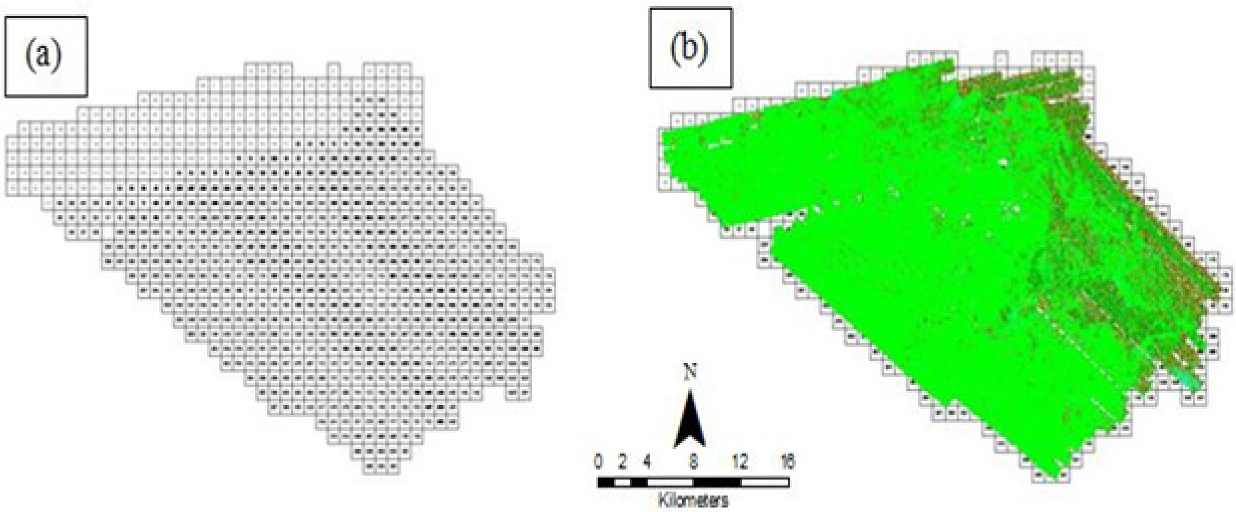


Figure 17. Tiles for Labo Floodplain (a) and classification results (b) in TerraScan.

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.

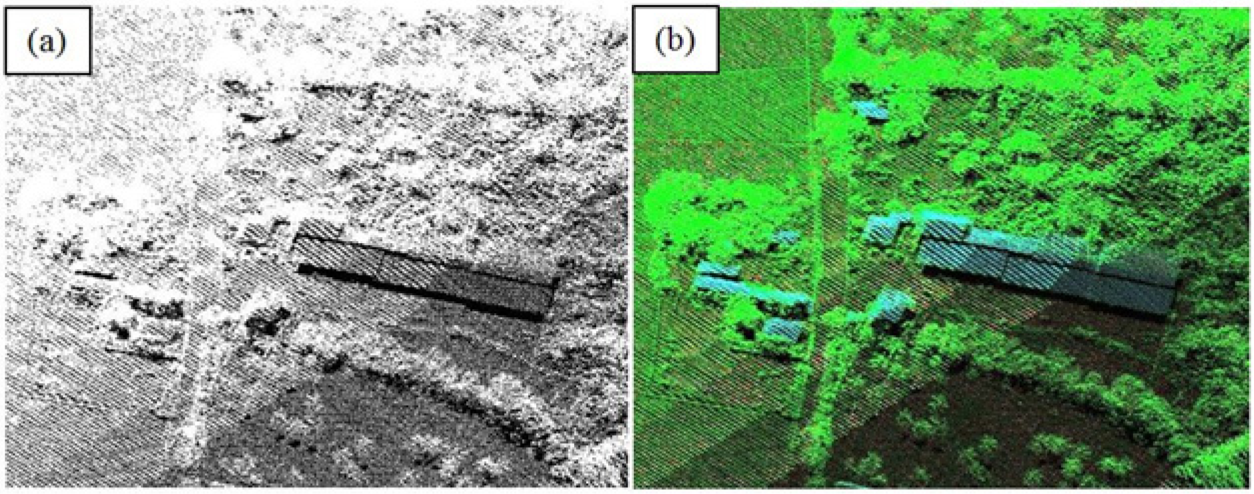


Figure 18. Point cloud before (a) and after (b) classification.

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.

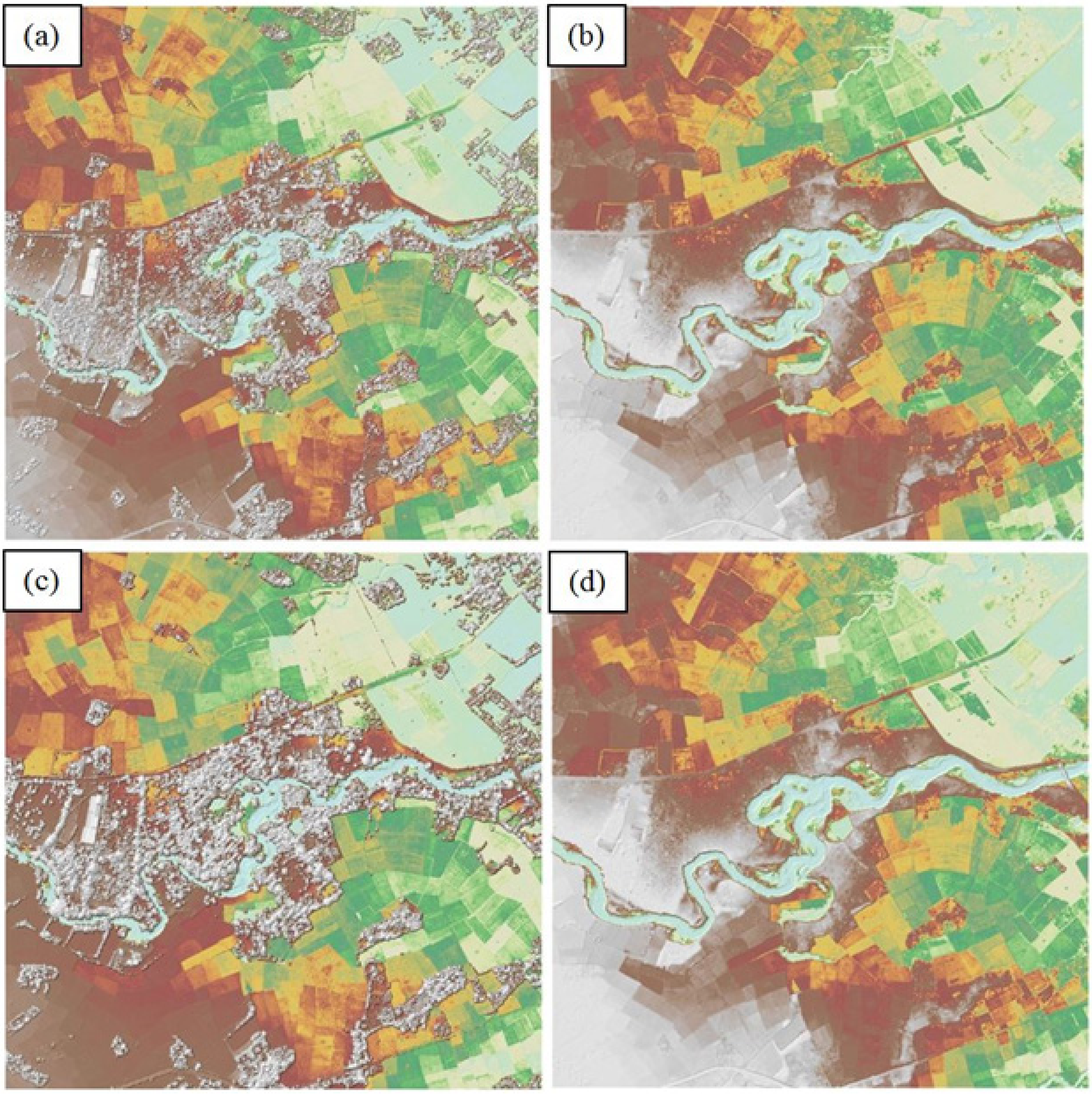


Figure 19. The Production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Labo Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 184 1km by 1km tiles area covered by Labo 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 Labo Floodplain has a total of 91.57 sq.km orthophotogaph coverage comprised of 291 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

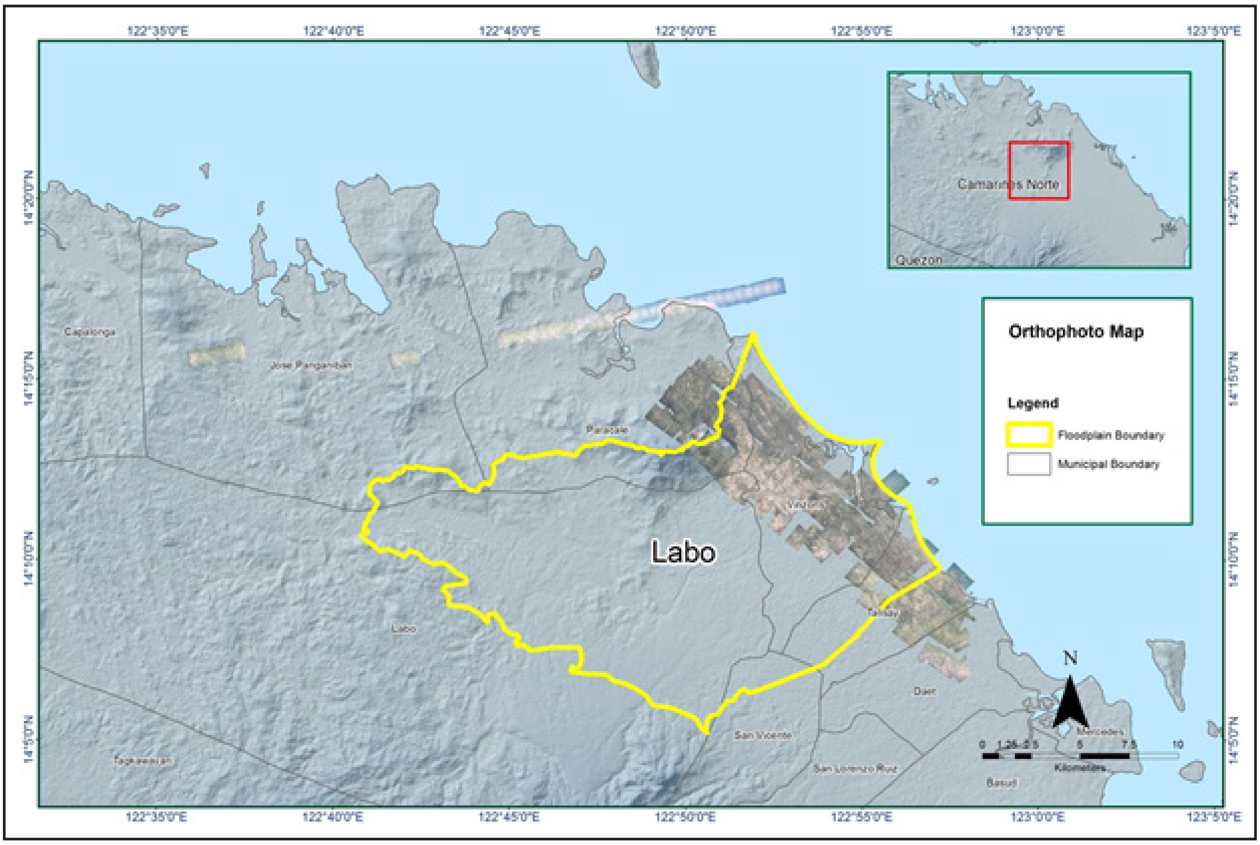


Figure 20. Labo Floodplain with available orthophotographs.

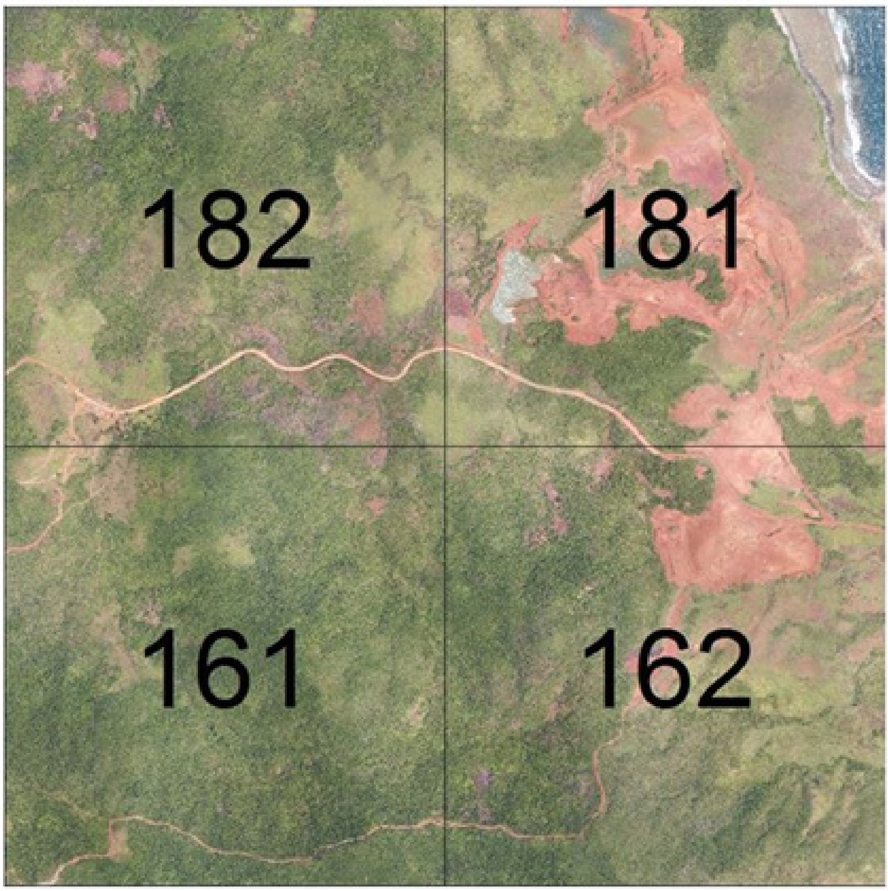


Figure 21. Sample orthophotograph tiles for Labo Floodplain.

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for Labo Floodplain. These blocks are composed of Bagasbas blocks with a total area of 750.00 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_Blk20A	140.08
Bagasbas_Blk20B	168.45
Bagasbas_Blk20C	216.97
Bagasbas_Blk20O_supplement1	175.26
Bagasbas_Blk20O_supplement1	49.24
TOTAL	**750.00 sq. km**

Portions of DTM before and after manual editing are shown in Figure 22. The bridge (Figure 22a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 22b) in order to hydrologically correct the river. Embankments (Figure 22c) have been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 22d) to allow the correct flow of water.Another example is a building that is still present in the DTM after classification (Figure 22e) and has to be removed through manual editing (Figure 22f).

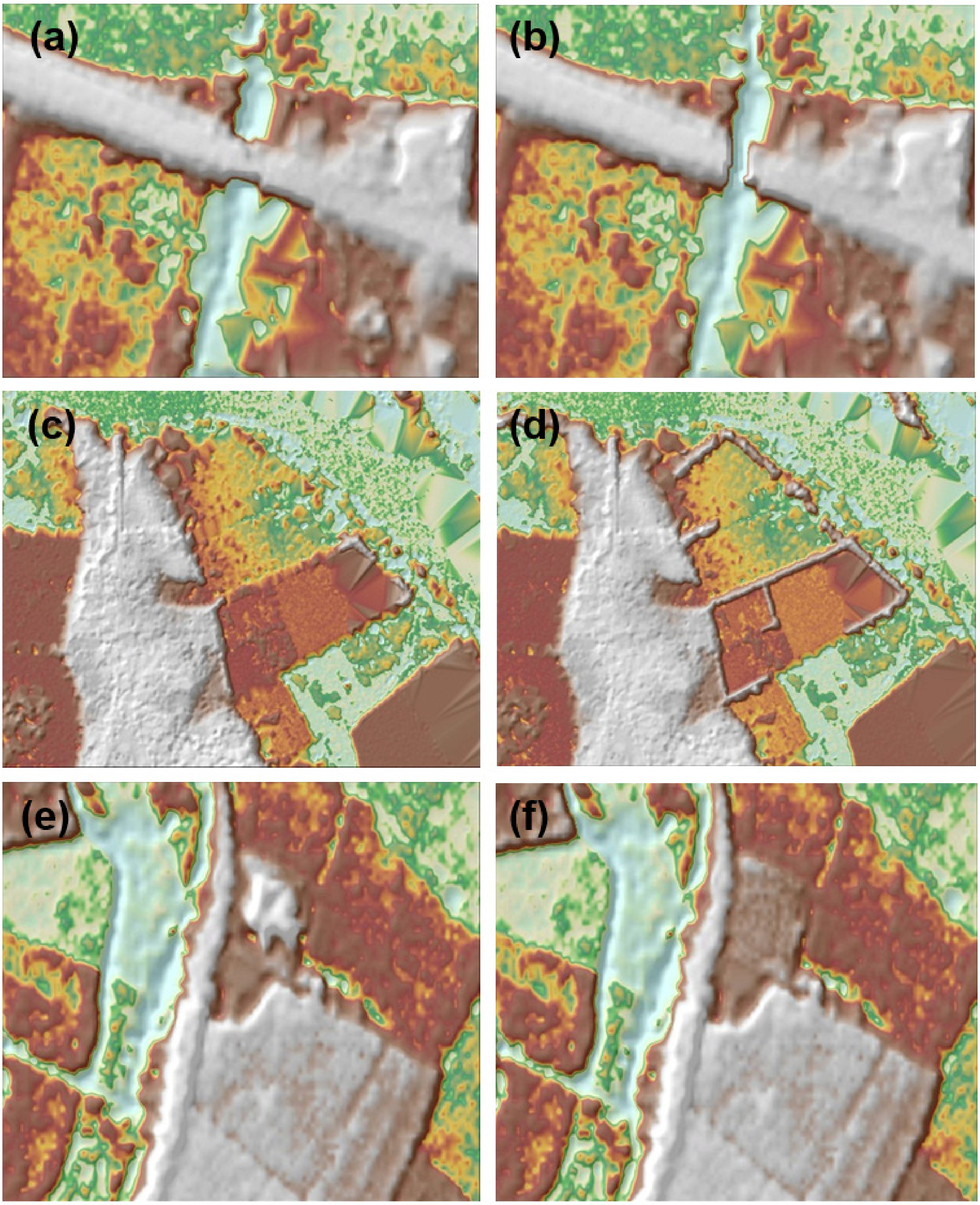


Figure 22. Portions in the DTM of Labo Floodplain – a bridge before (a) and after (b) manual editing; a fish ponds before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

Bagasbas_Blk20C was used as reference block at the start of mosaicking because there was no available reference DEM for shifting that overlaps with the blocks to be mosaicked. Table 16 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Labo Floodplain is shown in Figure 23. It can be seen that the entire Labo Floodplain is 98.96% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 16. Shift Values of each LiDAR Block of Labo Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Bagasbas_Blk20A	Reference block	Reference block	Reference block
Bagasbas_Blk20B	0.00	0.00	+0.04
Bagasbas_Blk20C	0.00	0.00	0.00
Bagasbas_Blk20O_supplement1	-0.57	+0.62	+0.01
Bagasbas_Blk20O_supplement2	-0.82	-0.23	+0.11

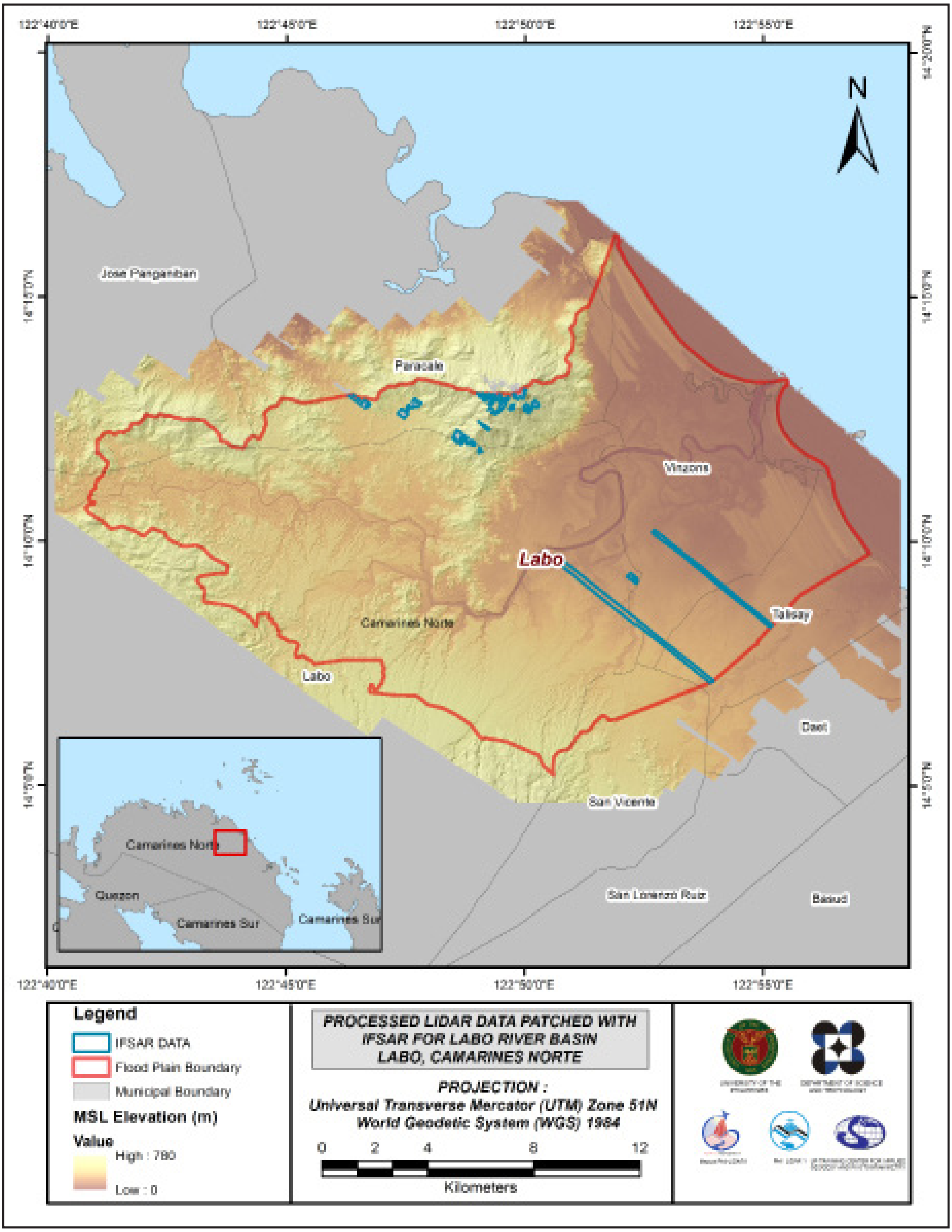


Figure 23. Map of Processed LiDAR Data for Labo Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Labo to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 9,023 survey points were used for calibration and validation of Labo LiDAR data. Random selection of 80% of the survey points, resulting in 7,218 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 2.89 meters with a standard deviation of 0.17 meters. Calibration of Labo LiDAR data was done by subtracting the height difference value, 2.89 meters, to Labo mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

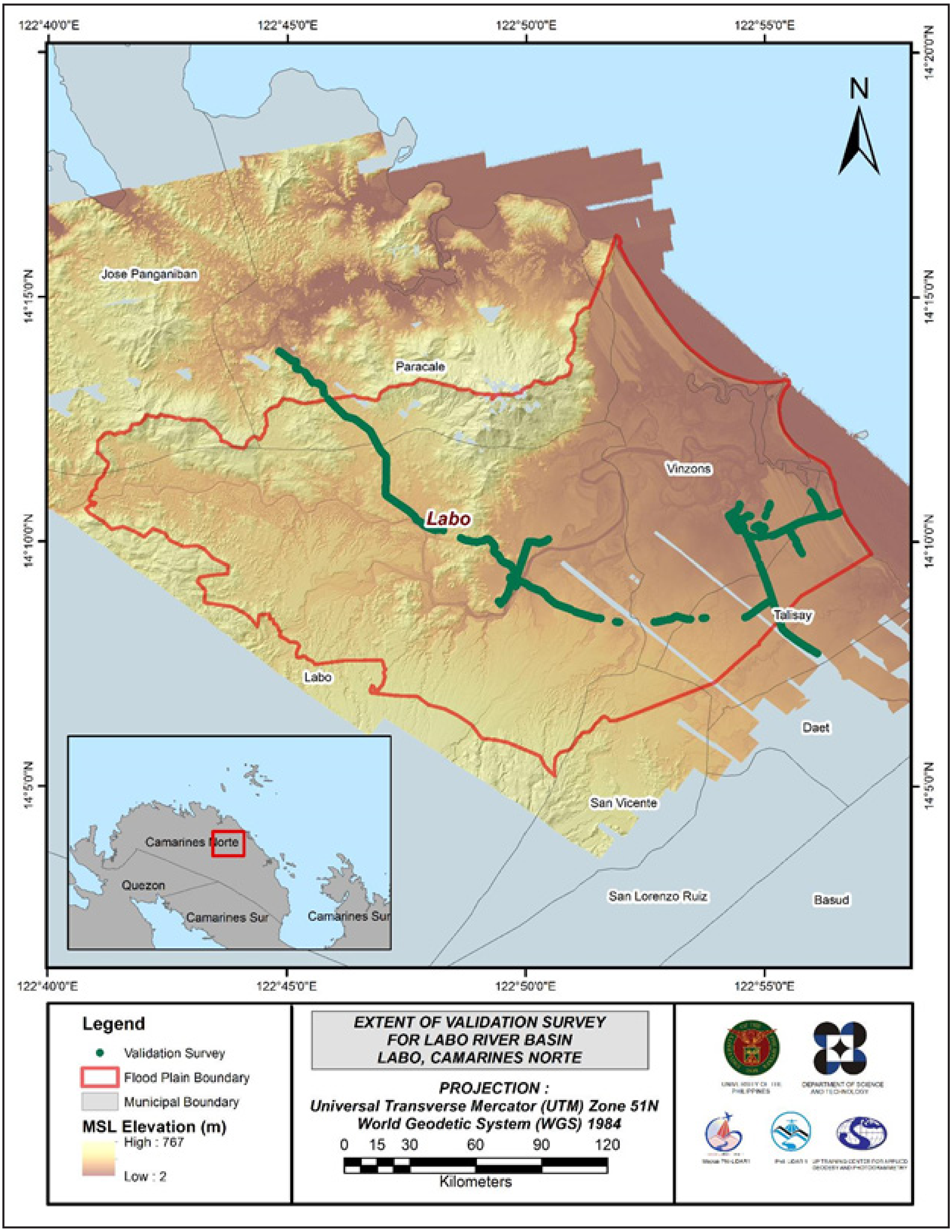


Figure 24. Map of Labo Floodplain with validation survey points in green.

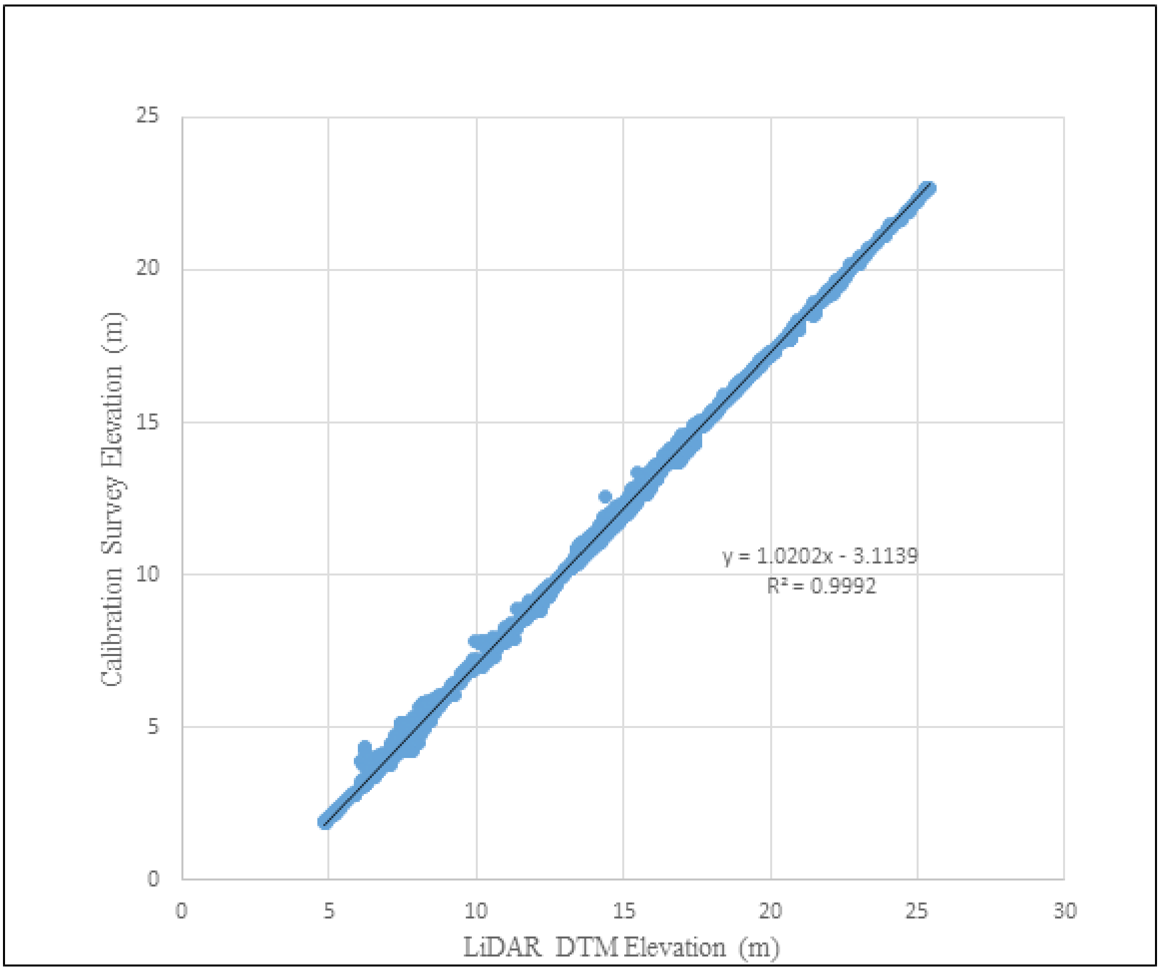


Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 17. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	-2.89
Standard Deviation	0.17
Average	2.89
Minimum	2.56
Maximum	3.22

The remaining 20% of the total survey points, resulting to 1,805 points, were used for the validation of calibrated Labo 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 0.16 meters with a standard deviation of 0.16 meters, as shown in Table 18.

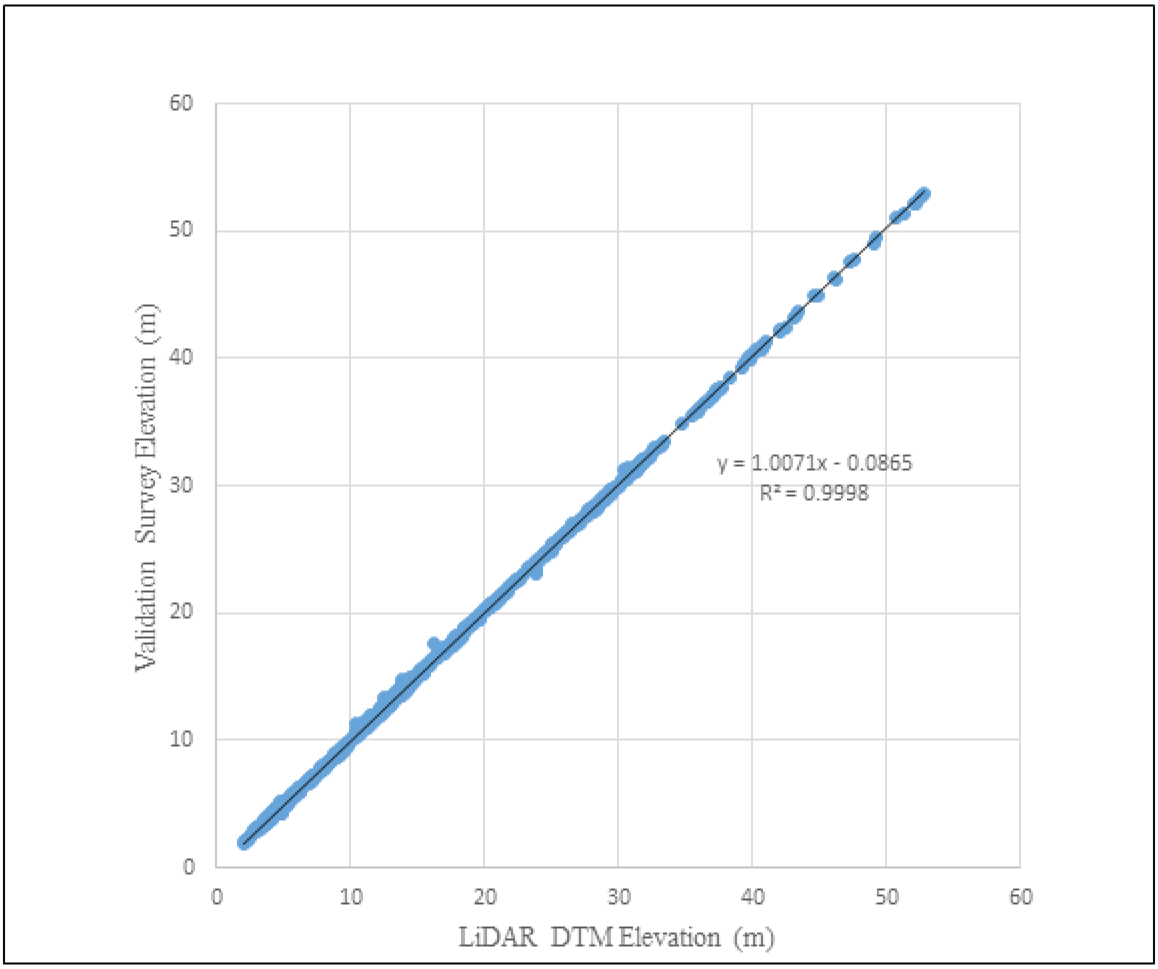


Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 18. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.16
Standard Deviation	0.16
Average	0.00
Minimum	-0.32
Maximum	0.32

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Labo with 9,774 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation (with barriers) method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.43 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Labo integrated with the processed LiDAR DEM is shown in Figure 27.

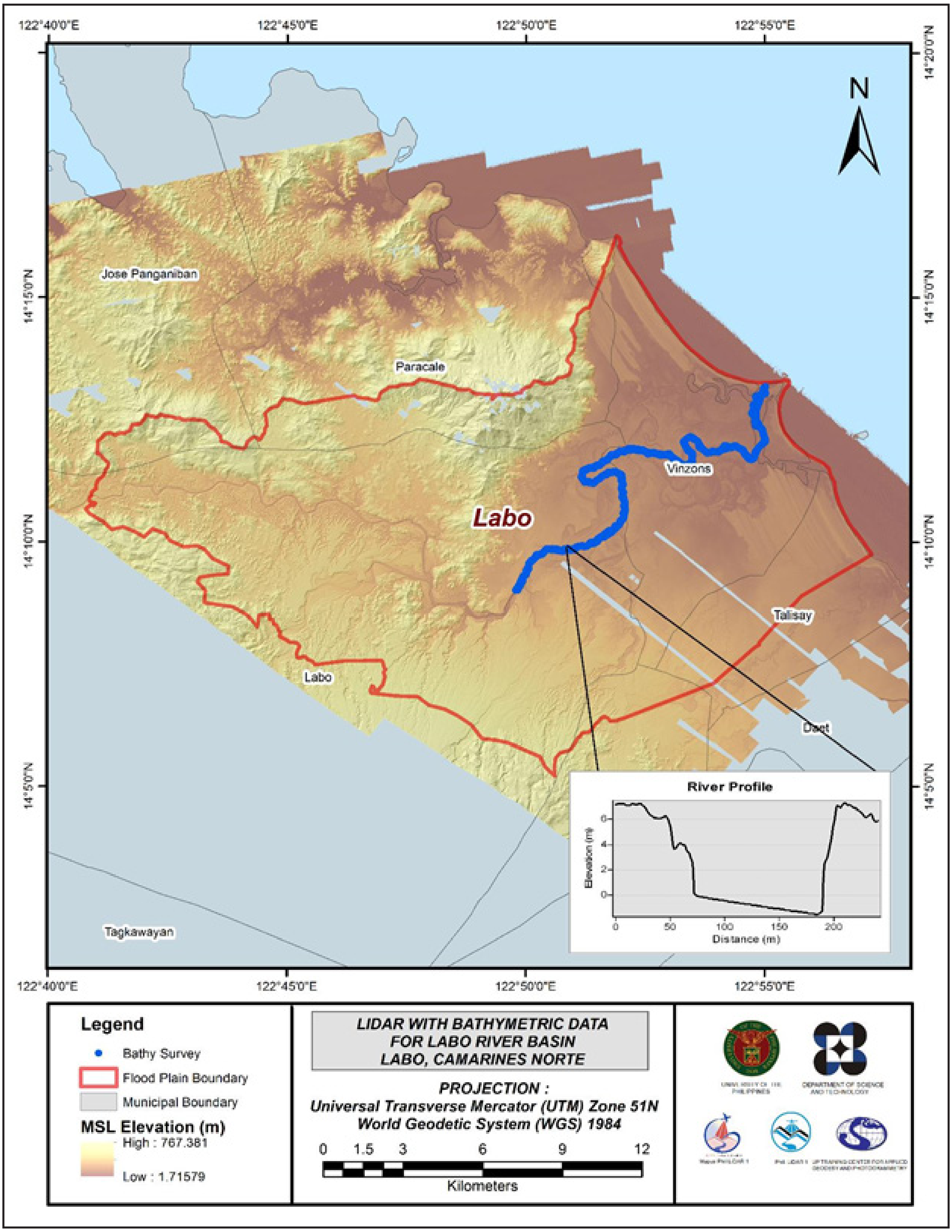


Figure 27. Map of Labo Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Labo Floodplain, including its 200 m buffer, has a total area of 303.43 sq km. For this area, a total of 10.00 sq km, corresponding to a total of 2,326 building features, are considered for QC. Figure 28 shows the QC blocks for Labo Floodplain.

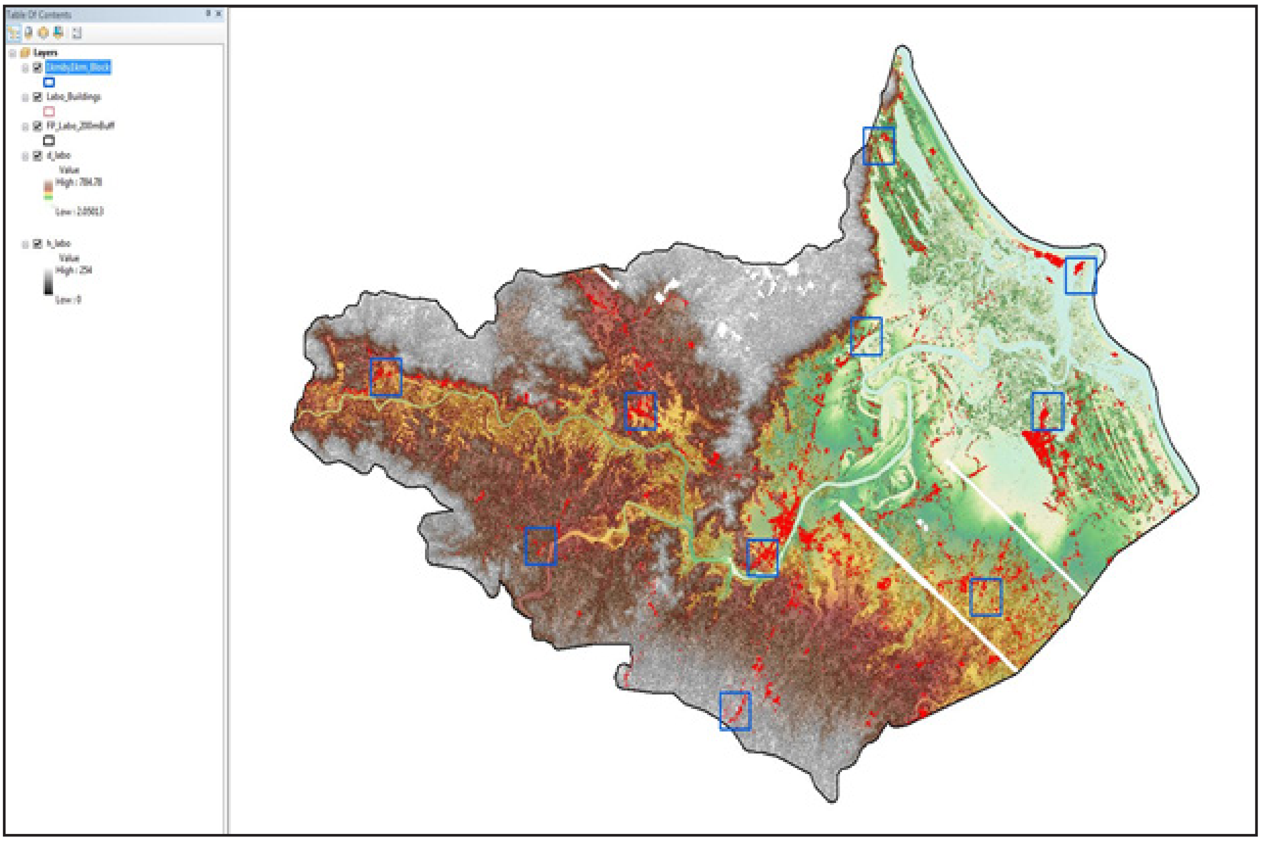


Figure 28. Blocks (in blue) for Labo building features subjected to QC.

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

Table 19. Quality Checking Ratings for Labo Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Labo	99.19	100.00	89.42	PASSED

3.12.2 Height Extraction

Height extraction was done for 19,484 building features in Labo Floodplain. Of these building features, 914 were filtered out after height extraction, resulting in 18,570 buildings with height attributes. The lowest building height is at 2.00 m while the highest building is at 10.13 m.

3.12.3 Feature Attribution

The attributes were obtained by field data gathering. GPS devices were used to determine the coordinates of important features. These points are uploaded and overlaid in ArcMap and are then integrated with the shapefiles.

Table 20 summarizes the number of building features per type. On the other hand, Table 21 shows the total length of each road type, while Table 22 shows the number of water features extracted per type.

Table 20. Number of Building Features Extracted for Labo Floodplain.

Facility Type	No. of Features
Residential	17,838
School	368
Market	16
Agricultural/Agro-Industrial Facilities	13
Medical Institutions	26
Barangay Hall	51
Military Institution	0
Sports Center/Gymnasium/Covered Court	32
Telecommunication Facilities	4
Transport Terminal	3
Warehouse	47
Power Plant/Substation	7
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	59
Bank	2
Factory	0
Gas Station	16
Fire Station	1
Other Government Offices	31
Other Commercial Establishments	56
Total	**18,570**

Table 21. Total Length of Extracted Roads for Labo Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Labo	190.60	93.34	0.00	30.42	0.00	**314.36**

Table 22. Number of Extracted Water Bodies for Labo Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Labo	18	7	0	0	2	**27**

A total of 62 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 Labo Floodplain overlaid with its ground features.

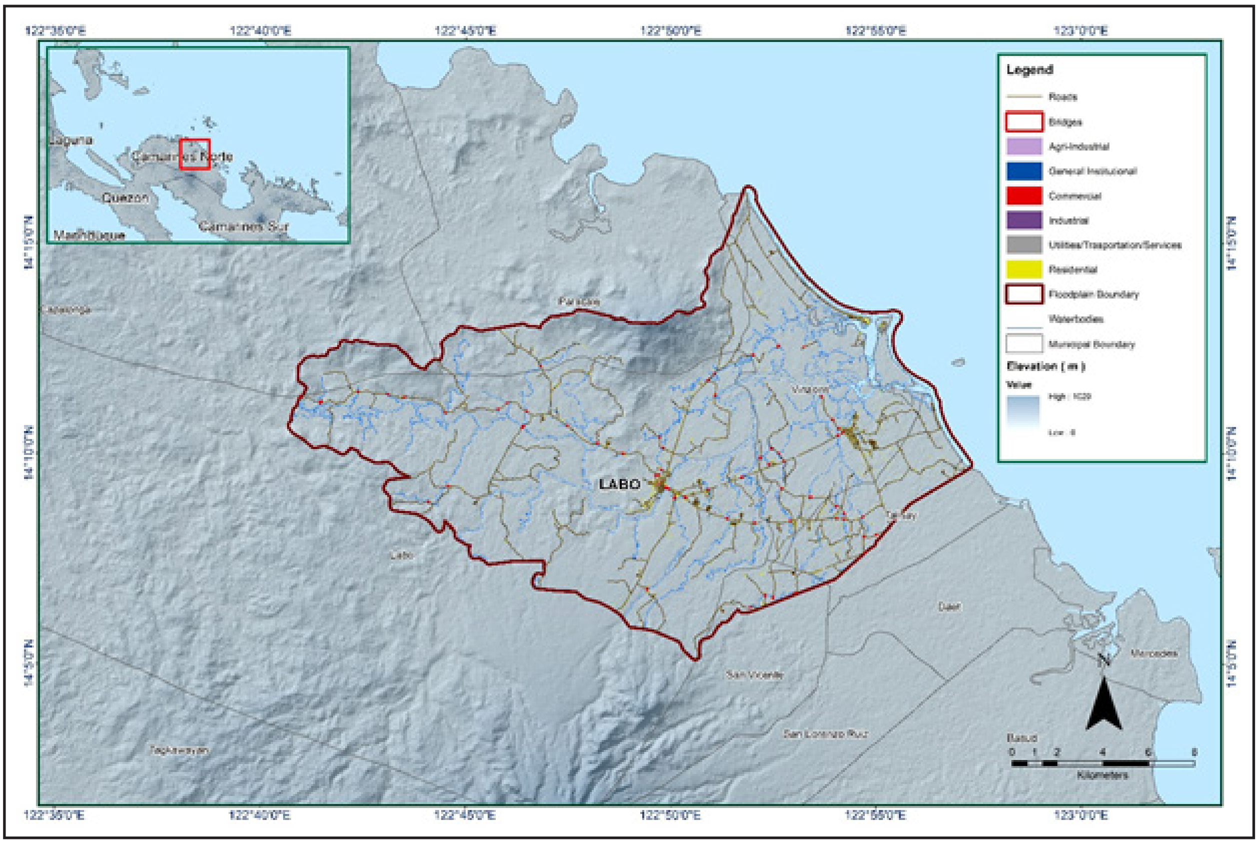


Figure 29. Extracted features for Labo Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE LABO 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, For. Rodel C. Alberto, Cybil Claire Atacador, Engr. Lorenz R. Taguse, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, For. Rodel C. Alberto, Cybil Claire Atacador, and Engr. Lorenz R. Taguse

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 Compoent (DVBC) conducted field survey in Labo River. The survey was conducted on January 26 – February 2, 2016 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section, as-built and water level marking in MSL of Labo Bridge in Brgy. Gumamela, Municipality of Labo, Camarines Norte; LiDAR Validation of about 46 km; and bathymetric survey from Brgy. Gumamela in the Municipality of Labo down to the mouth of the river in Brgy. Sula in the Municipality Vinzons, with an approximate length of 20.78 km using OHMEX™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique. See Figure 30.

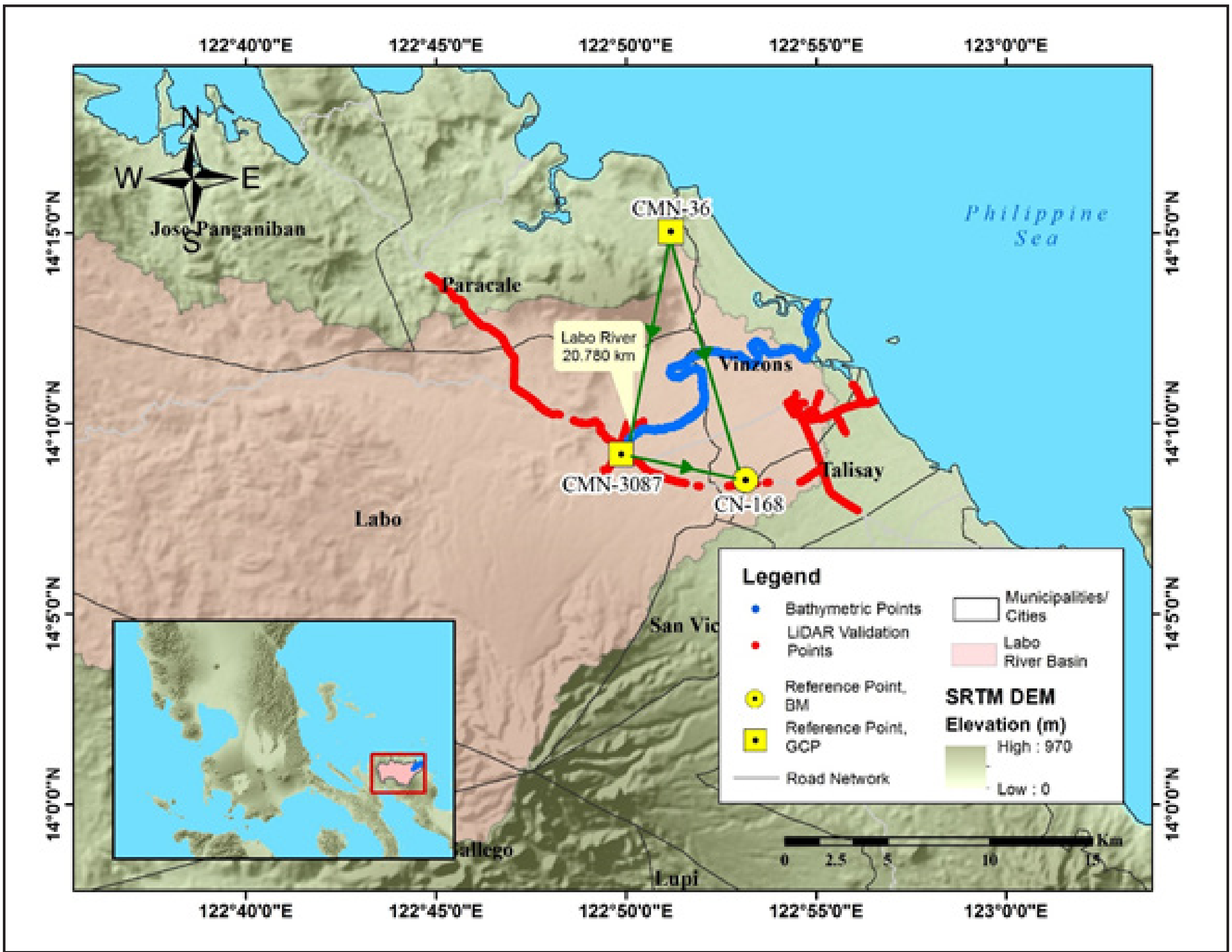


Figure 30. Survey extent for Labo River Basin

4.2 Control Survey

The GNSS network used for Labo River Basin is composed of a single loop established on January 28, 2016 occupying the following reference points: CN-168, a first-order BM, in Brgy. Sto. Domingo, Municipality of Vinzons; and CMN-36, a second-order GCP in Brgy. Mampungo, Municipality of Paracale.

A control point established by NAMRIA, CMN-3078, was also occupied and used as a marker for the network.

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

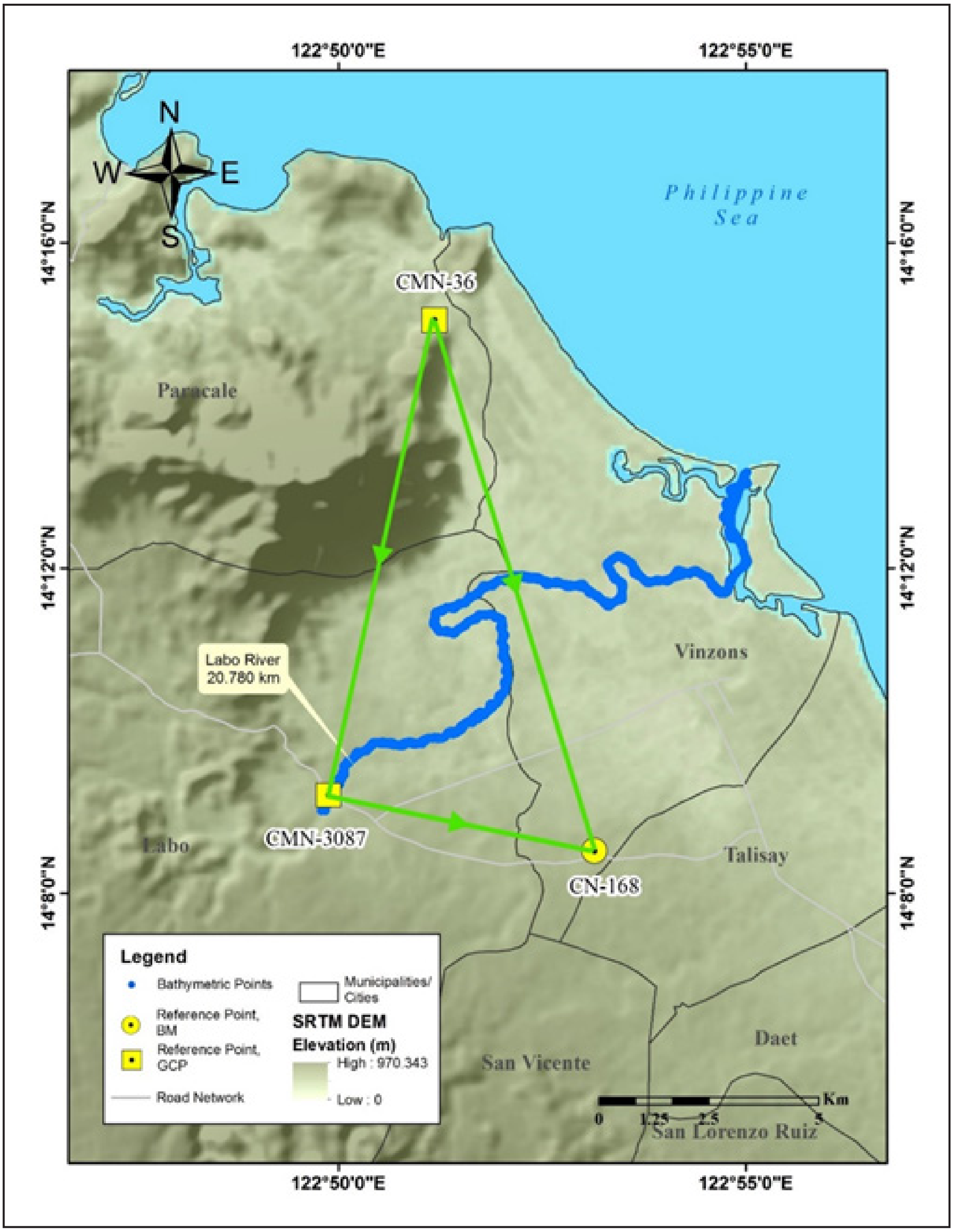


Figure 31. GNSS Network of Labo River field survey

Table 23. List of reference and control points occupied for Labo River Survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
CN-168	1st order, BM	-	-	62.569	12.721	2007
CMN-36	2nd order, GCP	14°15'02.89999"	122°51'10.48832"	54.569	-	2007
CMN-3087	Used as Marker	-	-	-	-	2007

The GNSS set up made in the location of the reference and control points are exhibited are shown in Figure 32 to Figure 34.

Figure 32. GNSS receiver set up, Trimble® SPS 882, at CN-168, a first-order BM, located near the flag pole inside Sto. Domingo Elementary School in Brgy. Sto. Domingo, Vinzons, Camarines Norte

Figure 33. GNSS receiver set up, Trimble® SPS 882, at CMN-36, a second-order GCP located at the approach of Manlicogan Bridge in Brgy. Mampungo, Municipality of Paracale, Camarines Norte

Figure 34. GNSS base set up, Trimble® SPS 852, at CMN-3087, a GCP used as a marker, located at Lobo Bridge along Maharlika Highway in Brgy. Gumamela, Municipality of Lobo, 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 was 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 Labo River Basin is summarized in Table 24 generated by TBC software.

Table 24. Baseline Processing Report for Labo River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CN-168 --- CMN-36 (B476)	1/28/2016	Fixed	0.006	0.026	163°37'02"	12547.729	8.003
CMN-3087 --- CN-168 (B477)	1/28/2016	Fixed	0.012	0.035	102°08'34"	6011.542	-2.102
CMN-3087 --- CMN-36 (B478)	1/28/2016	Fixed	0.004	0.014	192°14'37"	11023.962	10.088

As shown in Table 24, a total of three (3) baselines were processed with reference points CMN-36 and CN-168 held fixed for grid and elevation values respectively. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the Adjusted Grid Coordinates table of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 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 27 for the complete details.

The three (5) control points, CN-168, CMN-36 and CMN-3087 were occupied and observed simultaneously to form a GNSS loop. Coordinates of point CMN-36 and elevation value of CN-168 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)
CMN-36	Local	Fixed	Fixed		
CN-168	Grid				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 points CMN-36 and CN-168 have no values for grid errors and elevation error, respectively.

Table 26. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
CN-168	487663.511	0.008	1563433.736	0.008	12.721	?	e
CMN-36	484133.368	?	1575469.457	?	5.129	0.047	LL
CMN-3087	481789.697	0.007	1564701.974	0.005	14.905	0.050	

The network is fixed at reference point CMN-36 with known coordinates, and CN-168 with known elevation. As shown in Table 26, the standard errors (xe and ye) of CN-168 are 0.80 cm and 0.80 cm and CMN-3087 are 0.70 and 0.50 cm, respectively. With the mentioned equation, $\sqrt{((x_e)^2+(y_e)^2)}<20cm$ for horizontal accuracy, and $z_e<10\ cm$ for the vertical ; the computation for the accuracy for the controls are as follows:

a. CN-168

Horizontal Accuracy	=	√((0.80)² + (0.80)²
	=	√ (0.64 + 0.64)
	=	1.28 cm < 20 cm
Vertical Accuracy	=	Fixed

b. CMN-36

Horizontal Accuracy	=	Fixed
Vertical Accuracy	=	4.7 cm < 10 cm

c. CMN-3087

Horizontal Accuracy	=	√((0.70)² + (0.50)²
	=	√ (0.49 +0.25)
	=	0.74 cm < 20 cm
Vertical Accuracy	=	5.0 cm < 10 cm

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

Table 23. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
CN-168	N14°08'31.1946"	E122°53'08.4949"	62.569	?	e
CMN-36	N14°15'02.9000"	E122°51'10.4883"	54.569	0.047	LL
CMN-3087	N14°09'12.3613"	E122°49'52.5337"	64.661	0.050	

The corresponding geodetic coordinates of NAMRIA established reference points, CN-168, CMN-168 and CMN-3078 are within the required accuracy as shown in Table 27. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 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)
CN-168	1st order, BM	14°08'31.1946"N	122°53'08.4949"E	62.569	1563433.736	487663.511	12.721
CMN-36	2nd order, GCP	14°15'02.9000"N	122°51'10.4883"E	54.569	1575469.457	484133.368	5.129
CMN-3087	Used as marker	14°09'12.3613"N	122°49'52.5337"E	64.661	1564701.974	481789.697	14.905

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

Cross-section and as-built survey was conducted on January 30 and Feb 1, 2016 at the downstream side of Labo Bridge in Brgy. Gumamela, Municipality of Labo, Camarines Norte using GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 35.

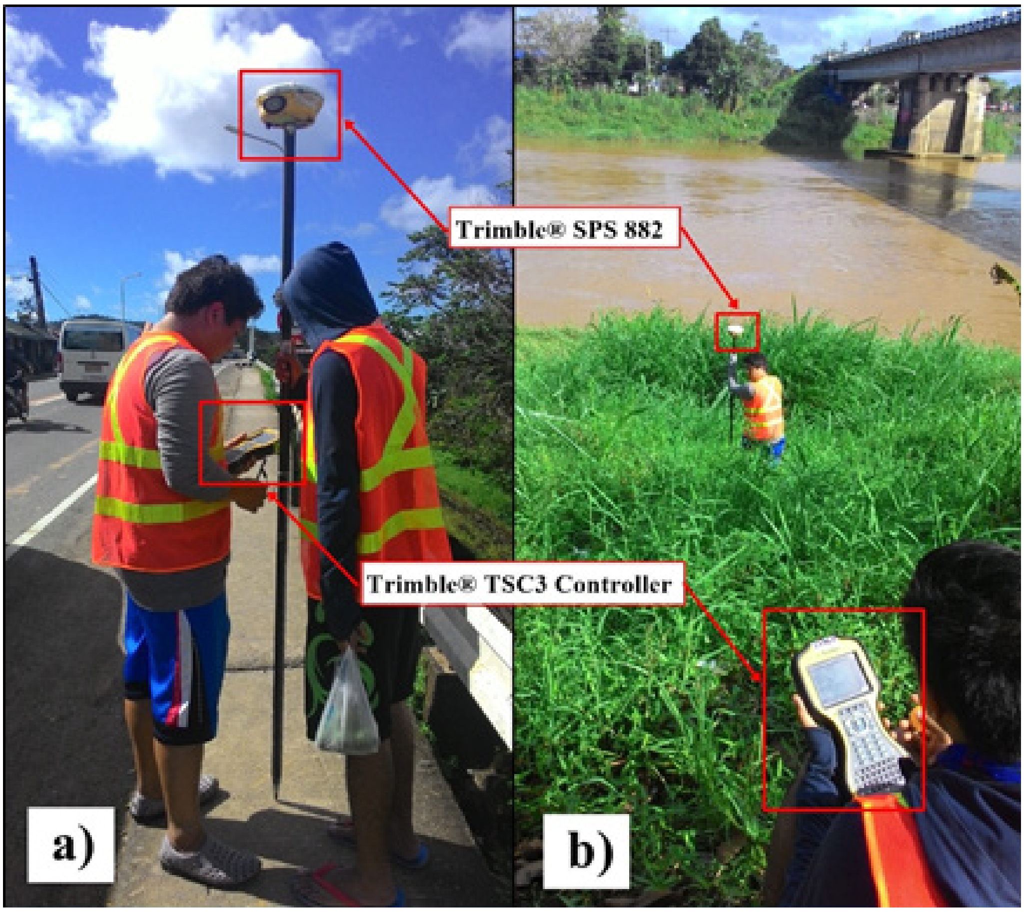


Figure 35. a) Bridge as-built and b) cross-section survey at the downstream side of Labo Bridge

The cross-sectional line length of Labo Bridge is about 163.49 m with 95 cross-sectional points acquired using CMN-3087 as the GNSS base station. The location map, cross section diagram, and the bridge data form are shown in Figure 36 to Figure 38, respectively.

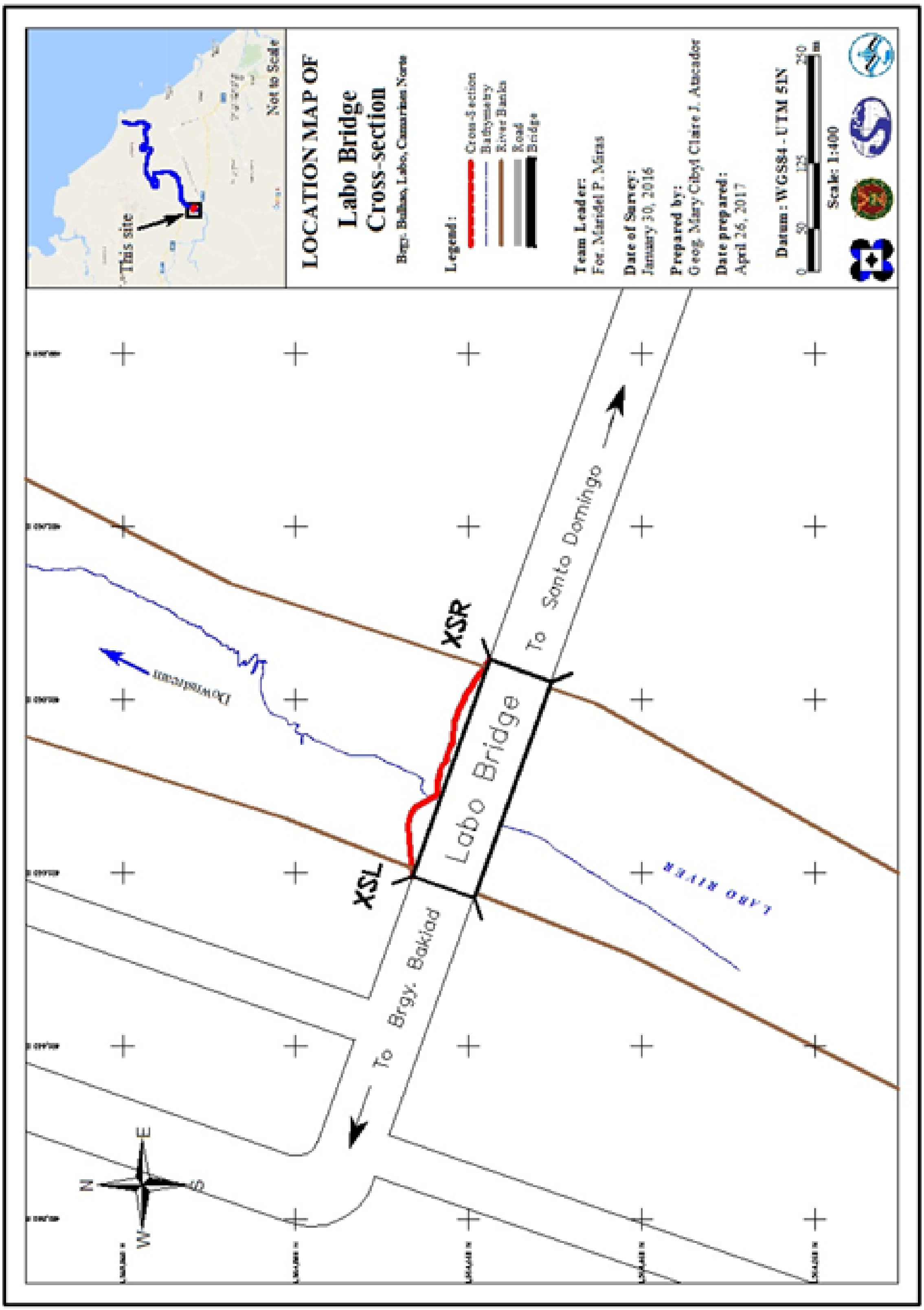


Figure 36. Labo bridge cross-section location map

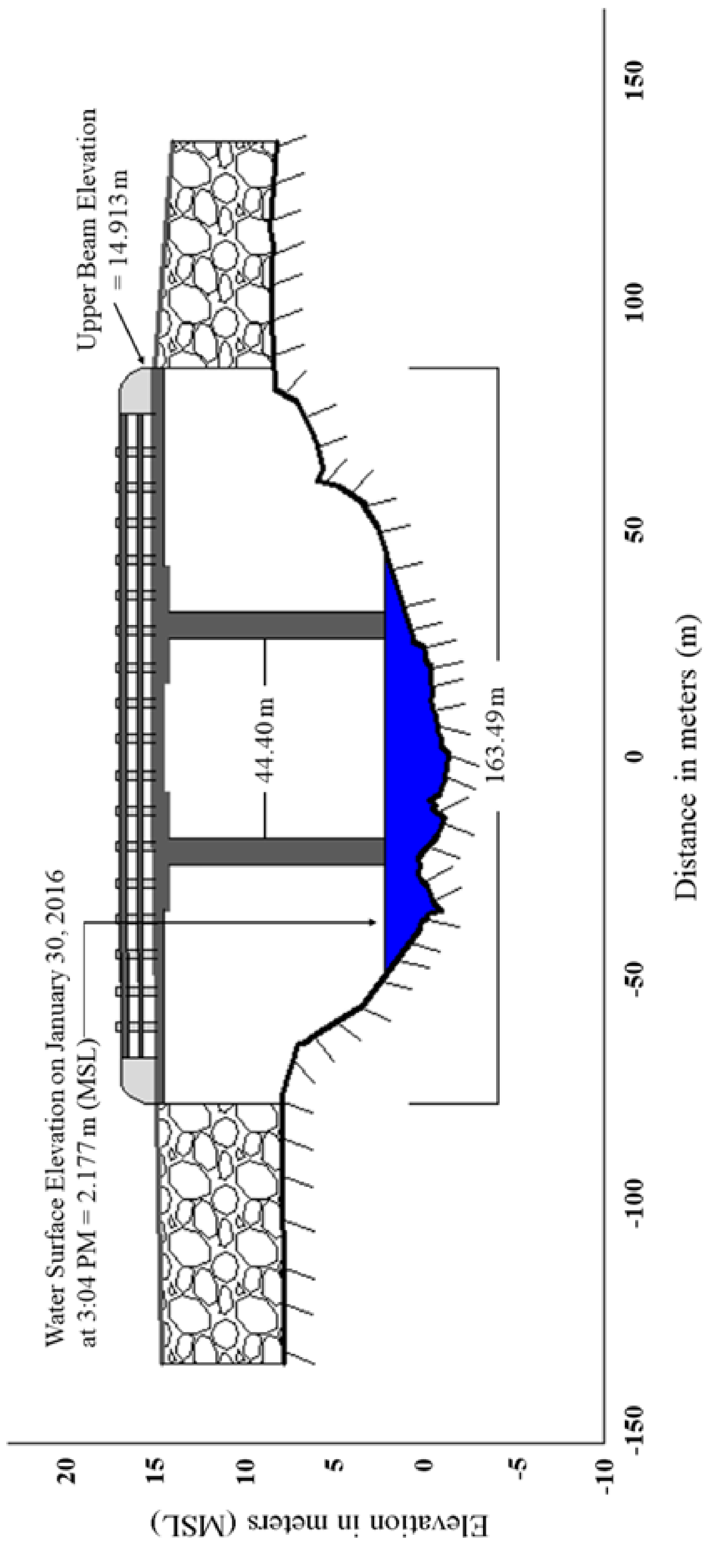


Figure 37. Labo Bridge cross-section diagram

Bridge Data Form

Bridge Name: Labo Bridge **Date:** February 1, 2016

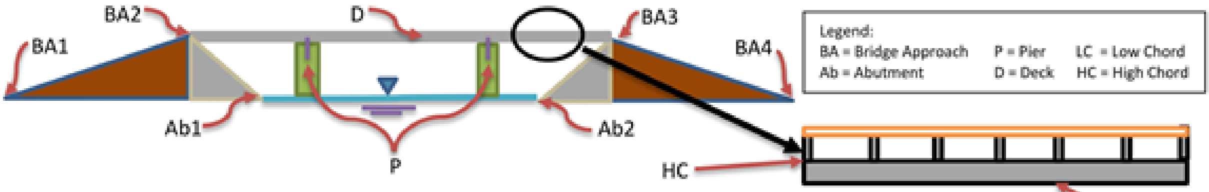
River Name: Labo River **Time:** 10:00 AM

Location (Brgy, City, Region): Brgy. Gumamela, Municipality of Labo, Camarines Norte

Survey Team: Camarines Norte Team

Flow condition: low (normal) high **Weather Condition:** (fair) rainy

Latitude: 14d09'12.36125" N **Longitude:** 122d49'52.53365" E



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

Elevation 14.905 m MSL **Width:** 9.74 m **Span (BA3-BA2):** 163.507 m

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 2	14.835 m	11.965 m
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	14.590 m	BA3	221.429 m	14.913 m
BA2	57.922 m	14.835 m	BA4	271.831 m	13.926 m

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: HEXAGONAL **Number of Piers:** 2 **Height of column footing:**

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	114.891 m	14.927 m	4 m
Pier 2	164.319 m	14.906 m	4 m

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

Figure 38. Labo Bridge Data Form

Water surface elevation in MSL of Labo River was determined using Trimble® SPS 882 in PPK mode technique on January 30, 2016 at 03:04 PM with a value of 2.177 m in MSL. This was translated onto marking on one of the bridge's deck with the value of 14.87 m MSL which was used by Mapúa PHIL-LiDAR 1 as shown in Figure 39. The marking served as their reference for flow data gathering and depth gauge deployment for Labo River.

