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

LiDAR Surveys and Flood Mapping of Balanga River

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

APRIL 2017

Published by the UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines – Diliman
Quezon City
1101 PHILIPPINES

This research project is supported by the Department of Science and Technology (DOST) as part of its Grants-in-Aid (GIA) Program and is to be cited as:

E. C. Paringit and A. M. Paz-Alberto (eds.) (2017), LiDAR Surveys and Flood Mapping of Balanga River, Quezon City: University of the Philippines Training Center on Applied Geodesy and Photogrammetry-217pp.

For questions/queries regarding this report, contact:

Dr. Annie Melinda Paz-Alberto
Project Leader, Phil-LiDAR 1 Program
Central Luzon State University
Science City of Muñoz, Nueva Ecija Philippines 3120
E-mail: melindapaz@gmail.com

Enrico C. Paringit, Dr. Eng.
Program Leader, Phil-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

National Library of the Philippines
ISBN: 978-621-430-001-3

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
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
Photo-grammetry	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 BALANGA RIVER

1.1 Background of the Phil-LiDAR 1 Program

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

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

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 Balanga River Basin

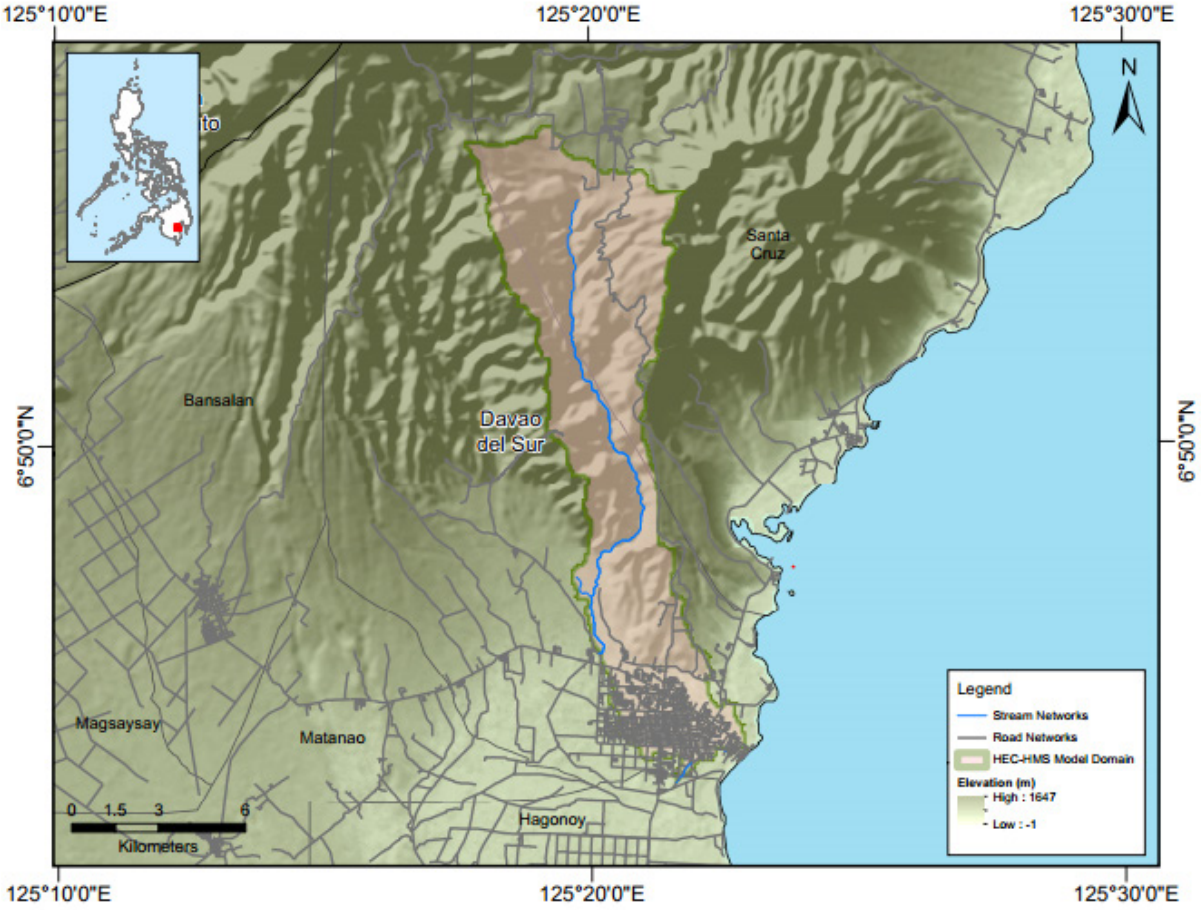


Figure 1. Map of Balanga River Basin.

Talisay River Basin covers Balanga City and three (3) municipalities in Bataan namely: Abucay, Bagac and Pilar. The DENR River Basin Control Office identified the basin to have a drainage area of 144 km2 and an estimated 161 million cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, the Talisay River, is part of the river systems in the Central Luzon Region. According to the 2015 national census of NSO, a total of 50,096persons are residing within the immediate vicinity of the river which is distributed among nine barangays in Balanga City and five barangays in Municipality of Pilar. Majority of the families in the area depend their livelihood to agriculture and fisheries industries. The city is also the center for trade, commerce, services and education in the Province of Bataan. There were severe floods on August 2012 and 2013 which were both brought by the southwest monsoon. This year, 66 families were evacuated due to rising floodwaters caused by the monsoon (http://newsinfo.inquirer.net/805909/villagers-in-5-provinces-suffer-from-flooding, 2016; http://www.manilatimes.net/balanga-city-drafts-flood-control-plan/65550/, 2014).

CHAPTER 2. LIDAR ACQUISITION OF THE BALANGA FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Christopher L. Joaquin, Ms. Jasmin M. Domingo

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 Balanga floodplain in Bataan. These missions were planned for ten (10) 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 Table 1 and Table 2. Figure 2 and Figure 3show the flight plans and base stations used for Balanga floodplain survey.

Table 1. Flight planning parameters for Pegasus 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)
BAL A	1000	30	50	200	30	130	5
BAL B	1000	30	50	150	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)
BAL B	1000	30	40	100	50	130	5
BTN A	1100	30	40	100	50	130	5
BTN B	1100	30	40	100	50	130	5
BLK 15	800	30	50	125	40	130	5
PAM S1	800	30	50	100	40	130	5
PAM S3	800	30	50	100	40	130	5

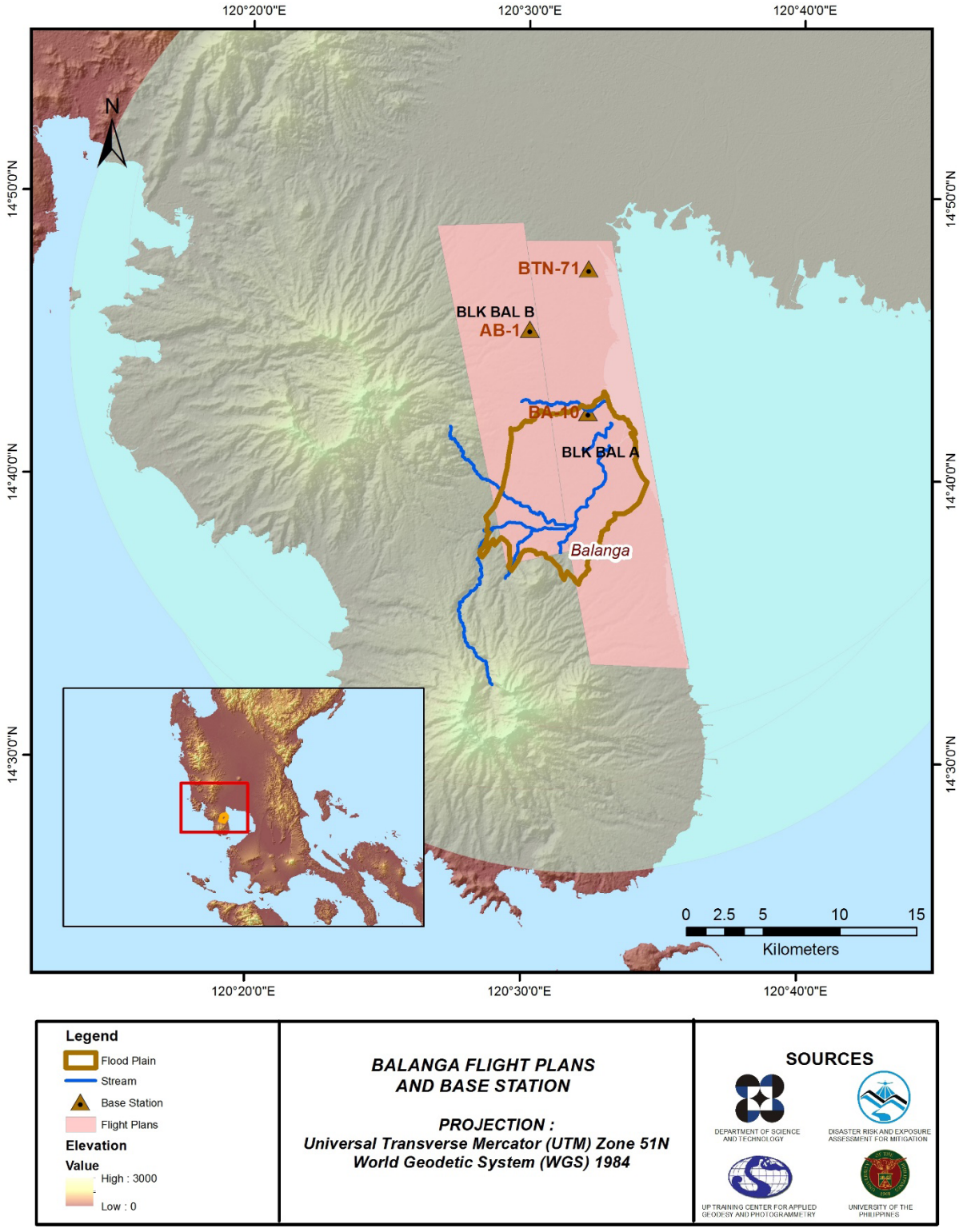


Figure 2. Flight plans and base stations used for Balanga floodplain survey using Pegasus Sensor

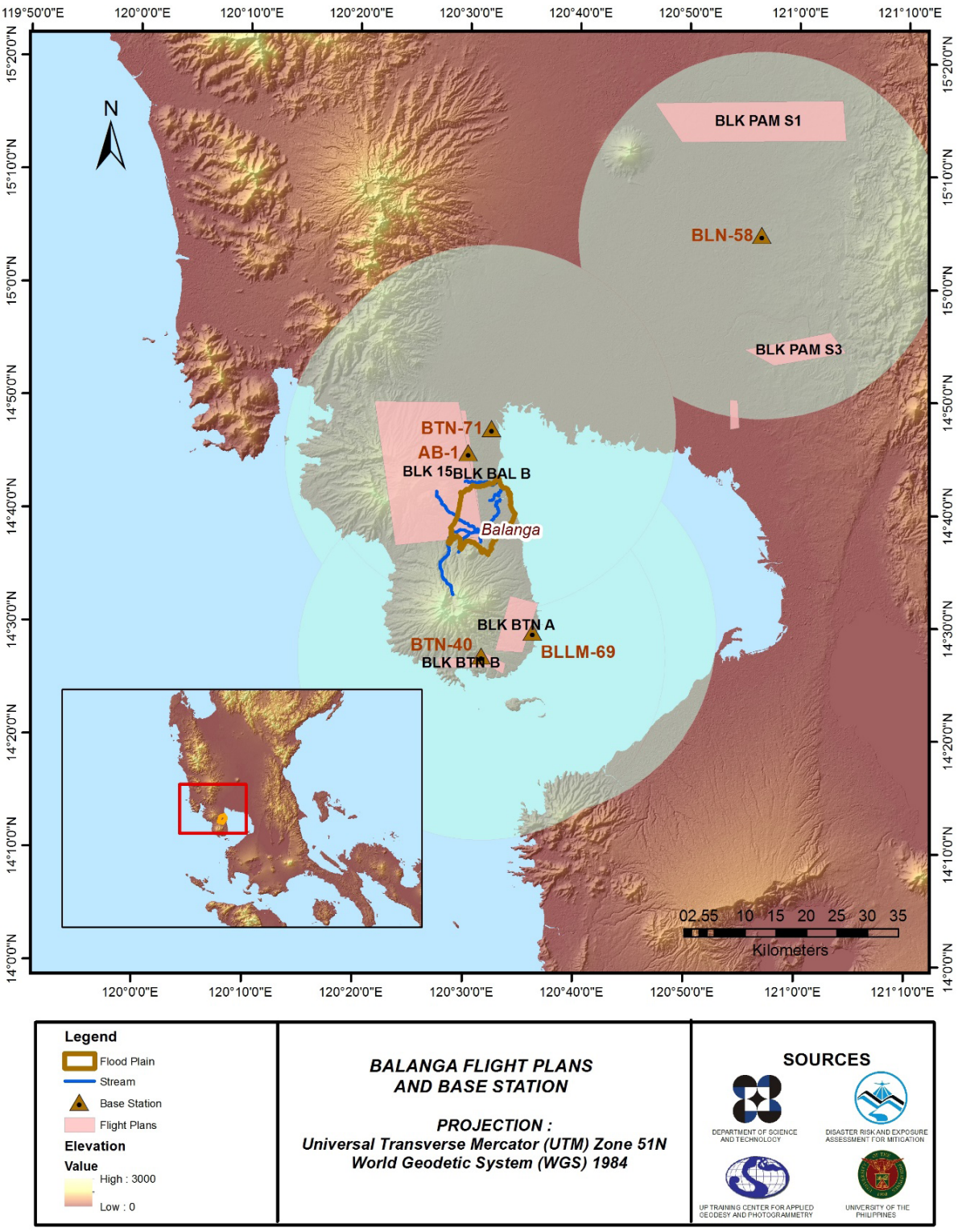


Figure 3. Flight plans and base stations used for Balanga floodplain using Gemini Sensor

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA horizontal ground control points: BTN-71and BLN-58 which are both of second (2nd) order accuracy. The project team also established one ground control point (AB-1). One (1) NAMRIA benchmark was recovered (BA-10). This benchmark was used as vertical reference point and was also established as ground control point. 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 9, 2014; May 20-25, 2014 and August 26, 2015). Base stations were observed using dual frequency GPS receivers:TOPCON GR5, TRIMBLE SPS852, and TRIMBLE SPS985. Flight plans and location of base stations used during the aerial LiDAR Acquisition in Balangafloodplain are shown in Figure 2 and Figure 3.

Figure 4 to Figure 5 show the recovered NAMRIA reference points within the area. In addition, Table 3 to Table 8show the details about the following NAMRIA control stations and established points, whileTable 9 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

(a)

(b)

Figure 4. 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 3. 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	2nd	
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

(a) (b)

Figure 5. GPS set-up over BTN-40situated adjacent to Kilometer Post No. 7 in Barangay Sisiman, Municipality of Mariveles, Bataan (a) and NAMRIA reference point BTN-40 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point BTN-40 used as base station for the LiDAR acquisition.

Station Name	BTN-40	
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° 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 5. Details of the recovered NAMRIA horizontal control point BLN-58 used as base station for the LiDAR acquisition.

Station Name	BLN-58	
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°04' 50.28672" North 120°56' 35.59715" East 24.21800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	493895.954 meters 1667726.854 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	15°04' 44.75323" North 120° 56' 40.45054" East 66.23600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	278,919.72 meters 1,668,175.07 meters

Table 6. 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	231096.890 meters
	Northing	1632616.365 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	14°45' 14.54340" North
	Longitude	120° 30' 08.19305" East
	Ellipsoidal Height	108.361 meters

Table 7. Details of the established NAMRIA horizontal control point BA-10 used as base station for the LiDAR acquisition.

Station Name	BA-10	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	14° 42' 24.60522" North
	Longitude	120° 32' 11.54465" East
	Ellipsoidal Height	14.871 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	234727.081 meters
	Northing	1627249.500 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	14° 42' 19.12527" North
	Longitude	120° 32' 16.43182" East
	Ellipsoidal Height	56.977 meters

Table 8. Details of the established NAMRIA horizontal control point BLLM-69 used as base station for the LiDAR acquisition.

Station Name	BLLM-69	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	14° 29' 28.60103" North
	Longitude	120° 36' 03.06232" East
	Ellipsoidal Height	25.701 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	241403.878 meters
	Northing	1603317.085 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	14° 29' 23.17631" North
	Longitude	120° 36' 07.96757" East
	Ellipsoidal Height	68.576 meters

Table 9. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
December 27, 2013	925P	1BALA361B	BTN-71 and AB-1
December 28, 2013	929P	1BALAS362B	BTN-71 and AB-1
December 29, 2013	924G	2BALB363B	BTN-71 and AB-1
January 2, 2014	935P	1BALAS002A	BTN-71 and BA-10
January 9, 2014	963P	1BALBS009A	BTN-71 and BA-10
May 20, 2014	7260GC	2BLK15S140A	BTN-40 and BLLM-69
May 25, 2014	7271GC	2PAMS1S3145B	BLN-58
August 26, 2015	2656G	2BTNAB238B	BTN-40 and BLLM-69

2.3Flight Missions

Eight (8) missions were conducted to complete LiDAR data acquisition in Balanga Floodplain, for a total of twenty six hours and fifteen minutes (26+15) of flying time for RP-C9022 and RP-9322. All missions were acquired using Pegasus and GeminiLiDAR systems. Table 10 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 11 presents the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions for LiDAR data acquisition in Balanga 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	925P	179.56	19.7	0.09	19.61	0	1	59
December 28, 2013	929P	179.56	119.41	21.58	97.83	0	3	29
December 29, 2013	924G	108.40	119.09	25.81	93.28	419	3	28
January 2, 2014	935P	179.56	95.46	27.63	67.83	0	4	23
January 9, 2014	963P	108.40	53.53	18.84	34.69	0	2	23
May 20, 2014	7260GC	322.64	105.15	28.03	77.12	0	3	11
May 25, 2014	7271GC	234.86	156.11	0	156.11	0	3	59

August 26, 2015	2656G	51.60	71.44	0	71.44	197	3	23
TOTAL		1364.58	804.28	122.02	682.26	616	26	15

Table 11. 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)**
925P	1000	30	50	200	30	130	5
929P	1000	30	50	200	30	130	5
924G	1000	30	40	100	50	130	5
935P	1200	30	50	150	30	130	5
963P	1000	30	50	200	30	130	5
7260GC	800	30	50	125	40	130	5
7271GC	800	30	50	100	40	130	5
2656G	1100	30	40	100	50	130	5

2.4Survey Coverage

Balanga floodplain is located in the province of Bataan. Majority of the floodplain is situated in the city of Balanga and municipality of Pilar. Municipalities of Abucay, Balanga City, Mariveles, Orion, and Hermosa 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 12. The actual coverage of the LiDAR acquisition for Balanga Floodplain is presented in Figure 6.

Table 12. List of municipalities and cities surveyed during Balanga floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Bataan	Orion	59.77	48.05	80.39%
	Pilar	41.16	29.02	70.51%
	Samal	46.81	31.91	68.17%
	Abucay	77.81	52.23	67.13%
	Balanga City	80.78	50.29	62.26%
	Orani	53.25	32.50	61.03%
	Limay	74.29	33.10	44.56%
	Hermosa	135.27	47.50	35.11%
	Mariveles	185.72	49.56	26.69%
	Dinalupihan	95.23	3.87	4.06%
Bulacan	Guiguinto	20.40	4.92	24.12%
	Pandi	41.84	9.31	22.25%
	Balagtas	19.21	3.93	20.46%
	Angat	53.62	7.38	13.76%
	Bustos	43.15	4.79	11.10%
	San Miguel	272.04	22.18	8.15%
	Bulacan	75.31	2.78	3.69%
	Plaridel	39.17	1.34	3.42%
	Norzagaray	238.95	3.26	1.36%
Nueva Ecija	San Isidro	44.49	12.75	28.66%
	Gapan City	163.45	31.48	19.26%
	Cabiao	110.18	17.08	15.50%
	San Antonio	169.06	12.82	7.58%
	San Leonardo	51.79	1.53	2.95%
	Jaen	93.66	1.30	1.39%
Pampanga	Santa Ana	52.19	3.34	6.40%
	Arayat	153.46	6.55	4.27%
	Porac	238.99	6.45	2.70%
	San Fernando City	72.06	1.76	2.44%
	Mexico	118.25	2.02	1.71%
TOTAL		2921.36	535	18.31%

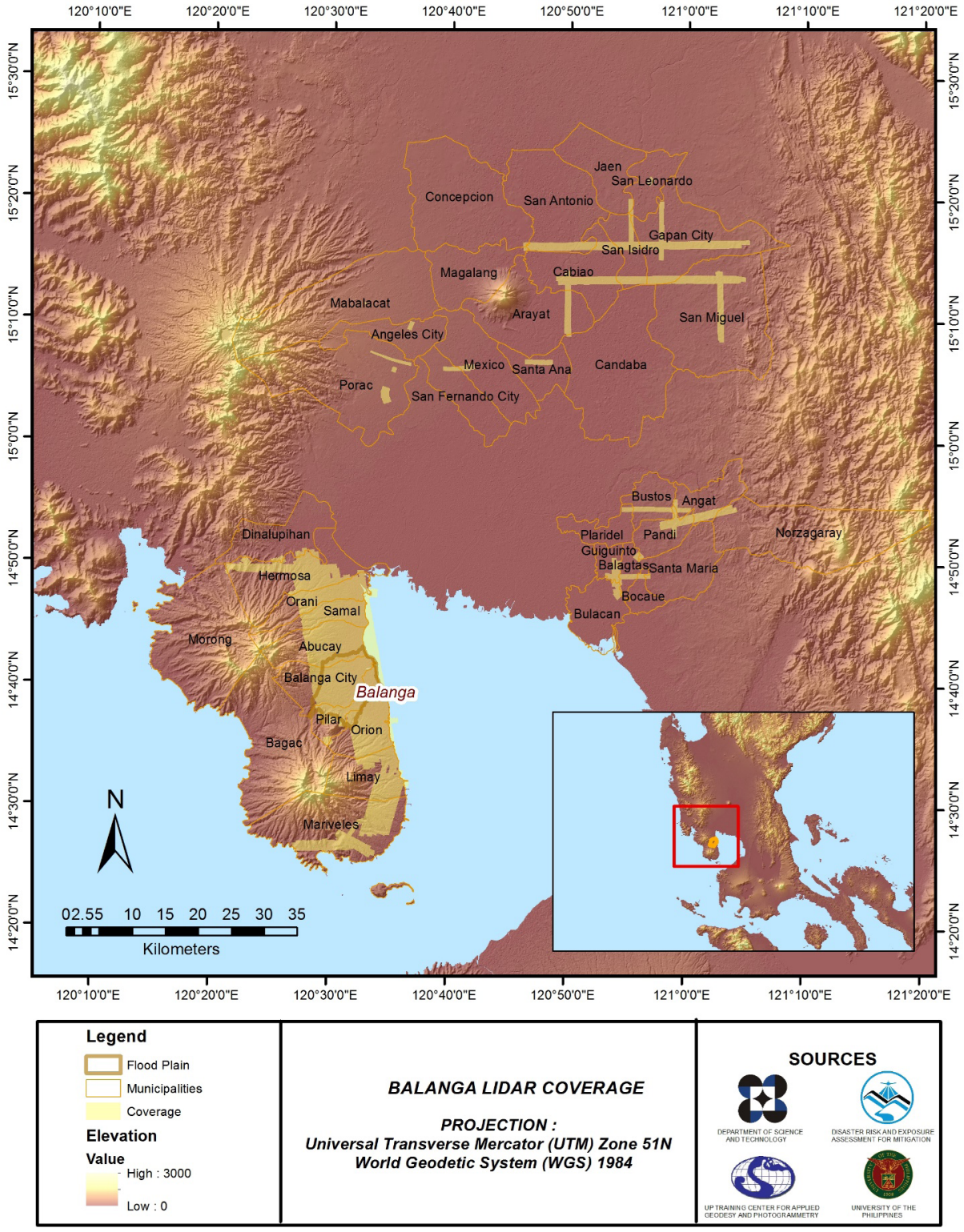


Figure 6. Actual LiDAR survey coverage for Balanga floodplain.

CHAPTER 3. LIDAR DATA PROCESSING OF THE BALANGA FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Gladys Mae Apat , Engr. Elainne R. Lopez , Engr. Mark Joshua A. Salvacion, Engr. Vincent Louise DL. Azucena, Engr. Abigail C. Ching, Engr. Jommer M. Medina, John Andrew B. Cruz

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

3.1 Overview of the LiDAR Data Pre-Processing

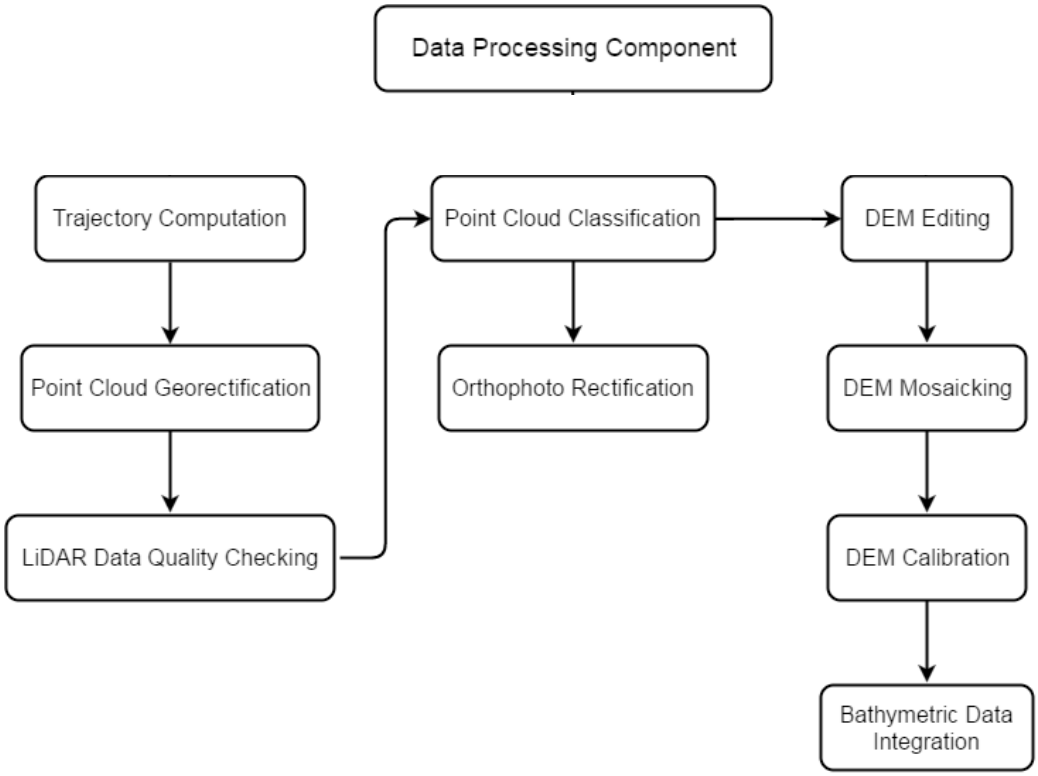


Figure 7. Schematic Diagram for Data Pre-Processing Component

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

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

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

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Balanga floodplain can be found in Annex 5. Missions flown over Balanga City and Pilar, Bataan during the first survey conducted on December 2013 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus and Gemini systems while missions acquired during the second and third surveys on May 2014 and August 2015, respectively, were flown using the Gemini system only. The Data Acquisition Component (DAC) transferred a total of 91.67 Gigabytes of Range data, 1.29 Gigabytes of POS data, 258.70 Megabytes of GPS base station data, and 33.37 Gigabytes of raw image data to the data server on January 10, 2014 for the first survey, on May 29, 2014 for the second survey, and on September 10, 2015 for the third survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Balanga was fully transferred on September 10, 2015, as indicated on the Data Transfer Sheets for Balanga floodplain.

3.3 Trajectory Computation

The *Smoothed Performance Metrics* of the computed trajectory for flight 2656G, one of the Balangaflights, which is the North, East, and Down position RMSE values are shown in Figure 8. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell onAugust 26, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

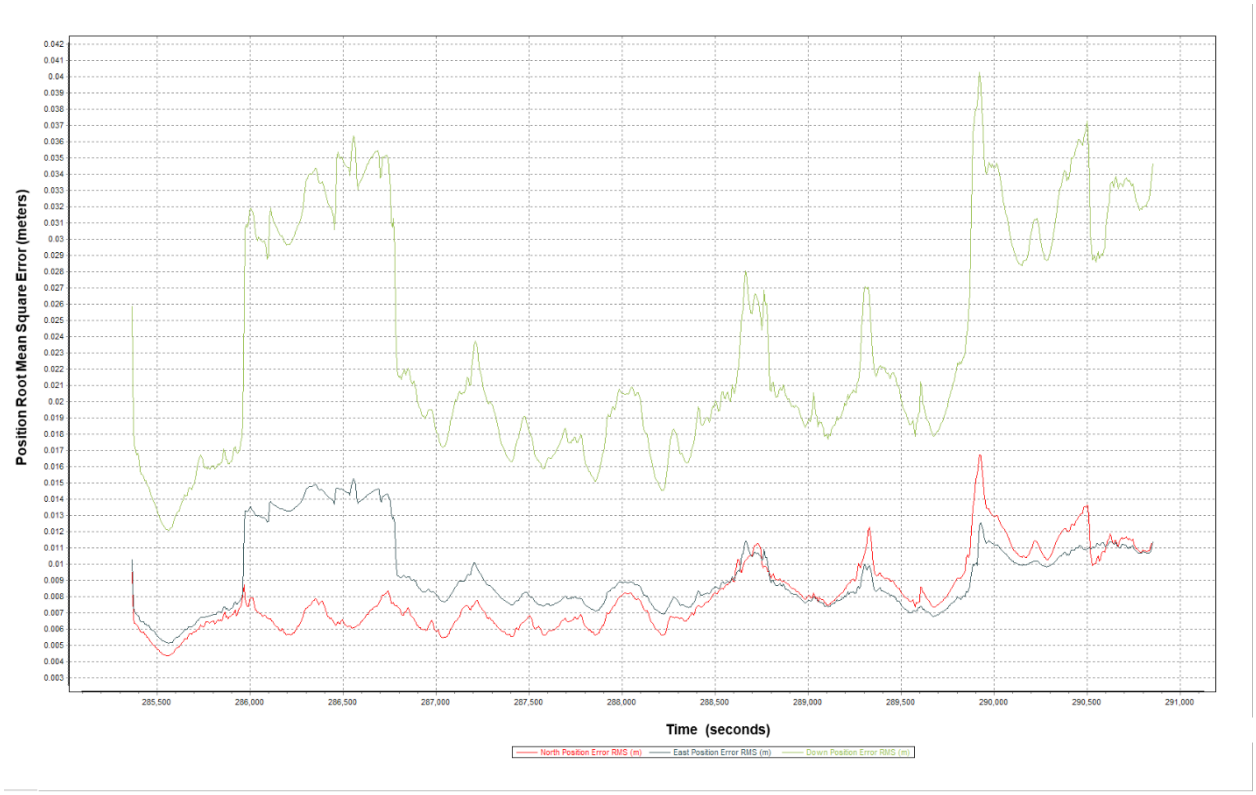


Figure 8. Smoothed Performance Metrics of Balanga Flight 2656G.

The time of flight was from 285,500 seconds to 291,000 seconds, which corresponds to afternoon of August 26, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 8 shows that the North position RMSE peaks at 1.70 centimeters, the East position RMSE peaks at 1. 55 centimeters, and the Down position RMSE peaks at 4.50 centimeters, which are within the prescribed accuracies described in the methodology.

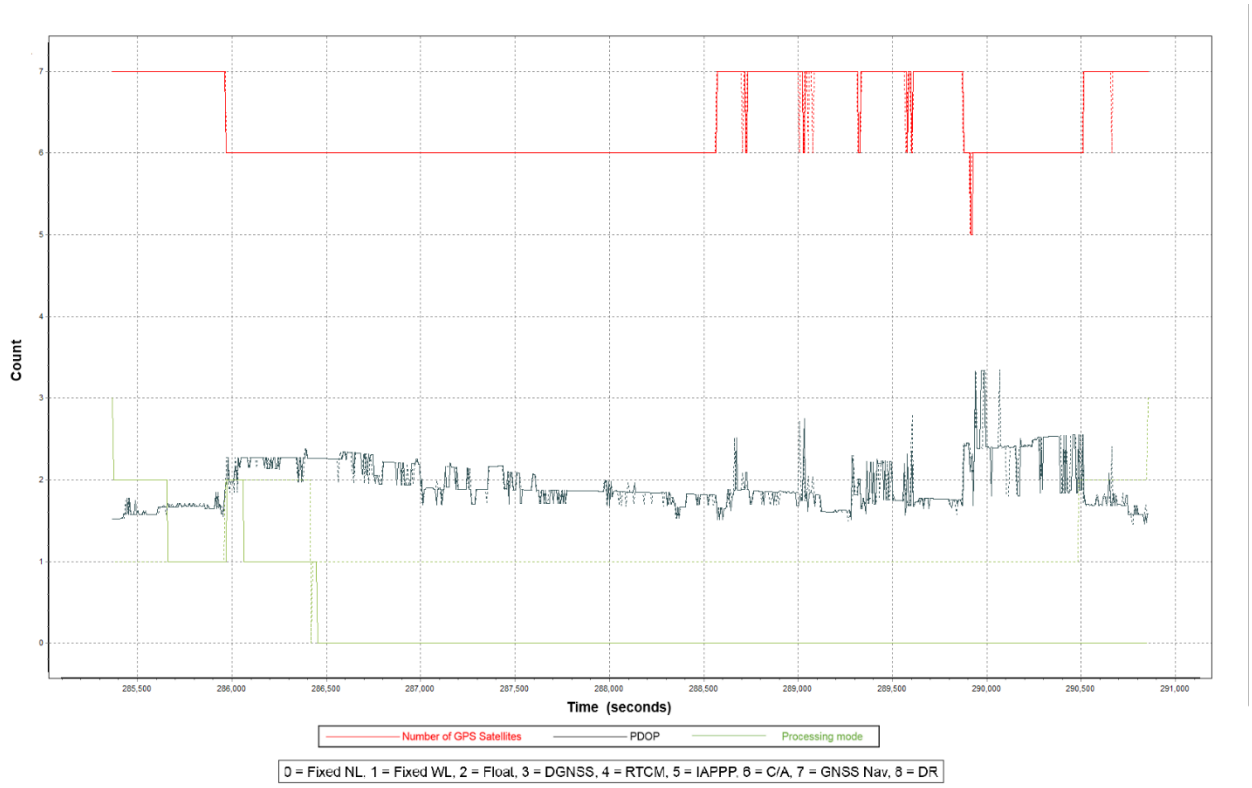


Figure 9. Solution Status Parameters of Balanga Flight 2656G.

The S*olution Status* parameters of flight 2656G, one of the Balanga flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used,are shown in Figure 9.The graphs indicate that the number of satellites during the acquisition did not go down to 5. Most of the time, the number of satellites tracked was between 5 and 7. ThePDOP value also did not go above the value of 3.40, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey with some peaks up to 1 and 2 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 Balanga flights is shown in Figure 10.

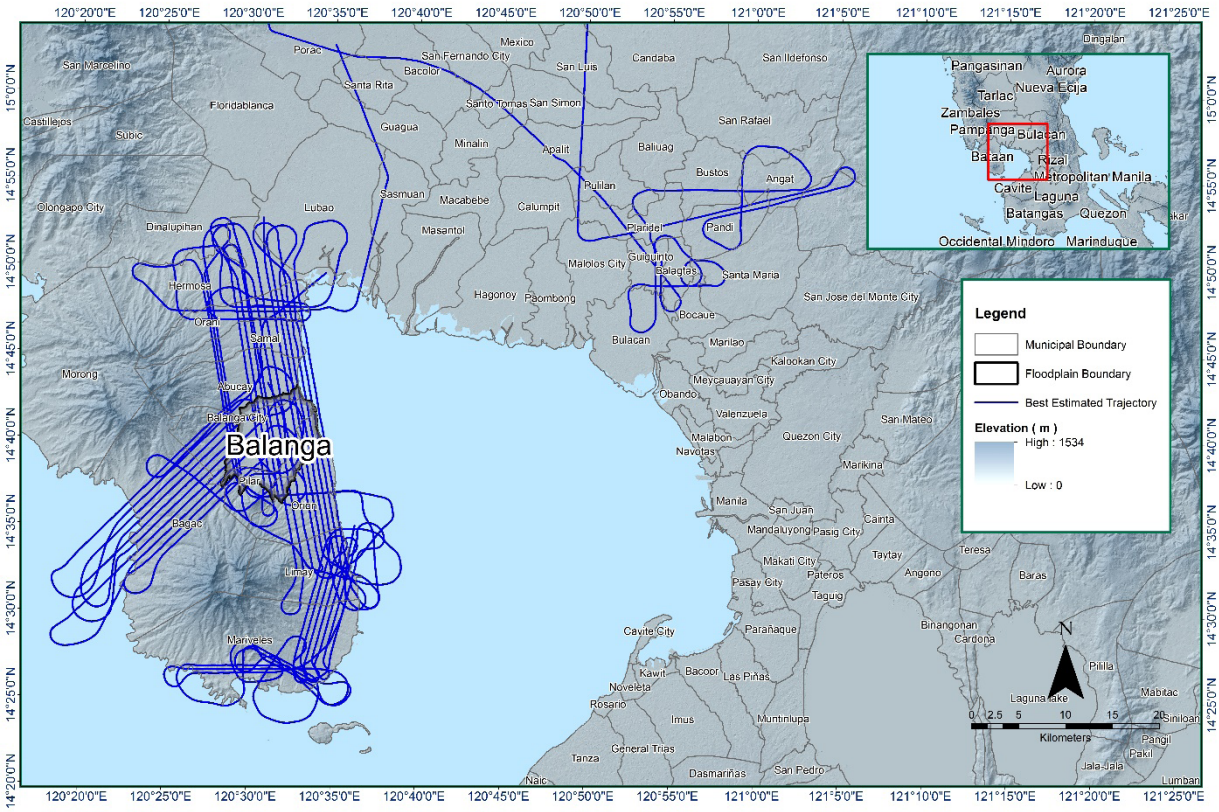


Figure 10. The best estimated trajectory of the LiDar missions conducted over the Balanga floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 55 flight lines, with 33 flight lines containing one channel since the Gemini system contains one channel only and 22 flight lines containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flightsover Balanga floodplain are given in Table 13.

Table 13. Self-Calibration Results values for Balanga flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000429
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000924
GPS Position Z-correction stdev	(<0.01meters)	0.0071

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

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data are shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

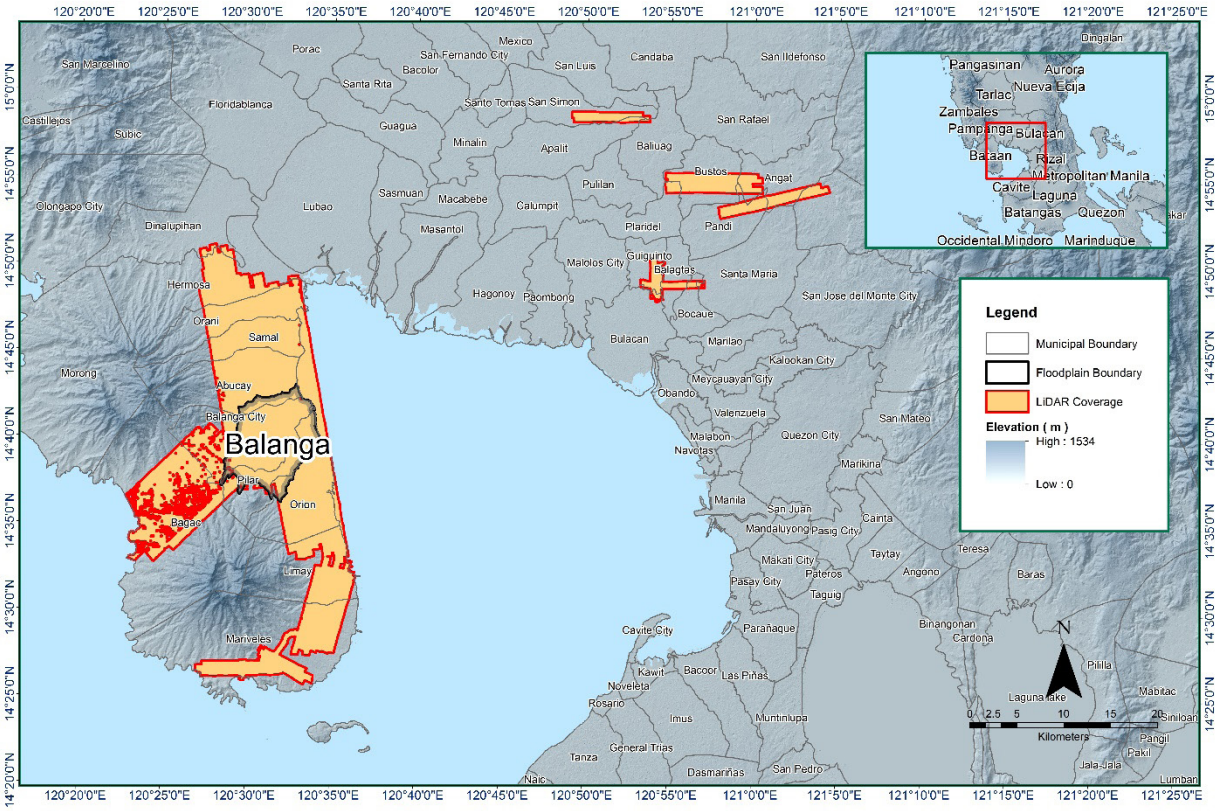


Figure 11. Boundaries of the processed LiDAR data on top of a SAR Elevation Data over Balanga Floodplain.

The total area covered by the Balanga missions is 563.80 sq.km that is comprised of seven (7) flight acquisitions grouped and merged into ten (10) blocks as shown in Table 14.

Table 14.List of LiDAR blocks for Balanga floodplain.

LiDAR Blocks	Flight Number	Area (sq. km.)
Bataan_Plg_BlkA	963P	48.01
Bataan_BalC	935P	97.79
Bataan_BalB	924G	26.87
Bataan_BalAs	935P	96.21
Bataan_BalA	929P	108.24
Clark_reflights_Btn_B	2656G	24.26
Clark_reflights_Btn_A	2656G	21.75
Pam_Agno_reflights_Pam_Blk8_reflight_cross	7271GC	5.25
Pam_Agno_reflights_Pam_Blk8_reflight	7271GC	49.65
Pam_Agno_reflights_Bal_reflight	7260GC	85.77
TOTAL		**563.80**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 12. Since the Gemini system employs 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.

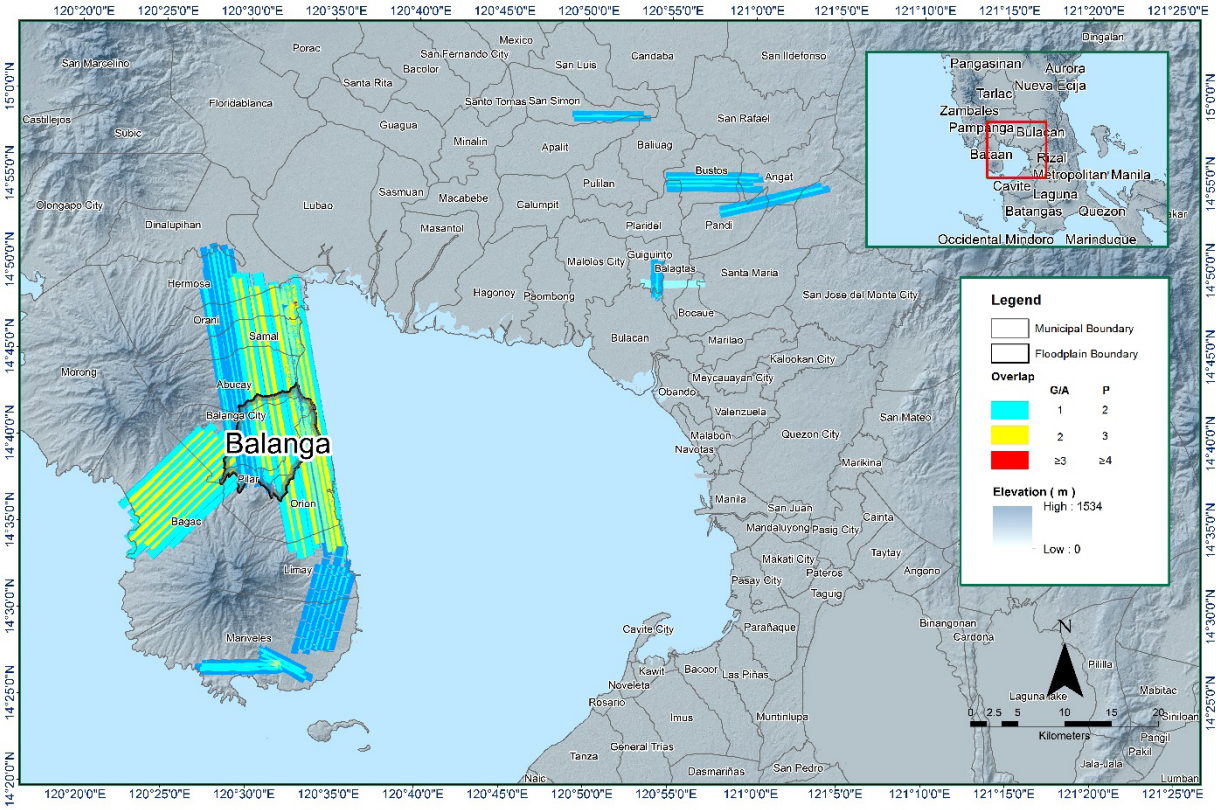


Figure 12. Image of data overlap for Balanga floodplain.

The overlap statistics per block for the Balanga 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 25.79% and 48.25% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 13. It was determined that all LiDAR data for Balanga floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.001 points per square meter.

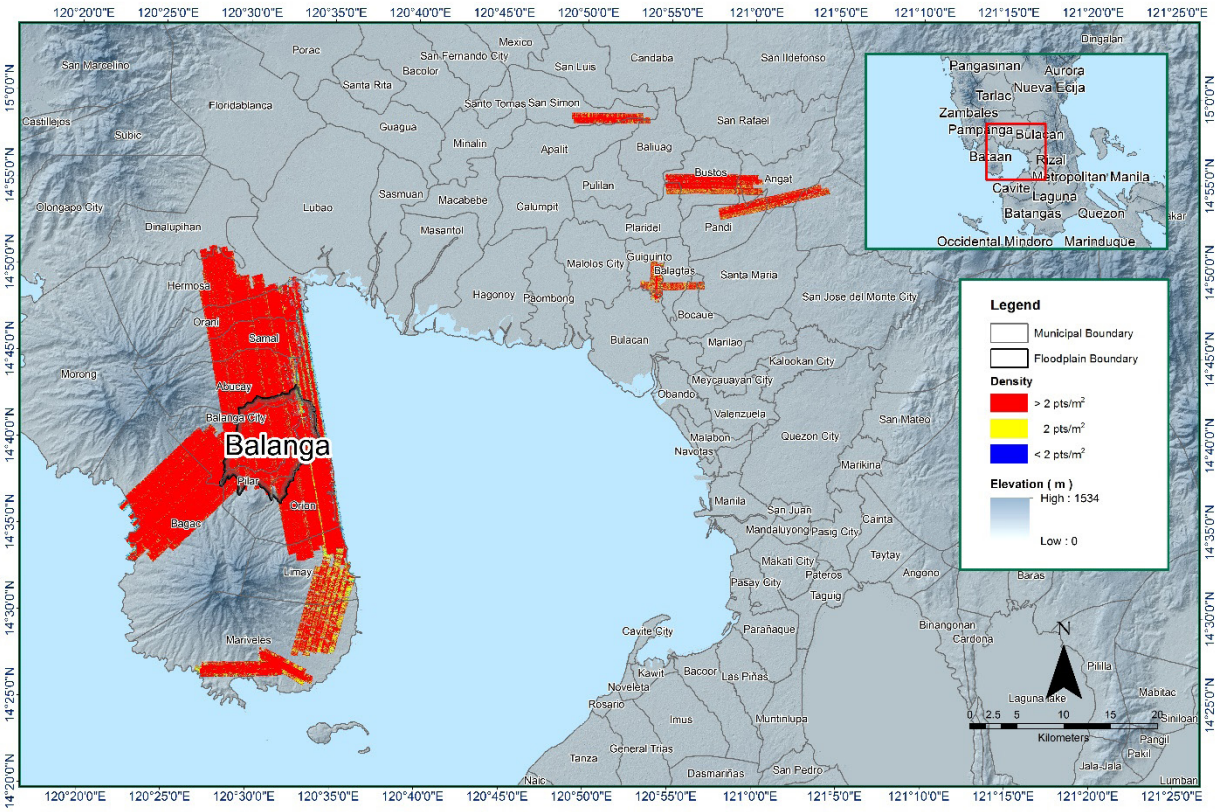


Figure 13. Pulse density map of merged LiDAR data for Balanga floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m 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.

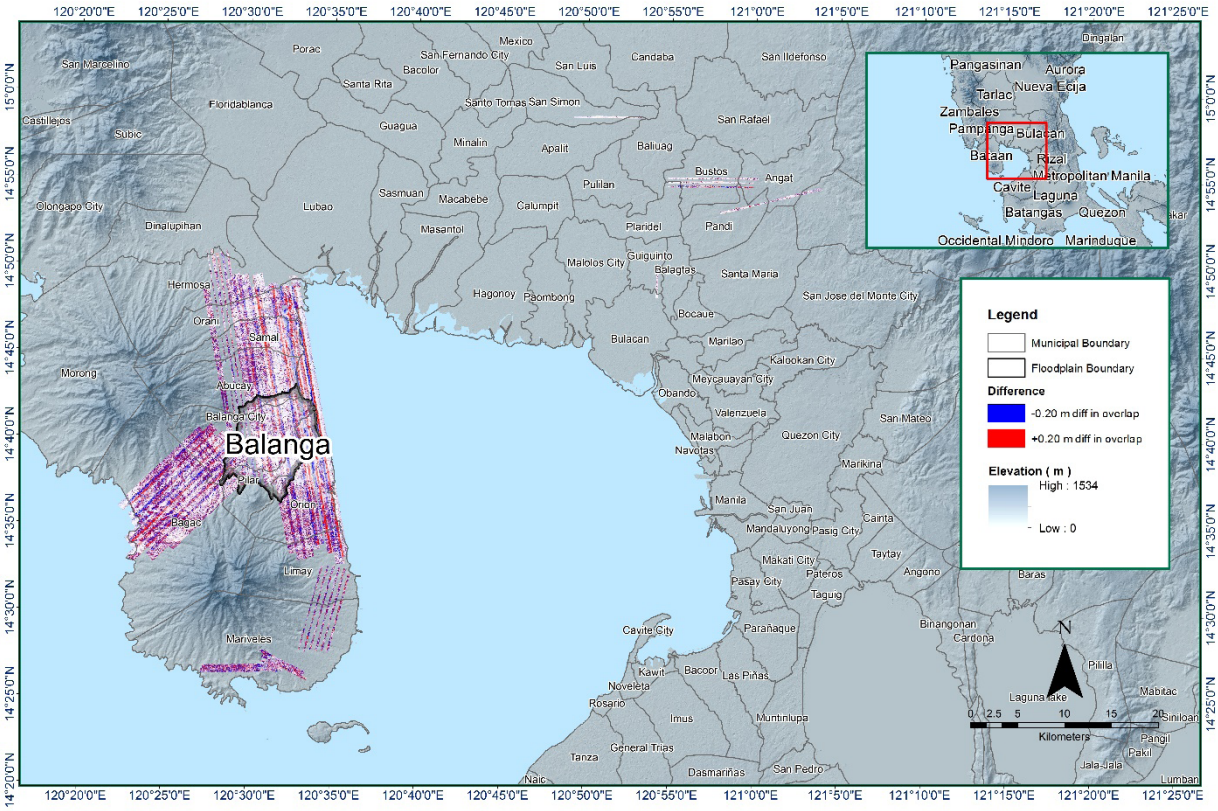


Figure 14. Elevation difference map between flight lines for Balanga floodplain.

A screen capture of the processed LAS data from Balanga flight 2656G loaded in QT Modeler is shown in Figure 15. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

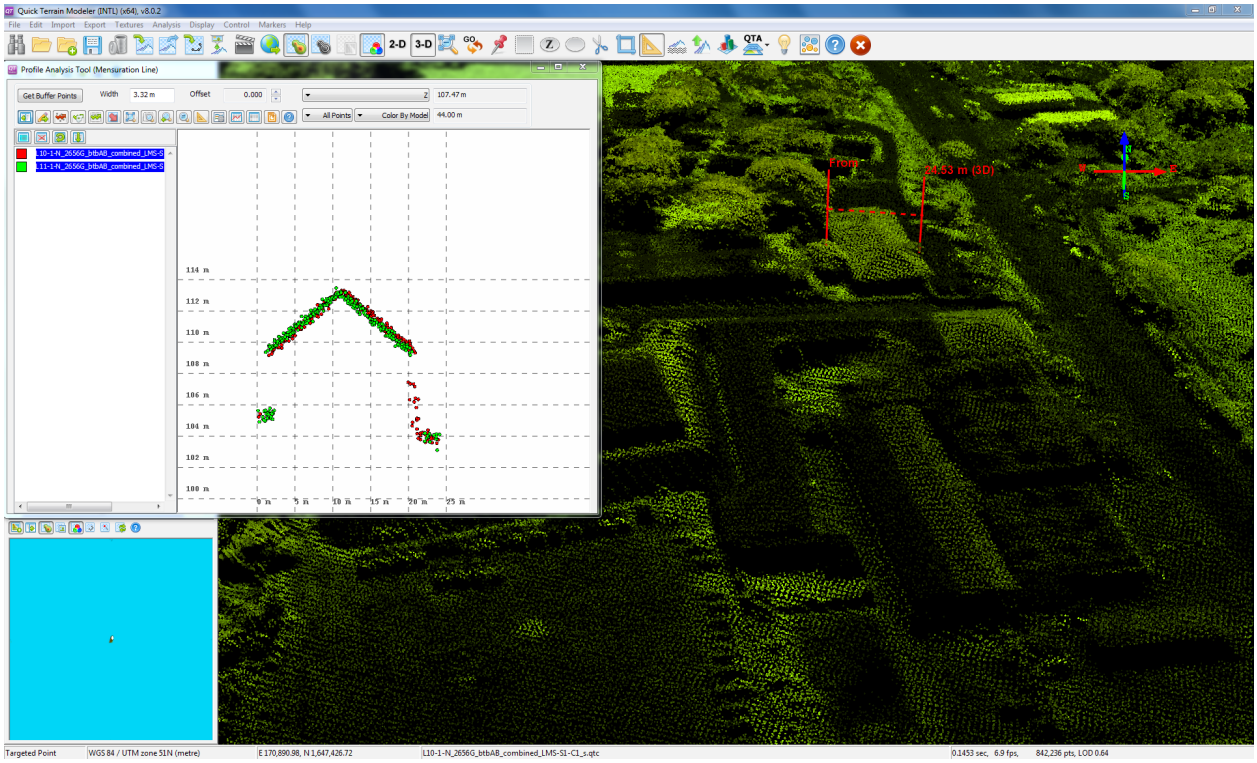


Figure 15. Quality checking for Balanga flight 2656G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Balanga classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	392,265,287
Low Vegetation	343,695,623
Medium Vegetation	507,639,290
High Vegetation	420,583,091
Building	42,001,977

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Balanga floodplain is shown in Figure 16. A total of 1001 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 15. The point cloud has a maximum and minimum height of 949.77 meters and 35.13 meters respectively.

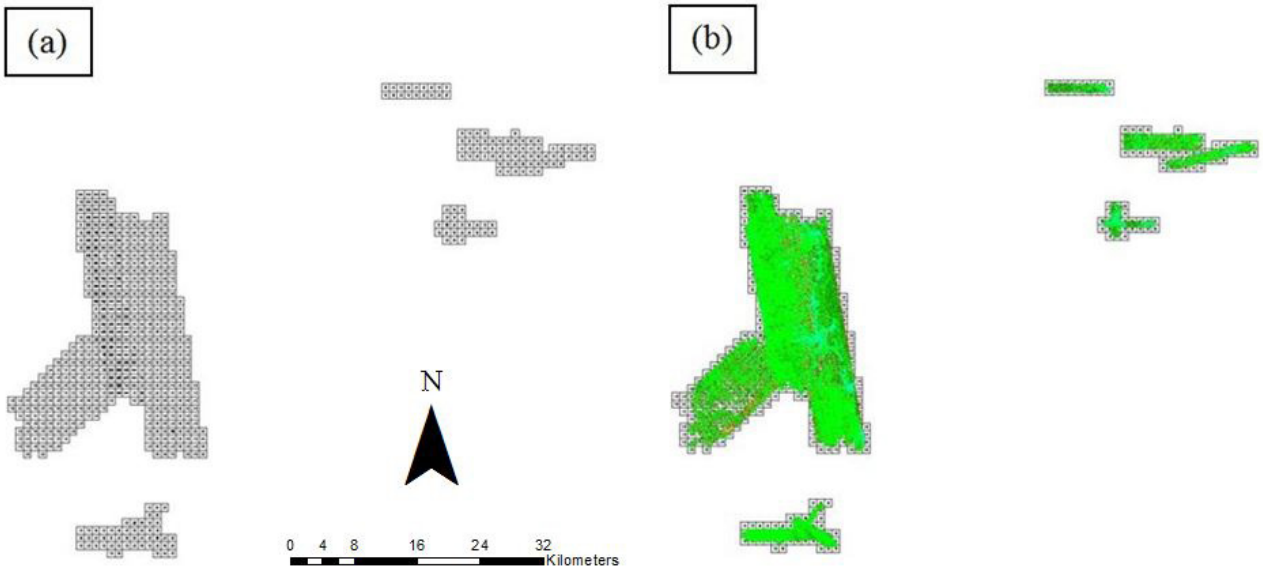


Figure 16. Tiles for Balanga floodplain (a) and classification results (b) in TerraScan.

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

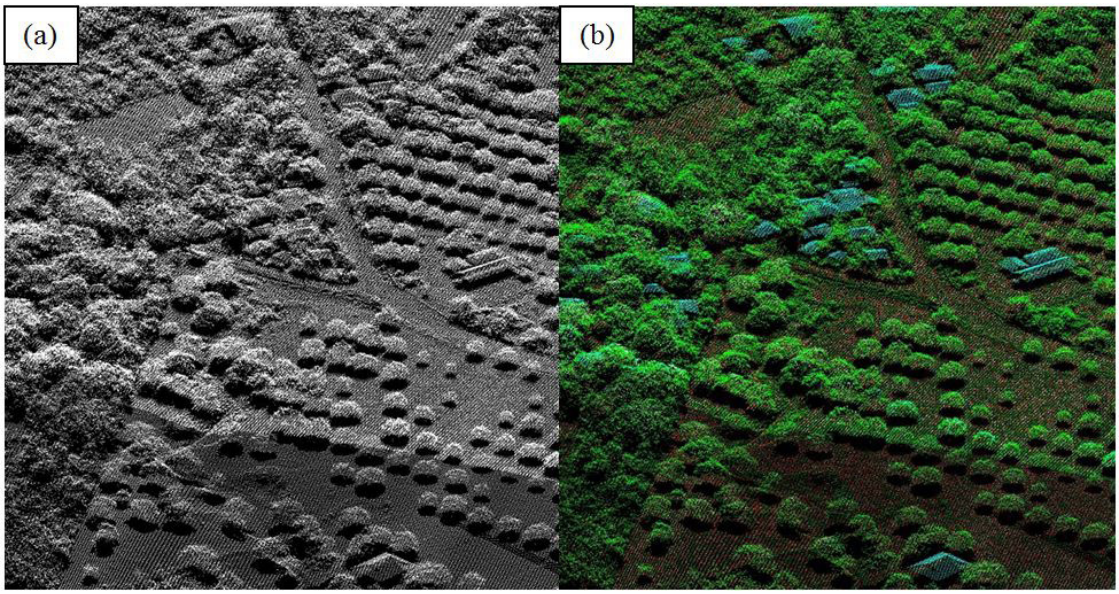


Figure 17. Point cloud before (a) and after (b) classification.

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

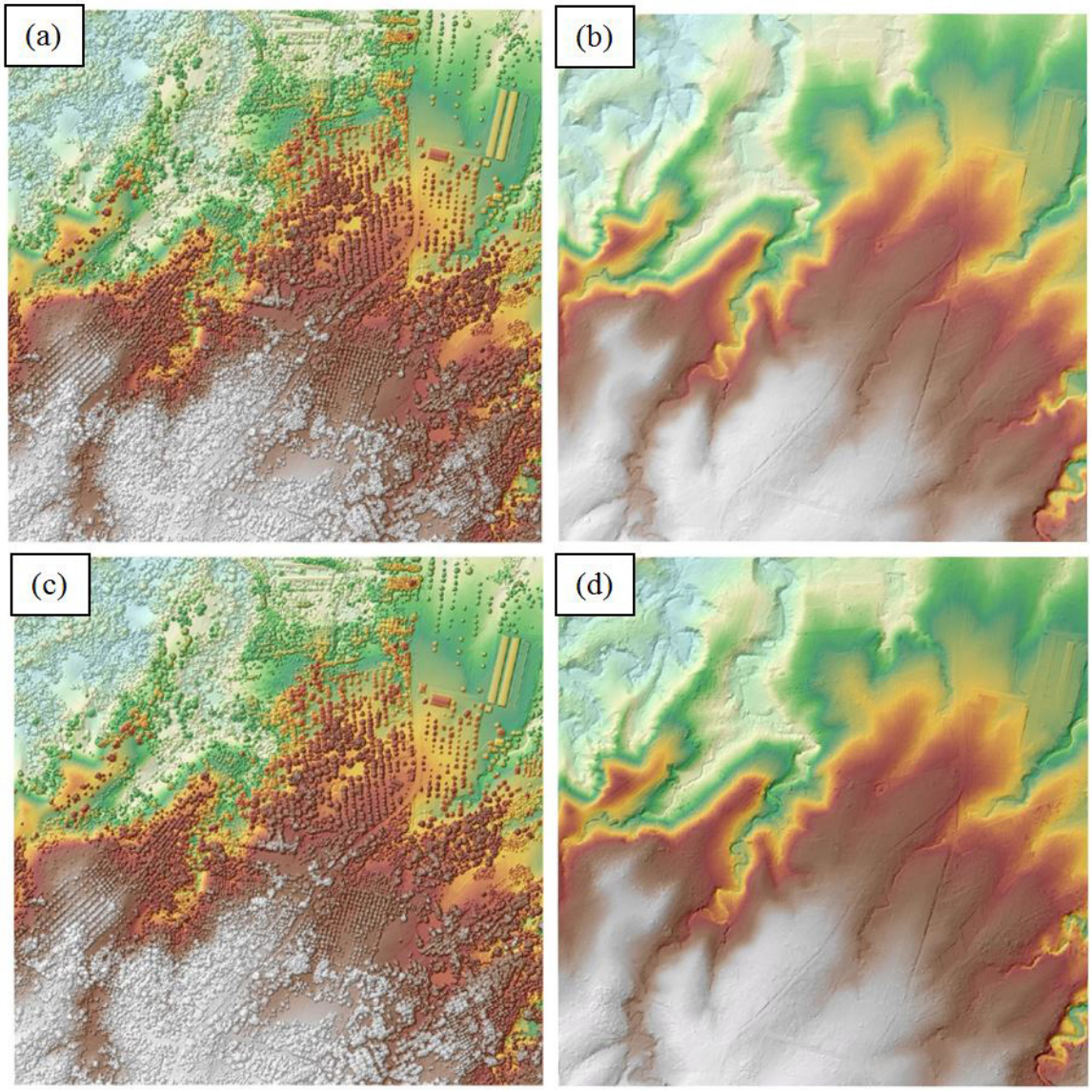


Figure 18.The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Balanga floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 144 1km by 1km tiles area covered by Balanga floodplain is shown in Figure 19. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Balanga floodplain has a total of 49.90 sq.km orthophotogaph coverage comprised of 264 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

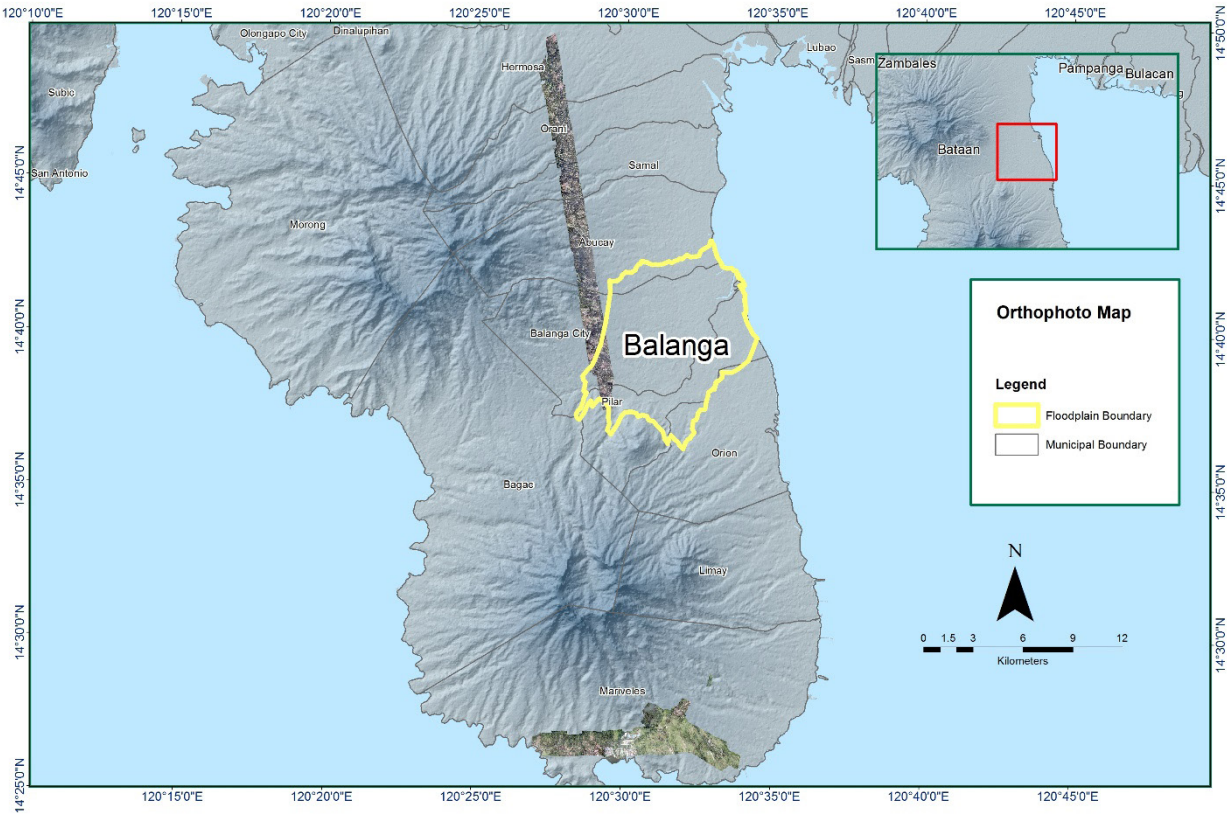


Figure 19.Balanga floodplain with available orthophotographs.

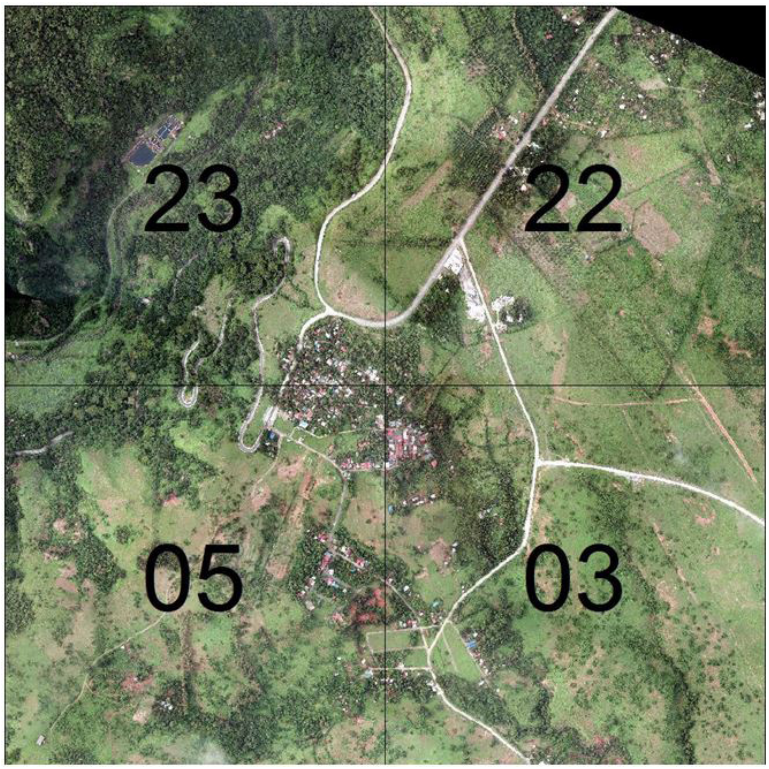


Figure 20.Sample orthophotograph tiles for Balanga floodplain.

3.8 DEM Editing and Hydro-Correction

Ten (10) mission blocks were processed for Balanga flood plain. These blocks are composed of BataanZambales, Clark Reflights and Pam Agno Reflights blocks with a total area of 563.8 square kilometers. Table 16 shows the name and corresponding area of each block in square kilometers.

Table 16.LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq. km.)
Bataan_Plg_BlkA	48.01
Bataan_BalC	97.79
Bataan_BalB	26.87
Bataan_BalAs	96.21
Bataan_BalA	108.24
Clark_reflights_Btn_B	24.26
Clark_reflights_Btn_A	21.75
Pam_Agno_reflights_Pam_Blk8_reflight_cross	5.25
Pam_Agno_reflights_Pam_Blk8_reflight	49.65
Pam_Agno_reflights_Bal_reflight	85.77
TOTAL	**563.80**

Portions of DTM before and after manual editing are shown in Figure 21. Areas along the river covered with thick vegetation and above ground features were misclassified as ground points (Figure 21a) and corrected (Figure 21b) to allow the flow of water. The bridge (Figure 21c) had to be removed (Figure 21d) in order to hydrologically correct the river. Buildings (Figure 21e) still present in V-ASCII tiles were interpolated during manual editing (Figure 21f).

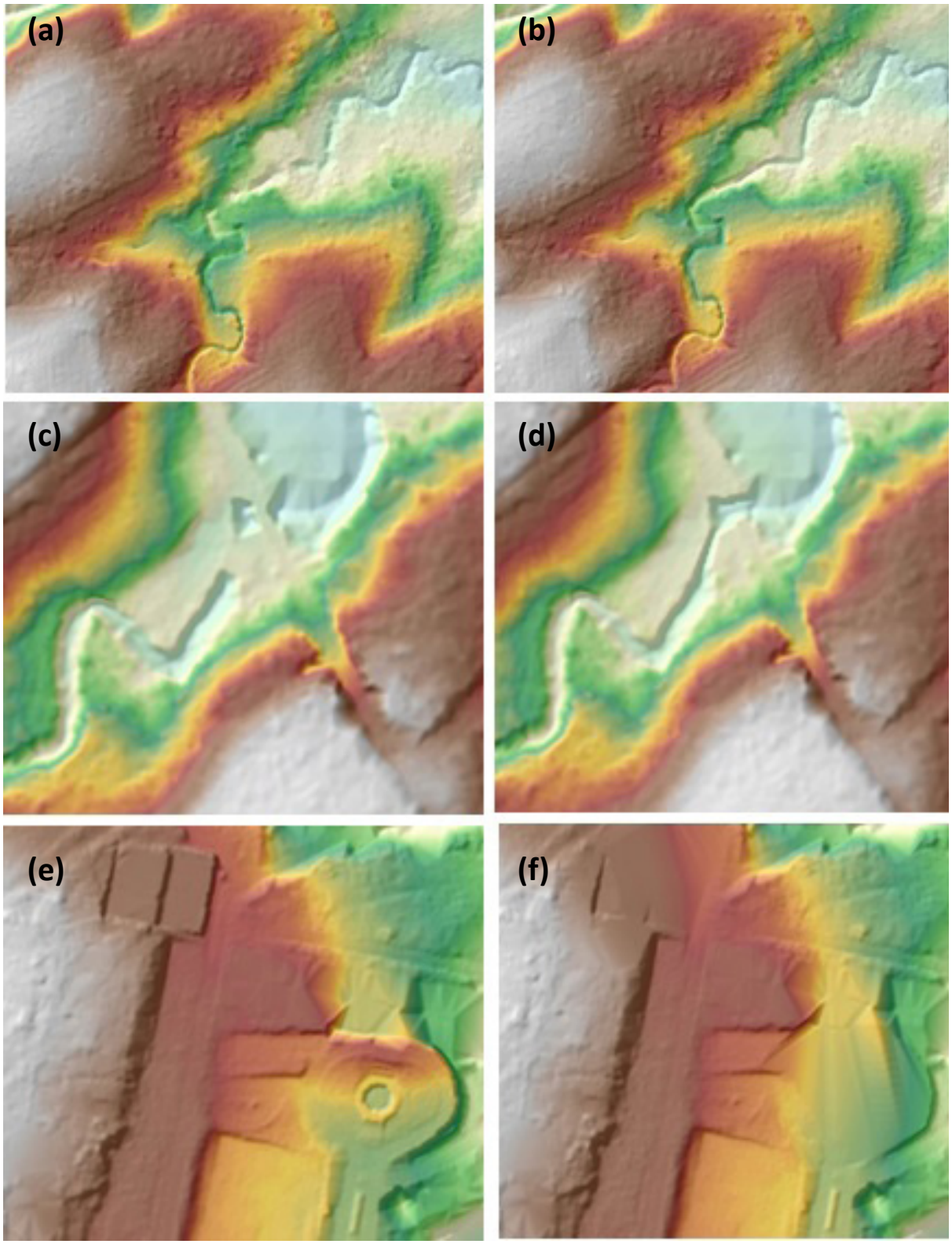


Figure 21. Portions in the DTM of Balanga floodplain – river embankments before (a) and after (b) interpolation; bridge before (c) and after (d) manual editing; and building before (e) and after (f) manual editing.

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 17 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Balanga floodplain is shown in Figure 21. It can be seen that the entire Balanga floodplain is 99.36% covered by LiDAR data.

Table 17.Shift Values of each LiDAR Block of Balanga floodplain.

