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

LiDAR Surveys and Flood Mapping of Bago River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Cebu

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AAC	v
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]

IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UPC	University of the Philippines Cebu
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND BAGO RIVER

Enrico C. Paringit, Dr. Eng. and Jonnifer Sinogaya, PhD.

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Phiippines Cebu (UPC). UPC 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 22 river basins in the Western Visayas region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Bago River Basin

Bago River Basin is located in the province of Negros Occidental located at the midwest of Negros Island. The floodplain and drainage area of 269.76 km² and 244.814 km² respectively covers the municipalities of Murcia and Salvador Benedicto and the cities of Bago, Talisay and San Carlos. The floodplain is 100% covered with LiDAR data which compromises 16 blocks. The LiDAR data was calibrated then mosaicked with an RMSE of -0.08 and then bathy burned. The bathy survey conducted reached a total length of 21.85 km starting from Quezon Bridge, Atipuluan, Bago City up to the river mouth with 32543 points surveyed. There are 36482 buildings, 871 km roads, 930 waterbodies and 40 bridges digitized based from the LiDAR data. Feature Extraction Attribution was conducted and among the building features, 34869 of them are Residential, 495 are schools and 10 are Medical Institutions.

The flood hazard map produced covers the 243.111 km², 243.56 km², 244.36 km² for the 5-year, 25-year, and 100 year rainfall return period in Bago City which affects 22 barangays as well as in La Carlota City which affects 1 barangay, in Murcia which affects 3 barangays, in Pulupandan which affects 20 barangays and in Valladolid which affects 9 barangays. A flood depth validation was conducted using 193 randomly generated points which were spread throughout the 6 ranges namely 0m-0.2m, 0.21m-0.5m, 0.51m-1m, 1.01m-2m, 2.10m-5m, 5m+ depth using the 25-yr rainfall flood depth map. It yielded a 0.784 m RMSE.

A rating curve was developed at Quezon Bridge, Bago City, Negros Occidental, which shows the relationship between the observed water levels at Quezon Bridge and outflow of the watershed at this location. This rating curve equation, expressed as $Q = 13.641x-134.27$, was used to compute the river outflow at Quezon Bridge for the calibration of the HEC-HMS model. The resulting outflow was used to simulate the flooded areas using HEC-RAS. The simulated model will be an integral part in determining the real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website.

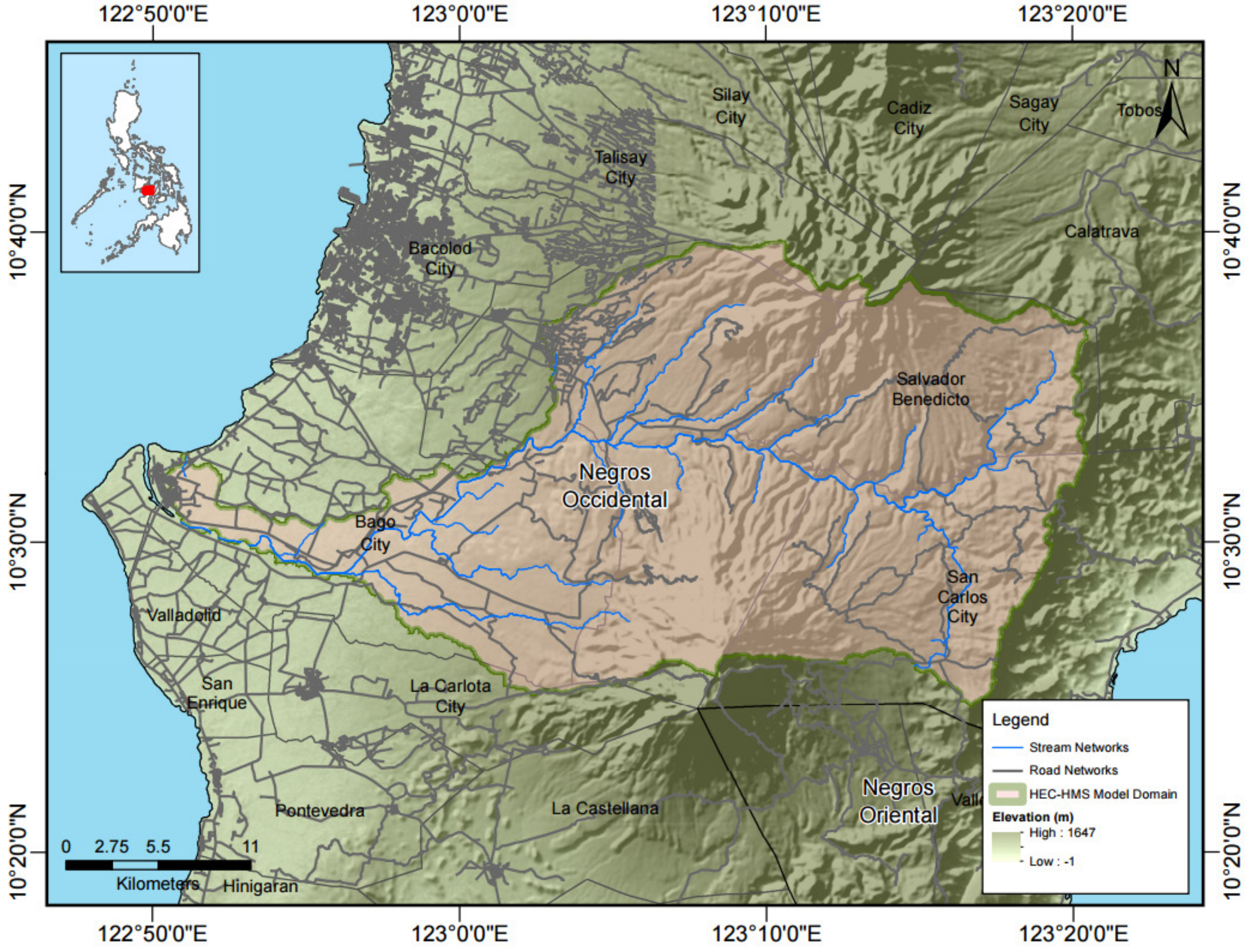


Figure 1. Map of the Bago River Basin (in brown)

Bago River Basin covers the municipalities of Murcia and Salvador Benedicto, and Cities of Bago and San Carlos in Negros Occidental. The DENR River Basin Control Office identified the basin to have a drainage area of 798 km2 and an estimated 1,015 million cubic meter (MCM) annual runoff (RBCO, 2016).

Its main stem, Bago River, is part of the 22 river systems in the Western Visayas Region. According to the 2015 national census of NSO, a total of 69,797 persons are residing within the immediate vicinity of the river which is distributed among nine (9) barangays in Bago City and two (2) barangays in Municipality of Pulupundan (NSO, 2015). The region of Negros Occidental is known as the “Sugarbowl of the Philippines” being the country’s major sugar producer. Sugarcane-based products are the leading traditional export, locally and internationally. In order to enhance the sustainability of the agricultural industry, its government introduced rotational cropping and diversification of crops; wherein other crops, such as corn, will be planted alongside sugarcane (Source: http://www.negros-occ.gov.ph/development-agenda/negros-first-development-agenda/negros-first-economic-development). On July 2015, heavy rains caused by tropical storm Egay or Chan-hom hit the City and destroyed some houses. Five families were evacuated due to flooding (http://newsinfo.inquirer.net/703098/egay-triggers-floods-in-northern-luzon, 2015).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BAGO FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Ms. Julie Pearl S. Mars, and For. Regina Aedrianne C. Felismino

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 Bago Floodplain in Negros Occidental, Iloilo and Guimaras. Each flight mission had an average of 12 lines and ran for at most four and a half (4.5) hours at most including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Tables 1 to 3. Figure 1 shows the flight plans and base stations for Bago floodplain.

Table 1. Flight planning parameters for the Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 43M	1200	40	50	200	30	140	5
BLK 43N	1200	40	50	200	30	140	5
BLK 43O	1100	40	50	200	30	120	5
BLK 45	1100	40	50	200	30	120	5
BLK 45A	1100	40	50	200	30	120	5
BLK 45B	1000	40	50	200	30	120	5
BLK45C	1000	40	50	200	30	120	5
BLK 45D	1100	40	50	200	30	120	5
BLK 46A	1100	40	50	200	30	120	5

Table 2. Flight planning parameters for the Gemini LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 43G	1100	50	50	100	40	120	5
BLK 43N	1000	50	50	100	40	120	5
BLK 43I	1000	50	50	100	40	120	5
BLK 43J	1100	50	50	100	40	120	5
BLK 43K	1100	50	50	100	40	120	5
BLK 43L	1000	50	50	100	40	120	5
BLK 43O	1000	50	50	100	40	120	5

Table 3. Flight planning parameters for the Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK 43L	500	40	45	50	36	140	5
BLK 46A	500	40	45	50	36	140	5

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

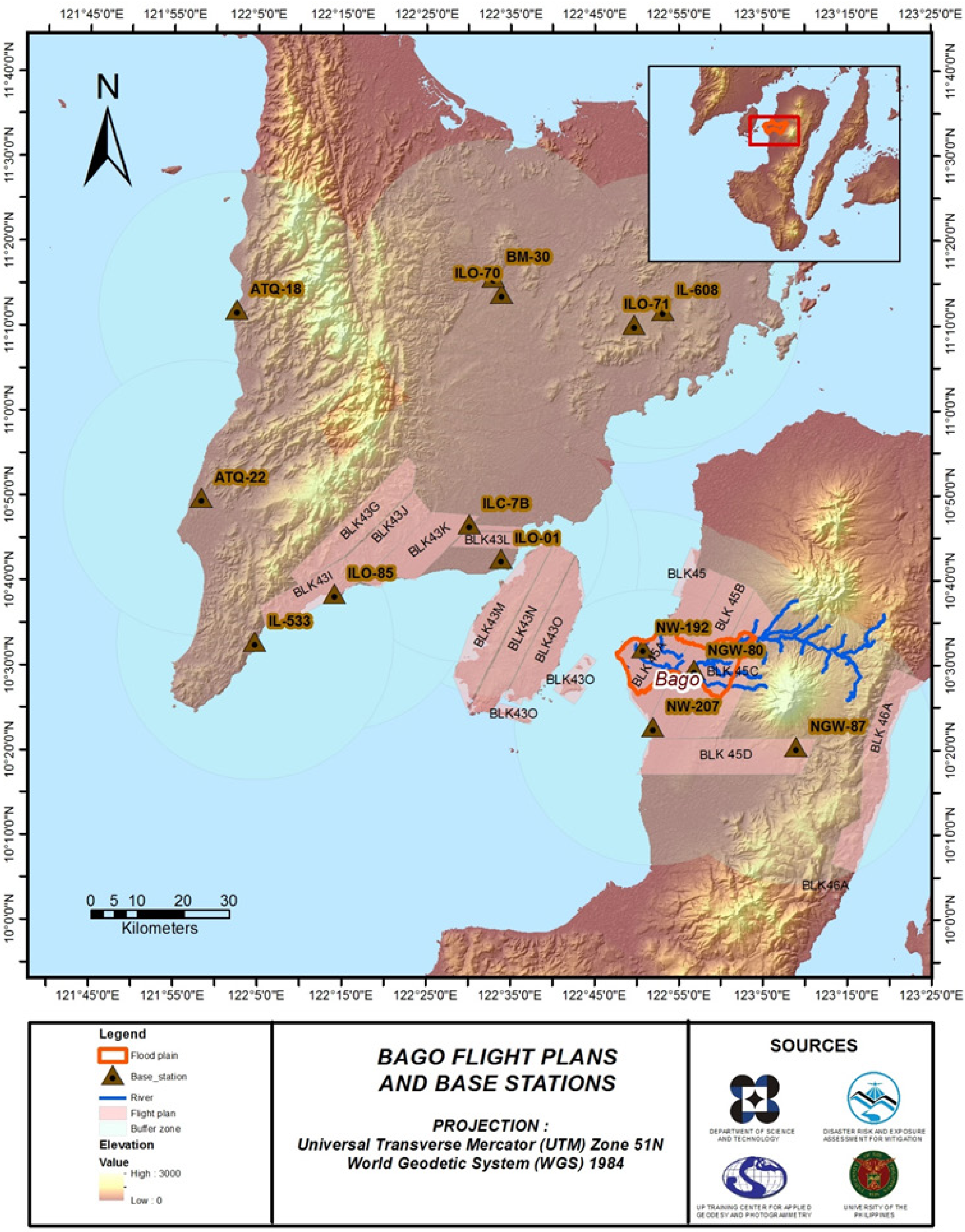


Figure 2. Flight Plan and base stations used for the Bago Floodplain survey.

2.2 Ground Base Stations

The project team was able to recover eight (8) NAMRIA reference points: NGW-80, NGW-87, NGW-80, ILO-1, ILO-85, ILO-70, ILO-71, ATQ-18 and ATQ-22 which are of second (2nd) order accuracy. Six (6) six[ONLY 5 are listed here] benchmark points: NW-192, NW-207, ILC-7B, IL-533 and BM-30, also of second (2nd) order accuracy were also recovered. The certification for the base station is found in Annex 4. These were used as base stations during flight operations for the entire duration of the survey (April to May 2014 and 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and TRIMBLE SPS 985. Flight plans and location of base stations used during the aerial LiDAR Acquisition in Bago floodplain are shown in Figure 1.

Figure 2 to Figure 17 show the recovered NAMRIA control station within the area, in addition, Table 3 to Table 18 show the details about the following NAMRIA control stations and established points. Table 19 shows the list of all ground control points occupied during the acquisition together with the dates they were utilized during the survey.

(a) (b)

Figure 3. Photo (a) shows GPS set-up over NGW-80 as recovered at the sidewalk of Quezon Bridge in Brgy. Ma-ao, Bago, Negros Occidental and (b) shows NAMRIA reference point NGW-80 as recovered by the field team.

Table 4 Details of the recovered NAMRIA horizontal control point NGW-80 used as base station for the LiDAR Acquisition

Station Name	**SMR-53**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference Of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 29’ 35.8609” 122° 56’ 43.79550” 30.72 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	494033.975 meters 1160287meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 29’ 31.60669” North 122° 56’ 49.03425” East 89.691 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	494036.06 meters 1159881.54 meters

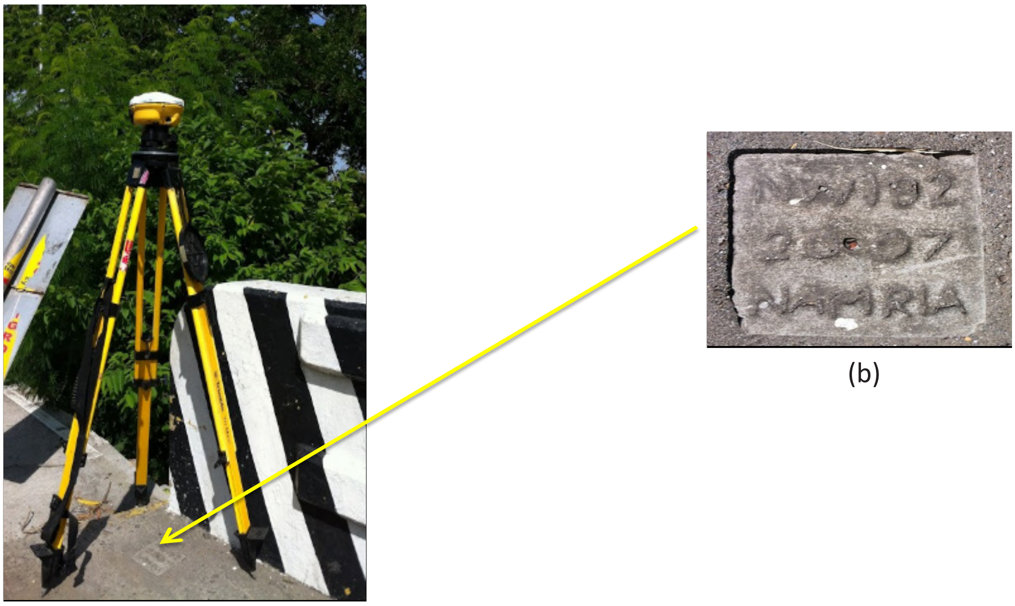
(b)

(a)

Figure 4. Photo (a) shows GPS set-up over NGW-87 as revovered at the SE side of Moises Padilla-Canlaon Road and NE of wooden electric post. Station is situated on top of headwall and (b) shows NAMRIA reference point NGW-87 as recovered by the field team.

Table 5 Details of the recovered NAMRIA horizontal control point NGW-87 used as base station for the LiDAR Acquisition

Station Name	**SMR-53**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 20' 32.34942" 123° 8' 53.05808" 333.326 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	516216.608 meters 1143593.27 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 20' 28.15138" North 123° 8' 58.30851" East 393.148 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	516210.93 meters 1143192.99 meters



(a) (b)

Figure 5 (a) GPS set-up over NW-192 as recovered on the SW end of Sibud Bridge, Brgy. Balingasag, Bago, Negros Occidental and (b) NAMRIA reference point NW-192 as recovered by the field team

Table 6 Details of the recovered benchmark ground control point NW-192 used as base station for the LiDAR Acquisition

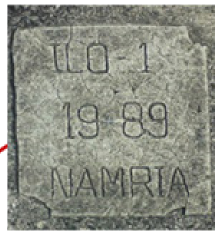
Station Name	NW-192	
Order of Accuracy	**1st**	
Relative Error (Horizontal positioning)	**1 in 100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 32’ 9.08721” 122° 50’ 40.76204” 7.334 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	483003.416 meters 1164591.004 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 32’ 04.81345” North 122° 50’ 45.99776” East 65.967 meters

Figure 6. GPS set-up over NW-207 as recovered at Barangay San Juan, Pontevedra, Negros Occidental and NAMRIA reference point NW-207 as recovered by the field team

Table 7 Details of the recovered benchmark ground control point NW-207 used as base station for the LiDAR Acquisition

Station Name	NGW-207	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 22’ 49.75933” 122° 51’ 55.33813” 8.446 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	485262.641 meters 1147412.335 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 22’ 45.52680” North 122° 52’ 00.58746” East 67.481 meters

(a)



(b)

Figure 7. (a) GPS set-up over ILO-1 as recovered on the rooftop of St. Clemente Church Bell Tower in La Paz, Iloilo City and (b) NAMRIA reference point ILO-1 as recovered by the filed team

Table 8 Details of the recovered NAMRIA vertical control point ILO-1 used as base station for the LiDAR Acquisition

Station Name	**ILO-1**	
Order of Accuracy	**1st**	
Relative Error (horizontal positioning)	**1 in 100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10°42’40.74251” 122° 33’ 48.38302” 28.93600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	452244.945 meters 1184434.202 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 42’ 36.40006” 122° 33’ 53.60515” 86.45300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	452261.66 meters 1184019.63 meters

(a)

(b)

Figure 8. (a) GPS set-up over ILO-85 as recovered at the Town Plaza in Miag-ao, Iloilo and (b) NAMRIA reference point ILO-85 as recovered by the field team

Table 9. Details of the recovered NAMRIA vertical control point ILO-85 used as base station for the LiDAR Acquisition

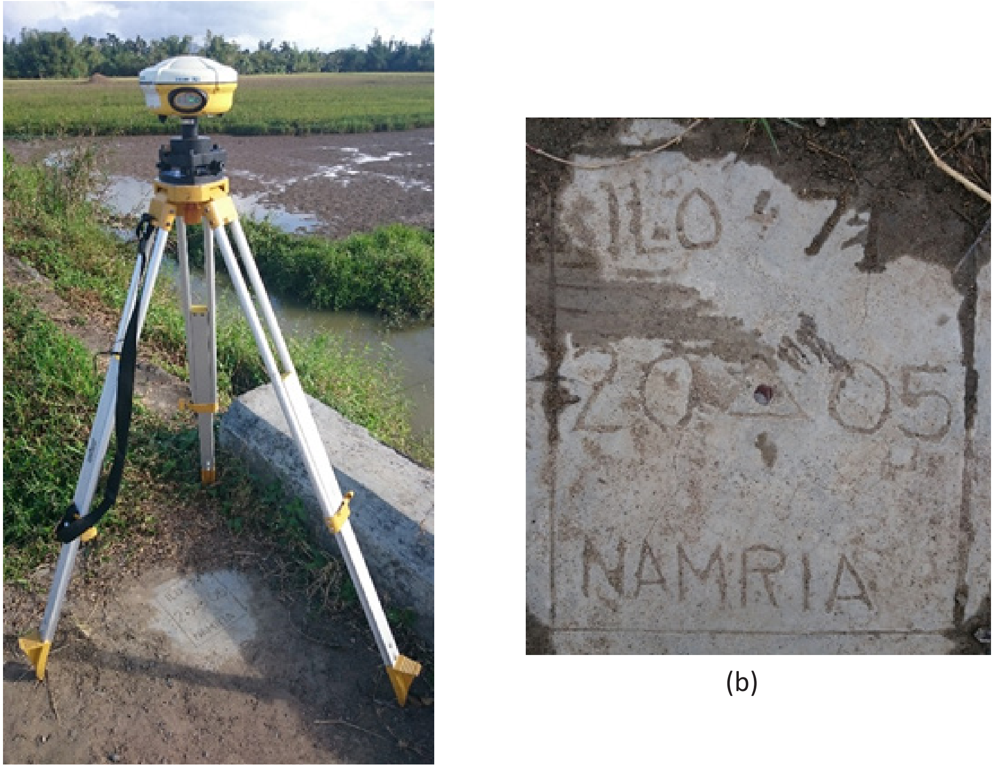
Station Name	ILO-85	
Order of Accuracy	2nd Order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 38’ 33.11352” 122° 14’ 3.70560” 21.96200 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	416226.997m 1176896.034m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10 o38’ 28.75996” 122 o14’ 8.93597” 78.82800 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	7416256.32 1176484.10

(a) (b)

Figure 9. (a) GPS set-up over ILC-7B as recovered in the Province of Iloilo and (b) benchmark ground control point ILC-7B as recovered by the field team

Table 10. Details of the recovered benchmark ground control point ILC-7B used as base station for the LiDAR Acquisition

Station Name	ILC-7B	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 46’ 44.10341” 122° 30’ 03.73070” 29.082 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	445301.176 meters 1191984.079 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 46’ 39.73852” North 122° 30’ 08.94728” East 86.285 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	445449.763 meters 1191504.268 meters



(a) (b)

Figure 10. (a) GPS set-up over ILO-71 in Barangay Poblacion, San Rafael, Province of Iloilo and (b) NAMRIA reference point ILO-71 as recovered by the field team

Table 11 Details of the recovered NAMRIA horizontal control point ILO-71 used as base station for the LiDAR Acquisition

Station Name	**ILO-71**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 10’ 14.95277” 122° 49’ 43.05170” 114.277 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	481282.443 meters 1235227.808 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 10’ 10.51756” North 122° 49’ 48.23144” East 171.35 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	481289.00 meters 1234795.46 meters

(a)

(b)

Figure 11. (a) GPS set-up over ILO-608 in San Rafael, Province of Iloilo and (b) NAMRIA reference point IL-608 as recovered by the field team

Table 12 Details of the recovered NAMRIA horizontal control point ILO-608 used as base station for the LiDAR Acquisition

Station Name	ILO-608	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 11’ 55.75892” 122° 53’ 03.09494” 9.514 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	487222.365 meters 1238386.268 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84	Latitude Longitude Ellipsoidal Height	11° 11’ 51.32138” North 122° 53’ 08.27190” East 141.068 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	487357.193 meters 1237888.532 meter

(a)

(b)

Figure 12. (a) GPS set-up over IL-533 as recovered in Barangay Amboyu-an, San Joaquin, Province of Iloilo and (b) NAMRIA reference point IL-533 as recovered by the field team

Table 13. Details of the recovered NAMRIA vertical control point IL-533 used as base station for the LiDAR Acquisition

Station Name	BMIL-533	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 32’ 49.29908” 122° 04’ 37.25566” 51.412 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	398848.891 meters 1166439.919 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 32’ 44.95602” 122° 04’ 42.49544” 64.135 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	399013.479 meters 1165970.645 meters

(a)

(b)

Figure 13. (a) GPS set-up over ATQ-18 as recovered in Barangay Cubay, Barbaza, Province of Antique and (b) NAMRIA reference point ATQ-18 as recovered by the field team

Table 14. Details of the recovered NAMRIA horizontal control point ATQ-18 used as base station for the LiDAR Acquisition .

Station Name	**ATQ-18**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 11’ 58.67081” 122° 2’ 22.83300” 10.902 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	395155.157 meters 1238579.674 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 11’ 54.16068” North 122° 2’ 28.01549” East 65.961 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	395155.87 meters 1238146.15 meters

(a)

(b)

Figure 14. (a) GPS set-up over ATQ-22 as recovered in Barangay Concepcion, Belison, Province of Antique and (b) NAMRIA reference point ATQ-22 as recovered by the field team

Table 15. Details of the recovered NAMRIA horizontal control point ATQ-22 used as base station for the LiDAR Acquisition

Station Name	**ATQ-22**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 49’ 46.66618” 121° 58’ 11.90221” 12.250 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	387365.279 meters 1197676.056 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 49’ 42.24271” North 121° 58’ 17.11770” East 68.022 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	387404.70 meters 1197256.85 meters

Figure 15. NAMRIA reference poit ILO-70 in Barangay Poblacion, Bingawan, Province of Iloilo as recovered by the field team

Table 16. Details of the recovered NAMRIA horizontal control point ILO-70 used as base station for the LiDAR Acquisition

Station Name	ILO-70	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 13’ 50.08819” 122° 33’56.83732” 76.803 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	452601.273 meters 1241432.381 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 13’45.61545” North 122°34’02.01364” East 133.04 meters

(a)

(b)

Figure 16. (a) GPS set-up over BM-30 as located in Capiz[No barangay and town name?] and (b) NAMRIA reference point BMT-30 as recovered by the field team

Table 17. Details of the recovered NAMRIA horizontal control point BM-30 GCP used as base station for the LiDAR Acquisition

Station Name	**BM-30**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 15’ 52.92327” 122° 32’ 52.37977” 41.592 m
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting Northing	450652.540 m 1245208.031 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 15’ 48.44044” 122° 32’ 57.55324” 97.746 m

Table 18. Ground Control Points used during LiDAR Data Acquisition .

Date Surveyed	Flight Number	Mission Name	Ground Control Points
21-Apr-14	1373P	1BLK45C111B	NGW-80, NW-192
22-Apr-14	1375P	1BLK45B111A	NGW-80, NW-192
22-Apr-14	1377P	1BLK45C111B	NGW-80, NW-192
25-Apr-14	1387P	1BLK45AC114A	NGW-80, NW-192
11-May-14	1453P	1BLK46AS131B	NGW-87, NW-192
12-May-14	1455P	1BLK45S132A	NGW-80, NW-192
6-Feb-15	2526G	2BLK43OKSV037A	ILO-01, ILO-85
7-Feb-15	2530G	2BLK43OSJS038A	ILO-01, ILO-85
12-Feb-15	2550G	2BLK37GNOV43A	ILO-01, ILC-7B
14-Feb-15	2558G	2BLK43G045A	ILO-01, ILO-85
16-Feb-15	2579P	1BLK43M047B	ILO-71, IL-608
17-Feb-15	2581P	1BLK43MN048A	ILO-85, IL-533
21-Feb-15	2597P	1BLK43N052A	ATQ-18, ATQ-22
5-Mar-15	2636G	2BLK43OS064B	ILO-70, BM-30
3-Mar-15	2637P	1BLK43NO062A	ILO-70, ILO-71
6-Mar-15	2638G	2BLK43OS065A	ILO-70, ILO-71
2-May-16	8473AC	3BLK46AS123A	NGW-87, NW-192
26-Oct-15	8513AC	3BLK43L300A	ILO-01, ILO-85
2-Oct-15	10007P	1BLK44LMSCALIB275A	NGW-80, NW-207

2.3 Flight Missions

Nineteen (19) missions were conducted to complete the LiDAR Data Acquisition in Bago Floodplain, for a total of seventy-four hours (74+00) of flying time for RP-C9022, 9122 and 9322. All missions were acquired using the Pegasus, Gemini and Aquarius LiDAR system. Table 19 shows the total area of actual coverage per mission and the flying length for each mission. Table 20 presents the actual parameters used during the LiDAR data acquisition.

Table 19. Flight missions for the LiDAR data acquisition of the Bago Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
21-Apr-14	1373P	246.88	192.87	52.59	140.28	439	2	41
22-Apr-14	1375P	539.95	458.98	99.31	359.67	686	4	23
22-Apr-14	1377P	246.88	219.35	55.07	164.28	333	2	47
25-Apr-14	1387P	504.98	295.49	87.9	207.59	691	4	29
11-May-14	1453P	241.02	183.85	0	183.85	339	2	59
12-May-14	1455P	765.25	384.37	91.22	293.15	123	4	53
6-Feb-15	2526G	391.05	333.65	0	333.65	547	4	23
7-Feb-15	2530G	306.59	228.19	0	228.19	666	4	29
12-Feb-15	2550G	647.07	329.62	0	329.62	593	4	5
14-Feb-15	2558G	188.42	477.14	0	477.14	668	4	11
16-Feb-15	2579P	219.85	153.91	0	153.91	496	3	41
17-Feb-15	2581P	430.32	203.65	0	203.65	560	4	35
21-Feb-15	2597P	210.47	195.83	0	195.83	541	3	59
5-Mar-15	2636G	248.18	64.83	0	64.83	374	3	29
3-Mar-15	2637P	458.65	139.13	0	139.13	471	3	50
6-Mar-15	2638G	248.18	115.62	0	115.62	374	3	14
2-May-16	8473AC	2.52	24.43	2.03	22.4	0	3	41
26-Oct-15	8513AC	46.89	83.38	0	83.38	0	3	49
2-Oct-15	10007P	241.02	90.16	43.06	47.1	252	4	23
TOTAL		6184.17	4174.45	431.18	3743.27	8153	74	00

Table 20 Actual Parameters used during LiDAR Data Acquisition

Flight Number	Flying Height (AGL) (m)	Overlap (%)	Field of View	PRF (Hz)	Scan Frequency (Hz)	Speed of Plane (Kts)	Average Turn times (Minutes)
1373P	1100	40	50	200	30	120	5
1375P	1100	40	50	200	30	120	5
1377P	1200	40	50	200	30	120	5
1387P	1100	40	50	200	30	120	5
1453P	1100	40	50	200	30	120	5
1455P	1100	40	50	200	30	120	5
2526G	1000	50	50	100	40	120	5
2530G	1000	50	50	100	40	120	5
2550G	1000	50	50	100	40	120	5
2558G	1000	50	50	100	40	120	5
2579P	1100	40	50	200	30	120	5
2581P	1100	40	50	200	30	120	5
2597P	1100	40	50	200	30	120	5
2636G	1000	50	50	100	40	120	5
2637P	1100	40	50	200	30	120	5
2638G	1000	50	50	100	40	120	5
8473AC	500	40	45	50	36	140	5
8513AC	500	40	45	50	36	140	5
10007P	1100	40	50	200	30	120	5

2.4 Survey Coverage

Bago floodplain is located in the provinces of Negros Occidental and Negros Oriental, with majority of the floodplain situated within the Municipality of Isabela, Negros Occidental. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 21. The actual coverage of the LiDAR acquisition for Bago floodplain is presented in Figure 16.

Table 21 List of Municipalities/Cities Surveyed in Antique and Iloilo

Province	Municipality/City	Area of Municipality/ City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed =(Total Area covered/ Area of Municipality)*100
Guimaras	San Lorenzo	118.69	118.68	100
	Sibunag	152.77	152.74	100
	Buenavista	109.72	109.29	100
	Nueva Valencia	122.76	122.28	100
	Jordan	100.59	99.98	99
Iloilo	San Miguel	31.53	22.71	72
	Pavia	27.89	19.73	71
	Miagao	170.53	114.11	67
	Oton	85.38	56.72	66
	Tubungan	87.73	56.60	65
	Igbaras	132.37	84.13	64
	Tigbauan	90.20	54.04	60
	Leon	147.46	74.42	50
	Iloilo City	70.78	29.97	42
	Guimbal	40.69	13.61	33
	Alimodian	118.19	33.69	29
	San Joaquin	200.06	47.51	24
	Santa Barbara	70.66	14.75	21
	Leganes	32.09	3.29	10
	Maasin	137.81	7.38	5

Negros Occidental	Valladolid	40.37	40.37	100
	Pulupandan	16.13	16.13	100
	San Enrique	27.48	27.48	100
	Pontevedra	115.03	113.85	99
	Bago City	350.91	337.51	96
	Bacolod City	152.24	137.39	90
	La Carlota City	121.01	89.51	74
	La Castellana	196.91	99.14	50
	Murcia	364.20	154.22	42
	San Carlos City	408.97	94.61	23
	Hinigaran	149.83	30.35	20
	Talisay City	199.01	6.81	3
	Silay City	196.52	1.34	1
	Calatrava	344.54	1.90	1
Negros Oriental	Vallehermoso	114.02	58.50	51
	Canlaon City	147.33	17.38	12
	La Libertad	130.62	14.43	11
	Guihulngan City	346.20	8.31	2

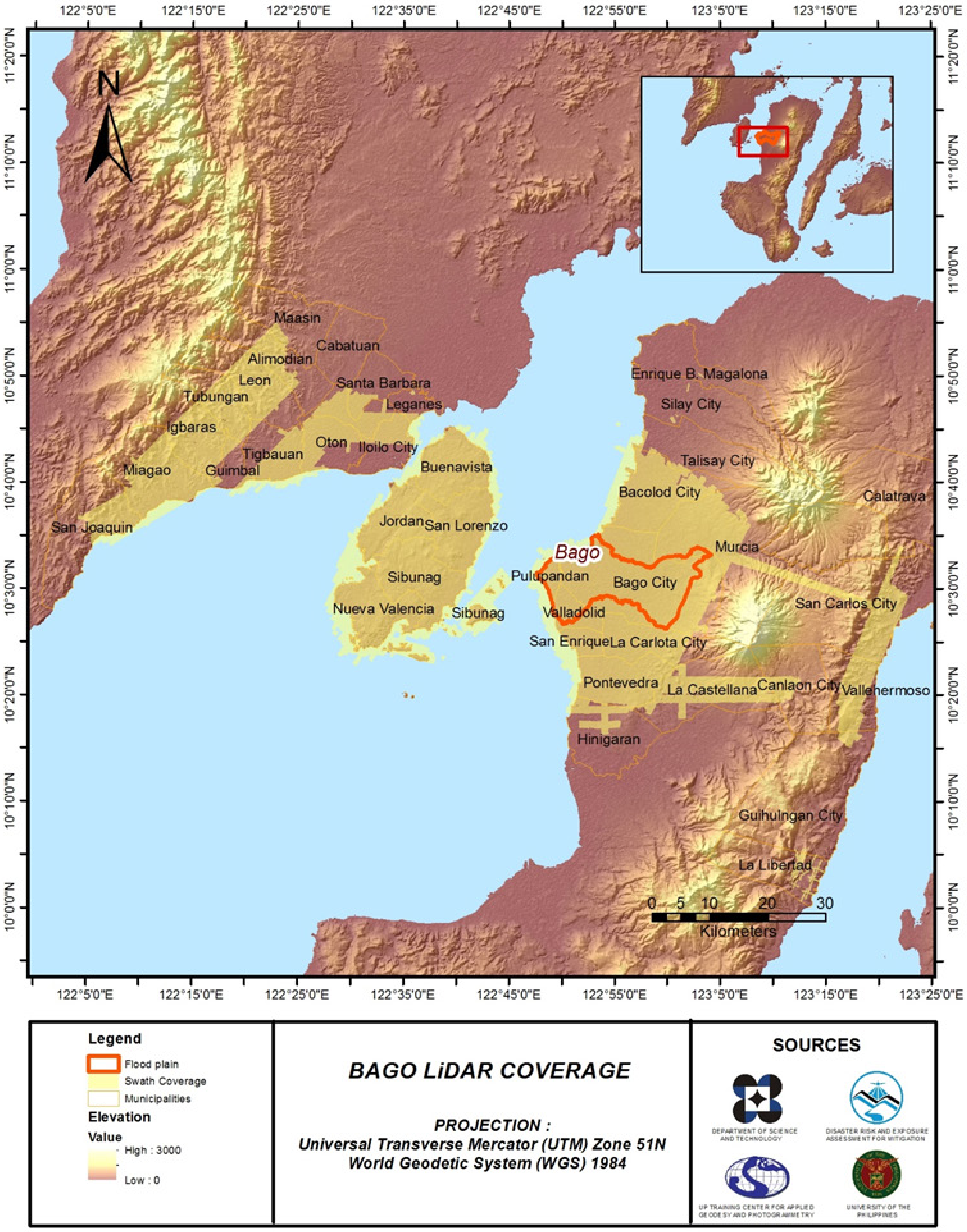


Figure 17. Actual LiDAR data acquisition for Bago Floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE BAGO FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flow chart shown in Figure 18.

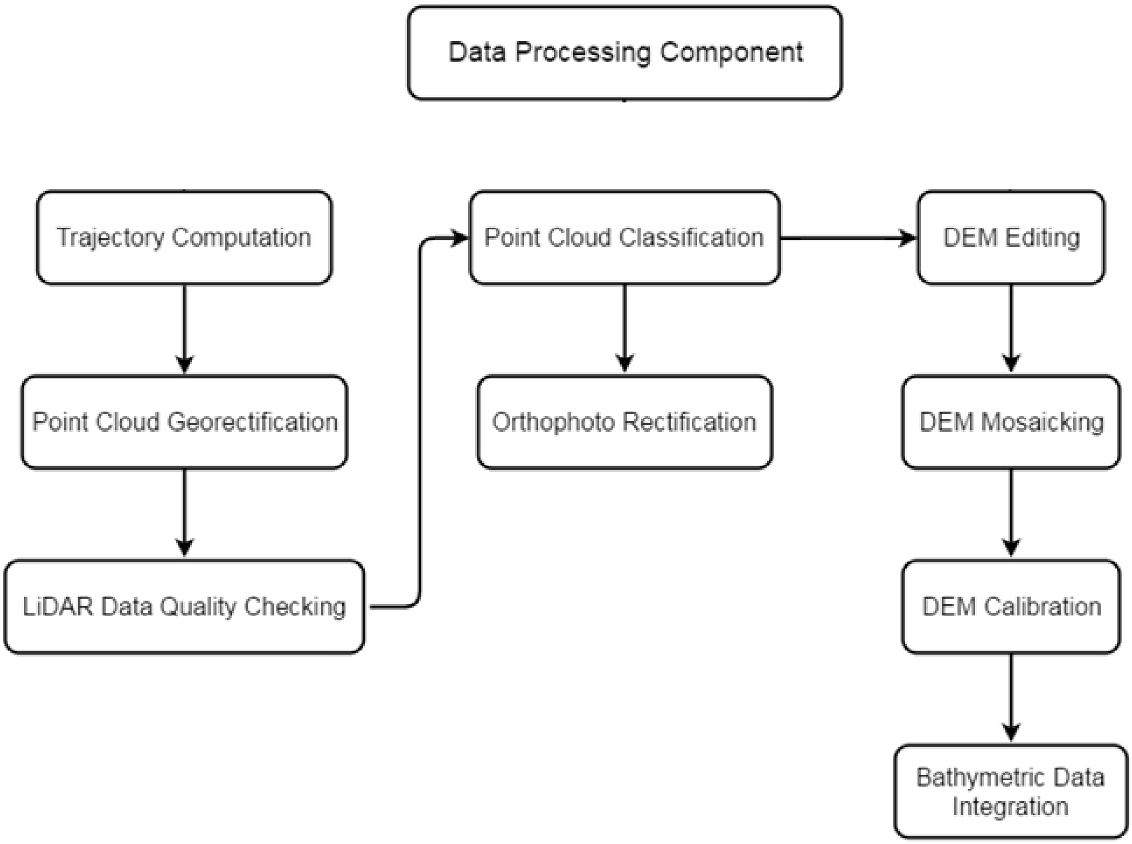


Figure 18. Schematic Diagram for Data

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Bago floodplain can be found in Annex 5. Missions flown during the first survey and second survey conducted on May 2014 and July 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Bacolod and Iloilo respectively. Gemini system was used for the third survey on February 2015, Pegasus and Gemini systems for the fourth survey on March 2015, Pegasus system for the fifth survey on November 2015. Third to fifth surveys were flown over Bago, Negros Occidental.

The Data Acquisition Component (DAC) transferred a total of 368.20 Gigabytes of Range data, 4.04 Gigabytes of POS data, 406.06 Megabytes of GPS base station data, and 513.56 Gigabytes of raw image data to the data server on May 26, 2014 for the first survey and November 22, 2016 up to the last survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Bago was fully transferred on November 22, 2016, as indicated on the Data Transfer Sheets for Bago floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1377P, one of the Bago flights, which is the North, East, and Down position RMSE values are shown in Figure 19. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on April 22, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

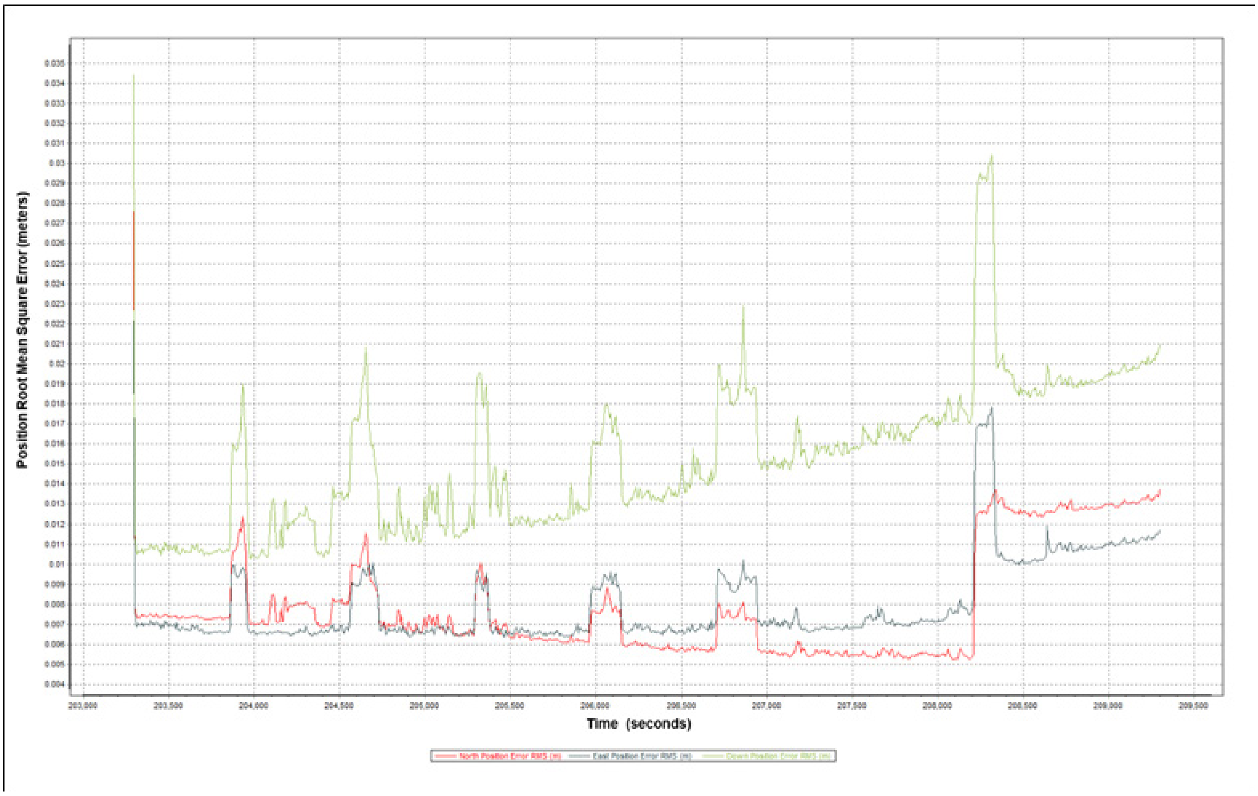


Figure 19. Smoothed Performance Metrics of Bago Flight 1377P

The time of flight was from 203300 seconds to 209300 seconds, which corresponds to afternoon of April 22, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values corresponds to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 19 shows that the North position RMSE peaks at 1.30 centimeters, the East position RMSE peaks at 1. 80 centimeters, and the Down position RMSE peaks at 3.00 centimeters, which are within the prescribed accuracies described in the methodology.

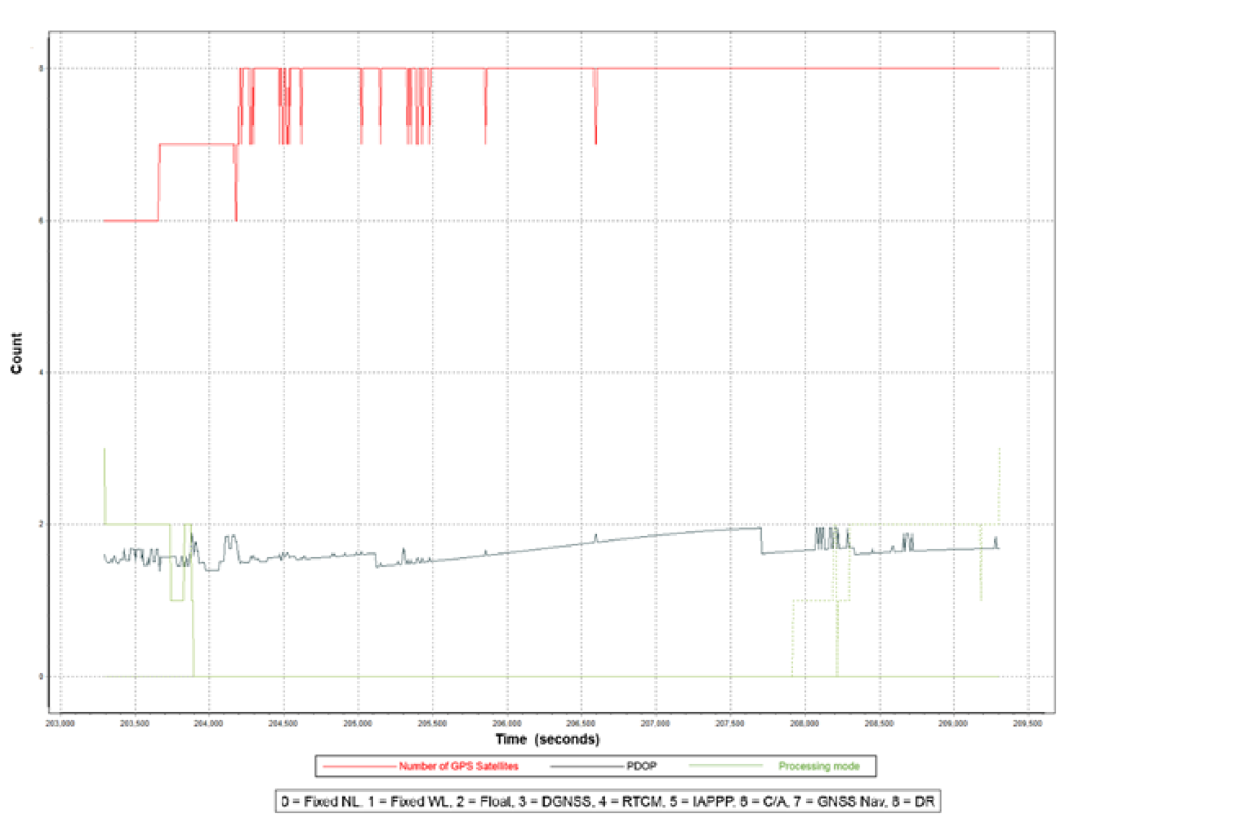


Figure 20. Solution Status Parameters of Bago Flight 1377P

The Solution Status parameters of Flight 1377P, one of the Bago flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 20. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 8. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Bago flights is shown in Figure 21.

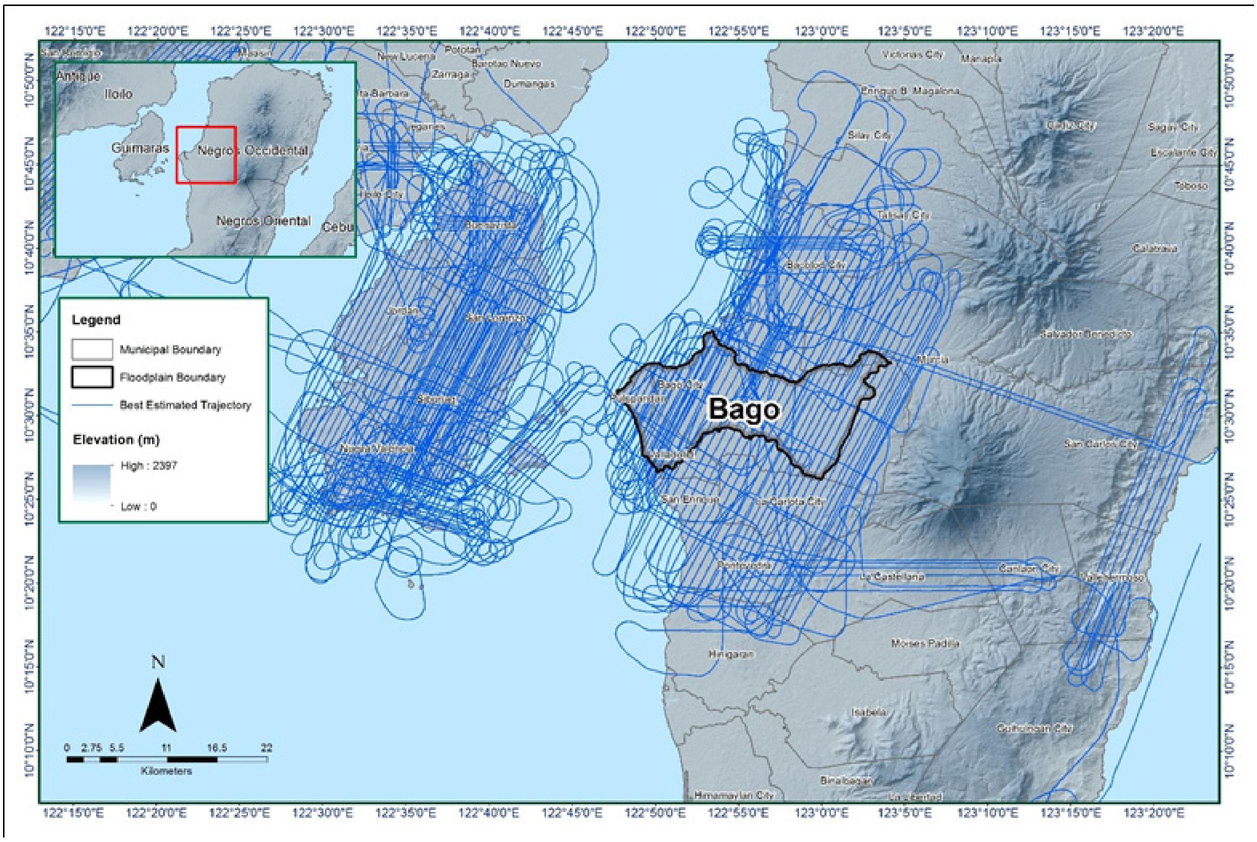


Figure 21. Best Estimated Trajectory or the LiDAR missions conducted over the Bago Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 184 flight lines, with some flight line containing one channel, since the Gemini and Aquarius systems both contain one channel only and two channels for the Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Bago floodplain are given in Table 22.

Table 22. Self-Calibration Results values for Bago flights

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000210
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000353
GPS Position Z-correction stdev)	<0.01meters	0.0011

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Bago Floodplain is shown in Figure 22. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

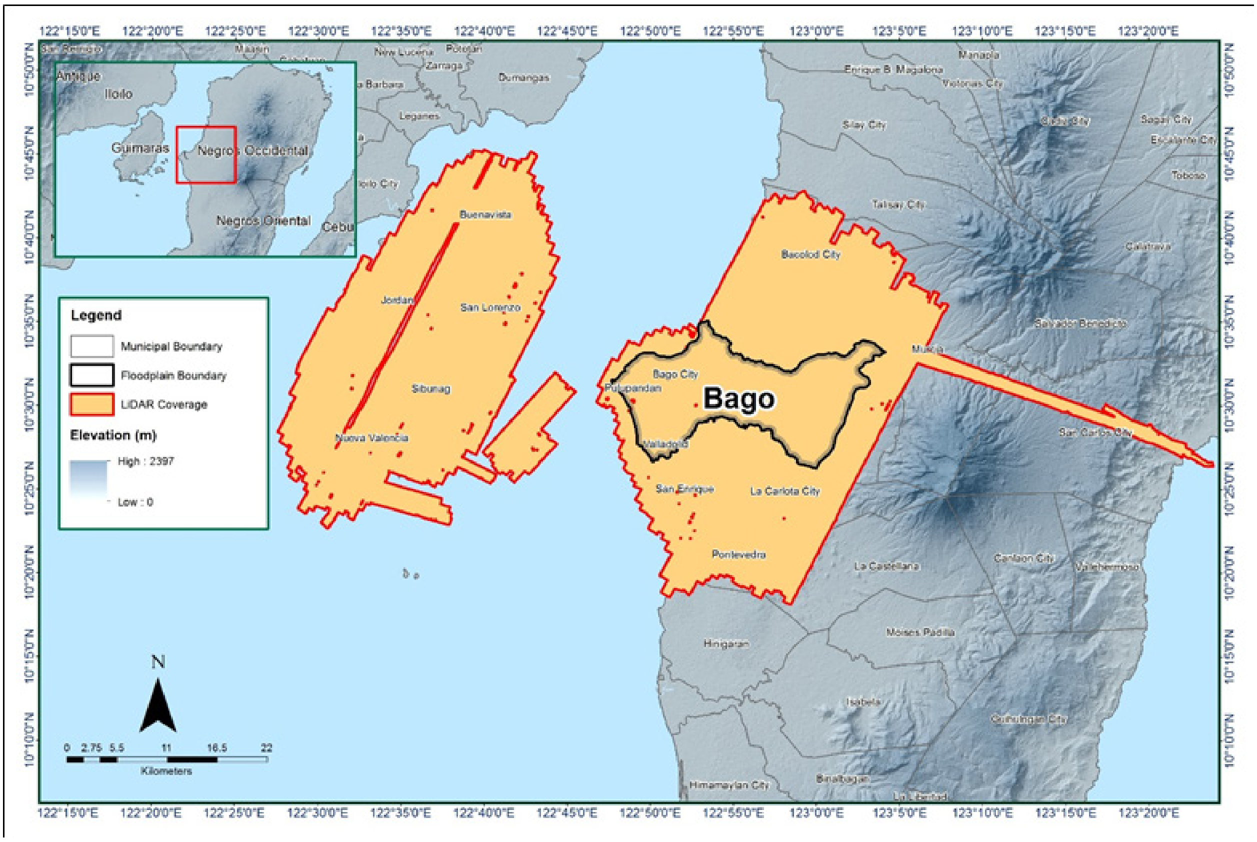


Figure 22. Boudaries of the processed LiDAR data over Bago Floodplain

The total area covered by the Bago missions is 2,313.84 sq.km. This is comprised of twenty (20) flight acquisitions grouped and merged into sixteen (16) blocks as shown in Table 23.

Table 23. List of LiDAR blocks for Bago Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Negros_Blk45A	1387P	214.24
	1455P	
Negros_Blk45A_additional	1387P	81.07
Negros_Blk45B	1373P	573.49
	1375P	
Negros_Blk45C	1377P	254.32
	1387P	
	1455P	
Negros _Blk46A_additional	1453P	51.66
NegrosOccidental_reflights_ Blk45A	10007P	38.61
Bacolod_Blk45A	8473AC	8.76
Iloilo_Blk43M	2579P	240.28
	2581P	

Iloilo_Blk43N	2581P	196.64
	2597P	
Iloilo_Blk43N_additional1	2550G	45.55
Iloilo_Blk43N_additional2	2558G	49.03
Iloilo_Blk43N_additional3	2637P	115.75
Iloilo_Blk43O	2526G	246.06
	2550G	
	2530G	
Iloilo_Blk43O_additional	2636G	104.29
	2638G	
Iloilo_Blk43O_supplement	2637P	33.15
Iloilo_reflights_Blk43N	8513AC	60.93
TOTAL		2,313.84 sq. km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 23 . Since the Gemini system employs one channel, it is expected that 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, it is expected that [Changed from "we can expect that.."]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.

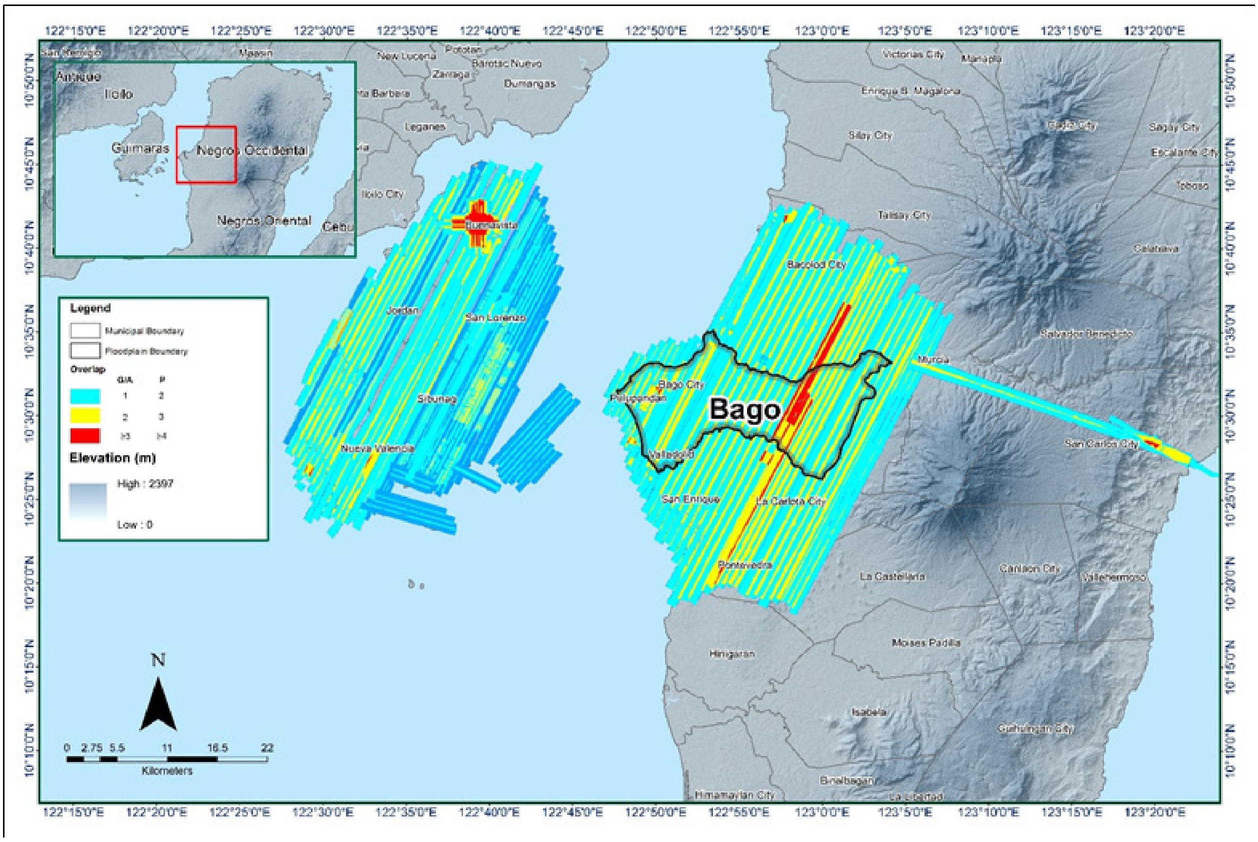


Figure 23. Image of data overlap for Bago Floodplain

The overlap statistics per block for the Bago 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 27.31% and 52.08% respectively, which passed the 25% requirement. (check annex numbers)

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 23. It was determined that all LiDAR data for Bago floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.17 points per square meter.

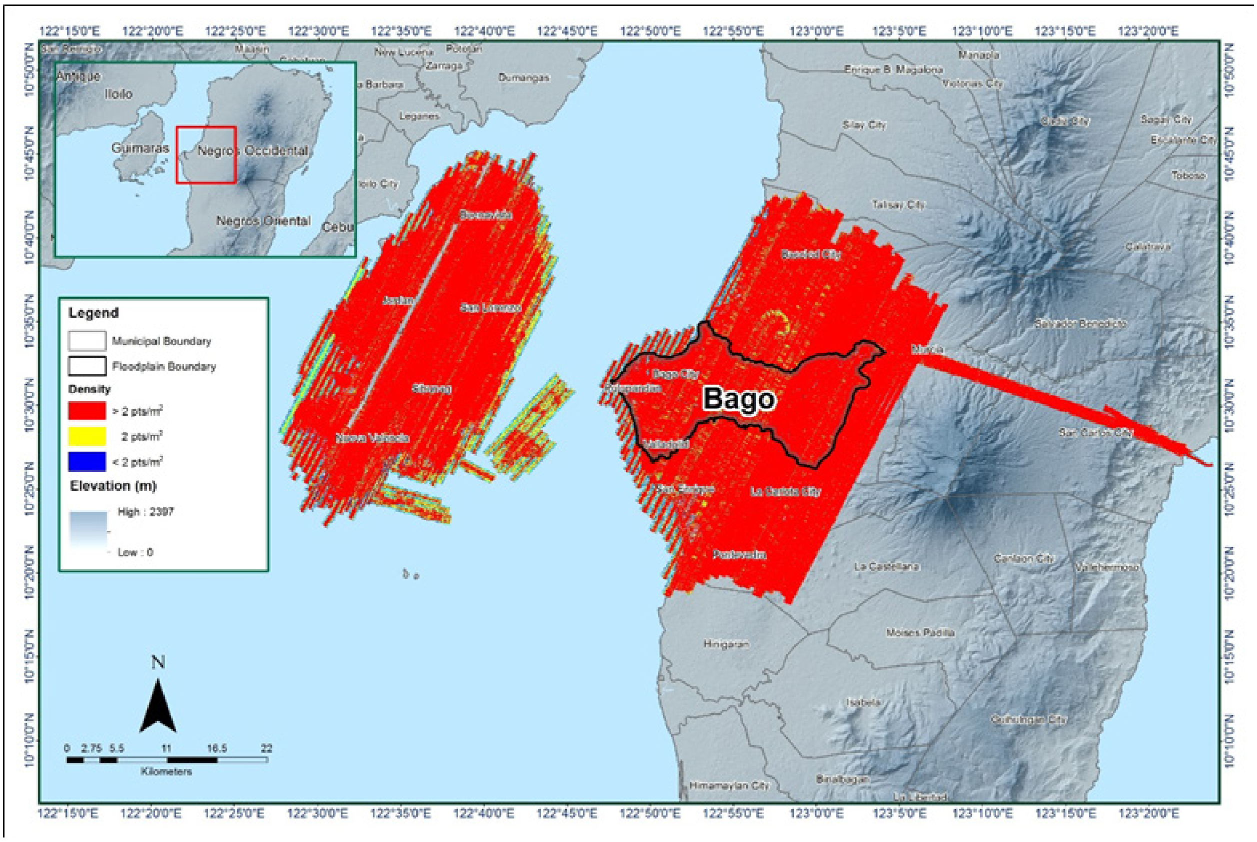


Figure 24. Pulse density map of merged LiDAR data for Bago Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 25. 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.

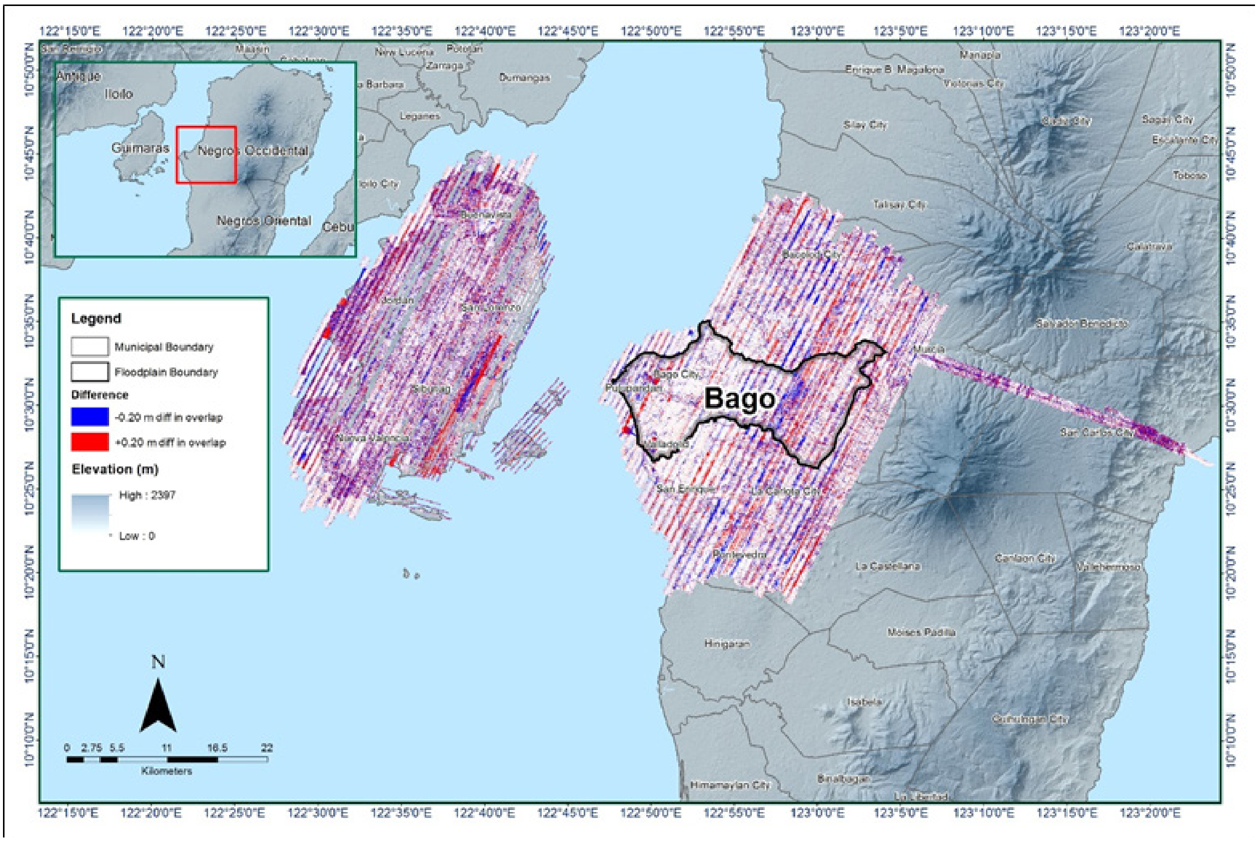


Figure 25. Elevation difference map between flight lines for Bago Floodplain

A screen capture of the processed LAS data from a Bago flight 1377P loaded in QT Modeler is shown in Figure 26. 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.

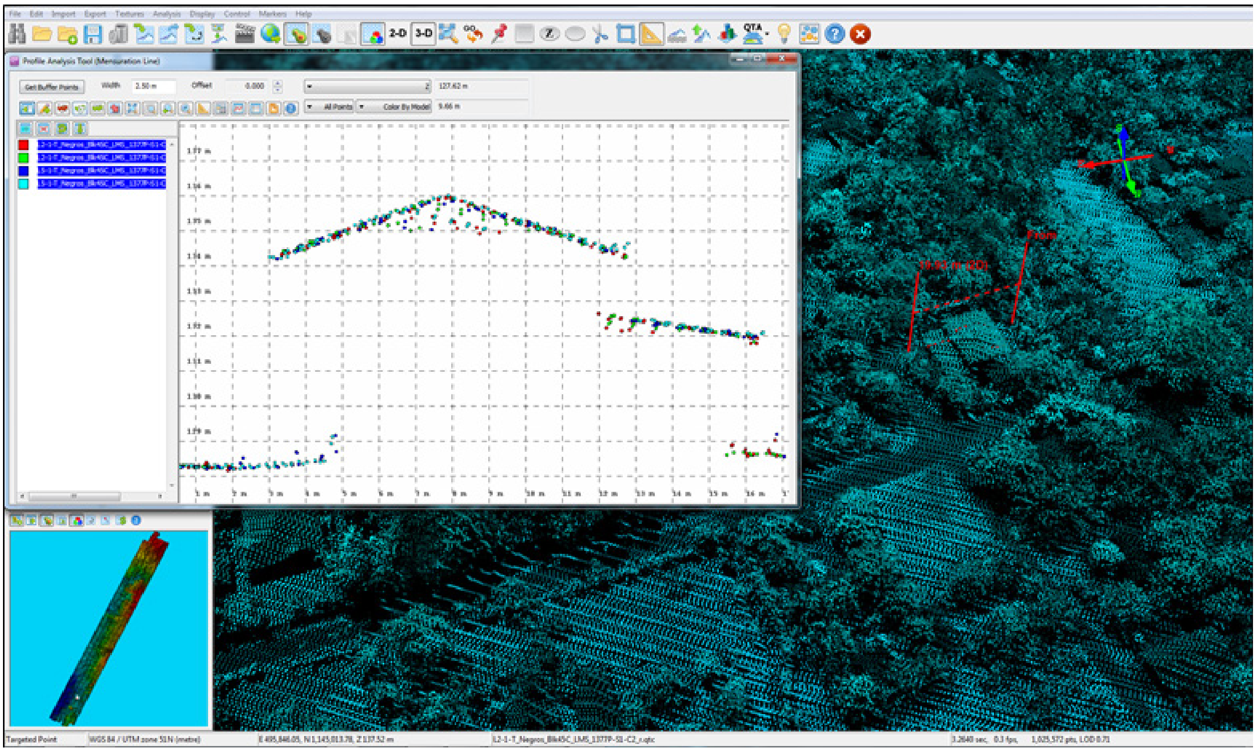


Figure 26. Quality checking for Bago Flight 1377P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 24. Bago classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	2,207,876,503
Low Vegetation	1,817,016,012
Medium Vegetation	2,581,739,460
High Vegetation	1,808,024,129
Building	106,673,754

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Bago floodplain is shown in Figure 27. A total of 3,340 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 24. The point cloud has a maximum and minimum height of 1,069.45 meters and 37.33 meters respectively.

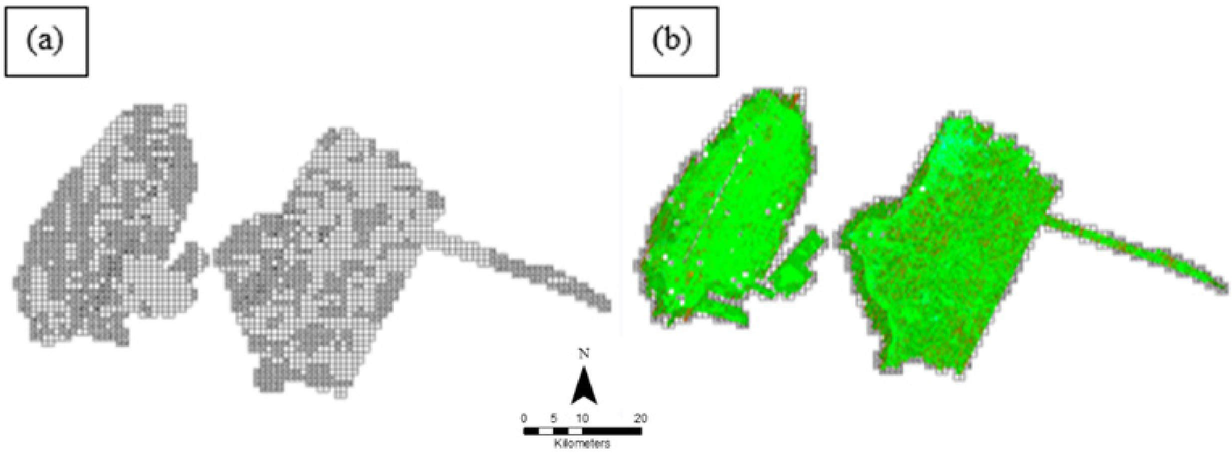


Figure 27. Tiles for Bago Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 28. 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.

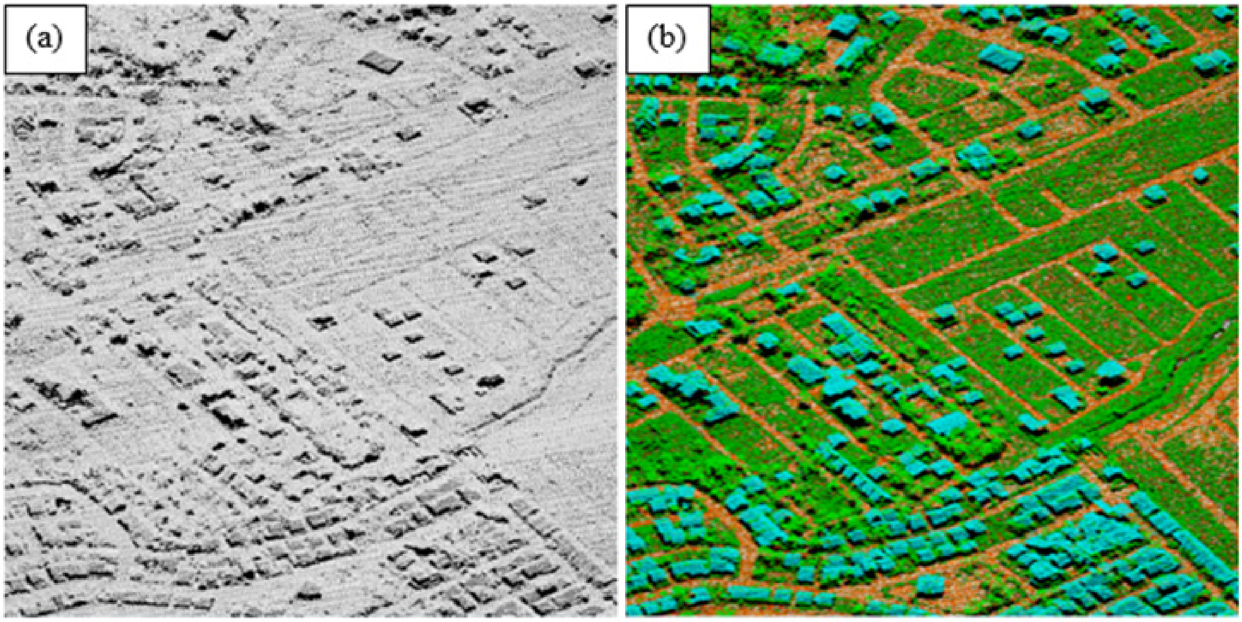


Figure 28. Point cloud before (a) and after (b) classification

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 29. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

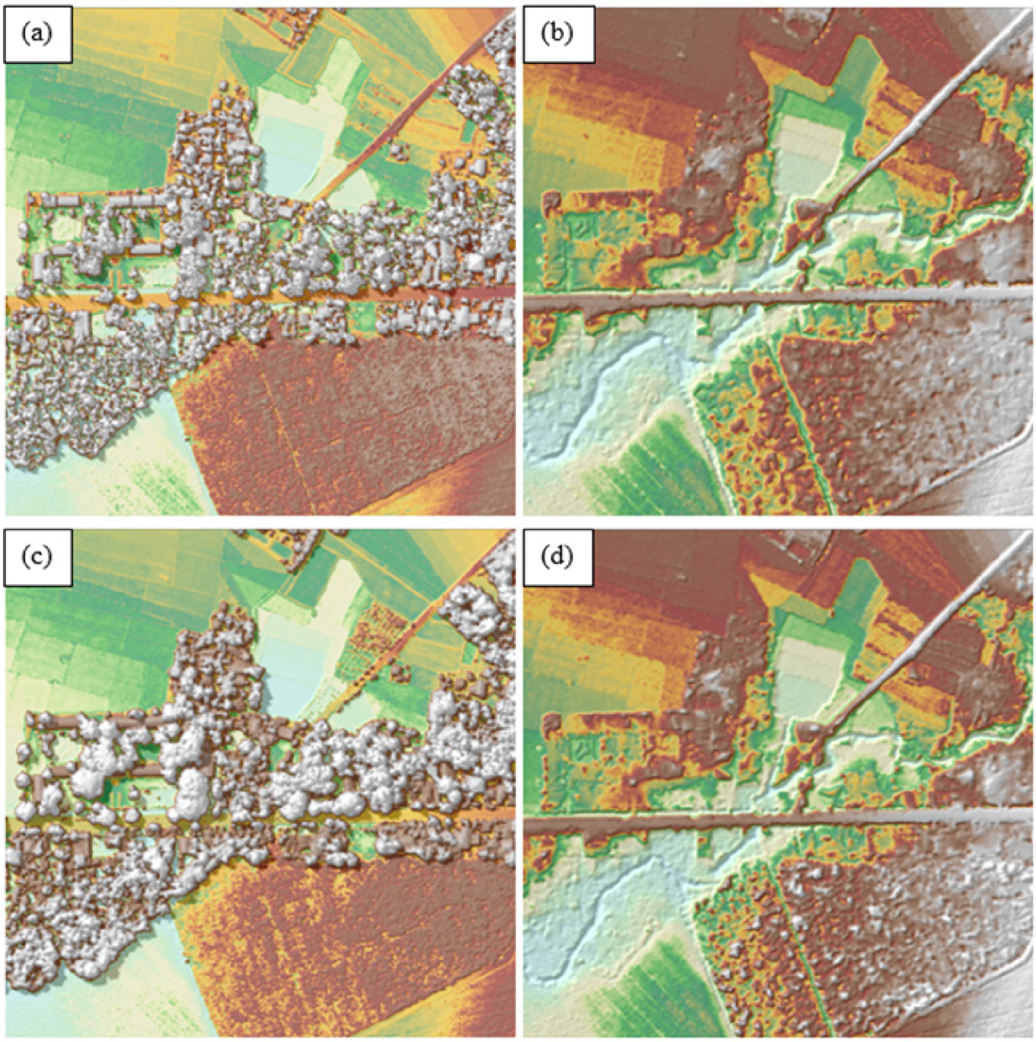


Figure 29. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Bago Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 2,388 1km by 1km tiles area covered by Bago floodplain is shown in Figure 30. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Bago floodplain has a total of 1,566.31 sq.km orthophotogaph coverage comprised of 4,928 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 31.

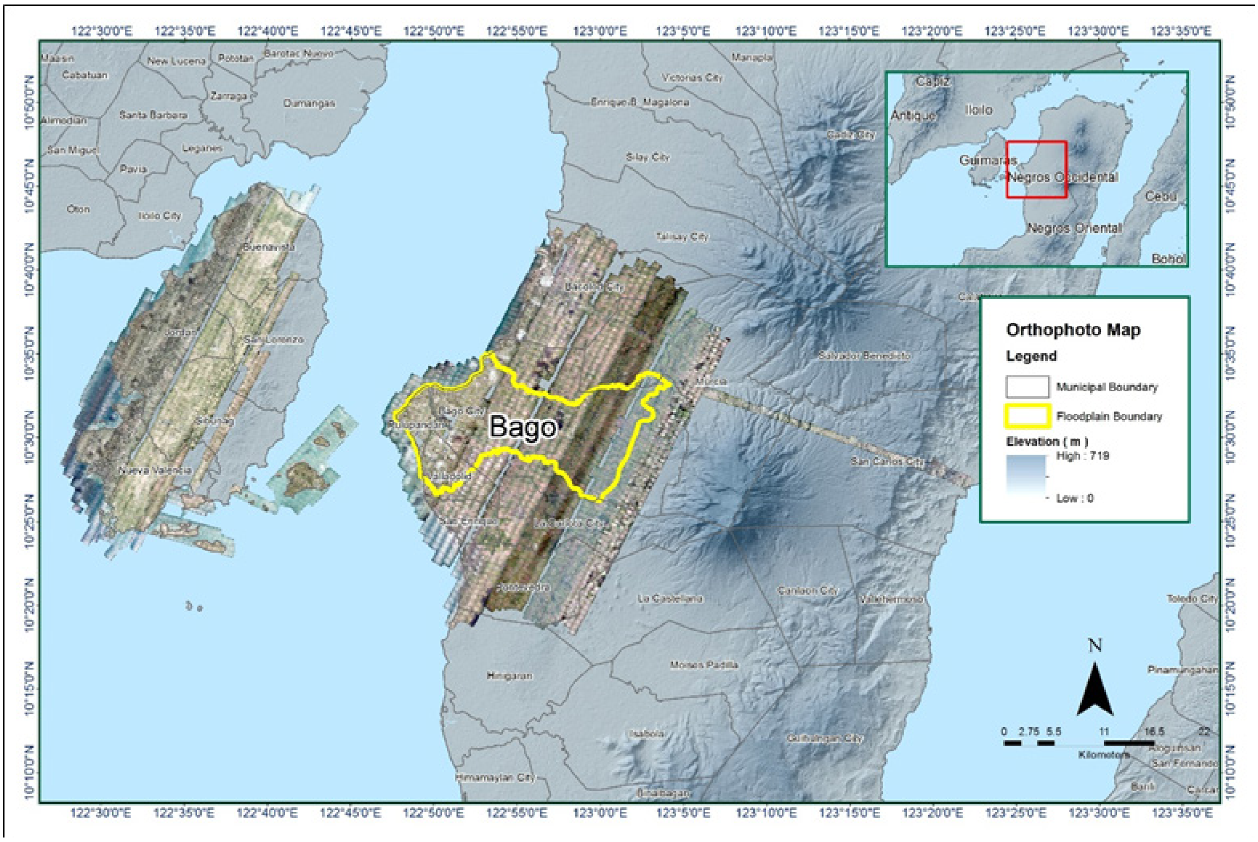


Figure 30. Bago Floodplain with available orthophotographs

Figure 31. Sample orthophotograph tiles for Bago Floodplain.

3.8 DEM Editing and Hydro-Correction

Sixteen (16) mission blocks were processed for Bago flood plain. These blocks are composed of Negros, Iloilo and its reflights and Bacolod blocks with a total area of 2313.84 square kilometers. Table 25B-4 shows the name and corresponding area of each block in square kilometers.

Table 25 LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
Negros _Blk45A	214.24
Negros _Blk45A_additional	81.07
Negros _Blk45B	573.49
Negros_Blk45C	254.32
Negros _Blk46A_additional	51.66
NegrosOccidental_reflights_Blk45A	38.61
Bacolod_Blk45A	8.76
Iloilo_Blk43M	240.28
Iloilo_Blk43N	196.64
Iloilo_Blk43N_additional1	45.55
Iloilo_Blk43N_additional2	49.03
Iloilo_Blk43N_additional3	115.75
Iloilo_Blk43O	246.06
Iloilo_Blk43O_additional	104.29
Iloilo_Blk43O_supplement	33.15
Iloilo_reflight_Blk43N	60.93
TOTAL	2313.84 sq. km

Portions of DTM before and after manual editing are shown in Figure 32. It shows that the paddy field (Figure 32a had been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 32b). The bridges (Figure 32c) was an impedance to the flow of water along the river and have to be removed (Figure 32d) in order to hydrologically correct the river. Another example is a road that had been misclassified (Figure 32e) and had to be retrieved through manual editing (Figure 32d).

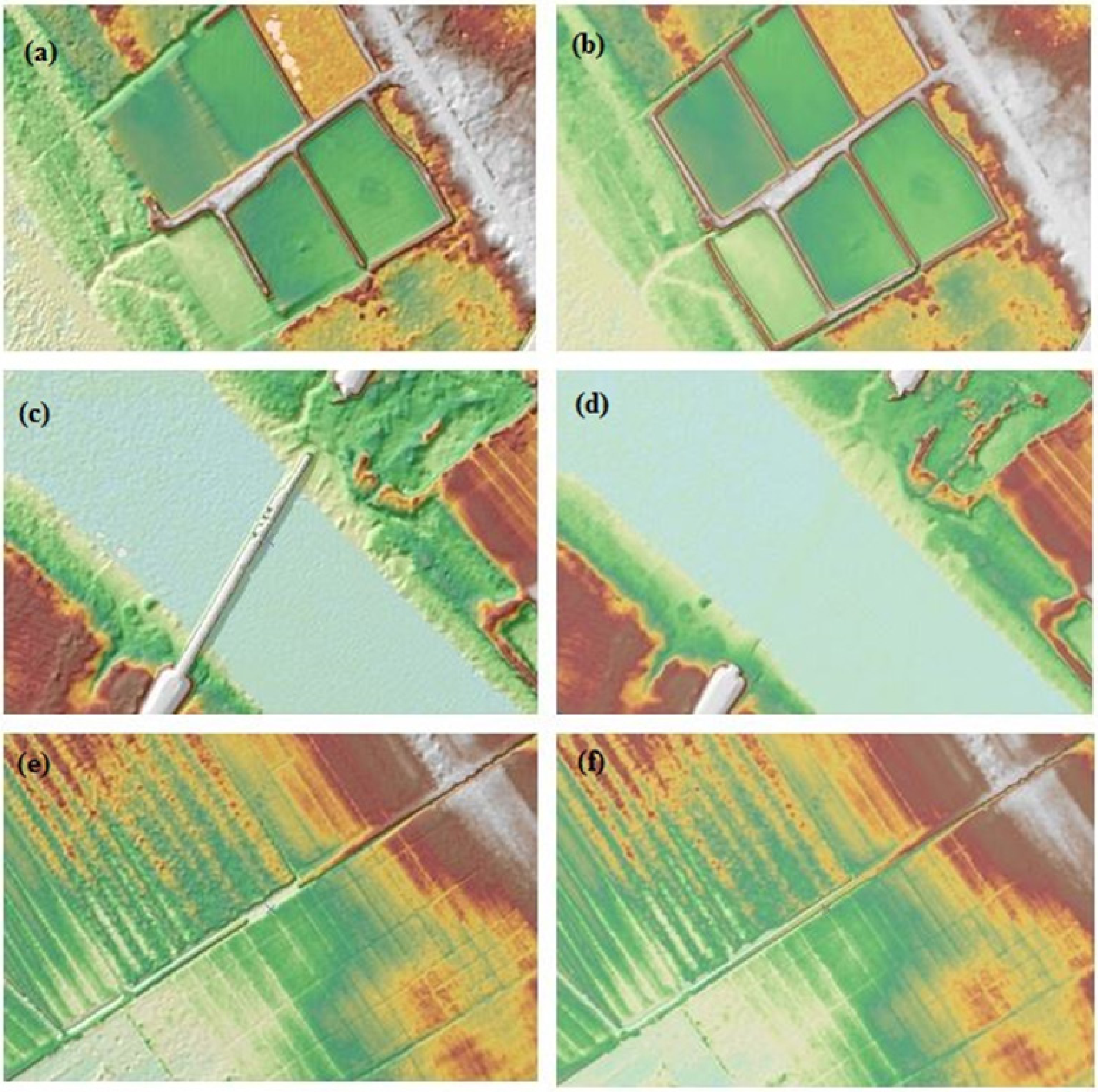


Figure 32. Portions in the DTM of Bago floodplain – a paddy field before (a) and after (b) data retrieval; bridges before (c) and after (d) manual editing; and a road before (e) and after (f) data retrieval

3.9 Mosaicking of Blocks

Negros_Blk45A was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 26shows the area of each LiDAR block and the shift values applied during mosaicking.

Table 26 Shift Values of each LiDAR Block of Bago floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Negros _Blk45A	0.00	0.00	0.20
Negros _Blk45A_additional	0.00	0.00	-0.05
Negros _Blk45B	0.00	0.00	0.57
Negros_Blk45C	1.00	1.00	0.48
Negros _Blk46A_additional	0.00	0.00	0.54
NegrosOccidental_reflights_Blk45A	0.00	0.00	0.34
Bacolod_Blk45A	2.00	-2.00	-4.33
Iloilo_Blk43M	0.00	0.00	0.00
Iloilo_Blk43N	0.00	0.00	0.17
Iloilo_Blk43N_additional1	-1.00	2.00	0.38
Iloilo_Blk43N_additional2	0.00	2.00	0.24
Iloilo_Blk43N_additional3	-1.00	3.00	-2.58
Iloilo_Blk43O	-1.00	2.00	2.54
Iloilo_Blk43O_additional	0.00	0.00	0.30
Iloilo_Blk43O_supplement	-1.00	2.00	-2.76
Iloilo_reflights_Blk43N	-1.00	2.00	-1.80

Mosaicked LiDAR DTM for Bago floodplain is shown on Figure 33. It can be seen that the entire Bago floodplain is 100% covered by LiDAR data.

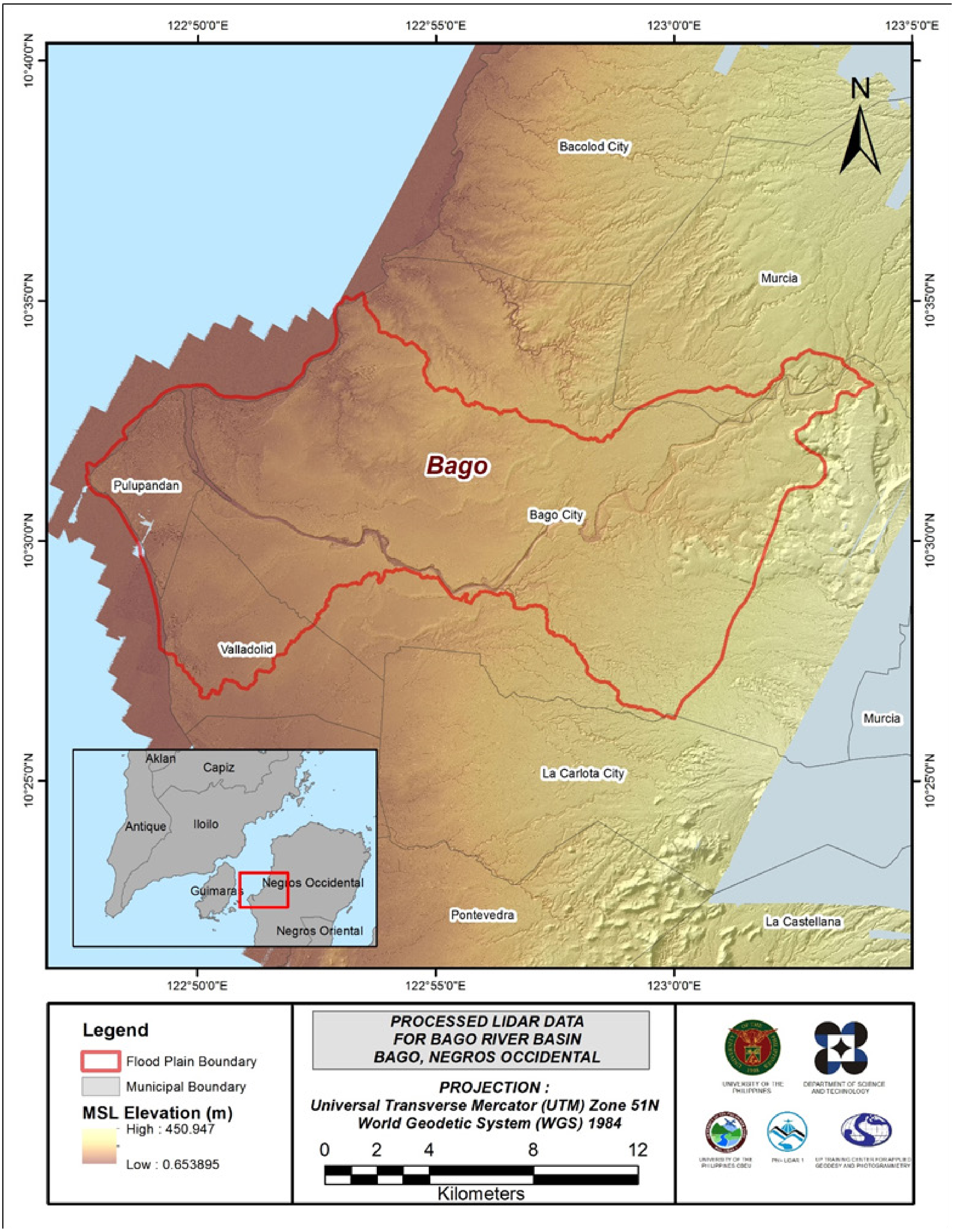


Figure 33. Map of Processed LiDAR Data for Bago Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in the Negros Island to collect points with which the LiDAR dataset is validated is shown in Figure 34. A total of 39,705 points were gathered for all the floodplains within the Negros Island wherein the Bago is located. Random selection of 80% of the survey points, resulting to 31,385 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 35. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.94 meters with a standard deviation of 0.15 meters. Calibration of Bago LiDAR data was done by subtracting the height difference value, 0.94 meters, to the mosaicked LiDAR data for Bago. Table 27 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

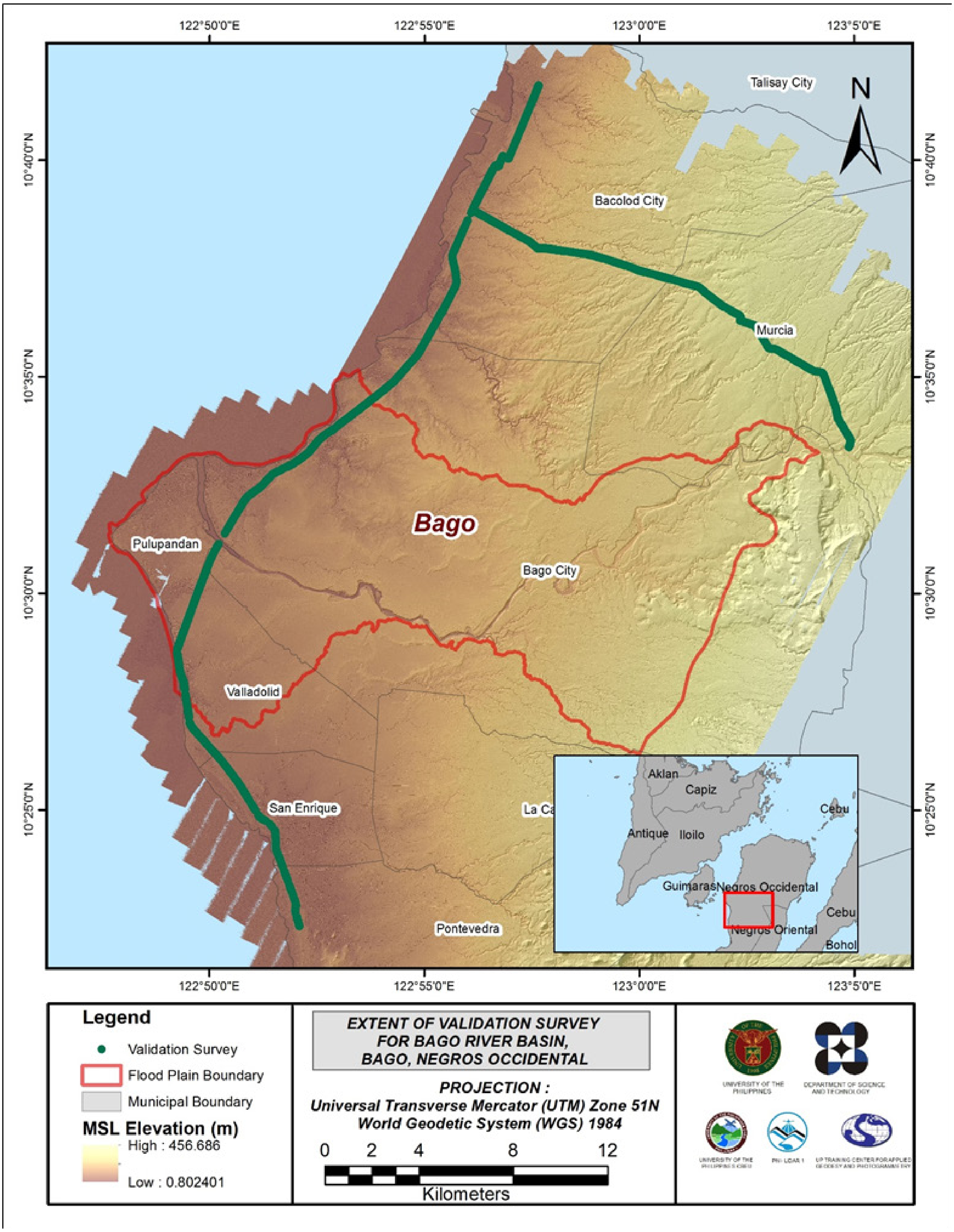


Figure 34. Map of Bago Floodplain with validation survey points in green

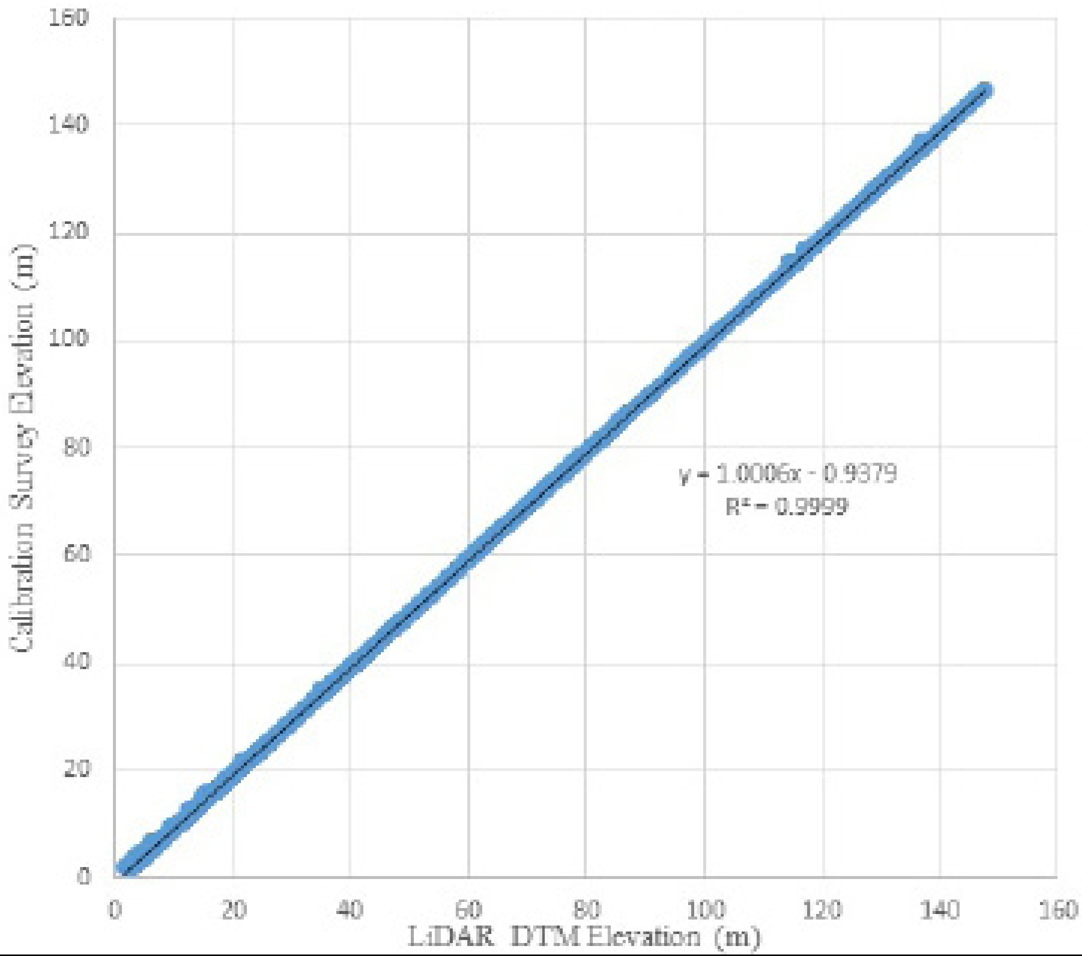


Figure 35. Correlation Plots between calibration survey points and LiDAR data

Table 27 Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.94
Standard Deviation	0.15
Average	-0.93
Minimum	-1.21
Maximum	0.89

A total of 621 survey points that are within Bago flood plain were used for the validation of the calibrated Bago 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 36. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.13 meters with a standard deviation of 0.12 meters, as shown in Table 28.

