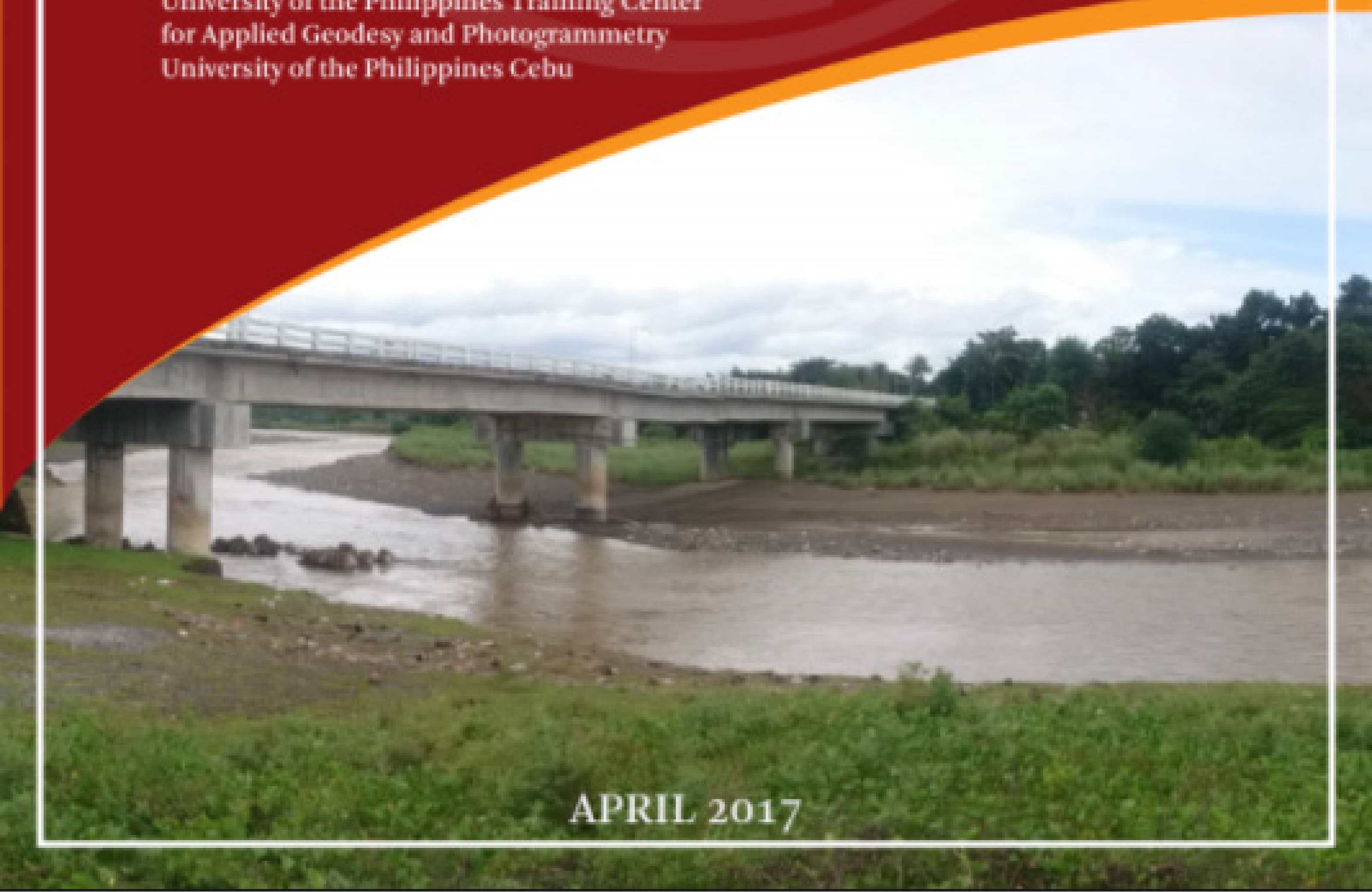
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Sibalom River

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



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LIST OF ACRONYMS AND ABBREVIATIONS

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

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND SIBALOM RIVER

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

1.1 Background of the Phil-LIDAR 1 Program

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

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for a 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 the DOST. The methods applied in this report are thoroughly described in a separate publication entitled “Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods” (Paringit, et. al., 2017), available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines 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 twenty-two (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 Sibalom River Basin

The Sibalom River Basin is located in the province of Iloilo, situated at the south of the Panay Island. It covers majority of the Municipalities of Leon and Tigbauan, and minor portions of Alimodian, Tubungan, Guimbal, and Oton, in the province of Iloilo. The Department of Environment and Natural Resources – River Basin Control Office (DENR-RBCO) identified the basin to have a drainage area of 222 km2, and an estimated 1,235 million cubic meters (MCM) in annual run-off (RBCO, 2016). The basin’s main stem, the Sibalom River, is among the twenty-two (22) river systems in the Western Visayas Region.

According to the 2015 national census of the National Statistics Office (NSO), the total population of residents within the immediate vicinity of the river is 23,480, distributed among fifteen (15) barangays in the Municipalities of Leon and Tigbauan (NSO, 2015). The Sibalom River serves as an irrigation system to the agricultural lands in Tigbauan, and some of those in Leon (source: http://myphilippinelife.com/big-panay-irrigation-project-brings-improvements-to-tigbauan/).

On August 2016, the Municipalities of Leon and Tigbauan, along with twelve (12) other towns in Iloilo, experienced heavy flooding due to torrential rains caused by the southwest monsoon (source: http://newsinfo.inquirer.net/805524/elderly-man-drowns-60-families-flee-from-floods-in-antique-iloilo-city).

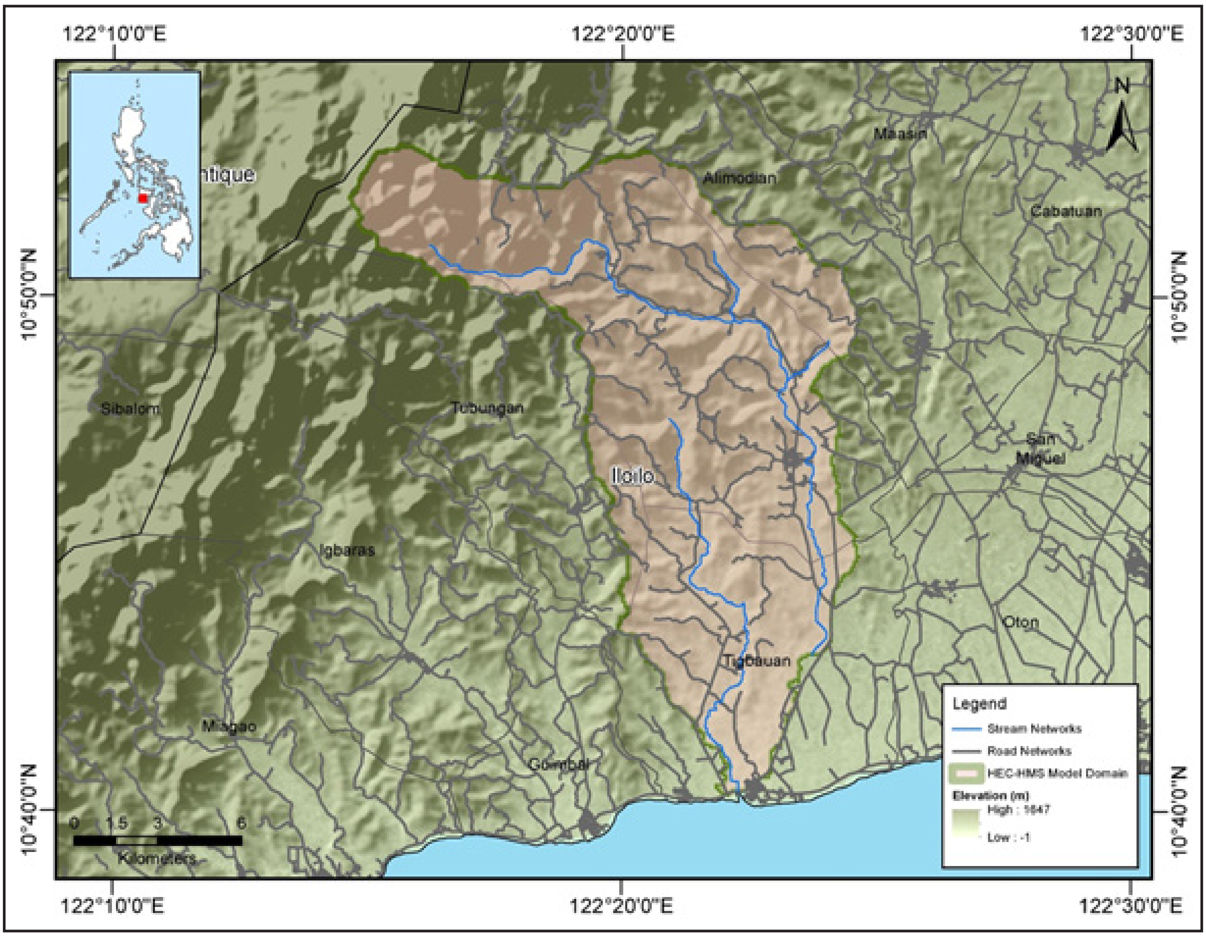

Figure 1. Location map of the Sibalom River Basin (in brown)

The Phil-LiDAR1 1 Program hopes to contribute to the mitigation of the impact of such flooding events in Filipino communities. In this particular LiDAR survey, the Sibalom floodplain area of 104.89 km2 was fully covered by LiDAR data, comprising of two (2) blocks. The LiDAR data was calibrated, mosaicked with an RMSE value of -1.09, and then bathy burned. The bathymetric survey conducted in the Sibalom River gathered 35,740 points and traversed a total length of 24.42 kilometers, starting at the Baltazar Aquino Bridge in Poblacion, Leon until the mouth of the river. A total of 15,181 buildings, 411-kilometer roads, 10 water bodies, and 17 bridges were digitized, based on the LiDAR data. Feature extraction attribution was conducted and among the building features in the floodplain, consisting of 14,381 residential buildings, 264 schools, and 13 medical institutions.

The flood hazard maps generated for the floodplain covers 28.43 km2, 32.65 km2, and 36.41 km2 for the 5-year, 25-year, and 100 year rainfall return periods, respectively, in the following municipalities: (i.) Guimbal, with five (5) barangays exposed to flooding; (ii.) Leon, with thirty-nine (39) barangays affected; (iii.) Oton, involving four (4) barangays; (iv.) Tigbauan, affecting fifty-two (52) barangays; and (v.) Tubungan, with ten (10) barangays exposed to flooding. A flood depth validation was conducted using one hundred and eighty-one (181) randomly generated points in the 25-year rainfall flood depth map, which are spread across six (6) ranges of flood levels (i.e., 0-0.2 meters, 0.21-0.5 meters, 0.51-1 meter, 1.01-2 meters, 2.10-5 meters, and more than 5 meters). The validation yielded an RMSE value of 0.683 meters.

The HEC-HMS model of the Sibalom River Basin still requires calibration. Several initial flow data gathering activities were performed at the Baltazar Aquino Bridge in the Municipality of Leon, Iloilo. However, the onset of the El Niño phenomenon, characterized by lack of rain events and minimal precipitation, coincided with the project duration, and consequently prevented the acquisition of sufficient flow and rainfall data.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SIBALOM FLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Sibalom floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in Iloilo. Each flight mission had an average of fifteen (15) lines that ran for at most four (4) hours, including take-off, landing, and turning time. The Pegasus and Gemini LiDAR systems were utilized for the missions (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR systems used in the survey are outlined in Table 1 and Table 2. Figure 2 illustrates the flight plans for the Sibalom floodplain survey.

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)
BLK43G_ additional	1000	30	50	200	30	130	5
BLK37O	1000	30	50	200	30	130	5
BLK37P	1000	30	50	200	30	130	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)
BLK43J	1000	30	50	125	50	130	5
BLK43KL	1000	30	50	125	50	130	5
BLK43H	1000	30	50	125	50	130	5
BLK43H_ additional	1000	30	50	125	50	130	5
BLK43I	1000	30	50	125	50	130	5
BLK43G	1000	30	50	125	50	130	5
BLK43G_ additional	1000, 850	30	50	125	50	130	5
BLK43L_ additional	1000	30	50	125	50	130	5

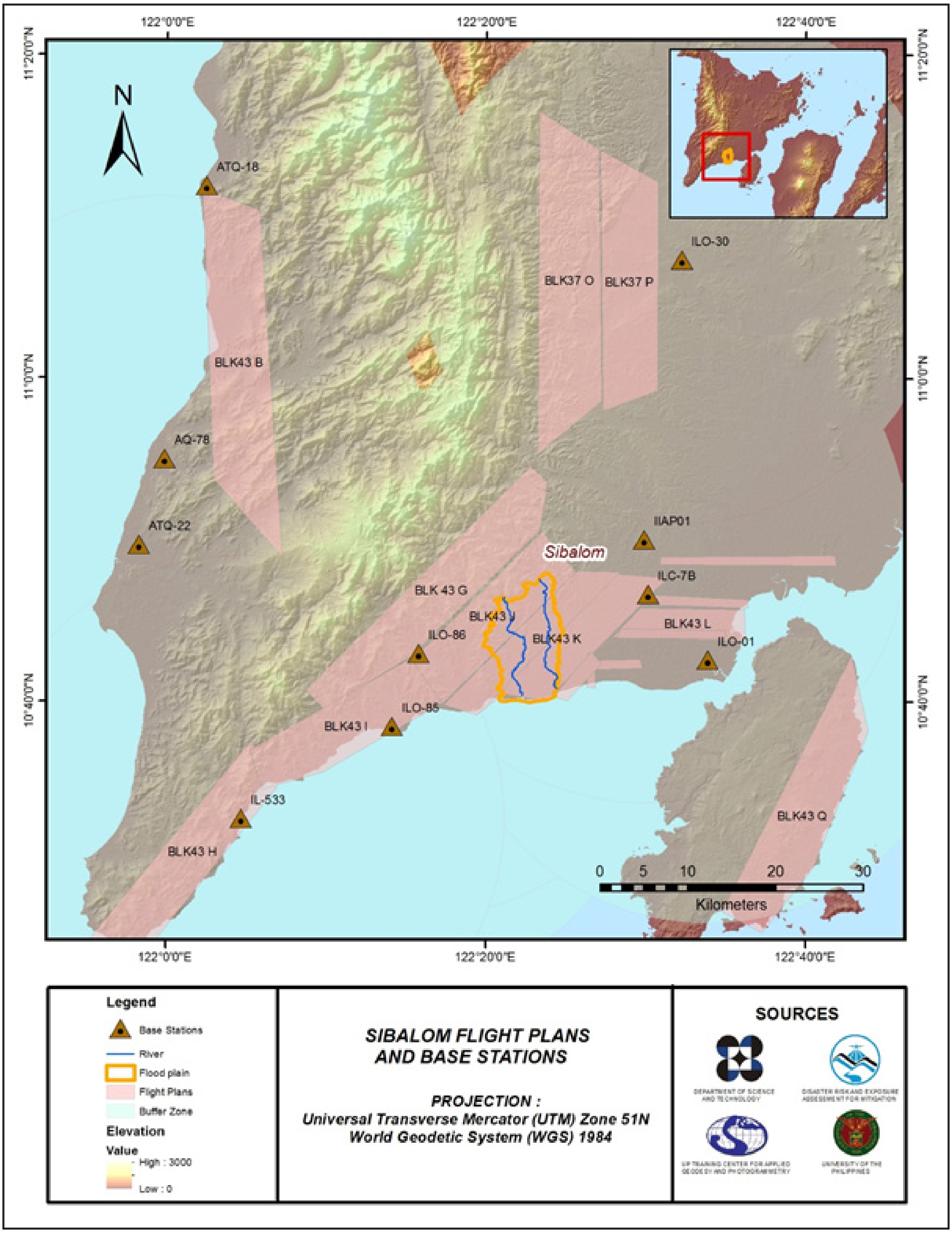

Figure 2. Flight plans and base stations used to cover the Sibalom floodplain survey

2.2 Ground Base Stations

The field team for this undertaking was able to recover five (5) NAMRIA reference points: ILO-1, which is of first (1st) order accuracy; and ILO-85, ILO-86, ATQ-22, and ATQ-18, which are of second (2nd) order accuracy. Two (2) NAMRIA benchmarks of first (1st) order accuracy, IL-533 and AQ-78 , were recovered. These benchmarks were used as vertical reference points, and were also established as ground control points. The field team established one (1) ground control point, IIAP-01 , and re-established ILC-7B, a NAMRIA reference point of third (3rd) order accuracy. The certifications for the NAMRIA reference points and benchmarks are found in Annex 2; and the baseline processing reports for the control points are provided in Annex 3. These were used as base stations during flight operations for the entire duration of the survey, held on February 5 – 27, 2016. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 985 and TRIMBLE SPS 882. The flight plans and the locations of base stations used during the aerial LiDAR acquisition in the Sibalom floodplain are shown in Figure 2. The composition of the full project team is given in Annex 4.

Figure 3 to Figure 10 exhibit the recovered NAMRIA reference points within the area. Table 3 to Table 10 provide the details about the NAMRIA control stations and established points. Table 11 lists all of the ground control points that were occupied during the acquisition, with the corresponding dates of utilization.

(a) **(b)**

Figure 3. (a) GPS set-up over ATQ-18 on the NE approach of the Binangbang Bridge, about 600 meters NE of Barbaza Town Hall, 4 meters from the road centerline, 50 meters SE of Barbaza Multi-Purpose Coop; and, (b) NAMRIA reference point ATQ-18, as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point ATQ-18, used as a 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	11’ 58.67081”119” North 122° 2’ 22.83300” East 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 PRS 1992)	Easting Northing	395155.87 meters 1238146.15 meters

(a) **(b)**

Figure 4. (a) GPS set-up over ATQ-22 on top of the N edge of the NW draft on an irrigation canal, 60 meters NE of the national highway centerline, 120 meters N of the road going to the barangay proper, and about 300 meters E of KM Post 110; and (b) NAMRIA reference point ATQ-22, as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point ATQ-18, used as a 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 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	387365.279 m 1197676.056 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 49' 42.24271" 121° 58' 17.11770" 68.022 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	387404.70 m 1197256.85 m

(a) **(b)**

Figure 5. (a) GPS set-up over ILO-1, on top of St. Clements Church bell tower, across the Western Institute of Technology; and (b) NAMRIA reference point ILO-1, as recovered by field team

Table 5. Details of the recovered NAMRIA horizontal control point ILO-1, used as a base station for the LiDAR acquisition

Station Name	ILO-1	
Order of Accuracy	1st	
Relative Error (Horizontal positioning)	1 : 100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 49' 46.66618" 121° 58' 11.90221" 12.250 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	387365.279 m 1197676.056 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 49' 42.24271" 121° 58' 17.11770" 68.022 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	387404.70 m 1197256.85 m

(a) (b)

Figure 6. (a) GPS set-up over ILO-85, at the corner of a planting strip and sidewalk at the town plaza of Barangay Poblacion, Miagao, Iloilo, about 14 m fronting the Rizal monument; and (b) NAMRIA reference point ILO-85, as recovered by the field team

Table 6. Details of the recovered NAMRIA horizontal control point ILO-85, used as a base station for the LiDAR acquisition

Station Name	ILO-85	
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° 38' 33.11352" North 122° 14' 03.70561" East 21.962 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	416097.644 meters 1176957.657 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 38' 28.75996" North 122° 14' 08.93597" East 78.828 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	416256.319 meters 1176484.099 meters

(a) **(b)**

Figure 7. (a) GPS set-up over ILO-86, about 12 m from the circular fountain at the center of the town plaza of Barangay Poblacion, Igbaras, Iloilo, about 14 m fronting the Rizal monument; and (b) NAMRIA reference point ILO-86, as recovered by the field team

Table 7. Details of the recovered NAMRIA horizontal control point ILO-86, used as a base station for the LiDAR acquisition

Station Name	**ILO-86**	
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° 43’ 04.36044” North 122° 15’ 48.62123” East 47.315 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	419306.197 meters 1185284.087 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 42’ 59.99043” North 122° 15’ 53.84473” East 104.076 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	419463.955 meters 1184807.437 meters

(a) (b)

Figure 8. (a) GPS set-up over AQ-78, located at the NW side of the sidewalk of the Ipayo Bridge at Barangay Ipayo, Patnongon, Antique; and (b) NAMRIA reference point AQ-78, as recovered by the field team

Table 8. Details of the recovered NAMRIA horizontal control point AQ-78, used as a base station for the LiDAR acquisition

Station Name	AQ-78	
Order of Accuracy	1st	
Relative Error (Horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 55’ 03.77330” North 121° 59’ 46.81987” East 48.448 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	390150.425 meters 1207471.411 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 54’ 59.33002” North 121° 59’ 52.02741” East 66.5525 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	390319.320 meters 1206987.603 meters

(a) (b)

Figure 9. (a) GPS set-up over IL-533, located 3 meters from the edge of the sidewalk of the Amboyu-an Bridge at Barangay Amboyu-an, San Joaquin, Iloilo; and (ii.) NAMRIA reference point IL-533, as recovered by the field team

Table 9. Details of the recovered NAMRIA horizontal control point IL-533, used as a base station for the LiDAR acquisition

Station Name	IL-533	
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' 49.29908" North 122° 04' 37.25566" East 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" North 122° 04' 42.49544" East 64.135 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	399013.479 meters 1165970.645 meters

(a) **(b)**

Figure 10. (a) GPS set-up over ILC-7B; and (b) NAMRIA reference point ILC-7B, as recovered by the field team

Table 10. Details of the recovered NAMRIA horizontal control point ILC-7B, used as a base station for the LiDAR acquisition

Station Name	ILC-7B	
Order of Accuracy	1st	
Relative Error (Horizontal positioning)	1 :100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 46’ 44.10341” North 122° 30’ 03.73070” East 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 PRS 1992)	Easting Northing	445449.763 meters 1191504.268 meters

Table 11. Ground control points used during the LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 5, 2015	2522G	2BLK43LK036A	ILO-1 and ILC-7B
February 6, 2015	2526G	2BLK43OKS037A	ILO-1 and ILC-7B
February 6, 2015	2528G	2BLK43KSJ037B	ILO-1 and ILC-7B
February 7, 2015	2530G	2BLK43OSJS038A	ILO-1 and ILO-85
February 7, 2015	2532G	2BLK43IV038B	ILO-1 and ILO-85
February 12, 2015	2550G	2BLK37GNOV43A	ILO-1 and ILC-7B
February 14, 2015	2558G	2BLK43G045A	IIAP-1 and ILO-85
February 17, 2015	2570G	2BLK43H048A	ILO-85 and IL-533
February 19, 2015	2578G	2BLK43GV050A	ILO-85 and ILO-86
February 20, 2015	2593P	1BLK43BDG051A	ATQ-22 and ATQ-18
February 25, 2015	2602G	2BLK43B056A	AQ-78 and ATQ-22
February 26, 2015	2606G	2BLK43BV057A	AQ-78 and ATQ-22
February 26, 2015	2617P	1BLK37OP057A	ATQ-22 and AQ-78
February 27, 2015	2610G	2BLK43BV058A	AQ-78 and ATQ-22
February 27, 2015	2621P	1BLK37P058A	ATQ-22 and AQ-78, IIAP-01 and ILO-30

2.3 Flight Missions

A total of fifteen (15) flight missions were conducted to complete the LiDAR data acquisition in the Sibalom floodplain, for a total of sixty hours and twenty minutes (60+20) of flying time for RP-C9022 and RP-C9122. All missions were acquired using the Pegasus and Gemini LiDAR systems. See Annex 6 for the flight logs of the missions.

Table 12 indicates the total area of actual coverage and the corresponding flying hours per mission; while Table 13 presents the actual parameters used during the LiDAR data acquisition.

Table 12. Flight missions for the LiDAR data acquisition in the Sibalom floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 5, 2015	2522G	47.217	182.86	27.71	155.15	683	4	29
February 6, 2015	2526G	358.15	333.65	39.48	294.18	556	4	23
February 6, 2015	2528G	236.85	192.81	54.54	138.28	545	4	17
February 7, 2015	2530G	308.64	228.19	5.83	222.36	670	4	29
February 7, 2015	2532G	155.79	198.86	0	196.86	603	3	53
February 12, 2015	2550G	189.53	329.63	0	329.63	594	4	5
February 14, 2015	2558G	163.14	198.86	0	198.86	668	4	11
February 17, 2015	2570G	162.07	175.42	0	175.42	698	4	35
February 19, 2015	2578G	189.32	83.04	0	83.04	132	3	41
February 20, 2015	2593P	249.92	180.32	0	180.32	427	3	29
February 25, 2015	2602G	228.28	89.83	0	89.83	119	3	17
February 26, 2015	2606G	228.28	221.79	0	221.79	319	4	5
February 26, 2015	2617P	239.47	283.32	0	283.32	901	4	23
February 27, 2015	2610G	228.28	34.35	0	34.35	47	3	5
February 27, 2015	2621P	172.23	249.35	0	249.35	819	3	58
TOTAL		**2472.33**	**2636.31**	**127.56**	**2506.77**	**7296**	**60**	**20**

Table 13. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)
2522G	1100	30	50	125	50
2526G	1100	30	50	125	50
2528G	1100	30	40	100	50
2530G	1100	30	40	100	50
2532G	1100	30	40	100	50
2550G	1100	30	40	100	50
2558G	1100	30	50	125	40
2570G	1100	30	40	100	50
2578G	1100	30	40	100	50
2593P	1000	30	50	200	30
2602G	2000	30	40	100	56
2606G	2000	30	40	70	56
2617P	1000	30	50	200	30
2610G	2000	30	34	70	56
2621P	1000	30	50	200	30

2.4 Survey Coverage

The Cangaranan floodplain is located in the provinces of Antique and Iloilo, with majority of the floodplain situated within the Municipalities of Bugasong and Valderrama in Antique. The Municipalities of Patnongon and Belison were mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 13. The actual coverage of the LiDAR acquisition for Cangaranan floodplain is presented in Figure 10. The flight status reports are found in Annex 7.

Table 14. List of municipalities/cities surveyed in Antique, Capiz, Guimaras, and Iloilo

Province	Municipality/ City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
		(km²)	(km²)	(%)
Antique	Anini-Y	55.15	45.01	82
	Patnongon	135.69	79.90	59
	Laua-An	165.65	78.93	48
	Bugasong	178.80	69.82	39
	Tobias Fornier	102.18	24.05	24
	San Remigio	370.90	59.90	16
	Valderrama	309.67	39.53	13
	Barbaza	171.23	14.32	8
	Belison	36.80	2.14	6
	Sibalom	240.55	2.60	1
Capiz	Tapaz	515.98	75.59	15
Guimaras	San Lorenzo	118.69	96.90	82
	Sibunag	152.77	72.66	48
	Buenavista	109.72	22.69	21
	Nueva Valencia	122.76	25.31	21
Iloilo	Tigbauan	90.20	90.20	100
	Guimbal	40.69	40.34	99
	San Miguel	31.53	27.84	88
	Oton	85.38	64.25	75
	Pavia	27.89	19.73	71
	Calinog	132.92	87.31	66
	San Joaquin	200.06	119.65	60
	Tubungan	87.73	49.23	56
	Leon	147.46	82.55	56
	Miagao	170.53	88.78	52
	Igbaras	132.37	65.80	50
	Janiuay	192.41	95.20	49
	Iloilo City	70.78	29.92	42
	Lambunao	417.81	173.31	41
	Santa Barbara	70.66	27.69	39
	Badiangan	62.28	20.54	33
	Alimodian	118.19	34.33	29
	Leganes	32.09	5.81	18
	Maasin	137.81	24.07	17
	Zarraga	37.96	5.10	13
	Dumangas	121.04	8.11	7

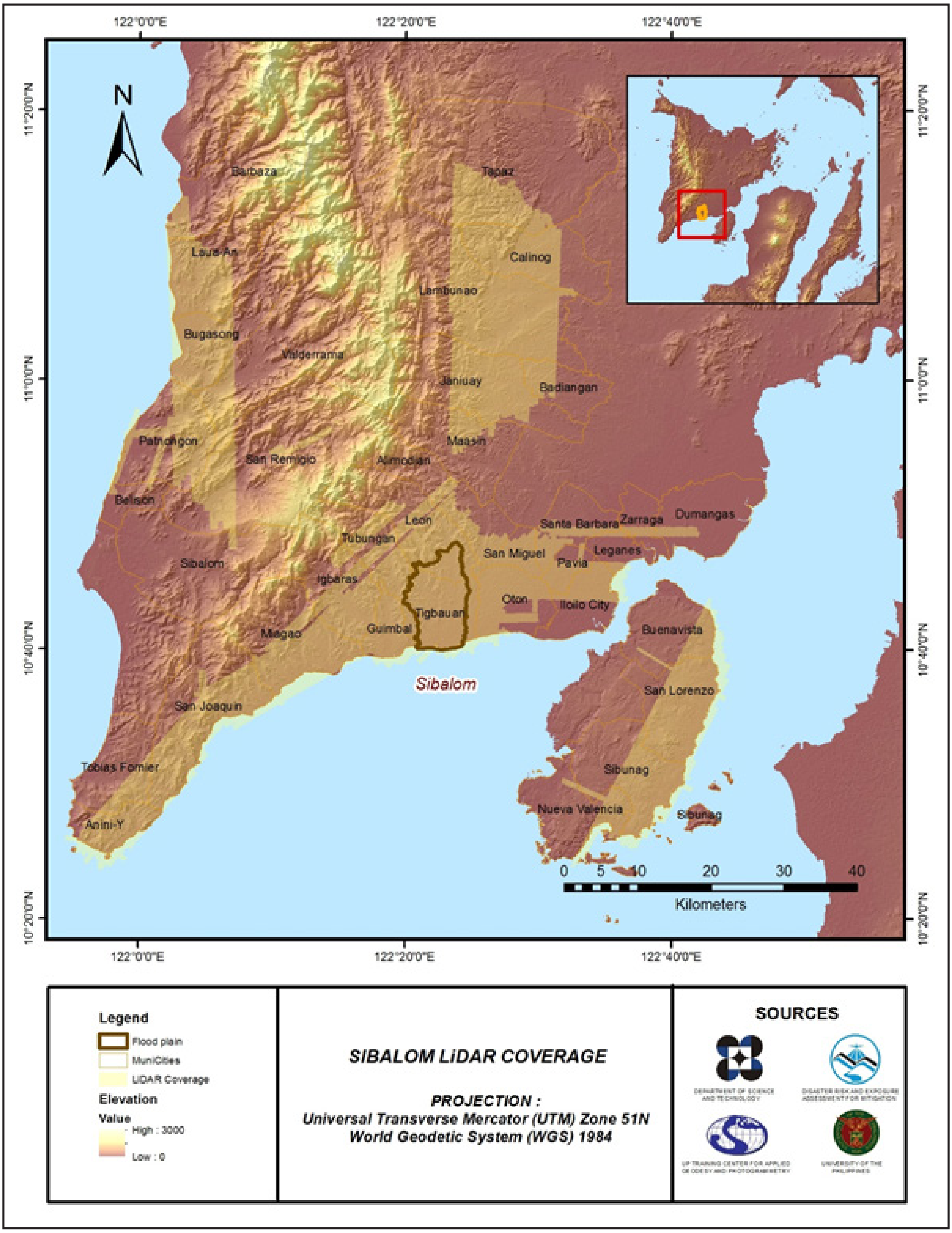

Figure 11. Actual LiDAR survey coverage of the Sibalom floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE SIBALOM 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 DAC were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate the correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality checking to ensure that the required accuracies of the program, which are the minimum point density, and the vertical and horizontal accuracies, were met. The point clouds were then categorized into various classes before generating Digital Elevation Models (DEMs), such as the Digital Terrain Model (DTM) and the Digital Surface Model (DSM).

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

These processes are summarized in the diagram in Figure 12.

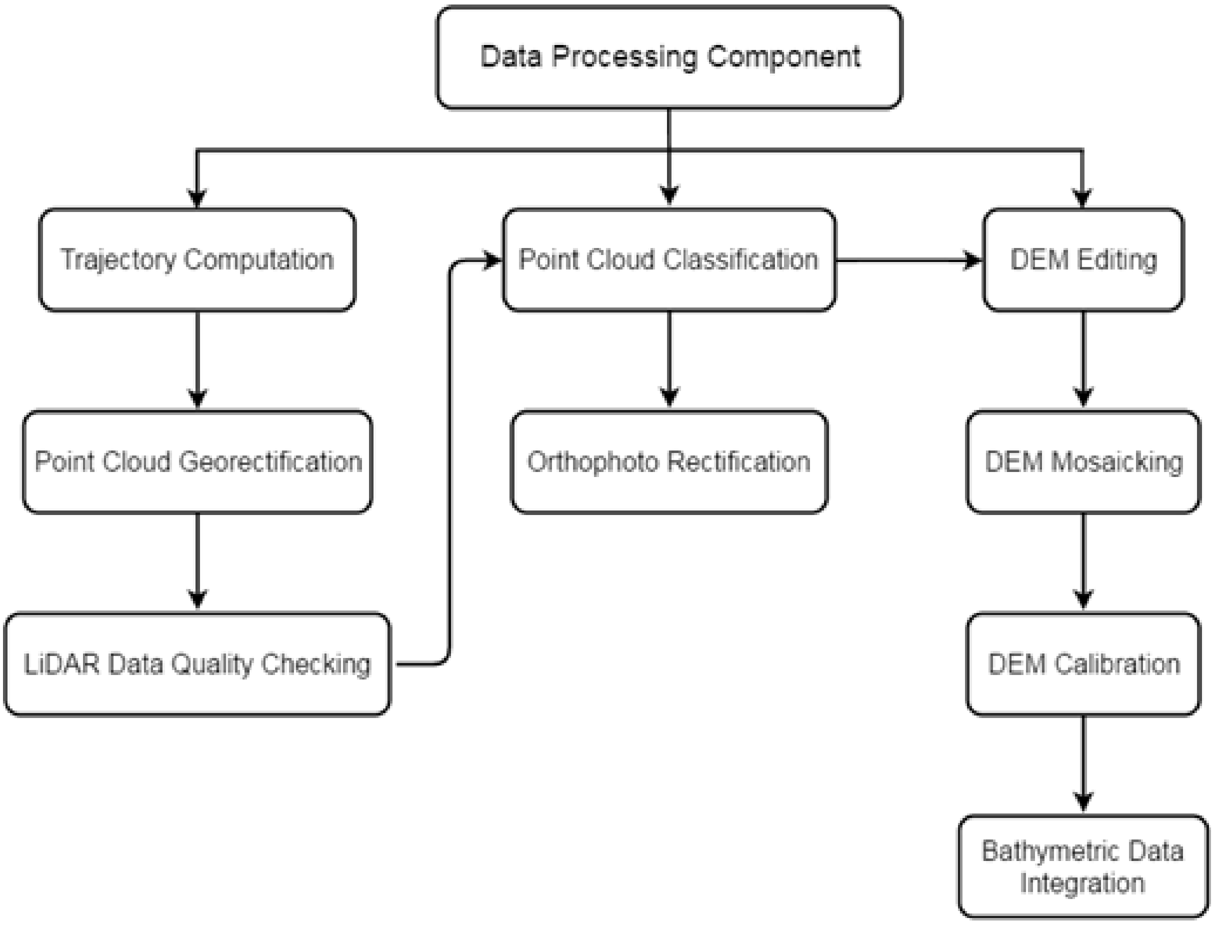


Figure 12. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Sibalom floodplain can be found in Annex 5. Missions flown during the first survey conducted in February 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system; while missions acquired during the second survey in March 2015 were flown using the Pegasus system over Iloilo .

The DAC transferred a total of 301.60 Gigabytes of Range data, 3.38 Gigabytes of POS data, 189.69 Megabytes of GPS base station data, and 503.59 Gigabytes of raw image data to the data server on February 5, 2015 for the first survey, and on March 6, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Sibalom survey was fully transferred on March 23, 2015, as indicated on the data transfer sheets for the Sibalom floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for Flight 2528G, one of the Sibalom flights, which are the North, East, and Down position RMSE values, are illustrated in Figure 13. 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 fell on February 6, 2015 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

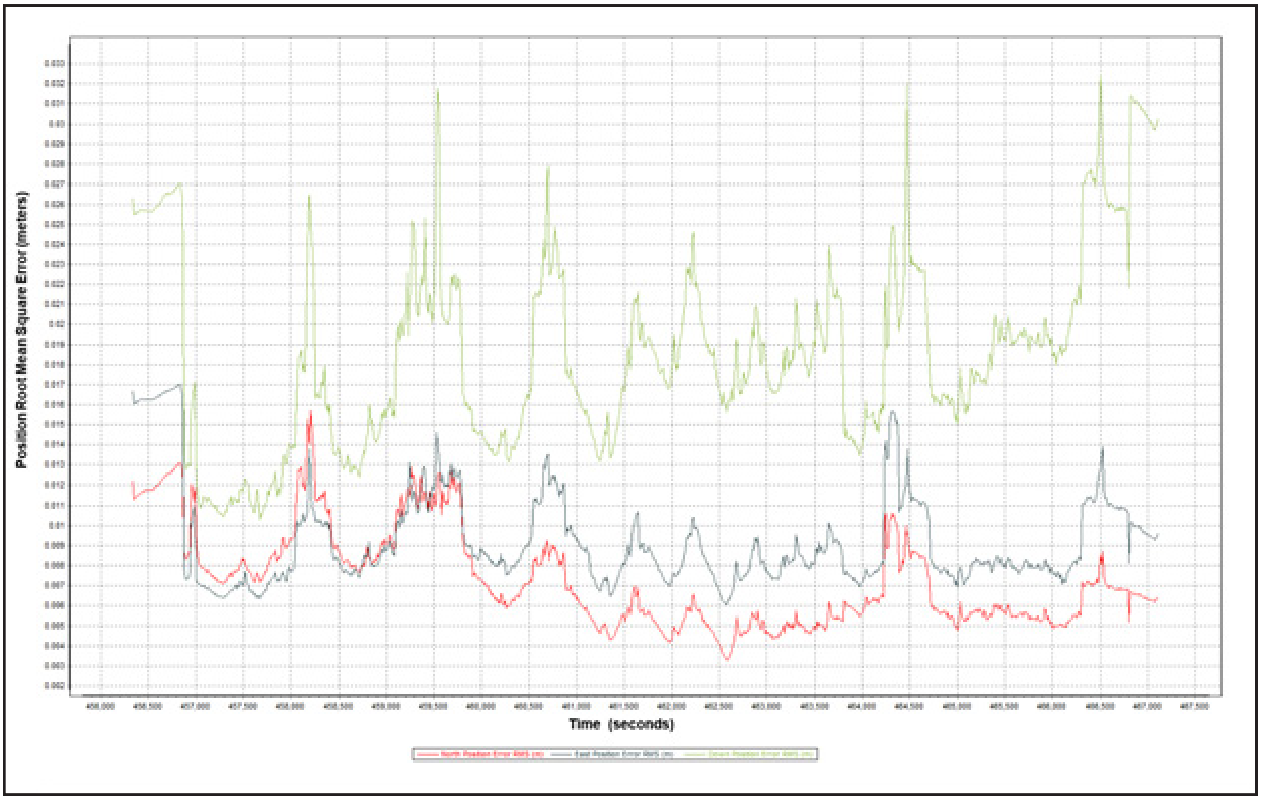


Figure 13. Smoothed Performance Metric Parameters of Sibalom Flight 2528G

The time of flight was from 456000 seconds to 467500 seconds, which corresponds to the afternoon of February 6, 2015. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE values of the positions. The periodic increase in RMSE values from an otherwise smoothly curving set of RMSE values signifies the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 13 demonstrates that the North position RMSE peaked at 1.60 centimeters, the East position RMSE peaked at 1.60 centimeters, and the Down position RMSE peaked at 3.30 centimeters, which are within the prescribed accuracies described in the methodology.

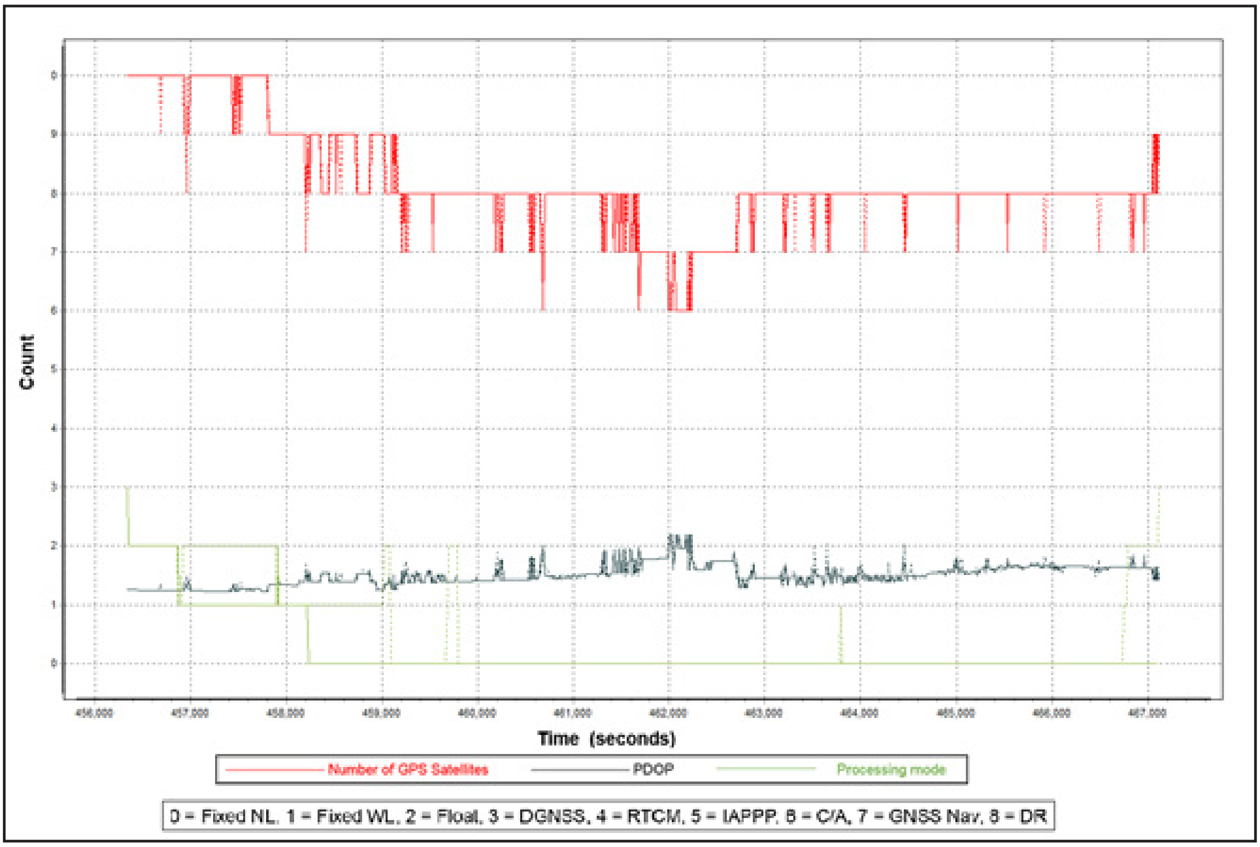


Figure 14. Solution Status Parameters of Sibalom Flight 2528G

The Solution Status parameters of Flight 2528G, one of the Sibalom flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are depicted in Figure 14. 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 10. The PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at the value of 0 for majority of the survey, with some peaks to up to 2, attributed to the turns performed by the aircraft. The value of 0 represents a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Sibalom flights is exhibited in Figure 15.

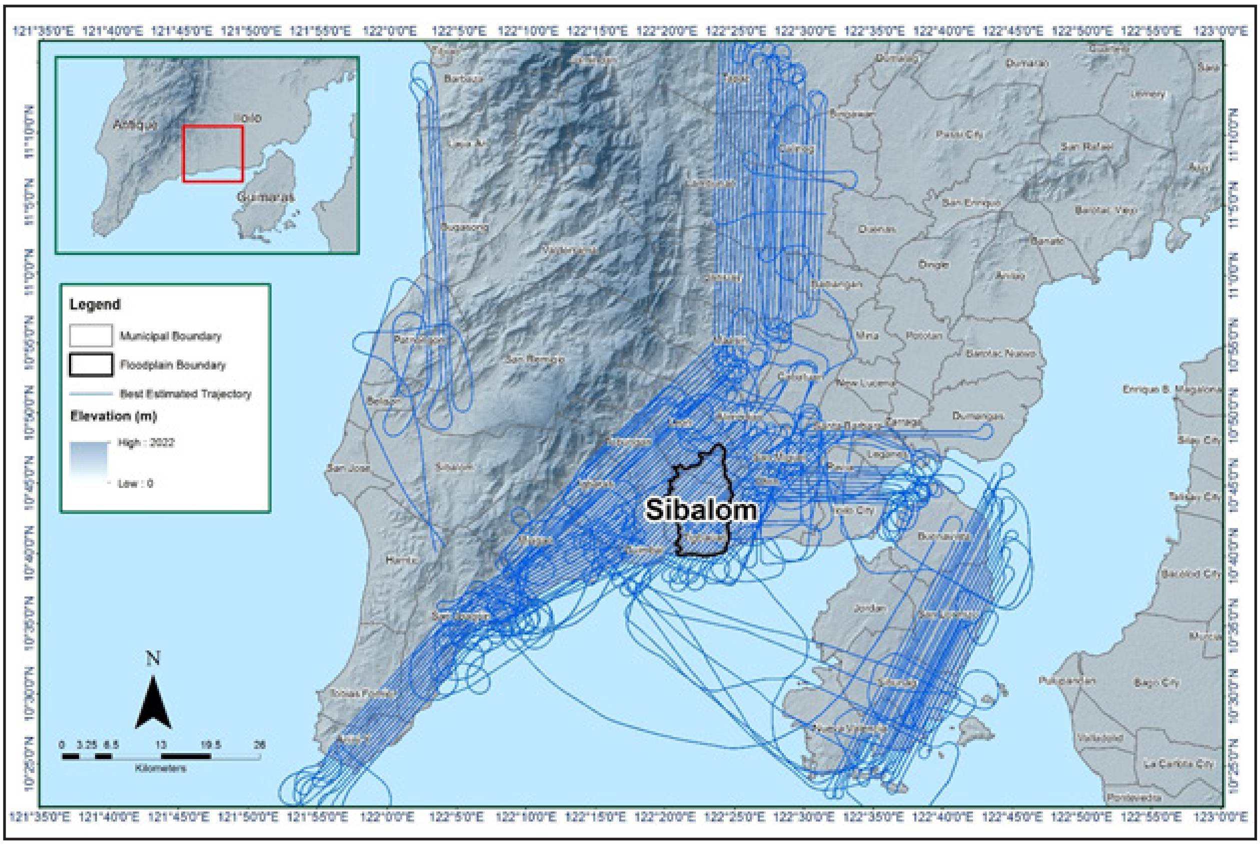


Figure 15. The best estimated trajectory conducted over the Sibalom floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains one hundred and seventy-eight (178) flight lines, with each flight line containing one (1) channel for the Gemini system and two (2) channels for the Pegasus system, because the former contains only one (1) channel and the latter contains two (2) channels. The summary of the self-calibration results for all flights over the Sibalom floodplain, obtained through LiDAR processing in the LiDAR Mapping Suite (LMS) software, is given in Table 15.

Table 15. Self-calibration results for the Sibalom flights

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000272
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000976
GPS Position Z-correction stdev)	<0.01meters	0.0085

Optimum accuracy was obtained for all Sibalom flights, based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for the individual blocks are available in Annex 8: Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Sibalom floodplain are represented in Figure 16. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

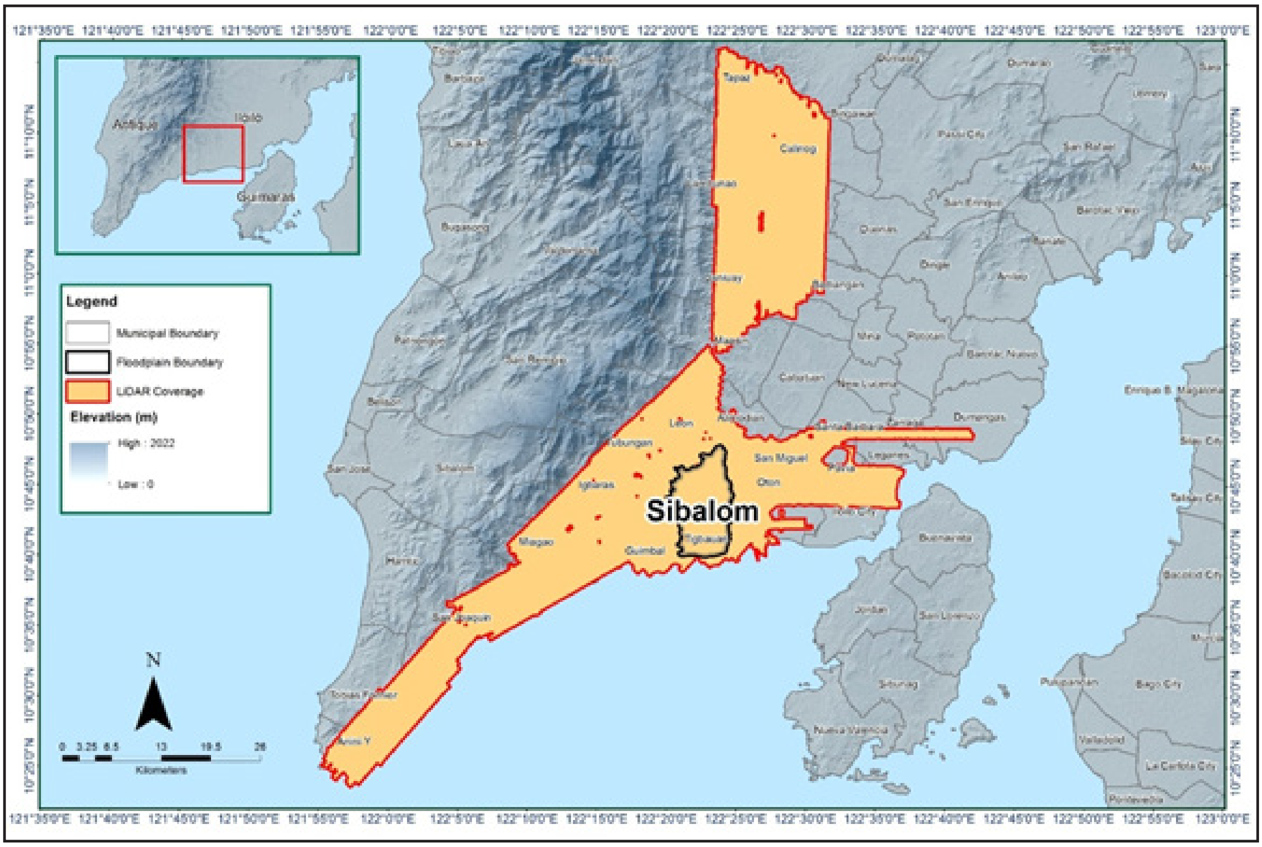


Figure 16. Boundaries of the processed LiDAR data over the Sibalom floodplain

The total area covered by the Sibalom missions is 1727.93 square kilometers, comprised of fifteen (15) flight acquisitions that were grouped and merged into ten (10) blocks, as indicated in Table 16.

Table 16. List of LiDAR blocks for the Sibalom floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Iloilo_Blk43J	2530G	95.44
Iloilo_Blk43KL	2522G	374.81
	2526G	
	2528G	
	2532G	
Iloilo_Blk43H	2570G	151.40
Iloilo_Blk43H_additional	2570G	9.41
Iloilo_Blk43I	2532G	171.60
Iloilo_Blk43G	2558G	184.70
Iloilo_Blk43G_additional	2593P	226.60
	2578G	
	2550G	
Iloilo_Blk37O	2617P	275.40
Iloilo_Blk37P	2621P	218.10

Iloilo_Antique_Blk43B_ additional	2602G	20.47
	2606G	
	2610G	
TOTAL		**1727.93 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is presented in Figure 17. Since the Gemini system employs one (1) channel, it is expected to have 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. For the Pegasus system which employs two (2) channels, it is expected to have 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.

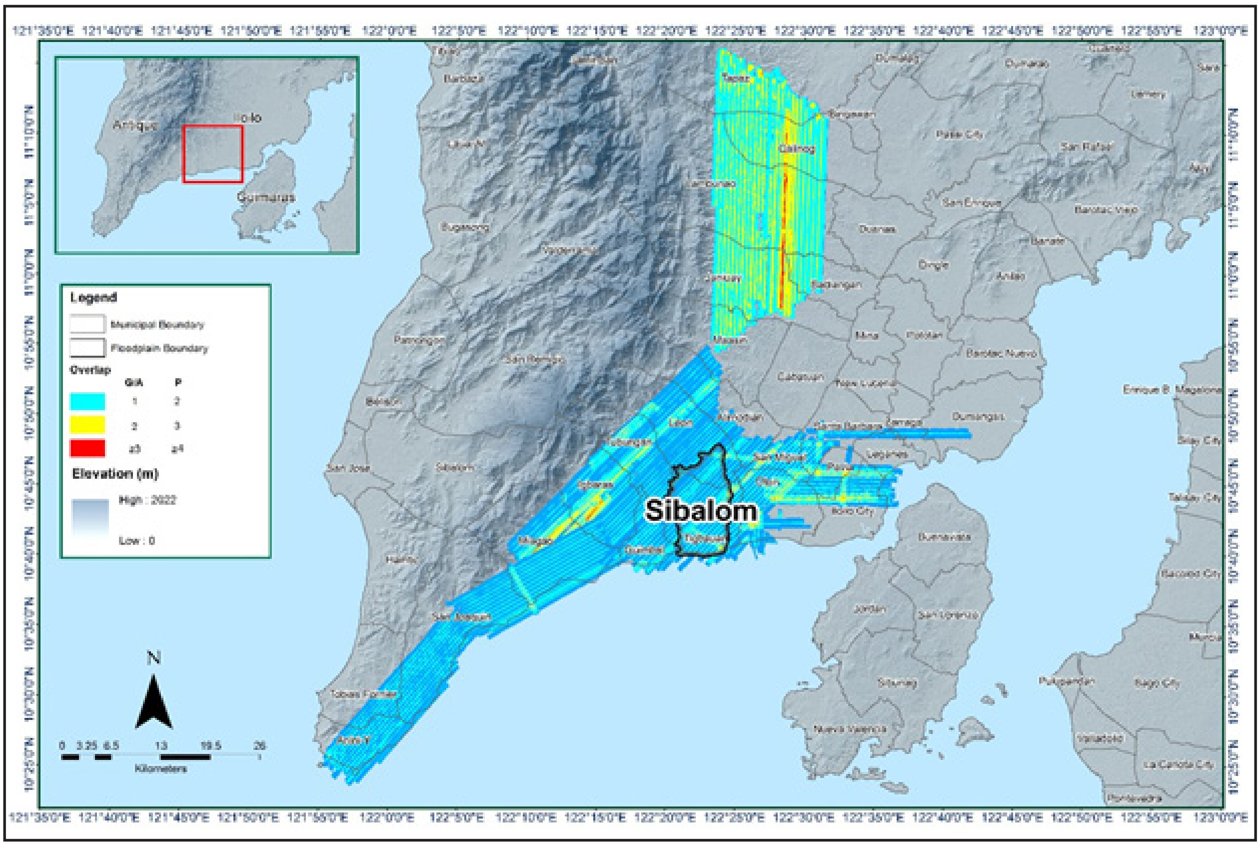


Figure 17. Image of data overlap for the Sibalom floodplain

The overlap statistics per block for the Sibalom floodplain can be found in Annex 8. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 26.03% and 45.86%, respectively, which satisfied the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion, is displayed in Figure 18. It was determined that all of the LiDAR data for the Sibalom floodplain satisfy the point density requirement, and that the average density for the entire survey area is 3.82 points per square meter.

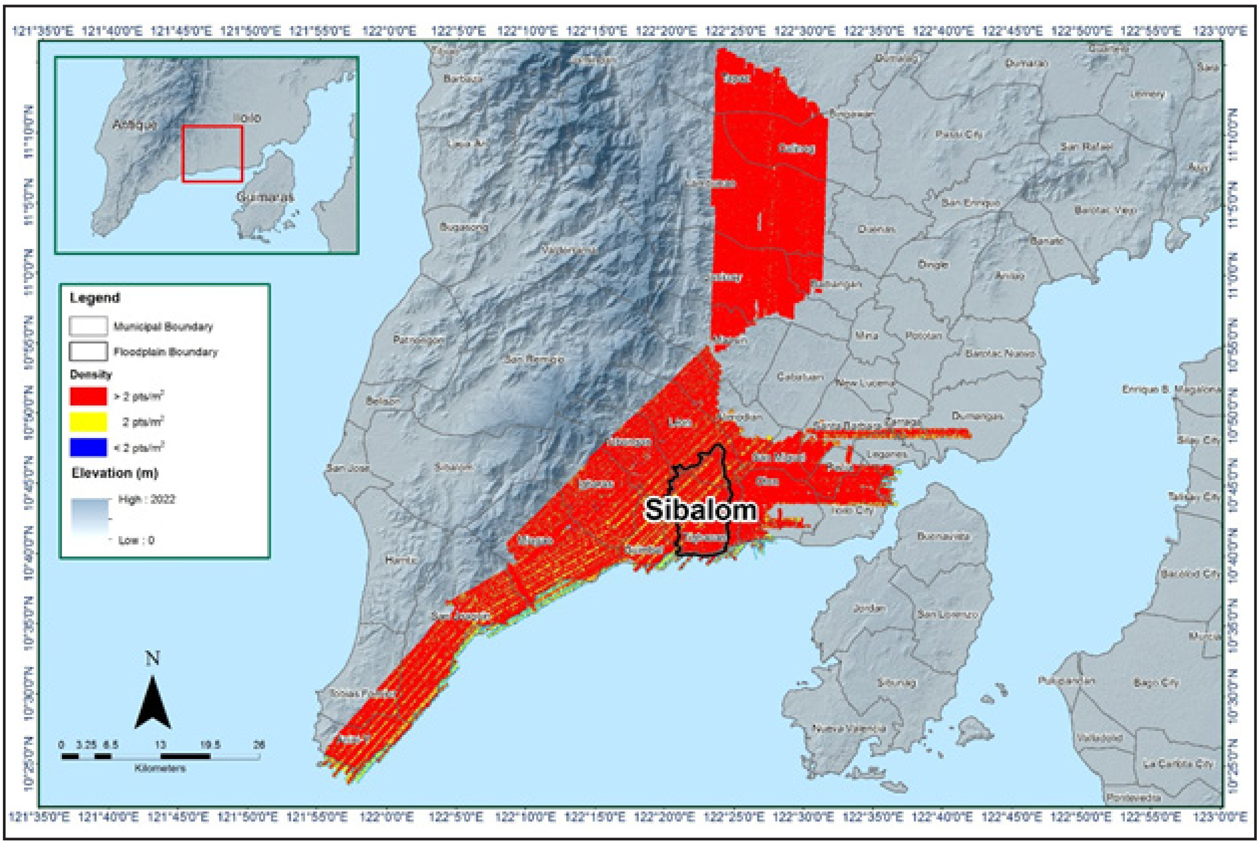


Figure 18. Pulse density map of merged LiDAR data for the Sibalom floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 19. The default color range is from blue to red. Bright blue areas signify portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 meters relative to the elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 meters relative to the elevations of its adjacent flight line. Areas with bright red or bright blue colors were investigated further using the Quick Terrain (QT) Modeler software.