Figure 39. Water-level marking at Labo Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on January 29 & 31, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached to the side of vehicle as shown in Figure 40. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 1.96 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 CMN-3087 occupied as the GNSS base stations in the conduct of the survey.

Figure 40. Validation points acquisition survey set up

On January 29, the survey started from Brgy. Kalamunding (Poblacion) in Labo going east to Brgy. Sto. Nino in Talisay via Maharlika Highway. The survey also covered a portion of Vinzons Avenue that traverses from Brgy. Itomang in Talisay going north towards Brgy. III (Poblacion) in Vinzons, Camarines Norte. On January 31, the survey ran from Brgy. Batobalani in Paracale going southeast towards Brgy. Bakiad in Labo via Maharlika Highway then turned left to reach Brgy. Cabusay via Sta. Cruz Road. The survey also roamed around the Poblacion barangays in Vinzons – Brgys. I, II, III, Del Carmen, Santa Elena, and Calangcawan Sur. CMN-3087 was used as GNSS base for the entire extent validation points acquisition survey, as drawn in a map in Figure 41.

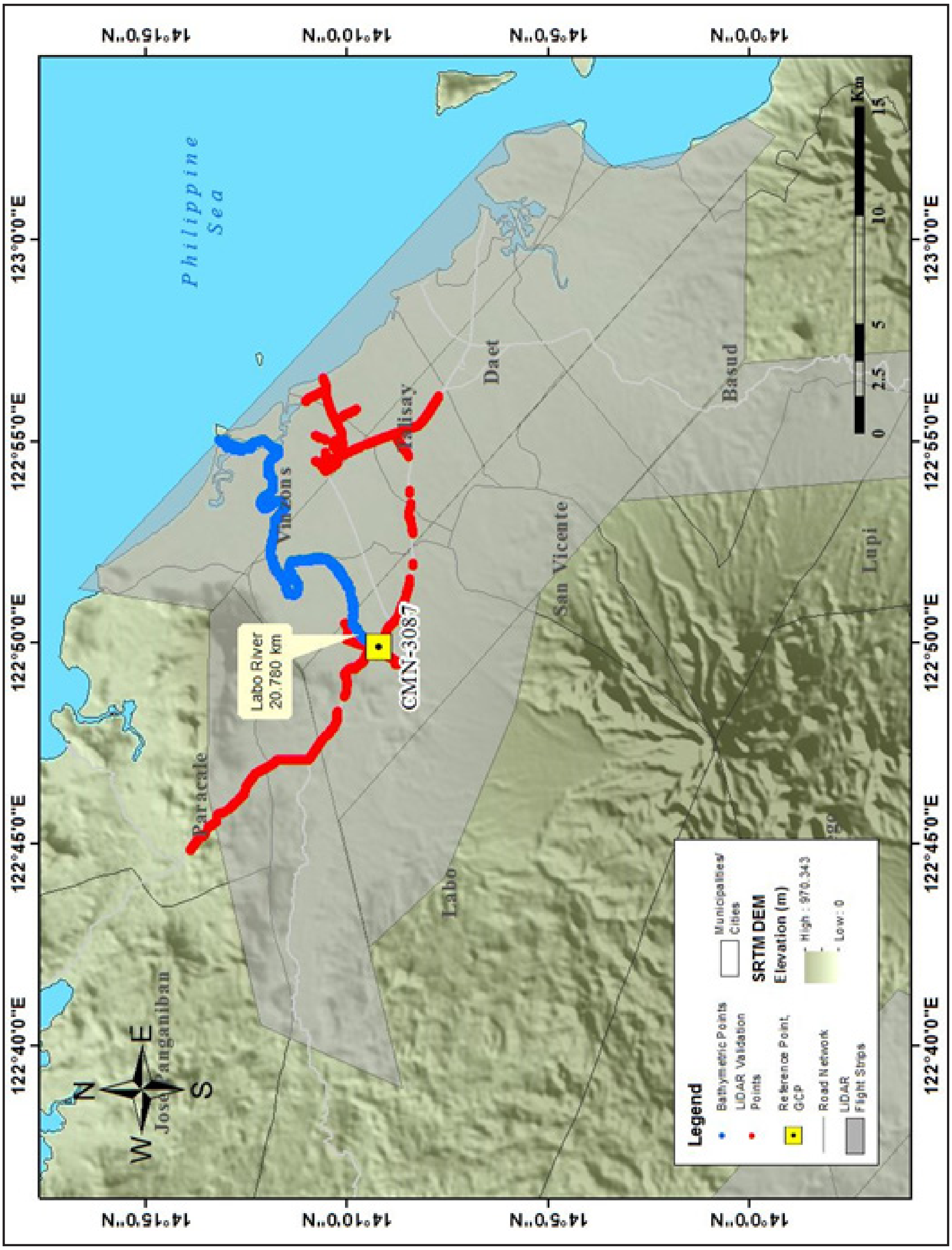


Figure 41. Validation point acquisition survey for the Labo River Basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on January 29 to 30, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique and Ohmex™ single beam echo sounder, as demonstrated in Figure 42. The extent of the survey is from the upstream in Brgy. Gumamela in the Municipality of Labo with coordinates 14°10'12.92495"N 122°51'42.35280"E, down to the mouth of the river in Brgy. Sula in the Municipality of Vinzon with coordinates 14°13'08.52066"N 122°55'00.02442"E, as illustrated in Figure 43. The control point CMN-3087 was used as the GNSS base station throughout this survey.

Figure 42. Bathymetry set up for Labo River survey

A CAD drawing was also produced to illustrate the riverbed profile of Labo River. As shown in Figure 44 and Figure 45, the highest and lowest elevation has a 9-meter difference. The highest elevation observed was 2.17 m above MSL located in Brgy. Bulhao in Labo while the lowest was 7.324 m below MSL located in Brgy. Calangcawan Norte in Vinzons. The bathymetric survey gathered a total of 28,588 points covering 20.78 km of the river traversing the ff. barangays from the upstream - Brgy. Gumamela, Brgy. Bulhao, Brgy. Cabusay, Brgy. Santa Cruz, Brgy. Bagacay and Brgy. Napilihan in the Municipality of Labo, and Brgy. Mangcayo, Brgy. Calangcawan Norte and Brgy. Sula in the Municipality of Vinzons.

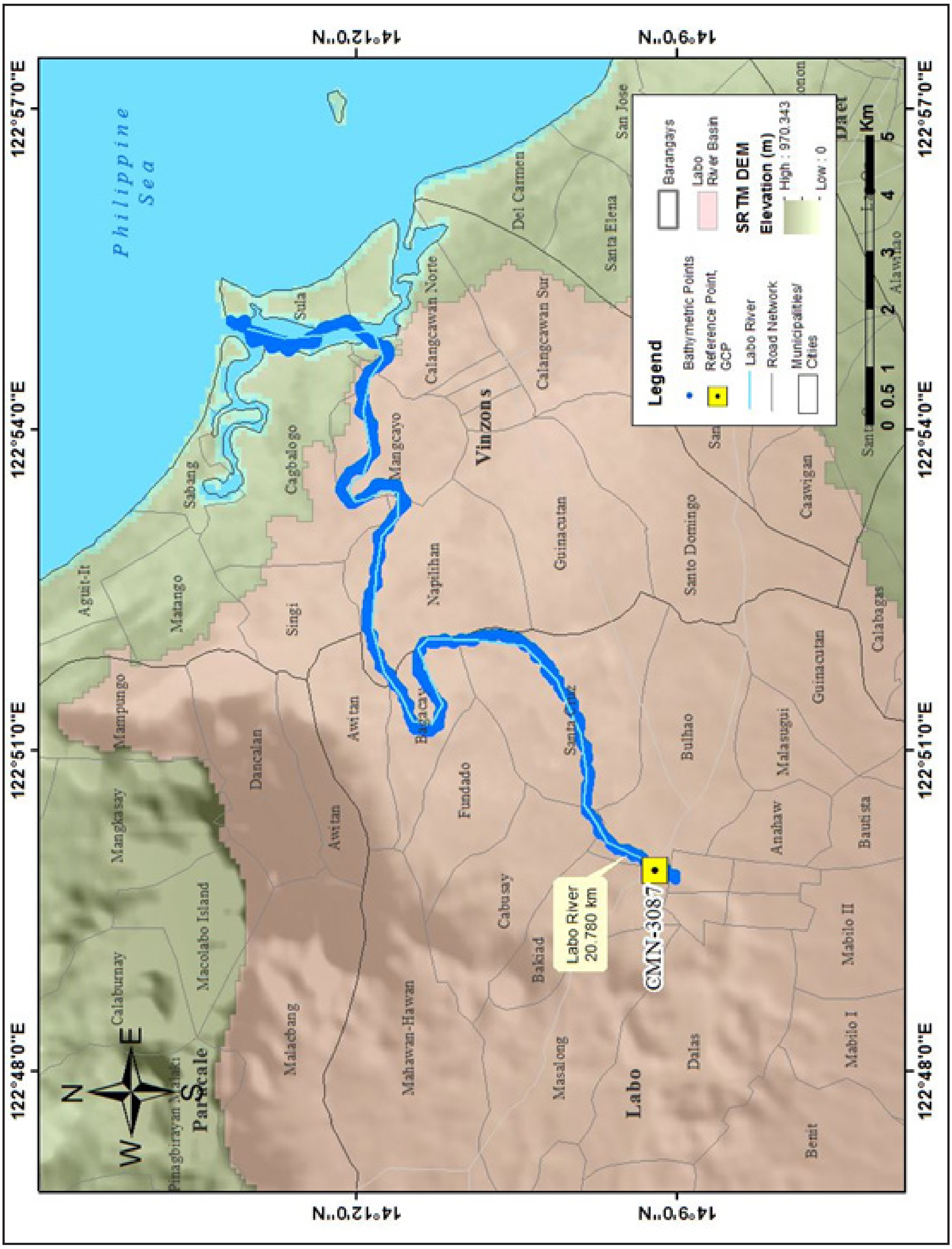


Figure 43. Bathymetric survey of Labo River

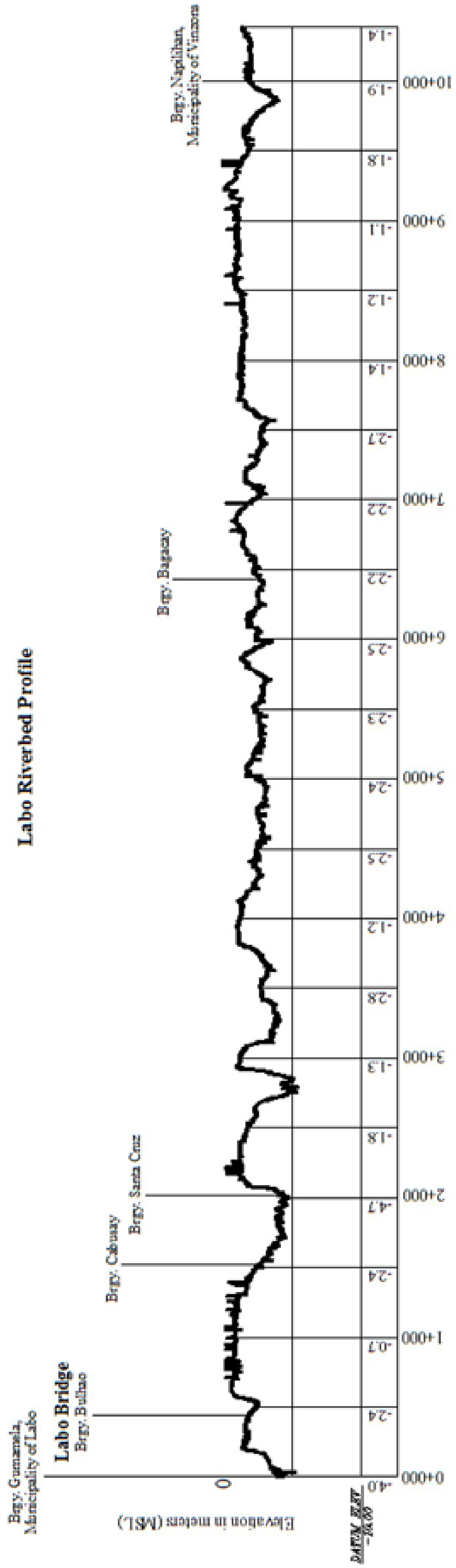


Figure 44. Riverbed profile of Labo River (1 of 2)

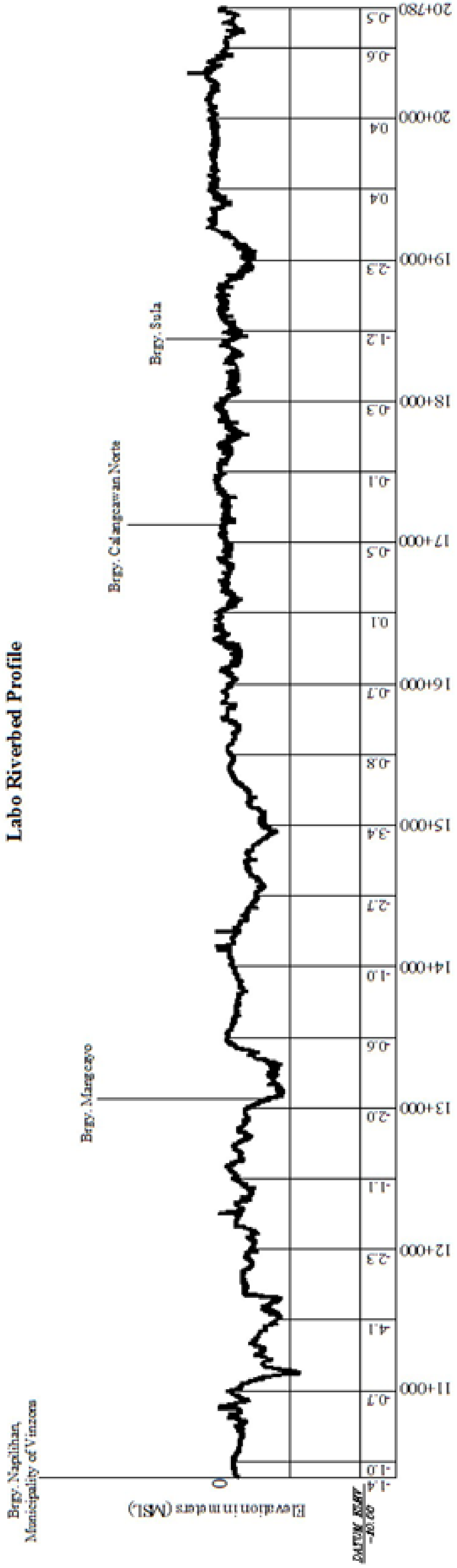


Figure 45. Riverbed profile of Labo River (2 of 2)

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, Pauline Racoma

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

Components and data that affect the hydrologic cycle of the 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 Labo River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from automatic rain gauges (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The ARG was installed at Brgy. Mahawan-Hawan, Labo, Camarines Norte (Figure 46). The precipitation data collection started from October 25, 2016 at 12:00 midnight to October 26, 2016 at 11:45 PM with 15 minutes recording interval.

The total precipitation for this event in Labo ARG was 49.8mm. It has a peak rainfall of 8 mm. on July 30, 2016 at 11:00 PM. The lag time between the peak rainfall and discharge is 5 hours and 50 minutes.

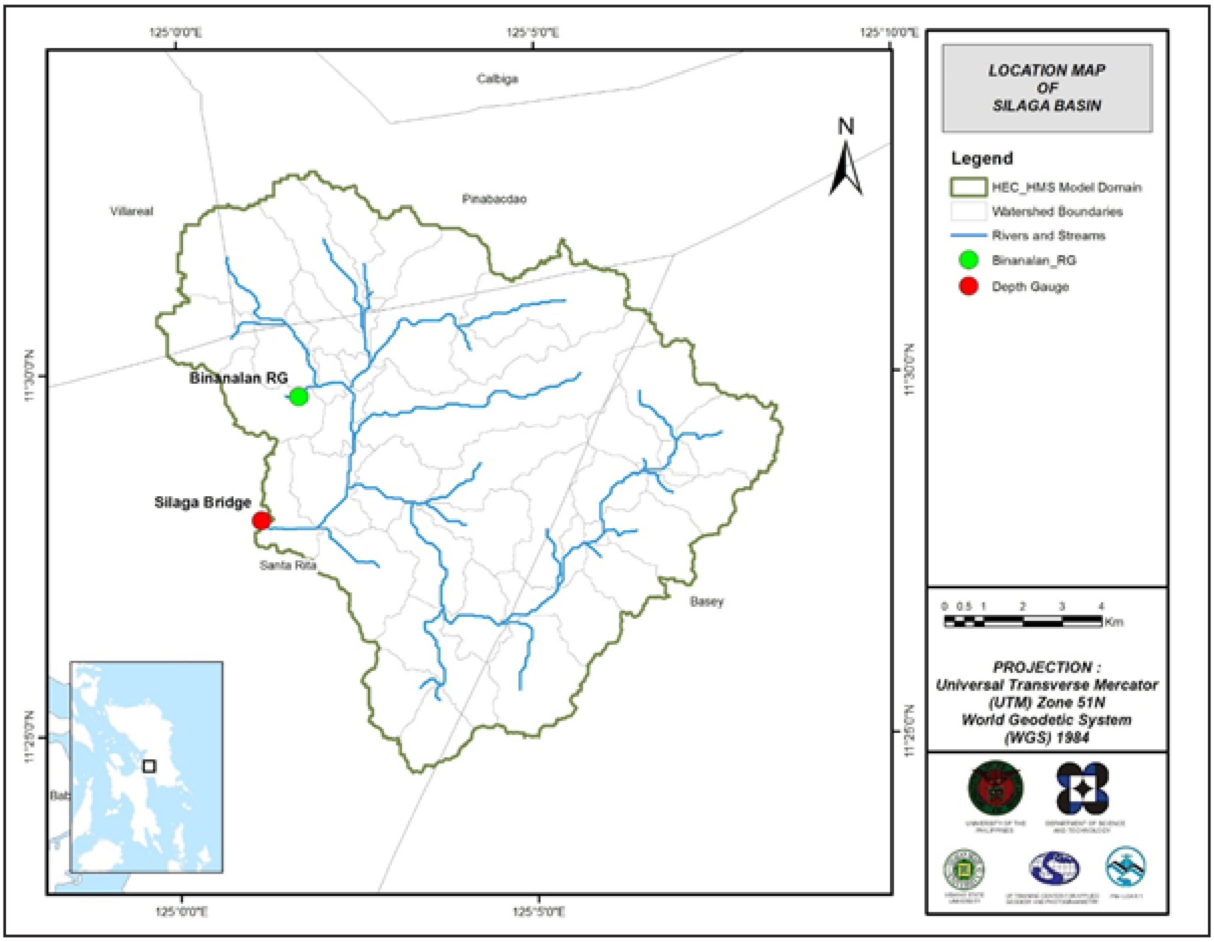


Figure 46. The location map of Labo HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Labo Bridge, Labo, Camarines Norte(14°9’11.56”N, 122° 49’54.66”E). It gives the relationship between the observed water levels at Labo Bridge and outflow of the watershed at this location.

For Labo Bridge, the rating curve is expressed as Q = 5.1109e1.2184h as shown in Figure 48.

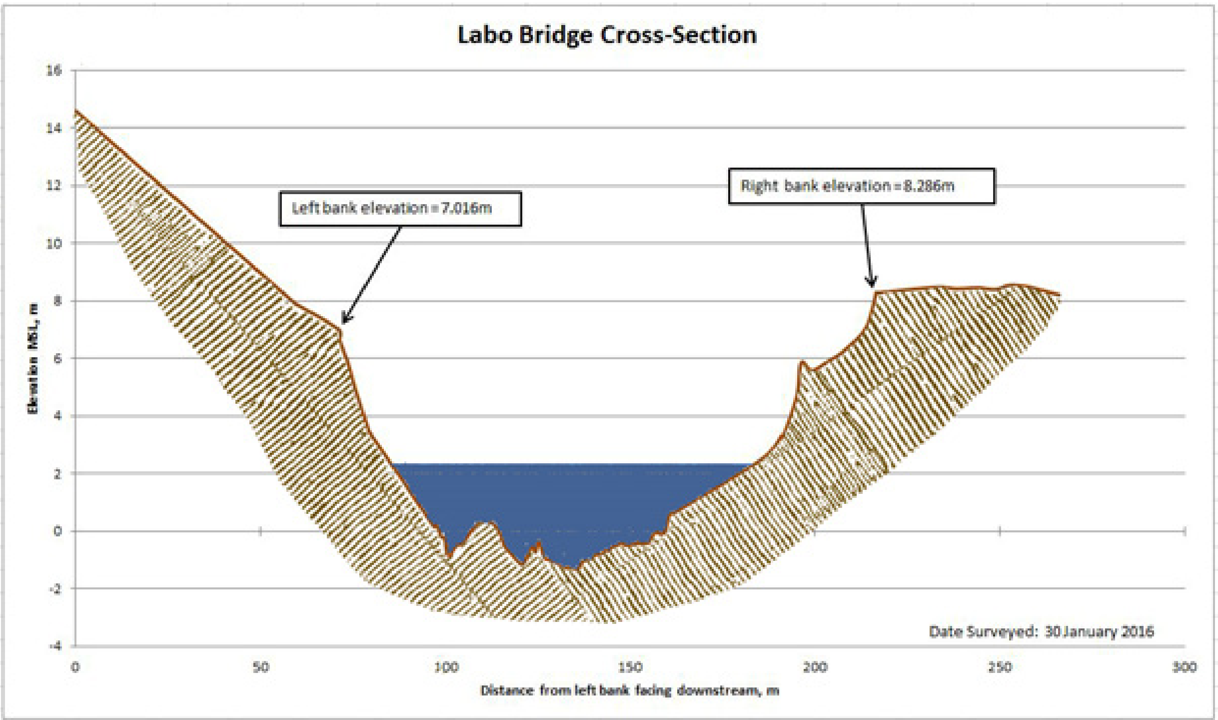


Figure 47. Cross-Section Plot of Labo Bridge

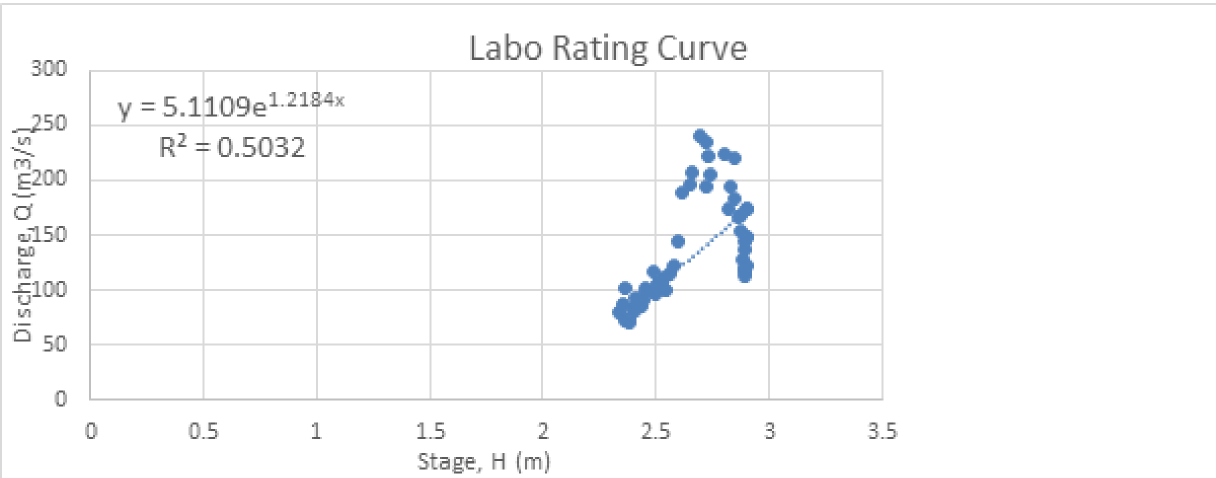


Figure 48. Rating Curve at Labo Bridge, Labo, Camarines Norte

This rating curve equation was used to compute the river outflow at Labo Bridge for the calibration of the HEC-HMS model shown in Figure 49. The total rainfall for this event is 74.6mm and the peak discharge is 102.5 m3 at 12:00 noon, July 30, 2016.

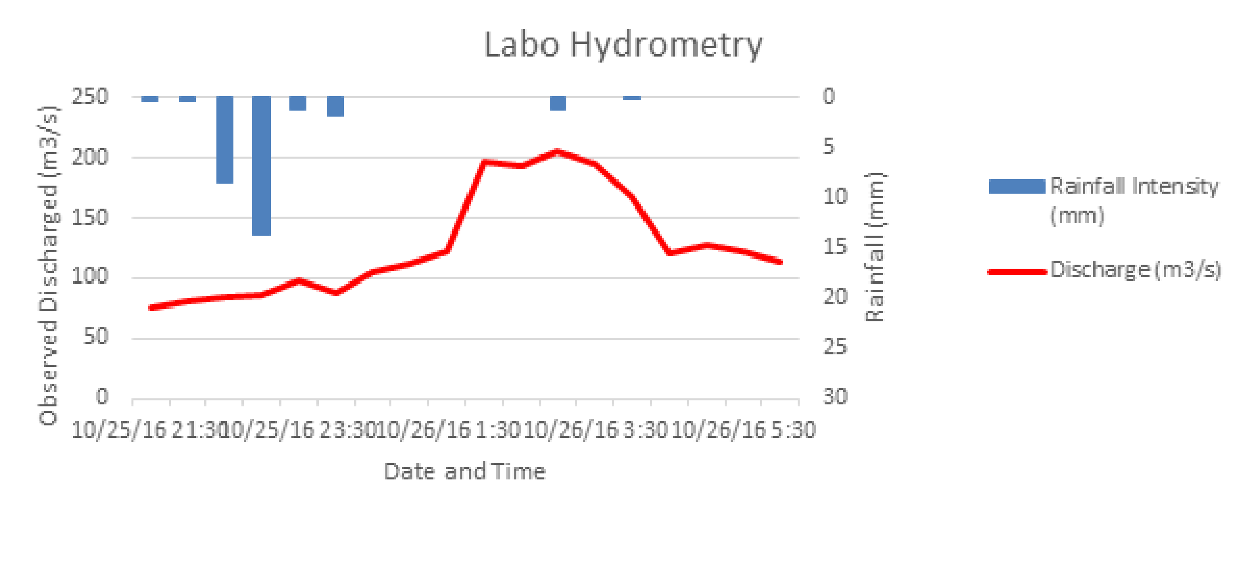


Figure 49. Rainfall and outflow data at Labo used for modeling

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 Labo watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 29. RIDF values for Labo Rain Gauge computed by PAG-ASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	21.8	33.8	43.1	59.6	84	101	130.4	163.2	190.4
5	31.8	47.2	59.1	81.9	120.3	146.8	194.7	236.8	278.7
10	38.5	56.1	69.7	96.7	144.4	177.1	237.2	285.6	337.2
15	42.3	61.1	75.7	105	158	194.1	261.2	313.1	370.2
20	44.9	64.6	79.9	110.8	167.5	206.1	278	332.4	393.3
25	46.9	67.3	83.1	115.3	174.8	215.3	291	347.2	411.1
50	53.2	75.6	93	129.2	197.3	243.7	330.8	392.9	465.9
100	59.4	83.9	102.9	143	271.9	271.9	370.4	438.3	520.3

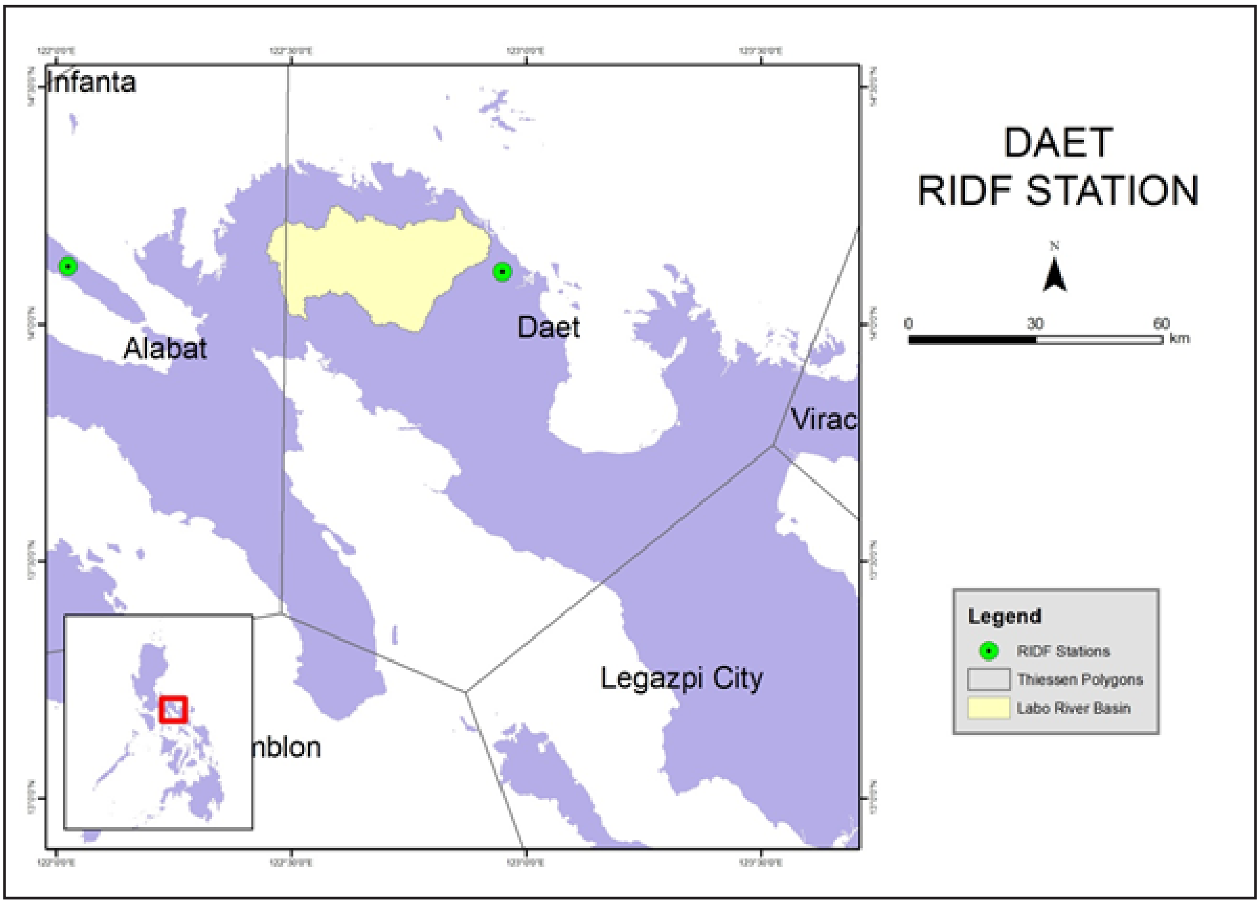


Figure 50. The location of the Daet RIDF station relative to the Labo River Basin

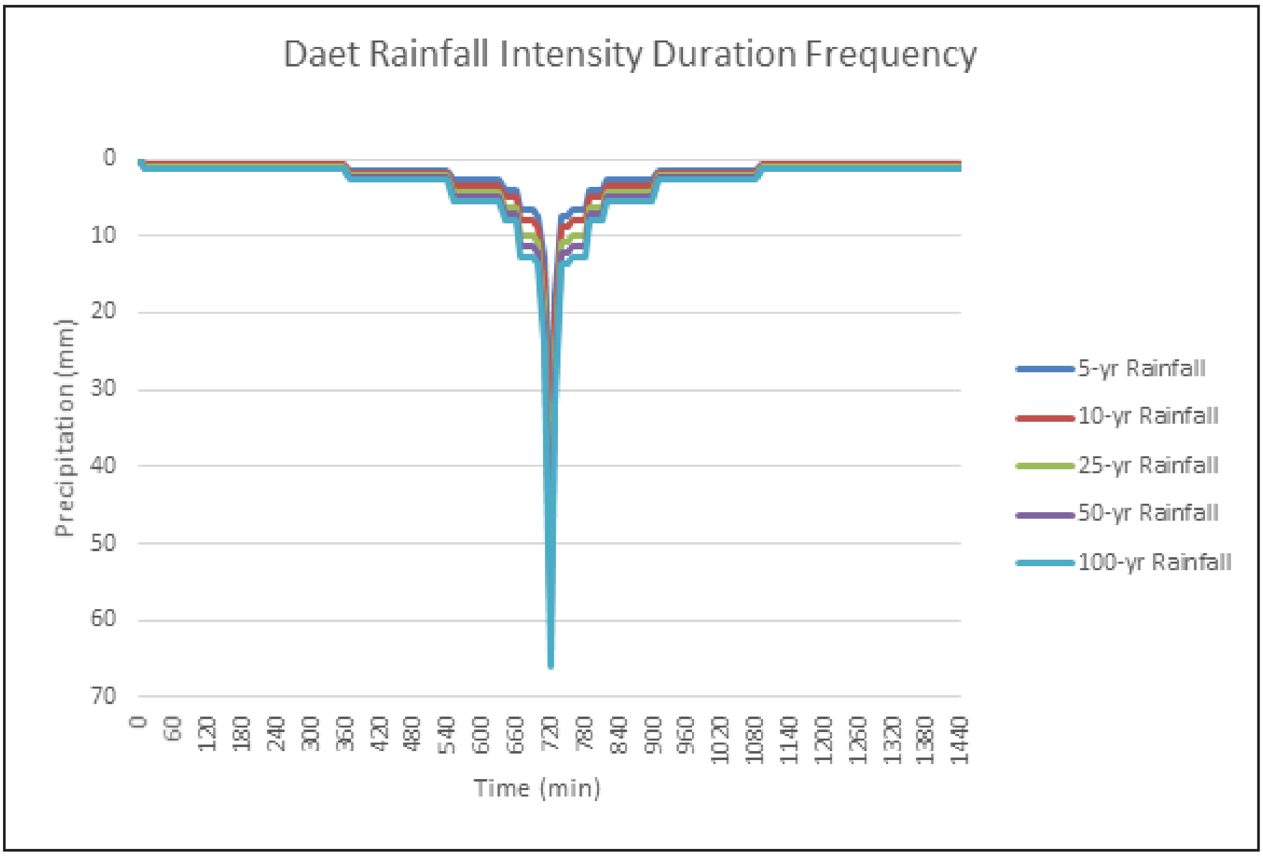


Figure 51. The synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA).The soil and land cover of the Labo River Basin are shown in Figures 52 and 53, respectively.

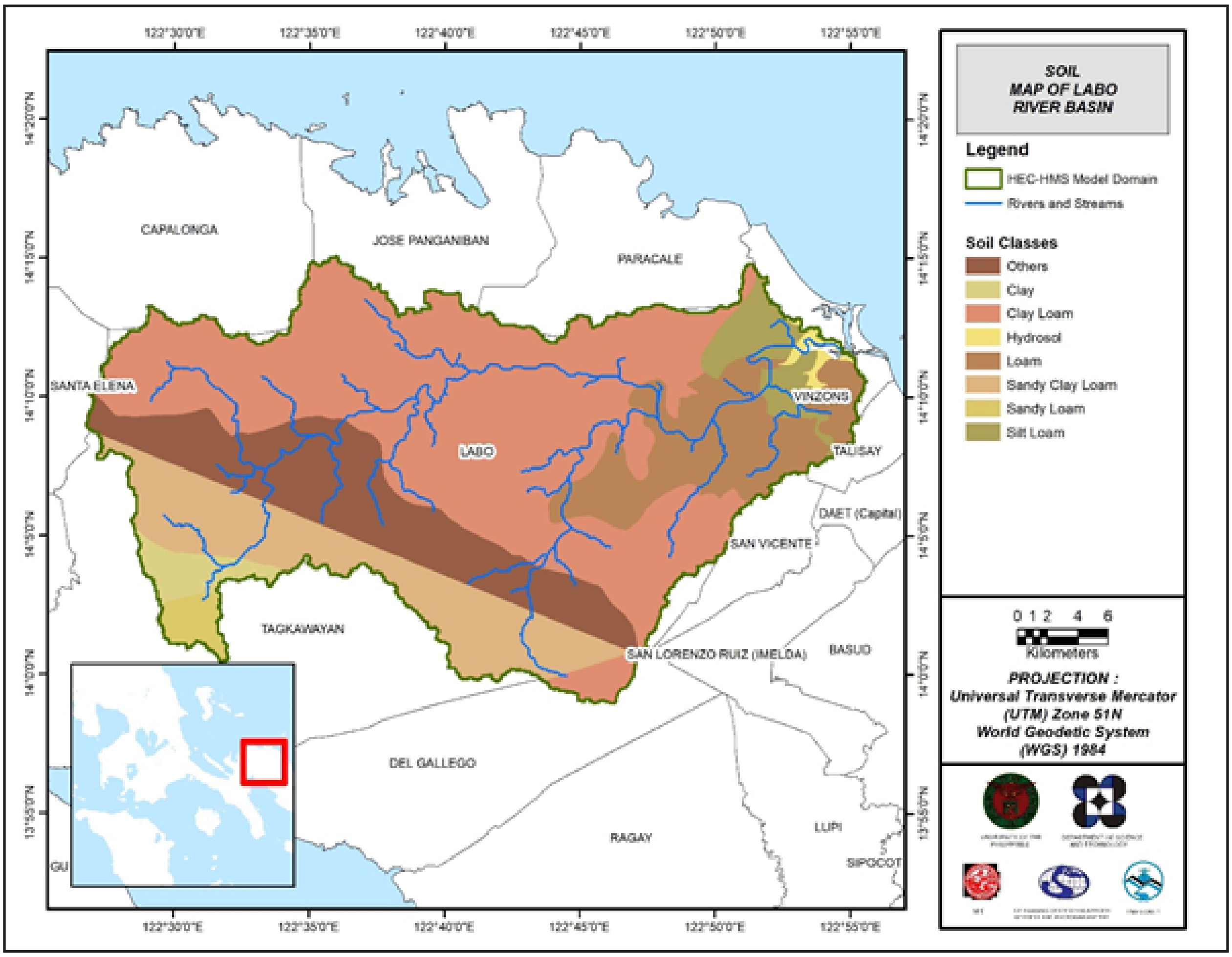


Figure 52. Soil Map of Labo River Basin

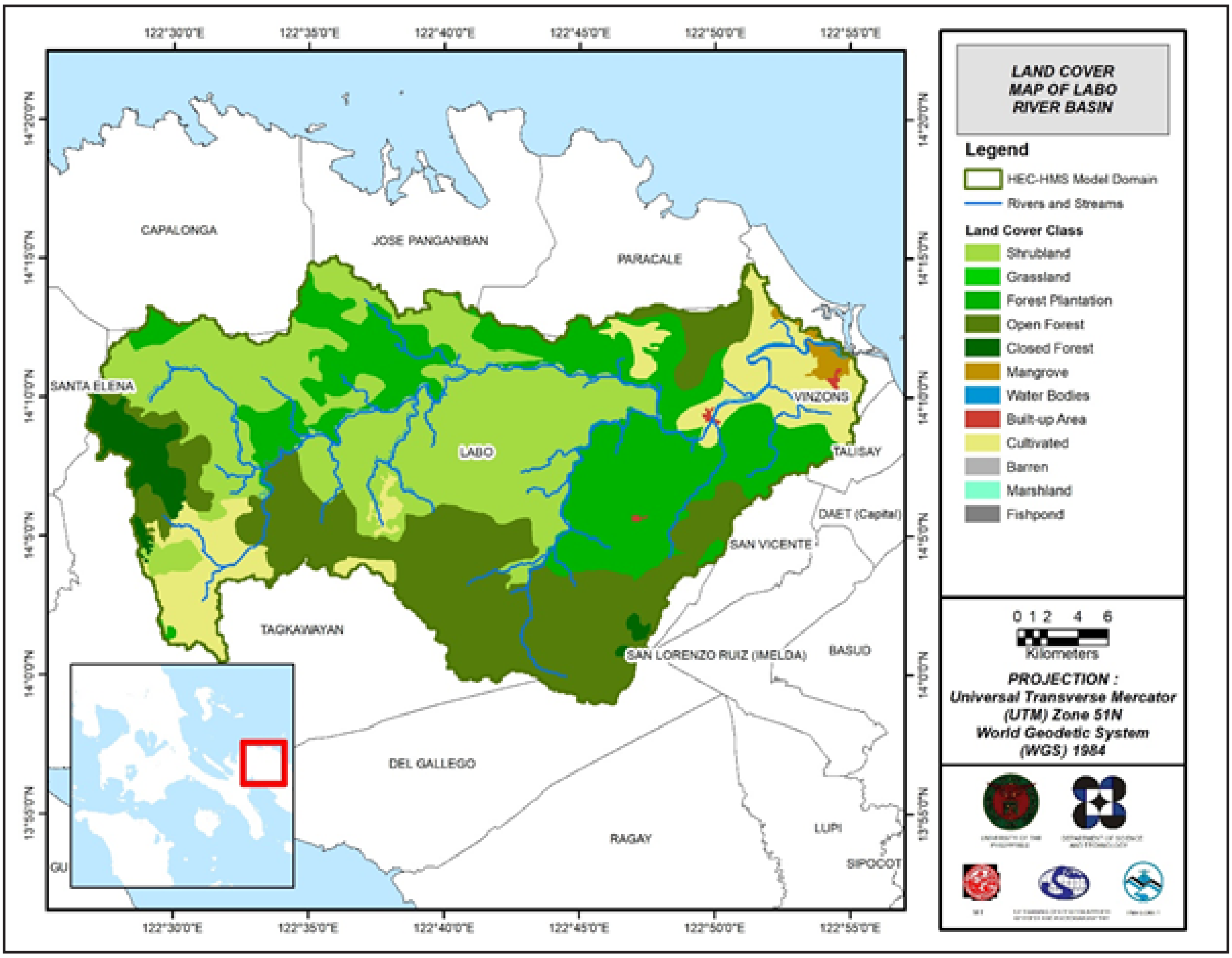


Figure 53. Land Cover Map of Labo River Basin

For Labo, the soil classes identified were clay loam, clay, hydrosol, loam, sandy clay loam, sandy loam, and silt loam. The land cover types identified were brushland, built-up, closed canopy, cultivated areas, inland water bodies, mangroves, open canopy forests, and tree plantations.

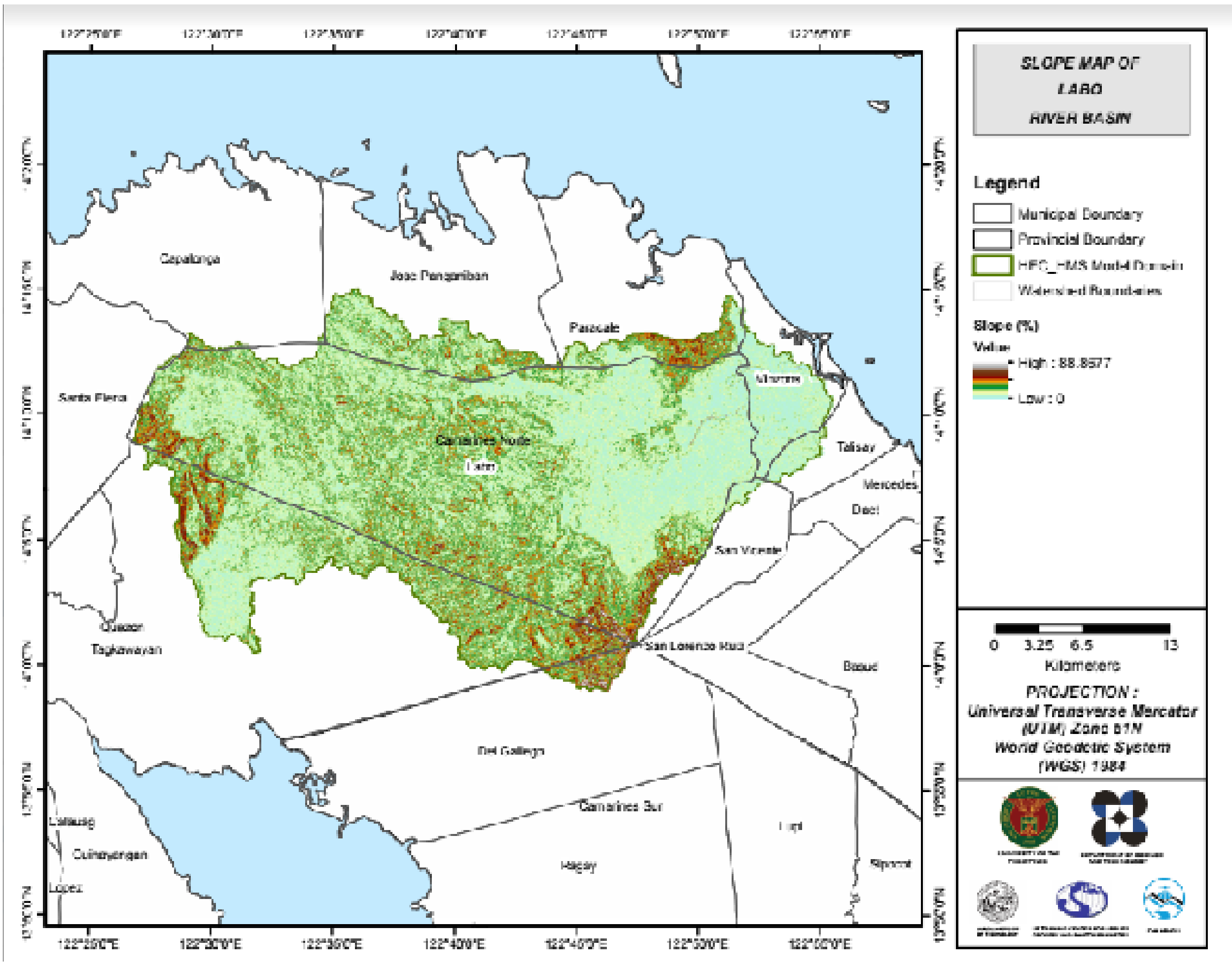


Figure 54. Slope map of Labo river basin

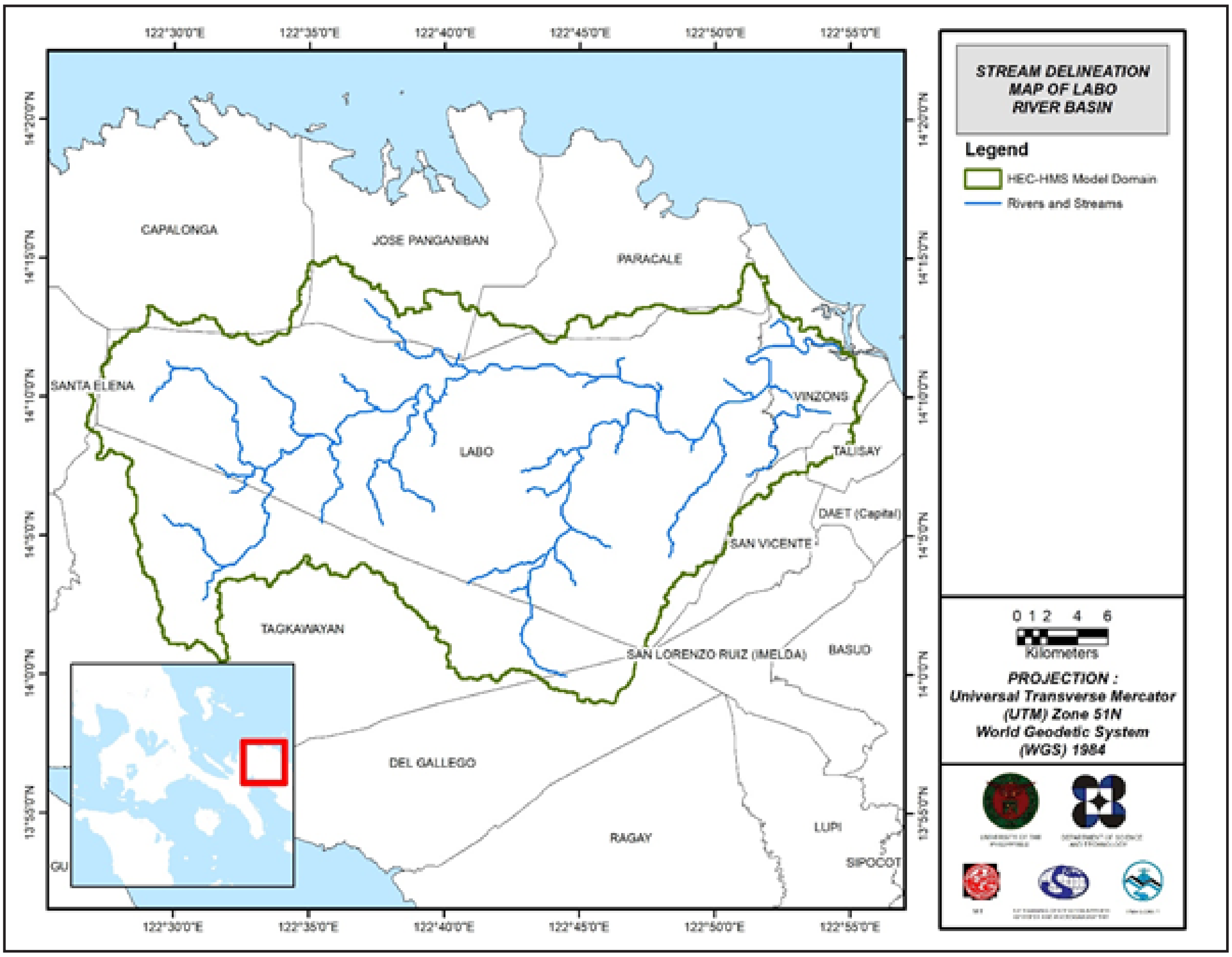


Figure 55. Stream delineation map of Labo river basin

Using the SAR-based DEM, the Labo basin was delineated and further subdivided into subbasins. The model consists of 93 sub basins, 46 reaches, and 46 junctions as shown in Figure 56. The main outlet is at Labo Bridge.

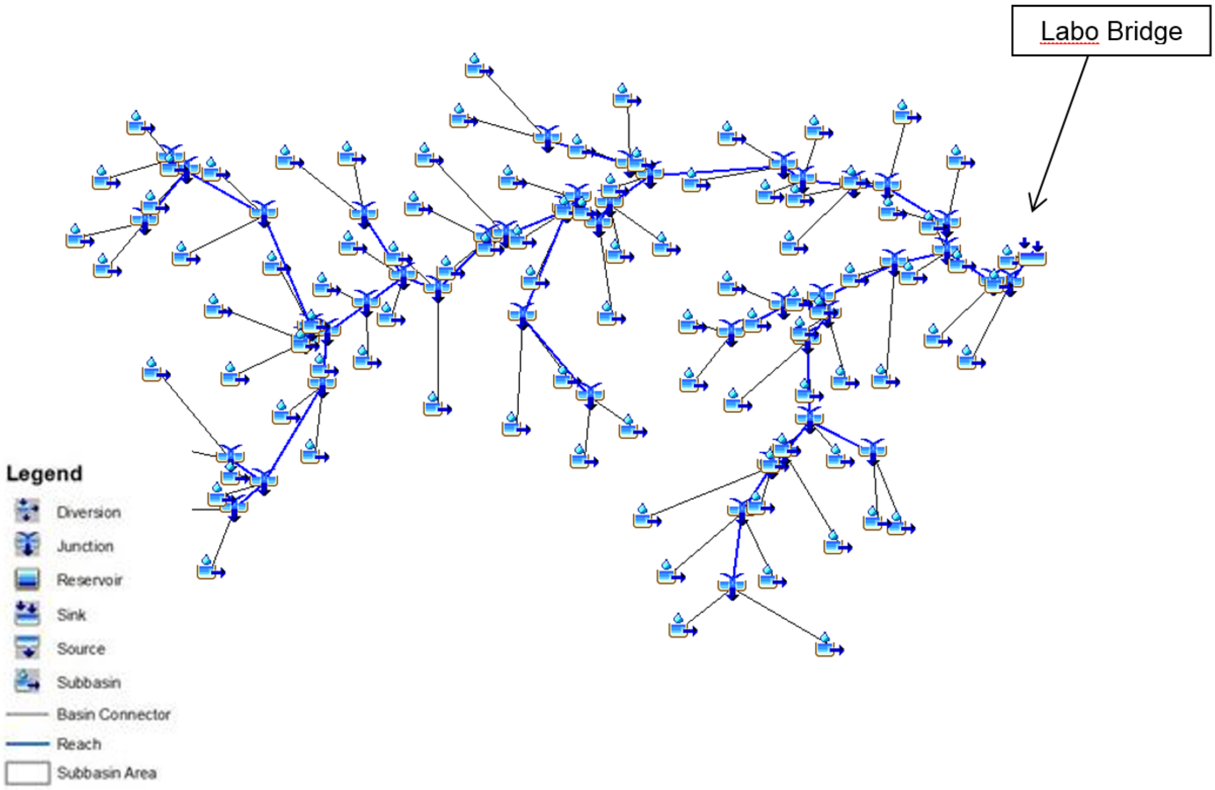


Figure 56. The Labo river basin model generated using HEC-HMS

5.4 Cross-section Data

The cross-section data is not available for this river basin.

5.5 Flo 2D Model

The automated modelling process allowed for the creation of a model with boundaries that are almost exactly coincidental with that of the catchment area. As such, they have approximately the same land area and location. The entire area was divided into square grid elements, 10 meter by 10 meter in size. Each element was 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 were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements and in eight directions (north, south, east, west, northeast, northwest, southeast, southwest).

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

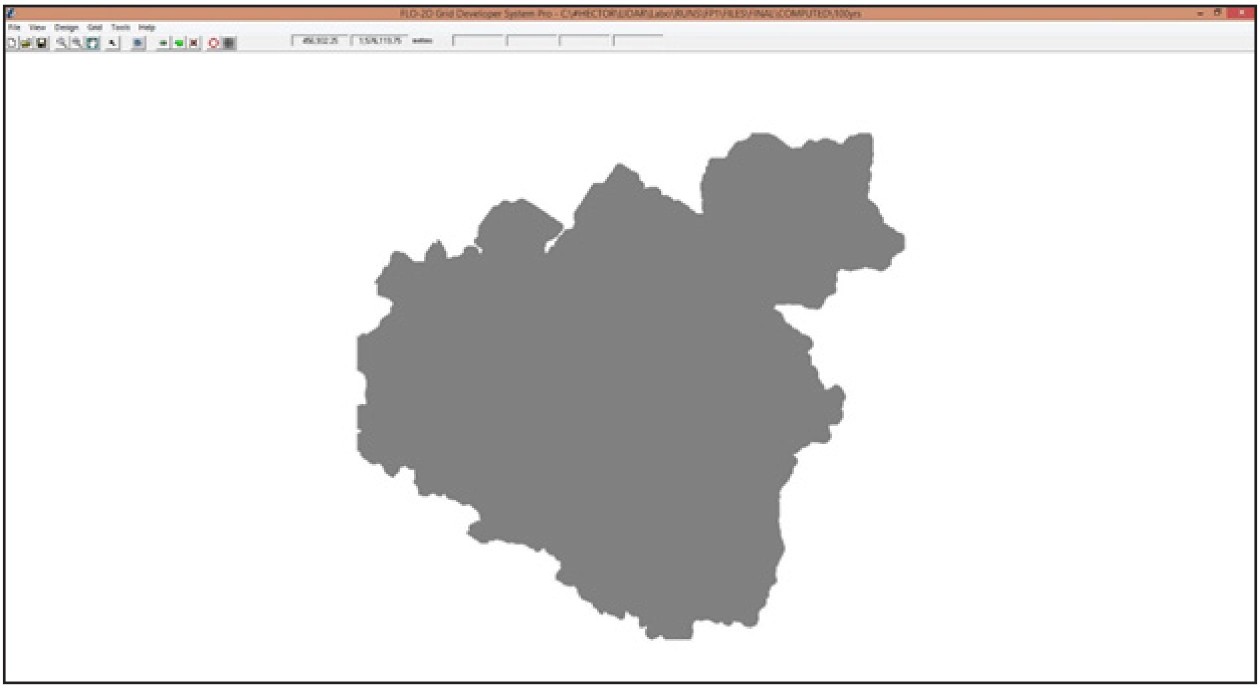


Figure 57. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation was then run through FLO-2D GDS Pro. This particular model had a computer run time of 107.81934 hours. After the simulation, FLO-2D Mapper Pro was used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

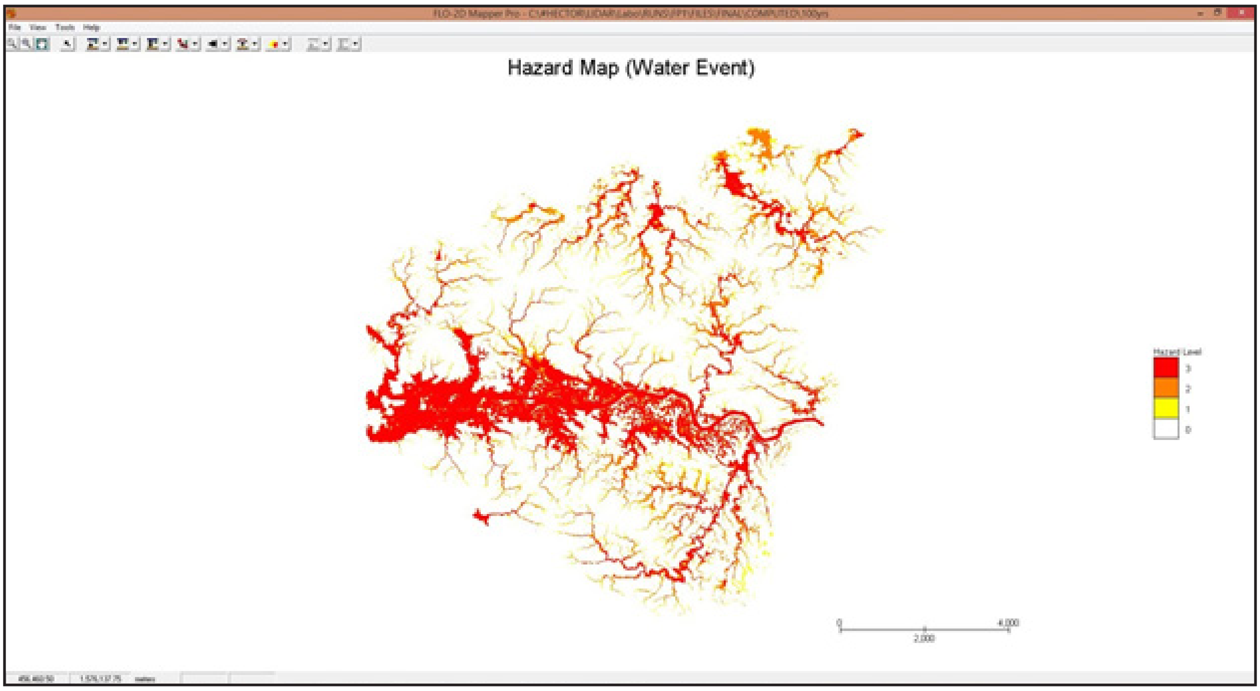


Figure 58. Generated 100-year rain return hazard map from FLO-2D Mapper

The creation of a flood hazard map from the model also automatically created a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts cover a maximum land area of 89856384.00 m2.

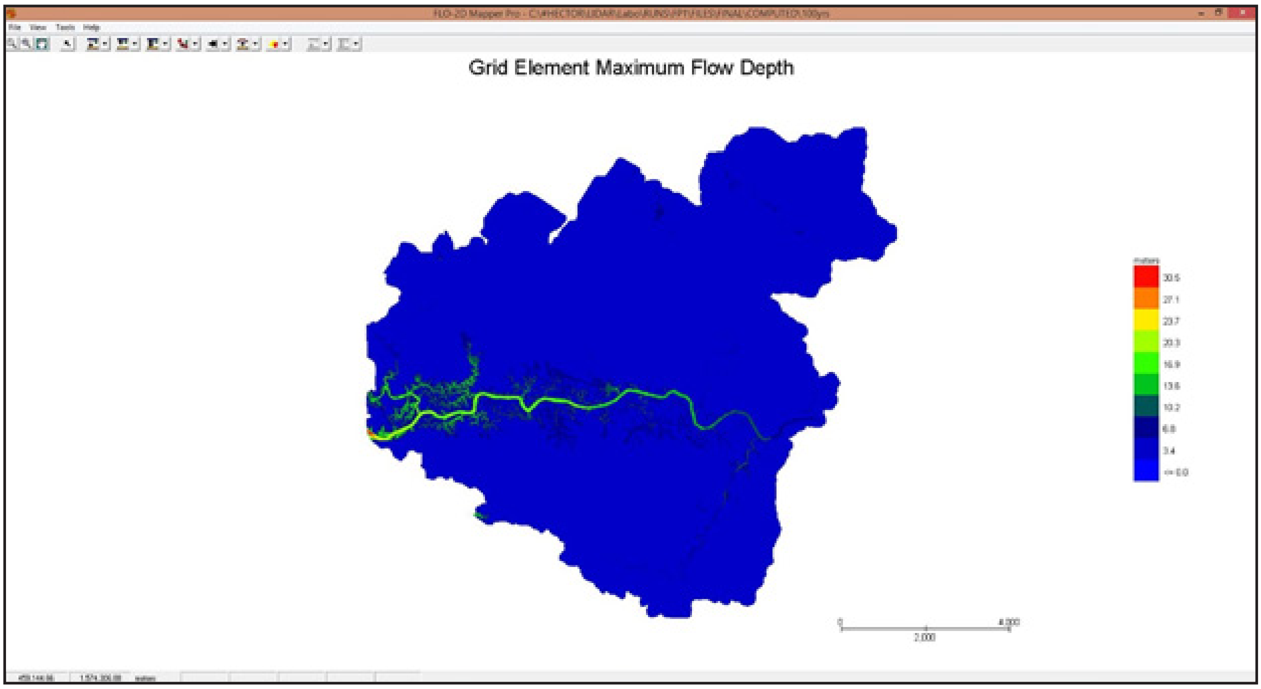


Figure 59. Generated 100-year rain return flow depth map from FLO-2D Mapper

5.6 Results of HMS Calibration

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

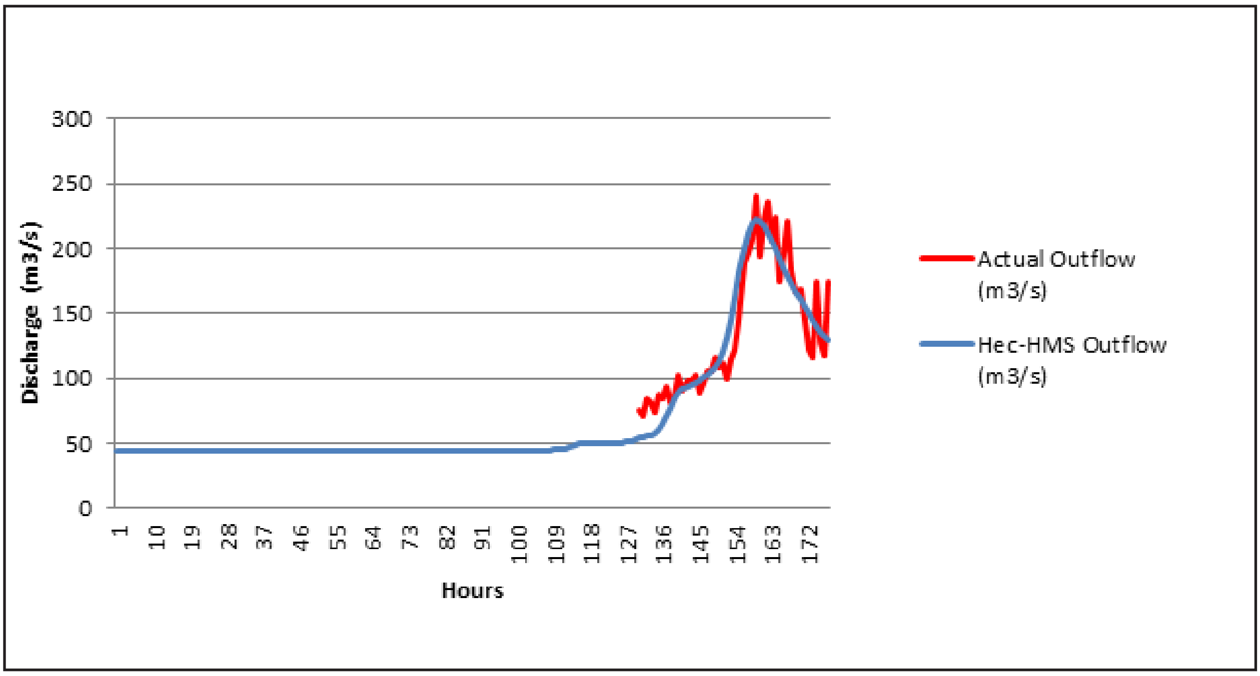


Figure 60. Outflow Hydrograph of Labo produced by the HEC-HMS model compared with observed outflow

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 Labo River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.26 – 24.60
			Curve Number	35.013 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.10 – 2.95
			Storage Coefficient (hr)	0.017 – 21.00
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.05
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.010 – 0.069

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 0.26mm to 24.60mm 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. Curve numbers for the watershed's subbasins range from 35.013 to 99.For Labo, the soil classes identified were clay loam, clay, hydrosol, loam, sandy clay loam, sandy loam, and silt loam. The land cover types identified were brushland, built-up, closed canopy, cultivated areas, inland water bodies, mangroves, open canopy forests, and tree plantations.

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 0.017 hours to 21 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. The Recession Constant for the basin is 1 while the Ratio to Peak is 0.05.

Manning's roughness coefficient of 0.010 – 0.069 corresponds to the common roughness in Labo watershed.

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

Accuracy measure	Value
RMSE	20.86
r2	0.99
NSE	0.81
PBIAS	2.95
RSR	0.44

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 20.86 (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 3.9.

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 0.81.

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 2.95.

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 0.44.

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 65) shows the Labo outflow using the Tacloban RIDF cruves in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAG-ASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

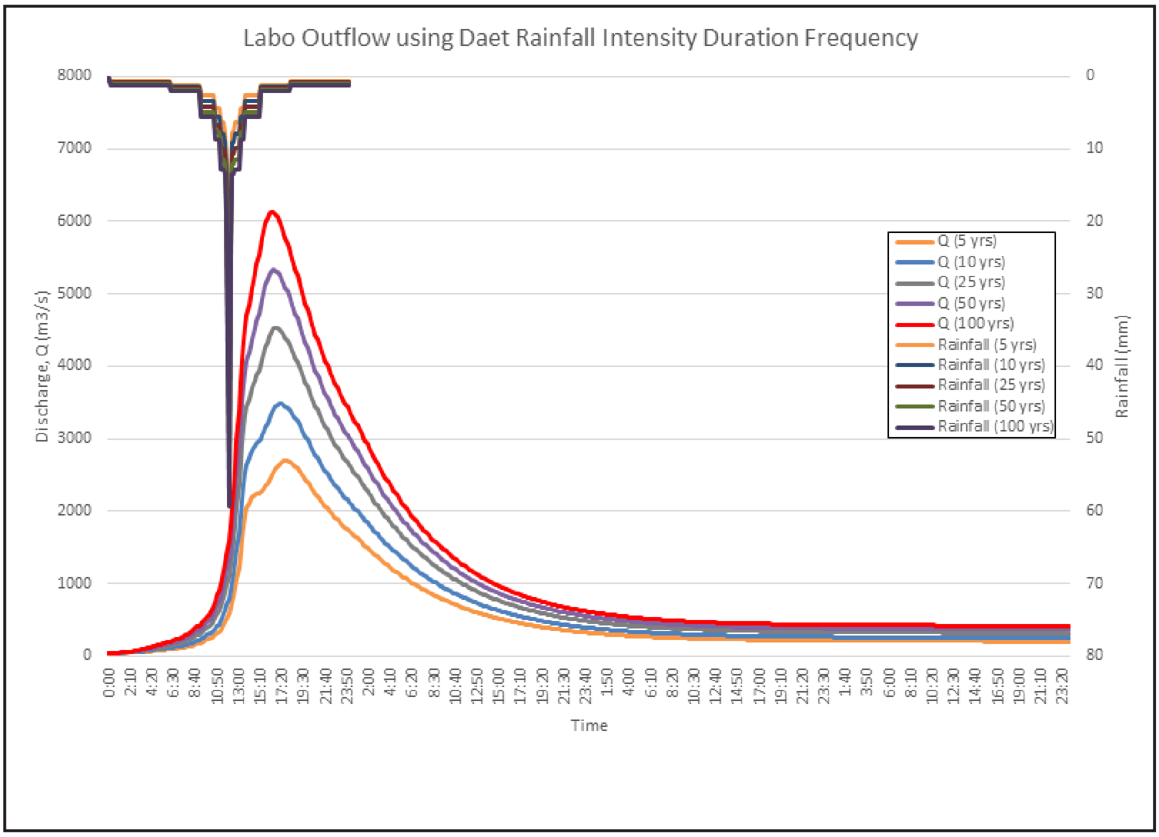


Figure 61. Outflow hydrograph at Labo Station generated using Daet RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Labo discharge using the Daet RIDF curves in five different return periods is shown in Table 32.