Mission Blocks	Shift Values (m)		
	x	y	z
BataanZambales_Bal_BlkA	0.00	0.00	0.00
BataanZambales_Bal_BlkA_supplement	-0.76	1.70	0.00
BataanZambales_Bal_BlkB	0.06	3.04	0.55
BataanZambales_Bal_BlkC	-0.60	2.67	0.20
Pam_Agno_reflights_Bal_reflight	-0.05	3.07	-0.10
Clark_reflights_Btn_A	0.00	0.00	0.00
Clark_reflights_Btn_B	0.00	0.00	0.00
BataanZambales_Plg_BlkA	0.81	-1.42	-0.40
Pam_Agno_reflights_Pam_Blk8_reflight	-5.00	1.00	0.61
Pam_Agno_reflights_Pam_Blk8_reflight_cross	-4.50	1.00	0.41

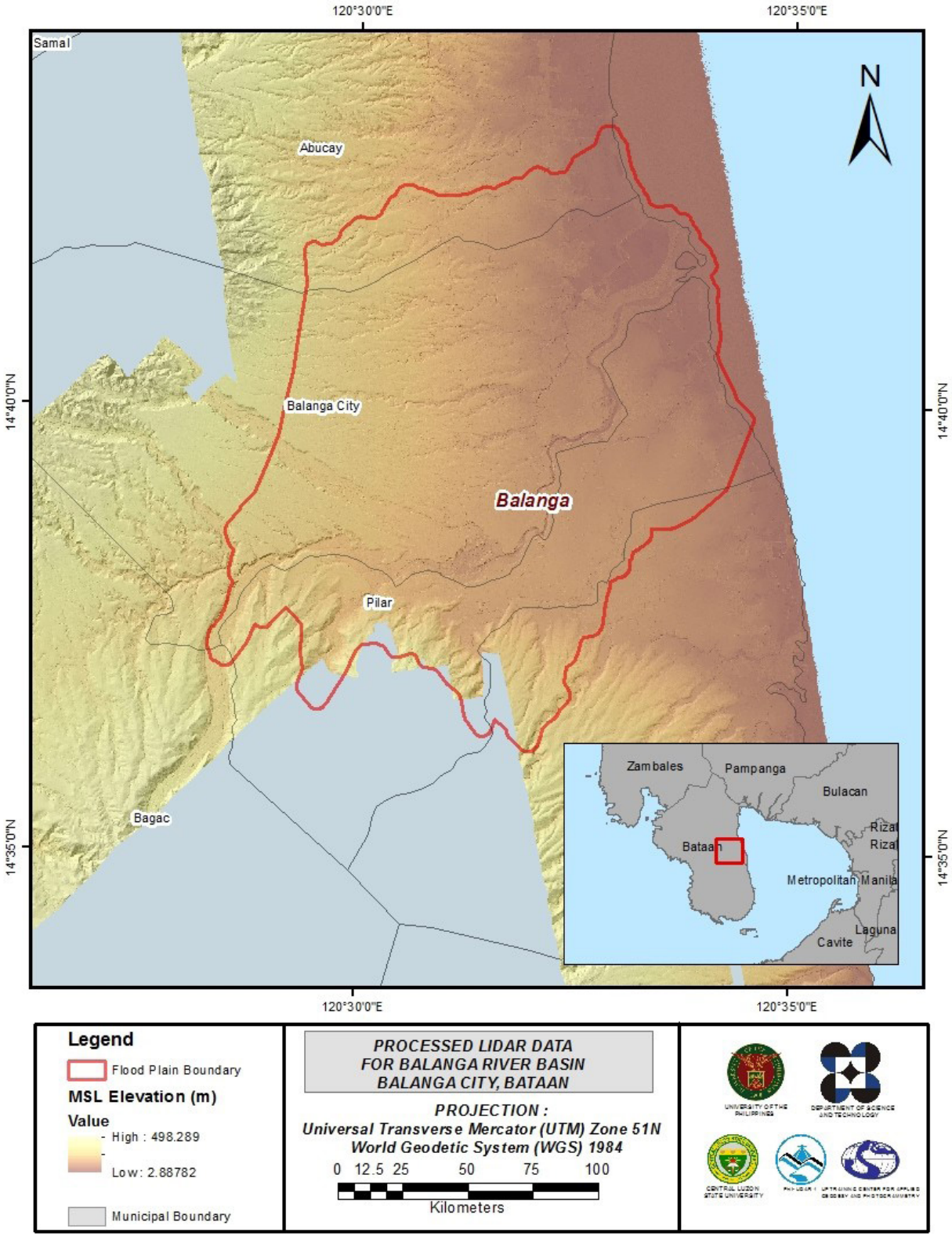


Figure 22.. Map of Processed LiDAR Data for Balanga Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Balanga to collect points with which the LiDAR dataset is validated is shown in Figure 23, with the validation survey points highlighted in green. Balanga 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 Balanga 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 24. 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 Morong LiDAR data was done by subtracting the height difference value, 4.15 meters, to BataanZambales mosaicked LiDAR data. Table 18 shows the statistical values of the compared elevation values between BataanZambales LiDAR data and calibration data.

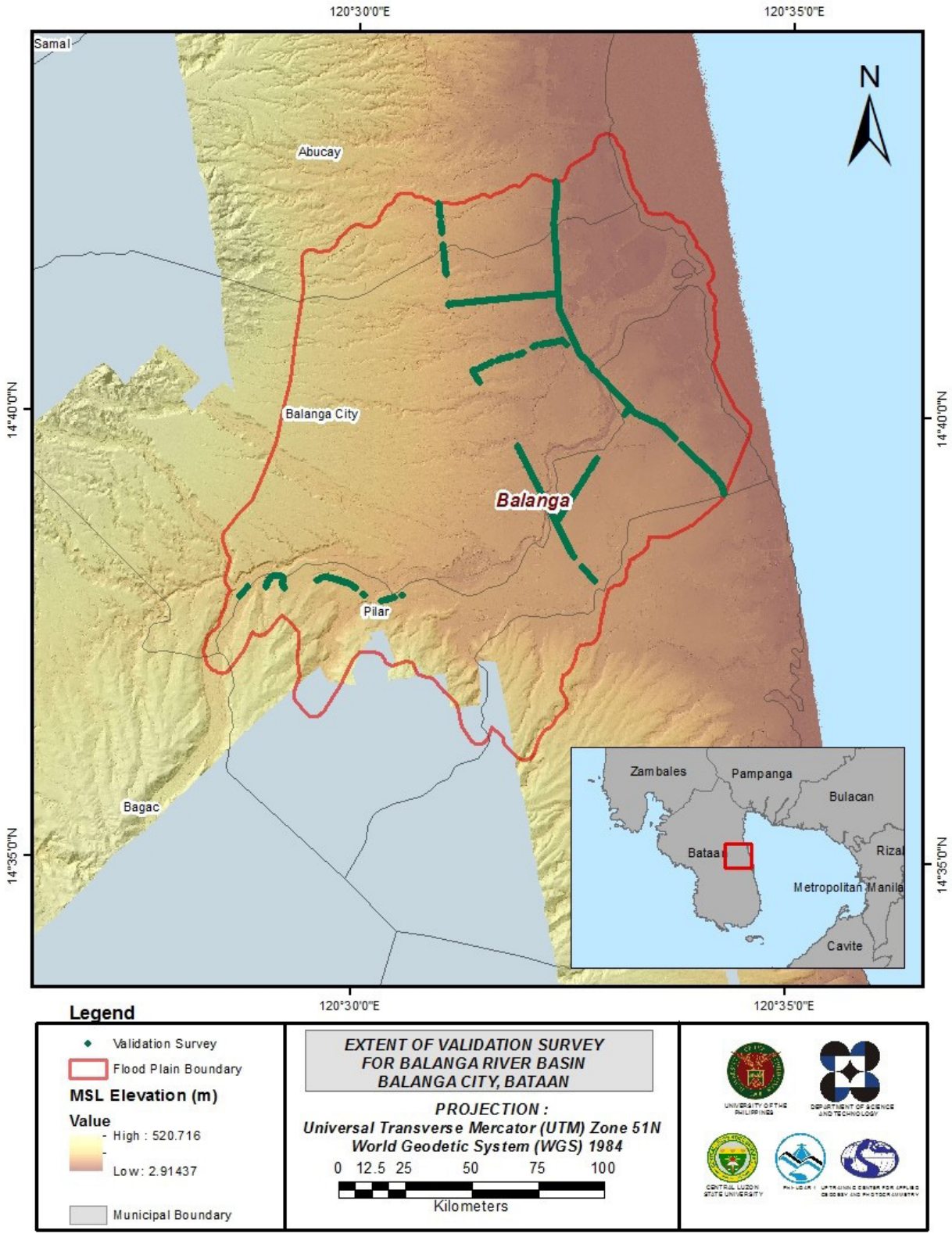


Figure 23.Map of Balanga Flood Plain with validation survey points in green.

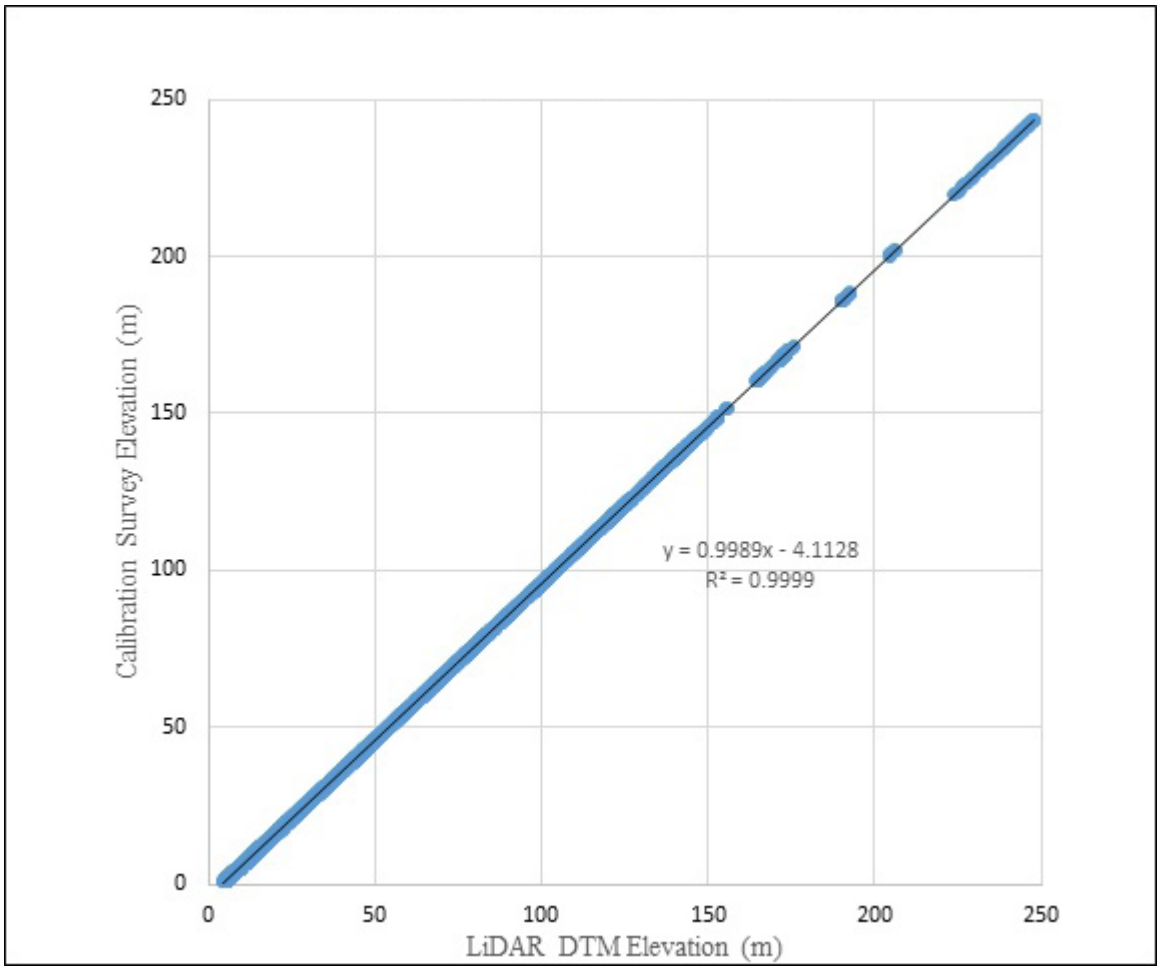


Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 18. 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 702 points were used for the validation of calibrated Balanga 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 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.16 meters with a standard deviation of 0.09 meters, as shown in Table 19.

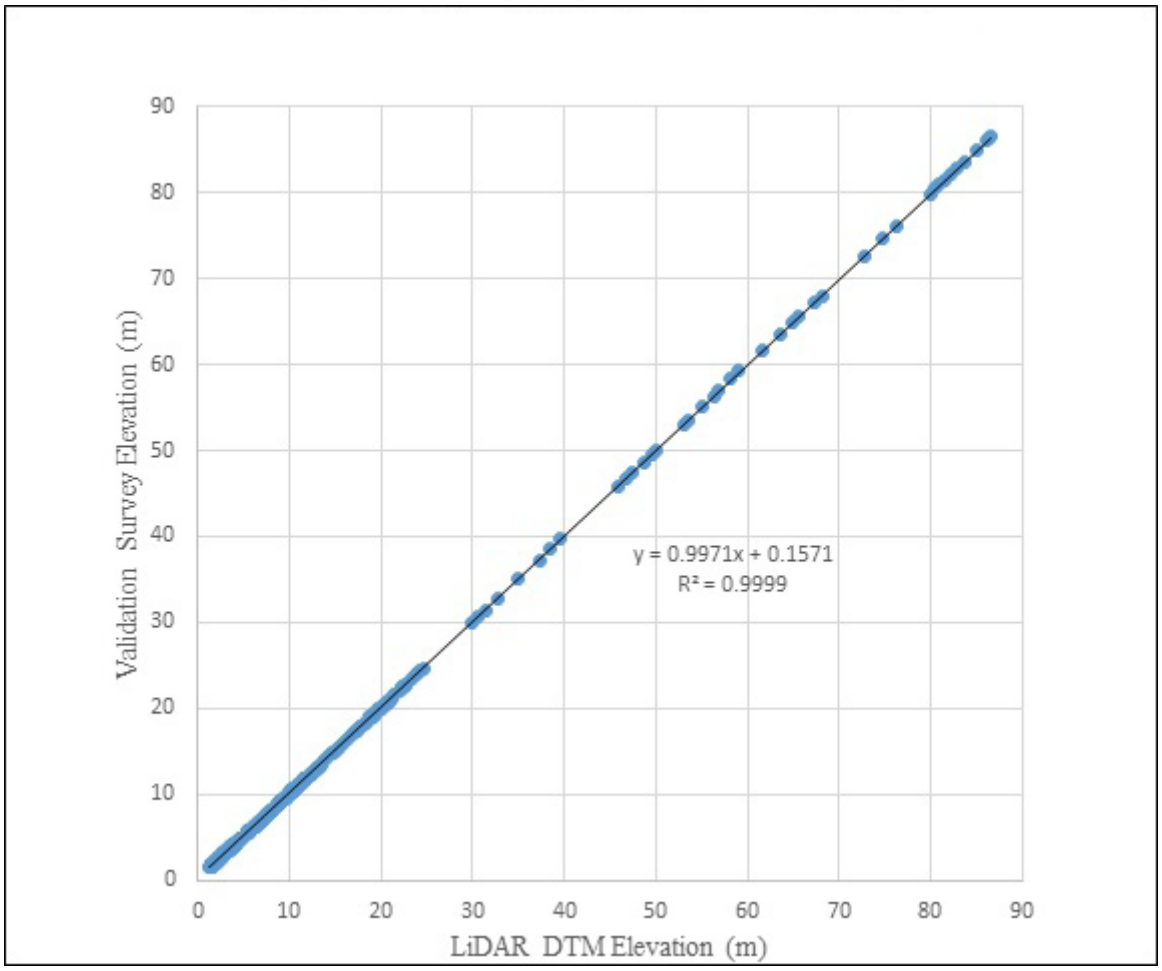


Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 19. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.16
Standard Deviation	0.09
Average	0.13
Minimum	-0.07
Maximum	0.33

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Balanga with 17,222 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barriers (KIB) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.28 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Balanga integrated with the processed LiDAR DEM is shown in Figure 26.

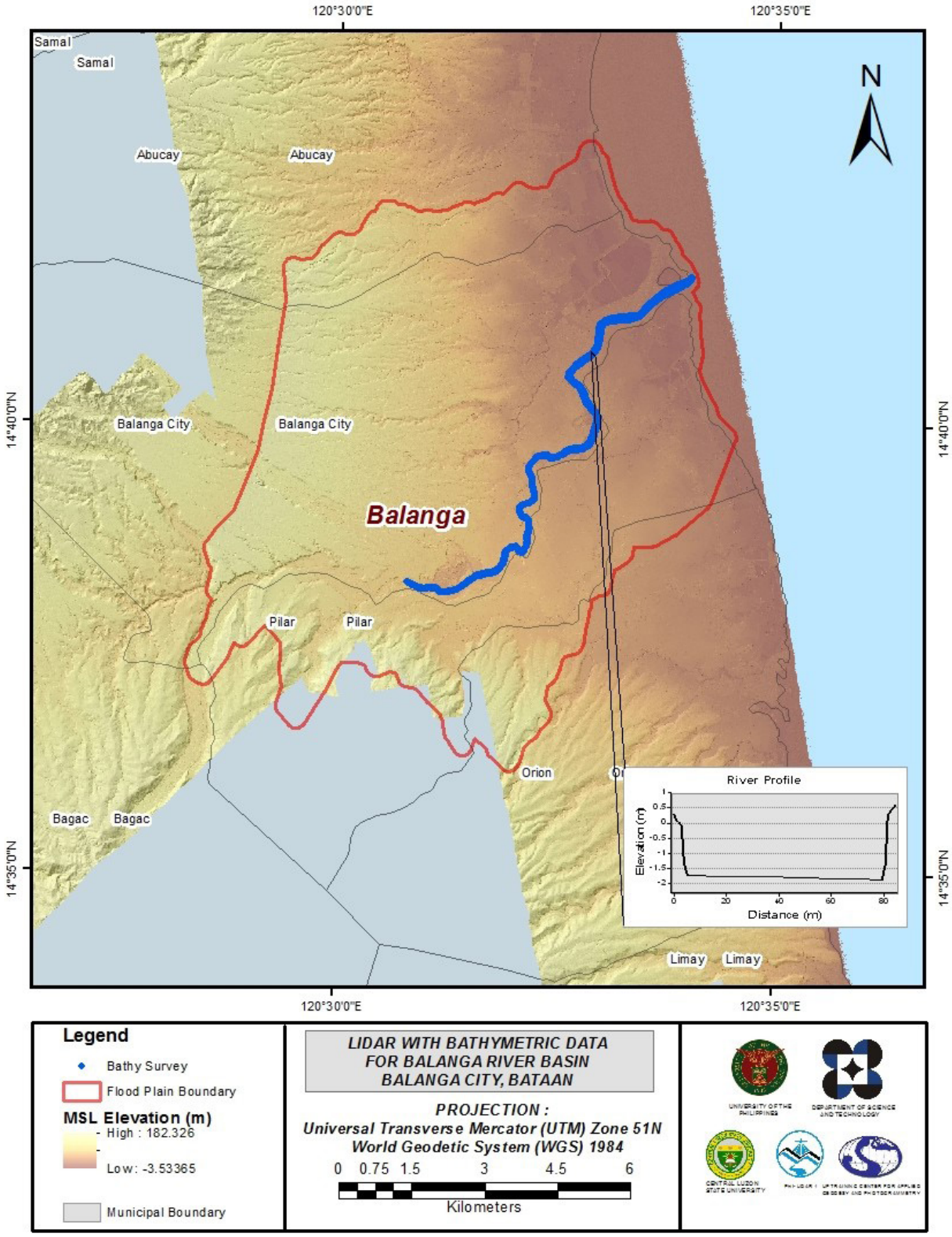


Figure 26.Map of Balanga Flood Plain with bathymetric survey points shown in blue.

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

Balanga floodplain, including its 200 m buffer, has a total area of 87.88 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 4555 building features, are considered for QC. Figure 27.shows the QC blocks for Balanga floodplain.

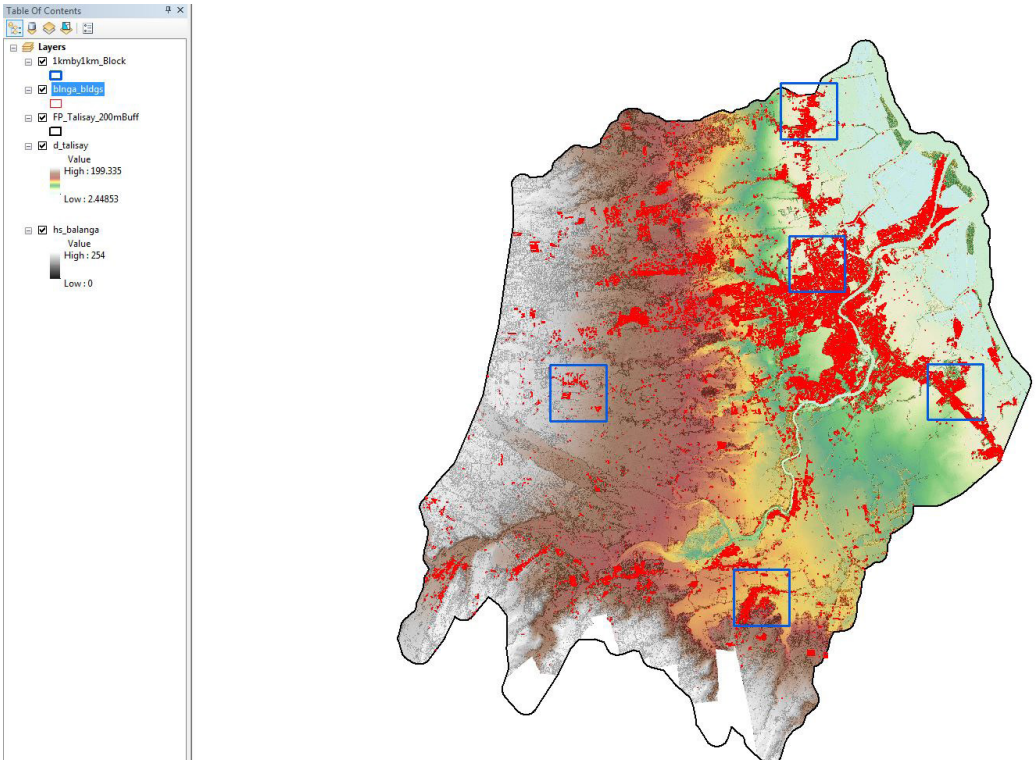


Figure 27.Blocks (in blue) of Balanga building features that were subjected to QC

Quality checking of Balanga building features resulted in the ratings shown in Table 20.

Table 20.Quality Checking Ratings for Balanga Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Balanga	99.98	100.00	99.96	PASSED

3.12.2 Height Extraction

Height extraction was done for 30,205 building features in Balanga floodplain. Of these building features, 181 was filtered out after height extraction, resulting to 30,024 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 3.75 m.

3.12.3 Feature Attribution

For improved accuracy in building footprints attribution, all the necessary data such as name and type were gathered, verified and field validated with the use of video-tagging device or geo tagged video capturing tool.

Table 21 summarizes the number of building features per type. On the other hand, Table 22 shows the total length of each road type, while Table 23 shows the number of water features extracted per type.

Table 21.Building Features Extracted for Balanga Floodplain.

Facility Type	No. of Features
Residential	28,036
School	585
Market	22
Agricultural/Agro-Industrial Facilities	150
Medical Institutions	56
Barangay Hall	40
Military Institution	9
Sports Center/Gymnasium/Covered Court	47
Telecommunication Facilities	7
Transport Terminal	13
Warehouse	31
Power Plant/Substation	13
NGO/CSO Offices	13
Police Station	15
Water Supply/Sewerage	13
Religious Institutions	157
Bank	26
Factory	7
Gas Station	42
Fire Station	2
Other Government Offices	111
Other Commercial Establishments	629
Total	**30,024**

Table 22.Total Length of Extracted Roads for Balanga Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Balanga	260.01	29.12	20.42	7.95	0	317.50

Table 23. Number of Extracted Water Bodies for Balanga Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Balanga	17.00	0	0	0	453	470.00

A total of 49 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 Balanga floodplain overlaid with its ground features.

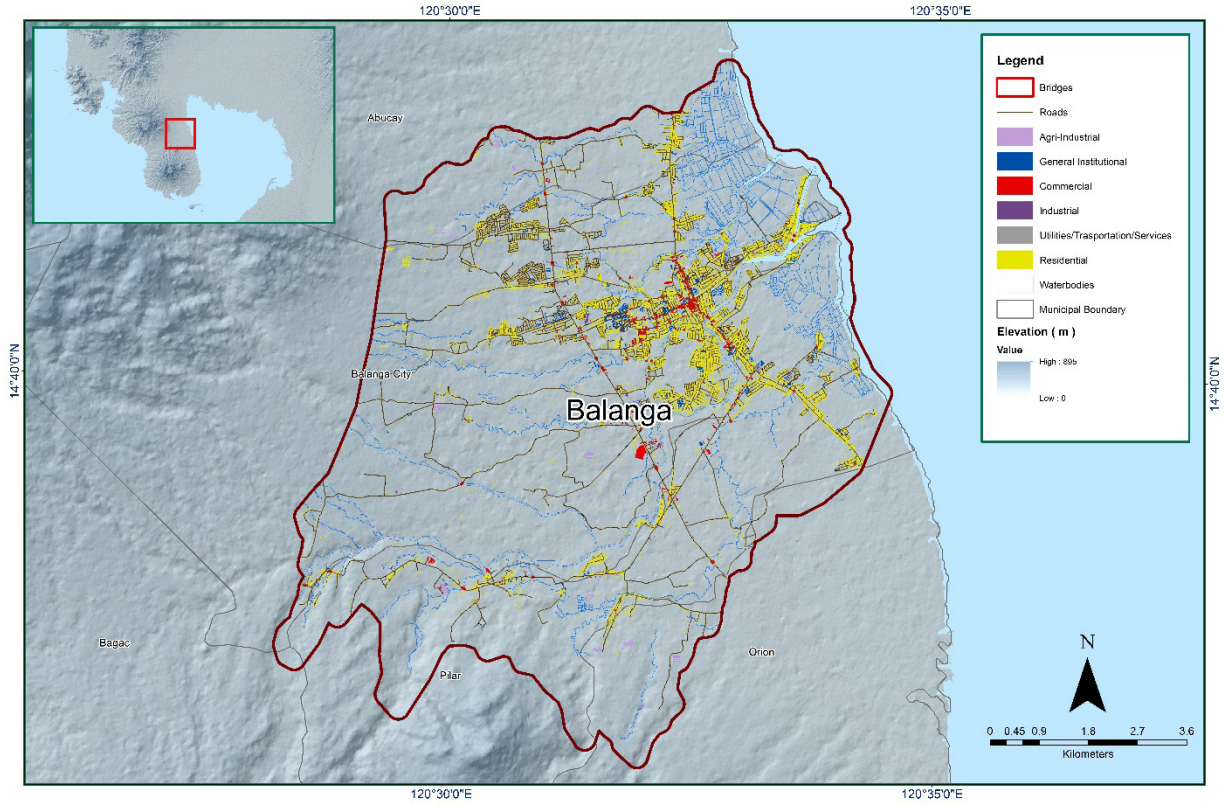


Figure 29. Extracted features for Balanga floodplain.

CHAPTER 4. LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE BALANGA RIVER BASIN

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Talisay River on July 22 – Aug 3, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey at Talisay Bridge in Brgy. Central, Balanga City; validation points acquisition of about 83.074 km covering the Talisay River Basin area; and bathymetric survey from its upstream in Brgy. Dangcol down to the mouth of the river located in Brgy. Tortugas, both in Balanga City, with an approximate length of 11.618 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 30).

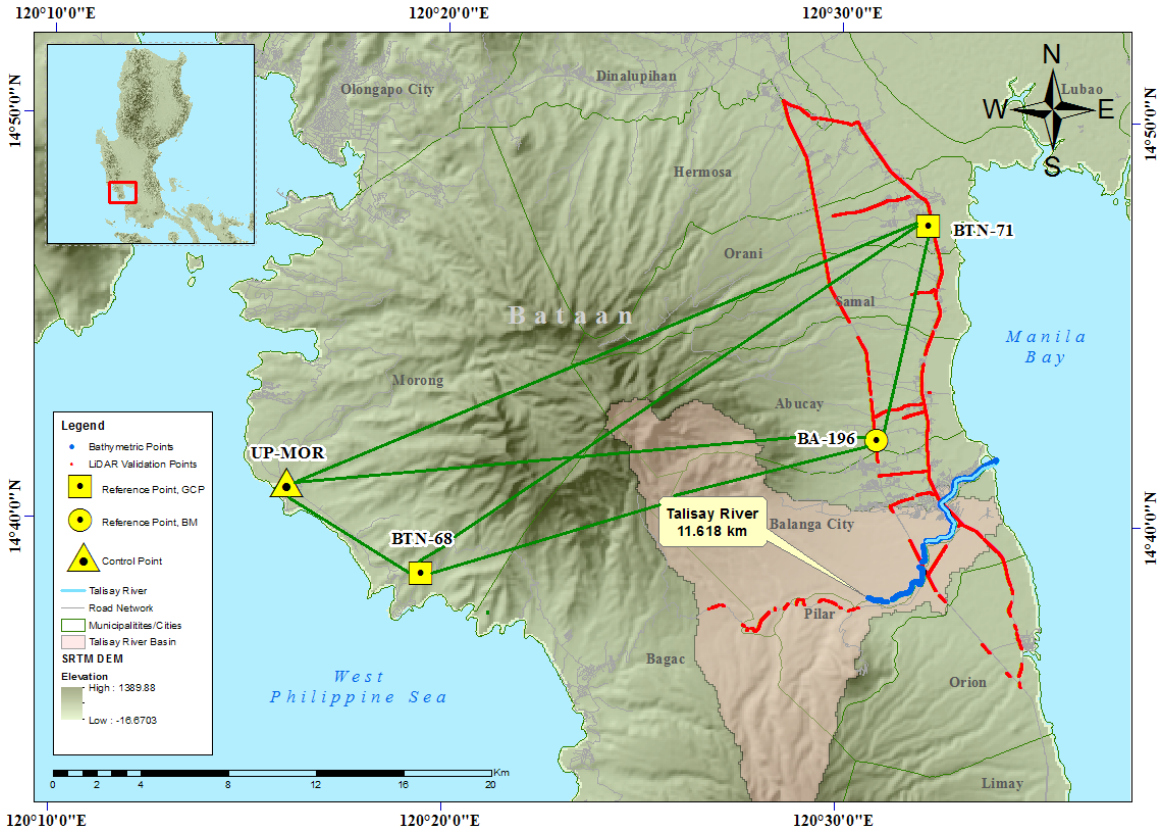


Figure 30.Talisay River Survey Extent

4.2 Control Survey

The GNSS network used for Talisay River Basin is composed of four (4) loops established on July 24, 2016 occupying the following reference points: BTN-68, a second-order GCP in Brgy. Nagbalayong, Municipality of Morong;BTN-71, a second order GCP, in Brgy. Apollo, Municipality of Orani; and BA-196, a first order BM, located in Brgy. Capitangan, Municipality of Abucay; all in Bataan.

A control point was established along the approach of Morong Bridge namely: UP-MOR, located in Brgy. Poblacion, Municipality of Morong, Bataan.

The summary of reference and control points and its location is summarized in Table 24 while the GNSS network established is illustrated in Figure 31.

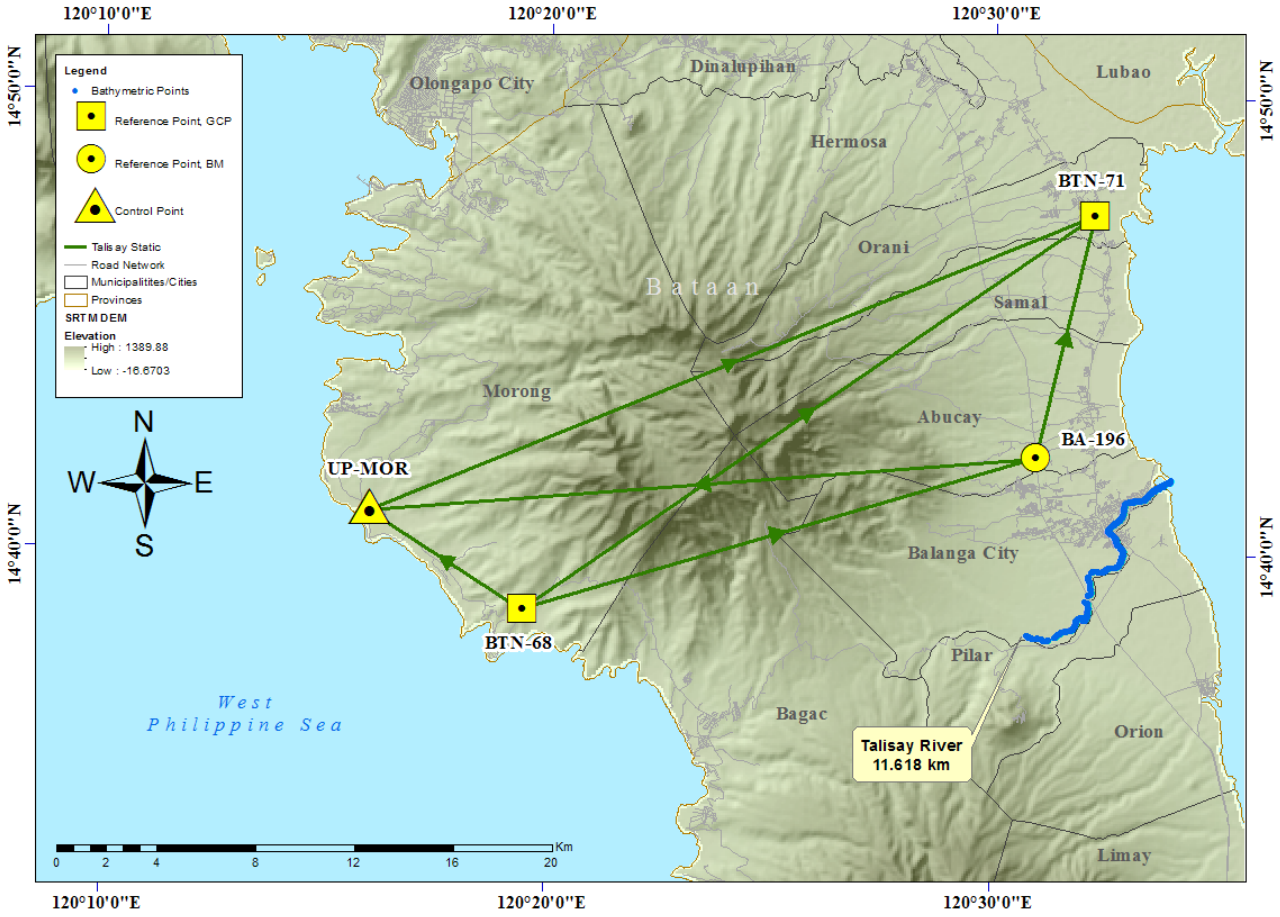


Figure 31.GNSS Network covering Talisay River

Table 24.. List of Reference and Control Points occupied for Talisay River Survey
(Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
BTN-68	2nd order, GCP	14°38'42.29096"N	120°19'26.94802"E	136.52	-	2016
BTN-71	2nd order, GCP	14°47'24.68277"N	120°32'14.83855"E	45.996	-	2014
BA-196	1st order, BM	-	-	65.611	22.836	2016
UP-MOR	UP Established	-	-	-	-	Jul 24, 2016 11:17 AM

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

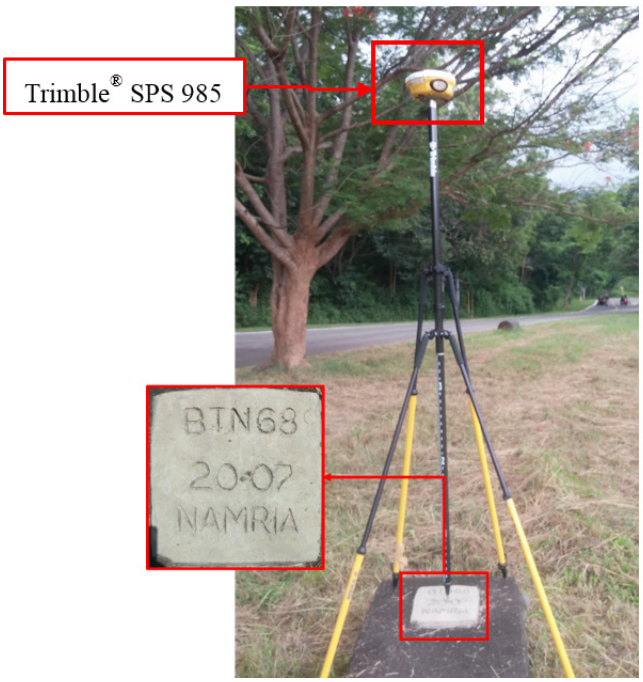


Figure 32.GNSS base set up, Trimble® SPS 882, at BTN-68, located just outside the Bataan Nuclear Power Plant along National High Way, Brgy. Nagbalayong, Municipality of Morong, Bataan

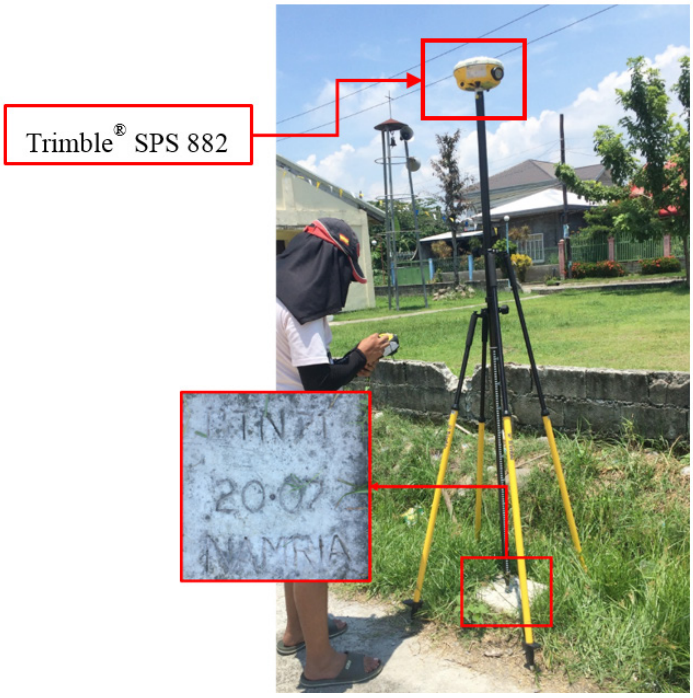


Figure 33.GNSS receiver setup, Trimble® SPS 882, at BTN-71, located at the middle of basketball court, Barangay Day Care Center and Barangay Chapel in Brgy. Apollo, Municipality of Orani, Bataan

Figure 34.GNSS receiver setup, Trimble® SPS 852, at BA-196, located at the approach of Capitangan Bridge in Brgy. Capitangan, Municipality of Abucay, Bataan

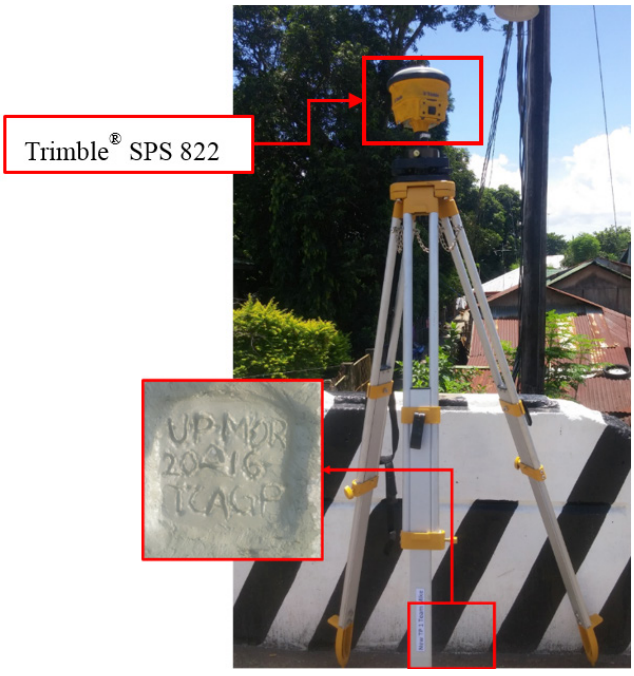


Figure 35.GNSS receiver setup, Trimble® SPS 985, at UP-MOR, located at the approach of Morong Bridge in Brgy. Poblacion, Municipality of Morong, Bataan

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Talisay River Basin is summarized in Table 25 generated by TBC software.

Table 25. Baseline Processing Summary Report for Talisay River Survey

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. **(Meter)**	**Height (Meter)**
BA196 --- BTN68	07-24-16	Fixed	0.005	0.018	73°05'46"	21610.115	-70.921
BTN68 --- UPMOR	07-24-16	Fixed	0.004	0.015	303°13'37"	7409.089	-87.926
BA196 --- BTN71	07-24-16	Fixed	0.003	0.015	13°12'16"	10046.745	-19.625
BA196 --- UPMOR	07-24-16	Fixed	0.003	0.013	265°19'07"	26966.019	-17.016
UPMOR --- BTN71	07-24-16	Fixed	0.003	0.016	67°36'23"	31535.946	-2.587
BTN68 --- BTN71	07-24-16	Fixed	0.005	0.022	55°01'14"	28025.680	-90.506

As shown Table 25 a total of six (6) baselines were processed with reference points BTN-68 and BTN-71 held fixed for coordinate values; and BA-196 fixed for elevation values. All of them passed the required accuracy.

4.4Network Adjustment

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

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

Where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

for each control point. See the Network Adjustment Report shown in Table 26 to Table 29 for complete details.

The four (4) control points, BTN-68, BTN-71, BA-196 and UP-MOR were occupied and observed simultaneously to form a GNSS loop. Coordinates of BTN-68 and BTN-71; and elevation value of BA-196 were held fixed during the processing of the control points as presented in Table 26. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 26. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
BTN-68	Local	Fixed	Fixed		
BTN-71	Local	Fixed	Fixed		
BA-196	Grid				Fixed
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 27. The fixed controls BTN-68 and BTN-71 have no values for grid errors while BA-68 has no value for elevation error.

Table 27. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	**Elevation Error (Meter)**	**Constraint**
BTN-68	211765.363	?	1620773.573	?	93.217	0.044	LL
BTN-71	234930.205	?	1636575.052	?	3.465	0.041	LL
BA-196	232526.227	0.006	1626815.229	0.005	22.836	?	e
UP-MOR	205612.090	0.008	1624909.162	0.007	5.340	0.039	

With the mentioned equation, for horizontal and for the vertical; the computation for the accuracy are as follows:

a. BTN-68
horizontal accuracy = Fixed
vertical accuracy = 4.4 cm < 10 cm

b. BTN-71
horizontal accuracy = Fixed
vertical accuracy = 4.1 cm < 10 cm

c. BA-196
horizontal accuracy = $\sqrt{((0.6)^2 + (0.5)^2}$
= $\sqrt{(0.36 + 0.25)}$
= 0.78 < 20 cm
vertical accuracy = Fixed

d. UP-MOR
horizontal accuracy = $\sqrt{((0.8)^2 + (0.7)^2}$
= $\sqrt{(0.64 + 0.49)}$
= 1.06 < 20 cm
vertical accuracy = 3.9 cm < 10 cm

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

Table 28. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
BTN-68	N14°38'42.29096	E120°19'26.94802"	136.520	0.044	LL
BTN-71	N14°47'24.68277"	E120°32'14.83855"	45.996	0.041	LL
BA-196	N14°42'06.44710"	E120°30'58.09376"	65.611	?	e
UP-MOR	N14°40'54.35855"	E120°15'59.79638"	48.592	0.039	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 28. 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 29.

Table 29. 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)
BTN-68	2nd order, GCP	13°55'14.18695"	122°36'12.89833"	59.636	1538981.558	457175.646	10.059
BTN-71	2nd order, GCP	13°49'14.33596"	122°47'41.49841"	60.994	1527900.59	477829.729	10.576
BA-196	1st order, BM	14°09'12.36125"	122°49'52.53365"	64.661	1564701.975	481789.697	14.905
UP-MOR	UP Established	14°03'52.37147"	122°58'30.23146"	55.501	1554865.116	497307.927	5.214

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

Cross-section and as-built survey were conducted on July 9, 2016 at the downstream side of Talisay Bridge in Brgy. Central, Balanga City, Bataanas shown in Figure 37. A total station through open traverse method and Trimble® SPS 882 GNSS PPK survey technique were utilized for this survey as shown in Figure 37.

Figure 36. Talisay Bridge facing downstream

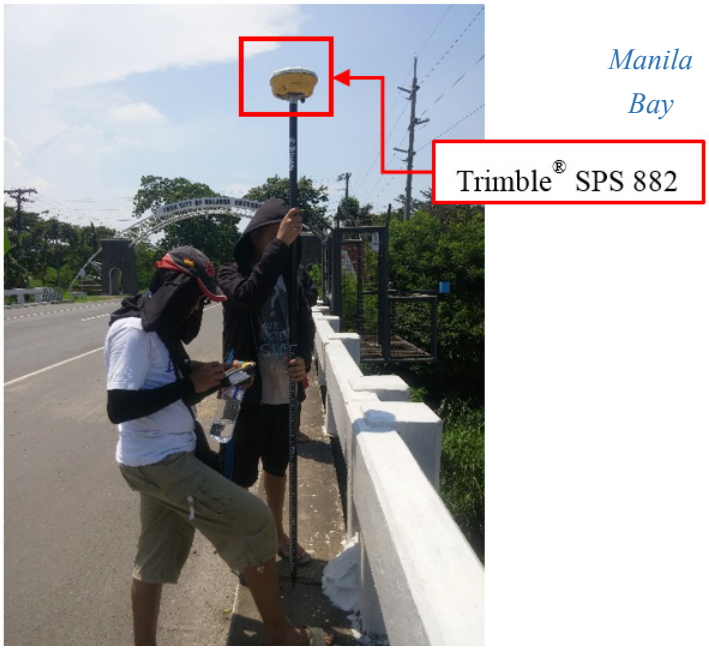


Figure 37. Bridge As-Built Survey using PPK Technique.

The cross-sectional line of Talisay Bridge is about 116.050 m with one hundred seven (107) cross-sectional points using the control point BA-196 as the GNSS base station. The cross-section diagram, planimetric map and the bridge data form are shown in Figure 38toFigure 40, respectively.

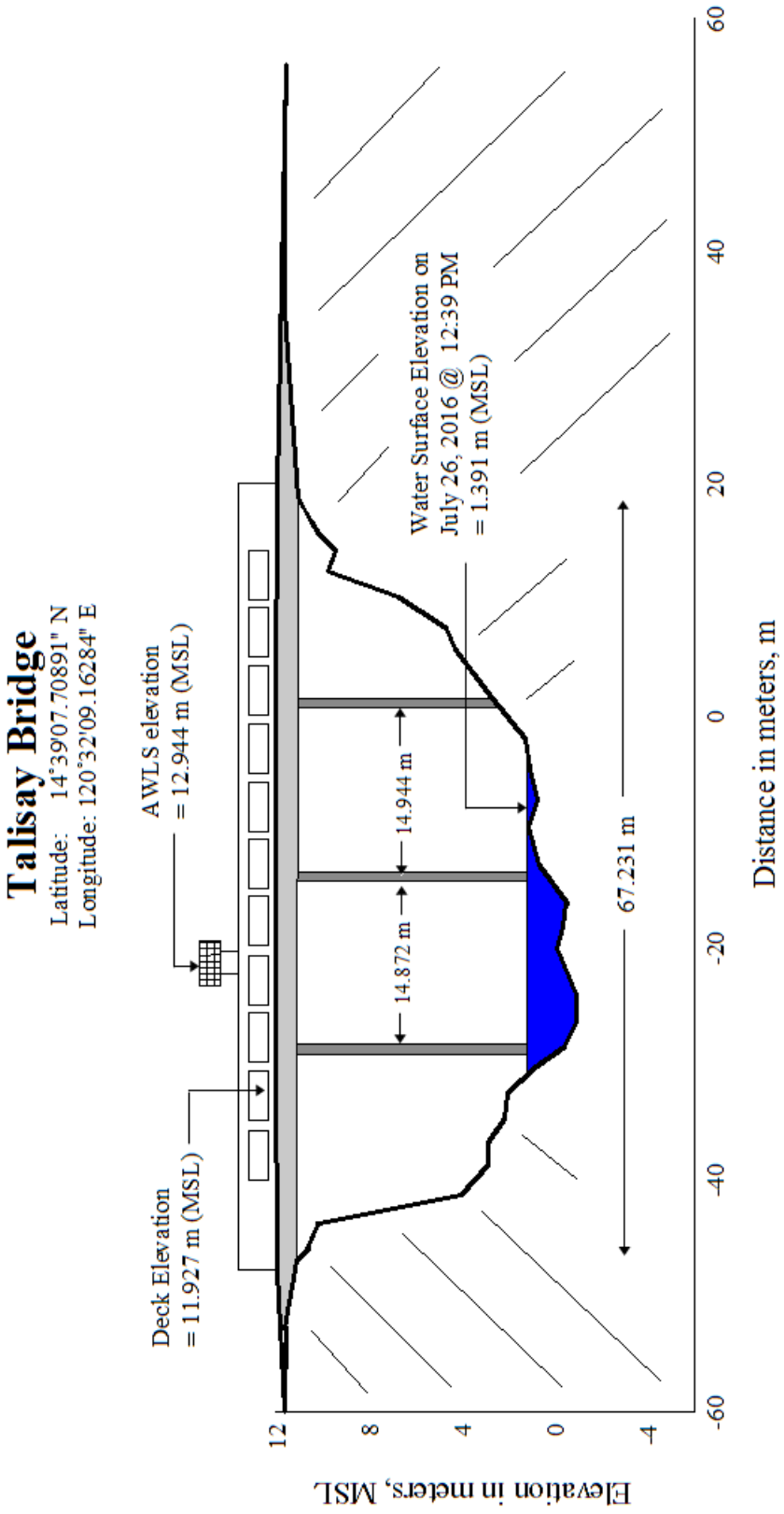


Figure 38. Talisay Bridge cross-section diagram

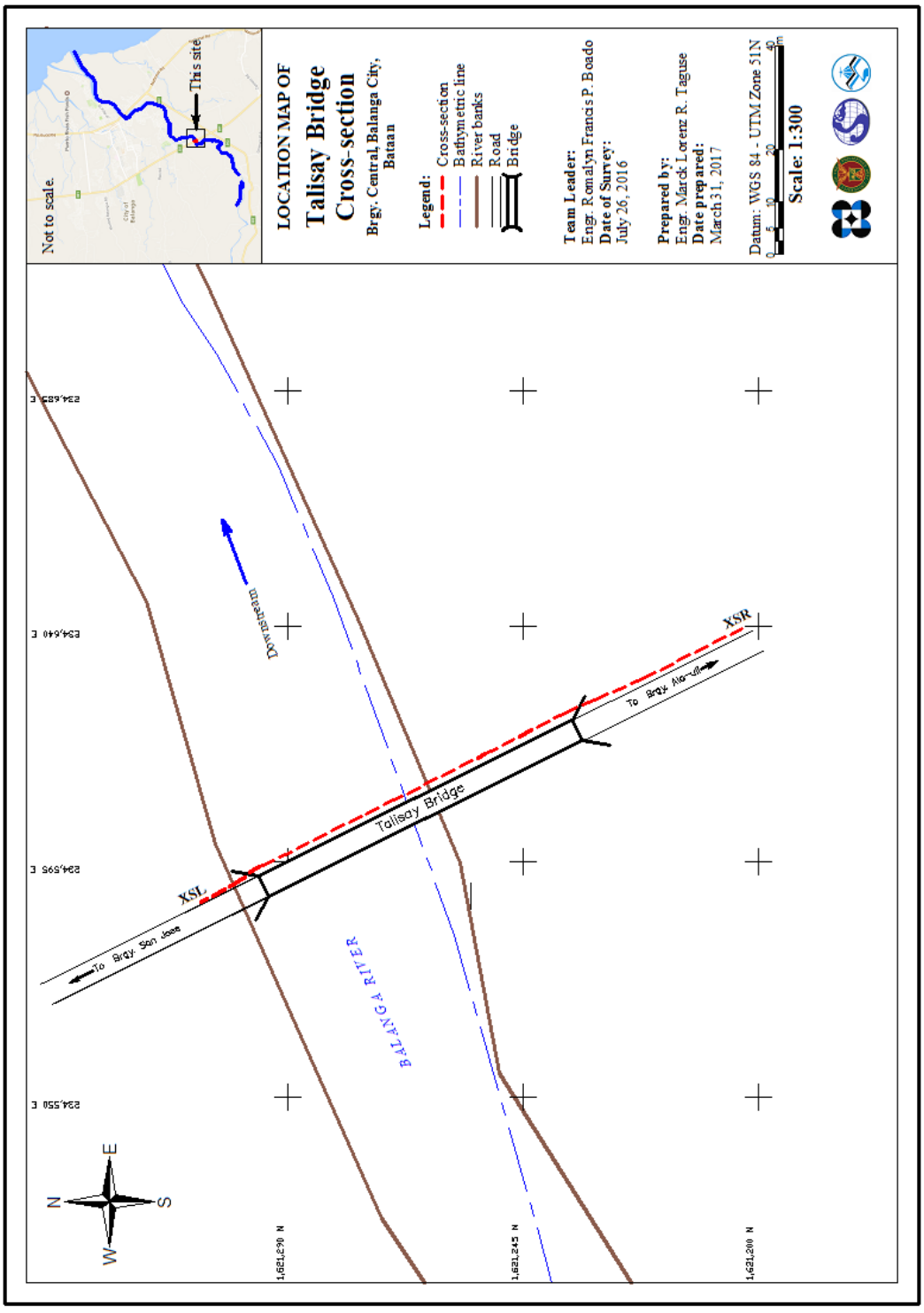


Figure 39. Talisay Bridge cross-section planimetric map

Bridge Data Form

Bridge Name: Talisay Bridge — **Date:** July 26, 2016

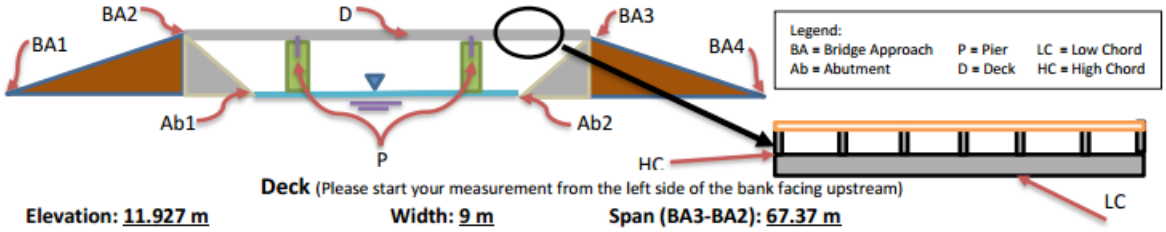
River Name: Talisay River — **Time:** 12:39 PM

Location (Brgy, City,Region): Brgy. Central, Balanga City, Bataan

Survey Team: Romalyn Boado, Lorenz Taguse, Marion Dimain

Flow condition: normal — **Weather Condition:** fair

Latitude: 14°39'07.70891" N — **Longitude:** 120°32'09.16284" E



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

Elevation: 11.927 m — **Width:** 9 m — **Span (BA3-BA2):** 67.37 m

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	11.590 m	BA3	79.408 m	11.948 m
BA2	12.185 m	11.927 m	BA4	116.034 m	11.527 m

Abutment: Is the abutment sloping? **Yes**; If yes, fill in the following information:

	Station (Distance from BA1)	Elevation
Ab1	16.158 m	10.177 m
Ab2	74.253 m	9.415 m

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

Shape: Flat Cylindrical — Number of Piers: 3 — Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	30.867 m	12.002 m	NA
Pier 2	45.728 m	12.016 m	NA
Pier 3	60.667 m	12.010 m	NA

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

Figure 40. Bridge as-built form of Talisay Bridge

Water surface elevation of Talisay River was determined using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on July 26, 2016 at 12:39 PM with a value of 1.391 m in MSL as shown in Figure 38. This was translated into marking on the bridge's pier using the same technique as shown in Figure 41. This will serve as reference for flow data gathering and depth gauge deployment of partner HEI responsible for Talisay river, the Central Luzon State University.

Figure 41. Water-level markings on Talisay Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on July 26, 27 and 28, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted in front of a vehicle as shown in Figure 42. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 1.8 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with BA-196 occupied as the GNSS base station.

Figure 42.Validation points acquisition survey set up along Talisay River Basin

The survey started from Brgy. Paihan, Municipality of Hermosa, going south traversing two parallel national highways along Balanga City and seven (7) more Municipalities in Bataan. It ended in Brgy. Santa Elena, Municipality of Orion, Bataan. A total of 11,158 points were gathered with approximate length of 83 km using BA-196 as GNSS base station for the entire extent validation points acquisition survey as illustrated in the map in Figure 43.

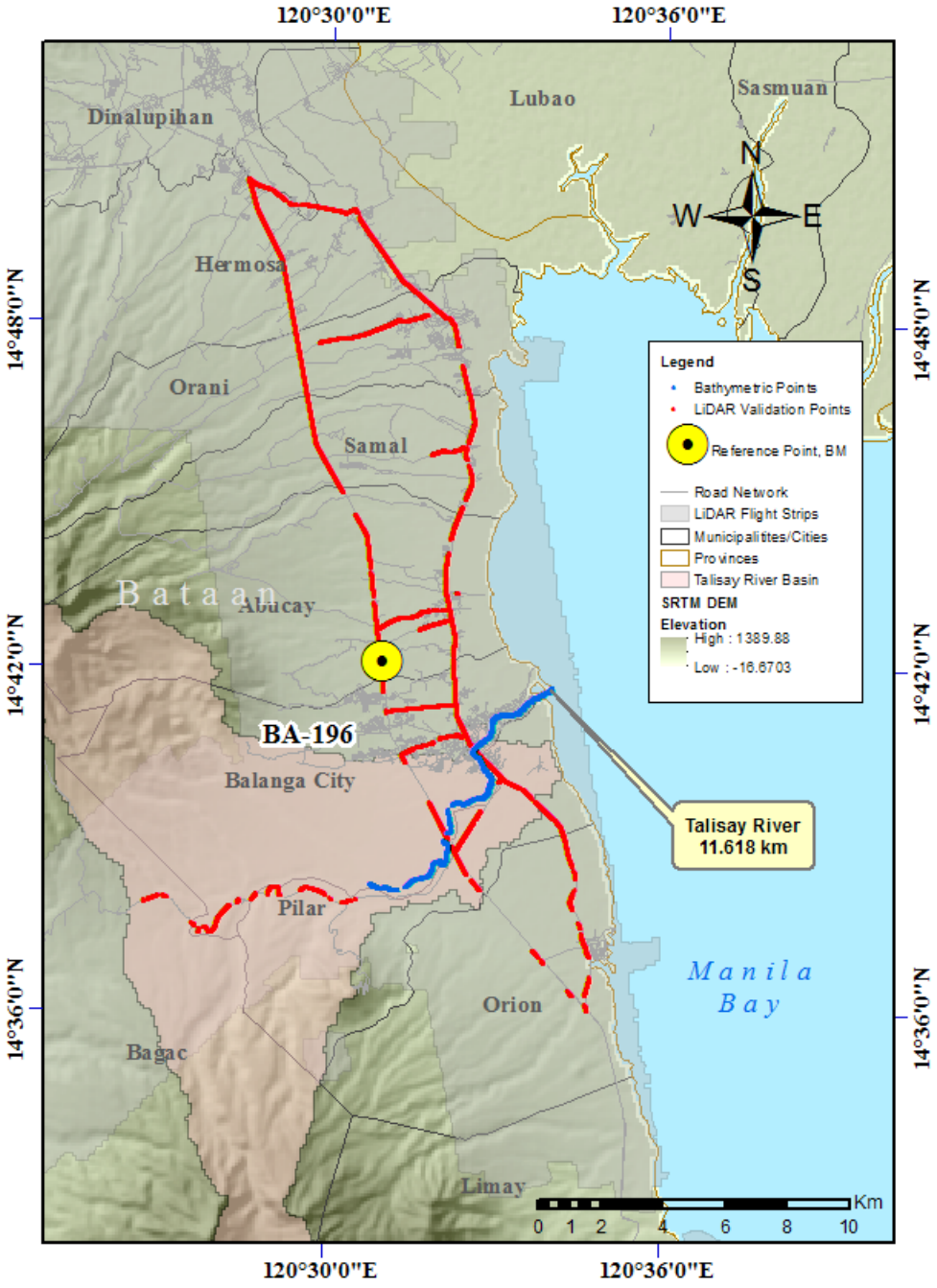


Figure 43. Validation point acquisition survey of Talisay River Basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on July 26, 2016 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 44. The survey started in Brgy. Central, Balanga City, with coordinates 14°39'38.89769"N, 120°32'19.37211"E, and ended at the mouth of the river in Brgy. Tortugas with coordinates 14°41'38.45683"N, 120°34'01.54769"E.

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

Manual bathymetric survey was executed on July 27 and 28, 2016 using Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode. The survey started in Brgy. Dangcol, Balanga City, with coordinates 14°38'13.42551"N, 120°30'49.51085"E, and ended at the starting point of the bathymetric survey using boat. The control point BA-196 was used as the GNSS base station throughout the entire survey.

The bathymetric survey for Talisay River gathered a total of 10,011 points covering 11.618 km of the river traversing nine (9) barangays in Balanga City. A CAD drawing was also produced to illustrate the riverbed profile of Talisay River. As shown in Figure 46, the highest and lowest elevation has a 25-m difference. The highest elevation observed was 13.155 m in MSL located at Brgy. Dangcol, while the lowest was -11.983 m below MSL located at the downstream portion of the river located in Brgy. Central, both in Balanga City.

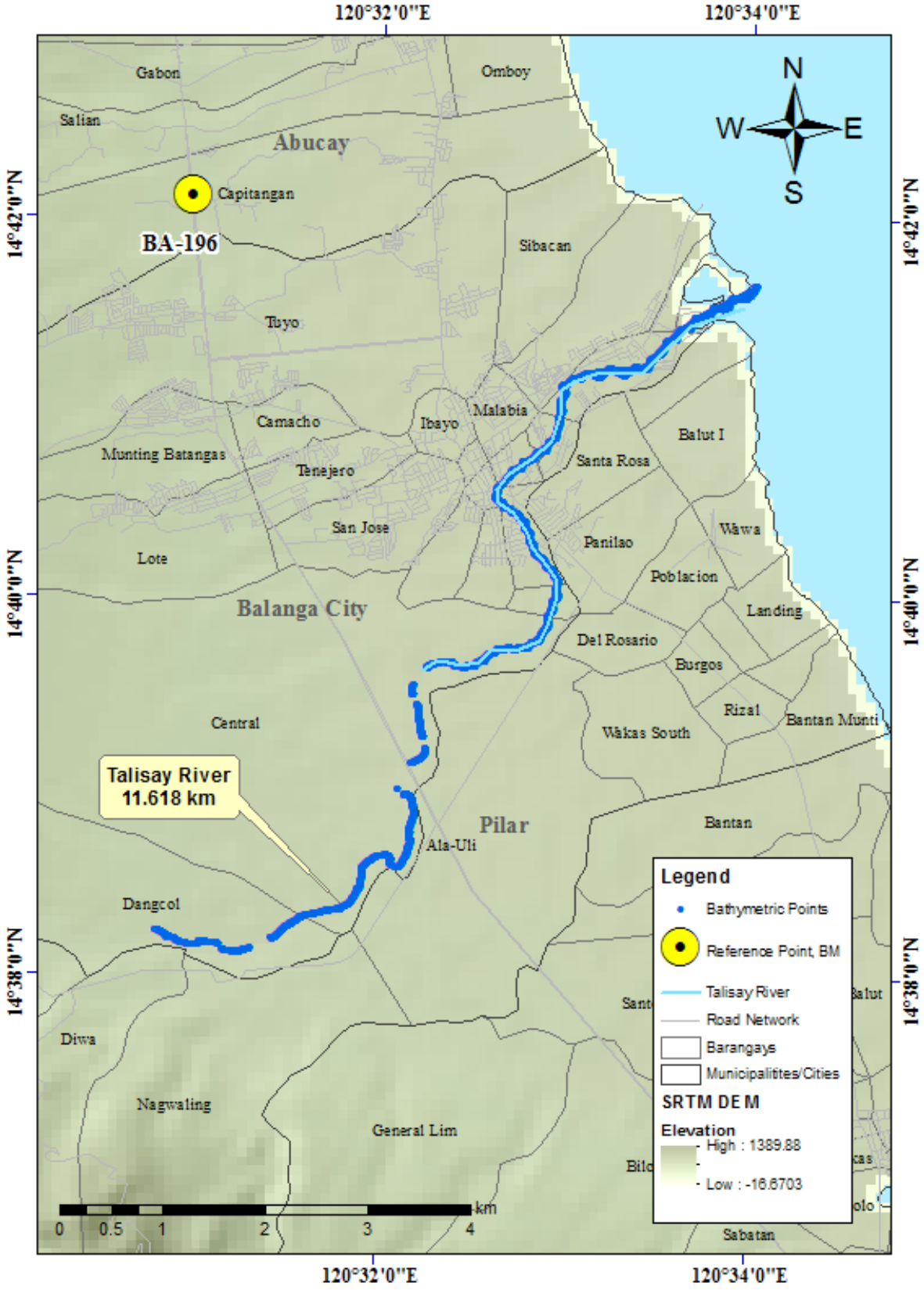


Figure 45. Extent of the bathymetric survey (in blue line) in Balanga (also known as Talisay) River

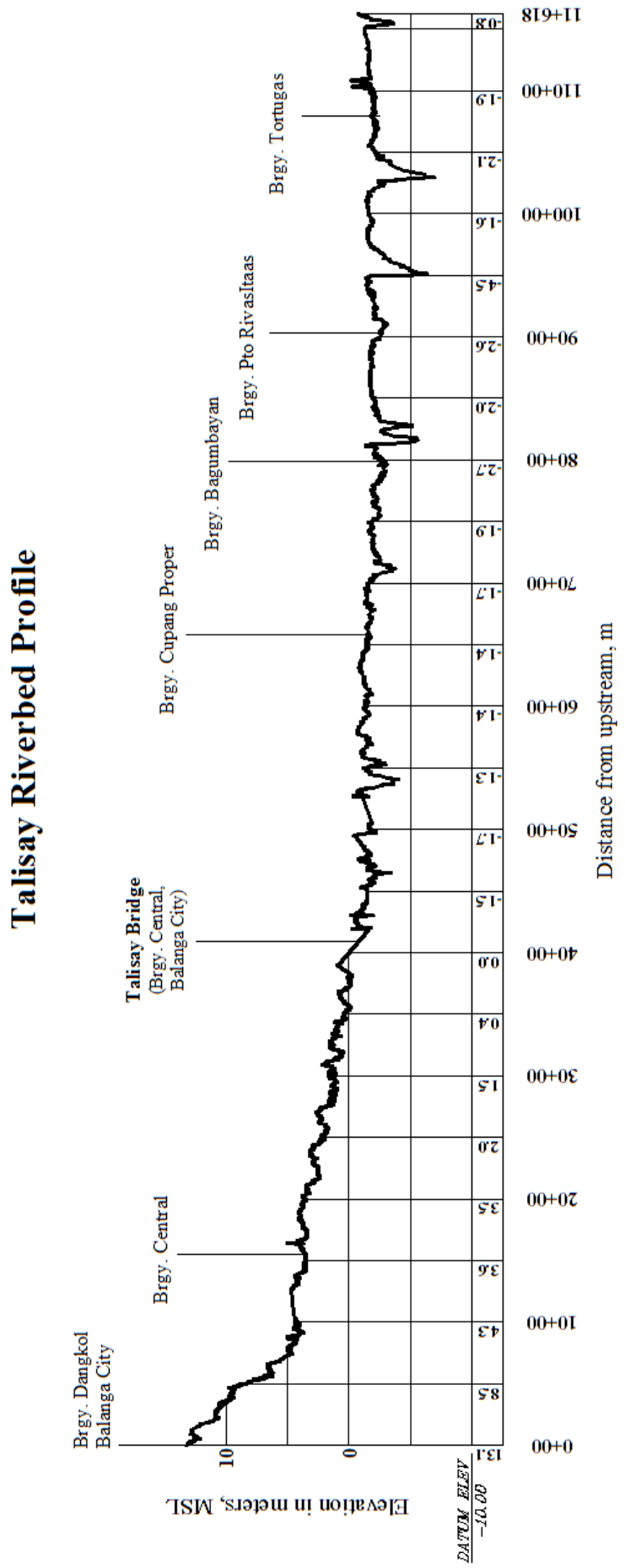


Figure 46. Talisay Riverbed Profile

CHAPTER 5. FLOOD MODELING AND MAPPING

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

5.1.1 Hydrometry and Rating Curves

Components and data that affect the hydrologic cycle of the river basin was monitored, collected, and analyzed. Rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Balanga river were monitored, collected and analyzed.

5.1.2 Precipitation

Precipitation data were taken from automatic rain gauge (Dangol ARG) installed by the Department of Science and Technology – Advance Science and Technology Institute (DOST-ASTI) located in Barangay Dangol, Balanga Bataan.

The total rain recorded in this event from the rain gauge is 31.24 mm. It peaked to 14.24 mm. on 17 September 2016 at 13:40PM. The lag time between the peak rainfall and discharge is 3 hours and 50 minutes.

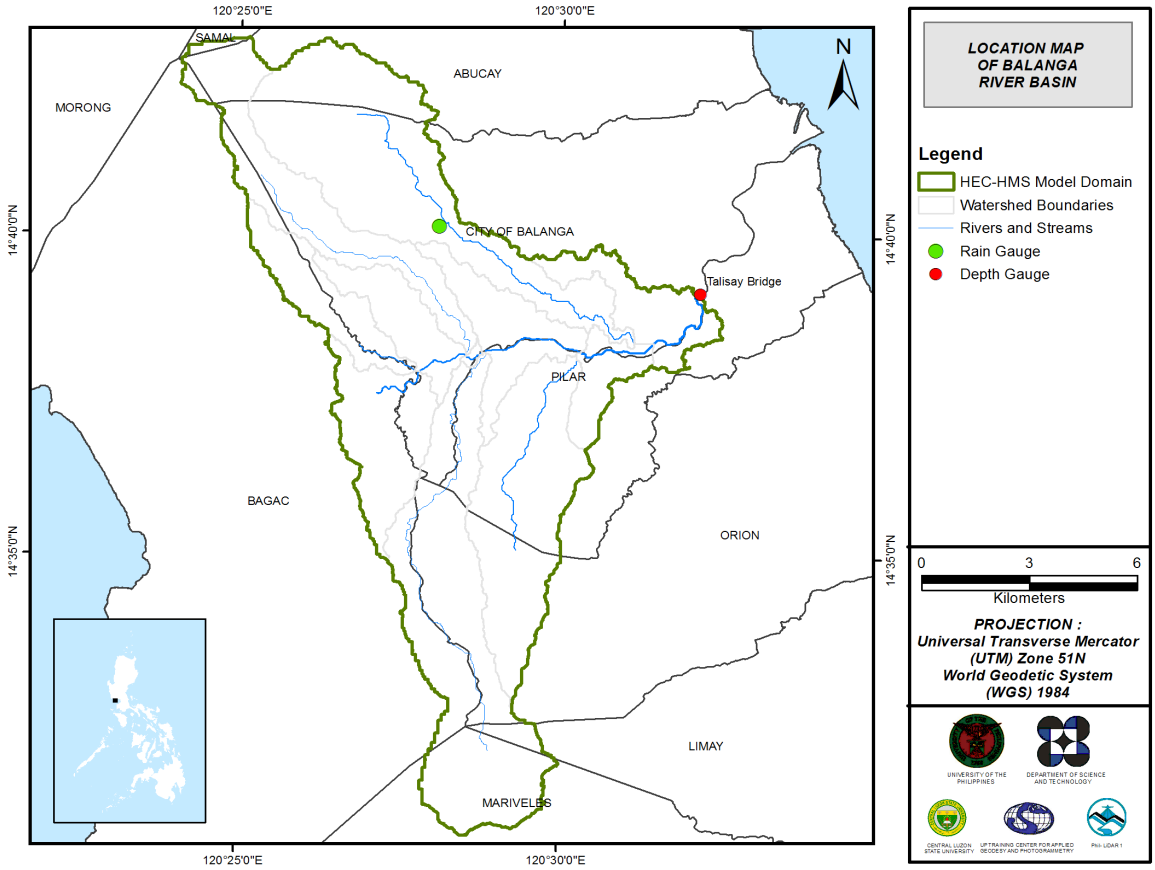


Figure 47. The location map of Balanga HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Talisay Bridge, Balanga, Bataan (14 °39' 7.22"N, 120° 32' 9.34"E). It gives the relationship between the observed water levels at Balanga Bridge and outflow of the watershed at this location.

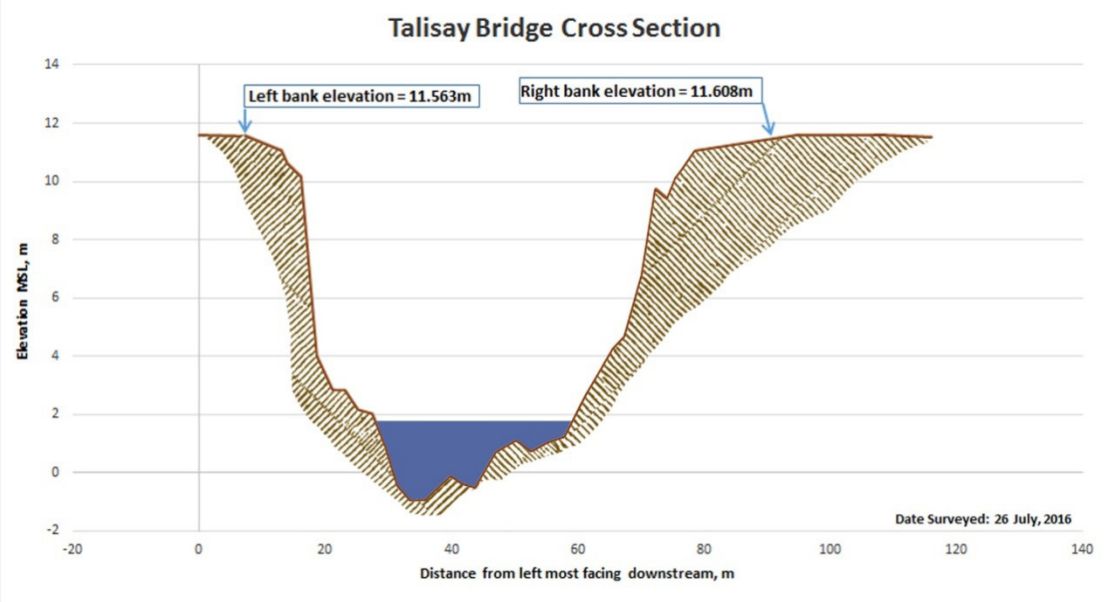


Figure 48. Cross Section Plot of Talisay Bridge

For Talisay Bridge, the rating curve is expressed as $Q = 7.471e^{1.0155h}$ as shown in Figure 49.