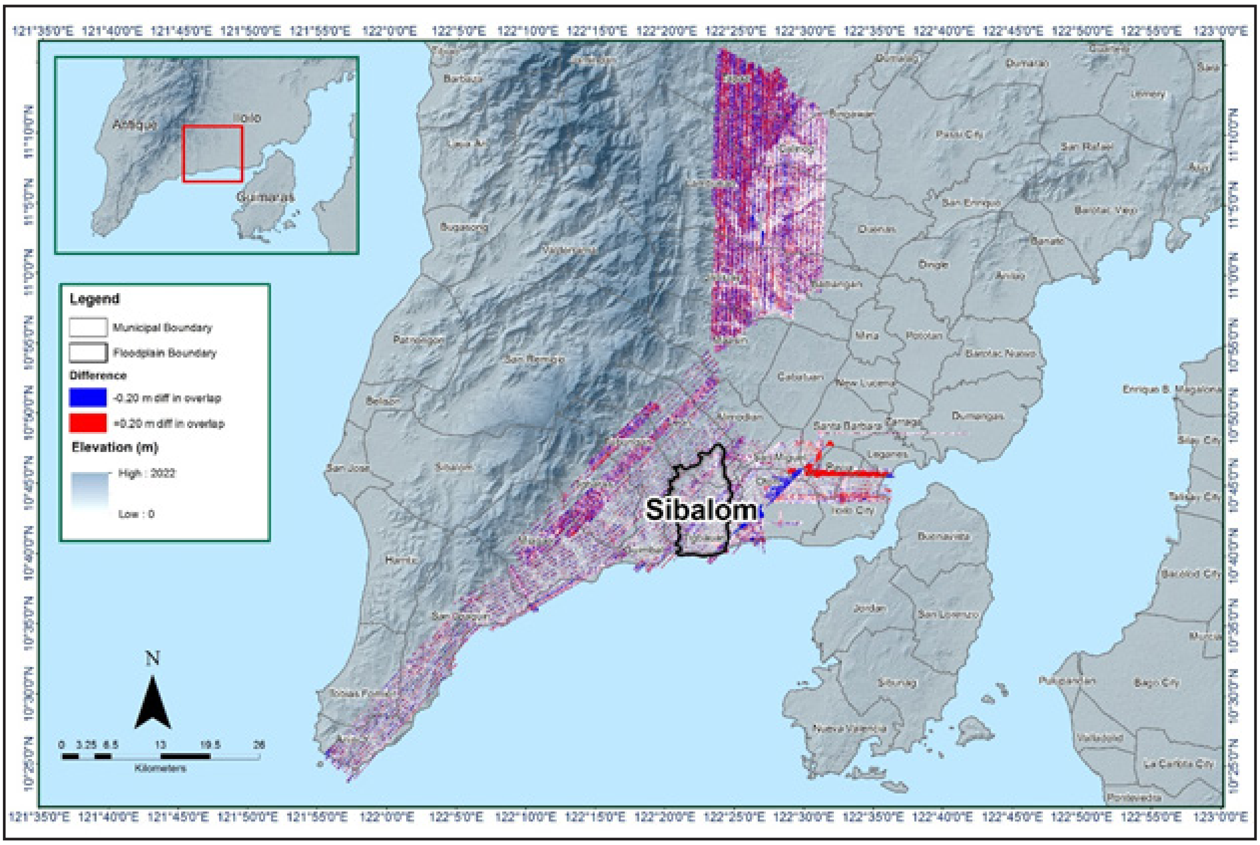


Figure 19. Elevation difference map between flight lines for the Sibalom floodplain

A screen capture of the processed LAS data from Sibalom Flight 2528G loaded in the QT Modeler is provided in Figure 20. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

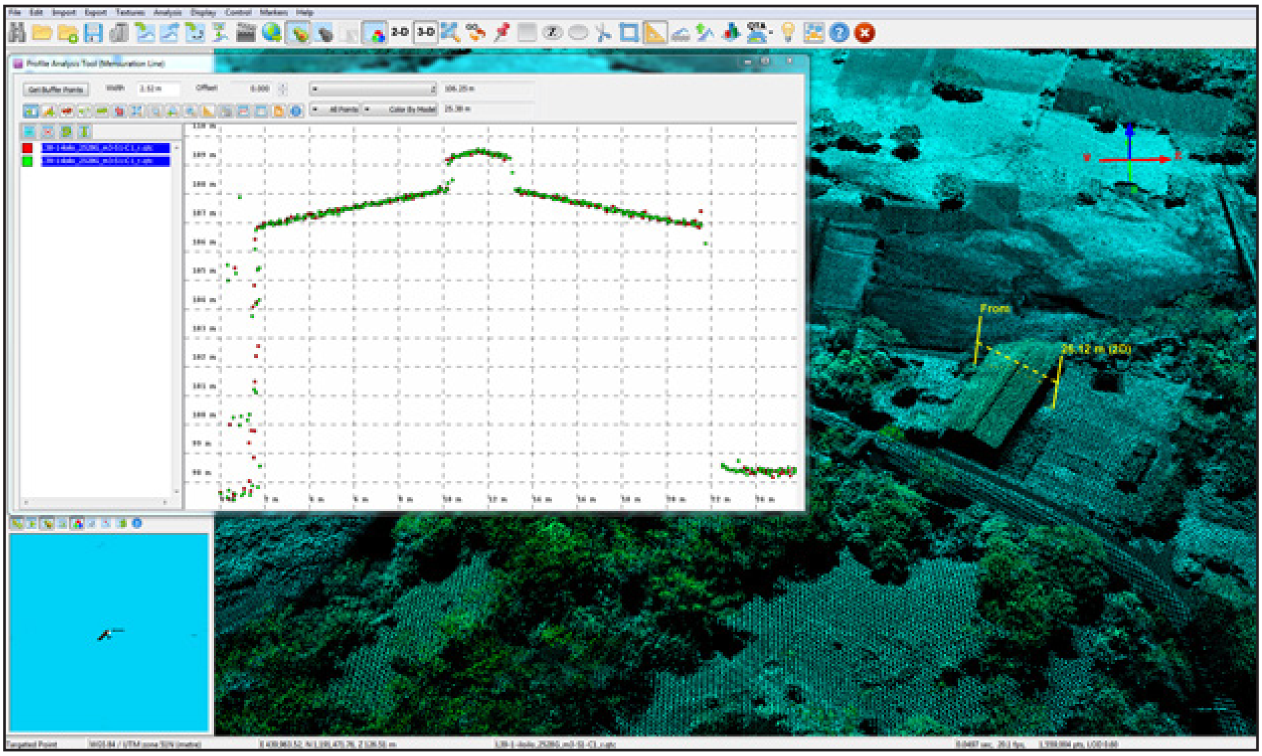


Figure 20. Quality checking for Sibalom Flight 2528G, using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. Sibalom classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	1,430,203,898
Low Vegetation	1,108,220,216
Medium Vegetation	2,074,713,523
High Vegetation	3,722,061,693
Building	62,436,291

The tile system that TerraScan employed for the LiDAR data, as well as the final classification image for a block in the Sibalom floodplain, are presented in Figure 21. A total of 2,327 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 17. The point cloud had a maximum and minimum height of 1475.44 meters and 54.15 meters, respectively.

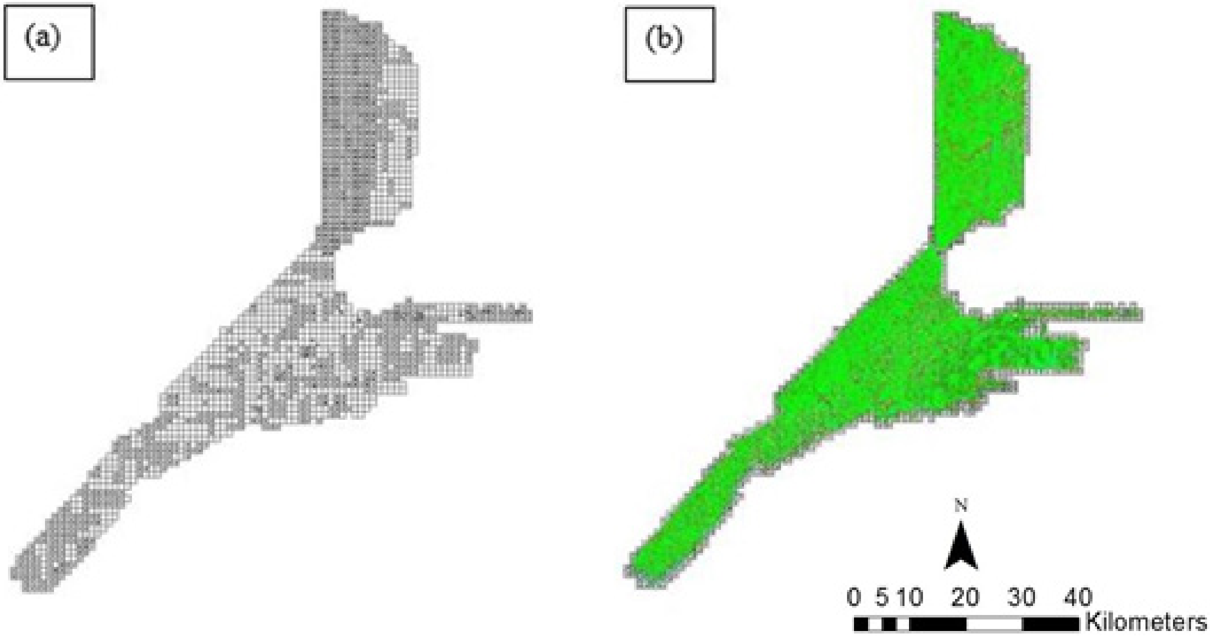


Figure 21. (a) Tiles for the Sibalom floodplain, and (b) classification results in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 22. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It is visible that the residential structures adjacent or even below canopy were classified correctly, due to the density of the LiDAR data.

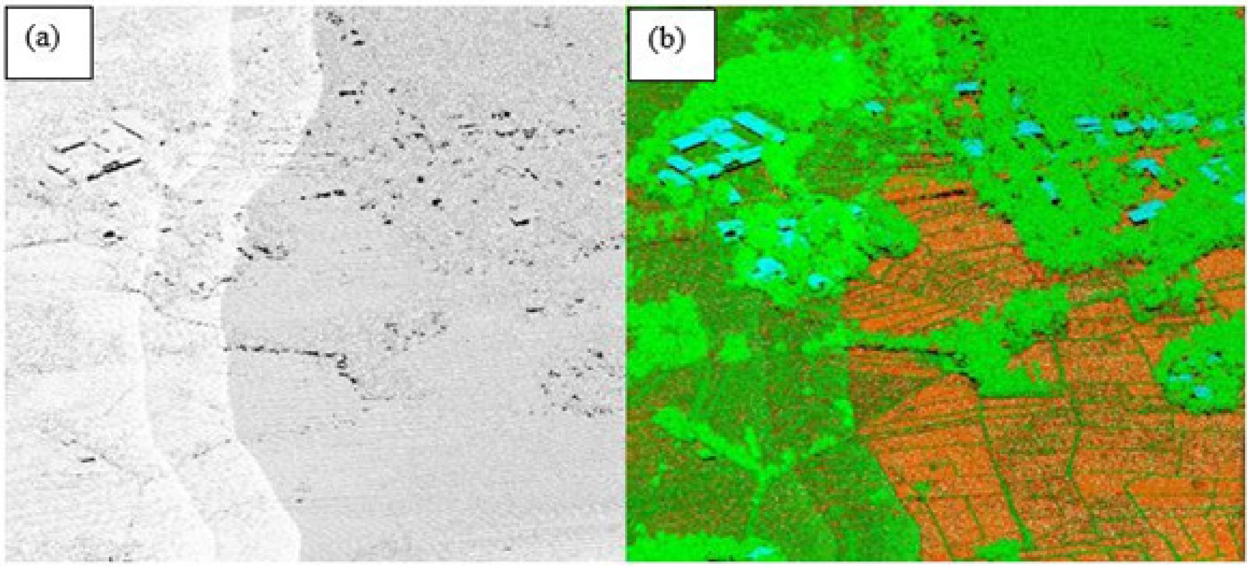


Figure 22. Point cloud (a) before and (b) after classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the area are illustrated in Figure 23, in top view display. The images convey that the DTMs are a representation of the bare earth; while the DSMs reflect all features that are present, such as buildings and vegetation.

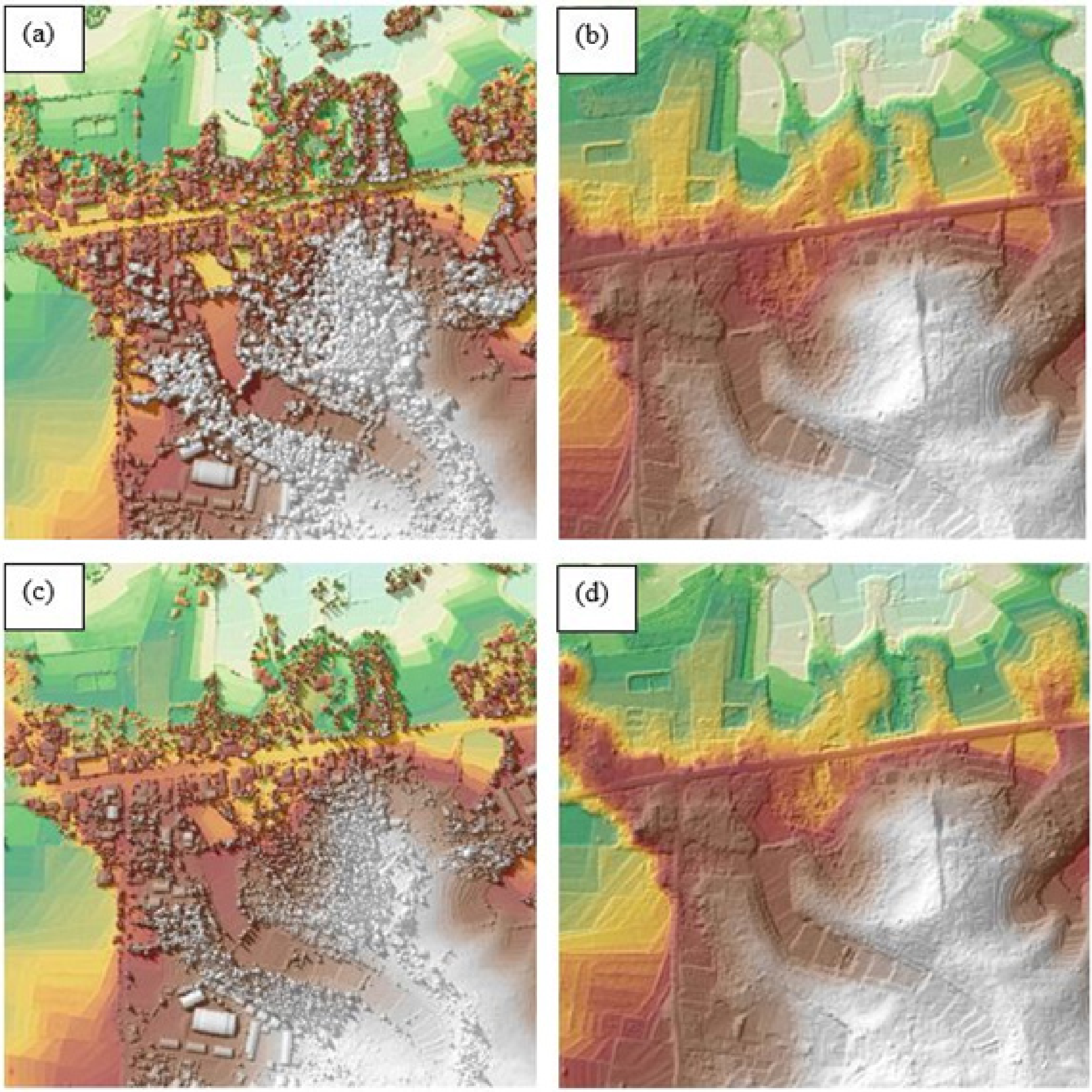


Figure 23. (a) The production of last return DSM and (b) DTM, (c) first return DSM and (d) secondary DTM in some portion of the Sibalom floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 907 1km by 1km tiles area covered by the Sibalom floodplain presented shown in Figure 24. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Sibalom floodplain survey attained a total of 671.02 square kilometers in orthophotographic coverage, comprised of 2,736 images. However, the block did not have a complete set of orthophotographs; and the orthophotographs did not cover the area of the Sibalom floodplain. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 25.

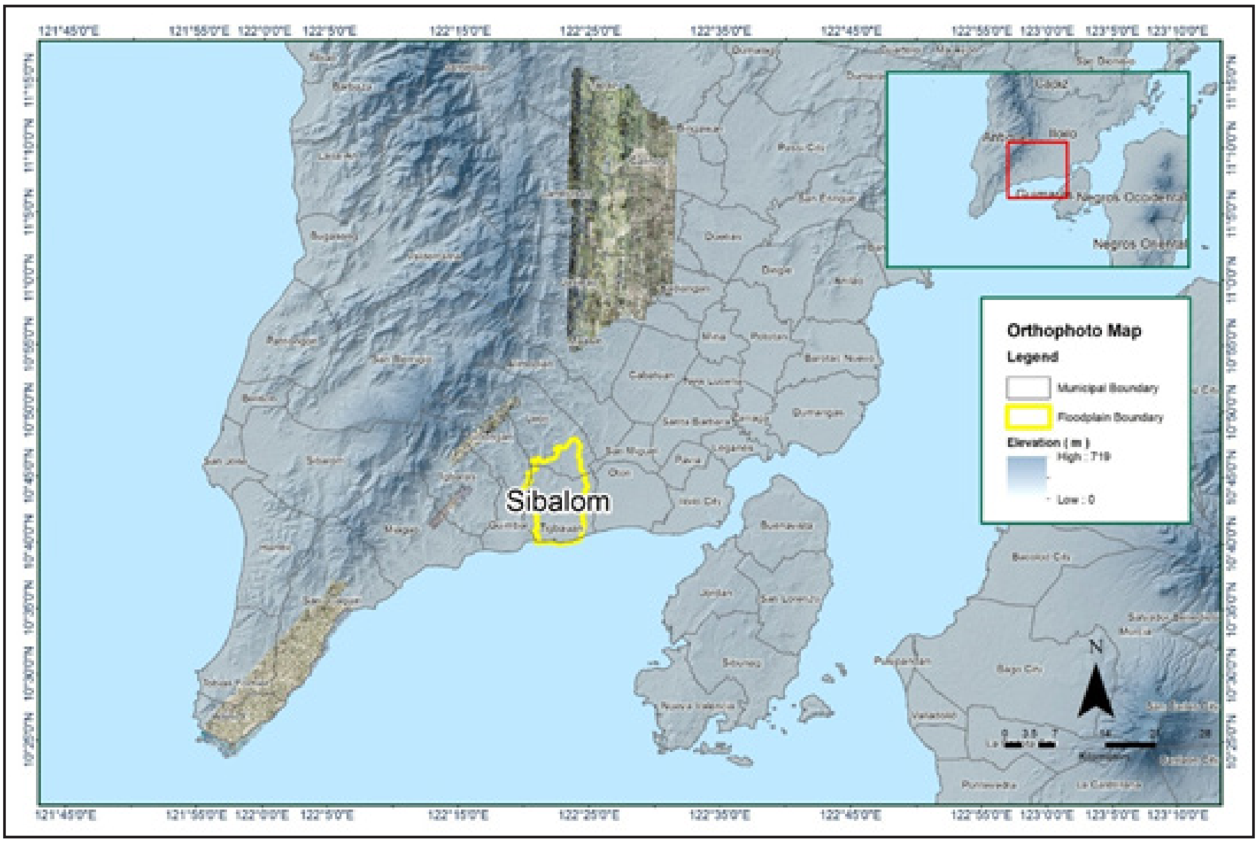


Figure 24. Available orthophotographs near the Sibalom floodplain

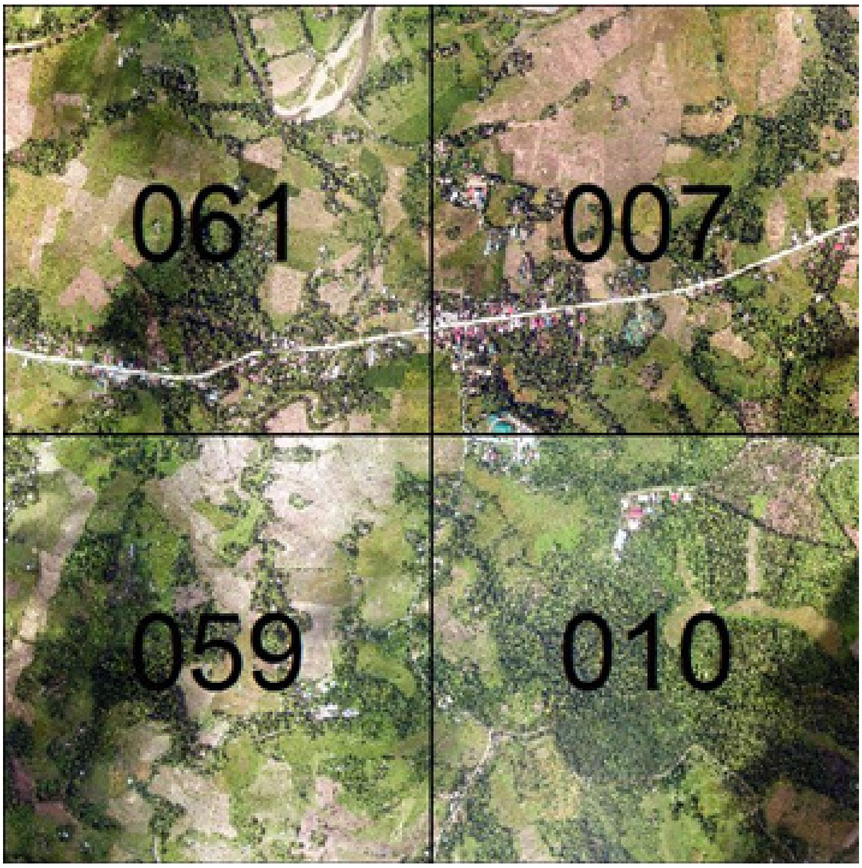


Figure 25. Sample orthophotograph tiles near the Sibalom floodplain

3.8 DEM Editing and Hydro-Correction

Ten (10) mission blocks were processed for the Sibalom floodplain. These blocks are composed of Iloilo and Antique blocks, with a total area of 1,727.93 square kilometers. Table 18 summarizes the names and corresponding areas of the blocks, in square kilometers.

Table 18. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
Iloilo_ Blk43J	95.44
Iloilo_ Blk43KL	374.81
Iloilo_ Blk43H	151.40
Iloilo_ Blk43H_additional	9.41
Iloilo_ Blk43I	171.60
Iloilo_ Blk43G	184.70
Iloilo_ Blk43G_additional	226.60
Iloilo_ Blk37O	275.40
Iloilo_ Blk37P	218.10
Iloilo_Antique_Blk43B_additional	20.47
TOTAL	**1727.93 sq.km**

Portions of the DTM before and after manual editing are exhibited in Figure 26. It shows that the bridge (Figure 26a) would impede the flow of water along the river, and had to be removed (Figure 26b) in order to hydrologically correct the river. The road (Figure 26c) and paddy field (Figure 26e) were misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 26d and Figure 26f).

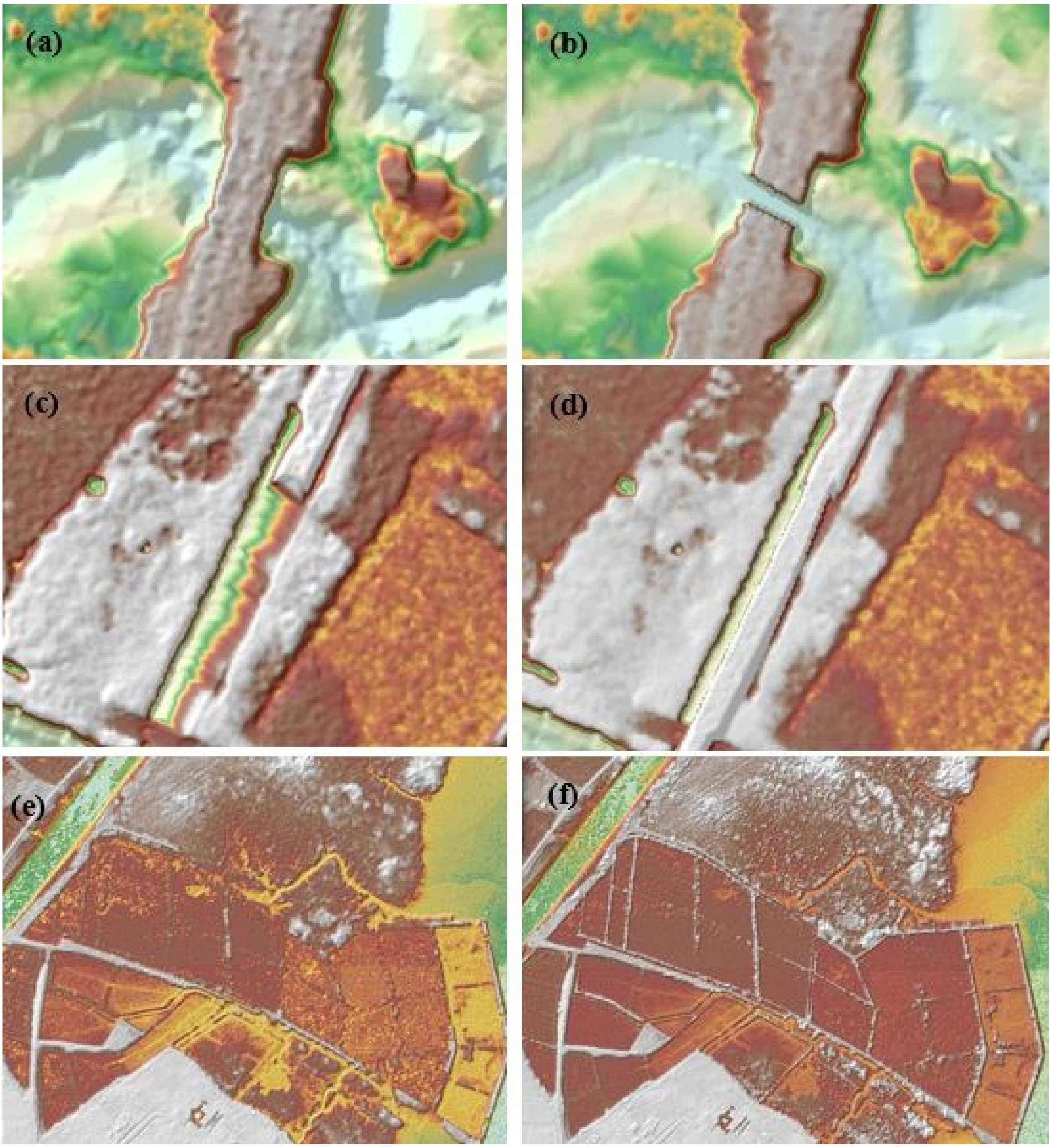


Figure 26. Portions in the DTM of the Sibalom floodplain – a bridge (a) before and (b) after manual editing; a road (c) before and (d) after data retrieval; and a paddy field (e) before and (f) after data retrieval

3.9 Mosaicking of Blocks

The Iloilo_ Blk43J block 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 19 lists the area of each LiDAR block, and the shift values applied during mosaicking.

The mosaicked LiDAR DTM for the Sibalom floodplain is presented in Figure 27. It demonstrates that the entire Sibalom floodplain is 100% covered by LiDAR data.

Table 19. Shift values of each LiDAR Block of the Sibalom floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Iloilo_ Blk43J	-1.00	2.00	-161.08
Iloilo_ Blk43KL	0.00	2.00	0.00
Iloilo_ Blk43H	-1.00	-1.00	0.08
Iloilo_ Blk43H_additional	-1.00	-1.00	0.15
Iloilo_ Blk43I (left)	0.00	2.00	-0.81
Iloilo_ Blk43I (right)	0.00	2.00	-0.73
Iloilo_ Blk43G	0.00	0.00	2.90
Iloilo_ Blk43G_additional	0.00	2.00	2.61
Iloilo_ Blk37O	0.00	0.00	-0.78
Iloilo_ Blk37P	0.00	0.00	0.32
Iloilo_Antique_Blk43B_additional	0.00	2.00	0.43

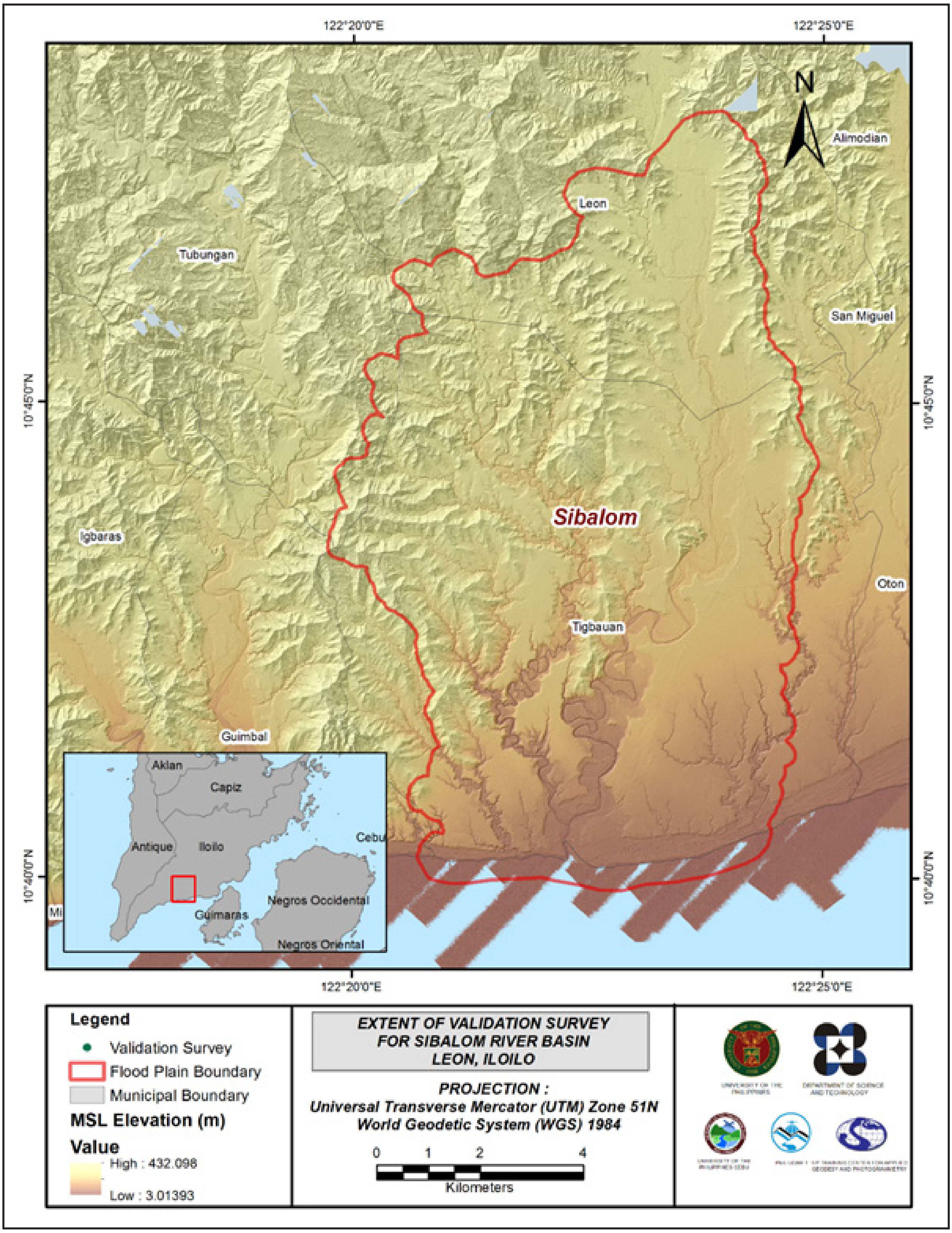


Figure 27. Map of processed LiDAR data for the Sibalom floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

To undertake the data validation of the Mosaicked LiDAR DEMs, the DVBC conducted a validation survey along the Sibalom floodplain. The extent of the validation survey done in Sibalom to collect points with which the LiDAR dataset was validated is shown in Figure 28, with the validation survey points highlighted in green. A total of 14,250 survey points were used for the calibration and validation of the Sibalom LiDAR data.

Random selection of 80% of the survey points resulted in 9,035 points, which were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is reflected in Figure 29. Statistical values were computed from the extracted LiDAR values using the selected points to assess the quality of data and to obtain the values for vertical adjustment. The computed height difference between the LiDAR DTM and the calibration elevation values is 3.83 meters, with a standard deviation of 0.12 meters. The calibration of Sibalom LiDAR data was performed by subtracting the height difference value, 3.83 meters, from the Sibalom mosaicked LiDAR data. Table 20 specifies the statistical measurements of the compared elevation values between the LiDAR data and the calibration data.

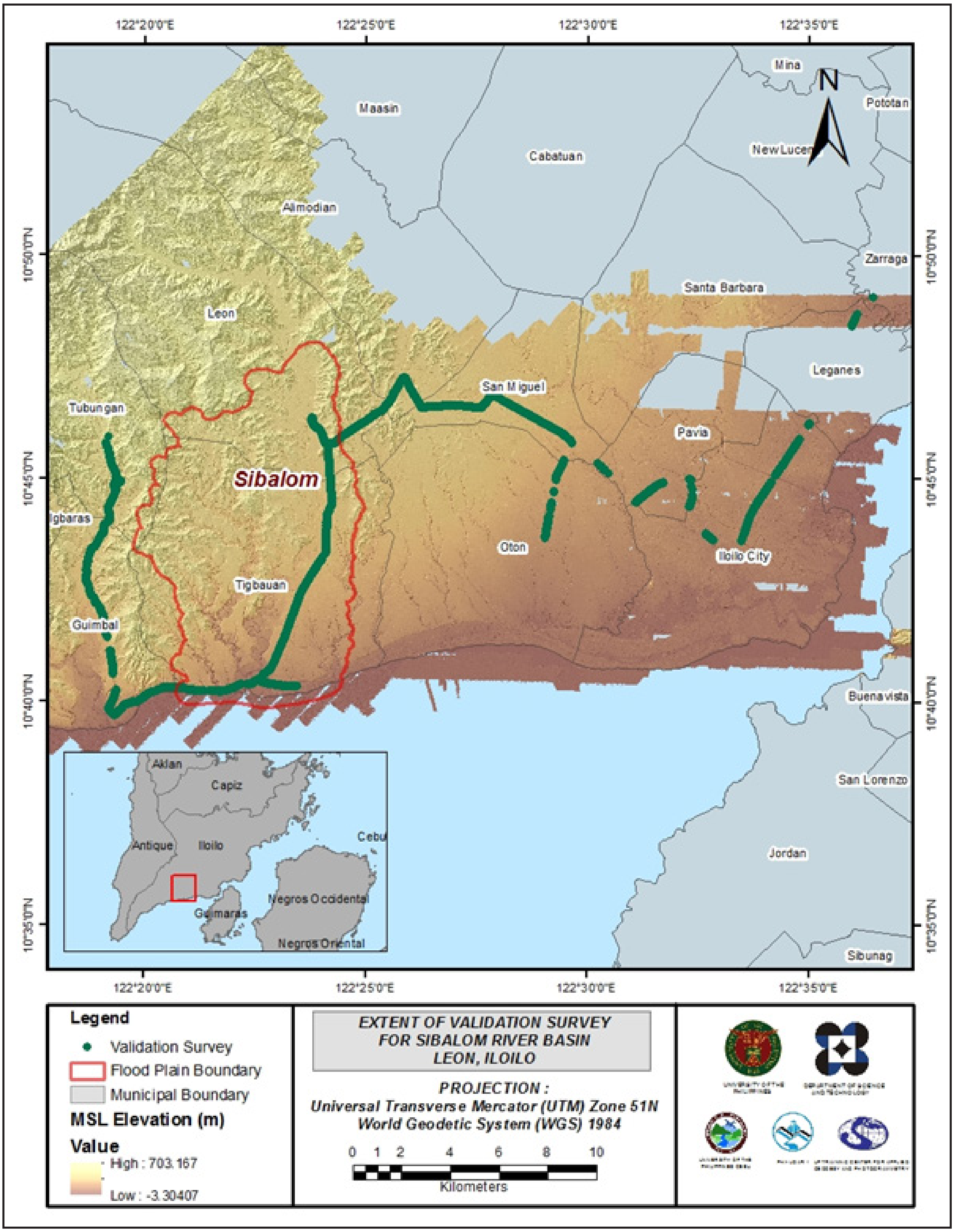


Figure 28. Map of the Sibalom floodplain, with the validation survey points in green

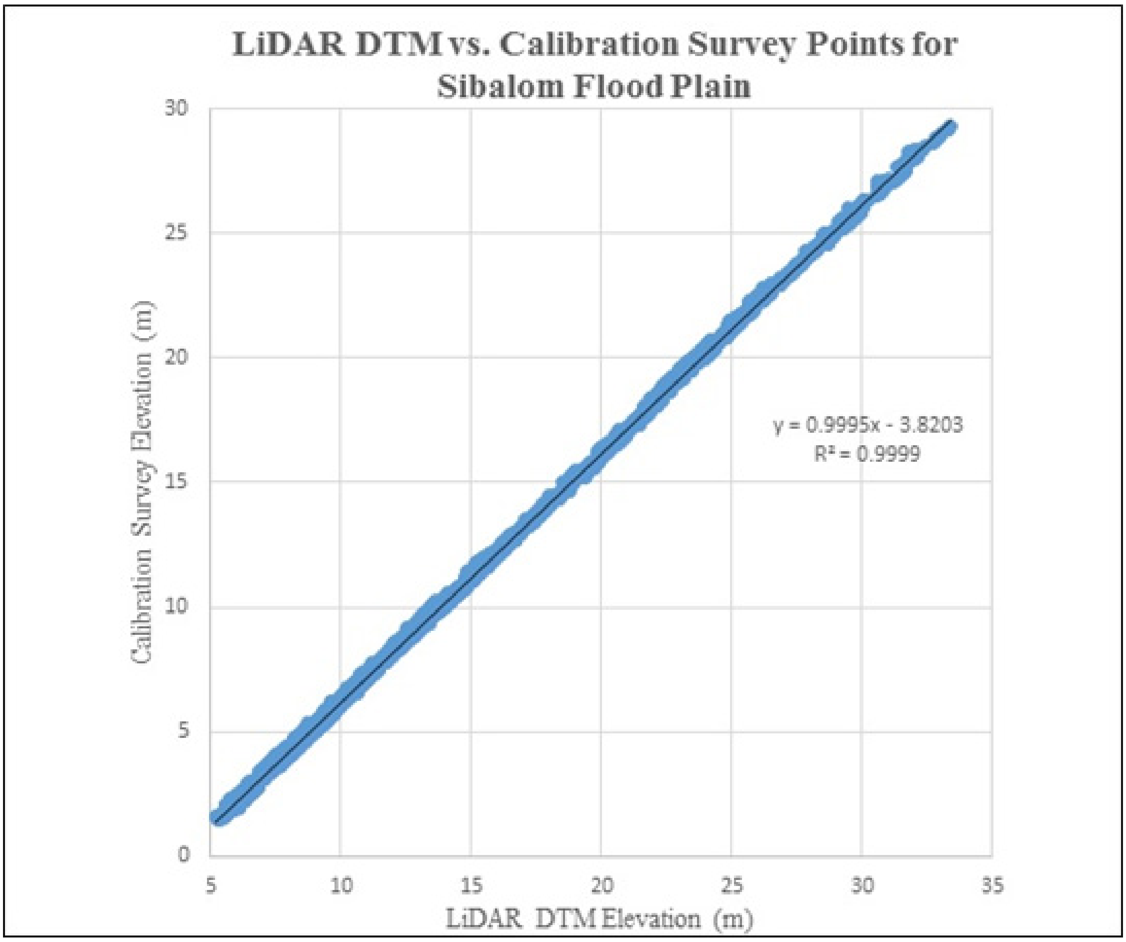


Figure 29. Correlation plot between the calibration survey points and the LiDAR data

Table 20. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	3.83
Standard Deviation	0.12
Average	-3.83
Minimum	-4.20
Maximum	-3.40

The remaining 20% of the total survey points, resulting in 2429 points, were used for the validation of calibrated Sibalom 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 demonstrated in Figure 30. The computed RMSE between the calibrated LiDAR DTM and the validation elevation values is 0.13 meters, with a standard deviation of 0.13 meters, as indicated in Table 21.

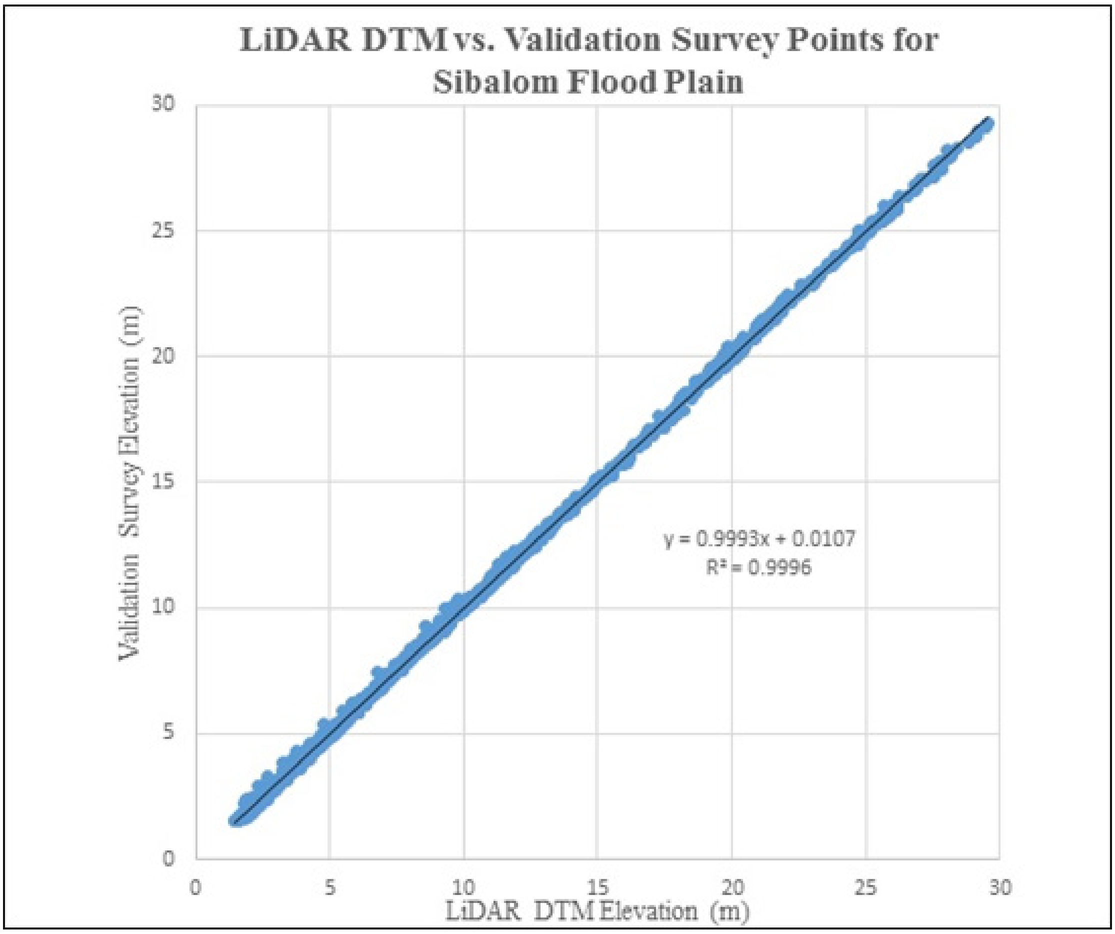


Figure 30. Correlation plot between the validation survey points and the LiDAR data

Table 21. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.13
Standard Deviation	0.0048
Average	0.13
Minimum	-0.41
Maximum	0.69

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, a total of 3,450 bathymetric survey points in centerline and zigzag data were used for Sibalom. The resulting raster surface produced was obtained through the 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 0.38 meters. The extent of the bathymetric survey done by the DVBC in Sibalom, integrated with the processed LiDAR DEM, is illustrated in Figure 31.

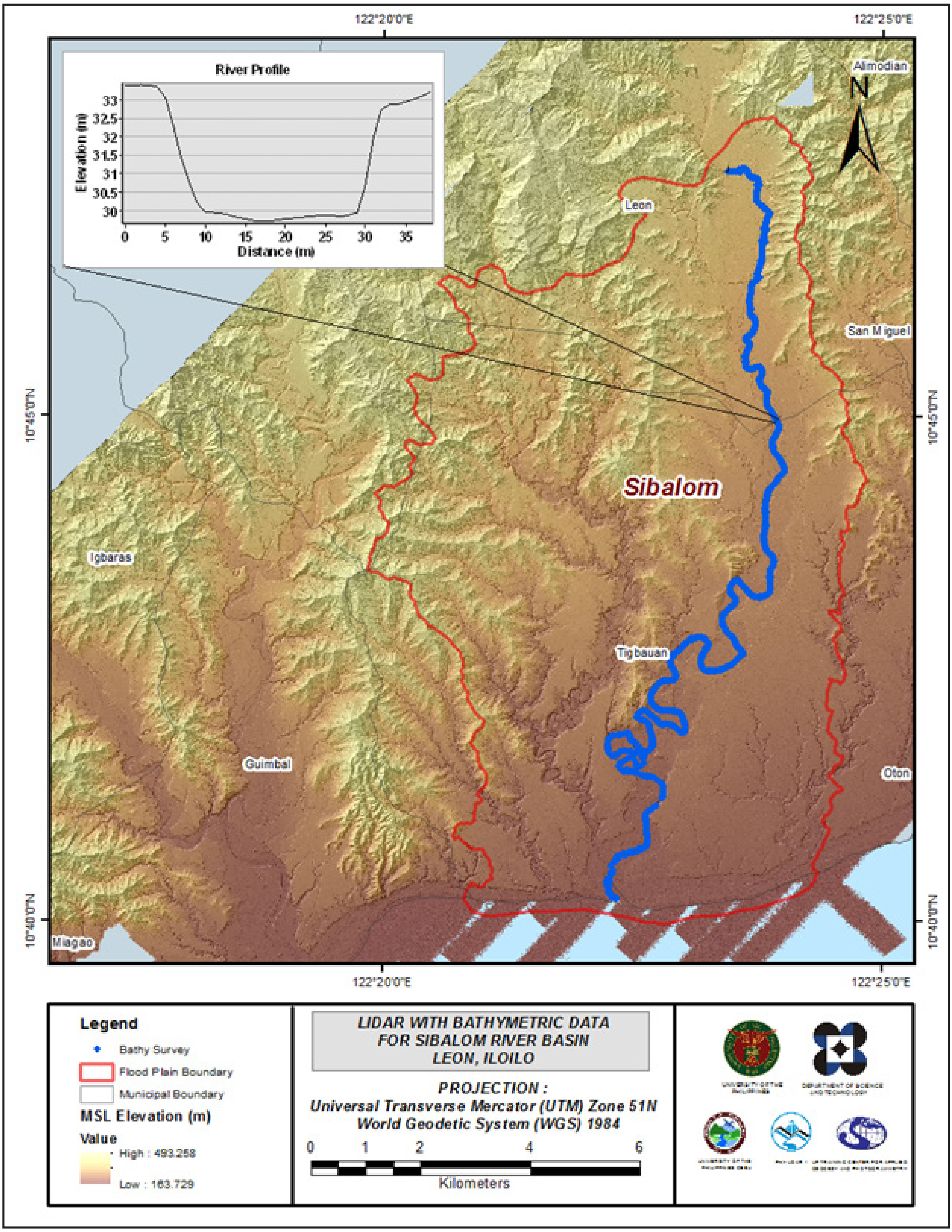


Figure 31. Map of the Sibalom floodplain, with bathymetric survey points shown in blue

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 z 200-meter buffer zone. Mosaicked LiDAR DEM with a 1-meter 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 – comprised of main thoroughfares, such as highways, and municipal and barangay roads – are essential for routing disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

The Sibalom floodplain, including its 200-meter buffer zone, covers a total area of 99.87 square kilometers. Of this area, a total of 5.0 square kilometers, corresponding to a total of 2,215 building features, were considered for quality checking (QC). Figure 32 shows the QC blocks for the Sibalom floodplain.

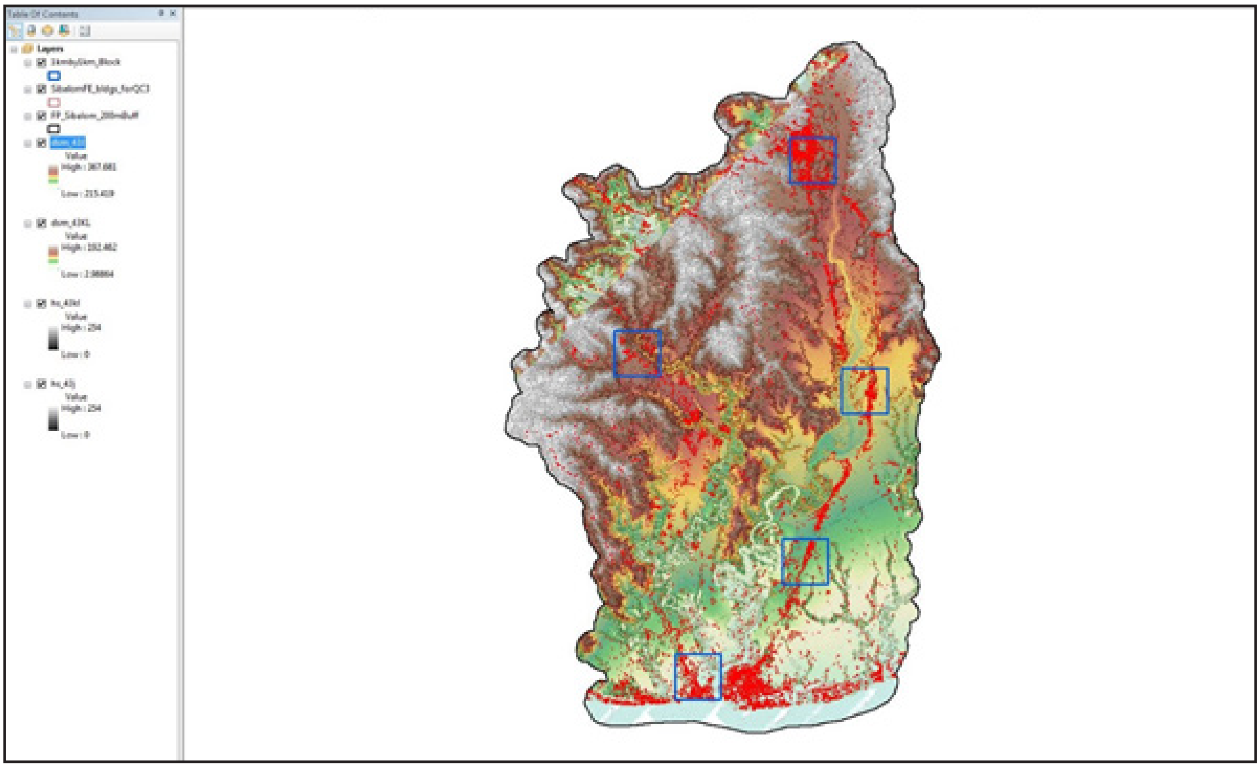


Figure 32. Blocks (in blue) of Sibalom building features that were subjected to QC

Quality checking of the Sibalom building features resulted in the ratings given in Table 22.

Table 22. Quality checking ratings for the Sibalom building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Sibalom	99.10	99.86	96.39	PASSED

3.12.2 Height Extraction

Height extraction was done for 15,219 building features in the Sibalom floodplain. Of these building features, 38 were filtered out after height extraction, resulting in 15,181 buildings with height attributes. The lowest building height is at 2.0 meters, while the highest building is at 15.68 meters.

3.12.3 Feature Attribution

The feature attribution survey was conducted through a participatory community-based mapping approach, in coordination with the local government units (LGUs) of the covered municipalities/cities. The research associates of the Phil-LiDAR 1 team visited local barangay units and interviewed key local personnel and officials who possessed expert knowledge of their local environments, in order to identify and map out features in the area.

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

Table 23 summarizes the number of building features per type. Table 24 indicates the total length of each road type, and Table 25 provides the number of water features extracted per type.

Table 23. Building features extracted for the Sibalom floodplain

Facility Type	No. of Features
Residential	14,389
School	264
Market	19
Agricultural/Agro-Industrial Facilities	34
Medical Institutions	13
Barangay Hall	44
Military Institution	1
Sports Center/Gymnasium/Covered Court	22
Telecommunication Facilities	5
Transport Terminal	4
Warehouse	5
Power Plant/Substation	0
NGO/CSO Offices	2
Police Station	1
Water Supply/Sewerage	1
Religious Institutions	62
Bank	3
Factory	0
Gas Station	11
Fire Station	1
Other Government Offices	139
Other Commercial Establishments	140
Others	21
Total	**15,181**

Table 24. Total length of extracted roads for the Sibalom floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Sibalom	271	62	5	15	58	**411**

Table 25. Number of extracted water bodies for the Sibalom floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Sibalom	6	0	0	0	4	10

A total of seventeen (17) 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 33 displays the Digital Surface Model (DSM) of the Sibalom floodplain, overlaid with its ground features.

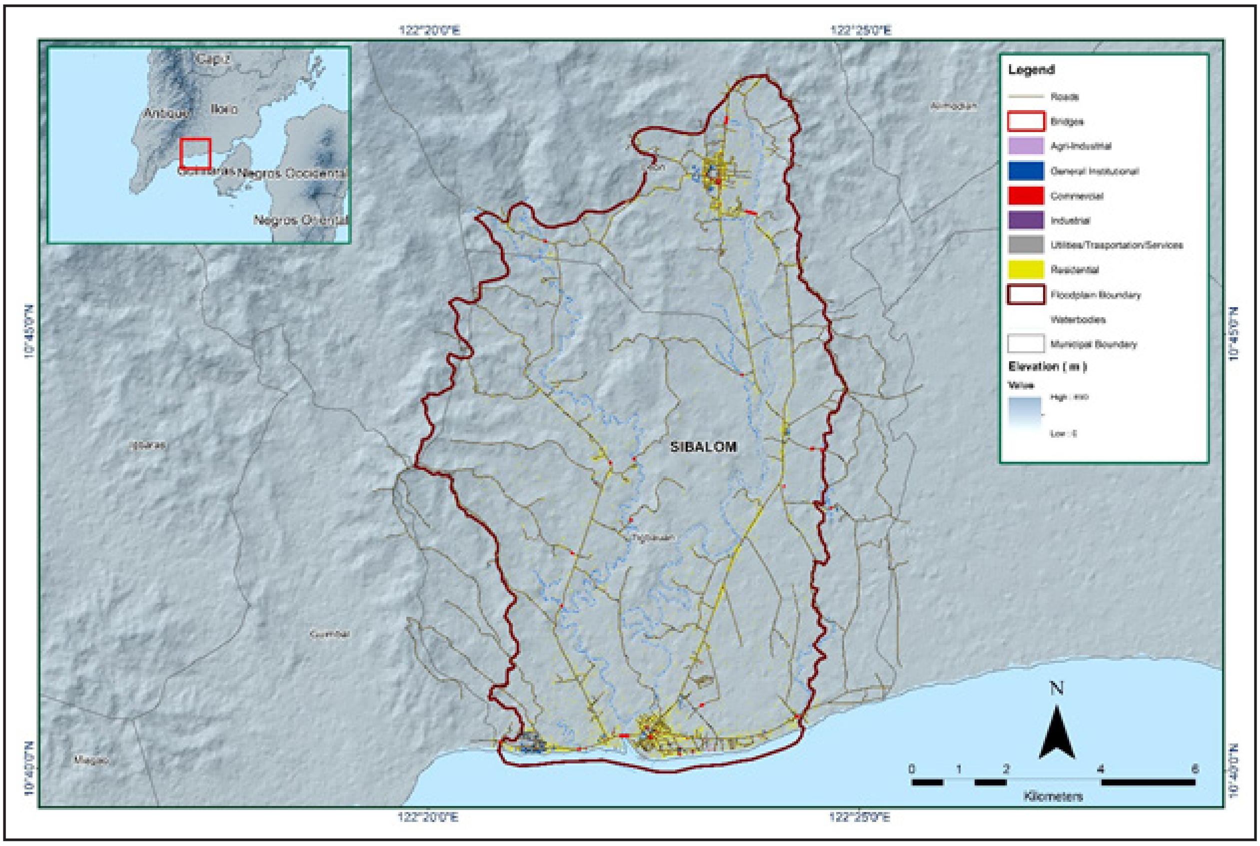


Figure 33. Extracted features for the Sibalom floodplain

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Patrizcia Mae. P. dela Cruz, Engr. Dexter T. Lozano, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, For. Rodel C. Alberto, Cybil Claire Atacador, and Engr. Lorenz R. Taguse

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

4.1 Summary of Activities

The DVBC conducted field surveys in the Sibalom River on October 10 – 21, 2015 for the following activities: (i.) initial reconnaissance; (ii.) control point survey; (iii.) cross-section and bridge as-built surveys at the Sibalom Bridge in Barangay Parara Norte, Municipality of Tigbauan, Iloilo; and (iv.) validation points acquisition of about 223.38 kilometers, covering the twenty (20) municipalities, including Iloilo City in the province of Iloilo.

Another set of fieldwork was conducted on September 13 – 27, 2016 for the conduct of: (i.) reconnaissance; (ii.) control point survey; (iii.) cross-section and bridge as-built surveys at the Baltazar Bridge in Barangay Poblacion, Municipality of Leon, Iloilo; (iv.) validation points acquisition of about 87.374 kilometers, covering the Sibalom River Basin; and (v.) re-surveyed bathymetric survey from the river's upstream portion in Barangay Poblacion, Municipality of Leon, to the mouth of the river located in Barangay Parara Norte in the Municipality of Tigbauan, with an approximate length of 24.524 kilometers using an Ohmex™ single beam echo sounder and a Trimble® SPS 882 in GNSS PPK survey technique. The extent of the conducted surveys is illustrated in Figure 34.

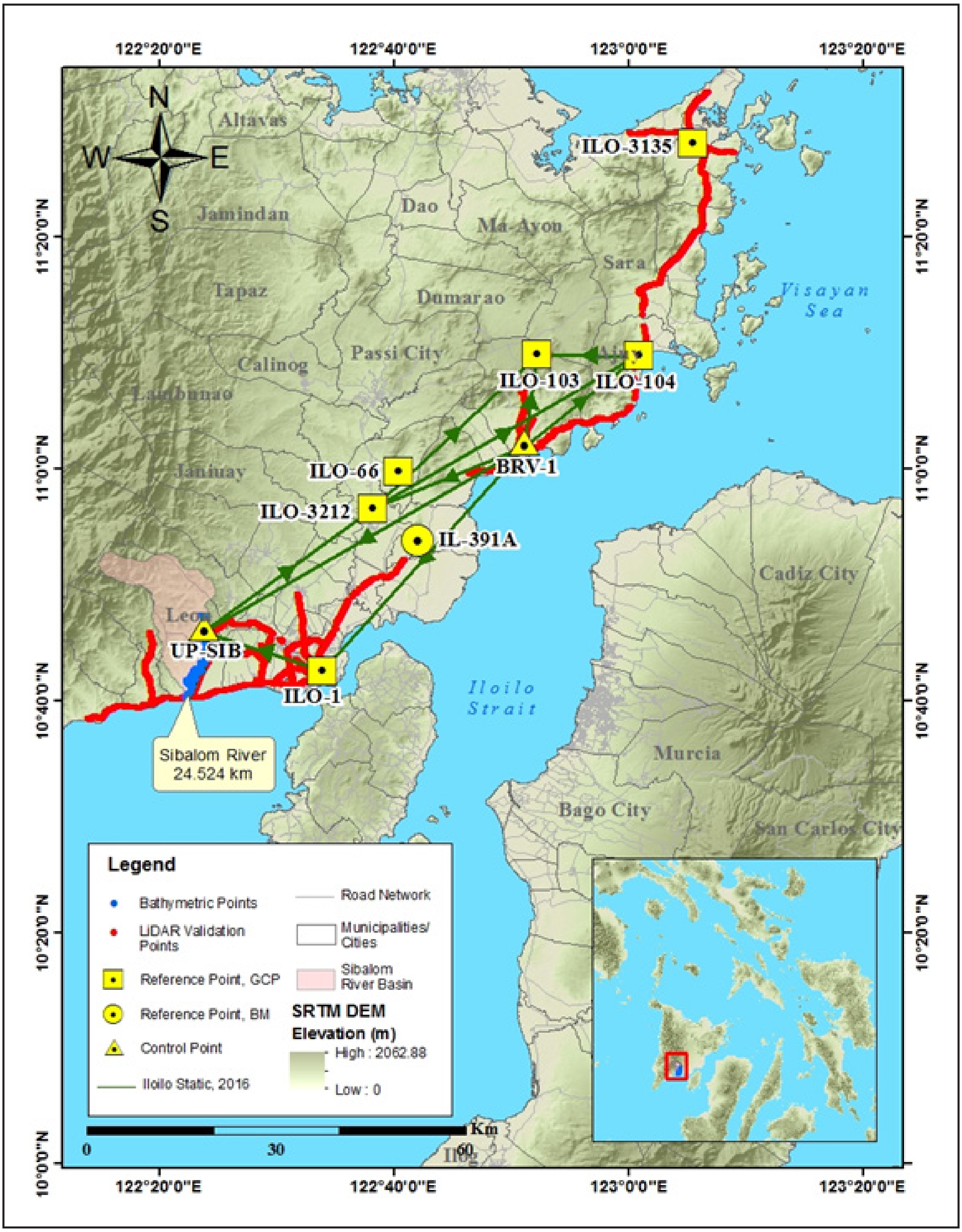


Figure 34. Extent of the bathymetric survey (in blue line) in the Sibalom River and the LiDAR data validation survey (in red)

4.2 Control Survey

A GNSS baseline was established on July 22, 2014, occupying the control point ILO-1, a 2nd order GCP in Barangay Magsaysay Village, Iloilo City; and on October 21, 2015, occupying: (i.) ILO-66, a 2nd order GCP in Barangay Dawis, Municipality of Dingle; and (ii.) IL-391A, a 1st order benchmark in Barangay Tabuc-suba, Municipality of Barotac Nuevo. All sites are in the province of Iloilo (Figure 35).