Table 32. Peak values of the Labo HEC-HMS Model outflow using the Tacloban RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	278.7	31.8	2693	18 hours, 30 minutes
10-Year	337.2	38.5	3483.4	17 hours,10 minutes
25-Year	411.1	46.9	4532.3	16 hours, 40 minutes
50-Year	465.9	53.2	5330.2	16 hours, 30 minutes
100-Year	520.3	59.4	6134.2	16 hours, 20 minutes

5.7.2 Discharge Data Using Dr. Horritt's Recommended Hydrologic Method

The river discharge values for the ninerivers entering the floodplain are shown in Figure 62 to Figure 65 and the peak values are summarized in Table 33 to Table 38.

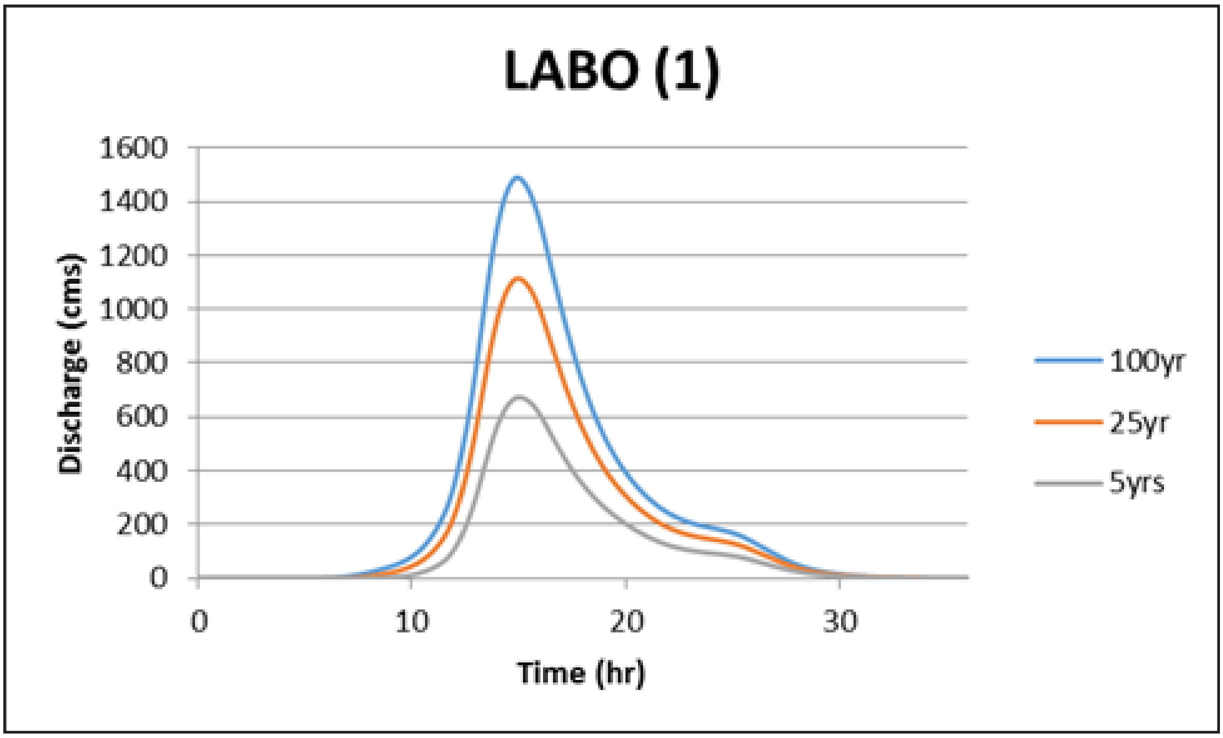


Figure 62. Labo river (1) generated discharge using 5-, 25-, and 100-year Daet rainfall intensity-duration-frequency (RIDF) in HEC-HMS

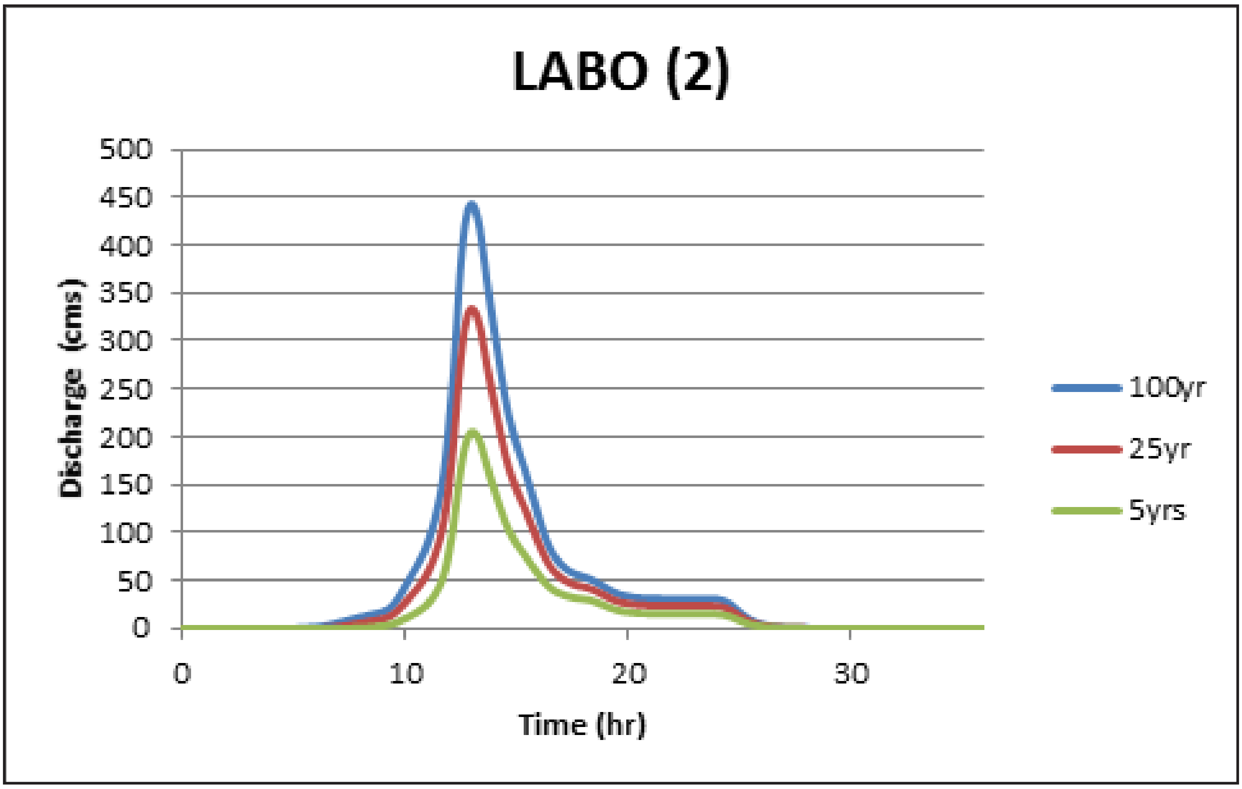


Figure 63. Labo river (2) generated discharge using 5-, 25-, and 100-year Daet rainfall intensity-duration-frequency (RIDF) in HEC-HMS

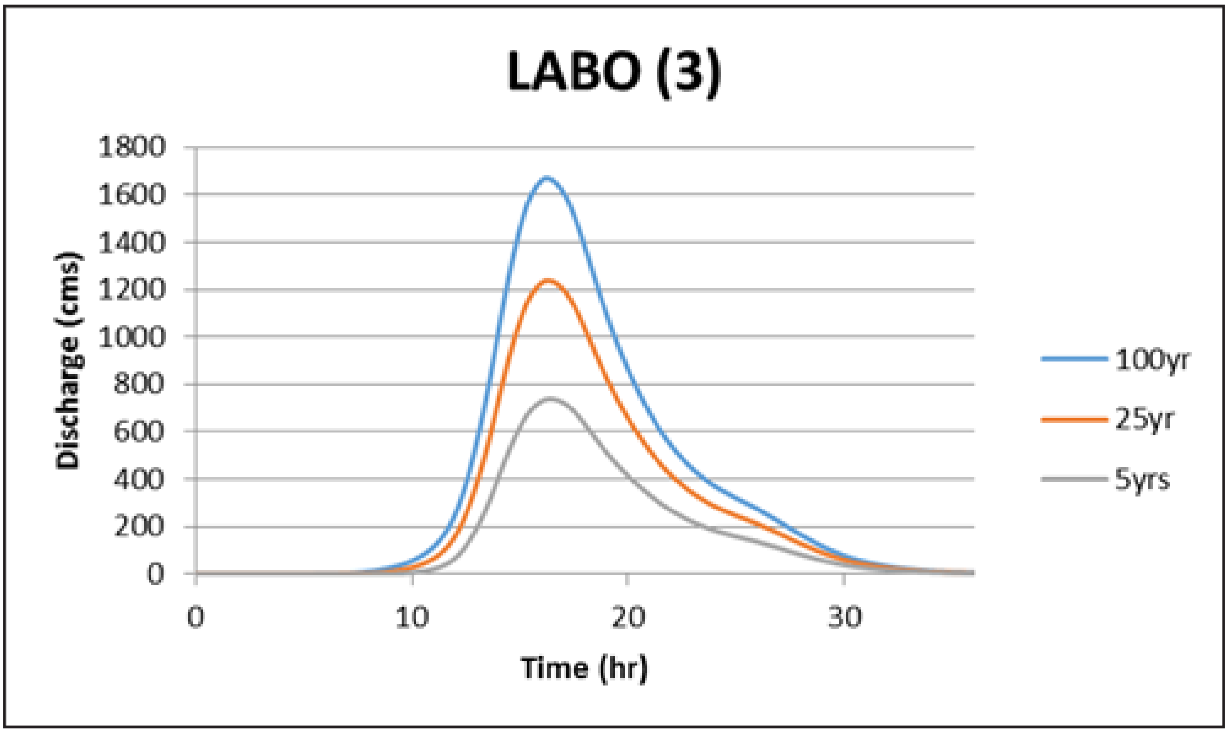


Figure 64. Labo river (3) generated discharge using 5-, 25-, and 100-year Daet rainfall intensity-duration-frequency (RIDF) in HEC-HMS

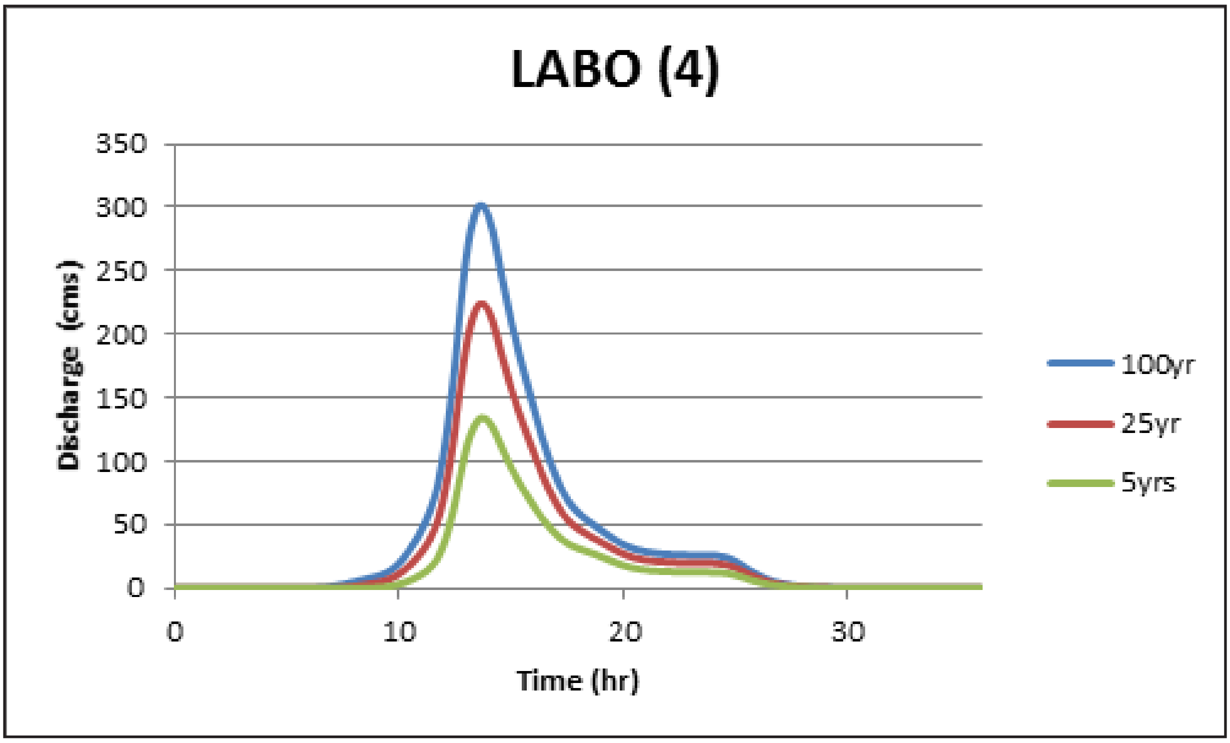


Figure 65. Labo river (4) generated discharge using 5-, 25-, and 100-year Daet rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 33. Summary of Labo river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1487.9	15 hours
25-Year	1113.8	15 hours
5-Year	674.2	15 hours

Table 34. Summary of Labo river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	4428.8	13 hours
25-Year	333.7	13 hours
5-Year	205	13 hours

Table 35. Summary of Labo river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1669.1	16 hours, 10 minutes
25-Year	1238.3	16 hours, 20 minutes
5-Year	739	16 hours, 20 minutes

Table 36. Summary of Labo river (4) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	301.7	13 hours, 40 minutes
25-Year	224.3	13 hours, 40 minutes
5-Year	134	13 hours, 40 minutes

Table 37. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Labo (1)	593.296	947.279	643.461	PASS	PASS
Labo (2)	180.400	2.215	208.291	FAIL	PASS
Labo (3)	650.320	355.234	808.105	FAIL	PASS
Labo (4)	117.920	0.719	185.643	FAIL	PASS

Only one from the HEC-HMS river discharge estimates was able to satisfy the conditions for validation using the bankful and specific discharge methods. Three estimates passed the conditions for validation only using the specific discharge method and these three did not pass bankful discharge methods and will need further recalculation. The passing values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

The RAS model simulation is not available for this river basin.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 66 to Figure 71 shows the 100-, 25-, and 5-year rain return scenarios of the Labo Floodplain. The floodplain, with an area of 408.08 sq. km., covers six municipalites namely Talisay, Labo and Vinzons. Table 38 shows the percentage of area affected by flooding per municipality.

Table 38. Municipalities affected in Labo Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Talisay	31.83	18.62	58.50%
Labo	628.22	188.11	29.94%
Paracale	157.3	62.61	39.80%
Vinzons	94.051	61.97	65.89%
Daet	50.19	5.92	11.79%
San Vicente	51.97	23.20	44.63%

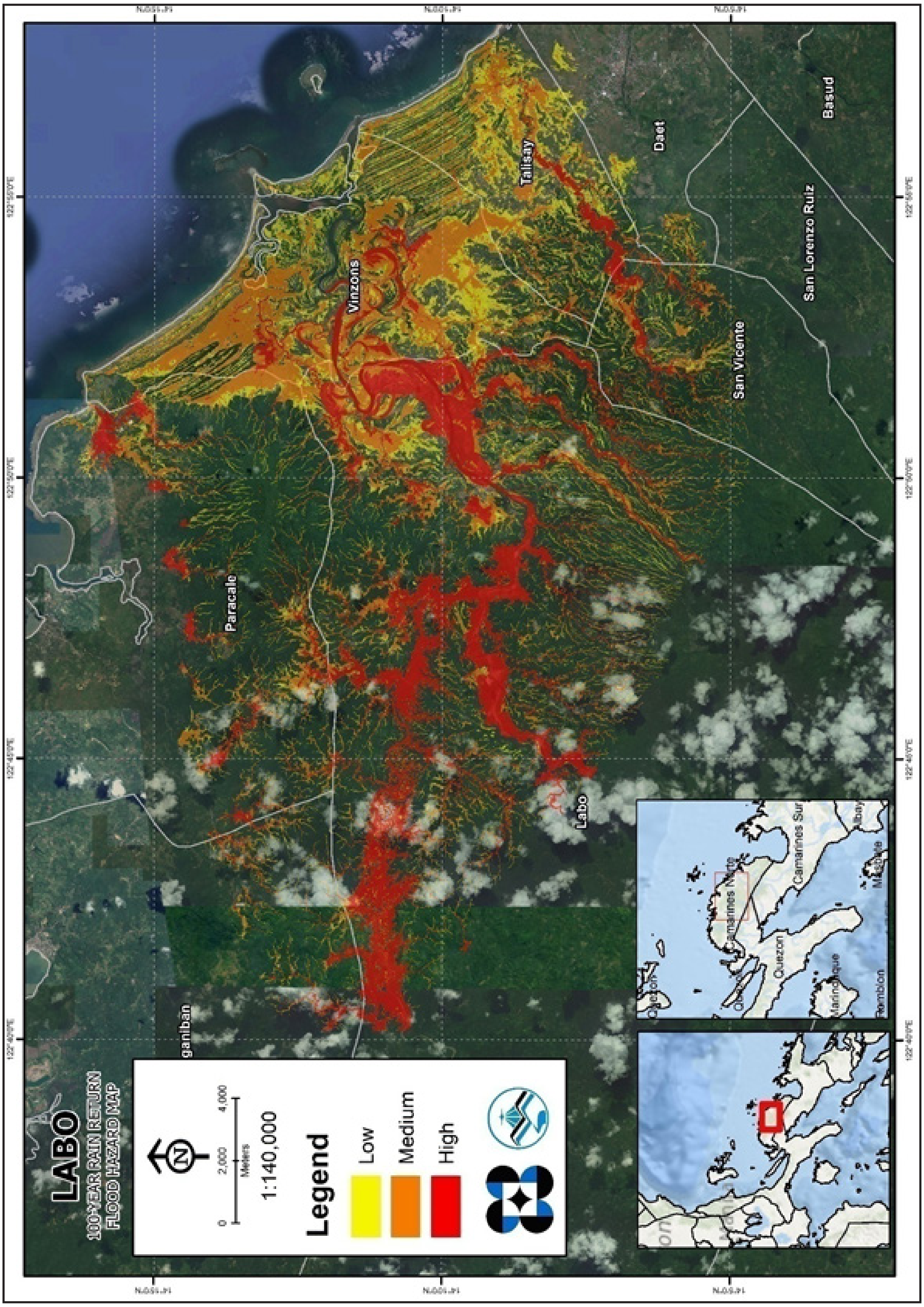


Figure 66. 100-year Hazard Map for Labo Floodplain

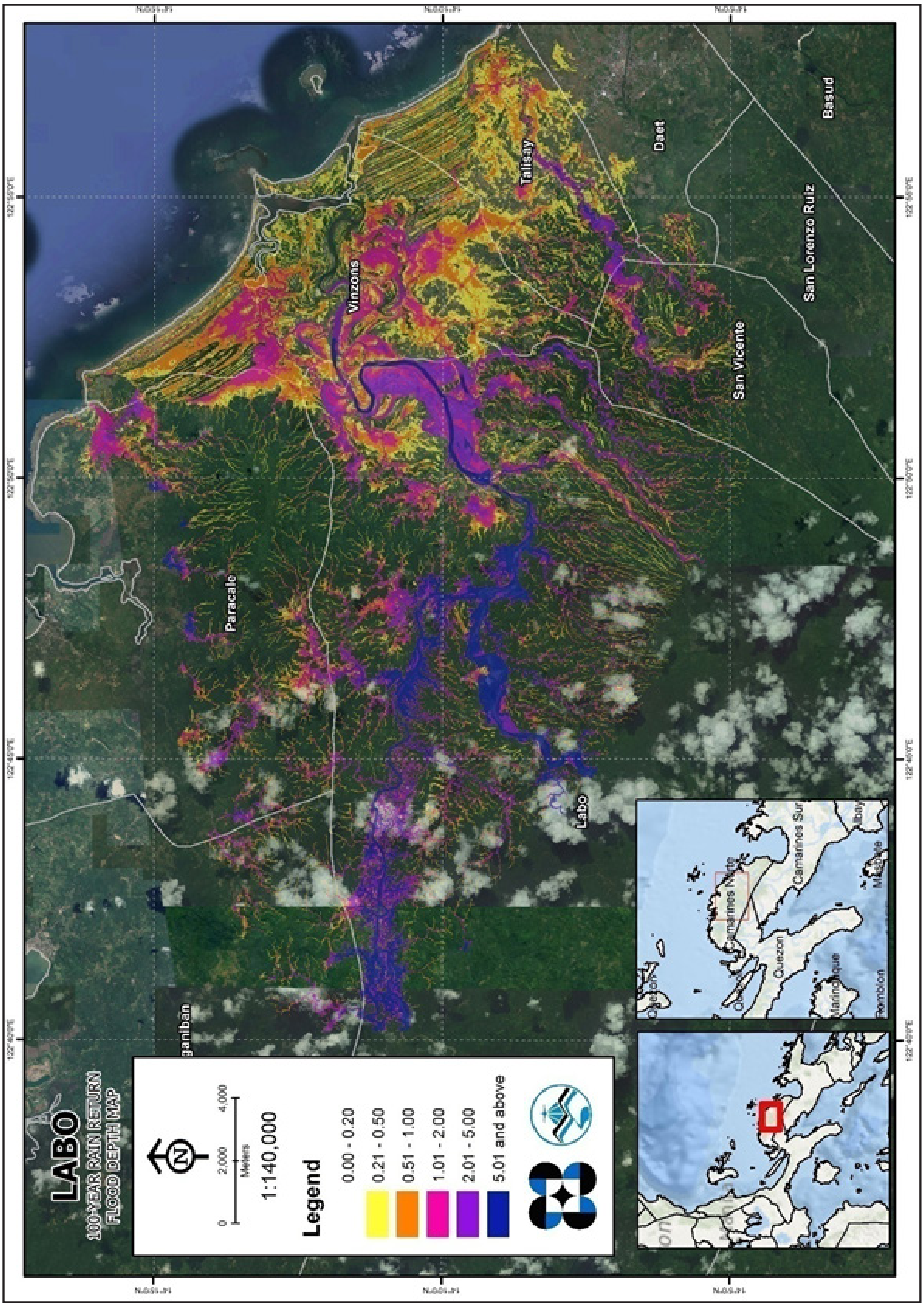


Figure 67. 100-year Flow Depth Map for Labo Floodplain

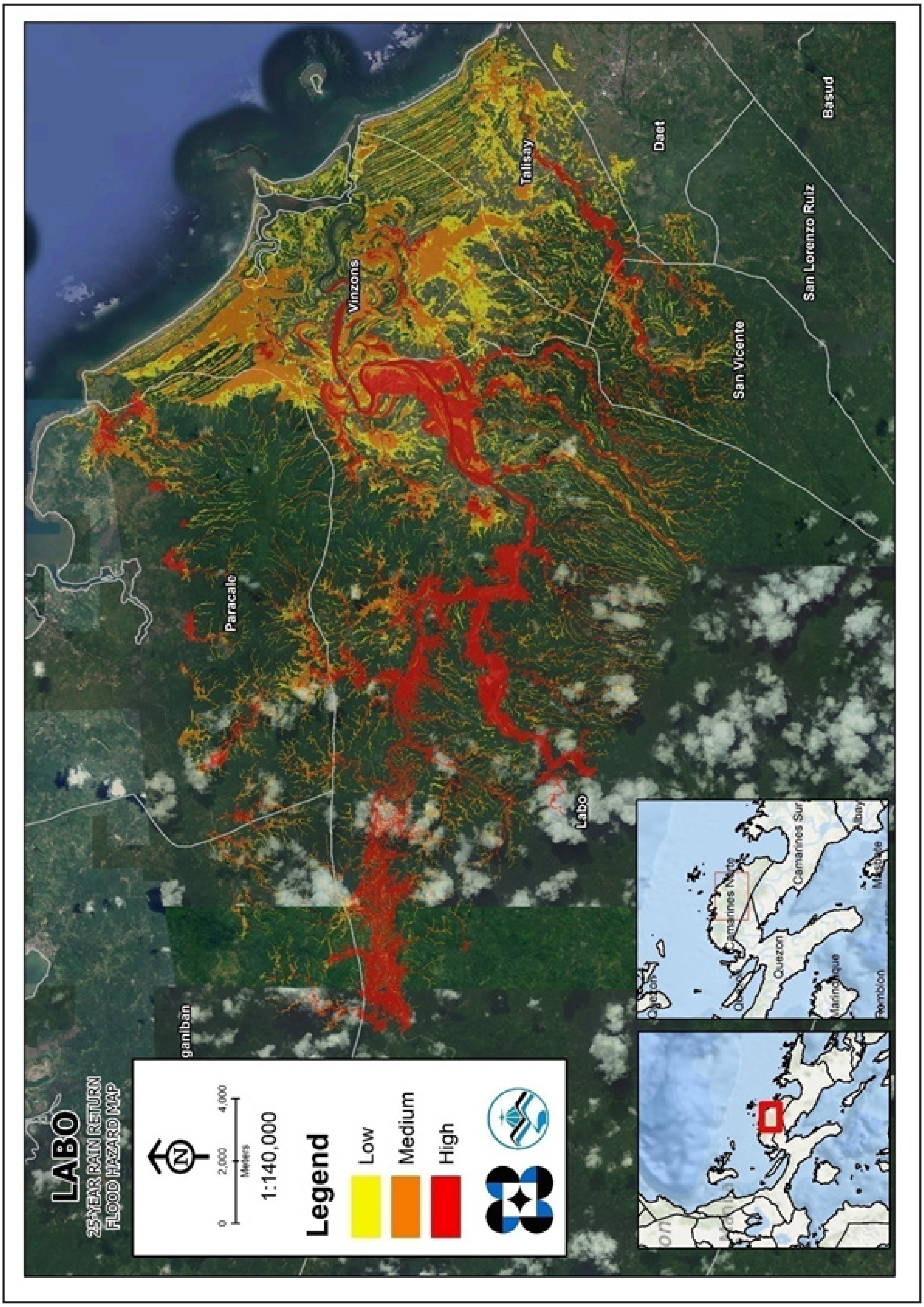


Figure 68. 25-year Hazard Map for Labo Floodplain

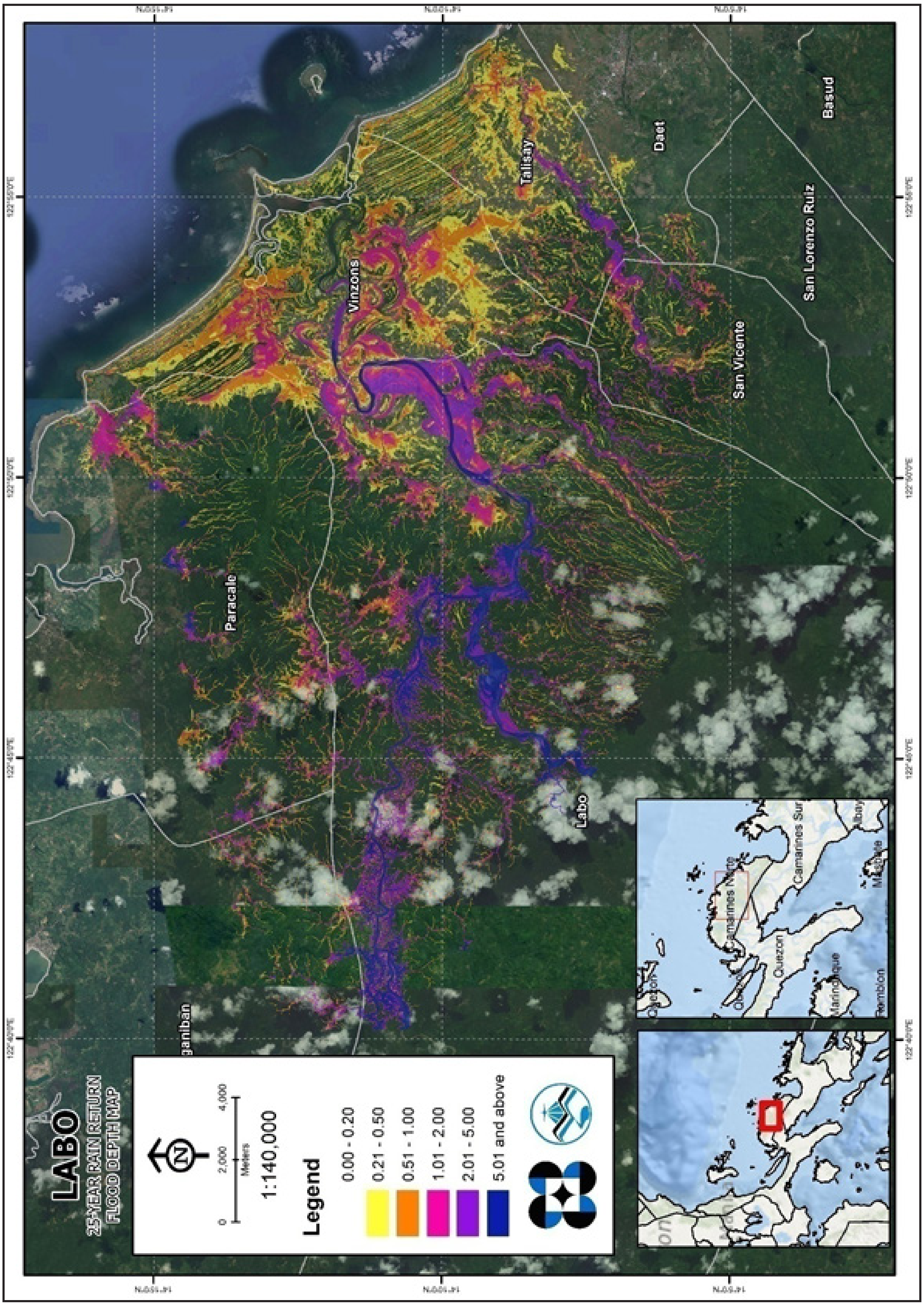


Figure 69. 25-year Flow Depth Map for Labo Floodplain

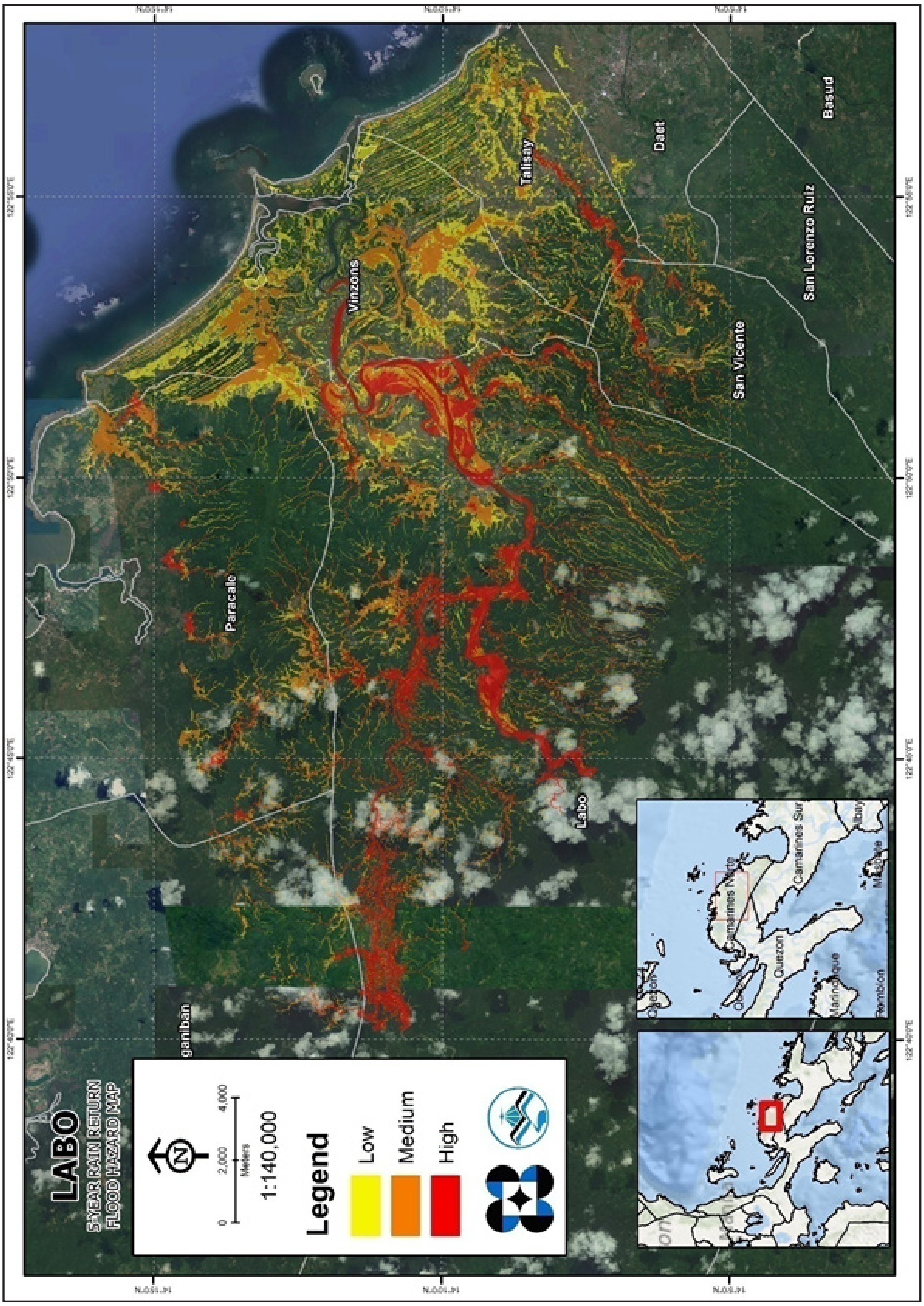


Figure 70. 5-year Hazard Map for Labo Floodplain

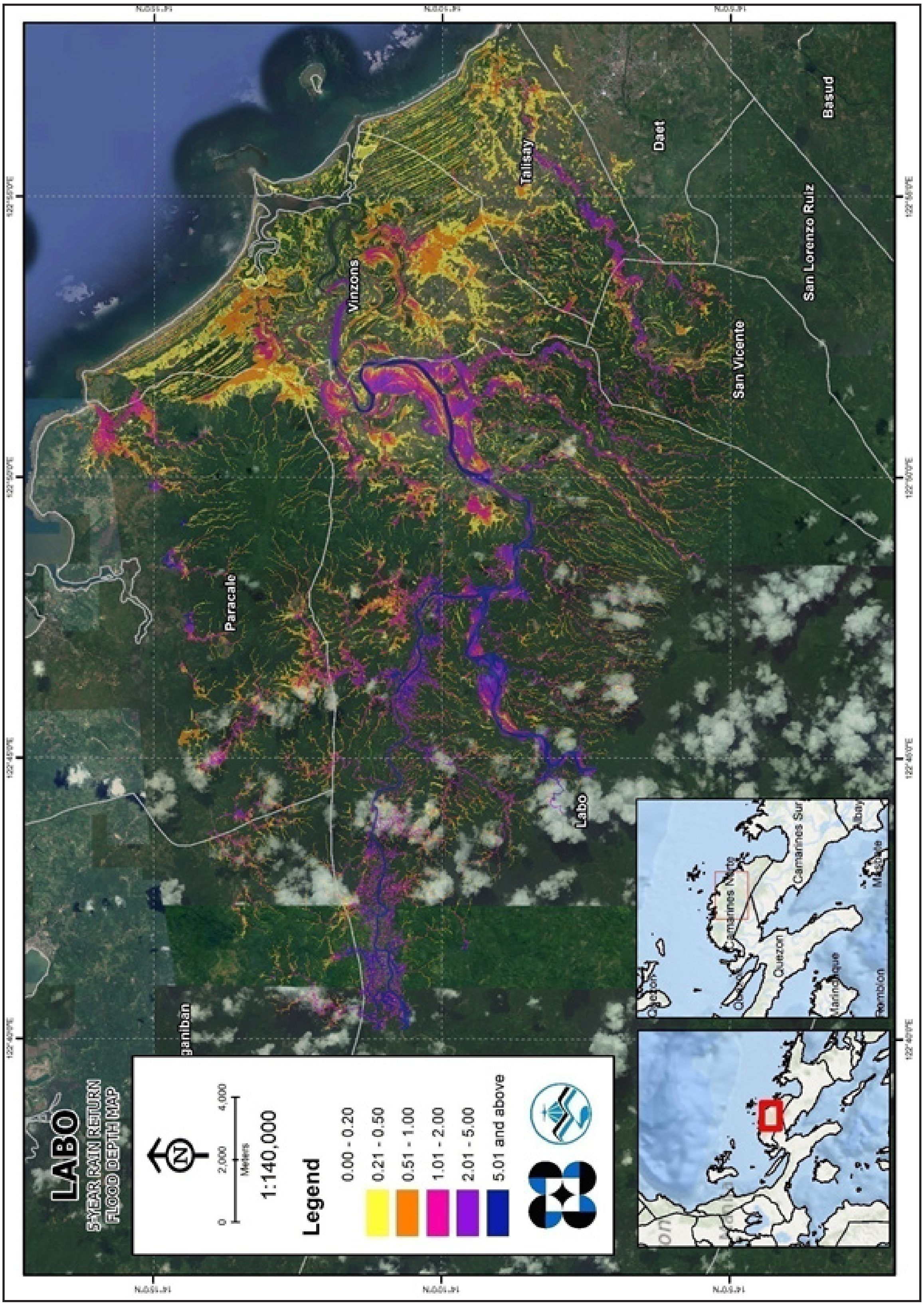


Figure 71. 5-year Flow Depth Map for Labo Floodplain

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Labo River Basin, grouped accordingly by municipality. For the said basin, six (6) municipalities consisting of 97 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 22.15% of the municipality of Labo with an area of 628.2236 sq. km. will experience flood levels of less than 0.20 meters; 1.73% of the area will experience flood levels of 0.21 to 0.50 meters while 1.61%, 1.74%, 1.73%, and 0.99% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 to Table 42 are the affected areas in square kilometers by flood depth per barangay.

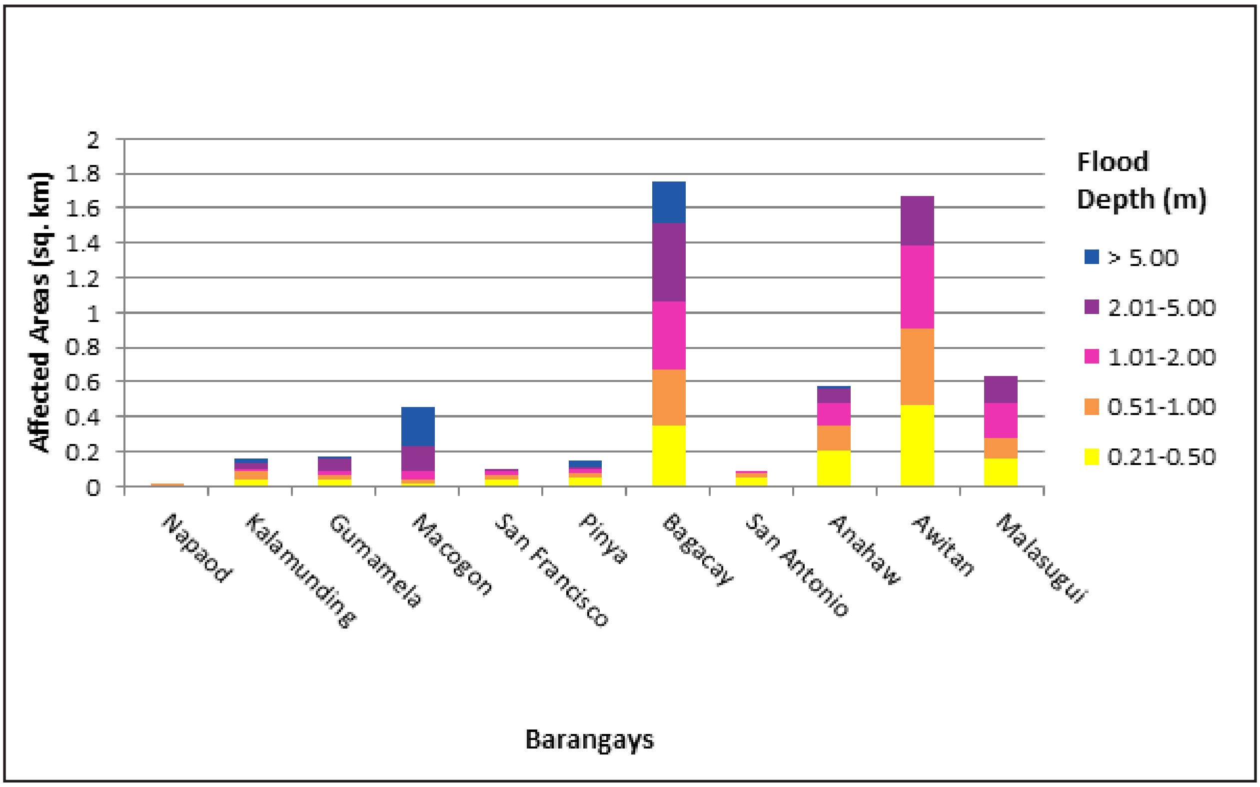


Figure 72. Affected areas in Labo, Camarines Norte during a 5-Year Rainfall Return Period. (1)

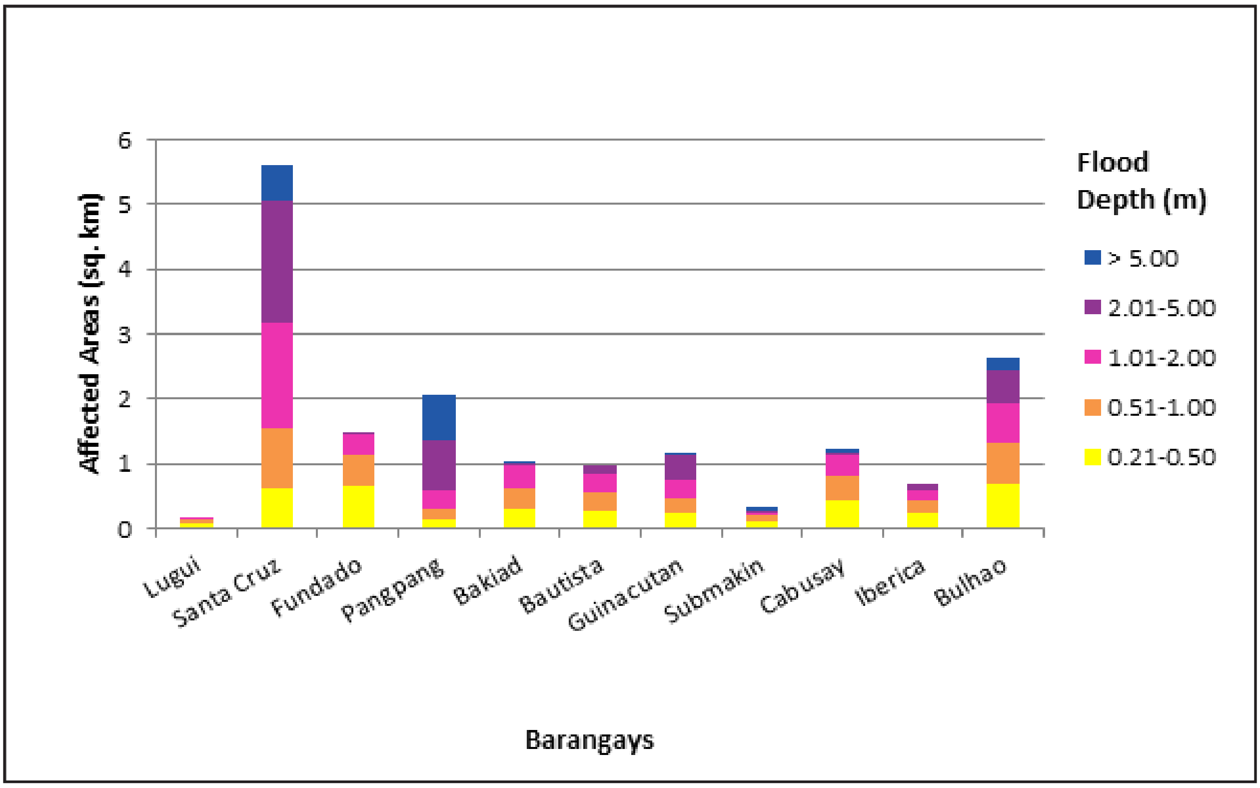


Figure 73. Affected areas in Labo, Camarines Norte during a 5-Year Rainfall Return Period. (2)

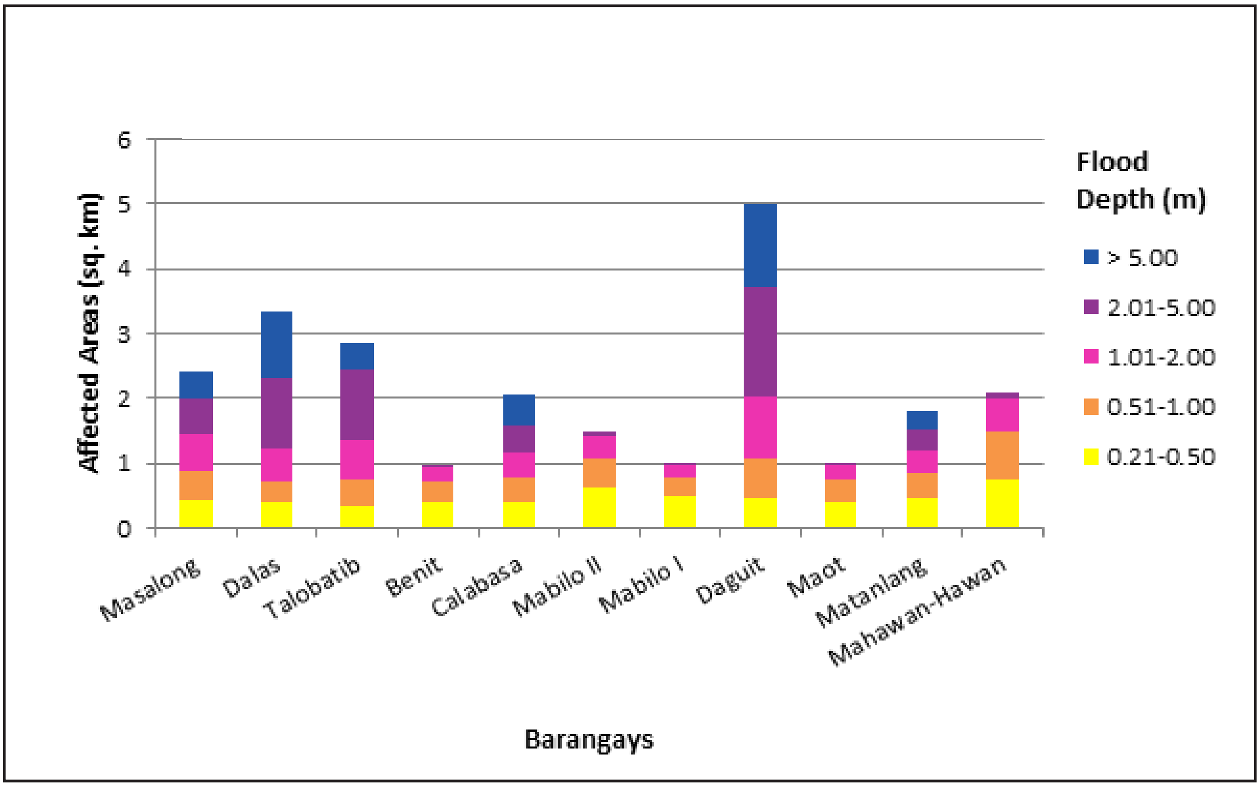


Figure 74. Affected areas in Lobo, Batangas during a 5-Year Rainfall Return Period.

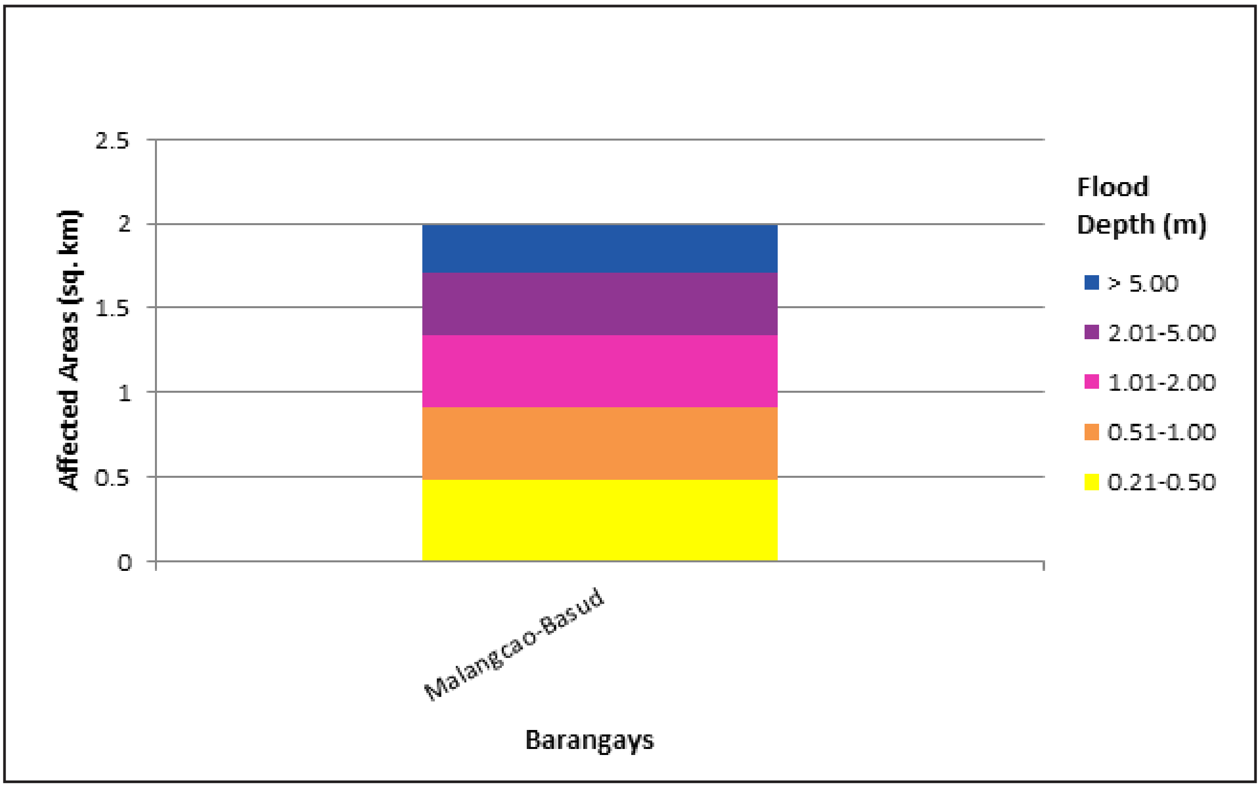


Figure 75. Affected areas in Labo, Camarines Norte during a 5-Year Rainfall Return Period. (4)

Table 39. Affected areas in Labo, Camarines Norte during a 5-Year Rainfall Return Period (1)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labo (in sq. km.)										
	Napaod	Kalamunding	Gumamela	Macogon	San Francisco	Pinya	Bagacay	San Antonio	Anahaw	Awitan	Malasugui
1	0.045	0.43	0.52	0.61	0.63	0.67	1.25	1.32	1.57	1.66	1.71
2	0.002	0.041	0.037	0.016	0.038	0.056	0.35	0.055	0.21	0.47	0.16
3	0.0005	0.049	0.028	0.026	0.025	0.026	0.32	0.027	0.14	0.44	0.12
4	0	0.011	0.02	0.05	0.023	0.013	0.4	0.0076	0.13	0.47	0.2
5	0	0.04	0.072	0.14	0.0004	0.011	0.45	0	0.084	0.29	0.15
6	0	0.023	0.0009	0.23	0	0.038	0.23	0	0.0085	0	0

Table 40. Affected areas in Labo, Camarines Norte during a 5-Year Rainfall Return Period (2)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labo (in sq. km.)										
	Lugui	Santa Cruz	Fundado	Pangpang	Bakiad	Bautista	Guinacutan	Submakin	Cabusay	Iberica	Bulhao
1	1.73	2.33	2.35	2.45	2.9	3.43	3.8	4.03	4.11	4.32	4.66
2	0.092	0.62	0.66	0.13	0.3	0.28	0.25	0.12	0.43	0.23	0.68
3	0.036	0.92	0.46	0.17	0.32	0.28	0.21	0.079	0.38	0.21	0.63
4	0.0084	1.64	0.33	0.3	0.34	0.29	0.28	0.05	0.31	0.16	0.62
5	0	1.88	0.034	0.75	0.041	0.12	0.39	0.034	0.037	0.074	0.5
6	0	0.54	0	0.7	0.0027	0	0.0067	0.044	0.055	0	0.21

Table 41. Affected areas in Labo, Camarines Norte during a 5-Year Rainfall Return Period (3)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labo (in sq. km.)										
	Masalong	Dalas	Talobatib	Benit	Calabasa	Mabilo II	Mabilo I	Daguit	Maot	Matanlang	Mahawan-Hawan
1	5.29	6.55	6.57	6.99	7.16	7.32	7.47	7.97	8.13	8.6	9.49
2	0.44	0.4	0.34	0.39	0.39	0.61	0.49	0.46	0.41	0.46	0.74
3	0.45	0.33	0.42	0.34	0.39	0.45	0.3	0.61	0.35	0.38	0.74
4	0.55	0.51	0.59	0.21	0.39	0.35	0.17	0.96	0.2	0.36	0.52
5	0.54	1.06	1.08	0.038	0.41	0.081	0.057	1.69	0.049	0.31	0.075
6	0.42	1.02	0.43	0	0.47	0	0	1.26	0	0.28	0

Table 42. Affected areas in Labo, Camarines Norte during a 5-Year Rainfall Return Period (4)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labo (in sq. km.)
	Malangcao-Basud
1	9.76
2	0.48
3	0.43
4	0.43
5	0.37
6	0.28

For the 5-year return period, 32.43% of the municipality of Paracale with an area of 157.3 sq. km. will experience flood levels of less than 0.20 meters; 2.83% of the area will experience flood levels of 0.21 to 0.50 meters while 2.51%, 1.52%, 0.40%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 43 to Table 44 are the affected areas in square kilometers by flood depth per barangay.

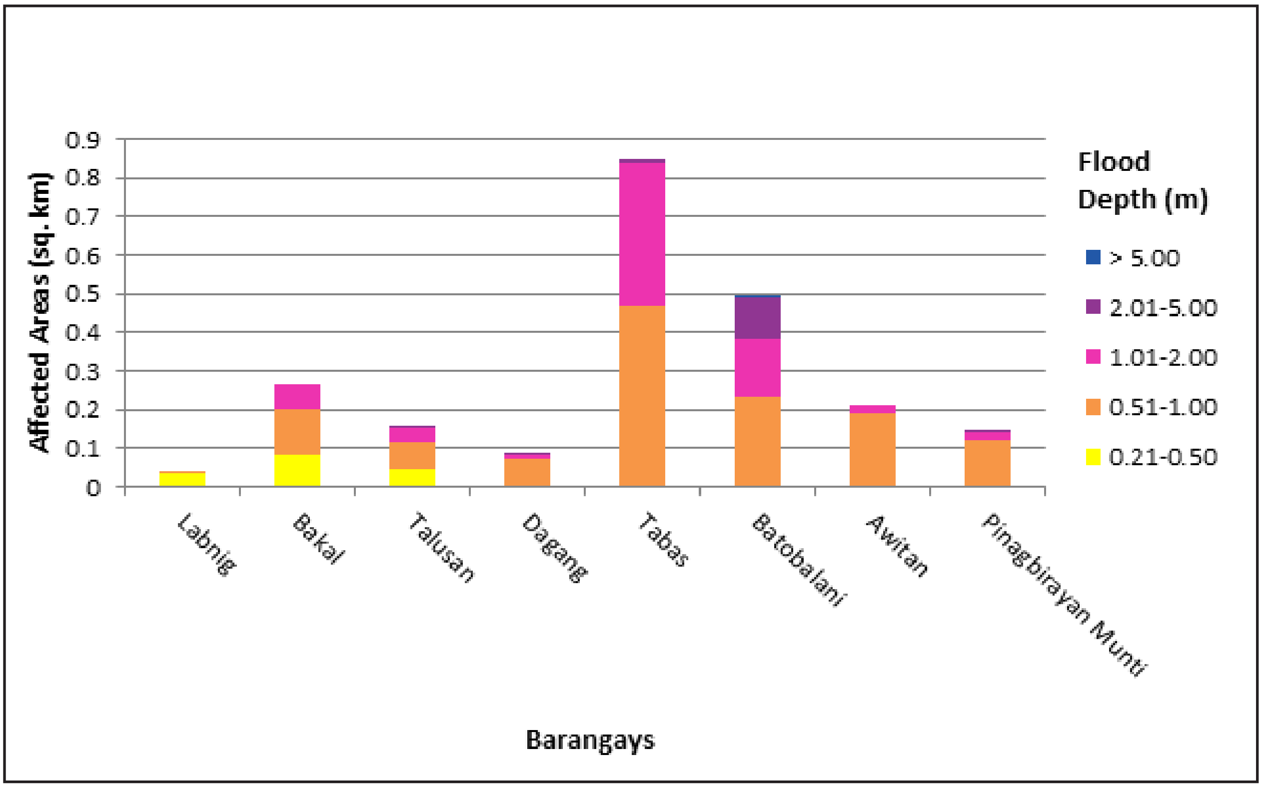


Figure 76. Areas affected by flooding in Paracale, Camarines Norte for a 5-Year Return Period rainfall event. (1)

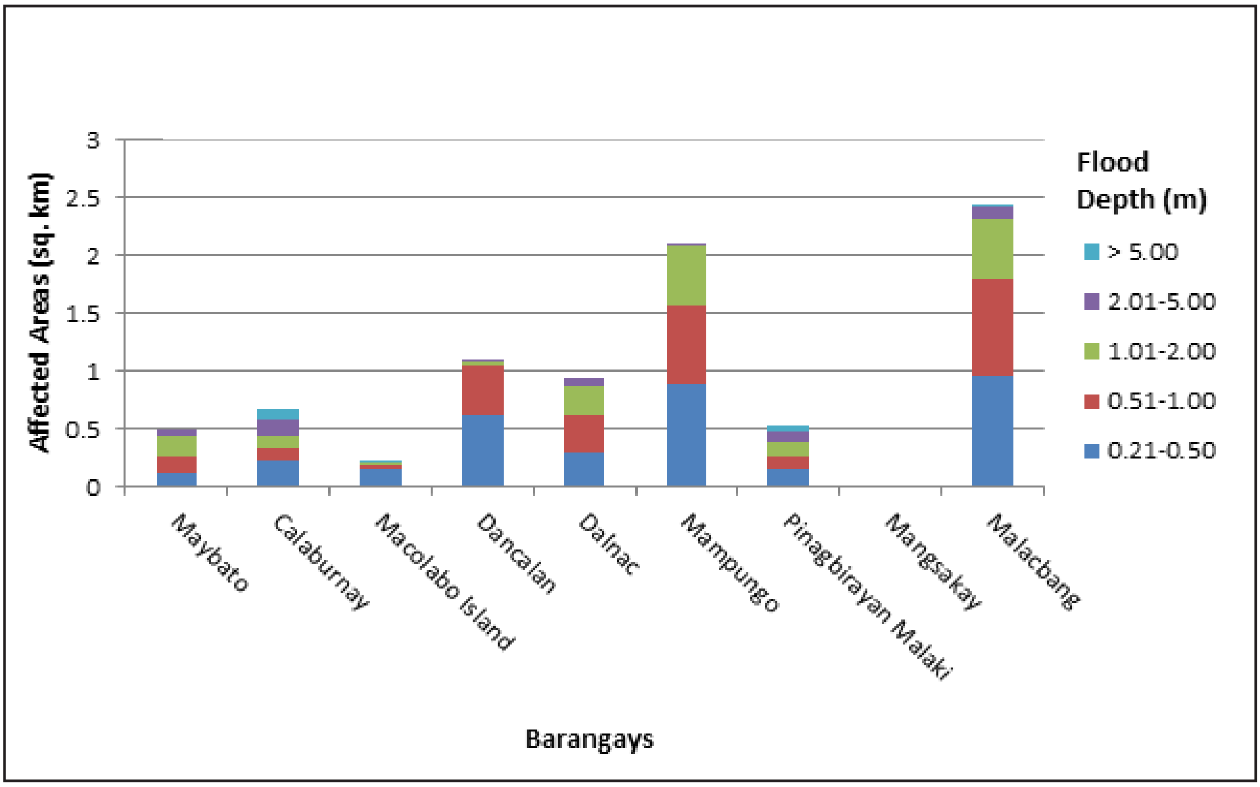


Figure 77. Areas affected by flooding in Paracale, Camarines Norte for a 5-Year Return Period rainfall event. (2)

Table 43. Affected areas in Paracale, Camarines Norte during a 5-Year Rainfall Return Period. (1)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Paracale (in sq. km.)							
	Labnig	Bakal	Talusan	Dagang	Tabas	Batobalani	Awitan	Pinagbirayan Munti
1	0.24	0.48	0.77	1.19	1.51	1.64	1.75	2.22
2	0.032	0.081	0.044	0.091	0.25	0.15	0.29	0.13
3	0.0012	0.12	0.069	0.074	0.47	0.23	0.19	0.12
4	0	0.066	0.037	0.0071	0.37	0.15	0.023	0.021
5	0	0	0.0024	0.0007	0.011	0.11	0	0.0003
6	0	0	0	0	0	0.0009	0	0

Table 44. Affected areas in Paracale, Camarines Norte during a 5-Year Rainfall Return Period. (2)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Paracale (in sq. km.)								
	Maybato	Calaburnay	Macolabo Island	Dancalan	Dalnac	Mampungo	Pinagbirayan Malaki	Mangsakay	Malacbang
1	2.47	2.88	3.83	4.22	4.4	4.59	4.87	0	13.96
2	0.12	0.22	0.15	0.61	0.29	0.89	0.15	0	0.96
3	0.14	0.11	0.039	0.44	0.32	0.67	0.11	0	0.84
4	0.17	0.11	0.0073	0.028	0.25	0.52	0.12	0	0.51
5	0.065	0.13	0.0018	0.0012	0.082	0.013	0.1	0	0.11
6	0	0.092	0.0011	0	0	0	0.044	0	0.0077

For the 5-year return period, 79.67% of the municipality of Talisay with an area of 31.83 sq. km. will experience flood levels of less than 0.20 meters; 22.65% of the area will experience flood levels of 0.21 to 0.50 meters while 7.75%, 3.15%, 2.47%, and 0.10% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 to Table 46 are the affected areas in square kilometers by flood depth per barangay.

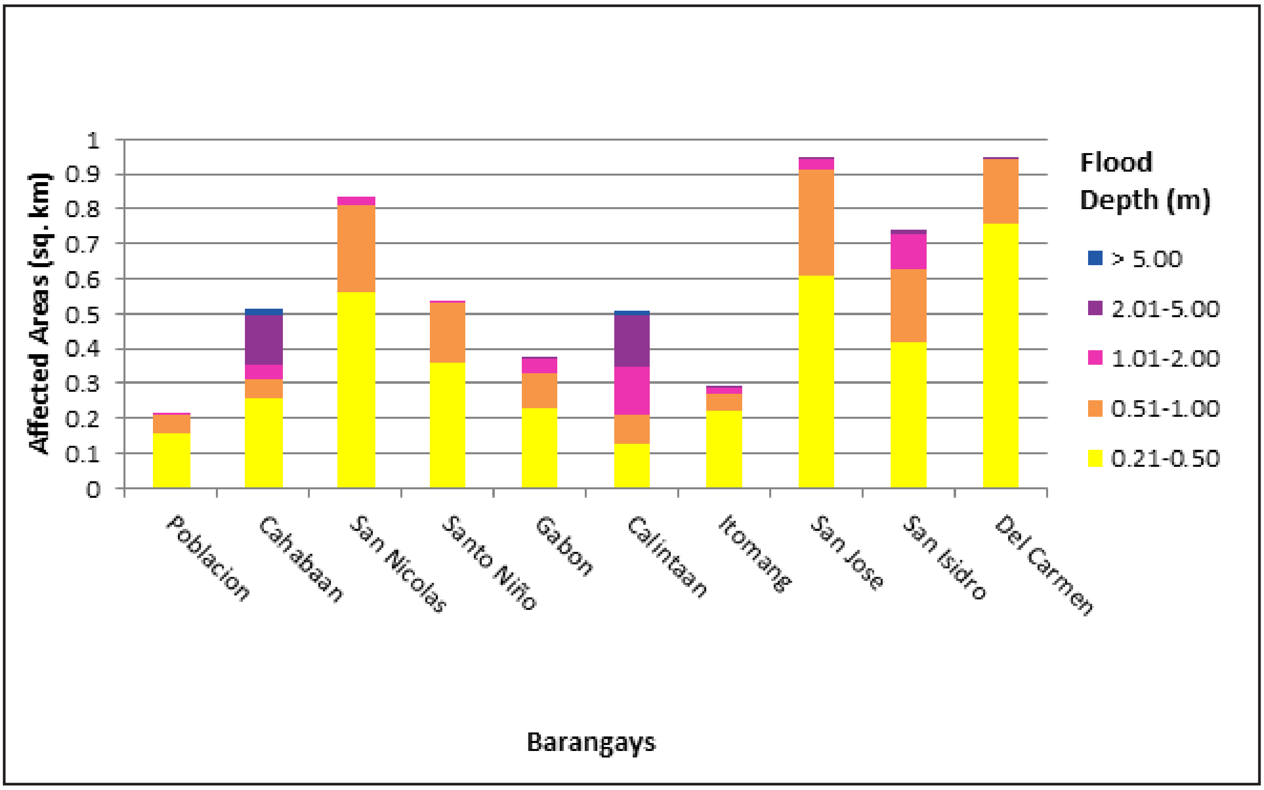


Figure 78. Affected areas in Talisay, Camarines Norte during a 5-Year Rainfall Return Period. (1)

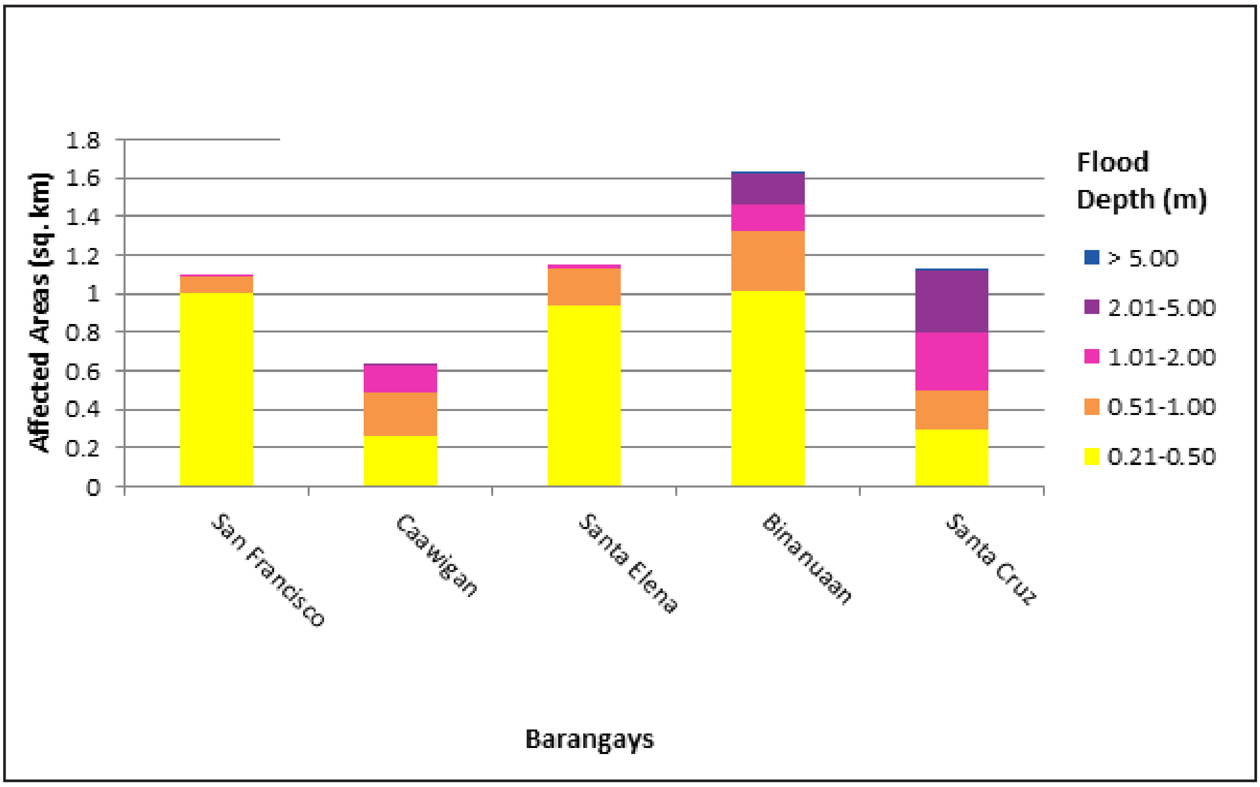


Figure 79. Affected areas in Talisay, Camarines Norte during a 5-Year Rainfall Return Period. (2)

Table 45. Affected areas in Talisay, Camarines Norte during a 5-Year Rainfall Return Period. (1)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Talisay (in sq. km.)									
	Poblacion	Cahabaan	San Nicolas	Santo Niño	Gabon	Calintaan	Itomang	San Jose	San Isidro	Del Carmen
1	0.5	1.04	1.07	1.13	1.21	1.23	1.44	1.47	1.95	2.01
2	0.16	0.26	0.56	0.36	0.23	0.13	0.22	0.61	0.42	0.76
3	0.048	0.05	0.25	0.17	0.1	0.079	0.053	0.3	0.21	0.18
4	0.0002	0.044	0.023	0.0026	0.04	0.14	0.014	0.032	0.1	0.0028
5	0	0.14	0	0	0.0025	0.15	0.0023	0.0004	0.0084	0.0001
6	0	0.02	0	0	0	0.012	0	0	0	0

Table 46. Affected areas in Talisay, Camarines Norte during a 5-Year Rainfall Return Period. (2)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Talisay (in sq. km.)				
	San Francisco	Caawigan	Santa Elena	Binanuaan	Santa Cruz
1	2.09	2.26	2.56	2.59	2.81
2	1	0.26	0.94	1.01	0.29
3	0.086	0.23	0.19	0.31	0.21
4	0.0067	0.14	0.018	0.14	0.3
5	0	0.0032	0	0.16	0.32
6	0	0	0	0.0001	0.0006

For the 5-year return period, 9.89% of the municipality of Daet with an area of 50.19 sq. km. will experience flood levels of less than 0.20 meters; 1.30% of the area will experience flood levels of 0.21 to 0.50 meters while 0.36%, 0.21%, 0.00%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 47 are the affected areas in square kilometers by flood depth per barangay.