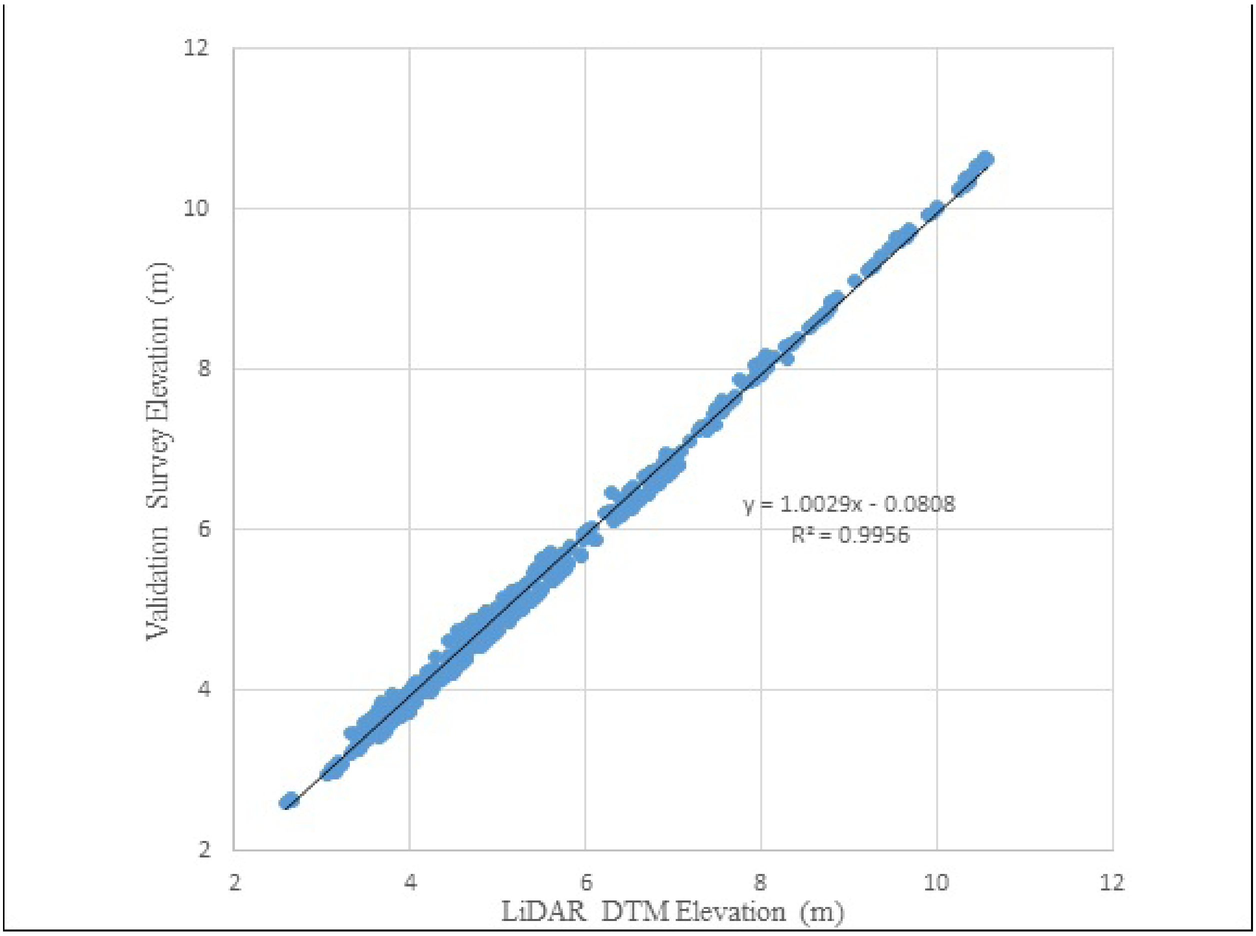


Figure 36. Correlation plot between validation survey points and LiDAR data

Table 28 Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.13
Standard Deviation	0.12
Average	-0.07
Minimum	-0.27
Maximum	0.21

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, a total of 32,381 bathymetric survey points in centerline and zigzag was used for Bago. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.7171 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Bago integrated with the processed LiDAR DEM is shown in Figure 37.

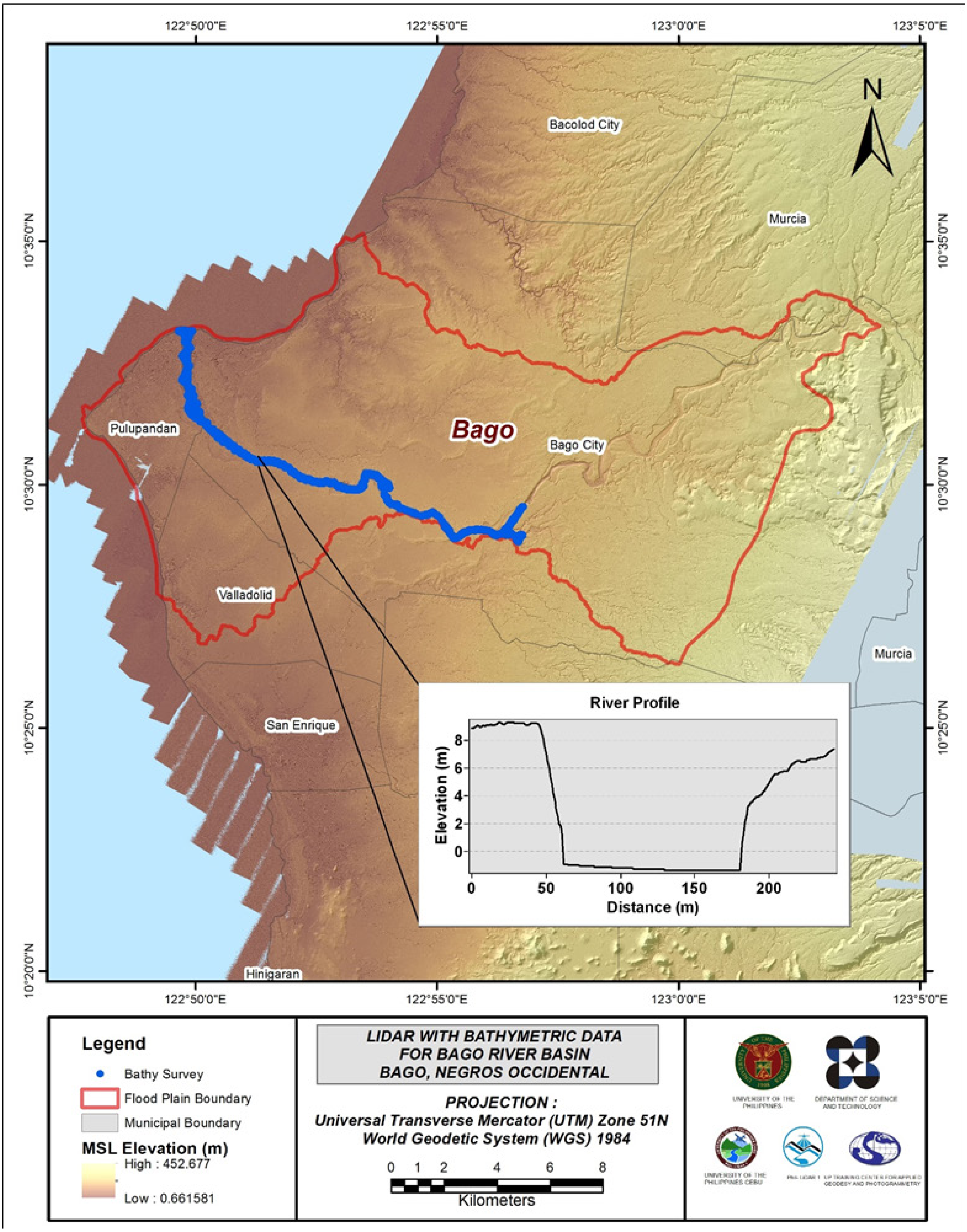


Figure 37. Map of Bago Floodplain with bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Bago floodplain, including its 200 m buffer, has a total area of 264.11 sq km. For this area, a total of 9.0 sq km, corresponding to a total of 3267 building features, are considered for QC. Figure 38 shows the QC blocks for Bago floodplain.

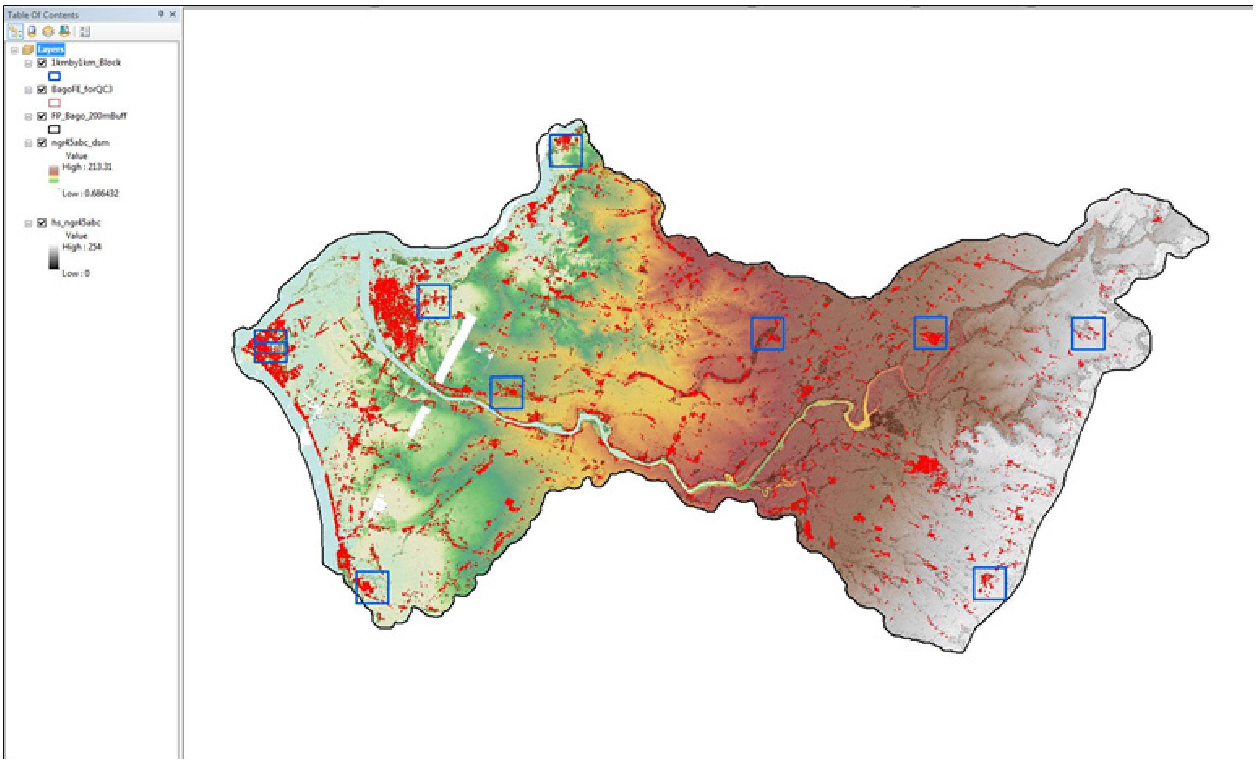


Figure 38. QC blocks for Bago building features

Quality checking of Bago building features resulted in the ratings shown in Table 29.

Table 29 Quality Checking Ratings for Bago Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Bago	99.39	100.00	99.89	PASSED

3.12.2 Height Extraction

Height extraction was done for 36,732 building features in Bago floodplain. Of these building features, 250 were filtered out after height extraction, resulting to 36,482 buildings with height attributes. The lowest building height is at 2.0 m, while the highest building is at 11.51 m.

3.12.3 Feature Attribution

The feature attribution survey was conducted through a participatory community-based mapping in coordination with the Local Government Units of the Municipality/City. The research associates of Phil-LiDAR 1 team visited local barangay units and interviewed key local personnel and officials who possessed expert knowledge of their local environments to identify and map out features.

Maps were displayed on a laptop and were presented to the interviewees for identification. The displayed map include the orthophotographs, Digital Surface Models, existing landmarks, and extracted feature shapefiles. Physical surveys of the barangays were also done by the Phil-LiDAR 1 team every after (or after every?) interview for validation. The number of days by which the survey was conducted was dependent on the number of features and number of barangays included in the flood plain of the river basin.

Table 30 summarizes the number of building features per type. On the other hand, Table 31 shows the total length of each road type, while Table 32 shows the number of water features extracted per type.

Table 30 Building Features Extracted for Bago Floodplain .

Facility Type	No. of Features
Residential	34,869
School	495
Market	55
Agricultural/Agro-Industrial Facilities	280
Medical Institutions	10
Barangay Hall	15
Military Institution	1
Sports Center/Gymnasium/Covered Court	24
Telecommunication Facilities	2
Transport Terminal	1
Warehouse	18
Power Plant/Substation	2
NGO/CSO Offices	7
Police Station	1
Water Supply/Sewerage	4
Religious Institutions	60
Bank	5
Factory	154
Gas Station	14
Fire Station	0
Other Government Offices	98
Other Commercial Establishments	355
N/A	12
Total	36,482

Table 31 Total Length of Extracted Roads for Bago Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Bago	241.76	14.9	0	75.61	501.28	833.55

Table 32 Number of Extracted Water Bodies for Bago Floodplain

Floodplain	Water Body Type						Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	Others	
Bago	1	0	0	0	910	11	930

A total of 40 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 39 shows the Digital Surface Model (DSM) of Bago floodplain overlaid with its ground features.

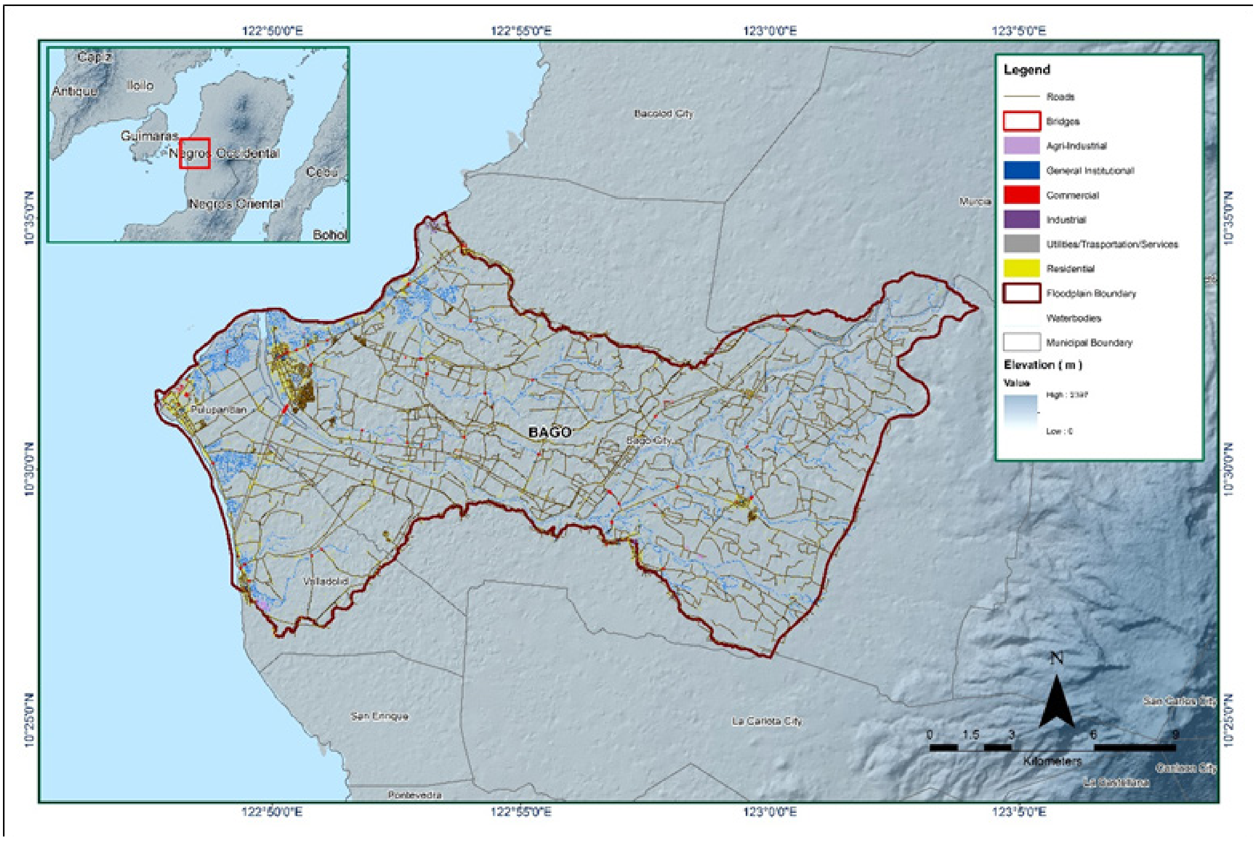


Figure 39. Extracted features for Bago Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE BAGO 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 field surveys in Bago River on October 17 – 31, 2016 for reconnaissance; control survey; cross section and as-built surveys at Quezon Bridge in Brgy. Atipuluan, Bago City, and at Maragandang Bridge in Brgy. Mao-Ao Barrio, also in Bago CIty, both of which are in Negros Occidental[Or use "(at Quezon Bridge in Brgy. Atipuluan, and at Maragandang Bridge in Brgy. Mao-Ao Barrio, both in Bago CIty, Negros Occidental)"]; validation points acquisition of about 62.433 km covering the Bago River Basin; and bathymetric survey from its upstream locations in Brgy. Atipuluan and in Brgy. Mao-Ao Barrio, both in Bago City, down to the downstream end of the river located in Brgy. Poblacion, with an approximate total length of 19.207 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique.

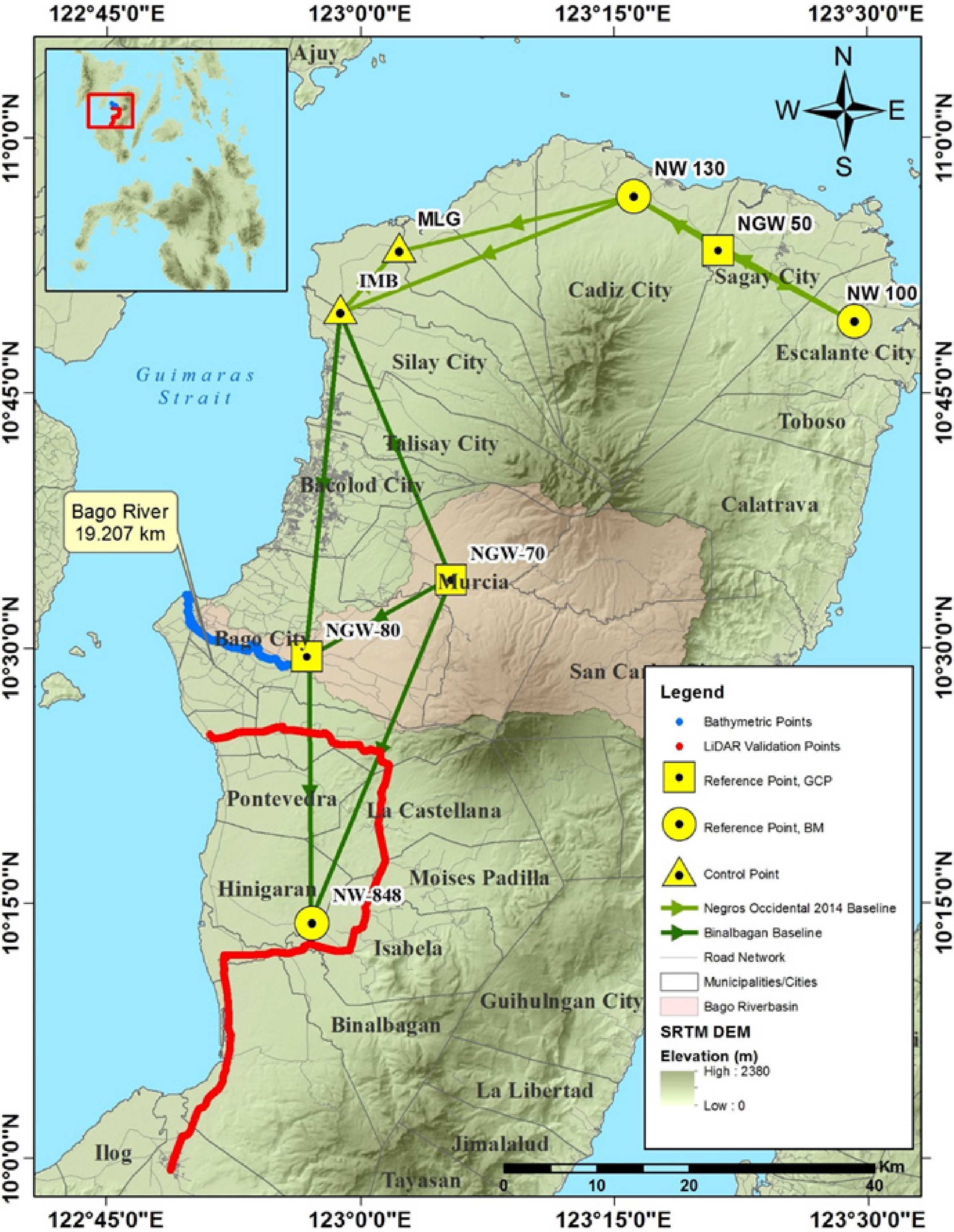


Figure 40. Extent of the bathymetric survey (in blue line) in Bago River and the LiDAR data validation survey (in red).

4.2 Control Survey

A GNSS network was established for a previous PHIL-LIDAR 1 DVBC fieldwork in Himogaan River on September 11, 2014 occupying the control points NGW-50, a 2nd order GCP in Brgy. Paraiso, Sagay City; and NW-100, a 1st order Benchmark in Brgy. Malasibog, Escalante City; all in Negros Occidental.

The GNSS network used for Bago River Basin is composed of two (2) loops established on October 18, 2016 occupying the reference points: IMB from the field survey on September 2014 for Himogaan River in Brgy. VI Poblacion, Silay City; NGW-70, a 2nd order GCP in Brgy. Sta. Rosa, Municipality of Murcia; and NW-848, a 1st order BM in Brgy. Rumirang, Municipality of Isabela; all in Negros Occidental.

A NAMRIA established control point namely, NGW-80, in Brgy. Ma-Ao Barrio, Bago City, Negros Occidental, was also occupied to use as marker for the survey.

The reference and control points and their locations are summarized in Table 33 while the GNSS network established is illustrated in Figure 41.

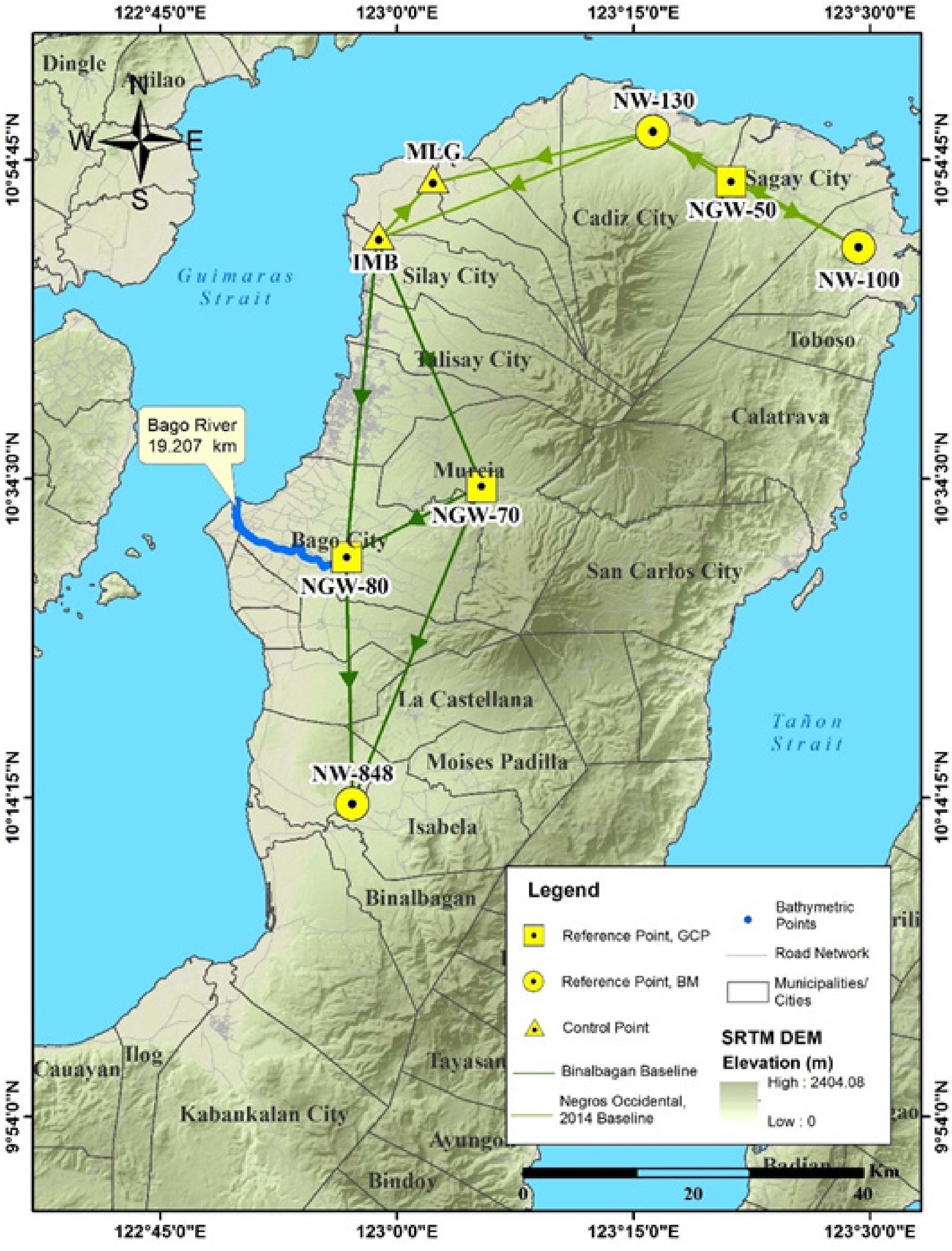


Figure 41. The GNSS Network established in the Bago River Survey.

Table 33 List of Reference and Control Points occupied for Bago River Survey

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
Control Survey on October 18, 2016						
IMB	fixed	10°49'57.92767"	122°58'49.65412"	69.623	8.554	09-13-14
NGW-70	2nd Order, GCP	10°34'02.36206"	123°05'21.65960"	197.488	-	10-18-16
NW-848	1st Order , BM	-	-	80.720	18.716	10-18-16
NGW-80	Used as marker	10°29'31.60387"	122°56'49.03428"	89.312	-	04-23-14
Control Survey on September 11, 2014						
NGW-50	2nd Order, GCP	10°53'22.52478"	123°21'11.86863"	74.422	13.0512	05-09-14
NW-100	1st Order, BM	10°49'12.14033"	123°29'16.71793"	68.325	7.227	05-09-14

The GNSS set-ups setups on recovered reference points and established control points in Bago River are shown in Figure 42 to Figure 45.

Figure 42. GNSS receiver set-up, Trimble® SPS 985, at IMB, located at the approach of Imbang Bridge in Brgy VI, Silay City, Negros Occidental

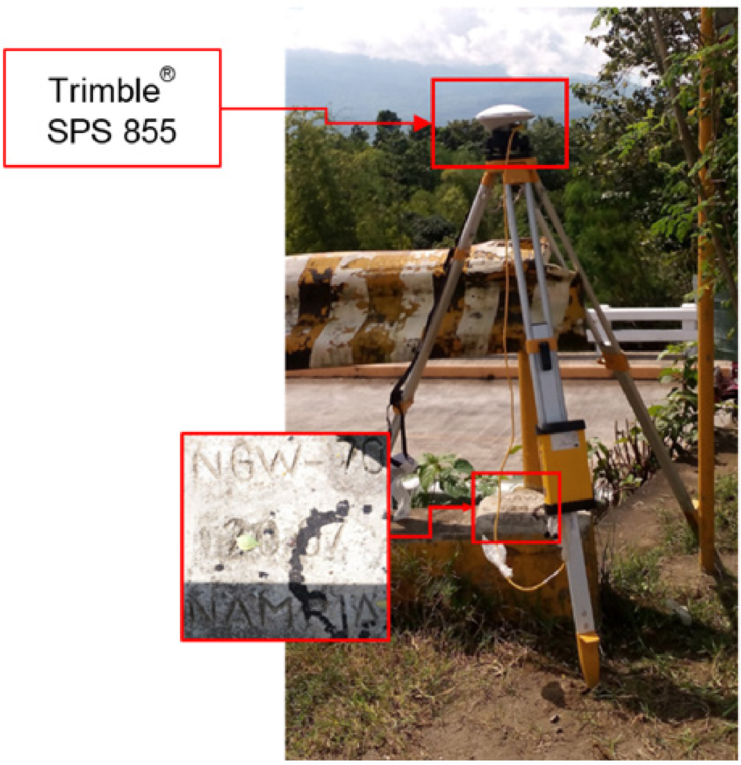


Figure 43. GNSS base set-up, Trimble® SPS 855, at NGW-70, located at the approach of Poncian Bridge in Brgy. Sta. Rosa, Municipality of Murcia, Negros Occidental

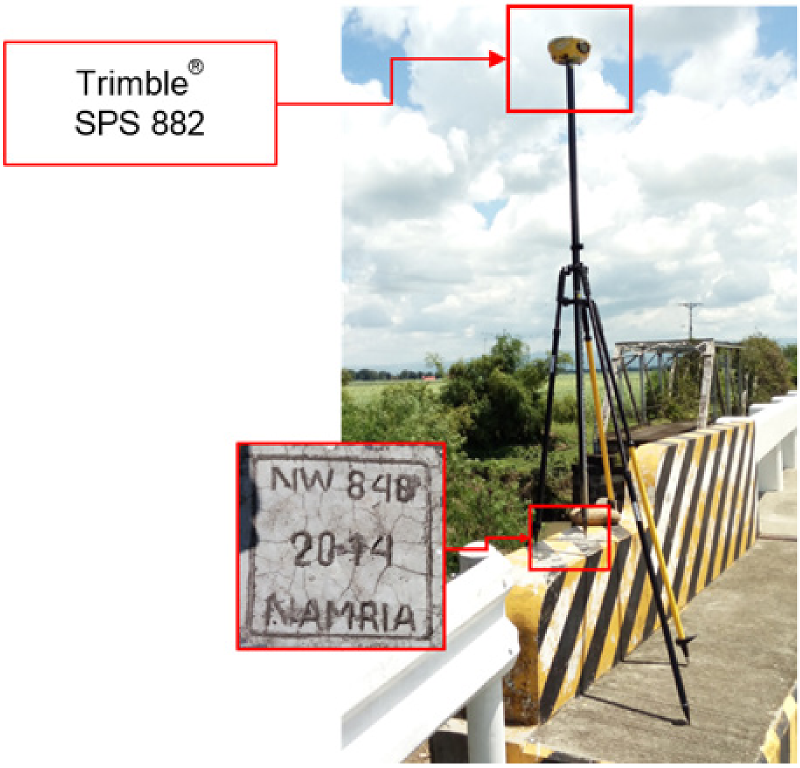


Figure 44. GNSS receiver set-up, Trimble® SPS 985 at NW-848, located at the approach of Binalbagan Bridge in Brgy. Rumirang, Municipality of Isabela, Negros Occidental

Figure 45. GNSS receiver set-up, Trimble® SPS 885, at NGW-80, located at the approach of Quezon Bridge in Brgy. Ma-ao Barrio, Bago City, Negros Occidental

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 Bago River Basin is summarized in Table 34 generated by TBC software.

Table 34 Baseline Processing Summary Report for Bago River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
NGW-70 --- IMB (B1)	10-18-16	Fixed	0.006	0.063	157°54'24"	31684.953	129.250
NGW-80 --- NGW-70 (B2)	10-18-16	Fixed	0.002	0.008	241°55'21"	17667.469	-108.173
NGW-70 --- NW-848 (B5)	10-18-16	Fixed	0.003	0.021	201°55'51"	40108.899	-116.691
NGW-80 --- NW-848 (B4)	10-18-16	Fixed	0.003	0.018	178°46'07"	28897.273	-8.543
NGW-80 --- IMB (B3)	10-18-16	Fixed	0.005	0.059	185°33'37"	37857.492	21.051

As shown Table 34 a total of five (5) baselines were processed with coordinate and elevation values of IMB fixed from Himogaan[Himogaan?] Survey; coordinate values of NGW-70; and elevation values of NW-848 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

((xe)2+(ye)2) <20cm and ze<10 cm

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

for each control point. See the Network Adjustment Report shown in Table 35 to Table 38 for complete details.

The four (4) control points, IMB, NGW-70, NW-848, and NGW-80 were occupied and observed simultaneously to form a GNSS loop. Coordinates of NGW-70; elevation value of NW-848; and fixed values of IMB were held fixed during the processing of the control points as presented in Table 35 . Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 35 Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
IMB	Grid	Fixed	Fixed		Fixed
NGW-70	Global	Fixed	Fixed		
NW-848	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 36. All fixed control points have no values for grid and elevation errors.

Table 36 Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
IMB	497864.124	?	1197487.542	?	8.554	?	ENe
NGW-70	509774.888	?	1168140.181	?	135.676	0.086	LL
NGW-80	494195.353	0.014	1159823.452	0.015	27.965	0.089	
NW-848	494811.479	0.029	1130944.297	0.032	18.716	?	e

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

a.IMB

horizontal accuracy	=	Fixed
vertical accuracy	=	Fixed

b.NGW-70

horizontal accuracy	=	Fixed
vertical accuracy	=	8.6 < 10 cm

c.NW-848

horizontal accuracy	=	$\sqrt{((2.9)^2 + (3.2)^2}$
	=	$\sqrt{(8.41 + 10.24)}$
	=	4.31 < 20 cm
vertical accuracy	=	Fixed

d.NGW-80

horizontal accuracy	=	$\sqrt{((1.4)^2 + (1.5)^2}$
	=	$\sqrt{(1.96 + 2.25)}$
	=	2.05 < 20 cm
vertical accuracy	=	8.9 < 10 cm

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

Table 37 Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
IMB	N10°49'57.92767"	E122°58'49.65412"	68.623	?	ENe
NGW-70	N10°34'02.36206"	E123°05'21.65960"	197.488	0.086	LL
NGW-80	N10°29'31.60387"	E122°56'49.03428"	89.312	0.089	
NW-848	N10°13'51.30934"	E122°57'09.44536"	80.720	?	e

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 37. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 38.

Table 38 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)
Control Survey on October 18, 2016							
IMB	Fixed	10°49'57.92767"	122°58'49.65412"	68.623	1197487.542	497864.124	8.554
NGW-50	2nd Order, GCP	10°34'02.36206"	123°05'21.65960"	197.488	1168140.181	509774.888	135.676
NW-848	1st Order, BM	10°13'51.30934"	122°57'09.44536"	80.720	1130944.297	494811.479	18.716
NGW-80	Used as marker	10°29'31.60387"	122°56'49.03428"	89.312	1159823.452	494195.353	27.965
Control Survey on September 11, 2016							
NGW-50	2nd Order, GCP	10°53'22.52478"	123°21'11.86863"	74.422	1203794	538610	13.051
NW-100	1st Order, BM	10°49'12.14033"	123°29'16.71793"	68.325	1196124	553341.2	7.227

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

Cross-section and as-built surveys were conducted on October 20 and 21, 2016 at the downstream side of Quezon bridge in Brgy. Atipuluan, Bago City as shown in Figure 46; and on Oct 30, 2016 at the downstream side of Maragandang Bridge in Brgy. Mao-Ao Barrio, Bago City as shown in Figure 47. A survey grade GNSS receiver Trimble® SPS 985 and 882 in PPK survey technique was utilized for this survey as shown in Figure 48 A and B, respectively.

Figure 46. Quezon Bridge facing downstream

Figure 47. Maragandang Bridge facing upstream

Figure 48. As-built survey of (a) Quezon Bridge and (B) Maragandang Bridge

The cross-sectional line of Quezon Bridge is about 183 m with one hundred and two (102) cross-sectional points; while the cross-sectional line along Maragandang Bridge is about 162 m with fifty two (52) cross-sectional points, both using the control point NGW-80 as the GNSS base station The location map, cross-section diagrams, and the bridge data forms are shown in Figure 49 to Figure 54, respectively.

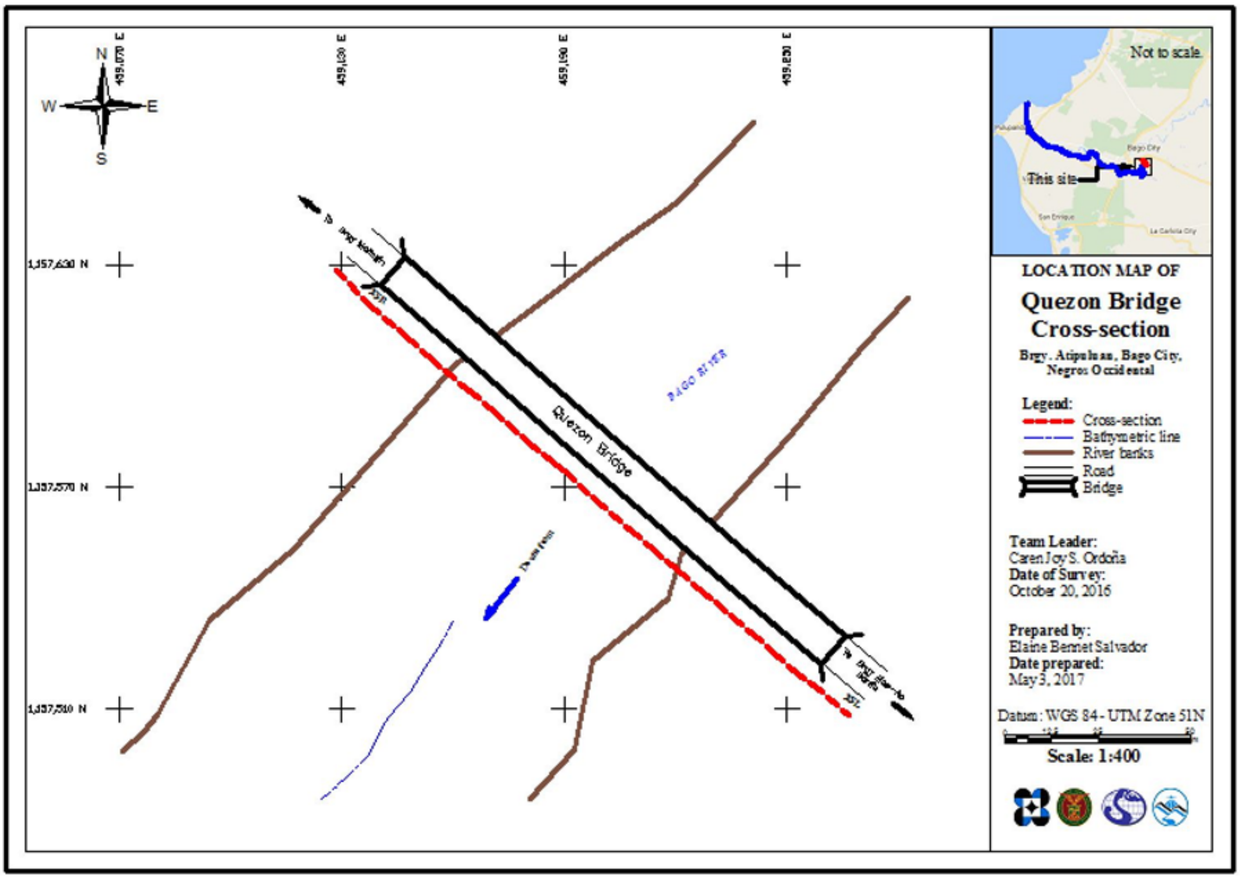


Figure 49. Location map of Quezon Bridge cross-section survey

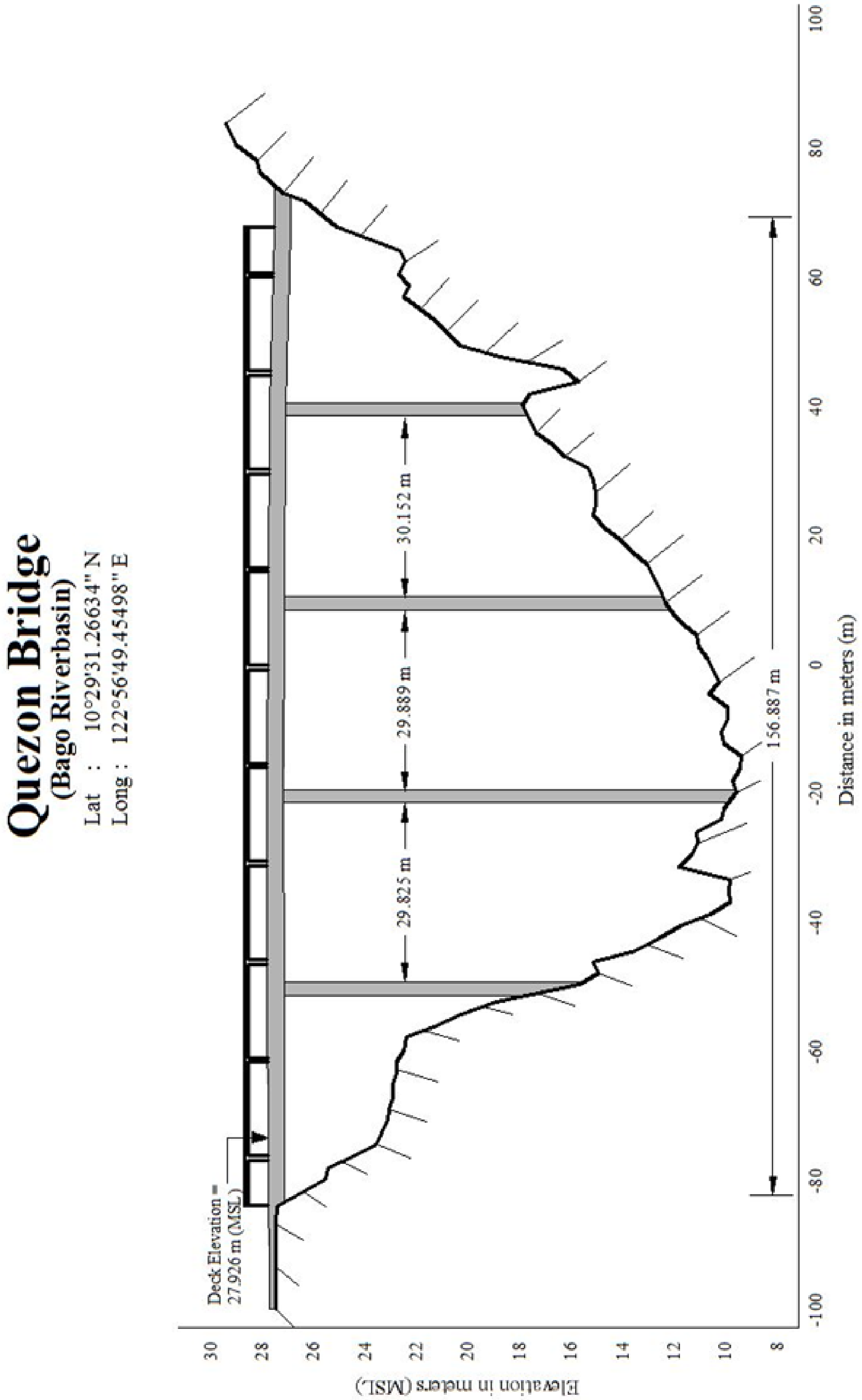


Figure 50 Quezon Bridge cross-section diagram

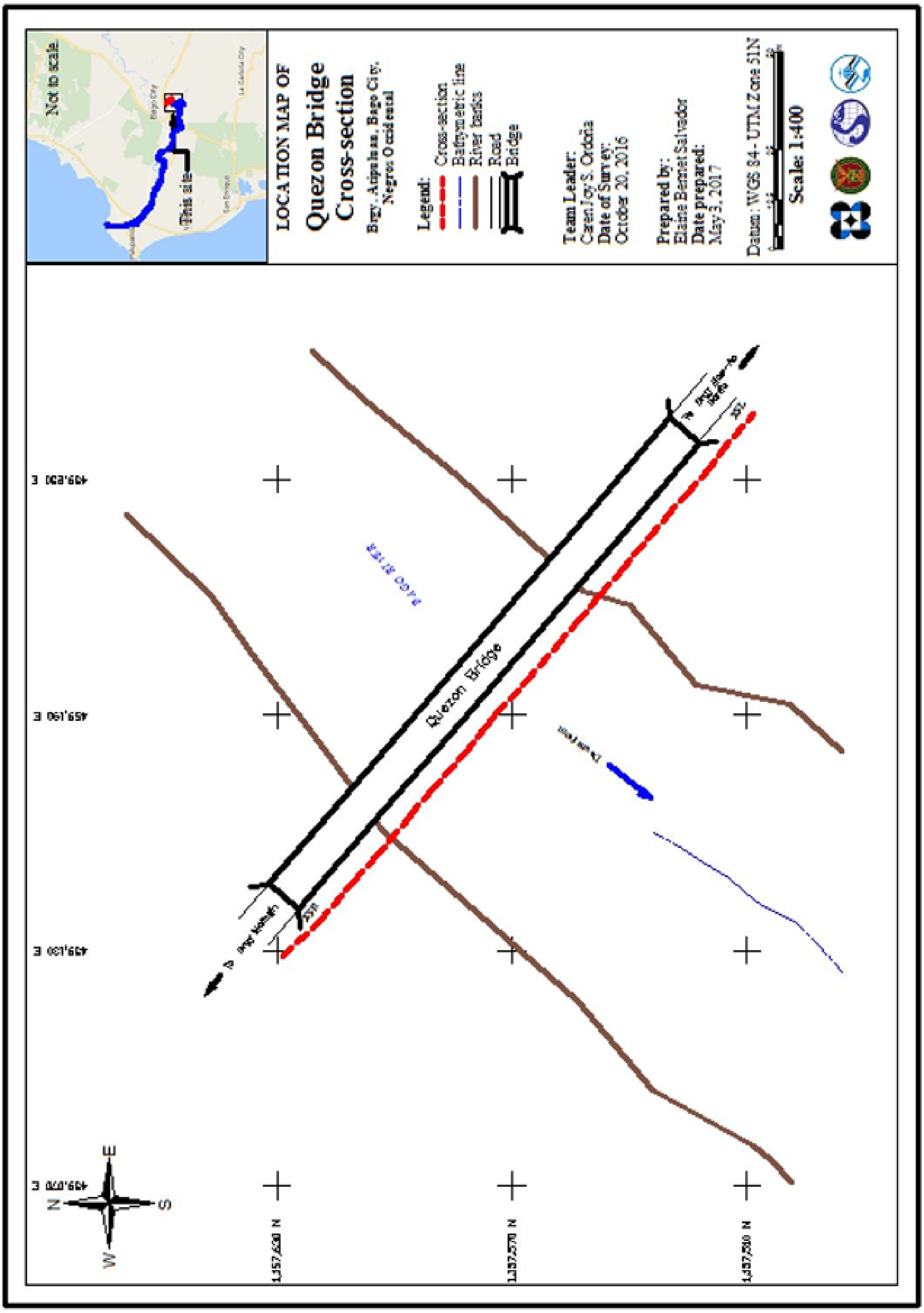


Figure 51. Maragandang Bridge cross-section location map

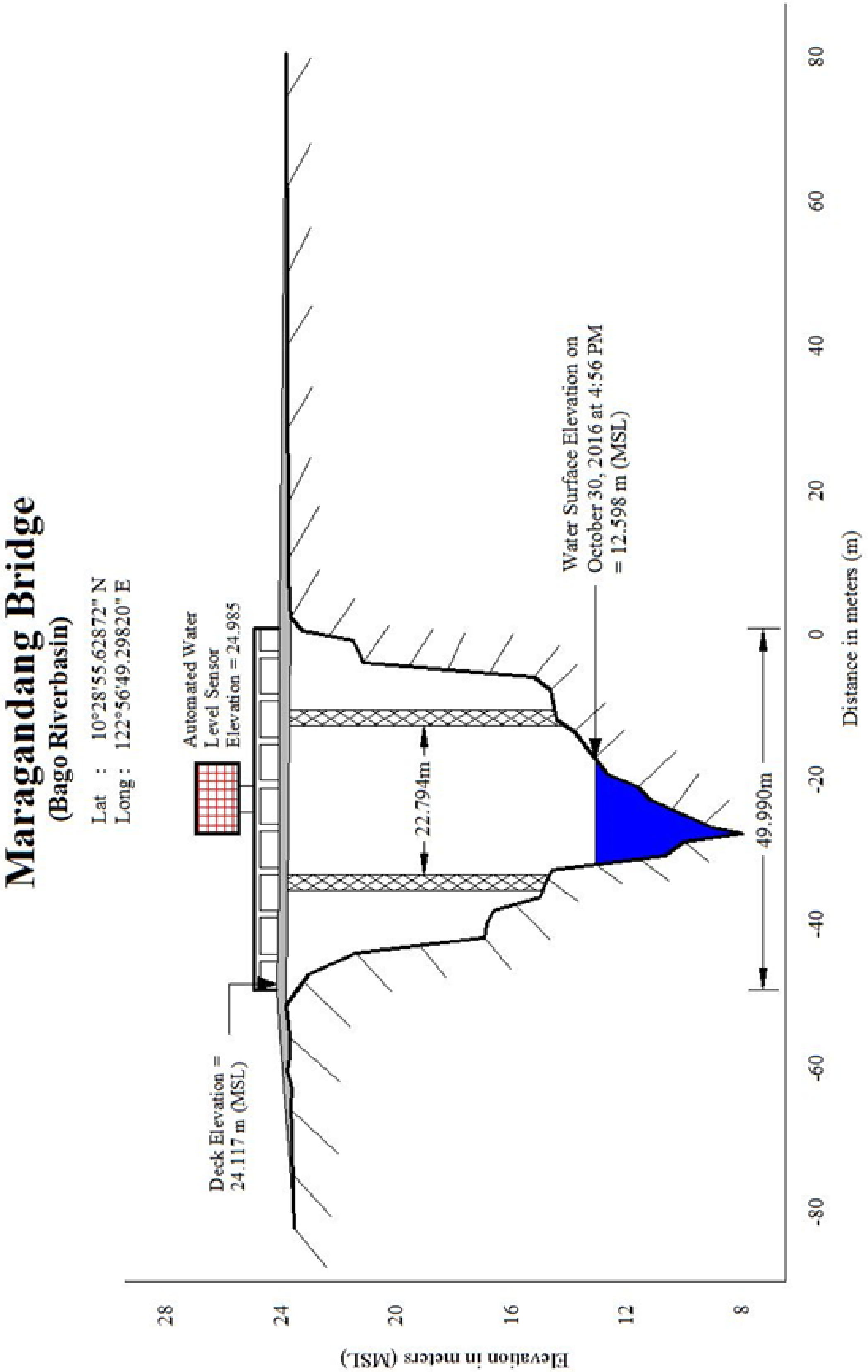
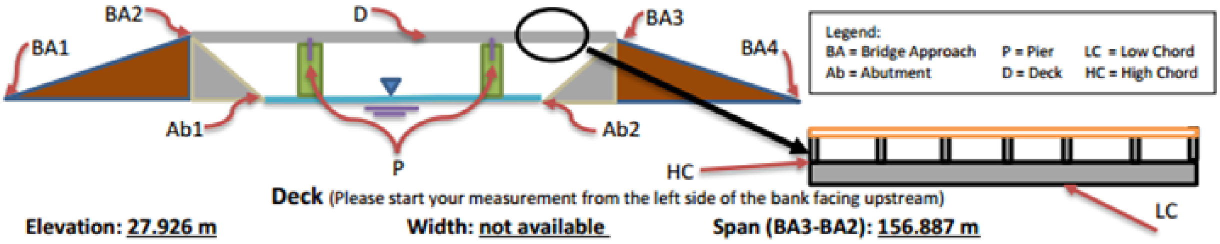


Figure 52. Margandang Bridge Cross-section Diagram

Bridge Data Form

Bridge Name: Quezon Bridge	**Date:** October 20, 2016
River Name: Bago River	**Time:** 4:54 PM
Location (Brgy, City,Region): Brgy. Atipuluan, Bago City, Negros Occidental	
Survey Team: Caren Joy Ordoña, Marion Dimain, Janina Jupiter	
Flow condition: average	**Weather Condition:** fair
Latitude: 10°28'55.62872"N	**Longitude:** 122°56'49.29820" E



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

Elevation: 27.926 m **Width:** not available **Span (BA3-BA2):** 156.887 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	27.935 m	BA3	156.898 m	27.926 m
BA2	0.012 m	27.926 m	BA4	163.617 m	27.711 m

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

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

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

Shape: round Number of Piers: 4 Height of column footing: Not available

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	33.604 m	27.994 m	Not available
Pier 2	63.429 m	28.011 m	Not available
Pier 3	93.318 m	27.988 m	Not available
Pier 4	123.470 m	27.922 m	Not available

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

Figure 53. Bridge as-built form of Quezon Bridge

Bridge Data Form

Bridge Name: Maragandang Bridge **Date:** October 30, 2016

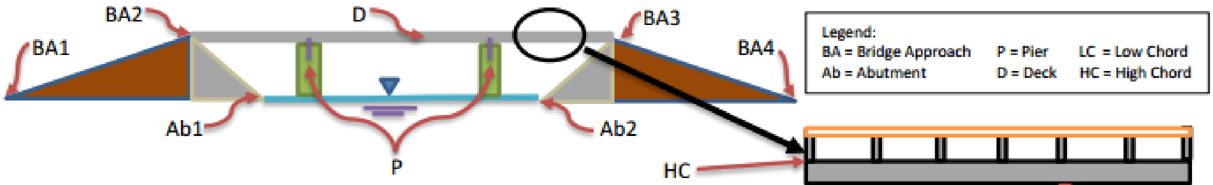
River Name: Bago River **Time:** 4:56 PM

Location (Brgy, City,Region): Brgy. Ma-Ao Barrio, Bago City, Negros Occidental

Survey Team: Caren Joy Ordoña, Marion Dimain, Janina Jupiter

Flow condition: average **Weather Condition:** fair

Latitude: 10˚28'55.62872"N **Longitude:** 122˚56'49.29820" E



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

Elevation: 24.117 m **Width:** not available **Span (BA3-BA2):** 44.990 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	23.502 m	BA3	81.663 m	24.007 m
BA2	31.673 m	24.117 m	BA4	161.255 m	23.679 m

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

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

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

Shape: round Number of Piers: 6 Height of column footing: Not available

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	46.305 m	24.028 m	1.25 m
Pier 2	69.099 m	24.027 m	1.25 m

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

Figure 54. Bridge as-built form of Maragandang Bridge

Water surface elevation of Bago River was determined by a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on October 21, 2016 at 4:56 PM at Maragandang area with a value of 12.598 m in MSL as shown in Figure 49[check first Maybe it should be Fig 51?].. This was translated into marking on the bridge's pier as shown in Figure 55[**check context of Fig 49 and Fig 51…….Fig 49 and fig 54 are about Quezon bridge, NOT maragandang bridge
]. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Bago River, the University of the Philippines Cebu.

Figure 55. Water level markings on Maragandang Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 19 and 21, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted at the side of a vehicle as shown in Figure 56. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.15 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[Change to topographic?] mode with NGW-80 occupied as the GNSS base station in the conduct of the survey.

Figure 56. Validation points acquisition survey set-up using a GNSS receiver fixed in a van along Bago River Basin

The survey started in Brgy. II, Municipality of Pontevedra going north along national highway covering three (3) Municipalities in Negros Occidental: Pontevedra, San Enrique and Valladolid; as well as two (2) cities: Bacolod and Bago CIty. It also covered seven (7) barangays in the Municipality of Murcia namely: Blumentrit Blumentritt, Caliban, Iglau-An Iglau-an, Lopez Jaena, Salvacion, San Miguel and Talotog. A total of 13,140 points with approximate length of 6 km using NGW-80 as GNSS base station for the entire extent validation points acquisition survey is illustrated in the map in Figure 57.

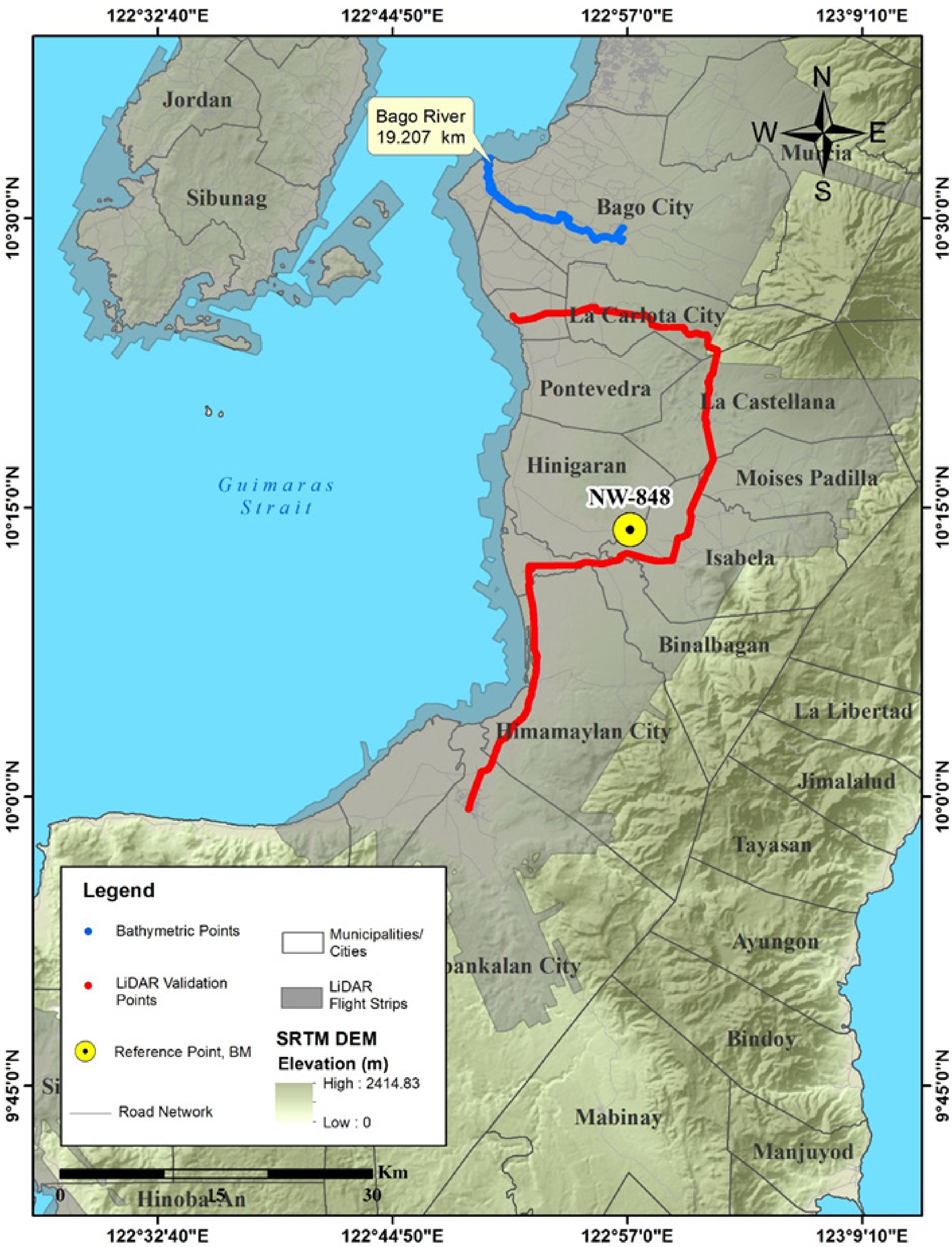


Figure 57. Validation point acquisition survey of Bago River Basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on October 19-21, 2016 using Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 58. It started in Brgy. Napoles, Bago City with coordinates 10°29'34.57030"N, 122°54'11.83952"E, and ended at the mouth of the river in Brgy. Poblacion, Bago City, with coordinates 10°33'09.67104"N, 122°49'48.32511"E. The control point NGW-80 was used as GNSS base station all throughout the entire survey.

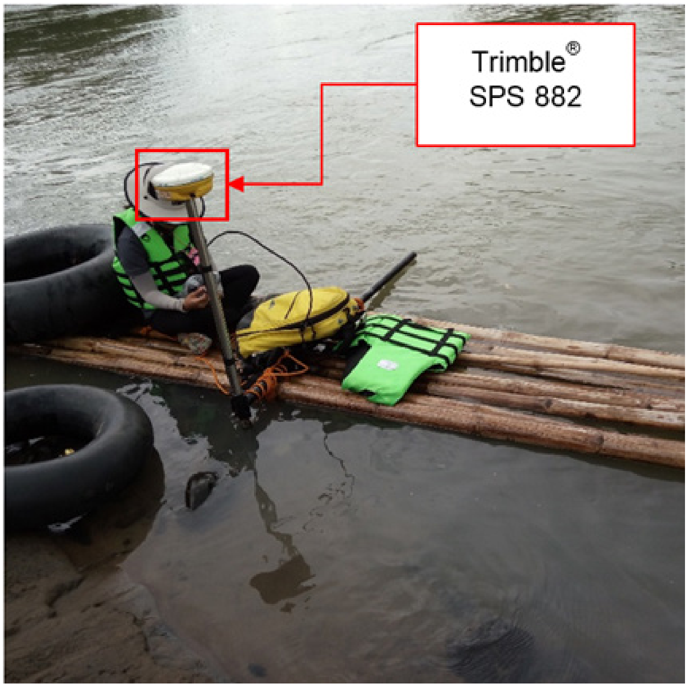


Figure 58. Bathymetric survey using a Trimble® SPS 882 in GNSS PPK survey technique in Bago River

Figure 59. Manual bathymetric survey using a Trimble® SPS 985 in GNSS PPK survey technique in Bago Rive[(move the figure 58 below the paragraph?)]r

Manual Bathymetric survey on the other hand was executed simultaneously on October 19-22, 2016 using Trimble® SPS 985 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 59. It started at the two upstream parts of the river: in Brgy. Atipuluan, Bago City with coordinates 10°29'32.68391"N, 122°56'47.24681"E; and in Brgy. Mao-Ao Barrio, Bago City with coordinates 10°28'57.91855"N, 122°56'46.75708"E, traversing down the river by foot and ended at the starting point of the bathymetric survey by boat. The control point NW-848 was used as GNSS base station all throughout the entire survey. The bathymetric survey for Bago River gathered a total of 35,443 points covering 19.207 km of the river traversing ten (10) barangays in Bago CIty; and Barangays Culo and Ubay of Municipality of Pulupandan; all in Negros Occidental. A CAD drawing was also produced to illustrate the riverbed profile of Bago River. As shown in Figure 61 and Figure 62, the highest and lowest elevation has a 24-m difference. The highest elevation observed was 13.904 m above MSL located in Brgy. Mao-Ao Barrio, Bago City; while the lowest was –11.754 m below MSL located in Brgy. Caridad, also in Bago City. About 20km of the total planned bathymetric line was not surveyed because the area already has available LIDAR DEM.

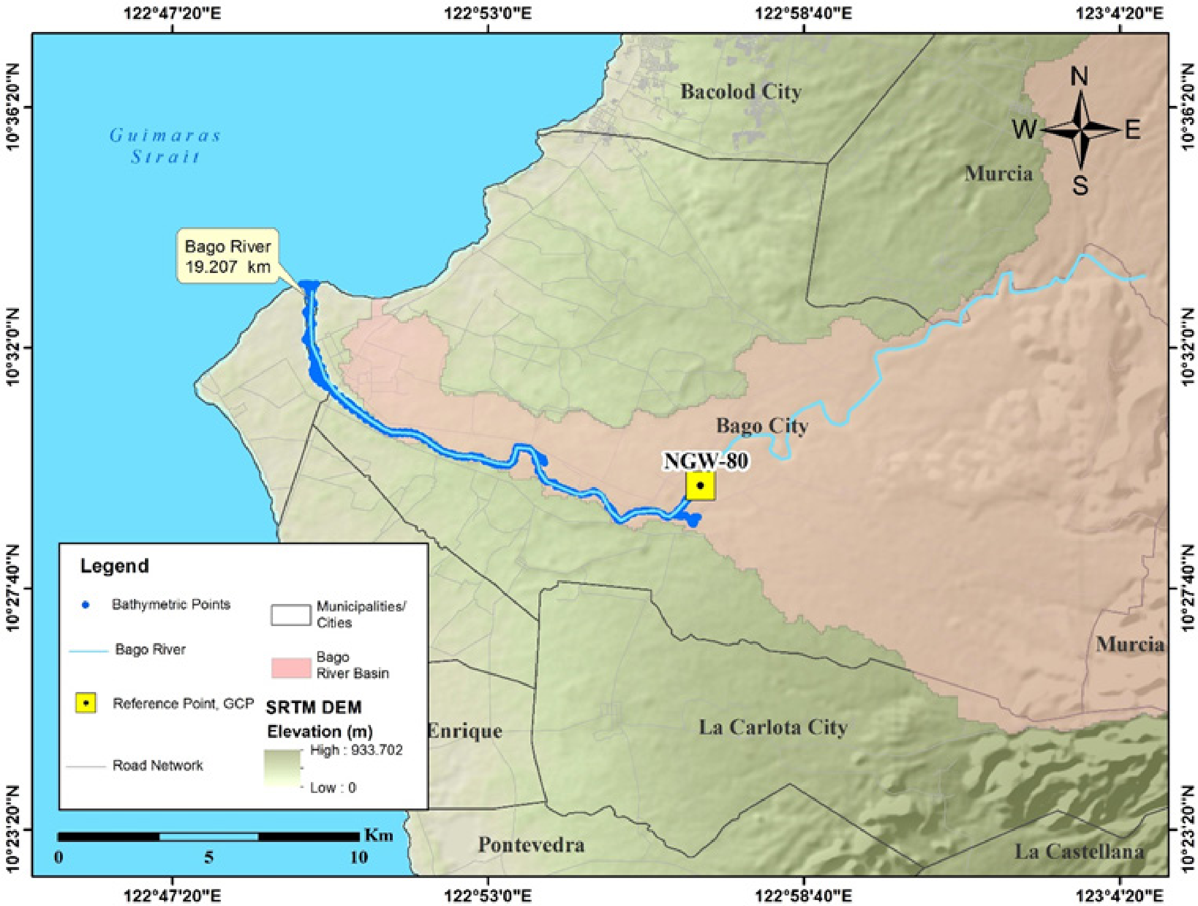


Figure 60. Bathymetric points gathered in Bago River

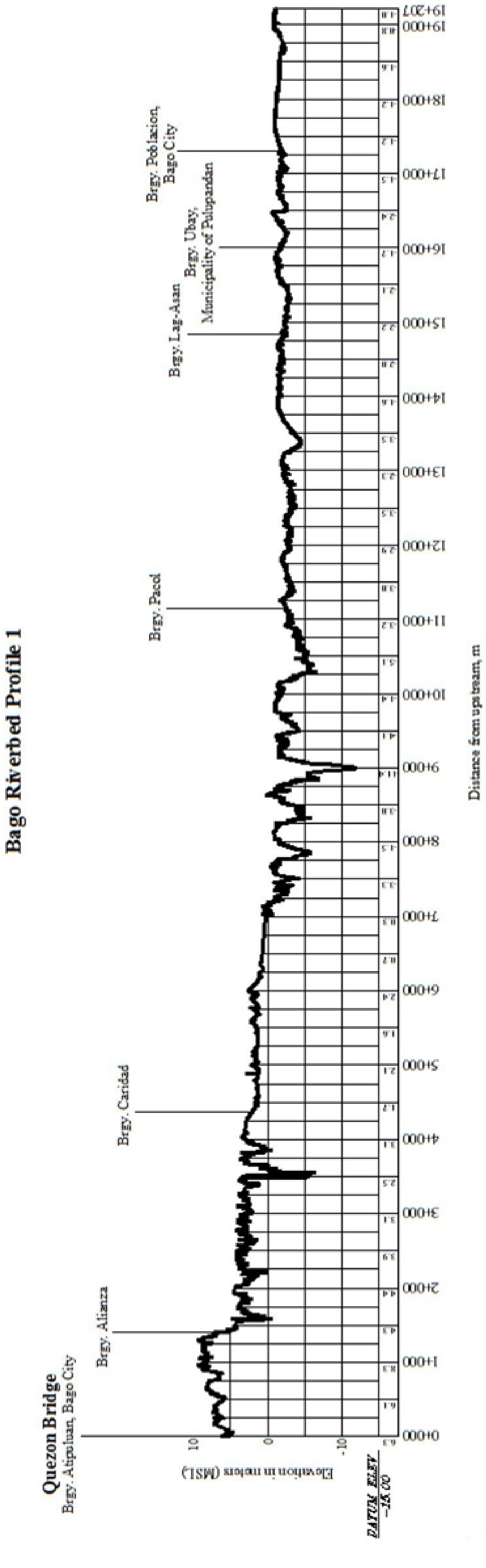


Figure 61. Bago Riverbed Profile from Quezon Bridge

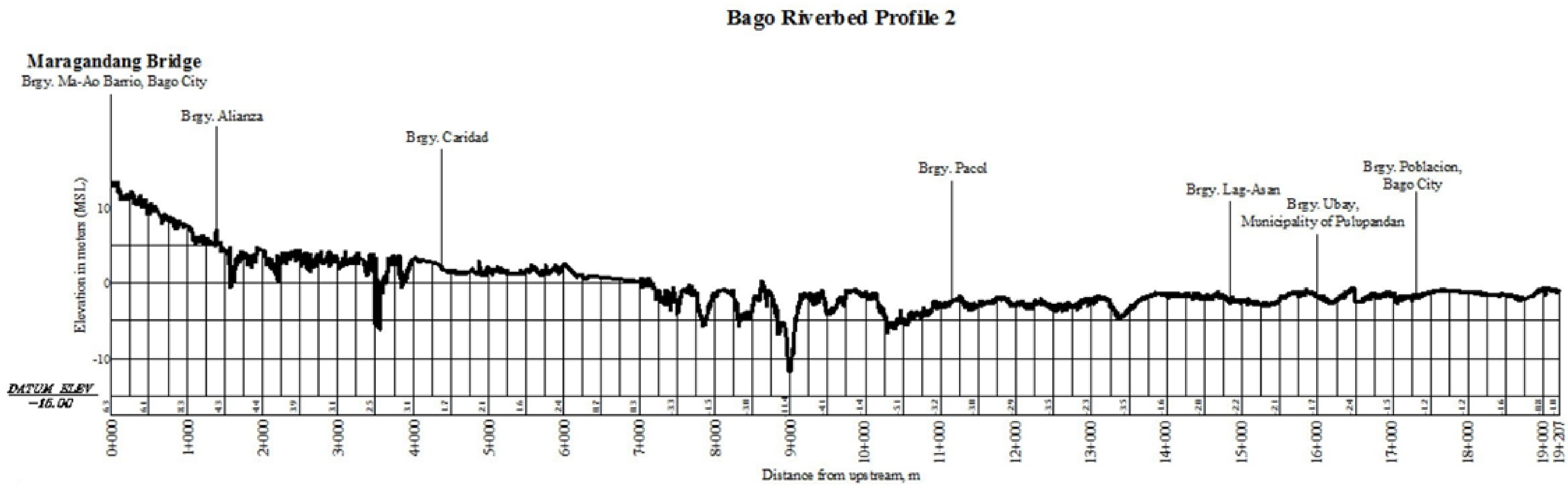


Figure 62. Bago Riverbed Profile from Maragandang Bridge

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, Narvin Clyd Tan, and Marvin Arias

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the UP Cebu Flood Modeling Component (FMC) team. The ARG was installed at Brgy. Abuanan, Bago City, Negros Occidental (Figure 621). The precipitation data collection started from January 9, 2017 at 2:30 AM to 2:10 PM with a recording interval of 10 minutes.

The total precipitation for this event in Brgy Puey ARG was 59.3 mm, with a peak rainfall of 2.80 mm. on January 16, 2017 at 5:35 in the morning. The lag time between the peak rainfall and discharge is 11 hours and 50 minutes.

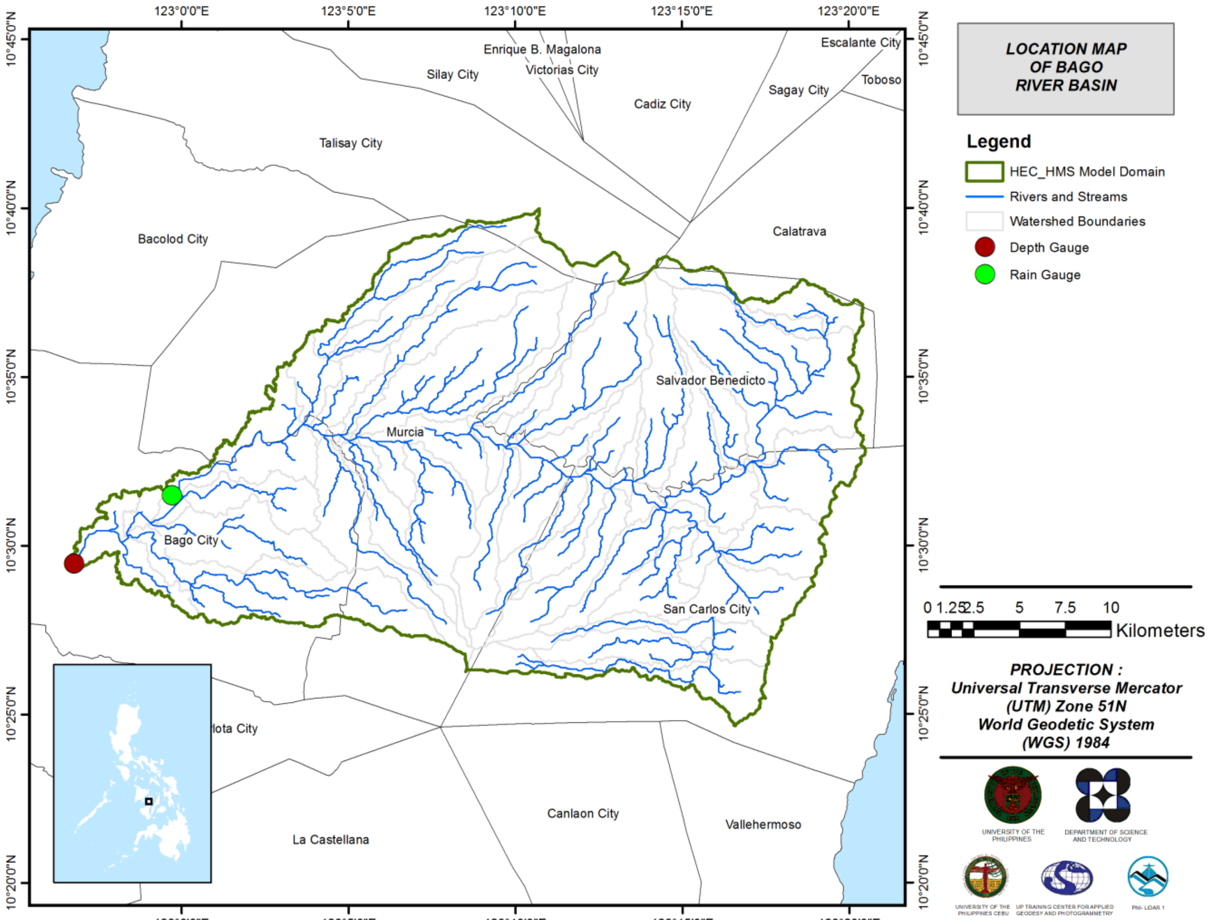


Figure 63. Location map of Bago HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section Figure 64 developed at Quezon Bridge, Bago City, Negros Occidental (10°29'32.98"N, 122°56'46.93"E) to establish the relationship between the observed water levels (H) at Quezon Bridge and outflow (Q) of the watershed at this location.

For Quezon Bridge, the rating curve is expressed as Q = 13.641x-134.27 as shown in Figure 65.

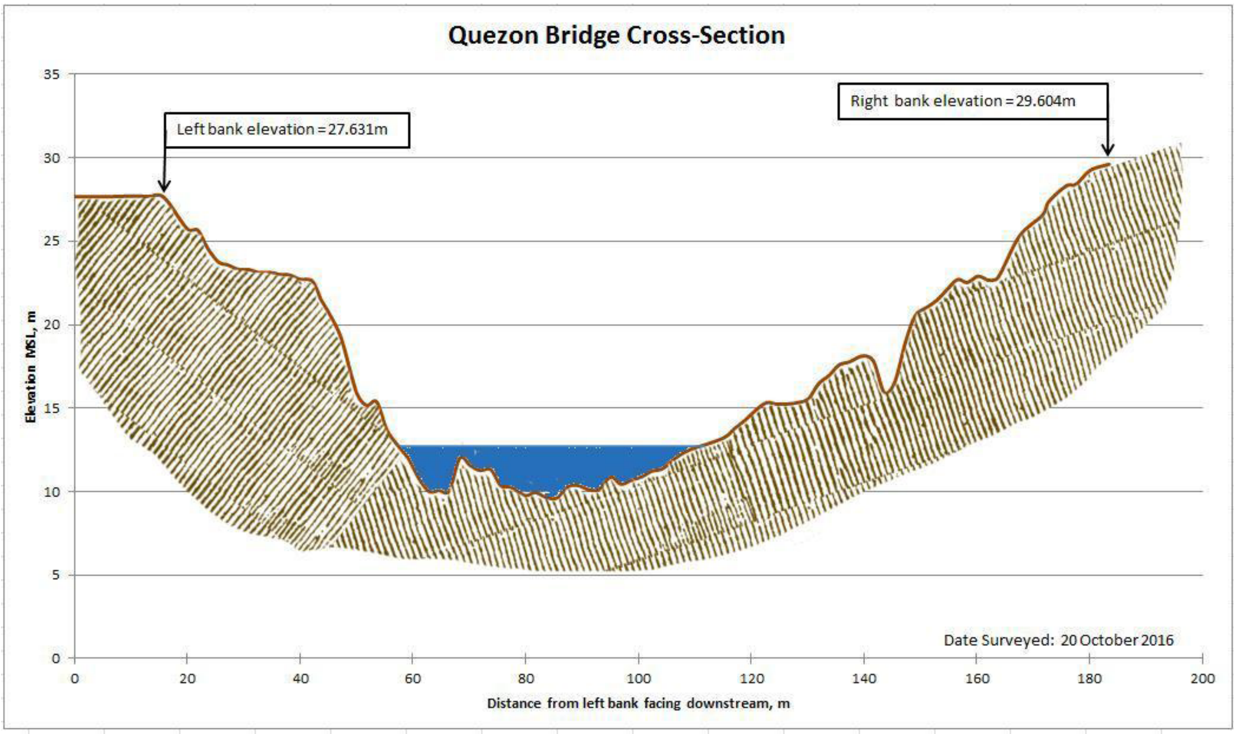


Figure 64. Cross-section plot of Quezon Bridge

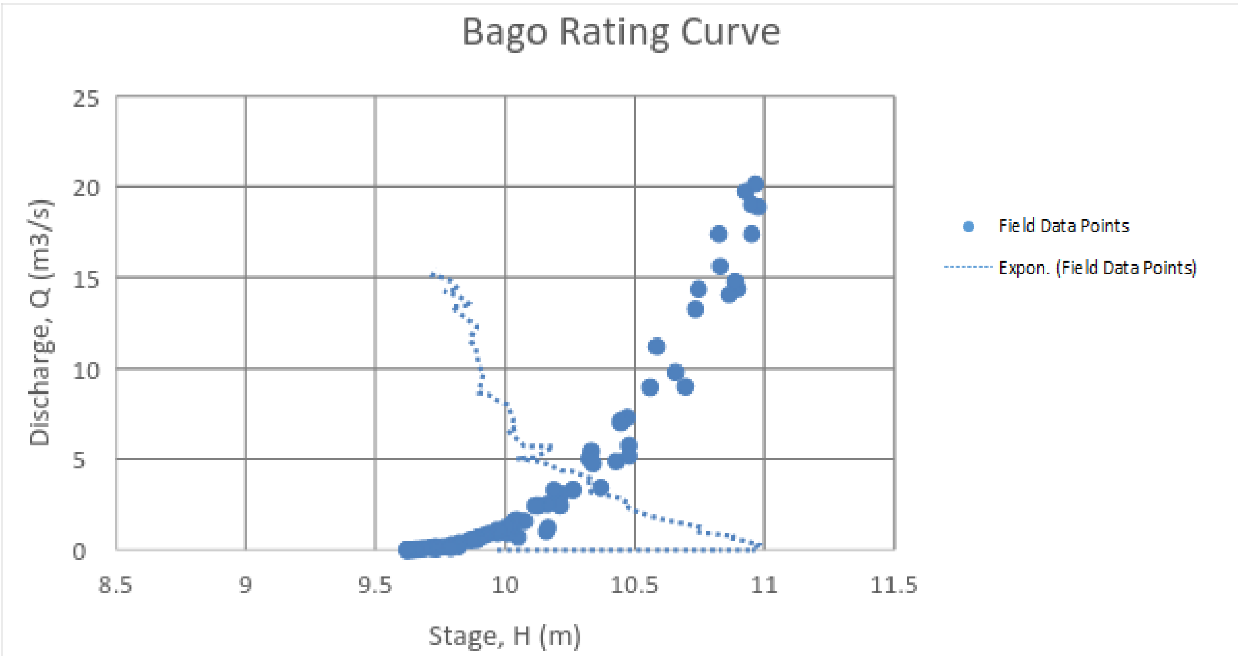


Figure 65. Rating Curve at Quezon Bridge, Bago City, Negros Occidental

This rating curve equation was used to compute the river outflow at Quezon Bridge for the calibration of the HEC-HMS model shown in Figure 66. The total rainfall for this event is 43.8mm and the peak discharge is 20.1 m^3 at 15:50 PM, January 16, 2017.

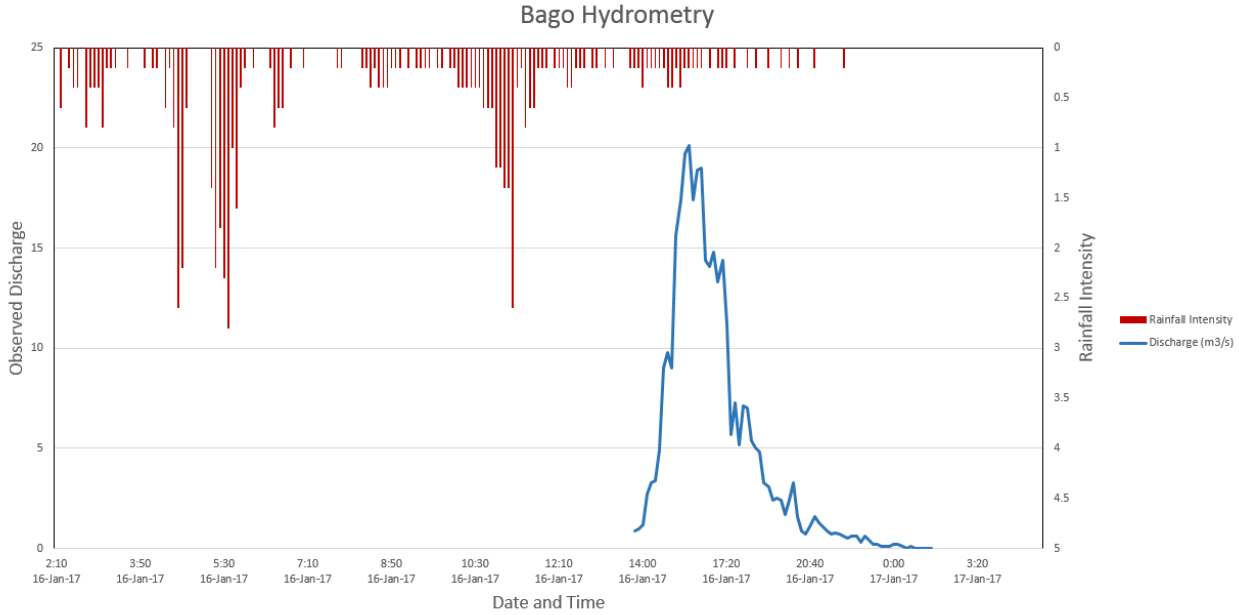


Figure 66. Rainfall and outflow data at Bago River Basin used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Iloilo 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 was chosen based on its proximity to the Bago watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 39. RIDF values for Iloilo 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
5	28.7	39.4	48	59.4	74.9	90	114.7	131.7	165.2
10	33.9	45.6	55.6	68.1	85	103.6	133.6	155.4	198.9
25	40.5	53.5	65.3	79.2	97.6	120.8	157.6	185.3	241.5
50	45.4	59.4	72.4	87.3	107	133.5	175.3	207.4	273.1
100	50.3	65.2	79.5	95.4	116.4	146.2	193	229.4	304.5

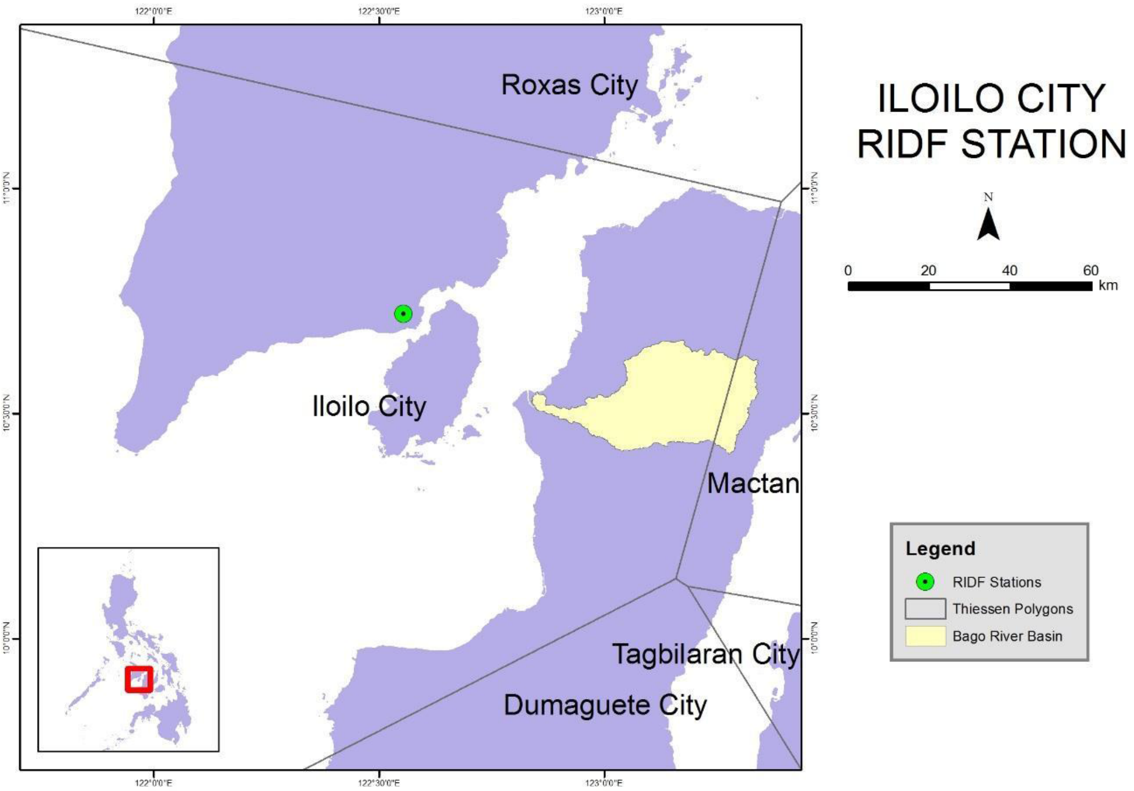


Figure 67. Location of Iloilo RIDF station relative to Bago River Basin

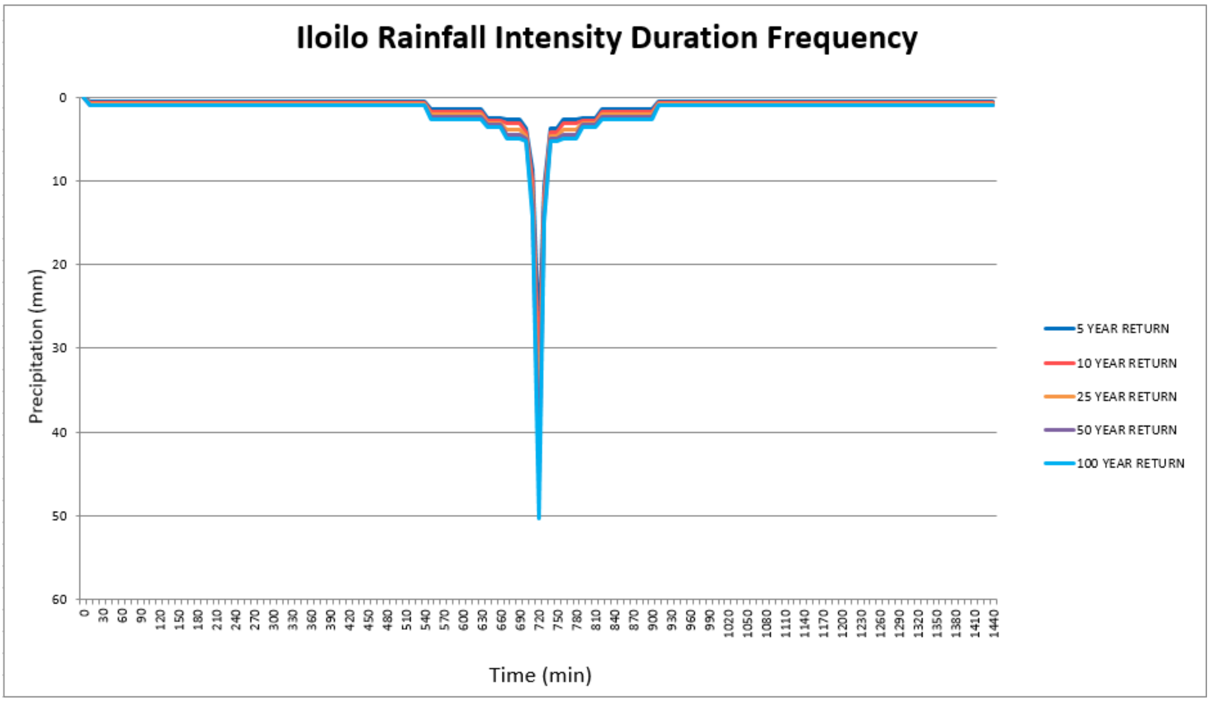


Figure 68. Synthetic Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management which is under the Department of Agriculture.. The land cover dataset is from the National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Bago River Basin are shown in Figures 69 and 70, respectively.

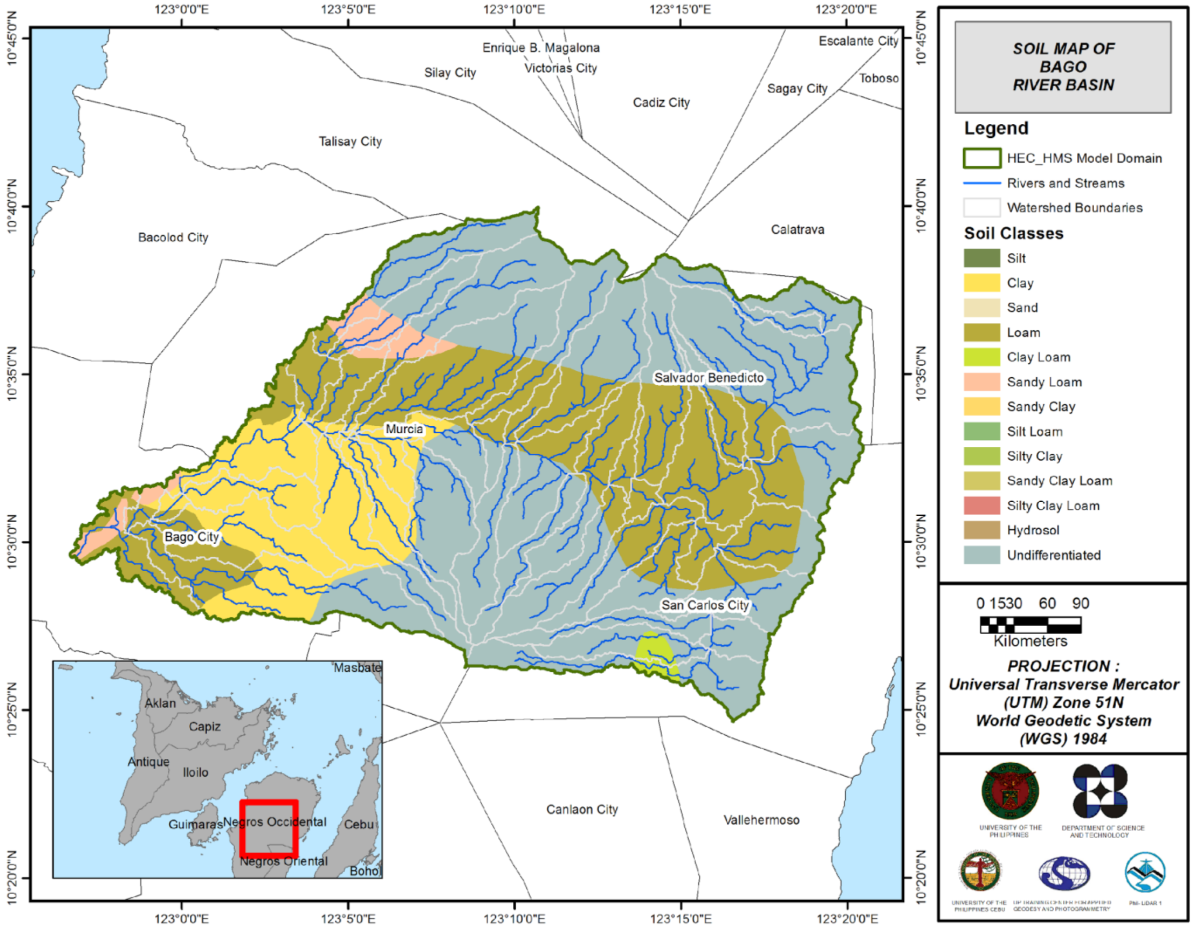


Figure 69. Soil map of Bago River Basin

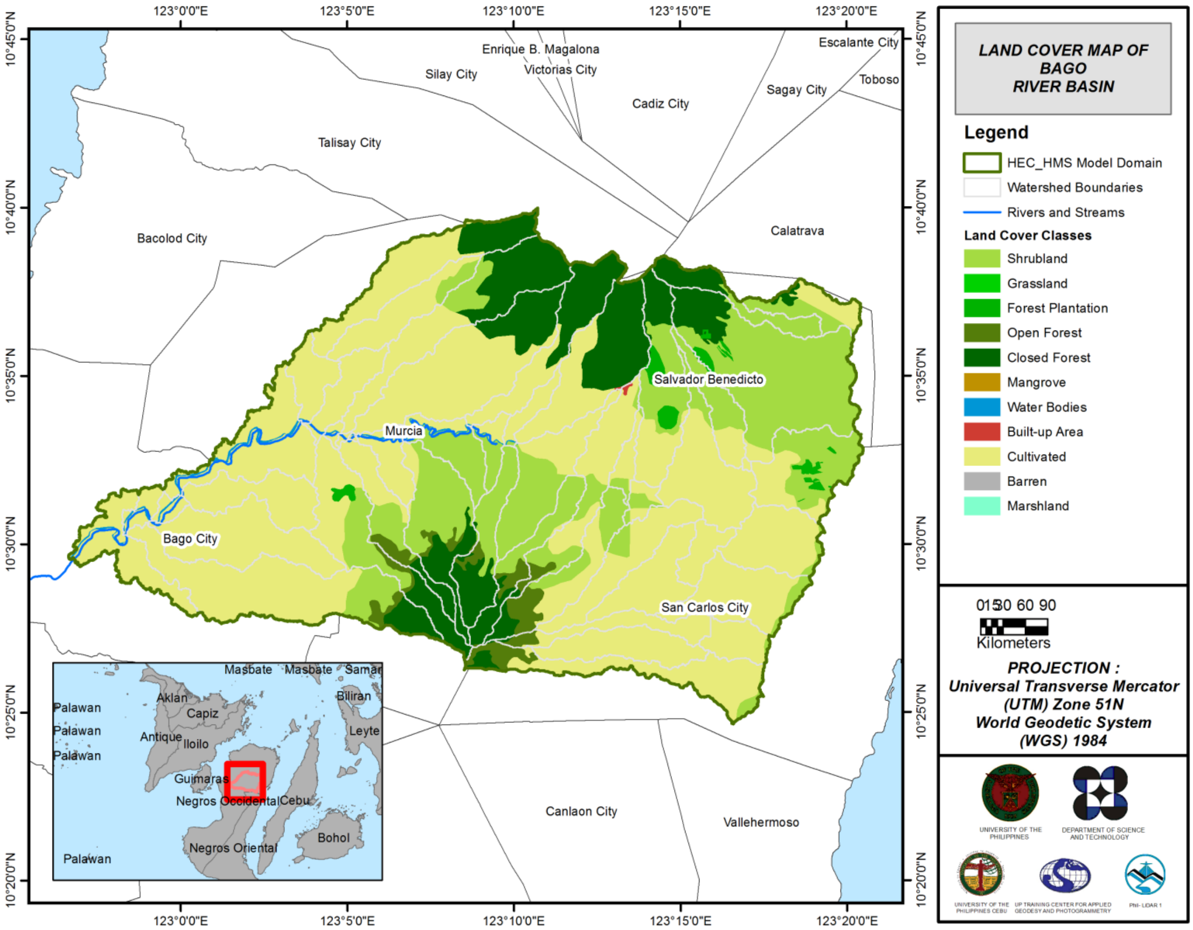


Figure 70. Land cover of Bago River Basin

For Bago, five soil classes were identified. These are loam, sandy loam, clay, clay loam, and undifferentiated soil as shown in Figure 71. Moreover, five land cover classes were identified. These are open and closed forest, shrubland forest plantation, and built-up area.