The GNSS network used for the Sibalom River Basin is composed of four (4) loops established on September 14, 15, and 22, 2016, occupying the established control points: (i.) UP-SIB, with values fixed from the first survey conducted in 2014 in the Sibalom River, located in Barangay Anonang, Municipality of Leon; and (ii.) BRV-1, also carrying the coordinates and elevation values from the first static network in 2014, located in Barangay Poblacion, Municipality of Barotac Viejo. Both are in Iloilo. The following NAMRIA established control points were also occupied and used as markers; (i.) ILO-103 in Barangay San Dionisio, Municipality of San Rafael; (ii.) ILO-104 in Barangay San Antonio, Municipality of Ajuy; and (iii.) ILO-3212 in Barangay San Jose Ward, Municipality of Pototan (See Figure 36).

The summary of reference and control points and their corresponding locations is given in Table 26; while the established GNSS networks are illustrated in Figure 35 and Figure 36.

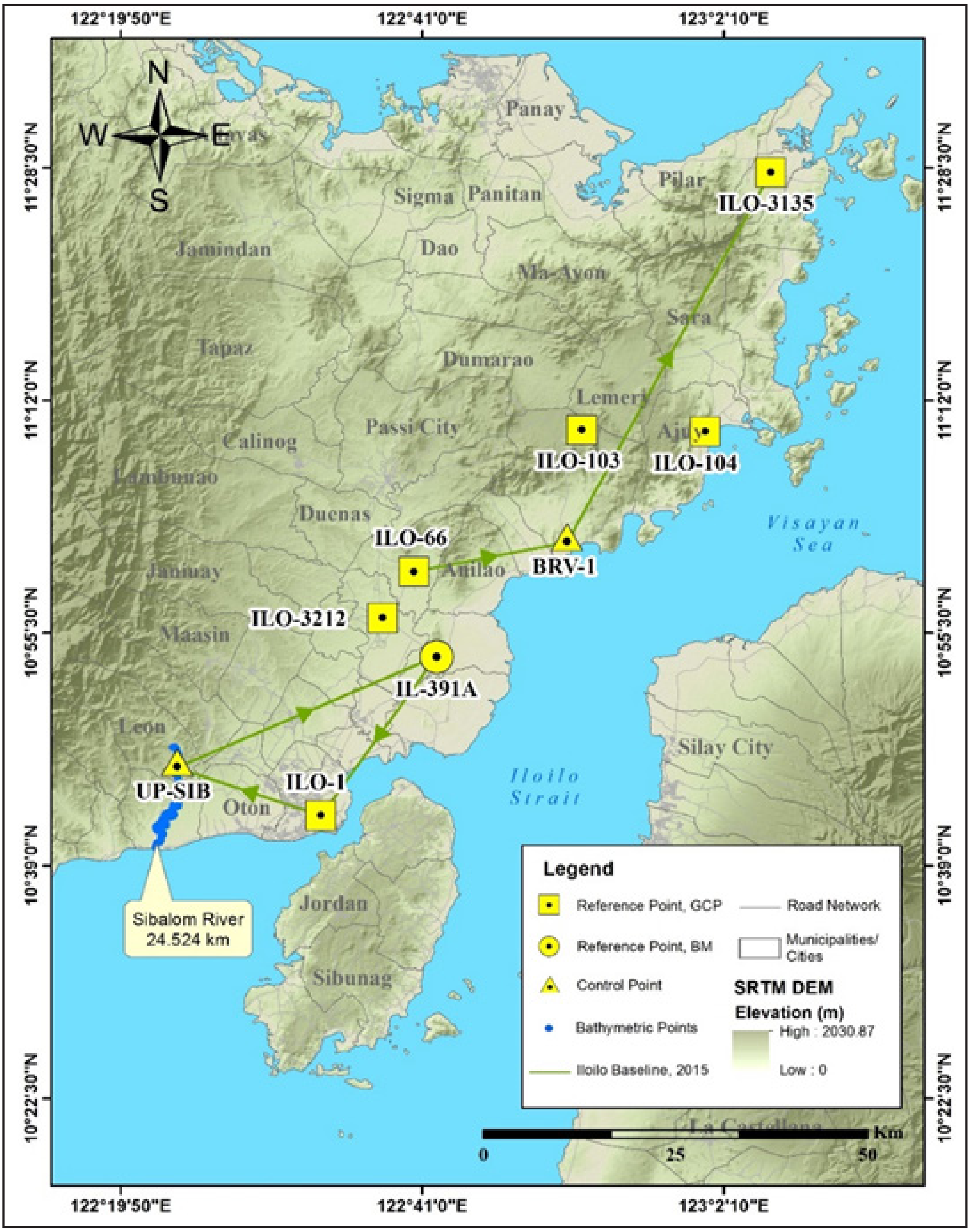


Figure 35. Sibalom River Basin 2014 static network

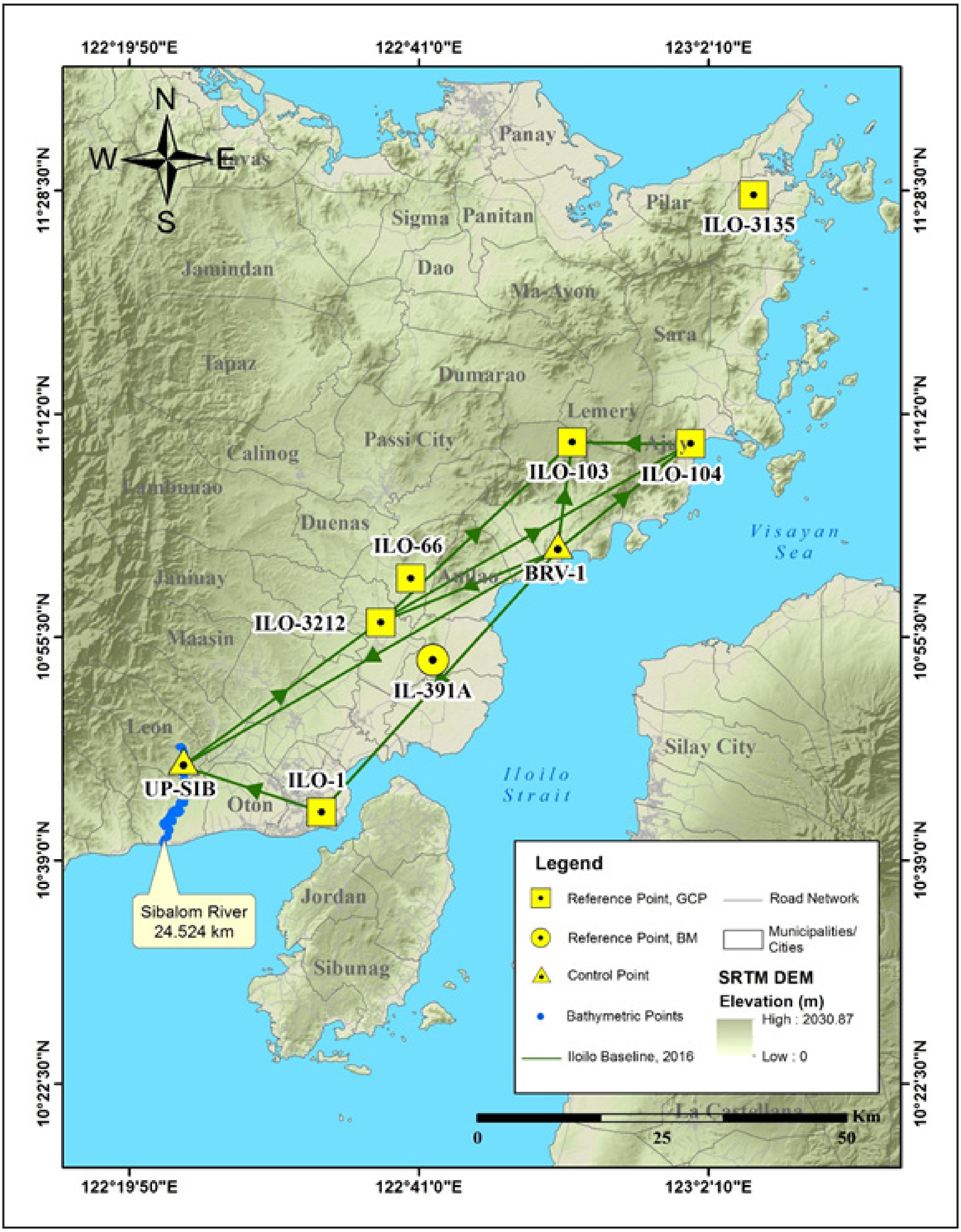


Figure 36. Sibalom River Basin 2016 static network

Table 24. List of reference and control points used during the survey in Tineg River (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	Elevation in MSL (m)	Date Established
Control Survey on July 22, 2014 and October 21, 2015						
ILO-66	2nd order, GCP	10°59'51.7441"N	122°40'23.8750"E	84.815	25.655	06-13-2013
ILO-1	2nd order, GCP	10°42'36.4675"N	122°33'53.5928"E	83.433	24.339	04-26-2013
IL-391A	1st order, BM	10°53'48.0549"N	122°41'59.8412"E	71.433	12.159	2012
Control Survey on September 14, 15 and 22, 2016						
BRV-1	2nd order, GCP	11°02'19.3291"N	122°51'07.2894"E	73.739	14.337	2014
UP-SIB	UP Established	10°46'22.0720"N	122°23'46.0273"E	112.338	55.148	10-21-2015
ILO-103	1st order, BM	-	-	-	-	2007
ILO-104	UP Established	-	-	-	-	2007
ILO-3212	UP Established	-	-	-	-	2007

The GNSS set-ups on recovered reference points and established control points in the Sibalom River are exhibited in Figure 37 to Figure 41.

Figure 37. GNSS base set-up, Trimble® SPS 852 at BRV-1, situated on top of Hollywood Star Inn in Barangay Poblacion, Municipality of Barotac Viejo, Iloilo

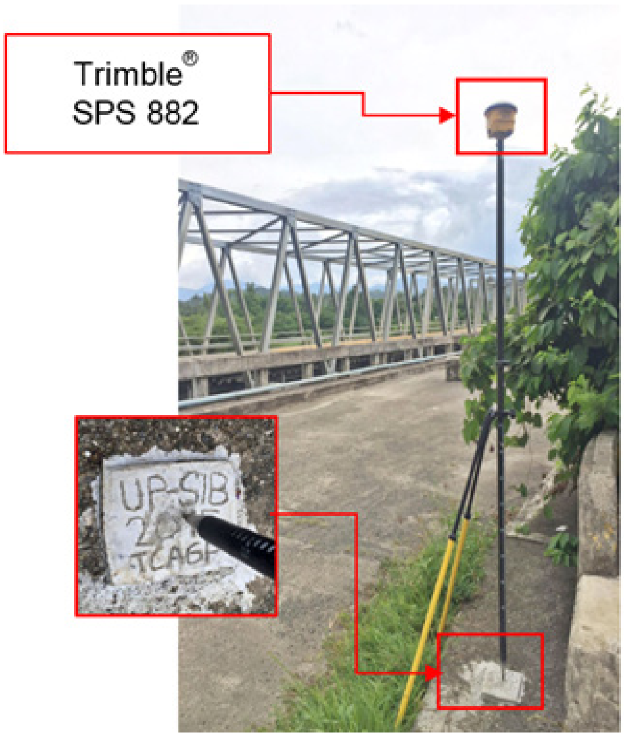


Figure 38. GNSS receiver set-up, Trimble® SPS 985 at UP-SIB, located at the approach of the Sibalom Bridge in Barangay Anonang, Municipality of Leon, Iloilo

Figure 39. GNSS receiver set-up, Trimble® SPS 882 at ILO-103, located inside Barangay San Dionisio Elementary School in Barangay San Dionisio, Municipality of San Rafael, Iloilo

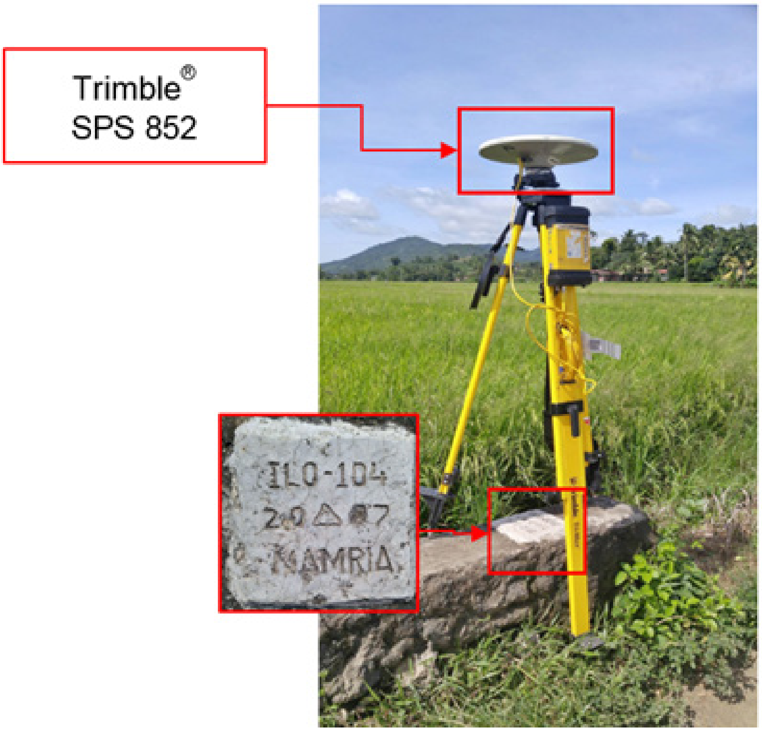


Figure 40. GNSS receiver set-up, Trimble® SPS 852 at ILO-104, located along the National Highway in Barangay San Antonio, Municipality of Ajuy, Iloilo

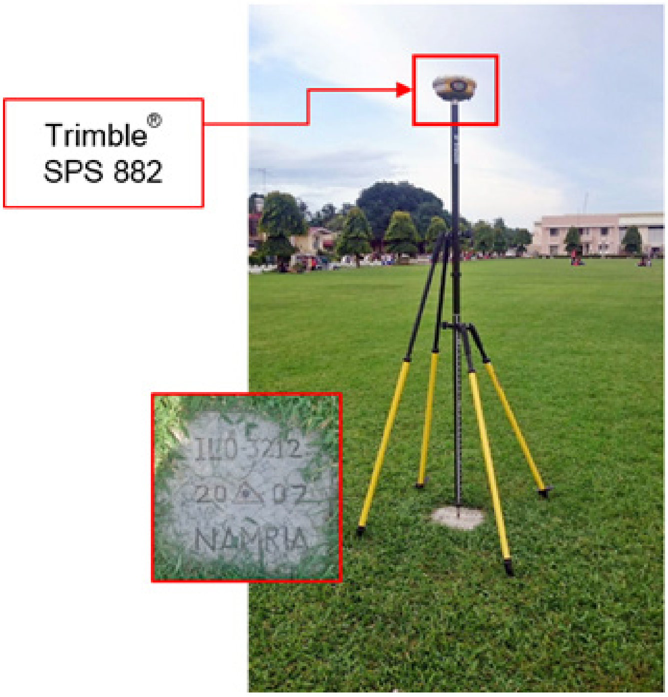


Figure 41. GNSS receiver set-up, Trimble® SPS 882 at ILO-3212, located in Pototan Town Plaza in Barangay San Jose Ward, Municipality of Pototan, Iloilo

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within the +/- 20-centimeter and +/- 10-centimeter requirement, respectively. In cases where one or more of the baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of 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, a re-survey is initiated. The baseline processing results of the control points in the Sibalom River Basin, generated by the TBC software, are summarized in Table 27.

Table 27. Baseline processing summary report for the Sibalom River survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ILO3212 --- ILO103 (B12)	09-15-2016	Fixed	0.003	0.013	46°03'27"	35345.220	124.652
BRV1 --- UPSIB (B18)	09-15-2016	Fixed	0.007	0.019	239°29'49"	57872.352	38.779
BRV1 --- ILO1 (B1)	09-15-2016	Fixed	0.003	0.012	220°50'49"	48026.221	9.069
ILO104 --- BRV1 (B5)	09-14-2016	Fixed	0.003	0.012	52°05'26"	22489.644	-5.269
BRV1 --- ILO104 (B7)	09-14-2016	Fixed	0.005	0.015	52°05'26"	22489.650	-5.257
ILO3212 --- ILO104 (B8)	09-14-2016	Fixed	0.006	0.020	59°26'50"	47903.104	-14.058

ILO104 --- ILO3212 (B11)	09-14-2016	Fixed	0.005	0.018	59°26'50"	47903.040	-14.048
BRV1 --- ILO3212 (B15)	09-15-2016	Fixed	0.003	0.012	245°56'30"	25763.890	8.631
BRV1 --- ILO3212 (B13)	09-15-2016	Fixed	0.003	0.013	245°56'30"	25763.873	8.776
BRV1 --- ILO3212 (B10)	09-15-2016	Fixed	0.005	0.018	245°56'30"	25763.895	8.806
ILO3212 --- UPSIB (B16)	09-15-2016	Fixed	0.003	0.014	54°17'24"	32400.633	-30.173
ILO1 --- UPSIB (B17)	09-15-2016	Fixed	0.004	0.017	290°35'49"	19718.729	29.724
ILO3212 --- ILO103 (B9)	09-15-2016	Fixed	0.003	0.013	46°03'27"	35345.248	124.685
ILO104 --- ILO103 (B4)	09-15-2016	Fixed	0.004	0.013	270°42'46"	15803.323	138.697
ILO104 --- ILO103 (B6)	09-22-2016	Fixed	0.003	0.013	270°42'45"	15803.319	138.721
BRV1 --- ILO103 (B2)	09-22-2016	Fixed	0.004	0.015	7°53'34"	14139.870	133.421
BRV1 --- ILO103 (B3)	09-22-2016	Fixed	0.004	0.013	7°53'34"	14139.872	133.453

As reflected in Table 27, a total of seventeen (17) baselines were processed, with values of reference points BRV-1 and UP-SIB, derived from the previous field survey, held fixed for coordinate and elevation values. All of the baselines satisfied the required accuracy.

4.5 Network Adjustment

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

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

where:

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

for each control point. See the Network Adjustment Report shown in Table 28 to Table 31 for complete details.

The six (6) control points – BRV-1, UP-SIB, ILO-103, ILO-104, and ILO-3212 – were occupied and observed simultaneously to form a GNSS loop. The coordinates and elevation values of BRV-1 and UP-SIB, derived from the previous field survey, were held fixed during the processing of the control points, as presented in Table 28. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 28. Constraints applied to the adjustments of the control points

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
BRV-1	Grid	Fixed	Fixed		Fixed
UP-SIB	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 29. The fixed control points, BRV-1 and UP-SIB, did not yield values for grid and elevation errors.

Table 29. Adjusted grid coordinates for the control points used in the Sibalom floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
BRV-1	483836.720	?	1220262.792	?	14.337	?	ENe
UP-SIB	485784.629	0.019	1234262.136	0.016	147.708	0.093	
ILO-103	501580.383	0.024	1234066.416	0.018	8.346	0.096	
ILO-104	460315.009	0.018	1209775.371	0.014	24.148	0.099	
ILO-3212	433978.538	?	1190922.799	?	55.148	?	ENe

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

a. BRV-1
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

b. UP-SIB
Horizontal Accuracy = Fixed
Vertical Accuracy = Fixed

c. ILO-103
Horizontal Accuracy = $\sqrt{((1.9)^2 + (1.6)^2}$
= $\sqrt{(3.61 + 2.56)}$
= 2.48 < 20 cm
Vertical Accuracy = 9.3 cm < 10 cm

d. ILO-104
Horizontal Accuracy = $\sqrt{((2.4)^2 + (1.8)^2}$
= $\sqrt{(5.7 + 3.24)}$
= 2.98 < 20 cm
Vertical Accuracy = 9.6 cm < 10 cm

e. ILO-3212
Horizontal Accuracy = $\sqrt{((3.24)^2 + (1.4)^2}$
= $\sqrt{(1.21 + 1.96)}$
= 1.78 < 20 cm
Vertical Accuracy = 9.9 cm < 10 cm

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

Table 30. Adjusted geodetic coordinates for control points used in the Sibalom River floodplain validation

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
BRV-1	N11°02'19.32911"	E122°51'07.28940"	73.739	?	ENe
UP-SIB	N10°46'22.07205"	E122°23'46.02739"	112.338	?	ENe
ILO-103	N11°09'55.15088"	E122°52'11.28672"	207.134	0.093	
ILO-104	N11°09'48.87918"	E123°00'52.10858"	68.437	0.096	
ILO-3212	N10°56'37.22766"	E122°38'12.48445"	82.417	0.099	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as shown in Table 30. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The computed coordinates of the reference and control points utilized in the Sibalom River GNSS Static Survey are indicated in Table 31.

Table 31. Reference and control points used in the Sibalom River Static Survey, with their corresponding locations (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 July 22, 2014 and October 21, 2015							
ILO-66	2nd order, GCP	10°59'51.74412"	122°40'23.87665"	84.815	1215745.274	464309.479	25.655
ILO-1	2nd order, GCP	10°42'36.46758"	122°33'53.59289"	83.433	1183962.237	452420.308	24.339
IL-391A	1st order, BM	10°53'48.05498"	122°41'59.84121"	71.433	1204571.776	467210.527	12.159
Control Survey on September 14, 15 and 22, 2016							
BRV-1	UP Established	11°02'19.32911"	122°51'07.28940"	73.739	1220262.792	483836.72	14.337
UP-SIB	UP Established	10°46'22.07205"	122°23'46.02739"	112.338	1190922.799	433978.538	55.148
ILO-103	Used as marker	11°09'55.15088"	122°52'11.28672"	207.134	1234262.136	485784.629	147.708
ILO-104	Used as marker	11°09'48.87918"	123°00'52.10858"	68.437	1234066.416	501580.383	8.346
ILO-3212	Used as marker	10°56'37.22766"	122°38'12.48445"	82.417	1209775.371	460315.009	24.148

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

The cross-section and bridge as-built surveys were conducted on September 21, 2016 at the downstream side of the Baltazar Bridge in Barangay Poblacion, Municipality of Leon, Iloilo, as depicted in Figure 42. A survey-grade GNSS receiver, Trimble® SPS 882 in PPK survey technique, was utilized for this survey, as demonstrated in Figure 43.

Figure 42. Baltazar Bridge, facing downstream

Figure 43. As-built survey of the Baltazar Bridge

The length of the cross-sectional line surveyed in the Baltazar Bridge is about 371 meters with three hundred and twenty five (325) cross-sectional points, using the control point UP-SIB as the GNSS base station. The location map, cross-section diagram, and the bridge data form are presented in Figure 44 to Figure 46.

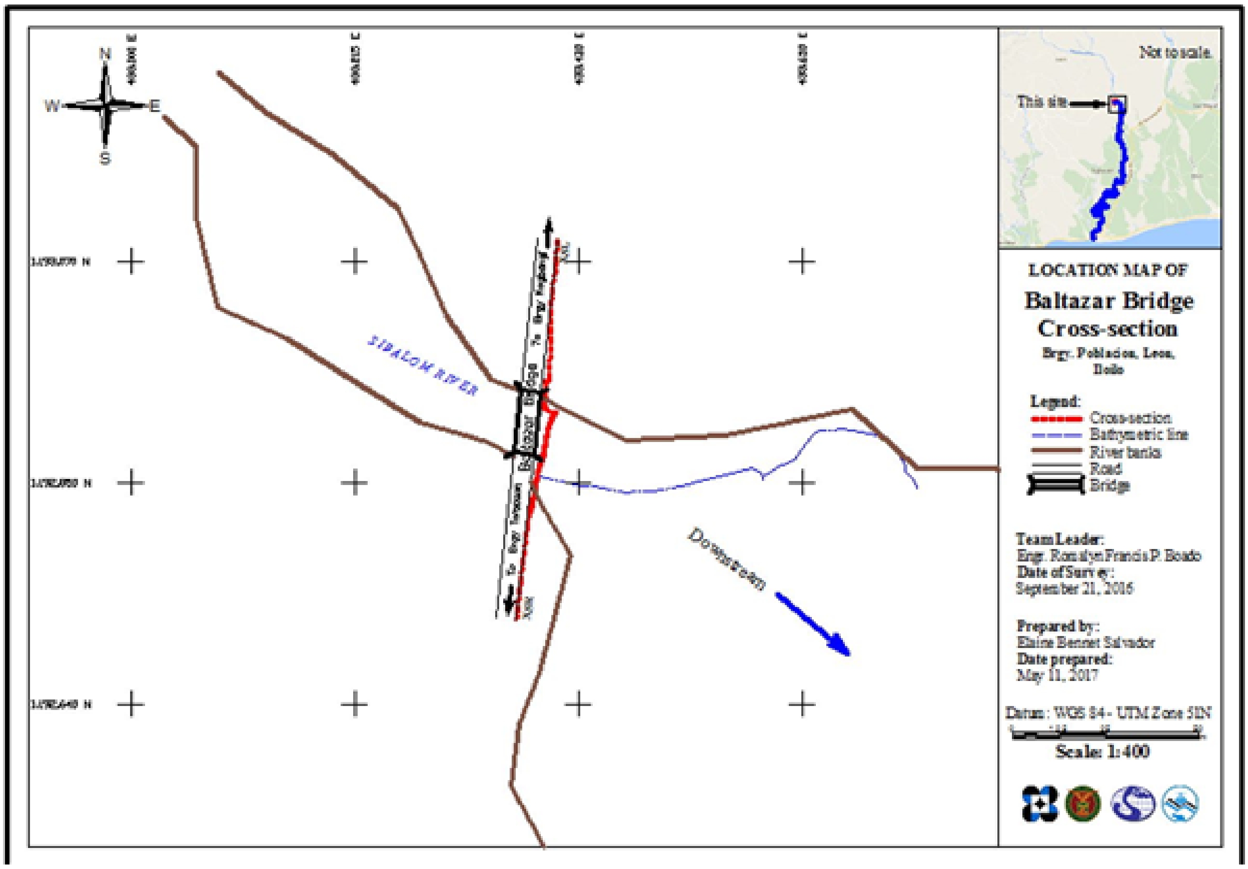


Figure 44. Baltazar Bridge cross-section location map

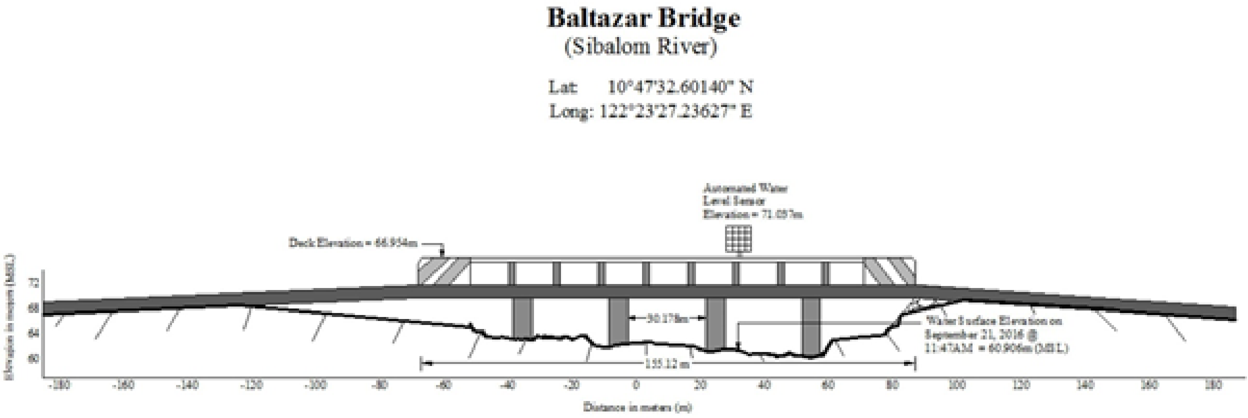


Figure 45. Baltazar Bridge cross-section diagram

Bridge Data Form

Bridge Name: Baltazar Bridge **Date:** September 21, 2016

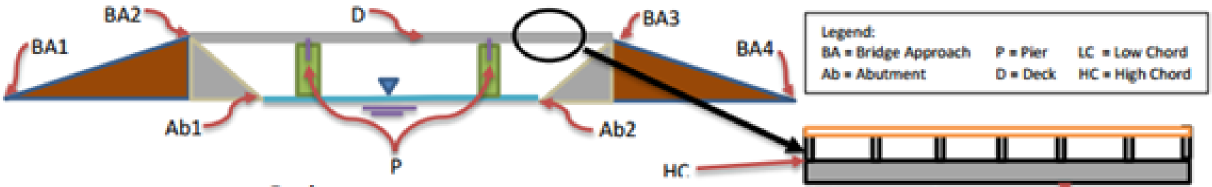
River Name: Sibalom River **Time:** 11:47 AM

Location (Brgy, City,Region): Brgy. Poblacion, Municipality of Leon, Iloilo

Survey Team: Romalyn Boado, Cibyl Atacador, John Christopher Santos

Flow condition: high **Weather Condition:** rainy

Latitude: 10°47'32.60140" N **Longitude:** 122°23'27.23627" E



LC

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

Elevation: 66.954 m **Width:** 9.39 m **Span (BA3-BA2):** 155.12 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	66.954 m	BA3	272.055 m	69.636 m
BA2	116.935 m	69.585 m	BA4	371.869 m	66.1 m

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

	Station (Distance from BA1)	Elevation
Ab1	Not available	Not available
Ab2	264.837 m	64.936 m

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	149.253 m	69.619 m	1.5 m
Pier 2	179.390 m	69.637 m	1.5 m
Pier 3	209.569 m	69.680 m	1.5 m
Pier 4	239.411 m	69.669 m	1.5 m

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

Figure 46. Bridge as-built form of the Baltazar Bridge

The water surface elevation of the Sibalom River was determined using a survey-grade GNSS receiver, Trimble® SPS 882 in PPK survey technique, on September 21, 2016 at 11:47 hrs. The elevation value obtained was 60.906 meters in MSL, as reflected in Figure 45. This was translated into markings on the bridge's deck using the same technique, as displayed in Figure 47. The markings served as reference for flow data gathering and depth gauge deployment of the UPC Phil-LiDAR1 Team.

Figure 47. Water-level markings on the Baltazar Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on October 11-15, and October 17-19, 2015, and on September 19- 20, 2016, using a survey-grade GNSS Rover receiver, Trimble® SPS 882. The receiver was mounted on the roof of a vehicle, as demonstrated in Figure 48. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 1.907 meters, measured from the ground up to the bottom of the notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode, with BRV-1 and UP-SIB occupied as the GNSS base stations.

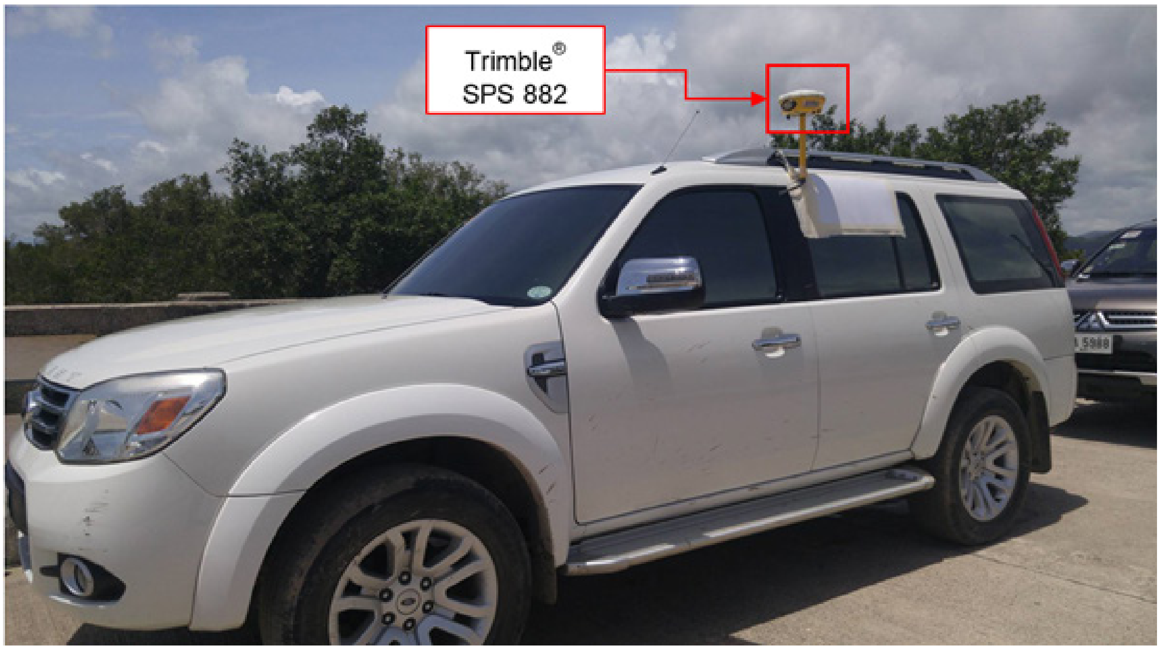


Figure 48. Validation points acquisition survey set-up along the Sibalom River Basin

The survey started at the Sibalom Bridge in Barangay Anonang, Municipality of Leon; and then headed southwest, covering the Municipalities of Guimbal, Miagao, Tigbauan and Tubungan. The survey then traveled southeast, covering the Municipalities of Alimodian, Leganes, Oton, Pavia, San Miguel, Santa Barbara, and Iloilo City. After this, the survey went north, traversing the Municipalities of Ajuy, Anilao, Balasan, Banate, Barotac Nuevo, Barotac Viejo, Batad, Carles, Dumangas, Estancia, San Dionisio, Sara, and Zarraga in the province of Iloilo; and ended in Municipality of Pilar in the province of Capiz. The survey gathered a total of 57,919 points with an approximate length of 226 kilometers; using BRV-1, UP-SIB and ILO-3135 as the GNSS base stations for the entire survey (See the map in Figure 49).

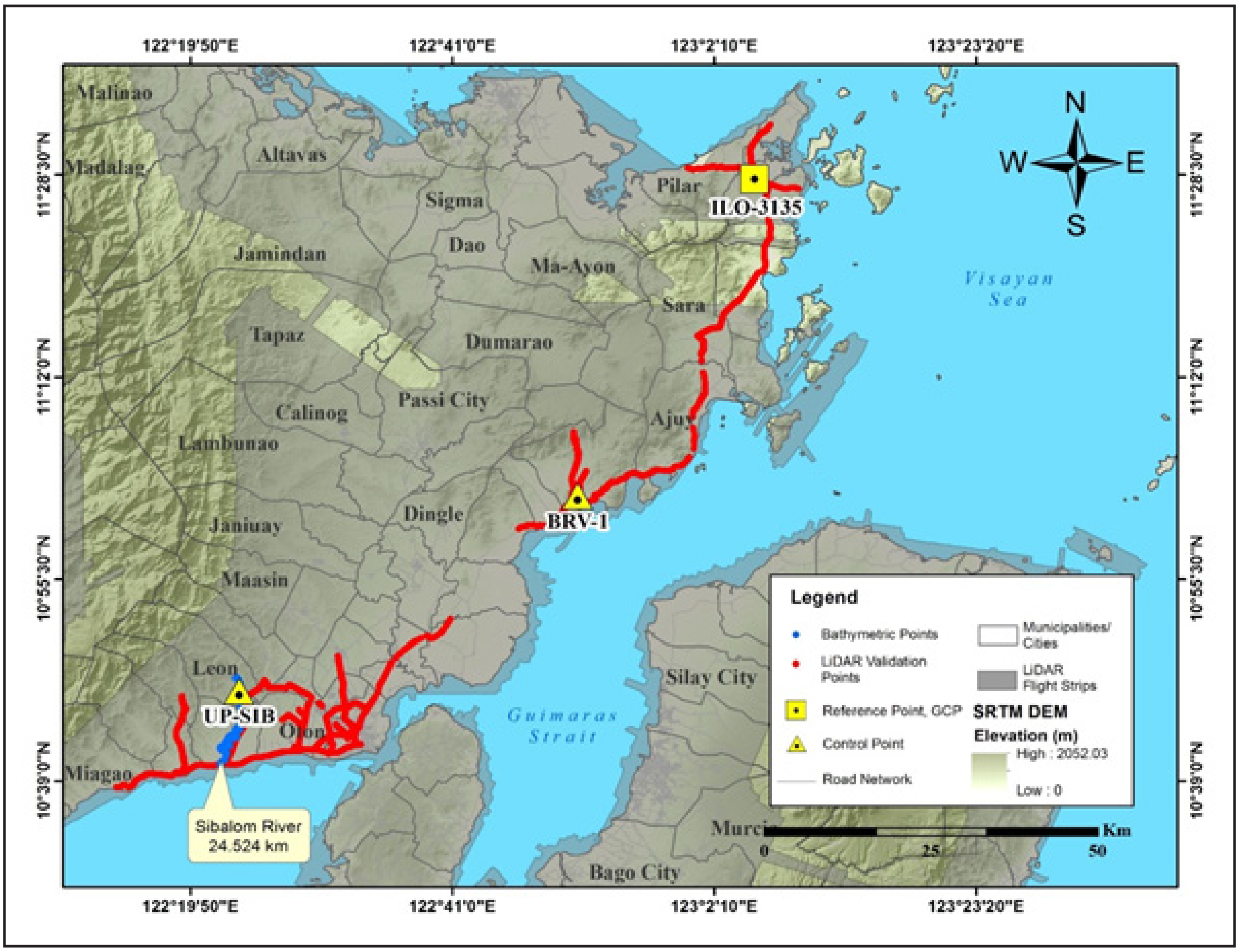


Figure 49. Extent of the LiDAR ground validation survey of Sibalom River basin

4.7 Bathymetric Survey

A manual bathymetric survey was executed on September 20- 21, 2016, using a Trimble® SPS 882 in GNSS PPK survey technique set in continuous topo mode, as illustrated in Figure 50. The survey started in Barangay Poblacion, Municipality of Leon, with coordinates 10°47'25.10924"N, 122°23'26.69639"E; and ended at the downstream part of the river in Barangay Bagumbayan, Municipality of Tigbauan, with coordinates 10°41'25.14861"N, 122°22'39.45588"E. The control point UP-SIB was used as the GNSS base station all throughout the survey.

Figure 50. Manual bathymetric survey using a Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode in the Sibalom River

The bathymetric survey for the Sibalom River gathered a total of 32,503 points covering 24.524 kilometers of the river, traversing six (6) barangays in Municipality of Leon, and eight (8) baragays in Municipality of Tigbauan. A CAD drawing was also produced to illustrate the riverbed profile of the Sibalom River, presented in Figure 52 and Figure 53. The profile conveys that the highest and lowest elevation had a 59-meter difference. The highest elevation observed was 60.831 meters above MSL, located in Barangay Poblacion, Municipality of Leon; while the lowest was 1.133 meters below MSL, located in Barangay Bagumbayan, Municipality of Tigbauan. The survey for the remaining 3 kilometers downstream of the river was cut, as the LiDAR DEM data of its riverbed was already available.

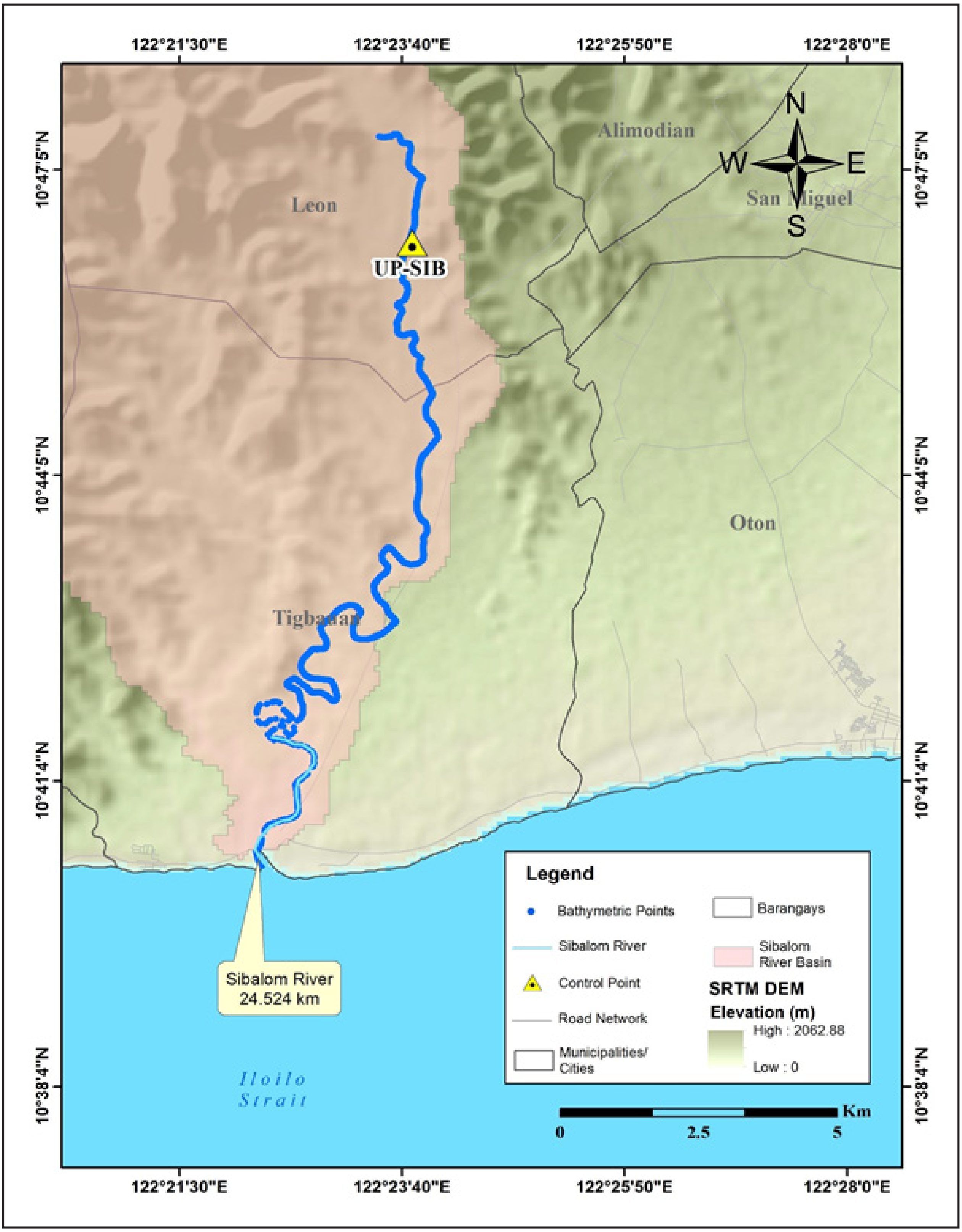


Figure 51. Extent of the bathymetric survey of the Sibalom River

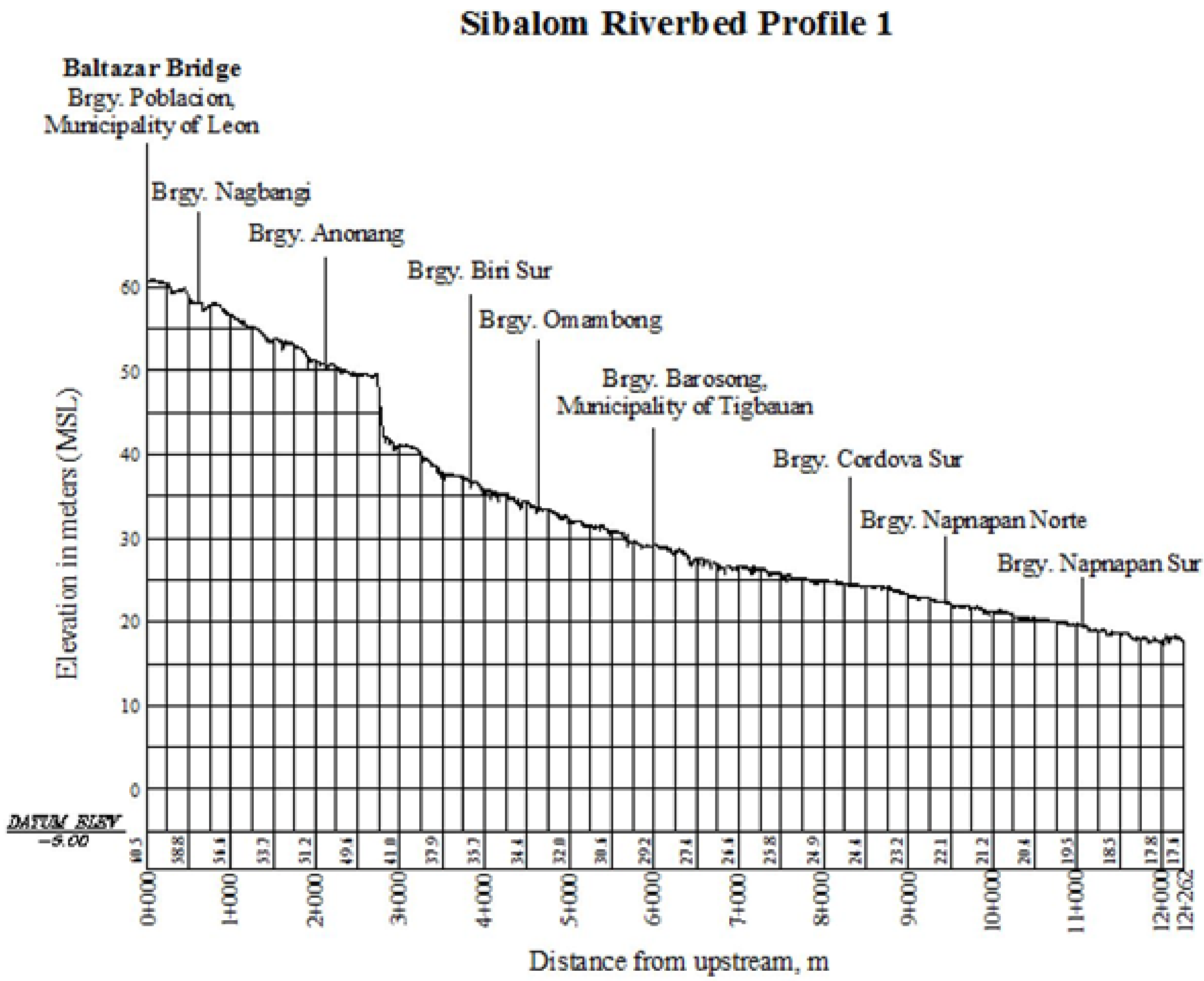


Figure 52. Sibalom riverbed profile 1

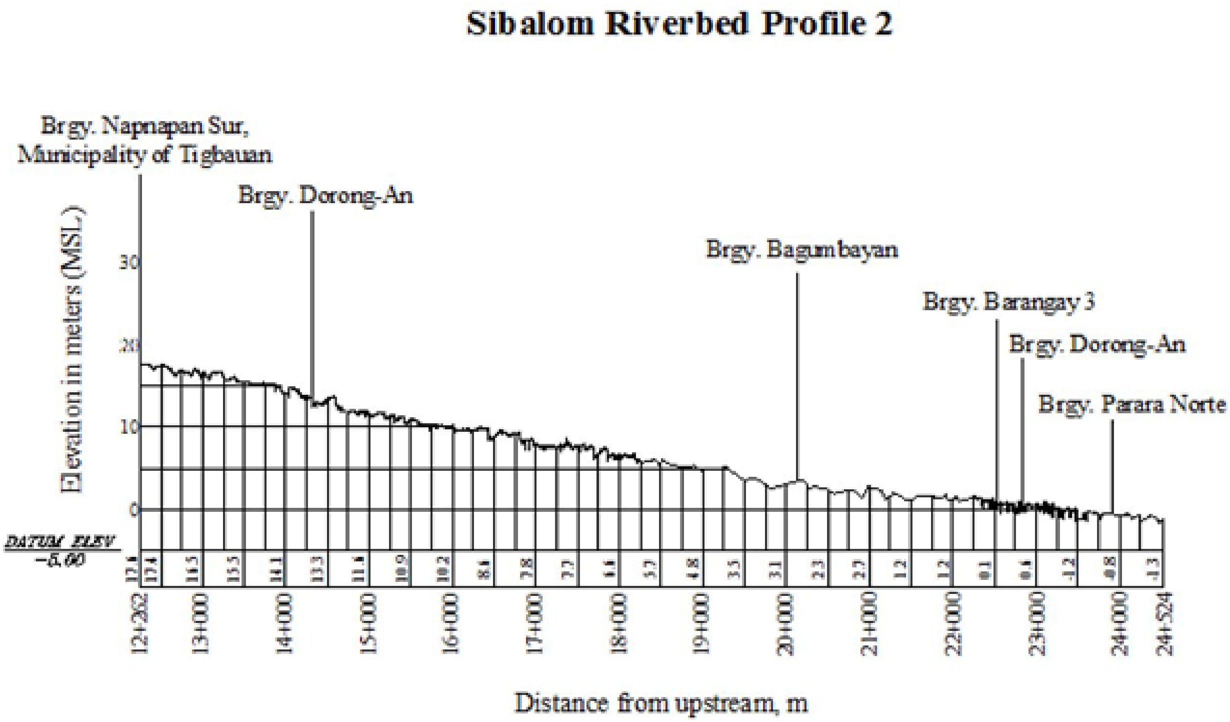


Figure 53. Sibalom riverbed profile 2

CHAPTER 5: FLOOD MODELING AND MAPPING

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

Rainfall, water level, and flow in a certain period of time, which are components and data that may affect the hydrologic cycle of the Sibalom 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, which was installed in Barangay Abuanan, Bago City, Negros Occidental (Figure 54). The precipitation data collection was held on January 9, 2017 at 02:30 hrs. until 14:10 hrs., with a recording interval of ten (10) minutes.

The total precipitation for this event in the Barangay Abuanan ARG was 59.3 millimeters, with a peak rainfall of 2.80 millimeters on January 16, 2017 at 05:35 hrs. The lag time between the peak rainfall and discharge was eleven (11) hours and fifty (50) minutes.

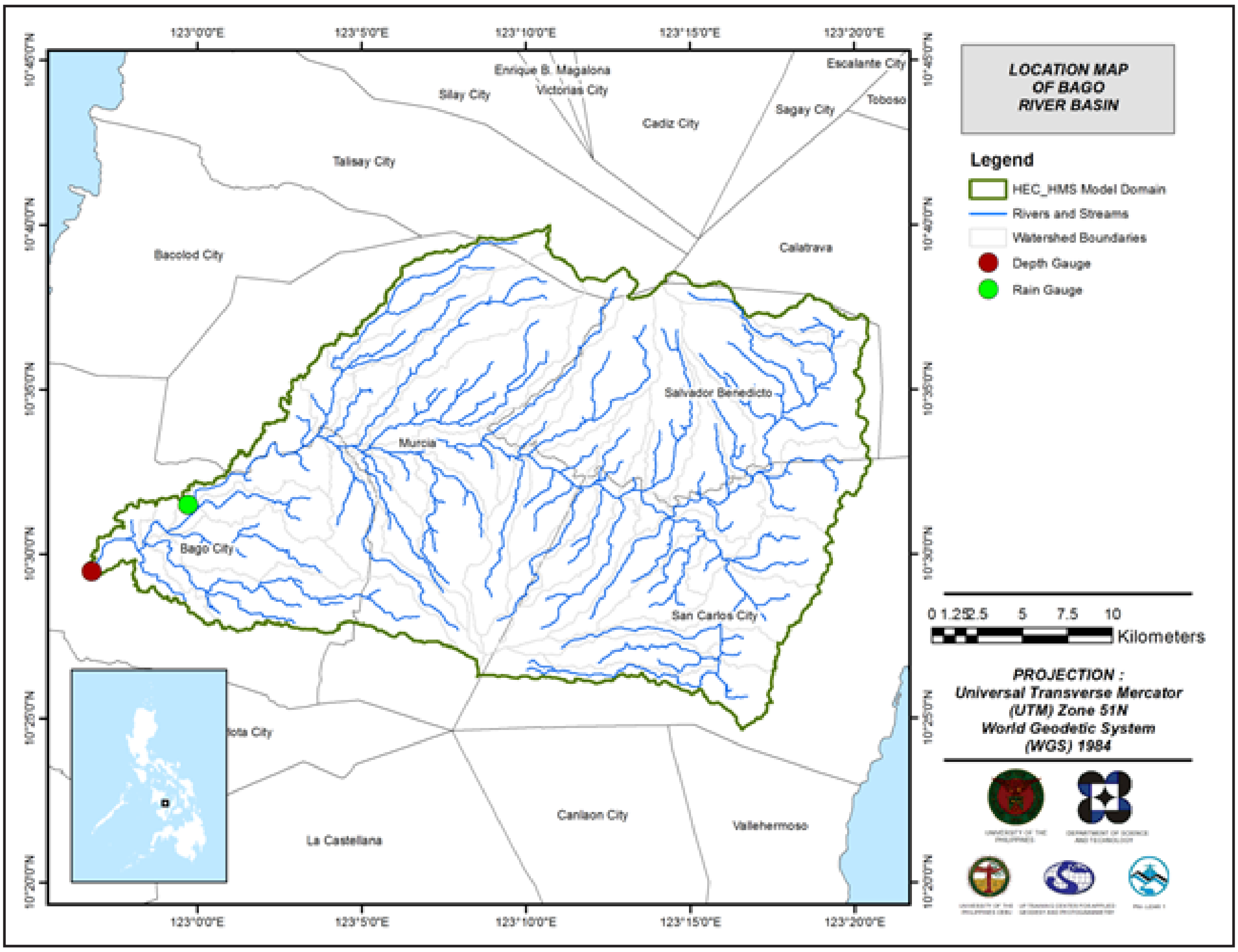


Figure 54. Location map of the Sibalom HEC-HMS model, which was used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 55) at the Baltazar Aquino Bridge in the Municipality of Leon, Iloilo (10°29'32.98"N, 122°56'46.93"E) to establish the relationship between the observed water levels (H) at the Baltazar Bridge and the outflow (Q) of the watershed at this location.

For the Baltazar Bridge, the rating curve is expressed as Q = 13.641x-134.27, as demonstrated in Figure 56.

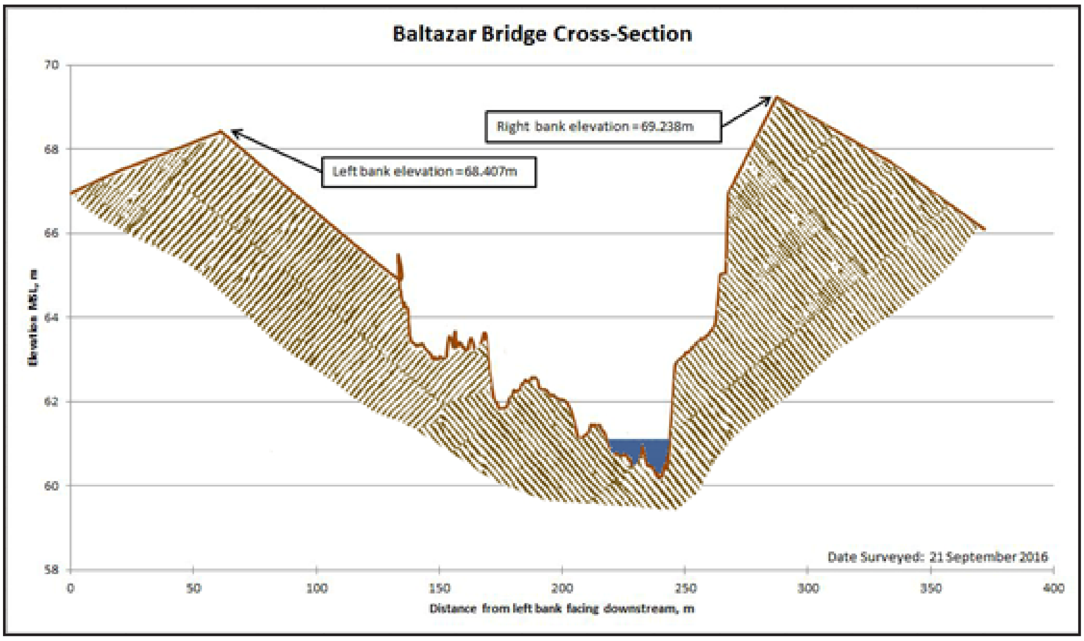


Figure 55. The cross-section plot of the Baltazar Bridge

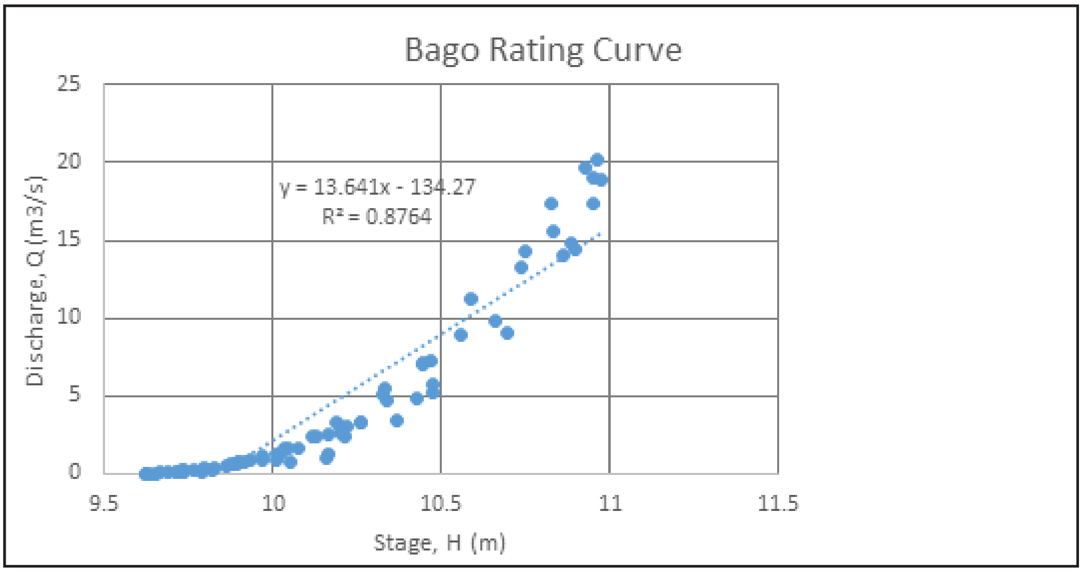


Figure 56. The rating curve at the Baltazar Bridge, Municipality of Leon, Iloilo

This rating curve equation was used to compute for the river outflow at the Baltazar Aquino Bridge for the calibration of the HEC-HMS model presented in Figure 57. The total rainfall collection for this event was 43.8 millimeters, and the recorded peak discharge was 20.1 m3 on January 16, 2017 at 15:50 hrs.