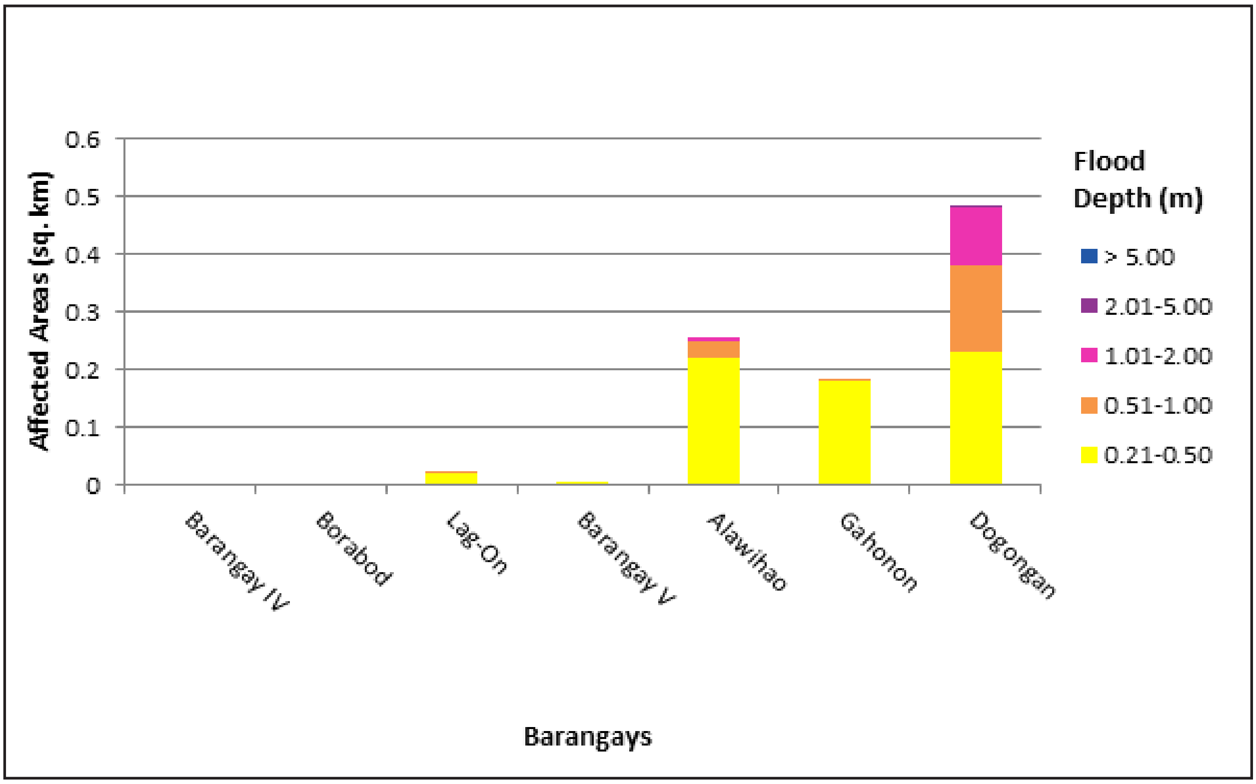


Figure 80. Affected Areas in Daet, Camarines Norte during a 5-Year Rainfall Return Period

Table 47. Affected areas in Daet, Camarines Norte by flood level for a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Daet (in sq. km.)						
	Barangay IV	Borabod	Lag-On	Barangay V	Alawihao	Gahonon	Dogongan
1	0.0055	0.0068	0.14	0.19	1.14	1.23	2.25
2	0	0	0.02	0.0025	0.22	0.18	0.23
3	0	0	0.0002	0	0.029	0.0005	0.15
4	0	0	0	0	0.0073	0	0.099
5	0	0	0	0	0	0	0.0011
6	0	0	0	0	0	0	0

For the 5-year return period, 35.98% of the municipality of San Vicente with an area of 51.97 sq. km. will experience flood levels of less than 0.20 meters; 3.12% of the area will experience flood levels of 0.21 to 0.50 meters while 2.47%, 1.83%, 1.16%, 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 more than 5 meters, respectively. Listed in Table 48 are the affected areas in square kilometers by flood depth per barangay.

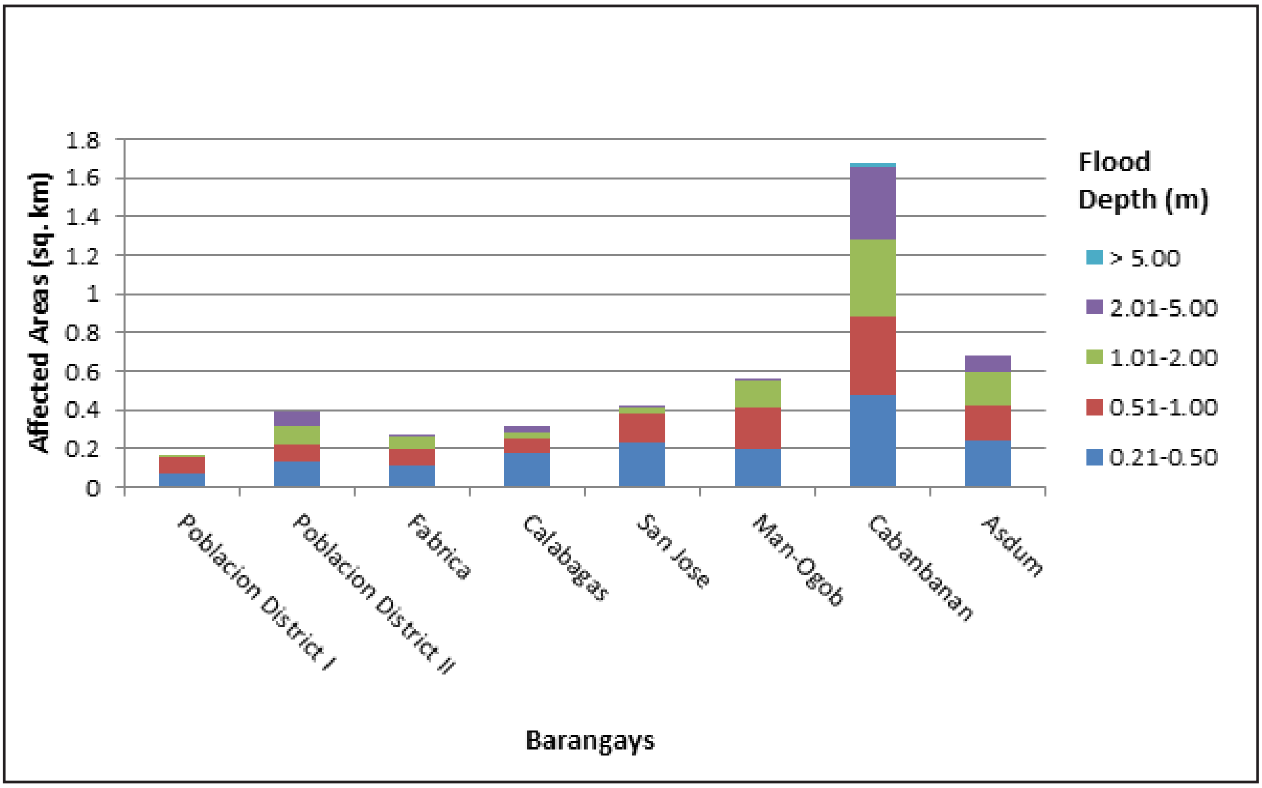


Figure 81. Affected Areas in San Vicente, Camarines Norte during a 5-Year Rainfall Return Period

Table 48. Affected areas in San Vicente, Camarines Norte by flood level for a 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Vicente (in sq. km.)							
	Poblacion District I	Poblacion District II	Fabrica	Calabagas	San Jose	Man-Ogob	Cabanbanan	Asdum
1	0.75	0.9469	1.7434	2.1741	2.2434	2.2701	3.7276	4.8452
2	0.0713	0.1335	0.1089	0.1721	0.2306	0.1936	0.474	0.2396
3	0.0828	0.089	0.0837	0.0763	0.1453	0.2151	0.4065	0.1827
4	0.0146	0.0931	0.0647	0.032	0.036	0.1382	0.3973	0.1758
5	0	0.0791	0.0193	0.0377	0.0022	0.0075	0.3712	0.0841
6	0	0	0	0	0	0	0.0295	0

For the 5-year return period, 35.98% of the municipality of Vinzons with an area of 51.97 sq. km. will experience flood levels of less than 0.20 meters. 3.12% of the area will experience flood levels of 0.21 to 0.50 meters while 2.47%, 1.83%, 1.16%, 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 more than 5 meters, respectively. Listed in Table 49 to Table 50 are the affected areas in square kilometers by flood depth per barangay.

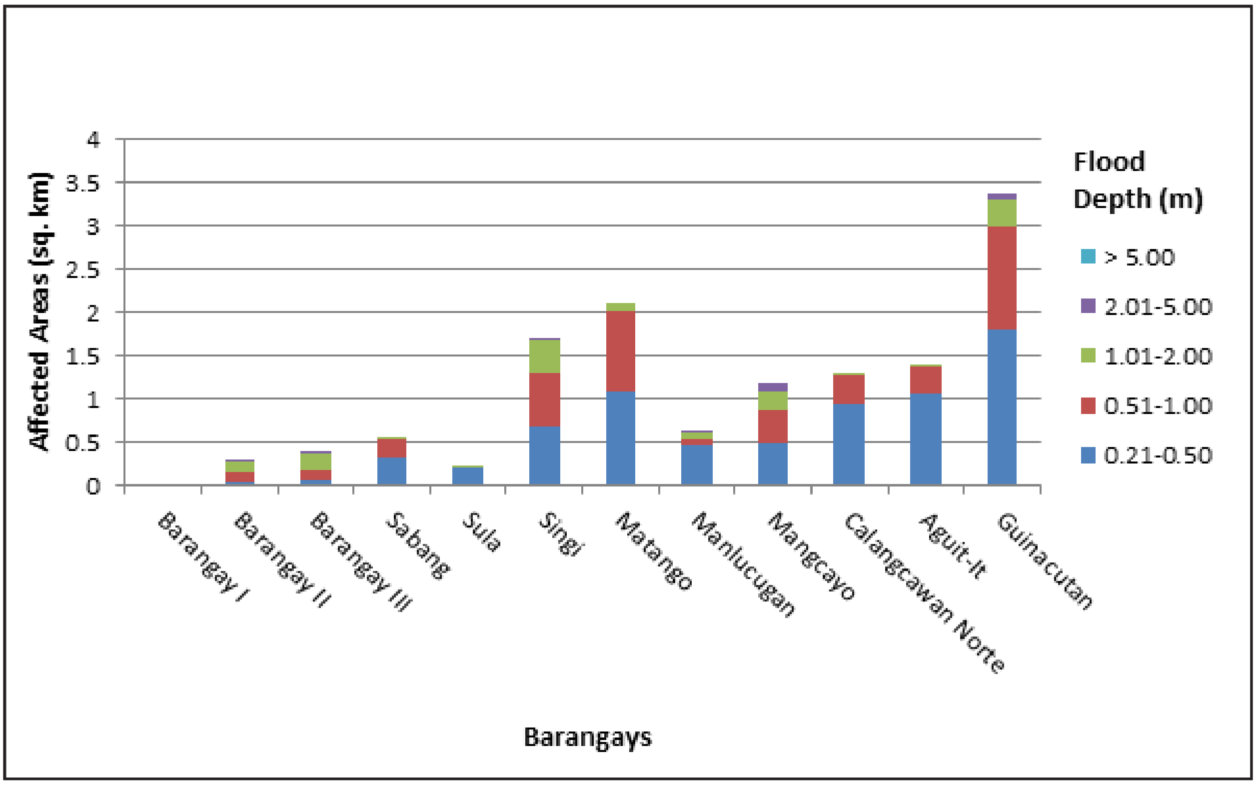


Figure 82. Affected Areas in Vinzons, Camarines Norte during a 5-Year Rainfall Return Period (1)

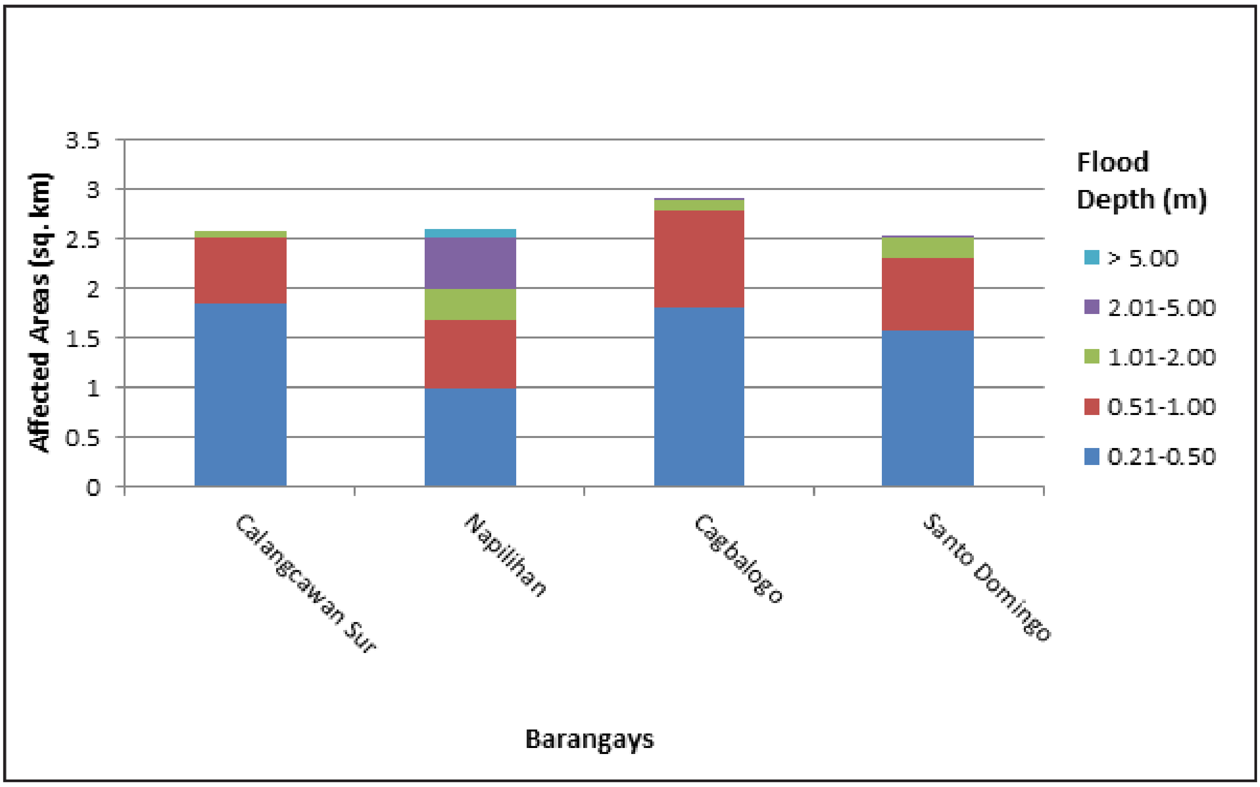


Figure 83. Affected Areas in Vinzons, Camarines Norte during a 5-Year Rainfall Return Period (1)

Table 49. Affected areas in Vinzons, Camarines Norte by flood level for a 5-Year Rainfall Return Period. (1)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Vinzons (in sq. km.)											
	Barangay I	Barangay II	Barangay III	Sabang	Sula	Singi	Matango	Manlucugan	Mangcayo	Calangcawan Norte	Aguit-It	Guinacutan
1	0	0.2	0.25	0.76	0.95	1.48	1.58	1.85	2.37	2.75	2.87	3.94
2	0	0.043	0.058	0.31	0.19	0.68	1.07	0.46	0.48	0.93	1.06	1.8
3	0	0.098	0.13	0.22	0.014	0.61	0.93	0.081	0.39	0.33	0.3	1.19
4	0	0.12	0.18	0.0084	0.004	0.38	0.1	0.065	0.22	0.015	0.017	0.3
5	0	0.0005	0.0006	0	0	0.021	0	0.0037	0.079	0	0	0.082
6	0	0	0	0	0	0	0	0	0	0	0	0

Table 50. Affected areas in Vinzons, Camarines Norte by flood level for a 5-Year Rainfall Return Period. (2)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Vinzons (in sq. km.)			
	Calangcawan Sur	Napilihan	Cagbalogo	Santo Domingo
1	4.16	4.39	5.03	5.82
2	1.85	0.99	1.8	1.58
3	0.65	0.68	0.98	0.73
4	0.063	0.31	0.11	0.19
5	0	0.52	0.0051	0.036
6	0	0.093	0	0

For the 25-year return period, 20.53% of the municipality of Labo with an area of 628.2236 sq. km. will experience flood levels of less than 0.20 meters; 1.74% of the area will experience flood levels of 0.21 to 0.50 meters while 1.61%, 1.93%, 2.46%, and 1.68% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 51 to Table 54 are the affected areas in square kilometers by flood depth per barangay.

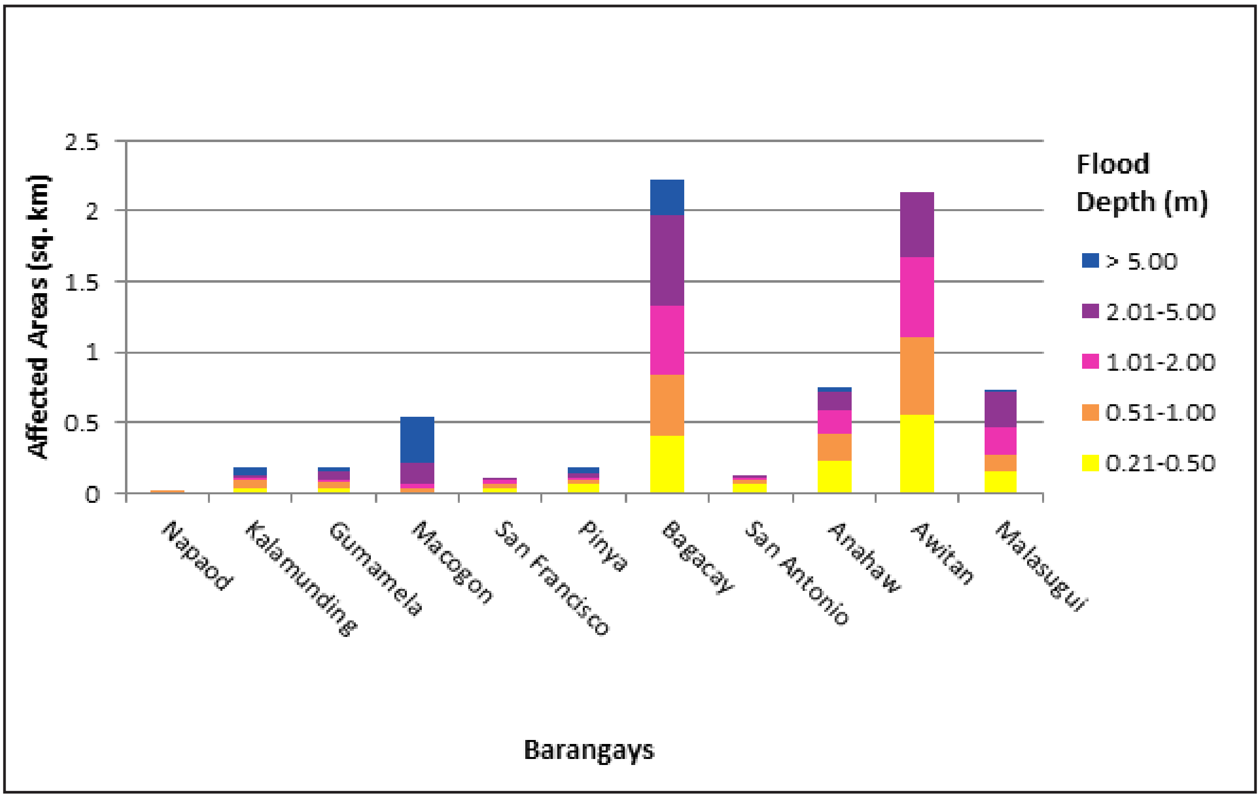


Figure 84. Affected areas in Labo, Camarines Norte during a 25-Year Rainfall Return Period. (1)

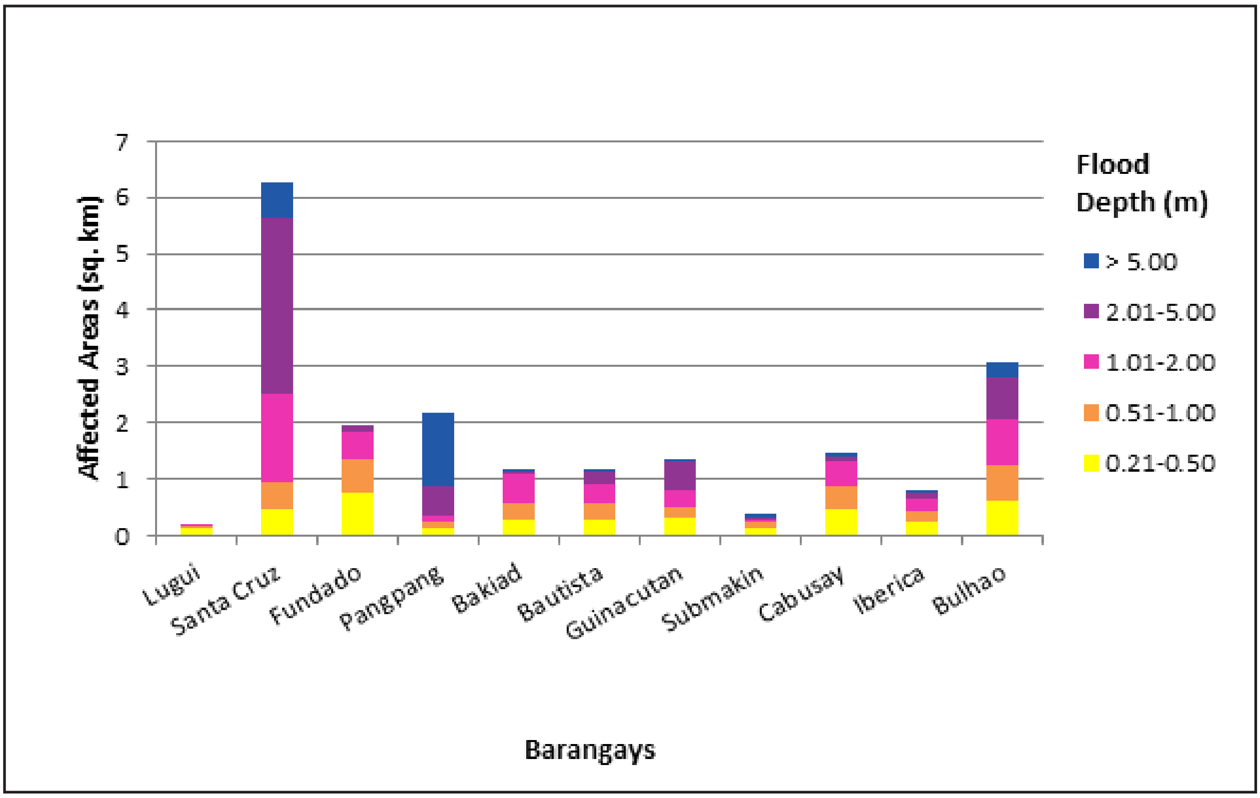


Figure 85. Affected areas in Labo, Camarines Norte during a 25-Year Rainfall Return Period. (2)

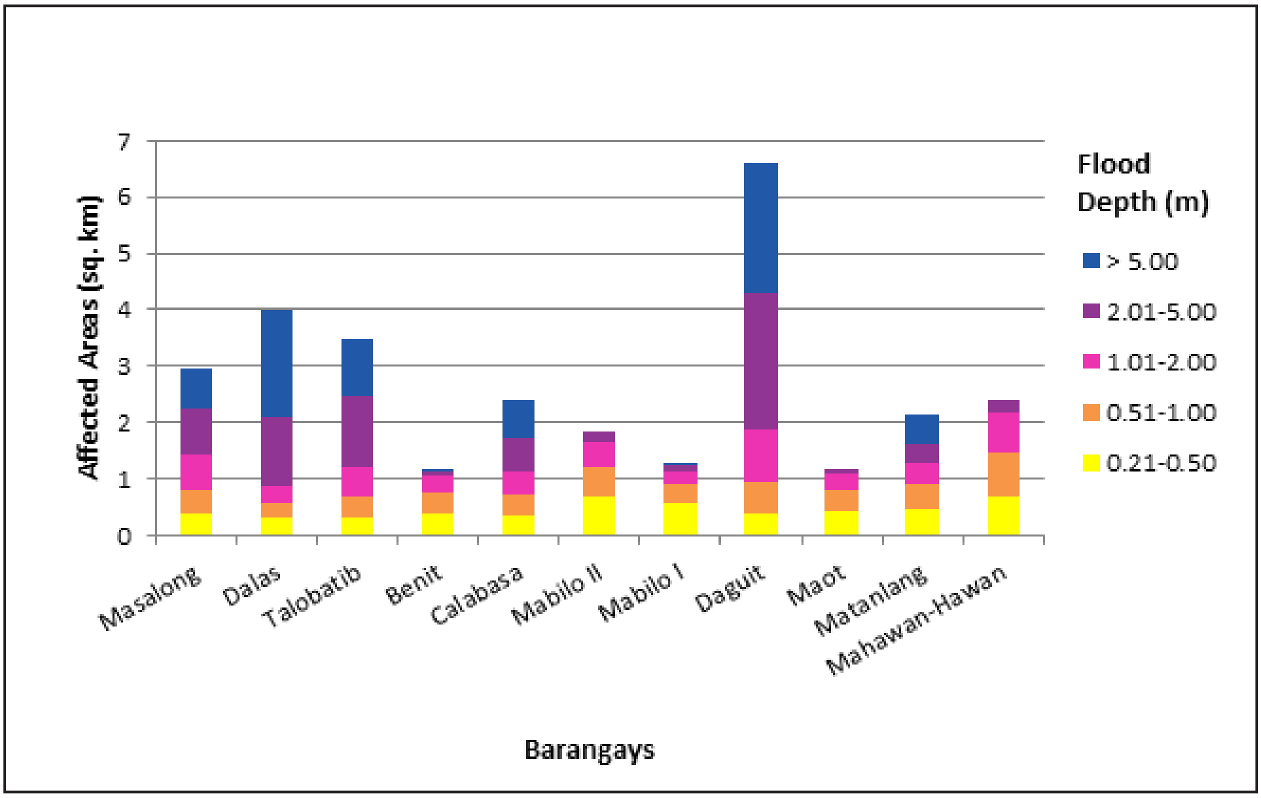


Figure 86. Affected areas in Labo, Camarines Norte during a 25-Year Rainfall Return Period. (3)

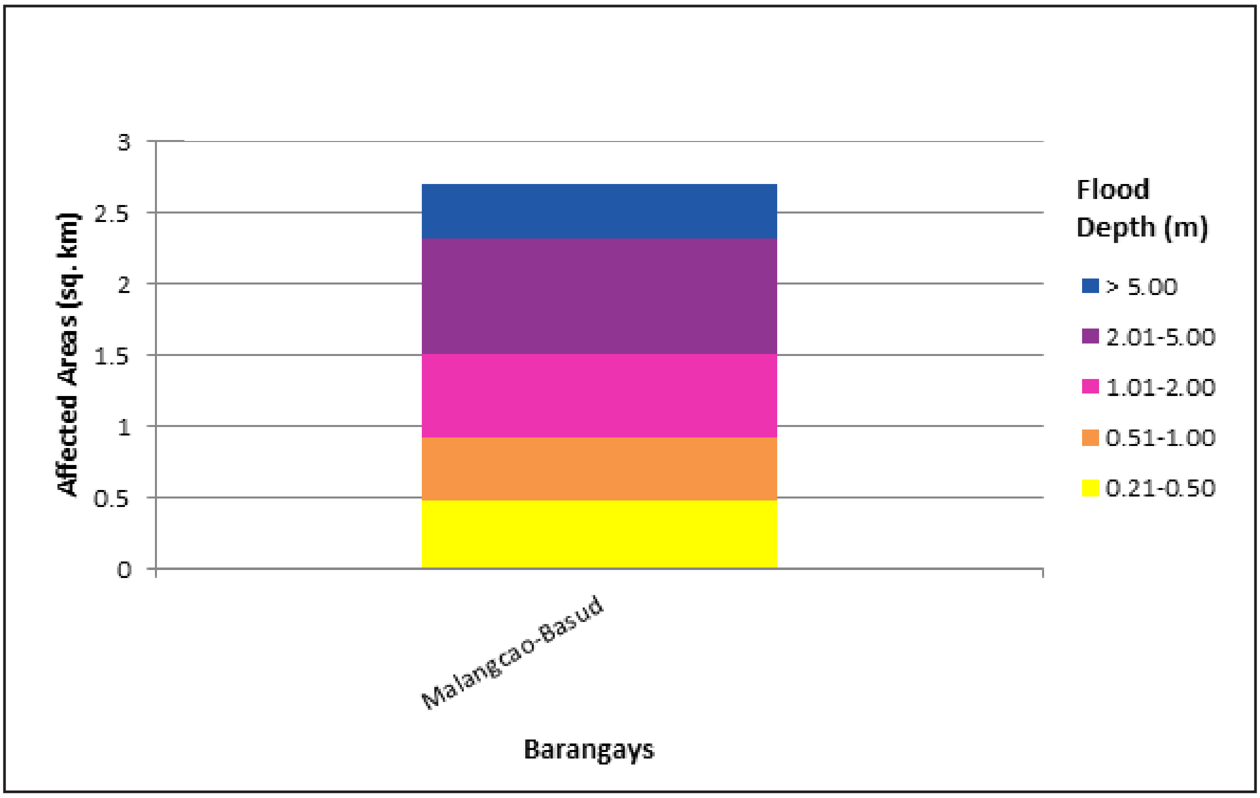


Figure 87. Affected areas in Labo, Camarines Norte during a 25-Year Rainfall Return Period. (4)

Table 51. Affected areas in Labo, Camarines Norte during a 25-Year Rainfall Return Period (1)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labo (in sq. km.)										
	Napaod	Kalamunding	Gumamela	Macogon	San Francisco	Pinya	Bagacay	San Antonio	Anahaw	Awitan	Malasugui
1	0.045	0.41	0.5	0.54	0.61	0.63	0.78	1.3	1.39	1.2	1.62
2	0.0023	0.035	0.039	0.012	0.043	0.061	0.41	0.061	0.23	0.56	0.16
3	0.0007	0.058	0.037	0.019	0.029	0.034	0.43	0.032	0.2	0.55	0.11
4	0	0.022	0.023	0.04	0.029	0.017	0.49	0.014	0.16	0.56	0.2
5	0	0.012	0.05	0.15	0.0026	0.021	0.64	0.0002	0.13	0.46	0.25
6	0	0.054	0.035	0.32	0	0.048	0.25	0	0.025	0	0.0016

Table 52. Affected areas in Labo, Camarines Norte during a 25-Year Rainfall Return Period (2)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labo (in sq. km.)										
	Lugui	Santa Cruz	Fundado	Pangpang	Bakiad	Bautista	Guinacutan	Submakin	Cabusay	Iberica	Bulhao
1	1.69	1.66	1.89	2.31	2.74	3.26	3.58	3.98	3.86	4.24	4.22
2	0.11	0.48	0.76	0.11	0.27	0.28	0.3	0.13	0.47	0.23	0.62
3	0.044	0.46	0.61	0.12	0.32	0.3	0.19	0.09	0.39	0.21	0.63
4	0.014	1.58	0.46	0.11	0.49	0.34	0.29	0.065	0.45	0.19	0.81
5	0	3.12	0.12	0.53	0.07	0.21	0.52	0.036	0.1	0.13	0.76
6	0	0.62	0	1.3	0.012	0.0008	0.049	0.063	0.059	0.0001	0.25

Table 53. Affected areas in Labo, Camarines Norte during a 25-Year Rainfall Return Period (3)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labo (in sq. km.)										
	Masalong	Dalas	Talobatib	Benit	Calabasa	Mabilo II	Mabilo I	Daguit	Maot	Matanlang	Mahawan-Hawan
1	4.72	5.88	5.93	6.84	6.8	6.98	7.24	6.37	7.96	8.26	9.17
2	0.39	0.33	0.31	0.4	0.36	0.68	0.56	0.39	0.42	0.48	0.68
3	0.41	0.24	0.36	0.37	0.36	0.52	0.35	0.55	0.39	0.41	0.79
4	0.62	0.3	0.55	0.27	0.42	0.46	0.23	0.94	0.28	0.38	0.7
5	0.84	1.24	1.25	0.083	0.57	0.17	0.11	2.43	0.085	0.34	0.22
6	0.7	1.88	1.02	0.0002	0.7	0	0.001	2.28	0	0.51	0

Table 54. Affected areas in Labo, Camarines Norte during a 25-Year Rainfall Return Period (4)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labo (in sq. km.)
	Malangcao-Basud
1	9.06
2	0.48
3	0.44
4	0.59
5	0.8
6	0.38

For the 25-year return period, 31.18% of the municipality of Paracale with an area of 157.3 sq. km. will experience flood levels of less than 0.20 meters; 2.87% of the area will experience flood levels of 0.21 to 0.50 meters while 2.66%, 2.20%, 0.72%, and 0.17% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 55 to Table 56 are the affected areas in square kilometers by flood depth per barangay.

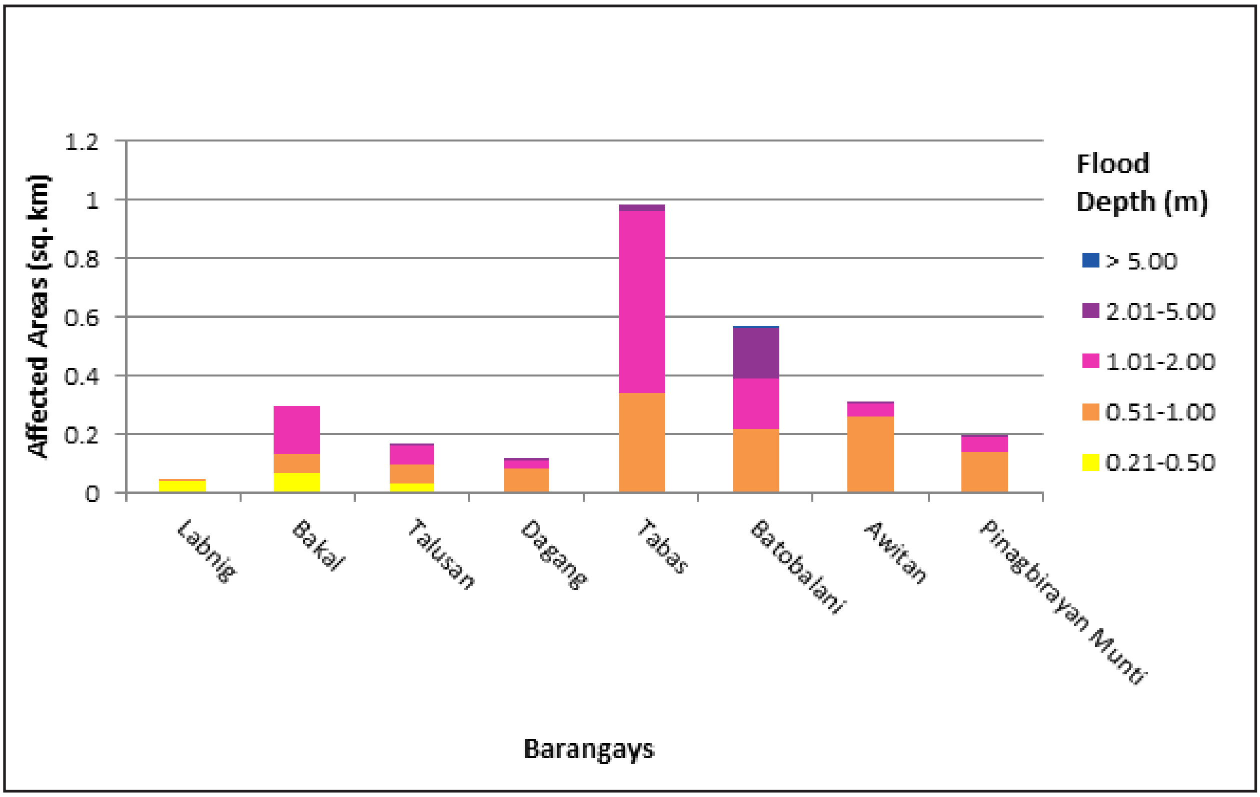


Figure 88. Areas affected by flooding in Paracale, Camarines Norte for a 25-Year Return Period rainfall event. (1)

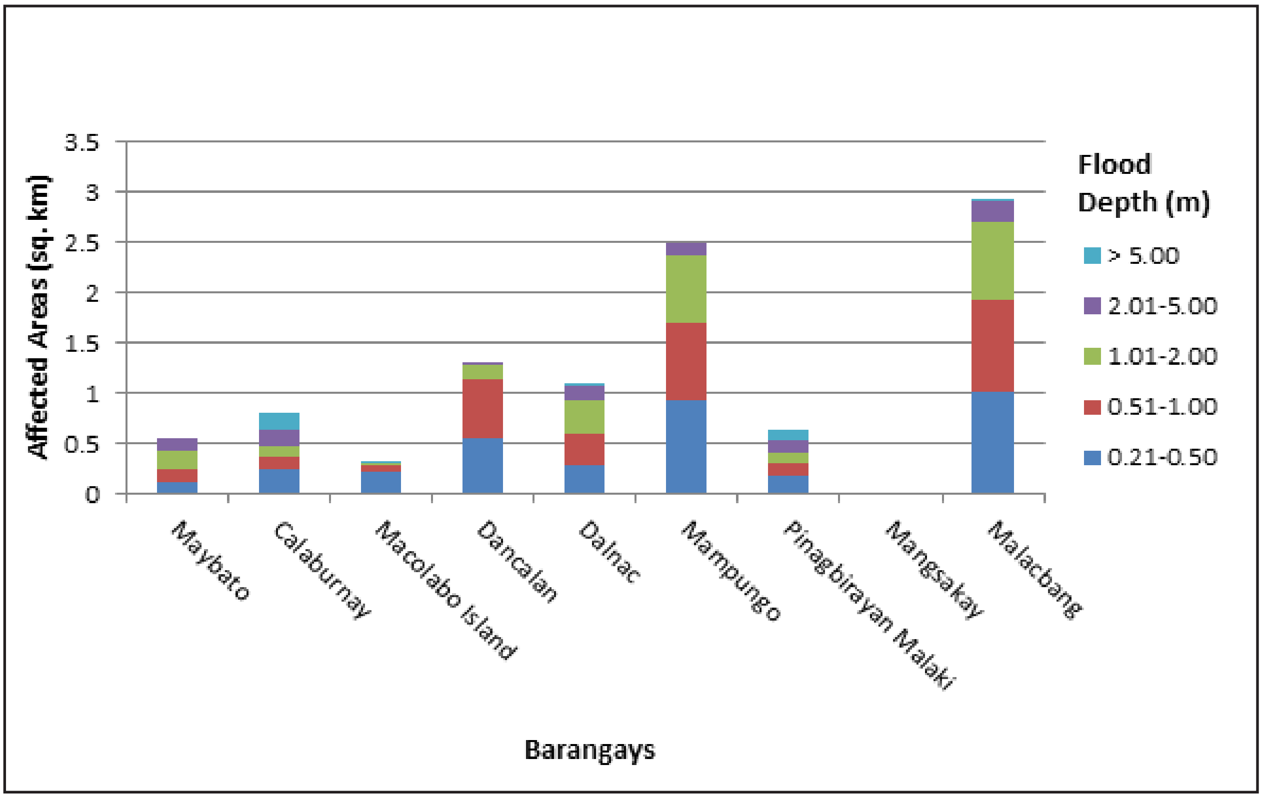


Figure 89. Areas affected by flooding in Paracale, Camarines Norte for a 25-Year Return Period rainfall event. (2)

Table 55. Affected areas in Paracale, Camarines Norte during a 25-Year Rainfall Return Period. (1)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Paracale (in sq. km.)							
	Labnig	Bakal	Talusan	Dagang	Tabas	Batobalani	Awitan	Pinagbirayan Munti
1	0.23	0.45	0.75	1.17	1.38	1.57	1.68	2.17
2	0.038	0.07	0.035	0.087	0.24	0.14	0.27	0.13
3	0.0049	0.059	0.061	0.085	0.34	0.22	0.26	0.14
4	0	0.17	0.061	0.023	0.62	0.17	0.045	0.051
5	0	0	0.011	0.0008	0.021	0.17	0.0006	0.003
6	0	0	0	0	0	0.0009	0	0

Table 56. Affected areas in Paracale, Camarines Norte during a 25-Year Rainfall Return Period. (2)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Paracale (in sq. km.)								
	Maybato	Calaburnay	Macolabo Island	Dancalan	Dalnac	Mampungo	Pinagbirayan Malaki	Mangsakay	Malacbang
1	2.41	2.75	3.73	4.02	4.27	4.2	4.77	0	13.49
2	0.11	0.23	0.22	0.56	0.28	0.93	0.18	0	1
3	0.13	0.13	0.06	0.58	0.32	0.77	0.11	0	0.92
4	0.18	0.11	0.014	0.14	0.32	0.66	0.12	0	0.77
5	0.14	0.17	0.0022	0.0044	0.16	0.12	0.12	0	0.21
6	0	0.16	0.0013	0	0.0004	0	0.095	0	0.0099

For the 25-year return period, 67.26% of the municipality of Talisay with an area of 31.83 sq. km. will experience flood levels of less than 0.20 meters; 27.05% of the area will experience flood levels of 0.21 to 0.50 meters while 13.43%, 4.27%, 3.53%, and 0.33% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 57 to Table 58 are the affected areas in square kilometers by flood depth per barangay.

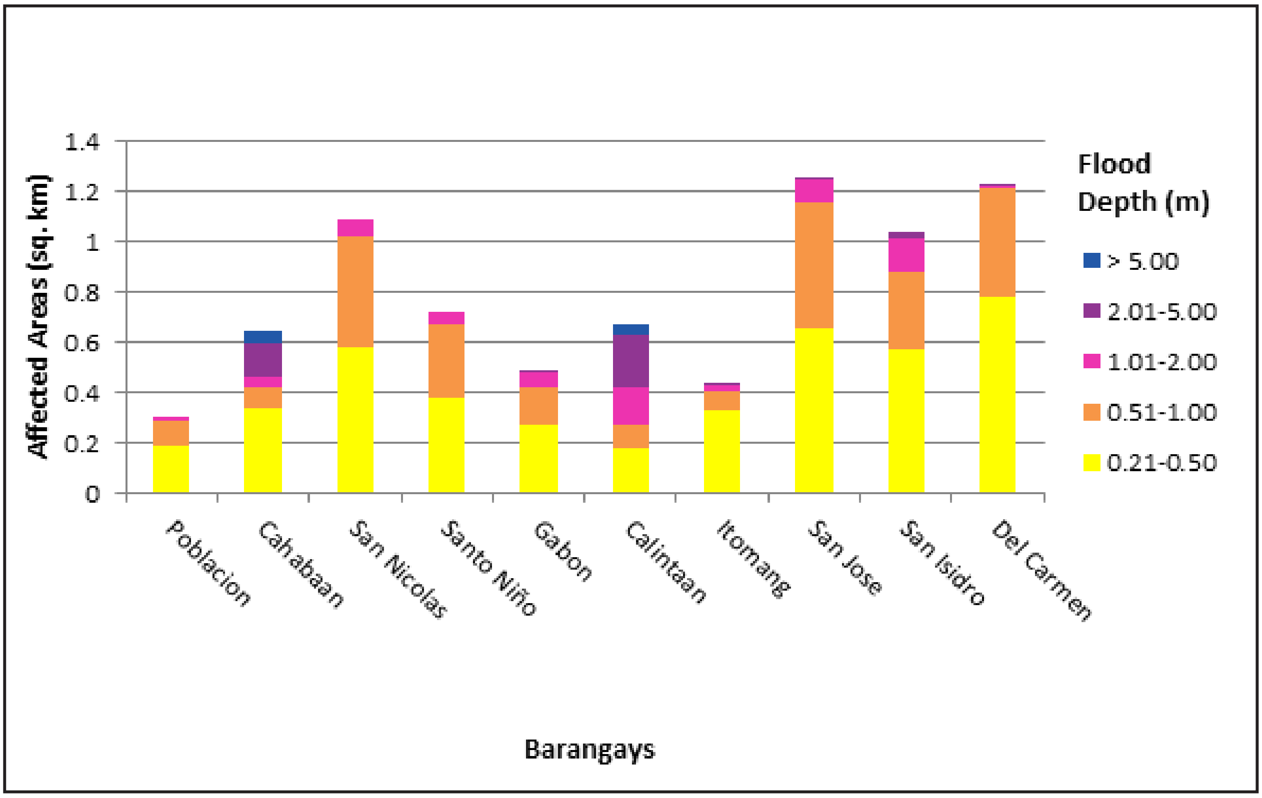


Figure 90. Affected areas in Talisay, Camarines Norte during a 25-Year Rainfall Return Period. (1)

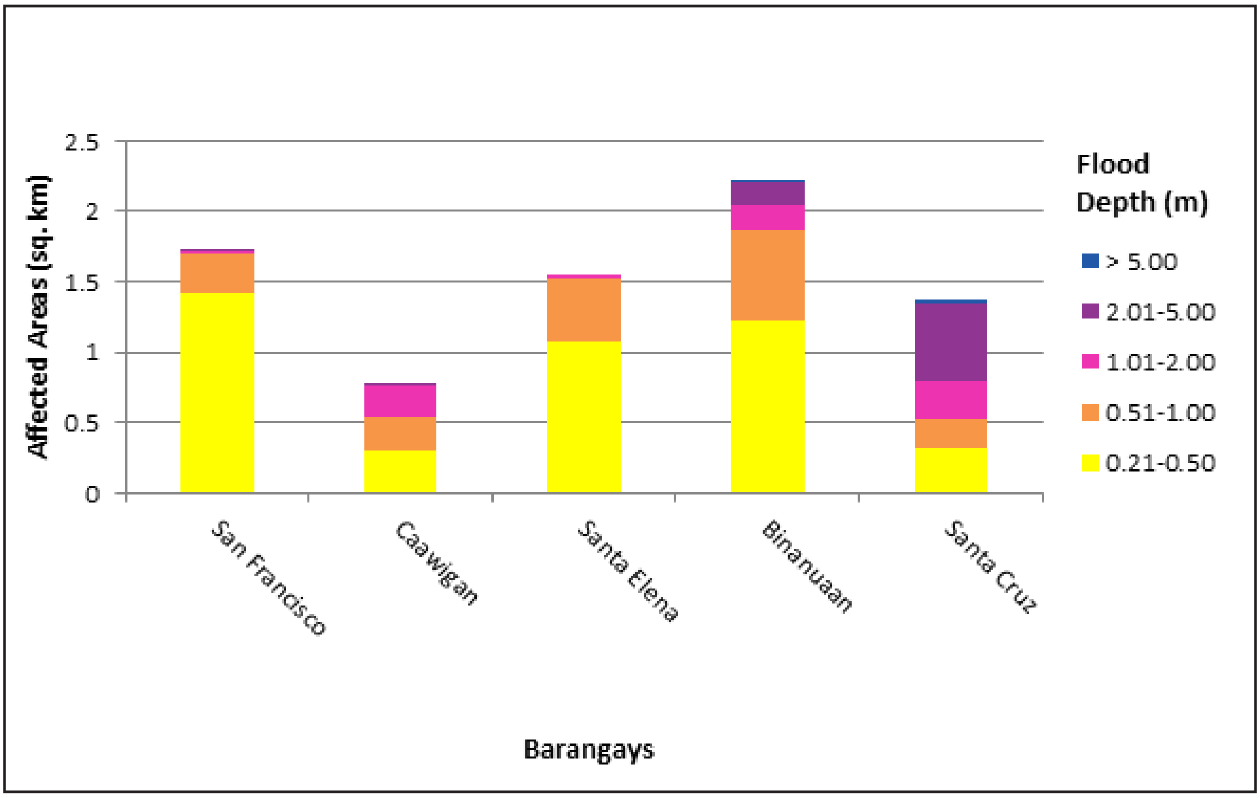


Figure 91. Affected areas in Talisay, Camarines Norte during a 25-Year Rainfall Return Period. (2)

Table 57. Affected areas in Talisay, Camarines Norte during a 25-Year Rainfall Return Period. (1)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Talisay (in sq. km.)									
	Poblacion	Cahabaan	San Nicolas	Santo Niño	Gabon	Calintaan	Itomang	San Jose	San Isidro	Del Carmen
1	0.41	0.9	0.82	0.94	1.1	1.08	1.29	1.17	1.66	1.74
2	0.19	0.34	0.58	0.38	0.27	0.18	0.33	0.65	0.57	0.78
3	0.098	0.078	0.44	0.29	0.15	0.092	0.077	0.5	0.31	0.43
4	0.017	0.04	0.063	0.046	0.055	0.15	0.023	0.093	0.13	0.013
5	0	0.14	0	0	0.0075	0.21	0.0032	0.003	0.025	0.0001
6	0	0.051	0	0	0	0.034	0	0	0	0

Table 58. Affected areas in Talisay, Camarines Norte during a 25-Year Rainfall Return Period. (2)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Talisay (in sq. km.)				
	San Francisco	Caawigan	Santa Elena	Binanuaan	Santa Cruz
1	1.47	2.11	2.15	2	2.57
2	1.42	0.31	1.07	1.22	0.32
3	0.28	0.23	0.45	0.65	0.2
4	0.0099	0.23	0.038	0.17	0.28
5	0.0005	0.014	0	0.17	0.55
6	0	0	0	0.0018	0.018

For the 25-year return period, 9.07% of the municipality of Daet with an area of 50.19 sq. km. will experience flood levels of less than 0.20 meters; 1.94% of the area will experience flood levels of 0.21 to 0.50 meters while 0.43%, 0.32%, 0.02%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 59 are the affected areas in square kilometers by flood depth per barangay.

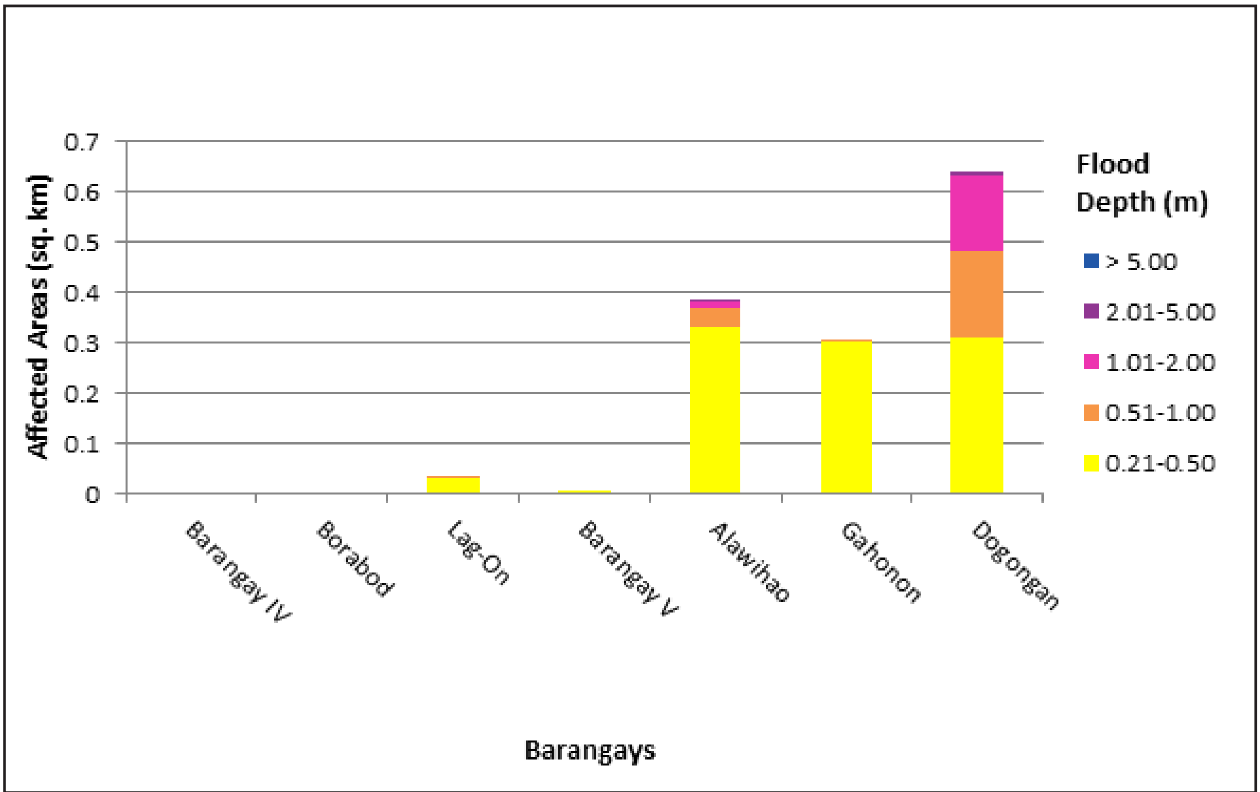


Figure 92. Affected Areas in Daet, Camarines Norte during a 25-Year Rainfall Return Period

Table 59. Affected areas in Daet, Camarines Norte by flood level for a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Daet (in sq. km.)						
	Barangay IV	Borabod	Lag-On	Barangay V	Alawihao	Gahonon	Dogongan
1	0.0055	0.0068	0.13	0.19	1.01	1.11	2.1
2	0	0	0.029	0.0049	0.33	0.3	0.31
3	0	0	0.0012	0	0.04	0.0043	0.17
4	0	0	0	0	0.01	0	0.15
5	0	0	0	0	0.0001	0	0.0089
6	0	0	0	0	0	0	0

For the 25-year return period, 34.22% of the municipality of San Vicente with an area of 51.97 sq. km. will experience flood levels of less than 0.20 meters; 3.42% of the area will experience flood levels of 0.21 to 0.50 meters while 2.74%, 2.45%, 1.69%, and 0.10% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 60 are the affected areas in square kilometers by flood depth per barangay.

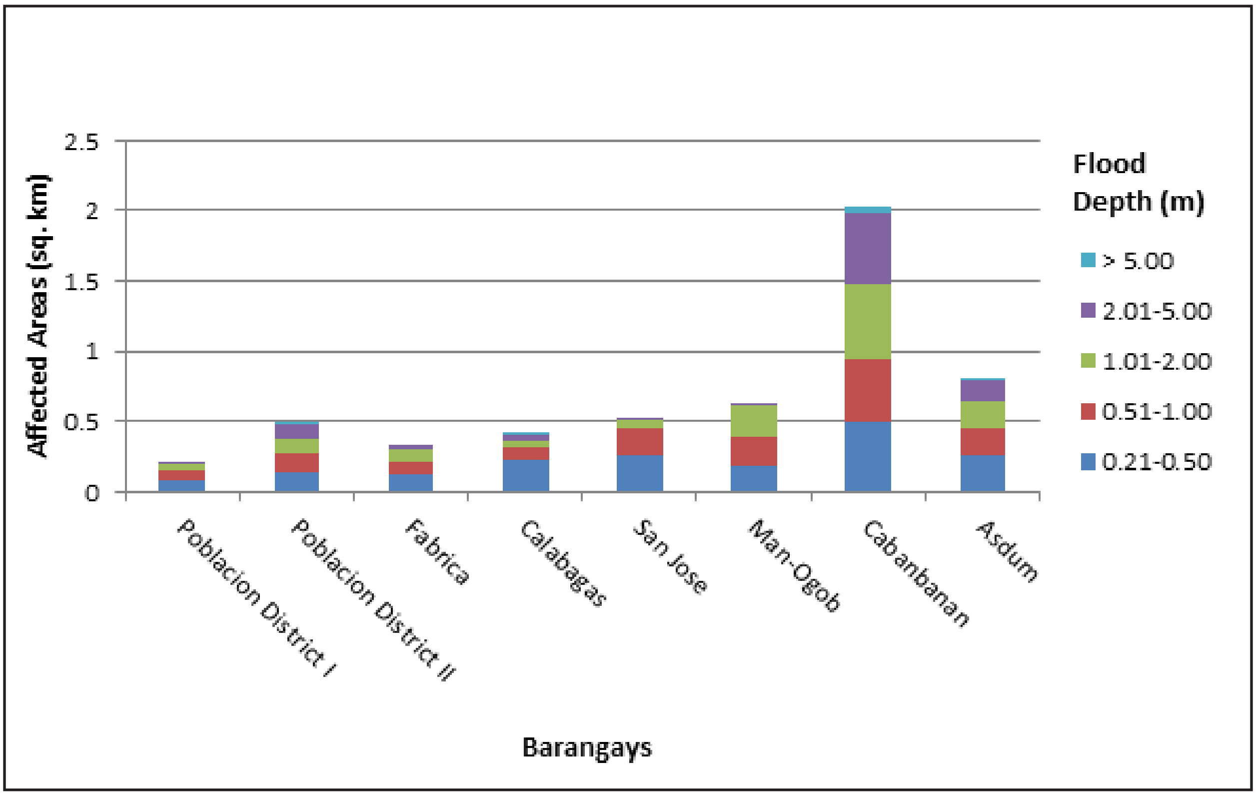


Figure 93. Affected Areas in San Vicente, Camarines Norte during a 25-Year Rainfall Return Period

Table 60. Affected areas in San Vicente, Camarines Norte by flood level for a 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Vicente (in sq. km.)							
	Poblacion District I	Poblacion District II	Fabrica	Calabagas	San Jose	Man-Ogob	Cabanbanan	Asdum
1	0.72	0.8543	1.6855	2.0774	2.1473	2.1898	3.3729	4.7356
2	0.0737	0.1457	0.1315	0.2298	0.261	0.1836	0.4979	0.2554
3	0.0808	0.1246	0.0845	0.0922	0.1843	0.2129	0.4456	0.198
4	0.0438	0.1009	0.0858	0.0416	0.0612	0.2193	0.5314	0.1917
5	0.0002	0.1152	0.0327	0.0507	0.0037	0.0189	0.51	0.1458
6	0	0.0009	0	0.0005	0	0	0.0483	0.0009

For the 25-year return period, 31.92% of the municipality of Vinzons with an area of 94.05 sq. km. will experience flood levels of less than 0.20 meters; 14.47% of the area will experience flood levels of 0.21 to 0.50 meters while 12.12%, 5.96%, 1.21%, and 0.20% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 61 and Table 62 are the affected areas in square kilometers by flood depth per barangay.

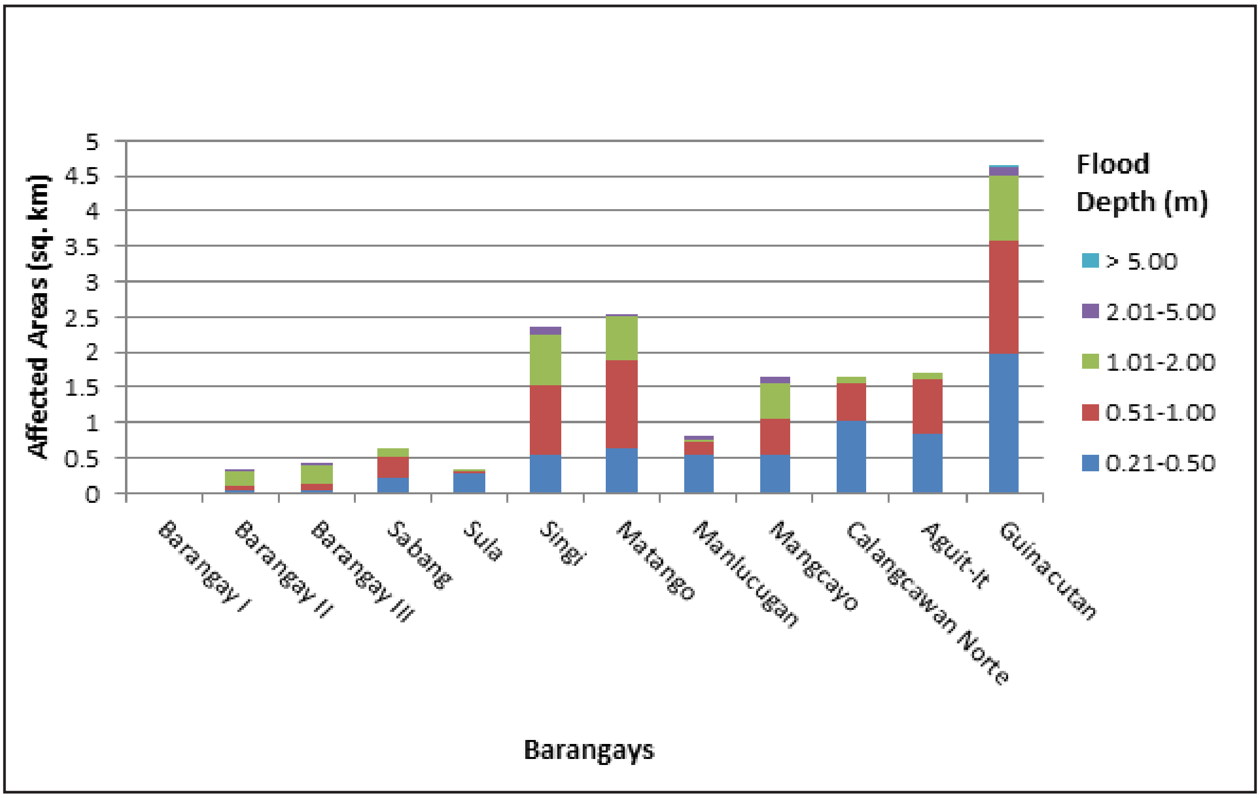


Figure 94. Affected Areas in Vinzons, Camarines Norte during a 25-Year Rainfall Return Period (1)

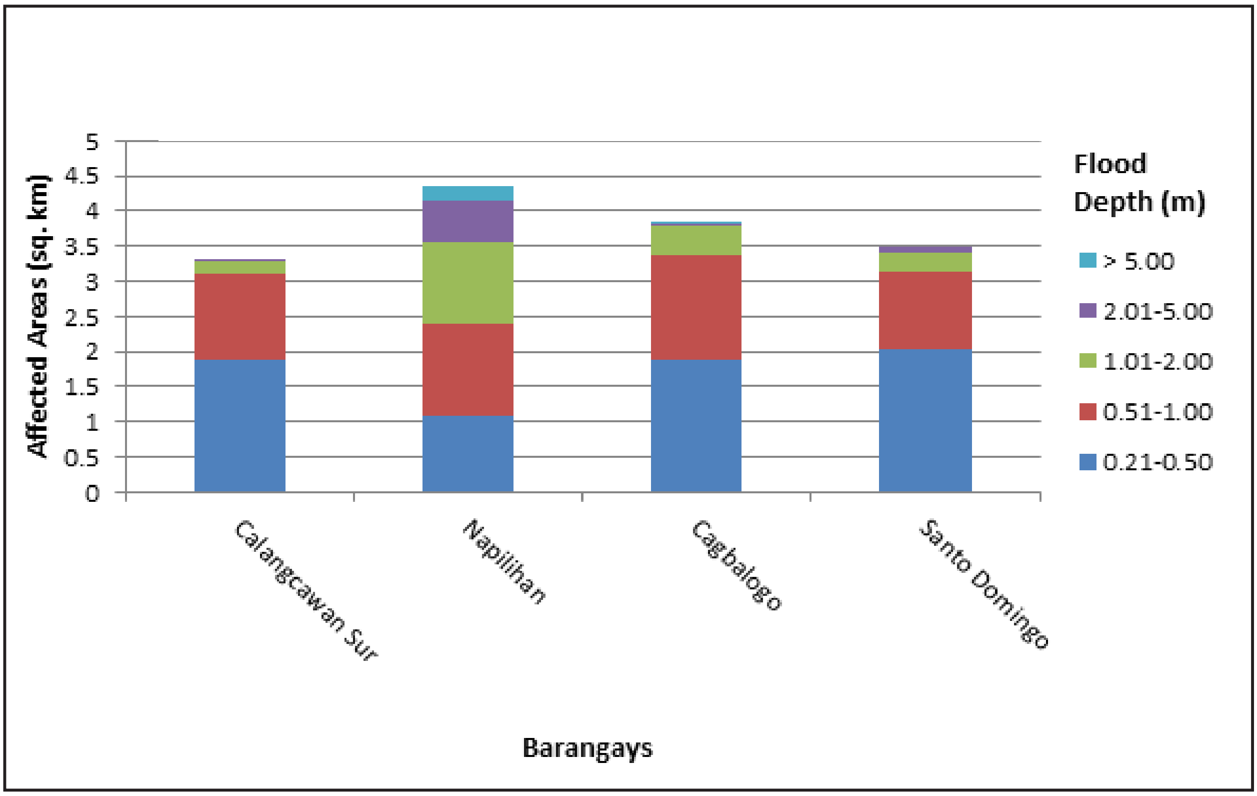


Figure 95. Affected Areas in Vinzons, Camarines Norte during a 25-Year Rainfall Return Period (2)

Table 61. Affected areas in Vinzons, Camarines Norte by flood level for a 25-Year Rainfall Return Period. (1)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Vinzons (in sq. km.)											
	Barangay I	Barangay II	Barangay III	Sabang	Sula	Singi	Matango	Manlucugan	Mangcayo	Calangcawan Norte	Aguit-It	Guinacutan
1	0	0.16	0.2	0.66	0.85	0.81	1.18	1.66	1.89	2.37	2.54	2.68
2	0	0.03	0.049	0.22	0.27	0.55	0.64	0.56	0.56	1.02	0.84	1.98
3	0	0.065	0.07	0.31	0.031	0.97	1.26	0.17	0.5	0.54	0.79	1.6
4	0	0.2	0.29	0.096	0.0052	0.71	0.61	0.039	0.49	0.1	0.082	0.93
5	0	0.0081	0.011	0	0	0.12	0.0002	0.046	0.11	0	0	0.12
6	0	0	0	0	0	0	0	0	0	0	0	0.0006

Table 50. Affected areas in Vinzons, Camarines Norte by flood level for a 5-Year Rainfall Return Period. (2)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Vinzons (in sq. km.)			
	Calangcawan Sur	Napilihan	Cagbalogo	Santo Domingo
1	3.41	2.62	4.11	4.88
2	1.88	1.08	1.9	2.03
3	1.22	1.31	1.46	1.1
4	0.2	1.15	0.42	0.28
5	0.0002	0.62	0.026	0.077
6	0	0.19	0.0004	0

For the 100-year return period, 19.45% of the municipality of Labo with an area of 628.2236 sq. km. will experience flood levels of less than 0.20 meters; 1.76% of the area will experience flood levels of 0.21 to 0.50 meters while 1.65%, 2.79%, 2.01%, and 2.28% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 63 to Table 66 are the affected areas in square kilometers by flood depth per barangay.

