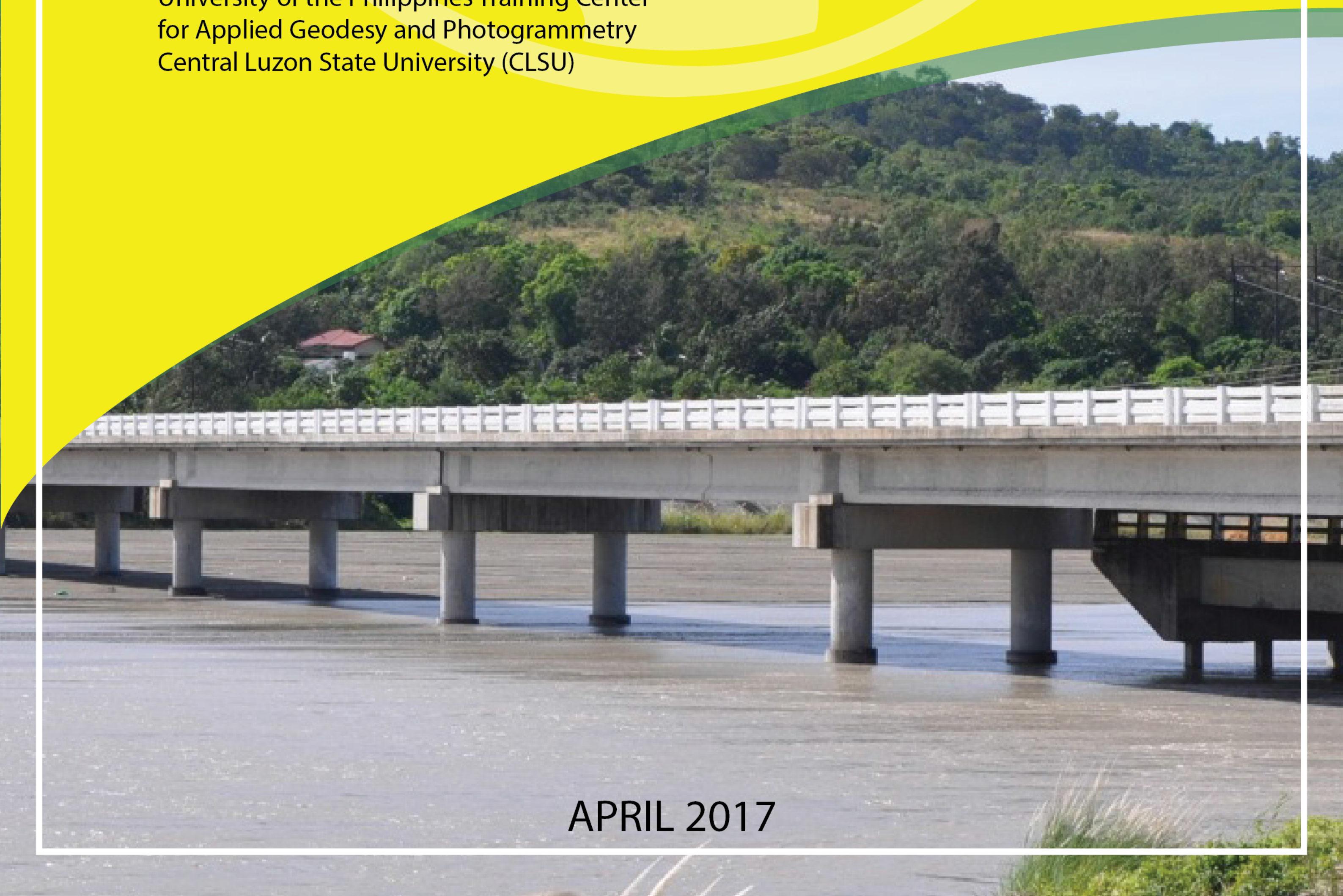
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Bucao River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Central Luzon State University (CLSU)



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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
CLSU	Central Luzon State University
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND BUCAO RIVER

Enrico C. Paringit, Dr. Eng., Dr. Annie Melinda Paz-Alberto, and Kathrina M. Mapanao

1.1 Background of the Phil-LIDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST.

The methods applied in this report are thoroughly described in a separate publication entitled "FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS" (Paringit, et. Al. 2017).

The implementing partner university for the Phil-LiDAR 1 Program is the Central Luzon State University (CLSU). CLSU 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 8 river basins in Central Luzon. The university is located in Muñoz City in the province of Nueva Ecija.

1.2 Overview of the Bucao River Basin

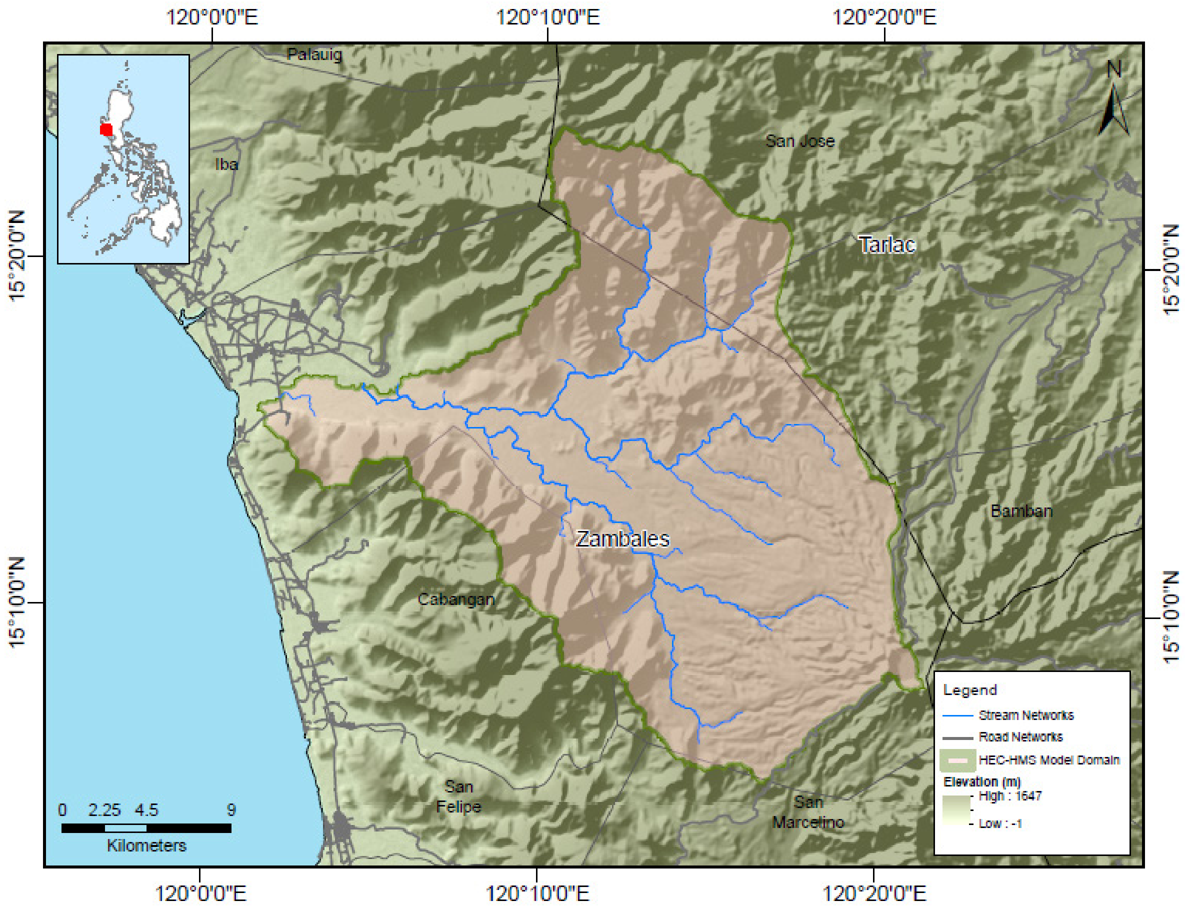

Figure 1. Map of the Bucao River in brown

Bucao River Basin covers the Municipality of Botolan, Zambales. The DENR River Basin Control Office (RBCO) identified it to be one of the 421 river basins in the Philippines, having a drainage area of 734 km^2 and an estimated 821 million cubic meter annual run-off. It is also one of the two (2) major river basins in Zambales.

Its main stem, Bucao River, passes along the Municipality of Botolan and serves as a natural boundary between barangays. It is part of the (8) river systems in Central Luzon Region under the PHIL-LiDAR 1 partner HEI, Central Luzon State University. There are about 5,990 people residing in the immediate vicinity of the river which is distributed among the five (5) barangays, namely: Bangan, Carael, Poonbato, Maguisguis, and Villar, all in the Municipality of Botolan (NSO, 2010). The riverbed is mostly sand and mudflow since it was among the affected areas by lahar when Mt. Pinatubo erupted in 1991. Due to typhoon Kiko (August 2009), heavy rains caused Bucao River to overflow which affected at least 10 barangays.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BUCAO 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 Bucao in Aurora and Quezon. These missions were planned for fourteen (14) lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system are found in Tables 1-4. Figure 2 shows the flight plans and base stations used for Bucao floodplain survey.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)cfv	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK BUC A	1200	30	50	200	30	130	5
BLK BUC B	1200	30	50	200	30	130	5
BLK BUC D	1200	30	50	200	30	130	5
BLK BAL A	1000	30	50	200	30	130	5
BLK BTN	1000	30	50	200	30	130	5
BLK BUC	1000/1600	30	50	200	30	130	5

Table 2. Flight planning parameters for Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK PAM S1	850/1000/1650	30	40	50/100/70	45/50	130	5
BLK PAM S3	850/1000/1650	30	40	100/70	50	130	5
BLK PAM S5	850	30	40	100	50	130	5
BLK PAM S8	1000	30	40	100	50	130	5
BLLK 15S	1000	30	40	100	50	130	5

Table 3. Flight planning parameters for Aquarius LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK NEJ V	600	30	36	50	50	130	5
BLK PAM V	600	30	36	50/36	50	130	5
BLK PAM S1	550	30	36	50	45	130	5

Table 4. Flight planning parameters for Leica LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 15A	1600	30	30	874	43	120	5

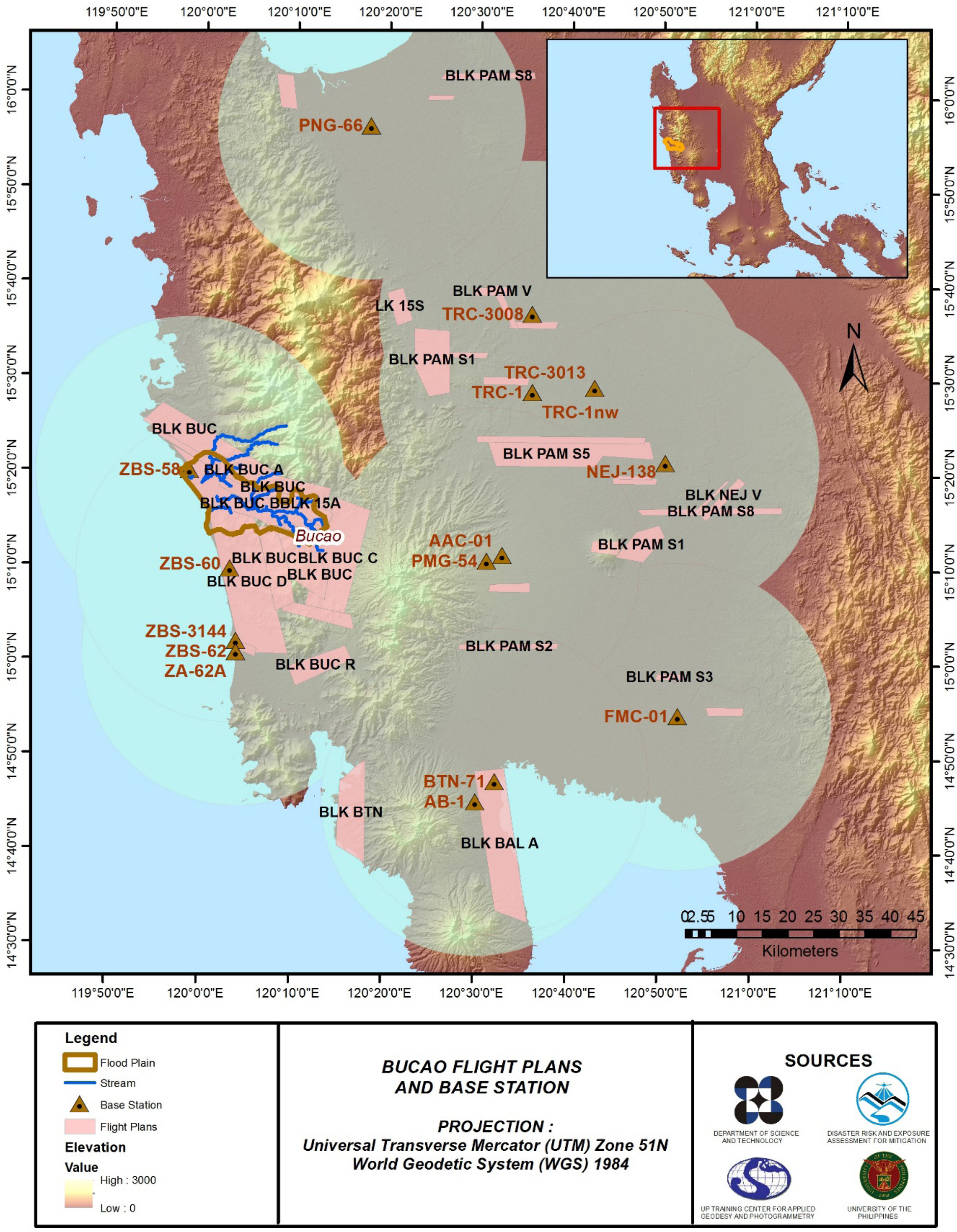

Figure 2. Flight plans and base stations used for Bucao floodplain survey

2.2 Ground Base Stations

The project team was able to recover seven (7) NAMRIA horizontal ground control points: TRC-01 which is of first (1st) order; BTN-71, NEJ-138, PNG-66, ZBS-58, ZBS-60 and ZBS-62) which are all of second order accuracy; and PMG-54 which is of third (3rd) order accuracy. The project team also established five (5) ground control points (AAC-01, AB-1, FMC-01, TRC-1nw and ZA-62A) and re-processed three (3) NAMRIA reference points (ZBS-3144, TRC-3013, and TRC-3008). The certification for the NAMRIA reference points and benchmark are found in Annex 2 while the baseline processing of the ground control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (December 27-January 5, 2013; May 16-24, 2014; December 5-6, 2014; January 20-28, 2015; and October 25-26, 2016; and July 29, 2016). Base stations were observed using dual frequency GPS receivers: TRIMBLE SPS852, TRIMBLE SPS882, TRIMBLE SPS985, TOPCON GR-5. Flight plans and location of base stations used during the aerial LiDAR Acquisition in Bucao floodplain are shown in Figure 2.

Figure 3 to Figure 6 show the recovered NAMRIA reference points within the area. In addition, Table 5 to Table 20 show the details about the following NAMRIA control stations and established points, while Table 21 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

(a)

(b)

Figure 3. GPS set-up over BTN-71 located in Brgy. Maria Fe, Orani, 30 meters southwest of the Day Care Center, 20 meters southeast of the basketball court and 15 meters of the chapel (a) and NAMRIA reference point BTN-71 (b) as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point BTN-71 used as base station for the LiDAR acquisition

Station Name	BTN-71	
Order of Accuracy	2^{nd}	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 47’ 30.18239” North 120° 32’ 9.95860” East 7.56300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	450060.675 meters 1635812.88 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 47’ 24.68277” North 120° 32’ 14.83855” East 49.42500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	234,782.54 meters 1,636,645.28 meters

Table 6. Details of the recovered NAMRIA horizontal control point NEJ-138 used as base station for the LiDAR acquisition.

Station Name	NEJ-138	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	15° 21' 17.34481" North
	Longitude	120° 50' 30.87881" East
	Ellipsoidal Height	18.43200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	483026.389 meters
	Northing	1698067.598 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	15° 21' 11.74037" North
	Longitude	120° 50' 35.70940" East
	Ellipsoidal Height	59.40200 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	268,325.74 meters
	Northing	1,698,622.77 meters

(a)

(b)

Figure 4. GPS set-up over PMG-54 located about 50 meters NE of Bldg. 2127 (Main Bldg.) of Clark Development Corp. and about 3 meters W of the Philippine flagpole (a) and NAMRIA reference point PMG-54 (b) as recovered by the field team

Table 7. Details of the recovered NAMRIA horizontal control point PMG-54 used as base station for the LiDAR acquisition.

Station Name	PMG-54	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 10’ 50.24016” North 120° 31’ 8.01131” East 213.00650 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	448156.978 meters 1678845.621 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 10’ 44.64998” North 120° 31’ 8.01131” East 253.69780 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	233,266.88 meters 1,679,714.68 meters

Table 8. Details of the recovered NAMRIA horizontal control point PNG-66 used as base station for the LiDAR acquisition.

Station Name	PNG-66	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 56’47.31803” North 120° 17’ 57.03550” East 10.57500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	424968.98 meters 1763650.683 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 56’ 41.53646” North 120° 18’ 1.81867” East 48.46800 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	210862.35 meters 1764780.62 meters

Table 9. Details of the recovered NAMRIA horizontal control point TRC-1 used as base station for the LiDAR acquisition.

Station Name	TRC-1	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 28’ 44.13765” North 120° 35’ 52.67202” East 46.89100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	456859.89 meters 1711833.357 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 28’ 38.48550” North 120° 35’ 57.49329” East 86.90220 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	242,278.30 meters 1,712, 636.20 meters

(a)

(b)

Figure 5. GPS set-up over ZBS-60 located inside the premises of San Antonio Barangay Hall in Cabangan, Zambales, six meters East of Barangay road and ten meters South of basketball court and Children’s Park (a) and NAMRIA reference point ZBS-60 (b) as recovered by the field team.

Table 10. Details of the recovered NAMRIA horizontal control point ZBS-60 used as base station for the LiDAR acquisition.

Station Name	ZBS-60	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	15° 09' 48.72475" North
	Longitude	120° 03' 4.60936" East
	Ellipsoidal Height	12.36500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	3998042.381 meters
	Northing	1677118.723 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	15° 09' 43.10078" North
	Longitude	120° 03' 9.45989" East
	Ellipsoidal Height	51.97200 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	183,107.00 meters
	Northing	1,678,445.32 meters

Table 11. Details of the recovered NAMRIA horizontal control point ZBS-58 used as base station for the LiDAR acquisition.

Station Name	ZBS-58	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	15° 20' 8.92898" North
	Longitude	119° 58' 34.69353" East
	Ellipsoidal Height	7.77100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	390073.626 meters
	Northing	1696218.486 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	15° 20' 3.25975" North
	Longitude	119° 58' 39.52976" East
	Ellipsoidal Height	46.69300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	819,598.83 meters
	Northing	1,697,561.97 meters

(a) (b)

Figure 6. GPS set-up over ZBS-62 located in the executive park of Barangay La Paz, San Narciso (a) and NAMRIA reference point ZBS-62 (b) as recovered by the field team.

Table 12. Details of the recovered NAMRIA horizontal control point ZBS-62 used as base station for the LiDAR acquisition.

Station Name	ZBS-62	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 0' 58.08330" North 120° 03' 50.43021" East 9.87700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	(b) 399340.98 meters 1660802.886 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 0' 52.49407" North 120° 03' 55.29320" East 49.94200 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	184,257.98 meters 1,662,105.93 meters

Table 13. Details of the established NAMRIA horizontal control point AAC-01 used as base station for the LiDAR acquisition.

Station Name	AAC-01	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 11' 27.81685" North 120° 32' 43.37833" East 154.260 meters

Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	2366272.483 meters 1680836.256 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 11' 22.22626" North 120° 32' 48.22418" East 194.988 meters

Table 14. Details of the established NAMRIA horizontal control point AB-1 used as base station for the LiDAR acquisition.

Station Name	AB-1	
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° 45' 14.54340" North 120° 30' 08.19305" East 108.361 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	231096.890 meters 1632616.365 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 45' 14.54340" North 120° 30' 08.19305" East 108.361 meters

Table 15. Details of the recovered NAMRIA horizontal control point TRC-1nw used as base station for the LiDAR acquisition

Station Name	TRC-1nw	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 28' 44.21062" North 120° 35' 52.67040" East 47.004 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 28' 28.55845" North 120° 35' 57.49166" East 87.016 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	242278.284 m 1712638.446 m

Table 16. Details of the recovered NAMRIA horizontal control point TRC-3008 used as base station for the LiDAR acquisition

Station Name	TRC-3008	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 37' 01.26741" North 120° 35' 46.76169" East 28.544 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 36' 55.58374" North 120° 35' 51.57129" East 68.142 m

Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	242274.052 m 1727923.206 m

Table 17. Details of the recovered NAMRIA horizontal control point TRC-3013 used as base station for the LiDAR acquisition

Station Name	TRC-3013	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 29’ 16.13287” North 120° 42’ 38.37631” East 23.362 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 29’ 10.48764” North 120° 42’ 43.19629” East 63.621 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	254385.958 m 1713487.619 m

Table 18. Details of the recovered NAMRIA horizontal control point FMC-01 used as base station for the LiDAR acquisition

Station Name	FMC-01	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 54’ 23.91904” North 120° 52’ 05.23142” East 23.646 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 54’ 29.41880” North 120° 52’ 05.23142” East 23.646 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	270660.1554 m 1649166.271 m

Table 19. Details of the established NAMRIA horizontal control point ZA-62A used as base station for the LiDAR acquisition.

Station Name	ZA-62A	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 00’ 57.82548” North 120° 03’ 50.43687” East 25.701 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	184258.065 meters 1662097.996 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 00’ 52.23627” North 120° 03’ 55.29987” East 50.155 meters

Table 20. Details of the established NAMRIA horizontal control point ZBS-3144 used as base station for the LiDAR acquisition.

Station Name	ZBS-3144	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	15° 10' 03.47052" North 120° 02' 45.42344" East 12.404 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	182639.933 meters 1678906.602 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15° 09' 57.84519" North 120° 02' 50.27364" East 51.986 meters

Date Surveyed	Flight Number	Mission Name	Ground Control Points
December 27, 2013	923P	1BUCD361A	ZBS-60 and ZBS-62
December 27, 2013	925P	1BUCB361B	BTN-71 and AB-1
December 28, 2013	927P	1BUCD362A	ZBS-60 and ZBS-3144
December 29, 2013	931P	1BUCDS363A	ZBS-60 and ZBS-62
January 3, 2014	941P	1BUCBS003B	ZBS-58, ZBS-60, ZBS-62, and ZA-62A
January 4, 2014	943P	1BUCAB004A	ZBS-60, ZBS-62 and ZA-62A
January 5, 2014	947P	1BUCACS005A	ZBS-60 and ZBS-62
May 16, 2014	7253GC	2PAMS1S3136A	PMG-54 and FMC-1
May 17, 2014	7255GC	2PAMS2137B	PMG-54 and ZBS-60
May 18, 2014	7256GC	2PAMS5138A	NEJ-138 and TRC-3013
May 23, 2014	7266GC	2BLK15S143A	PNG-66 and TRC-3008
May 24, 2014	7268GC	2PAMS8144A	PNG-66 and TRC-3008
December 5, 2014	2274A	3NEJV339A	PNG-66 and TRC-3008
December 6, 2014	2278A	3PAMV340A	AAC-01
January 20, 2015	2471P	1BUC020A	PMG-54
January 21, 2015	2473P	1BUC021A	PMG-54
January 23, 2015	2481P	1BTN023A	AAC-01
January 26, 2015	2493P	1BUC026A	PMG-54 and AAC-01
January 27, 2015	2497P	1BUC027A	AAC-01
January 28, 2015	2501P	1BUC028A	PMG-54
October 25, 2016	8411AC	3PAMS1088A	TRC-1 and TRC-1nw
October 26, 2016	8412AC	3PAMS1089A	TRC-1 and TRC-1nw
July 29, 2016	10214L	4BLK15A211A	ZBS-62 and ZBS-62A

Table 21. Ground control points used during LiDAR data acquisition

2.3 Flight Missions

Twenty three (23) missions were conducted to complete LiDAR data acquisition in Bucao Floodplain, for a total of eighty three hours and forty three minutes (83+43) of flying time for RP-C9022, RP-C9122, RP-C9322, and RP-C9522. All missions were acquired using Pegasus, Gemini, and Aquarius LiDAR systems. Table 22 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 23 presents the actual parameters used during the LiDAR data acquisition.

Table 22. Flight missions for LiDAR data acquisition in Bucao floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
December 27, 2013	923P	248.49	60.25	44.60	15.65	NA	3	17
December 27, 2013	925P	179.56	19.7	0	19.70	NA	1	59
December 28, 2013	927P	248.49	224.19	39.98	184.21	NA	4	35
December 29, 2013	931P	248.49	247.59	88.52	159.07	NA	4	47
January 3, 2014	941P	148.74	111.58	88.10	23.48	NA	3	35
January 4, 2014	943P	368.33	260.67	116.28	144.39	NA	4	41
January 5, 2014	947P	390.79	151.29	1.54	149.75	NA	4	11
May 16, 2014	7253GC	178.68	97.09	0	97.09	NA	4	7
May 17, 2014	7255GC	254.97	47.83	0	47.83	NA	2	17
May 18, 2014	7256GC	186.58	166.11	0	166.11	NA	3	53
May 23, 2014	7266GC	78.47	105.72	0	105.72	NA	3	47
May 24, 2014	7268GC	78.55	148.32	0	148.32	NA	3	46
December 5, 2014	2274A	157.61	27.07	0	27.07	NA	2	53
December 6, 2014	2278A	49.02	60.4	0	60.40	NA	3	53
January 20, 2015	2471P	111.26	111.96	79.13	32.83	435	3	6
January 21, 2015	2473P	108.77	127.5	51.73	75.77	419	4	5

January 23, 2015	2481P	133.76	164.91	0.81	164.10	NA	4	23
January 26, 2015	2493P	87.98	92.07	12.14	79.93	443	3	17
January 27, 2015	2497P	105.30	68.59	8.66	59.93	345	3	11
January 28, 2015	2501P	95.54	109.79	9.94	99.85	326	3	29
October 25, 2016	8411AC	74.32	35.08	0	35.08	NA	2	59
October 26, 2016	8412AC	74.32	61.34	0	61.34	NA	3	53
July 29, 2016	10214L	29.53	34.19	7.82	26.37	183	3	39
TOTAL		3637.55	2533.24	549.25	1983.99	2151	83	43

Table 23. 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)
923P	1200	30	50	150	30	130	5
925P	1000	30	50	200	30	130	5
927P	1200	30	50	200	30	130	5
931P	1200	30	50	200	30	130	5
941P	1200	30	50	200	30	130	5
943P	1200	30	50	200	30	130	5
947P	1200	30	50	200	30	130	5
7253GC	850	30	40	100	50	130	5
	1000	30	40	100	50	130	5
	1650	30	40	70	50	130	5
7255GC	850	30	40	100	50	130	5
7256GC	945	30	40	100	50	130	5
7266GC	1000	30	40	100	50	130	5
7268GC	1070	40	40	100	50	130	5
2274A	670	30	36	50	50	130	5
2278A	670	30	30	36	50	130	5
2471P	1000	30	50	200	30	130	5
2473P	1000	30	50	200	30	130	5
2481P	1000	30	50	200	30	130	5
2493P	1000	30	50	200	30	130	5
2497P	1600	30	50	200	30	130	5
2501P	1000	30	50	200	30	130	5
8411AC	550	30	36	50	45	130	5
8412AC	550	30	36	50	45	130	5
10214L	1600	30	30	874	43	120	5

2.4 Survey Coverage

Bucao floodplain is located in the province of Zambales. Majority of the floodplain is situated in the municipalities of Botolan and Iba in Zambales. Municipalities of Cabangan and Botolan are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 24. The actual coverage of the LiDAR acquisition for Bucao floodplain is presented in Figure 7.

Table 24. List of municipalities and cities surveyed during Bucao floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Bataan	Morong	240.57	70.04	29.11%
	Orani	53.25	8.33	15.64%
	Orion	59.77	1.32	2.21%
Bulacan	Bustos	43.15	12.31	28.53%
	Angat	53.62	3.32	6.19%
Nueva Ecija	San Antonio	169.06	64.81	38.34%
	Cabiao	110.18	30.54	27.72%
	Gapan City	163.45	45.28	27.70%
	San Isidro	44.49	11.44	25.71%
	San Leonardo	51.79	2.79	5.39%
	Jaen	93.66	2.60	2.78%
Pampanga	Arayat	153.46	34.62	22.56%
	Santa Rita	28.49	5.15	18.08%
	San Simon	50.46	8.02	15.89%
	Magalang	99.89	10.32	10.33%
	Porac	238.99	24.58	10.28%
	Angeles City	64.60	6.29	9.74%
	Bacolor	82.99	5.83	7.02%
	Apalit	63.38	2.62	4.13%
	Floridablanca	176.48	6.10	3.46%
Pangasinan	Labrador	92.63	29.74	32.11%
	Mapandan	21.35	6.26	29.32%
	Laoac	40.70	7.50	18.43%
	Santa Barbara	64.71	9.10	14.06%
	Manaoag	42.42	4.54	10.70%
	Binalonan	78.54	6.18	7.87%
	Mangaldan	43.42	2.50	5.76%
	Lingayen	68.74	1.69	2.46%
	Asingan	65.93	1.22	1.85%
	Bugallon	158.15	2.41	1.52%

Tarlac	Santa Ignacia	145.32	53.43	36.77%
	Concepcion	234.56	72.97	31.11%
	Paniqui	108.69	18.94	17.43%
	Gerona	128.21	19.03	14.84%
	Mayantoc	244.09	35.17	14.41%
	Capas	467.83	67.26	14.38%
	La Paz	122.26	15.60	12.76%
	Pura	28.52	2.59	9.08%
	Camiling	130.78	10.53	8.05%
	San Jose	626.98	40.80	6.51%
	San Clemente	69.75	4.29	6.15%
	Tarlac City	241.67	13.89	5.75%
	Victoria	107.37	3.18	2.96%
Zambales	Cabangan	231.28	200.83	86.83%
	San Felipe	96.23	77.81	80.86%
	Botolan	649.68	452.42	69.64%
	San Narciso	83.24	53.53	64.31%
	Iba	219.08	94.52	43.14%
	San Marcelino	337.57	85.65	25.37%
	Palauig	242.92	51.05	21.02%
	Olongapo City	178.25	11.18	6.27%
TOTAL		7412.60	1812.12	24.45%

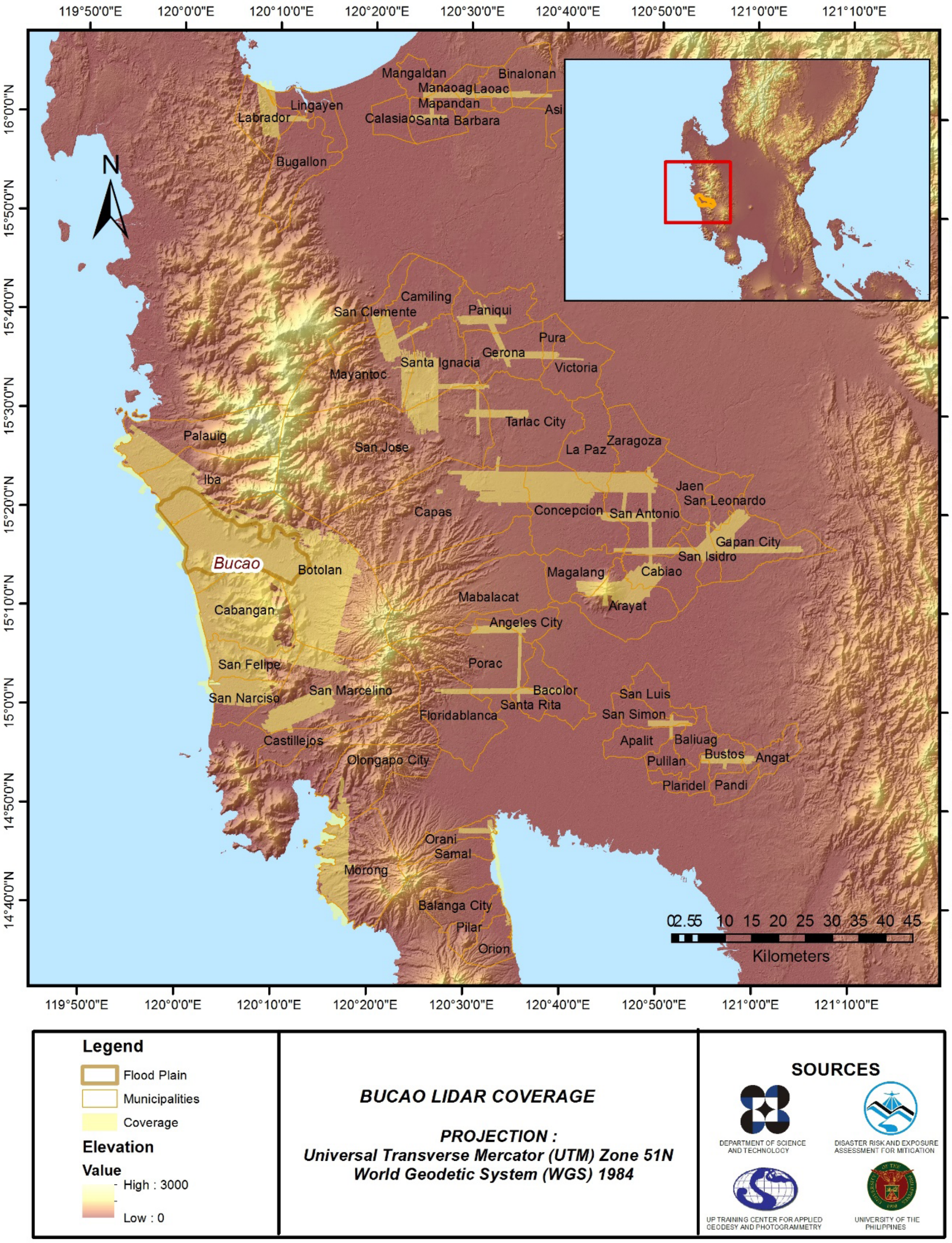

Figure 7. Actual LiDAR survey coverage for Bucao floodplain

CHAPTER 3: LIDAR DATA PROCESSING FOR BUCAO FLOODPLAIN

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

3.1 LiDAR Data Processing for Bucao Floodplain

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

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

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

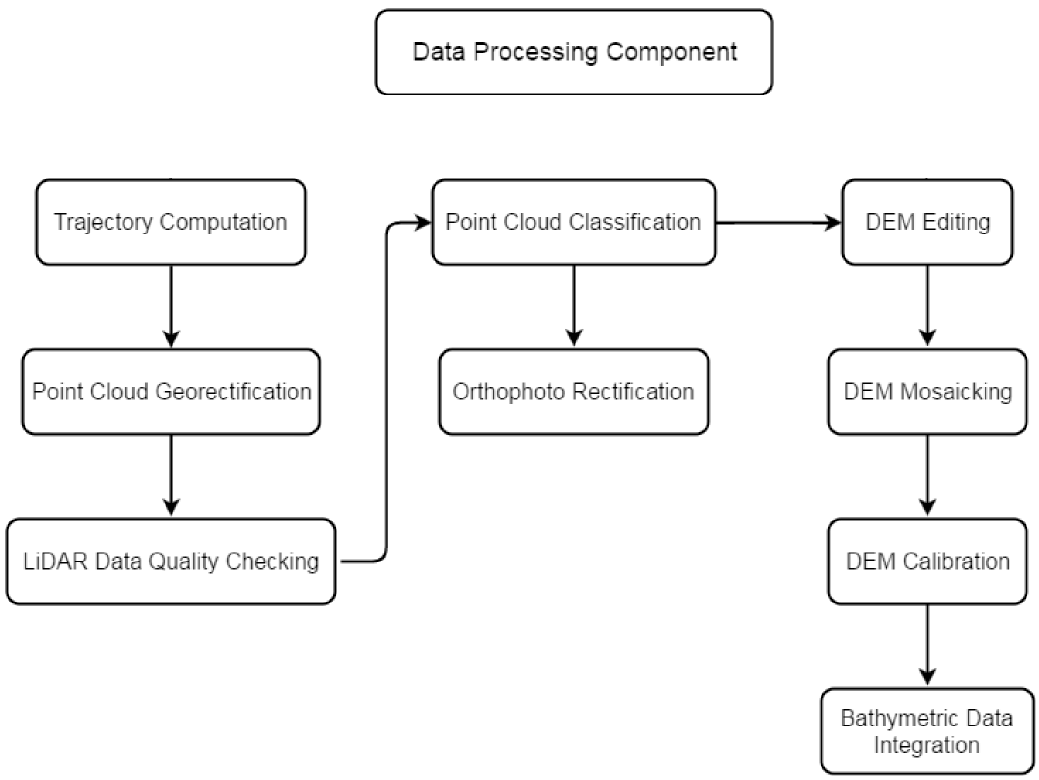

Figure 8. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Bucao floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the first survey conducted on May 2014 in Pampanga used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini-Compact Airborne Spectrographic Imager (CASI) system, Aquarius-CASI and Gemini-CASI systems on the second survey on December 2014 in Clark, Pegasus system on the third survey on January 2015 in Cark, Aquarius-CASI system on the fourth survey on March and April 2016 in Clark and Leica system on the fifth survey on July 2016 in Umiray. The Data Acquisition Component (DAC) transferred a total of 243.21 Gigabytes of Range data, 3.96 Gigabytes of POS data, 578.91 Megabytesof GPS base station data, and 176.20 Gigabytes of raw image data to the data server on May 26, 2014 for the first survey up to August 9, 2016 for the last set of data acquisition. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Bucao was fully transferred on August 9, 2016, as indicated on the Data Transfer Sheets for Bucao floodplain.

3.3 Trajectory Computation

The *Smoothed Performance Metrics* of the computed trajectory for flight 939P, one of the Bucao 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 onJanuary 3, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

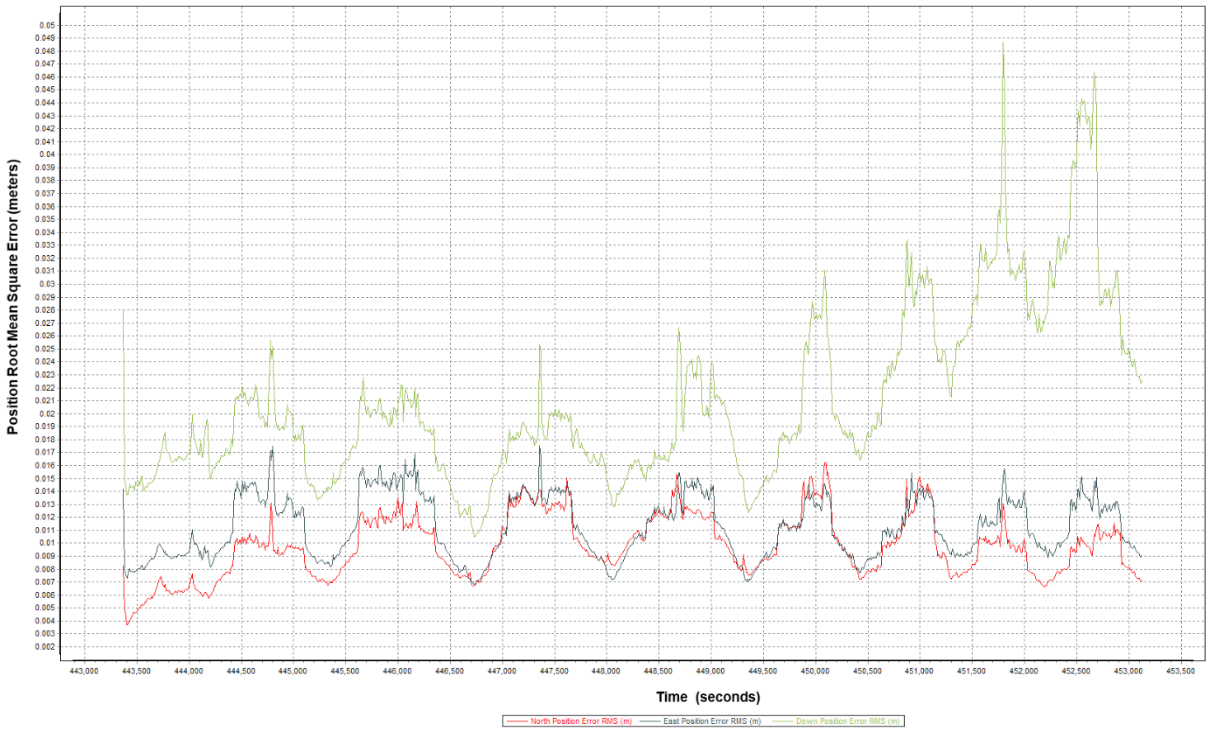

Figure 9. Smoothed Performance Metrics of a Bucao Flight 939P

The time of flight was from 443400 seconds to 453100 seconds, which corresponds to morning of January 3, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9shows that the North position RMSE peaks at 1.60 centimeters, the East position RMSE peaks at 1. 80 centimeters, and the Down position RMSE peaks at 4.90 centimeters, which are within the prescribed accuracies described in the methodology.

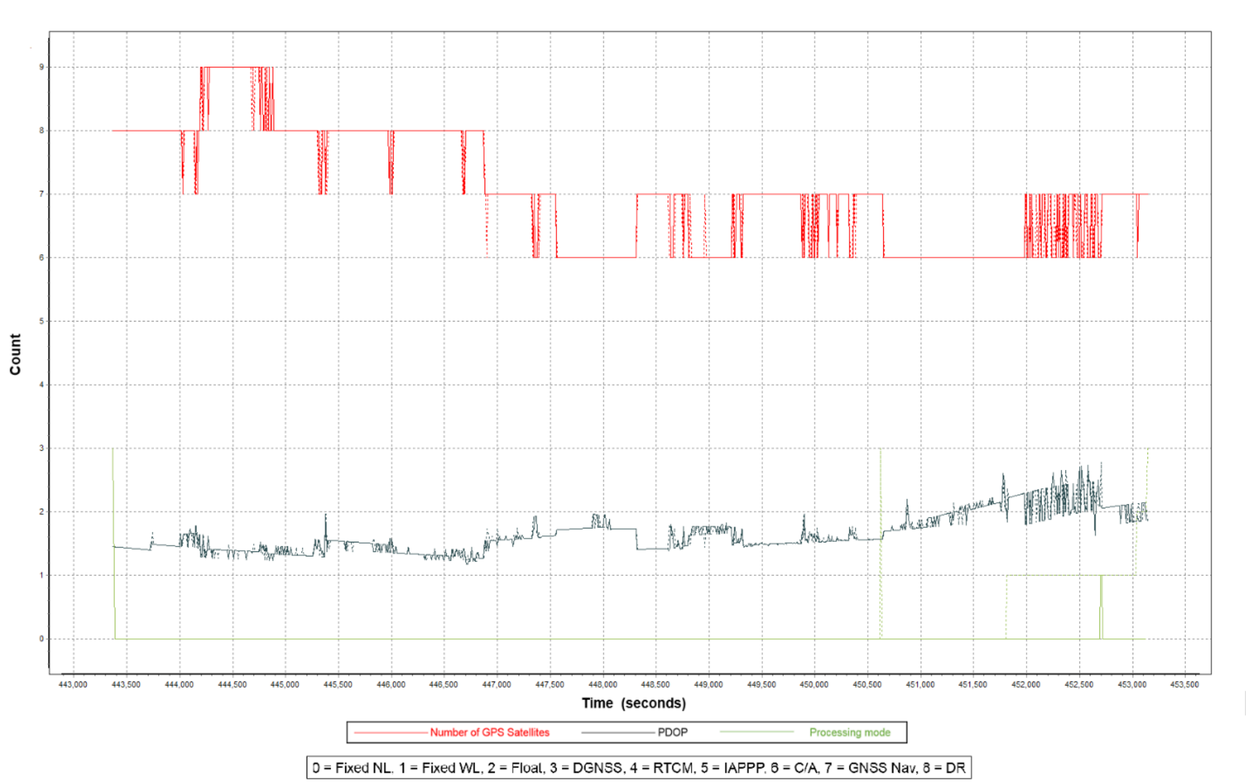

Figure 10. Solution Status Parameters of Bucao Flight 939P.

The S*olution Status* parameters of flight 939P, one of the Bucaoflights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Most of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Bucao flights is shown in Figure 11.

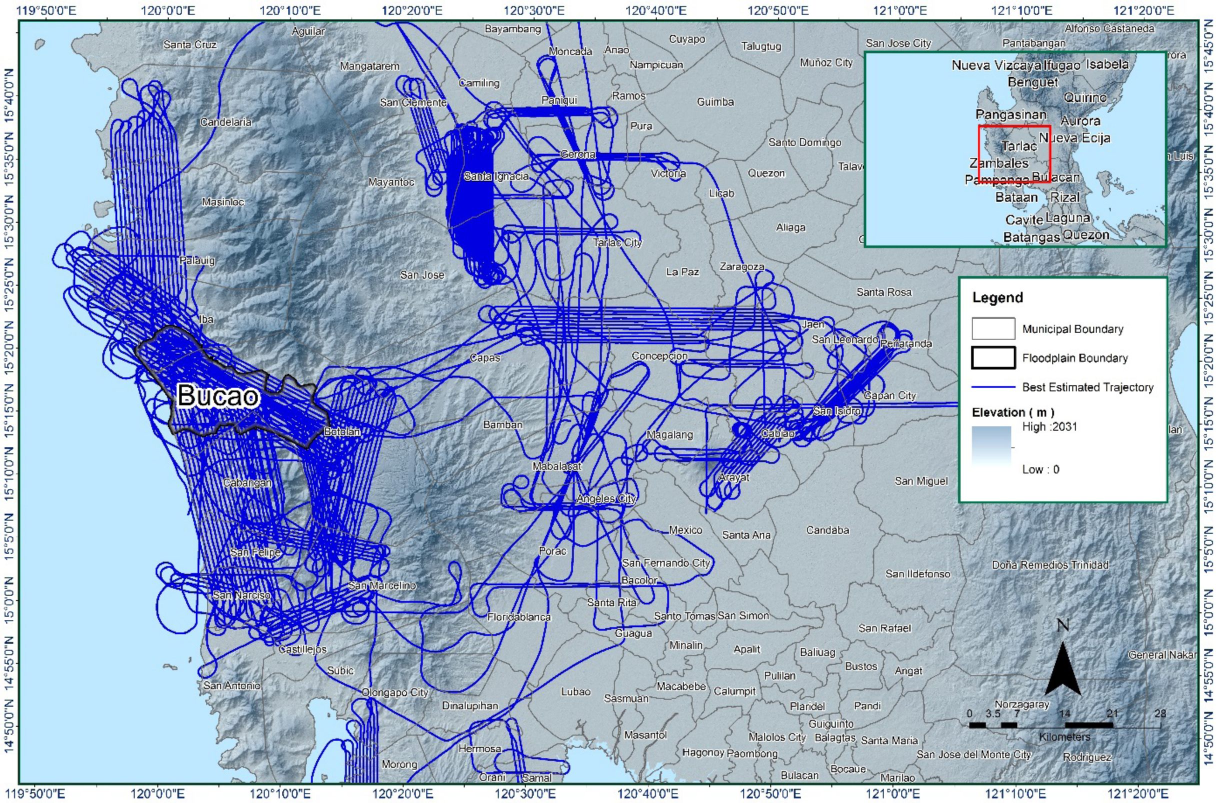

Figure 11. The best estimated trajectory of the LiDAR missions conducted over the Bucao floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 268 flight lines, with each flight line containing one channel, since Gemini-CASI, Aquarius-CASI, and Aquarius systems contain one channel only and two channels for Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Bucao floodplain are given in Table 25.

Table 25. Self-Calibration Results values for Bucao flights

Parameter	Absolute Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000429
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000438
GPS Position Z-correction stdev	(<0.01meters)	0.0058

The optimum accuracy values for all Bucao flights were calculated based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for individual blocks are presented in the Mission Summary Reports (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.

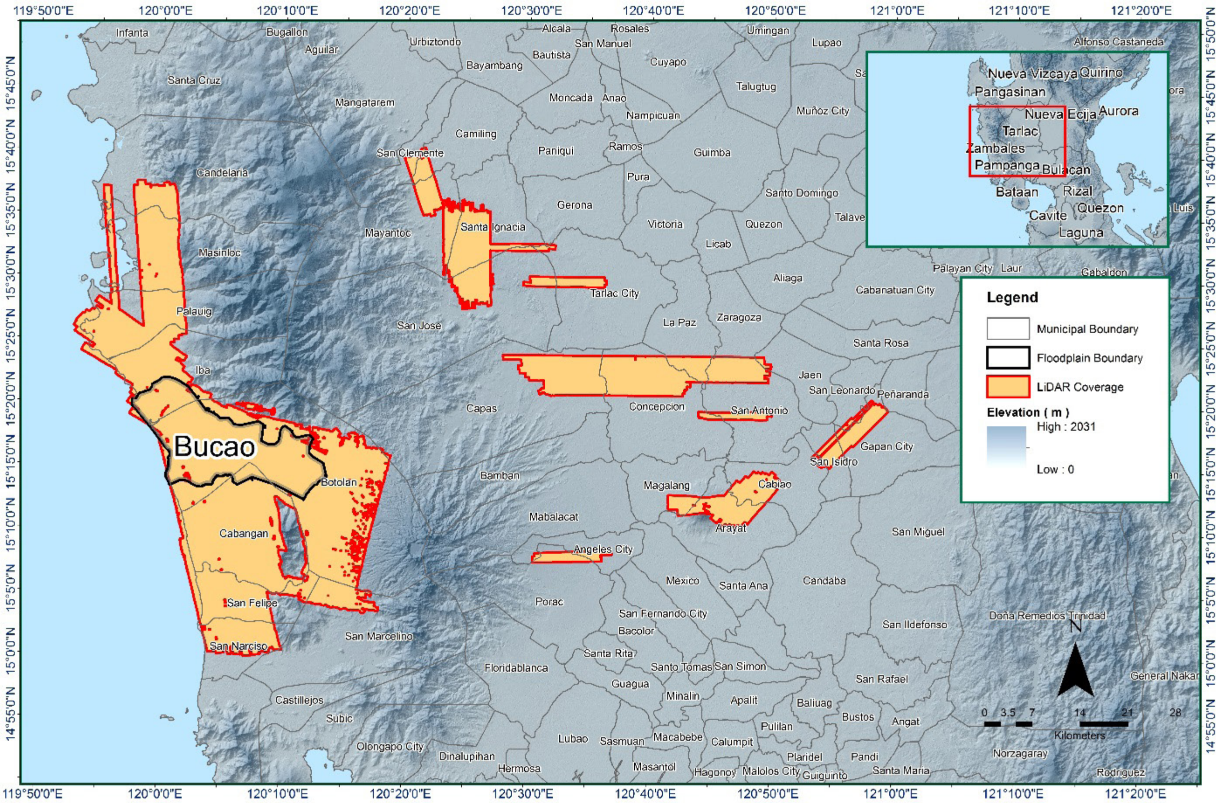

Figure 12. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Bucao Floodplain.

The total area covered by the Bucao missions is 1763.39 sq.km that is comprised of twenty-two (22) flight acquisitions grouped and merged into nineteen (19) blocks as shown in Table 26.

Table 26. List of LiDAR blocks for Bucao floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Bataan_Plg_BlkA	939P 947P	165.47
Bataan_Buc_BlkBs	941P	100.53
Bataan_Buc_BlkABC	943P	60.06
Bataan_Buc_BlkAsB	943P	136.43
Bataan_Buc_BlkD	927P 931P 923P	382.91
Bataan_Reflights_Buc_BlkABC_additional	2481P	61.71
Bataan_Reflights_Buc_BlkBs_additional	2493P 2497P	135.58
Bataan_Reflights_BlkAsB_additional	2471P 2473P	137.55
Bataan_Reflights_Plg_BlkA_additional	2501P	109.42
Zambales_Blk15D	10214L	33.60
Clark_reflights_Pam3D_additional1	2274A	9.77
Clark_reflights_Pam3D_additional2	2278A	2.31
Pam_Nej_Reflights_Blk10G	8411AC 8412AC	91.69
Pam_Agno_Blk7A_reflight	7255GC	15.47
Pam_Agno_Blk10J_reflight	7266G	28.76
Pam_Agno_Blk10G_reflight	7266G	28.92
Pam_Agno_Blk10E_reflight	7268GC	45.76
Pam_Agno_Blk10D_reflight	7256GC	152.94
Pam_Agno_Blk3A_reflight	7253GC	64.51
	TOTAL	**1763.39 sq.km**

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

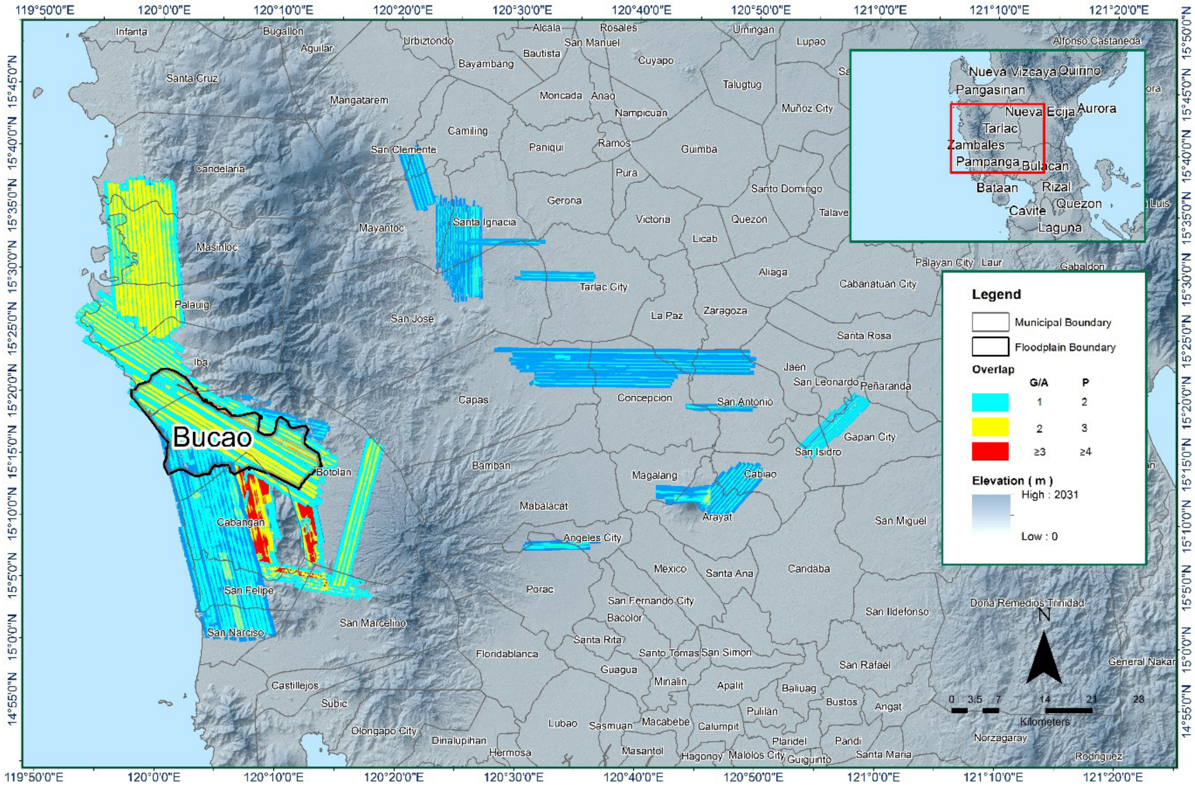

Figure 13. Image of data overlap for Bucao floodplain

The overlap statistics per block for the Bucao floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 17.24% and 70.03% 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 Bucao floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.825 points per square meter.

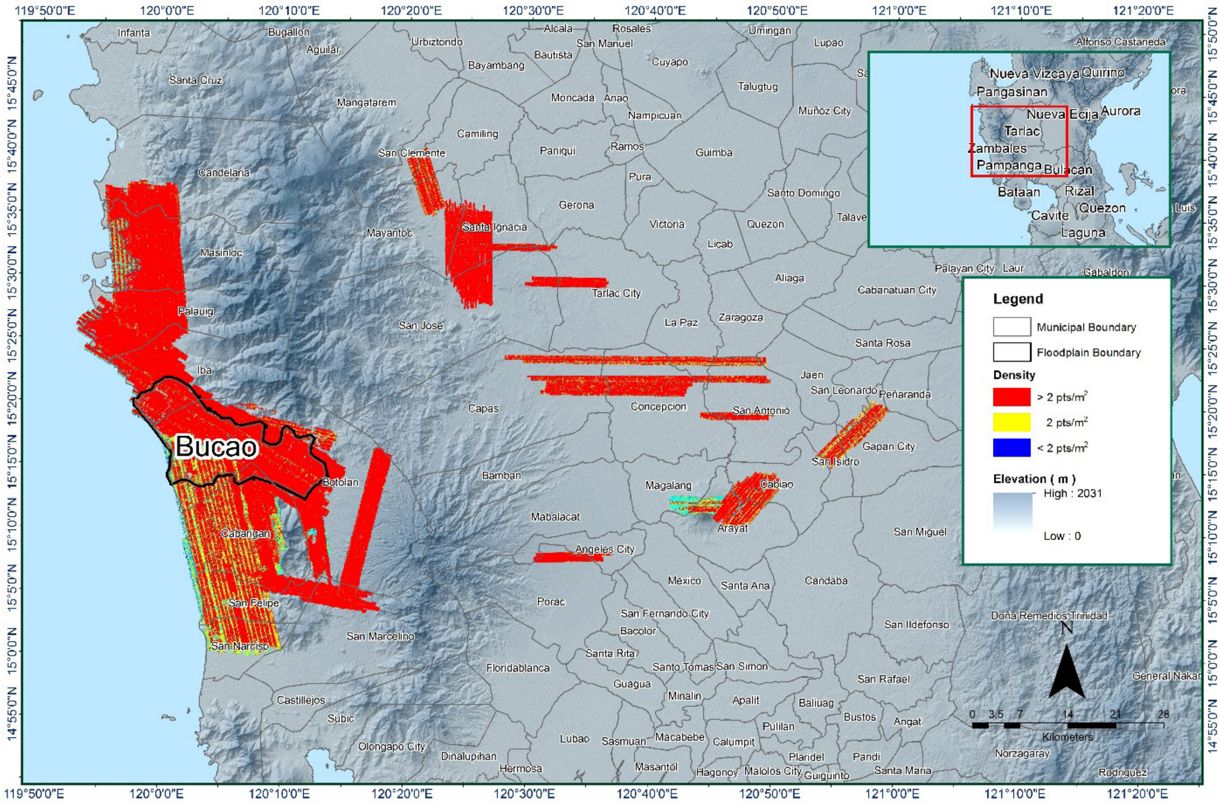

Figure 14. Pulse density map of merged LiDAR data for Bucao floodplain

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.

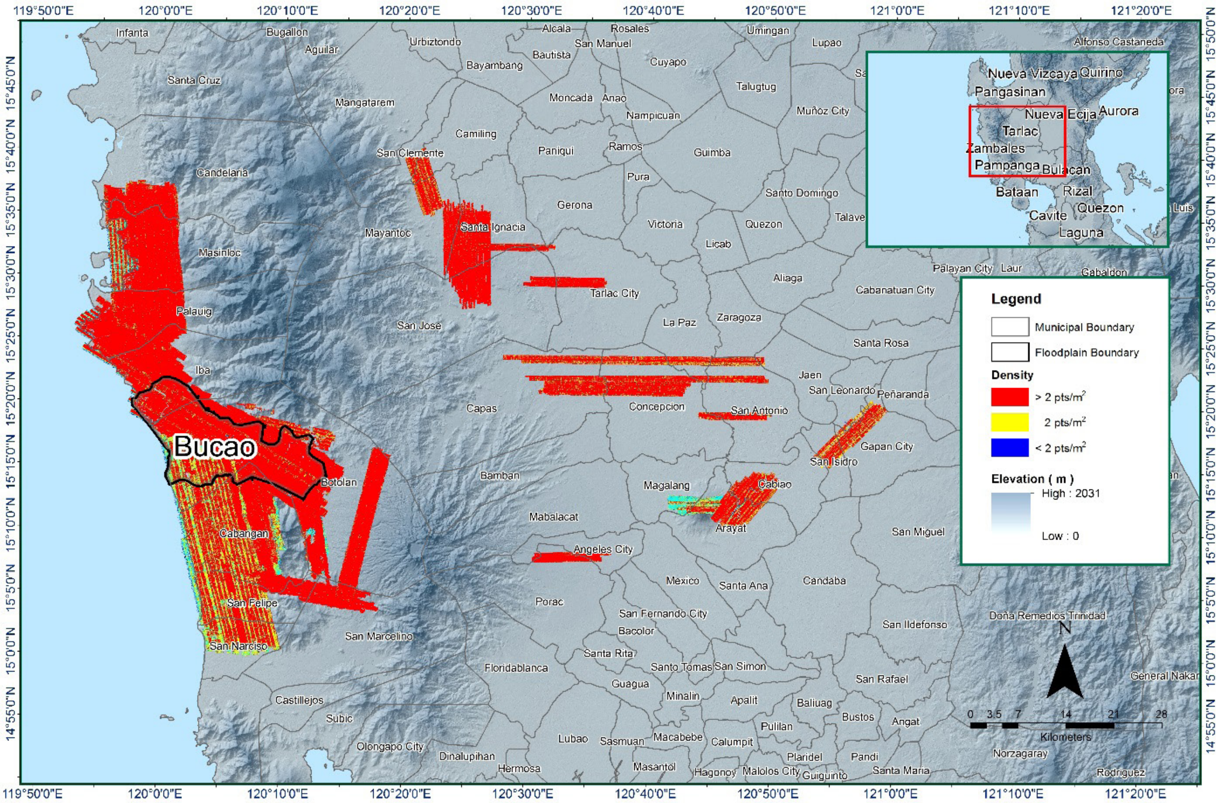

Figure 15. Elevation difference map between flight lines for Bucao floodplain

A screen capture of the processed LAS data from a Bucao flight 939P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

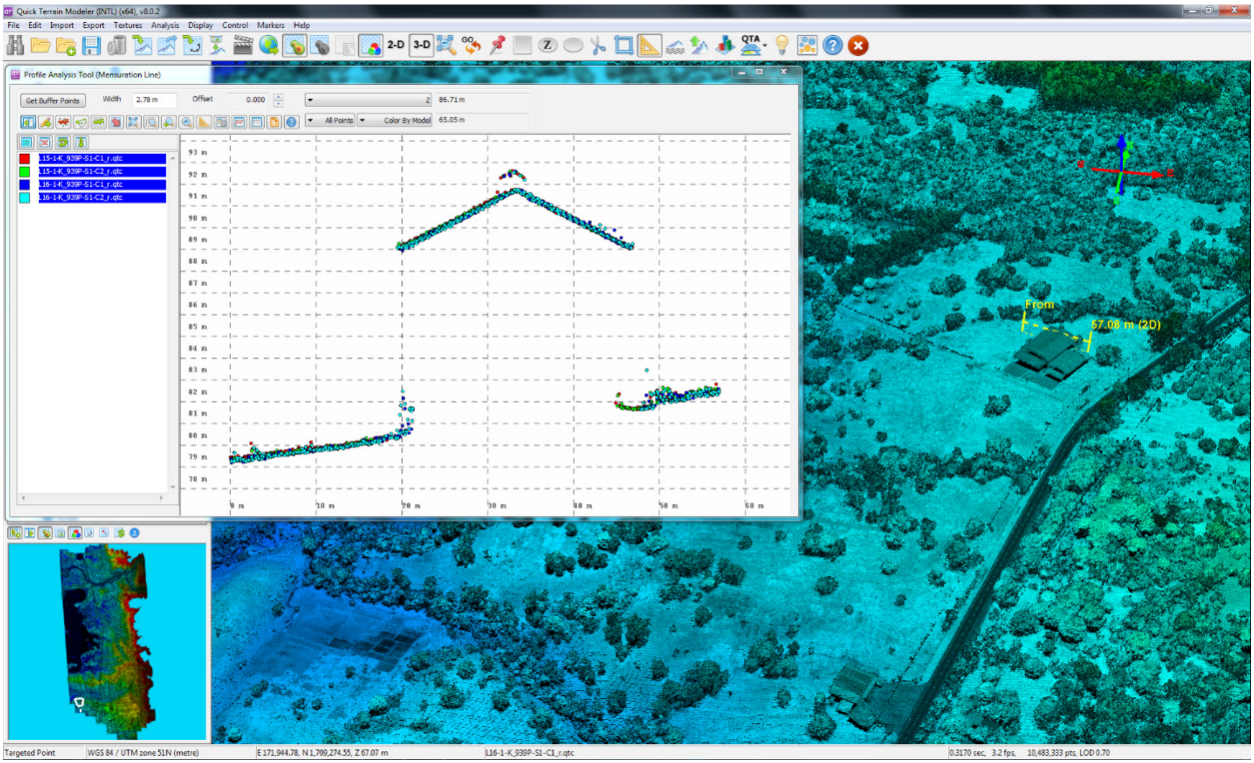

Figure 16. Quality checking for a Bucao flight 939P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 27. Bucao classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	1,295,297,741
Low Vegetation	1,144,987,640
Medium Vegetation	1,620,678,684
High Vegetation	1,326,218,831
Building	53,967,068

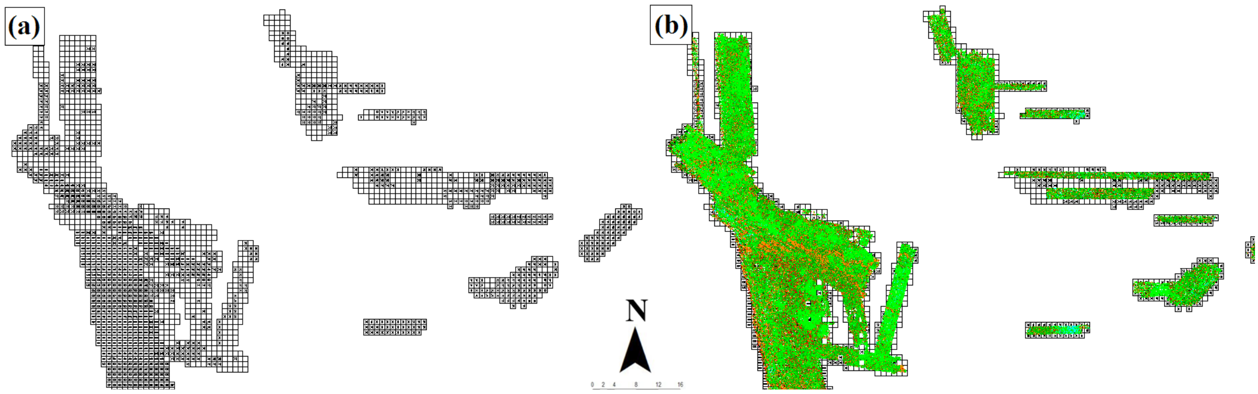

Figure 17. Tiles for Bucao floodplain (a) and classification results (b) in TerraScan

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.

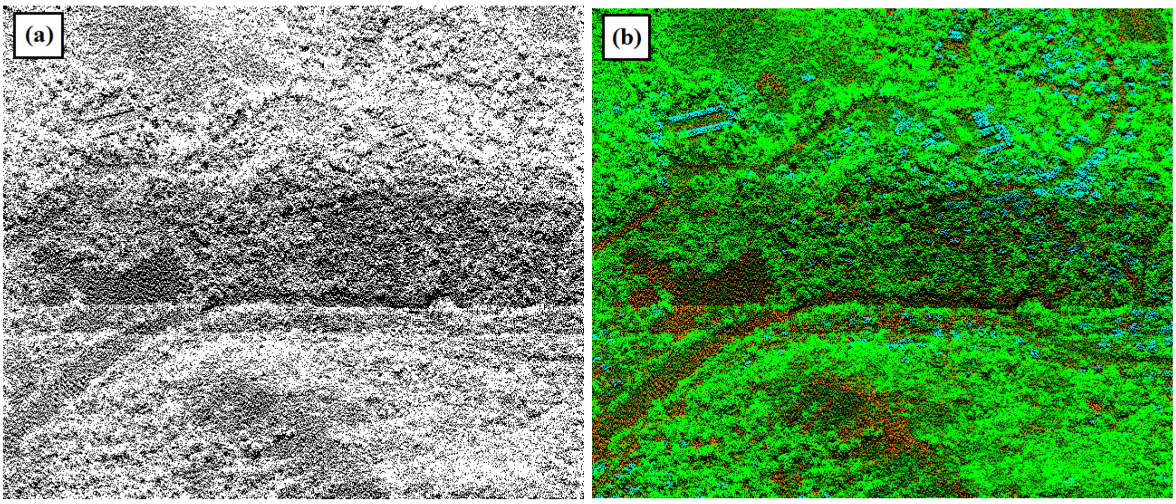

Figure 18. Point cloud before (a) and after (b) classification

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.

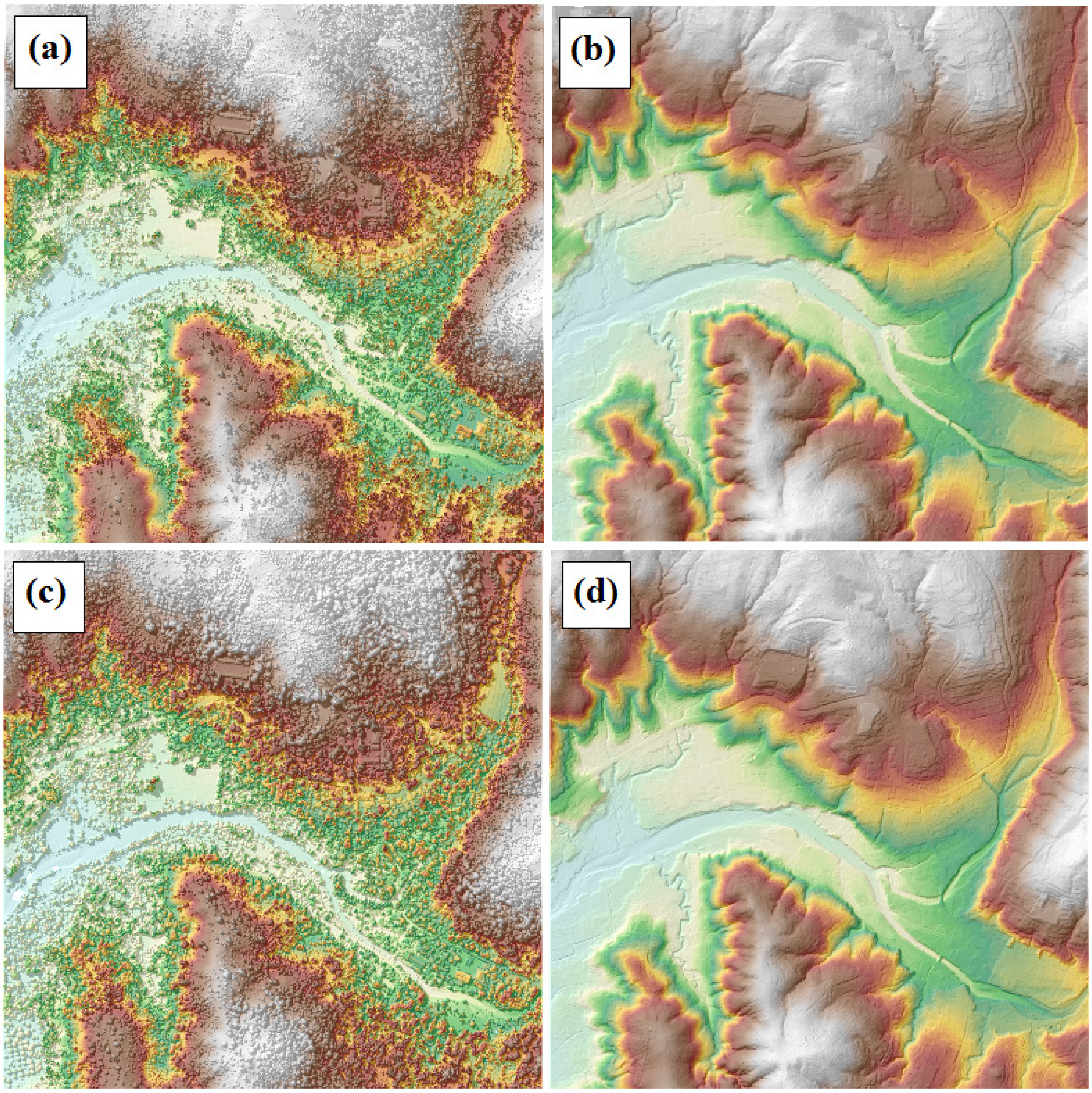

Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Bucao floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 573 1km by 1km tiles area covered by Bucao 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 Bucao floodplain survey attained a total of 401.43 km^2 in orthophotogaph coverage, comprised of 1,802 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

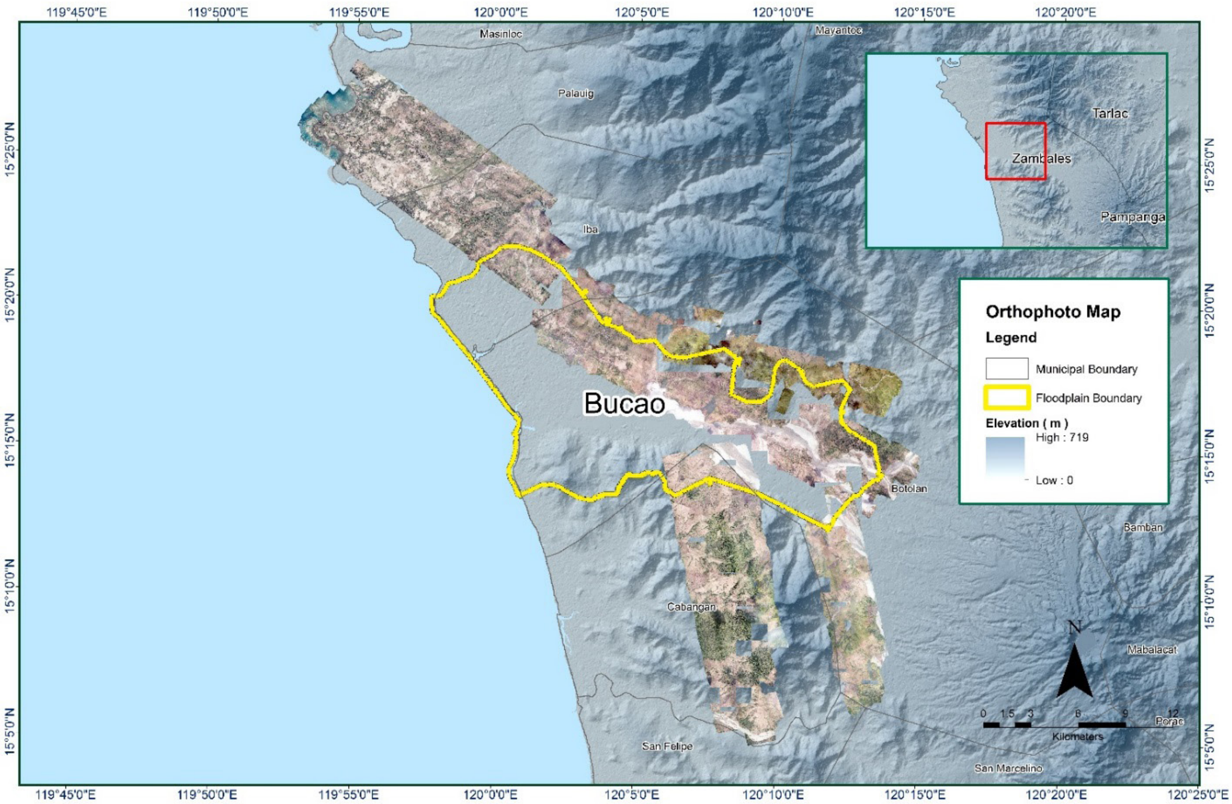

Figure 20. Bucao floodplain with available orthophotographs

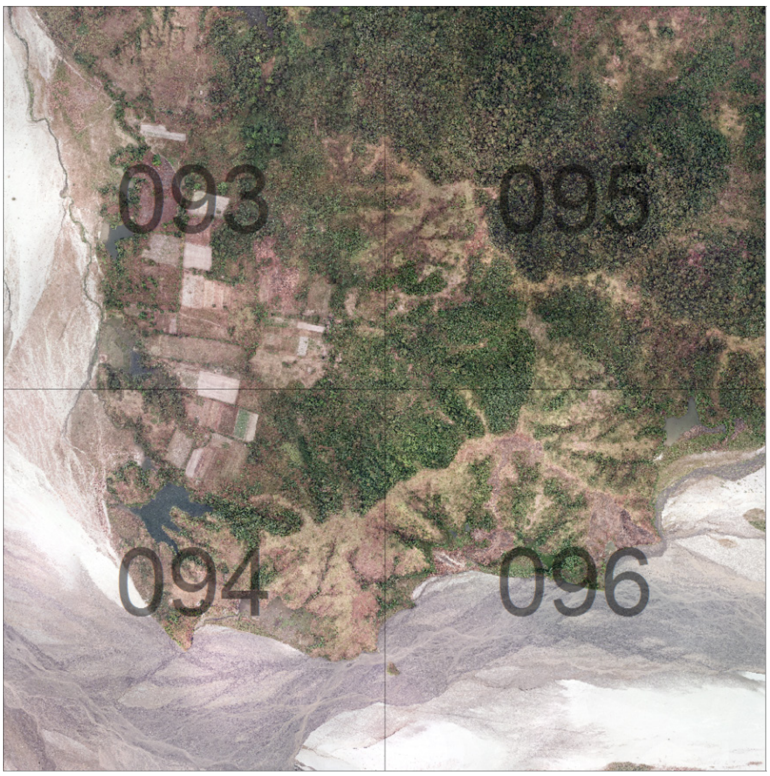

Figure 21. Sample orthophotograph tiles for Bucao floodplain

3.8 DEM Editing and Hydro-Correction

Nineteen (19) mission blocks were processed for Bucao flood plain. These blocks are composed of Bataan, Bataan Reflights, Zambales, Clark Reflights, Pam_Nej Reflights, Pam_Agno Reflights blocks with a total area of 1763.39 square kilometers. Table 28 shows the name and corresponding area of each block in square kilometers.

Table 28. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq. km)
Bataan_Plg_BlkA	165.47
Bataan_Buc_BlkBs	100.53
Bataan_Buc_BlkABC	60.06
Bataan_Buc_BlkAsB	136.43
Bataan_Buc_BlkD	382.91
Bataan_Reflights_Buc_BlkABC_additional	61.71
Bataan_Reflights_Buc_BlkBs_additional	135.58
Bataan_Reflights_Buc_BlkAsB_additional	137.55
Bataan_Reflights_Plg_BlkA_additional	109.42
Zambales_Blk15D	33.60
Clark_reflights_Pam3D_additional1	9.77
Clark_reflights_Pam3D_additional2	2.31
Pam_Nej_Reflights_Blk10G	91.69
Pam_Agno_Blk7A_reflight	15.47
Pam_Agno_Blk10J_reflight	28.76
Pam_Agno_Blk10G_reflight	28.92
Pam_Agno_Blk10E_reflight	45.76
Pam_Agno_Blk10D_reflight	152.94
Pam_Agno_Blk3A_reflight	64.51
TOTAL	**1763.39 sq.km**

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

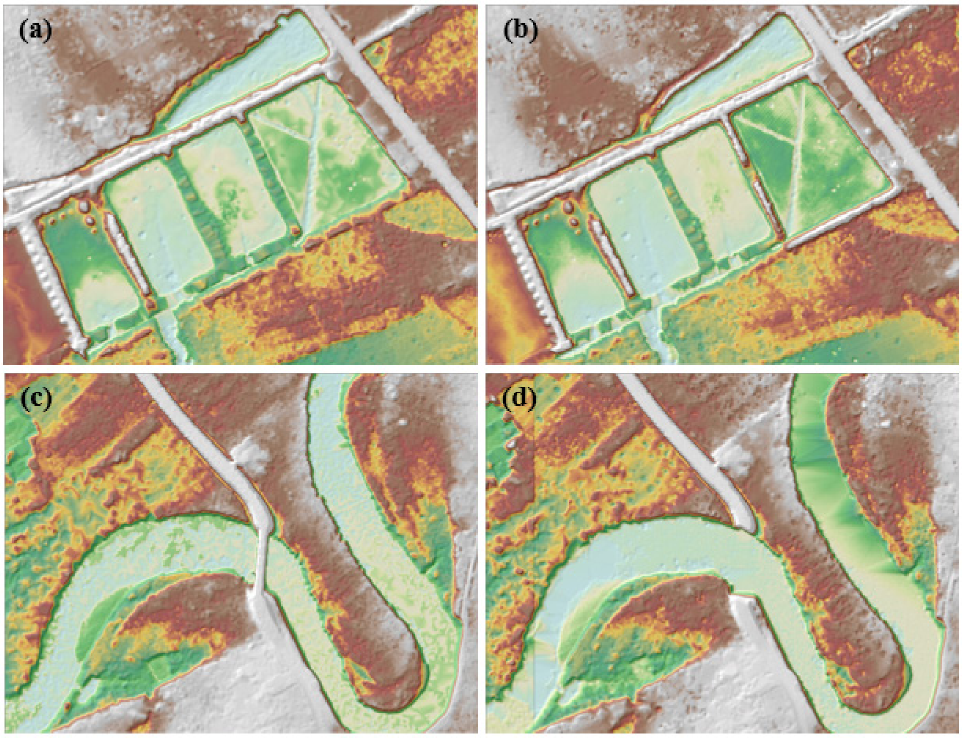

Figure 22. Portions in the DTM of Bucao floodplain – a paddy field before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

The mosaicking of blocks for Bucao, Sto Tomas, Morong and Balanga were done simultaneously because the validation survey datasets used for the said floodplains are connected. Balanga_BlkA was used as the reference block at the start of mosaicking, as one of the first blocks to be first edited. Table 29 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Bucao floodplain is shown in Figure 23. It can be seen that the entire Bucao floodplain is 99.36% covered by LiDAR data.

Table 29. Shift Values of each LiDAR Block of Bucao floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Pam_Agno_Blk10J_reflight	-0.90	-0.20	-1.59
Pam_Agno_Blk10G_reflight	N/A		
Pam_Agno_Blk10E_reflight	N/A		
Pam_Agno_Blk10D_reflight	-5.19	0.00	-0.02
Bataan_Buc_BlkAsB (lower)	-3.11	1.99	0.00
Bataan_Buc_BlkAsB (upper)	0.86	-0.90	0.20
Bataan_Reflights_Buc_BlkAsB_additional	-1.65	-7.9	-0.93
Bataan_Buc_BlkABC	0.33	0.66	-0.40
Bataan_Reflights_Buc_BlkABC_additional	-1.36	0.91	0.40
Bataan_Buc_BlkBs	0.00	0.00	0.20
Bataan_Reflights_Buc_BlkBs_additional	0.00	0.00	-0.85
Bataan_Buc_BlkD	-0.93	1.14	0.10
Clark_reflights_Pam3D_additional1	-5.63	-459.98	-3.3
Clark_reflights_ Pam3D _additional2	-7.12	-1.03	-3.20
Bataan_Plg_BlkA	0.81	-1.42	-0.40
Bataan_Plg_BlkA_additional	0.79	-1.46	-0.40
Pam_Agno_Blk3A_reflight	-12.5	-8.5	-0.84
Pam_Agno_Blk7A_reflight	-12.5	-9.25	-0.89
Pam_NEJ_reflights_10G	-0.55	0.00	0.21
Zambales_Blk15D	0.00	0.00	0.00

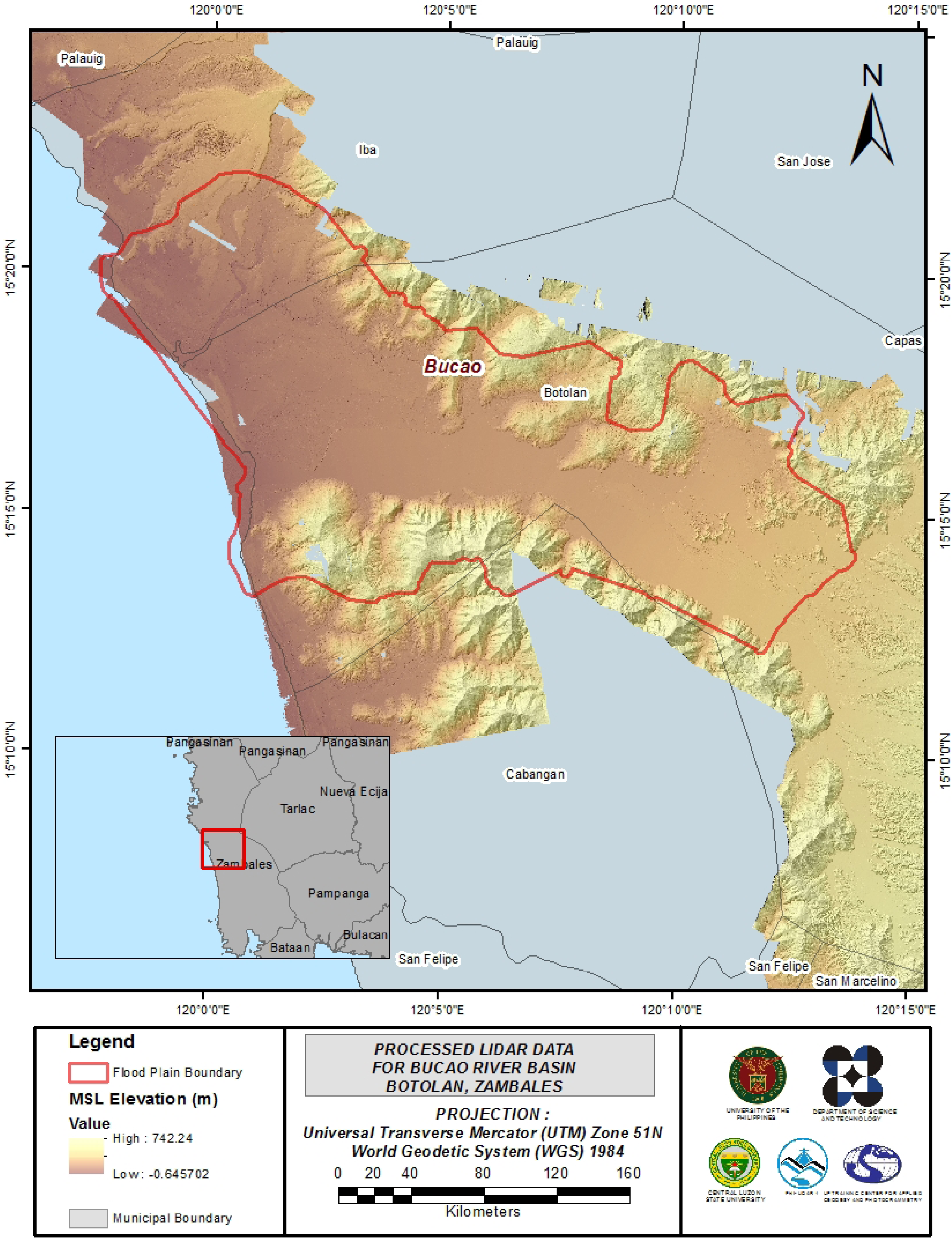

Figure 23. Map of Processed LiDAR Data for Bucao Flood Plain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Bucao to collect points with which the LiDAR dataset is validated is shown in Figure 24, with the validation survey points highlighted in green. Bucao LiDAR data was calibrated using the validation survey points provided for BataanZambales area to be consistent with the other floodplains covered by the mosaicked blocks. A total of 30,472 survey points were gathered within BataanZambales wherein the Bucao floodplain is located. Random selection of 80% of the survey points, resulting to 24,377 points, were used for calibration.

A good correlation between the uncalibrated BataanZambales LiDAR DTM and 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 points is 4.15 meters with a standard deviation of 0.15 meters. Calibration of Bucao LiDAR data was done by subtracting the height difference value, 4.15 meters, to BataanZambales mosaicked LiDAR data. Table 30 shows the statistical values of the compared elevation values between BataanZambales LiDAR data and calibration data.

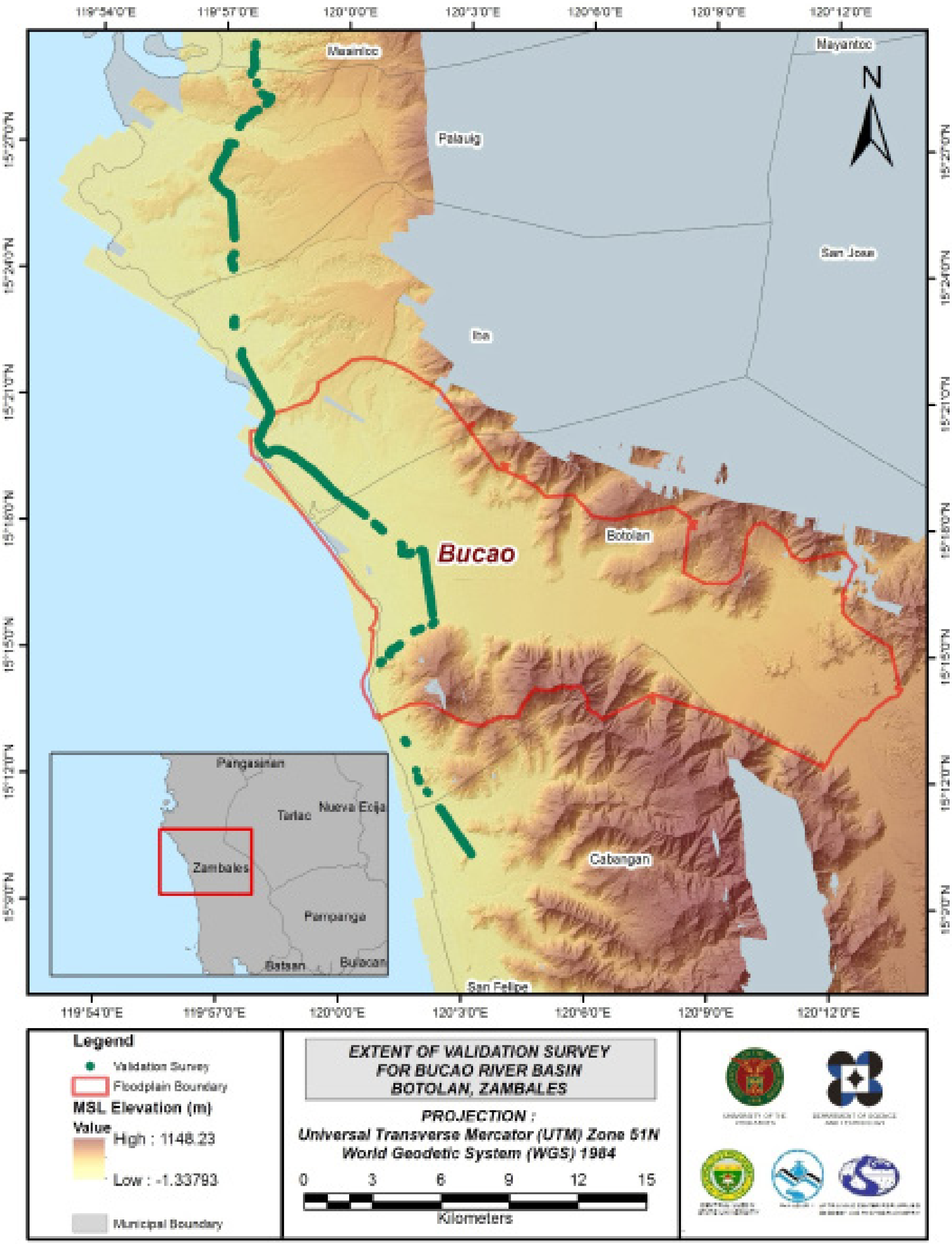

Figure 24. Map of Bucao Flood Plain with validation survey points in green

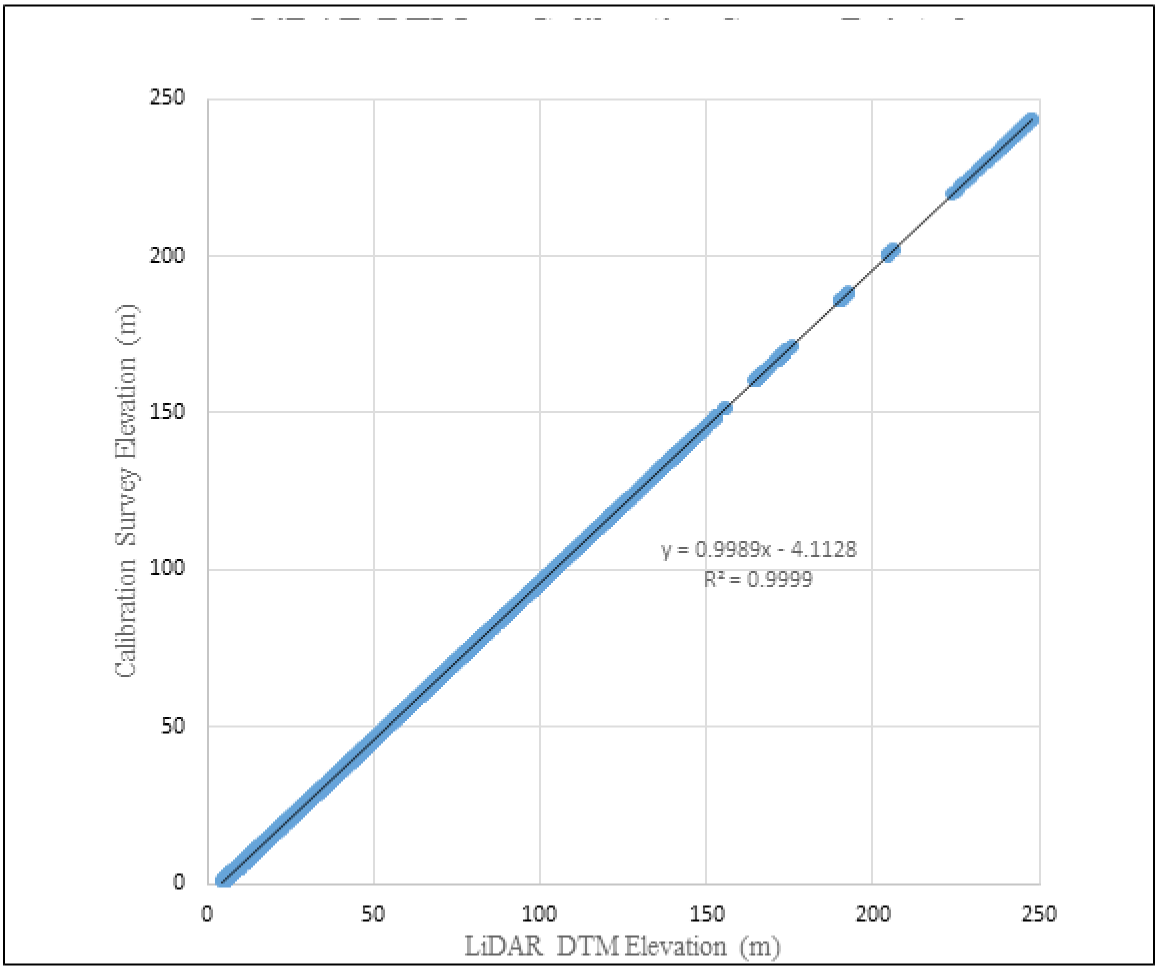

Figure 25. Correlation plot between calibration survey points and LiDAR data

Table 30. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	4.15
Standard Deviation	0.15
Average	-4.14
Minimum	-4.50
Maximum	-3.85

A total of 335 points were used for the validation of calibrated Bucao 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 0.08 meters with a standard deviation of 0.07 meters, as shown in Table 31.

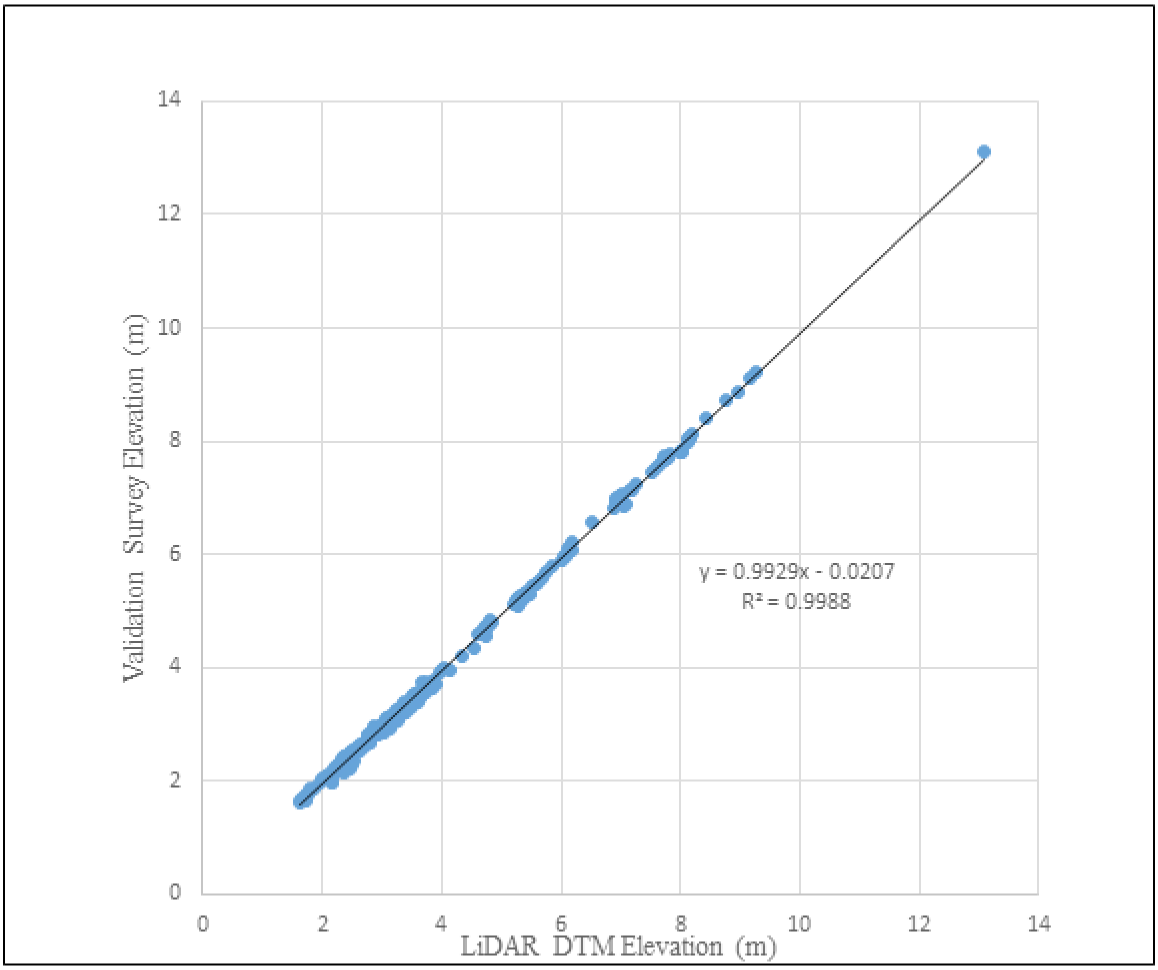

Figure 26. Correlation plot between validation survey points and LiDAR data

Table 31. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.08
Standard Deviation	0.07
Average	-0.05
Minimum	-0.21
Maximum	0.10

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Bucao with 9,536 bathymetric survey points. A trial was done to produce a raster surface, using Inverse Distance Weighted (IDW) interpolation method. After assessing the interpolated surface, it was found that the water level along Bucao is shallow and the LiDAR pulses were able to get to the bottom of the river, thus, creating the river surface. It has been decided to treat the originally produced LiDAR data as the river surface, without the integration of bathymetric data to the LiDAR data. This assumption was checked by computing the RMSE value between the bathymetric data and the original LiDAR surface, which resulted to 0.48meter.The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Bucao integrated with the processed LiDAR DEM is shown in Figure 27.

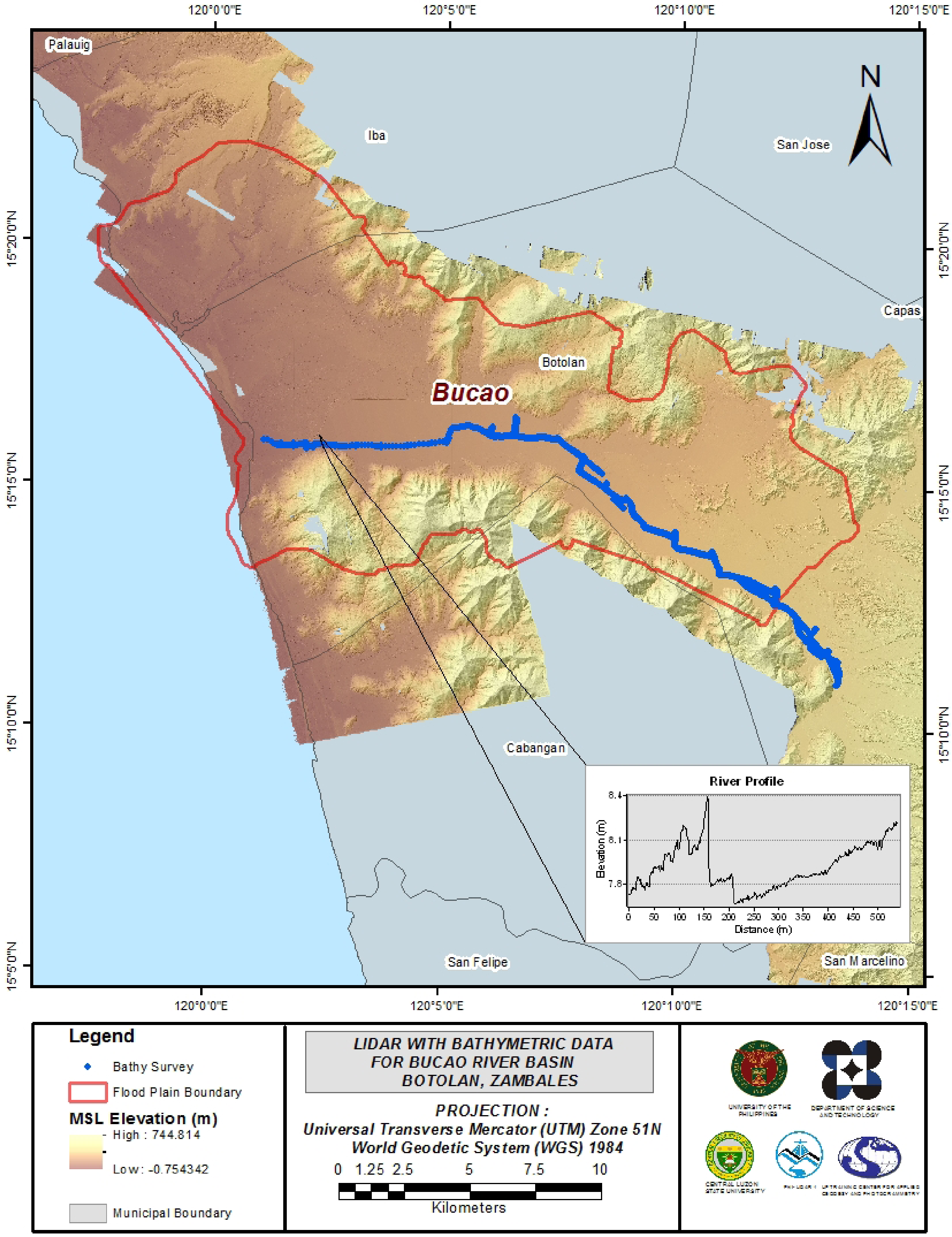

Figure 27. Map of Bucao Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Bucao floodplain, including its 200 m buffer, has a total area of 260.89 sq km. For this area, a total of 8.0 sq km, corresponding to a total of 3312 building features, are considered for QC. Figure 28 shows the QC blocks for Bucao floodplain.

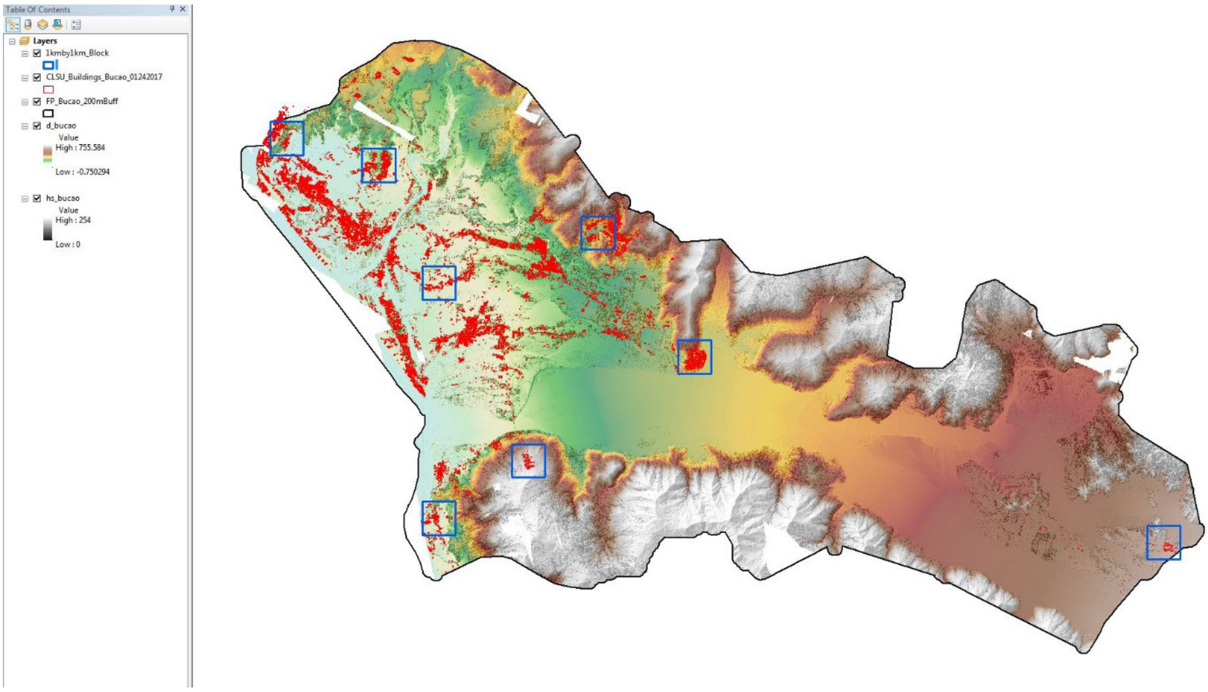

Figure 28. Blocks (in blue) of Bucao building features that were subjected to QC

Quality checking of Bucao building features resulted in the ratings shown in Table 32.

Table 32. Quality Checking Ratings for Bucao Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Bucao	100.00	100.00	81.89	PASSED

3.12.2 Height Extraction

Height extraction was done for 24,339 building features in Bucao floodplain. Of these building features, 832 were filtered out after height extraction, resulting to 23,507 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 7.66 m.

3.12.3 Feature Attribution

Field data gathering and ground verification were conducted in order to correct and complete the information needed in the attribution of the digitized features in the flood plains of the river basins.

Since field validation and ground verification is dreadfully laborious aside from the lack of budget and equipment, the team took a chance to seek assistance from the officials of the barangays within the flood plains of the Bucao river basin for year 2 of the project. Using the barangay boundaries from DENR, features extracted were clustered within each barangay boundaries for the purpose that every feature will be visible and be easily identified. Courtesy call for the Barangay Captains of Botolan, Zambales was performed last September 11, 2015 during their monthly meeting. Furthermore, the team has been distributed the clustered maps within the flood plains of Bucao river basin that served as their materials in gathering the necessary data for the attribution of features extracted in their respective barangays. With the collected data from the cooperative Barangay officials, extracted building features in the flood plains of Bucao river basin had been attributed.

Table 33 summarizes the number of building features per type. On the other hand, Table 34 shows the total length of each road type, while Table 35 shows the number of water features extracted per type.

Table 33. Building Features Extracted for Bucao Floodplain

Facility Type	No. of Features
Residential	22,280
School	365
Market	64
Agricultural/Agro-Industrial Facilities	67
Medical Institutions	24
Barangay Hall	29
Military Institution	
Sports Center/Gymnasium/Covered Court	40
Telecommunication Facilities	4
Transport Terminal	10
Warehouse	31
Power Plant/Substation	13
NGO/CSO Offices	7
Police Station	2
Water Supply/Sewerage	1
Religious Institutions	75
Bank	7
Factory	
Gas Station	16
Fire Station	4
Other Government Offices	182
Other Commercial Establishments	286
Total	**23,507**

Table 34. Total Length of Extracted Roads for Bucao Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Bucao	136.03	26.99	51.97	0	0	**215.00**

Table 35. Number of Extracted Water Bodies for Bucao Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Bucao	19	108	0	0	0	**128**

A total of 48 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 Bucao floodplain overlaid with its ground features.

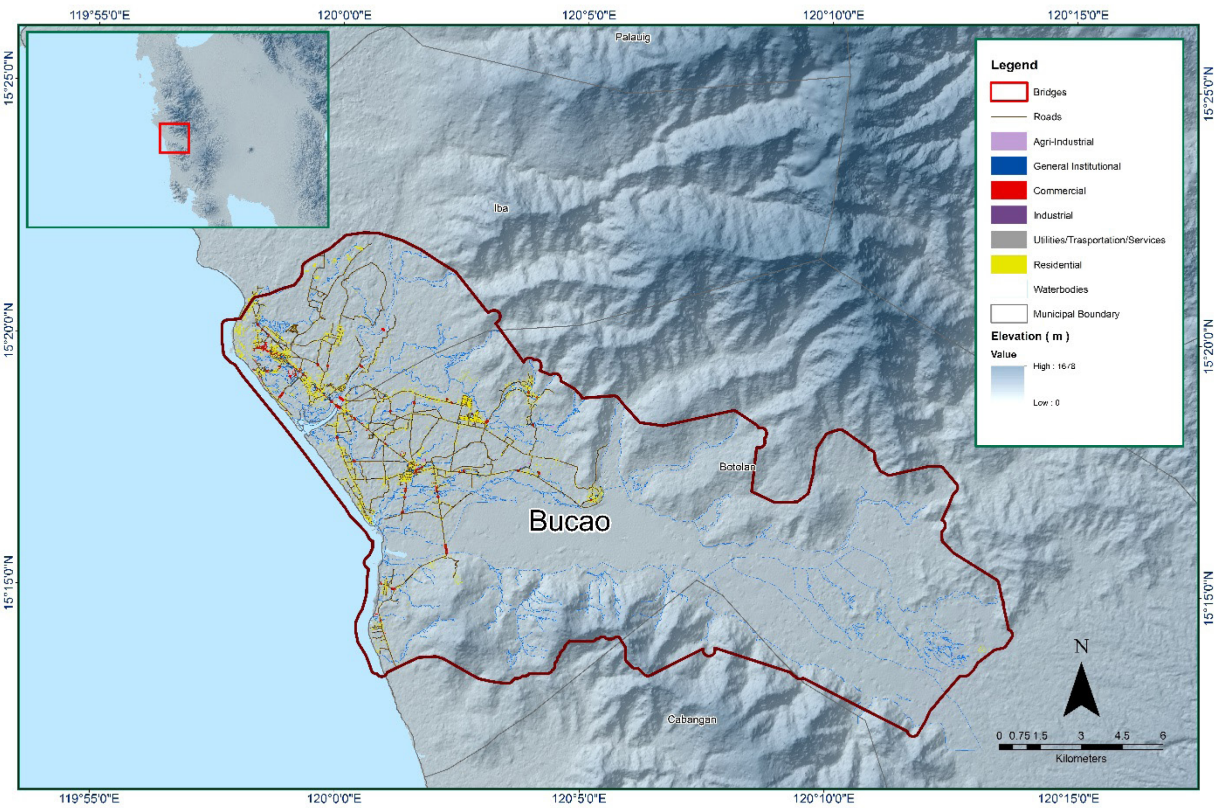

Figure 29. Extracted features for Bucao floodplain

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

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

4.1 Summary of Activities

The project team conducted a field survey in Bucao River from December 2 to 13, 2014 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section, bridge as-built and elevation marking of Bucao Bridge piers; ground validation data acquisition of about 64.94 km covering the national highway from the Municipality of Masinloc up to the Municipality of Cabangan; and bathymetric survey from Brgy. Villar, Municipality of Botolan, Zambales down to the mouth of the river in Brgy. Bangan, Municipality of Botolan, Zambales with an estimated length of 28.323 km using GNSS PPK survey technique as shown in Figure 30.

Figure 30. Extent of the bathymetric survey (in blue line) in Bucao River Basin and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS Network used for Bucao River Basin is composed of a single loop and a baseline established on December 3 and 4, 2014 occupying the following reference points: ZBS-62, a second-order GCP, in Brgy. La Paz, Municipality of San Narciso; and ZA-62A, a first-order BM in Brgy. Sindol, Municipality of San Felipe, all in Zambales.

Two (2) Control points were established along the approach of bridges, namely: UP-MAC, located at the approach of Maculcol Bridge in Brgy. Alusiis, Municipality of San Narciso; andBUC-1, located at Bucao Birdge in Brgy. Carael, Municipality of Botolan, Zambales

The summary of reference and control points and its location is summarized in Table 36while the GNSS network established is illustrated in Figure 31.