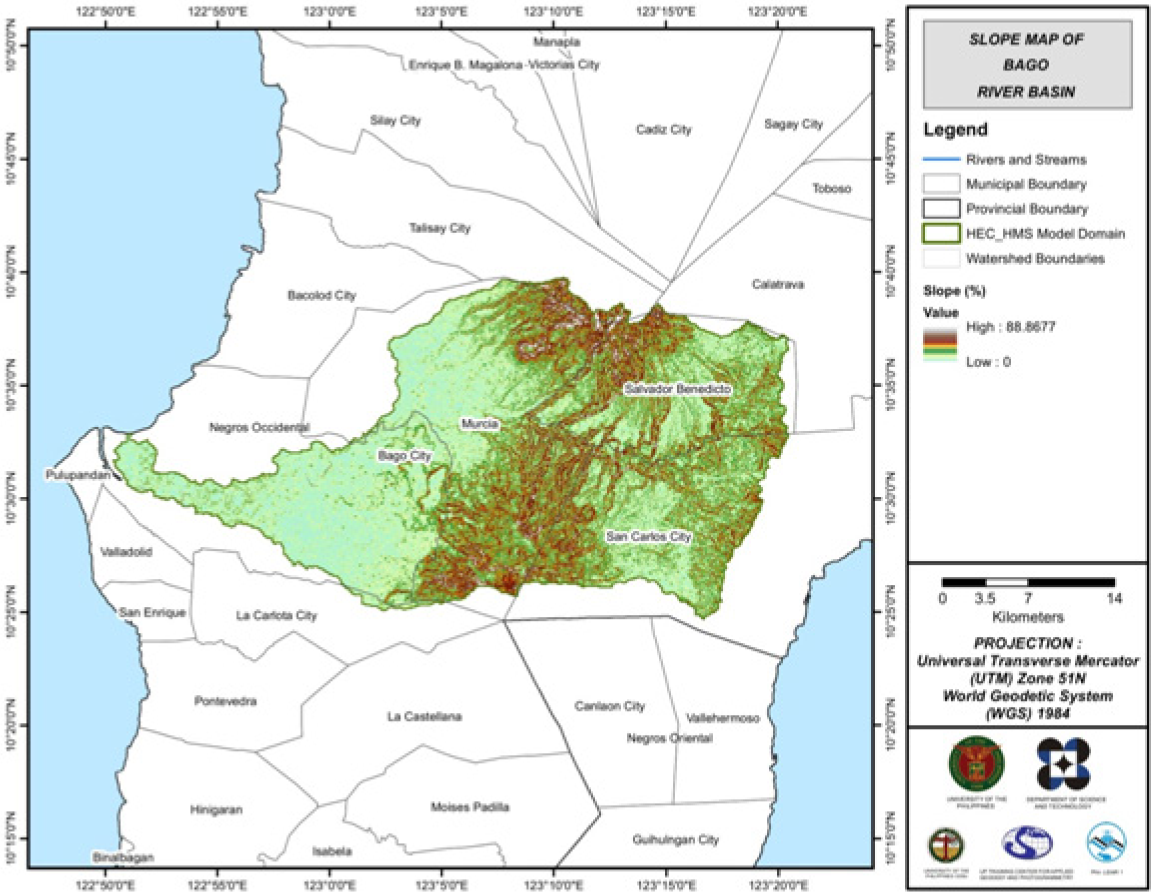


Figure 71. Slope map of Bago River Basin

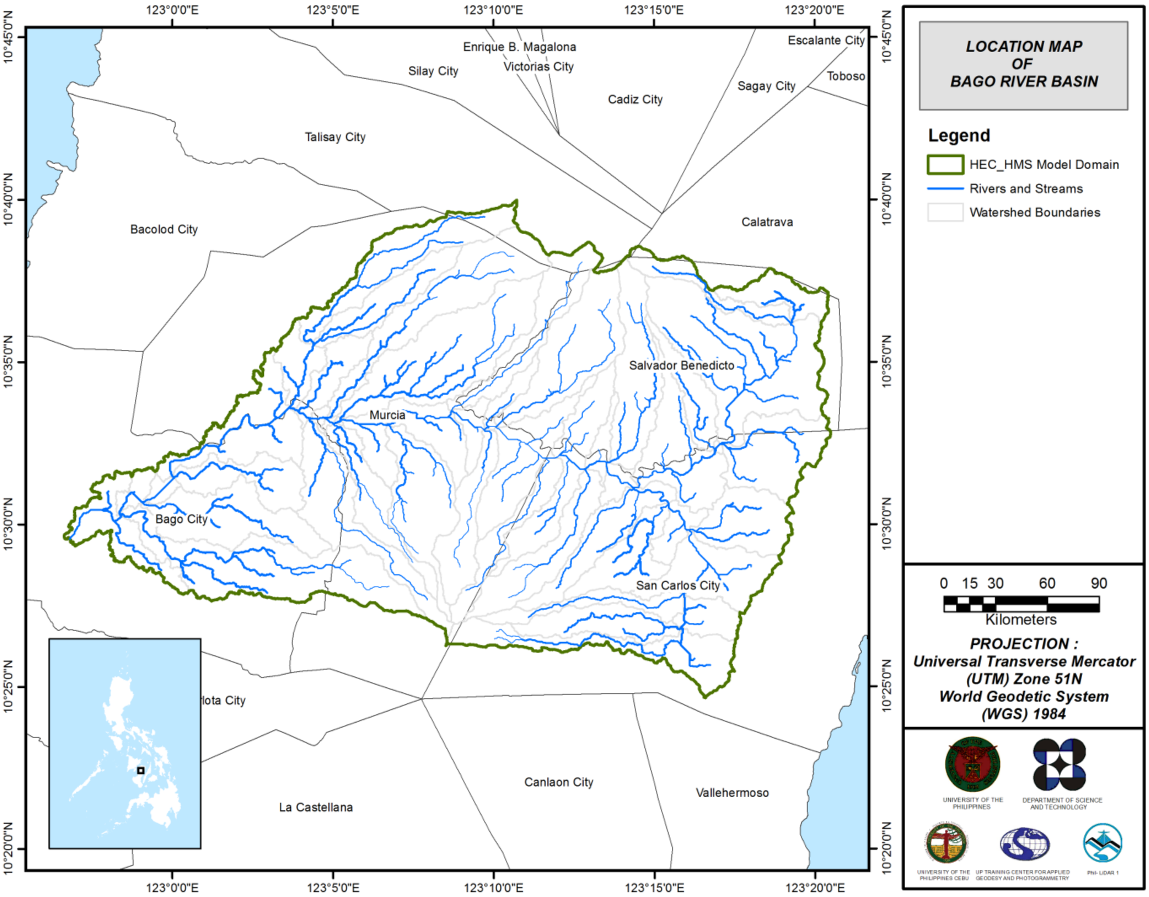


Figure 72. Stream delineation map of Bago River Basin

Using the SAR-based DEM, the Bago basin was delineated and further subdivided into subbasins. The model consists of 47 sub basins, 23 reaches, and 23 junctions as shown in Figure 73. The main outlet is at Quezon Bridge.

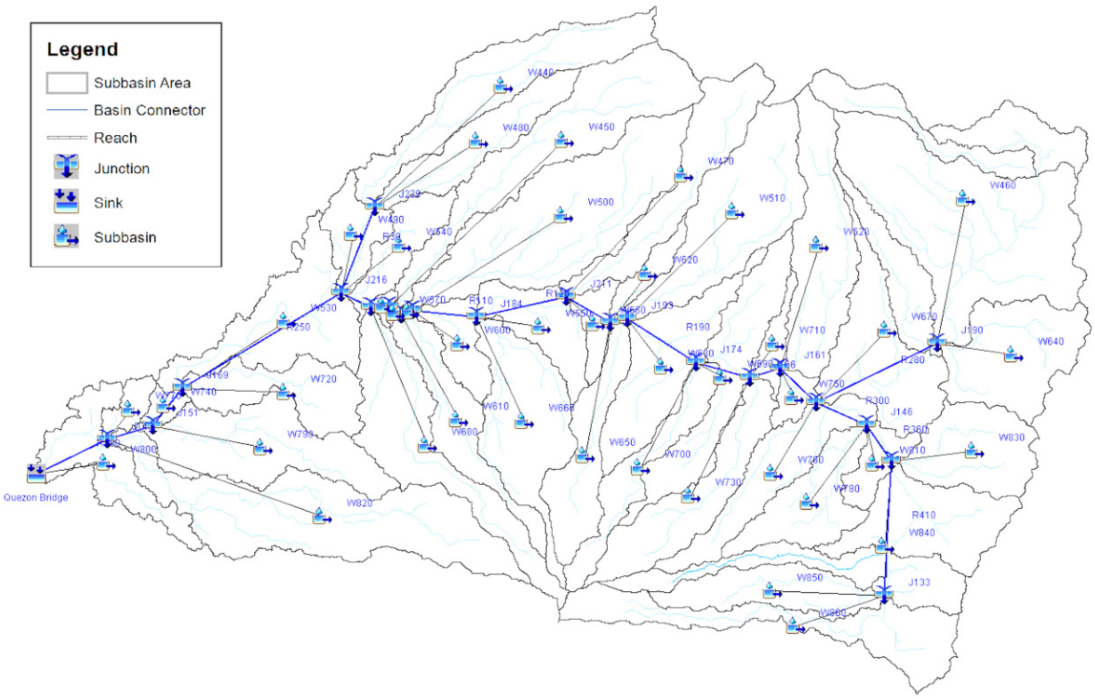


Figure 73. Bago River Basin model generated using HEC-HMS

5.4 Cross-section Data

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

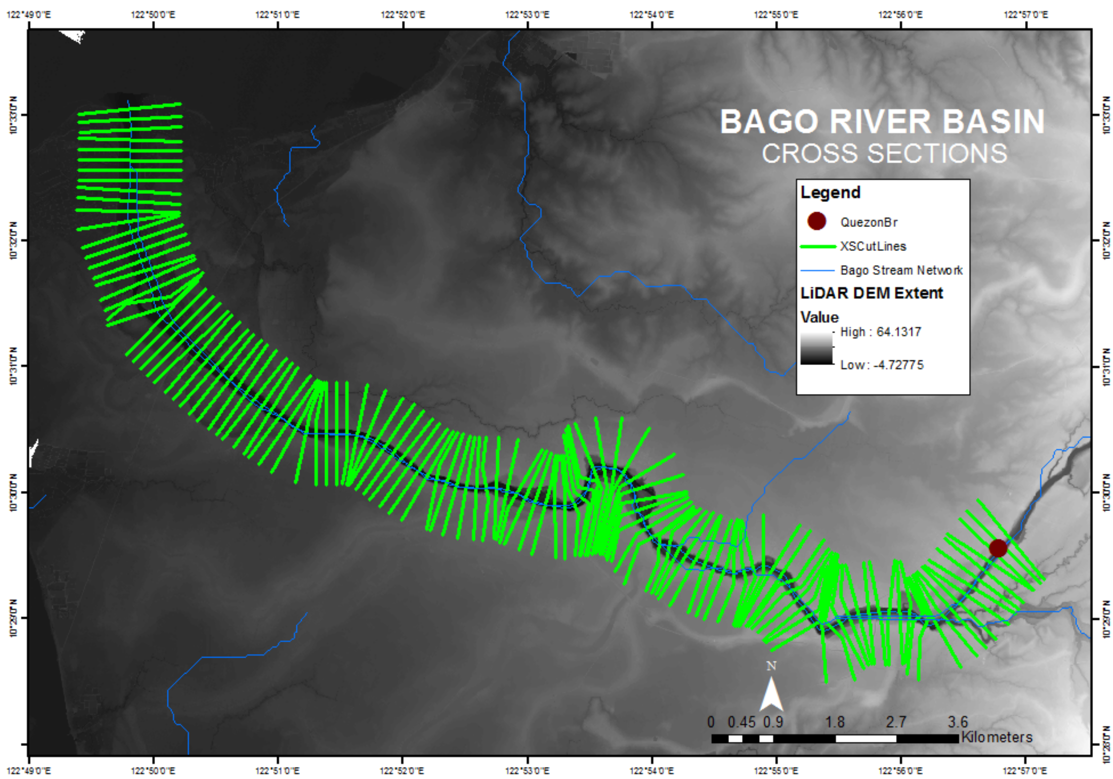


Figure 74. River cross-section of Bago River generated through Arcmap HEC GeoRAS tool

5.5 Flo-2D Model

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

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

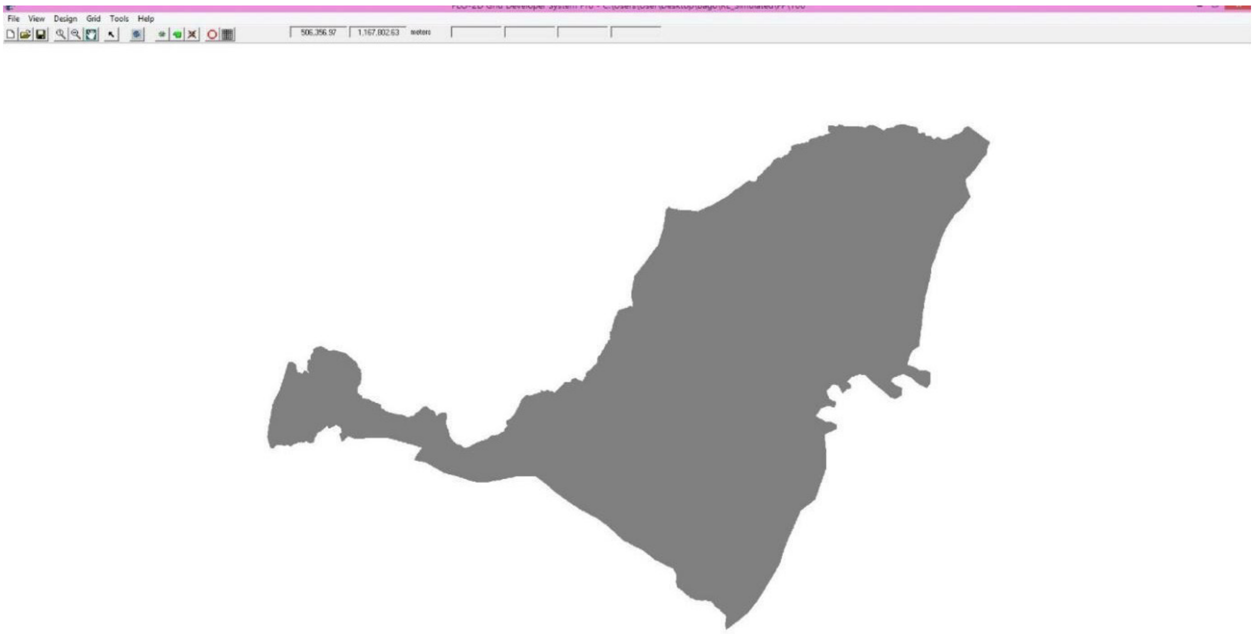


Figure 75. Screenshot of subcatchment with computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 30.2 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 m2/s.

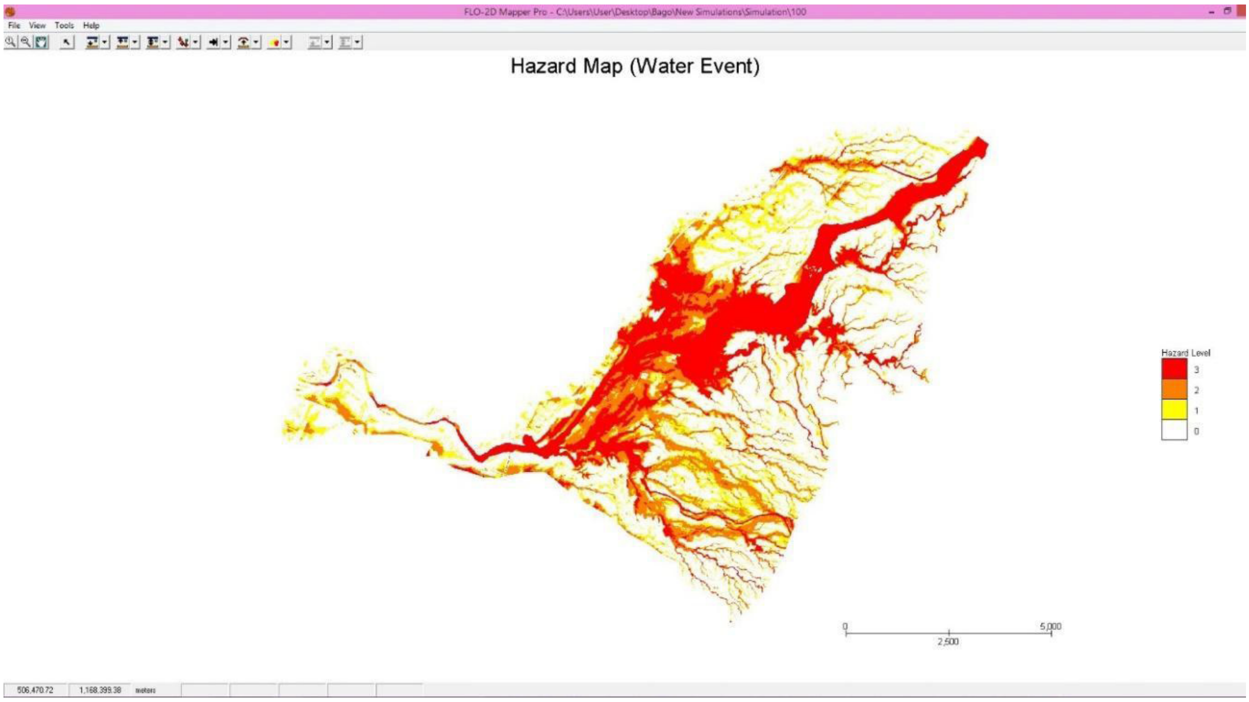


Figure 76. Generated 100-year rain return hazard map from FLO-2D Mapper

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 34,460,300.00 m2.

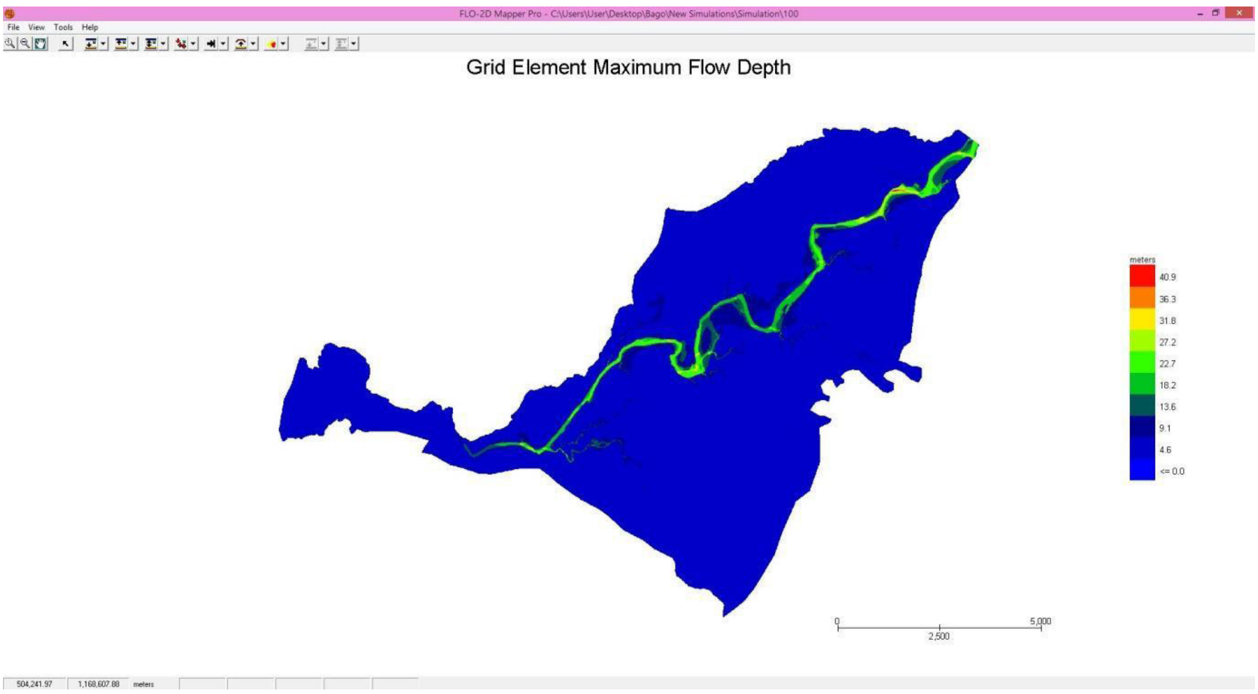


Figure 77. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 144,299,474.92 m3 of water entering the model, of which 10,969,326.12 m3 is due to rainfall and 133,330,148.80 m3 is inflow from basins upstream. 3,713,013.50 m3 of this water is lost to infiltration and interception, while 3,117,052.76 m3 is stored by the flood plain. The rest, amounting up to 133,527,319.84m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Bago HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 78 shows the comparison between the two discharge data.

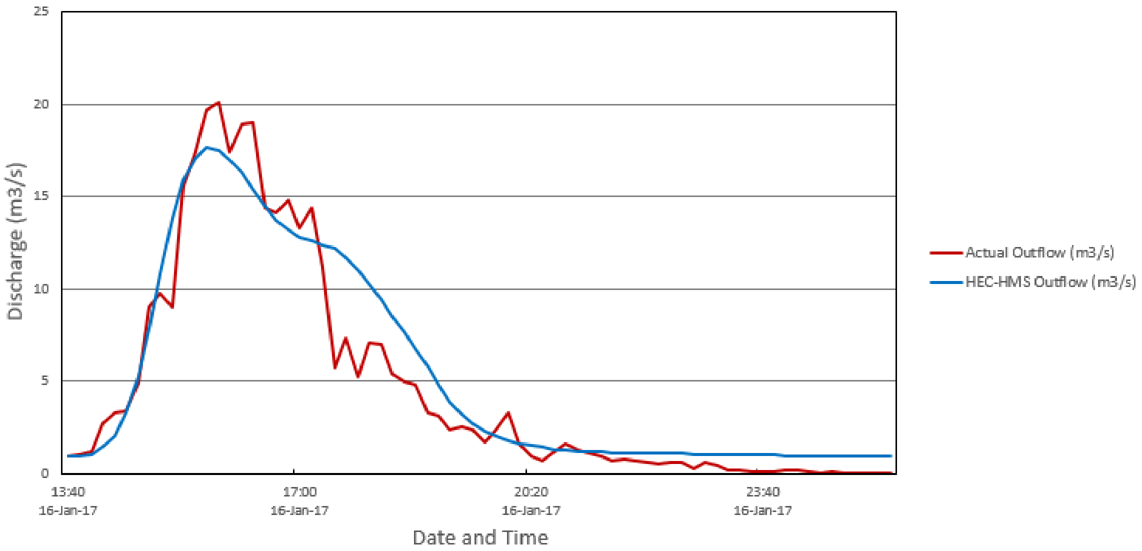


Figure 78. Outflow Hydrograph of Bago produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 40 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 40. Range of Calibrated Values for Bago River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	5-20
			Curve Number	65-90
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	4-12
			Storage Coefficient (hr)	2-7
	Baseflow	Recession	Recession Constant	0.9
			Ratio to Peak	0.2
Reach	Routing	Muskingum-Cunge	Slope	0.001-0.006
			Manning's Coefficient	0.0001

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

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 65 to 90 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M.

Horritt, personal communication, 2012). For Bago, the basin mostly consists of closed and open forests, shurublands, forest plantations, and cultivated areas, and the soil consists of clay, sandy loam, loam, clay loam, and undifferentiated soils

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 4 hours to 12 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.9 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.2 indicates a slightly steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.0001 for the Bago river basin is lower than the usual Manning's n value in the Philippines (Brunner, 2010).

Table 41. Summary of the Efficiency Test of Bago HMS Model

Accuracy Measure	Value
RMS Error	1.8
r^2	0.9595
NSE	0.91
RSR	0.30
PBIAS	-11.00

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 1.8 (m3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9595.

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 0.91.

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 -11.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.30.

5.7 Calculated outflow hydrographs and discharge values for different rainfall return periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 79) shows the Bago outflow using the Iloilo Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods from 165.2m^3 in a 5-year return period to 304.5m^3 for a 100-year return period.

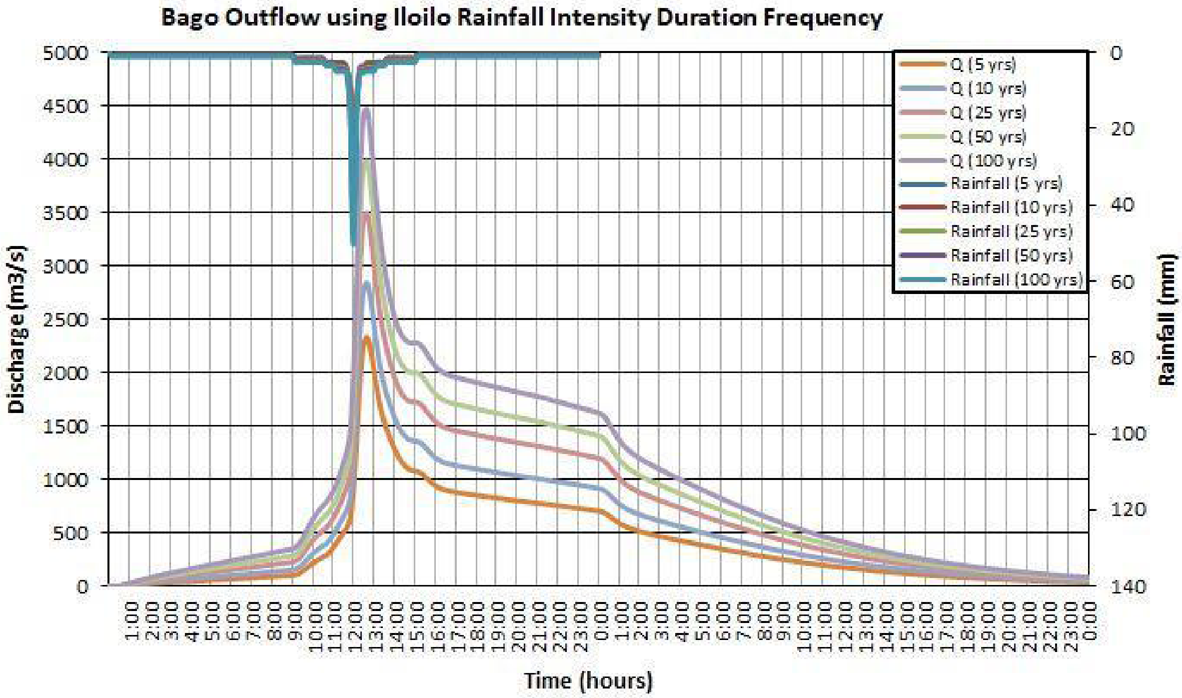


Figure 79. Outflow hydrograph at Bago Station generated using Iloilo RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Bago discharge using the Iloilo Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 42.

Table 42. Peak values of the Bago HEC-HMS Model outflow using the Iloilo RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	165.2	28.7	2333.9	40 minutes
10-Year	198.9	33.9	2841.2	40 minutes
25-Year	241.5	40.5	3496.3	40 minutes
50-Year	273.1	45.4	3980.1	40 minutes
100-Year	304.5	50.3	4466.7	40 minutes

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

The river discharges entering the floodplain are shown in Figure 80 to Figure 82 and the peak values are summarized in Table 5 to Table 7.

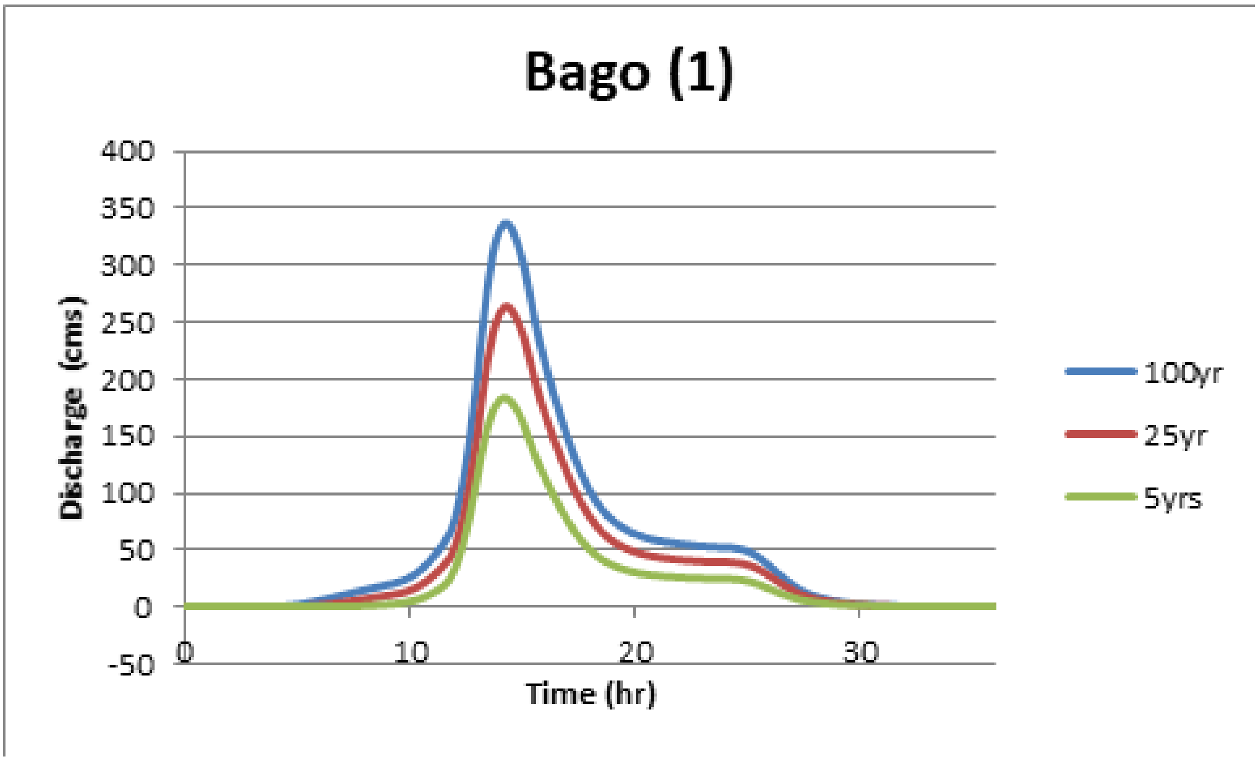


Figure 80. Bago river (1) generated discharge using 5-, 25-, and 100-year Iloilo City rainfall intensity-duration-frequency (RIDF) in HEC-HMS

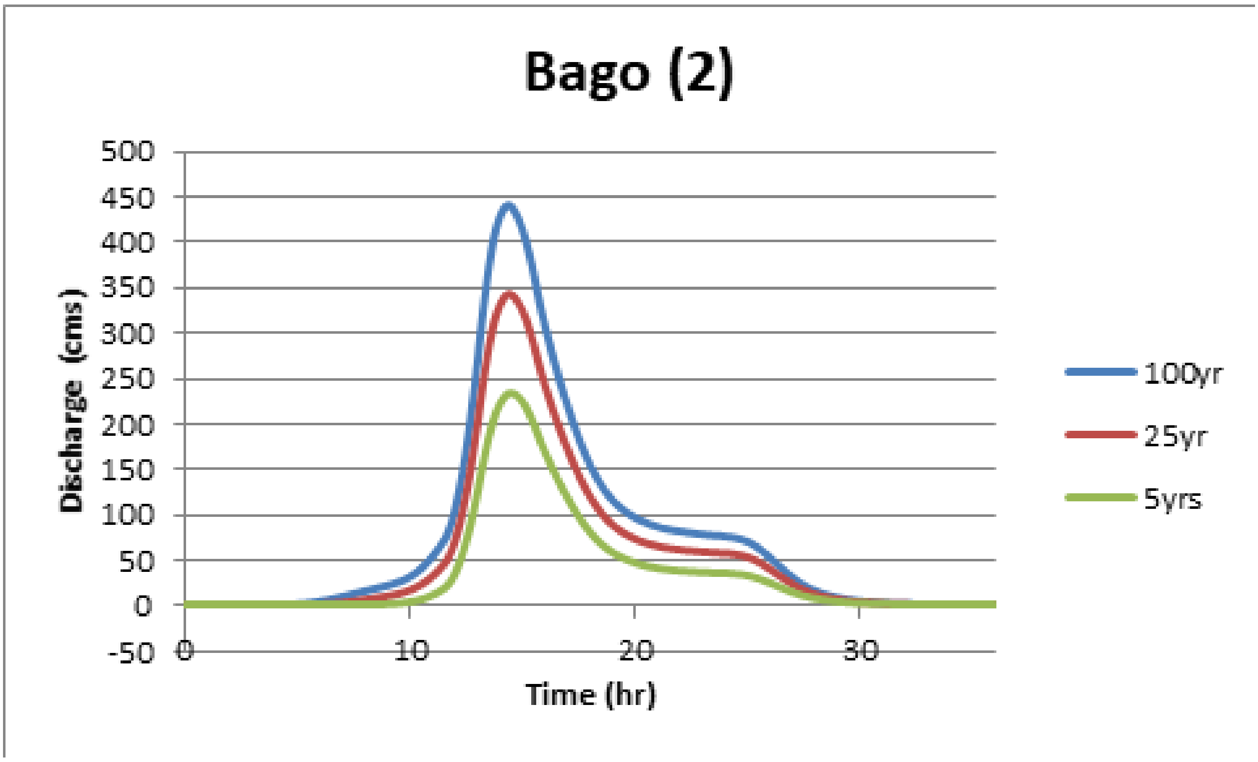


Figure 81. Bago river (2) generated discharge using 5-, 25-, and 100-year Iloilo City rainfall intensity-duration-frequency (RIDF) in HEC-HMS

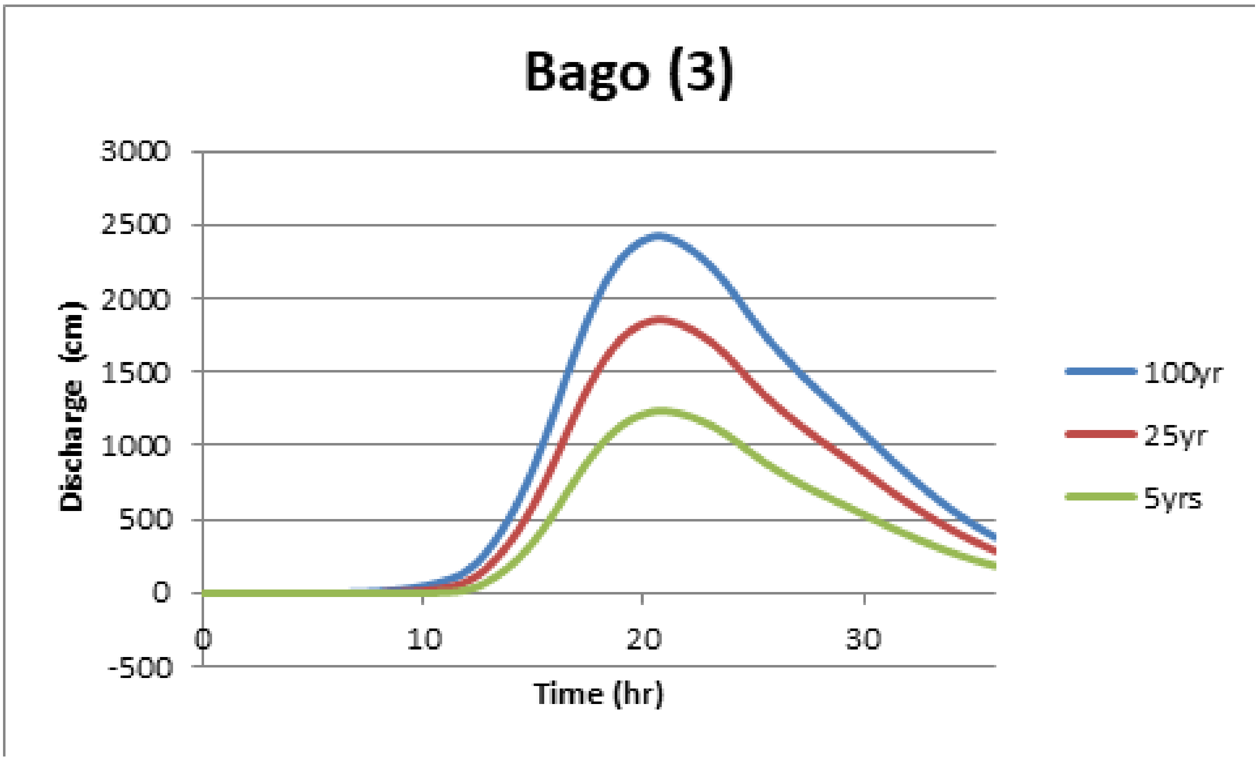


Figure 82. Bago river (3) generated discharge using 5-, 25-, and 100-year Iloilo City rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 43. Summary of Bago river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	184.2	14 hours, 20 minutes
25-Year	264.2	14 hours, 20 minutes
5-Year	335.5	14 hours, 10 minutes

Table 44. Summary of Bago river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	442.1	14 hours, 20 minutes
25-Year	343	14 hours, 20 minutes
5-Year	234.7	14 hours, 30 minutes

Table 45. Summary of Bago river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	2431.5	19 hours, 40 minutes
25-Year	1861	20 hours, 50 minutes
5-Year	1228.4	20 hours, 50 minutes

Table 46. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Bago (1)	162.096	128345.504	114.380	Fail	Pass
Bago (2)	206.536	366838.592	147.979	Fail	Pass
Bago (3)	1080.992	181004.323	681.025	Fail	Fail

Two out of three of the results from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the specific discharge methods and failed in bankful discharge. One did not pass both and will need further recalculation. The passing values are based on theory but are supported using other discharge computation methods so they were good to use for flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis 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 sample generated map of Bago River using the calibrated HMS event flow is shown in Figure 83.

Figure 83. Sample output of map of Bago RAS Model

5.9 Flood Hazard Map and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figure 81 to Figure 86 shows the 5-, 25-, and 100-year rain return scenarios of the Bago floodplain. The floodplain, with an area of 611.747 sq.km., covers nine municipalities namely, Bago City, La Carlota City, Murcia, Pulupandan, and Valladolid.

Table 43. Municipalities affected in Bago Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Bago City	350.91	199.0073	56.71179
La Carlota City	121.01	4.90423	4.052748
Murcia	364.2	6.312371	1.733216
Pulupandan	16.13	15.85762	98.33132
Valladolid	40.37	21.29958	52.76091

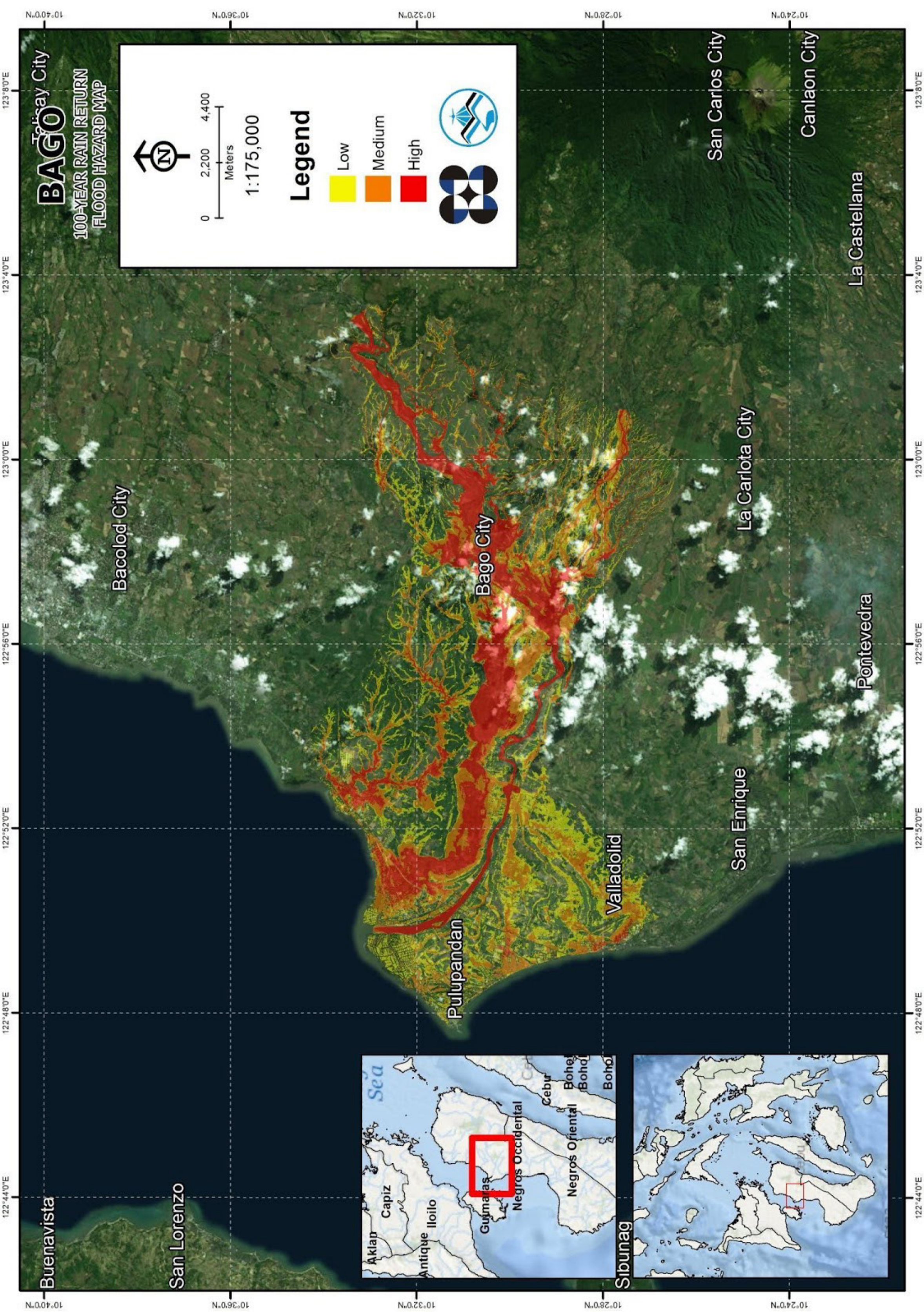


Figure 84. Flood hazard map of Bago Floodplain using 100-year rainfall return

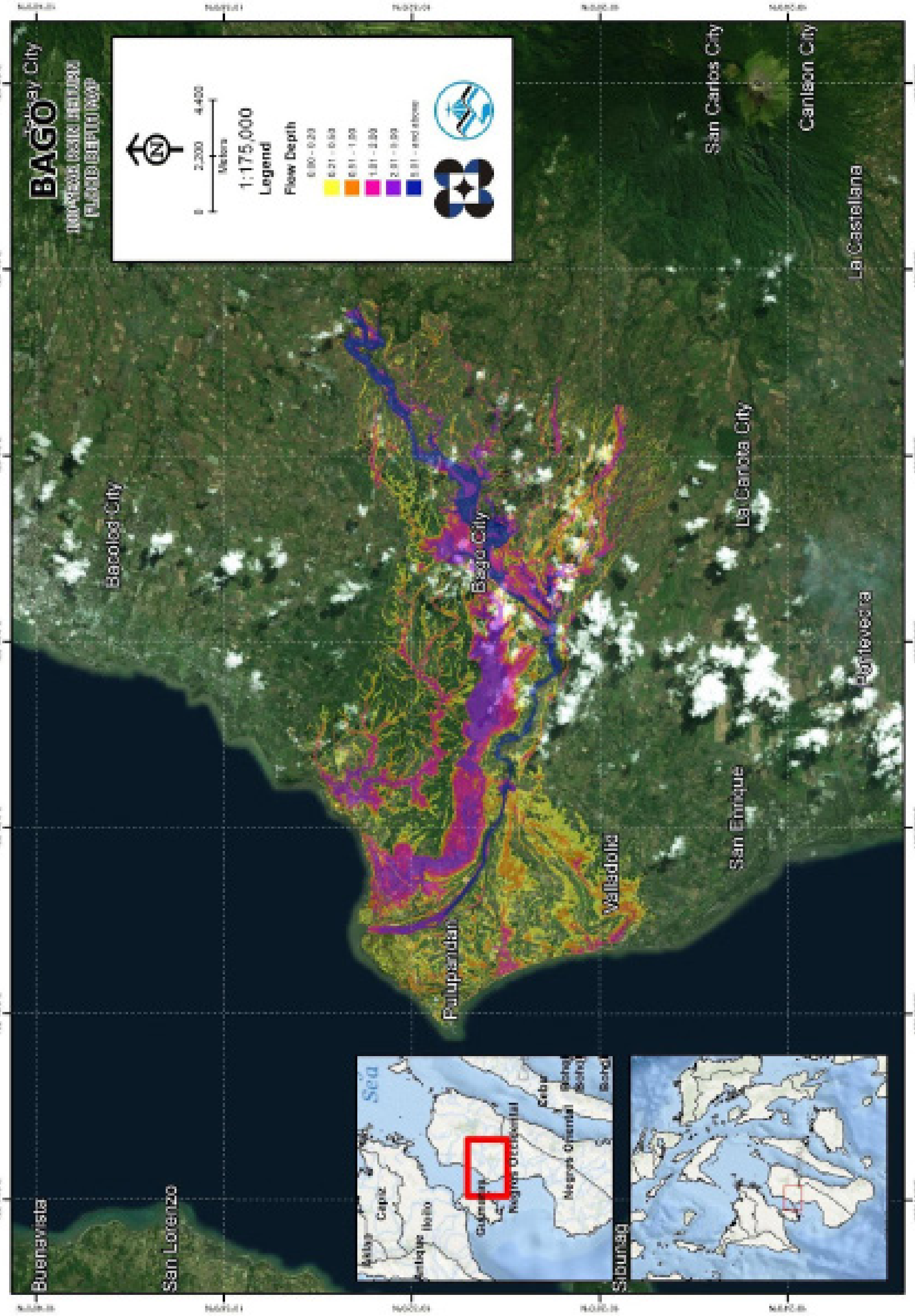


Figure 85. Flow depth map of Bago Floodplain using 100-year rainfall return

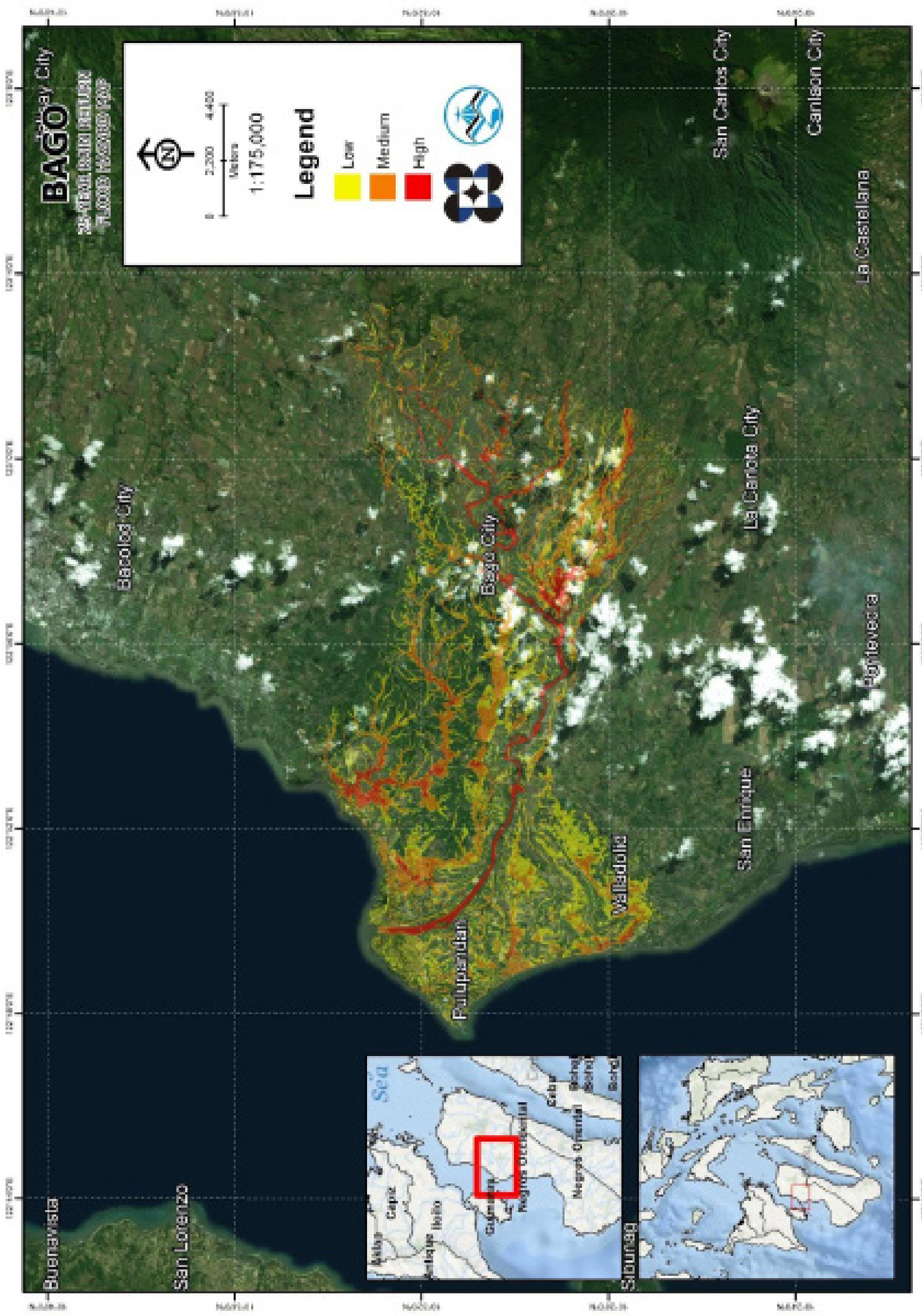


Figure 86. Flood hazard map of Bago Floodplaing using 25-year rainfall return

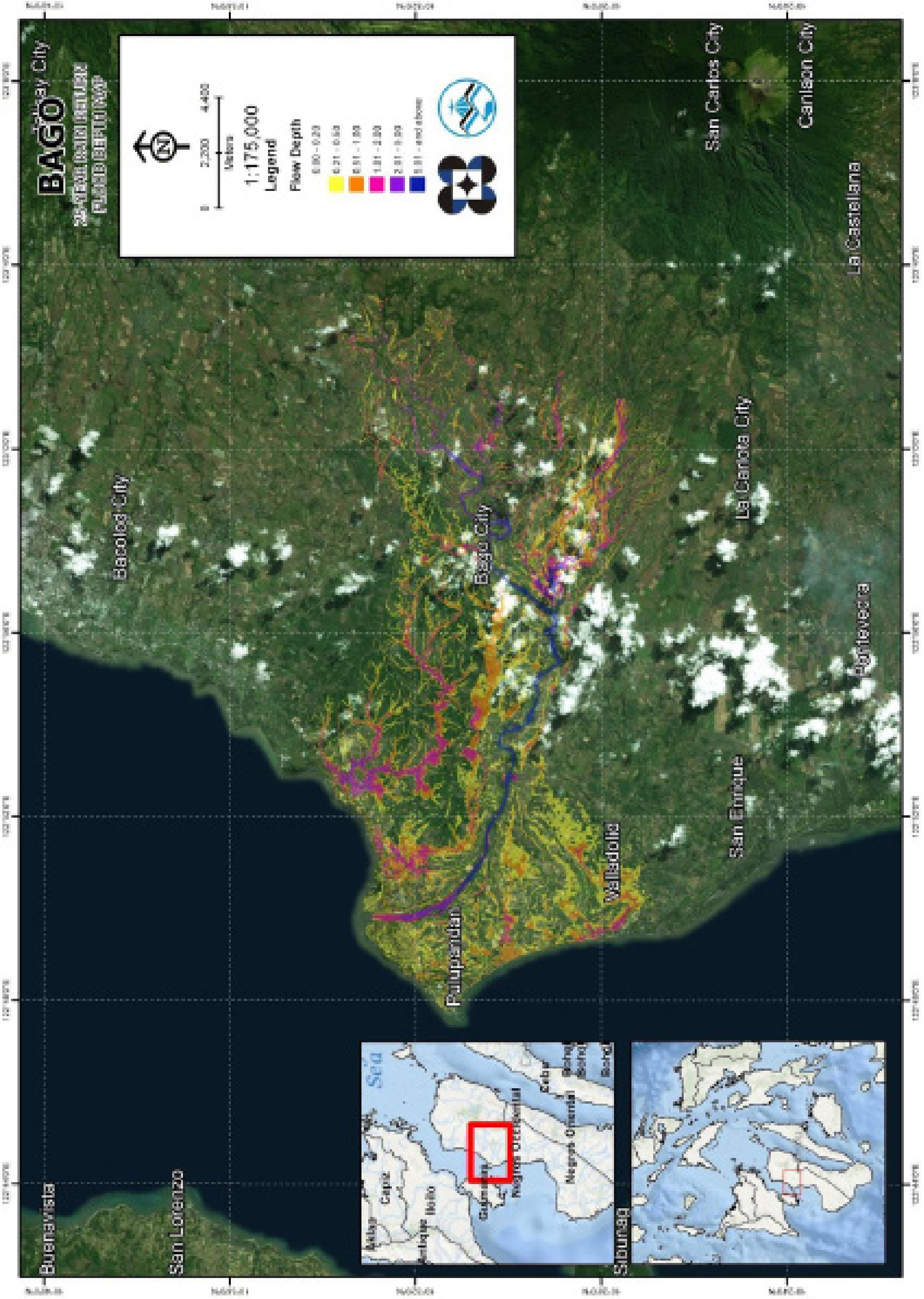


Figure 87. Flow depth map of Bago Floodplaing using 25-year rainfall return

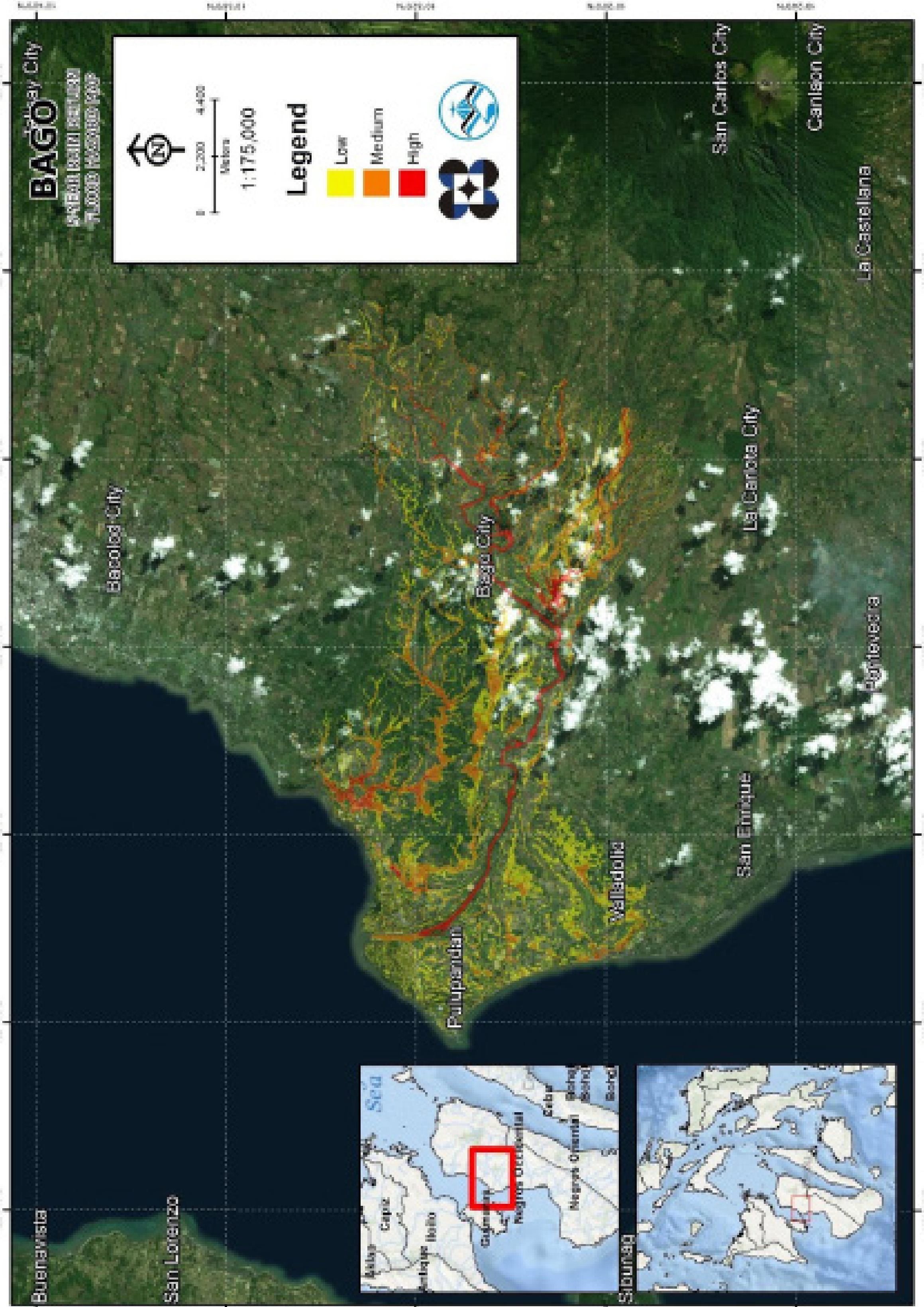


Figure 88. Flood hazard map of Bago Floodplain using 5-year rainfall return

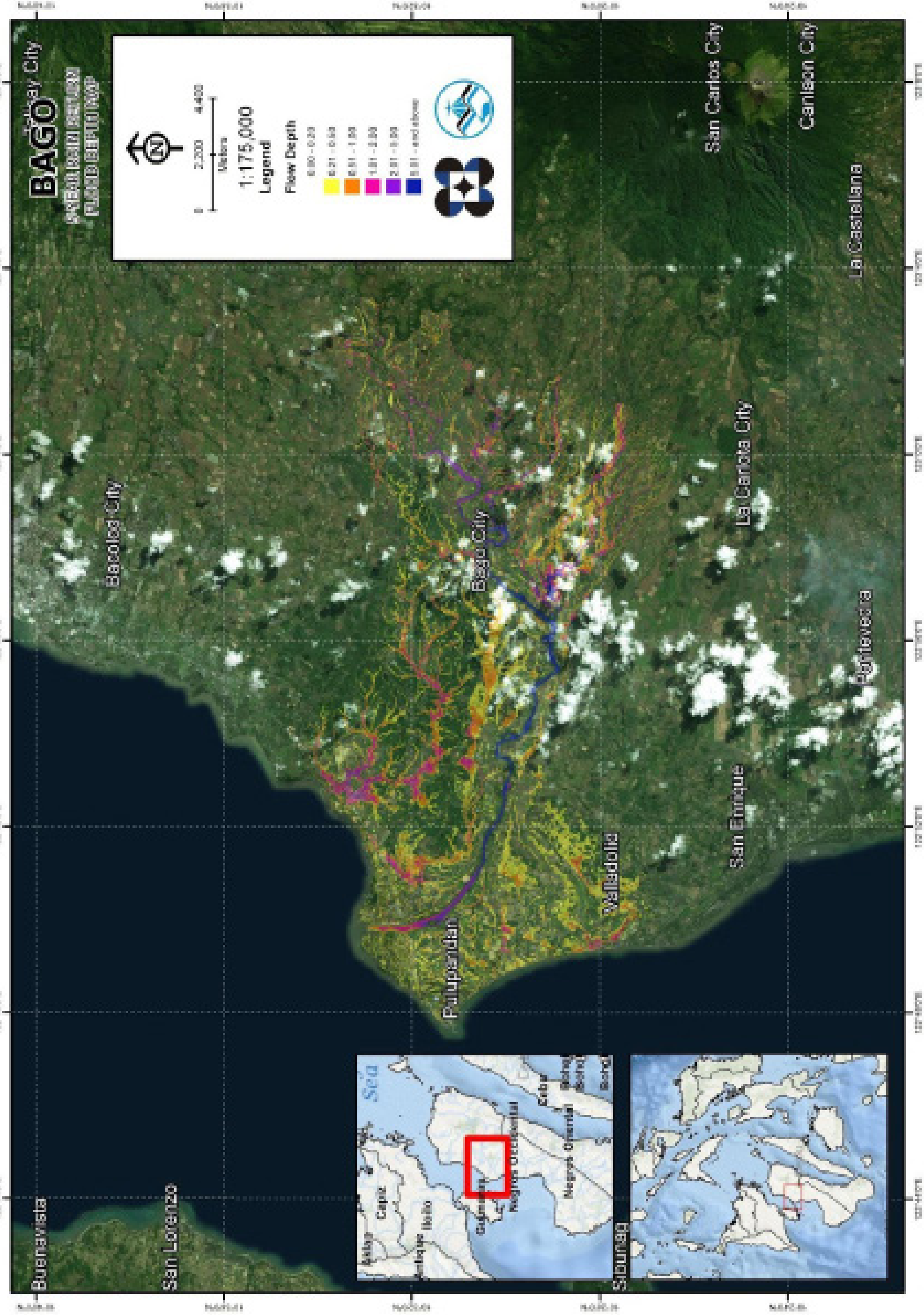


Figure 89. Flow depth map of Bago Floodplain using 5-year rainfall return

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Bago river basin, grouped by municipality, are listed below. For the said basin, five cities and municipalities consisting of 56 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 42.29% of the city of Bago with an area of 350.91 sq. km. will experience flood levels of less 0.20 meters. 7.35% of the area will experience flood levels of 0.21 to 0.50 meters while 3.68%, 1.83%, 0.82%, and 0.75% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 are the affected areas in square kilometres by flood depth per barangay.

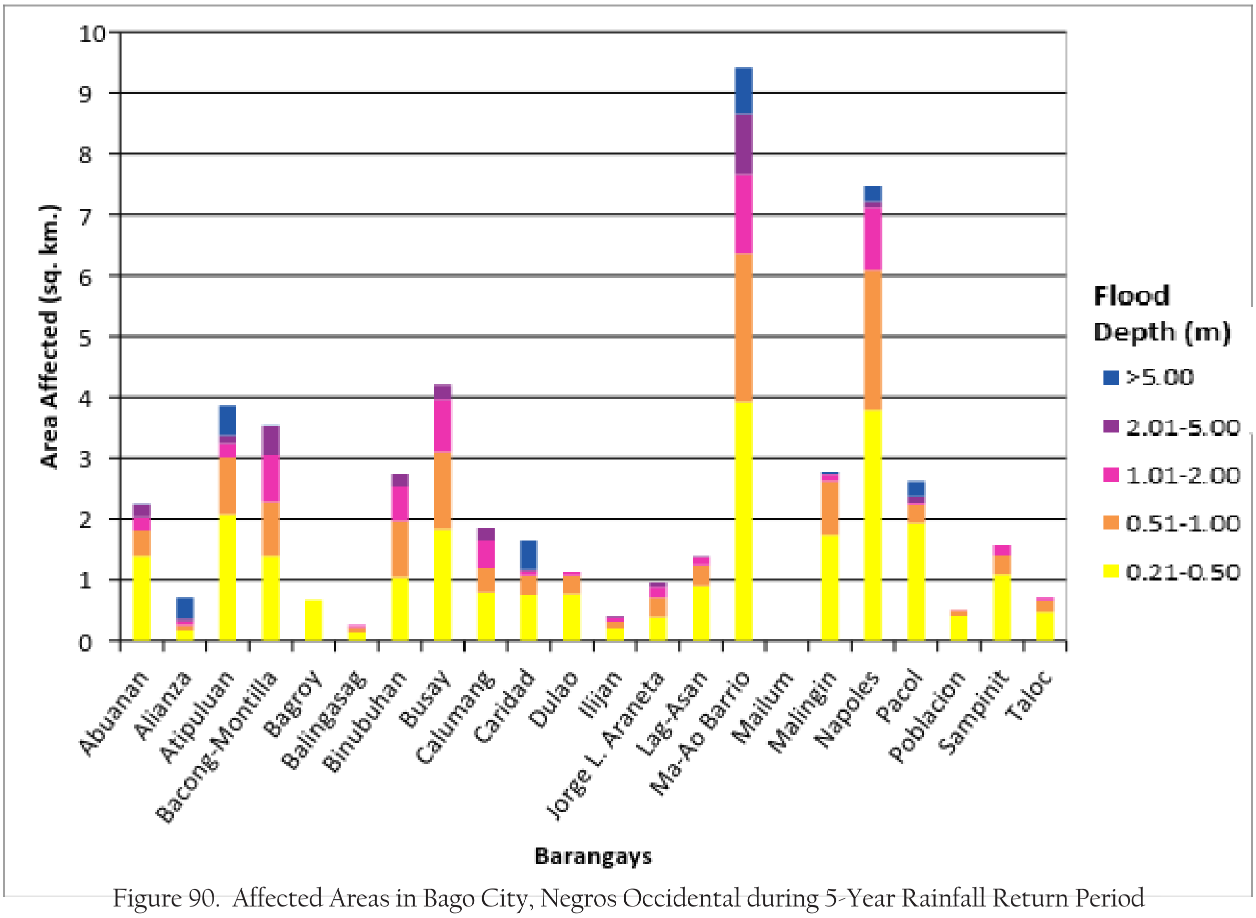


Figure 90. Affected Areas in Bago City, Negros Occidental during 5-Year Rainfall Return Period

Table 50 Affected Areas in Bago City, Negros Occidental during 5-Year Rainfall Return Period

Affected Areas (in sq. km.) by flood depth (in m.)	Affected Barangays in Bago City (in sq. km.)										
	Abuanan	Alianza	Atipuluan	Bacong-Montilla	Bagroy	Balingasag	Binubuhan	Busay	Calumang	Caridad	Dulao
0.03-0.20	9.91	1.21	12.07	20.96	1.6	0.53	6.63	11.17	4.27	3.89	4.96
0.21-0.50	1.39	0.16	2.07	1.39	0.66	0.13	1.04	1.83	0.79	0.75	0.77
0.51-1.00	0.42	0.09	0.94	0.88	0.004	0.08	0.93	1.27	0.41	0.32	0.3
1.01-2.00	0.22	0.06	0.23	0.78	0	0.04	0.57	0.86	0.45	0.067	0.063
2.01-5.00	0.21	0.05	0.13	0.47	0	0.0006	0.2	0.24	0.21	0.034	0.0001
> 5.00	0.01	0.33	0.49	0.01	0	0	0.001	0	0	0.47	0
Affected Areas (in sq. km.) by flood depth (in m.)	Affected Barangays in Bago City (in sq. km.)										
	Ilijan	Jorge L. Araneta	Lag-Asan	Ma-Ao Barrio	Mailum	Malingin	Napoles	Pacol	Poblacion	Sampinit	Taloc
0.03-0.20	2.4	2.02	3.63	27.18	0.006	6.37	15.82	5.78	1.45	2.36	4.19
0.21-0.50	0.2	0.39	0.9	3.92	0.00044	1.74	3.79	1.93	0.41	1.08	0.47
0.51-1.00	0.11	0.32	0.34	2.44	0.0003	0.88	2.3	0.3	0.083	0.31	0.19
1.01-2.00	0.081	0.17	0.13	1.3	0	0.11	1.03	0.03	0.014	0.17	0.051
2.01-5.00	0.021	0.077	0.013	0.99	0	0.0046	0.09	0.11	0	0.00088	0.0011
> 5.00	0	0.0027	0	0.76	0	0.034	0.26	0.24	0	0	0

For the city of La Carlota, with an area of 121.01 sq. km., 3.47% will experience flood levels of less 0.20 meters. 0.39% of the area will experience flood levels of 0.21 to 0.50 meters while 0.16%, 0.04%, and 0.0001% 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.

Table 51. Affected Areas in La Carlota City, Negros Occidental during 5-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangay in La Carlota City (in sq. km)
	Taloc
0.03-0.20	4.19
0.21-0.50	0.47
0.51-1.00	0.19
1.01-2.00	0.051
2.01-5.00	0.0011
> 5.00	0

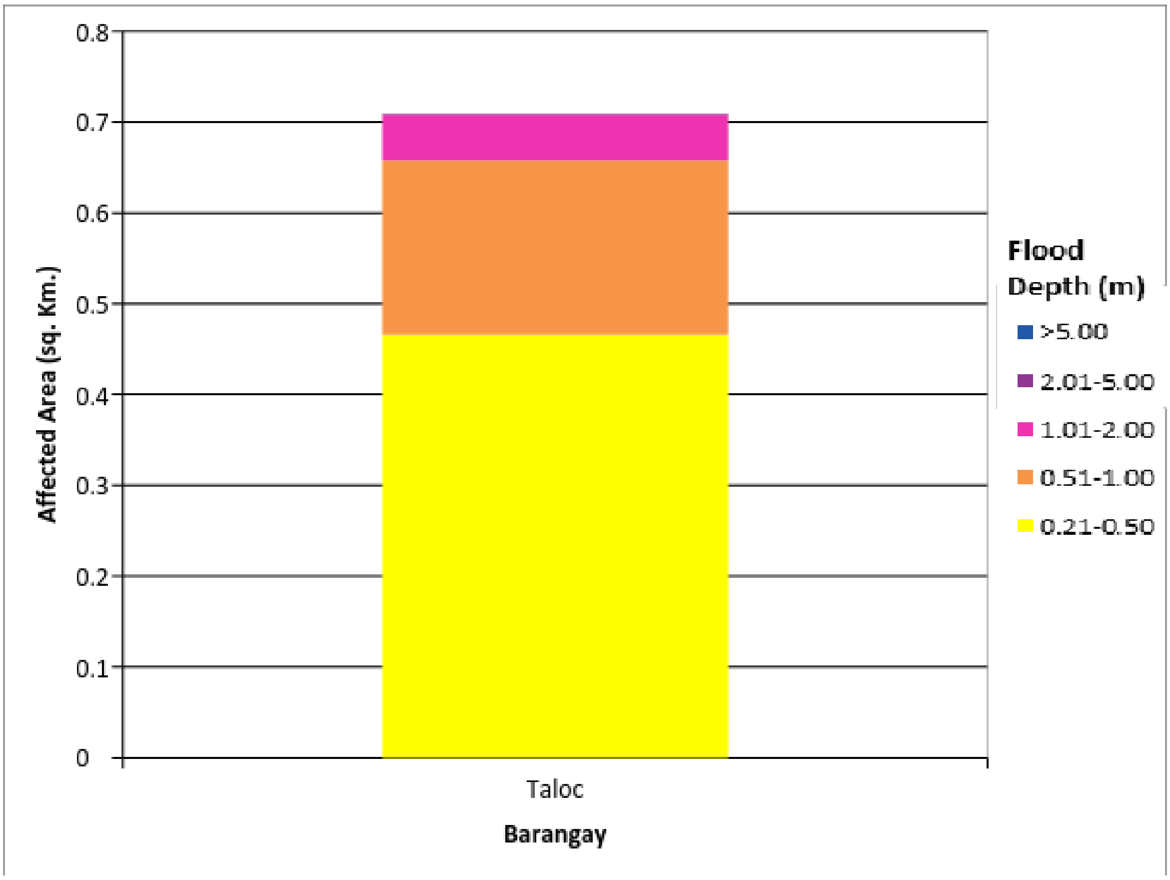


Figure 91. Affected Areas in La Carlota City, Negros Occidental during 5-Year Rainfall Return Period

For the municipality of Murcia, with an area of 364.2 sq. km., 1.5% will experience flood levels of less 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters while 0.07%, 0.042%, and 0.001% 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.

Table 52 Affected Areas in Murcia, Negros Occidental during 5-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in Murcia (in sq. km.)		
	Damsite	Iglau-An	Talotog
0.03-0.20	3.83	1.41	0.24
0.21-0.50	0.33	0.074	0.015
0.51-1.00	0.19	0.047	0.0068
1.01-2.00	0.12	0.033	0.0033
2.01-5.00	0.02	0.0079	0
> 5.00	0	0	0

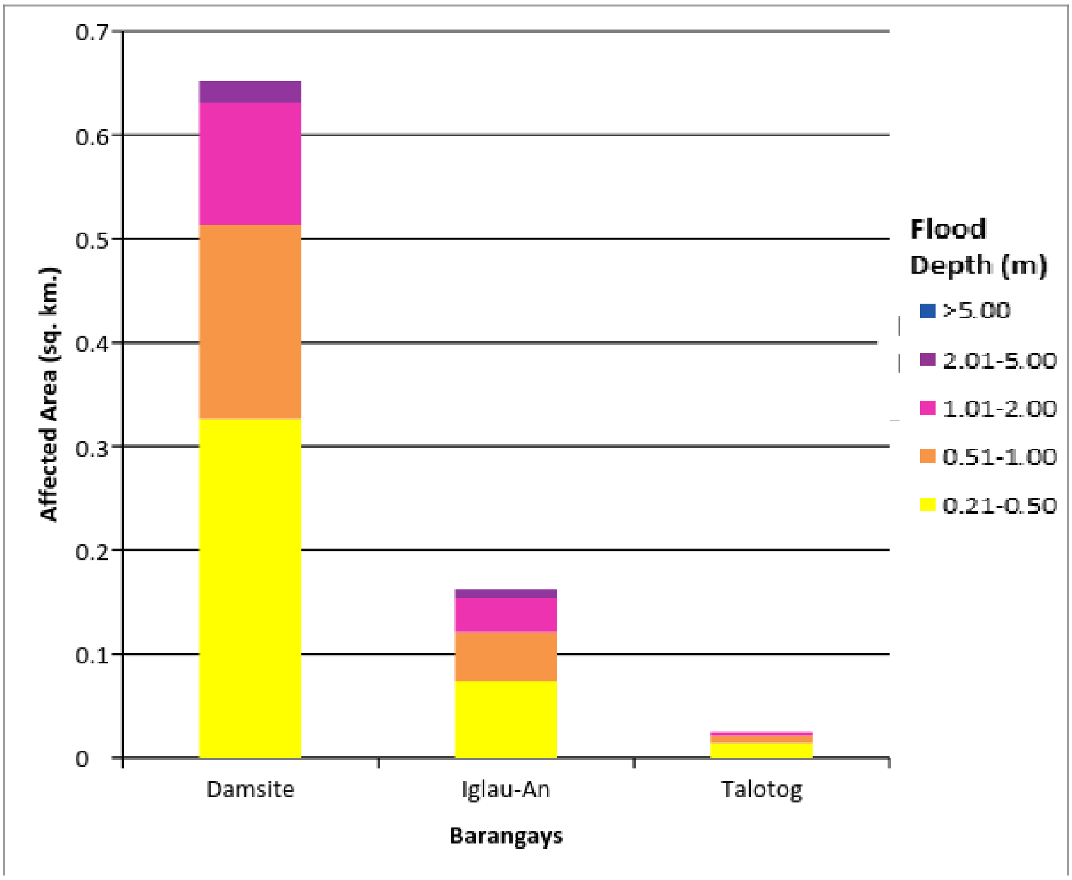


Figure 92. Affected Areas in Murcia, Negros Occidental during 5-Year Rainfall Return Period

For the municipality of Pulupandan, with an area of 16.13 sq. km., 68.31% will experience flood levels of less 0.20 meters. 25.5% of the area will experience flood levels of 0.21 to 0.50 meters while 3.79%, 0.5%, and 0.21% 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.

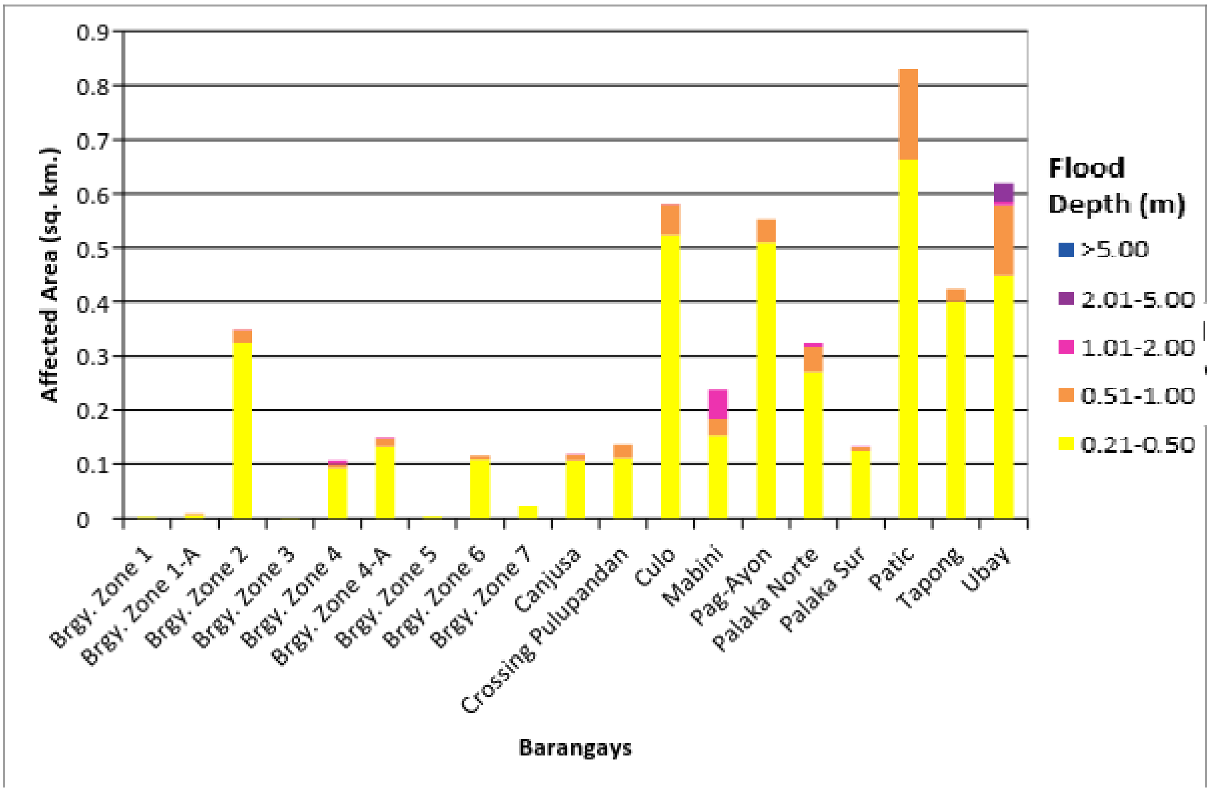


Figure 93. Affected Areas in Pulupandan, Negros Occidental during 5-Year Rainfall Return Period

Table 53 Affected Areas in Pulupandan, Negros Occidental during 5-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in Pulupandan (in sq. km.)									
	Brgy. Zone 1	Brgy. Zone 1-A	Brgy. Zone 2	Brgy. Zone 3	Brgy. Zone 4	Brgy. Zone 4-A	Brgy. Zone 5	Brgy. Zone 6	Brgy. Zone 7	Canjusa
0.03-0.20	0.05	0.023	0.57	0.015	0.25	0.32	0.076	0.32	0.039	0.32
0.21-0.50	0.0032	0.0063	0.32	0.001	0.092	0.13	0.0043	0.11	0.023	0.11
0.51-1.00	0	0.0032	0.024	0	0.0073	0.015	0	0.0075	0.000016	0.011
1.01-2.00	0	0	0.0001	0	0.0068	0.0022	0	0	0	0.001
2.01-5.00	0	0	0	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0
Affected Barangays in Bago City (in sq. km.)	**Affected Barangays in Pulupandan (in sq. km.)**									
	Crossing Pulupandan	Culo	Mabini	Pag-Ayon	PalakaN-orte	Palaka Sur	Patic	Tapong	Ubay	Utod
0.03-0.20	0.35	1.29	0.63	1	0.38	0.31	1.63	1.12	2.02	0.28
0.21-0.50	0.11	0.52	0.15	0.51	0.27	0.12	0.66	0.4	0.45	0.11
0.51-1.00	0.025	0.057	0.031	0.042	0.046	0.0081	0.17	0.024	0.13	0.012
1.01-2.00	0.0001	0.0005	0.054	0	0.0081	0.0004	0.0003	0	0.0066	0.000048
2.01-5.00	0	0	0	0	0	0	0	0	0.035	0
> 5.00	0	0	0	0	0	0	0	0	0	0

For the municipality of Valladolid, with an area of 40.37 sq. km., 35.46% will experience flood levels of less 0.20 meters. 13.7% of the area will experience flood levels of 0.21 to 0.50 meters while 2.8%, 0.81%, and 0.006% 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.

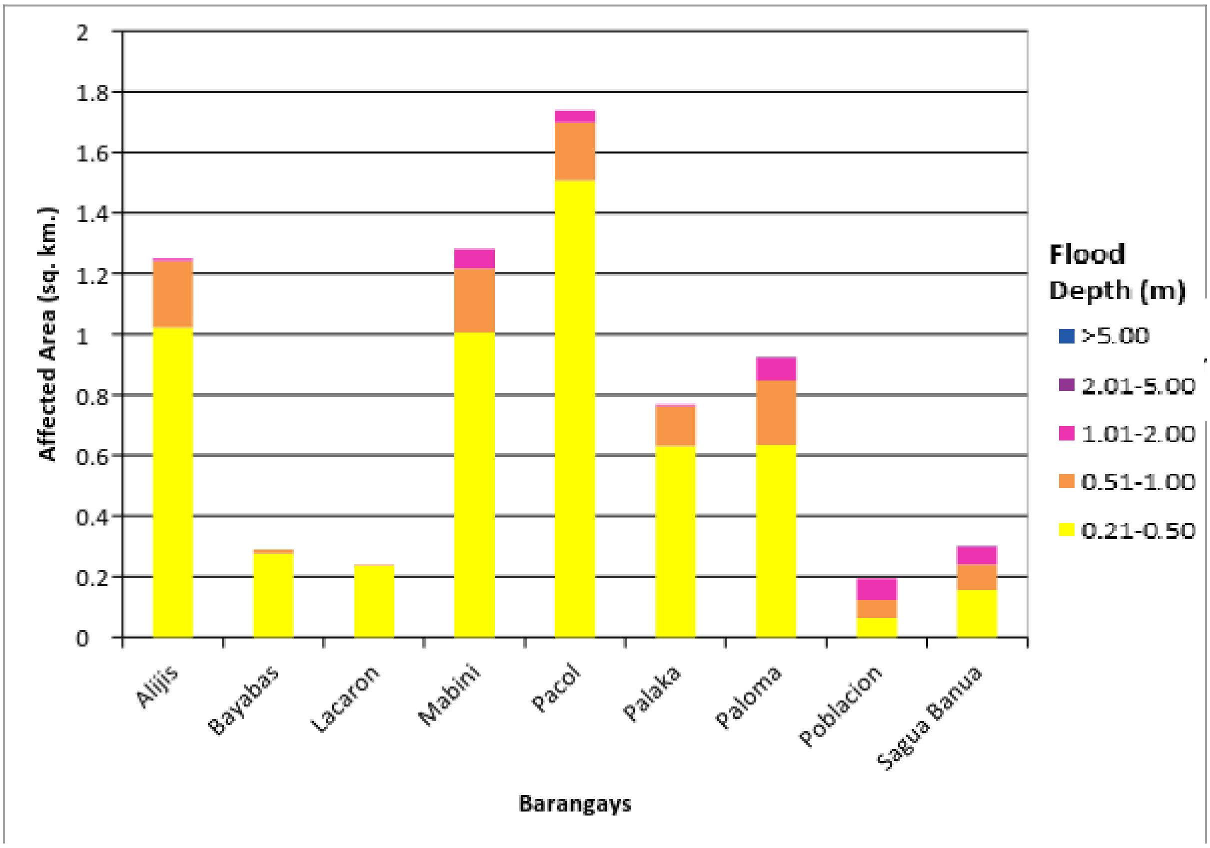


Figure 94. Affected Areas in Valladolid, Negros Occidental during 5-Year Rainfall Return Period

Table 54. Affected Areas in Valladolid, Negros Occidental during 5-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in Valladolid (in sq. km.)								
	Alijis	Bayabas	Lacaron	Mabini	Pacol	Palaka	Paloma	Poblacion	Sagua Banua
0.03-0.20	2.1	0.9	1.13	3.53	2.95	1.41	1.6	0.34	0.36
0.21-0.50	1.02	0.28	0.24	1.01	1.51	0.63	0.63	0.062	0.16
0.51-1.00	0.22	0.012	0.0032	0.21	0.19	0.13	0.21	0.06	0.083
1.01-2.00	0.0093	0	0	0.065	0.04	0.0041	0.078	0.071	0.061
2.01-5.00	0	0	0	0	0.0003	0	0.00084	0	0.0014
> 5.00	0	0	0	0	0	0	0	0	0

For the 25-year return period, 39.07% of the city of Bago with an area of 350.91 sq. km. will experience flood levels of less 0.20 meters. 8.2% of the area will experience flood levels of 0.21 to 0.50 meters while 4.8%, 2.73%, 1.06%, and 1.75% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 55 are the affected areas in square kilometres by flood depth per barangay.

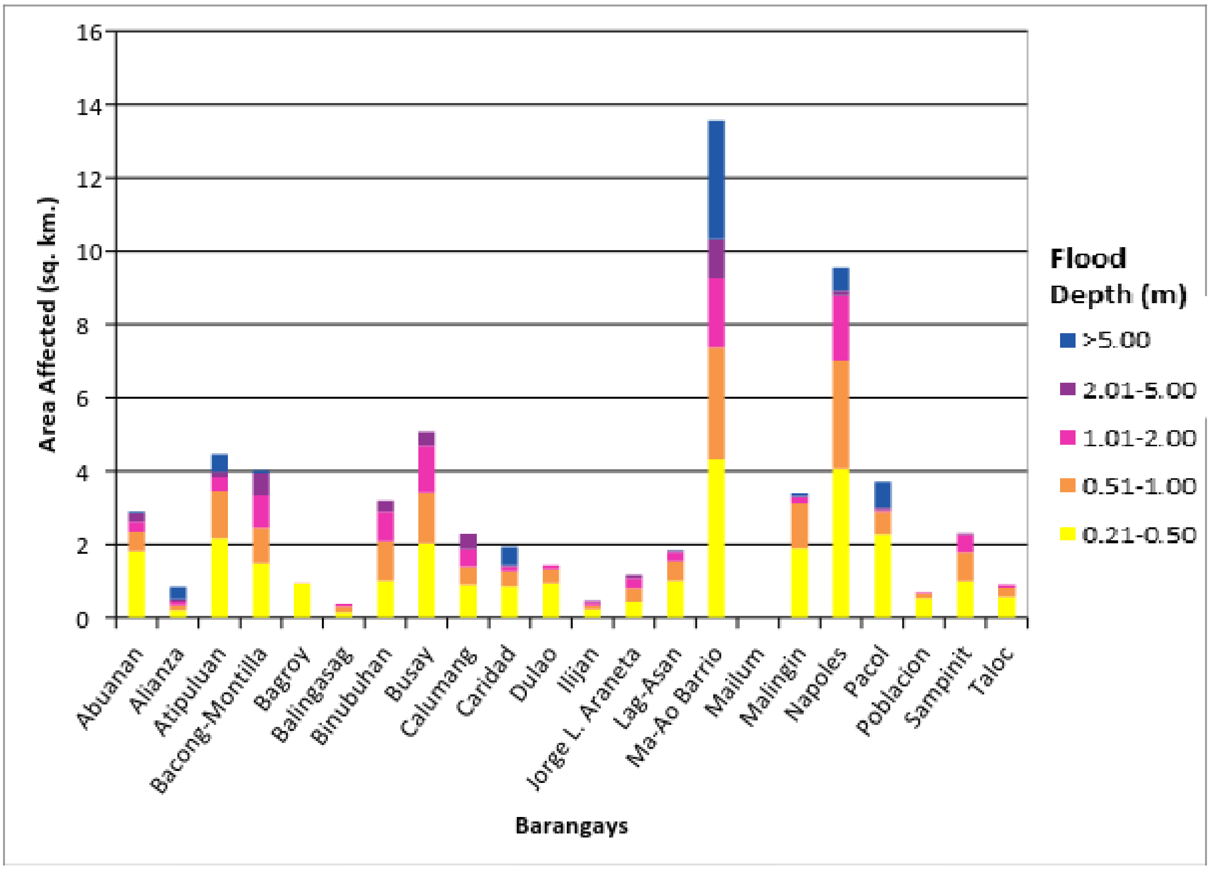


Figure 95. Affected Areas in Bago City, Negros Occidental during 25-Year Rainfall Return Period

Table 55. Affected Areas in Bago City, Negros Occidental during 25-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in Bago City (in sq. km.)										
	Abuanan	Alianza	Atipuluan	Bacong-Mon-tilla	Bagroy	Balingasag	Binubuhan	Busay	Calumang	Caridad	Dulao
0.03-0.20	**9.26**	**1.06**	**11.45**	**20.45**	**1.33**	**0.4**	**6.17**	**10.31**	**3.83**	**3.59**	**4.66**
0.21-0.50	1.82	0.2	2.17	1.49	0.93	0.15	1.01	2.04	0.9	0.85	0.94
0.51-1.00	0.54	0.12	1.28	0.96	0.0088	0.16	1.07	1.36	0.5	0.41	0.37
1.01-2.00	0.26	0.11	0.38	0.88	0	0.063	0.8	1.3	0.48	0.13	0.11
2.01-5.00	0.24	0.066	0.15	0.61	0	0.01	0.29	0.37	0.42	0.037	0.0001
> 5.00	0.034	0.34	0.48	0.088	0	0	0.001	0	0	0.5	0
Affected areas (sq. km.) by flood depth (in m)	**Affected Barangays in Bago City (in sq. km.)**										
	Ilijan	**Jorge L. Araneta**	**Lag-Asan**	**Ma-Ao Barrio**	**Mailum**	**Malingin**	**Napoles**	**Pacol**	**Poblacion**	**Sampinit**	**Taloc**
0.03-0.20	2.34	1.8	3.18	25.43	0.0057	5.79	14.09	5.06	1.26	1.63	4.01
0.21-0.50	0.22	0.43	1	4.33	0.0005	1.9	4.06	2.28	0.52	0.99	0.57
0.51-1.00	0.11	0.38	0.54	3.06	0.00048	1.22	2.96	0.6	0.15	0.8	0.24
1.01-2.00	0.094	0.26	0.25	1.87	0.000039	0.18	1.76	0.04	0.025	0.49	0.08
2.01-5.00	0.038	0.1	0.043	1.05	0	0.011	0.14	0.066	0.0039	0.032	0.0029
> 5.00	0	0.0039	0.01	3.24	0	0.095	0.63	0.72	0	0	0

For the city of La Carlota, with an area of 121.01 sq. km., 3.15% will experience flood levels of less 0.20 meters. 0.47% of the area will experience flood levels of 0.21 to 0.50 meters while 0.20%, 0.07%, and 0.002% 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.

Table 56 Affected Areas in La Carlota City, Negros Occidental during 25-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in La Carlota City (in sq. km.)
	Taloc
0.03-0.20	4.01
0.21-0.50	0.57
0.51-1.00	0.24
1.01-2.00	0.08
2.01-5.00	0.0029
> 5.00	0

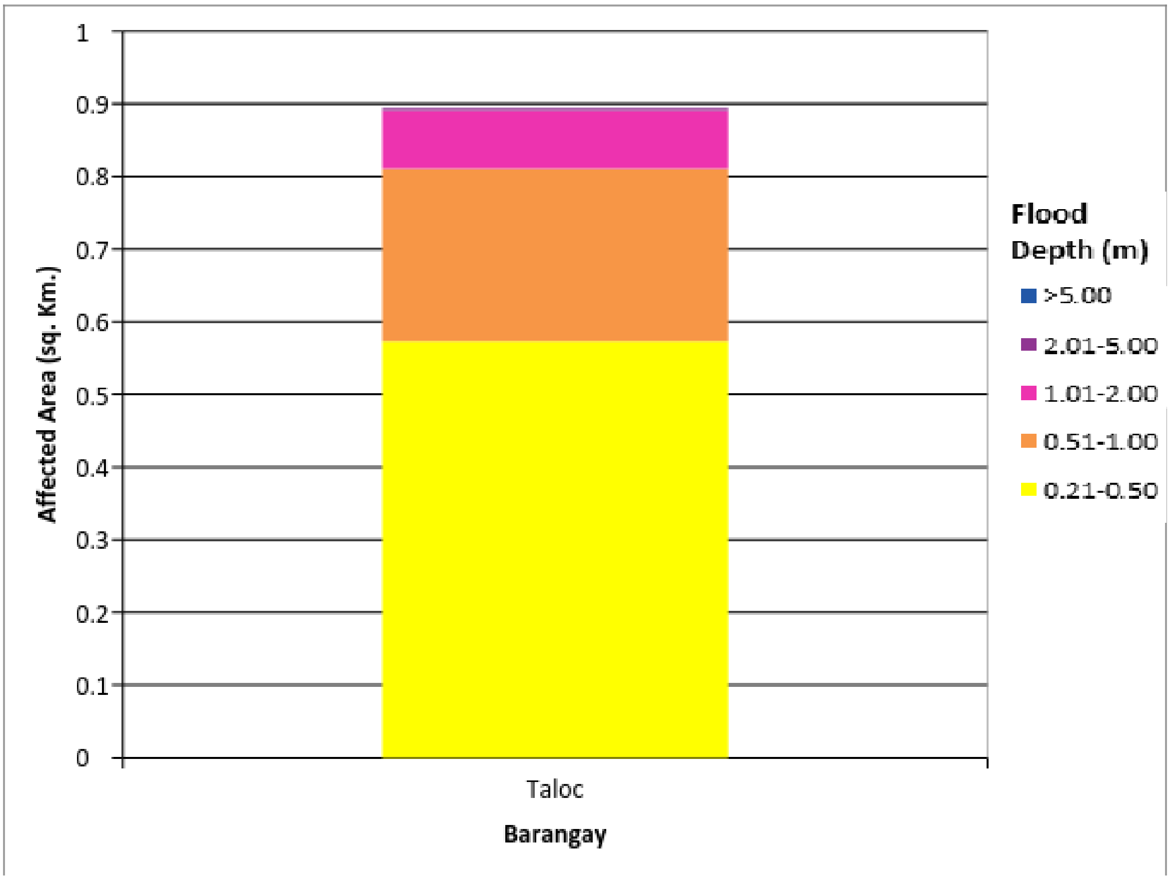


Figure 96. Affected Areas in La Carlota City, Negros Occidental during 25-Year Rainfall Return Period

For the municipality of Murcia, with an area of 364.2 sq. km., 1.48% will experience flood levels of less 0.20 meters. 0.12% of the area will experience flood levels of 0.21 to 0.50 meters while 0.07%, 0.053%, 0.009%, and 0.008 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.