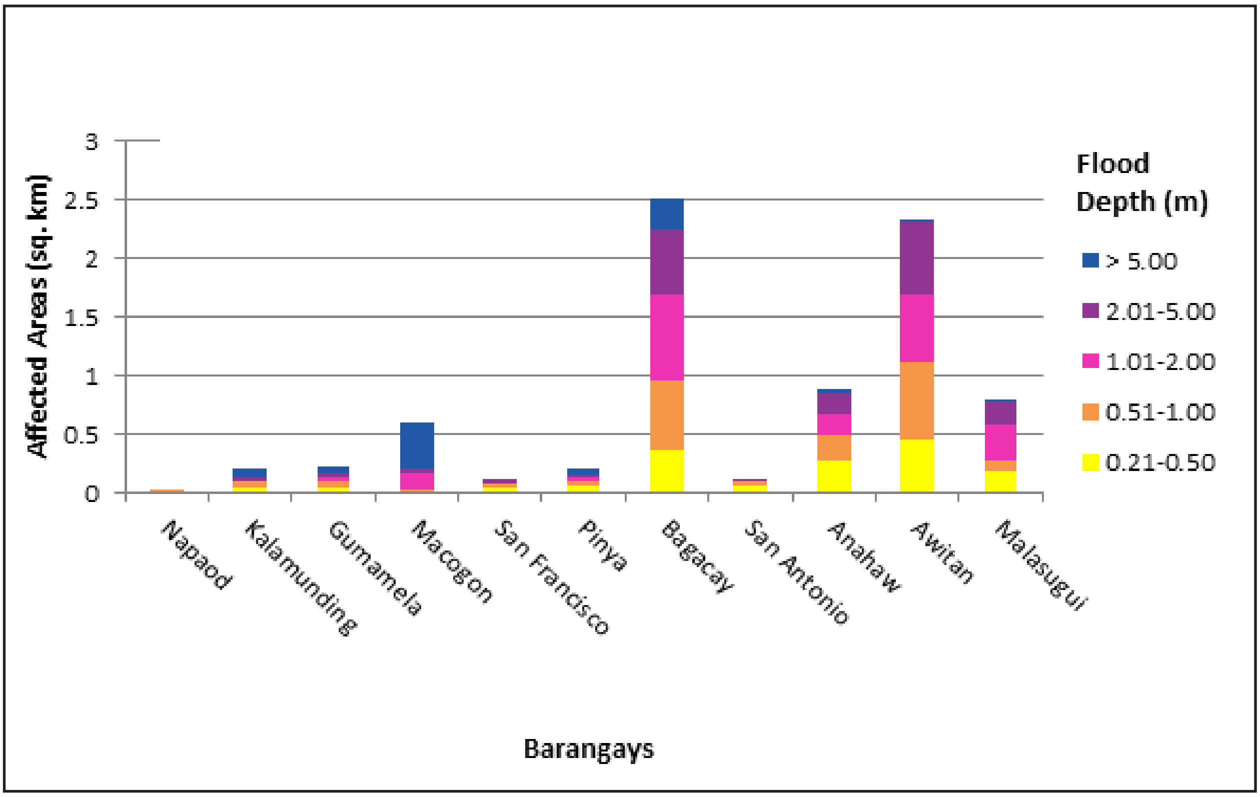


Figure 96. Affected areas in Labo, Camarines Norte during a 100-Year Rainfall Return Period. (1)

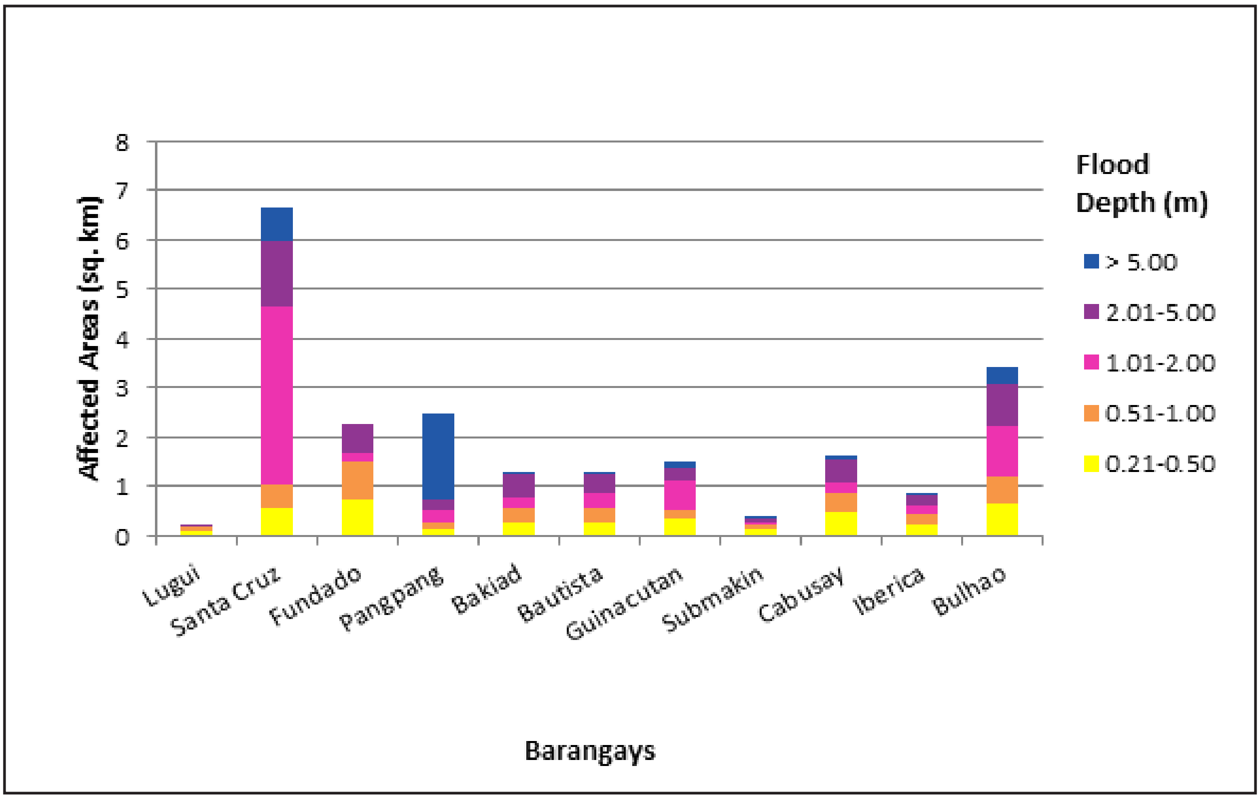


Figure 97. Affected areas in Labo, Camarines Norte during a 100-Year Rainfall Return Period. (2)

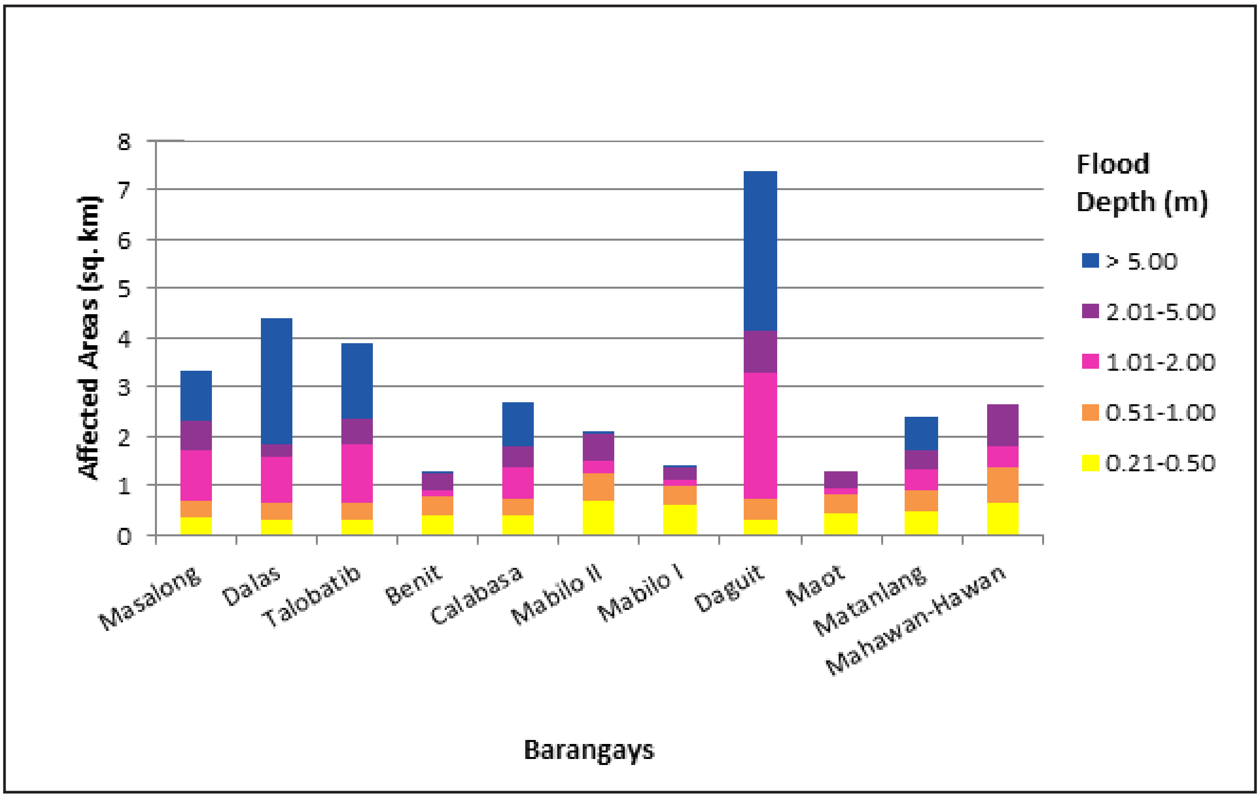


Figure 98. Affected areas in Labo, Camarines Norte during a 100-Year Rainfall Return Period. (3)

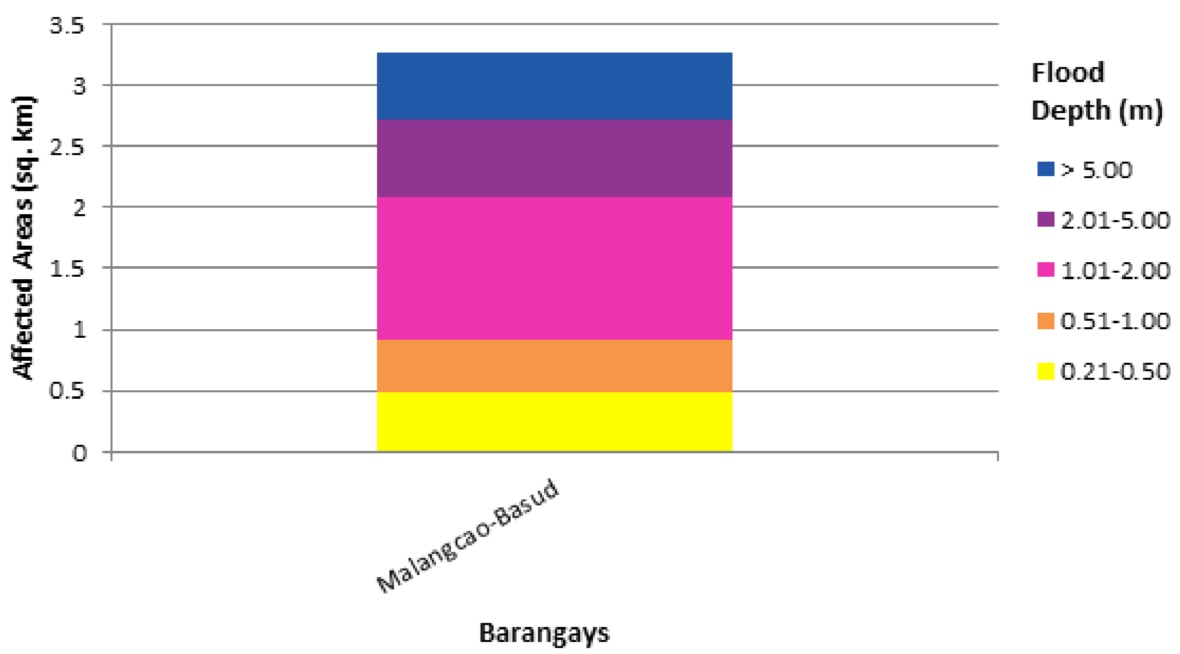


Figure 99. Affected areas in Labo, Camarines Norte during a 100-Year Rainfall Return Period. (4)

Table 63. Affected areas in Labo, Camarines Norte during a 100-Year Rainfall Return Period (1)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labo (in sq. km.)										
	Napaod	Kalamunding	Gumamela	Macogon	San Francisco	Pinya	Bagacay	San Antonio	Anahaw	Awitan	Malasugui
1	0.044	0.4	0.46	0.48	0.6	0.61	0.49	1.29	1.25	1.02	1.56
2	0.003	0.034	0.048	0.013	0.048	0.065	0.37	0.067	0.27	0.46	0.18
3	0.0009	0.056	0.041	0.016	0.03	0.036	0.59	0.035	0.22	0.66	0.095
4	0	0.0042	0.041	0.13	0.0049	0.023	0.73	0.0008	0.17	0.57	0.31
5	0	0.038	0.03	0.039	0.033	0.018	0.55	0.018	0.19	0.62	0.19
6	0	0.064	0.056	0.4	0	0.056	0.27	0	0.034	0.0004	0.012

Table 64. Affected areas in Labo, Camarines Norte during a 100-Year Rainfall Return Period (2)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labo (in sq. km.)										
	Lugui	Santa Cruz	Fundado	Pangpang	Bakiad	Bautista	Guinacutan	Submakin	Cabusay	Iberica	Bulhao
1	1.67	1.25	1.57	1.99	2.6	3.16	3.43	3.94	3.7	4.18	3.89
2	0.12	0.59	0.75	0.13	0.28	0.28	0.35	0.13	0.49	0.23	0.65
3	0.054	0.43	0.74	0.15	0.3	0.31	0.18	0.096	0.38	0.22	0.56
4	0.0002	3.63	0.18	0.26	0.22	0.28	0.59	0.04	0.19	0.16	1.04
5	0.019	1.31	0.6	0.21	0.47	0.37	0.27	0.075	0.5	0.2	0.84
6	0	0.71	0	1.73	0.029	0.0036	0.12	0.076	0.063	0.0007	0.32

Table 65. Affected areas in Labo, Camarines Norte during a 100-Year Rainfall Return Period (3)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labo (in sq. km.)										
	Masalong	Dalas	Talobatib	Benit	Calabasa	Mabilo II	Mabilo I	Daguit	Maot	Matanlang	Mahawan-Hawan
1	4.36	5.5	5.55	6.72	6.54	6.76	7.09	5.57	7.85	7.98	8.93
2	0.34	0.33	0.31	0.41	0.38	0.71	0.6	0.31	0.43	0.48	0.66
3	0.37	0.31	0.34	0.39	0.36	0.56	0.38	0.43	0.4	0.43	0.72
4	1.03	0.94	1.18	0.13	0.63	0.25	0.15	2.54	0.13	0.41	0.42
5	0.59	0.26	0.51	0.31	0.42	0.55	0.26	0.86	0.33	0.42	0.84
6	0.99	2.55	1.53	0.002	0.89	0.0002	0.002	3.23	0	0.65	0

Table 66. Affected areas in Labo, Camarines Norte during a 100-Year Rainfall Return Period (4)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Labo (in sq. km.)
	Malangcao-Basud
1	8.48
2	0.48
3	0.44
4	1.16
5	0.64
6	0.54

For the 100-year return period, 30.32% of the municipality of Paracale with an area of 157.3 sq. km. will experience flood levels of less than 0.20 meters; 2.85% of the area will experience flood levels of 0.21 to 0.50 meters while 2.63%, 1.08%, 2.68%, and 0.24% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 67 to Table 68 are the affected areas in square kilometers by flood depth per barangay.

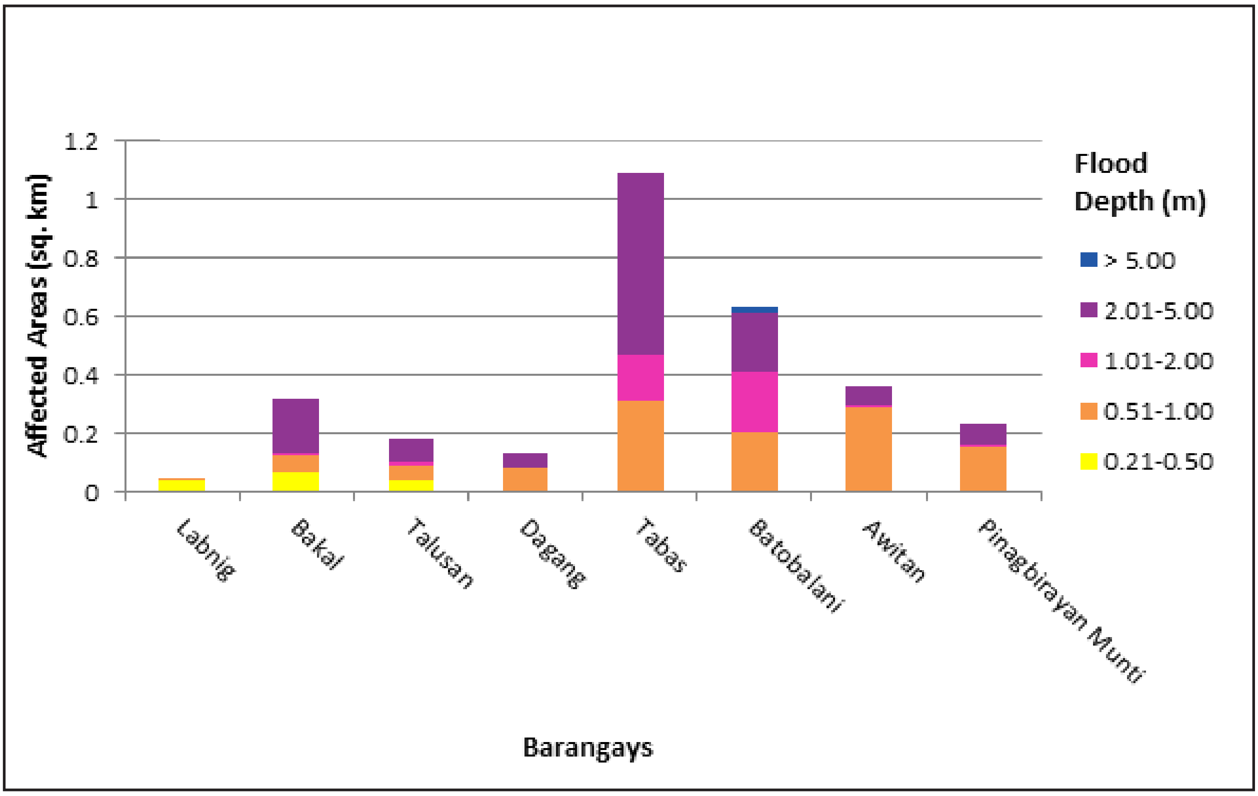


Figure 100. Areas affected by flooding in Paracale, Camarines Norte for a 100-Year Return Period rainfall event. (1)

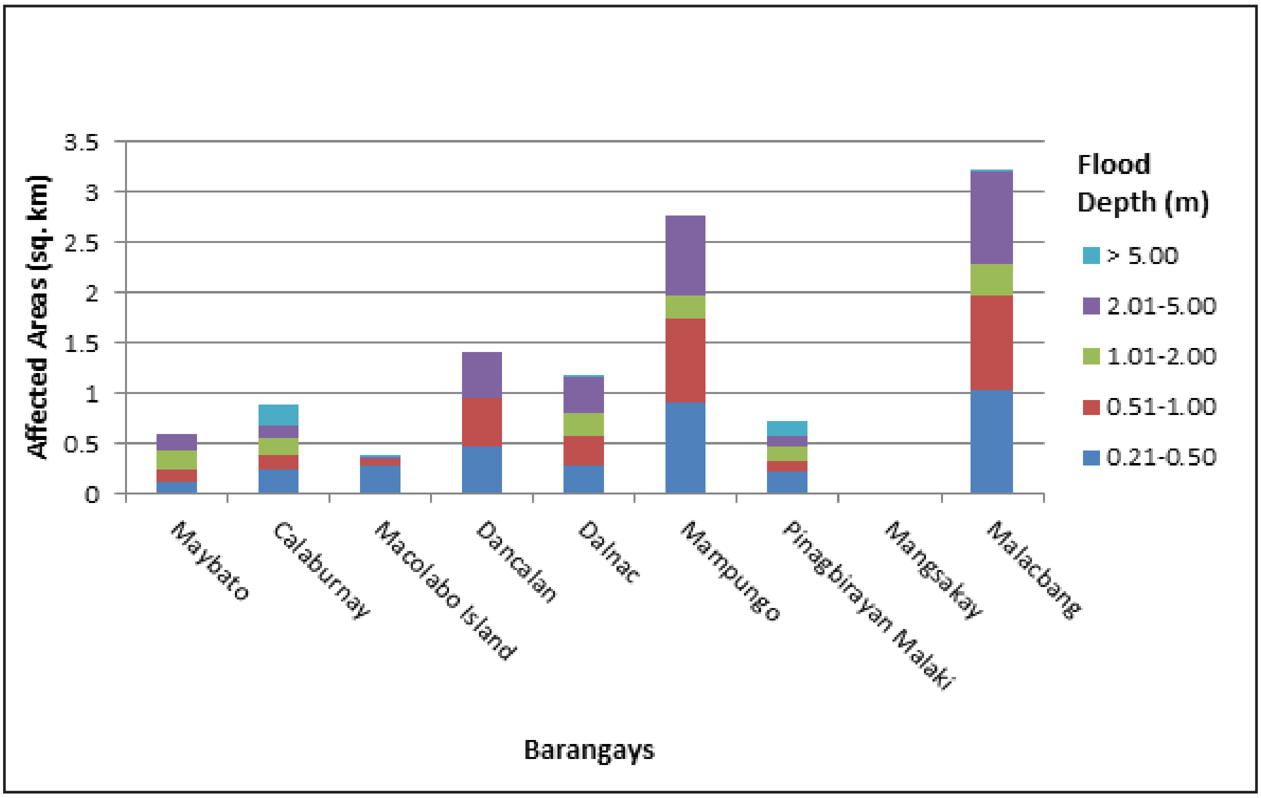


Figure 101. Areas affected by flooding in Paracale, Camarines Norte for a 100-Year Return Period rainfall event. (2)

Table 67. Affected areas in Paracale, Camarines Norte during a 100-Year Rainfall Return Period. (1)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Paracale (in sq. km.)							
	Labnig	Bakal	Talusan	Dagang	Tabas	Batobalani	Awitan	Pinagbirayan Munti
1	0.23	0.43	0.74	1.15	1.27	1.52	1.64	2.14
2	0.036	0.065	0.036	0.083	0.25	0.14	0.24	0.12
3	0.013	0.056	0.05	0.083	0.31	0.2	0.29	0.15
4	0	0.0084	0.019	0.001	0.16	0.21	0.0029	0.01
5	0	0.19	0.074	0.045	0.62	0.2	0.07	0.073
6	0	0	0	0	0	0.018	0	0

Table 68. Affected areas in Paracale, Camarines Norte during a 100-Year Rainfall Return Period. (2)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Paracale (in sq. km.)								
	Maybato	Calaburnay	Macolabo Island	Dancalan	Dalnac	Mampungo	Pinagbirayan Malaki	Mangsakay	Malacbang
1	2.37	2.67	3.66	3.89	4.18	3.94	4.69	0	13.17
2	0.11	0.24	0.27	0.47	0.27	0.91	0.21	0	1.03
3	0.12	0.14	0.075	0.47	0.31	0.82	0.11	0	0.94
4	0.19	0.18	0.0023	0.0075	0.23	0.23	0.15	0	0.3
5	0.18	0.11	0.021	0.46	0.34	0.79	0.11	0	0.93
6	0	0.22	0.0013	0	0.0024	0	0.13	0	0.013

For the 100-year return period, 57.37% of the municipality of Talisay with an area of 31.83 sq. km. will experience flood levels of less than 0.20 meters; 29.78% of the area will experience flood levels of 0.21 to 0.50 meters while 18.44%, 4.23%, 5.47%, and 0.57% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 69 to Table 70 are the affected areas in square kilometers by flood depth per barangay.

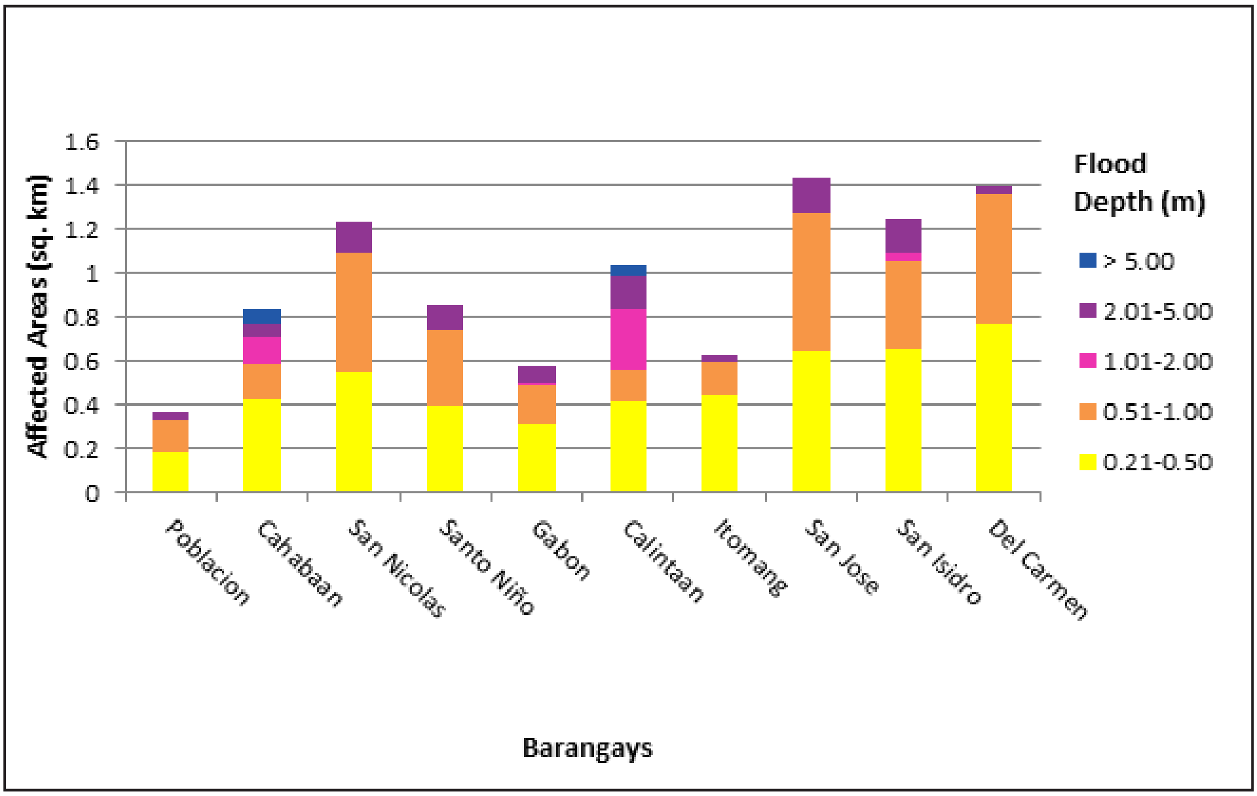


Figure 102. Affected areas in Talisay, Camarines Norte during a 100-Year Rainfall Return Period. (1)

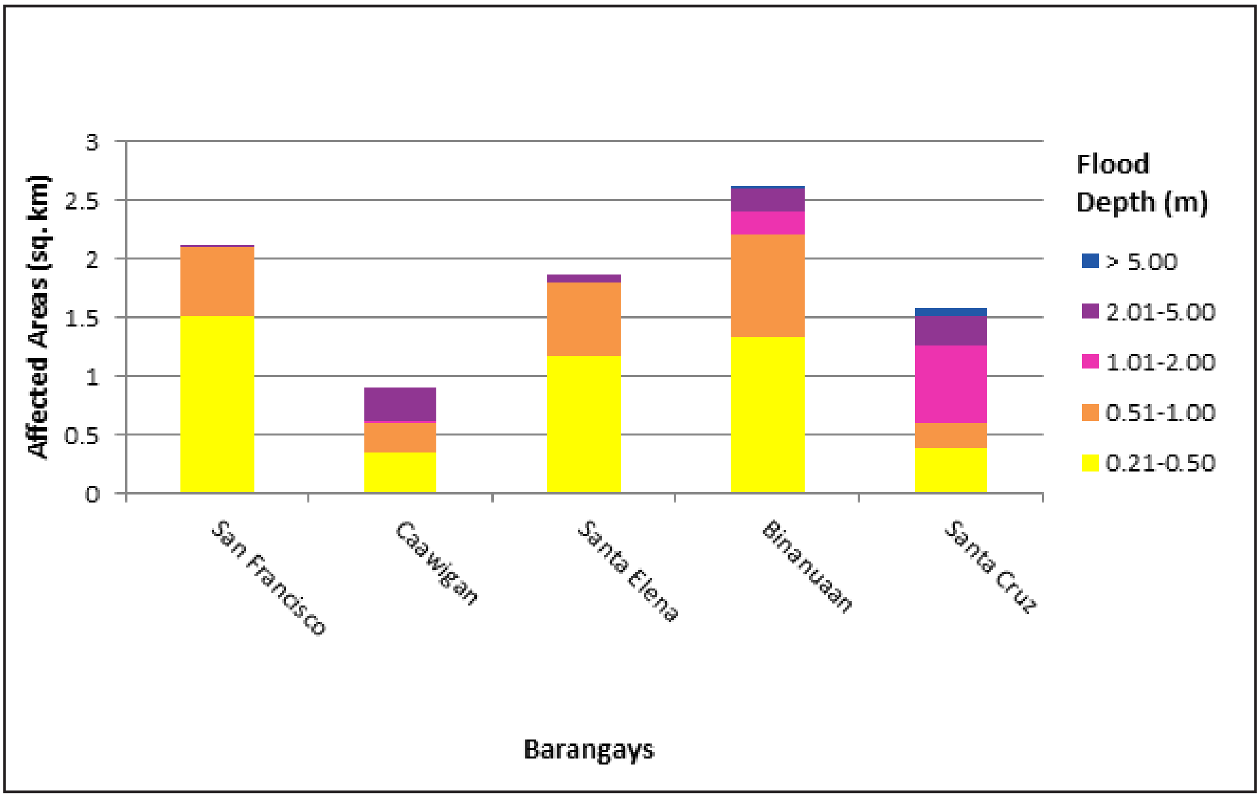


Figure 103. Affected areas in Talisay, Camarines Norte during a 100-Year Rainfall Return Period. (2)

Table 69. Affected areas in Talisay, Camarines Norte during a 100-Year Rainfall Return Period. (1)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Talisay (in sq. km.)									
	Poblacion	Cahabaan	San Nicolas	Santo Niño	Gabon	Calintaan	Itomang	San Jose	San Isidro	Del Carmen
1	0.35	0.72	0.67	0.82	1.01	0.72	1.1	0.99	1.45	1.55
2	0.18	0.42	0.55	0.39	0.31	0.41	0.44	0.64	0.65	0.77
3	0.15	0.16	0.54	0.35	0.18	0.15	0.15	0.63	0.4	0.59
4	0	0.13	0.0001	0	0.013	0.27	0.0048	0.0042	0.041	0.0001
5	0.036	0.052	0.14	0.11	0.069	0.15	0.031	0.16	0.15	0.032
6	0	0.066	0	0	0	0.051	0	0	0	0

Table 58. Affected areas in Talisay, Camarines Norte during a 25-Year Rainfall Return Period. (2)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Talisay (in sq. km.)				
	San Francisco	Caawigan	Santa Elena	Binanuaan	Santa Cruz
1	1.08	1.99	1.85	1.61	2.35
2	1.5	0.35	1.16	1.32	0.39
3	0.59	0.25	0.64	0.89	0.2
4	0.0011	0.022	0	0.19	0.67
5	0.02	0.28	0.062	0.2	0.25
6	0	0	0	0.0031	0.06

For the 100-year return period, 8.47% of the municipality of Daet with an area of 50.19 sq. km. 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 0.54%, 0.05%, 0.38%, and 0.00% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 71 are the affected areas in square kilometers by flood depth per barangay.

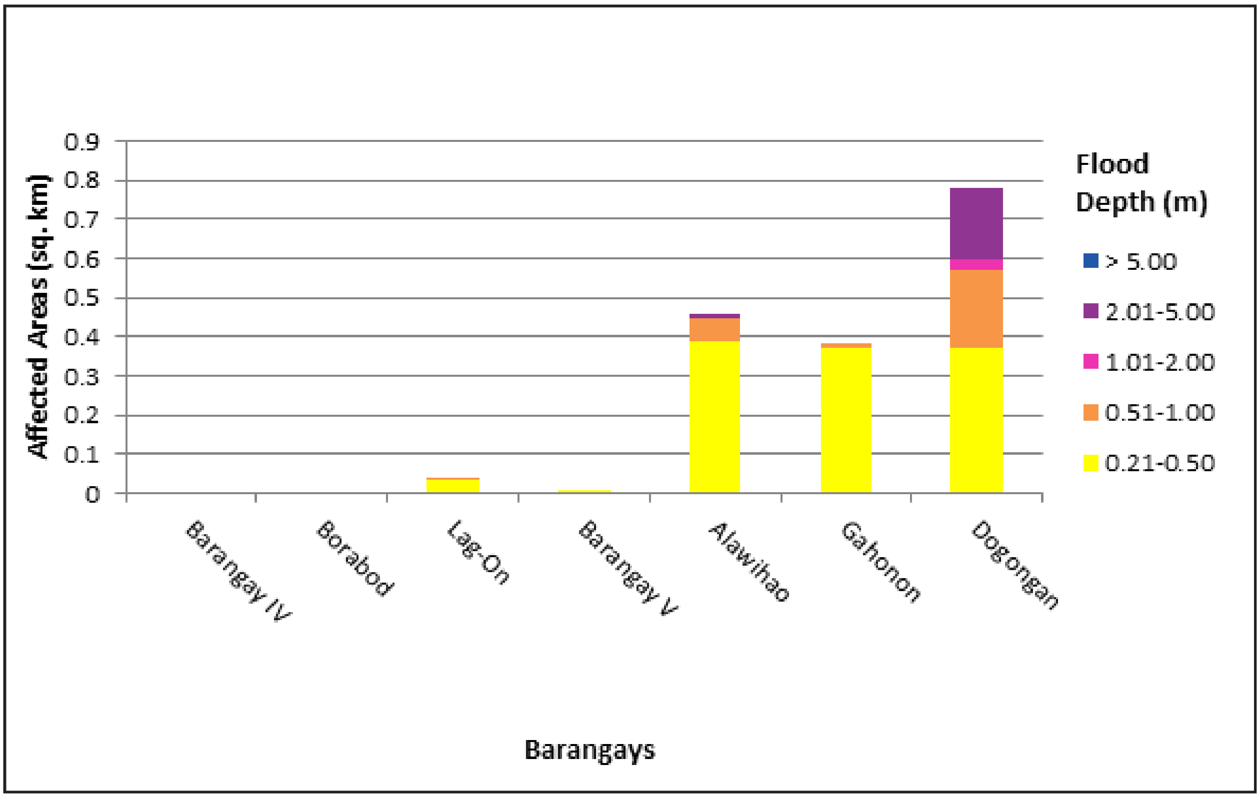


Figure 104. Affected Areas in Daet, Camarines Norte during a 100-Year Rainfall Return Period

Table 71. Affected areas in Daet, Camarines Norte by flood level for a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Daet (in sq. km.)						
	Barangay IV	Borabod	Lag-On	Barangay V	Alawihao	Gahonon	Dogongan
1	0.0055	0.0068	0.13	0.19	0.93	1.03	1.96
2	0	0	0.036	0.008	0.39	0.37	0.37
3	0	0	0.0025	0	0.056	0.014	0.2
4	0	0	0	0	0.0001	0	0.027
5	0	0	0	0	0.012	0	0.18
6	0	0	0	0	0	0	0

For the 100-year return period, 33.05% of the municipality of San Vicente with an area of 51.97 sq. km. will experience flood levels of less than 0.20 meters; 3.64% of the area will experience flood levels of 0.21 to 0.50 meters while 2.82%, 2.14%, 2.82%, and 0.16% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 72 are the affected areas in square kilometers by flood depth per barangay.

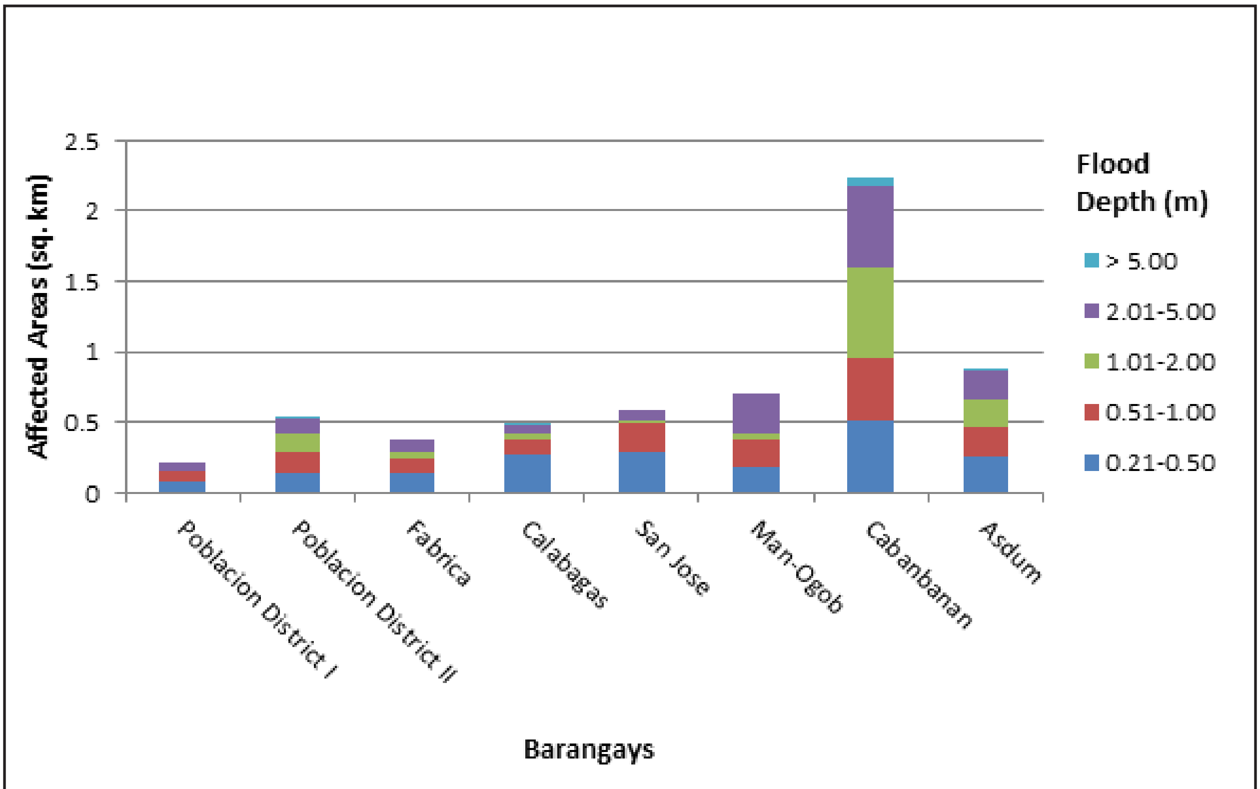


Figure 105. Affected Areas in San Vicente, Camarines Norte during a 100-Year Rainfall Return Period

Table 72. Affected areas in San Vicente, Camarines Norte by flood level for a 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Vicente (in sq. km.)							
	Poblacion District I	Poblacion District II	Fabrica	Calabagas	San Jose	Man-Ogob	Cabanbanan	Asdum
1	0.71	0.8098	1.6387	2.0074	2.0662	2.1244	3.1653	4.6562
2	0.0744	0.1449	0.1468	0.2711	0.292	0.1811	0.5156	0.2649
3	0.0762	0.1365	0.0954	0.1024	0.2106	0.1965	0.4377	0.2089
4	0.0007	0.1376	0.0451	0.0536	0.0059	0.0435	0.642	0.1862
5	0.0659	0.1097	0.094	0.0517	0.0828	0.279	0.5781	0.2062
6	0	0.0031	0	0.006	0	0	0.0674	0.005

For the 100-year return period, 26.88% of the municipality of Vinzons with an area of 94.05 sq. km. will experience flood levels of less than 0.20 meters; 13.87% of the area will experience flood levels of 0.21 to 0.50 meters while 14.04%, 1.85%, 9.02%, 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 more than 5 meters, respectively. Listed in Table 73 to Table 74 are the affected areas in square kilometers by flood depth per barangay.

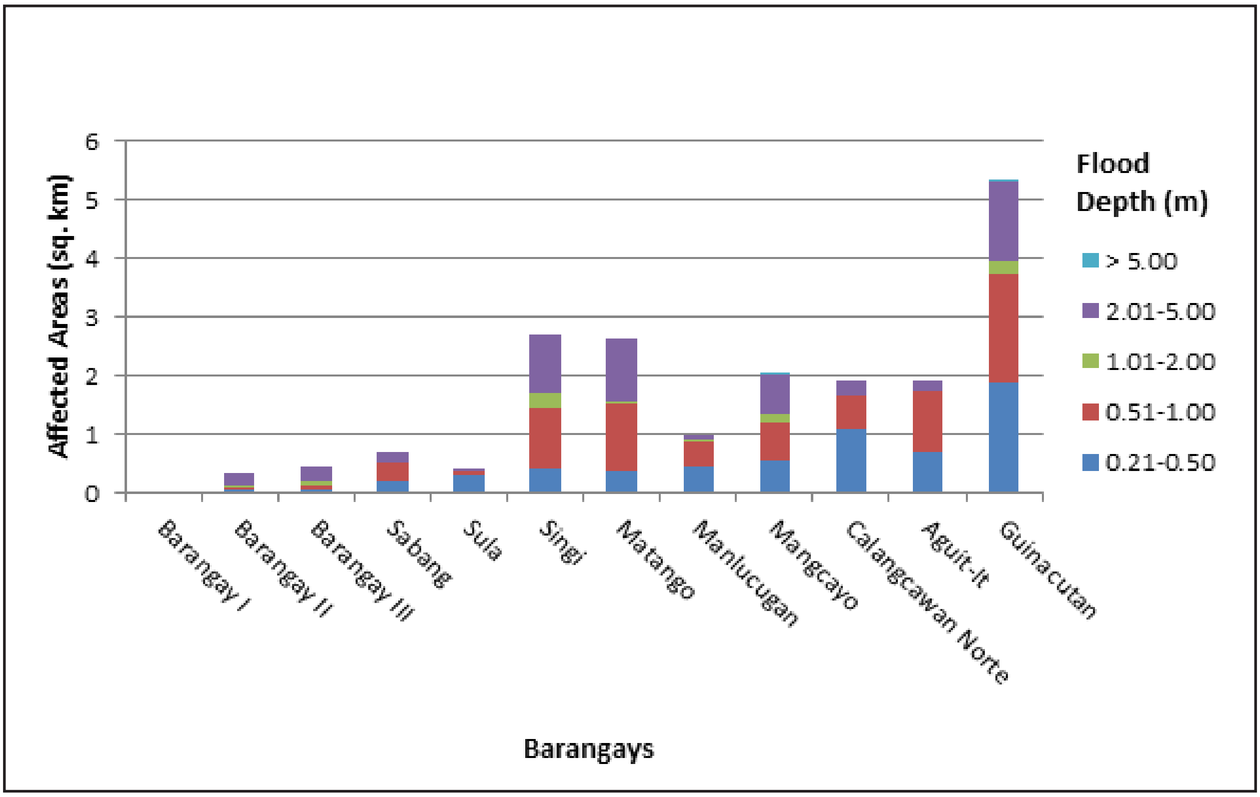


Figure 106. Affected Areas in Vinzons, Camarines Norte during a 100-Year Rainfall Return Period (1)

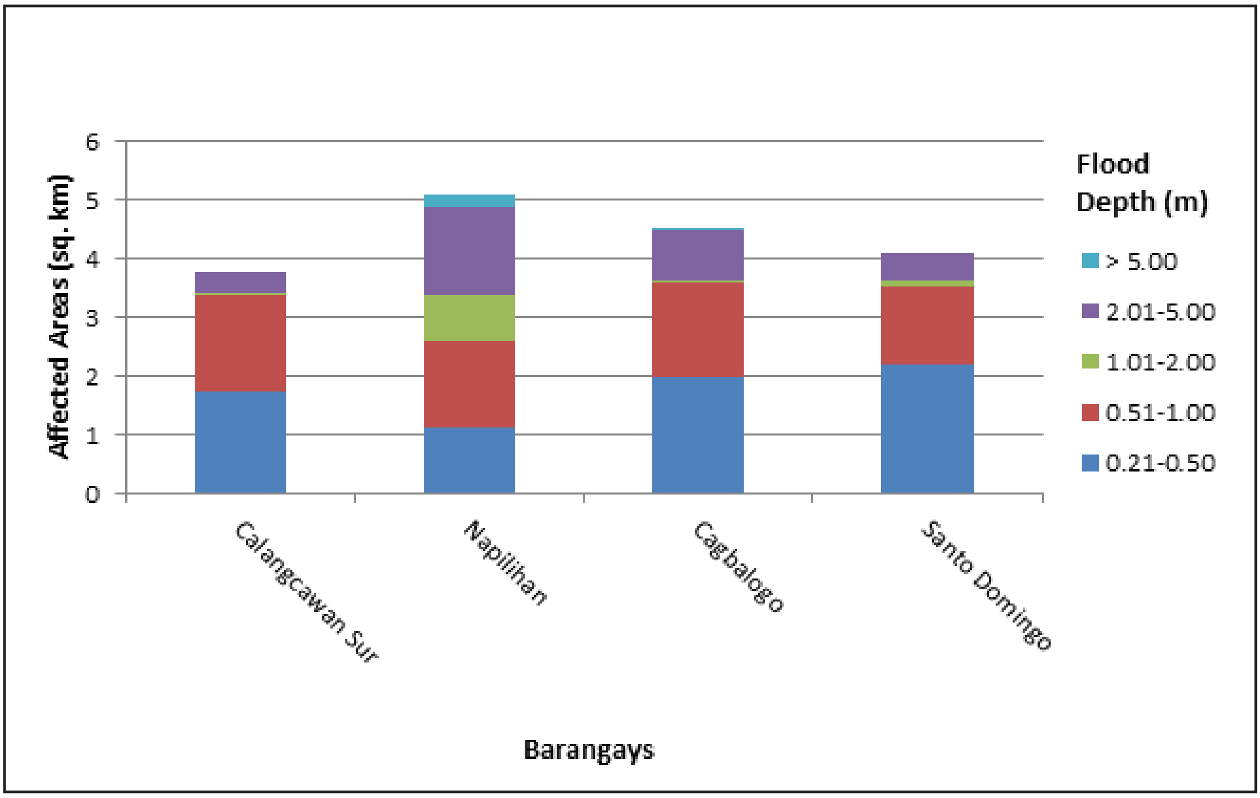


Figure 107. Affected Areas in Vinzons, Camarines Norte during a 100-Year Rainfall Return Period (2)

Table 73. Affected areas in Vinzons, Camarines Norte by flood level for a 100-Year Rainfall Return Period. (1)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Vinzons (in sq. km.)											
	Barangay I	Barangay II	Barangay III	Sabang	Sula	Singi	Matango	Manlucugan	Mangcayo	Calangcawan Norte	Aguit-It	Guinacutan
1	0	0.13	0.17	0.61	0.79	0.47	1.07	1.51	1.5	2.11	2.34	1.99
2	0	0.035	0.049	0.19	0.31	0.41	0.38	0.45	0.56	1.07	0.7	1.86
3	0	0.052	0.055	0.32	0.051	1.04	1.15	0.41	0.62	0.58	1.04	1.87
4	0	0.027	0.094	0	0	0.24	0.02	0.064	0.14	0	0	0.21
5	0	0.22	0.25	0.17	0.006	1.02	1.07	0.038	0.71	0.27	0.17	1.37
6	0	0	0	0	0	0	0	0	0.0013	0	0	0.0022

Table 74. Affected areas in Vinzons, Camarines Norte by flood level for a 100-Year Rainfall Return Period. (2)

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Vinzons (in sq. km.)			
	Calangcawan Sur	Napilihan	Cagbalogo	Santo Domingo
1	2.96	1.91	3.45	4.27
2	1.73	1.13	1.97	2.2
3	1.64	1.44	1.63	1.31
4	0.023	0.79	0.029	0.1
5	0.37	1.5	0.84	0.48
6	0	0.21	0.0015	0

Moreover, the generated flood hazard maps for the Labo Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps ("Low", "Medium", and "High"), the affected institutions were given their individual assessment for each Flood Hazard Scenario (5-year, 25-year, and 10-year).

Table 75. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	40.80	42.80	43.43
Medium	38.42	48.83	55.59
High	27.86	41.98	52.00
TOTAL	**107.080**	**133.60**	**151.017**

Of the 70 identified Education Institute in Labo Floodplain, twelve (12) schools were discovered exposed to Low-level flooding during a 5-year scenario, while six (6) schools were found exposed to Medium-level flooding in the same scenario. Two (2) schools were exposed to High-level flooding.

In the 25-year scenario, eleven (11) schools were found exposed to Low-level flooding, while thirteen (13) schools were discovered exposed to Medium-level flooding. Two (2) schools were exposed to High-level flooding.

For the 100-year scenario, sixteen (16) schools were discovered exposed to Low-level flooding while eighteen (18) schools were exposed to Medium-level flooding. In the same scenario, two (2) schools were found exposed to High-level flooding.

Apart from this, fourteen (14) Medical Institutions were identified in the Labo Floodplain, with one (1) and two (2) exposed to low- and medium-level flooding, respectively for the 5-year scenario.

For the 25-year scenario, one (1) was found exposed to low-level flooding while two (2) and one (1) were exposed to medium- and high-level flooding.

For the 100-year scenario, one (1) medical institution was found exposed to low-level flooding while two (2) were exposed to medium-level flooding. One (1) institution was found exposed to high-level flooding.

5.11 Flood Validation

To check and validate the extent of flooding in different river systems, there is a need to perform validation survey work. Field personnel gathered secondary data regarding flood 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 were 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 interview with some residents who have knowledge of or have had experienced flooding in a particular area.

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 109.
The flood validation consists of 190 points randomly selected all over the Labo Floodplain (Figure 108). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 2.27m. Table 76 shows a contingency matrix of the comparison.

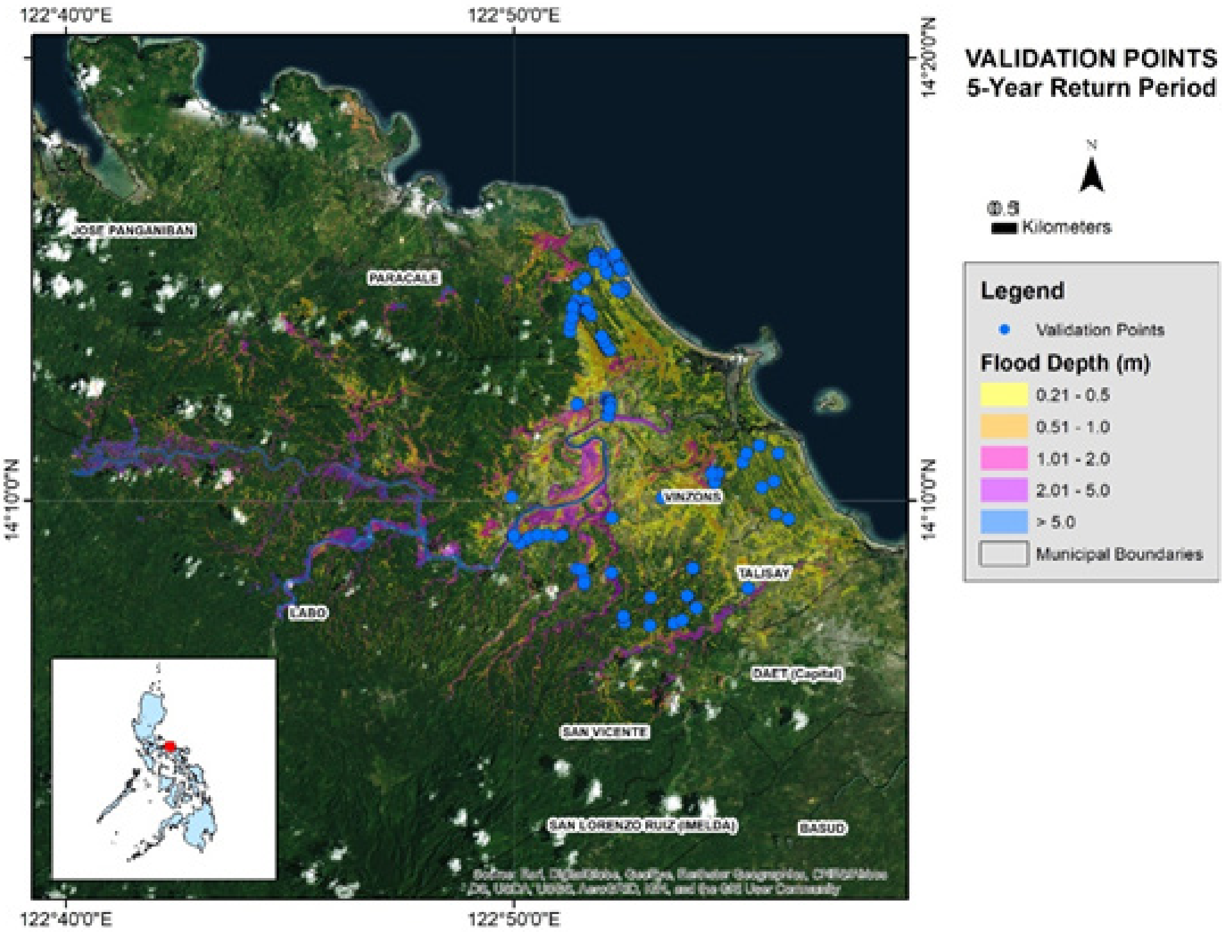


Figure 108. Validation points for 5-year Flood Depth Map of Labo Floodplain

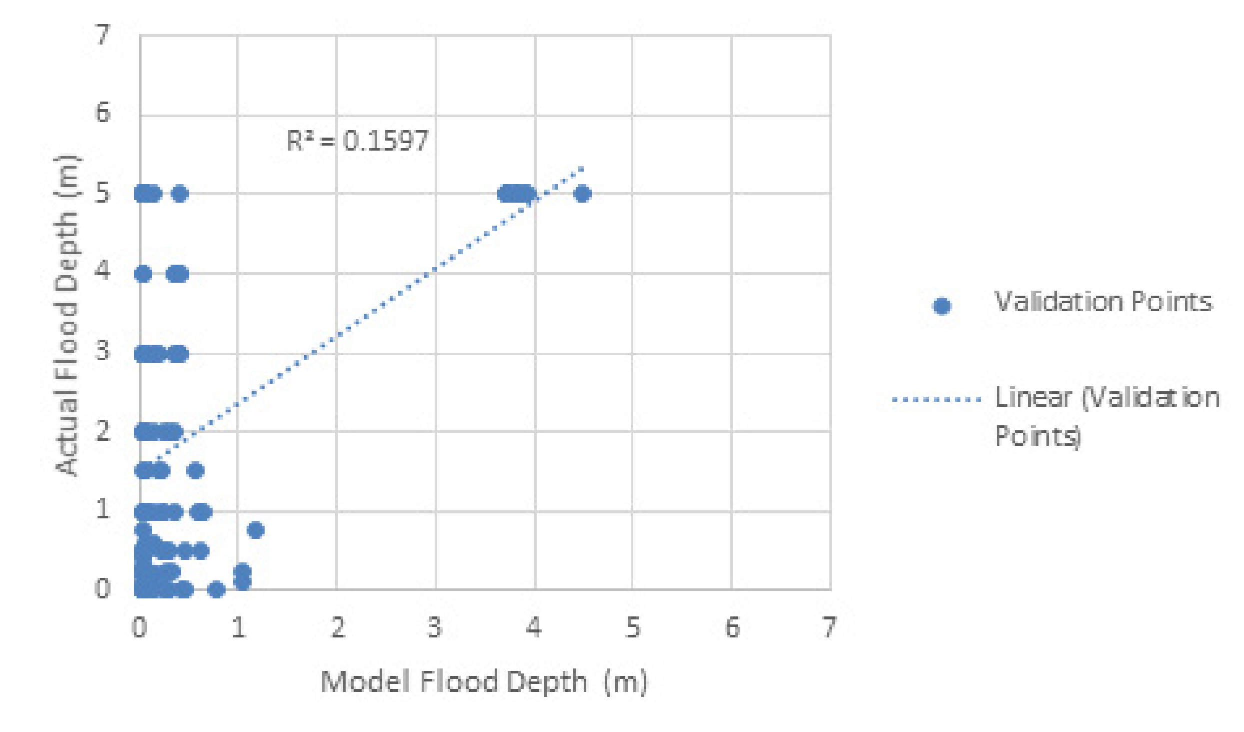


Figure 109. Flood map depth vs actual flood depth

Table 76. Actual Flood Depth vs Simulated Flood Depth

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	36	6	1	1	0	0	44
0.21-0.50	36	7	1	1	0	0	45
0.51-1.00	12	3	3	1	0	0	19
1.01-2.00	11	4	1	0	0	0	16
2.01-5.00	40	15	0	0	11	0	66
> 5.00	0	0	0	0	0	0	0
Total	135	35	6	3	11	0	190

The overall accuracy generated by the flood model is estimated at 30.00% with 57 points correctly matching the actual flood depths. In addition, there were 45 points estimated one level above and below the correct flood depths while there were 18 points and 67 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 122 points were underestimated in the modeled flood depths of Labo.

Table 77. Summary of Accuracy Assessment in Labo River Basin

	No. of Points	%
Correct	57	30.00
Overestimated	11	5.79
Underestimated	122	64.21
Total	190	100.00

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

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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.

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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. Technical Specifications of the LIDAR Sensors used in the Labo Floodplain Survey

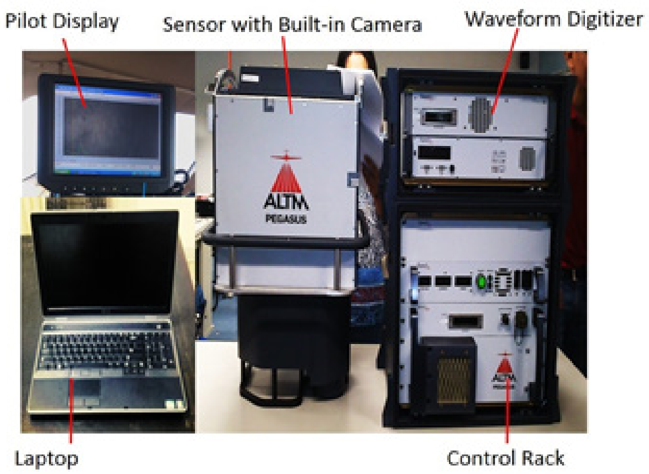


Figure A-1.1 Pegasus Sensor

Table A-1.1 Parameters and Specifications

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**
Municipality: **JOSE PANGANIBAN**
Barangay: **BATOBALANI**
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

Figure A-2.1 CMN-33

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

Figure A-2.2 CMN-29

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

Figure A-3.1 DENR

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°58'54.64262"	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

Figure A-3.2 CM-198

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

Figure A-3.3 CN-211

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

Figure A-3.4 CMN-J2

ANNEX 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

<table>
<tr><th>Data Acquisition Component Sub-Team</th><th>Designation</th><th>Name</th><th>Agency/ Affiliation</th></tr>
<tr><td>PHIL-LIDAR 1</td><td>Program Leader</td><td>ENRICO C. PARINGIT, D.ENG</td><td>UP-TCAGP</td></tr>
<tr><td>Data Acquisition Component Leader</td><td>Data Component Project Leader – I</td><td>ENGR. LOUIE BALICANTA</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3">Survey Supervisor</td><td>Chief Science Research Specialist (CSRS)</td><td>ENGR. CHRISTOPHER CRUZ</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Supervising Science Research Specialist (Supervising SRS)</td><td>LOVELY GRACIA ACUÑA</td><td rowspan="2">UP-TCAGP</td></tr>
<tr><td>LOVELYN ASUNCION</td></tr>
<tr><th colspan="4">FIELD TEAM</th></tr>
<tr><td rowspan="6">LiDAR Operation</td><td rowspan="2">Senior Science Research Specialist (SSRS)</td><td>JASMINE ALVIAR</td><td>UP-TCAGP</td></tr>
<tr><td>PAULINE JOANNE ARCEO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="4">Research Associate (RA)</td><td>KRISTINE JOY ANDAYA</td><td>UP-TCAGP</td></tr>
<tr><td>MILLIE SHANE REYES</td><td>UP-TCAGP</td></tr>
<tr><td>JONATHAN ALMALVEZ</td><td>UP-TCAGP</td></tr>
<tr><td>JERIEL PAUL ALAMBAN</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Ground Survey, Data Download and Transfer</td><td rowspan="2">Research Associate (RA)</td><td>JASMIN DOMINGO</td><td>UP-TCAGP</td></tr>
<tr><td>GEF SORIANO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="6">LiDAR Operation</td><td rowspan="2">Airborne Security</td><td>SSG. ERWIN DELOS SANTOS</td><td rowspan="2">PHILIPPINE AIR FORCE (PAF)</td></tr>
<tr><td>SSG JAYCO MANZANO</td></tr>
<tr><td rowspan="4">Pilot</td><td>CAPT. CESAR ALFONSO III</td><td rowspan="4">ASIAN AEROSPACE CORPORATION (AAC)</td></tr>
<tr><td>CAPT. MARK TANGONAN</td></tr>
<tr><td>CAPT. RANDY LAGCO</td></tr>
<tr><td>CAPT. KHALIL ANTHONY CHI</td></tr>
</table>

ANNEX 5. Data Transfer Sheet Labo Floodplain

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 KJ ANDAYA
Position RA
Signature

Name Irish Cortez 4/11/16
Position RA
Signature

Figure A-5.1. Transfer Sheet for Labo Floodplain (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 [signature]

Received by

Name Ac Bongat
Position SSRS
Signature [signature] 5/18/16

16-31

Figure A-5.2. Transfer Sheet for Labo Floodplain (2)

ANNEX 6. Flight logs for the flight missions

1. Flight Log for 23172P Mission


Data Acquisition Flight Log

Flight Log No.: 23172P

1 LIDAR Operator: MS Reyes
2 ALTM Model: Pegasus
3 Mission Name: 1BLK20A195
4 Type: VFR
5 Aircraft Type: CesnnaT206H
6 Aircraft Identification: 9122
7 Pilot: M. Tangonan
8 Co-Pilot: R. Lagco
9 Route:
10 Date: 3-9-16
12 Airport of Departure (Airport, City/Province): Bagasbas
12 Airport of Arrival (Airport, City/Province): Bagasbas
13 Engine On: 13:33
14 Engine Off: 15:59
15 Total Engine Time: 2+26
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. Completed 11 lines at BLK20A.

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

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

Acquisition Flight Certified by: AIC Jaime Sarmiento PAF — Signature over Printed Name (PAF Representative)

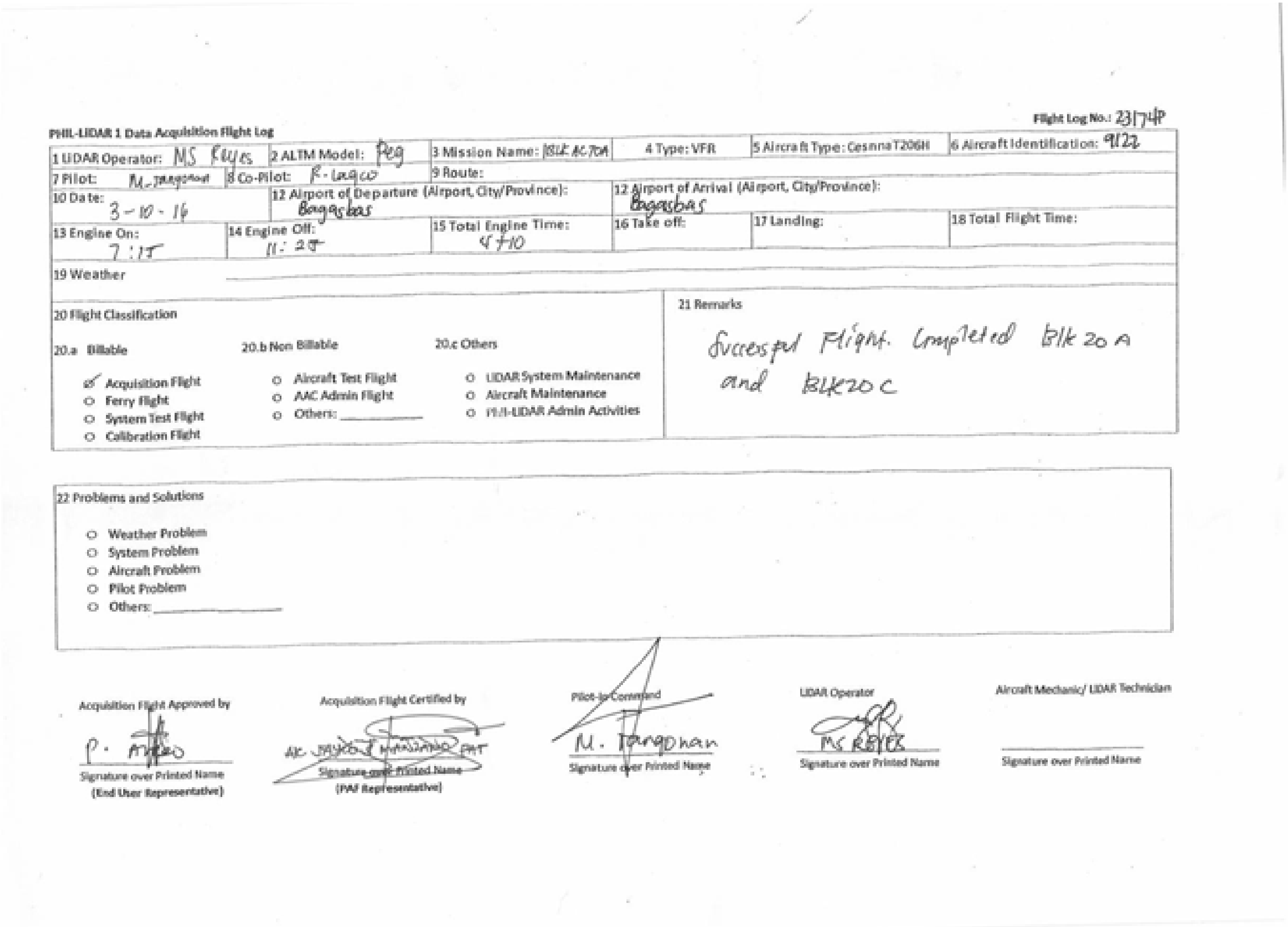
Pilot-in-Command: M. Tangonan — Signature over Printed Name

Lidar Operator: MS. Reyes — Signature over Printed Name

Aircraft Mechanic/ Technician: ____________ Signature over Printed Name

Figure A-6.1 Flight Log for 23172P Mission

2. Flight Log for 23174P Mission



Flight Log No.: 23174P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: MS Reyes	2 ALTM Model: Peg	3 Mission Name: 1BLK AC70A	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: 3-10-16	12 Airport of Departure (Airport, City/Province): Bagasbas		12 Airport of Arrival (Airport, City/Province): Bagasbas		
13 Engine On: 7:15	14 Engine Off: 11:25	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. Completed Blk 20 A and BLK20 C

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

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

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

Pilot-in-Command: M. Tangonan — Signature over Printed Name

LiDAR Operator: MC Reyes — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Figure A-6.2 Flight Log for 23174P Mission

3. Flight Log for 23176P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 23176P

1 LIDAR Operator: J. Almalvez	2 ALTM Model: Pegasus	3 Mission Name: 1BLK5708	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: M. Tangonan	8 Co-Pilot: R. Lagco	9 Route:			
10 Date: 3-10-16	12 Airport of Departure (Airport, City/Province): Bagasbas		12 Airport of Arrival (Airport, City/Province): Bagasbas		
13 Engine On: 13:32	14 Engine Off: 16:12	15 Total Engine Time: 2+40	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

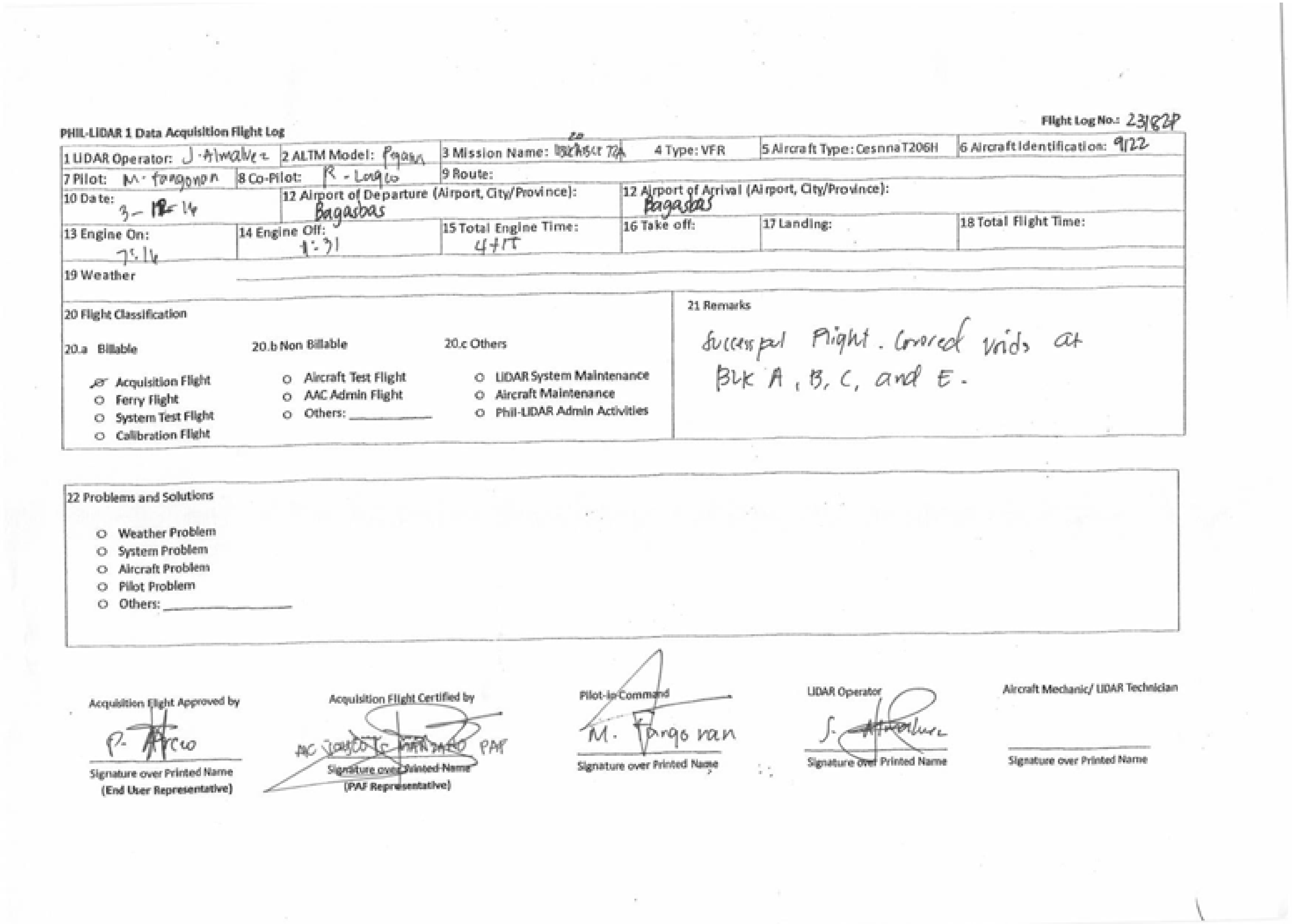
Successful flight surveyed 6 lines at Blk 20B.