Figure 31. GNSS Network of Bucao River field survey

Table 36. List of references and control points used in Bucao River Survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	BM Ortho (m)	Date Established
ZBS-62	2nd Order, GCP	15°00’52.08330”	120°03’55.29320”	46.764	-	2007
ZA-62A	1st Order, BM	-	-	47.286	4.164	1992
UP-MAC	UP established	-	-	-	-	12-3-2014
BUC-1	UP established	-	-	-	-	12-4-2014

The GNSS set ups made in the location of the reference and control points are exhibited in Figure 32to Figure 35.

Figure 32. GNSS Base station setup, Trimble® SPS 852, at ZBS-62 located inside Barangay Executive Park in Brgy. La Paz, unicipality of San Narciso, Zambales

Figure 33. Trimble® SPS 882 occupying control point ZA-62A, located at the approach of Sindol Bridge, Municipality of San Felipe, Zambales

Figure 34. GNSS base receiver, Trimble® SPS 852, at established control point UP-MAC at Maculcol Bridge, in Brgy. Alusiis, Municipality of San Narciso, Zambales

Figure 35. GNSS base receiver, Trimble® SPS 852, at established control point BUC-1 in Bucao Bridge, Brgy. Carael, Municipality of Botolan, Zambales

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Bucao River Basin is summarized in Table 37 by TBC software.

Table 37. Baseline Processing Report for Bucao River Basin control survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ZBS-62 --- UP-MAC	12-3-2014	Fixed	0.003	0.012	23°20’37”	2728.214	10.290
UP-MAC --- ZA-62A	12-3-2014	Fixed	0.004	0.019	348°33’22”	4744.407	-9.735
ZBS-62--- ZA-62A	12-3-2014	Fixed	0.008	0.032	1°07’01”	7156.314	0.553
ZBS-62--- BUC-1	12-4-2014	Fixed	0.005	0.021	351°41’11”	27829.009	10.137

As shown in Table 37, a total of four (4) baselines were processed and all of them passed the required accuracy set by the project.

4.4 Network Adjustment

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

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

where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

The four control points, ZBS-61, ZA-62A, UP-MAC and BUC-1, were occupied and observed simultaneously to form a GNSS loop. Coordinates of ZBS-62 and elevation of ZA-62A were held fixed during the processing of the control points as presented in Table 38. Through these references points, the coordinates and elevation of the unknown control points were computed.

Table 38. Control Point Constraint

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ZA-62A	Grid				Fixed
ZBS-62	Local	Fixed	Fixed		
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 39. All fixed control points have no values for grid and elevation errors.

Table 39. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
UP-MAC	185520.290	0.006	1664513.687	0.006	14.031	0.050	
ZA-62A	184640.040	0.009	1669179.71	0.010	4.164	?	e
ZBS-62	184405.132	?	1662021.317	?	4.033	0.055	LL

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown inTable 40.Using the equation for horizontal and for the vertical; below is the computation for accuracy that passed the required precision:

a. **ZBS-62**

horizontal accuracy	=	Fixed
vertical accuracy	=	5.5 cm < 10 cm

b. **ZA-62A**

horizontal accuracy	=	√((0.9)² + (1.0)²
	=	√(0.81 + 1.0)
	=	1.34 cm < 20 cm
vertical accuracy	=	Fixed cm < 10 cm

c. **UP-MAC**

horizontal accuracy	=	√((0.6)² + (0.6)²
	=	√(0.36 + 0.36)
	=	0.84 cm < 20 cm
vertical accuracy	=	5.0 cm < 10 cm

The list of adjusted geodetic coordinates: Latitude, Longitude, Height and computed standard errors of the control points in the network are shown in Table 40. Following the given formula, the horizontal and vertical accuracy result of the two occupied control points are within the required accuracy of the project.

.

Table 40. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
UP-MAC	N15°02'13.58015"	E120°04'31.48480"	57.042	0.050	
ZA-62A	N15°04'44.87136"	E120°03'59.96470"	47.286	?	e
ZBS-62	N15°00'52.08330"	E120°03'55.29320"	46.764	0.055	LL

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 40. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 41.

Table 41. 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)
ZBS-62	2nd order, GCP	15°00'52.08330"	120°03'55.29320"	46.764	1662021.317	184405.132	4.033
ZA-62A	1st order, BM	15°04'44.87136"	120°03'59.96470"	47.286	1669179.716	184640.04	4.164
UP-MAC	UP Established	15°02'13.58015"	120°04'31.48480"	57.042	1664513.687	185520.29	14.031
BUC-1	UP Established	15°15'52.00270"	120°02'12.72793"	56.817	1689743.384	181713.095	13.708

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

Cross-section and as-built survey were conducted on October 23, 2014 at the downstream side of Bucao Bridge in Brgy. Carael, Municipality of Botolan, Zambales as shown in Figure 36. A GNSS receiver Trimble® SPS 882 in PPK survey technique was used for the survey as shown in Figure 37.

Figure 36. Bucao Bridge facing downstream

Figure 37. (A) Bridge as-built survey and (B) Cross-section survey in Bucao Bridge,

The cross-sectional line length of Bucao bridge is about 32.81 m with 37 cross-sectional points using BUC-1 as the GNSS base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 38, Figure 39, andFigure 40.

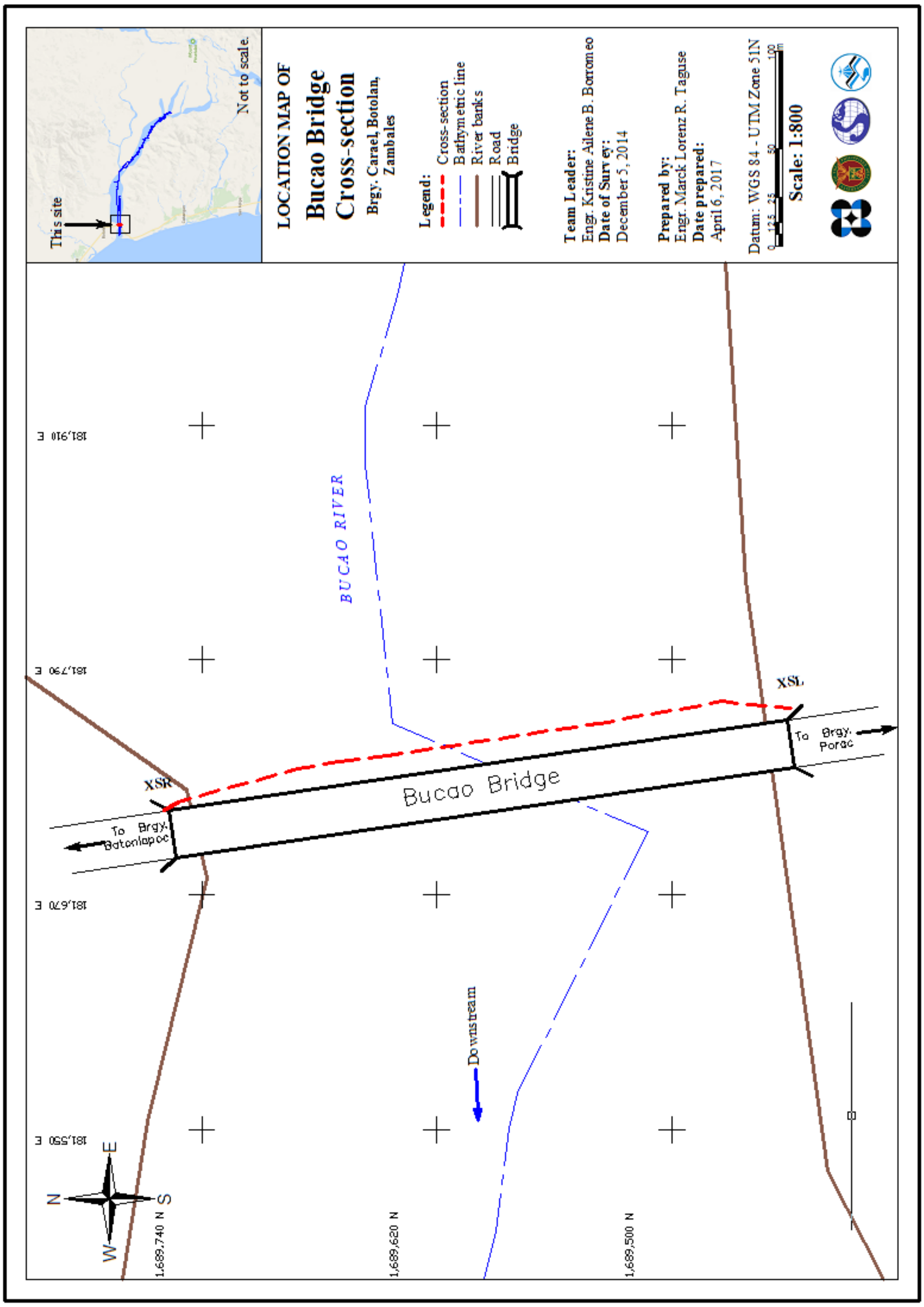


Figure 38.Bucao Bridge Cross-section location map

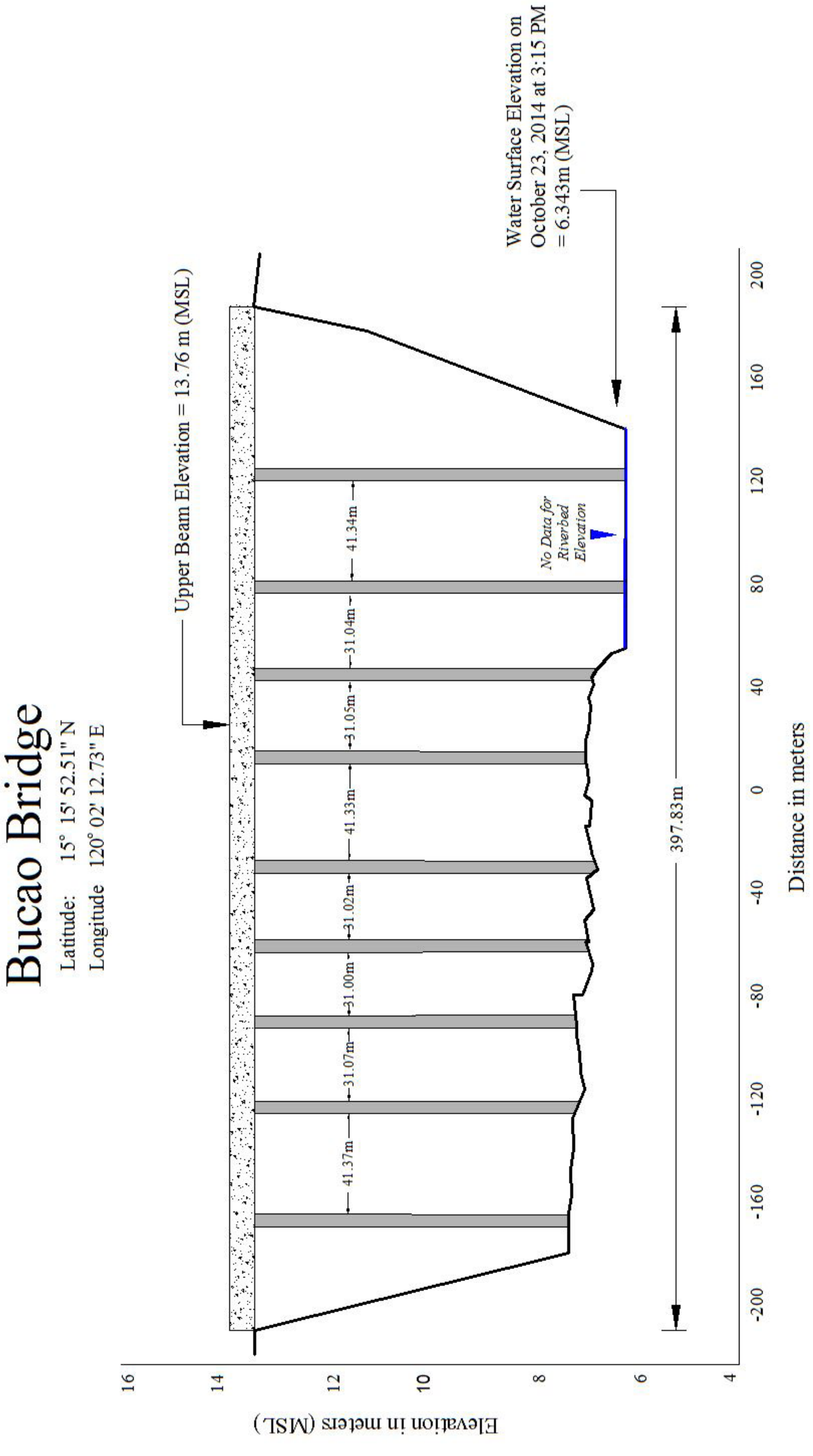


Figure 39. Bucao Bridge cross-section diagram

Bridge Data Form

Bridge Name: **Bucao Bridge** **Date:** **December 5, 2014**

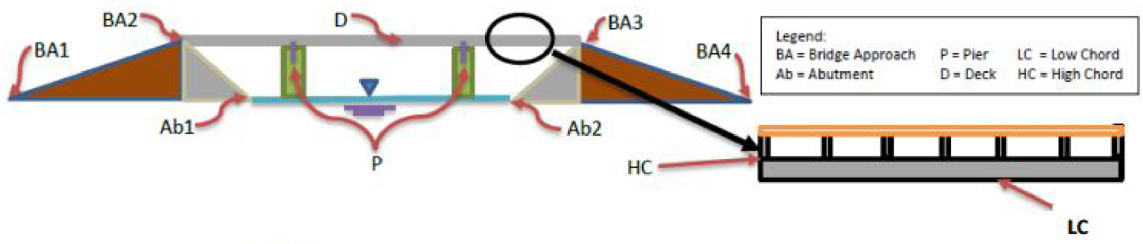
River Name: **Bucao River** **Time:** **10-11:30am**

Location (Brgy, City,Region): **Municipality of Botolan, Province of Zambales**

Survey Team: **Zambales Survey Team**

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

Latitude: **15°15'52.41"** **Longitude:** **120°02'12.73"**



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

Elevation: ______ **Width:** ______ **Span (BA3-BA2):** ______

	Station	High Chord Elevation	Low Chord Elevation
1			
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	13.38m	BA3	339.146	13.705m
BA2	20.183	13.74m	BA4	N/A	N/A

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

	Station (Distance from BA1)	Elevation
Ab1	24.711	11.374
Ab2	334.005	11.256

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

Shape: ______ Number of Piers: ______ Height of column footing: ______

Figure 40. Bucao Bridge Data Form (1 of 2)

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	34.747	13.739	
Pier 2	76.118	13.749	
Pier 3	107.187	13.750	
Pier 4	138.191	13.767	
Pier 5	169.213	13.761	
Pier 6	210.545	13.749	
Pier 7	241.599	13.755	
Pier 8	272.640	13.755	
Pier 9	313.975	13.735	

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

Figure 41. Bucao Bridge Data Form (2 of 2)

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted in two (2) days, on December 8 and 11, 2014, using a survey-grade GNSS Rover receiver Trimble® SPS 882 mounted on a pole which was attached in front of the vehicle as sown in Figure 42. It was secured with a nylon rope and cable ties to ensure that it was horizontally and vertically balanced. The antenna height, 2.03 m, was measured from the ground up to the bottom of the notch of the GNSS Rover receiver. The survey was conducted using PPK technique on a continuous topography mode.

The first day of the survey started from the Municipality of Castillejos to Municipality of Cabangan which traversed the main roads. On the second day, the survey continued from the Municipality of Cabangan up to the Municipality of Masinloc. BUC-1 was occupied as the GNSS base station for the survey.

Figure 42. (A) The occupied GNSS base station, BUC-1, in Municipality of Botolan with Trimble® SPS 882 and (B) the setup of Trimble® SPS 882 in a vehicle for validation points acquisition survey

The survey acquired 5,629 ground validation points with an approximate length of 64.94 km. The coverage of the validation survey is shown in Figure 43.

Figure 43. Validation points acquisition survey along Bacarra River Basin

4.7 River Bathymetric Survey

The bathymetric survey for Bucao River was completed in three (3) days on December 5, 6 and 11, 2014. The bathymetric team was divided into two (2) groups performing bathymetric survey manually and thru a vehicle. The team setup Trimble® SPS 852 at BUC-1 which served as the GNSS base station for the bathymetric survey.

Figure 44. Bathymetric Survey along Bucao River from the bridge going upstream

The first group performed manual bathymetry which commenced from the mouth of the river in Brgy. Bangan eith coordinates 15°15’53.05262”120°01’09.55508”going upstream to Brgy. Carael, Municipality of Botolan wit coordinates 15°15’53.87624”120°05’01.35644”(Figure 44). The second group conducted bathymetric survey by attaching a range pole with Trimble® SPS-882 GNSS receiver on a four-wheel drive vehicle from Brgy. Villa with coordinates 15°10’57.90190”120°13’24.17387”going downstream up to the end point of manual bathymetric survey by foot (Figure 45).

Figure 45. Bathymetric Survey along Bucao River using Trimble® SPS-882 GNSS receiver attached to a four wheel drive vehicle borrowed from the LGU of Botolan

Figure 46. Bathymetric points gathered along Bucao River

The processed data was generated into a map using GIS and processed further using CAD for plotting the riverbed of the river. The generated map, shown in Figure C-17, exhibits the bathymetric survey coverage while Figure 47 and Figure 48 illustrate the Bucao riverbed profile. There is a change in elevation of about 43.5 m within 9 km. An approximation of 28.323 km was covered during the bathymetric survey. The highest elevation value observed was 187.50 m in MSL located in Brgy. Villar, while the lowest elevation value observed was 0.9718 m below MSL located in Brgy. Bangan.

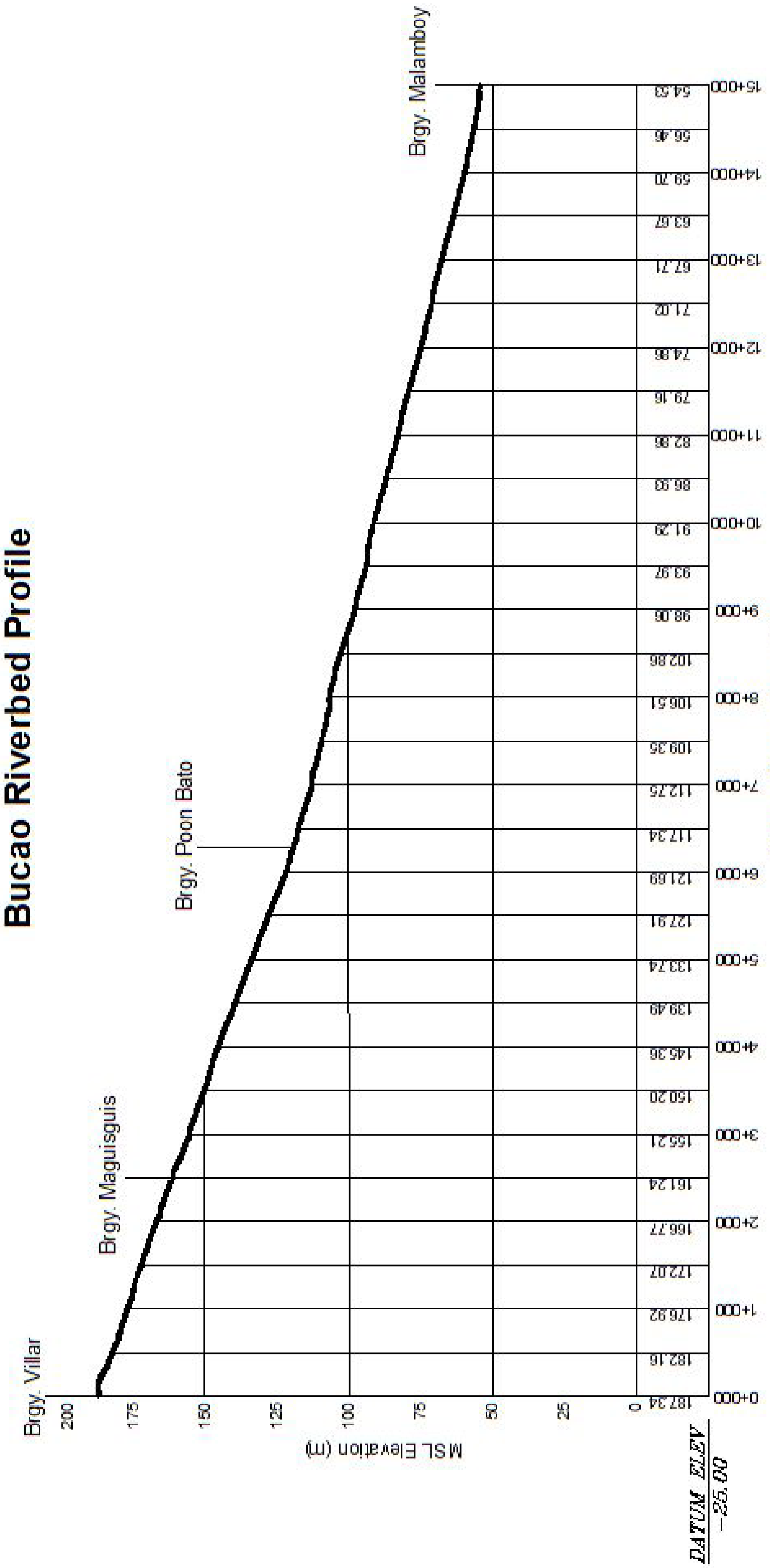


Figure 47. Riverbed Profile of Bucao River (1 of 2)

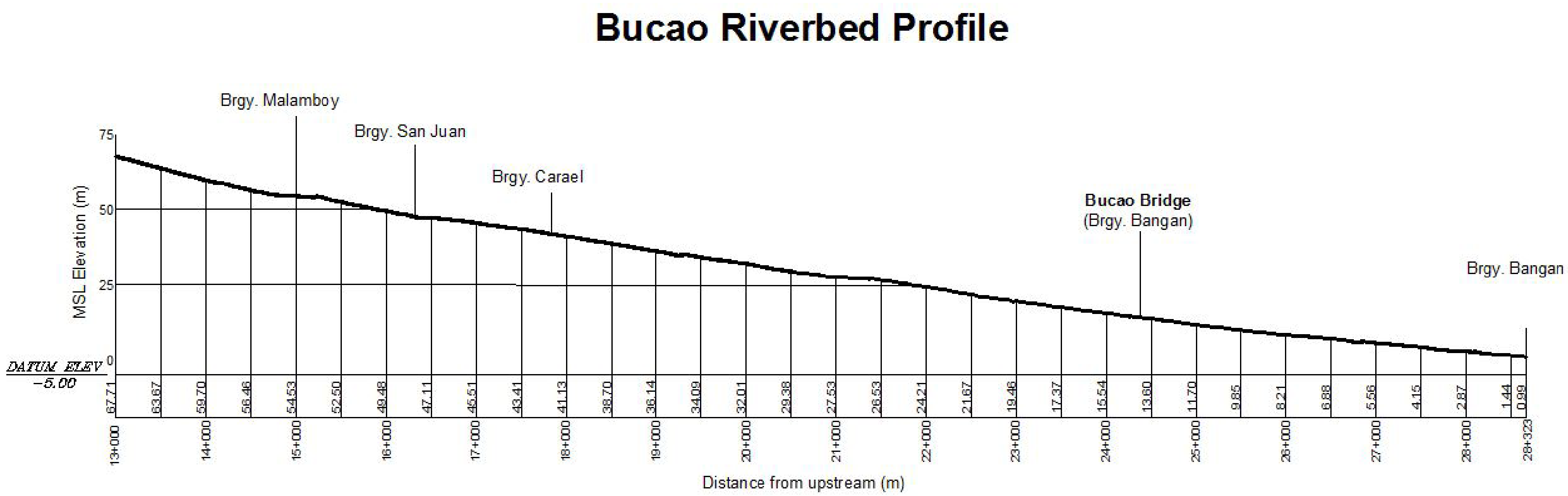


Figure 48. Riverbed Profile of Bucao River (2 of 2)

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, Girlie David, Mariel Monteclaro, Eleazar Raneses, Jr. and Jose T. Gavino

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

5.5.1 Hydrometry and Ratings Curve

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

5.5.2 Precipitation

In the absence of automatic rain gauge in Bucao, precipitation data was recorded through manual reading in an 8 inches standard rain gauge installed in the study area. The rain gauge was installed one (1) kilometer upstream from the flow measurement site.

The total rain recorded in this event from the rain gauge is 76.94 mm. It peaked to 10.25 mm. on 09 July 2015 at 23:00 PM. The lag time between the peak rainfall and discharge is 13 hours.

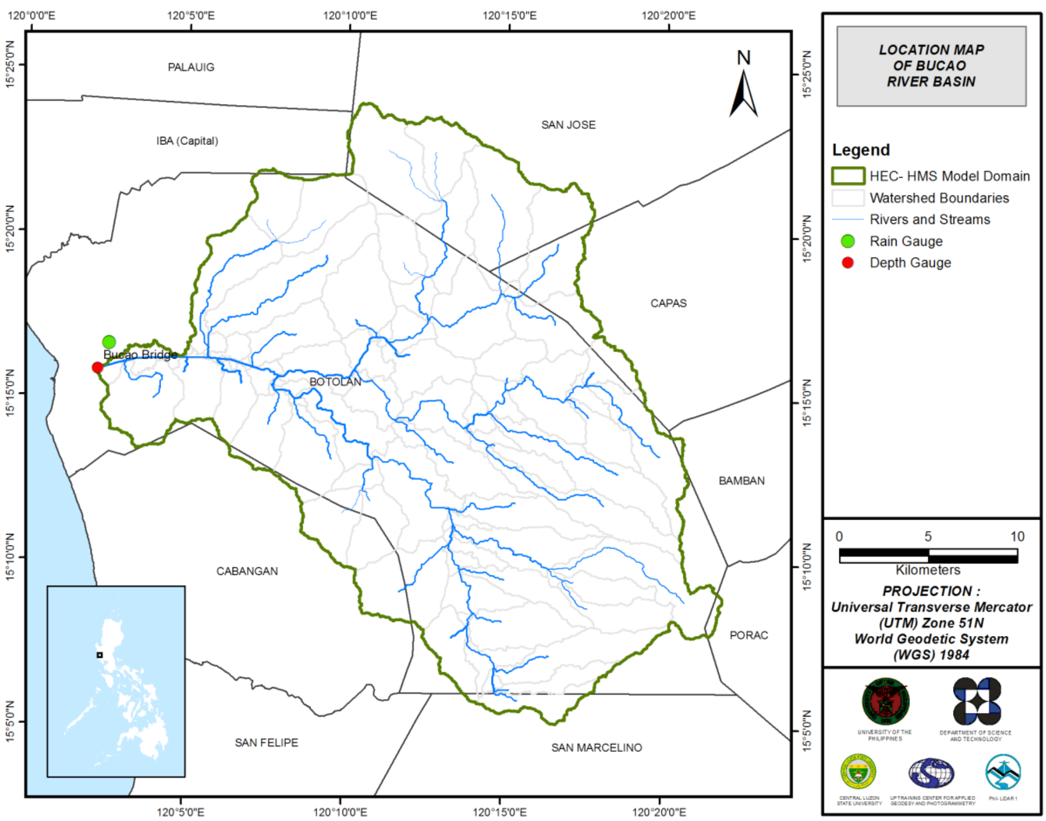


Figure 49. The location map of Bucao HEC-HMS model used for calibration

5.5.3 Rating Curves and River Outflow

A rating curve was developed at Bucao Bridge Botolan, Zambales (15°15'48.5876"N, 120°2'13.3418"E). It gives the relationship between the observed water levels at Bucao Bridge and outflow of the watershed at this location.

For Bucao Bridge, the rating curve is expressed as $Q = 0.0000001e^{2.907h}$ as shown in Figure 51.

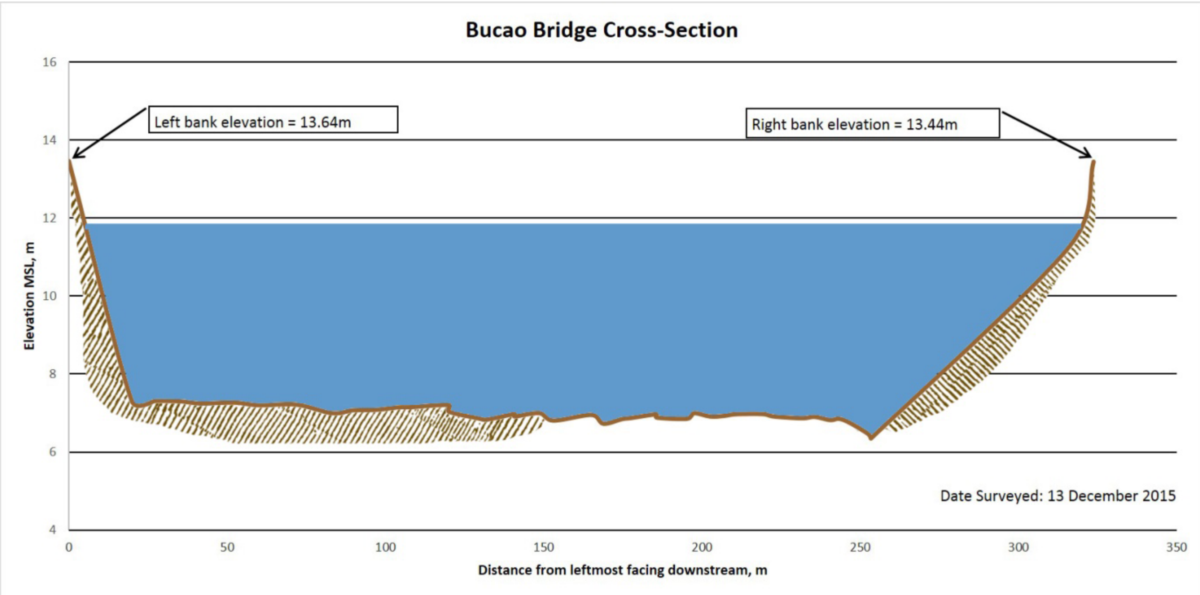


Figure 50. Cross-Section Plot of Bucao

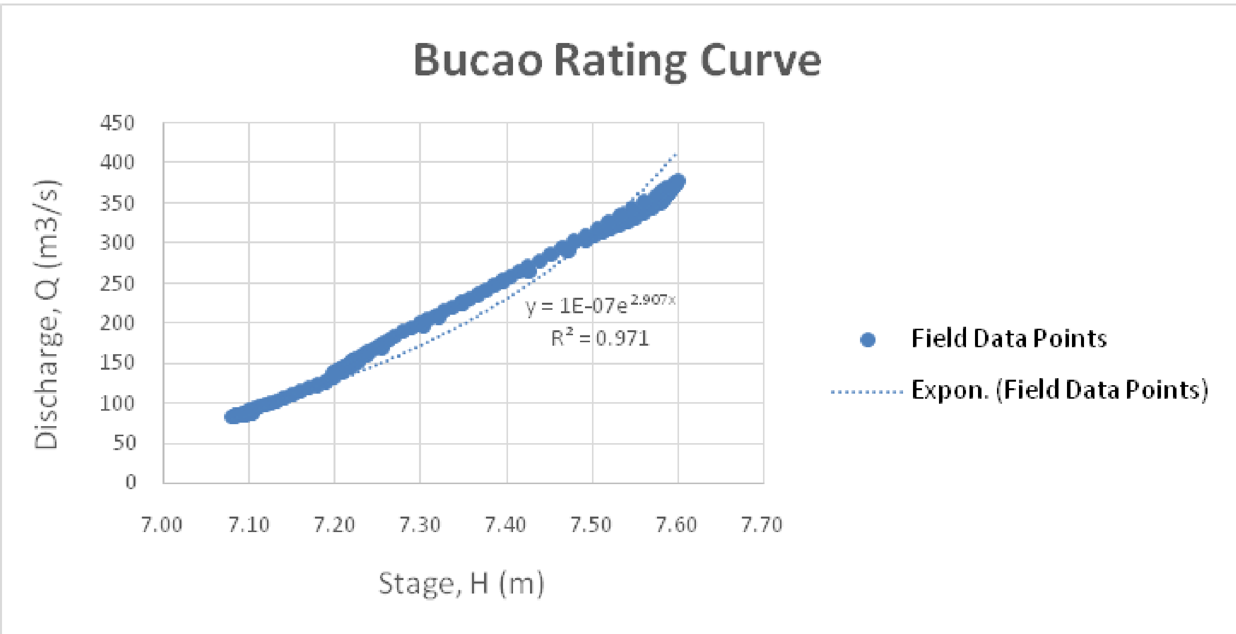


Figure 51. Rating Curve at Bucao Bridge Botolan, Zambales

This rating curve equation was used to compute the river outflow at Bucao Bridge for the calibration of the HEC-HMS model shown in Figure 50. Peak discharge is 378.9 cms at 6:20 AM, July 10, 2015.

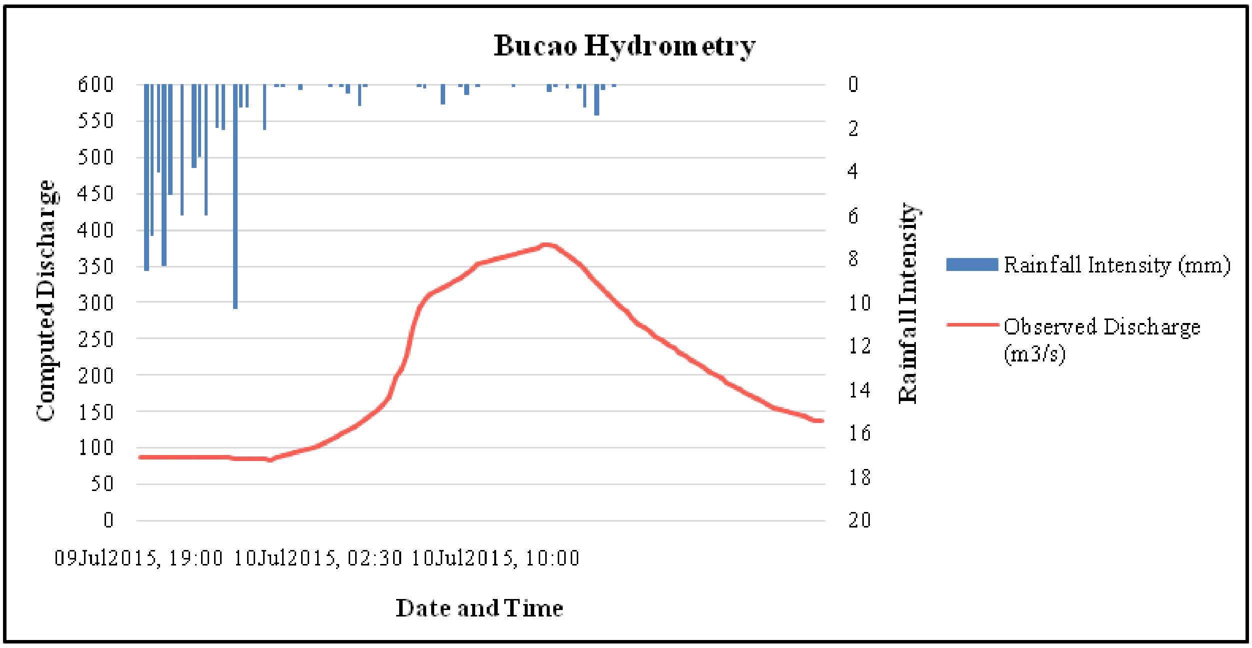


Figure 52. Rainfall and outflow data at Bucao which was used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Iba, Zambales Rain Gauge. 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 chosen based on its proximity to the Bucao watershed. The extreme values for this watershed were computed based on a 26-year record

Table 42. RIDF values for Iba Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	26.3	41.1	52	67.9	93.7	110.8	148	186.3	224.1
5	36.1	55.9	70.2	92.5	131.7	156.5	208.2	259.5	307
10	42.6	65.8	82.2	108.8	156.9	186.8	248.1	307.9	361.8
15	46.2	71.3	89	118	171.1	203.8	270.6	335.2	392.8
20	48.7	75.2	93.8	124.5	181.1	215.8	286.3	354.4	414.4
25	50.7	78.2	97.4	129.4	188.7	225	298.5	369.1	431.1
50	56.8	87.4	108.7	144.7	212.3	253.4	335.8	414.5	482.5
100	62.8	96.5	119.9	159.9	235.8	281.5	372.9	459.6	533.6

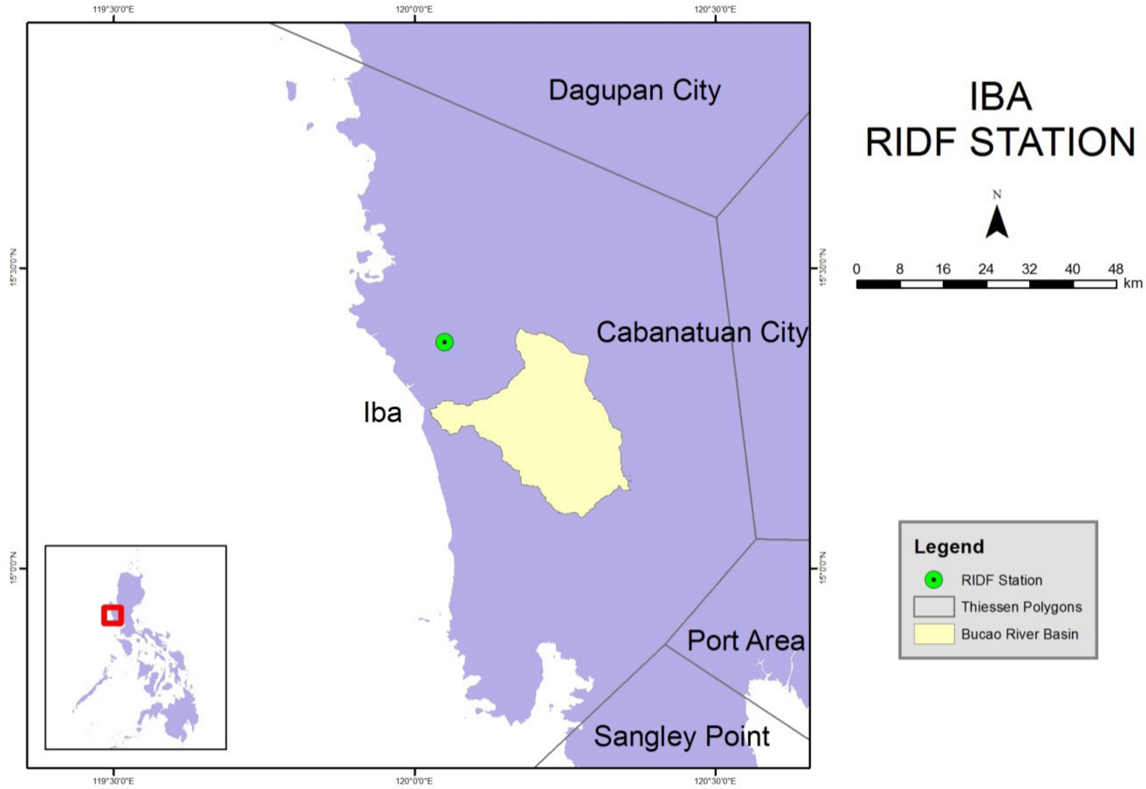


Figure 53. Iba RIDF location relative to Bucao River Basin

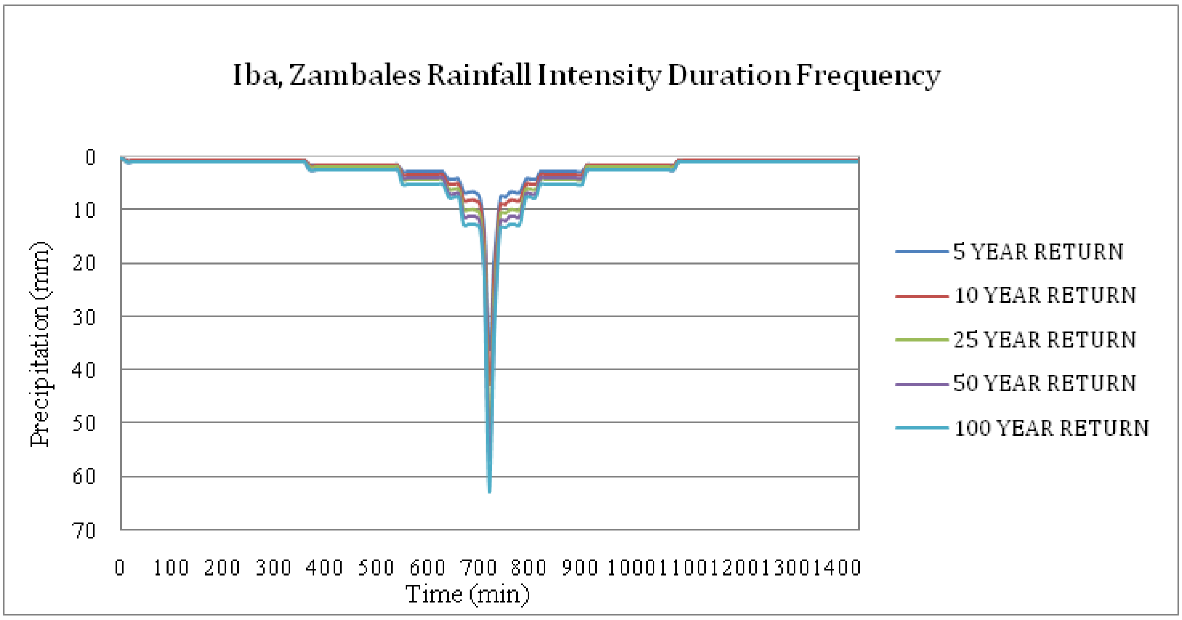


Figure 54. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset (dated pre-2004) was taken from the Bureau of Soils and Water Management under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Bucao River Basin are shown in Figures 55 and 56, respectively.

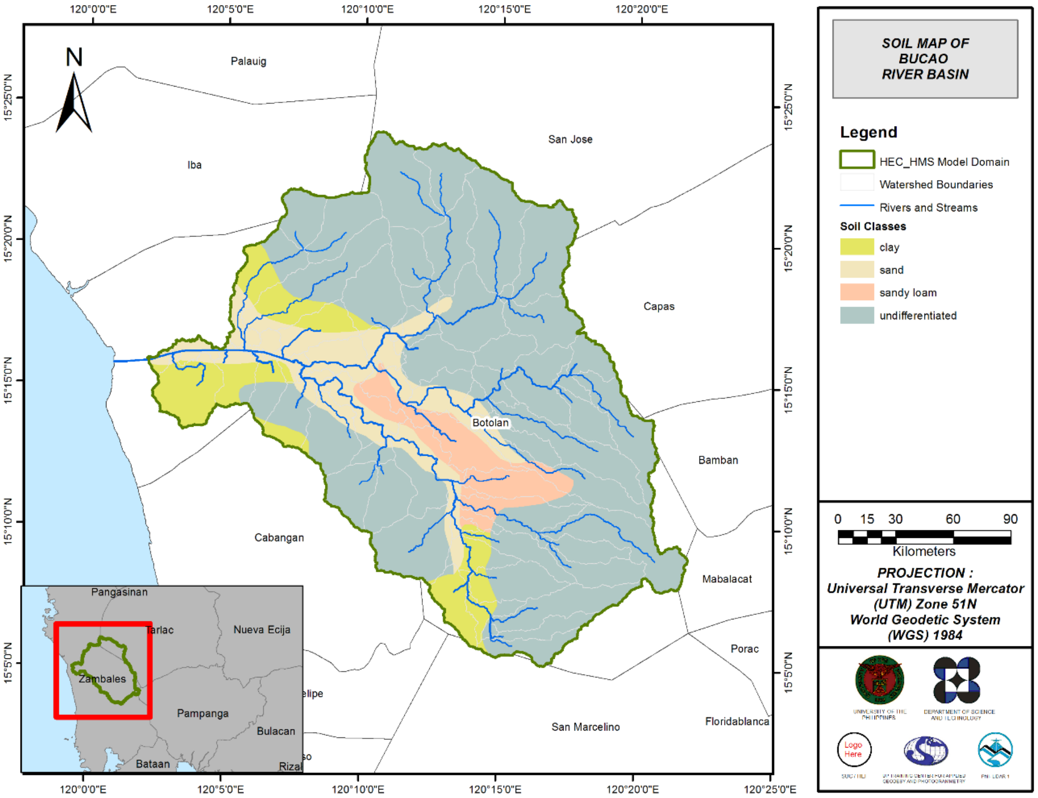


Figure 55. Soil Map of Bucao River Basin

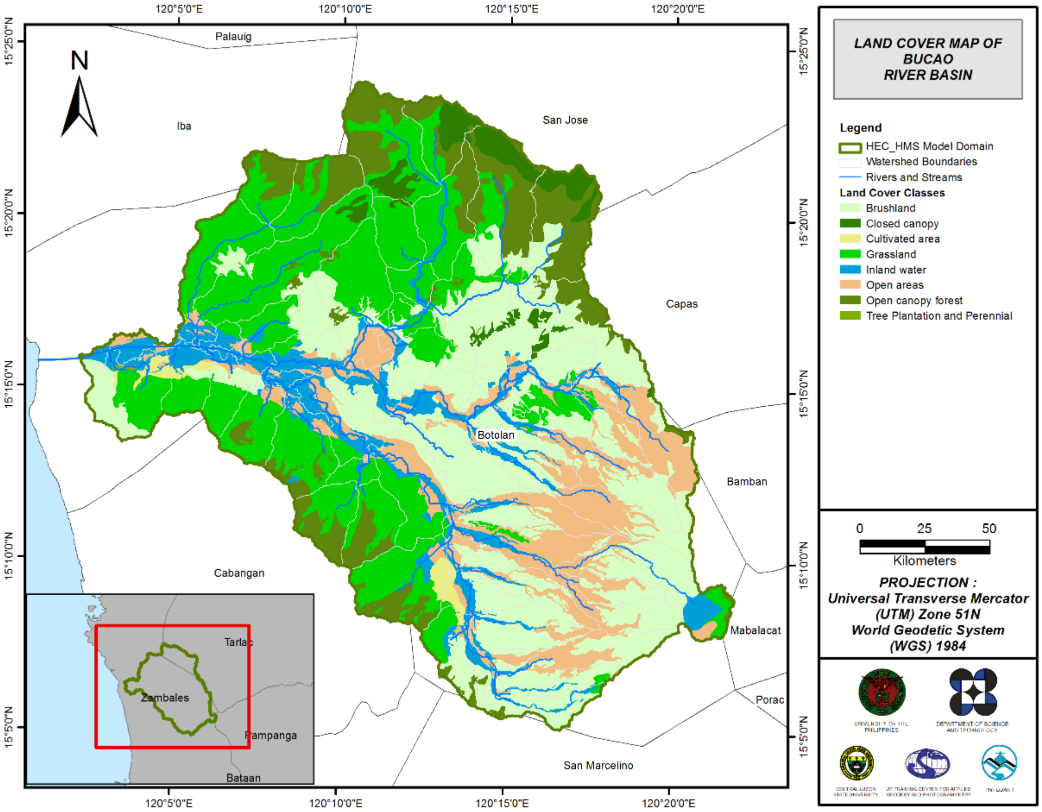


Figure 56. Land Cover Map of Bucao River Basin (Source: NAMRIA)

For Silaga, four soil classes were identified. These are clay, sand, sandy loam and undifferentiated soil. Moreover, eight land cover classes were identified. These are brushland, closed canopy, cultivated area, grassland, inland water, open areas, open canopy forest and tree plantation and perennial.

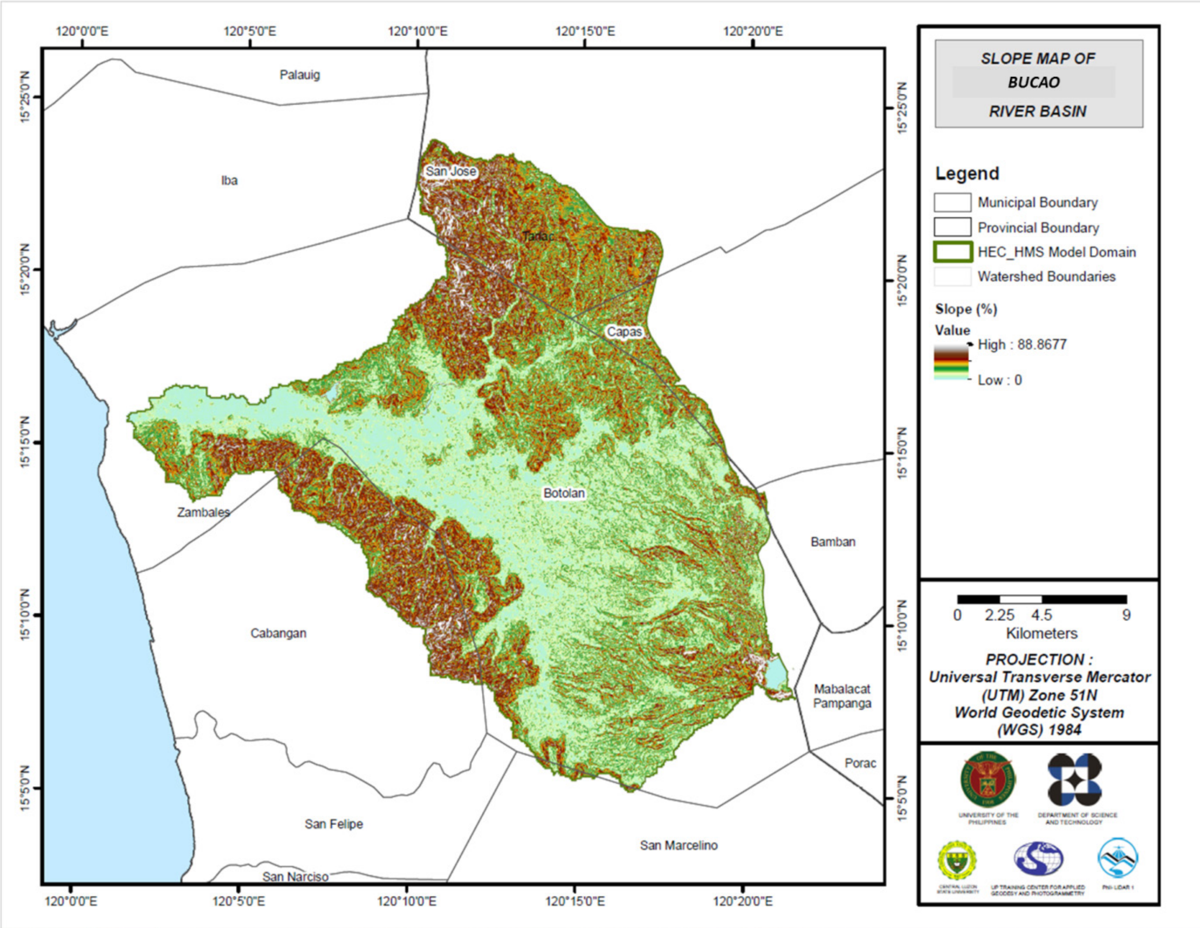


Figure 57. Slope Map of Bucao River Basin

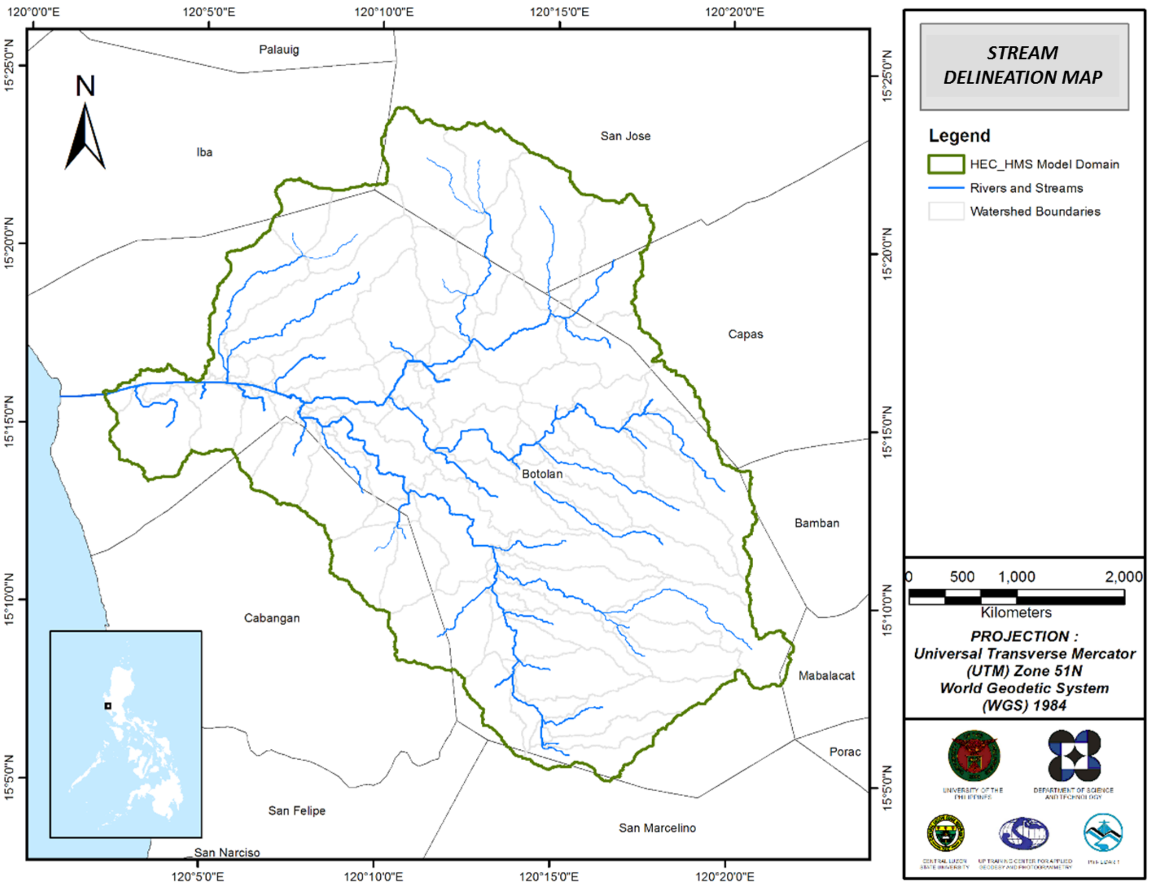


Figure 58. Stream Delineation Map of Bucao River Basin

Using the SAR-based DEM, the Bucao basin was delineated and further subdivided into subbasin. The Bucao basin model consists of 74 sub basins, 37 reaches, and 37 junctions as shown in Figure 59. The main outlet is J343. Finally, it was calibrated using depth gauge installed in Bucao Bridge.

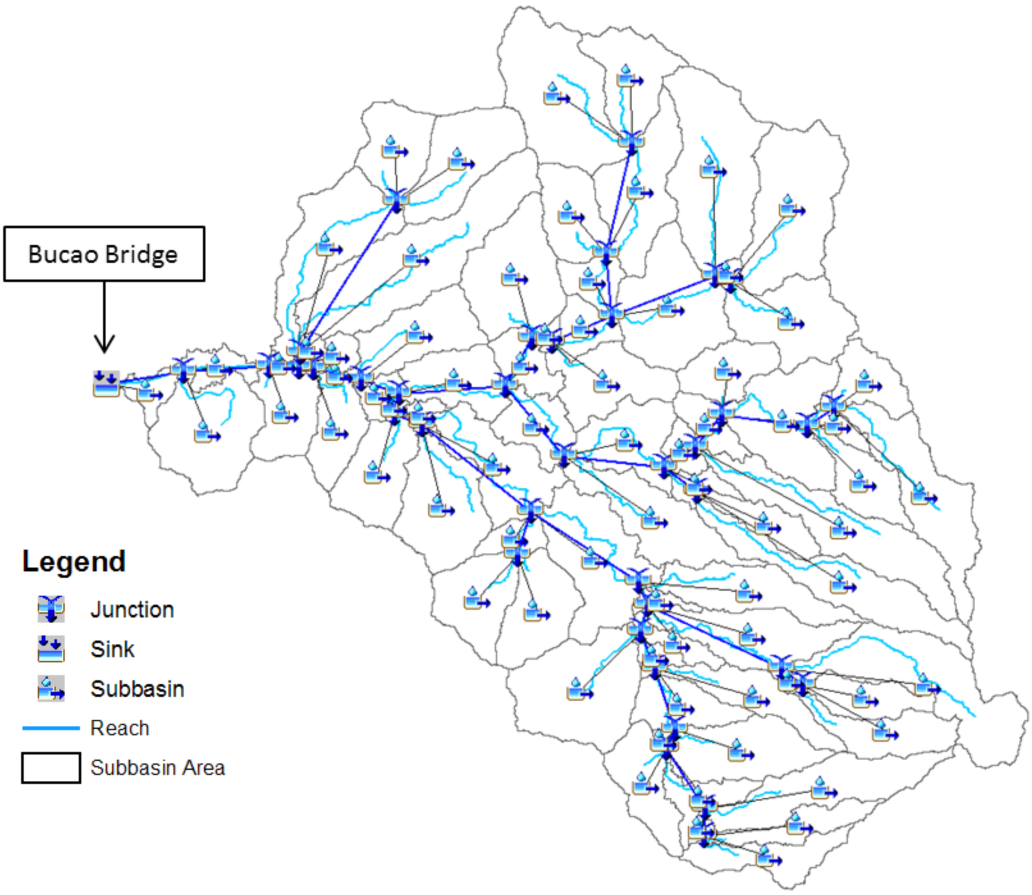


Figure 59. The Bucao river basin model generated using HEC-HMS

5.4 Cross-section Data

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

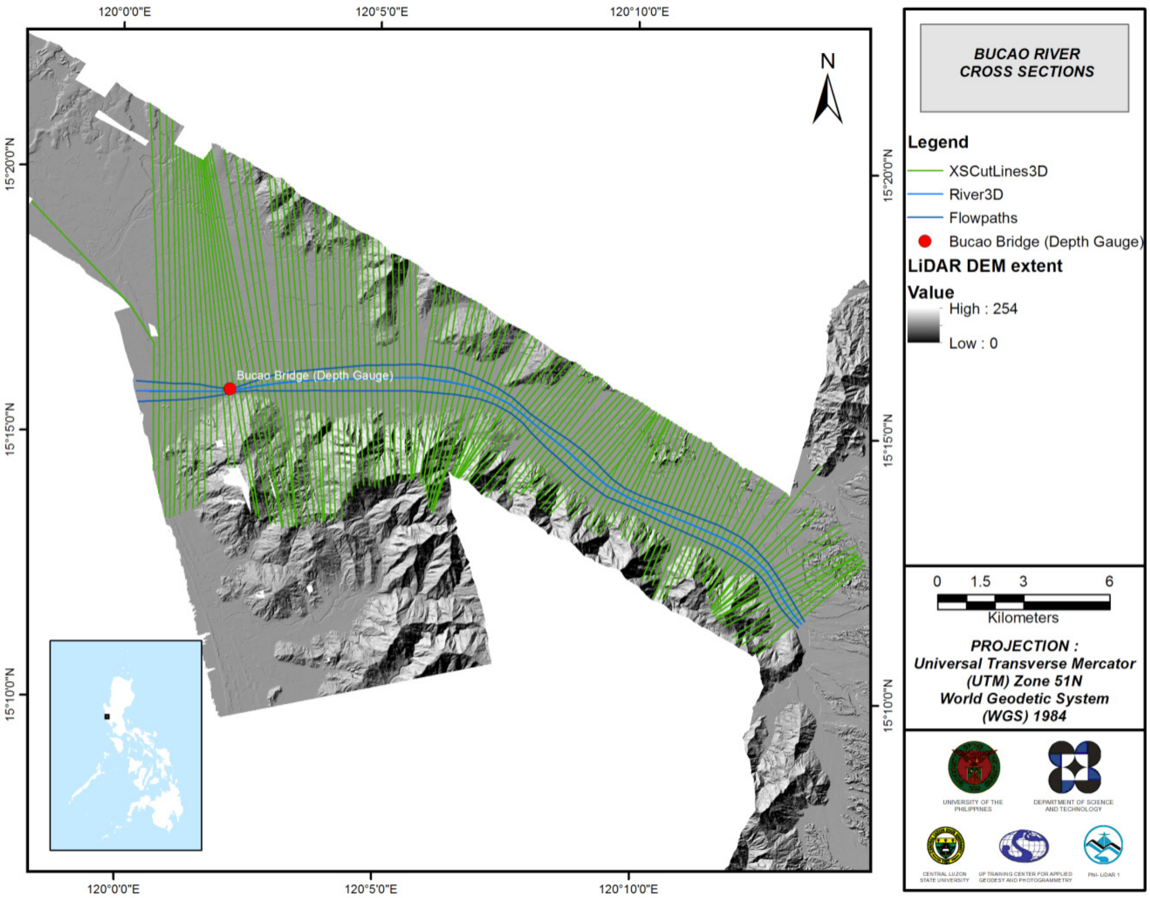


Figure 60. River cross-section of Bucao River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

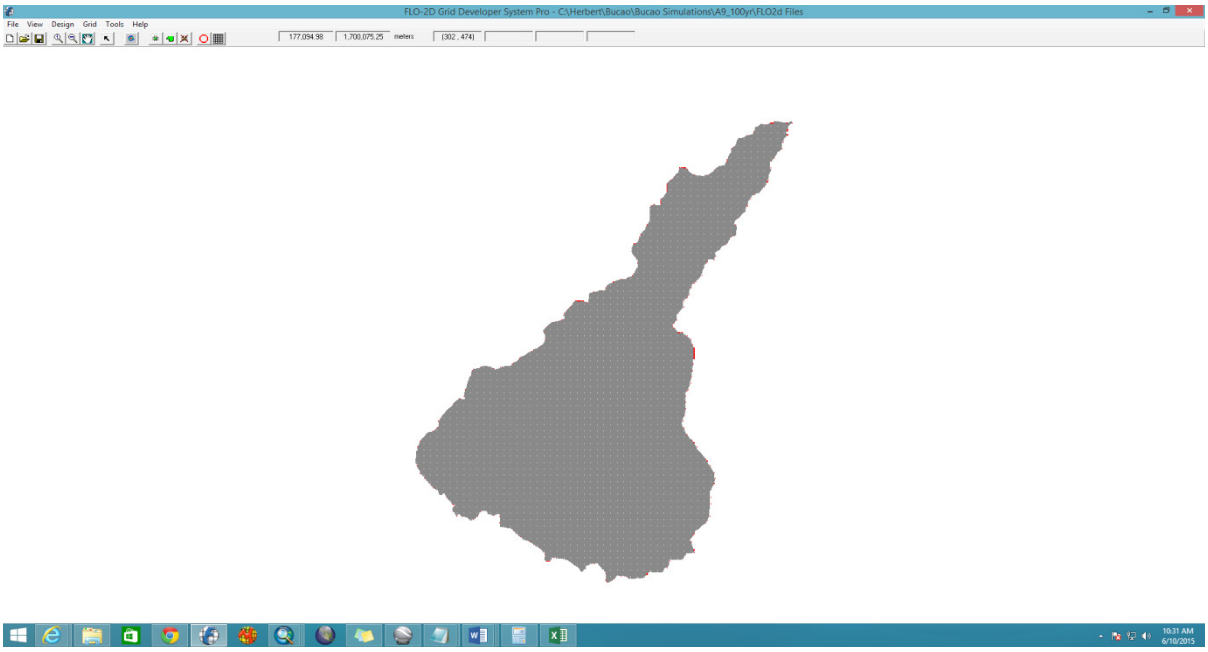


Figure 61. Screenshot of sub-catchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 9.66479 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m^2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 25284600.00 m^2.

There is a total of 13476551.50 m^3 of water entering the model, of which 13476551.50 m^3 is due to rainfall and 0.00 m^3 is inflow from basins upstream. 1822756.75 m^3 of this water is lost to infiltration and interception, while 768081.18 m^3 is stored by the flood plain. The rest, amounting up to 10885714.11 m^3,is outflow.

5.6 Results of HMS Calibration

After calibrating the Bucao HEC-HMS river basin model, its accuracy was measured against the observed values (see Annex 8. Bucao Model Basin Parameters). Figure 14 shows the comparison between the two discharge data.

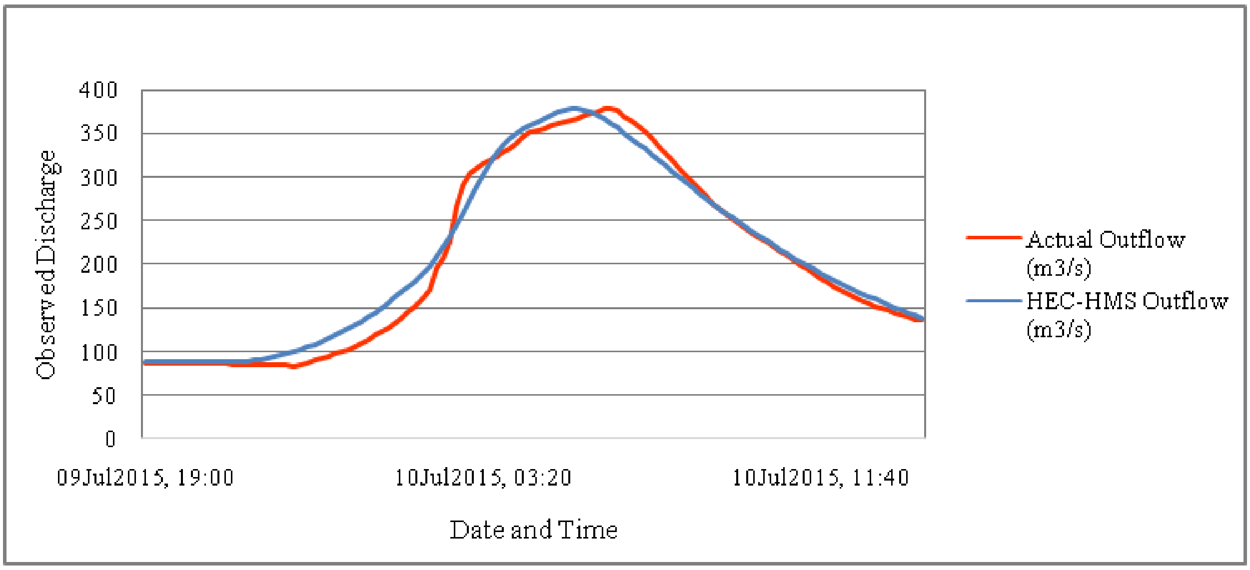


Figure 62. Outflow Hydrograph of Bucao produced by the HEC-HMS model compared with observed outflow

Table 43 shows adjusted ranges of values of the parameters used in calibrating the model.

Table 43. Range of calibrated values for the Bucao River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	20 - 43
			Curve Number	73 - 85
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.88 - 11
			Storage Coefficient (hr)	0.88 - 11
	Baseflow	Recession	Recession Constant	0.08 – 0.18
			Ratio to Peak	0.1
Reach	Routing	Muskingum-Cunge	Manning’s Coefficient	0.02

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 20mm to 43mm signifies that there is minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 73 to 85 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Bucao, the basin mostly consists of brushland, grassland and open areas and the soil mostly consists of undifferentiated soil.

The time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.88 hour to 11 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.08 – 0.18 indicates that the basin is likely to quickly go back to its original discharge. Ratio to peak of 0.1 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.02 corresponds to the common roughness in Bucao watershed, which is determined to be a cultivated area but with no crop (Brunner, 2010).

Table 44. Summary the Efficiency Test of the Bucao HMS Model

Accuracy Measure	Value
RMSE	13.4
r^2	0.98
NSE	0.99
PBIAS	-0.21
RSR	0.17

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed at 13.4 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. A value of r2 = 0.987 was computed for this model.

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 0.99.

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 negative 1.78.

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 are quantified. The model has an RSR value of 0.09.

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 63) shows the Bucao outflow using the Iba Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

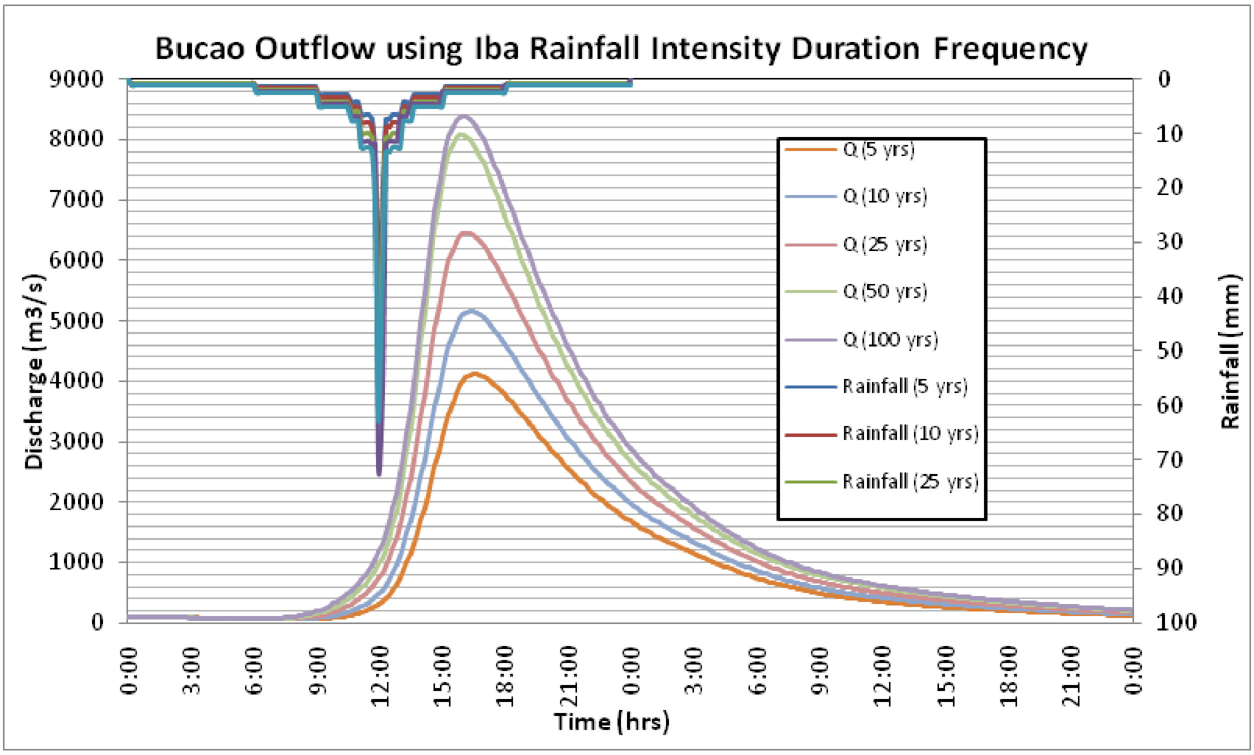


Figure 63. Outflow hydrograph at Bucao Station generated using Iba RIDF simulated in HEC HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Bucao discharge using the Zambales Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 45.

Table 45. Peak values of the Bucao HEC-HMS Model outflow using the Zambales RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	286.74	36.1	4121.6	4 hours, 40 min
10-Year	335.485	42.6	5152.9	4 hours, 20 min
25-Year	403.072	50.7	6458	4 hours, 10 min
50-Year	451.456	56.8	8080	4 hours
100-Year	499.306	62.8	8397.9	4 hours

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

The river discharge values for the nine rivers entering the floodplain are shown in Figure 64 to Figure 72 and the peak values are summarized in Table 46 to Table 54.

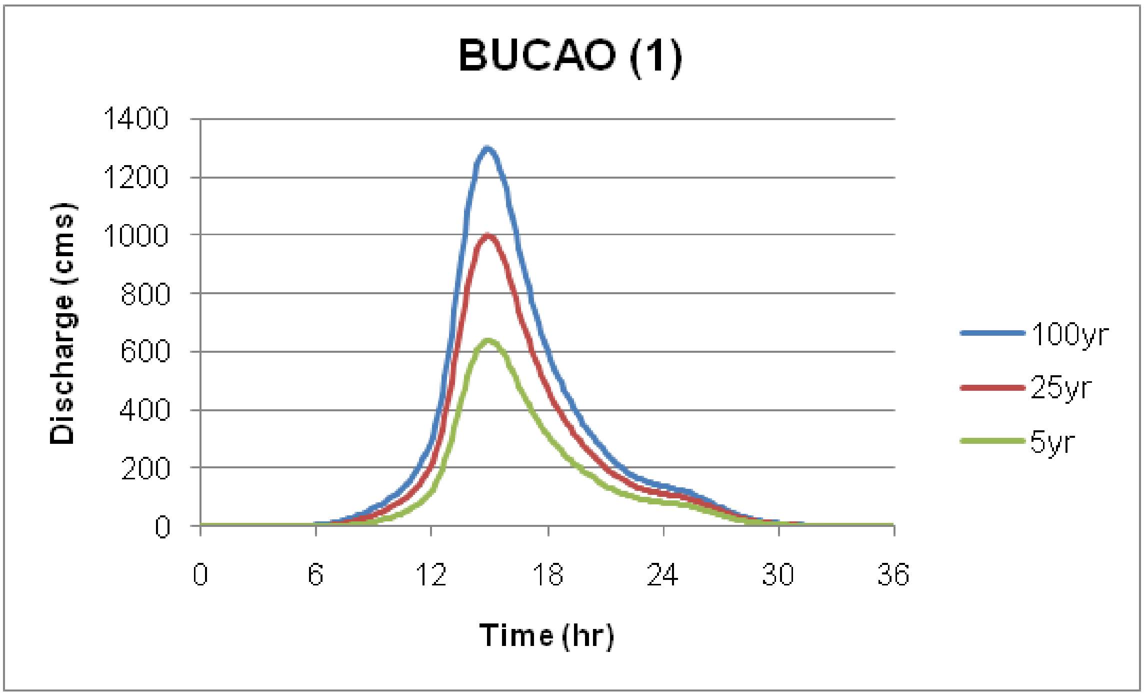


Figure 64. Bucao river (1) generated discharge using 5-, 25-, and 100-year Iba rainfall intensity-duration-frequency (RIDF) in HEC-HMS

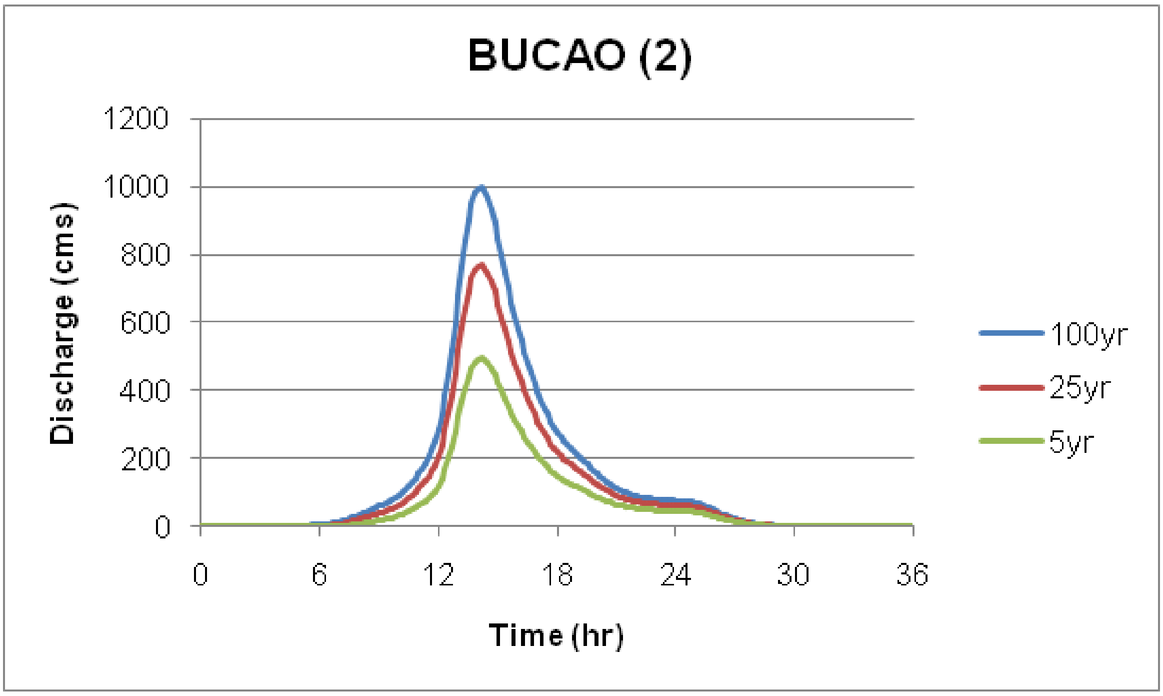


Figure 65. Bucao river (2) generated discharge using 5-, 25-, and 100-year Iba rainfall intensity-duration-frequency (RIDF) in HEC-HMS

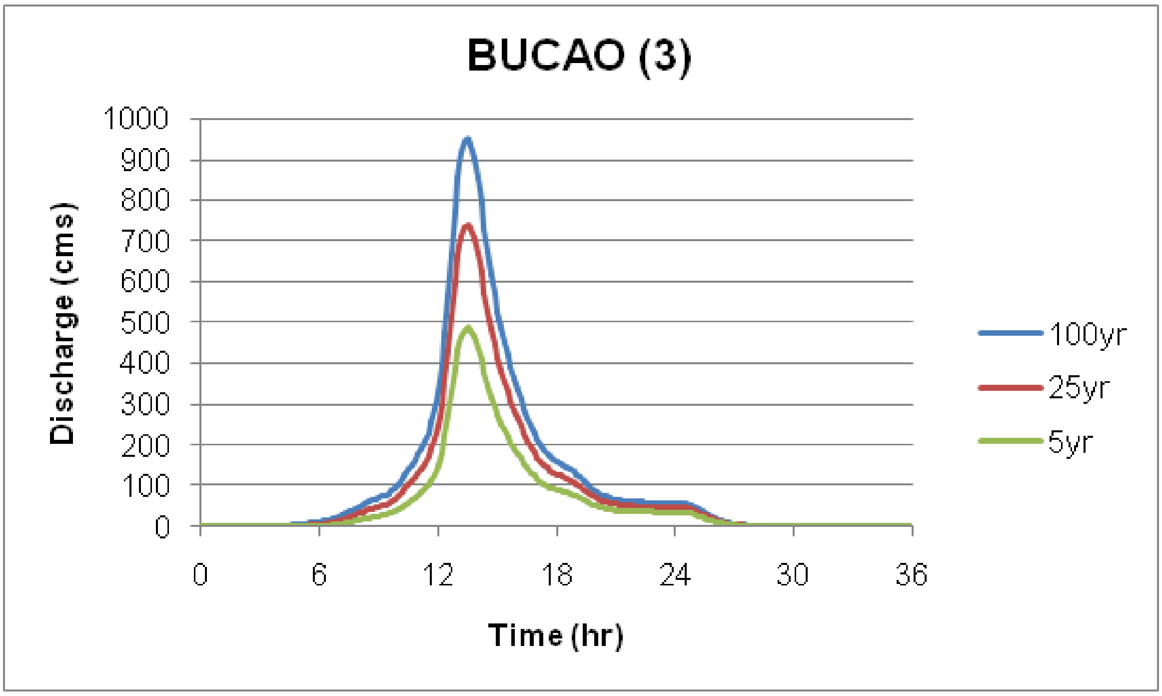


Figure 66. Bucao river (3) generated discharge using 5-, 25-, and 100-year Iba rainfall intensity-duration-frequency (RIDF) in HEC-HMS

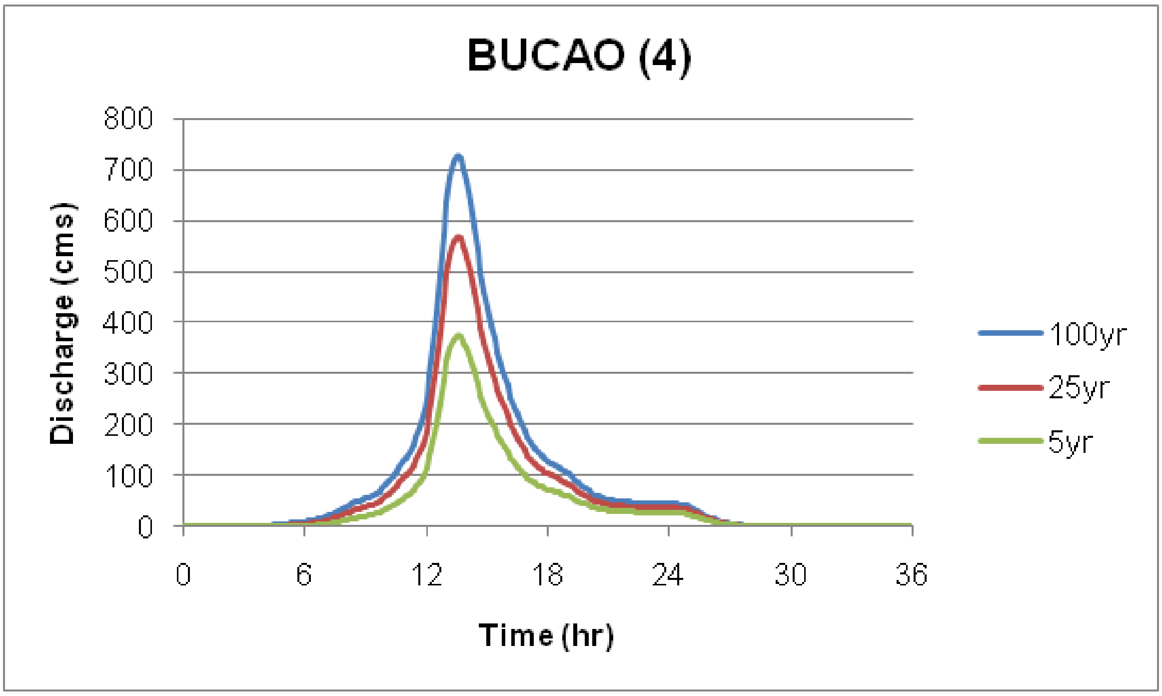


Figure 67. Bucao river (4) generated discharge using 5-, 25-, and 100-year Iba rainfall intensity-duration-frequency (RIDF) in HEC-HMS

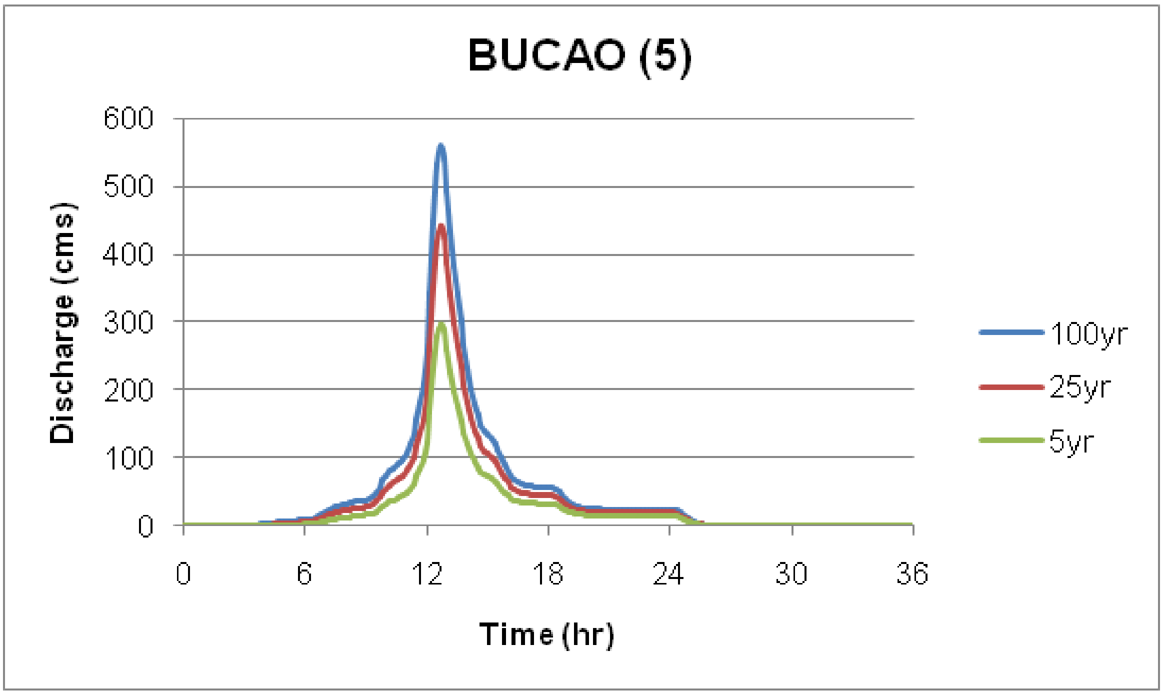


Figure 68. Bucao river (5) generated discharge using 5-, 25-, and 100-year Iba rainfall intensity-duration-frequency (RIDF) in HEC-HMS

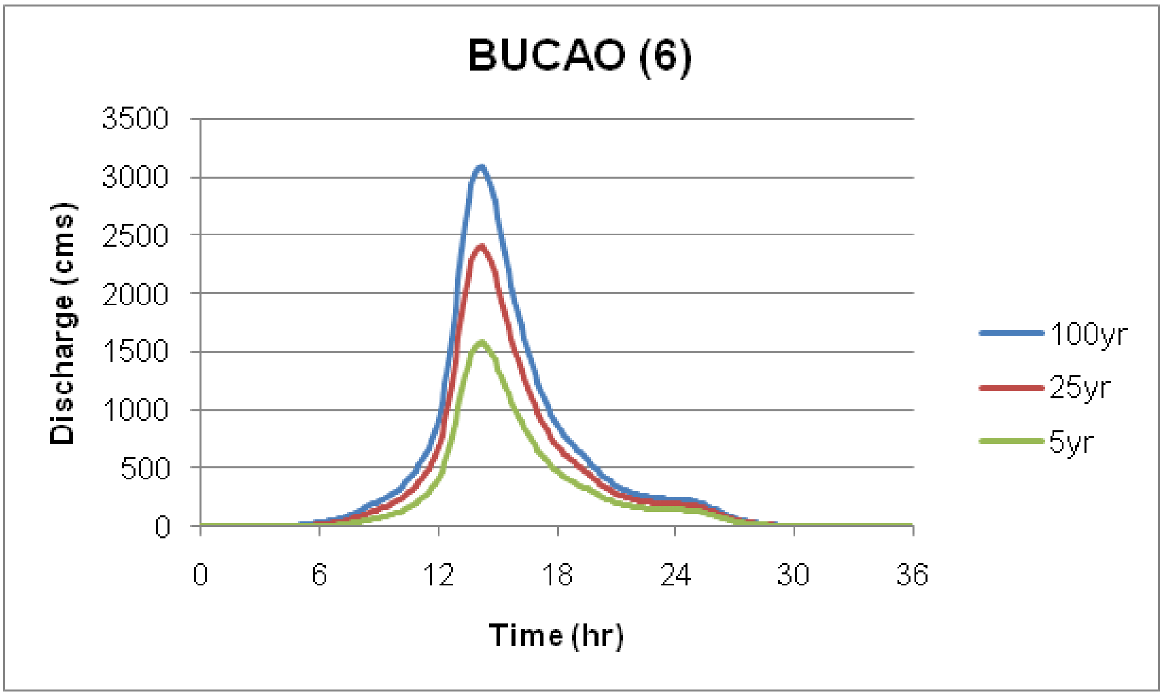


Figure 69. Bucao river (6) generated discharge using 5-, 25-, and 100-year Iba rainfall intensity-duration-frequency (RIDF) in HEC-HMS

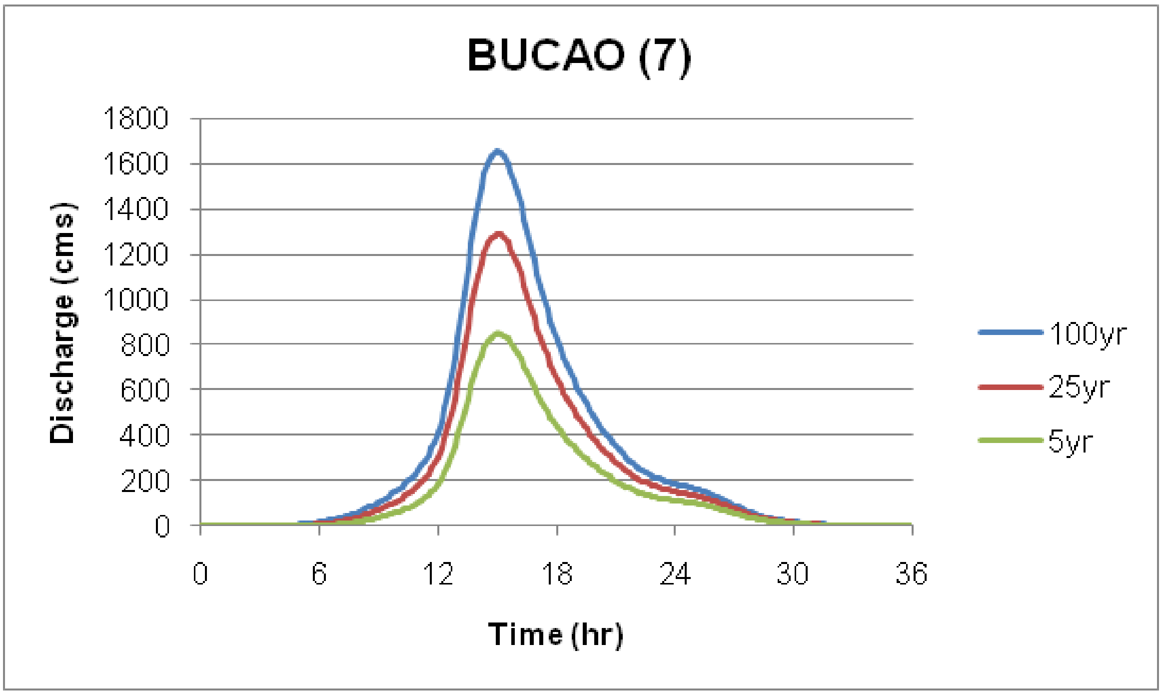


Figure 70. Bucao river (7) generated discharge using 5-, 25-, and 100-year Iba rainfall intensity-duration-frequency (RIDF) in HEC-HMS

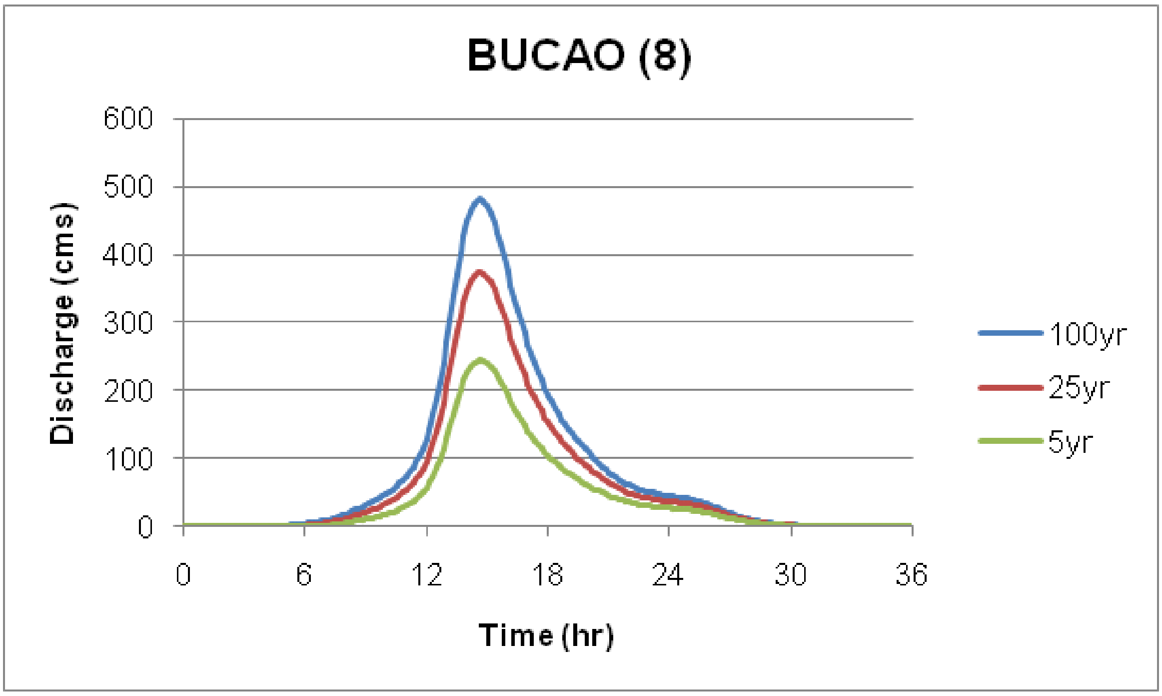


Figure 71. Bucao river (8) generated discharge using 5-, 25-, and 100-year Iba rainfall intensity-duration-frequency (RIDF) in HEC-HMS

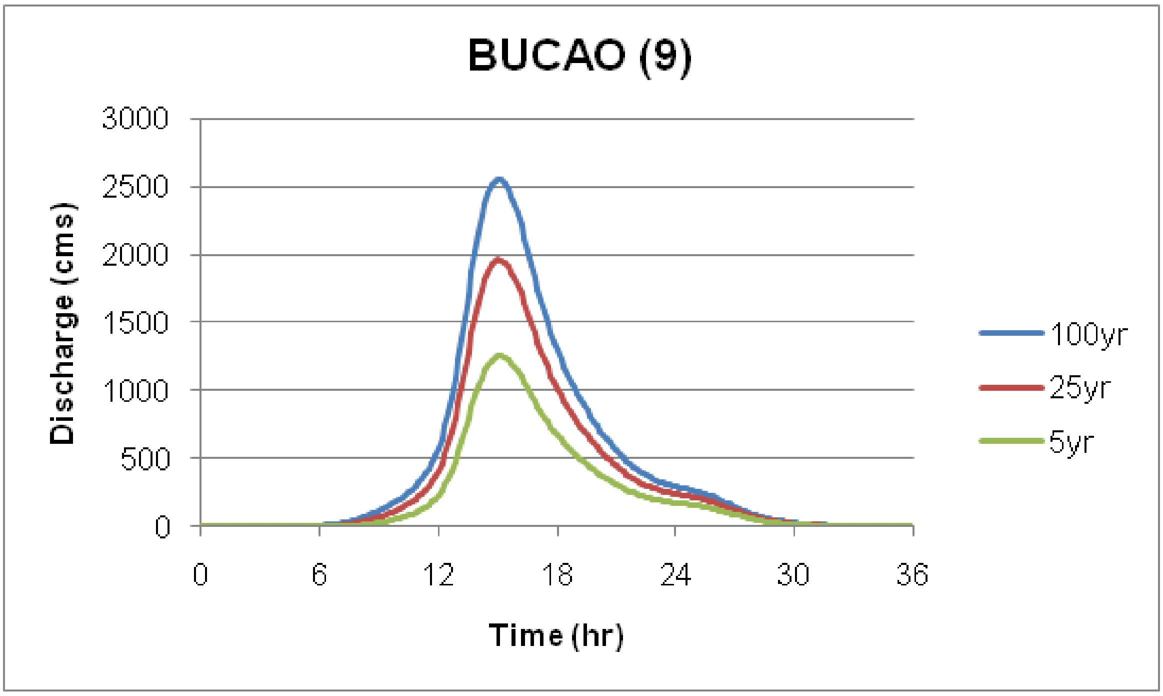


Figure 72. Bucao river (9) generated discharge using 5-, 25-, and 100-year Iba rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 46. Summary of Bucao river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1296.7	14 hours, 50 minutes
25-Year	997.8	14 hours, 50 minutes
5-Year	638.4	14 hours, 50 minutes

Table 47. Summary of Bucao river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	997.1	14 hours, 10 minutes
25-Year	769.2	14 hours, 10 minutes
5-Year	494.3	14 hours, 10 minutes

Table 48. Summary of Bucao river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	948.9	13 hours, 30 minutes
25-Year	739.9	13 hours, 30 minutes
5-Year	486.1	13 hours, 30 minutes

Table 49. Summary of Bucao river (4) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	725.6	13 hours, 30 minutes
25-Year	566.4	13 hours, 30 minutes
5-Year	373.1	13 hours, 30 minutes

Table 50. Summary of Bucao river (5) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	560.1	12 hours, 40 minutes
25-Year	441.5	12 hours, 40 minutes
5-Year	296.8	12 hours, 40 minutes

Table 51. Summary of Bucao river (6) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	3090.3	14 hours, 10 minutes
25-Year	2405.1	14 hours, 10 minutes
5-Year	1574.8	14 hours, 10 minutes

Table 52. Summary of Bucao river (7) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1654.8	15 hours
25-Year	1290.6	15 hours
5-Year	849.5	15 hours

Table 53. Summary of Bucao river (8) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	481.6	14 hours, 40 minutes
25-Year	374.6	14 hours, 40 minutes
5-Year	245.2	14 hours, 40 minutes

Table 54. Summary of Bucao river (9) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	2552.8	15 hours
25-Year	1961.1	15 hours
5-Year	1251	15 hours, 10 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 55.

Table 55. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Bucao (1)	561.792	567.447	491.665	Pass	Pass
Bucao (2)	434.984	884.826	367.472	Fail	Pass
Bucao (3)	427.768	175.612	307.973	Fail	Pass
Bucao (4)	328.328	726.403	257.753	Fail	Pass
Bucao (5)	261.184	519.433	162.072	Pass	Fail
Bucao (6)	1385.824	647.059	750.530	Fail	Fail
Bucao (7)	747.560	658.107	570.944	Pass	Pass
Bucao (8)	215.776	213.071	235.348	Pass	Pass
Bucao (9)	1100.880	723.699	769.590	Fail	Pass

Eight out of nine of the results from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods. One did not pass and will need further recalculation. The eight passing values are based on theory but is 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 HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown, since only the Bucao river base flow was calibrated. The sample generated map of Bucao River using the calibrated HMS flow is shown in Figure 73.

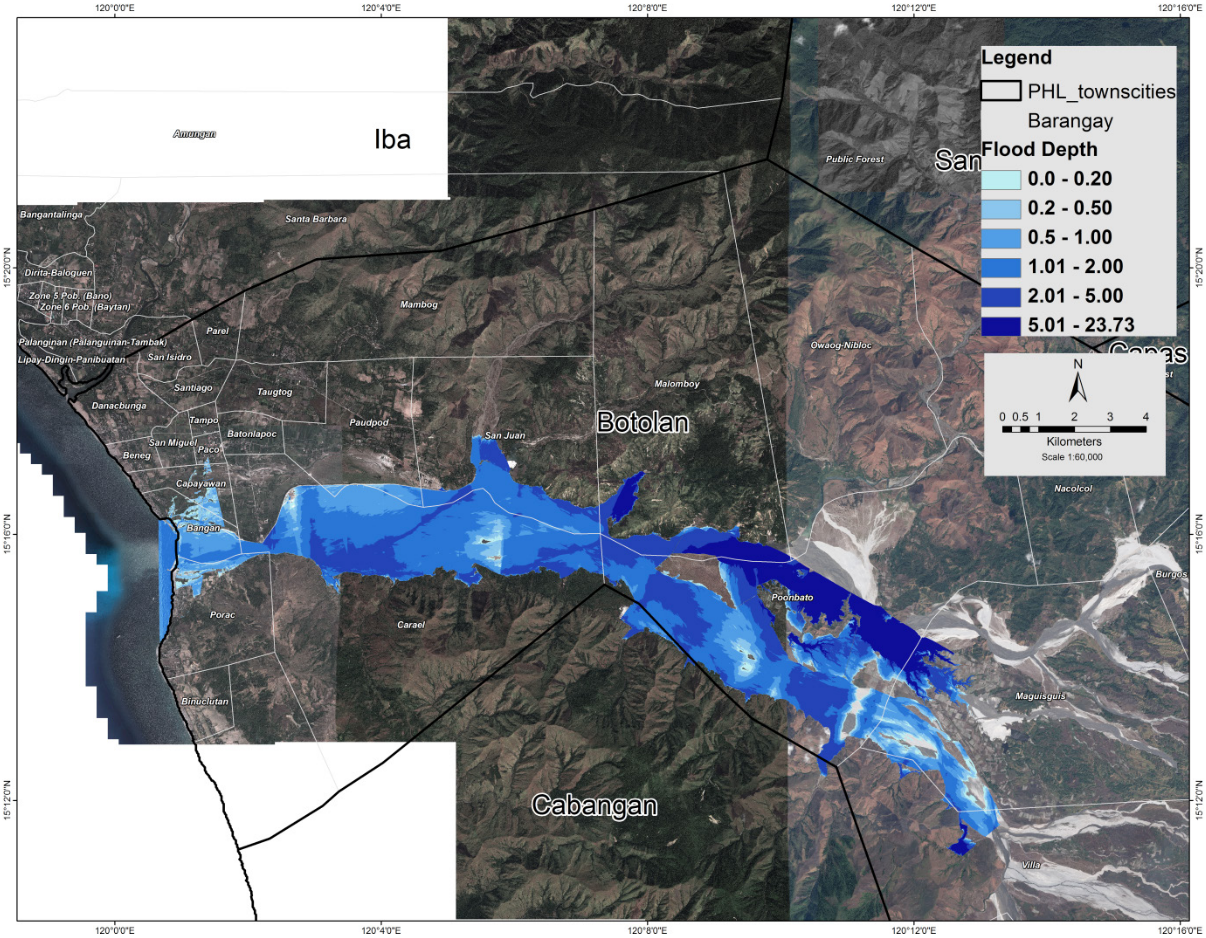


Figure 73. Sample output of Bucao RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 25 to Figure 30 shows the 5-, 25-, and 100-year rain return scenarios of the Bucao floodplain. The floodplain, with an area of 245.70 sq. km., covers four municipalities namely Botolan, Cabangan and Iba. Table 56 shows the percentage of area affected by flooding per municipality.

Table 56. Municipalities affected in Bucao floodplain

Municipality	Total Area	Area Flooded	% Flooded
Botolan	649.68	190.46	29%
Cabangan	231.28	31.00	13%
Iba	219.10	24.24	11%

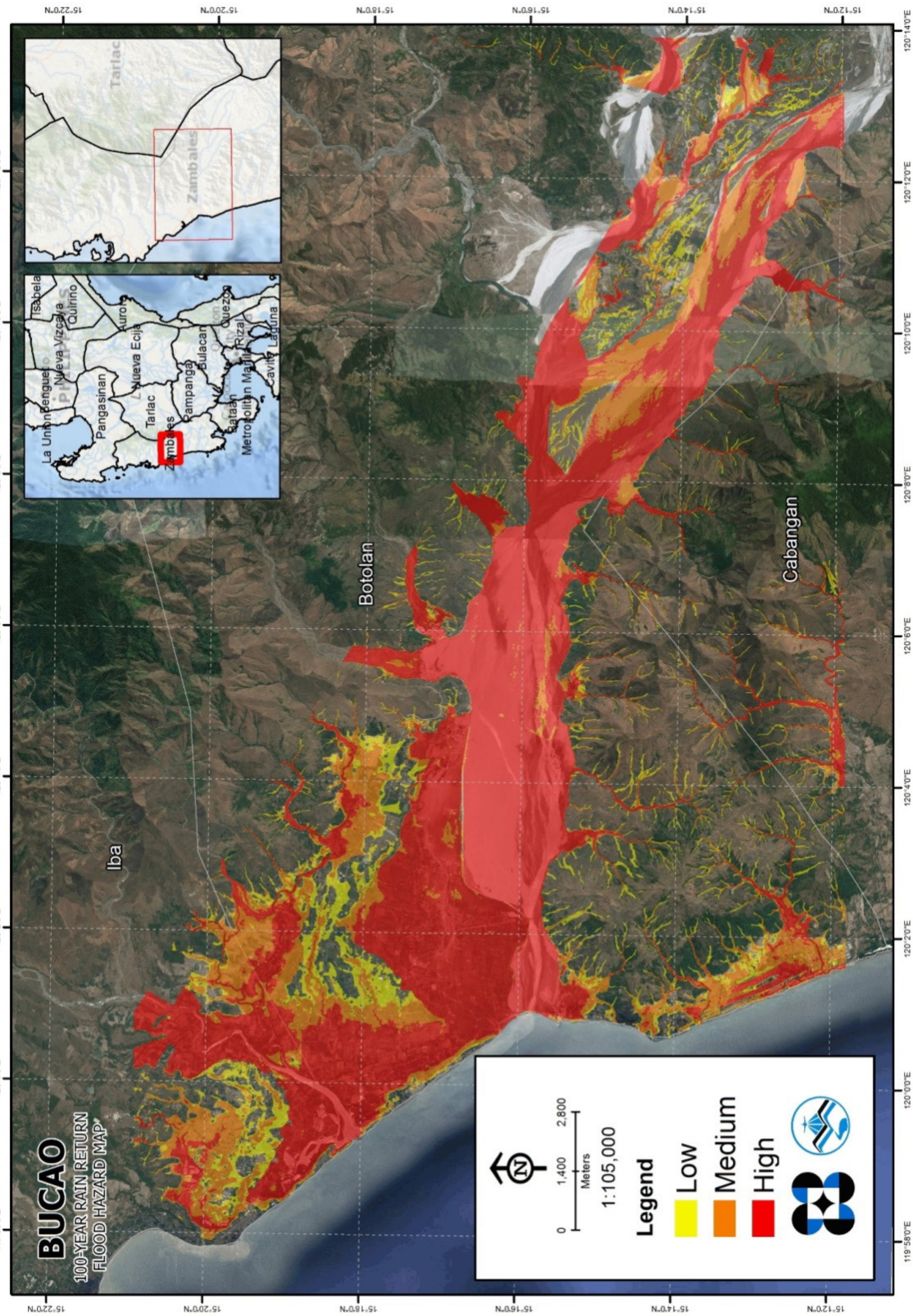


Figure 74. 100-year Flood Hazard Map for Bucao Floodplain

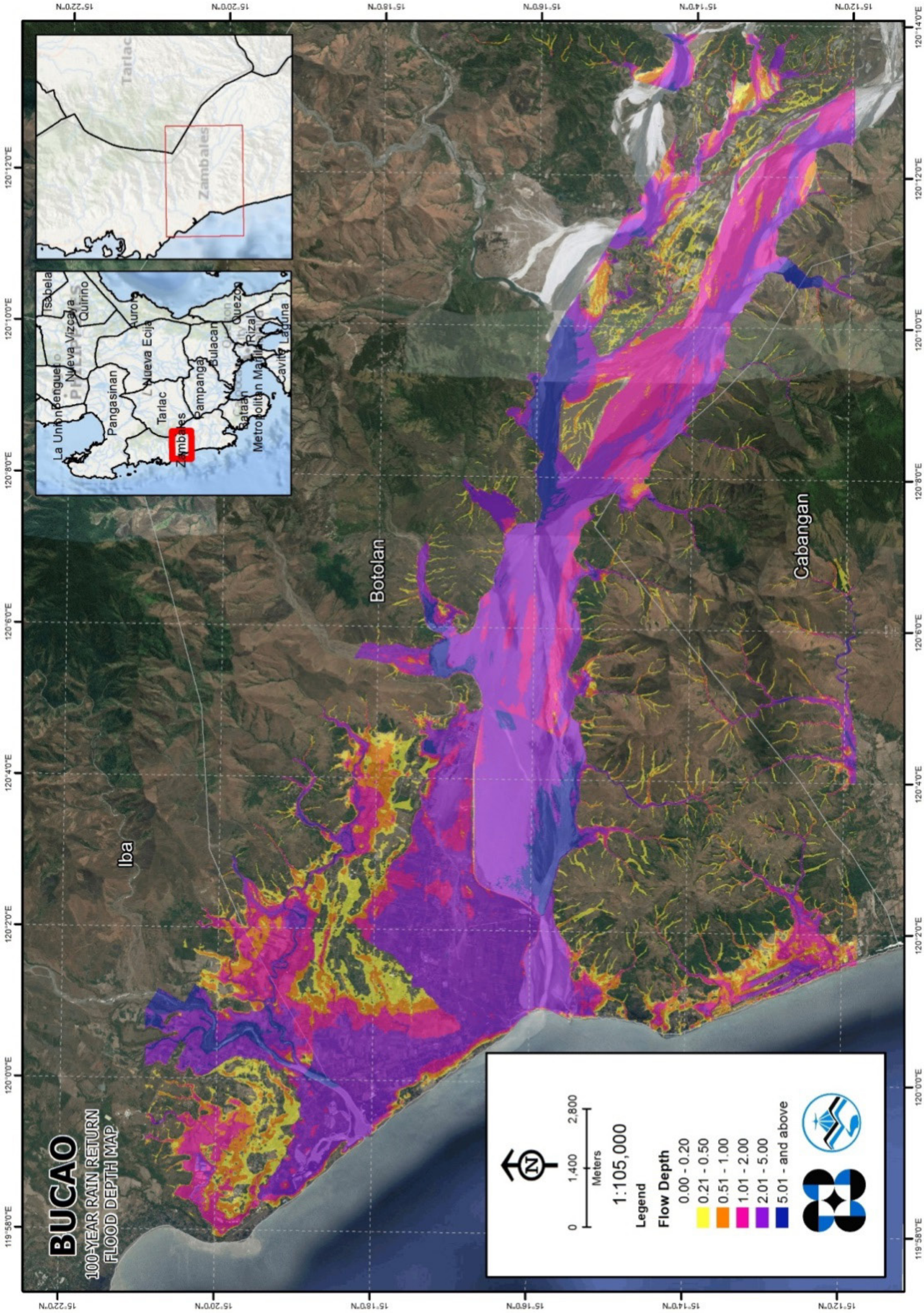


Figure 75. 100-year Flow Depth Map for Bucao Floodplain

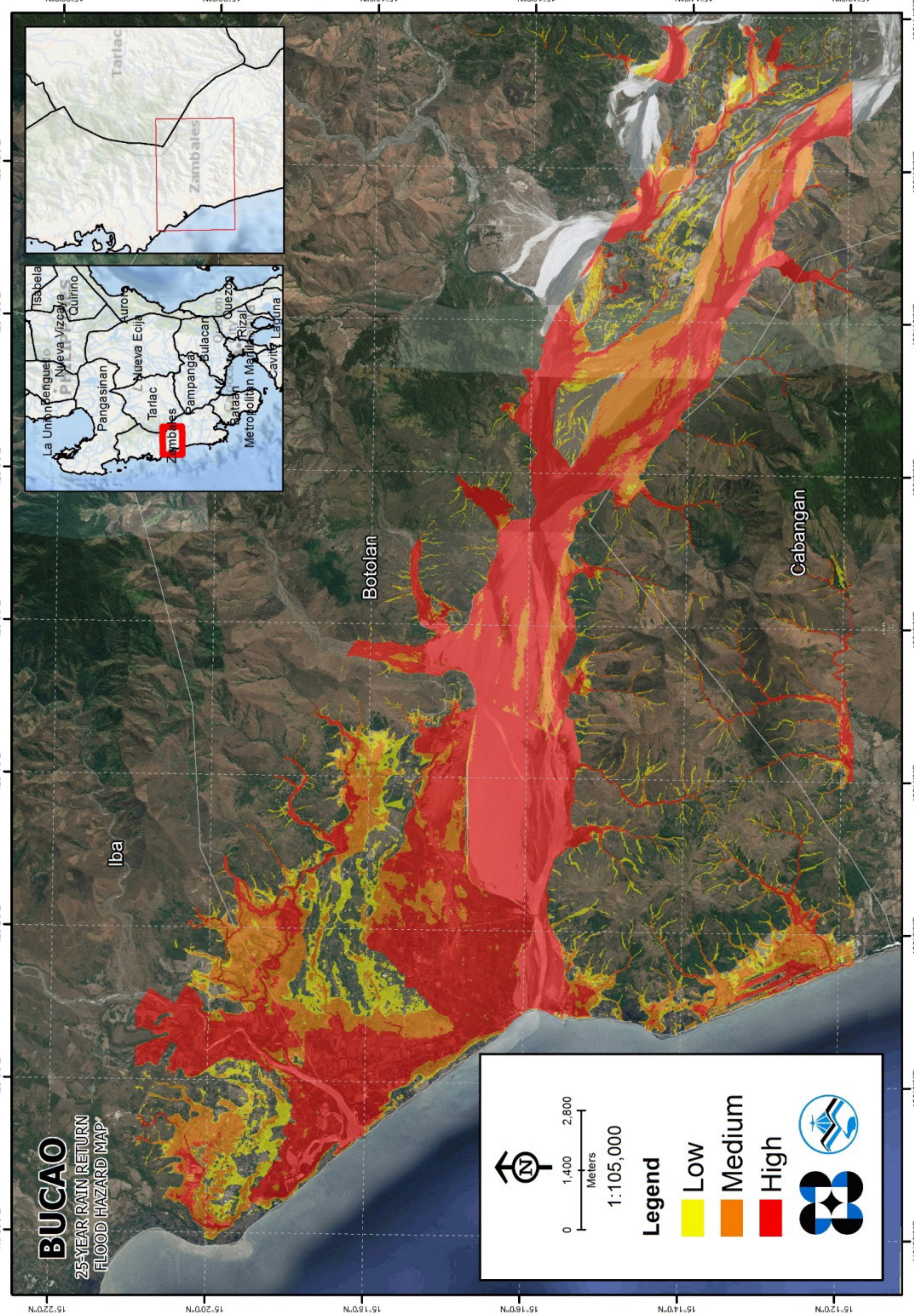


Figure 76. 25-year Flood Hazard Map for Bucao Floodplain

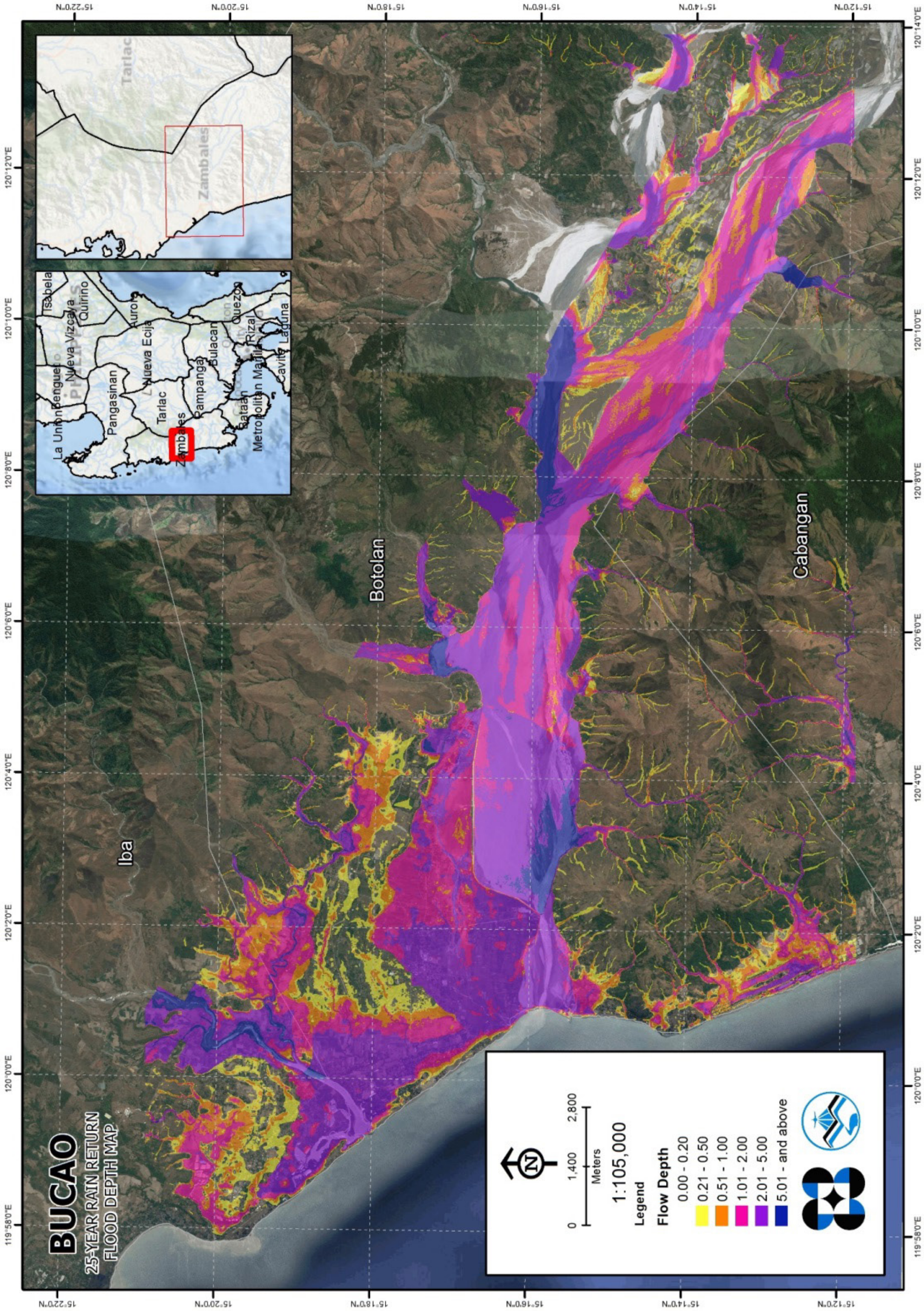


Figure 77. 25-year Flow Depth Map for Bucao Floodplain

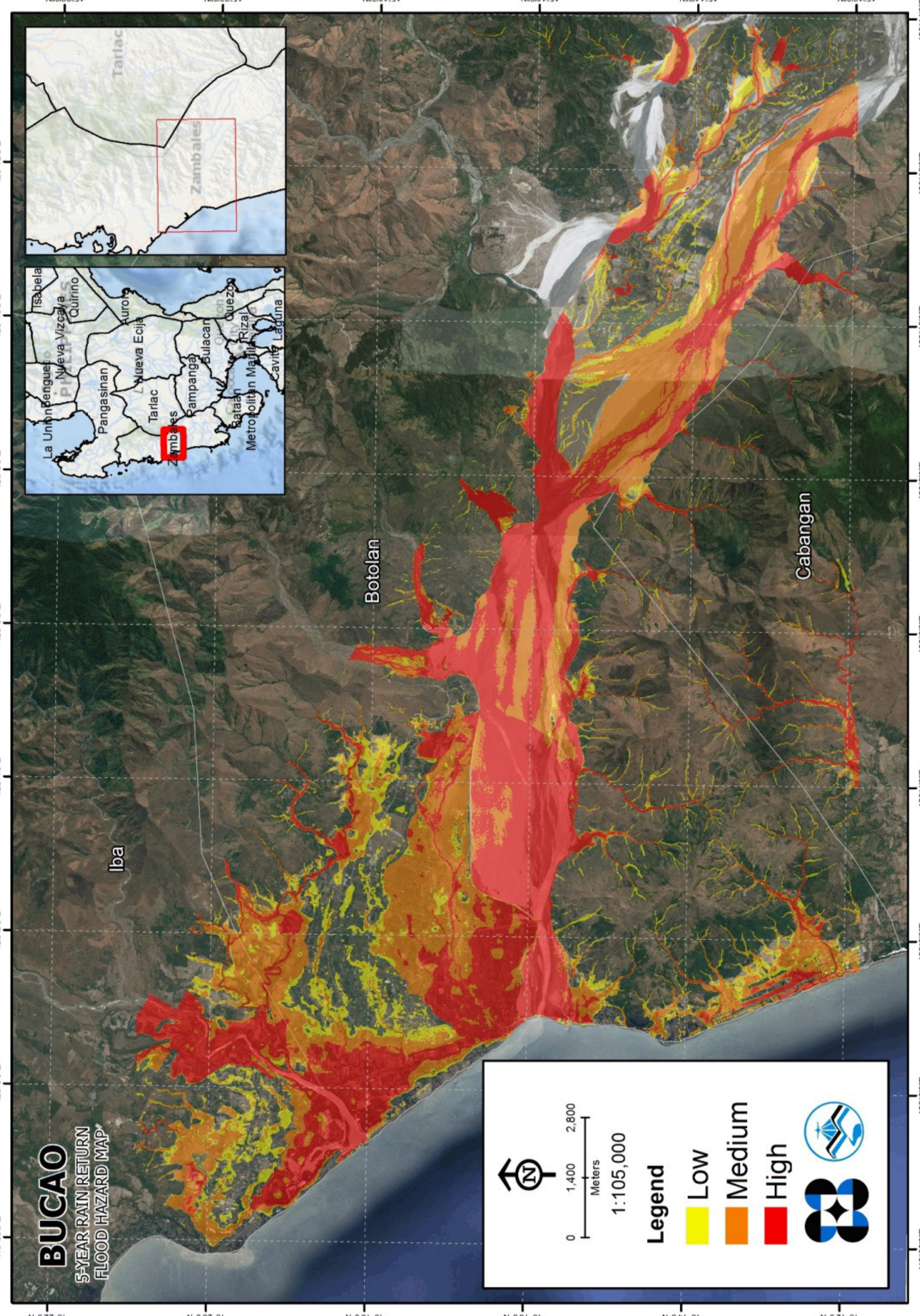


Figure 78. 5-year Flood Hazard Map for Bucao Floodplain

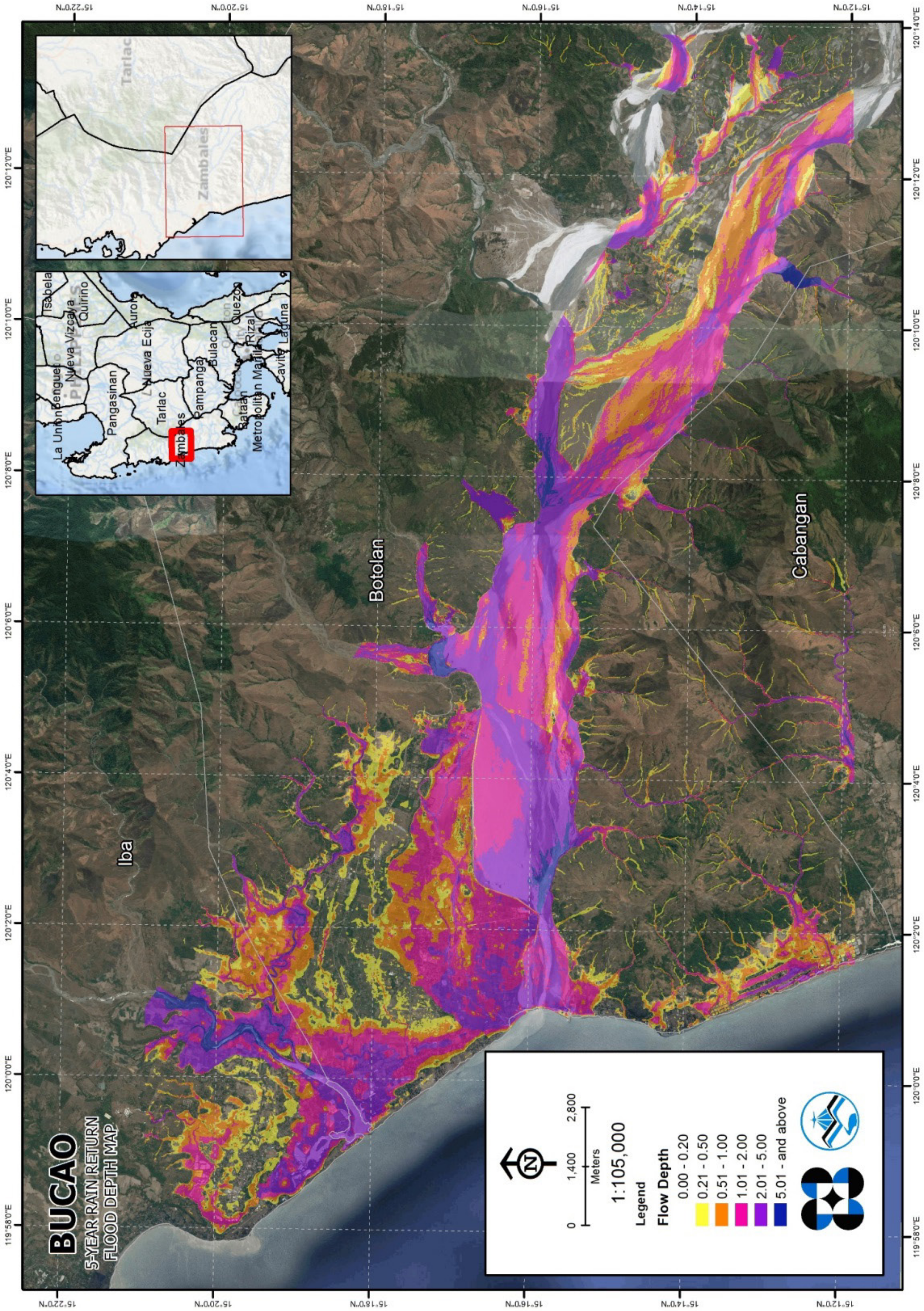


Figure 79. 5-year Flood Depth Map for Bucao Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Bucao river basin, grouped by municipality, are listed below. For the said basin, three municipalities consisting of 41 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period. All educational and health institutions affected by flooding the Bucao floodplain can be found in Annexes 11 and 12, respectively.