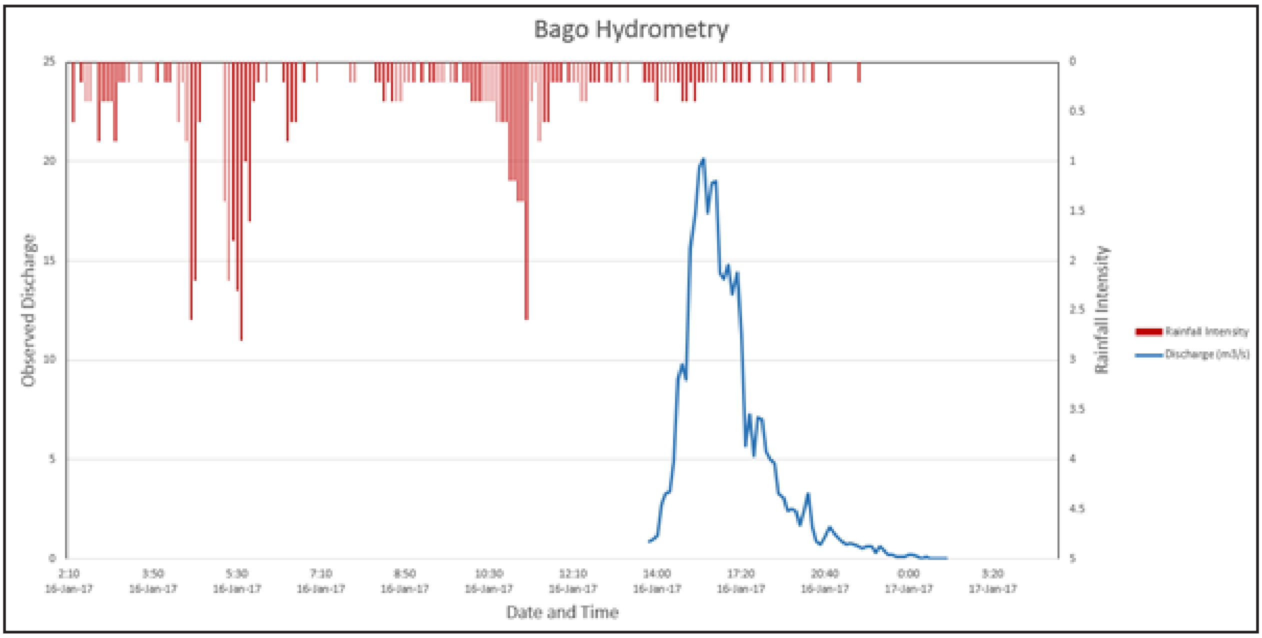


Figure 57. Rainfall and outflow data at Sibalom , which were used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Iloilo Rain Gauge (Table 32). This station was selected based on its proximity to the Sibalom watershed (Figure 58). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values such that certain peak values were attained at a certain time. The extreme values for this watershed were computed based on a 59-year record.

Table 32. RIDF values for the 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

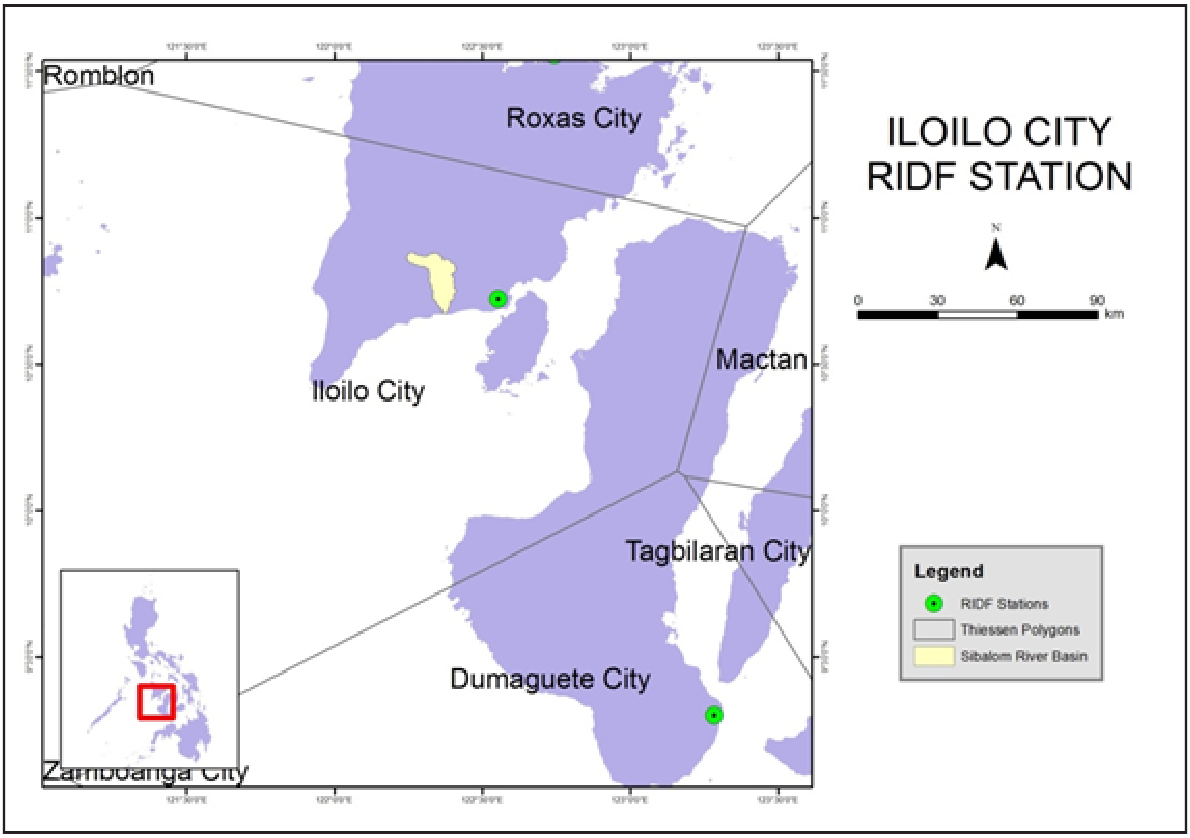


Figure 58. Location of the Iloilo RIDF station, relative to the Sibalom River Basin

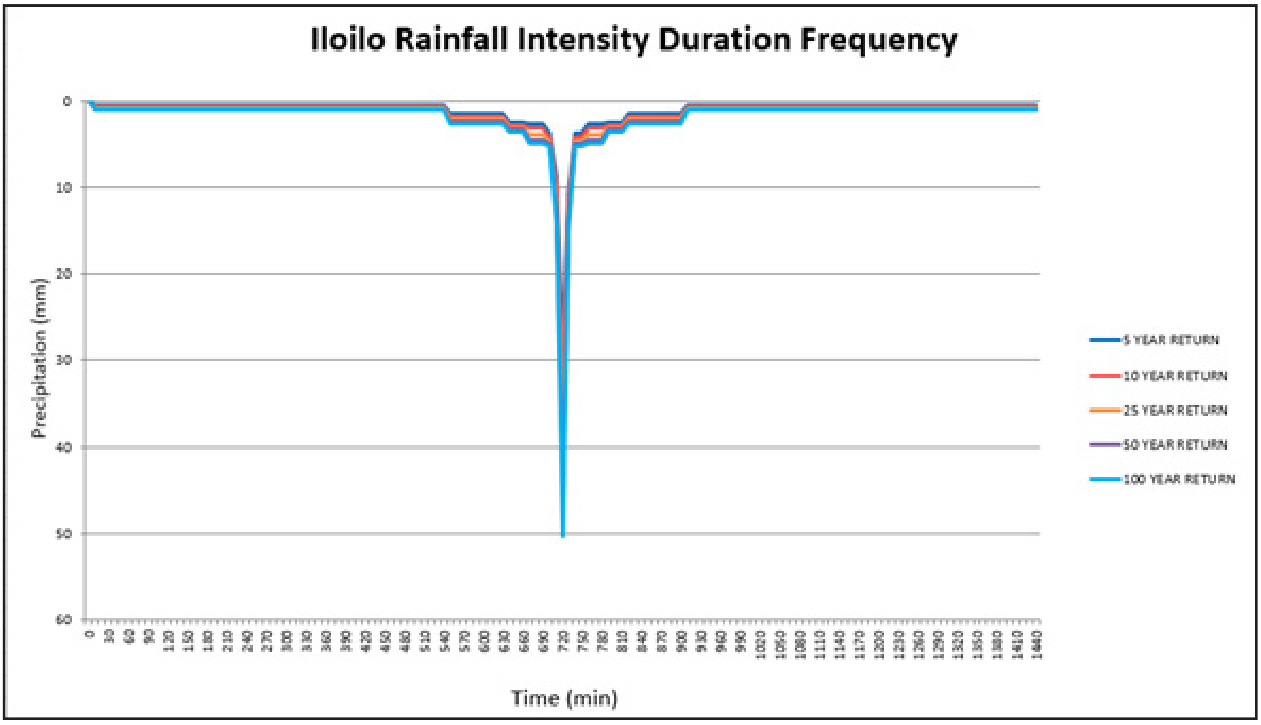


Figure 59. Synthetic storm generated from a 24-hour period rainfall, for various return periods

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004. The soil and land cover maps of the Sibalom River Basin are provided in Figures 60 and 61, respectively.

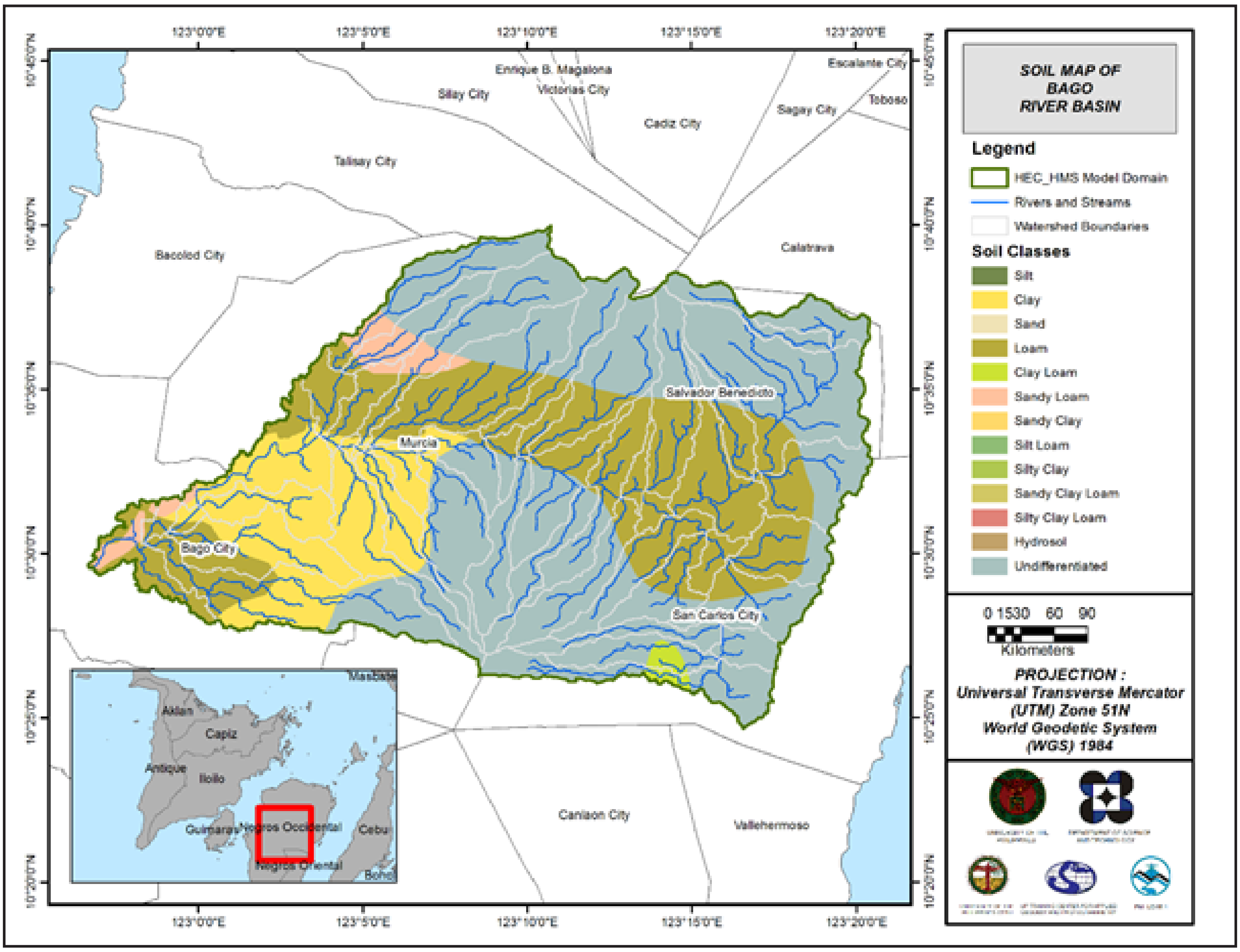


Figure 60. Soil map of the Sibalom River Basin (Source: DA)

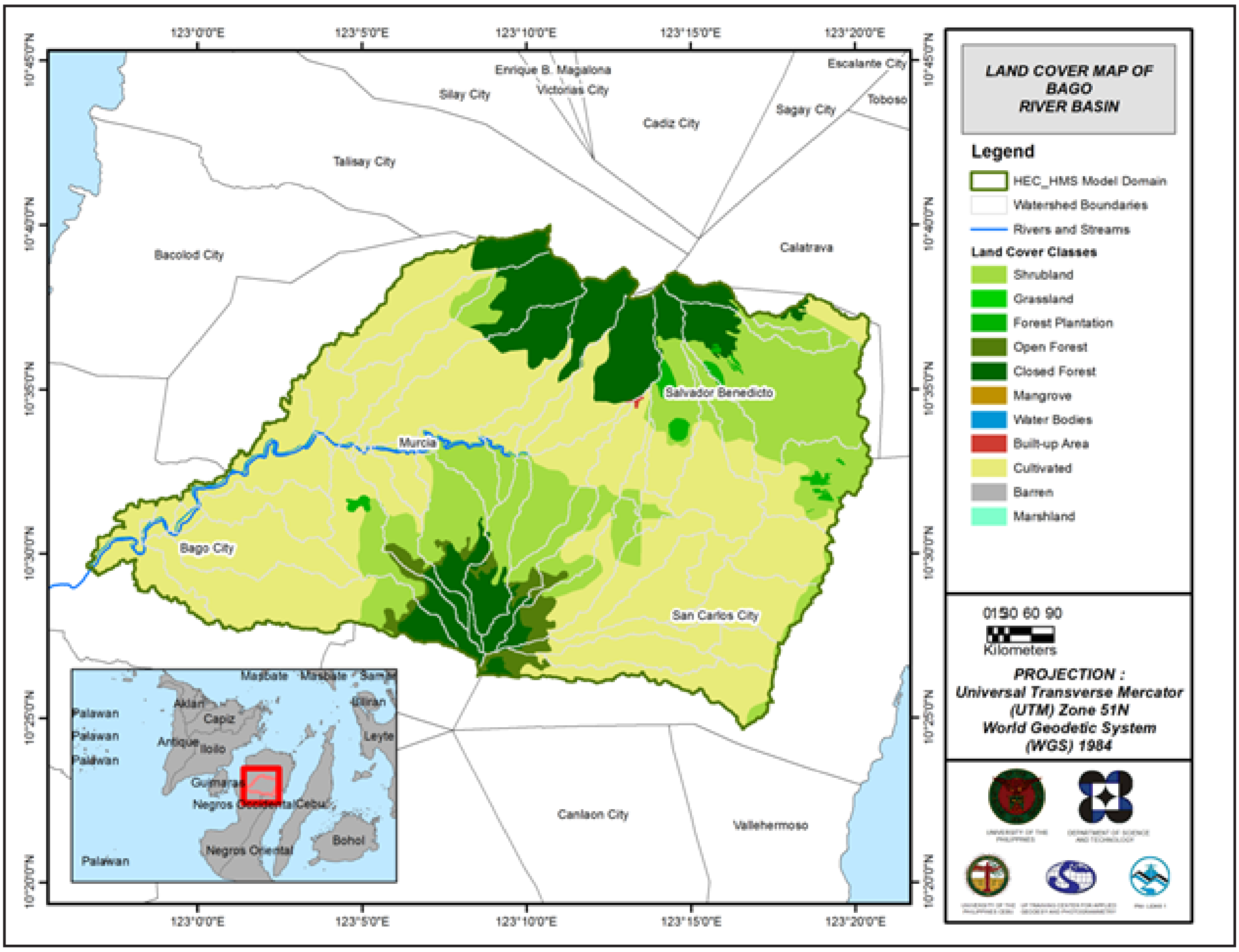


Figure 61. Land cover map of the Sibalom River Basin (Source: NAMRIA)

Five (5) soil classes were identified in the Sibalom River Basin. These are loam, sandy loam, clay, clay loam, and undifferentiated soil. Moreover, five (5) land cover classes were identified. These are open and closed forests, shrub lands, forest plantations, and built-up areas.

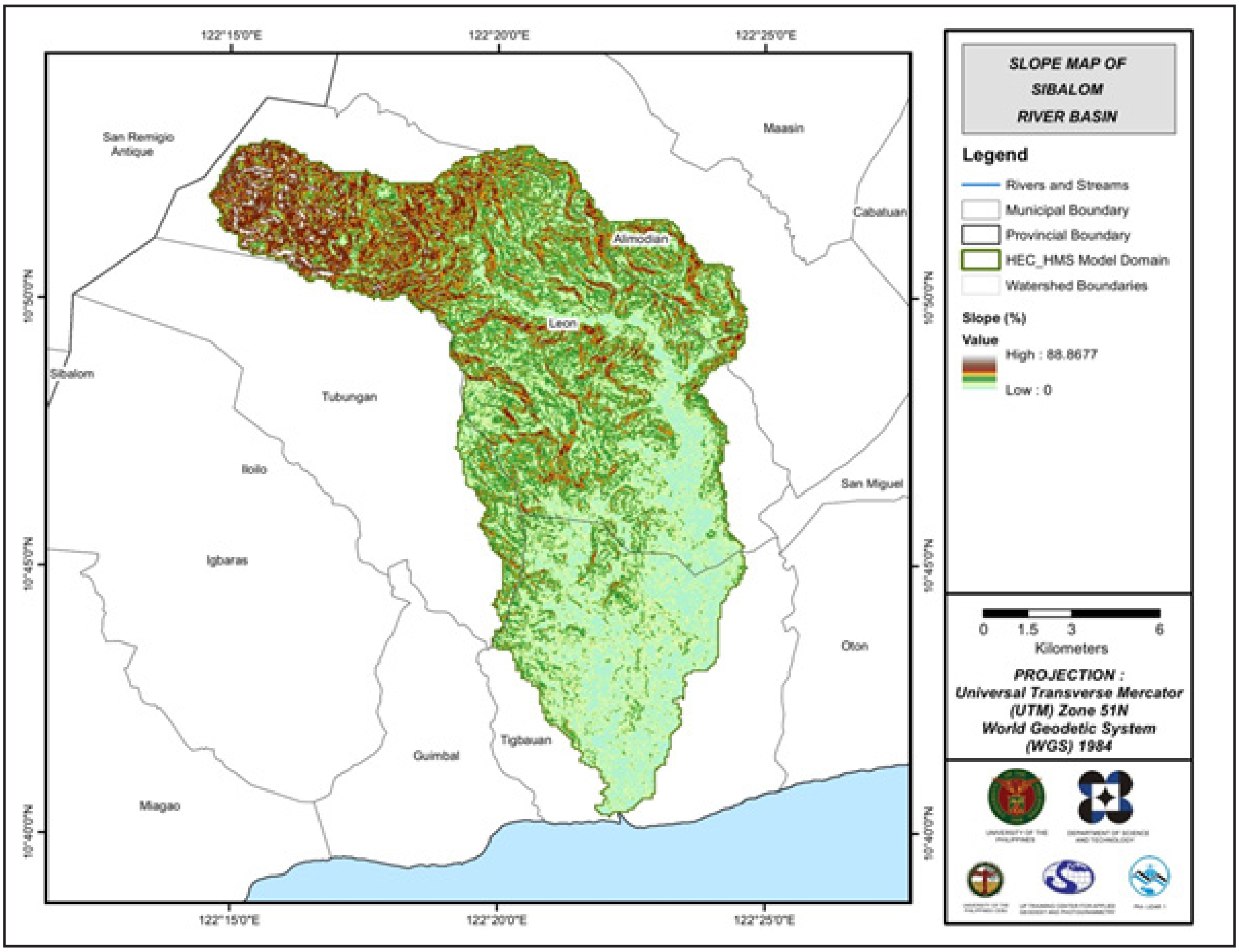


Figure 62. Slope map of the Sibalom River Basin

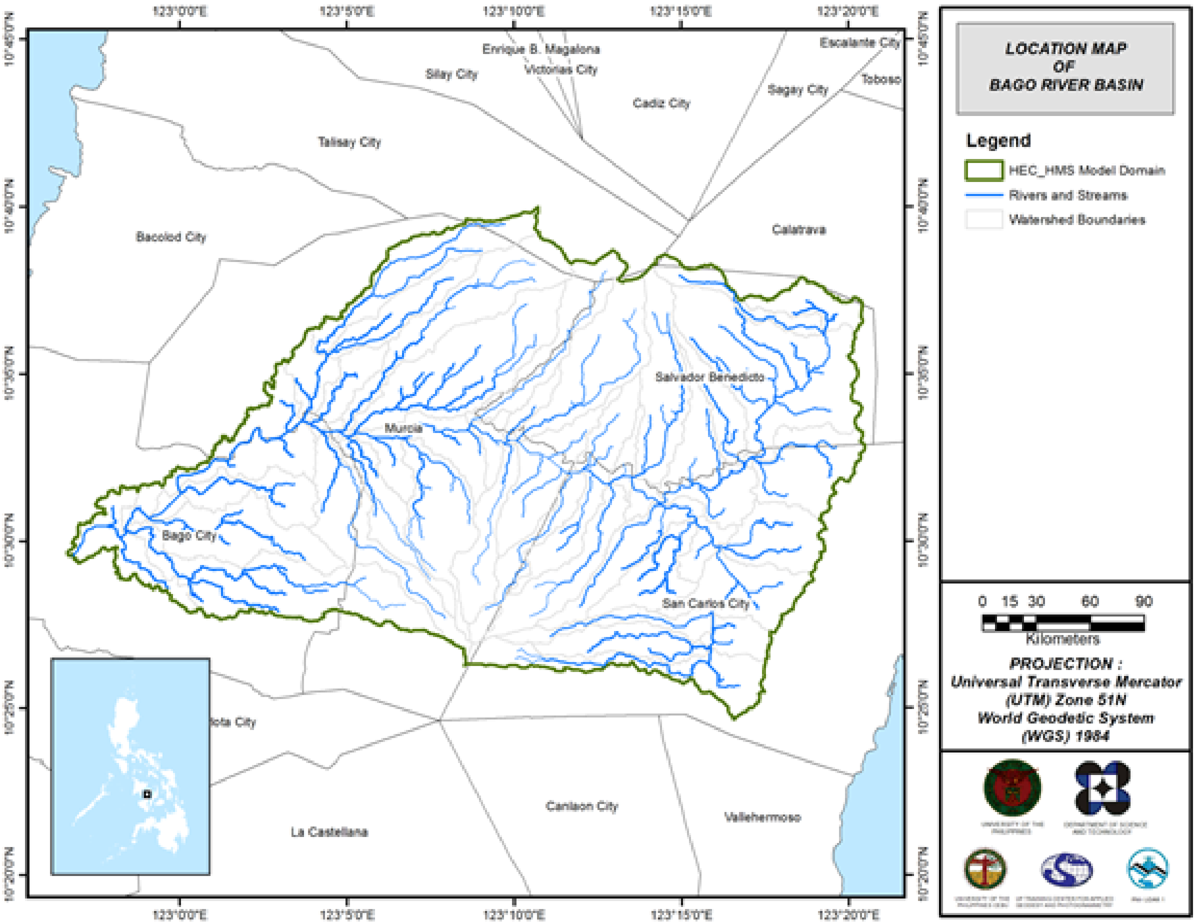


Figure 63. Stream delineation map of Sibalom River basin

Using the SAR-based DEM, the Sibalom basin was delineated and further subdivided into sub-basins. The model consists of forty-seven (47) sub-basins, twenty-three (23) reaches, and twenty-three (23) junctions, as illustrated in Figure 7. The main outlet is at the Baltazar Bridge. See Annex 10 for the Sibalom Model Reach Parameters.

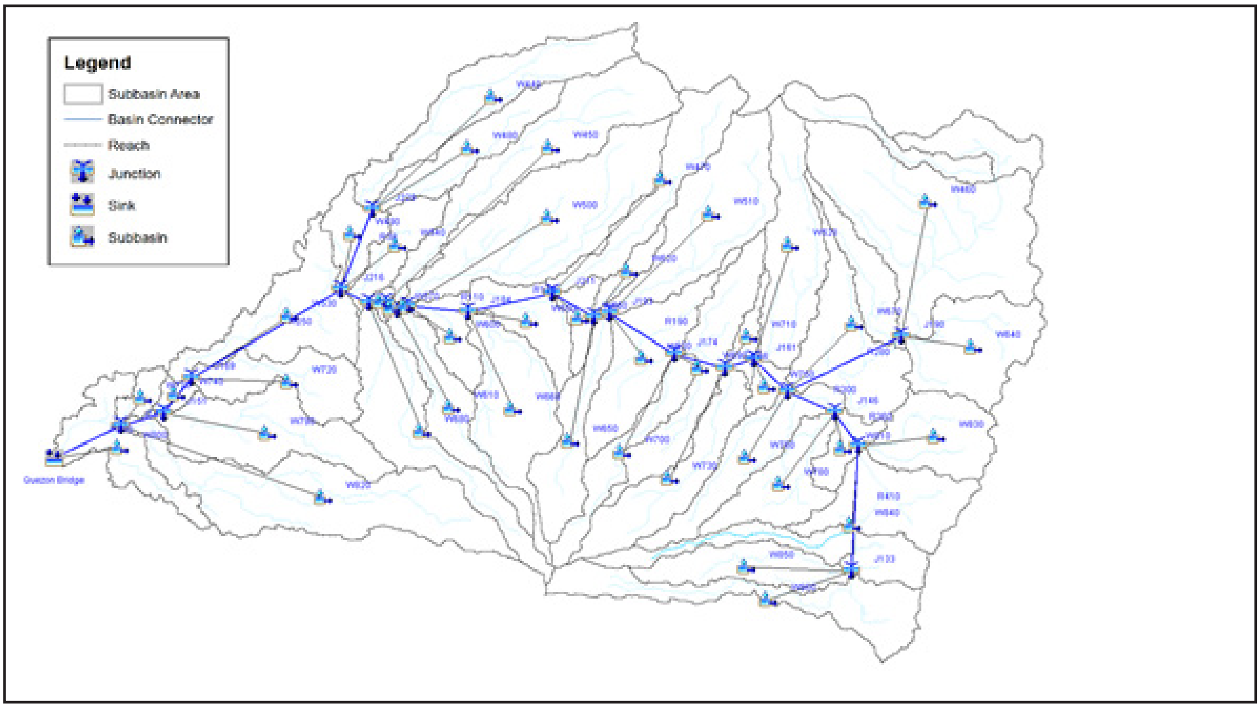


Figure 64. The Sibalom River Basin model, generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool, and was post-processed in ArcGIS (Figure 65).

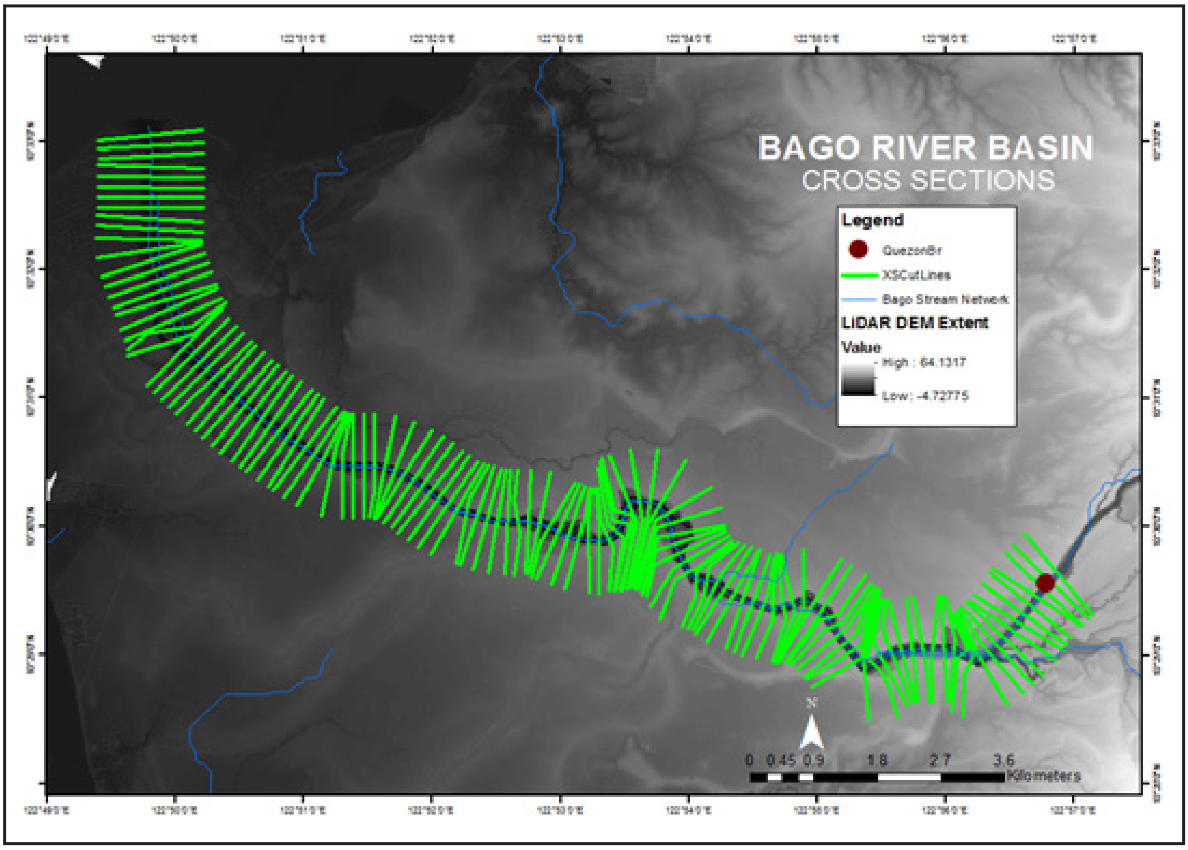


Figure 65. River cross-section of the Sibalom River, generated through the ArcMap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modeling process allowed for the creation of a model, with boundaries that are almost exactly coincidental with that of the catchment area. As such, they have approximately the same land area and location. The entire area was divided into square grid elements, 10 meters by 10 meters in size. Each element was assigned a unique grid element number, which served as its identifier. The elements were then attributed with the parameters required for modeling, such as x- and y-coordinates of centroid, names of adjacent grid elements, Manning's coefficient of roughness, infiltration, and elevation values. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements in eight (8) directions (i.e., north, south, east, west, northeast, northwest, southeast, and southwest).

Based on the elevation and flow direction, it was determined 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 were assigned as inflow and outflow elements, respectively.

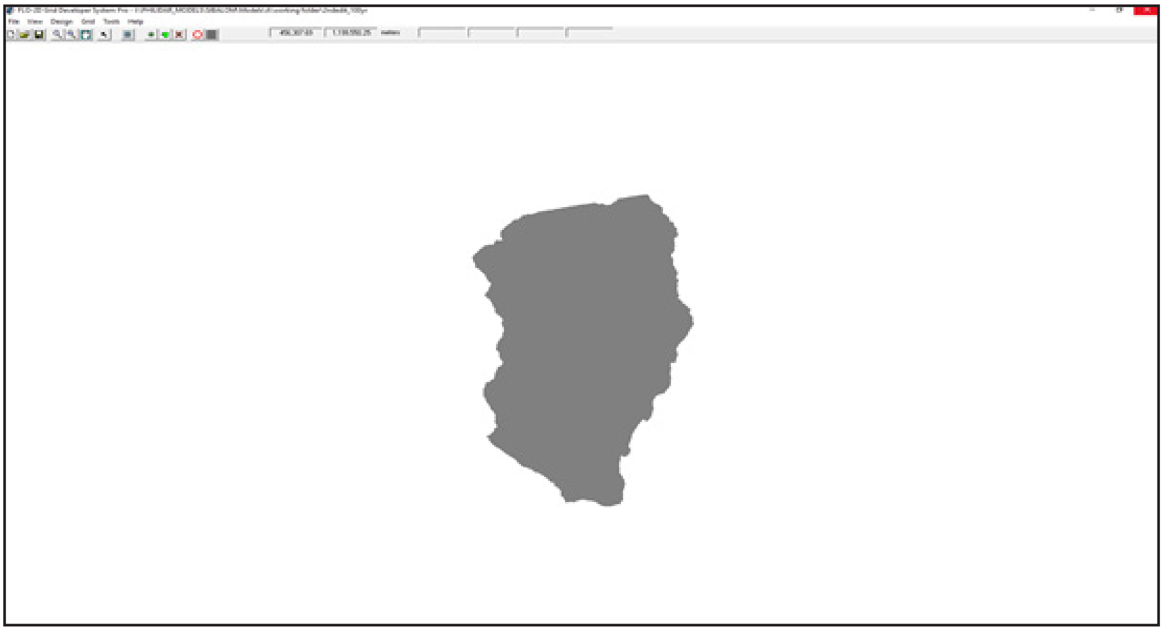


Figure 66. Screenshot of a sub-catchment with the computational area to be modeled in the FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

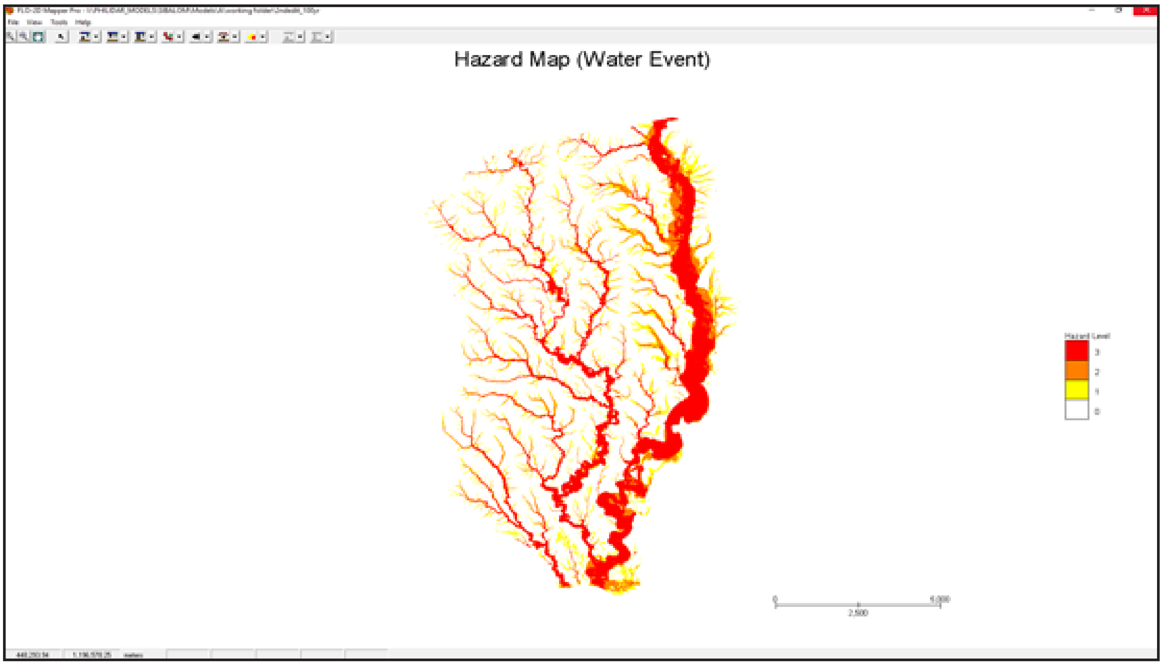


Figure 67. Generated 100-year rain return hazard map from the FLO-2D mapper

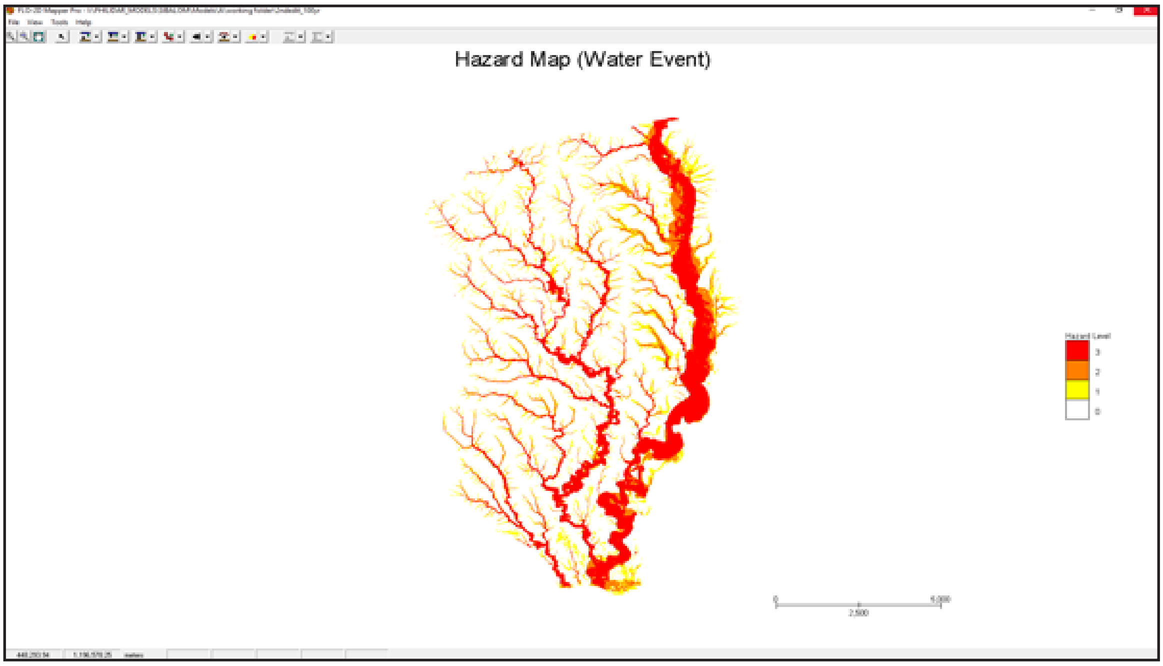


Figure 68. Generated 100-year rain return flow depth map from the FLO-2D Mapper

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

The creation of a flood hazard map from the model also automatically generated a flow depth map, depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper was not a good representation of the range of flood inundation values, so a different legend was used for the layout. In this particular model, the inundated parts covered a maximum land area of __ m2. There was a total of __ m3 of water that entered the model. Of this amount, __ m3 was due to rainfall, while __ m3 was inflow from areas outside the model. __ m3 of this water was lost to infiltration and interception, while __ m3 was stored by the floodplain. The rest, amounting to up to __ m3, was outflow.

5.6 Results of HMS Calibration

After calibrating the Sibalom HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 69 depicts the comparison between the two discharge data. The Sibalom Model Basin Parameters are available in Annex 9.

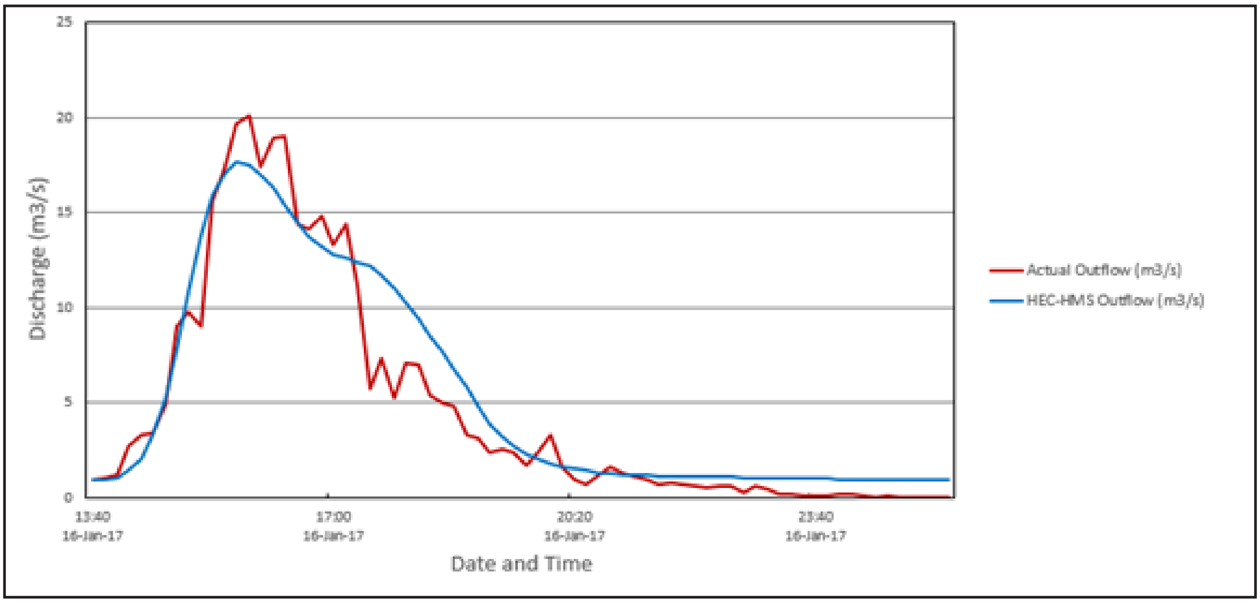


Figure 69. Outflow hydrograph of Sibalom produced by the HEC-HMS model, compared with observed outflow

Enumerated in Table 33 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 33. Range of calibrated values for the Sibalom model

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

The initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. A range of values of 5-20 millimeters for the initial abstraction signifies a minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range of 65-90 for the curve number is advisable for Philippine watersheds, depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Sibalom, the basin mostly consists of open and closed forests, shrub lands, forest plantations, and built-up areas; and the soil consists of loam, sandy loam, clay, clay loam, and undifferentiated soil.

The time of concentration and the storage coefficient are the travel time and the 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 decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; and ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 0.9 implies that the basin is unlikely to quickly revert to its original discharge, and will be higher instead. A ratio to peak of 0.2 indicates a slightly steeper receding limb of the outflow hydrograph.

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

Table 34. Efficiency Test of the Sibalom HMS Model

Accuracy measure	Value
RMSE	1.8
r2	0.9595
NSE	0.91
PBIAS	0.30
RSR	-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 (r2) assesses the strength of the linear relationship between the observations and the model. A coefficient value close to 1 represents an almost perfect match of the observed discharge and the resulting discharge from the HEC-HMS model. In the model, it was measured at 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 a bias towards over-prediction. 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 units of the values are quantified. The model attained 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 in Figure 70 illustrates the Sibalom outflow using the Iloilo RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods – from 165.2m3 in a 5-year return period, to 304.5m3 for a 100-year return period.

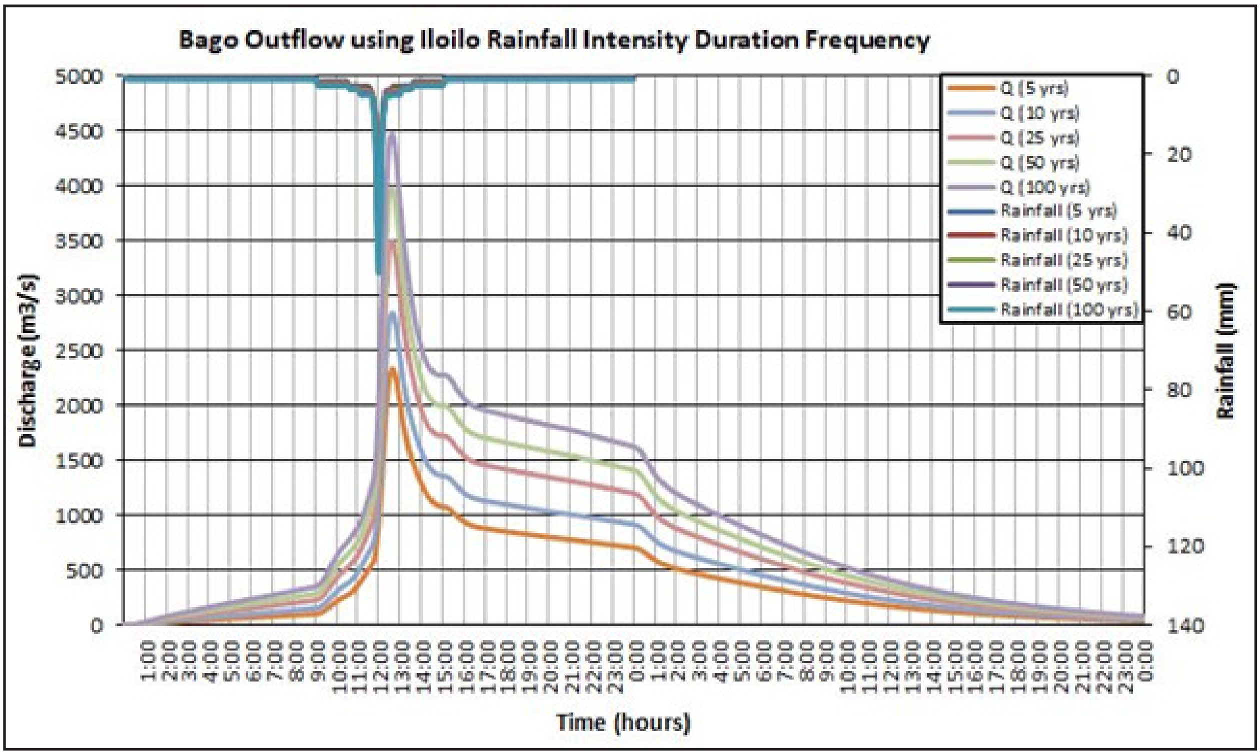


Figure 70. Outflow hydrograph at the Sibalom Station generated using the Iloilo RIDF, simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Sibalom discharge using the Iloilo RIDF curves in five (5) different return periods is shown in Table 35.

Table 35. Peak values of the Sibalom 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 displayed in Figure 71 to Figure 73; and the peak values are summarized in Tables 36, 38 and 40.

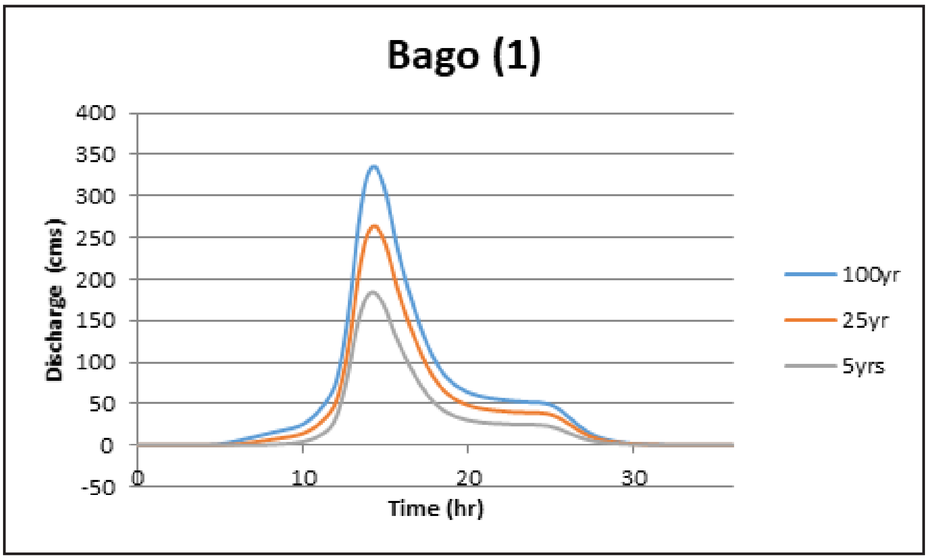


Figure 71. Sibalom River (1) generated discharge using 5-, 25-, and 100-year Iloilo City RIDF in HEC-HMS

Table 36. Summary of Sibalom 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 37. 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

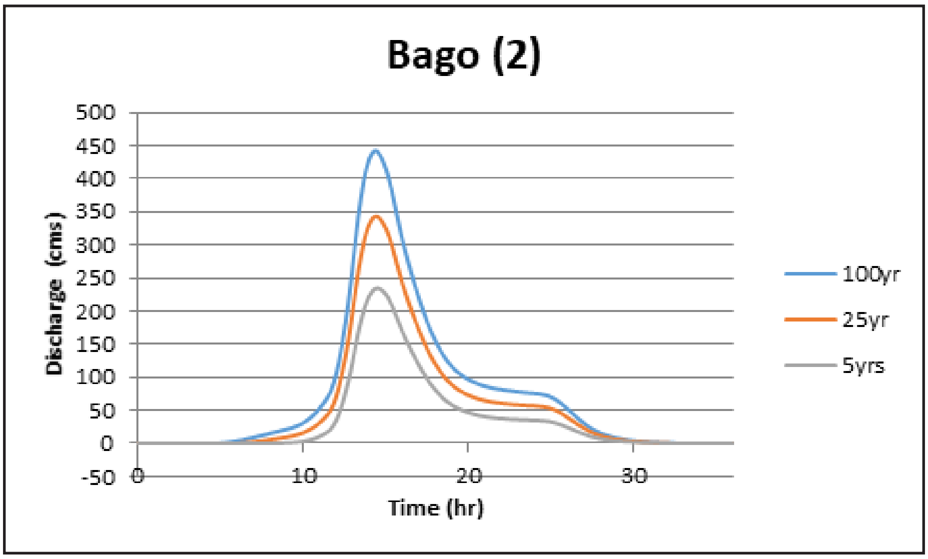


Figure 72. Sibalom River (2) generated discharge using 5-, 25-, and 100-year Iloilo City RIDF in HEC-HMS

Table 38. Summary of Sibalom River (1) 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 39. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Bago (2)	206.536	366838.592	147.979	Fail	Pass

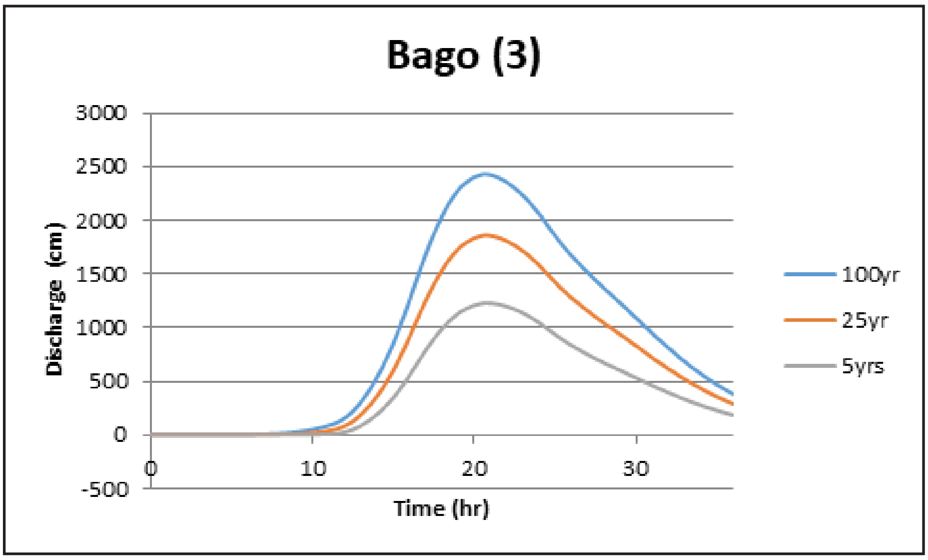


Figure 73. Sibalom River (3) generated discharge using 5-, 25-, and 100-year Iloilo City RIDF in HEC-HMS

Table 40. Summary of Sibalom 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 41. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Bago (3)	1080.992	181004.323	681.025	Fail	Fail

Two (2) of the three (3) 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 the bankful discharge method. One (1) result did not pass both, and will thus need further recalculation. The passing values are based on theory but are supported by other discharge computation methods; hence, they were appropriate 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 (RAS) Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining the real-time flood inundation extent of the river, after it has been automated and uploaded on the DREAM website. The sample generated map of the Sibalom River using the calibrated HMS event flow is shown in Figure 74.

Figure 74. Sample output map of the Sibalom RAS Model

5.9 Flow Depth and Flood Hazard

The resulting flood hazard and flow depth maps have a 10-meter resolution. Figure 75 to Figure 80 exhibit the 5-year, 25-year, and 100-year rain return scenarios of the Sibalom floodplain. The floodplain, with an area of 134.32 square kilometers, covers five (5) municipalities, namely Guimbal, Leon, Oton, Tigbauan, and Tubungan.