Table 57 Affected Areas in Murcia, Negros Occidental during 25-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in Murcia (in sq. km.)		
	Damsite	Iglau-An	Talotog
0.03-0.20	3.76	1.4004	0.25
0.21-0.50	0.37	0.068	0.0057
0.51-1.00	0.18	0.051	0.00405
1.01-2.00	0.15	0.042	0.0036
2.01-5.00	0.022	0.0109	0.0002
> 5.00	0.403	0.307	0.0024

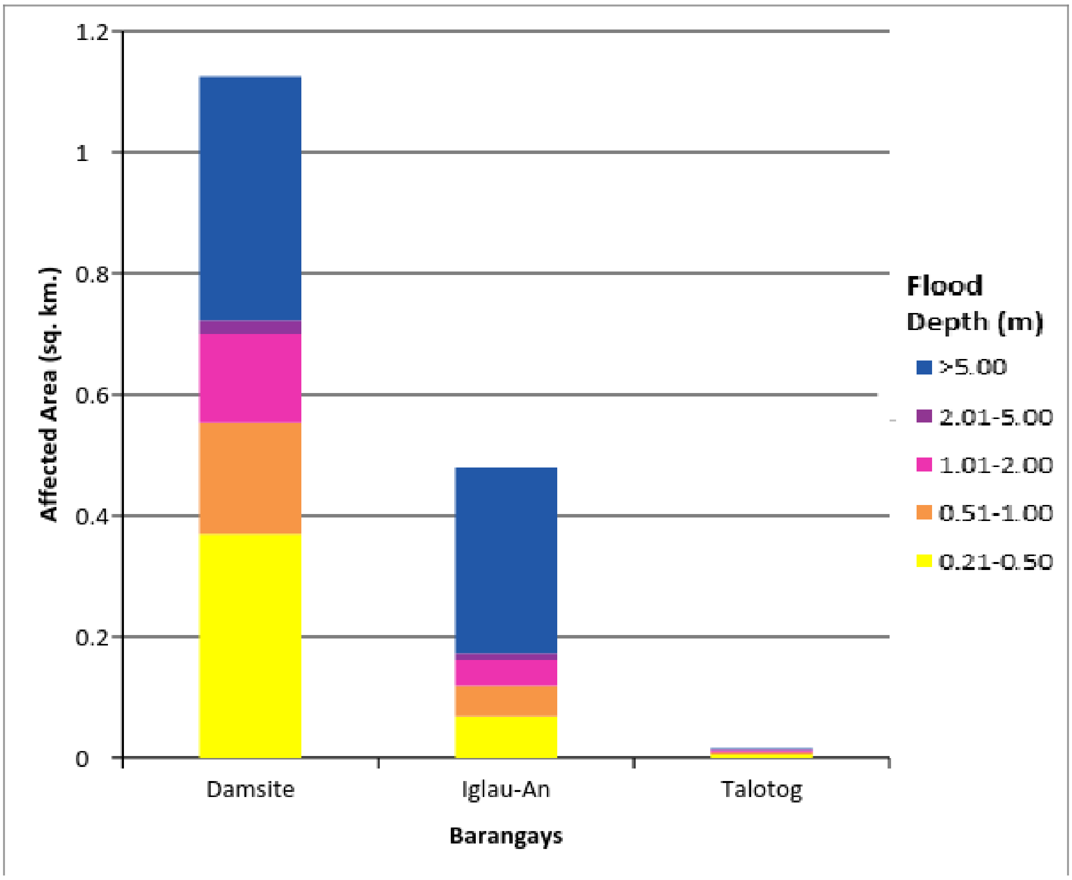


Figure 97. Affected Areas in Murcia, Negros Occidental during 25-Year Rainfall Return Period

For the municipality of Pulupandan, with an area of 16.13 sq. km., 57.54% will experience flood levels of less 0.20 meters. 28.7% of the area will experience flood levels of 0.21 to 0.50 meters while 10.43%, 1.37%, 0.27%, and 0.03 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.

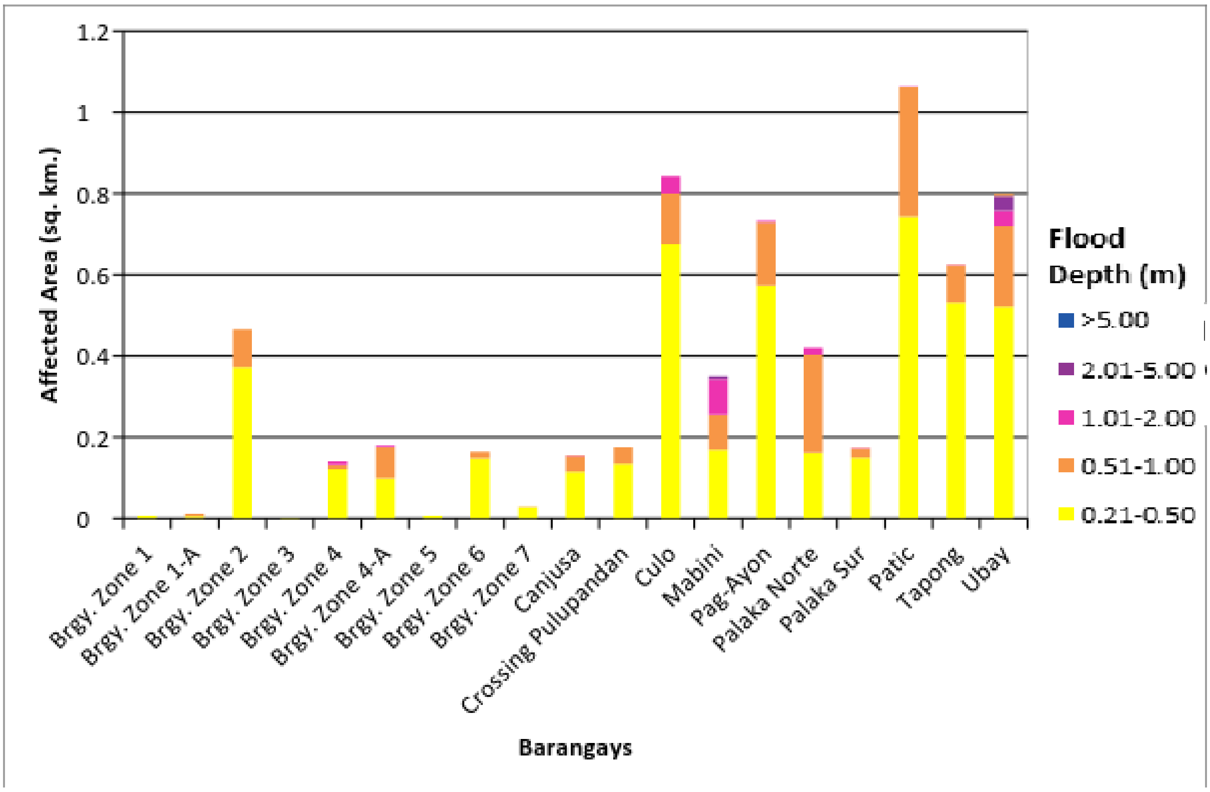


Figure 98. Affected Areas in Pulupandan, Negros Occidental during 25-Year Rainfall Return Period

Table 58 Affected Areas in Pulupandan, Negros Occidental during 25-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in Pulupandan (in sq. km.)									
	Brgy. Zone 1	Brgy. Zone 1-A	Brgy. Zone 2	Brgy. Zone 3	Brgy. Zone 4	Brgy. Zone 4-A	Brgy. Zone 5	Brgy. Zone 6	Brgy. Zone 7	Canjusa
0.03-0.20	0.0473	0.021	0.46	0.015	0.22	0.29	0.074	0.28	0.033	0.28
0.21-0.50	0.00604	0.0056	0.37	0.0017	0.12	0.098	0.0062	0.15	0.027	0.11
0.51-1.00	0	0.0052	0.094	0	0.012	0.076	0	0.016	0.0016	0.040
1.01-2.00	0	0	0.0001	0	0.008	0.0036	0	0	0	0.0012
2.01-5.00	0	0	0	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0
Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in Pulupandan (in sq. km.)									
	Crossing Pu-lupandan	Culo	Mabini	Pag-Ayon	PalakaN-orte	Palaka Sur	Patic	Tapong	Ubay	Utod
0.03-0.20	0.31	1.031	0.51	0.82	0.29	0.27	1.40	0.92	1.85	0.16
0.21-0.50	0.13	0.68	0.169	0.57	0.16	0.15	0.74	0.53	0.52	0.074
0.51-1.00	0.041	0.12	0.086	0.16	0.24	0.023	0.33	0.093	0.20	0.15
1.01-2.00	0.0006	0.043	0.087	0.004	0.017	0.0011	0.0019	0.0005	0.037	0.015
2.01-5.00	0	0	0.0071	0	0.0002	0	0	0	0.036	0.0001
> 5.00	0	0	0	0	0	0	0	0	0.0049	0

For the municipality of Valladolid, with an area of 40.37 sq. km., 29.46% will experience flood levels of less 0.20 meters. 16.51% of the area will experience flood levels of 0.21 to 0.50 meters while 5.4%, 1.34%, and 0.06% 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

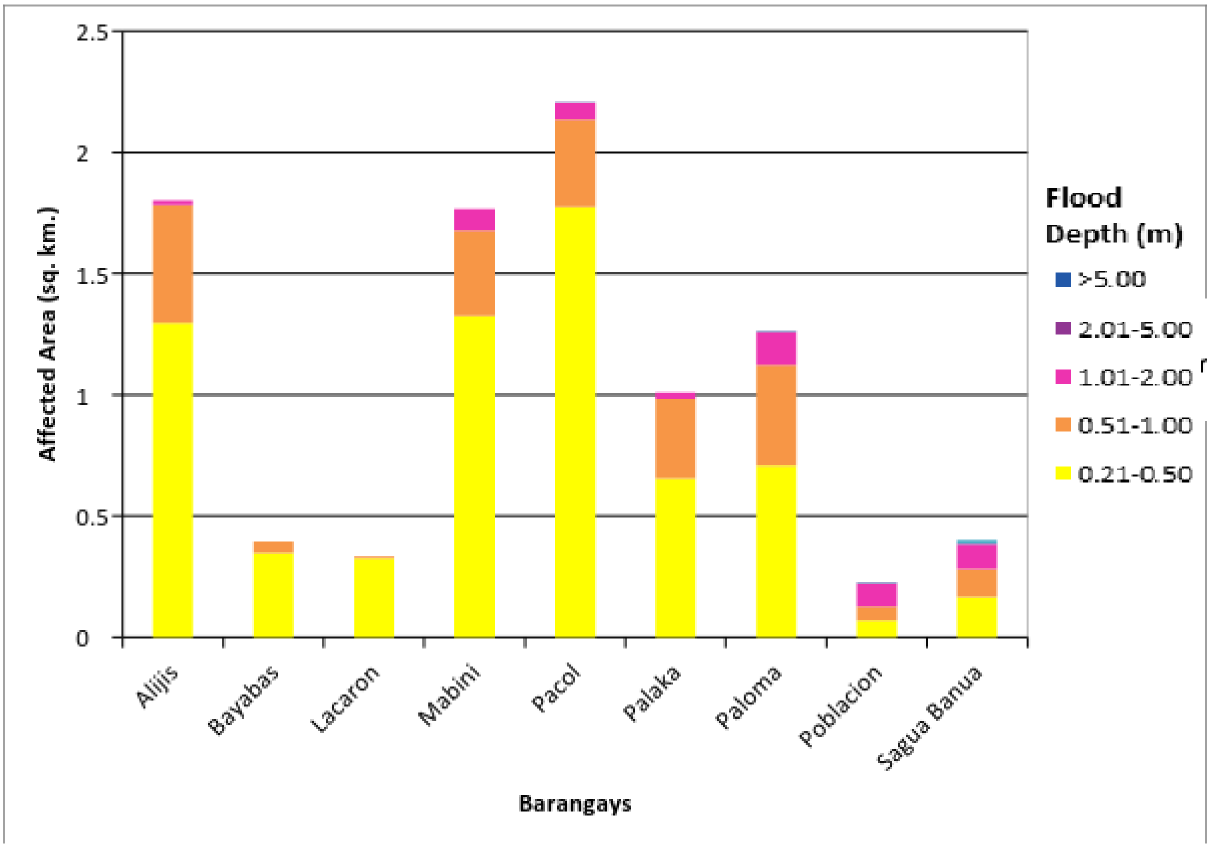


Figure 99. Affected Areas in Valladolid, Negros Occidental during 5-Year Rainfall Return Period

Table 59. Affected Areas in Valladolid, Negros Occidental during 25-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in Valladolid (in sq. km.)								
	Alijis	Bayabas	Lacaron	Mabini	Pacol	Palaka	Paloma	Poblacion	SaguaBanua
0.03-0.20	1.55	0.8	1.03	3.04	2.48	1.16	1.26	0.31	0.27
0.21-0.50	1.3	0.35	0.33	1.33	1.77	0.65	0.71	0.068	0.17
0.51-1.00	0.49	0.046	0.0082	0.35	0.36	0.33	0.42	0.058	0.12
1.01-2.00	0.018	0	0	0.086	0.071	0.027	0.14	0.098	0.1
2.01-5.00	0	0	0	0.0001	0.001	0	0.0036	0.0036	0.017
> 5.00	0	0	0	0	0	0	0	0	0

For the 100-year return period, 30.25% of the city of Bago with an area of 350.91 sq. km. will experience flood levels of less 0.20 meters. 7.5% of the area will experience flood levels of 0.21 to 0.50 meters while 5.59%, 6.16%, 4.78%, and 2.4% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 60, there are 19 affected areas in square kilometres by flood depth per barangay.

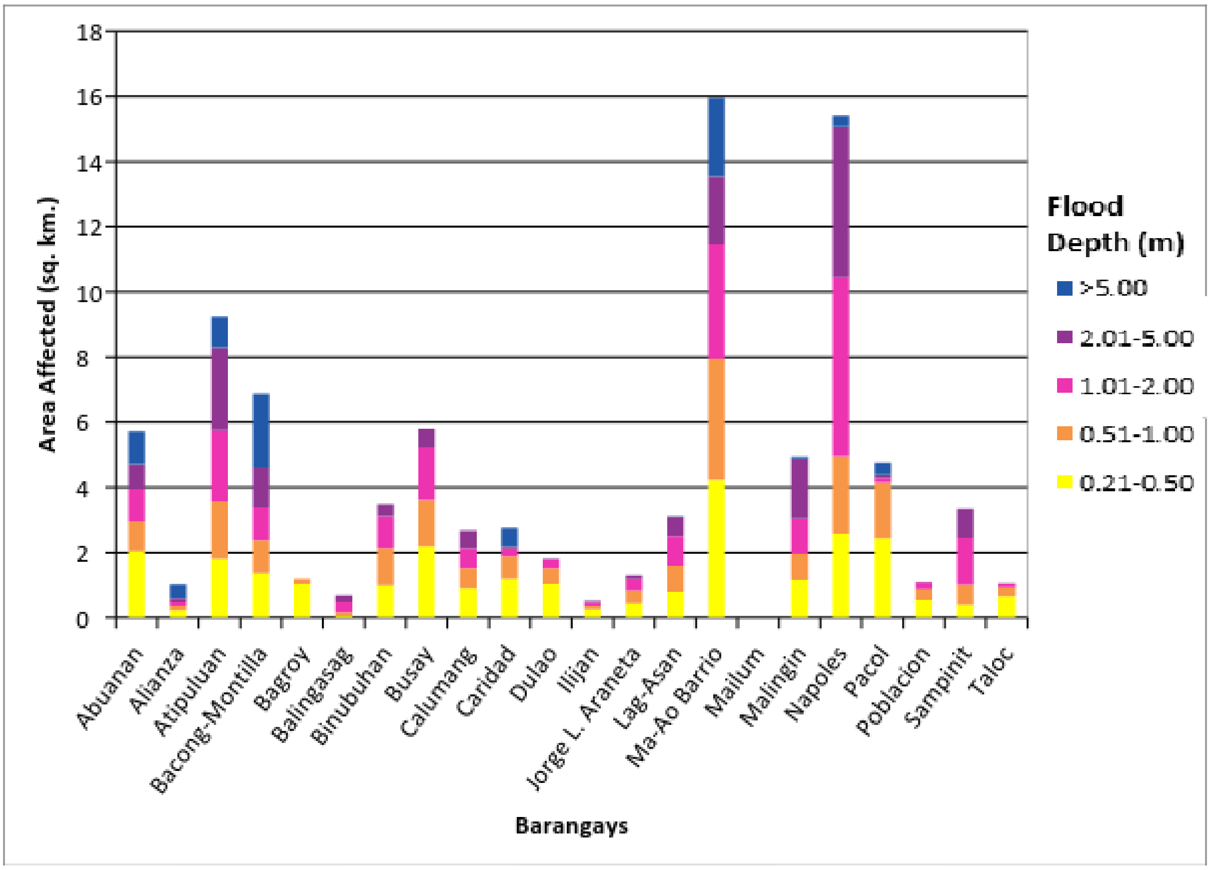


Figure 100. Affected Areas in Bago City, Negros Occidental during 100-Year Rainfall Return Period

Table 60. Affected Areas in Bago City, Negros Occidental during 100-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in Bago City (in sq. km.)										
	Abuanan	Alianza	Atipuluan	Ba-cong-Mon-tilla	Bagroy	Balingasag	Binubuhan	Busay	Calumang	Caridad	Dulao
0.03-0.20	6.43	0.86	6.56	17.61	1.07	0.1	5.87	9.59	3.45	2.86	4.27
0.21-0.50	2.05	0.22	1.81	1.36	1.04	0.055	1	2.19	0.9	1.2	1.05
0.51-1.00	0.91	0.14	1.76	1.03	0.16	0.1	1.14	1.42	0.61	0.69	0.48
1.01-2.00	0.98	0.12	2.19	1	0.0002	0.32	0.97	1.63	0.6	0.23	0.26
2.01-5.00	0.78	0.1	2.54	1.24	0	0.2	0.38	0.55	0.56	0.068	0.04
> 5.00	1.01	0.44	0.94	2.25	0	0	0.0015	0.0004	0	0.58	0

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in Bago City (in sq. km.)										
	Ilijan	Jorge L. Araneta	Lag-Asan	Ma-Ao Barrio	Mailum	Malingin	Napoles	Pacol	Pobla-cion	Samp-init	Taloc
0.03-0.20	2.28	1.67	1.91	20.54	0.0053	4.21	7.95	3.63	0.86	0.58	3.86
0.21-0.50	0.25	0.43	0.79	4.23	0.0003	1.17	2.58	2.44	0.54	0.39	0.66
0.51-1.00	0.12	0.39	0.81	3.73	0.0006	0.8	2.38	1.72	0.32	0.62	0.28
1.01-2.00	0.096	0.35	0.9	3.52	0.00048	1.06	5.49	0.13	0.22	1.45	0.11
2.01-5.00	0.061	0.12	0.6	2.07	0.000039	1.86	4.62	0.098	0.0065	0.89	0.0052
> 5.00	0	0.0049	0.0073	2.41	0	0.06	0.35	0.37	0	0	0

For the city of La Carlota, with an area of 121.01 sq. km., 0.01% will experience flood levels of less 0.20 meter and. 0.0004% of the area will experience flood levels of 0.21 to 0.50 meters.

Table 61. Affected Areas in La Carlota City, Negros Occidental during 100-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in La Carlota City (in sq. km.)
	Balabag
0.03-0.20	0.012
0.21-0.50	0.00045
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

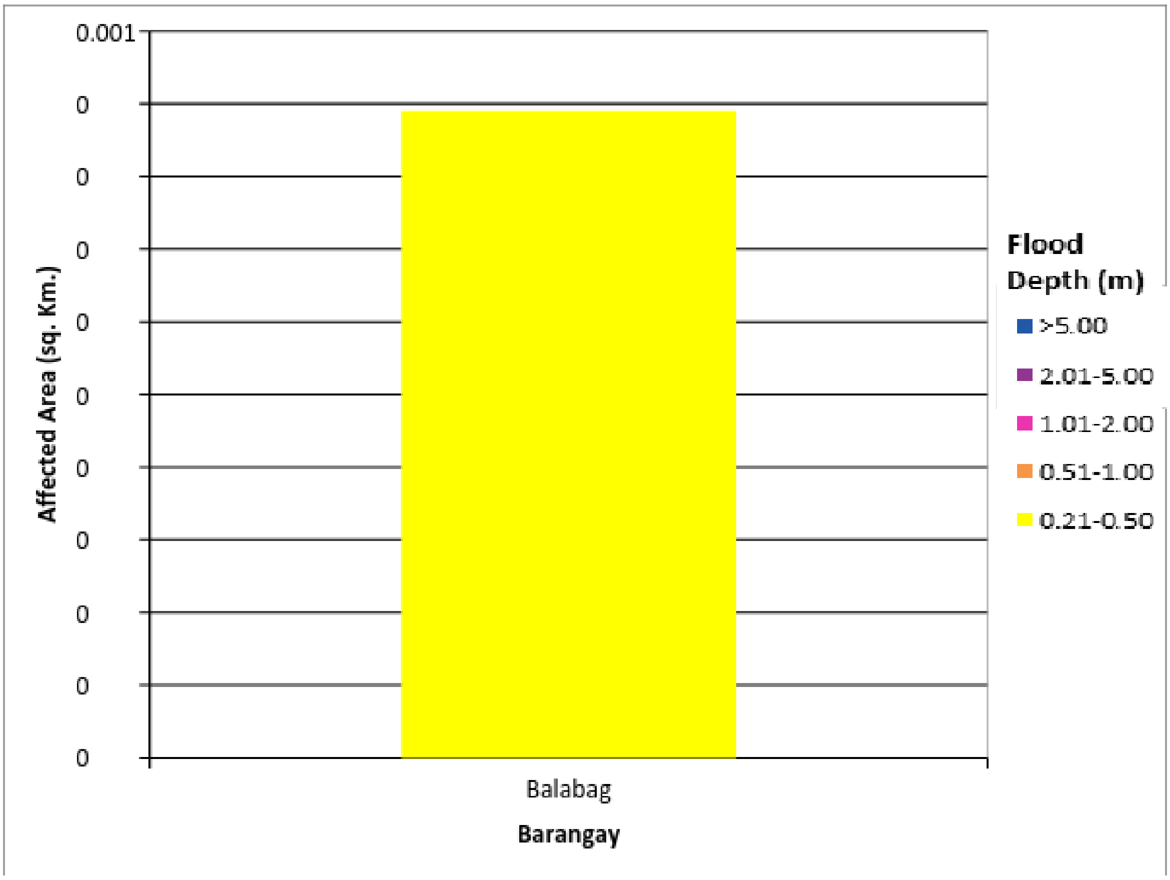


Figure 101. Affected Areas in La Carlota City, Negros Occidental during 100-Year Rainfall Return Period

For the municipality of Murcia, with an area of 364.2 sq. km., 1.2% will experience flood levels of less 0.20 meters. 0.15% of the area will experience flood levels of 0.21 to 0.50 meters while 0.073%, 0.053%, 0.055%, and 0.2 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.

Table 62. Affected Areas in Murcia, Negros Occidental during 100-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in Murcia (in sq. km.)		
	Damsite	Iglau-An	Talotog
0.03-0.20	3.17	0.96	0.24
0.21-0.50	0.49	0.062	0.0067
0.51-1.00	0.22	0.043	0.0036
1.01-2.00	0.12	0.073	0.0045
2.01-5.00	0.076	0.13	0.00023
> 5.00	0.403	0.31	0.0024

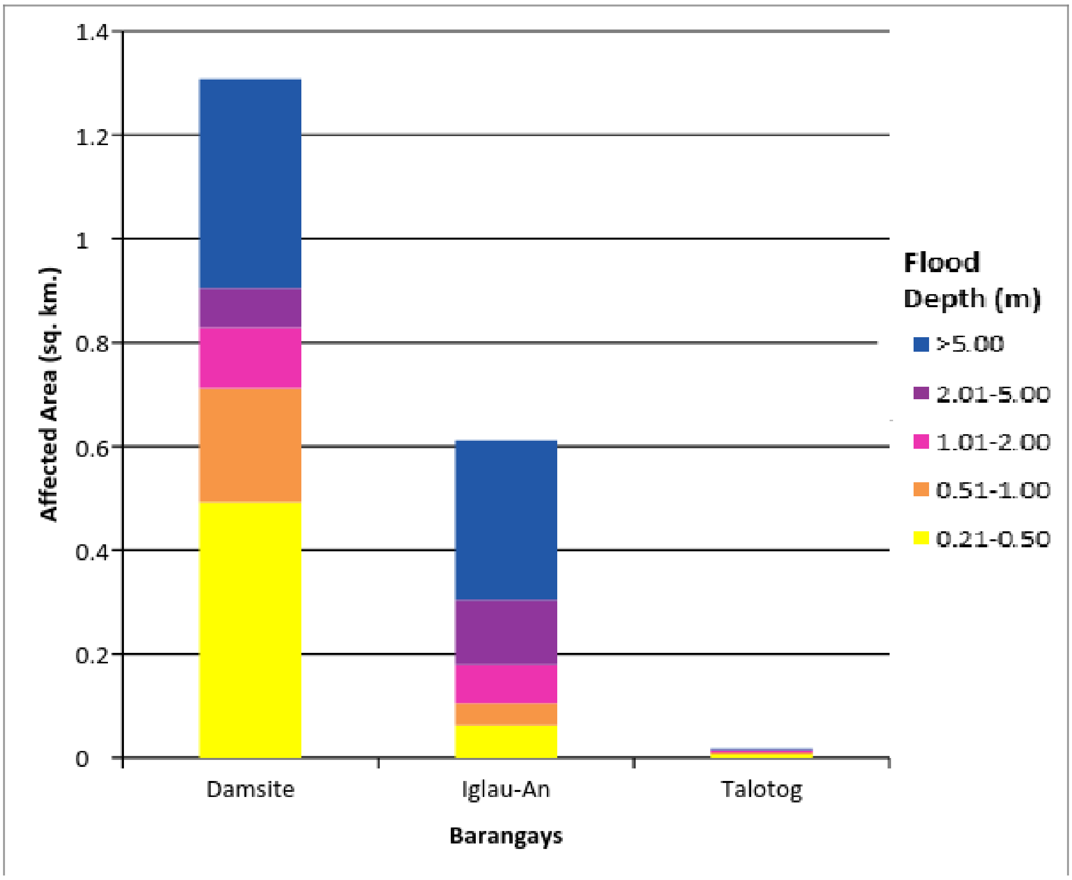


Figure 102. Affected Areas in Murcia, Negros Occidental during 100-Year Rainfall Return Period

For the municipality of Pulupandan, with an area of 16.13 sq. km., 51.19% will experience flood levels of less 0.20 meters. 28.37% of the area will experience flood levels of 0.21 to 0.50 meters while 14.29%, 3.85%, 0.58%, and 0.03 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.

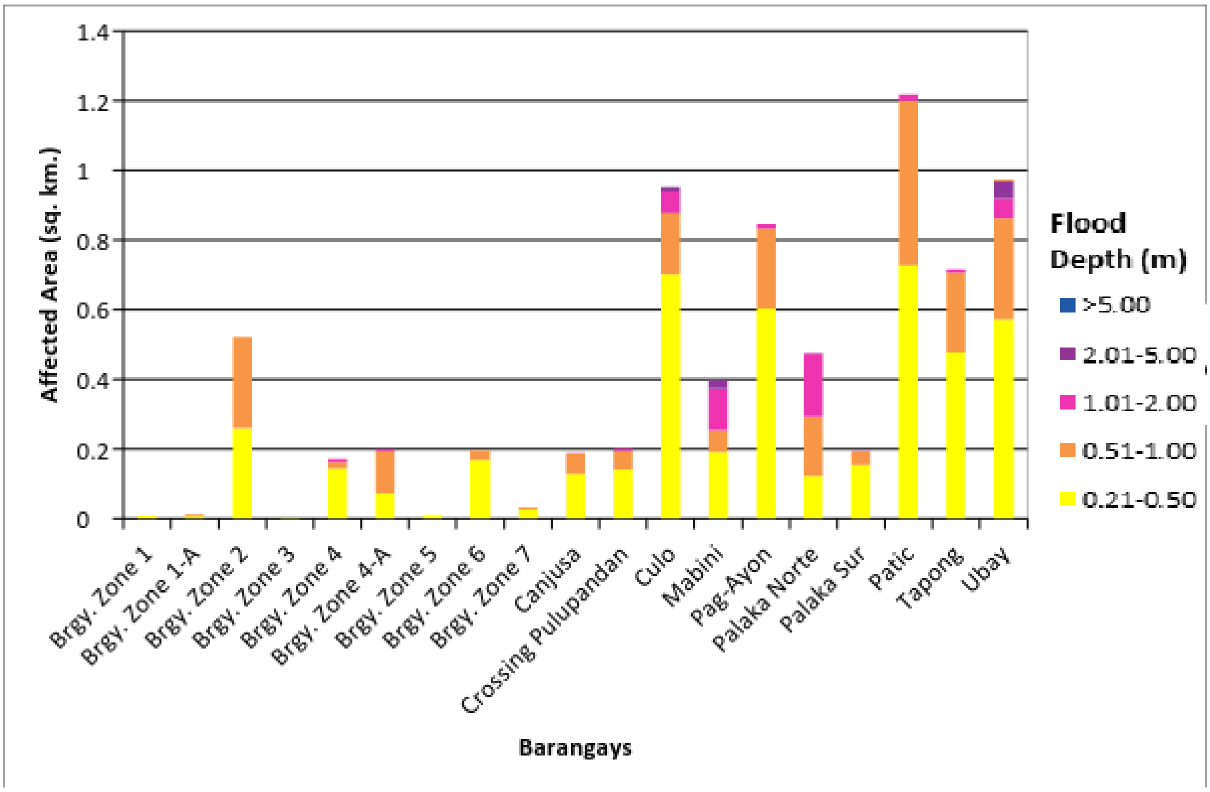


Figure 103. Affected Areas in Pulupandan, Negros Occidental during 100-Year Rainfall Return Period

Table 63 Affected Areas in Pulupandan, Negros Occidental during 100-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in Pulupandan (in sq. km.)									
	Brgy. Zone 1	Brgy. Zone 1-A	Brgy. Zone 2	Brgy. Zone 3	Brgy. Zone 4	Brgy. Zone 4-A	Brgy. Zone 5	Brgy. Zone 6	Brgy. Zone 7	Canjusa
0.03-0.20	0.045	0.021	0.401	0.0142	0.19	0.27	0.072	0.24	0.0308	0.25
0.21-0.50	0.00802	0.0056	0.26	0.00205	0.14	0.072	0.0089	0.17	0.026	0.13
0.51-1.00	0	0.0057	0.26	0	0.019	0.12	0	0.027	0.0056	0.059
1.01-2.00	0	0	0.0001	0	0.0083	0.0051	0	0	0	0.0015
2.01-5.00	0	0	0	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0
Affected areas (sq. km.) by flood depth (in m)	**Affected Barangays in Pulupandan (in sq. km.)**									
	Crossing Pu-lupandan	**Culo**	**Mabini**	**Pag-Ayon**	**PalakaNorte**	**Palaka Sur**	**Patic**	**Tapong**	**Ubay**	**Utod**
0.03-0.20	0.29	0.92	0.46	0.708	0.23	0.24968	1.242977	0.829849	1.67	0.11
0.21-0.50	0.14	0.7002	0.19	0.603	0.12	0.152925	0.726455	0.475942	0.57	0.070
0.51-1.00	0.053	0.18	0.062	0.23	0.17	0.039316	0.474506	0.228185	0.29	0.0808
1.01-2.00	0.0076	0.062	0.12	0.014	0.18	0.0017	0.017629	0.011	0.057	0.14
2.01-5.00	0	0.013	0.026	0	0.0018	0	0	0	0.049	0.00309
> 5.00	0	0	0	0	0	0	0	0	0.0049	0

For the municipality of Valladolid, with an area of 40.37 sq. km., 25.61% will experience flood levels of less 0.20 meters. 17.16% of the area will experience flood levels of 0.21 to 0.50 meters while 8%, 1.84%, and 0.13% 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.

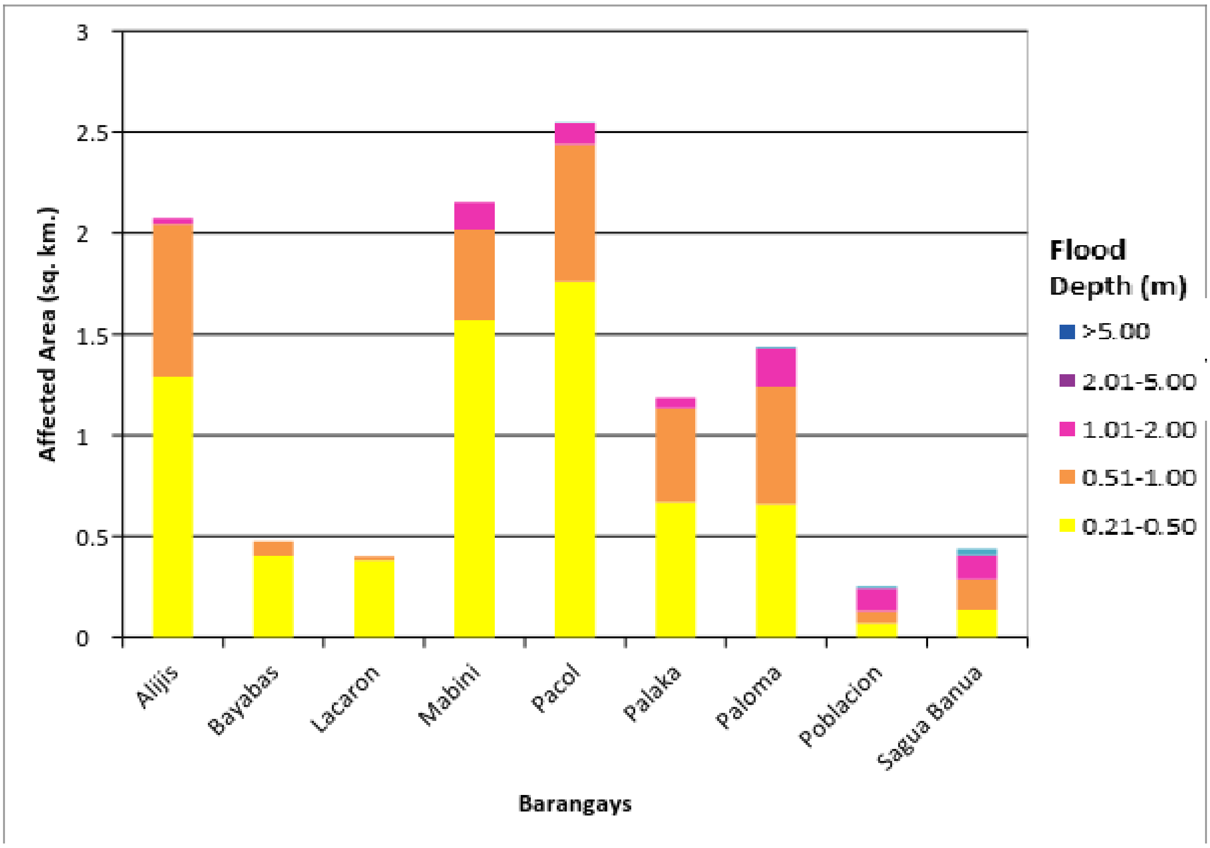


Figure 104. Affected Areas in Valladolid, Negros Occidental during 100-Year Rainfall Return Period

Table 64 Affected Areas in Valladolid, Negros Occidental during 100-Year Rainfall Return Period

Affected areas (sq. km.) by flood depth (in m)	Affected Barangays in Valladolid (in sq. km.)								
	Alijis	Bayabas	Lacaron	Mabini	Pacol	Palaka	Paloma	Poblacion	SaguaBanua
0.03-0.20	1.28	0.72	0.97	2.65	2.14	0.99	1.08	0.28	0.23
0.21-0.50	1.29	0.4	0.38	1.57	1.76	0.67	0.66	0.069	0.13
0.51-1.00	0.75	0.072	0.018	0.45	0.68	0.47	0.58	0.06	0.15
1.01-2.00	0.029	0	0	0.14	0.11	0.051	0.19	0.11	0.12
2.01-5.00	0	0	0	0.0002	0.0016	0	0.0071	0.01	0.034
> 5.00	0	0	0	0	0	0	0	0	0

Among the barangays in the city of Bago, Ma-Ao Barrio is projected to have the highest percentage of area that will experience flood levels at 10.43%. Meanwhile, Bacong-Montilla posted the second highest percentage of area that may be affected by flood depths at 6.98%.

Among the barangays in the city of La Carlota, Taloc is projected to have the highest percentage of area that will experience flood levels at 3.47%.

Among the barangays in the municipality of Murcia, Damsite is projected to have the highest percentage of area that will experience flood levels of at 1.23%. Meanwhile, Iglau-An posted the percentage of area that may be affected by flood depths of at 0.43%.

Among the barangays in the municipality of Pulupandan, Ubay is projected to have the highest percentage of area that will experience flood levels at 16.39%. Meanwhile, Culo posted the second highest percentage of area that may be affected by flood depths of at 11.62%.

Among the barangays in the municipality of Valladolid, Mabini is projected to have the highest percentage of area that will experience flood levels at 11.91%. Meanwhile, Pacol posted the second highest percentage of area that may be affected by flood depths of at 11.62%.

Moreover, the generated flood hazard maps for the Bago 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 yr, 25 yr, and 100 yr).

Table 65 Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	38.73	43.46	40.79
Medium	21.55	30.306	41.39
High	8.24	11.66	37.72
TOTAL	**68.52**	**85.426**	**119.9**

Of the sixty-seven (67) identified Education Institutions in Bago Flood plain, 13 schools were assessed to be exposed to the Low level flooding during a 5 year scenario, while 2 schools were assessed to be exposed to the Medium level flooding in the same scenario. In the 25 year scenario, 14 schools were assessed to be exposed to the Low level flooding while 5 schools were assessed to be exposed to medium level flooding. For the 100 year scenario, 19 schools were assessed to be exposed to the Low level flooding, 10 schools were assessed to be exposed to the medium level flooding, and 5 schools were assessed to be exposed to the high level flooding.

Nine (9) Medical Institutions were identified in the Bago Floodplain, 1 school was assessed to be exposed to the Low level flooding during a 5 year scenario. In the 25 year scenario, 1 school was assessed to be exposed to the Low level flooding. In the 100 year scenario, 2 schools were assessed to be exposed to the Low level flooding, while 1 school was assessed to be exposed to the high level flooding.

5.11 Flood Validation

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

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

The validation personnel went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering can was 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 points in the flood map versus its corresponding validation depths are shown in Figure 106.

The flood validation data were obtained on April 20, 2017. The flood validation consisted of 193 points randomly selected all over the Bago floodplain. It has an RMSE value of 0.78m. Table 63 shows a contingency matrix of the comparison.

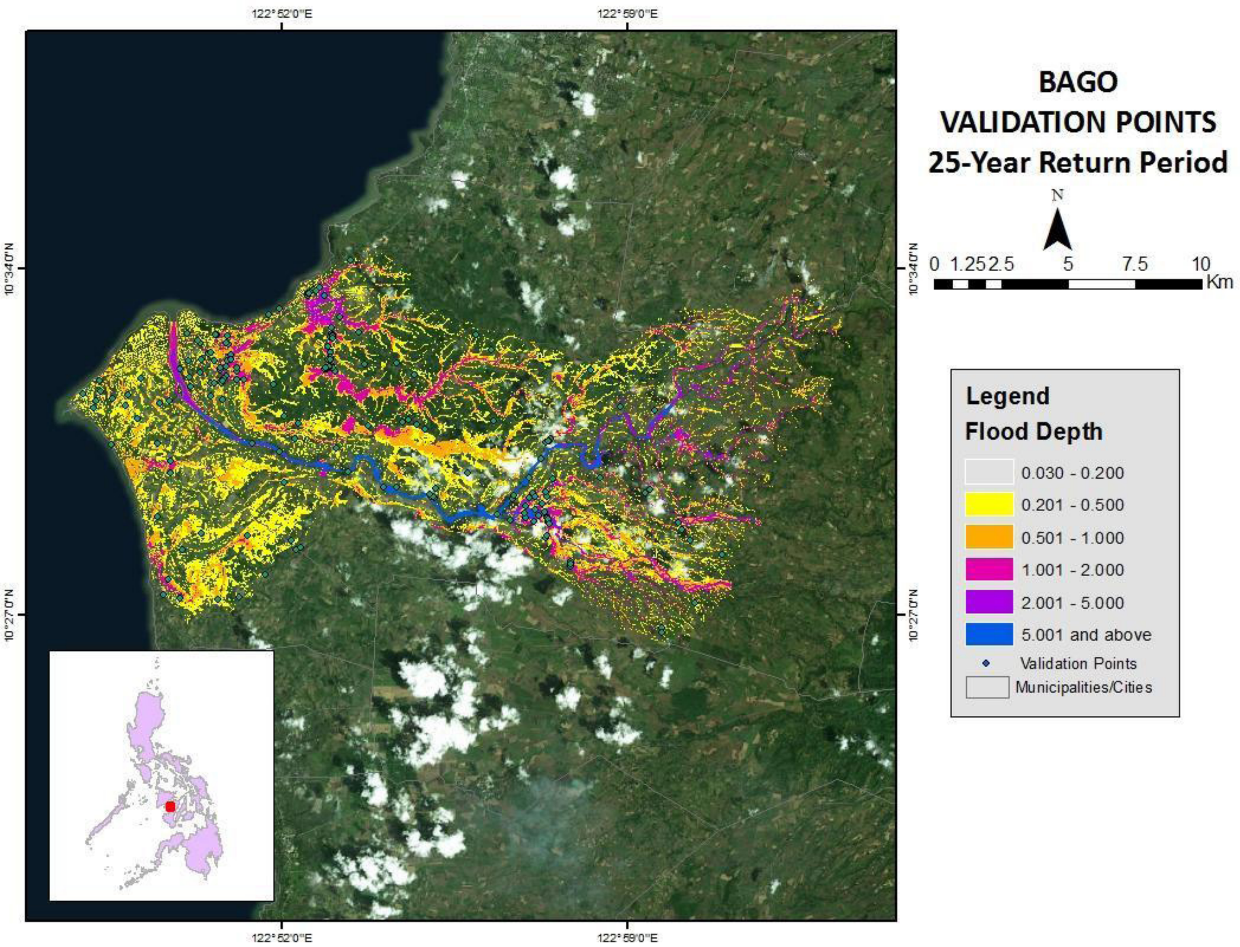


Figure 105. Validation points for 25-year Flood Depth Map of Bago Floodplain

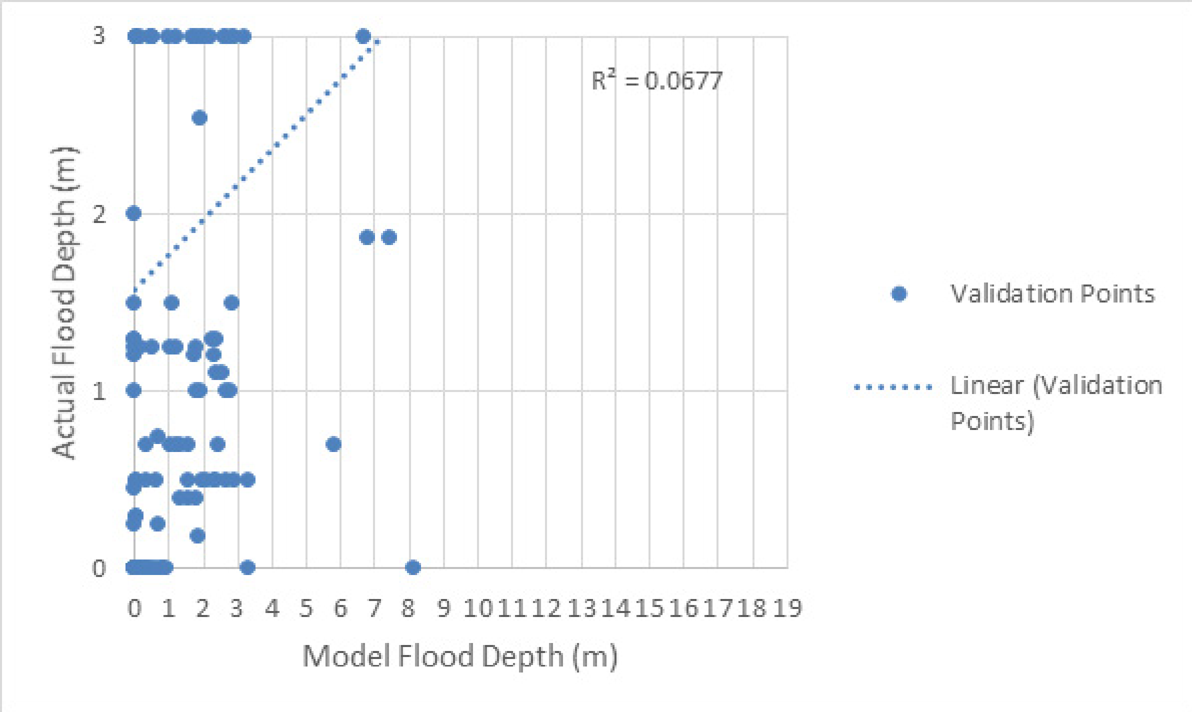


Figure 106. Flood map depth vs actual flood depth

Table 66. Actual Flood Depth vs Simulated Flood Depth at different levels in the Bago River Basin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	48	6	1	10	16	5	86
0.21-0.50	8	1	1	1	6	2	19
0.51-1.00	6	2	1	0	3	0	12
1.01-2.00	1	5	6	5	9	2	28
2.01-5.00	1	6	3	6	18	2	36
> 5.00	1	0	1	2	8		12
Total	65	20	13	24	60	11	193

The overall accuracy generated by the flood model is estimated at 37.82%, with 73 points correctly matching the actual flood depths. In addition, there were 48 points estimated one level above and below the correct flood depths while there were 23 points and 24 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 64 points were overestimated while a total of 56 points were underestimated in the modelled flood depths of Bago. Table 67 depicts the summary of the Accuracy Assessment in the Bago River Basin Survey.

Table 67. Summary of Accuracy Assessment in the Bago River Basin Survey

	No. of Points	%
Correct	73	37.82
Overestimated	64	33.16
Underestimated	56	29.02
Total	193	100

REFERENCES

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

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 Technifical Specification of the Pegasus and Gemini Sensors

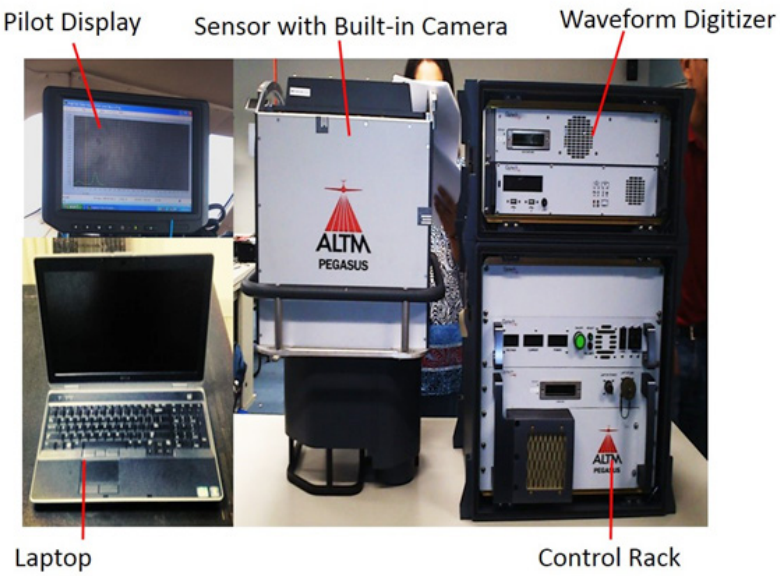


Figure A-1.1 Pegasus Sensor

Table A-1.1 Parameters and Specifications of the Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1Ó
Elevation accuracy (2)	< 5-20 cm, 1Ó
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 (optional)
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

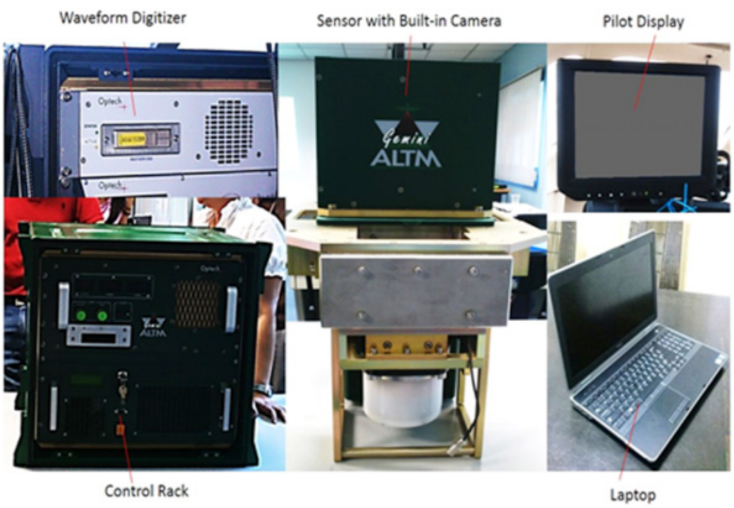


Figure A-1.2 Gemini Sensor

Table A-1.2 Parameters and Specifications of the Gemini Sensor

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

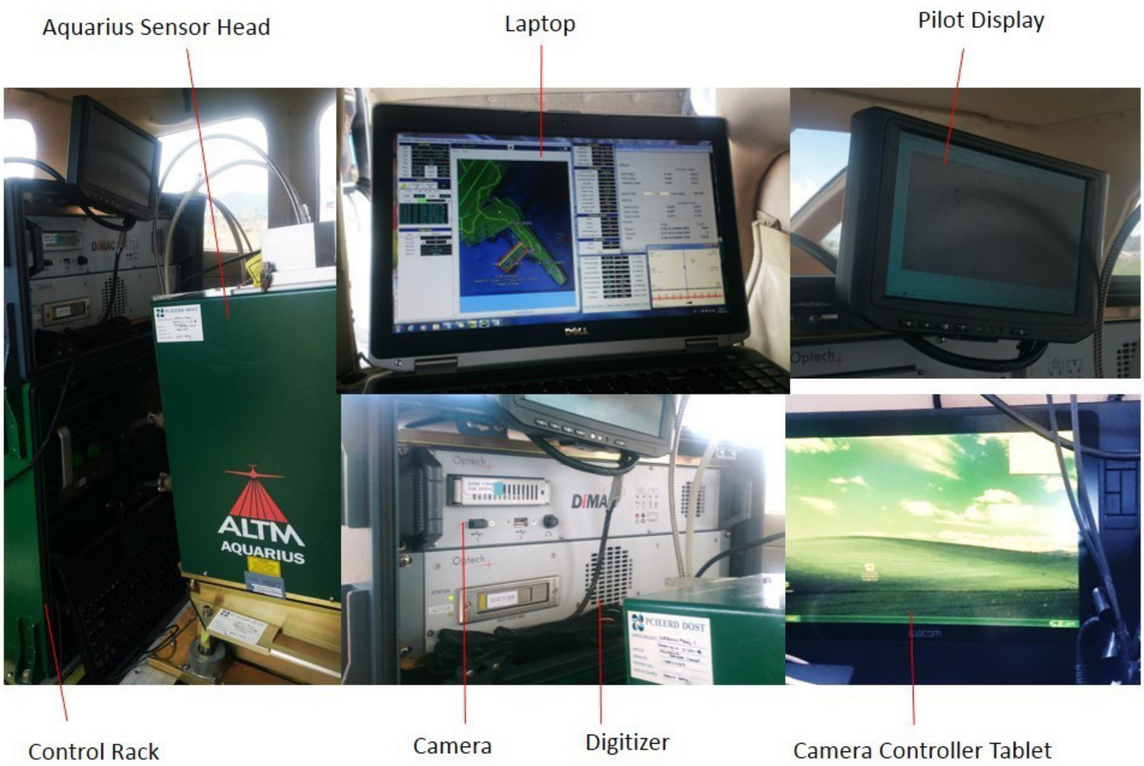


Figure A-1.2 Aquarius Sensor

Table A-1.2 Parameters and Specifications of the Aquarius Sensor

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

Annex 2. NAMRIA Certificates of Reference Points Used

1.NGW-80

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

April 23, 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: **NEGROS OCCIDENTAL**
Station Name: **NGW-80**
Order: **2nd**

Island: **VISAYAS**
Municipality: **BAGO**
Barangay: **MA-AO**

PRS92 Coordinates

Latitude: **10° 29' 35.86090"** Longitude: **122° 56' 43.79550"** Ellipsoidal Hgt: **30.72000 m.**

WGS84 Coordinates

Latitude: **10° 29' 31.60669"** Longitude: **122° 56' 49.03425"** Ellipsoidal Hgt: **89.69100 m.**

PTM Coordinates

Northing: **1160287.663 m.** Easting: **494033.975 m.** Zone: **4**

UTM Coordinates

Northing: **1,159,881.54** Easting: **494,036.06** Zone: **51**

Location Description

NGW-80
From Ma-ao Provincial Road, turn right on the road heading to Sum-ag. The Quezon Bridge is at Km 33+188. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty with inscriptions "NGW-80; 2007; NAMRIA". The station is on the SW sidewalk of the Quezon Bridge.

Requesting Party: **Engr. Christopher Cruz/ UP-DREAM**
Pupose: **Reference**
OR Number: **8796021 A**
T.N.: **2014-921**

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

9904232014154943

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 NGW-80

2. NW-192

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

April 23, 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: **NEGROS OCCIDENTAL**
Station Name: **NW-192**

Island: **VISAYAS**	Municipality: **BAGO CITY**	Barangay: **BALINGASAG**
Elevation: **4.7349 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM NW-192 is in the province of Negros Occidental, City of Bago, Barangay Balingasag, Purok Violeta, along Bacolod – Bago highway.

Station is located on concrete sidewalk, Southwest end of Sibud bridge, 0.15 meter above the ground, 5 meters West of the road centerline.

Mark is the head of a 4" copper nail set on a drilled hole and flushed to a 6" x 6" cement putty with inscription "NW-192, 2007, NAMRIA".

Requesting Party: **Engr. Christopher Cruz/ UP-DREAM**
Pupose: **Reference**
OR Number: **8796021 A**
T.N.: **2014-925**

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

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CIP/4701/12/09/814

Figure A-2.2 NW-192

3. ILO-1

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

April 10, 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: **ILOILO**
Station Name: **ILO-1**
Order: **1st**

Island: **VISAYAS**
Municipality: **ILOILO CITY**
Barangay: **LA PAZ**

PRS92 Coordinates

Latitude:	10° 42' 40.74251"	Longitude:	122° 33' 48.38302"	Ellipsoidal Hgt:	28.93600 m.

WGS84 Coordinates

Latitude:	10° 42' 36.40006"	Longitude:	122° 33' 53.60515"	Ellipsoidal Hgt:	86.45300 m.

PTM Coordinates

Northing:	1184434.202 m.	Easting:	452244.945 m.	Zone:	4

UTM Coordinates

Northing:	1,184,019.63	Easting:	452,261.66	Zone:	51

Location Description

ILO-1
From Iloilo Capitol Bldg., travel W towards Jaro for 2.2 km. along Luna St. in La Paz, Iloilo. The station is located on top of St. Clemente Church bell tower which is across Western Institute of Technology. Station mark; cross cut on top of a 0.15 m. x 0.01 m. dia. brass rod drilled on center top of concrete floor of St. Clemente Church bell tower with 0.30 cm. x 0.30 cm. cement patty, 0.01 m. above surface and inscribed on top with station name. Reference mark numbers 1, 3 and 4 are 0.05 m. dia. holes on top of ledge, reference number 2 is 0.07 m. dia. hole on top of ledge.

recomputed 3/19/2014

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-834**

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

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Figure A-2.3 ILO-1

4. ILO-85

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

April 10, 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: **ILOILO**
Station Name: **ILO-85**
Order: **2nd**

Island: **VISAYAS**
Municipality: **MIAG-AO**
Barangay: **UBOS ILAWOD (POB.)**

PRS92 Coordinates

Latitude: **10° 38' 33.11352"** Longitude: **122° 14' 3.70560"** Ellipsoidal Hgt: **21.96200 m.**

WGS84 Coordinates

Latitude: **10° 38' 28.75996"** Longitude: **122° 14' 8.93597"** Ellipsoidal Hgt: **78.82800 m.**

PTM Coordinates

Northing: **1176896.034 m.** Easting: **416226.997 m.** Zone: **4**

UTM Coordinates

Northing: **1,176,484.10** Easting: **416,256.32** Zone: **51**

Location Description

ILO-85
From Iloilo City, travel W for about 40 km. to the Mun. of Miag-ao. Then proceed directly to the Town Plaza, where the station is located. Station is located at the corner of a planting strip and sidewalk, about 14 m. fronting the Rizal monument. Mark is the head of a 4 in. copper nail set flushed on top of a 30 cm. x 30 cm. concrete monument protruding 20 cm. above the ground, with inscriptions "ILO-85 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-836**

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

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Figure A-2.4 ILO-85

5. ATQ-18

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

March 02, 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: **ANTIQUE**
Station Name: **ATQ-18**
Order: **2nd**

Island:	**VISAYAS**	Barangay:	**CUBAY**		
Municipality:	**BARBAZA**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**11° 11' 58.67081"**	Longitude:	**122° 2' 22.83300"**	Ellipsoidal Hgt:	**10.90200 m.**
		WGS84 Coordinates			
Latitude:	**11° 11' 54.16068"**	Longitude:	**122° 2' 28.01549"**	Ellipsoidal Hgt:	**65.96100 m.**
		PTM / PRS92 Coordinates			
Northing:	**1238579.674 m.**	Easting:	**395119.157 m.**	Zone:	**4**
		UTM / PRS92 Coordinates			
Northing:	**1,238,146.15**	Easting:	**395,155.87**	Zone:	**51**

Location Description

ATQ-18
From San Jose, travel N to the Mun. of Barbaza. Then from the town proper, proceed to Brgy. Cubay. Station is located on the NE approach of Binangbang Bridge, about 600 m. NE of Barbaza Town Hall, 4 m. from the road centerline, 50 m. SE of Barbaza Multi-Purpose Coop./Natco Network and 25 m. SE of a funeral service outlet. Mark is the head of a 4 in. copper nail centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ATQ-18 2007 NAMRIA".

Requesting Party: **PHIL-LIDAR 1**
Purpose: **Reference**
OR Number: **8077754 I**
T.N.: **2015-0504**

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

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CIP/4701/12/09/814

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Figure A-2.5 ATQ-18

6. ATQ-22

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

March 02, 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: **ANTIQUE**
Station Name: **ATQ-22**
Order: **2nd**

Island: **VISAYAS**
Municipality: **BELISON**
Barangay: **CONCEPCION**
MSL Elevation:

PRS92 Coordinates

Latitude: **10° 49' 46.66618"** Longitude: **121° 58' 11.90221"** Ellipsoidal Hgt: **12.25000 m.**

WGS84 Coordinates

Latitude: **10° 49' 42.24271"** Longitude: **121° 58' 17.11770"** Ellipsoidal Hgt: **68.02200 m.**

PTM / PRS92 Coordinates

Northing: **1197676.056 m.** Easting: **387365.279 m.** Zone: **4**

UTM / PRS92 Coordinates

Northing: **1,197,256.85** Easting: **387,404.70** Zone: **51**

Location Description

ATQ-22

From San Jose, travel N to Belison for about 20 km. Station is located on top of the N edge of the NW draft on an irrigation canal, 60 m. NE to the nat'l. highway centerline, 120 m. N of the road going to the brgy. proper and about 300 m. E of Km. Post No. 110. Mark is the head of a 4 in. copper nail centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ATQ-22 2007 NAMRIA".

Requesting Party: **PHIL-LIDAR 1**
Purpose: **Reference**
OR Number: **8077754 I**
T.N.: **2015-0503**

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

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CIF/4701/12/09/814

Figure A-2.6 ATQ-22

7. ILO-71

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

June 15, 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: **ILOILO**
Station Name: **ILO-71**
Order: **2nd**

Island: **VISAYAS**
Municipality: **SAN RAFAEL**
Barangay: **POBLACION (SITIO ILOCO)**
MSL Elevation:

PRS92 Coordinates

Latitude:	**11° 10' 14.95277"**	Longitude:	**122° 49' 43.05170"**	Ellipsoidal Hgt:	**114.27700 m.**

WGS84 Coordinates

Latitude:	**11° 10' 10.51756"**	Longitude:	**122° 49' 48.23144"**	Ellipsoidal Hgt:	**171.35000 m.**

PTM / PRS92 Coordinates

Northing:	**1235227.808 m.**	Easting:	**481282.443 m.**	Zone:	**4**

UTM / PRS92 Coordinates

Northing:	**1,234,795.46**	Easting:	**481,289.00**	Zone:	**51**

Location Description

ILO-71
From the municipal hall, travel S about 800 m. passing the bridge with a 75 km. post/marker. It is located on the E side of the box culvert and about 10 m. E of no. 1179 transmission line post. Mark is the head of a 4 in. copper nail centered and embedded on a 30 cm. x 30 cm. cement putty, with inscriptions "ILO-71 2005 NAMRIA".

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8084005 I**
T.N.: **2015-1262**

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

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Figure A-2.7 ILO-71

8. ILO-85

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

April 10, 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: **ILOILO**
Station Name: **ILO-85**
Order: **2nd**

Island: **VISAYAS**
Municipality: **MIAG-AO**
Barangay: **UBOS ILAWOD (POB.)**

PRS92 Coordinates

Latitude: **10° 38' 33.11352"**	Longitude: **122° 14' 3.70560"**	Ellipsoidal Hgt: **21.96200 m.**

WGS84 Coordinates

Latitude: **10° 38' 28.75996"**	Longitude: **122° 14' 8.93597"**	Ellipsoidal Hgt: **78.82800 m.**

PTM Coordinates

Northing: **1176896.034 m.**	Easting: **416226.997 m.**	Zone: **4**

UTM Coordinates

Northing: **1,176,484.10**	Easting: **416,256.32**	Zone: **51**

Location Description

ILO-85
From Iloilo City, travel W for about 40 km. to the Mun. of Miag-ao. Then proceed directly to the Town Plaza, where the station is located. Station is located at the corner of a planting strip and sidewalk, about 14 m. fronting the Rizal monument. Mark is the head of a 4 in. copper nail set flushed on top of a 30 cm. x 30 cm. concrete monument protruding 20 cm. above the ground, with inscriptions "ILO-85 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-836**

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

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Figure A-2.8 ILO-85

9. NGW-87

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

May 09, 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: **NEGROS OCCIDENTAL**
Station Name: **NGW-87**
Order: **2nd**

Island: **VISAYAS**
Municipality: **LA CASTELLANA**
Barangay: **BALUCANAG**

PRS92 Coordinates

Latitude: **10° 20' 32.34942"**	Longitude: **123° 8' 53.05808"**	Ellipsoidal Hgt: **333.32600 m.**

WGS84 Coordinates

Latitude: **10° 20' 28.15138"**	Longitude: **123° 8' 58.30851"**	Ellipsoidal Hgt: **393.14800 m.**

PTM Coordinates

Northing: **1143593.27 m.**	Easting: **516216.608 m.**	Zone: **4**

UTM Coordinates

Northing: **1,143,192.99**	Easting: **516,210.93**	Zone: **51**

Location Description

NGW-87
The station is at the SE side of Moises Padilla-Canlaon road. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on top of the headwall with inscriptions "NGW-87; 2007; NAMRIA". The station is on the SE side of the road, NE of the wooden electric post.

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8796117 A**
T.N.: **2014-1071**

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

9905092014102451

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Figure A-2.9 NGW-87

10. IL-533

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

March 02, 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: **ILOILO**
Station Name: **IL-533**

Island: **PANAY**	Municipality: **SAN JOAQUIN**	Barangay: **AMBOYU-AN**
Elevation: **8.0971 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude: **10° 32' 45.00000"**	Longitude: **122° 4' 42.48000"**	

Location Description

BM IL-533
Station is located at the sidewalk of Ambuyuan bridge 0.30m. from thr edge. Mark is the head of a 4in. copper nail set flush on a cement putty with inscriptions " IL-533, 2007, NAMRIA."

Requesting Party:	**PHIL-LIDAR 1**
Purpose:	**Reference**
OR Number:	**8077754 I**
T.N.:	**2015-0505**

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

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Figure A-2.10 IL-533

Annex 3. Baseline Processing Reports

1. ILO-70 and BM-30

Vector Components (Mark to Mark)

From:	ILO-70				
Grid		Local		Global	
Easting	452601.273 m	Latitude	N11°13'50.08819"	Latitude	N11°13'45.61545"
Northing	1241432.381 m	Longitude	E122°33'56.83732"	Longitude	E122°34'02.01364"
Elevation	75.679 m	Height	76.803 m	Height	133.084 m

To:	BM-30				
Grid		Local		Global	
Easting	450652.540 m	Latitude	N11°15'52.92327"	Latitude	N11°15'48.44044"
Northing	1245208.031 m	Longitude	E122°32'52.37977"	Longitude	E122°32'57.55324"
Elevation	40.463 m	Height	41.592 m	Height	97.746 m

Vector					
ΔEasting	-1948.733 m	NS Fwd Azimuth	332°36'56"	ΔX	2062.745 m
ΔNorthing	3775.650 m	Ellipsoid Dist.	4250.470 m	ΔY	402.643 m
ΔElevation	-35.216 m	ΔHeight	-35.211 m	ΔZ	3694.725 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	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000092434		
Y	-0.0000126725	0.0000220221	
Z	-0.0000032947	0.0000051774	0.0000020031

Figure A-3.1 ILO-70 and BM-30

2. NW-192

Vector Components (Mark to Mark)

From:	NGW80				
Grid		Local		Global	
Easting	494036.064 m	Latitude	N10°29'35.86090"	Latitude	N10°29'31.60669"
Northing	1159881.542 m	Longitude	E122°56'43.79550"	Longitude	E122°56'49.03425"
Elevation	28.344 m	Height	30.720 m	Height	89.691 m

To:	NW192				
Grid		Local		Global	
Easting	483003.416 m	Latitude	N10°32'09.08721"	Latitude	N10°32'04.81345"
Northing	1164591.004 m	Longitude	E122°50'40.76204"	Longitude	E122°50'45.99776"
Elevation	5.181 m	Height	7.334 m	Height	65.957 m

Vector					
Δ Easting	-11032.647 m	NS Fwd Azimuth	293°06'22"	ΔX	9747.899 m
Δ Northing	4709.462 m	Ellipsoid Dist.	12000.542 m	ΔY	5254.606 m
Δ Elevation	-23.163 m	Δ Height	-23.385 m	ΔZ	4624.032 m

Standard Errors

Vector errors:					
σ Δ Easting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ Δ Northing	0.002 m	σ Ellipsoid Dist.	0.003 m	σ ΔY	0.008 m
σ Δ Elevation	0.010 m	σ Δ Height	0.010 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000330925		
Y	-0.0000405370	0.0000678199	
Z	-0.0000084194	0.0000139783	0.0000055557

Figure A-3.2 NW-192

3. IL-608

Vector Components (Mark to Mark)

From:	ILO-71				
Grid		Local		Global	
Easting	481288.995 m	Latitude	N11°10'14.95277"	Latitude	N11°10'10.51756"
Northing	1234795.456 m	Longitude	E122°49'43.05170"	Longitude	E122°49'48.23144"
Elevation	112.175 m	Height	114.277 m	Height	171.350 m

To:	IL-608				
Grid		Local		Global	
Easting	487357.226 m	Latitude	N11°11'55.75853"	Latitude	N11°11'51.32104"
Northing	1237888.520 m	Longitude	E122°53'03.09601"	Longitude	E122°53'08.27292"
Elevation	81.685 m	Height	83.941 m	Height	141.083 m

Vector					
ΔEasting	6068.231 m	NS Fwd Azimuth	62°57'29"	ΔX	-4756.148 m
ΔNorthing	3093.063 m	Ellipsoid Dist.	6813.760 m	ΔY	-3822.447 m
ΔElevation	-30.490 m	ΔHeight	-30.336 m	ΔZ	3032.745 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

Figure A-3.3 IL-608

Annex 4. The LiDAR Survey Team Composition

Table A-4.1 LiDAR Survey Team Composition

Data Acquisition Component Sub-team	Designation	Name	Agency/Affiliation
Data Acquisition Component Leader	Data Component Program Leader	ENRICO C. PARINGIT	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader -I	ENGR. CZAR JAKIRI S. SARMIENTO ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP TCAGP
LiDAR Operation	Senior Science Research Specialist	ENGR. GEROME HIPOLITO ENGR. IRO NIEL ROXAS ENGR. CHRISTOPHER JOAQUIN PAULINE JOANNE ARCEO	UP TCAGP
LiDAR Operation	Research Associate	MA. VERLINA TONGA JONALYN GONZALES KRISTINE ANDAYA	UP TCAGP
	Research Associate	REGINA FELISMINO MILLIE SHANE REYES MA. REMEDIOS VILLANUEVA	UP TCAGP
Ground Survey	Research Associate	LANCE CINCO ENGR. GEF SORIANO ENGR. KENNETH QUISADO SANDRA POBLETE	UP TCAGP
Data Download and Transfer	Senior Science Research Specialist	REGINA FELISMINO MILLIE SHANE REYES MA. REMEDIOS VILLANUEVA	UP TCAGP
LiDAR Operation	Airborne Security	SSG. LEE JAY PUNZALAN SSG. KRISTOFF LACANLALE	PILIPPINE AIR FORCE (PAF)
LiDAR Operation	Pilot	CAPT. BRYAN DONGUINES CAPT. JEFFREY ALAJAR CAPT. SHERWIN ALFONSO III CAPT. ALBERT LIM	ASIAN AEROSPACE CORPORATION (AAC)
LiDAR Operation	Co-Pilot	CAPT. JUSTINE HOYA CAPT. JERICO JECIEL CAPT. BRYAN DONGUINES CAPT. RANDY LAGCO	AAC

Annex 5. Data Transfer Sheets for Bago Floodplain

DATA TRANSFER SHEET
5/5/2014(Bacolod ~~Pending~~) Ready

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Apr 21, 2014	1371P	1BLK45DE110A	PEGASUS	1.83GB	300KB	7.87MB	165MB	43.7GB	336KB	16.9GB	N/A	14.8MB	103B	0B	53.3KB/48.8KB/ 39.9KB/53.3KB/	1.67KB	Z:\Airborne_Raw\1371P
Apr 21, 2014	1373P	1BLK45B110B	PEGASUS	1.93GB	1.42MB	7.76MB	149MB	23.2GB	221KB	17.2GB	N/A	14.8MB	103B	230B	39.9KB	1.67KB	Z:\Airborne_Raw\1373P
Apr 22, 2014	1375P	1BLK45B111A	PEGASUS	3.72GB	1.65MB	13.9MB	264MB	46.0GB	366KB	34.9GB	N/A	13.6MB	103B	527B	28.3KB/37.8KB/ 41.0KB	1.67KB	Z:\Airborne_Raw\1375P
Apr 22, 2014	1377P	1BLK45C111B	PEGASUS	1.73GB	1.06MB	7.10MB	154MB	17.5GB	4.19KB/ 164KB	15.6GB	N/A	13.6MB	103B	250B	3.44KB/49.6KB	1.67KB	Z:\Airborne_Raw\1377P
Apr 25, 2014	1387P	1BLK45AC114A	PEGASUS	2.59GB	672KB	13.2MB	275MB	44.2GB	350KB	27.3GB	N/A	7.15MB	103B	457B	73.5KB/62.3KB/ 57.8KB	1.67KB	Z:\Airborne_Raw\1387P
Apr 26, 2014	1391P	1BLK44CB115A	PEGASUS	3.40GB	1.51MB	12.6MB	257MB	52.0GB	159KB/ 168KB	30.7GB	N/A	12.3MB	152B	460B	51KB/48.8KB/7. 25KB/63.8KB/3.	2.01KB	Z:\Airborne_Raw\1391P
Apr 27, 2014	1393P	1BLK44AB115B	PEGASUS	2.92GB	2.91MB	13.3MB	264MB	45.0GB	356KB	30.6GB	N/A	12.3MB	152B	666B	51.3KB/49.1KB	2.01KB	Z:\Airborne_Raw\1393P

Received from

Name GRACE B. SINADJAN
Position RA
Signature

Received by

Name Benjamin Magallon
Position
Signature
5/26/2014

Figure A-5.1 Data Transfer Sheet for Bago Floodplain - A

DATA TRANSFER SHEET
5/19/2014(Bacolod Ready)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
4/29/2014	1403P	1BLK44DE119A	PEGASUS	2.89GB	2078KB	13.3	550	54.5	431	57.1	NA	7.14MB	1KB	1KB	92/75/52/56	NA	Z:\Airborne_Raw\1403P
5/1/2014	1411P	1BLK44D121A	PEGASUS	NA	88KB	10.9	221	31.5	264	26.5	NA	6.74MB	1KB	1KB	82/69/56	NA	Z:\Airborne_Raw\1411P
5/2/2014	1415P	1BLK44H122A	PEGASUS	3.27GB	2121KB	14.1	266	40.3	346	32.8	NA	7.32MB	1KB	1KB	37/38/46	NA	Z:\Airborne_Raw\1415P
5/5/2014	1427P	1BLK45E125A	PEGASUS	2.73GB	661KB	10.6	219	NA	NA	25.7	NA	6.12	1KB	1KB	30.9	NA	Z:\Airborne_Raw\1427P
5/6/2014	1431P	1BLK44GHS126A	PEGASUS	3.11	1612KB	13	254	51.3	370	29.2	NA	14.4	1KB	1KB	144/137/110	NA	Z:\Airborne_Raw\1431P
5/6/2014	1433P	1BLK44FGS126B	PEGASUS	3.04	1652	12.8	271	59	495	27.8	NA	14.4	1KB	1KB	144/137/110	NA	Z:\Airborne_Raw\1433P
5/7/2014	1435P	1BLK44DS127A	PEGASUS	2.94	712	14	285	NA	NA	19.6	NA	7.14	1KB	1KB	114	NA	Z:\Airborne_Raw\1435P
5/10/2014	1447P	1BLK45FG130A	PEGASUS	3.45	1382	14.4	294	NA	NA	32.3	NA	6.21	1KB	1KB	43	NA	Z:\Airborne_Raw\1447P
5/11/2014	1451P	1BLK45S132A	PEGASUS	2.42	500	11.5	243	NA	NA	27.2	NA	11.4	1KB	1KB	53	NA	Z:\Airborne_Raw\1451P
5/11/2014	1453P	1BLK45DFGS133A	PEGASUS	1.8	581	7.34	170	21.5	171	16.6	NA	11.4	1KB	1KB	49.3	NA	Z:\Airborne_Raw\1453P
5/12/2014	1455P	1IHLS134A	PEGASUS	3.05	530	13.2	298	NA	NA	26.3	NA	8.9	1KB	1KB	81/82/33/23	NA	Z:\Airborne_Raw\1455P
5/13/2014	1459P	1IHLS136A	PEGASUS	3.23	577	14.6	287	NA	NA	31.1	NA	7.18	1KB	1KB	88	NA	Z:\Airborne_Raw\1459P
5/14/2014	1463P	1IHLX137A	PEGASUS	782MB	249	5.69	148	NA	NA	8.26	NA	6.42	1KB	1KB	119	NA	Z:\Airborne_Raw\1463P

Received from

Name C - Joaquin
Position RA
Signature

Received by

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

Figure A-5.2 Data Transfer Sheet for Bago Floodplain - B

DATA TRANSFER SHEET
6/02/2014(Bacolod additional)

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	
5/12/2014	1455P	1BLK45S132A	PEGASUS	3.05	530	13.2	298	NA	NA	26.3	NA	8.9	1KB	1KB	82	na	Z:\Airborne_Raw\1455P
5/13/2014	1459P	1BLK45DFGS133A	PEGASUS	3.23	577	14.6	287	NA	NA	31.1	NA	7.18	1KB	1KB	88	na	Z:\Airborne_Raw\1459P
5/14/2014	1463P	1IHLS134A	PEGASUS	782	249	5.69	148	NA	NA	8.26	NA	6.42	1KB	1KB	119	na	Z:\Airborne_Raw\1463P
5/16/2014	1471P	1IHLS136A	PEGASUS	2.58	na	11.7	253	49.2	340	24.6	NA	12.4	1KB	1KB	129	na	Z:\Airborne_Raw\1471P
5/17/2014	1475P	1IHLX137A	PEGASUS	2.63	na	11	273	NA	NA	24.2	NA	9.91	1KB	1KB	39	na	Z:\Airborne_Raw\1475P

Received from

Name C. JOAQUIN
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 6/2/2014

Figure A-5.3 Data Transfer Sheet for Bago Floodplain - C

DATA TRANSFER SHEET
BACOLOD 5/18/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
April 22,2016	8453AC	3BLK44AS113A	AQUA/CASI	NA	343	769	246	NA	NA	13.9	101	99.1	1KB	1KB	6	14	Z:\DAC\RAW DATA
April 23,2016	8455AC	3BLK44AS114A	AQUA/CASI	NA	247	663	233	38.5	43	10.2	85.3	91	1KB	1KB	20	30	Z:\DAC\RAW DATA
April 24,2016	8457AC	3BLK44EDS115A	AQUA/CASI	NA	197	544	222	39.6	221	8.64	66.9	94	1KB	1KB	40	22	Z:\DAC\RAW DATA
April 25,2016	8459AC	3BLK44IJS116A	AQUA/CASI	NA	240	603	262	43.4	248	10.3	66.5	100	1KB	1KB	18	38	Z:\DAC\RAW DATA
April 26,2016	8462AC	3BLK46AS117B	AQUA/CASI	NA	194	502	229	37.4	187	8.59	67.4	107	1KB	1KB	8	20	Z:\DAC\RAW DATA
April 27,2016	8464AC	3BLK46AS118B	AQUA/CASI	NA	81	209	143	9.78	3.23	4	23.9	158	1KB	1KB	8	20	Z:\DAC\RAW DATA
May 1,2016	8471AC	3BLK44FGHS122A	AQUA/CASI	NA	191	541	241	45.3	263	8.33	139	90.5	1KB	1KB	10	22	Z:\DAC\RAW DATA
May 2,2016	8473AC	3BLK46AS123A	AQUA/CASI	NA	88	320	206	5.45	3.7	4.59	55.3	64.6	1KB	NA	16	22	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

Received by

Name AC Bongat
Position SSRS
Signature ACBongat 5/20/16

Figure A-5.4 Data Transfer Sheet for Bago Floodplain - D

DATA TRANSFER SHEET
7/3/2014(Iloilo)

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	
25-Feb-15	2602G	2BLK43B056A	GEMINI	NA	278	402	167	8.44	61	5.95	NA	9.49	1KB	1KB	12	17	Z:\DAC\RAW DATA
26-Feb-15	2606G	2BLK43BV057A	GEMINI	NA	739	932	208	22.5	92	12.6	NA	9.26	1KB	1KB	12	18	Z:\DAC\RAW DATA
27-Feb-15	2610G	2BLK43BV058A	GEMINI	NA	100	190	173	2.88	25	2.95	NA	8.94	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
5-Mar-15	2634G	2BLK37FV064A	GEMINI	NA	298	532	170	14.6	122	5.2	NA	22.7	1KB	1KB	8	13	Z:\DAC\RAW DATA
5-Mar-15	2636G	2BLK43OS064B	GEMINI	NA	468	770	205	23.2	105	5.05	NA	22.7	1KB	1KB	8	18	Z:\DAC\RAW DATA
6-Mar-15	2638G	2BLK43OS065A	GEMINI	NA	581	894	234	27.5	190	12.5	NA	20.1	1KB	1KB	13	21	Z:\DAC\RAW DATA
25-Feb-15	2613P	1BLK37IFV056A	PEGASUS	1.94	652	6.14	151	17.6	134	10	NA	16.6	1KB	1KB	101/76	NA	Z:\DAC\RAW DATA
26-Feb-15	2617P	1BLK37OP057A	PEGASUS	7.28	2.14	12.3	260	55.2	457	34.5	NA	18.7	1KB	1KB	196	NA	Z:\DAC\RAW DATA
27-Feb-15	2621P	1BLK37P058A	PEGASUS	3.11	1.93	12.8	245	48.1	414	27.3	NA	15.5	1KB	1KB	160	NA	Z:\DAC\RAW DATA
3-Mar-15	2637P	1BLK43NO062A	PEGASUS	1.82	1.15	9.81	245	32.8	237	18.3	NA	10.7	1KB	1KB	21/107	NA	Z:\DAC\RAW DATA
3-Mar-15	2639P	1BLK37M062B	PEGASUS	858	510	4.92	114	9.94	89	8.09	1.65	10.7	1KB	1KB	172	NA	Z:\DAC\RAW DATA
5-Mar-15	2645P	1BLK37Q064A	PEGASUS	2.74	.99	10.1	263	35.8	264	18.3	53.5	22.7	1KB	1KB	185/188	NA	Z:\DAC\RAW DATA
5-Mar-15	2647P	1BLK37MQ064B	PEGASUS	NA	1.16	9.62	235	71.5	4	17.8	NA	22.7	1KB	1KB	238/154	NA	Z:\DAC\RAW DATA
6-Mar-15	2649P	1BLK37Q065A	PEGASUS	582	505	5.92	202	15.1	105	7.9	50.4	20.1	1KB	1KB	231/210	NA	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position
Signature

Received by

Name Angelo Carlo Bongat
Position SSRS
Signature

Figure A-5.5 Data Transfer Sheet for Bago Floodplain - E

DATA TRANSFER SHEET
03/23/2015(bdb-peg)

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	
14-Feb-15	2569P	1BLK43DO45A	pegasus	1.28	840	6.06	196	10.5	38/48	14.4	na	10.5	1KB	1KB	76	na	Z:\DAC\RAW DATA
16-Feb-15	2579P	1BLK43MO47B	pegasus	1.77	1.21	10.4	221	28.4	251	19.1	na	12.2	1KB	1KB	77/18	na	Z:\DAC\RAW DATA
17-Feb-15	2581P	1BLK43MN048A	pegasus	2.06	1.35	9.99	253	34.3	265	21.4	na	20.2	1KB	1KB	76/77/21	na	Z:\DAC\RAW DATA
17-Feb-15	2583P	1BLK43DO48B	pegasus	1.11	719	6.06	170	14	137	11.4	na	20.2	1KB	1KB	86/70	na	Z:\DAC\RAW DATA
18-Feb-15	2585P	1BLK43EF049A	pegasus	2.91	1.71	9.97	263	42	314	27.8	na	14.3	1KB	1KB	89/117	na	Z:\DAC\RAW DATA
18-Feb-15	2587P	1BLK43ED049B	pegasus	1.7	1.02	9.05	190	19.9	90/71	17.4	na	7.46	1KB	1KB	1/607/77	na	Z:\DAC\RAW DATA
19-Feb-15	2589P	1BLK43EFD050A	pegasus	1.2	739	7.78	417	17.3	139	13.3	na	16.7	1KB	1KB	86/77/620/92 1	na	Z:\DAC\RAW DATA
19-Feb-15	2591P	1BLK37I050B	pegasus	5.53	1.62	9.47	199	49.9	343	25.3	na	9.75	1KB	1KB	64	na	Z:\DAC\RAW DATA
20-Feb-15	2593P	1BLK43BDG051A	pegasus	3.14	1.81	7.62	213	27	218	16.3	na	11	1KB	1KB	114	na	Z:\DAC\RAW DATA
21-Feb-15	2597P	1BLK43N052A	pegasus	2.09	1.29	9.69	257	37.9	274	21	na	11.5	1KB	1KB	32	na	Z:\DAC\RAW DATA
22-Feb-15	2601P	1BLK37IFV053A	pegasus	2.13	1.27	9.06	225	32.2	258	20.7	na	17.7	1KB	1KB	101/76	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin II
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature

3/23/2015

Figure A-5.6 Data Transfer Sheet for Bago Floodplain - F

DATA TRANSFER SHEET
02/16/2015(ILOILO)

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-Feb-15	2522G	2BLK43LK036A	GEMINI	NA	1027	1.58	268	46.2	730/184	25.4	NA	7	1KB	1KB	5	14	Z:\DAC\RAW DATA
6-Feb-15	2526G	2BLK43OKSV037A	GEMINI	NA	1906	1.56	256	37.7	135/143	22	4.45	15	1KB	1KB	9	20	Z:\DAC\RAW DATA
6-Feb-15	2528G	2BLK43KSJ037B	GEMINI	NA	1004	1.47	244	35.7	9.61/	21.6	4.45	15	1KB	1KB	9	20	Z:\DAC\RAW DATA
7-Feb-15	2530G	2BLK43OSIS038A	GEMINI	NA	1187	1.8	266	43.4	312	25.2	5.4	19.1	1KB	1KB	6	16	Z:\DAC\RAW DATA
7-Feb-15	2532G	2BLK43IV038B	GEMINI	NA	1003	1.46	218	38	424/304	20.8	4.42	19.1	1KB	1KB	8	16	Z:\DAC\RAW DATA

Received from

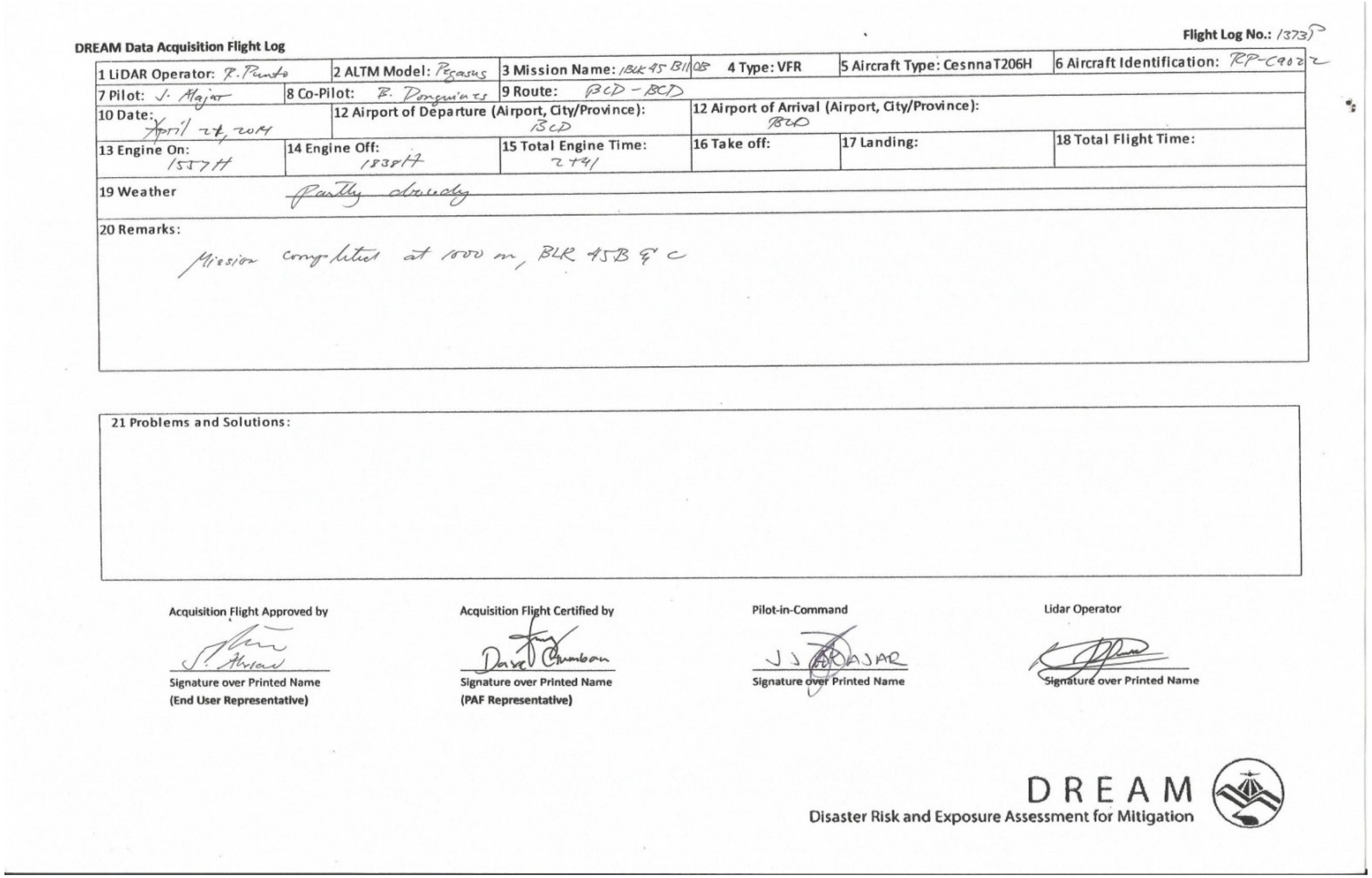
Name C.JOAQUIN
Position
Signature

Received by

Name AC Bongat 2/17/15
Position SSRS
Signature

Figure A-5.7 Data Transfer Sheet for Bago Floodplain - G

Annex 6. Flight Logs



DREAM Data Acquisition Flight Log

Flight Log No.: 1373P

1 LiDAR Operator: R. Punto	2 ALTM Model: Pegasus	3 Mission Name: 1BLK45B110B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Donguines	9 Route: BCD - BCD			
10 Date: April 27, 2014	12 Airport of Departure (Airport, City/Province): BCD		12 Airport of Arrival (Airport, City/Province): BCD		
13 Engine On: 1557H	14 Engine Off: 1838H	15 Total Engine Time: 2+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Partly cloudy				

20 Remarks:

Mission completed at 1000 m, BLK 45B & C

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	Dave Chamban	J J ALAJAR	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.1 Flight Log for Mission 1373P

DREAM Data Acquisition Flight Log

Flight Log No.: 1375P

1 LiDAR Operator: J. Abrar	2 ALTM Model: Peg	3 Mission Name: 1BLK45B111A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Penguines	9 Route: BCD - BCD			
10 Date: April 22, 2014	12 Airport of Departure (Airport, City/Province): BCD		12 Airport of Arrival (Airport, City/Province): BCD		
13 Engine On: 1025H	14 Engine Off: 1448	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					
20 Remarks: Mission successful					

21 Problems and Solutions:

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

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

Pilot-in-Command
JJ ALAJAR
Signature over Printed Name

Lidar Operator
Jasmine Alviar
Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.2 Flight Log for Mission 1375P

Flight Log No.: 1377P

DREAM Data Acquisition Flight Log

1 LiDAR Operator: R. Punto	2 ALTM Model: Pegasus	3 Mission Name: 1BLK45C111B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Dongulfes	9 Route:			
10 Date: April 22, 2014	12 Airport of Departure (Airport, City/Province): BCD		12 Airport of Arrival (Airport, City/Province): BCD		
13 Engine On: 15+52	14 Engine Off: 18+39	15 Total Engine Time: 2+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	partly cloudy				
20 Remarks:	Mission successful				

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	Dave Gumban	JJ Alajar	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.3 Flight Log for Mission 1377P

Flight Log No.: 1387P

DREAM Data Acquisition Flight Log

1 LiDAR Operator: R. Punto	2 ALTM Model: Pegasus	3 Mission Name: 1BLK45AC114A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Donguines	9 Route: Bacolod			
10 Date: April 25, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 0753H	14 Engine Off: 1222H	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Data acquired in BLK 44A but with voids due to clouds; data acquired in BLK 44C but lacks 1 line for overlap

21 Problems and Solutions:

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.4 Flight Log for Mission 1387P

DREAM Data Acquisition Flight Log

Flight Log No.: 1453P

1 LiDAR Operator: D. ALDOVINO	2 ALTM Model: PEGASUS	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. ALAJAR	8 Co-Pilot: B. DONGUINES	9 Route: NEGROS OCC.			
10 Date: MAY 11, 2014	12 Airport of Departure (Airport, City/Province): BACOLOD		12 Airport of Arrival (Airport, City/Province): BACOLOD		
13 Engine On: 15+40	14 Engine Off: 18+39	15 Total Engine Time: 2+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					
20 Remarks: Mission successful					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	Dave Dumban	J. ALAJAR	DAN ALDOVINO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.5 Flight Log for Mission 1453P

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2526

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK430KSV037A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: Iloilo			
10 Date: 6 FEB 15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province): Iloilo		
13 Engine On: 7:58	14 Engine Off: 12:21	15 Total Engine Time: 4+23	16 Take off: 8:03	17 Landing: 12:16	18 Total Flight Time: 4+13
19 Weather: Fair					

20 Remarks:

Surveyed five lines of BLK 43O and remaining voids of 43K

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
C. Alparto	LV Pumalan	FOW: J. Bisson	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.6 Flight Log for Mission 2526G

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2536

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK43OSJSO38A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajor	8 Co-Pilot: A. Lim	9 Route: iloilo			
10 Date: 7 Feb 2015	12 Airport of Departure (Airport, City/Province): iloilo		12 Airport of Arrival (Airport, City/Province): iloilo		
13 Engine On: 8:00	14 Engine Off: 12:29	15 Total Engine Time: 4+29	16 Take off: 08:05	17 Landing: 12:24	18 Total Flight Time: 4+19
19 Weather: fair					
20 Remarks: Mission completed for both blocks.					

21 Problems and Solutions:

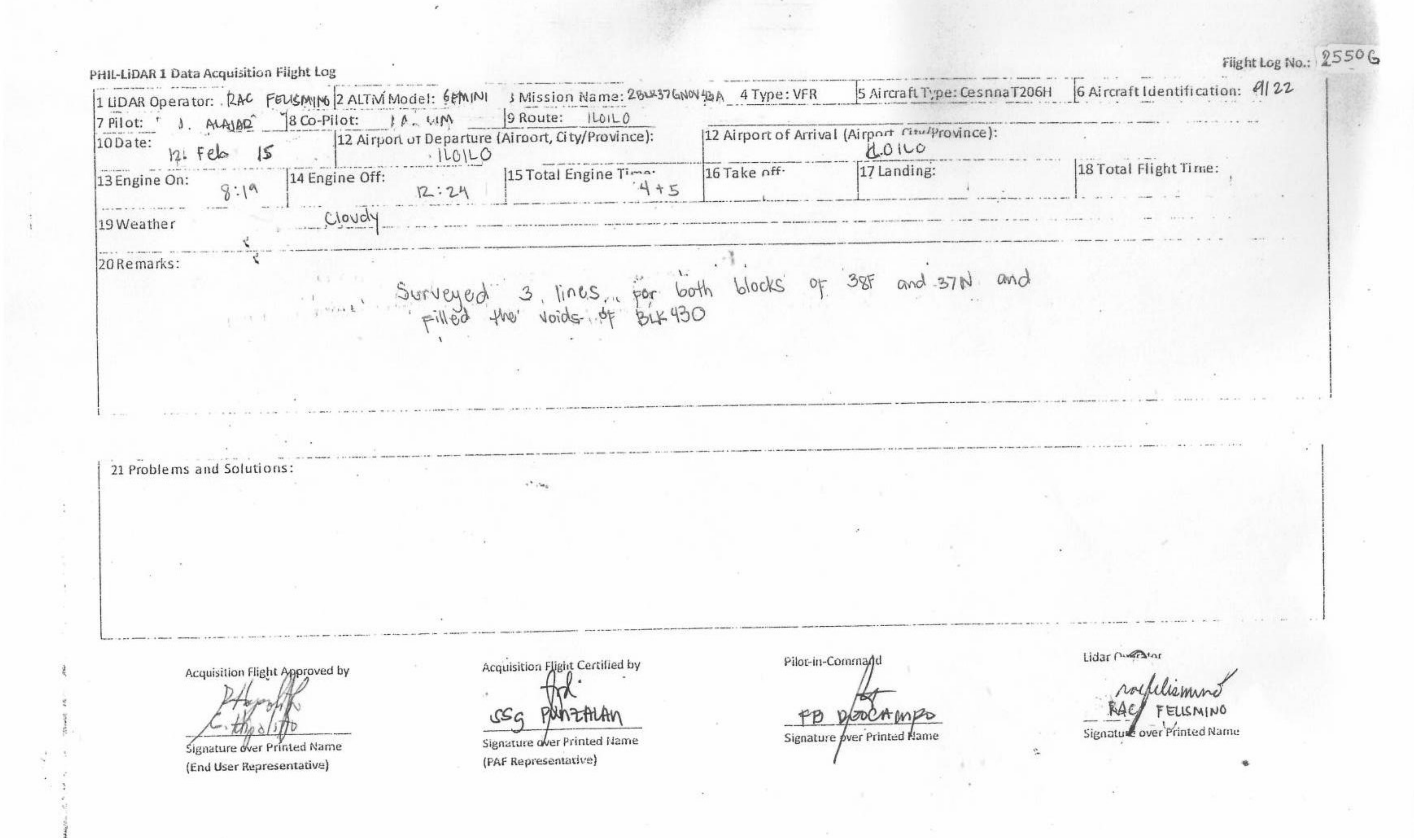
Acquisition Flight Approved by
G. HIPOLITO
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
For: J. ALAJOR
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.7 Flight Log for Mission 2530G


PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2550G

1 LiDAR Operator: RAC FELISMINO	2 ALTM Model: GEMINI	3 Mission Name: 2BLK37GNOV43A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. ALAJAR	8 Co-Pilot: A. LIM	9 Route: ILOILO			
10 Date: 12 Feb 15	12 Airport of Departure (Airport, City/Province): ILOILO		12 Airport of Arrival (Airport, City/Province): ILOILO		
13 Engine On: 8:19	14 Engine Off: 12:24	15 Total Engine Time: 4+5	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather: Cloudy

20 Remarks:

Surveyed 3 lines for both blocks of 38F and 37N and filled the voids of BLK430

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
C. Hipolito	SSG PANZALAN	FB DEOCAMPO	RAC FELISMINO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.8 Flight Log for Mission 2550G

Flight Log No.: 2558

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: RA FELISMINO	2 ALTM Model: Gemini	3 Mission Name: 2BLK43DSN 045A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot:	8 Co-Pilot:	9 Route: Iloilo			
10 Date: 14 FEB 15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province): Iloilo		
13 Engine On: 8:54	14 Engine Off: 13:05	15 Total Engine Time: 4+11	16 Take off: 8:59	17 Landing: 13:00	18 Total Flight Time: 4+01

19 Weather: Cloudy

20 Remarks:

Completed test of BLK43D and covered ks of BLK43N

21 Problems and Solutions:

Acquisition Flight Approved by
G. Hipolito
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
FOR: S. Dizon
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.9 Flight Log for Mission 2558G

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2579

1 LiDAR Operator: KJ Andaya	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43M047B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 02-16-2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1428	14 Engine Off: 1815	15 Total Engine Time: 3+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	cloudy				
20 Remarks: Surveyed over BLK 43M.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
S. Hipolito	LJ Pamzalan	C. Alfonso III	K. Andaya
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.10 Flight Log for Mission 2579P

DREAM Data Acquisition Flight Log

Flight Log No.: 2581P

1 LiDAR Operator: I. ROXAS	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK43MN048A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. ALAJAR	8 Co-Pilot: J. JOYA	9 Route: ILOILO			
10 Date: 17 FEB 2015	12 Airport of Departure (Airport, City/Province): ILOILO		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 4+38	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	CLOUDY				

20 Remarks:

Successful flight ; Put on hold by tower.