For the 5-year return period, 15.22% of the municipality of Botolan with an area of 649.679259 sq. km. will experience flood levels of less than 0.20 meters. 2.04% of the area will experience flood levels of 0.21 to 0.50 meters while 3.08%, 5.00%, 3.74%, 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 57. Affected Areas in Botolan, Zambales during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Botolan (in sq. km)												
	Bancal	Bangan	Batonl-apoc	Beneg	Binuclu-tan	Capay-awan	Carael	Danac-bunga	Maguis-guis	Malom-boy	Mam-bog	Nacolcol	Owaog-Nibloc
0.03-0.20	0	0.11	0.057	0.25	1.34	0.17	28.83	0.36	10.55	4.08	6.01	0.66	0.00077
0.21-0.50	0	0.032	0.11	0.093	0.42	0.073	1.67	0.16	1.36	0.21	0.7	0.037	0.0036
0.51-1.00	0.0037	0.09	1.06	0.21	0.45	0.19	2.65	0.17	2.62	0.15	0.71	0.011	0.00092
1.01-2.00	0.5	0.99	0.65	0.31	0.29	1.03	9.38	0.85	2.36	0.27	0.6	0.0053	0.00045
2.01-5.00	0.82	1.68	0.035	0.12	0.041	1.06	8.31	0.93	0.93	2.52	0.47	0.00058	0.000022
> 5.00	0	0	0	0	0	0	0.58	0	0	0.33	0.038	0	0

Table 58. Affected Areas in Botolan, Zambales during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Botolan (in sq. km)												
	Paco	Panan	Parel	Paudpod	Poonba-to	Porac	San Isidro	San Juan	San Miguel	Santiago	Tampo	Taugtog	Villar
0.03-0.20	0.032	7.59	0.31	3.13	11.49	6.12	0.38	9.35	0.58	1.32	0.44	2.76	2.95
0.21-0.50	0.0021	0.82	0.22	1.34	2.37	0.71	0.45	0.56	0.42	0.4	0.12	0.85	0.11
0.51-1.00	0.093	1.03	0.91	2.09	5.18	0.54	0.5	0.55	0.11	0.13	0.066	0.37	0.11
1.01-2.00	0.43	0.8	0.31	3.16	6.77	0.86	0.48	2.09	0.07	0.14	0.00088	0.1	0.037
2.01-5.00	0.091	0.31	0.067	0.64	2.65	0.16	0.015	3.16	0.13	0.01	0	0.13	0.0073
> 5.00	0	0	0.032	0.014	0.22	0	0	0.35	0	0	0	0.016	0

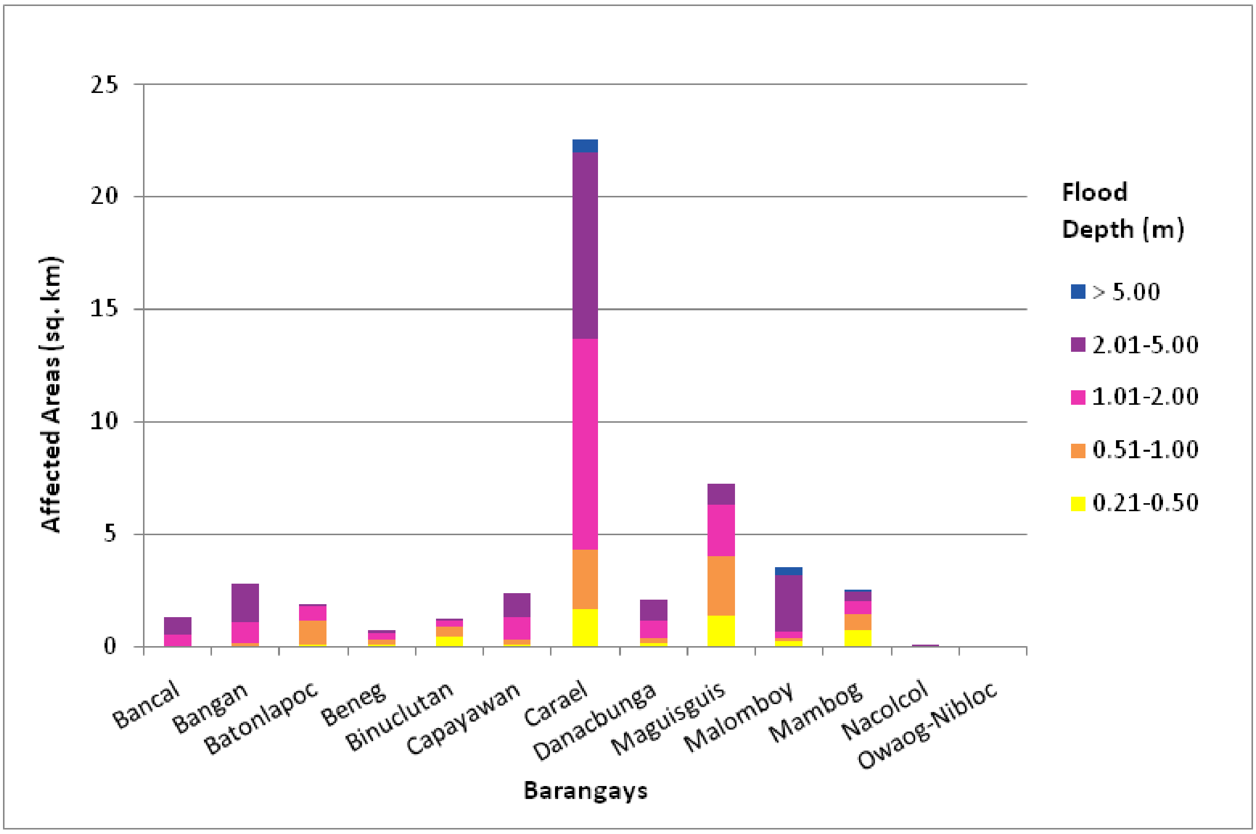


Figure 80. Affected Areas in Botolan, Zambales during 5-Year Rainfall Return Period

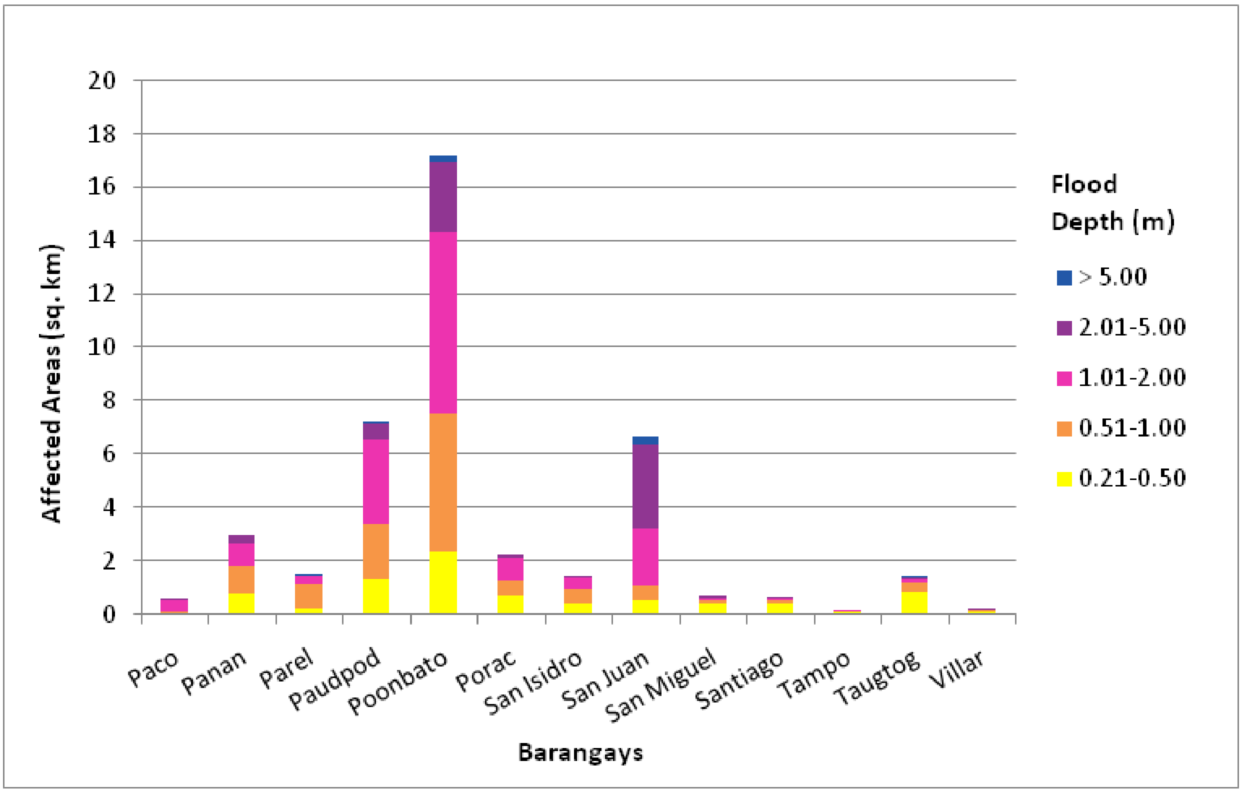


Figure 81. Affected Areas in Botolan, Zambales during 5-Year Rainfall Return Period

For the 5-year return period, 11.94% of the municipality of Cabangan with an area of 231.275832 sq. km. will experience flood levels of less than 0.20 meters. 0.44% of the area will experience flood levels of 0.21 to 0.50 meters while 0.31%, 0.36%, 0.29%, 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 59. Affected Areas in Cabangan, Zambales during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cabangan (in sq. km)		
	Cadmang-Reserva	Mabanglit	San Rafael
0.03-0.20	26.39	1.21	0.023
0.21-0.50	0.98	0.038	0.0000047
0.51-1.00	0.69	0.03	0
1.01-2.00	0.82	0.014	0
2.01-5.00	0.67	0.0035	0
> 5.00	0.13	0	0

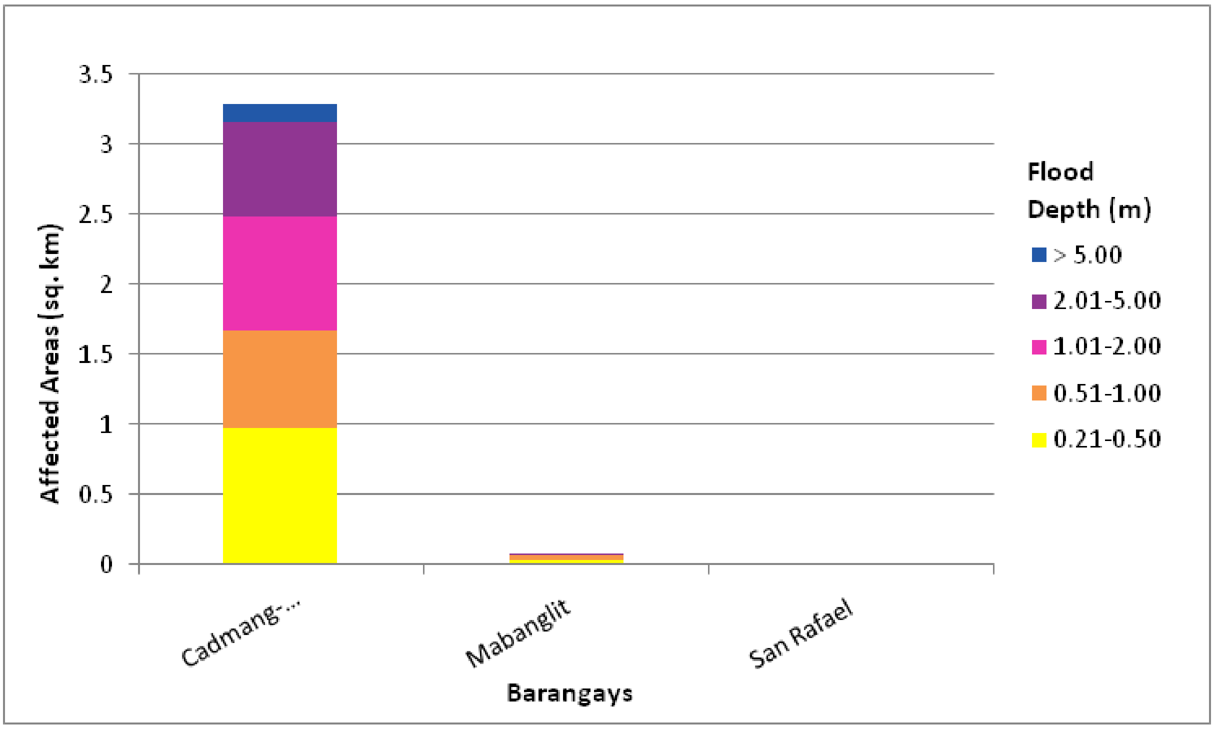


Figure 82. Affected Areas in Cabangan, Zambales during 5-Year Rainfall Return Period

For the 5-year return period, 4.23% of the municipality of Iba with an area of 219.08328 sq. km. will experience flood levels of less than 0.20 meters. 1.25% of the area will experience flood levels of 0.21 to 0.50 meters while 1.47%, 1.66%, 2.05%, and 0.42% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 60. Affected Areas in Iba, Zambales during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Iba (in sq. km)											
	Bangan-talinga	Dirita-Baloguen	Lipay-Dingin-Panibuatan	Palangi-nan	Santa Barbara	Santo Rosario	Zone 1 Poblacion	Zone 2 Poblacion	Zone 3 Poblacion	Zone 4 Poblacion	Zone 5 Poblacion	Zone 6 Poblacion
0.03-0.20	1.69	0.5	0.36	0.43	4.8	0.31	0.13	0.27	0.25	0.16	0.12	0.24
0.21-0.50	0.2	0.35	0.17	0.27	1.03	0.12	0.027	0.061	0.074	0.13	0.17	0.14
0.51-1.00	0.42	0.65	0.14	0.44	1.27	0.16	0.024	0.017	0.0041	0.01	0.062	0.018
1.01-2.00	0.48	0.33	0.22	1.28	1.09	0.23	0	0	0	0	0	0
2.01-5.00	0.032	0	0.65	1.45	2.35	0	0	0	0	0	0	0
> 5.00	0	0	0	0.11	0.8	0	0	0	0	0	0	0

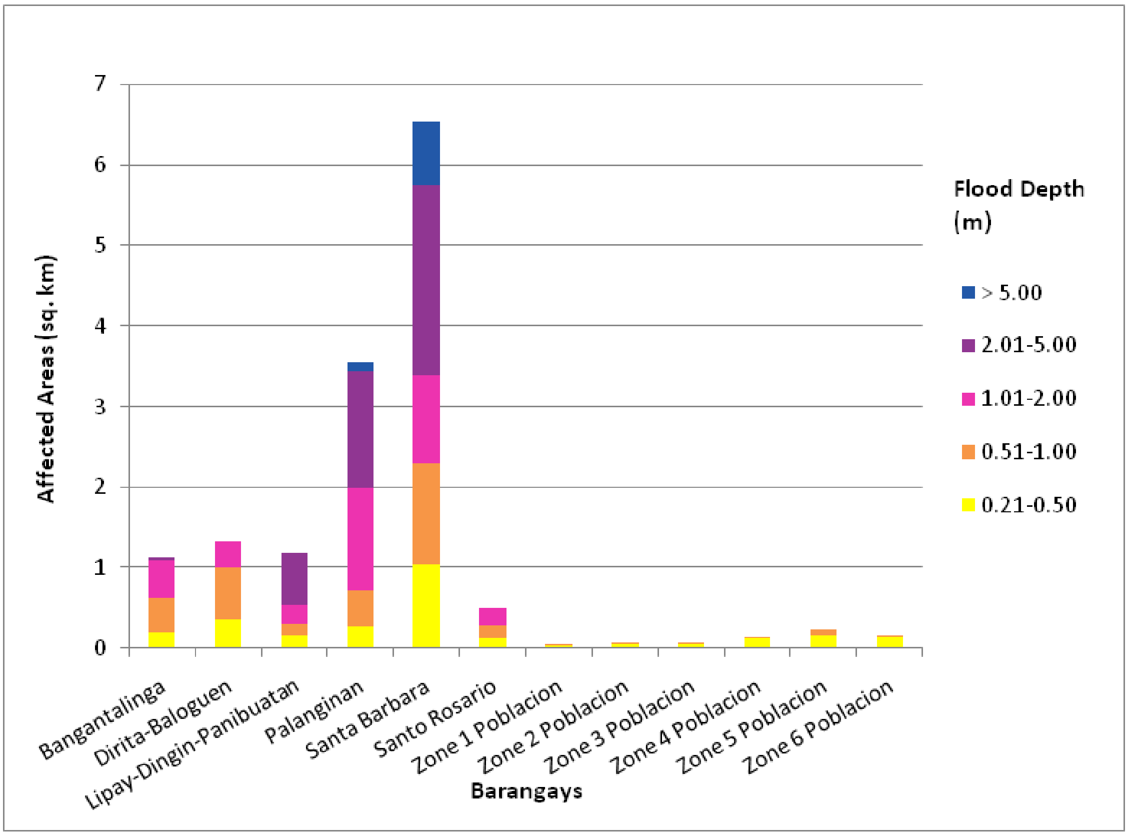


Figure 83. Affected Areas in Iba, Zambales during 5-Year Rainfall Return Period

For the 25-year return period, 14.03% of the municipality of Botolan with an area of 649.679259 sq. km. will experience flood levels of less than 0.20 meters. 1.83% of the area will experience flood levels of 0.21 to 0.50 meters while 1.94%, 4.77%, 5.96%, and 0.78% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 61. Affected Areas in Botolan, Zambales during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Botolan (in sq. km)												
	Bancal	Bangan	Batonl-apoc	Beneg	Binuclu-tan	Capay-awan	Carael	Danac-bunga	Maguis-guis	Malom-boy	Mam-bog	Nacolcol	Owaog-Nibloc
0.03-0.20	0	0.066	0.05	0.11	1.15	0.087	28.05	0.2	9.89	3.83	5.61	0.65	0
0.21-0.50	0	0.023	0.0057	0.059	0.38	0.023	1.62	0.067	1.19	0.21	0.7	0.042	0
0.51-1.00	0	0.053	0.0023	0.092	0.52	0.057	1	0.16	1.49	0.1	0.75	0.013	0
1.01-2.00	0.0061	0.32	1.06	0.36	0.37	0.3	5.61	0.35	3.6	0.2	0.79	0.0077	0.0043
2.01-5.00	1.32	2.43	0.8	0.35	0.11	2.05	13.38	1.68	1.64	1.05	0.61	0.0018	0.0014
> 5.00	0.000074	0	0	0	0	0	1.76	0	0.011	2.16	0.077	0	0

Table 62. Affected Areas in Botolan, Zambales during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Botolan (in sq. km)												
	Paco	Panan	Parel	Paudpod	Poonba-to	Porac	San Isidro	San Juan	San Miguel	Santiago	Tampo	Taugtog	Villar
0.03-0.20	0.03	7.28	0.21	2.5	10.13	5.79	0.12	9.02	0.19	0.9	0.28	2.11	2.92
0.21-0.50	0.0029	0.76	0.17	0.92	1.87	0.78	0.31	0.62	0.29	0.49	0.26	1	0.08
0.51-1.00	0	0.91	0.44	1.38	3.13	0.6	0.37	0.36	0.28	0.22	0.037	0.47	0.14
1.01-2.00	0.0064	1.06	0.91	3.72	8.32	0.74	0.63	1.47	0.36	0.26	0.014	0.49	0.055
2.01-5.00	0.61	0.54	0.08	1.78	4.79	0.48	0.38	4.13	0.19	0.13	0.035	0.15	0.021
> 5.00	0	0	0.037	0.077	0.43	0	0	0.47	0	0	0	0.017	0

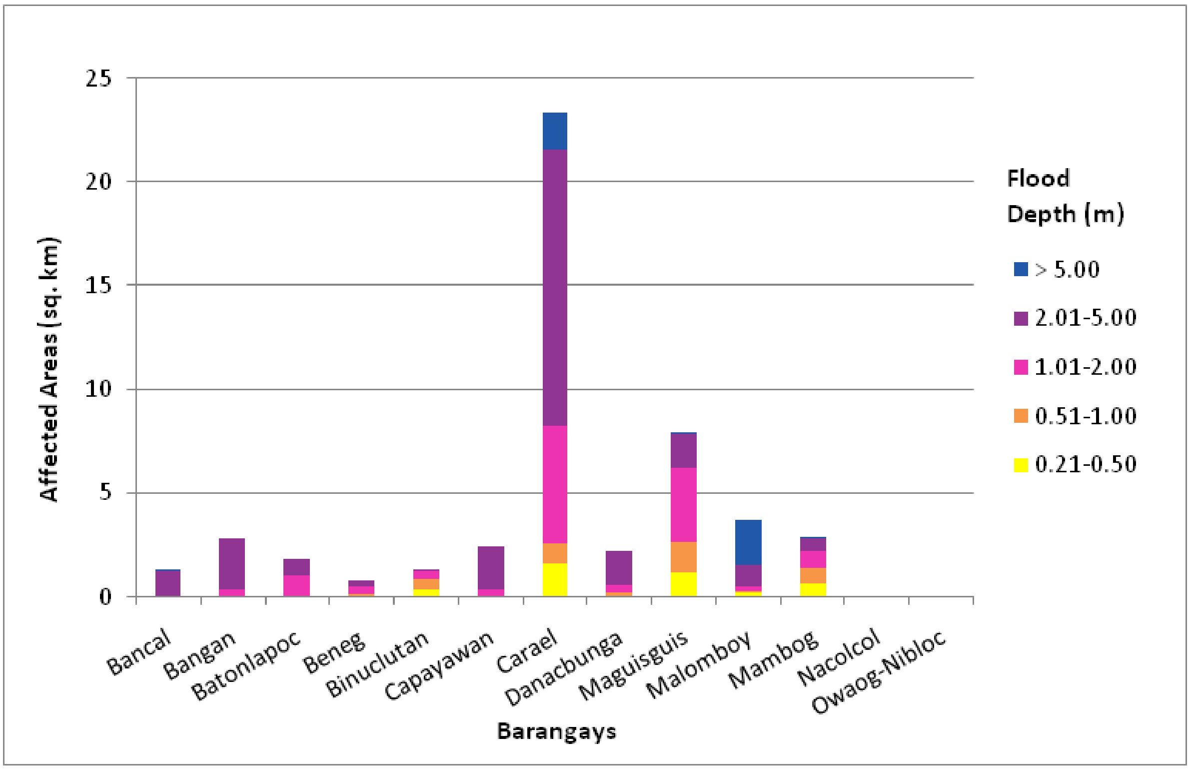


Figure 84. Affected Areas in Botolan, Zambales during 25-Year Rainfall Return Period

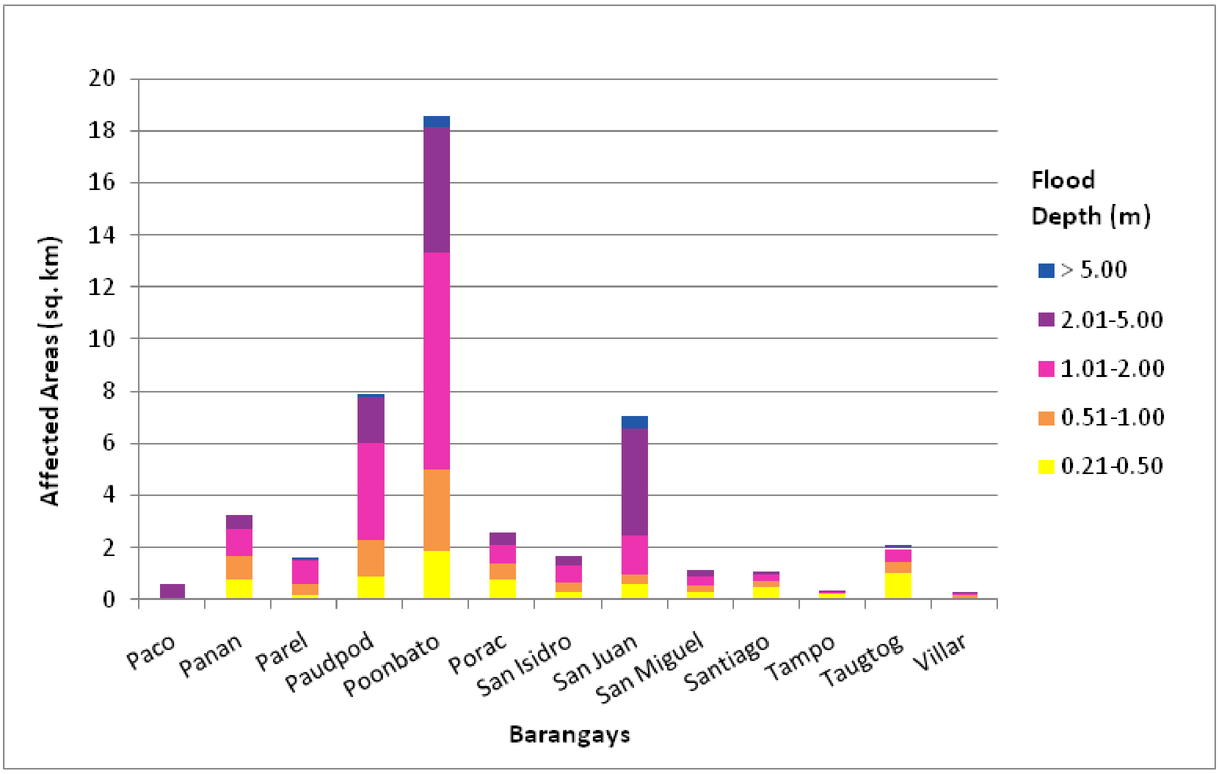


Figure 85. Affected Areas in Botolan, Zambales during 25-Year Rainfall Return Period

For the 25-year return period, 11.72% of the municipality of Cabangan with an area of 231.275832 sq. km. will experience flood levels of less than 0.20 meters. 0.48% of the area will experience flood levels of 0.21 to 0.50 meters while 0.31%, 0.40%, 0.41%, 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 63 . Affected Areas in Cabangan, Zambales during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cabangan (in sq. km)		
	Cadmang-Reserva	Mabanglit	San Rafael
0.03-0.20	25.9	1.19	0.023
0.21-0.50	1.06	0.051	0.000043
0.51-1.00	0.68	0.027	0
1.01-2.00	0.9	0.022	0
2.01-5.00	0.94	0.0049	0
> 5.00	0.21	0	0

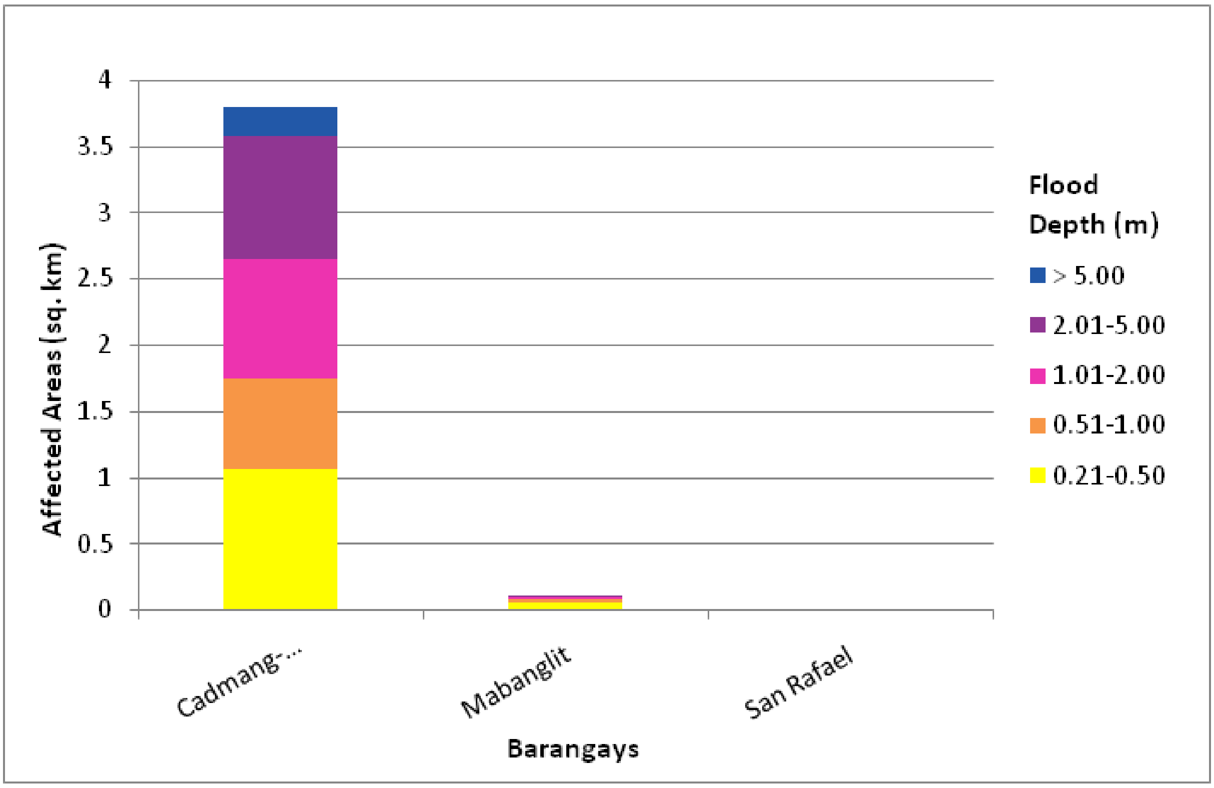


Figure 86. Affected Areas in Cabangan, Zambales during 25-Year Rainfall Return Period

For the 25-year return period, 3.51% of the municipality of Iba with an area of 219.08328 sq. km. will experience flood levels of less than 0.20 meters. 1.25% of the area will experience flood levels of 0.21 to 0.50 meters while 1.25%, 1.78%, 2.69%, and 0.59% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 64. Affected Areas in Iba, Zambales during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Iba (in sq. km)											
	Bangan-talinga	Dirita-Baloguen	Lipay-Dingin-Panibuatan	Palanginan	Santa Barbara	Santo Rosario	Zone 1 Poblacion	Zone 2 Poblacion	Zone 3 Poblacion	Zone 4 Poblacion	Zone 5 Poblacion	Zone 6 Poblacion
0.03-0.20	1.61	0.28	0.26	0.27	4.26	0.21	0.099	0.14	0.21	0.073	0.08	0.19
0.21-0.50	0.16	0.24	0.2	0.28	0.99	0.14	0.046	0.16	0.076	0.17	0.14	0.14
0.51-1.00	0.26	0.65	0.15	0.17	1	0.15	0.025	0.06	0.035	0.048	0.12	0.077
1.01-2.00	0.72	0.65	0.19	0.88	1.1	0.33	0.0083	0.0015	0	0.0005	0.013	0
2.01-5.00	0.063	0.0075	0.75	2.17	2.9	0	0	0	0	0	0	0
> 5.00	0.0029	0	0	0.2	1.08	0	0	0	0	0	0	0

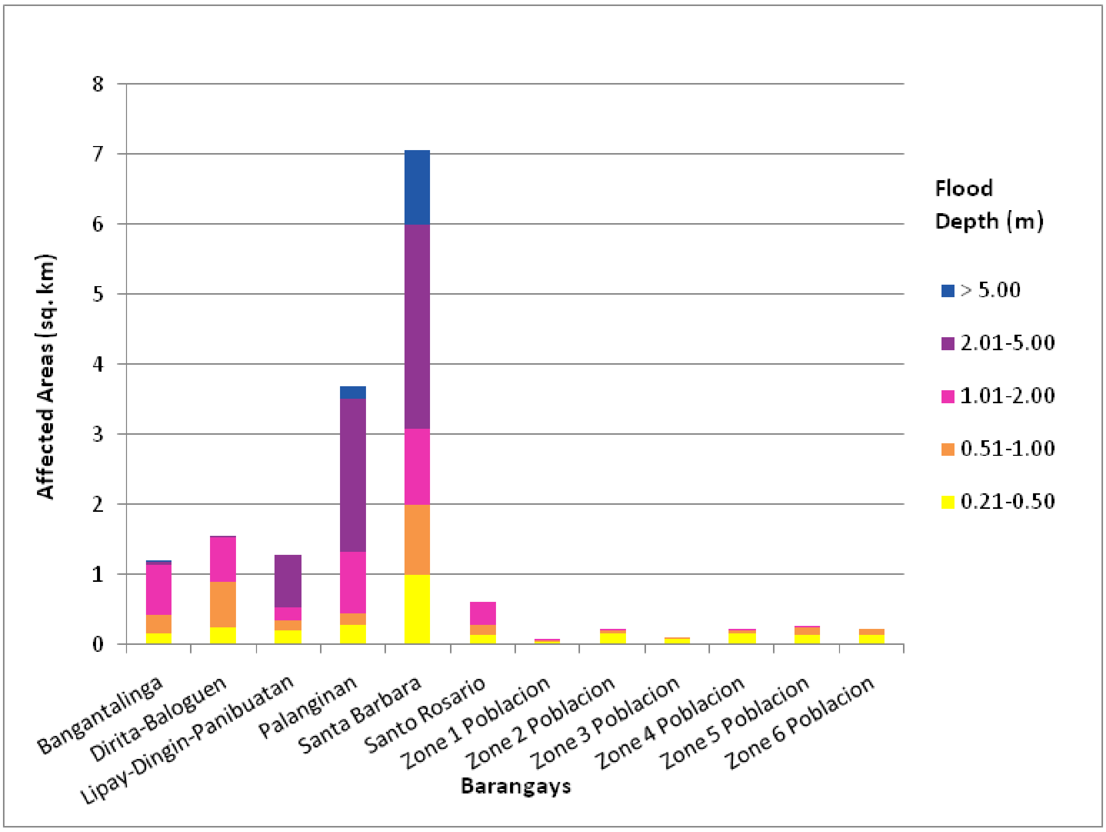


Figure 87. Affected Areas in Iba, Zambales during 25-Year Rainfall Return Period

For the 100-year return period, 13.31% of the municipality of Botolan with an area of 649.679259 sq. km. will experience flood levels of less than 0.20 meters. 1.82% of the area will experience flood levels of 0.21 to 0.50 meters while 1.53%, 3.96%, 7.65%, and 1.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 65. Affected Areas in Botolan, Zambales during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Botolan (in sq. km)												
	Bancal	Bangan	Batonl-apoc	Beneg	Binuclu-tan	Capay-awan	Carael	Danac-bunga	Maguis-guis	Malom-boy	Mam-bog	Nacolcol	Owaog-Nibloc
0.03-0.20	0	0.04	0.046	0.06	1.05	0.053	27.59	0.16	9.47	3.7	5.34	0.64	0
0.21-0.50	0	0.021	0.0092	0.05	0.35	0.029	1.82	0.064	1.16	0.24	0.74	0.042	0
0.51-1.00	0	0.039	0.0003	0.084	0.54	0.033	0.82	0.076	1.18	0.088	0.72	0.017	0
1.01-2.00	0.0001	0.13	0.051	0.27	0.44	0.16	3.37	0.33	3.59	0.15	0.91	0.0089	0
2.01-5.00	1.31	2.67	1.81	0.51	0.16	2.24	15.12	1.84	2.37	1.05	0.71	0.003	0.0048
> 5.00	0.018	0	0	0	0	0.003	2.73	0	0.066	2.32	0.12	0	0.00087

Table 66. Affected Areas in Botolan, Zambales during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Botolan (in sq. km)												
	Paco	Panan	Parel	Paudpod	Poonba-to	Porac	San Isidro	San Juan	San Miguel	Santiago	Tampo	Taugtog	Villar
0.03-0.20	0.019	7.09	0.14	2.19	9.27	5.54	0.063	8.76	0.02	0.62	0.17	1.55	2.9
0.21-0.50	0.014	0.74	0.18	0.82	1.79	0.81	0.16	0.7	0.15	0.47	0.35	1	0.087
0.51-1.00	0	0.81	0.33	1.26	1.32	0.65	0.35	0.33	0.32	0.33	0.061	0.44	0.11
1.01-2.00	0	1.22	1.06	2.17	7.99	0.62	0.65	0.86	0.6	0.35	0.003	0.7	0.087
2.01-5.00	0.62	0.69	0.099	3.82	7.55	0.77	0.61	4.68	0.22	0.23	0.048	0.54	0.034
> 5.00	0.000061	0.0025	0.041	0.12	0.76	0	0	0.74	0	0	0	0.026	0

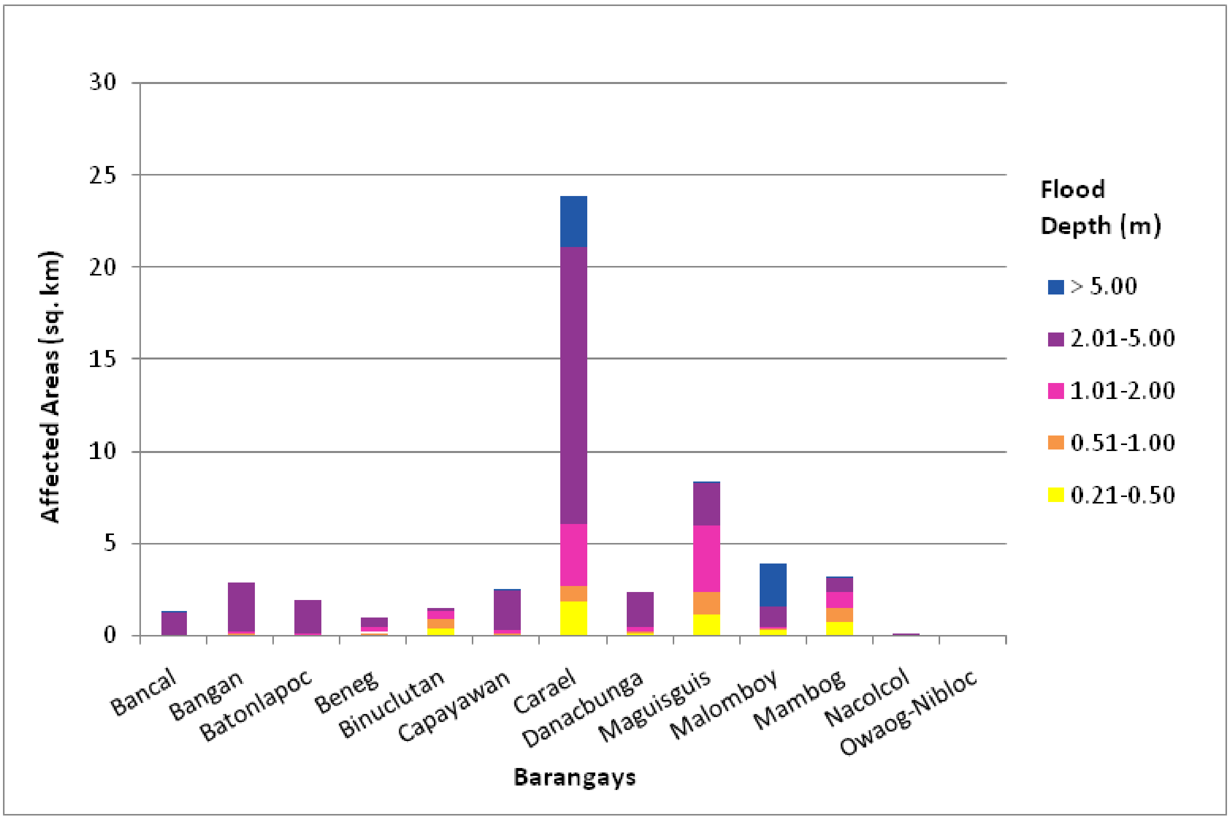


Figure 88. Affected Areas in Botolan, Zambales during 100-Year Rainfall Return Period

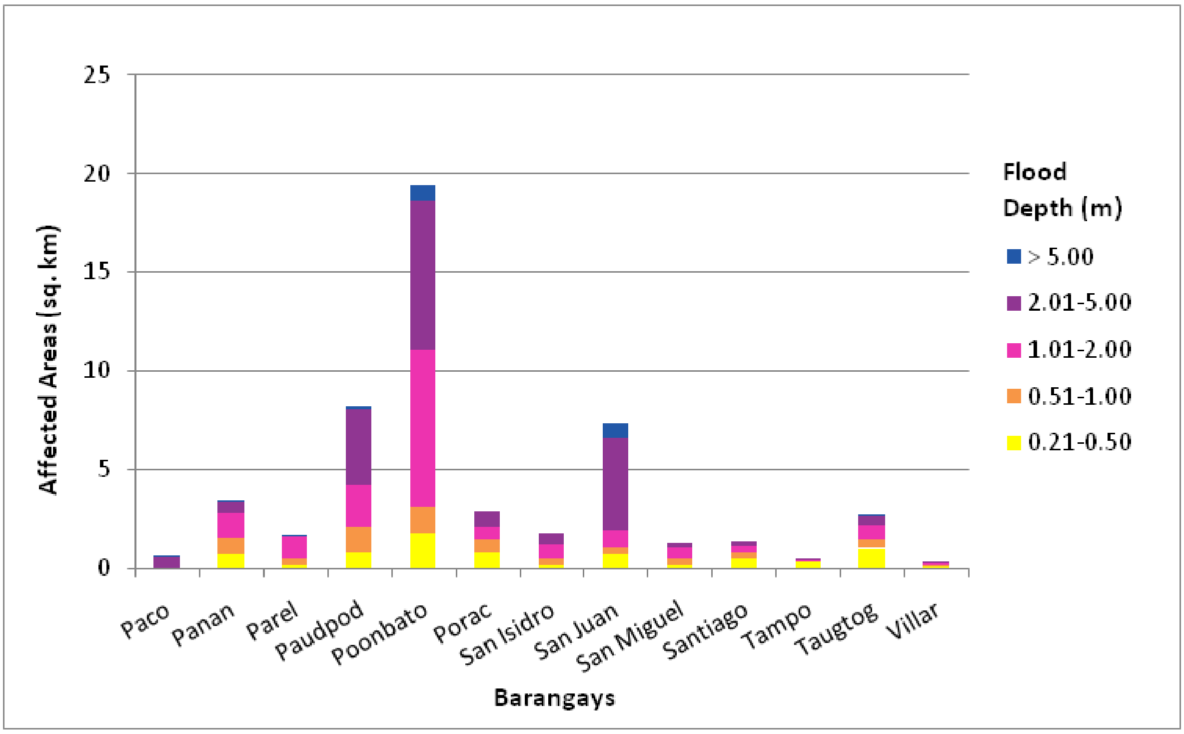


Figure 89. Affected Areas in Botolan, Zambales during 100-Year Rainfall Return Period

For the 100-year return period, 11.57% of the municipality of Cabangan with an area of 231.275832 sq. km. will experience flood levels of less than 0.20 meters. 0.51% of the area will experience flood levels of 0.21 to 0.50 meters while 0.30%, 0.40%, 0.50%, and 0.13% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 67. Affected Areas in Cabangan, Zambales during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cabangan (in sq. km)		
	Cadmang-Reserva	Mabanglit	San Rafael
0.03-0.20	25.56	1.17	0.023
0.21-0.50	1.12	0.058	0.000043
0.51-1.00	0.66	0.028	0
1.01-2.00	0.9	0.029	0
2.01-5.00	1.16	0.0061	0
> 5.00	0.29	0	0

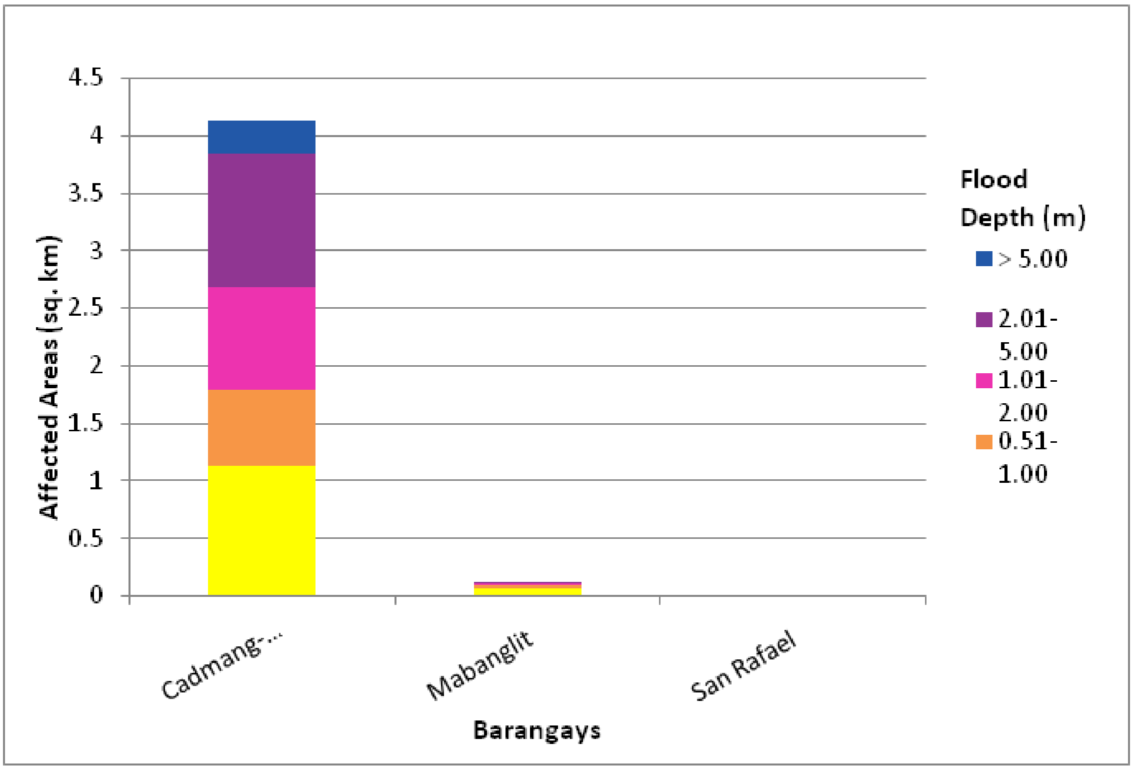


Figure 90. Affected Areas in Cabangan, Zambales during 100-Year Rainfall Return Period

For the 100-year return period, 3.15% of the municipality of Iba with an area of 219.08328 sq. km. will experience flood levels of less than 0.20 meters. 1.17% of the area will experience flood levels of 0.21 to 0.50 meters while 1.27%, 1.82%, 2.85%, and 0.81% 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 the table are the affected areas in square kilometers by flood depth per barangay.

Table 68. Affected Areas in Iba, Zambales during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Iba (in sq. km)											
	Bangan-talinga	Dirita-Ba-loguen	Lipay-Din-gin-Panibuatan	Palangi-nan	Santa Barbara	Santo Rosario	Zone 1 Poblacion	Zone 2 Poblacion	Zone 3 Poblacion	Zone 4 Poblacion	Zone 5 Poblacion	Zone 6 Poblacion
0.03-0.20	1.55	0.19	0.21	0.2	3.98	0.18	0.072	0.092	0.17	0.031	0.059	0.16
0.21-0.50	0.15	0.19	0.18	0.3	0.99	0.081	0.061	0.12	0.079	0.18	0.11	0.13
0.51-1.00	0.21	0.52	0.17	0.15	0.94	0.2	0.03	0.13	0.078	0.085	0.15	0.11
1.01-2.00	0.74	0.88	0.21	0.51	1.21	0.37	0.016	0.012	0.00069	0.0034	0.039	0.0039
2.01-5.00	0.16	0.055	0.77	2.54	2.72	0.0048	0	0	0	0	0	0
> 5.00	0.0054	0	0	0.28	1.5	0	0	0	0	0	0	0

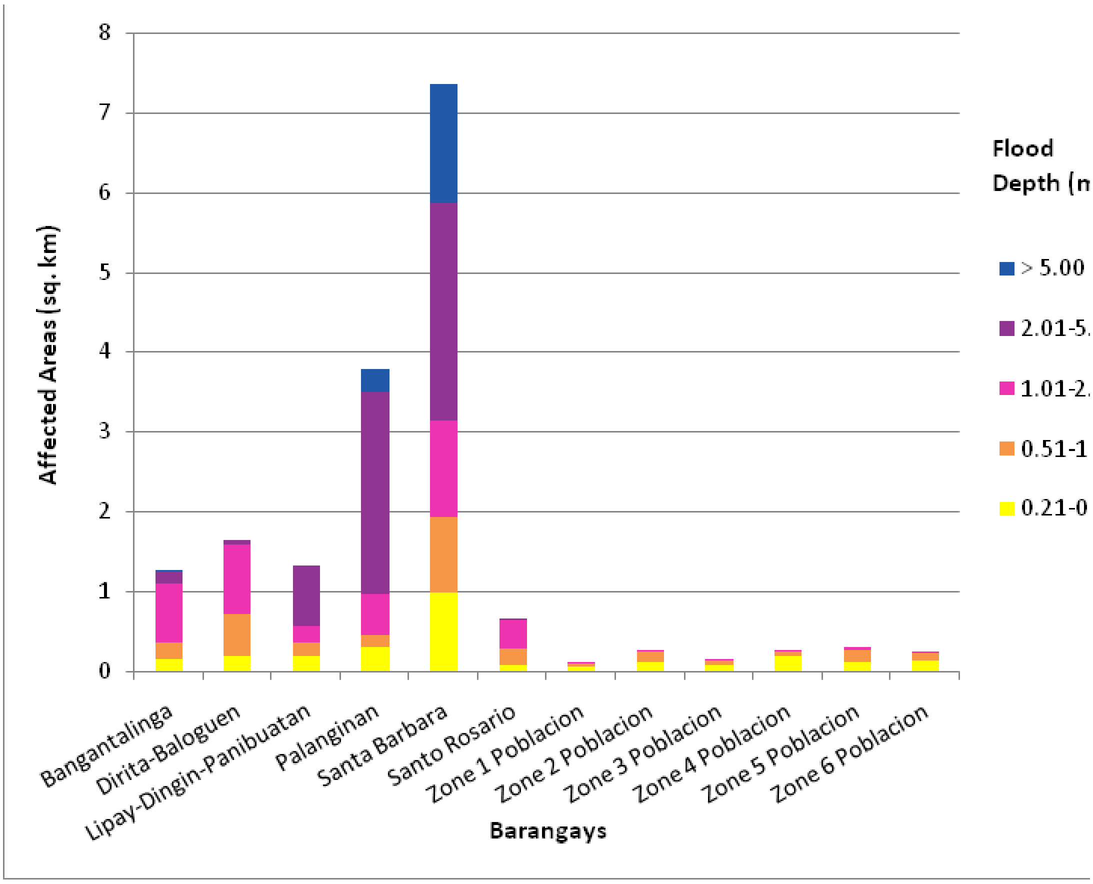


Figure 91. Affected Areas in Iba, Zambales during 100-Year Rainfall Return Period

Among the barangays in the municipality of Botolan in Zambales, Carael is projected to have the highest percentage of area that will experience flood levels at 7.92%. Meanwhile, Poonbato posted the second highest percentage of area that may be affected by flood depths at 4.41%.

Among the barangays in the municipality of Cabangan in Zambales, Cadmang-Reserva is projected to have the highest percentage of area that will experience flood levels at 4.57%. Meanwhile, Mabanglit posted the second highest percentage of area that may be affected by flood depths at 0.20%.

Among the barangays in the municipality of Iba in Zambales, Santa Barbara is projected to have the highest percentage of area that will experience flood levels at 1.75%. Meanwhile, Palanginan posted the second highest percentage of area that may be affected by flood depths at 0.61%.

Moreover, the generated flood hazard maps for the Bucao 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 69. 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	17.12	15.81	15.56
Medium	43.66	34.23	28.19
High	50.57	71.04	83.29
Total	111.35	121.08	127.04

Of the 374 identified buildings of Educational Institutions in Bucao Flood Plain, sixty three (63) school buildings were discovered exposed to Low-level flooding while ninety four (94) school buildings were found exposed to Medium-level flooding, both during a 5-year scenario. In the same scenario, thirty seven (37) school buildings were discovered exposed to High-level flooding.

For the 25-year scenario, eighty six (86) school buildings were discovered exposed to Low-level flooding while fifty (50) school buildings were found exposed to Medium-level flooding. In the same scenario, one hundred six (106) school buildings were discovered exposed to High-level flooding.

For the 100-year scenario, eighty two (82) school buildings were discovered exposed to Low-level flooding while fifty eight (58) school buildings were found exposed to Medium-level flooding. In the same scenario, one hundred thirteen (113) school buildings were discovered exposed to High-level flooding.

Of the 23 identified buildings of Medical Institutions in Bucao Flood Plain, two (2) buildings were discovered exposed to Low-level flooding while seven (7) buildings were found exposed to Medium-level flooding, both during a 5-year scenario.

For the 25-year scenario, five (5) buildings were discovered exposed to Low-level flooding while five (5) buildings were found exposed to Medium-level flooding. In the same scenario, three (3) buildings were discovered exposed to High-level flooding.

For the 100-year scenario, eight (8) buildings were discovered exposed to Low-level flooding while one (10) buildings was found exposed to Medium-level flooding. In the same scenario, eight (8) buildings were discovered exposed to High-level flooding.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, a validation survey work was performed. Field personnel gathered secondary data regarding flood occurrence in the area within the river system.

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

The validation personnel went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events and through interviews of some residents with knowledge of or have had experienced flooding in a particular area.

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

The flood validation consists of 30 points randomly selected all over the Bucao flood plain (Figure 92). It has an RMSE value of 0.61. The validation points are found in Annex 10.

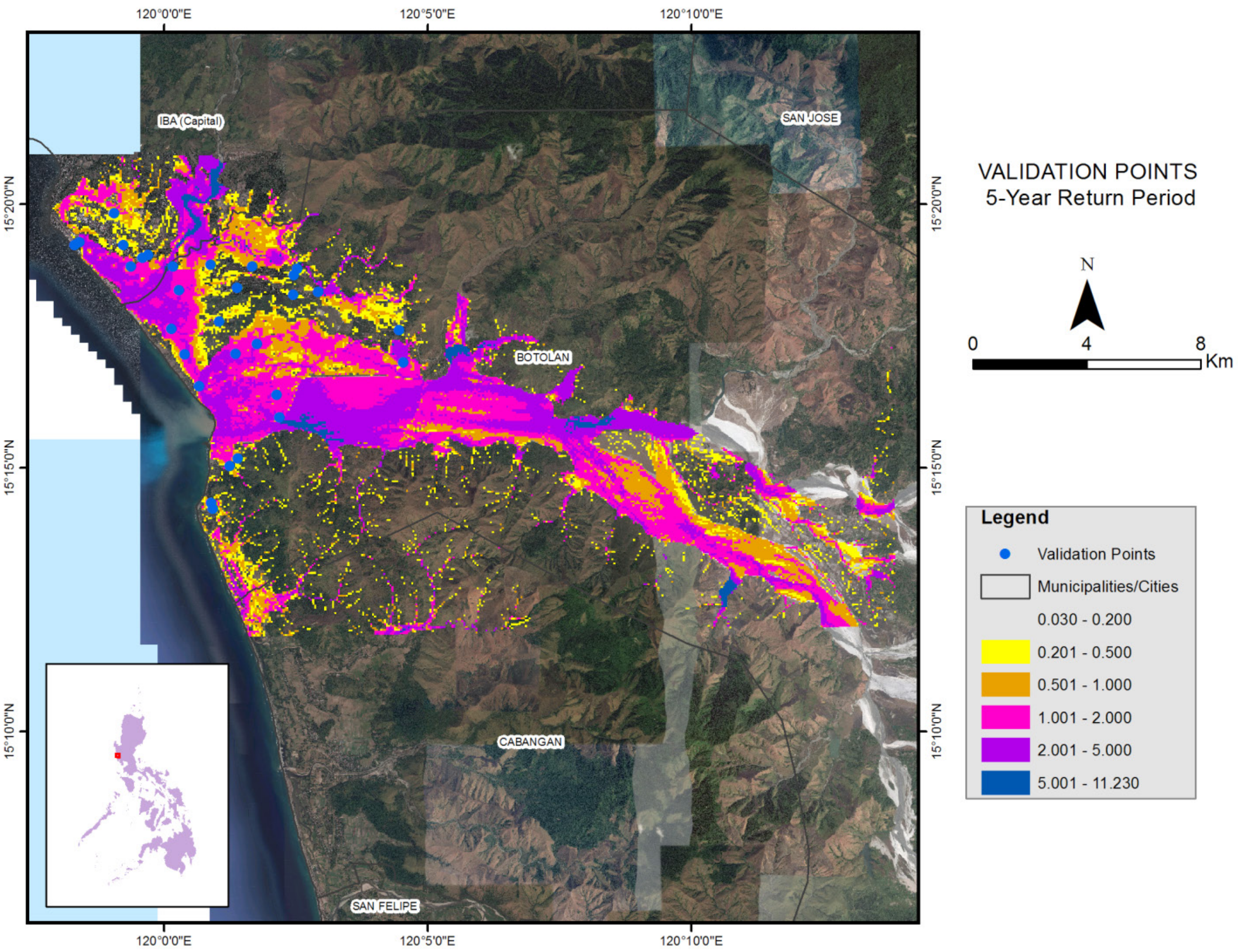


Figure 92. Validation points for 5-year Flood Depth Map of Bucao Floodplain

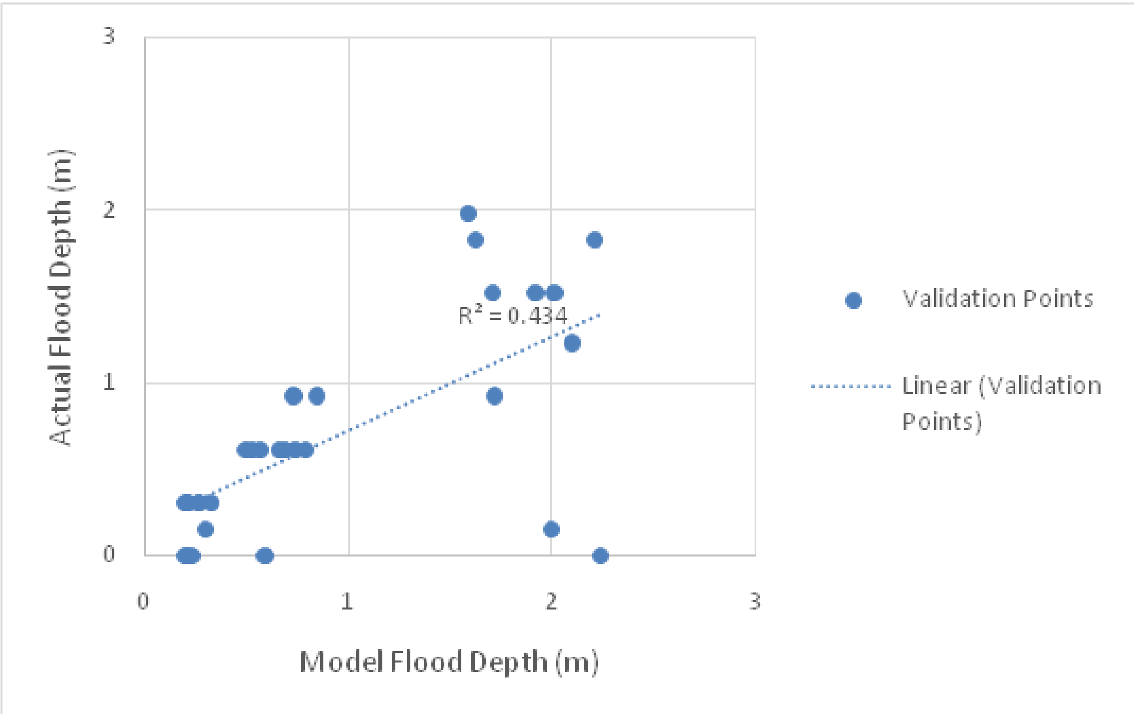


Figure 93. Model flood depth vs actual flood depth

Table 70. Actual Flood Depth vs Simulated Flood Depth in Bucao

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	1	3	1	1	1	0	7
0.21-0.50	1	5	0	0	0	0	6
0.51-1.00	0	0	9	1	0	0	10
1.01-2.00	0	0	0	4	3	0	7
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	2	8	10	6	4	0	30

The overall accuracy generated by the flood model is estimated at 63.33% with 19 points correctly matching the actual flood depths. In addition, there were 8 points estimated one level above and below the correct flood depths while there were 1 point and 2 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 1 point was underestimated in the modelled flood depths of Bucao

Table 71. Summary of Accuracy Assessment in Bucao

No. of Points		%
Correct	19	**63.33**
Overestimated	10	**33.33**
Underestimated	1	**3.33**
Total	30	**100.00**

REFERENCES

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LIDAR Sensors used in the Bucao Floodplain Survey

1. PEGASUS

Figure A-1.1. Pegasus Sensor

Table A-1.1. Parameters and Specification of Pegasus Sensor

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

1 Target reflectivity ≥20%

2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility

3 Angle of incidence ≤20°

4 Target size ≥ laser footprint5 Dependent on system configuration

2. GEMINI

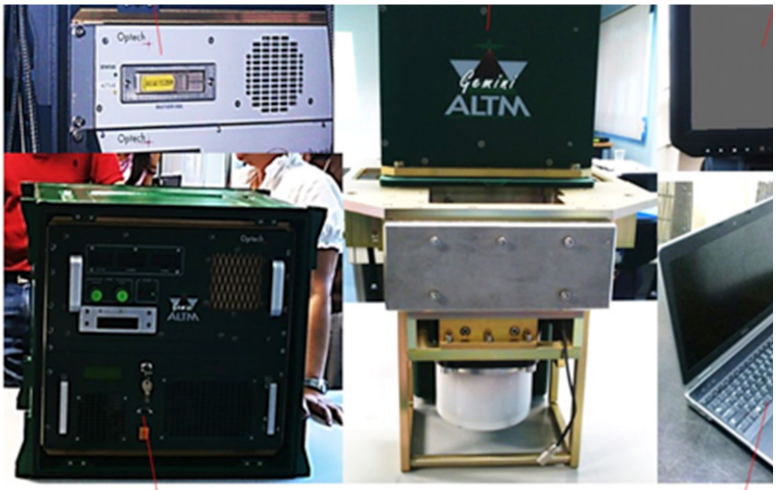

Figure A-1.2. Gemini Sensor

Table A-1.2. Parameters and Specification of Gemini Sensor

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

3. AQUARIUS

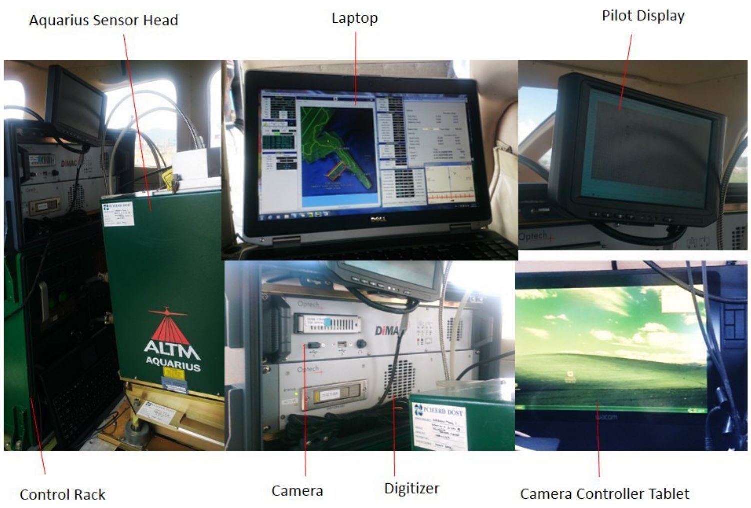

Figure A-1.3. Aquarius Sensor

Table A-1.3. Parameters and Specification of Aquarius Sensor

Parameter	Specification
Operational altitude	300-600 m AGL
Laser pulse repetition rate	33, 50. 70 kHz
Scan rate	0-70 Hz
Scan half-angle	0 to ± 25 ˚
Laser footprint on water surface	30-60 cm
Depth range	0 to > 10 m (for k < 0.1/m)
Topographic mode	
Operational altitiude	300-2500
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	12-bit dynamic measurement range
Position and orientation system	POS AVTM 510 (OEM) includes embedded 72-channel GNSS receiver (GPS and GLONASS)
Data Storage	Ruggedized removable SSD hard disk (SATA III)
Power	28 V, 900 W, 35 A
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Dimensions and weight	Sensor:250 x 430 x 320 mm; 30 kg; Control rack: 591 x 485 x 578 mm; 53 kg
Operating temperature	0-35˚C
Relative humidity	0-95% no-condensing

4. LEICA

Table A-1.4. Parameters and Specification of Leica Sensor

Parameter	Specification
Operational altitude	100 to 3500 m max AGL
Maximum measurement rate	1000 kHz
Maximum scan rate	200 Hz for sine; 158 for triangle;120 for raster
Field of view (degrees, full angle, user-adjustable)	0 to 72
Roll Stabilization(automatic adaptive, degrees)	72 – active FOV
Number of returns	unlimited
Number of intensity measurements	3(first, second and third)
Data Storage	ALS80: removable SSD hard disk (800GB each volume)
Power Consumption	922 W @ 22.0-30.3 VDC
Dimensions and weight	Scanner:37 W x 68 L x 26 H cm; 47 kg; Control Electronics: 45 W x 47 D x 25 H cm; 33 kg
Operating temperature	0-40˚C

Annex 2. NAMRIA Certification of Reference Points Used in the LIDAR Survey

1. BTN-71

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

January 02, 2014

CERTIFICATION

To whom it may concern:

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

Province: **BATAAN**
Station Name: **BTN-71**
Order: **2nd**

Island: **LUZON**
Municipality: **ORANI**
Barangay: **MARIA FE**

	PRS92 Coordinates	
Latitude: **14° 47' 30.18239"**	Longitude: **120° 32' 9.95860"**	Ellipsoidal Hgt: **7.56300 m.**
	WGS84 Coordinates	
Latitude: **14° 47' 24.68277"**	Longitude: **120° 32' 14.83855"**	Ellipsoidal Hgt: **49.42500 m.**
	PTM Coordinates	
Northing: **1635812.88 m.**	Easting: **450060.675 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,636,645.28**	Easting: **234,782.54**	Zone: **51**

Location Description

BTN-71
Is located in Brgy. Maria Fe, 30 m Sw of the Day Care Center, 20 m SE of the basketball court and 15 m NE of the chapel of the said barangay. It is also situated on the W edge of the concrete pavement used as volleyball court. Mark is the head of a 4" copper nail centered on a 30 cm x 30 cm concrete monument flushed on the ground with inscriptions BTN-71 2007 NAMRIA.

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8794989 A**
T.N.: **2014-4**

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

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

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

Figure A-2.1. BTN-71

2. NEJ-138

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

May 29, 2014

CERTIFICATION

To whom it may concern:

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

Province: **NUEVA ECIJA**
Station Name: **NEJ-138**
Order: **2nd**

Island: **LUZON**
Municipality: **SAN ANTONIO**
Barangay: **SAN FRANCISCO**

PRS92 Coordinates

Latitude: **15° 21' 17.34481"** Longitude: **120° 50' 30.87881"** Ellipsoidal Hgt: **18.43200 m.**

WGS84 Coordinates

Latitude: **15° 21' 11.74037"** Longitude: **120° 50' 35.70940"** Ellipsoidal Hgt: **59.40200 m.**

PTM Coordinates

Northing: **1698067.598 m.** Easting: **483026.389 m.** Zone: **3**

UTM Coordinates

Northing: **1,698,622.77** Easting: **268,325.74** Zone: **51**

Location Description

NEJ-138
From San Antonio Mun. Hall, travel along the road going to Zaragoza until reaching the Y-road going to Along-Along River and San Francisco at Brgy. Papaya. Turn right to the road going to San Francisco. Then turn right to the road junction until reaching San Francisco Brgy. Hall. Station is located along the ESE side of the multipurpose concrete pavement, about 18 m. SE of the brgy. hall, about 3 m. SSW of the ENE corner of the pavement and approx. 8 m. NNE of the shed. Mark is the head of a 4 in. copper nail centered on a 30 cm. x 30 cm. concrete monument protruding 40 cm. above the ground surface, with inscriptions "NEJ-138 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8796226 A**
T.N.: **2014-1184**

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

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. NEJ-138

3. PMG-54

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

January 20, 2014

CERTIFICATION

To whom it may concern:

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

Province: **PAMPANGA**
Station Name: **PMG-54**
Order: **3rd**

Island: **LUZON**
Municipality: **CLARK DEV'T. CORP.**
Barangay: **C.S.E.Z.**

PRS92 Coordinates

Latitude: **15° 10' 50.24016"**	Longitude: **120° 31' 3.16452"**	Ellipsoidal Hgt: **213.00650 m.**

WGS84 Coordinates

Latitude: **15° 10' 44.64998"**	Longitude: **120° 31' 8.01131"**	Ellipsoidal Hgt: **253.69780 m.**

PTM Coordinates

Northing: **1678845.621 m.**	Easting: **448156.978 m.**	Zone: **3**

UTM Coordinates

Northing: **1,679,714.68**	Easting: **233,266.88**	Zone: **51**

Location Description

PMG-54
Is located about 50 m. NE of Bldg. 2127 (Main Bldg.) of Clark Development Corp. and about 3 m. W of the Phil. flagpole. Mark is the head of a 1 in. concrete nail driven on the marbled tiled footing of a historical mark commemorating the turnover of the U.S. Military Base to the Philippine Gov't.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795097 A**
T.N.: **2014-96**

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

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

Figure A-2.3. PMG-54

4. PNG-66

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

May 29, 2014

CERTIFICATION

To whom it may concern:

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

Province: **PANGASINAN**
Station Name: **PNG-66**
Order: **2nd**

Island: **LUZON**
Municipality: **SAN CARLOS**
Barangay: **CALOMBOYAN**

	PRS92 Coordinates	
Latitude: **15° 56' 47.31803"**	Longitude: **120° 17' 57.03550"**	Ellipsoidal Hgt: **10.57500 m.**
	WGS84 Coordinates	
Latitude: **15° 56' 41.53646"**	Longitude: **120° 18' 1.81867"**	Ellipsoidal Hgt: **48.46800 m.**
	PTM Coordinates	
Northing: **1763650.683 m.**	Easting: **424968.98 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,764,780.62**	Easting: **210,862.35**	Zone: **51**

Location Description

PNG-66

From San Carlos Mun. Hall, travel along the highway going to Binmaley. Then turn left to the brgy. road going to Brgy. Pangalangan. Station is located inside the compound of Calomboyan Elem. School. It is situated along and beside the SE side of the concrete base of the flagpole, which is about 20 m. NW of the gate. Mark is the head of a 4 in. copper nail centered and embedded in a 30 cm. x 30 cm. concrete block protruding 20 cm. ìabove ground surface, with inscriptions "PNG-66 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8796226 A**
T.N.: **2014-1185**

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

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CIP/4701/12/09/814

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Figure A-2.4. PNG-66

5. TRC-1

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

May 10, 2013

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: **TARLAC**
Station Name: **TRC-1**
Order: **1st**

Island: **LUZON**
Municipality: **TARLAC**
Barangay: **SAN ROQUE**

	PRS92 Coordinates	
Latitude: **15° 28' 44.13765"**	Longitude: **120° 35' 52.67202"**	Ellipsoidal Hgt: **46.89100 m.**
	WGS84 Coordinates	
Latitude: **15° 28' 38.48550"**	Longitude: **120° 35' 57.49329"**	Ellipsoidal Hgt: **86.90220 m.**
	PTM Coordinates	
Northing: **1711833.357 m.**	Easting: **456859.89 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,712,636.20**	Easting: **242,278.30**	Zone: **51**

Location Description

TRC-1
Is located in a NIA irrigation canal concrete floodgate 300 m. E of the natl. highway, 1.5 km. SE of Tarlac town proper. From Manila, travel along MacArthur Highway to Tarlac. A small bridge, 10 m. NW of Sombrero Food Center along the irrigation canal bank to the railroad. It is 2 m. W of the railroad on the eastern floodgate wall, which is 5 min. walk from highway. Mark is a 0.15 m. x 0.01 m. dia. brass rod set on a drilled hole in a standard concrete block with cement putty, 0.03 m. above the top of the concrete railing, inscribed with station name. Reference marks (RM): RM's 1, 2 & 3 are 0.15 m. x 0.01 m. dia. brass rods set in a drilled hole with cement putties. RM-2 is a 0.15 m. x 0.01 m. dia. brass rod set on concrete block, 0.6 m. below ground level; Sub-RM is a 0.15 m. x 0.01 m. dia. brass rod set on a drilled hole on top of the concrete railing.

Requesting Party: **Christopher Cruz**
Pupose: **Reference**
OR Number: **3943636B**
T.N.: **2013-0420**

RUEL DM. BELEN, MNSA
Director, Mapping and Geodesy Department

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CERTIFICATION INTERNATIONAL ISO 9001:2008
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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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Figure A-2.5. TRC-1

6. 0ZBS-58

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

January 02, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBALES**
Station Name: **ZBS-58**
Order: **2nd**

Island: **LUZON**
Municipality: **IBA (CAPITAL)**
Barangay: **DIRITA-BALOGUEN**

PRS92 Coordinates

Latitude: **15° 20' 8.92898"**	Longitude: **119° 58' 34.69353"**	Ellipsoidal Hgt: **7.77100 m.**

WGS84 Coordinates

Latitude: **15° 20' 3.25975"**	Longitude: **119° 58' 39.52976"**	Ellipsoidal Hgt: **46.69300 m.**

PTM Coordinates

Northing: **1696218.486 m.**	Easting: **390073.626 m.**	Zone: **3**

UTM Coordinates

Northing: **1,697,561.97**	Easting: **819,598.83**	Zone: **50**

Location Description

ZBS-58
The station is inside Barangay Center of Dirita, Iba, Zambales. It is approximately 1m. from the foot of the basketball court at east direction. Mark is the head of 4 inch copper nail, centered on a 30 cm x 30 cmconcrete block flushed on the ground with inscription "IBA-56, 2007,DENR".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8794989 A**
T.N.: **2014-2**

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

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

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

Figure A-2.6. ZBS-58

7. ZBS-60

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

January 02, 2014

CERTIFICATION

To whom it may concern:

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

Province: **ZAMBALES**
Station Name: **ZBS-60**
Order: **2nd**

Island: **LUZON**
Municipality: **CABANGAN**
Barangay: **SAN ANTONIO**

PRS92 Coordinates

Latitude: **15° 9' 48.72475"**	Longitude: **120° 3' 4.60936"**	Ellipsoidal Hgt: **12.36500 m.**

WGS84 Coordinates

Latitude: **15° 9' 43.10078"**	Longitude: **120° 3' 9.45989"**	Ellipsoidal Hgt: **51.97200 m.**

PTM Coordinates

Northing: **1677118.723 m.**	Easting: **398042.381 m.**	Zone: **3**

UTM Coordinates

Northing: **1,678,445.32**	Easting: **183,107.00**	Zone: **51**

Location Description

ZBS-60
From Cabangan, travel southward along the National Road for about 300 m until reaching Barangay San Antonio Proper. Station mark is located inside the Barngay Hall compound about 6 m E of Barangay road. It is situated about 10 m S of basketball court and Children's Park. Mark is the head of 4 inch copper nail, centered on a 30 cm x 30 cm concrete block flushed on the ground with inscription "ZBS-60, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8794989 A**
T.N.: **2014-3**

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

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

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

Figure A-2.7. ZBS-60

8. ZBS-62

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

January 02, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **ZAMBALES**	
	Station Name: **ZBS-62**	
Island: **LUZON**	Order: **2nd**	Barangay: **LA PAZ**
Municipality: **SAN NARCISO**		
	PRS92 Coordinates	
Latitude: **15° 0' 58.08330"**	Longitude: **120° 3' 50.43021"**	Ellipsoidal Hgt: **9.87700 m.**
	WGS84 Coordinates	
Latitude: **15° 0' 52.49407"**	Longitude: **120° 3' 55.29320"**	Ellipsoidal Hgt: **49.94200 m.**
	PTM Coordinates	
Northing: **1660802.886 m.**	Easting: **399340.98 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,662,105.93**	Easting: **184,257.98**	Zone: **51**

Location Description

ZBS-62
the mark is located in the EXECUTIVE PARK of Barangay La Paz, San Narciso. It is situated on the NW corner of the stage of said plaza about 15 m W of Magsaysay Boulevard. Mark is the head of 4 inch copper nail, centered on a 30 cm x 30 cm concrete block fkushed on the ground with inscription ZBS-62, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8794989 A**
T.N.: **2014-1**

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

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

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

Figure A-2.9. ZBS-62

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

1. AAC-01

Table A-3.1. AAC-01

Vector Components (Mark to Mark)

From:	TRC-01				
Grid		Local		Global	
Easting	242278.307 m	Latitude	N15°28'44.13767"	Latitude	N15°28'38.48550"
Northing	1712636.202 m	Longitude	E120°35'52.67202"	Longitude	E120°35'57.49329"
Elevation	44.420 m	Height	46.891 m	Height	86.902 m

To:	AAC-01				
Grid		Local		Global	
Easting	236272.483 m	Latitude	N15°11'27.81685"	Latitude	N15°11'22.22626"
Northing	1680836.256 m	Longitude	E120°32'43.37833"	Longitude	E120°32'48.22418"
Elevation	151.882 m	Height	154.260 m	Height	194.988 m

Vector					
ΔEasting	-6005.824 m	NS Fwd Azimuth	190°03'34"	ΔX	523.697 m
ΔNorthing	-31799.946 m	Ellipsoid Dist.	32347.854 m	ΔY	10213.192 m
ΔElevation	107.461 m	ΔHeight	107.369 m	ΔZ	-30689.417 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	0.011 m
σ ΔElevation	0.013 m	σ ΔHeight	0.013 m	σ ΔZ	0.004 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000413905		
Y	-0.0000661260	0.0001225849	
Z	-0.0000191610	0.0000334556	0.0000154812

2. AB-1

Table A-3.2. AB-1

Vector Components (Mark to Mark)

From:	BTN 71				
Grid		Local		Global	
Easting	234930.205 m	Latitude	N14°47'24.68277"	Latitude	N14°47'24.68277"
Northing	1636575.052 m	Longitude	E120°32'14.83855"	Longitude	E120°32'14.83855"
Elevation	6.893 m	Height	49.425 m	Height	49.425 m

To:	AB 1				
Grid		Local		Global	
Easting	231096.890 m	Latitude	N14°45'14.54340"	Latitude	N14°45'14.54340"
Northing	1632615.365 m	Longitude	E120°30'08.19305"	Longitude	E120°30'08.19305"
Elevation	65.511 m	Height	108.361 m	Height	108.361 m

Vector					
ΔEasting	-3833.315 m	NS Fwd Azimuth	223°26'34"	ΔX	2715.948 m
ΔNorthing	-3959.688 m	Ellipsoid Dist.	5508.556 m	ΔY	2851.138 m
ΔElevation	58.618 m	ΔHeight	58.936 m	ΔZ	-3852.668 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000113896		
Y	-0.0000161358	0.0000296663	
Z	-0.0000055777	0.0000092764	0.0000038726

3. FMC-01

Table A-3.3. FMC-01

Vector Components (Mark to Mark)

From:	PMG-54				
Grid		Local		Global	
Easting	233266.879 m	Latitude	N15°10'50.24034"	Latitude	N15°10'44.64998"
Northing	1679714.686 m	Longitude	E120°31'03.16450"	Longitude	E120°31'08.01131"
Elevation	220.332 m	Height	223.018 m	Height	263.709 m

To:	FMC-1				
Grid		Local		Global	
Easting	270660.154 m	Latitude	N14°54'29.41880"	Latitude	N14°54'23.91904"
Northing	1649166.271 m	Longitude	E120°52'05.23142"	Longitude	E120°52'10.09982"
Elevation	23.745 m	Height	23.646 m	Height	65.981 m

Vector					
ΔEasting	37393.275 m	NS Fwd Azimuth	128°36'08"	ΔX	-36313.138 m
ΔNorthing	-30548.415 m	Ellipsoid Dist.	48267.727 m	ΔY	-12679.923 m
ΔElevation	-196.587 m	ΔHeight	-199.372 m	ΔZ	-29162.699 m

Standard Errors

Vector errors:					
σ ΔEasting	0.004 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.009 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.003 m	σ ΔY	0.012 m
σ ΔElevation	0.015 m	σ ΔHeight	0.015 m	σ ΔZ	0.004 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000868373		
Y	-0.0000999365	0.0001486951	
Z	-0.0000311237	0.0000462768	0.0000158611

4. ZA-62A

Table A-3.4. ZA-62A

Vector Components (Mark to Mark)

From:	ZBS-62				
Grid		Local		Global	
Easting	184257.971 m	Latitude	N15°00'58.08330"	Latitude	N15°00'52.49407"
Northing	1662105.928 m	Longitude	E120°03'50.43021"	Longitude	E120°03'55.29320"
Elevation	7.211 m	Height	9.877 m	Height	49.942 m

To:	ZBS-62A				
Grid		Local		Global	
Easting	184258.065 m	Latitude	N15°00'57.82548"	Latitude	N15°00'52.23627"
Northing	1662097.996 m	Longitude	E120°03'50.43687"	Longitude	E120°03'55.29987"
Elevation	7.424 m	Height	10.090 m	Height	50.155 m

Vector					
ΔEasting	0.094 m	NS Fwd Azimuth	178°33'38"	ΔX	-1.304 m
ΔNorthing	-7.932 m	Ellipsoid Dist.	7.926 m	ΔY	1.855 m
ΔElevation	0.213 m	ΔHeight	0.213 m	ΔZ	-7.698 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'10"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000003174		
Y	-0.0000002549	0.0000005198	
Z	-0.0000001284	0.0000001364	0.0000001616

5. ZBS-3144

Table A-3.5. ZBS-3144

Vector Components (Mark to Mark)

From:	ZBS-60				
Grid		Local		Global	
Easting	183106.993 m	Latitude	N15°09'48.72475"	Latitude	N15°09'43.10078"
Northing	1678445.326 m	Longitude	E120°03'04.60936"	Longitude	E120°03'09.45989"
Elevation	9.942 m	Height	12.365 m	Height	51.972 m

To:	ZBS-3144				
Grid		Local		Global	
Easting	182539.933 m	Latitude	N15°10'03.47052"	Latitude	N15°09'57.84519"
Northing	1678906.602 m	Longitude	E120°02'45.42344"	Longitude	E120°02'50.27364"
Elevation	10.011 m	Height	12.404 m	Height	51.986 m

Vector					
ΔEasting	-567.060 m	NS Fwd Azimuth	308°21'17"	ΔX	555.128 m
ΔNorthing	461.276 m	Ellipsoid Dist.	730.364 m	ΔY	184.210 m
ΔElevation	0.068 m	ΔHeight	0.039 m	ΔZ	437.415 m

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000005678		
Y	-0.0000006230	0.0000019733	
Z	-0.0000001950	0.0000006095	0.0000004810

6. TRC-1nw

Table A-3.6. TRC-1nw

Vector Components (Mark to Mark)

From:	TRC-1				
Grid		Local		Global	
Easting	242278.307 m	Latitude	N15°28'44.13767"	Latitude	N15°28'38.48550"
Northing	1712636.202 m	Longitude	E120°35'52.67202"	Longitude	E120°35'57.49329"
Elevation	44.841 m	Height	46.891 m	Height	86.902 m

To:	TRC-1nw				
Grid		Local		Global	
Easting	242278.284 m	Latitude	N15°28'44.21062"	Latitude	N15°28'38.55846"
Northing	1712638.446 m	Longitude	E120°35'52.67040"	Longitude	E120°35'57.49166"
Elevation	44.954 m	Height	47.004 m	Height	87.016 m

Vector					
ΔEasting	-0.023 m	NS Fwd Azimuth	358°45'43"	ΔX	0.291 m
ΔNorthing	2.244 m	Ellipsoid Dist.	2.243 m	ΔY	-0.397 m
ΔElevation	0.113 m	ΔHeight	0.113 m	ΔZ	2.191 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'57"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000006452		
Y	-0.0000005187	0.0000013843	
Z	-0.0000000966	0.0000002676	0.0000002145

7. TRC-3013

Table A.3.7. TRC-3013

Vector Components (Mark to Mark)

From:	NEJ-138				
Grid		Local		Global	
Easting	268325.748 m	Latitude	N15°21'17.34481"	Latitude	N15°21'11.74037"
Northing	1698622.772 m	Longitude	E120°50'30.87881"	Longitude	E120°50'35.70940"
Elevation	17.687 m	Height	18.432 m	Height	59.402 m

To:	TRC-3013				
Grid		Local		Global	
Easting	254385.958 m	Latitude	N15°29'16.13287"	Latitude	N15°29'10.48764"
Northing	1713487.619 m	Longitude	E120°42'38.37631"	Longitude	E120°42'43.19629"
Elevation	21.976 m	Height	23.362 m	Height	63.621 m

Vector					
ΔEasting	-13939.790 m	NS Fwd Azimuth	316°15'55"	ΔX	14104.405 m
ΔNorthing	14864.847 m	Ellipsoid Dist.	20372.249 m	ΔY	3851.155 m
ΔElevation	4.289 m	ΔHeight	4.930 m	ΔZ	14186.769 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000085225		
Y	-0.0000123948	0.0000293264	
Z	-0.0000049510	0.0000111604	0.0000049504

Vector Components (Mark to Mark)

From:	PNG-66				
Grid		Local		Global	
Easting	210862.353 m	Latitude	N15°56'47.31803"	Latitude	N15°56'41.53646"
Northing	1764780.617 m	Longitude	E120°17'57.03550"	Longitude	E120°18'01.81867"
Elevation	5.601 m	Height	10.575 m	Height	48.468 m

To:	TRC-3008				
Grid		Local		Global	
Easting	242274.052 m	Latitude	N15°37'01.26741"	Latitude	N15°36'55.58374"
Northing	1727923.206 m	Longitude	E120°35'46.76169"	Longitude	E120°35'51.57129"
Elevation	25.975 m	Height	28.544 m	Height	68.142 m

Vector					
ΔEasting	31411.699 m	NS Fwd Azimuth	138°49'32"	ΔX	-32482.383 m
ΔNorthing	-36857.412 m	Ellipsoid Dist.	48401.442 m	ΔY	-7573.227 m
ΔElevation	20.374 m	ΔHeight	17.969 m	ΔZ	-35074.763 m

8

Standard Errors

Vector errors:					
σ ΔEasting	0.018 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.016 m
σ ΔNorthing	0.003 m	σ Ellipsoid Dist.	0.013 m	σ ΔY	0.016 m
σ ΔElevation	0.014 m	σ ΔHeight	0.014 m	σ ΔZ	0.004 m

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 rowspan="2">Data Acquisition Component Leader</td><td>Data Component Project Leader - I</td><td>ENGR. CZAR JAKIRI SARMIENTO</td><td>UP-TCAGP</td></tr>
<tr><td>Data Component Project Leader – I</td><td>ENGR. LOUIE P. 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>UP-TCAGP</td></tr>
<tr><td>LOVELYN ASUNCION</td><td>UP-TCAGP</td></tr>
<tr><td colspan="4">FIELD TEAM</td></tr>
<tr><td rowspan="13">LiDAR Operation</td><td>Senior Science Research Specialist (SSRS)</td><td>JASMINE ALVIAR</td><td>UP-TCAGP</td></tr>
<tr><td>SSRS</td><td>ENGR. GEROME HIPOLITO</td><td>UP-TCAGP</td></tr>
<tr><td>SSRS</td><td>JULIE PEARL MARS</td><td>UP-TCAGP</td></tr>
<tr><td>SSRS</td><td>PAULINE JOANNE ARCEO</td><td>UP-TCAGP</td></tr>
<tr><td>SSRS</td><td>AUBREY PAGADOR</td><td>UP-TCAGP</td></tr>
<tr><td>SUP SRS</td><td>ENGR. LOVELYN ASUNCION</td><td>UP-TCAGP</td></tr>
<tr><td>Research Associate (RA)</td><td>MARY CATHERINE ELIZABETH BALIGUAS</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>FOR. VERLINA TONGA</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>ENGR. LARAH KRISELLE PARAGAS</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>FOR. MA. REMEDIOS VILLANUEVA</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>FOR. REGINA AEDRIANNE FELISMINO</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>JONALYN GONZALES</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="4">LiDAR Operation/ Ground Survey, Data Download and Transfer</td><td>RA</td><td>ENGR. RENAN PUNTO</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>ENGR. IRO ROXAS</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>ENGR. GEF SORIANO</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>ENGR. KENNETH QUISADO</td><td>UP-TCAGP</td></tr>
</table>

LiDAR Operation	Airborne Security	SSG DIOSCORO SOBERANO	PHILIPPINE AIR FORCE (PAF)
		SSG LEE JAY PUNZALAN	PAF
		SSG GERONIMO BALICAO	PAF
	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JEFFREY JEREMY ALAJAR	AAC
		CAPT. JERICHO JECIEL	AAC
		CAPT. ALBERT LIM	AAC
		CAPT. BRIAN DONGINES	AAC
		CAPT. SHERWIN ALFONSO III	AAC
		CAPT. MARK LAWRENCE TANGONAN	AAC
		CAPT. DANTHONY LOGRONIO	AAC

Annex 5. Data Transfer Sheet for Bucao Floodplain

DATA TRANSFER SHEET
Jan 10, 2013

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Jan 2 2014	926G	2BALE002A	GEMINI	N/A	N/A	4.05 MB	243 MB	27.2 GB	201 KB	13.3 GB	101 GB	8.23 MB	174 BYTES	471 BYTES	4.68 KB	101 KB	Y:\Airborne_Raw\926G
Jan 3 2014	930G	2BUCE003A	GEMINI	N/A	N/A	848 KB	277 MB	35.2 GB	245 KB	18.9 GB	1.29 GB	27.7 MB	376 BYTES	485 BYTES	5.77 KB	432 KB	Y:\Airborne_Raw\930G
Jan 3 2014	932G	2BUCES003A	GEMINI	N/A	N/A	329 KB	86.8 MB	N/A	N/A	809 MB	N/A	27.7 MB	376 BYTES	438 BYTES	5.77 KB	432 KB	Y:\Airborne_Raw\932G
Jan 4 2014	934G	2BUCF004A	GEMINI	N/A	N/A	0.99 MB	299 MB	7.19 GB	N/A	27.6 GB	189 GB	21.3 MB	278 BYTES	527 BYTES	5.63 KB	664 KB	Y:\Airborne_Raw\934G
Jan 2 2014	935P	1BALAS002A	PEGASUS	970 KB	1124 KB	9.79 MB	265 MB	N/A	N/A	18.5 GB	87.3 GB	8.23 MB	174 BYTES	604 BYTES	19.0 KB	145 KB	Y:\Airborne_Raw\935G
Jan 4 2014	943P	1BUCABC004A	PEGASUS	1415 KB	1152 KB	11.6 MB	274 MB	N/A	N/A	21.6 GB	78.2 GB	21.3 MB	278 BYTES	616 BYTES	47.6 KB	60.7 KB	Y:\Airborne_Raw\943P
Jan 3 2014	941P	1BUCBS003B	PEGASUS	574 KB	699 KB	6.43 MB	205 MB	N/A	N/A	10.8 GB	36.3 GB	27.7 MB	376 BYTES	320 BYTES	22.6 KB	53.4 KB	Y:\Airborne_Raw\941P
Jan 4 2014	945P	1BUCCS004B	PEGASUS	211 KB	258 KB	5.52 MB	172 MB	N/A	N/A	4.69 GB	562 MB	21.3 MB	278 BYTES	374 BYTES	29.2 KB	53.4 KB	Y:\Airborne_Raw\945P
Jan 3 2014	939P	1PLGA003A	PEGASUS	1.38 MB	1.68 MB	10.0 MB	295 MB	N/A	N/A	26.1 GB	121 GB	27.7 MB	376 BYTES	524 BYTES	29.6 KB	18.6 KB	Y:\Airborne_Raw\939P
Jan 5 2014	949P	1BUCGS005B	PEGASUS	671 KB	823 KB	7.24 MB	228 MB	N/A	N/A	12.9 GB	42.9 GB	16.1 MB	222 BYTES	558 BYTES	23.8 KB	243 KB	Y:\Airborne_Raw\949P
Jan 6 2014	951P	1BALF006A	PEGASUS	420 KB	528 KB	6.41 MB	178 MB	N/A	N/A	9.51 GB	41.5 GB	12.8 MB	221 BYTES	442 BYTES	19 KB	158 KB	Y:\Airborne_Raw\951P

Received from
Name Pat Alcantara
Position RA
Signature

Received by
Name JOIDA PRIETO
Position SSRS
Signature

Verified by
Name JOIDA PRIETO
Position SSRS
Signature

Figure A-5.1. Transfer Sheet for Bucao Floodplain - A

DATA TRANSFER SHEET
5/22/2014(PAMPANGA REFLIGHTS)

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	
5/16/2014	7253GC	2PAMS1S3136A	GEMINI	na	140	350	228	NA	NA	10.8	NA	11.7	1KB	1KB	93	30	Z:\Airborne_Raw\7253GC
5/17/2014	7254GC	2BLK15S1S2137A	GEMINI	na	59.7	141	191	NA	NA	5.17	NA	7.17	1KB	1KB	40	NA	Z:\Airborne_Raw\7254GC
5/17/2014	7255GC	2PAMS2137B	GEMINI	na	78.4	167	121	NA	NA	6.45	NA	7.17	1KB	1KB	53	5	Z:\Airborne_Raw\7255GC
5/18/2014	7256GC	2PAMS5138A	GEMINI	na	245	486	227	NA	NA	18.9	NA	18.7	1KB	1KB	216	NA	Z:\Airborne_Raw\7256GC
5/18/2014	7257GC	2PAMS7138B & 2NEJS1138B	GEMINI	na	318	197	146	NA	NA	6.22	NA	18.7	1KB	1KB	216	32	Z:\Airborne_Raw\7257GC
5/20/2014	7260GC	2BLK17S1140A	GEMINI	na	209	301	183	NA	NA	14.5	NA	10.7	1KB	1KB	241	NA	Z:\Airborne_Raw\7260GC

Received from

Name C. Joaquin IV
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature
5/26/2014

14-2n

Figure A-5.2. Transfer Sheet for Bucao Floodplain - B

DATA TRANSFER SHEET
5/29/2014(Pampanga Ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(KB)	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	
5/22/2014	7264GC	2BLK15S142A	GEMINI	NA	89.2	276	205	NA	NA	8.92	NA	6.63	1KB	1KB	187	24	Z:\Airborne_Raw\7264GC
5/23/2014	7266GC	2BLK15S143A	GEMINI	NA	168	374	220	NA	NA	14.4	NA	13.2	1KB	1KB	13	18	Z:\Airborne_Raw\7266GC
5/24/2014	7268GC	2PAMS8144A	GEMINI	NA	192	364	223	NA	NA	14.7	NA	11.3	1KB	1KB	23	26	Z:\Airborne_Raw\7268GCA
5/24/2014	7269GC	2PAMS8144B	GEMINI	NA	236	197	140	NA	NA	7.93	NA	11.3	1KB	1KB	18	NA	Z:\Airborne_Raw\7269GC
5/25/2014	7271GC	2PAMS1S3145B	GEMINI	NA	91.8	383	233	NA	NA	15.5	NA	3.68	1KB	1KB	17	na	Z:\Airborne_Raw\7271GC

Received from

Name C. JOAQUIN
Position RA
Signature

Received by

Name JOIDA PRIETO
Position SSRS
Signature 5/29/14

14-217

Figure A-5.3. Transfer Sheet for Bucao Floodplain - C

15-06

DATA TRANSFER SHEET
02/09/2015(CLARK)

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	
4-Dec-14	2270A	3PAMV338A	AQUARIUS	NA	173	352	201	NA	NA	7.79	14.8	23.7	1KB	1KB	NA	48	Z:\DAC\RAW DATA
5-Dec-14	2274A	3NEJV339A	AQUARIUS	NA	70	180	163	NA	NA	3.8	473MB	17.2	1KB	1KB	23	23	Z:\DAC\RAW DATA
6-Dec-14	2278A	3PAMV340A	AQUARIUS	NA	181	425	238	NA	NA	8.18	NA	26.5	1KB	1KB	23	NA	Z:\DAC\RAW DATA
10-Dec-14	2294A	3TRCV344A	AQUARIUS	NA	128	266	174	NA	NA	5.02	652	28.9	1KB	1KB	23	48	Z:\DAC\RAW DATA
11-Dec-14	7670GC	2TRCV345A	GEMINI	NA	301	1.89	256	NA	NA	13.4	NA	8.41	1KB	1KB	1.15MB		Z:\DAC\RAW DATA
11-Dec-14	2298A	3NEJV345A	AQUARIUS	NA	301	455	216	NA	NA	8.18	NA	19.3	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
12-Dec-14	2302A	3NEJV346A	AQUARIUS	NA	113	259	169	NA	NA	5.17	NA	31.1	1KB	1KB	29	57	Z:\DAC\RAW DATA
12-Dec-14	2304A	3NEJV346B	AQUARIUS	NA	NA	515	173	NA	NA	4.2	NA	31.1	1KB	1KB	29	NA	Z:\DAC\RAW DATA

Received from

Name C. So[illegible]
Position
Signature [illegible]

Received by

Name AC Bongat 2/12/15
Position SSRS
Signature ACBongat

Figure A-5.4. Transfer Sheet for Bucao Floodplain - D

15-13

DATA TRANSFER SHEET
03/09/2015(Clark)

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	
20-Jan	2471P	1BUC020A	pegasus	847	na	7.8	192	25.1	217	15.5	na	5.41	1KB	1KB	50	na	Z:\DAC\RAW DATA
21-Jan	2473P	1BUC021A	pegasus	1.69	na	10.3	252	31	208	16	na	4.14	1KB	1KB	44	na	Z:\DAC\RAW DATA
22-Jan	2477P	1NEJ022A	pegasus	1.04	na	7.5	197	na	na	10.2	na	4.16	1KB	1KB	na	na	Z:\DAC\RAW DATA
23-Jan	2481P	1BTN023A	pegasus	2.44	na	11.7	273	na	na	24.4	na	2.82	1KB	1KB	113	na	Z:\DAC\RAW DATA
26-Jan	2493P	1BUC026A	pegasus	2.44	na	11.7	273	18.7/11.1	13682.4q	6.71	na	8.56	1KB	1KB	113	na	Z:\DAC\RAW DATA
27-Jan	2497P	1BUC027A	pegasus	631	na	6.73	195	21	170	7.47	na	2.41	1KB	1KB	63	na	Z:\DAC\RAW DATA
28-Jan	2501P	1BUC028A	pegasus	1.9	na	8.65	184	22.5	161	20.7	na	5.3	1KB	1KB	89	na	Z:\DAC\RAW DATA

Received from

Name C JOAQUIN
Position
Signature

Received by

Name AC Bongat 3/9/15
Position CSRS
Signature

Figure A-5.5. Transfer Sheet for Bucao Floodplain - E

DATA TRANSFER SHEET
Clark 4/12/16

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	
3/28/2016	8411AC	3PAMS1088A	Aquarius	NA	151	359 KB	162	NA	NA	6.7GB	54.1GB	93.8MB	1KB	NA	27KB	NA	Z:\DAC\RAW DATA
3/29/2016	8412AC	3PAMS1089A	Aquarius	NA	384	5.67MB	230	51.3	246KB	10 GB	79.9 GB	144MB	1KB	1KB	28KB	NA	Z:\DAC\RAW DATA
3/31/2016	8416AC	3NEJS1091A	Aquarius	NA	145	313 KB	210	26.3	84KB	6.85 GB	44.0 GB	146MB	1KB	1KB	28KB	NA	Z:\DAC\RAW DATA
4/1/2016	8418AC	3TRCD1092A	Aquarius	NA	NA	22.1KB	180	22 GB	270KB	NA	NA	149MB	1KB	NA	4KB	NA	Z:\DAC\RAW DATA
4/1/2016	8419AC	3TRCD2092B	Aquarius	NA	NA	19.2KB	195	43.3 GB	270KB	NA	NA	149MB	1KB	1KB	4KB	NA	Z:\DAC\RAW DATA
4/2/2016	8420AC	3TRCD2093A	Aquarius	NA	NA	27.3B	133	20.3GB	239KB	NA	NA	101MB	1KB	1KB	4KB	NA	Z:\DAC\RAW DATA
4/2/2016	8421AC	3TRCD1093B	Aquarius	NA	NA	61.4KB	144	28.7GB	239KB	NA	NA	101MB	1KB	1KB	4KB	NA	Z:\DAC\RAW DATA

Received from

Name Millie Shane Reyes
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature 4/22/16

16-25

Figure A-5.6. Transfer Sheet for Bucao Floodplain - F

16-44

DATA TRANSFER SHEET
UMIRAY 8/3/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	KML (swath)	GnssImu	LogFiles	TestData	RawLaser	RawTDC	RawWFD	WebCam	RCD30 RAW IMAGES	BASE STATION(S)		SERVER LOCATION
													BASE STATION(S)	Base Info (.txt)	
27-Jul-16	10210L	4UMRY209A	ALS 80	NA	358	102	20.3	5.6	4.5	NA	76.4	16.9	129	1KB	Z:\DAC\RAW DATA
28-Jul-16	10212L	4UMRY210A	ALS 80	NA	460	121	35.3	12.2	8.27	NA	137	30.5	123	1KB	Z:\DAC\RAW DATA
29-Jul-16	10214L	4BLK15A211A	ALS 80	NA	382	100	20.2	2.72	1.64	NA	54.4	14.2	130	1KB	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

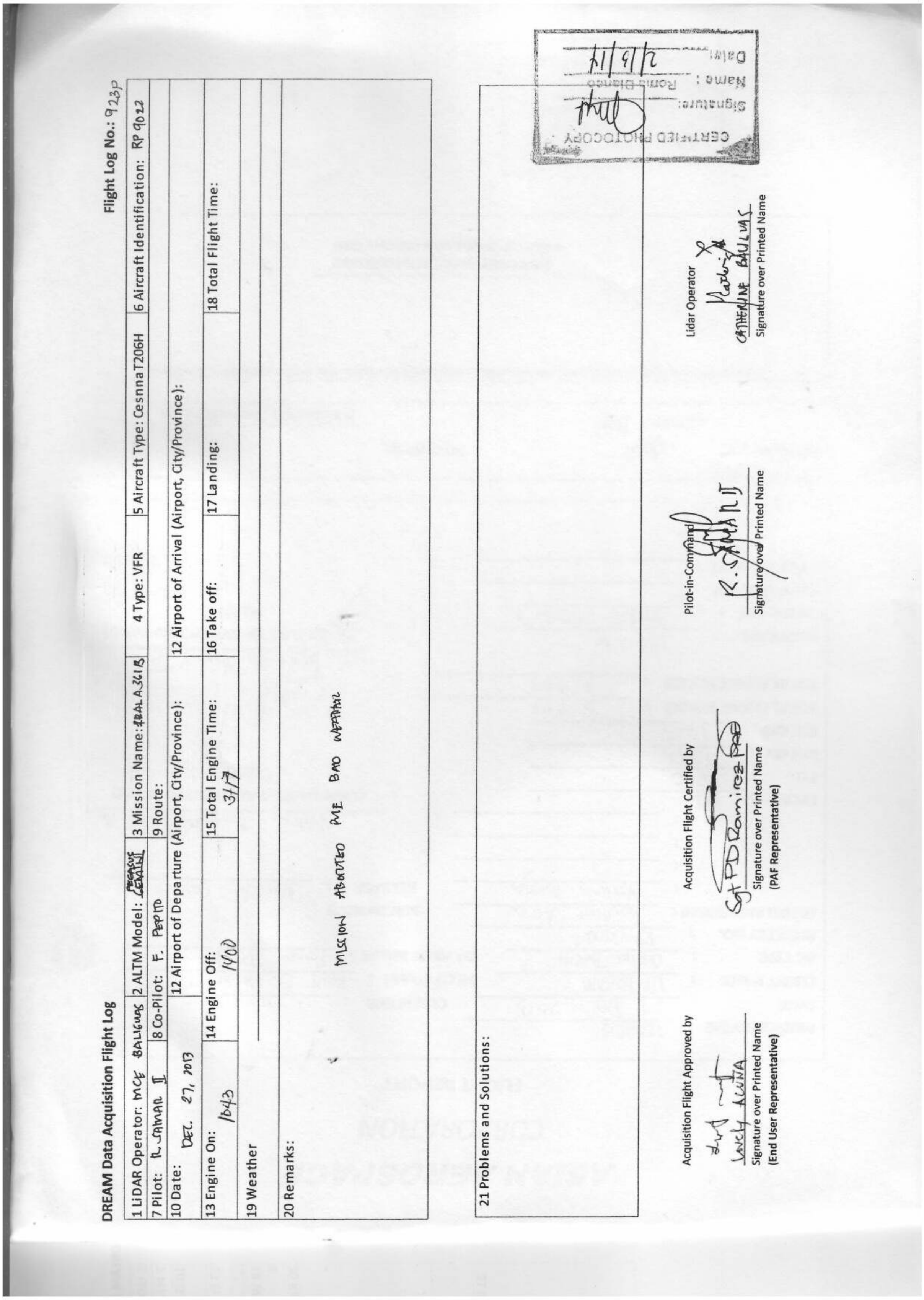
Received by

Name AC Bongat
Position SSRS
Signature ACBongat 8/9/16

Figure A-5.7. Transfer Sheet for Bucao Floodplain - G

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 923P



DREAM Data Acquisition Flight Log

Flight Log No.: 923P

1 LiDAR Operator: MCE BALIGUAS	2 ALTM Model: PEGASUS	3 Mission Name: 2BLK36IB	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP 9022
7 Pilot: R. SAMANIEGO II	8 Co-Pilot: F. PEPITO	9 Route:			
10 Date: DEC. 27, 2013	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1043	14 Engine Off: 1400	15 Total Engine Time: 3+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

MISSION ABORTED DUE BAD WEATHER

21 Problems and Solutions:

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

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

Pilot-in-Command
R. SAMANIEGO II
Signature over Printed Name

Lidar Operator
CATHERINE BALIGUAS
Signature over Printed Name

CERTIFIED PHOTOCOPY
Signature:
Name: Romi Bianco
Date: 2/6/14

Figure A-6.1. Flight Log for Mission 923P

2. Flight Log for Mission 925P

DREAM Data Acquisition Flight Log — **Flight Log No.:** 925P

1 LiDAR Operator: P. ARCEO	2 ALTM Model: PEGASUS	3 Mission Name: 1BUCB 361A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP 9022
7 Pilot: R. SAMAR II	8 Co-Pilot: E. PEPITO	9 Route:			
10 Date: DEC. 27, 2013	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1536 H	14 Engine Off: 1735 H	15 Total Engine Time: 1+59 H	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	VERY CLOUDY / NIMBUS STRATUS				

20 Remarks:

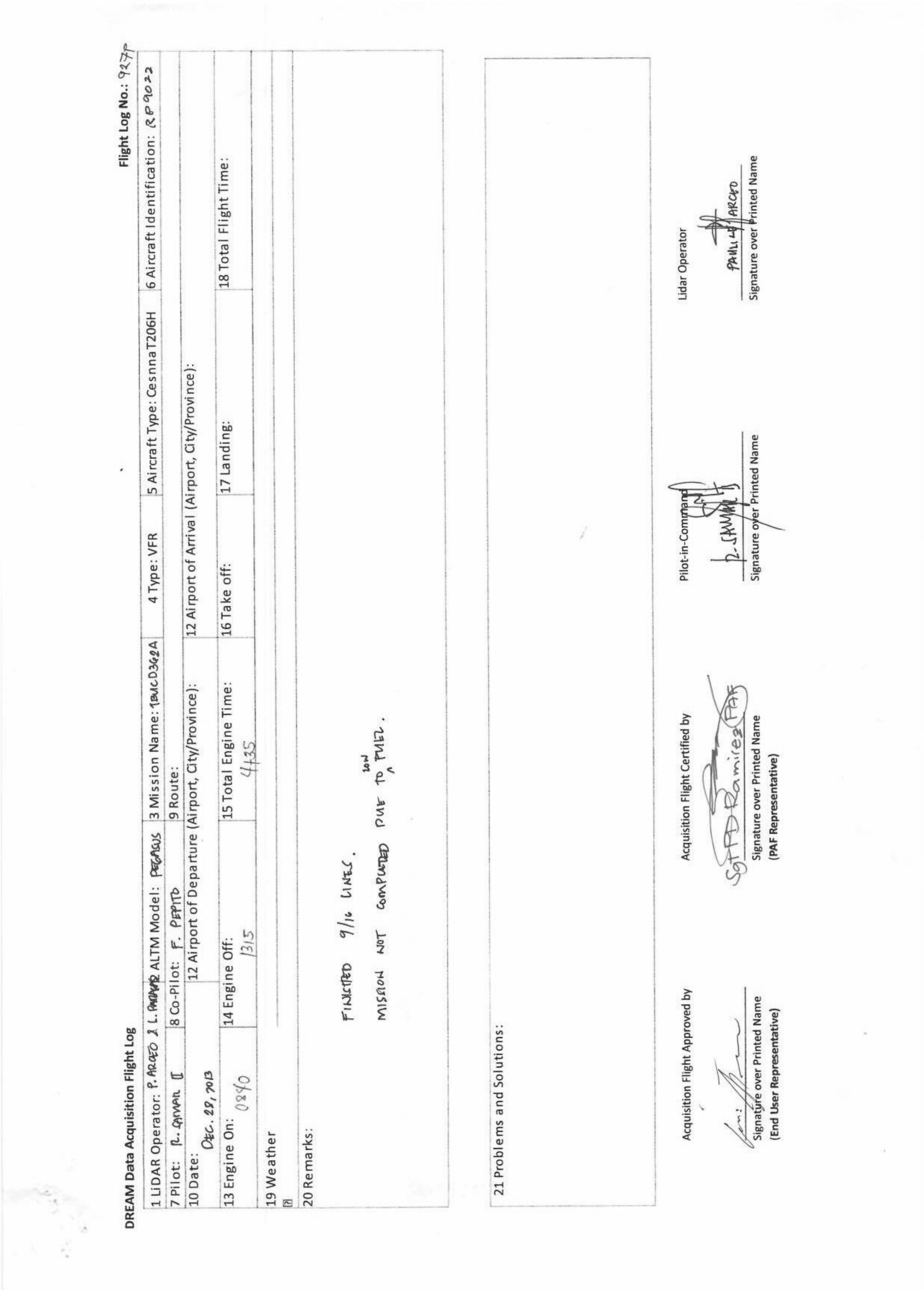
MISSION ABORTED DUE TO BAD WEATHER / HEAVY CLOUD BUILD UP IN SURVEY AREAS & OTHER PARTS OF ZAMBALES.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUÑA	SGT PD Ramirez PAF	R. SAMAR II	PAULINE ARCEO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for Mission 925P

3. Flight Log for Mission 927P



DREAM Data Acquisition Flight Log

Flight Log No.: 927P

1 LiDAR Operator: P. ARCEO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLKCD362A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9022
7 Pilot: R. GAMAN II	8 Co-Pilot: F. PEPITO	9 Route:			
10 Date: DEC. 29, 2013	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0840	14 Engine Off: 1315	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FINISHED 9/16 LINES. MISSION NOT COMPLETED DUE TO FUEL.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
	SgtFD Ramirez PAF	R. GAMAN II	PAUL ARCEO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.3. Flight Log for Mission 927P

4. Flight Log for Mission 931P

DREAM Data Acquisition Flight Log **Flight Log No.:** 931P

1 LiDAR Operator: P. ARCEO	2 ALTM Model: PEGASUS	3 Mission Name: 1BUCDS363A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP9022
7 Pilot: R. SAMAR II	8 Co-Pilot: F. PEPITO	9 Route:			
10 Date: DEC. 29, 2013	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 8:23	14 Engine Off: 1310	15 Total Engine Time: 4+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: MISSION COMPLETED. PLUS ADDITIONAL PLAN BUT FINISHED ONLY TWO LINES DUE TO LOW FUEL.					