Table 42. Municipalities affected in the Sibalom floodplain

Municipality	Total Area (km^2)	Area Flooded (km^2)	% Flooded
Guimbal	43.2633	2.788477	6.445363
Leon	139.034	36.24959	26.07246
Oton	85.3579	2.271583	2.661245
Tigbauan	90.2285	84.86121	94.05145
Tubungan	90.2509	5.762084	6.384517

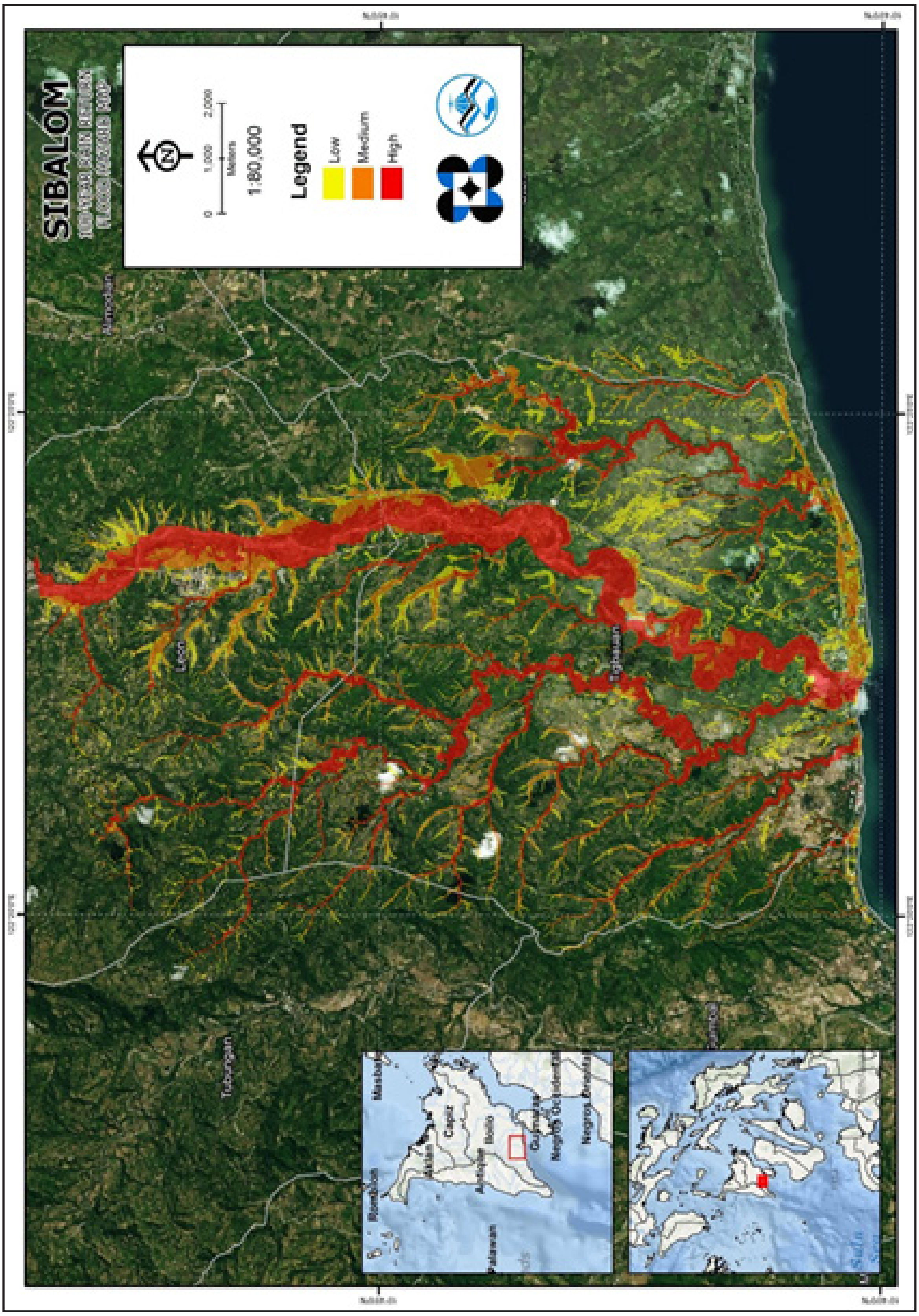


Figure 75. 100-year flood hazard map for the Sibalom floodplain, overlaid on Google Earth imagery

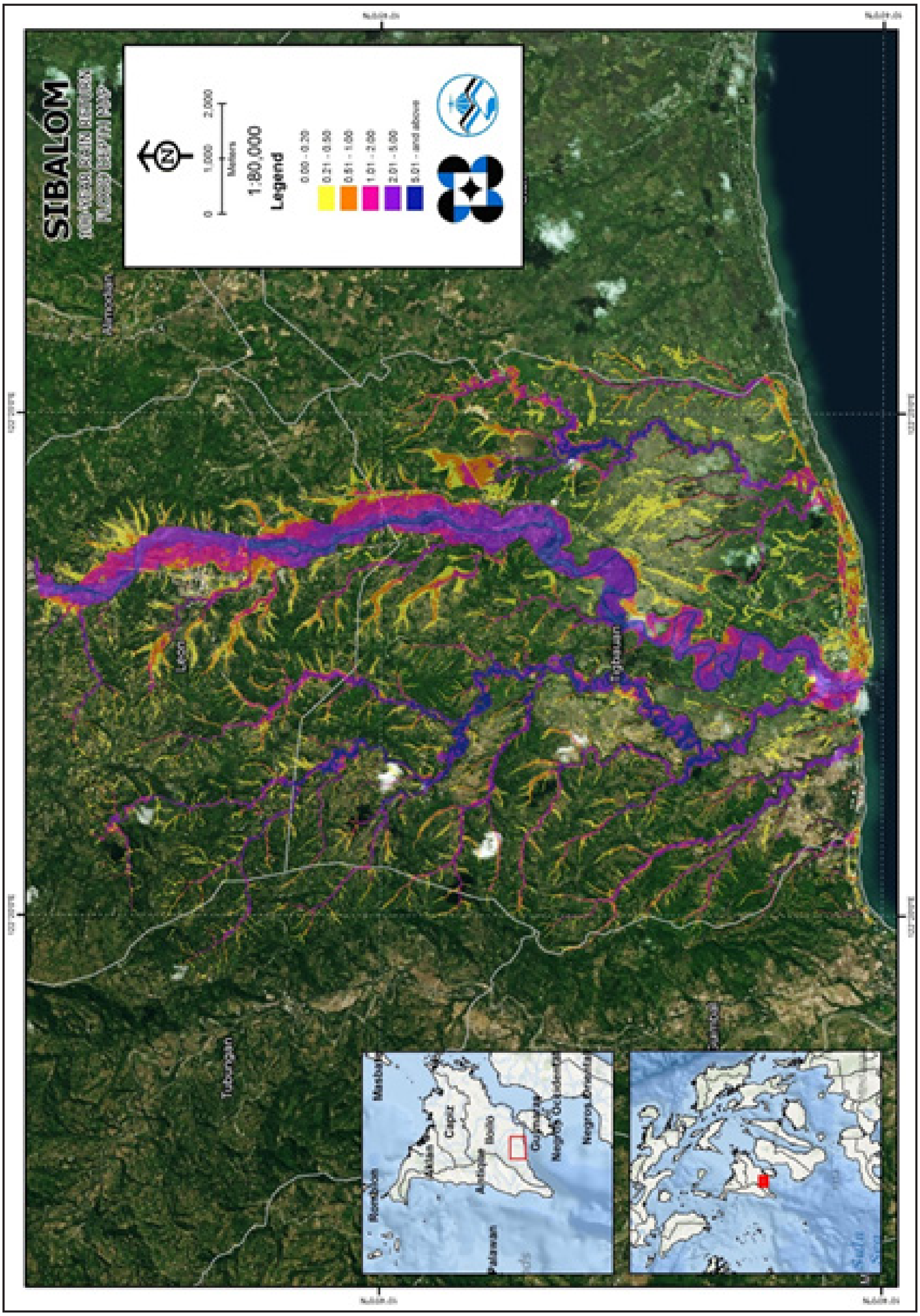


Figure 76. 100-year flow depth map for the Sibalom floodplain, overlaid on Google Earth imagery

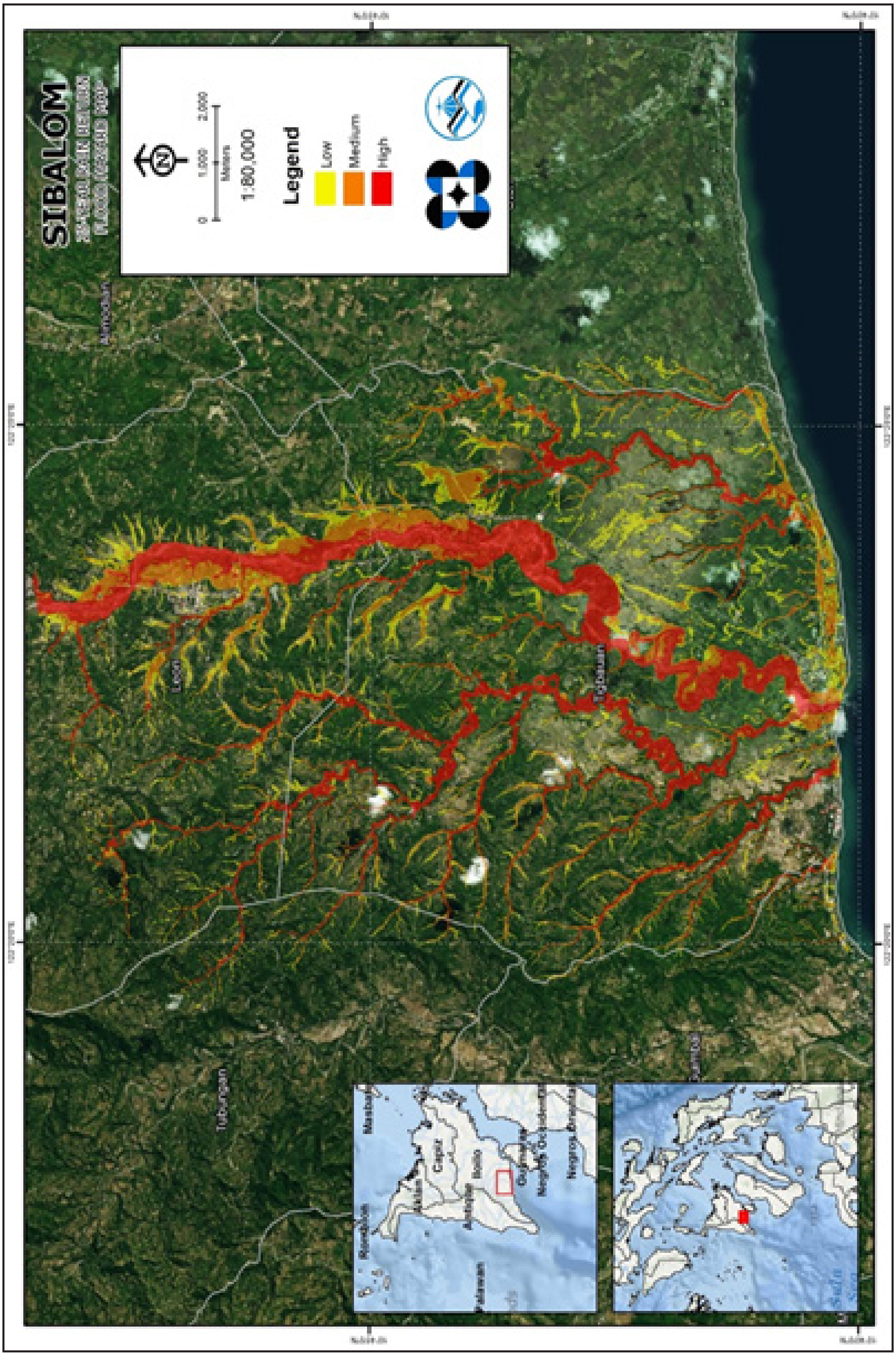


Figure 77. 25-year flood hazard Map for the Sibalom floodplain, overlaid on Google Earth imagery

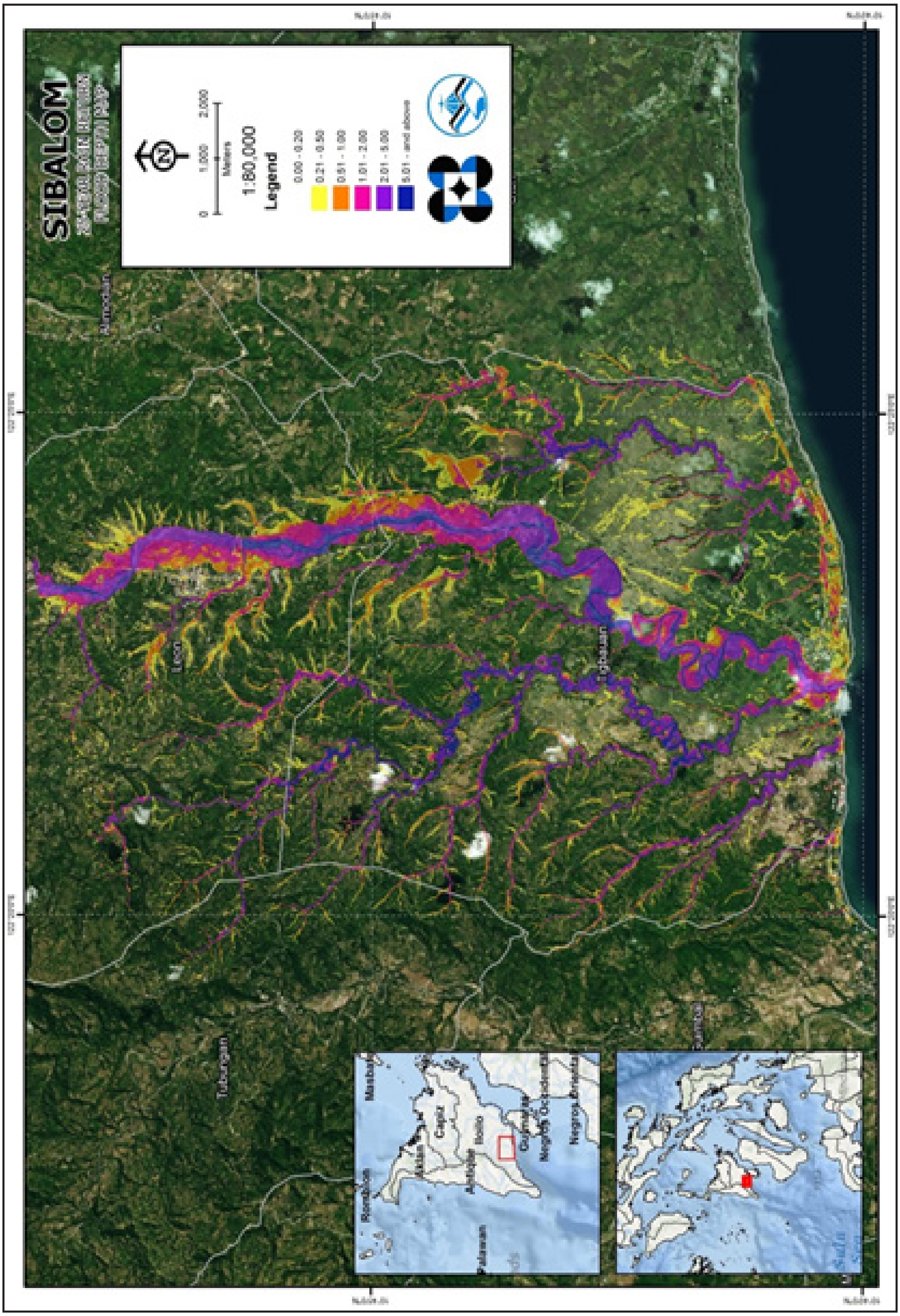


Figure 78. 25-year flow depth map for the Sibalom floodplain, overlaid on Google Earth imagery

Figure 79. 5-year flood hazard map for the Sibalom floodplain, overlaid on Google Earth imagery

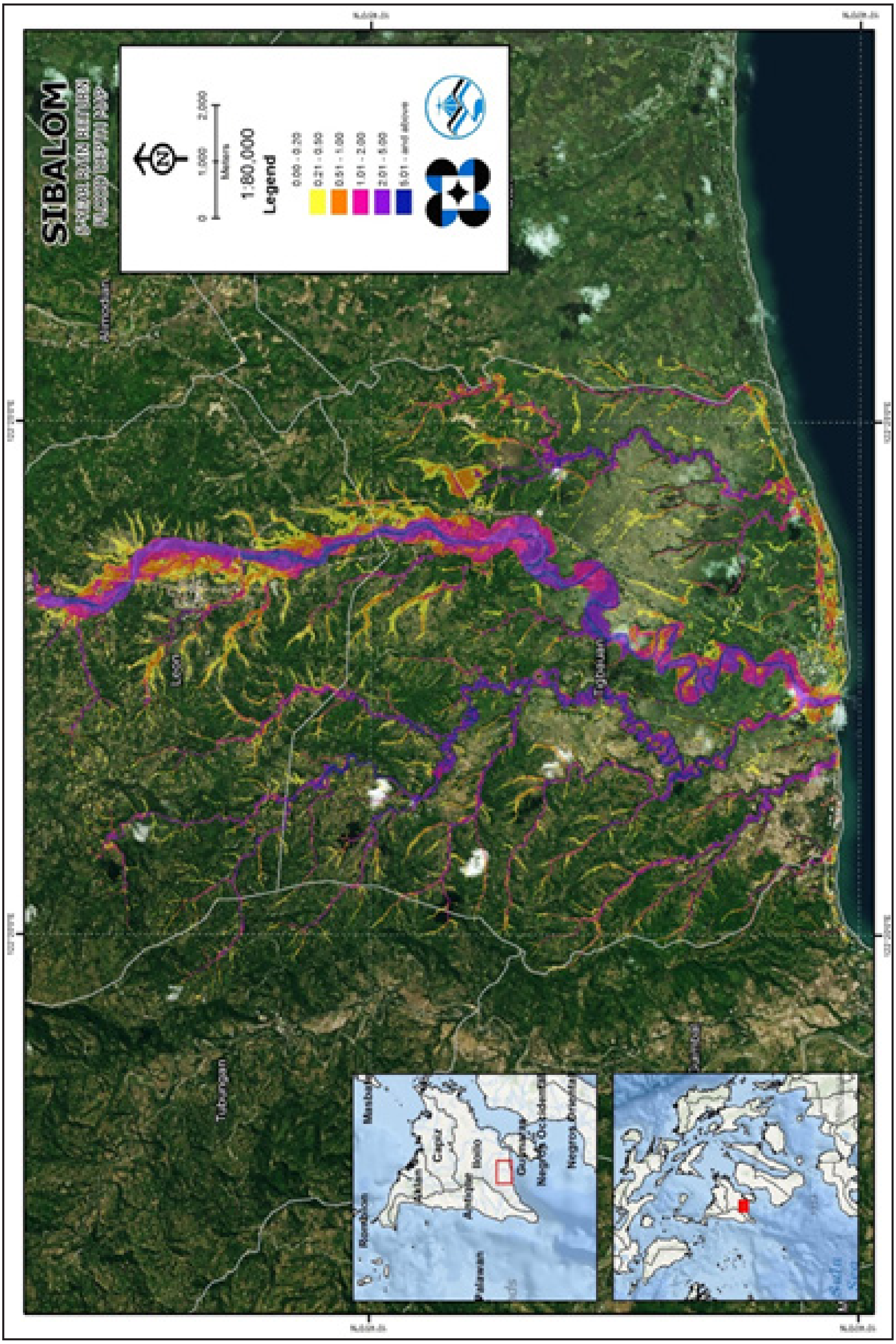


Figure 80. 5-year flow depth map for the Sibalom floodplain, overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Sibalom River Basin, grouped by municipality, are listed below. For the said basin, five (5) municipalities consisting of one hundred and fourteen (114) barangays are expected to experience flooding when subjected to 5-year, 25-year, and 100-year rainfall return periods.

For the 5-year return period, 5.76% of the Municipality of Guimbal, with an area of 43.26 square kilometers, will experience flood levels of less than 0.20 meters. 0.31% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.19%, 0.14%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 43 are the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected areas in Guimbal, Iloilo during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guimbal (in sq. km.)					
	Balantad-Carlos Fruto	Camangahan	Igcocolo	Nahapay	Nanga	Rizal-Tuguisan
0.03-0.20	0.17	0.15	0.39	0.023	1.64	0.11
0.21-0.50	0.0062	0.0061	0.007	0	0.1	0.01
0.51-1.00	0.007	0.0068	0.0004	0	0.063	0.0028
1.01-2.00	0.005	0.003	0.00092	0	0.049	0.0025
2.01-5.00	0.00034	0.0003	0.0005	0	0.019	0.00061
>5.00	0	0	0	0	0	0

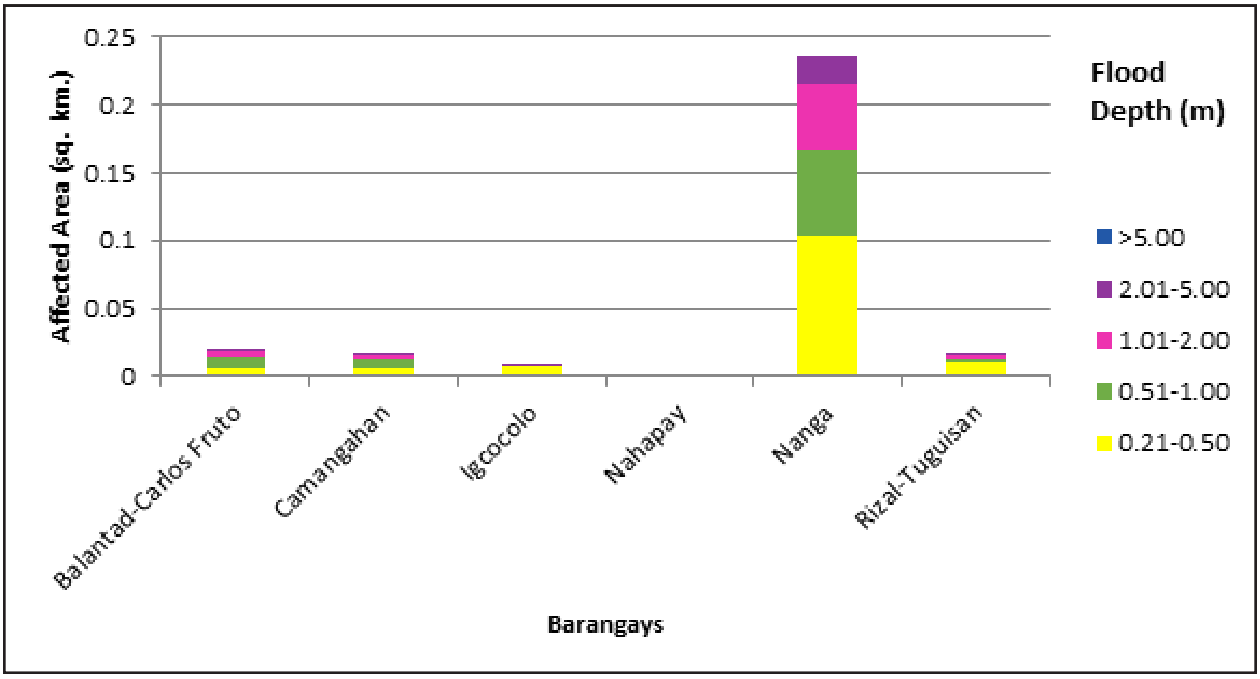


Figure 81. Affected areas in Guimbal, Iloilo during a 5-year rainfall return period

For the Municipality of Leon, with an area of 139.034 square kilometers, 20.57% will experience flood levels of less than 0.20 meters. 1.92% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.29%, 0.96%, 1.08%, and 0.26% 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 44 are the affected areas, in square kilometers, by flood depth per barangay.

Table 44. Affected areas in Leon, Iloilo during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Leon (in sq. km.)										
	Agboy Sur	Ambulong	Anonang	Avanzada	Awis	Ayubo	Baje	Barasan	Bayag Norte	Bayag Sur	Binolbog
0.03-0.20	0.037	0.34	1.17	1.13	0.0066	0.28	0.5	0.92	0.26	0.54	0.56
0.21-0.50	0	0.025	0.24	0.042	0	0.0055	0.022	0.094	0.013	0.021	0.036
0.51-1.00	0	0.0063	0.14	0.014	0	0.004	0.017	0.036	0.0087	0.019	0.017
1.01-2.00	0	0.012	0.04	0.012	0	0.0021	0.023	0.015	0.012	0.013	0.0055
2.01-5.00	0	0.0056	0.17	0.025	0	0.0013	0.0078	0.0048	0.022	0.019	0.00084
>5.00	0	0	0.1	0.00024	0	0	0	0	0	0.0059	0
Affected area (sq. km.) by flood depth (in m.)	**Area of affected barangays in Leon (in sq. km.)**										
	Biri Norte	Biri Sur	Buenavista	Buga	Cabutongan	Camando	Cananaman	Capt. Fernando	Carolina	Gumboc	Isian Norte
0.03-0.20	2.36	0.31	0.27	0.42	0.34	0.56	0.35	0.85	0.29	0.84	0.85
0.21-0.50	0.18	0.021	0.037	0.072	0.019	0.022	0.013	0.036	0.025	0.038	0.061
0.51-1.00	0.086	0.054	0.02	0.033	0.0058	0.036	0.0067	0.021	0.002	0.017	0.072
1.01-2.00	0.072	0.087	0.0037	0.072	0.0054	0.092	0.0092	0.028	0.0016	0.011	0.043
2.01-5.00	0.052	0.084	0	0.13	0.011	0.11	0.0067	0.05	0.008	0.0075	0.036
>5.00	0	0.059	0	0.027	0.0009	0.024	0	0.0039	0	0	0
Affected area (sq. km.) by flood depth (in m.)	**Area of affected barangays in Leon (in sq. km.)**										
	Isian Victoria	Jamog Gines	Lanag	Lang-Og	Lonoc	Mina	Nagbangi	Odong-Odong	Omambong	Pandan	Panginman
0.03-0.20	0.77	0.77	0.73	1.29	0.37	0.46	1.33	0.52	0.87	0.33	0.44
0.21-0.50	0.024	0.048	0.057	0.068	0.0099	0.015	0.27	0.019	0.28	0.029	0.056
0.51-1.00	0.011	0.018	0.022	0.02	0.0001	0.012	0.11	0.0085	0.12	0.0098	0.014
1.01-2.00	0.0079	0.012	0.008	0.0061	0	0.0091	0.065	0.01	0.11	0.0018	0
2.01-5.00	0.0034	0.028	0.0048	0.0017	0	0.021	0.18	0.016	0.088	0	0
>5.00	0	0.0031	0.01	0	0	0.0064	0.0053	0.0001	0.075	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Leon (in sq. km.)							
	Paoy	Pepe	Poblacion	Salngan	Tacuyong Sur	Talacuan	Tina-An Sur	Tu-Og
0.03-0.20	0.35	0.57	2.5	0.96	0.2	0.94	1.98	0.023
0.21-0.50	0.019	0.0037	0.34	0.049	0.0098	0.24	0.1	0.0001
0.51-1.00	0.019	0	0.47	0.028	0.0047	0.26	0.039	0
1.01-2.00	0.027	0	0.39	0.029	0.0097	0.091	0.0025	0
2.01-5.00	0.026	0	0.31	0.022	0.018	0.025	0.0001	0
>5.00	0	0	0.029	0	0.0001	0.00036	0	0

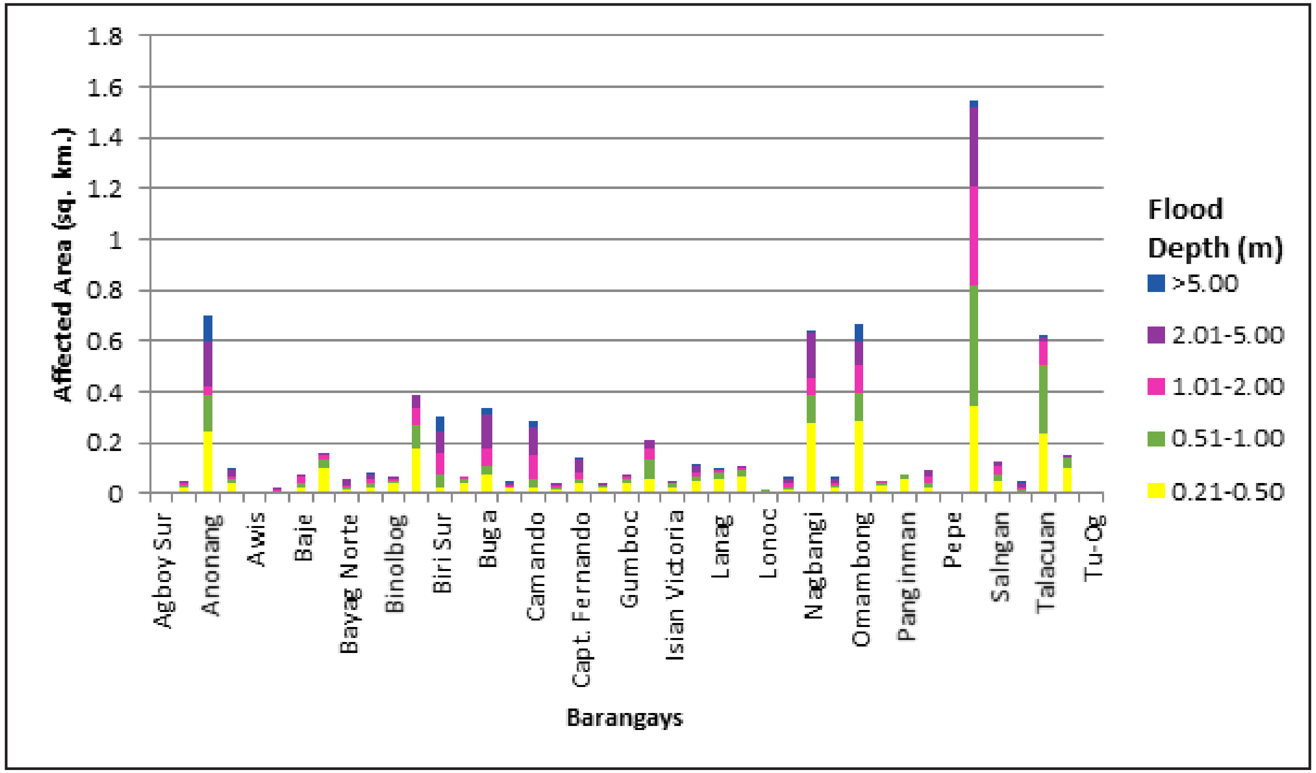


Figure 82. Affected areas in Leon, Iloilo during a 5-year rainfall return period

For the Municipality of Oton, with an area of 85.36 square kilometers, 2.36% will experience flood levels of less than 0.20 meters. 0.17% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.074%, 0.059%, 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. Listed in Table 45 are the affected areas, in square kilometers, by flood depth per barangay.

Table 45. Affected areas in Oton, Iloilo during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oton (in sq. km.)			
	Batuan Ilaud	Batuan Ilaya	Cabanbanan	Sambaludan
0.03-0.20	0.36	0.083	0.073	1.5
0.21-0.50	0.025	0.0032	0.0028	0.11
0.51-1.00	0.0047	0.0078	0.0041	0.047
1.01-2.00	0	0.0065	0.025	0.018
2.01-5.00	0	0.000059	0.0017	0.0001
>5.00	0	0	0	0

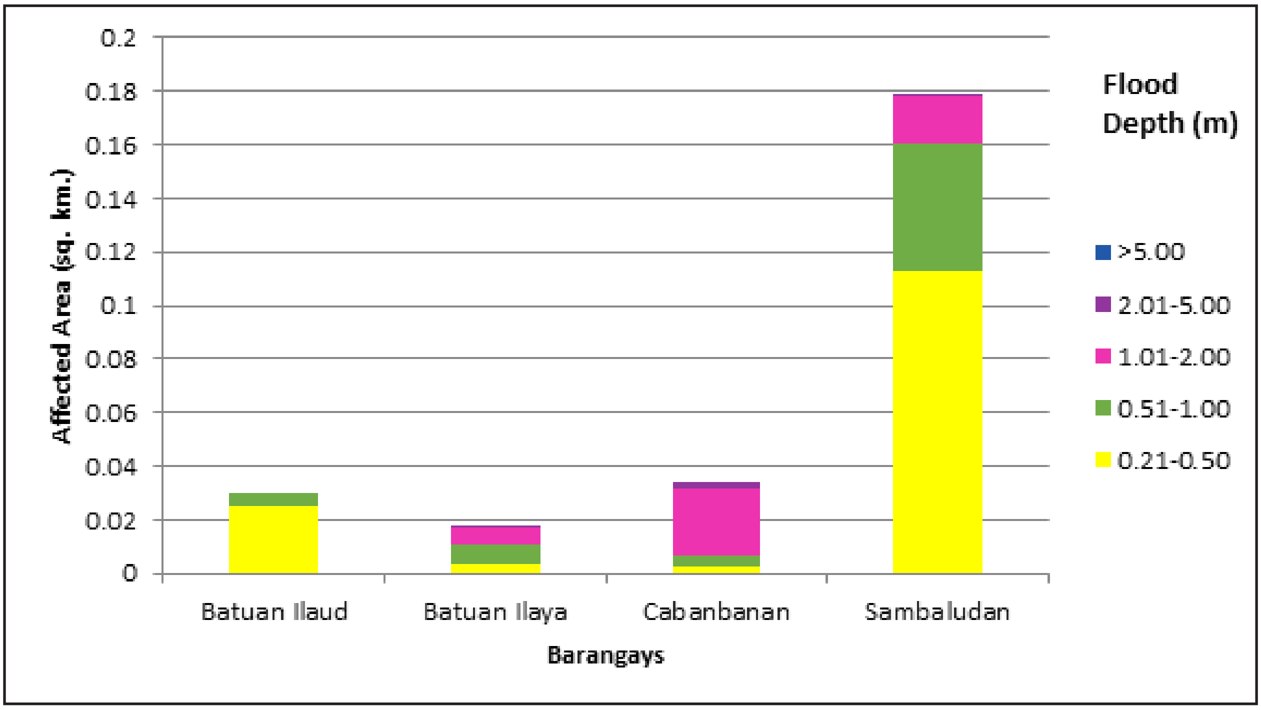


Figure 83. Affected areas in Oton, Iloilo during a 5-year rainfall return period

For the Municipality of Tigbauan, with an area of 90.23 square kilometers, 72.88% will experience flood levels of less than 0.20 meters. 5.64% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 3.91%, 4.57%, 5.56%, and 1.49% 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 46 are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected areas in Tigbauan, Iloilo during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tigbauan (in sq. km.)										
	Alupidian	Atabayan	Bagacay	Baguingin	Bagumbayan	Bangkal	Bantud	Barangay 1	Barangay 2	Barangay 3	Barangay 4
0.03-0.20	1.25	0.75	3.4	2.41	1.39	1.02	1.19	0.049	0.074	0.4	0.43
0.21-0.50	0.068	0.054	0.15	0.23	0.15	0.067	0.14	0.031	0.017	0.018	0.037
0.51-1.00	0.04	0.035	0.097	0.2	0.048	0.058	0.11	0.0041	0.031	0.017	0.0057
1.01-2.00	0.035	0.021	0.13	0.26	0.081	0.085	0.072	0	0.0085	0.078	0.0021
2.01-5.00	0.047	0.016	0.21	0.19	0.084	0.18	0.014	0	0.00057	0.055	0
>5.00	0.0032	0.0011	0.0056	0.017	0.032	0.036	0.0005	0	0	0.01	0
Affected area (sq. km.) by flood depth (in m.)	**Area of affected barangays in Tigbauan (in sq. km.)**										
	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Barosong	Barroc	Bayuco	Binaliuan Mayor	Binaliuan Menor	Bitas
0.03-0.20	0.073	0.049	0.037	0.06	0.081	1.84	0.14	0.61	1.7	1.24	2.89
0.21-0.50	0.0059	0.019	0.01	0.046	0.041	0.22	0.068	0.04	0.083	0.05	0.25
0.51-1.00	0	0.0022	0.018	0.025	0.013	0.25	0.085	0.021	0.067	0.028	0.22
1.01-2.00	0	0	0.011	0.007	0.0004	0.43	0.056	0.043	0.036	0.038	0.27
2.01-5.00	0	0	0	0	0	0.33	0.0058	0.17	0.082	0.12	0.23
>5.00	0	0	0	0	0	0.12	0	0.062	0.0071	0.045	0.093
Affected area (sq. km.) by flood depth (in m.)	**Area of affected barangays in Tigbauan (in sq. km.)**										
	Buenavista	Bugasongan	Buyu-An	Canabuan	Cansilayan	Cordova Norte	Cordova Sur	Danao	Dapdap	Dorong-An	Guisian
0.03-0.20	0.85	1.39	1.11	2.14	1.16	2.46	1.36	1.07	1.79	3.25	0.55
0.21-0.50	0.036	0.049	0.051	0.21	0.06	0.61	0.075	0.045	0.096	0.18	0.033
0.51-1.00	0.023	0.045	0.04	0.085	0.044	0.46	0.054	0.016	0.071	0.27	0.019
1.01-2.00	0.019	0.044	0.053	0.012	0.06	0.16	0.29	0.011	0.058	0.57	0.018
2.01-5.00	0.041	0.0092	0.051	0.0031	0.053	0.035	0.35	0.001	0.079	0.72	0.025
> 5.00	0.002	0	0.0008	0	0	0.0034	0.029	0	0.0086	0.25	0.0015

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tigbauan (in sq. km.)							
	Parara Norte	Parara Sur	San Rafael	Sermon	Sipitan	Supa	Tan Pael	Taro
0.03-0.20	0.69	0.99	0.71	1.26	0.14	2.41	0.019	0.64
0.21-0.50	0.1	0.086	0.031	0.056	0.0021	0.094	0.0062	0.022
0.51-1.00	0.084	0.033	0.021	0.037	0	0.061	0.008	0.013
1.01-2.00	0.052	0.079	0.032	0.035	0	0.068	0.005	0.019
2.01-5.00	0.056	0.076	0.12	0.17	0	0.054	0	0.049
>5.00	0.0036	0.0007	0.044	0.11	0	0.0002	0	0.022

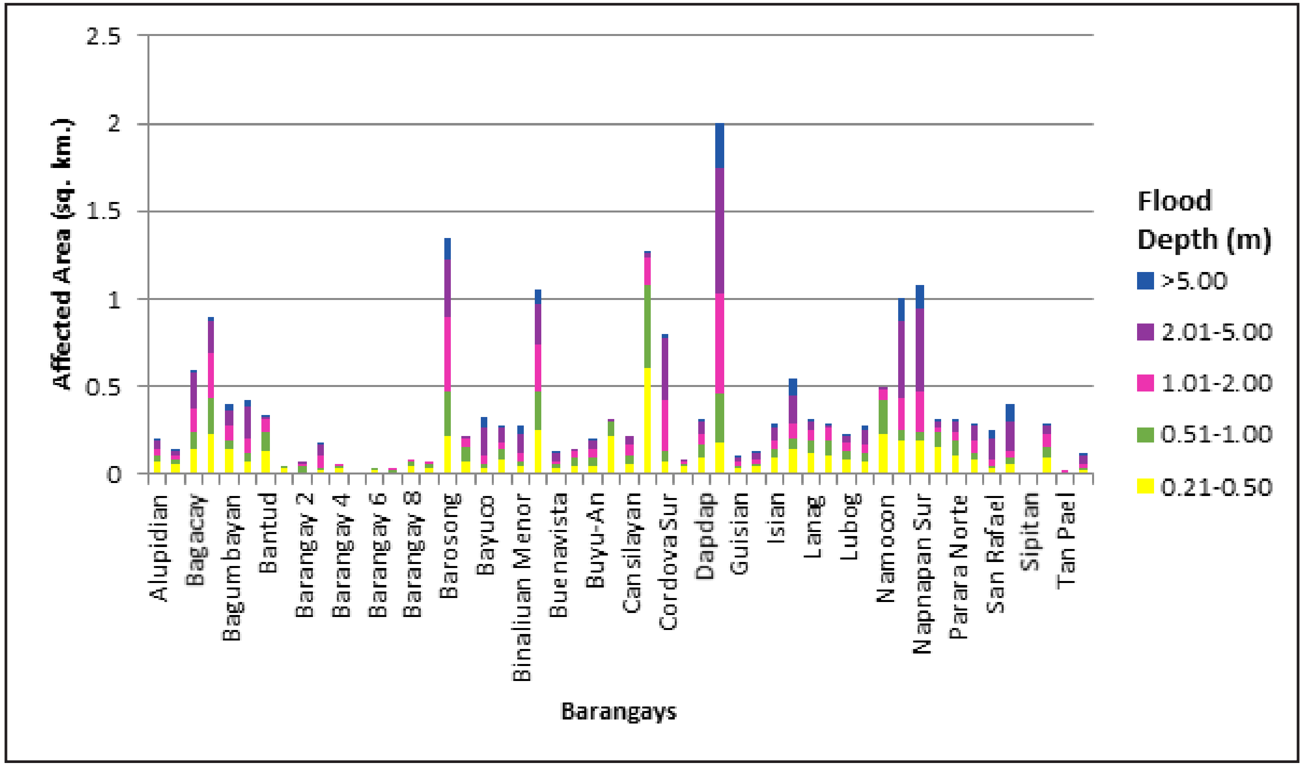


Figure 84. Affected areas in Tigbauan, Iloilo during a 5-year rainfall return period

For the Municipality of Tubungan, with an area of 90.25 square kilometers, 5.91% will experience flood levels of less than 0.20 meters. 0.24% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.105%, 0.07%, 0.06%, and 0.0008% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 47 are the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected areas in Tubungan, Iloilo during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tubungan (in sq. km.)										
	Alupidian	Atabayan	Bagacay	Baguingin	Bagumbayan	Bangkal	Bantud	Barangay 1	Barangay 2	Barangay 3	Barangay 4
0.03-0.20	0.47	0.0068	0.01	0.92	1.21	0.027	0.061	1.44	0.23	0.78	0.17
0.21-0.50	0.024	0	0.0018	0.036	0.052	0.0011	0.0001	0.066	0.0028	0.027	0.002
0.51-1.00	0.012	0	0.001	0.02	0.027	0.0007	0.0001	0.024	0.0001	0.0094	0.0002
1.01-2.00	0.0039	0	0.0026	0.0073	0.022	0	0	0.023	0.000085	0.0068	0.0001
2.01-5.00	0.0012	0	0.001	0.0018	0.023	0	0	0.019	0	0.01	0
>5.00	0	0	0	0	0.0002	0	0	0.0004	0	0.0001	0

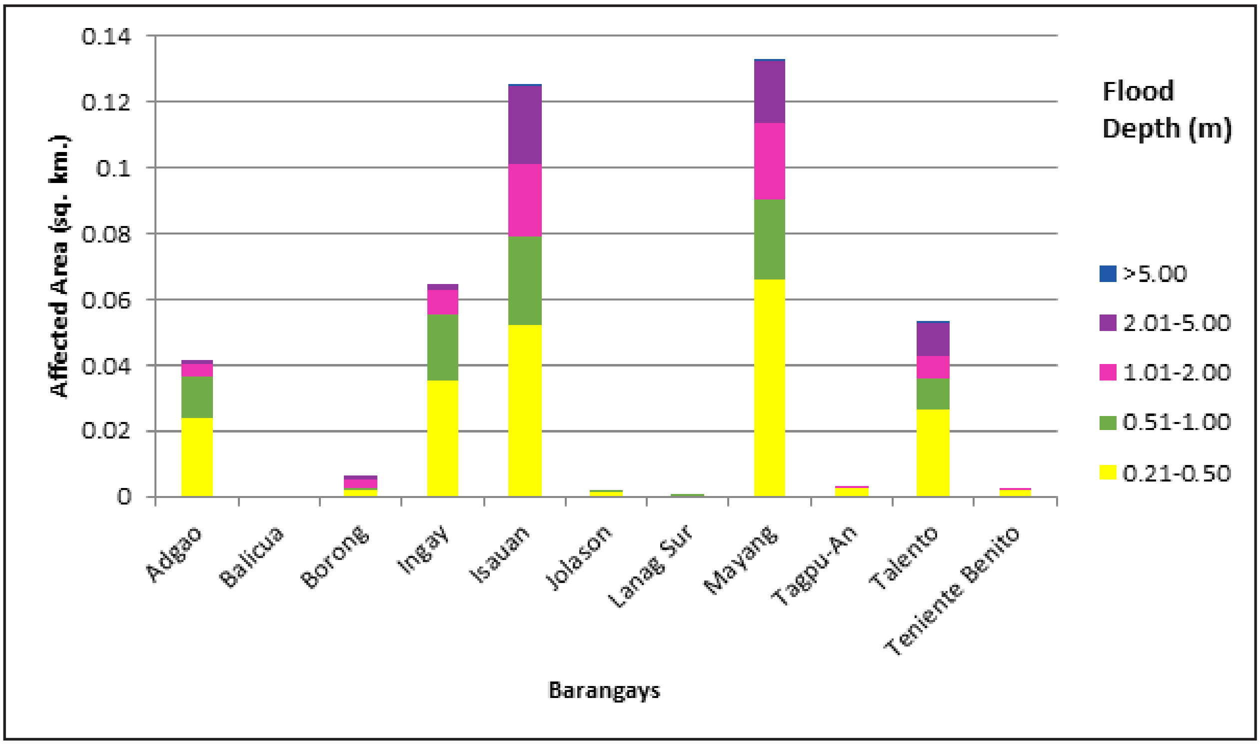


Figure 85. Affected areas in Tubungan, Iloilo during a 5-year rainfall return period

For the 25-year return period, 5.66% of the Municipality of Guimbal, with an area of 43.26 square kilometers, will experience flood levels of less than 0.20 meters. 0.34% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.21%, 0.17%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 48 are the affected areas, in square kilometers, by flood depth per barangay.

Table 48. Affected areas in Guimbal, Iloilo during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guimbal (in sq. km.)					
	Balantad-Carlos Fruto	Camangahan	Igcocolo	Nahapay	Nanga	Rizal-Tuguisan
0.03-0.20	0.17	0.15	0.39	0.023	1.61	0.11
0.21-0.50	0.0061	0.0077	0.009	0	0.11	0.011
0.51-1.00	0.0073	0.0066	0.00076	0	0.073	0.0037
1.01-2.00	0.006	0.0047	0.001	0	0.057	0.003
2.01-5.00	0.00084	0.0005	0.0007	0	0.025	0.00076
>5.00	0	0	0	0	0	0

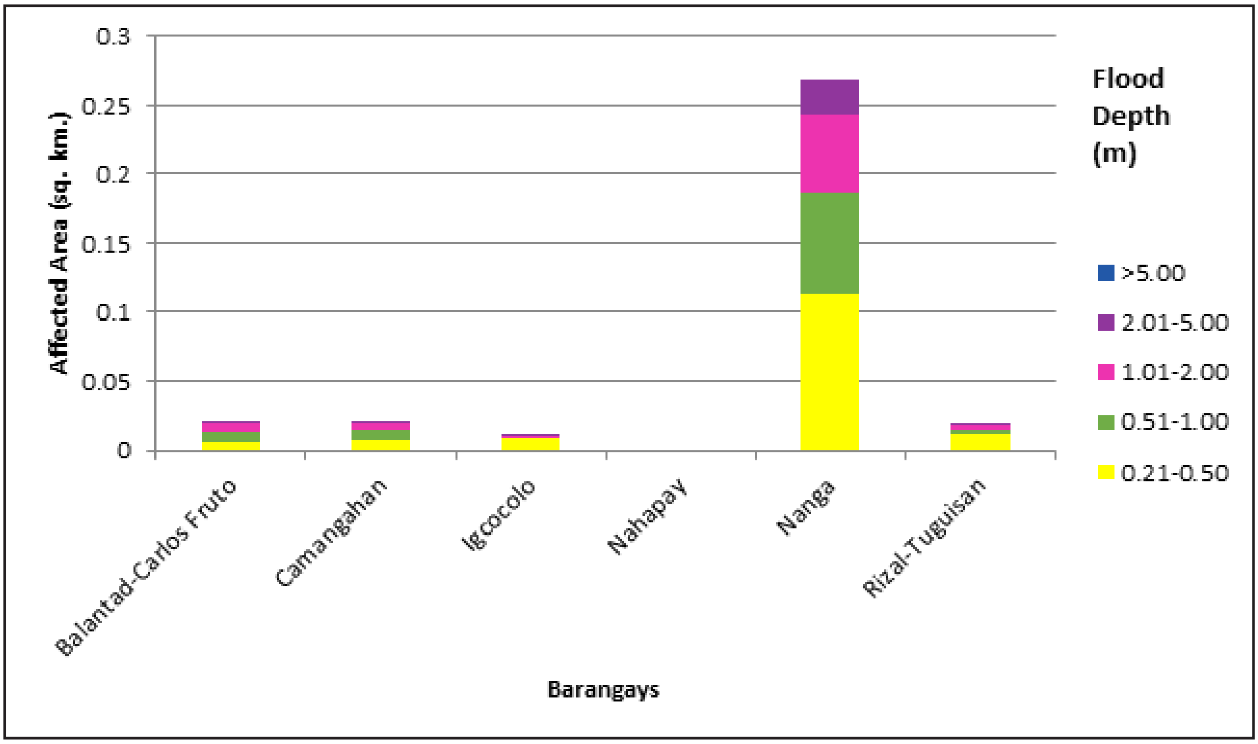


Figure 86. Affected areas in Guimbal, Iloilo during a 25-year rainfall return period

For the Municipality of Leon, with an area of 139.034 square kilometers, 19.79% will experience flood levels of less than 0.20 meters. 1.85% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.22%, 1.48%, 1.36%, and 0.36% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 49 are the affected areas, in square kilometers, by flood depth per barangay.

Table 49. Affected areas in Leon, Iloilo during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Leon (in sq. km.)										
	Agboy Sur	Ambulong	Anonang	Avanzada	Awis	Ayubo	Baje	Barasan	Bayag Norte	Bayag Sur	Binolbog
0.03-0.20	0.037	0.33	1.08	1.11	0.0066	0.27	0.49	0.89	0.25	0.53	0.55
0.21-0.50	0	0.033	0.18	0.054	0	0.0073	0.024	0.1	0.015	0.024	0.041
0.51-1.00	0	0.0082	0.11	0.017	0	0.0041	0.016	0.049	0.01	0.02	0.02
1.01-2.00	0	0.011	0.2	0.012	0	0.0032	0.027	0.019	0.011	0.016	0.0074
2.01-5.00	0	0.0083	0.16	0.031	0	0.0014	0.012	0.0061	0.027	0.02	0.0013
>5.00	0	0	0.15	0.00044	0	0	0.000021	0	0.0001	0.0098	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Leon (in sq. km.)										
	Biri Norte	Biri Sur	Buenavista	Buga	Cabutongan	Camando	Cananaman	Capt. Fernando	Carolina	Gumboc	Isian Norte
0.03-0.20	2.3	0.3	0.26	0.38	0.33	0.55	0.34	0.83	0.28	0.83	0.83
0.21-0.50	0.19	0.03	0.045	0.089	0.026	0.02	0.017	0.041	0.03	0.043	0.055
0.51-1.00	0.09	0.0066	0.021	0.023	0.0064	0.018	0.0078	0.022	0.0036	0.022	0.075
1.01-2.00	0.1	0.065	0.0089	0.075	0.0066	0.078	0.0088	0.03	0.0022	0.011	0.059
2.01-5.00	0.069	0.14	0	0.15	0.011	0.15	0.0098	0.055	0.0078	0.011	0.044
>5.00	0.0004	0.077	0	0.04	0.0022	0.03	0	0.0079	0.0012	0	0.0004

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Leon (in sq. km.)										
	Isian Victoria	Jamog Gines	Lanag	Lang-Og	Lonoc	Mina	Nagbangi	Odong-Odong	Omambong	Pandan	Panginman
0.03-0.20	0.76	0.75	0.71	1.27	0.37	0.46	1.25	0.51	0.71	0.31	0.43
0.21-0.50	0.032	0.057	0.064	0.081	0.013	0.014	0.29	0.023	0.18	0.035	0.058
0.51-1.00	0.011	0.018	0.021	0.029	0.00055	0.013	0.096	0.011	0.18	0.014	0.025
1.01-2.00	0.0092	0.016	0.018	0.0072	0	0.011	0.12	0.0099	0.21	0.0013	0.0005
2.01-5.00	0.0052	0.031	0.0085	0.0023	0	0.021	0.2	0.019	0.16	0.002	0
>5.00	0	0.0058	0.011	0	0	0.01	0.015	0.001	0.095	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Leon (in sq. km.)							
	Paoy	Pepe	Poblacion	Salngan	Tacuyong Sur	Talacuan	Tina-An Sur	Tu-Og
0.03-0.20	0.34	0.57	2.36	0.94	0.19	0.86	1.94	0.023
0.21-0.50	0.025	0.0063	0.26	0.053	0.011	0.17	0.12	0.0001
0.51-1.00	0.022	0	0.37	0.033	0.0069	0.24	0.055	0
1.01-2.00	0.027	0	0.61	0.03	0.0068	0.23	0.0038	0
2.01-5.00	0.03	0	0.41	0.031	0.021	0.051	0.0002	0
>5.00	0.0001	0	0.047	0	0.00098	0.0021	0	0

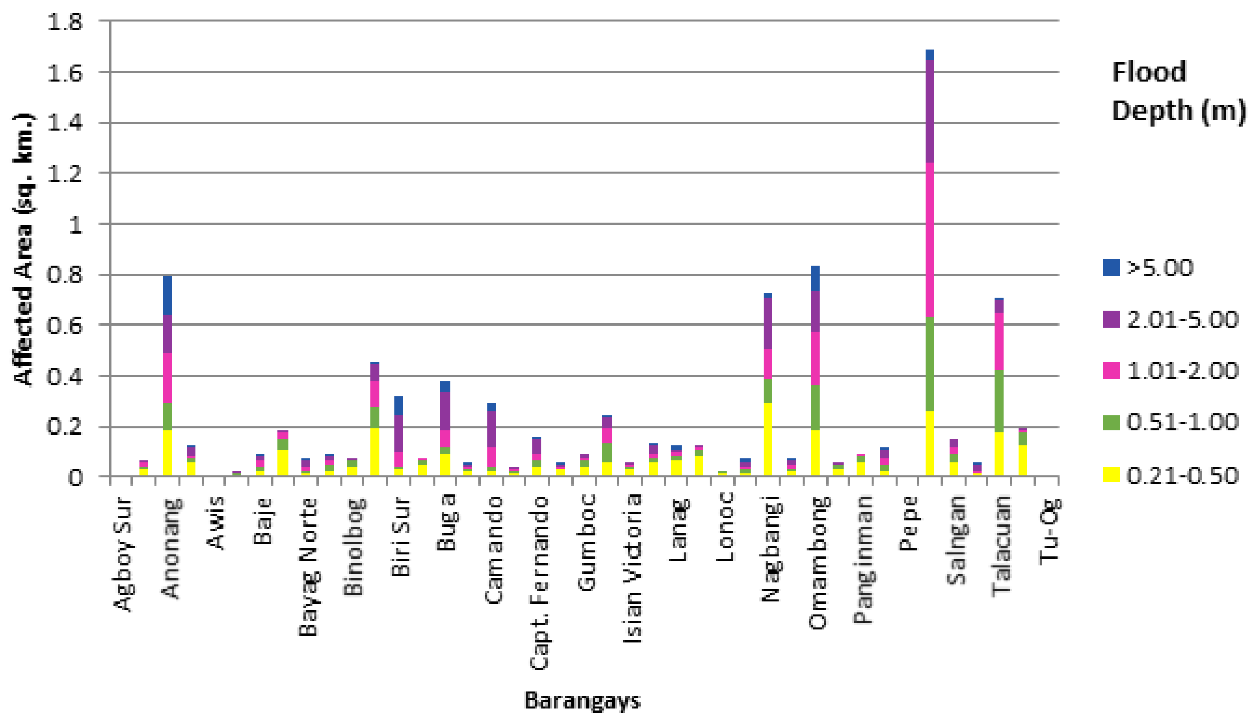


Figure 87. Affected areas in Leon, Iloilo during a 25-year rainfall return period

For the Municipality of Oton, with an area of 85.36 square kilometers, 2.27% will experience flood levels of less than 0.20 meters. 0.22% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.084%, 0.06%, and 0.018%, of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 50 are the affected areas, in square kilometers, by flood depth per barangay.

Table 50. Affected areas in Oton, Iloilo during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oton (in sq. km.)			
	Batuan Ilaud	Batuan Ilaya	Cabanbanan	Sambaludan
0.03-0.20	0.35	0.082	0.071	1.44
0.21-0.50	0.03	0.0031	0.0028	0.16
0.51-1.00	0.007	0.0047	0.0039	0.056
1.01-2.00	0	0.011	0.014	0.026
2.01-5.00	0	0.000059	0.015	0.00078
>5.00	0	0	0	0

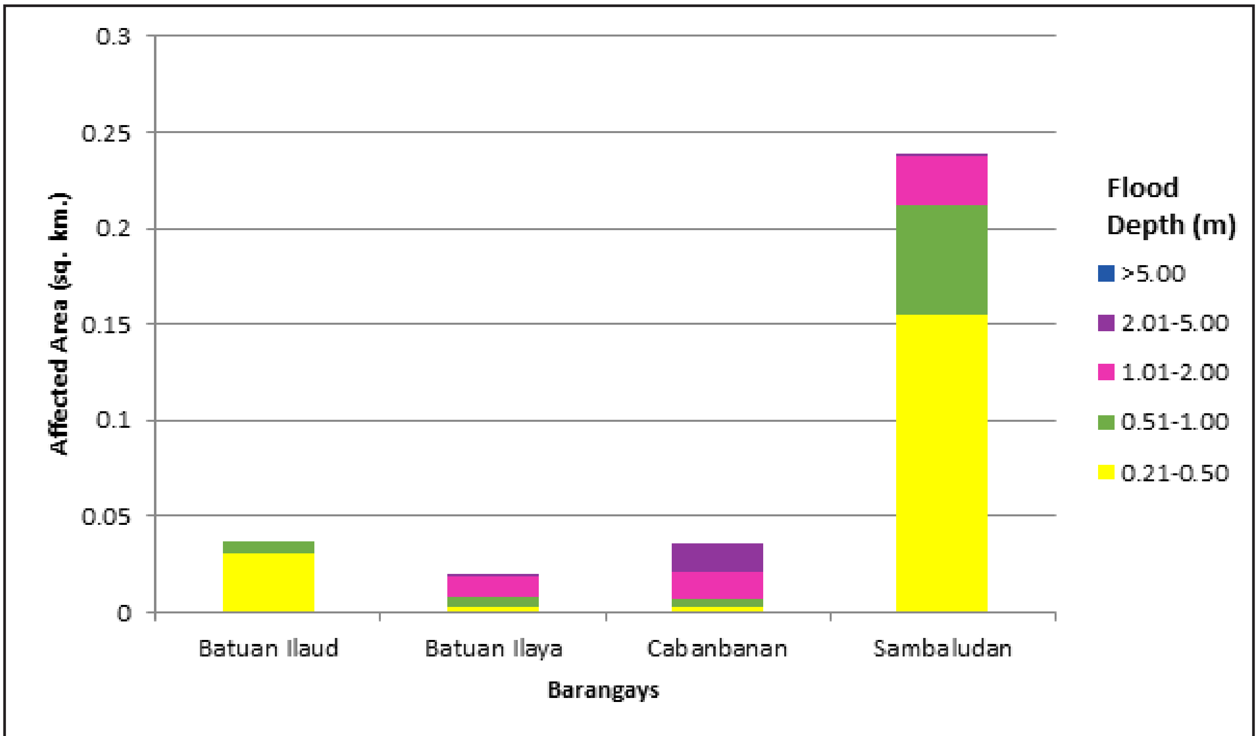


Figure 88. Affected areas in Oton, Iloilo during a 25-year rainfall return period

For the Municipality of Tigbauan, with an area of 90.23 square kilometers, 71.64% will experience flood levels of less than 0.20 meters. 6.49% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.17%, 4.68%, 6.84%, and 2.30% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 51 are the affected areas, in square kilometers, by flood depth per barangay.

Table 51. Affected areas in Tigbauan, Iloilo during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tigbauan (in sq. km.)										
	Alupidian	Atabayan	Bagacay	Baguingin	Bagumbayan	Bangkal	Bantud	Barangay 1	Barangay 2	Barangay 3	Barangay 4
0.03-0.20	1.22	0.73	3.33	2.3	1.32	0.95	1.15	0.033	0.067	0.38	0.41
0.21-0.50	0.071	0.062	0.16	0.26	0.16	0.074	0.14	0.029	0.0075	0.022	0.049
0.51-1.00	0.047	0.044	0.11	0.2	0.071	0.052	0.12	0.021	0.023	0.013	0.0084
1.01-2.00	0.04	0.021	0.13	0.27	0.079	0.082	0.098	0.00045	0.03	0.05	0.0025
2.01-5.00	0.052	0.019	0.25	0.24	0.12	0.21	0.022	0	0.0013	0.097	0
>5.00	0.0069	0.0015	0.012	0.027	0.035	0.082	0.0007	0	0	0.012	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tigbauan (in sq. km.)										
	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Barosong	Barroc	Bayuco	Binaliuan Mayor	Binaliuan Menor	Bitas
0.03-0.20	0.07	0.037	0.034	0.048	0.055	1.71	1.78	0.57	1.66	1.21	2.71
0.21-0.50	0.0084	0.03	0.011	0.053	0.057	0.22	0.17	0.057	0.081	0.06	0.32
0.51-1.00	0	0.0033	0.018	0.029	0.024	0.18	0.082	0.027	0.082	0.033	0.16
1.01-2.00	0	0	0.013	0.0086	0.0004	0.49	0.081	0.036	0.047	0.036	0.36
2.01-5.00	0	0	0.013	0	0	0.41	0.083	0.17	0.084	0.11	0.28
>5.00	0	0	0	0	0	0.18	0.01	0.083	0.017	0.068	0.12

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tigbauan (in sq. km.)										
	Buenavista	Bugasongan	Buyu-An	Canabuan	Cansilayan	Cordova Norte	Cordova Sur	Danao	Dapdap	Dorong-An	Guisian
0.03-0.20	0.83	1.37	1.08	2.08	1.13	2.21	1.29	1.06	1.75	3.11	0.54
0.21-0.50	0.043	0.054	0.064	0.23	0.067	0.51	0.1	0.052	0.099	0.18	0.035
0.51-1.00	0.026	0.044	0.043	0.12	0.047	0.59	0.043	0.022	0.082	0.18	0.022
1.01-2.00	0.023	0.052	0.048	0.014	0.068	0.37	0.1	0.012	0.066	0.52	0.018
2.01-5.00	0.044	0.015	0.067	0.0052	0.067	0.061	0.55	0.0024	0.085	0.91	0.03
> 5.00	0.0054	0	0.001	0	0.0002	0.0057	0.082	0	0.022	0.34	0.0023

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tigbauan (in sq. km.)							
	Parara Norte	Parara Sur	San Rafael	Sermon	Sipitan	Supa	Tan Pael	Taro
0.03-0.20	0.63	0.95	0.69	1.21	0.14	2.36	0.018	0.62
0.21-0.50	0.098	0.11	0.031	0.059	0.0026	0.11	0.0068	0.03
0.51-1.00	0.072	0.033	0.029	0.051	0	0.069	0.008	0.014
1.01-2.00	0.11	0.054	0.026	0.038	0	0.07	0.0061	0.02
2.01-5.00	0.075	0.11	0.13	0.12	0	0.071	0	0.051
>5.00	0.0074	0.001	0.063	0.19	0	0.0003	0	0.029

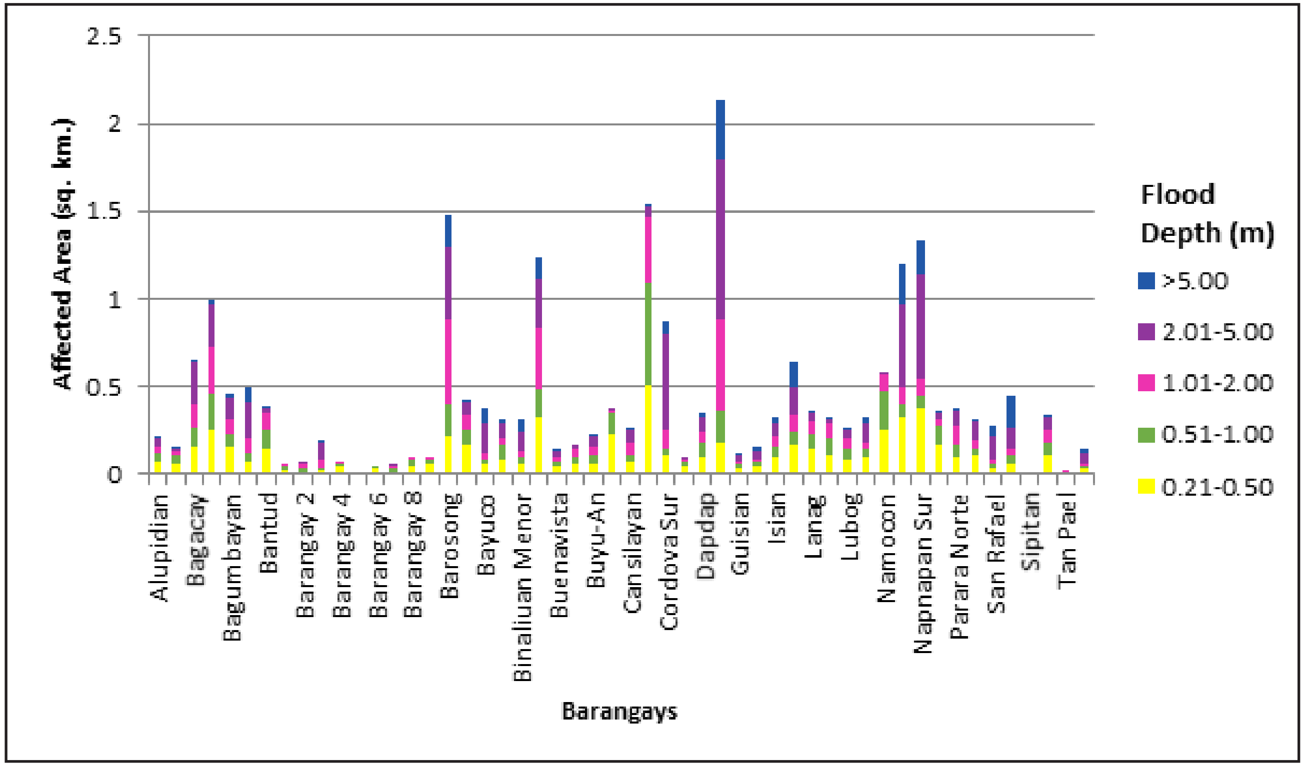


Figure 89. Affected areas in Tigbauan, Iloilo during a 25-year rainfall return period

For the Municipality of Tubungan, with an area of 90.25 square kilometers, 6.29% will experience flood levels of less than 0.20 meters. 0.29% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.13%, 0.079%, 0.08%, and 0.004% 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 52 are the affected areas, in square kilometers, by flood depth per barangay.