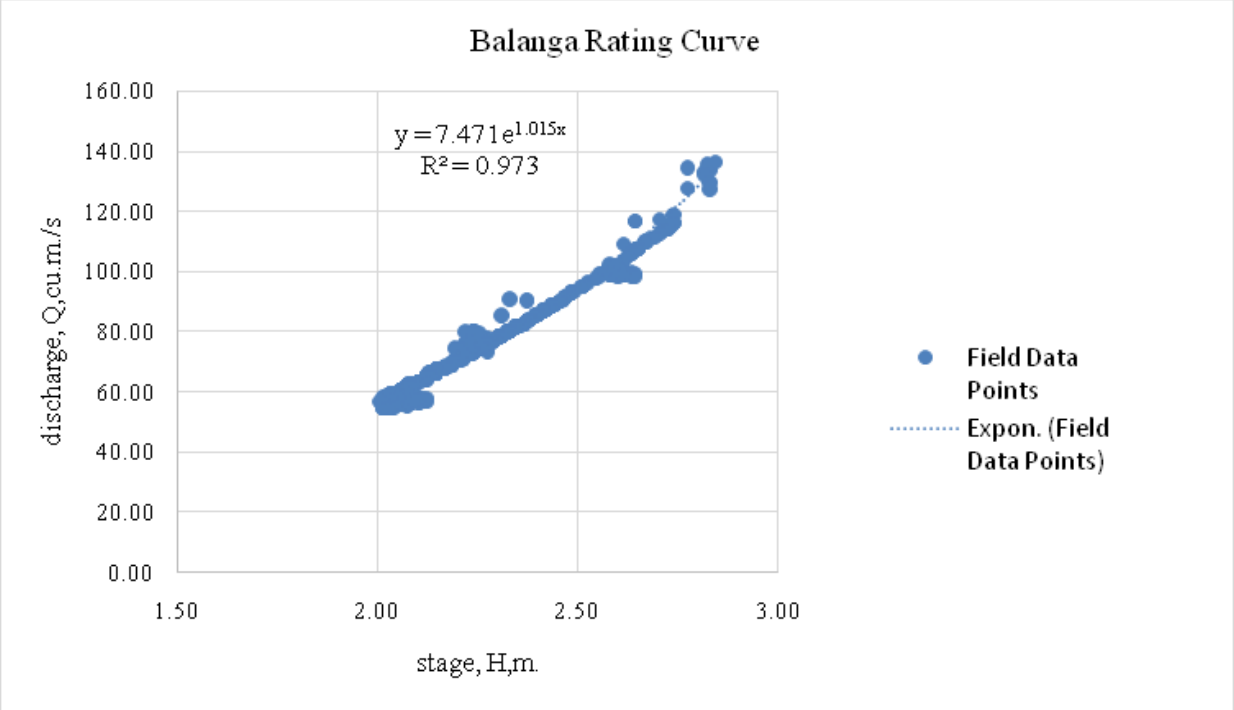


Figure 49. Rating Curve at Talisay Bridge, Balanga, Bataan

This rating curve equation was used to compute the river outflow at Talisay Bridge for the calibration of the HEC-HMS model shown in Figure 49. Peak discharge is 92.5 cms at 17:30, September, 17, 2016

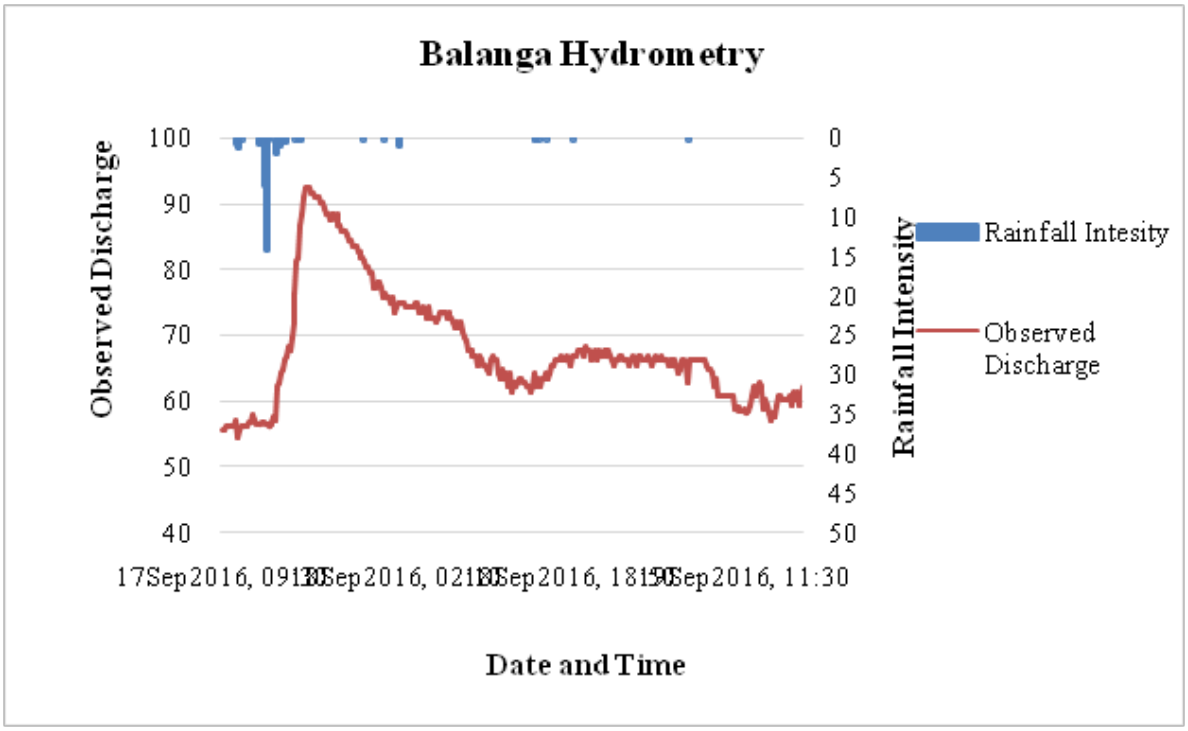


Figure 50. Rainfall and outflow data at Balanga used for modeling

5.2RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Sangley Point 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 Balanga watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 30. RIDF values for Sangley Point 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	20.3	30	36.6	46.4	63.2	74.6	96.6	119.6	147.9
5	28.3	41.8	50.8	64.6	89.8	106.8	140.3	174	209.4
10	33.6	49.7	60.2	76.7	107.3	128.2	169.2	210	250.1
15	36.6	54.1	65.5	83.5	117.2	140.3	185.6	230.3	273.1
20	38.7	57.2	69.2	88.3	124.2	148.7	197	244.6	289.1
25	40.3	59.6	72.1	91.9	129.5	155.2	205.8	255.5	301.5
50	45.3	66.9	80.9	103.3	146	175.2	233	289.3	339.7
100	50.3	74.2	89.7	114.5	162.3	195.1	259.9	322.8	377.6

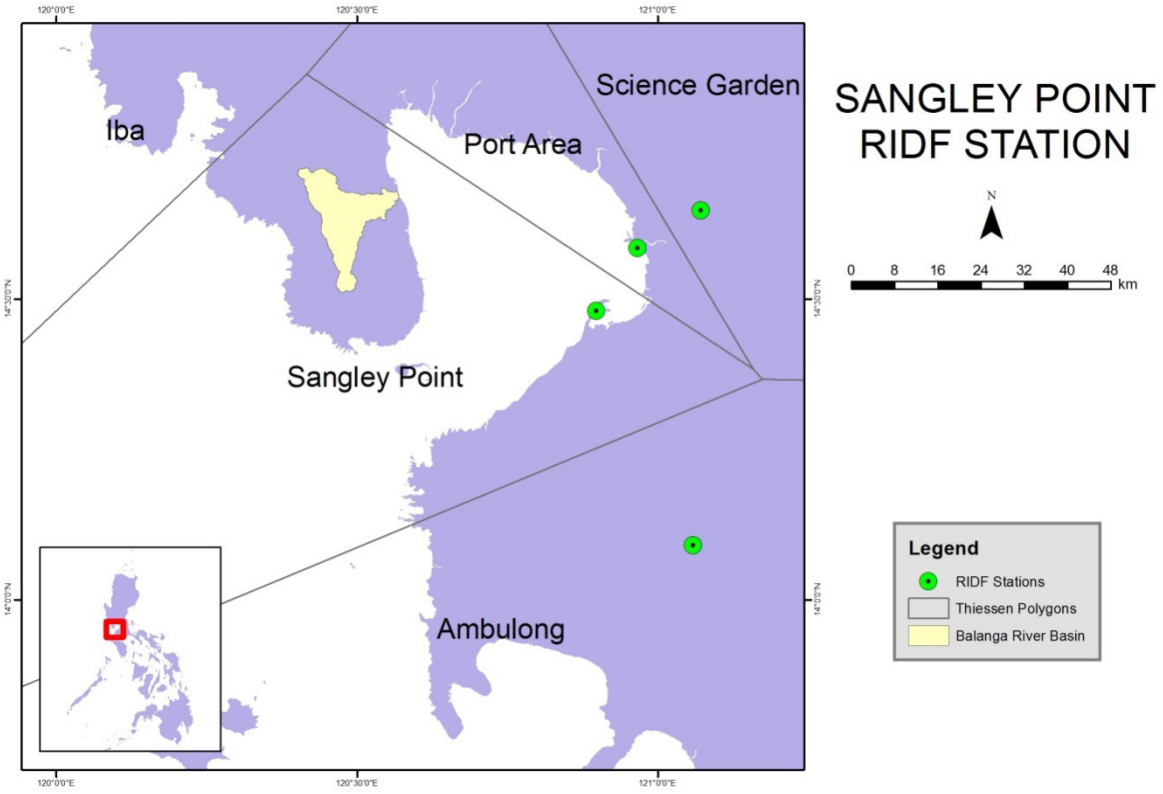


Figure 51. Sangley Point RIDF location relative to Balanga River Basin

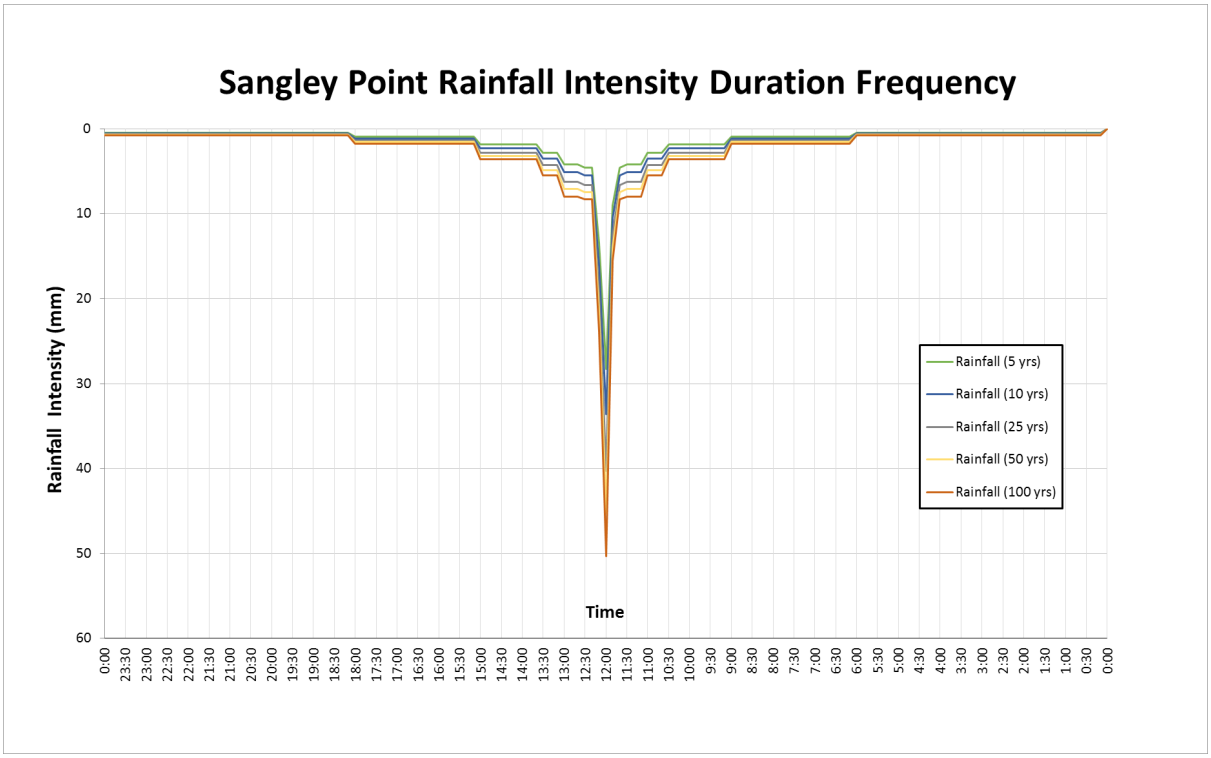


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3HMS Model

The soil dataset was taken before 2004 by the Bureau of Soils and Water Management (BSWM), under the Department of Agriculture (DA). The land cover dataset file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Balanga River Basin are shown in Figures 53 and 54, respectively.

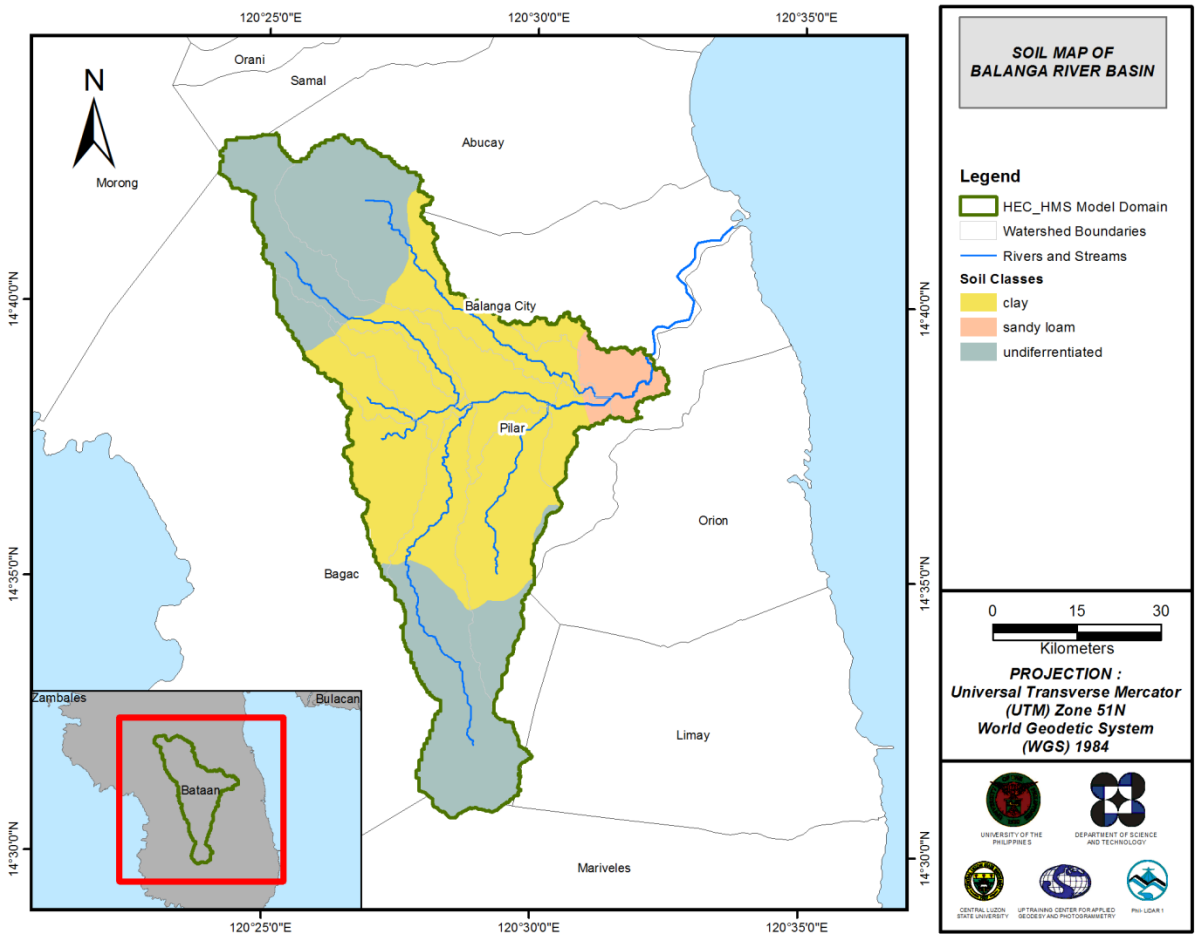


Figure 53.Soil Map of Balanga River Basin (Source: NAMRIA)

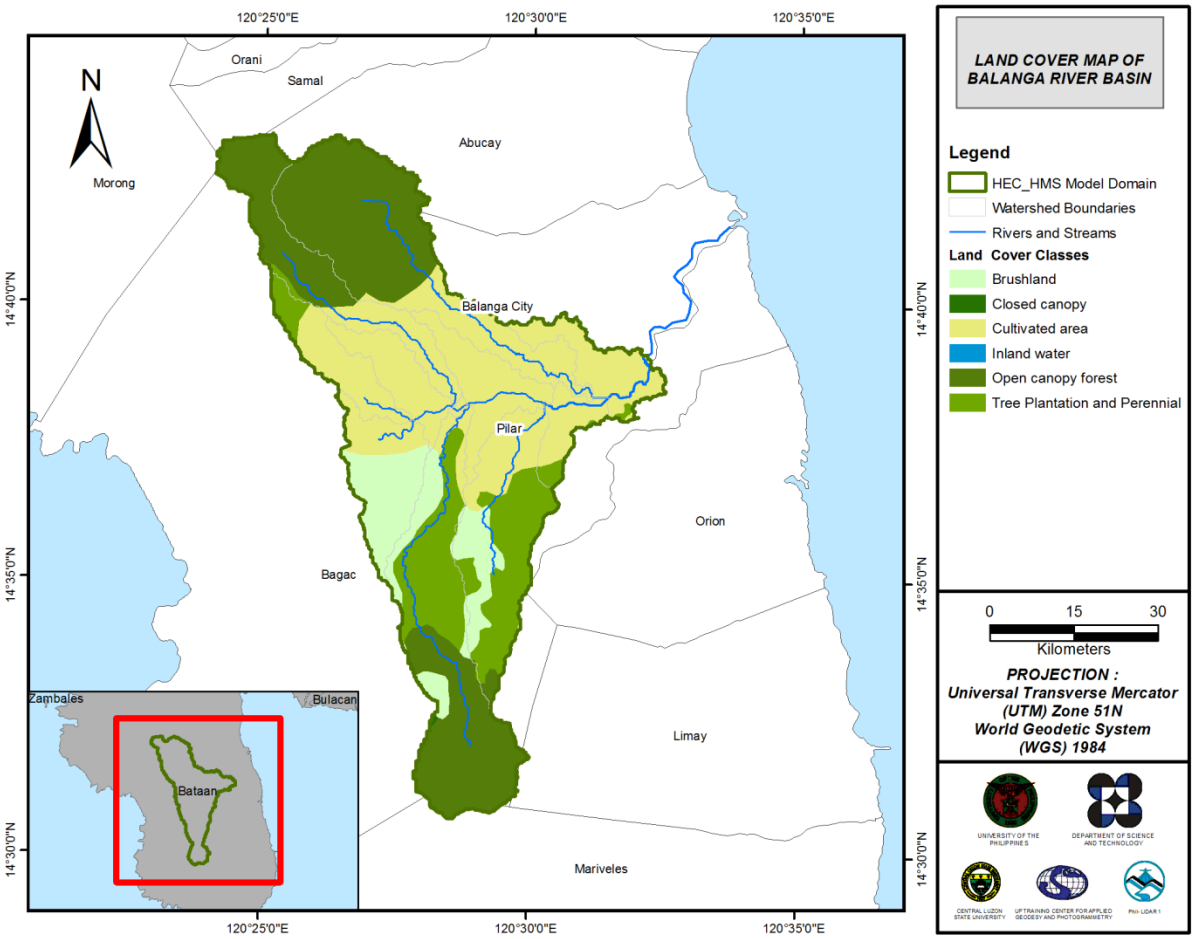


Figure 54. Land Cover Map of Balanga River Basin (Source: NAMRIA)

For Balanga, three soil classes were identified. These are clay, sandy loam, and undifferentiated. Moreover, six land cover classes were identified. These are brushland, closed canopy, cultivated area, inland water, open canopy forest and tree plantation and perennial.

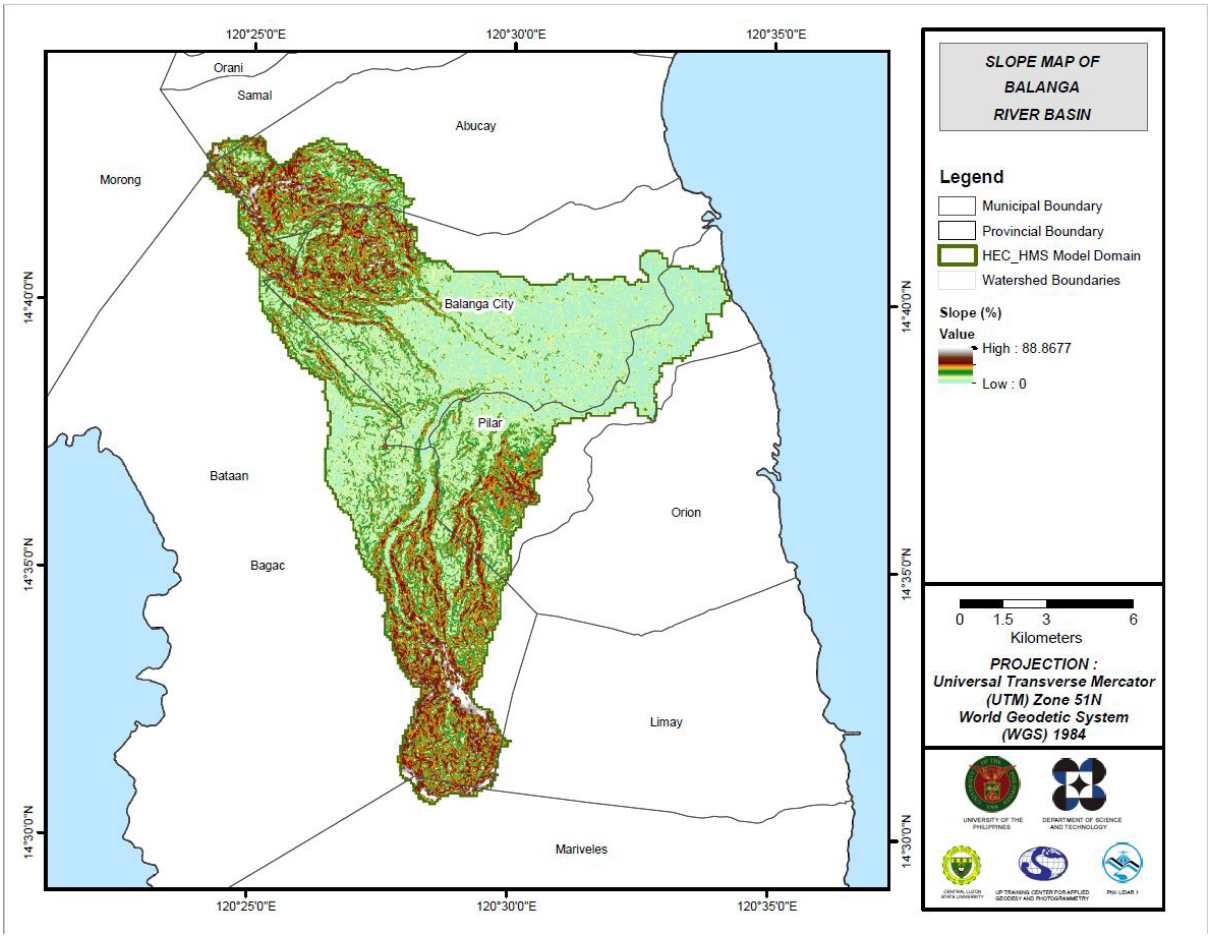


Figure 55.Slope Map of Balanga River Basin

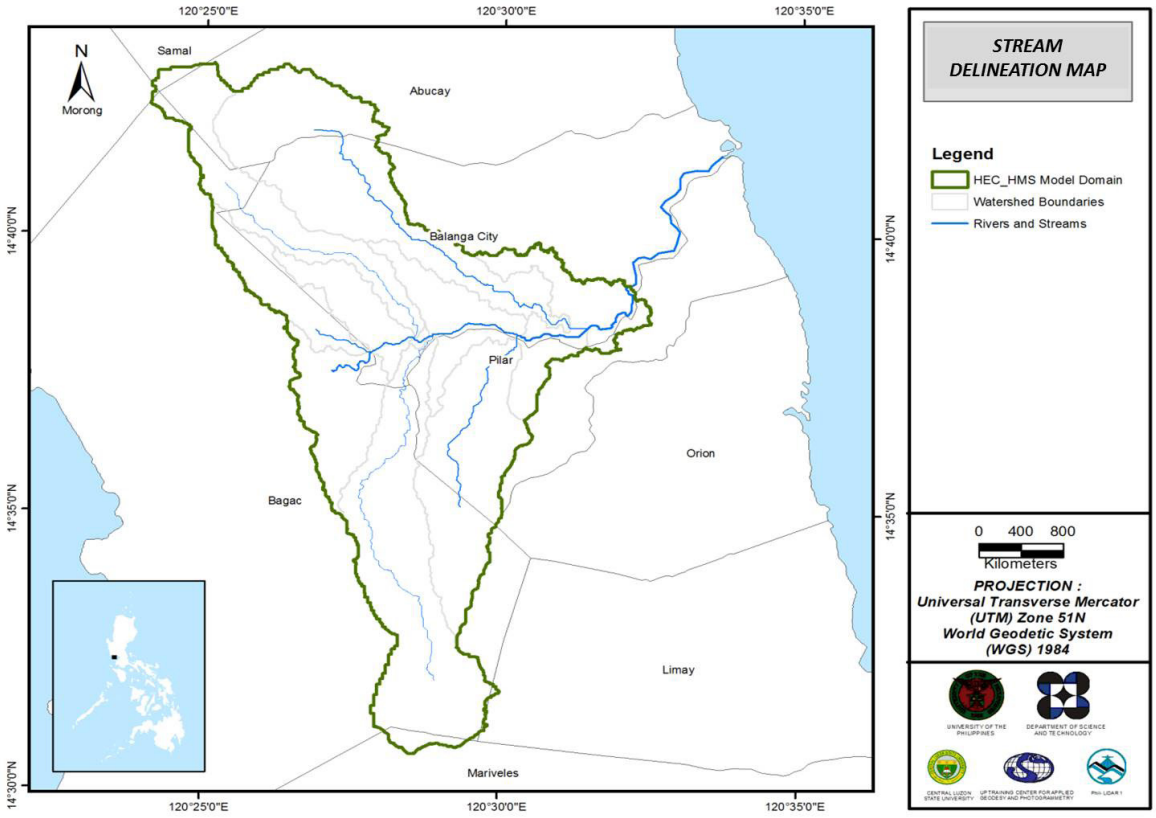


Figure 56.Stream Delineation Map of Balanga River Basin

Using the SAR-based DEM, the Balanga basin was delineated and further subdivided into subbasin. The Balanga basin model consists of 11 sub basins, 5 reaches, and 5 junctions as shown in Figure 57. Finally, it was calibrated using depth gauge installed in Balanga Bridge.

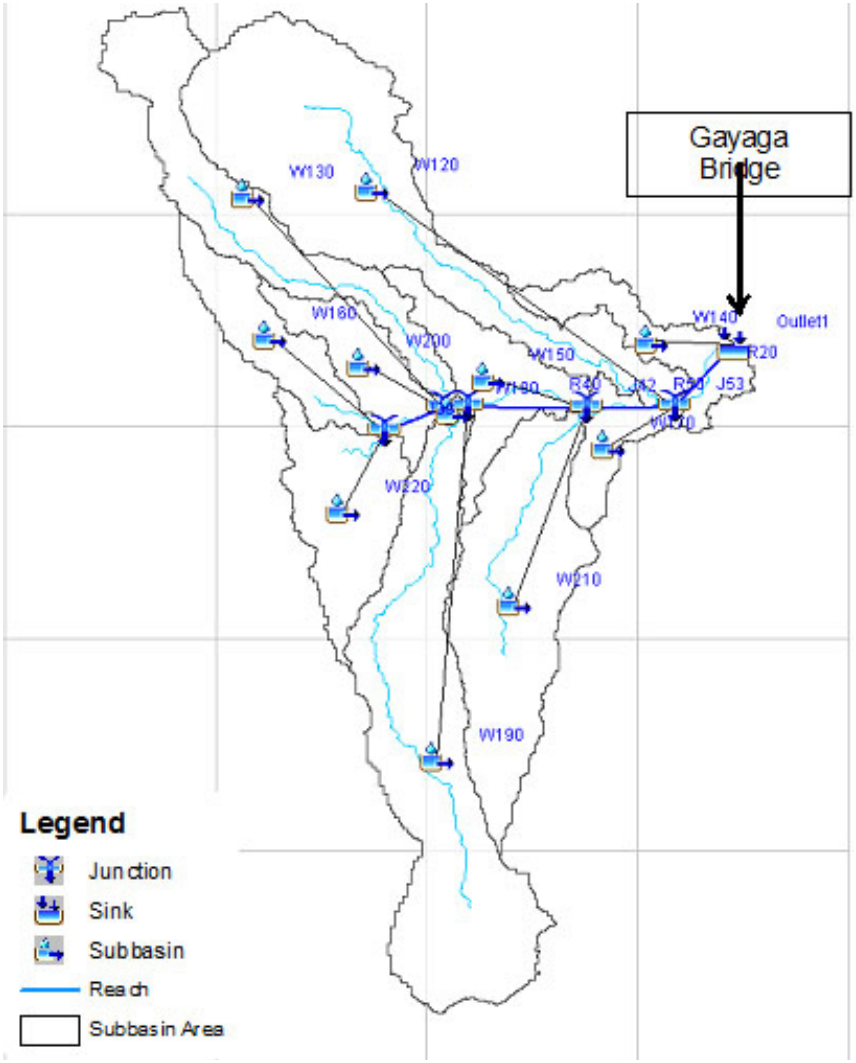


Figure 57.The Balanga river basin model generated using HEC-HMS

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.

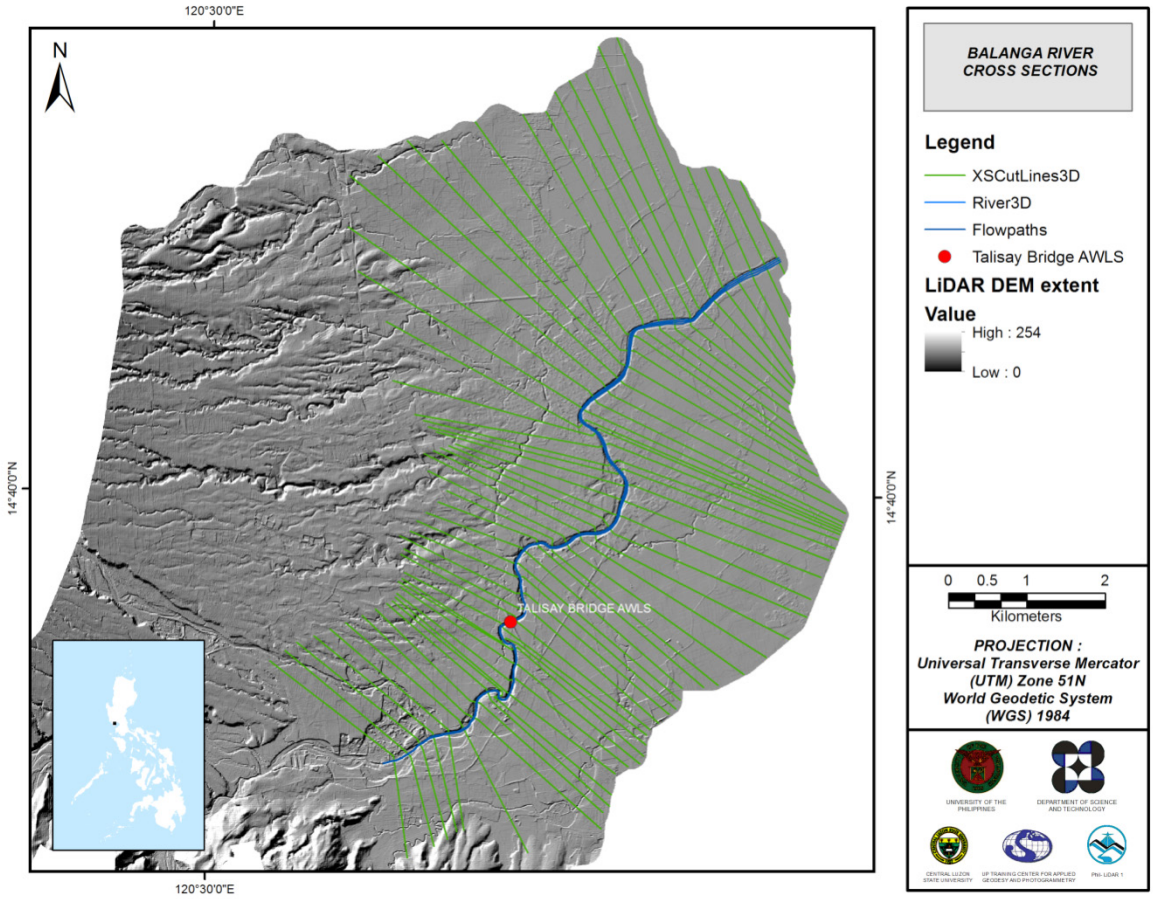


Figure 58. River cross-section of Balanga River generated through Arcmap HEC GeoRAS tool

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 southwest of the model to the northeast, following the main channel. As such, boundary elements east of the model are assigned as outflow elements.

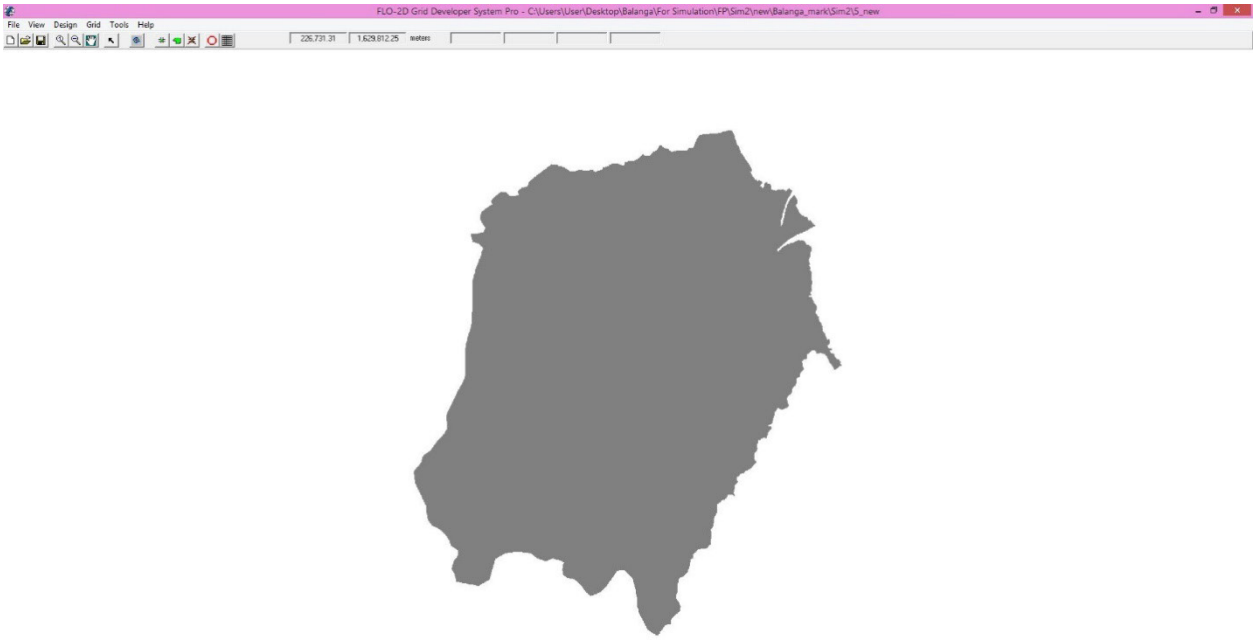


Figure 59.Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 71.29 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 70,603,600.00 m^2.

There is a total of 62,199,133.12 m^3 of water entering the model, of which 24,398,985.20 m^3 is due to rainfall and 37,800,147.92 m^3 is inflow from basins upstream. 10,941,391.00 m^3 of this water is lost to infiltration and interception, while 14,229,471.37 m^3 is stored by the flood plain. The rest, amounting up to 37,028,289.67 m^3,is outflow.

5.6 Results of HMS Calibration

After calibrating the Balanga HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 60 shows the comparison between the two discharge data. (See Annex 9 for the Balanga Model Basin Parameters)

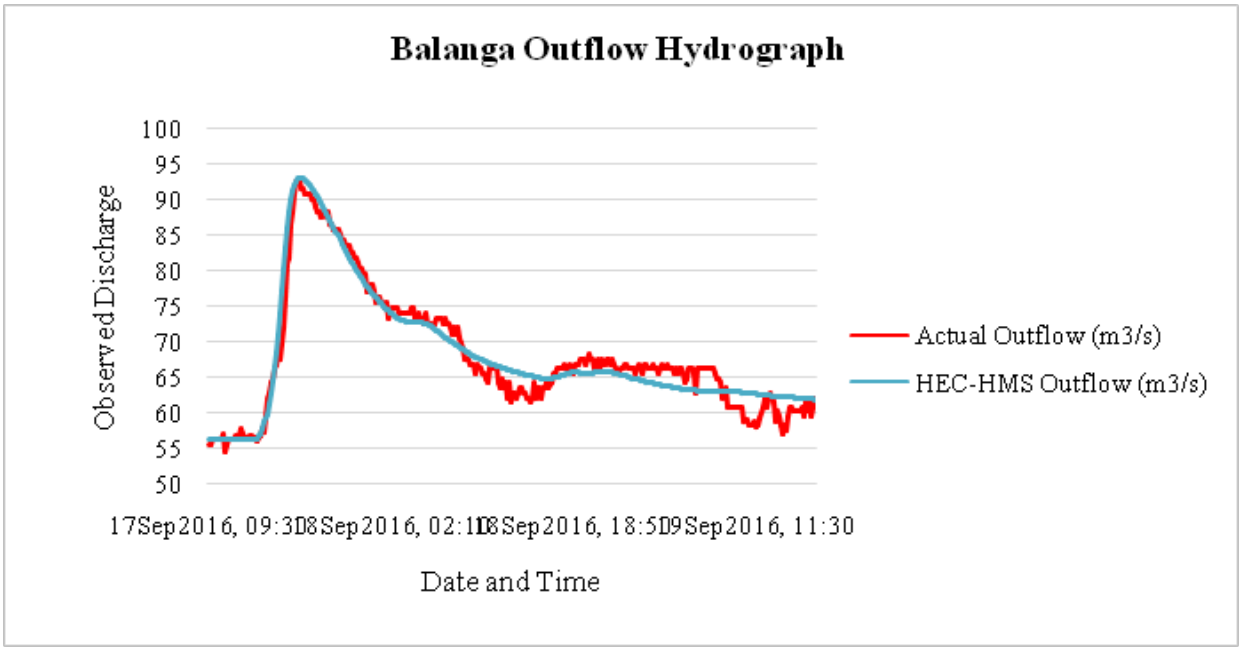


Figure 60. Outflow Hydrograph of Balanga produced by the HEC-HMS model compared with observed outflow

Table 31 shows adjusted ranges of values of the parameters used in calibrating the model.

Table 31.Range of calibrated values for the Balanga River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	**Range of Calibrated Values**
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	5 - 19
			Curve Number	98 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.12 - 7
			Storage Coefficient (hr)	0.65 - 15
	Baseflow	Recession	Recession Constant	0.99 - 1
			Ratio to Peak	0.34 – 0.51
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04 – 0.12

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 5mm to 19mm signifies that there is minimal 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 for the curve number of Balanga River Basin is 98 to 99. For Balanga, the basin mostly consists of closed canopy, cultivated area and tree plantation and perennial and the soil consists of clay and 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 0.12 hours to 15 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 base flow recedes between storm events, while ratio to peak is the ratio of the base flow discharge to the peak discharge. Recession constant of 0.99 - 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.34 – 0.51 indicates a steep receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.04 – 0.12 corresponds to the common roughness in Balanga watershed, which is determined to have medium to dense brush (Brunner, 2010).

Table 32.Summary of the Efficiency Test of Balanga HMS Model

Accuracy Measure	Value
RMSE	2.1
r^2	0.94
NSE	0.97
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 2.1 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 = 0.94 was computed for this model. This means that the degree of collinearity between simulated and measured data is relatively high.

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 0.97, which means that the model has a very good performance rating in simulating discharge.

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 -0.21, which implies that the model was overestimated at 0.21 percent difference in streamflow volume between simulated and measured data for a particular period.

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 0.17, which indicates that the model has a better simulation performance due to low value of computed RSR.

5.7 Calculated Outflow Hydrographys and Discharge Values for Different Rainfall Return Models

5.7.1 Hydrograph Using the Rainfall Runoff Model

The summary graph (Figure 61) shows the Balanga outflow using the Sangley Point 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.

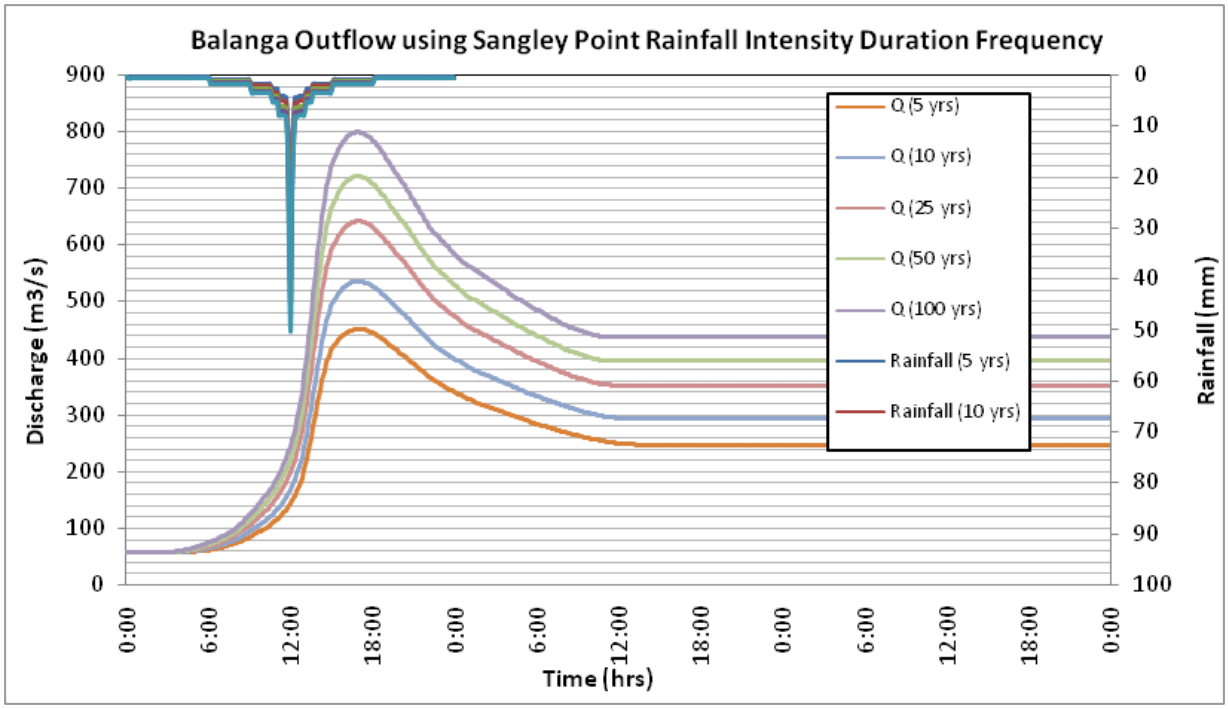


Figure 61.Outflow hydrograph at Balanga Station generated using Sangley Point RIDF simulated in HEC HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Balanga discharge using the Sangley Point Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 33.

Table 33.Peak values of the Balanga HEC-HMS Model outflow using the Sangley Point RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	**Peak outflow (m^3/s)**	**Time to Peak**
5-Year	209.4	28.3	450.7	5 hours
10-Year	250.1	33.6	535	5 hours
25-Year	301.5	40.3	641.4	5 hours
50-Year	339.7	45.3	720.4	5 hours
100-Year	377.6	50.3	798.5	4 hours and 50 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website.

The Balanga model has a minimum and maximum flow discharge of 55.6 and 92.5 m3/s, respectively and this was needed for unsteady flow analysis as input file. The simulation results also showed that there is no overflow of water along the banks of the river. However, some floodplain areas were being filled with water due to its elevation like agricultural areas located in Barangay Sibacan, Doña Francisca, Balut 1 and Balut II (located at the downstream portion of the river). The sample 1D flood hazard map using the calibrated discharge of Balanga river from HMS model is shown in Figure 62.

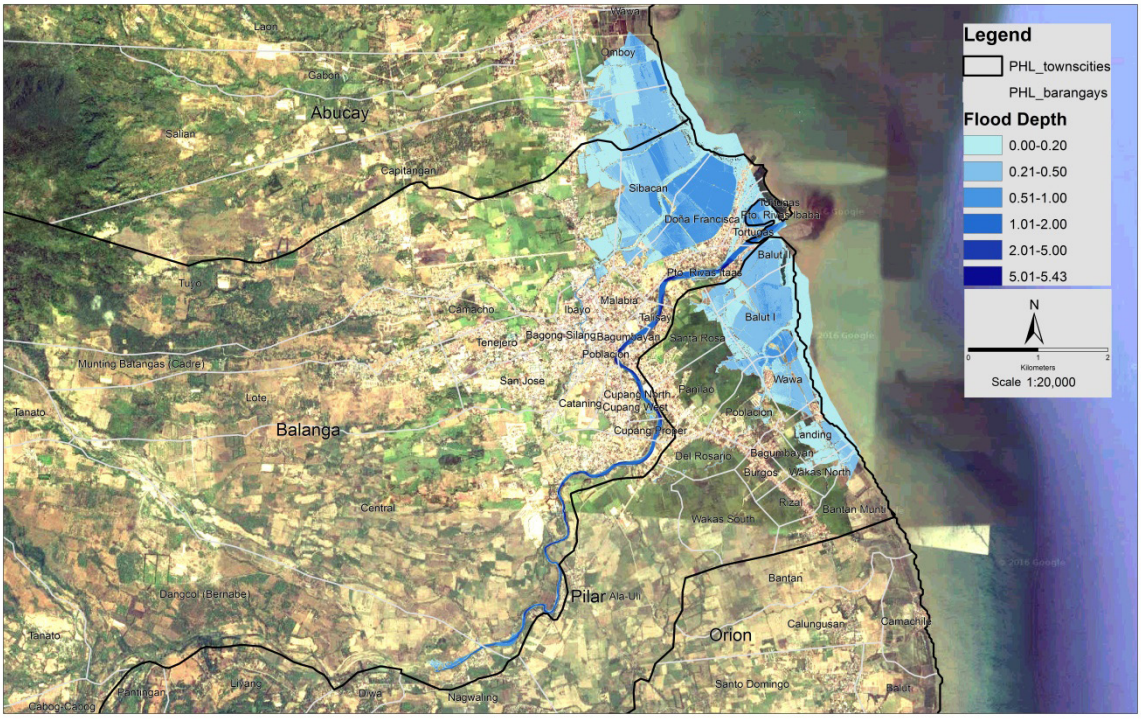


Figure 62.Sample output of Balanga RAS Model

5.9Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 63 to Figure 68 shows the 5-, 25-, and 100-year rain return scenarios of the Balanga floodplain. The floodplain, with an area of 70.41 sq. km., covers four municipalities namely Abucay, Balanga City, Orion and Pilar. Table 34 shows the percentage of area affected by flooding per municipality.

Table 34. Municipalities affected in Balanga floodplain

Municipality	Total Area	Area Flooded	% Flooded
Abucay	77.81	6.72	9%
Balanga City	80.78	41.59	51%
Orion	59.77	2.81	5%
Pilar	41.16	19.29	47%

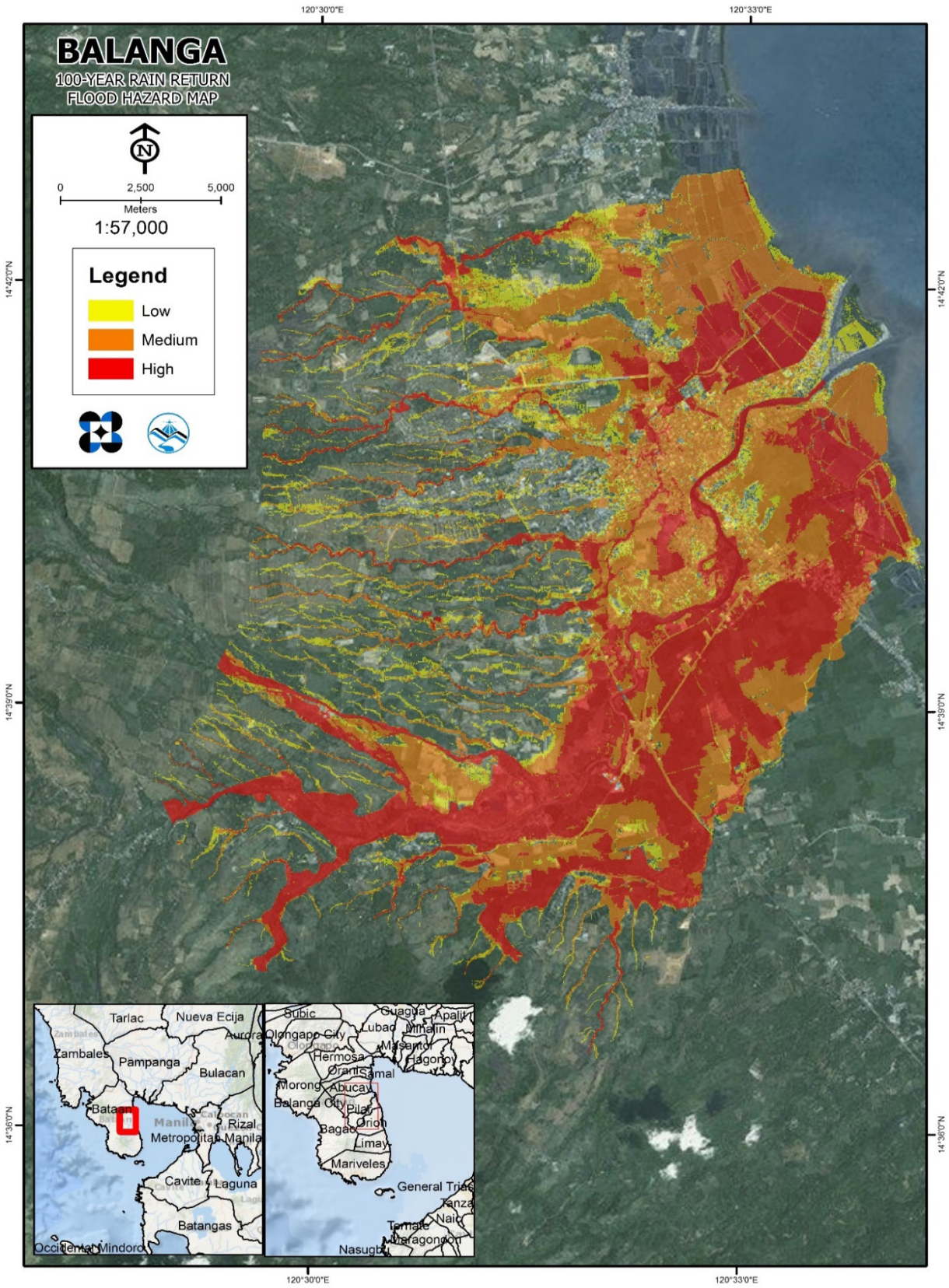


Figure 63.100-year Flood Hazard Map for Balanga Floodplain

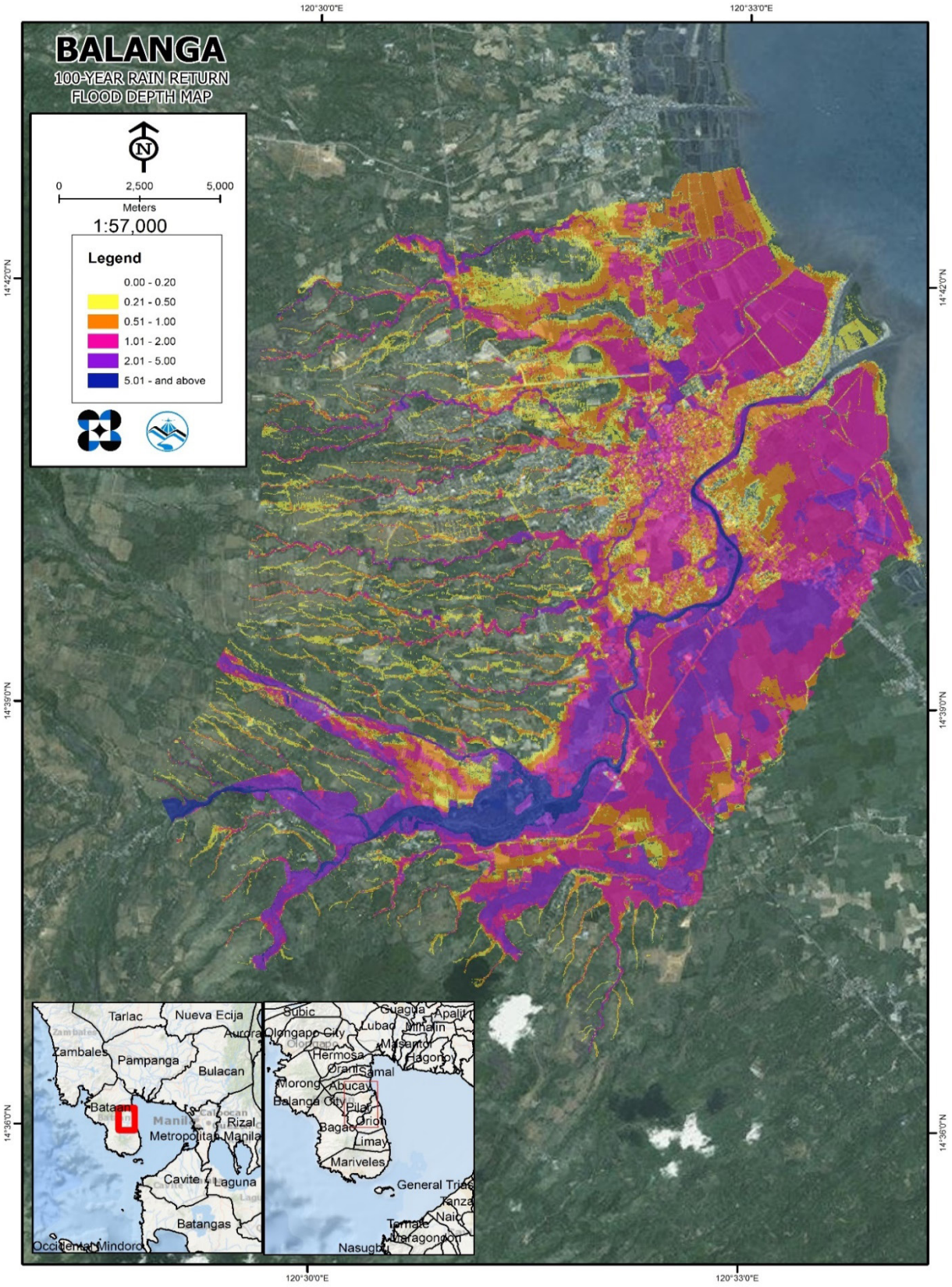


Figure 64. 100-year Flow Depth Map for Balanga Floodplain

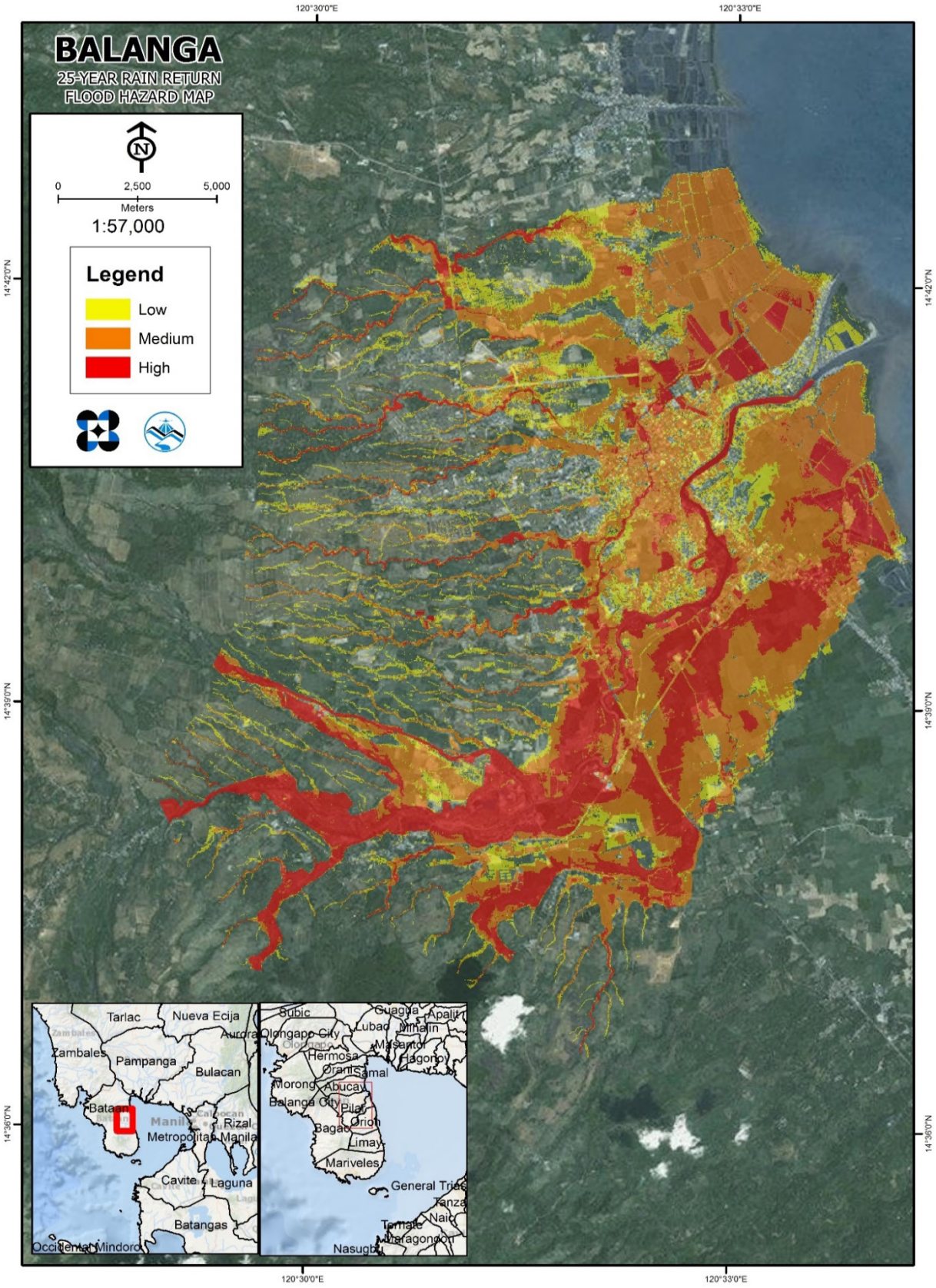


Figure 65.25-year Flood Hazard Map for Balanga Floodplain

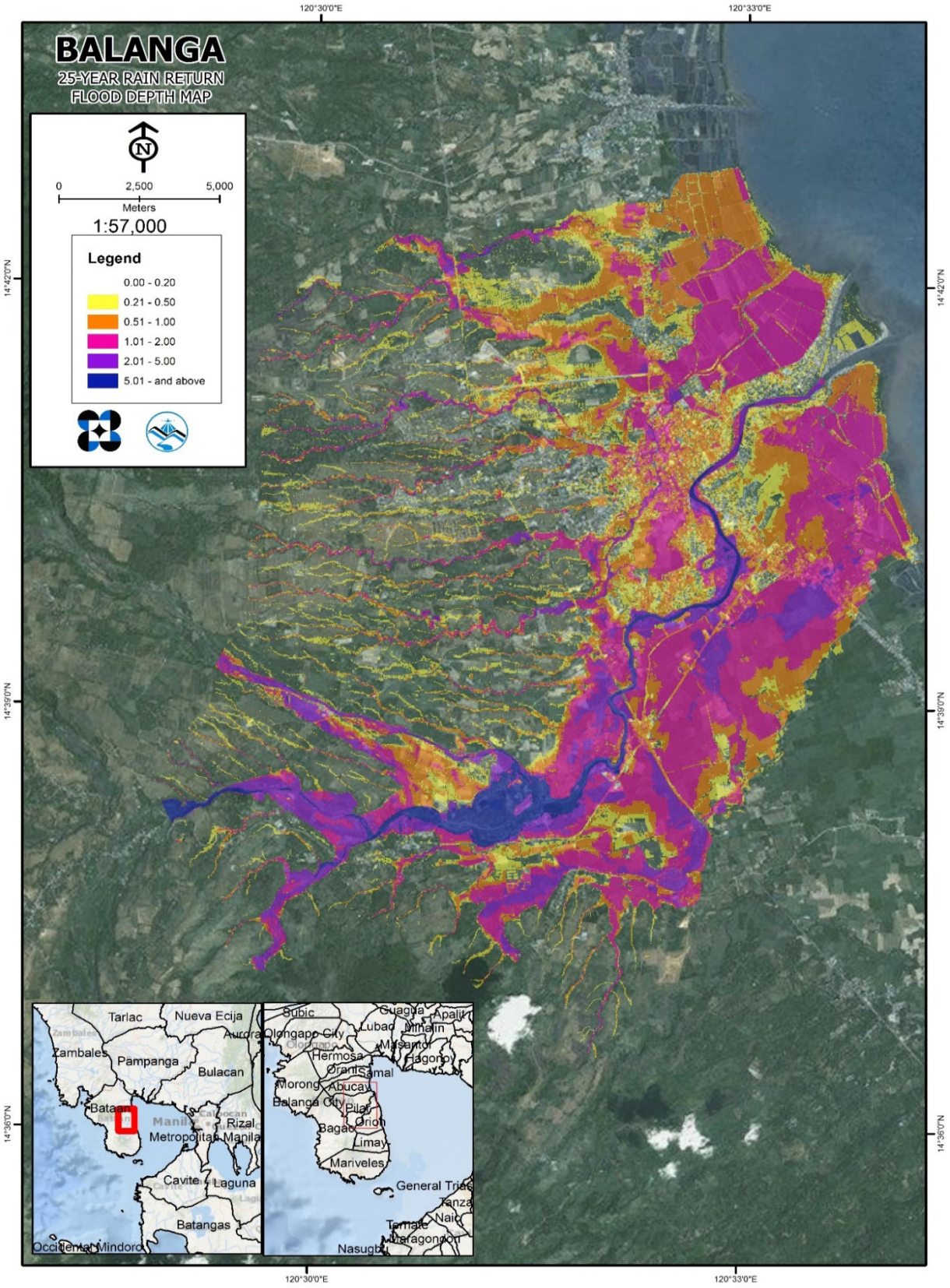


Figure 66.25-year Flow Depth Map for Balanga Floodplain

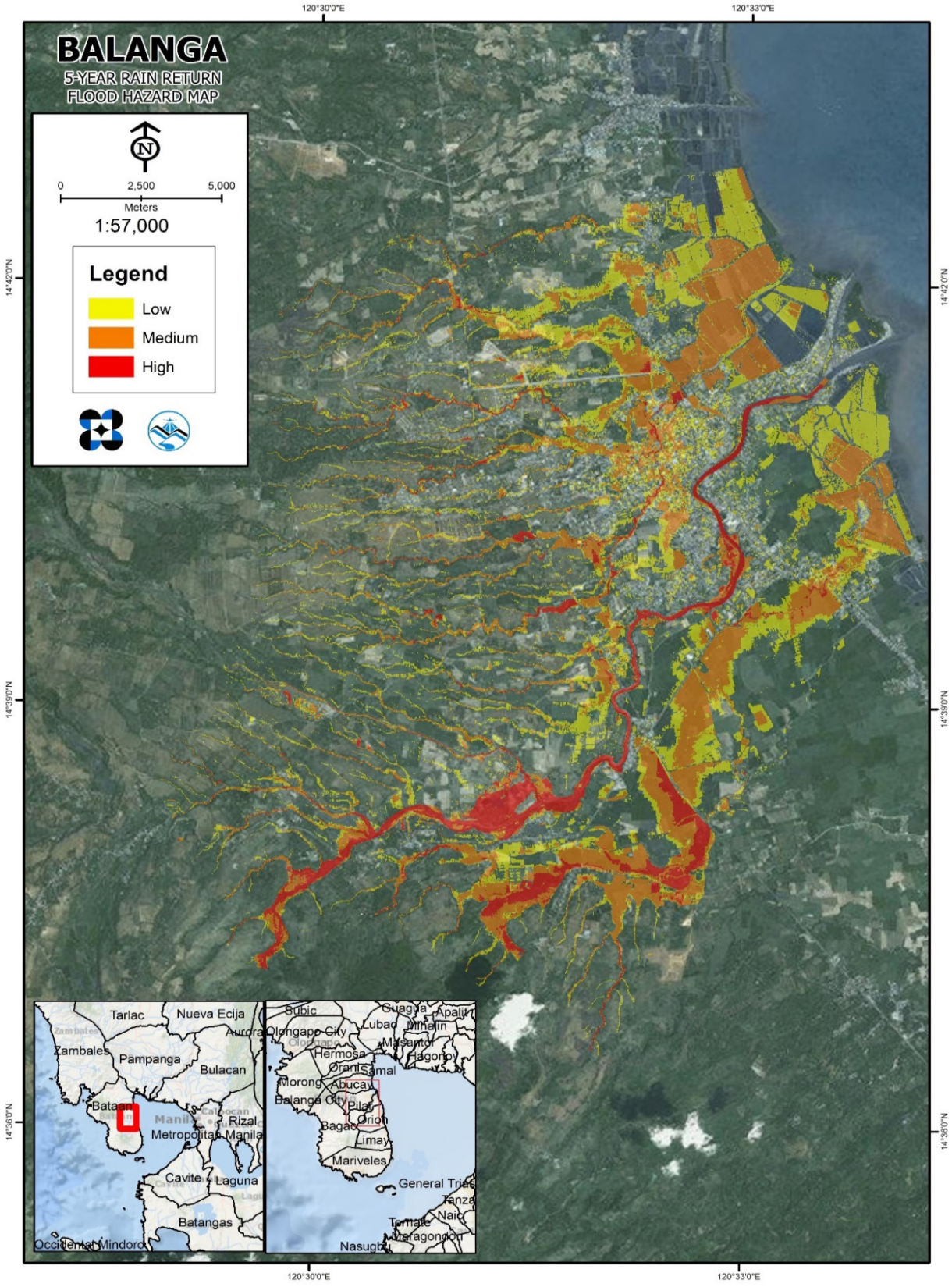


Figure 67.5-year Flood Hazard Map for Balanga Floodplain

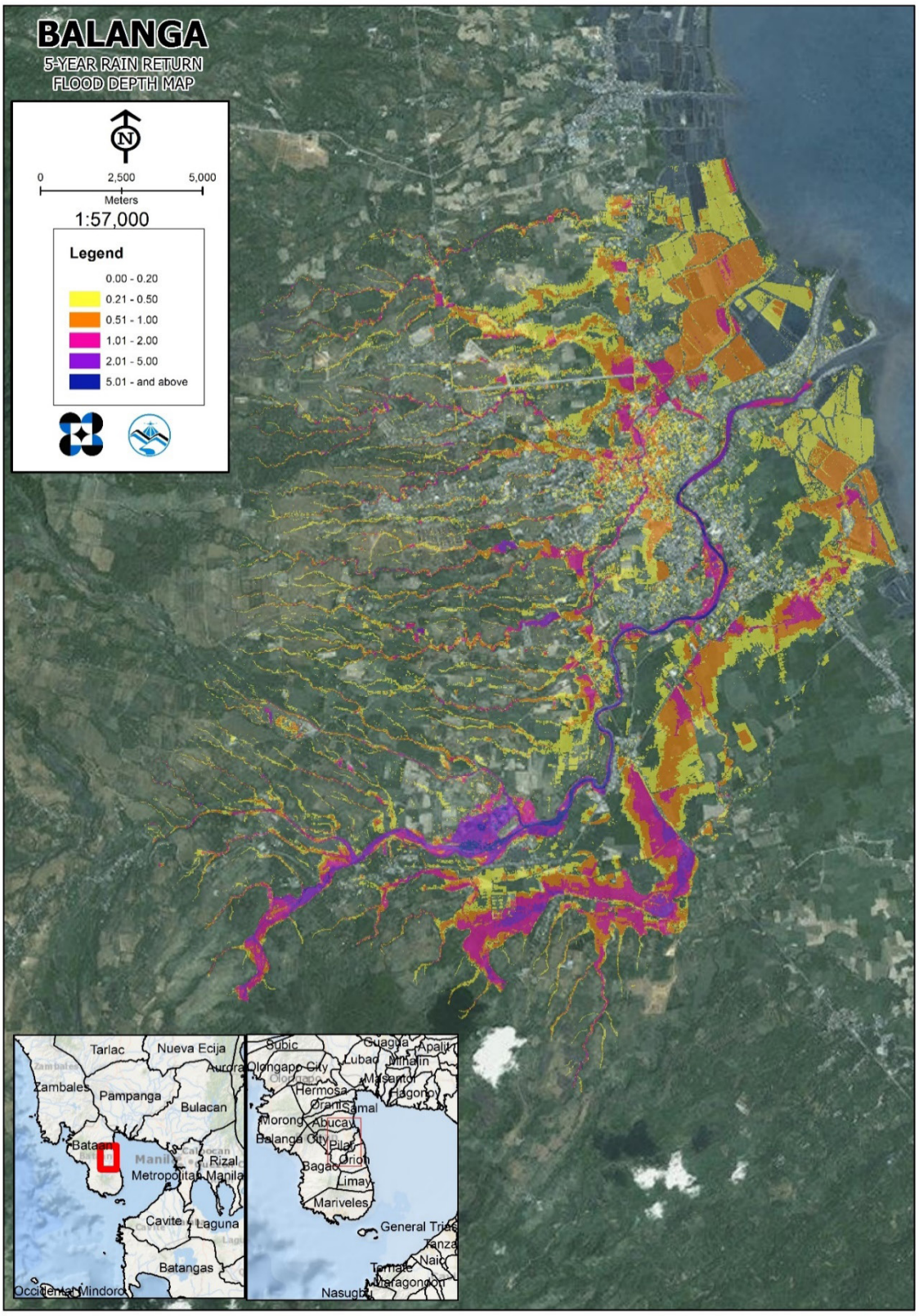


Figure 68.5-year Flood Depth Map for Balanga Floodplain

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Affected barangays in Balanga river basin, grouped by municipality, are listed below. For the said basin, four municipalities consisting of 46 barangays are expected to experience flooding when subjected to 5-, 25-, and 100-yr rainfall return period.

For the 5-year return period, 6.45% of the municipality of Abucay with an area of 77.814755 sq. km. will experience flood levels of less than 0.20 meters. 1.50% of the area will experience flood levels of 0.21 to 0.50 meters while 0.52%, 0.14%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay. Educational institutions and medical institutions exposed to flooding in Balanga flood plain are seen in Annex 12 and Annex 13 respectively.