21 Problems and Solutions:

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

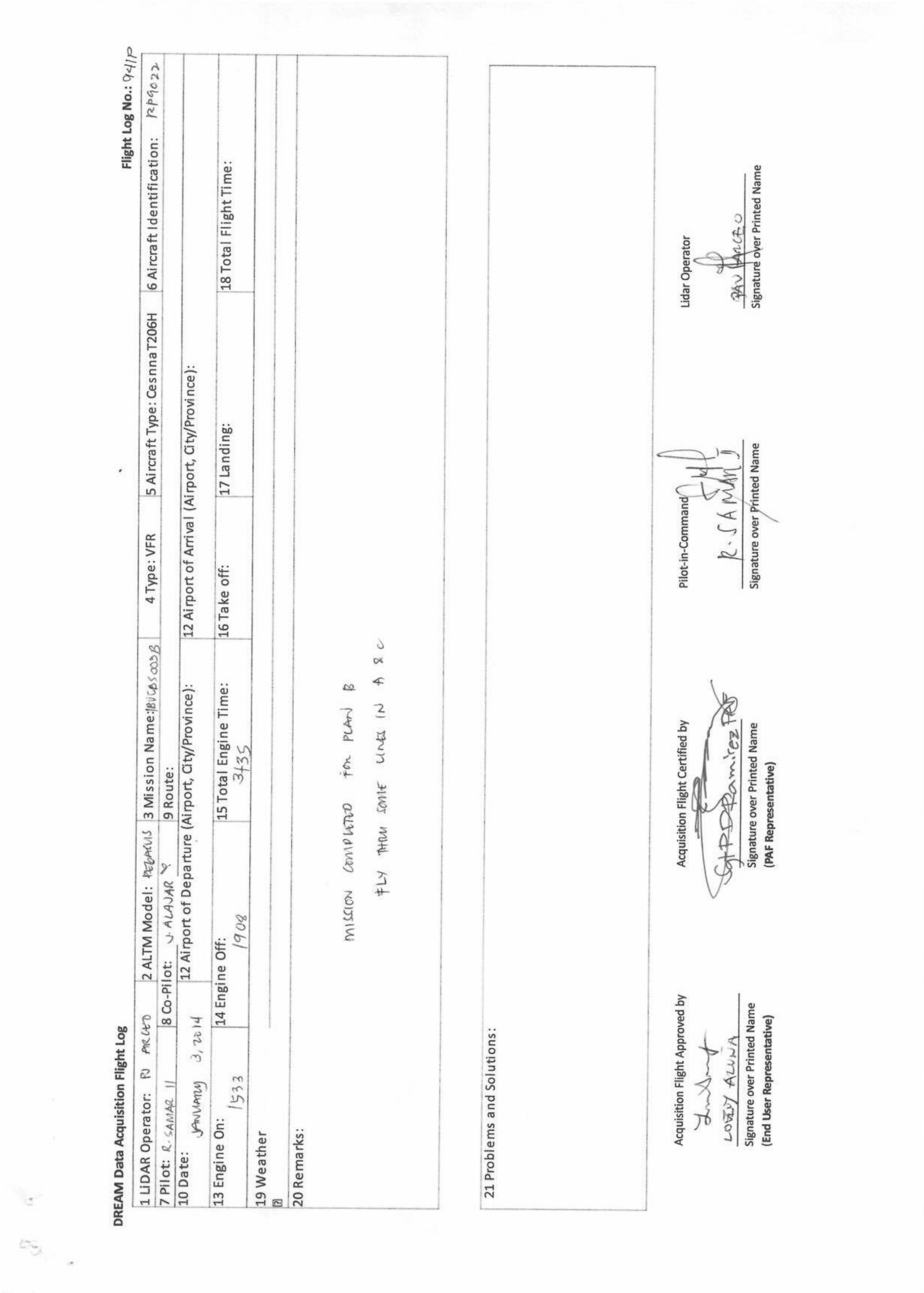
Acquisition Flight Certified by
Sgt PD Ramirez PAF
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
R. SAMAR II
Signature over Printed Name

Lidar Operator
PAULINE ARCEO
Signature over Printed Name

Figure A-6.4. Flight Log for Mission 931P

5. Flight Log for Mission 941P



DREAM Data Acquisition Flight Log

Flight Log No.: 941P

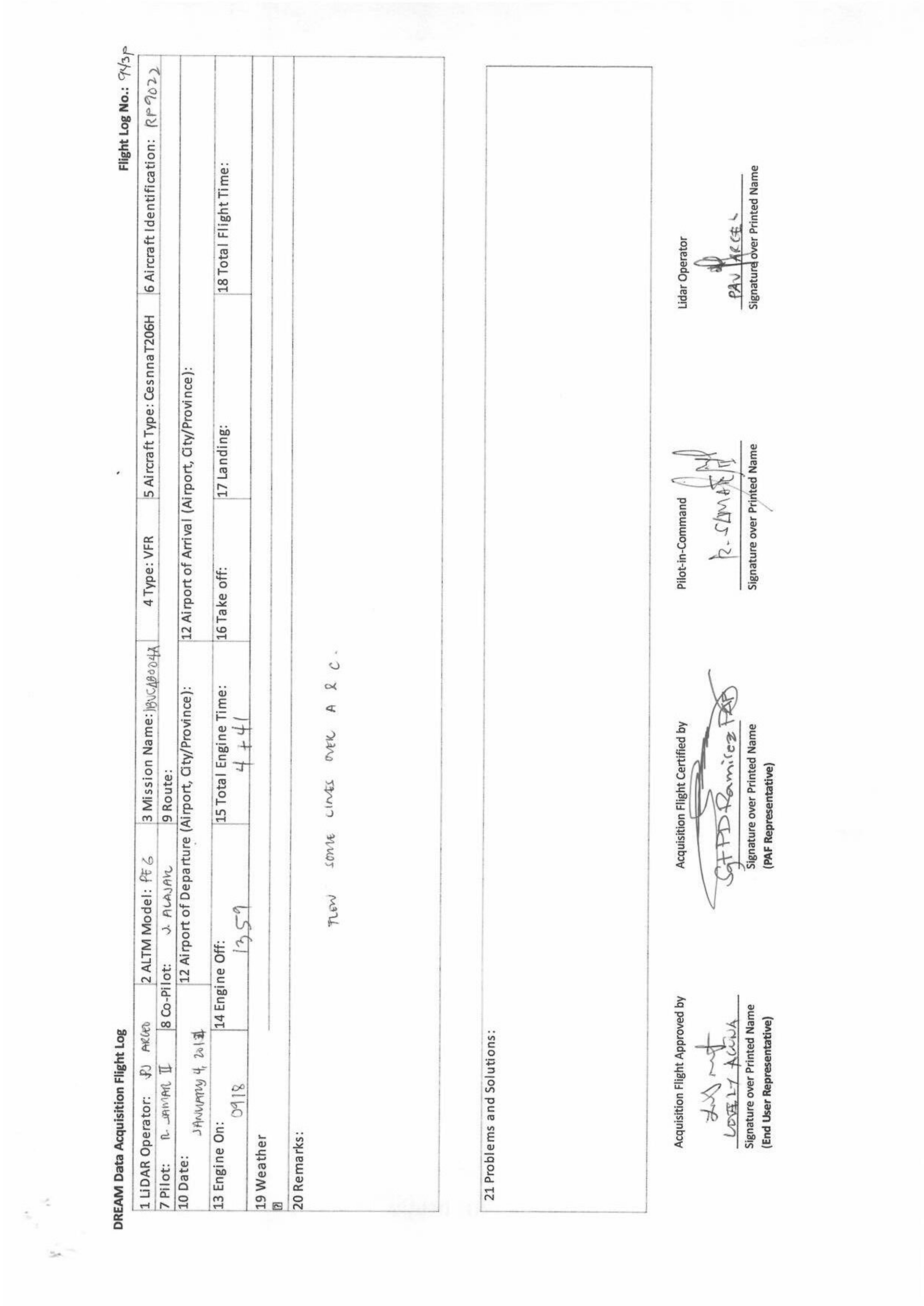
1 LiDAR Operator: R. ARCEO	2 ALTM Model: PEGASUS	3 Mission Name: 1BVCBS003B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP9022
7 Pilot: R. SAMAR II	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: JANUARY 3, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1533	14 Engine Off: 1908	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: MISSION COMPLETED FOR PLAN B FLY THRU SOME LINES IN A & C					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ALUNA	SGT PD Ramirez PAF	R. SAMAR II	RAV ARCEO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.5. Flight Log for Mission 941P

6. Flight Log for Mission 943P



DREAM Data Acquisition Flight Log

Flight Log No.: 943P

1 LiDAR Operator: PJ ARCEO	2 ALTM Model: PE 6	3 Mission Name: 1BUCAB004A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP9022
7 Pilot: R. JAMAR II	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: JANUARY 4, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0918	14 Engine Off: 1359	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FLEW SOME LINES OVER A & C.					

21 Problems and Solutions:

Acquisition Flight Approved by: LOVELY ACUNA, Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: SGT PD Ramirez PAF, Signature over Printed Name (PAF Representative)

Pilot-in-Command: R. JAMAR II, Signature over Printed Name

Lidar Operator: PJ ARCEO, Signature over Printed Name

Figure A-6.6. Flight Log for Mission 943P

7. Flight Log for Mission 947P

DREAM Data Acquisition Flight Log

Flight Log No.: 947P

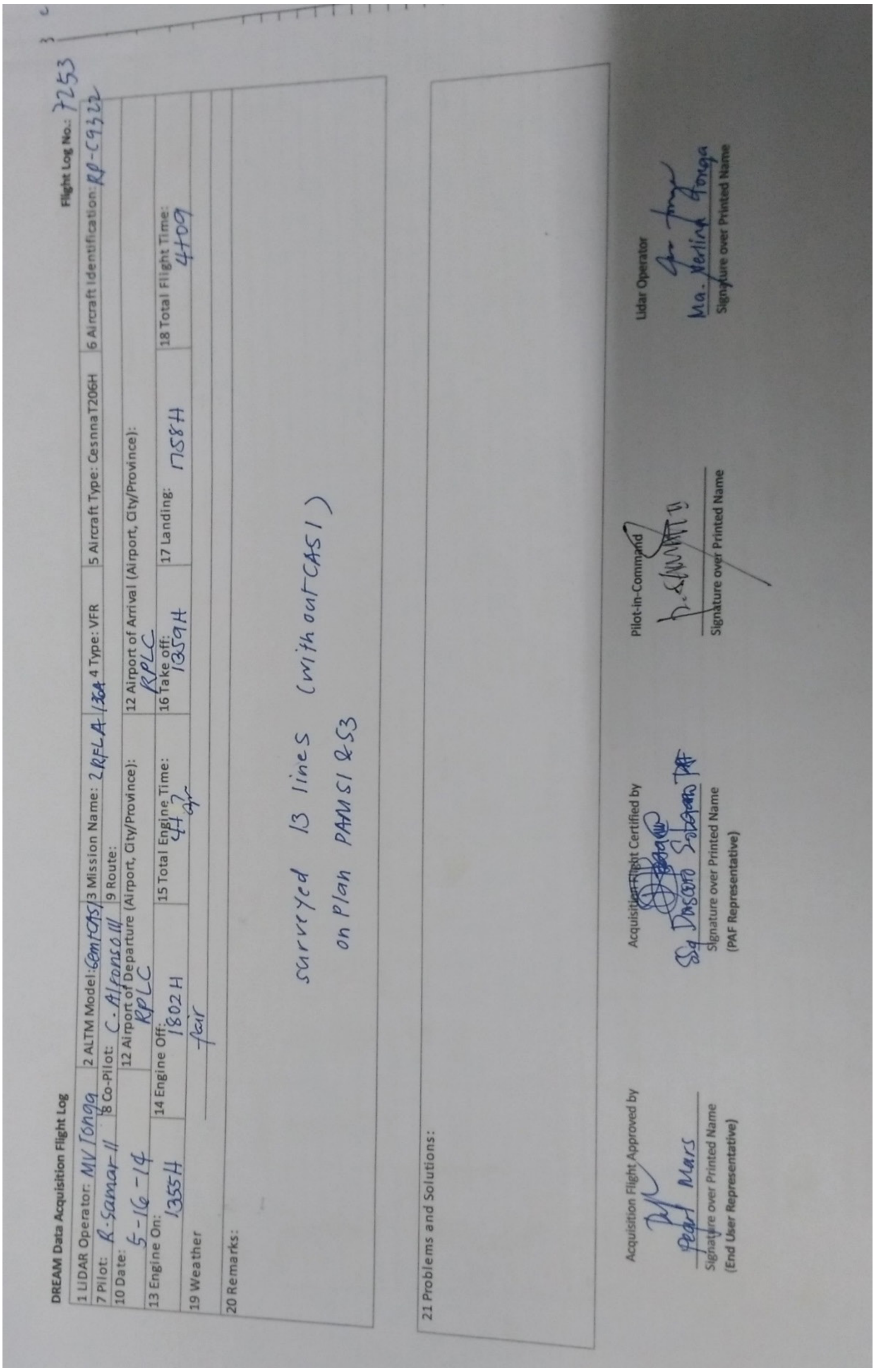
1 LiDAR Operator: R ARCEO	2 ALTM Model: PEG	3 Mission Name: IBUGACS005A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP 9022
7 Pilot: R. SAMAN II	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: JANUARY 5, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0926	14 Engine Off: 1337	15 Total Engine Time: 4+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: MISSION COMPLETED					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
LOVELY ACUESTA	Sgt PD Ramirez PAF	R. SAMANTE	PAV ARCEO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.7. Flight Log for Mission 947P

8. Flight Log for Mission 7253GC



DREAM Data Acquisition Flight Log

Flight Log No.: 7253

1 LiDAR Operator: MV Tonga	2 ALTM Model: Gemini/CAS	3 Mission Name: 2RFLA 136A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: C. Alfonso III	9 Route:			
10 Date: 5-16-14	12 Airport of Departure (Airport, City/Province): RPLC		12 Airport of Arrival (Airport, City/Province): RPLC		
13 Engine On: 1355H	14 Engine Off: 1802H	15 Total Engine Time: 4+07	16 Take off: 1359H	17 Landing: 1758H	18 Total Flight Time: 4+09
19 Weather	fair				

20 Remarks:

surveyed 13 lines (without CAS I) on Plan PAN S1 & S3

21 Problems and Solutions:

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

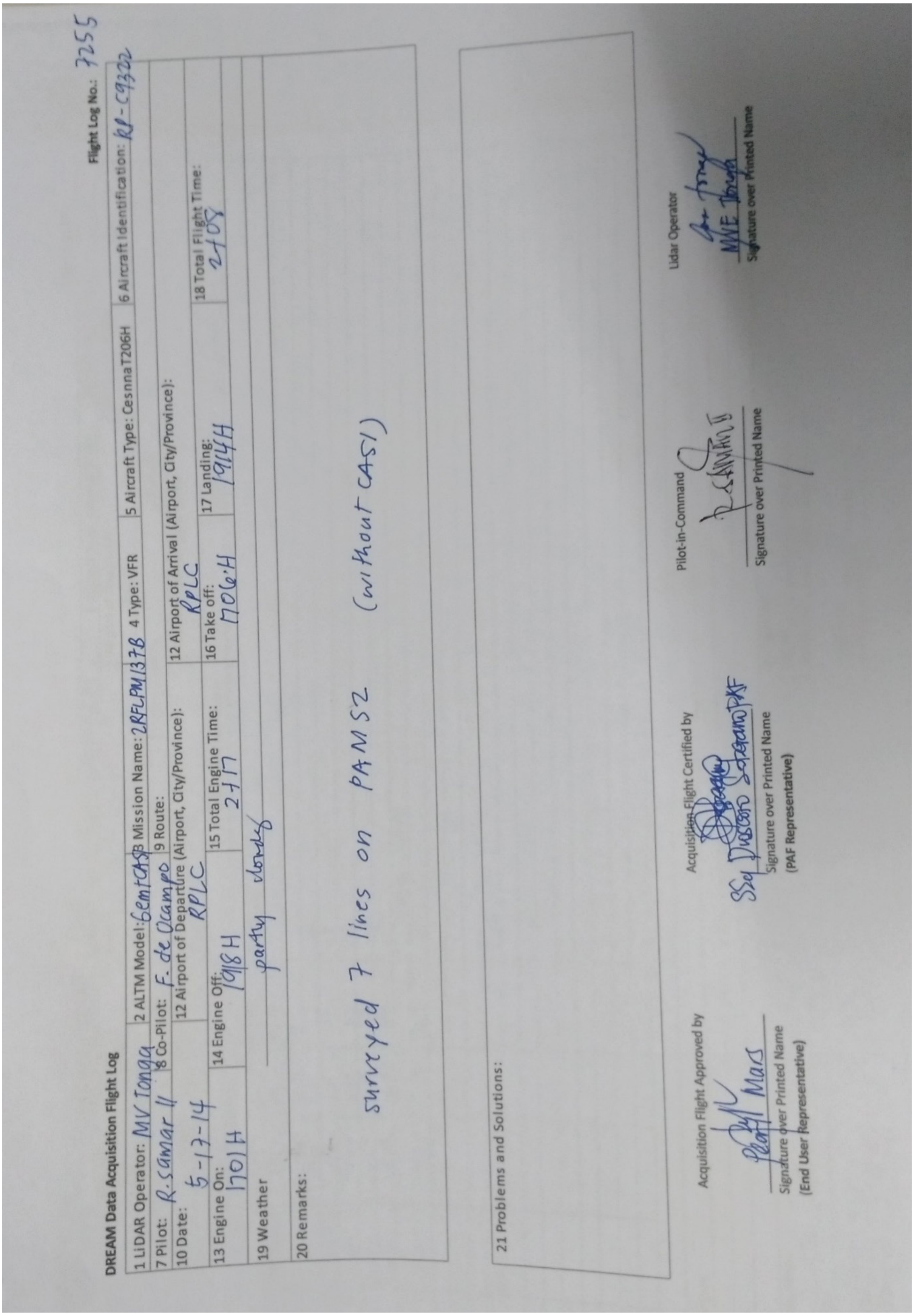
Acquisition Flight Certified by: SSg Dioscoro Sotero PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: R. Samar II — Signature over Printed Name

Lidar Operator: Ma. Verlina Tonga — Signature over Printed Name

Figure A-6.8. Flight Log for Mission 7253GC

9. Flight Log for Mission 7255GC



Flight Log No.: 7255

DREAM Data Acquisition Flight Log

1 LiDAR Operator: MV Tonga	2 ALTM Model: GemCASI	3 Mission Name: 2RFLPM137B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: F. de Ocampo	9 Route:			
10 Date: 5-17-14	12 Airport of Departure (Airport, City/Province): RPLC		12 Airport of Arrival (Airport, City/Province): RPLC		
13 Engine On: 1701H	14 Engine Off: 1918H	15 Total Engine Time: 2+17	16 Take off: 1706H	17 Landing: 1914H	18 Total Flight Time: 2+08
19 Weather	partly cloudy				

20 Remarks:

surveyed 7 lines on PAMS2 (without CASI)

21 Problems and Solutions:

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

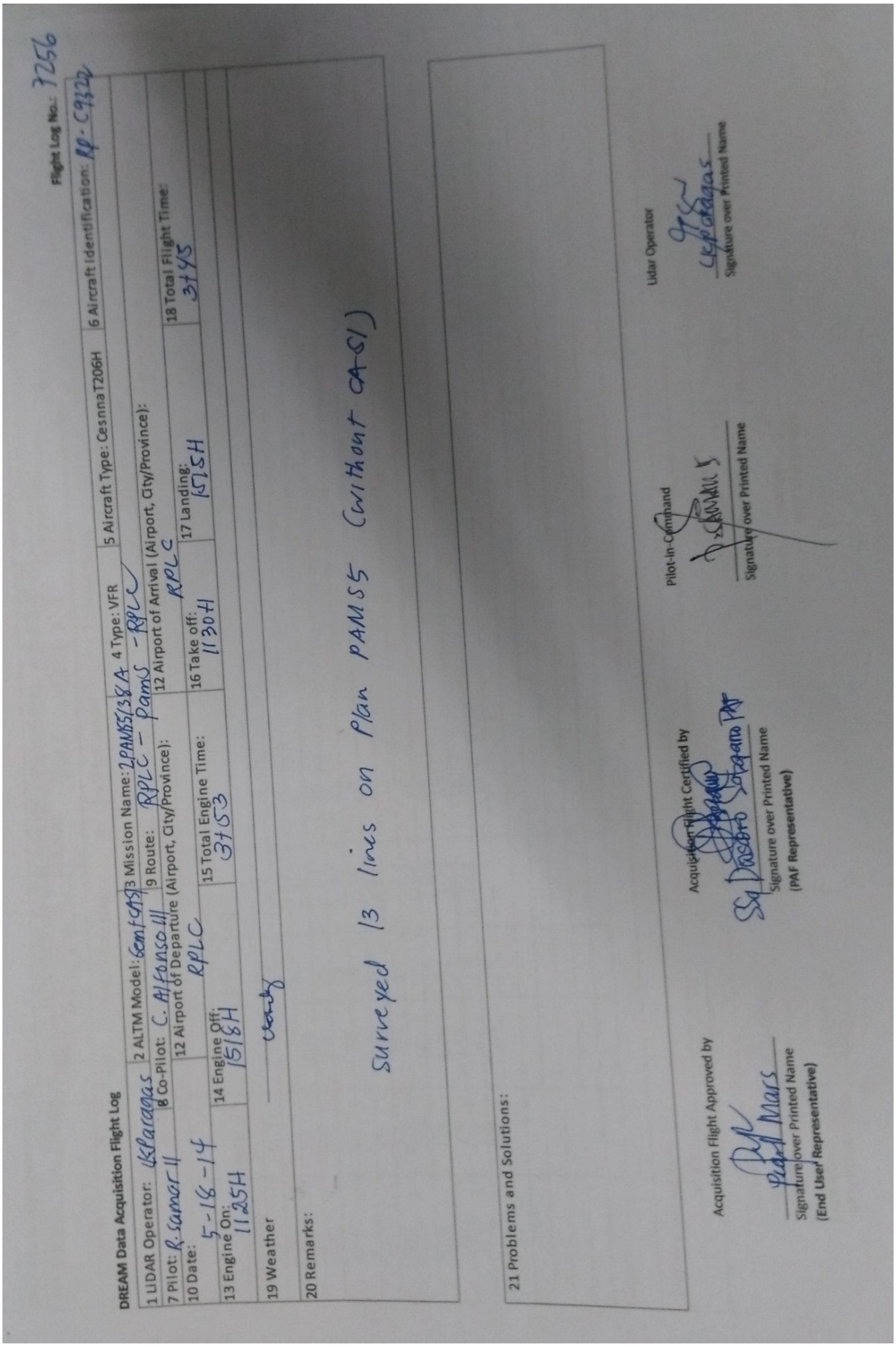
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — MVE Tonga — Signature over Printed Name

Figure A-6.9. Flight Log for Mission 7255GC

10. Flight Log for Mission 7256GC



Flight Log No.: 7256

DREAM Data Acquisition Flight Log

1 LiDAR Operator: LK Paragas	2 ALTM Model: Gemini/CASI	3 Mission Name: 2PAMS5138A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R. Samar II	8 Co-Pilot: C. Alfonso III	9 Route: RPLC - PAMS - RPLC			
10 Date: 5-18-14	12 Airport of Departure (Airport, City/Province): RPLC	12 Airport of Arrival (Airport, City/Province): RPLC			
13 Engine On: 1125H	14 Engine Off: 1518H	15 Total Engine Time: 3+53	16 Take off: 1130H	17 Landing: 1515H	18 Total Flight Time: 3+45
19 Weather: cloudy					
20 Remarks: Surveyed 13 lines on plan PAMS5 (without CASI)					
21 Problems and Solutions:					

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

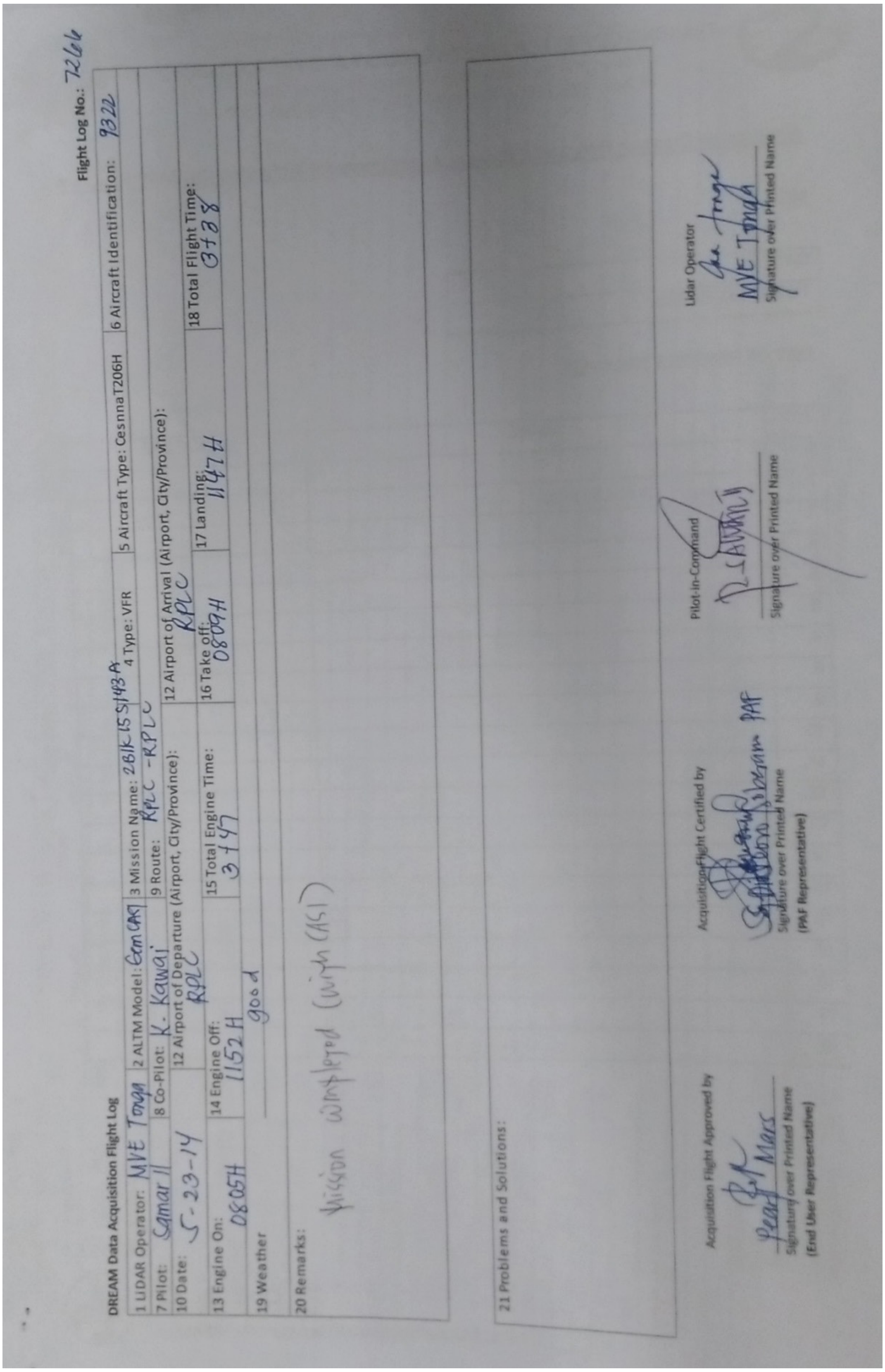
Acquisition Flight Certified by: SSg Dasoro Spagano PAF, Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

Lidar Operator: LK Paragas, Signature over Printed Name

Figure A-6.10. Flight Log for Mission 7256GC

11. Flight Log for Mission 7266GC


DREAM Data Acquisition Flight Log

Flight Log No.: 7266

1 LIDAR Operator: MVE Tonga	2 ALTM Model: Gem CAS	3 Mission Name: 2BlK15S143A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: Samar II	8 Co-Pilot: K. Kawai	9 Route: RPLC -RPLC			
10 Date: 5-23-14	12 Airport of Departure (Airport, City/Province): RPLC		12 Airport of Arrival (Airport, City/Province): RPLC		
13 Engine On: 0805H	14 Engine Off: 1152H	15 Total Engine Time: 3+47	16 Take off: 0809H	17 Landing: 1147H	18 Total Flight Time: 3+38
19 Weather	good				

20 Remarks:

Mission completed (with CAS)

21 Problems and Solutions:

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

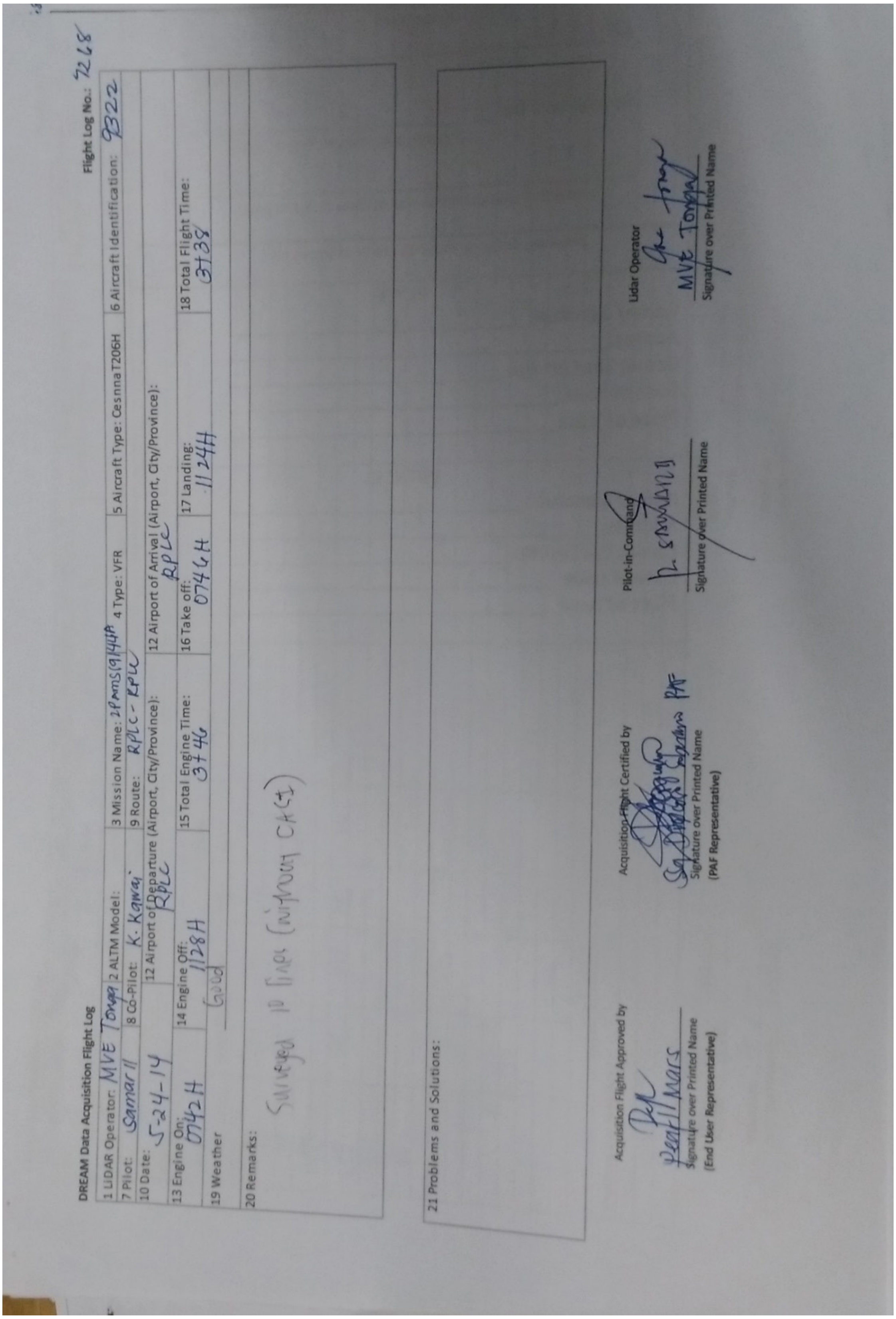
Acquisition Flight Certified by
[illegible] PAF
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
D. SAMAR II
Signature over Printed Name

Lidar Operator
MVE Tonga
Signature over Printed Name

Figure A-6.11. Flight Log for Mission 7253GC

12. Flight Log for Mission 7268GC


DREAM Data Acquisition Flight Log

Flight Log No.: 7268

1 LiDAR Operator: MVE Tonga	2 ALTM Model:	3 Mission Name: 2PAMS19144A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Samar II	8 Co-Pilot: K. Kawai	9 Route: RPLC - RPLC			
10 Date: 5-24-14	12 Airport of Departure (Airport, City/Province): RPLC		12 Airport of Arrival (Airport, City/Province): RPLC		
13 Engine On: 0742H	14 Engine Off: 1128H	15 Total Engine Time: 3+46	16 Take off: 0744H	17 Landing: 1124H	18 Total Flight Time: 3+38
19 Weather	Good				

20 Remarks:

Surveyed 10 lines (without CAT)

21 Problems and Solutions:

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

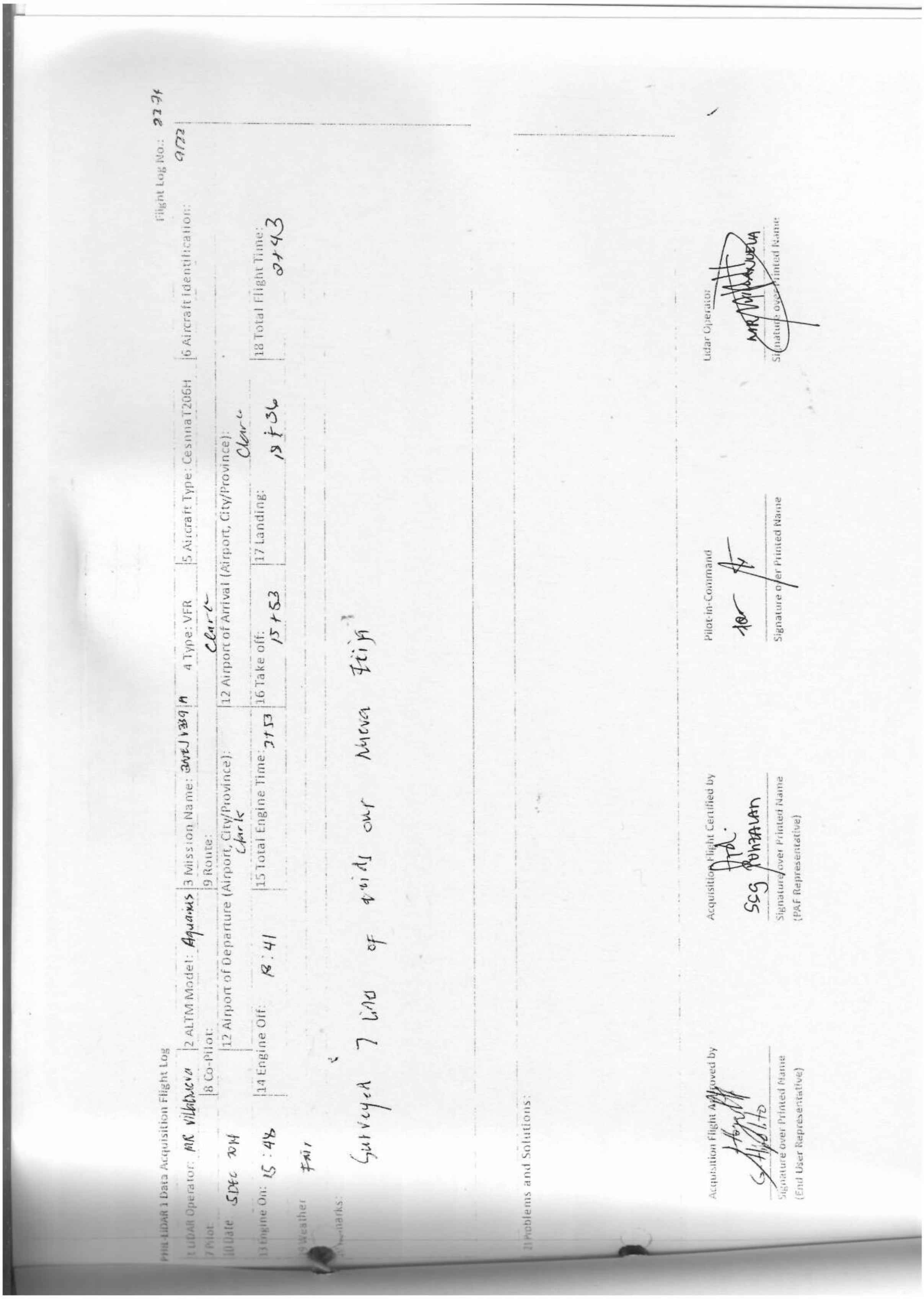
Acquisition Flight Certified by
PAF
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
Signature over Printed Name

Lidar Operator
MVE Tongol
Signature over Printed Name

Figure A-6.12. Flight Log for Mission 7268GC

13. Flight Log for Mission 2274A



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2274

1 LIDAR Operator: MR Villanueva | 2 ALTM Model: Aquarius | 3 Mission Name: [illegible] | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: 9122

7 Pilot: | 8 Co-Pilot: | 9 Route: Clark

10 Date: 5 Dec 2014 | 12 Airport of Departure (Airport, City/Province): Clark | 12 Airport of Arrival (Airport, City/Province): Clark

13 Engine On: 15:48 | 14 Engine Off: 18:41 | 15 Total Engine Time: 2+53 | 16 Take off: 15+53 | 17 Landing: 18+36 | 18 Total Flight Time: 2+43

19 Weather: Fair

20 Remarks: Surveyed 7 lines of gaps over Nueva Ecija

21 Problems and Solutions:

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

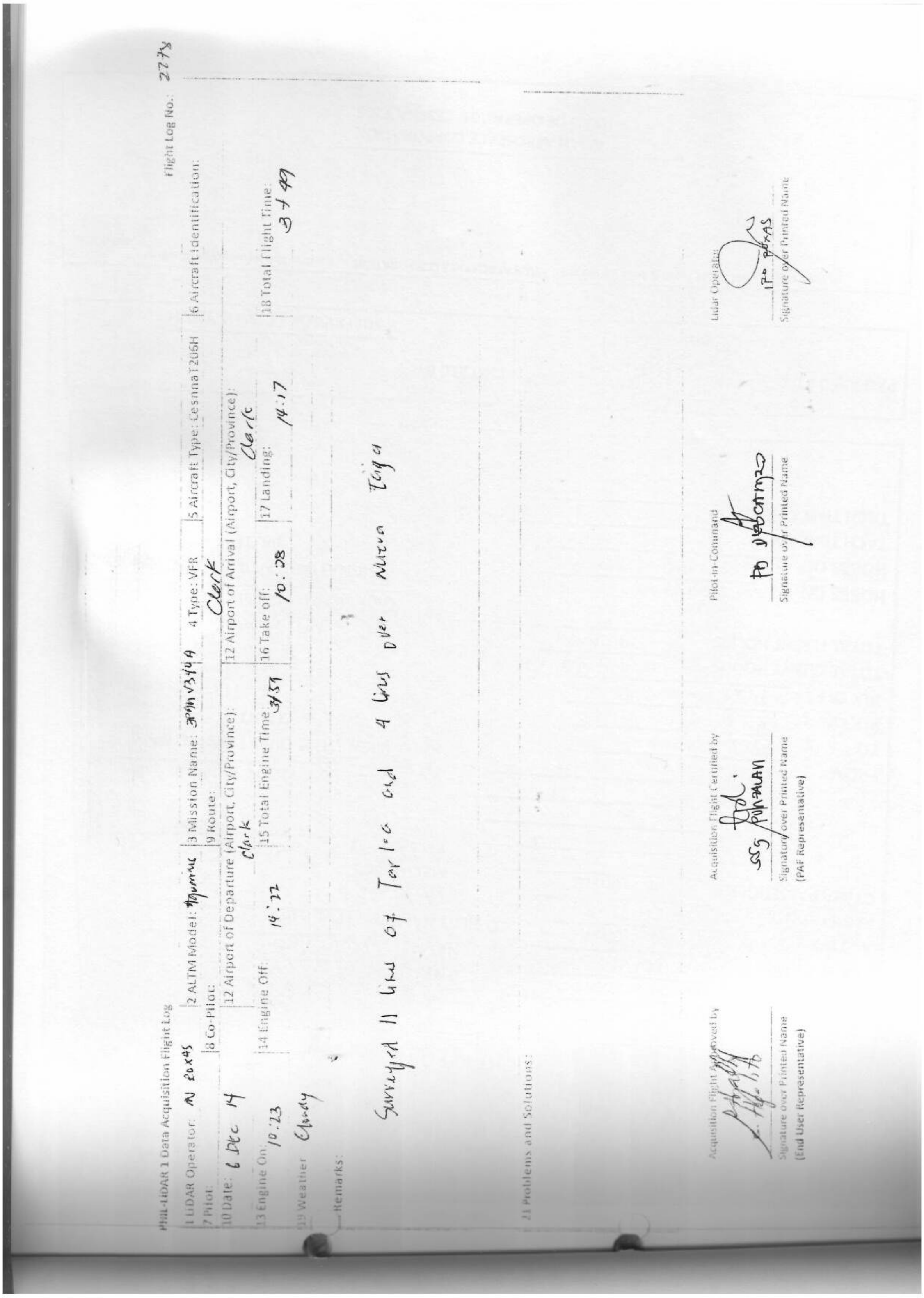
Acquisition Flight Certified by: SSG Punzalan, Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

Lidar Operator: MR Villanueva, Signature over Printed Name

Figure A-6.13. Flight Log for Mission 2274A

14. Flight Log for 2278A Mission


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2278

1 LiDAR Operator: N Leras	2 ALTM Model: Aquarius	3 Mission Name: 3FHV349A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date: 6 Dec 14	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark		
13 Engine On: 10:23	14 Engine Off: 14:22	15 Total Engine Time: 3+59	16 Take off: 10:28	17 Landing: 14:17	18 Total Flight Time: 3+49
19 Weather: Cloudy					

Remarks:

Surveyed 11 lines of Tarlac and 4 lines over Nueva Ecija

21 Problems and Solutions:

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

Acquisition Flight Certified by: SSG Pujalan, Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

Figure A-6.14. Flight Log for Mission 2278A

15. Flight Log for Mission 2471P

DREAM Data Acquisition Flight Log | **Flight Log No.:** 2471

1 LiDAR Operator: I. ROXAS	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK26ZDA	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. ALAJAR	8 Co-Pilot: J. JOYA	9 Route: ZAMBALES			
10 Date: JAN. 20, 2015	12 Airport of Departure (Airport, City/Province): CLARK		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 14+22	14 Engine Off: 17+28	15 Total Engine Time: 3+6	16 Take off: 1427H	17 Landing: 17+23	18 Total Flight Time: 3+1
19 Weather					
20 Remarks: Successful flight					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	Edwin Delos Santos	J. Alajar	Efo Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.15. Flight Log for Mission 2471P

16. Flight Log for Mission 2473P

DREAM Data Acquisition Flight Log

Flight Log No.: 2473

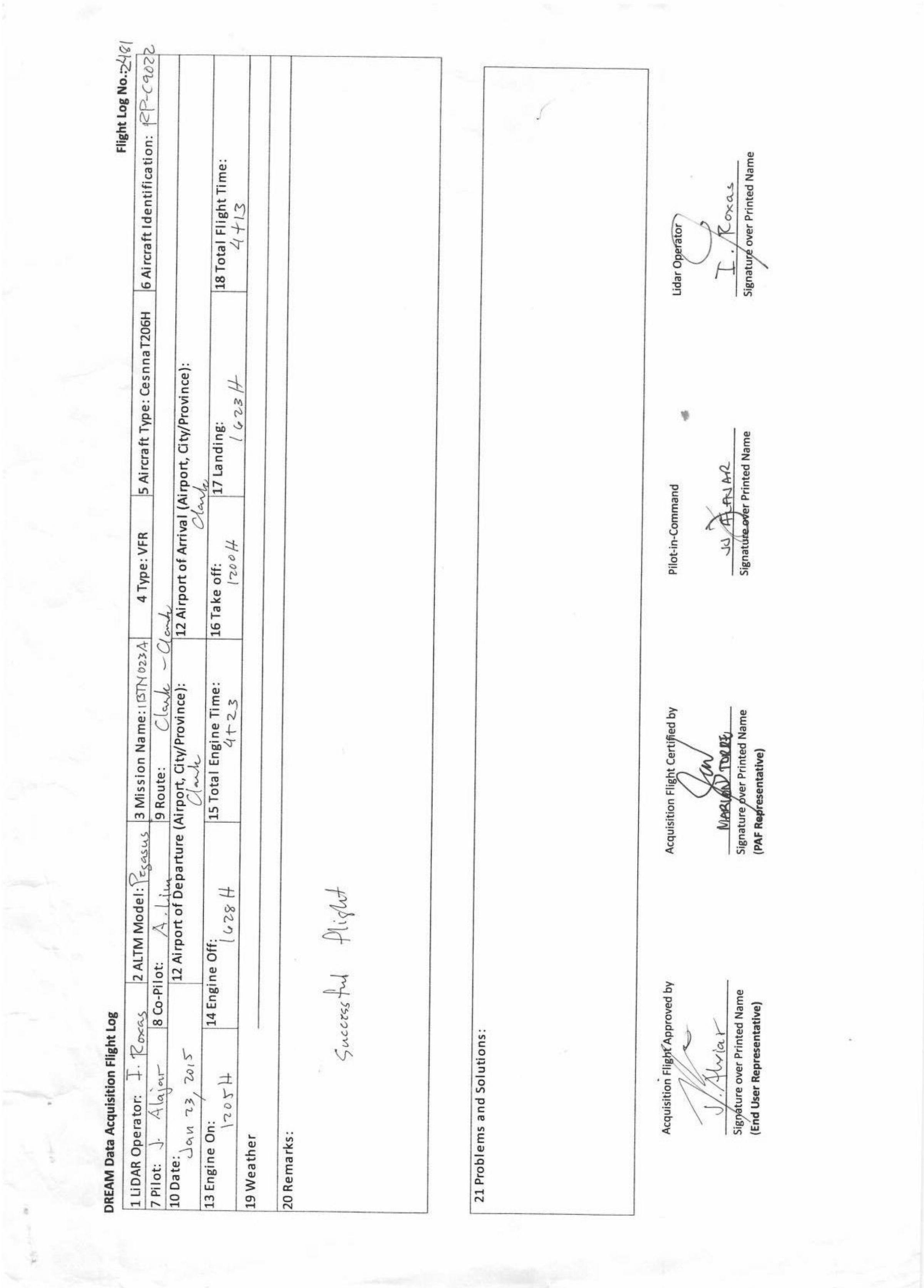
1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEGASUS	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. ALAJAR	8 Co-Pilot: A. LIM	9 Route: ZAMBALES			
10 Date: JAN. 21, 2015	12 Airport of Departure (Airport, City/Province): CLARK		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 10+57	14 Engine Off: 15+2	15 Total Engine Time: 4+5	16 Take off: 1102	17 Landing: 1457	18 Total Flight Time: 3+55
19 Weather: partly cloudy					
20 Remarks: Successful flight					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Rinion	ERWIN DELOS SANTOS	J. ALAJAR	R. PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.16. Flight Log for Mission 2473P

17. Flight Log for 2481P Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 2481

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BTN023A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: Clark - Clark			
10 Date: Jan 23, 2015	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark		
13 Engine On: 1205H	14 Engine Off: 1628H	15 Total Engine Time: 4+23	16 Take off: 1200H	17 Landing: 1623H	18 Total Flight Time: 4+13
19 Weather					

20 Remarks:

Successful Flight

21 Problems and Solutions:

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

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

Pilot-in-Command: JJ Alajar — Signature over Printed Name

Lidar Operator: I. Roxas — Signature over Printed Name

Figure A-6.17. Flight Log for Mission 2481P

18. Flight Log for 2493P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 2493

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK02GA	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joya	9 Route:			
10 Date: Jan. 26, 2015	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1017H	14 Engine Off: 1334H	15 Total Engine Time: 3+17	16 Take off: 1022H	17 Landing: 1329H	18 Total Flight Time: 3+7
19 Weather	Partly cloudy				

20 Remarks:

Successful mission, 1800m flying height at 100PRF

21 Problems and Solutions:

Cam assertion failed

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
	Marlon Torre	C. Alfonso III Cesar Alfonso	J. Alviar
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.18. Flight Log for Mission 2493P

19. Flight Log for Mission 2497P

DREAM Data Acquisition Flight Log

Flight Log No.: 2497

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK027A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jaya	9 Route: Clark - Clark			
10 Date: Jan. 27, 2015	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark		
13 Engine On: 1147H	14 Engine Off: 1458H	15 Total Engine Time: 3+11	16 Take off: 1152H	17 Landing: 1453H	18 Total Flight Time: 3+01
19 Weather: Cloudy					
20 Remarks: Surveyed Zambales gaps at variable flying heights					
21 Problems and Solutions:					

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	Marlon Torre	Alfonso III / Cesar Alfonso III	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.19. Flight Log for Mission 2497P

20. Flight Log for 2501P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 2501

1 LiDAR Operator: J. Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BUC028A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: B. Donguines	8 Co-Pilot: J. Jogo	9 Route:			
10 Date: Jan. 28, 2015	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1141H	14 Engine Off: 1510H	15 Total Engine Time: 3+29	16 Take off: 1144H	17 Landing: 1505H	18 Total Flight Time: 3+24
19 Weather	Partly cloudy				

20 Remarks:

Surveyed Iba-Palauig gaps

21 Problems and Solutions:

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

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

Pilot-in-Command: Signature over Printed Name

Lidar Operator: J. Alviar — Signature over Printed Name

Figure A-6.20. Flight Log for Mission 2501P

21. Flight Log for Mission 8411AC

Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: R.C. FELISMINO	2 ALTM Model: AQUARIUS + CASI	3 Mission Name: 3PAMS1088A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: CP-9022
7 Pilot: B. LAGCO (ALFONSO)	8 Co-Pilot: C. ALFONSO	9 Route: TARLAC			
10 Date: MARCH 28, 2016	12 Airport of Departure (Airport, City/Province): CLARK		12 Airport of Arrival (Airport, City/Province): CLARK		
13 Engine On: 12:01	14 Engine Off: 15:00	15 Total Engine Time: 2+59	16 Take off: 1204H	17 Landing: 1455H	18 Total Flight Time: 2+49
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

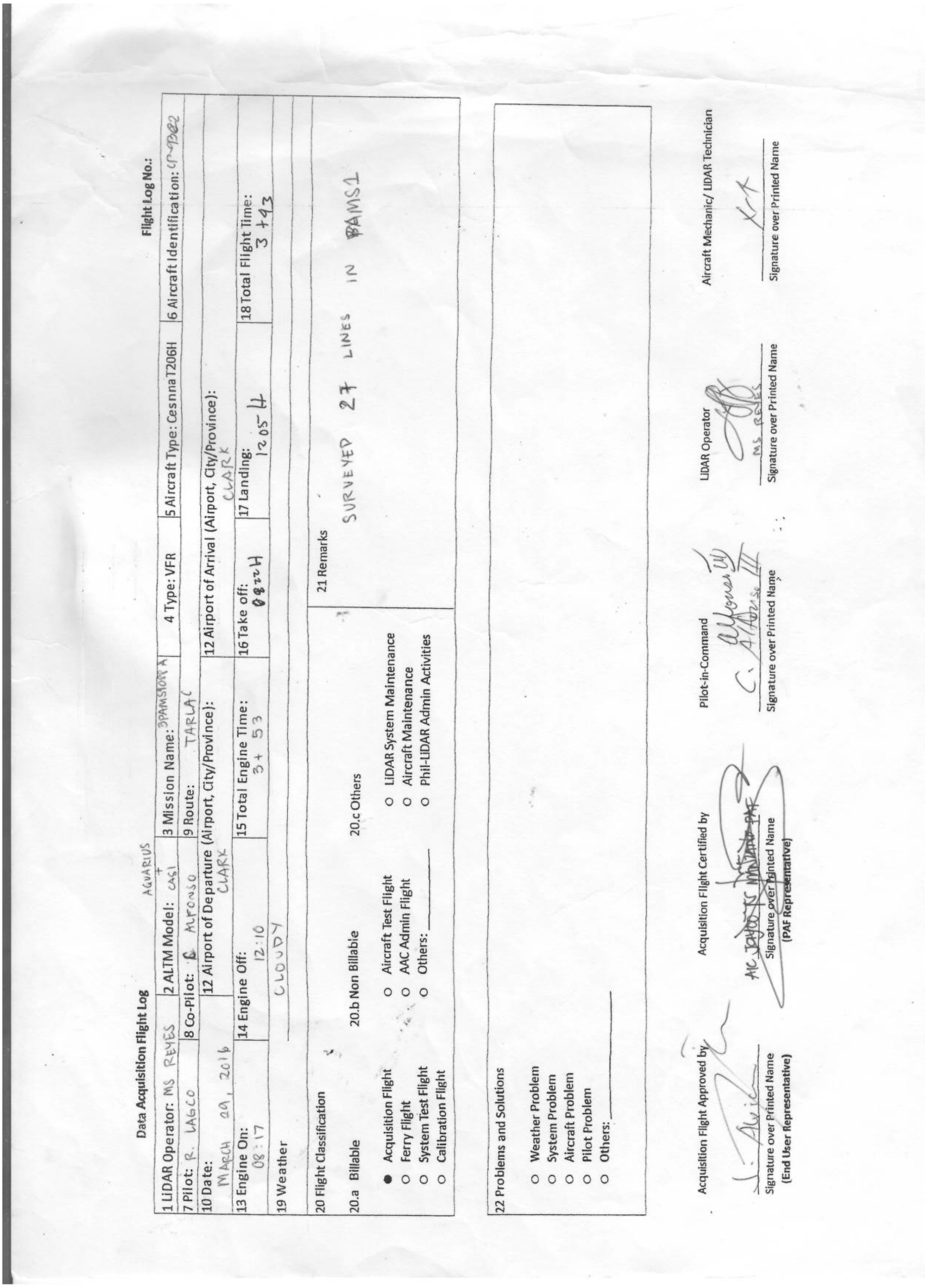
PARTIAL SHORT RANGE DUE TO RADIO; SURVEYED PAMS1

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	A1C Jayed S Magbano PAF	C. Alfonso III	RAC Felismino	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.21. Flight Log for Mission 8411AC

22. Flight Log for Mission 8412AC



Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: MS REYES	2 ALTM Model: CASI + AQUARIUS	3 Mission Name: 3PAMS10[illegible]A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: R. LAGCO	8 Co-Pilot: C. ALFONSO	9 Route: TARLAC			
10 Date: MARCH 09, 2016	12 Airport of Departure (Airport, City/Province): CLARK		12 Airport of Arrival (Airport, City/Province): CLARK		
13 Engine On: 08:17	14 Engine Off: 12:10	15 Total Engine Time: 3+53	16 Take off: 0822H	17 Landing: 1205H	18 Total Flight Time: 3+43
19 Weather	CLOUDY				

20 Flight Classification

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

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

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

21 Remarks

SURVEYED 27 LINES IN BAMS1

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

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

Acquisition Flight Certified by: A1C JOHNOTS ... PAF — Signature over Printed Name (PAF Representative)

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

LiDAR Operator: MS REYES — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: Signature over Printed Name

Figure A-6.22. Flight Log for Mission 8412AC

23. Flight Log for Mission 10214L

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator: J. Gonzales	2 ALTM Model: Leica ALS	3 Mission Name: 4BLK15A211A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9522
7 Pilot: M. Tangonan	8 Co-Pilot: D. Lozarnio	9 Route:			
10 Date: July 29, 2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0928	14 Engine Off: 1307	15 Total Engine Time: 3+35	16 Take off: 0933	17 Landing: 1302	18 Total Flight Time: 3+25
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 some lines in BLK 15A

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 over Printed Name (End User Representative)	G. Dalida Signature over Printed Name (PAF Representative)	M.C. Tangonan Signature over Printed Name	Jonathan Gonzales Signature over Printed Name	Signature over Printed Name

Figure A-6.23. Flight Log for Mission 10214L

Annex 7. Flight StatusReports

FLIGHT STATUS REPORT

Zambales, Umiray, Clark Reflights

(January 22-29, 2014; May 16-25, 2014; December 5-12, 2014; August 28-30, 2015; and July 27-28, 2016)

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
923P	BUC D	1BUCD361A	PJ ARCEO & MVE TONGA	DECEMBER 27, 2013	SURVEYED BUC D
925P	BAL A	1BALA361B	PJ ARCEO	DECEMBER 27, 2013	SURVEYED BAL A
927P	BUC C, D	1BUCD362A	PJ ARCEO & LK PARAGAS	DECEMBER 28, 2013	FINISHED 11 LINES OF BUC D
931P	BUC C, D	1BUCDS363A	PJ ARCEO	DECEMBER 29, 2013	COMPLETED THE REST OF BUC D. FINISHED 2 LINES OF BUC B
941P	BUC B	1BUCBS003B	PJ ARCEO	JANUARY 3, 2014	FINISHED 4 OF BUC B
943P	BUC A, B	1BUCAB004A	PJ ARCEO & MCE BALIGUAS	JANUARY 4, 2014	COMPLETED BUC B. FINISHED 4 LINES OF BUC C
947P	BUC A, C	1BUCACS005A	PJ ARCEO	JANUARY 5, 2014	SURVEYED BUC A, C
7253G	PAMS1, PAMS3	2PAMS1S3136A	MVE TONGA	MAY 16, 2014	MT. ARAYAT FLOWN AT 1650M (PAMS3); BULACAN AREA AT 850M(PAMS1)
7255GC	PAM S2	2PAMS2137B	MVE TONGA	MAY 17, 2014	COMPLETED 7 LINES OF PAMS2 AT 850M
7256GC	PAMS5	2PAMS5138A	LARA PARAGAS	MAY 18, 2014	COMPLETED 13 LINES OF PAMS5 AT 850M
7266GC	BLK15S	2BLK15S143A	VERLINA TONGA	MAY 23, 2014	COMPLETED 20 LINES; CHANGED ALTITUDE 3 TIMES DUE TO CLOUDS
7268GC	PAMS8	2PAMS8144A	VERLINA TONGA	MAY 24, 2014	COMPLETED 10 LINES AT 1000M
2274A	NEJ	3NEJV339A	MR VILLANUEVA	DECEMBER 5, 2014	SURVEYED 8 LINES
2278A	PAM	3PAMV340A	I ROXAS	DECEMBER 6, 2014	NO DIGITIZER

2471P	ZAMBALES	1BUC020A	I ROXAS	JANUARY 20, 2015	W/ RANGE; SWATH NOT UPDATING RESTARTED FMSNAV FMSNAV LOST CONNECTION WITH POS; WILL RESTART SYSTEM AND CHECK SOLVED BY RESTART
2473P	BUC R	1BUCR021A	R PUNTO	JANUARY 21, 2015	FILLED UP GAPS IN STO. TOMAS AND BUCAO
2481P	BTN	1BTN023A	I ROXAS	JANUARY 23, 2015	FILLED UP GAPS IN BUCAO, SURVEYED MORONG
2493P	ZAMBALES	1BUC026A	J ALVIAR	JANUARY 26, 2015	CAM ASSERTION FAILED; 1800M FLYING HEIGHT AT 100 PRF
2497P	ZAMBALES, BATAAN	1BUC027A	I ROXAS	JANUARY 27, 2015	VARIABLE FLYING HEIGHTS; PLEASE CHECK OP LOGS
2501P	ZAMBALES	1BUC028A	J ALVIAR	JANUARY 28, 2015	IBA-PALAUIG GAP
8411AC	PAM S1	3PAMS1088A	R FELISMINO	OCTOBER 25, 2016	SURVEYED PAM S1
8412AC	PAM S1	3PAMS1089A	M REYES	OCTOBER 26, 2016	SURVEYED PAM S1
10214L	BLK15 BOTOLAN	4BLK15A211A	J GONZALES	JULY 29, 2016	SURVEYED A FEW LINES OVER BOTOLAN

SWATH/LAS PER MISSION

Flight No. :	923P	
Area:	BUC D	
Mission Name:	1BUCD361A	
Parameters:	Altitude: 1200	Scan Frequency: 30
	Angle: 25	Overlap: 30

SWATH

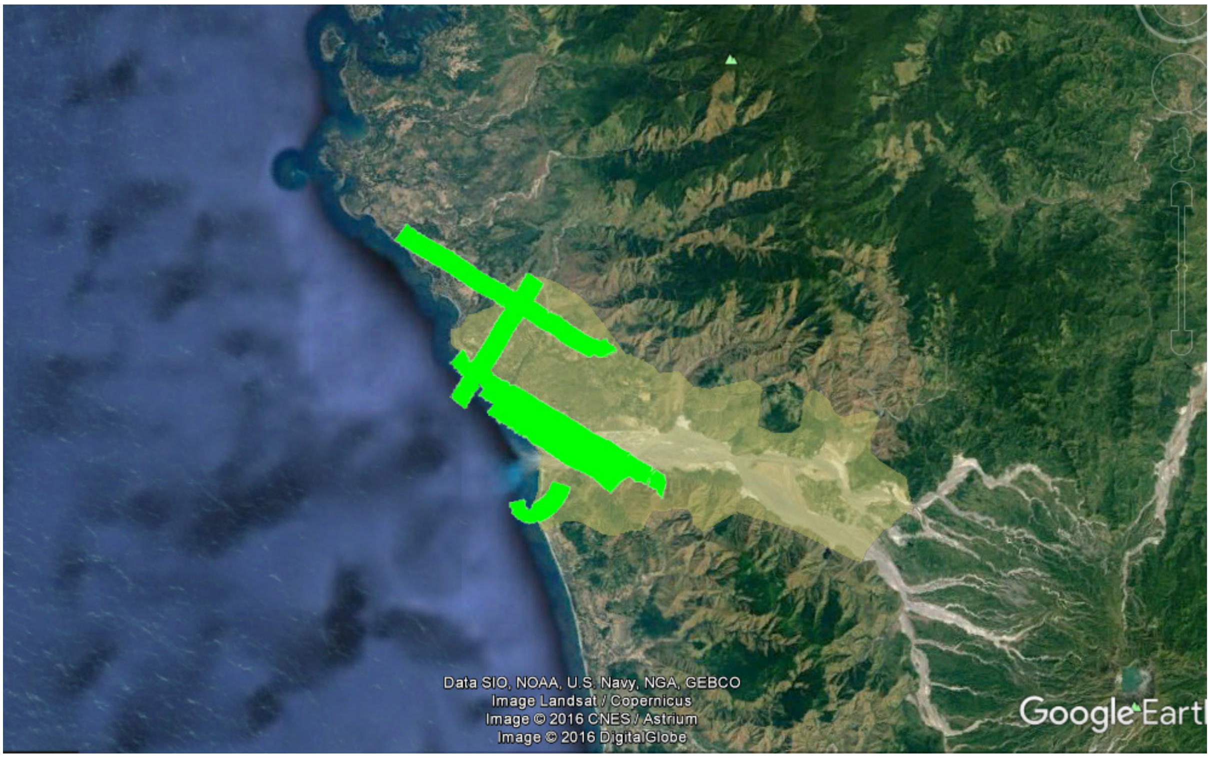


Figure A-7.1. Swath for Flight No. 923P

Flight No. :	925P	
Area:	BAL A	
Mission Name:	1BALA361B	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

SWATH

Figure A-7.2. Swath for Flight No. 925P

Flight No. :	927P	
Area:	BUC C, D	
Mission Name:	1BUCD362A	
Parameters:	Altitude: 1200	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

SWATH

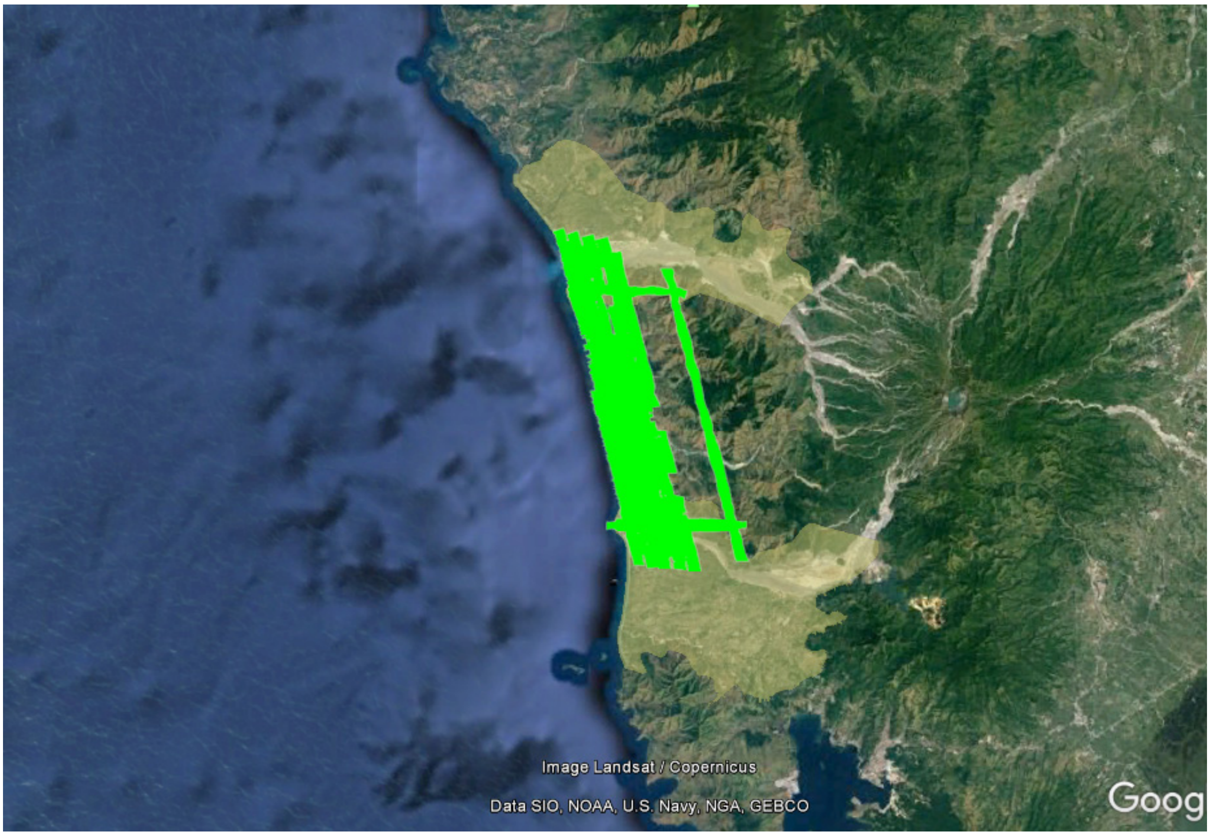


Figure A-7.3. Swath for Flight No. 927P

Flight No. :	931P	
Area:	BUC C, D	
Mission Name:	1BUCDS363A	
Parameters:	Altitude: 1200	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

SWATH

Figure A-7.4. Swath for Flight No. 931P

Flight No. :	941P	
Area:	BUC C, B	
Mission Name:	1BUCBS003B	
Parameters:	Altitude: 1200	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

SWATH

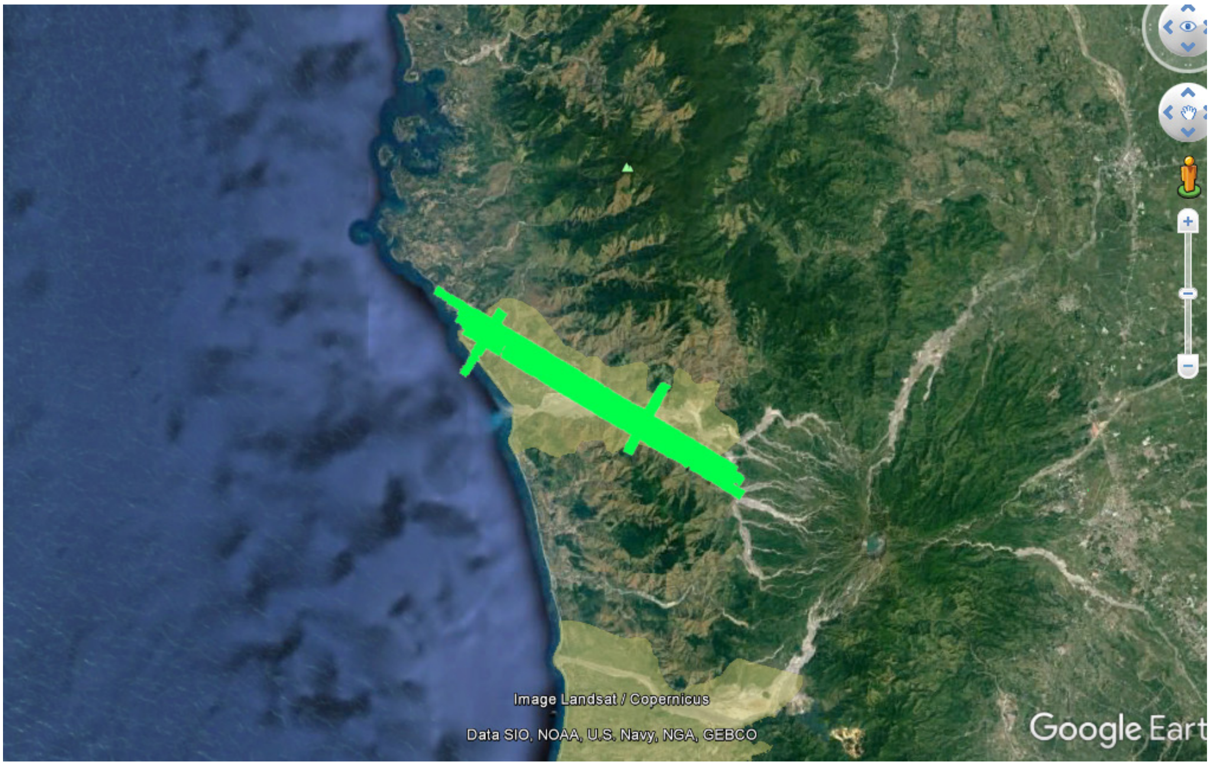


Figure A-7.5. Swath for Flight No. 941P

Flight No. :	943P	
Area:	BUC A, B	
Mission Name:	1BUCAB004A	
Parameters:	Altitude: 1200	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

SWATH

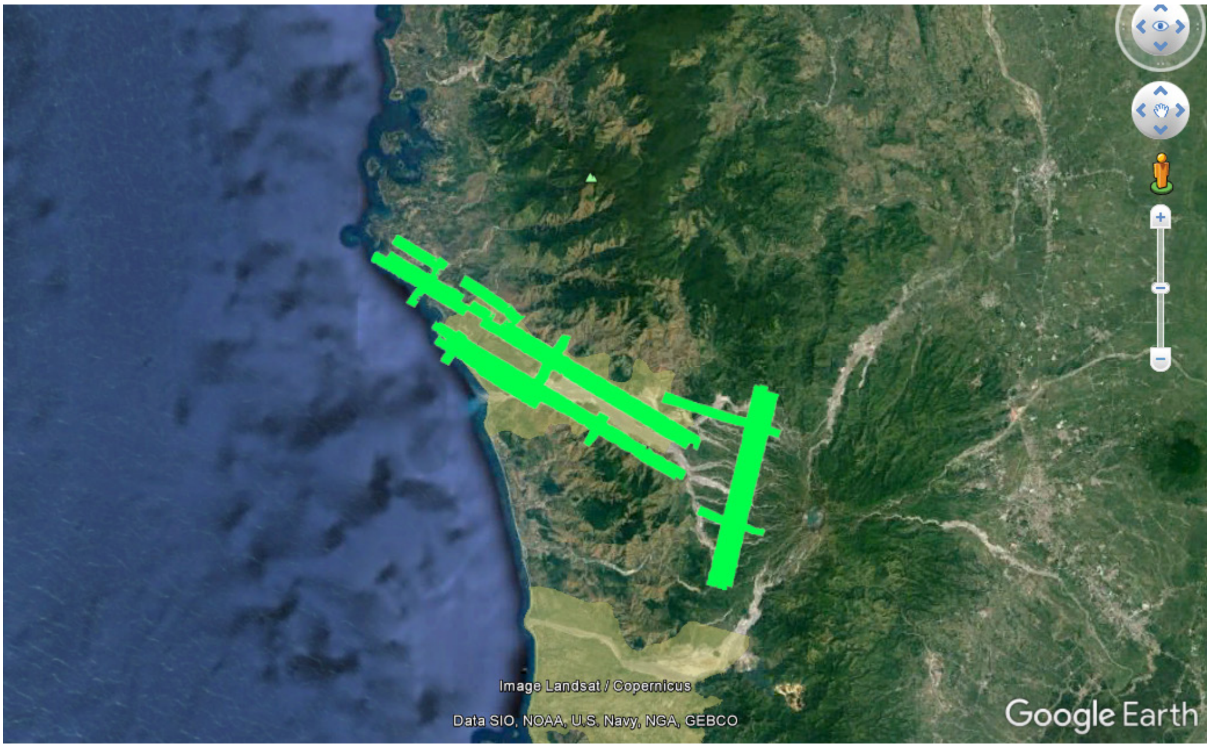


Figure A-7.6. Swath for Flight No. 943P

Flight No. :	947P	
Area:	BUC A, C	
Mission Name: 1	BUCACS005A	
Parameters:	Altitude: 1200	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

SWATH

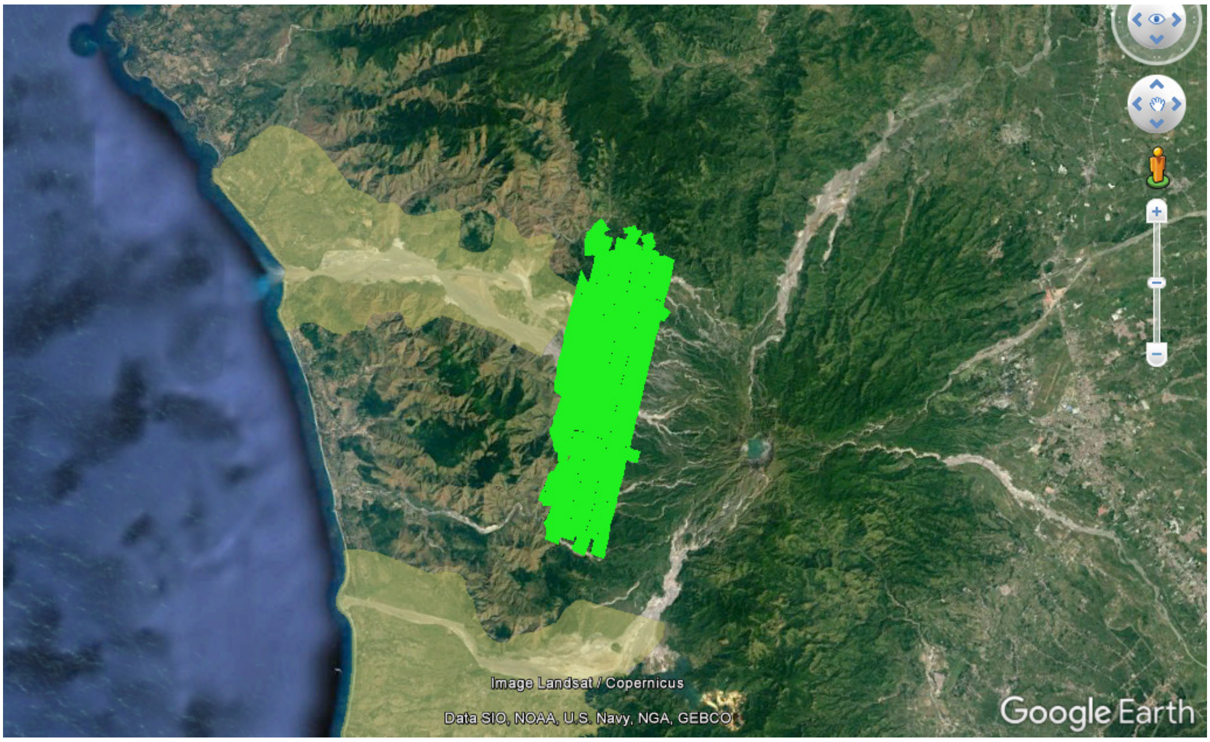


Figure A-7.7. Swath for Flight No. 947P

Flight No. :	7253G	
Area:	PAM S1, PAM S3	
Mission Name:	2PAMS1S3136A	
Parameters:	Altitude: 1650-800	Scan Frequency: 50
	Scan Angle: 20	Overlap: 30

SWATH

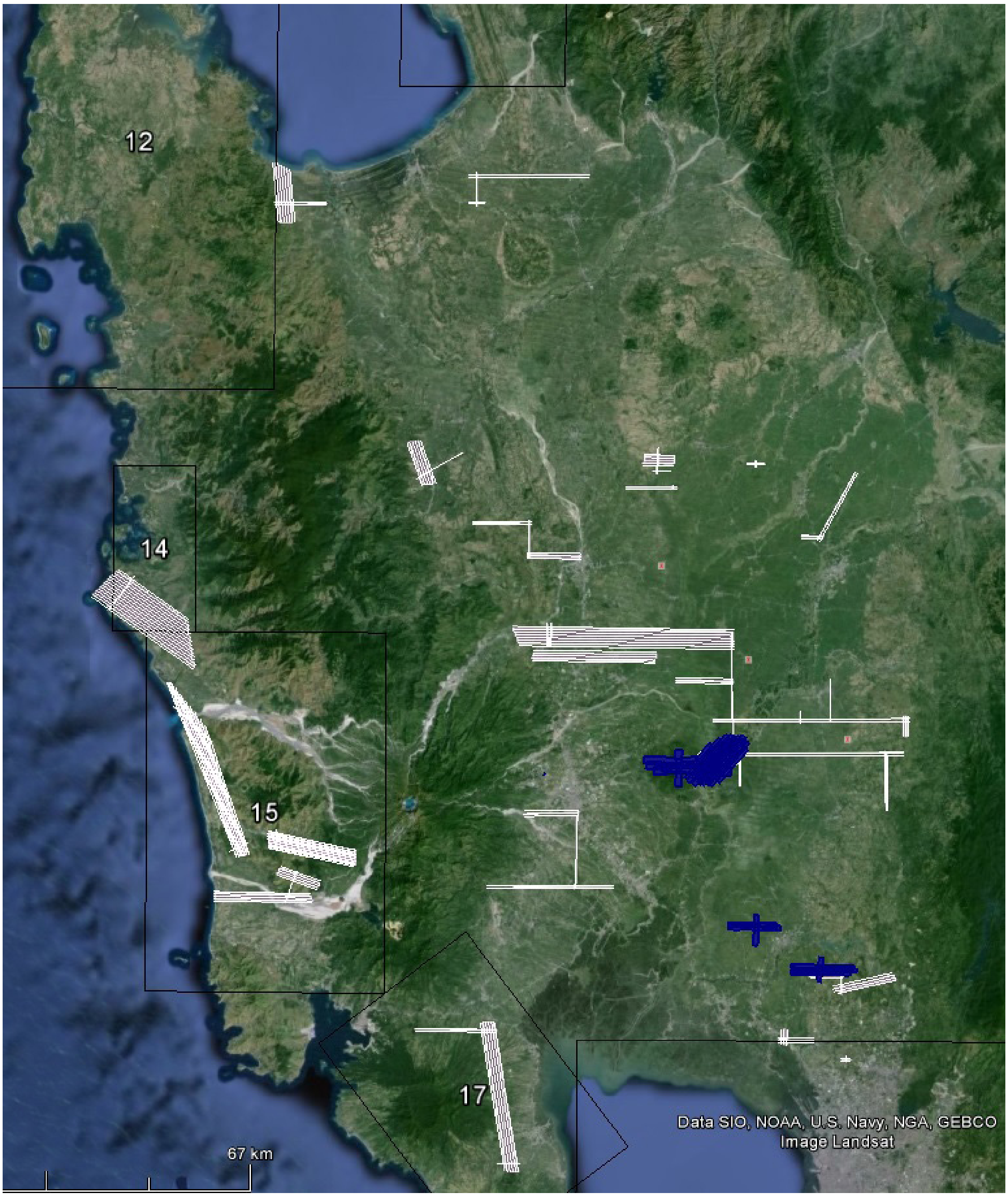


Figure A-7.8. Swath for Flight No. 7253G

Flight No. :	7255GC	
Area:	PAM S2	
Mission Name:	2PAMS2137B	
Parameters:	Altitude: 850	Scan Frequency: 50
	Scan Angle: 20	Overlap: 30

SWATH

Figure A-7.9. Swath for Flight No. 7255GC

Flight No. :	7256GC	
Area:	PAM S5	
Mission Name:	2PAMS5138A	
Parameters:	Altitude: 850	Scan Frequency: 50
	Scan Angle: 20	Overlap: 30

SWATH

Figure A-7.10. Swath for Flight No. 7256GC

Flight No. :	7266GC	
Area:	BLK 15S	
Mission Name:	2BLK15S143A	
Parameters:	Altitude: 1000	Scan Frequency: 50
	Scan Angle: 20	Overlap: 30

SWATH

Figure A-7.11. Swath for Flight No. 7266GC

Flight No. :	7268GC	
Area:	PAM S8	
Mission Name:	2PAMS8144B	
Parameters:	Altitude: 1000	Scan Frequency: 50
	Scan Angle: 20	Overlap: 40

SWATH

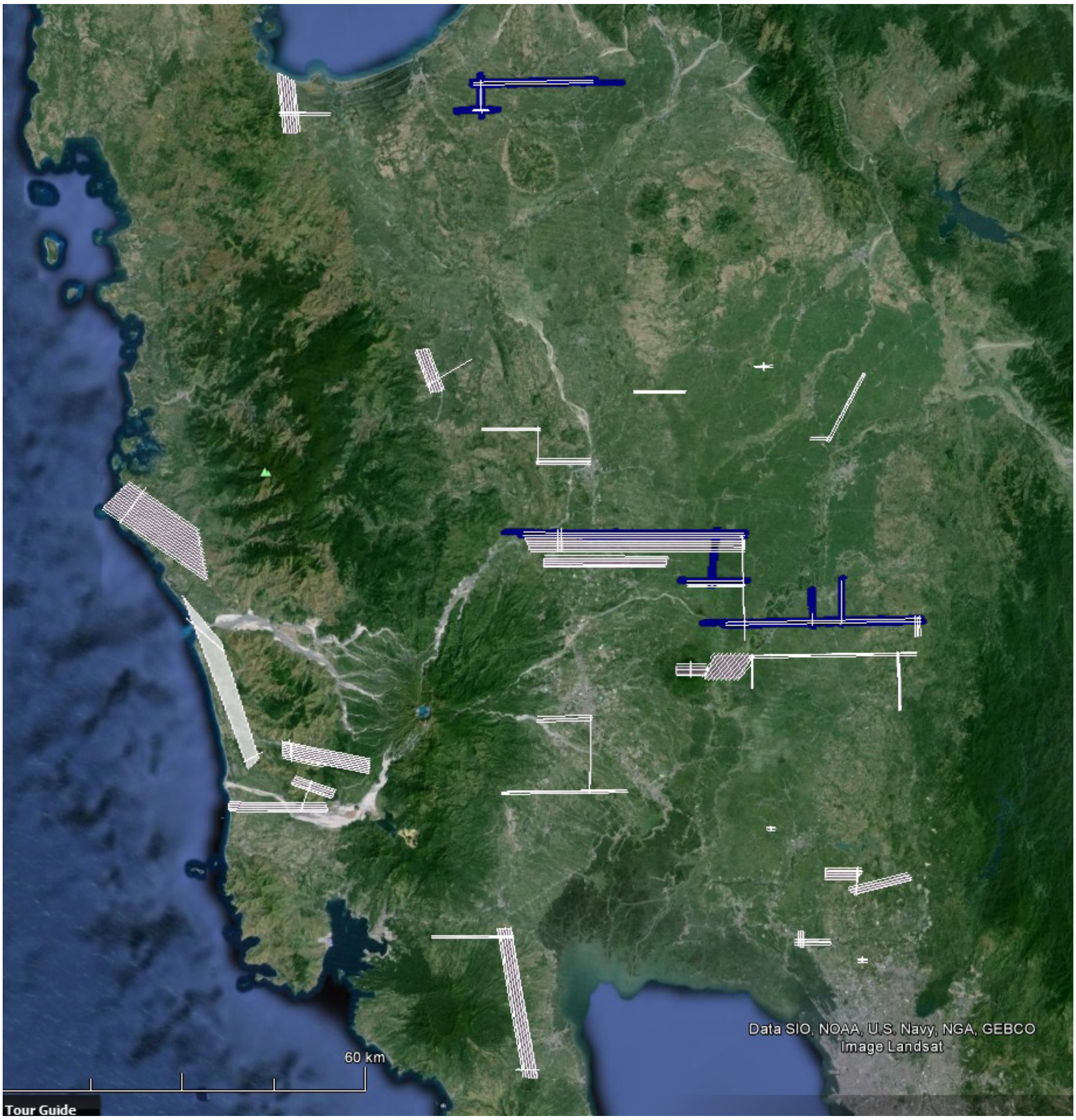


Figure A-7.12. Swath for Flight No. 7268GC

Flight No. :	2274A	
Area:	NEJ V	
Mission Name:	3NEJV339A	
Parameters:	Altitude: 600	Scan Frequency: 50
	Scan Angle: 18	Overlap: 30

SWATH

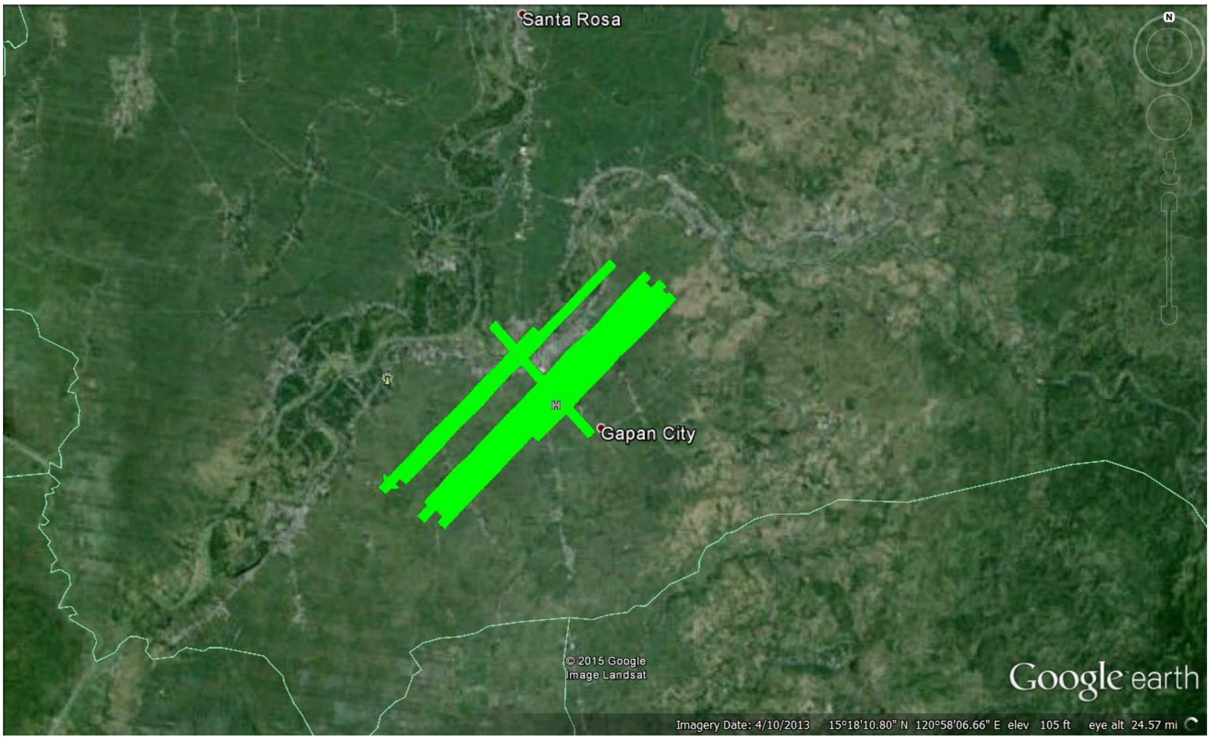


Figure A-7.13. Swath for Flight No. 2274A

Flight No. :	2278A	
Area:	PAM V	
Mission Name:	3PAMV340A	
Parameters:	Altitude: 600	Scan Frequency: 50
	Scan Angle: 18	Overlap: 30

SWATH

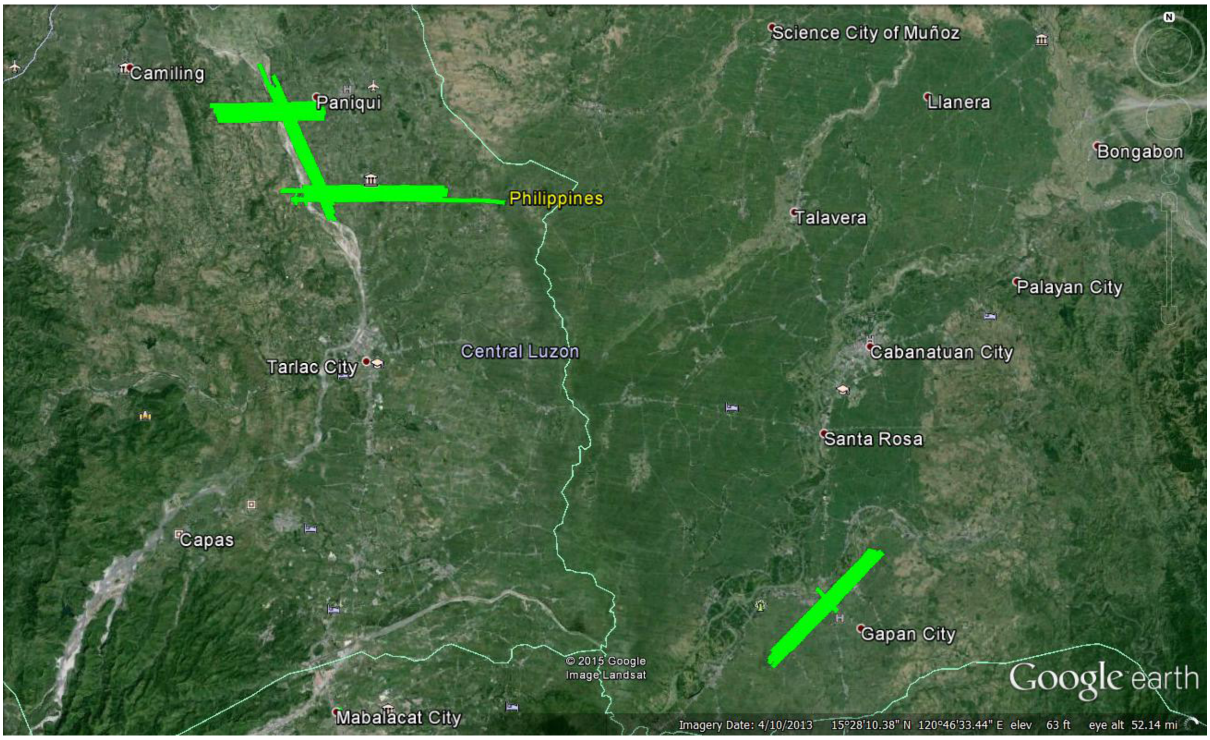


Figure A-7.14. Swath for Flight No. 2278A

Flight No. :	2471P	
Area:	BUC	
Mission Name:	1BUC020A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

LAS

Figure A-7.15. Swath for Flight No. 2471P

Flight No. :	2473P	
Area:	BUC R	
Mission Name:	1BUCR021A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

SWATH

Figure A-7.16. Swath for Flight No. 2473P

Flight No. :	2481P	
Area:	BTN	
Mission Name:	1BTN023A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

LAS

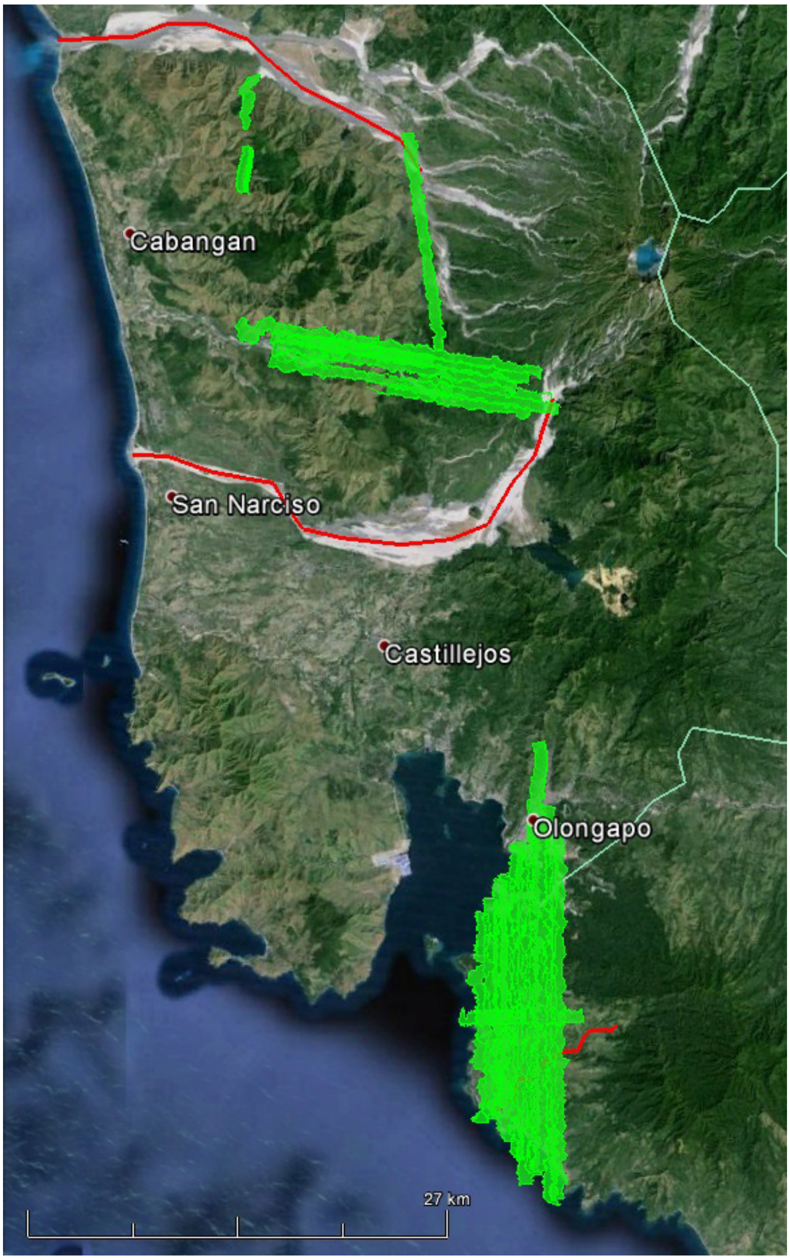


Figure A-7.17. Swath for Flight No. 2481P

Flight No. :	2493P	
Area:	BUC	
Mission Name:	1BUC026A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

LAS

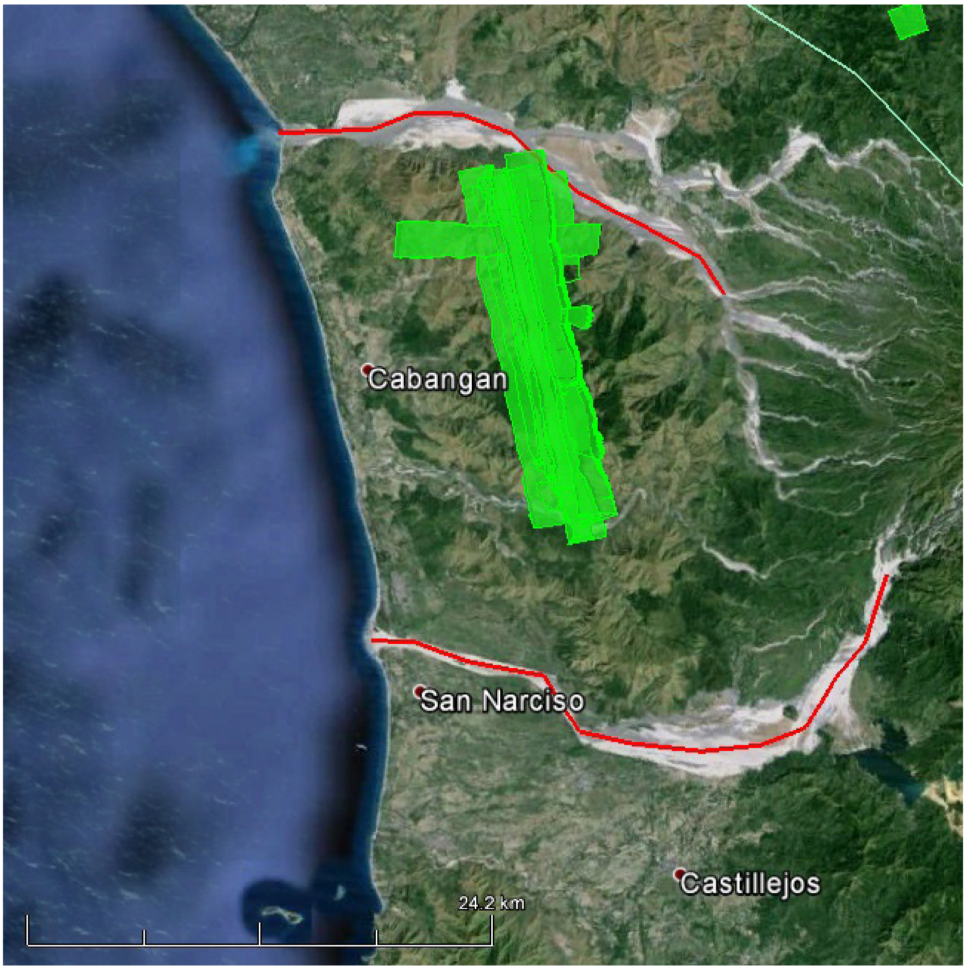


Figure A-7.18. Swath for Flight No. 2493P

Flight No. :	2497P	
Area:	BUC	
Mission Name:	1BUC027A	
Parameters:	Altitude: 1600	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

LAS

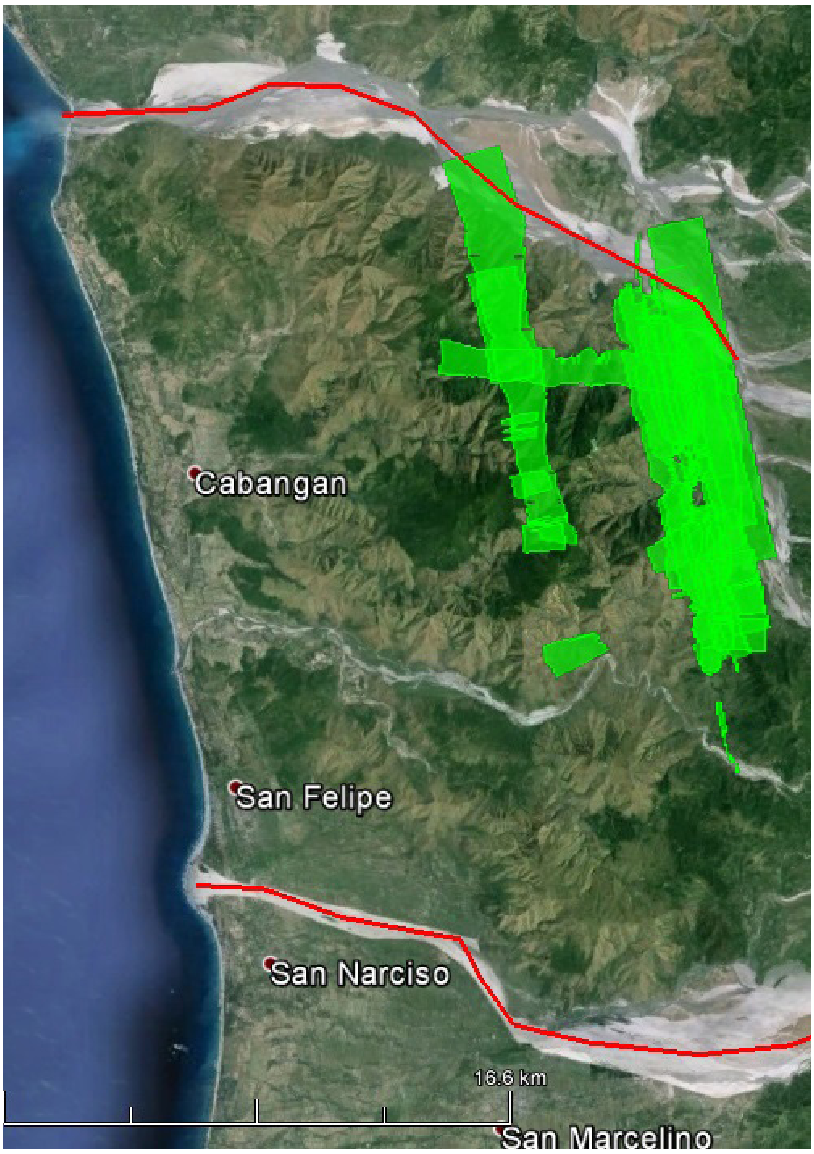


Figure A-7.19. Swath for Flight No. 2497P

Flight No. :	2501P	
Area:	BUC	
Mission Name:	1BUC028A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

LAS

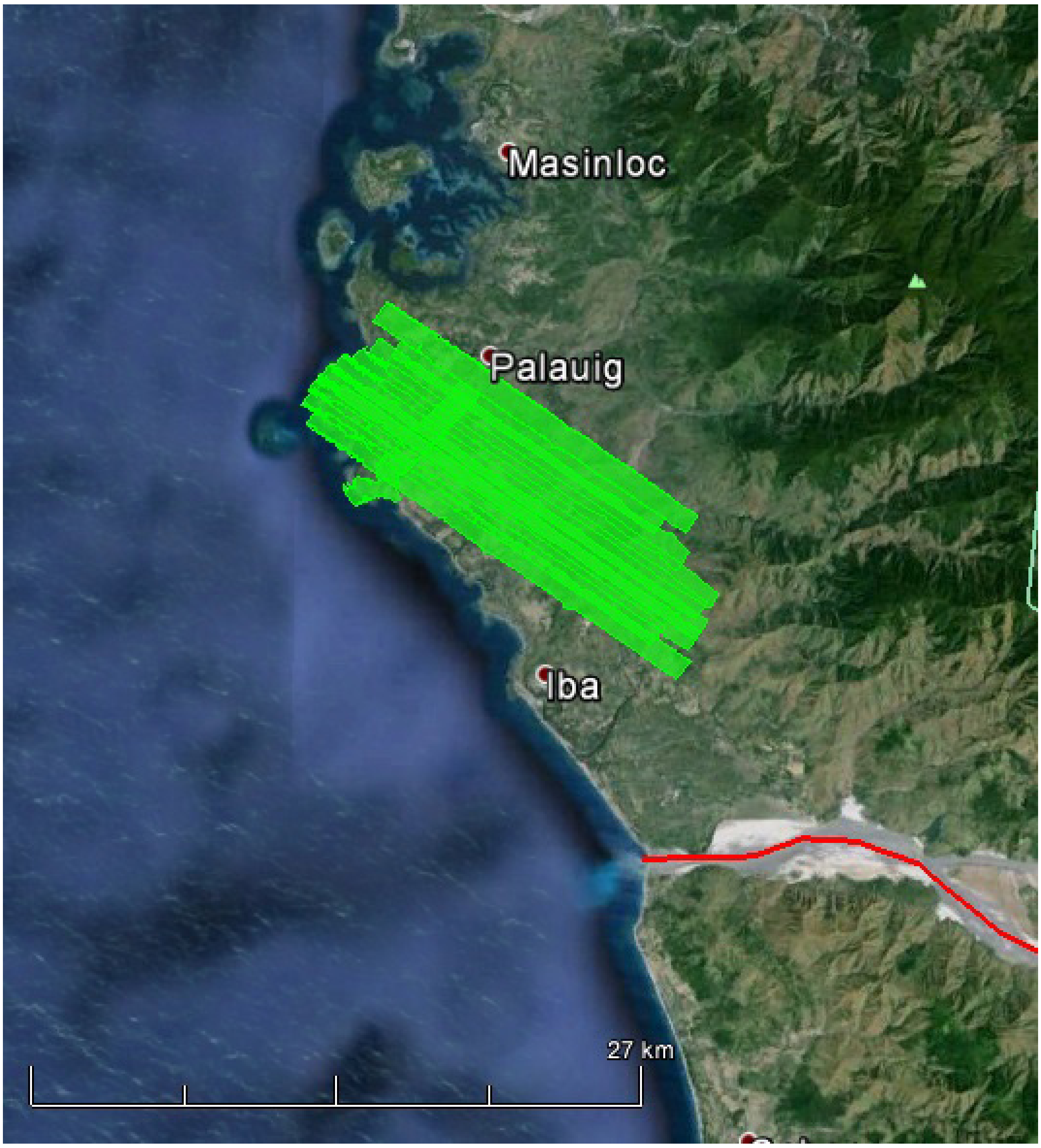


Figure A-7.20. Swath for Flight No. 2501P

Flight No. :	8411AC	
Area:	PAM S1	
Mission Name:	3PAMS1088A	
Parameters:	Altitude: 600	Scan Frequency: 45
	Scan Angle: 18	Overlap: 30