21 Problems and Solutions:

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

Figure A-6.11 Flight Log for Mission 2581P

Flight Log No.: 2597

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: MR Villanueva	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43N052A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 02 - 21 - 2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0901	14 Engine Off: 1306	15 Total Engine Time: 4+5	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	fair				
20 Remarks: Surveyed BLK 43N.					
21 Problems and Solutions:					

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
C. Hipolito	LJ Punzalan	C. Alfonso III	MR Villanueva
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.12 Flight Log for Mission 2597P

Flight Log No.: 2636G

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK430S064B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: ILOILO			
10 Date: 5 Mar 15	12 Airport of Departure (Airport, City/Province): ILOILO		12 Airport of Arrival (Airport, City/Province): ILOILO		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					

20 Remarks:

Surveyed lines of Guimaras at 33PRF and high percentage of DO

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
C. Hipolito	SSG PANTALAN	PB DEOCAMPO	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.13 Flight Log for Mission 2636G

Flight Log No.: 2637 P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: MR Villanueva	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43N0062A	Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 03 - 03 - 15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 3 + 50	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks:

Surveyed vads over BLK 43 M and N ; Performed calibration

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

L. Panganiban

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

C. Alfonso III

Signature over Printed Name

Lidar Operator

MR Villanueva

Signature over Printed Name

Figure A-6.14 Flight Log for Mission 2637P

Flight Log No.: 2638G

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK43OS065A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: ILOILO			
10 Date: 11 Feb 15	12 Airport of Departure (Airport, City/Province): ILOILO		12 Airport of Arrival (Airport, City/Province): ILOILO		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 3+14	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					
20 Remarks: Surveyed islands of Guimaras; laser is worked fine.					
21 Problems and Solutions:					

Acquisition Flight Approved by
C. Hipolito
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
FB Docampo
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.15 Flight Log for Mission 2638G

Flight Log No.: 8473

DREAM Program's Data Acquisition Flight Log

1 LIDAR Operator: J. Gonzales	2 ALTM Model: Aqua +CAST	3 Mission Name: 3BLK46AS123A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: R. Lagco	8 Co-Pilot: J. Jeciel	9 Route:			
10 Date: May 21, 2016		12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod	
13 Engine On: 0915	14 Engine Off: 1256	15 Total Engine Time: 3+41	16 Take off: 09:20	17 Landing: 1251	18 Total Flight Time: 3+31
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Covered voids over BLK46As

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
CHRIS SORIANO	LEE JAY R. PUNZALAN	RAMON B. LAGCO	JONALYN GONZALES	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.16 Flight Log for Mission 8473AC

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 8513 AC

1 LiDAR Operator: RAC FELISMINO	2 ALTM Model: AQUARIUS + CAS1	3 Mission Name: 3BLK43D300A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: D. LOGRONIO	8 Co-Pilot: J. NASTOR	9 Route: GUIMARAS			
10 Date: OCT. 26, 2016	12 Airport of Departure (Airport, City/Province): ILOILO CITY		12 Airport of Arrival (Airport, City/Province): ILOILO CITY		
13 Engine On: 09 26	14 Engine Off: 13 25	15 Total Engine Time: 3+59	16 Take off: 09 31	17 Landing: 13 20	18 Total Flight Time: 3 + 49
19 Weather: WINDY					

20 Flight Classification

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

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

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

21 Remarks

COVERED VOIDS ABOVE GUIMARAS ISLAND

22 Problems and Solutions

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LIDAR Technician
I. ROXAS	TSg Antonio T Valenzuela Jr PAF	D ANTHONY LOGRONIO	RAC FELISMINO	-
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.17 Flight Log for Mission 8513AC

Data Acquisition Flight Log — **Flight Log No.:** 10007P

1 LiDAR Operator: K Gonzales G MC Reyes	2 ALTM Model: Pegasus	3 Mission Name: LMC Calib 275A BLK 44	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9522
7 Pilot: Alfonso III	8 Co-Pilot: Loquo	9 Route:			
10 Date: Oct. 2, 2015	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 11:58	14 Engine Off: 1621	15 Total Engine Time: 4+23	16 Take off: 1203	17 Landing: 1616	18 Total Flight Time: 4+13
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Mission successful; Undergoed LMC and Camera Calibration and Surveyed BLK 44

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Pauline Arceo	Kristof Lacanlale	C. Alfonso III	Jonalyn S. Gonzales	Japhet T. Vivero
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.18 Flight Log for Mission 10007P

Annex 7. Flight Status

Table A-7.1 Flight Status Report

FLIGHT STATUS REPORT BAGO (April to May 2014 and 2016)					
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1373P	BLK45 C	1BLK45B110B	R. Punto	Apr 21	Mission successful at 1000m, surveyed BLK 45B and C areas
1375P	BLK 45BA	1BLK45B111A	J. Alviar	Apr 22	Mission completed at 1200m, surveyed BLK 45B and parts of BLK 45A
1377P	BLK 45C	1BLK45C111B	R. Punto	Apr 22	Mission successful at 1200m, surveyed BLK 45C
1387P	BLK 45AC	1BLK45AC114A	R. Punto	Apr 25	Data acquired in BLK 45A first at 1200m but lowered to 750m due to low ceiling; with voids due to clouds; data acquired in BLK 45C at 900m but has gaps due to overlap
1453P	BLK 46A	1BLK46AS131B	D. Aldovino	May 11	Surveyed remaining half of BLK 46A
1455P	BLK 45ACD	1BLK45S132A	J. Alviar	May 12	Mission completed at 1200m; filled gaps in BLK 45ACD
2526G	BLK 43K, 43O & 43L	2BLK43OKS-V037A	MVE TONGA & RA FELIS-MINO	06 FEB 15	Surveyed five (5) lines of BLK43O, two lines of BLK43K and voids of BLK43L
2530G	BLK 43J & 43O	2BLK43OSJS038A	MVE TONGA & RA FELIS-MINO	07 FEB 15	Mission completed for both blocks
2550G	BLK 43G, 43N, 43O	2BLK37GNO-V43A	RA FELIS-MINO	12 FEB 15	Surveyed 3 lines for BLK37F & 37N, filled voids of 43O
2558G	BLK 43G	2BLK43G045A	RA FELIS-MINO	14 FEB 15	2 lines in BLK43N, with voids
2579P	BLK 43M	1BLK43M047B	KJ AN-DAYA	16 FEB 15	Put on hold by tower during traffic
2581P	BLK 43M, 43N	1BLK43MN048A	IRO ROXAS	17 FEB 15	Put on hold by tower during traffic

2597P	BLK 43N	1BLK43N052A	MR VIL-LANUE-VA	21 FEB 15	Surveyed BLK 43N
2636G	BLK 43O & islands	2BLK43OS064B	MVE TONGA	05 MAR 15	Surveyed islands of Guimaras at 33PRF and high percentage of DO
2637P	BLK 43N, 43O	1BLK43NO062A	MR VIL-LANUE-VA	03 MAR 15	Performed calibration and covered voids over BLK 43MN
2638G	BLK 43O & islands	2BLK43OS065A	MVE TONGA	06 MAR 15	Surveyed islands of Guimaras; laser is worked fine
8473AC	BLK46AS	3BLK46AS123A			
8513AC	BLK43L	3BLK43L300A	RA FELISMINO	3BLK43D300A	BLK43D
10007P	BLK45	1BLK44LMSCALI-B275A	JS GONZALES & MS REYES	03-Oct-15	Mission successful; Conducted LMS and Camera Calibration and Surveyed

LAS Boundaries per Mission Flight

Flight No. : 1371P

Area: BLK 45D

Mission Name: 1BLK45DE110A

Area Surveyed: 2 00.55 sq.km.

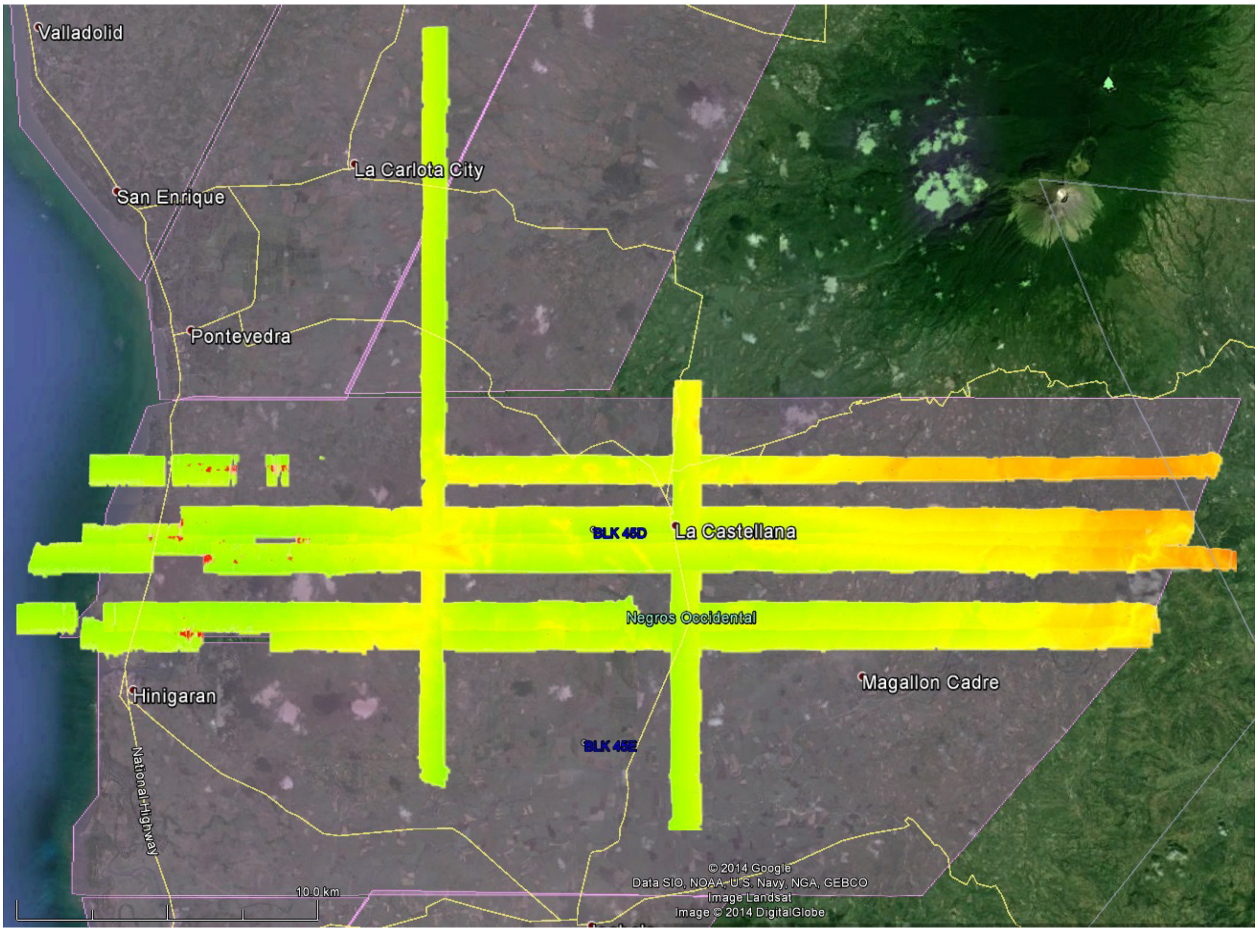


Figure A-7.1 Swath for Flight No. 1371P

Flight No. : 1411P

Area: BLK 44DE

Mission Name: 1BLK44D121A

Area Surveyed: 356.01 sq.km.

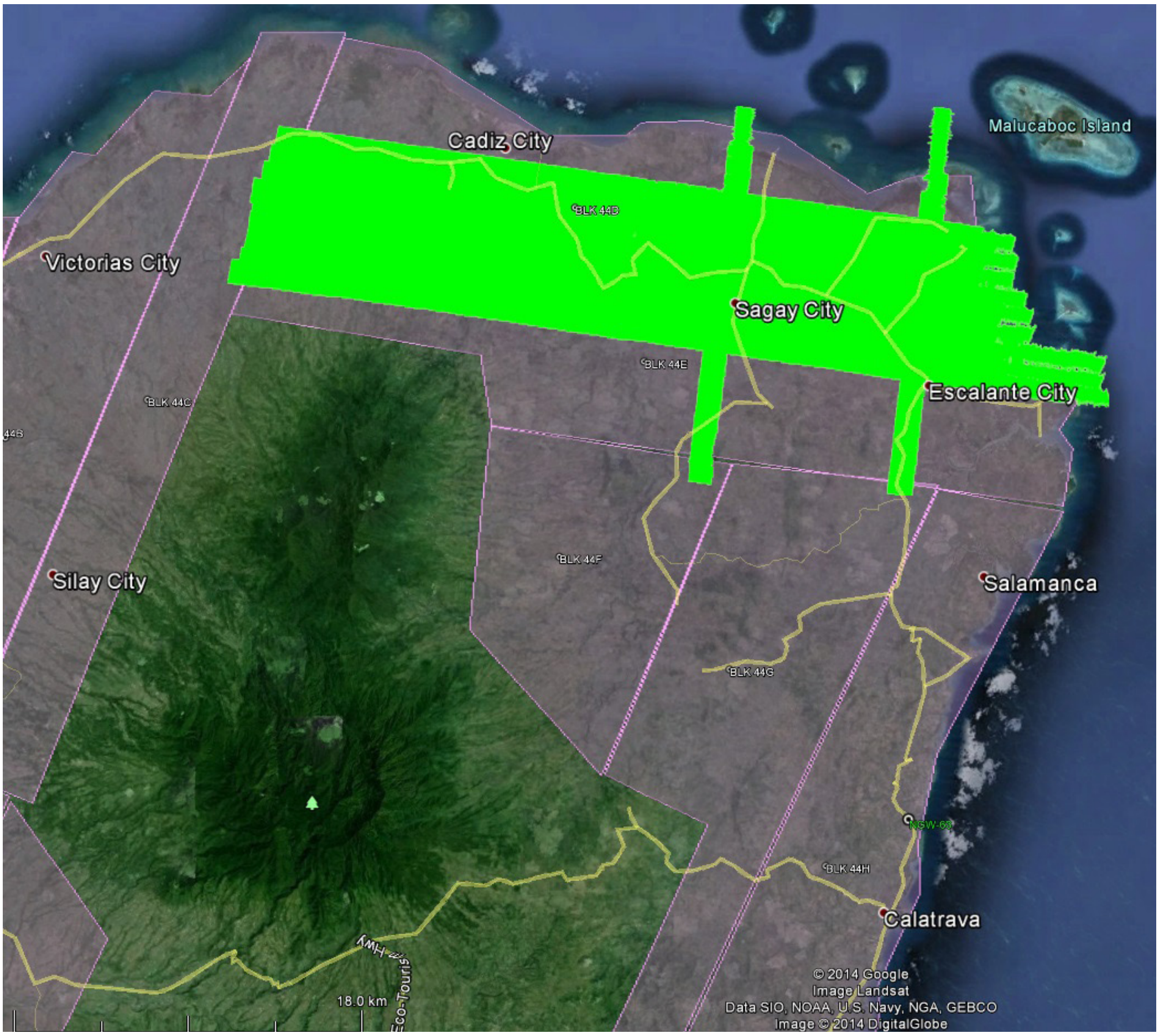


Figure A-7.2 Swath for Flight No. 1411P

Flight No. : 1427P

Area: BLK 45E

Mission Name: 1BLK44E125A

Area Surveyed: 316.84 sq.km

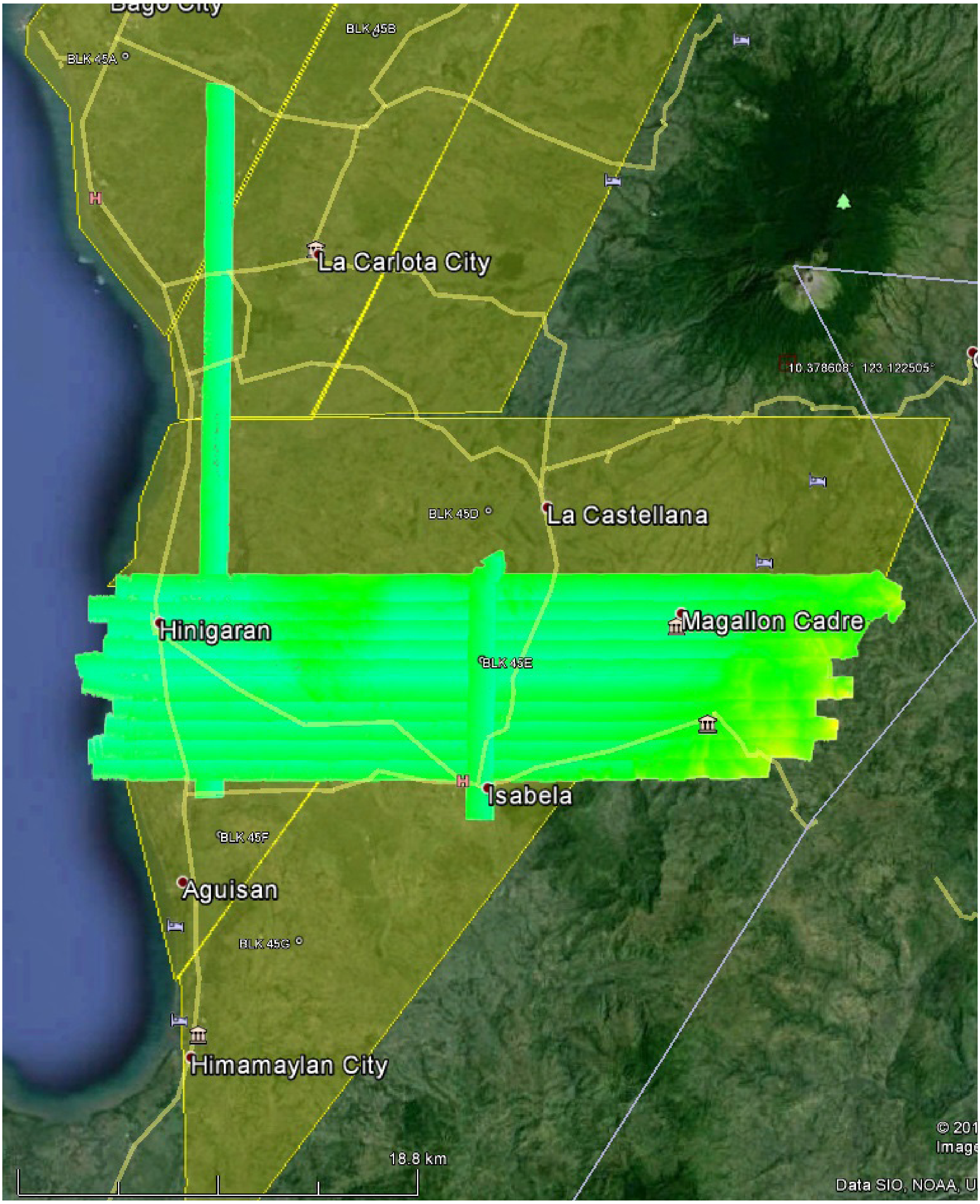


Figure A-7.3 Swath for Flight No. 1427P

Flight No. : 1435P

Area: BLK 44D, 44E, 44F, 44G

Mission Name: 1BLK44DS127A

Area Surveyed: 139.55 sq.km new area; 131.307 gap filling

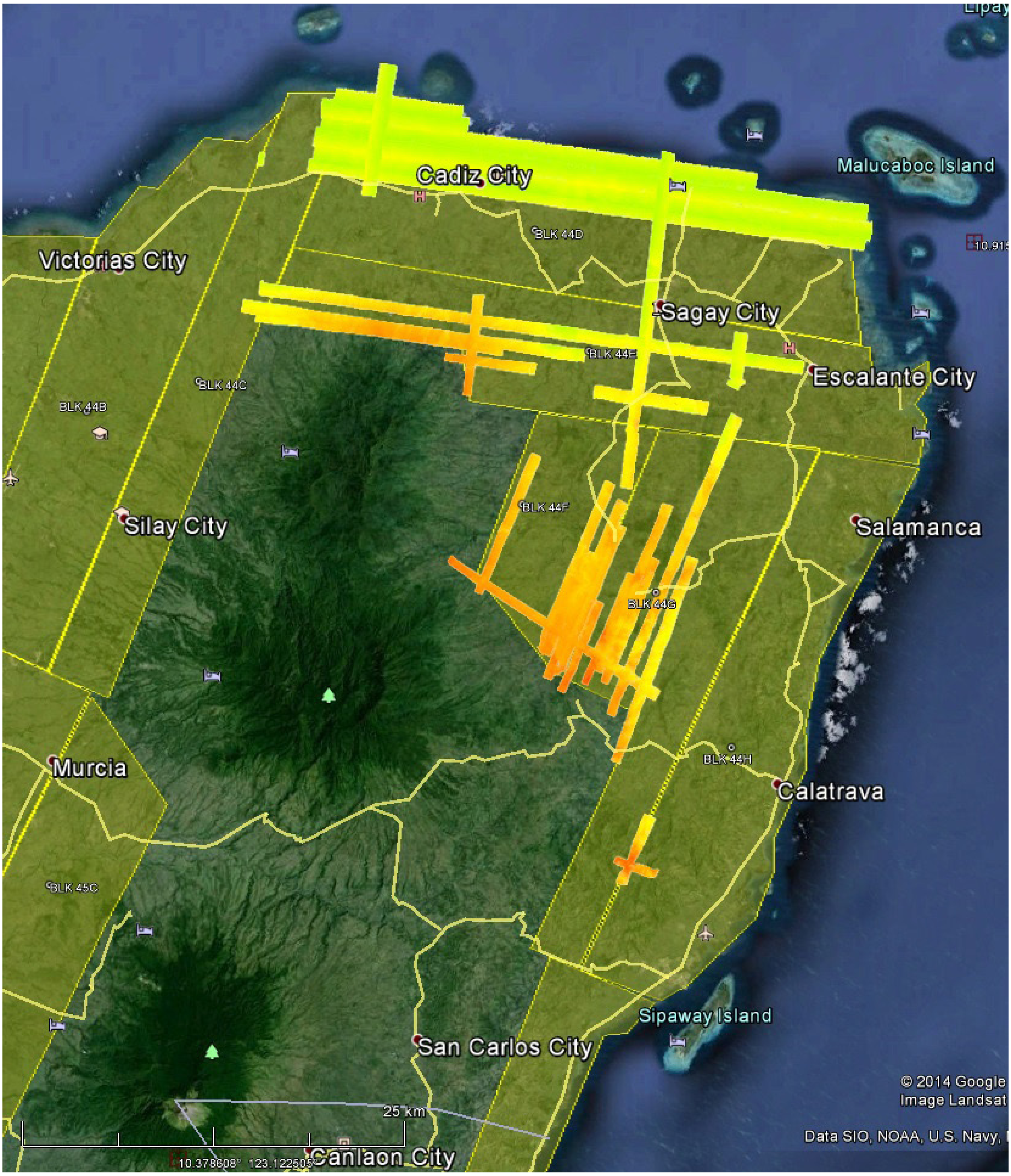


Figure A-7.4 Swath for Flight No. 1435P

Flight No. :	1447P
Area:	BLK 45F, 45G
Mission Name:	1BLK45FG130A
Area Surveyed:	296.4 sq.km.

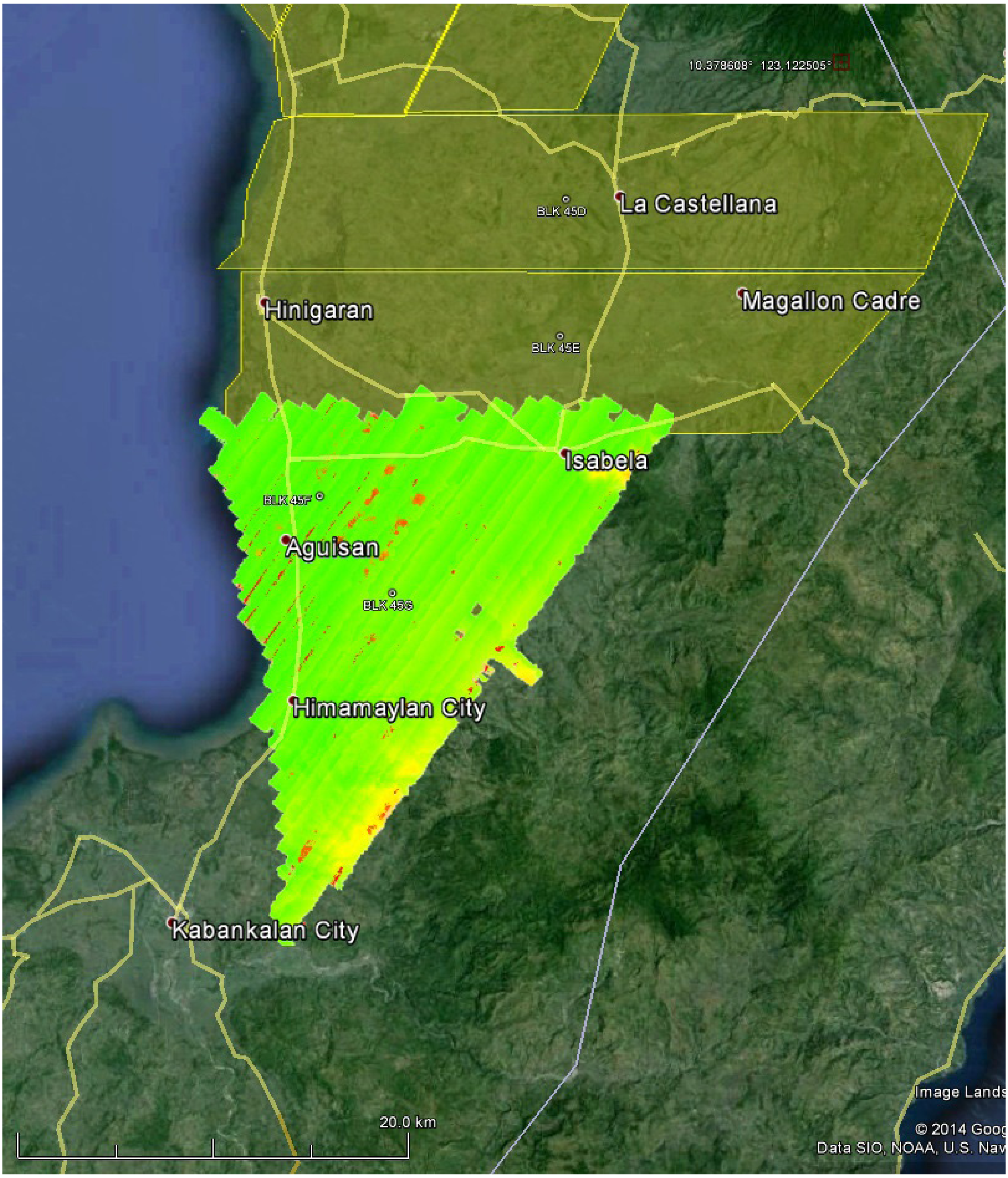


Figure A-7.5 Swath for Flight No. 1447P

Flight No. :	1455P
Area:	BLK 45ACD
Mission Name:	1BLK45S132A
Area Surveyed:	364.45 sq.km. gap filling

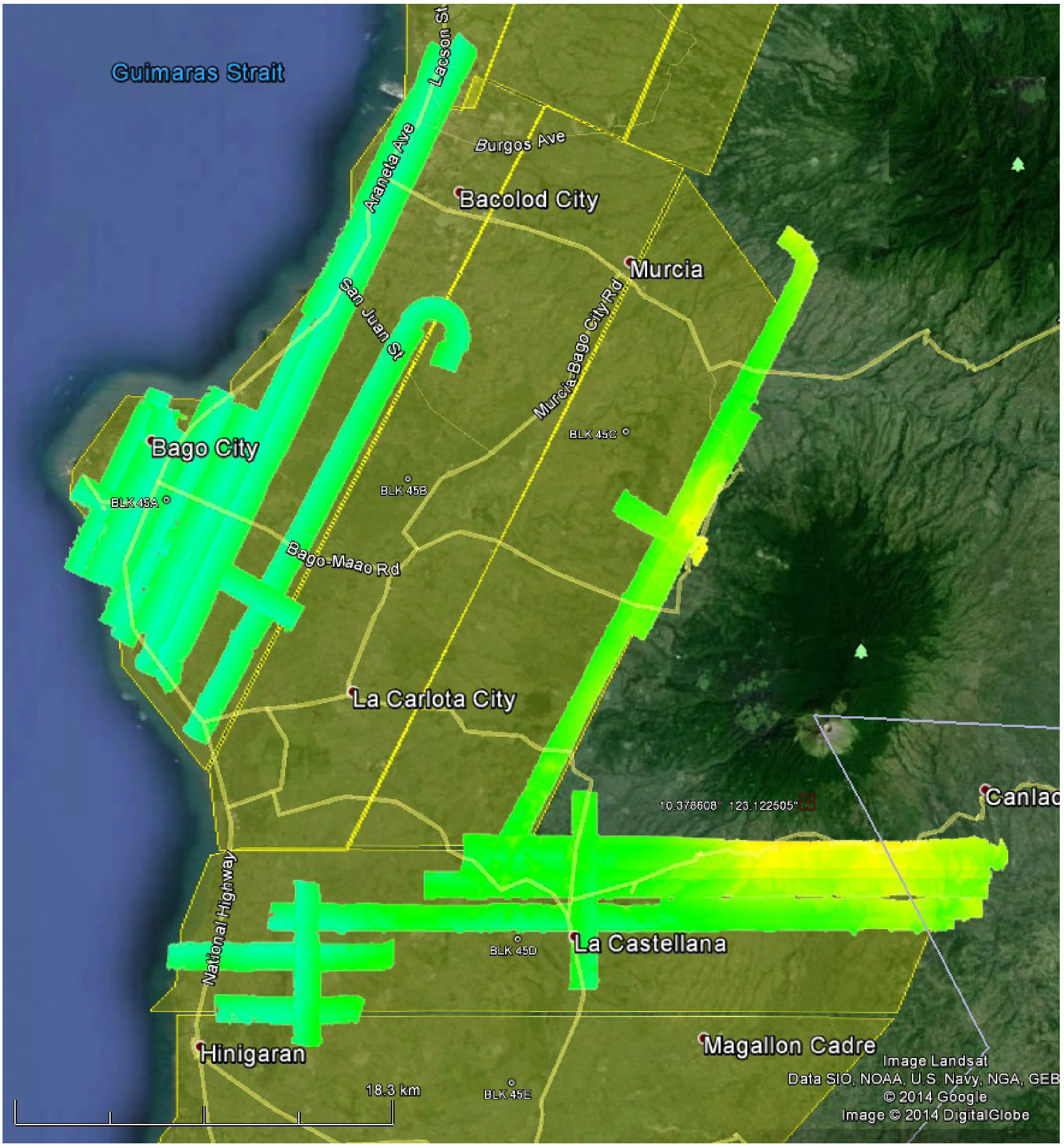


Figure A-7.6 Swath for Flight No. 1455P

Flight No. :	1459P
Area:	BLK 45DEFG
Mission Name:	1BLK45DFGS133A
Area Surveyed:	360.93 sq.km gap filling

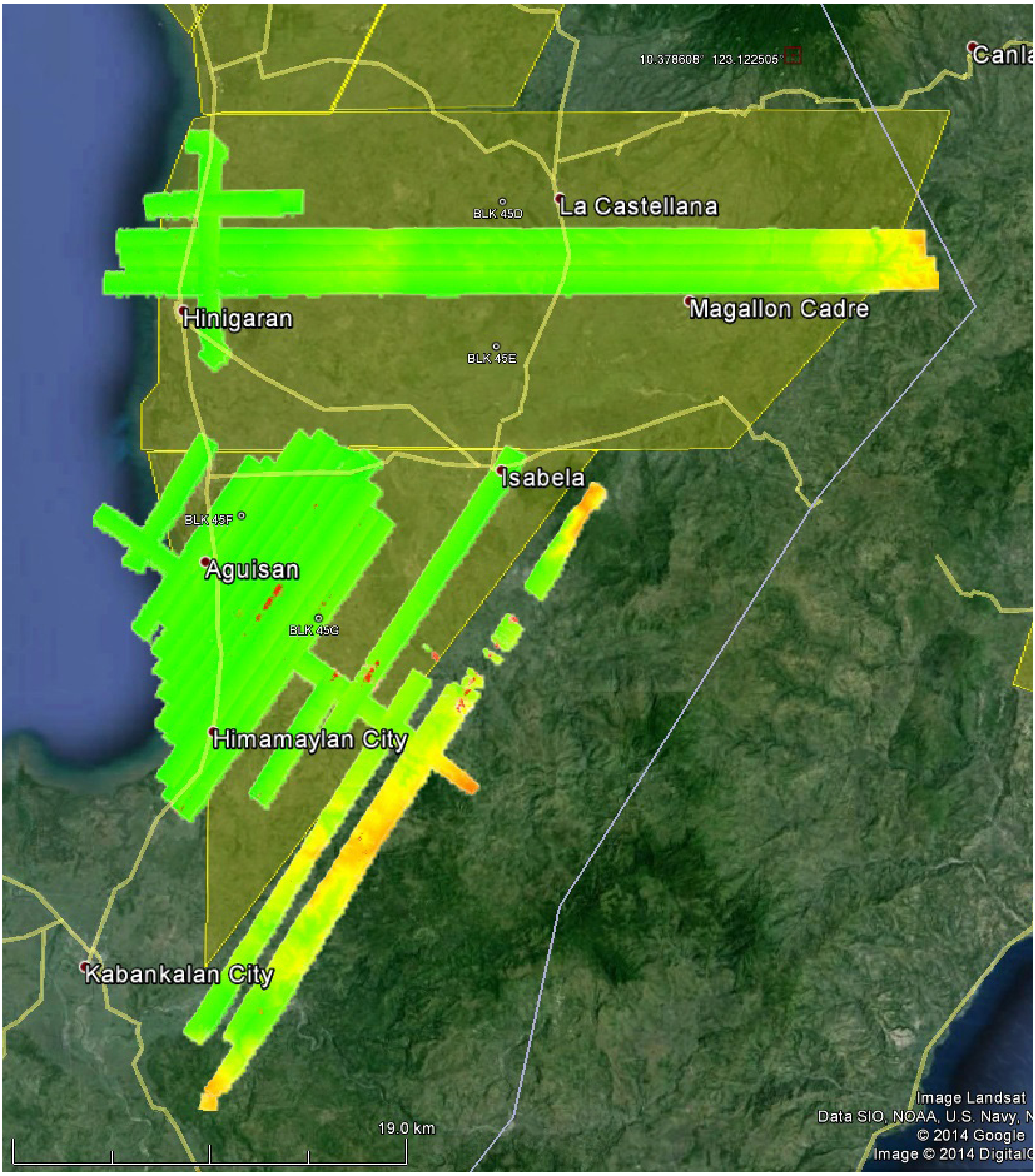


Figure A-7.7 Swath for Flight No. 1459P

Flight No. :	1463P
Area:	BLK 45FG, Ilog Hilabangan gaps
Mission Name:	1IHLS134A
Area Surveyed:	gap filling

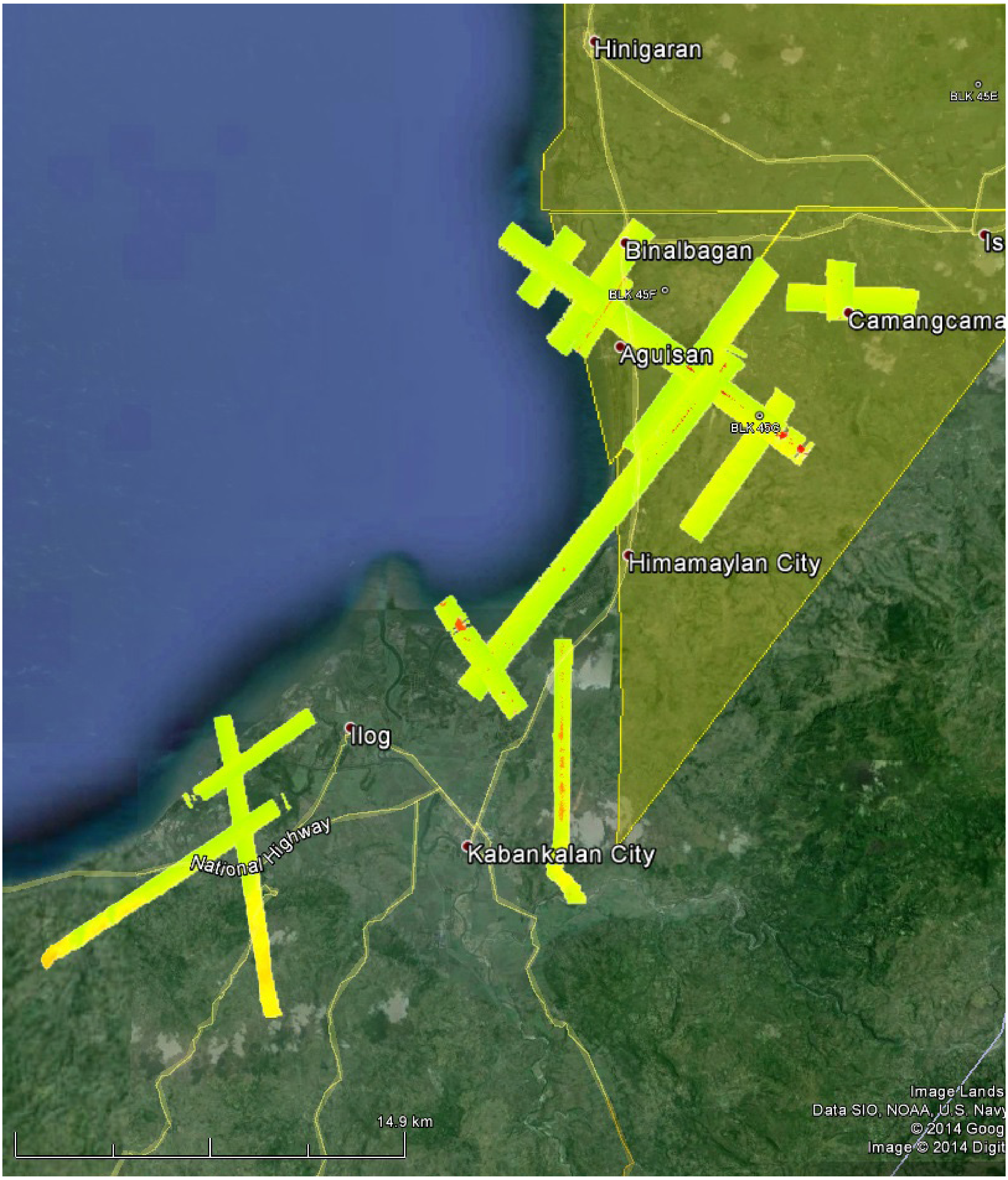


Figure A-7.8 Swath for Flight No. 1463P

Flight No. : 1471P

Area: BLK 45FG and Ilog Hilabangan gaps

Mission Name: 1IHLS136A

Area Surveyed: gap filling

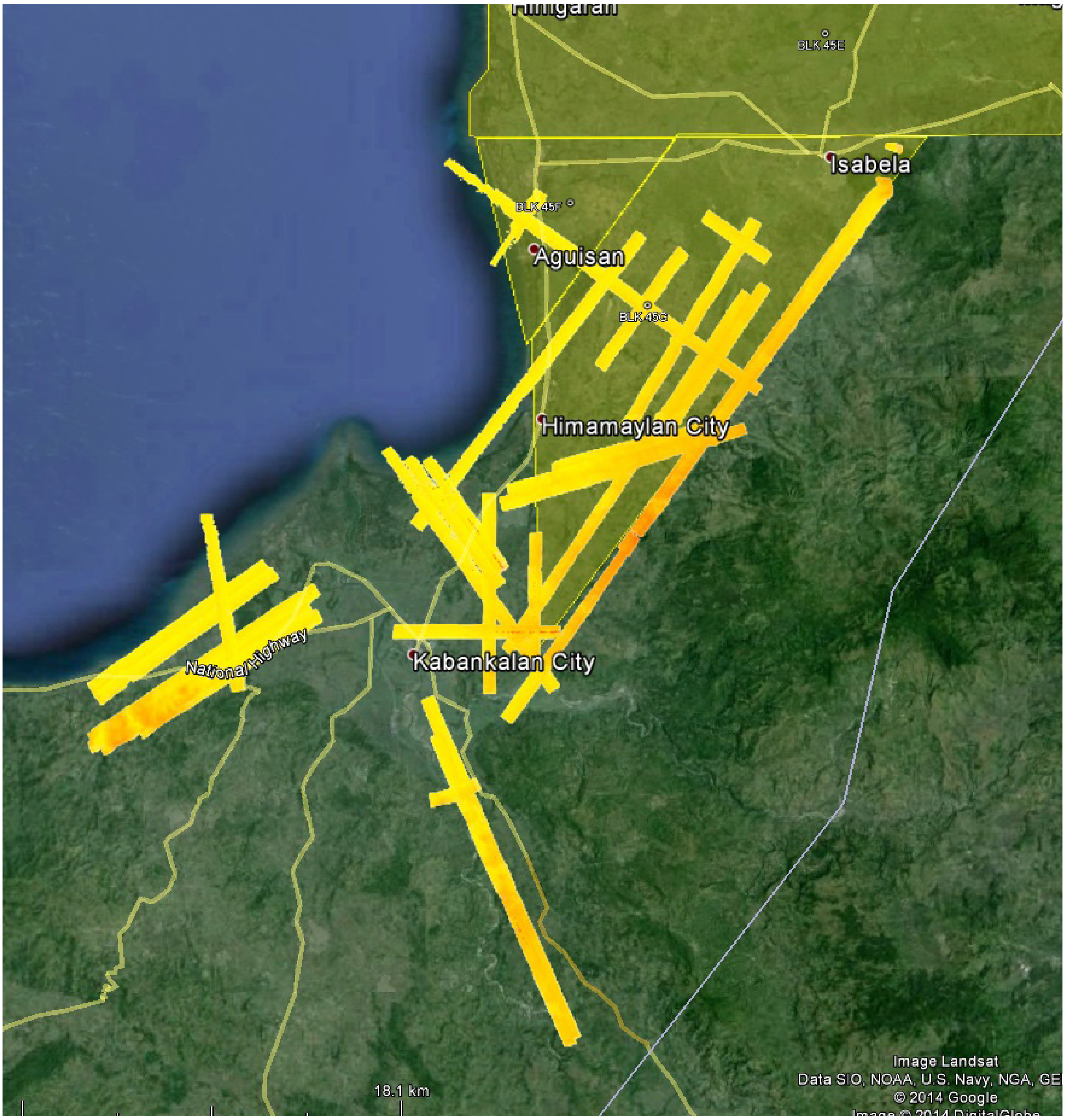


Figure A-7.9 Swath for Flight No. 1471P

FLIGHT NO.: 10009

AREA: Himamaylan and La Castelana

MISSION NAME: 1BLK45BLK46276B

ALT: 1000 m SCAN FREQ:30 SCAN ANGLE: 25

SURVEYED AREA: 158 km^2

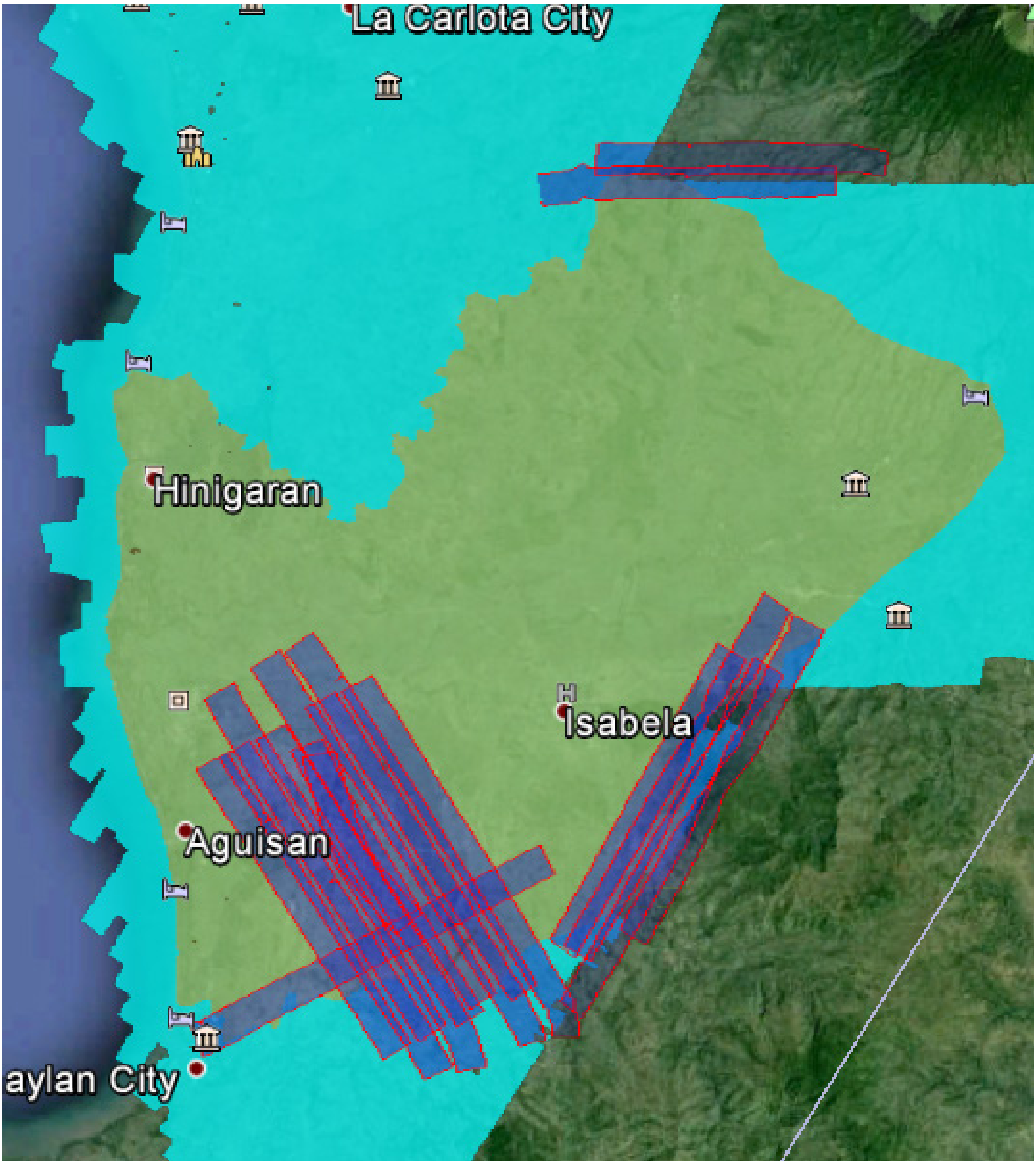


Figure A-7.10 Swath for Flight No. 10009

Annex 8. Mission Summary Report

Table A-8.1 Mission Summary Report for Blk45A

Flight Area	Negros
Mission Name	**Blk45A**
Inclusive Flights	1387P, 1455P
Range data size	53.6 GB
Base data size	16.05 MB
POS	573 MB
Image	52.11 GB
Transfer date	May 26, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.49
RMSE for East Position (<4.0 cm)	1.95
RMSE for Down Position (<8.0 cm)	3.59
Boresight correction stdev (<0.001deg)	0.000481
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	0.0243
Minimum % overlap (>25)	29.18%
Ave point cloud density per sq.m. (>2.0)	3.25
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	323
Maximum Height	167.32 m
Minimum Height	57.24 m
Classification (# of points)	
Ground	214,190,028
Low vegetation	165,392,522
Medium vegetation	144,819,072
High vegetation	58,876,709
Building	29,334,184
Orthophoto	No
Processed by	Victoria Rejuso, Engr. Velina Angela Bemida, Engr. Sueden Lyle Magtalas

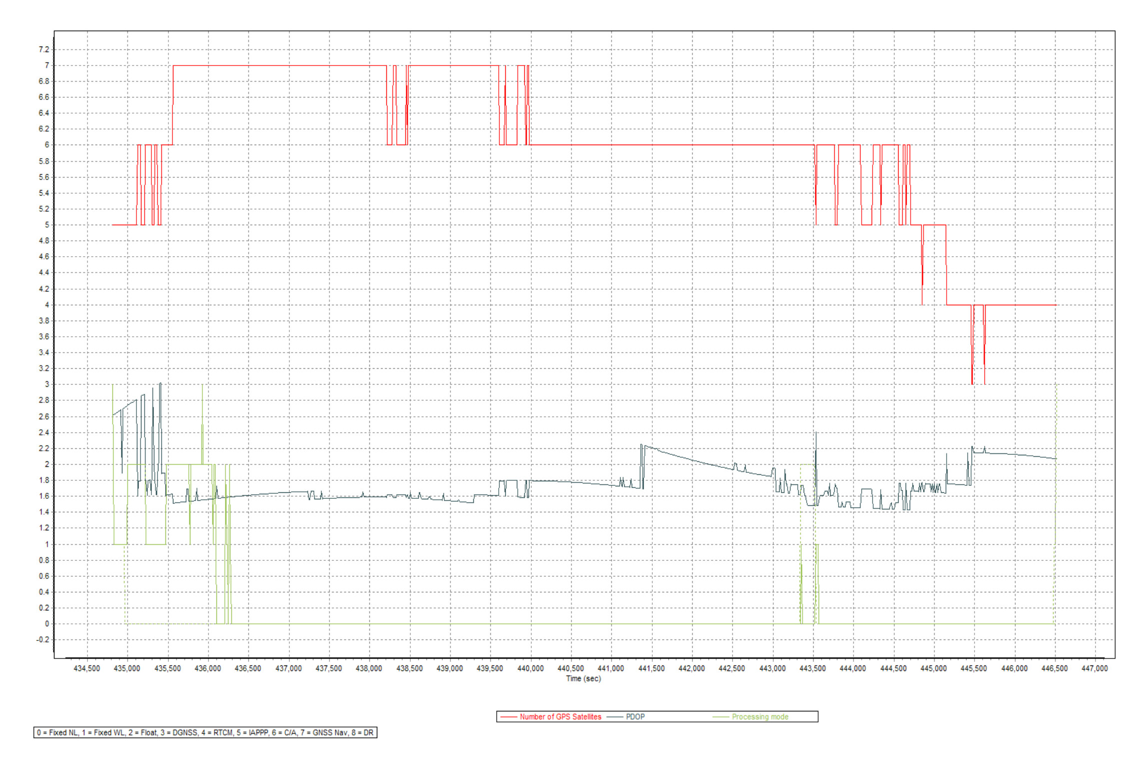


Figure A-8.1 Solution Status

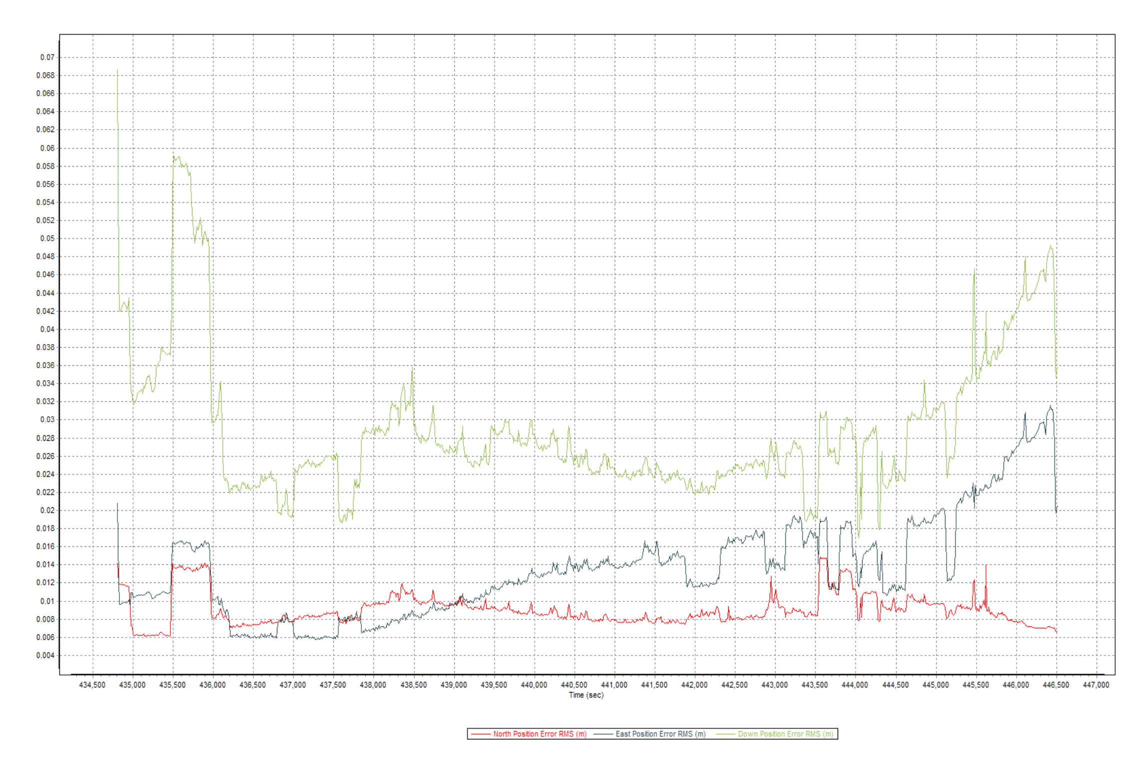


Figure A-8.2 Smoothed Performance Metric Parameters

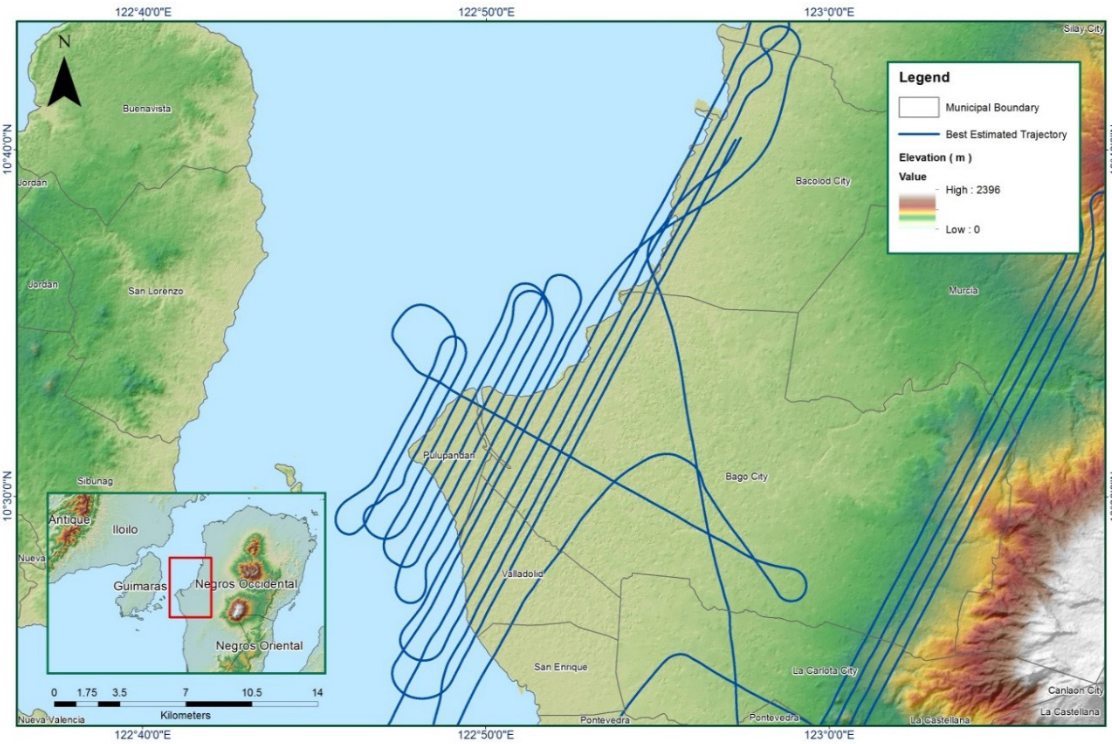


Figure A-8.3 Best Estimated Trajectory

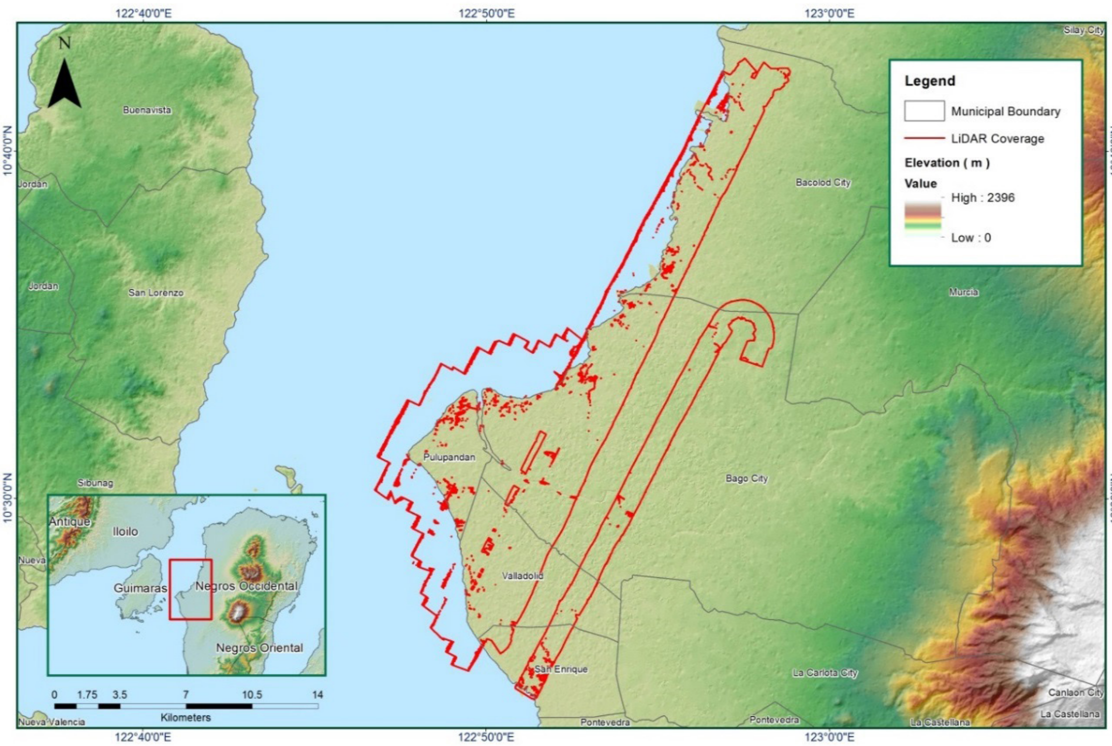


Figure A-8.4 Coverage of LIDAR data

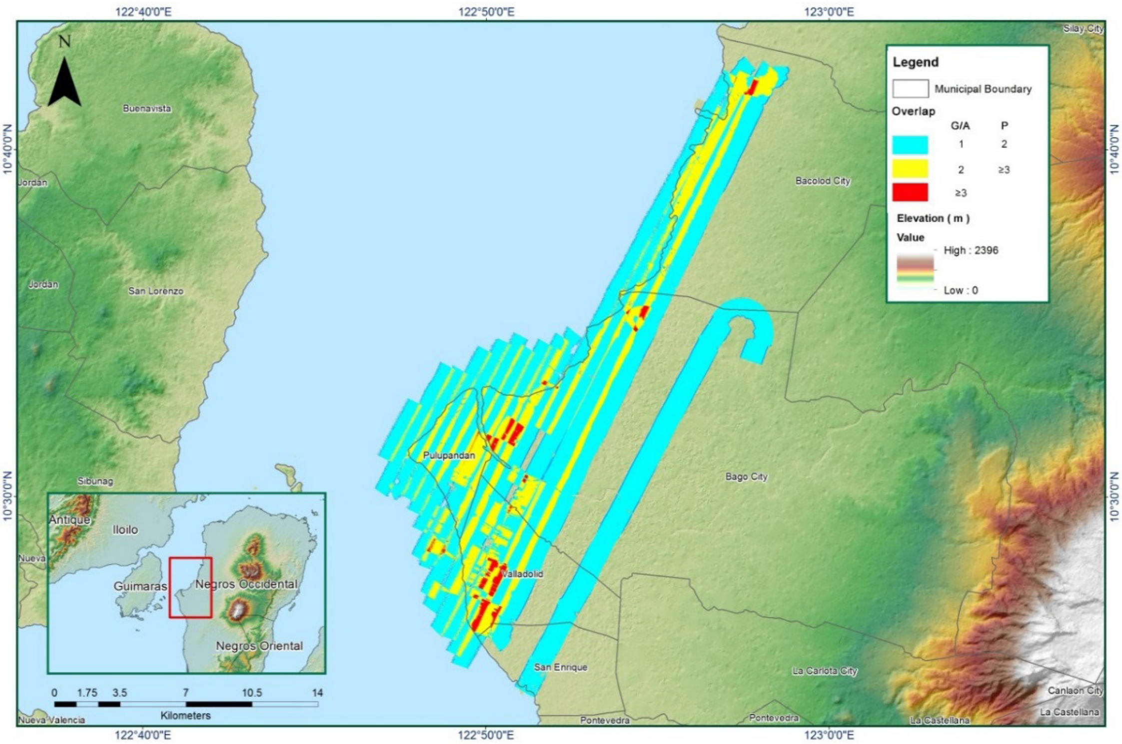


Figure A-8.5 Image of Data Overlap

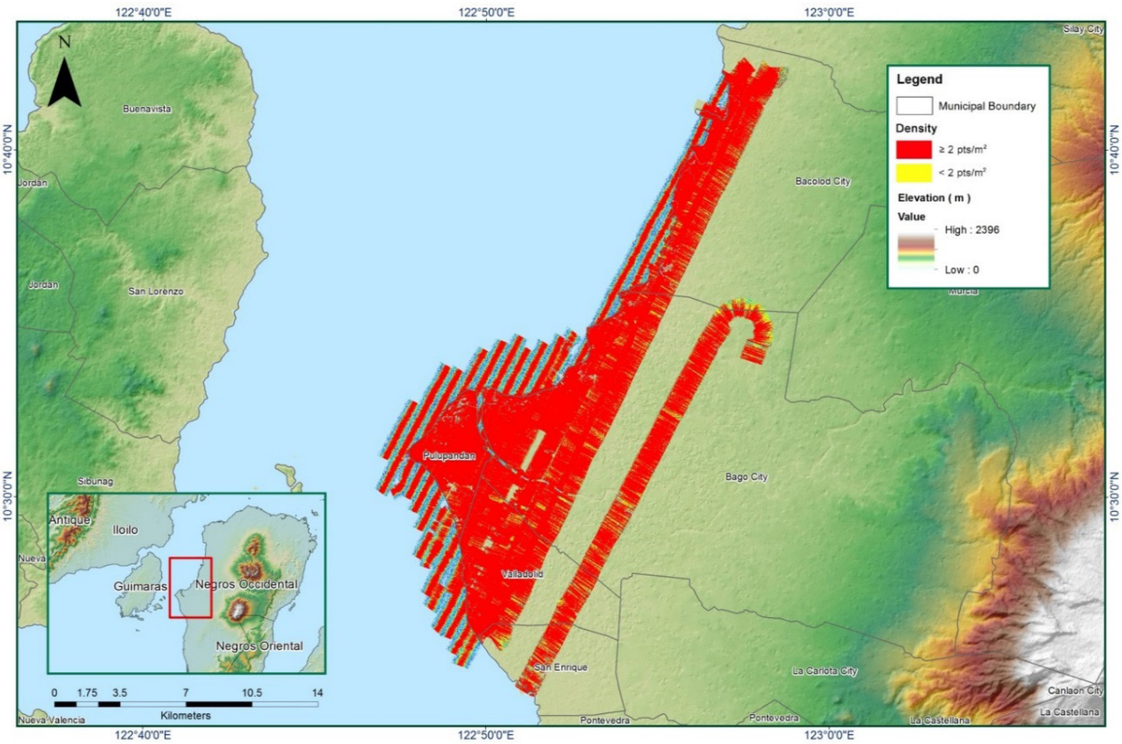


Figure A-8.6 Density map of merged LIDAR data

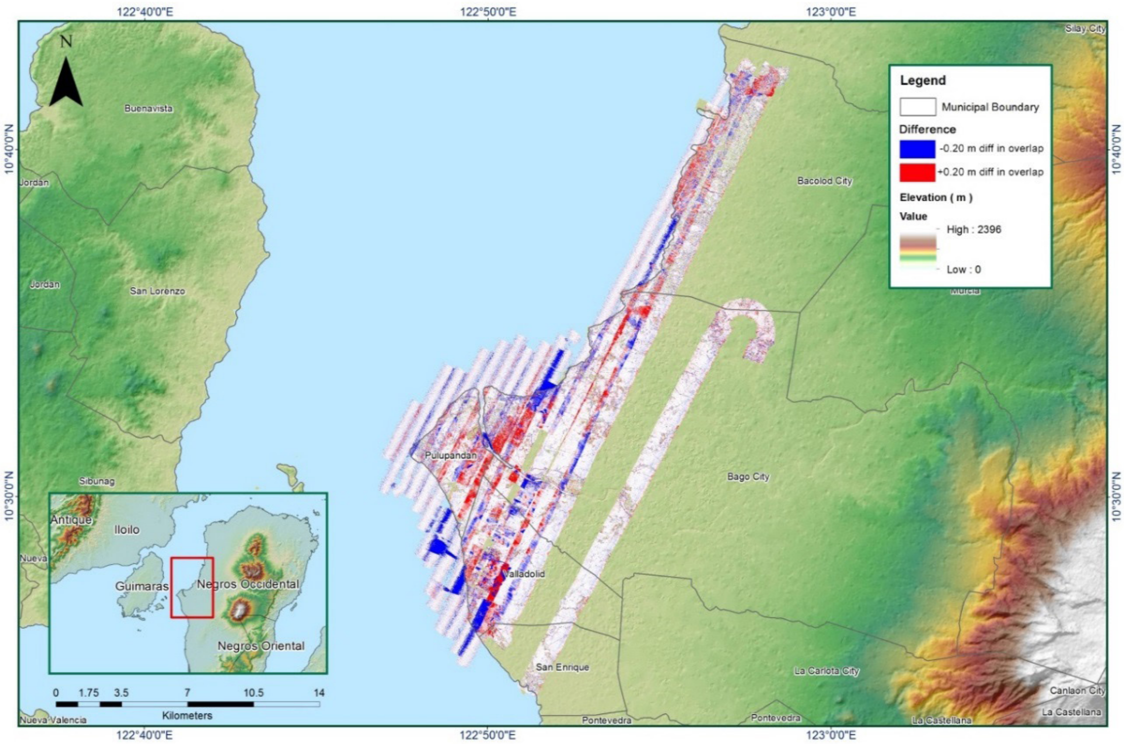


Figure A-8.7 Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Blk45A additional

Flight Area	**Negros**
Mission Name	**Blk45A additional**
Inclusive Flights	1455P, 1387P
Range data size	53.6 GB
Base data size	16.05 MB
POS	573 MB
Image	52.11 GB
Transfer date	May 26, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.49
RMSE for East Position (<4.0 cm)	1.95
RMSE for Down Position (<8.0 cm)	3.59
Boresight correction stdev (<0.001deg)	0.000481
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	0.0243
Minimum % overlap (>25)	13.75 %
Ave point cloud density per sq.m. (>2.0)	1.775
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	142
Maximum Height	521.55
Minimum Height	51.07
Classification (# of points)	
Ground	132,379,761
Low vegetation	125,752,184
Medium vegetation	199,077,351
High vegetation	599,574,573
Building	15,255,571
Orthophoto	Yes
Processed by	Victoria Rejuso, Engr. Antonio Chua, Jr. , Engr. Mark Sueden Lyle Magtalas

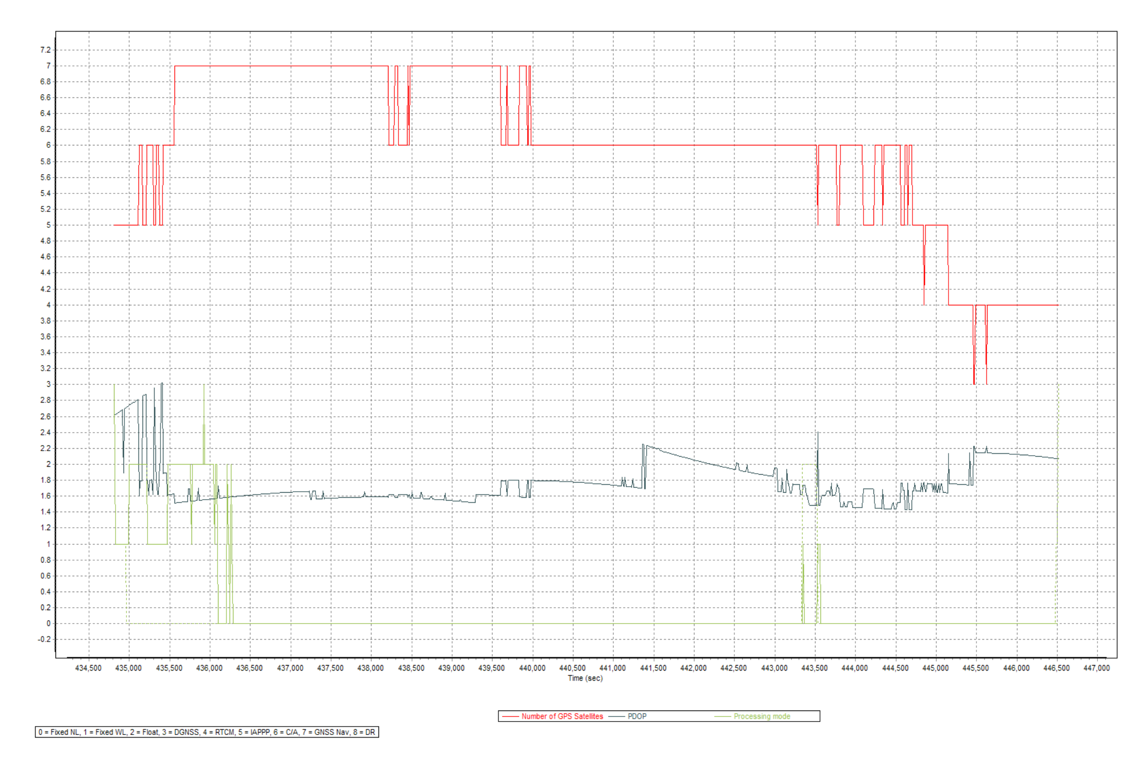


Figure A-8.8 Solution Status

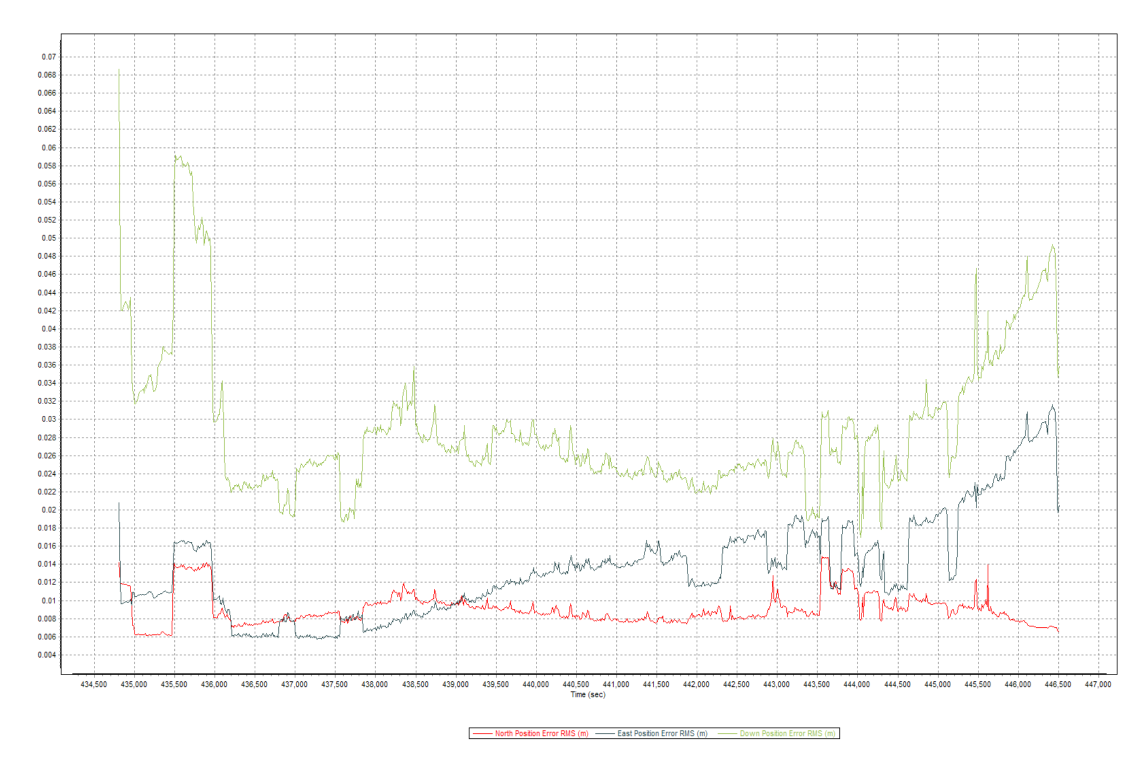


Figure A-8.9 Smoothed Performance Metric Parameters

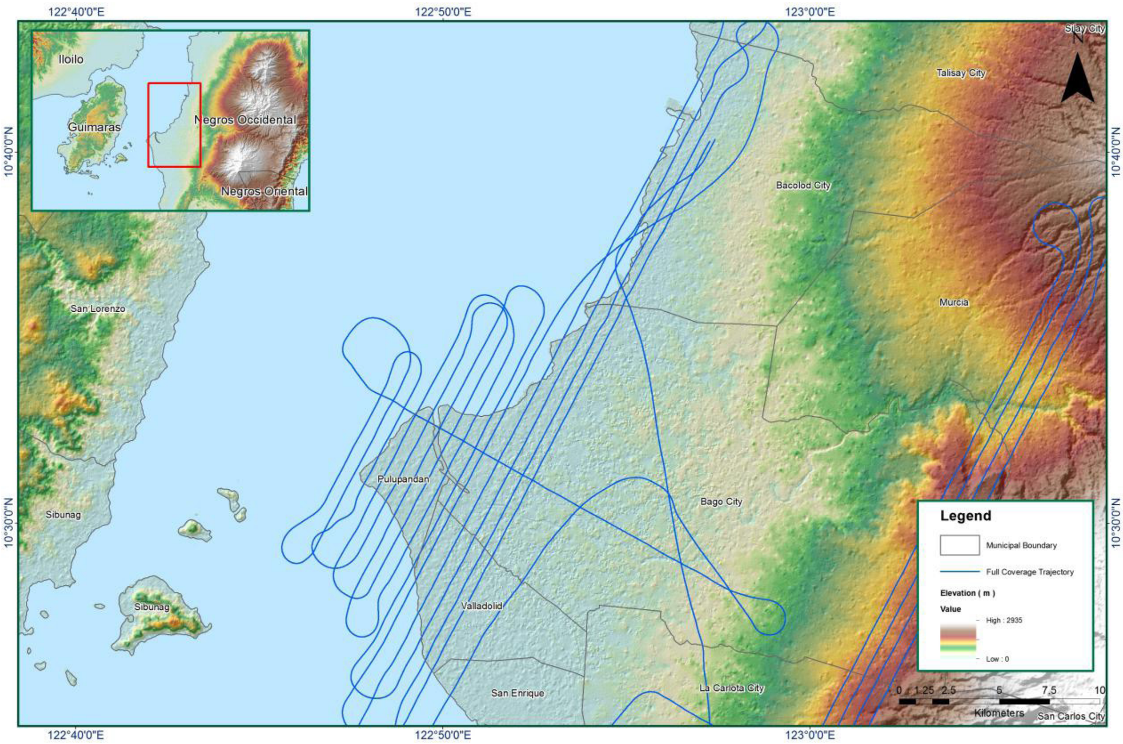


Figure A-8.10 Best Estimated Trajectory

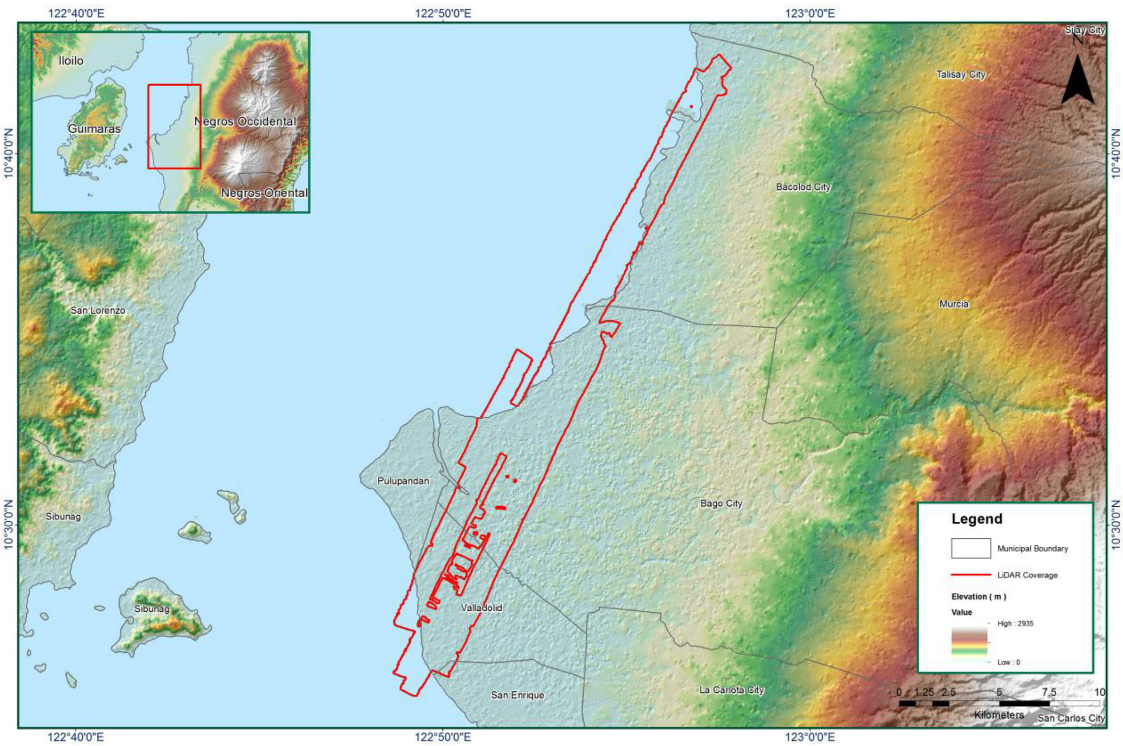


Figure A-8.11 Coverage of LIDAR data

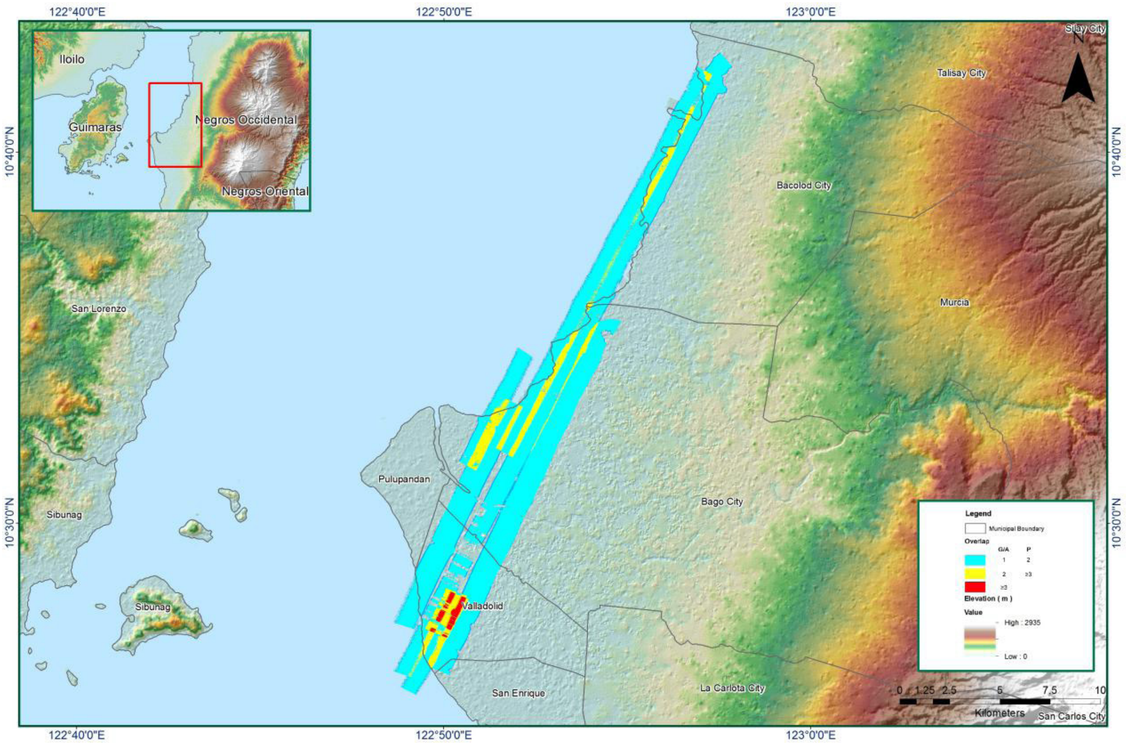


Figure A-8.12 Image of Data Overlap

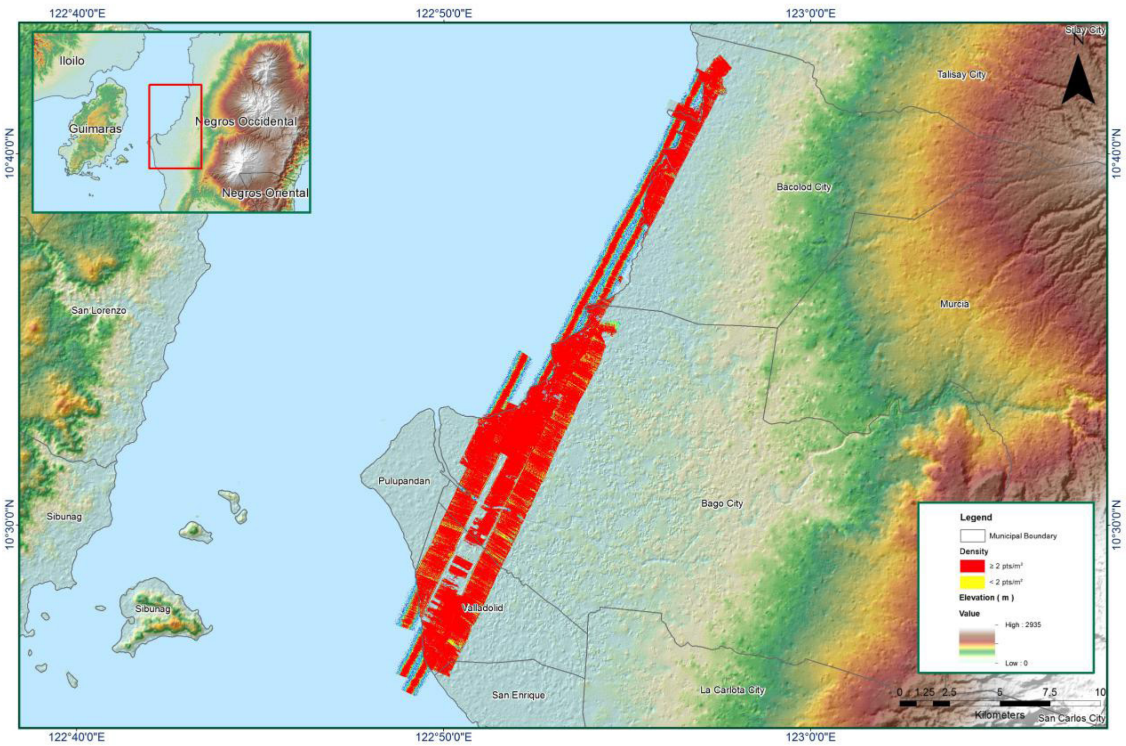


Figure A-8.13 Density map of merged LIDAR data

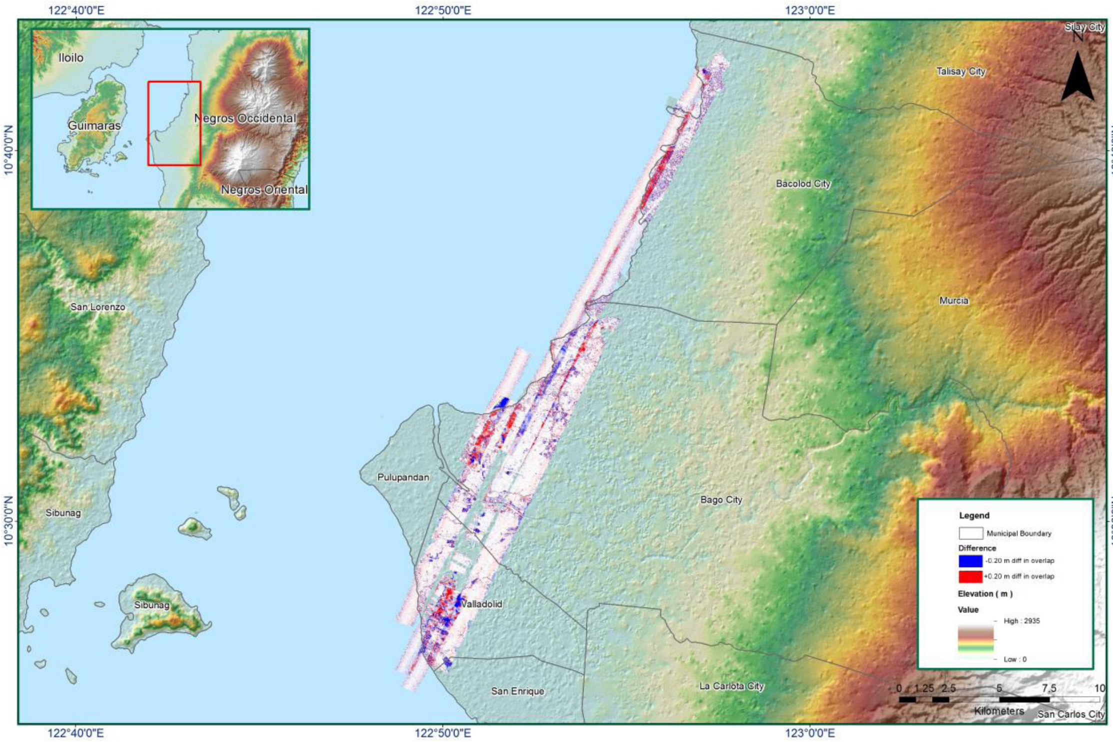


Figure A-8.14 Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Blk45B

Flight Area	Negros
Mission Name	**Blk45B**
Inclusive Flights	1373P, 1375P
Range data size	52.1 GB
Base data size	28.4 MB
POS	413 MB
Image	69.2 GB
Transfer date	May 26, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.82
RMSE for East Position (<4.0 cm)	1.89
RMSE for Down Position (<8.0 cm)	3.83
Boresight correction stdev (<0.001deg)	0.000483
IMU attitude correction stdev (<0.001deg)	0.001814
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	40.77%
Ave point cloud density per sq.m. (>2.0)	4.28
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	660
Maximum Height	389.89 m
Minimum Height	58.87 m
Classification (# of points)	
Ground	598,271,558
Low vegetation	575,599,055
Medium vegetation	625,391,066
High vegetation	139,475,138
Building	32,148,481
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Engr. Chelou Prado, Engr. Gladys Mae Apat