Table 35.Affected Areas in Abucay, Bataan during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Abucay (in sq. km)		
	Capitangan	Omboy	Salian
0.03-0.20	4.57	0.23	0.22
0.21-0.50	1.01	0.13	0.026
0.51-1.00	0.37	0.02	0.015
1.01-2.00	0.096	0.01	0.0041
2.01-5.00	0.013	0	0.0002
> 5.00	0	0	0

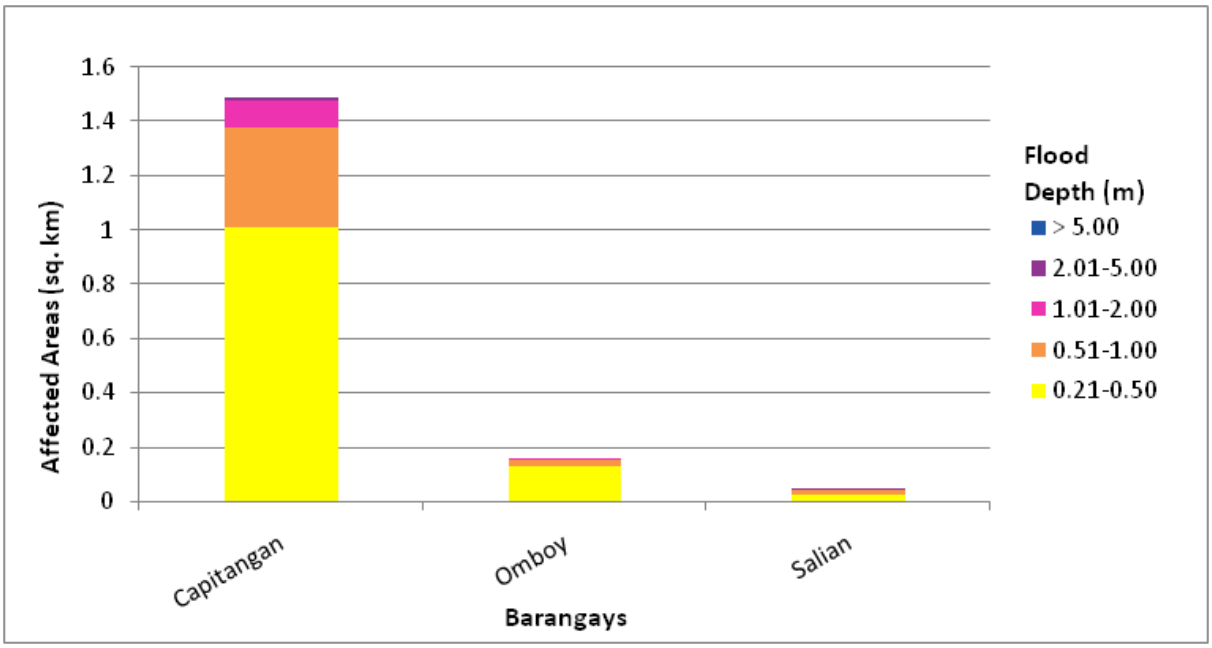


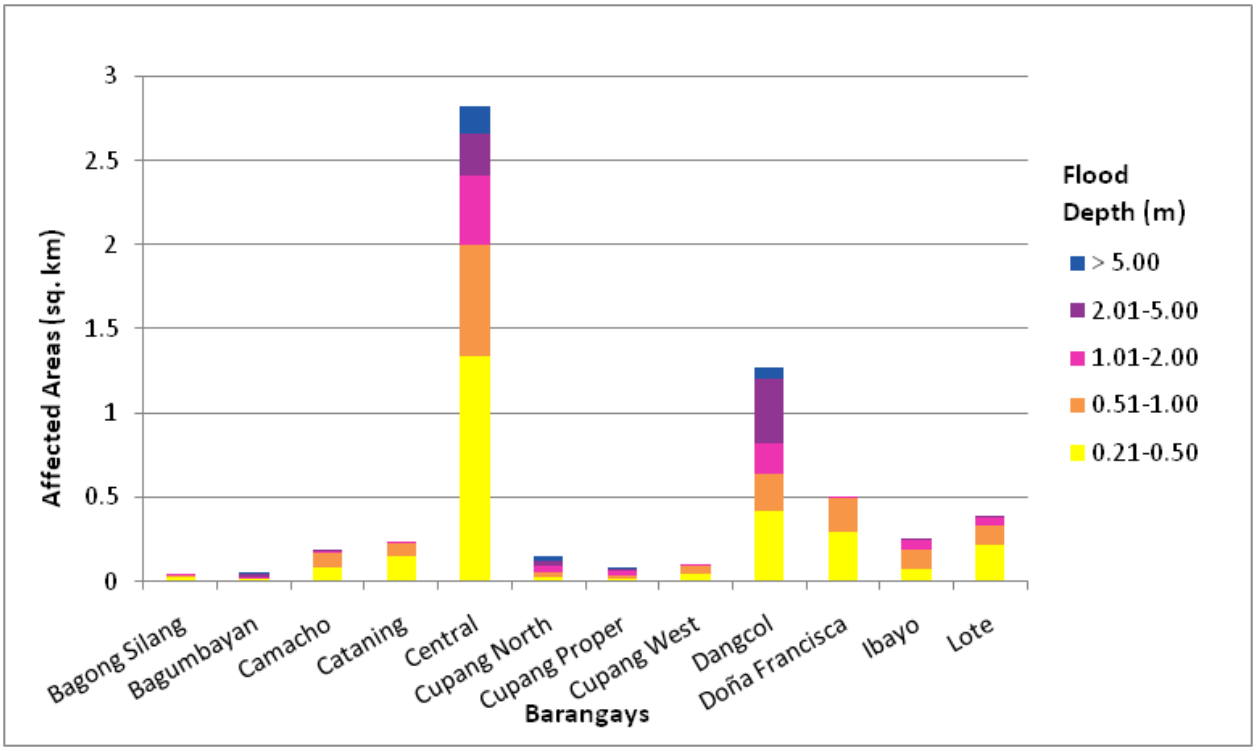
Figure 69.Affected Areas in Abucay, Bataan during 5-Year Rainfall Return Period

For the 5-year return period, 37.66% of the municipality of Balanga City with an area of 80.777152 sq. km. will experience flood levels of less than 0.20 meters. 6.16% of the area will experience flood levels of 0.21 to 0.50 meters while 4.51%, 1.74%, 1.07%, and 0.33% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 36.Affected Areas in Balanga City, Bataan during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balanga City (in sq. km)											
	Bagong Silang	Bagumbayan	Camacho	Cataning	Central	Cupang North	Cupang Proper	Cupang West	Dangcol	Doña Francisca	**Ibayo**	**Lote**
0.03-0.20	0.028	0.13	0.42	0.22	10.61	0.22	0.086	0.23	4.51	1.06	0.092	2.69
0.21-0.50	0.028	0.023	0.086	0.15	1.34	0.031	0.016	0.05	0.42	0.3	0.077	0.22
0.51-1.00	0.018	0.0043	0.084	0.091	0.66	0.026	0.019	0.05	0.22	0.2	0.11	0.11
1.01-2.00	1.7E-06	0.0019	0.019	0.0022	0.41	0.039	0.033	0.0011	0.18	0.0083	0.059	0.049
2.01-5.00	0	0.025	0.002	0	0.25	0.031	0.018	0	0.38	0	0.0077	0.017
> 5.00	0	0.0046	0	0	0.16	0.023	0.0039	0	0.069	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balanga City (in sq. km)										
	Malabia	Munting Batangas	Poblacion	Pto. Rivas Ibaba	Pto. Rivas Itaas	San Jose	Sibacan	Talisay	Tenejero	Tortugas	Tuyo
0.03-0.20	0.2	1.59	0.046	0.14	0.46	0.84	0.28	0.17	0.63	0.14	5.63
0.21-0.50	0.11	0.11	0.027	0.017	0.056	0.23	0.21	0.022	0.092	0.0071	1.35
0.51-1.00	0.037	0.061	0.019	0	0.018	0.17	0.9	0.0069	0.079	0	0.76
1.01-2.00	0.018	0.03	0.0017	0	0.044	0.081	0.076	0.00077	0.025	0	0.33
2.01-5.00	0	0.011	0.0011	0	0.036	0.028	0	0.02	0.00031	0	0.034
> 5.00	0	0	0.0038	0	0.0012	0	0	0	0	0	0



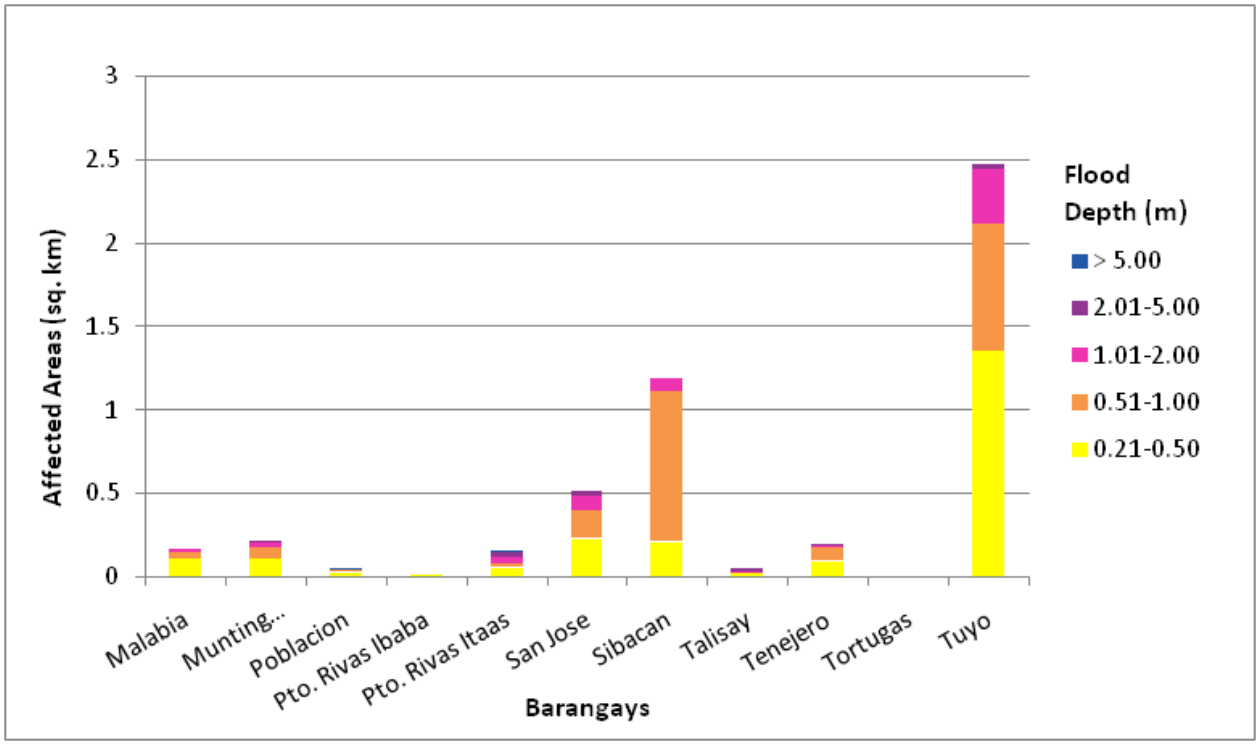


Figure 70. Affected Areas in Balanga City, Bataan during 5-Year Rainfall Return Period

For the 5-year return period, 3.69% of the municipality of Orion with an area of 59.765298 sq. km. will experience flood levels of less than 0.20 meters. 0.27% of the area will experience flood levels of 0.21 to 0.50 meters while 0.35%, 0.34%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 37.Affected Areas in Orion, Bataan during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Orion (in sq. km)			
	Bantan	General Lim	Santo Domingo	Calungusan
0.03-0.20	0.12	2.08	0.0033	0
0.21-0.50	0.0067	0.15	0.0066	0.000031
0.51-1.00	0.0005	0.19	0.019	0
1.01-2.00	0	0.2	0.0041	0
2.01-5.00	0	0.039	0.0023	0
> 5.00	0	0	0	0

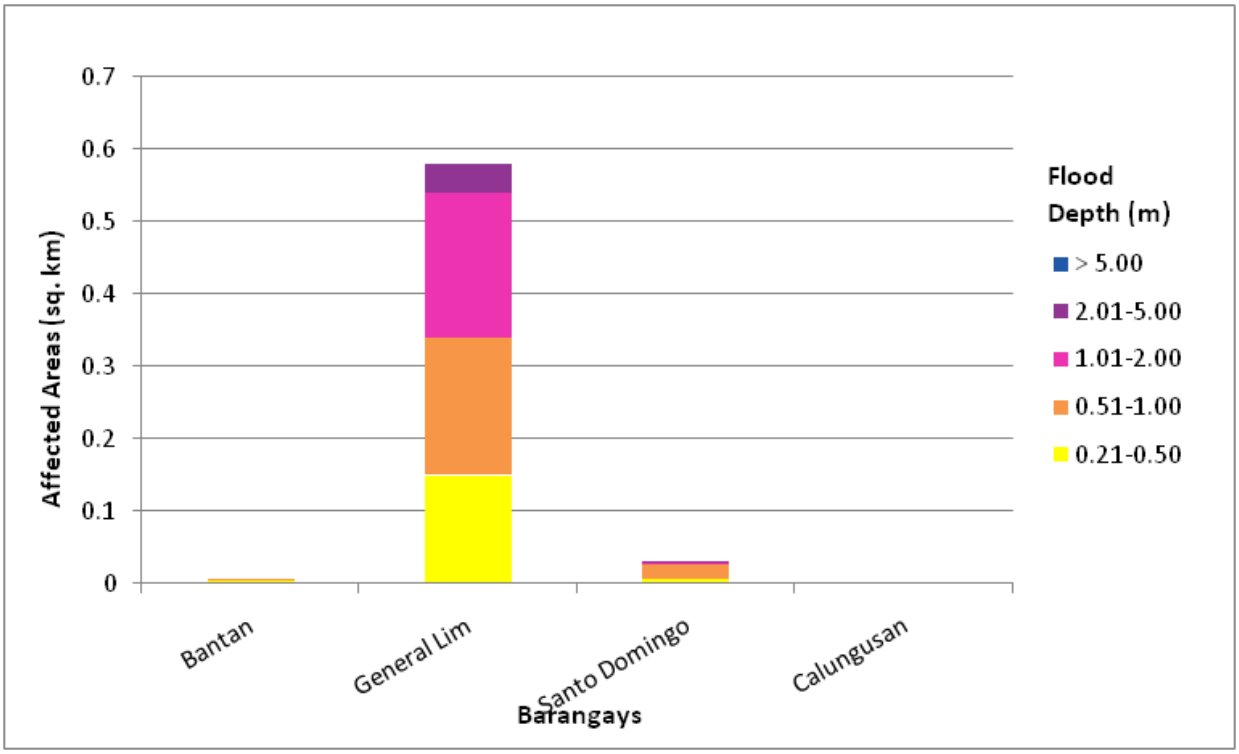


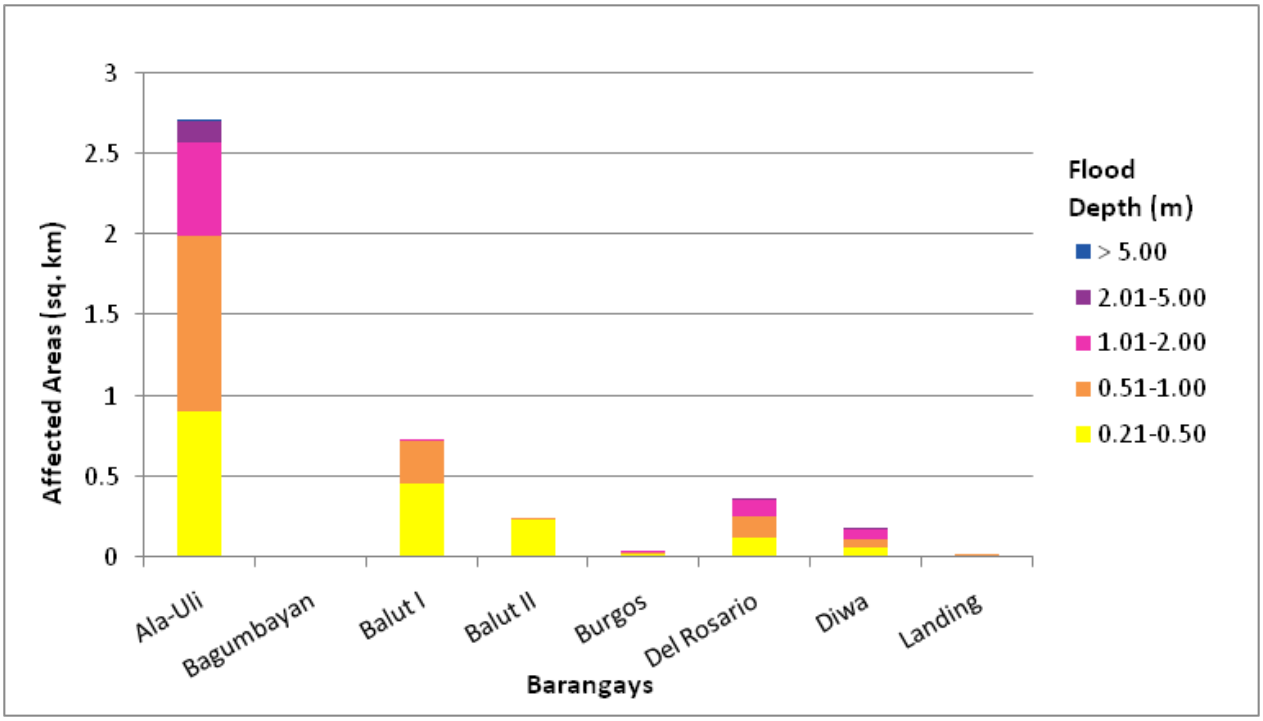
Figure 71.Affected Areas in Orion, Bataan during 5-Year Rainfall Return Period

For the 5-year return period, 28.43% of the municipality of Pilar with an area of 41.160747 sq. km. will experience flood levels of less than 0.20 meters. 7.63% of the area will experience flood levels of 0.21 to 0.50 meters while 6.08%, 3.71%, 0.94%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 38.Affected Areas in Pilar, Bataan during 5-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km)							
	Ala-Uli	Bagumbayan	Balut I	Balut II	Burgos	Del Rosario	Diwa	Landing
0.03-0.20	2.73	0.063	0.2	0.21	0.15	0.21	1.23	0.14
0.21-0.50	0.9	0.013	0.46	0.24	0.02	0.12	0.065	0.011
0.51-1.00	1.09	0.0004	0.26	0.0032	0.02	0.13	0.05	0.011
1.01-2.00	0.58	0	0.017	0	0.003	0.11	0.063	0
2.01-5.00	0.15	0	0	0	0	0.007	0.0092	0
> 5.00	0.000025	0	0	0	0	0	0	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km)							
	Liyang	Nagwaling	Panilao	Pantingan	Poblacion	Santa Rosa	Wakas South	Wawa
0.03-0.20	2.23	1.82	0.82	0.089	0.29	0.68	0.7	0.14
0.21-0.50	0.12	0.36	0.17	0.0016	0.21	0.17	0.16	0.12
0.51-1.00	0.13	0.35	0.057	0.002	0.12	0.011	0.02	0.25
1.01-2.00	0.21	0.48	0.0012	0.001	0.033	0	0.0026	0.027
2.01-5.00	0.12	0.1	0	0.0001	0.0007	0	0	0
> 5.00	0.0043	0	0	0	0	0	0	0



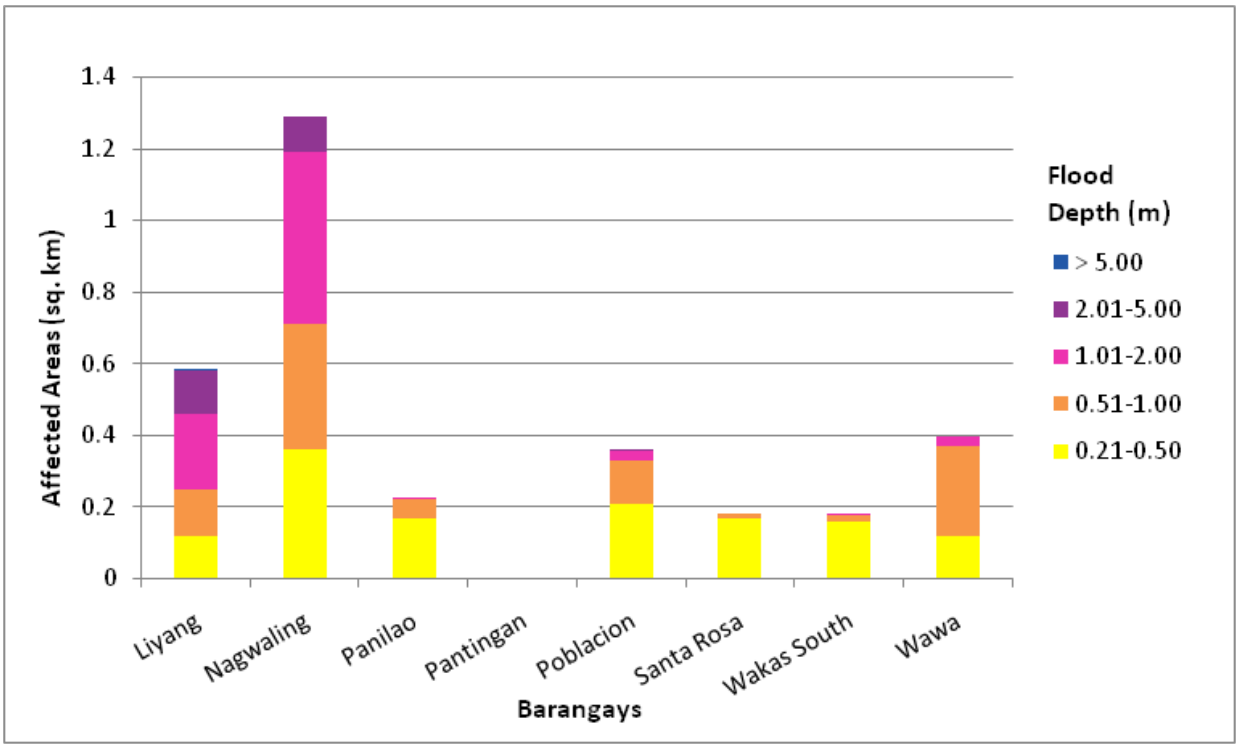


Figure 72.Affected Areas in Pilar, Bataan during 5-Year Rainfall Return Period

For the 25-year return period, 4.41% of the municipality of Abucay with an area of 77.814755 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 2.15%, 0.62%, 0.20%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 39.Affected Areas in Abucay, Bataan during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Abucay (in sq. km)		
	Capitangan	Omboy	Salian
0.03-0.20	3.26	0.031	0.14
0.21-0.50	0.89	0.05	0.036
0.51-1.00	1.35	0.28	0.04
1.01-2.00	0.42	0.025	0.037
2.01-5.00	0.14	0	0.015
> 5.00	0.0065	0	0

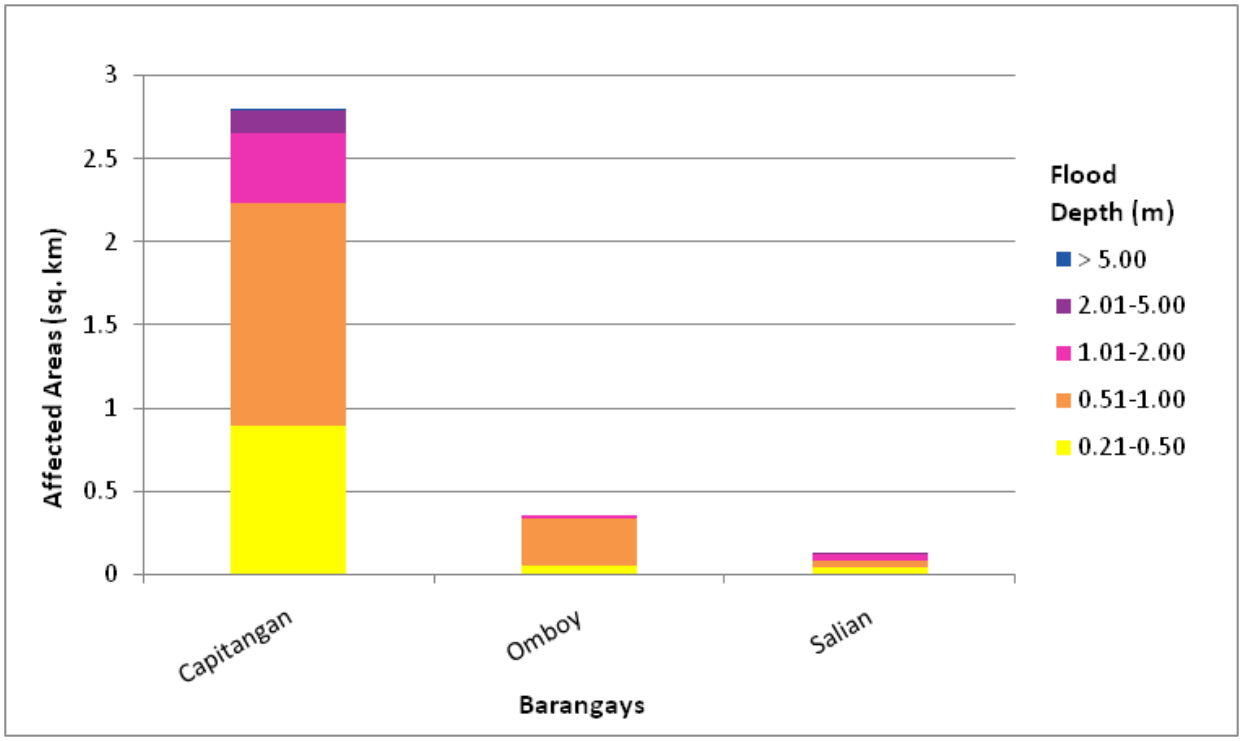


Figure 73.Affected Areas in Abucay, Bataan during 25-Year Rainfall Return Period

For the 25-year return period, 26.43% of the municipality of Balanga City with an area of 80.777152 sq. km. will experience flood levels of less than 0.20 meters. 6.10% of the area will experience flood levels of 0.21 to 0.50 meters while 6.67%, 7.55%, 2.95%, and 1.76% 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 40.Affected Areas in Balanga City, Bataan during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balanga City (in sq. km)											
	Bagong Silang	Bagumbayan	Camacho	Cataning	Central	Cupang North	Cupang Proper	Cupang West	Dangcol	Doña Francisca	Ibayo	Lote
0.03-0.20	0.0036	0.029	0.34	0.011	7.73	0.042	0.0055	0.04	2.73	0.26	0.041	2.48
0.21-0.50	0.011	0.058	0.1	0.05	1.44	0.051	0.01	0.065	0.4	0.21	0.032	0.32
0.51-1.00	0.042	0.063	0.12	0.2	1.24	0.097	0.022	0.11	0.55	0.18	0.11	0.13
1.01-2.00	0.017	0.0064	0.043	0.21	1.54	0.045	0.048	0.11	0.47	0.92	0.15	0.099
2.01-5.00	0	0.022	0.006	0.0006	1.02	0.094	0.075	0.011	0.77	0	0.017	0.051
> 5.00	0	0.013	0	0	0.46	0.045	0.016	0	0.87	0	0	0.0003

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balanga City (in sq. km)										
	Malabia	Munting Batangas	Poblacion	Pto. Rivas Ibaba	Pto. Rivas Itaas	San Jose	Sibacan	Talisay	Tenejero	Tortugas	Tuyo
0.03-0.20	0.042	1.49	0.0039	0.12	0.24	0.58	0.087	0.073	0.58	0.13	4.29
0.21-0.50	0.083	0.15	0.012	0.032	0.18	0.23	0.069	0.07	0.097	0.018	1.24
0.51-1.00	0.19	0.086	0.045	0.0004	0.077	0.29	0.2	0.037	0.09	0	1.51
1.01-2.00	0.048	0.048	0.03	0	0.039	0.2	1.1	0.018	0.054	0	0.9
2.01-5.00	0.0001	0.021	0.002	0	0.072	0.052	0	0.019	0.0014	0	0.15
> 5.00	0	0	0.0049	0	0.0035	0	0	0.0043	0	0	0.0038

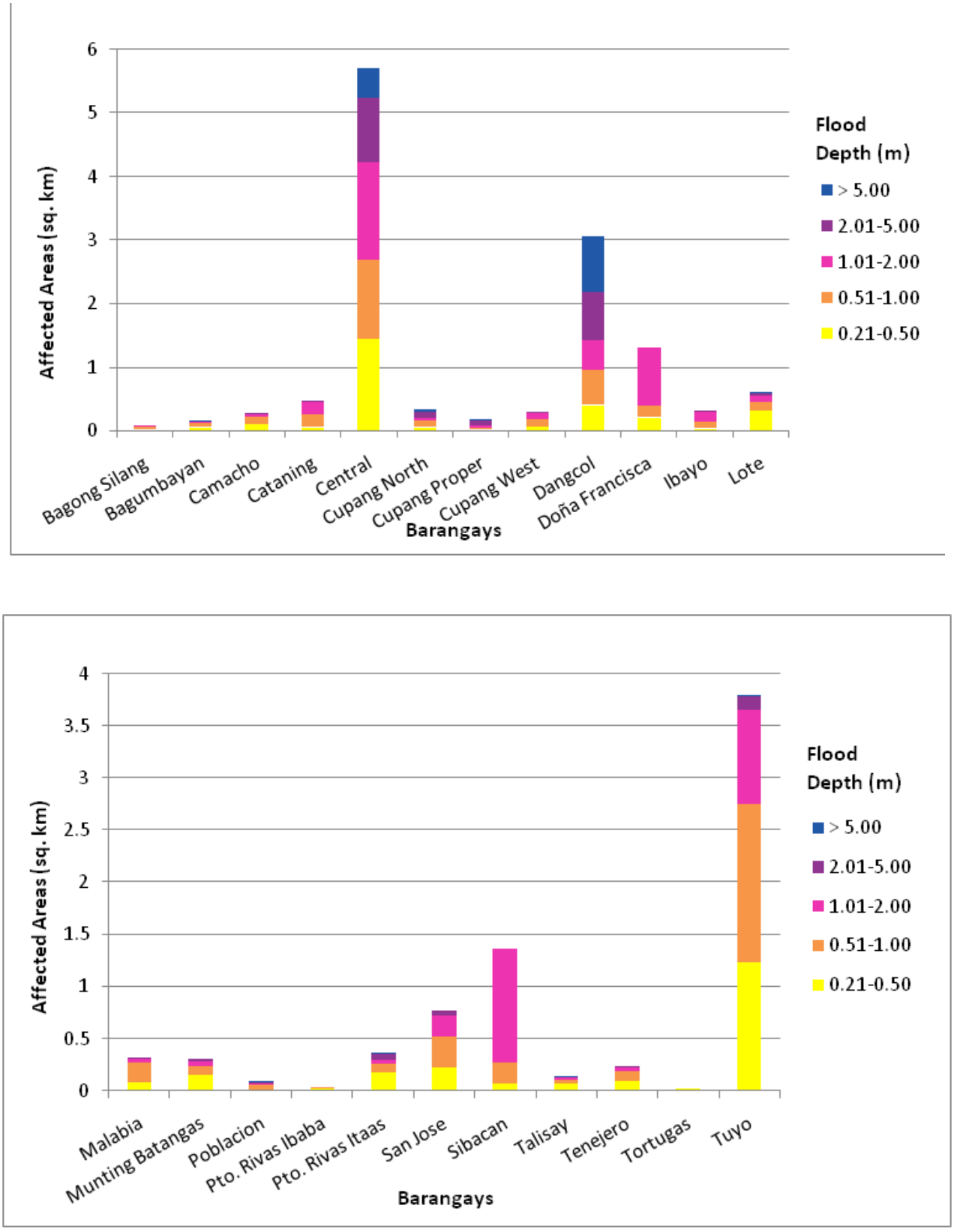


Figure 74.Affected Areas in Balanga City, Bataan during 25-Year Rainfall Return Period

For the 25-year return period, 3.44% of the municipality of Orion with an area of 59.765298 sq. km. will experience flood levels of less than 0.20 meters. 0.25% of the area will experience flood levels of 0.21 to 0.50 meters while 0.32%, 0.56%, and 0.14% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 41.Affected Areas in Orion, Bataan during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Orion (in sq. km)			
	Bantan	Calungusan	General Lim	Santo Domingo
0.03-0.20	0.043	0	2.01	0.000087
0.21-0.50	0.026	0	0.12	0.0009
0.51-1.00	0.043	0.000031	0.14	0.0074
1.01-2.00	0.013	0	0.3	0.023
2.01-5.00	0	0	0.081	0.0031
> 5.00	0	0	0	0

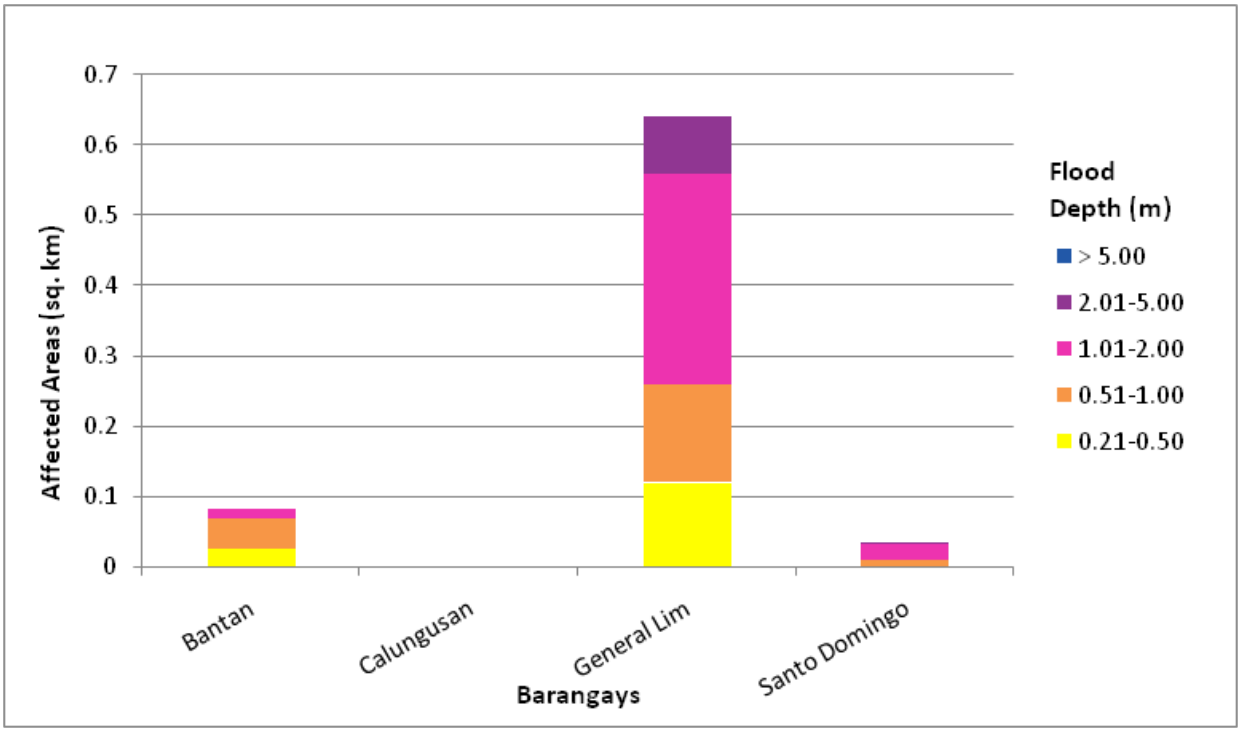


Figure 75.Affected Areas in Orion, Bataan during 25-Year Rainfall Return Period

For the 25-year return period, 4.04% of the municipality of Pilar with an area of 41.160747 sq. km. will experience flood levels of less than 0.20 meters. 1.59% of the area will experience flood levels of 0.21 to 0.50 meters while 3.89%, 10.29%, 2.74%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 42.Affected Areas in Pilar, Bataan during 25-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km)							
	Ala-Uli	Bagumbayan	Balut I	Balut II	Burgos	Del Rosario	Diwa	Landing
0.03-0.20	0.32	0	0.045	0.049	0.0056	0.021	1.14	0.084
0.21-0.50	0.45	0.0026	0.036	0.032	0.01	0.018	0.075	0.029
0.51-1.00	1.05	0.03	0.12	0.2	0.091	0.032	0.047	0.031
1.01-2.00	2.85	0.045	0.71	0.18	0.069	0.26	0.098	0.024
2.01-5.00	0.79	0	0.014	0	0.021	0.25	0.054	0
> 5.00	0.0012	0	0	0	0	0	0.0045	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km)							
	Liyang	Nagwaling	Panilao	Pantingan	Poblacion	Santa Rosa	Wakas South	Wawa
0.03-0.20	2.02	1.53	0.09	0.083	0.003	0.14	0.048	0.014
0.21-0.50	0.11	0.32	0.15	0.0042	0.0075	0.25	0.087	0.022
0.51-1.00	0.065	0.35	0.42	0.0017	0.11	0.35	0.28	0.079
1.01-2.00	0.2	0.61	0.37	0.0012	0.49	0.13	0.4	0.42
2.01-5.00	0.4	0.29	0.017	0.0007	0.053	0	0.061	0.015
> 5.00	0.02	0.0014	0	0.0036	0	0	0	0

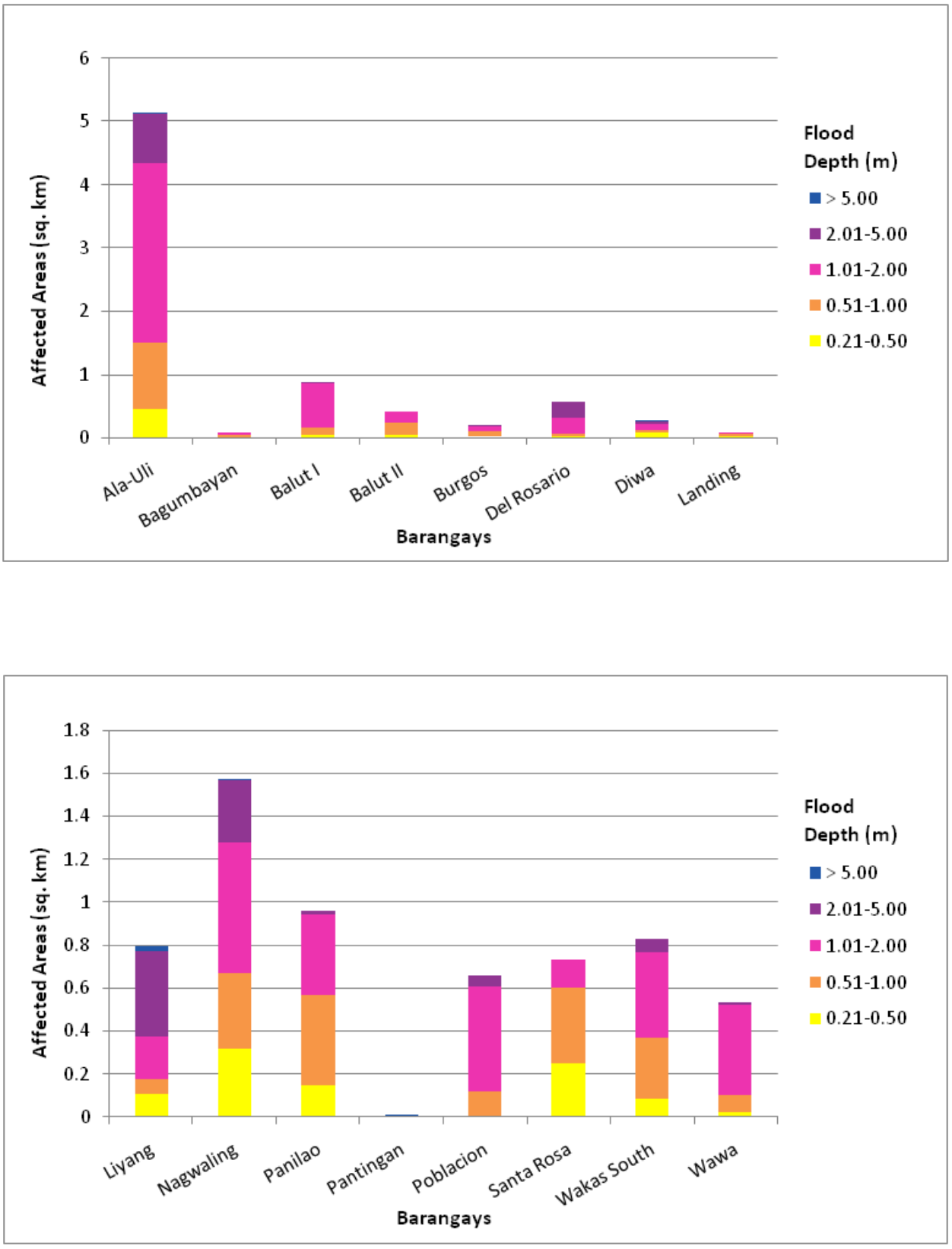


Figure 76.Affected Areas in Pilar, Bataan during 25-Year Rainfall Return Period

For the 100-year return period, 4.01% of the municipality of Abucay with an area of 77.814755 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 1.99%, 1.13%, 0.24%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 43.Affected Areas in Abucay, Bataan during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Abucay (in sq. km)		
	Capitangan	Omboy	Salian
0.03-0.20	2.97	0.02	0.13
0.21-0.50	0.9	0.036	0.034
0.51-1.00	1.22	0.29	0.041
1.01-2.00	0.8	0.036	0.041
2.01-5.00	0.17	0	0.02
> 5.00	0.0077	0	0

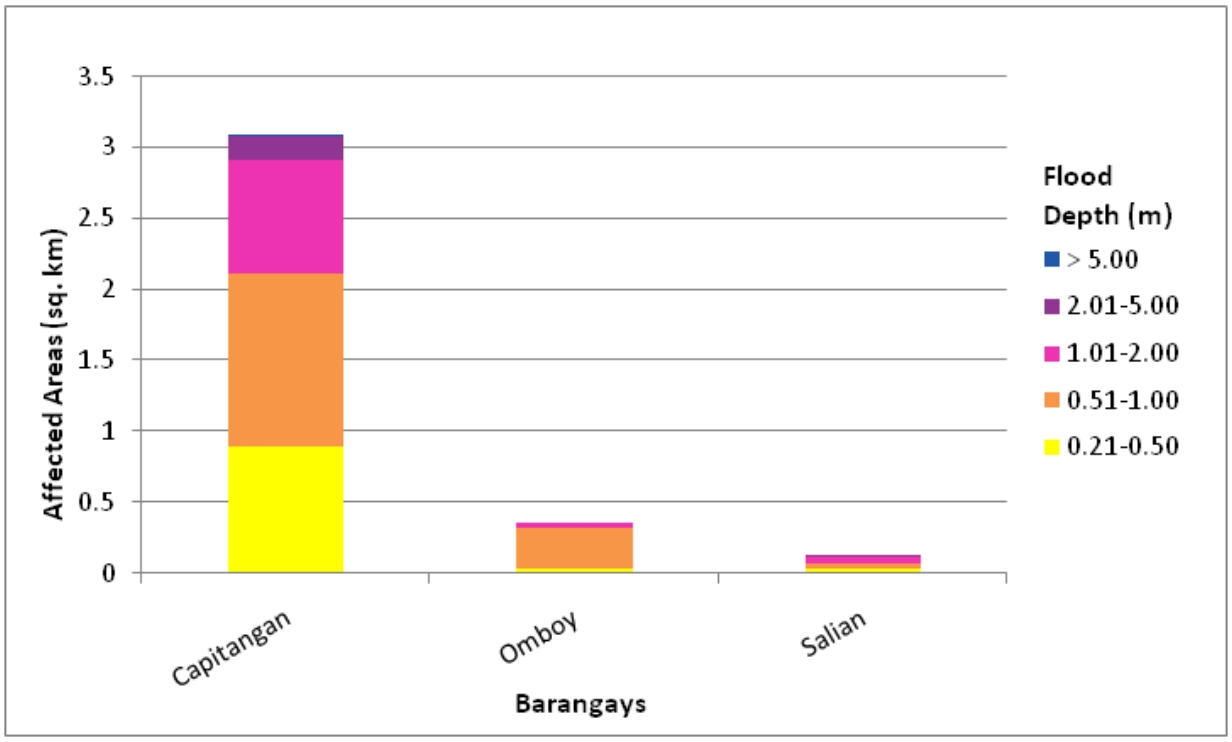


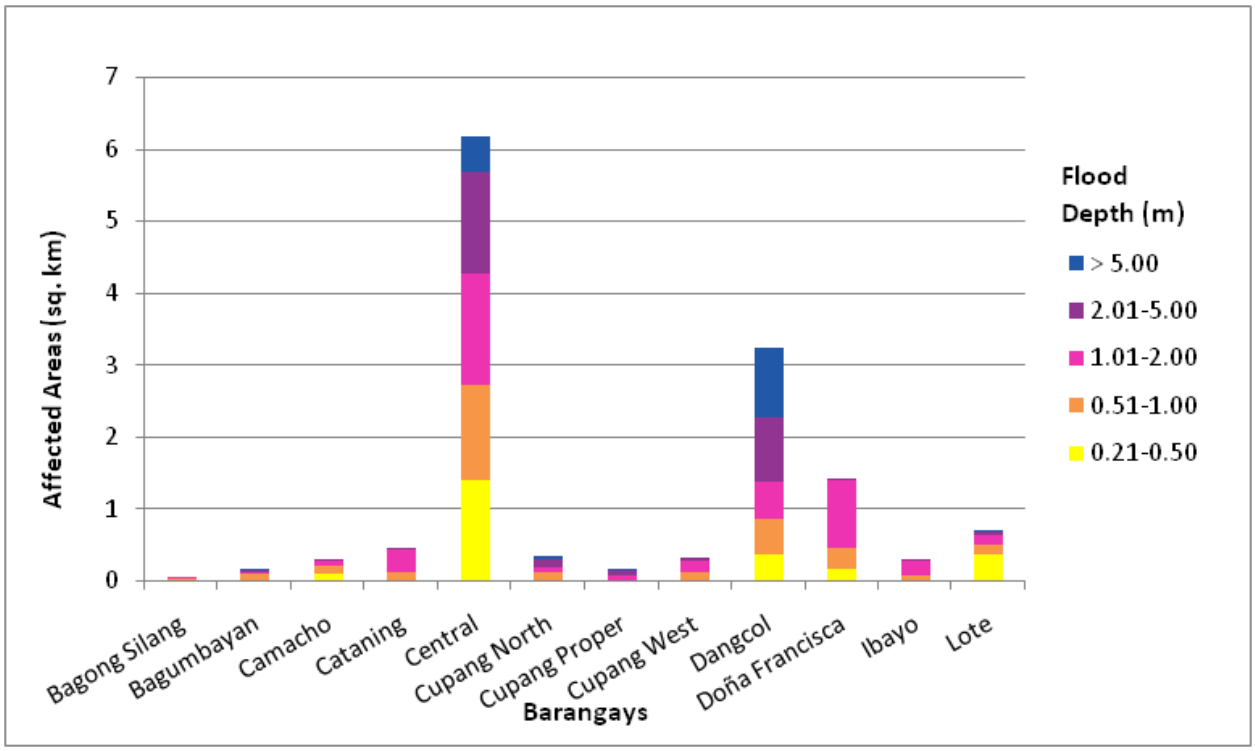
Figure 77.Affected Areas in Abucay, Bataan during 100-Year Rainfall Return Period

For the 100-year return period, 24.21% of the municipality of Balanga City with an area of 80.777152 sq. km. will experience flood levels of less than 0.20 meters. 5.59% of the area will experience flood levels of 0.21 to 0.50 meters while 6.91%, 8.83%, 4.00%, and 1.95% 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 44.Affected Areas in Balanga City, Bataan during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balanga City (in sq. km)											
	Bagong Silang	Bagumbayan	Camacho	Cataning	Central	Cupang North	Cupang Proper	Cupang West	Dangcol	Doña Francisca	Ibayo	Lote
0.03-0.20	0.0014	0.01	0.31	0.0026	7.25	0.018	0.0011	0.0082	2.57	0.13	0.03	2.38
0.21-0.50	0.0046	0.026	0.11	0.02	1.4	0.033	0.0053	0.031	0.37	0.17	0.02	0.37
0.51-1.00	0.03	0.1	0.12	0.12	1.32	0.096	0.02	0.11	0.51	0.3	0.073	0.15
1.01-2.00	0.038	0.017	0.067	0.32	1.55	0.082	0.054	0.14	0.5	0.94	0.19	0.12
2.01-5.00	0	0.019	0.0074	0.0021	1.41	0.098	0.079	0.046	0.89	0.027	0.035	0.068
> 5.00	0	0.017	0	0	0.5	0.047	0.017	0	0.97	0	0	0.0011

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balanga City (in sq. km)										
	Malabia	Munting Batangas	Poblacion	Pto. Rivas Ibaba	Pto. Rivas Itaas	San Jose	Sibacan	Talisay	Tenejero	Tortugas	Tuyo
0.03-0.20	0.019	1.45	0.0015	0.099	0.1	0.51	0.058	0.021	0.54	0.12	3.93
0.21-0.50	0.039	0.17	0.0046	0.049	0.13	0.17	0.052	0.065	0.12	0.024	1.13
0.51-1.00	0.2	0.093	0.032	0.0057	0.22	0.32	0.14	0.081	0.087	0.00063	1.45
1.01-2.00	0.097	0.059	0.052	0	0.064	0.28	1.17	0.029	0.074	0	1.29
2.01-5.00	0.0094	0.027	0.0023	0	0.085	0.072	0.045	0.019	0.0019	0	0.29
> 5.00	0	0	0.0049	0	0.0063	0	0	0.0062	0	0	0.0064



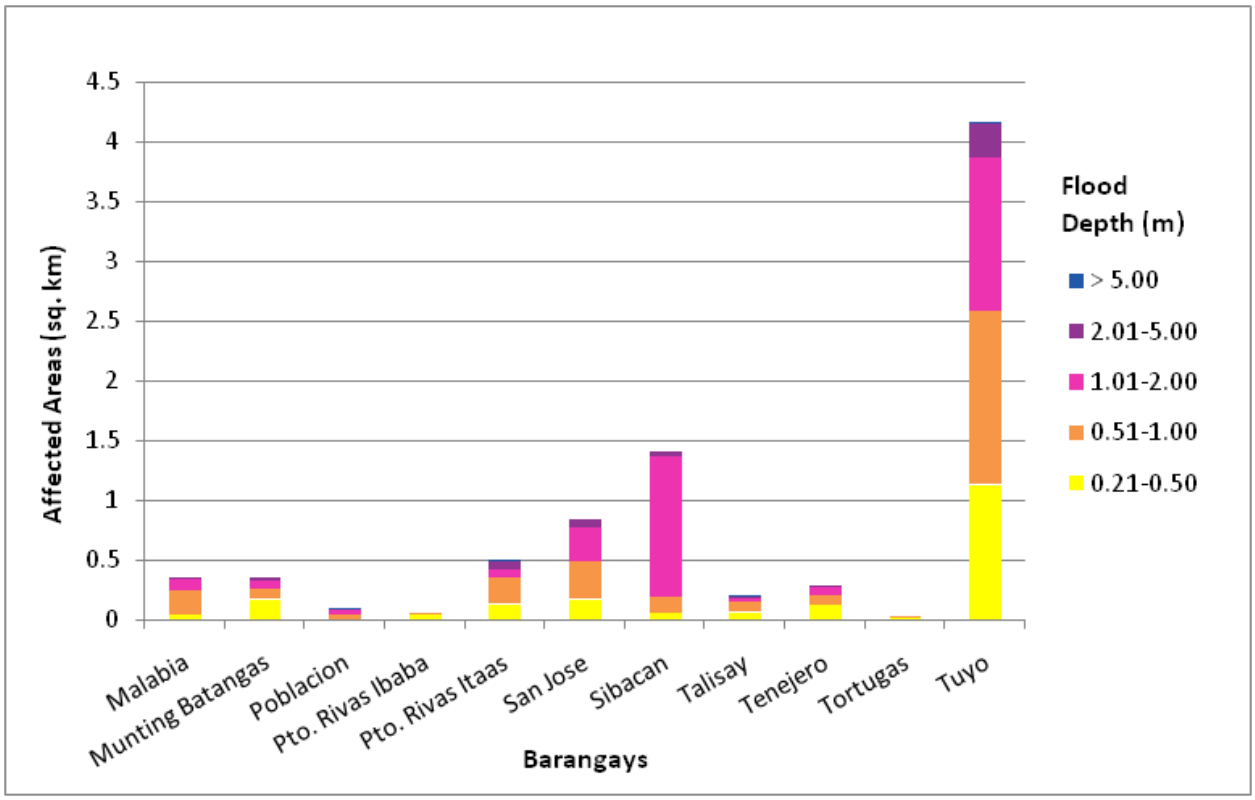


Figure 78.Affected Areas in Balanga City, Bataan during 100-Year Rainfall Return Period

For the 100-year return period, 3.34% of the municipality of Orion with an area of 59.765298 sq. km. will experience flood levels of less than 0.20 meters. 0.23% of the area will experience flood levels of 0.21 to 0.50 meters while 0.22%, 0.63%, and 0.28% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 45.Affected Areas in Orion, Bataan during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Orion (in sq. km)			
	Bantan	Calungusan	General Lim	Santo Domingo
0.03-0.20	0.017	0	1.98	0
0.21-0.50	0.016	0	0.12	0
0.51-1.00	0.03	0.000031	0.1	0.0013
1.01-2.00	0.062	0	0.29	0.027
2.01-5.00	0	0	0.16	0.0065
> 5.00	0	0	0.0003	0

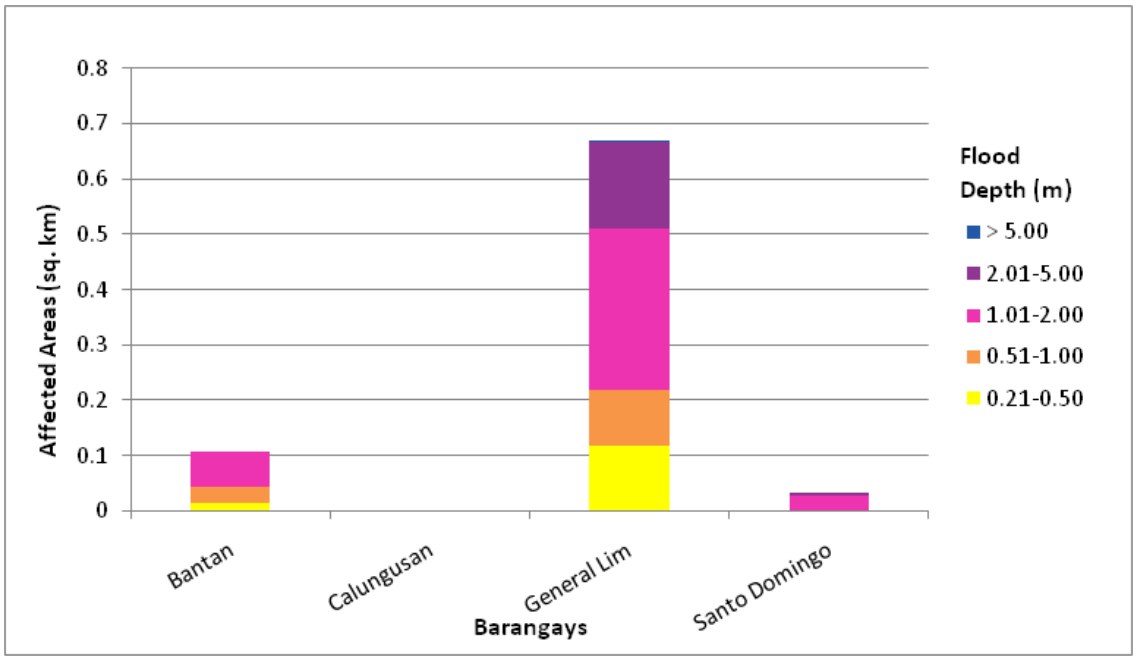


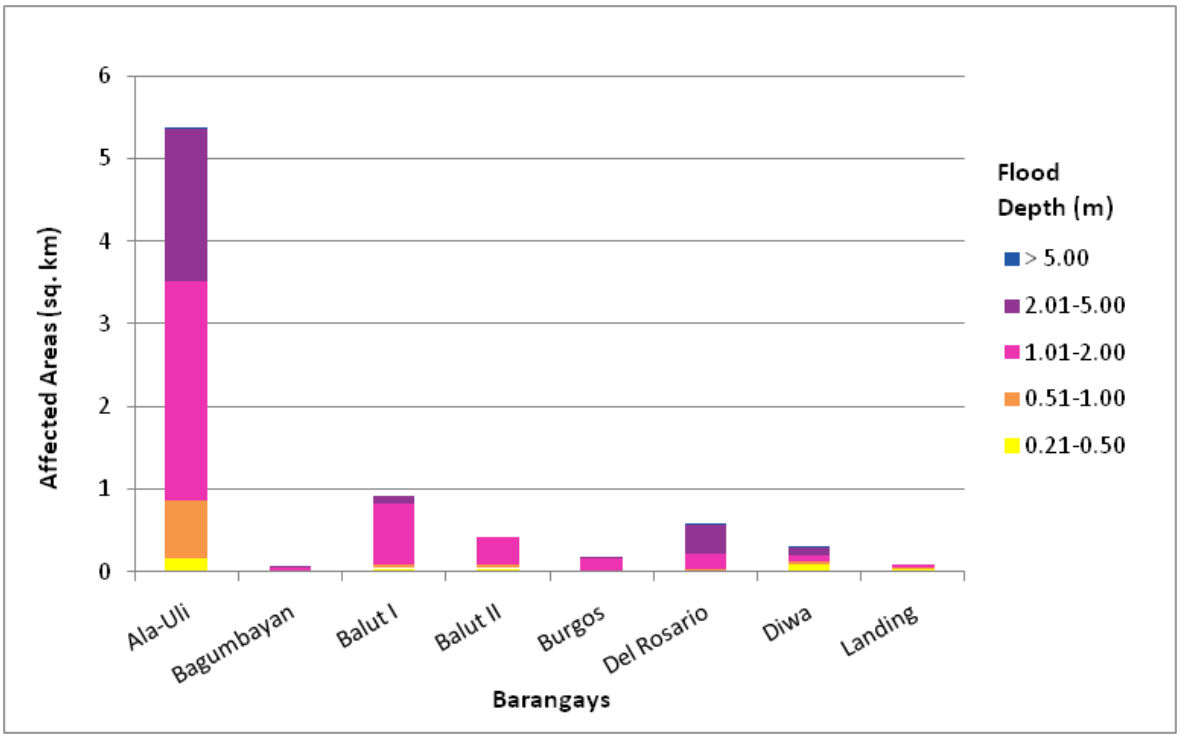
Figure 79.Affected Areas in Orion, Bataan during 100-Year Rainfall Return Period

For the 100-year return period, 11.80% of the municipality of Pilar with an area of 41.160747 sq. km. will experience flood levels of less than 0.20 meters. 2.18% of the area will experience flood levels of 0.21 to 0.50 meters while 5.14%, 17.91%, 9.72%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in the table are the affected areas in square kilometers by flood depth per barangay.

Table 46.Affected Areas in Pilar, Bataan during 100-Year Rainfall Return Period

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km)							
	Ala-Uli	**Bagum-bayan**	**Balut I**	**Balut II**	**Burgos**	**Del Rosario**	**Diwa**	**Landing**
0.03-0.20	0.085	0	0.013	0.025	0.0014	0.0037	1.11	0.07
0.21-0.50	0.16	0	0.041	0.035	0.0026	0.013	0.086	0.031
0.51-1.00	0.7	0.0068	0.054	0.063	0.019	0.029	0.046	0.027
1.01-2.00	2.66	0.068	0.74	0.33	0.14	0.18	0.074	0.039
2.01-5.00	1.85	0.002	0.078	0	0.03	0.36	0.098	0
> 5.00	0.0023	0	0	0	0	0.0001	0.0086	0

Affected Area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km)							
	Liyang	Nagwaling	Panilao	Pantingan	Poblacion	Santa Rosa	Wakas South	Wawa
0.03-0.20	1.99	1.38	0.032	0.08	0.0014	0.057	0.0015	0.0054
0.21-0.50	0.12	0.18	0.084	0.0057	0.0013	0.11	0.012	0.015
0.51-1.00	0.061	0.37	0.29	0.0019	0.017	0.27	0.11	0.052
1.01-2.00	0.11	0.69	0.57	0.0011	0.48	0.43	0.52	0.34
2.01-5.00	0.5	0.48	0.072	0.00062	0.16	0.0015	0.24	0.13
> 5.00	0.032	0.0017	0	0.0043	0	0	0	0



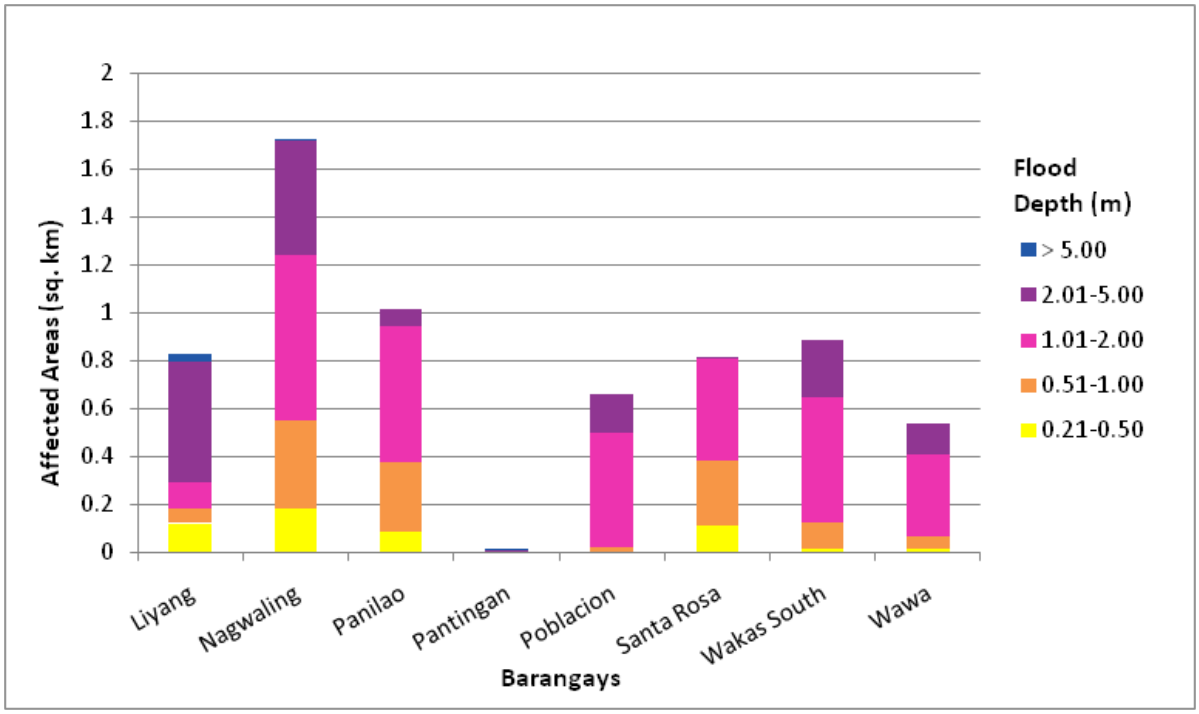


Figure 80. Affected Areas in Pilar, Bataan during 100-Year Rainfall Return Period

Among the barangays in the municipality of Abucay in Bataan, Capitangan is projected to have the highest percentage of area that will experience flood levels at 7.80%. Meanwhile, Omboy posted the second highest percentage of area that may be affected by flood depths at 0.49%.

Among the barangays in the municipality of Balanga City in Bataan, Central is projected to have the highest percentage of area that will experience flood levels at 17.26%. Meanwhile, Tuyo posted the second highest percentage of area that may be affected by flood depths at 10.40%.

Among the barangays in the municipality of Orion in Bataan, General Lim is projected to have the highest percentage of area that will experience flood levels at 3.41%. Meanwhile, Bantan posted the second highest percentage of area that may be affected by flood depths at 0.16%.

Among the barangays in the municipality of Pilar in Bataan, Ala-Uli is projected to have the highest percentage of area that will experience flood levels at 7.01%. Meanwhile, Nagwaling posted the second highest percentage of area that may be affected by flood depths at 3.99%.

Moreover, the generated flood hazard maps for the Balanga 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 47.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	9.50	7.75	6.63
Medium	8.96	18.93	17.54
High	2.66	11.41	16.84
Total	21.12	38.09	41.01

Of the 579 identified buildings of Educational Institutions in Balanga Flood Plain, one hundred forty six (146) school buildings were discovered exposed to Low-level flooding and forty eight (48) school buildings were found exposed to Medium-level flooding, both during a 5-year scenario. In the same scenario, two (2) school buildings were discovered exposed to High-level flooding.

For the 25-year scenario, one hundred ten (110) school buildings were discovered exposed to Low-level flooding while two hundred sixty eight (268) school buildings were found exposed to Medium-level flooding. In the same scenario, fifteen (15) school buildings were discovered exposed in High-level flooding.

For the 100-year scenario, sixty six (66) school buildings were discovered exposed to Low-level flooding while three hundred six (306) school buildings were found exposed to Medium-level flooding. In the same scenario, forty eight (48) school buildings were discovered exposed in High-level flooding.

Of the 56 identified buildings of Medical Institutions in Balanga Flood Plain, seventeen (17) buildings were discovered exposed to Low-level flooding while six (6) buildings were found exposed to Medium-level flooding, both during a 5-year scenario.

For the 25-year scenario, four (4) buildings were discovered exposed to Low-level flooding while twenty five (25) buildings were found exposed to Medium-level flooding.

For the 100-year scenario, one (1) building was discovered exposed to Low-level flooding while twenty eight (28) buildings were found exposed to Medium-level flooding. In the same scenario, one (1) building was discovered exposed in High-level flooding.

5.11 Flood Validation

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

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

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

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

The flood validation consisted of 180 points randomly selected all over the Balanga flood plain (Figure 35). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.65 m. Table 48shows a contingency matrix of the comparison.

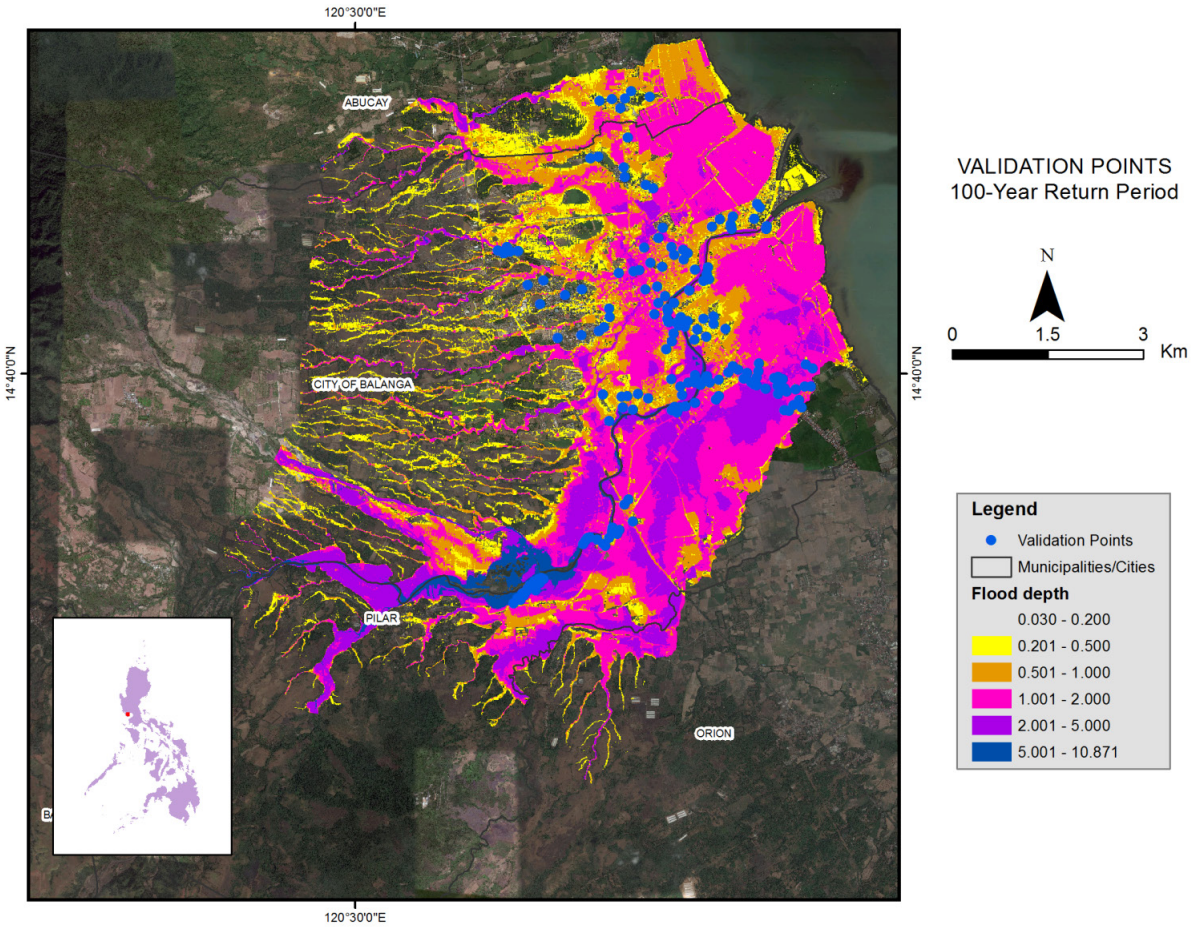


Figure 81.Validation points for 5-year Flood Depth Map of Balanga Floodplain

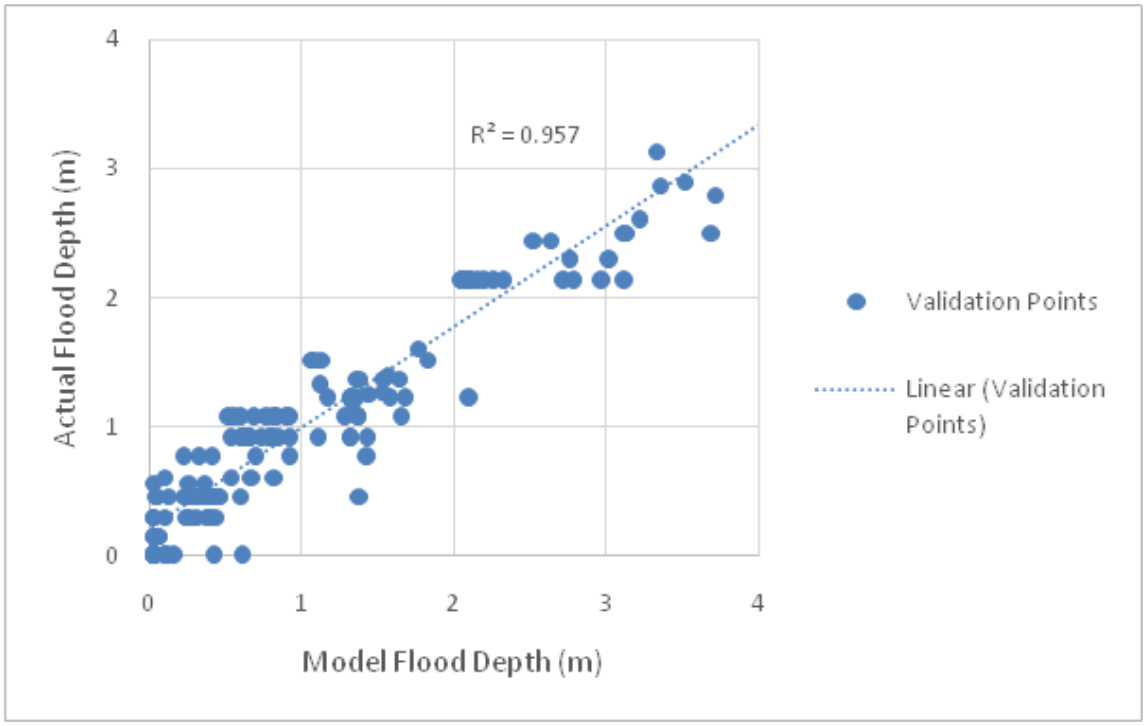


Figure 82.Model flood depth vs actual flood depth

Table 48.Actual Flood Depth vs Simulated Flood Depth

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	21	1	1	0	0	0	23
0.21-0.50	7	24	1	1	0	0	33
0.51-1.00	2	5	19	5	0	0	31
1.01-2.00	0	0	9	24	1	0	34
2.01-5.00	0	0	0	0	29	5	34
> 5.00	0	0	0	0	0	25	25
Total	30	30	30	30	30	30	180

The overall accuracy generated by the flood model is estimated at 78.89% with 142 points correctly matching the actual flood depths. In addition, there were 29 points estimated one level above and below the correct flood depths while there were 4 points and 0 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 23 points were underestimated in the modelled flood depths of Balanga.

Table 49.Summary of Accuracy Assessment in Balanga River Basin Survey

No. of Points		%
Correct	142	**78.89**
Overestimated	15	**8.33**
Underestimated	23	**12.78**
Total	180	**100.00**

REFERENCES

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

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

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

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

Paringit E.C, Balicanta L.P., Ang, M.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.

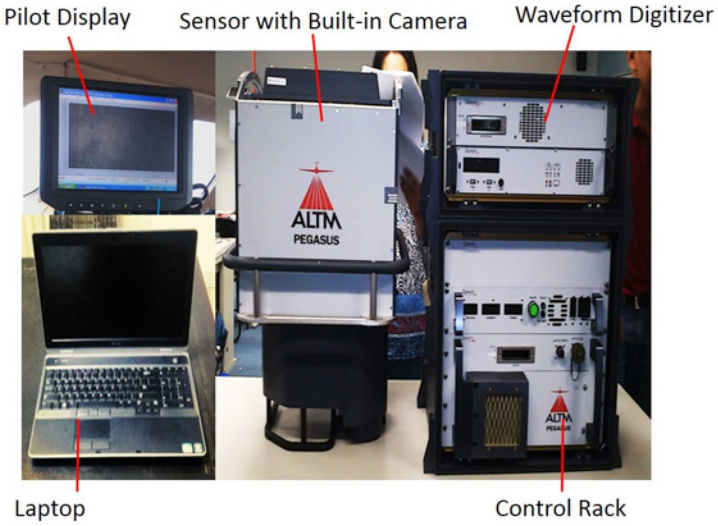
Sarmiento C., Paringit E.C., et al. 2014. DREAM Data Acquisition Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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. OPTECH TECHNICAL SPECIFICATION OF THE SENSORS

Pegasus



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

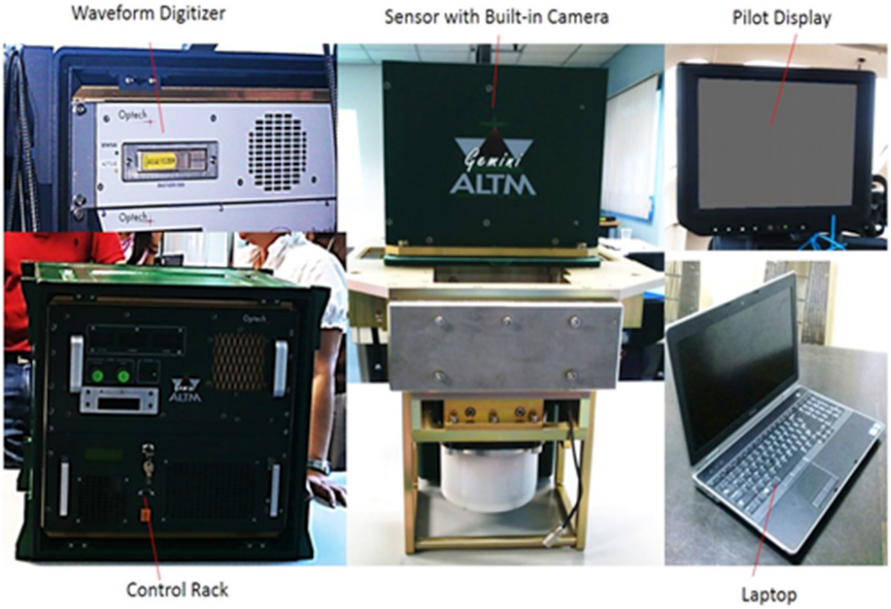
1 Target reflectivity ≥20%

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

Gemini



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

ANNEX 2. NAMRIA CERTIFICATES OF REFERENCE POINTS USED

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

9901022014123502

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

2. BTN-40

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

September 04, 2015

CERTIFICATION

To whom it may concern:

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

Province: **BATAAN**
Station Name: **BTN-40**
Order: **3rd**

Island: **LUZON**
Municipality: **MARIVELES**
Barangay: **SISIMAN**
MSL Elevation:

PRS92 Coordinates

Latitude: **14° 27' 19.71999"** Longitude: **120° 31' 25.47703"** Ellipsoidal Hgt: **240.98820 m.**

WGS84 Coordinates

Latitude: **14° 27' 14.29750"** Longitude: **120° 31' 30.38557"** Ellipsoidal Hgt: **283.77700 m.**

PTM / PRS92 Coordinates

Northing: **1598615.254 m.** Easting: **448652.445 m.** Zone: **3**

UTM / PRS92 Coordinates

Northing: **1,599,443.15** Easting: **233,045.46** Zone: **51**

Location Description

BTN-40
From Mariveles town proper, travel NE along the national highway for 7 km. until reaching Km. Post # 7. Station is situated just adjacent to the said km. post. Mark is the head of a 4" copper nail centered and embedded on a standard concrete monument, with inscription "BTN-40, 2004, NAMRIA".