SWATH

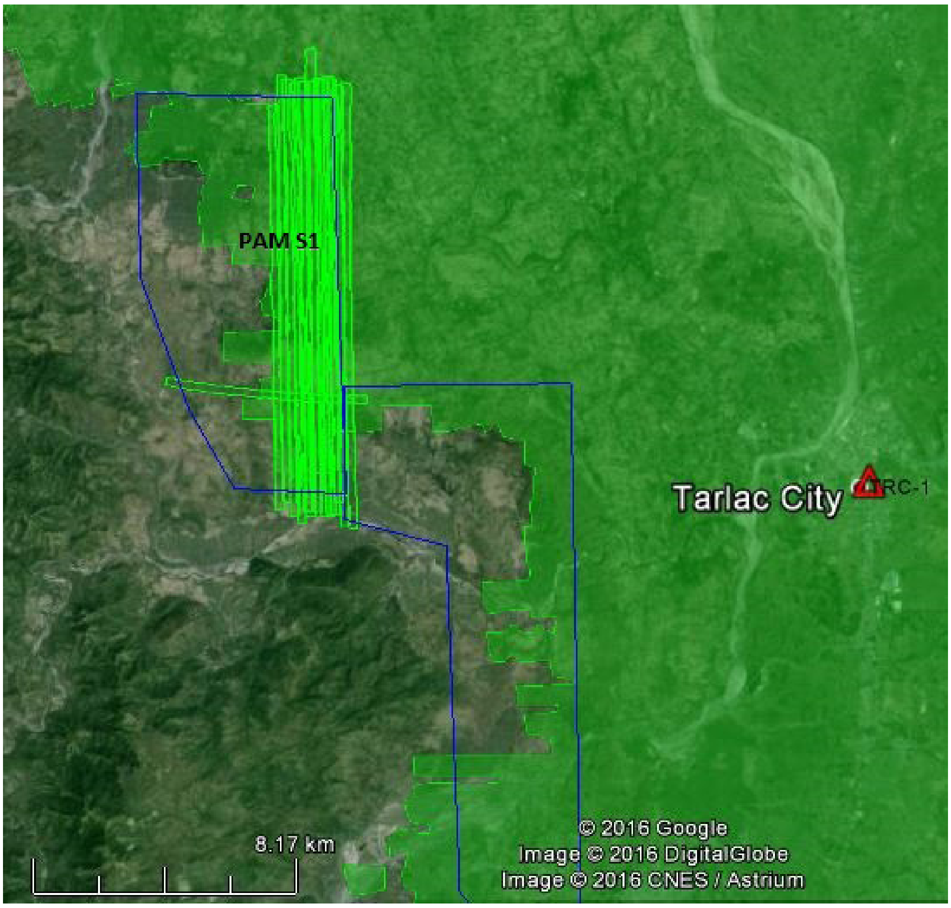


Figure A-7.21. Swath for Flight No. 8411AC

Flight No. :	8412AC	
Area:	PAM S1	
Mission Name:	3PAMS1089A	
Parameters:	Altitude: 500	Scan Frequency: 45
	Scan Angle: 18	Overlap: 30

SWATH

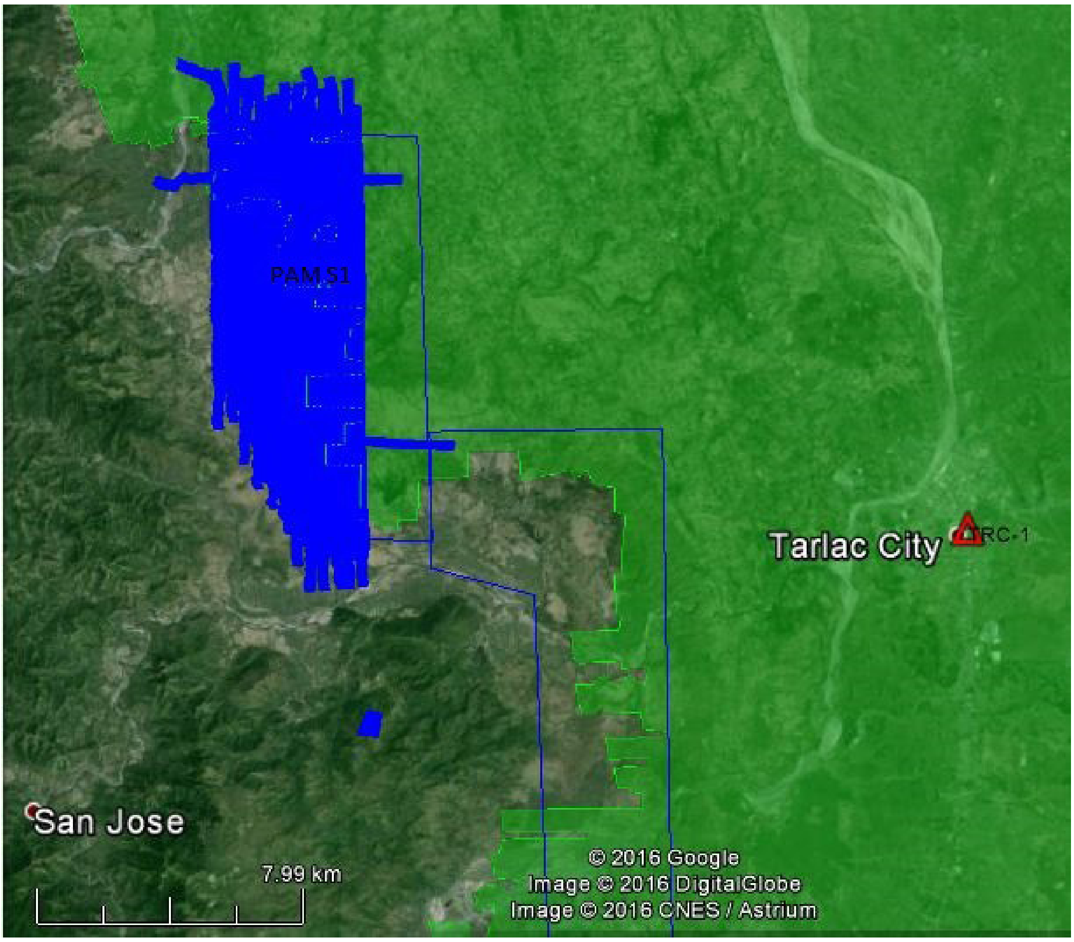


Figure A-7.22. Swath for Flight No. 8412AC

Flight No. :	10214L	
Area:	BLK 15A	
Mission Name:	4BLK15A211A	
Parameters:	Altitude: 1600	Scan Frequency: 43
	Scan Angle: 15	Overlap: 30

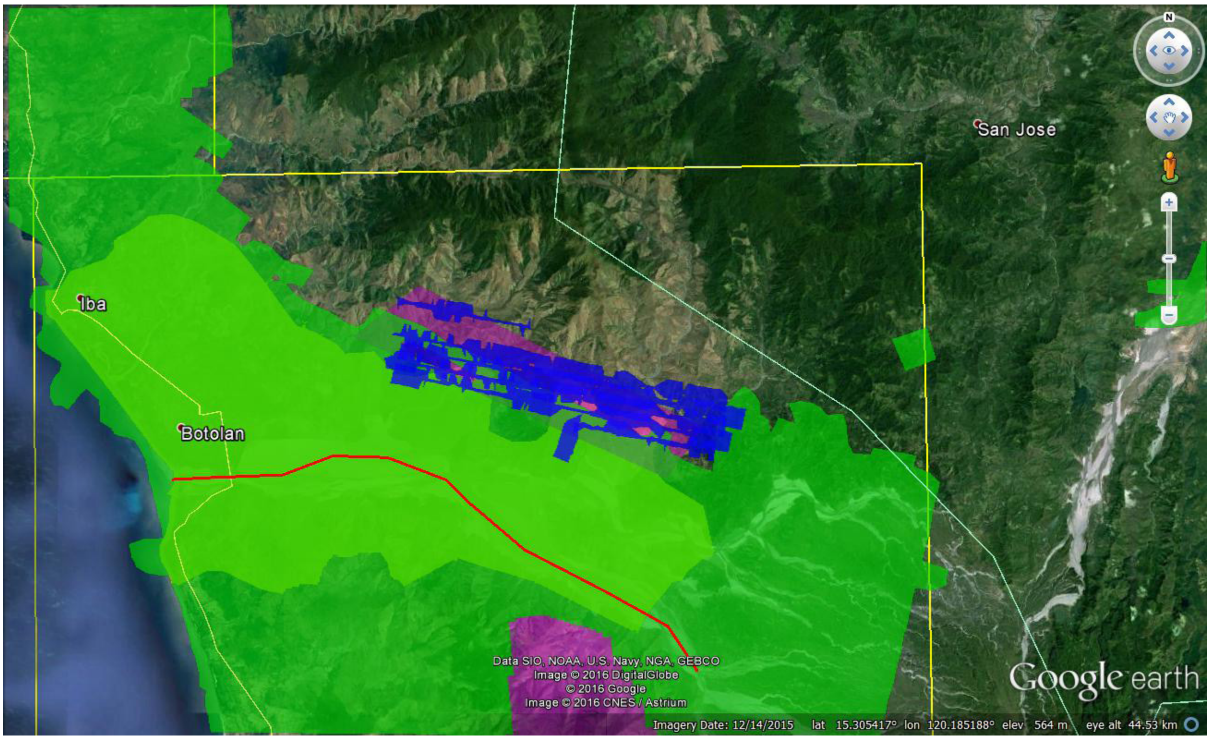


Figure A-7.23. Swath for Flight No. 10214L

Annex 8. Mission Summary Report

Flight Area	Bataan
Mission Name	**BataanZambales_PlgA**
Inclusive Flights	939P
Range data size	26.1 GB
POS	295 MB
Base data size	27.7 MB
Image	n/a
Transfer date	January 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.5
RMSE for East Position (<4.0 cm)	4.0
RMSE for Down Position (<8.0 cm)	10
Boresight correction stdev (<0.001deg)	0.000429
IMU attitude correction stdev (<0.001deg)	0.002169
GPS position stdev (<0.01m)	0.0132
Minimum % overlap (>25)	68.60
Ave point cloud density per sq.m. (>2.0)	5.74
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	227
Maximum Height	843.89 m
Minimum Height	44.04 m
Classification (# of points)	
Ground	118,623,052
Low vegetation	103,349,282
Medium vegetation	223,381,336
High vegetation	175,729,875
Building	989,747
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Kenneth Solidum, Ma. Celina Rosete, Engr. Gladys Mae Apat

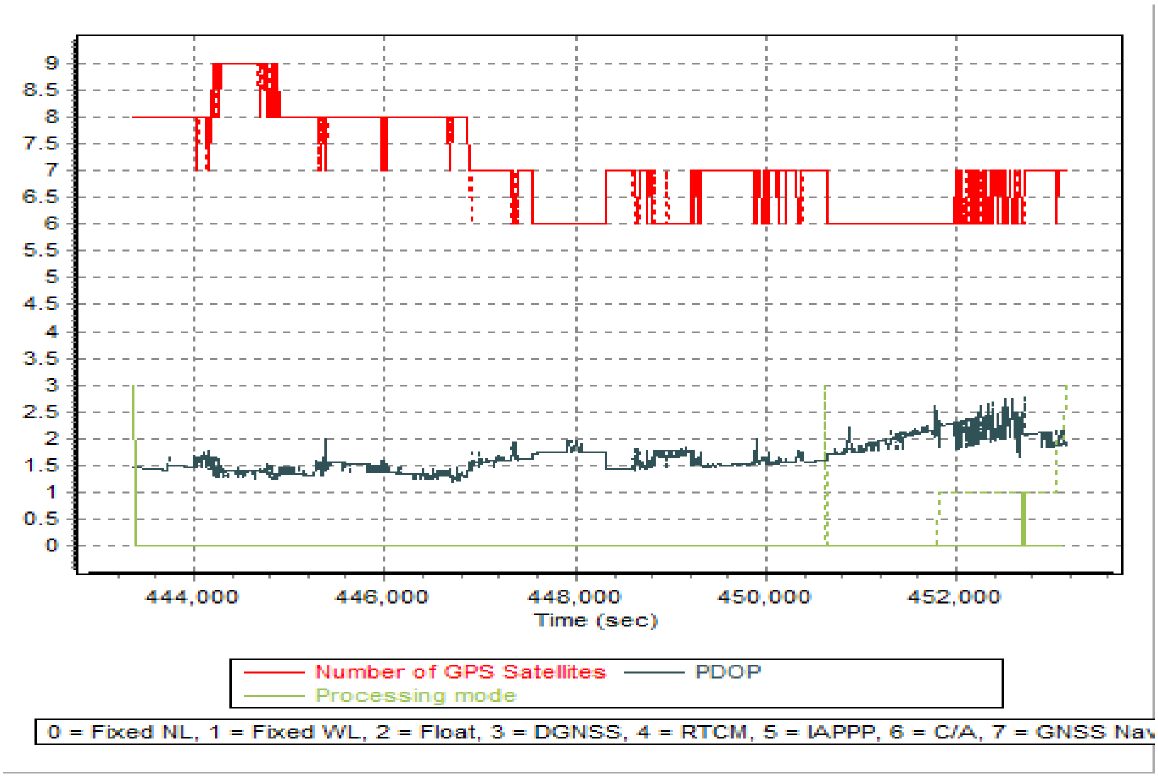


Figure 1.1.1. Solution Status

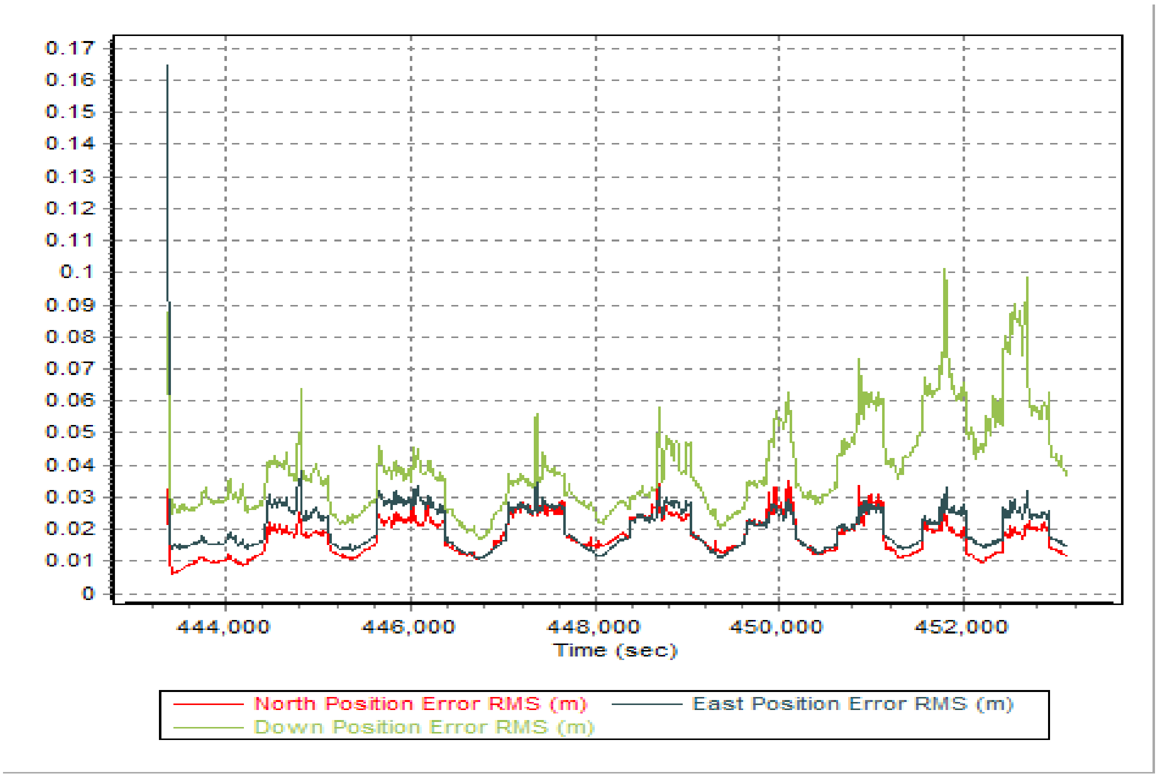


Figure 1.1.2. Smoothed Performance Metric Parameters

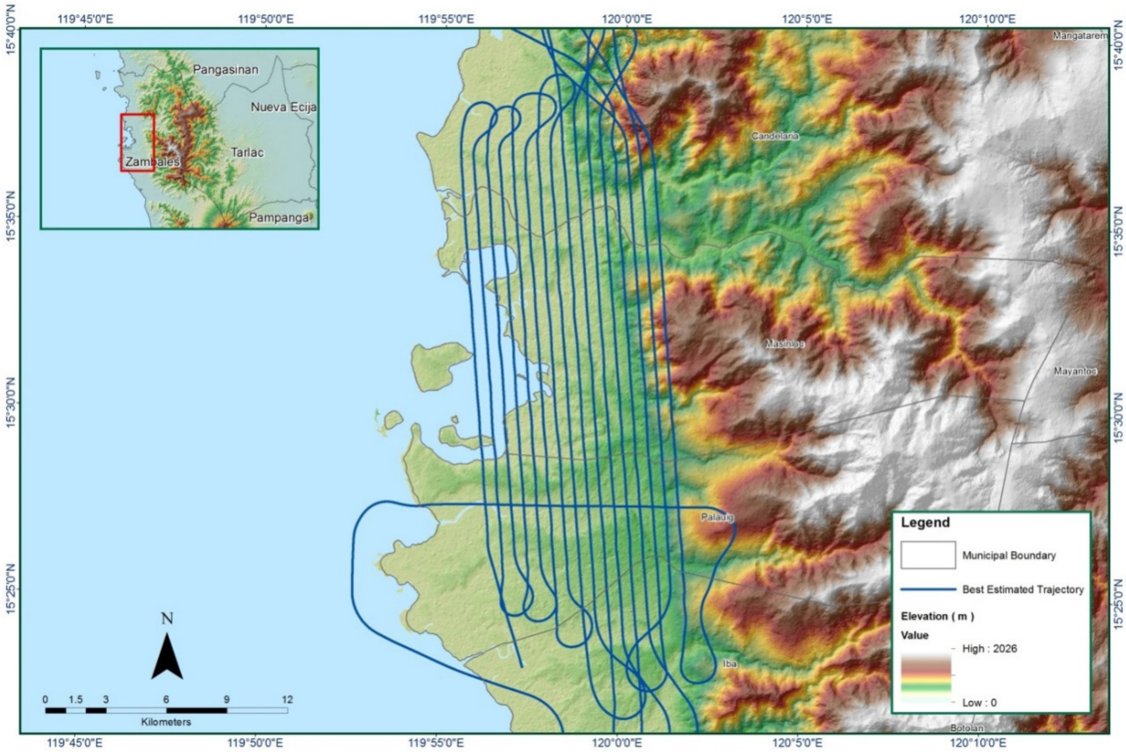


Figure 1.1.3. Best Estimated Trajectory

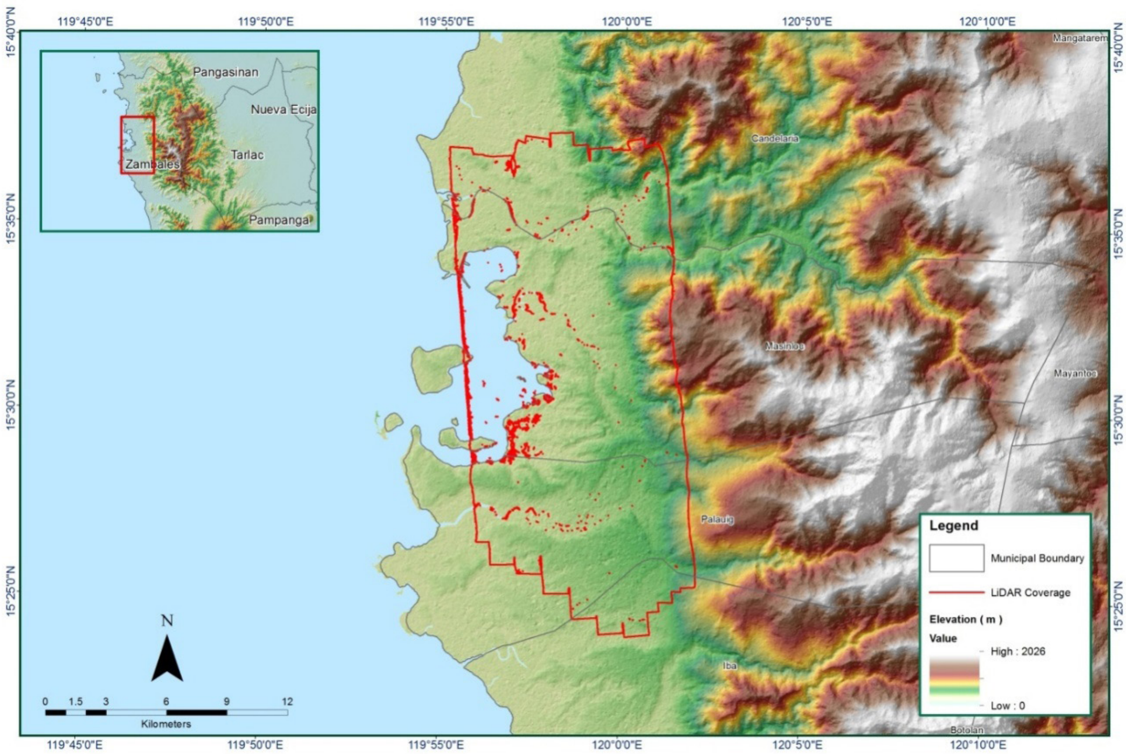


Figure 1.1.4. Coverage of LiDAR Data

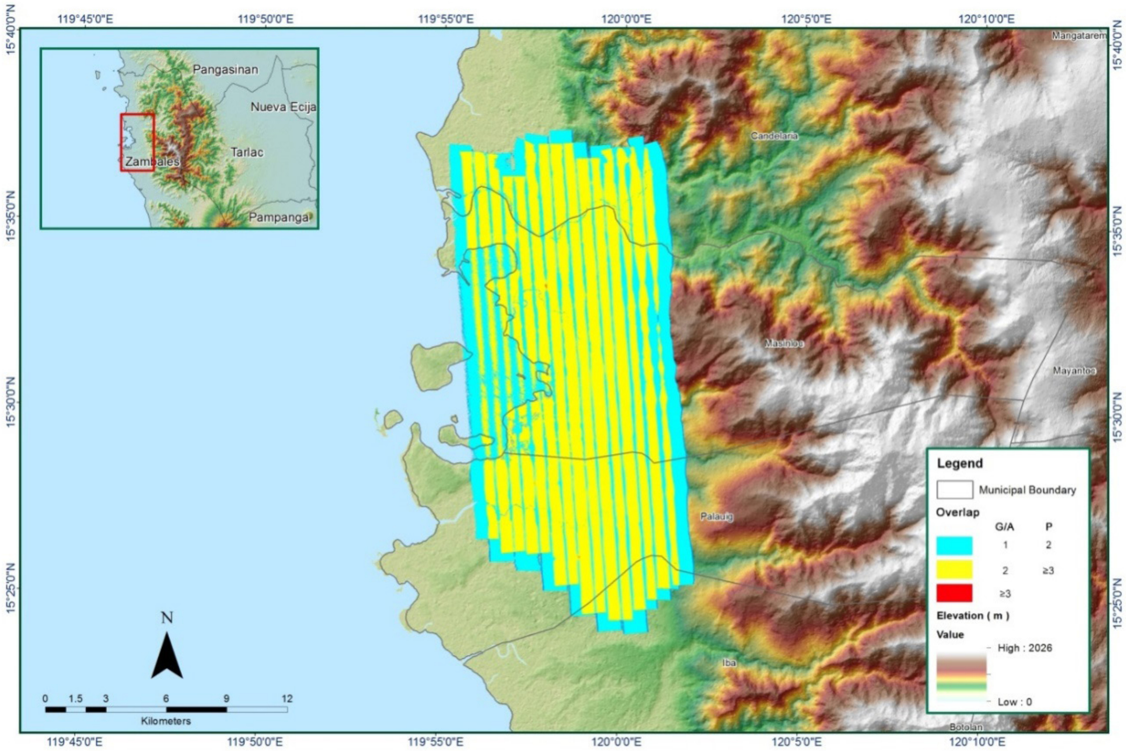


Figure 1.1.5. Image of data overlap

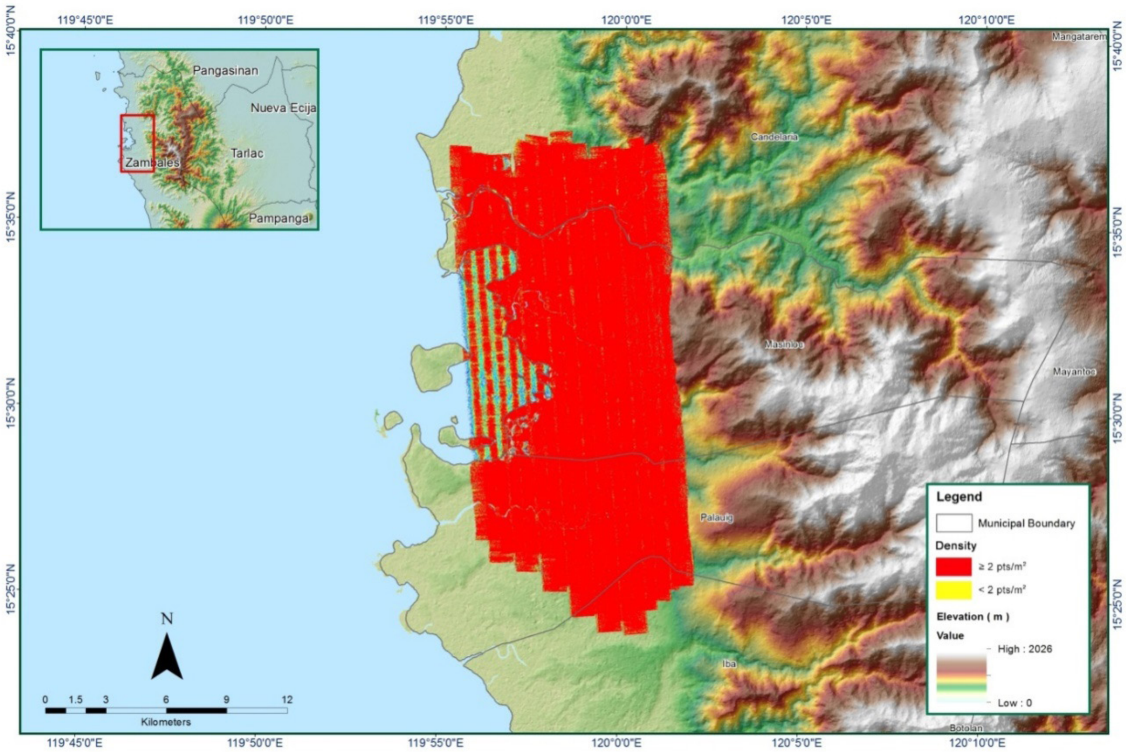


Figure 1.1.6. Density map of merged LiDAR data

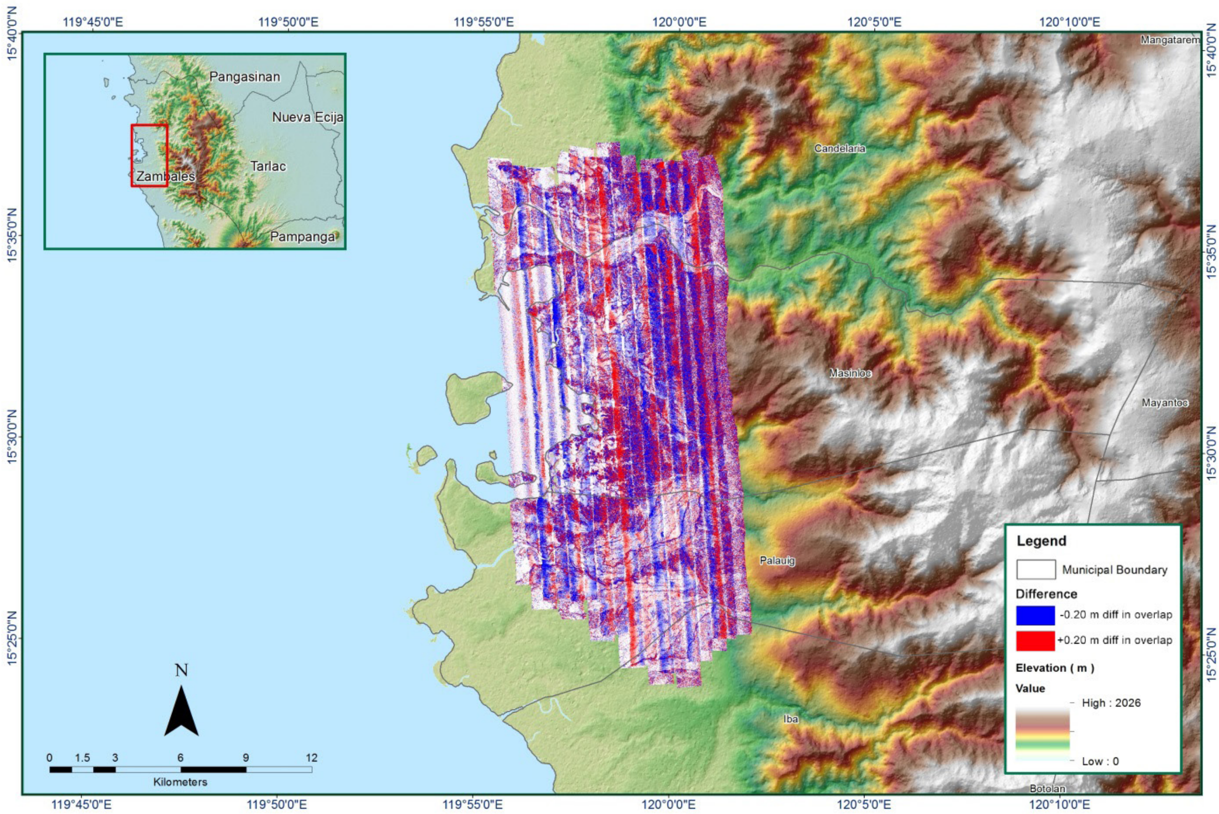


Figure 1.1.7. Elevation difference between flight lines

Flight Area	Bataan
Mission Name	**BataanZambales_BucBs**
Inclusive Flights	941P
Range data size	10.8 GB
POS	205 MB
Base data size	27.7 MB
Image	n/a
Transfer date	January 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.5
RMSE for East Position (<4.0 cm)	4.0
RMSE for Down Position (<8.0 cm)	12
Boresight correction stdev (<0.001deg)	0.000549
IMU attitude correction stdev (<0.001deg)	0.003036
GPS position stdev (<0.01m)	0.0110
Minimum % overlap (>25)	50.93
Ave point cloud density per sq.m. (>2.0)	4.32
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	156
Maximum Height	570.97 m
Minimum Height	44.32 m
Classification (# of points)	
Ground	125,538,438
Low vegetation	94,244,893
Medium vegetation	90,391,073
High vegetation	27,117,862
Building	2,868,707
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Chelou Prado, Engr. John Dill Macapagal

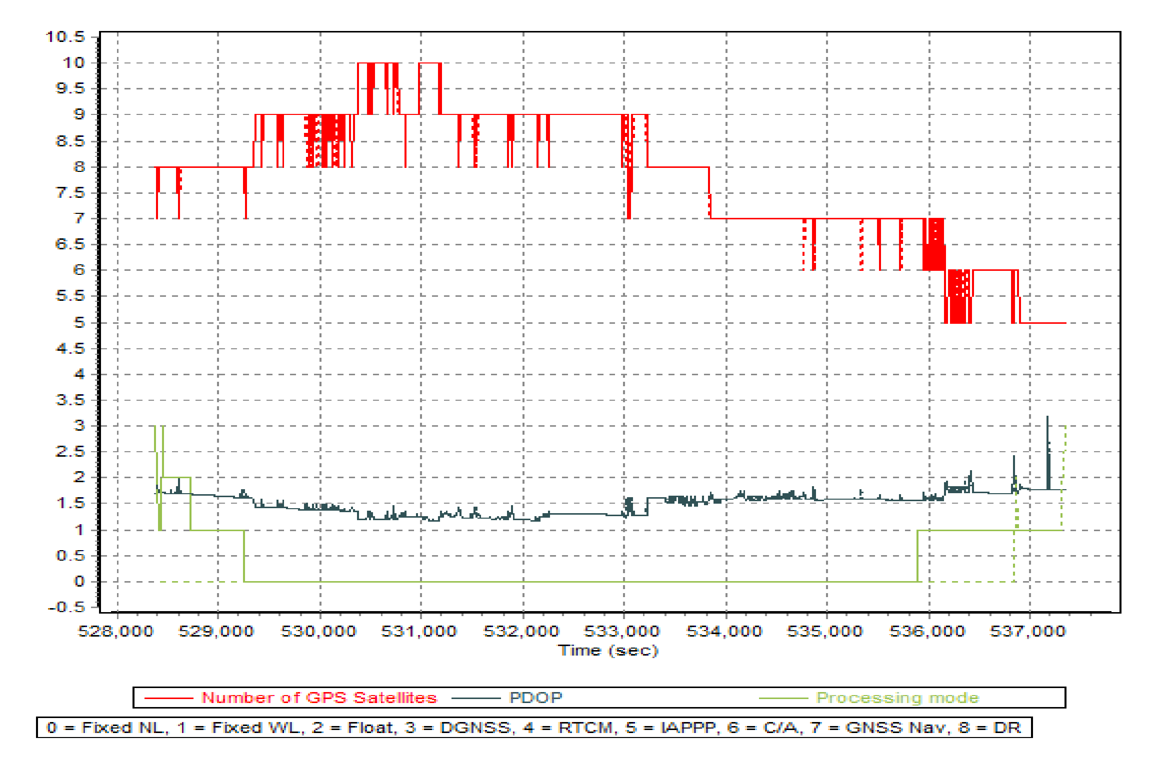


Figure 1.2.1. Solution Status

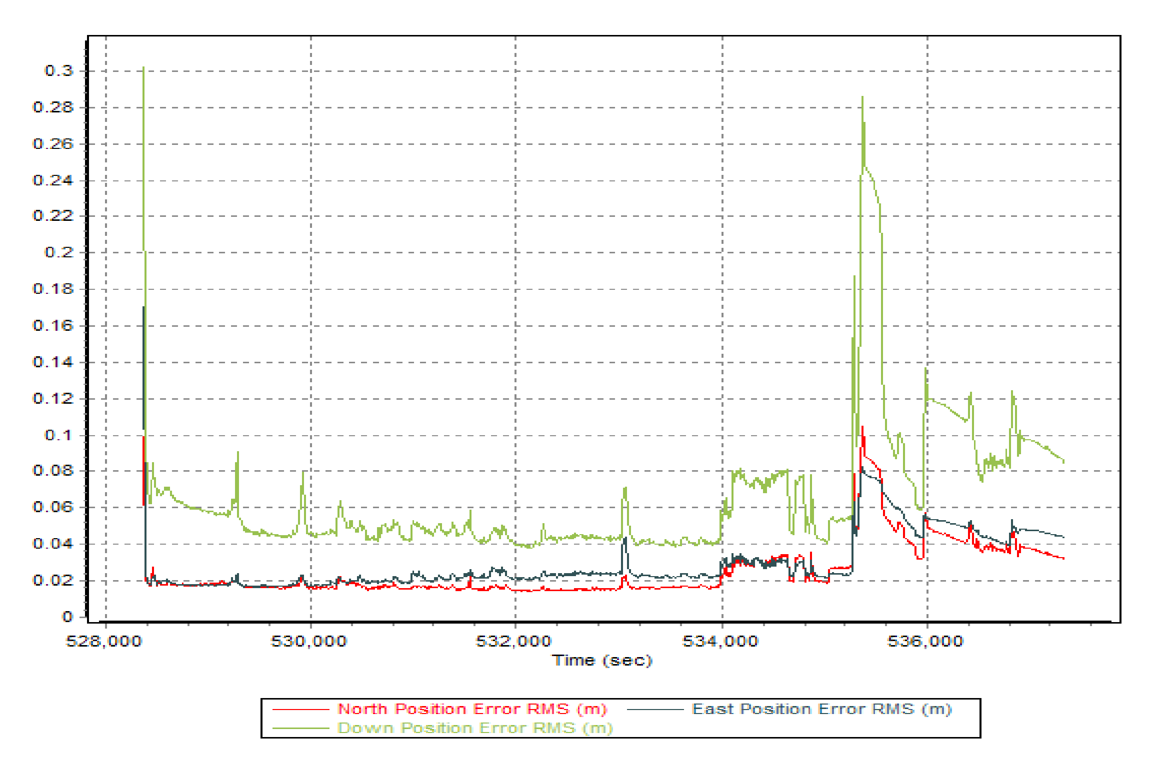


Figure 1.2.2. Smoothed Performance Metric Parameters

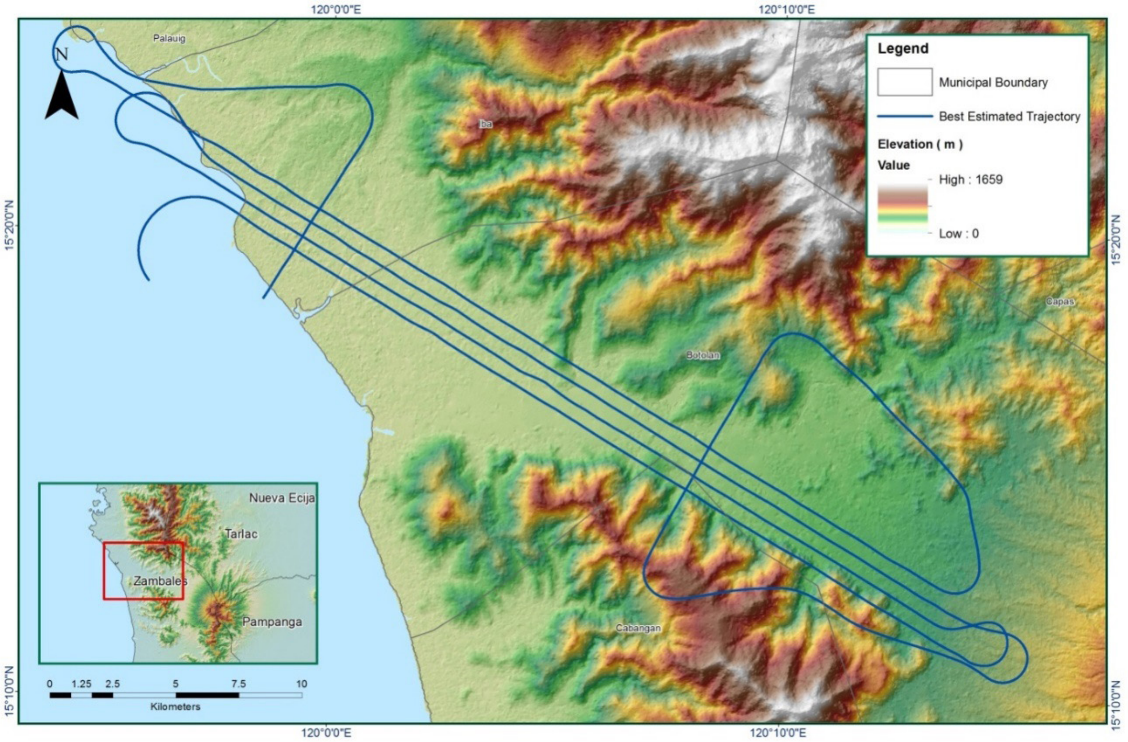


Figure 1.2.3. Best Estimated Trajectory

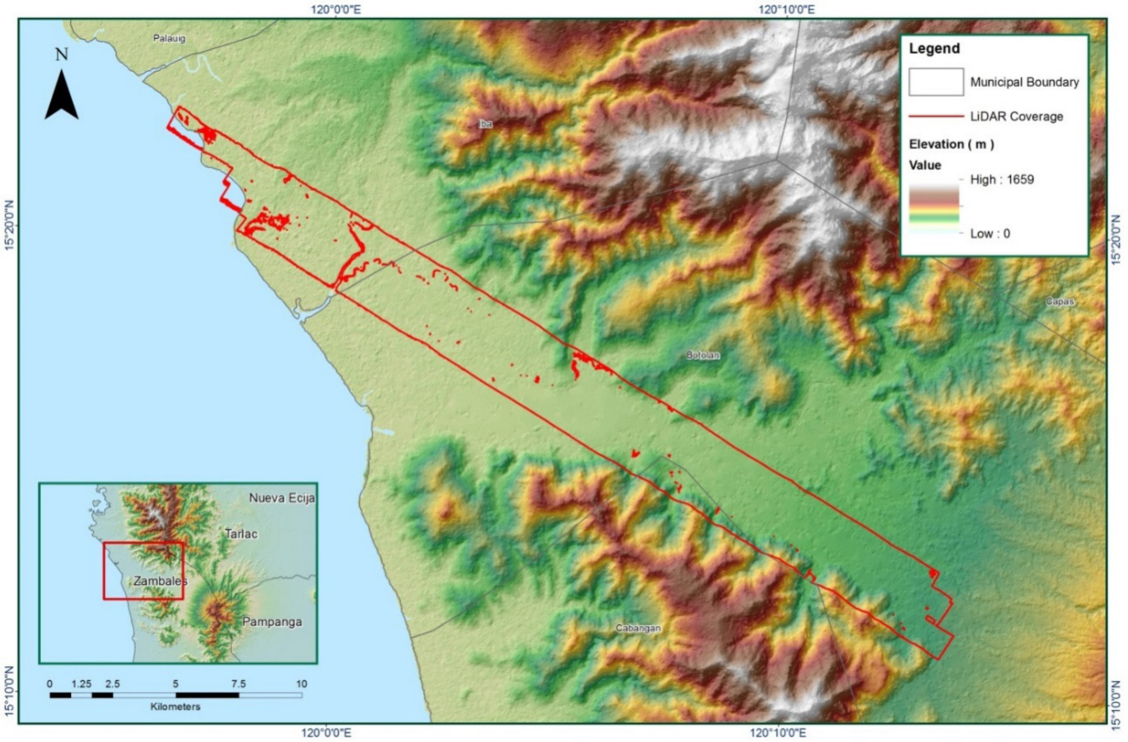


Figure 1.2.4. Coverage of LiDAR Data

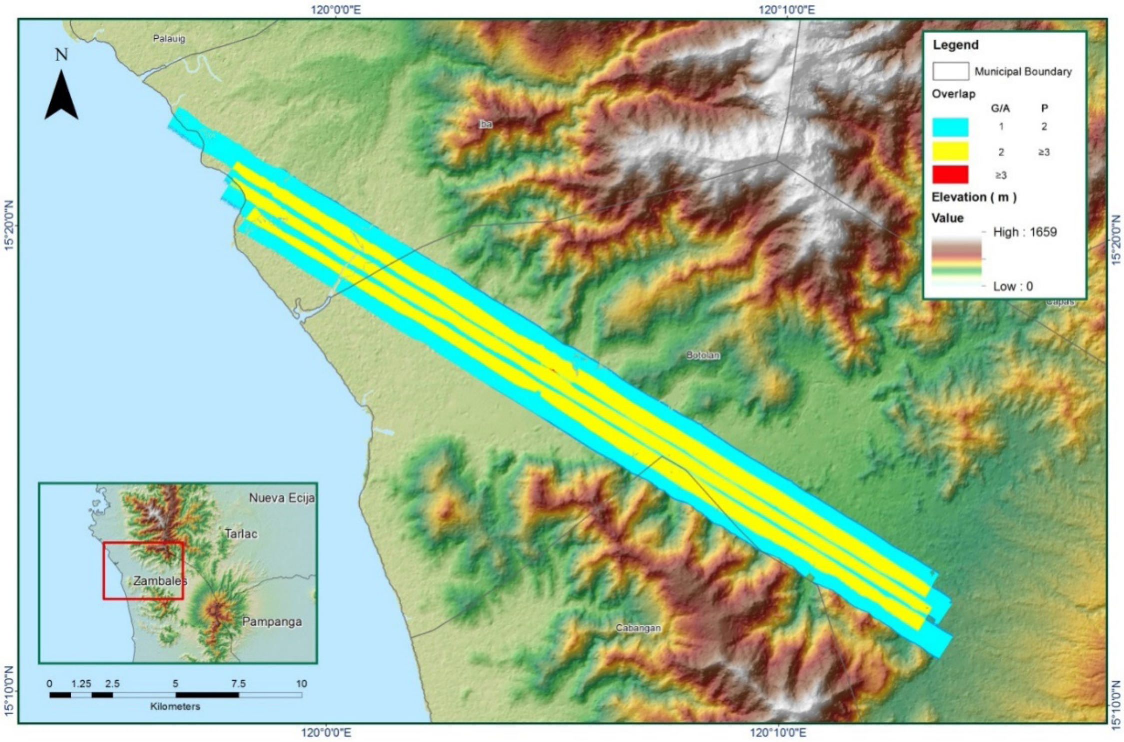


Figure 1.2.5. Image of data overlap

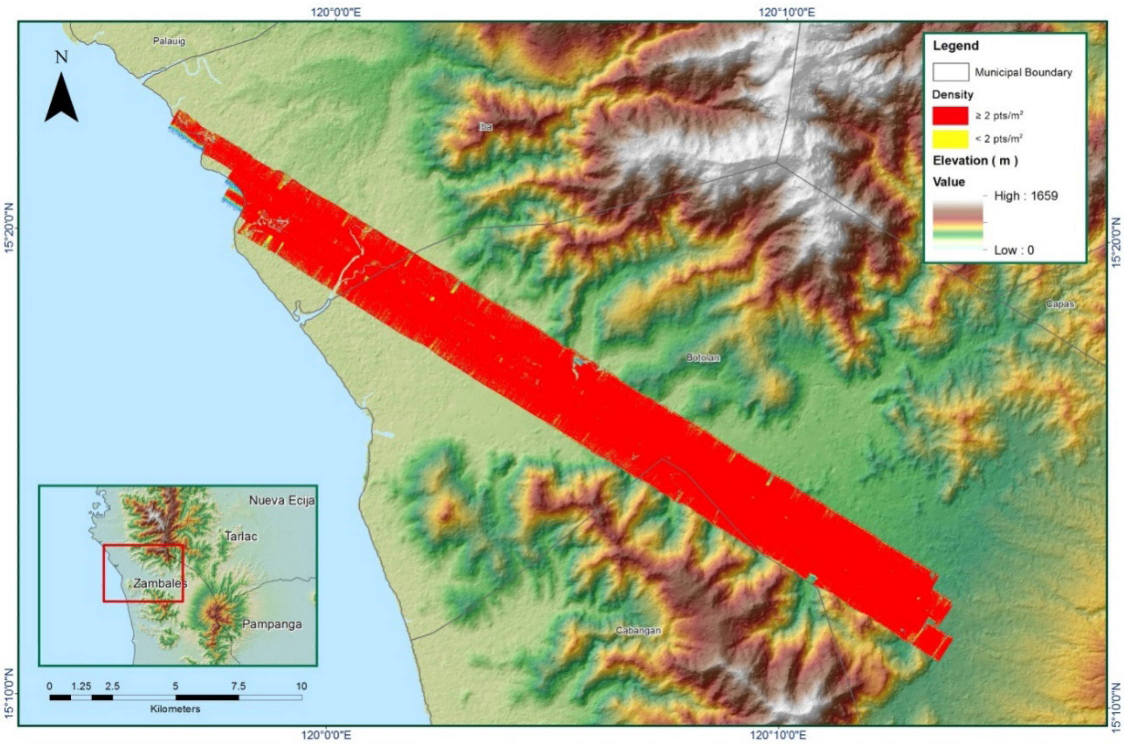


Figure 1.2.6. Density map of merged LiDAR data

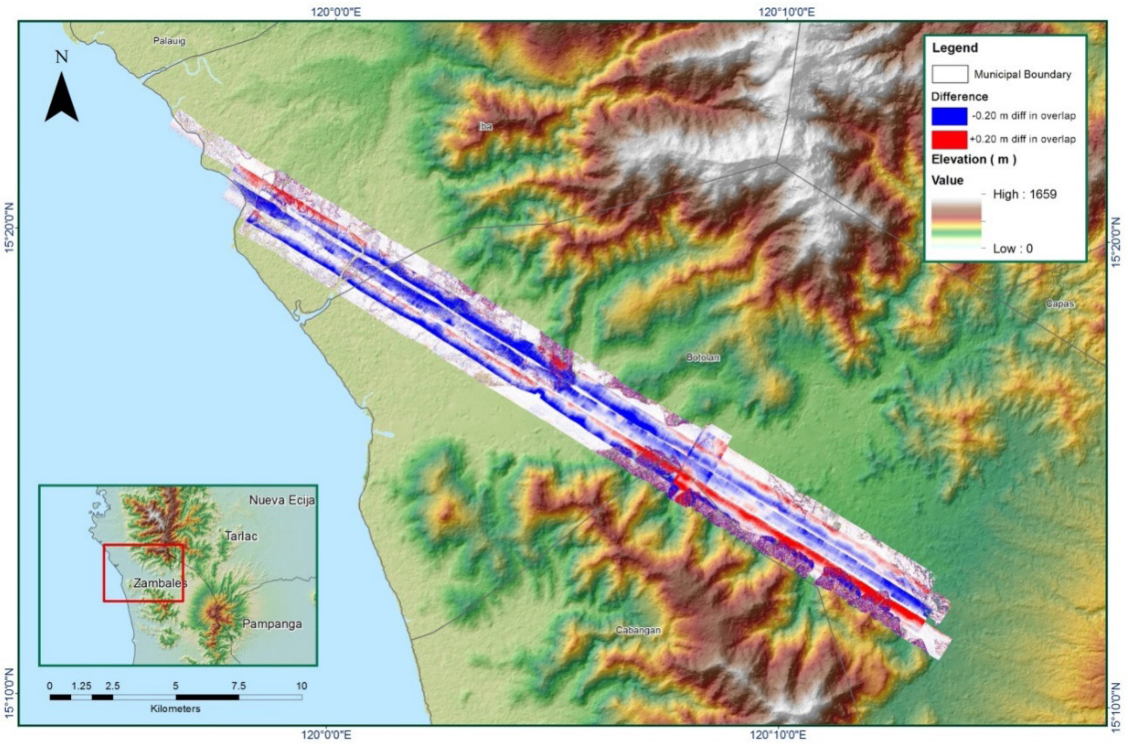


Figure 1.2.7. Elevation difference between flight lines

Flight Area	Bataan
Mission Name	**BataanZambales_BucABC**
Inclusive Flights	943P
Range data size	9.51 GB
POS	274 MB
Base data size	21.3 MB
Image	n/a
Transfer date	January 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	10
RMSE for East Position (<4.0 cm)	8.0
RMSE for Down Position (<8.0 cm)	28
Boresight correction stdev (<0.001deg)	0.001063
IMU attitude correction stdev (<0.001deg)	0.034563
GPS position stdev (<0.01m)	0.0238
Minimum % overlap (>25)	32.68
Ave point cloud density per sq.m. (>2.0)	6.71
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	93
Maximum Height	640.40 m
Minimum Height	232.76 m
Classification (# of points)	
Ground	35,495,193
Low vegetation	19,246,678
Medium vegetation	83,005,544
High vegetation	138,346,566
Building	6,804,068
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Christy Lubiano, Engr. Elainne Lopez

Figure 1.3.1. Solution Status

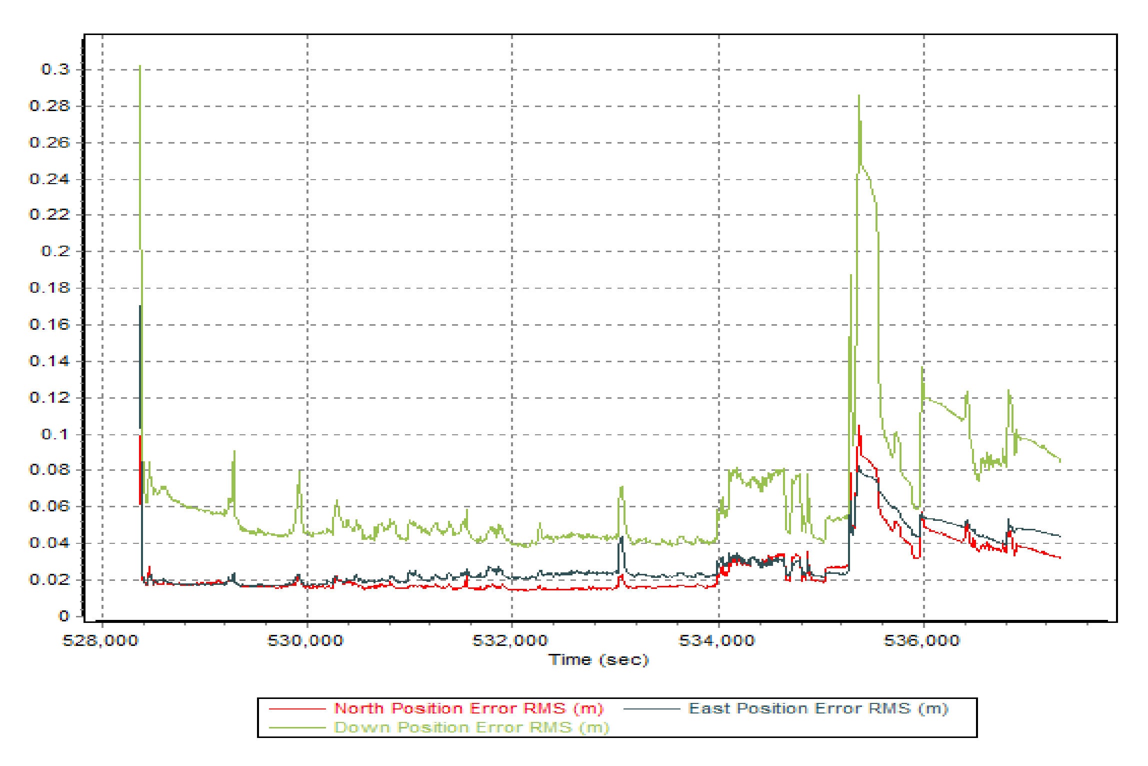


Figure 1.3.2. Smoothed Performance Metric Parameters

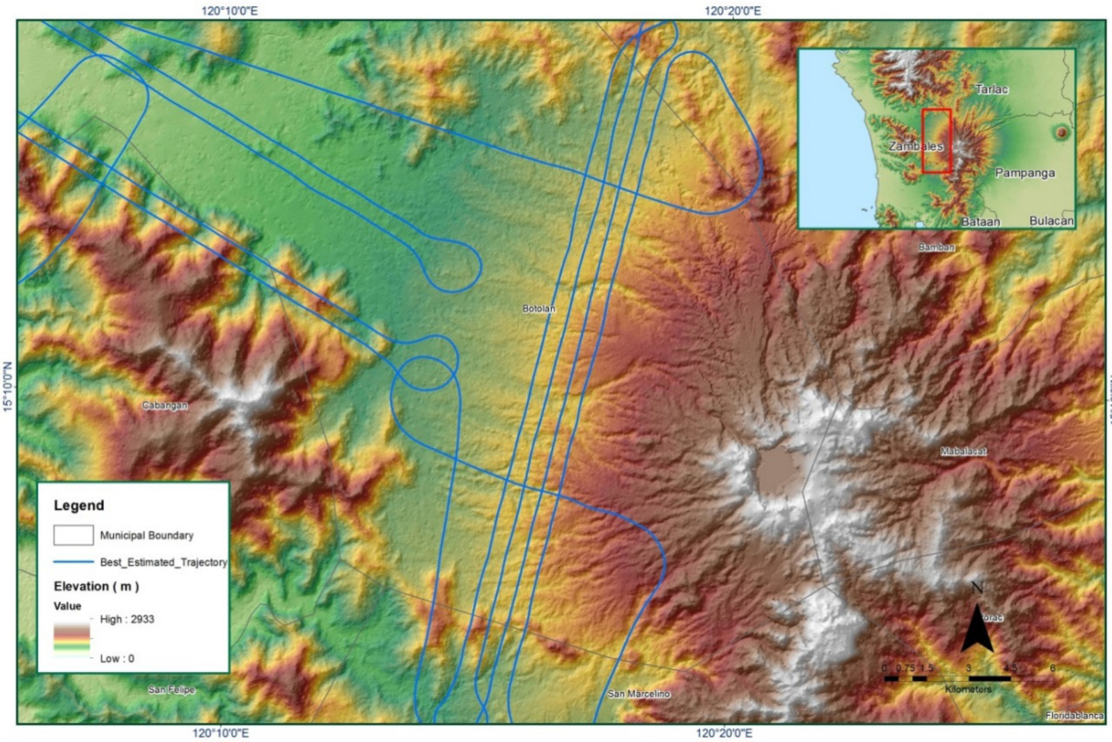


Figure 1.3.3. Best Estimated Trajectory

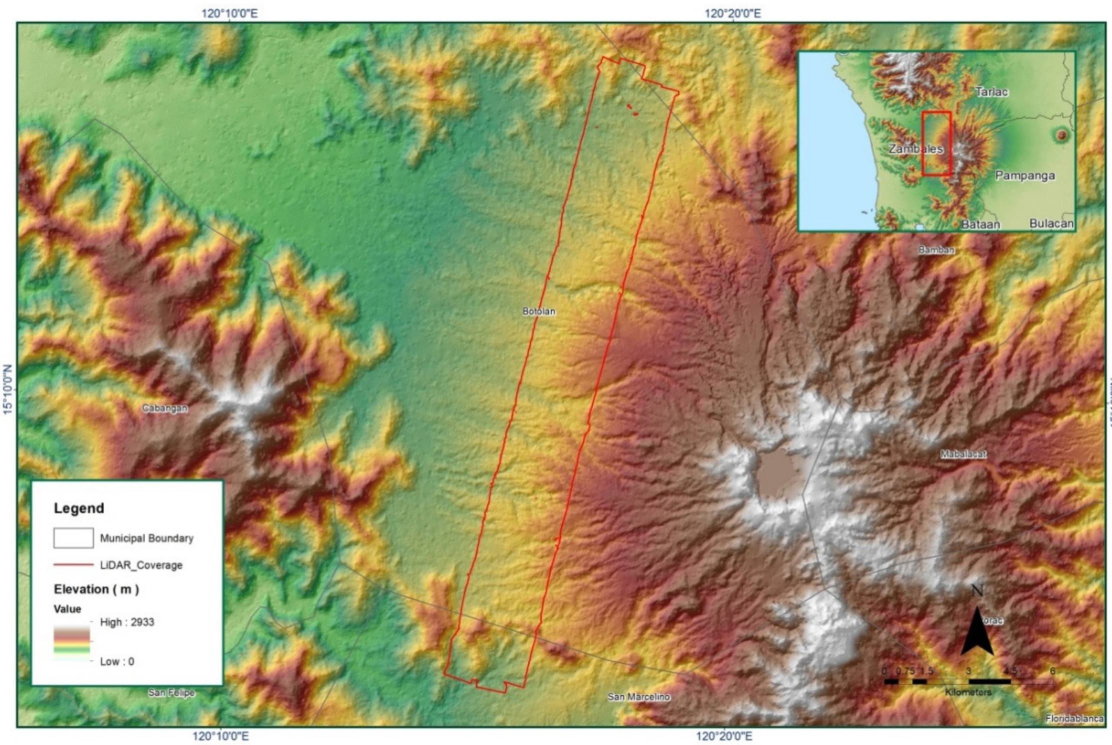


Figure 1.3.4. Coverage of LiDAR Data

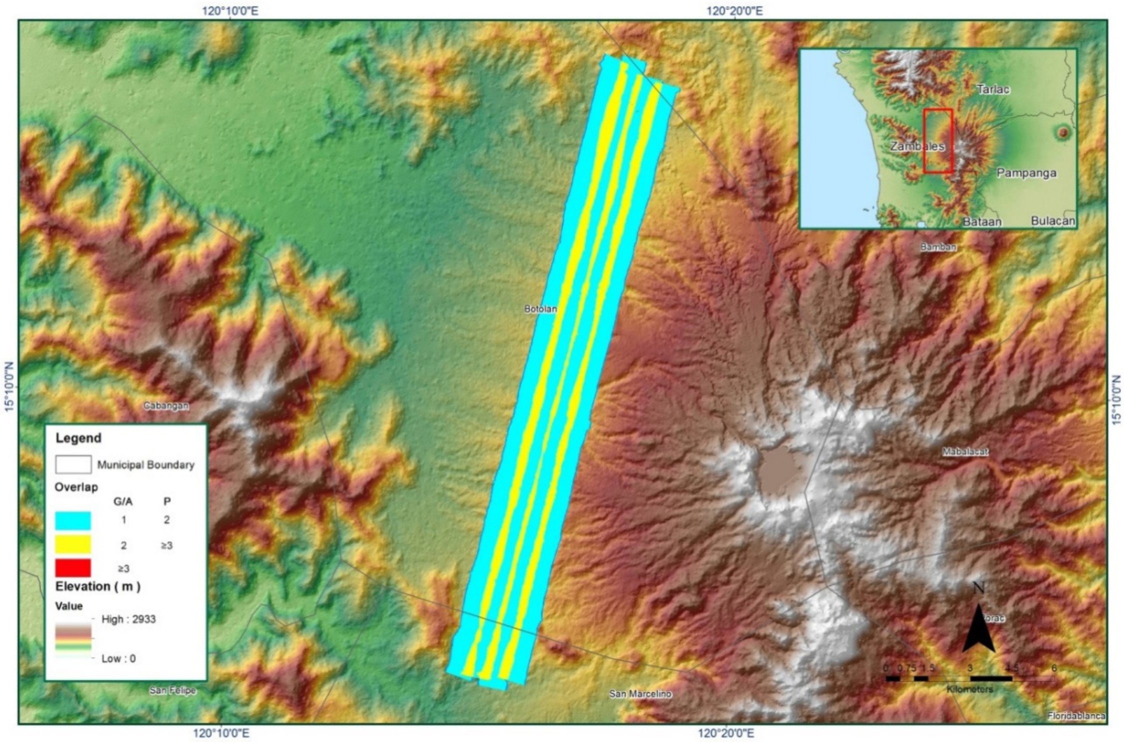


Figure 1.3.5. Image of data overlap

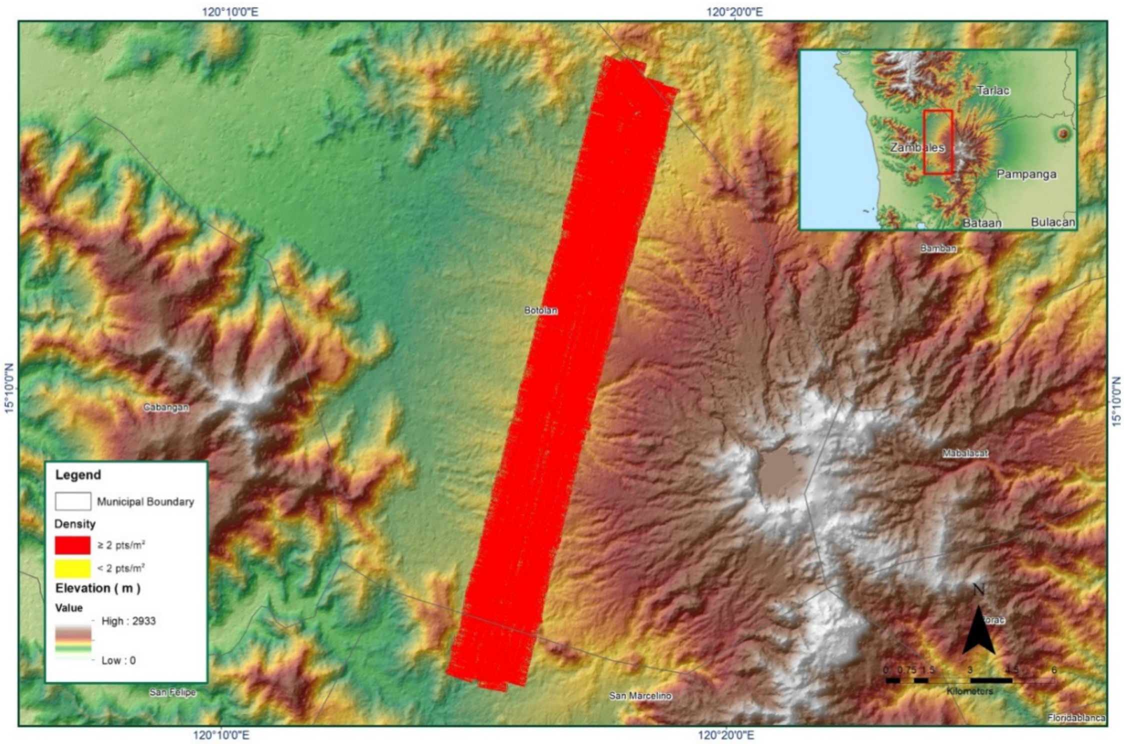


Figure 1.3.6. Density map of merged LiDAR data

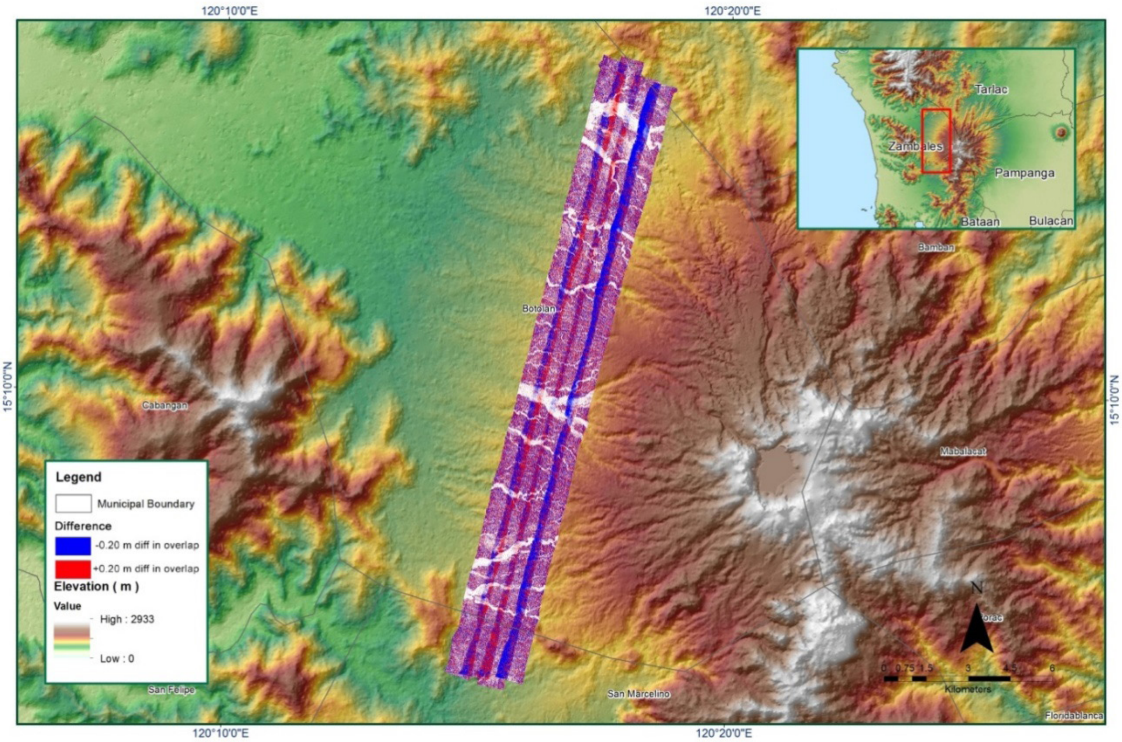


Figure 1.3.7. Elevation difference between flight lines

Flight Area	Bataan
Mission Name	**BataanZambales_BucAsB**
Inclusive Flights	943P
Range data size	9.51 GB
POS	274 MB
Base data size	21.3 MB
Image	n/a
Transfer date	January 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	10
RMSE for East Position (<4.0 cm)	8.0
RMSE for Down Position (<8.0 cm)	28
Boresight correction stdev (<0.001deg)	0.001063
IMU attitude correction stdev (<0.001deg)	0.034563
GPS position stdev (<0.01m)	0.0238
Minimum % overlap (>25)	23.01
Ave point cloud density per sq.m. (>2.0)	3.84
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	250
Maximum Height	785.37 m
Minimum Height	42.60 m
Classification (# of points)	
Ground	154,420,124
Low vegetation	95,773,939
Medium vegetation	124,271,377
High vegetation	35,832,014
Building	4,429,891
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Ma. Celina Rosete, Engr. Elainne Lopez

Figure 1.4.1. Solution Status

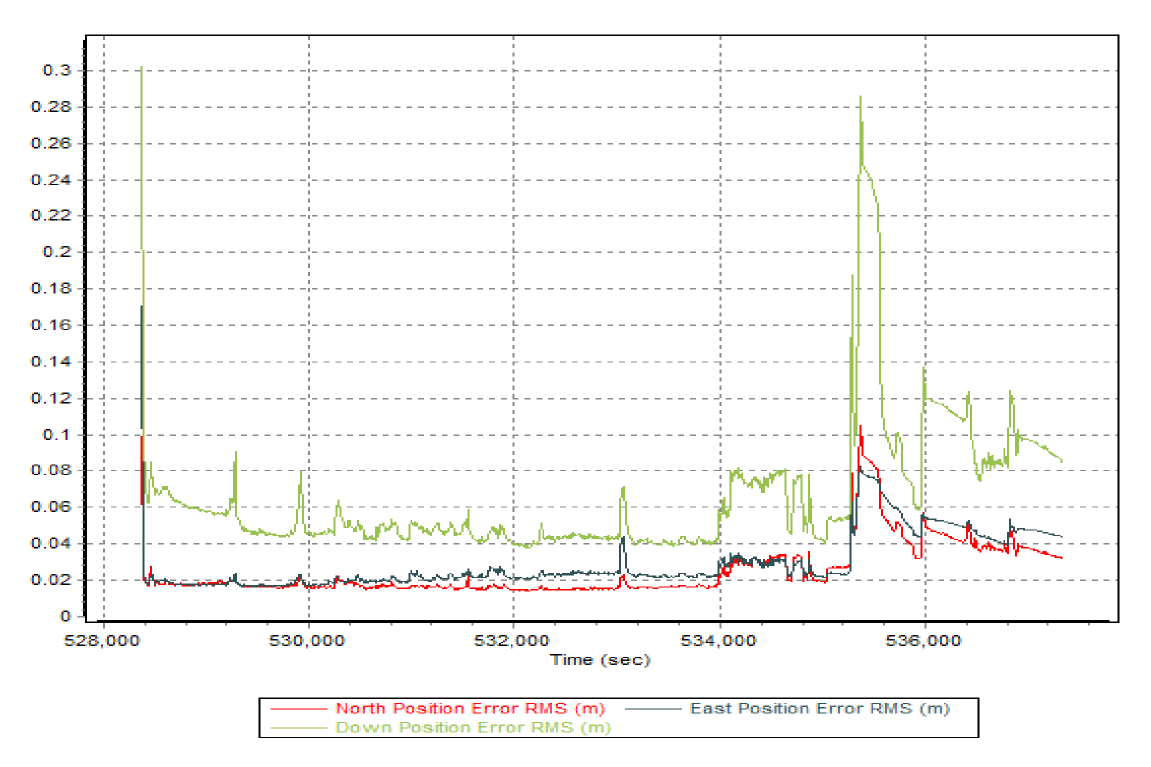


Figure 1.4.2. Smoothed Performance Metric Parameters

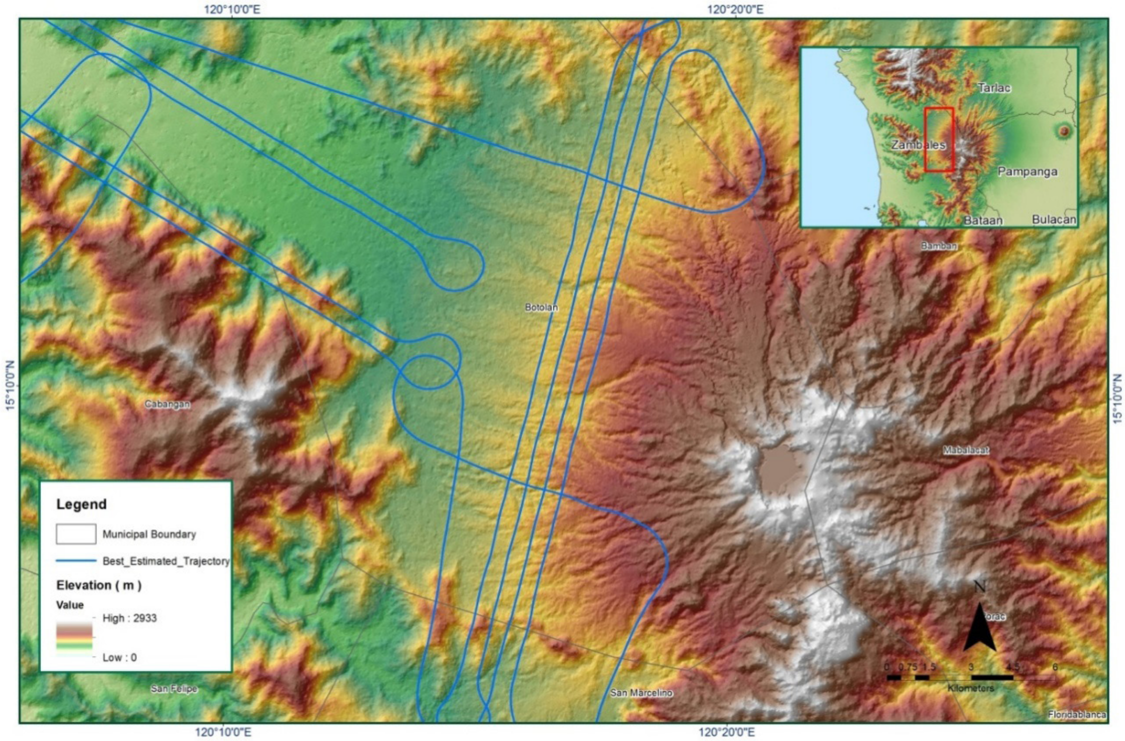


Figure 1.4.3. Best Estimated Trajectory

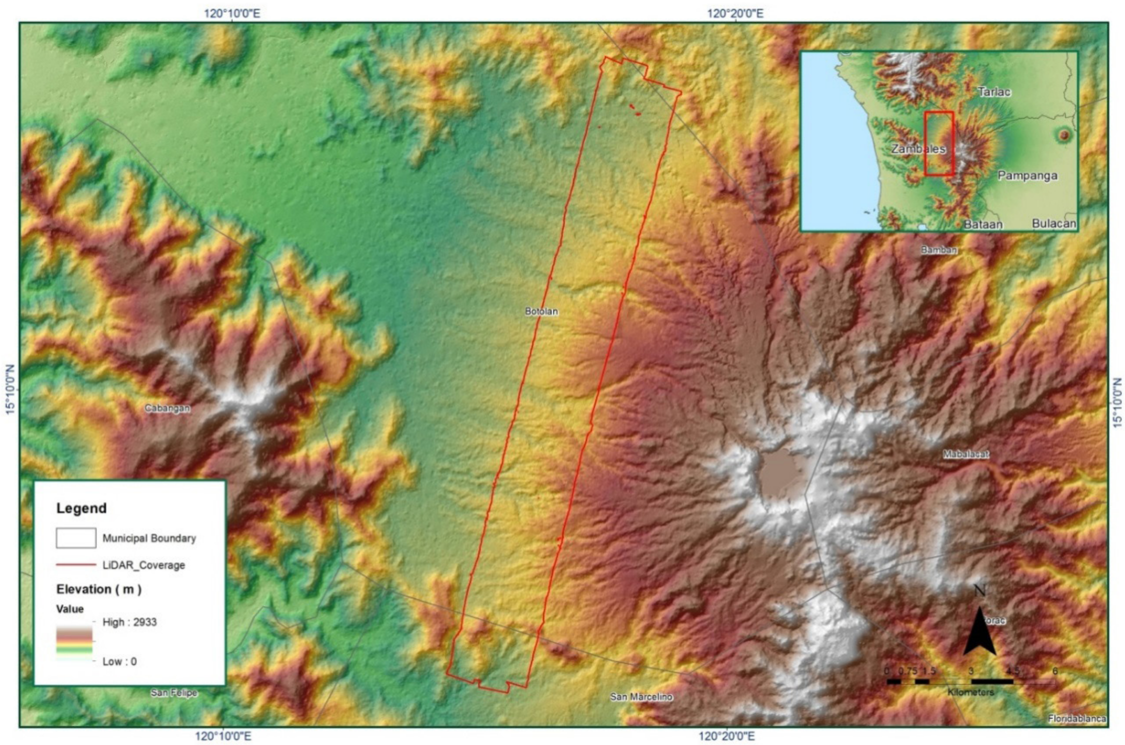


Figure 1.4.4. Coverage of LiDAR Data

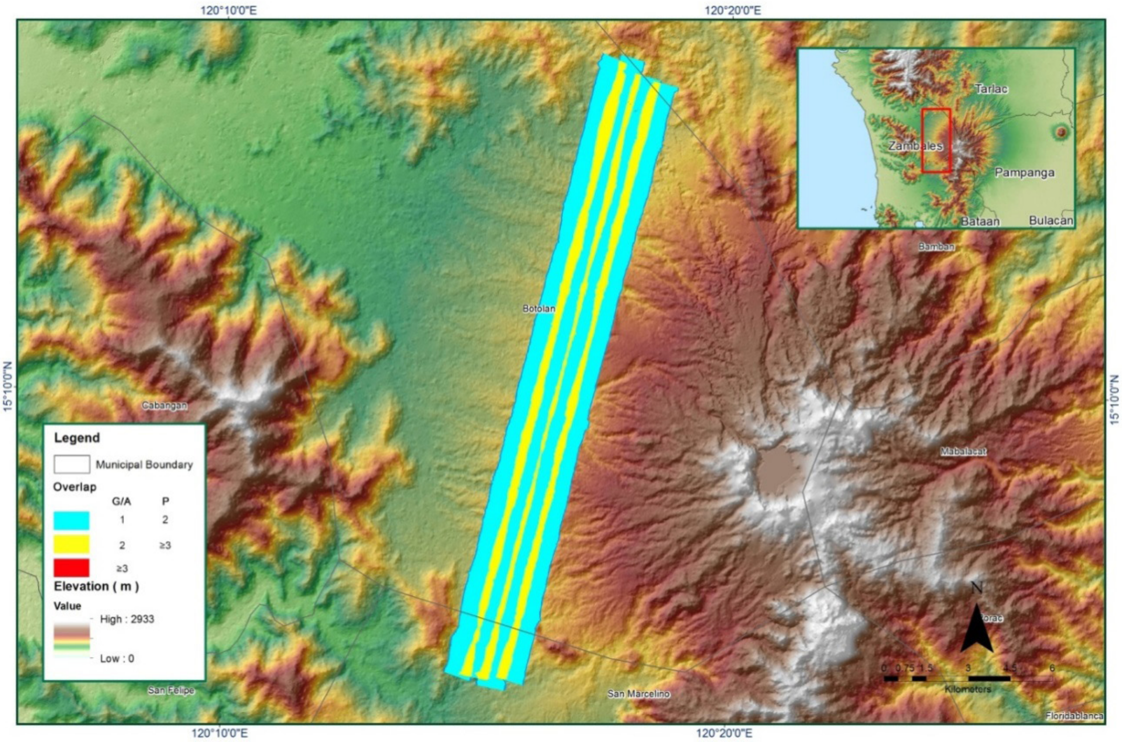


Figure 1.4.5. Image of data overlap

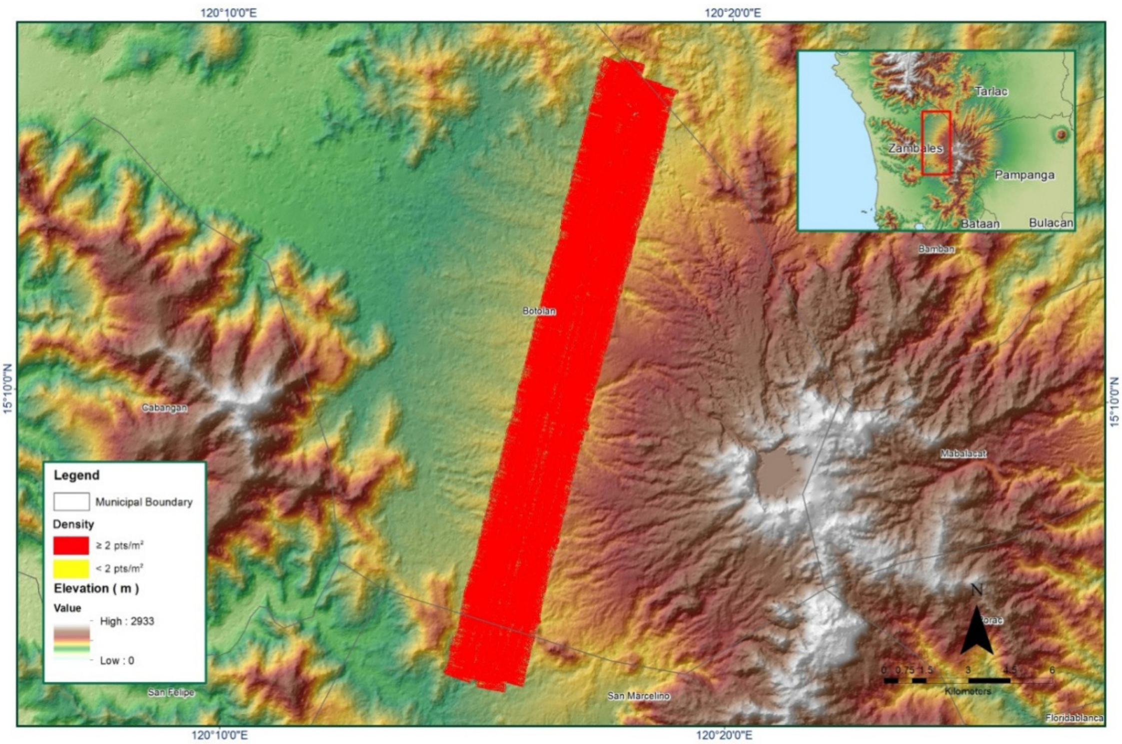


Figure 1.4.6. Density map of merged LiDAR data

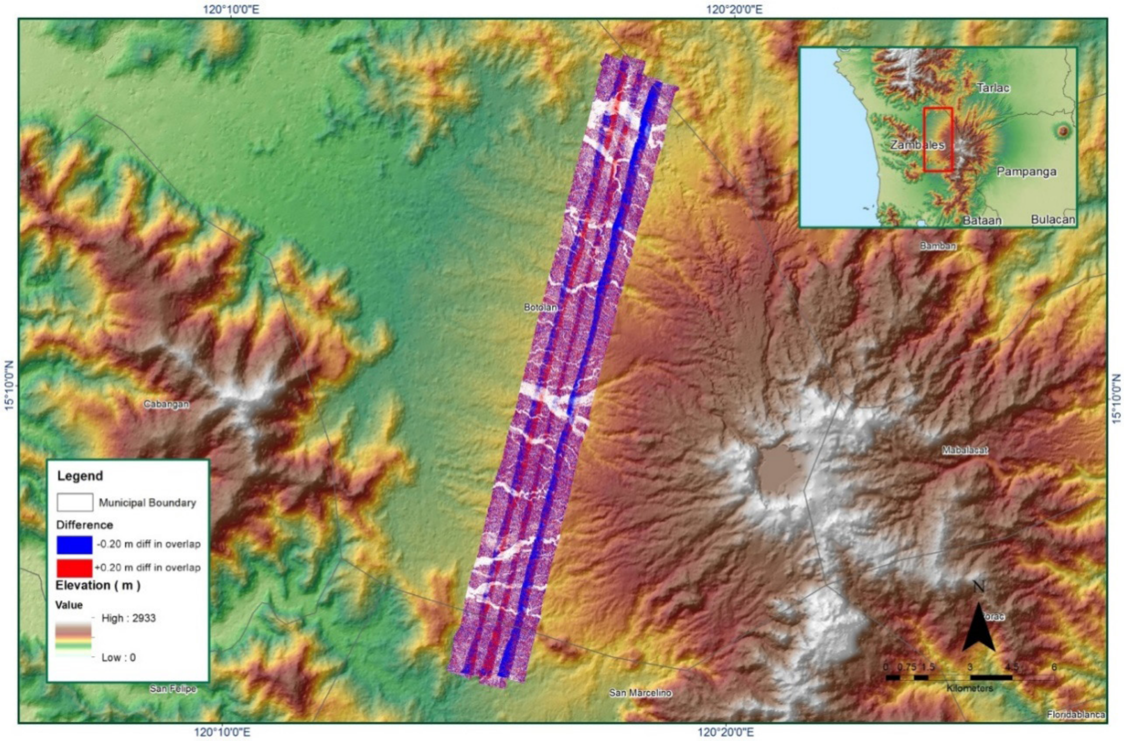


Figure 1.4.7. Elevation difference between flight lines

Flight Area	Bataan_Reflights
Mission Name	**Buc_ABC_additional**
Inclusive Flights	2481P
Range data size	24.4 GB
POS	273 MB
Base data size	2.82 MB
Image	NA
Transfer date	March 9, 2015
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)	1.60
RMSE for East Position (<4.0 cm)	1.69
RMSE for Down Position (<8.0 cm)	3.98
Boresight correction stdev (<0.001deg)	0.000241
IMU attitude correction stdev (<0.001deg)	0.000948
GPS position stdev (<0.01m)	0.0117
Minimum % overlap (>25)	25.92
Ave point cloud density per sq.m. (>2.0)	4.81
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	122
Maximum Height	758.34 m
Minimum Height	66.28 m
Classification (# of points)	
Ground	81,099,279
Low vegetation	61,229,996
Medium vegetation	172,103,022
High vegetation	94,306,817
Building	853,319
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Chelou Prado, Engr. Gladys Mae Apat

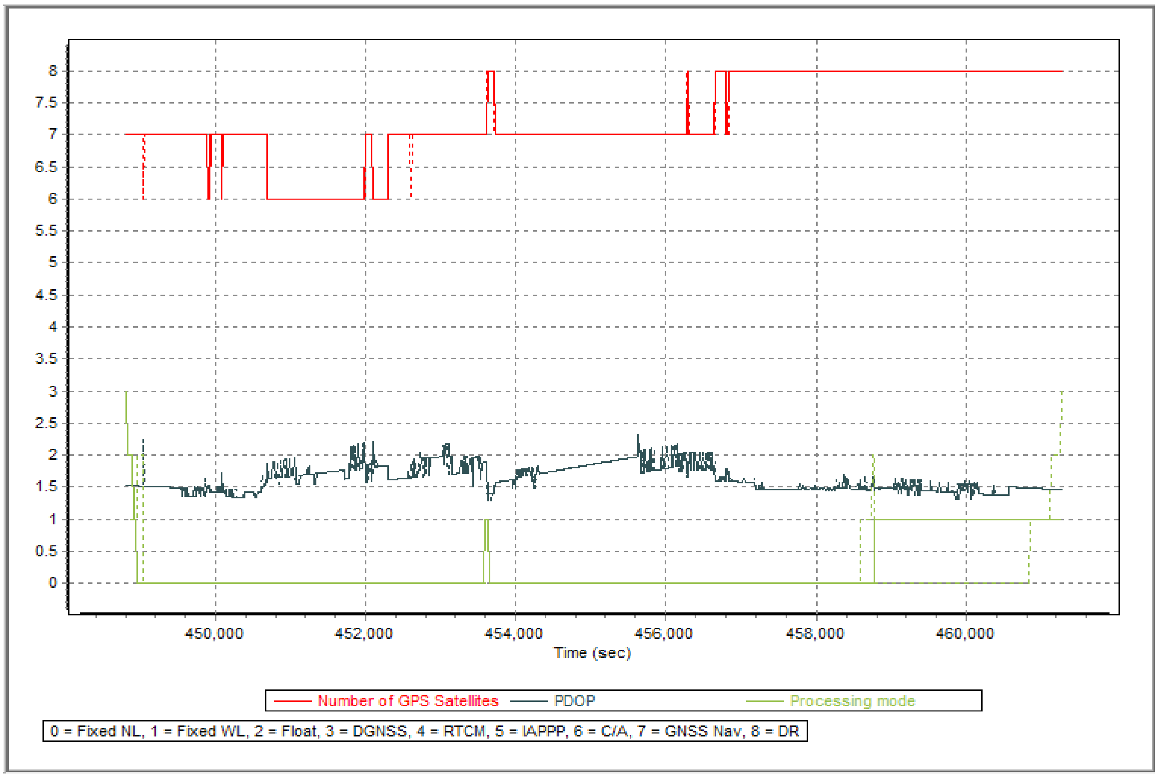


Figure 1.5.1. Solution Status

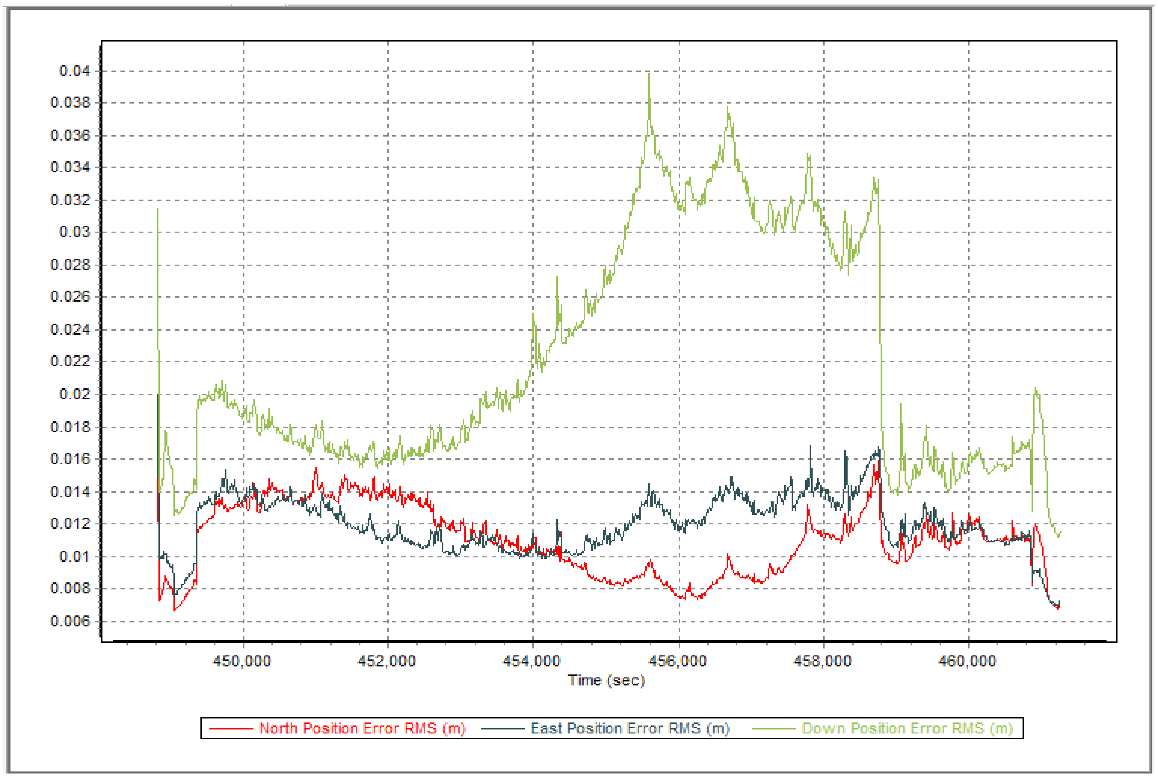


Figure 1.5.2. Smoothed Performance Metric Parameters

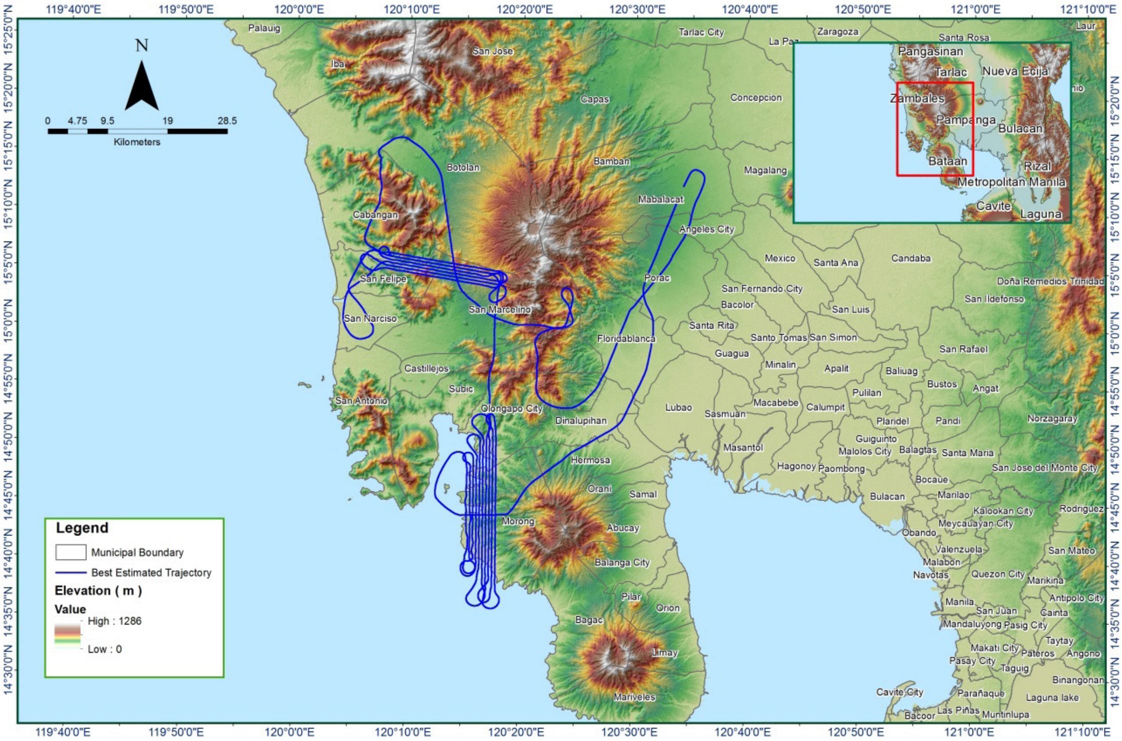


Figure 1.5.3. Best Estimate Trajectory

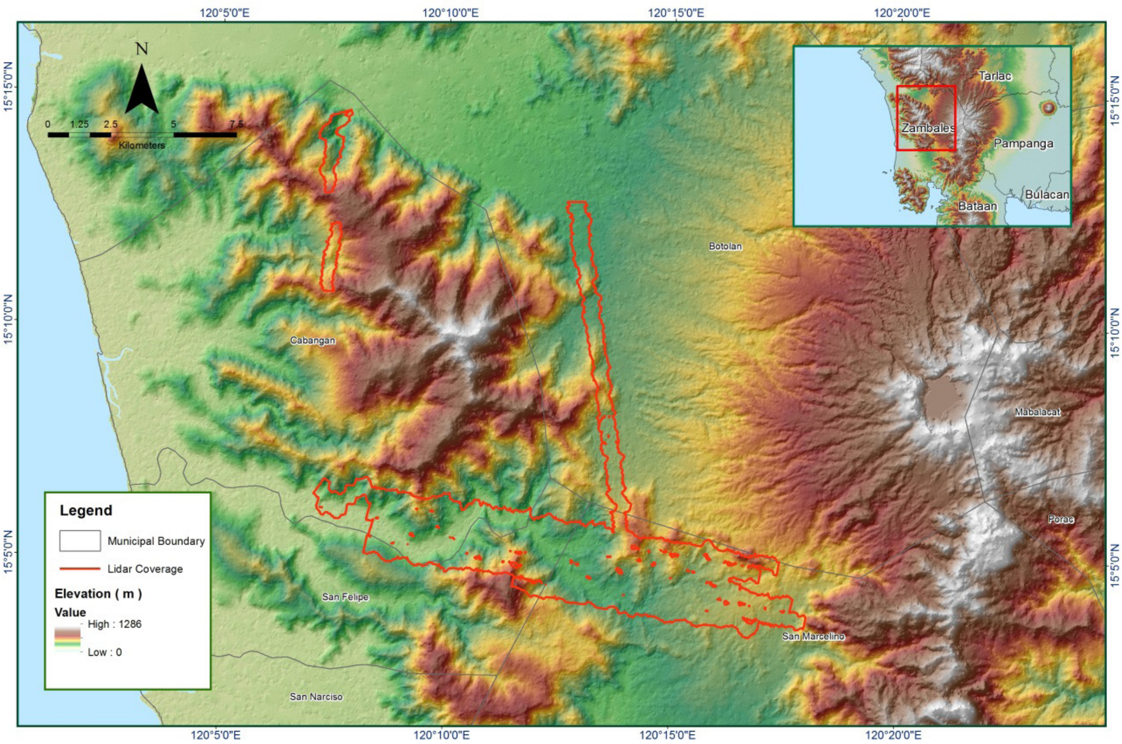


Figure 1.5.4. Coverage of LiDAR data

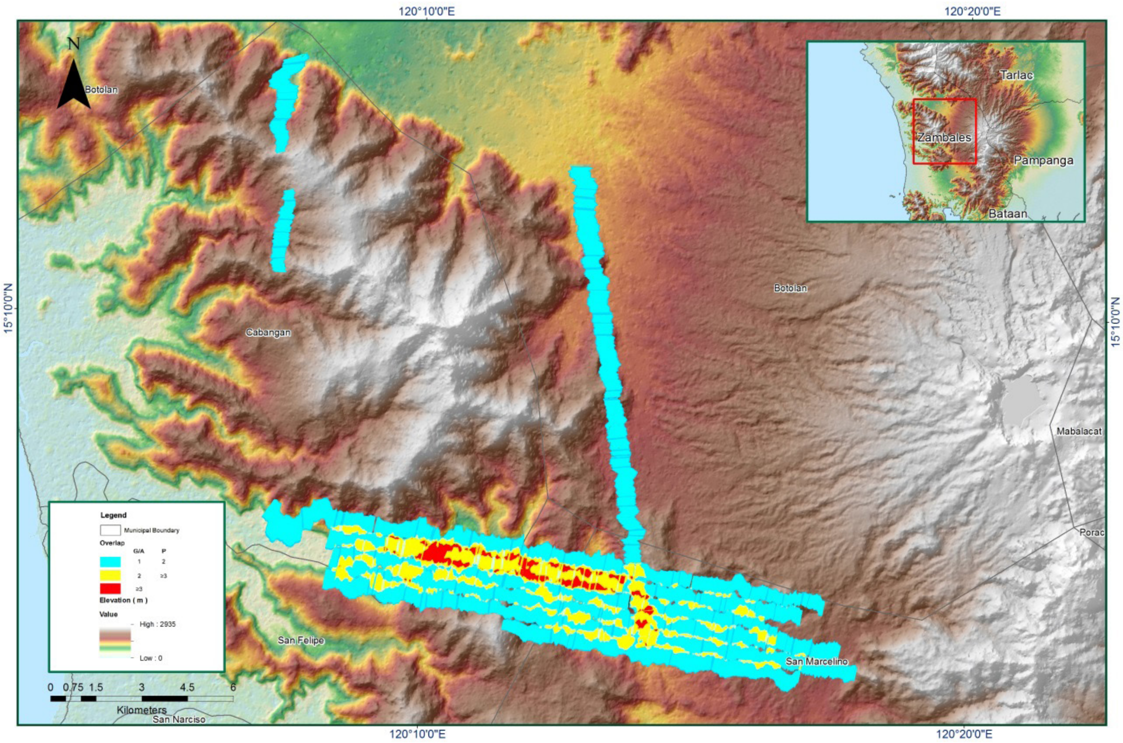


Figure 1.5.5 Image of data overlap

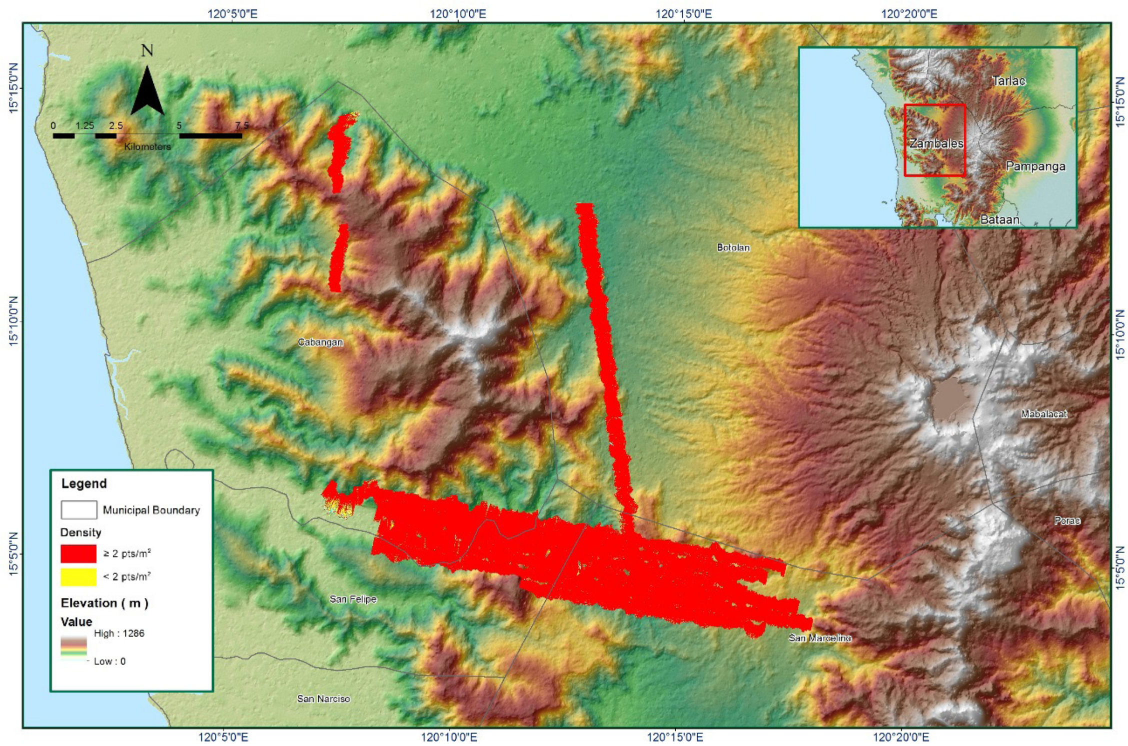


Figure 1.5.6 Density Map of merged LiDAR data

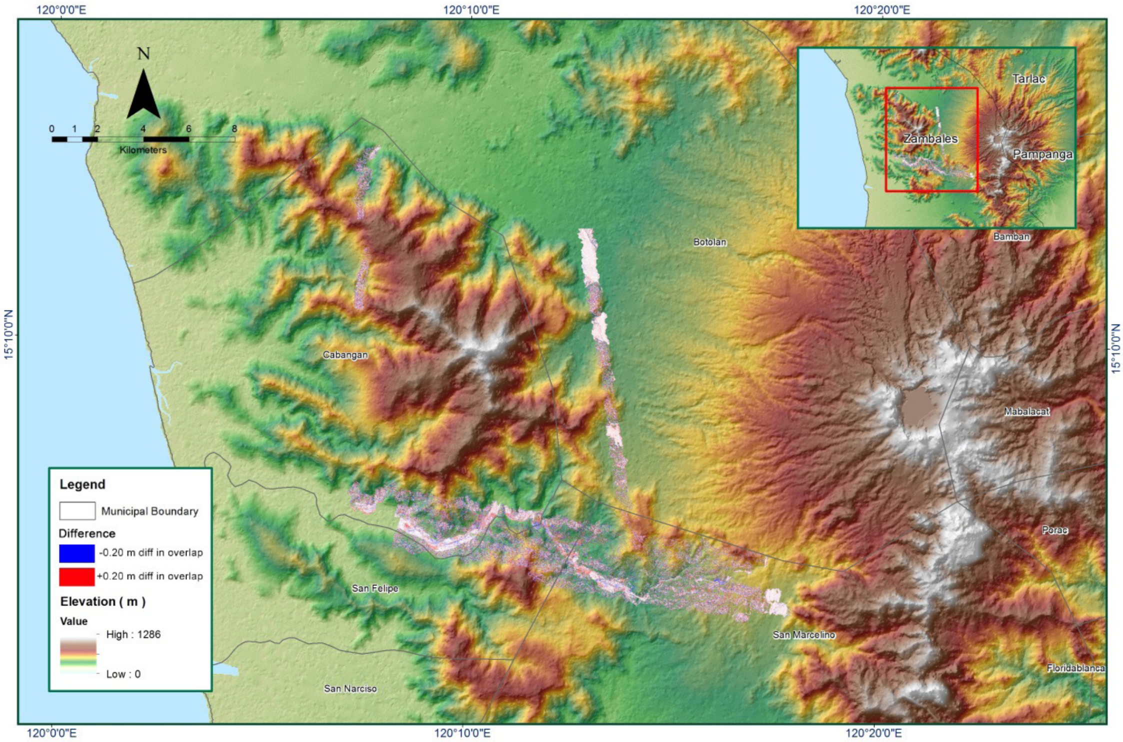


Figure 1.5.7 Elevation Difference Between flight lines

Flight Area	Bataan_Reflights
Mission Name	**Buc_Bs_Additional**
Inclusive Flights	2493P, 2497P
Range data size	7.47 GB
POS	195 MB
Base data size	10.97 MB
Image	21 MB
Transfer date	March 9, 2015
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)	6.80
RMSE for East Position (<4.0 cm)	2.04
RMSE for Down Position (<8.0 cm)	9.80
Boresight correction stdev (<0.001deg)	0.000092
IMU attitude correction stdev (<0.001deg)	0.000217
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	67.64
Ave point cloud density per sq.m. (>2.0)	2.12
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	187
Maximum Height	1217.28 m
Minimum Height	70.39 m
Classification (# of points)	
Ground	90356779
Low vegetation	68122055
Medium vegetation	193950611
High vegetation	188989209
Building	1567155
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Chelou Prado, Engr. Gladys Mae Apat