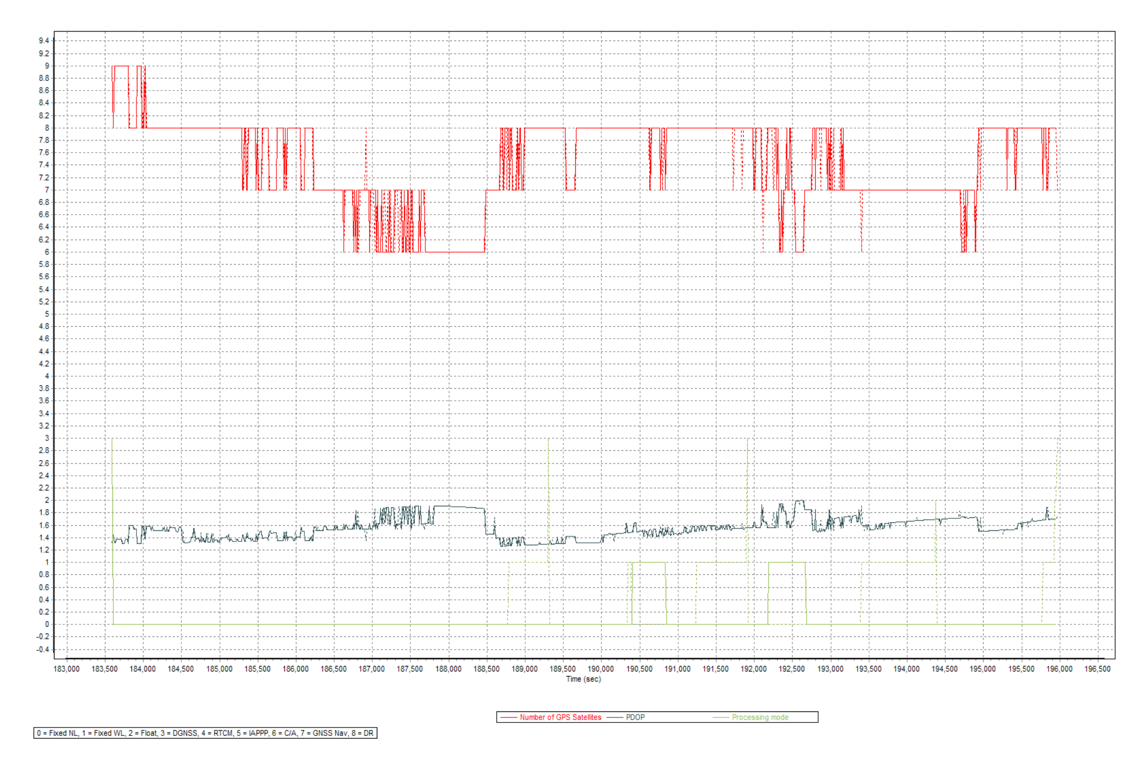


Figure A-8.15 Solution Status

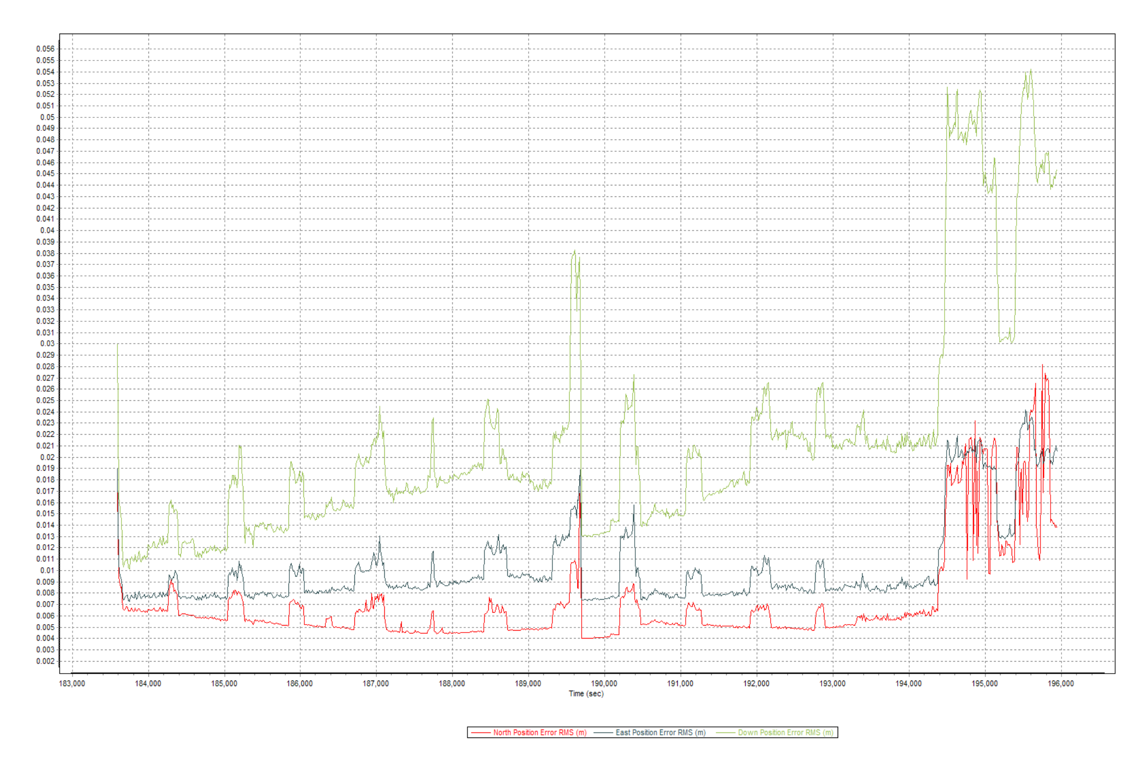


Figure A-8.16 Smoothed Performance Metric Parameter

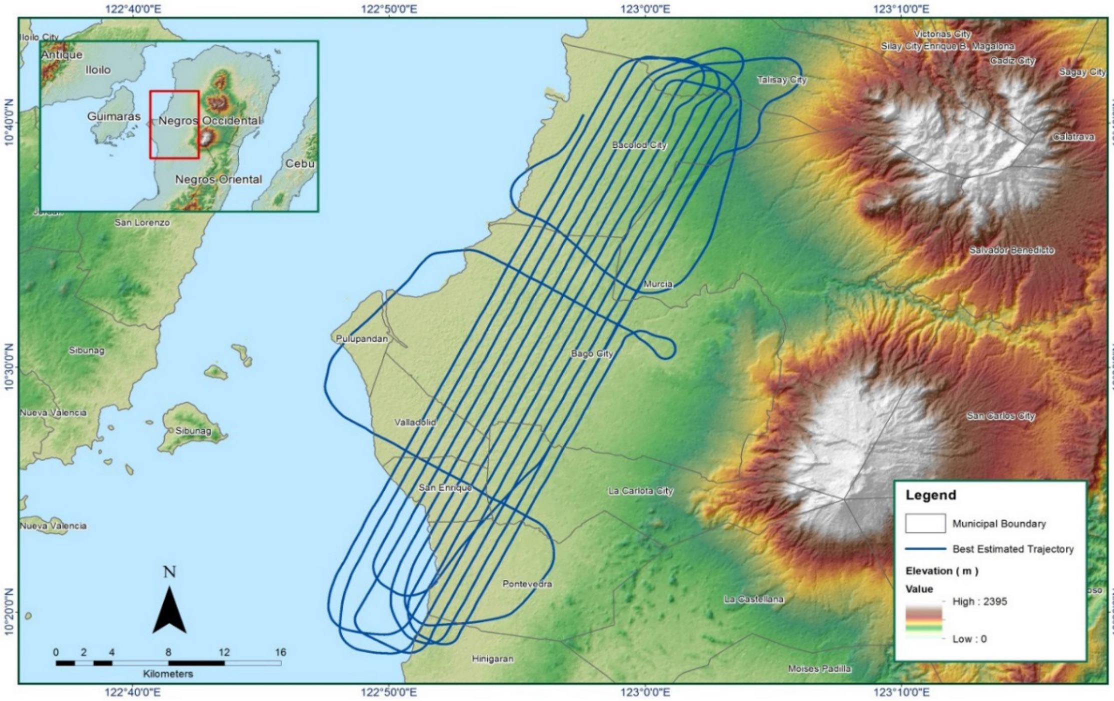


Figure A-8.17 Best Estimated Trajectory

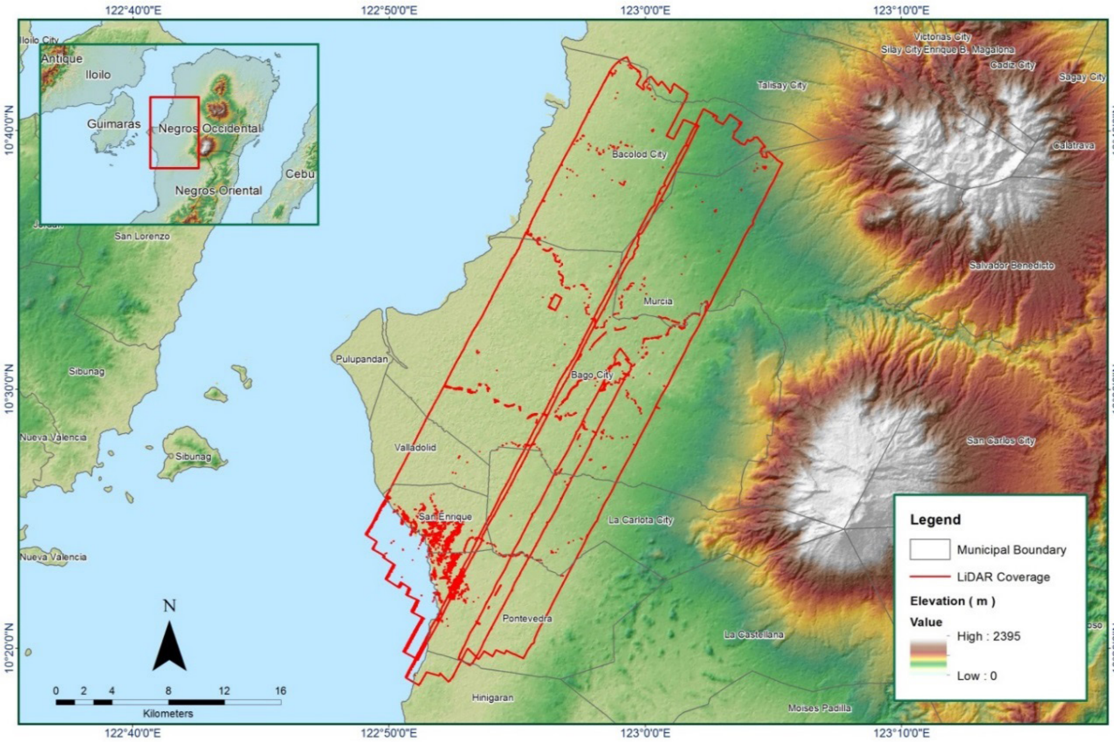


Figure A-8.18 Coverage of LIDAR data

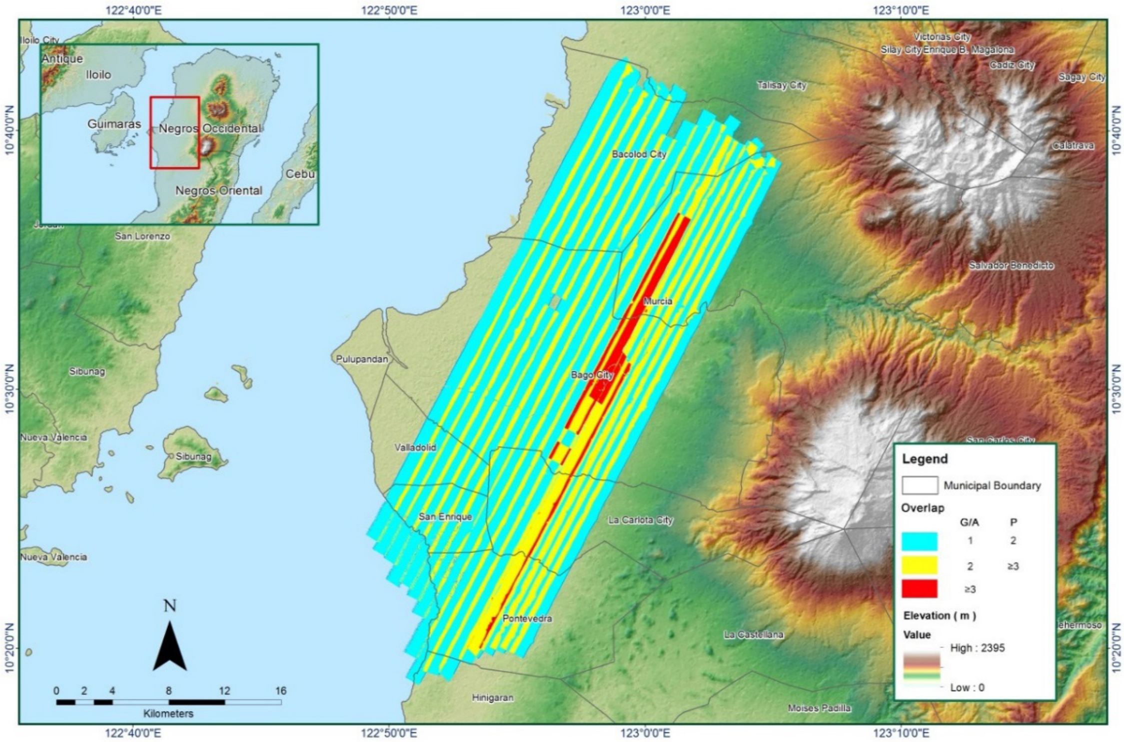


Figure A-8.19 Image of Data Overlap

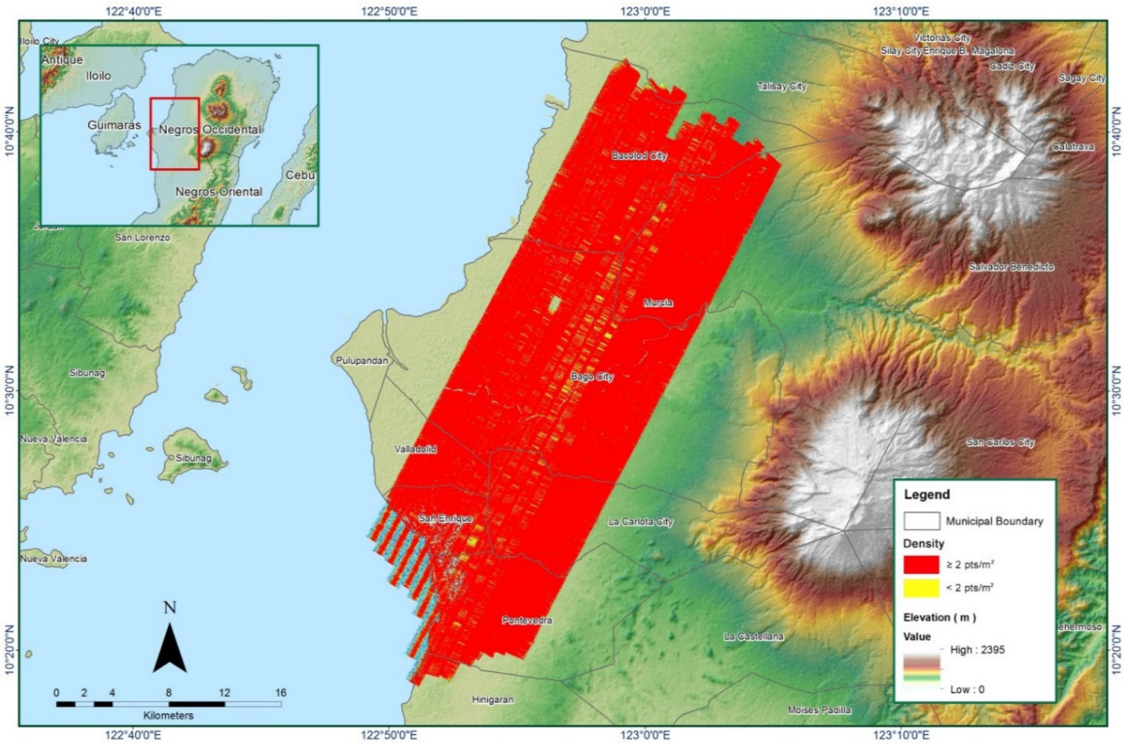


Figure A-8.20 Density map of merged LIDAR data

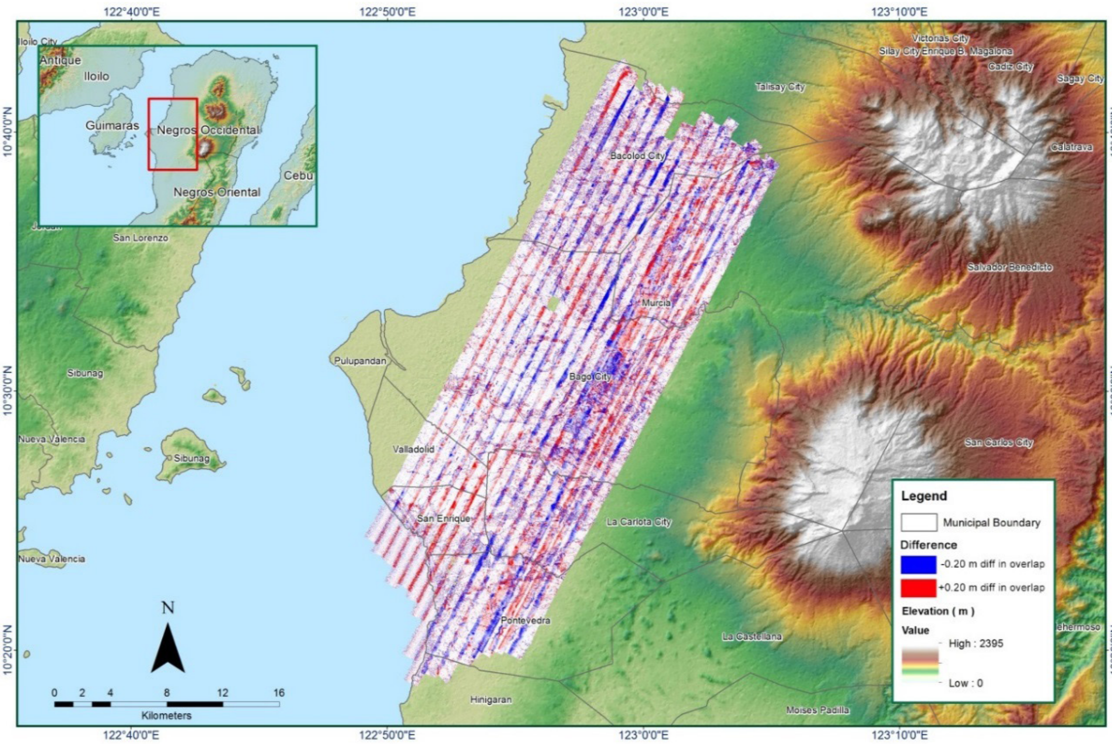


Figure A-8.21 Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Blk45C

Flight Area	**Negros**
Mission Name	**Blk45C**
Inclusive Flights	1377P, 1387P, 1455P
Range data size	69.2 GB
Base data size	29.65 MB
POS	727 MB
Image	69.61 GB
Transfer date	May 26, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.37
RMSE for East Position (<4.0 cm)	1.78
RMSE for Down Position (<8.0 cm)	3.05
Boresight correction stdev (<0.001deg)	0.000318
IMU attitude correction stdev (<0.001deg)	0.037668
GPS position stdev (<0.01m)	0.0253
Minimum % overlap (>25)	29.40%
Ave point cloud density per sq.m. (>2.0)	4.87
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	319
Maximum Height	527.28
Minimum Height	76.78
Classification (# of points)	
Ground	274,151,263
Low vegetation	260,185,264
Medium vegetation	355,146,321
High vegetation	82,026,158
Building	3,573,115
Orthophoto	Yes
Processed by	Victoria Rejuso, Engr. Harmond Santos, Engr. Gladys Mae Apat

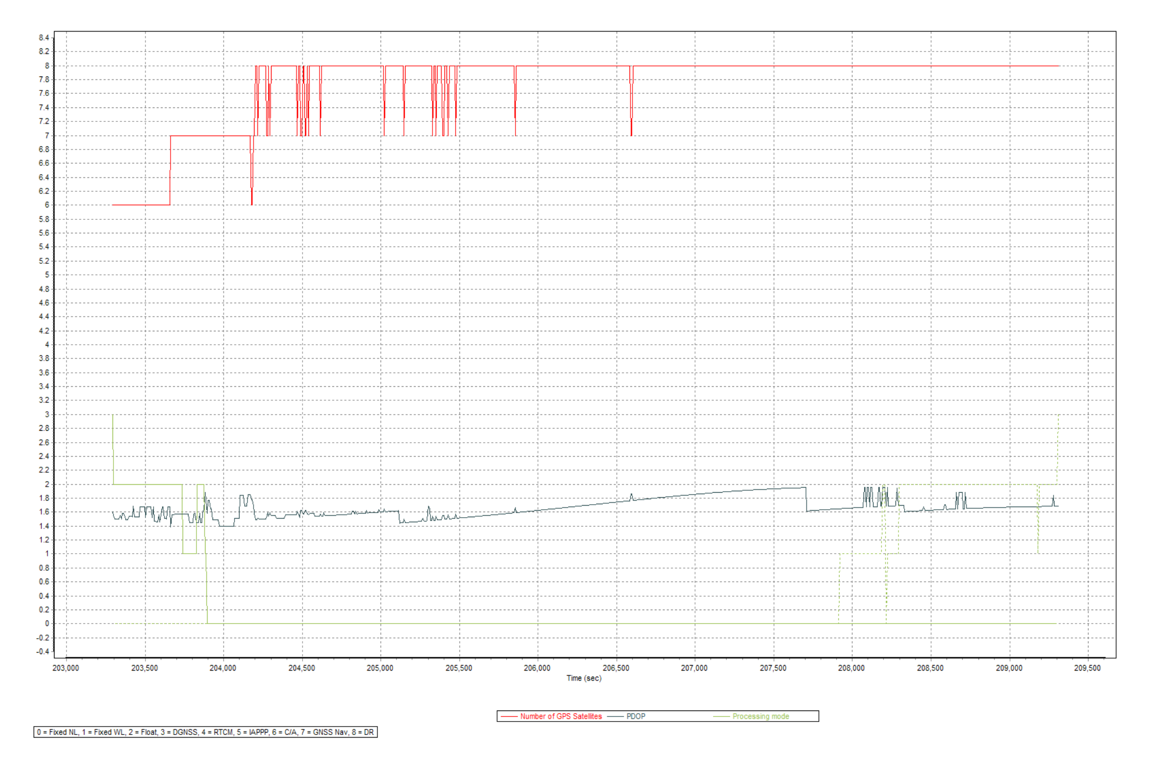


Figure A-8.22 Solution Status

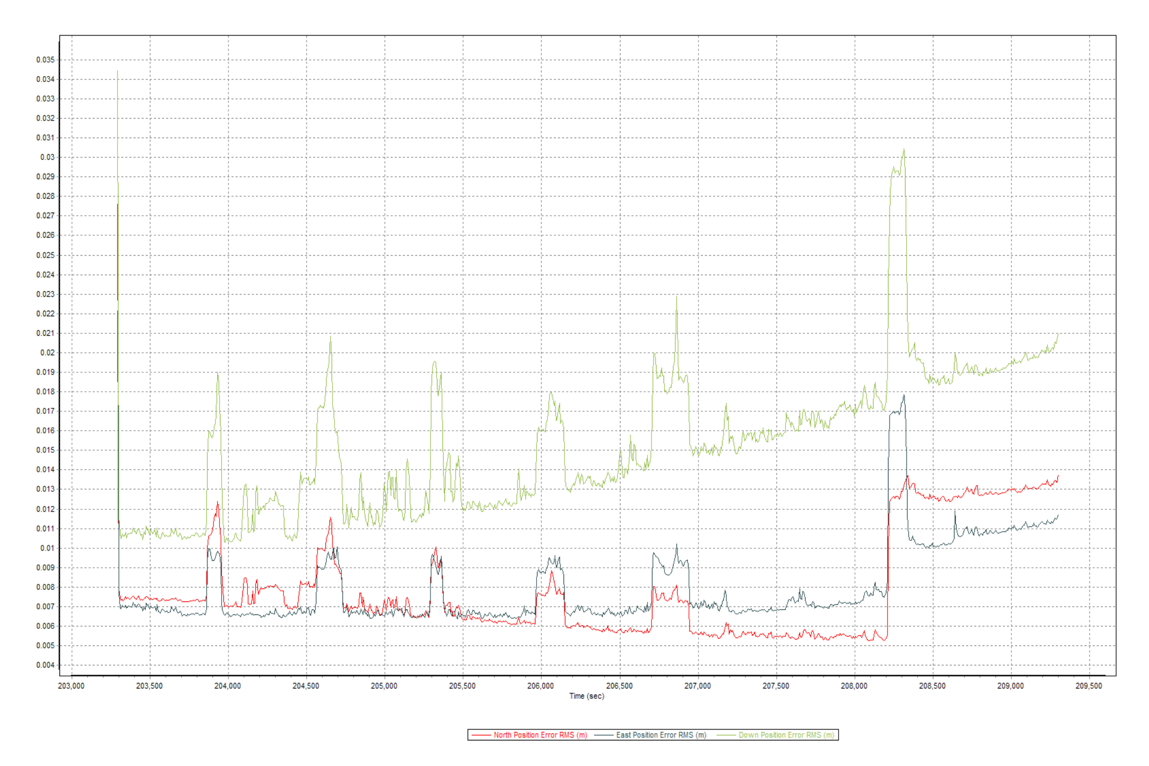


Figure A-8.23 Smoothed Performance Metric Parameters

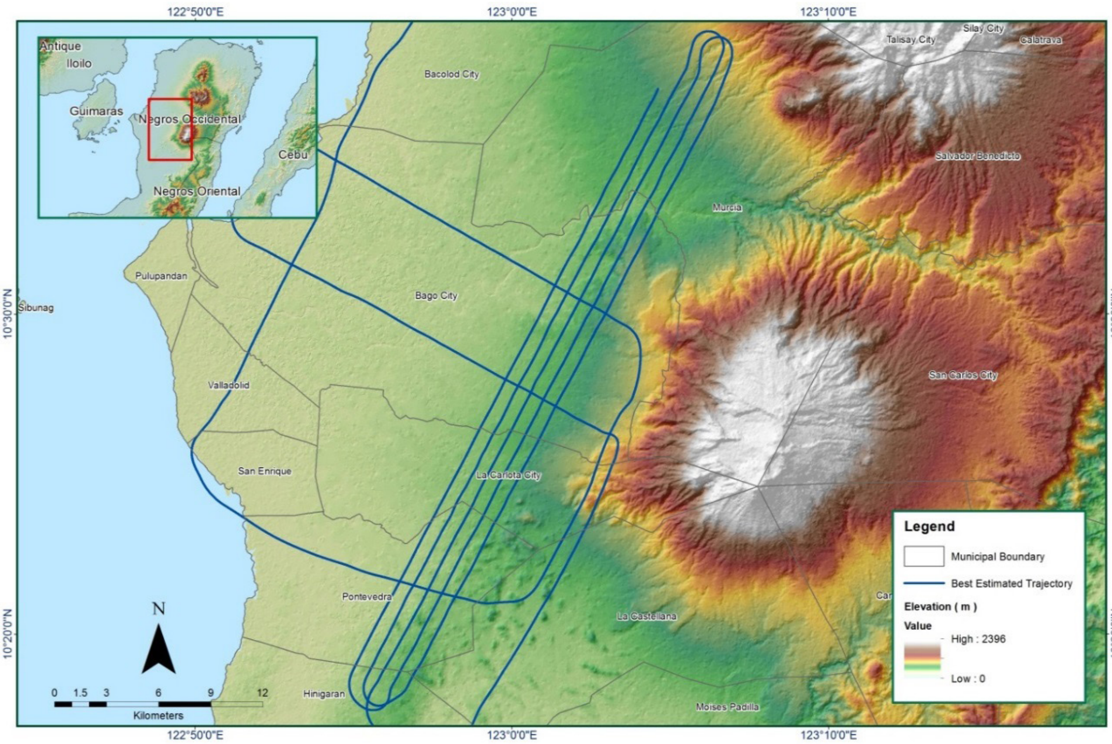


Figure A-8.24 Best Estimated Trajectory

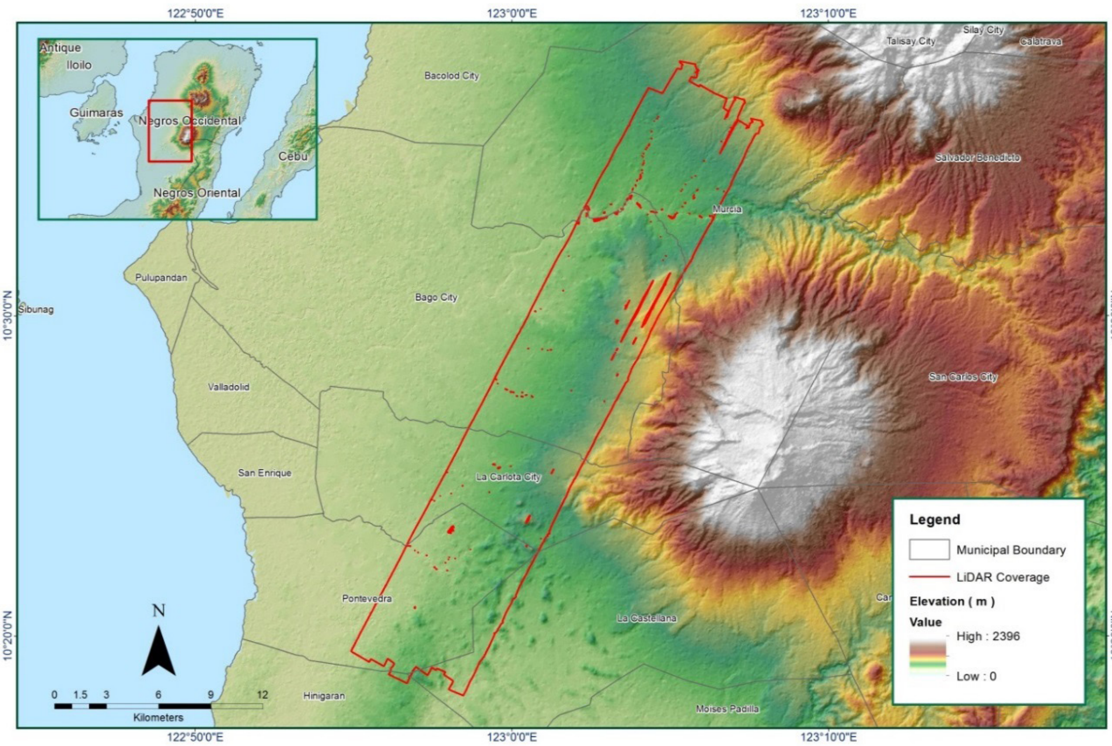


Figure A-8.25 Coverage of LIDAR data

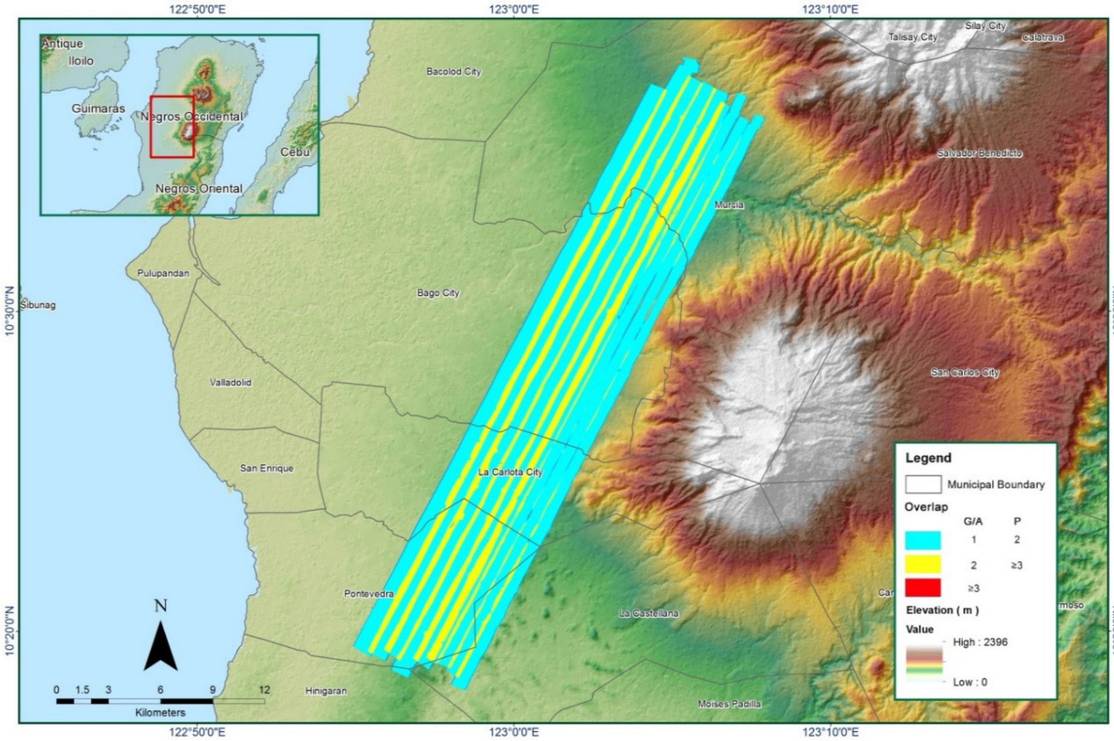


Figure A-8.26 Image of Data Overlap

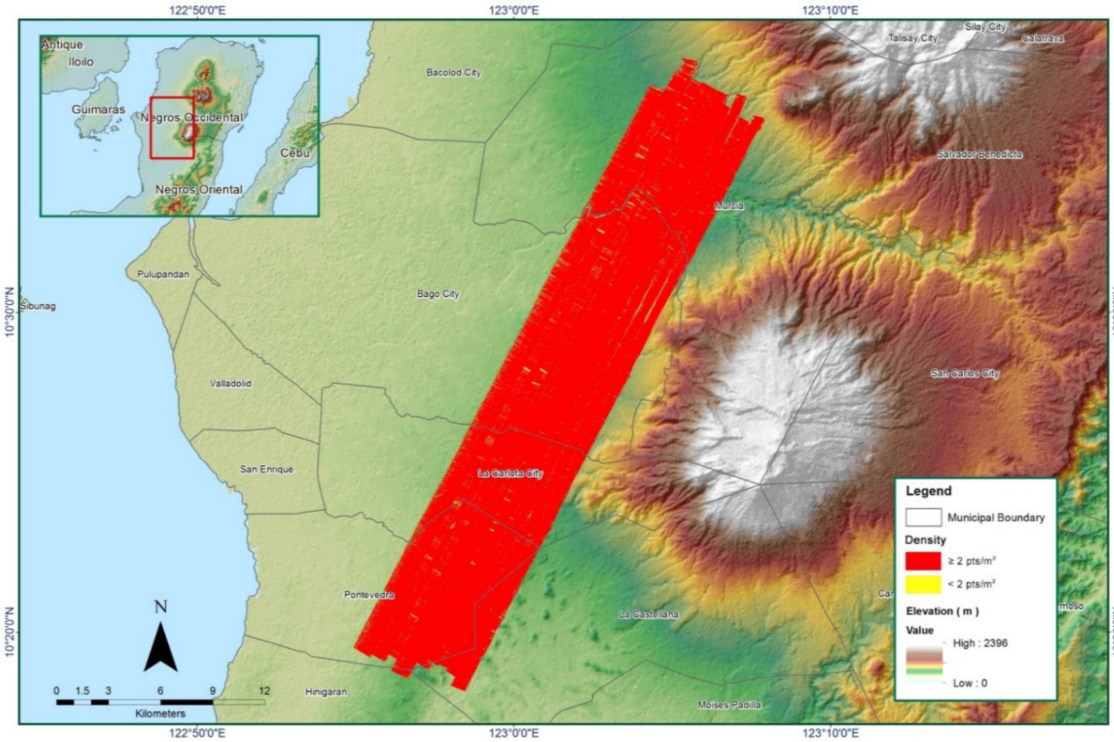


Figure A-8.27 Density map of merged LIDAR data

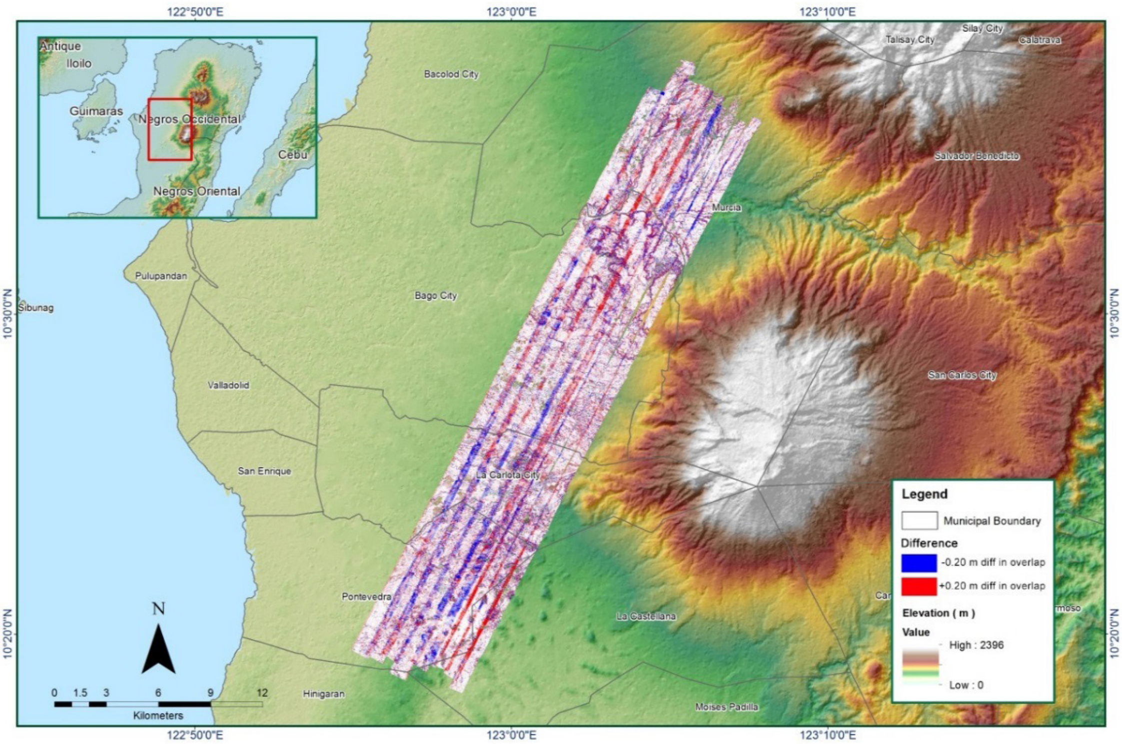


Figure A-8.28 Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Blk46A additional

Flight Area	Negros
Mission Name	**Blk46A additional**
Inclusive Flights	1453P, 1451P
Range data size	43.8 GB
Base data size	22.8 MB
POS	413 MB
Image	21.5 GB
Transfer date	May 26, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.93
RMSE for East Position (<4.0 cm)	1.15
RMSE for Down Position (<8.0 cm)	2.28
Boresight correction stdev (<0.001deg)	0.000266
IMU attitude correction stdev (<0.001deg)	0.001576
GPS position stdev (<0.01m)	0.0092
Minimum % overlap (>25)	21.38 %
Ave point cloud density per sq.m. (>2.0)	2.98
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	103
Maximum Height	904.48
Minimum Height	61.72
Classification (# of points)	
Ground	68,632,636
Low vegetation	42,374,849
Medium vegetation	80,184,232
High vegetation	97,809,178
Building	2,190,225
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Velina Angela Bemida, Engr. Krisha Marie Bautista

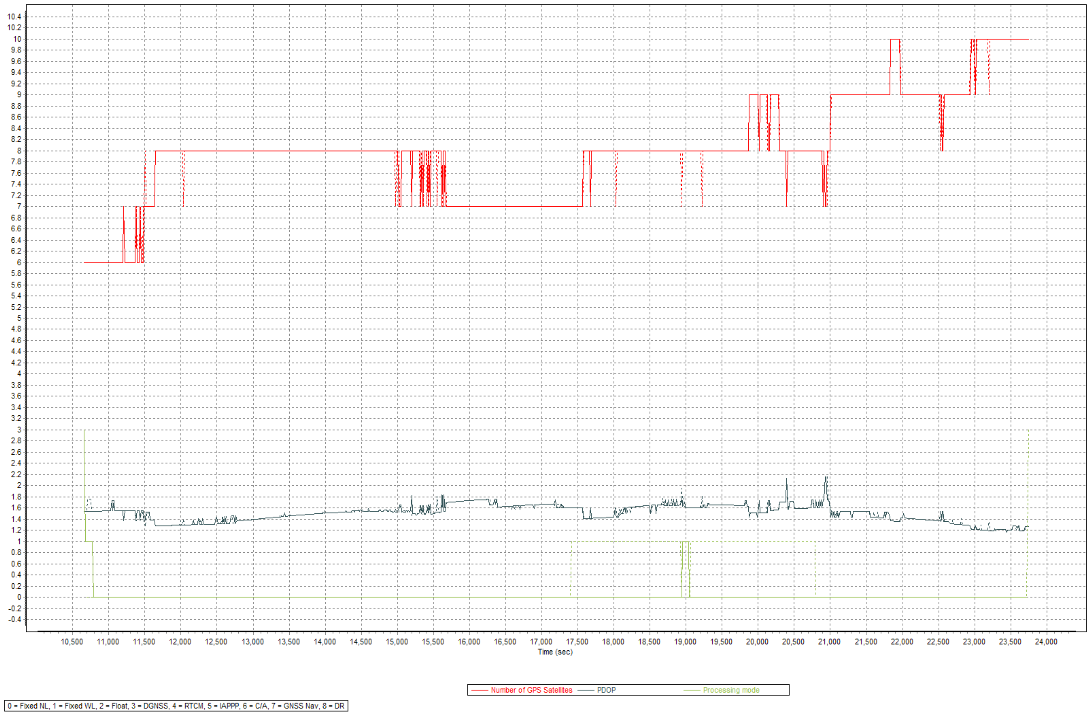


Figure A-8.29 Solution Status

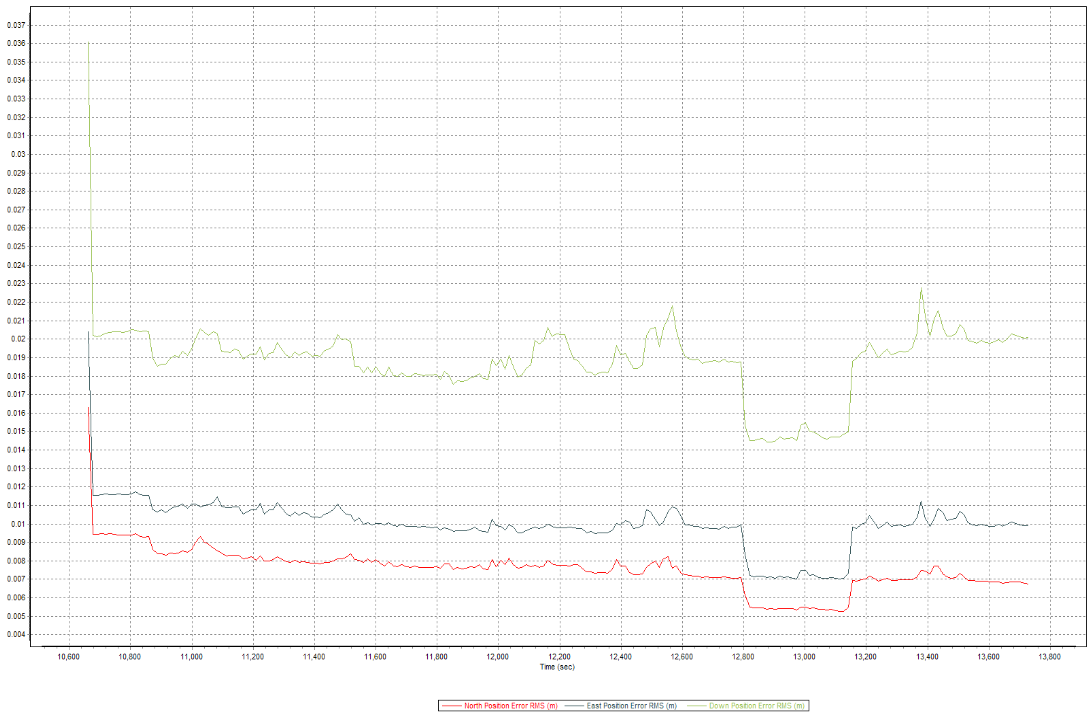


Figure A-8.30 Smoothed Performance Metric Parameters

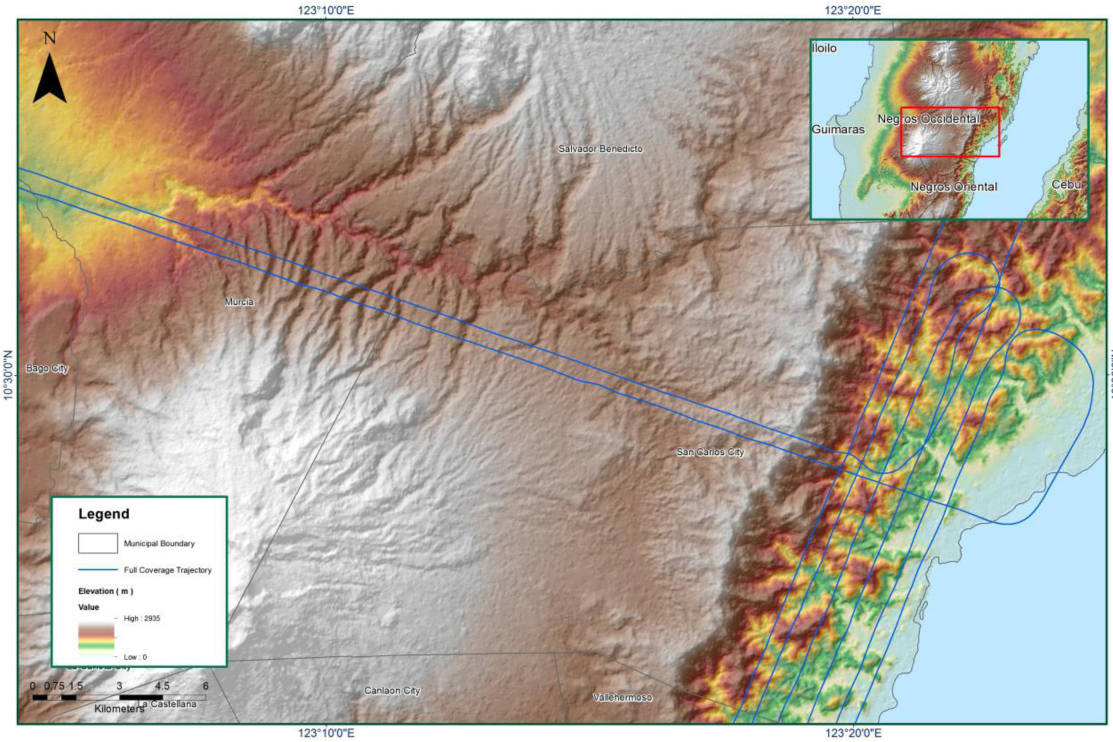


Figure A-8.31 Best Estimated Trajectory

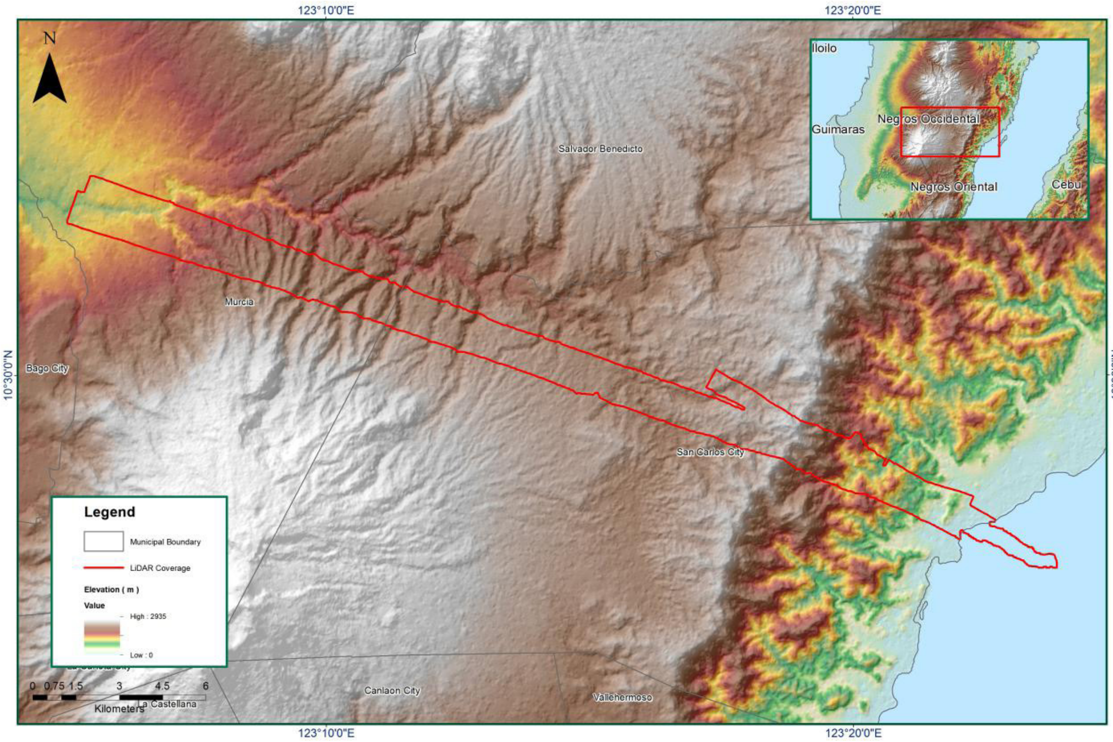


Figure A-8.32 Coverage of LIDAR data

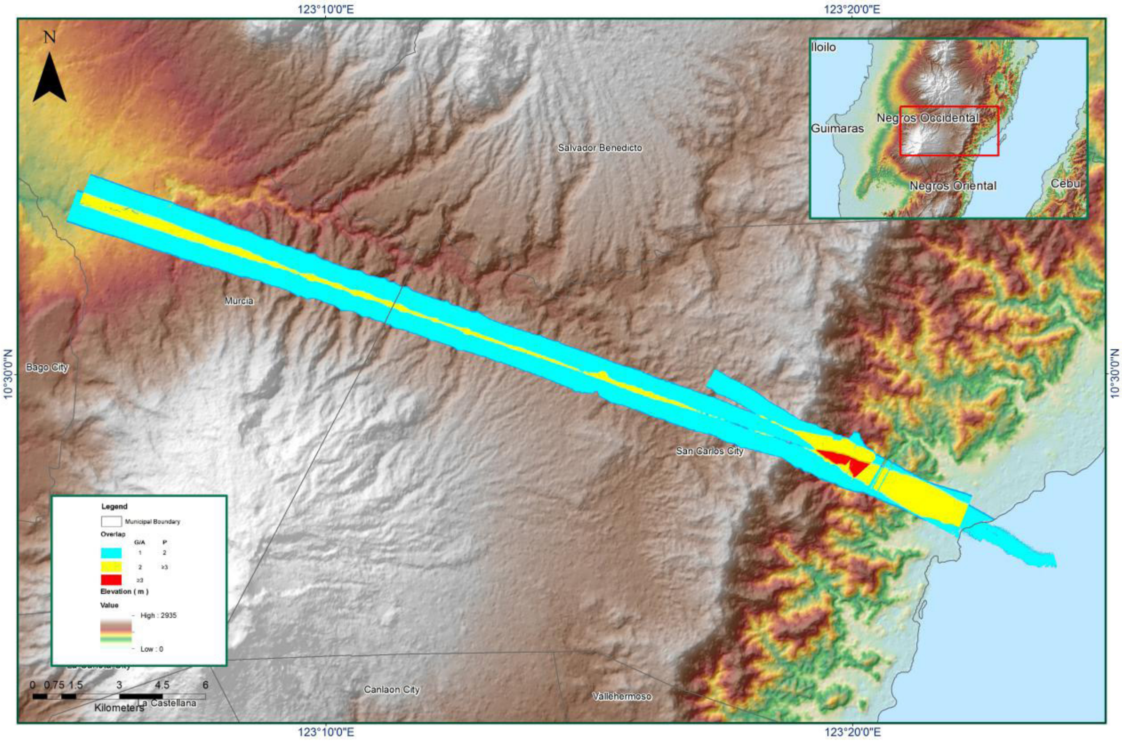


Figure A-8.33 Image of Data Overlap

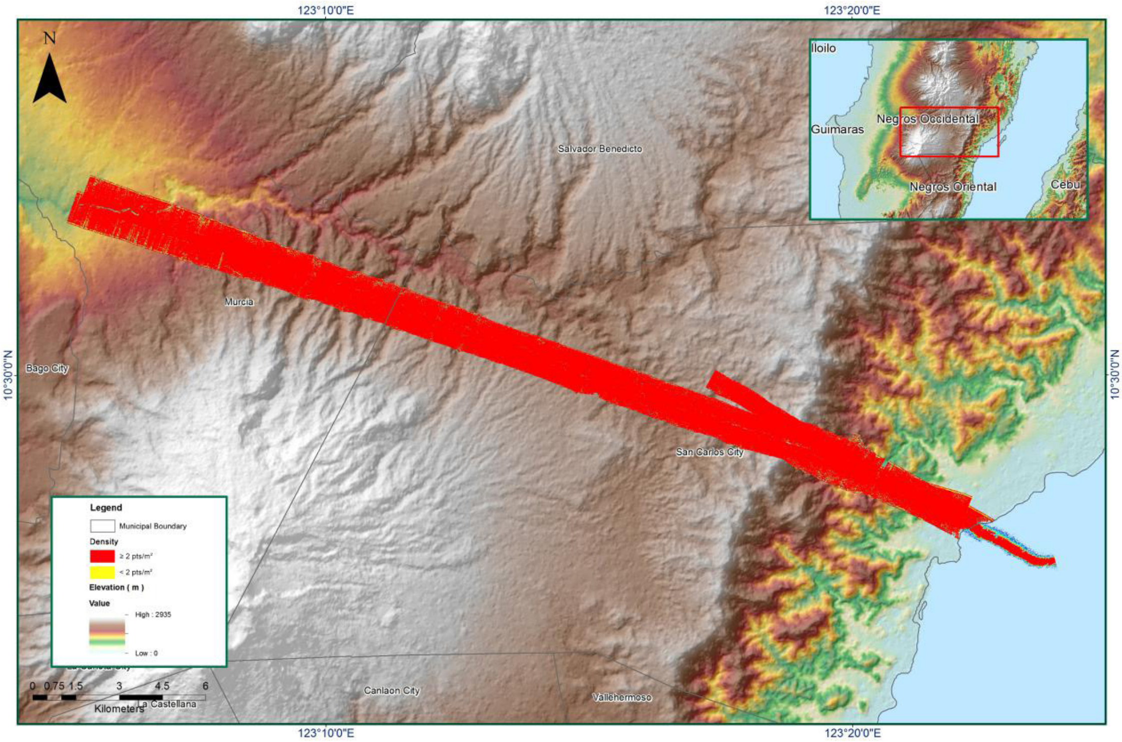


Figure A-8.34 Density map of merged LIDAR data

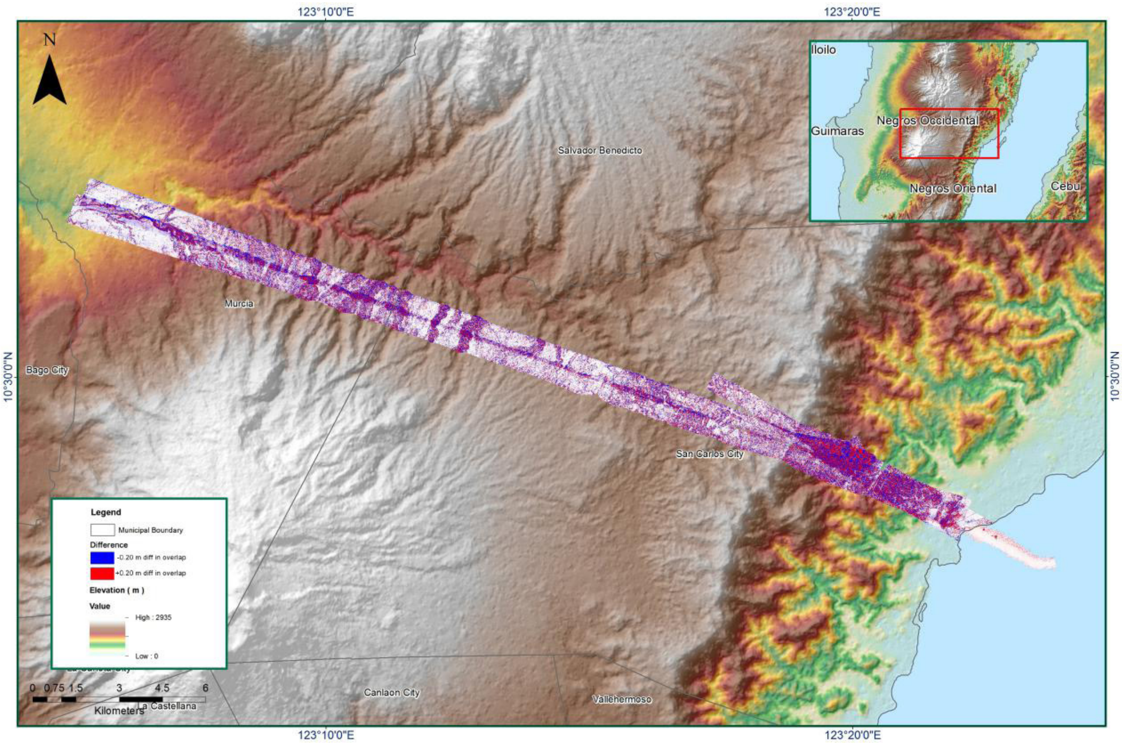


Figure A-8.35 Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Blk45A

Flight Area	Negros Occidental Reflights
Mission Name	**Blk45A**
Inclusive Flights	10007P
Range data size	19.6 GB
Base data size	5.71 MB
POS	263 MB
Image	53.26 GB
Transfer date	November 3, 2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.97
RMSE for East Position (<4.0 cm)	1.41
RMSE for Down Position (<8.0 cm)	5.68
Boresight correction stdev (<0.001deg)	0.000210
IMU attitude correction stdev (<0.001deg)	0.000353
GPS position stdev (<0.01m)	0.0011
Minimum % overlap (>25)	36.86
Ave point cloud density per sq.m. (>2.0)	2.40
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	67
Maximum Height	118.27
Minimum Height	37.33
Classification (# of points)	
Ground	49,519,964
Low vegetation	43,589,766
Medium vegetation	43,792,628
High vegetation	23,060,503
Building	3,937,267
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Marie Denise Bueno

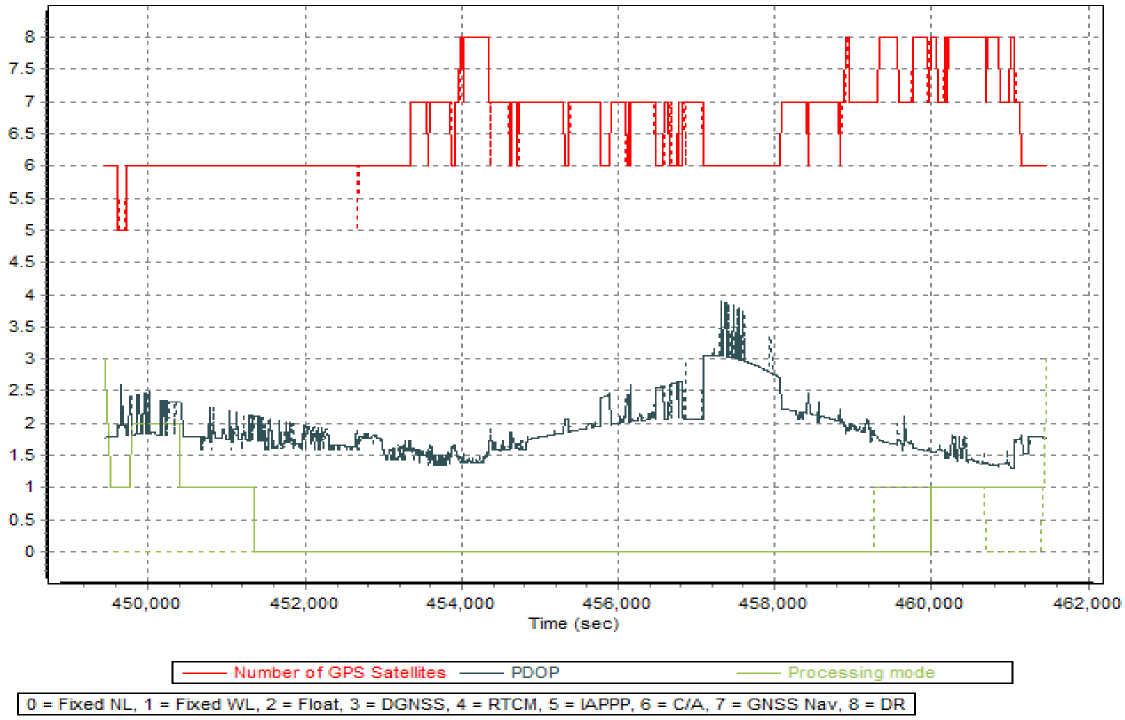


Figure A-8.36. Solution Status

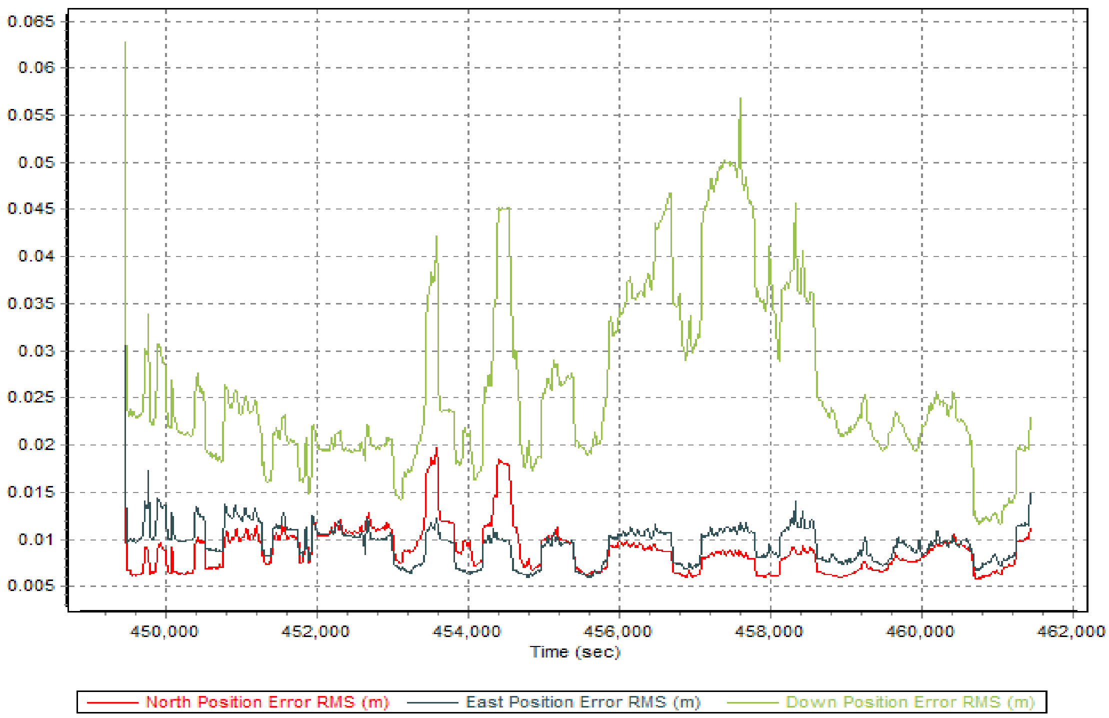


Figure A-8.37. Smoothed Performance Metric Parameters

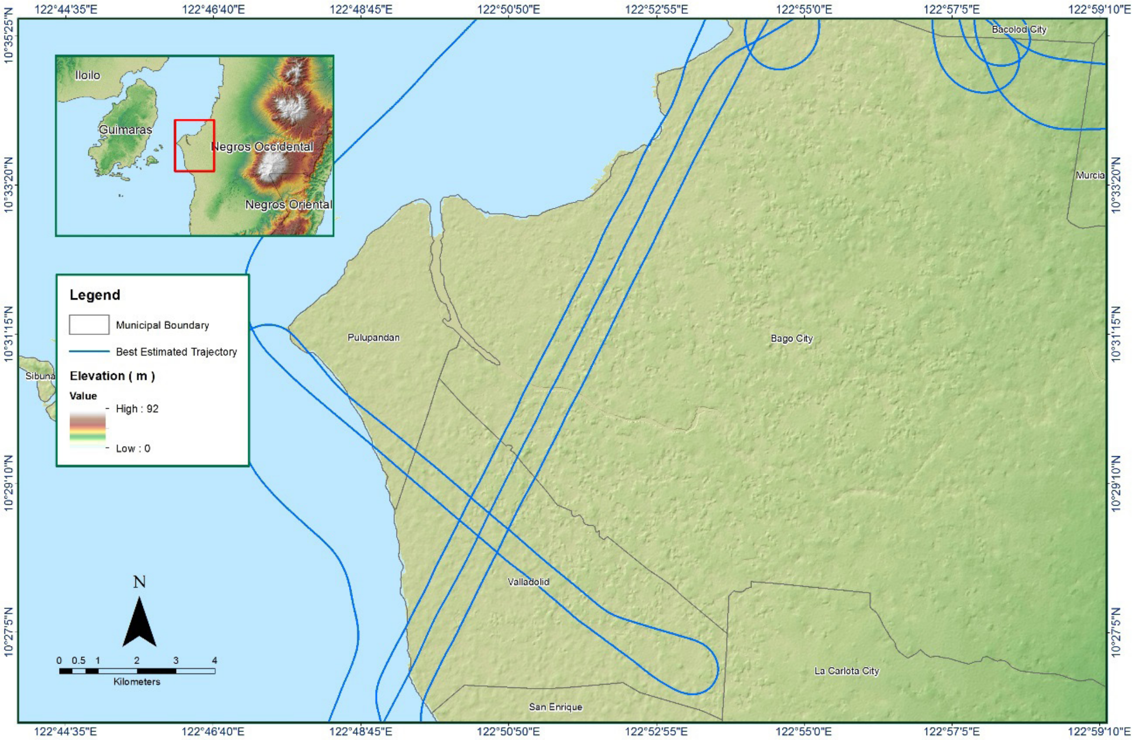


Figure A-8.38. Best estimate trajectory

Figure A-8.39. Coverage of LiDAR data

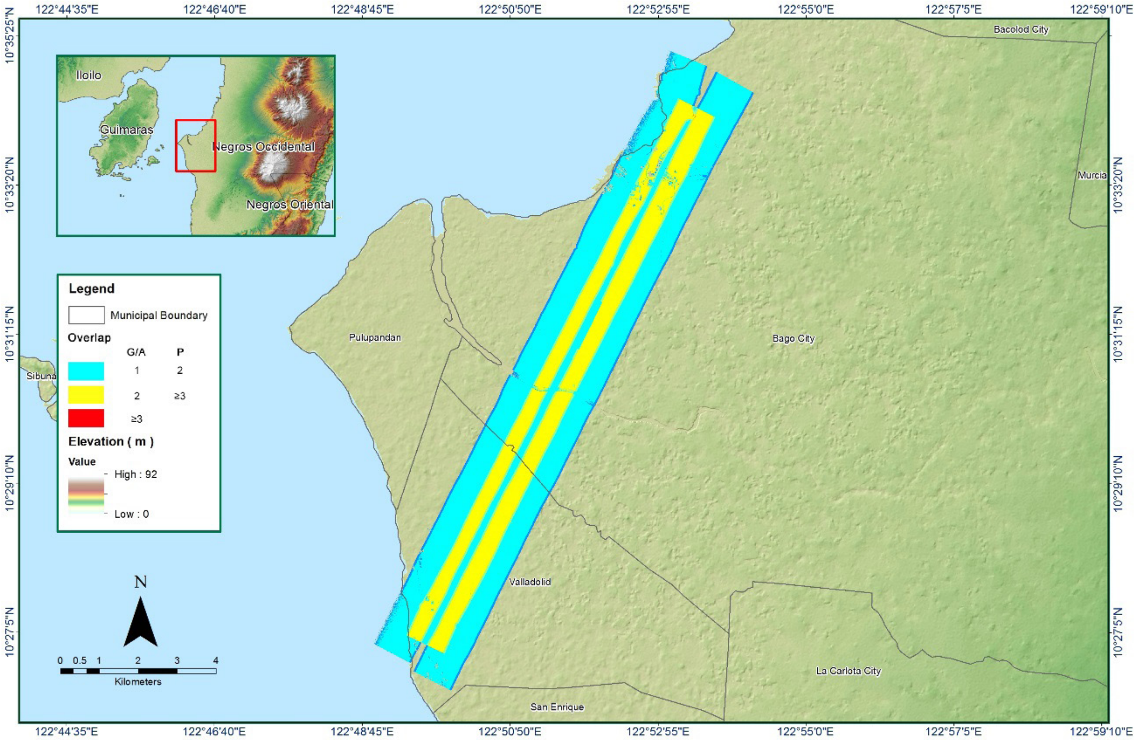


Figure A-8.40. Image of data overlaps

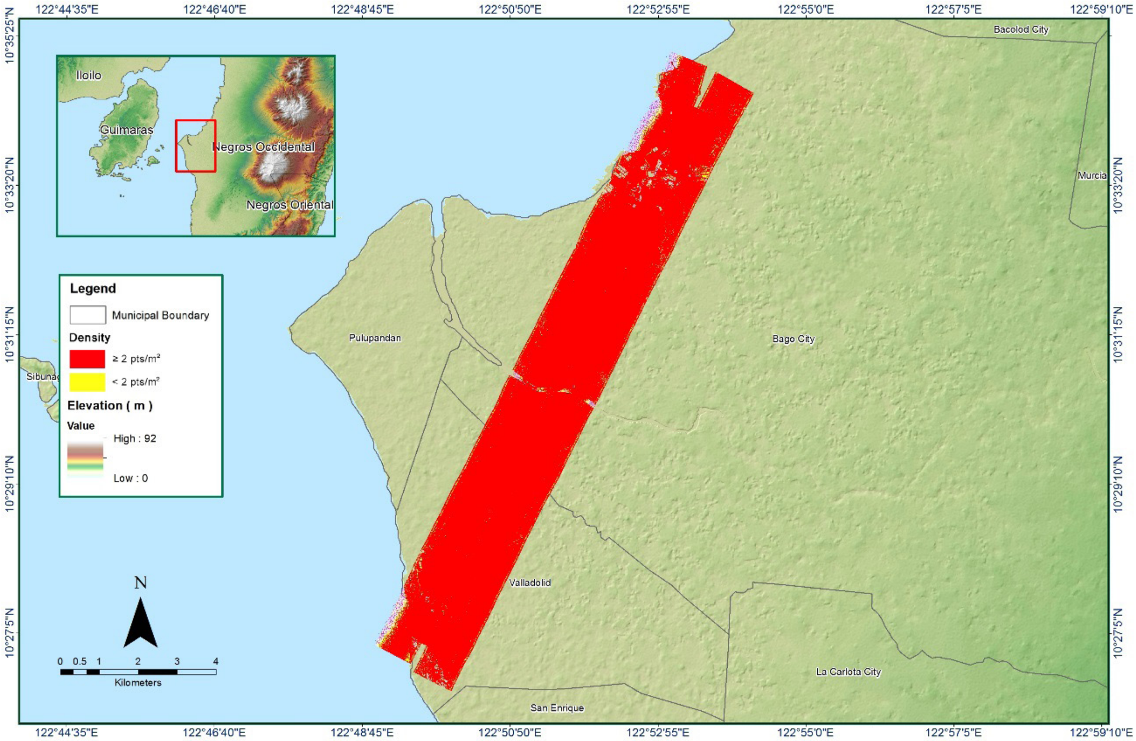


Figure A-8.41. Density of merged LiDAR data

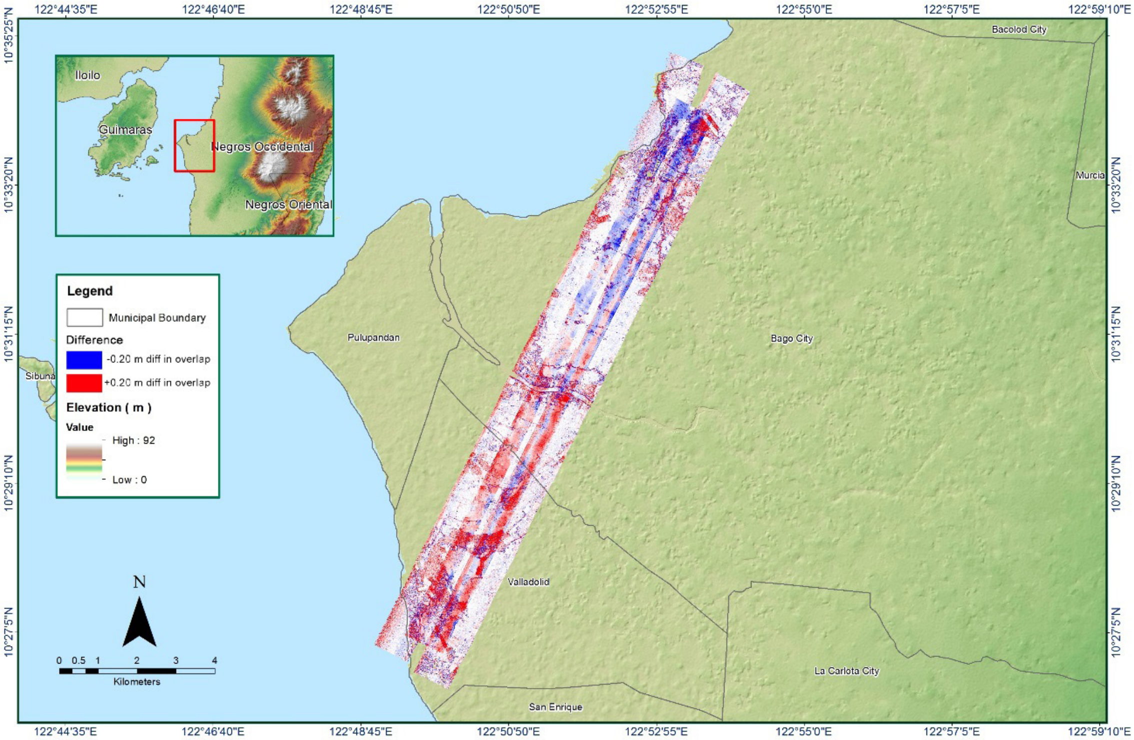


Figure A-8.42. Elevation difference between flight lines

Table A-8.7 Mission Summary Report for Block 45A

Flight Area	Bacolod
Mission Name	**Block 45A**
Inclusive Flights	8473AC
Range data size	4.59 GB
Base data size	64.6 MB
POS data size	206 MB
Base data size	64.6
Image	5.45
Transfer date	May 20, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.118
RMSE for East Position (<4.0 cm)	1.774
RMSE for Down Position (<8.0 cm)	4.038
Boresight correction stdev (<0.001deg)	0.000713
IMU attitude correction stdev (<0.001deg)	0.001675
GPS position stdev (<0.01m)	0.0112
Minimum % overlap (>25)	31.27
Ave point cloud density per sq.m. (>2.0)	3.27
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	19
Maximum Height	115.22
Minimum Height	67.45
Classification (# of points)	
Ground	10,830,784
Low vegetation	17,591,457
Medium vegetation	7,293,519
High vegetation	4,173,122
Building	410,383
Orthophoto	None
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga, Jr., Engr. Elainne Lopez

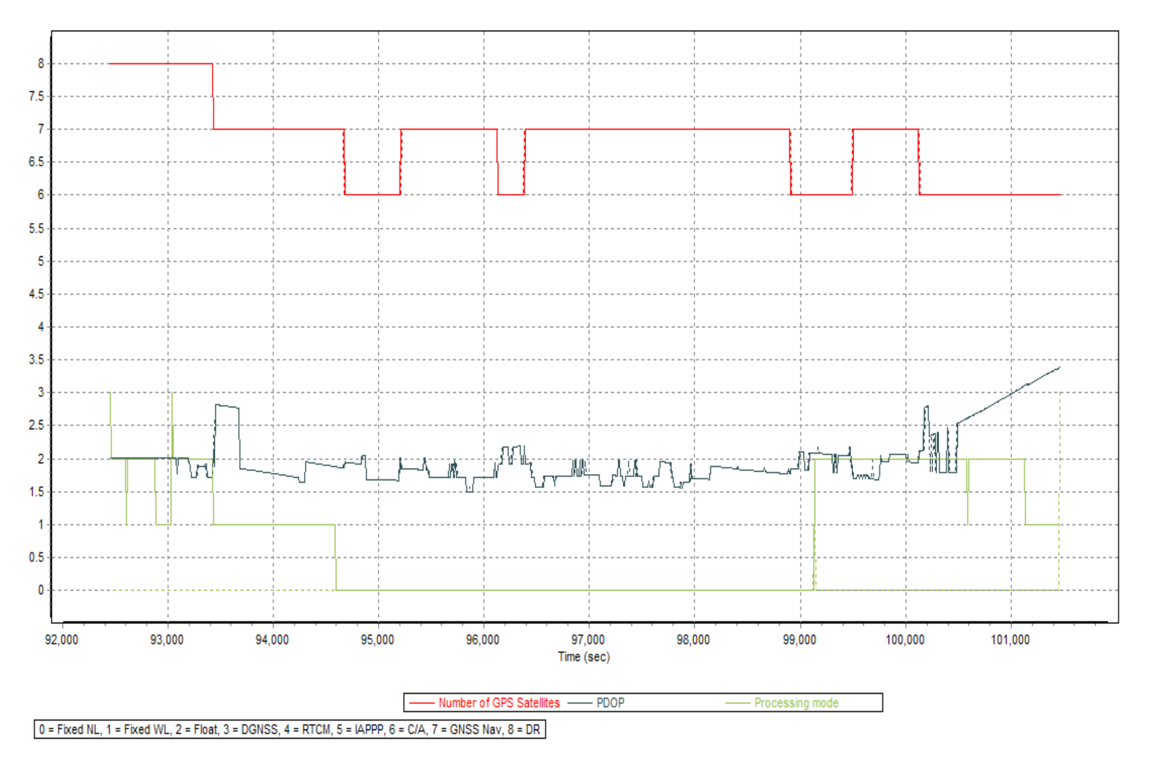


Figure A-8.43. Solution Status

Figure A-8.44. Smoothed Performance Metric Parameters

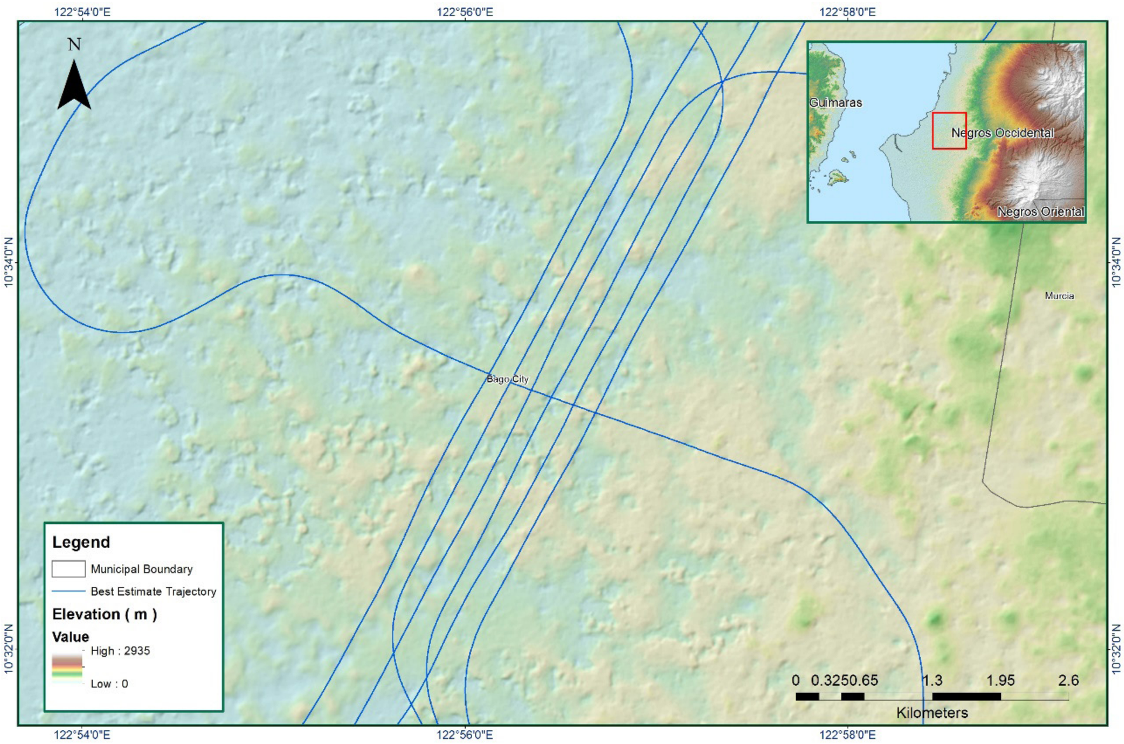


Figure A-8.45. Best Estimated Trajectory

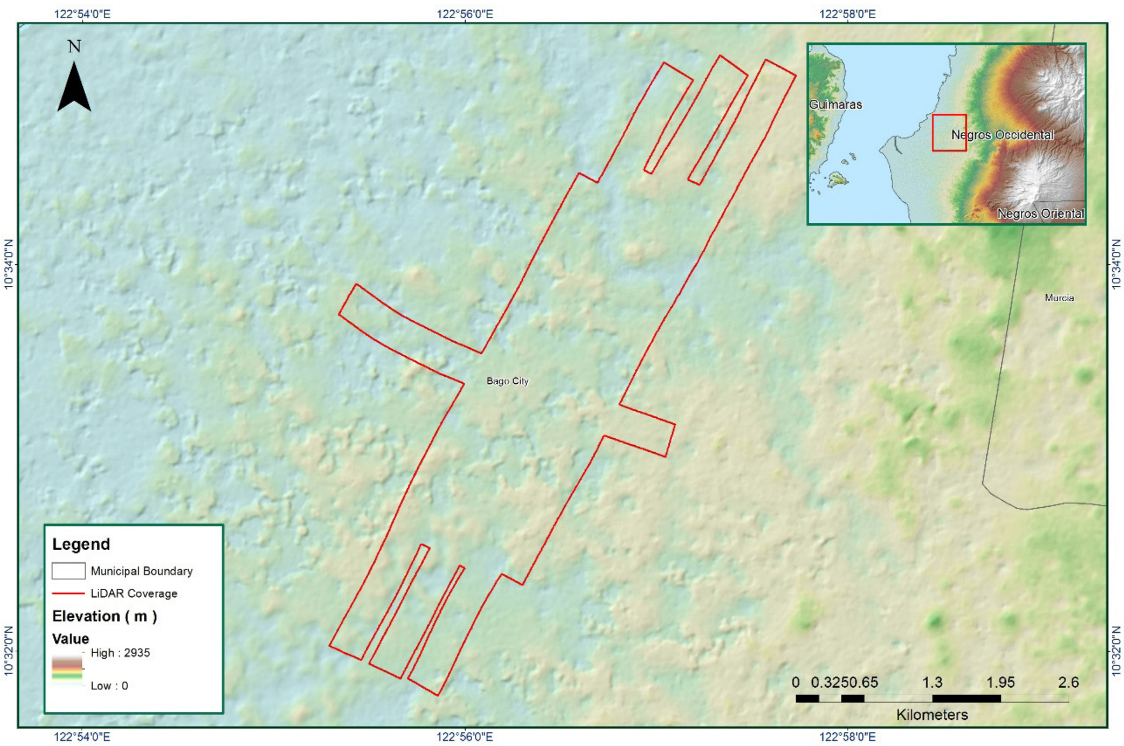


Figure A-8.46. Coverage of LiDAR Data

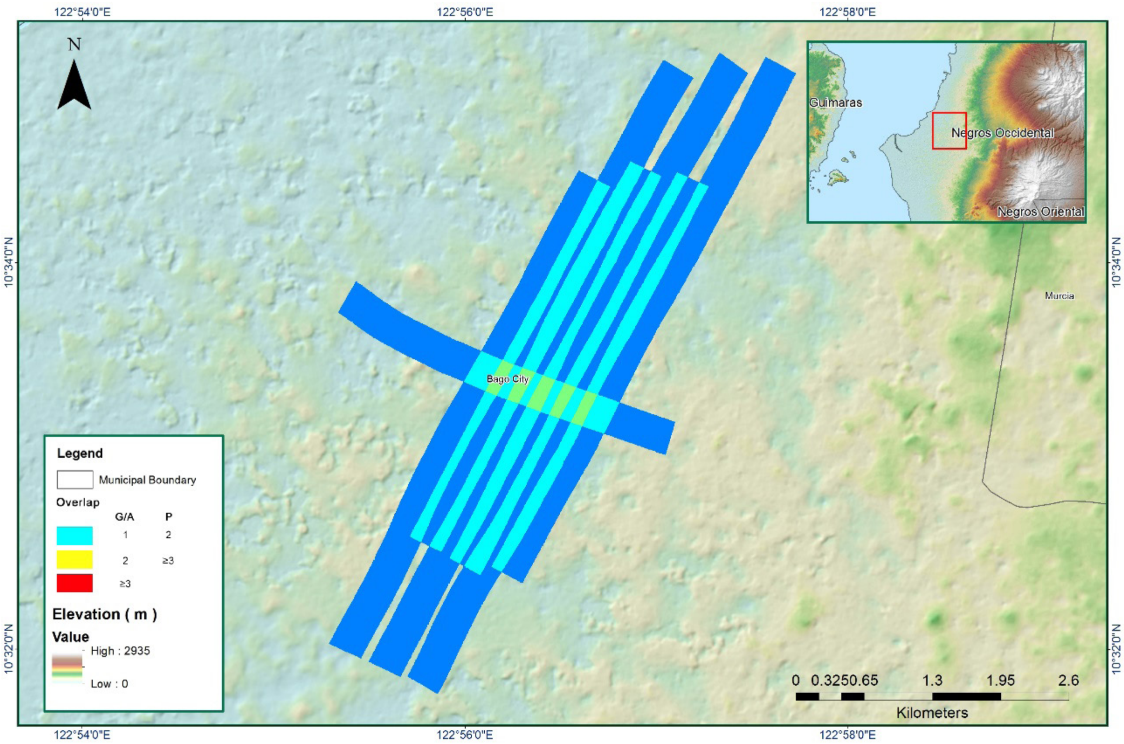


Figure A-8.47. Image of data overlap

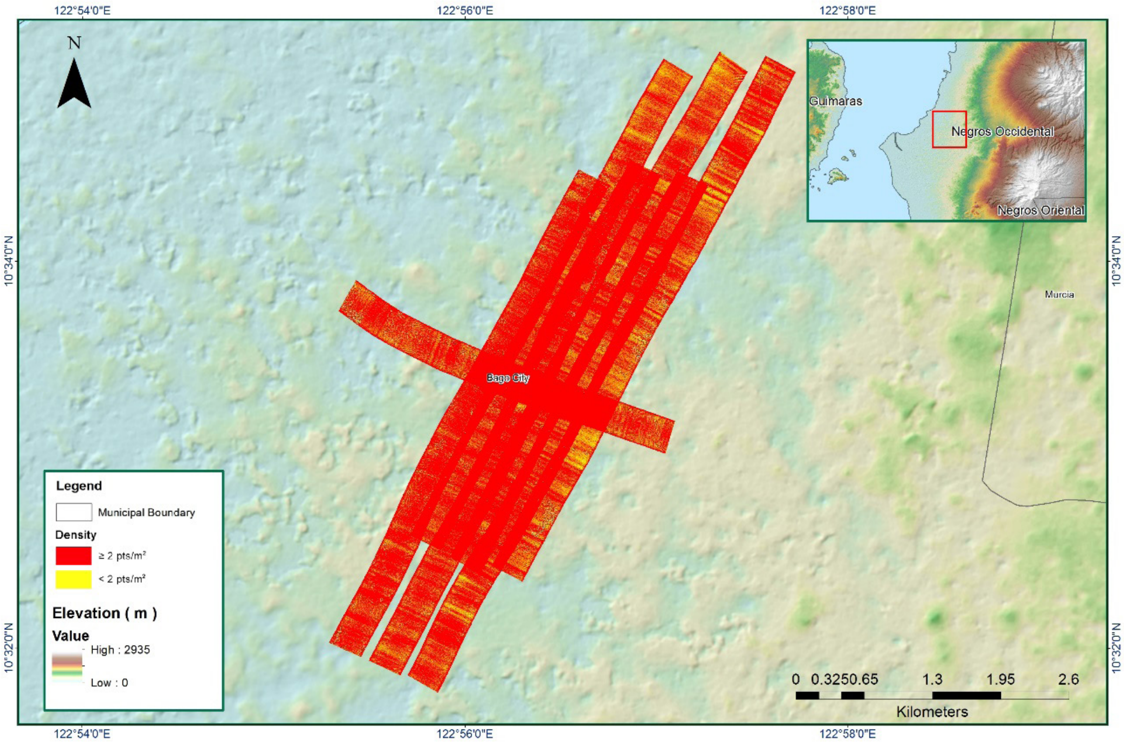


Figure A-8.48. Density map of merged LiDAR data

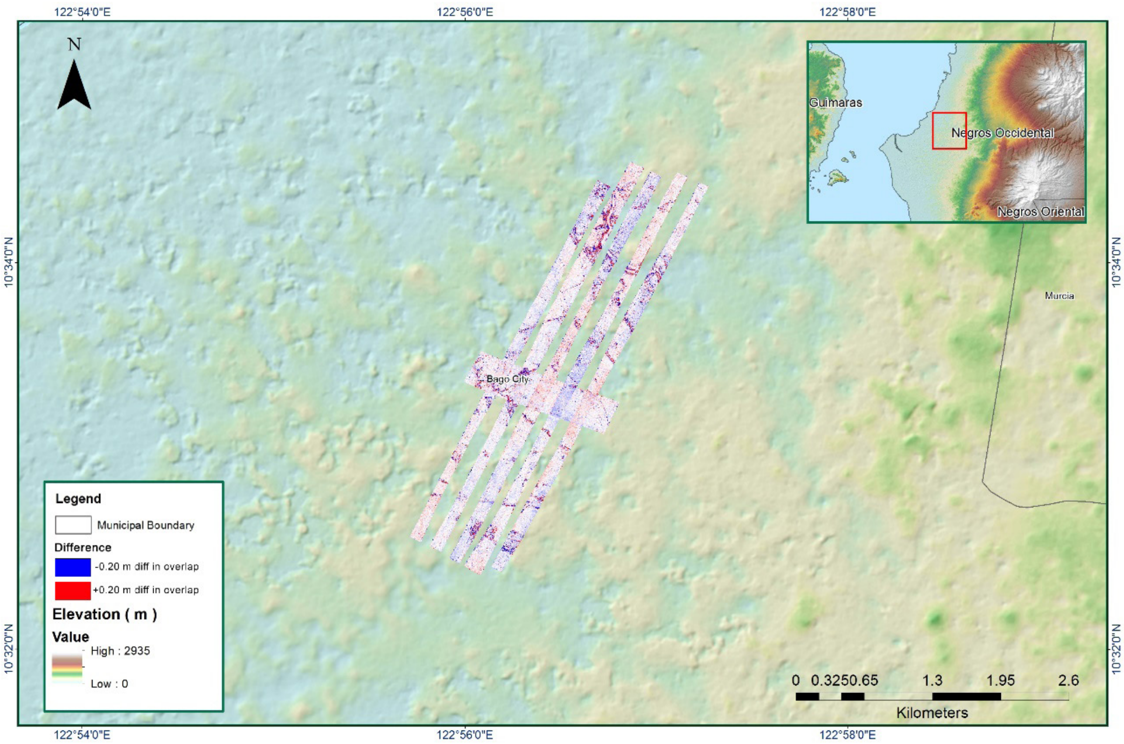


Figure A-8.49. Elevation difference between flight lines

Table A-8.8 Mission Summary Report for Blk43M

Flight Area	**Iloilo**
Mission Name	**Blk43M**
Inclusive Flights	2579P, 2581P
Range data size	40.5 GB
Base data size	32.4 MB
POS	496 MB
Image	62.7 GB
Transfer date	March 23, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.94
RMSE for East Position (<4.0 cm)	1.71
RMSE for Down Position (<8.0 cm)	3.39
Boresight correction stdev (<0.001deg)	0.000212
IMU attitude correction stdev (<0.001deg)	0.023476
GPS position stdev (<0.01m)	0.016
Minimum % overlap (>25)	27.31%
Ave point cloud density per sq.m. (>2.0)	3.32
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	315
Maximum Height	311.08 m
Minimum Height	58.29 m
Classification (# of points)	
Ground	205,591,420
Low vegetation	152,352,437
Medium vegetation	260,225,887
High vegetation	181,450,405
Building	5,394,357
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Aljon Rie Araneta, Ryan James Nicholai Dizon

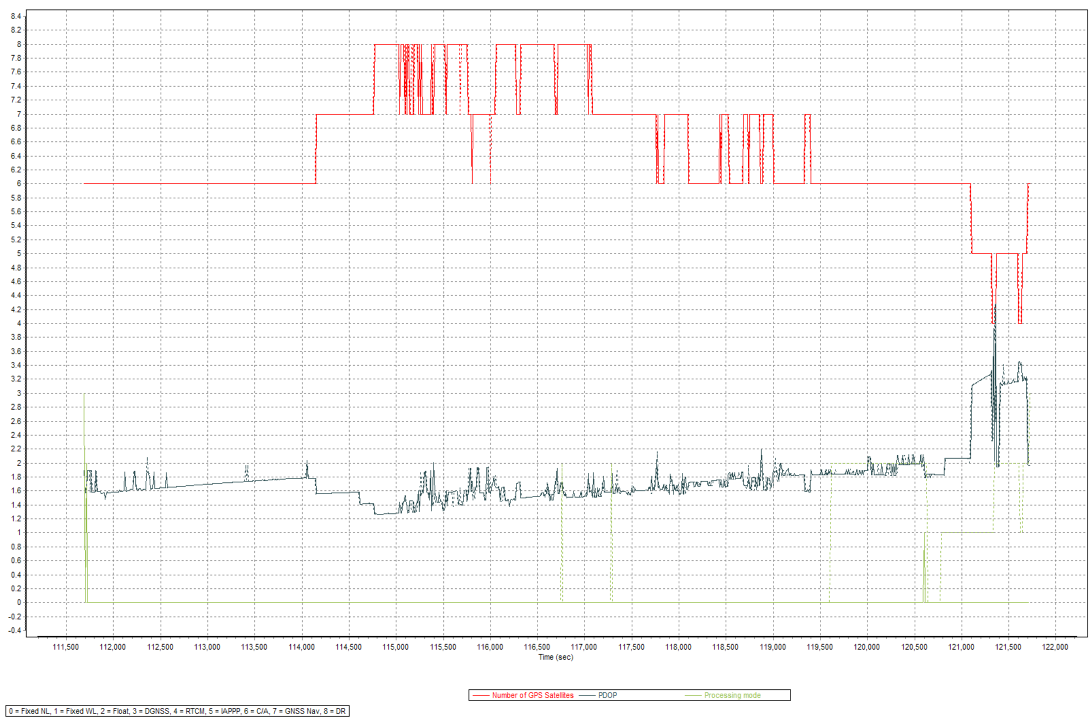


Figure A-8.50 Solution Status

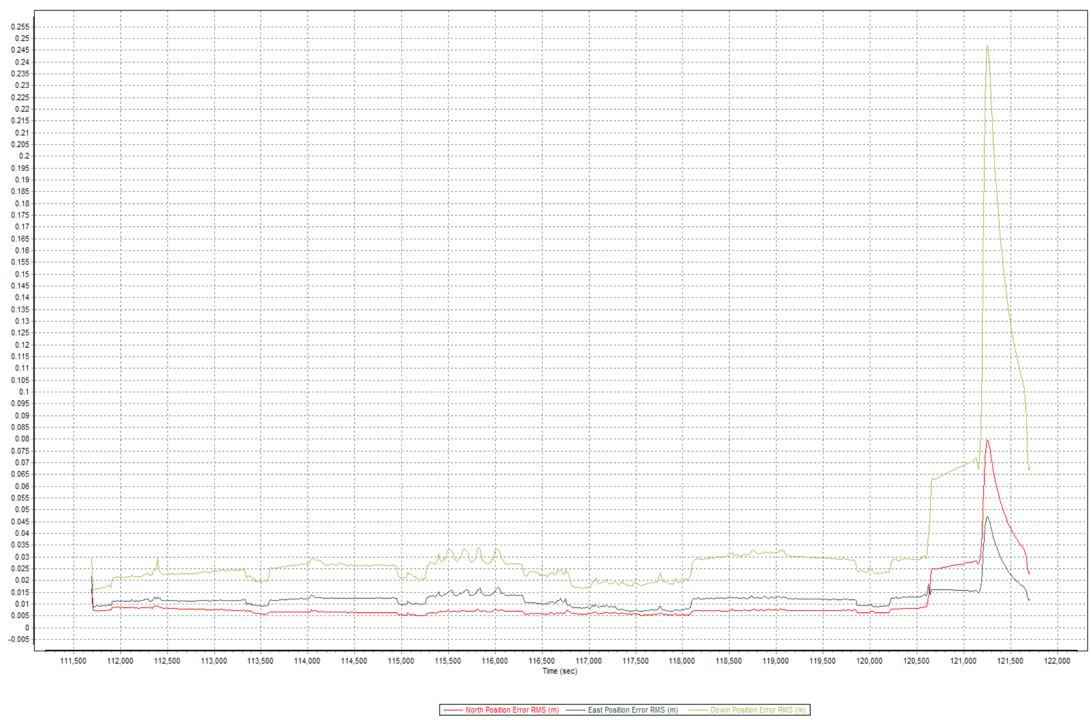


Figure A-8.51 Smoothed Performance Metric Parameters

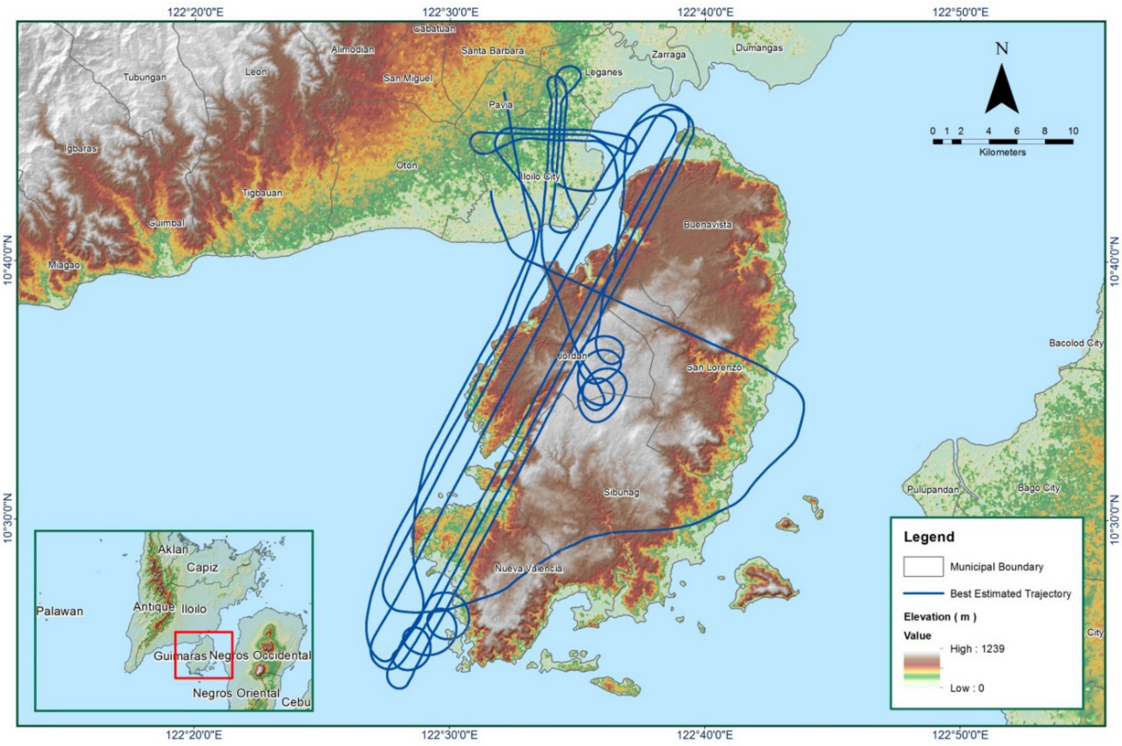


Figure A-8.52 Best Estimated Trajectory

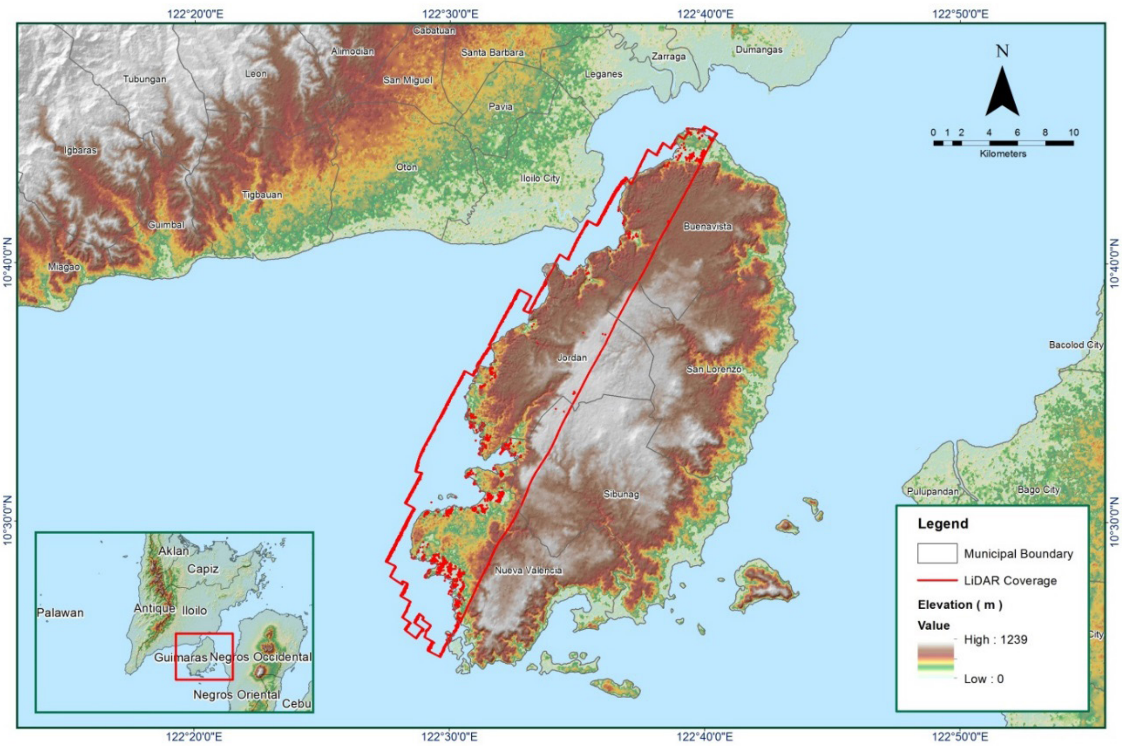


Figure A-8.53 Coverage of LiDAR data

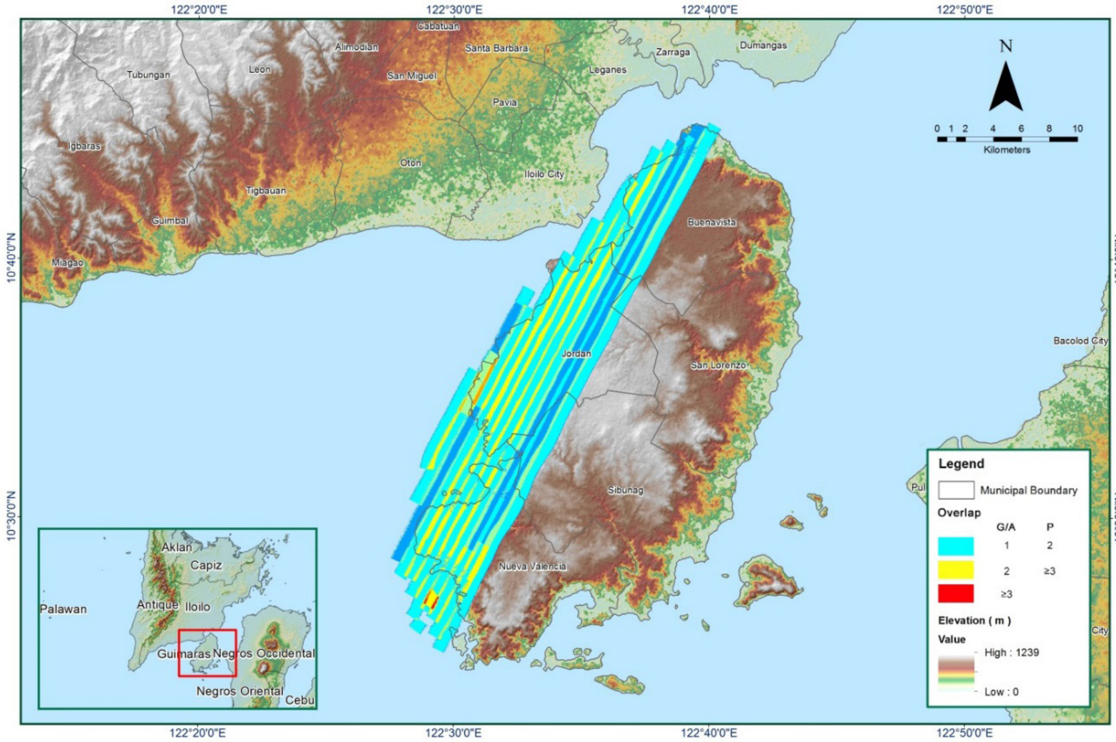


Figure A-8.54 Image of data overlap

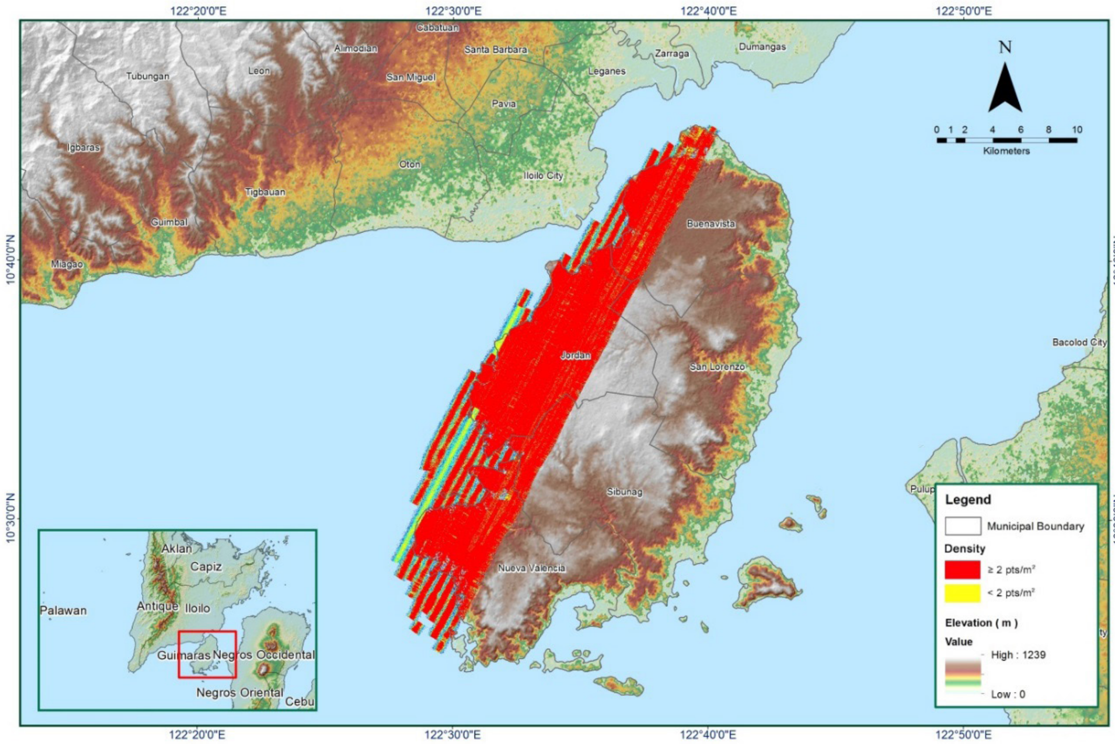


Figure A-8.55 Density map of merged LiDAR data

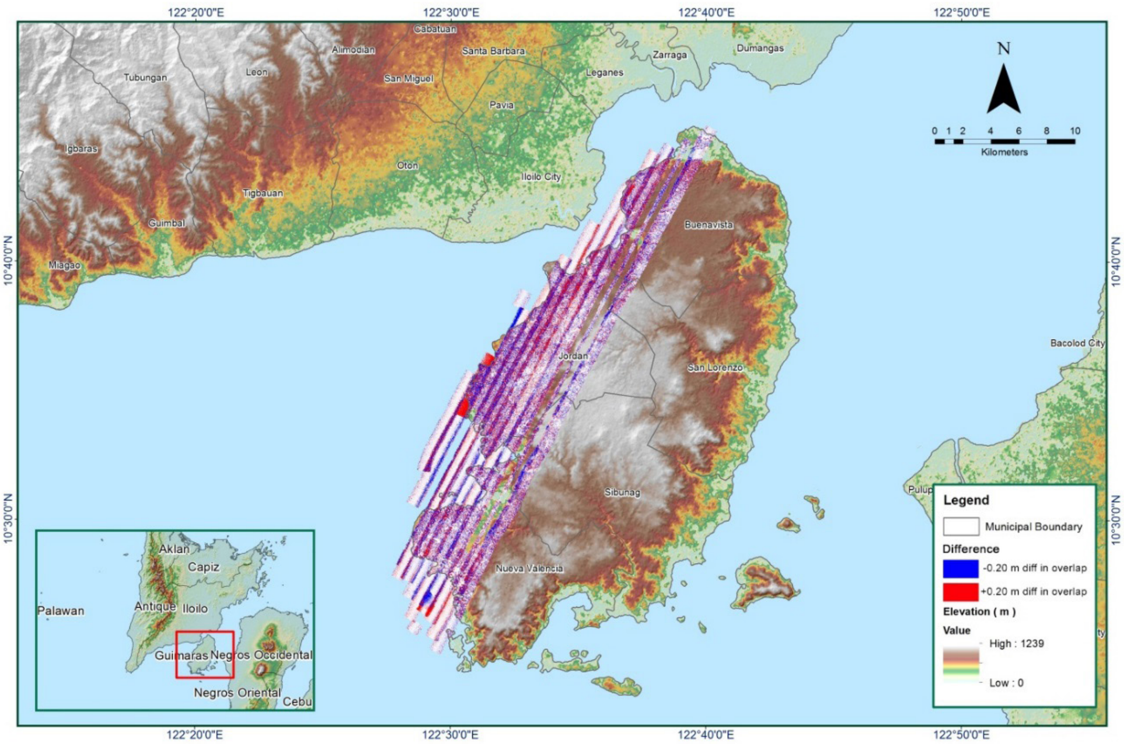


Figure A-8.56 Elevation difference between flight lines

Table A-8.9 Mission Summary Report for Blk43N

Flight Area	**Iloilo**
Mission Name	**Blk43N**
Inclusive Flights	2550G, 2581P, 2597P, 2558G
Range data size	88.9 GB
Base data size	47.8 MB
POS	970 MB
Image	154.1 GB
Transfer date	March 23, 2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.76
RMSE for East Position (<4.0 cm)	2.07
RMSE for Down Position (<8.0 cm)	4.7
Boresight correction stdev (<0.001deg)	0.001616
IMU attitude correction stdev (<0.001deg)	0.144619
GPS position stdev (<0.01m)	0.0206
Minimum % overlap (>25)	34.12%
Ave point cloud density per sq.m. (>2.0)	3.48
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	272
Maximum Height	343.58 m
Minimum Height	59.42 m
Classification (# of points)	
Ground	252,227,020
Low vegetation	171,249,907
Medium vegetation	237,449,605
High vegetation	191,458,839
Building	3,728,768
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Edgardo Gubatanga, Jr., Engr. Melissa Fernandez