Requesting Party: **Christopher Cruz**
Purpose: **Reference**
OR Number: **8087193 I**
T.N.: **2015-2548**

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

9909042015154053

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. BLN-58

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: **BULACAN**
Station Name: **BLN-58**
Order: **2nd**

Island: **LUZON**
Municipality: **SAN ILDEFONSO**
Barangay: **POBLACION**

PRS92 Coordinates

Latitude: **15° 4' 50.28672"** Longitude: **120° 56' 35.59715"** Ellipsoidal Hgt: **24.21800 m.**

WGS84 Coordinates

Latitude: **15° 4' 44.75323"** Longitude: **120° 56' 40.45054"** Ellipsoidal Hgt: **66.23600 m.**

PTM Coordinates

Northing: **1667726.854 m.** Easting: **493895.954 m.** Zone: **3**

UTM Coordinates

Northing: **1,668,175.07** Easting: **278,919.72** Zone: **51**

Location Description

BLN-58
The station is located in San Ildefonso Elementary School North District, about 10 m S of Gusaling Gabaldon and about 6 m NE of the SW corner of Math area. Mark is the head of a 4" copper nail centered on a 0.30 m x 0.30 m x 1 m concrete monument flushed on the ground with inscriptions BLN-58 2007 NAMRIA.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8796226 A**
T.N.: **2014-1187**

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

9 9 0 5 2 9 2 0 1 4 1 2 4 5 3 6

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

4. BA-10

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: **BATAAN**
Station Name: **BA-10**

Island: **LUZON**	Municipality: **DINALUPIHAN**	Barangay: **SAN BENITO**
Elevation: **13.3459 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BA 10
Is in the province of Bataan, town of Dinalupihan, barrio San Benito, along National Highway No.7, on top of the NE end of the NW concrete walk of bridge marked 105.02, 4.10 m. NW of the centerline of the road, stamped. Mark is a 4" x 1/2" diameter brass rod set flush in a drilled hole on top of walk. PC&GS BA 10 1956 are inscribed on a cement putty on top of walk.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795097 A**
T.N.: **2014-99**

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

9901202014143852

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

ANNEX 3. BASELINE PROCESSING REPORTS OF REFERENCE POINTS USED

1. BA-10

Vector Components (Mark to Mark)

From:	BTN-71				
Grid		Local		Global	
Easting	234780.128 m	Latitude	N14°47'30.39069"	Latitude	N14°47'24.89107"
Northing	1636651.711 m	Longitude	E120°32'09.87566"	Longitude	E120°32'14.75560"
Elevation	14.732 m	Height	15.402 m	Height	57.263 m

To:	BA-10				
Grid		Local		Global	
Easting	234727.081 m	Latitude	N14°42'24.60522"	Latitude	N14°42'19.12527"
Northing	1627249.500 m	Longitude	E120°32'11.54465"	Longitude	E120°32'16.43182"
Elevation	14.370 m	Height	14.871 m	Height	56.977 m

Vector					
ΔEasting	-53.047 m	NS Fwd Azimuth	179°41'44"	ΔX	-1258.605 m
ΔNorthing	-9402.211 m	Ellipsoid Dist.	9397.940 m	ΔY	2034.807 m
ΔElevation	-0.362 m	ΔHeight	-0.531 m	ΔZ	-9088.288 m

Standard Errors

Vector errors:					
σ ΔEasting	0.004 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.008 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.012 m
σ ΔElevation	0.015 m	σ ΔHeight	0.015 m	σ ΔZ	0.005 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000610091		
Y	-0.0000802998	0.0001536132	
Z	-0.0000316368	0.0000504973	0.0000212187

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. BLLM-69

Vector Components (Mark to Mark)

From:	08-26-15 BTN40 (1_WLC8				
Grid		Local		Global	
Easting	233045.459 m	Latitude	N14°27'19.71997"	Latitude	N14°27'14.29750"
Northing	1599443.145 m	Longitude	E120°31'25.47707"	Longitude	E120°31'30.38557"
Elevation	240.986 m	Height	240.988 m	Height	283.777 m

To:	08-26-15 BLLM69 (1_ECQW				
Grid		Local		Global	
Easting	241403.878 m	Latitude	N14°29'28.60103"	Latitude	N14°29'23.17631"
Northing	1603317.085 m	Longitude	E120°36'03.06232"	Longitude	E120°36'07.96757"
Elevation	26.010 m	Height	25.701 m	Height	68.576 m

Vector					
ΔEasting	8358.420 m	NS Fwd Azimuth	64°30'51"	ΔX	-6548.742 m
ΔNorthing	3873.941 m	Ellipsoid Dist.	9208.341 m	ΔY	-5258.929 m
ΔElevation	-214.976 m	ΔHeight	-215.288 m	ΔZ	3781.652 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.006 m
σ ΔElevation	0.008 m	σ ΔHeight	0.008 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000139437		
Y	-0.0000218156	0.0000400546	
Z	-0.0000074105	0.0000127039	0.0000054013

ANNEX 4. THE SURVEY TEAM

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JULIE PEARL MARS	UP-TCAGP
	SSRS	AUBREY PAGADOR	UP-TCAGP
	SSRS)/ Research Associate (2014)	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	FOR. MA. VERLINA TONGA	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
	RA	MA. CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
	RA	FOR. REGINA FELISMINO	UP-TCAGP
LiDAR Operation/ Ground Survey, Data Download and Transfer	RA	ENGR. KENNETH QUISADO	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
LiDAR Operation	Airborne Security	SSG DIOSCORO SOBERANO	PHILIPPINE AIR FORCE (PAF)
		SSG PRADYUMA DAS RAMIREZ	
	Pilot	CAPT. RAUL CZ SAMAR II	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JOHN BRYAN DONGUINES	AAC
		CAPT. JERICHO JECIEL	AAC
		CAPT. ALBERT LIM	AAC
		CAPT. SHERWIN ALFONSO III	AAC

ANNEX 5. DATA TRANSFER SHEET FOR BALANGAFLOODPLAIN

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 PA
Signature

Received by

Name JOIDA PRIETO
Position SRS
Signature

Verified by

Name JOIDA P RIETO
Position SRS
Signature 01/10/14
2013

13-21

DATA TRANSFER SHEET - BatZam
29-02-2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(KB)	POS	RAW IMAGE S/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	
2014-01-09	963	1BALBS009A	Pegasus	0 B	639.67 KB	0 B	125.7 MB	0 B	N/A	5.83 GB	0 B	3.1 MB	178 B	234 B	0 B	963	Z:\DAC\RAWDATA\963\P
2014-01-06	951	1BALF006A	Pegasus	0 B	442 B	6.42 MB	178.45 MB	0 B	N/A	9.52 GB	41.59 GB	12.85 MB	221 B	442 B	177.52 KB	951	Z:\DAC\RAWDATA\951\P
2014-01-05	949	1BUCGS005B	Pegasus	0 B	558 B	7.25 MB	228.81 MB	0 B	N/A	12.95 GB	42.96 GB	16.14 MB	222 B	558 B	266.63 KB	949	Z:\DAC\RAWDATA\949\P
2014-01-05	947	1BUCACS005A	Pegasus	0 B	1.96 MB	9.9 MB	250.4 MB	0 B	N/A	17.31 GB	33.29 GB	16.14 MB	222 B	668 B	0 B	947	Z:\DAC\RAWDATA\947\P
2014-01-04	945	1BUCCS004B	Pegasus	0 B	374 B	5.52 MB	172.21 MB	0 B	N/A	4.69 GB	562.43 MB	21.32 MB	278 B	374 B	82.7 KB	945	Z:\DAC\RAWDATA\945\P

Received from

Name R. PUNTO group RA
Position
Signature

Received by

Name AC BORGAT group DDPL
n SSRS
ure ACBorgat 2/29/16

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\7 253GC
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\7 254GC
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\7 255GC
5/18/2014	7256GC	2PAMS5138A	GEMINI	na	245	486	227	NA	NA	18.9	NA	18.7	1KB	1KB	216	NA	Z:\Airborne_Raw\7 256GC
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\7 257GC
5/20/2014	7260GC	2BLK17S1140A	GEMINI	na	209	301	183	NA	NA	14.5	NA	10.7	1KB	1KB	241	NA	Z:\Airborne_Raw\7 260GC

Received from

Name: Ca Jordan IV
Position: KA
Signature:

Received by

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

14-21

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. SORIANO
Position RA
Signature

Received by

Name JOIDA PRIETO
Position SSRS
Signature 5/29/14

14-27

DATA TRANSFER SHEET

~~Dalaharzon~~ 9/10/15 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	
26-Aug-15	2656G	2BTNAB238B	gemini	na	202	385	185	9.17/1.8/361	81/15/4	9.15	1.22	175	1KB	1KB	8	7	Z:\DAC\RAW DATA
27-Aug-15	2658G	2BTNCD239A	gemini	na	298	623	232	11.6/9.83	1/1/1	13.3	537	94.8	1KB	1KB	10	17	Z:\DAC\RAW DATA
28-Aug-15	2662G	2UMYA240A	gemini	na	273	482	231	134/25.1	2/198	8.59	0	137	1KB	1KB	12	30	Z:\DAC\RAW DATA
29-Aug-15	2666G	2UMYAB241A	gemini	na	301	554	238	17.6	139	12.5	673	104	1KB	1KB	12	na	Z:\DAC\RAW DATA
30-Aug-15	2670G	2CLBUMYABS242A	gemini	na	379	635	247	29.1	233	16.4	321	84.5	1KB	1KB	5	7	Z:\DAC\RAW DATA

Received from

Name C. VARGAS JR

Position RA

Signature

Received by

Name AC Bongat 9/11/15 calib: 10/5/15

Position SSR3

Signature

15-26

ANNEX 6. FLIGHT LOGS

1. Flight Log for 925P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 925P

1 LiDAR Operator: P. ARCED	2 ALTM Model: PEGASUS	3 Mission Name: 18ULB341A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP 9622
7 Pilot: R. SAMPAR 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	14 Engine Off: 1735	15 Total Engine Time: 1.59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	VERY CLOUDY / WINDY SPEARMS				
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

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

Signature over Printed Name

2. Flight Log for 929P Mission

DREAM Data Acquisition Flight Log — **Flight Log No.:** 929P

1 LiDAR Operator: MCE BALUGAS	2 ALTM Model: PEGASUS	3 Mission Name: IBALAS3628	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP 9022
7 Pilot: F. DECAMPO	8 Co-Pilot: J. ALASAR	9 Route:			
10 Date: DEC. 08, 2013	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1508	14 Engine Off: 1841	15 Total Engine Time: 3.2.9	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FLIGHED 6/11 LINES. MISSION NOT COMPLETED DUE VFR DESTINATION					
21 Problems and Solutions:					

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

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

Pilot-in-Command
F/O DECAMPO
Signature over Printed Name

Lidar Operator
CATHERINE BALUGAS
Signature over Printed Name

3. Flight Log for 924G Mission

DREAM Data Acquisition Flight Log

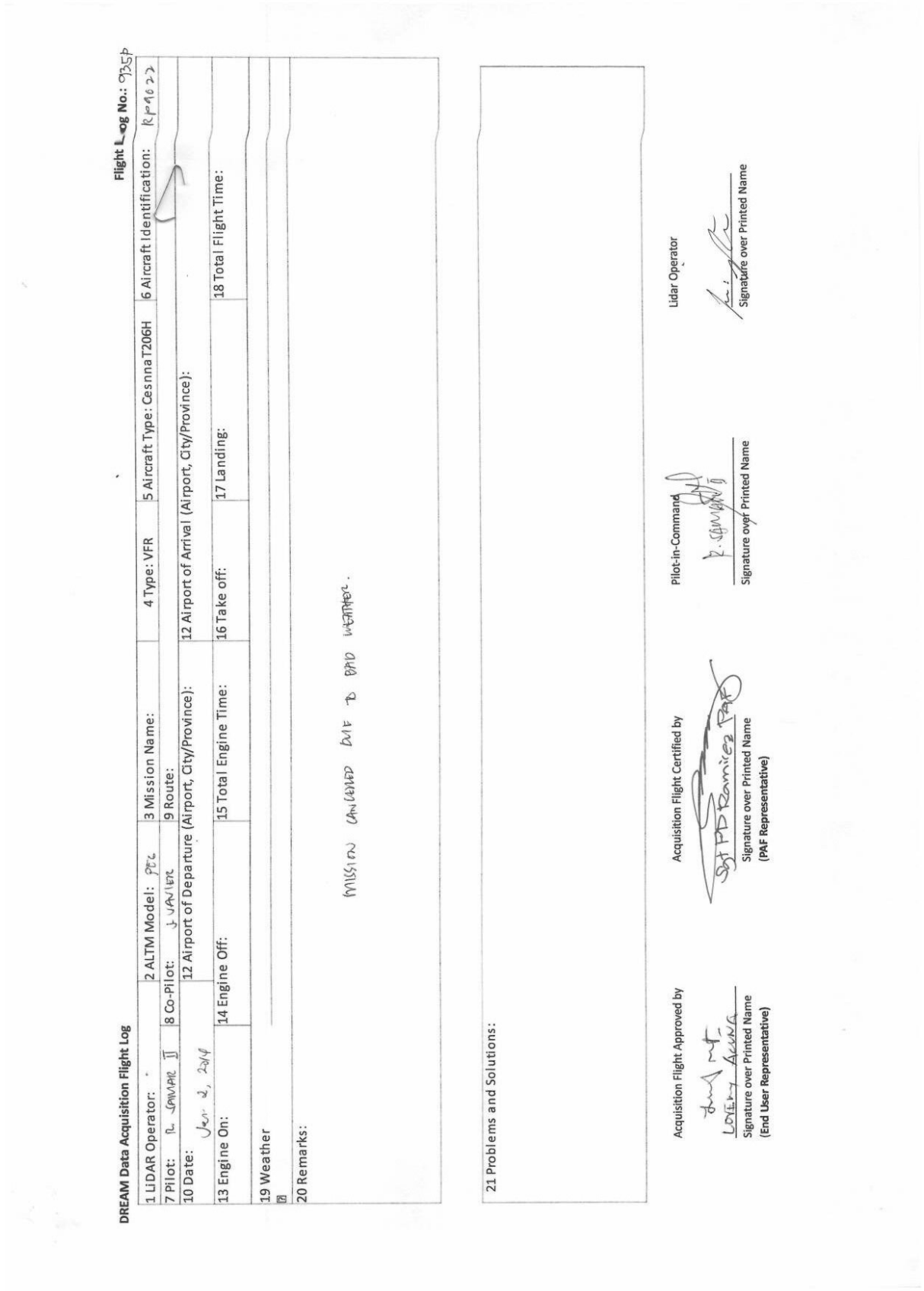
Flight Log No.: 912

1 LiDAR Operator: V. TONGA	2 ALTM Model: GEMINI	3 Mission Name: 2BALB363B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP 9122
7 Pilot: F. DE OCAMPO	8 Co-Pilot: J. ALAJAR	9 Route:			
10 Date: DEC. 29, 2013	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1448	14 Engine Off: 1816	15 Total Engine Time: 3+28	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: FINISHED 11/15 LINES.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
	SgtFD Ramirez PAF	FB DE OCAMPO	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

4. Flight Log for 935P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 935P

1 LiDAR Operator:	2 ALTM Model:	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date:	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather

20 Remarks:

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)

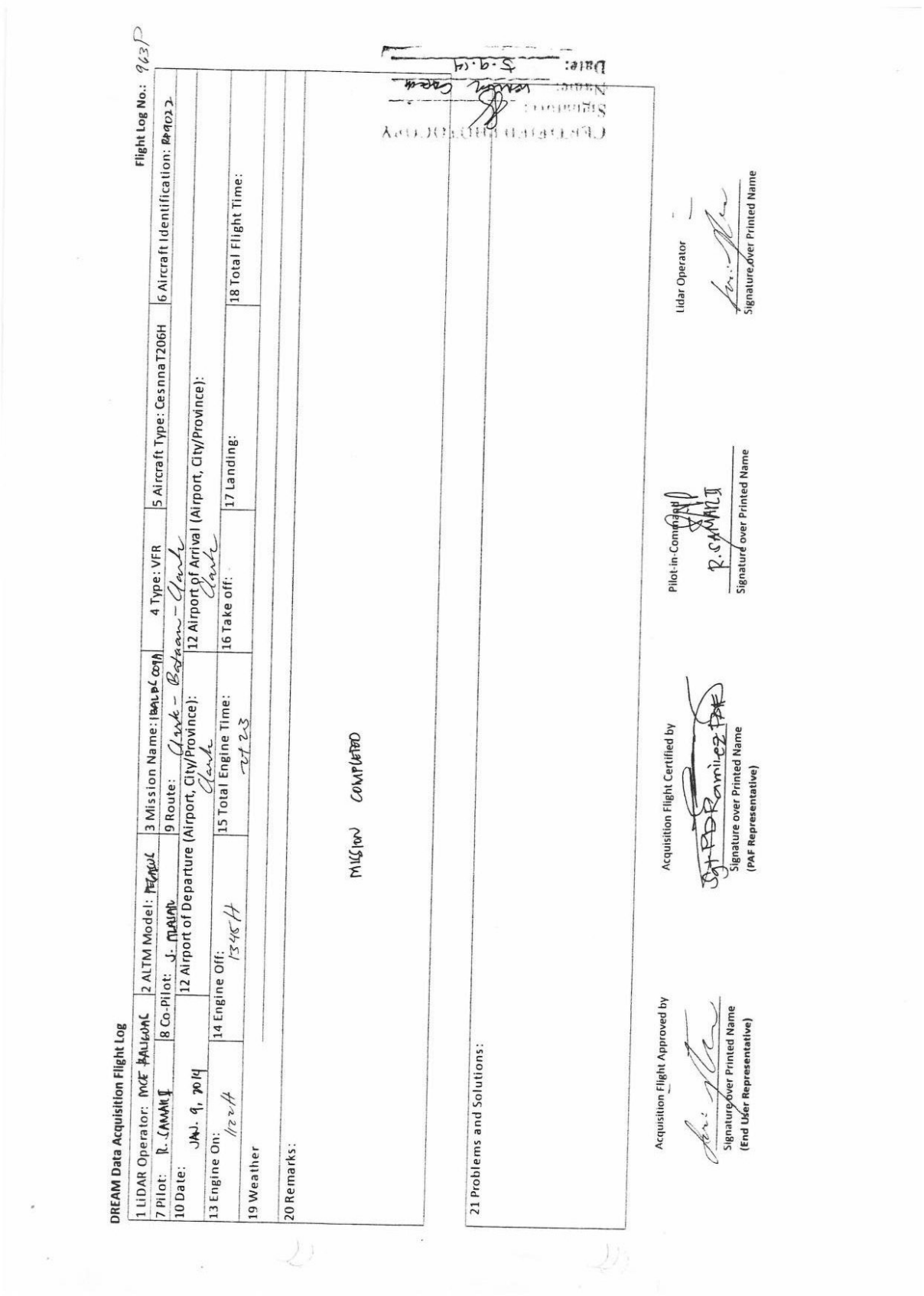
Pilot-in-Command

Signature over Printed Name

Lidar Operator

Signature over Printed Name

5. Flight Log for 963P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 963P

1 LiDAR Operator: MCE BALGOS	2 ALTM Model: PEGASUS	3 Mission Name: IBAL BL 001A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C2022
7 Pilot: R. CAMACHO	8 Co-Pilot: J. MAMO	9 Route: Clark – Batanes – Clark			
10 Date: JAN. 9, 2014	12 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark		
13 Engine On: 1122/H	14 Engine Off: 1345/H	15 Total Engine Time: 2+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: MISSION COMPLETED					
21 Problems and Solutions:					

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Sgt FDR Ramirez PAF

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

R. CAMACHO

Signature over Printed Name

Lidar Operator

Signature over Printed Name

Date: 5.9.14

6. Flight Log for 7260GC Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 7260

1 LIDAR Operator: LK Paragas	2 ALTM Model: Gemini	Mission Name: 28LC13SUDA Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9322
7 Pilot: R.S Gamarra	8 Co-Pilot: C. Alfonso III	9 Route: RPLC - BIK17 - RPLC		
10 Date: 5-20-14	12 Airport of Departure (Airport, City/Province): RPLC		13 Airport of Arrival (Airport, City/Province): RPLC	
13 Engine On: 0918 H	14 Engine Off: 1229 H	15 Total Engine Time: 3+11	16 Take off: 0922 H	17 Landing: 1225 H
				18 Total Flight Time: 3+03

19 Weather: cloudy

20 Remarks:

Surveyed 10 lines in BIK17SI, mission completed

NO CASI

21 Problems and Solutions:

Acquisition Flight Approved by

Raul Mars

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

SGT Rosario Soriano PAF

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

R.S Gamarra III

Signature over Printed Name

Lidar Operator

LK Paragas

Signature over Printed Name

DREAM Data Acquisition Flight Log Flight Log No.: 7271

1 LiDAR Operator: UP Paragas	2 ALTM Model: GemCAS	3 Mission Name: 2PAm155314S	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. Samar II	8 Co-Pilot: B. Dorguinos	9 Route: RPLC-RPLC BP1000			
10 Date: 05-25-14	12 Airport of Departure (Airport, City/Province): RPLC - RPLC	12 Airport of Arrival (Airport, City/Province): RPLC			
13 Engine On: 1131H	14 Engine Off: 1530H	15 Total Engine Time: 3+59	16 Take off: 1135H	17 Landing: 1525H	18 Total Flight Time: 3+50
19 Weather	cloudy				
20 Remarks:	Surveyed riside in Pampanga and Bulacan area (without CAM)				

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

8. Flight Log for 2656G Mission

Flight Log No.:

1 LiDAR Operator: Baligad, Rafael	2 ALTM Model: Gemini	3 Mission Name: 2656G	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: A. Lim	8 Co-Pilot: J. Jeuel	9 Route: Clark - Limay			
10 Date: 6-26-15	11 Airport of Departure (Airport, City/Province): Clark		12 Airport of Arrival (Airport, City/Province): Clark		
13 Engine On: 14:15	14 Engine Off: 17:28	15 Total Engine Time: 3+23	16 Take off: 14:21	17 Landing: 17:23	18 Total Flight Time: 3+13
19 Weather: Cloudy in north					
20 Remarks: SUCCESSFUL FLIGHT OVER LIMAY					
21 Problems and Solutions:					

Acquisition Flight Approved by
A. DIPASADOK
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
A. Lim
Signature over Printed Name

Lidar Operator
Signature over Printed Name

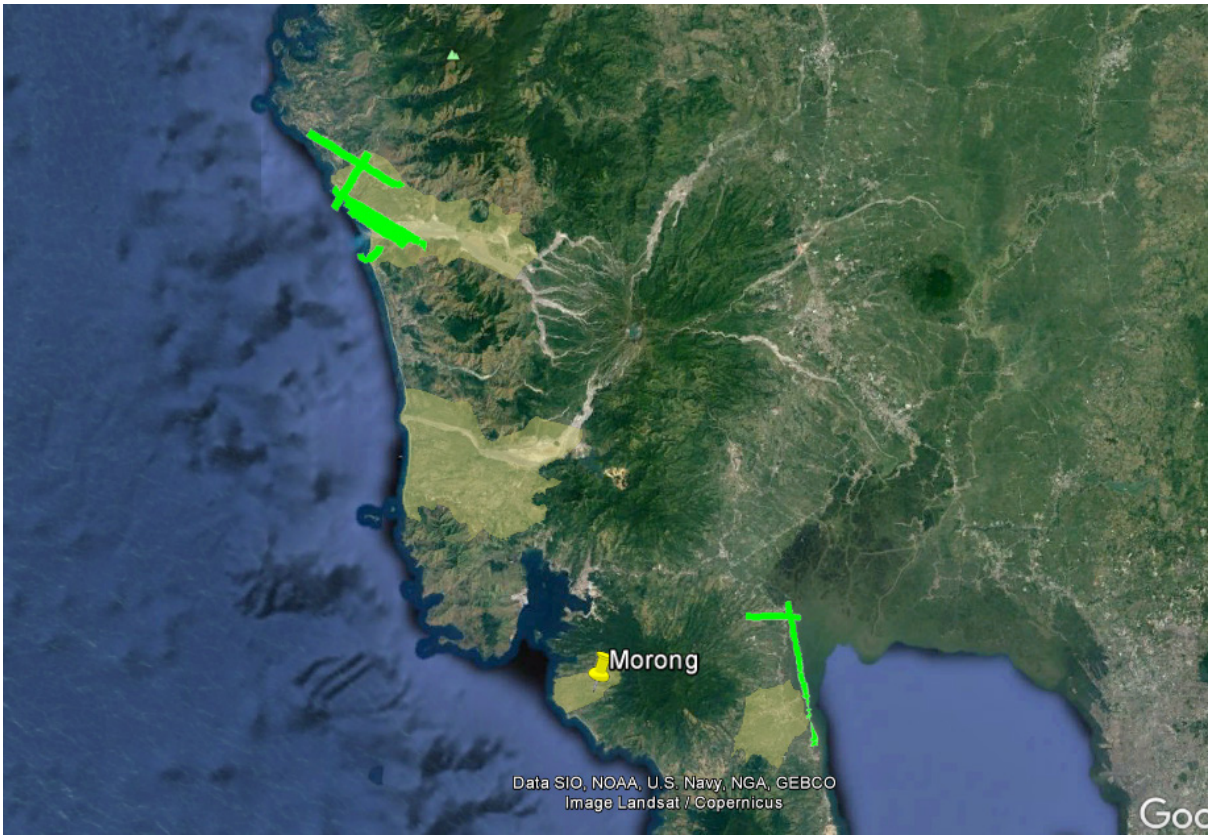
ANNEX 7. FLIGHT STATUS REPORT

FLIGHT STATUS REPORT
Bataan and Umiray; Clark Reflights
December 27-January 9, 2014; May 20-25, 2014 and August 26, 2015

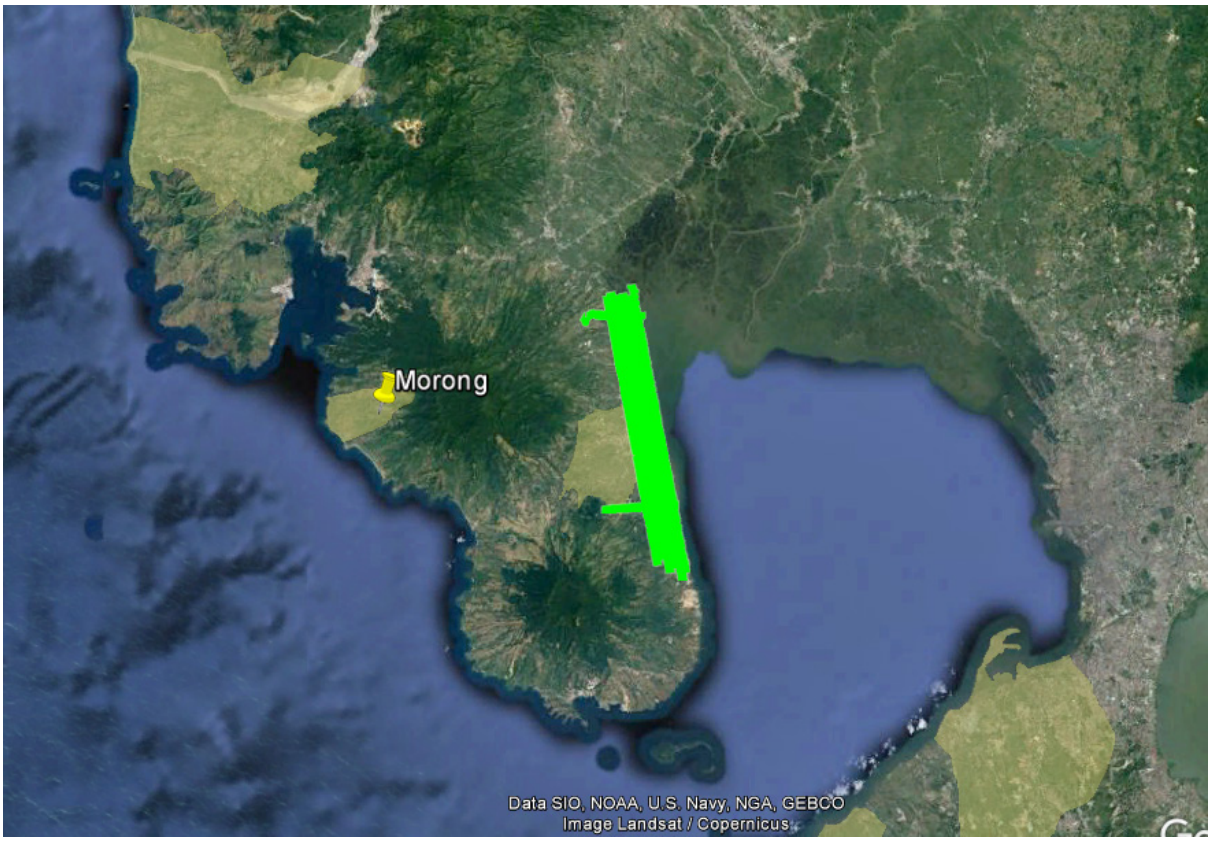
FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
925P	BAL A	1BALA361B	PJ ARCEO	December 27, 2013	Surveyed few lines for BAL A
929P	BAL A	1BALAS362B	MCE BALIGUAS	December 28, 2013	Supplementary flight for BAL A
924G	BAL B	2BALB363B	V TONGA	December 29, 2013	Surveyed few lines for BAL B
935P	BAL A	1BALAS002A	PJ ARCEO	January 2, 2014	Surveyed few lines for BAL A
963P	BAL B	1BALBS009A	MCE BALIGUAS	January 9, 2014	Surveyed few lines for BAL B
7260GC	BLK15	2BLK15S140A	LK PARAGAS	May 20, 2014	Completed 9 lines of BLK17S1 at 800m
7271GC	PAMS1, PAM S3	2PAMS1S3145B	LK PARAGAS	May 25, 2014	Completed 15 lines at 1000m
2656G	BTNA, B	2BTNAB238B	AM PAGADOR & MCE BALIGUAS	August 26, 2015	Mission Completed; Supplementary flight for BTNA and finished area BTNB

SWATH/LAS PER MISSION

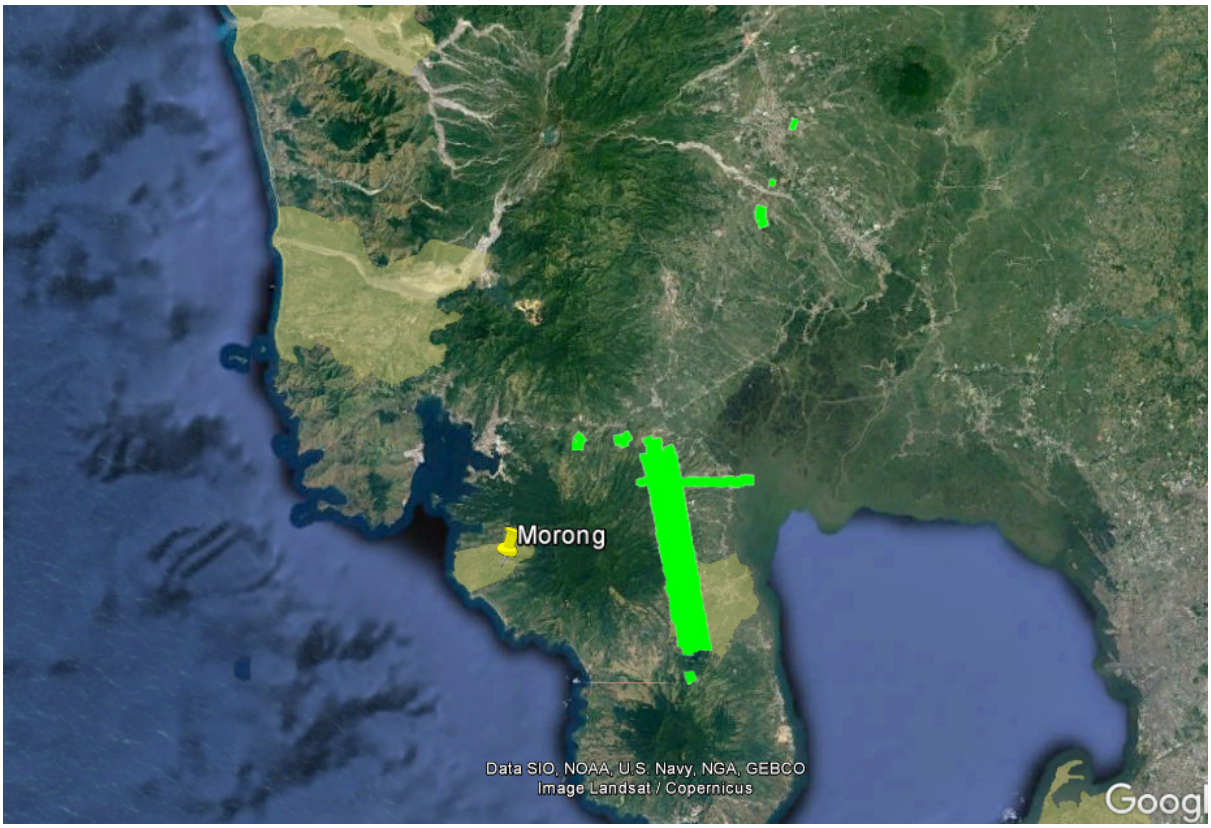
Flight No. :	925P	
Area:	BAL A	
Mission Name:	1BALA361B	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30



Flight No. :	929P	
Area:	BAL A	
Mission Name:	1BALAS362B	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

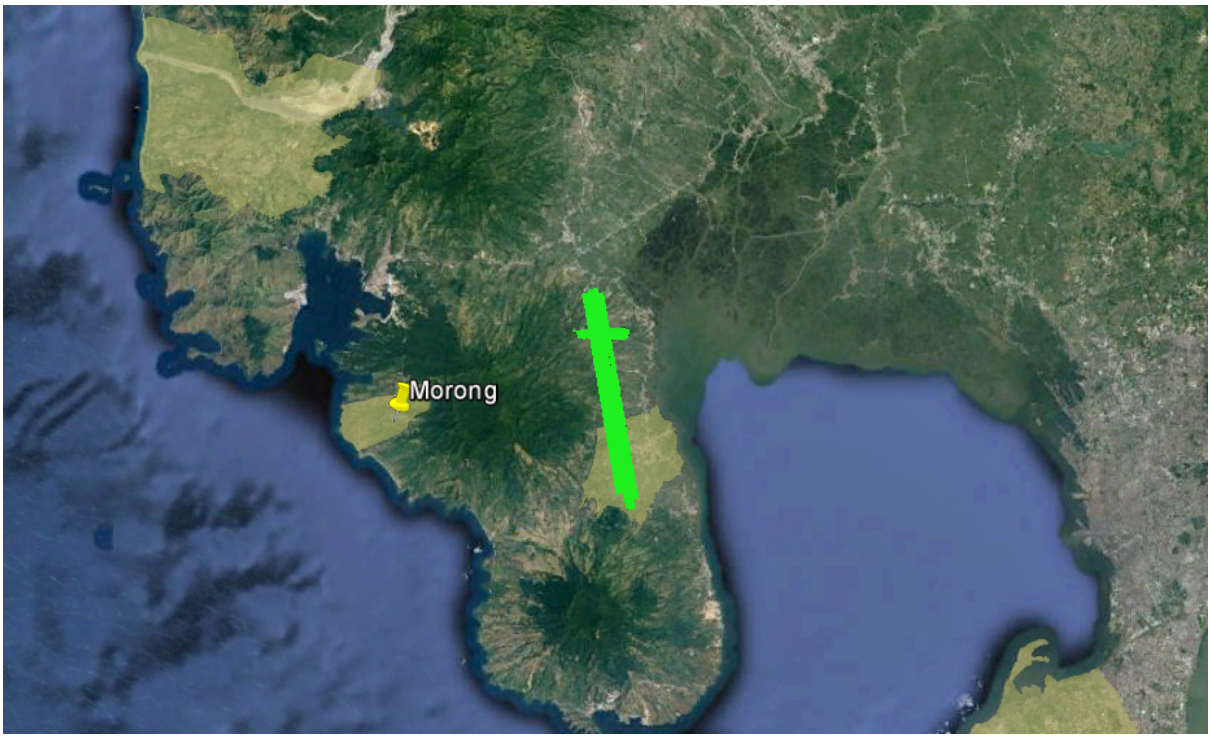


Flight No. :	924G	
Area:	BAL B	
Mission Name:	2BALB363B	
Parameters:	Altitude: 1000	Scan Frequency: 50
	Scan Angle: 20	Overlap: 30



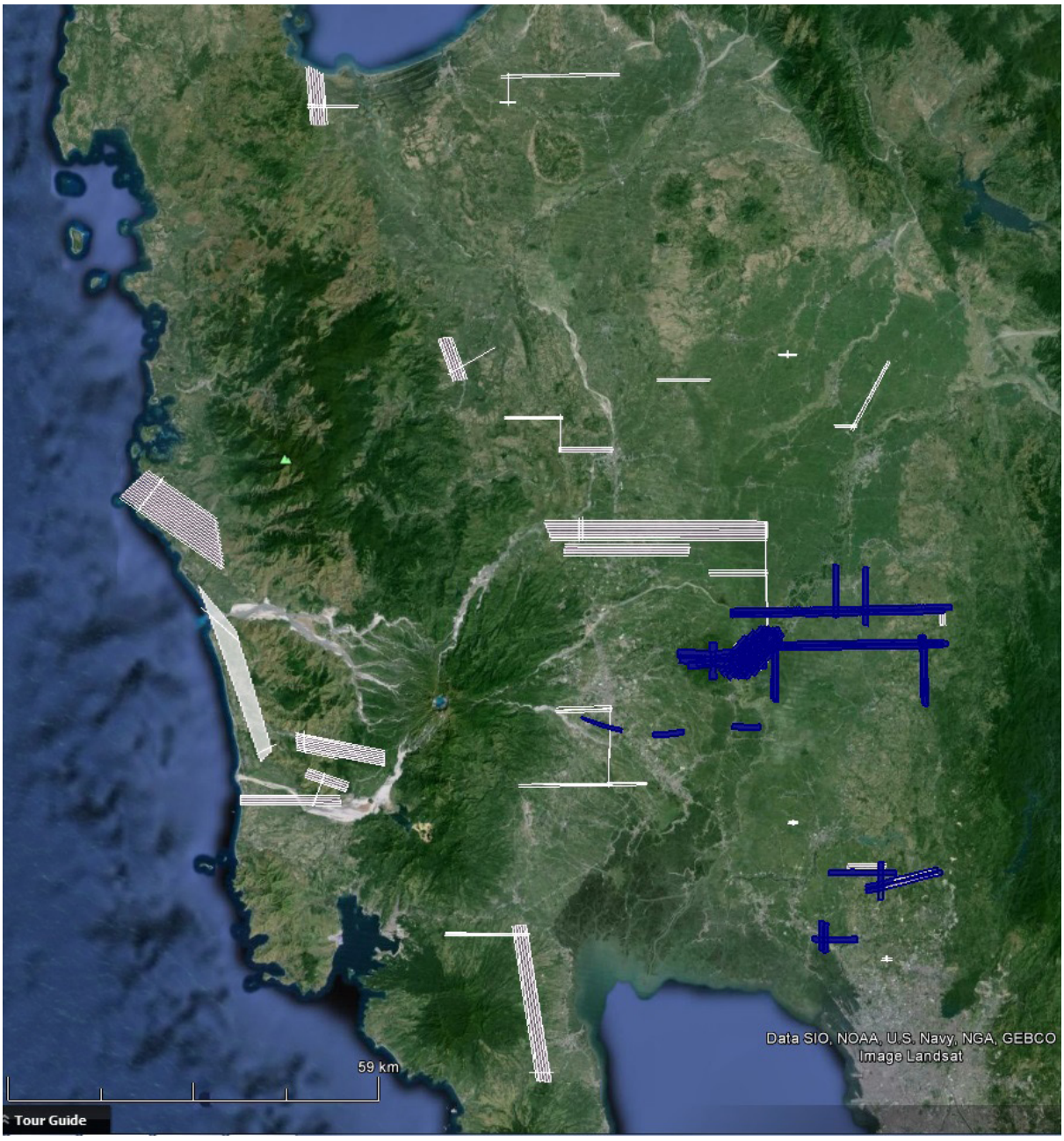
Flight No. :	935P	
Area:	BAL A	
Mission Name:	1BALAS002A	
Parameters:	Altitude: 1200	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

Flight No. :	963P	
Area:	BAL B	
Mission Name:	1BALBS009A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 25	Overlap: 30

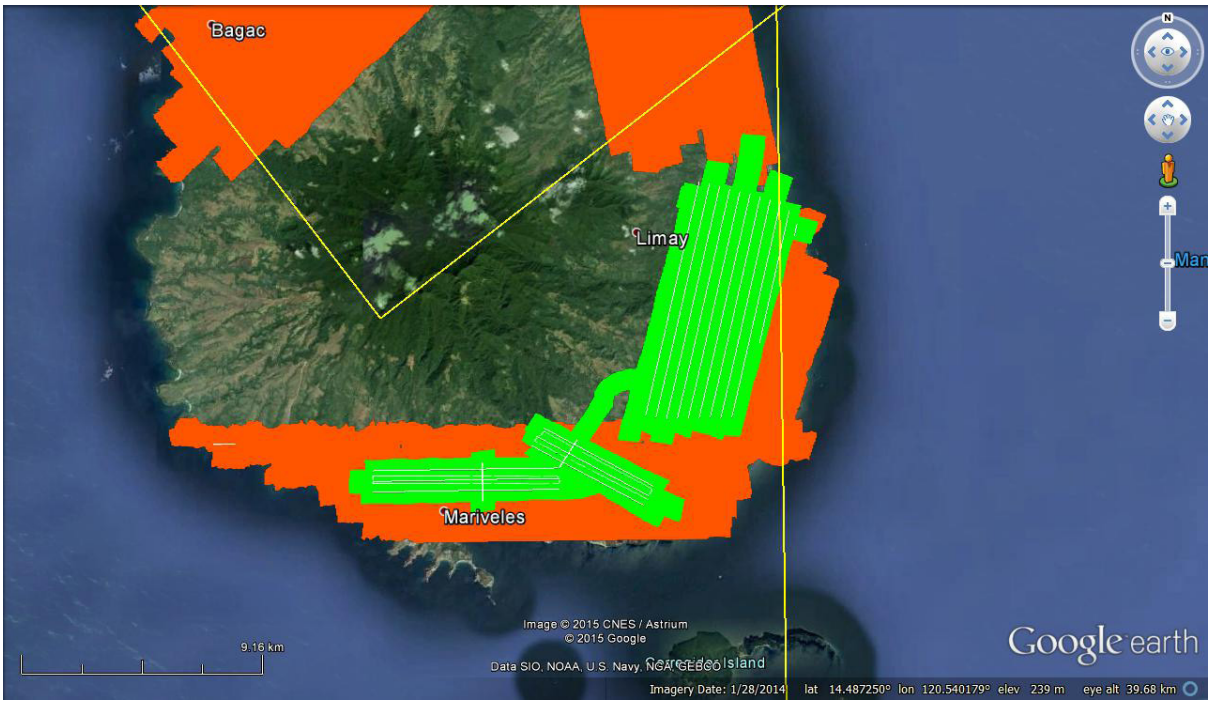


Flight No. :	7260GC	
Area:	BLK 15	
Mission Name:	2BLK15S140A	
Parameters:	Altitude: 800	Scan Frequency: 40
	Scan Angle: 25	Overlap: 30

Flight No. : 7271GC
Area: PAM S1, S3
Mission Name: 2PAMS1S3145B
Parameters: Altitude: 800 Scan Frequency: 40
Scan Angle: 25 Overlap: 30



Flight No. :	2656G	
Area:	BTN A, B	
Mission Name:	2BTNAB238B	
Parameters:	Altitude: 1100	Scan Frequency: 50
	Scan Angle: 20	Overlap: 30



ANNEX 8. Mission Summary Reports

Flight Area	Bataan
Mission Name	**BataanZambales_PlgA_963P**
Inclusive Flights	963P
Range data size	5.82 GB
POS	125 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)	2.5
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	4.5
Boresight correction stdev (<0.001deg)	0.000967
IMU attitude correction stdev (<0.001deg)	0.000811
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	32.10%
Ave point cloud density per sq.m. (>2.0)	5.51
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	79
Maximum Height	412.14 m
Minimum Height	49.06 m
Classification (# of points)	
Ground	61,768,516
Low vegetation	40,978,880
Medium vegetation	52,311,283
High vegetation	31,391,760
Building	3,643,862
Orthophoto	No
Processed by	Engr. Irish Cortez, Celina Rosete, Engr. Gladys Mae Apat

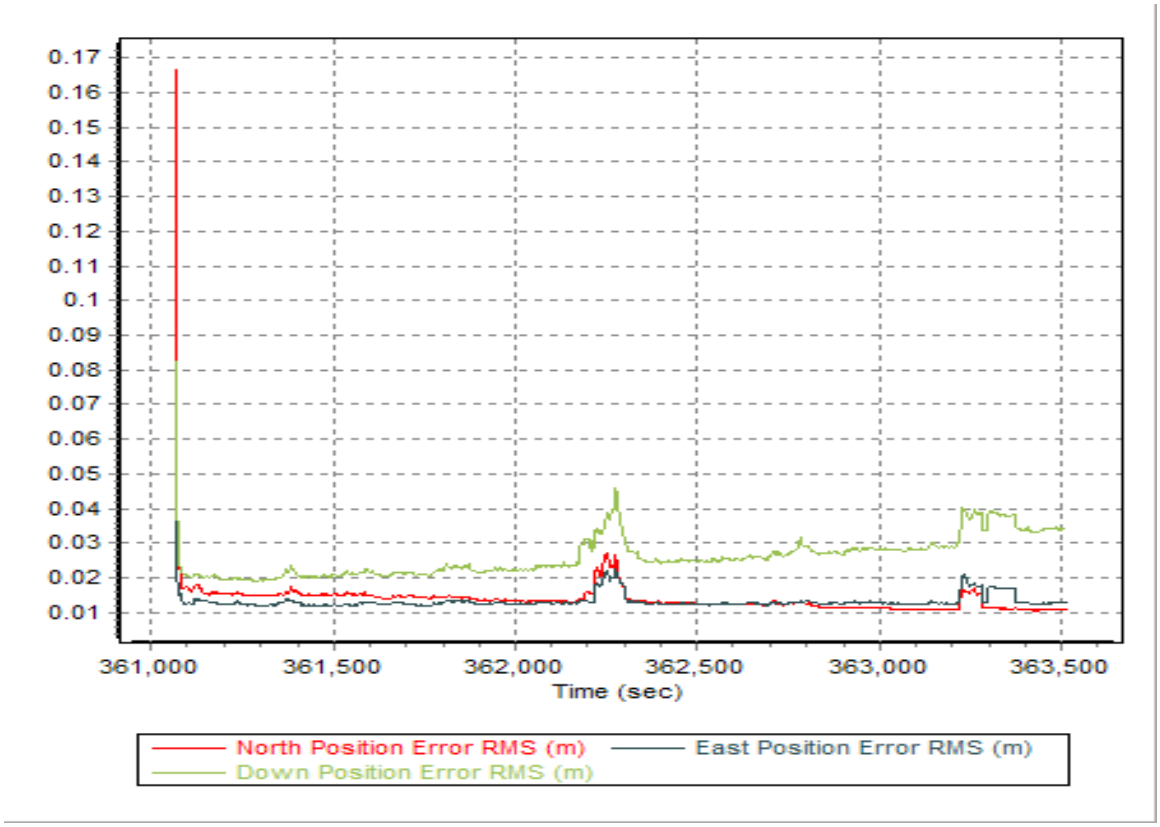


Figure 1.1.1. Solution Status

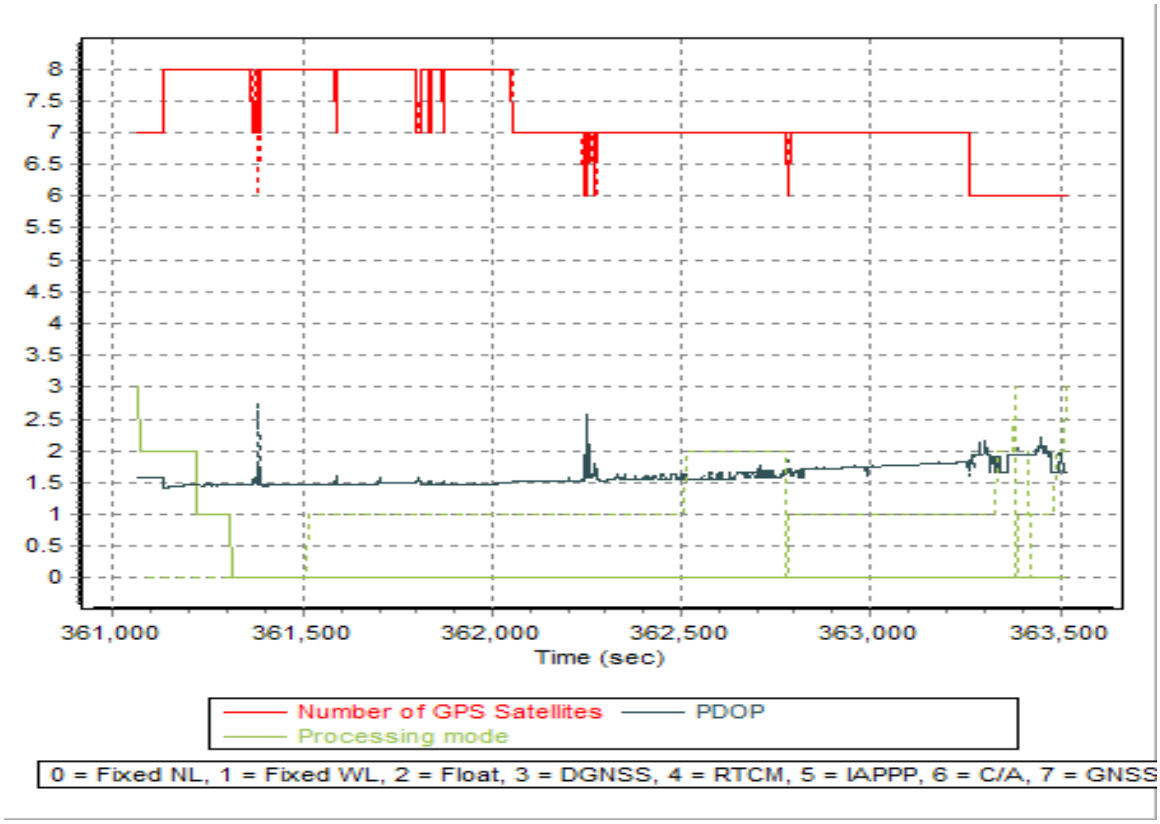


Figure 1.1.2. Smoothed Performance Metric Parameters

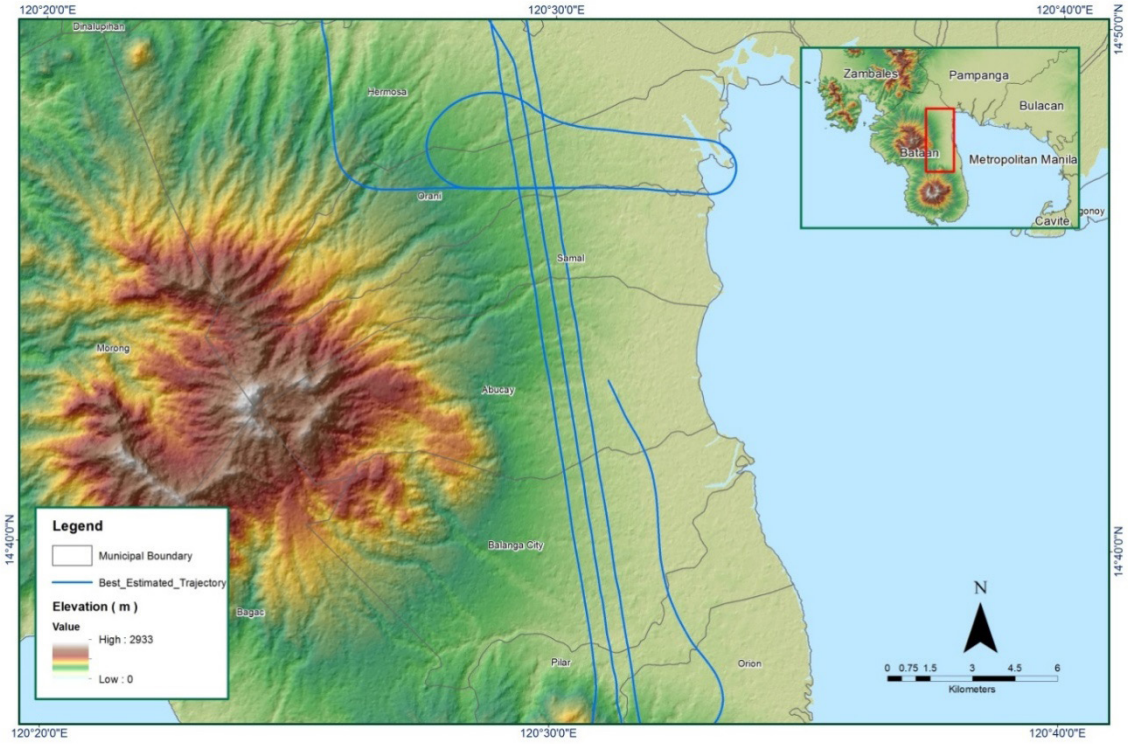


Figure 1.1.3. Best Estimated Trajectory

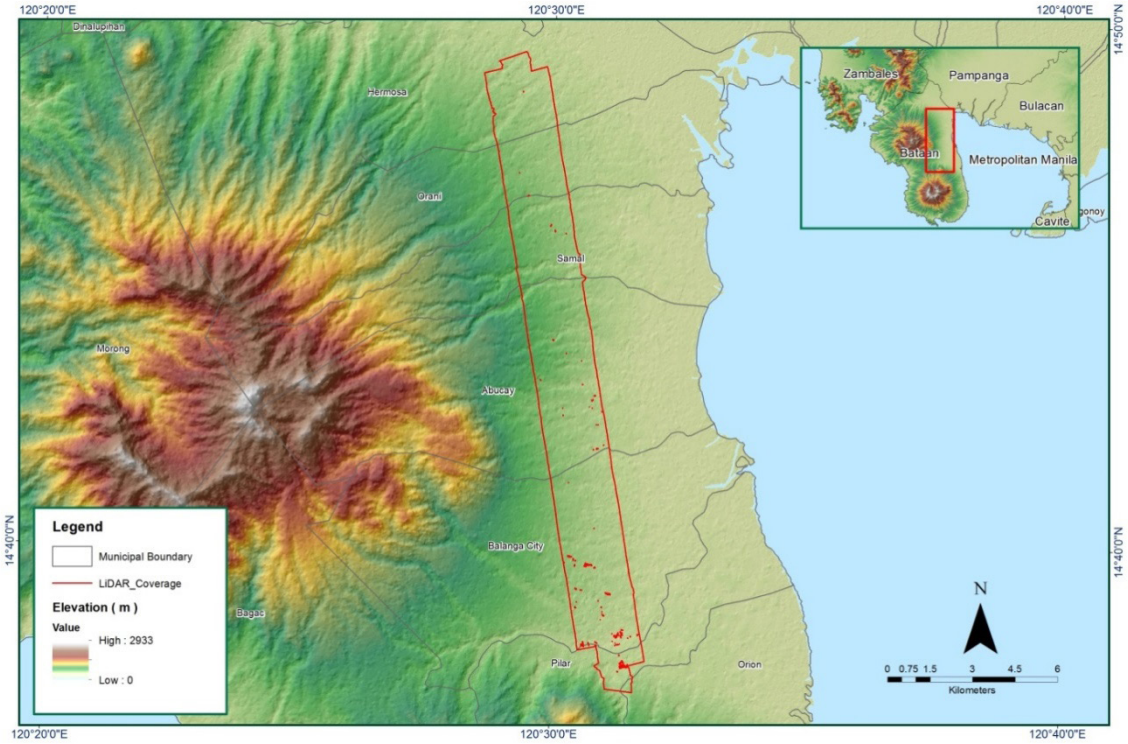


Figure 1.1.4. Coverage of LiDAR Data

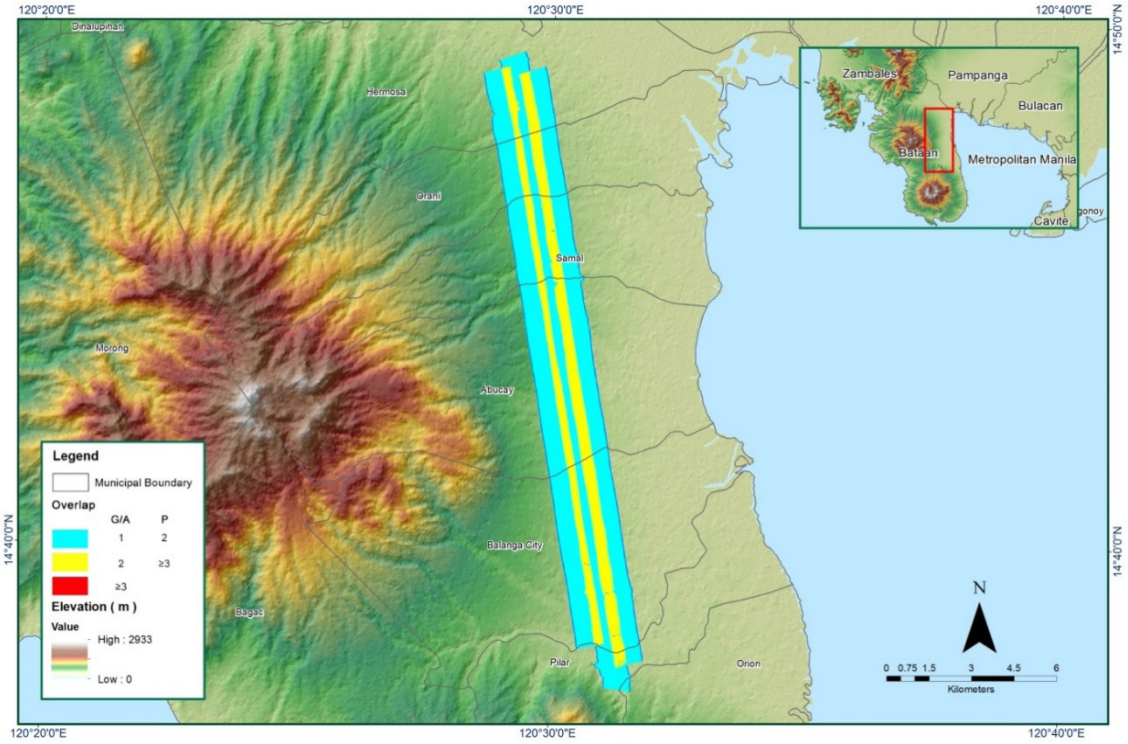


Figure 1.1.5. Image of data overlap

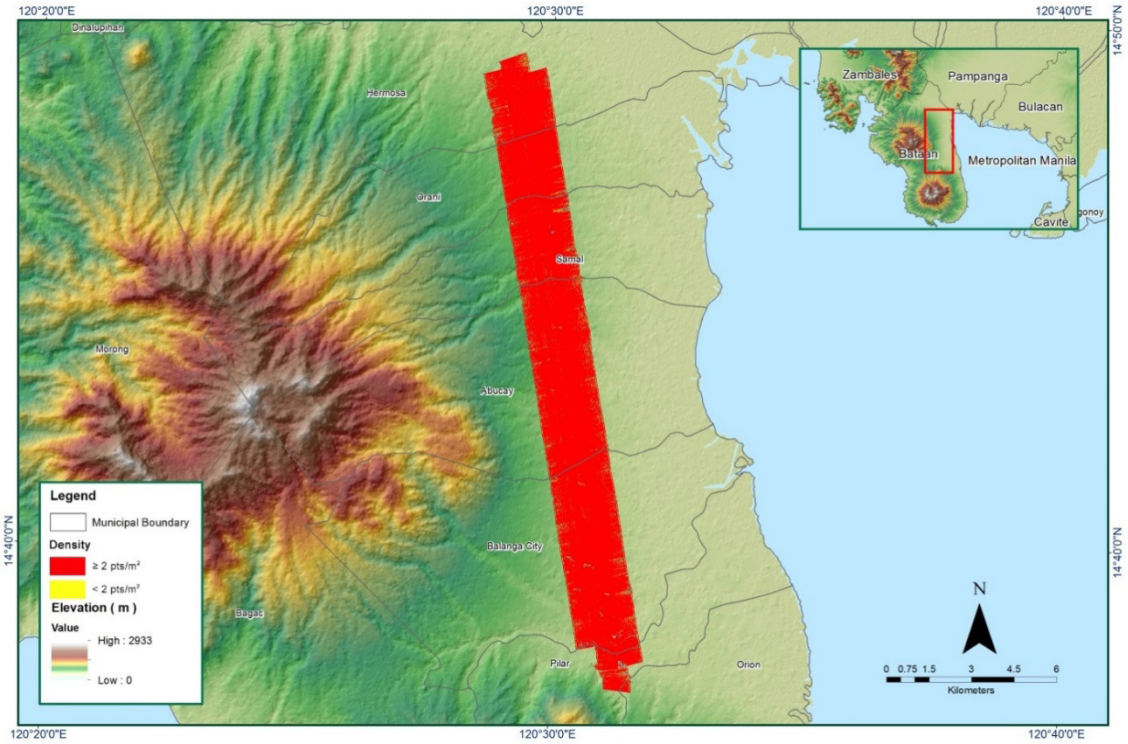


Figure 1.1.6. Density map of merged LiDAR data

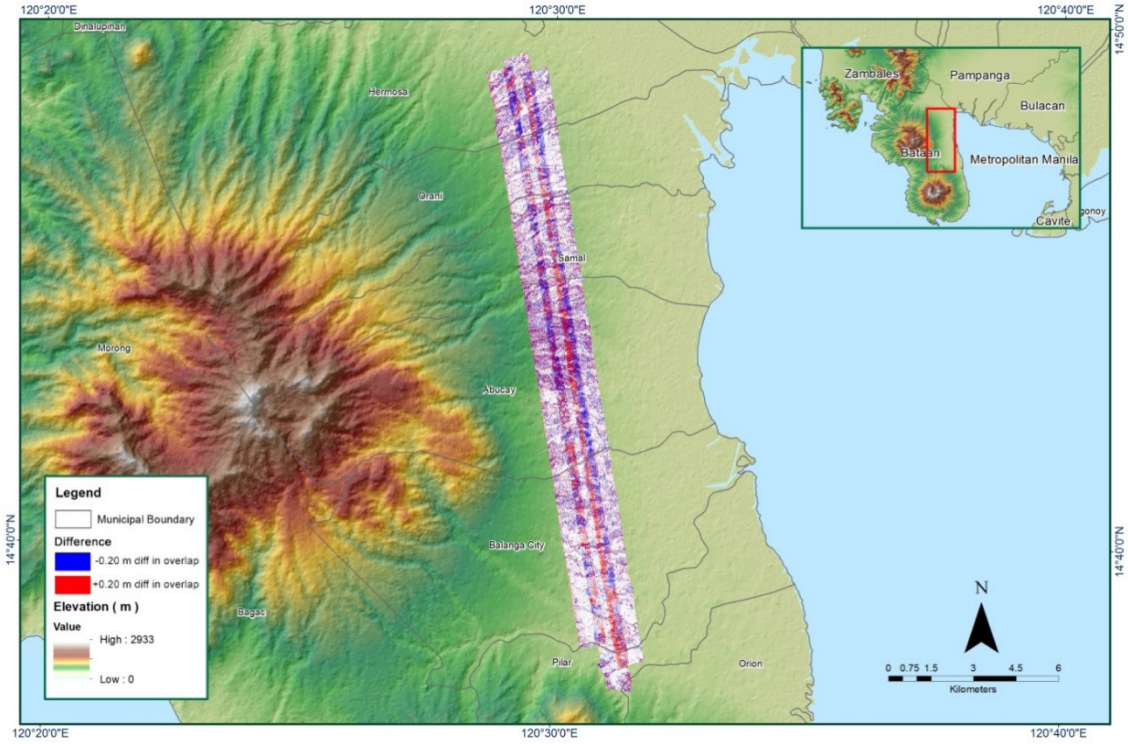


Figure 1.1.7. Elevation difference between flight lines

Flight Area	Bataan
Mission Name	BalC
Inclusive Flights	935P
Range data size	18.5 GB
POS data size	265 MB
Base data size	8.23 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)	3.0
RMSE for East Position (<4.0 cm)	4.4
RMSE for Down Position (<8.0 cm)	8.5
Boresight correction stdev (<0.001deg)	0.000364
IMU attitude correction stdev (<0.001deg)	0.001459
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	25.79
Ave point cloud density per sq.m. (>2.0)	4.08
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	132
Maximum Height	463.91 m
Minimum Height	46.26 m
Classification (# of points)	
Ground	18,860,921
Low vegetation	14,715,644
Medium vegetation	34,914,237
High vegetation	29,638,959
Building	200,801
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Melanie Hingpit, Simonette Lat

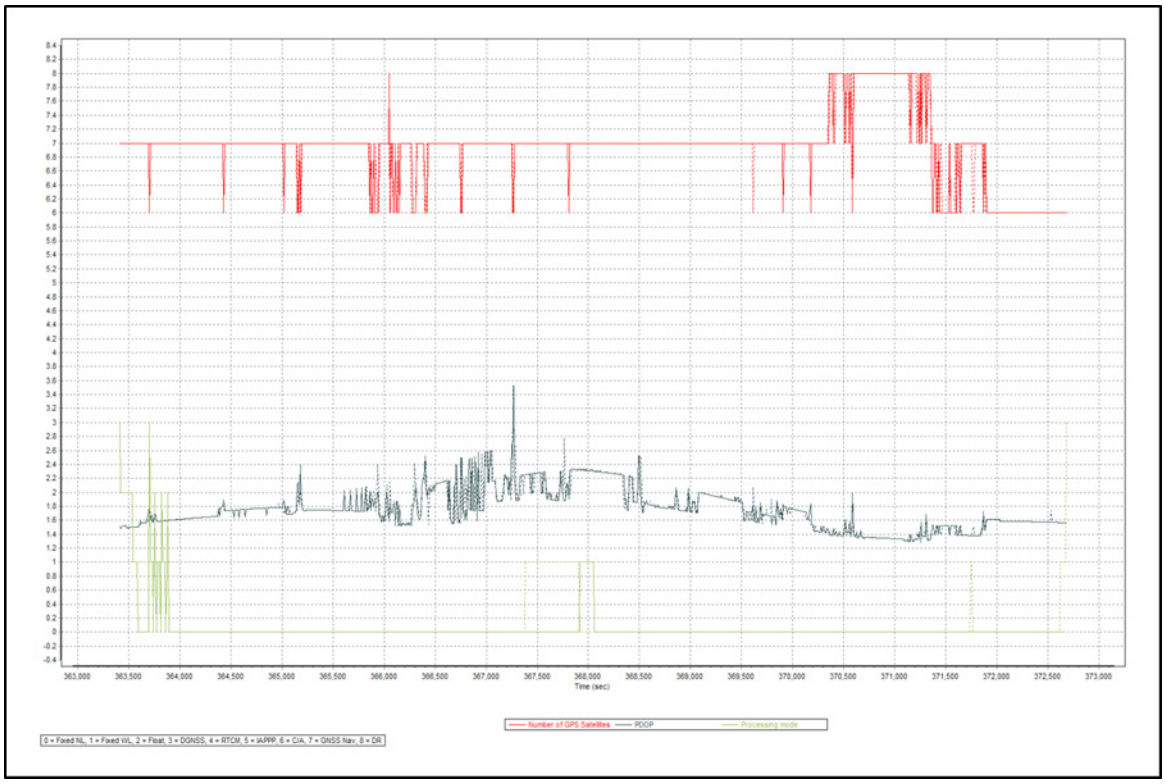


Figure 1.2.1. Solution Status

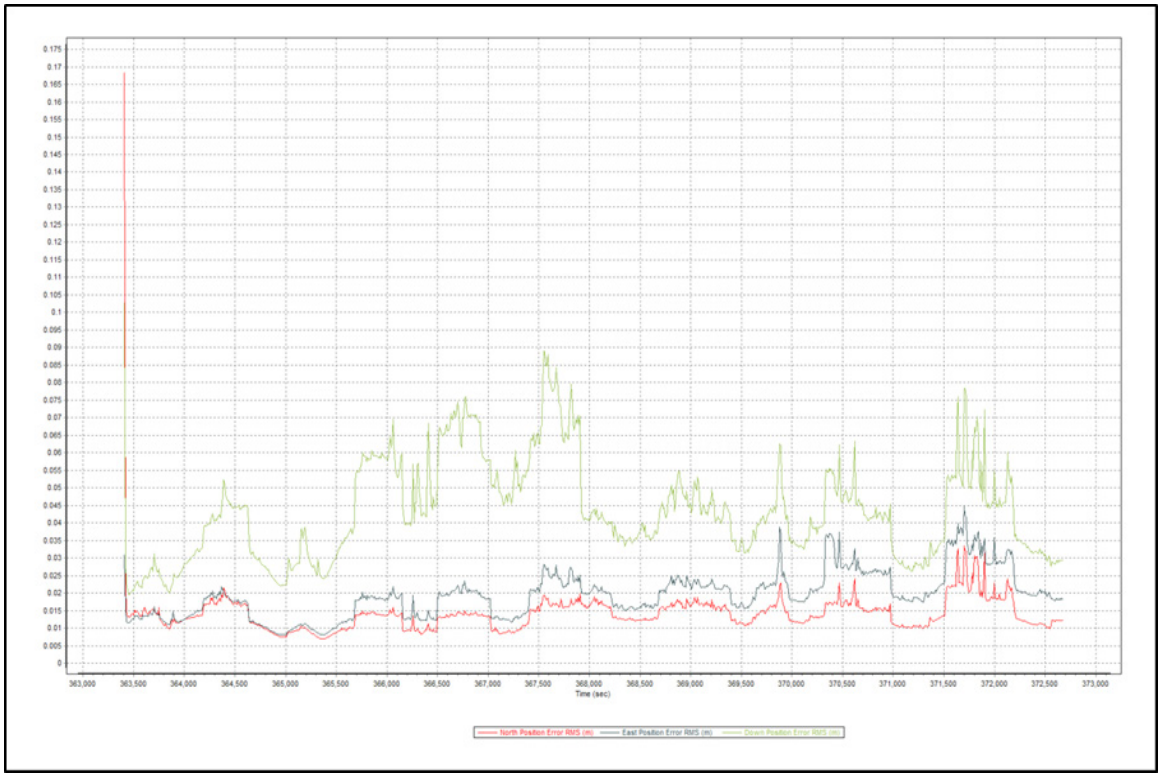


Figure 1.2.2. Smoothed Performance Metric Parameters

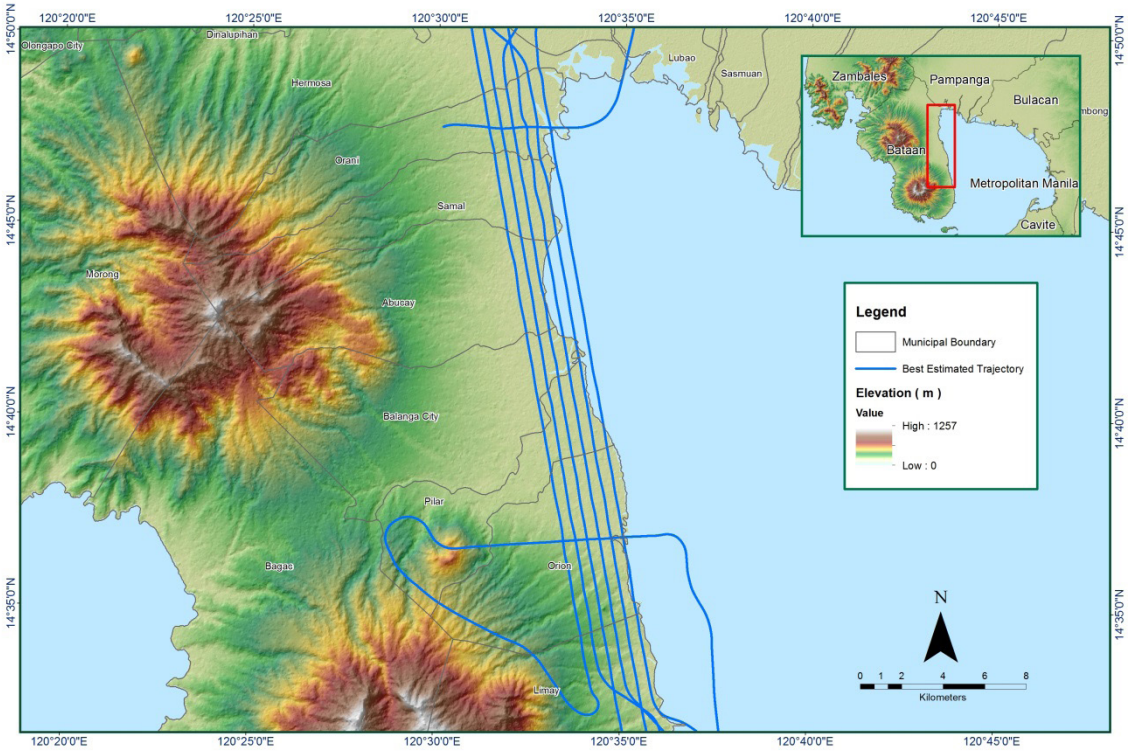


Figure 1.2.3. Best Estimated Trajectory

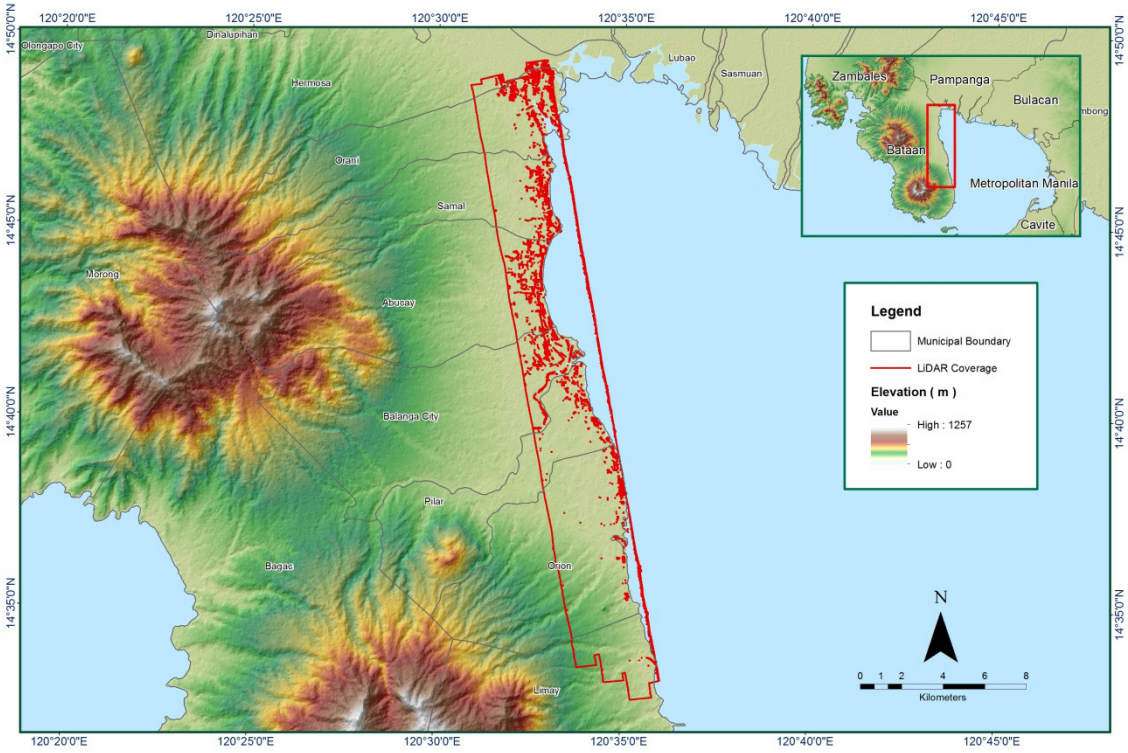


Figure 1.2.4. Coverage of LiDAR Data

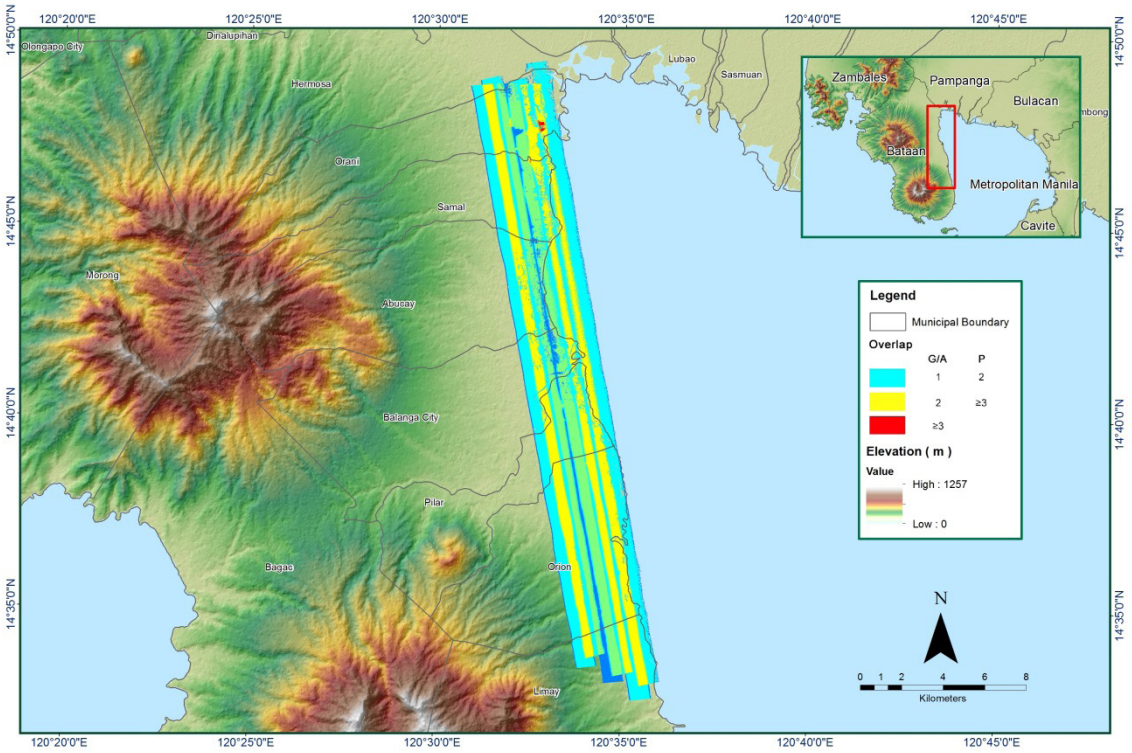


Figure 1.2.5. Image of data overlap

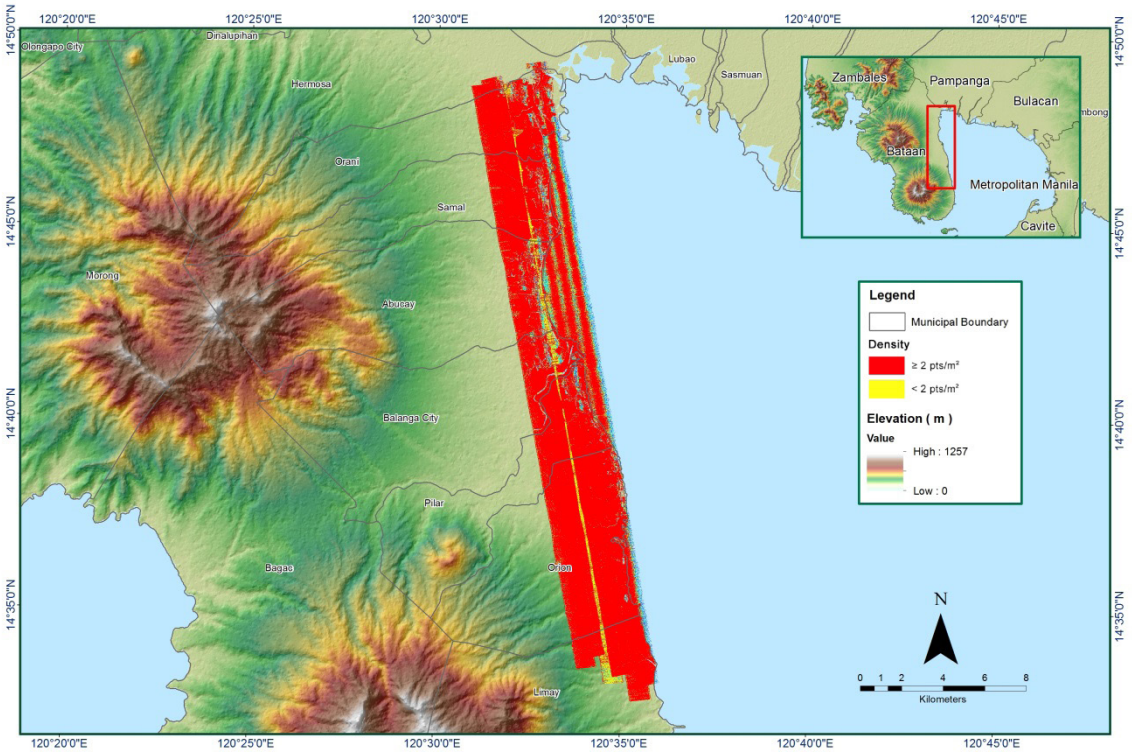


Figure 1.2.6. Density map of merged LiDAR data

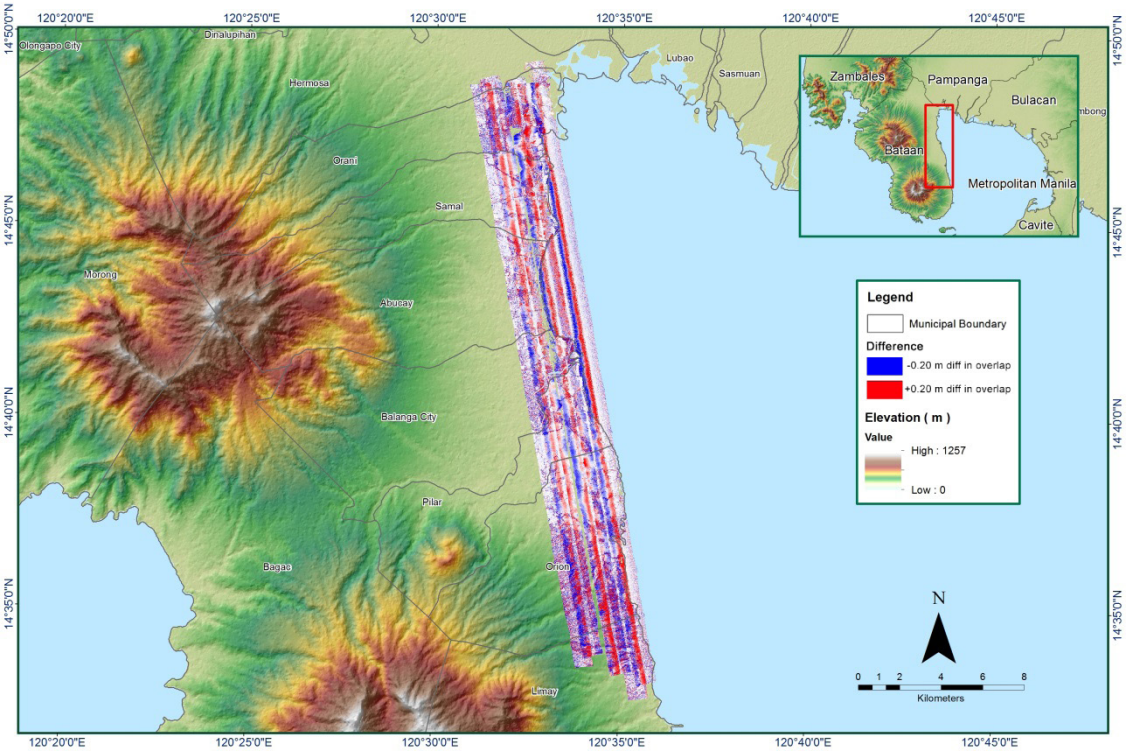


Figure 1.2.7. Elevation difference between flight lines

Flight Area	Bataan
Mission Name	BataanZambales_BalB
Inclusive Flights	924G
Range data size	14.2 GB
POS data size	91.5 MB
Base data size	8.26 MB
Image	24.2 GB
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)	1.3
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	1.7
Boresight correction stdev (<0.001deg)	0.000740
IMU attitude correction stdev (<0.001deg)	0.000523
GPS position stdev (<0.01m)	0.0014
Minimum % overlap (>25)	40.90
Ave point cloud density per sq.m. (>2.0)	4.05
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	57
Maximum Height	547.77 m
Minimum Height	65.18 m
Classification (# of points)	
Ground	11,509,583
Low vegetation	10,948,688
Medium vegetation	24,384,010
High vegetation	52,524,204
Building	1,849,232
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Celina Rosete, Jovy Narisma