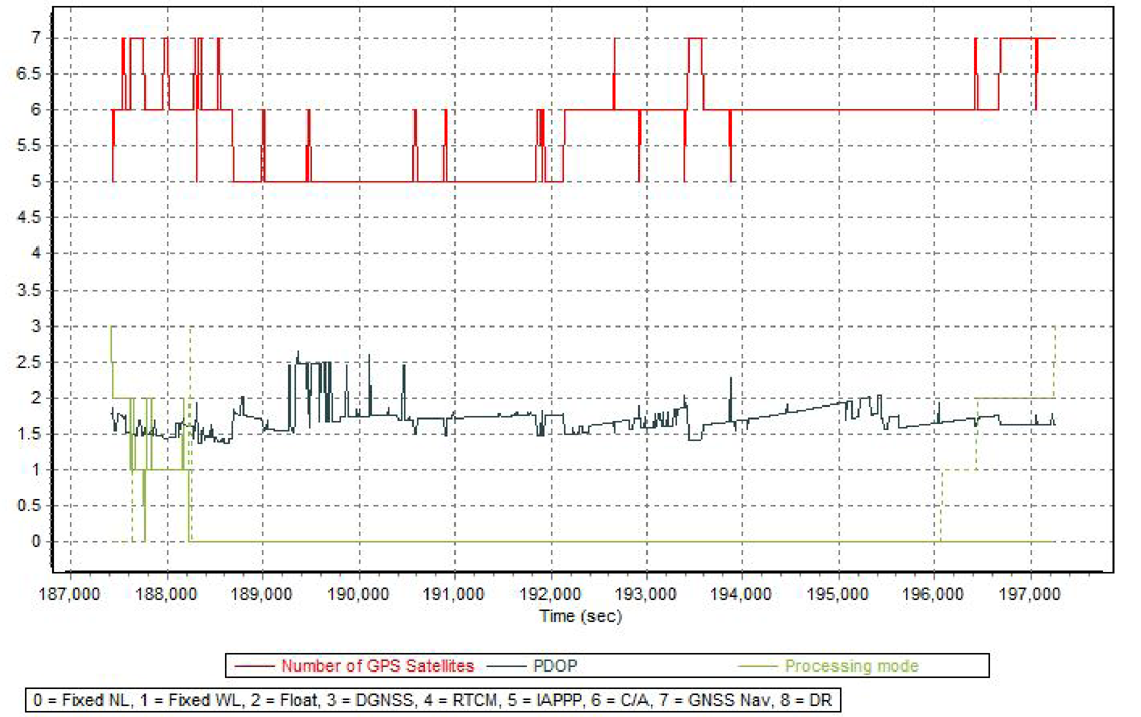


Figure 1.6.1. Solution Status

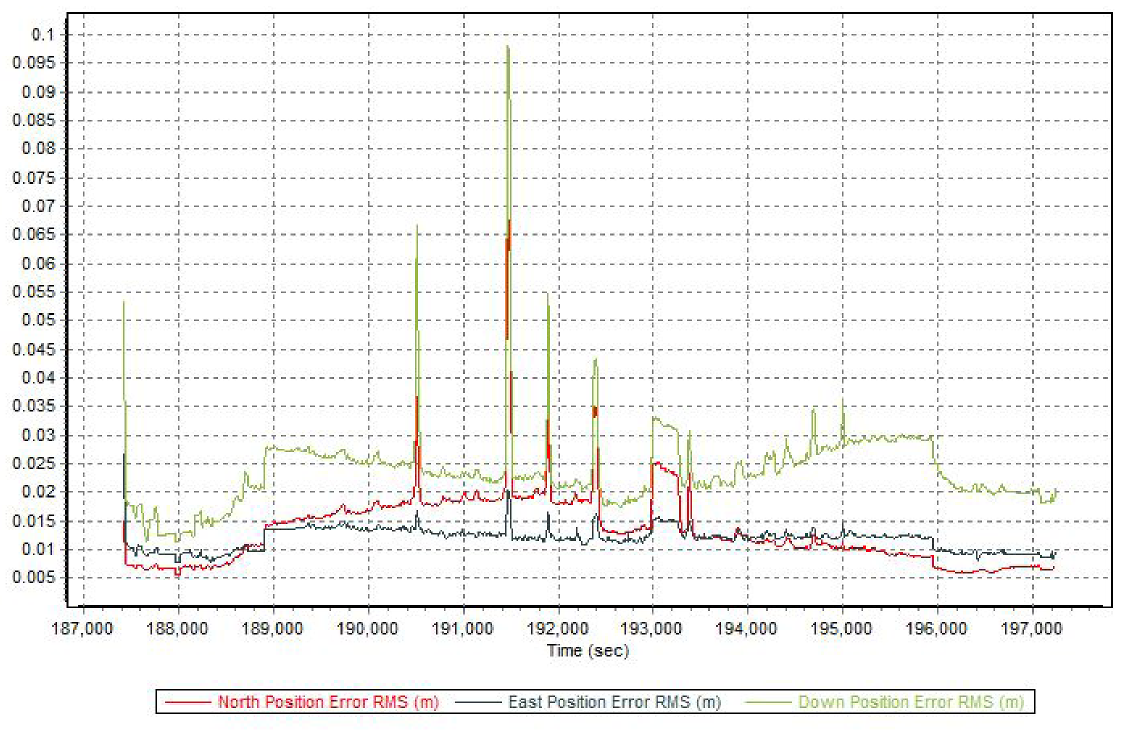


Figure 1.6.2. Smoothed Performance Metric Parameters

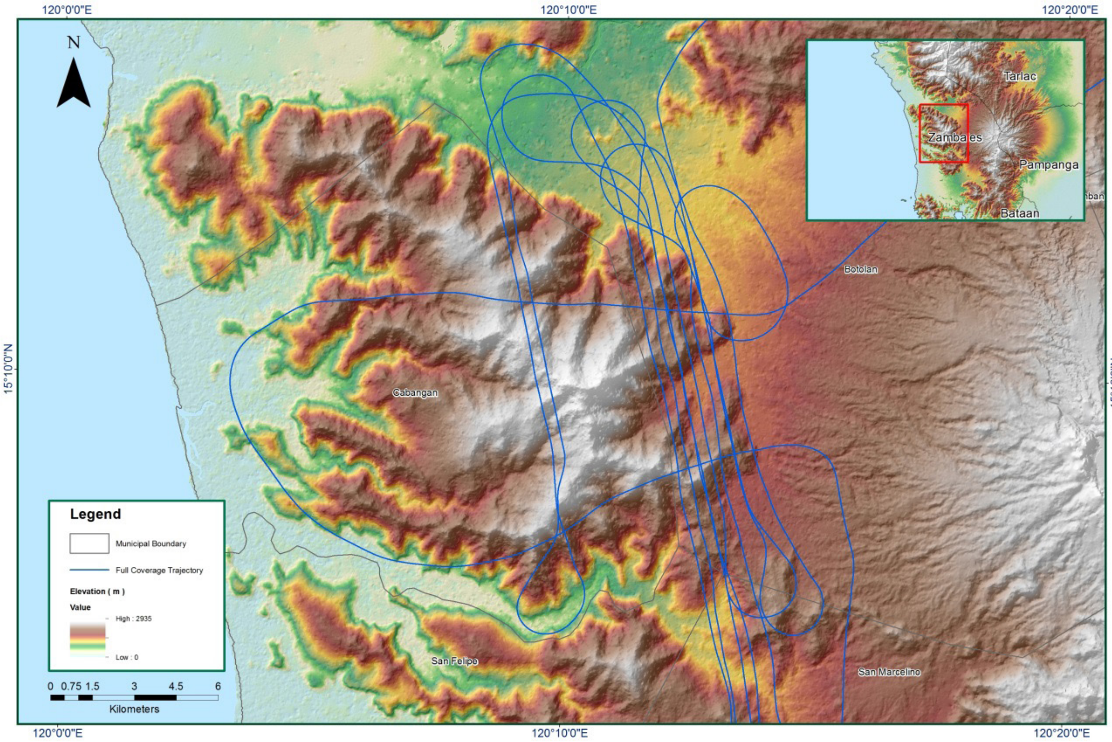


Figure 1.6.3. Best Estimate Trajectory

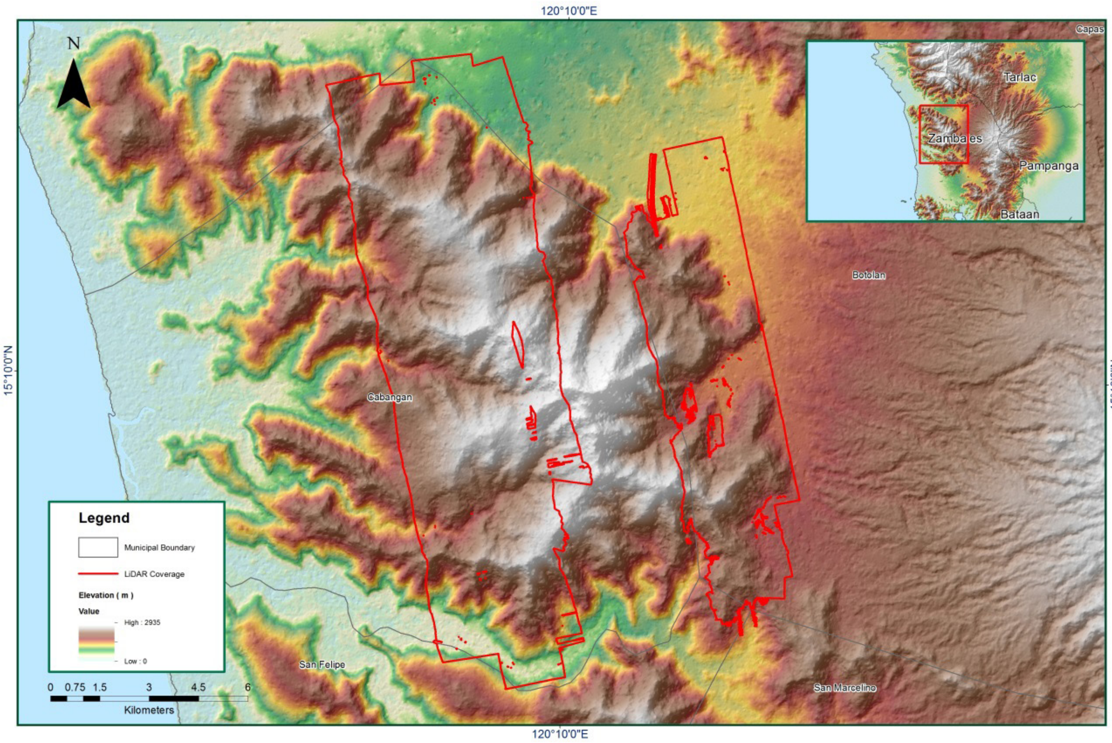


Figure 1.6.4. Coverage of LiDAR data

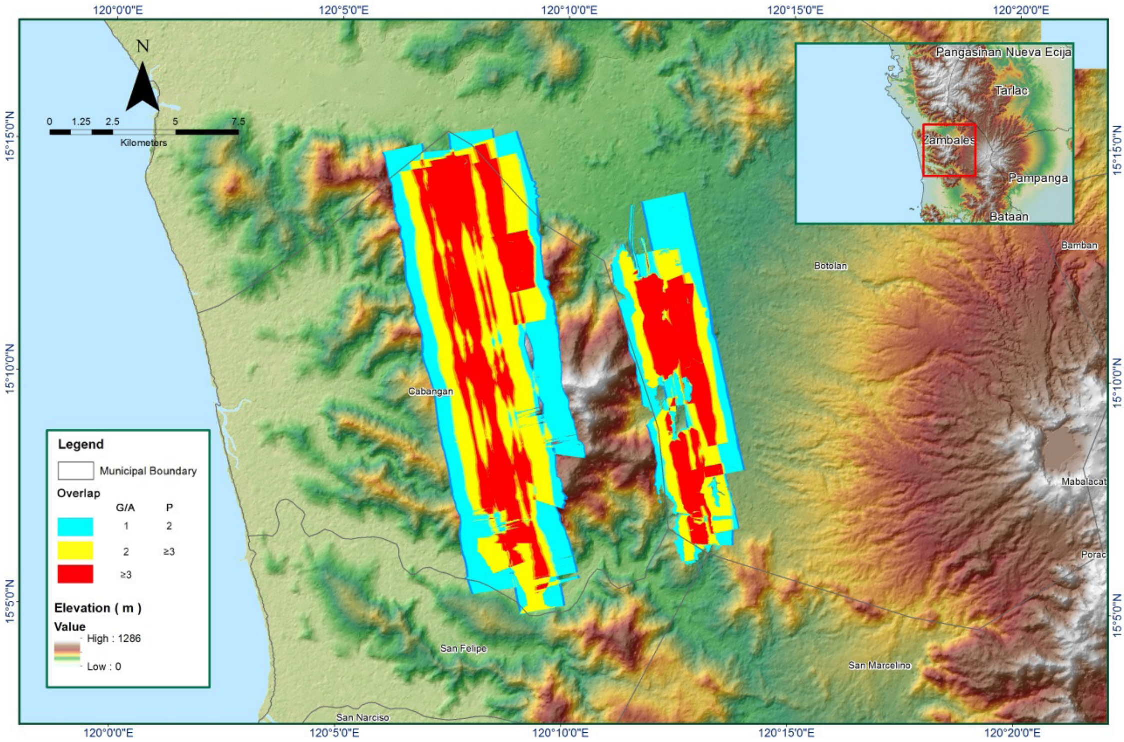


Figure 1.6.5 Image of data overlap

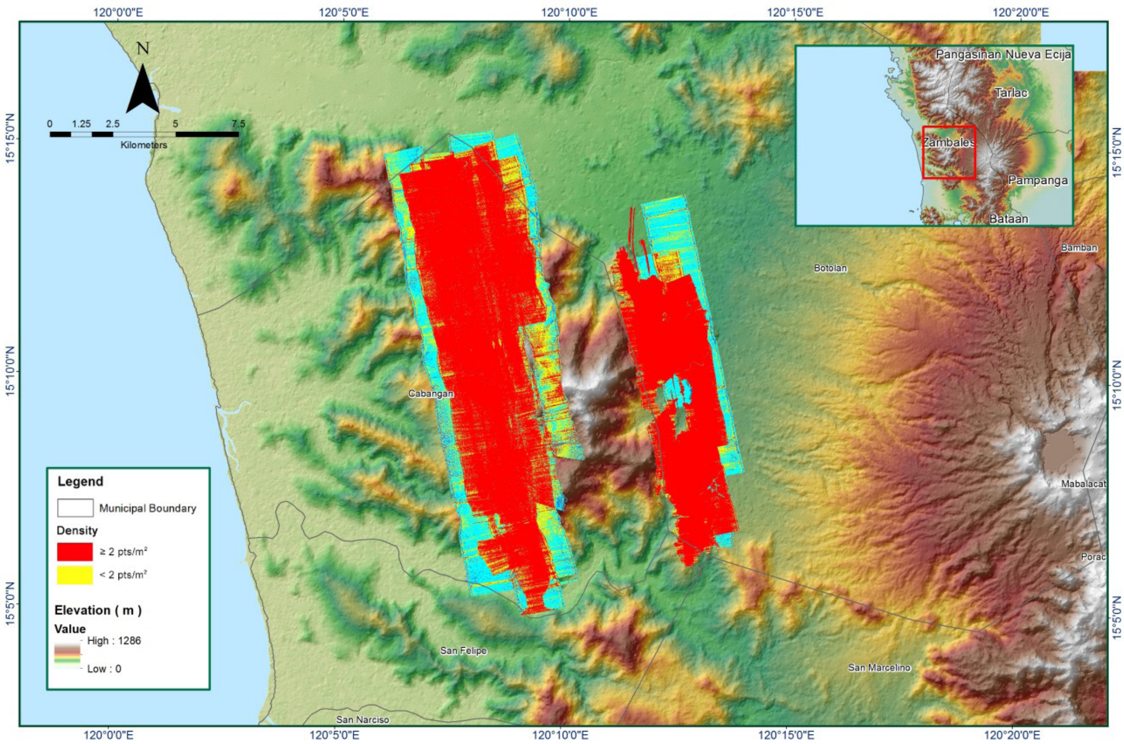


Figure 1.6.6 Density Map of merged LiDAR data

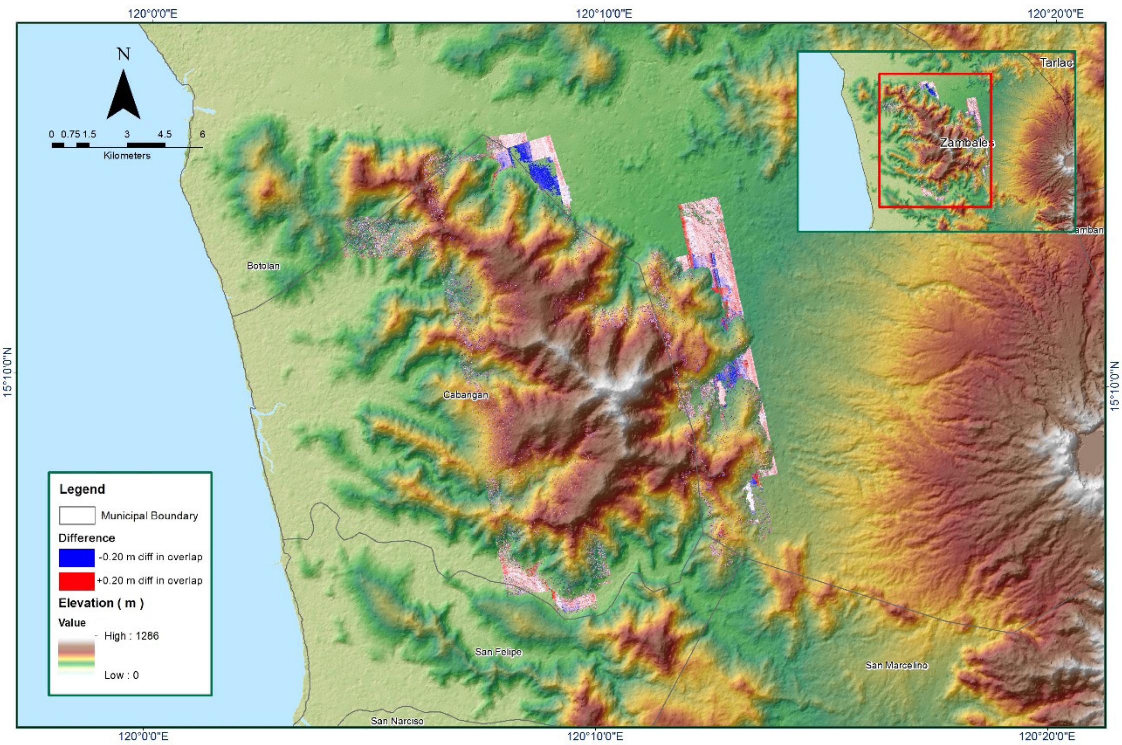


Figure 1.6.7 Elevation Difference Between flight lines

Flight Area	Bataan_Reflights
Mission Name	**Buc_AsB_Additional**
Inclusive Flights	2471P, 2473P
Range data size	15.5 GB
POS	192 MB
Base data size	9.55 MB
Image	25.1 MB
Transfer date	March 9, 2015
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)	1.50
RMSE for East Position (<4.0 cm)	1.22
RMSE for Down Position (<8.0 cm)	2.95
Boresight correction stdev (<0.001deg)	0.000247
IMU attitude correction stdev (<0.001deg)	0.000741
GPS position stdev (<0.01m)	0.0023
Minimum % overlap (>25)	3.89
Ave point cloud density per sq.m. (>2.0)	52.63
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	183
Maximum Height	701.32 m
Minimum Height	47.33 m
Classification (# of points)	
Ground	199,506,831
Low vegetation	177,953,422
Medium vegetation	291,014,610
High vegetation	264,973,146
Building	7,450,353
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Monalyne Rabino

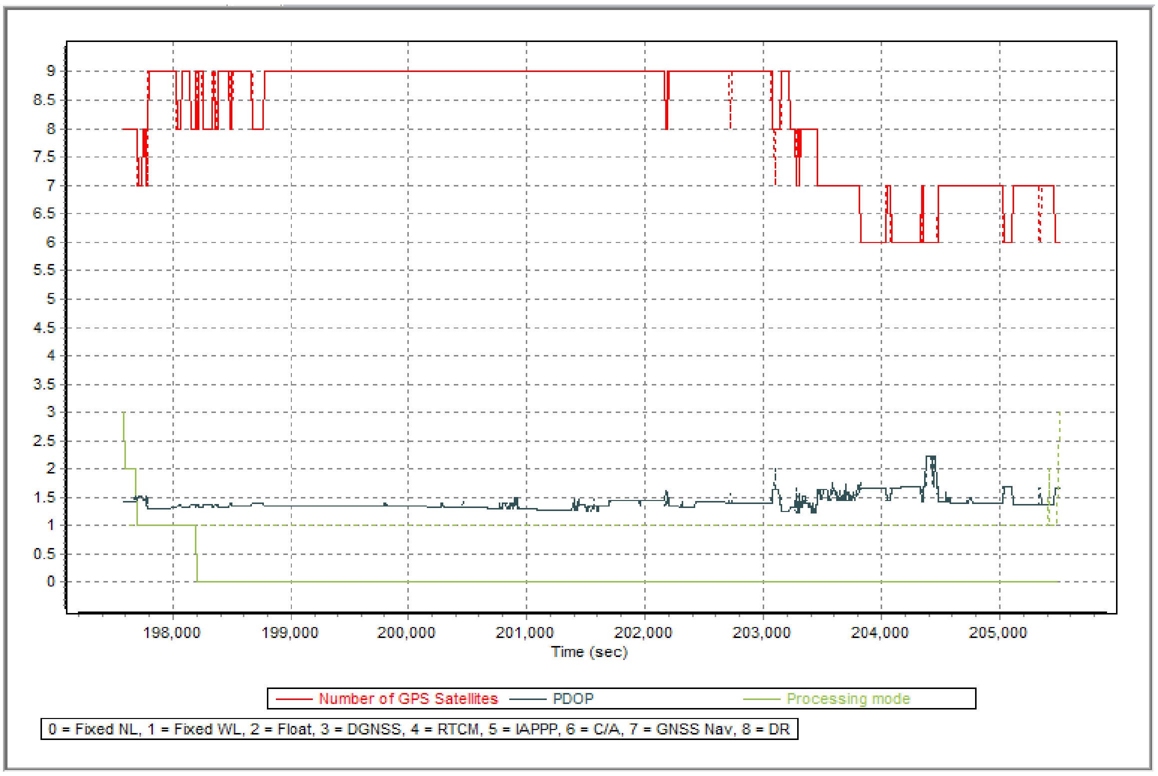


Figure 1.7.1. Solution Status

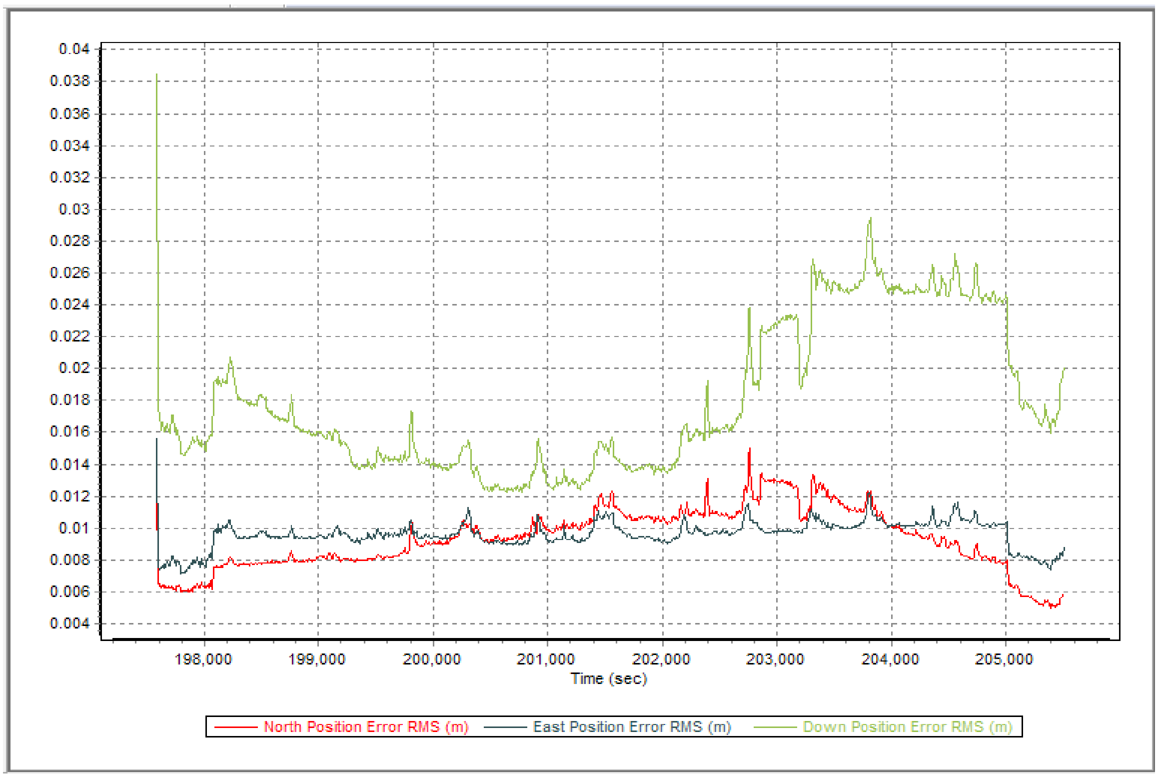


Figure 1.7.2. Smoothed Performance Metric Parameters

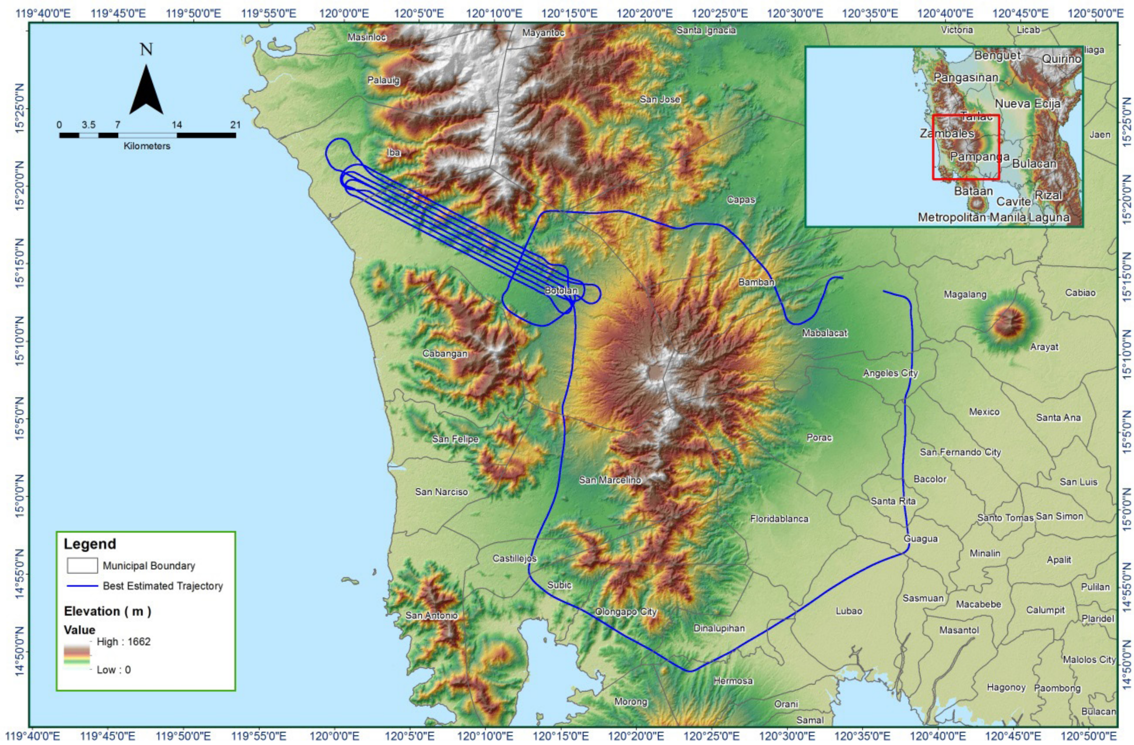


Figure 1.7.3. Best Estimate Trajectory

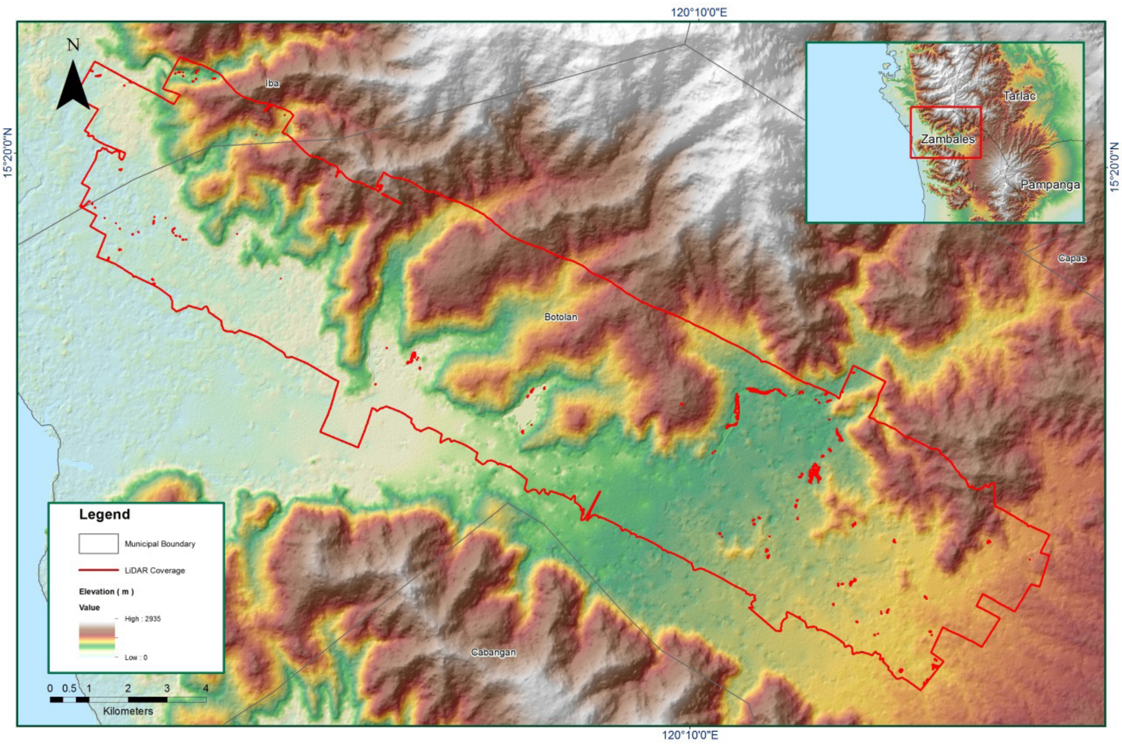


Figure 1.7.4. Coverage of LiDAR data

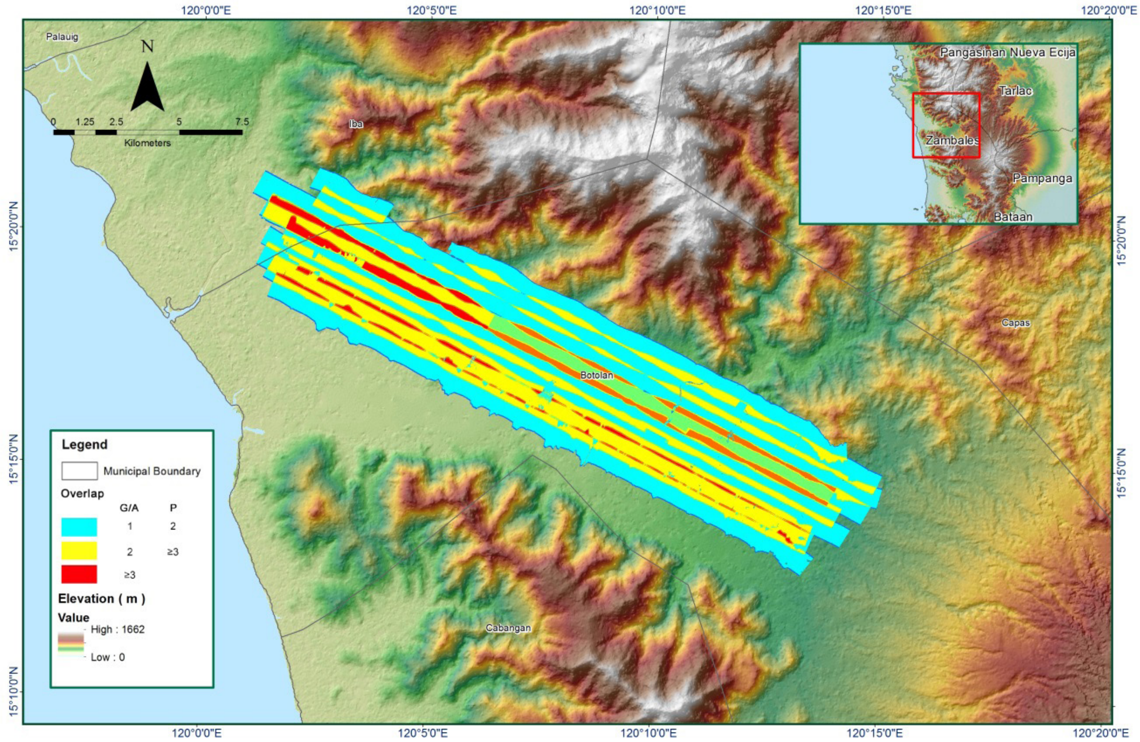


Figure 1.7.5 Image of data overlap

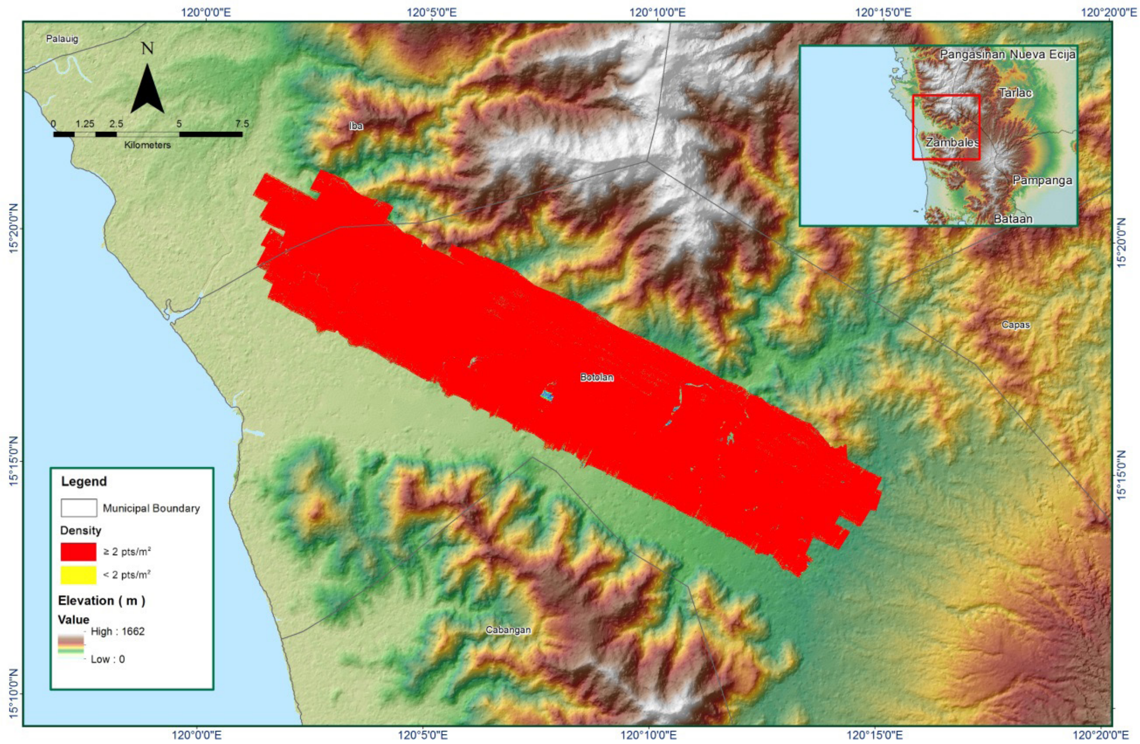


Figure 1.7.6 Density Map of merged LiDAR data

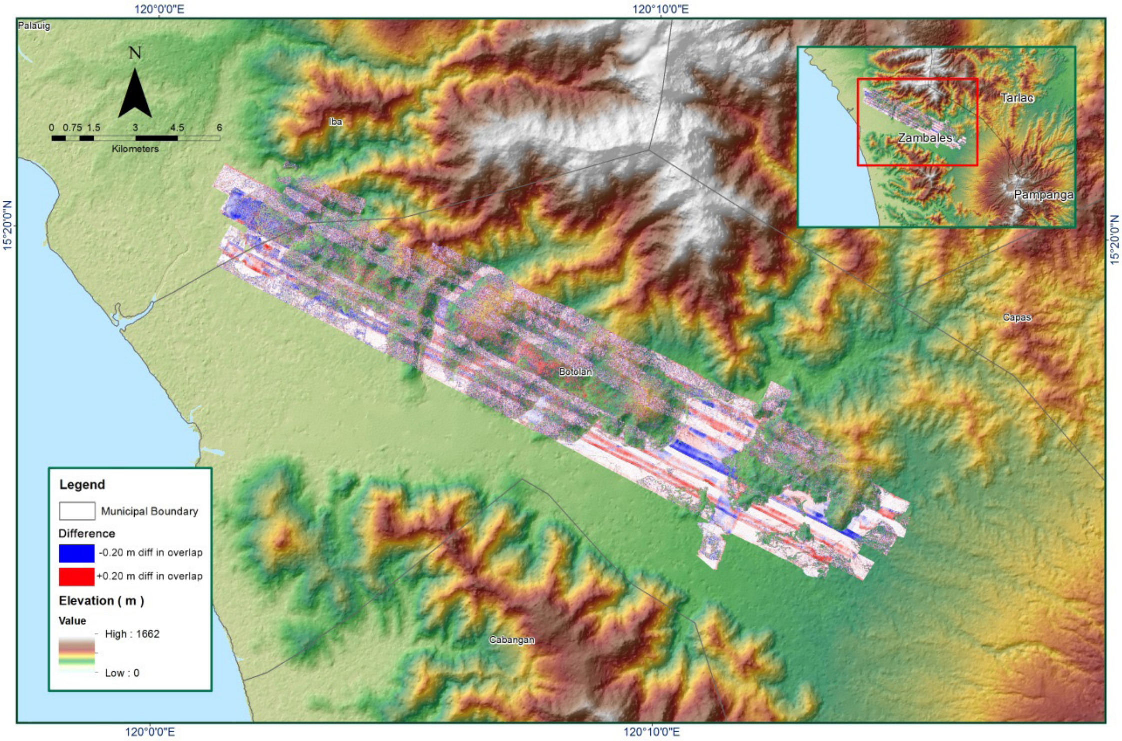


Figure 1.7.7 Elevation Difference Between flight lines

Flight Area	Bataan_Reflights
Mission Name	**Plg_A_Additional**
Inclusive Flights	2501P
Range data size	20.7 GB
POS	184 MB
Base data	5.3 MB
Image	22.5 MB
Transfer date	March 9, 2015
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)	2.0
RMSE for East Position (<4.0 cm)	2.11
RMSE for Down Position (<8.0 cm)	5.69
Boresight correction stdev (<0.001deg)	0.000291
IMU attitude correction stdev (<0.001deg)	0.000677
GPS position stdev (<0.01m)	0.0010
Minimum % overlap (>25)	39.06
Ave point cloud density per sq.m. (>2.0)	2.99
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	144
Maximum Height	485.57 m
Minimum Height	44.31 m
Classification (# of points)	
Ground	156,528,446
Low vegetation	112,236,110
Medium vegetation	131,424,154
High vegetation	186,647,516
Building	5,678,146
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Edgardo Gubatanga, Jr., Engr. Gladys Mae Apat

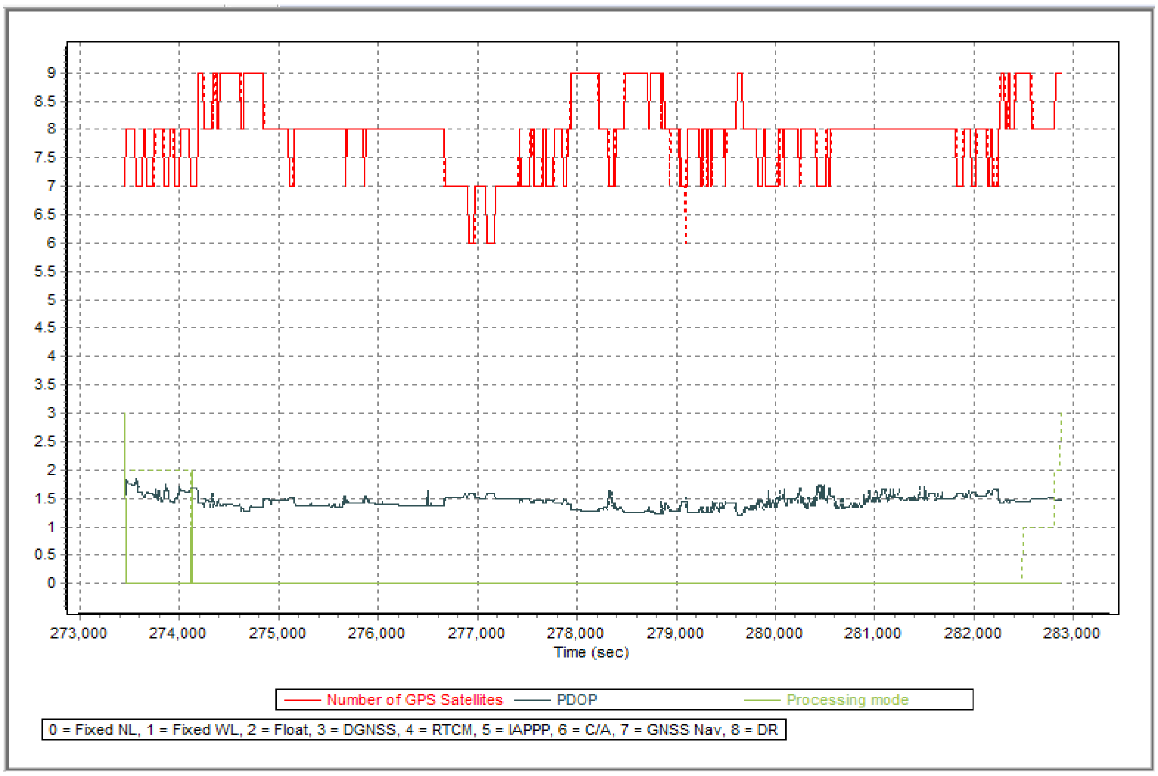


Figure 1.8.1. Solution Status

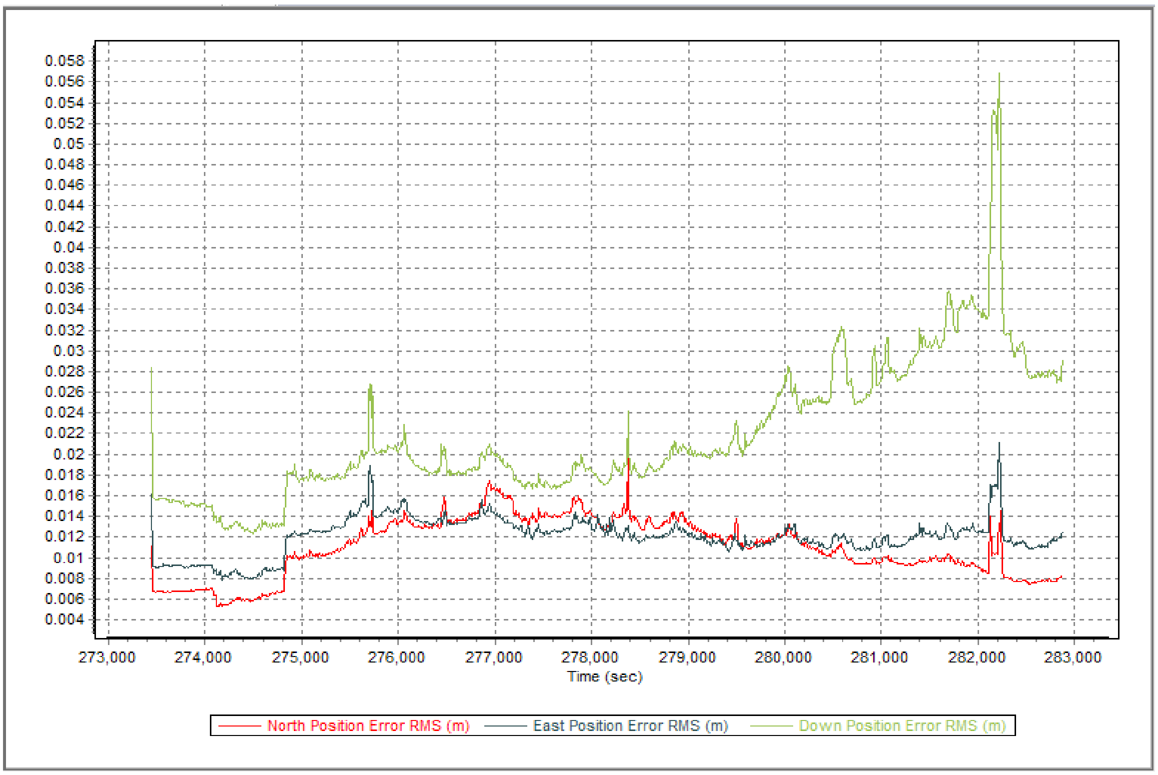


Figure 1.8.2. Smoothed Performance Metric Parameters

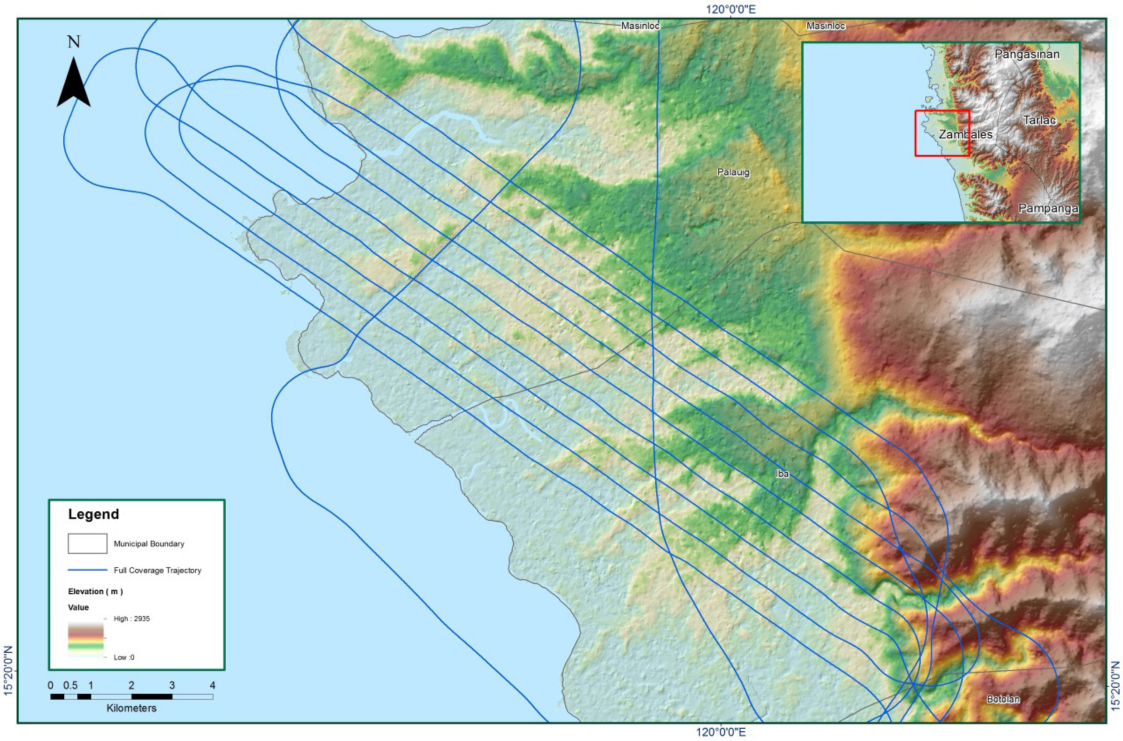


Figure 1.8.3. Best Estimate Trajectory

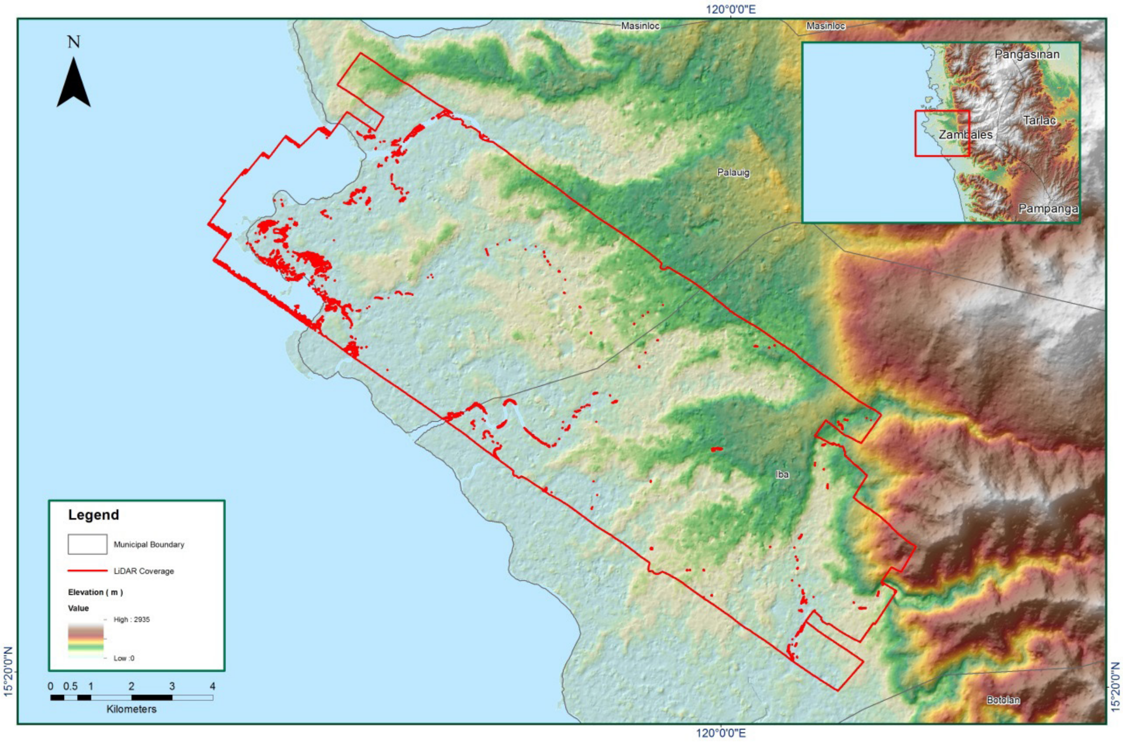


Figure 1.8.4. Coverage of LiDAR data

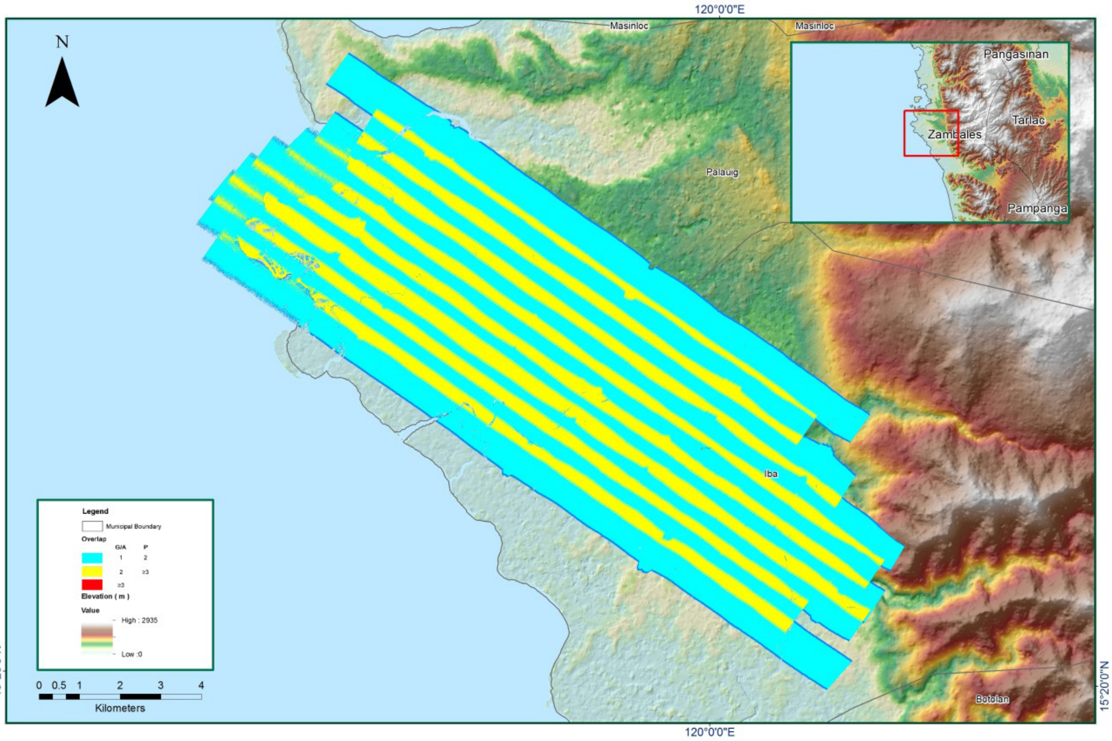


Figure 1.8.5 Image of data overlap

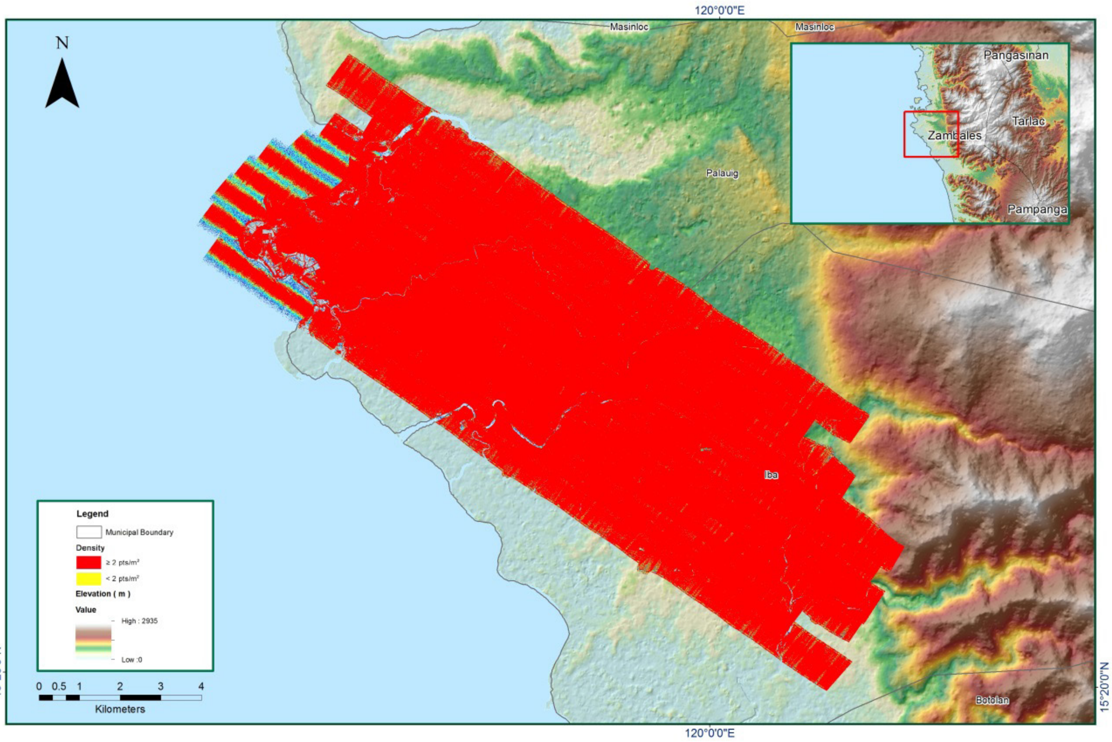


Figure 1.8.6 Density Map of merged LiDAR data

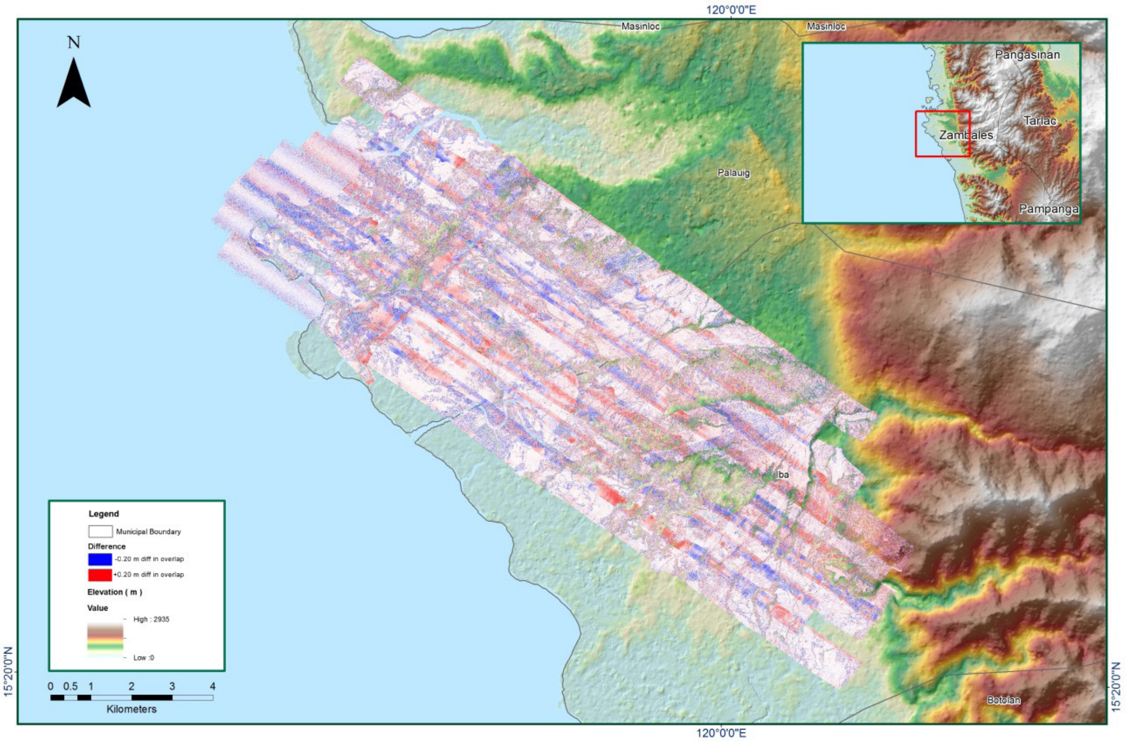


Figure 1.8.7 Elevation Difference Between flight lines

Flight Area	Zambales
Mission Name	Blk15D
Inclusive Flights	10153L
RawLaser	2.72 GB
GnssImu	382 MB
Base data size	62.6 MB
Image	14.2 GB
Transfer date	8/3/2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Combined Separation (-0.1 up to 0.1)	Yes
Estimated Position Accuracy (in cm)	
Estimated Standard Devation for North Position (<4.0 cm)	0.55
Estimated Standard Devation for East Position (<4.0 cm)	0.55
Estimated Standard Devation for Height Position (<8.0 cm)	0.90
Minimum % overlap (>25)	24.20
Ave point cloud density per sq.m. (>2.0)	5.65
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	70
Maximum Height	1,644.24 m
Minimum Height	141.95 m
Classification (# of points)	
Ground	20,639,652
Low vegetation	13,097,237
Medium vegetation	38,418,903
High vegetation	33,064,811
Building	1,042,558
Orthophoto	Yes
Processed by	Ben Joseph Harder, Engr. Merven Matthew Natino, Marie Denise Bueno

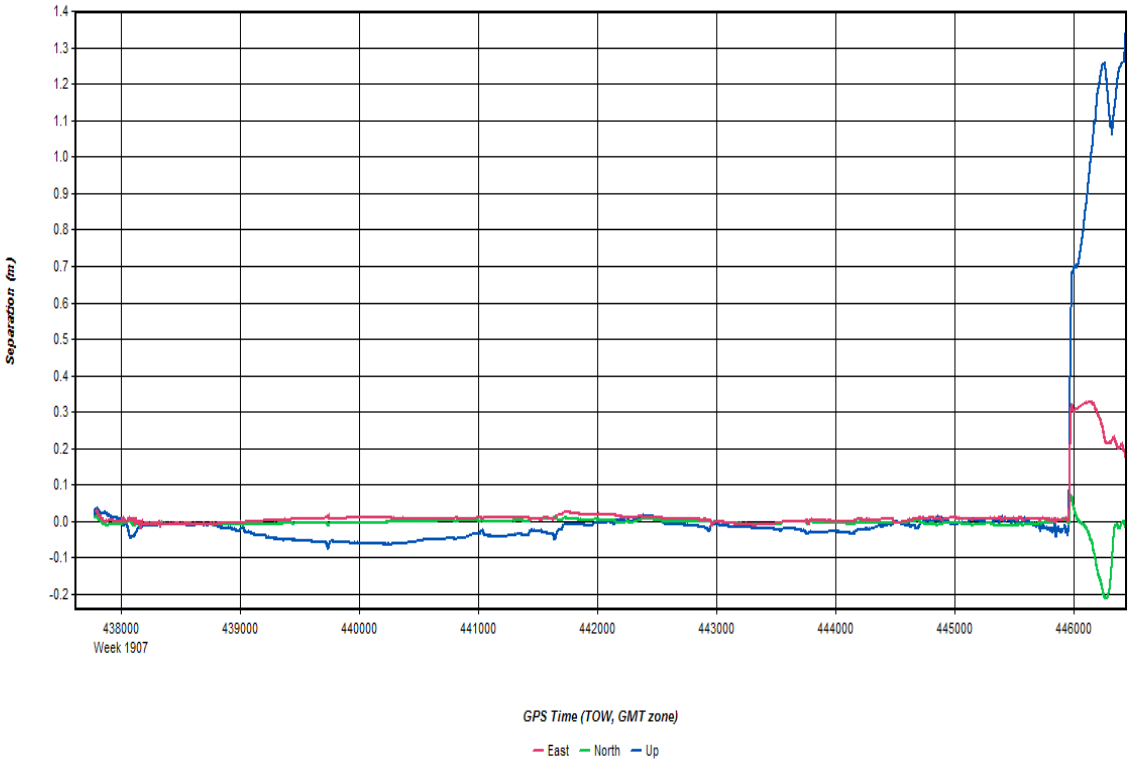


Figure 1.9.1 Combined Separation

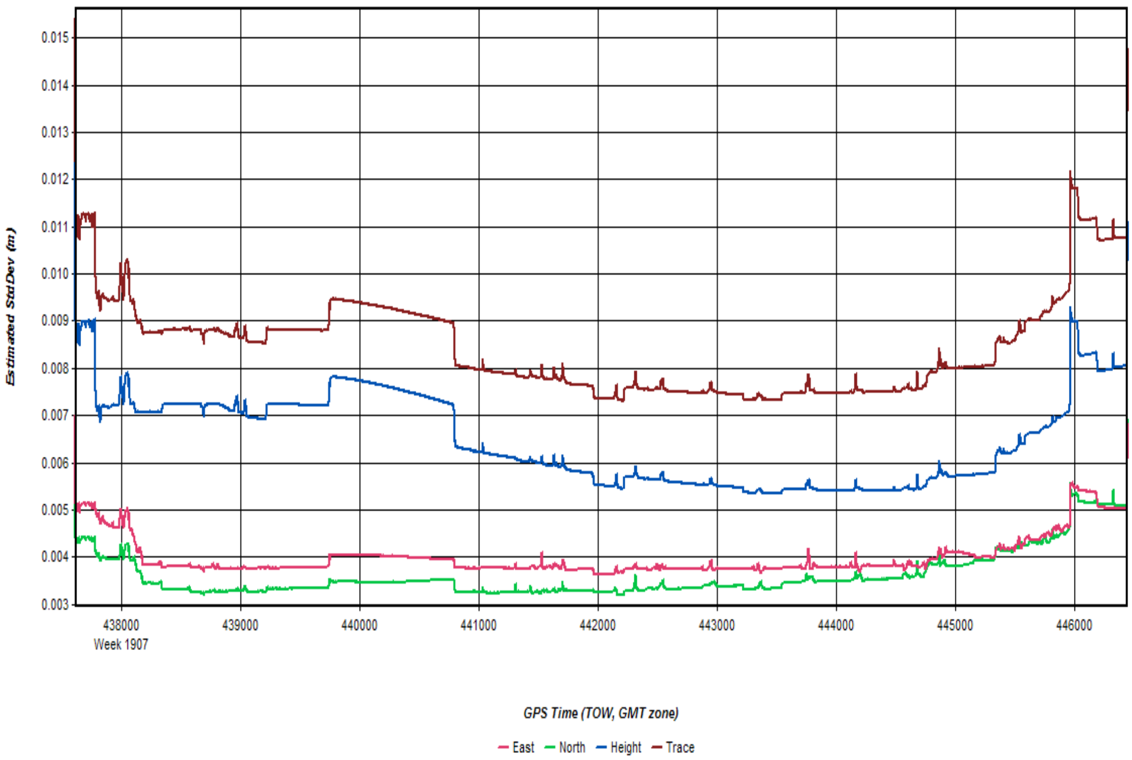


Figure 1.9.2 Estimated Position of Accuracy

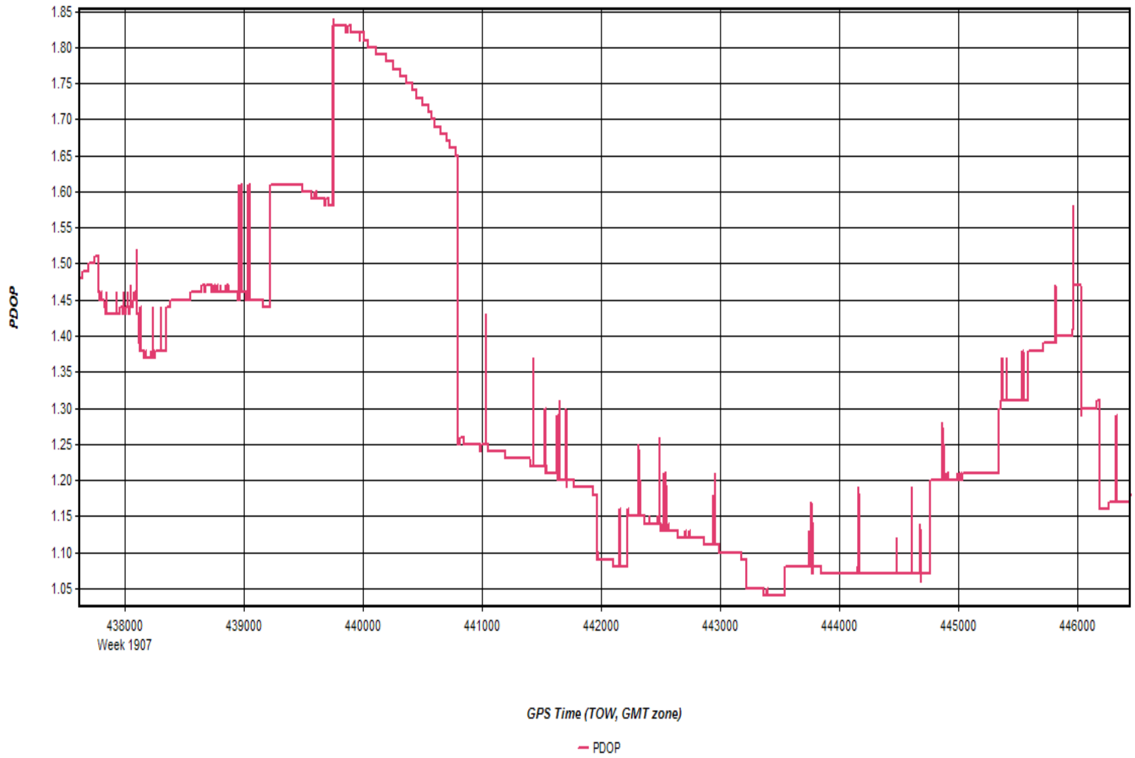


Figure 1.9.3 PDOP

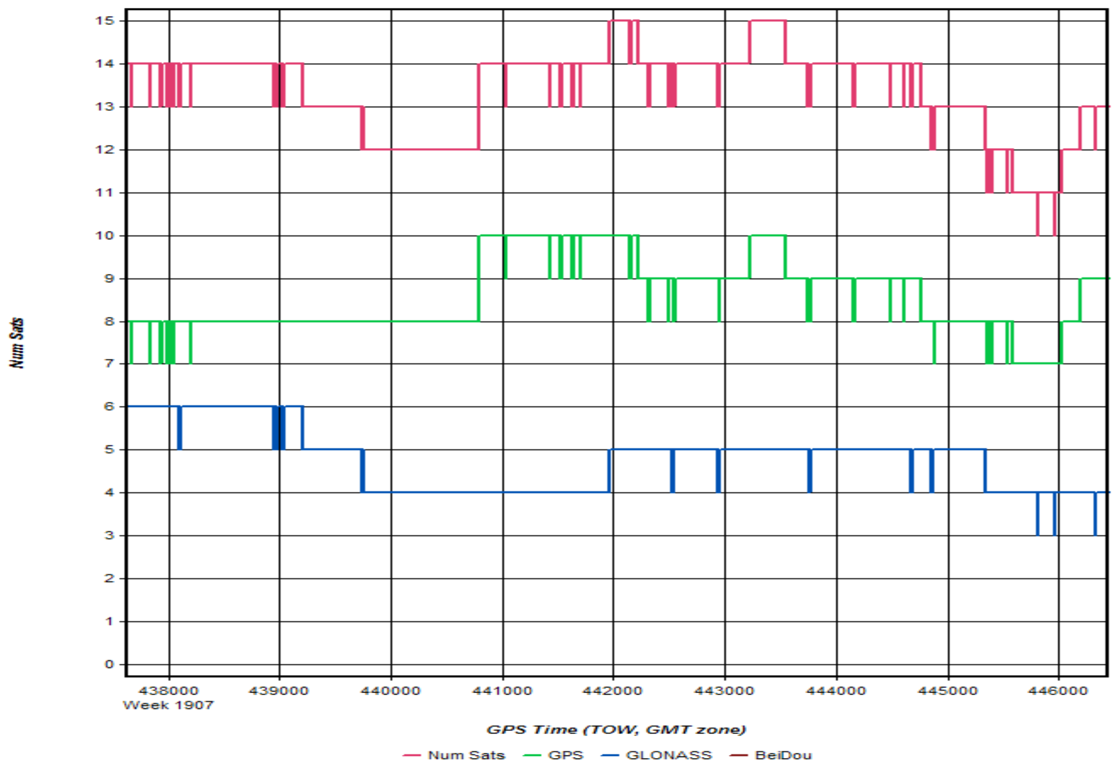


Figure 1.9.4 Number of Satellites

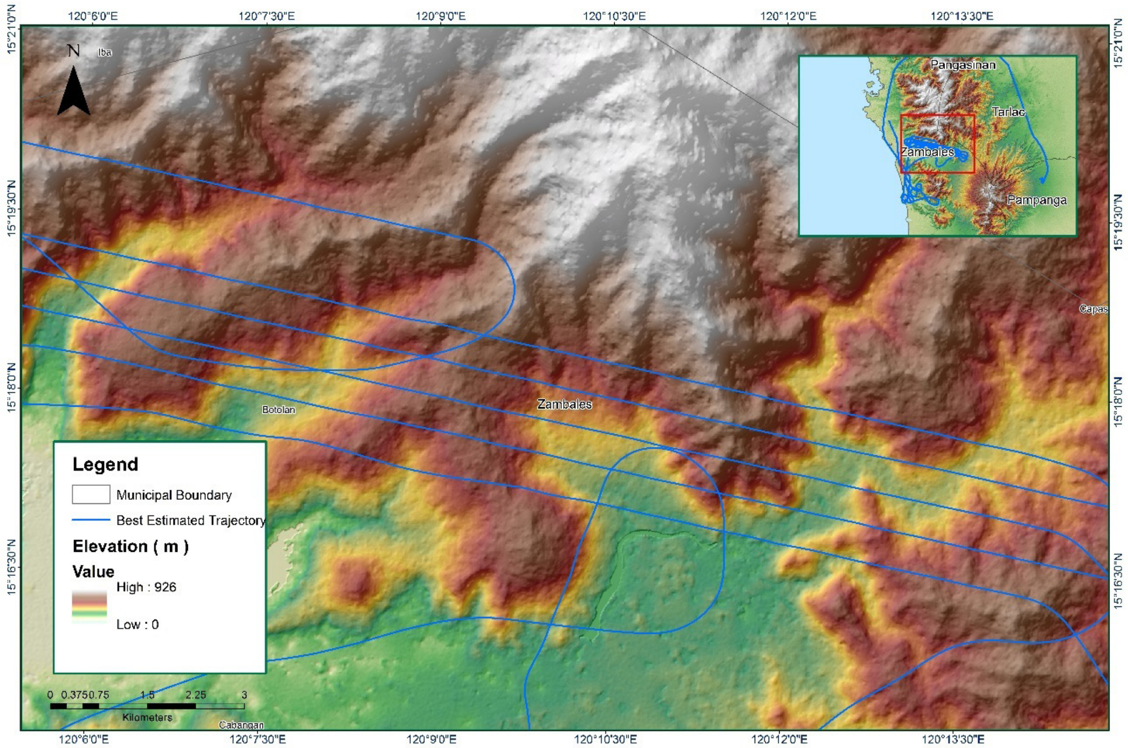


Figure 1.9.5 Best Estimated Trajectory

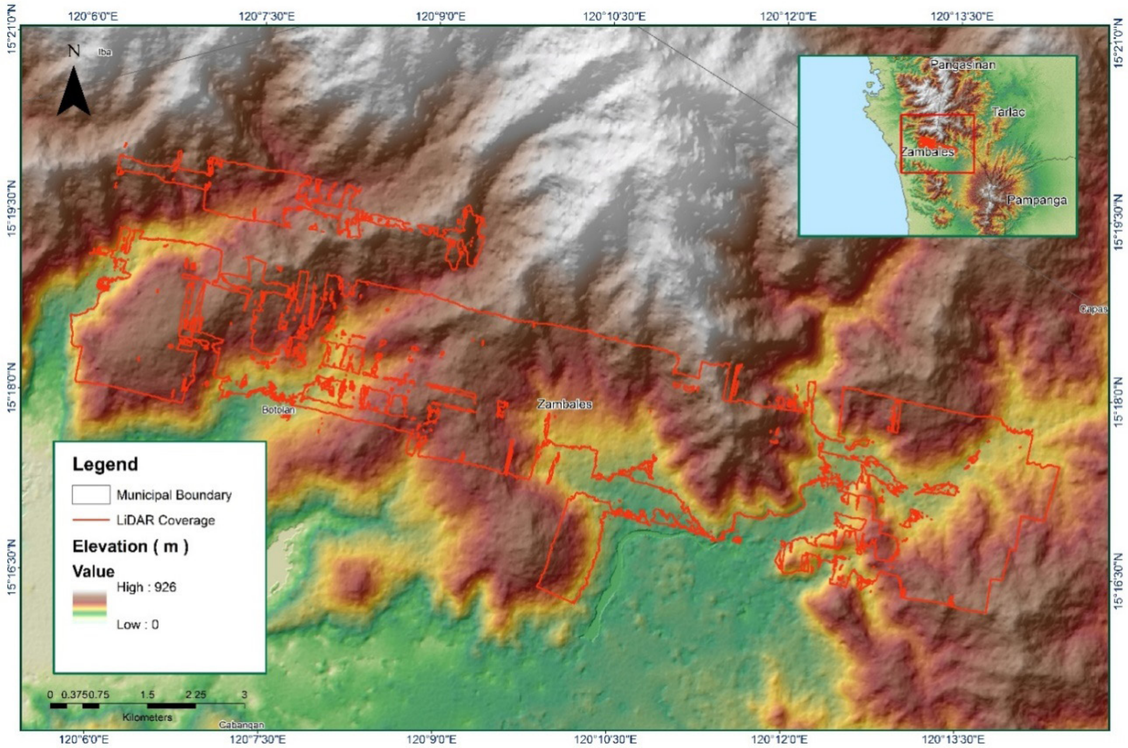


Figure 1.9.6 Coverage of LiDAR data

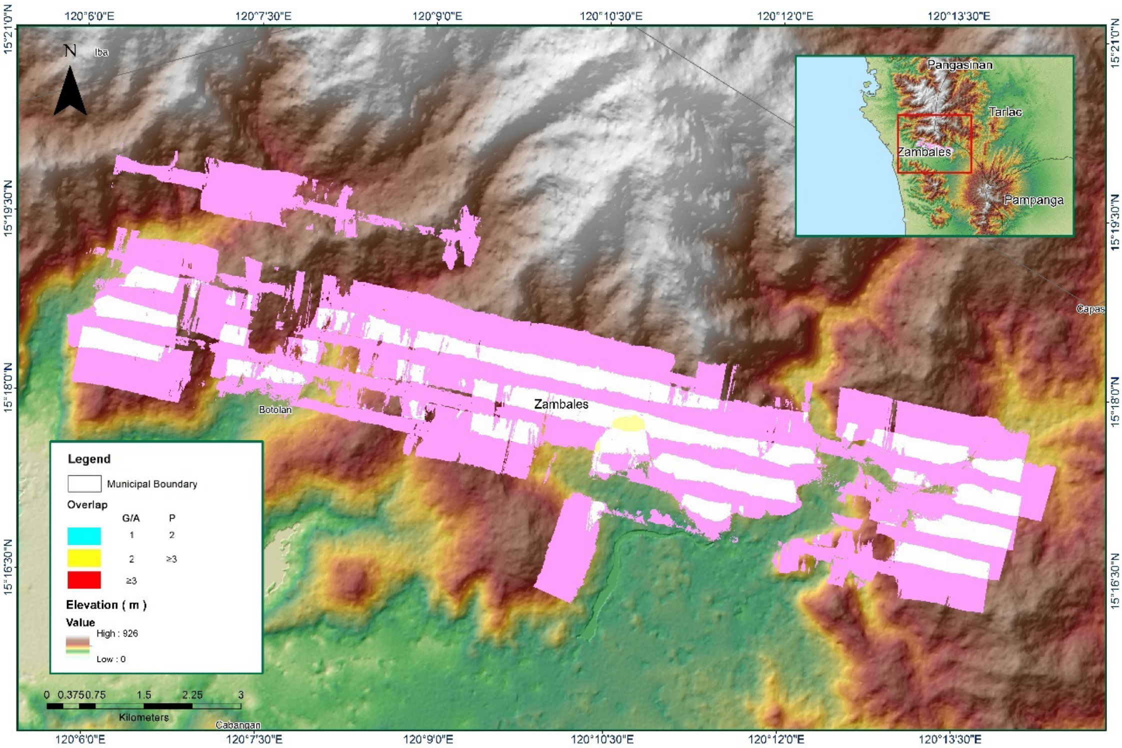


Figure 1.9.7 Image of data overlap

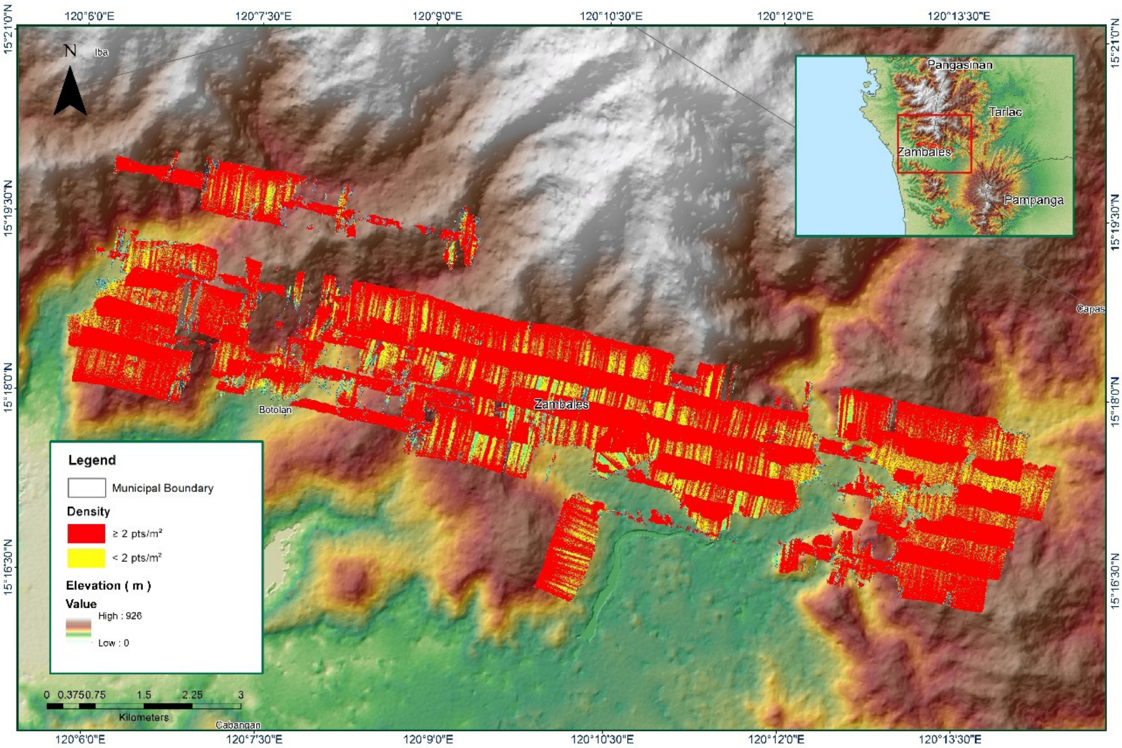


Figure 1.9.8 Density map of merged LiDAR data

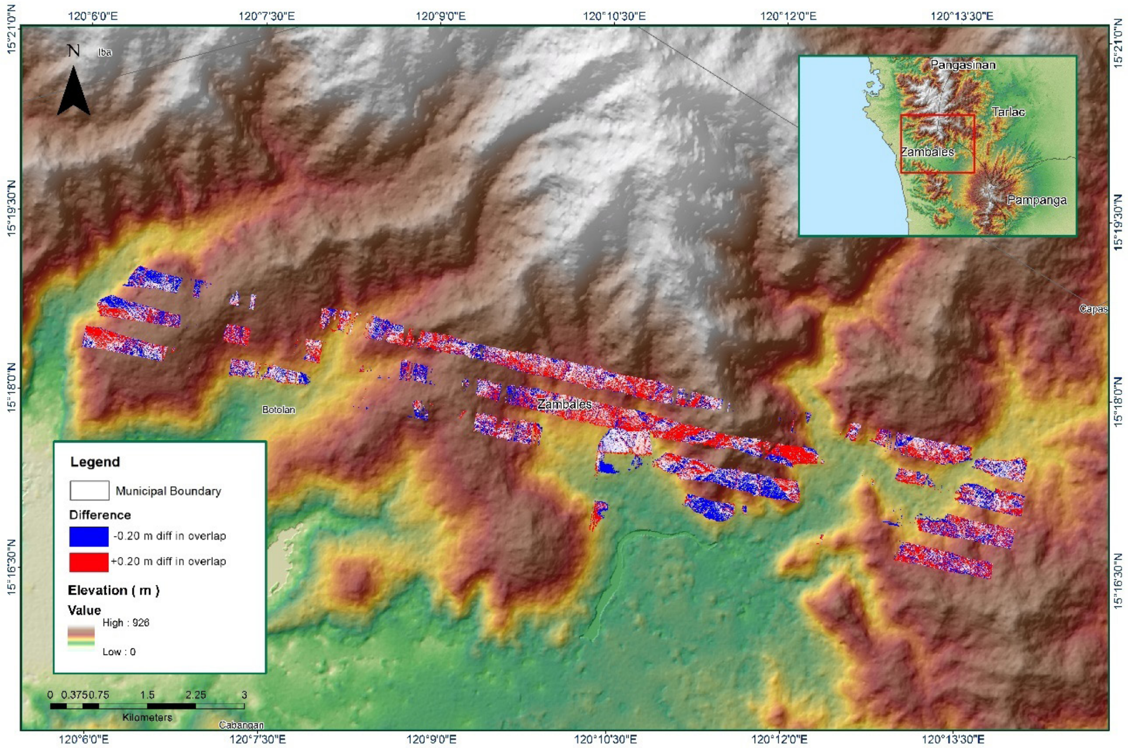


Figure 1.9.9 Elevation difference between flight lines

Flight Area	Clark reflights
Mission Name	**Clark_reflights_Pam3Dadd1**
Inclusive Flights	2274A
Range data size	3.8 GB
POS data size	163MB
Base data size	17.2 MB
Image	n/a
Transfer date	February 12,2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.5
RMSE for East Position (<4.0 cm)	4.0
RMSE for Down Position (<8.0 cm)	5.9
Boresight correction stdev (<0.001deg)	0.001146
IMU attitude correction stdev (<0.001deg)	0.003070
GPS position stdev (<0.01m)	0.0099
Minimum % overlap (>25)	22.86
Ave point cloud density per sq.m. (>2.0)	2.60
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	61
Maximum Height	121.45
Minimum Height	53.81
Classification (# of points)	
Ground	14,860,147
Low vegetation	15,895,852
Medium vegetation	6,250,228
High vegetation	1,347,962
Building	1,010,155
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Edgardo Gubatanga, Jr., Engr. Gladys Mae Apat

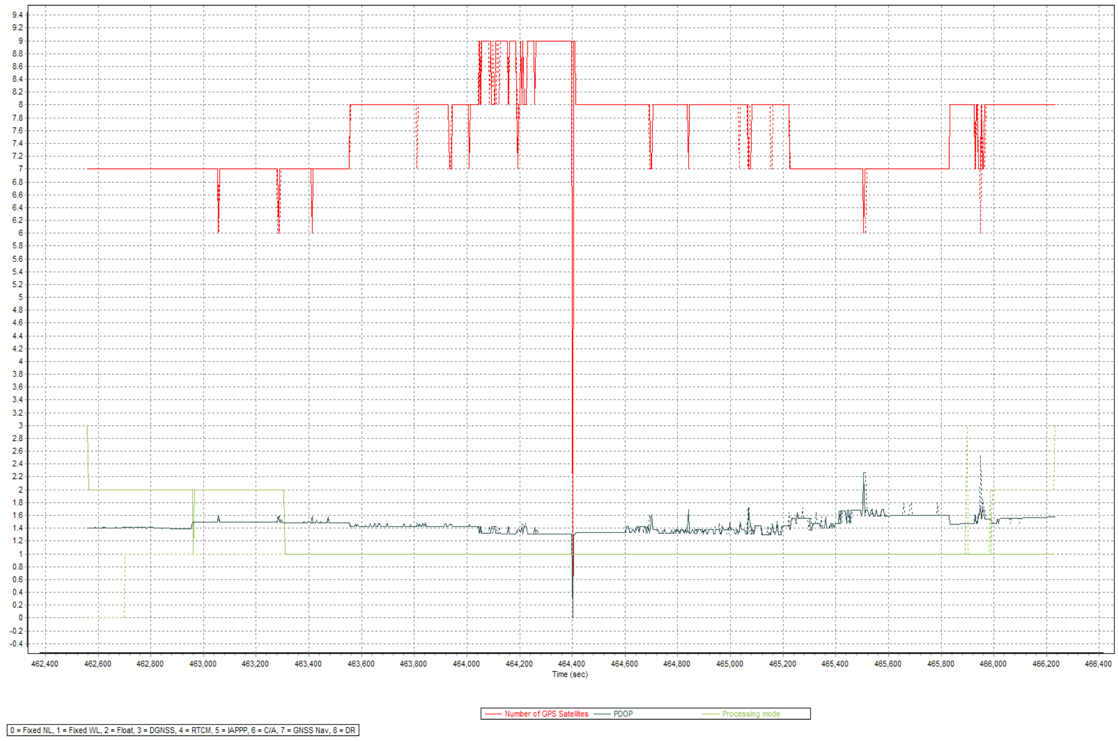


Figure 1.10.1. Solution Status

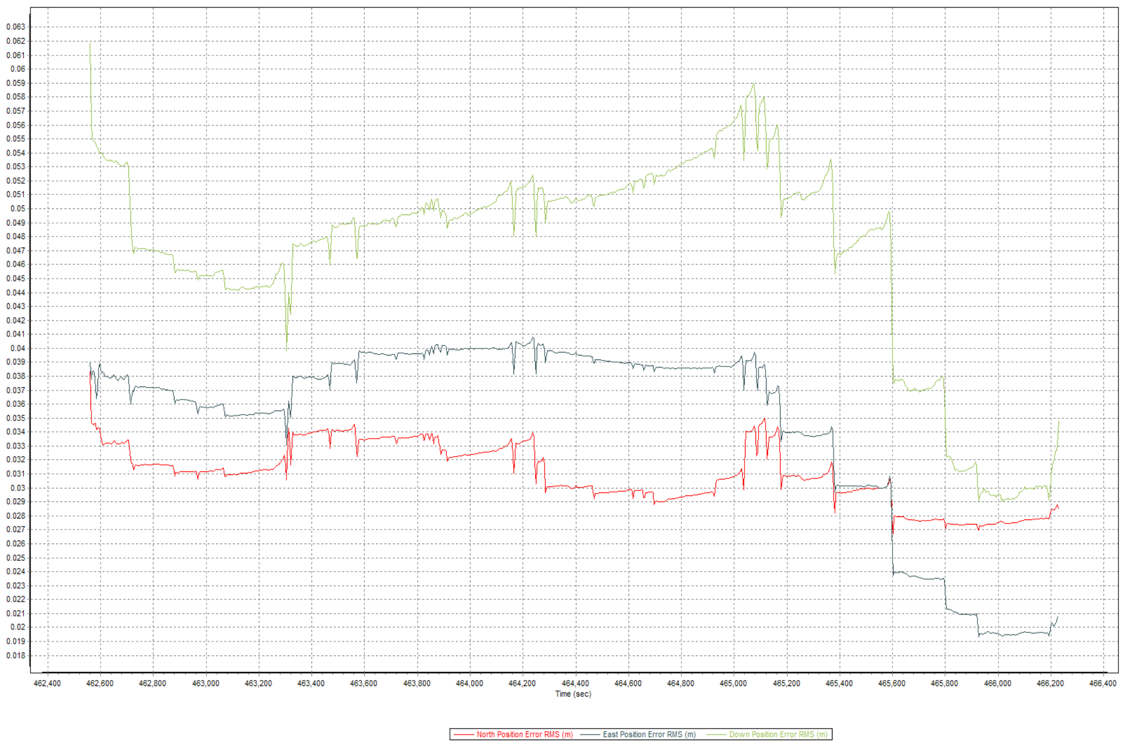


Figure 1.10.2. Smoothed Performance Metric Parameters

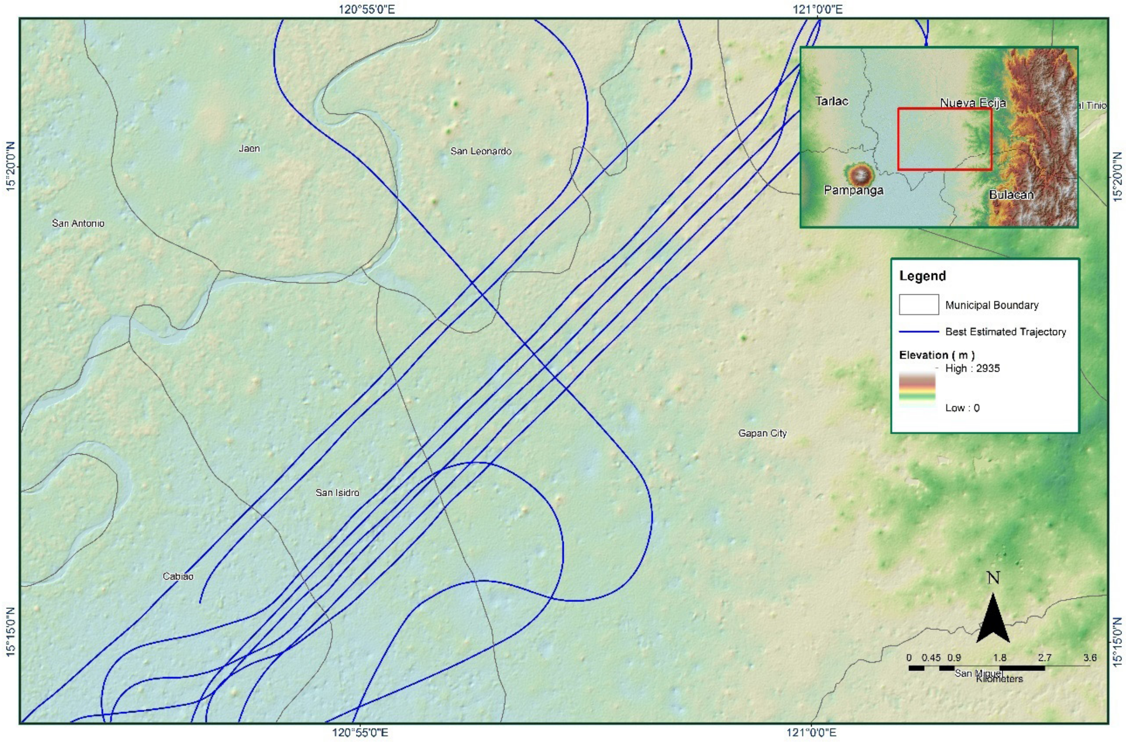


Figure 1.10.3. Best Estimated Trajectory

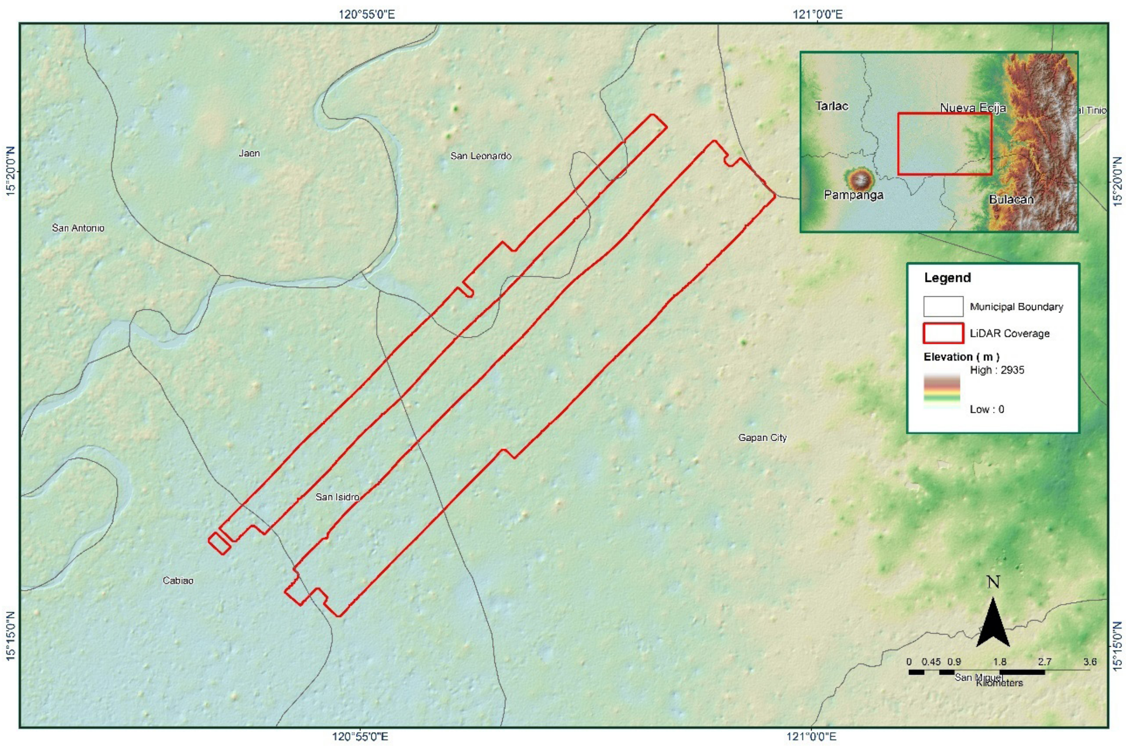


Figure 1.10.4. Coverage of LiDAR Data

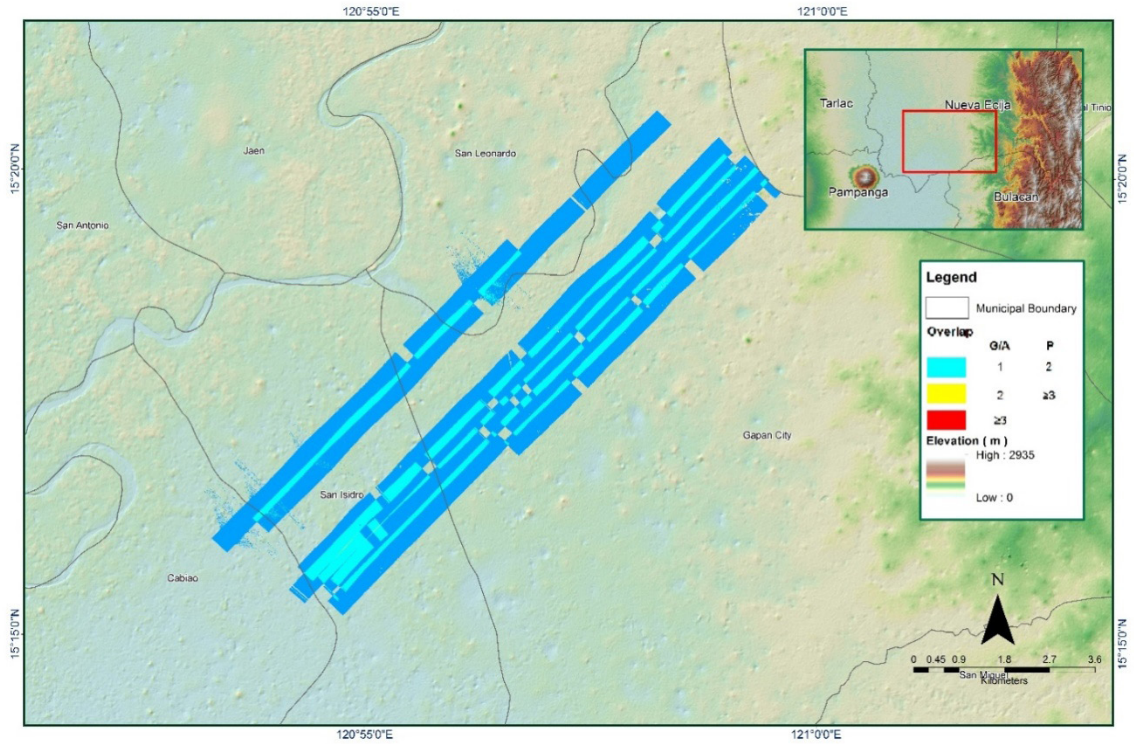


Figure 1.10.5. Image of data overlap

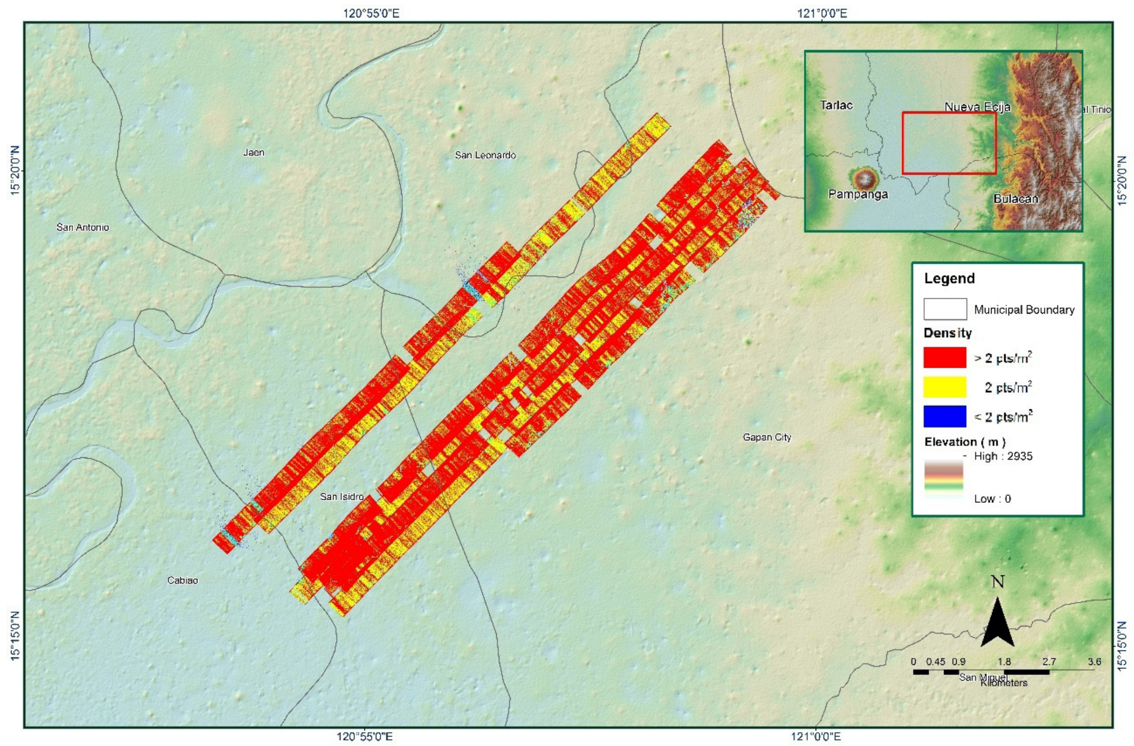


Figure 1.10.6. Density map of merged LiDAR data

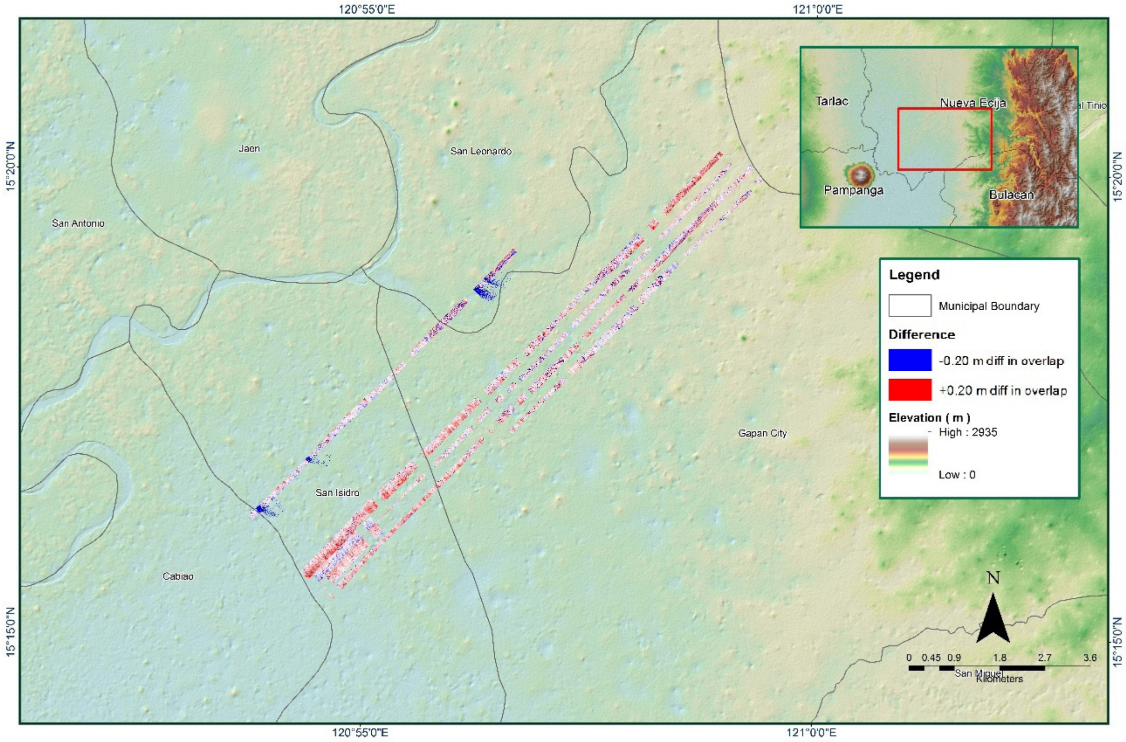


Figure 1.10.7. Elevation difference between flight lines

Flight Area	Clark reflights
Mission Name	**Clark_reflights_Pan3D_add2**
Inclusive Flights	2278A
Range data size	8.18 GB
POS data size	238MB
Base data size	26.5 MB
Image	n/a
Transfer date	February 12,2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.5
RMSE for East Position (<4.0 cm)	4.0
RMSE for Down Position (<8.0 cm)	5.9
Boresight correction stdev (<0.001deg)	0.000662
IMU attitude correction stdev (<0.001deg)	0.001249
GPS position stdev (<0.01m)	0.0105
Minimum % overlap (>25)	70.03
Ave point cloud density per sq.m. (>2.0)	4.25
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	38
Maximum Height	114.75 m
Minimum Height	52.83 m
Classification (# of points)	
Ground	11,720,858
Low vegetation	17,395,354
Medium vegetation	12,269,532
High vegetation	3,883,846
Building	1,854,437
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Aljon Rie Araneta, Vincent Louise Azucena

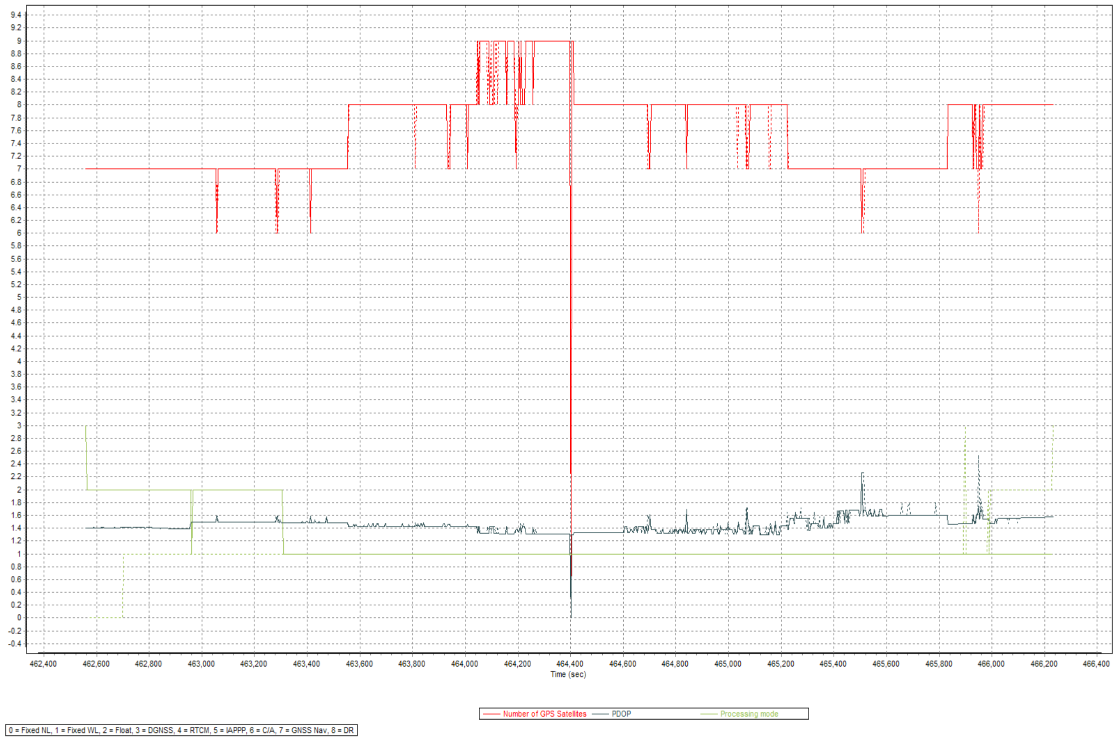


Figure 1.11.1. Solution Status

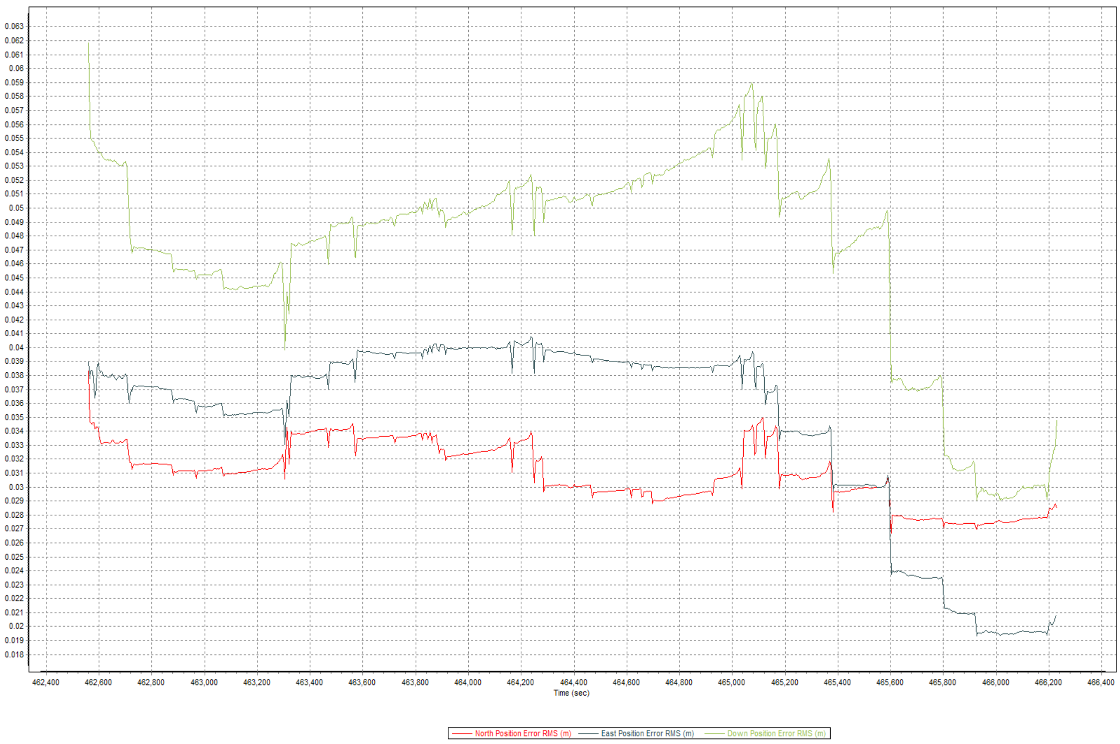


Figure 1.11.2. Smoothed Performance Metric Parameters

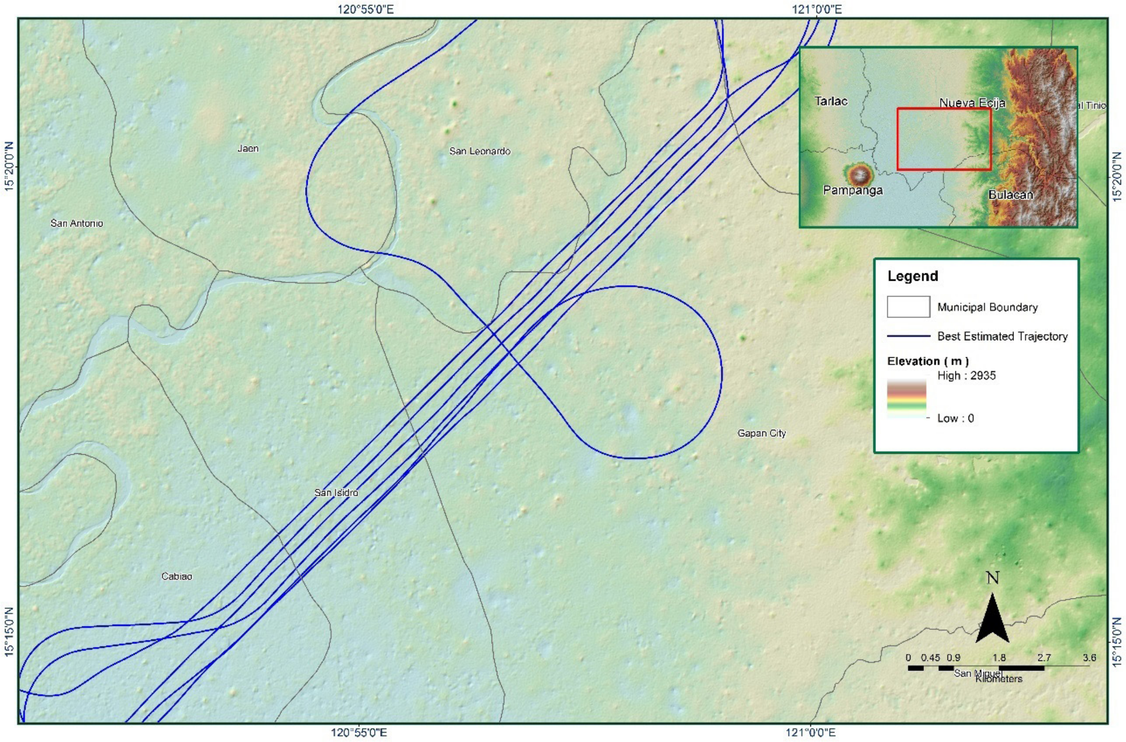


Figure 1.11.3. Best Estimated Trajectory

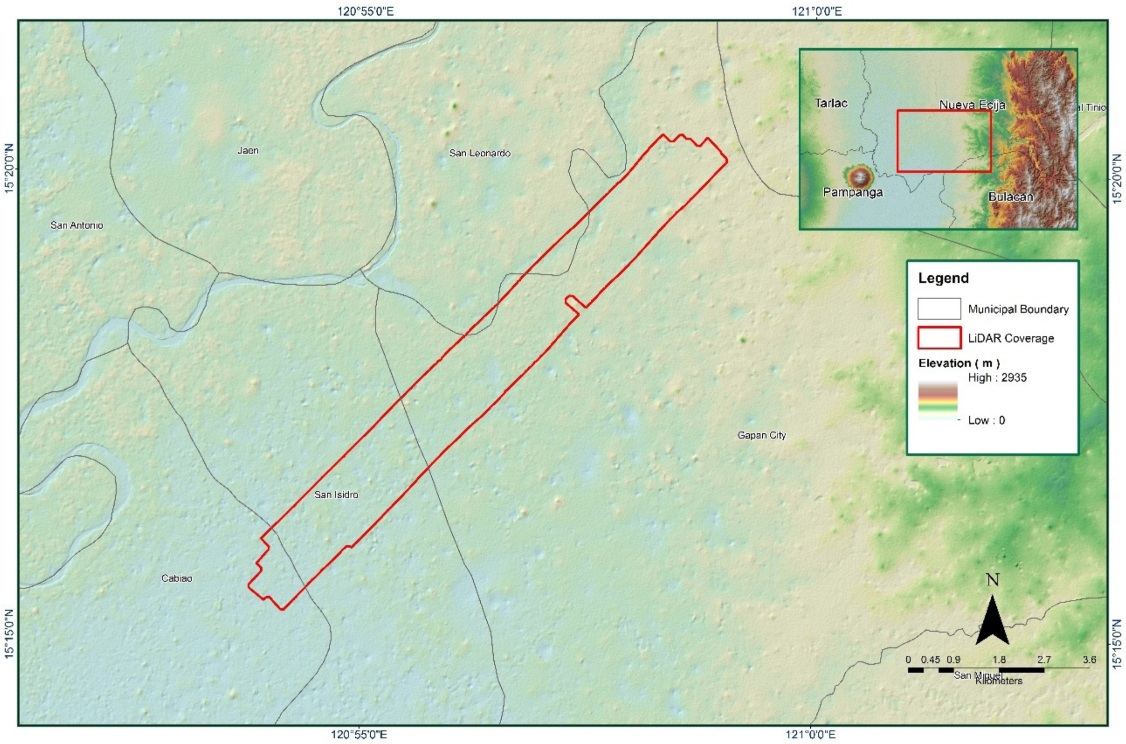


Figure 1.11.4. Coverage of LiDAR Data

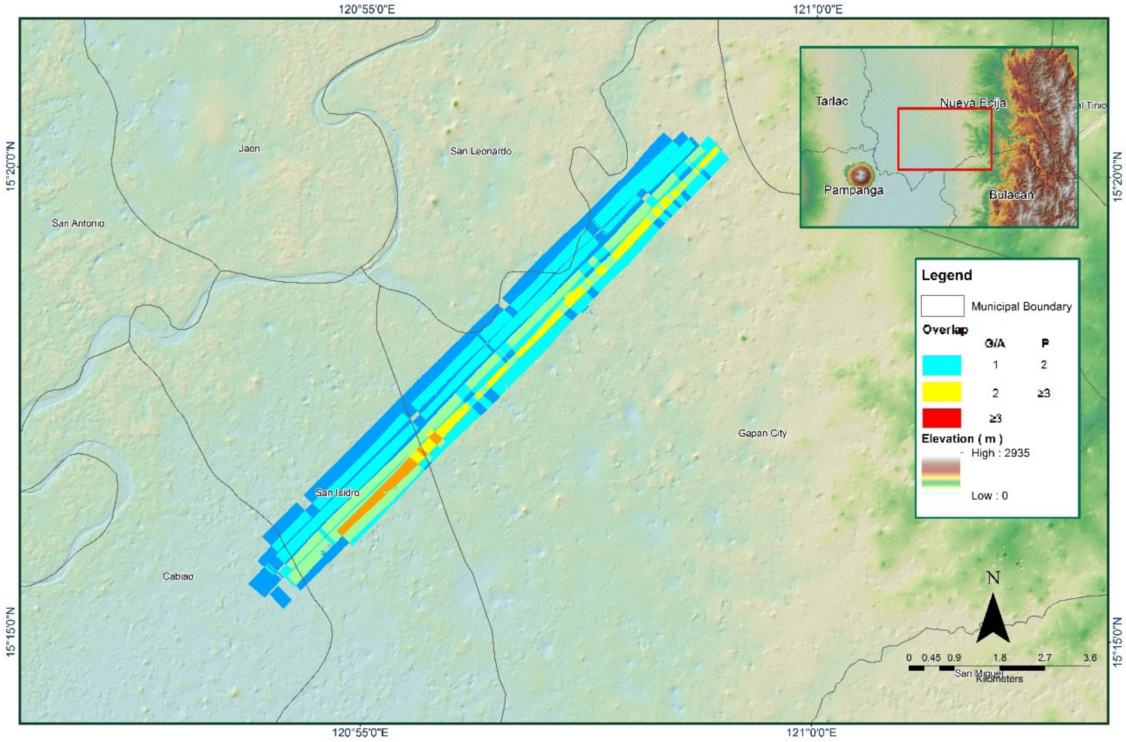


Figure 1.11.5. Image of data overlap

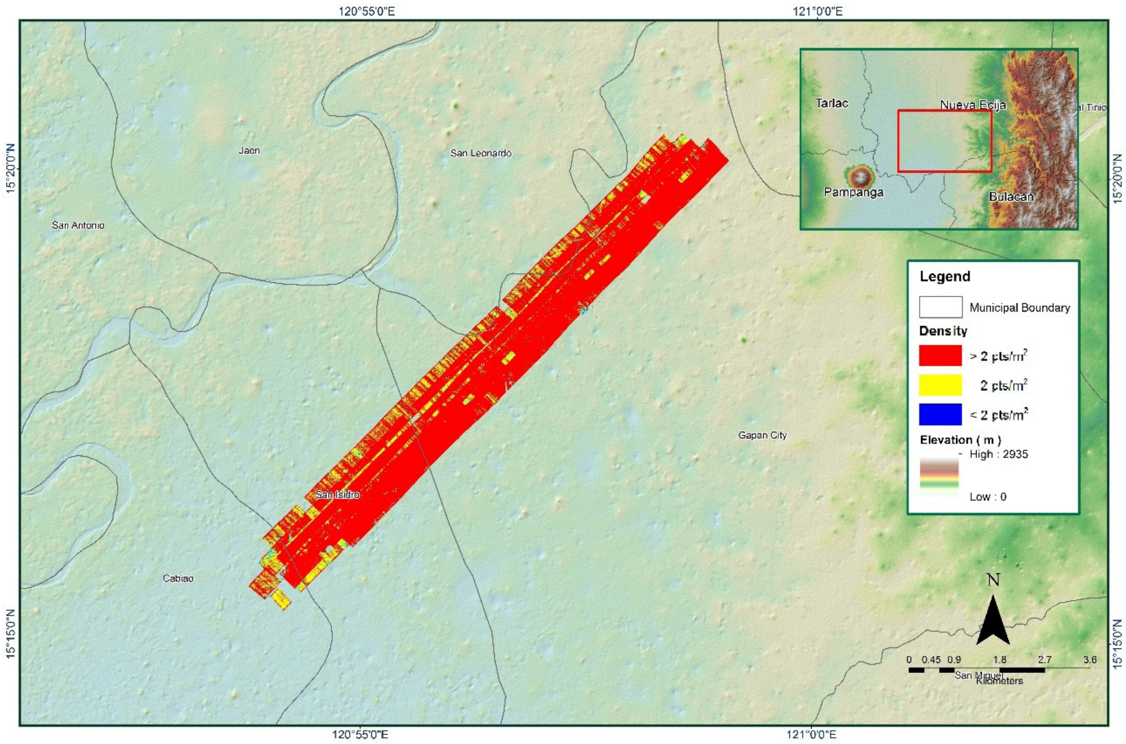


Figure 1.11.6. Density map of merged LiDAR data

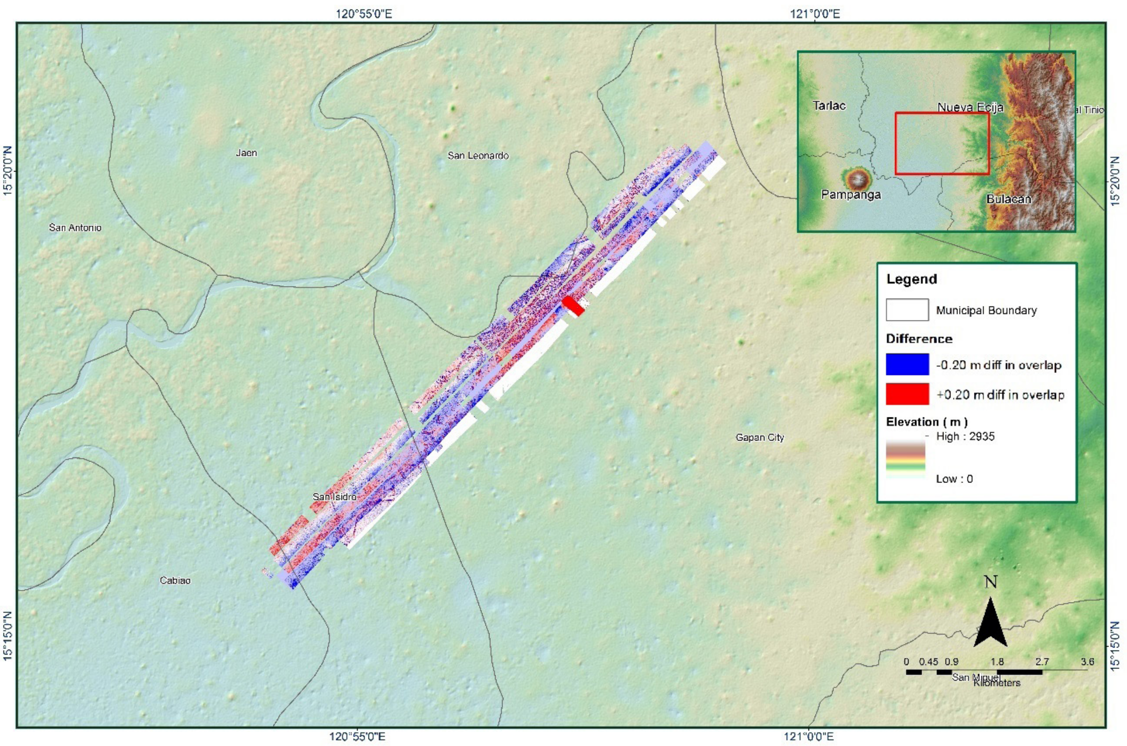


Figure 1.11.7. Elevation difference between flight lines

Flight Area	**Pam_Neh_Reflights**
Mission Name	**Pam_Nej_Reflights_10G**
Inclusive Flights	8411AC, 8412AC
Range data size	10GB
POS data size	230 MB
Base data size	144 MB
Image	51.3
Transfer date	April 22, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.7
RMSE for East Position (<4.0 cm)	1.0
RMSE for Down Position (<8.0 cm)	1.7
Boresight correction stdev (<0.001deg)	n/a
IMU attitude correction stdev (<0.001deg)	n/a
GPS position stdev (<0.01m)	n/a
Minimum % overlap (>25)	40.95
Ave point cloud density per sq.m. (>2.0)	5.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	128
Maximum Height	334.73 m
Minimum Height	81.88 m
Classification (# of points)	
Ground	117,769,545
Low vegetation	138,014,605
Medium vegetation	75,297,899
High vegetation	83,419,140
Building	2,847,806
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Velina Angela Bemida, Maria Tamsyn Malabanan