Table 52. Affected areas in Tubungan, Iloilo during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tubungan (in sq. km.)										
	Alupidian	Atabayan	Bagacay	Baguingin	Bagumbayan	Bangkal	Bantud	Barangay 1	Barangay 2	Barangay 3	Barangay 4
0.03-0.20	0.63	0.95	0.69	1.21	0.14	2.36	0.018	0.62	0.23	0.78	0.17
0.21-0.50	0.098	0.11	0.031	0.059	0.0026	0.11	0.0068	0.03	0.0028	0.027	0.002
0.51-1.00	0.072	0.033	0.029	0.051	0	0.069	0.008	0.014	0.0001	0.0094	0.0002
1.01-2.00	0.11	0.054	0.026	0.038	0	0.07	0.0061	0.02	0.000085	0.0068	0.0001
2.01-5.00	0.075	0.11	0.13	0.12	0	0.071	0	0.051	0	0.01	0
>5.00	0.0074	0.001	0.063	0.19	0	0.0003	0	0.029	0	0.0001	0

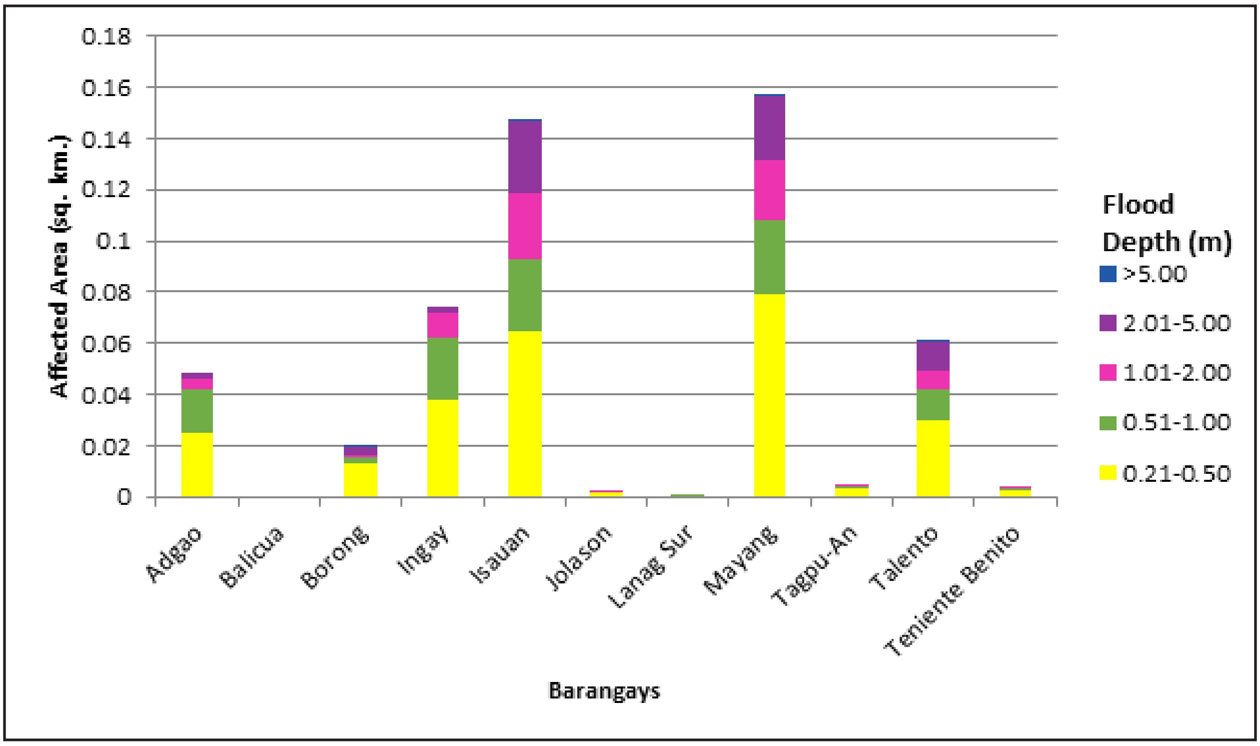


Figure 90. Affected areas in Tubungan, Iloilo during a 25-year rainfall return period

For the 100-year return period, 3.82% of the Municipality of Guimbal, with an area of 43.26 square kilometers, will experience flood levels of less than 0.20 meters. 7.5% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.2%, 6.89%, and 8.18% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 53 are the affected areas, in square kilometers, by flood depth per barangay.

Table 53. Affected areas in Guimbal, Iloilo during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Guimbal (in sq. km.)					
	Balantad-Carlos Fruto	Camangahan	Igcocolo	Nahapay	Nanga	Rizal-Tuguisan
0.03-0.20	0.17	0.11	0.0066	0.51	0.54	0.32
0.21-0.50	0.15	0.037	0.27	0	2.24	0.54
0.51-1.00	0.39	0.32	0.49	0	0.29	0.33
1.01-2.00	0.023	1.03	0.87	0	0.24	0.81
2.01-5.00	1.58	1.08	0.24	0	0.36	0.27
>5.00	0	0	0	0	0	0

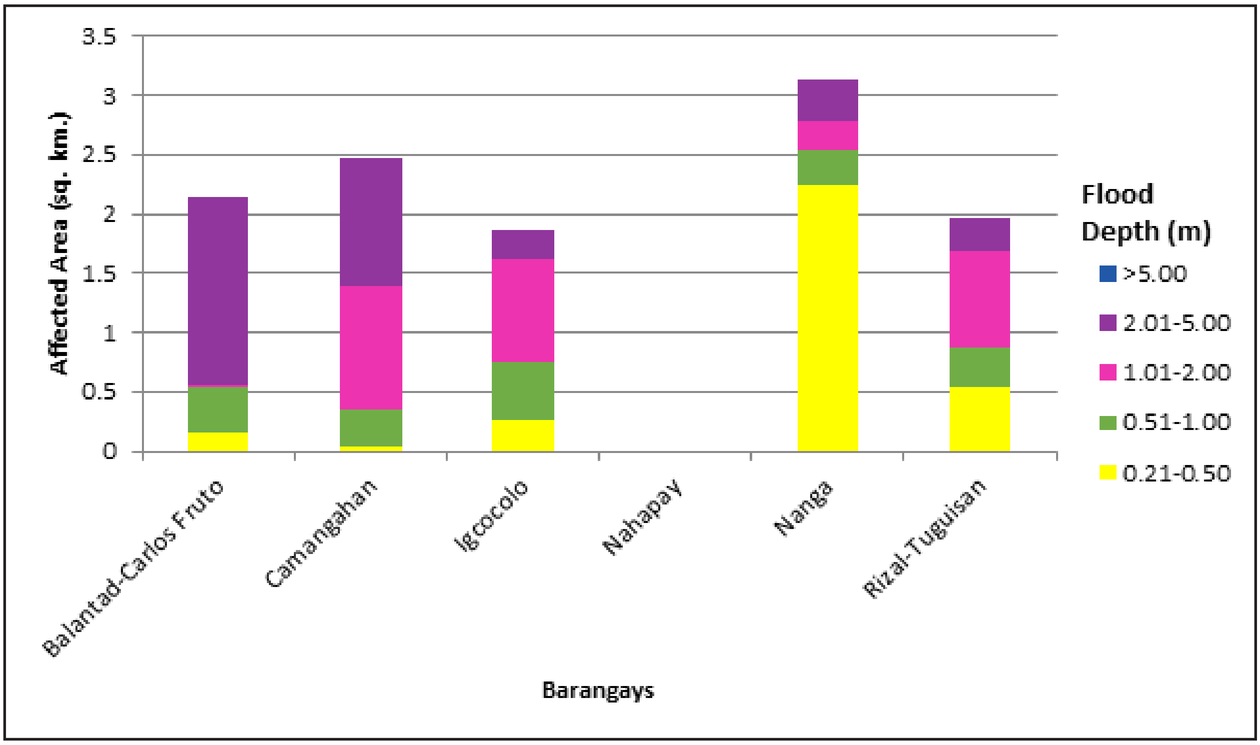


Figure 91. Affected areas in Guimbal, Iloilo during a 100-year rainfall return period

For the Municipality of Leon, with an area of 139.034 square kilometers, 15.62% will experience flood levels of less than 0.20 meters. 10.22% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 10.71%, 14.45%, 11.57%, and 6.45% 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 54 are the affected areas, in square kilometers, by flood depth per barangay.

Table 54. Affected areas in Leon, Iloilo during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Leon (in sq. km.)										
	Agboy Sur	Ambulong	Anonang	Avanzada	Awis	Ayubo	Baje	Barasan	Bayag Norte	Bayag Sur	Binolbog
0.03-0.20	0.81	0.81	0.36	0.41	0.81	1.9	1.38	0.84	0.4	1.62	0.81
0.21-0.50	0	0.75	0.45	0.33	0	0.023	1.2	1.1	0.058	1.71	1.35
0.51-1.00	0	0.73	1.18	0.56	0	0.34	0.71	0.018	0.024	0.49	1.05
1.01-2.00	0	0.69	0.5	2.25	0	0.08	3.27	0.061	0.03	1.63	2.03
2.01-5.00	0	1.24	0.66	0.92	0	0.07	2.2	0.35	0.032	1.17	1.1
>5.00	0	0	0.3	0.19	0	0	1.27	0	0.021	2.58	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Leon (in sq. km.)										
	Biri Norte	Biri Sur	Buenavista	Buga	Cabutongan	Camando	Cananaman	Capt. Fernando	Carolina	Gumboc	Isian Norte
0.03-0.20	2.06	0.65	1.69	1.26	2.32	0.9	0.76	0.12	0.023	0.037	0.05
0.21-0.50	1.21	1.26	1.1	0.58	0.016	1.17	0.17	0.012	0.12	0.05	0.035
0.51-1.00	1.05	2.82	2.83	0.91	0.6	0.026	0.0059	0.04	0.017	0.069	0.053
1.01-2.00	1.72	2.72	1.98	0.66	0.46	0.061	0.0072	0.13	0.028	0.033	0.051
2.01-5.00	2.95	1.18	0	1.17	0.0068	1.39	0.013	0.069	0.05	0.025	0.041
>5.00	0.53	1.45	0	0.14	0.43	0.23	0	0.01	0.2	0.02	0.07

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Leon (in sq. km.)										
	Isian Victoria	Jamog Gines	Lanag	Lang-Og	Lonoc	Mina	Nagbangi	Odong-Odong	Omambong	Pandan	Panginman
0.03-0.20	0.073	0.028	0.29	0.035	0.072	0.17	0.06	0.23	0.049	0.13	0.049
0.21-0.50	0.098	0.14	0.059	0.0038	0.18	0.099	0.021	0.2	0.064	0.056	0.099
0.51-1.00	0.018	0.04	0.013	0.0023	0.29	0.14	0.04	0.067	0.084	0.1	0.19
1.01-2.00	0.015	0.058	0.16	0.19	0	0.012	0.013	0.088	0.25	0.22	0.16
2.01-5.00	0.3	0.026	0.15	0.08	0	0.0055	0.049	0.072	0.074	0.037	0
>5.00	0	0.01	0.0001	0	0	0.047	0.048	0.37	0.47	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Leon (in sq. km.)							
	Paoy	Pepe	Poblacion	Salngan	Tacuyong Sur	Talacuan	Tina-An Sur	Tu-Og
0.03-0.20	0.12	0.19	0.036	0.028	0.089	0.0017	0.0041	0.021
0.21-0.50	0.1	0.097	0.065	0.016	0.0047	0.076	0.019	0.11
0.51-1.00	0.1	0.14	0.0031	0.043	0.038	0.0044	0.059	0
1.01-2.00	0.29	0	0.13	0.076	0.0042	0.0099	0.011	0
2.01-5.00	0.46	0	0.0079	0.0018	0.0075	0.15	0.02	0
>5.00	0.52	0	0.034	0.0003	0.007	0.02	0	0

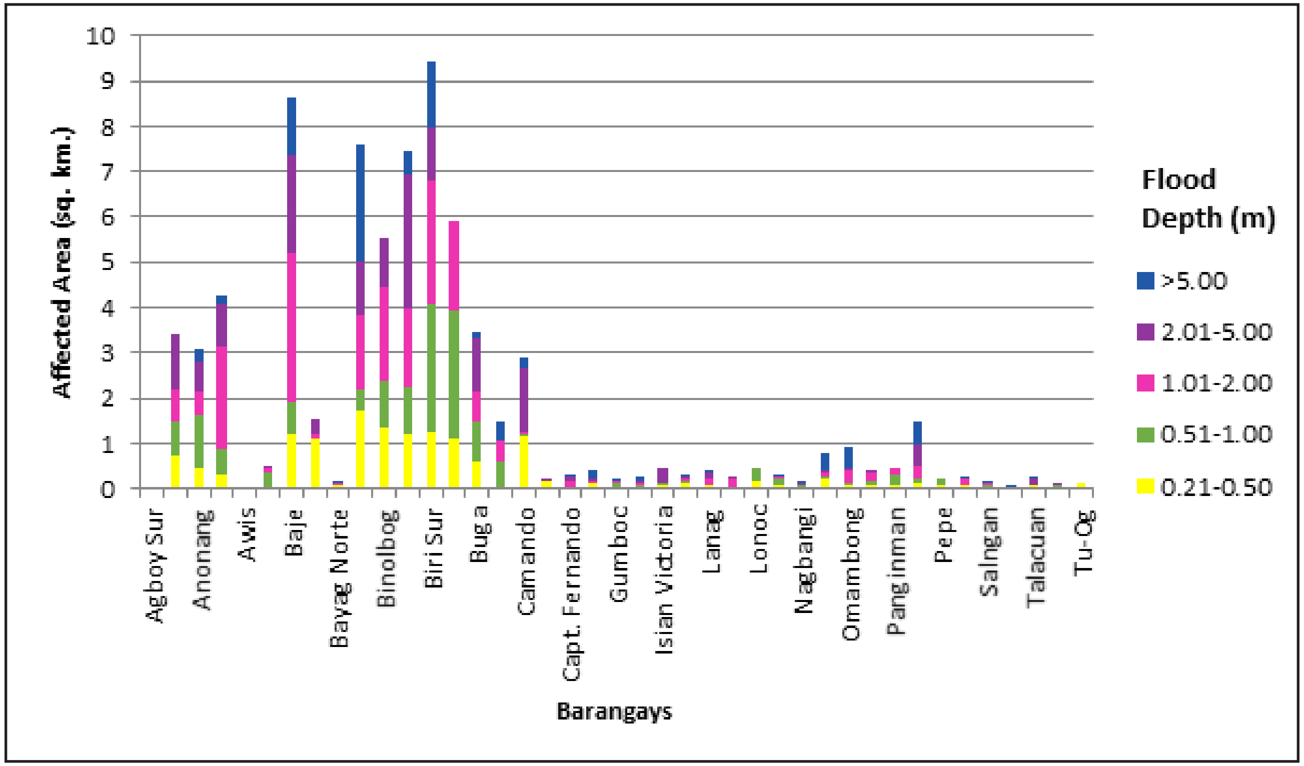


Figure 92. Affected areas in Leon, Iloilo during a 100-year rainfall return period

For the Municipality of Oton, with an area of 85.36 square kilometers, 0.09% will experience flood levels of less than 0.20 meters. 0.13% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.096%, 0.018%, and 0.045%, of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 55 are the affected areas, in square kilometers, by flood depth per barangay.

Table 55. Affected areas in Oton, Iloilo during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Oton (in sq. km.)			
	Batuan Ilaud	Batuan Ilaya	Cabanbanan	Sambaludan
0.03-0.20	0.0091	0.0061	0.025	0.033
0.21-0.50	0.023	0.013	0.071	0.0013
0.51-1.00	0.047	0.0098	0.012	0.013
1.01-2.00	0	0.024	0.02	0.11
2.01-5.00	0	0.006	0.02	0.012
>5.00	0	0	0	0

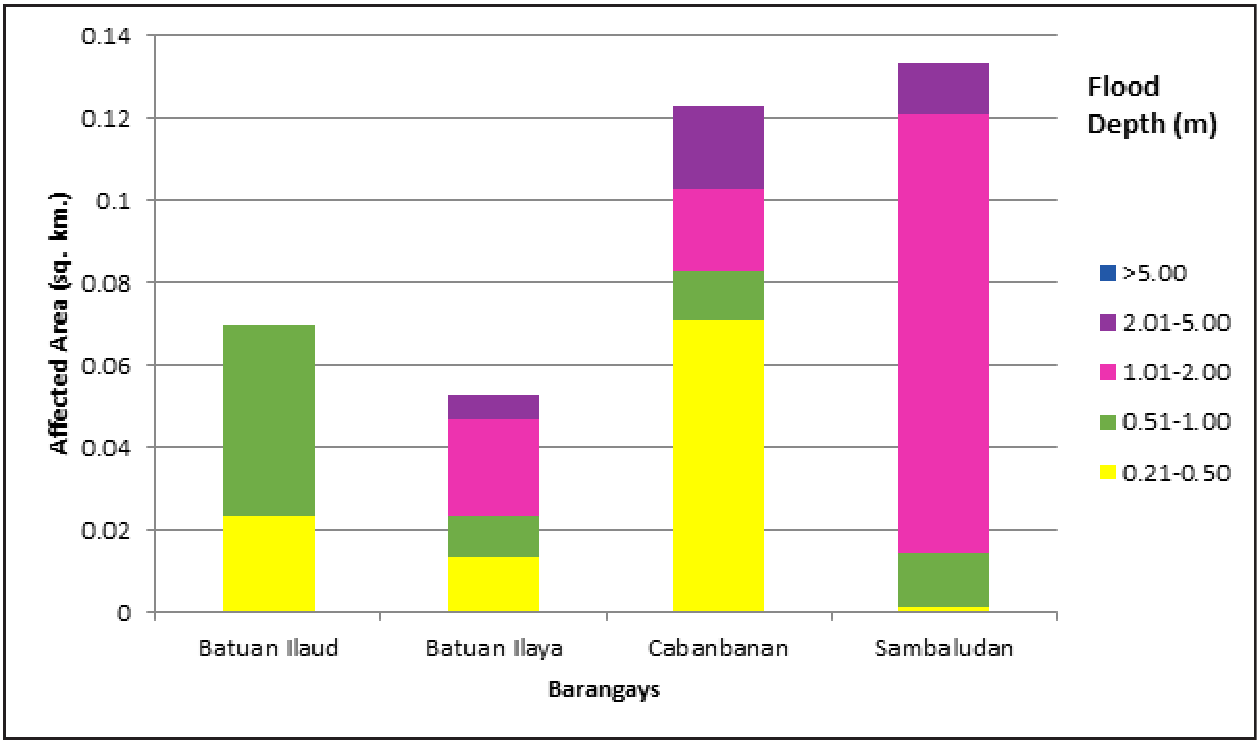


Figure 93. Affected areas in Oton, Iloilo during a 100-year rainfall return period

For the Municipality of Tigbauan, with an area of 90.23 square kilometers, 3.48% will experience flood levels of less than 0.20 meters. 5.39% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 3.10%, 4.15%, 3.73%, and 3.95% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 56 are the affected areas, in square kilometers, by flood depth per barangay.

Table 56. Affected areas in Tigbauan, Iloilo during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tigbauan (in sq. km.)										
	Alupidian	Atabayan	Bagacay	Baguingin	Bagumbayan	Bangkal	Bantud	Barangay 1	Barangay 2	Barangay 3	Barangay 4
0.03-0.20	0.12	0.038	0.0035	0.051	0.011	0.15	0.03	0.052	0.026	0.1	0.12
0.21-0.50	0.017	0.0077	0.063	0.054	0.000079	0.096	0.043	0.027	0.026	0.058	0.032
0.51-1.00	0.037	0.22	0.054	0.1	0.0068	0.051	0.043	0.086	0.072	0.061	0.036
1.01-2.00	0.02	0.07	0.049	0.037	0.018	0.084	0.16	0.13	0.084	0.24	0.029
2.01-5.00	0.000011	0.01	0.11	0.0073	0.044	0.034	0.052	0	0.1	0.075	0.047
>5.00	0.25	0.0032	0.2	0.014	0.061	0.18	0.5	0	0	0.12	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tigbauan (in sq. km.)										
	Barangay 5	Barangay 6	Barangay 7	Barangay 8	Barangay 9	Barosong	Barroc	Bayuco	Binaliuan Mayor	Binaliuan Menor	Bitas
0.03-0.20	0.000002	0.019	0.032	0.00069	0.0055	0.011	0.012	0.054	0.014	0.013	0.026
0.21-0.50	0.075	0.019	0.0007	0.015	0.00082	0.18	0.02	0.0069	0.075	0.14	0.65
0.51-1.00	0.0074	0.0037	0.0001	0.0003	0.062	0.014	0.0099	0.054	0.01	0.011	0.029
1.01-2.00	0	0.027	0.036	0.0068	0.0033	0.0035	0.083	0.0082	0.018	0.27	0.0053
2.01-5.00	0	0	0	0	0	0.028	0.012	0.03	0.025	0.0013	0.27
>5.00	0	0	0	0	0	0.022	0.012	0.0022	0.0098	0.0014	0.0069

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tigbauan (in sq. km.)										
	Buenavista	Bugasongan	Buyu-An	Canabuan	Cansilayan	Cordova Norte	Cordova Sur	Danao	Dapdap	Dorong-An	Guisian
0.03-0.20	0.014	0.28	0.042	0.0058	0.041	0.07	0.019	0.063	0.038	0.0073	0.0003
0.21-0.50	0.0092	0.095	0.027	0.26	0.33	0.48	0.014	0.044	0.13	0.021	0.024
0.51-1.00	0.033	0.086	0.0029	0.083	0.026	0.061	0.059	0.11	0.05	0.0056	0.000085
1.01-2.00	0.04	0.14	0.0003	0.047	0.055	0.013	0.099	0.093	0.031	0.00076	0.0069
2.01-5.00	0.021	0.018	0.014	0.058	0.05	0.073	0.074	0.084	0.048	0.011	0.0001
> 5.00	0.13	0	0.014	0	0.017	0.33	0.096	0	0.073	0.026	0.0013

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tigbauan (in sq. km.)							
	Parara Norte	Parara Sur	San Rafael	Sermon	Sipitan	Supa	Tan Pael	Taro
0.03-0.20	0.091	0.066	0.6	0.085	0.03	0.0019	0.057	0.0031
0.21-0.50	1.13	0.026	0.05	0.05	0.013	0.000021	0.0029	0.0003
0.51-1.00	0.033	0.055	0.15	0.0021	0.17	0.0007	0.039	0.0011
1.01-2.00	0.058	0.1	0.13	0.0031	0	0.013	0.015	0.01
2.01-5.00	0.084	0.0029	0.11	0.0037	0	0.0017	0	0.012
>5.00	0.17	0.45	0.096	0.033	0	0.094	0	0.013

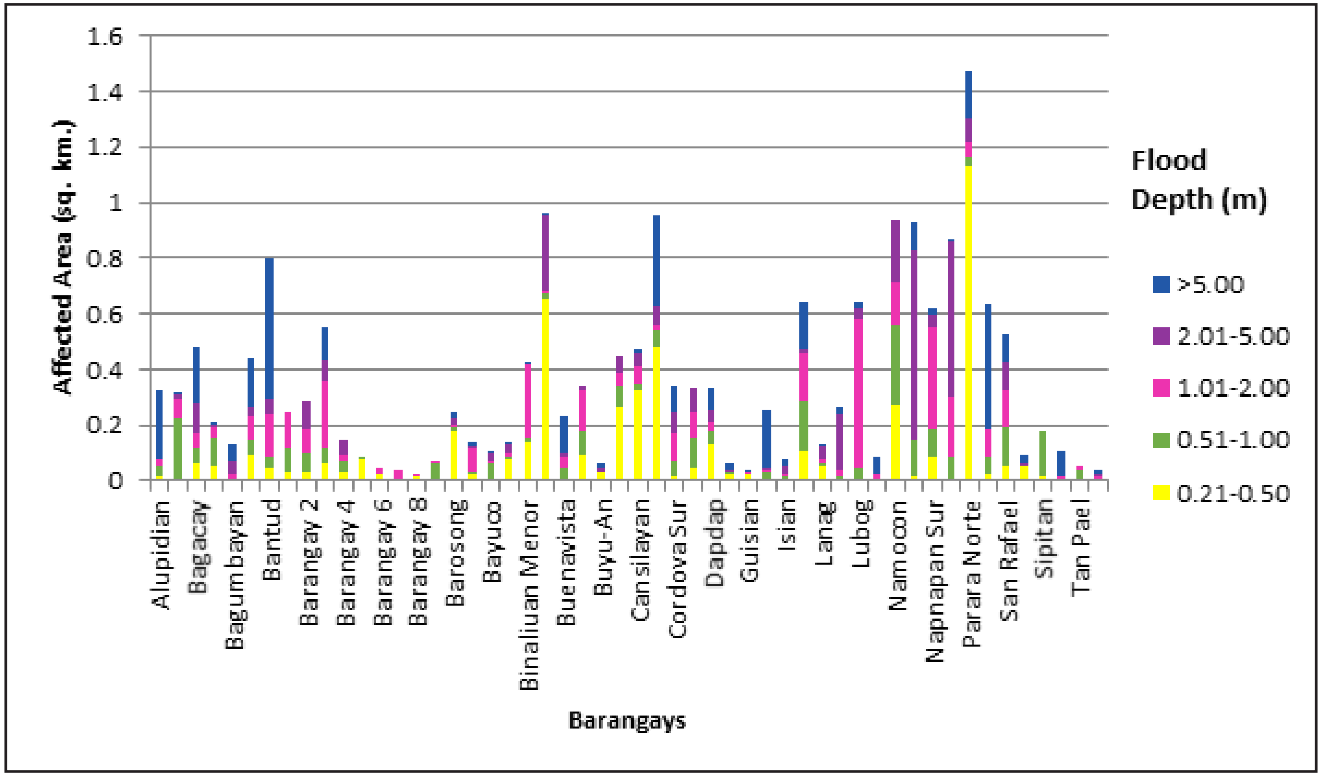


Figure 94. Affected areas in Tigbauan, Iloilo during a 100-year rainfall return period

For the Municipality of Tubungan, with an area of 90.25 square kilometers, 1.16% will experience flood levels of less than 0.20 meters. 0.79% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.74%, 0.22%, 0.41%, and 0.13% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 57 are the affected areas, in square kilometers, by flood depth per barangay.

Table 57. Affected areas in Tubungan, Iloilo during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tubungan (in sq. km.)										
	Alupidian	Atabayan	Bagacay	Baguingin	Bagumbayan	Bangkal	Bantud	Barangay 1	Barangay 2	Barangay 3	Barangay 4
0.03-0.20	0.032	0.0002	0.0017	0.038	0.12	0.0015	0.49	0.038	0.32	0.0021	0.0001
0.21-0.50	0.0016	0	0.0038	0.15	0.027	0.011	0.0042	0.18	0.24	0.098	0.0008
0.51-1.00	0.11	0	0.0099	0.0008	0.11	0.15	0.035	0.0045	0.011	0.23	0.0011
1.01-2.00	0.00089	0	0.0023	0.014	0.13	0.035	0	0.0015	0.015	0.0005	0.0015
2.01-5.00	0.069	0	0.027	0.23	0.0089	0	0	0.0025	0	0.037	0
>5.00	0	0	0.04	0.019	0.0014	0	0	0.054	0	0.0014	0

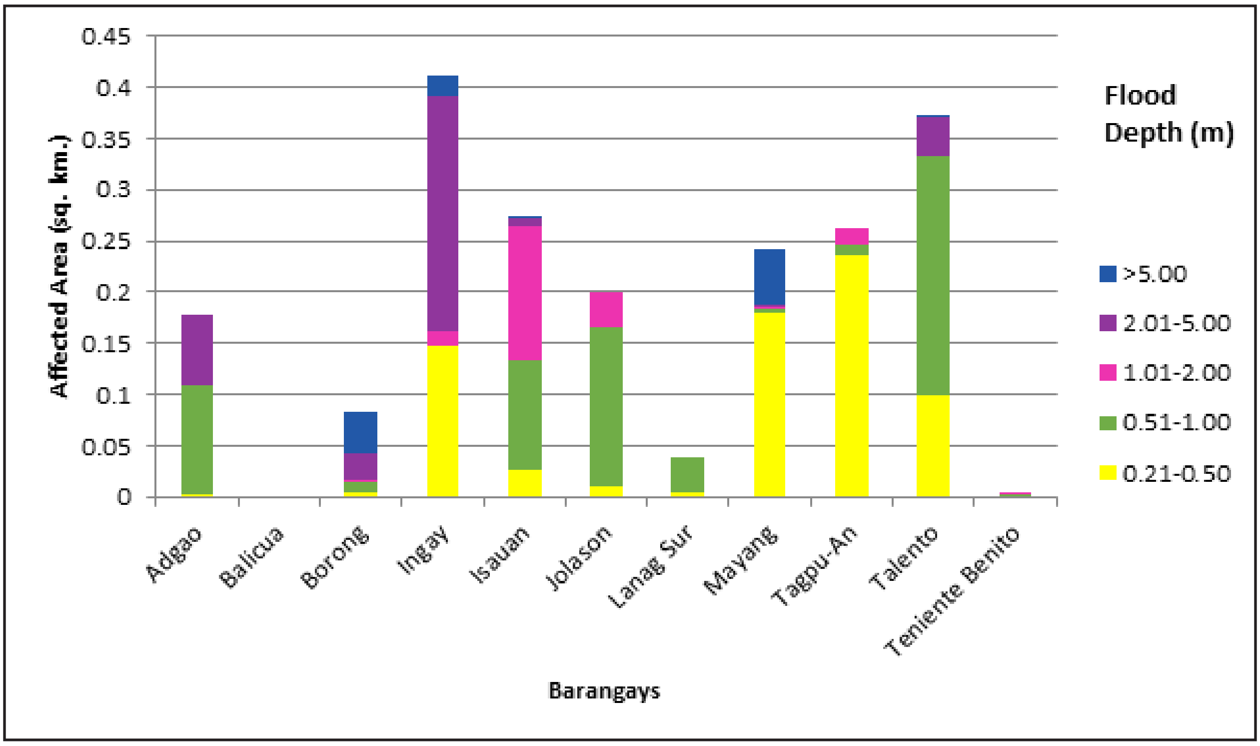


Figure 95. Affected areas in Tubungan, Iloilo during a 100-year rainfall return period

Among the barangays in the Municipality of Guimbal, Nanga is projected to have the highest percentage of area that will experience flood levels, at 4.33%. Meanwhile, Igcocolo posted the second highest percentage of area that may be affected by flood depths, at 0.93%.

Among the barangays in the Municipality of Leon, Poblacion is projected to have the highest percentage of area that will experience flood levels, at 2.91%. Meanwhile, Biri Norte posted the second highest percentage of area that may be affected by flood depths, at 1.97%.

Among the barangays in the Municipality of Oton, Sambaludan is projected to have the highest percentage of area that will experience flood levels, at 1.96%. Meanwhile, Batuan Ilaud posted the second highest percentage of area that may be affected by flood depths, at 0.45%.

Among the barangays in the Municipality of Tigbauan, Dorong-An is projected to have the highest percentage of area that will experience flood levels, at 5.81%. Meanwhile, Napnapan Norte posted the second highest percentage of area that may be affected by flood depths, at 4.69%.

Among the barangays in the Municipality of Tubungan, Mayang is projected to have the highest percentage of area that will experience flood levels, at 1.74%. Meanwhile, Isauan No posted the second highest percentage of area that may be affected by flood depths, at 1.48%.

The generated flood hazard maps for the Sibalom floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for the flood hazard maps – "Low", "Medium", and "High" – the affected institutions were given an individual assessment for each flood hazard scenario (i.e., 5-year, 25-year, and 100-year).

Table 58. 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	8.72	9.52	10.68
Medium	9.01	9.43	9.29
High	10.76	13.77	16.54
TOTAL	**28.49**	**32.77**	**35.61**

Of the eighty-two (82) identified educational institutions in the Sibalom floodplain, nine (9) were assessed to be exposed to Low-level flooding during a 5-year scenario; while two (2) schools were found to be exposed to Medium-level flooding in the same scenario. In the 25-year scenario, nine (9) schools were discovered to be exposed to Low-level flooding, and five (5) to Medium-level flooding. In the 100-year scenario, six (6) schools were assessed to be exposed to Low-level flooding, nine (9) to Medium-level flooding, and one (1) to High-level flooding. See Annex 12 for a detailed enumeration of schools in the Sibalom floodplain.

Twelve (12) medical institutions were identified in the Sibalom floodplain, and one (1) of these was assessed to be exposed to Low-level flooding during a 5-year scenario. Another one (1) was found to be exposed to Medium-level flooding in the same scenario. In the 25-year scenario, two (2) institutions were discovered to be exposed to Low-level flooding, while one (1) was assessed to be exposed to Medium-level flooding. In the 100-year scenario, two (2) medical establishments were assessed to be exposed Low-level flooding, and one (1) was projected to experience Medium-level flooding in the same scenario. See Annex 13 for a detailed enumeration of hospitals and clinics in the Sibalom floodplain.

5.11 Flood Validation

In order to check and validate the extent of flooding in the different river systems, there is a need to perform validation survey work. For this purpose, field personnel gathered secondary data regarding flood occurrences in the respective areas within the major river systems in the Philippines.

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

The validation personnel then went to the specified points identified in a river basin to gather data regarding the actual flood levels in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents with knowledge or experience of flooding in a particular area.

After which, the actual data from the field were compared with the simulated data to assess the accuracy of the flood depth maps produced, and to improve on the results of the flood map. The points in the flood map versus the corresponding validation depths are illustrated in Figure 97.
The flood validation consists of one hundred and forty-seven (147) points, randomly selected all over the Sibalom floodplain. Comparing the validation with the flood depth map of the nearest storm event, the map attained an RMSE value of 0.68 meters. Table 59 presents a contingency matrix of the comparison. The validation points are found in Annex 11.

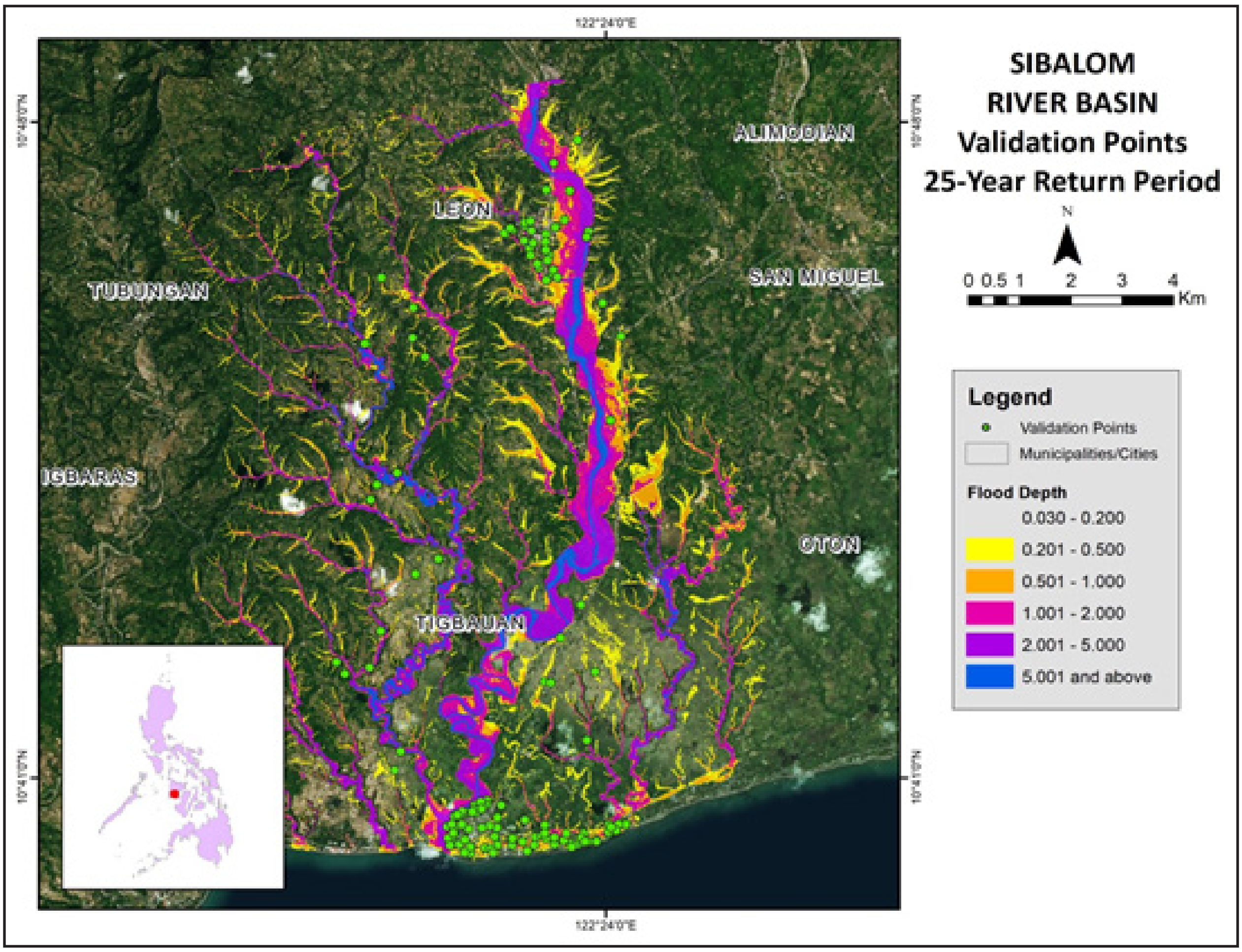


Figure 96. Validation points for a 25-year flood depth map of the Sibalom floodplain

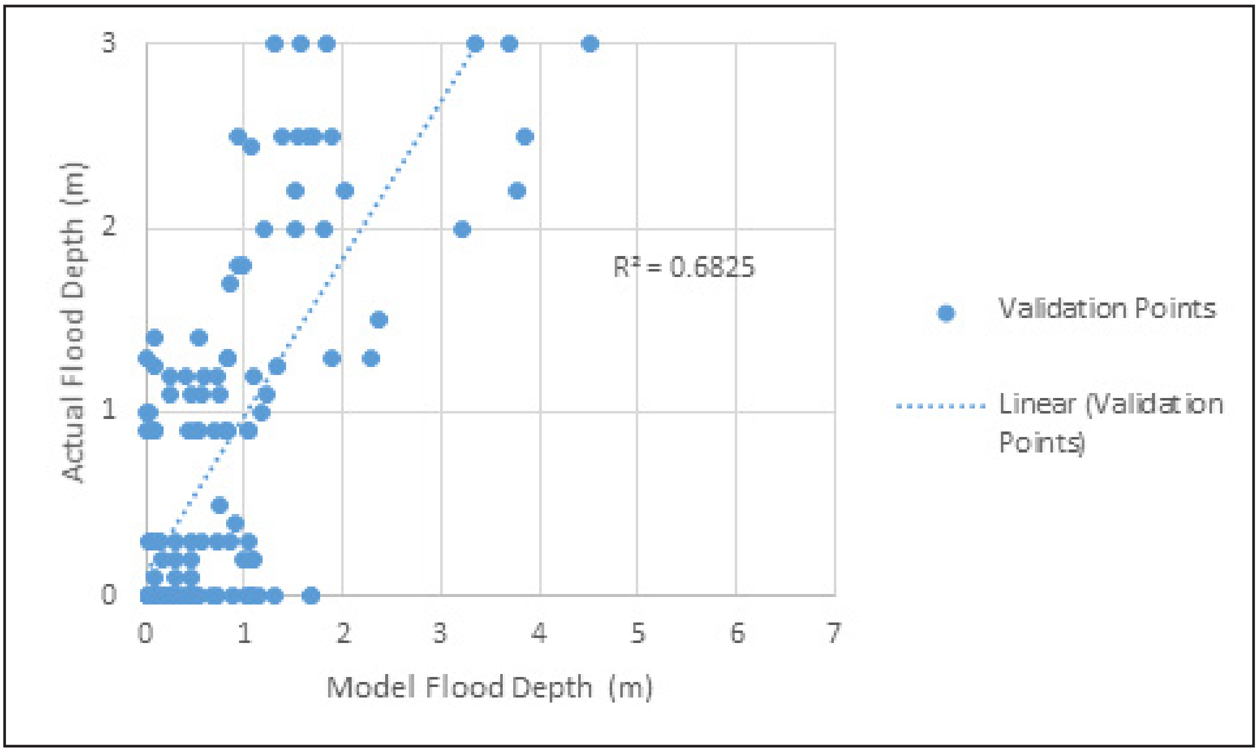


Figure 97. Flood map depth vs. actual flood depth

Table 59. Actual flood depth vs. simulated flood depth at different levels in the Sibalom 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	41	13	6	9	0	0	69
0.21-0.50	7	2	5	1	0	0	15
0.51-1.00	6	1	5	3	0	0	15
1.01-2.00	3	4	10	7	3	0	27
2.01-5.00	0	0	1	10	8	0	19
> 5.00	0	0	0	0	0	2	2
Total	57	20	27	30	11	2	147

The overall accuracy generated by the flood model is estimated at 44.22%, with sixty-five (65) points correctly matching the actual flood depths. In addition, there were fifty-one (51) points estimated one (1) level above and below the correct flood depths. Meanwhile, there were eighteen (18) points and twelve (12) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood depths, respectively. A total of four (4) points were overestimated, while a total of forty-two (42) points were underestimated in the modeled flood depths of Sibalom. Table 60 depicts the summary of the Accuracy Assessment in the Sibalom River Basin Survey.

Table 60. Summary of the Accuracy Assessment in the Sibalom River Basin Survey

No. of Points		%
Correct	65	44.22
Overestimated	40	27.21
Underestimated	42	28.57
Total	147	100.00

REFERENCES

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

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

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

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

ANNEXES

ANNEX 1. Technical Specifications of the LiDAR Sensors used in the Sibalom Floodplain Survey

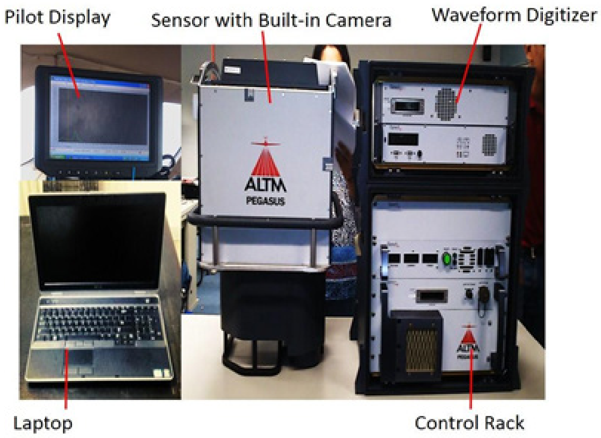

Figure A-1.1. Pegasus Sensor

Table A-1.1. Technical 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, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Vertical target separation distance	<0.7 m
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

1 Target reflectivity ≥20%
2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility
3 Angle of incidence ≤20˚
4 Target size ≥ laser footprint5 Dependent on system configuration

Table A-1.2. Technical specifications of the D-8900 Aerial Digital Camera

Parameter	Specification
Camera Head	
Sensor type	60 Mpix full frame CCD, RGB
Sensor format (H x V)	8, 984 x 6, 732 pixels
Pixel size	6µm x 6 µm
Frame rate	1 frame/2 sec.
FMC	Electro-mechanical, driven by piezo technology (patented)
Shutter	Electro-mechanical iris mechanism 1/125 to 1/500++ sec. f-stops: 5.6, 8, 11, 16
Lenses	50 mm/70 mm/120 mm/210 mm
Filter	Color and near-infrared removable filters
Dimensions (H x W x D)	200 x 150 x 120 mm (70 mm lens)
Weight	~4.5 kg (70 mm lens)
Controller Unit	
Computer	Mini-ITX RoHS-compliant small-form-factor embedded computers with AMD TurionTM 64 X2 CPU 4 GB RAM, 4 GB flash disk local storage IEEE 1394 Firewire interface
Removable storage unit	~500 GB solid state drives, 8,000 images
Power consumption	~8 A, 168 W
Dimensions	2U full rack; 88 x 448 x 493 mm
Weight	~15 kg
Image Pre-Processing Software	
Capture One	Radiometric control and format conversion, TIFF or JPEG
Image output	8,984 x 6,732 pixels 8 or 16 bits per channel (180 MB or 360 MB per image)

Figure A-1.2. Gemini Sensor

Table A-1.3. Technical 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

ANNEX 2. NAMRIA Certification of Reference Points used in the LiDAR Survey

1. 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

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

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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. ATQ-18

2. 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**	Barangay: **CONCEPCION**	
Municipality: **BELISON**	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

9903022015130958

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Figure A-2.2. ATQ-22

3. ILO-1

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

April 26, 2013

CERTIFICATION

To whom it may concern:

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

Province: **ILOILO**
Station Name: **ILO-1**
Order: **1st**

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

PRS92 Coordinates

Latitude: **10° 42' 40.81004"**	Longitude: **122° 33' 48.37076"**	Ellipsoidal Hgt: **25.91600 m.**

WGS84 Coordinates

Latitude: **10° 42' 36.46758"**	Longitude: **122° 33' 53.59289"**	Ellipsoidal Hgt: **83.43300 m.**

PTM Coordinates

Northing: **1184436.277 m.**	Easting: **452244.576 m.**	Zone: **4**

UTM Coordinates

Northing: **1,184,021.70**	Easting: **452,261.29**	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.

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **3943584 B**
T.N.: **2013-0359**

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

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

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

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

9904102014140459

CIF/4701/12/09/814

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.4. ILO-85

5. ILO-86

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-86**
Order: **2nd**

Island: **VISAYAS**		Barangay: **BARANGAY 3 POBLACION**
Municipality: **IGBARAS**		
	PRS92 Coordinates	
Latitude: **10º 43' 4.36044"**	Longitude: **122º 15' 48.62123"**	Ellipsoidal Hgt: **47.31500 m.**
	WGS84 Coordinates	
Latitude: **10º 42' 59.99043"**	Longitude: **122º 15' 53.84473"**	Ellipsoidal Hgt: **104.07600 m.**
	PTM Coordinates	
Northing: **1185222.285 m.**	Easting: **419435.758 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,184,807.44**	Easting: **419,463.96**	Zone: **51**

Location Description

ILO-86
From Iloilo City, travel W to the Mun. of Igbaras. Then proceed directly to the Town Plaza, where the station is located. Station is located about 12 m. from the circular fountain at the center of the said plaza.

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-86 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-837**

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

9904102014140516

CIP/4701/12/09/814

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Figure A-2.5. ILO-86

6. AQ-78

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: **AQ-78**

Island: **Visayas**	Municipality: **PATNONGON**	Barangay: **IPAYO**
Elevation: **10.6092 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude: **10° 54' 59.40000"**	Longitude: **121° 59' 52.10000"**	

Location Description

BM AQ-78
Station is located at the northwestern side of the side walk of Ipayo Bridge km. 122+244.79. Mark is the head of a 4in. copper nail set flush on a cement putty with inscriptions "AQ-78,2007,NAMRIA".

Requesting Party:	**PHIL-LIDAR 1**
Purpose:	**Reference**
OR Number:	**8077754 I**
T.N.:	**2015-0506**

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

9903022015131414

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Figure A-2.6. AQ-78

7. 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

9903022015131355

CIP/4701/12/09/814

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Figure A-2.7. IL-533

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

1. ILC-7B

Table A-3.1. ILC -7B

Vector Components (Mark to Mark)

From:	ILO-01				
Grid		Local		Global	
Easting	452261.660 m	Latitude	N10°42'40.74252"	Latitude	N10°42'36.40006"
Northing	1184019.629 m	Longitude	E122°33'48.38302"	Longitude	E122°33'53.60515"
Elevation	28.037 m	Height	28.936 m	Height	86.453 m

To:	ILC-7B				
Grid		Local		Global	
Easting	445449.752 m	Latitude	N10°46'44.10400"	Latitude	N10°46'39.73911"
Northing	1191504.286 m	Longitude	E122°30'03.73035"	Longitude	E122°30'08.94692"
Elevation	28.504 m	Height	29.088 m	Height	86.291 m

Vector					
ΔEasting	-6811.909 m	NS Fwd Azimuth	317°36'46"	ΔX	6504.524 m
ΔNorthing	7484.657 m	Ellipsoid Dist.	10124.106 m	ΔY	2495.750 m
ΔElevation	0.467 m	ΔHeight	0.152 m	ΔZ	7345.790 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000148601		
Y	-0.0000191728	0.0000349849	
Z	-0.0000053912	0.0000085457	0.0000038643

2. IIAP-01

Table A-3.2. IIAP-01

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
IIAP-01 --- ILO-85 (B1)	ILO-85	IIAP-01	Fixed	0.005	0.021	53°20'16"	35787.597	21.428
IIAP-01 --- ILO-85 (B2)	ILO-85	IIAP-01	Fixed	0.004	0.019	53°20'16"	35787.597	21.398

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	ILO-85				
Grid		Local		Global	
Easting	416256.319 m	Latitude	N10°38'33.11352"	Latitude	N10°38'28.75996"
Northing	1176484.099 m	Longitude	E122°14'03.70561"	Longitude	E122°14'08.93597"
Elevation	22.539 m	Height	21.962 m	Height	78.828 m

To:	IIAP-01				
Grid		Local		Global	
Easting	445007.365 m	Latitude	N10°50'08.21923"	Latitude	N10°50'03.83971"
Northing	1197773.997 m	Longitude	E122°29'48.82359"	Longitude	E122°29'54.03518"
Elevation	42.806 m	Height	43.390 m	Height	100.449 m

Vector					
ΔEasting	28751.046 m	NS Fwd Azimuth	53°20'16"	ΔX	-22136.041 m
ΔNorthing	21289.898 m	Ellipsoid Dist.	35787.597 m	ΔY	-18716.081 m
ΔElevation	20.268 m	ΔHeight	21.428 m	ΔZ	20987.226 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.009 m
σ ΔElevation	0.011 m	σ ΔHeight	0.011 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000339995		
Y	-0.0000470076	0.0000752539	
Z	-0.0000131643	0.0000196178	0.0000077986

ANNEX 4. The LIDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

<table>
<tr><th>Data Acquisition Component Sub-Team</th><th>Designation</th><th>Name</th><th>Agency/ Affiliation</th></tr>
<tr><td>PHIL-LIDAR 1</td><td>Program Leader</td><td>ENRICO C. PARINGIT, D.ENG</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Data Acquisition Component Leader</td><td rowspan="2">Data Component Project Leader – I</td><td>ENGR. CZAR JAKIRI SARMIENTO</td><td>UP-TCAGP</td></tr>
<tr><td>ENGR. LOUIE P. BALICANTA</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3">Survey Supervisor</td><td>Chief Science Research Specialist (CSRS)</td><td>ENGR. CHRISTOPHER CRUZ</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Supervising Science Research Specialist (Supervising SRS)</td><td>LOVELY GRACIA ACUNA</td><td>UP TCAGP</td></tr>
<tr><td>LOVELYN ASUNCION</td><td>UP TCAGP</td></tr>
<tr><td colspan="4">FIELD TEAM</td></tr>
<tr><td rowspan="5">LiDAR Operation</td><td>Senior Science Research Specialist (SSRS)</td><td>ENGR. GEROME B. HIPOLITO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="4">Research Associate (RA)</td><td>REGINA FELISMINO</td><td>UP-TCAGP</td></tr>
<tr><td>KRISTINE ANDAYA</td><td>UP-TCAGP</td></tr>
<tr><td>VERLINA TONGA</td><td>UP-TCAGP</td></tr>
<tr><td>REMEDIOS VILLANUEVA</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Ground Survey, Data Download and Transfer</td><td rowspan="2">RA</td><td>KENNETH QUISADO</td><td>UP-TCAGP</td></tr>
<tr><td>IRO ROXAS</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="5">LiDAR Operation</td><td>Airborne Security</td><td>SSG. RAYMUND DOMINE</td><td>PHILIPPINE AIR FORCE (PAF)</td></tr>
<tr><td rowspan="4">Pilot</td><td>CAPT. SHERWIN ALFONSO III</td><td rowspan="4">ASIAN AEROSPACE CORPORATION (AAC)</td></tr>
<tr><td>CAPT. FERDINAND DE OCAMPO</td></tr>
<tr><td>CAPT. BRYAN DONGUINES</td></tr>
<tr><td>CAPT. JUSTINE JOYA</td></tr>
</table>

ANNEX 5. Data Transfer Sheets for the Sibalom Floodplain Flights

DATA TRANSFER SHEET

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	
16-Feb-15	2566G	2BLK37V047A	gemini	na	1517	1.13	209	25	206	13	1.36	10.7	1KB	1KB	13	13	Z:\DAC\RAW DATA
16-Feb-15	2568G	2BLK37GSIV047B	gemini	na	952	1.34	222	46.8	383	21.9	2.12	6.81	1KB	1KB	7/4	15/12	Z:\DAC\RAW DATA
17-Feb-15	2570G	2BLK43H048A	gemini	na	1078	1.43	222	40.5	342	21.7	3.4	14.4	1KB	1KB	3	3	Z:\DAC\RAW DATA
19-Feb-15	2578G	2BLK43GV050A	gemini	na	586	851	184	8.07	67.8	10.4	na	11.1	1KB	1KB	7	na	Z:\DAC\RAW DATA
19-Feb-15	2580G	2BLK43F050B	gemini	na	740	950	163	25.6	203	16.2	3.29	4.11	1KB	1KB	4	8	Z:\DAC\RAW DATA
20-Feb-15	2582G	2BLK43A051A	gemini	na	169	284	106	6.84	87.4	4.65	na	11	1KB	1KB	6	13	Z:\DAC\RAW DATA
21-Feb-15	2586G	2BLK43A052A	gemini	na	613	675	182	15.4	63.9	8.3	1.43	11.5	1KB	1KB	5	10	Z:\DAC\RAW DATA
22-Feb-15	2590G	2BLK43A053A	gemini	na	694	0.97	198	21.2	54.4/628	12.1	na	17	1KB	1KB	5	10	Z:\DAC\RAW DATA
23-Feb-15	2594G	2BLK43C054A	gemini	na	856	1.05	240	26.2	17.2/183	16.3	na	11.6	1KB	1KB	6	14	Z:\DAC\RAW DATA

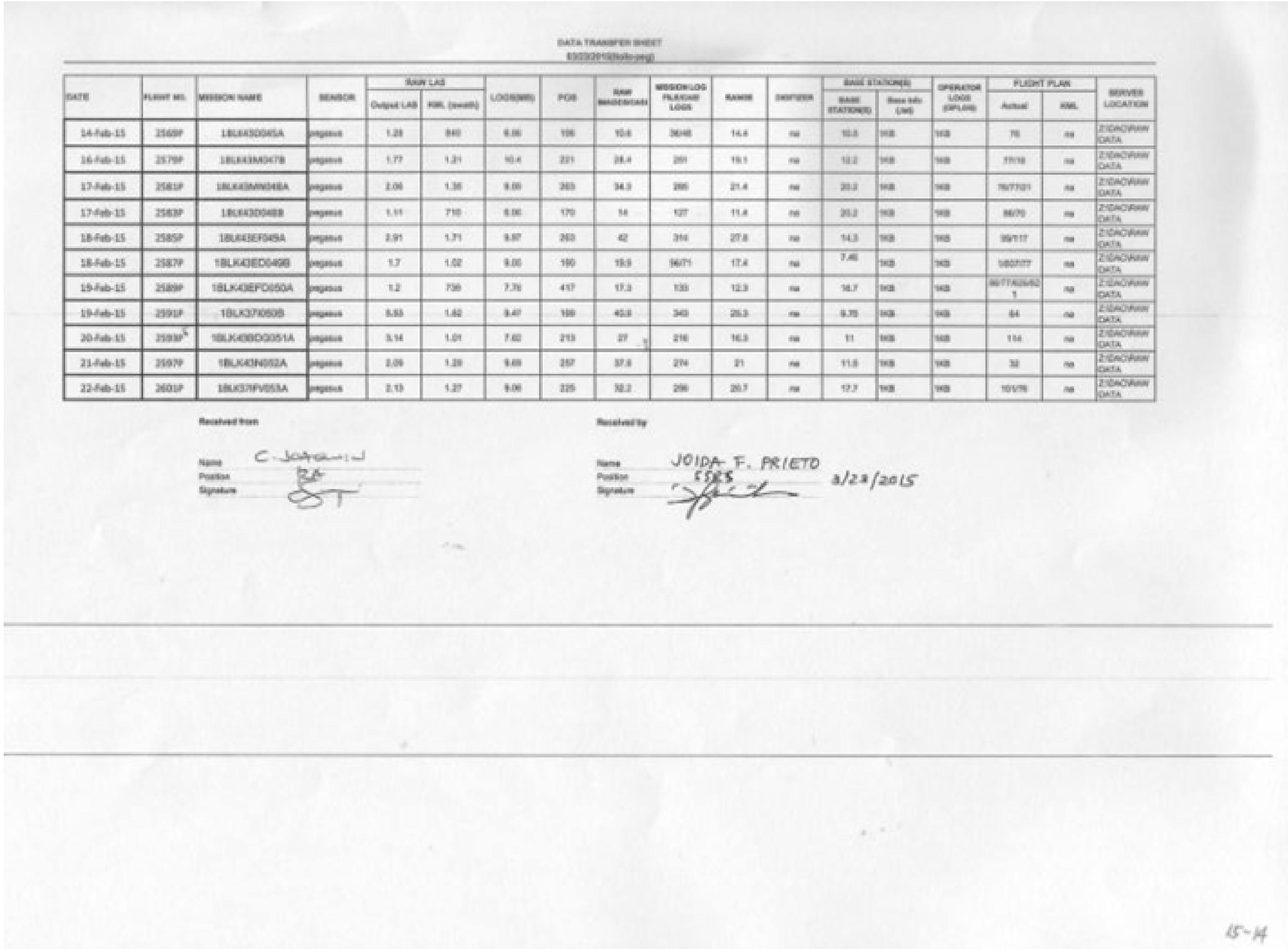
Received from

Name C. [illegible]
Position FA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature
3/23/2015

Figure A-5.1. Data Transfer Sheet for Sibalom Floodplain – A



DATA TRANSFER SHEET
03/23/2015(Iloilo-pegi)

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	156	10.6	36/48	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	201	19.1	na	12.2	1KB	1KB	77/18	na	Z:\DAC\RAW DATA
17-Feb-15	2581P	1BLK43MNO48A	pegasus	2.06	1.38	9.05	263	34.3	286	21.4	na	20.2	1KB	1KB	76/77/21	na	Z:\DAC\RAW DATA
17-Feb-15	2583P	1BLK43DO48B	pegasus	1.11	710	6.06	170	14	127	11.4	na	20.2	1KB	1KB	86/70	na	Z:\DAC\RAW DATA
18-Feb-15	2585P	1BLK43EFO49A	pegasus	2.91	1.71	9.87	263	42	314	27.8	na	14.3	1KB	1KB	95/117	na	Z:\DAC\RAW DATA
18-Feb-15	2587P	1BLK43EDO49B	pegasus	1.7	1.02	9.05	190	19.9	96/71	17.4	na	7.46	1KB	1KB	180/177	na	Z:\DAC\RAW DATA
19-Feb-15	2589P	1BLK43EFO50A	pegasus	1.2	736	7.76	417	17.3	133	12.3	na	16.7	1KB	1KB	86/77/82/82 1	na	Z:\DAC\RAW DATA
19-Feb-15	2591P	1BLK37IO50B	pegasus	5.55	1.62	8.47	169	40.8	343	25.3	na	8.75	1KB	1KB	84	na	Z:\DAC\RAW DATA
20-Feb-15	2593P	1BLK43BDO51A	pegasus	3.14	1.01	7.62	213	27	216	16.3	na	11	1KB	1KB	114	na	Z:\DAC\RAW DATA
21-Feb-15	2597P	1BLK43NO52A	pegasus	2.09	1.28	9.69	257	37.8	274	21	na	11.8	1KB	1KB	32	na	Z:\DAC\RAW DATA
22-Feb-15	2601P	1BLK37IFVO53A	pegasus	2.13	1.27	9.06	225	32.2	298	20.7	na	17.7	1KB	1KB	101/76	na	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position RA
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 3/23/2015