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. A[illegible]	A1C Jaylo V. Manzano 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

Figure A-6.3 Flight Log for 23176P Mission

4. 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: 2BLK35CT 72A	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: 3-12-14	12 Airport of Departure (Airport, City/Province): Bagasbas		12 Airport of Arrival (Airport, City/Province): Bagasbas		
13 Engine On: 7:16	14 Engine Off: 1:31	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: P. Arceo — Signature over Printed Name (End User Representative)

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

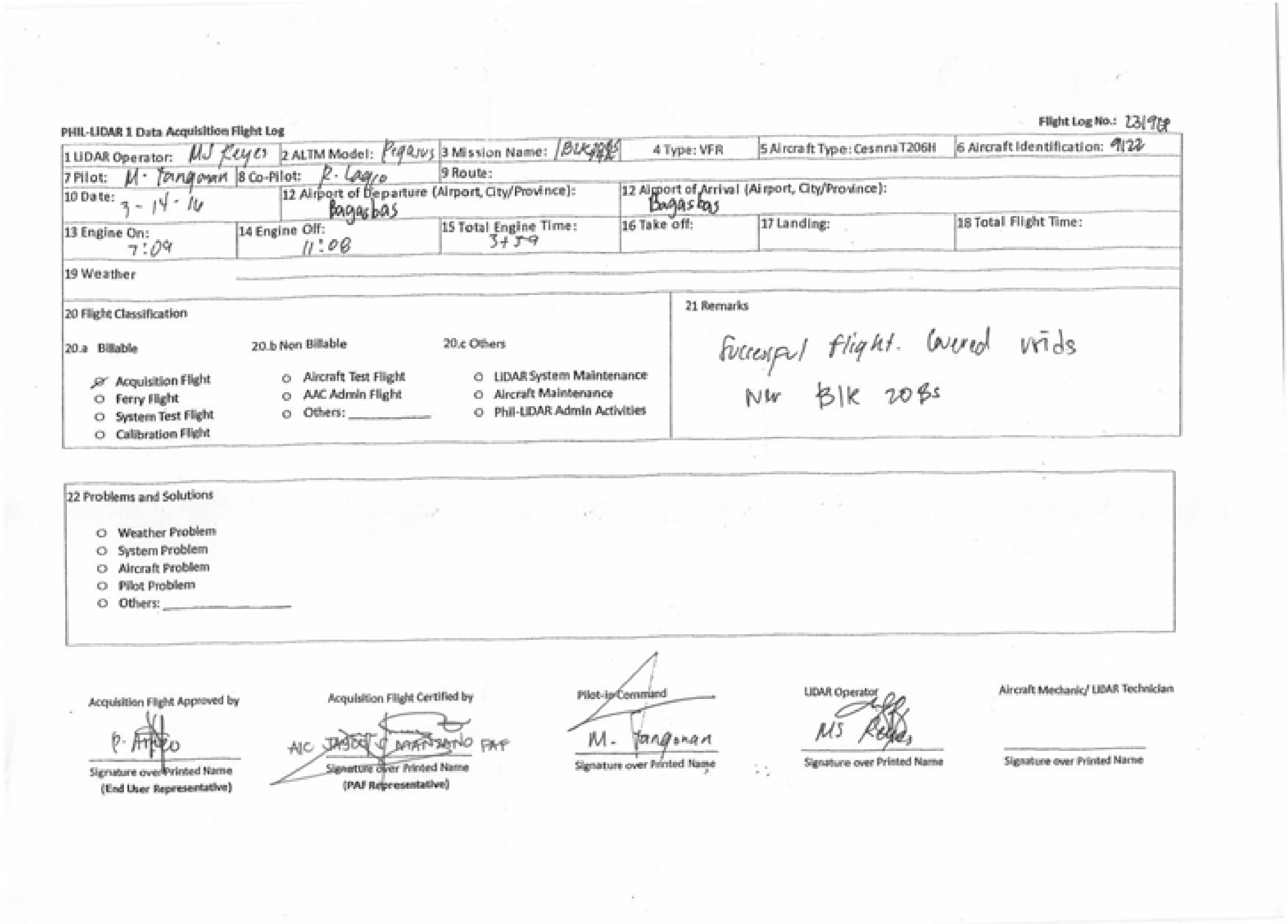
Pilot-in-Command: M. Tangonan — Signature over Printed Name

LIDAR Operator: J. Almalvez — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: Signature over Printed Name

Figure A-6.4 Flight Log for 23182P Mission

5. 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: P. Arceo — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: A1C Jason C Maristano PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: M. Tangonan — Signature over Printed Name

LIDAR Operator: MS Reyes — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: Signature over Printed Name

Figure A-6.5 Flight Log for 23190P Mission

6. 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: 1BLK20TA	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: M. Tangonan	8 Co-Pilot: R. Cagco	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 Blk20N 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
[signature]	A1C Jackson ... PAF [signature]	M. Tangonan [signature]	J. Almalvez [signature]	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.6 Flight Log for 23202P Mission

7. Flight log for 23226P (renamed from 3072P) Mission

Data Acquisition Flight Log

Flight Log No.: 3072

1 LIDAR Operator: R. Quisando	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20A098A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Dart - Dart			
10 Date: April 7, 2016	12 Airport of Departure (Airport, City/Province): Dart		12 Airport of Arrival (Airport, City/Province): Dart		
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
- 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

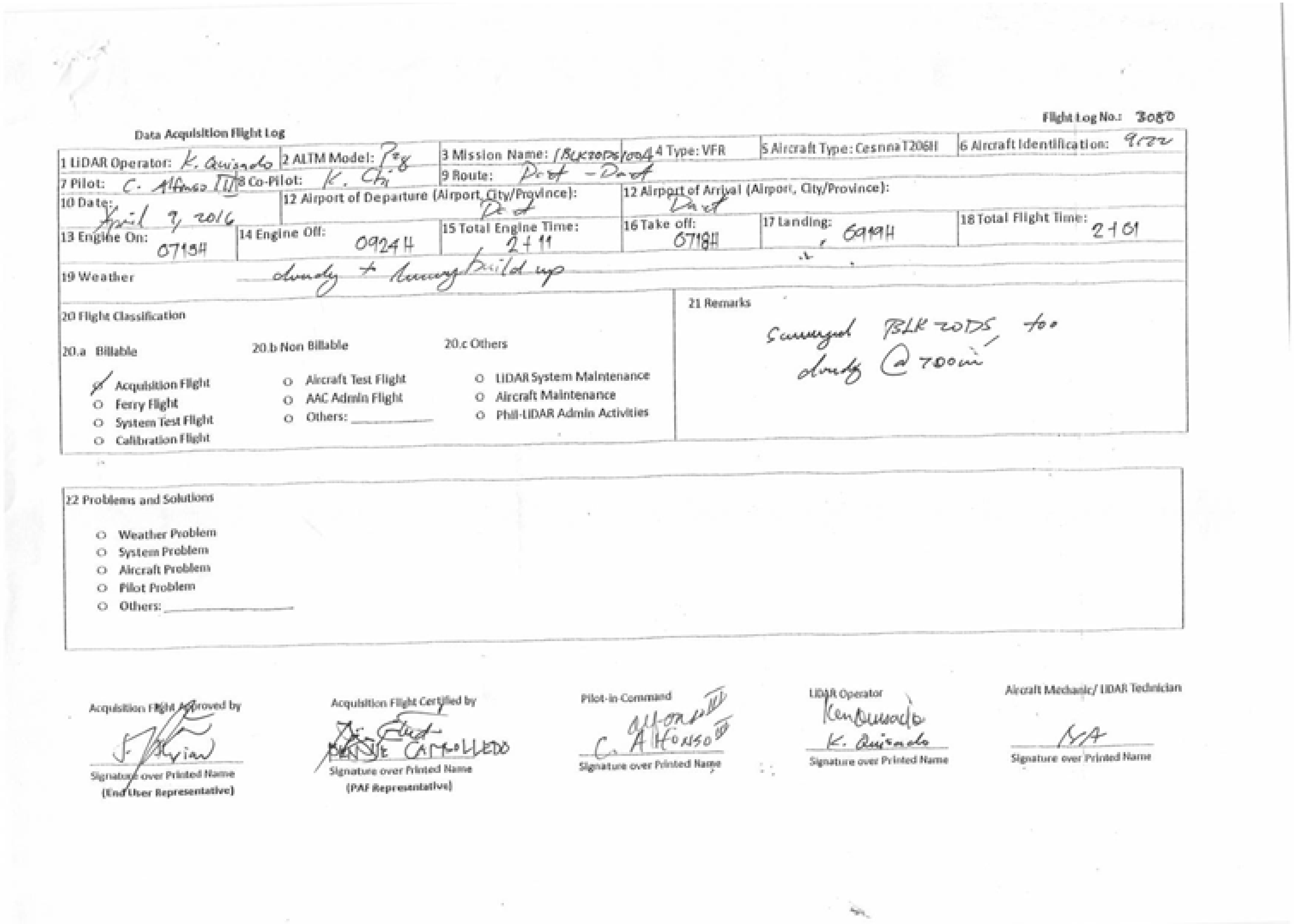
Cancelled due to transition error (Rx shutters)

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	Castillejo	C. Alfonso III	R. Quisando	MA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.7 Flight Log for 23226P (renamed from 3072P) Mission

8. 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: 1BLK20DS100A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Dvet - Dvet			
10 Date: April 9, 2016	12 Airport of Departure (Airport, City/Province): Dvet		12 Airport of Arrival (Airport, City/Province): Dvet		
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 + cumulus 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 — J. Arian — Signature over Printed Name (End User Representative)

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

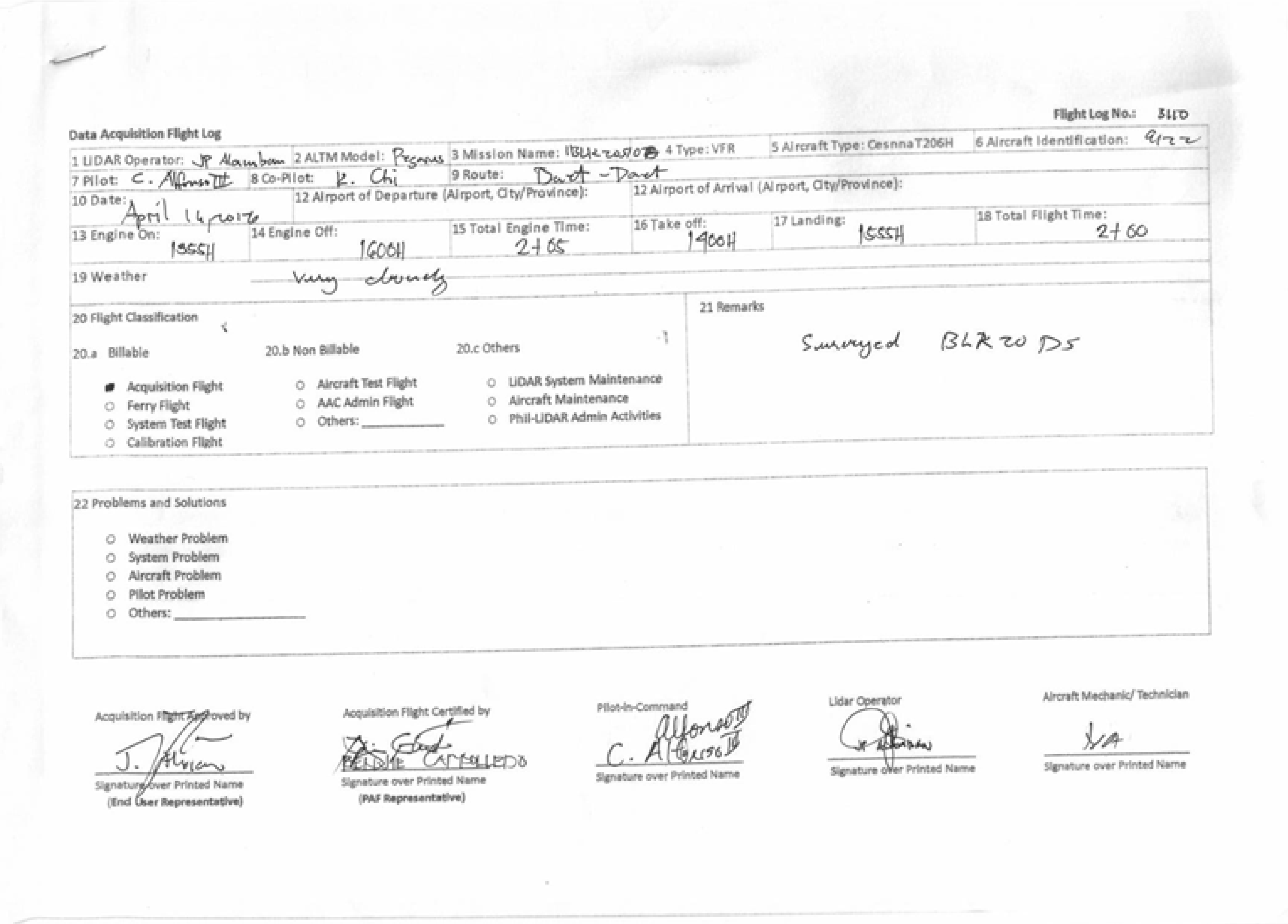
Pilot-in-Command — C. Alfonso III — Signature over Printed Name

LiDAR Operator — K. Quisado — Signature over Printed Name

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

Figure A-6.8 Flight Log for 23234P (renamed from 3080P) Mission

9. Flight log for 23264P (renamed from 3110P) Mission


Flight Log No.: 3110

Data Acquisition Flight Log

1 LIDAR Operator: JP Alambra	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20S107B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Chi	9 Route: Davt - Davt			
10 Date: April 14, 2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1355H	14 Engine Off: 1600H	15 Total Engine Time: 2+05	16 Take off: 1400H	17 Landing: 1555H	18 Total Flight Time: 2+60
19 Weather	Very 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 BLK20DS

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

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

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

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

Lidar Operator: [signature] — Signature over Printed Name

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

Figure A-6.9 Flight Log for 23264P (renamed from 3110P) Mission

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

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3112

1 LiDAR Operator: JP Alamban	2 ALTM Model: Pegasus	3 Mission Name: 1BLK20S108A	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

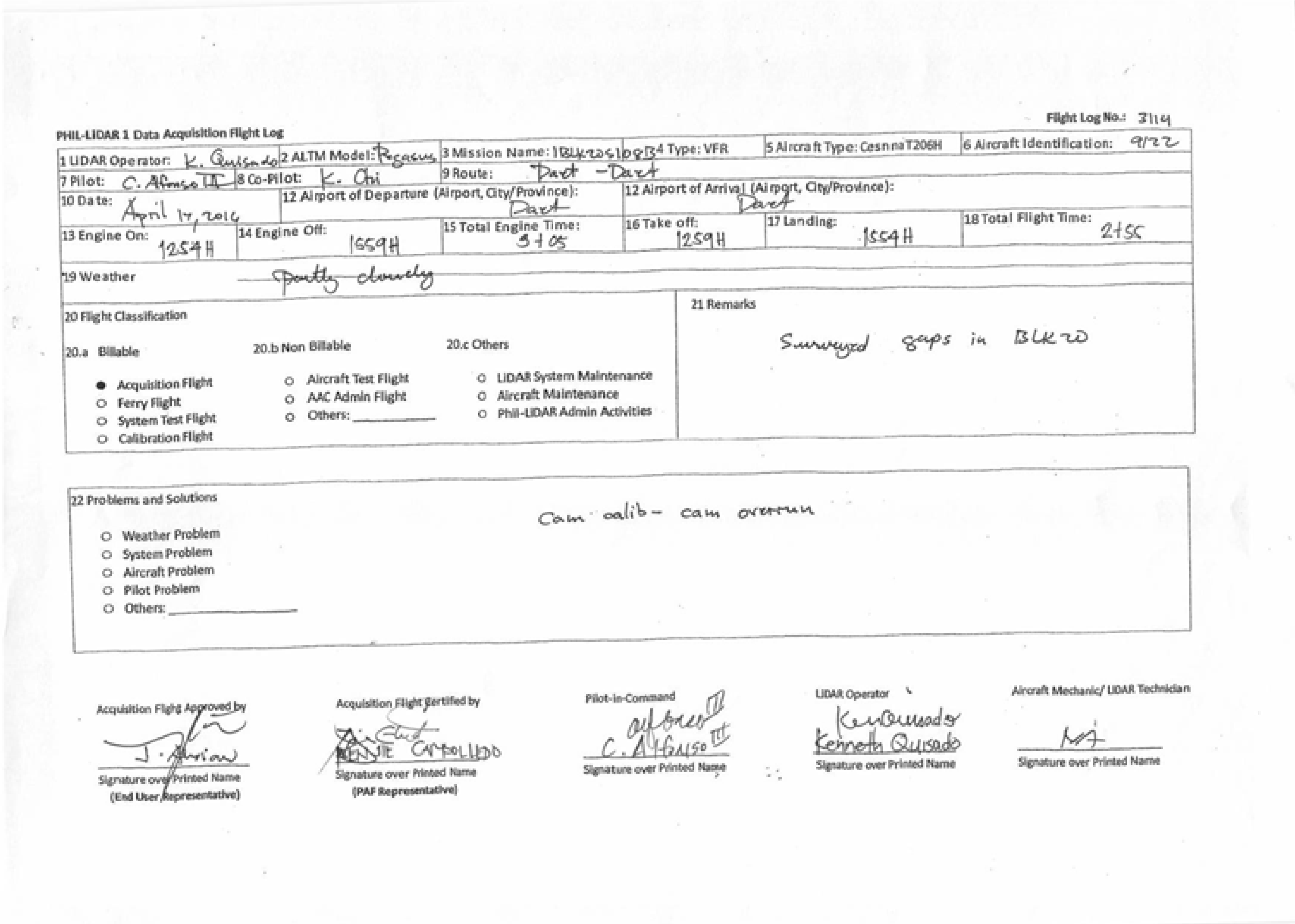
Surveyed BLK 20S

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
J. Alviar	Eddie Cabollero	C. Alfonso III	JP Alamban	[signature]
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.10 Flight Log for 23266P(3112P) Mission

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



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3114

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, 2014	12 Airport of Departure (Airport, City/Province): Daet		12 Airport of Arrival (Airport, City/Province): Daet		
13 Engine On: 1254H	14 Engine Off: 1659H	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 BLK20

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

Cam calib - cam overrun

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

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

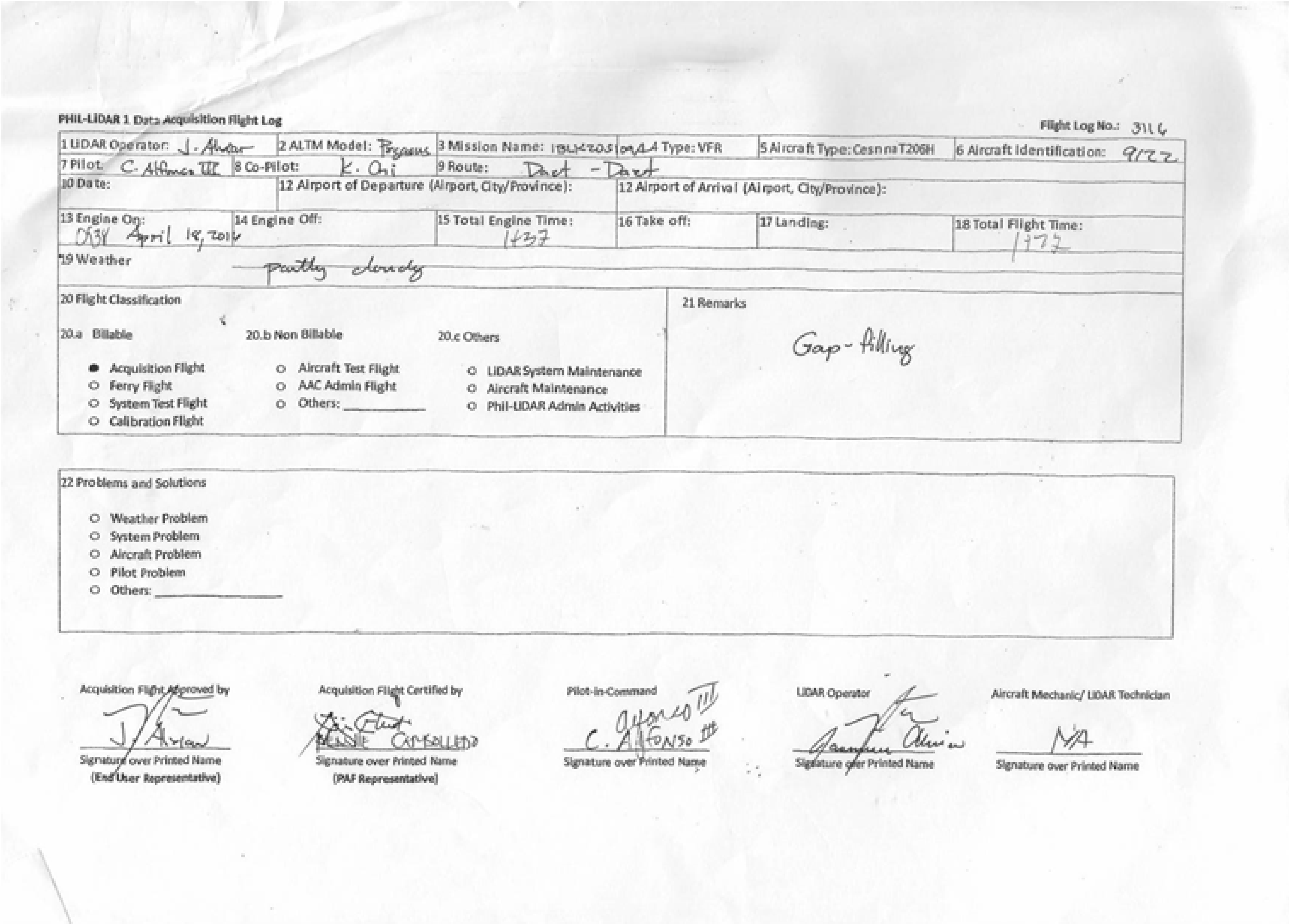
Pilot-in-Command: C. Alfonso III — Signature over Printed Name

LIDAR Operator: Kenneth Quisado — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: [signature] — Signature over Printed Name

Figure A-6.11 Flight Log for 23268P (renamed from 3114P) Mission

12. 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: 1BLK2051094A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. Alfonso III	8 Co-Pilot: K. Ani	9 Route: Daet - Daet			
10 Date:	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0534 April 18, 2016	14 Engine Off:	15 Total Engine Time: 1437	16 Take off:	17 Landing:	18 Total Flight Time: 1?7?
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: 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: [signature] — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: N/A — Signature over Printed Name

Figure A-6.12 Flight Log for 23270P (renamed from 3116P) Mission

ANNEX 7. Flight status reports

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

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
23172P	BAGASBAS	1BLK20A69B	M.S. REYES	09-Mar-16	COMPLETED 11 LINES AT BLK 20A.
23174P	BAGASBAS	1BLK20ASC70A	M.S. REYES	10-Mar-16	COMPLETED BLK20A AND BLK20C
23176P	BAGASBAS	1BLK20B70B	J. ALMALVEZ	10-Mar-16	SURVEYED 6 LINES AT BLK20B
23182P	BAGASBAS	1BLK20ABCE72A	J. ALMALVEZ	12-Mar-16	COVERED VOIDS AT BLK 20A, 20B, 20C, AND 20E.
23190P	BAGASBAS	1BLK20BS74A	M.S. REYES	14-Mar-16	COVERED VOIDS AT BLK20B
23202P	BAGASBAS	1BLK20N77A	J. ALMALVEZ	17-Mar-16	SUCCESSFUL FLIGHT OVER BLK20N WITH VOIDS
23226P	BLK 20DE DAET, PARACALE	1BLK20D098A	K QUISADO	Apr-07	SURVEYED BLK 20D,E 224.61 SQ.KM
23234P	PARACALE	1BLK20D100A	J ALAMBAN	Apr-09	SURVEYED BLK PARACALE; HEAVY BUILD UP 45.78 SQ.KM
23264P	BLK 20DS	1BLK20S107B	J ALAMBAN	Apr-16	SURVEYED PARACALE, JOSE PANGANIBAN 131.68 SQ.KM
23266P	BLK 20DS, JOSE PANGANIBAN GAPS	1BLK20S108A	J ALAMBAN	Apr-17	SURVEYED GAPS IN BLK20D 183.08 SQ.KM
23268P	BLK 20DES	1BLK20S108	K QUISADO	Apr-17	SURVEYED BLK20DES 161.62 SQ.KM
23270P	BLK 20S	1BLK20S109A	J ALVIAR	Apr-18	SURVEYED REMAINING GAPS IN BLK 20 31.02 SQ.KM

LAS BOUNDARIES PER FLIGHT

FLIGHT NO.:	23172		
AREA:	Bagasbas		
MISSION NAME:	1BLK20A69B		
ALT: 600-1100m	SCAN FREQ: 30	SCAN ANGLE: 50	
SURVEYED AREA:	89.16		

LAS

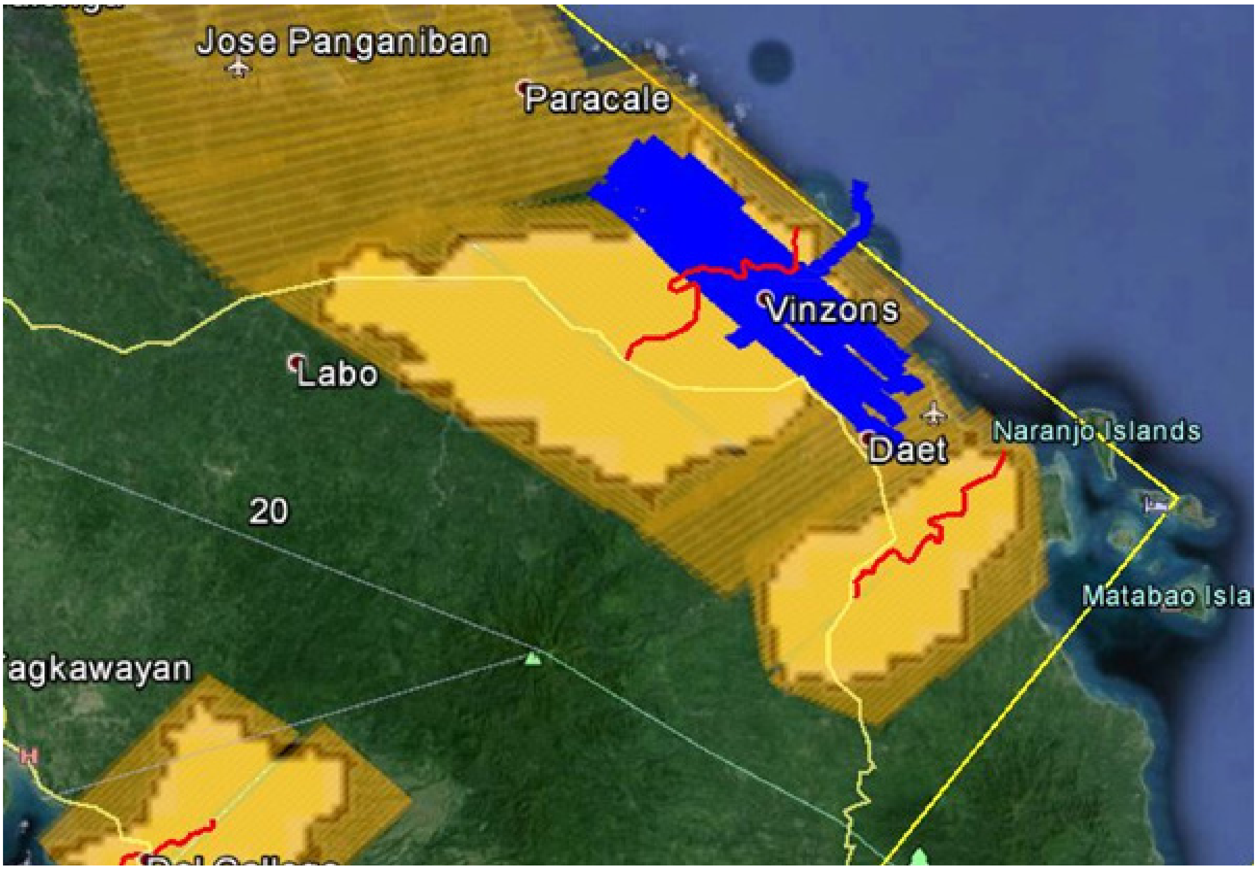


Figure A-7.1. Swath Coverage of Mission 1BLK20A69B

FLIGHT NO.: 23174
AREA: Bagasbas
MISSION NAME: 1BLK20ASC70A
ALT: 600-1100m SCAN FREQ: 30 SCAN ANGLE: 50
SURVEYED AREA: 234.09

LAS

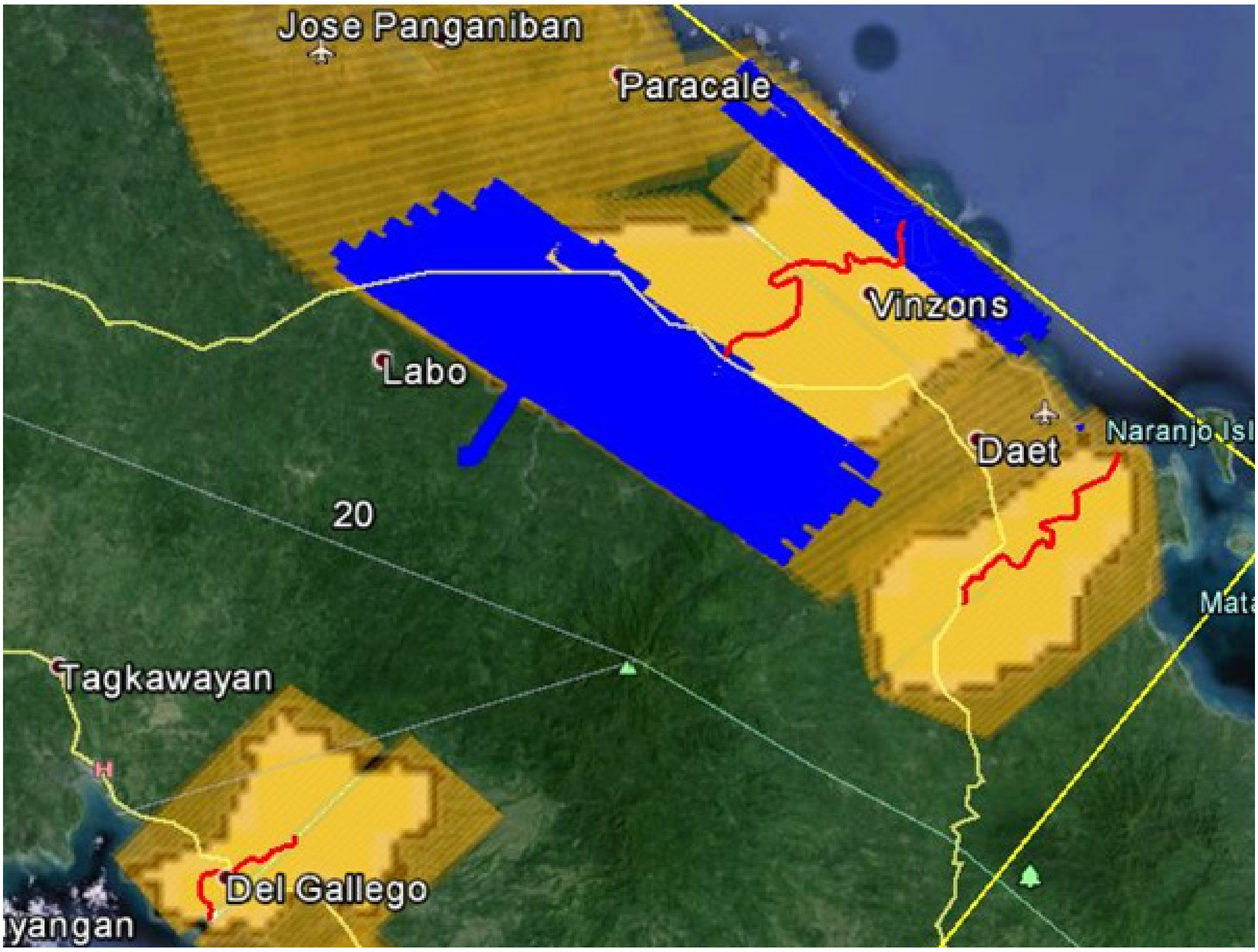


Figure A-7.2. Swath Coverage of Mission 1BLK20ASC70A

FLIGHT NO.: 23176
AREA: Bagasbas
MISSION NAME: 1BLK20B70B
ALT: 600-1100m SCAN FREQ: 30 SCAN ANGLE: 50
SURVEYED AREA: 89.79

LAS

Figure A-7.3. Swath Coverage of Mission 1BLK20B70B

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

LAS

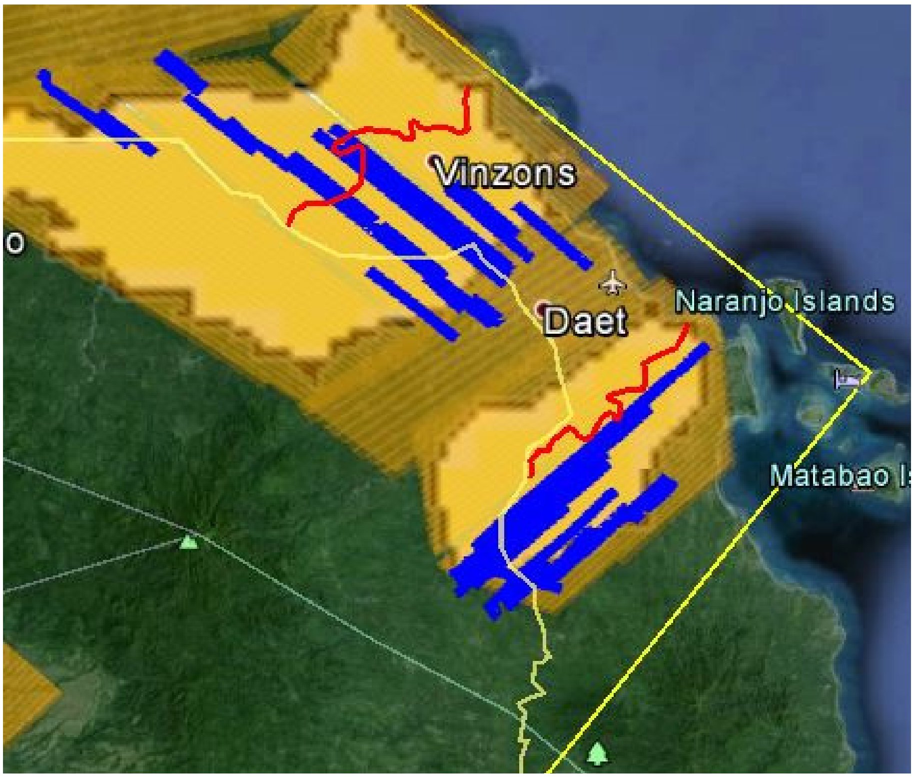


Figure A-7.4. Swath Coverage of Mission 1BLK20ABCE72A

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

LAS

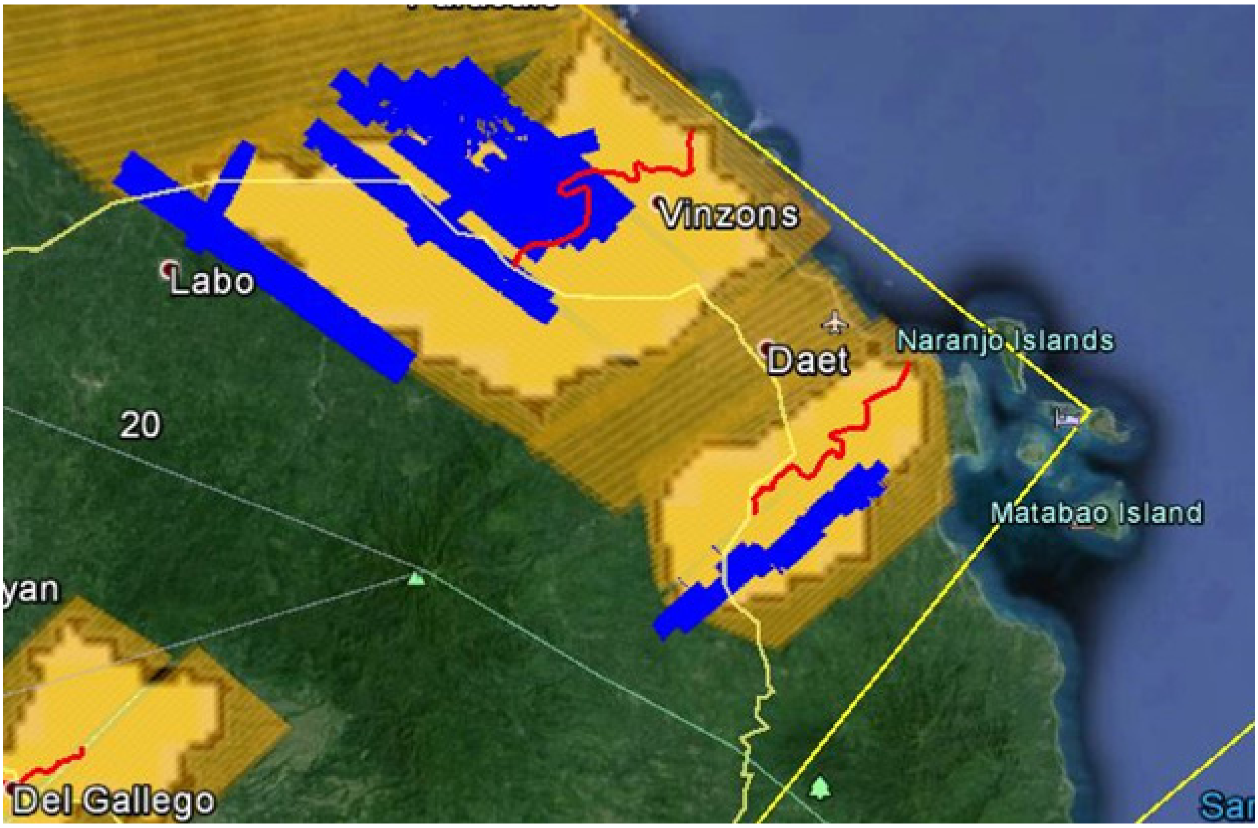


Figure A-7.5. Swath Coverage of Mission 1BLK20BS74A

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

LAS

Figure A-7.6. Swath Coverage of Mission 1BLK20N77A

Flight No. : 23226P
Parameters: PRF 200 SF 30 FOV 50

LAS/SWATH

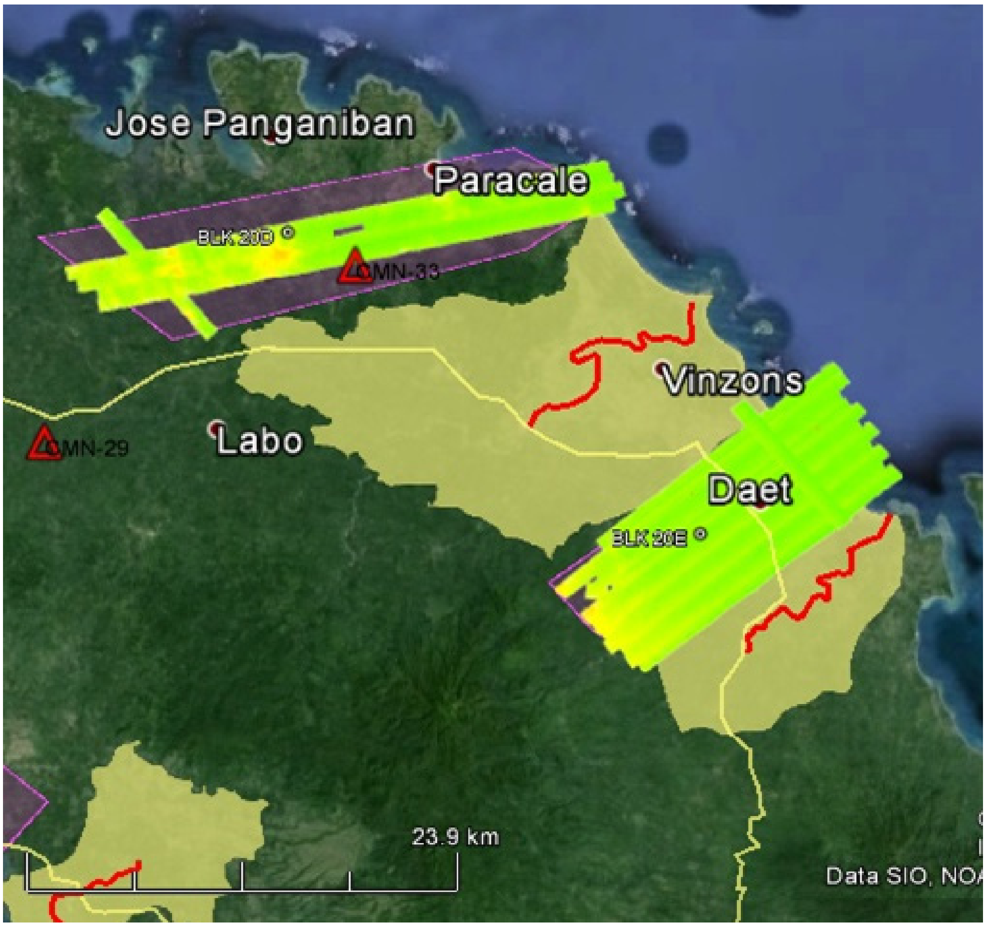


Figure A-7.7. Swath Coverage of Mission

Flight No. :	23234P					
Parameters:	PRF 200	SF	30	FOV	50	

LAS/SWATH

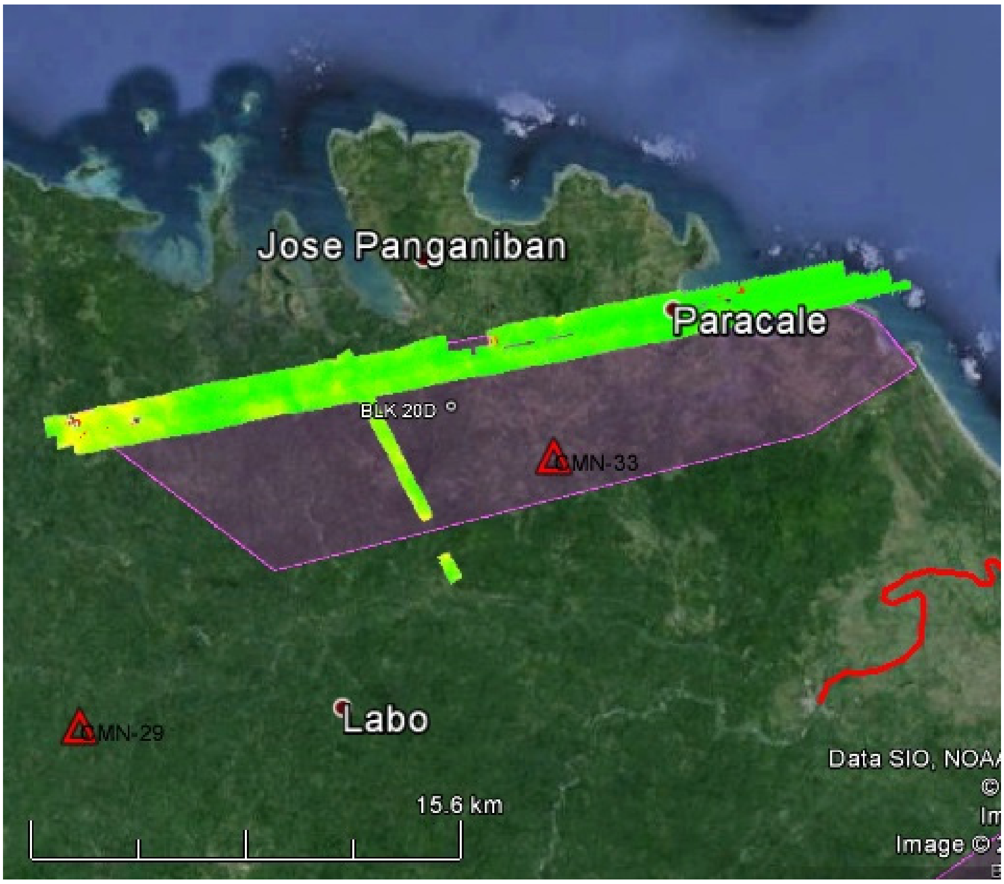


Figure A-7.8. Swath Coverage of Mission

Flight No. : 23264P
Parameters: PRF 200 SF 30 FOV 50

LAS/SWATH

Figure A-7.9. Swath Coverage of Mission

Flight No. :	23266P				
Parameters:	PRF 200	SF	30	FOV	50

LAS/SWATH

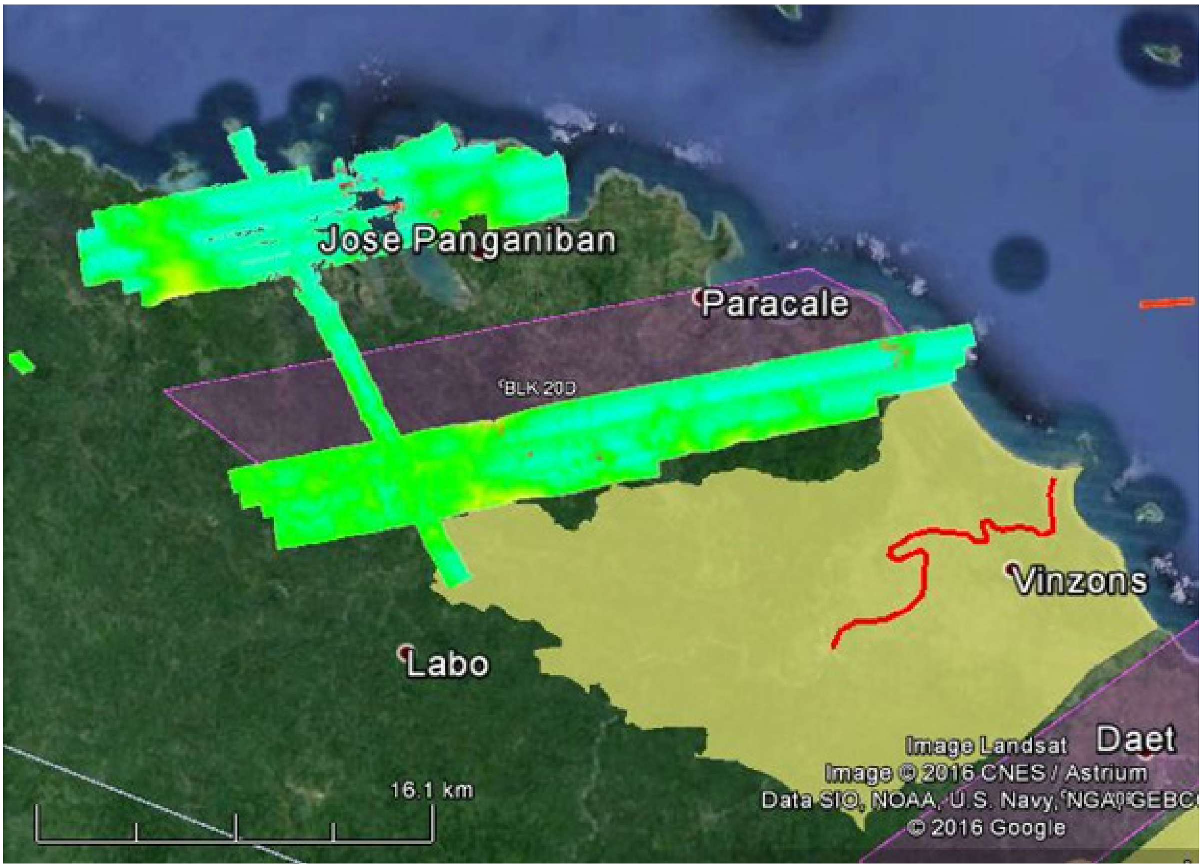


Figure A-7.10. Swath Coverage of Mission

Flight No. :	23268P				
Parameters:	PRF 200	SF	30	FOV	50

LAS/SWATH

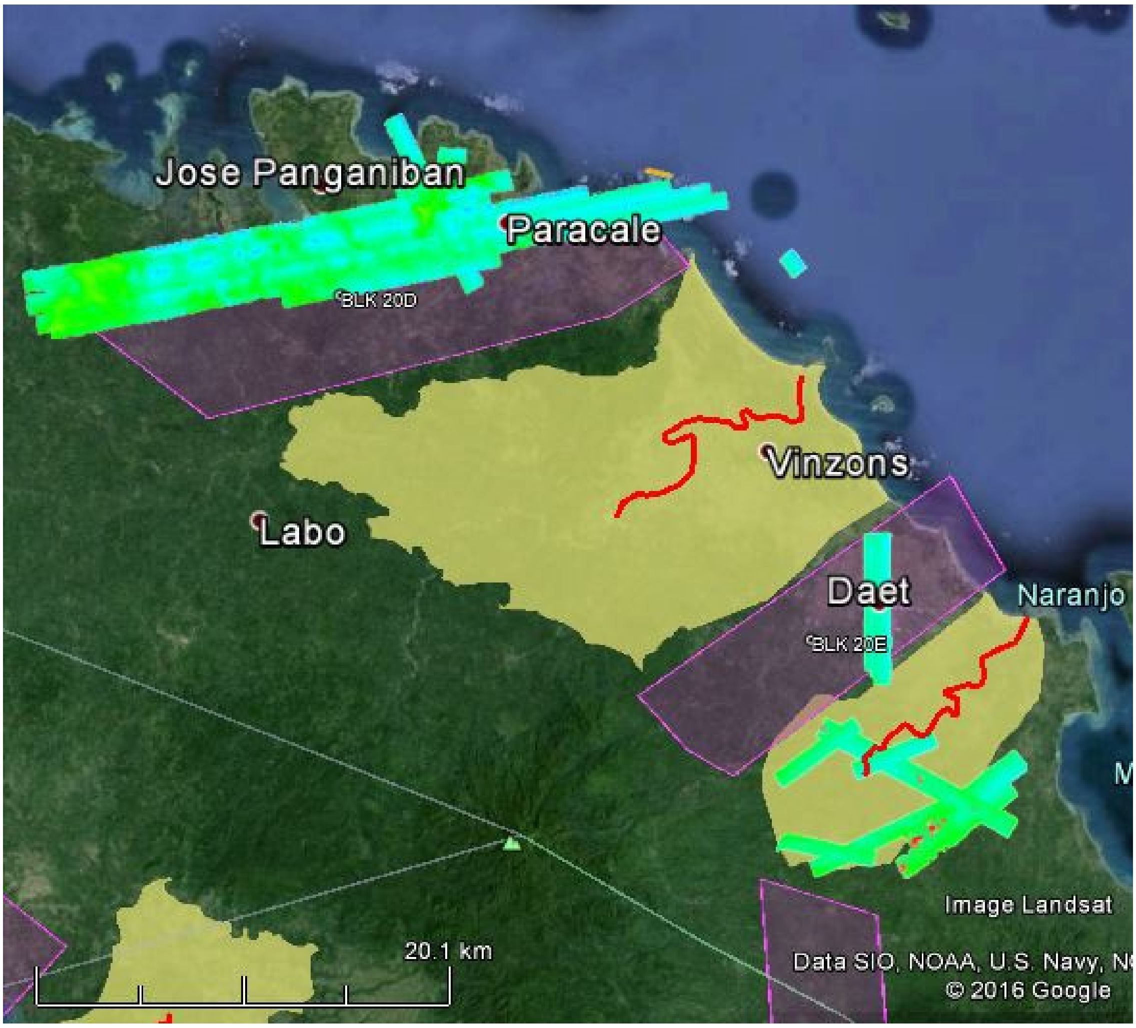


Figure A-7.11. Swath Coverage of Mission

Flight No. :	23270P				
Parameters:	PRF 200	SF	30	FOV	50

LAS/SWATH

Figure A-7.12. Swath Coverage of Mission

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Bagasbasa_Blk20A

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20A
Inclusive Flights	23172P
Range data size	8.3 GB
POS data size	149MB
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)	1.1
RMSE for East Position (<4.0 cm)	0.9
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	0.000279
IMU attitude correction stdev (<0.001deg)	0.001017
GPS position stdev (<0.01m)	0.0090
Minimum % overlap (>25)	55.51%
Ave point cloud density per sq.m. (>2.0)	2.48
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	187
Maximum Height	697.11 m
Minimum Height	40.94 m
Classification (# of points)	
Ground	120,840,006
Low vegetation	138,505,410
Medium vegetation	133,987,797
High vegetation	91,364,313
Building	3,441,124
Orthophoto	Yes
Processed by	Engr. Abigail Joy Ching, Engr. Justine Francisco, Maria Tamsyn Malabanan

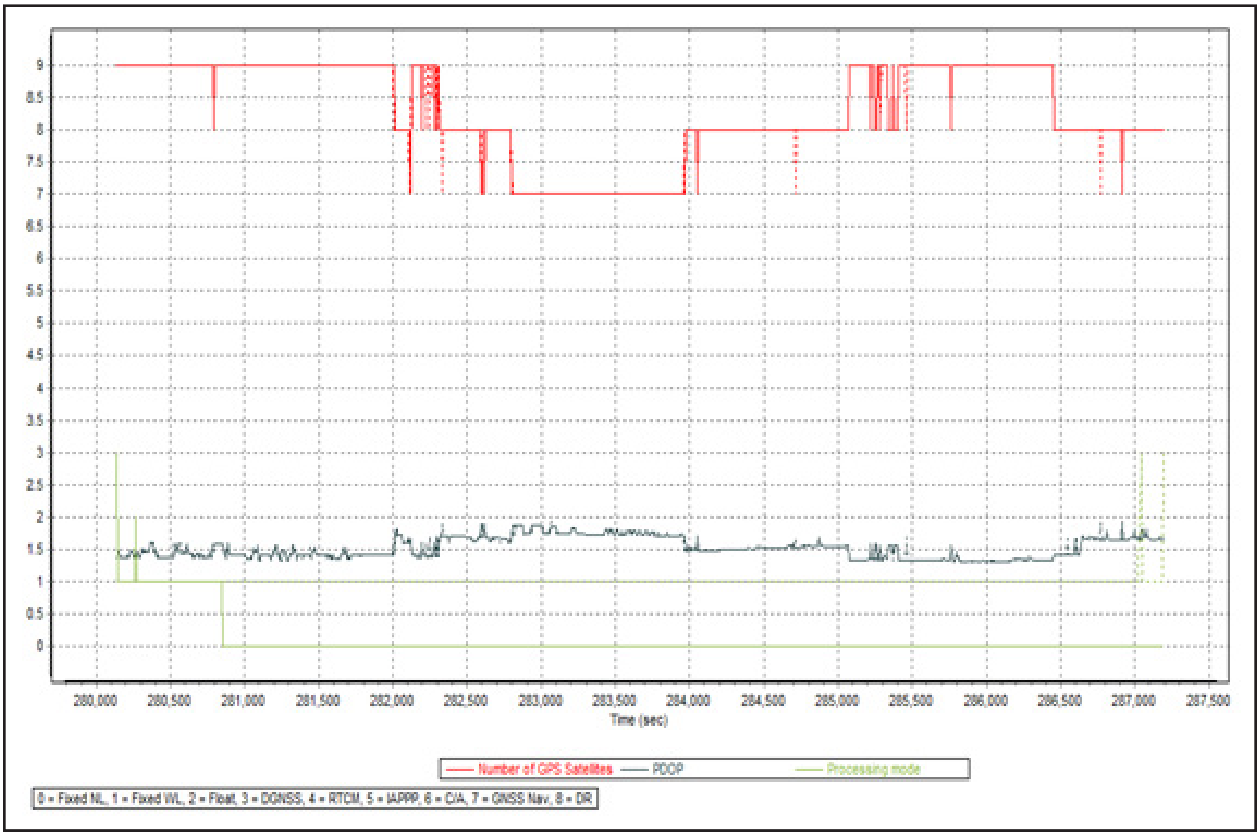


Figure A-8.1 Solution Status

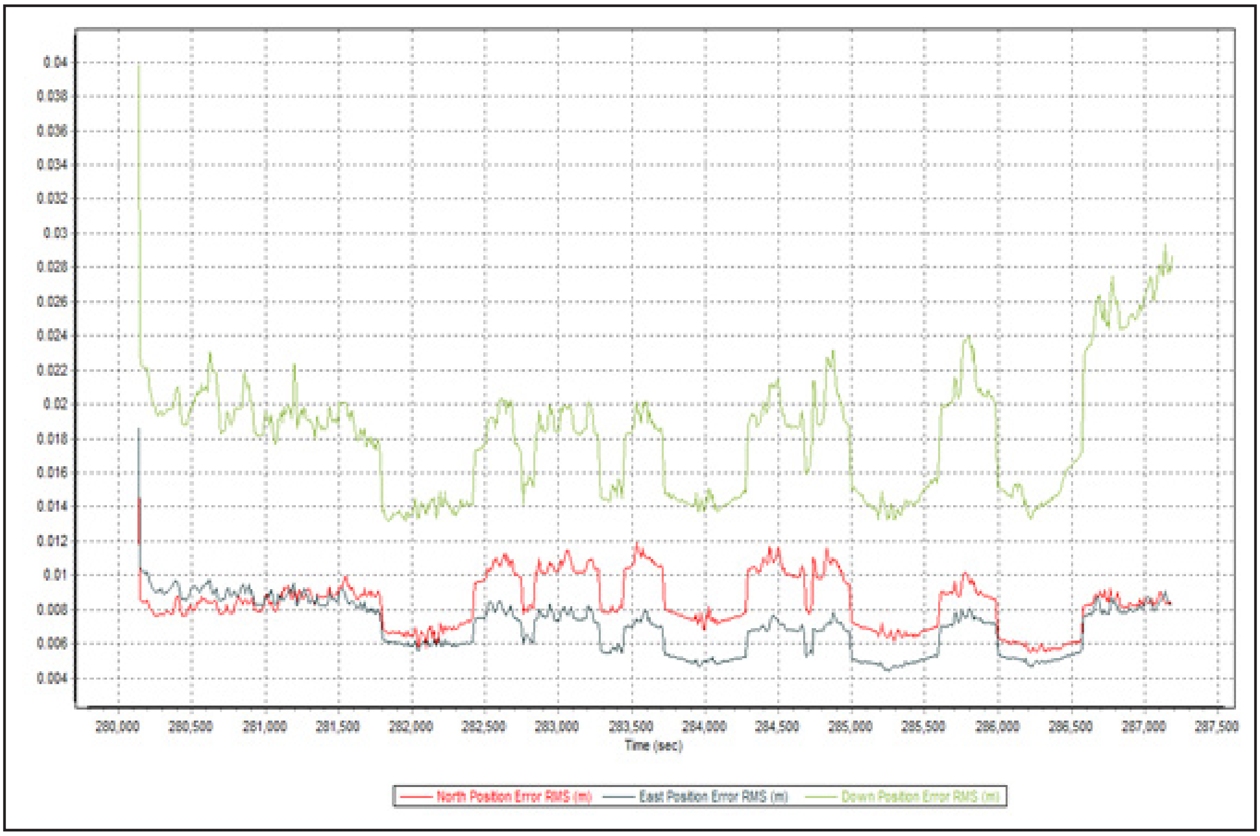


Figure A-8.2. Smoothed Performance Metrics Parameters

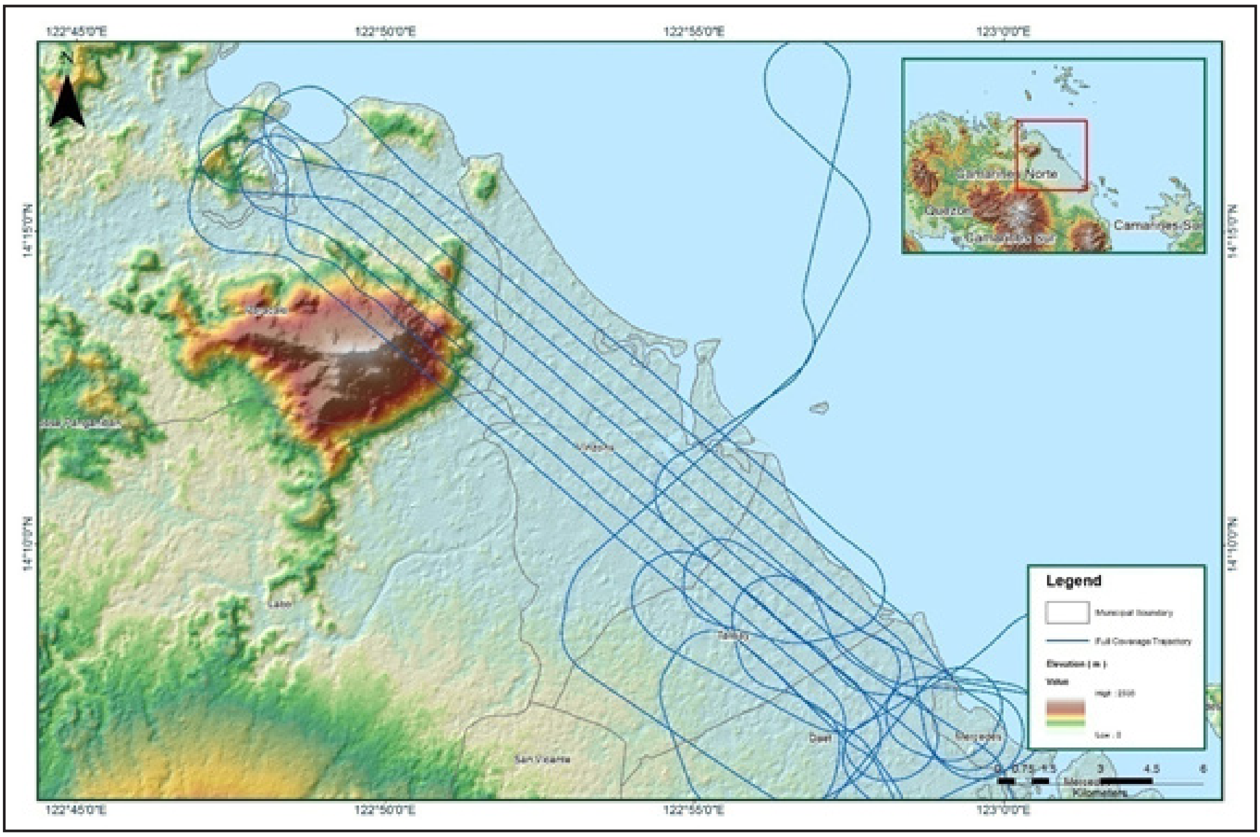


Figure A-8.3. Best Estimated Trajectory

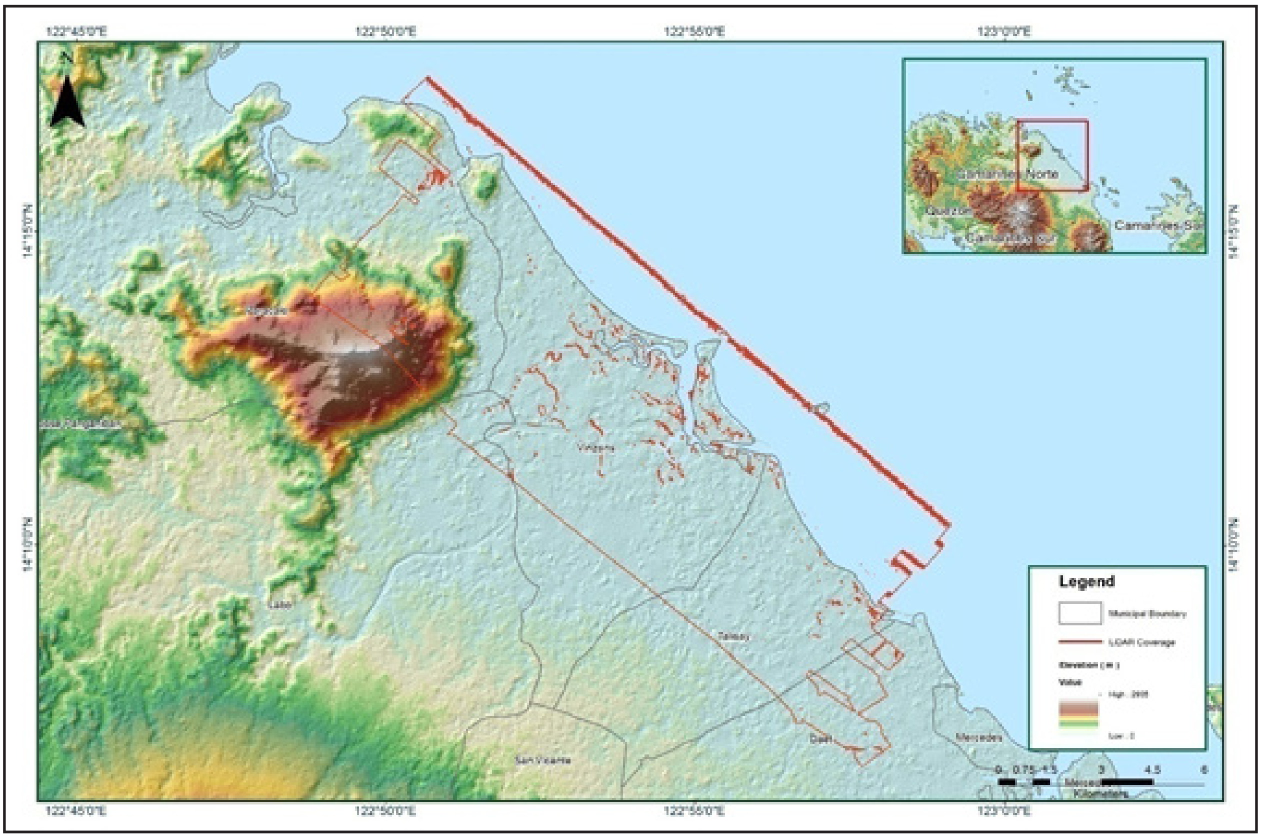


Figure A-8.4. Coverage of LiDAR data

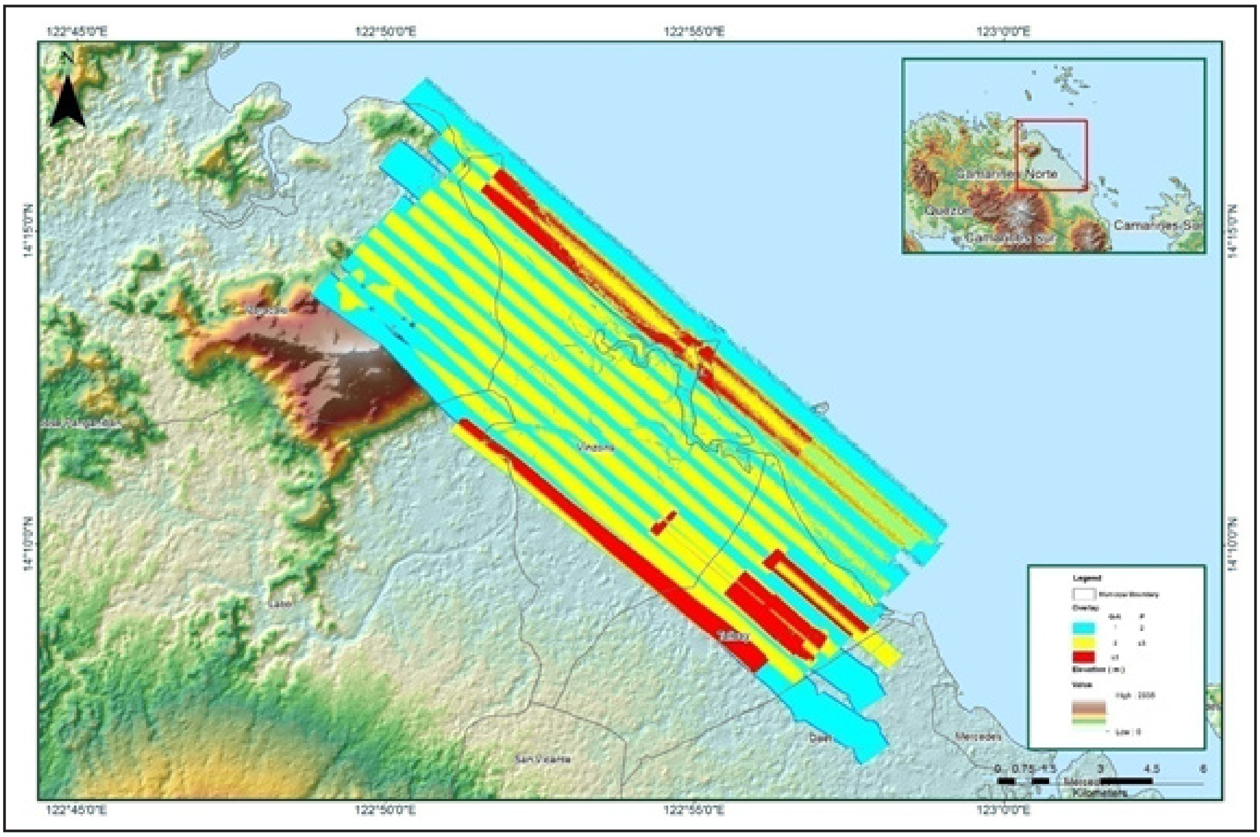


Figure A-8.5. Image of data overlap

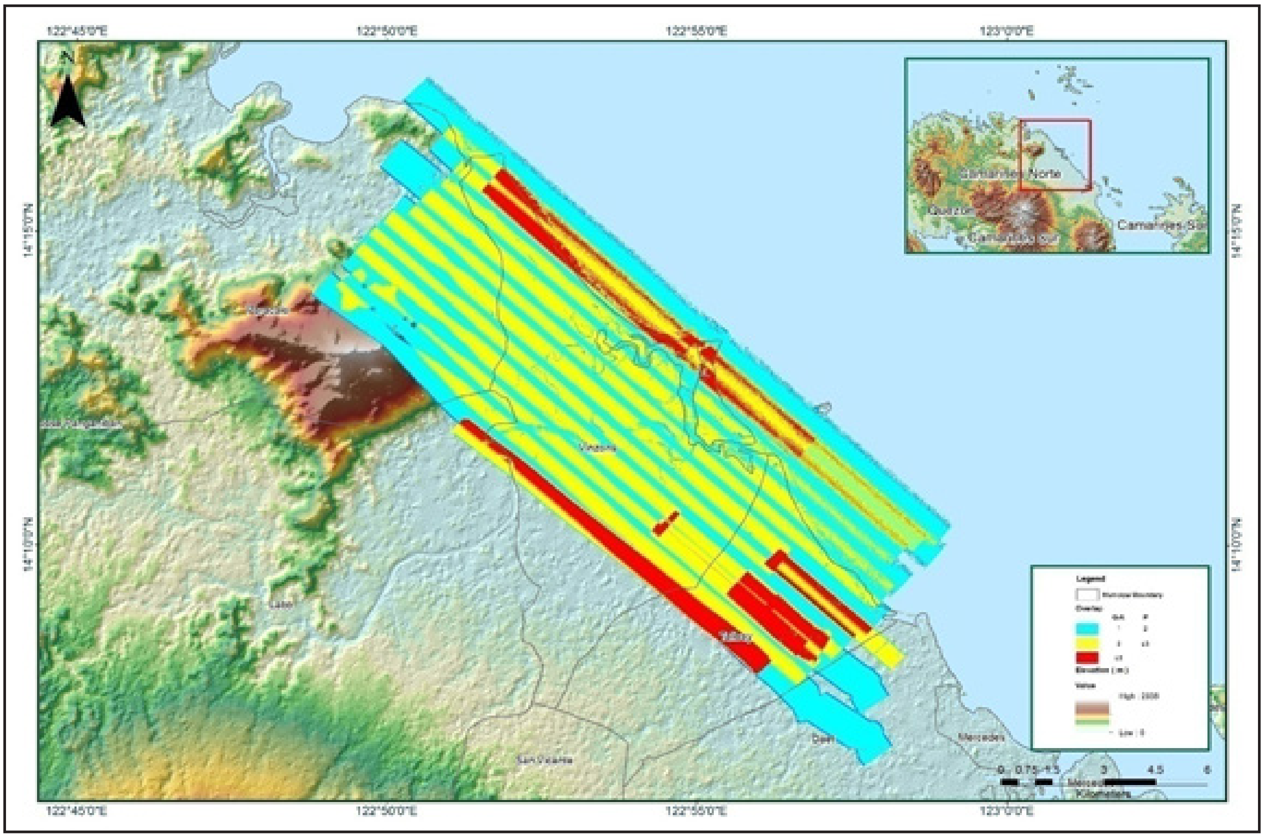


Figure A-8.6. Density map of merged LiDAR data

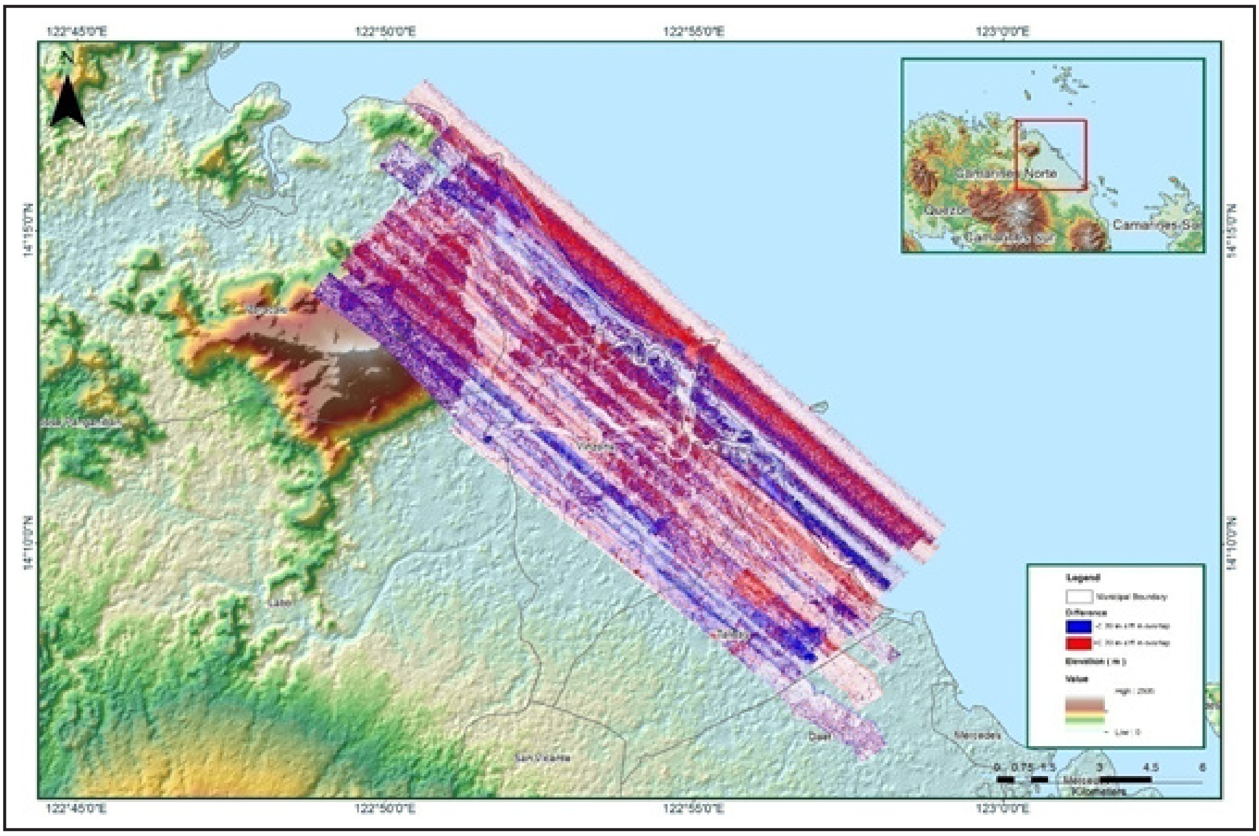


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Bagasbasa_Blk20B

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20B
Inclusive Flights	23190P
Range data size	17.4 GB
POS data size	254 MB
Base data size	69.3
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)	Yes
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)	3.2
Boresight correction stdev (<0.001deg)	0.000488
IMU attitude correction stdev (<0.001deg)	0.008276
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	55.06%
Ave point cloud density per sq.m. (>2.0)	4.00
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	230
Maximum Height	840.48 m
Minimum Height	51.83 m
Classification (# of points)	
Ground	143,967,626
Low vegetation	155,024,720
Medium vegetation	229,085,366
High vegetation	656,060,346
Building	12,349,618
Orthophoto	No
Processed by	Engr. Sheila-Maye Santillan, AljonRieAraneta, Engr. Czarina Jean Añonuevo