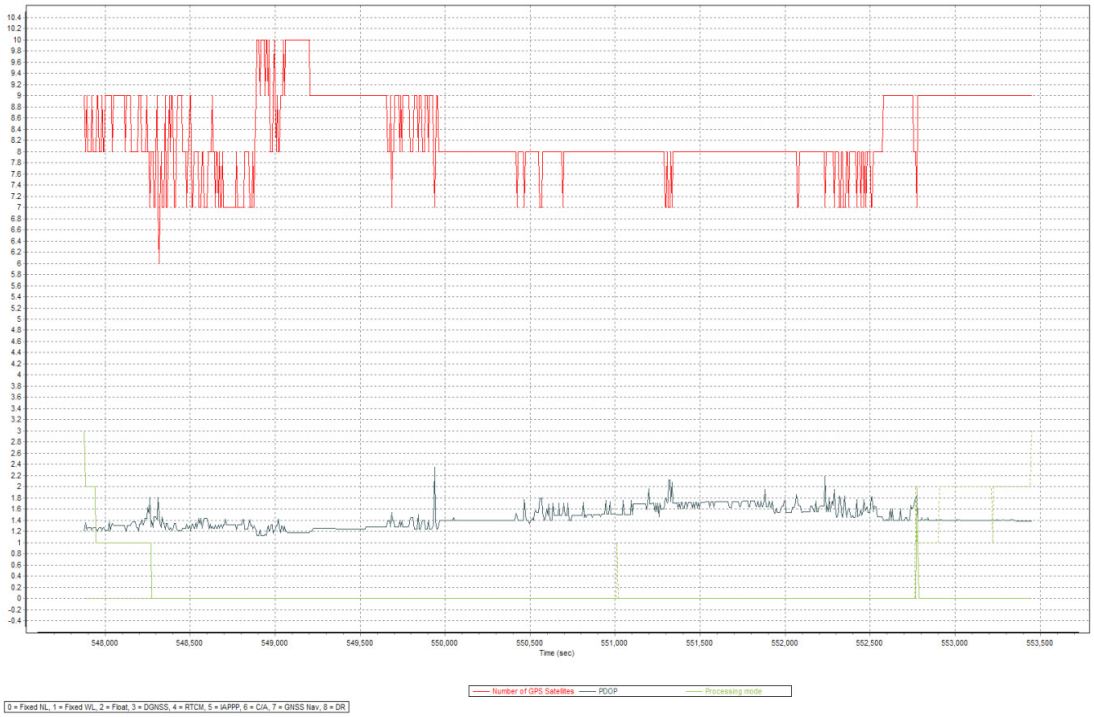


Figure 1.3.1. Solution Status

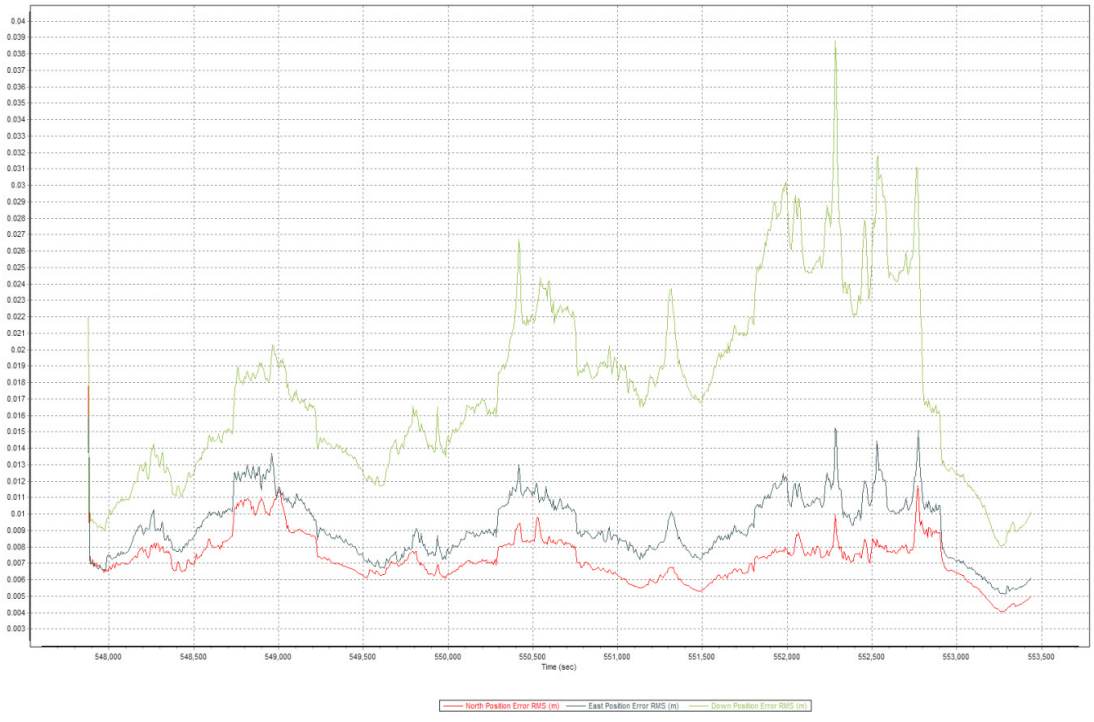


Figure 1.3.2. Smoothed Performance Metric Parameters

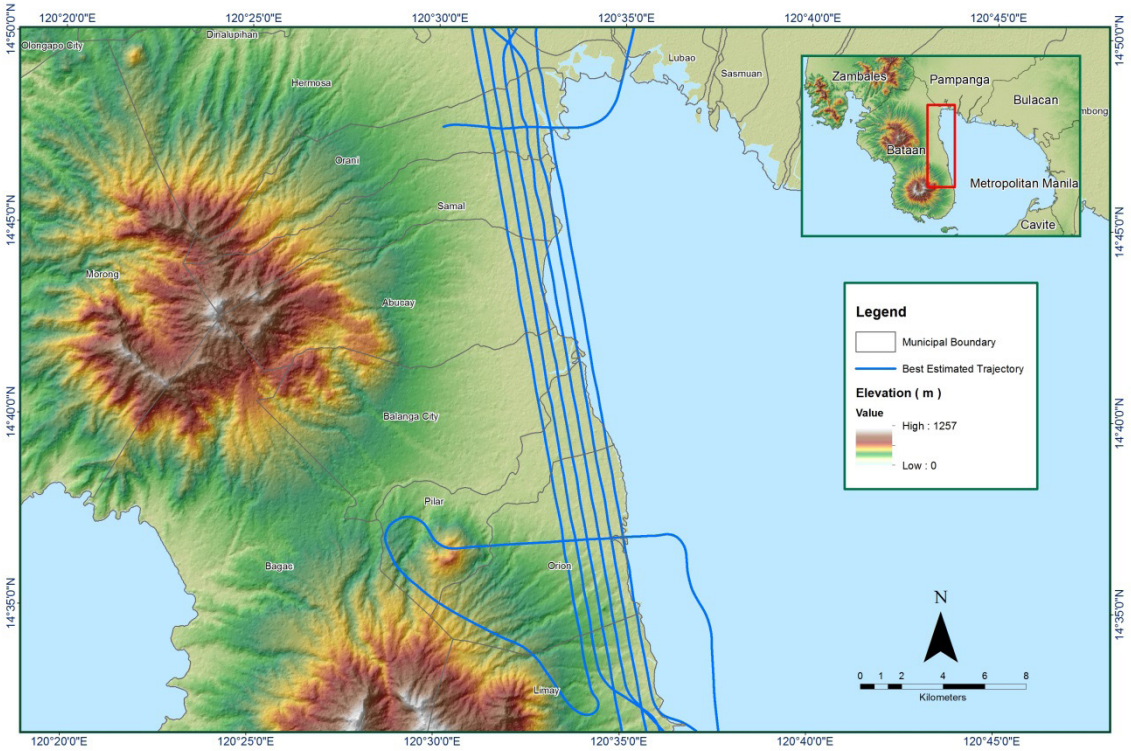


Figure 1.3.3. Best Estimated Trajectory

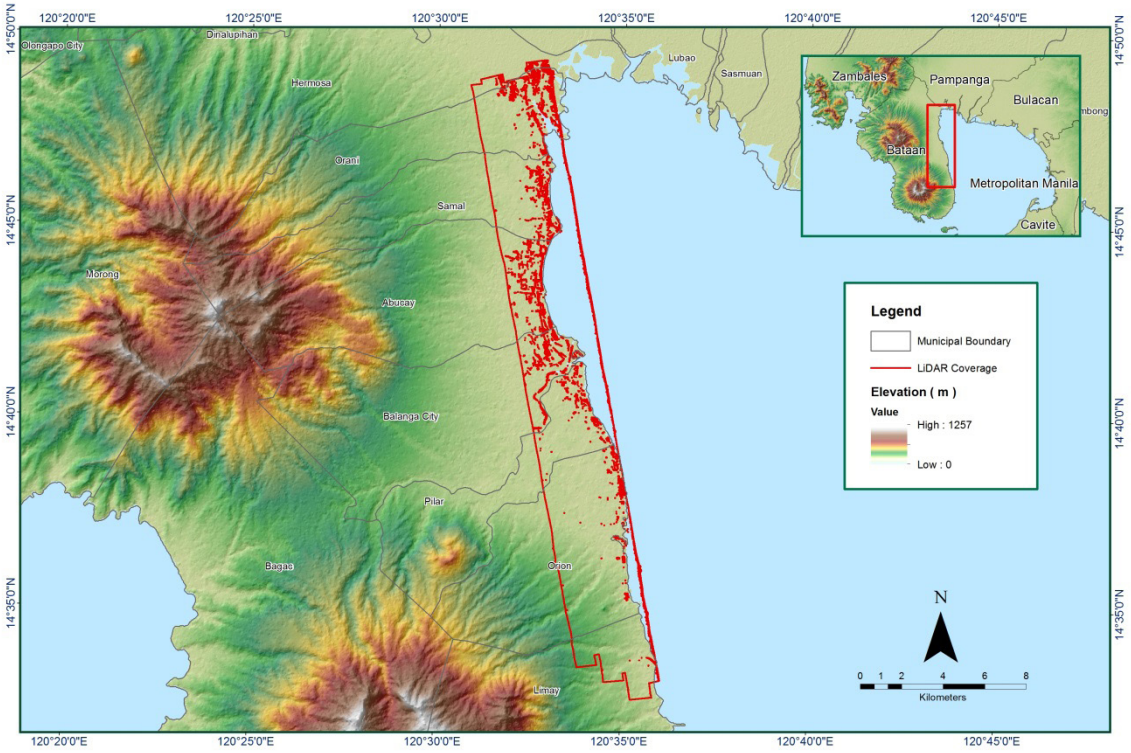


Figure 1.3.4. Coverage of LiDAR Data

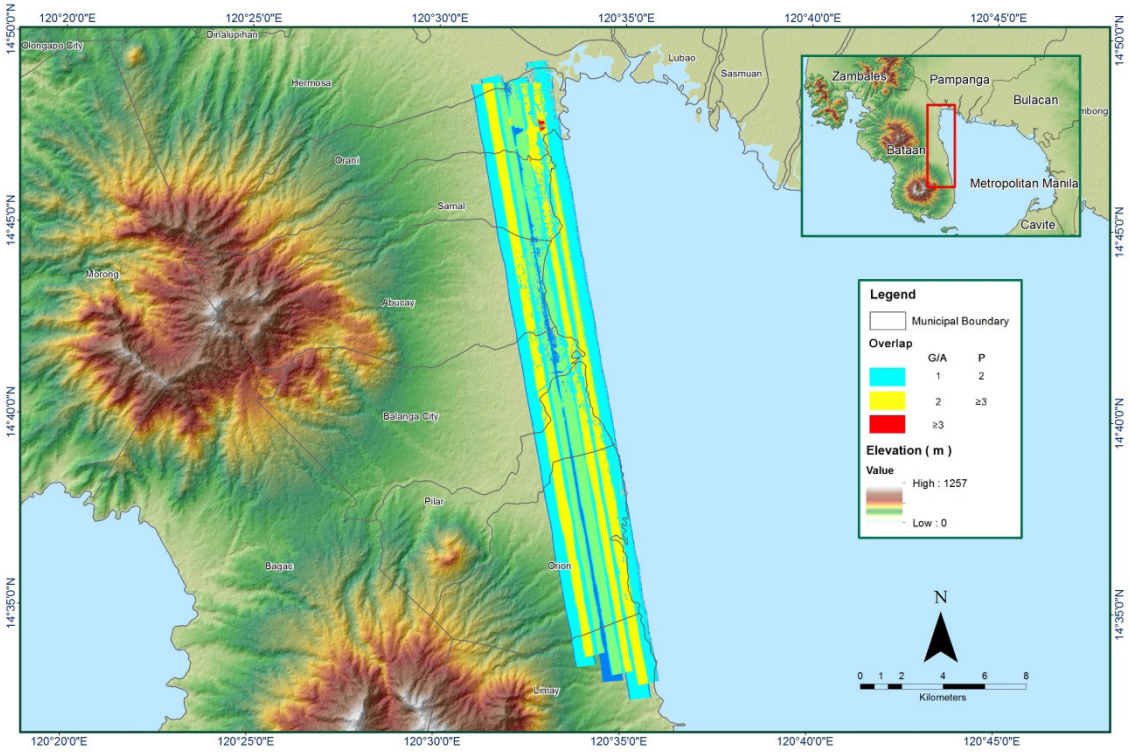


Figure 1.3.5. Image of data overlap

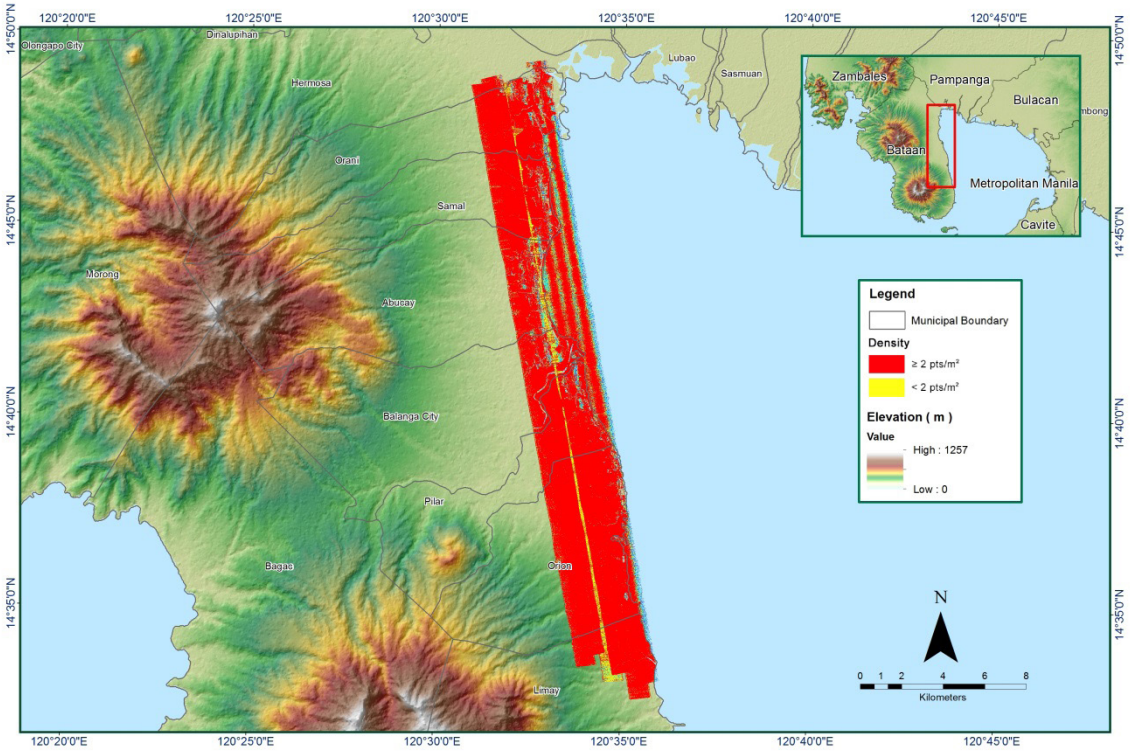


Figure 1.3.6. Density map of merged LiDAR data

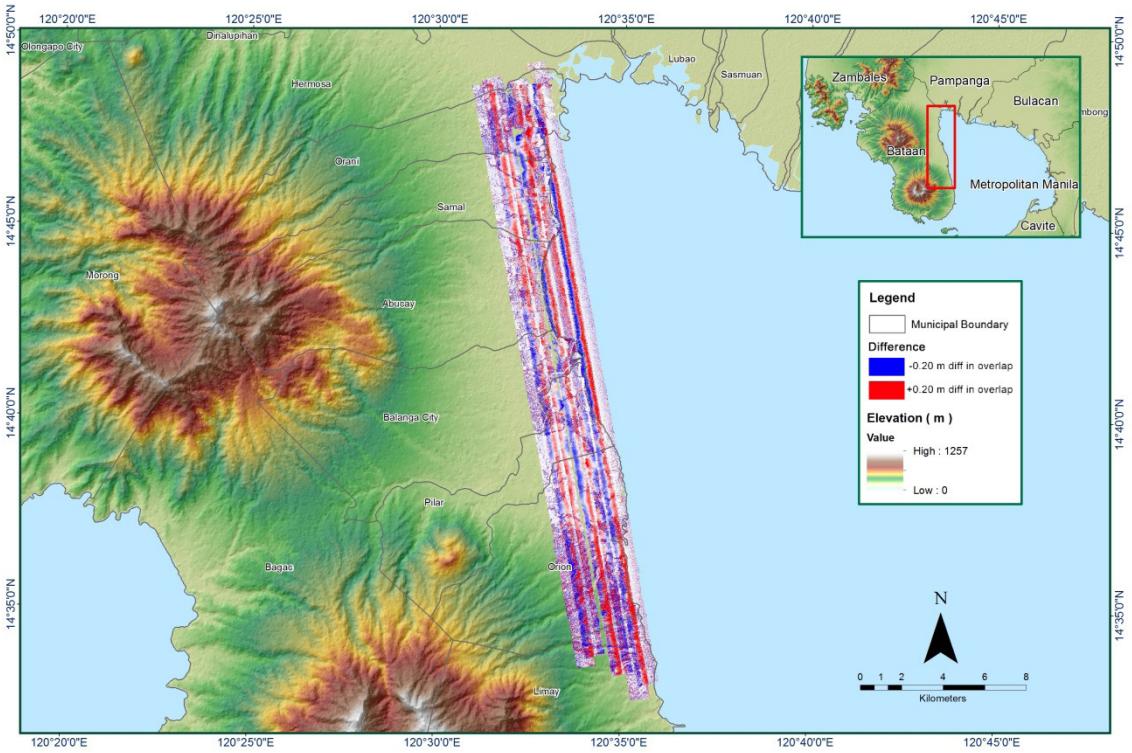


Figure 1.3.7. Elevation difference between flight lines

Flight Area	Bataan
Mission Name	BalA_supplement
Inclusive Flights	935P
Range data size	18.5 GB
POS data size	265 MB
Base data size	8.23 MB
Image	n/a
Transfer date	January 06, 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)	3.0
RMSE for East Position (<4.0 cm)	4.4
RMSE for Down Position (<8.0 cm)	8.5
Boresight correction stdev (<0.001deg)	0.000364
IMU attitude correction stdev (<0.001deg)	0.001459
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	25.79
Ave point cloud density per sq.m. (>2.0)	4.08
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	158
Maximum Height	423.75 m
Minimum Height	41.05 m
Classification (# of points)	
Ground	95,183,835
Low vegetation	61,402,204
Medium vegetation	76,100,361
High vegetation	53,789,741
Building	6,232,874
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Melanie Hingpit, Engr. Jeffrey Delica,

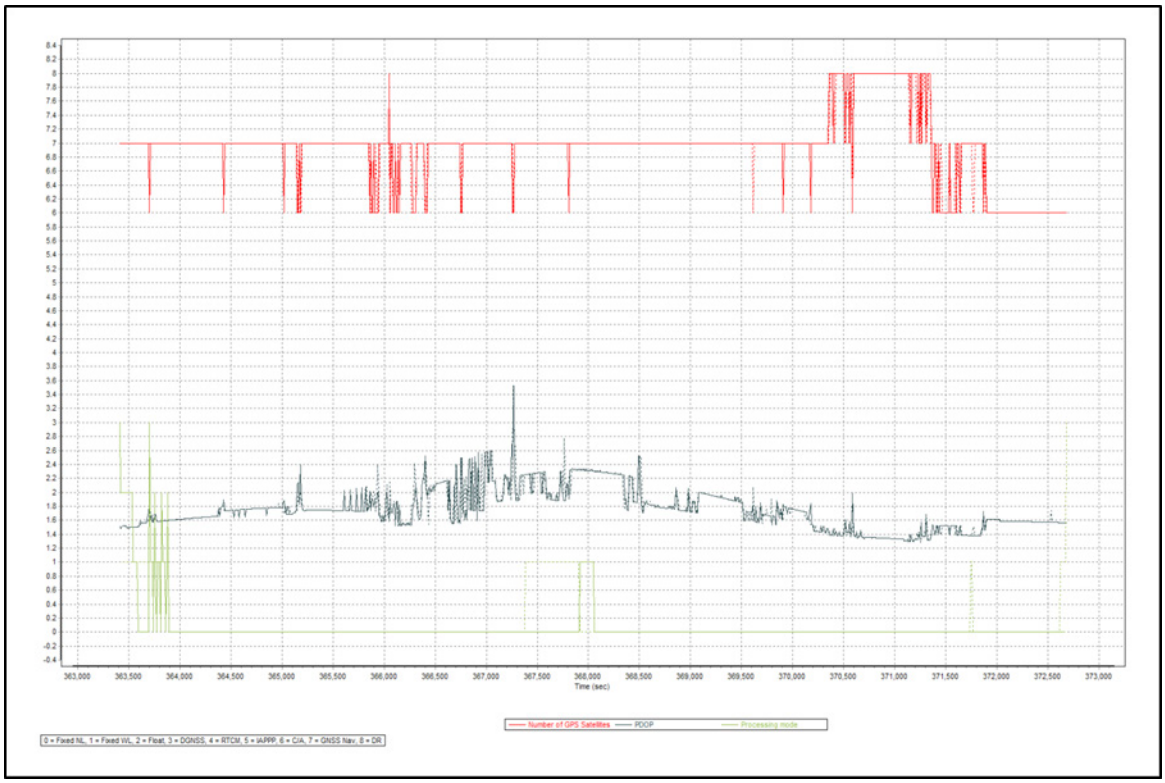


Figure 1.4.1. Solution Status

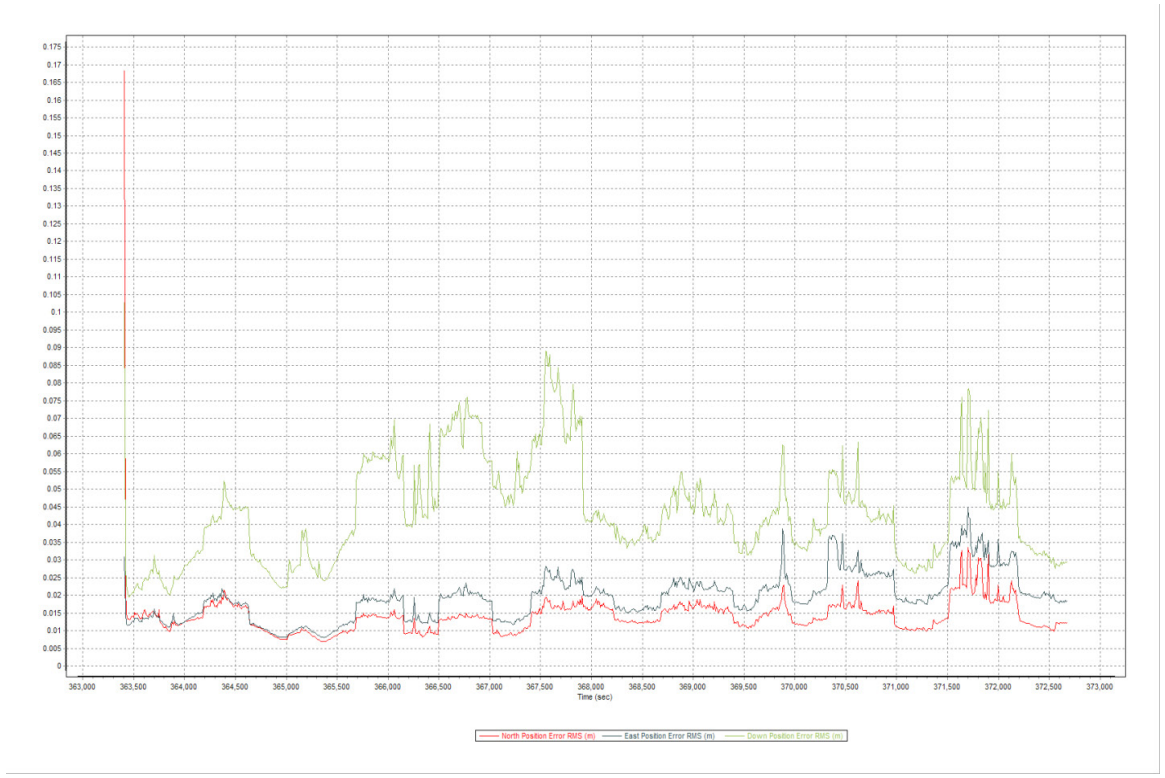


Figure 1.4.2. Smoothed Performance Metric Parameters

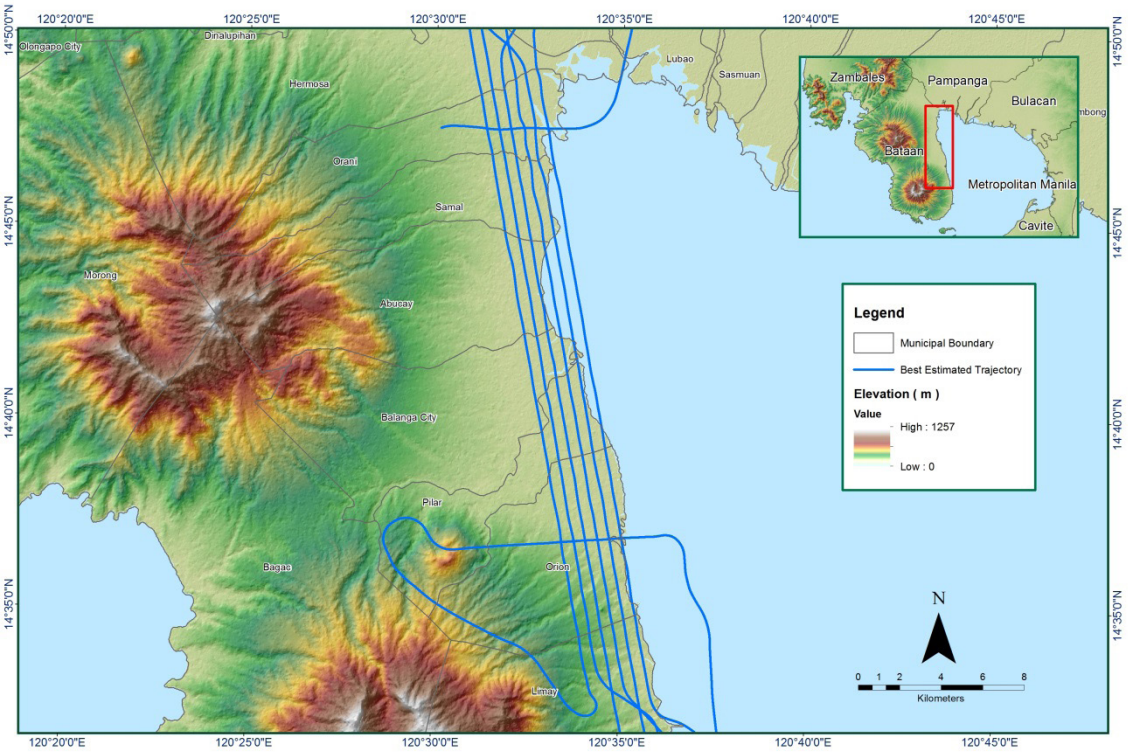


Figure 1.4.3. Best Estimated Trajectory

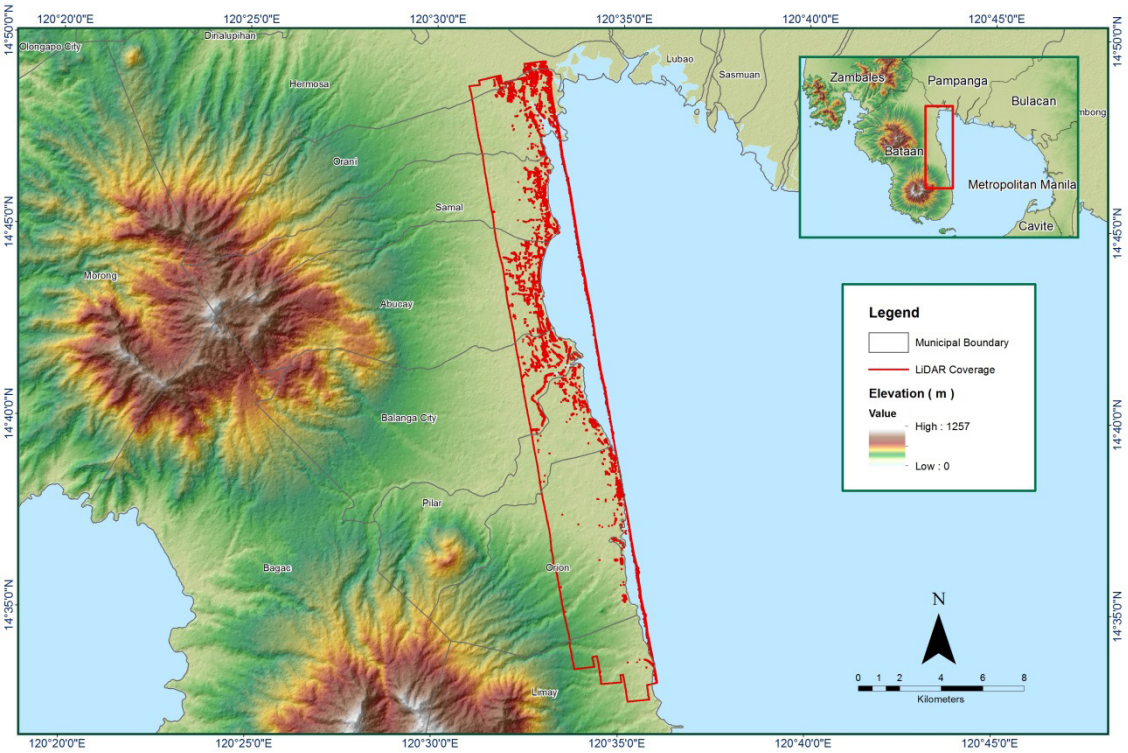


Figure 1.4.4. Coverage of LiDAR Data

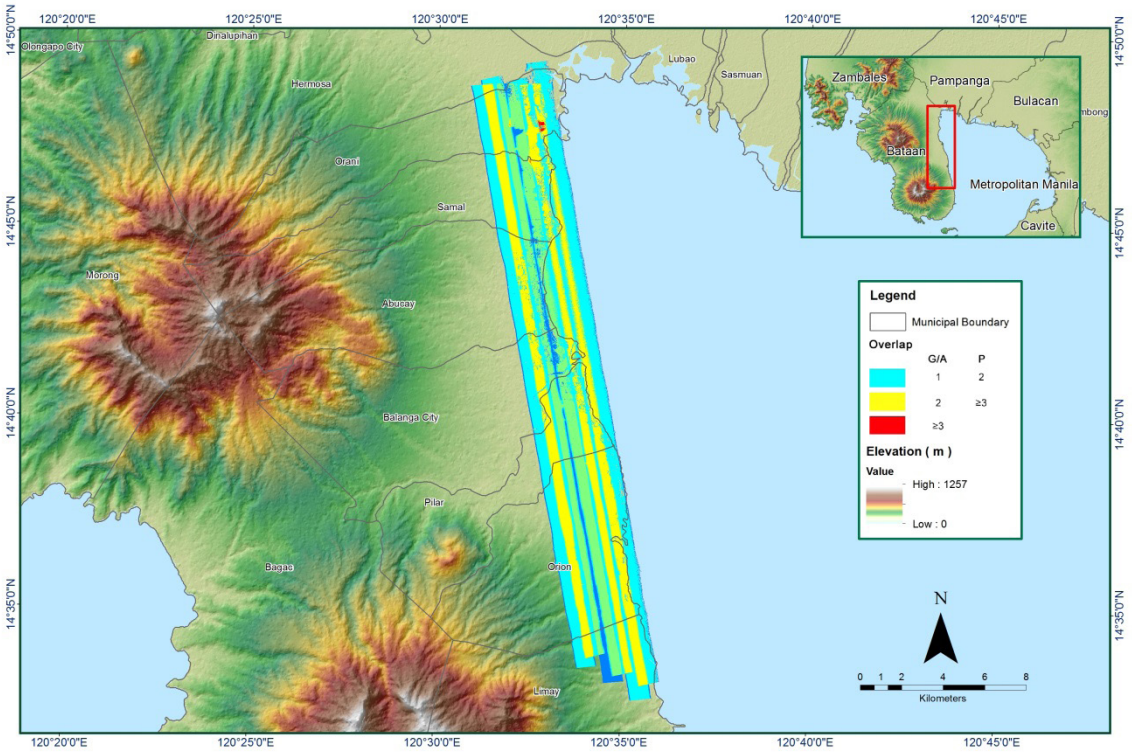


Figure 1.4.5. Image of data overlap

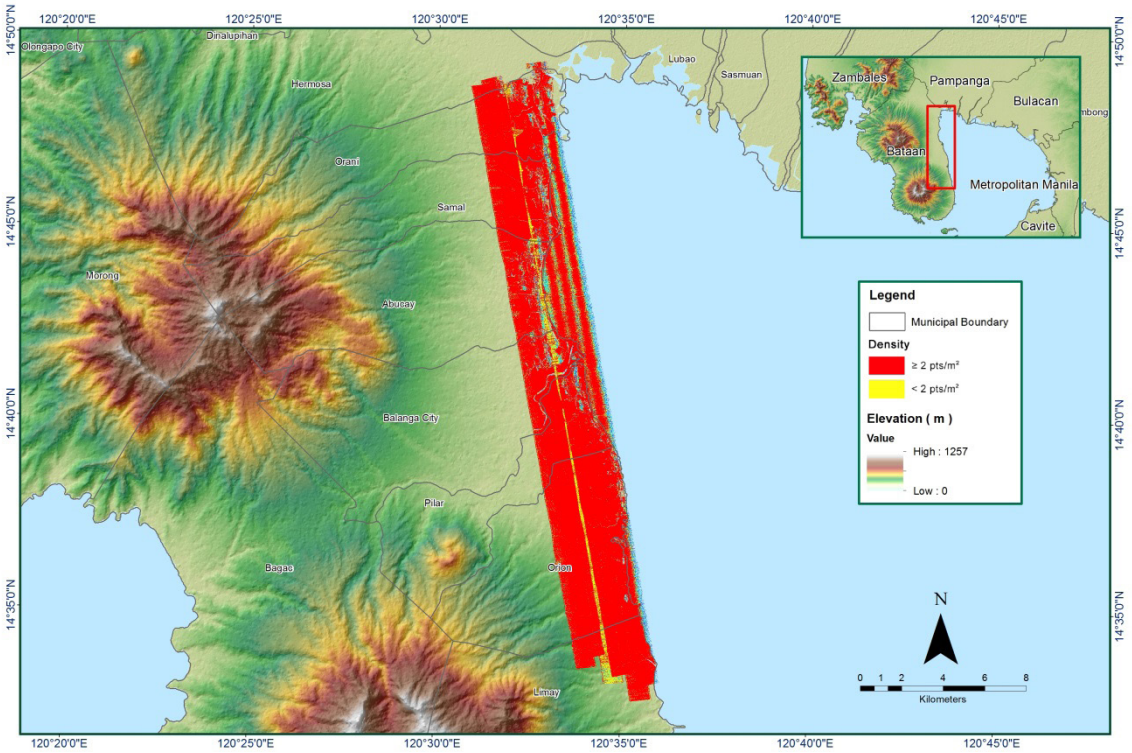


Figure 1.4.6. Density map of merged LiDAR data

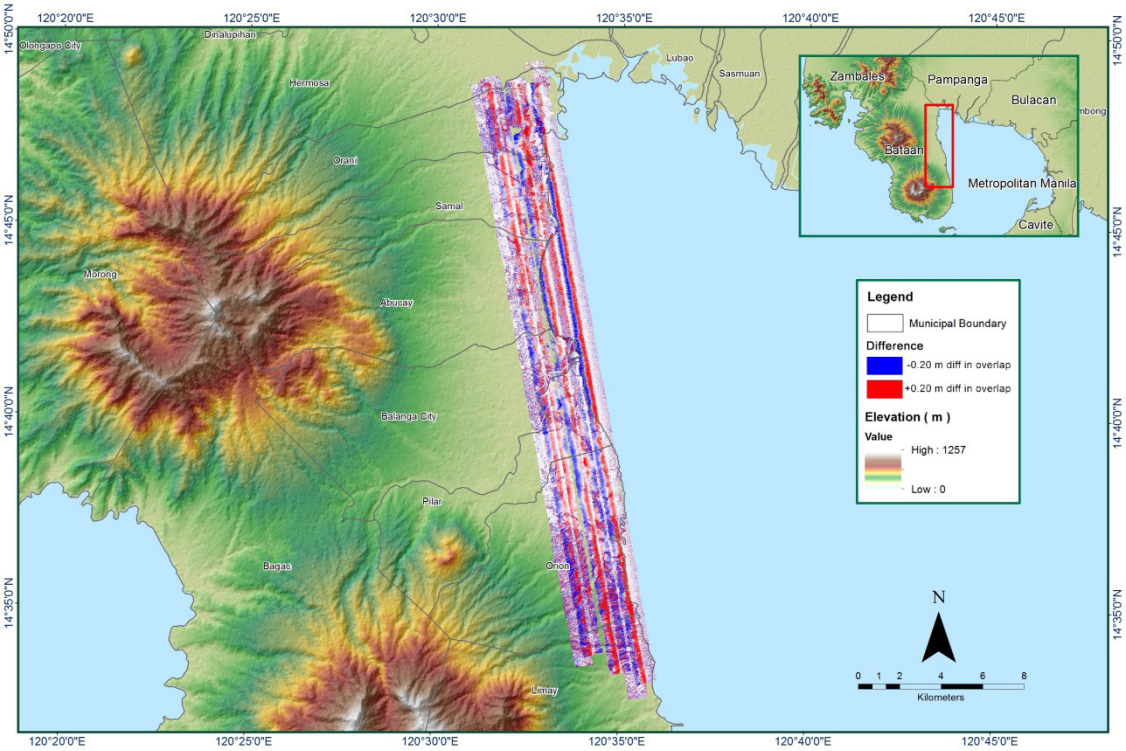


Figure 1.4.7. Elevation difference between flight line

Flight Area	Bataan
Mission Name	BataanZambales_BalA
Inclusive Flights	929P
Range data size	14GB
POS data size	206MB
Base data size	41.1 MB
Image	n/a
Transfer date	January 06, 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)	3.0
RMSE for East Position (<4.0 cm)	3.5
RMSE for Down Position (<8.0 cm)	7.5
Boresight correction stdev (<0.001deg)	0.000865
IMU attitude correction stdev (<0.001deg)	0.001788
GPS position stdev (<0.01m)	0.0087
Minimum % overlap (>25)	52.0
Ave point cloud density per sq.m. (>2.0)	4.77
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	156
Maximum Height	210.7 m
Minimum Height	36.36 m
Classification (# of points)	
Ground	115,860,150
Low vegetation	109,534,527
Medium vegetation	90,221,618
High vegetation	61,244,408
Building	21,424,829
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibañez, Ailyn Biñas, Jovy Narisma

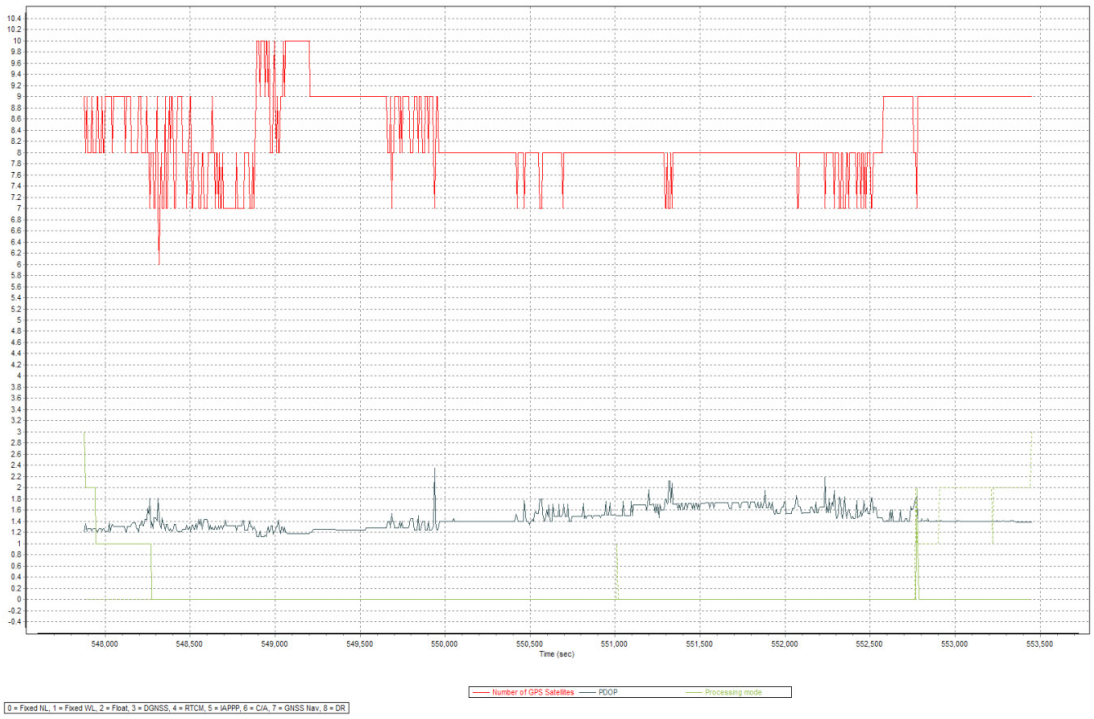


Figure 1.5.1. Solution Status

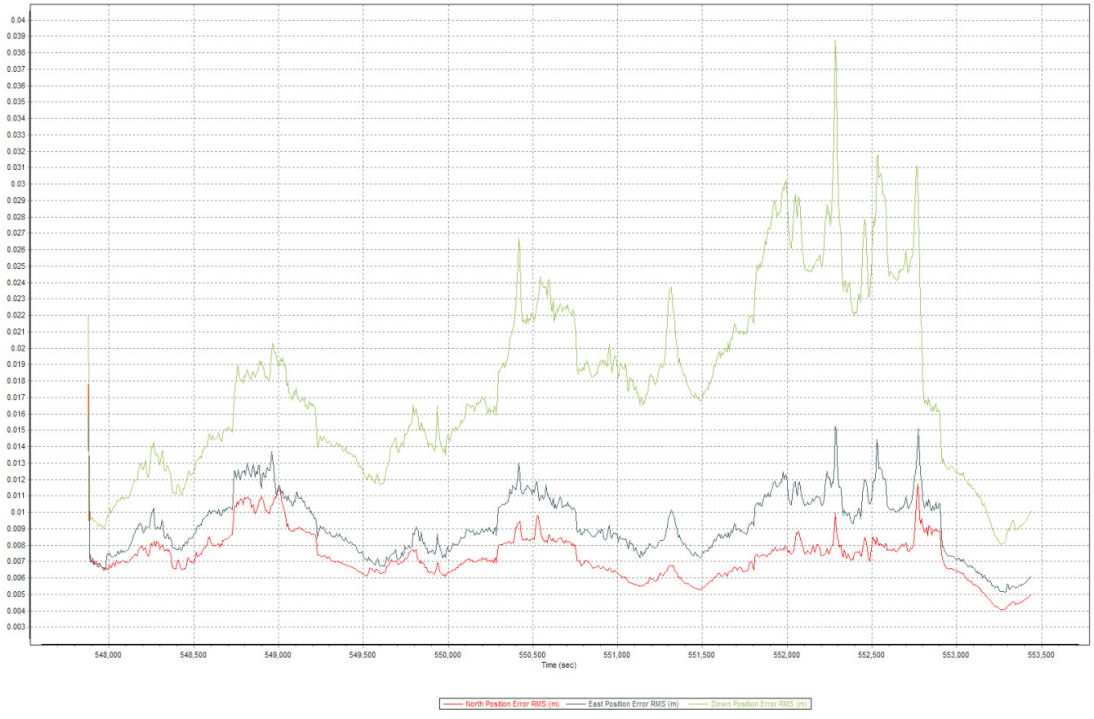


Figure 1.5.2. Smoothed Performance Metric Parameters

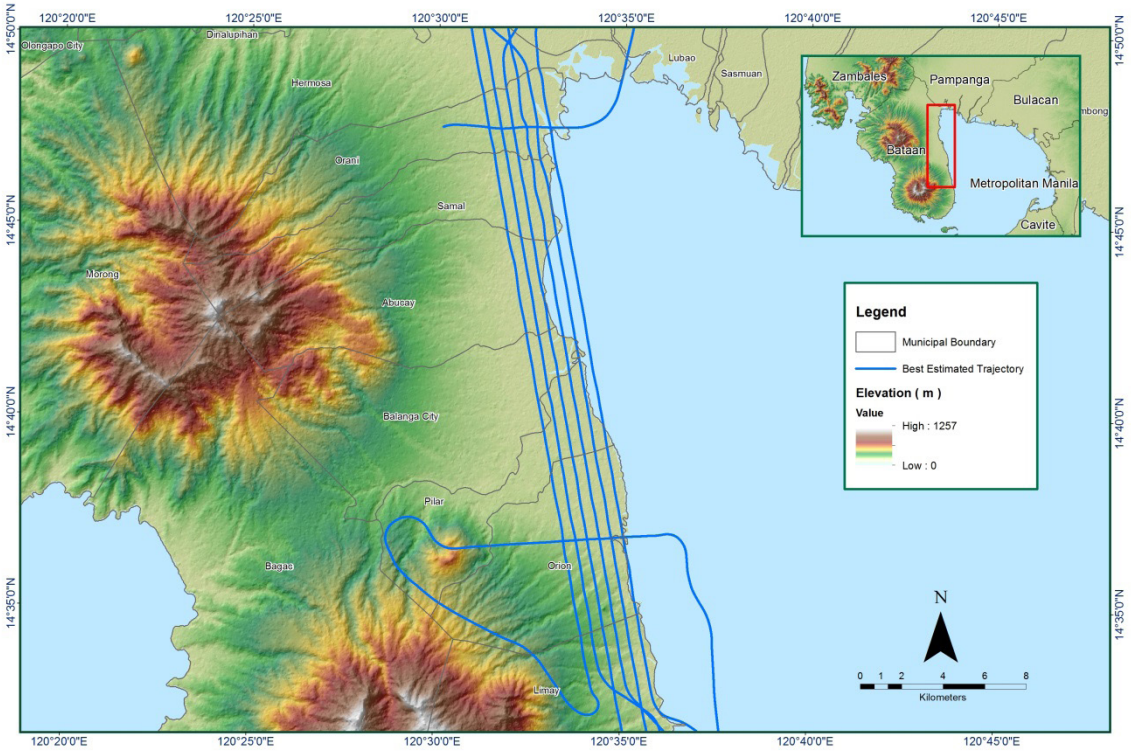


Figure 1.5.3. Best Estimated Trajectory

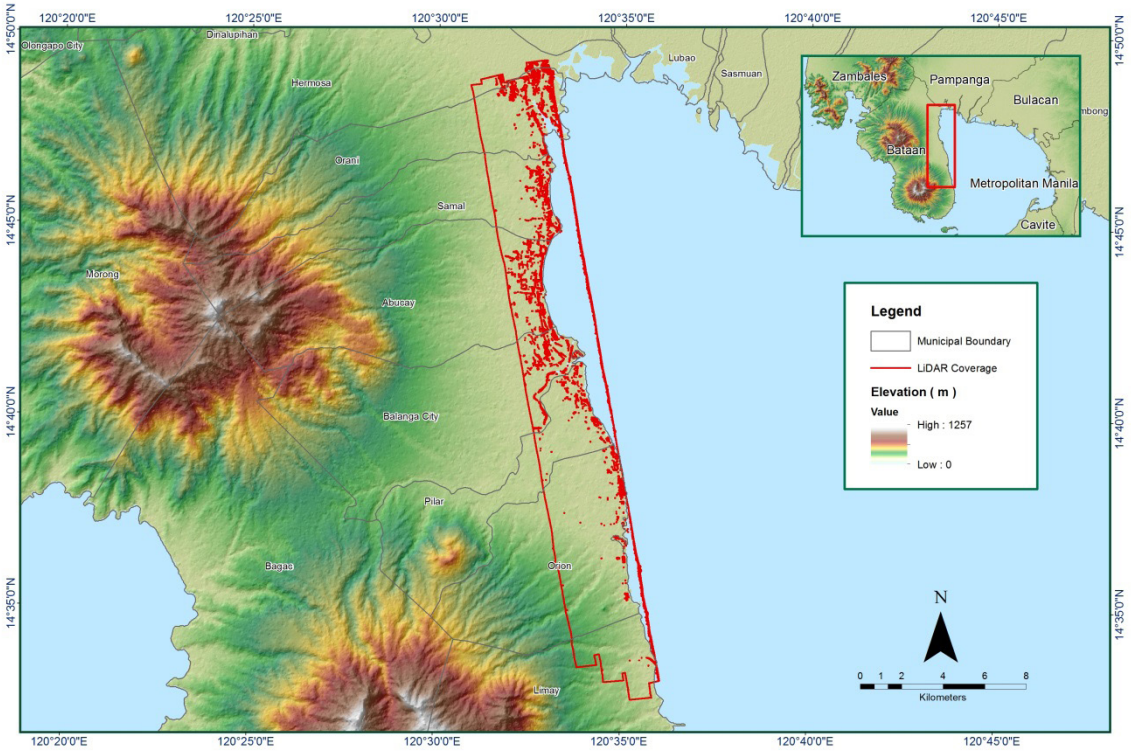


Figure 1.5.4. Coverage of LiDAR Data

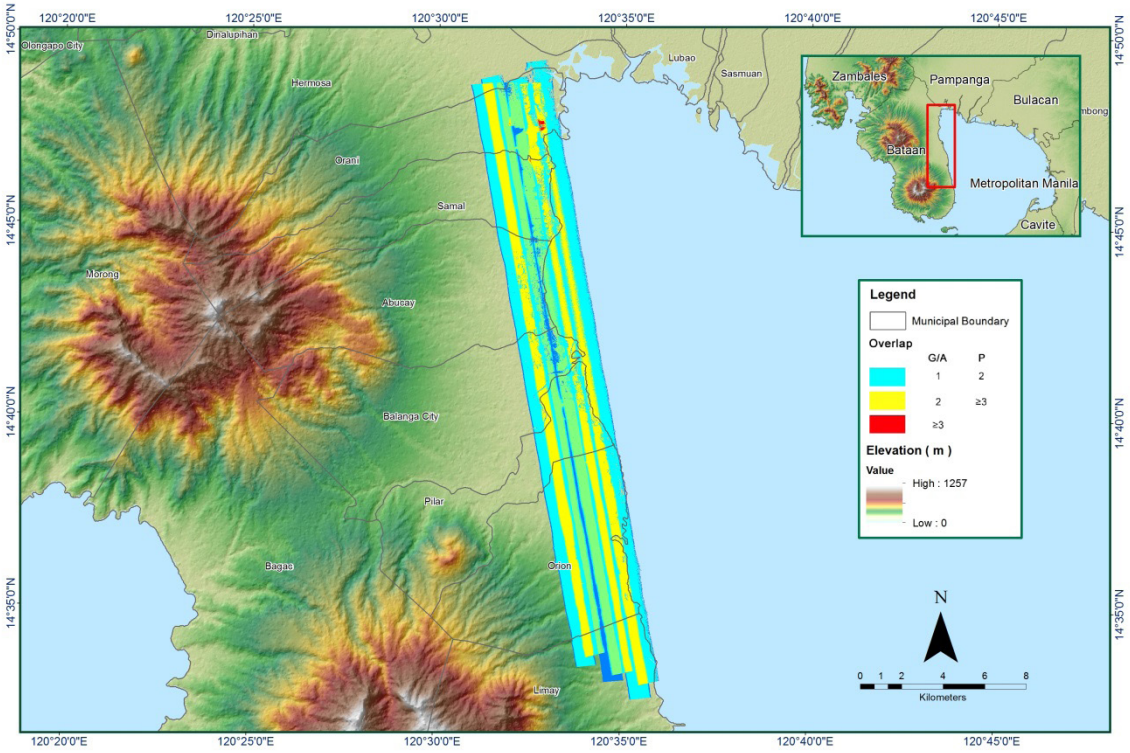


Figure 1.5.5. Image of data overlap

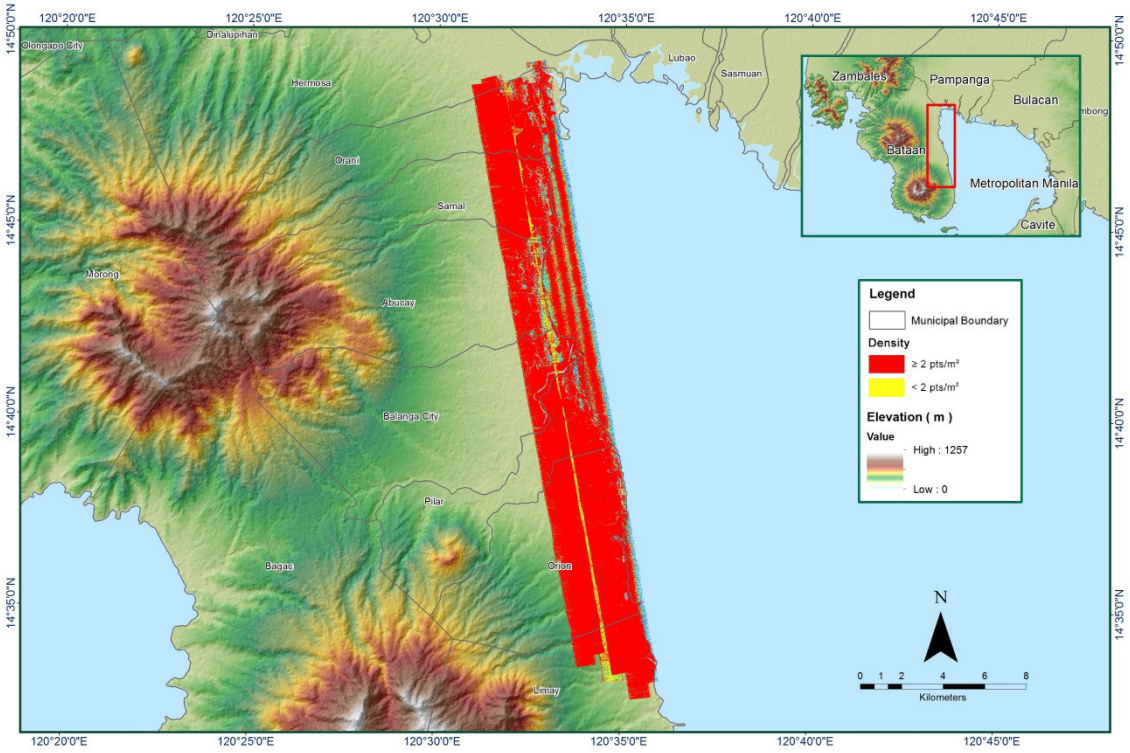


Figure 1.5.6. Density map of merged LiDAR data

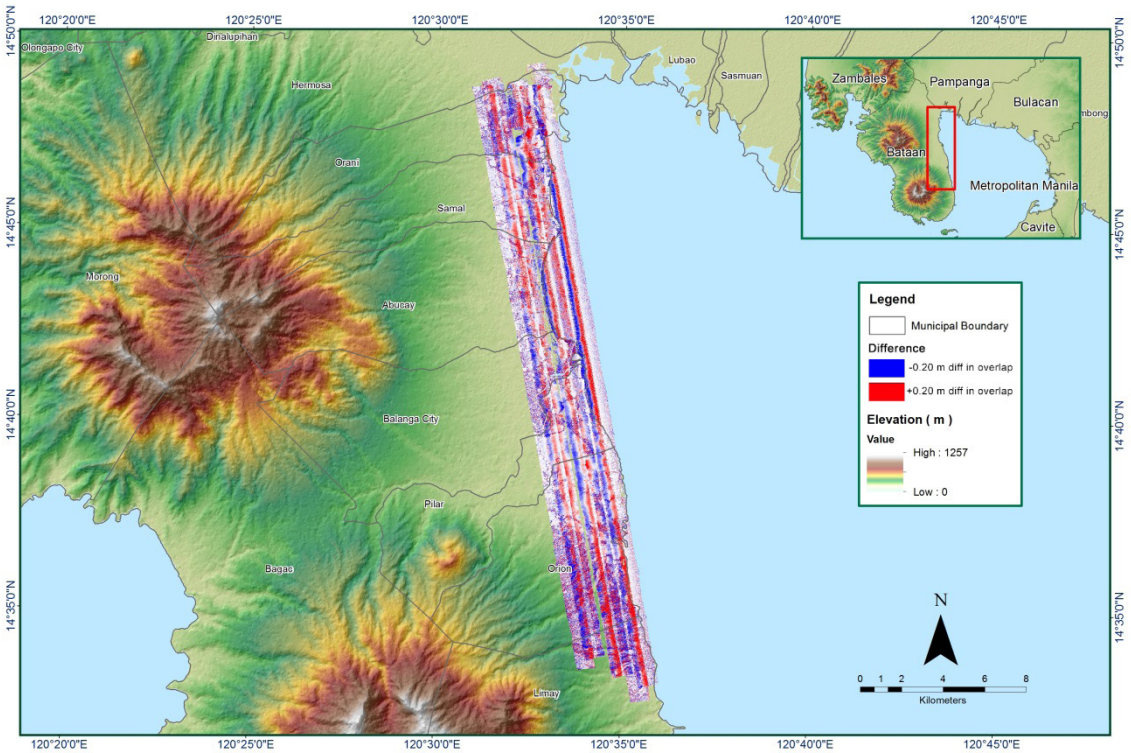


Figure 1.5.7. Elevation difference between flight lines

Flight Area	Clark Reflights
Mission Name	Blk Btn_B
Inclusive Flights	2656G
Range data size	9.15 GB
POS data size	185 MB
Base data size	17.5 MB
Image	9.17 GB
Transfer date	August 26, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.65
RMSE for East Position (<4.0 cm)	4.0
RMSE for Down Position (<8.0 cm)	4.0
Boresight correction stdev (<0.001deg)	0.002363
IMU attitude correction stdev (<0.001deg)	0.015698
GPS position stdev (<0.01m)	0.0235
Minimum % overlap (>25)	47.54%
Ave point cloud density per sq.m. (>2.0)	3.58
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	138
Maximum Height	756.92 m
Minimum Height	42.19 m
Classification (# of points)	
Ground	7,676,575
Low vegetation	5,808,718
Medium vegetation	39,066,000
High vegetation	33,700,534
Building	189,801
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Aljon Rie Araneta, Maria Tamsyn Malabanan

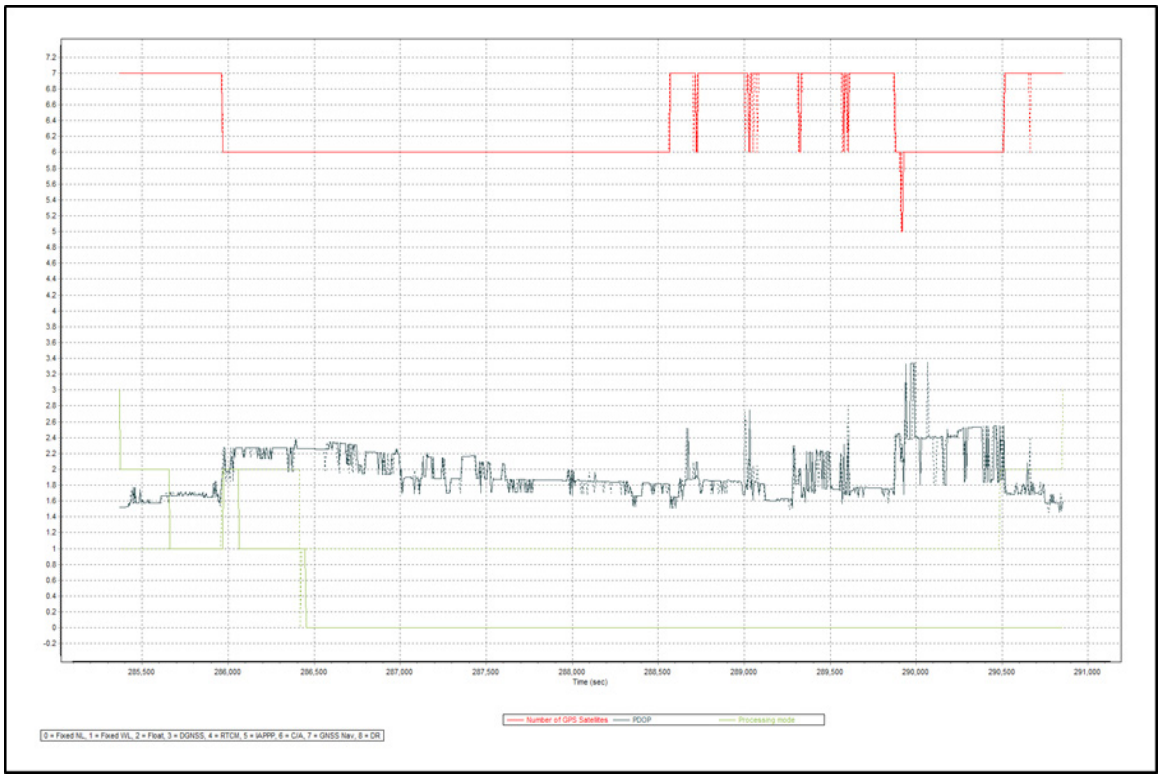


Figure 1.6.1 Solution Status

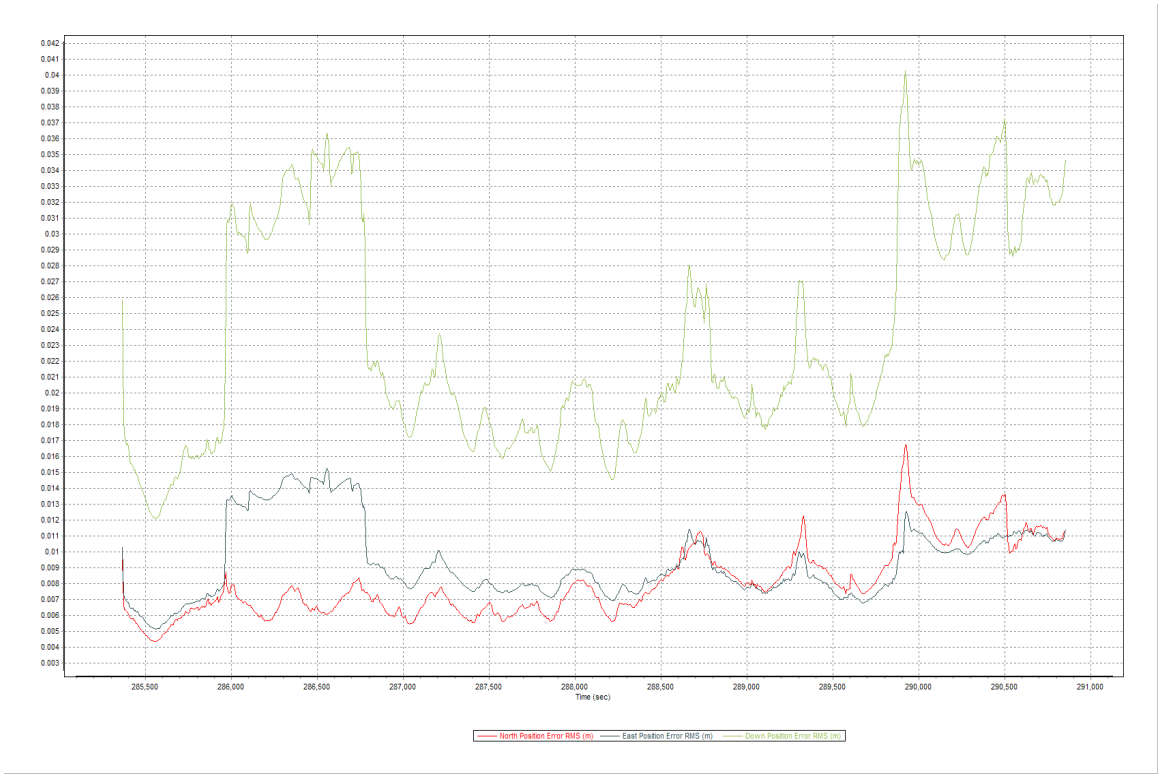


Figure 1.6.2 Smoothed Performance Metric Parameters

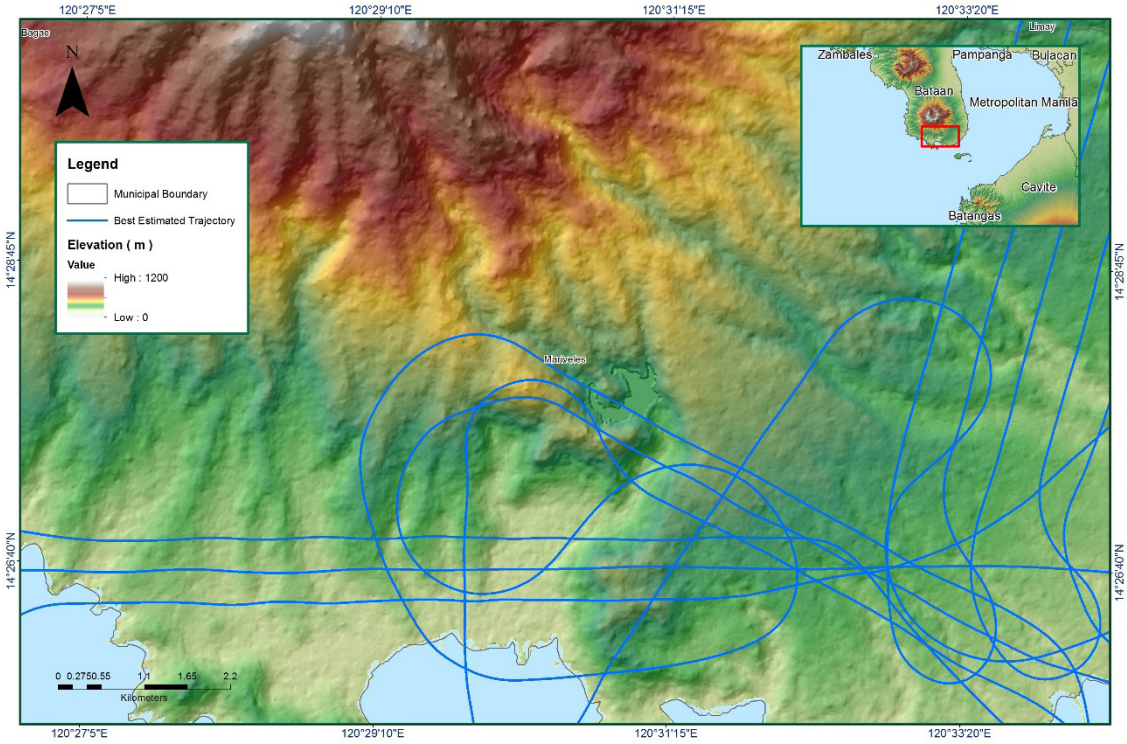


Figure 1.6.3 Best Estimated Trajectory

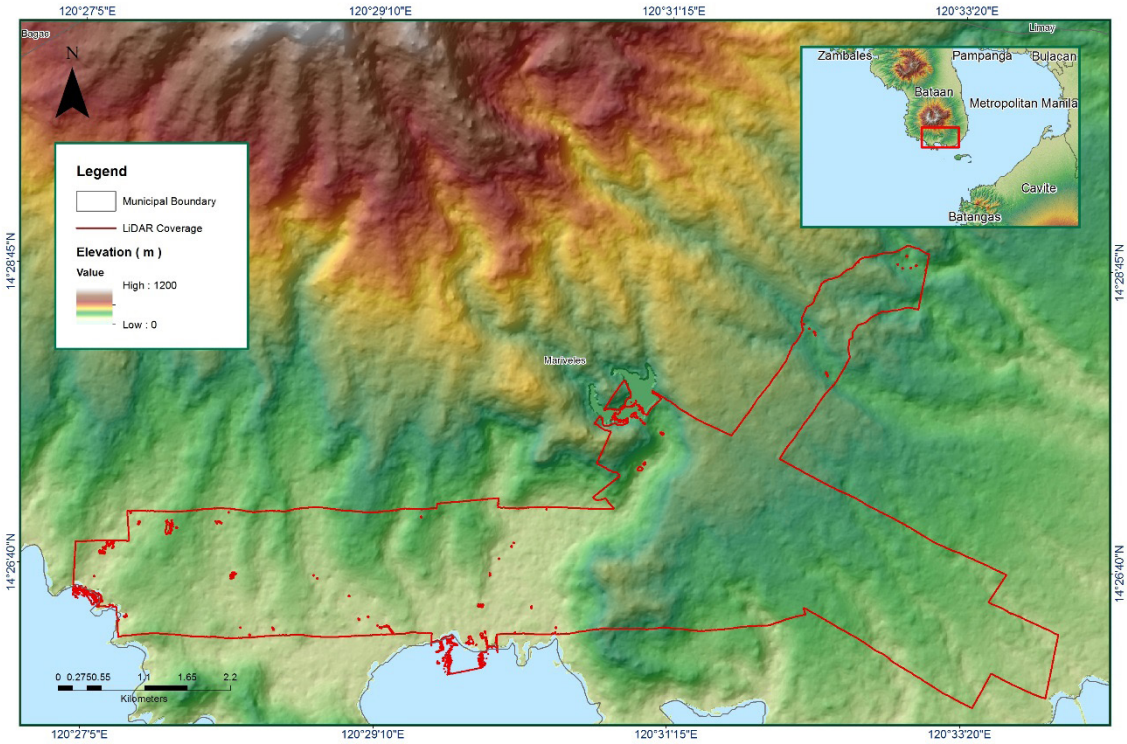


Figure 1.6.4 Coverage of LiDAR data

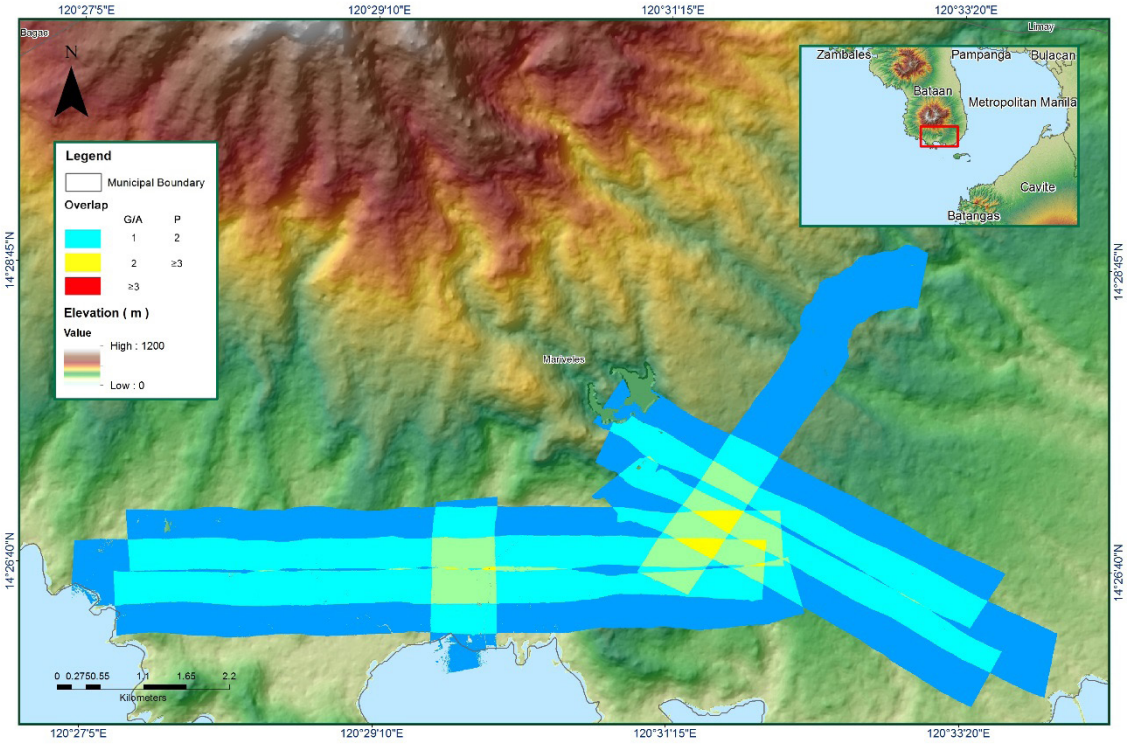


Figure 1.6.5 Image of data overlap

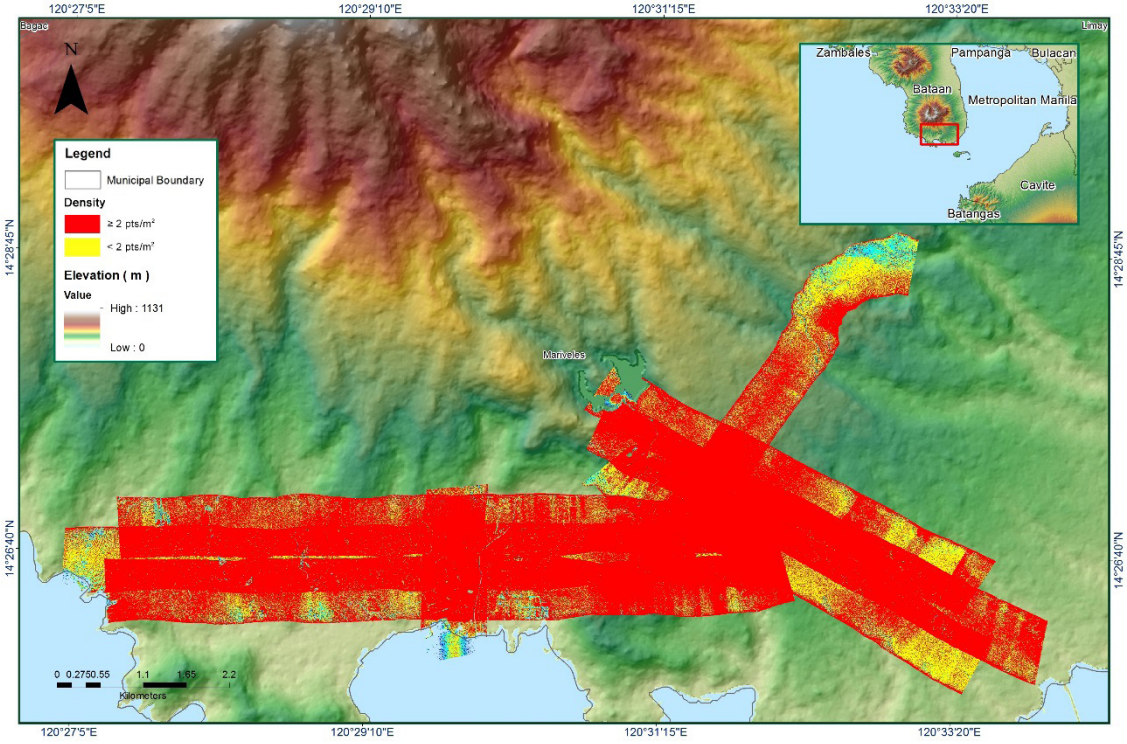


Figure 1.6.6 Density map of merged LiDAR data

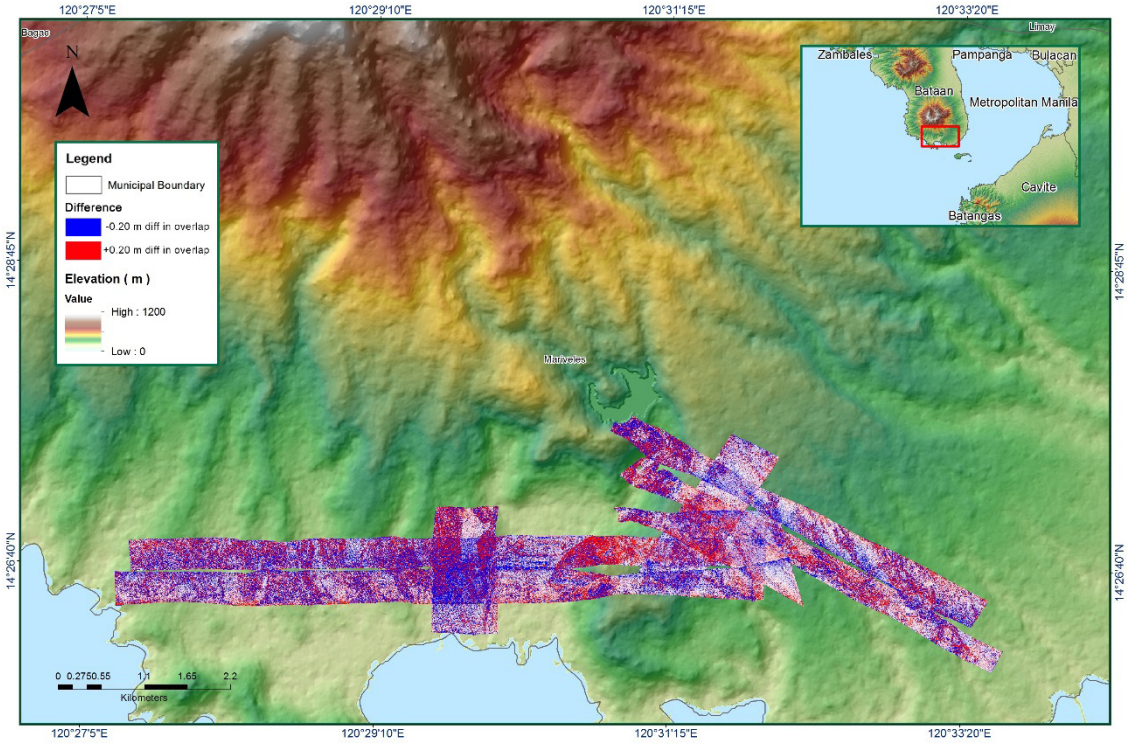


Figure 1.6.7 Elevation difference between flight lines

Flight Area	Clark Reflights
Mission Name	Blk Btn_A
Inclusive Flights	2656G
Range data size	9.15 GB
POS data size	185 MB
Base data size	17.5 MB
Image	9.17 GB
Transfer date	August 26, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.65
RMSE for East Position (<4.0 cm)	4.0
RMSE for Down Position (<8.0 cm)	4.0
Boresight correction stdev (<0.001deg)	0.002363
IMU attitude correction stdev (<0.001deg)	0.015698
GPS position stdev (<0.01m)	0.0235
Minimum % overlap (>25)	48.25%
Ave point cloud density per sq.m. (>2.0)	3.49
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	43
Maximum Height	363.27 m
Minimum Height	35.13 m
Classification (# of points)	
Ground	6,992,932
Low vegetation	5,369,115
Medium vegetation	33,576,369
High vegetation	29,342,708
Building	132,974
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Mark Joshua Salvacion, Maria Tamsyn Malabanan