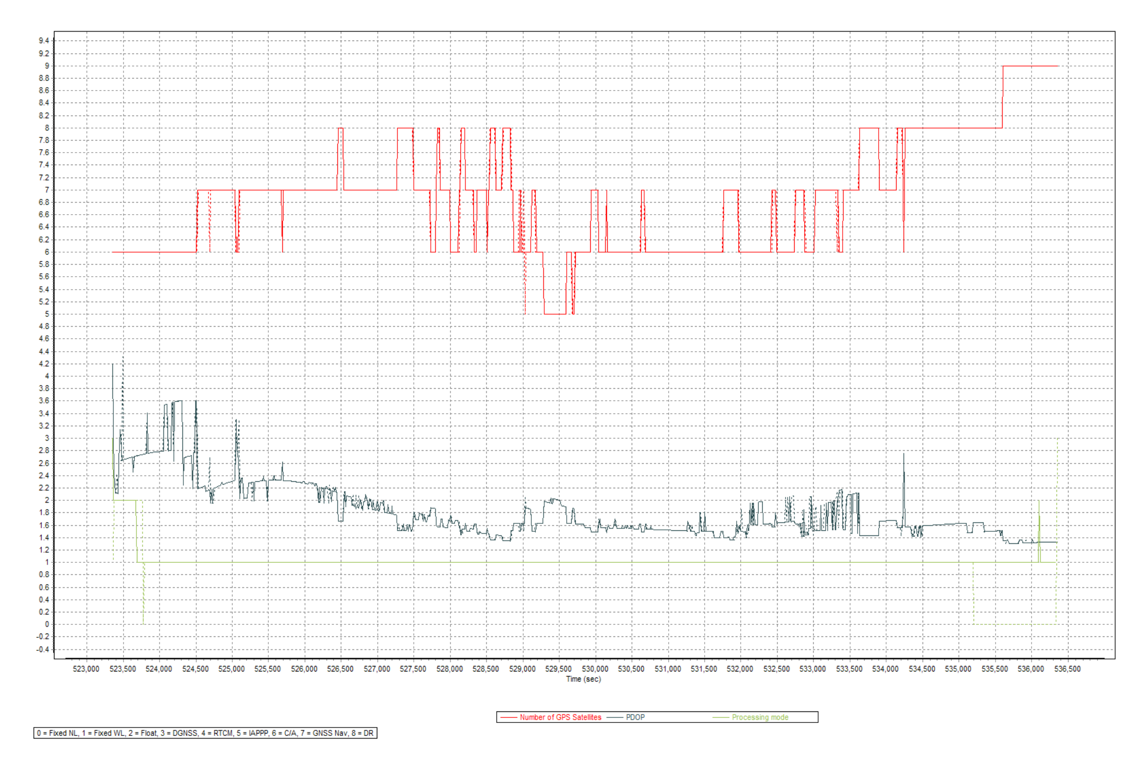


Figure A-8.57 Solution Status

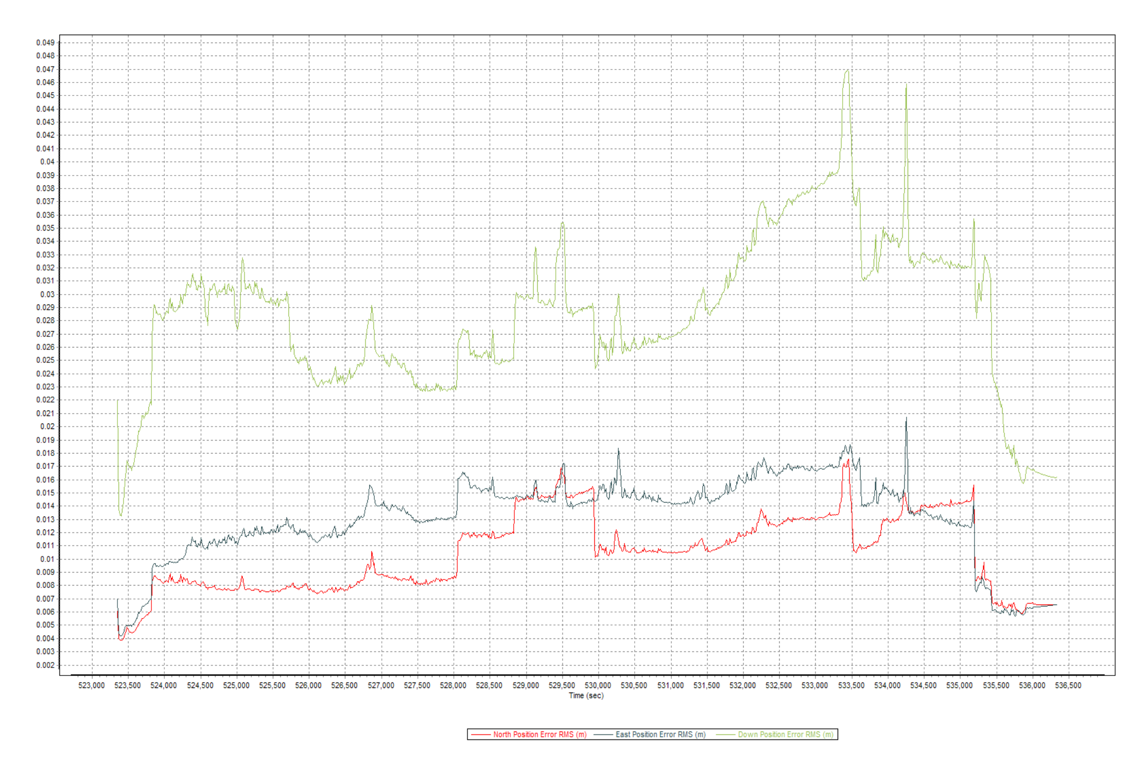


Figure A-8.58 Smoothed Performance Metric Parameters

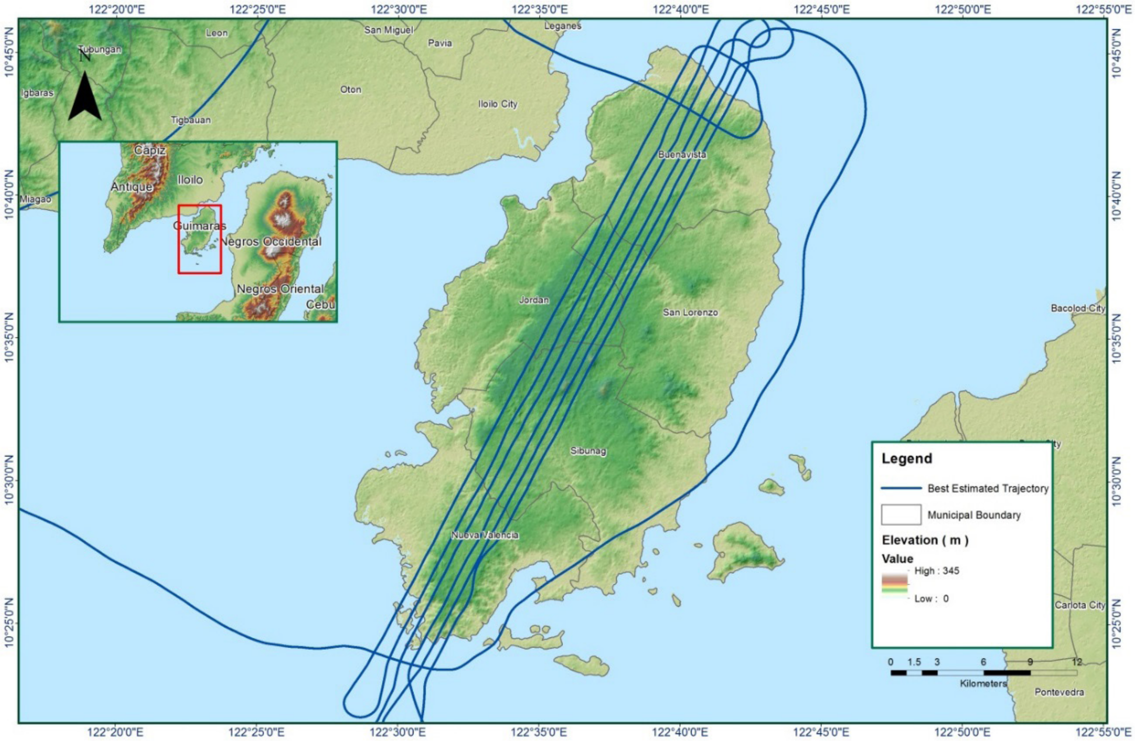


Figure A-8.59 Best Estimated Trajectory

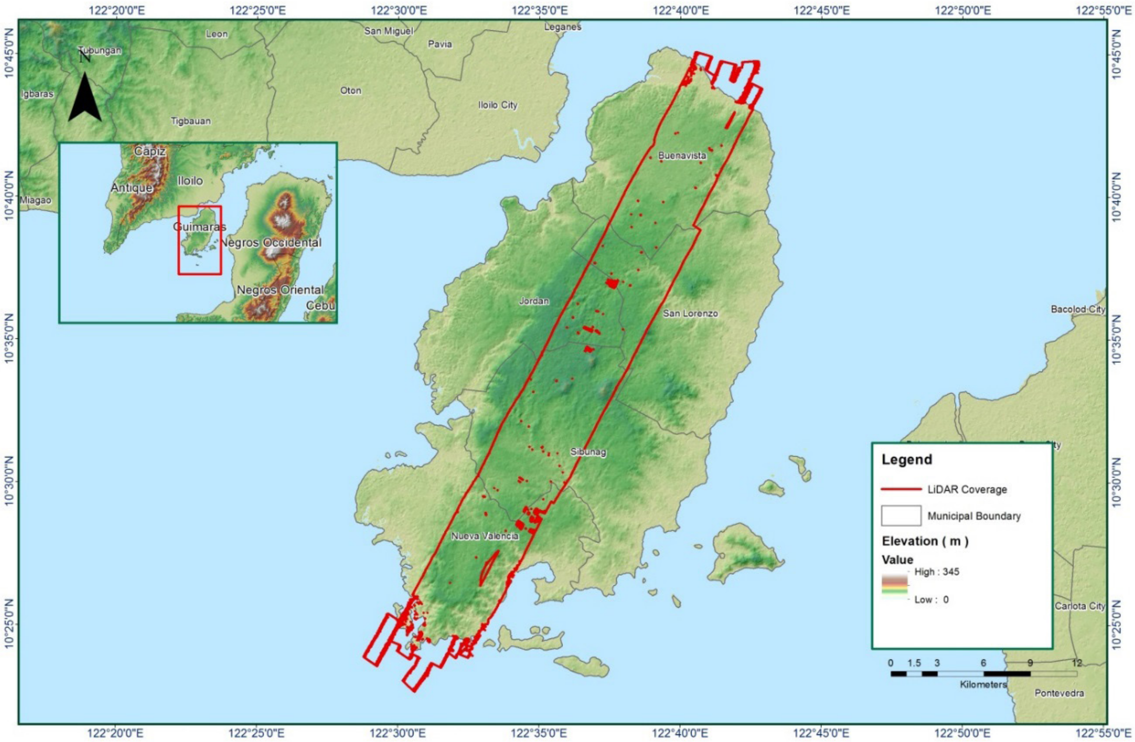


Figure A-8.60 Coverage of LiDAR data

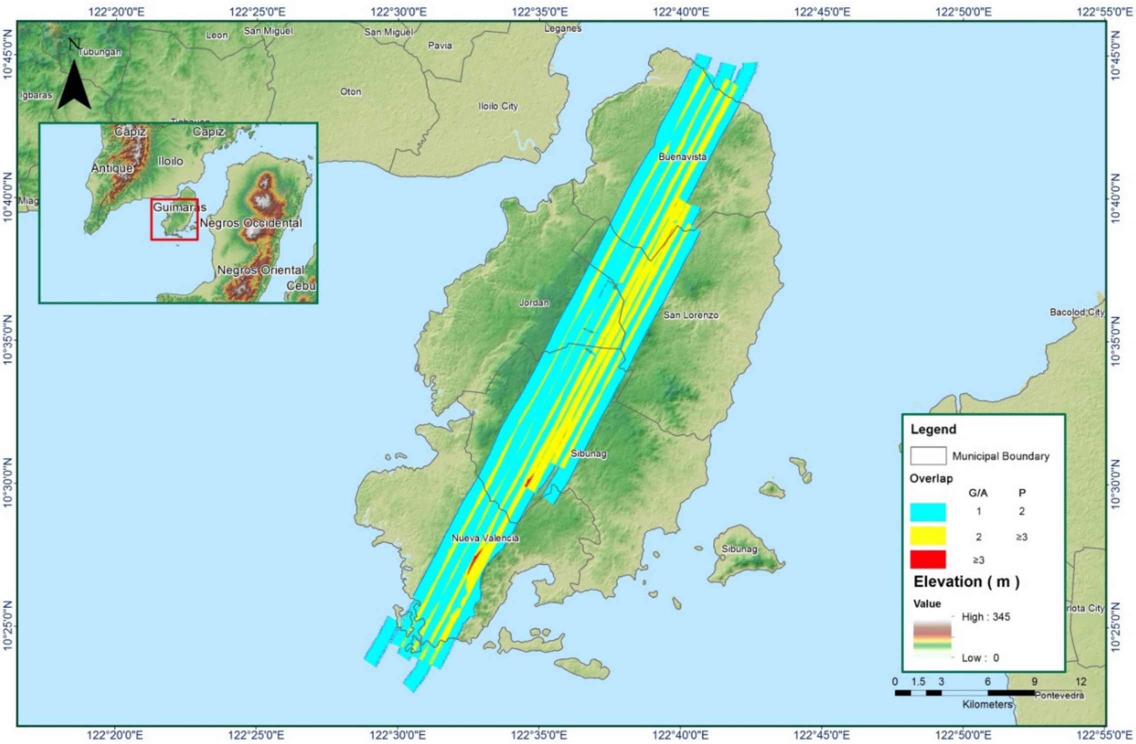


Figure A-8.61 Image of data overlap

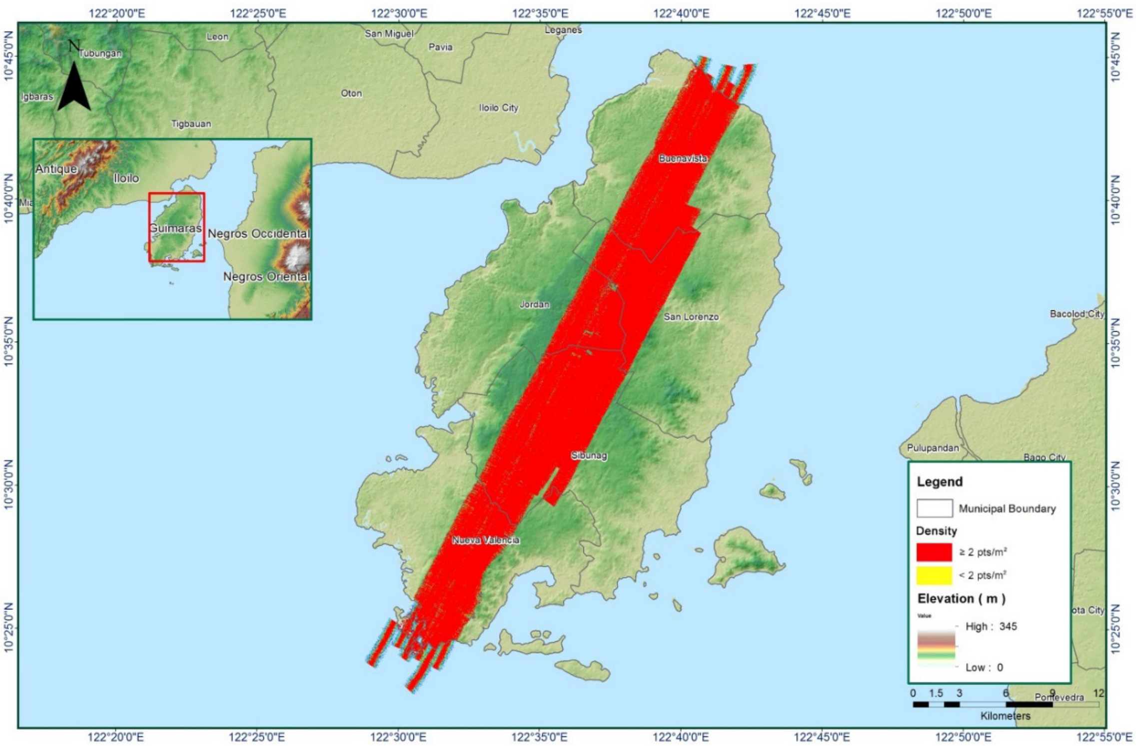


Figure A-8.62 Density map of merged LiDAR data

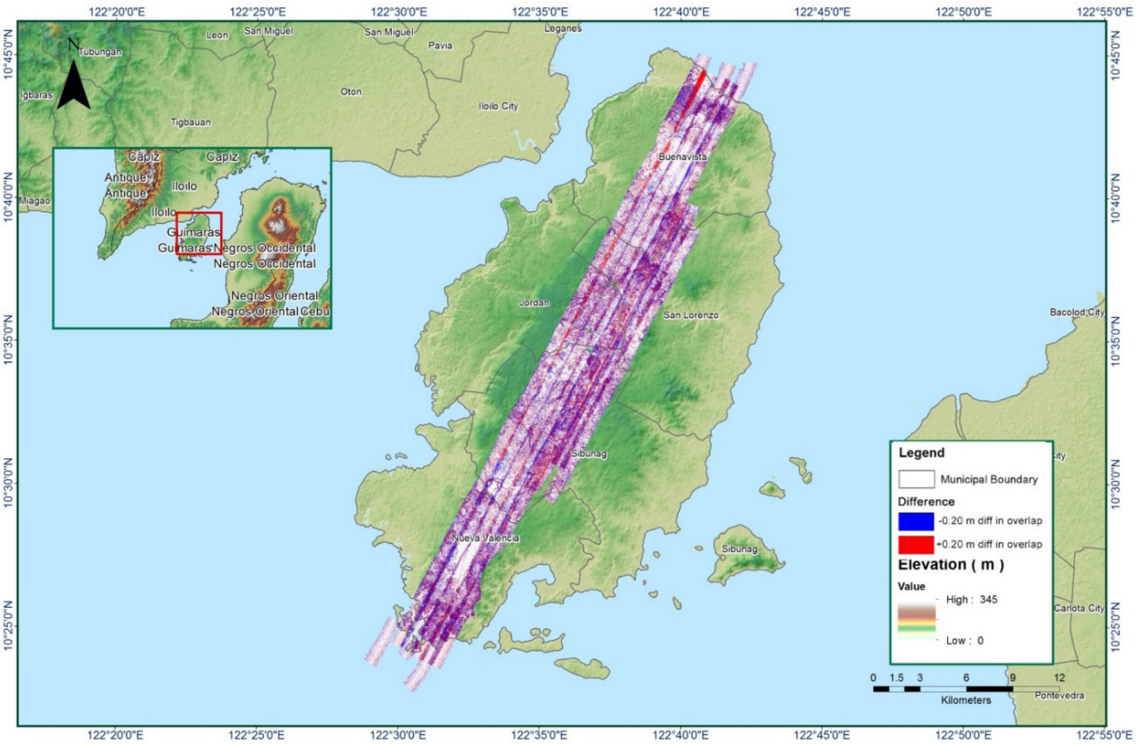


Figure A-8.63 Elevation difference between flight lines

Table A-8.10 Mission Summary Report for Blk43N_additional1

Flight Area	Iloilo
Mission Name	**Blk43N_additional1**
Inclusive Flights	2550G
Range data size	19.2 GB
Base data size	5.6 MB
POS	209 MB
Image	39.7 GB
Transfer date	March 23, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.74
RMSE for East Position (<4.0 cm)	7.22
RMSE for Down Position (<8.0 cm)	16.04
Boresight correction stdev (<0.001deg)	0.001616
IMU attitude correction stdev (<0.001deg)	0.144619
GPS position stdev (<0.01m)	0.0206
Minimum % overlap (>25)	13.58%
Ave point cloud density per sq.m. (>2.0)	4.89
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	104
Maximum Height	326.42 m
Minimum Height	59.58 m
Classification (# of points)	
Ground	30,243,364
Low vegetation	33,328,197
Medium vegetation	59,938,903
High vegetation	87,510,529
Building	1,519,566
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Antonio Chua, Jr. , Engr. Melissa Fernandez

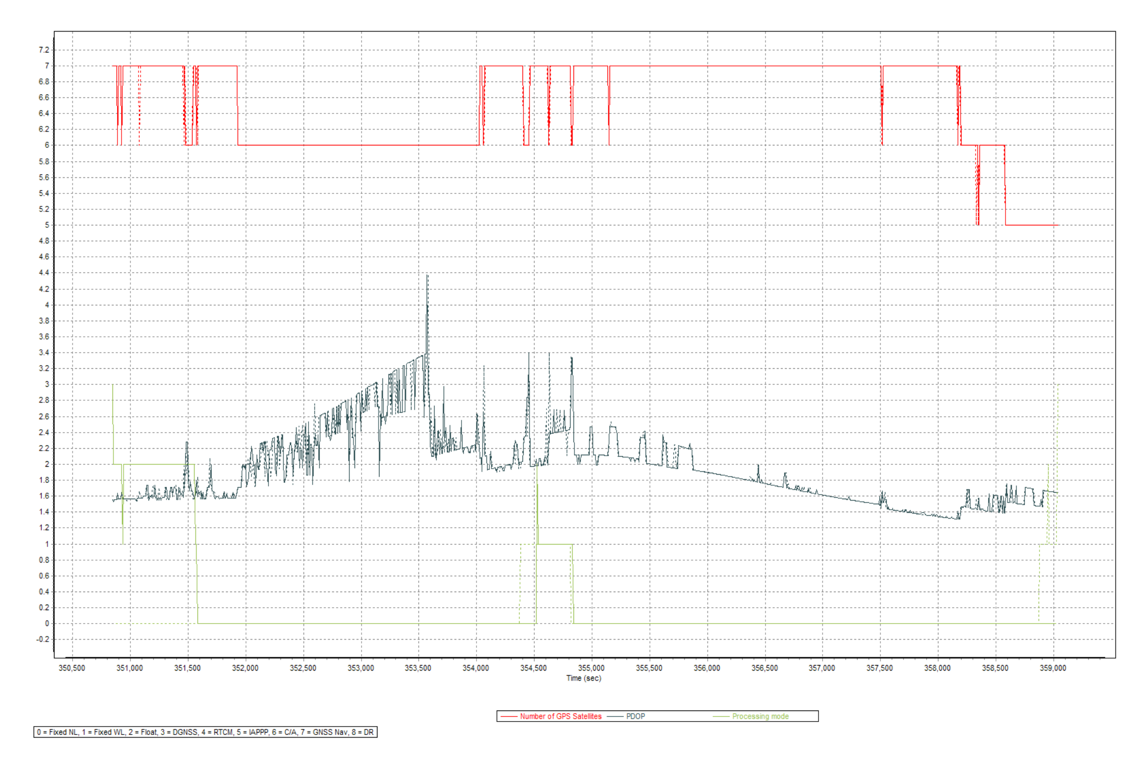


Figure A-8.64 Solution Status

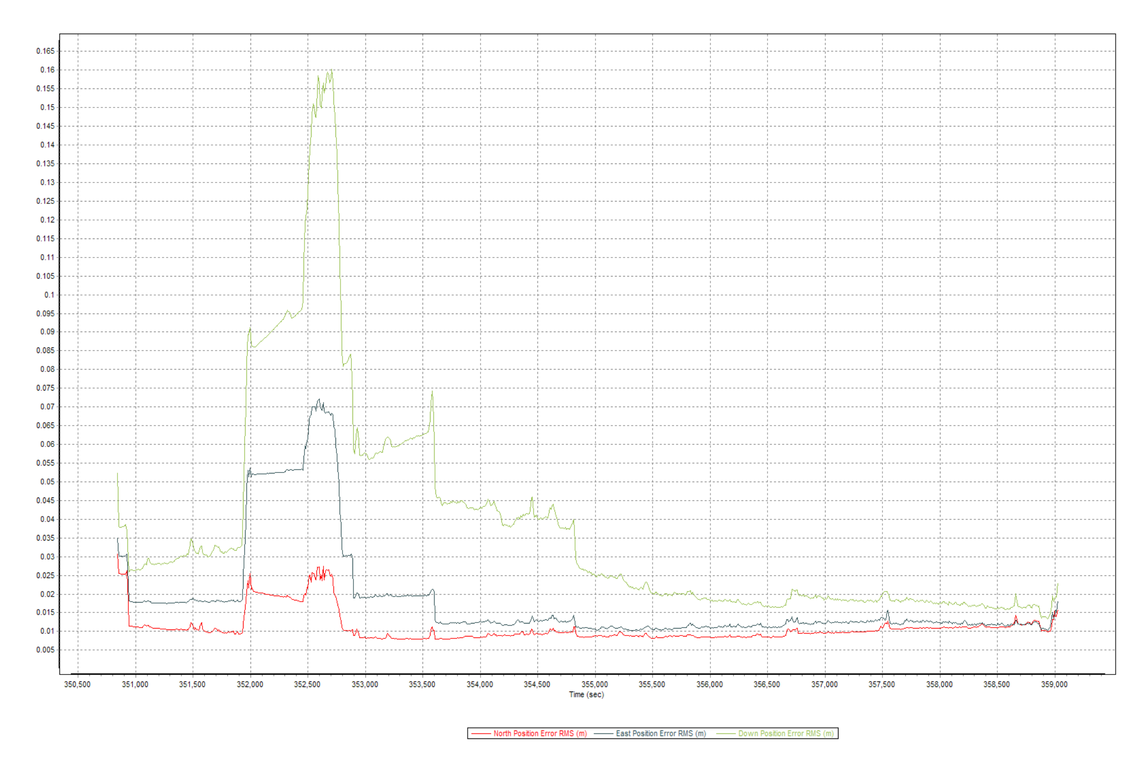


Figure A-8.65 Smoothed Performance Metric Parameters

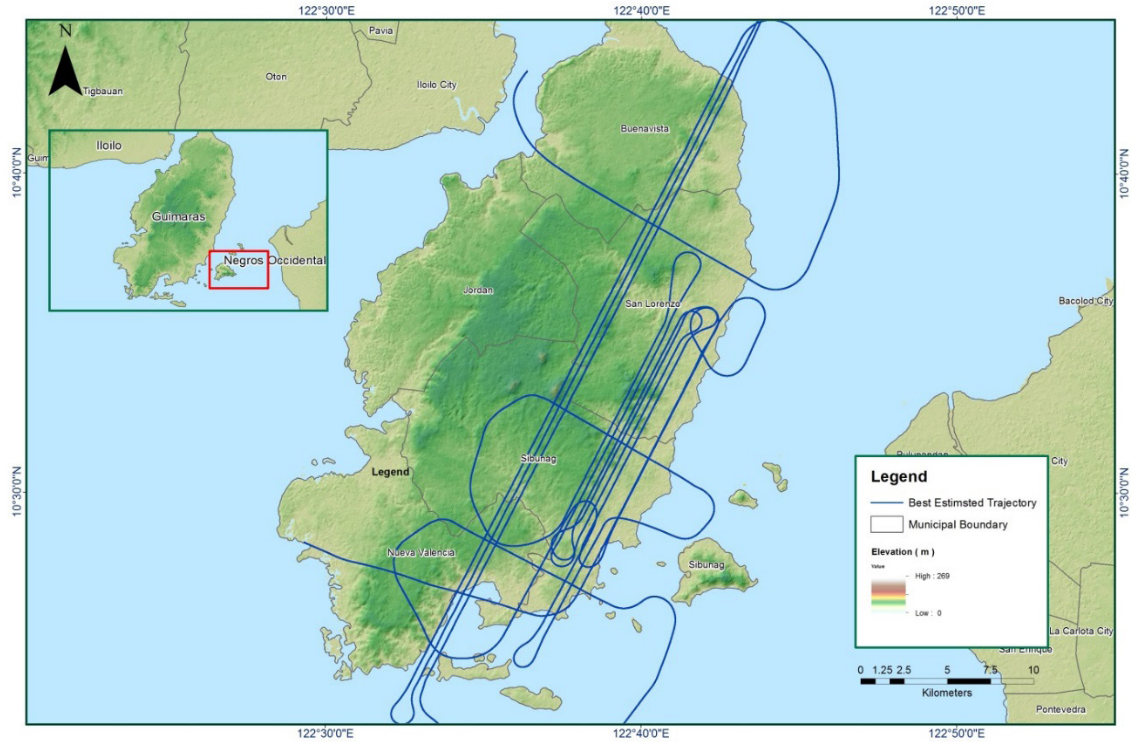


Figure A-8.66 Best Estimated Trajectory

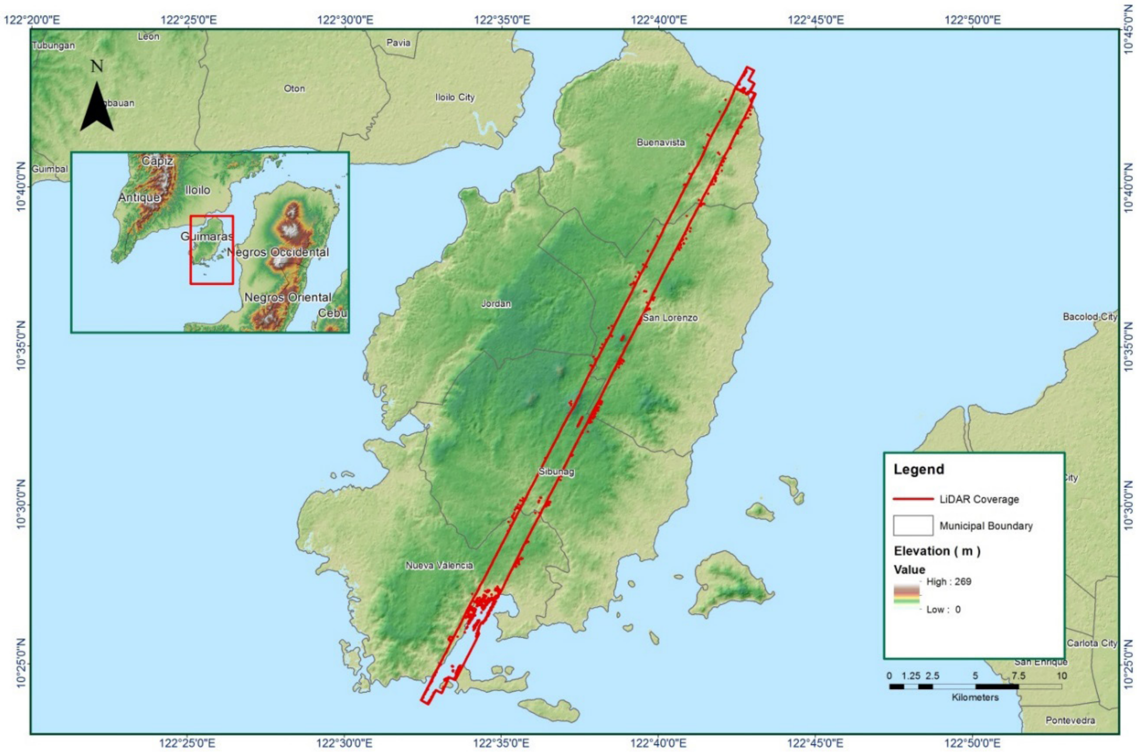


Figure A-8.67 Coverage of LiDAR data

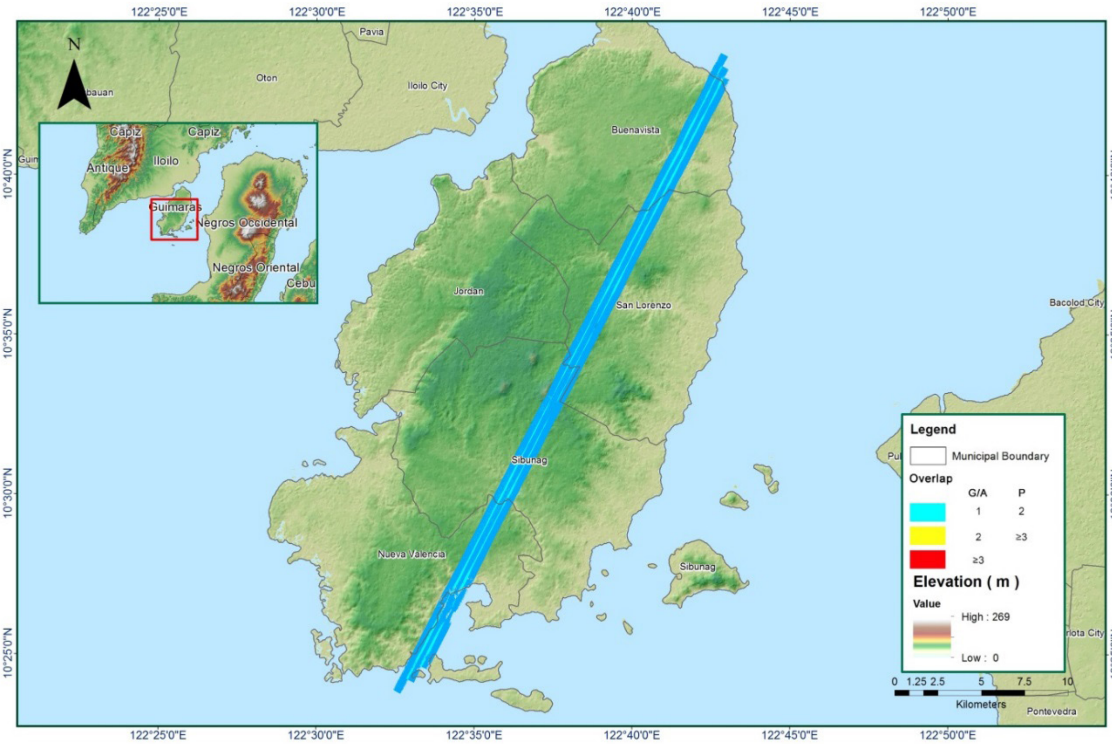


Figure A-8.68 Image of data overlap

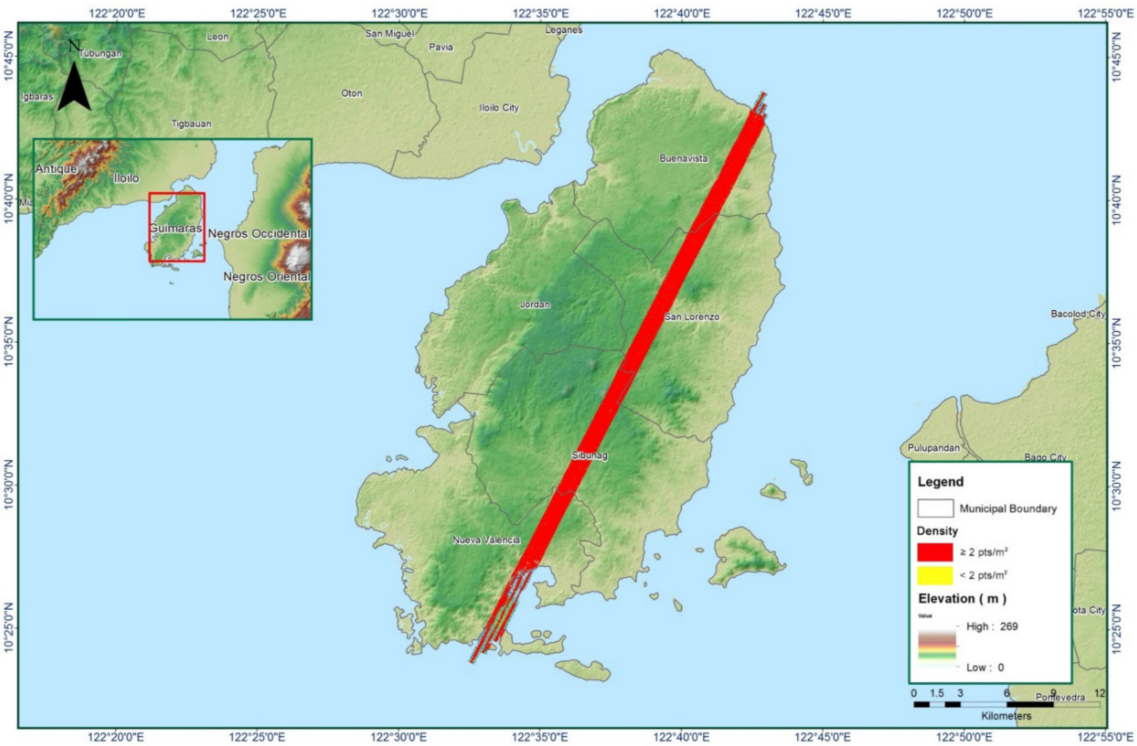


Figure A-8.69 Density map of merged LiDAR data

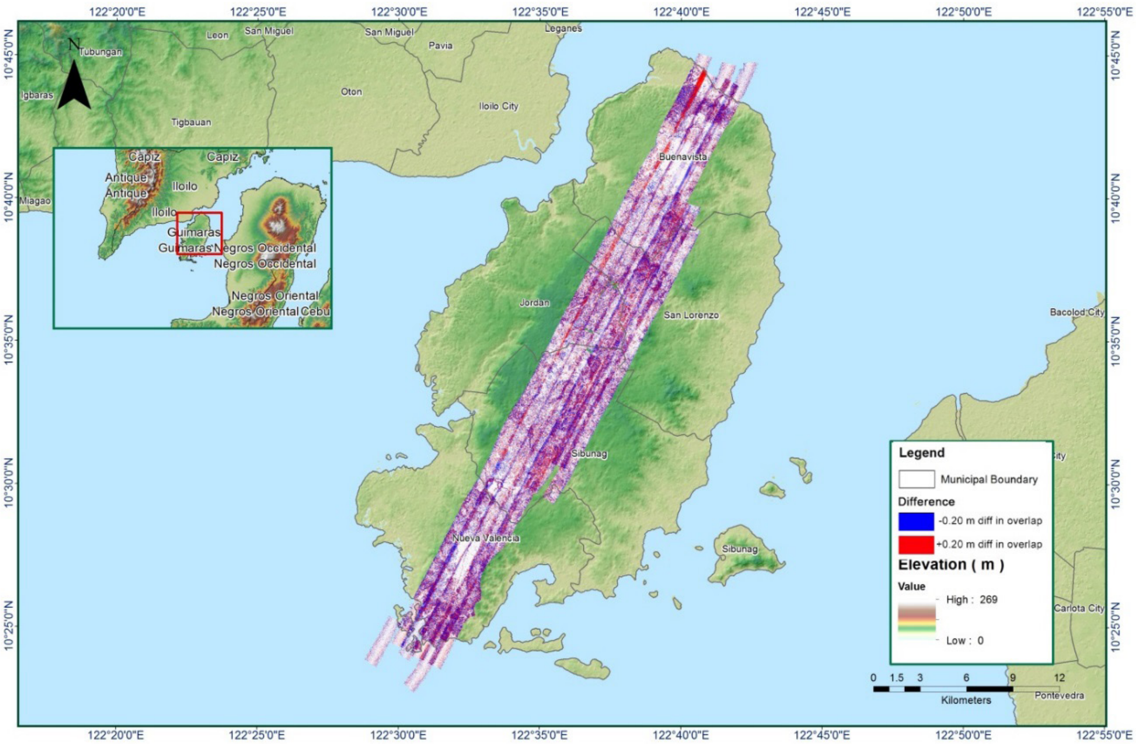


Figure A-8.70 Elevation difference between flight lines

Table A-8.11 Mission Summary Report for Blk43N_additional2

Flight Area	Iloilo
Mission Name	**Blk43N_additional2**
Inclusive Flights	2558G
Range data size	27.3 GB
Base data size	10.5 MB
POS	241 MB
Image	42.2 GB
Transfer date	March 23, 2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.62
RMSE for East Position (<4.0 cm)	1.74
RMSE for Down Position (<8.0 cm)	3.31
Boresight correction stdev (<0.001deg)	0.001616
IMU attitude correction stdev (<0.001deg)	0.144619
GPS position stdev (<0.01m)	0.0206
Minimum % overlap (>25)	11.24%
Ave point cloud density per sq.m. (>2.0)	4.06
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	122
Maximum Height	1069.45 m
Minimum Height	58.17 m
Classification (# of points)	
Ground	22,906,493
Low vegetation	9,393,779
Medium vegetation	45,525,551
High vegetation	72,172,036
Building	182,837
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Merven Matthew Natino, Engr. Sueden Lyle Magtalas

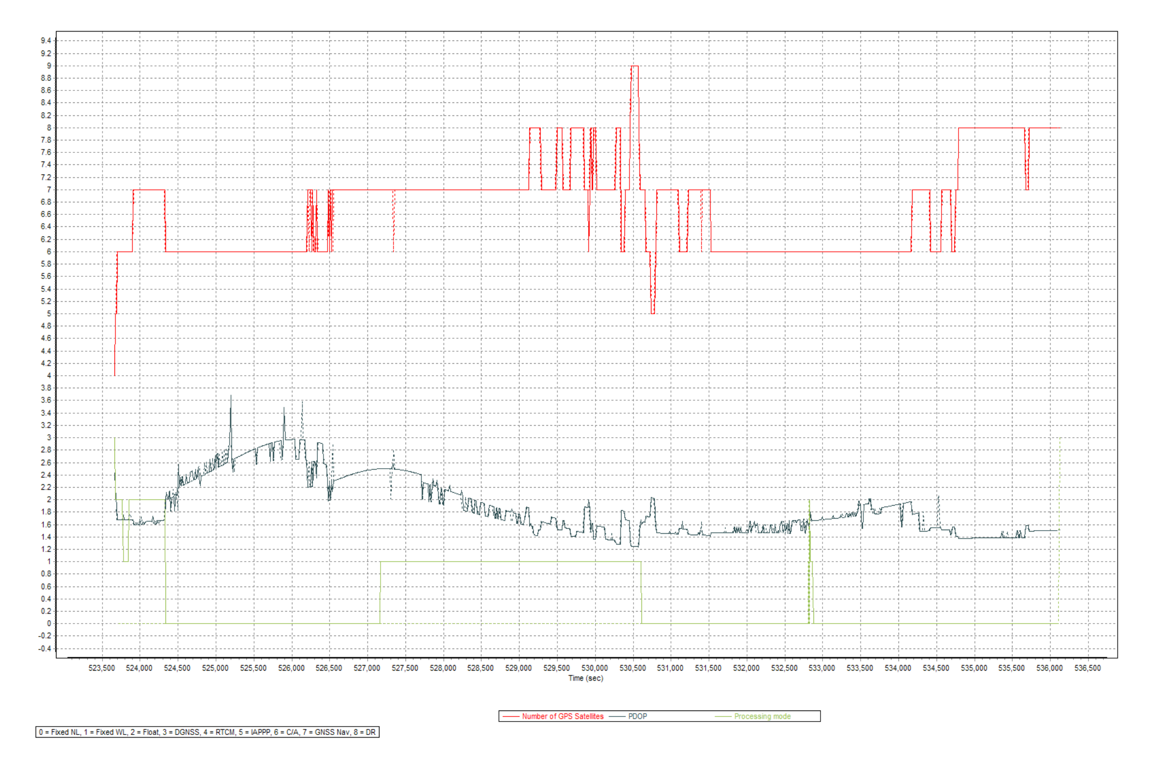


Figure A-8.71 Solution Status

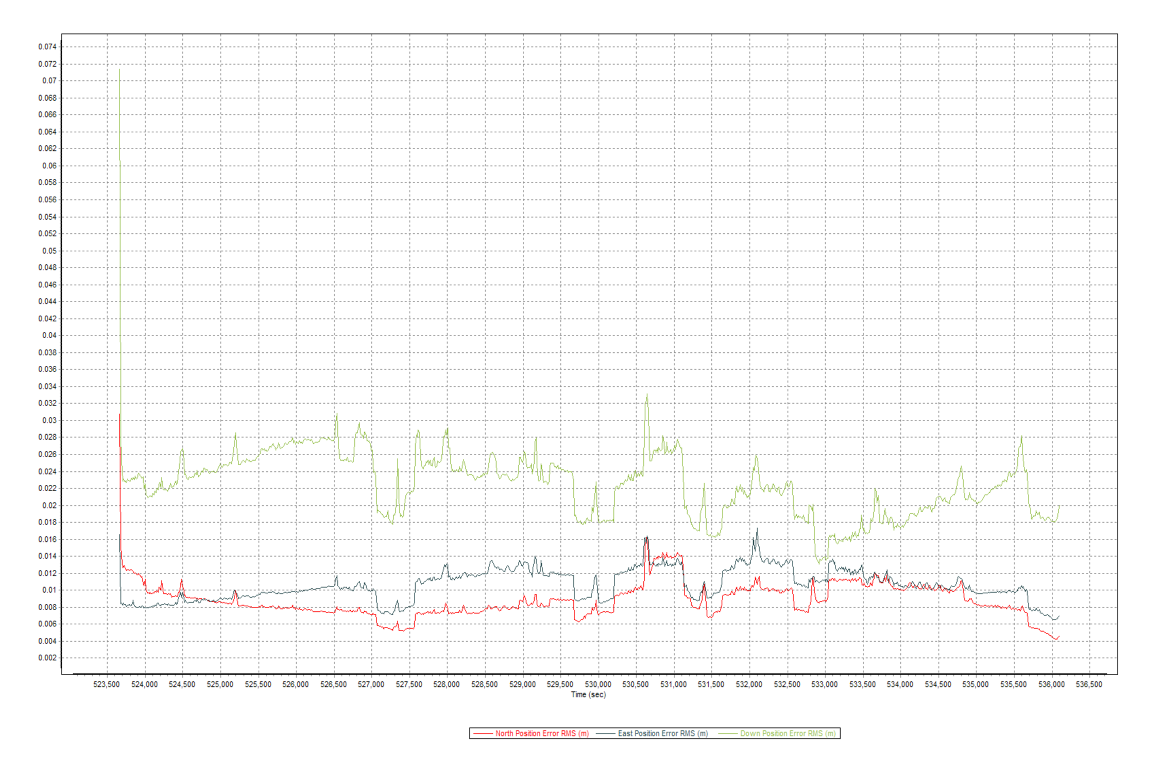


Figure A-8.72 Smoothed Performance Metric Parameters

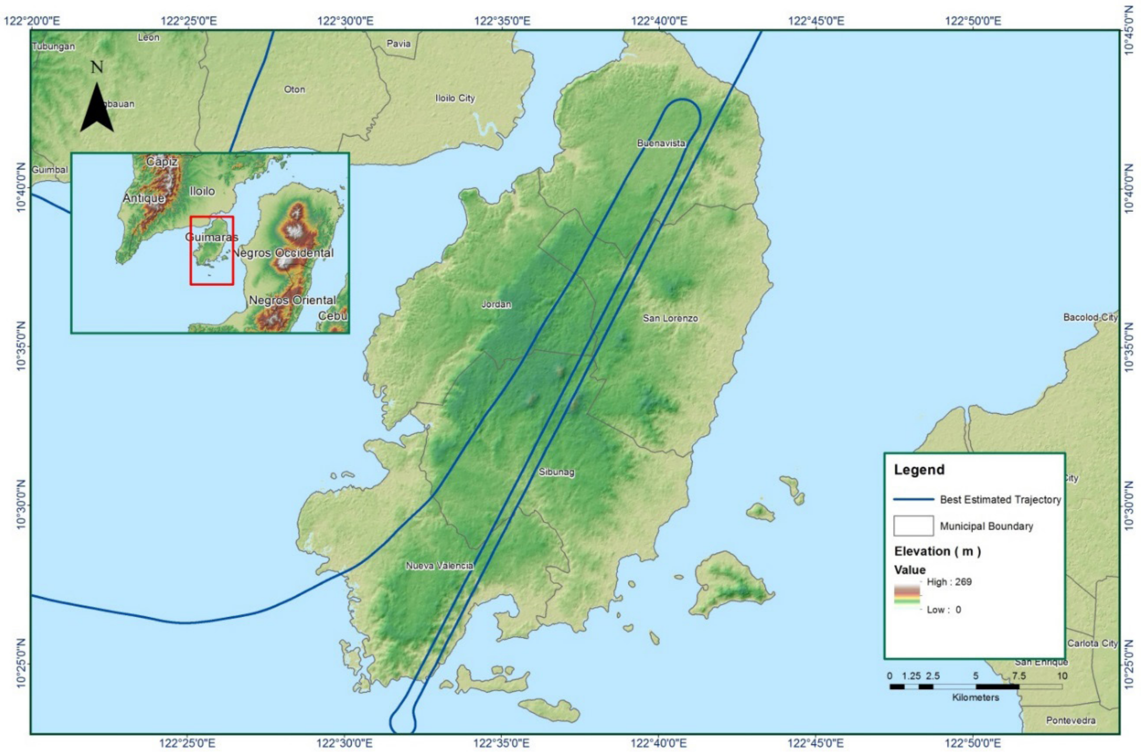


Figure A-8.73 Best Estimated Trajectory

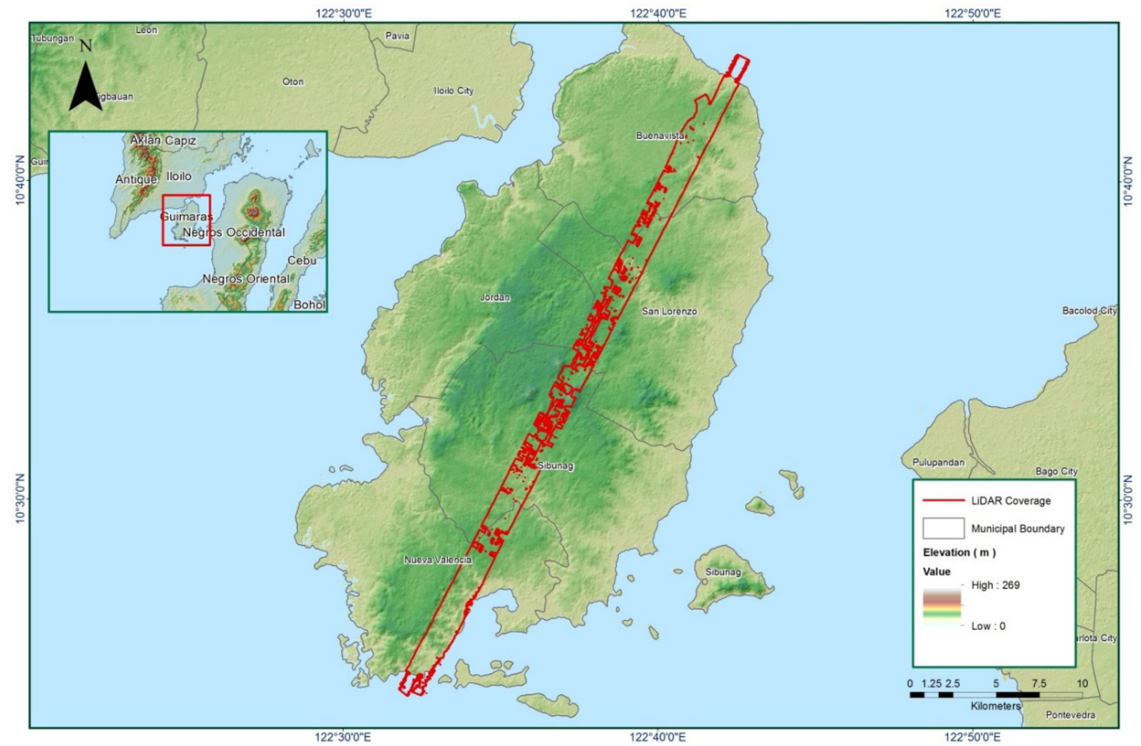


Figure A-8.74 Coverage of LiDAR data

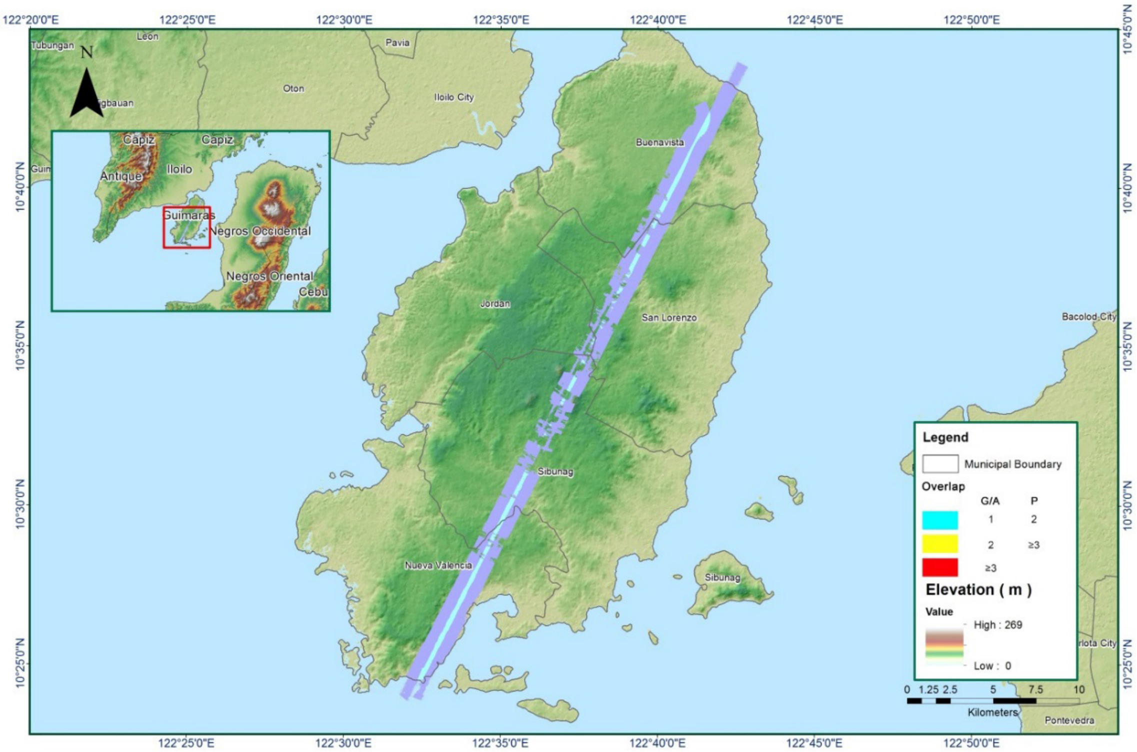


Figure A-8.75 Image of data overlap

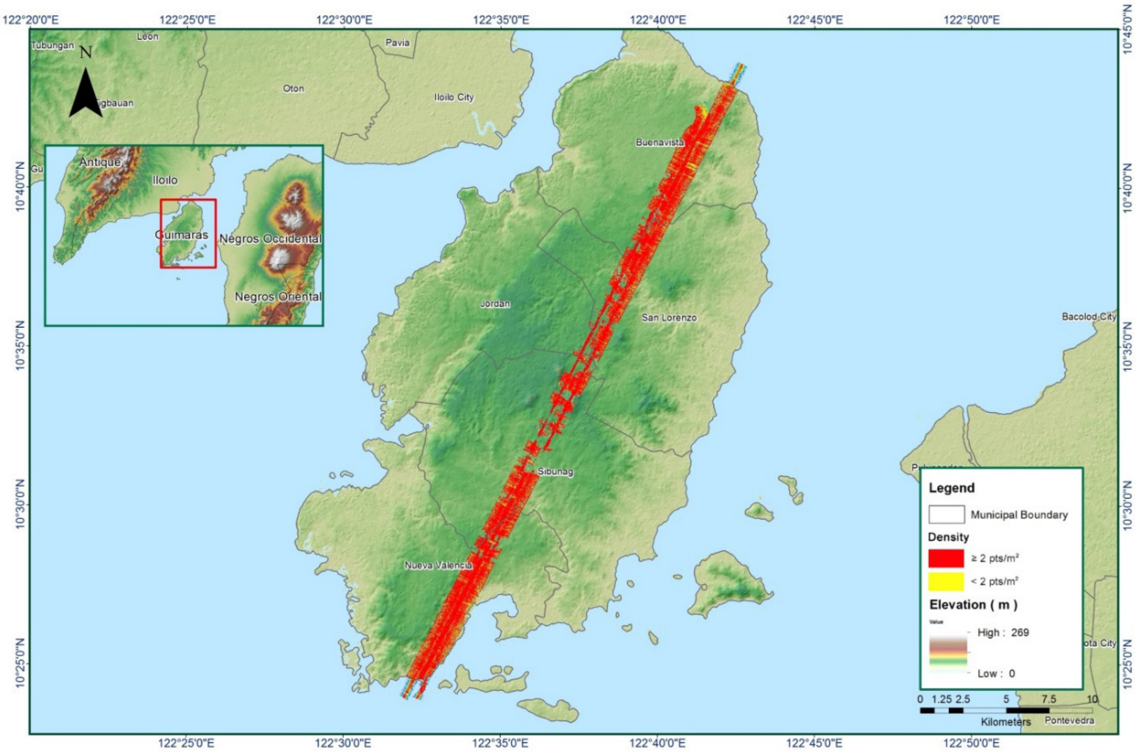


Figure A-8.76 Density map of merged LiDAR data

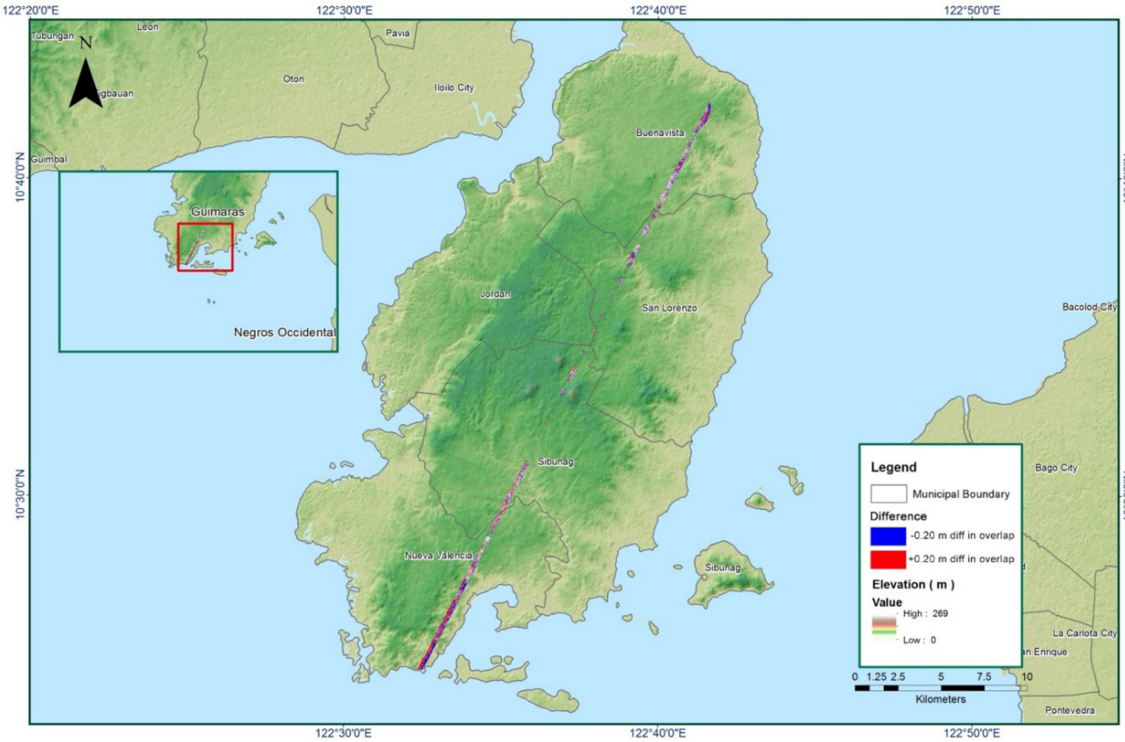


Figure A-8.77 Elevation difference between flight lines

Table A-8.12 Mission Summary Report for Blk43N_additional3

Flight Area	Iloilo
Mission Name	**Blk43N_additional3**
Inclusive Flights	2637P
Range data size	18.3 GB
Base data size	10.7 MB
POS	245 MB
Image	32.8 GB
Transfer date	July 07, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.61
RMSE for East Position (<4.0 cm)	2.45
RMSE for Down Position (<8.0 cm)	6.16
Boresight correction stdev (<0.001deg)	0.000328
IMU attitude correction stdev (<0.001deg)	0.001531
GPS position stdev (<0.01m)	0.0138
Minimum % overlap (>25)	23.22%
Ave point cloud density per sq.m. (>2.0)	3.59
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	210
Maximum Height	346.44 m
Minimum Height	49.30 m
Classification (# of points)	
Ground	122,085,477
Low vegetation	28,786,513
Medium vegetation	110,779,224
High vegetation	238,495,142
Building	6,680,099
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Antonio Chua, Jr. , Engr. Krisha Marie Bautista

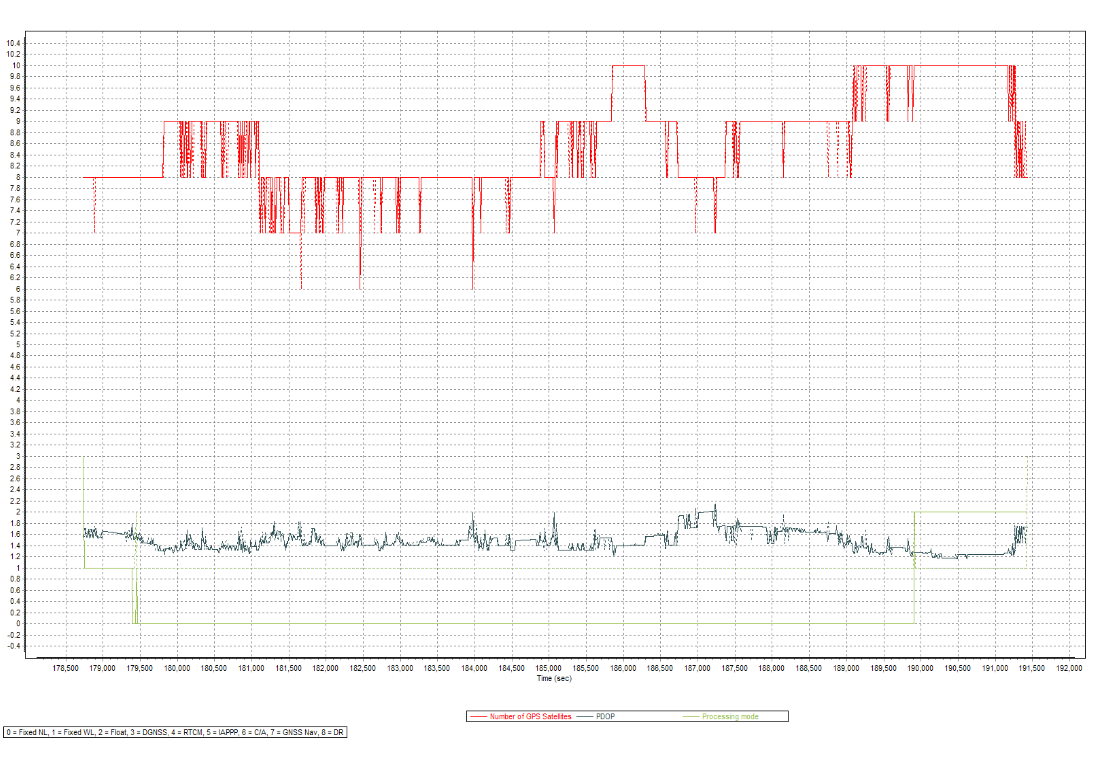


Figure A-8.78 Solution Status

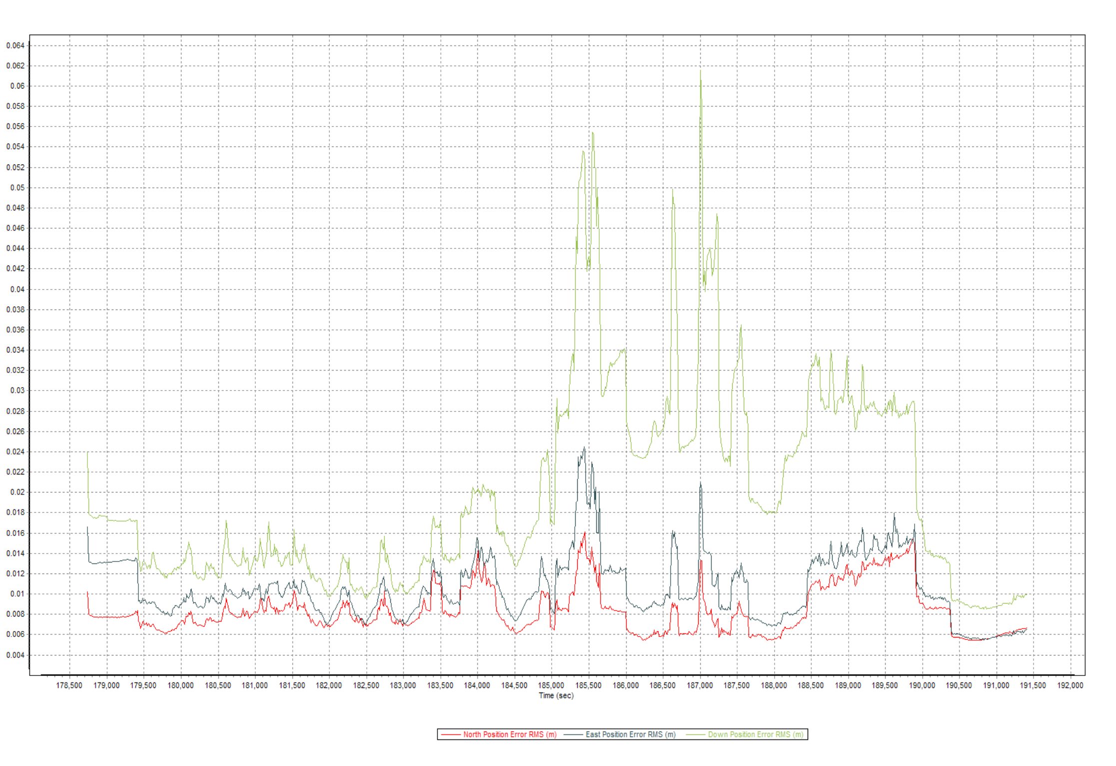


Figure A-8.79 Smoothed Performance Metric Parameters

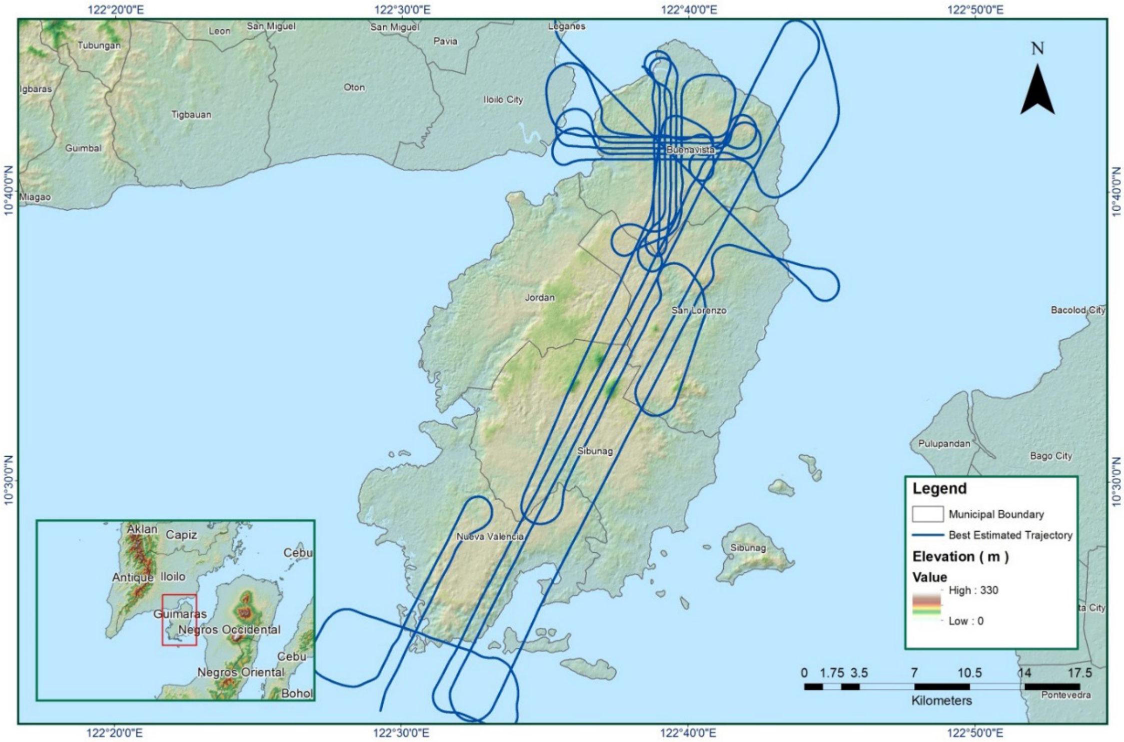


Figure A-8.80 Best Estimated Trajectory

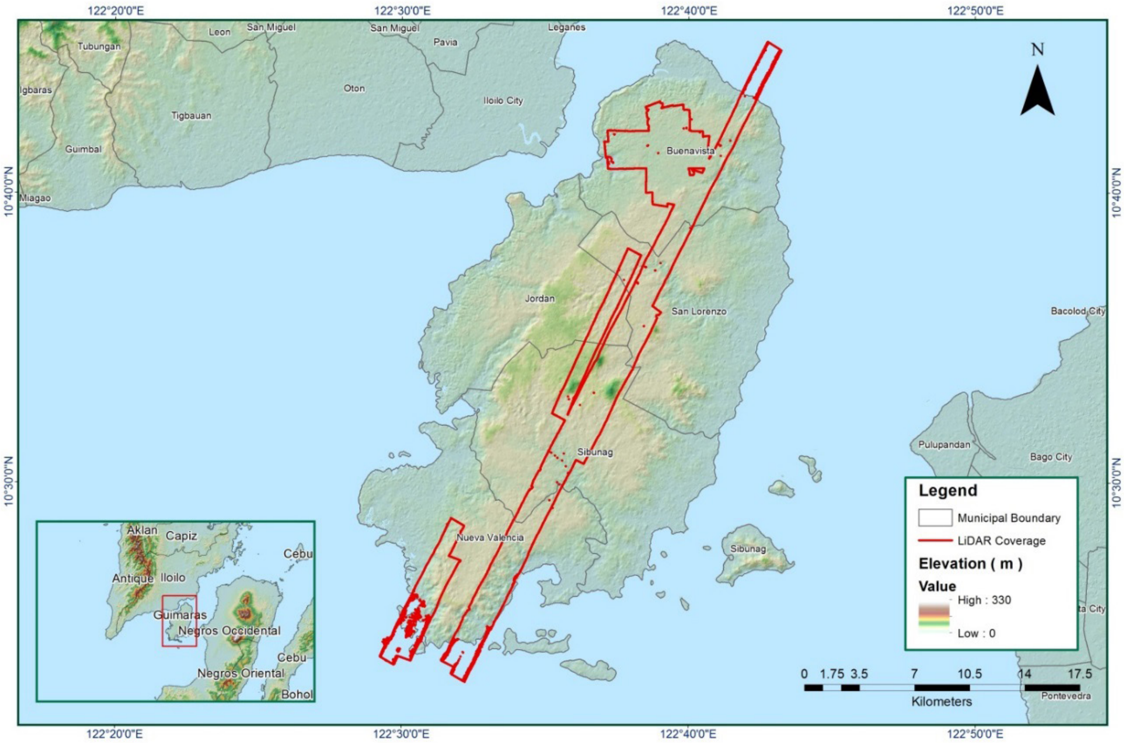


Figure A-8.81 Coverage of LiDAR data

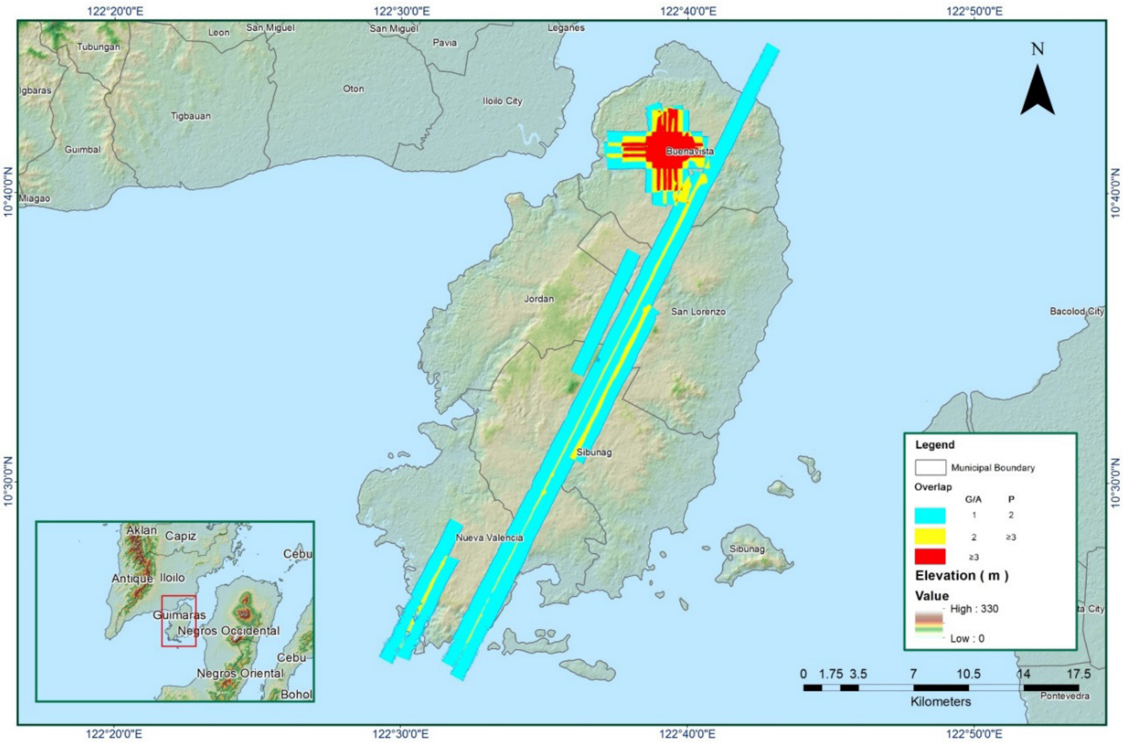


Figure A-8.82 Image of data overlap

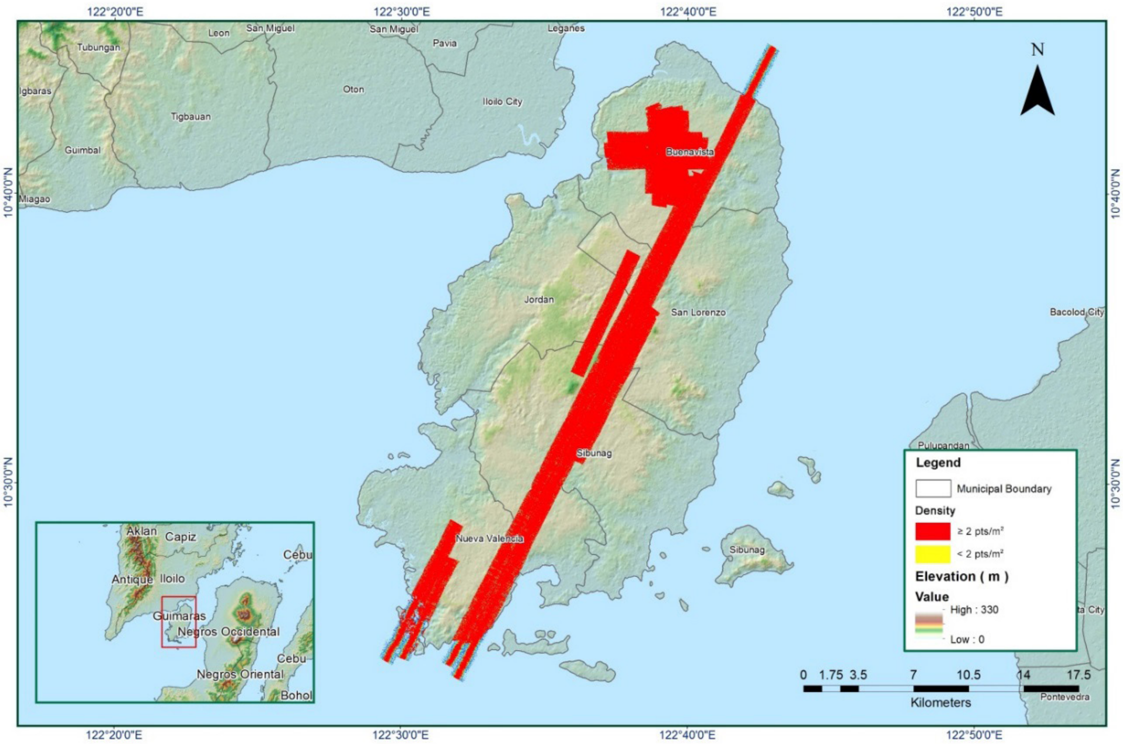


Figure A-8.83 Density map of merged LiDAR data

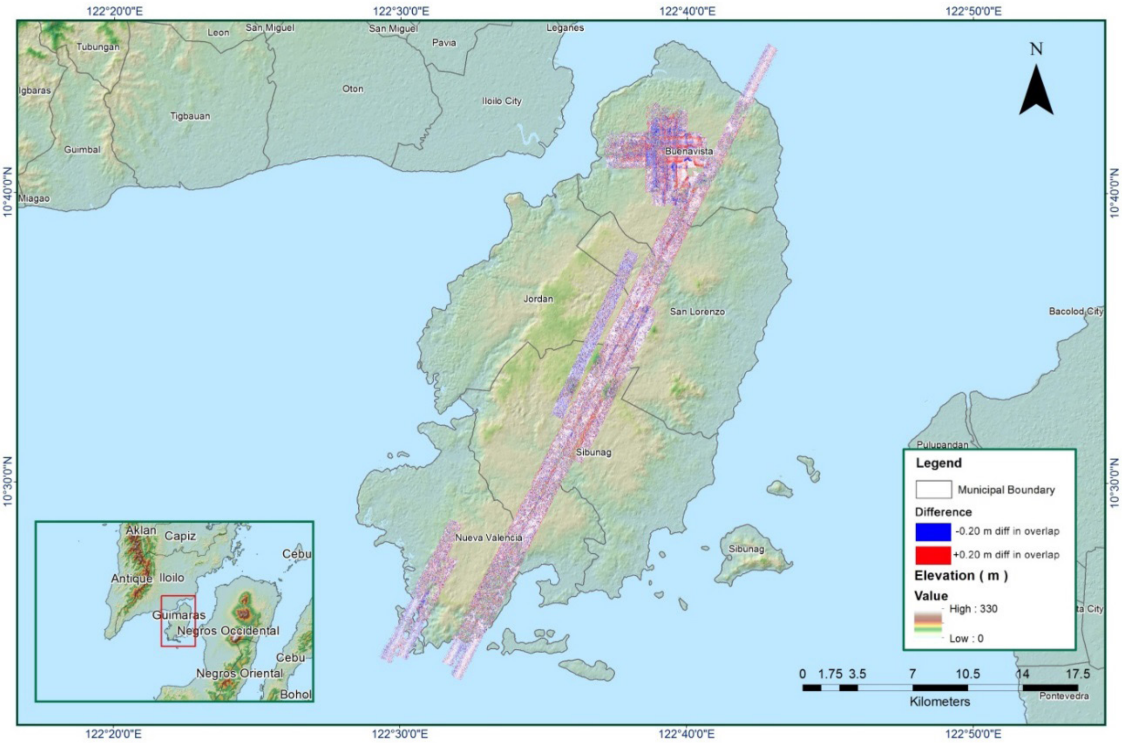


Figure A-8.84 Elevation difference between flight lines

Table A-8.13 Mission Summary Report for Blk43O

Flight Area	Iloilo
Mission Name	**Blk43O**
Inclusive Flights	2526G, 2550G, 2530G
Range data size	66.4 GB
Base data size	39.7 MB
POS	733 MB
Image	120.8 GB
Transfer date	February 17, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.74
RMSE for East Position (<4.0 cm)	7.22
RMSE for Down Position (<8.0 cm)	16.04
Boresight correction stdev (<0.001deg)	0.000336
IMU attitude correction stdev (<0.001deg)	0.004556
GPS position stdev (<0.01m)	0.0049
Minimum % overlap (>25)	52.08%
Ave point cloud density per sq.m. (>2.0)	5.19
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	304
Maximum Height	329.30 m
Minimum Height	59.16 m
Classification (# of points)	
Ground	141,475,313
Low vegetation	179,189,082
Medium vegetation	387,061,282
High vegetation	368,016,433
Building	3,528,315
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Kenneth Solidum, Engr. Analyn Naldo, Engr. Melanie Hingpit, Kathryn Claudyn Zarate