15-14

Figure A-5.2. Data Transfer Sheet for Sibalom Floodplain – B

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	12[illegible]	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	10[illegible]	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	[illegible]	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. J[illegible]
Position
Signature

Received by
Name [illegible] Carlo Bragat
Position [illegible]
Signature

Figure A-5.3. Data Transfer Sheet for Sibalom Floodplain – C

ANNEX 6. Flight logs for the flight missions

1. Flight Log for 2522G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2522

1 LIDAR Operator: M V E Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK43LK036A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: Iloilo			
10 Date: 05 FEB 15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province): Iloilo		
13 Engine On: 08:40	14 Engine Off: 13:9	15 Total Engine Time: 4+29	16 Take off: 08:45	17 Landing: 13:04	18 Total Flight Time: 4+19
19 Weather: Fair					

20 Remarks:

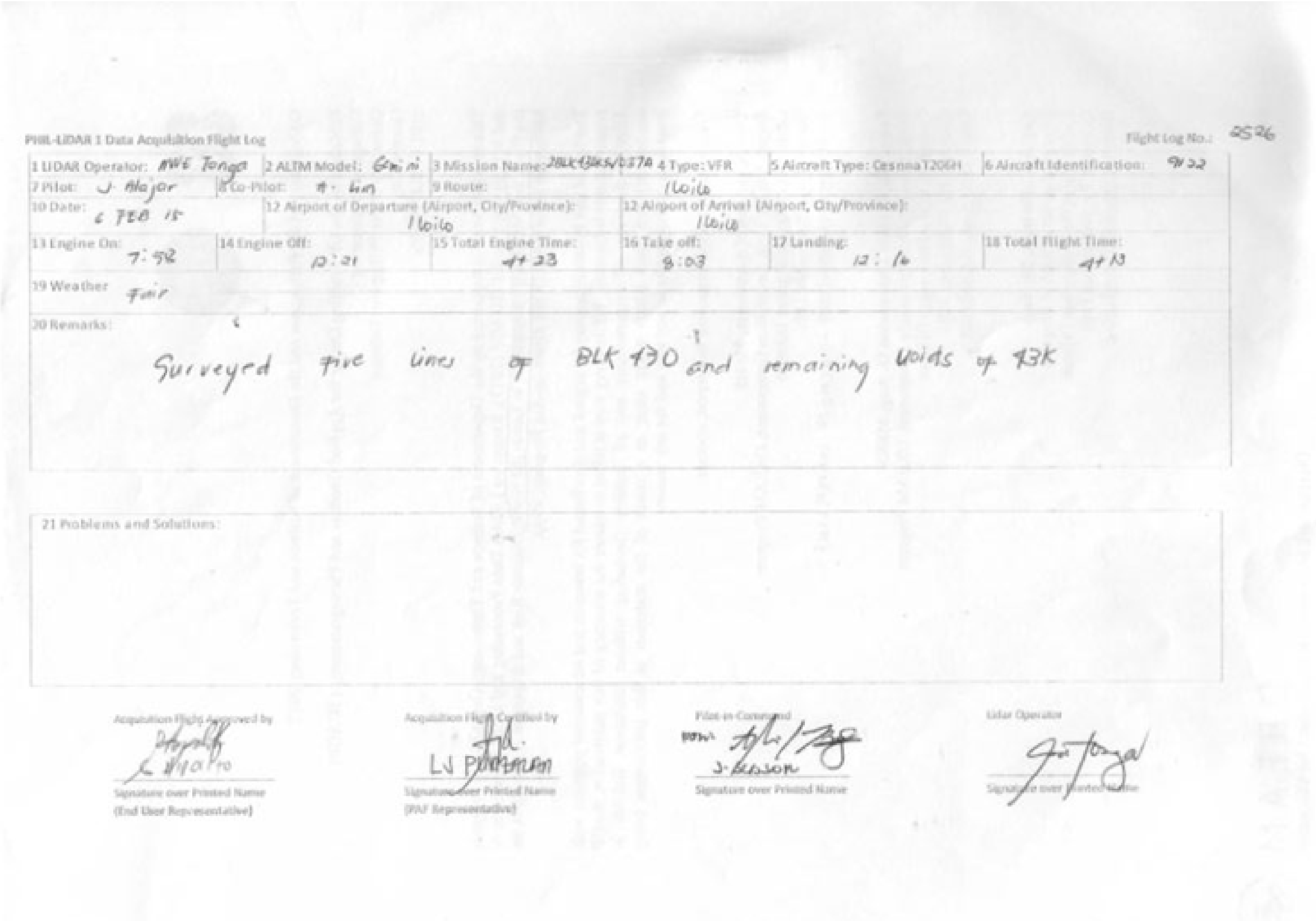
Mission completed for BLK 43L and surveyed 10 Lines of BLK 43K

21 Problems and Solutions:

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

Figure A-6.1. Flight Log for Mission 2522G

2. Flight Log for 2526G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2526

1 LIDAR Operator: AWE Tonga	2 ALTM Model: Gemini	3 Mission Name: [illegible]	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: 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: L. Magalto — Signature over Printed Name (End User Representative)

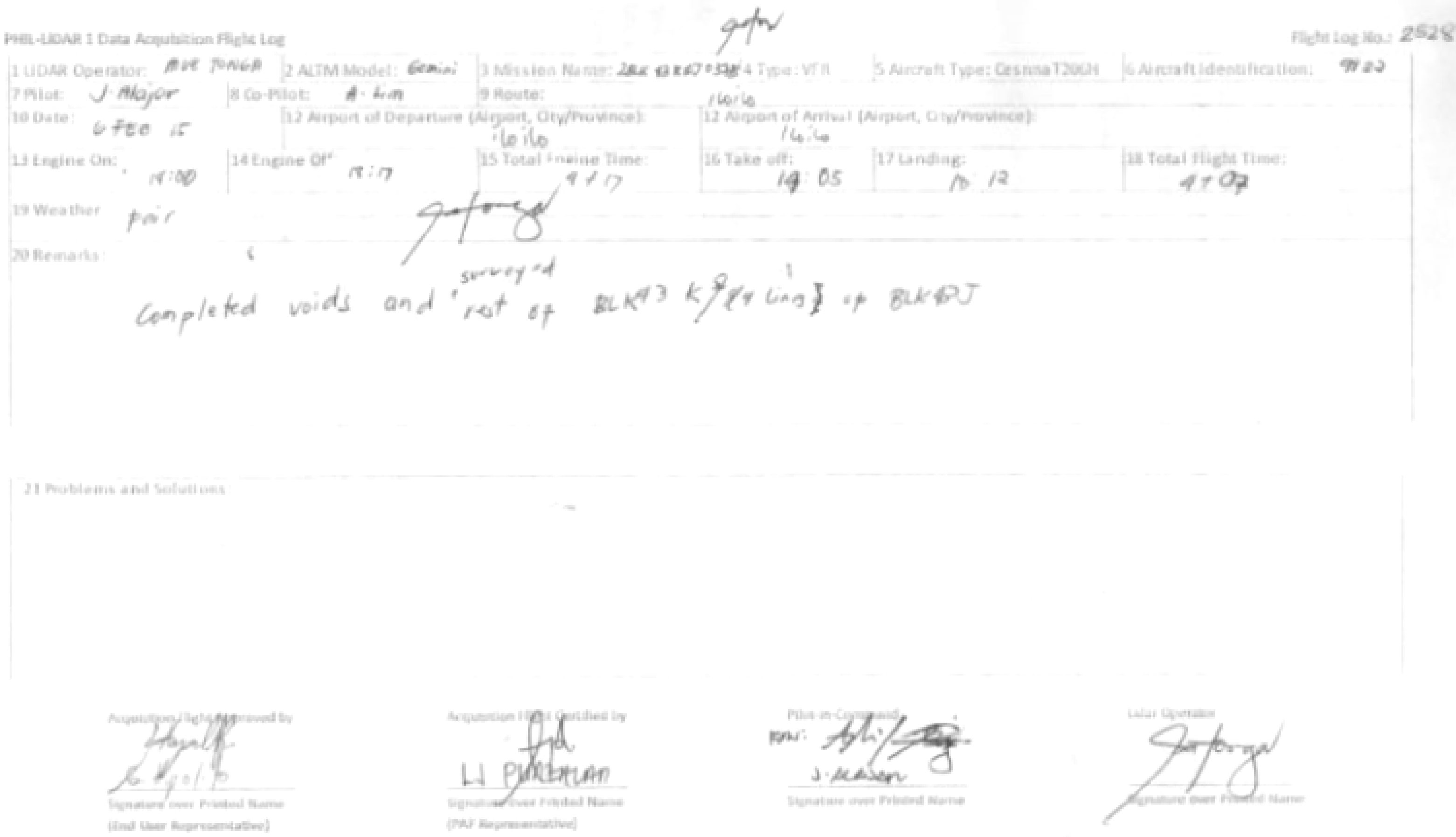
Acquisition Flight Certified by: LJ Pinlaman — Signature over Printed Name (PAF Representative)

Pilot-in-Command: J. Alajar — Signature over Printed Name

Lidar Operator: Signature over Printed Name

Figure A-6.2. Flight Log for Mission 2526G

3. Flight Log for 2528G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2528

1 LiDAR Operator: AVE TONGA	2 ALTM Model: Gemini	3 Mission Name: 2BLK 43 K47 0	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajor	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: 14:00	14 Engine Off: 18:17	15 Total Engine Time: 4+17	16 Take off: 14:05	17 Landing: 18:12	18 Total Flight Time: 4+07
19 Weather: fair					

20 Remarks:

Completed voids and surveyed rest of BLK43 K (4 lines) of BLK43J

21 Problems and Solutions

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

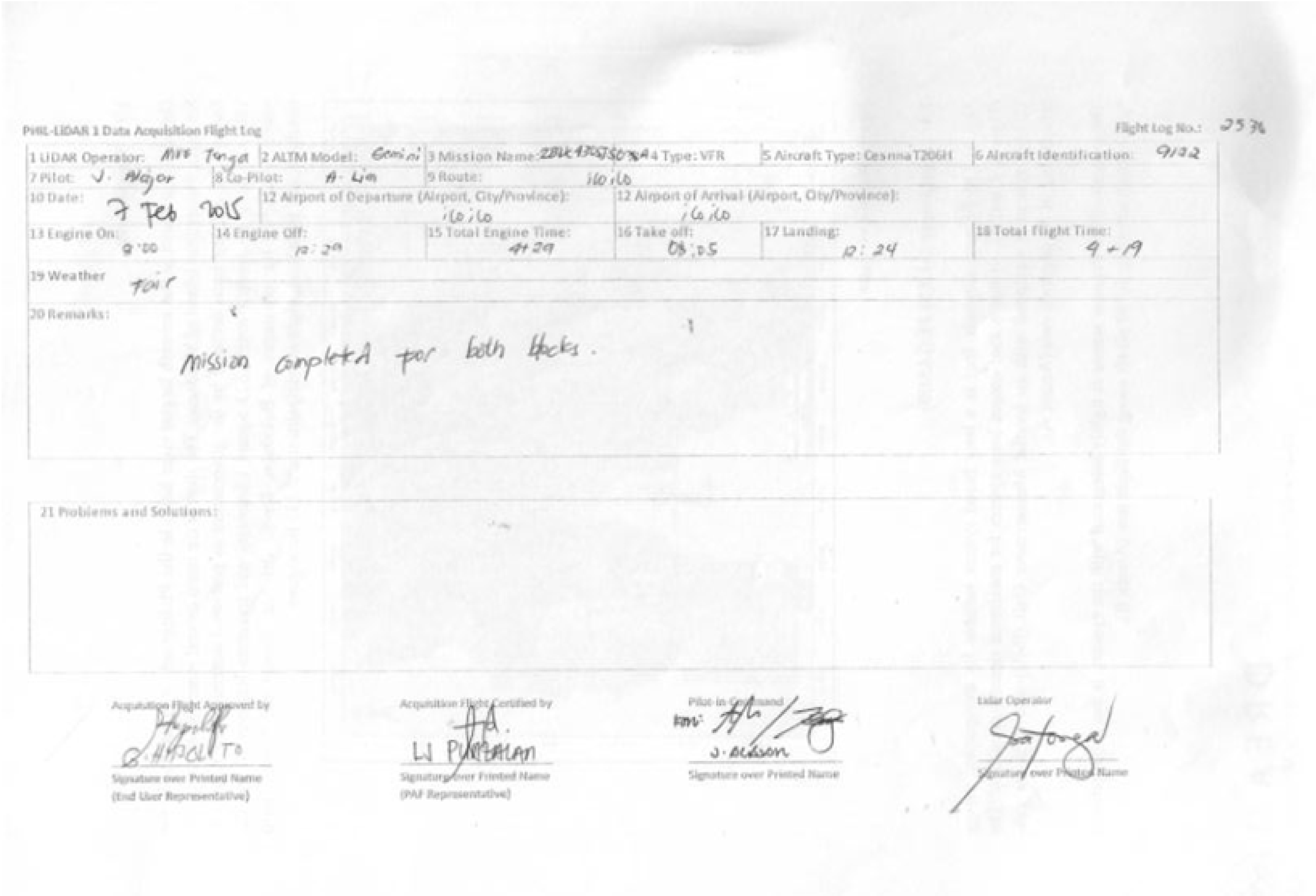
Acquisition Flight Certified by — LJ Pakaman — Signature over Printed Name (PAF Representative)

Pilot-in-Command — J. Alajor — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.3. Flight Log for Mission 2528G

4. Flight Log for 2530G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2536

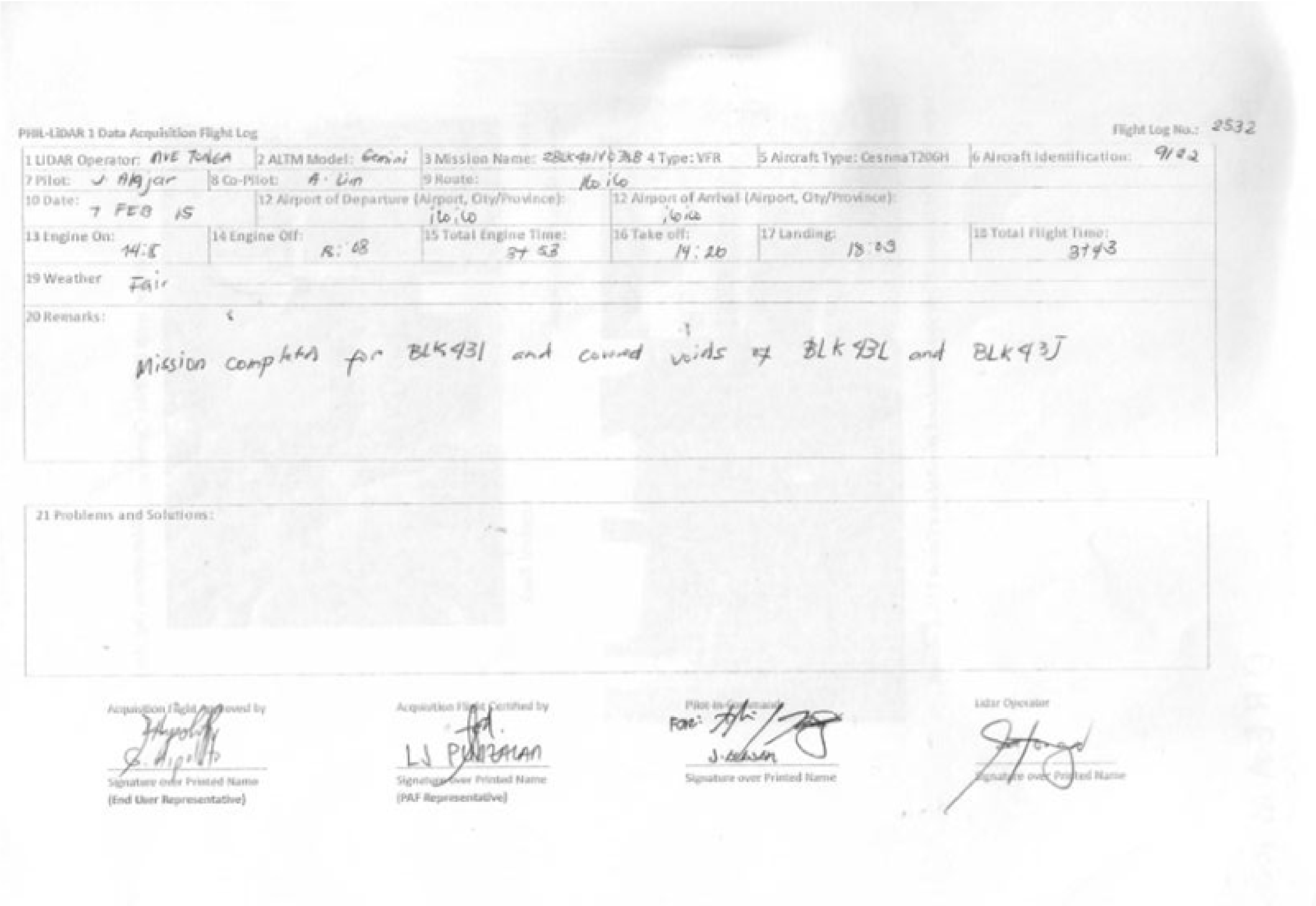
1 LIDAR Operator: Mre Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK47GJS036A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajor	8 Co-Pilot: A. Lim	9 Route: Iloilo			
10 Date: 7 Feb 2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of 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	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. HIPOLITO	LJ PUNZALAN	J. ALAJOR	M. Tonga
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.4. Flight Log for Mission 2530G

5. Flight Log for 2532G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2532

1 LIDAR Operator: AVE TONGA	2 ALTM Model: Gemini	3 Mission Name: 2BLK43IVC38B	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: 7 FEB 15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province): Iloilo		
13 Engine On: 14:15	14 Engine Off: 18:08	15 Total Engine Time: 3+53	16 Take off: 14:20	17 Landing: 18:03	18 Total Flight Time: 3+43
19 Weather: Fair					

20 Remarks:

Mission completed for BLK43I and covered voids of BLK43L and BLK43J

21 Problems and Solutions:

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

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

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

Lidar Operator — Signature over Printed Name

Figure A-6.5. Flight Log for Mission 2532G

6. Flight Log for 2550G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2550

1 LiDAR Operator: RA Feliciano	2 ALTM Model: Gemini	3 Mission Name: 2BLK37...	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: 8:24	17 Landing: 12:19	18 Total Flight Time: 3+55
19 Weather: Cloudy					

20 Remarks:

Surveyed three lines for both blocks of 38? and 37N and filled void of BLK 43 O

21 Problems and Solutions:

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

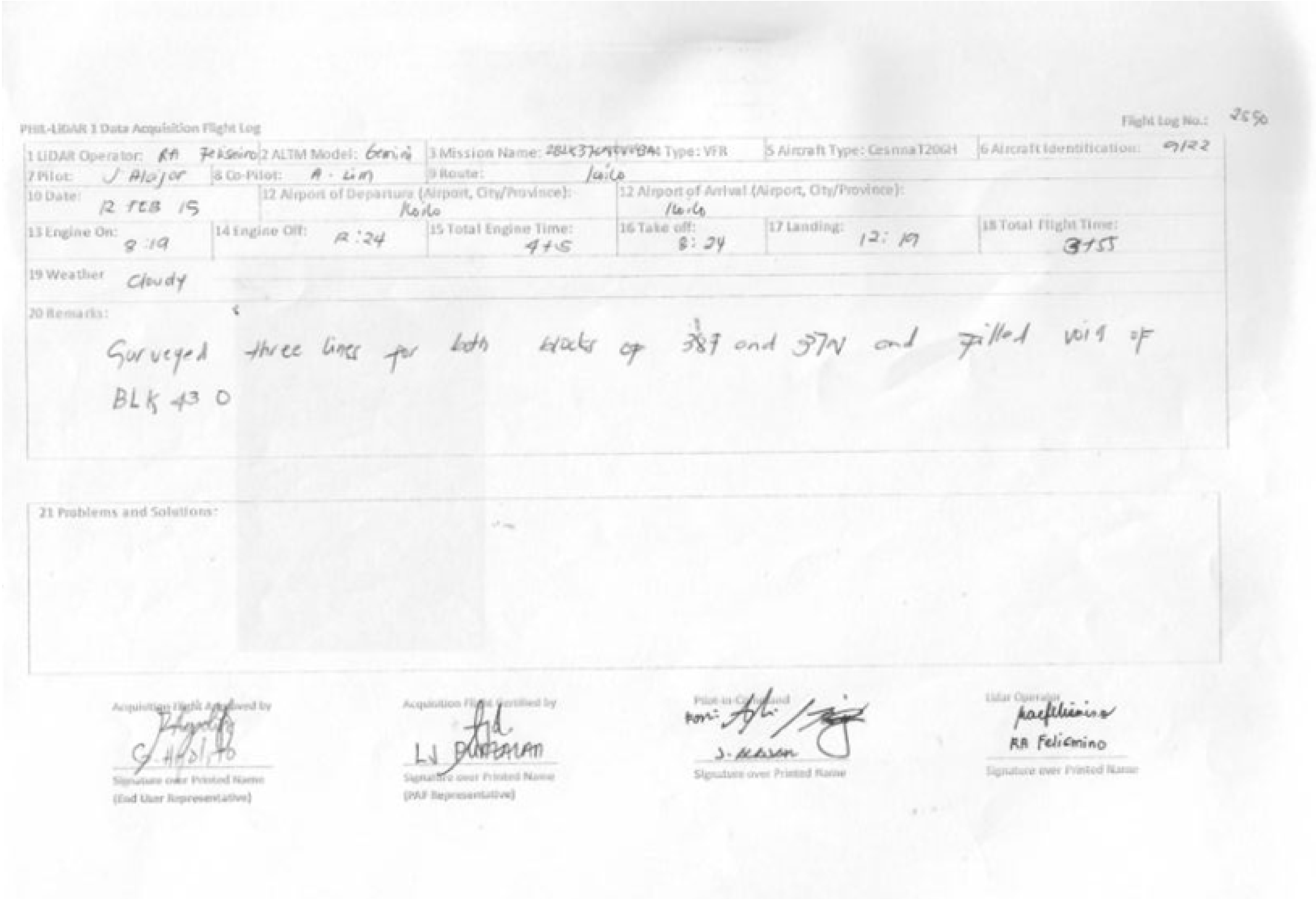
Acquisition Flight Certified by
LJ Dumalan
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
J. Alajar
Signature over Printed Name

Lidar Operator
RA Feliciano
Signature over Printed Name

Figure A-6.6. Flight Log for Mission 2550G

7. Flight Log for 2558G Mission


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2550

1 LiDAR Operator: RA Feliciano	2 ALTM Model: Gemini	3 Mission Name: 2BLK37...	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: 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: 8:24	17 Landing: 12:19	18 Total Flight Time: 3+55
19 Weather: Cloudy					

20 Remarks:

Surveyed three lines for both blocks of 38T and 37N and filled void of BLK 43 O

21 Problems and Solutions:

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

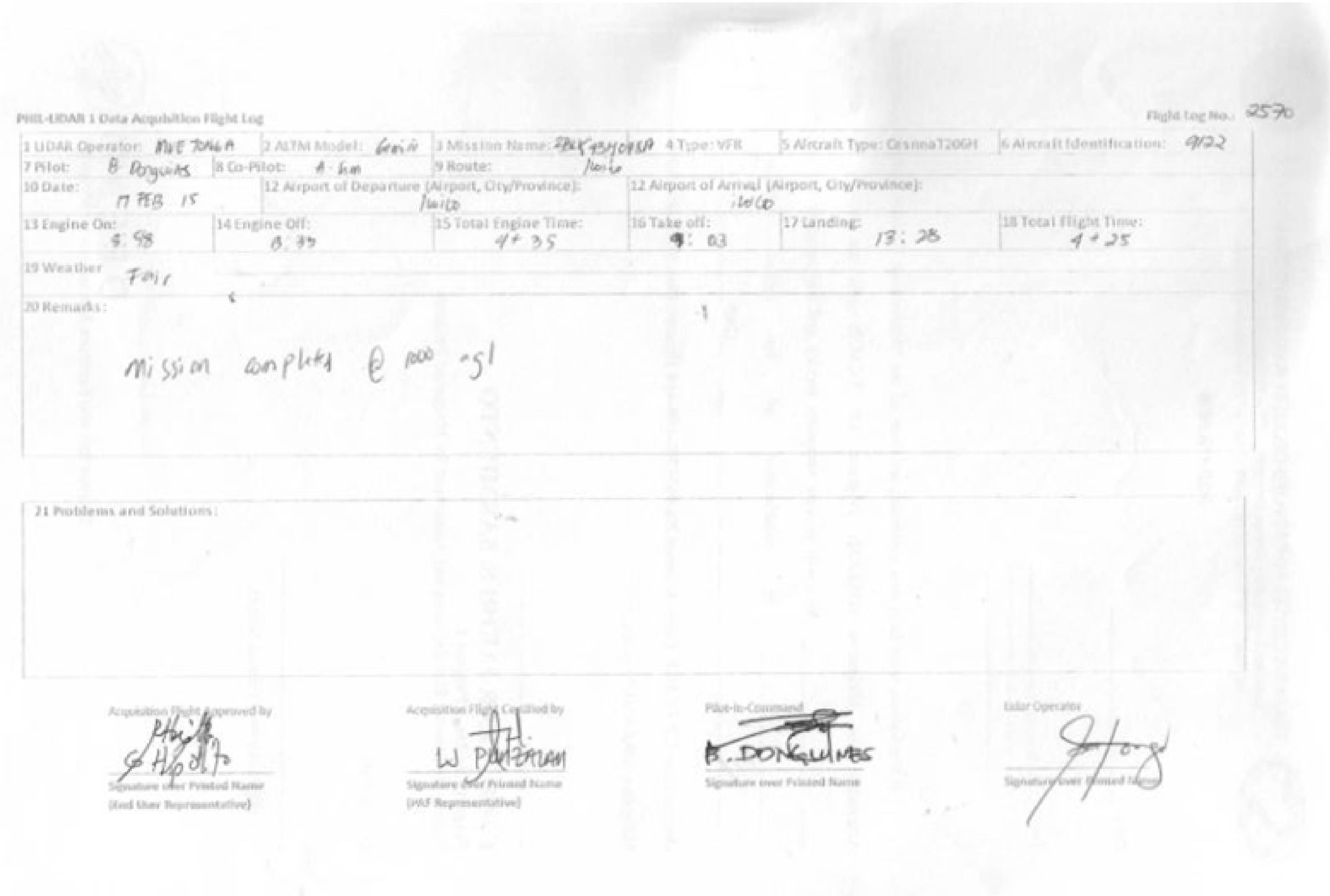
Acquisition Flight Certified by: LJ Dumagan — Signature over Printed Name (PAF Representative)

Pilot-in-Command: J. Alajar — Signature over Printed Name

Lidar Operator: RA Feliciano — Signature over Printed Name

Figure A-6.7. Flight Log for Mission 2558G

8. Flight Log for 2570G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2570

1 LIDAR Operator: MVE TONGA	2 ALTM Model: Gemini	3 Mission Name: 2BLK45MOB48A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: B. Donguines	8 Co-Pilot: A. Lim	9 Route: Iloilo			
10 Date: 17 FEB 15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province): Iloilo		
13 Engine On: 8:58	14 Engine Off: 13:33	15 Total Engine Time: 4+35	16 Take off: 9:03	17 Landing: 13:28	18 Total Flight Time: 4+25
19 Weather: Fair					

20 Remarks:

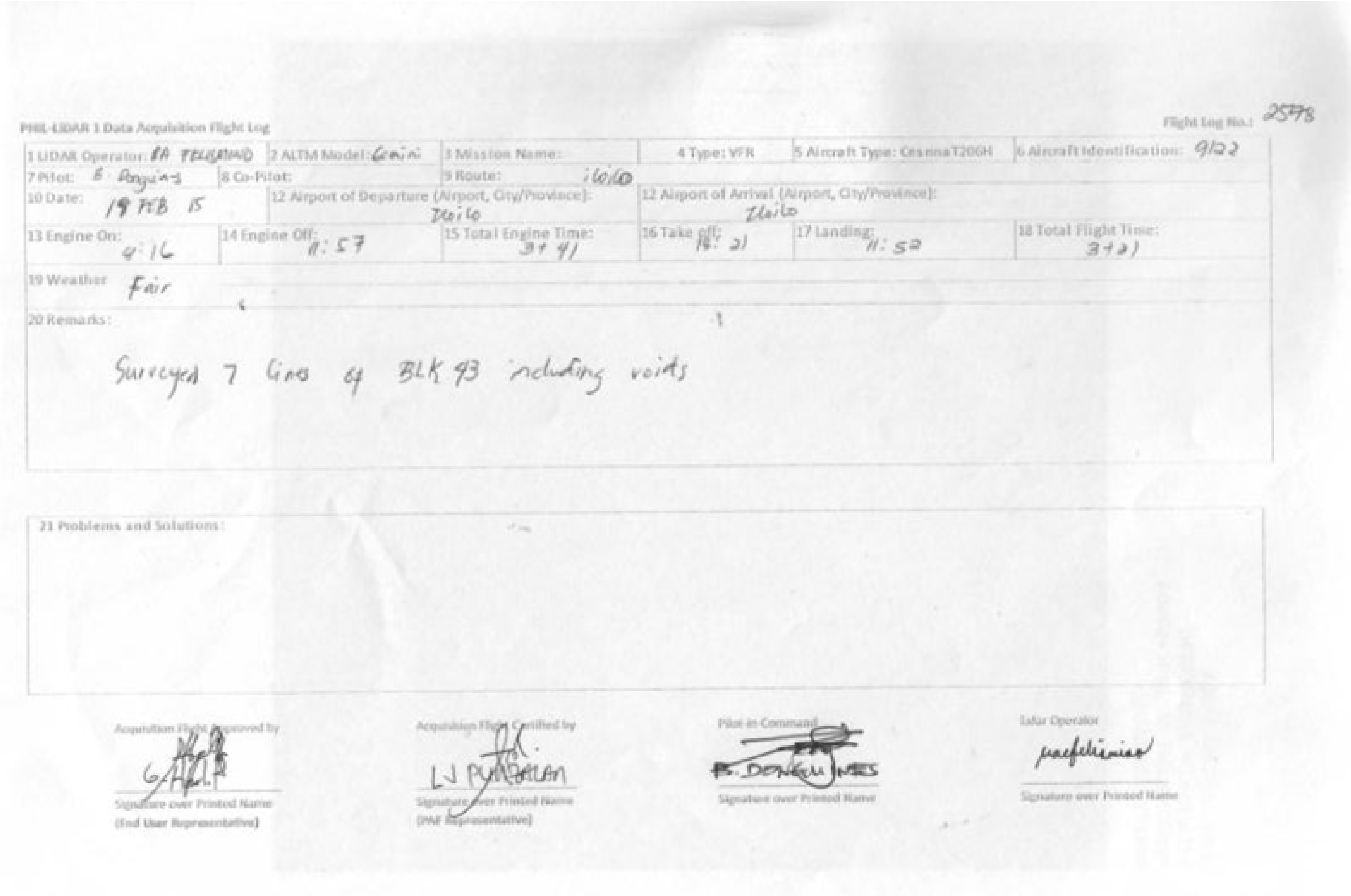
Mission completed @ 1000 agl

21 Problems and Solutions:

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

Figure A-6.8. Flight Log for Mission 2570G

9. Flight Log for 2578G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2578

1 LIDAR Operator: BA FELISMINO	2 ALTM Model: Gemini	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: B. Dongui-as	8 Co-Pilot:	9 Route: iloilo			
10 Date: 19 FEB 15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province): Iloilo		
13 Engine On: 4:16	14 Engine Off: 11:57	15 Total Engine Time: 3+41	16 Take off: 18:21	17 Landing: 11:52	18 Total Flight Time: 3+31
19 Weather: Fair					

20 Remarks:

Surveyed 7 lines of BLK 93 including voids

21 Problems and Solutions:

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

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

Pilot-in-Command: B. Dongui-ines — Signature over Printed Name

Lidar Operator: — Signature over Printed Name

Figure A-6.9. Flight Log for Mission 2578G

10. Flight Log for 2593P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2593

1 LiDAR Operator: I. Roxas
2 ALTM Model: Pegasus
3 Mission Name: 1BLK43BDG051A
4 Type: VFR
5 Aircraft Type: CesnnaT206H
6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso
8 Co-Pilot: J. Joyd
9 Route:
10 Date: 02 - 20 - 2015
12 Airport of Departure (Airport, City/Province): Iloilo
12 Airport of Arrival (Airport, City/Province):
13 Engine On: 1341
14 Engine Off: 1710
15 Total Engine Time: 3+29
16 Take off:
17 Landing:
18 Total Flight Time:
19 Weather: fair

20 Remarks:

Surveyed BLK 43B and voids over BLK 43D and 43G.

21 Problems and Solutions:

Acquisition Flight Approved by
E. Nepol, fo
Signature over Printed Name
(End User Representative)

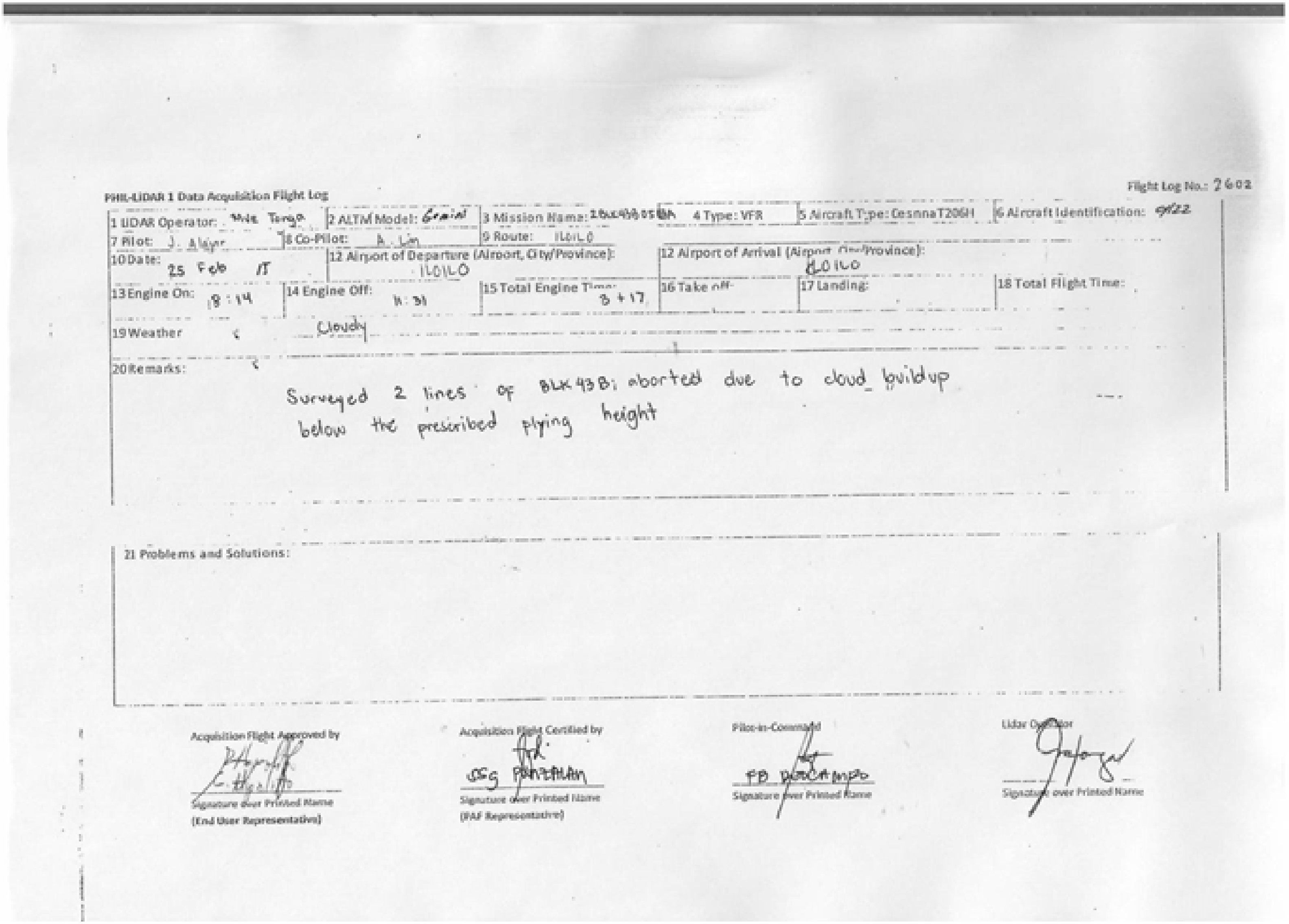
Acquisition Flight Certified by
LJ Puyataan
Signature over Printed Name
(PAF Representative)

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

Lidar Operator
I. Roxas
Signature over Printed Name

Figure A-6.10. Flight Log for Mission 2593P

11. Flight Log for 2602G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2602

1 LiDAR Operator: Mie Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK43B056A	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: 25 Feb 15	12 Airport of Departure (Airport, City/Province): ILOILO		12 Airport of Arrival (Airport, City/Province): ILOILO		
13 Engine On: 8:14	14 Engine Off: 11:31	15 Total Engine Time: 3+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Surveyed 2 lines of BLK 43B; aborted due to cloud buildup below the prescribed flying height

21 Problems and Solutions:

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

Figure A-6.11. Flight Log for Mission 2602G

12. Flight Log for 2606G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2617

1 LiDAR Operator: KJ Andaya	2 ALTM Model: Pegasus	3 Mission Name: 1BLK37OP057A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9022
7 Pilot: F. De Ocampo	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 02 - 26 - 2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1317	14 Engine Off: 1750	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					
20 Remarks: Surveyed voids over BLK 37O and 37P.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
	LJ Pugeman	F. De Ocampo	KJ Andaya
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.12. Flight Log for Mission 2606G

13. Flight Log for 2617P Mission

PLACEHOLDER

Figure A-6.13. Flight Log for Mission 2617P

14. Flight Log for 2621P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2621

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK37P058A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9022
7 Pilot: F. De Ocampo	8 Co-Pilot: J. Joyo	9 Route:			
10 Date: 02-27-2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1326	14 Engine Off: 1724	15 Total Engine Time: 3+58	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

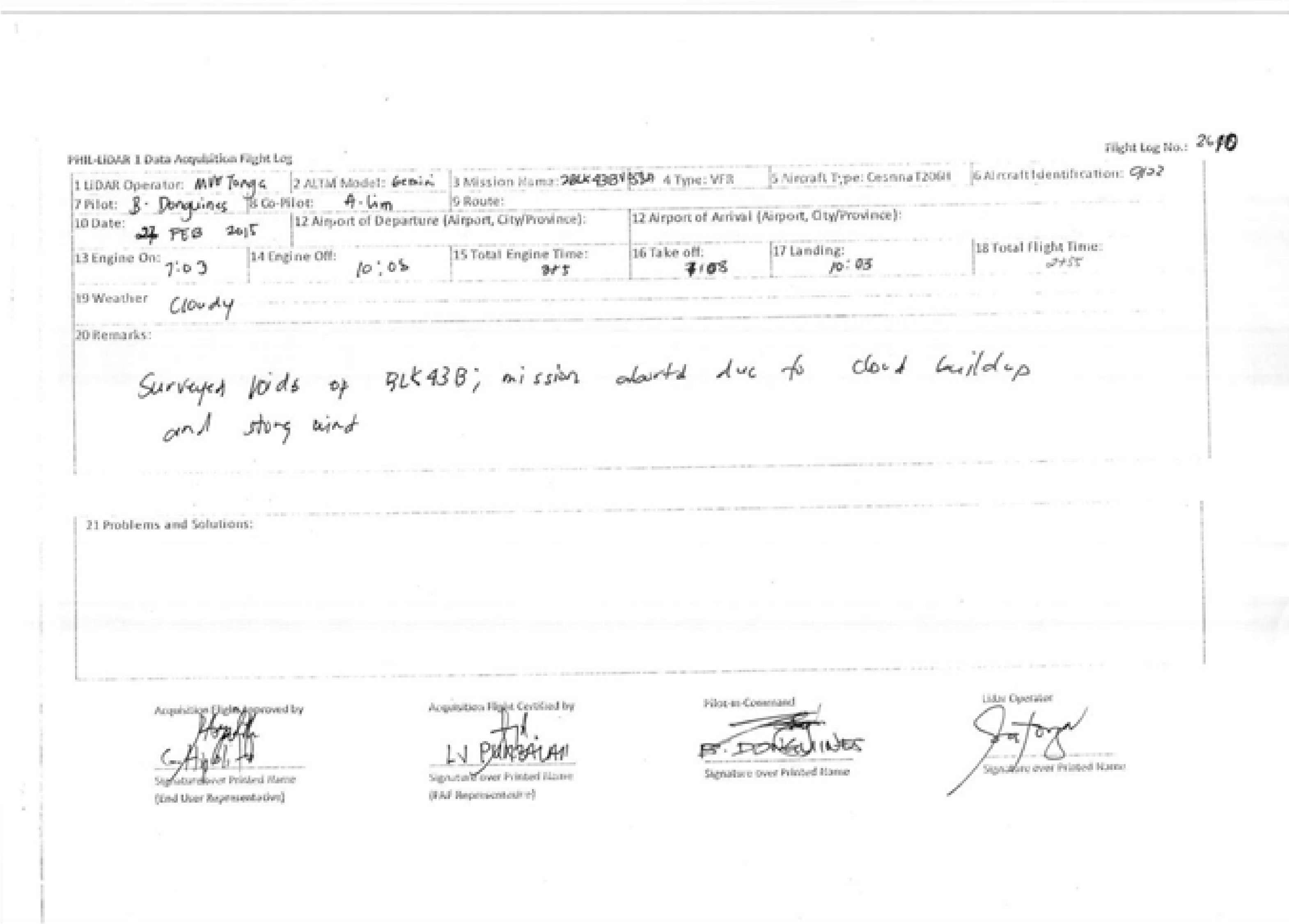
Completed BLK 37P.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
C. Hipolito	LJ Puntalan	FP De Ocampo	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.14. Flight Log for Mission 2621P

15. Flight Log for 2610G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2610

1 LiDAR Operator: MV Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK43B58A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: B. Donguines	8 Co-Pilot: A. Lim	9 Route:			
10 Date: 27 FEB 2015	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 7:03	14 Engine Off: 10:08	15 Total Engine Time: 3+5	16 Take off: 7:08	17 Landing: 10:03	18 Total Flight Time: 2+55
19 Weather: Cloudy					

20 Remarks:

Surveyed voids of BLK43B; mission aborted due to cloud buildup and strong wind

21 Problems and Solutions:

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

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

Pilot-in-Command: B. DONGUINES — Signature over Printed Name

Lidar Operator: Signature over Printed Name

Figure A-6.15. Flight Log for Mission 2610G

ANNEX 7. Flight status reports

Table A-7.1. Flight Status Report

FLIGHT STATUS REPORT
ILOILO
FEBRUARY 5 - 27, 2015

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2522G	BLK43L & 43K	2BLK43LK036A	MVE TONGA & RA FELISMINO	February 5, 2015	Mission completed FOR BLK43L and surveyed 10 lines of BLK23K
2526G	BLK43K, 43O & 43L	2BLK43OKSV037A	MVE TONGA & RA FELISMINO	February 6, 2015	Surveyed five (5) lines of BLK43O, two lines of BLK43K and voids of BLK43L
2528G	BLK43L	2BLK43KSJ037B	MVE TONGA & RA FELISMINO	February 6, 2015	Completed voids and rest of BLK43K and four (4) lines of BLK43J
2530G	BLK43J & 43O	2BLK43OSJS038A	MVE TONGA & RA FELISMINO	February 7, 2015	Mission completed for both blocks
2532G	BLK43I	2BLK43IV038B	MVE TONGA & RA FELISMINO	February 7, 2015	Mission completed for BLK43I and covered voids of BLK43L and BLK43J
2550G	BLK43G, 37N & 37O	2BLK37GNOV43A	RA FELISMINO	February 12, 2015	Surveyed 3 lines for BLK37F & 37N, filled voids of 43O
2558G	BLK43G	2BLK43 G045A	RA FELISMINO	February 14, 2015	2 lines in BLK43N, with voids
2570G	BLK43H	2BLK43 H048A	MVE TONGA	February 17, 2015	Mission complete at 1000m AGL
2578G	BLK43G	2BLK43 GV050A	RA FELISMINO	February 19, 2015	Surveyed 7 lines of BLK 43G including voids
2593P	BLK43B, 43D & 43G	1BLK43BDG051A	IRO ROXAS	February 20, 2015	Surveyed BLK43B and voids on BLK 43D and 43G
2602G	BLK 43B	2BLK43B056A	MVE TONGA	25 FEB 15	Surveyed 2 lines of BLK43B; aborted due to cloud buildup below the prescribed flying height
2606G	BLK 43B	2BLK43BV057A	RA FELISMINO	26 FEB 15	Surveyed 10 lines of BLK43B
2610G	BLK 43B, 43C	2BLK43BV058A	MVE TONGA	27 FEB 15	Surveyed voids of BLK43B; mission aborted due to cloud buildup and strong wind
2617P	BLK37O & 37P	1BLK37P058A	KJ ANDAYA	February 26, 2015	Surveyed voids over BLK 37P and finish BLK 37O
2621G	BLK37P	1BLK37P058A	IRO ROXAS	February 27, 2015	Completed BLK 37P

LAS BOUNDARIES PER FLIGHT

Flight No.:	2522G
Area:	BLK 43L & 43K
Mission Name:	2BLK43LK036A
Parameters:	Altitude: 1100; Scan Frequency: 50; Scan Angle: 25; Overlap: 30%

LAS

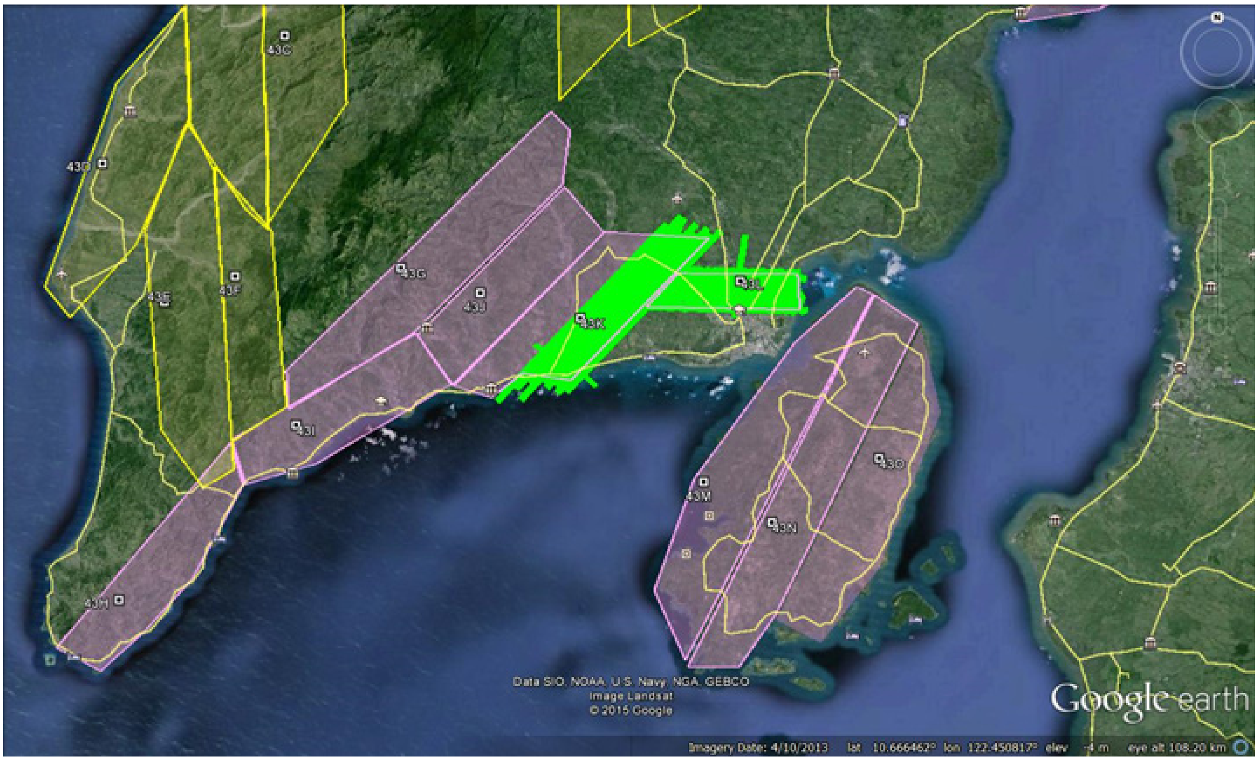


Figure A-7.1. Swath for Flight No. 2522G

Flight No.:	2526G
Area:	BLK 43K, 43O & 43L
Mission Name:	2BLK43OKSV037A
Parameters:	Altitude: 1100; Scan Frequency: 50; Scan Angle: 25; Overlap: 30%

LAS

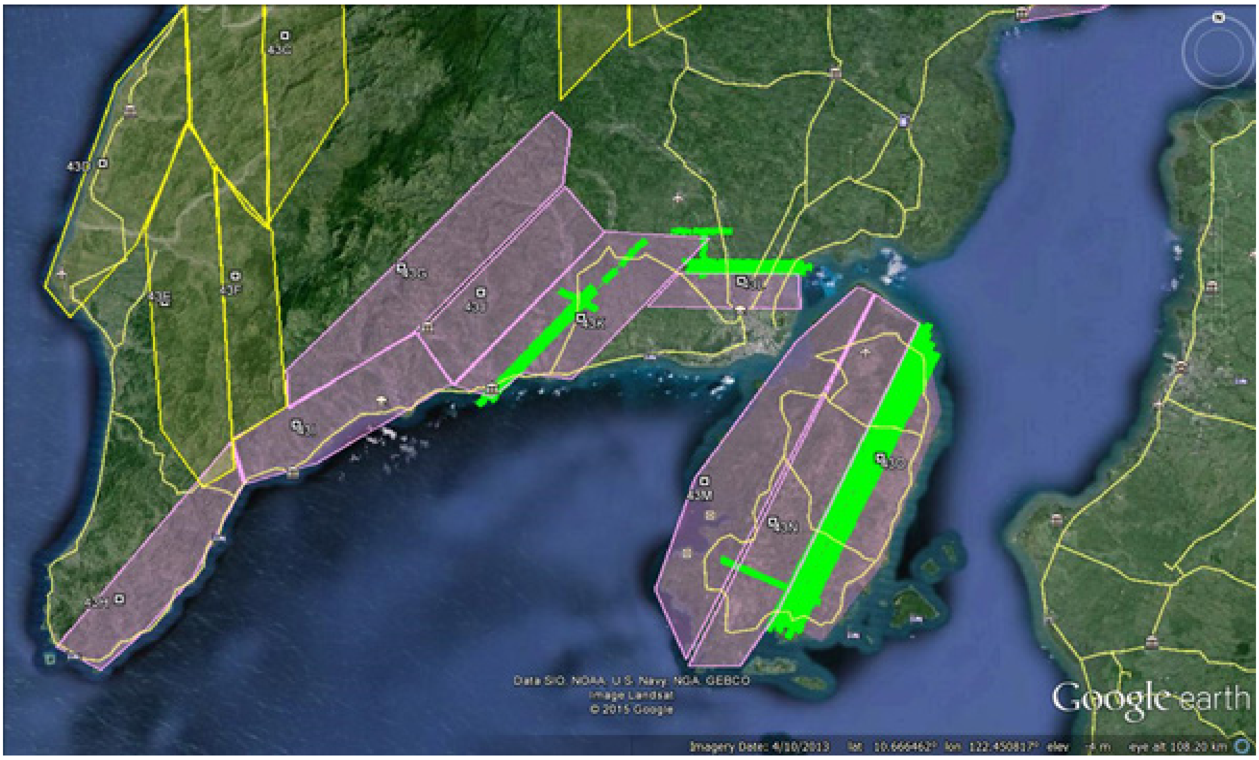


Figure A-7.2. Swath for Flight No. 2526G

Flight No.:	2528G
Area:	BLK 43L
Mission Name:	2BLK43KSJ037B
Parameters:	Altitude: 1100; Scan Frequency: 50; Scan Angle: 20; Overlap: 30%

LAS

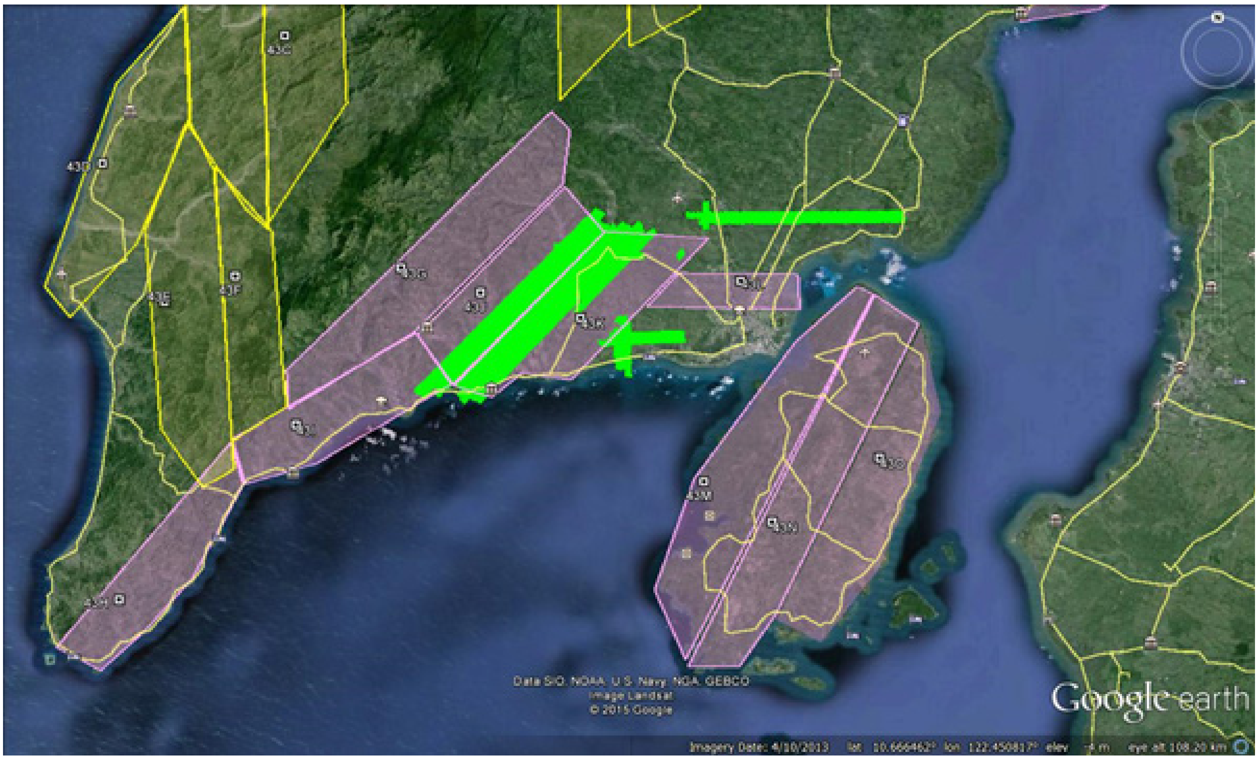


Figure A-7.3. Swath for Flight No. 2528G

Flight No.: 2530G
Area: BLK 43J & 43O
Mission Name: 2BLK43OSJS038A
Parameters: Altitude: 1100; Scan Frequency: 50; Scan Angle: 20; Overlap: 30%

LAS

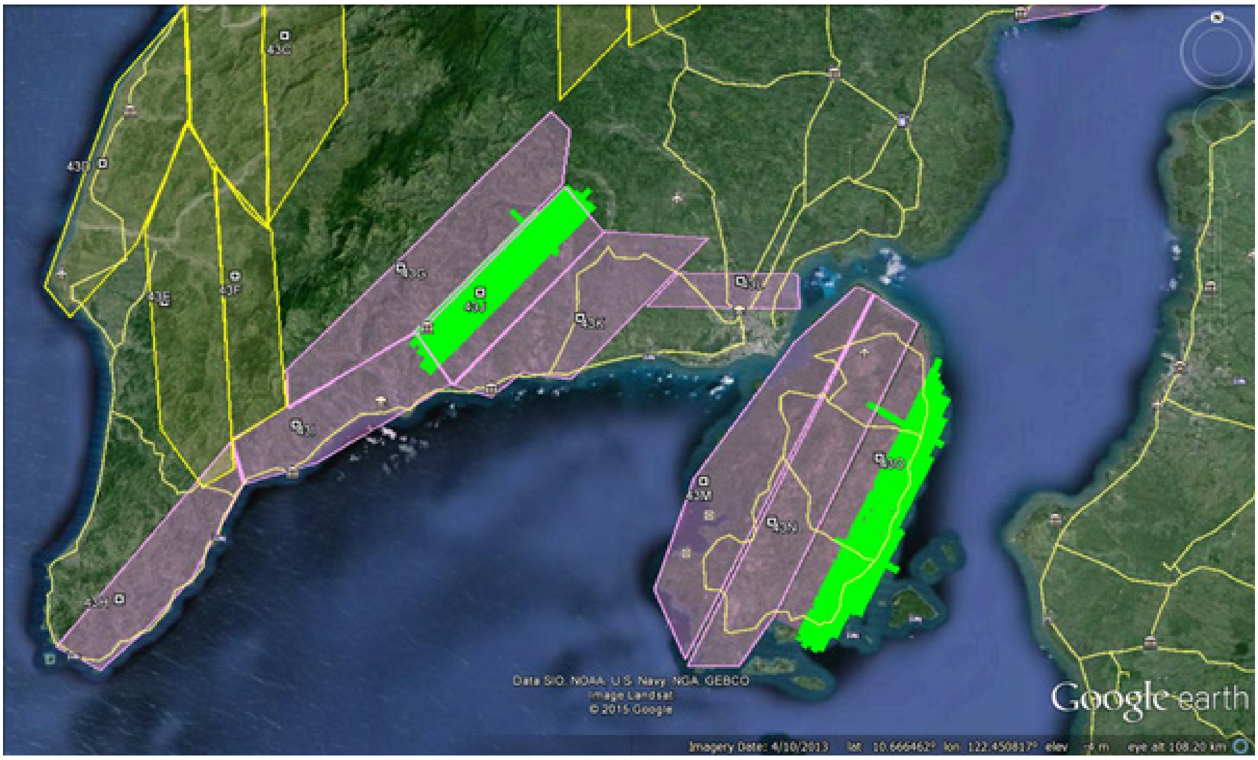


Figure A-7.4. Swath for Flight No. 2530G

Flight No.:	2532G
Area:	BLK 43I
Mission Name:	2BLK43IVS038B
Parameters:	Altitude: 1100; Scan Frequency: 50; Scan Angle: 20; Overlap: 30%