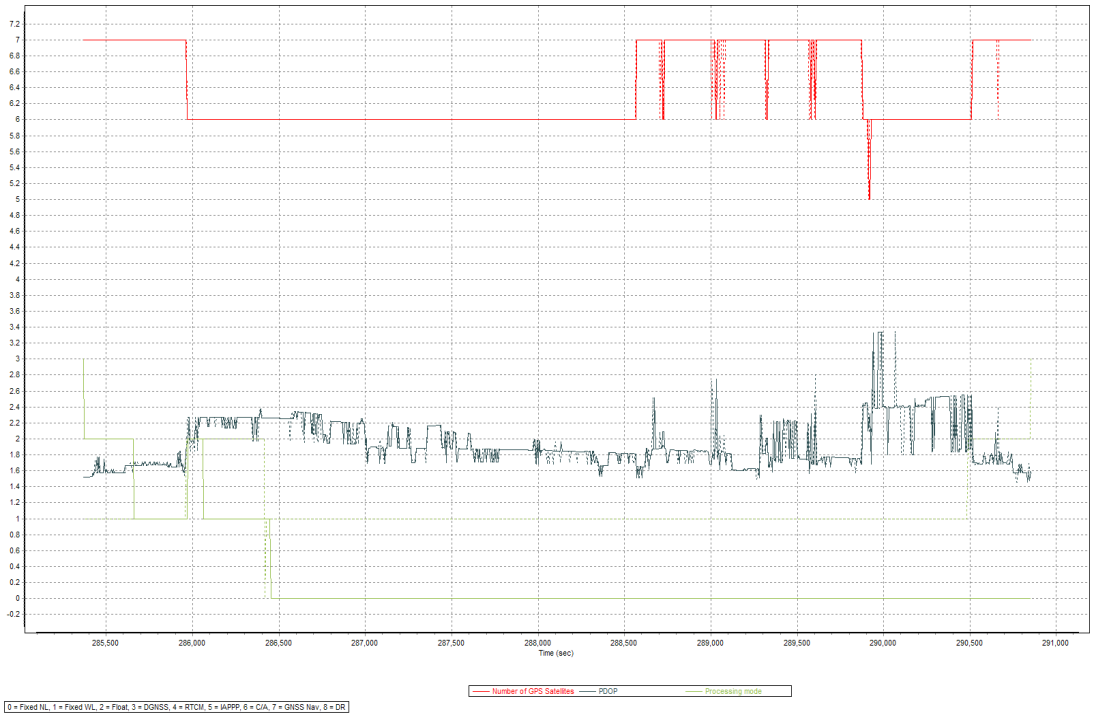


Figure 1.7.1 Solution Status

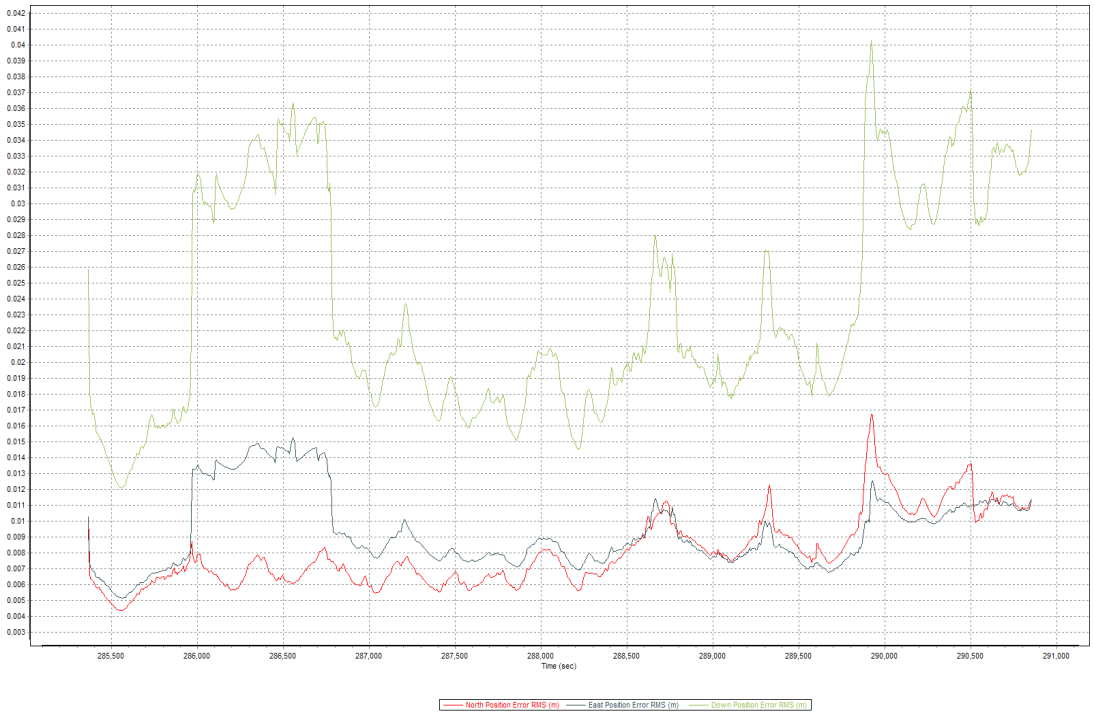


Figure 1.7.2 Smoothed Performance Metric Parameters

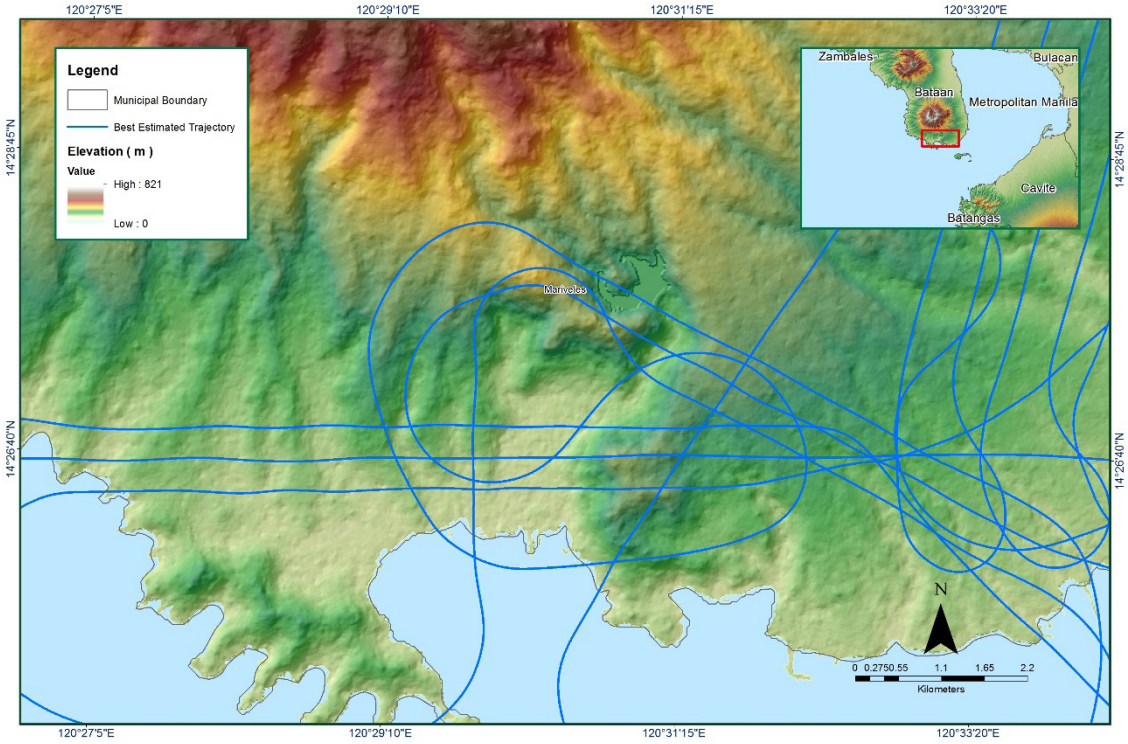


Figure 1.7.3 Best Estimated Trajectory

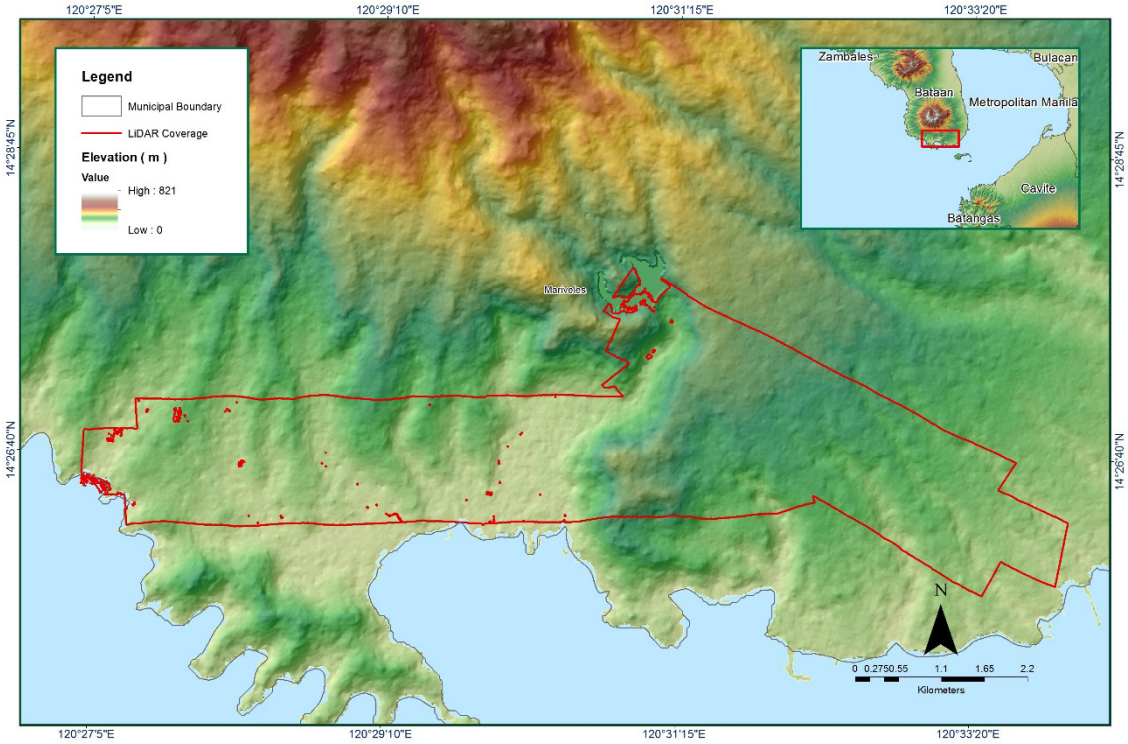


Figure 1.7.4 Coverage of LiDAR data

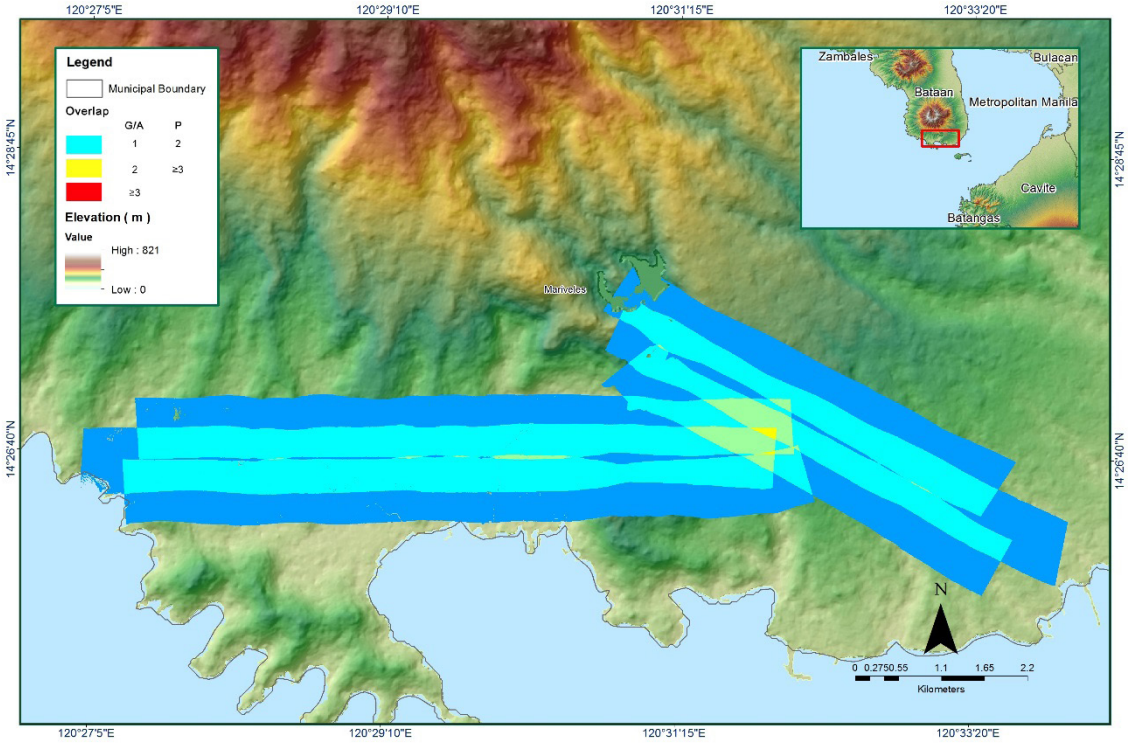


Figure 1.7.5 Image of data overlap

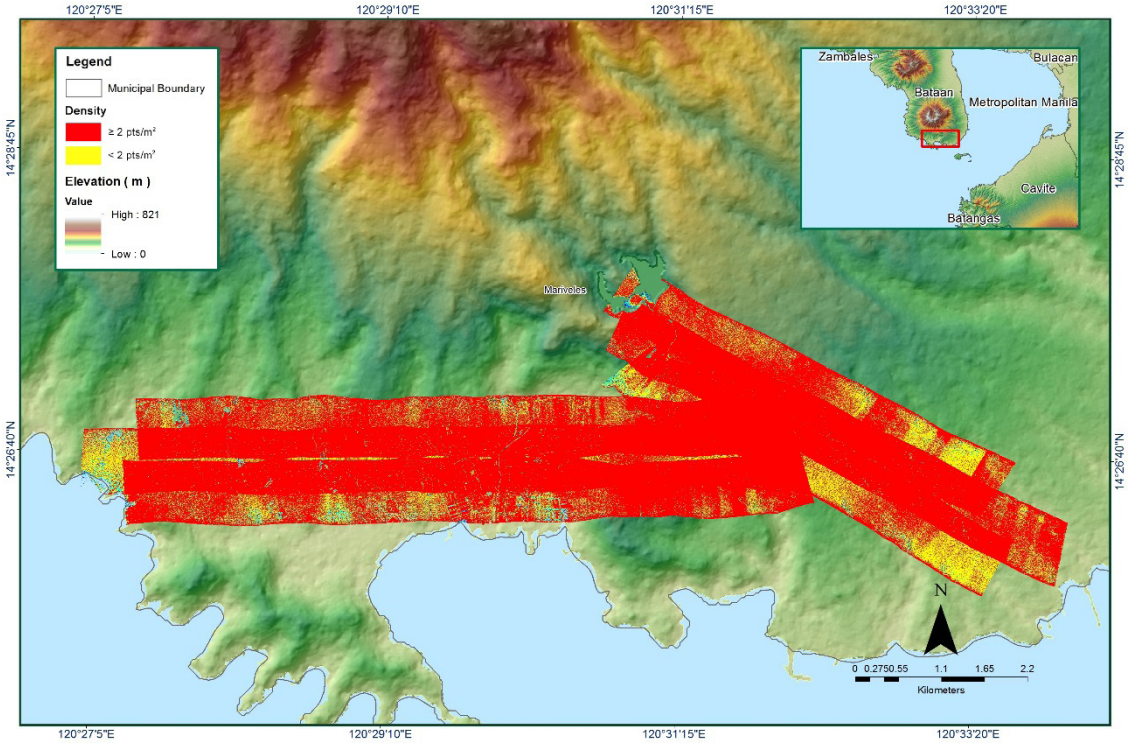


Figure 1.7.6 Density map of merged LiDAR data

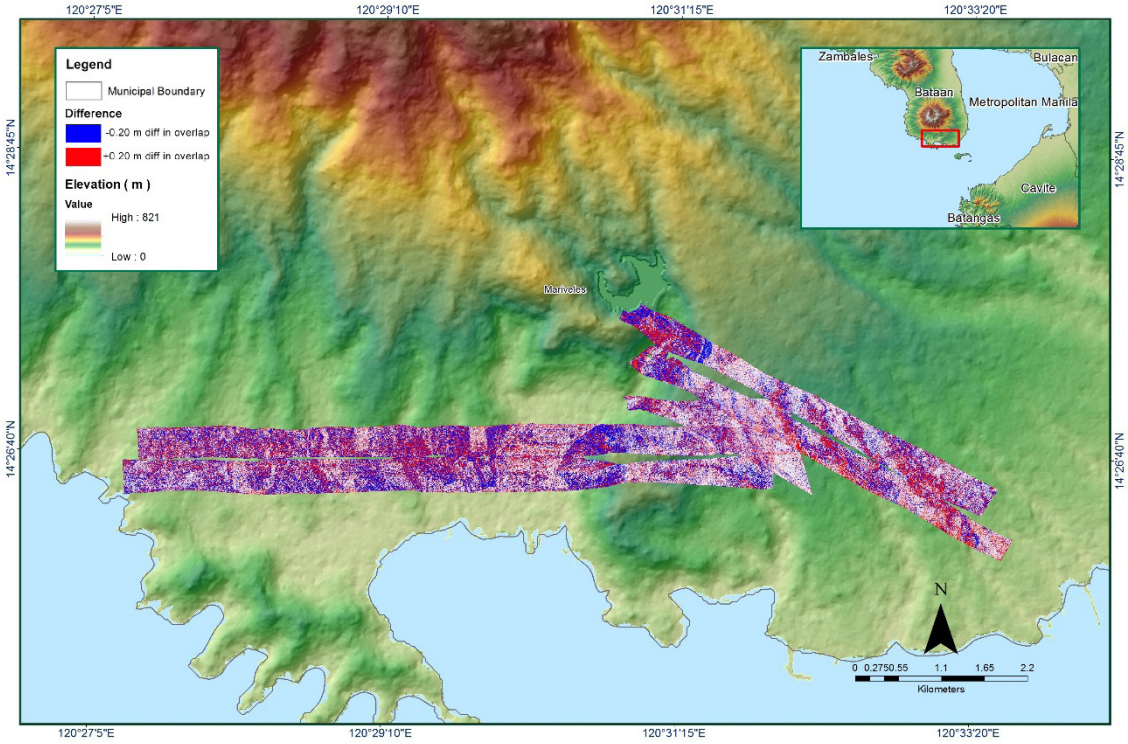


Figure 1.7.7 Elevation difference between flight lines

Flight Area	Pam_Agno Reflights
Mission Name	Pam_Blk8_reflight_cross
Inclusive Flights	7271GC
Range data size	15.5 GB
POS data size	233 MB
Base data size	3.68 MB
Image	N/A
Transfer date	May 25, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.82
RMSE for East Position (<4.0 cm)	1.82
RMSE for Down Position (<8.0 cm)	4.7
Boresight correction stdev (<0.001deg)	0.000368
IMU attitude correction stdev (<0.001deg)	0.000917
GPS position stdev (<0.01m)	0.0139
Minimum % overlap (>25)	N/A
Ave point cloud density per sq.m. (>2.0)	2.24
Elevation difference between strips (<0.20 m)	No
Number of 1km x 1km blocks	16
Maximum Height	98.09 m
Minimum Height	44.80 m
Classification (# of points)	
Ground	2,908,124
Low vegetation	3,130,976
Medium vegetation	1,933,133
High vegetation	1,759,545
Building	1,328,239
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Antonio Chua Jr., Engr. Elainne Lopez

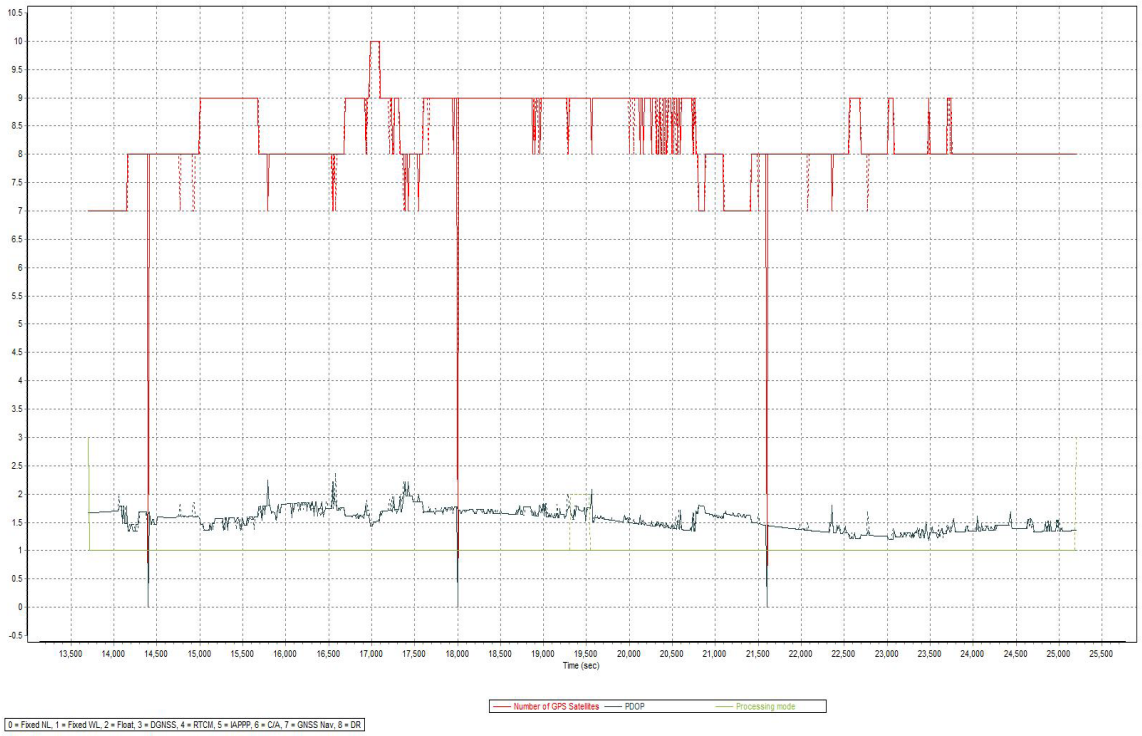


Figure 1.8.1. Solution Status

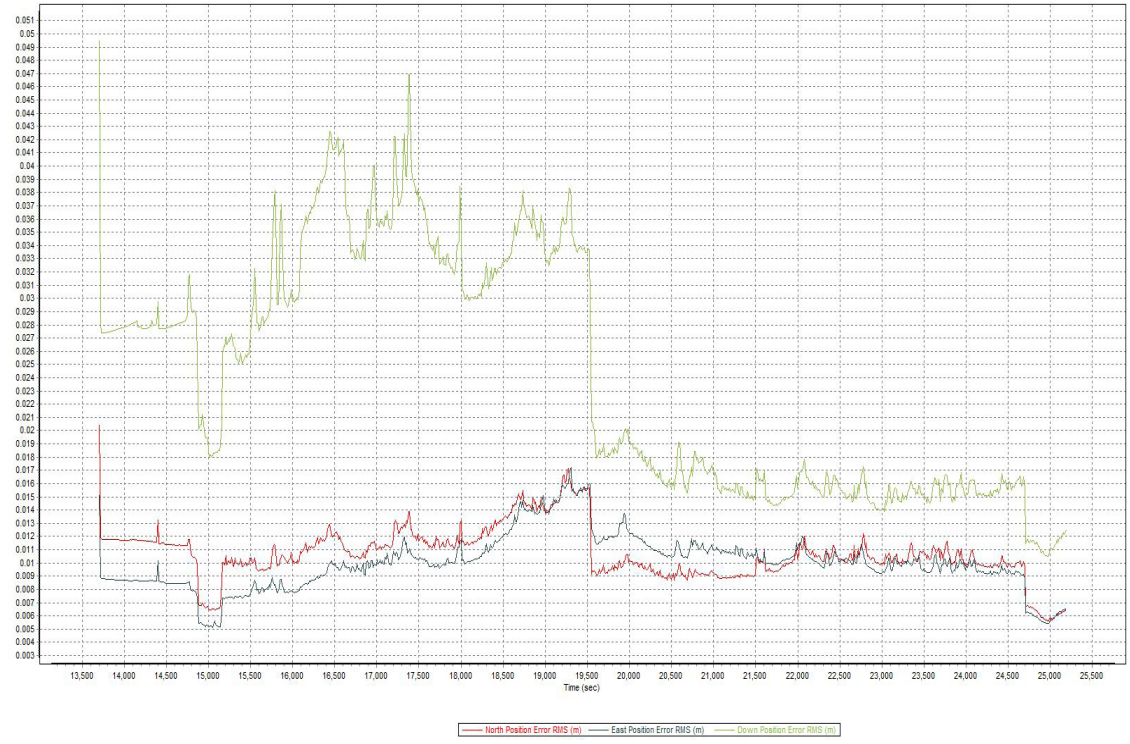


Figure 1.8.2. Smoothed Performance Metric Parameters

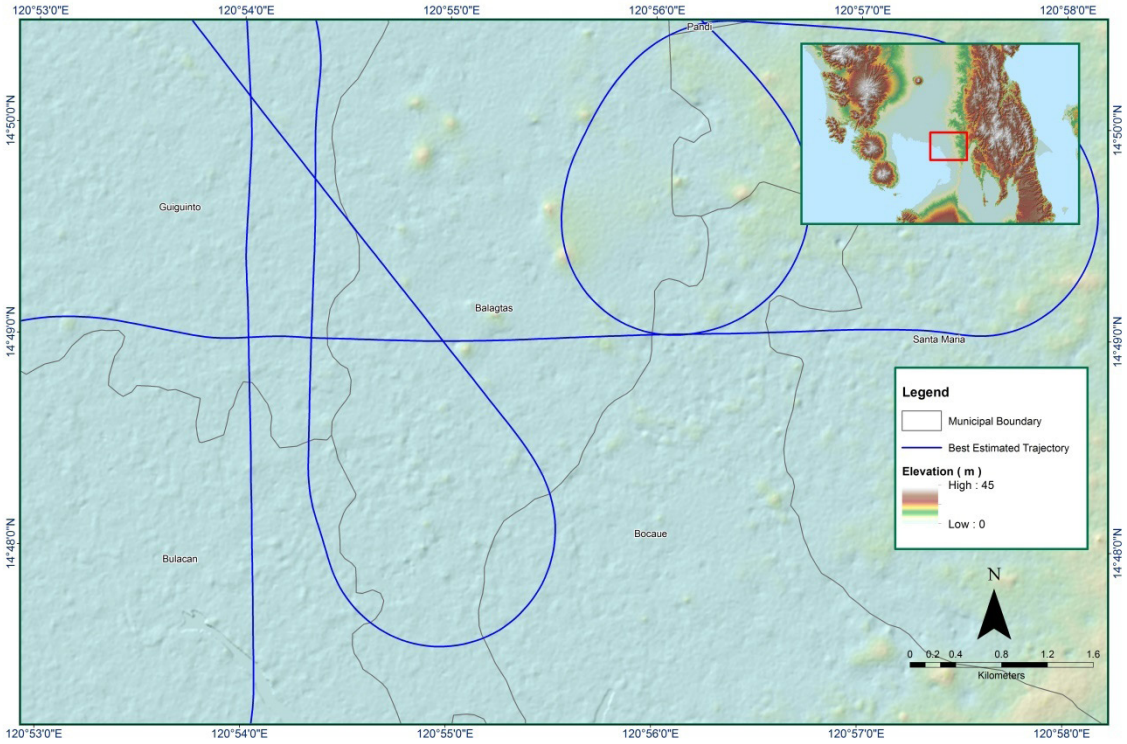


Figure 1.8.3. Best Estimate Trajectory

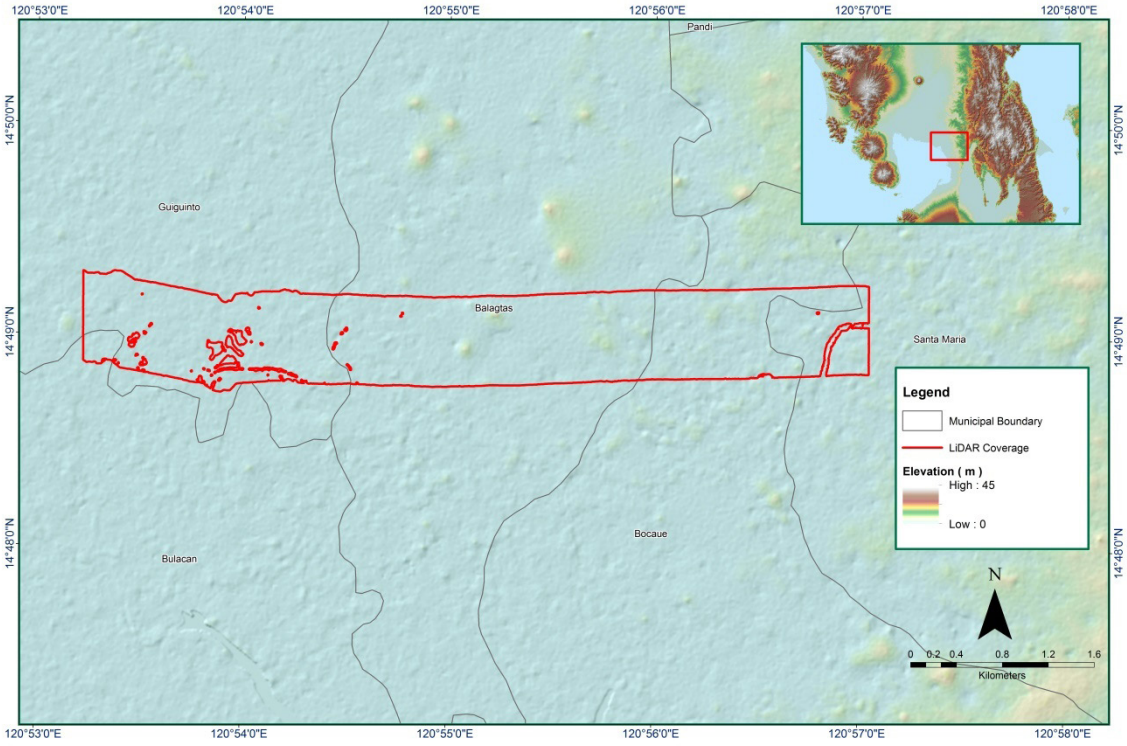


Figure 1.8.4. Coverage of LiDAR data

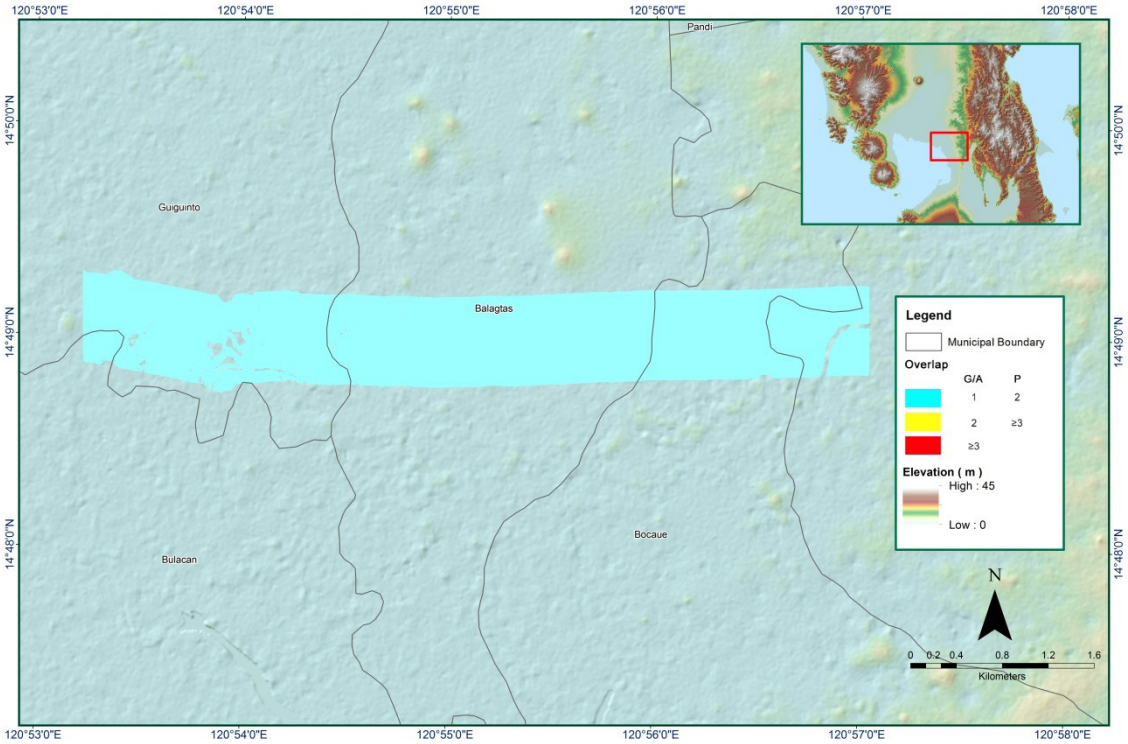


Figure 1.8.5 Image of data overlap

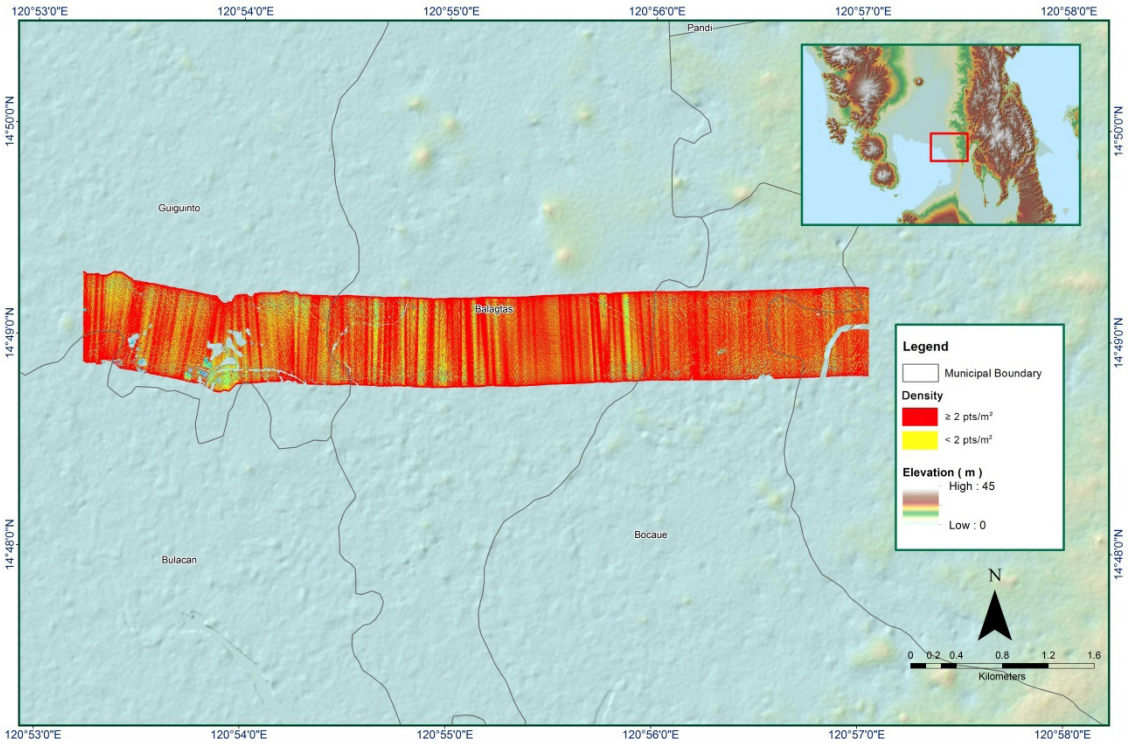


Figure 1.8.6 Density Map of merged LiDAR data

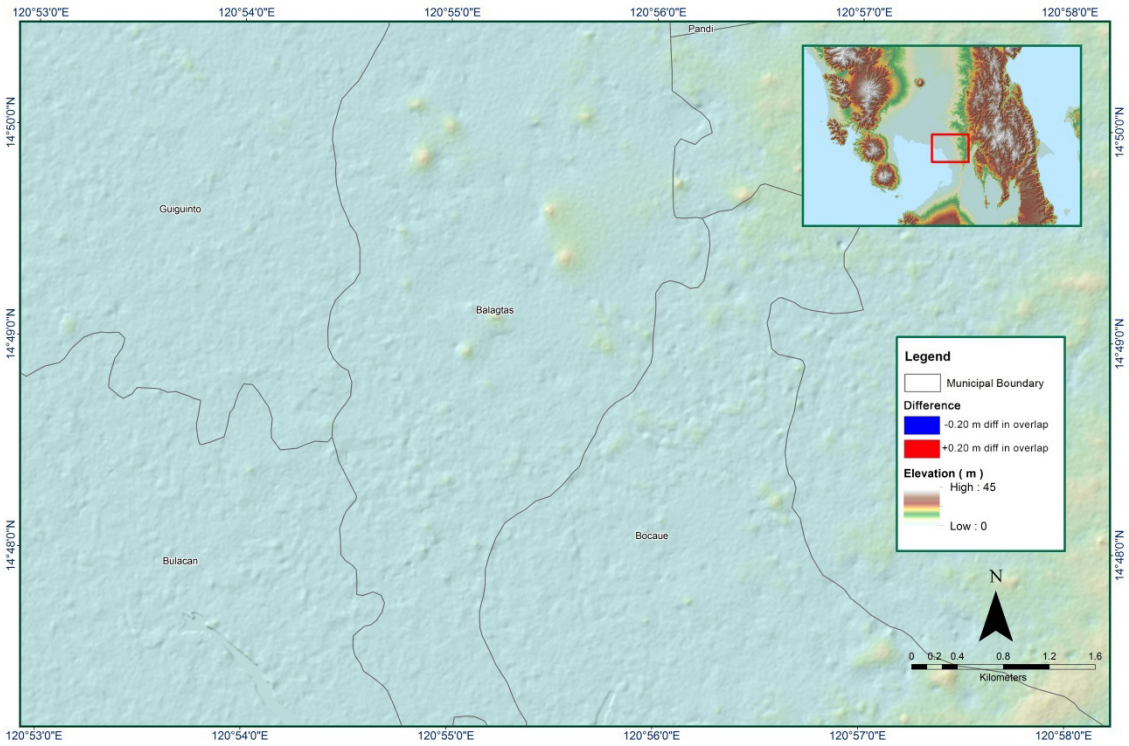


Figure 1.8.7 Elevation Difference Between flight lines

Flight Area	Pam_Agno Reflights
Mission Name	Pam_Blk8_reflight
Inclusive Flights	7271GC
Range data size	15.5 GB
POS data size	233 MB
Base data size	3.68 MB
Image	N/A
Transfer date	May 25, 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)	1.047
RMSE for East Position (<4.0 cm)	1.328
RMSE for Down Position (<8.0 cm)	2.604
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	20.91
Ave point cloud density per sq.m. (>2.0)	2.89
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	98
Maximum Height	176.48 m
Minimum Height	44.84 m
Classification (# of points)	
Ground	34,953,002
Low vegetation	42,476,033
Medium vegetation	24,414,658
High vegetation	24,414,658
Building	5,910,094
Orthophoto	No
Processed by	Engr. Jommer Medina,Engr. Harmond Santos, Engr. Melissa Fernandez

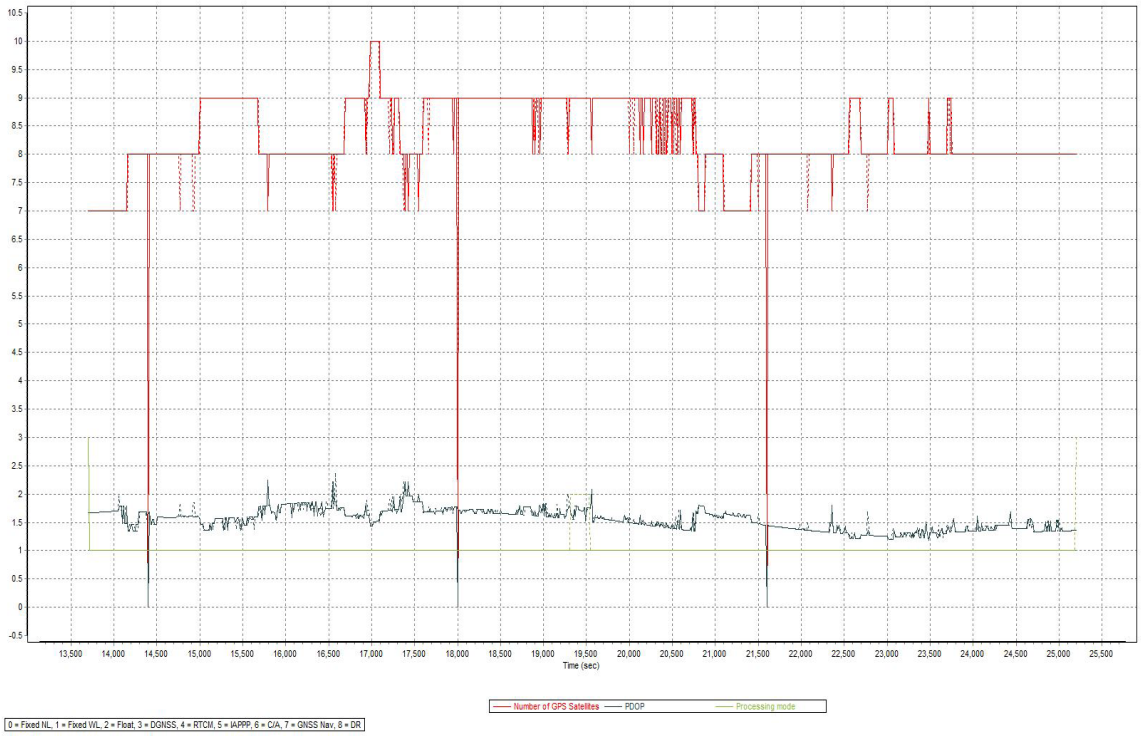


Figure 1.9.1. Solution Status

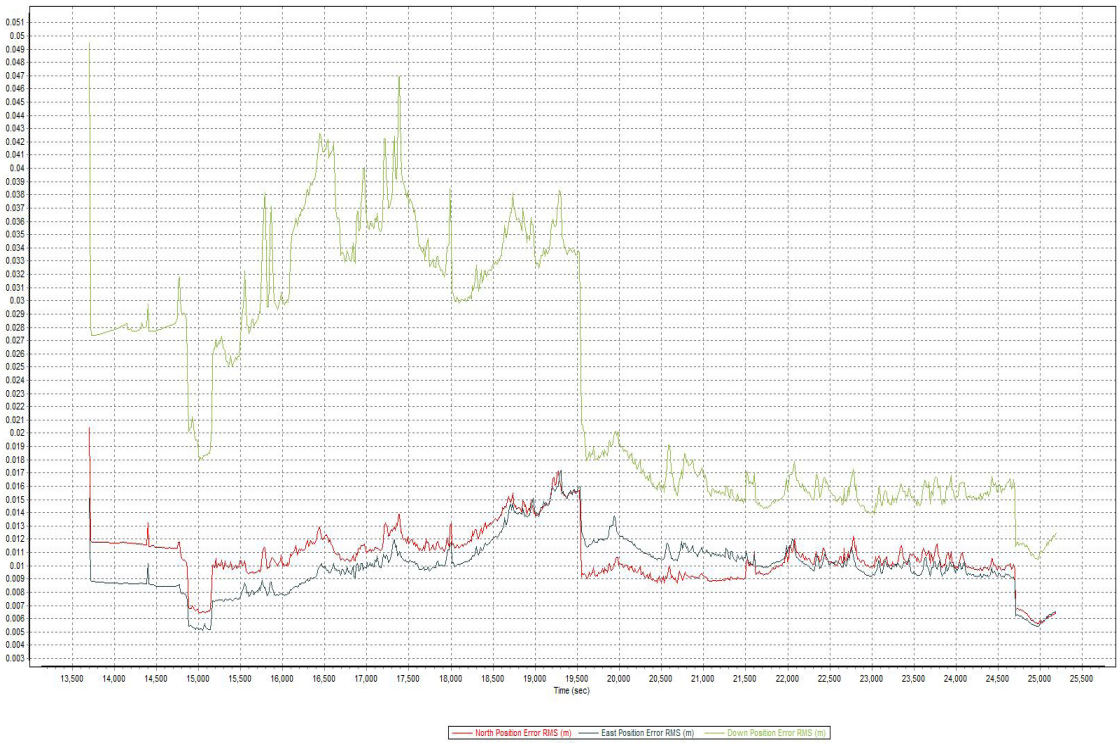


Figure 1.9.2. Smoothed Performance Metric Parameters

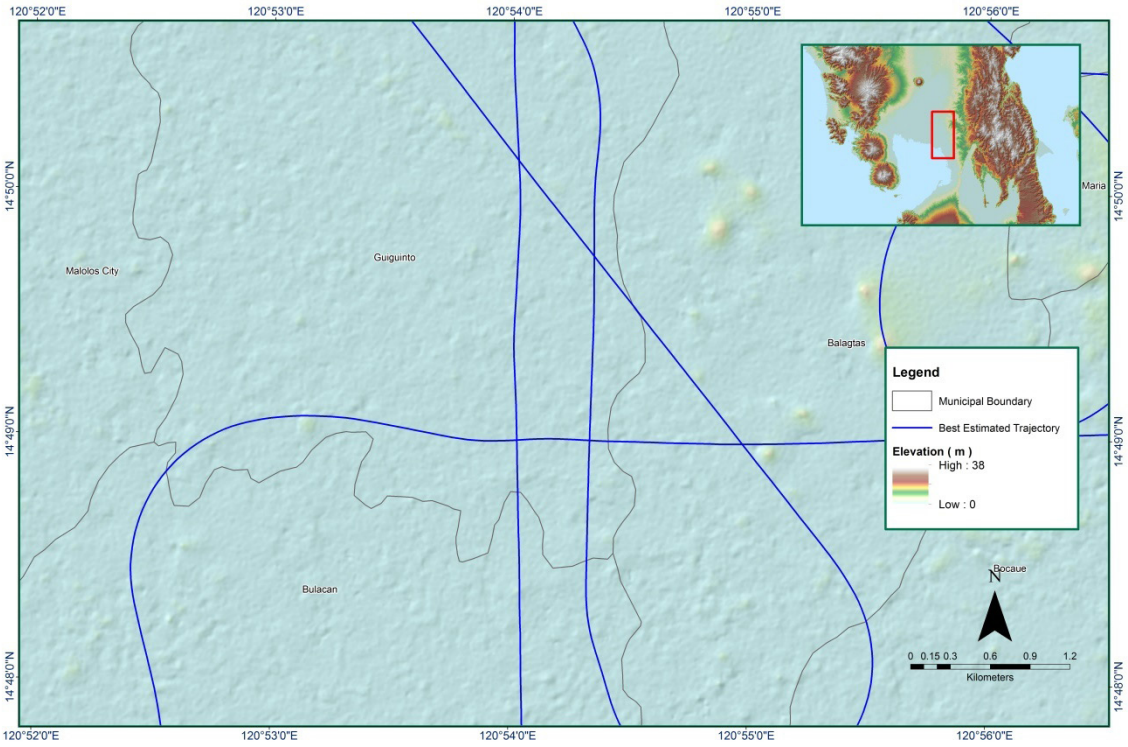


Figure 1.9.3. Best Estimate Trajectory

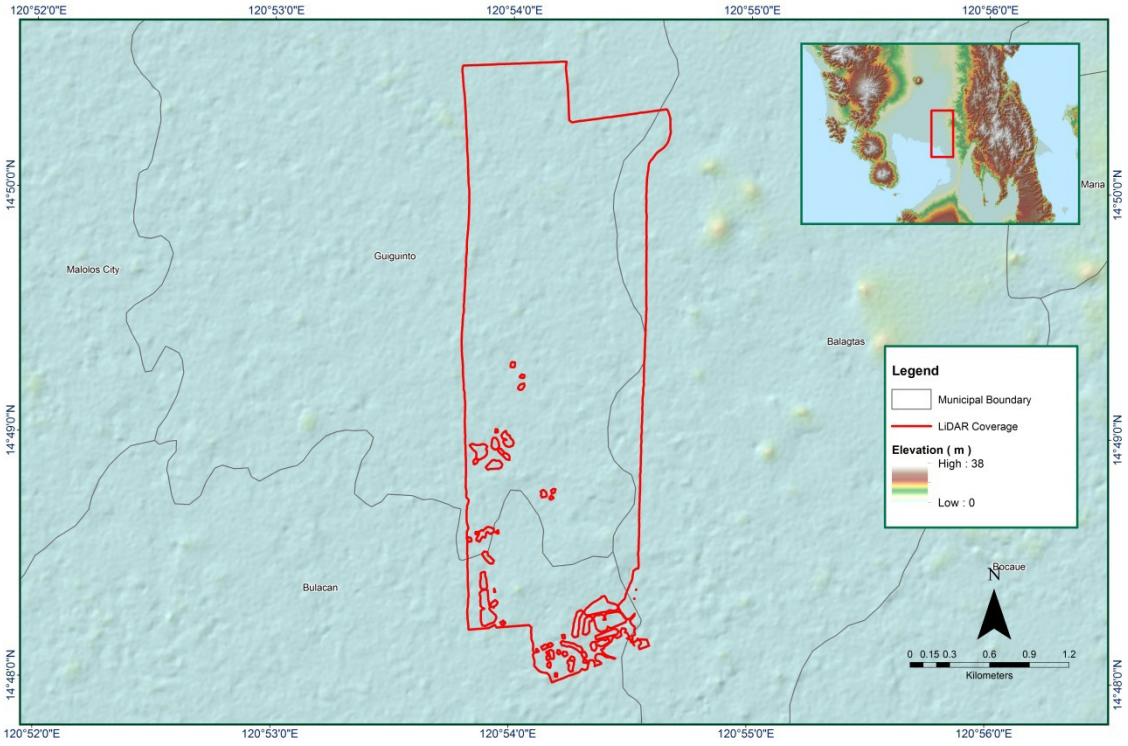


Figure 1.9.4. Coverage of LiDAR data

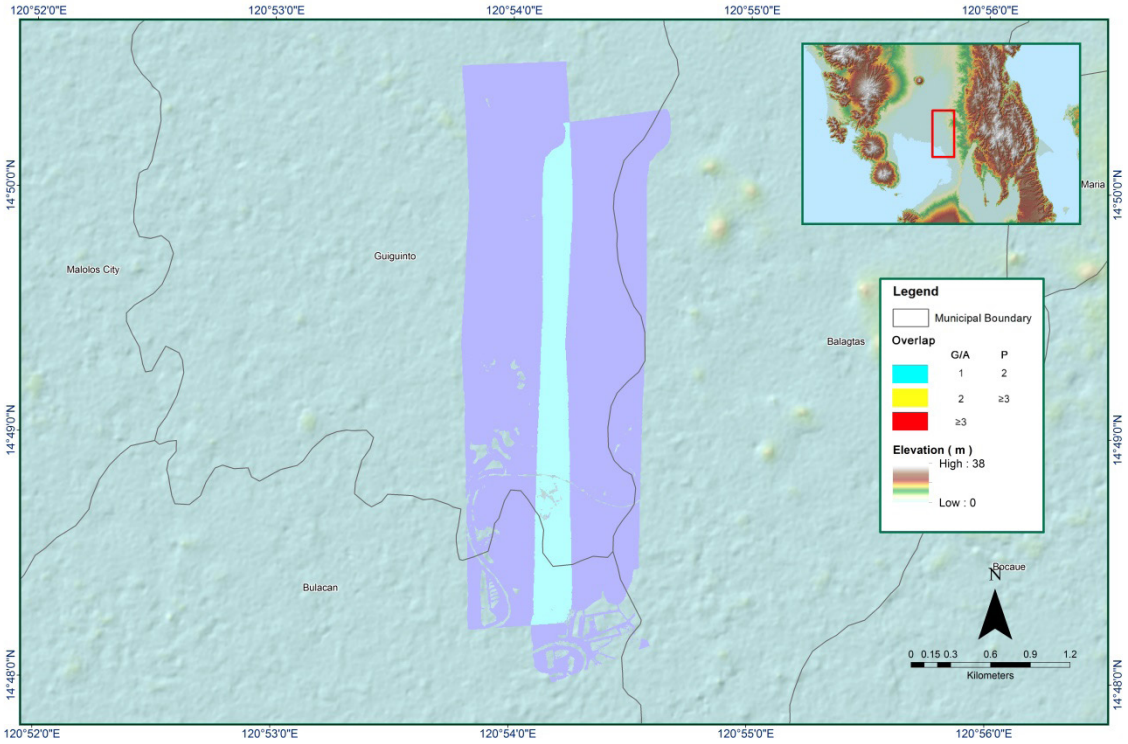


Figure 1.9.5 Image of data overlap

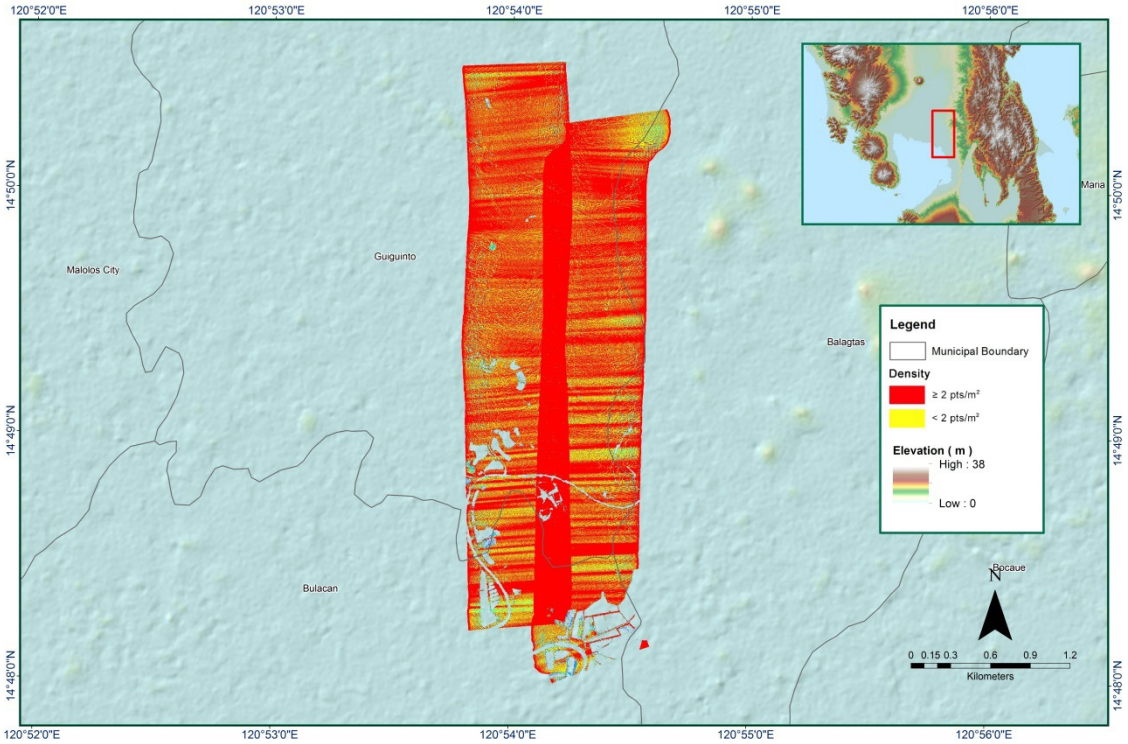


Figure 1.9.6 Density Map of merged LiDAR data

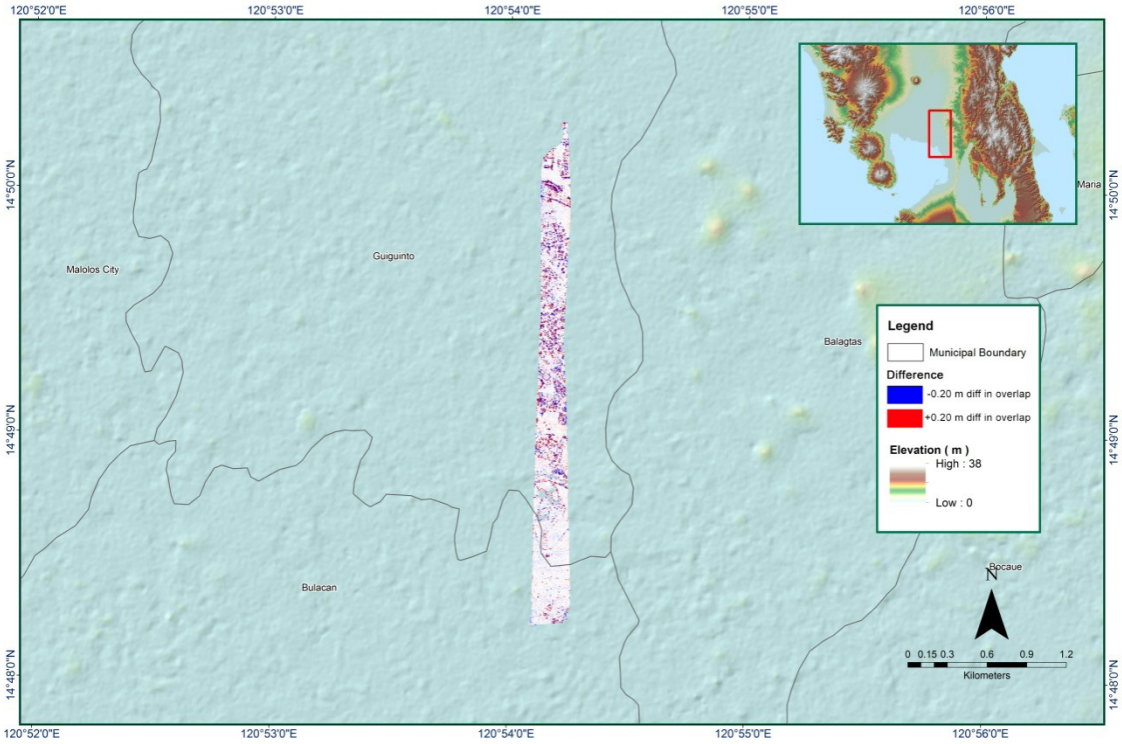


Figure 1.9.7 Elevation Difference Between flight lines

Flight Area	Pam_Agno Reflights
Mission Name	Bal_reflight
Inclusive Flights	7260GC
Range data size	14.5 GB
POS data size	183 MB
Base data size	10.7 MB
Image	N/A
Transfer date	May 20, 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)	1.715
RMSE for East Position (<4.0 cm)	1.720
RMSE for Down Position (<8.0 cm)	4.692
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)	27.24
Ave point cloud density per sq.m. (>2.0)	3.83
Elevation difference between strips (<0.20 m)	No
Number of 1km x 1km blocks	124
Maximum Height	362.23 m
Minimum Height	48.98 m
Classification (# of points)	
Ground	36,551,649
Low vegetation	49,330,838
Medium vegetation	130,717,621
High vegetation	102,911,481
Building	1,089,271
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Antonio Chua Jr., Engr. Elainne Lopez

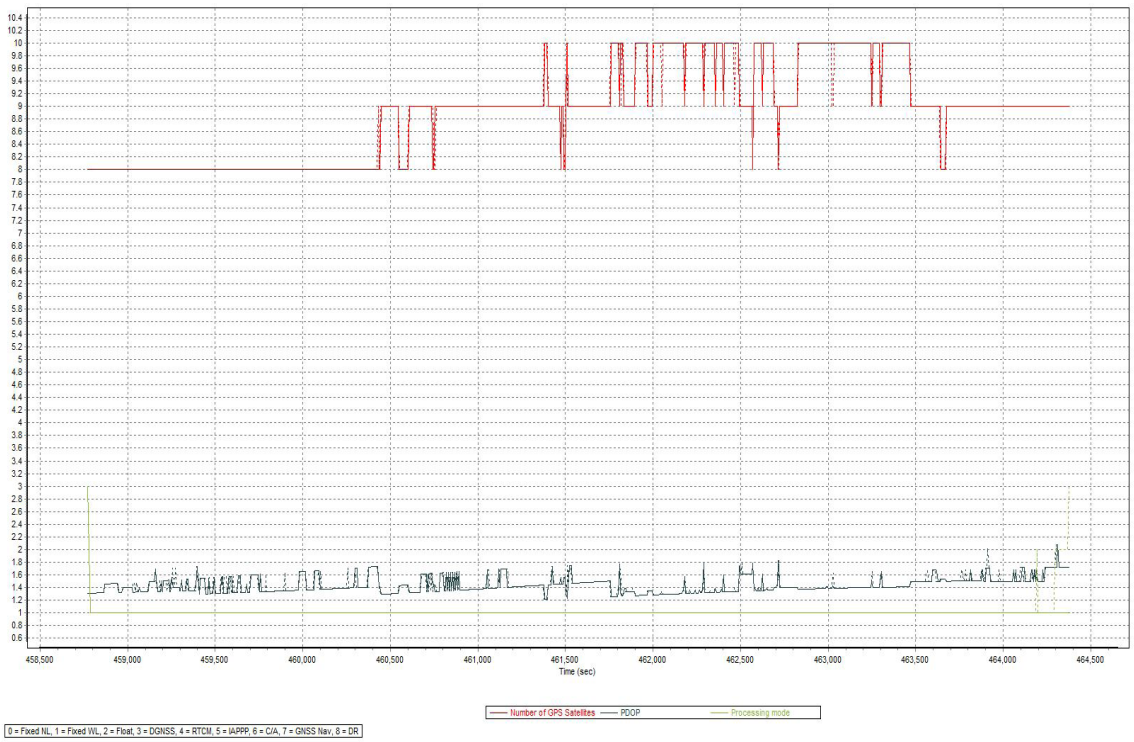


Figure 1.10.1. Solution Status

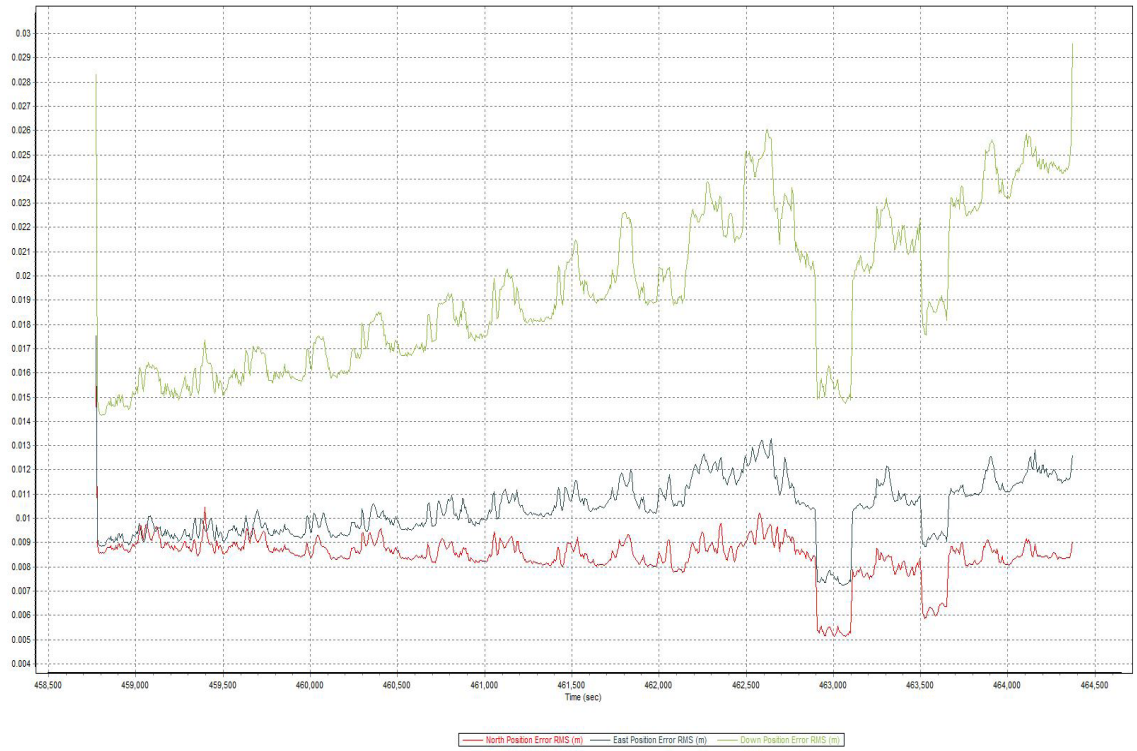


Figure 1.10.2. Smoothed Performance Metric Parameters

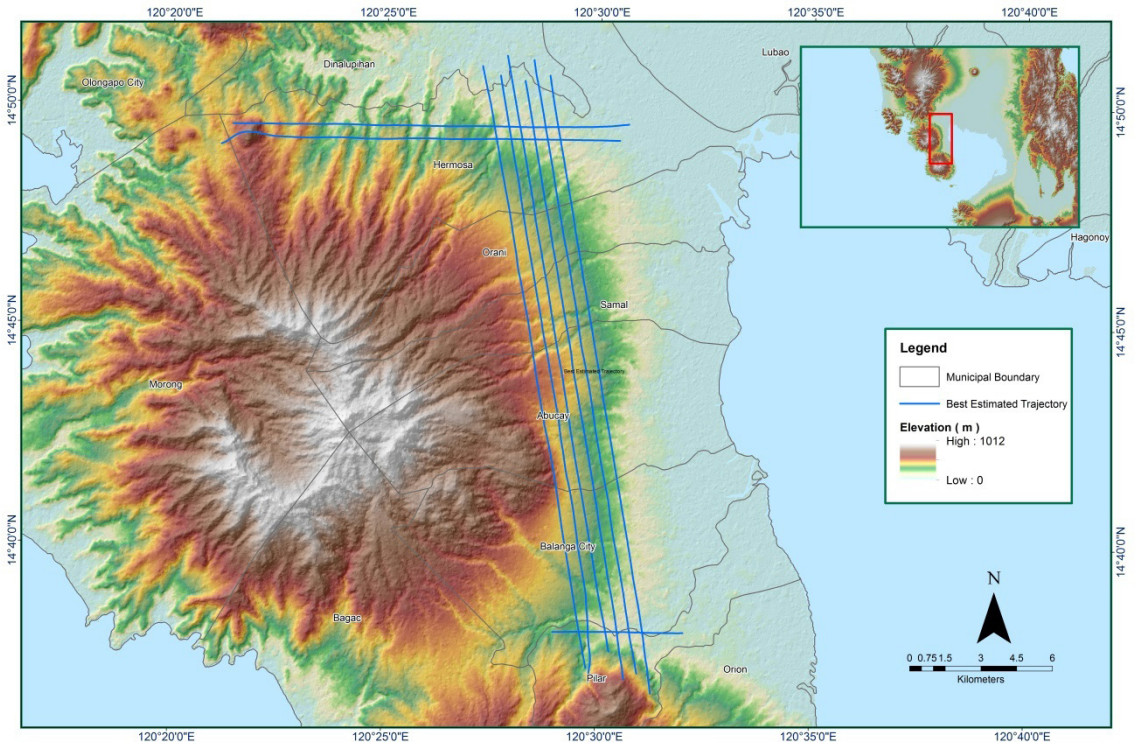


Figure 1.10.3. Best Estimate Trajectory

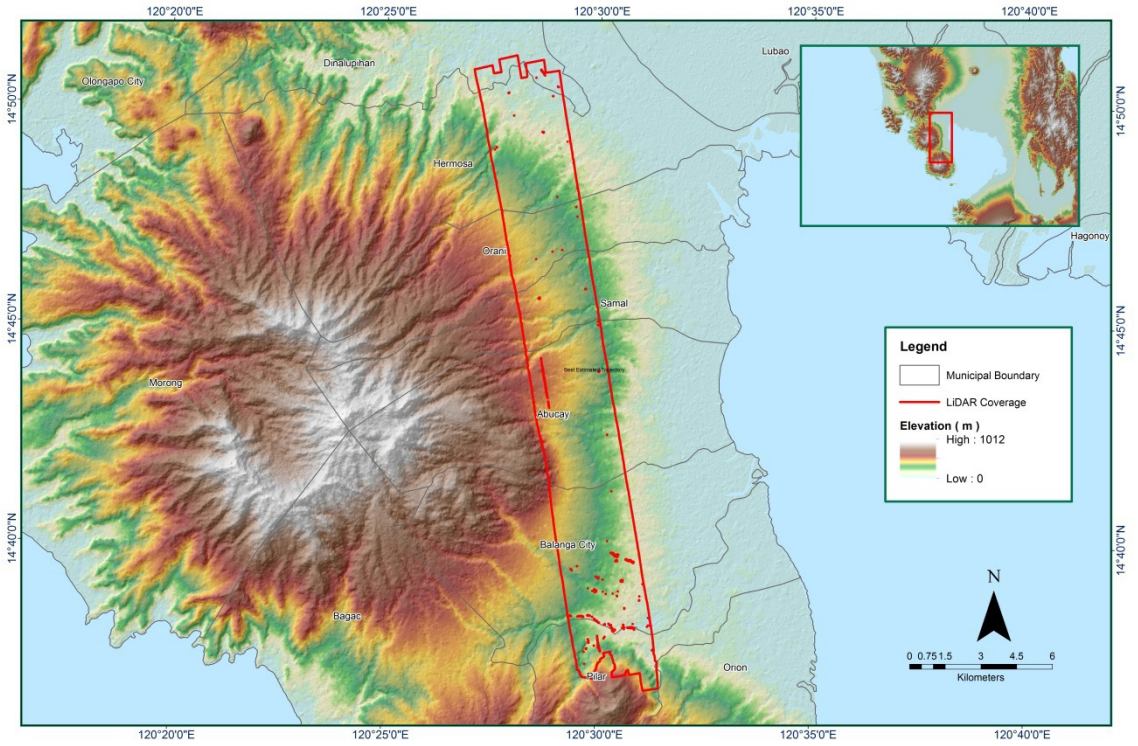


Figure 1.10.4. Coverage of LiDAR data

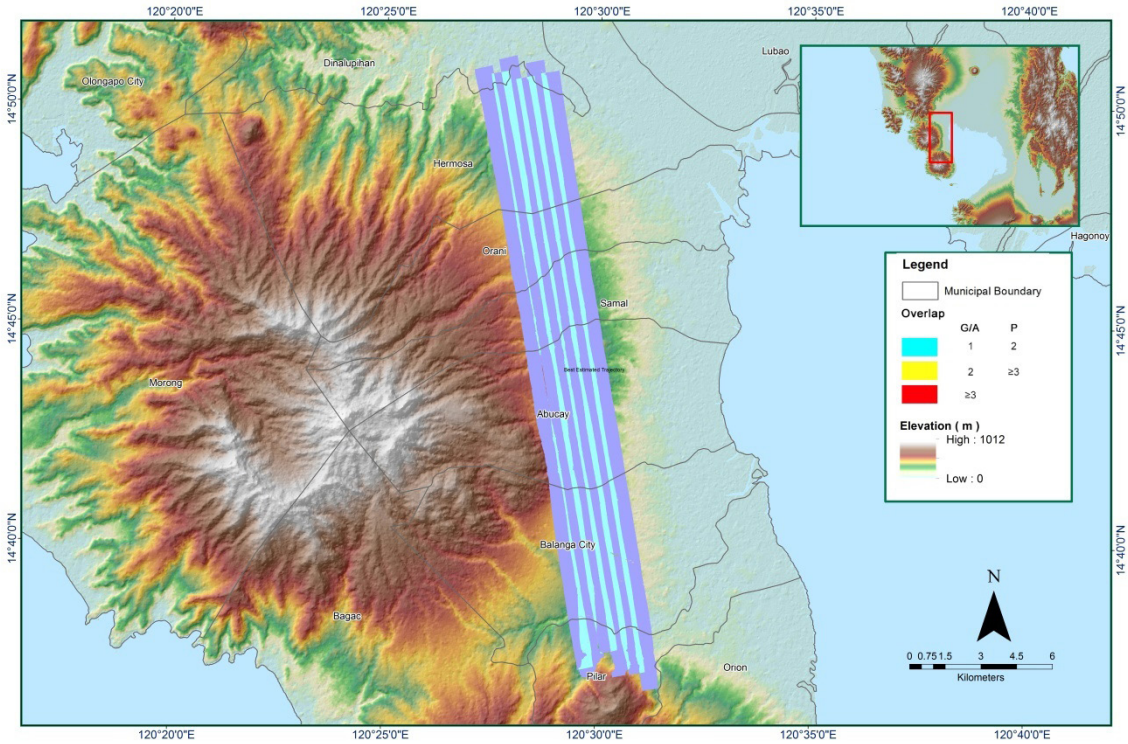


Figure 1.10.5 Image of data overlap

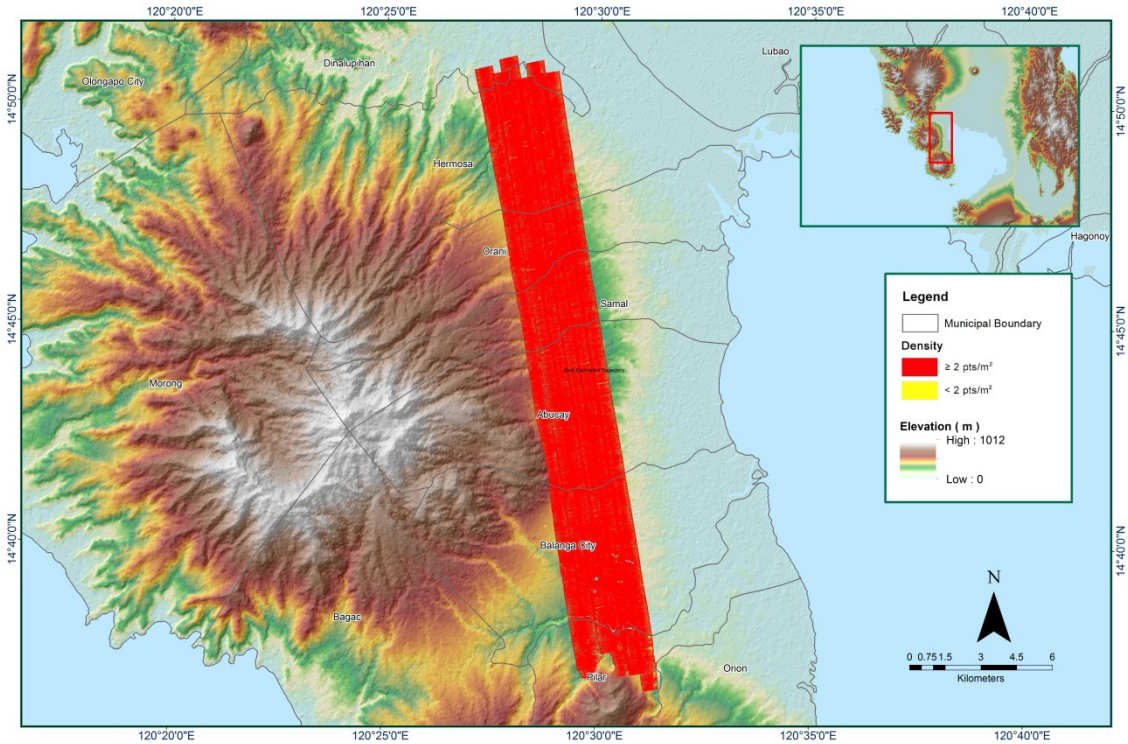


Figure 1.10.6 Density Map of merged LiDAR data

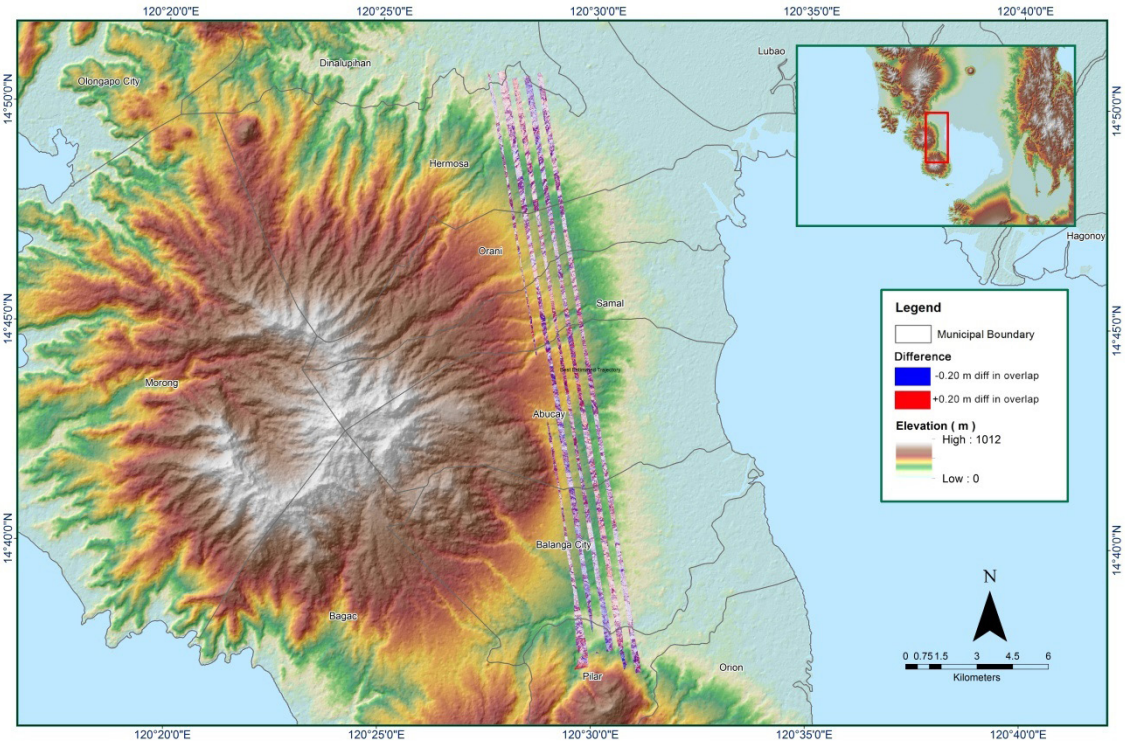


Figure 1.10.7 Elevation Difference Between flight lines

ANNEX 9. BALANGAMODEL 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
W120	15.82	98.844	0	5.8148	14.341	Discharge	12.37	0.99781	Ratio to Peak	0.5
W130	16.857	99	0	6.7564	11.447	Discharge	5.9551	1	Ratio to Peak	0.5
W140	13.612	97.847	0	2.7794	10.894	Discharge	2.5758	1	Ratio to Peak	0.5
W150	4.8115	98.56	0	3.5706	6.5608	Discharge	3.3755	1	Ratio to Peak	0.48874
W160	8.2321	99	0	2.0835	3.1723	Discharge	2.982	1	Ratio to Peak	0.50592
W170	7.6063	99	0	1.2296	8.0709	Discharge	1.6535	1	Ratio to Peak	0.33614
W180	4.4883	99	0	0.12072	0.65149	Discharge	0.10608	0.99415	Ratio to Peak	0.50515
W190	19.363	99	0	5.8166	14.582	Discharge	12.211662	1	Ratio to Peak	0.5
W200	5.1097	98.879	0	2.0772	7.1379	Discharge	2.5621	1	Ratio to Peak	0.49147
W210	11.166	99	0	2.7693	5.3184	Discharge	8.2354	1	Ratio to Peak	0.49077
W220	11.269	98.403	0	2.3457	7.0514	Discharge	4.273	1	Ratio to Peak	0.5