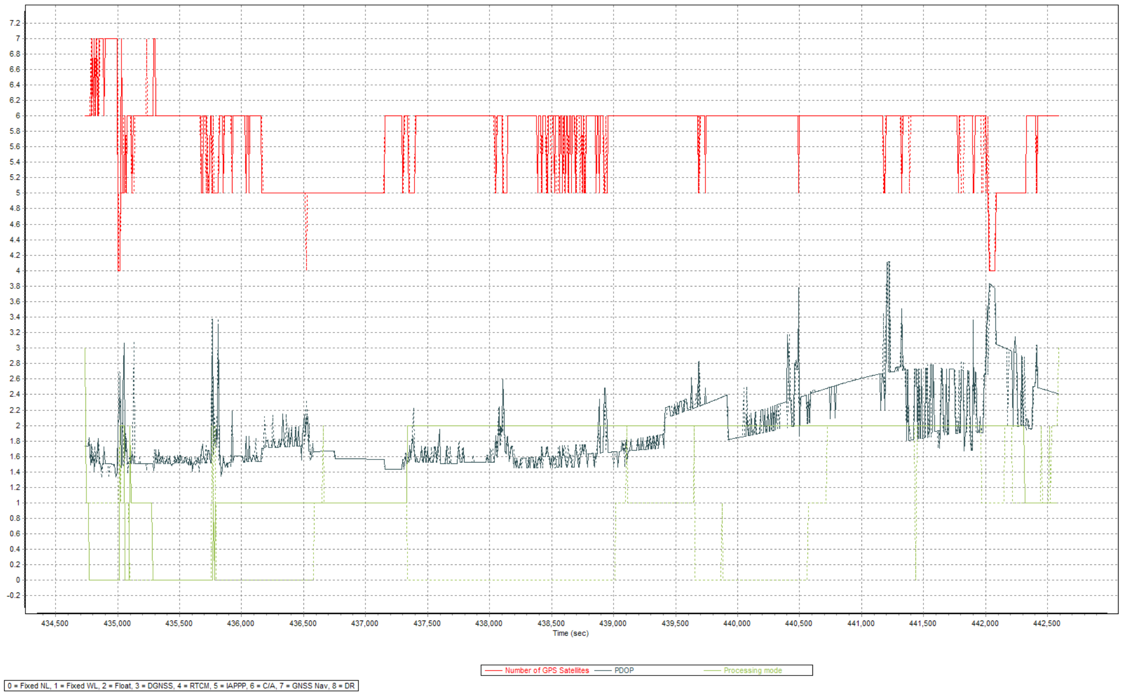


Figure 1.12.1. Solution Status

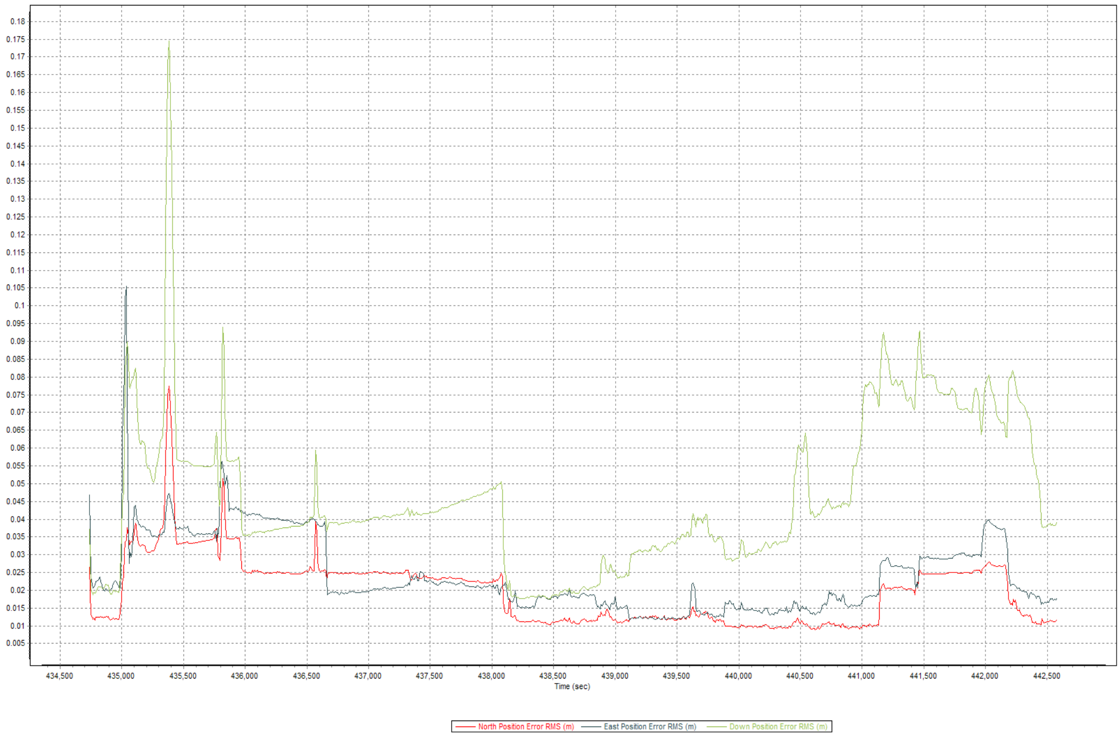


Figure 1.12.2. Smoothed Performance Metric Parameters

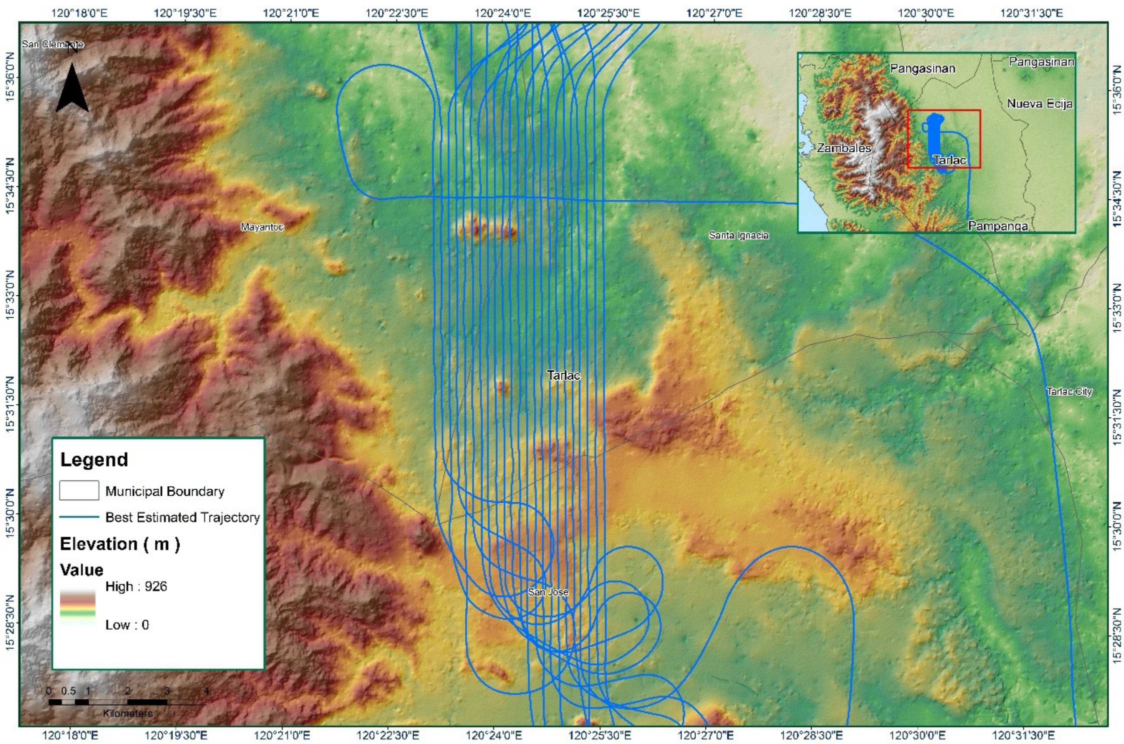


Figure 1.12.3. Best Estimated Trajectory

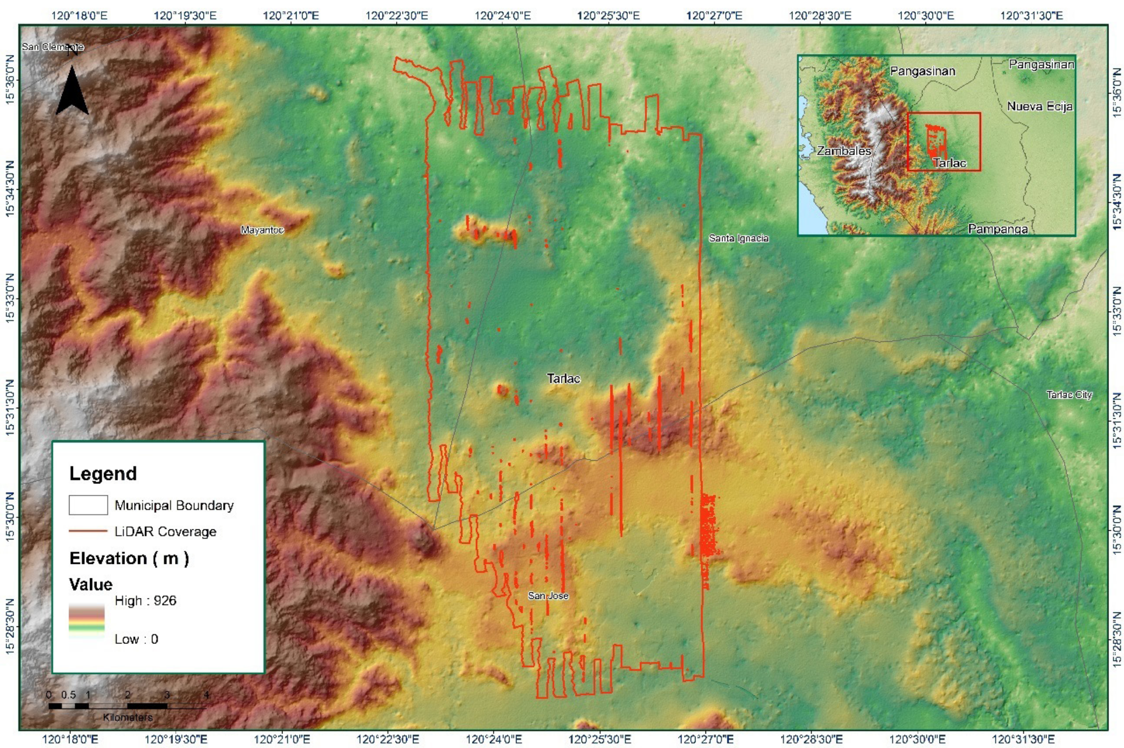


Figure 1.12.4. Coverage of LiDAR Data

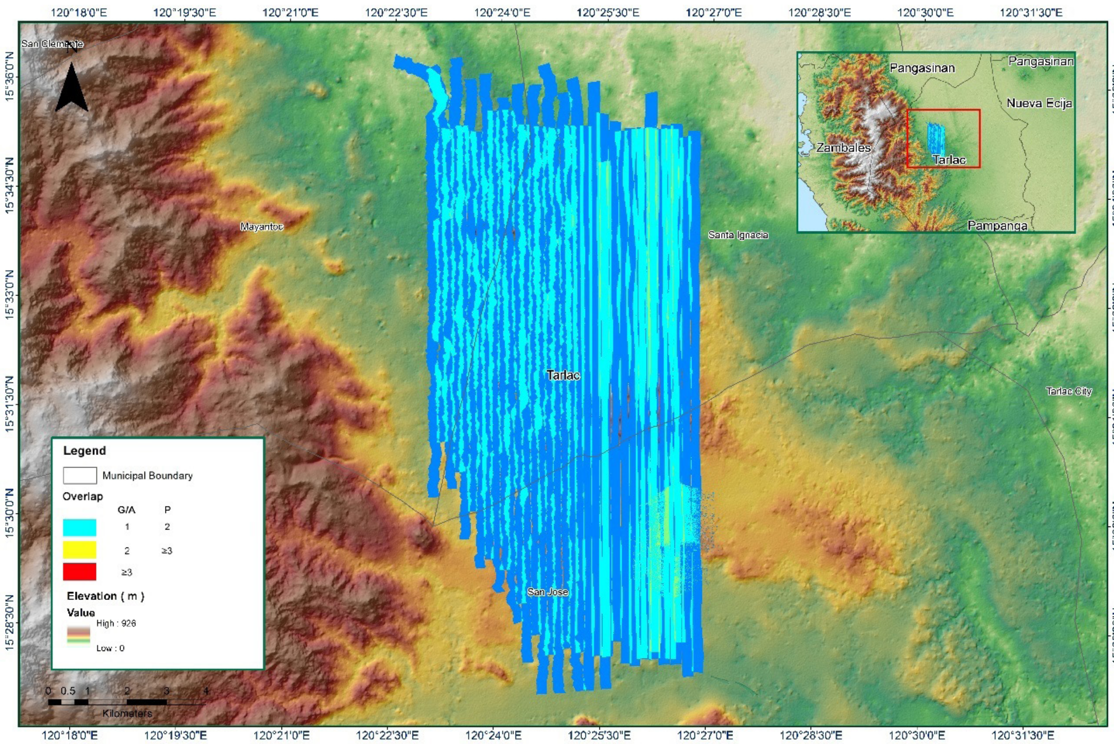


Figure 1.12.5. Image of data overlap

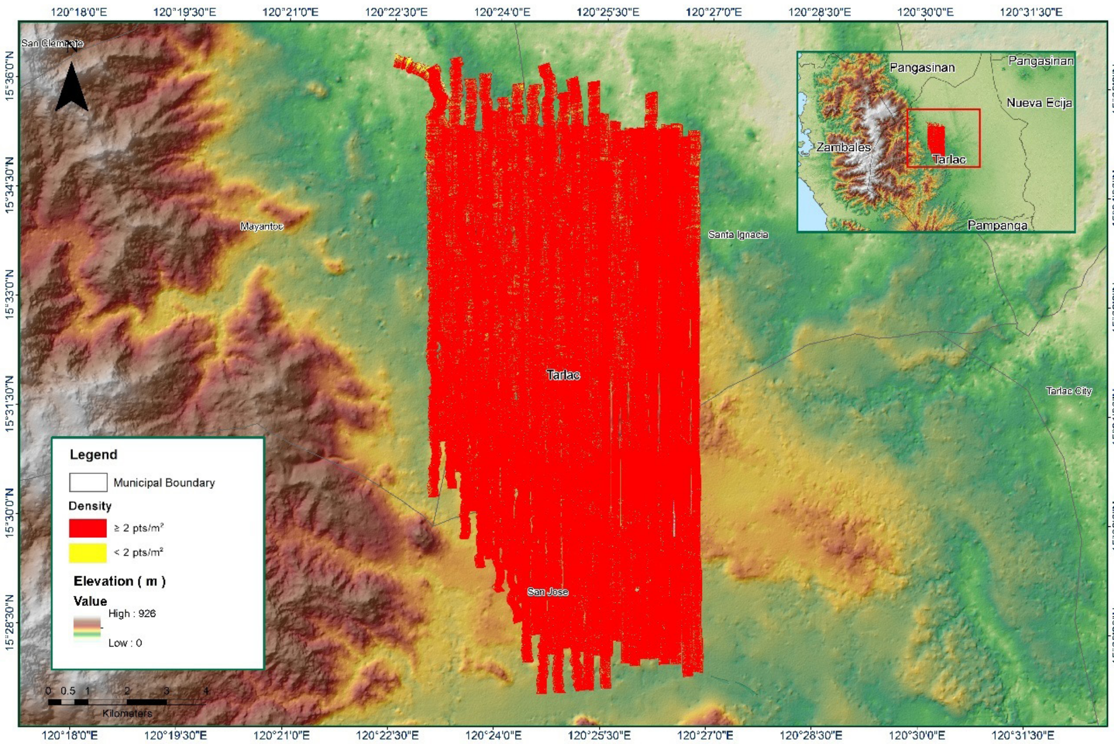


Figure 1.12.6. Density map of merged LiDAR data

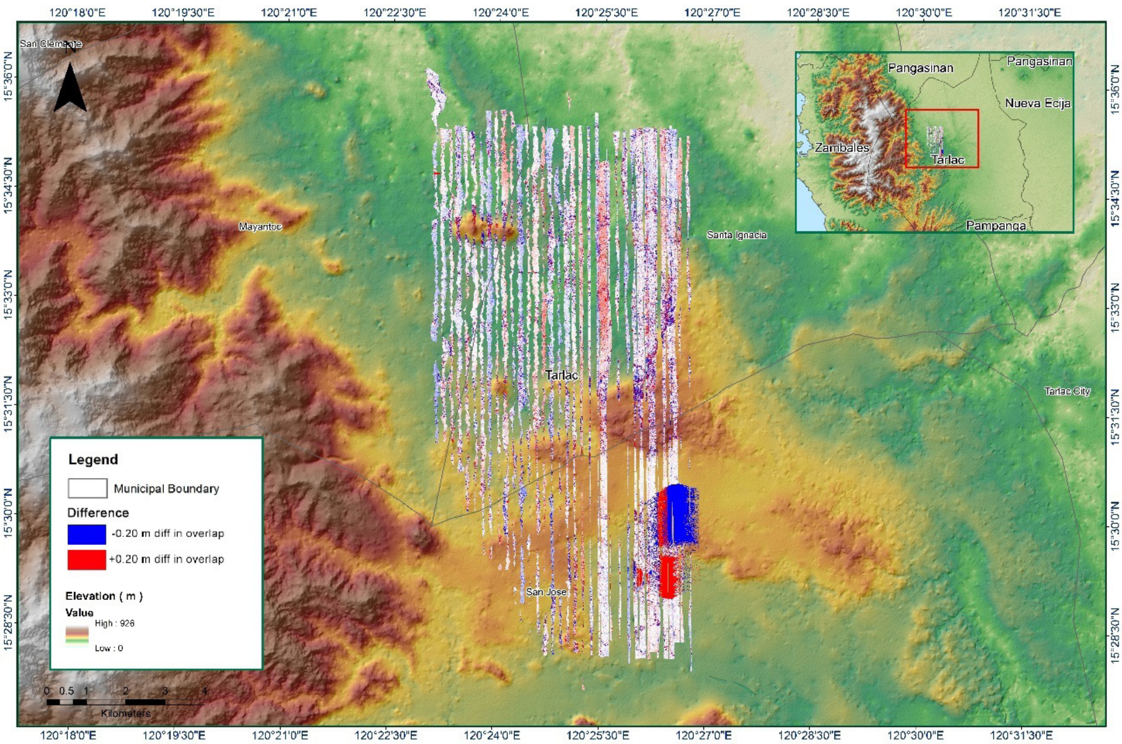


Figure 1.12.7. Elevation difference between flight lines

Flight Area	Pam_Agno_Reflights
Mission Name	Blk Pam7A
Inclusive Flights	7255GC
Range data size	6.45 GB
POS data size	121 MB
Base data size	7.17 MB
Image	NA
Transfer date	May 26, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.85
RMSE for East Position (<4.0 cm)	1.00
RMSE for Down Position (<8.0 cm)	1.55
Boresight correction stdev (<0.001deg)	0.000185
IMU attitude correction stdev (<0.001deg)	0.000993
GPS position stdev (<0.01m)	0.0137
Minimum % overlap (>25)	45.07
Ave point cloud density per sq.m. (>2.0)	4.42
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	35
Maximum Height	290.46 m
Minimum Height	113.36 m
Classification (# of points)	
Ground	12,311,736
Low vegetation	19,301,565
Medium vegetation	15,314,078
High vegetation	8,566,649
Building	7,479,984
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Engr. Edgardo Gubatanga, Jr., Engr. Jeffrey Delica

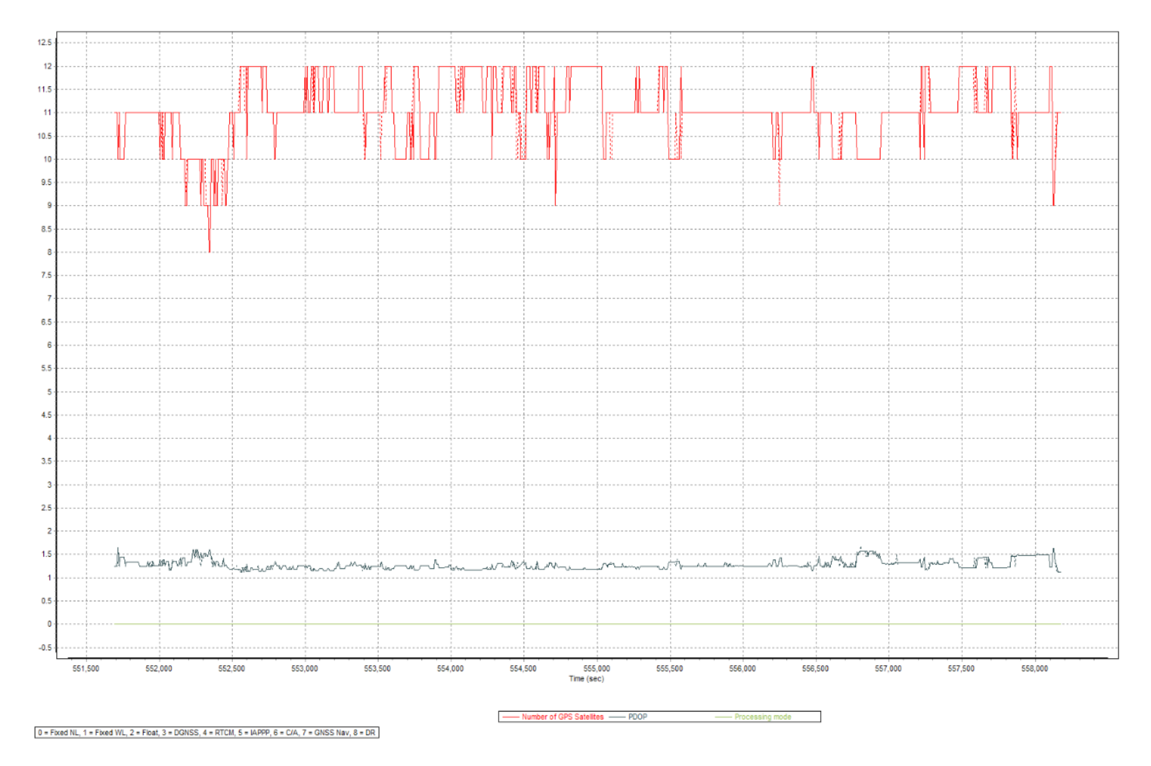


Figure 1.13.1. Solution Status

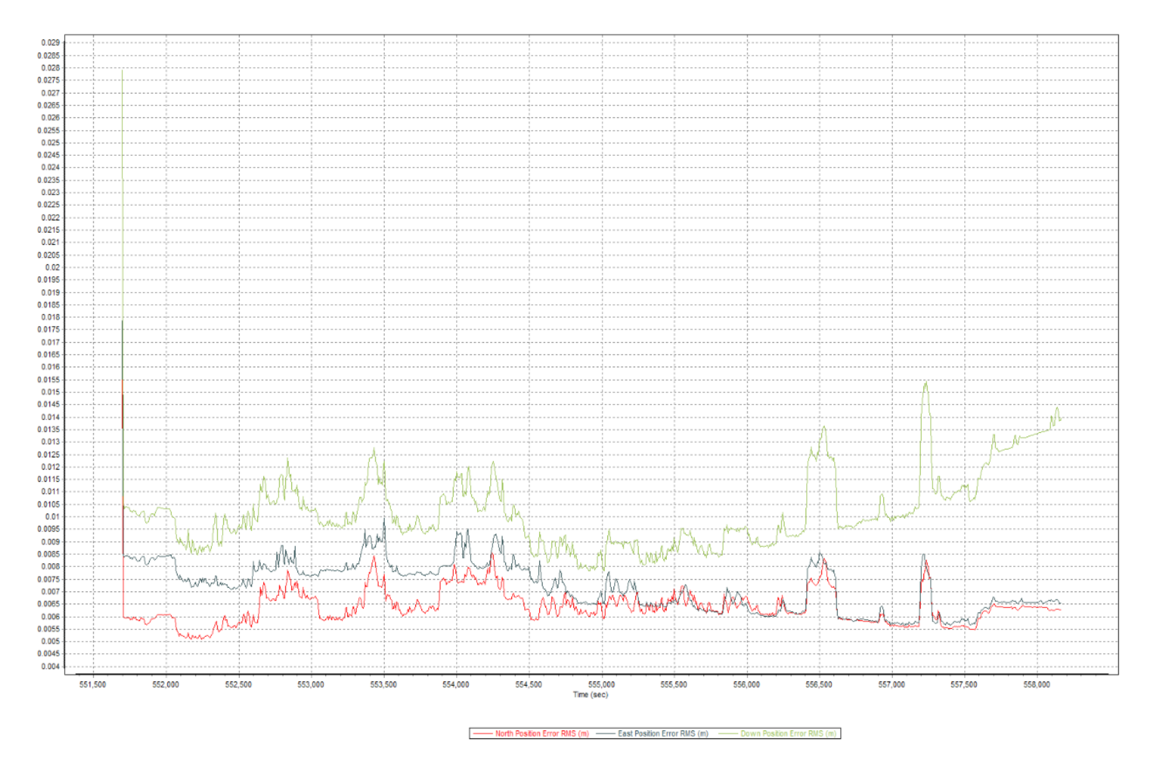


Figure 1.13.2. Smoothed Performance Metric Parameters

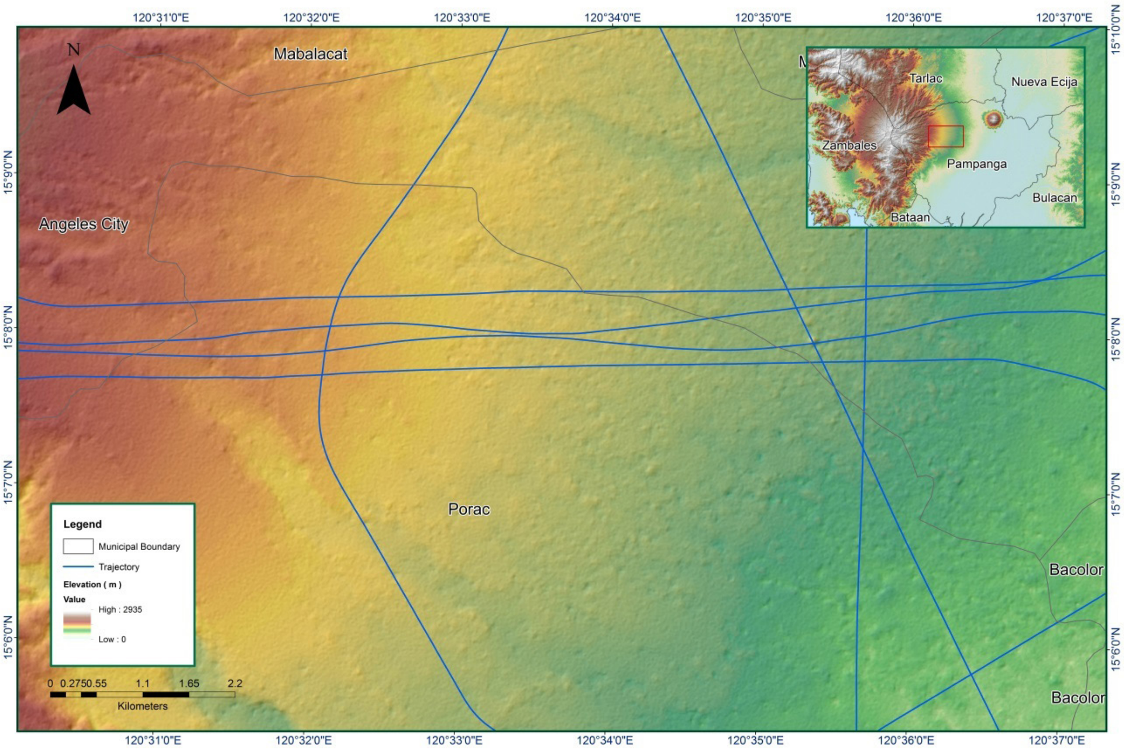


Figure 1.13.3. Best Estimated Trajectory

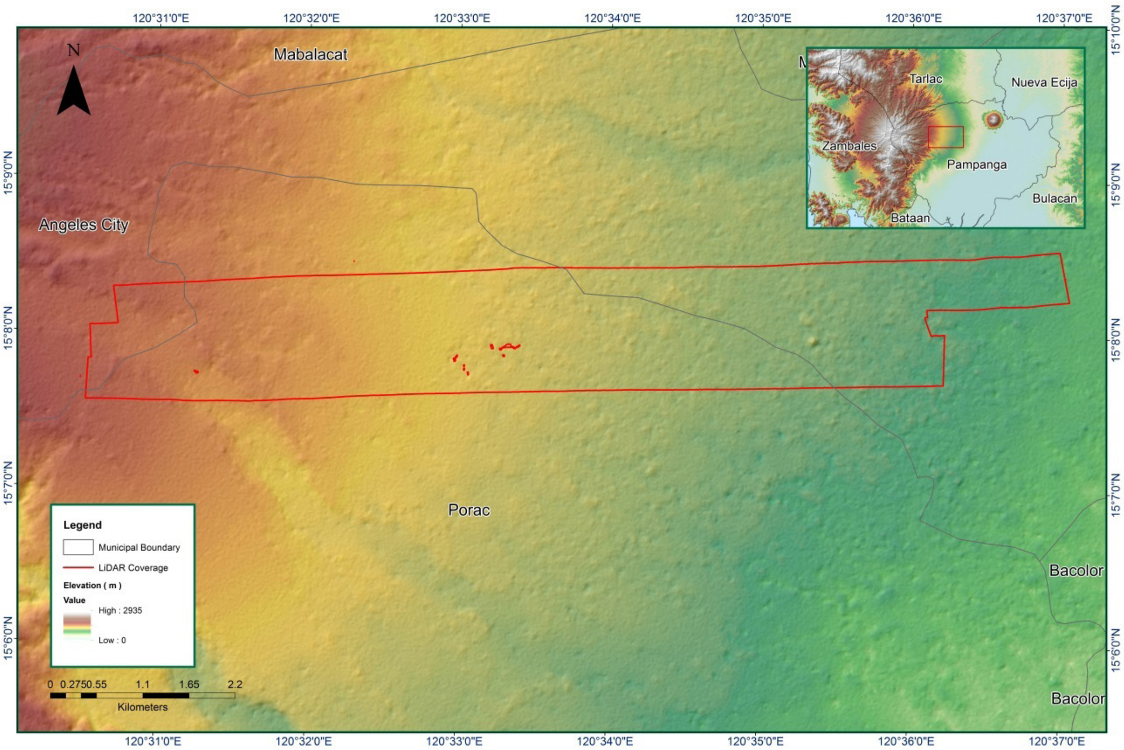


Figure 1.13.4. Coverage of LiDAR Data

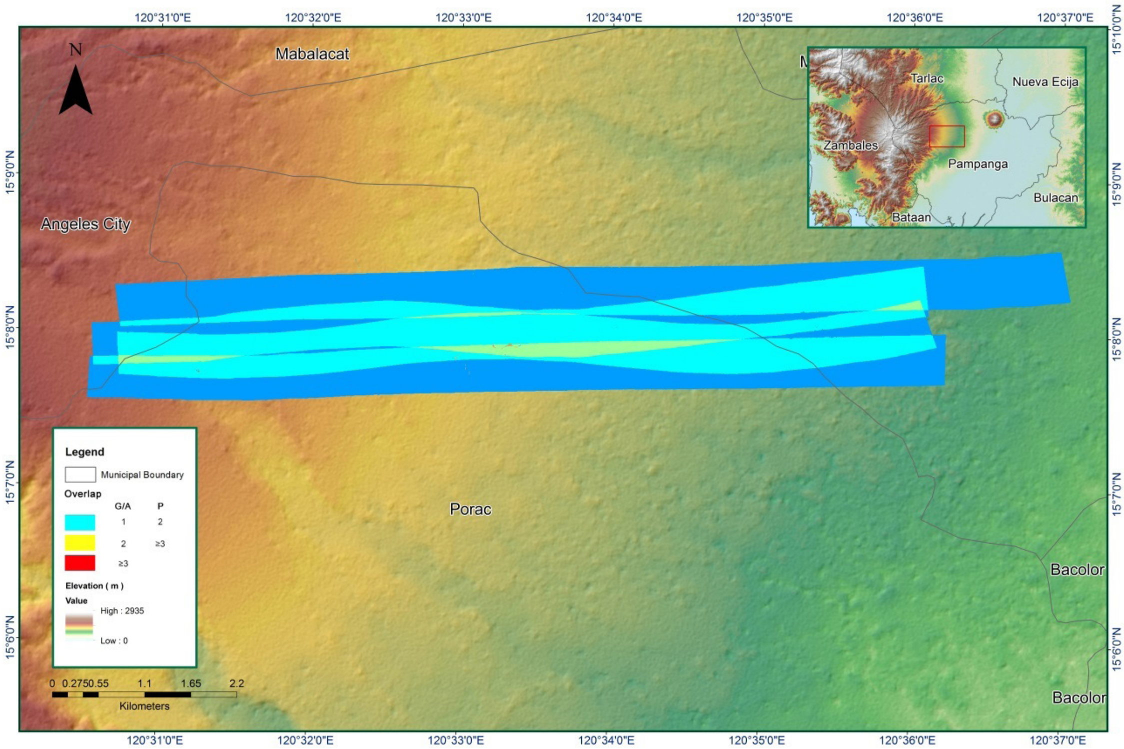


Figure 1.13.5. Image of data overlap

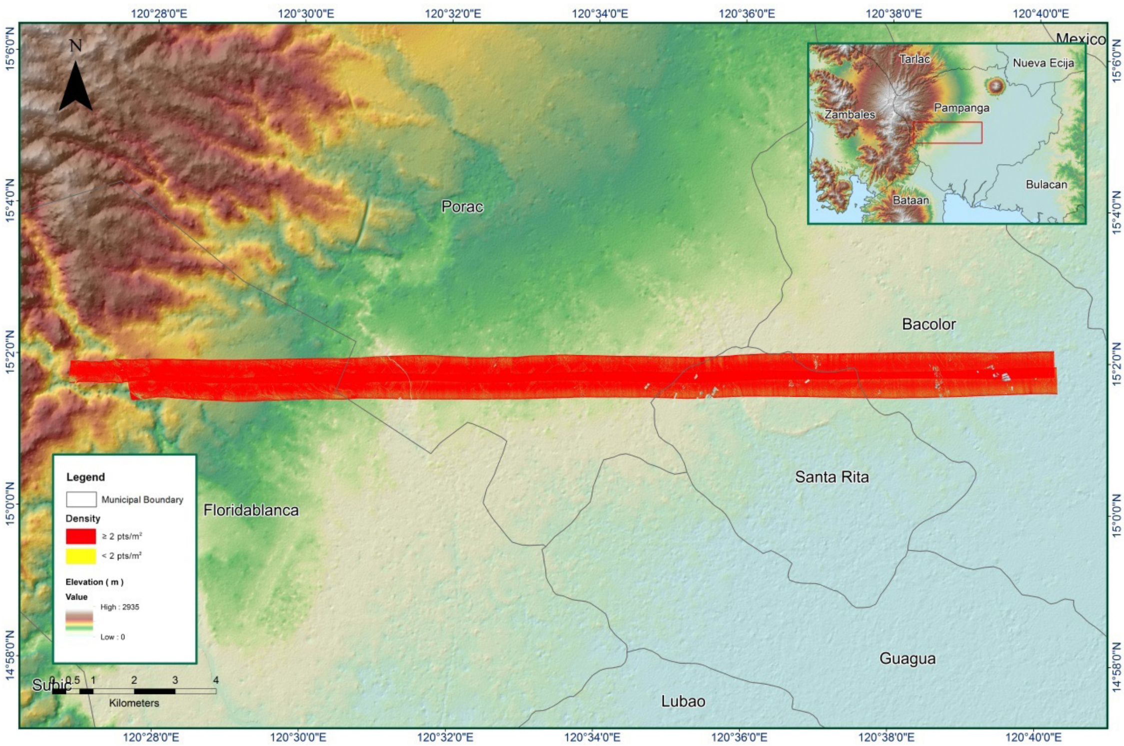


Figure 1.13.6. Density map of merged LiDAR data

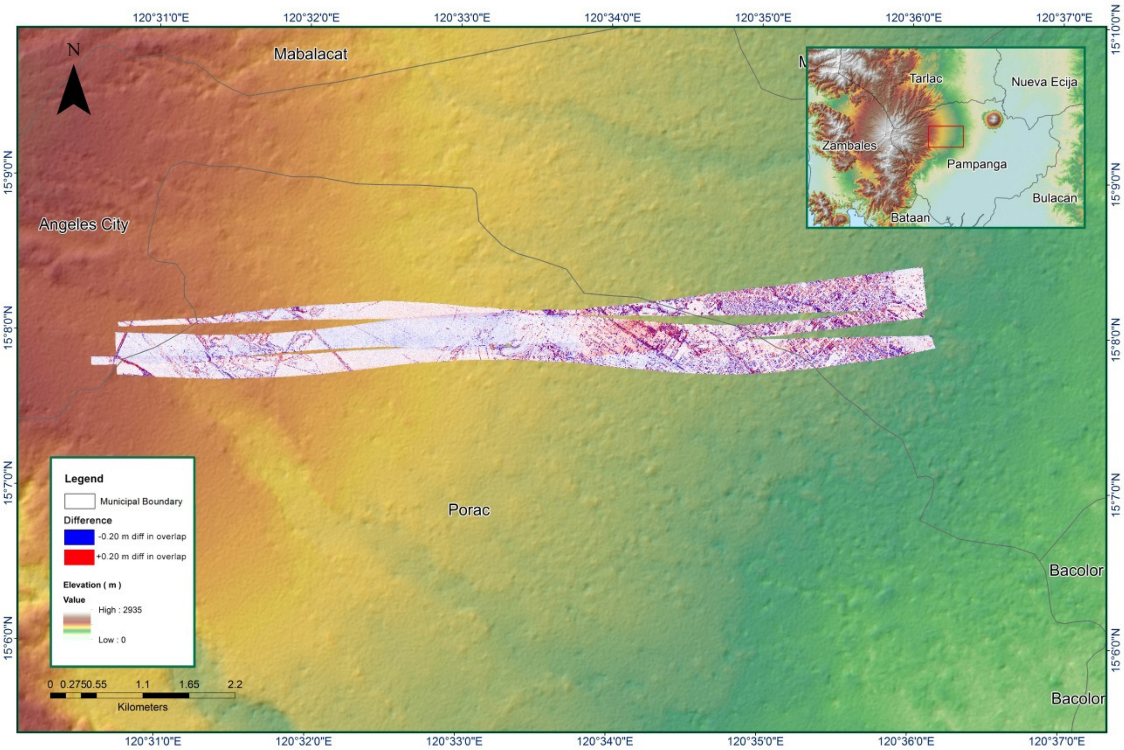


Figure 1.13.7. Elevation difference between flight lines

Flight Area	Pam_Agno Reflights
Mission Name	**Agno_Blk10J_reflight**
Inclusive Flights	7266GC
Range data size	14.4 GB
POS data size	220 MB
Base data size	13.2 MB
Image	NA
Transfer date	May 29, 2014
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)	1.31
RMSE for East Position (<4.0 cm)	1.41
RMSE for Down Position (<8.0 cm)	4.00
Boresight correction stdev (<0.001deg)	0.000516
IMU attitude correction stdev (<0.001deg)	0.003137
GPS position stdev (<0.01m)	0.0320
Minimum % overlap (>25)	31.56
Ave point cloud density per sq.m. (>2.0)	3.00
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	47
Maximum Height	229.39 m
Minimum Height	72.82 m
Classification (# of points)	
Ground	20,748,045
Low vegetation	25,619,227
Medium vegetation	16,157,709
High vegetation	15,966,807
Building	512,332
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Chelou Prado, Ailyn Biñas

Figure 1.14.1. Solution Status

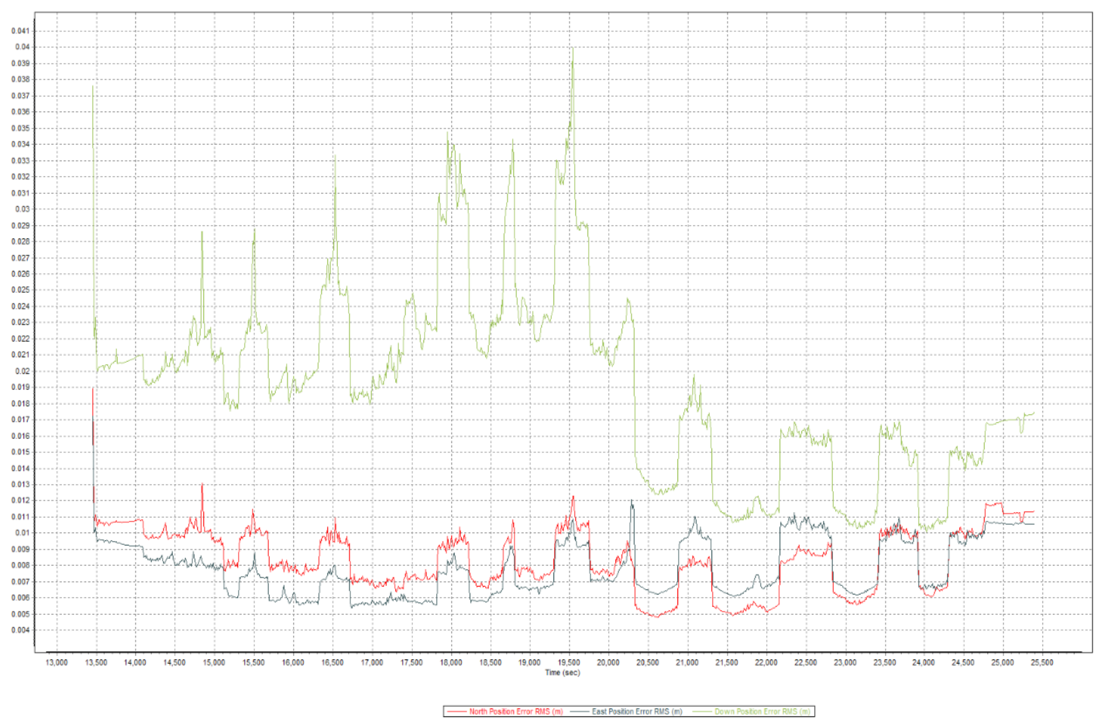


Figure 1.14.2. Smoothed Performance Metric Parameters

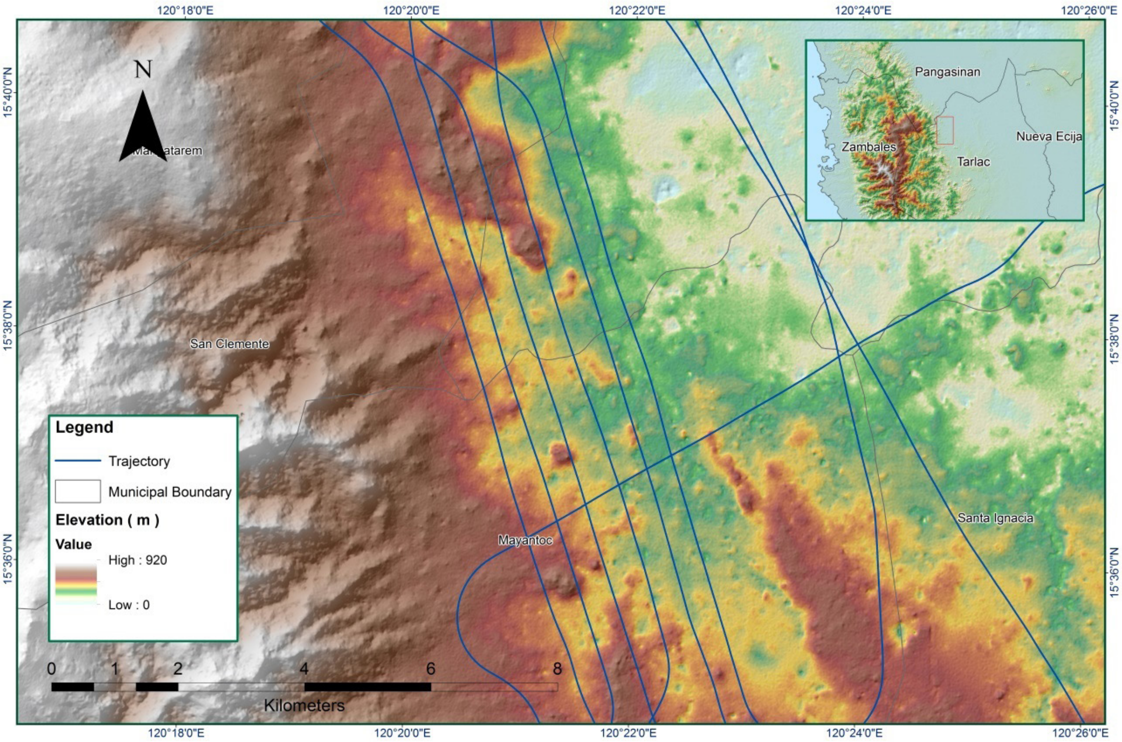


Figure 1.14.3. Best Estimated Trajectory

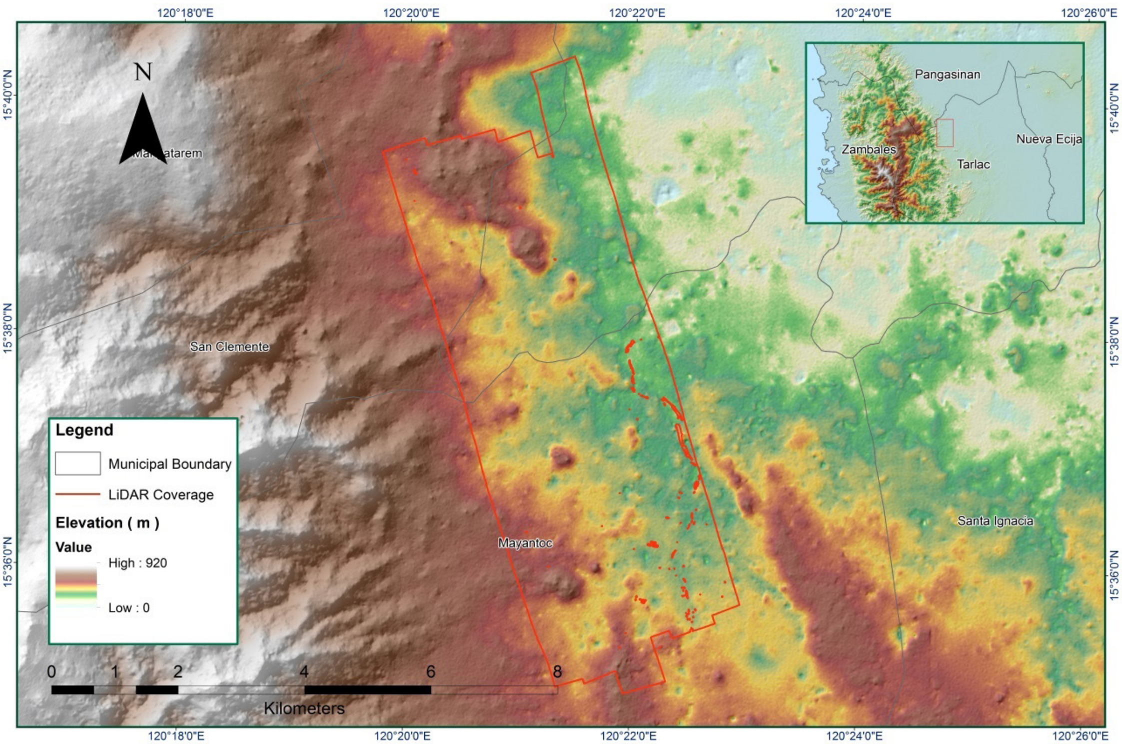


Figure 1.14.4. Coverage of LiDAR Data

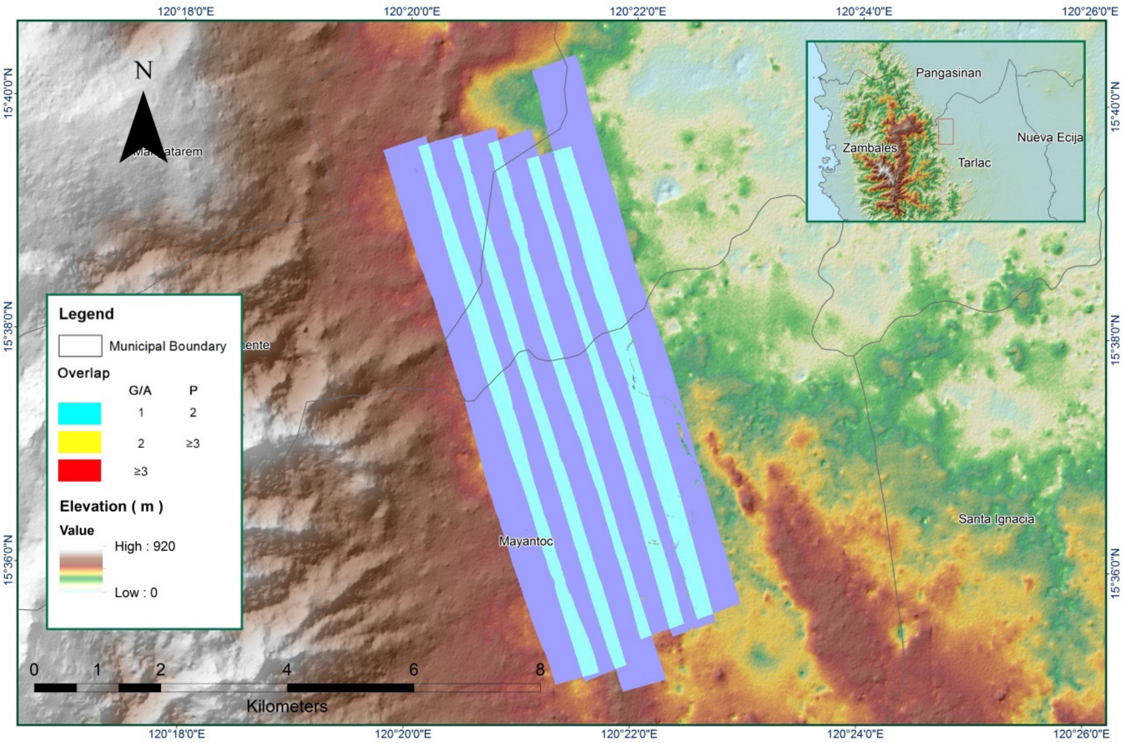


Figure 1.14.5. Image of data overlap

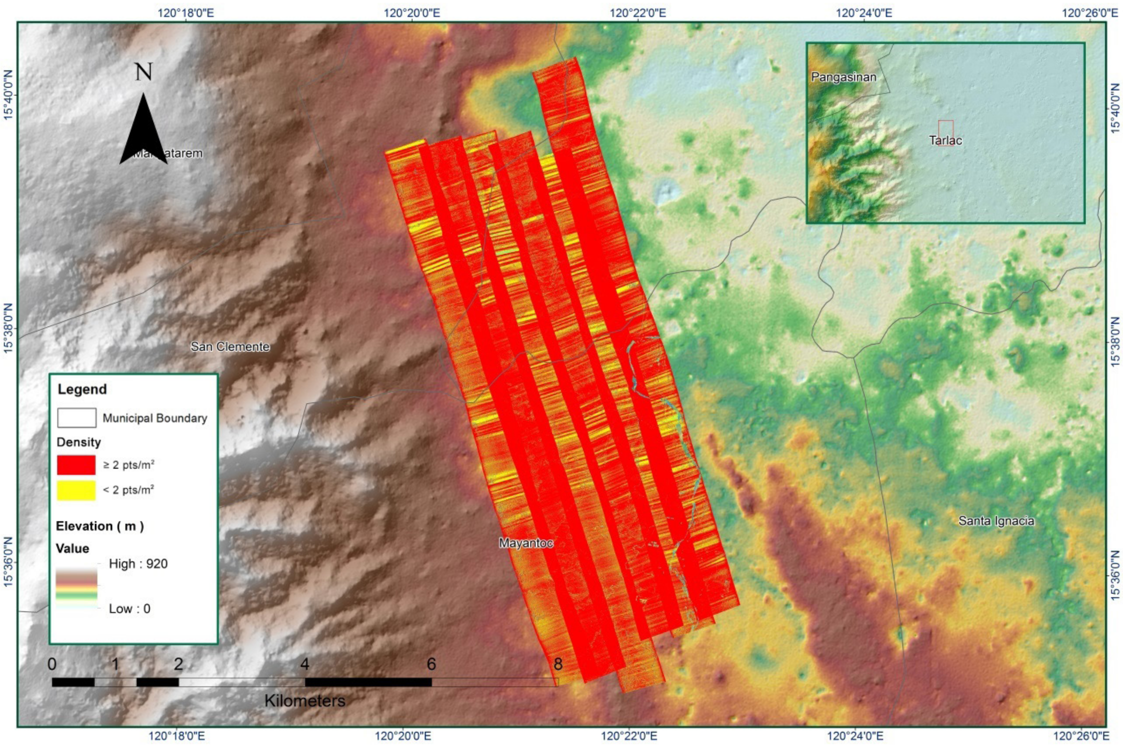


Figure 1.14.6. Density map of merged LiDAR data

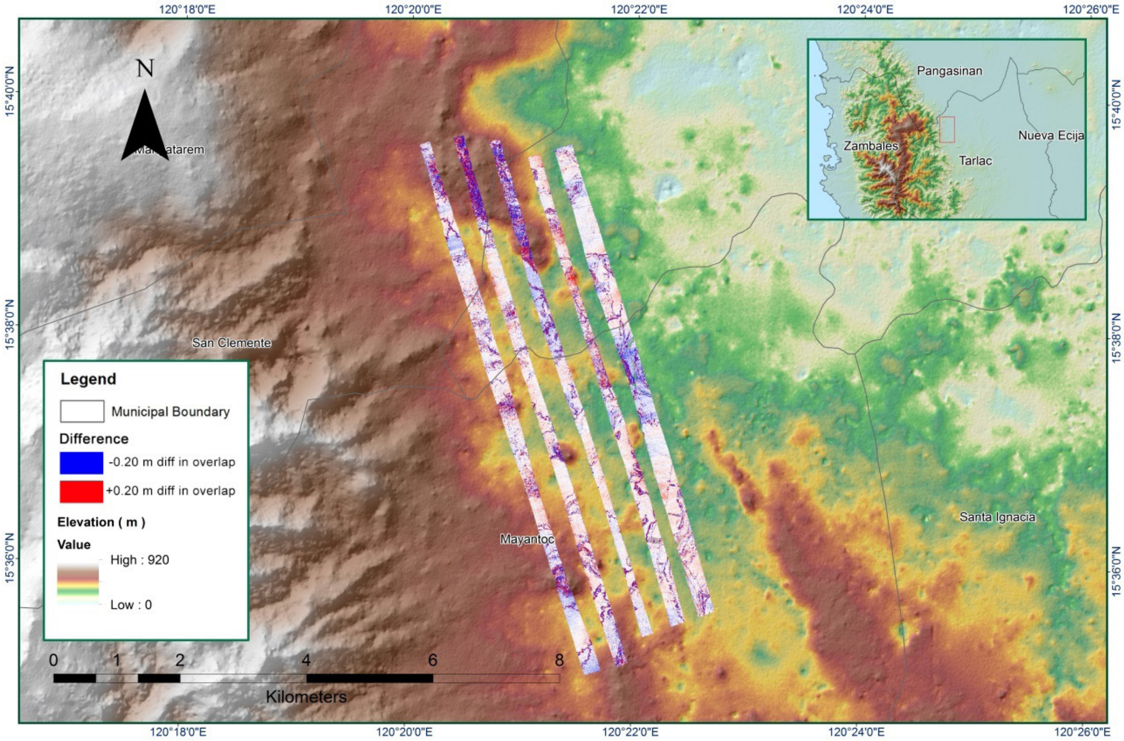


Figure 1.14.7. Elevation difference between flight lines

Flight Area	Pam_Agno Reflights
Mission Name	**Agno_Blk10G_reflight**
Inclusive Flights	7266GC
Range data size	14.4 GB
POS data size	220 MB
Base data size	13.2 MB
Image	NA
Transfer date	May 29, 2014
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)	0.81
RMSE for East Position (<4.0 cm)	1.21
RMSE for Down Position (<8.0 cm)	2.69
Boresight correction stdev (<0.001deg)	0.000516
IMU attitude correction stdev (<0.001deg)	0.003137
GPS position stdev (<0.01m)	0.0320
Minimum % overlap (>25)	17.24
Ave point cloud density per sq.m. (>2.0)	3.46
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	54
Maximum Height	247.29 m
Minimum Height	80.18 m
Classification (# of points)	
Ground	24,576,604
Low vegetation	26,934,580
Medium vegetation	19,687,597
High vegetation	15,010,647
Building	3,740,883
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Chelou Prado, Engr. Gladys Mae Apat

Figure 1.15.1. Solution Status

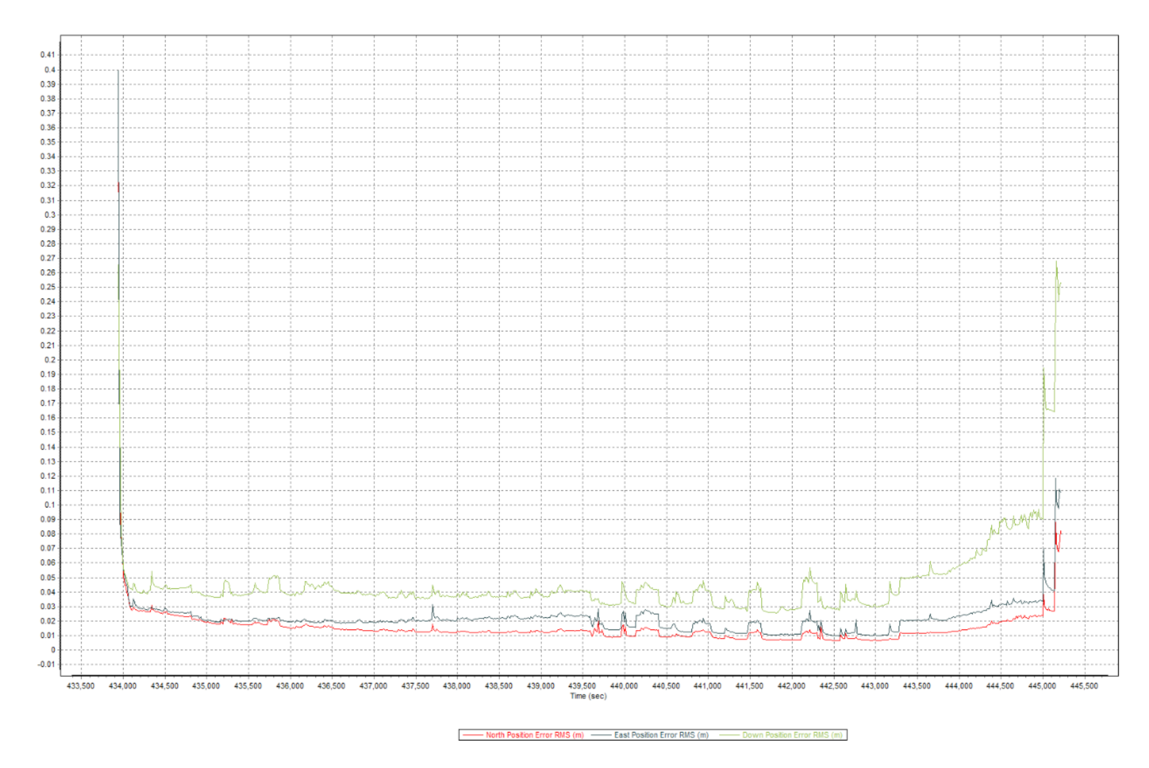


Figure 1.15.2. Smoothed Performance Metric Parameters

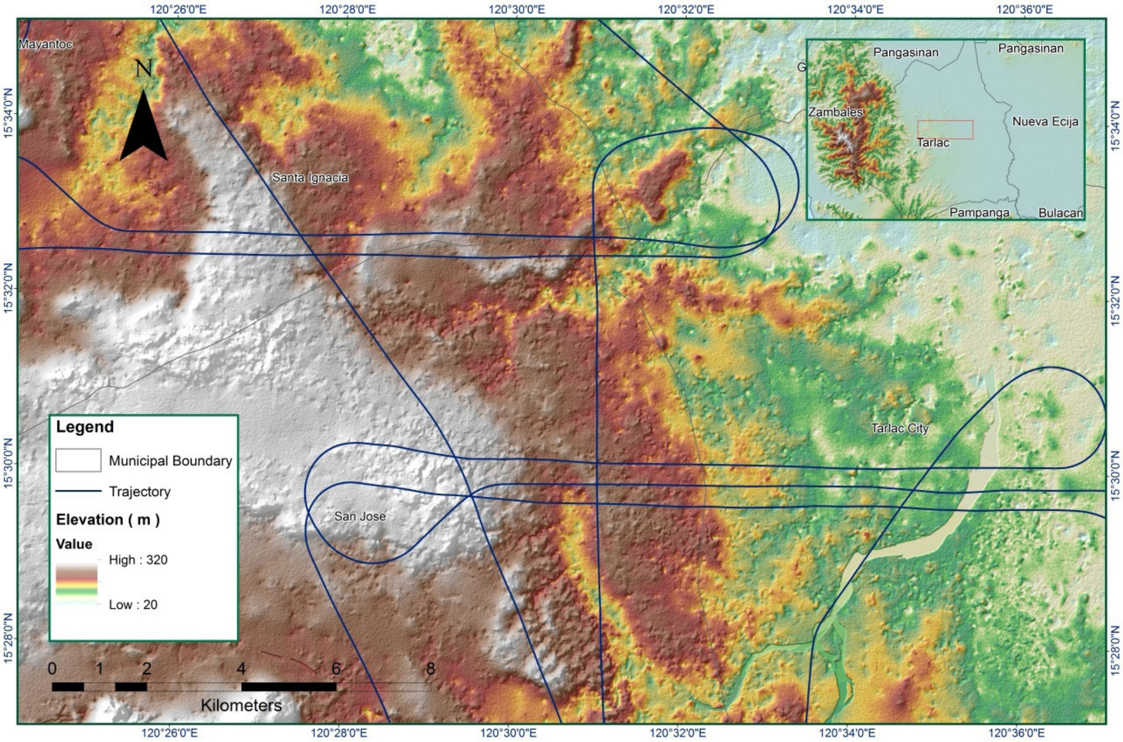


Figure 1.15.3. Best Estimated Trajectory

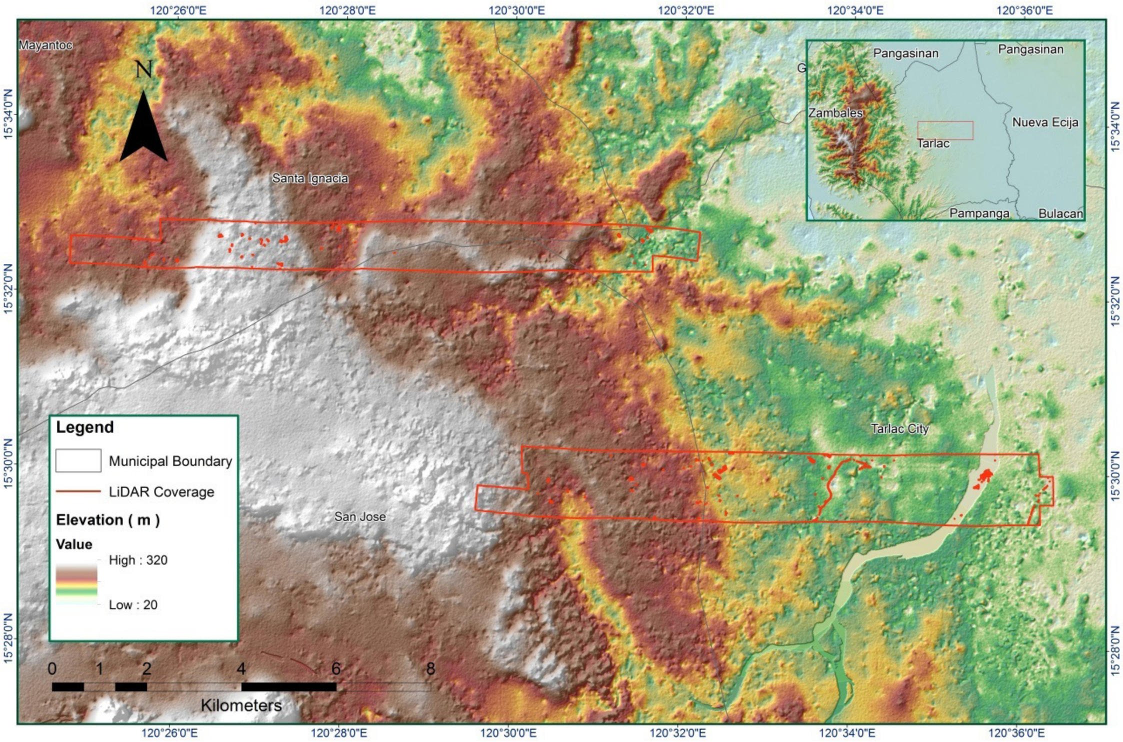


Figure 1.15.4. Coverage of LiDAR Data

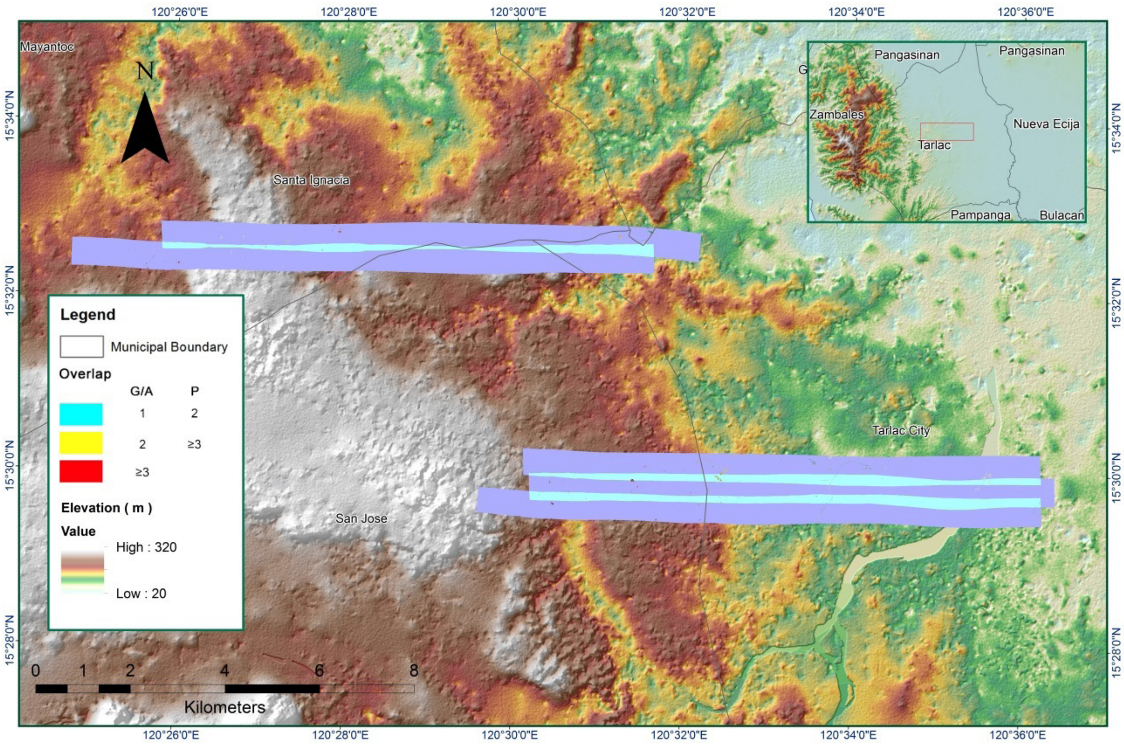


Figure 1.15.5. Image of data overlap

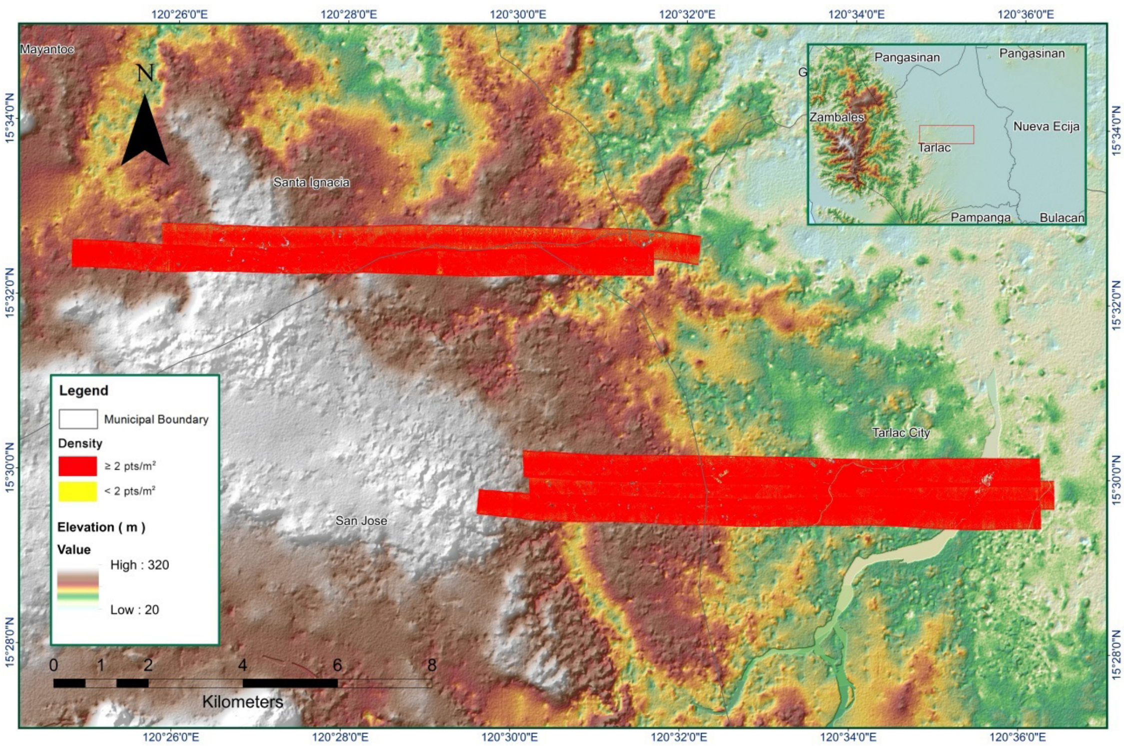


Figure 1.15.6. Density map of merged LiDAR data

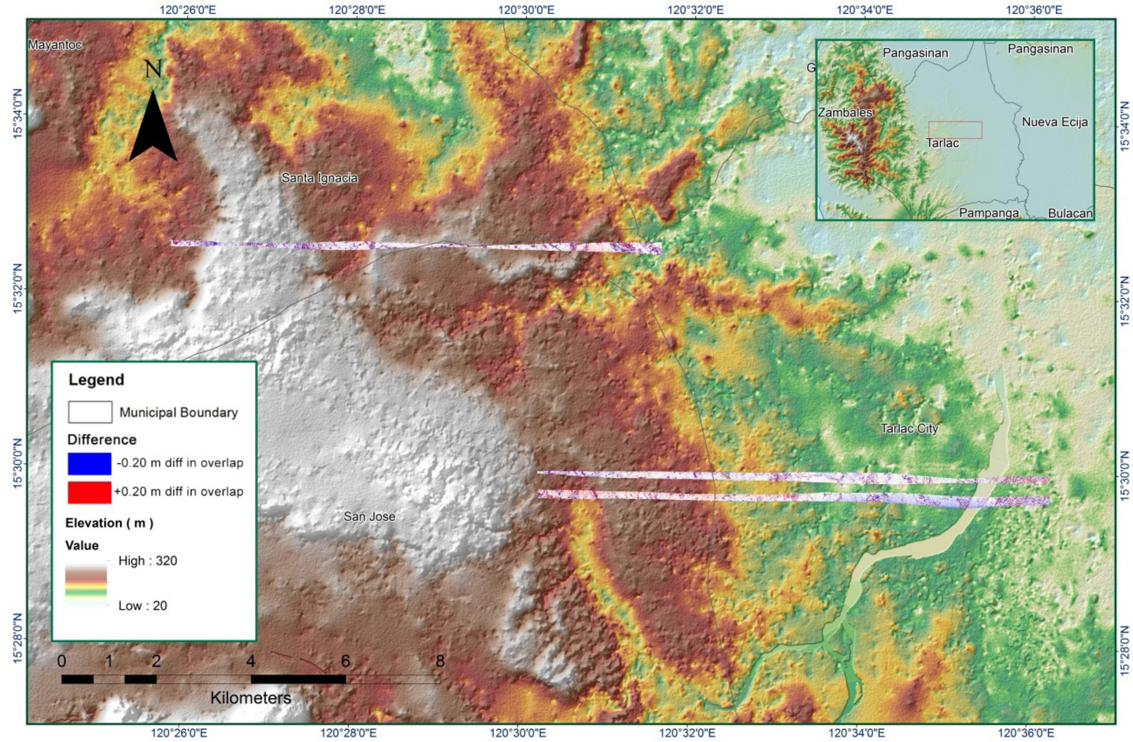


Figure 1.15.7. Elevation difference between flight lines

Flight Area	Pam_Agno Reflights
Mission Name	**Agno_Blk10E_reflight**
Inclusive Flights	7268GC
Range data size	14.7 GB
POS data size	223 MB
Base data size	11.3 MB
Image	NA
Transfer date	May 29, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.195
RMSE for East Position (<4.0 cm)	2.540
RMSE for Down Position (<8.0 cm)	8.215
Boresight correction stdev (<0.001deg)	0.000470
IMU attitude correction stdev (<0.001deg)	0.008570
GPS position stdev (<0.01m)	0.0178
Minimum % overlap (>25)	17.32
Ave point cloud density per sq.m. (>2.0)	2.67
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks Maximum Height Minimum Height *Classification (# of points)* Ground Low vegetation Medium vegetation High vegetation Building Orthophoto	96 245.54 m 53.24 m 29,938,943 40,725,814 38,393,475 4,878,806 894,740 No
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Gladys Mae Apat

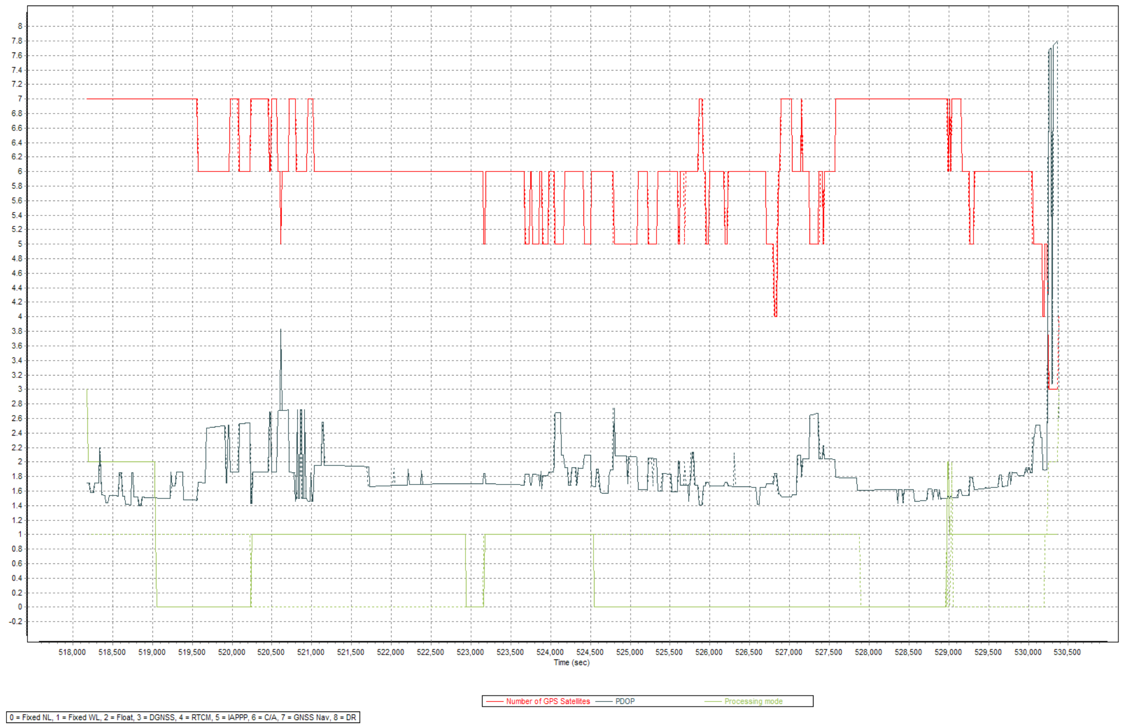


Figure 1.16.1. Solution Status

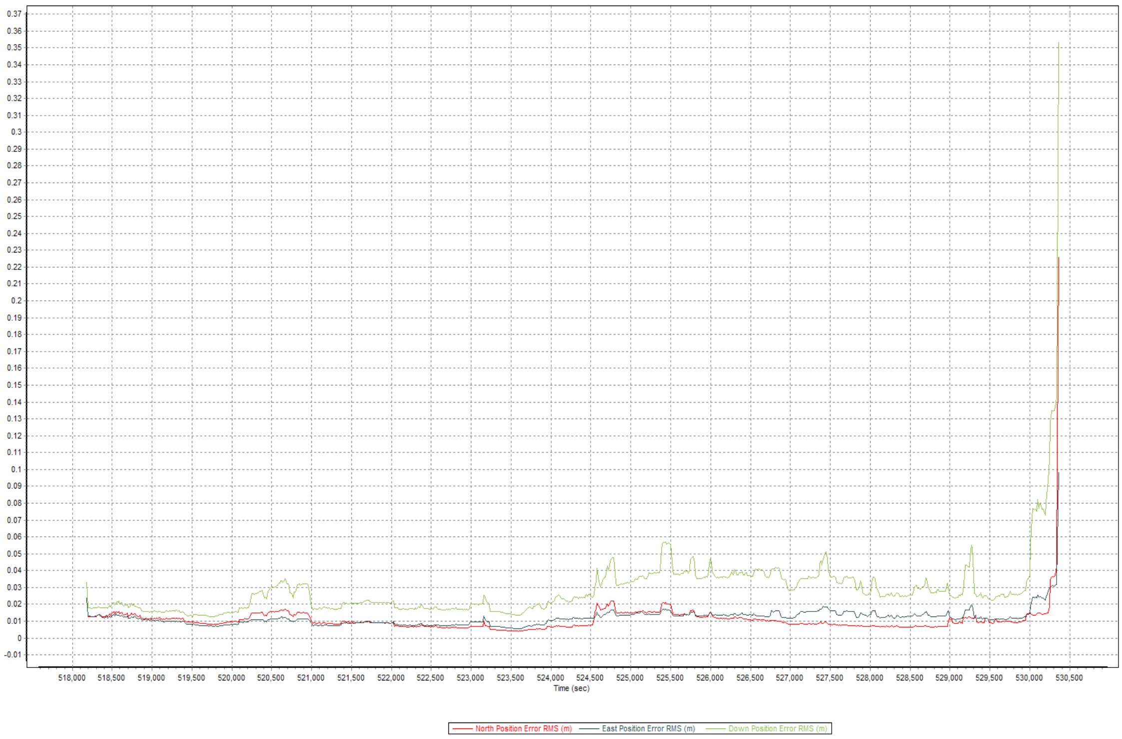


Figure 1.16.2. Smoothed Performance Metric Parameters

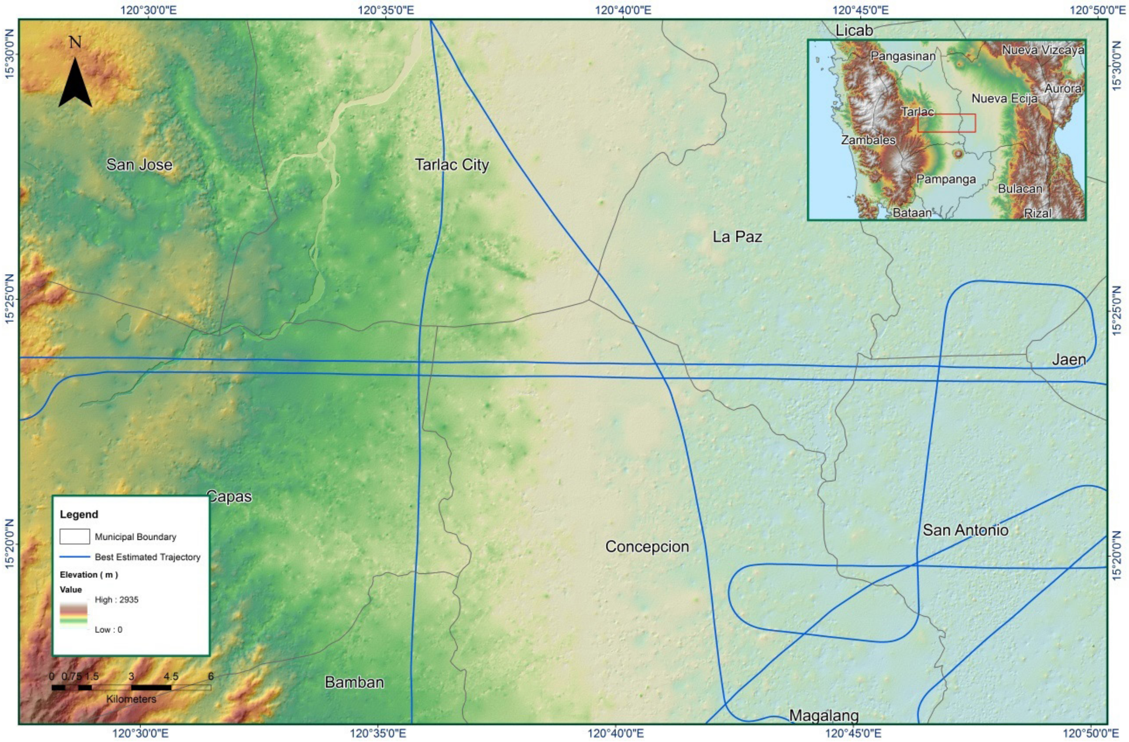


Figure 1.16.3. Best Estimated Trajectory

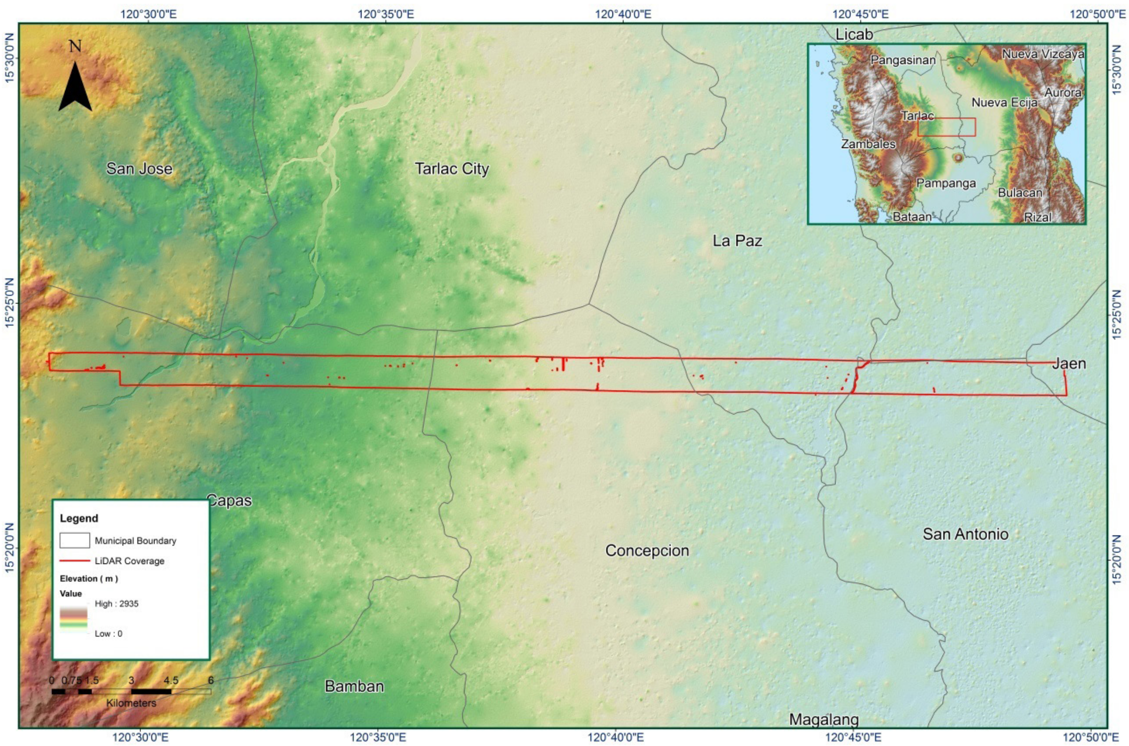


Figure 1.16.4. Coverage of LiDAR Data

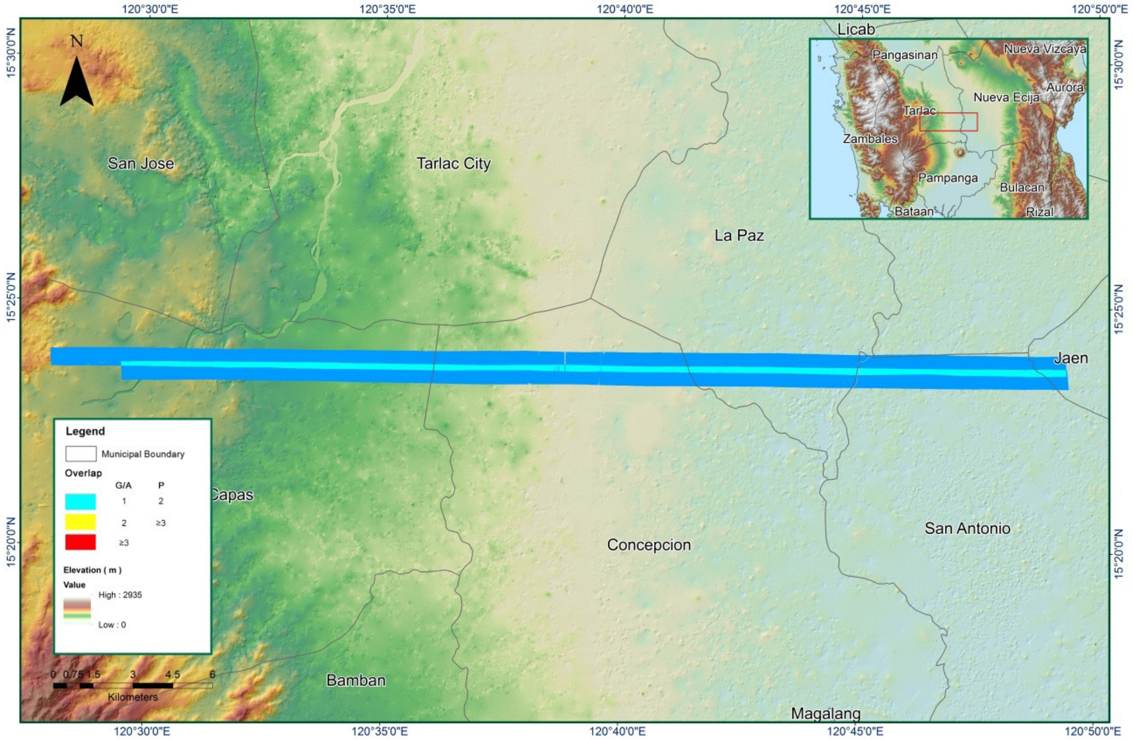


Figure 1.16.5. Image of data overlap

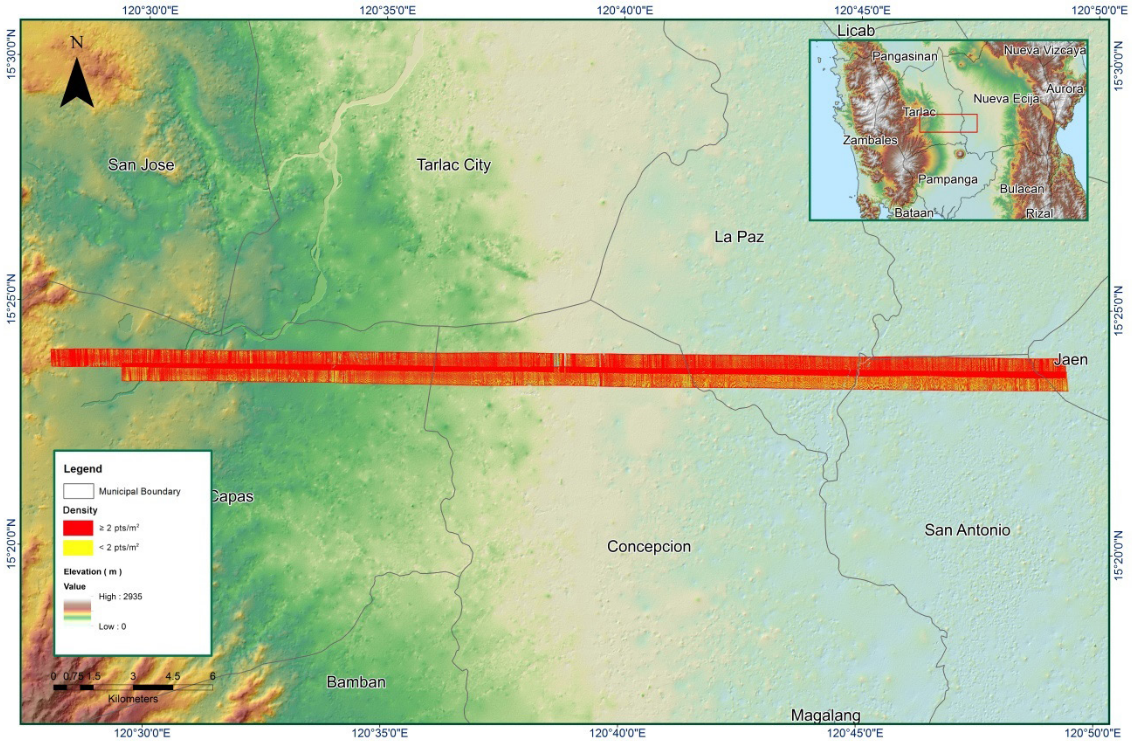


Figure 1.16.6. Density map of merged LiDAR data

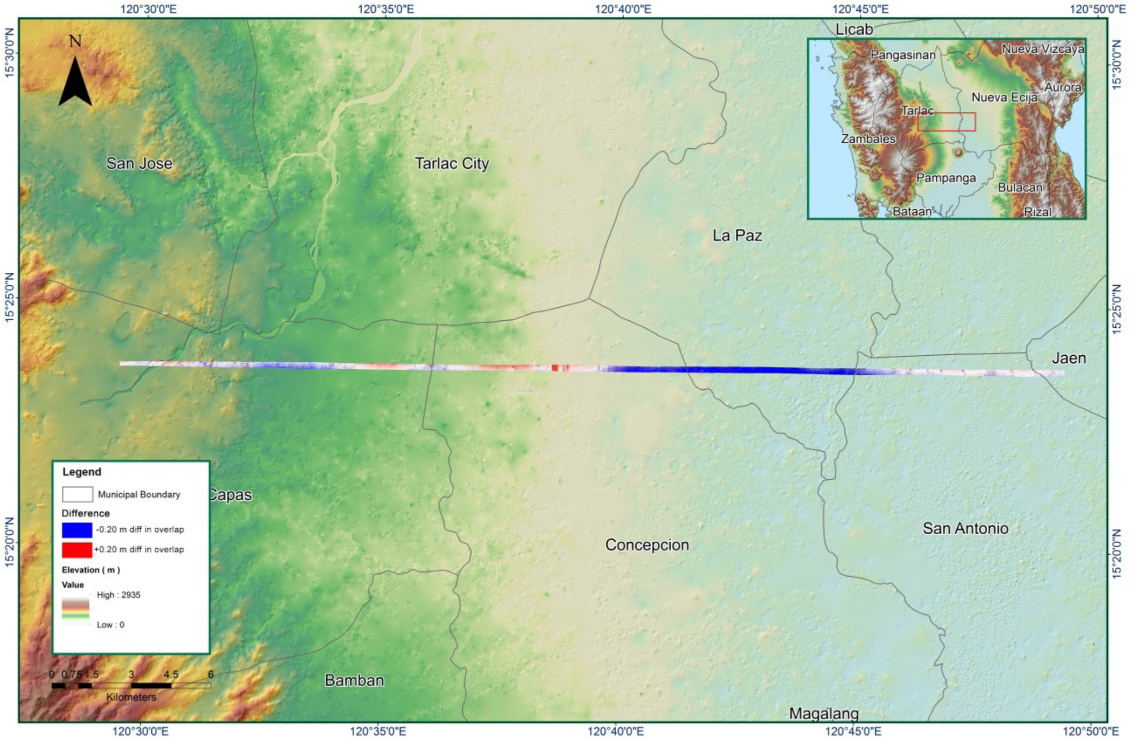


Figure 1.16.7. Elevation difference between flight lines

Flight Area	Pam_Agno Reflights
Mission Name	**Agno_Blk10D_reflight**
Inclusive Flights	7256GC
Range data size	18.9 GB
POS data size	227 MB
Base data size	18.7 MB
Image	NA
Transfer date	May 26, 2014
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)	1.31
RMSE for East Position (<4.0 cm)	1.21
RMSE for Down Position (<8.0 cm)	4.00
Boresight correction stdev (<0.001deg)	0.000361
IMU attitude correction stdev (<0.001deg)	0.001574
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	19.12
Ave point cloud density per sq.m. (>2.0)	3.21
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks Maximum Height Minimum Height *Classification (# of points)* Ground Low vegetation Medium vegetation High vegetation Building Orthophoto	63 236.49 m 52.19 m 40,569,252 60,274,345 36,369,432 6,707,663 2,114,996 No
Processed by	Engr. Angelo Carlo Bongat, Engr. Mark Joshua Salvacion, Ryan James Nicholai Dizon

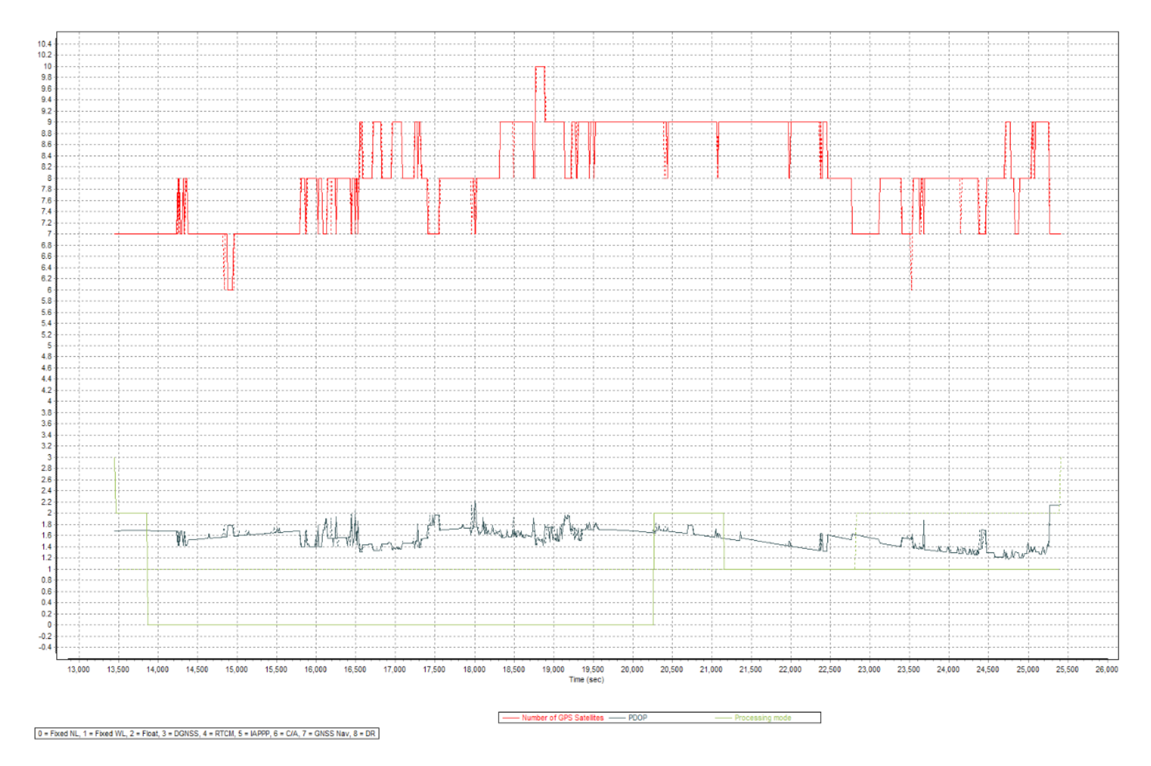


Figure 1.17.1. Solution Status

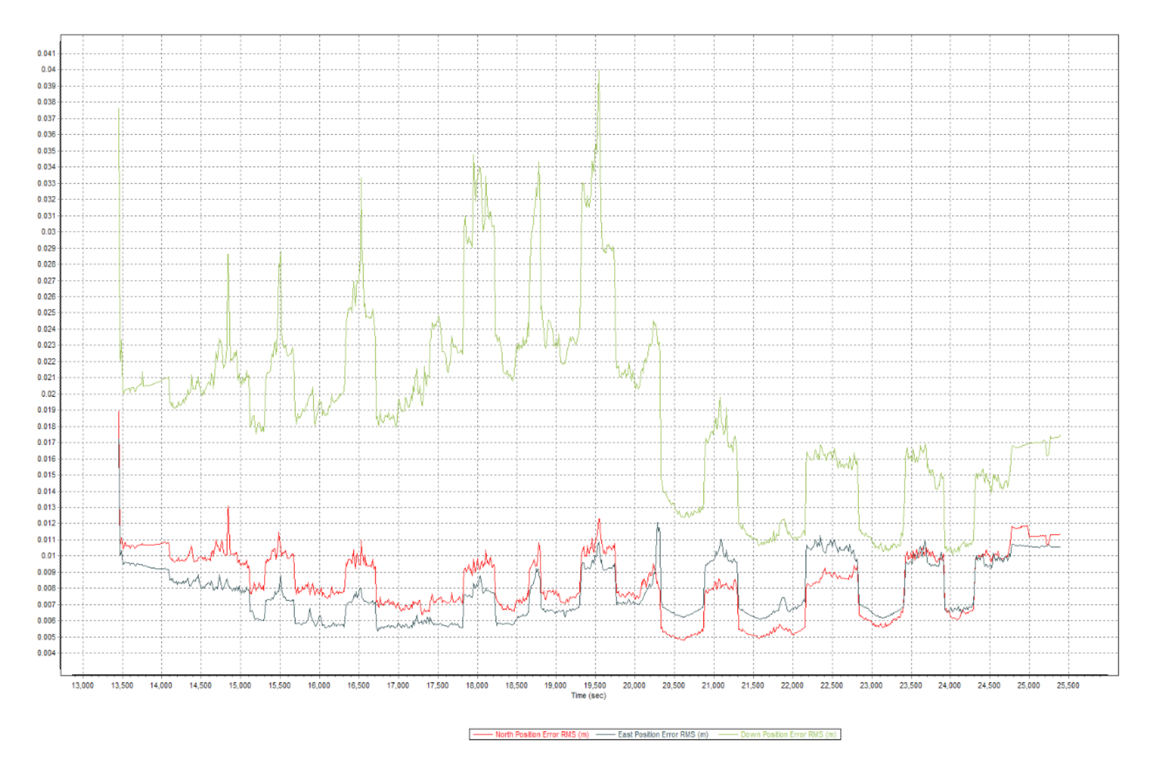


Figure 1.17.2. Smoothed Performance Metric Parameters

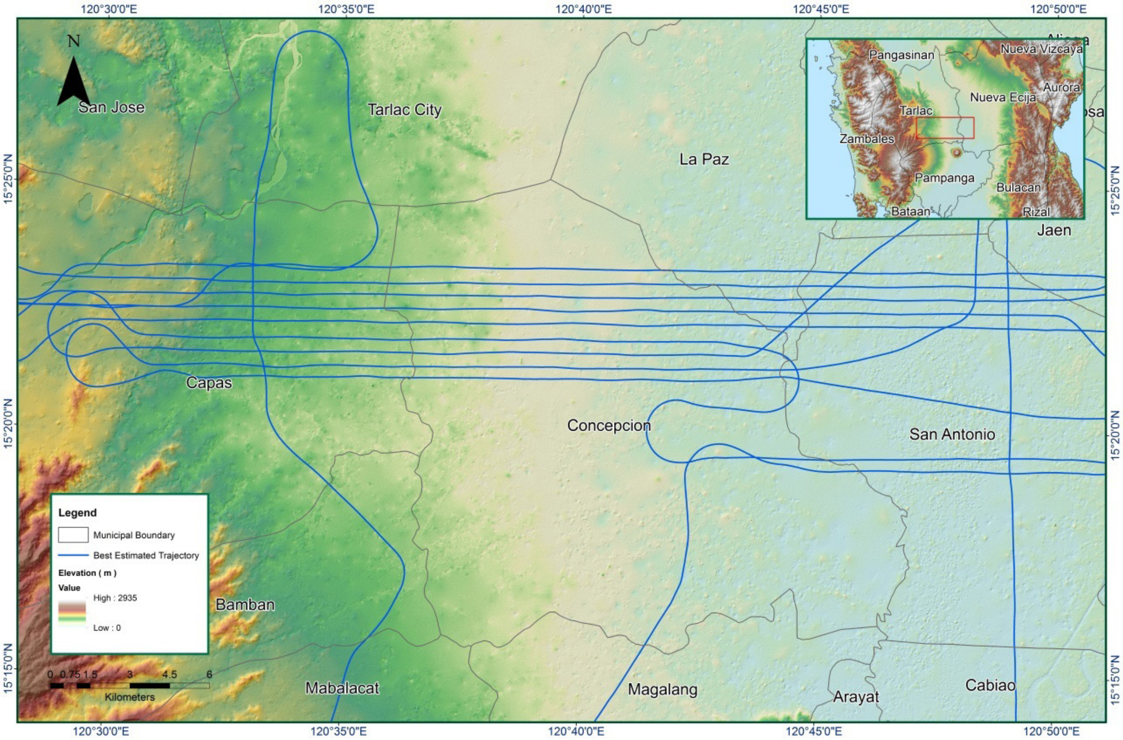


Figure 1.17.3. Best Estimated Trajectory

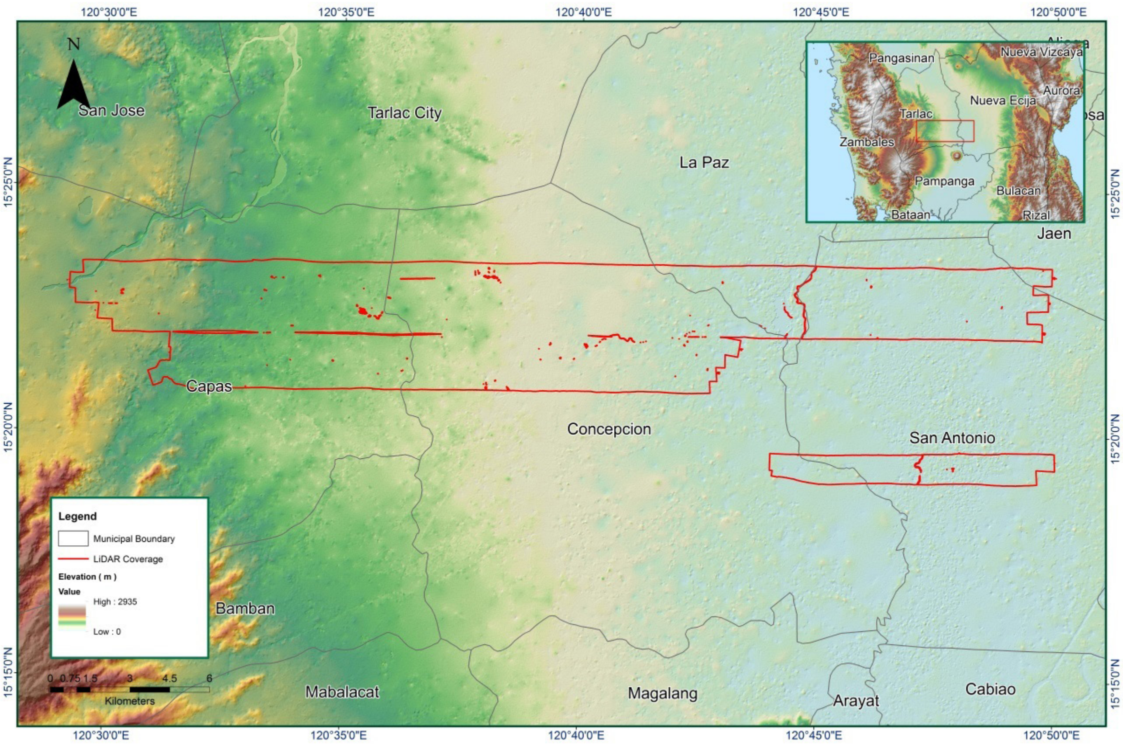


Figure 1.17.4. Coverage of LiDAR Data

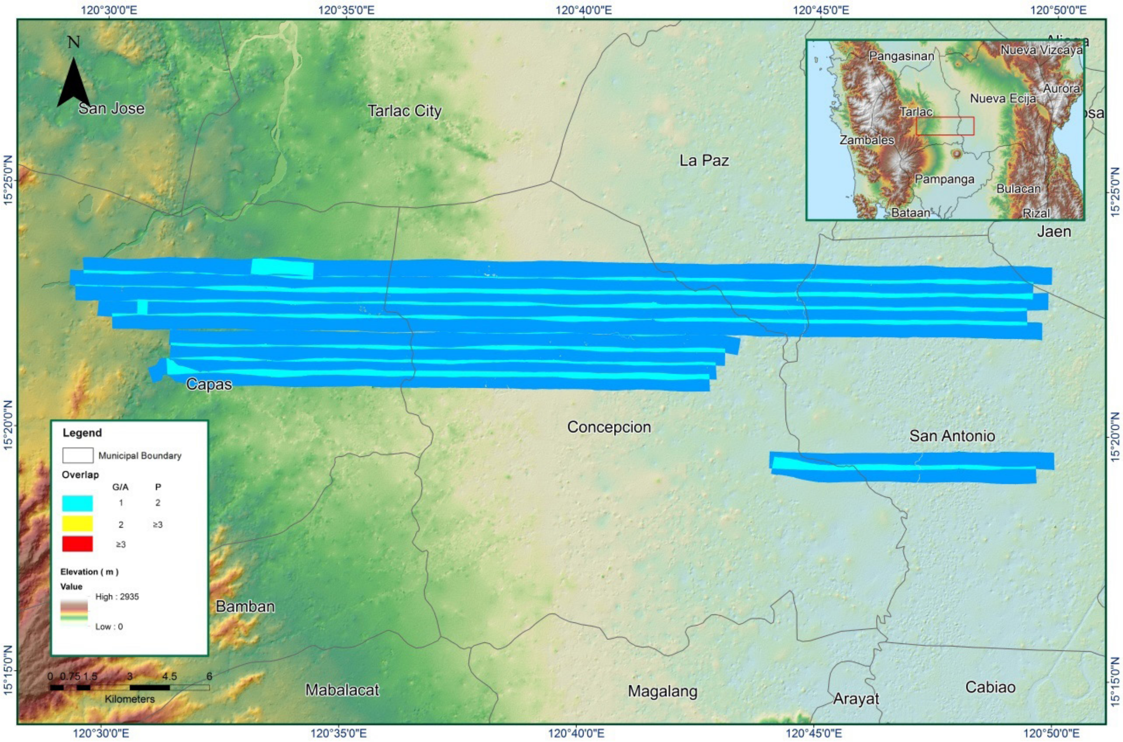


Figure 1.17.5. Image of data overlap

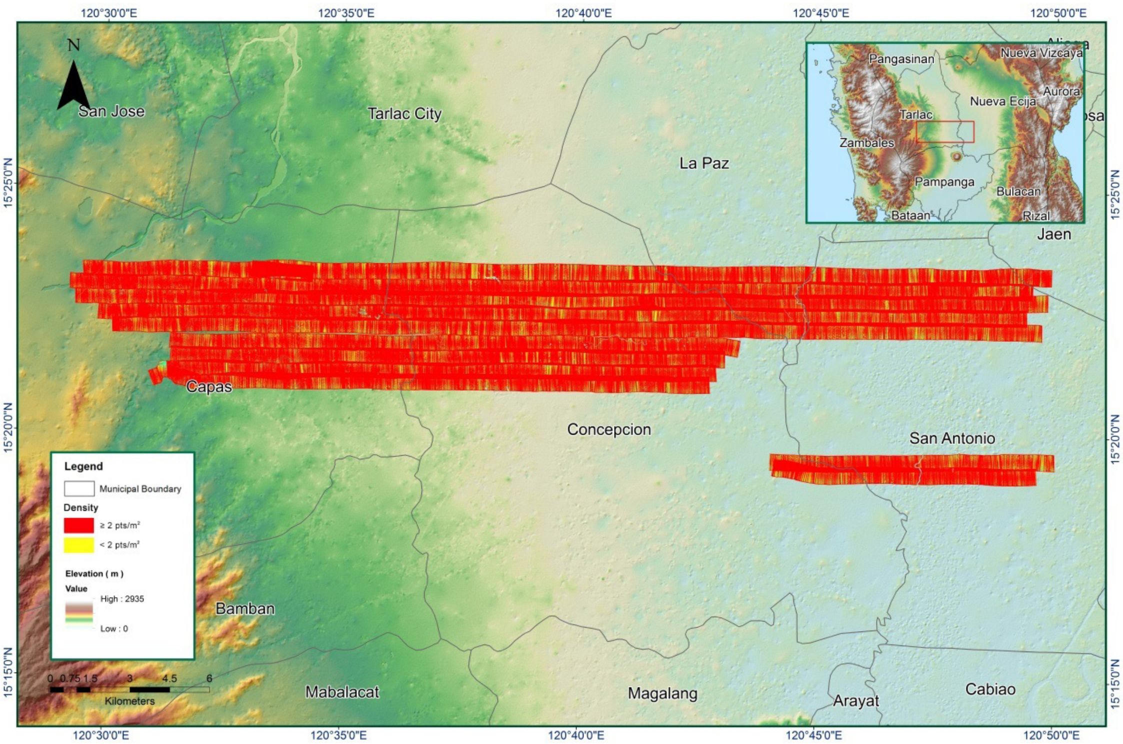


Figure 1.17.6. Density map of merged LiDAR data

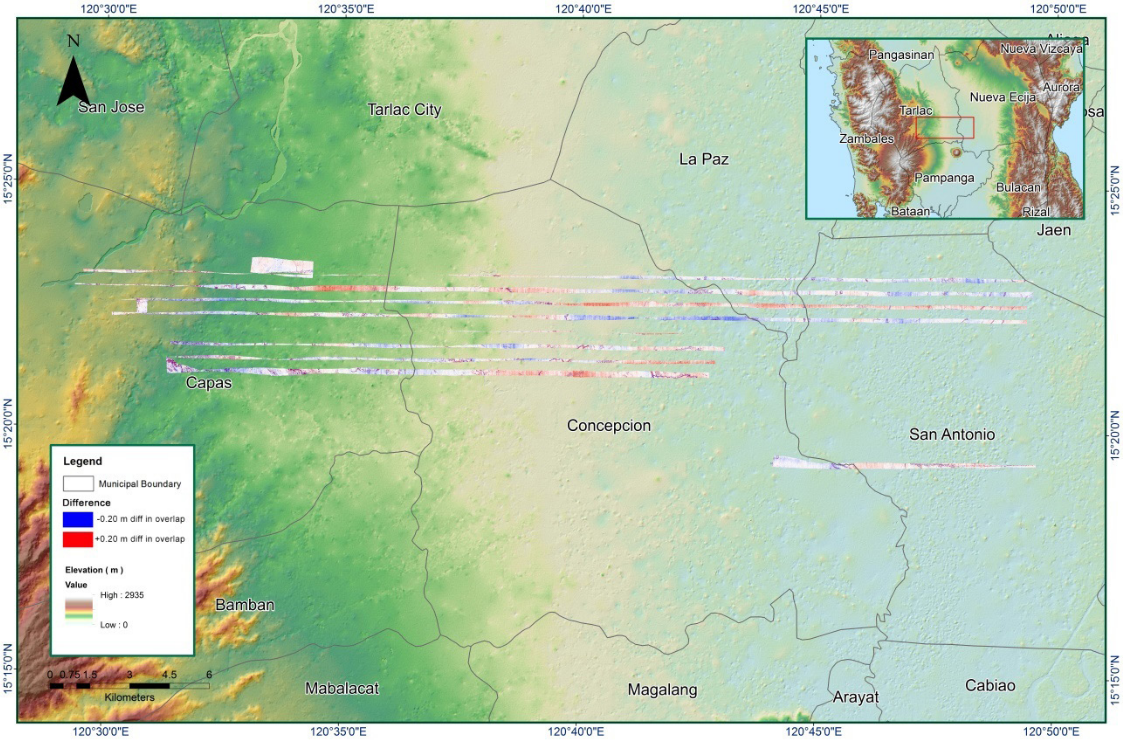


Figure 1.17.7. Elevation difference between flight lines

Flight Area	**Pam_Agno_Reflights**
Mission Name	Blk Pam3A
Inclusive Flights	7253GC
Range data size	10.8 GB
POS data size	228 MB
Base data size	11.7 MB
Image	NA
Transfer date	May 26, 2014
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)	1.047
RMSE for East Position (<4.0 cm)	1.330
RMSE for Down Position (<8.0 cm)	2.605
Boresight correction stdev (<0.001deg)	0.000302
IMU attitude correction stdev (<0.001deg)	0.000532
GPS position stdev (<0.01m)	0.0101
Minimum % overlap (>25)	40.19
Ave point cloud density per sq.m. (>2.0)	2.71
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	96
Maximum Height	1091.86 m
Minimum Height	46.49 m
Classification (# of points)	
Ground	41,411,461
Low vegetation	56,414,342
Medium vegetation	53,269,637
High vegetation	41,483,560
Building	1,874,931
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Mark Joshua Salvacion, Engr. Elainne Lopez