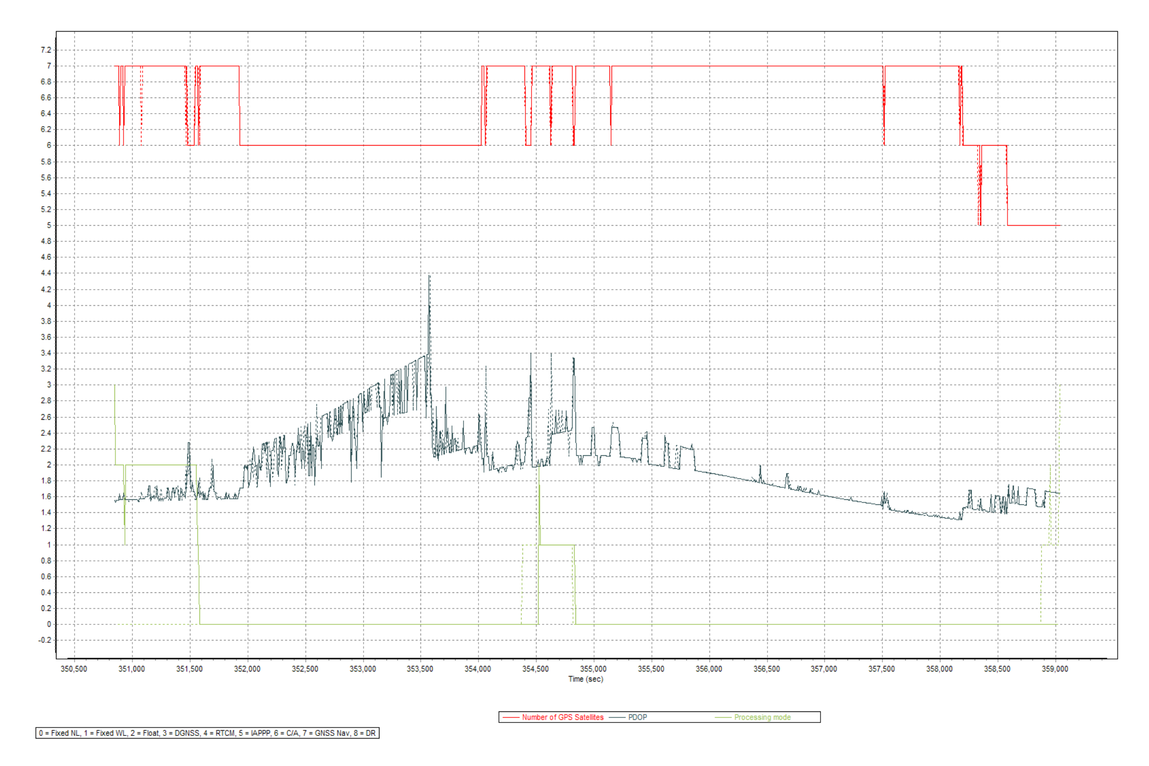


Figure A-8.85 Solution Status

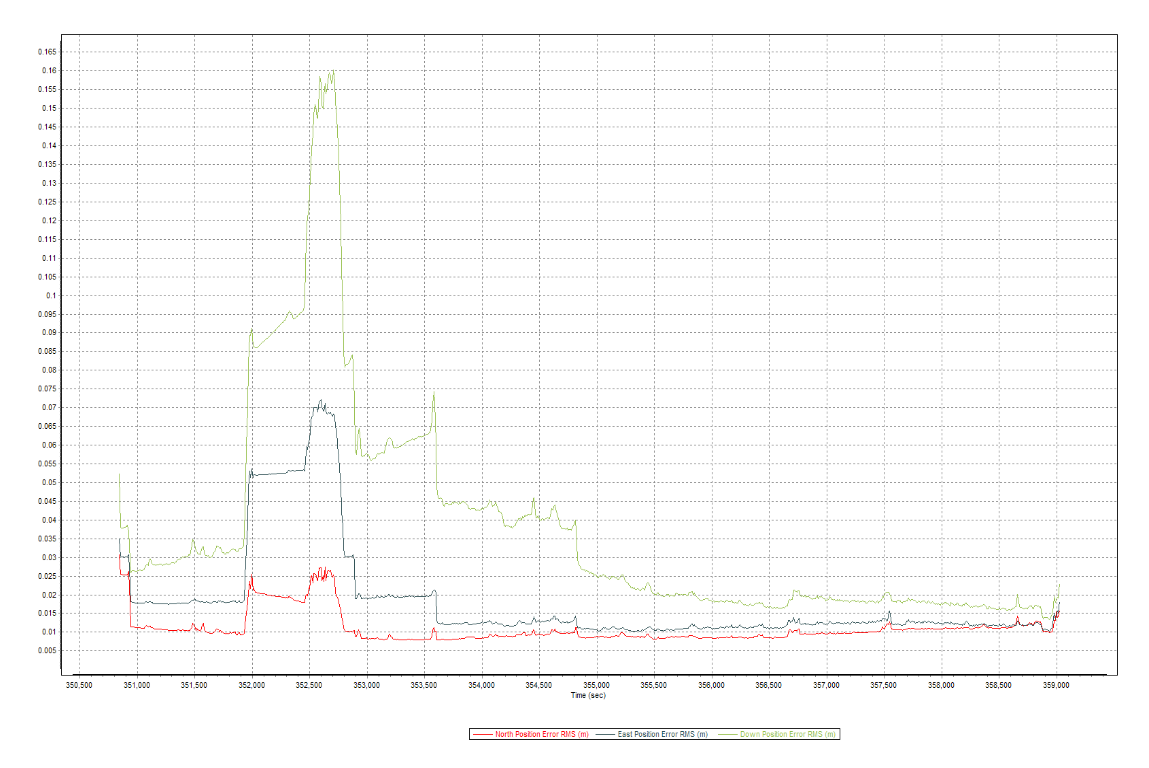


Figure A-8.86 Smoothed Performance Metric Parameters

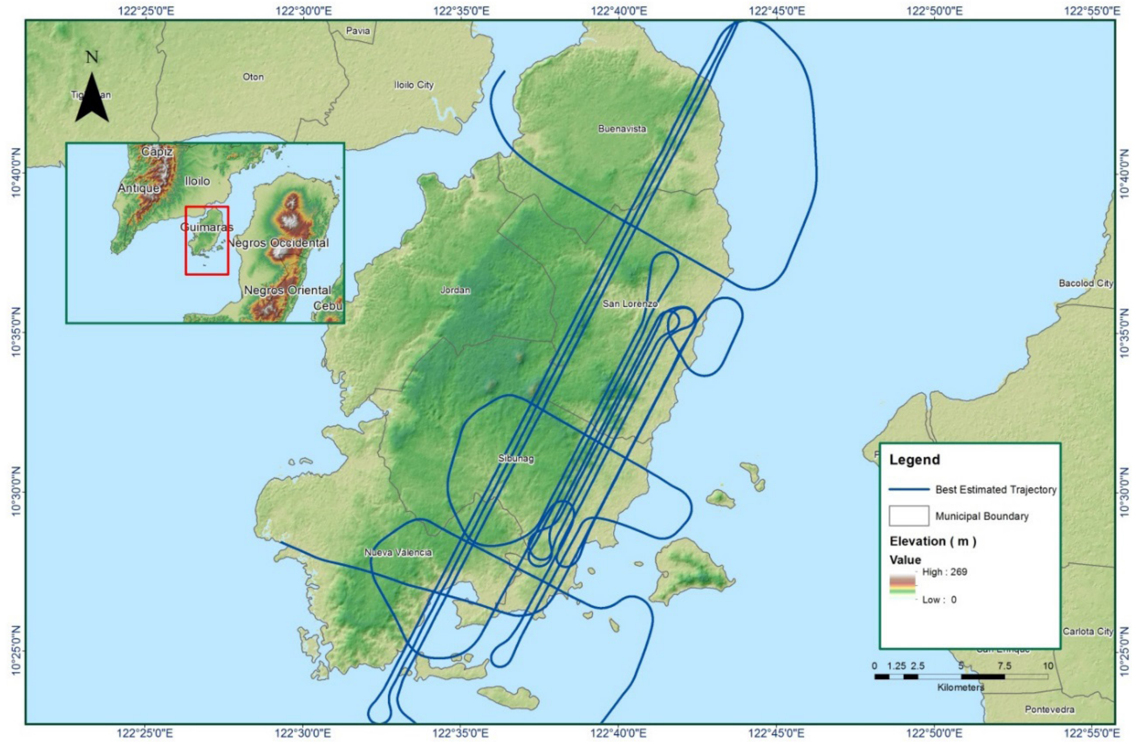


Figure A-8.87 Best Estimated Trajectory

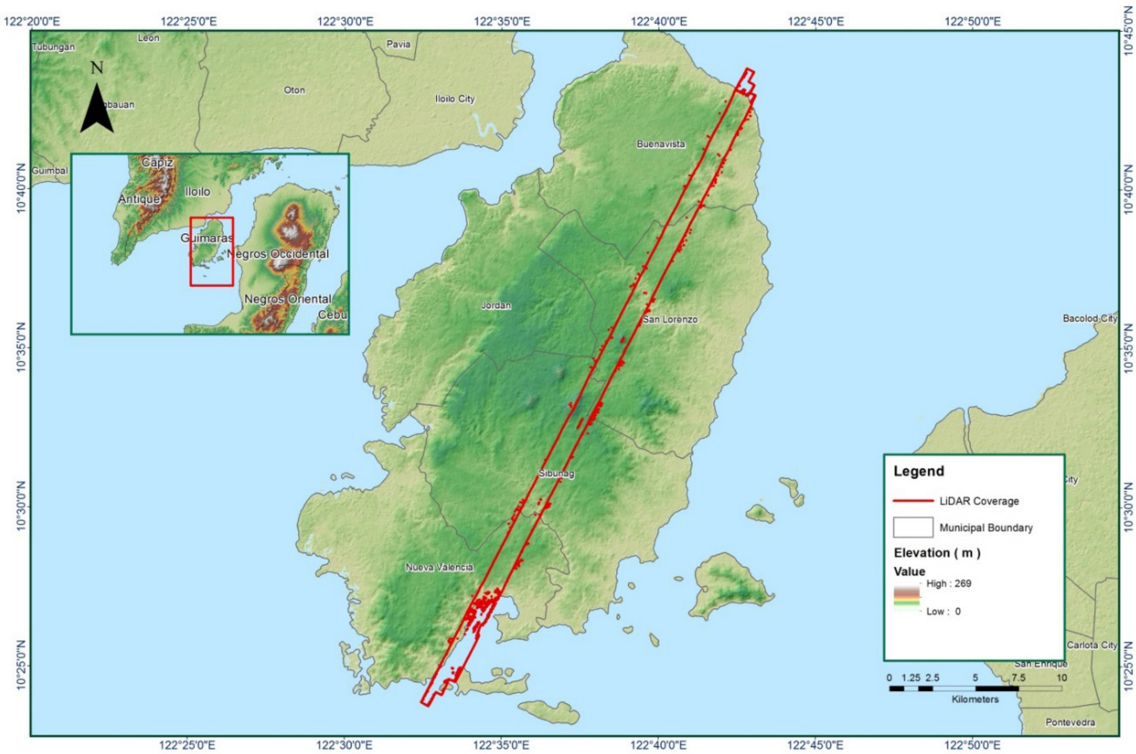


Figure A-8.88 Coverage of LiDAR data

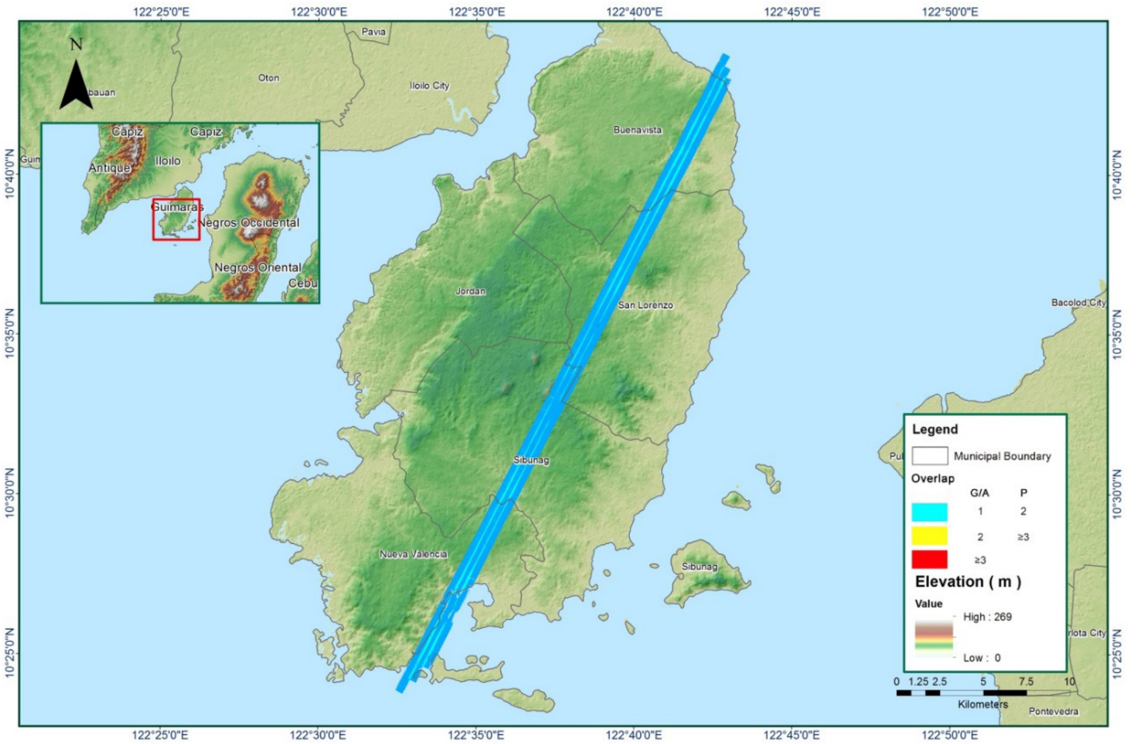


Figure A-8.89 Image of data overlap

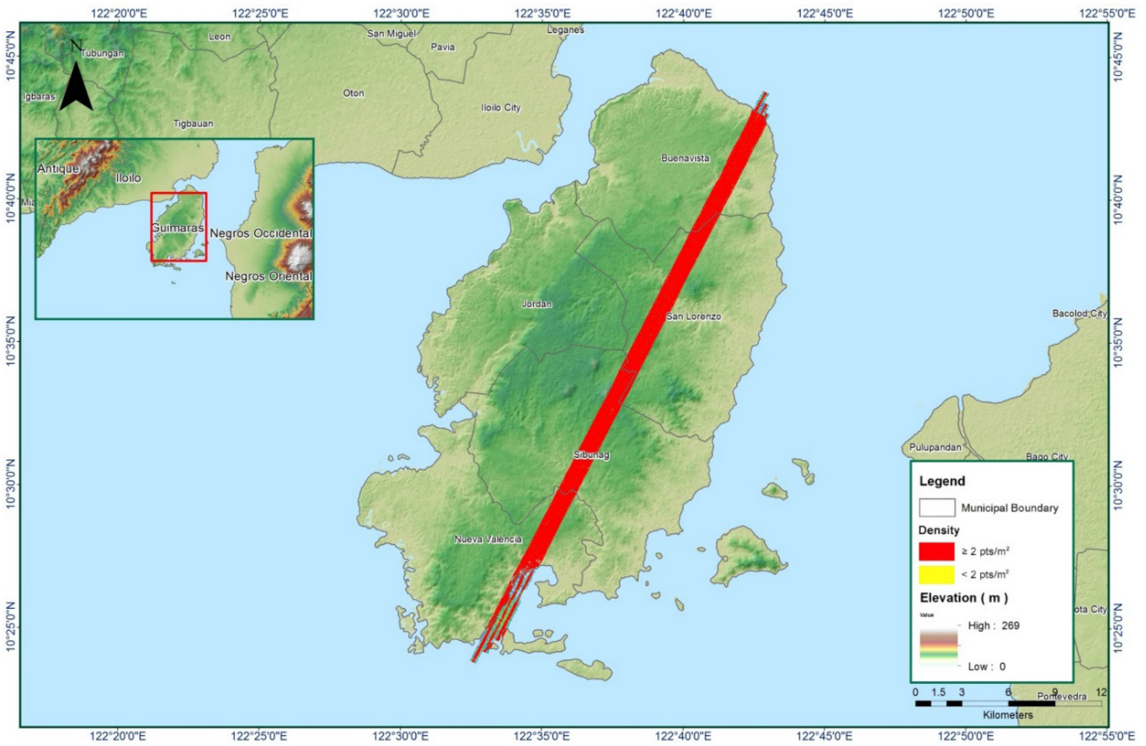


Figure A-8.90 Density map of merged LiDAR data

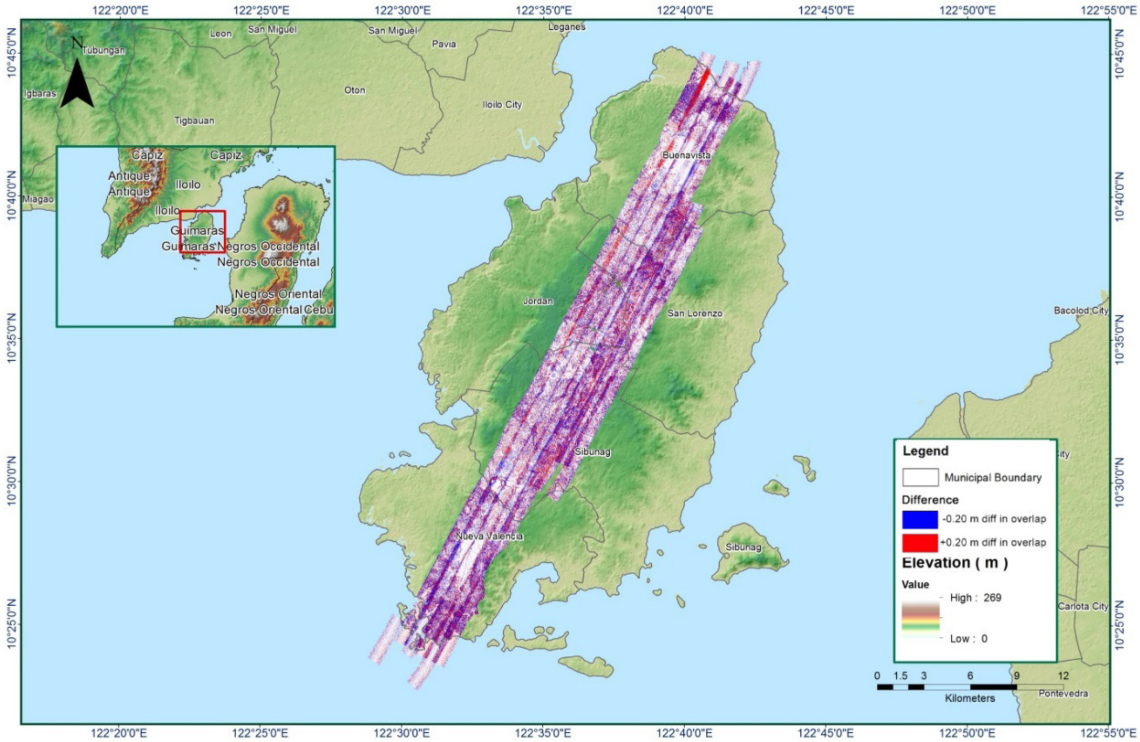


Figure A-8.91 Elevation difference between flight lines

Table A-8.14 Mission Summary Report for Blk43O_additional

Flight Area	Iloilo
Mission Name	**Blk43O_additional**
Inclusive Flights	2638G
Range data size	12.5 GB
Base data size	20.1 MB
POS	234 MB
Image	27.5 GB
Transfer date	July 07, 2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.23
RMSE for East Position (<4.0 cm)	2.58
RMSE for Down Position (<8.0 cm)	6.67
Boresight correction stdev (<0.001deg)	0.000555
IMU attitude correction stdev (<0.001deg)	0.002425
GPS position stdev (<0.01m)	0.0191
Minimum % overlap (>25)	19.84%
Ave point cloud density per sq.m. (>2.0)	2.27
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	184
Maximum Height	273.84 m
Minimum Height	59.75 m
Classification (# of points)	
Ground	42,279,666
Low vegetation	29,486,782
Medium vegetation	84,900,261
High vegetation	69,544,848
Building	422,883
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Aljon Rie Araneta, Engr. Sueden Lyle Magtalas

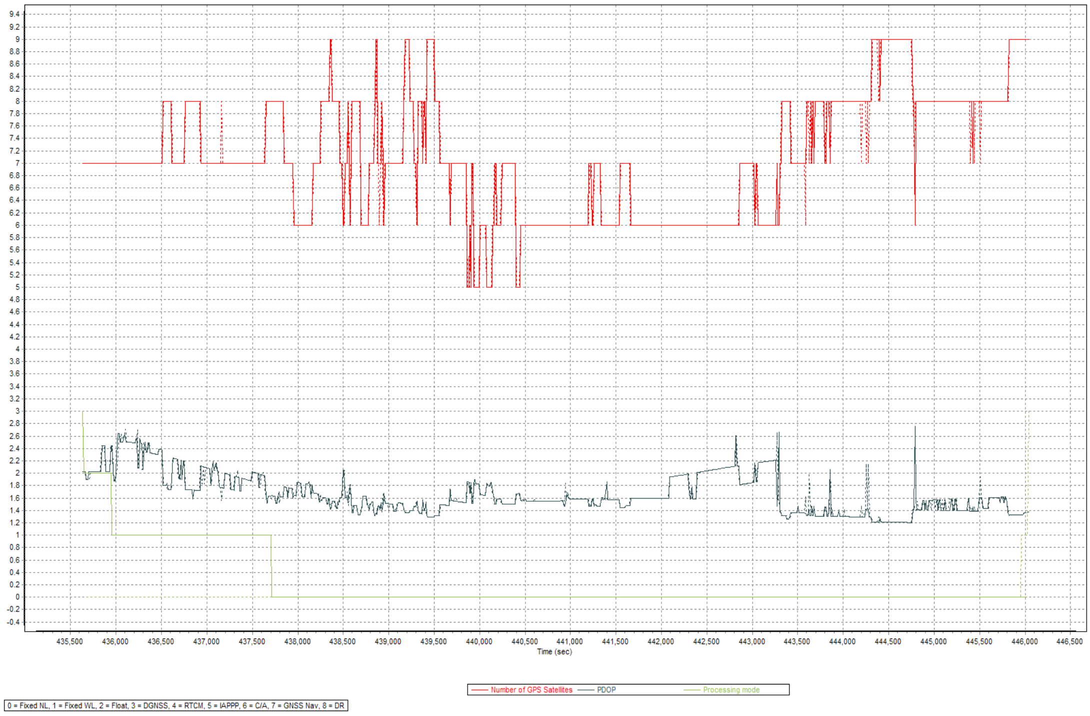


Figure A-8.92 Solution Status

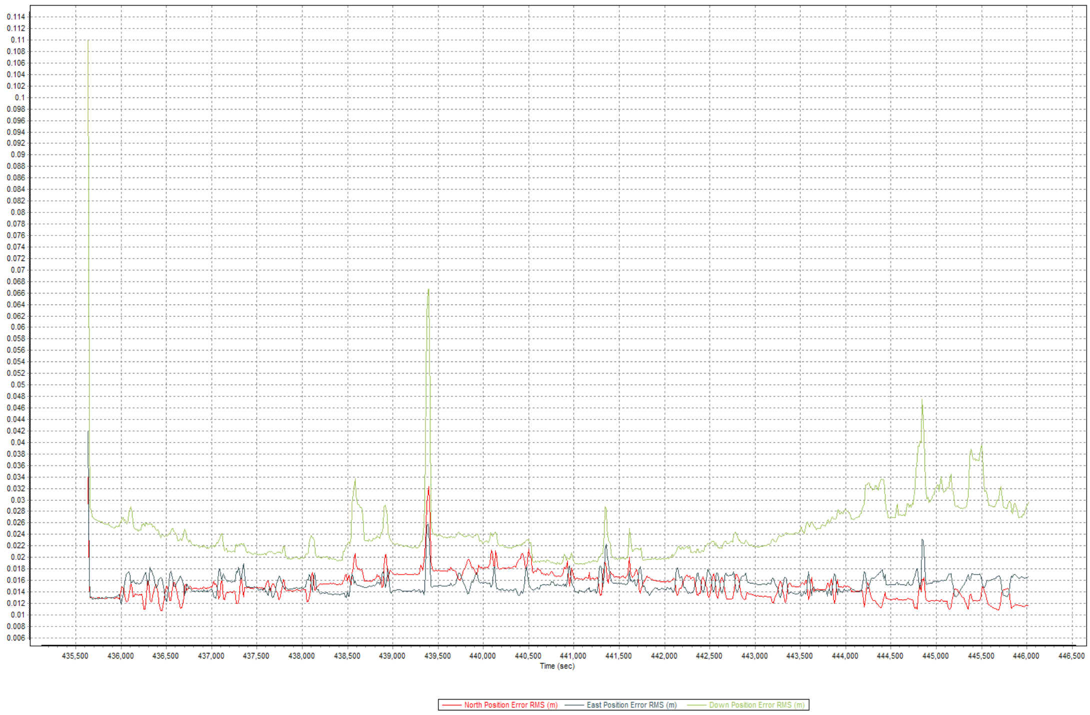


Figure A-8.93 Smoothed Performance Metric Parameters

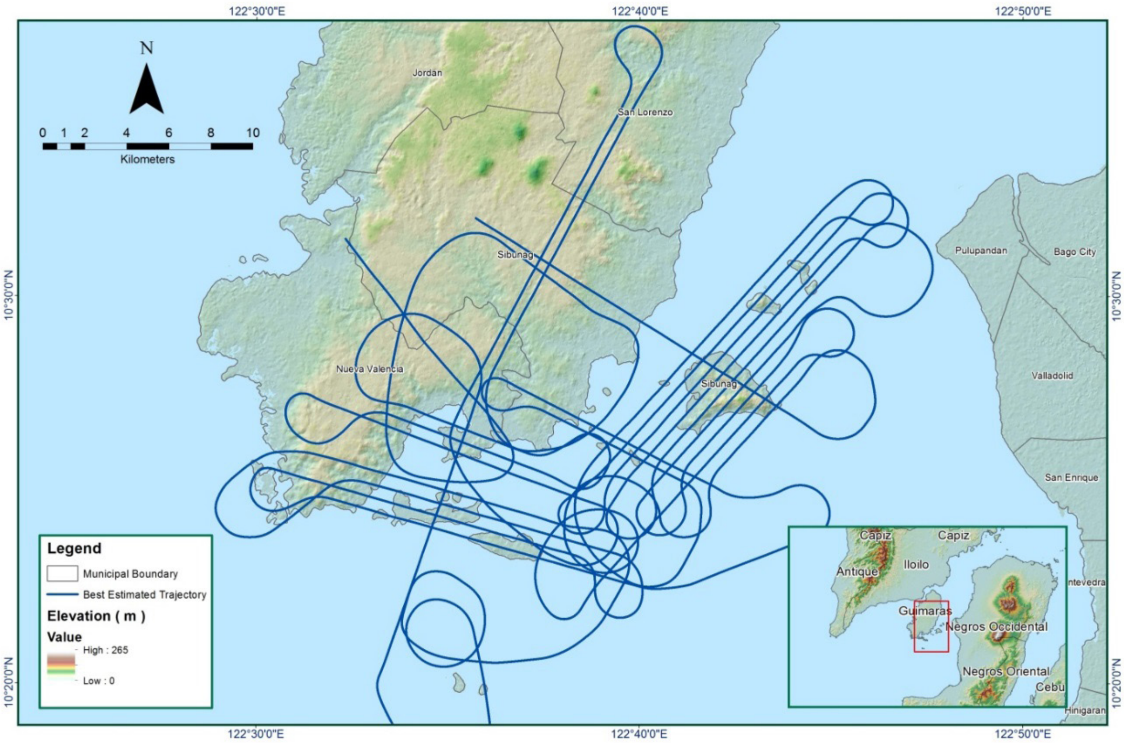


Figure A-8.94 Best Estimated Trajectory

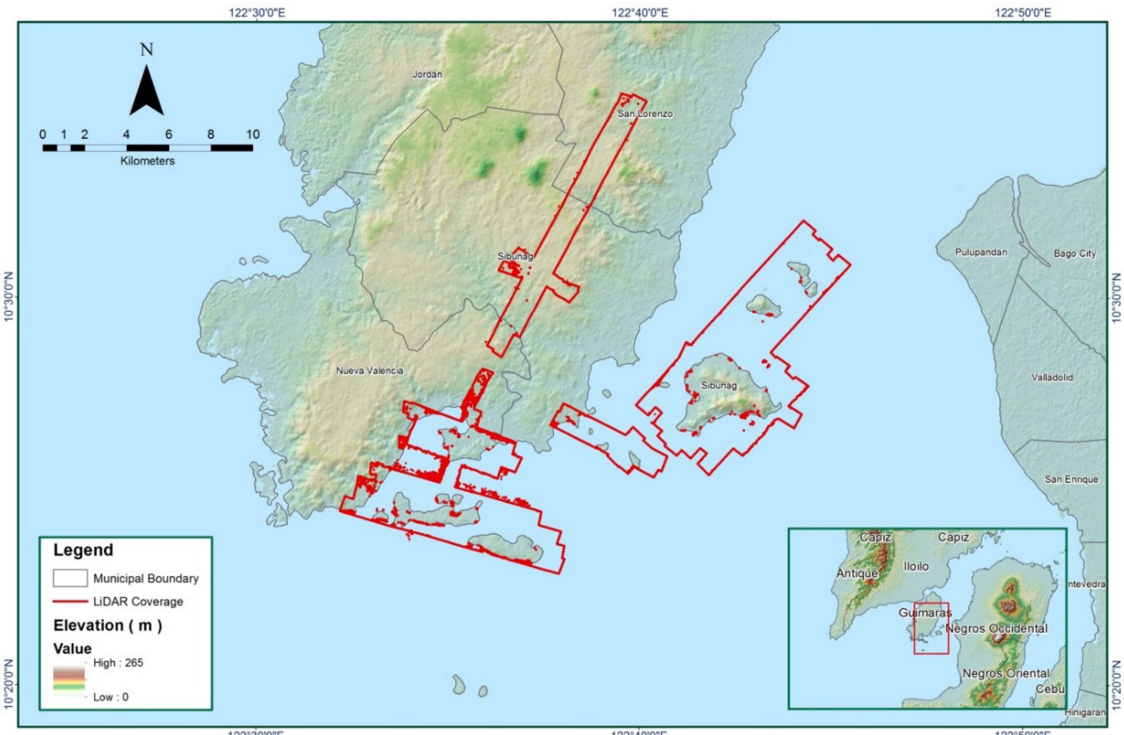


Figure A-8.95 Coverage of LiDAR data

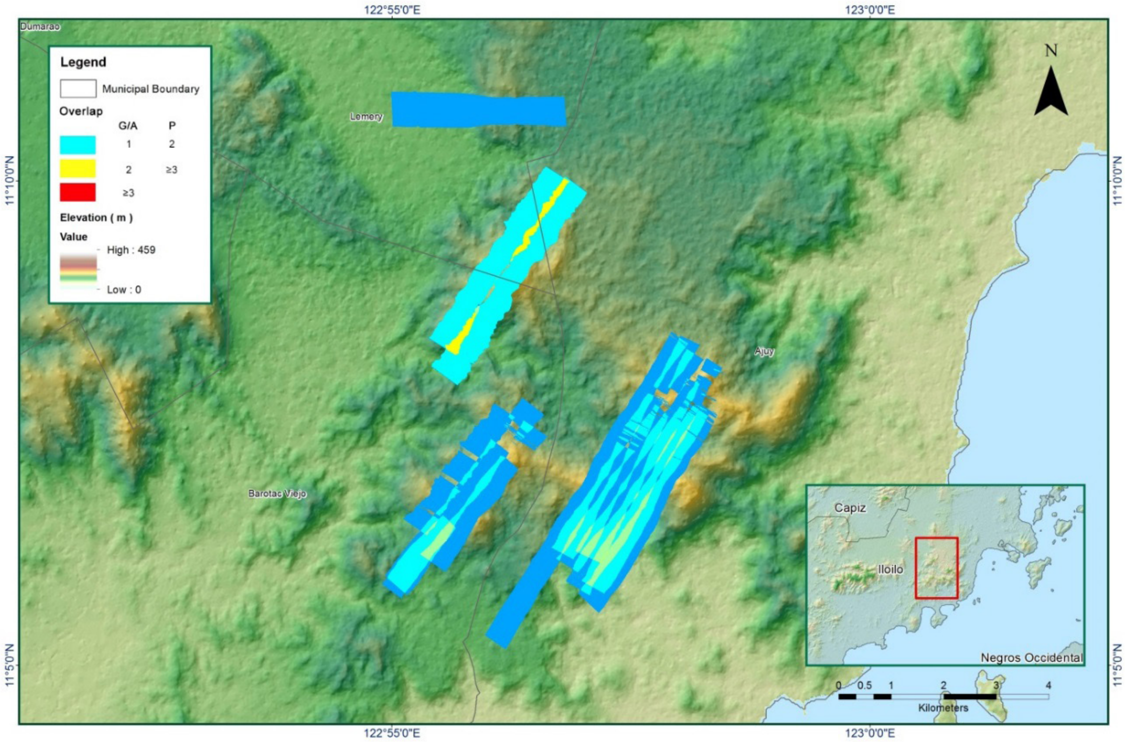


Figure A-8.96 Image of data overlap

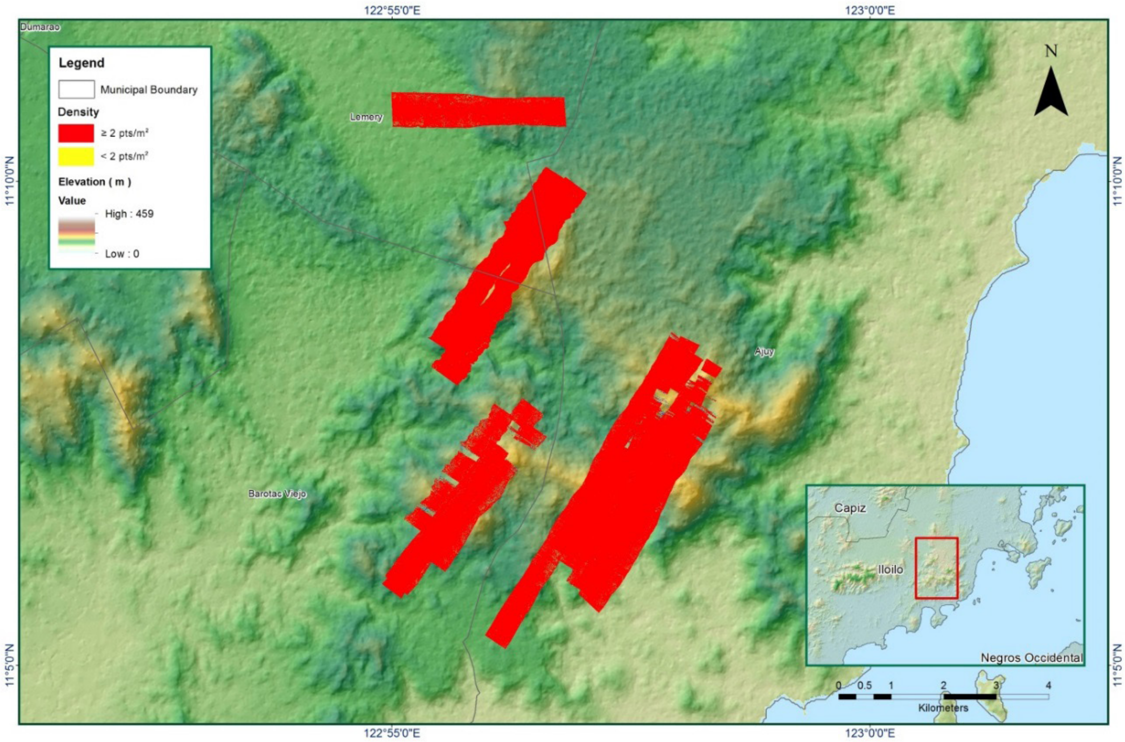


Figure A-8.97 Density map of merged LiDAR data

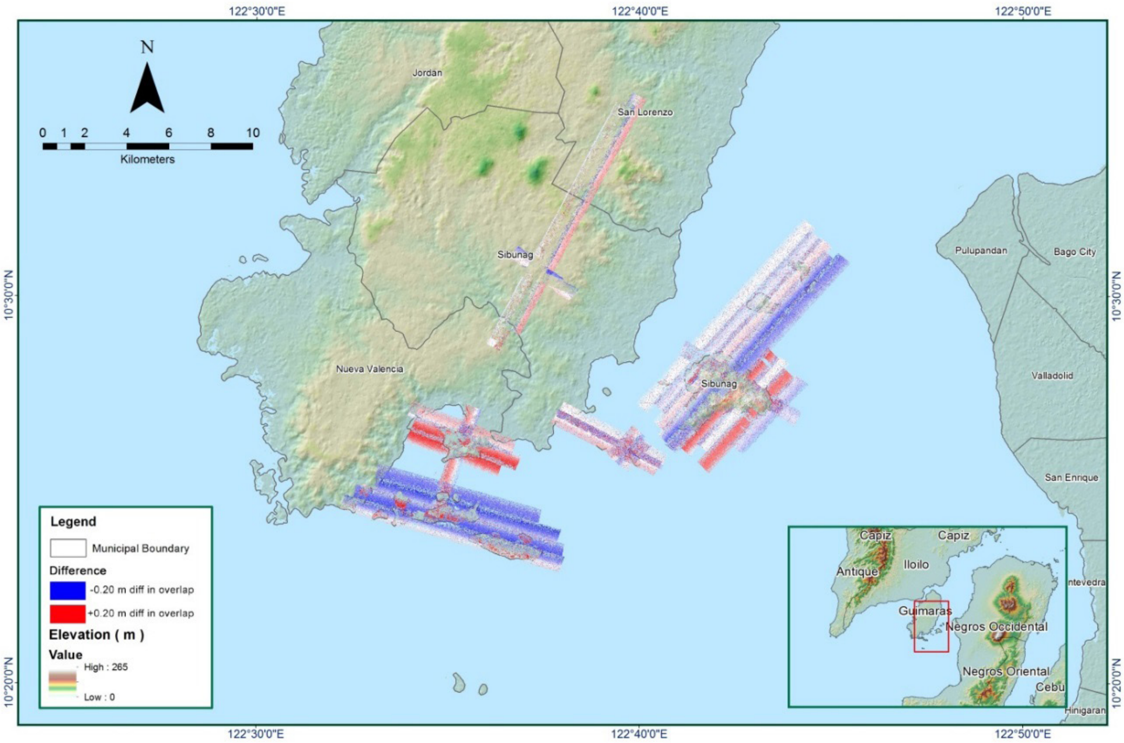


Figure A-8.98 Elevation difference between flight lines

Table A-8.15 Mission Summary Report for Blk43O supplement

Flight Area	Iloilo
Mission Name	**Blk43O supplement**
Inclusive Flights	2637P
Range data size	18.3 GB
Base data size	10.7 MB
POS	245 MB
Image	32.8 GB
Transfer date	July 3, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.61
RMSE for East Position (<4.0 cm)	2.45
RMSE for Down Position (<8.0 cm)	6.16
Boresight correction stdev (<0.001deg)	0.000328
IMU attitude correction stdev (<0.001deg)	0.001531
GPS position stdev (<0.01m)	0.0138
Minimum % overlap (>25)	2.37 %
Ave point cloud density per sq.m. (>2.0)	2.385
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	74
Maximum Height	258.19
Minimum Height	63.70
Classification (# of points)	
Ground	33,663,994
Low vegetation	20,083,337
Medium vegetation	33,186,779
High vegetation	62,500,449
Building	390,277
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Merven Matthew Natino, Engr. Monalyne Rabino

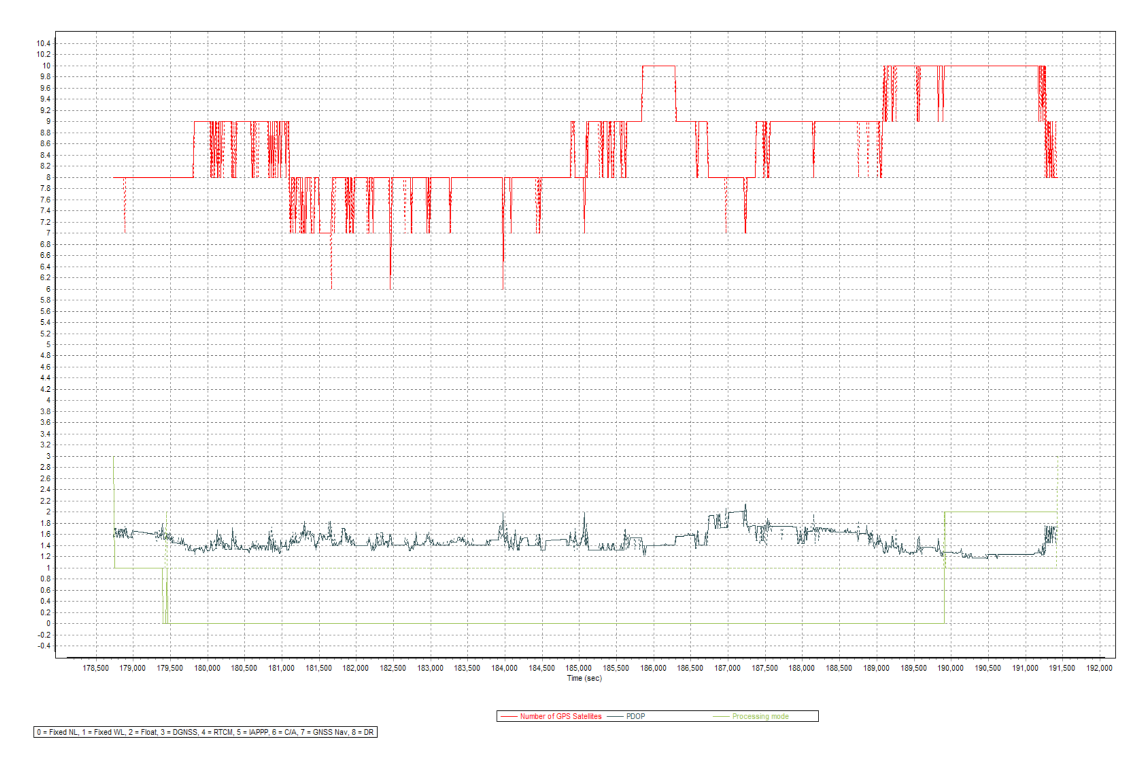


Figure A-8.99 Solution Status

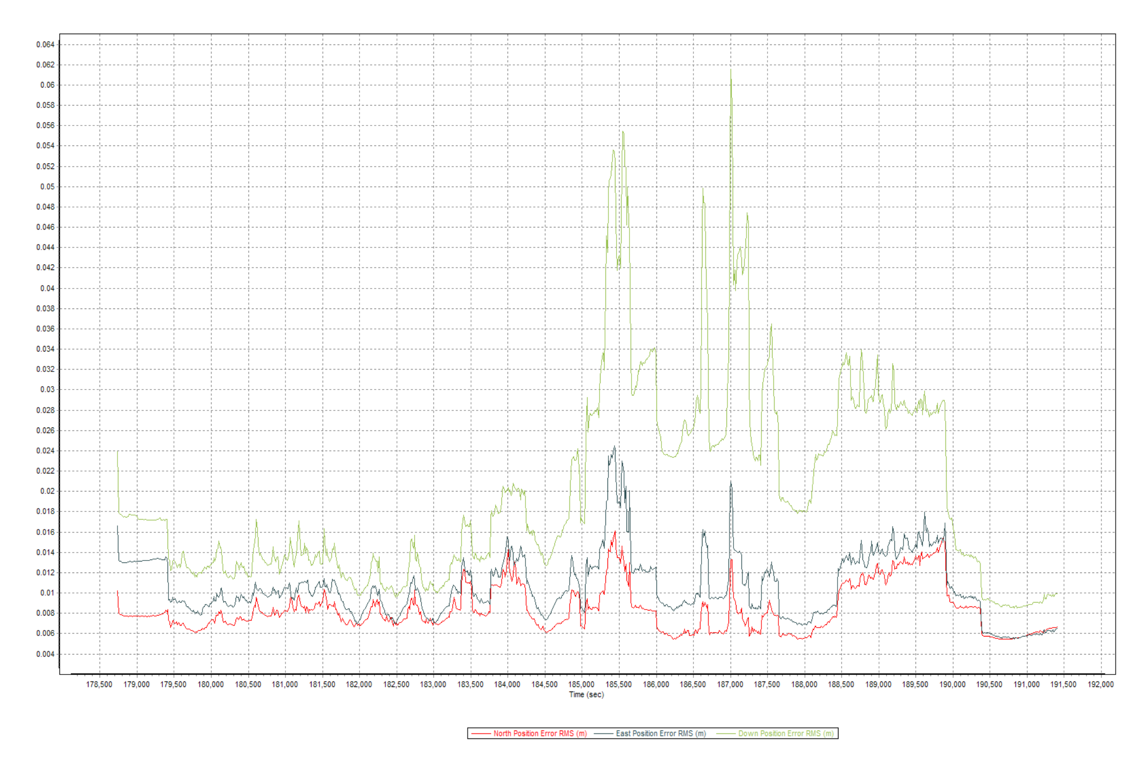


Figure A-8.100 Smoothed Performance Metric Parameters

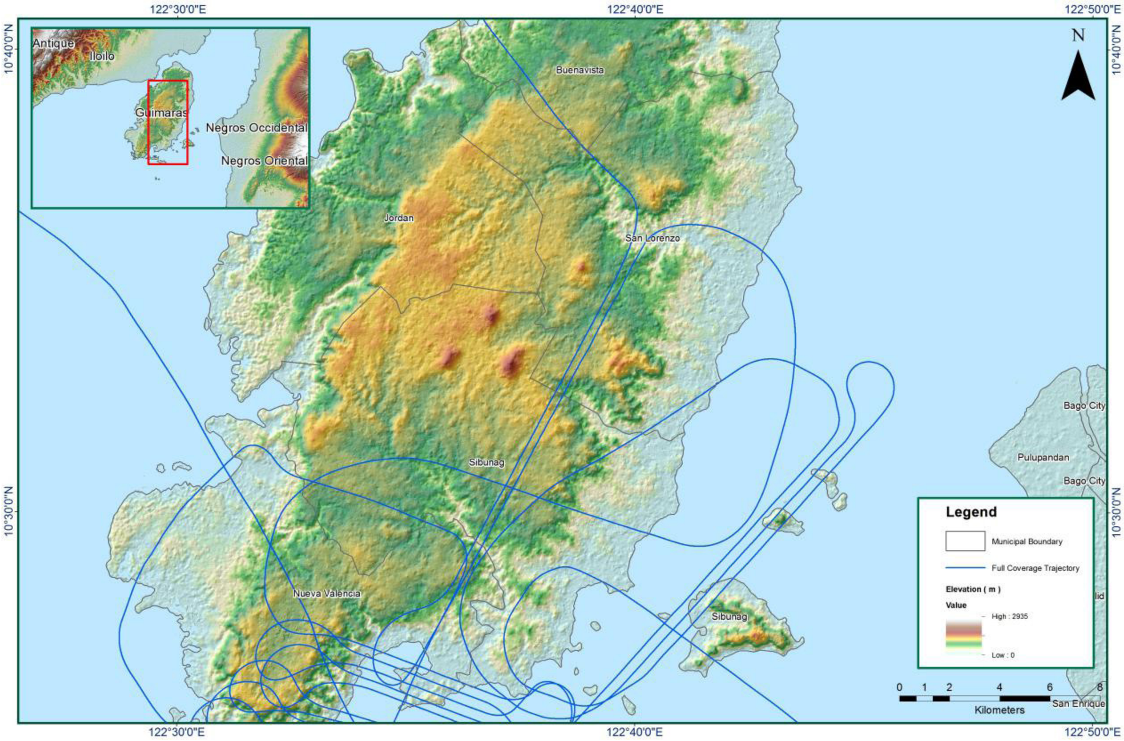


Figure A-8.101 Best Estimated Trajectory

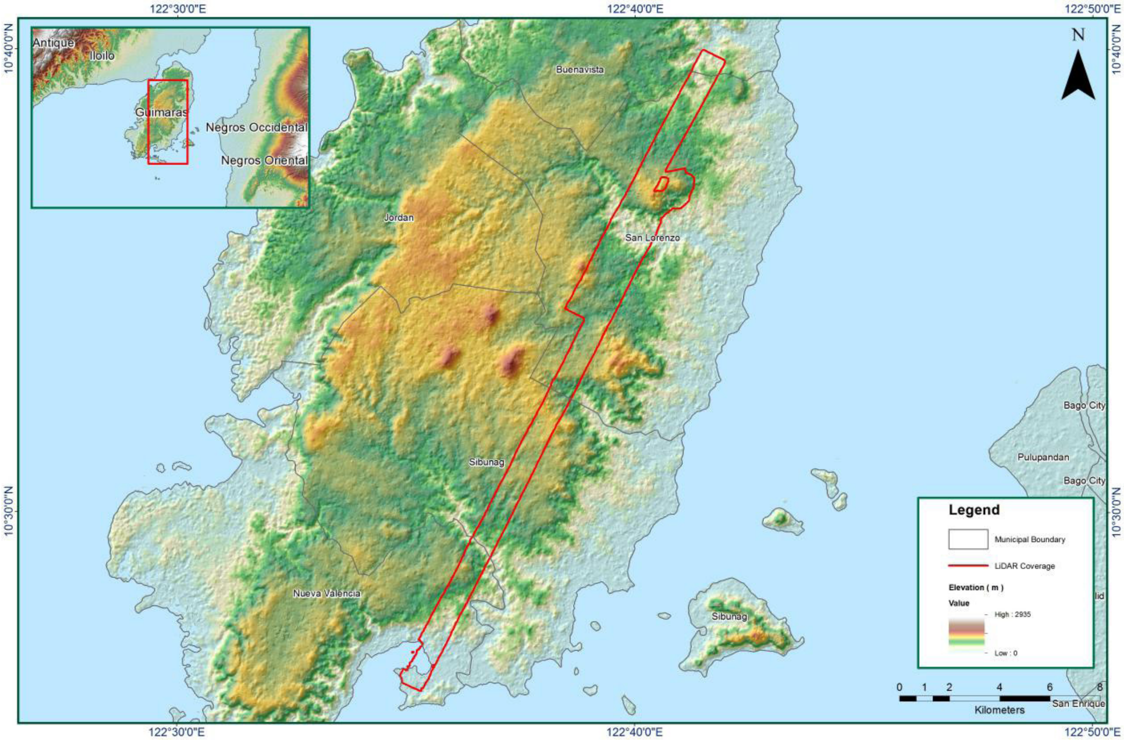


Figure A-8.102 Coverage of LIDAR data

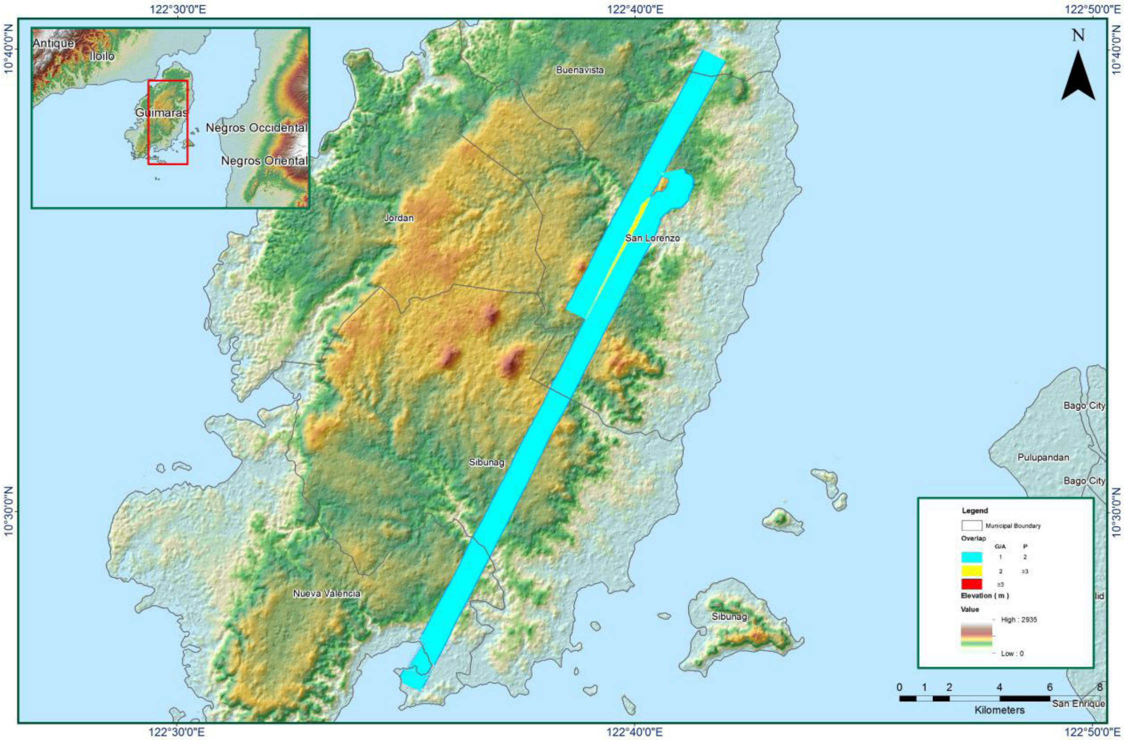


Figure A-8.103 Image of Data Overlap

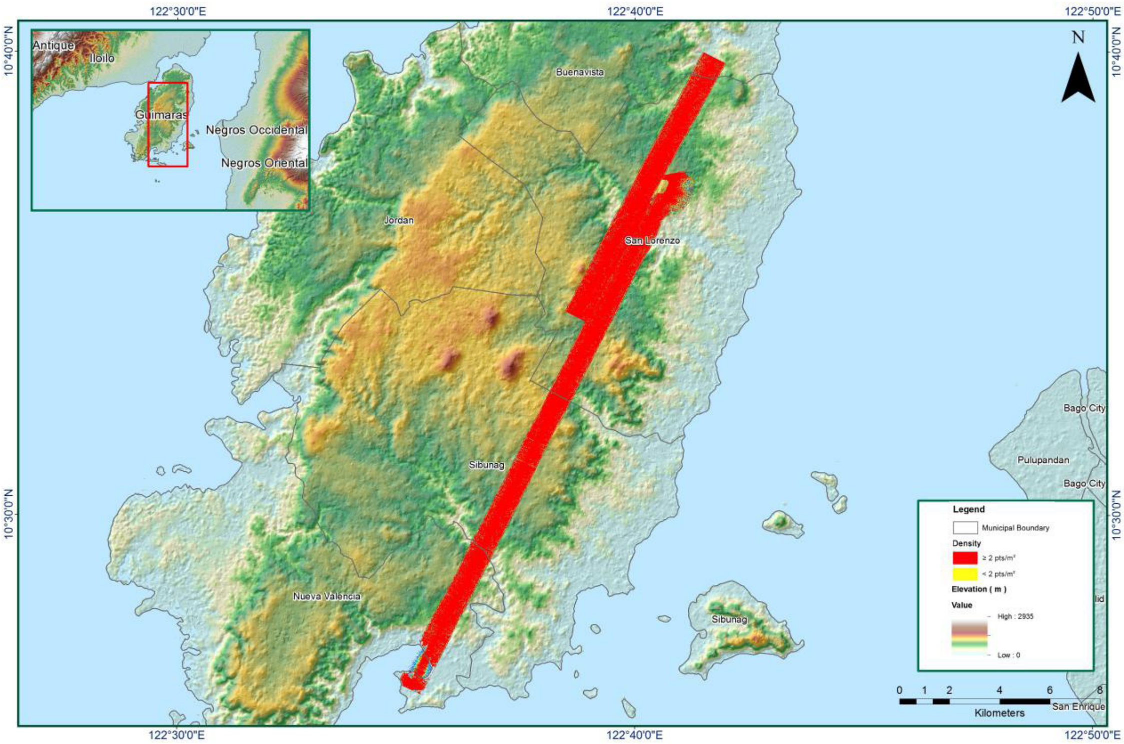


Figure A-8.104 Density map of merged LIDAR data

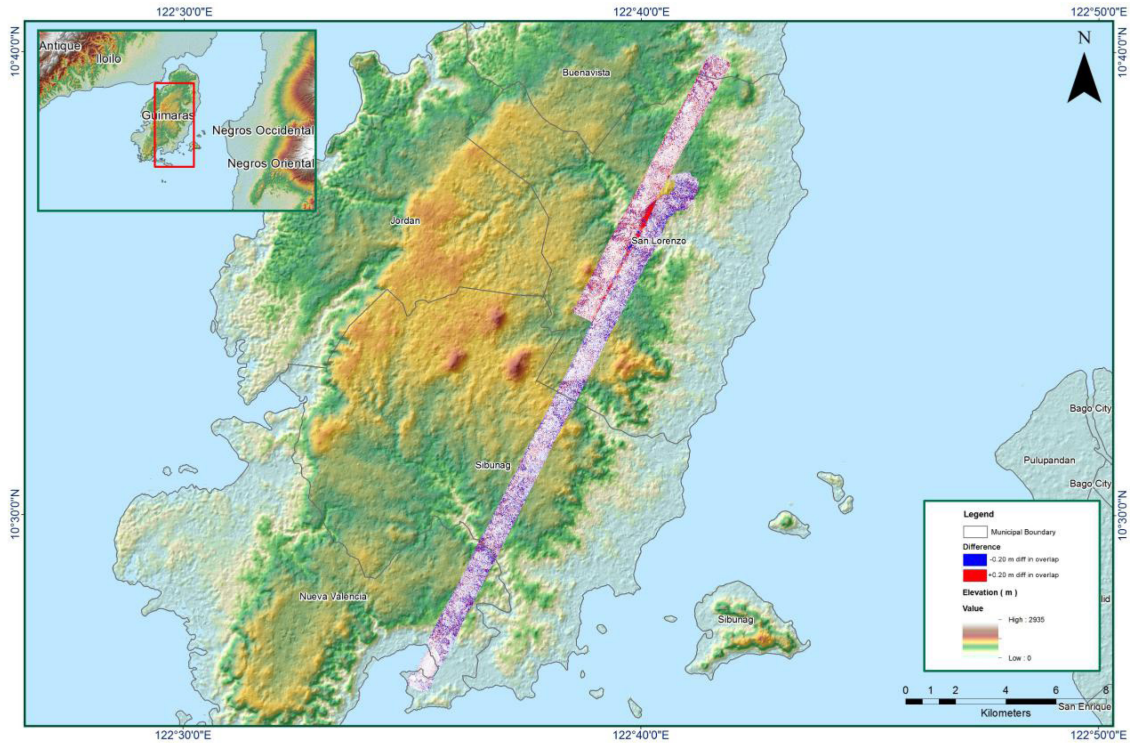


Figure A-8.105 Elevation difference between flight lines

Table A-8.16 Mission Summary Report for Blk43N

Flight Area	Iloilo Reflights
Mission Name	**Blk43N**
Inclusive Flights	8513AC
Range data size	13.2 GB
Base data size	208 MB
POS	244 MB
Image	NA
Transfer date	October 26, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.22
RMSE for East Position (<4.0 cm)	1.93
RMSE for Down Position (<8.0 cm)	3.55
Boresight correction stdev (<0.001deg)	0.000402
IMU attitude correction stdev (<0.001deg)	0.001333
GPS position stdev (<0.01m)	0.0102
Minimum % overlap (>25)	50.36
Ave point cloud density per sq.m. (>2.0)	4.95
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	122
Maximum Height	321.2 m
Minimum Height	51.24 m
Classification (# of points)	
Ground	57,758,610
Low vegetation	29,830,731
Medium vegetation	57,463,868
High vegetation	90,310,244
Building	90,310,244
Orthophoto	Yes
Processed by	Engr. James Kevin Dimaculangan, Engr. Merven Matthew Natino, Engr. Gladys Mae Apat

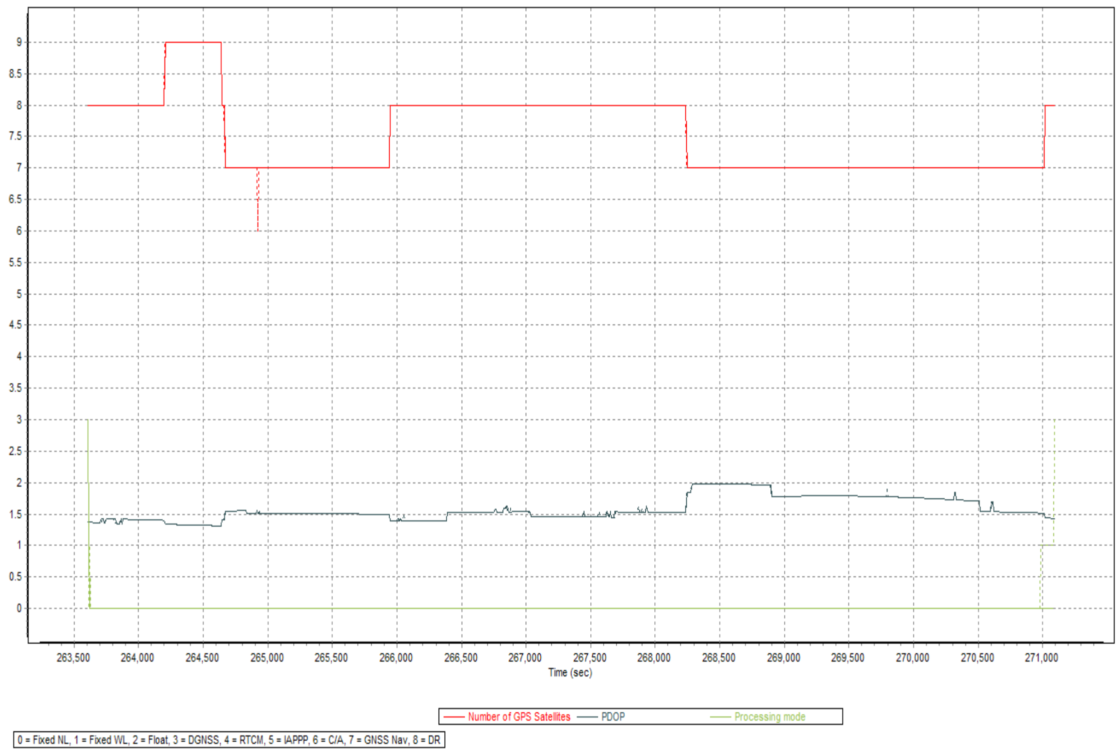


Figure A-8.106 Solution Status

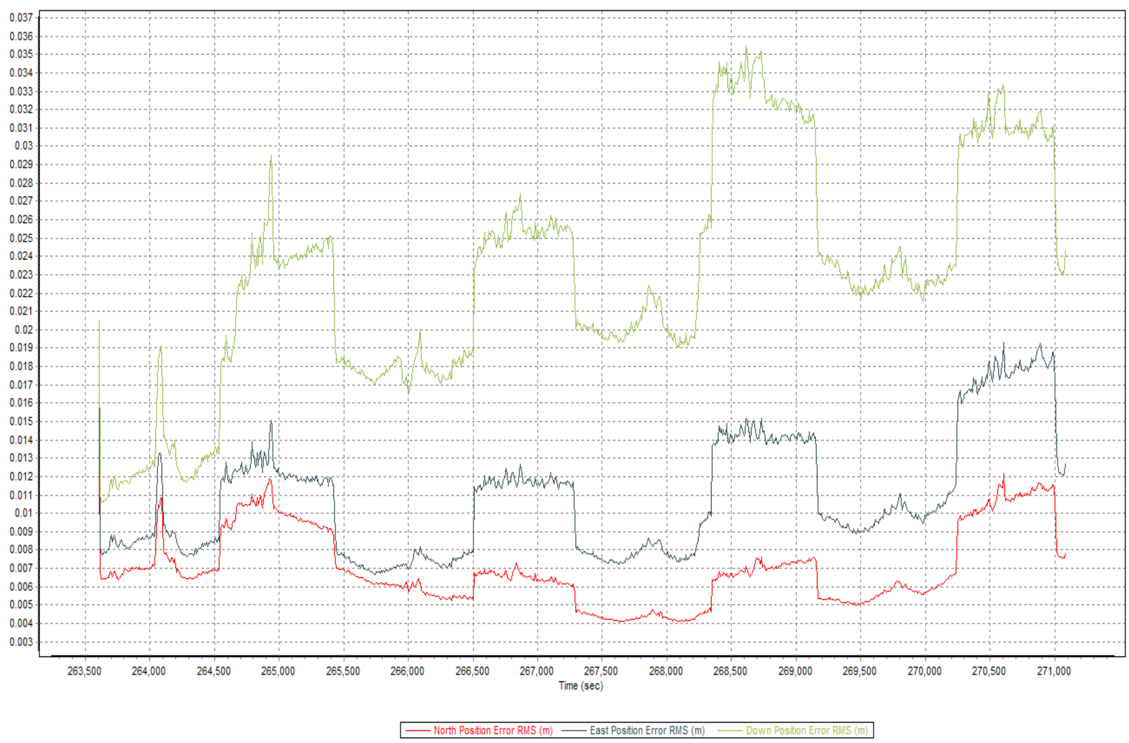


Figure A-8.107 Smoothed Performance Metric Parameters

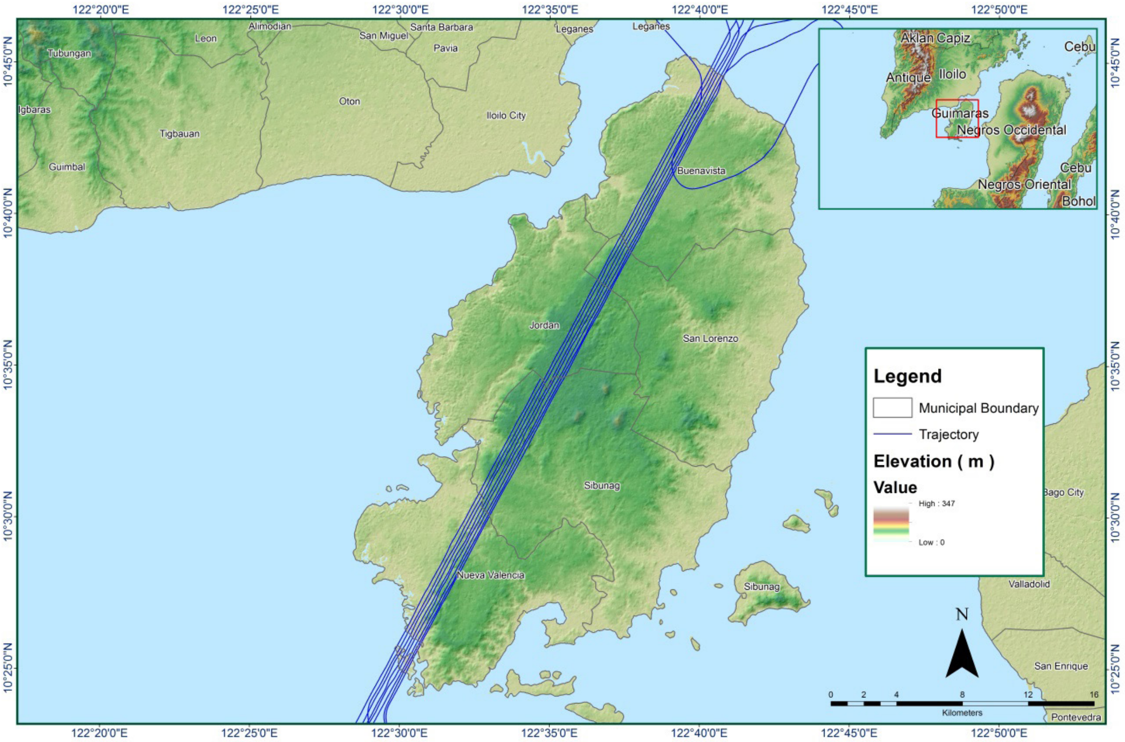


Figure A-8.108 Best Estimated Trajectory

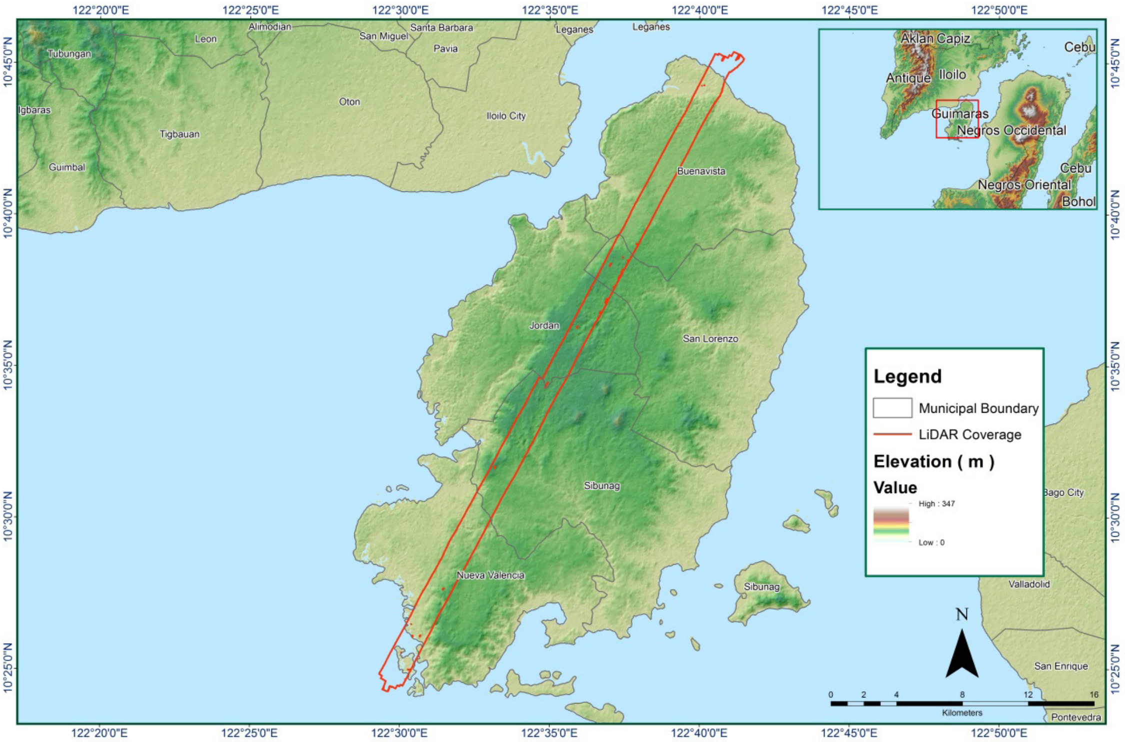


Figure A-8.109 Coverage of LiDAR data

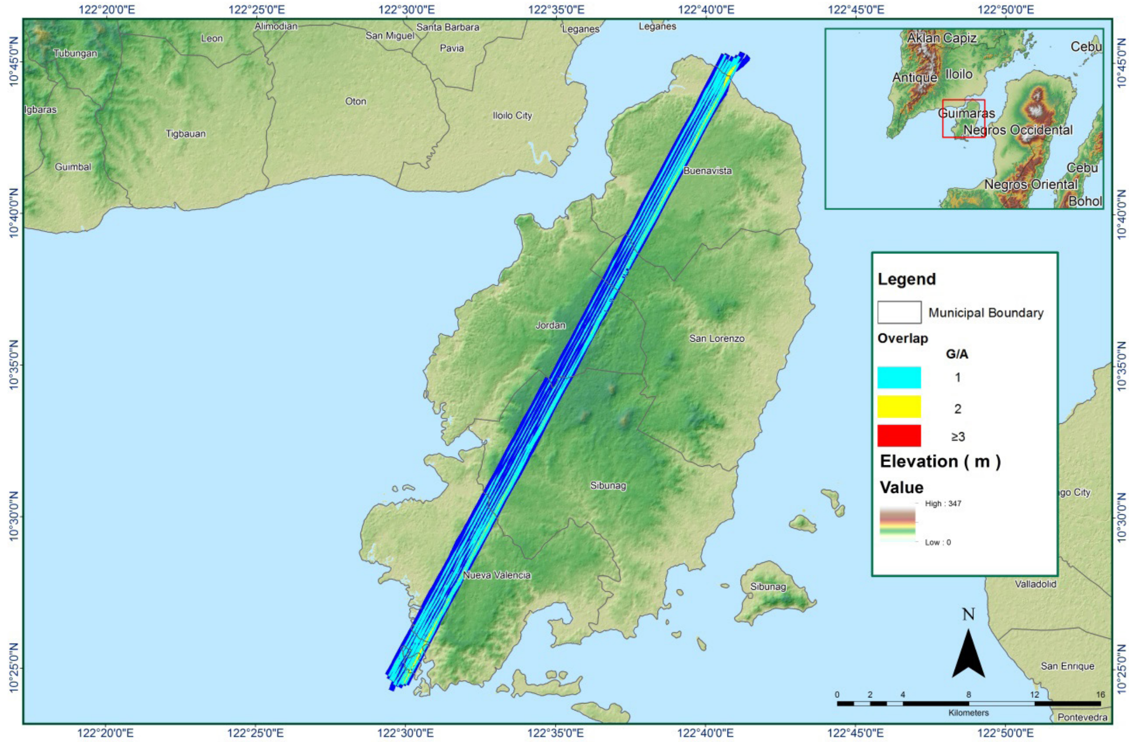


Figure A-8.110 Image of data overlap

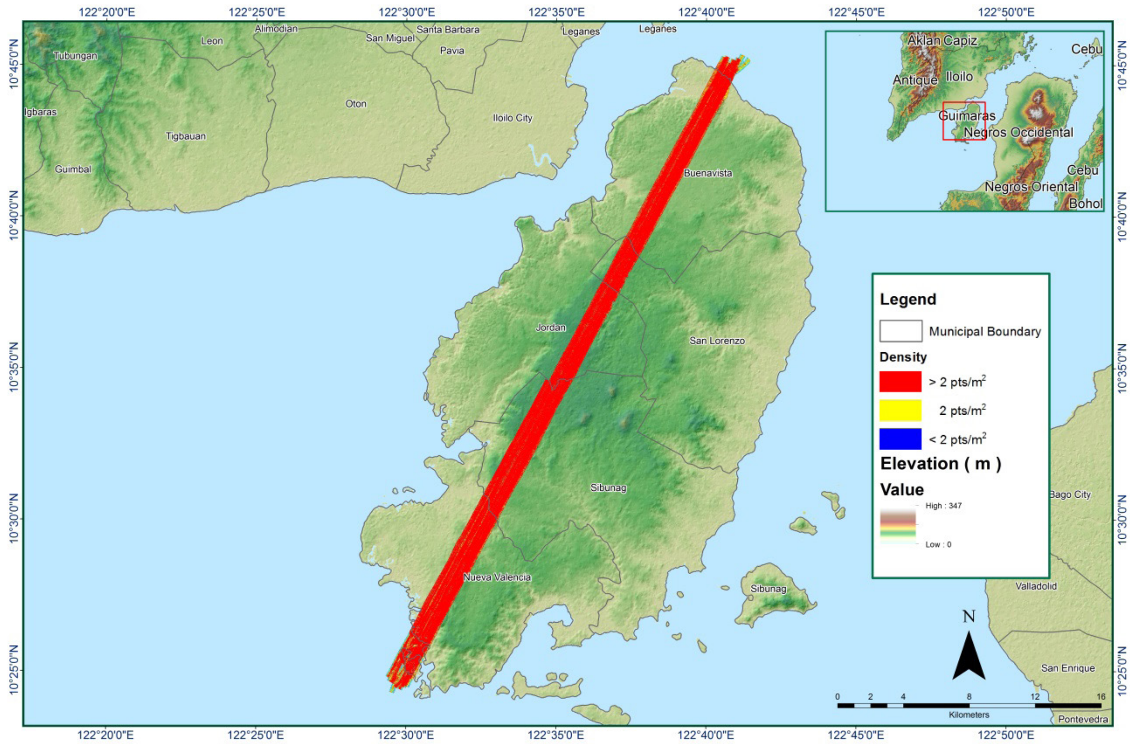


Figure A-8.111 Density map of merged LiDAR data

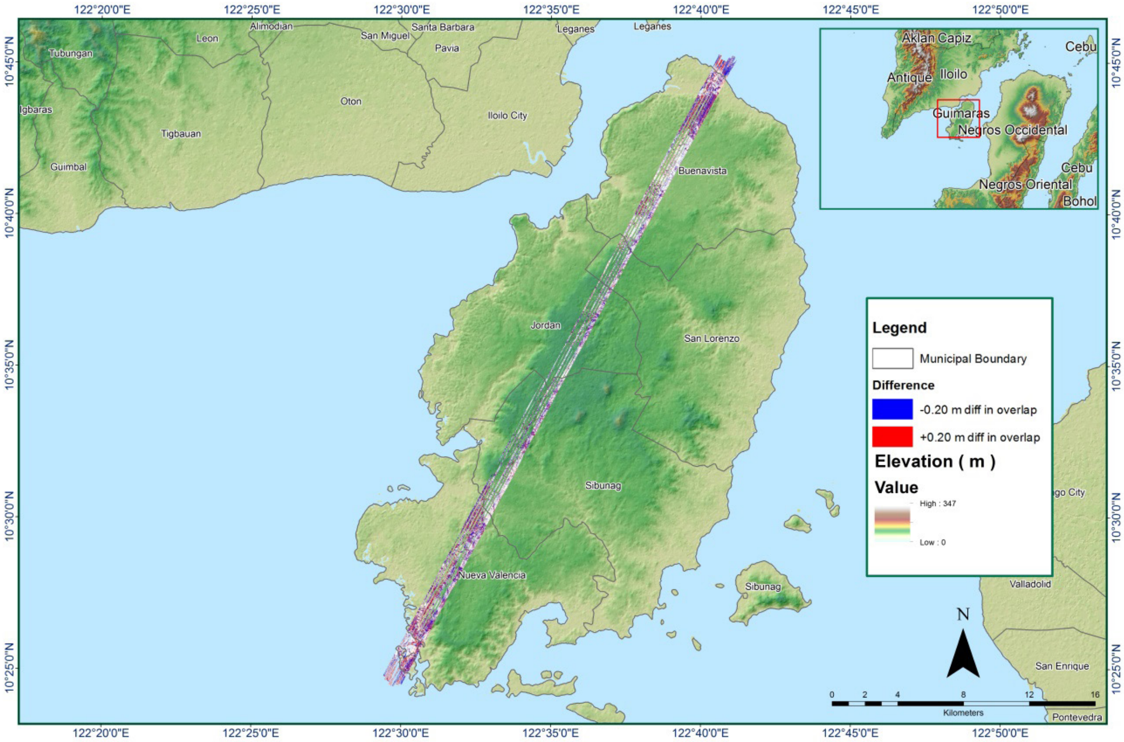


Figure A-8.112 Elevation difference between flight lines

Annex 9. Bago Model Basin Parameters

Table A-9.1 Bago Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W440	3.6193	70.088	0	19.452	5.7027	Discharge	0.0284584	0.00001	Ratio to Peak	0.0001
W450	3.6197	62.357	0	11.057	7.2687	Discharge	0.0358655	0.00001	Ratio to Peak	0.0001
W460	2.3747	52.853	0	18.013	7.9369	Discharge	0.0862123	0.00001	Ratio to Peak	0.0001
W470	2.098	65.66	0	11.312	3.4524	Discharge	0.0223259	0.00001	Ratio to Peak	0.0001
W480	3.2645	73.113	0	33.146	2.9387	Discharge	0.0166115	0.00001	Ratio to Peak	0.0001
W490	2.3758	79.505	0	0.70886	0.77214	Discharge	0.0095096	0.00001	Ratio to Peak	0.0001
W500	1.0036	70.107	0	0.44191	1.0353	Discharge	0.0493643	0.00001	Ratio to Peak	0.0001
W510	4.6791	65.587	0	5.459	3.5894	Discharge	0.0339394	0.00001	Ratio to Peak	0.0001
W520	1.6859	61.277	0	5.9316	8.6941	Discharge	0.028154	0.00001	Ratio to Peak	0.0001
W530	0.89043	79.399	0	9.0782	13.285	Discharge	0.027799	0.00001	Ratio to Peak	0.0001
W540	3.6649	78.957	0	4.833	3.1795	Discharge	0.0105641	0.00001	Ratio to Peak	0.0001
W550	5.1795	63.344	0	4.8788	3.2066	Discharge	0.0132725	0.00001	Ratio to Peak	0.0001
W560	0.29818	63.639	0	0.97992	0.72275	Discharge	0.0053229	0.00001	Ratio to Peak	0.0001
W570	0.16753	99	0	0.19258	0.28944	Discharge	0.000426448	0.00001	Ratio to Peak	0.0001
W580	0.21258	99	0	0.65983	0.29943	Discharge	0.0011075	0.00001	Ratio to Peak	0.0001
W590	0.26622	99	0	0.18092	0.26105	Discharge	0.000187145	0.00001	Ratio to Peak	0.0001
W600	0.19776	99	0	0.91514	0.39947	Discharge	0.0084785	0.00001	Ratio to Peak	0.0001
W610	0.22348	85.766	0	0.75871	0.41623	Discharge	0.0166028	0.00001	Ratio to Peak	0.0001
W620	0.45848	82.125	0	0.95631	0.26143	Discharge	0.0046303	0.00001	Ratio to Peak	0.0001

W630	3.872	60.65	0	4.813	3.1571	Discharge	0.0242959	0.00001	Ratio to Peak	0.0001
W640	4.0303	59.63	0	9.6244	4.2351	Discharge	0.0256199	0.00001	Ratio to Peak	0.0001
W650	5.2466	53.046	0	3.5329	7.7192	Discharge	0.0176086	0.00001	Ratio to Peak	0.0001
W660	2.0312	56.646	0	13.142	3.8755	Discharge	0.0274746	0.00001	Ratio to Peak	0.0001
W670	1.711	46.82	0	11.292	7.4117	Discharge	0.0378866	0.00001	Ratio to Peak	0.0001
W680	1.7557	72.649	0	1.115	0.55939	Discharge	0.0297976	0.00001	Ratio to Peak	0.0001
W690	2.7572	68.583	0	3.6082	2.3791	Discharge	0.0236694	0.00001	Ratio to Peak	0.0001
W700	5.3986	52.405	0	8.8739	5.8862	Discharge	0.0139659	0.00001	Ratio to Peak	0.0001
W710	0.39333	74.628	0	0.18859	0.63876	Discharge	0.0044033	0.00001	Ratio to Peak	0.0001
W720	0.1968	98.364	0	0.7986	0.52469	Discharge	0.0171293	0.00001	Ratio to Peak	0.0001
W730	3.6979	61.757	0	4.9829	7.2961	Discharge	0.0223483	0.00001	Ratio to Peak	0.0001
W740	0.16967	99	0	0.17585	0.28026	Discharge	0.0025183	0.00001	Ratio to Peak	0.0001
W750	0.30214	63.326	0	0.18784	0.44007	Discharge	0.0037516	0.00001	Ratio to Peak	0.0001
W760	0.28635	73.567	0	0.65074	0.47996	Discharge	0.0192934	0.00001	Ratio to Peak	0.0001
W770	0.34897	77.503	0	0.344	1.1847	Discharge	0.0042625	0.00001	Ratio to Peak	0.0001
W780	0.32543	70.105	0	0.6636	2.2853	Discharge	0.0172641	0.00001	Ratio to Peak	0.0001
W790	0.12742	88.765	0	1.0267	0.74206	Discharge	0.0291398	0.00001	Ratio to Peak	0.0001
W800	2.7349	77.013	0	6.2317	6.1123	Discharge	0.0173869	0.00001	Ratio to Peak	0.0001
W810	0.14025	82.801	0	0.39106	0.57874	Discharge	0.0066268	0.00001	Ratio to Peak	0.0001
W820	4.0747	77.046	0	4.3979	6.4455	Discharge	0.051334	0.00001	Ratio to Peak	0.0001
W830	0.21066	84.082	0	0.54788	0.58211	Discharge	0.0197129	0.00001	Ratio to Peak	0.0001
W840	2.6157	76.266	0	4.977	7.3027	Discharge	0.0425653	0.00001	Ratio to Peak	0.0001
W850	0.41076	81.693	0	0.55802	0.59288	Discharge	0.0164589	0.00001	Ratio to Peak	0.0001
W860	1.3056	51.377	0	23.982	3.1759	Discharge	0.026654	0.00001	Ratio to Peak	0.0001

Annex 10. Bago Model Reach Parameters

Table A-10.1 Bago Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R30	Automatic Fixed Interval	4579.31	0.013934	0.0001	Trapezoid	70.48	1
R60	Automatic Fixed Interval	1456.1	0.007061	0.0001	Trapezoid	70.48	1
R70	Automatic Fixed Interval	889.411	0.016001	0.0001	Trapezoid	70.48	1
R90	Automatic Fixed Interval	636.69	0.000118	0.0001	Trapezoid	70.48	1
R100	Automatic Fixed Interval	507.99	0.003275	0.0001	Trapezoid	70.48	1
R110	Automatic Fixed Interval	2839.53	0.007204	0.0001	Trapezoid	70.48	1
R120	Automatic Fixed Interval	5008.18	0.012202	0.0001	Trapezoid	70.48	1
R150	Automatic Fixed Interval	2289.36	0.018505	0.0001	Trapezoid	70.48	1
R160	Automatic Fixed Interval	770.416	0.013281	0.0001	Trapezoid	70.48	1
R190	Automatic Fixed Interval	3596.59	0.015821	0.0001	Trapezoid	70.48	1
R220	Automatic Fixed Interval	2607.65	0.005366	0.0001	Trapezoid	70.48	1
R230	Automatic Fixed Interval	1451.25	0.013598	0.0001	Trapezoid	70.48	1
R250	Automatic Fixed Interval	10359.9	0.004838	0.0001	Trapezoid	70.48	1
R270	Automatic Fixed Interval	2509.66	0.018178	0.0001	Trapezoid	70.48	1
R280	Automatic Fixed Interval	7315.95	0.010304	0.0001	Trapezoid	70.48	1
R300	Automatic Fixed Interval	3154.92	0.022818	0.0001	Trapezoid	70.48	1
R310	Automatic Fixed Interval	2156.64	0.000074	0.0001	Trapezoid	70.48	1
R320	Automatic Fixed Interval	3706.52	0.000489	0.0001	Trapezoid	70.48	1
R360	Automatic Fixed Interval	2200.66	0.00469	0.0001	Trapezoid	70.48	1
R380	Automatic Fixed Interval	5672.12	0.075335	0.0001	Trapezoid	70.48	1
R410	Automatic Fixed Interval	7115.36	0.00644	0.0001	Trapezoid	70.48	1

Annex 11. Bago Field Validation

Table A-11.1 Bago Field Validation

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event / Date	Rain Return / Scenario
	Latitude	Longtitude					
1	122.8753	10.55762	0.389999986	0	0.152		
2	122.8897	10.56979	0.140000001	0	0.020		
3	122.8269	10.45693	0.180000007	0	0.032		
4	122.8287	10.52232	0.649999976	0	0.422		
5	122.8092	10.50745	0	0	0.000		
6	122.8945	10.5346	0.029999999	0	0.001		
7	122.9114	10.53085	0.029999999	0	0.001		
8	122.8332	10.47175	0.029999999	0	0.001		
9	122.8291	10.49797	0.779999971	0	0.608		
10	122.8396	10.53622	0.029999999	0	0.001		
11	122.8958	10.51392	0.029999999	0	0.001		
12	122.9379	10.51525	0.079999998	0	0.006		
13	122.9186	10.49279	0.079999998	0	0.006		
14	122.8293	10.5018	0.150000006	0	0.023		
15	122.8053	10.52883	0.029999999	0	0.001		
16	122.9891	10.49098	0.029999999	0	0.001		
17	122.8675	10.49468	0.029999999	0	0.001		
18	122.9073	10.51513	0.029999999	0	0.001		
19	122.9122	10.51434	0.029999999	0	0.001		
20	122.9149	10.51256	0.029999999	0	0.001		
21	122.8033	10.51961	0.039999999	0	0.002		
22	122.8466	10.52248	0.280000001	0	0.078		
23	122.87	10.47526	0.029999999	0	0.001		
24	122.855	10.47665	0.209999993	0	0.044		
25	122.8396	10.47734	0.400000006	0	0.160		
26	122.9294	10.49781	0.129999995	0	0.017		
27	122.8732	10.47253	0.029999999	0	0.001		
28	122.9738	10.49632	0.540000021	0	0.292		
29	122.8713	10.4719	0.029999999	0	0.001		
30	122.9373	10.53936	0.07	0	0.005		
31	122.9922	10.5191	0.829999983	0	0.689		
32	122.9542	10.50245	3.309999943	0	10.956		
33	122.8247	10.50792	0.319999993	0	0.102		
34	122.8658	10.55338	0	0	0.000		
35	122.9709	10.5325	0.180000007	0	0.032		
36	122.9055	10.53473	0.050000001	0	0.003		
37	123.0016	10.47884	0.029999999	0	0.001		
38	123.0042	10.47523	0.029999999	0	0.001		
39	122.9052	10.49305	0.029999999	0	0.001		
40	122.9322	10.54432	0.07	0	0.005		
41	122.8638	10.52778	0.119999997	0	0.014		

42	123.0058	10.45384	0.039999999	0	0.002		
43	122.8624	10.55129	0.029999999	0	0.001		
44	122.8724	10.51475	0.029999999	0	0.001		
45	122.8677	10.5169	0.129999995	0	0.017		
46	122.9809	10.52026	0.029999999	0	0.001		
47	122.9909	10.4921	0.280000001	0	0.078		
48	122.9581	10.49593	2.50999999	3.66	1.323	Uring	5-Year
49	122.9555	10.49126	2.99000001	3.66	0.449	Uring	5-Year
50	122.836	10.52697	3.200000048	3	0.040	Ruping	5-Year
51	122.884	10.54318	2.019999981	3	0.960	Uring	5-Year
52	122.8832	10.53599	1.75	3	1.563	Uring	5-Year
53	122.9947	10.4454	1.230000019	3	3.133	Ondoy	5-Year
54	122.8863	10.55056	0.430000007	3	6.605	Senyang	5-Year
55	122.9948	10.44404	0.970000029	3	4.121	Ondoy	5-Year
56	123.0002	10.48113	1.929999948	2.54	0.372	Uring	5-Year
57	122.9092	10.51558	0	2	4.000	Uring	5-Year
58	122.8429	10.53845	2.269999981	1.3	0.941	Ruping	5-Year
59	122.8357	10.53007	2.539999962	1.1	2.074	Ruping	5-Year
60	122.8852	10.50627	2.400000095	1.1	1.690	Uring	5-Year
61	122.8147	10.52405	2.670000076	1	2.789	Uring	5-Year
62	122.8142	10.5204	1.929999948	1	0.865	Uring	5-Year
63	122.8191	10.52988	1.799999952	1	0.640	Uring	5-Year
64	122.7997	10.52456	5.809999943	0.7	26.112		
65	122.8042	10.52225	1.350000024	0.7	0.423	Ruping	5-Year
66	122.8347	10.54494	2.430000067	0.7	2.993	Ruping	5-Year
67	122.8928	10.54547	0.360000014	0.7	0.116	Ondoy	5-Year
68	122.871	10.50926	1.00999999	0.7	0.096	Uring	5-Year
69	122.861	10.46361	1.230000019	0.7	0.281	Frank	5-Year
70	122.825	10.48312	1.549999952	0.7	0.722	Ruping	5-Year
71	122.839	10.53176	1.549999952	0.5	1.102	Caloy	5-Year
72	122.846	10.53349	0.600000024	0.5	0.010	Yolanda	5-Year
73	122.8056	10.5253	1.960000038	0.5	2.132	Ruping	5-Year
74	122.8392	10.5416	2.900000095	0.5	5.760	Ruping	5-Year
75	122.8326	10.53275	3.299999952	0.5	7.840	Uring	5-Year
76	122.8283	10.46212	2.690000057	0.5	4.796	Ruping	5-Year
77	122.8255	10.52116	2.400000095	0.5	3.610	Ruping	5-Year
78	122.8324	10.45559	2.109999895	0.5	2.592	Yolanda	5-Year
79	122.8354	10.53556	0	0.45	0.203	Ruping	5-Year
80	122.8096	10.52293	1.779999971	0.4	1.904	Ruping	5-Year
81	122.8452	10.45507	1.549999952	0.4	1.322	Ondoy	5-Year
82	122.8182	10.51618	1.299999952	0.4	0.810	Ruping	5-Year
83	122.8524	10.45608	0.029999999	0.3	0.073	Ondoy	5-Year
84	123.0152	10.47018	1.850000024	0.18	2.789	Yolanda	5-Year
85	122.9516	10.48163	0	1.5	2.250	Norming	5-Year
86	122.9514	10.49085	1.049999952	4	8.703	Yolanda	5-Year
87	122.9534	10.48329	1.100000024	1.5	0.160	Norming	5-Year
88	122.95	10.48953	2.019999981	4	3.920	Yolanda	5-Year

89	122.9519	10.48529	2.849999905	1.5	1.822	Norming	5-Year
90	122.9545	10.48728	2.789999962	1	3.204	Uring	5-Year
91	122.9436	10.4817	2.980000019	5.5	6.350	Uring	5-Year
92	122.9519	10.48974	0.340000004	4	13.396	Yolanda	5-Year
94	122.8515	10.53195	0.029999999	0	0.001	Yolanda	5-Year
95	122.8518	10.5292	0.029999999	0	0.001	Yolanda	5-Year
96	122.8538	10.52936	0.129999995	0	0.017	Yolanda	5-Year
97	122.8421	10.53798	1.730000019	1.2	0.281	Undang	5-Year
98	122.8486	10.54142	6.769999981	1.87	24.010	Undang	5-Year
99	122.8445	10.54455	2.349999905	1.3	1.102	Ondoy	5-Year
100	122.844	10.53555	2.299999952	1.2	1.210	Undang	5-Year
102	122.8483	10.54395	0.829999983	0	0.689	Undang	5-Year
103	122.8386	10.54229	0	1.2	1.440	Undang	5-Year
104	122.8449	10.54467	0	1.3	1.690	Ondoy	5-Year
106	122.8445	10.54456	0	1.3	1.690	Ondoy	5-Year
107	122.8458	10.53258	0	0	0.000	Glenda	5-Year
108	122.9641	10.46623	1.779999971	1.25	0.281	Marce	5-Year
109	122.8773	10.55979	0	0	0.000		
110	122.8762	10.55864	0	0	0.000	Uring	5-Year
111	122.8756	10.55849	0	0	0.000	Uring	5-Year
112	122.876	10.55853	0	0	0.000	Uring	5-Year
113	122.8496	10.53591	0	1	1.000	Senyang	5-Year
114	122.8516	10.53315	0	0	0.000	Yolanda	5-Year
115	122.9641	10.46725	0	1.25	1.563	Marce	5-Year
116	122.8794	10.56034	6.199999809	3.5	7.290	Uring	5-Year
119	122.8892	10.49835	0.170000002	5	23.329	Uring	5-Year
121	122.9181	10.48956	0.239999995	5.5	27.668	Uring	5-Year
122	122.9572	10.50928	0.5	3	6.250	Uring	5-Year
123	122.9168	10.48998	0.159999996	5.5	28.516	Uring	5-Year
124	122.9566	10.50875	0.119999997	5	23.814	Uring	5-Year
126	122.9182	10.48952	2.460000038	5.5	9.242	Uring	5-Year
127	122.9172	10.48989	0.239999995	5.5	27.668	Uring	5-Year
128	122.9168	10.48999	1.100000024	5.5	19.360	Uring	5-Year
130	122.9164	10.49079	1.190000057	5.5	18.576	Uring	5-Year
131	122.8567	10.50765	0.209999993	5	22.944	Yolanda	5-Year
132	122.9009	10.49307	0.239999995	5	22.658	Uring	5-Year
133	122.9486	10.48419	0.140000001	5.5	28.730	Uring	5-Year
134	122.8659	10.50502	0.300000012	5	22.090	Yolanda	5-Year
135	122.9443	10.48911	0.829999983	5	17.389	Uring	5-Year
136	122.95	10.49636	0.07	5	24.305	Uring	5-Year
137	122.9559	10.48966	0.059999999	0	0.004		
138	122.9487	10.48666	0.289999992	0	0.084		
139	122.8481	10.53367	0.150000006	1.25	1.210	Ondoy	5-Year
140	122.8483	10.53588	0.029999999	0	0.001		
141	122.8495	10.53764	0.709999979	0.75	0.002	Ruping	5-Year
142	122.848	10.5306	0.029999999	1.25	1.488	Ondoy	5-Year
143	122.847	10.52971	1.190000057	1.25	0.004	Ondoy	5-Year

144	122.8461	10.5285	0.899999976	0	0.810		
145	122.8842	10.53266	0.029999999	0.5	0.221	Ruping	5-Year
146	122.8426	10.52372	0.330000013	0.5	0.029	Marce	5-Year
147	122.8439	10.52805	0.029999999	0.3	0.073	Auring	5-Year
148	122.8463	10.52805	0.360000014	0	0.130		
149	122.8835	10.5445	1.860000014	3	1.300	Ruping	5-Year
150	122.8466	10.52888	1.049999952	1.25	0.040	Ondoy	5-Year
151	122.9558	10.47579	2.119999886	5	8.294	Uring	5-Year
152	122.9558	10.47687	2.5	5	6.250	Uring	5-Year
153	122.8818	10.53272	0.519999981	3	6.150	Ondoy	5-Year
154	122.8823	10.54029	1.649999976	3	1.823	Ruping	5-Year
155	122.8837	10.5341	0	0.25	0.063	Ondoy	5-Year
156	122.8832	10.53865	2.880000114	3	0.014	Ruping	5-Year
157	122.8833	10.54488	1.940000057	3	1.124	Ruping	5-Year
158	122.956	10.4828	4.920000076	5	0.006	Uring	5-Year
159	122.9638	10.46799	0.029999999	1.25	1.488	Ferdie	5-Year
160	122.8847	10.53201	2.289999962	0.5	3.204	Ruping	5-Year
161	122.8816	10.53303	0.039999999	3	8.762	Ondoy	5-Year
163	122.9556	10.50821	0.090000004	0	0.008		
164	122.8832	10.53363	0.680000007	0.25	0.185	Ondoy	5-Year
165	122.8828	10.53343	0.5	1.25	0.563	Ondoy	5-Year
166	122.8832	10.54366	0.029999999	3	8.821	Ruping	5-Year
167	122.8827	10.53353	0.029999999	1.25	1.488	Ondoy	5-Year
168	122.8839	10.54464	0.050000001	3	8.702	Ruping	5-Year
169	122.884	10.53319	0.07	0.5	0.185	Ferdie	5-Year
171	122.8812	10.53292	2.180000067	3	0.672	Ondoy	5-Year
172	122.8839	10.5442	2.609999895	3	0.152	Ruping	5-Year
173	122.8825	10.53602	2.650000095	3	0.122	Ruping	5-Year
174	122.8816	10.53319	0.140000001	3	8.180	Ondoy	5-Year
175	122.8832	10.5368	2.859999895	3	0.020	Ruping	5-Year
176	122.9564	10.4811	3.680000067	5	1.742	Uring	5-Year
177	122.8823	10.536	6.679999828	3	13.542	Ruping	5-Year
178	122.9552	10.48458	5.800000191	5	0.640	Uring	5-Year
179	122.9565	10.4814	2.220000029	5	7.728	Uring	5-Year
180	122.9554	10.48462	2.799999952	5	4.840	Uring	5-Year
181	122.9562	10.48242	5.880000114	5	0.774	Uring	5-Year
182	122.9561	10.48262	4.489999771	5	0.260	Uring	5-Year
183	122.9562	10.48261	1.75	5	10.563	Uring	5-Year
186	122.9563	10.48216	2.710000038	5	5.244	Uring	5-Year
187	122.9554	10.48455	1.419999957	5	12.816	Uring	5-Year
191	122.9552	10.4846	0.029999999	5	24.701	Uring	5-Year
194	122.945	10.49004	0.039999999	5	24.602	Uring	5-Year

Annex 12. Educational Institutions Affected in Bago Floodplain

Table A-12.1 Educational Institutions in Bago City, Negros Occidental Affected by Flooding in the Bago Floodplain

Negros Occidental				
Bago City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Abuanan Elementary School	Abuanan	Low	Low	Low
Abuanan Proper Day Care Center	Abuanan			
Dr. P. F. Elizalde Elementary School	Bacong-Montilla			
J. Montilla Elementary School	Bacong-Montilla			
Najaba Elementary School	Bacong-Montilla			
Bagroy Elementary School	Bagroy			
Barangay Bagroy Daycare Center	Bagroy			
Bago City College	Balingasag	Low	Low	Low
Notre Dame	Balingasag			Medium
Ramon Torres National High School-Main	Balingasag	Medium	Medium	Medium
T. M. Morada Elementary School	Calumangan			
T.M. Morada Elementary School	Calumangan			
Binubuhan Elementary School	Ilijan			
Ma-ao Sugar Central Elementary School	Jorge L. Araneta			
Ramon Torres M-ao Central National High School	Jorge L. Araneta			
Ramon Torres Ma-ao Central National High School	Jorge L. Araneta			
Ramon Torres National High School-Main	Lag-Asan			Low
Regina Rosarii School, Inc.	Lag-Asan	Low	Medium	Medium
Regnia Rosarii School, Inc.	Lag-Asan			Medium
Technological Foundation Institute	Lag-Asan			Low
Admin Building Sanitary Landfill	Ma-Ao Barrio			
Louisiana Elementary School & Ramon Torres Nation*	Ma-Ao Barrio			
Ma-ao Elementary School	Ma-Ao Barrio			
Materials Recovery Facility	Ma-Ao Barrio			
Monitoring Well and Septic Vault	Ma-Ao Barrio			
Our Lady of Pillar Academy	Ma-Ao Barrio	Low	Medium	Low
Storage Room	Ma-Ao Barrio	Low	Low	Low
Jalsis Elementary School	Malingin	Low	Low	High
Ramon Torres Malingin National High School	Malingin			Medium
L. De la Rama Elementary School	Napoles			Medium
L. de la Rama Elementary School	Napoles		Low	High
Ramon Torres Malingin National High School	Napoles			High
Bago City Elementary School	Poblacion	Low	Low	Medium
Bagosphere Building	Poblacion			
Brookside Garden Academy	Poblacion			Medium
Gen. Juan A. Araneta Elementary School	Poblacion	Medium	Medium	High

Ramon Torres National High School-Main	Poblacion			Low
TFI Vocational School	Poblacion			Low
SILOAM School	Sampinit	Low	Low	High
Marietta Village Day Care Center	Taloc			
Newton-Jison Elementary School	Taloc			

Table A-12.2 Educational Institutions in Pulupandan, Negros Occidental Affected by Flooding in the Bago Floodplain

Pulupandan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Enriquetta Montilla de Esteban Memorial High Scho*	Barangay Zone 2			Low
Municipal Auditorium	Barangay Zone 4			Low
Pulupandan East Elementary School	Barangay Zone 4			
Pulupandan Municipal Building	Barangay Zone 4			
PCCS Church/School	Barangay Zone 6		Low	Low
Pulupandan Elementary School	Barangay Zone 6	Low	Low	Low
Water Tank	Barangay Zone 6			
Municipal Auditorium	Barangay Zone 7			Low
Sago Elementary School	Crossing Pu-lupandan			
Cavan Elementary School	Culo			
Pag-ayon Elementary School	Pag-Ayon			Low
Palaka Elementary School	Palaka Sur			
Patic Elementary School	Patic			
Sago Elementary School	Patic		Low	Low
Pag-ayon Elementary School	Tapong	Low	Low	Medium
Enriquetta Montilla de Esteban Memorial High Scho*	Ubay			
Ubay Elementary School	Ubay		Low	Low
Patic Elementary School	Utod			

Table A-12.3 Educational Institutions in Valladolid, Negros Occidental Affected by Flooding in the Bago Floodplain

Valladolid				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Emilio Enfante Elem. School	Mabini	Low	Low	Low
Pacol Elementary School	Pacol			
Palaka Day Care Center	Palaka	Low	Medium	Medium
Valladolid National High School	Palaka			Low

FRANSISCO INFANTE MEMORIAL HIGH SCHOOL(PRIVATE)	Poblacion			
Guadalope Kinder School	Poblacion	Low	Low	Low
Valladolid Elemtary School	Poblacion			

Annex 13. Health Institutions Affected in Bago Floodplain

Table A-13.1 Health Institutions in Bago City, Negros Occidental Affected by Flooding in the Bago Floodplain

Negros Occidental				
Bago City				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Abuanan Barangay Health Station	Abuanan			
Bacong Montilla Barangay Health Station	Bacong-Montilla			Low
Bagroy Barangay Health Station	Bagroy			
Barangay Health Center	Ma-Ao Barrio			
Malingin Barangay Health Station	Malingin			Low
Bago City Hospital	Napoles	Low	Medium	High
City Health Office/GSO	Poblacion			

Table A-13.2 Health Institutions in Valladolid, Negros Occidental Affected by Flooding in the Bago Floodplain

Valladolid				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Dr. Abadea Clinic	Poblacion			
Poblacion Barangay Health Center	Poblacion			

Annex 14. UPC Phil-LiDAR 1 Team Composition

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