ANNEX 10. BALANGA MODEL REACH PARAMETERS

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R20	Automatic Fixed Interval	2434	0.0060054	0.0602259	Trapezoid	36.71	1
R40	Automatic Fixed Interval	3171.8	0.0101976	0.11902	Trapezoid	44.86	1
R50	Automatic Fixed Interval	2284.7	0.0060054	0.0533523	Trapezoid	93.01	1
R60	Automatic Fixed Interval	729.12	0.0126305	0.0405879	Trapezoid	31.94	1
R80	Automatic Fixed Interval	1571	0.0112525	0.0591967	Trapezoid	27.24	1

ANNEX 11. BALANGA FIELD VALIDATION

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
1	120.55153	14.66574	0.03	0.00	-0.03	Habagat, 2013	5 -Year
2	120.54476	14.66583	0.12	0.00	-0.116	Habagat, 2013	5 -Year
3	120.54409	14.67006	0.17	0.00	-0.17	Habagat, 2013	5 -Year
4	120.53823	14.70559	0.13	0.46	0.334	Habagat, 2013	5 -Year
5	120.5376	14.70418	0.03	0.56	0.53	Habagat, 2013	5 -Year
6	120.53636	14.70547	0.05	0.46	0.411	Habagat, 2013	5 -Year
7	120.53464	14.70522	0.03	0.00	-0.03	Habagat, 2013	5 -Year
8	120.54172	14.70578	0.03	0.30	0.27	Habagat, 2013	5 -Year
9	120.53915	14.70657	0.04	0.46	0.418	Habagat, 2013	5 -Year
10	120.53861	14.70006	0.03	0.00	-0.03	Habagat, 2013	5 -Year
11	120.53822	14.69449	0.10	0.30	0.2	Habagat, 2013	5 -Year
12	120.53807	14.69584	0.03	0.15	0.12	Habagat, 2013	5 -Year
13	120.54117	14.69333	0.03	0.00	-0.03	Habagat, 2013	5 -Year
14	120.53336	14.69711	0.07	0.15	0.079	Habagat, 2013	5 -Year
15	120.53445	14.69736	0.03	0.00	-0.03	Habagat, 2013	5 -Year
16	120.5436	14.68728	0.10	0.00	-0.1	Habagat, 2013	5 -Year
17	120.54299	14.68579	0.03	0.00	-0.03	Habagat, 2013	5 -Year
18	120.54226	14.69282	0.10	0.61	0.514	Habagat, 2013	5 -Year
19	120.52115	14.68362	0.07	0.15	0.083	Habagat, 2013	5 -Year
20	120.52204	14.68388	0.03	0.15	0.12	Habagat, 2013	5 -Year
21	120.52027	14.68409	0.03	0.15	0.12	Habagat, 2013	5 -Year
22	120.52154	14.6845	0.03	0.30	0.27	Habagat, 2013	5 -Year
23	120.52311	14.68397	0.06	0.15	0.09	Habagat, 2013	5 -Year
24	120.52976	14.67778	0.03	0.00	-0.03	Habagat, 2013	5 -Year
25	120.53214	14.67851	0.03	0.00	-0.03	Habagat, 2013	5 -Year
26	120.52673	14.67985	0.03	0.30	0.27	Habagat, 2013	5 -Year
27	120.52452	14.67918	0.03	0.00	-0.03	Habagat, 2013	5 -Year
28	120.52628	14.67645	0.03	0.00	-0.03	Habagat, 2013	5 -Year
29	120.53208	14.67208	0.04	0.00	-0.038	Habagat, 2013	5 -Year
30	120.52875	14.67163	0.03	0.00	-0.03	Habagat, 2013	5 -Year
31	120.55732	14.69017	0.43	0.00	-0.432	Habagat, 2013	5 -Year
32	120.5582	14.68709	0.32	0.46	0.145	Habagat, 2013	5 -Year
33	120.5532	14.68776	0.31	0.46	0.148	Habagat, 2013	5 -Year
34	120.55652	14.68851	0.23	0.46	0.235	Habagat, 2013	5 -Year
35	120.55694	14.69062	0.36	0.56	0.203	Habagat, 2013	5 -Year
36	120.55832	14.68751	0.27	0.56	0.287	Habagat, 2013	5 -Year
37	120.5533	14.6873	0.47	0.46	-0.007	Habagat, 2013	5 -Year
38	120.54985	14.68067	0.41	0.30	-0.105	Habagat, 2013	5 -Year
39	120.54937	14.67971	0.23	0.76	0.526	Habagat, 2013	5 -Year
40	120.55017	14.68001	0.33	0.76	0.432	Habagat, 2013	5 -Year
41	120.54516	14.68343	0.25	0.30	0.047	Habagat, 2013	5 -Year
42	120.54649	14.68413	0.41	0.76	0.348	Habagat, 2013	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
43	120.54098	14.68443	0.32	0.30	-0.022	Habagat, 2013	5 -Year
44	120.5448	14.68451	0.44	0.46	0.019	Habagat, 2013	5 -Year
45	120.5471	14.68362	0.39	0.30	-0.085	Habagat, 2013	5 -Year
46	120.55079	14.67363	0.33	0.46	0.127	Habagat, 2013	5 -Year
47	120.55082	14.6747	0.39	0.46	0.067	Habagat, 2013	5 -Year
48	120.54972	14.67184	0.47	0.46	-0.009	Habagat, 2013	5 -Year
49	120.54848	14.67283	0.38	0.46	0.076	Habagat, 2013	5 -Year
50	120.54708	14.67407	0.43	0.46	0.029	Habagat, 2013	5 -Year
51	120.54618	14.6746	0.27	0.46	0.186	Habagat, 2013	5 -Year
52	120.54936	14.67437	0.27	0.30	0.032	Habagat, 2013	5 -Year
53	120.55249	14.67295	0.43	0.46	0.03	Habagat, 2013	5 -Year
54	120.54803	14.67142	0.30	0.46	0.158	Habagat, 2013	5 -Year
55	120.53597	14.67584	0.38	0.30	-0.08	Habagat, 2013	5 -Year
56	120.53607	14.67458	0.24	0.30	0.059	Habagat, 2013	5 -Year
57	120.53524	14.67319	0.44	0.30	-0.144	Habagat, 2013	5 -Year
58	120.53453	14.67261	0.38	0.46	0.08	Habagat, 2013	5 -Year
59	120.54633	14.66359	0.40	0.30	-0.102	Habagat, 2013	5 -Year
60	120.54009	14.66376	0.40	0.46	0.06	Habagat, 2013	5 -Year
61	120.53713	14.64396	0.61	0.00	-0.612	Habagat, 2013	5 -Year
62	120.53936	14.64571	0.83	0.61	-0.217	Habagat, 2013	5 -Year
63	120.53742	14.6445	0.60	0.46	-0.144	Habagat, 2013	5 -Year
64	120.53871	14.64878	0.92	0.76	-0.163	Habagat, 2013	5 -Year
65	120.53812	14.6481	0.68	0.61	-0.074	Habagat, 2013	5 -Year
66	120.53598	14.65995	0.78	1.07	0.294	Habagat, 2013	5 -Year
67	120.53792	14.6618	0.83	0.91	0.08	Habagat, 2013	5 -Year
68	120.53932	14.66152	0.69	1.07	0.382	Habagat, 2013	5 -Year
69	120.53774	14.66334	0.62	0.91	0.287	Habagat, 2013	5 -Year
70	120.53859	14.66342	0.90	1.07	0.173	Habagat, 2013	5 -Year
71	120.54149	14.6631	0.67	0.91	0.241	Habagat, 2013	5 -Year
72	120.53509	14.66365	0.62	0.91	0.292	Habagat, 2013	5 -Year
73	120.54812	14.68135	0.54	0.91	0.367	Habagat, 2013	5 -Year
74	120.54733	14.67835	0.80	0.91	0.106	Habagat, 2013	5 -Year
75	120.54523	14.6766	0.85	0.91	0.057	Habagat, 2013	5 -Year
76	120.54999	14.68163	0.53	1.07	0.545	Habagat, 2013	5 -Year
77	120.54654	14.68274	0.93	1.07	0.138	Habagat, 2013	5 -Year
78	120.5435	14.6817	0.66	0.91	0.247	Habagat, 2013	5 -Year
79	120.54181	14.6823	0.92	0.91	-0.009	Habagat, 2013	5 -Year
80	120.53947	14.6811	0.70	0.76	0.061	Habagat, 2013	5 -Year
81	120.54109	14.67855	0.84	1.07	0.23	Habagat, 2013	5 -Year
82	120.5428	14.67891	0.83	1.07	0.239	Habagat, 2013	5 -Year
83	120.54389	14.67756	0.57	1.07	0.505	Habagat, 2013	5 -Year
84	120.54298	14.67663	0.74	0.91	0.173	Habagat, 2013	5 -Year
85	120.53738	14.68084	0.65	0.91	0.263	Habagat, 2013	5 -Year
86	120.54027	14.68129	0.79	0.91	0.125	Habagat, 2013	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
87	120.55351	14.68885	0.63	0.91	0.285	Habagat, 2013	5 -Year
88	120.5517	14.68849	0.60	1.07	0.472	Habagat, 2013	5 -Year
89	120.55052	14.68744	0.54	0.61	0.066	Habagat, 2013	5 -Year
90	120.55333	14.68712	0.61	0.91	0.296	Habagat, 2013	5 -Year
91	120.56144	14.66137	1.39	0.46	-0.925	Habagat, 2013	5 -Year
92	120.56206	14.66213	1.28	1.07	-0.21	Habagat, 2013	5 -Year
93	120.56326	14.66184	1.11	0.91	-0.203	Habagat, 2013	5 -Year
94	120.56284	14.66288	1.37	1.07	-0.296	Habagat, 2013	5 -Year
95	120.56241	14.6644	1.68	1.22	-0.463	Habagat, 2013	5 -Year
96	120.56451	14.66478	1.66	1.07	-0.586	Habagat, 2013	5 -Year
97	120.5611	14.6641	1.77	1.61	-0.159	Habagat, 2013	5 -Year
98	120.55983	14.66485	1.64	1.37	-0.267	Habagat, 2013	5 -Year
99	120.56367	14.66482	1.43	0.91	-0.518	Habagat, 2013	5 -Year
100	120.5608	14.6614	1.44	0.76	-0.681	Habagat, 2013	5 -Year
101	120.56477	14.66735	1.09	1.52	0.431	Habagat, 2013	5 -Year
102	120.5638	14.66789	1.58	1.22	-0.363	Habagat, 2013	5 -Year
103	120.55609	14.66546	1.57	1.40	-0.166	Habagat, 2013	5 -Year
104	120.555	14.6659	1.32	0.91	-0.408	Habagat, 2013	5 -Year
105	120.55283	14.66679	1.33	1.20	-0.128	Habagat, 2013	5 -Year
106	120.55427	14.6672	1.55	1.37	-0.178	Habagat, 2013	5 -Year
107	120.55551	14.66667	1.83	1.52	-0.305	Habagat, 2013	5 -Year
108	120.55688	14.66605	1.37	1.07	-0.3	Habagat, 2013	5 -Year
109	120.55711	14.66691	1.12	1.32	0.196	Habagat, 2013	5 -Year
110	120.5572	14.6681	1.17	1.22	0.046	Habagat, 2013	5 -Year
111	120.55354	14.66765	1.34	1.22	-0.12	Habagat, 2013	5 -Year
112	120.54812	14.66244	1.36	1.22	-0.142	Habagat, 2013	5 -Year
113	120.54606	14.66476	1.53	1.27	-0.262	Habagat, 2013	5 -Year
114	120.54719	14.66534	1.14	1.52	0.384	Habagat, 2013	5 -Year
115	120.55024	14.66533	1.34	1.22	-0.118	Habagat, 2013	5 -Year
116	120.55114	14.66295	1.45	1.25	-0.201	Habagat, 2013	5 -Year
117	120.55149	14.66344	1.32	0.91	-0.405	Habagat, 2013	5 -Year
118	120.54509	14.67231	1.36	1.37	0.007	Habagat, 2013	5 -Year
119	120.54237	14.67504	1.38	1.37	-0.005	Habagat, 2013	5 -Year
120	120.54488	14.67117	1.08	1.52	0.437	Habagat, 2013	5 -Year
121	120.54491	14.6614	4.59	3.68	-0.909	Habagat, 2013	5 -Year
122	120.54519	14.66161	4.71	3.90	-0.808	Habagat, 2013	5 -Year
123	120.54543	14.66165	4.99	4.34	-0.653	Habagat, 2013	5 -Year
124	120.54558	14.66113	4.42	4.13	-0.285	Habagat, 2013	5 -Year
125	120.54682	14.66196	2.11	2.13	0.02	Habagat, 2013	5 -Year
126	120.5599	14.66374	2.12	2.13	0.015	Habagat, 2013	5 -Year
127	120.56039	14.66449	2.11	1.22	-0.893	Habagat, 2013	5 -Year
128	120.56079	14.66453	2.06	2.13	0.071	Habagat, 2013	5 -Year
129	120.55998	14.66515	2.07	2.13	0.06	Habagat, 2013	5 -Year
130	120.55818	14.66447	2.79	2.13	-0.657	Habagat, 2013	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
131	120.55685	14.66495	2.15	2.13	-0.016	Habagat, 2013	5 -Year
132	120.55644	14.66511	2.05	2.13	0.076	Habagat, 2013	5 -Year
133	120.56055	14.66586	2.33	2.13	-0.195	Habagat, 2013	5 -Year
134	120.55989	14.66617	3.14	2.50	-0.639	Habagat, 2013	5 -Year
135	120.55933	14.66599	2.73	2.13	-0.595	Habagat, 2013	5 -Year
136	120.54972	14.66597	3.36	2.87	-0.485	Habagat, 2013	5 -Year
137	120.54981	14.6662	3.33	3.13	-0.203	Habagat, 2013	5 -Year
138	120.54919	14.66542	3.70	2.50	-1.2	Habagat, 2013	5 -Year
139	120.54899	14.66501	2.21	2.13	-0.079	Habagat, 2013	5 -Year
140	120.54814	14.66537	3.13	2.13	-1.003	Habagat, 2013	5 -Year
141	120.54813	14.66591	2.53	2.44	-0.09	Habagat, 2013	5 -Year
142	120.54814	14.66639	3.13	2.50	-0.631	Habagat, 2013	5 -Year
143	120.54673	14.67328	3.22	2.60	-0.615	Habagat, 2013	5 -Year
144	120.5459	14.67418	3.72	2.80	-0.918	Habagat, 2013	5 -Year
145	120.54583	14.67341	2.76	2.29	-0.465	Habagat, 2013	5 -Year
146	120.54551	14.6738	3.52	2.90	-0.616	Habagat, 2013	5 -Year
147	120.54439	14.67387	3.03	2.29	-0.74	Habagat, 2013	5 -Year
148	120.54427	14.67438	2.98	2.13	-0.85	Habagat, 2013	5 -Year
149	120.54425	14.67584	2.64	2.44	-0.198	Habagat, 2013	5 -Year
150	120.54433	14.67548	2.27	2.13	-0.138	Habagat, 2013	5 -Year
151	120.52342	14.63459	5.26	5.20	-0.059	Habagat, 2013	5 -Year
152	120.52393	14.63523	6.02	5.50	-0.524	Habagat, 2013	5 -Year
153	120.52426	14.63575	7.72	5.82	-1.895	Habagat, 2013	5 -Year
154	120.52505	14.6363	5.71	4.13	-1.579	Habagat, 2013	5 -Year
155	120.52481	14.63666	7.57	5.70	-1.871	Habagat, 2013	5 -Year
156	120.52545	14.63719	7.31	5.90	-1.411	Habagat, 2013	5 -Year
157	120.5262	14.63696	6.02	5.55	-0.47	Habagat, 2013	5 -Year
158	120.52673	14.63754	5.58	5.20	-0.382	Habagat, 2013	5 -Year
159	120.5256	14.63595	5.35	4.90	-0.445	Habagat, 2013	5 -Year
160	120.52528	14.6369	6.55	5.80	-0.747	Habagat, 2013	5 -Year
161	120.53548	14.64226	5.61	5.13	-0.483	Habagat, 2013	5 -Year
162	120.53522	14.64247	5.49	5.13	-0.36	Habagat, 2013	5 -Year
163	120.5343	14.64315	5.40	5.29	-0.105	Habagat, 2013	5 -Year
164	120.53298	14.64334	6.47	5.55	-0.92	Habagat, 2013	5 -Year
165	120.53325	14.64346	6.69	5.64	-1.054	Habagat, 2013	5 -Year
166	120.53267	14.64294	5.87	5.13	-0.74	Habagat, 2013	5 -Year
167	120.54548	14.66152	5.22	5.44	0.222	Habagat, 2013	5 -Year
168	120.54603	14.66182	5.47	5.44	-0.028	Habagat, 2013	5 -Year
169	120.54524	14.66189	5.03	4.44	-0.594	Habagat, 2013	5 -Year
170	120.52604	14.6375	8.10	5.80	-2.302	Habagat, 2013	5 -Year
171	120.52452	14.63615	5.70	5.13	-0.57	Habagat, 2013	5 -Year
172	120.52304	14.63481	9.27	5.85	-3.421	Habagat, 2013	5 -Year
173	120.53229	14.64245	6.11	4.90	-1.214	Habagat, 2013	5 -Year
174	120.53597	14.64335	5.02	4.60	-0.42	Habagat, 2013	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return /Scenario
	Lat	Long					
175	120.53636	14.64432	7.65	5.80	-1.853	Habagat, 2013	5 -Year
176	120.53645	14.64482	5.21	5.10	-0.111	Habagat, 2013	5 -Year
177	120.52251	14.63411	7.05	5.29	-1.762	Habagat, 2013	5 -Year
178	120.52378	14.63552	9.11	5.45	-3.661	Habagat, 2013	5 -Year
179	120.52558	14.63664	6.12	5.66	-0.458	Habagat, 2013	5 -Year
180	120.52652	14.63769	7.20	5.70	-1.501	Habagat, 2013	5 -Year

ANNEX 12. EDUCATIONAL INSTITUTIONS AFFECTED IN BALANGAFLOOD PLAIN

Bataan				
Abucay				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
CAPITANGAN ELEMENTARY SCHOOL 1	Capitangan		Medium	Medium
CAPITANGAN ELEMENTARY SCHOOL 2	Capitangan		Medium	Medium
CAPITANGAN ELEMENTARY SCHOOL 3	Capitangan		Medium	Medium
CAPITANGAN ELEMENTARY SCHOOL 4	Capitangan		Low	Medium
CAPITANGAN ELEMENTARY SCHOOL 5	Capitangan		Low	Medium
CAPITANGAN ELEMENTARY SCHOOL 6	Capitangan		Low	Low
CAPITANGAN ELEMENTARY SCHOOL 7	Capitangan		Low	Low
KALAYAAN COLLEGE BATAAN 1	Capitangan			
KALAYAAN COLLEGE BATAAN 2	Capitangan			
ST. JOSEPHS COLLEGE OF BALANGA 1	Capitangan			
ST. JOSEPHS COLLEGE OF BALANGA 2	Capitangan			
ST. JOSEPHS COLLEGE OF BALANGA 3	Capitangan			

Balanga City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BATAAN PENINSULA STATE UNIVERSITY 24	Bagong Silang	Medium	Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 25	Bagong Silang	Medium	Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 35	Bagong Silang	Medium	Medium	Medium
BAGUMBAYAN DAY CARE CENTER	Bagumbayan		Low	Medium
BALANGA ELEMENTARY SCHOOL 1	Bagumbayan		Medium	Medium
BALANGA ELEMENTARY SCHOOL 10	Bagumbayan	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 11	Bagumbayan	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 12	Bagumbayan		Medium	Medium
BALANGA ELEMENTARY SCHOOL 13	Bagumbayan	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 2	Bagumbayan	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 25	Bagumbayan		Medium	Medium
BALANGA ELEMENTARY SCHOOL 3	Bagumbayan		Low	Medium
BALANGA ELEMENTARY SCHOOL 4	Bagumbayan	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 5	Bagumbayan	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 7	Bagumbayan		Medium	Medium
BALANGA ELEMENTARY SCHOOL 8	Bagumbayan	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 9	Bagumbayan	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 12	Bagumbayan	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 14	Bagumbayan	Medium	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 15	Bagumbayan	Medium	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 17	Bagumbayan	Medium	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 23	Bagumbayan	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 36	Bagumbayan		Low	Medium

CITY OF BALANGA HIGH SCHOOL 37	Bagumbayan			Low
CITY OF BALANGA HIGH SCHOOL 38	Bagumbayan		Low	Medium
CITY OF BALANGA HIGH SCHOOL 39	Bagumbayan		Low	Medium
CITY OF BALANGA HIGH SCHOOL 4	Bagumbayan	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 40	Bagumbayan		Low	Low
CITY OF BALANGA HIGH SCHOOL 41	Bagumbayan		Low	Medium
CITY OF BALANGA HIGH SCHOOL 5	Bagumbayan		Low	Medium
CITY OF BALANGA HIGH SCHOOL 7	Bagumbayan		Medium	Medium
CITY OF BALANGA HIGH SCHOOL 8	Bagumbayan		Low	Medium
MARANTHA CHRISTIAN ACADEMY	Bagumbayan		Low	Medium
SANTA ROSA ELEMENTARY SCHOOL 1	Bagumbayan		Medium	Medium
SANTA ROSA ELEMENTARY SCHOOL 10	Bagumbayan		Medium	Medium
SANTA ROSA ELEMENTARY SCHOOL 11	Bagumbayan	Low	Medium	Medium
SANTA ROSA ELEMENTARY SCHOOL 12	Bagumbayan	Low	Medium	Medium
SANTA ROSA ELEMENTARY SCHOOL 13	Bagumbayan		Medium	Medium
SANTA ROSA ELEMENTARY SCHOOL 2	Bagumbayan	Low	Medium	Medium
SANTA ROSA ELEMENTARY SCHOOL 3	Bagumbayan		Medium	Medium
SANTA ROSA ELEMENTARY SCHOOL 4	Bagumbayan	Low	Medium	Medium
SANTA ROSA ELEMENTARY SCHOOL 5	Bagumbayan	Low	Medium	Medium
SANTA ROSA ELEMENTARY SCHOOL 6	Bagumbayan		Medium	Medium
SANTA ROSA ELEMENTARY SCHOOL 7	Bagumbayan	Low	Medium	Medium
SANTA ROSA ELEMENTARY SCHOOL 8	Bagumbayan		Low	Medium
SANTA ROSA ELEMENTARY SCHOOL 9	Bagumbayan		Low	Medium
T. CAMACHO SR. ELEMENTARY SCHOOL 1	Camacho			
T. CAMACHO SR. ELEMENTARY SCHOOL 2	Camacho			
T. CAMACHO SR. ELEMENTARY SCHOOL 3	Camacho			
T. CAMACHO SR. ELEMENTARY SCHOOL 5	Camacho			Low
T. CAMACHO SR. ELEMENTARY SCHOOL 6	Camacho			
T. CAMACHO SR. ELEMENTARY SCHOOL 7	Camacho			
ABBYWOOD LEARNING SCHOOL OF BATAAN INC. 1	Central		Low	Low
ABBYWOOD LEARNING SCHOOL OF BATAAN INC. 2	Central		Low	Low
ABBYWOOD LEARNING SCHOOL OF BATAAN INC. 3	Central			Low
ABBYWOOD LEARNING SCHOOL OF BATAAN INC. 4	Central			Low
ABBYWOOD LEARNING SCHOOL OF BATAAN INC. 5	Central			
BANI ELEMENTARY SCHOOL 1	Central			
BANI ELEMENTARY SCHOOL 2	Central			
BANI ELEMENTARY SCHOOL 3	Central			
BANI ELEMENTARY SCHOOL 4	Central			Low
BANI ELEMENTARY SCHOOL 5	Central			
BANI ELEMENTARY SCHOOL 6	Central			
BANI ELEMENTARY SCHOOL 7	Central			Low
BARRIO CENTRAL ELEMENTARY SCHOOL 1	Central		Low	Low

BARRIO CENTRAL ELEMENTARY SCHOOL 2	Central		Low	Medium
BATAAN ANGEL'S GARDEN SCHOOL 1	Central			
BATAAN ANGEL'S GARDEN SCHOOL 2	Central			
BATAAN CHRISTIAN SCHOOL 11	Central	Low	Medium	Medium
BATAAN CHRISTIAN SCHOOL 12	Central		Low	Medium
BATAAN CHRISTIAN SCHOOL 14	Central	Low	Medium	Medium
BATAAN CHRISTIAN SCHOOL 2	Central		Low	Medium
BATAAN CHRISTIAN SCHOOL 8	Central		Low	Medium
BATAAN HEROES MEMORIAL COLLEGE 7	Central		Low	Low
BATAAN HEROES MEMORIAL COLLEGE 8	Central		Low	Low
BATAAN HEROES MEMORIAL COLLEGE 9	Central			
BATAAN MONTESSORI SCHOOL, INC. 3	Central		Medium	Medium
BATAAN MONTESSORI SCHOOL, INC. 1	Central		Medium	Medium
BATAAN MONTESSORI SCHOOL, INC. 10	Central		Low	Low
BATAAN MONTESSORI SCHOOL, INC. 11	Central		Low	Low
BATAAN MONTESSORI SCHOOL, INC. 12	Central		Low	Medium
BATAAN MONTESSORI SCHOOL, INC. 13	Central		Low	Low
BATAAN MONTESSORI SCHOOL, INC. 2	Central		Medium	Medium
BATAAN MONTESSORI SCHOOL, INC. 4	Central		Low	Medium
BATAAN MONTESSORI SCHOOL, INC. 5	Central		Medium	Medium
BATAAN MONTESSORI SCHOOL, INC. 6	Central		Medium	Medium
BATAAN MONTESSORI SCHOOL, INC. 7	Central			Low
BATAAN MONTESSORI SCHOOL, INC. 8	Central		Low	Medium
BATAAN MONTESSORI SCHOOL, INC. 9	Central			Low
BTGY. CENTRAL DAY CARE	Central		Medium	Medium
DAY CARE CENTER	Central	Low	Low	Low
MIRAI DAYCARE CENTER	Central			Low
PAARALANG ELEMENTARYA NG BRGY. CENTRAL 1	Central		Medium	Medium
PAARALANG ELEMENTARYA NG BRGY. CENTRAL 2	Central		Medium	Medium
PAARALANG ELEMENTARYA NG BRGY. CENTRAL 3	Central		Low	Medium
PAARALANG ELEMENTARYA NG BRGY. CENTRAL 4	Central		Medium	Medium
PAARALANG ELEMENTARYA NG BRGY. CENTRAL 5	Central	Low	Medium	Medium
PAARALANG ELEMENTARYA NG BRGY. CENTRAL 6	Central		Medium	Medium
PAARALANG ELEMENTARYA NG BRGY. CENTRAL 7	Central		Low	Medium
PAARALANG ELEMENTARYA NG BRGY. CENTRAL 8	Central		Medium	Medium
NORTHRIDGE MONTESSORI SCHOOL 1	Cupang North	Low	Medium	Medium
NORTHRIDGE MONTESSORI SCHOOL 2	Cupang North	Low	Medium	Medium
NORTHRIDGE MONTESSORI SCHOOL 3	Cupang North		Low	Medium
NORTHRIDGE MONTESSORI SCHOOL 4	Cupang North		Low	Low
NORTHRIDGE MONTESSORI SCHOOL 5	Cupang North		Low	Medium

NORTHRIDGE MONTESSORI SCHOOL 6	Cupang North		Medium	Medium
PHILIPPINE ACADEMY OF TECHNICAL STUDIES	Cupang North	Low	Low	Medium
BATAAN CHRISTIAN SCHOOL 8	Cupang Proper		Low	Medium
BATAAN MARITIME INSTITUTE 1	Cupang Proper	Low	High	High
BATAAN MARITIME INSTITUTE 2	Cupang Proper	Medium	High	High
BATAAN MARITIME INSTITUTE 3	Cupang Proper		Medium	Medium
BATAAN MARITIME INSTITUTE 2	Cupang West	Low	High	High
BATAAN MARITIME INSTITUTE 3	Cupang West	Low	High	High
CUPANG ELEMENTARY SCHOOL 1	Cupang West		Medium	Medium
CUPANG ELEMENTARY SCHOOL 10	Cupang West		Medium	Medium
CUPANG ELEMENTARY SCHOOL 11	Cupang West		Medium	Medium
CUPANG ELEMENTARY SCHOOL 12	Cupang West		Medium	Medium
CUPANG ELEMENTARY SCHOOL 13	Cupang West		Medium	Medium
CUPANG ELEMENTARY SCHOOL 15	Cupang West		Medium	Medium
CUPANG ELEMENTARY SCHOOL 16	Cupang West	Low	Medium	Medium
CUPANG ELEMENTARY SCHOOL 17	Cupang West		Medium	Medium
CUPANG ELEMENTARY SCHOOL 2	Cupang West		Medium	Medium
CUPANG ELEMENTARY SCHOOL 3	Cupang West	Low	Medium	Medium
CUPANG ELEMENTARY SCHOOL 4	Cupang West		Medium	Medium
CUPANG ELEMENTARY SCHOOL 5	Cupang West		Medium	Medium
CUPANG ELEMENTARY SCHOOL 6	Cupang West		Medium	Medium
CUPANG ELEMENTARY SCHOOL 7	Cupang West		Medium	Medium
CUPANG ELEMENTARY SCHOOL 8	Cupang West		Medium	Medium
DAY CARE CENTER	Dangcol		High	High
NAGWALING ELEMENTARY SCHOOL 1	Dangcol		Medium	High
NAGWALING ELEMENTARY SCHOOL 2	Dangcol		Medium	High
NAGWALING ELEMENTARY SCHOOL 3	Dangcol		Medium	Medium
NAGWALING ELEMENTARY SCHOOL 4	Dangcol		Medium	Medium
NAGWALING ELEMENTARY SCHOOL 5	Dangcol		Medium	Medium
NAGWALING ELEMENTARY SCHOOL 6	Dangcol			Medium
NAGWALING ELEMENTARY SCHOOL 7	Dangcol			Medium
M.P.CUADERNO SR. MEMORIAL ELEMENTARY SCHOOL 1	Doña Francisca	Low	Medium	Medium
M.P.CUADERNO SR. MEMORIAL ELEMENTARY SCHOOL 2	Doña Francisca		Medium	Medium
M.P.CUADERNO SR. MEMORIAL ELEMENTARY SCHOOL 3	Doña Francisca	Low	Medium	Medium
M.P.CUADERNO SR. MEMORIAL ELEMENTARY SCHOOL 4	Doña Francisca	Medium	Medium	Medium
M.P.CUADERNO SR. MEMORIAL ELEMENTARY SCHOOL 5	Doña Francisca		Medium	Medium
M.P.CUADERNO SR. MEMORIAL ELEMENTARY SCHOOL 6	Doña Francisca		Medium	Medium
M.P.CUADERNO SR. MEMORIAL ELEMENTARY SCHOOL 7	Doña Francisca	Low	Medium	Medium
M.P.CUADERNO SR. MEMORIAL ELEMENTARY SCHOOL 8	Doña Francisca		Medium	Medium

M.P.CUADERNO SR. MEMORIAL ELEMENTARY SCHOOL 9	Doña Francisca	Low	Medium	Medium
PUERTO RIVAS ELEMENTARY SCHOOL 2	Doña Francisca		Low	Low
PUERTO RIVAS ELEMENTARY SCHOOL 3	Doña Francisca			
PUERTO RIVAS ELEMENTARY SCHOOL 4	Doña Francisca			
PUERTO RIVAS ELEMENTARY SCHOOL 5	Doña Francisca			
PUERTO RIVAS ELEMENTARY SCHOOL 6	Doña Francisca			Low
ST. JOSEPH CHILD DEVELOPMENT CENTER INC. 1	Doña Francisca		Medium	Medium
ST. JOSEPH CHILD DEVELOPMENT CENTER INC. 2	Doña Francisca	Low	Medium	Medium
ASIA PACIFIC COLLEGE OF ADVANCED STUDIES 2	Ibayo	Low	Medium	Medium
ASIA PACIFIC COLLEGE OF ADVANCED STUDIES 3	Ibayo			Low
ASIA PACIFIC COLLEGE OF ADVANCED STUDIES 4	Ibayo	High	High	High
BATAAN PENINSULA STATE UNIVERSITY 24	Ibayo	Medium	Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 25	Ibayo			
BATAAN PENINSULA STATE UNIVERSITY 35	Ibayo	Medium	Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 40	Ibayo	Low	Medium	Medium
BRGY. MALABIA DAY CARE CENTER	Ibayo	Medium	Medium	Medium
EASTWOODS COLLEGE OF SCIENCE AND TECHNOLOGY	Ibayo	Medium	Medium	High
BAGONG SILANG ELEMENTARY SCHOOL 1	Lote			
BAGONG SILANG ELEMENTARY SCHOOL 2	Lote			
BAGONG SILANG ELEMENTARY SCHOOL 3	Lote			
BAGONG SILANG ELEMENTARY SCHOOL 4	Lote			
BAGONG SILANG ELEMENTARY SCHOOL 5	Lote		Low	Low
BAGONG SILANG ELEMENTARY SCHOOL 6	Lote			
BAGONG SILANG ELEMENTARY SCHOOL 7	Lote	Low	Low	Low
BAGONG SILANG ELEMENTARY SCHOOL 8	Lote	Low	Low	Low
BAGONG SILANG ELEMENTARY SCHOOL 9	Lote			
BATAAN HEROES MEMORIAL COLLEGE 1	Lote			
BATAAN NATIONAL HIGH SCHOOL 1	Lote			
BATAAN NATIONAL HIGH SCHOOL 12	Lote			
BATAAN NATIONAL HIGH SCHOOL 13	Lote	Low	Low	Low
BATAAN NATIONAL HIGH SCHOOL 14	Lote	Low	Low	Low
BATAAN NATIONAL HIGH SCHOOL 15	Lote	Low	Low	Low
BATAAN NATIONAL HIGH SCHOOL 16	Lote			
BATAAN NATIONAL HIGH SCHOOL 19	Lote			
BATAAN NATIONAL HIGH SCHOOL 20	Lote			
BATAAN NATIONAL HIGH SCHOOL 21	Lote			
BATAAN NATIONAL HIGH SCHOOL 22	Lote	Low	Low	Low
BATAAN NATIONAL HIGH SCHOOL 23	Lote			
BATAAN NATIONAL HIGH SCHOOL 24	Lote			
BATAAN NATIONAL HIGH SCHOOL 25	Lote			
BATAAN NATIONAL HIGH SCHOOL 26	Lote			

BATAAN NATIONAL HIGH SCHOOL 28	Lote			
BATAAN NATIONAL HIGH SCHOOL 29	Lote			
BATAAN NATIONAL HIGH SCHOOL 30	Lote			
BATAAN NATIONAL HIGH SCHOOL 31	Lote			
BATAAN NATIONAL HIGH SCHOOL 33	Lote			
BATAAN NATIONAL HIGH SCHOOL 34	Lote			
BATAAN NATIONAL HIGH SCHOOL 35	Lote			
BATAAN NATIONAL HIGH SCHOOL 6	Lote			
BATAAN NATIONAL HIGH SCHOOL 7	Lote	Low	Low	Low
BATAAN NATIONAL HIGH SCHOOL 8	Lote	Medium	Medium	Medium
BATAAN NATIONAL HIGH SCHOOL 9	Lote			
DAY CARE CENTER 1	Lote	Low	Low	Low
DAY CARE CENTER 2	Lote			Low
JIL CHRISTIAN SCHOOL	Lote			
ALTERNATIVE LEARNING SYSTEM	Malabia		Medium	Medium
BALANGA ELEMENTARY SCHOOL 13	Malabia	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 14	Malabia	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 15	Malabia	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 16	Malabia	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 17	Malabia	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 18	Malabia	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 19	Malabia	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 20	Malabia	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 21	Malabia	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 22	Malabia	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 23	Malabia	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 24	Malabia	Low	Medium	Medium
BALANGA ELEMENTARY SCHOOL 25	Malabia		Medium	Medium
BALANGA ELEMENTARY SCHOOL 5	Malabia	Low	Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 11	Malabia	Medium	Medium	High
BATAAN PENINSULA STATE UNIVERSITY 13	Malabia	Medium	Medium	High
BATAAN PENINSULA STATE UNIVERSITY 2	Malabia	Medium	Medium	High
BATAAN PENINSULA STATE UNIVERSITY 24	Malabia	Medium	Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 4	Malabia	Medium	Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 42	Malabia	Medium	Medium	High
BATAAN PENINSULA STATE UNIVERSITY 44	Malabia		Low	Medium
BATAAN PENINSULA STATE UNIVERSITY 45	Malabia		Low	Medium
BATAAN PENINSULA STATE UNIVERSITY 47	Malabia	Medium	Medium	High
BATAAN PENINSULA STATE UNIVERSITY 5	Malabia	Medium	Medium	High
BATAAN PENINSULA STATE UNIVERSITY 50	Malabia	Medium	Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 53	Malabia		Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 54	Malabia	Low	Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 55	Malabia		Low	Medium
BATAAN PENINSULA STATE UNIVERSITY 9	Malabia	Medium	High	High
BRGY. TALISAY DAY CARE CENTER 1	Malabia		Low	Low
BRGY. TALISAY DAY CARE CENTER 2	Malabia		Low	Medium

CITY OF BALANGA HIGH SCHOOL 24	Malabia		Low	Medium
CITY OF BALANGA HIGH SCHOOL 25	Malabia	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 26	Malabia	Medium	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 27	Malabia		Medium	Medium
CITY OF BALANGA HIGH SCHOOL 28	Malabia	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 29	Malabia		Medium	Medium
CITY OF BALANGA HIGH SCHOOL 30	Malabia	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 31	Malabia	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 32	Malabia	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 33	Malabia	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 34	Malabia		Medium	Medium
CITY OF BALANGA HIGH SCHOOL 35	Malabia	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 5	Malabia	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 7	Malabia		Medium	Medium
SCHOOLS DIVISION OF CITY OF BALANGA 1	Malabia	Low	Medium	Medium
SCHOOLS DIVISION OF CITY OF BALANGA 2	Malabia		Low	Medium
SCHOOLS DIVISION OF CITY OF BALANGA 4	Malabia	Low	Medium	Medium
SCHOOLS DIVISION OF CITY OF BALANGA 5	Malabia	Low	Medium	Medium
SCHOOLS DIVISION OF CITY OF BALANGA 6	Malabia	Medium	Medium	Medium
BATAAN NATIONAL HIGH SCHOOL 10	Munting Batangas			
BATAAN NATIONAL HIGH SCHOOL 11	Munting Batangas			
BATAAN NATIONAL HIGH SCHOOL 13	Munting Batangas	Low	Low	Low
BATAAN NATIONAL HIGH SCHOOL 17	Munting Batangas			
BATAAN NATIONAL HIGH SCHOOL 18	Munting Batangas			
BATAAN NATIONAL HIGH SCHOOL 2	Munting Batangas			
BATAAN NATIONAL HIGH SCHOOL 27	Munting Batangas			
BATAAN NATIONAL HIGH SCHOOL 3	Munting Batangas			
BATAAN NATIONAL HIGH SCHOOL 32	Munting Batangas			
BATAAN NATIONAL HIGH SCHOOL 33	Munting Batangas			
BATAAN NATIONAL HIGH SCHOOL 34	Munting Batangas			
BATAAN NATIONAL HIGH SCHOOL 36	Munting Batangas			
BATAAN NATIONAL HIGH SCHOOL 4	Munting Batangas			
BATAAN NATIONAL HIGH SCHOOL 5	Munting Batangas			
BATAAN NATIONAL HIGH SCHOOL 6	Munting Batangas			

OUR LADY OF LOURDES ELEMENTARY SCHOOL 1	Munting Batangas			
OUR LADY OF LOURDES ELEMENTARY SCHOOL 10	Munting Batangas			
OUR LADY OF LOURDES ELEMENTARY SCHOOL 2	Munting Batangas			
OUR LADY OF LOURDES ELEMENTARY SCHOOL 3	Munting Batangas			
OUR LADY OF LOURDES ELEMENTARY SCHOOL 4	Munting Batangas	Low	Low	Low
OUR LADY OF LOURDES ELEMENTARY SCHOOL 5	Munting Batangas	Low	Low	Medium
OUR LADY OF LOURDES ELEMENTARY SCHOOL 6	Munting Batangas			
OUR LADY OF LOURDES ELEMENTARY SCHOOL 7	Munting Batangas		Low	Low
OUR LADY OF LOURDES ELEMENTARY SCHOOL 8	Munting Batangas			
OUR LADY OF LOURDES ELEMENTARY SCHOOL 9	Munting Batangas			
JOSEFA B. SIOSON MEMORIAL SCHOOL FOUNDATION INC.	Poblacion	Medium	Medium	High
ST. JOSEPH CITY SCHOOL OF BALANGA	Poblacion	Low	Medium	Medium
TORTUGAS ELEMENTARY SCHOOL 1	Pto. Rivas Ibaba			
TORTUGAS ELEMENTARY SCHOOL 10	Pto. Rivas Ibaba			Low
TORTUGAS ELEMENTARY SCHOOL 2	Pto. Rivas Ibaba			
TORTUGAS ELEMENTARY SCHOOL 3	Pto. Rivas Ibaba			
TORTUGAS ELEMENTARY SCHOOL 4	Pto. Rivas Ibaba			
TORTUGAS ELEMENTARY SCHOOL 5	Pto. Rivas Ibaba			
TORTUGAS ELEMENTARY SCHOOL 6	Pto. Rivas Ibaba			
TORTUGAS ELEMENTARY SCHOOL 7	Pto. Rivas Ibaba			
BALUT ELEMENTARY SCHOOL 1	Pto. Rivas Itaas		Low	Low
BALUT ELEMENTARY SCHOOL 10	Pto. Rivas Itaas		Low	Medium
BALUT ELEMENTARY SCHOOL 2	Pto. Rivas Itaas	Low	Medium	Medium
BALUT ELEMENTARY SCHOOL 3	Pto. Rivas Itaas		Low	Medium
BALUT ELEMENTARY SCHOOL 4	Pto. Rivas Itaas		Medium	Medium
BALUT ELEMENTARY SCHOOL 5	Pto. Rivas Itaas	Low	Medium	Medium
BALUT ELEMENTARY SCHOOL 6	Pto. Rivas Itaas		Low	Medium
BALUT ELEMENTARY SCHOOL 7	Pto. Rivas Itaas		Low	Medium
BALUT ELEMENTARY SCHOOL 8	Pto. Rivas Itaas		Low	Medium
BALUT ELEMENTARY SCHOOL 9	Pto. Rivas Itaas		Low	Medium
DAY CARE CENTER	Pto. Rivas Itaas			Low

PANG-ALAALANG PAARALANG ELEMENTARYA NG M. DELOS REYES 1	Pto. Rivas Itaas	Low	Low	Medium
PANG-ALAALANG PAARALANG ELEMENTARYA NG M. DELOS REYES 10	Pto. Rivas Itaas	Low	Low	Medium
PANG-ALAALANG PAARALANG ELEMENTARYA NG M. DELOS REYES 11	Pto. Rivas Itaas	Low	Low	Medium
PANG-ALAALANG PAARALANG ELEMENTARYA NG M. DELOS REYES 12	Pto. Rivas Itaas			Low
PANG-ALAALANG PAARALANG ELEMENTARYA NG M. DELOS REYES 13	Pto. Rivas Itaas	Low	Low	Medium
PANG-ALAALANG PAARALANG ELEMENTARYA NG M. DELOS REYES 2	Pto. Rivas Itaas	Low	Low	Medium
PANG-ALAALANG PAARALANG ELEMENTARYA NG M. DELOS REYES 3	Pto. Rivas Itaas		Low	Medium
PANG-ALAALANG PAARALANG ELEMENTARYA NG M. DELOS REYES 4	Pto. Rivas Itaas	Low	Low	Medium
PANG-ALAALANG PAARALANG ELEMENTARYA NG M. DELOS REYES 5	Pto. Rivas Itaas		Low	Low
PANG-ALAALANG PAARALANG ELEMENTARYA NG M. DELOS REYES 7	Pto. Rivas Itaas	Low	Low	Medium
PANG-ALAALANG PAARALANG ELEMENTARYA NG M. DELOS REYES 8	Pto. Rivas Itaas	Low	Low	Medium
PANG-ALAALANG PAARALANG ELEMENTARYA NG M. DELOS REYES 9	Pto. Rivas Itaas		Low	Medium
ASIA PACIFIC COLLEGE OF ADVANCED STUDIES 1	San Jose	Medium	High	High
ASIA PACIFIC COLLEGE OF ADVANCED STUDIES 2	San Jose	Low	Medium	Medium
ASIA PACIFIC COLLEGE OF ADVANCED STUDIES 3	San Jose			Low
ASIA PACIFIC COLLEGE OF ADVANCED STUDIES 4	San Jose	High	High	High
BATAAN HEROES MEMORIAL COLLEGE 2	San Jose			
BATAAN HEROES MEMORIAL COLLEGE 3	San Jose			
BATAAN HEROES MEMORIAL COLLEGE 4	San Jose			
BATAAN HEROES MEMORIAL COLLEGE 5	San Jose			
BATAAN HEROES MEMORIAL COLLEGE 6	San Jose			
CATANING ELEMENTARY SCHOOL 1	San Jose	Low	Medium	Medium
CATANING ELEMENTARY SCHOOL 10	San Jose	Low	Medium	Medium
CATANING ELEMENTARY SCHOOL 11	San Jose		Medium	Medium
CATANING ELEMENTARY SCHOOL 12	San Jose		Medium	Medium
CATANING ELEMENTARY SCHOOL 13	San Jose	Low	Medium	Medium
CATANING ELEMENTARY SCHOOL 2	San Jose	Low	Medium	Medium
CATANING ELEMENTARY SCHOOL 3	San Jose	Low	Medium	Medium
CATANING ELEMENTARY SCHOOL 4	San Jose	Low	Medium	Medium
CATANING ELEMENTARY SCHOOL 5	San Jose		Medium	Medium
CATANING ELEMENTARY SCHOOL 6	San Jose	Low	Medium	Medium
CATANING ELEMENTARY SCHOOL 7	San Jose	Low	Medium	Medium
CATANING ELEMENTARY SCHOOL 8	San Jose			
CATANING ELEMENTARY SCHOOL 9	San Jose	Low	Medium	Medium

CRIZELDA MARIE BUILDING 1	San Jose	Low	Medium	Medium
CRIZELDA MARIE BUILDING 2	San Jose		Low	Medium
DAY CARE CENTER	San Jose	Low	Medium	Medium
EASTWOODS COLLEGE OF SCIENCE AND TECHNOLOGY	San Jose	Medium	Medium	Medium
TOMAS DEL ROSARIO COLLEGE 1	San Jose	Medium	Medium	Medium
TOMAS DEL ROSARIO COLLEGE 10	San Jose		Low	Medium
TOMAS DEL ROSARIO COLLEGE 11	San Jose	Low	Medium	Medium
TOMAS DEL ROSARIO COLLEGE 12	San Jose	Medium	Medium	Medium
TOMAS DEL ROSARIO COLLEGE 13	San Jose	Medium	Medium	Medium
TOMAS DEL ROSARIO COLLEGE 14	San Jose	Low	Medium	Medium
TOMAS DEL ROSARIO COLLEGE 15	San Jose	Low	Medium	Medium
TOMAS DEL ROSARIO COLLEGE 2	San Jose	Medium	Medium	Medium
TOMAS DEL ROSARIO COLLEGE 3	San Jose			
TOMAS DEL ROSARIO COLLEGE 4	San Jose			
TOMAS DEL ROSARIO COLLEGE 5	San Jose		Low	Medium
TOMAS DEL ROSARIO COLLEGE 6	San Jose	Medium	Medium	Medium
TOMAS DEL ROSARIO COLLEGE 7	San Jose	Low	Medium	Medium
TOMAS DEL ROSARIO COLLEGE 8	San Jose	Medium	Medium	Medium
TOMAS DEL ROSARIO COLLEGE 9	San Jose	Medium	Medium	High
BRGY. TALISAY DAY CARE CENTER 2	Talisay			Low
CITY OF BALANGA HIGH SCHOOL 1	Talisay	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 10	Talisay	Medium	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 11	Talisay	Medium	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 12	Talisay	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 13	Talisay		Medium	Medium
CITY OF BALANGA HIGH SCHOOL 15	Talisay			
CITY OF BALANGA HIGH SCHOOL 16	Talisay	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 17	Talisay	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 18	Talisay	Medium	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 19	Talisay	Medium	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 2	Talisay	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 20	Talisay	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 21	Talisay	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 22	Talisay	Medium	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 23	Talisay		Low	Medium
CITY OF BALANGA HIGH SCHOOL 27	Talisay	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 30	Talisay	Low	Medium	Medium
CITY OF BALANGA HIGH SCHOOL 5	Talisay		Medium	Medium
CITY OF BALANGA HIGH SCHOOL 6	Talisay		Medium	Medium
CITY OF BALANGA HIGH SCHOOL 8	Talisay		Low	Medium
CITY OF BALANGA HIGH SCHOOL 9	Talisay		Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 56	Tenejero	Low	Low	Low
BATAAN PENINSULA STATE UNIVERSITY 1	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 10	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 12	Tenejero	Medium	Medium	Medium

BATAAN PENINSULA STATE UNIVERSITY 14	Tenejero	Low	Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 15	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 16	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 17	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 18	Tenejero	Low	Low	Medium
BATAAN PENINSULA STATE UNIVERSITY 19	Tenejero	Medium	Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 20	Tenejero	Low	Medium	Medium
BATAAN PENINSULA STATE UNIVERSITY 21	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 22	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 23	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 26	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 27	Tenejero	Low	Low	Low
BATAAN PENINSULA STATE UNIVERSITY 28	Tenejero	Low	Low	Low
BATAAN PENINSULA STATE UNIVERSITY 29	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 3	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 30	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 31	Tenejero			Low
BATAAN PENINSULA STATE UNIVERSITY 32	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 33	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 34	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 36	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 37	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 38	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 39	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 41	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 43	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 46	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 48	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 49	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 51	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 52	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 6	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 7	Tenejero			
BATAAN PENINSULA STATE UNIVERSITY 8	Tenejero			
MICROCITY COMPUTER COLLEGE FOUNDATION, INC.	Tenejero		Low	Medium
TENEJERO ELEMENTARY SCHOOL 1	Tenejero		Low	Low
TENEJERO ELEMENTARY SCHOOL 10	Tenejero		Low	Low
TENEJERO ELEMENTARY SCHOOL 11	Tenejero			
TENEJERO ELEMENTARY SCHOOL 12	Tenejero	Low	Low	Low
TENEJERO ELEMENTARY SCHOOL 13	Tenejero			
TENEJERO ELEMENTARY SCHOOL 14	Tenejero			
TENEJERO ELEMENTARY SCHOOL 15	Tenejero			
TENEJERO ELEMENTARY SCHOOL 2	Tenejero			
TENEJERO ELEMENTARY SCHOOL 3	Tenejero			
TENEJERO ELEMENTARY SCHOOL 4	Tenejero	Low	Low	Low

TENEJERO ELEMENTARY SCHOOL 5	Tenejero			
TENEJERO ELEMENTARY SCHOOL 6	Tenejero			
TENEJERO ELEMENTARY SCHOOL 7	Tenejero			
TENEJERO ELEMENTARY SCHOOL 8	Tenejero			Low
TENEJERO ELEMENTARY SCHOOL 9	Tenejero			Low
VILLA LINA DAY CARE CENTER	Tenejero		Low	Low
TORTUGAS DAY CARE CENTER	Tortugas			
TORTUGAS ELEMENTARY SCHOOL 10	Tortugas	Low	Low	Low
TORTUGAS ELEMENTARY SCHOOL 5	Tortugas			
TORTUGAS ELEMENTARY SCHOOL 6	Tortugas			Low
TORTUGAS ELEMENTARY SCHOOL 7	Tortugas			
TORTUGAS ELEMENTARY SCHOOL 8	Tortugas			
TORTUGAS ELEMENTARY SCHOOL 9	Tortugas			
TORTUGAS LEARNING CENTER FOR CHILDREN INC.	Tortugas			
CAMACHO BARANGAY DAY CARE CENTER	Tuyo			
G.L. DAVID MEM. ELEMENTARY SCHOOL 1	Tuyo			
G.L. DAVID MEM. ELEMENTARY SCHOOL 2	Tuyo			
G.L. DAVID MEM. ELEMENTARY SCHOOL 3	Tuyo			
G.L. DAVID MEM. ELEMENTARY SCHOOL 4	Tuyo			
G.L. DAVID MEM. ELEMENTARY SCHOOL 5	Tuyo			
G.L. DAVID MEM. ELEMENTARY SCHOOL 6	Tuyo			
G.L. DAVID MEM. ELEMENTARY SCHOOL 7	Tuyo			
G.L. DAVID MEM. ELEMENTARY SCHOOL 8	Tuyo			
G.L. DAVID MEM. ELEMENTARY SCHOOL 9	Tuyo			

Pilar				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ALA-ULI ELEMENTARY SCHOOL 9	Ala-Uli	Low	Medium	Medium
ALAULI ELEMENTARY SCHOOL 1	Ala-Uli	Medium	High	High
ALAULI ELEMENTARY SCHOOL 10	Ala-Uli	Low	Medium	Medium
ALAULI ELEMENTARY SCHOOL 11	Ala-Uli		Medium	Medium
ALAULI ELEMENTARY SCHOOL 12	Ala-Uli		Medium	Medium
ALAULI ELEMENTARY SCHOOL 13	Ala-Uli	Low	Medium	Medium
ALAULI ELEMENTARY SCHOOL 2	Ala-Uli	Medium	Medium	High
ALAULI ELEMENTARY SCHOOL 3	Ala-Uli	Medium	High	High
ALAULI ELEMENTARY SCHOOL 4	Ala-Uli	Medium	High	High
ALAULI ELEMENTARY SCHOOL 5	Ala-Uli	Medium	High	High
ALAULI ELEMENTARY SCHOOL 6	Ala-Uli	Medium	Medium	High
ALAULI ELEMENTARY SCHOOL 7	Ala-Uli	Low	Medium	Medium
ALAULI ELEMENTARY SCHOOL 8	Ala-Uli	Low	Medium	Medium
BAGUMBAYAN ELEMENTARY SCHOOL 1	Bagumbayan		Medium	High
BAGUMBAYAN ELEMENTARY SCHOOL 11	Bagumbayan	Low	Medium	High
BAGUMBAYAN ELEMENTARY SCHOOL 2	Bagumbayan		Medium	High
BAGUMBAYAN ELEMENTARY SCHOOL 3	Bagumbayan		Medium	Medium

BAGUMBAYAN ELEMENTARY SCHOOL 4	Bagumbayan		Medium	Medium
BAGUMBAYAN ELEMENTARY SCHOOL 5	Bagumbayan		Medium	High
BAGUMBAYAN ELEMENTARY SCHOOL 6	Bagumbayan		Medium	High
BAGUMBAYAN ELEMENTARY SCHOOL 7	Bagumbayan		Medium	High
BAGUMBAYAN ELEMENTARY SCHOOL 8	Bagumbayan		Medium	Medium
BAGUMBAYAN ELEMENTARY SCHOOL 9	Bagumbayan		Medium	Medium
BATAAN CHRISTIAN SCHOOL 1	Del Rosario		Low	Medium
BATAAN CHRISTIAN SCHOOL 11	Del Rosario		Medium	Medium
BATAAN CHRISTIAN SCHOOL 12	Del Rosario		Low	Medium
BATAAN CHRISTIAN SCHOOL 13	Del Rosario	Low	Medium	Medium
BATAAN CHRISTIAN SCHOOL 14	Del Rosario			
BATAAN CHRISTIAN SCHOOL 15	Del Rosario		Low	Medium
BATAAN CHRISTIAN SCHOOL 16	Del Rosario		Low	Medium
BATAAN CHRISTIAN SCHOOL 3	Del Rosario		Medium	Medium
BATAAN CHRISTIAN SCHOOL 4	Del Rosario		Low	Medium
BATAAN CHRISTIAN SCHOOL 5	Del Rosario		Medium	Medium
BATAAN CHRISTIAN SCHOOL 6	Del Rosario		Medium	Medium
BATAAN CHRISTIAN SCHOOL 7	Del Rosario		Medium	Medium
BATAAN CHRISTIAN SCHOOL 8	Del Rosario		Low	Medium
BATAAN CHRISTIAN SCHOOL 9	Del Rosario		Medium	Medium
DIWA ELEMENTARY SCHOOL 1	Diwa			
DIWA ELEMENTARY SCHOOL 2	Diwa			
DIWA ELEMENTARY SCHOOL 3	Diwa			
DIWA ELEMENTARY SCHOOL 4	Diwa			
DIWA ELEMENTARY SCHOOL 5	Diwa			
BAGUMBAYAN ELEMENTARY SCHOOL 12	Landing		Medium	Medium
BAGUMBAYAN ELEMENTARY SCHOOL 7	Landing		Medium	Medium
DAY CARE CENTER	Landing			Low
LIYANG ELEMENTARY SCHOOL 1	Liyang		Low	Low
LIYANG ELEMENTARY SCHOOL 2	Liyang			
LIYANG ELEMENTARY SCHOOL 3	Liyang			
LIYANG ELEMENTARY SCHOOL 5	Liyang			
DAY CARE CENTER (GEN. LIM)	Nagwaling			
GEN. LIM ELEMENTARY SCHOOL 1	Nagwaling			
GEN. LIM ELEMENTARY SCHOOL 3	Nagwaling			
GEN. LIM ELEMENTARY SCHOOL 4	Nagwaling			
GEN. LIM ELEMENTARY SCHOOL 5	Nagwaling			
GEN. LIM ELEMENTARY SCHOOL 6	Nagwaling			
GEN. LIM ELEMENTARY SCHOOL 7	Nagwaling			
GEN. LIM ELEMENTRAY SCHOOL 2	Nagwaling			
DAY CARE CENTER	Panilao		Medium	Medium
NORTHRIDGE MONTESSORI SCHOOL 3	Panilao		Low	Medium
NORTHRIDGE MONTESSORI SCHOOL 4	Panilao			
NORTHRIDGE MONTESSORI SCHOOL 6	Panilao		Medium	Medium
PABLO RAMON NATIONAL HIGH SCHOOL 1	Panilao		Medium	Medium
PABLO RAMON NATIONAL HIGH SCHOOL 19	Panilao		Medium	Medium

PABLO ROMAN NATIONAL HIGH SCHOOL 10	Panilao		Medium	Medium
PABLO ROMAN NATIONAL HIGH SCHOOL 11	Panilao	Low	Medium	Medium
PABLO ROMAN NATIONAL HIGH SCHOOL 12	Panilao			Low
PABLO ROMAN NATIONAL HIGH SCHOOL 13	Panilao			Low
PABLO ROMAN NATIONAL HIGH SCHOOL 14	Panilao		Low	Medium
PABLO ROMAN NATIONAL HIGH SCHOOL 15	Panilao		Low	Medium
PABLO ROMAN NATIONAL HIGH SCHOOL 16	Panilao		Medium	Medium
PABLO ROMAN NATIONAL HIGH SCHOOL 17	Panilao	Low	Medium	Medium
PABLO ROMAN NATIONAL HIGH SCHOOL 18	Panilao		Medium	Medium
PABLO ROMAN NATIONAL HIGH SCHOOL 3	Panilao		Low	Medium
PABLO ROMAN NATIONAL HIGH SCHOOL 4	Panilao		Low	Medium
PABLO ROMAN NATIONAL HIGH SCHOOL 5	Panilao		Medium	Medium
PABLO ROMAN NATIONAL HIGH SCHOOL 6	Panilao		Low	Medium
PABLO ROMAN NATIONAL HIGH SCHOOL 7	Panilao		Medium	Medium
PABLO ROMAN NATIONAL HIGH SCHOOL 8	Panilao		Medium	Medium
PABLO ROMAN NATIONAL HIGH SCHOOL 9	Panilao	Low	Medium	Medium
PANILAO ELEMENTARY SCHOOL 1	Panilao	Low	Medium	Medium
PANILAO ELEMENTARY SCHOOL 10	Panilao	Low	Medium	Medium
PANILAO ELEMENTARY SCHOOL 11	Panilao		Medium	Medium
PANILAO ELEMENTARY SCHOOL 12	Panilao		Low	Medium
PANILAO ELEMENTARY SCHOOL 13	Panilao	Low	Medium	Medium
PANILAO ELEMENTARY SCHOOL 2	Panilao	Low	Medium	Medium
PANILAO ELEMENTARY SCHOOL 3	Panilao	Low	Medium	Medium
PANILAO ELEMENTARY SCHOOL 4	Panilao	Low	Medium	Medium
PANILAO ELEMENTARY SCHOOL 5	Panilao	Low	Medium	Medium
PANILAO ELEMENTARY SCHOOL 6	Panilao	Low	Medium	Medium
PANILAO ELEMENTARY SCHOOL 7	Panilao		Medium	Medium
PANILAO ELEMENTARY SCHOOL 8	Panilao		Medium	Medium
PANILAO ELEMENTARY SCHOOL 9	Panilao	Low	Medium	Medium
PHILIPPINE ACADEMY OF TECHNICAL STUDIES	Panilao		Low	Low
WELLCARE INSTITUTE OF SCIENCE AND TECHNOLOGY/BATAAN ACADEMIA SCHOOL FOR SKILLS TRAINING 1	Panilao			Low
WELLCARE INSTITUTE OF SCIENCE AND TECHNOLOGY/BATAAN ACADEMIA SCHOOL FOR SKILLS TRAINING 2	Panilao		Medium	Medium
J.S. HERRERA SR. MEMORIAL ELEMENTARY SCHOOL 1	Poblacion		Medium	High
J.S. HERRERA SR. MEMORIAL ELEMENTARY SCHOOL 2	Poblacion		Medium	Medium
J.S. HERRERA SR. MEMORIAL ELEMENTARY SCHOOL 3	Poblacion		Medium	Medium
J.S. HERRERA SR. MEMORIAL ELEMENTARY SCHOOL 4	Poblacion		Medium	High
J.S. HERRERA SR. MEMORIAL ELEMENTARY SCHOOL 5	Poblacion		Medium	Medium
J.S. HERRERA SR. MEMORIAL ELEMENTARY SCHOOL 6	Poblacion	Low	Medium	High

J.S. HERRERA SR. MEMORIAL ELEMENTARY SCHOOL 7	Poblacion		Medium	Medium
J.S. HERRERA SR. MEMORIAL ELEMENTARY SCHOOL 8	Poblacion		Medium	High
J.S. HERRERA SR. MEMORIAL ELEMENTARY SCHOOL 9	Poblacion	Low	Medium	High
PILAR ELEMENTARY SCHOOL 1	Poblacion	Low	Medium	High
PILAR ELEMENTARY SCHOOL 10	Poblacion		Medium	High
PILAR ELEMENTARY SCHOOL 11	Poblacion		Medium	Medium
PILAR ELEMENTARY SCHOOL 12	Poblacion		Medium	Medium
PILAR ELEMENTARY SCHOOL 13	Poblacion		Medium	Medium
PILAR ELEMENTARY SCHOOL 14	Poblacion		Medium	Medium
PILAR ELEMENTARY SCHOOL 15	Poblacion		Medium	Medium
PILAR ELEMENTARY SCHOOL 16	Poblacion		Medium	Medium
PILAR ELEMENTARY SCHOOL 17	Poblacion	Low	Medium	High
PILAR ELEMENTARY SCHOOL 3	Poblacion		Medium	Medium
PILAR ELEMENTARY SCHOOL 4	Poblacion	Low	Medium	High
PILAR ELEMENTARY SCHOOL 5	Poblacion	Low	Medium	High
PILAR ELEMENTARY SCHOOL 6	Poblacion		Medium	High
PILAR ELEMENTARY SCHOOL 7	Poblacion		Medium	High
PILAR ELEMENTARY SCHOOL 8	Poblacion	Low	High	High
PILAR ELEMENTARY SCHOOL 9	Poblacion	Low	Medium	High
THE SHINING PILLAR SCHOOL 1	Poblacion	Low	High	High
THE SHINING PILLAR SCHOOL 2	Poblacion	Low	Medium	High
PHILIPPINE ACADEMY OF TECHNICAL STUDIES	Santa Rosa		Low	Low

ANNEX 13. MEDICAL INSTITUTIONS AFFECTED IN BALANGA FLOOD PLAIN

Bataan				
Balanga City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
SACRED HEART PEDIATRIC CLINIC	Bagong Silang	Low	Medium	Medium
DE OCAMPO DENTAL LABORATORY	Bagumbayan		Low	Medium
BATAAN KIDNEY DIALYSIS CENTER	Ibayo	Medium	Medium	Medium
ISAAC & CATALINA MEDICAL CENTER	Ibayo	Medium	Medium	Medium
SEVILLA CLINICAL LABORATORY	Ibayo	Medium	Medium	Medium
ST. JOSEPH HOSPITAL	Ibayo	Low	Medium	Medium
ALAMANI MEDICAL CENTER 1	Malabia	Low	Medium	Medium
ALAMANI MEDICAL CENTER 2	Malabia	Low	Medium	Medium
BATAAN DOCTOR'S HOSPITAL 1	Malabia	Medium	Medium	Medium
BATAAN DOCTOR'S HOSPITAL 2	Malabia	Low	Medium	Medium
BATAAN DOCTOR'S HOSPITAL 3	Malabia	Low	Medium	Medium
BATAAN DOCTOR'S HOSPITAL 4	Malabia	Low	Medium	Medium
CABANAG CLINIC	Malabia		Medium	Medium
DENTAL, OB-GYN AND OPTICAL CLINIC	Malabia	Low	Medium	Medium
DENTISTA PO! DENTAL CLINIC	Malabia	Low	Medium	Medium
LBL DENTAL CLINIC	Malabia	Low	Medium	Medium
MANALO DENTAL CLINIC	Malabia	Low	Medium	Medium
SEVILLA CLINICAL LABORATORY	Malabia	Low	Medium	Medium
STROKE, EPILEPSY AND HEADACHE CLINIC	Malabia	Low	Medium	Medium
CLINIC	Poblacion		Low	Medium
SACRED HEART PEDIATRIC CLINIC	Poblacion		Medium	Medium
BATAAN DIAGNOSTIC CLINIC	San Jose	Low	Medium	Medium
BATAAN KIDNEY DIALYSIS CENTER	San Jose	Medium	Medium	High
BATAAN WOMEN'S HOSPITAL	San Jose	Medium	Medium	Medium
CLINICA NEPHROLEGIA DIALYSIS CENTER	San Jose			Low
DELA CRUZ DENTAL CLINIC	San Jose	Low	Medium	Medium
LABTECH DIAGNOSTIC CENTER	San Jose	Low	Medium	Medium
TOTAL CARE DENTAL CLINIC	San Jose	Low	Medium	Medium
BATAAN GENERAL HOSPITAL 1	Tenejero			
BATAAN GENERAL HOSPITAL 10	Tenejero			
BATAAN GENERAL HOSPITAL 11	Tenejero			
BATAAN GENERAL HOSPITAL 12	Tenejero			
BATAAN GENERAL HOSPITAL 13	Tenejero			
BATAAN GENERAL HOSPITAL 14	Tenejero			
BATAAN GENERAL HOSPITAL 15	Tenejero			
BATAAN GENERAL HOSPITAL 16	Tenejero			
BATAAN GENERAL HOSPITAL 2	Tenejero			
BATAAN GENERAL HOSPITAL 3	Tenejero			
BATAAN GENERAL HOSPITAL 4	Tenejero			

BATAAN GENERAL HOSPITAL 5	Tenejero			
BATAAN GENERAL HOSPITAL 6	Tenejero			
BATAAN GENERAL HOSPITAL 7	Tenejero			
BATAAN GENERAL HOSPITAL 8	Tenejero			
BATAAN GENERAL HOSPITAL 9	Tenejero			
PROVINCIAL HEALTH OFFICE 1	Tenejero			
PROVINCIAL HEALTH OFFICE 10	Tenejero			
PROVINCIAL HEALTH OFFICE 2	Tenejero			
PROVINCIAL HEALTH OFFICE 3	Tenejero			
PROVINCIAL HEALTH OFFICE 4	Tenejero			
PROVINCIAL HEALTH OFFICE 5	Tenejero			
PROVINCIAL HEALTH OFFICE 6	Tenejero			
PROVINCIAL HEALTH OFFICE 7	Tenejero			
PROVINCIAL HEALTH OFFICE 8	Tenejero			
PROVINCIAL HEALTH OFFICE 9	Tenejero			
ISAAC & CATALINA MEDICAL CENTER	Tuyo		Low	Medium

Pilar				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
J. GRAGASIN SOLOMON DENTAL CARE	Panilao		Low	Medium