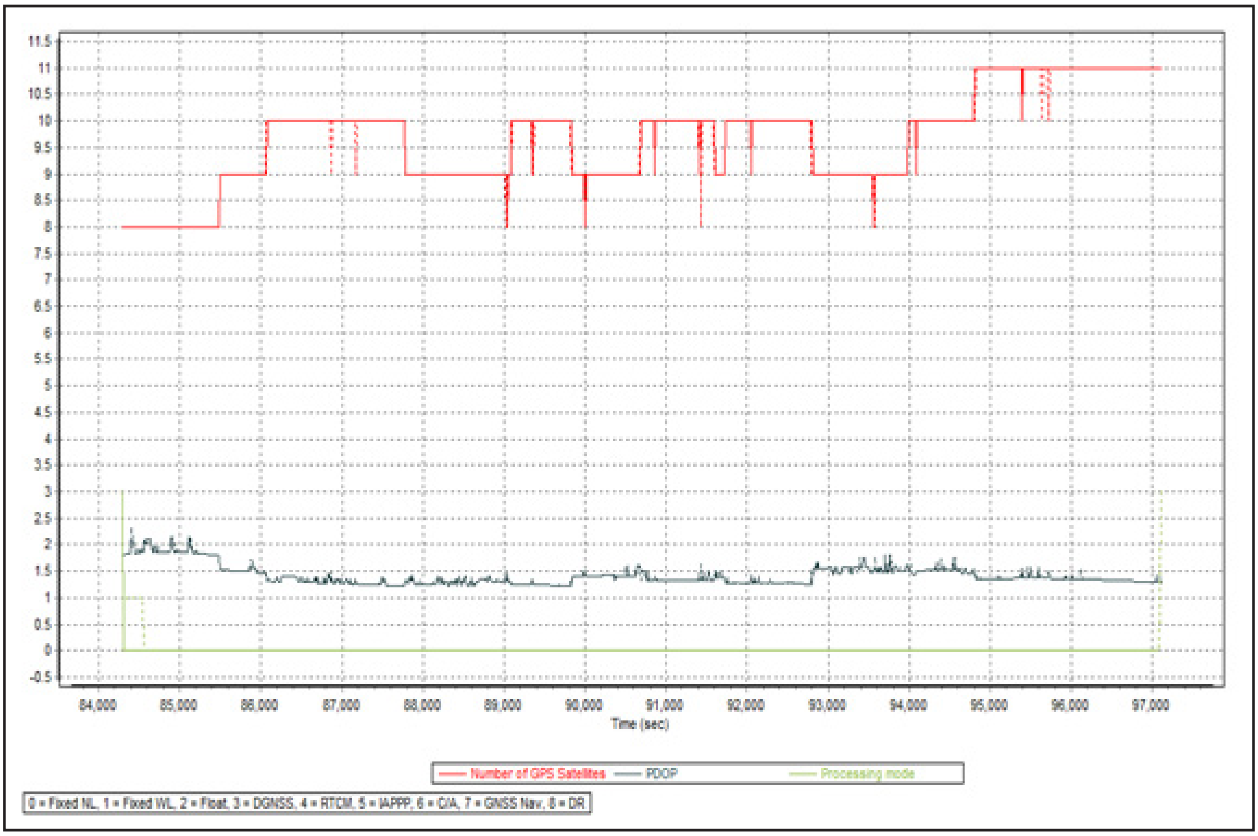


Figure A-8.8. Solution

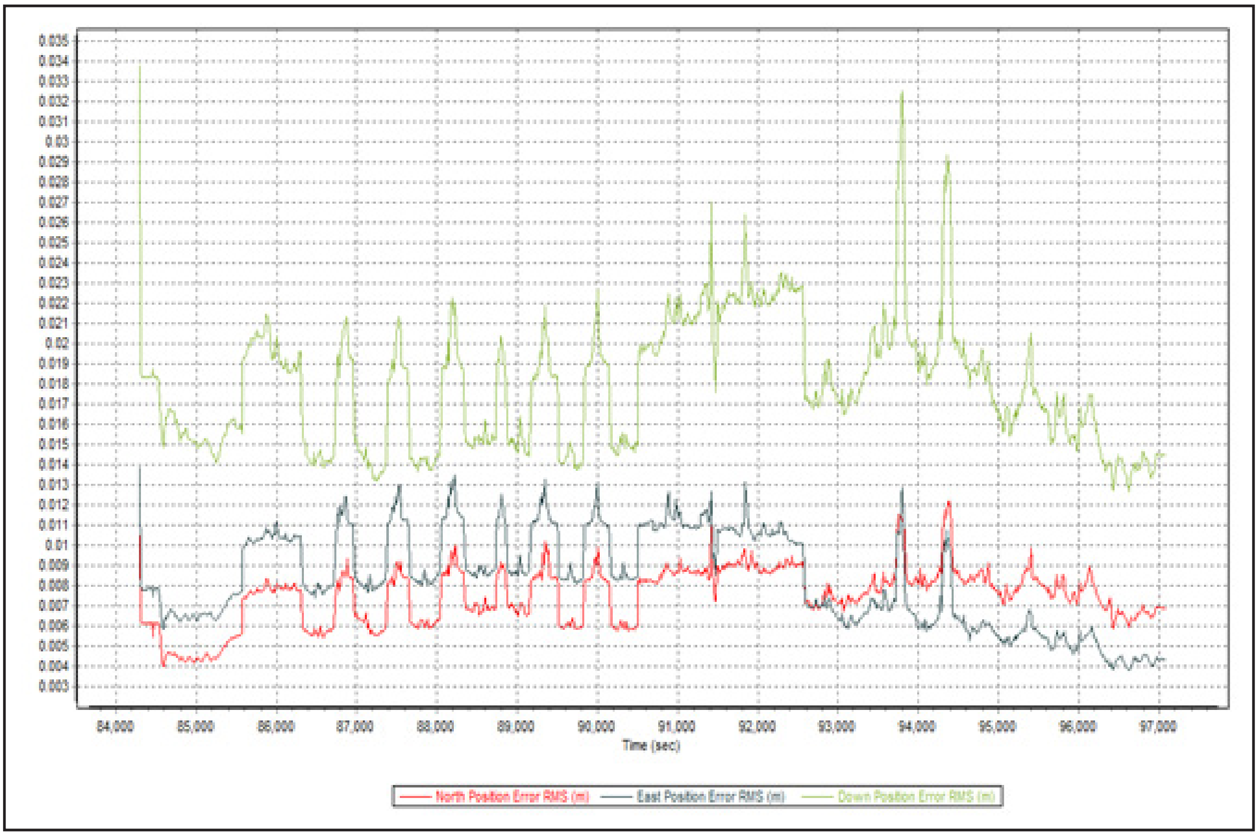


Figure A-8.9. Smoothed Performance Metrics Parameters

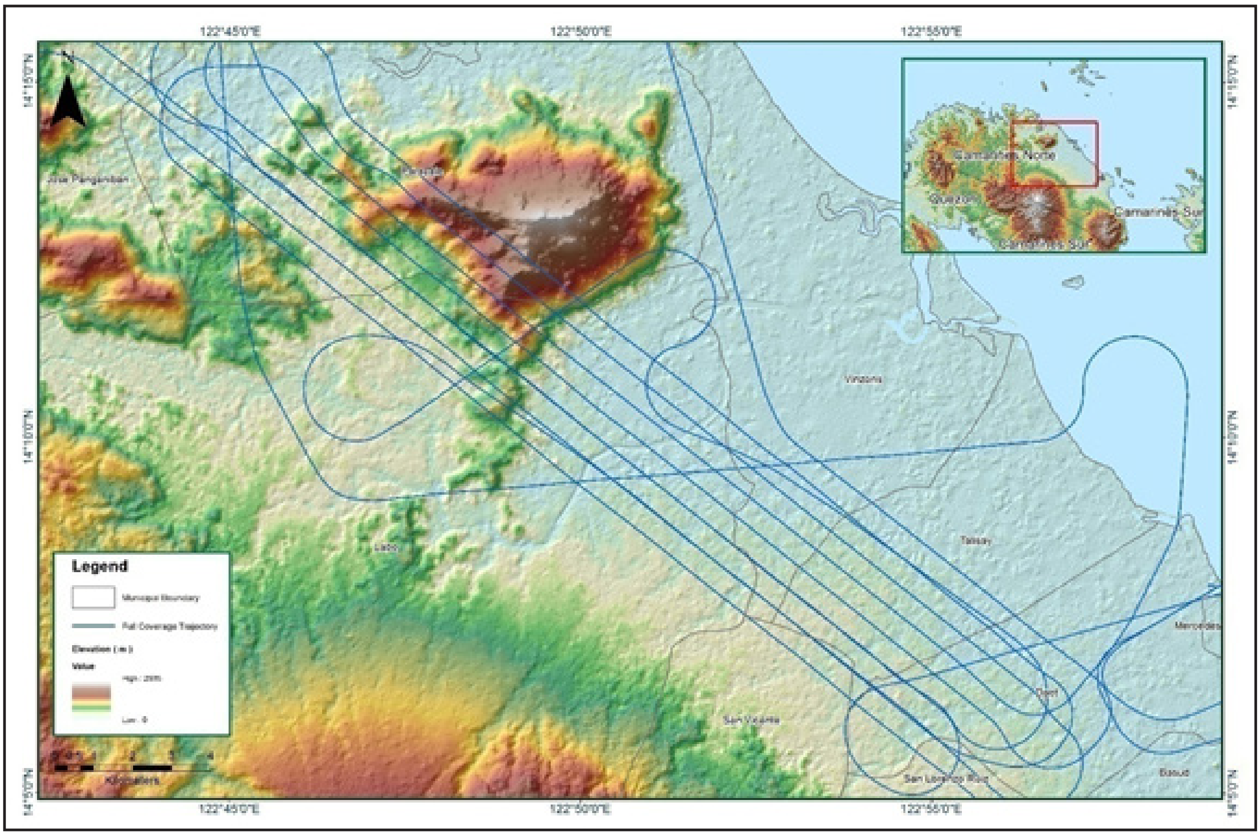


Figure A-8.10. Best Estimated Trajectory

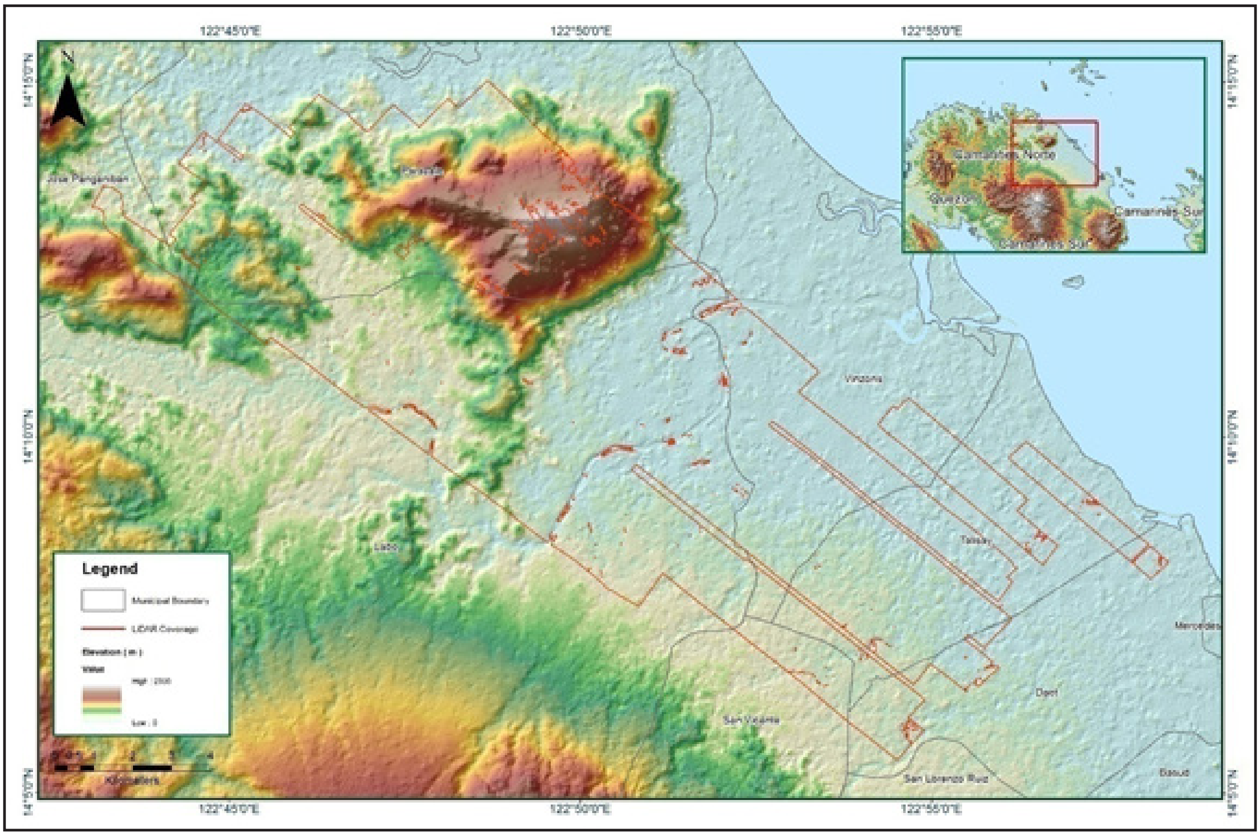


Figure A-8.11. Coverage of LiDAR data

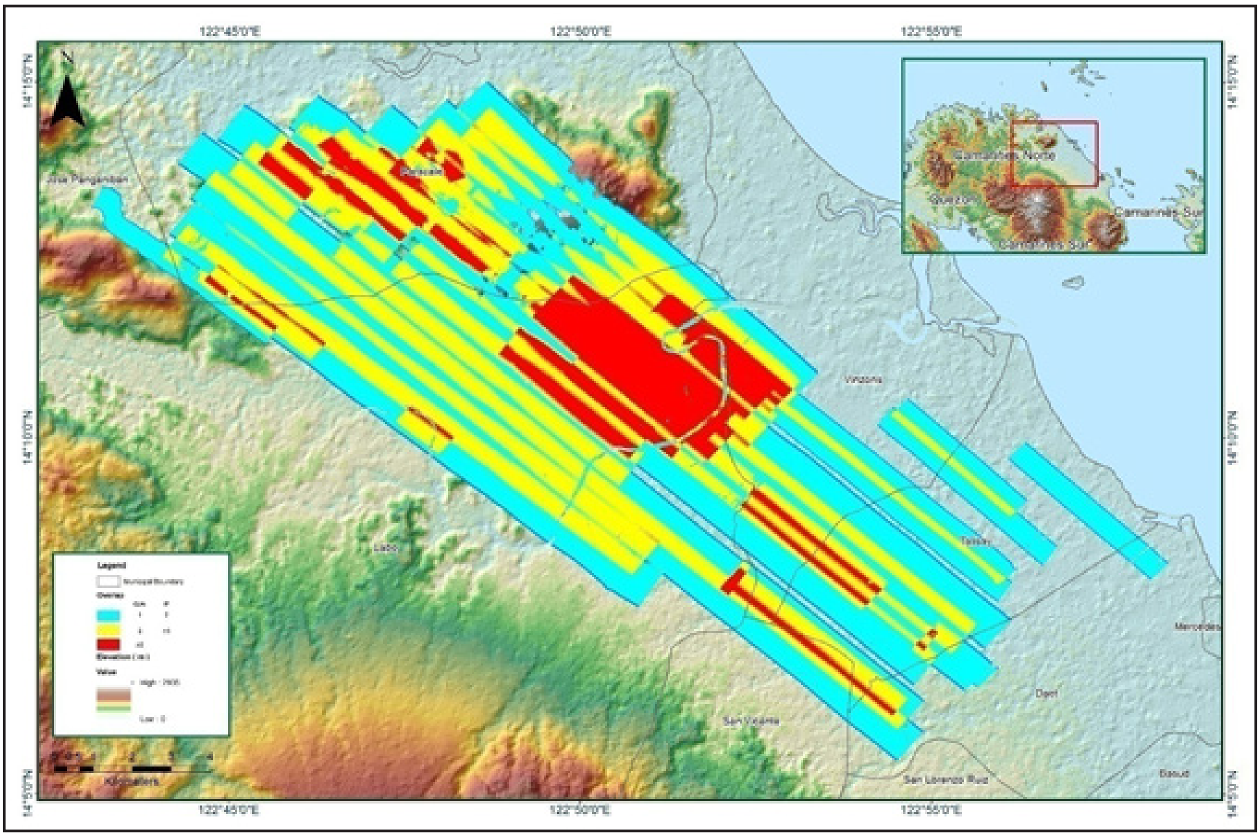


Figure A-8.12. Image of data overlap

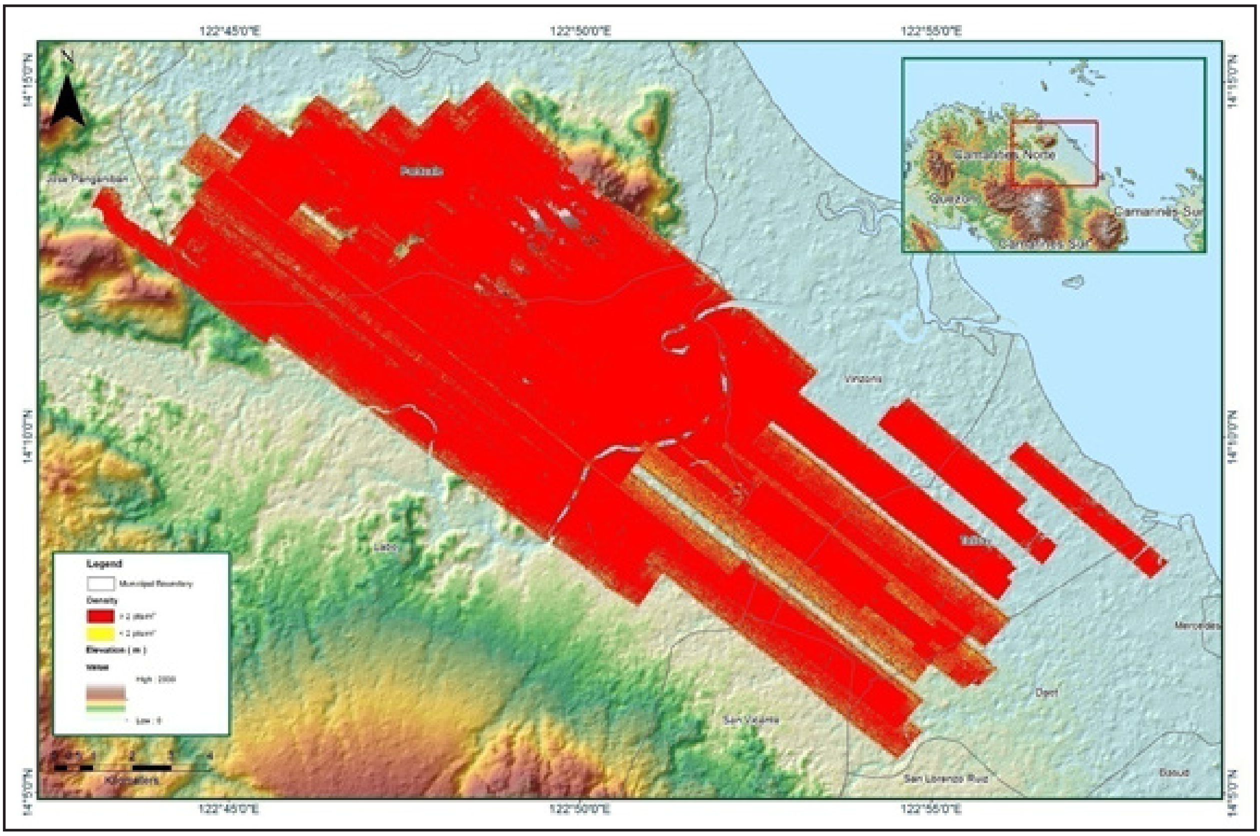


Figure A-8.13 Density map of merged LiDAR data

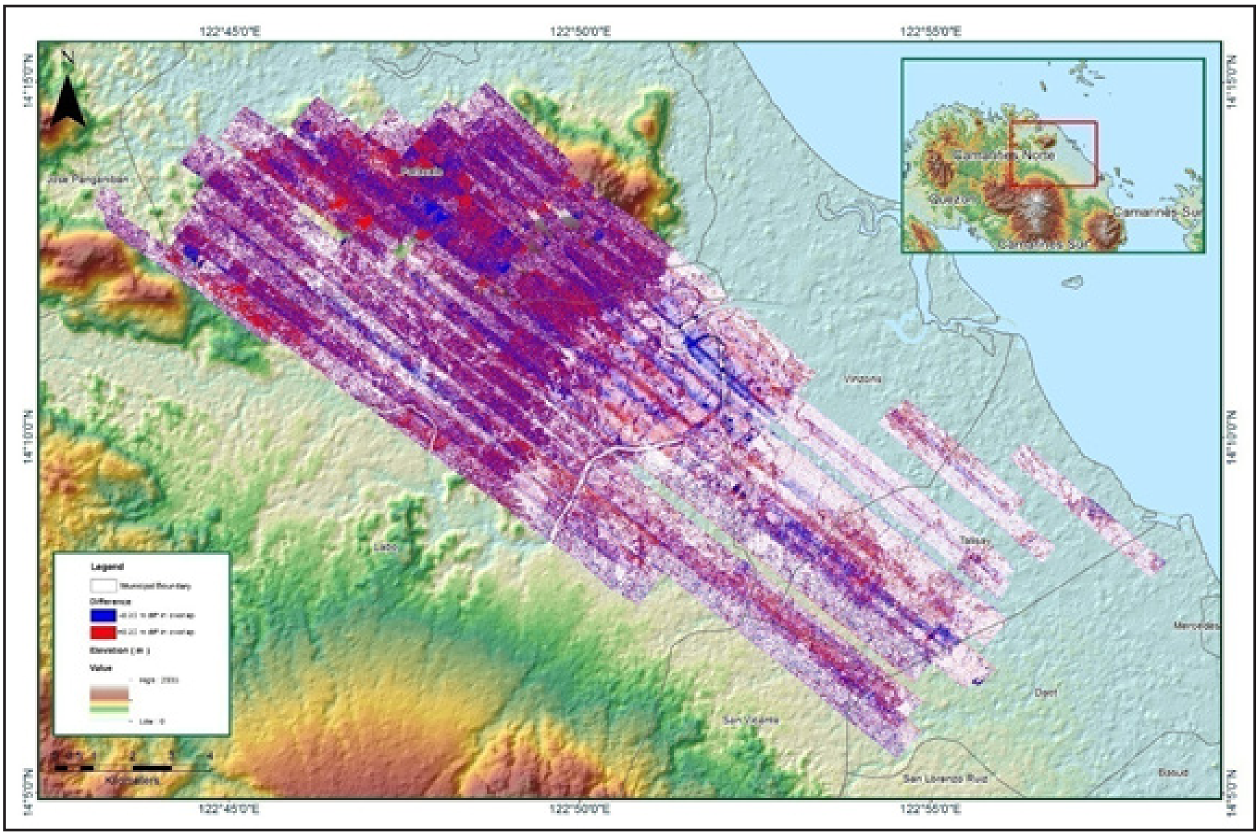


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Bagasbasa_Blk20C

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20C
Inclusive Flights	23174P
Range data size	22.5 GB
POS data size	266 MB
Base data size	186 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)	1.1
RMSE for Down Position (<8.0 cm)	1.8
Boresight correction stdev (<0.001deg)	0.000336
IMU attitude correction stdev (<0.001deg)	0.364986
GPS position stdev (<0.01m)	0.0310
Minimum % overlap (>25)	62.25%
Ave point cloud density per sq.m. (>2.0)	3.90
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	268
Maximum Height	447.08 m
Minimum Height	53.21 m
Classification (# of points)	
Ground	131,192,981
Low vegetation	110,062,352
Medium vegetation	306,545,161
High vegetation	1,082,250,364
Building	11,798,844
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Merven Matthew Natino, Engr. MonalyneRabino

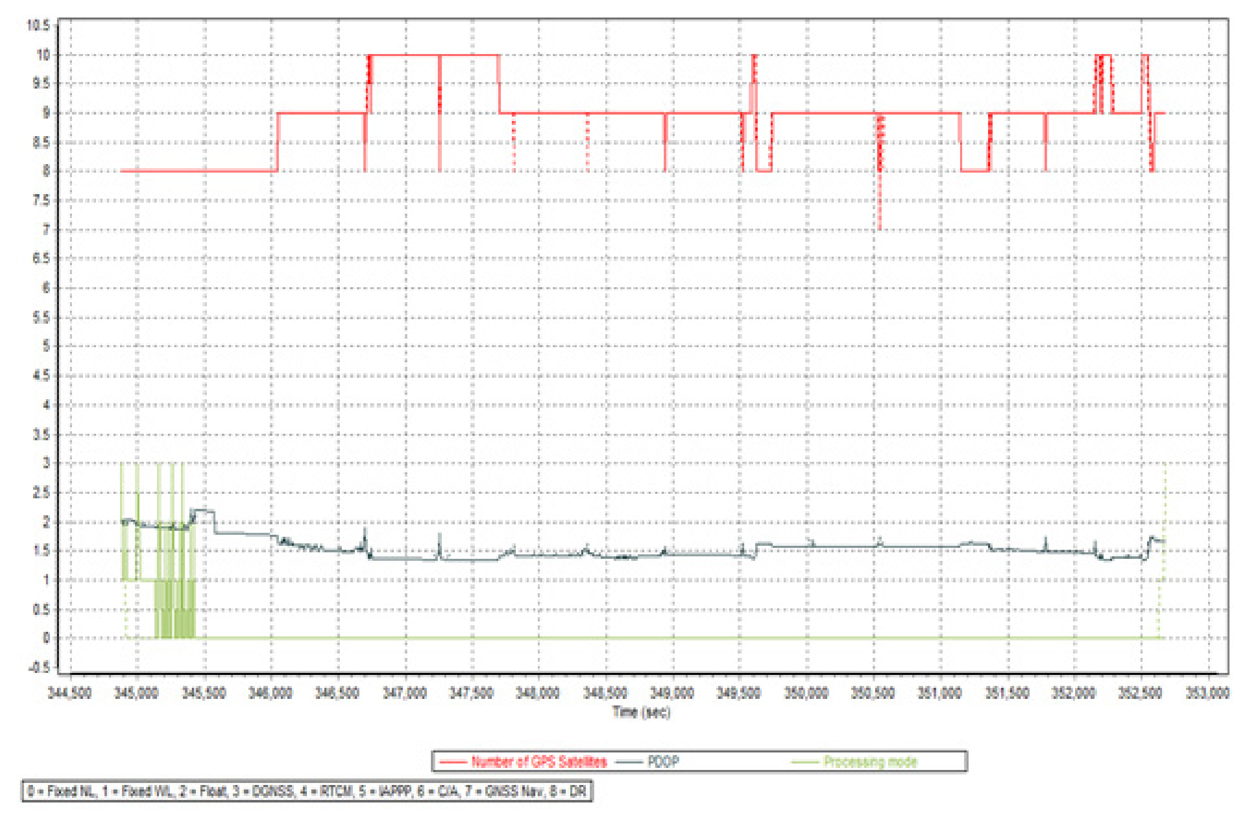


Figure A-8.15 Solution Status

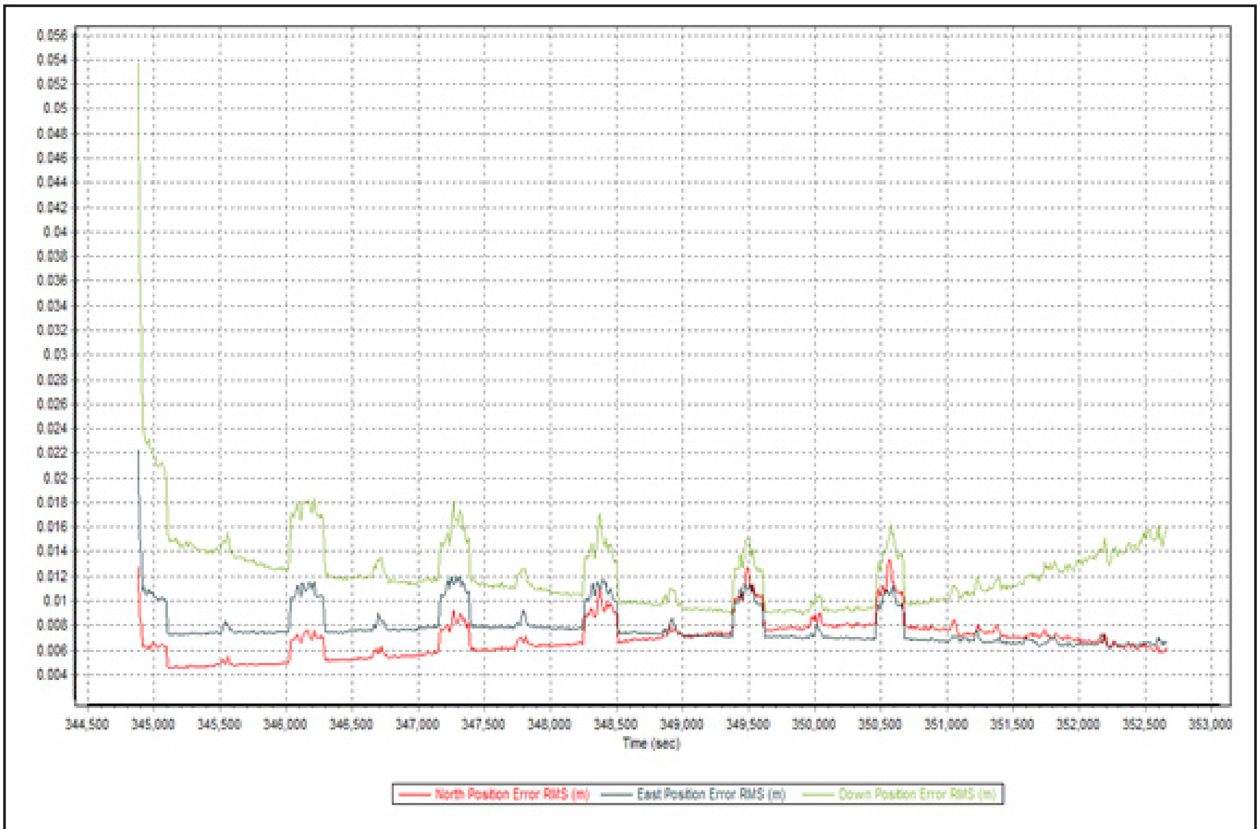


Figure A-8.16 Smoothed Performance Metric Parameters

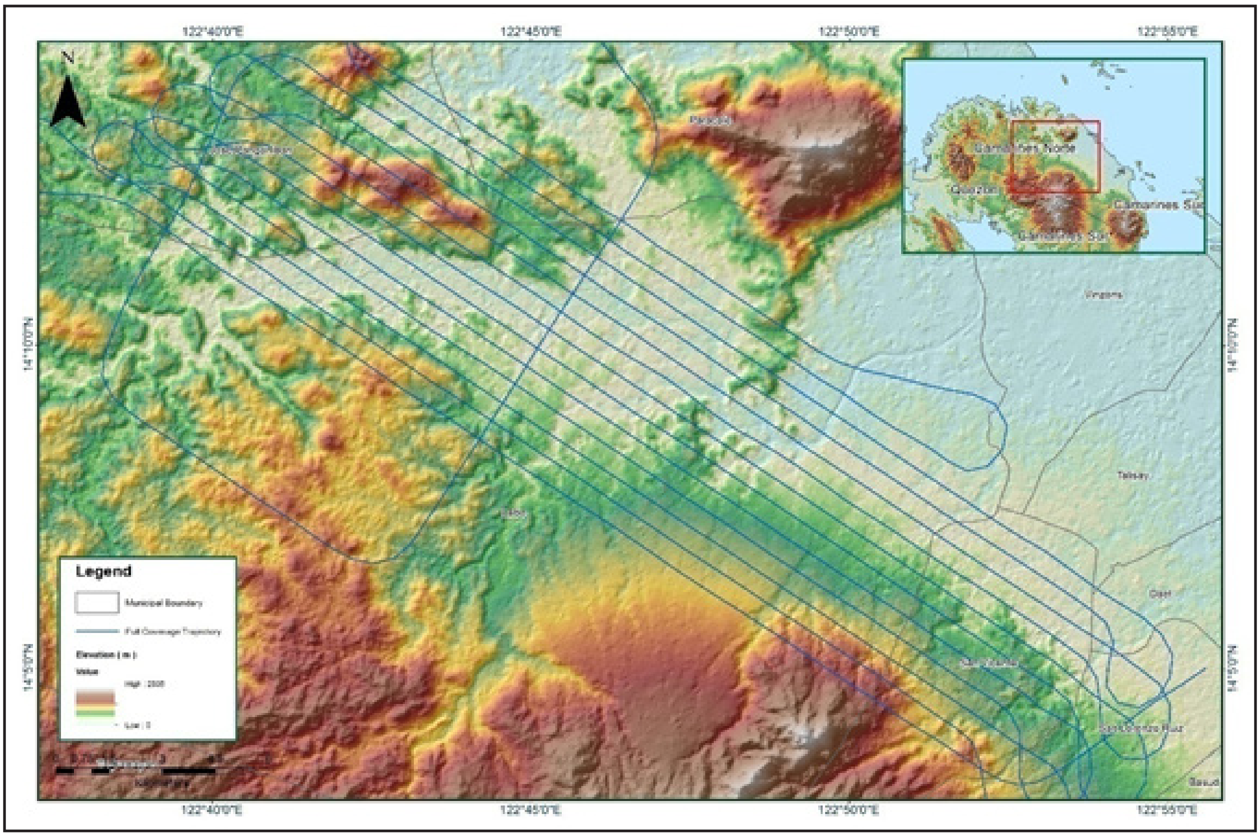


Figure A-8.17 Best Estimated Trajectory

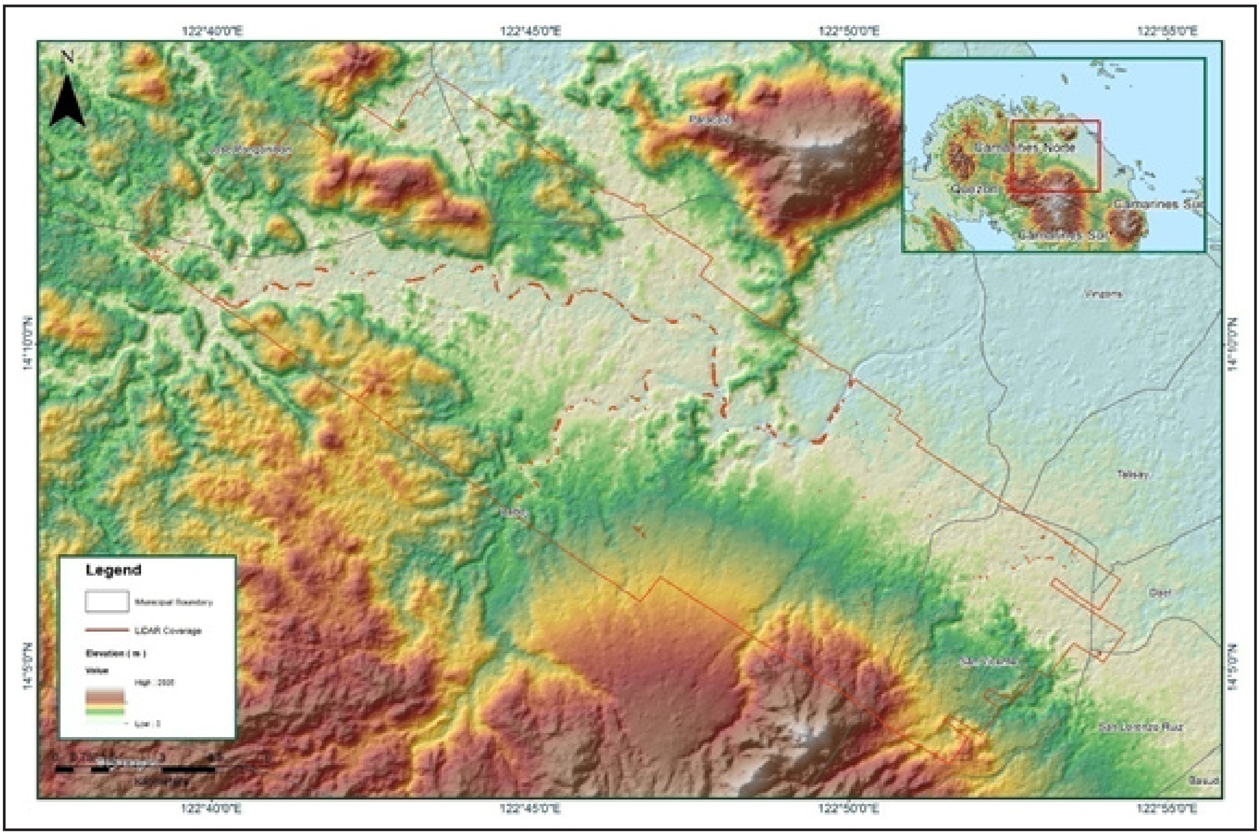


Figure A-8.18 Coverage of LiDAR Data

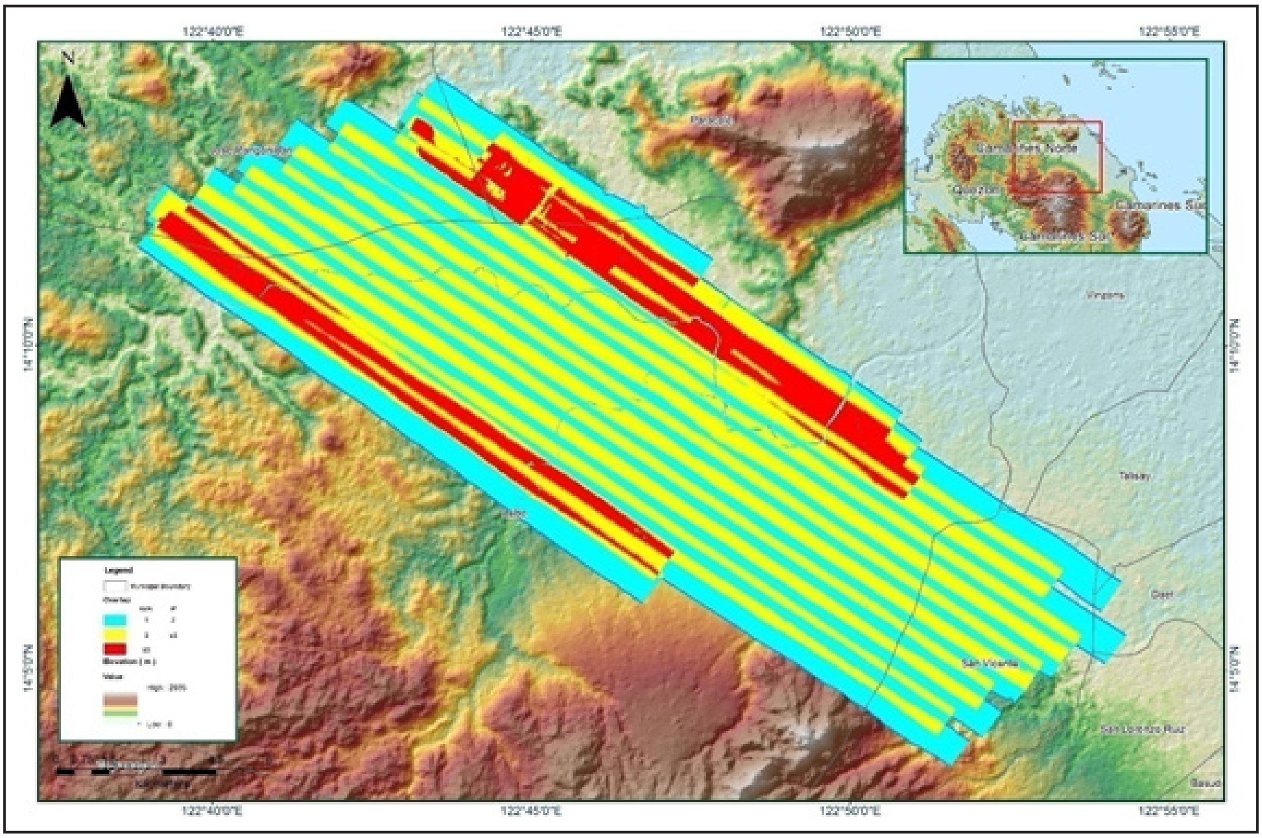


Figure A-8.19 Image of data overlap

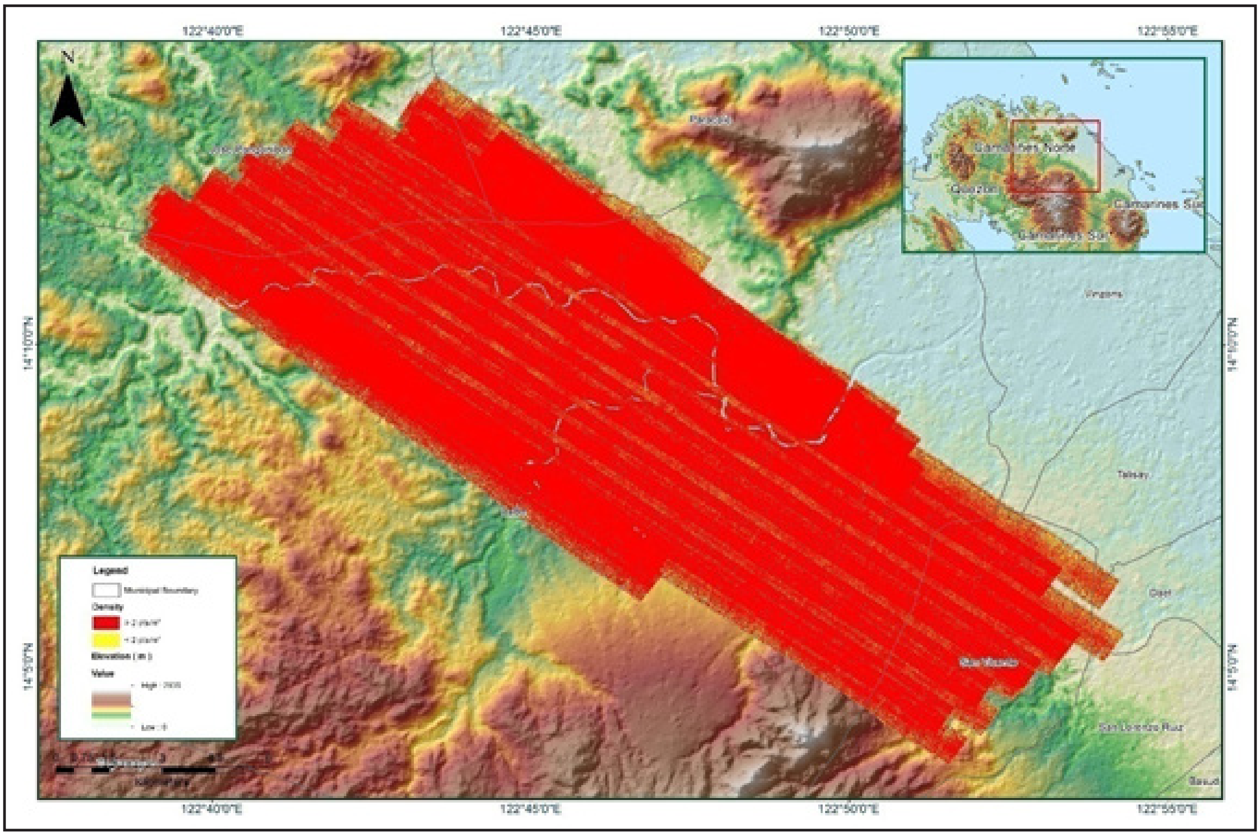


Figure A-8.20 Density map of merged LiDAR data

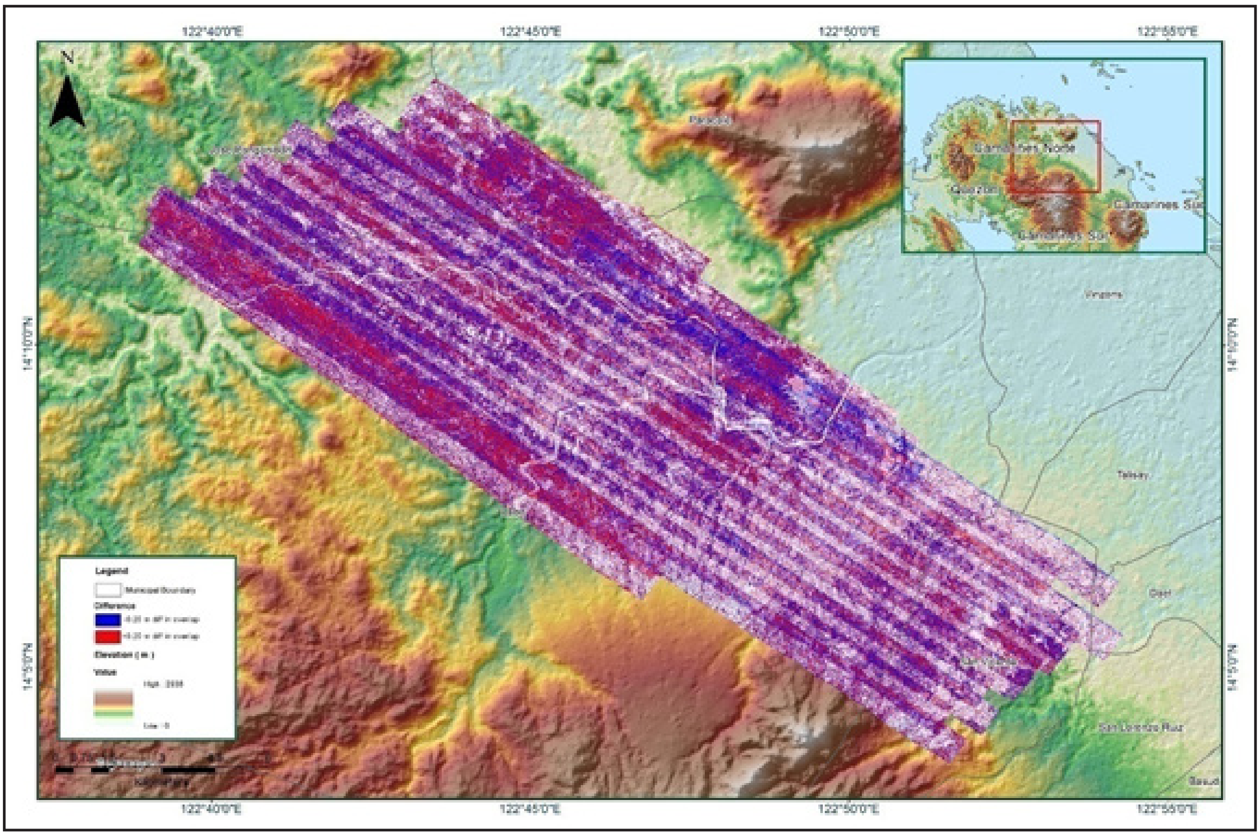


Figure A-8.21 Elevation difference between flight line

Table A-8.4. Mission Summary Report for Mission Bagasbasa_Blk20O_supplement1

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20O_supplement1
Inclusive Flights	23264P
Range data size	16 GB
POS data size	456 MB
Base data size	83 MB
Image	n/a
Transfer date	May 18 ,2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.1
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	5.0
Boresight correction stdev (<0.001deg)	0.000362
IMU attitude correction stdev (<0.001deg)	0.000566
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	46.15%
Ave point cloud density per sq.m. (>2.0)	4.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	225
Maximum Height	352.77 m
Minimum Height	42.38 m
Classification (# of points)	
Ground	159,768,865
Low vegetation	97,766,648
Medium vegetation	298,831,286
High vegetation	757,129,903
Building	8,599,740
Orthophoto	Yes
Processed by	Engr. Don Matthew Banatin, Engr. Velina Angela Bemida, Engr. MonalyneRabino

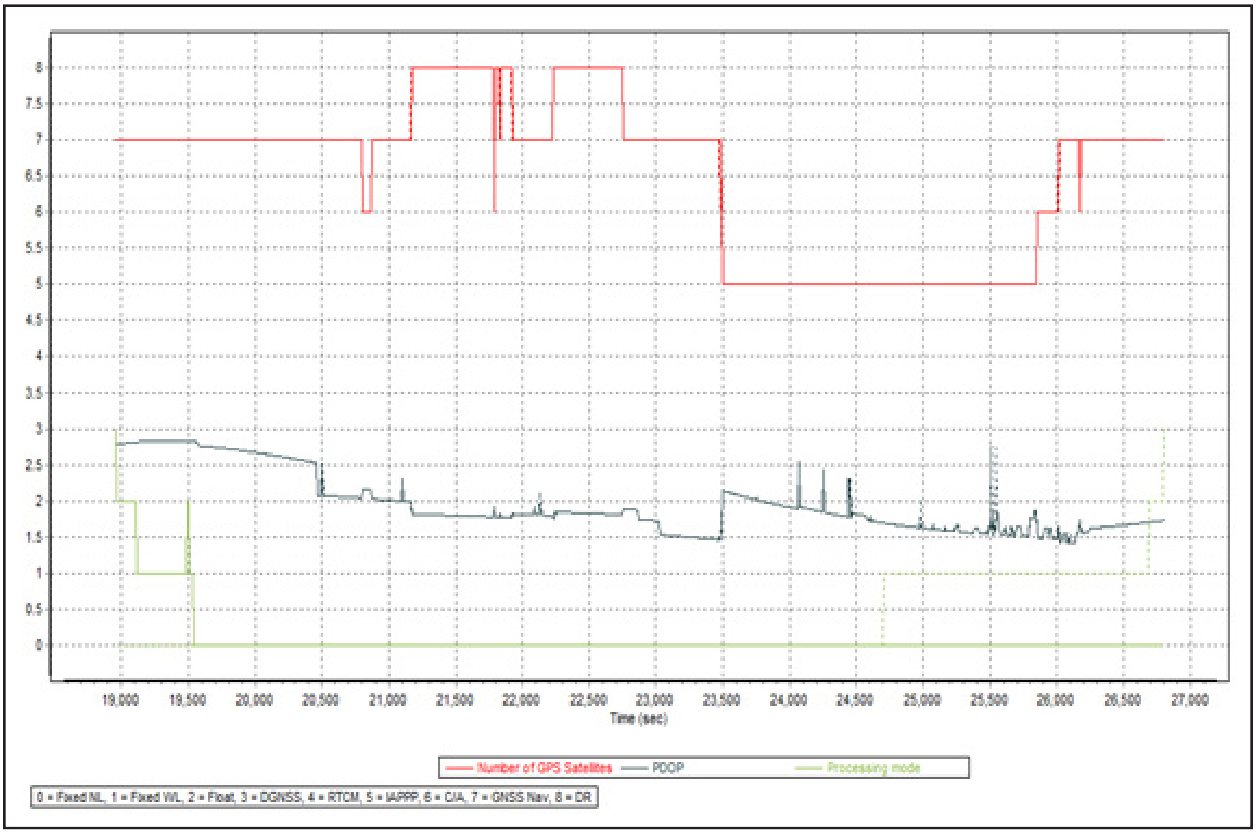


Figure A-8.22 Solution Status

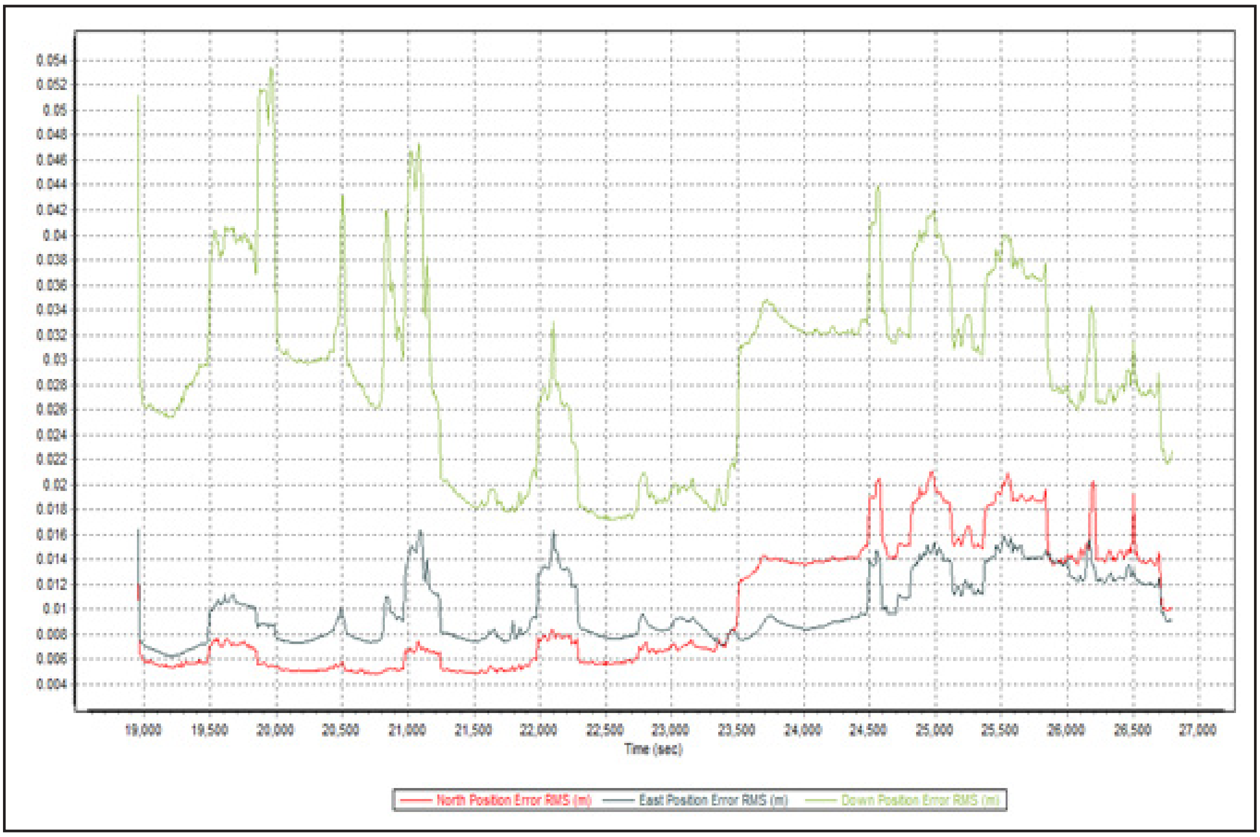


Figure A-8.23 Smoothed Performance Metric Parameters

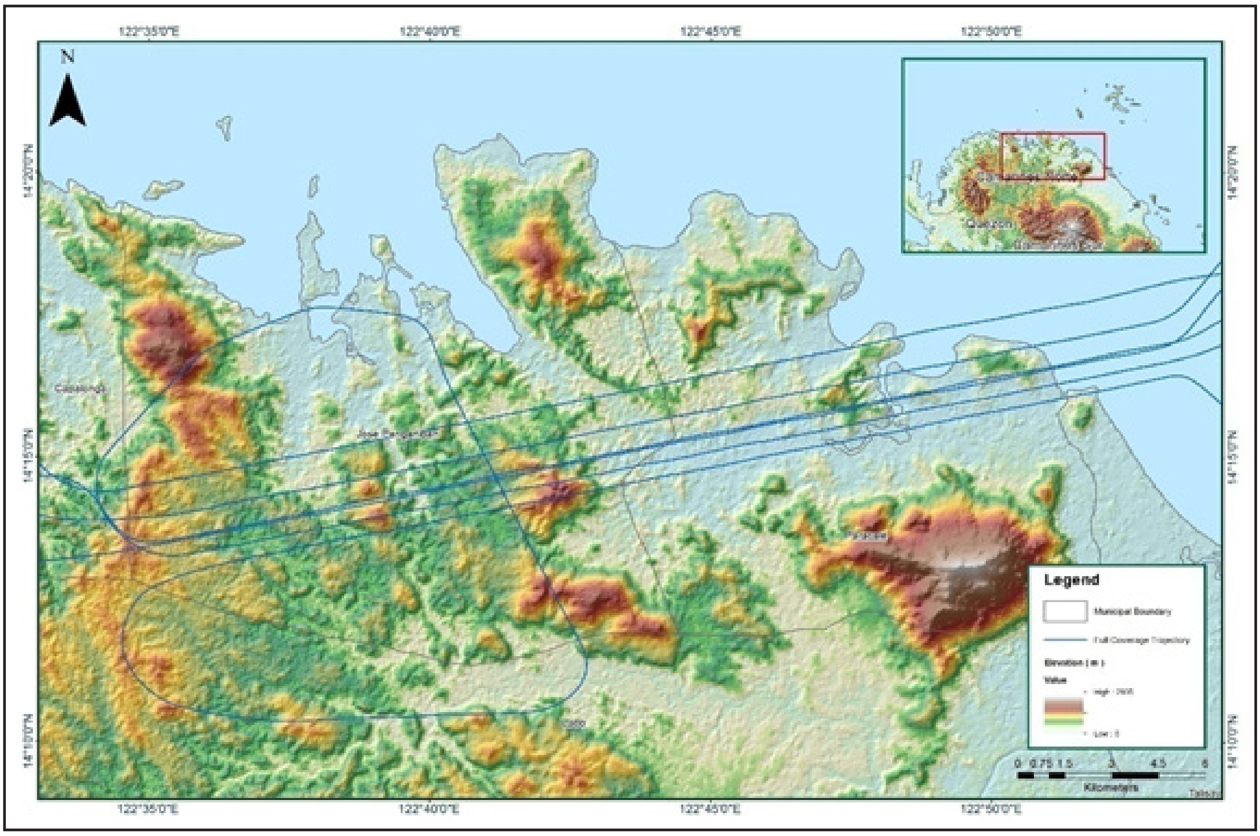


Figure A-8.24 Best Estimated Trajectory

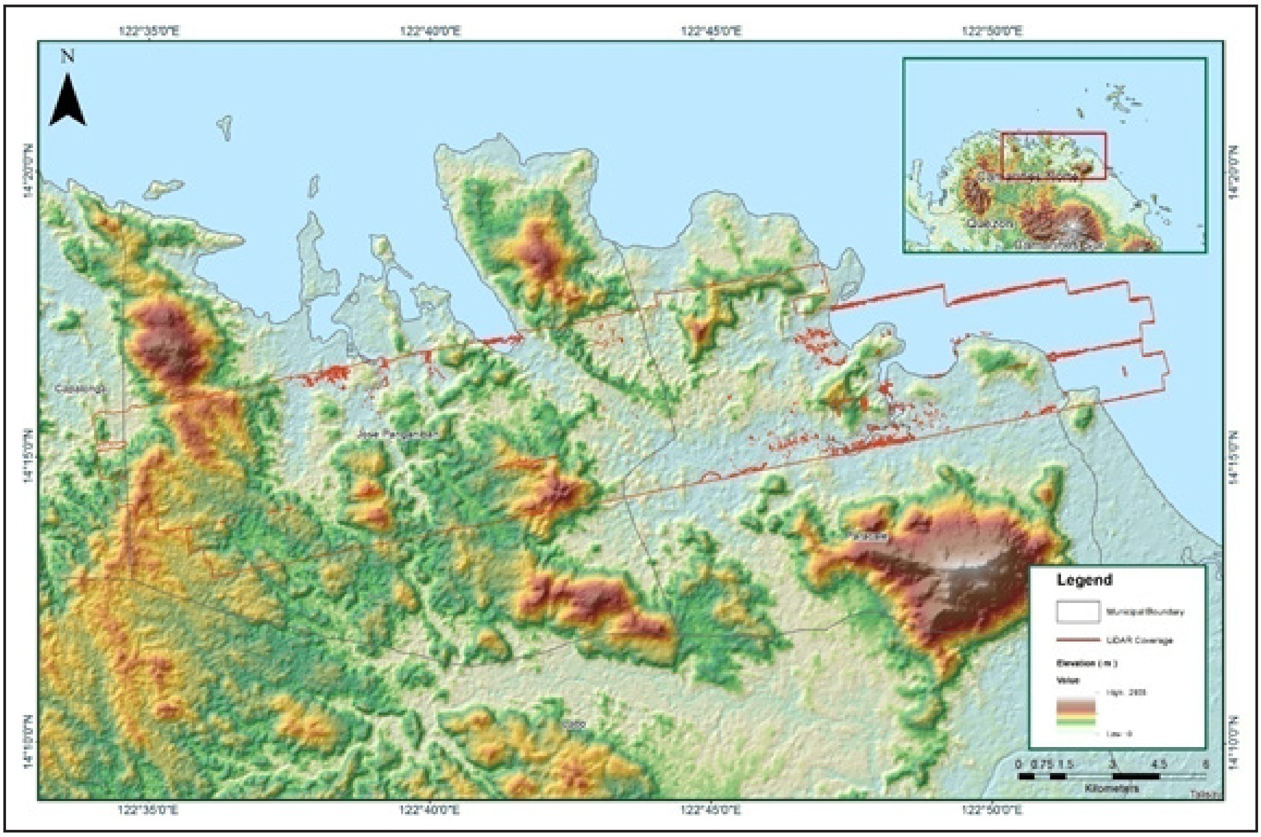


Figure A-8.25 Coverage of LiDAR Data

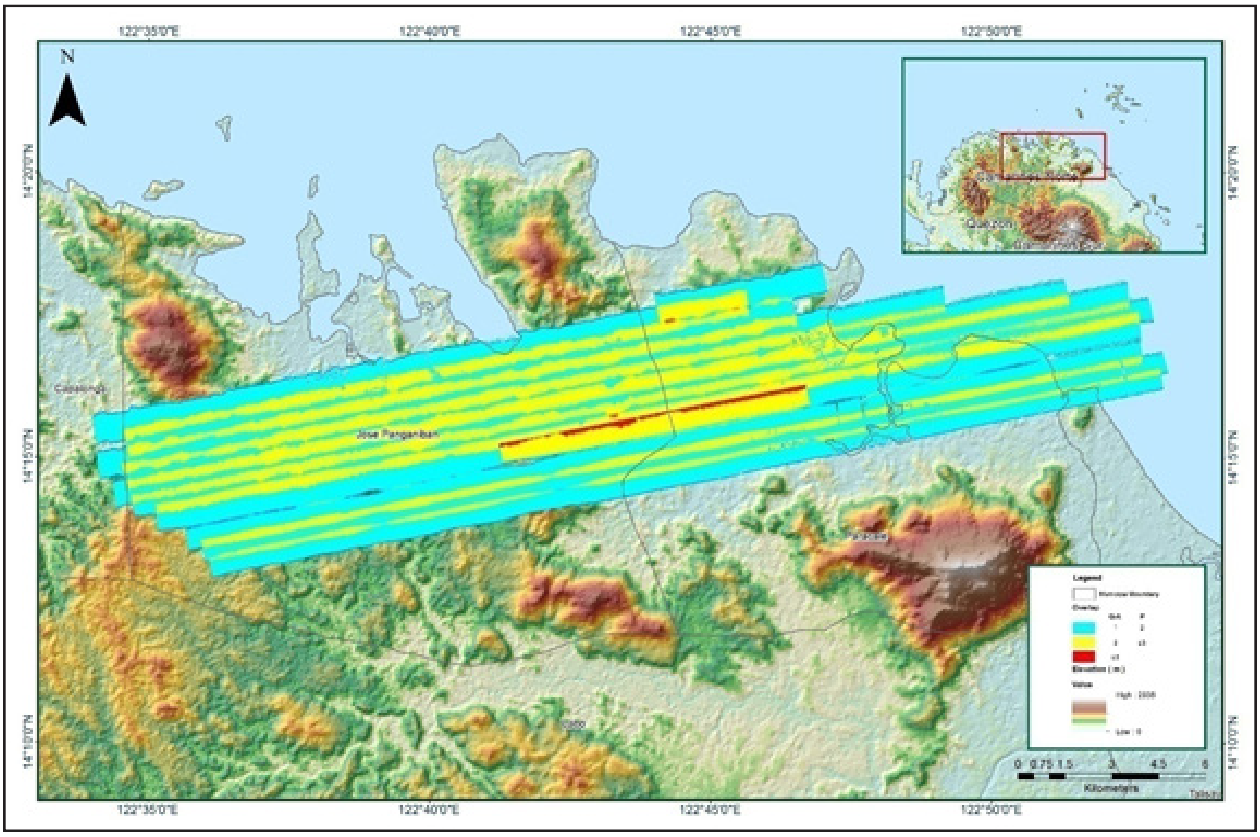


Figure A-8.26 Image of data overlap

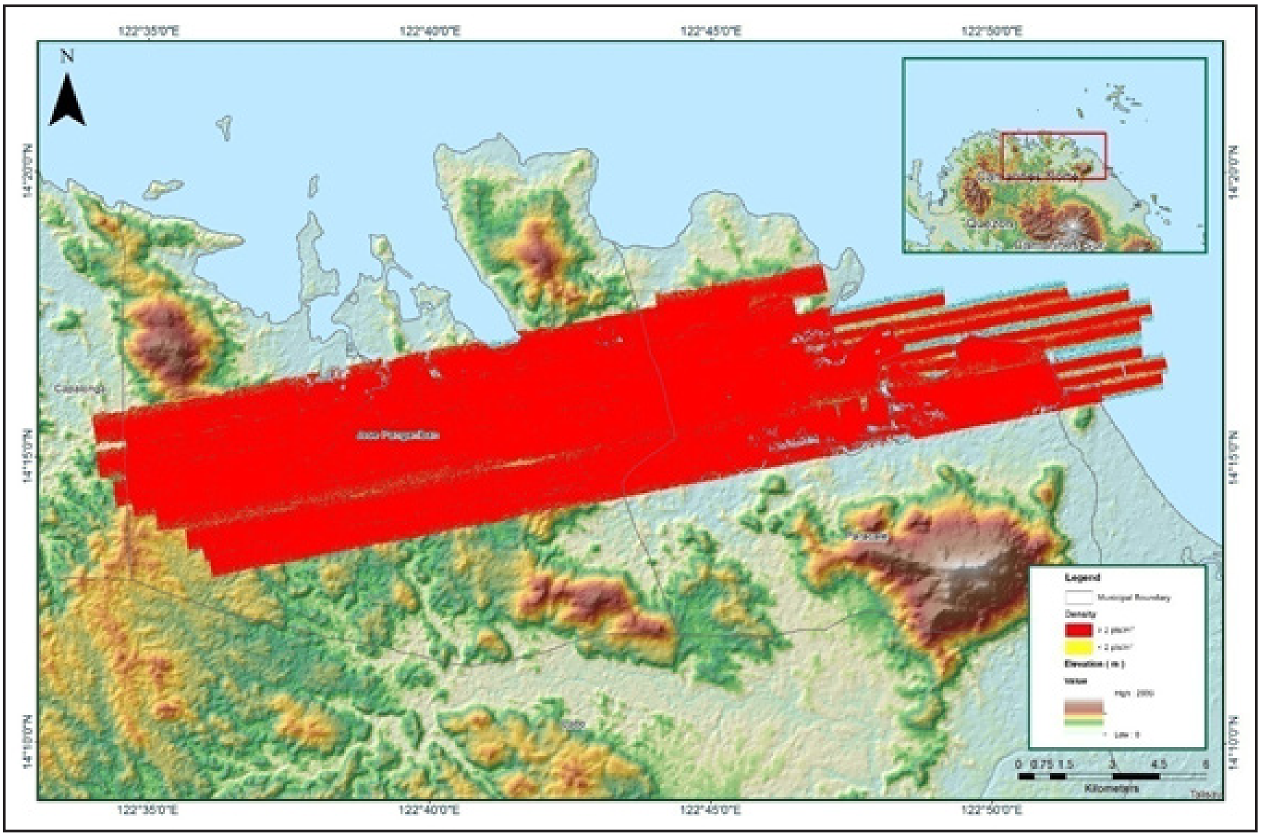


Figure A-8.27 Density map of merged LiDAR data

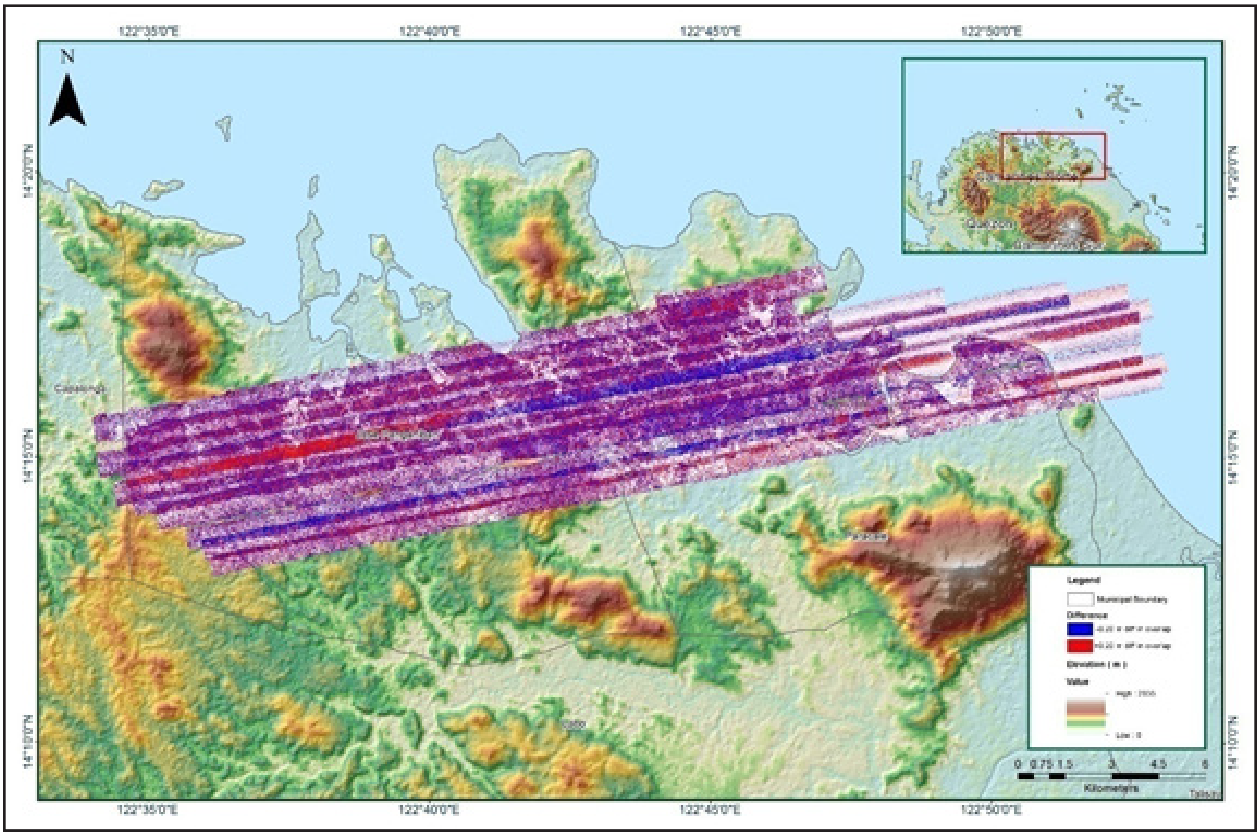


Figure A-8.28 Elevation difference between flight line

Table A-8.5. Mission Summary Report for Mission Bagasbasa_Blk20O_supplement2

Flight Area	Bagasbas
Mission Name	Bagasbasa_Blk20O_supplement2
Inclusive Flights	23264P
Range data size	16 GB
POS data size	456 MB
Base data size	83 MB
Image	n/a
Transfer date	May 18 ,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	2.3
Boresight correction stdev (<0.001deg)	0.000362
IMU attitude correction stdev (<0.001deg)	0.000566
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	25.55%
Ave point cloud density per sq.m. (>2.0)	3.42
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	85
Maximum Height	329.33 m
Minimum Height	43.47 m
Classification (# of points)	
Ground	29,836,179
Low vegetation	22,583,678
Medium vegetation	54,475,312
High vegetation	171,328,897
Building	3,093,867
Orthophoto	No
Processed by	Engr. Don Matthew Banatin, Engr. Ma. Joanne Balaga, Engr. MonalyneRabino