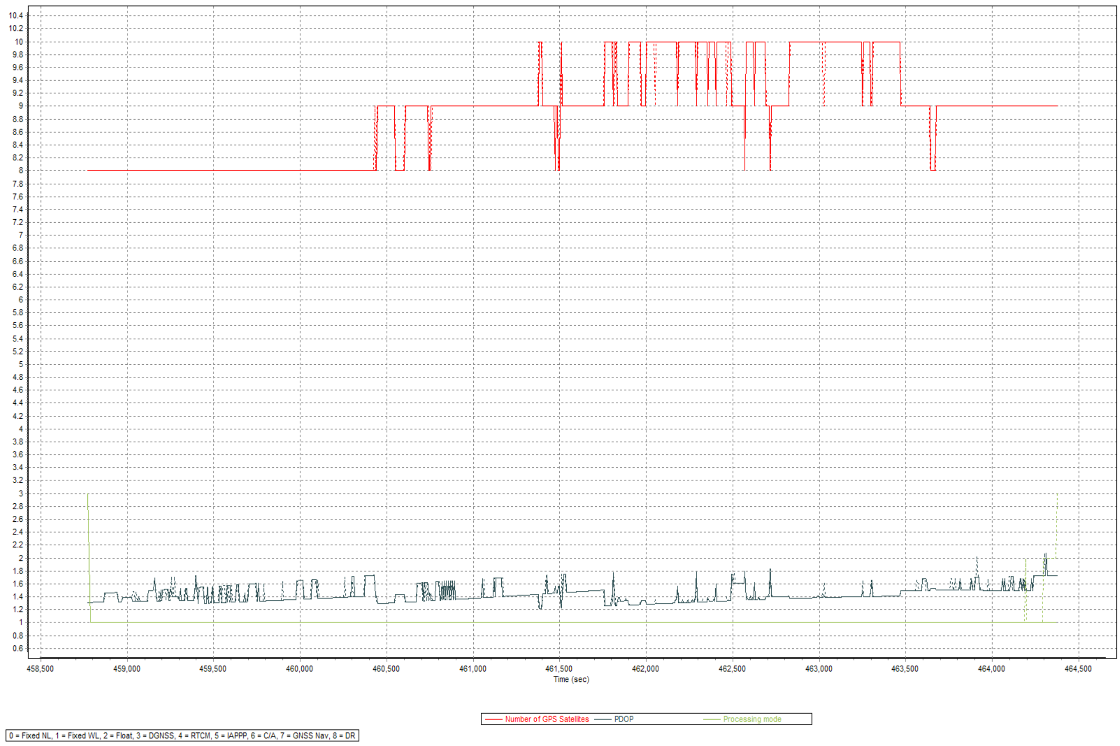


Figure 1.18.1. Solution Status

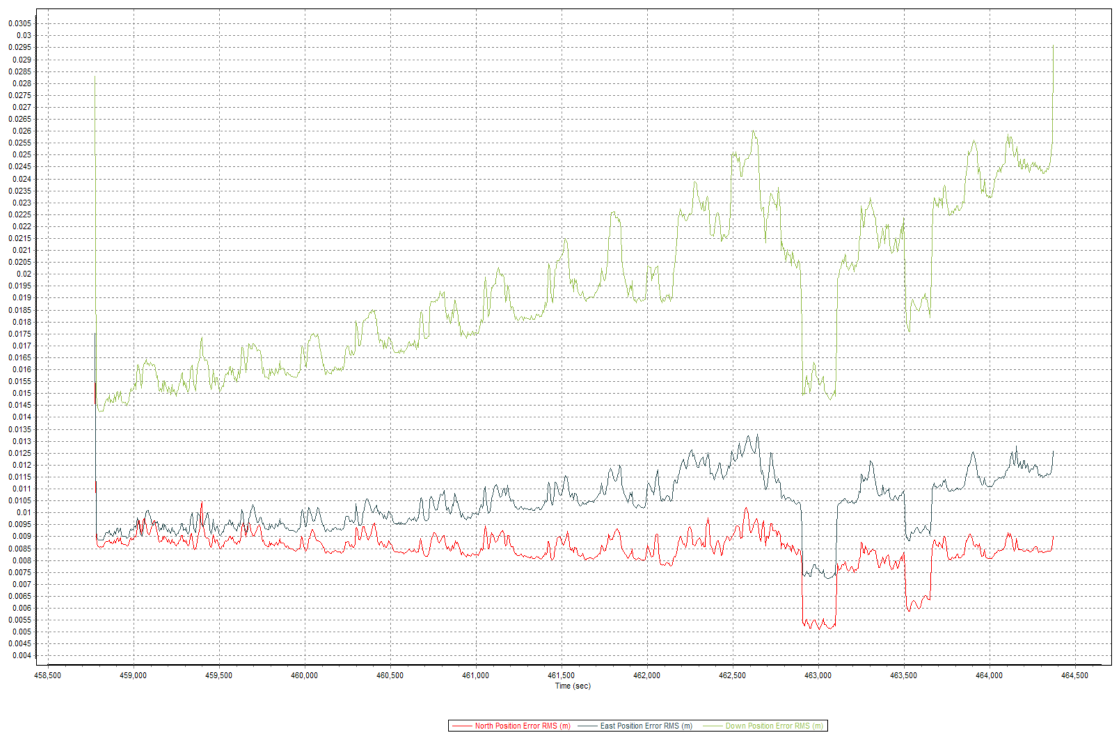


Figure 1.18.2. Smoothed Performance Metric Parameters

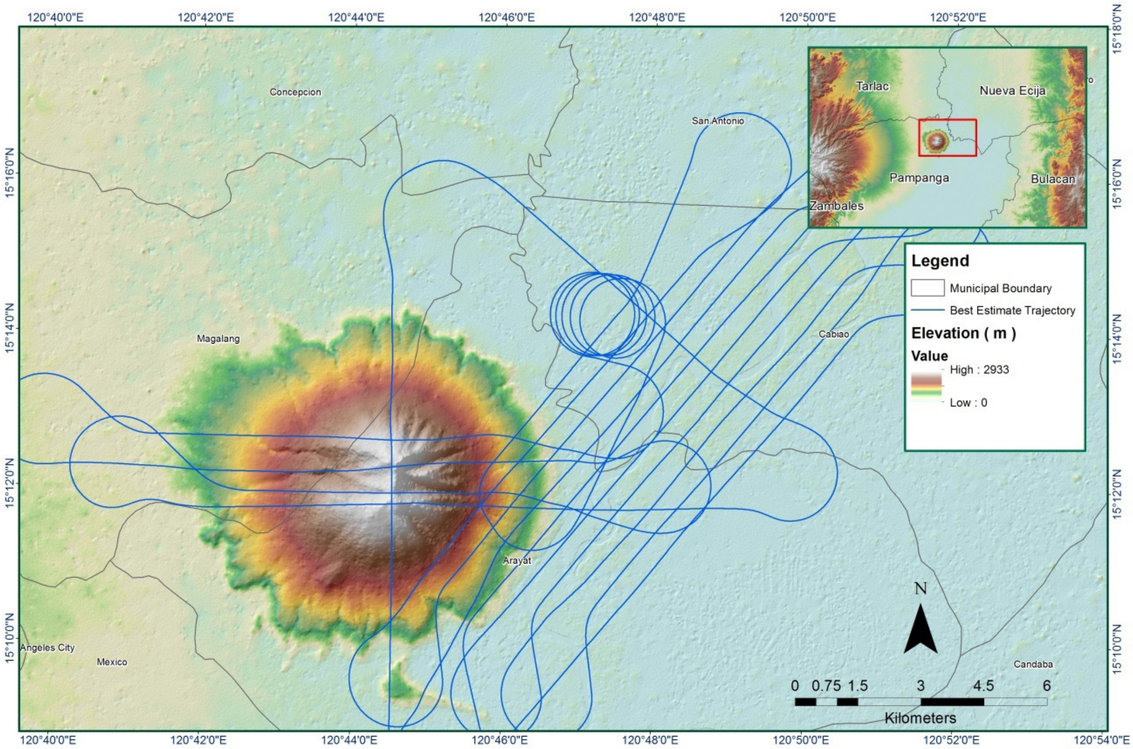


Figure 1.18.3. Best Estimated Trajectory

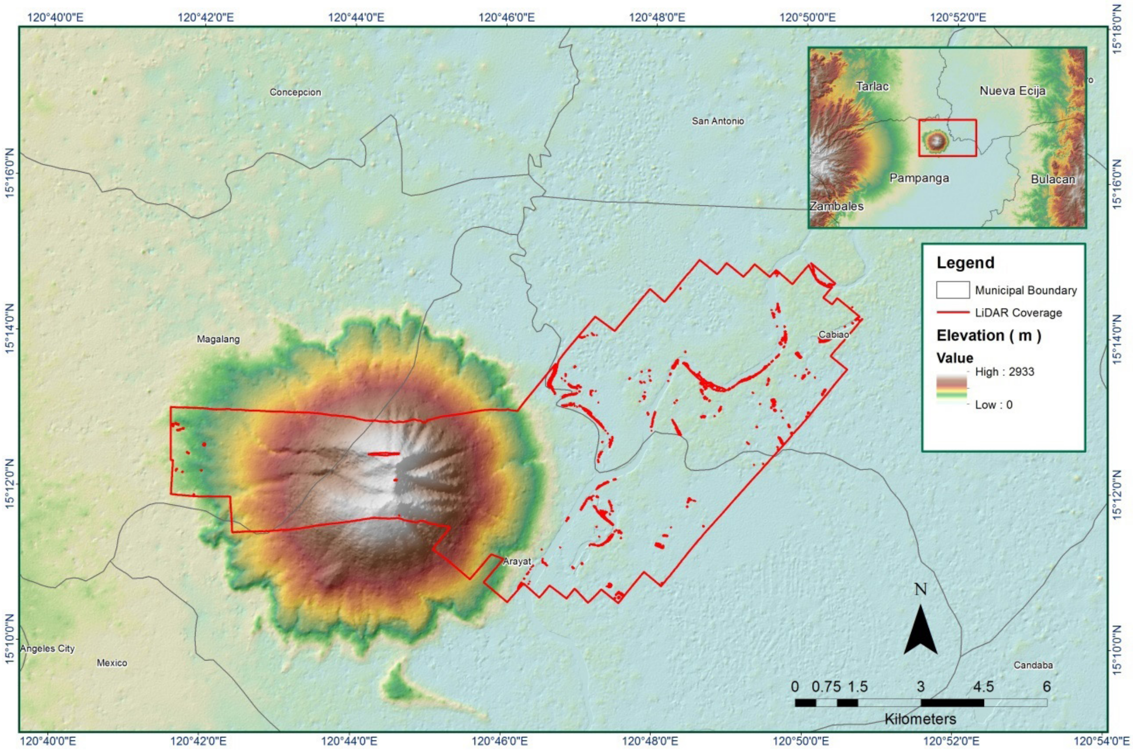


Figure 1.18.4. Coverage of LiDAR Data

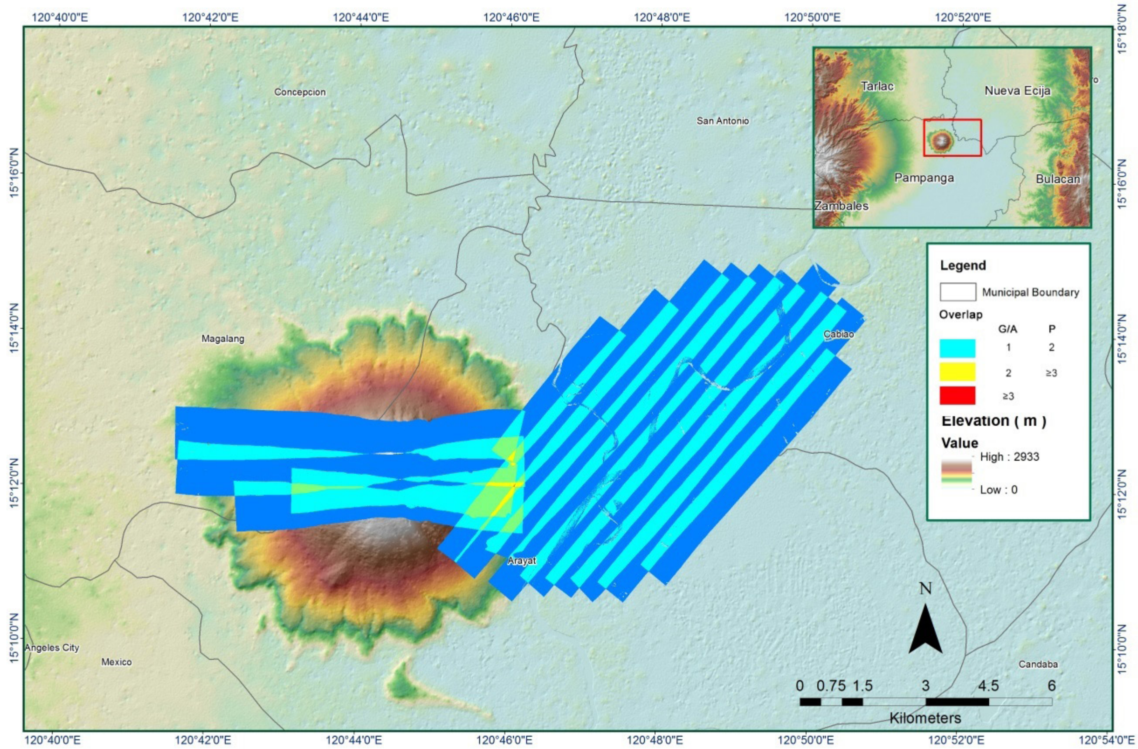


Figure 1.18.5. Image of data overlap

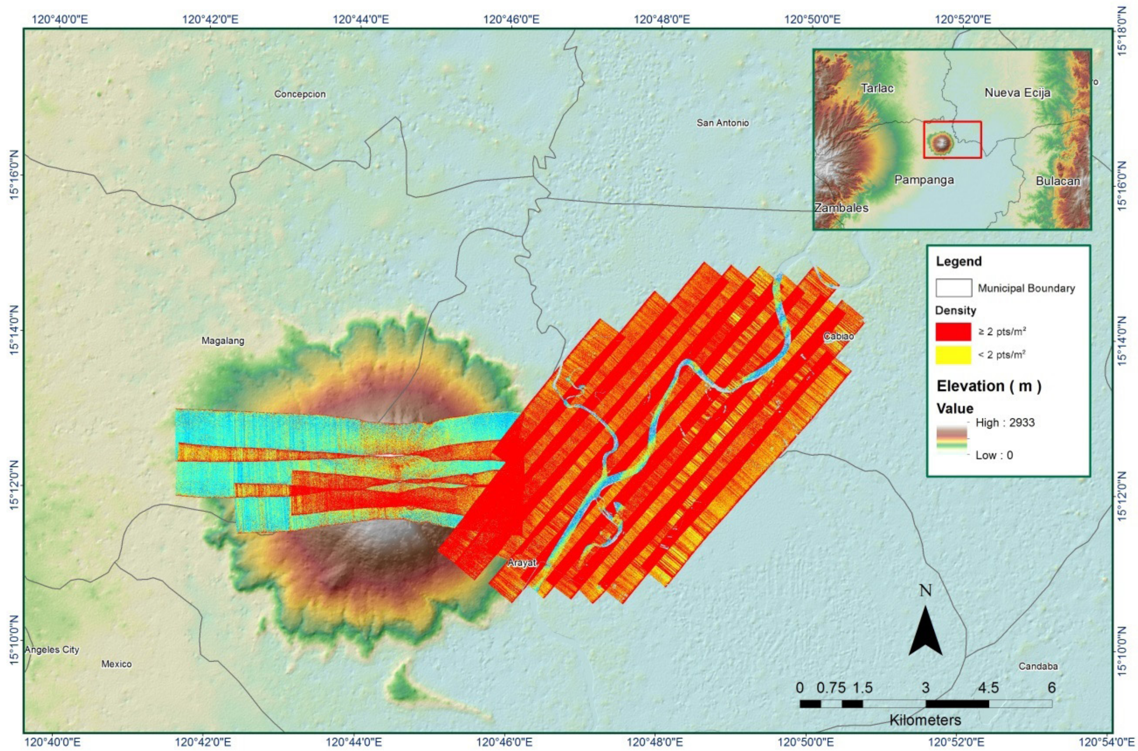


Figure 1.18.6. Density map of merged LiDAR data

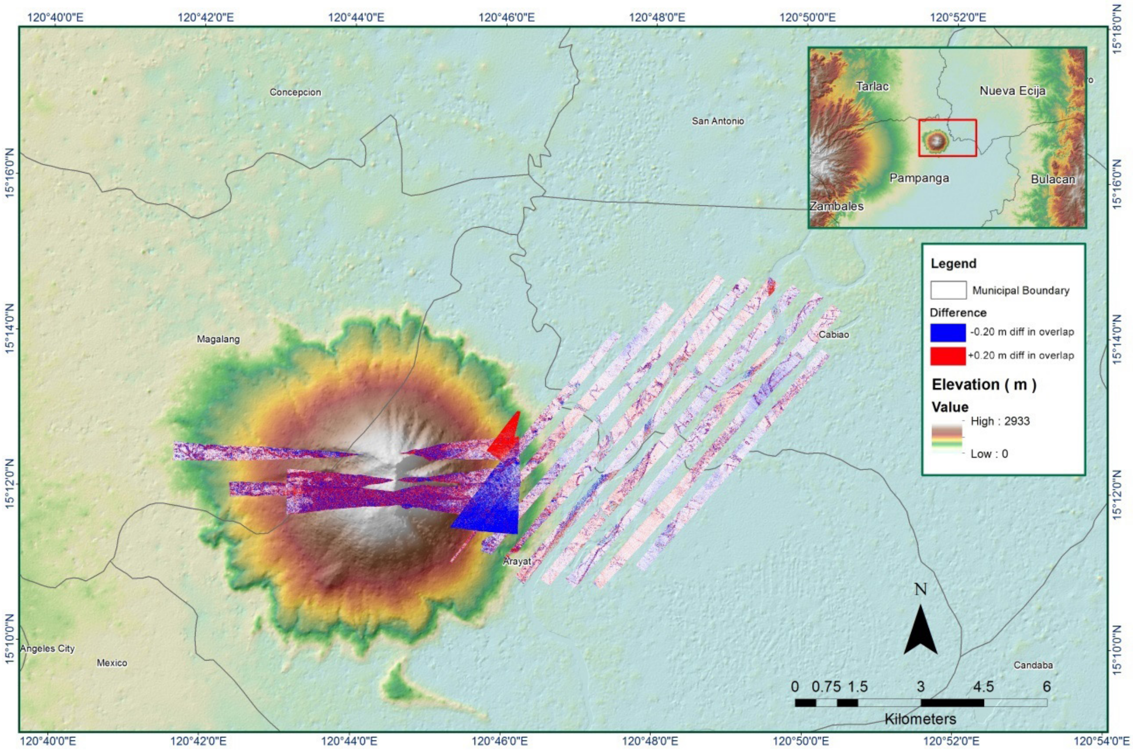


Figure 1.18.7. Elevation difference between flight lines

Flight Area	Bataan
Mission Name	**BataanZambales_BucD**
Inclusive Flights	923P
Range data size	5.72 GB
POS	189 MB
Image	n/a
Transfer date	January 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.0
RMSE for East Position (<4.0 cm)	7.0
RMSE for Down Position (<8.0 cm)	12
Boresight correction stdev (<0.001deg)	0.000327
IMU attitude correction stdev (<0.001deg)	0.001505
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	5.76%
Ave point cloud density per sq.m. (>2.0)	1.14
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	501
Maximum Height	809.55 m
Minimum Height	40.61 m
Classification (# of points)	
Ground	270,366,880
Low vegetation	137,148,891
Medium vegetation	282,532,413
High vegetation	105,320,651
Building	3,623,320
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Harmond Santos, Engr. Roa Shalemar Redo, Engr. John Dill Macapagal, Engr. Jeffrey Delica

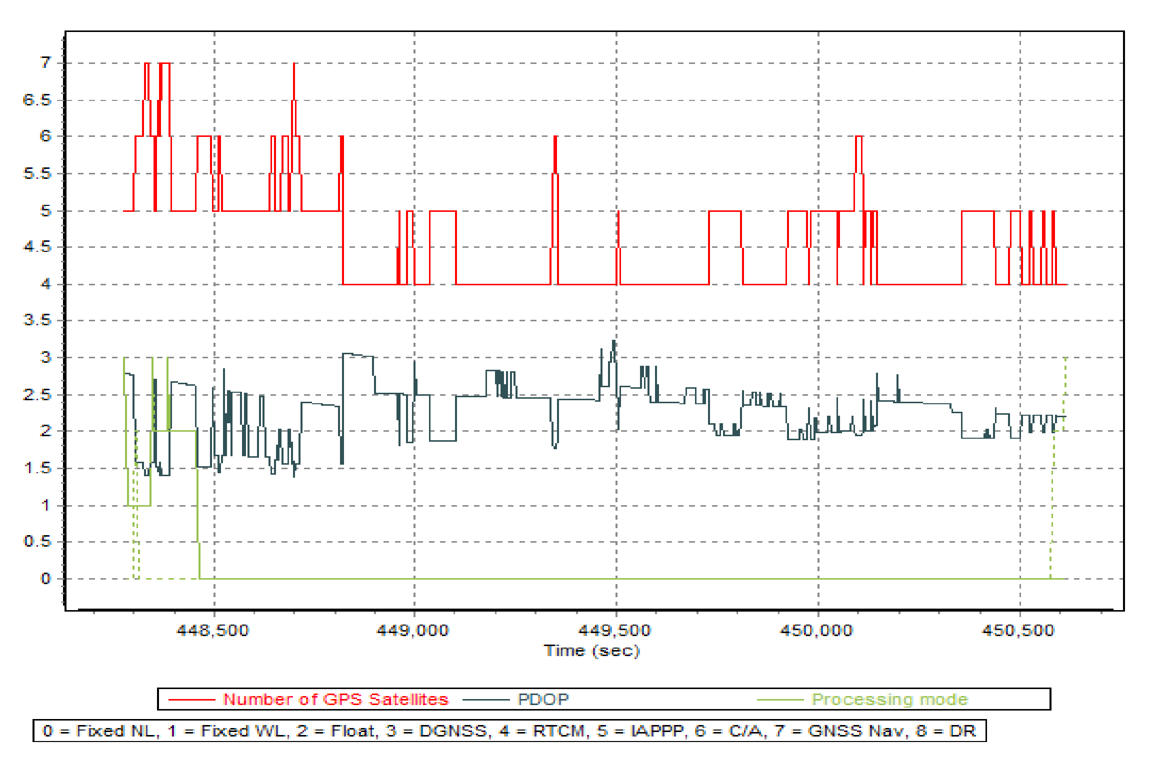


Figure 1.19.1. Solution Status

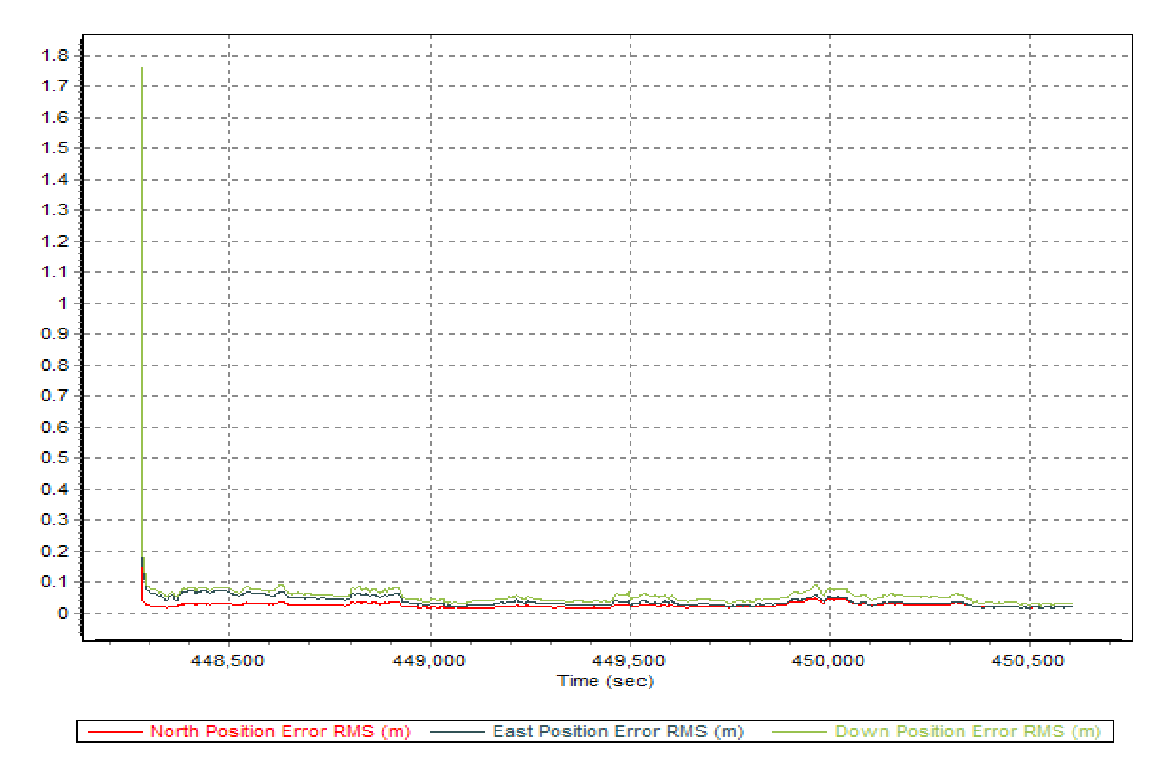


Figure 1.19.2. Smoothed Performance Metric Parameters

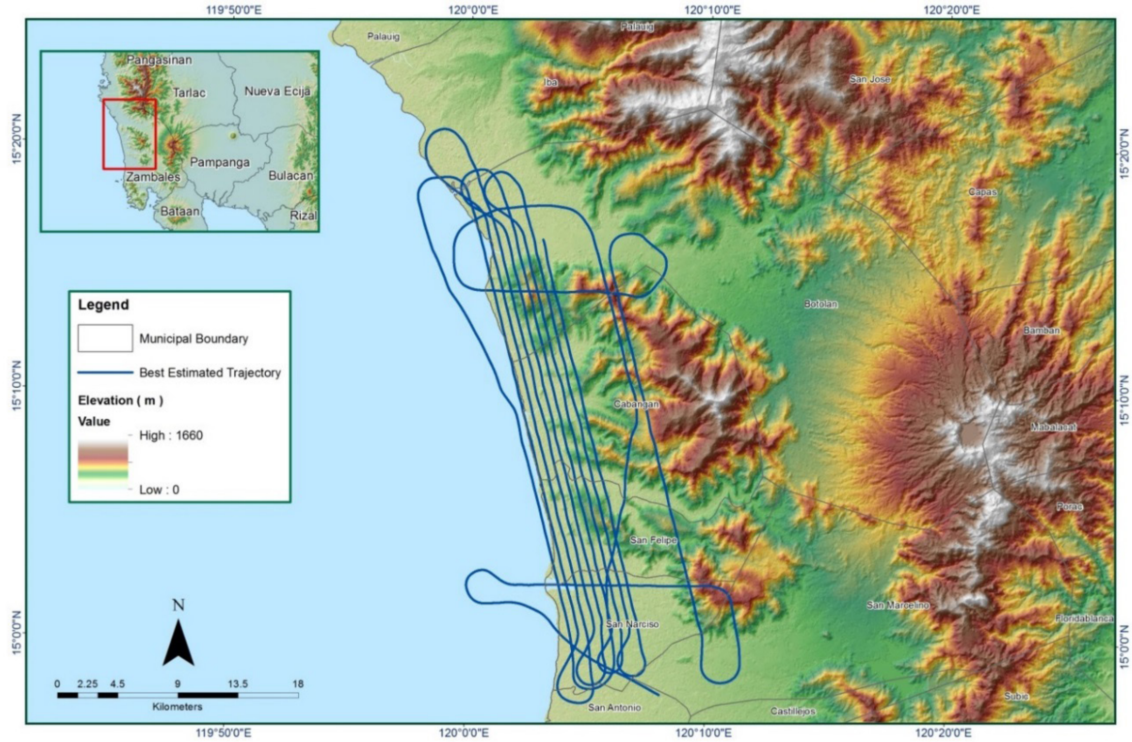


Figure 1.19.3. Best Estimated Trajectory

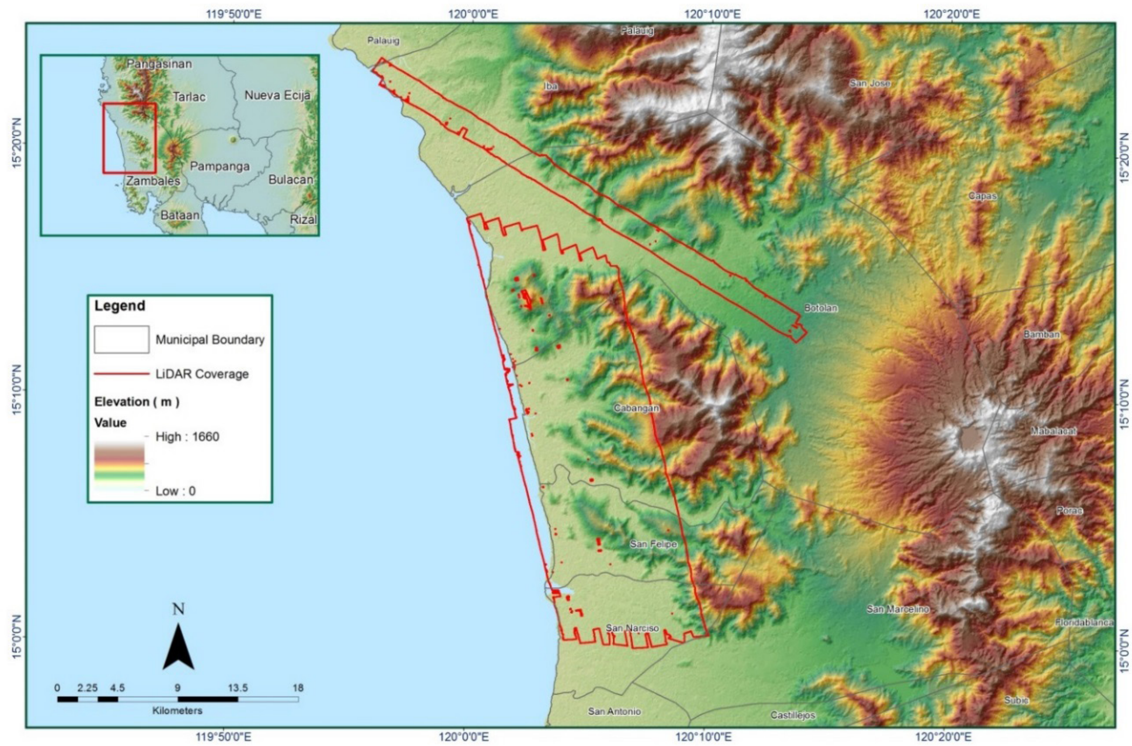


Figure 1.19.4. Coverage of LiDAR Data

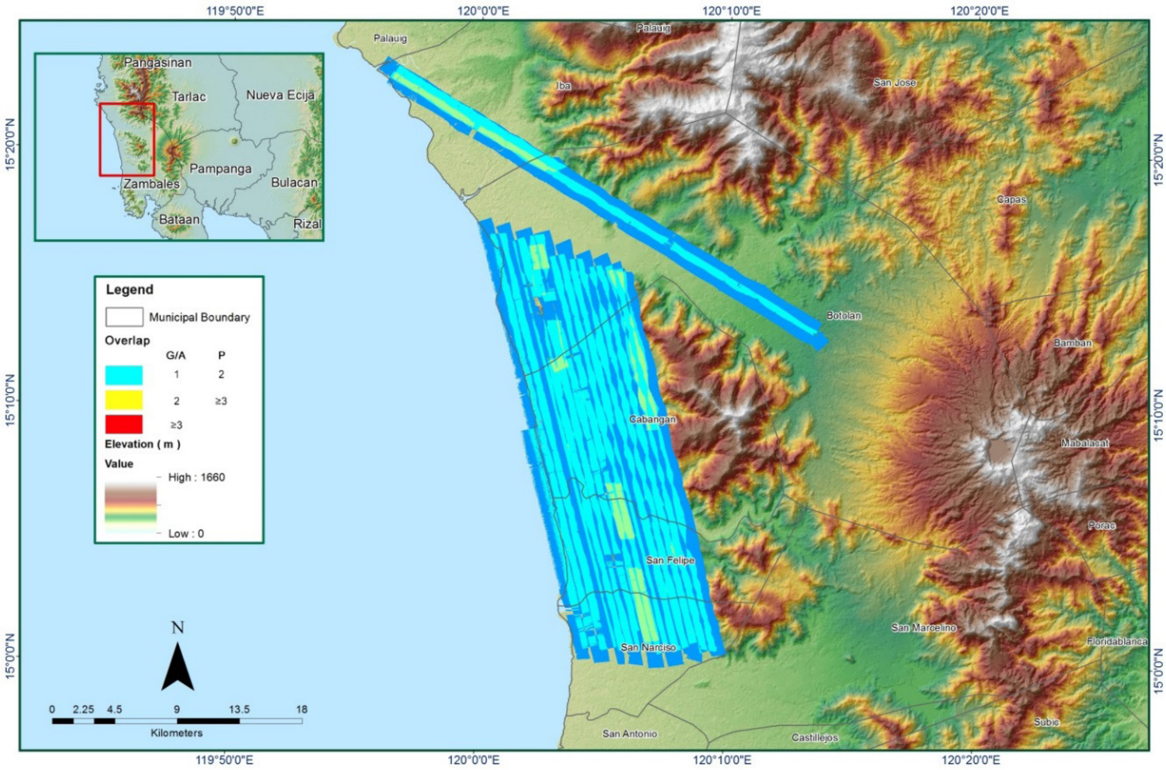


Figure 1.19.5. Image of data overlap

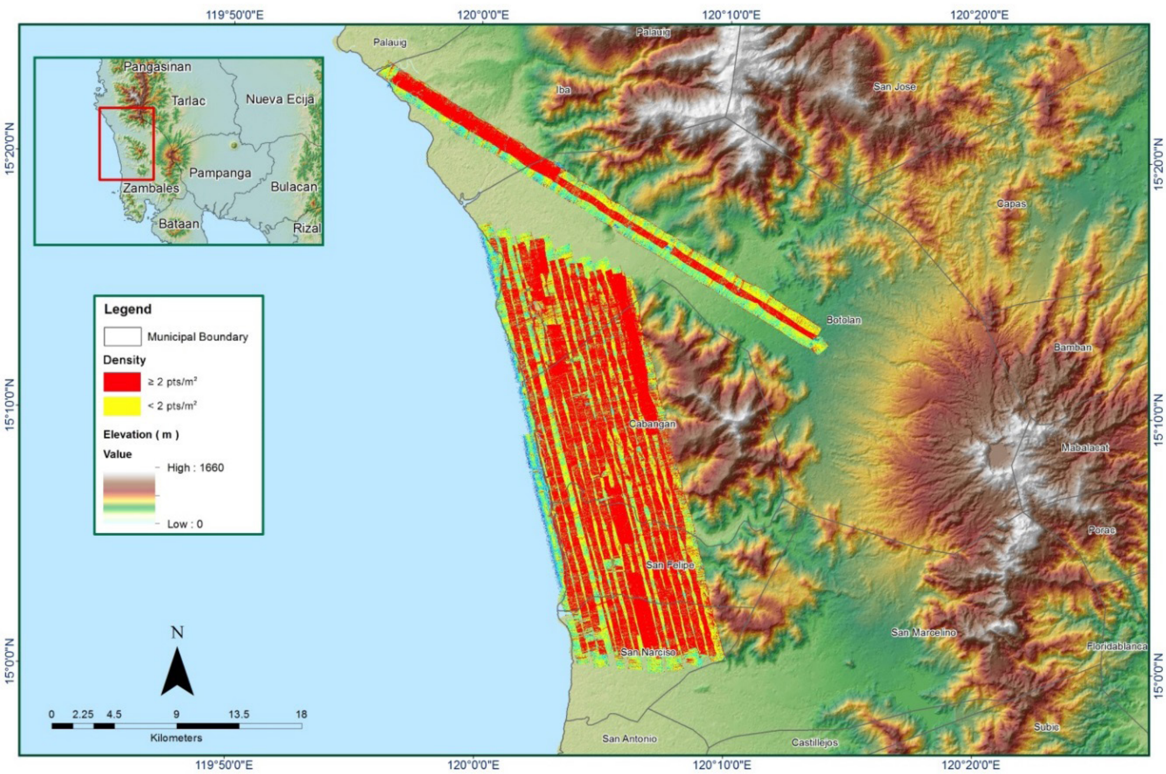


Figure 1.19.6. Density map of merged LiDAR data

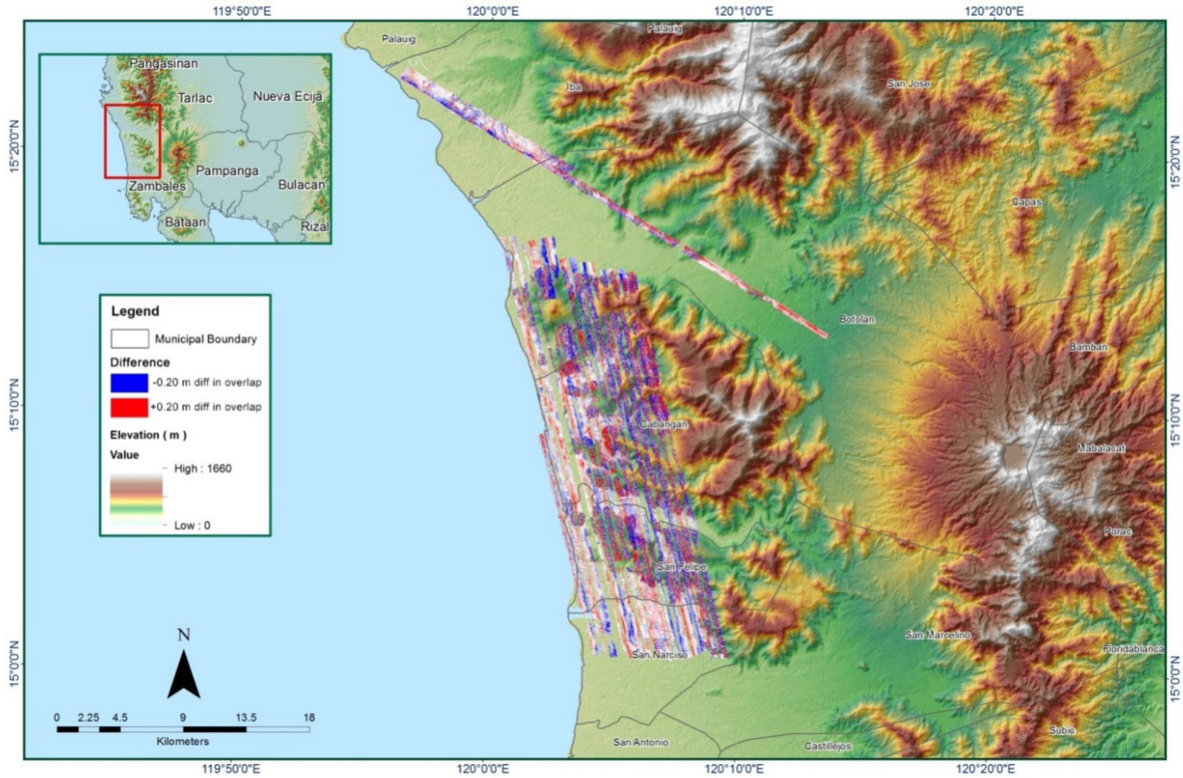


Figure 1.19.7. Elevation difference between flight lines

Flight Area	Bataan
Mission Name	**BataanZambales_PlgA_947P**
Inclusive Flights	947P
Range data size	17.3 GB
POS	250 MB
Image	n/a
Transfer date	January 10, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.0
RMSE for East Position (<4.0 cm)	3.0
RMSE for Down Position (<8.0 cm)	6.0
Boresight correction stdev (<0.001deg)	0.000361
IMU attitude correction stdev (<0.001deg)	0.001116
GPS position stdev (<0.01m)	0.0016
Minimum % overlap (>25)	51.85%
Ave point cloud density per sq.m. (>2.0)	2.43
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	192
Maximum Height	778.35 m
Minimum Height	138.75 m
Classification (# of points)	
Ground	188,069,445
Low vegetation	132,291,782
Medium vegetation	325,590,309
High vegetation	163,157,248
Building	5,200,602
Orthophoto	No
Processed by	Engr. Irish Cortez, Celina Rosete, Engr. Kenneth. Solidum, Engr. Gladys Mae Apat

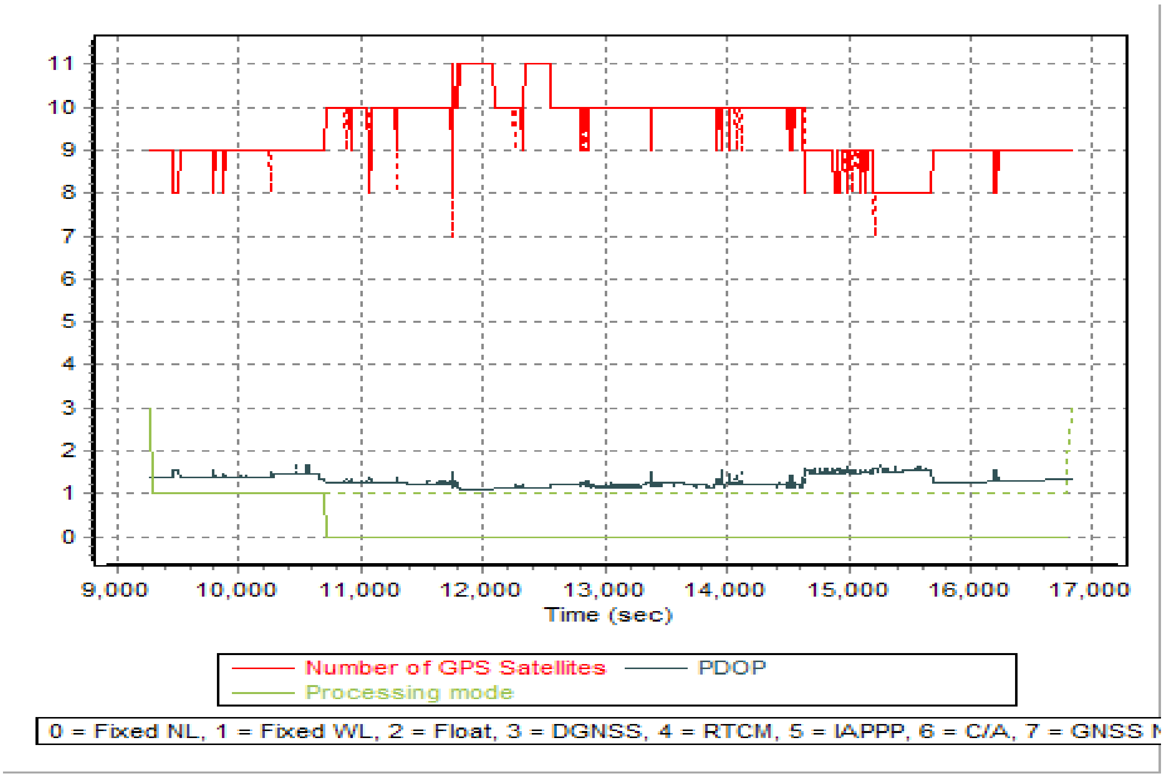


Figure 1.20.1. Solution Status

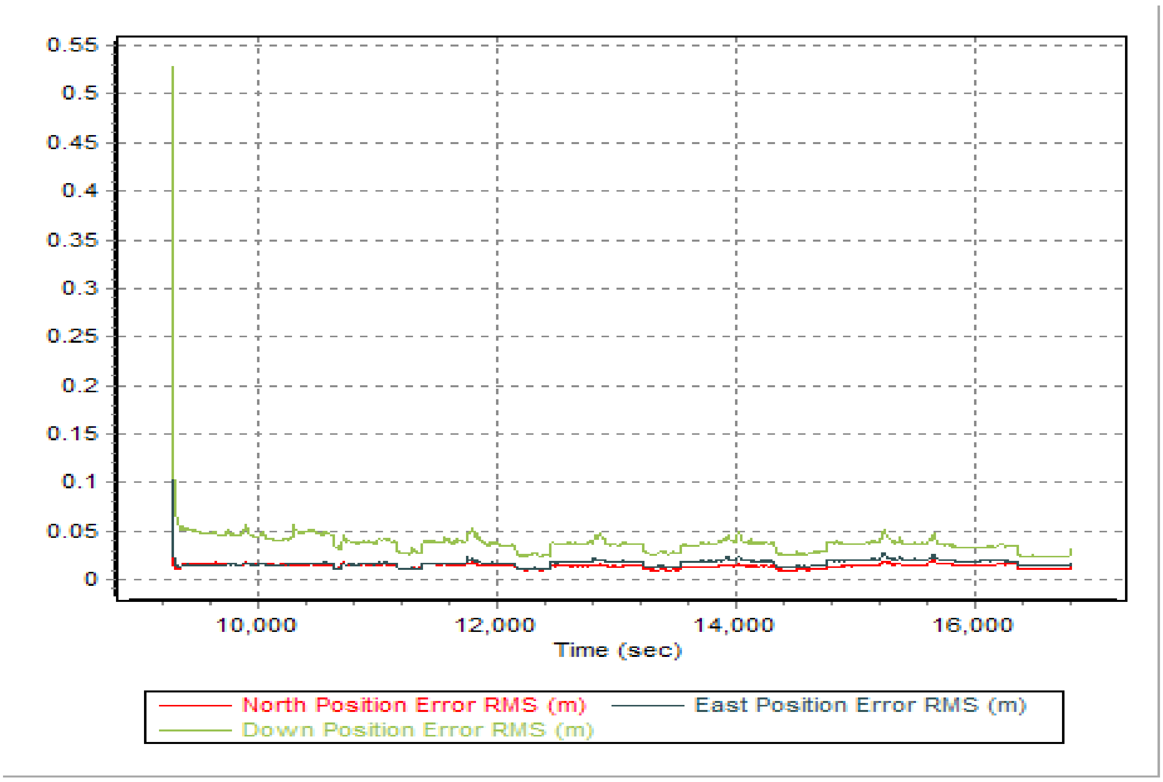


Figure 1.20.2. Smoothed Performance Metric Parameters

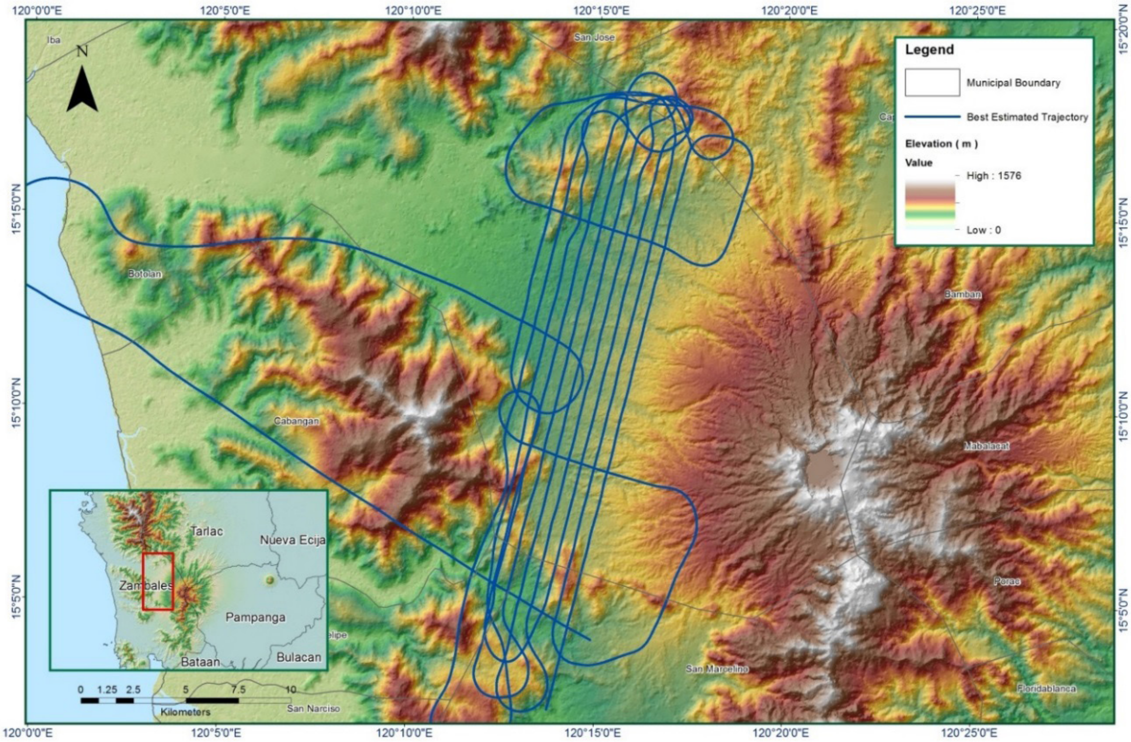


Figure 1.20.3. Best Estimated Trajectory

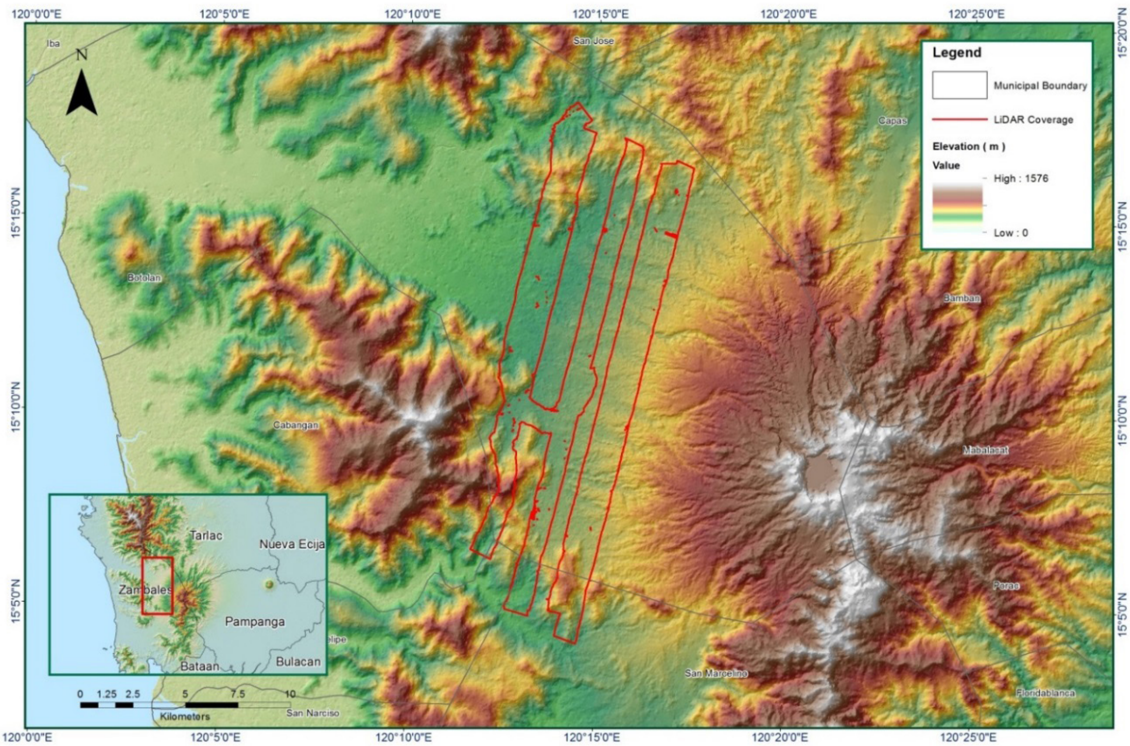


Figure 1.20.4. Coverage of LiDAR Data

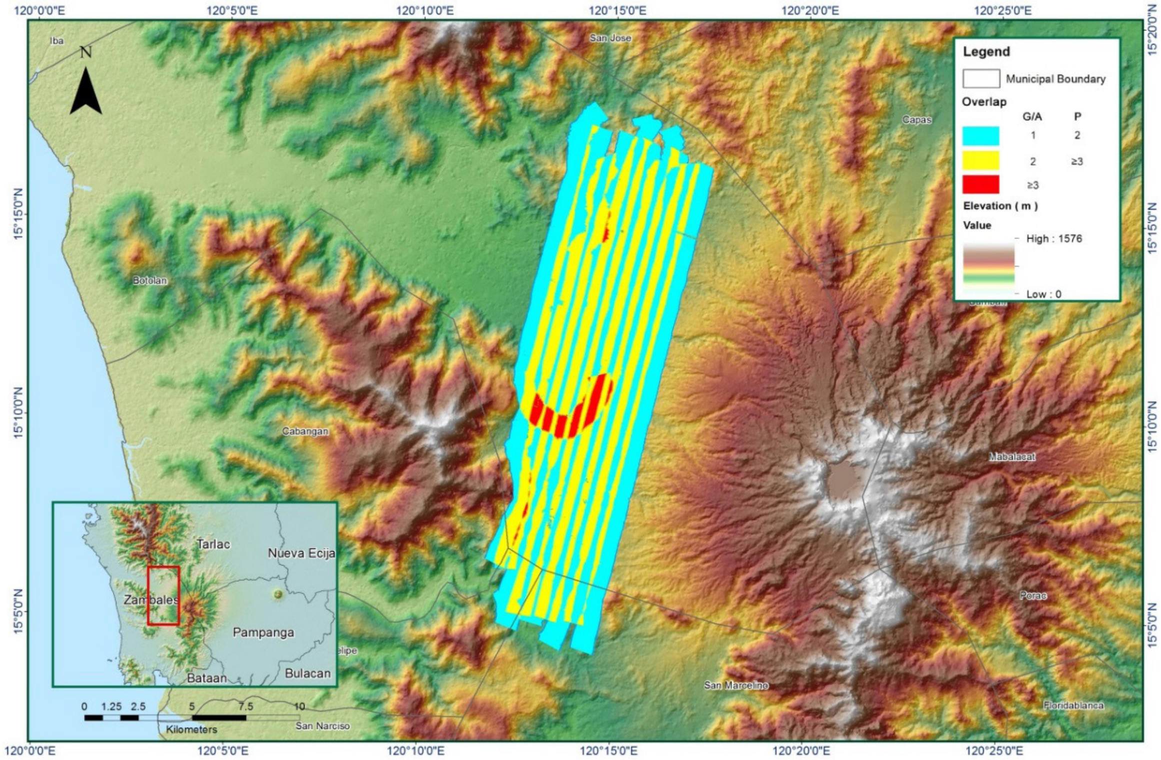


Figure 1.20.5. Image of data overlap

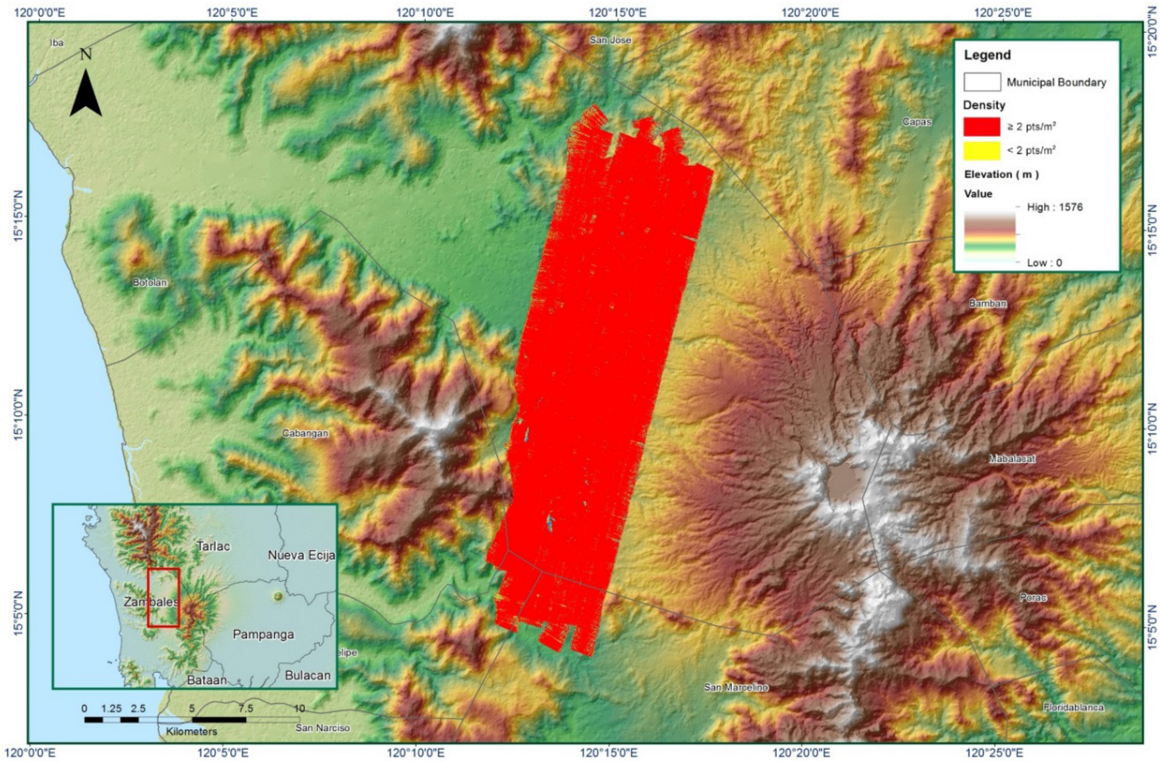


Figure 1.20.6. Density map of merged LiDAR data

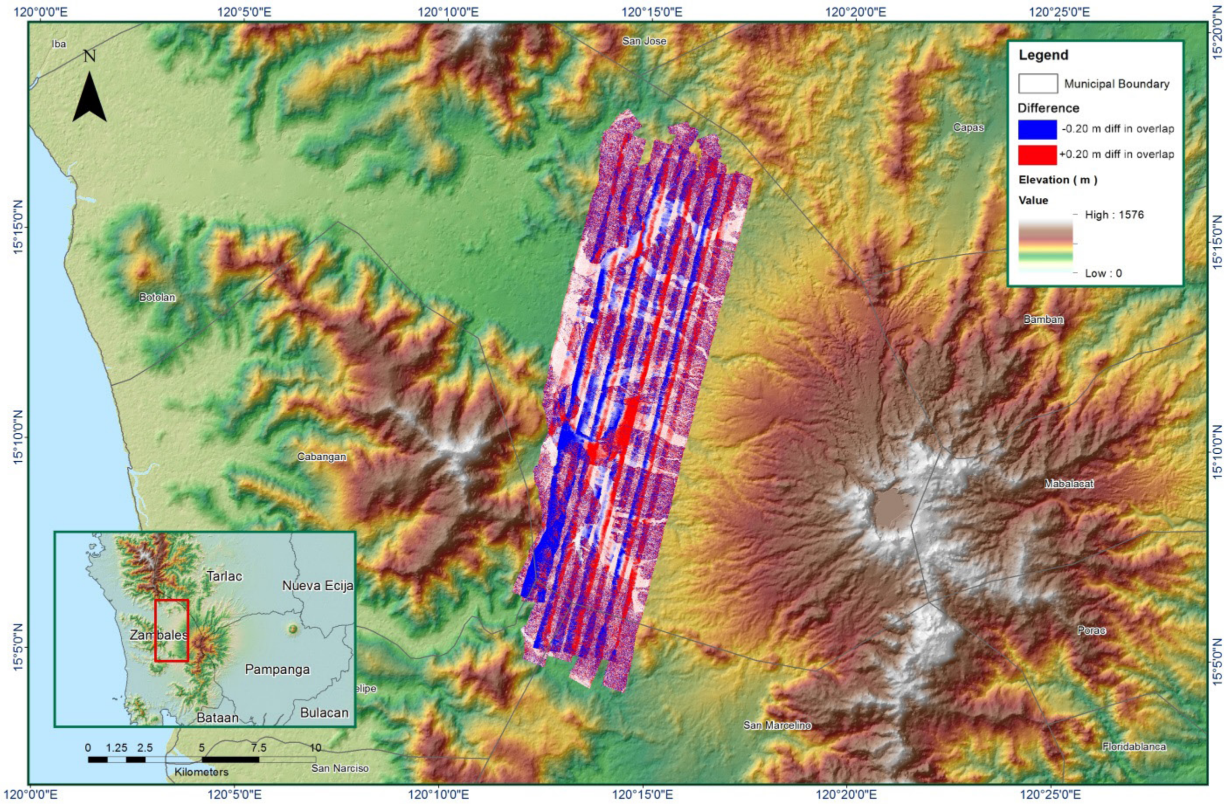


Figure 1.20.7. Elevation difference between flight lines

Annex 9. Bucao Model Basin Parameters

Table A-9.1. Bucao 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
W1000	22.56	83.51616	0	1.619808	1.619808	Discharge	0.291	0.08	Ratio to Peak	0.1
W1010	25.436	81.79704	0	1.78848	1.78848	Discharge	0.094	0.08	Ratio to Peak	0.1
W1020	29.422	79.5288	0	1.216992	1.216992	Discharge	0.398	0.08	Ratio to Peak	0.1
W1030	28.966	79.78152	0	1.973472	1.973472	Discharge	0.96	0.12	Ratio to Peak	0.1
W1040	22.401	83.61288	0	1.179552	1.179552	Discharge	0.317	0.12	Ratio to Peak	0.1
W1050	25.46	81.783	0	2.954784	2.954784	Discharge	1.171	0.08	Ratio to Peak	0.1
W1060	26.877	80.96244	0	1.92768	1.92768	Discharge	2.08	0.08	Ratio to Peak	0.1
W1070	29.9080593	79.26048	0	2.795328	2.795328	Discharge	0.806	0.12058	Ratio to Peak	0.1
W1080	28.782	79.88448	0	1.864992	1.864992	Discharge	0.066	0.08	Ratio to Peak	0.1
W1090	31.463	78.41496	0	5.063616	5.063616	Discharge	1.974	0.12058	Ratio to Peak	0.1
W1100	25.966	81.48816	0	2.48496	2.48496	Discharge	0.903	0.12059	Ratio to Peak	0.1
W1110	23.973	82.66284	0	4.948704	4.948704	Discharge	0.877	0.08	Ratio to Peak	0.1
W1120	20.253	84.94824	0	4.42464	4.42464	Discharge	2.151	0.12058	Ratio to Peak	0.1
W1130	25.556	81.72684	0	2.027616	2.027616	Discharge	0.318	0.08	Ratio to Peak	0.1
W1140	27.651	80.52096	0	5.572128	5.572128	Discharge	1.592	0.08	Ratio to Peak	0.1
W1150	28.366	80.11692	0	1.93344	1.93344	Discharge	0.209	0.08	Ratio to Peak	0.1
W1160	25.3695148	81.83604	0	1.744512	1.744512	Discharge	1.348	0.08	Ratio to Peak	0.1
W1170	27.576	80.56308	0	5.981952	5.981952	Discharge	1.306	0.18	Ratio to Peak	0.1
W1180	25.5	81.7596	0	2.6616	2.6616	Discharge	0.567	0.12056	Ratio to Peak	0.1
W1190	22.621	83.47872	0	3.044736	3.044736	Discharge	0.964	0.12056	Ratio to Peak	0.1

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
W1200	28.972	79.7784	0	1.547904	1.547904	Discharge	0.347	0.18	Ratio to Peak	0.1
W1210	30.096	79.15752	0	2.823744	2.823744	Discharge	1.888	0.08	Ratio to Peak	0.1
W1220	23.967	82.66596	0	3.061344	3.061344	Discharge	0.316	0.12059	Ratio to Peak	0.1
W1230	26.1647651	81.37272	0	11.21952	11.21952	Discharge	1.786	0.12058	Ratio to Peak	0.1
W1240	31.637	78.32136	0	6.033312	6.033312	Discharge	2.41	0.12059	Ratio to Peak	0.1
W1250	23.533	82.92648	0	3.115104	3.115104	Discharge	0.69	0.12059	Ratio to Peak	0.1
W1260	28.2776543	80.16684	0	4.70976	4.70976	Discharge	2.271	0.12059	Ratio to Peak	0.1
W1270	22.188	83.74392	0	1.222656	1.222656	Discharge	0.416	0.08	Ratio to Peak	0.1
W1280	25.189	81.94212	0	1.642368	1.642368	Discharge	1.338	0.11089	Ratio to Peak	0.1
W1290	22.6006554	83.4912	0	2.062944	2.062944	Discharge	1.373	0.12058	Ratio to Peak	0.1
W1300	19.628	85.34448	0	6.037152	6.037152	Discharge	2.063	0.1206	Ratio to Peak	0.1
W1310	26.3454185	81.2682	0	6.04848	6.04848	Discharge	1.502	0.12058	Ratio to Peak	0.1
W1320	23.148	83.15892	0	2.321088	2.321088	Discharge	0.198	0.12059	Ratio to Peak	0.1
W1330	24.908	82.10748	0	4.326624	4.326624	Discharge	0.365	0.12059	Ratio to Peak	0.1
W1340	20.465	84.81408	0	4.165824	4.165824	Discharge	1.706	0.12058	Ratio to Peak	0.1
W1350	21.193	84.35856	0	2.330016	2.330016	Discharge	2.533	0.12056	Ratio to Peak	0.1
W1360	25.797	81.58644	0	1.757568	1.757568	Discharge	0.235	0.12059	Ratio to Peak	0.1
W1370	25.423	81.80484	0	4.137408	4.137408	Discharge	2.74	0.12058	Ratio to Peak	0.1
W1380	25.668	81.66132	0	3.814464	3.814464	Discharge	1.127	0.12059	Ratio to Peak	0.1
W1390	27.045	80.86572	0	1.523328	1.523328	Discharge	0.087	0.12059	Ratio to Peak	0.1
W1400	27.483	80.61612	0	2.494176	2.494176	Discharge	0.823	0.12059	Ratio to Peak	0.1
W1410	33.823	77.1654	0	3.25872	3.25872	Discharge	1.12	0.12059	Ratio to Peak	0.1
W1420	33.322	77.42748	0	2.498592	2.498592	Discharge	0.927	0.12059	Ratio to Peak	0.1

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
W1430	32.927	77.63496	0	0.88368	0.88368	Discharge	0.071	0.1206	Ratio to Peak	0.1
W1440	31.762	78.25428	0	3.561312	3.561312	Discharge	1.651	0.12059	Ratio to Peak	0.1
W1450	31.289	78.50856	0	1.774656	1.774656	Discharge	1.137	0.12059	Ratio to Peak	0.1
W1460	31.451	78.4212	0	2.17056	2.17056	Discharge	0.607	0.12059	Ratio to Peak	0.1
W1470	34.301	76.91736	0	4.142016	4.142016	Discharge	1.872	0.12059	Ratio to Peak	0.1
W1480	30.449	78.96408	0	1.87704	1.87704	Discharge	0.117	0.12059	Ratio to Peak	0.1
W1490	43.302	72.5244	0	4.017216	4.017216	Discharge	0.737	0.12059	Ratio to Peak	0.1
W1500	39.163	74.48064	0	4.407648	4.407648	Discharge	0.973	0.12	Ratio to Peak	0.1
W760	31.981	78.13728	0	2.583264	2.583264	Discharge	2.831	0.12	Ratio to Peak	0.1
W770	30.361	79.01244	0	2.273376	2.273376	Discharge	1.378	0.12	Ratio to Peak	0.1
W780	30.555	78.90636	0	3.652608	3.652608	Discharge	3.081	0.12	Ratio to Peak	0.1
W790	30.538	78.91572	0	3.101664	3.101664	Discharge	1.885	0.12	Ratio to Peak	0.1
W800	31.469	78.41184	0	1.50672	1.50672	Discharge	1.162	0.12	Ratio to Peak	0.1
W810	38.271	74.91588	0	2.043072	2.043072	Discharge	1.729	0.12	Ratio to Peak	0.1
W820	25.837	81.56304	0	3.570336	3.570336	Discharge	2.147	0.12	Ratio to Peak	0.1
W830	29.727	79.36032	0	3.462432	3.462432	Discharge	2.689	0.12	Ratio to Peak	0.1
W840	31.431	78.43212	0	4.7088	4.7088	Discharge	3.411	0.12	Ratio to Peak	0.1
W850	33.874	77.13888	0	1.712448	1.712448	Discharge	1.124	0.12	Ratio to Peak	0.1
W860	25.263	81.89844	0	1.9752	1.9752	Discharge	0.57	0.12	Ratio to Peak	0.1
W870	23.884	82.71588	0	3.454944	3.454944	Discharge	2.323	0.12	Ratio to Peak	0.1
W880	28.907	79.81428	0	1.004928	1.004928	Discharge	0.105	0.12	Ratio to Peak	0.1
W890	31.626	78.3276	0	4.086336	4.086336	Discharge	1.743	0.12	Ratio to Peak	0.1
W900	27.021	80.87976	0	2.332224	2.332224	Discharge	0.571	0.12	Ratio to Peak	0.1

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
W910	31.879	78.19188	0	2.51904	2.51904	Discharge	2.094	0.12	Ratio to Peak	0.1
W920	25.449	81.78924	0	3.525792	3.525792	Discharge	1.421	0.12	Ratio to Peak	0.1
W930	24.0560828	82.61292	0	5.632992	5.632992	Discharge	0.664	0.12	Ratio to Peak	0.1
W940	21.5422433	84.14172	0	1.046016	1.046016	Discharge	0.109	0.12	Ratio to Peak	0.1
W950	26.313	81.28692	0	1.887264	1.887264	Discharge	0.15	0.12	Ratio to Peak	0.1
W960	31.194	78.56004	0	3.608352	3.608352	Discharge	1.404	0.12	Ratio to Peak	0.1
W970	23.821	82.75332	0	2.869248	2.869248	Discharge	0.472	0.12	Ratio to Peak	0.1
W980	24.581	82.30092	0	0.983808	0.983808	Discharge	0.041	0.12	Ratio to Peak	0.1
W990	24.187	82.53492	0	1.076064	1.076064	Discharge	1.077	0.12	Ratio to Peak	0.1

Annex 10. Bucao Model Reach Parameters

Table A-10.1. Bucao Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R100	Automatic Fixed Interval	3477.8	0.01989	0.018	Trapezoid	131.44	1
R120	Automatic Fixed Interval	5717.2	0.00966	0.018	Trapezoid	30.52	1
R140	Automatic Fixed Interval	863.85	0.00547	0.018	Trapezoid	50.05	1
R150	Automatic Fixed Interval	3193.9	0.0072	0.018	Trapezoid	36.54	1
R160	Automatic Fixed Interval	9787.9	0.01991	0.018	Trapezoid	82.8	1
R190	Automatic Fixed Interval	1182.4	0.00757	0.018	Trapezoid	2130	1
R200	Automatic Fixed Interval	621.42	0.00072	0.018	Trapezoid	846	1
R210	Automatic Fixed Interval	594.85	0.00376	0.018	Trapezoid	2381	1
R220	Automatic Fixed Interval	3498.7	0.00277	0.018	Trapezoid	2399	1
R230	Automatic Fixed Interval	2092.3	0.00489	0.018	Trapezoid	1306	1
R250	Automatic Fixed Interval	2563.8	0.00073	0.018	Trapezoid	289.16	1
R260	Automatic Fixed Interval	2320.8	0.00072	0.018	Trapezoid	87.88	1
R280	Automatic Fixed Interval	2022	0.00416	0.018	Trapezoid	1071.92	1
R290	Automatic Fixed Interval	5146.5	0.00407	0.018	Trapezoid	353.77	1
R320	Automatic Fixed Interval	1139.8	0.00446	0.018	Trapezoid	839.71	1
R350	Automatic Fixed Interval	1383.3	0.00097	0.018	Trapezoid	1666.5	1
R360	Automatic Fixed Interval	1541.7	0.01683	0.018	Trapezoid	90.44	1
R370	Automatic Fixed Interval	5039.7	0.01159	0.018	Trapezoid	180.62	1
R380	Automatic Fixed Interval	2235.2	0.00855	0.018	Trapezoid	546.85	1
R400	Automatic Fixed Interval	4547.7	0.00869	0.018	Trapezoid	681.33	1
R420	Automatic Fixed Interval	1852	0.00599	0.018	Trapezoid	220.76	1
R430	Automatic Fixed Interval	6149.4	0.00738	0.018	Trapezoid	462.36	1
R440	Automatic Fixed Interval	1793.1	0.01214	0.018	Trapezoid	196.32	1
R480	Automatic Fixed Interval	8610.5	0.00619	0.018	Trapezoid	515.76	1
R510	Automatic Fixed Interval	2312.7	0.00992	0.018	Trapezoid	30.36	1
R540	Automatic Fixed Interval	7429.3	0.00877	0.018	Trapezoid	1391.69	1
R570	Automatic Fixed Interval	1171.8	0.01232	0.018	Trapezoid	321.12	1
R580	Automatic Fixed Interval	1264	0.00388	0.018	Trapezoid	113.13	1
R590	Automatic Fixed Interval	7739.8	0.02	0.018	Trapezoid	519.28	1
R60	Automatic Fixed Interval	5835.7	0.02438	0.018	Trapezoid	54.9	1
R600	Automatic Fixed Interval	1798.5	0.00689	0.018	Trapezoid	476.94	1
R620	Automatic Fixed Interval	1260.2	0.03956	0.018	Trapezoid	119.99	1
R670	Automatic Fixed Interval	3314.5	0.00962	0.018	Trapezoid	166.91	1
R690	Automatic Fixed Interval	958.82	0.0095	0.018	Trapezoid	263.91	1
R710	Automatic Fixed Interval	3485.9	0.01729	0.018	Trapezoid	567.59	1
R730	Automatic Fixed Interval	1169.7	0.00148	0.018	Trapezoid	45.39	1
R80	Automatic Fixed Interval	768.41	0.03199	0.018	Trapezoid	25.14	1

Annex 11. Bucao Field Validation Points

Table A-11.1 Bucao Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return / Scenario
	Lat	Long					
1	15° 19’ 13.516” N	119° 58’ 19.198” E	0.20	0.30	-0.10	Habagat 2012	5 - Year
2	15° 18’ 38.829” N	120° 2’ 28.840” E	0.30	0.15	0.15	Habagat 2013	5 - Year
3	15° 17’ 36.746” N	120° 4’ 24.313” E	0.22	0.30	-0.08	Habagat 2012	5 - Year
4	15° 18’ 16.631” N	120° 2’ 28.018” E	0.22	0.30	-0.08	Habagat 2012	5 - Year
5	15° 18’ 58.671” N	119° 59’ 36.234” E	0.26	0.30	-0.04	Habagat 2012	5 - Year
6	15° 19’ 13.491” N	119° 59’ 14.550” E	0.27	0.30	-0.03	Habagat 2012	5 - Year
7	15° 18’ 24.525” N	120° 1’ 24.124” E	0.33	0.30	0.03	Kiko 2009	5 - Year
8	15° 17’ 46.496” N	120° 1’ 3.367” E	0.22	0	0.22	None	5 - Year
9	15° 15’ 10.428” N	120° 1’ 25.015” E	0.24	0	0.24	None	5 - Year
10	15° 14’ 13.090” N	120° 0’ 56.347” E	0.20	0	0.20	None	5 - Year
11	15° 19’ 16.583” N	119° 58’ 24.316” E	0.85	0.91	-0.06	Habagat 2012	5 - Year
12	15° 19’ 49.492” N	119° 59’ 3.995” E	0.51	0.61	-0.10	Habagat 2013	5 - Year
13	15° 14’ 19.993” N	120° 0’ 54.442” E	0.79	0.61	0.18	Lando 2015	5 - Year
14	15° 18’ 19.733” N	120° 2’ 56.000” E	0.60	0	0.60	None	5 - Year
15	15° 18’ 46.650” N	120° 2’ 32.761” E	0.57	0.61	-0.04	Habagat 2012	5 - Year
16	15° 18’ 49.164” N	120° 0’ 10.976” E	0.66	0.61	0.05	Habagat 2012	5 - Year
17	15° 18’ 49.295” N	120° 1’ 41.121” E	0.74	0.91	-0.17	Habagat 2012	5 - Year
18	15° 18’ 50.808” N	120° 0’ 53.950” E	0.75	0.61	0.14	Lando 2015	5 - Year
19	15° 19’ 2.154” N	119° 59’ 42.786” E	0.53	0.61	-0.08	Habagat 2012	5 - Year
20	15° 15’ 2.363” N	120° 1’ 15.599” E	0.69	0.61	0.08	Habagat 2013	5 - Year
21	15° 15’ 56.993” N	120° 2’ 11.825” E	2.24	0	2.24	None	5 - Year
22	15° 17’ 0.053” N	120° 4’ 33.066” E	2.21	1.83	0.38	Habagat 2012	5 - Year
23	15° 18’ 49.127” N	119° 59’ 23.032” E	2.02	1.52	0.50	Habagat 2012	5 - Year
24	15° 16’ 32.582” N	120° 0’ 40.397” E	2.10	1.22	0.88	Habagat 2012	5 - Year
25	15° 18’ 21.739” N	120° 0’ 17.562” E	1.93	1.52	0.41	Habagat 2012	5 - Year

26	15° 17' 9.129" N	120° 0' 23.978" E	1.71	1.52	0.19	Kiko 2009	5 - Year
27	15° 17' 9.673" N	120° 1' 21.921" E	1.72	0.91	0.81	Kiko 2009	5 - Year
28	15° 17' 38.193" N	120° 0' 9.089" E	2.00	0.15	1.85	Habagat 2012	5 - Year
29	15° 17' 20.853" N	120° 1' 46.466" E	1.59	1.98	-0.39	Kiko 2009	5 - Year
30	15° 16' 22.847" N	120° 2' 8.693" E	1.63	1.83	-0.20	Habagat 2012	5 - Year

Annex 12. Educational Institutions affected by flooding in Bucao Floodplain

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

Zambales				
Botolan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BANCAL ELEMENTARY SCHOOL 1	Bancal	High	High	High
BANCAL ELEMENTARY SCHOOL 2	Bancal	High	High	High
BANCAL ELEMENTARY SCHOOL 3	Bancal	High	High	High
BANCAL ELEMENTARY SCHOOL 4	Bancal	High	High	High
BANCAL ELEMENTARY SCHOOL 5	Bancal	High	High	High
BANCAL ELEMENTARY SCHOOL 6	Bancal	High	High	High
BANCAL ELEMENTARY SCHOOL 7	Bancal	High	High	High
PAREL ELEMENTARY SCHOOL 1	Bancal	High	High	High
PAREL ELEMENTARY SCHOOL 2	Bancal	High	High	High
BANGAN-CAPAYAWAN ELEMENTARY SCHOOL 1	Bangan	Low	Medium	High
BANGAN-CAPAYAWAN ELEMENTARY SCHOOL 2	Bangan	Low	Medium	High
BANGAN-CAPAYAWAN ELEMENTARY SCHOOL 3	Bangan		Medium	Medium
BANGAN-CAPAYAWAN ELEMENTARY SCHOOL 4	Bangan		Medium	Medium
BANGAN-CAPAYAWAN ELEMENTARY SCHOOL 5	Bangan	Low	Medium	Medium
BANGAN-CAPAYAWAN ELEMENTARY SCHOOL 6	Bangan		Medium	Medium
BANGAN-CAPAYAWAN ELEMENTARY SCHOOL 7	Bangan		Medium	Medium
BANGAN-CAPAYAWAN ELEMENTARY SCHOOL 8	Bangan		Medium	Medium
BANGAN DAY CARE CENTER	Bangan			
BATONLAPOC ELEMENTARY SCHOOL 1	Batonlapoc	Medium	High	High
BATONLAPOC ELEMENTARY SCHOOL 2	Batonlapoc	Medium	High	High
BATONLAPOC ELEMENTARY SCHOOL 3	Batonlapoc	Medium	High	High
BATONLAPOC ELEMENTARY SCHOOL 4	Batonlapoc	Medium	High	High
BATONLAPOC ELEMENTARY SCHOOL 5	Batonlapoc	Medium	High	High
BATONLAPOC ELEMENTARY SCHOOL 6	Batonlapoc	Medium	High	High
LYCEUM OF WESTERN LUZON ZAMBALES 1	Batonlapoc	High	High	High
LYCEUM OF WESTERN LUZON ZAMBALES 2	Batonlapoc	High	High	High
BENEG ELEMENTARY SCHOOL 1	Capayawan	Medium	High	High
BENEG ELEMENTARY SCHOOL 2	Capayawan	Medium	High	High
BENEG ELEMENTARY SCHOOL 3	Capayawan	Medium	High	High
BENEG ELEMENTARY SCHOOL 4	Capayawan	Medium	High	High
BENEG ELEMENTARY SCHOOL 5	Capayawan	Medium	High	High
BENEG ELEMENTARY SCHOOL 6	Capayawan	High	High	High
BENEG ELEMENTARY SCHOOL 7	Capayawan	Medium	High	High
BENEG ELEMENTARY SCHOOL 8	Capayawan	Medium	High	High
CARAEL ELEMENTARY SCHOOL 1	Carael	Medium	High	High
CARAEL ELEMENTARY SCHOOL 2	Carael	Medium	High	High
CARAEL ELEMENTARY SCHOOL 3	Carael	Medium	High	High
CARAEL ELEMENTARY SCHOOL 4	Carael	Medium	High	High

CARAEL ELEMENTARY SCHOOL 5	Carael	Medium	High	High
CARAEL ELEMENTARY SCHOOL 6	Carael	Medium	High	High
CARAEL ELEMENTARY SCHOOL 7	Carael	Medium	High	High
CARAEL ELEMENTARY SCHOOL 8	Carael	Medium	High	High
CARAEL ELEMENTARY SCHOOL 9	Carael	Medium	High	High
DANACBUNGA BRGY DAY CARE	Danacbunga	High	High	High
DANACBUNGA ELEMENTARY SCHOOL 1	Danacbunga	High	High	High
DANACBUNGA ELEMENTARY SCHOOL 2	Danacbunga	High	High	High
DANACBUNGA ELEMENTARY SCHOOL 3	Danacbunga	High	High	High
DANACBUNGA ELEMENTARY SCHOOL 4	Danacbunga	High	High	High
DANACBUNGA ELEMENTARY SCHOOL 5	Danacbunga	High	High	High
DANACBUNGA ELEMENTARY SCHOOL 6	Danacbunga	High	High	High
LOOB-BUNGA ELEMENTARY SCHOOL 1	Mambog	Medium	High	High
LOOB-BUNGA ELEMENTARY SCHOOL 2	Mambog			
LOOB-BUNGA ELEMENTARY SCHOOL 3	Mambog	Medium	Medium	High
LOOB-BUNGA ELEMENTARY SCHOOL 4	Mambog		Medium	Medium
LOOB-BUNGA ELEMENTARY SCHOOL 5	Mambog			
LOOB-BUNGA HIGH SCHOOL 1	Mambog			
LOOB-BUNGA HIGH SCHOOL 10	Mambog			
LOOB-BUNGA HIGH SCHOOL 11	Mambog			
LOOB-BUNGA HIGH SCHOOL 12	Mambog			
LOOB-BUNGA HIGH SCHOOL 13	Mambog			
LOOB-BUNGA HIGH SCHOOL 14	Mambog			
LOOB-BUNGA HIGH SCHOOL 15	Mambog			
LOOB-BUNGA HIGH SCHOOL 16	Mambog			
LOOB-BUNGA HIGH SCHOOL 17	Mambog			
LOOB-BUNGA HIGH SCHOOL 18	Mambog			
LOOB-BUNGA HIGH SCHOOL 19	Mambog			
LOOB-BUNGA HIGH SCHOOL 2	Mambog			
LOOB-BUNGA HIGH SCHOOL 3	Mambog			
LOOB-BUNGA HIGH SCHOOL 4	Mambog			
LOOB-BUNGA HIGH SCHOOL 5	Mambog			
LOOB-BUNGA HIGH SCHOOL 6	Mambog			
LOOB-BUNGA HIGH SCHOOL 7	Mambog			
LOOB-BUNGA HIGH SCHOOL 9	Mambog			
OWAOG-NEBLOC DAY CARE CENTER	Mambog	Medium	Medium	Medium
BOTOLAN COMMUNITY COLLEGE 1	Paco	Medium	High	High
BOTOLAN COMMUNITY COLLEGE 2	Paco	High	High	High
BOTOLAN NATIONAL HIGH SCHOOL 10	Paco	Medium	High	High
BOTOLAN NATIONAL HIGH SCHOOL 2	Paco	Medium	High	High
BOTOLAN NATIONAL HIGH SCHOOL 3	Paco	Medium	High	High
BOTOLAN NATIONAL HIGH SCHOOL 4	Paco	Medium	High	High
BOTOLAN NATIONAL HIGH SCHOOL 5	Paco	Medium	High	High
BOTOLAN NATIONAL HIGH SCHOOL 7	Paco	Medium	High	High
BOTOLAN NATIONAL HIGH SCHOOL 8	Paco	Medium	High	High
BOTOLAN NATIONAL HIGH SCHOOL 9	Paco	Medium	High	High

BOTOLAN NORTH CENTRAL SCHOOL 1	Paco	Medium	High	High
BOTOLAN NORTH CENTRAL SCHOOL 2	Paco	Medium	High	High
BOTOLAN NORTH CENTRAL SCHOOL 3	Paco	Medium	High	High
BOTOLAN NORTH CENTRAL SCHOOL 4	Paco	Medium	High	High
BOTOLAN NORTH CENTRAL SCHOOL 5	Paco	Medium	High	High
BOTOLAN NORTH CENTRAL SCHOOL 6	Paco	Medium	High	High
BOTOLAN NORTH CENTRAL SCHOOL 7	Paco	Medium	High	High
BOTOLAN NORTH CENTRAL SCHOOL 8	Paco	Medium	High	High
BOTOLAN SOUTH CENTRAL SCHOOL 1	Paco	Medium	High	High
BOTOLAN SOUTH CENTRAL SCHOOL 10	Paco	Medium	High	High
BOTOLAN SOUTH CENTRAL SCHOOL 11	Paco	Medium	High	High
BOTOLAN SOUTH CENTRAL SCHOOL 12	Paco	Medium	High	High
BOTOLAN SOUTH CENTRAL SCHOOL 13	Paco	Medium	High	High
BOTOLAN SOUTH CENTRAL SCHOOL 2	Paco	Medium	High	High
BOTOLAN SOUTH CENTRAL SCHOOL 3	Paco	Medium	High	High
BOTOLAN SOUTH CENTRAL SCHOOL 4	Paco	Medium	High	High
BOTOLAN SOUTH CENTRAL SCHOOL 5	Paco	Medium	High	High
BOTOLAN SOUTH CENTRAL SCHOOL 6	Paco	Medium	High	High
BOTOLAN SOUTH CENTRAL SCHOOL 7	Paco	Medium	High	High
BOTOLAN SOUTH CENTRAL SCHOOL 8	Paco	Medium	High	High
BOTOLAN SOUTH CENTRAL SCHOOL 9	Paco	Medium	High	High
PACO BARANGAY DAY CARE	Paco	High	High	High
TAMPO BRGY DAY CARE	Paco	Medium	High	High
MAMBOG ELEMENTARY SCHOOL 1	Parel	Medium	Medium	Medium
MAMBOG ELEMENTARY SCHOOL 2	Parel	Medium	Medium	Medium
MAMBOG ELEMENTARY SCHOOL 3	Parel	Medium	Medium	Medium
MAMBOG ELEMENTARY SCHOOL 4	Parel	Medium	Medium	Medium
MAMBOG ELEMENTARY SCHOOL 5	Parel	Medium	Medium	Medium
MAMBOG ELEMENTARY SCHOOL 6	Parel	Medium	Medium	Medium
MAMBOG ELEMENTARY SCHOOL 7	Parel	Medium	Medium	Medium
MAMBOG ELEMENTARY SCHOOL 8	Parel	Medium	Medium	Medium
DOJOC-BALITE DAY CARE	Paudpod	Medium	High	High
PAUDPOD ELEMENTARY SCHOOL 1	Paudpod	Medium	High	High
PAUDPOD ELEMENTARY SCHOOL 2	Paudpod	Medium	High	High
PAUDPOD ELEMENTARY SCHOOL 3	Paudpod	Medium	High	High
SAN JUAN ELEMENTARY SCHOOL 1	Paudpod	Low	Medium	High
SAN JUAN ELEMENTARY SCHOOL 2	Paudpod		Medium	Medium
SAN JUAN ELEMENTARY SCHOOL 3	Paudpod		Medium	Medium
SAN JUAN ELEMENTARY SCHOOL 4	Paudpod		Medium	Medium
SAN JUAN ELEMENTARY SCHOOL 5	Paudpod		Medium	Medium
SAN JUAN ELEMENTARY SCHOOL 6	Paudpod	Low	Medium	Medium
SAN JUAN ELEMENTARY SCHOOL 7	Paudpod	Low	Medium	High
SAN JUAN ELEMENTARY SCHOOL 8	Paudpod	Low	Medium	High
SAN JUAN ELEMENTARY SCHOOL 9	Paudpod	Low	Medium	High
BINOCLUTAN ELEMENTARY SCHOOL 1	Porac	Low	Low	Medium
BINOCLUTAN ELEMENTARY SCHOOL 2	Porac		Low	Medium

BINOCLUTAN ELEMENTARY SCHOOL 3	Porac		Low	Medium
BINOCLUTAN ELEMENTARY SCHOOL 4	Porac	Low	Low	Medium
BINOCLUTAN ELEMENTARY SCHOOL 5	Porac	Low	Medium	Medium
BUCAO ELEMENTARY SCHOOL 1	Porac			
BUCAO ELEMENTARY SCHOOL 2	Porac			
PORAC ELEMENTARY SCHOOL	Porac		Low	Medium
PORAC ELEMENTARY SCHOOL 2	Porac	Low	Medium	Medium
PORAC ELEMENTARY SCHOOL 3	Porac	Medium	Medium	Medium
PORAC ELEMENTARY SCHOOL 4	Porac	Medium	Medium	Medium
PORAC ELEMENTARY SCHOOL 5	Porac	Low	Medium	Medium
RMTU FACILITY 1	Porac			
RMTU FACILITY 10	Porac			
RMTU FACILITY 11	Porac			
RMTU FACILITY 12	Porac			
RMTU FACILITY 13	Porac			
RMTU FACILITY 14	Porac			
RMTU FACILITY 15	Porac			
RMTU FACILITY 16	Porac			
RMTU FACILITY 17	Porac			
RMTU FACILITY 18	Porac	Medium	Medium	Medium
RMTU FACILITY 19	Porac	Medium	Medium	Medium
RMTU FACILITY 2	Porac			
RMTU FACILITY 20	Porac	Medium	Medium	Medium
RMTU FACILITY 21	Porac	Medium	Medium	Medium
RMTU FACILITY 22	Porac	Medium	Medium	Medium
RMTU FACILITY 23	Porac	Low	Medium	Medium
RMTU FACILITY 3	Porac			
RMTU FACILITY 4	Porac	Low	Low	Low
RMTU FACILITY 5	Porac			
RMTU FACILITY 6	Porac			
RMTU FACILITY 7	Porac			
RMTU FACILITY 8	Porac			
RMTU FACILITY 9	Porac			
SAN ISIDRO ELEMENTARY SCHOOL 1	San Isidro	Medium	Medium	Medium
SAN ISIDRO ELEMENTARY SCHOOL 2	San Isidro	Medium	Medium	Medium
SAN ISIDRO ELEMENTARY SCHOOL 3	San Isidro	Medium	Medium	Medium
SAN ISIDRO ELEMENTARY SCHOOL 4	San Isidro	Medium	Medium	Medium
SAN ISIDRO ELEMENTARY SCHOOL 5	San Isidro	Low	Medium	Medium
BAQUILAN RESETTLEMENT HIGH SCHOOL 1	San Juan			
BAQUILAN RESETTLEMENT HIGH SCHOOL 2	San Juan			
BAQUILAN RESETTLEMENT HIGH SCHOOL 3	San Juan			
BAQUILAN RESETTLEMENT HIGH SCHOOL 4	San Juan			
BAQUILAN RESETTLEMENT SCHOOL 1	San Juan			
BAQUILAN RESETTLEMENT SCHOOL 10	San Juan			
BAQUILAN RESETTLEMENT SCHOOL 11	San Juan			
BAQUILAN RESETTLEMENT SCHOOL 12	San Juan			

BAQUILAN RESETTLEMENT SCHOOL 13	San Juan			
BAQUILAN RESETTLEMENT SCHOOL 2	San Juan			
BAQUILAN RESETTLEMENT SCHOOL 3	San Juan			
BAQUILAN RESETTLEMENT SCHOOL 4	San Juan			
BAQUILAN RESETTLEMENT SCHOOL 5	San Juan			
BAQUILAN RESETTLEMENT SCHOOL 6	San Juan			
BAQUILAN RESETTLEMENT SCHOOL 7	San Juan			
BAQUILAN RESETTLEMENT SCHOOL 8	San Juan			
BAQUILAN RESETTLEMENT SCHOOL 9	San Juan			
NEW TAUGTOG ELEMENTARY SCHOOL 1	Taugtog		Low	Low
NEW TAUGTOG ELEMENTARY SCHOOL 10	Taugtog	Low	Low	Low
NEW TAUGTOG ELEMENTARY SCHOOL 11	Taugtog	Low	Low	Low
NEW TAUGTOG ELEMENTARY SCHOOL 12	Taugtog	Low	Low	Low
NEW TAUGTOG ELEMENTARY SCHOOL 13	Taugtog	Low	Low	Low
NEW TAUGTOG ELEMENTARY SCHOOL 2	Taugtog		Low	Low
NEW TAUGTOG ELEMENTARY SCHOOL 4	Taugtog	Low	Low	Low
NEW TAUGTOG ELEMENTARY SCHOOL 5	Taugtog		Low	Low
NEW TAUGTOG ELEMENTARY SCHOOL 6	Taugtog		Low	Low
NEW TAUGTOG ELEMENTARY SCHOOL 7	Taugtog		Low	Low
NEW TAUGTOG ELEMENTARY SCHOOL 8	Taugtog		Low	Low
NEW TAUGTOG ELEMENTARY SCHOOL 9	Taugtog			
NEW TAUGTOG NATIONAL HIGH SCHOOL 1	Taugtog	Low	Low	Low
NEW TAUGTOG NATIONAL HIGH SCHOOL 10	Taugtog	Low	Medium	Medium
NEW TAUGTOG NATIONAL HIGH SCHOOL 11	Taugtog	Low	Medium	Medium
NEW TAUGTOG NATIONAL HIGH SCHOOL 12	Taugtog	Low	Low	Low
NEW TAUGTOG NATIONAL HIGH SCHOOL 13	Taugtog	Low	Low	Low
NEW TAUGTOG NATIONAL HIGH SCHOOL 2	Taugtog	Low	Low	Low
NEW TAUGTOG NATIONAL HIGH SCHOOL 3	Taugtog			
NEW TAUGTOG NATIONAL HIGH SCHOOL 4	Taugtog			
NEW TAUGTOG NATIONAL HIGH SCHOOL 5	Taugtog		Low	Low
NEW TAUGTOG NATIONAL HIGH SCHOOL 6	Taugtog	Low	Low	Low
NEW TAUGTOG NATIONAL HIGH SCHOOL 7	Taugtog	Low	Low	Low
NEW TAUGTOG NATIONAL HIGH SCHOOL 8	Taugtog	Low	Low	Low
NEW TAUGTOG NATIONAL HIGH SCHOOL 9	Taugtog	Low	Low	Medium
TAUGTOG DAY CARE CENTER	Taugtog	Medium	Medium	Medium

Table A-12.2. Educational Institutions in Iba, Zambales affected by flooding in Bucao Floodplain

Iba				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
LITTLE BAGUIO ELEMENTARY SCHOOL 2	Bangantalinga			
LITTLE BAGUIO ELEMENTARY SCHOOL 3	Bangantalinga			
LITTLE BAGUIO ELEMENTARY SCHOOL 4	Bangantalinga			
LITTLE BAGUIO ELEMENTARY SCHOOL 5	Bangantalinga			
DIRITA-BALOGUEN ELEMENTARY SCHOOL 1	Dirita-Baloguen		Low	Low

DIRITA-BALOGUEN ELEMENTARY SCHOOL 2	Dirita-Baloguen		Low	Medium
DIRITA-BALOGUEN ELEMENTARY SCHOOL 3	Dirita-Baloguen		Low	Medium
DIRITA-BALOGUEN ELEMENTARY SCHOOL 4	Dirita-Baloguen		Low	Medium
DIRITA-BALOGUEN ELEMENTARY SCHOOL 5	Dirita-Baloguen		Low	Medium
DIRITA-BALOGUEN ELEMENTARY SCHOOL 6	Dirita-Baloguen		Low	Low
IBA CHRISTIAN ACADEMY 1	Dirita-Baloguen	Medium	Medium	Medium
IBA CHRISTIAN ACADEMY 2	Dirita-Baloguen	Medium	Medium	Medium
LIPAY-DINGIN-PANIBUATAN BRGY DAY CARE CENTER	Lipay-Dingin-Panibuatan	Medium	Medium	Medium
LIPAY DINGGIN ELEMENTARY SCHOOL 1	Lipay-Dingin-Panibuatan	High	High	High
LIPAY DINGGIN ELEMENTARY SCHOOL 10	Lipay-Dingin-Panibuatan	High	High	High
LIPAY DINGGIN ELEMENTARY SCHOOL 11	Lipay-Dingin-Panibuatan	High	High	High
LIPAY DINGGIN ELEMENTARY SCHOOL 12	Lipay-Dingin-Panibuatan	High	High	High
LIPAY DINGGIN ELEMENTARY SCHOOL 2	Lipay-Dingin-Panibuatan	High	High	High
LIPAY DINGGIN ELEMENTARY SCHOOL 3	Lipay-Dingin-Panibuatan	High	High	High
LIPAY DINGGIN ELEMENTARY SCHOOL 4	Lipay-Dingin-Panibuatan	High	High	High
LIPAY DINGGIN ELEMENTARY SCHOOL 5	Lipay-Dingin-Panibuatan	High	High	High
LIPAY DINGGIN ELEMENTARY SCHOOL 6	Lipay-Dingin-Panibuatan	High	High	High
LIPAY DINGGIN ELEMENTARY SCHOOL 7	Lipay-Dingin-Panibuatan	High	High	High
LIPAY DINGGIN ELEMENTARY SCHOOL 8	Lipay-Dingin-Panibuatan	High	High	High
LIPAY DINGGIN ELEMENTARY SCHOOL 9	Lipay-Dingin-Panibuatan	High	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COLLEGE OF LAW/OSA	Lipay-Dingin-Panibuatan	Low	Low	Medium
ZAMBALES NATIONAL HIGH SCHOOL 8	Lipay-Dingin-Panibuatan			Low
ZAMBALES NATIONAL HIGH SCHOOL 9	Lipay-Dingin-Panibuatan	Low	Low	Medium
PAULO ABASTILLAS SENIOR MEMORIAL ELEMENTARY SCHOOL	Palanginan	Low	Low	Low
PAULO ABASTILLAS SENIOR MEMORIAL ELEMENTARY SCHOOL COMPOUND BLDG 1	Palanginan	Low	Low	Low
PAULO ABASTILLAS SENIOR MEMORIAL ELEMENTARY SCHOOL COMPOUND BLDG 2	Palanginan	Low	Low	Low

PAULO ABASTILLAS SENIOR MEMORIAL ELEMENTARY SCHOOL COMPOUND BLDG 3	Palanginan	Low	Low	Low
PAULO ABASTILLAS SENIOR MEMORIAL ELEMENTARY SCHOOL COMPOUND BLDG 4	Palanginan	Low	Low	Low
PAULO ABASTILLAS SENIOR MEMORIAL ELEMENTARY SCHOOL COMPOUND BLDG 5	Palanginan	Low	Low	Low
PAULO ABASTILLAS SENIOR MEMORIAL ELEMENTARY SCHOOL COMPOUND BLDG 6	Palanginan	Low	Low	Low
PAULO ABASTILLAS SENIOR MEMORIAL ELEMENTARY SCHOOL COMPOUND BLDG 7	Palanginan	Low	Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY ADMINISTRATION BLDG	Palanginan			Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY CANTEEN	Palanginan	High	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY CCIT/COLLEGE OF NURSING	Palanginan	Medium	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COLLEGE OF ARTS AND SCIENCE	Palanginan		Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COLLEGE OF EDUCATION	Palanginan		Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COLLEGE OF ENGINEERING	Palanginan	Low	Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COLLEGE OF LAW/OSA	Palanginan	Low	Low	Medium
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COLLEGE OF P.E./GYMNASIUM	Palanginan	Medium	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 1	Palanginan	Medium	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 10	Palanginan	Low	Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 16	Palanginan	Low	Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 17	Palanginan	Low	Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 18	Palanginan	Low	Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 19	Palanginan	Low	Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 2	Palanginan	Medium	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 20	Palanginan	Low	Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 21	Palanginan	Low	Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 24	Palanginan		Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 25	Palanginan	Medium	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 26	Palanginan	Medium	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 27	Palanginan	Medium	High	High

RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 28	Palanginan	Medium	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 29	Palanginan	High	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 3	Palanginan	Medium	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 30	Palanginan		Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 31	Palanginan		Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 33	Palanginan		Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 34	Palanginan		Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 35	Palanginan	Low	Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 36	Palanginan			
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 37	Palanginan			
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 38	Palanginan	Medium	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 4	Palanginan	Medium	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 5	Palanginan			
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 6	Palanginan			
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 7	Palanginan	High	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 8	Palanginan	High	High	High
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 9	Palanginan			Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY CTHHRM BLDG	Palanginan		Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY FARMERS' INFORMATION AND TECHNOLOGY SERVICES	Palanginan			Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY GRADUATE SCHOOL BLDG	Palanginan		Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY MEDICAL AND DENTAL CLINIC	Palanginan		Low	Low
MICRO ASIA COLLEGE OF SCIENCE AND TECHNOLOGY COMPOUND BLDG 2	Santo Rosario	Low	Low	Medium
MICRO ASIA COLLEGE OF SCIENCE AND TECHNOLOGY COMPOUND BLDG 3	Santo Rosario	Low	Low	Medium
LIBABA ELEMENTARY SCHOOL 2	Zone 1 Poblacion			
LIBABA ELEMENTARY SCHOOL 3	Zone 1 Poblacion			
LIBABA ELEMENTARY SCHOOL 4	Zone 1 Poblacion			

LIBABA ELEMENTARY SCHOOL 1	Zone 2 Poblacion			
LIBABA ELEMENTARY SCHOOL 2	Zone 2 Poblacion			
LIBABA ELEMENTARY SCHOOL 4	Zone 2 Poblacion			
LIBABA ELEMENTARY SCHOOL 5	Zone 2 Poblacion			
SAINT AGUSTINE'S SCHOOL	Zone 2 Poblacion		Low	Low
CHALLENGER MONTESSORI SCHOOL, INC. 1	Zone 3 Poblacion			
CHALLENGER MONTESSORI SCHOOL, INC. 2	Zone 3 Poblacion			
CHALLENGER MONTESSORI SCHOOL, INC. 3	Zone 3 Poblacion			
CHALLENGER MONTESSORI SCHOOL, INC. 4	Zone 3 Poblacion			
CHALLENGER MONTESSORI SCHOOL, INC. 5	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 1	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 10	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 11	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 12	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 13	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 14	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 15	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 16	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 17	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 18	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 19	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 2	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 20	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 21	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 22	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 3	Zone 3 Poblacion			

IBA CENTRAL SCHOOL 4	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 5	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 6	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 7	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 8	Zone 3 Poblacion			
IBA CENTRAL SCHOOL 9	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 1	Zone 3 Poblacion			Low
ZAMBALES NATIONAL HIGH SCHOOL 10	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 11	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 12	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 13	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 14	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 15	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 16	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 17	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 18	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 19	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 20	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 21	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 22	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 23	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 24	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 25	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 26	Zone 3 Poblacion			Low
ZAMBALES NATIONAL HIGH SCHOOL 27	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 28	Zone 3 Poblacion			

ZAMBALES NATIONAL HIGH SCHOOL 29	Zone 3 Poblacion	Low	Low	Low
ZAMBALES NATIONAL HIGH SCHOOL 3	Zone 3 Poblacion		Low	Low
ZAMBALES NATIONAL HIGH SCHOOL 4	Zone 3 Poblacion			Low
ZAMBALES NATIONAL HIGH SCHOOL 5	Zone 3 Poblacion			Low
ZAMBALES NATIONAL HIGH SCHOOL 6	Zone 3 Poblacion			Low
ZAMBALES NATIONAL HIGH SCHOOL 7	Zone 3 Poblacion			Low
ZAMBALES NATIONAL HIGH SCHOOL 8	Zone 3 Poblacion			
ZAMBALES NATIONAL HIGH SCHOOL 9	Zone 3 Poblacion	Low	Low	Low
IBA KIDDIELAND MONTESSORI SCHOOL, INC. 1	Zone 4 Poblacion		Low	Low
IBA KIDDIELAND MONTESSORI SCHOOL, INC. 10	Zone 4 Poblacion	Low	Low	Low
IBA KIDDIELAND MONTESSORI SCHOOL, INC. 2	Zone 4 Poblacion	Low	Low	Low
IBA KIDDIELAND MONTESSORI SCHOOL, INC. 3	Zone 4 Poblacion	Low	Low	Low
IBA KIDDIELAND MONTESSORI SCHOOL, INC. 4	Zone 4 Poblacion		Low	Low
IBA KIDDIELAND MONTESSORI SCHOOL, INC. 5	Zone 4 Poblacion	Low	Low	Low
IBA KIDDIELAND MONTESSORI SCHOOL, INC. 6	Zone 4 Poblacion	Low	Low	Low
IBA KIDDIELAND MONTESSORI SCHOOL, INC. 7	Zone 4 Poblacion		Low	Low
IBA KIDDIELAND MONTESSORI SCHOOL, INC. 8	Zone 4 Poblacion	Low	Low	Low
IBA KIDDIELAND MONTESSORI SCHOOL, INC. 9	Zone 4 Poblacion		Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 11	Zone 4 Poblacion		Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 12	Zone 4 Poblacion		Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 13	Zone 4 Poblacion			Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 21	Zone 4 Poblacion	Low	Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY COMPOUND BLDG 23	Zone 4 Poblacion	Low	Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY CTHHRM BLDG	Zone 4 Poblacion		Low	Low
RAMON MAGSAYSAY TECHNOLOGICAL UNIVERSITY GRADUATE SCHOOL BLDG	Zone 4 Poblacion		Low	Low
ZAMBALES NATIONAL HIGH SCHOOL 1	Zone 4 Poblacion		Low	Low

ZAMBALES NATIONAL HIGH SCHOOL 2	Zone 4 Poblacion		Low	Low
ZAMBALES NATIONAL HIGH SCHOOL 29	Zone 4 Poblacion			

Annex 13. Health Institutions affected by flooding in Bucao Floodplain

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

Zambales				
Iba				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL	Palanginan		Low	Low
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 1	Palanginan		Low	Low
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 10	Palanginan			
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 11	Palanginan	Medium	High	High
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 12	Palanginan	Medium	High	High
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 13	Palanginan			Low
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 14	Palanginan			Low
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 15	Palanginan	Medium	Medium	High
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 16	Palanginan	Medium	Medium	High
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 17	Palanginan	Medium	Medium	High
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 18	Palanginan	Medium	Medium	High
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 19	Palanginan	Low	Medium	High
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 2	Palanginan			Low
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 20	Palanginan		Low	Low
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 21	Palanginan		Low	Low
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 3	Palanginan			
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 4	Palanginan			
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 5	Palanginan			
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 6	Palanginan			Low
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 7	Palanginan			
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 8	Palanginan	Medium	High	High
PRESIDENT RAMON MAGSAYSAY MEMORIAL HOSPITAL COMPOUND BLDG 9	Palanginan			
STA. CECILIA MEDICAL CENTER	Zone 5 Poblacion	Low	Low	Medium