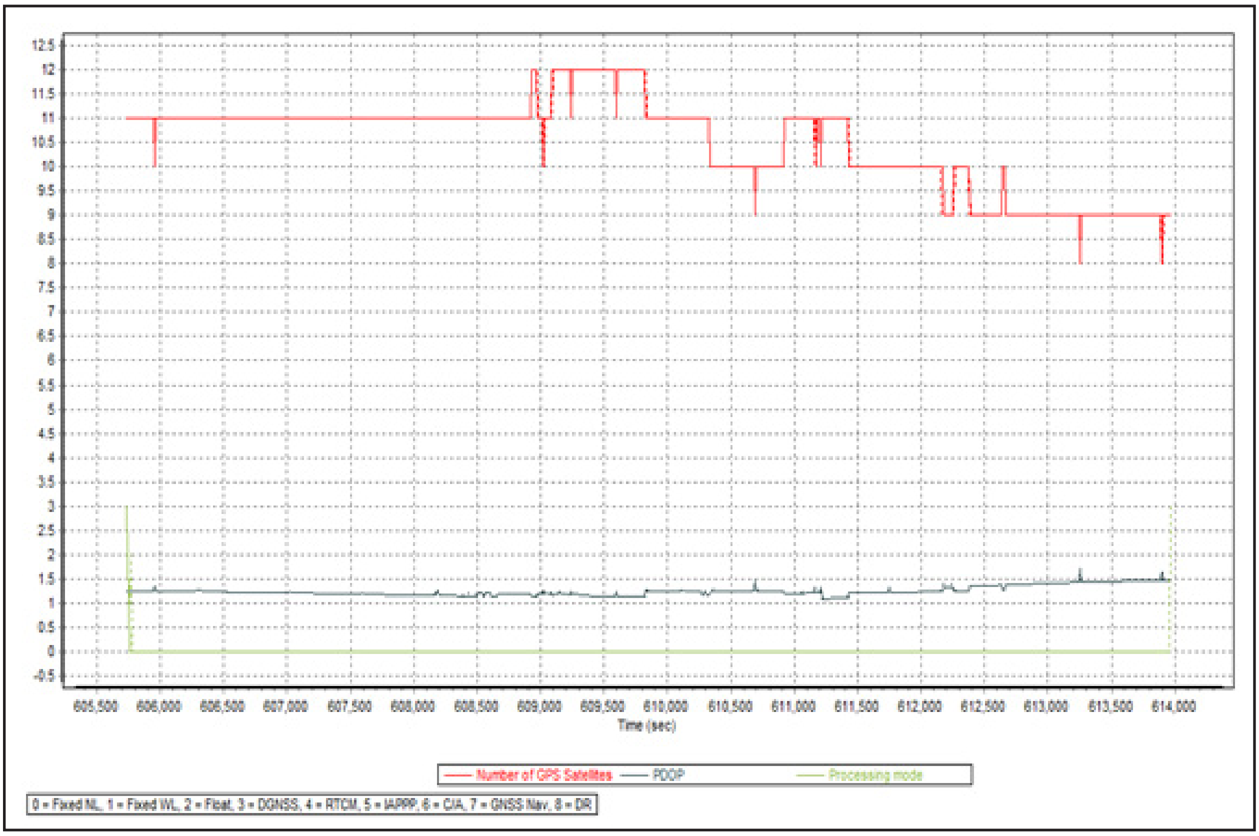


Figure A-8.29 Solution Status

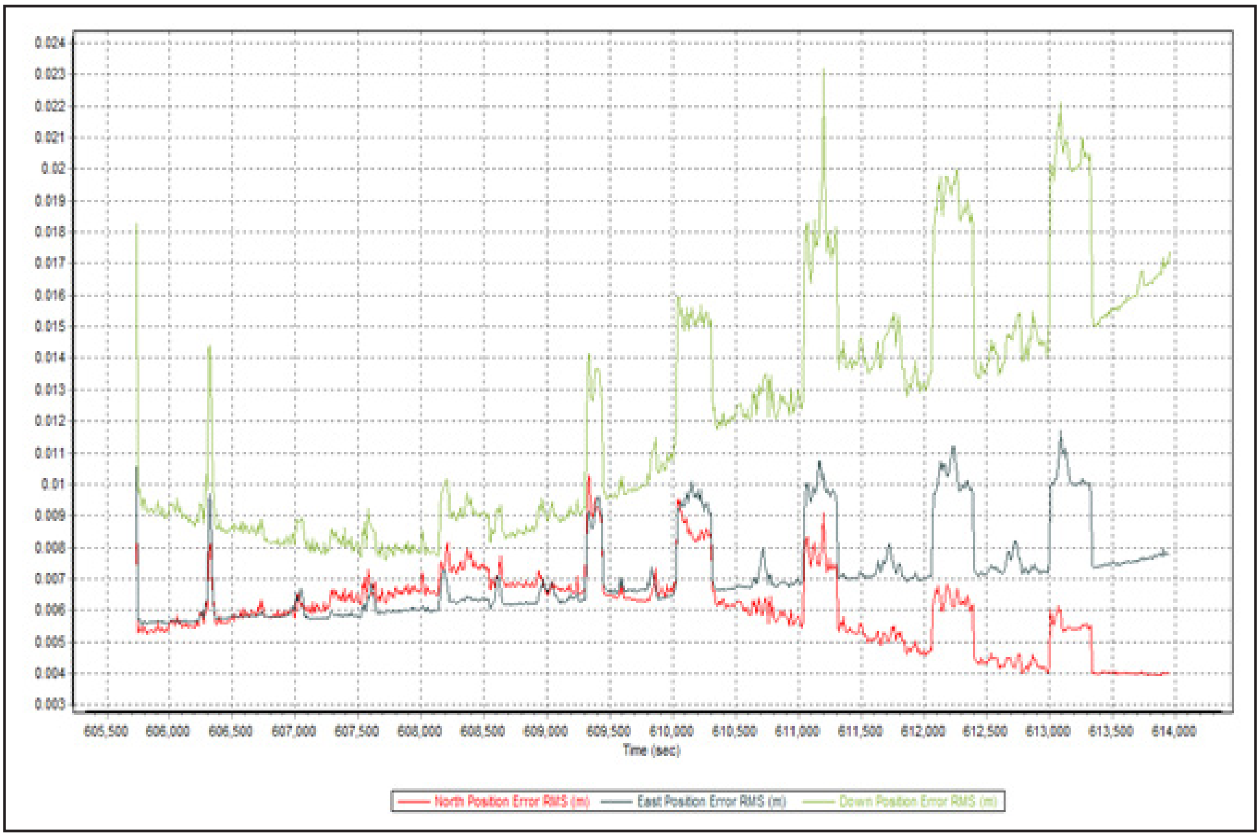


Figure A-8.30 Smoothed Performance Metric Parameters

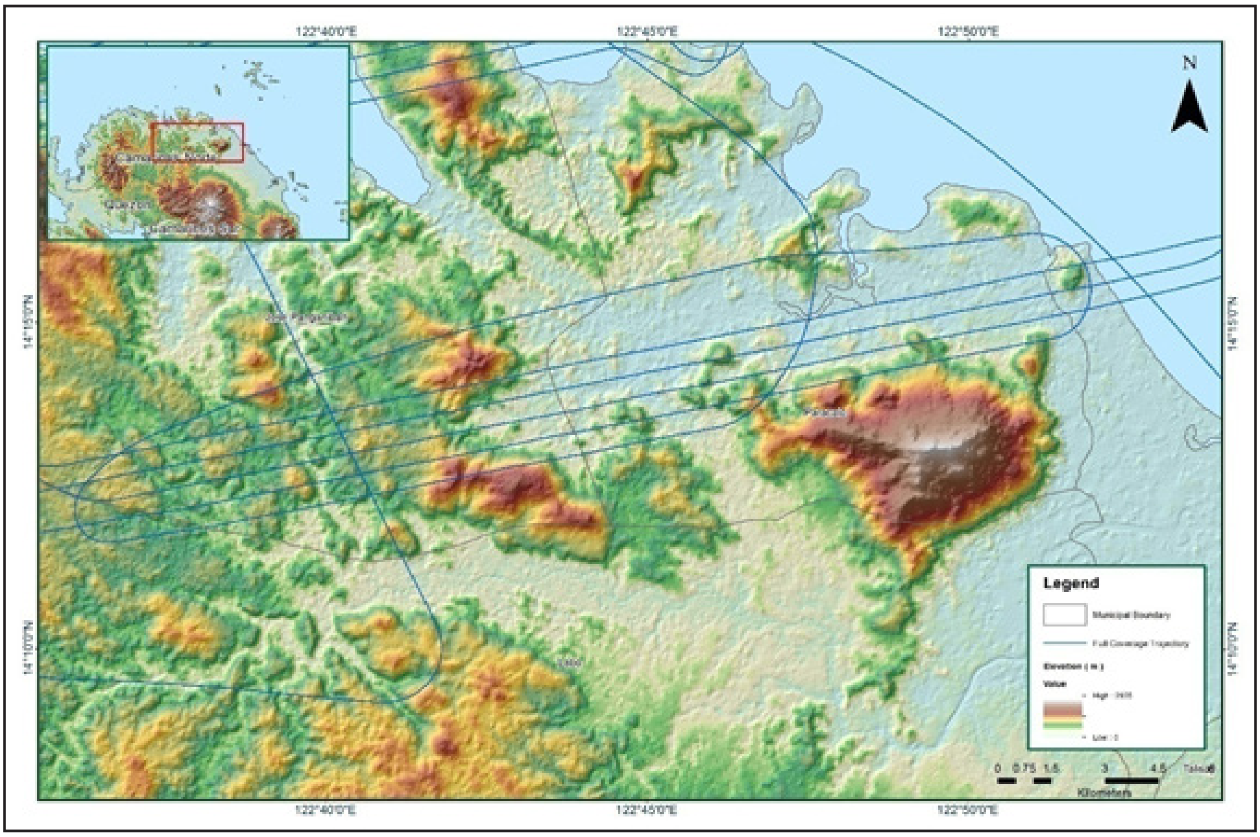


Figure A-8.31 Best Estimated Trajectory

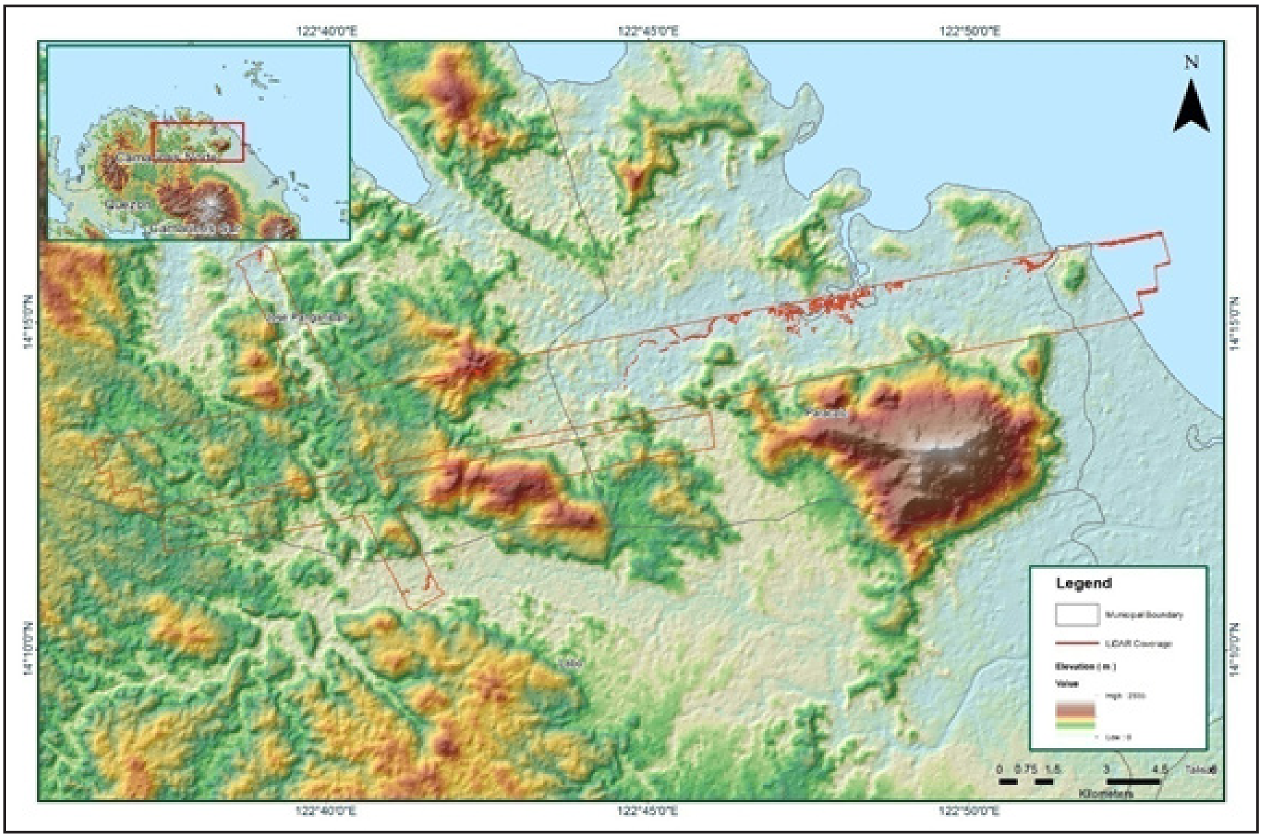


Figure A-8.33 Image of data overlap

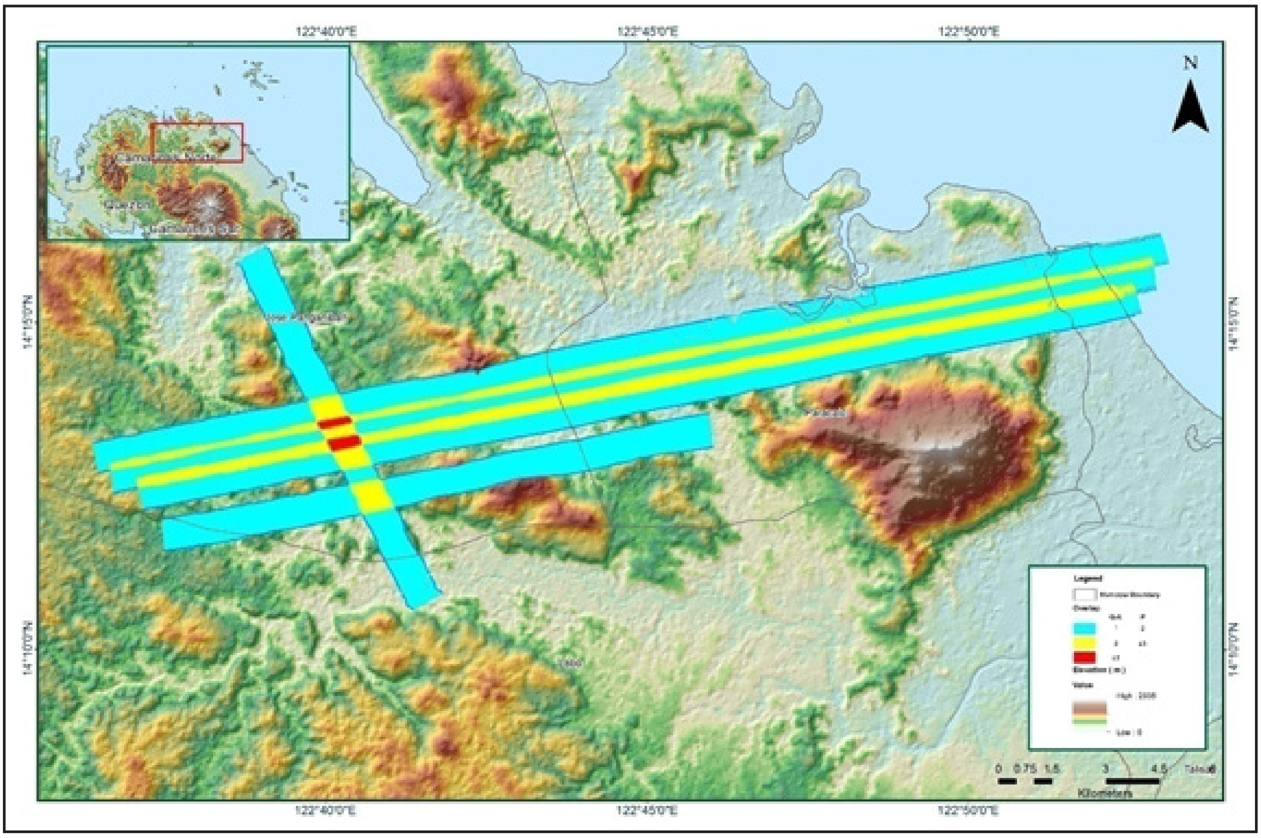


Figure A-8.33 Image of data overlap

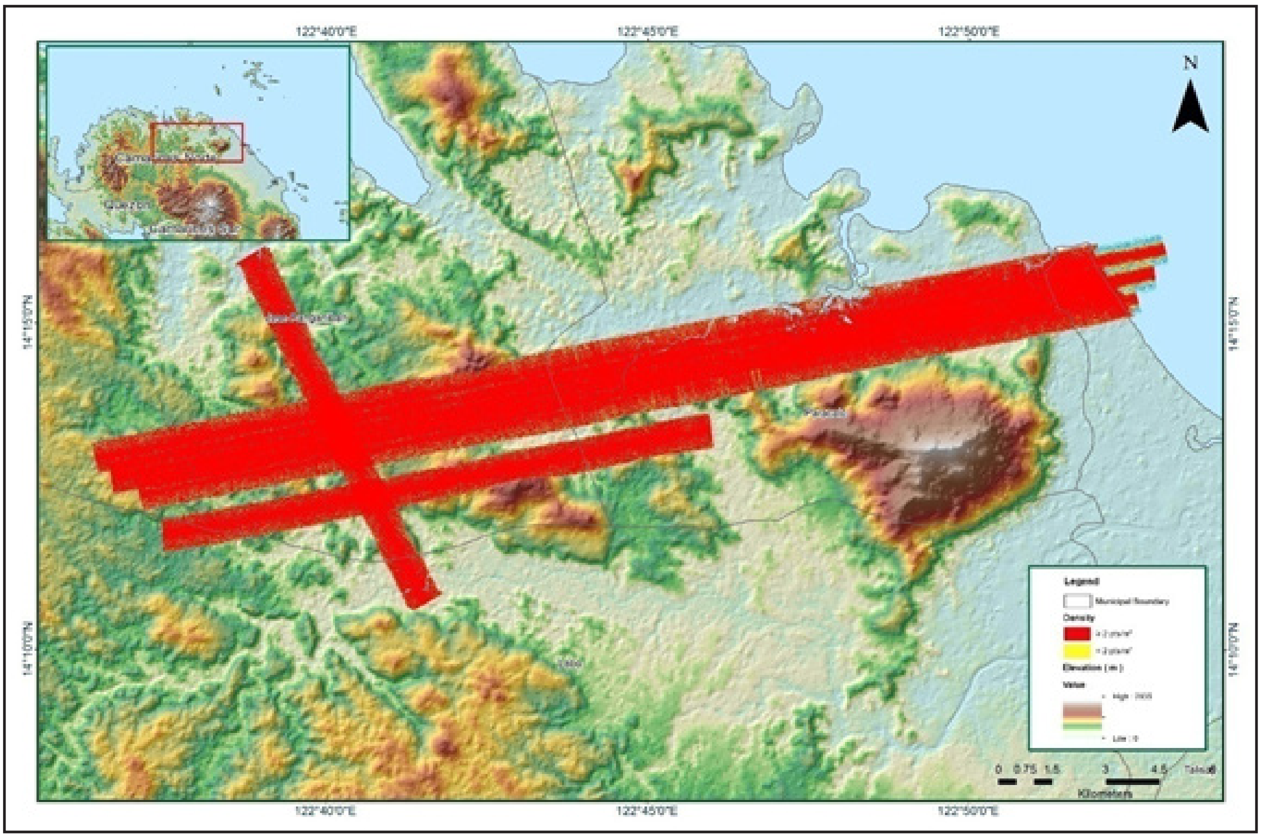


Figure A-8.34 Density map of merged LiDAR data

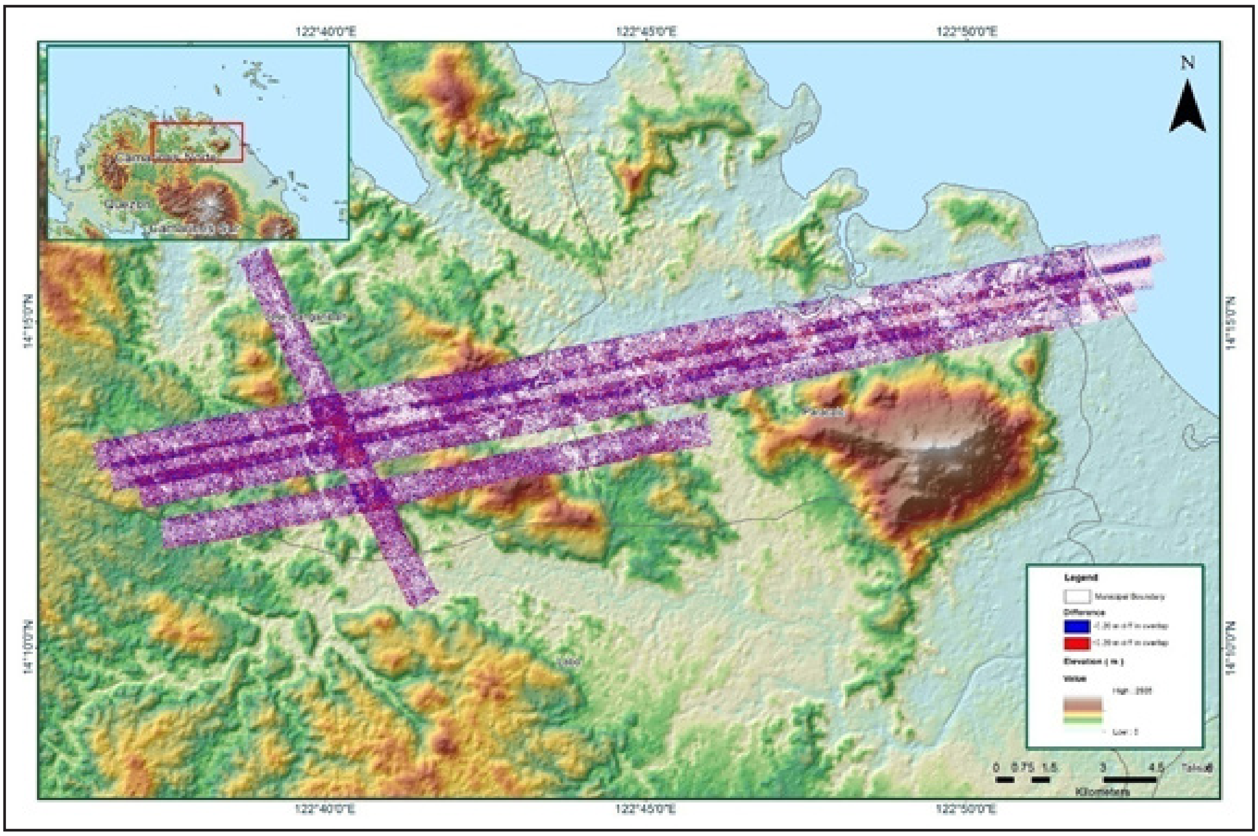


Figure A-8.35 Elevation difference between flight line

ANNEX 9. Labo Model Basin Parameters

Table A-9.1. Labo Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1860	4.654	81.68	0	0.70196	9.2949	Discharge	1.3315	1	Ratio to Peak	0.05
W1850	2.852	78.694	0	0.274744	12.16	Discharge	0.57297	1	Ratio to Peak	0.05
W1840	0.85652	83.011	0	0.492056	2.146	Discharge	0.7434	1	Ratio to Peak	0.05
W1830	4.8502	74.9	0	0.307224	8.6974	Discharge	0.65387	1	Ratio to Peak	0.05
W1820	7.6356	72.907	0	2.9408	17.228	Discharge	0.64713	1	Ratio to Peak	0.05
W1810	2.0853	91.508	0	0.575792	7.5148	Discharge	0.38875	1	Ratio to Peak	0.05
W1800	1.9862	92.23	0	0.88064	5.8454	Discharge	0.22108	1	Ratio to Peak	0.05
W1790	0.56729	67.533	0	0.576688	7.7175	Discharge	0.25561	1	Ratio to Peak	0.05
W1780	24.595	70.97	0	0.708064	20.997	Discharge	1.4436	1	Ratio to Peak	0.05
W1770	2.1043	91.475	0	0.4464	3.8839	Discharge	0.067449	1	Ratio to Peak	0.05
W1760	3.3012	83.195	0	0.701624	6.0807	Discharge	0.5828	1	Ratio to Peak	0.05
W1750	1.7731	85.986	0	0.401368	1.5833	Discharge	0.2918	1	Ratio to Peak	0.05
W1740	1.8805	84.923	0	0.258	1.4695	Discharge	0.30496	1	Ratio to Peak	0.05
W1730	2.197	70.185	0	0.8512	3.3898	Discharge	0.92398	1	Ratio to Peak	0.05
W1720	2.7265	84.819	0	0.17792	1.0065	Discharge	0.03131	1	Ratio to Peak	0.05
W1710	1.8988	91.153	0	0.36672	1.3878	Discharge	0.36876	1	Ratio to Peak	0.05
W1700	2.5013	86.542	0	0.351392	1.3667	Discharge	0.18371	1	Ratio to Peak	0.05
W1690	5.7185	79.877	0	1.1984	10.477	Discharge	0.80458	1	Ratio to Peak	0.05
W1680	5.1944	73.038	0	0.650888	5.8055	Discharge	0.3521	1	Ratio to Peak	0.05
W1670	14.223	67.681	0	1.49832	11.391	Discharge	0.55512	1	Ratio to Peak	0.05
W1660	3.9572	85.567	0	0.708512	9.2472	Discharge	0.29059	1	Ratio to Peak	0.05
W1650	2.6124	87.844	0	1.25992	10.932	Discharge	1.0248	1	Ratio to Peak	0.05

W1640	4.6117	74.709	0	1.642	6.4135	Discharge	0.81724	1	Ratio to Peak	0.05
W1630	1.6207	77.154	0	1.34704	7.9493	Discharge	1.056	1	Ratio to Peak	0.05
W1620	6.5971	67.227	0	1.306	7.6488	Discharge	0.1713	1	Ratio to Peak	0.05
W1610	1.0548	72.204	0	0.74368	4.0414	Discharge	0.27194	1	Ratio to Peak	0.05
W1600	7.1066	75.25	0	0.94432	5.4765	Discharge	0.73109	1	Ratio to Peak	0.05
W1590	11.94	61.919	0	2.07384	12.105	Discharge	0.8367	1	Ratio to Peak	0.05
W1580	1.548	87.091	0	0.745304	6.56	Discharge	0.39195	1	Ratio to Peak	0.05
W1570	11.116	52.446	0	0.75264	5.0487	Discharge	0.050827	1	Ratio to Peak	0.05
W1560	6.8941	65.948	0	0.307168	2.6864	Discharge	0.022532	1	Ratio to Peak	0.05
W1550	1.5561	80.3	0	0.644448	2.4807	Discharge	0.32808	1	Ratio to Peak	0.05
W1540	1.0973	78.024	0	0.89312	3.3273	Discharge	0.36056	1	Ratio to Peak	0.05
W1530	5.802	70.509	0	1.84752	10.665	Discharge	0.96645	1	Ratio to Peak	0.05
W1520	0.962	80.797	0	0.598864	3.42	Discharge	0.11146	1	Ratio to Peak	0.05
W1510	6.6408	66.917	0	2.26176	13.063	Discharge	1.7354	1	Ratio to Peak	0.05
W1500	2.2418	80.3	0	0.512472	1.3207	Discharge	0.13221	1	Ratio to Peak	0.05
W1490	0.70571	61.563	0	0.609976	2.4989	Discharge	0.29931	1	Ratio to Peak	0.05
W1480	6.796	44.355	0	1.01888	6.7746	Discharge	0.29729	1	Ratio to Peak	0.05
W1470	4.6778	50.548	0	0.85992	4.9867	Discharge	0.48575	1	Ratio to Peak	0.05
W1460	2.3112	99	0	0.18732	1.1012	Discharge	0.025552	1	Ratio to Peak	0.05
W1450	3.2953	99	0	0.35728	2.0292	Discharge	0.11562	1	Ratio to Peak	0.05
W1440	2.2363	76.985	0	0.483952	6.5075	Discharge	0.6552	1	Ratio to Peak	0.05
W1430	4.0474	99	0	0.104456	0.40589	Discharge	0.023392	1	Ratio to Peak	0.04802
W1420	0.89974	70.224	0	2.94744	11.541	Discharge	0.50896	1	Ratio to Peak	0.05
W1410	8.2316	60.016	0	1.47576	8.5597	Discharge	0.3275	1	Ratio to Peak	0.05
W1400	5.3553	47.464	0	0.80632	7.0149	Discharge	0.24459	1	Ratio to Peak	0.05
W1390	3.4921	99	0	0.22224	1.9041	Discharge	0.30148	1	Ratio to Peak	0.05
W1380	0.36782	76.56	0	2.10064	7.9986	Discharge	0.80665	1	Ratio to Peak	0.05
W1370	9.2013	68.825	0	2.3424	10.484	Discharge	0.65644	1	Ratio to Peak	0.05

W1360	0.25517	53.668	0	1.81104	3.1426	Discharge	0.36904	1	Ratio to Peak	0.05
W1350	3.0157	99	0	0.252472	1.001	Discharge	0.27094	1	Ratio to Peak	0.04802
W1340	9.0653	45.415	0	1.13184	6.5969	Discharge	0.4392	1	Ratio to Peak	0.05
W1330	0.56875	78.343	0	2.42656	6.2889	Discharge	0.36836	1	Ratio to Peak	0.05
W1320	10.371	80.949	0	0.438176	2.5538	Discharge	0.028917	1	Ratio to Peak	0.05
W1310	10.204	88.009	0	0.87296	5.0873	Discharge	0.37611	1	Ratio to Peak	0.05
W1300	10.492	50.167	0	2.42616	14.152	Discharge	0.10176	1	Ratio to Peak	0.05
W1290	12.846	77.158	0	1.528	13.297	Discharge	1.0534	1	Ratio to Peak	0.05
W1280	9.3408	59.969	0	0.740696	14.571	Discharge	0.41936	1	Ratio to Peak	0.05
W1270	9.7506	82.508	0	1.00088	5.8325	Discharge	0.30841	1	Ratio to Peak	0.05
W1260	5.3668	78.624	0	0.744728	6.4774	Discharge	0.27732	1	Ratio to Peak	0.05
W1250	6.3261	45.225	0	1.14008	10.016	Discharge	0.47376	1	Ratio to Peak	0.05
W1240	5.5693	68.204	0	0.425376	8.3676	Discharge	0.33564	1	Ratio to Peak	0.05
W1230	13.14	50.096	0	1.1616	6.7708	Discharge	0.49724	1	Ratio to Peak	0.05
W1220	12.753	76.845	0	0.87448	7.6088	Discharge	0.56884	1	Ratio to Peak	0.05
W1210	11.871	52.444	0	0.607696	3.5416	Discharge	0.20392	1	Ratio to Peak	0.05
W1200	0.51755	75.144	0	2.23608	5.7933	Discharge	0.29571	1	Ratio to Peak	0.05
W1190	9.9623	86.863	0	0.243696	0.95169	Discharge	0.023573	1	Ratio to Peak	0.05
W1180	12.895	81.282	0	0.41664	2.4273	Discharge	0.081232	1	Ratio to Peak	0.05
W1170	11.067	86.558	0	0.76912	6.6893	Discharge	0.40938	1	Ratio to Peak	0.05
W1160	12.399	76.527	0	1.16712	10.46	Discharge	0.72104	1	Ratio to Peak	0.05
W1150	2.2294	99	0	1.15072	2.9876	Discharge	0.30484	1	Ratio to Peak	0.05
W1140	0.41606	82.305	0	0.731	2.8246	Discharge	0.24587	1	Ratio to Peak	0.05
W1130	16.546	77.75	0	0.628928	8.2046	Discharge	0.20796	1	Ratio to Peak	0.05
W1120	3.5841	53.24	0	0.98336	8.5716	Discharge	0.93887	1	Ratio to Peak	0.05
W1110	3.7395	37.199	0	0.669144	5.8585	Discharge	0.23522	1	Ratio to Peak	0.05
W1100	3.8354	46.272	0	1.02464	8.852	Discharge	0.4928	1	Ratio to Peak	0.05
W1090	18.545	74.763	0	0.243864	0.91828	Discharge	0.051325	1	Ratio to Peak	0.05

W1080	0.2896	79.82	0	1.01016	3.9874	Discharge	0.21615	1	Ratio to Peak	0.05
W1070	17.506	77.879	0	0.93288	5.7395	Discharge	0.79731	1	Ratio to Peak	0.05
W1060	0.62198	86.689	0	0.584208	0.6662	Discharge	0.52652	1	Ratio to Peak	0.04802
W1050	5.7309	35.013	0	1.28	11.132	Discharge	0.70066	1	Ratio to Peak	0.05
W1040	5.635	56.225	0	0.238904	0.98771	Discharge	0.02493	1	Ratio to Peak	0.05
W1030	8.5043	37.233	0	0.541752	0.016667	Discharge	0.51195	1	Ratio to Peak	0.05
W1020	1.7921	89.416	0	0.236632	3.0836	Discharge	0.93639	1	Ratio to Peak	0.05
W1010	0.82218	88.248	0	0.730256	0.7096	Discharge	0.34448	1	Ratio to Peak	0.04706
W1000	2.5589	57.953	0	0.67956	5.8226	Discharge	0.48798	1	Ratio to Peak	0.05
W990	11.806	87.746	0	0.73136	9.5442	Discharge	0.41941	1	Ratio to Peak	0.05
W980	5.0335	88.521	0	1.12624	9.7604	Discharge	0.65001	1	Ratio to Peak	0.05
W970	6.7256	89.394	0	2.11128	8.2386	Discharge	0.90225	1	Ratio to Peak	0.05
W960	1.7382	92.194	0	0.87472	3.4265	Discharge	0.70159	1	Ratio to Peak	0.05
W950	11.759	73.979	0	0.81576	4.7979	Discharge	0.68491	1	Ratio to Peak	0.05
W940	6.9999	82.715	0	1.45704	18.924	Discharge	1.2796	1	Ratio to Peak	0.05

ANNEX 10. Labo Model Reach Parameters

Table A-10.1 Rosario-Lobo Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R70	Automatic Fixed Interval	4886	0.0019	0.045346	Trapezoid	164	1
R80	Automatic Fixed Interval	924.97	0.001263	0.023452	Trapezoid	164	1
R90	Automatic Fixed Interval	1160.5	0.002998	0.068331	Trapezoid	164	1
R100	Automatic Fixed Interval	6285.8	0.00116	0.068781	Trapezoid	164	1
R110	Automatic Fixed Interval	1092.7	0.00022	0.012298	Trapezoid	164	1
R130	Automatic Fixed Interval	2377.8	0.001243	0.029128	Trapezoid	164	1
R140	Automatic Fixed Interval	1467	0.000711	0.028925	Trapezoid	164	1
R170	Automatic Fixed Interval	2706.9	0.000533	0.03504	Trapezoid	164	1
R180	Automatic Fixed Interval	771.54	0.003672	0.034966	Trapezoid	164	1
R190	Automatic Fixed Interval	4304.9	0.004595	0.049204	Trapezoid	164	1
R230	Automatic Fixed Interval	3426.8	0.006238	0.012594	Trapezoid	164	1
R240	Automatic Fixed Interval	1824.1	0.001261	0.035116	Trapezoid	164	1
R250	Automatic Fixed Interval	1109.1	0.003481	0.03506	Trapezoid	164	1
R260	Automatic Fixed Interval	3628.4	0.000489	0.020118	Trapezoid	164	1
R320	Automatic Fixed Interval	822.13	0.005775	0.04551	Trapezoid	164	1
R330	Automatic Fixed Interval	3219.5	0.001376	0.030106	Trapezoid	164	1
R350	Automatic Fixed Interval	1184.9	0.005933	0.045126	Trapezoid	164	1
R370	Automatic Fixed Interval	3394.6	0.002905	0.020103	Trapezoid	164	1
R380	Automatic Fixed Interval	4316.8	0.004326	0.0345	Trapezoid	164	1
R390	Automatic Fixed Interval	2732.2	0.000577	0.019451	Trapezoid	164	1
R400	Automatic Fixed Interval	1874.3	0.000413	0.02	Trapezoid	164	1
R410	Automatic Fixed Interval	745.56	0.001038	0.025931	Trapezoid	164	1
R420	Automatic Fixed Interval	1722.4	0.004352	0.023139	Trapezoid	164	1

R430	Automatic Fixed Interval	4103.7	0.000671	0.020504	Trapezoid	164	1
R440	Automatic Fixed Interval	4875	0.004122	0.020109	Trapezoid	164	1
R450	Automatic Fixed Interval	2106.6	0.002569	0.030231	Trapezoid	164	1
R470	Automatic Fixed Interval	2247.2	0.01084	0.044932	Trapezoid	164	1
R500	Automatic Fixed Interval	884.97	0.005393	0.031158	Trapezoid	164	1
R510	Automatic Fixed Interval	6244.3	0.003974	0.033771	Trapezoid	164	1
R530	Automatic Fixed Interval	6863.1	0.001255	0.029539	Trapezoid	164	1
R540	Automatic Fixed Interval	744.56	0.001117	0.05175	Trapezoid	164	1
R550	Automatic Fixed Interval	2772.2	0.004692	0.023198	Trapezoid	164	1
R570	Automatic Fixed Interval	3113.2	0.017546	0.010165	Trapezoid	164	1
R600	Automatic Fixed Interval	633.55	0.007672	0.067569	Trapezoid	164	1
R610	Automatic Fixed Interval	1551	0.004986	0.029106	Trapezoid	164	1
R660	Automatic Fixed Interval	3099.2	0.001899	0.020066	Trapezoid	164	1
R680	Automatic Fixed Interval	5519.8	0.005512	0.020347	Trapezoid	164	1
R690	Automatic Fixed Interval	3990.9	0.006675	0.019803	Trapezoid	164	1
R740	Automatic Fixed Interval	1932.1	0.015102	0.012996	Trapezoid	164	1
R760	Automatic Fixed Interval	3437.2	0.032255	0.022203	Trapezoid	164	1
R800	Automatic Fixed Interval	844.68	0.011347	0.019585	Trapezoid	164	1
R820	Automatic Fixed Interval	1900.4	0.003162	0.026709	Trapezoid	164	1
R830	Automatic Fixed Interval	6035.5	0.003419	0.020238	Trapezoid	164	1
R840	Automatic Fixed Interval	1967.5	0.001923	0.02645	Trapezoid	164	1
R850	Automatic Fixed Interval	2804.5	0.021971	0.018654	Trapezoid	164	1
R910	Automatic Fixed Interval	3624.8	0.024313	0.02	Trapezoid	164	1

ANNEX 11. Labo Field Validation Points

Table A-11.1. Labo Field Validation

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	14.24158	122.86	0.03	0.25	-0.220	Typhoon Rosing	5-Year
2	14.24793	122.86	0.32	0.25	0.070	Typhoon Rosing	5-Year
3	14.2498	122.86	0.03	0.25	-0.220	Typhoon Rosing	5-Year
4	14.24985	122.86	0.03	0.25	-0.220	Typhoon Rosing	5-Year
5	14.25801	122.86	0.03	0.25	-0.220	Typhoon Rosing	5-Year
6	14.25798	122.86	0.03	0.25	-0.220	Typhoon Rosing	5-Year
7	14.25212	122.87	0.03	0.25	-0.220	Typhoon Rosing	5-Year
8	14.25288	122.87	0.03	0.25	-0.220	Typhoon Rosing	5-Year
9	14.25574	122.87	0.03	0.25	-0.220	Typhoon Rosing	5-Year
10	14.22683	122.87	0.08	0.25	-0.170	Typhoon Rosing	5-Year
11	14.22488	122.87	0.03	0.25	-0.220	Typhoon Rosing	5-Year
12	14.22461	122.87	0.05	0.25	-0.200	Typhoon Rosing	5-Year
13	14.22435	122.87	0.03	0.25	-0.220	Typhoon Rosing	5-Year
14	14.22426	122.87	0.28	0.25	0.030	Typhoon Rosing	5-Year
15	14.23938	122.86	0.07	0.25	-0.180	Typhoon Rosing	5-Year
16	14.23968	122.86	0.03	0.25	-0.220	Typhoon Rosing	5-Year
17	14.24011	122.86	0.07	0.25	-0.180	Typhoon Rosing	5-Year
18	14.22835	122.87	1.05	0.25	0.800	Typhoon Rosing	5-Year
19	14.24567	122.87	0.03	0.5	-0.470	Typhoon Rosing	5-Year
20	14.23884	122.86	0.47	0.5	-0.030	Typhoon Rosing	5-Year
21	14.22645	122.87	0.04	0.5	-0.460	Typhoon Rosing	5-Year
22	14.23681	122.86	0.07	0.5	-0.430	Typhoon Rosing	5-Year
23	14.23619	122.86	0.21	0.5	-0.290	Typhoon Rosing	5-Year
25	14.24976	122.86	0.63	0.5	0.130	Typhoon Rosing	5-Year
26	14.24975	122.86	0.26	0.5	-0.240	Typhoon Rosing	5-Year
27	14.25026	122.86	0.03	0.5	-0.470	Typhoon Rosing	5-Year
28	14.25981	122.86	0.03	0.5	-0.470	Typhoon Rosing	5-Year
29	14.24518	122.87	0.03	0.5	-0.470	Typhoon Rosing	5-Year
30	14.23848	122.86	0.28	0.5	-0.220	Typhoon Rosing	5-Year
31	14.24502	122.87	0.03	0.5	-0.470	Typhoon Rosing	5-Year
32	14.24606	122.87	0.03	0.5	-0.470	Typhoon Rosing	5-Year
33	14.15354	122.85	0.03	0.5	-0.470	Typhoon Rosing	5-Year
34	14.23854	122.86	0.03	0.5	-0.470	Typhoon Rosing	5-Year
35	14.2387	122.86	0.06	0.5	-0.440	Typhoon Rosing	5-Year
36	14.23863	122.86	0.04	0.5	-0.460	Typhoon Rosing	5-Year
37	14.23853	122.86	0.06	0.5	-0.440	Typhoon Rosing	5-Year
38	14.23841	122.86	0.3	0.5	-0.200	Typhoon Rosing	5-Year
40	14.23841	122.86	0.07	0.5	-0.430	Typhoon Rosing	5-Year
41	14.23842	122.86	0.03	0.5	-0.470	Typhoon Rosing	5-Year

42	14.24679	122.87	0.11	0	0.110	Typhoon Rosing	5-Year
43	14.2466	122.87	0.13	0	0.130	Typhoon Rosing	5-Year
44	14.24594	122.87	0.03	0	0.030	Typhoon Rosing	5-Year
45	14.23202	122.85	0.03	0	0.030	Typhoon Rosing	5-Year
46	14.23023	122.85	0.04	0	0.040	Typhoon Rosing	5-Year
47	14.15133	122.84	0.03	0	0.030	Typhoon Rosing	5-Year
48	14.15194	122.84	0.12	0	0.120	Typhoon Rosing	5-Year
49	14.15274	122.84	0.46	0	0.460	Typhoon Rosing	5-Year
50	14.15368	122.85	0.78	0	0.780	Typhoon Rosing	5-Year
51	14.15305	122.85	0.03	0	0.030	Typhoon Rosing	5-Year
52	14.22333	122.87	0.43	0	0.430	Typhoon Rosing	5-Year
53	14.14098	122.86	0.03	0	0.030	Typhoon Rosing	5-Year
54	14.14069	122.86	0.06	0	0.060	Typhoon Rosing	5-Year
55	14.13697	122.86	0.15	0	0.150	Typhoon Rosing	5-Year
56	14.13575	122.86	0.29	0	0.290	Typhoon Rosing	5-Year
57	14.13512	122.86	0.1	0	0.100	Typhoon Rosing	5-Year
58	14.13956	122.87	0.04	0	0.040	Typhoon Rosing	5-Year
59	14.12082	122.87	0.03	0	0.030	Typhoon Rosing	5-Year
60	14.12288	122.87	0.03	0	0.030	Typhoon Rosing	5-Year
61	14.12308	122.87	0.03	0	0.030	Typhoon Rosing	5-Year
62	14.22322	122.87	0.03	0	0.030	Typhoon Rosing	5-Year
63	14.2236	122.87	0.03	0	0.030	Typhoon Rosing	5-Year
64	14.22424	122.87	0.03	0	0.030	Typhoon Rosing	5-Year
65	14.2502	122.86	0.03	0	0.030	Typhoon Rosing	5-Year
66	14.25993	122.86	0.04	0	0.040	Typhoon Rosing	5-Year
67	14.25905	122.87	0.03	0	0.030	Typhoon Rosing	5-Year
68	14.24713	122.87	0.03	0	0.030	Typhoon Rosing	5-Year
69	14.22316	122.87	0.06	0	0.060	Typhoon Rosing	5-Year
70	14.25803	122.86	0.03	1.5	-1.470	Typhoon Rosing	5-Year
71	14.25813	122.86	0.21	1.5	-1.290	Typhoon Rosing	5-Year
72	14.25949	122.86	0.56	1.5	-0.940	Typhoon Rosing	5-Year
73	14.20414	122.87	0.19	1.5	-1.310	Typhoon Rosing	5-Year
74	14.25796	122.86	0.05	1.5	-1.450	Typhoon Rosing	5-Year
75	14.25934	122.86	0.14	1	-0.860	Typhoon Rosing	5-Year
76	14.23752	122.86	0.1	1	-0.900	Typhoon Rosing	5-Year
77	14.23511	122.85	0.63	1	-0.370	Typhoon Rosing	5-Year
78	14.23301	122.85	0.04	1	-0.960	Typhoon Rosing	5-Year
79	14.23812	122.86	0.35	1	-0.650	Typhoon Rosing	5-Year
80	14.20321	122.86	0.25	1	-0.750	Typhoon Rosing	5-Year
81	14.20297	122.86	0.22	1	-0.780	Typhoon Rosing	5-Year
82	14.15046	122.84	0.65	1	-0.350	Typhoon Rosing	5-Year
83	14.24971	122.86	0.6	1	-0.400	Typhoon Rosing	5-Year
85	14.25023	122.86	0.03	1	-0.970	Typhoon Rosing	5-Year
86	14.25826	122.86	0.03	1	-0.970	Typhoon Rosing	5-Year
87	14.25829	122.86	0.07	1	-0.930	Typhoon Rosing	5-Year

88	14.25862	122.86	0.03	1	-0.970	Typhoon Rosing	5-Year
89	14.25883	122.86	0.03	1	-0.970	Typhoon Rosing	5-Year
91	14.24972	122.86	0.05	1	-0.950	Typhoon Rosing	5-Year
92	14.20384	122.87	0.06	2	-1.940	Typhoon Rosing	5-Year
93	14.20371	122.87	0.06	2	-1.940	Typhoon Rosing	5-Year
94	14.25782	122.86	0.26	2	-1.740	Typhoon Rosing	5-Year
95	14.25776	122.86	0.03	2	-1.970	Typhoon Rosing	5-Year
96	14.25822	122.86	0.03	2	-1.970	Typhoon Rosing	5-Year
97	14.25843	122.86	0.14	2	-1.860	Typhoon Rosing	5-Year
98	14.24191	122.86	0.35	2	-1.650	Typhoon Rosing	5-Year
99	14.24006	122.86	0.31	2	-1.690	Typhoon Rosing	5-Year
100	14.23966	122.86	0.03	2	-1.970	Typhoon Rosing	5-Year
101	14.2393	122.86	0.03	2	-1.970	Typhoon Rosing	5-Year
102	14.25793	122.86	0.03	2	-1.970	Typhoon Rosing	5-Year
103	14.2039	122.87	0.03	3	-2.970	Typhoon Rosing	5-Year
104	14.20358	122.87	0.03	3	-2.970	Typhoon Rosing	5-Year
105	14.20342	122.87	0.03	3	-2.970	Typhoon Rosing	5-Year
106	14.2005	122.87	0.03	3	-2.970	Typhoon Rosing	5-Year
107	14.20025	122.87	0.03	3	-2.970	Typhoon Rosing	5-Year
108	14.19917	122.87	0.03	3	-2.970	Typhoon Rosing	5-Year
109	14.19885	122.87	0.03	3	-2.970	Typhoon Rosing	5-Year
110	14.19881	122.87	0.03	3	-2.970	Typhoon Rosing	5-Year
111	14.20015	122.87	0.06	3	-2.940	Typhoon Rosing	5-Year
112	14.16792	122.83	0.13	3	-2.870	Typhoon Rosing	5-Year
113	14.25759	122.86	0.03	3	-2.970	Typhoon Rosing	5-Year
114	14.1536	122.84	0.18	3	-2.820	Typhoon Rosing	5-Year
115	14.25748	122.86	0.35	3	-2.650	Typhoon Rosing	5-Year
116	14.25738	122.86	0.37	3	-2.630	Typhoon Rosing	5-Year
117	14.25731	122.86	0.41	3	-2.590	Typhoon Rosing	5-Year
118	14.25741	122.86	0.39	3	-2.610	Typhoon Rosing	5-Year
119	14.2575	122.86	0.2	3	-2.800	Typhoon Rosing	5-Year
120	14.25766	122.86	0.07	3	-2.930	Typhoon Rosing	5-Year
121	14.20389	122.87	0.18	3	-2.820	Typhoon Rosing	5-Year
122	14.25767	122.86	0.41	3	-2.590	Typhoon Rosing	5-Year
123	14.25718	122.86	0.41	4	-3.590	Typhoon Rosing	5-Year
124	14.2573	122.86	0.03	4	-3.970	Typhoon Rosing	5-Year
125	14.23541	122.85	0.36	4	-3.640	Typhoon Rosing	5-Year
126	14.25696	122.86	0.37	4	-3.630	Typhoon Rosing	5-Year
127	14.25685	122.86	0.39	4	-3.610	Typhoon Rosing	5-Year
128	14.25675	122.86	0.39	4	-3.610	Typhoon Rosing	5-Year
129	14.25663	122.86	0.41	4	-3.590	Typhoon Rosing	5-Year
131	14.25664	122.86	0.4	4	-3.600	Typhoon Rosing	5-Year
132	14.25666	122.86	0.35	4	-3.650	Typhoon Rosing	5-Year
133	14.25695	122.86	0.37	4	-3.630	Typhoon Rosing	5-Year
134	14.25703	122.86	0.03	4	-3.970	Typhoon Rosing	5-Year

135	14.25404	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
136	14.25546	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
137	14.25619	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
138	14.25656	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
139	14.25696	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
140	14.25744	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
141	14.25803	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
142	14.25851	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
143	14.25882	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
145	14.25829	122.86	0.03	5	-4.970	Typhoon Rosing	5-Year
146	14.25894	122.87	0.04	5	-4.960	Typhoon Rosing	5-Year
150	14.25939	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
151	14.20167	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
152	14.20124	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
153	14.19858	122.87	0.14	5	-4.860	Typhoon Rosing	5-Year
154	14.20536	122.87	3.8299999	5	-1.170	Typhoon Rosing	5-Year
155	14.15274	122.83	0.04	5	-4.960	Typhoon Rosing	5-Year
156	14.25366	122.87	3.73	5	-1.270	Typhoon Rosing	5-Year
157	14.15284	122.83	3.72	5	-1.280	Typhoon Rosing	5-Year
158	14.15293	122.83	3.71	5	-1.290	Typhoon Rosing	5-Year
159	14.15293	122.83	3.73	5	-1.270	Typhoon Rosing	5-Year
160	14.15296	122.83	3.8900001	5	-1.110	Typhoon Rosing	5-Year
161	14.15305	122.83	3.9400001	5	-1.060	Typhoon Rosing	5-Year
162	14.15312	122.83	4.48	5	-0.520	Typhoon Rosing	5-Year
163	14.15326	122.83	3.8199999	5	-1.180	Typhoon Rosing	5-Year
164	14.15336	122.83	3.77	5	-1.230	Typhoon Rosing	5-Year
165	14.15337	122.83	3.8499999	5	-1.150	Typhoon Rosing	5-Year
166	14.15345	122.83	0.04	5	-4.960	Typhoon Rosing	5-Year
167	14.25326	122.87	0.05	5	-4.950	Typhoon Rosing	5-Year
168	14.25305	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
169	14.25332	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
170	14.25359	122.87	0.07	5	-4.930	Typhoon Rosing	5-Year
171	14.25444	122.87	0.03	5	-4.970	Typhoon Rosing	5-Year
172	14.25494	122.87	0.4	5	-4.600	Typhoon Rosing	5-Year
173	14.25681	122.86	0.03	5	-4.970	Typhoon Rosing	5-Year
174	14.17679	122.91	1.03	0.1	0.930	Typhoon Rosing	5-Year
175	14.17632	122.91	0.1	0.1	0.000	Typhoon Rosing	5-Year
176	14.13079	122.9	0.03	0.1	-0.070	Typhoon Rosing	5-Year
177	14.12623	122.9	0.06	0.1	-0.040	Typhoon Rosing	5-Year
178	14.13077	122.9	0.14	0.2	-0.060	Typhoon Rosing	5-Year
179	14.16159	122.93	0.03	0.2	-0.170	Typhoon Rosing	5-Year
180	14.17751	122.91	0.26	0.2	0.060	Typhoon Rosing	5-Year
181	14.12043	122.89	0.16	0.2	-0.040	Typhoon Rosing	5-Year
182	14.11962	122.88	0.04	0.3	-0.260	Typhoon Rosing	5-Year
183	14.12159	122.9	0.03	0.4	-0.370	Typhoon Rosing	5-Year

184	14.17691	122.91	0.04	0.5	-0.460	Typhoon Rosing	5-Year
185	14.16757	122.89	0.03	0.5	-0.470	Typhoon Rosing	5-Year
186	14.16013	122.87	0.03	0.5	-0.470	Typhoon Rosing	5-Year
187	14.13368	122.92	0.03	0.5	-0.470	Typhoon Rosing	5-Year
188	14.15974	122.94	0.14	0.6	-0.460	Typhoon Rosing	5-Year
189	14.17665	122.91	0.06	0.6	-0.540	Typhoon Rosing	5-Year
190	14.1845	122.93	0.03	0.75	-0.720	Typhoon Rosing	5-Year
191	14.18449	122.92	1.1799999	0.75	0.430	Typhoon Rosing	5-Year
192	14.13018	122.88	0.03	0	0.030	Typhoon Rosing	5-Year
193	14.17163	122.93	0.25	0	0.250	Typhoon Rosing	5-Year
194	14.17386	122.93	0.03	0	0.030	Typhoon Rosing	5-Year
195	14.18735	122.92	0.03	0	0.030	Typhoon Rosing	5-Year
196	14.18099	122.92	0.03	0	0.030	Typhoon Rosing	5-Year
197	14.17338	122.91	0.03	0	0.030	Typhoon Rosing	5-Year
198	14.17349	122.91	0.09	0	0.090	Typhoon Rosing	5-Year
199	14.1412	122.9	0.43	0	0.430	Typhoon Rosing	5-Year

ANNEX 12. Educational Institutions affected by flooding in Labo Floodplain

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

Camarines Norte				
Labo				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Aguit It Elementary School	Brgy. Aguit It	Medium	Medium	Medium
Bautista Elementary School	Brgy. Bautista	Low	Low	Low
Benit Elementary School	Brgy. Benit	None	None	None
Bulhao Elementary School	Brgy. Bulhao	None	None	None
Caawigan Day Care Center	Brgy. Caawigan	None	None	Low
Cagbalogo Elementary School	Brgy. Cagbalogo	None	None	Low
Calabagas Day Care Center	Brgy. Calabagas	None	None	None
Calabagas Elementary School	Brgy. Calabagas	None	None	None
Calabasa Elementary School	Brgy. Calabasa	None	None	None
Calangcawan Norte Elementary School	Brgy. Calangcawan Norte	None	None	None
Camarines Norte College	Brgy. Anahaw	High	High	High
Camarines Norte State College	Brgy. Talobatib	Medium	Medium	Medium
Camia Day Care Center	Brgy. Kalamunding	None	None	Low
Claudio Villagen Elementary School	Brgy. Talobatib	None	None	None
Cleopas R. Dando Elemetary School	Brgy. Malangcao	None	None	None
Covered Court	Brgy. Bagacay	None	Medium	Medium
D.Q Liwag National High School	Brgy. Sto. Domingo	None	None	None
Daguit Elemetary School	Brgy. Daguit	High	High	High
Daguit National High School	Brgy. Daguit	None	None	None
Dalas High School	Brgy. Dalas	Low	Medium	Medium
Dalnac Elementary School	Brgy. Dalnac	Medium	Medium	Medium
Dancalan Elementary School	Brgy. Dancalan	None	None	None
Day Care	Brgy. Pinya	None	Medium	Medium
Day Care Center	Brgy. Bakiad	None	None	None
Day Care Center	Brgy. Benit	None	None	None
Day Care Center	Brgy. Bulhao	Low	Low	Medium
Day Care Center	Brgy. Cagbalogo	None	None	None

Day Care Center	Brgy. Calabasa	None	None	None
Day Care Center	Brgy. Dalas	None	None	None
Day Care Center	Brgy. Dancalan	None	None	None
Day Care Center	Brgy. Fundado	None	None	Medium
Day Care Center	Brgy. Gumamela	None	None	None
Day Care Center	Brgy. Malangcao	None	None	None
Day Care Center	Brgy. Mampungo	None	None	None
Day Care Center	Brgy. Napilihan	None	Low	Medium
Day Care Center	Brgy. Pampang	None	None	None
Day Care Center	Brgy. Sabang	None	None	None
Don Miguel Lukban Elementary School	Brgy. Manlucugan	None	None	None
E. Obmana Elementary School	Brgy. Sta. Cruz	None	None	Low
El Trino P. Zenarosa Elementary School	Brgy. Sabang	Low	Low	Low
Fundado Elementary School	Brgy. Fundado	None	None	Low
Fundado National High School	Brgy. Fundado	None	None	None
Gonzales Ascutia High School	Brgy. Sta. Cruz	None	None	None
Guinacutan Day Care Center	Brgy. Guinacutan	None	None	Low
Holy Trinity College Seminary	Brgy. Bautista	None	Low	Medium
Iberica Elementary School	Brgy. Guinacutan	None	Low	Low
Ignacio Español Elementary School	Brgy. Malacbang	Medium	Medium	Medium
L. Villamonte Elementary School	Brgy. Bagacay	None	None	None
Labo Elementary School	Labo East District	Medium	Medium	Medium
Mabilao II High School	Brgy. Mabilao II	None	None	None
Mahawan Hawan Elementary School	Brgy. Mahawan-Hawan	Low	Medium	Medium
Malasugui Elementary School	Brgy. Malasugui	Low	Medium	Medium
Mampungo Elementary School	Brgy. Mampungo	Low	Low	Medium
Maot Elementary School	Brgy. Maot	None	None	None
Marcos Pimental Elementary School	Brgy. Masalong	None	None	None
Matango Elementary School	Brgy. Matango	None	None	Low
Mcacho Elem. School	Brgy. San Jose	Low	Low	Low
Napilihan Elementary School	Brgy. Napilihan	None	None	Low

Paaralang Elementarya nf Don Miquel Lukban	Brgy. Mabilao II	None	None	None
Pampang Elementary School	Brgy. Pampang	None	None	None
Sabang National High School	Brgy. Sabang	None	None	None
San Isidro Elem. School	Brgy. San Isidro	Low	Low	Low
Singi Elementary School	Brgy. Singi	None	Medium	Medium
Sta. Elena Elem. School	Brgy. Sta. Elena	None	None	Low
Sto. Domingo Day Care Center	Brgy. Sto. Domingo	None	None	None
Sto. Domingo Elementary School	Brgy. Sto. Domingo	Low	Low	Low
Sula Elementary School	Brgy. Sula	None	None	None
Vinzons Pilot Elem. School	Brgy. Calangcawan Sur	Low	Low	Low
Vinzons Pilot Elem. School	Brgy. II	Low	Medium	Medium
Vinzons Pilot High School	Brgy. Calangcawan Sur	Medium	Medium	Medium

Annex 13. Health Institutions affected by flooding in Labo Floodplain

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

Camarines Norte				
Labo				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Health Center	Brgy. Bakiad	None	None	None
Health Center	Brgy. Benit	None	None	None
Health Center	Brgy. Daguit	Low	High	High
Health Center	Brgy. Mabilao II	Medium	Medium	Medium
Health Center	Brgy. Malangcao	None	None	None
Health Center	Brgy. Maot	Medium	Medium	Medium
Health Center	Brgy. Matango	None	None	None
Health Station	Brgy. Mampungo	None	None	None
Iberica Health Station	Brgy. Iberica	None	None	None
Labo District Hospital	Brgy. Talobatib	None	Low	Low
Sto. Domingo Liwag Dental Clinic	Brgy. Sto. Domingo	None	None	None
The Generics Pharmacy	Brgy. Calangcawan Sur	None	None	None
Vinzons Health Office	Brgy. Calangcawan Sur	None	None	None
Women Crisis Center	Brgy. Gumamela	None	None	None