LAS

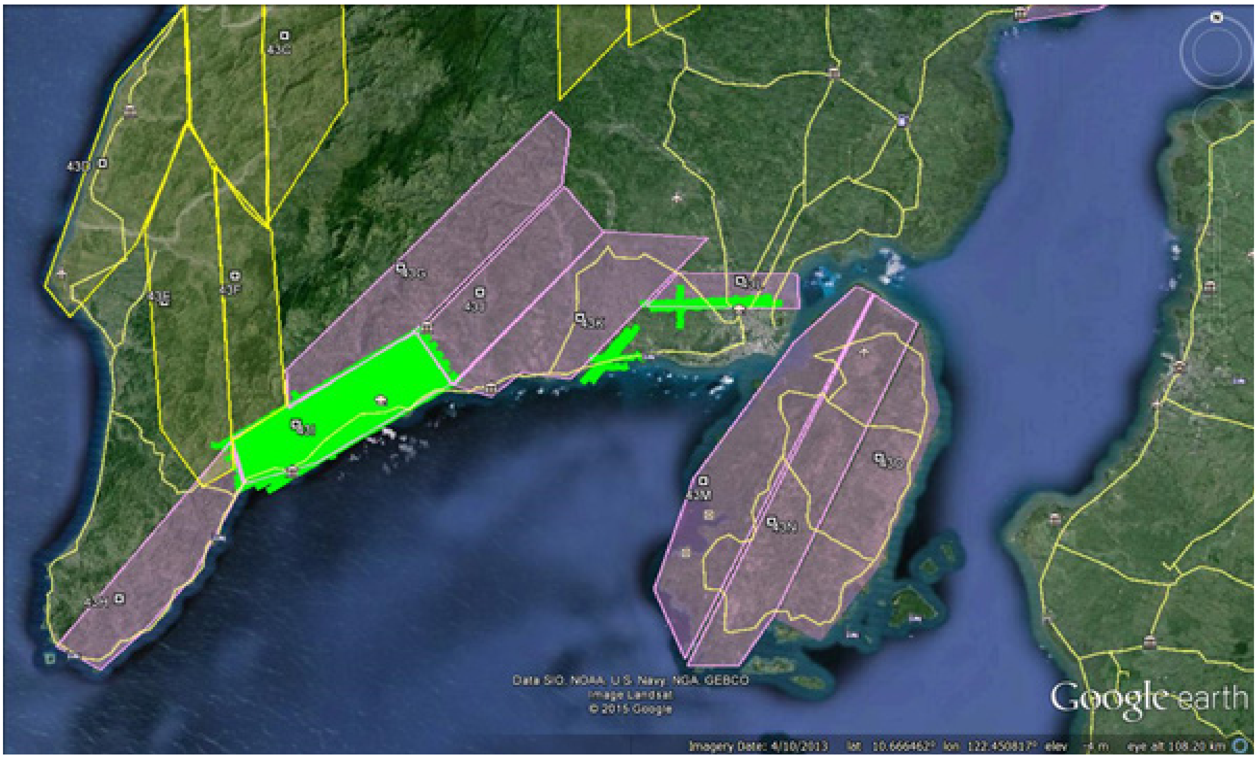


Figure A-7.5. Swath for Flight No. 2532G

Flight No.:	2550G
Area:	BLK 43G, 37N, 37O
Mission Name:	2BLK37GNOV43A
Parameters:	Altitude: 1100; Scan Frequency: 50; Scan Angle: 20; Overlap: 30%

LAS

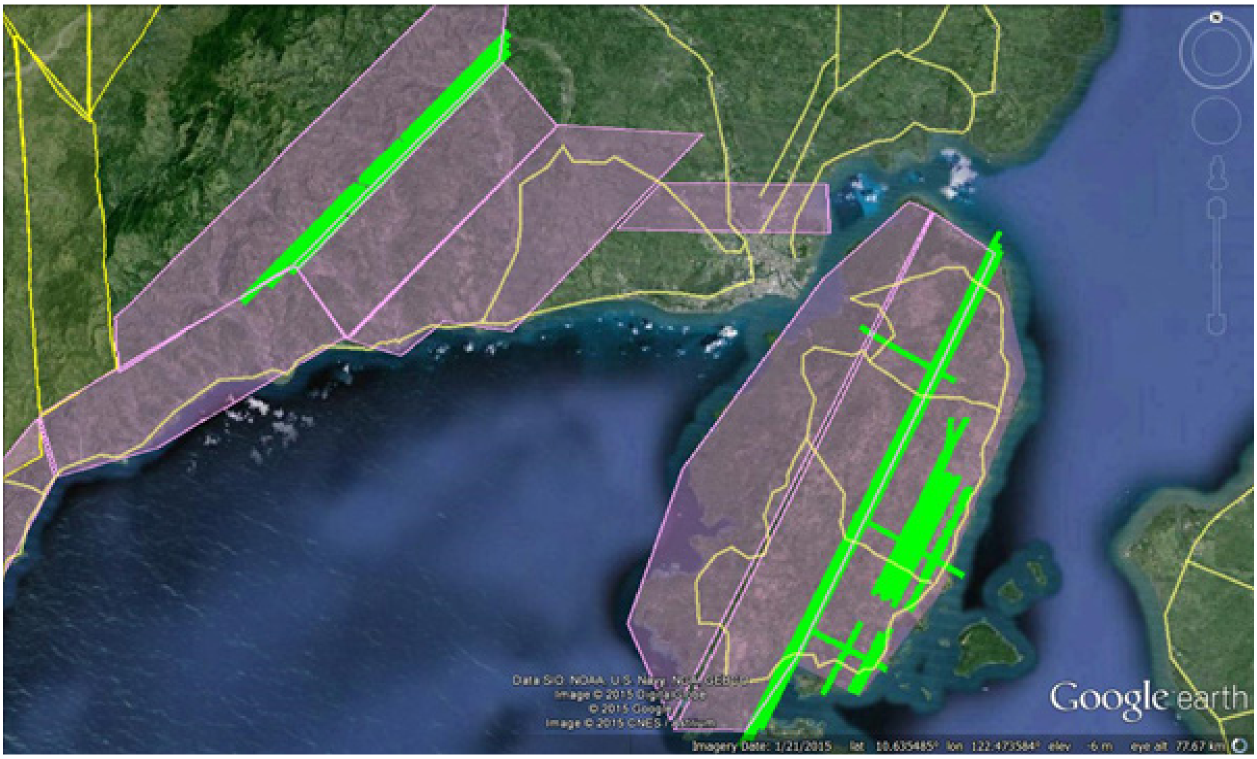


Figure A-7.6. Swath for Flight No. 2550G

Flight No.:	2558G
Area:	BLK 43G
Mission Name:	2BLK37G045A
Parameters:	Altitude: 1100; Scan Frequency: 40; Scan Angle: 25; Overlap: 30%

LAS

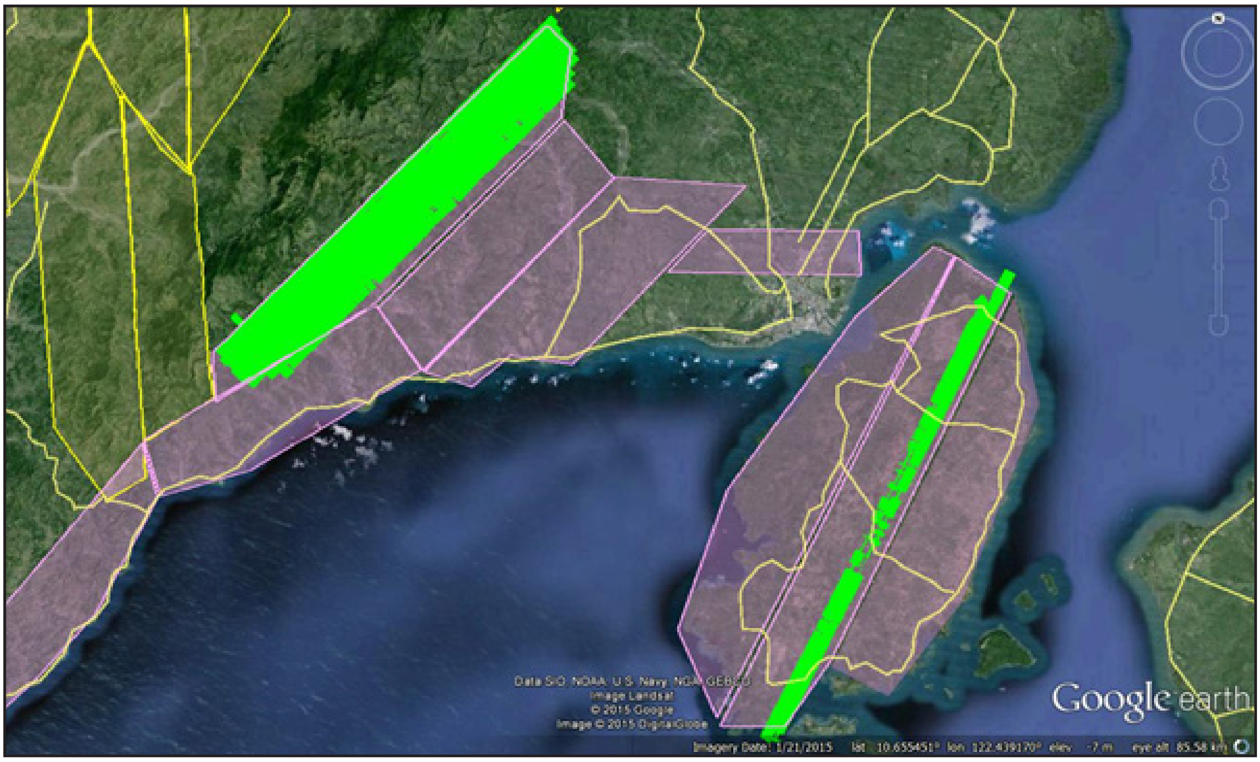


Figure A-7.7. Swath for Flight No. 2558G

Flight No.: 2570G
Area: BLK 43H
Mission Name: 2BLK43H048A
Parameters: Altitude: 1100; Scan Frequency: 50; Scan Angle: 20; Overlap: 30%

LAS

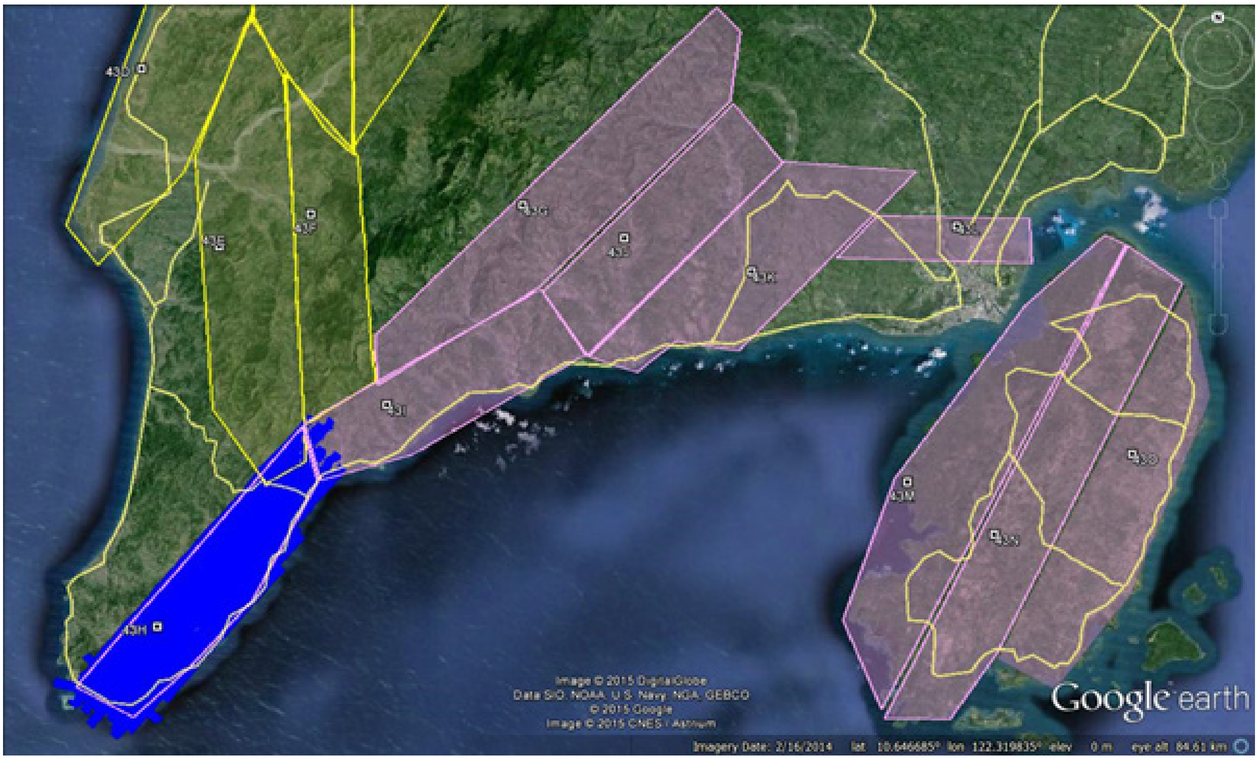


Figure A-7.8. Swath for Flight No. 2570G

Flight No.:	2578G
Area:	BLK 43G
Mission Name:	2BLK43GV050A
Parameters:	Altitude: 1100; Scan Frequency: 50; Scan Angle: 20; Overlap: 30%

LAS

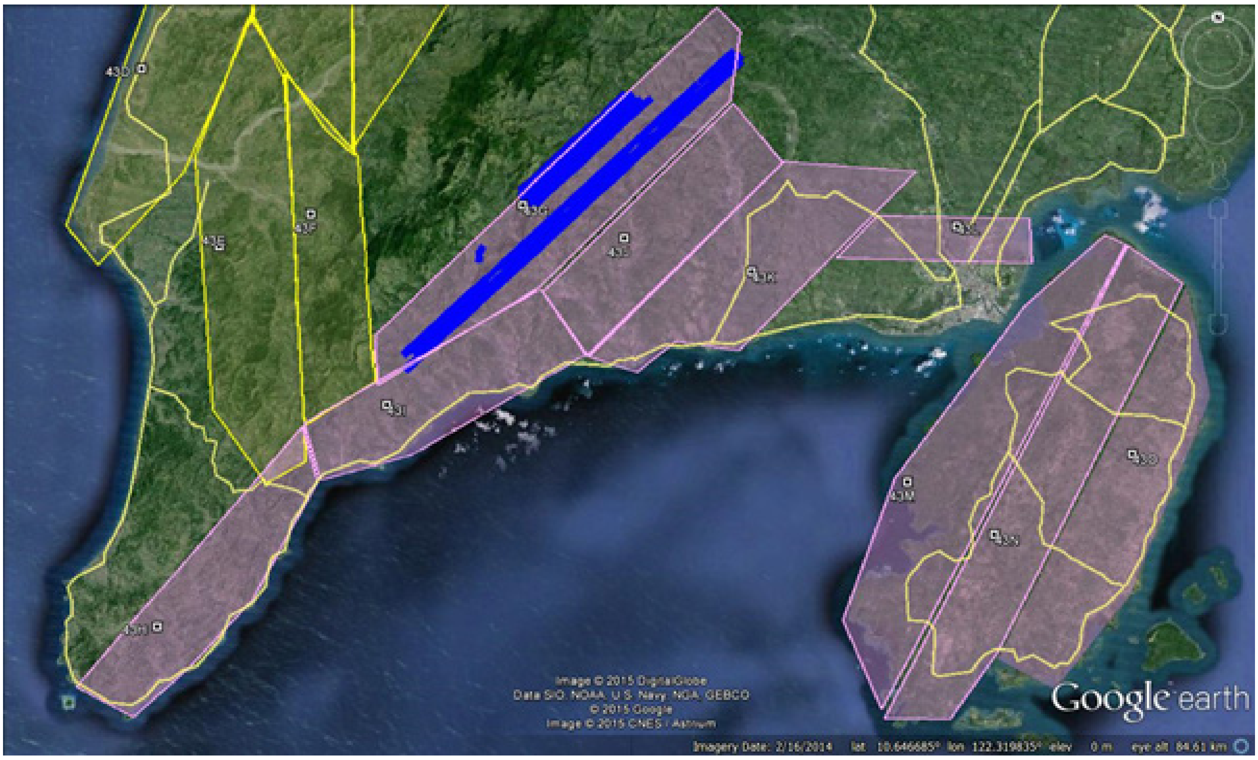


Figure A-7.9. Swath for Flight No. 2578G

Flight No.:	2593P
Area:	BLK 43B, 43D & 43G
Mission Name:	1BLK43BC051A
Parameters:	Altitude: 1000; Scan Frequency: 30; Scan Angle: 25; Overlap: 30%

LAS

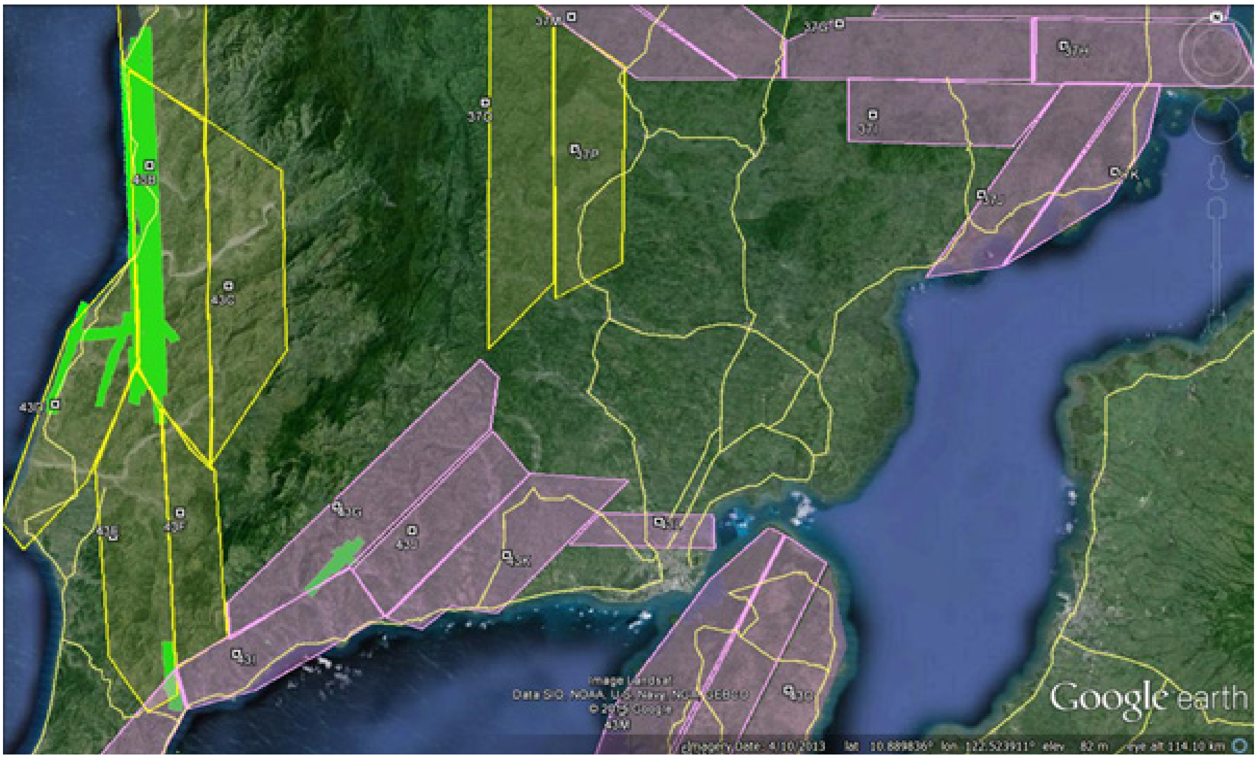


Figure A-7.10. Swath for Flight No. 2593P

Flight No.:	2602G
Area:	BLK 43B
Mission Name:	2BLK43B056A
Parameters:	Altitude: 2000; Scan Frequency: 56; Scan Angle: 20; Overlap: 30%

LAS

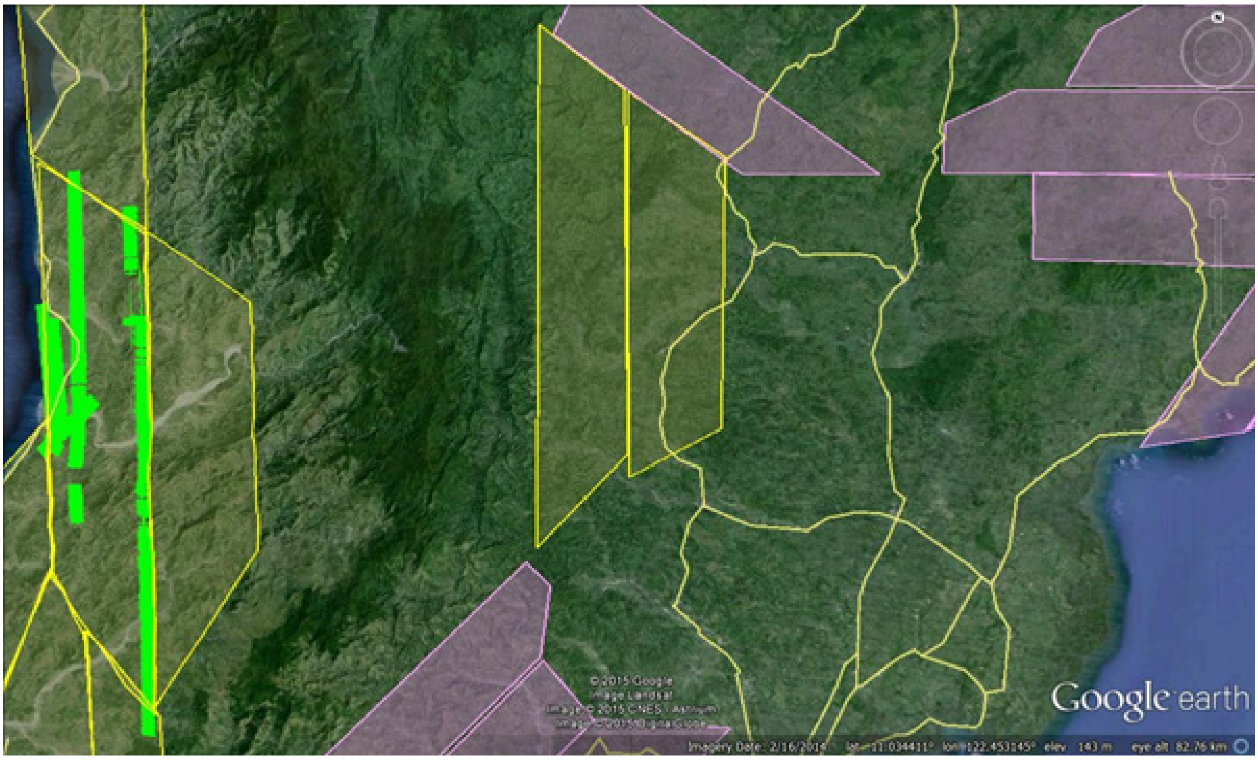


Figure A-7.11. Swath for Flight No. 2602G

Flight No.:	2606G
Area:	BLK 43B
Mission Name:	2BLK43B057A
Parameters:	Altitude: 2000; Scan Frequency: 56; Scan Angle: 20; Overlap: 30%

LAS

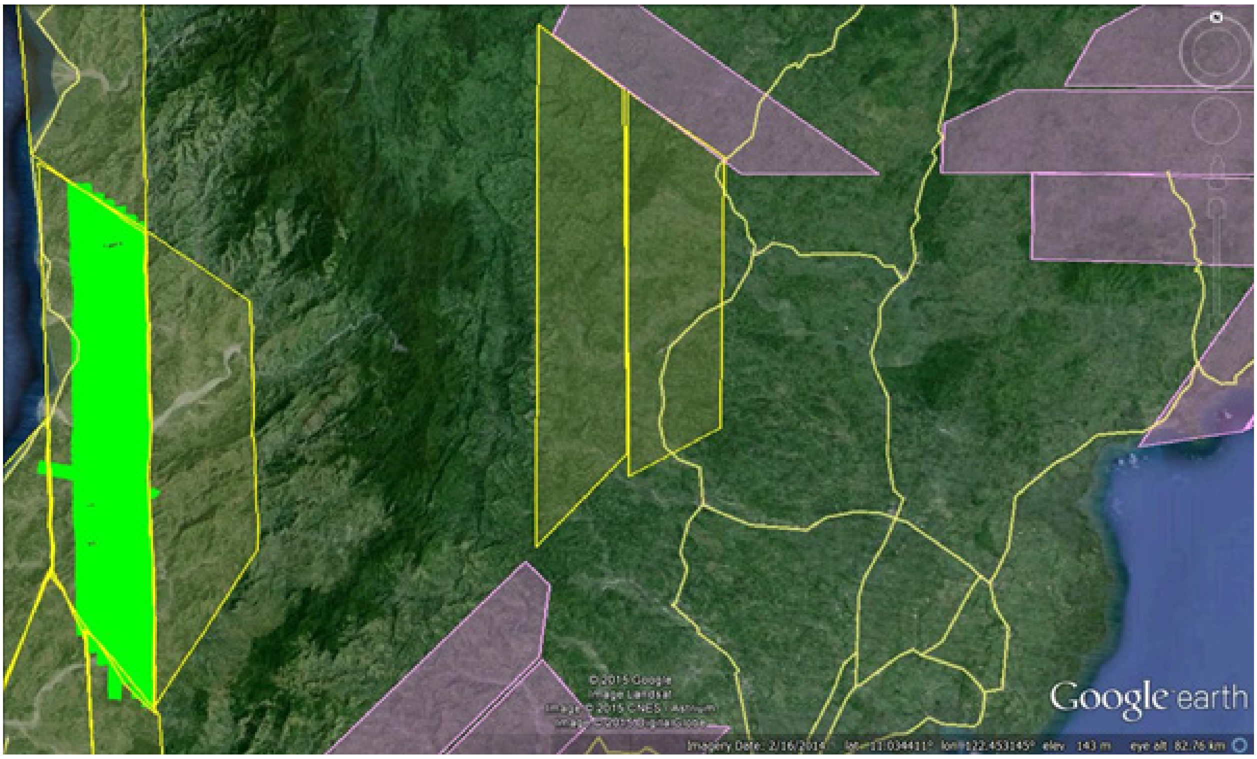


Figure A-7.12. Swath for Flight No. 2606G

Flight No.:	2610G
Area:	BLK 43B & 43C
Mission Name:	2BLK43BV058A
Parameters:	Altitude: 2000; Scan Frequency: 56; Scan Angle: 16; Overlap: 30%

LAS

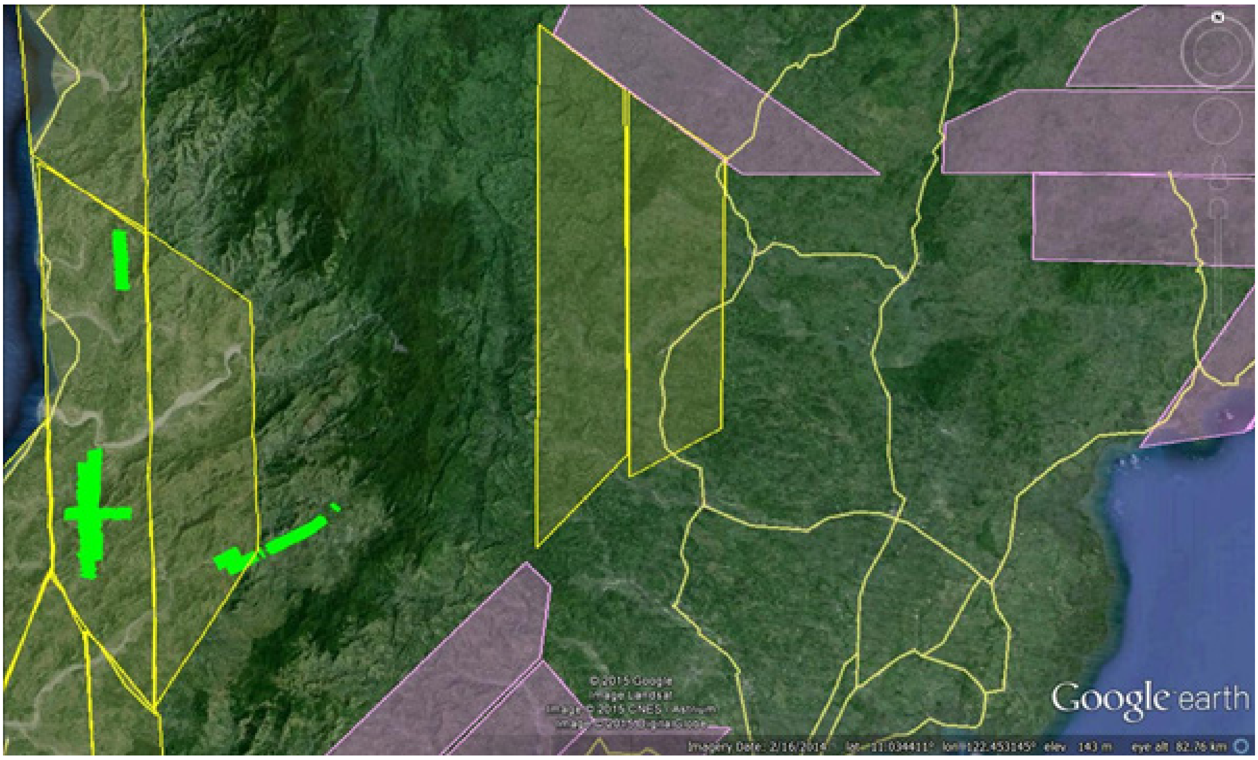


Figure A-7.13. Swath for Flight No. 2610G

Flight No.: 2617P
Area: BLK 37O & 37P
Mission Name: 1BLK37OP057A
Parameters: Altitude: 1000; Scan Frequency: 30; Scan Angle: 25; Overlap: 30%

LAS

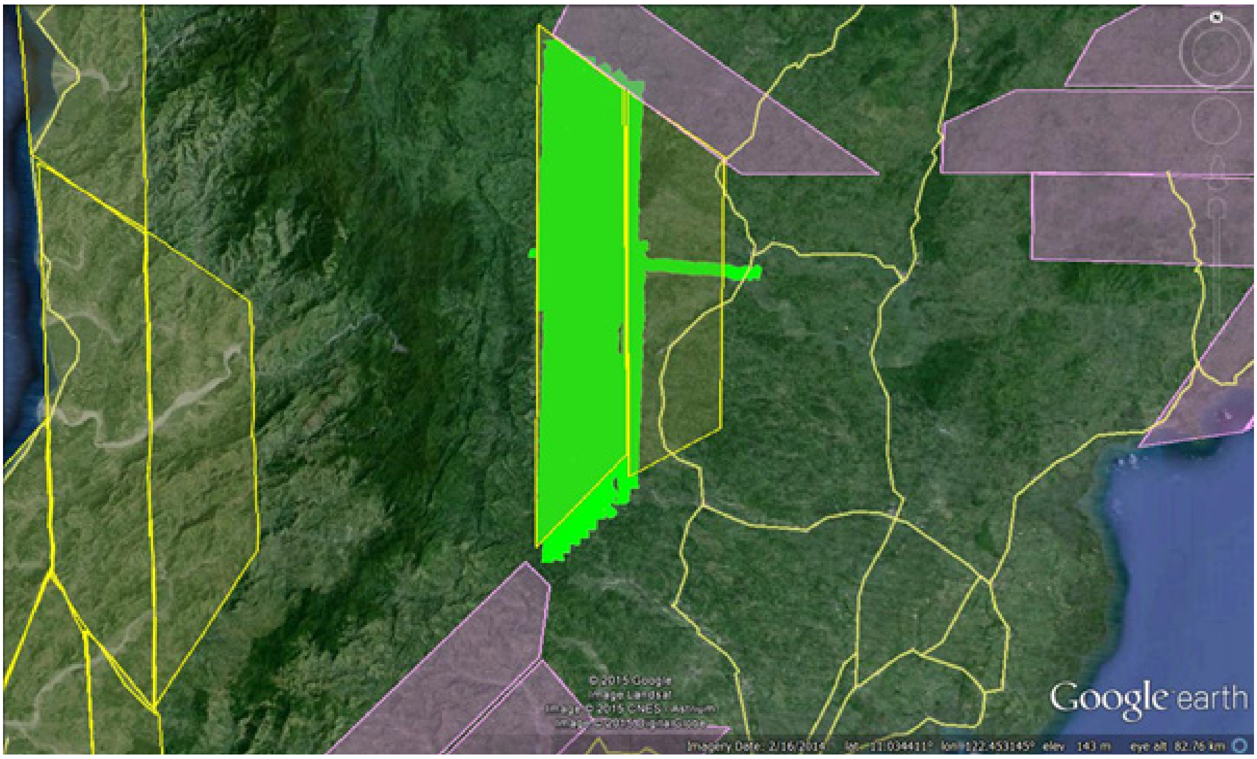


Figure A-7.14. Swath for Flight No. 2617P

Flight No.: 2621P
Area: BLK 37P
Mission Name: 1BLK37P058A
Parameters: Altitude: 1000; Scan Frequency: 30; Scan Angle: 25; Overlap: 30%

LAS

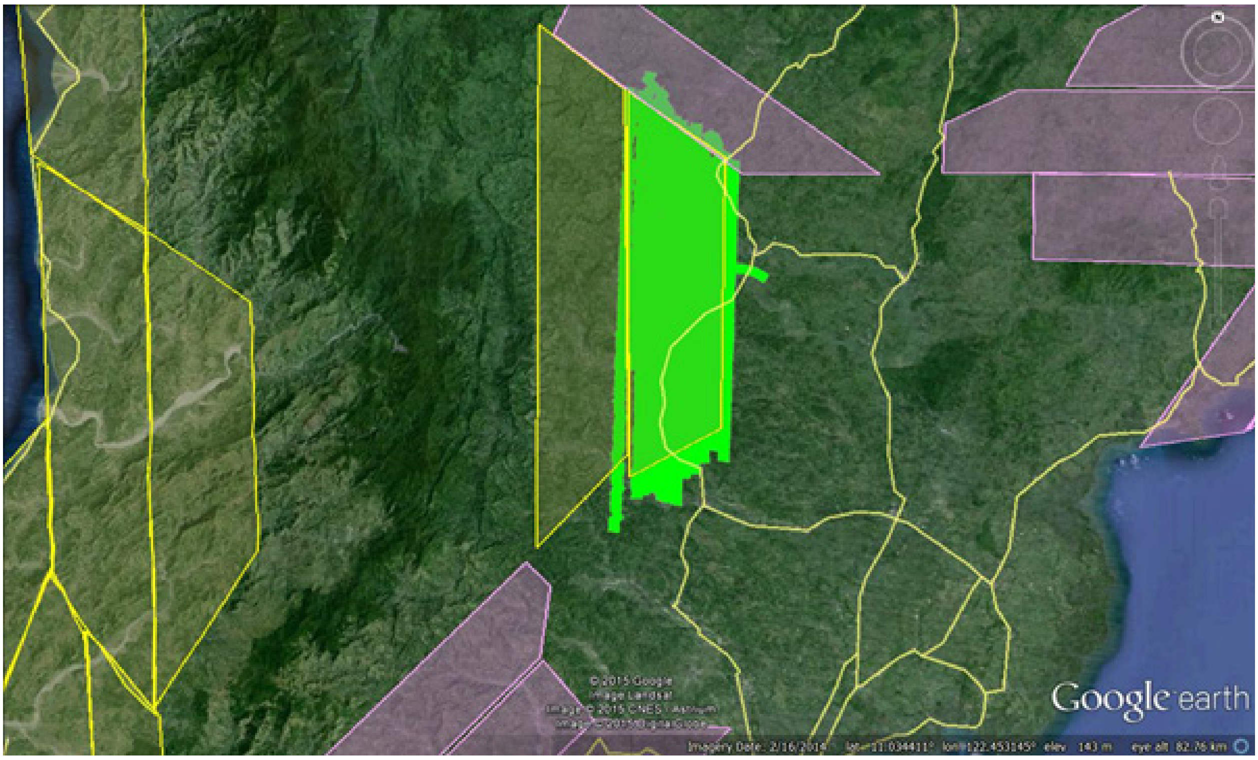


Figure A-7.15. Swath for Flight No. 2621P

ANNEX 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk43J

Flight Area	Iloilo
Mission Name	Blk43J
Inclusive Flights	2530G
Range data size	25.2 GB
Base data size	19.1 MB
POS	268 MB
Image	43.4 GB
Transfer date	February 17, 2015
Solution Status	Yes
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.62
RMSE for East Position (<4.0 cm)	2.11
RMSE for Down Position (<8.0 cm)	4.83
Boresight correction stdev (<0.001deg)	0.000303
IMU attitude correction stdev (<0.001deg)	0.000478
GPS position stdev (<0.01m)	0.0091
Minimum % overlap (>25)	26.03%
Ave point cloud density per sq.m. (>2.0)	3.39
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	141
Maximum Height	578.25 m
Minimum Height	241.03 m
Classification (# of points)	
Ground	56,539,363
Low vegetation	45,808,864
Medium vegetation	47,700,695
High vegetation	160,842,707
Building	2,092,797
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Melanie Hingpit, Alex John Escobido

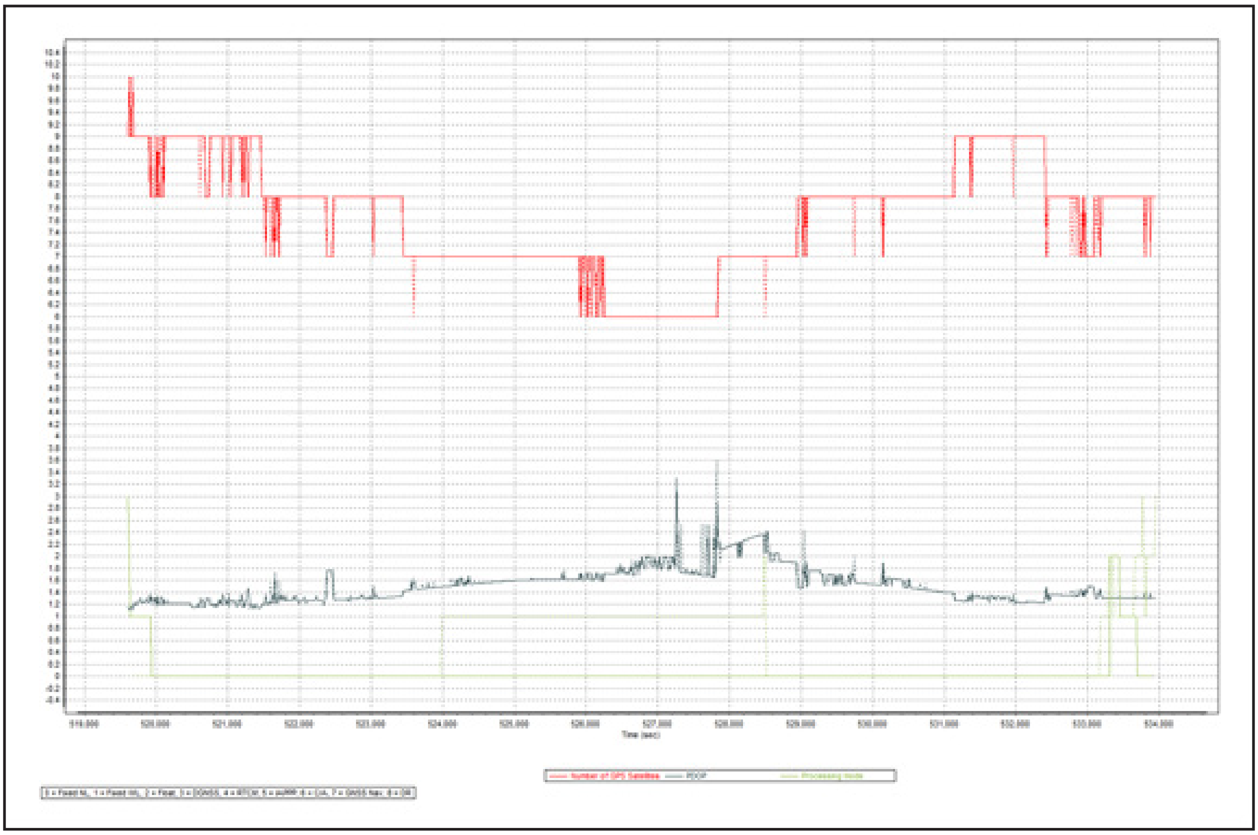


Figure A-8.1. Solution Status

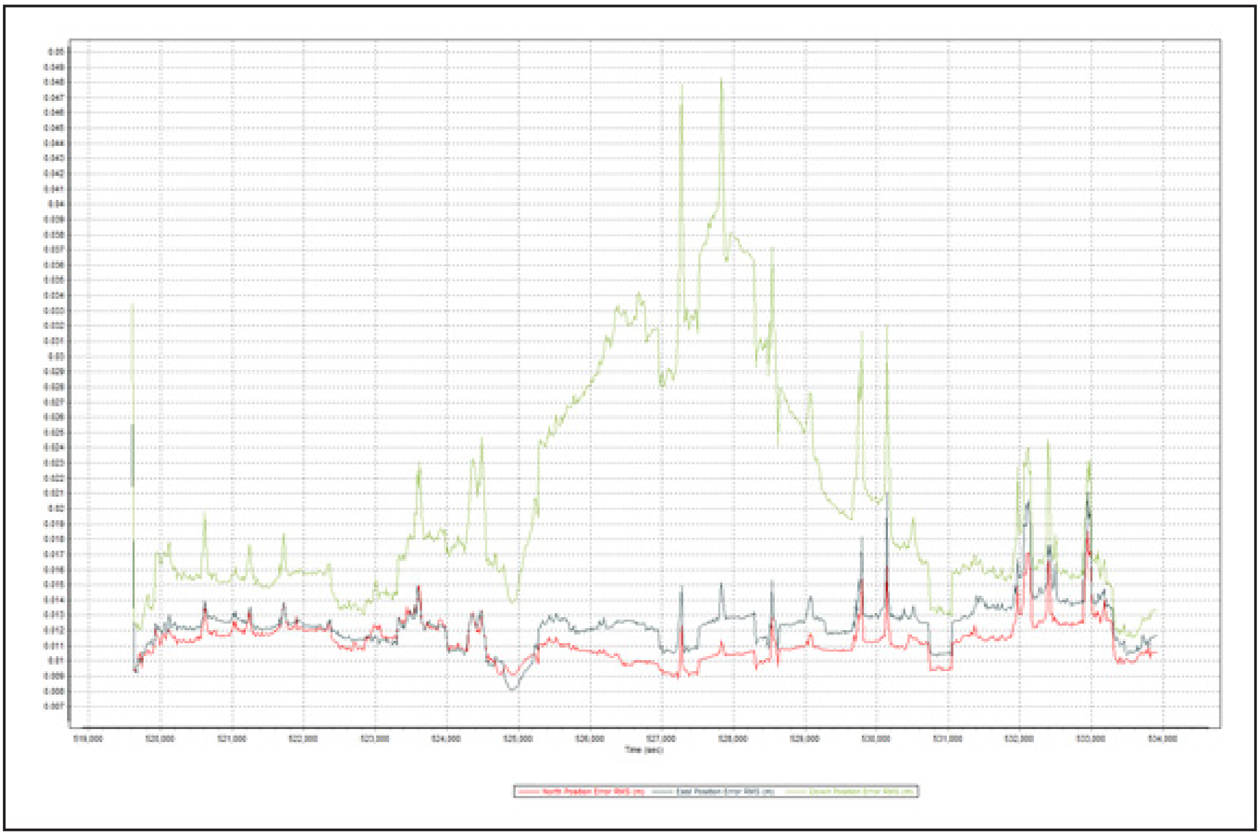


Figure A-8.2. Smoothed Performance Metric Parameters

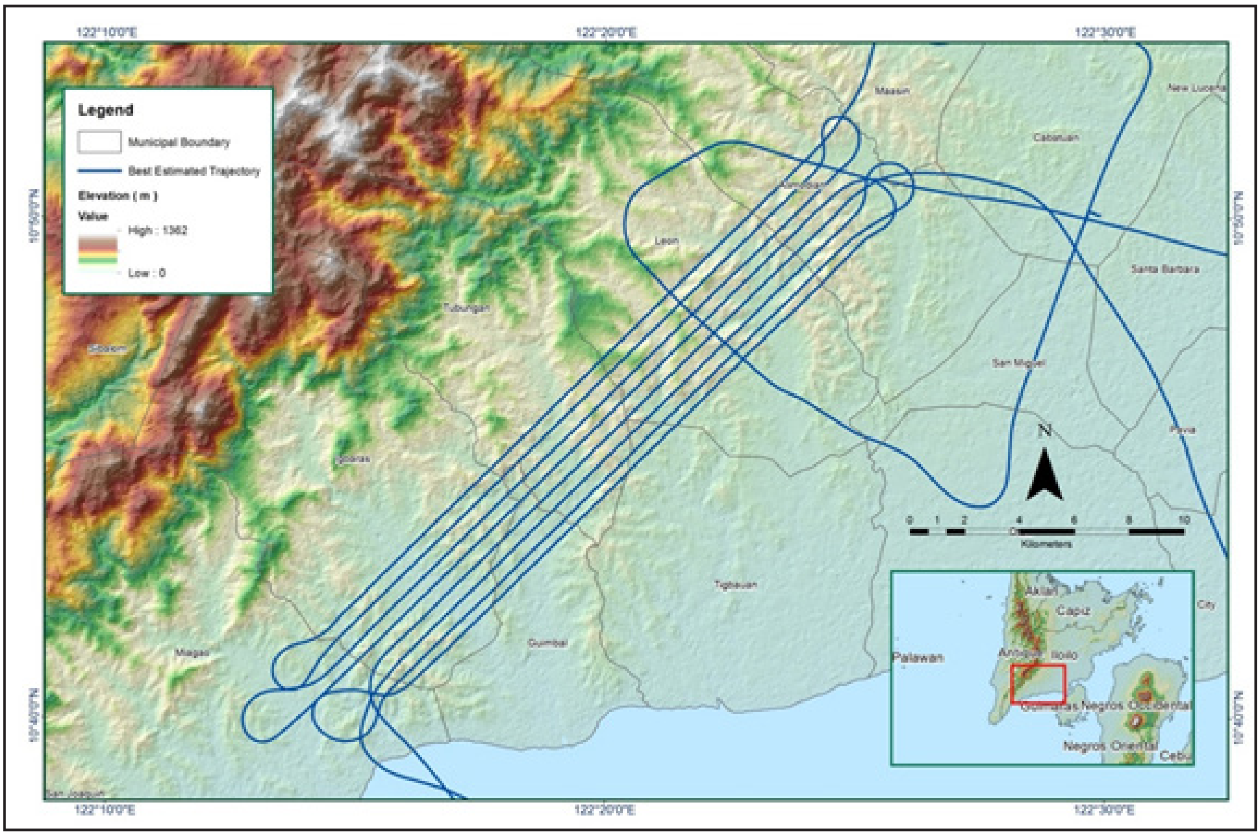


Figure A-8.3. Best Estimated Trajectory

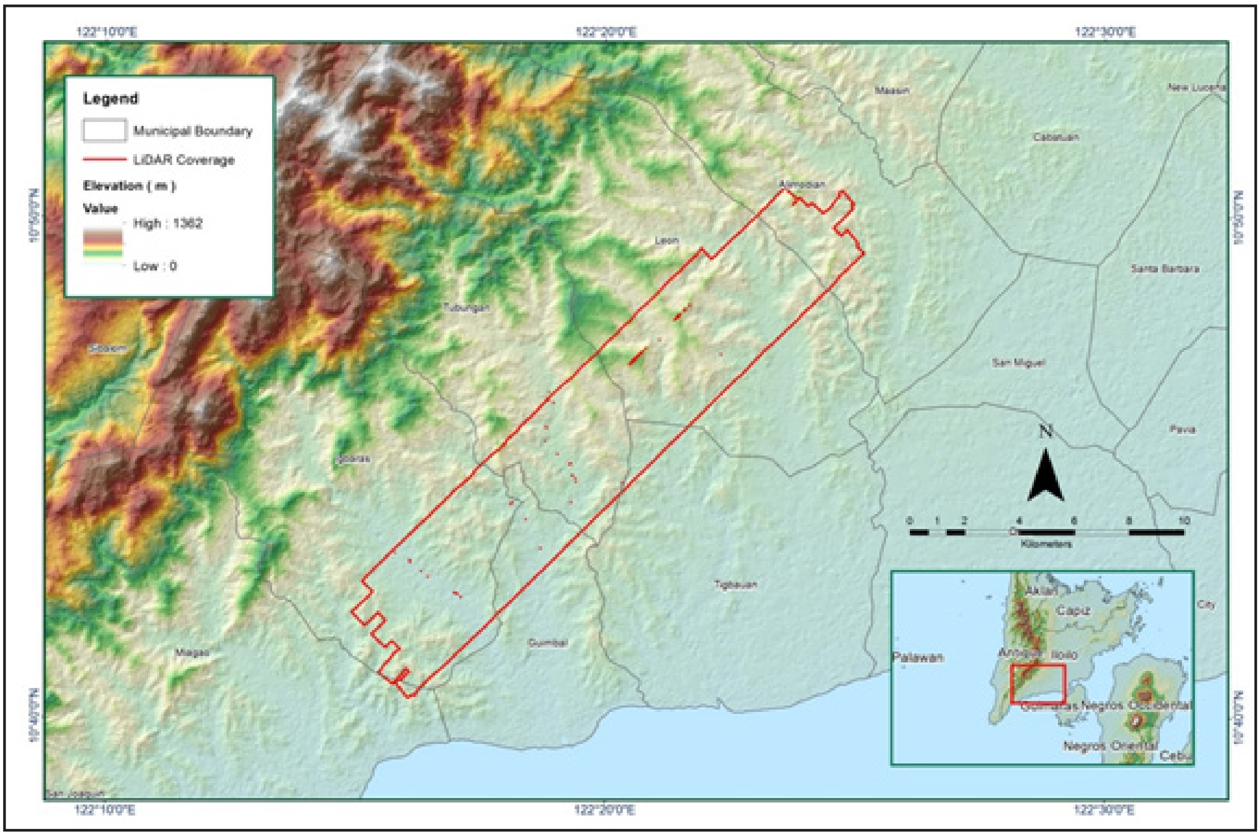


Figure A-8.4. Coverage of LiDAR data

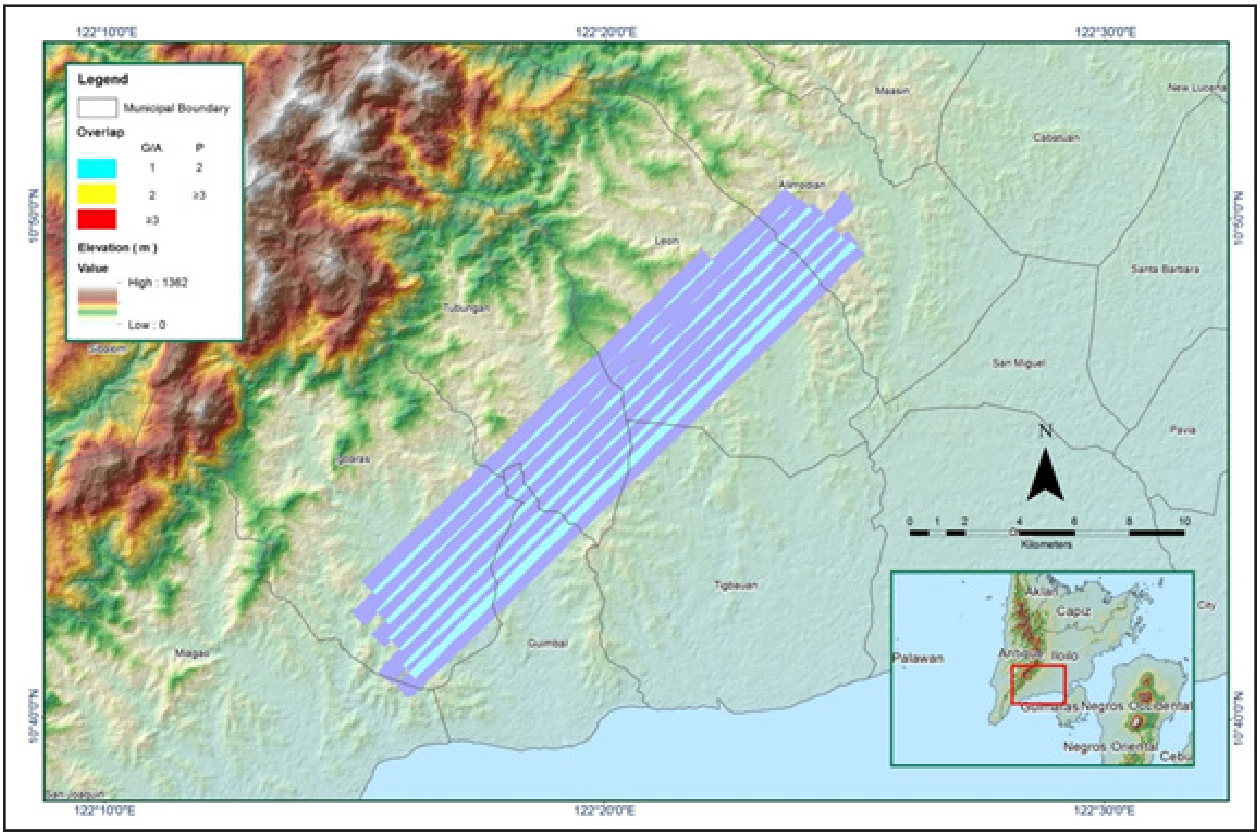


Figure A-8.5. Image of data overlap

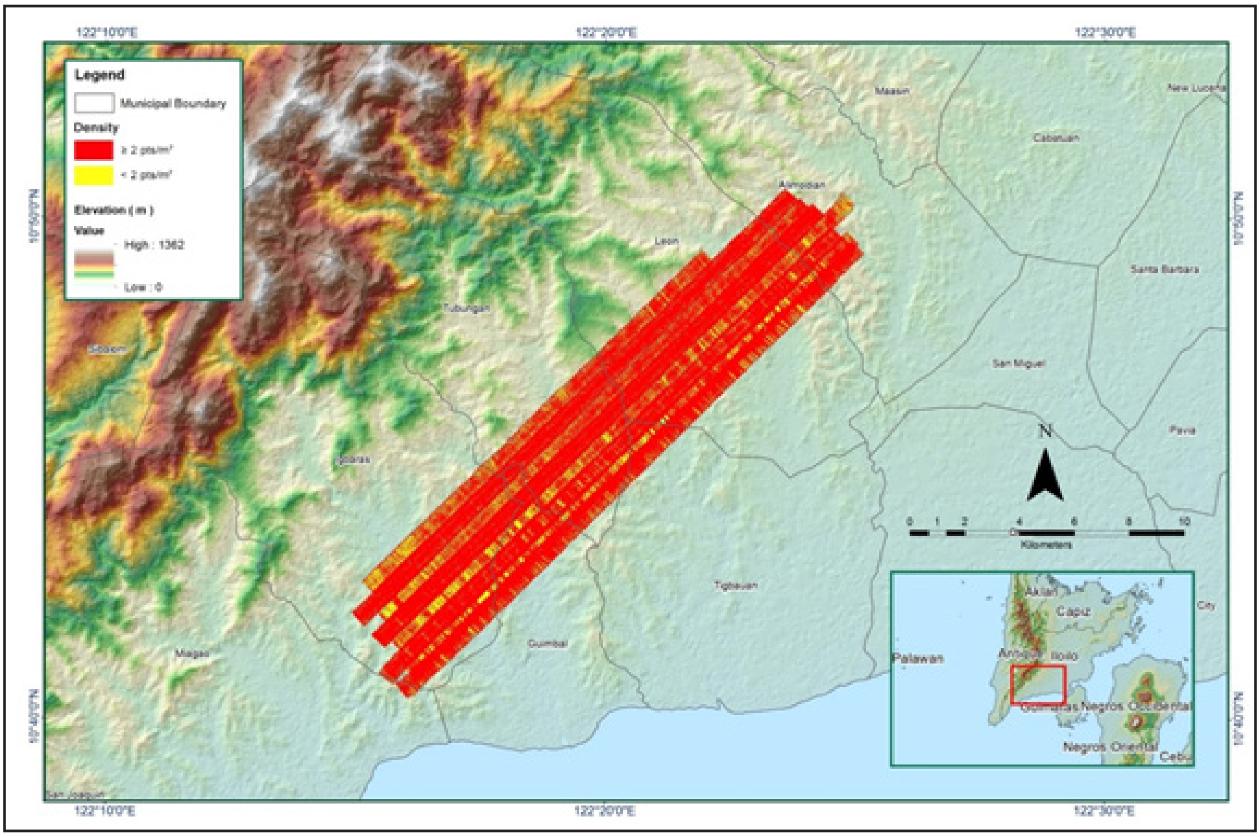


Figure A-8.6. Density map of merged LiDAR data

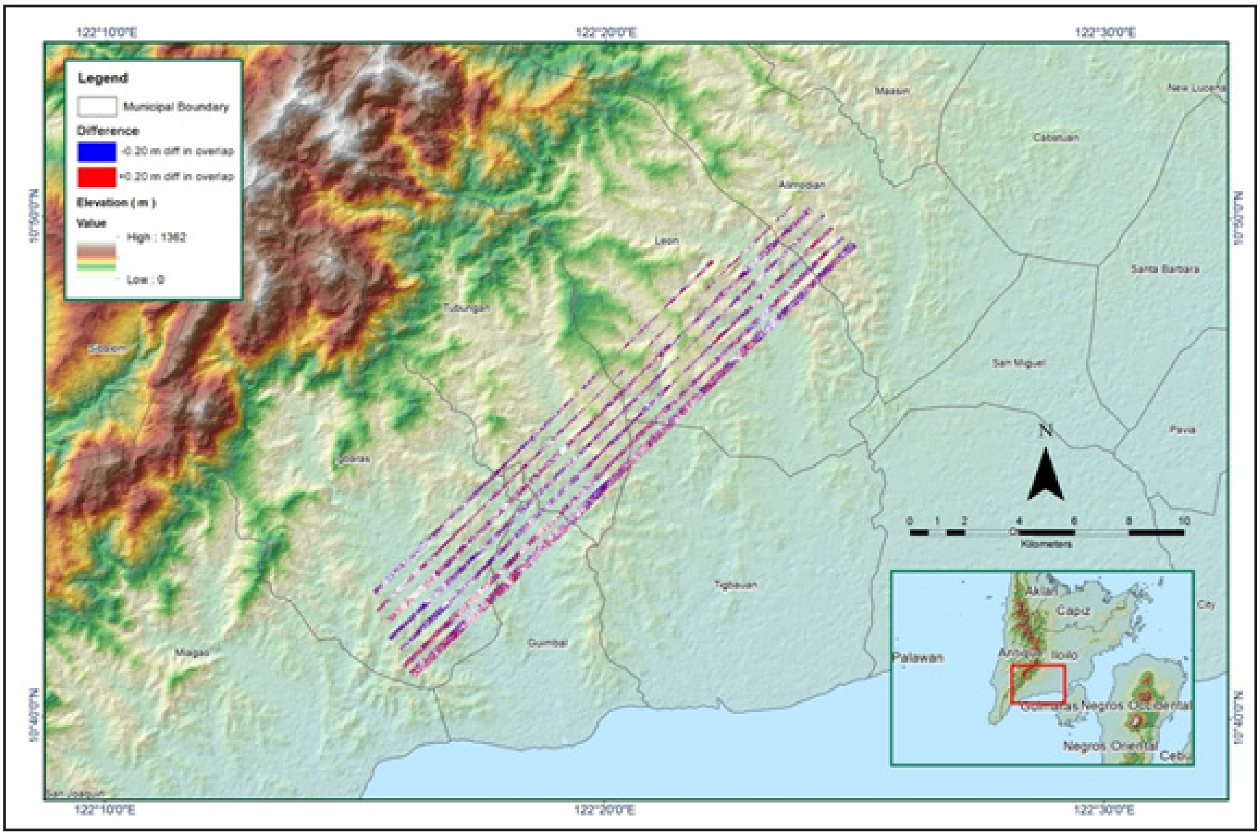


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk43KL

Flight Area	Iloilo
Mission Name	Blk43KL
Inclusive Flights	2522G, 2526G, 2528G, 2532G
Range data size	89.8 GB
Base data size	58.1 MB
POS	986 MB
Image	157.6 GB
Transfer date	February 17, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.5
RMSE for East Position (<4.0 cm)	2.36
RMSE for Down Position (<8.0 cm)	6.16
Boresight correction stdev (<0.001deg)	0.000272
IMU attitude correction stdev (<0.001deg)	0.003944
GPS position stdev (<0.01m)	0.008
Minimum % overlap (>25)	45.86%
Ave point cloud density per sq.m. (>2.0)	4.00
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	516
Maximum Height	297.42 m
Minimum Height	58.46 m
Classification (# of points)	
Ground	228,449,608
Low vegetation	324,501,914
Medium vegetation	442,110,053
High vegetation	403,401,337
Building	20,712,774
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Jommer Medina, Engr. Irish Cortez, Aljon Rie Araneta, Engr. Melissa Fernandez

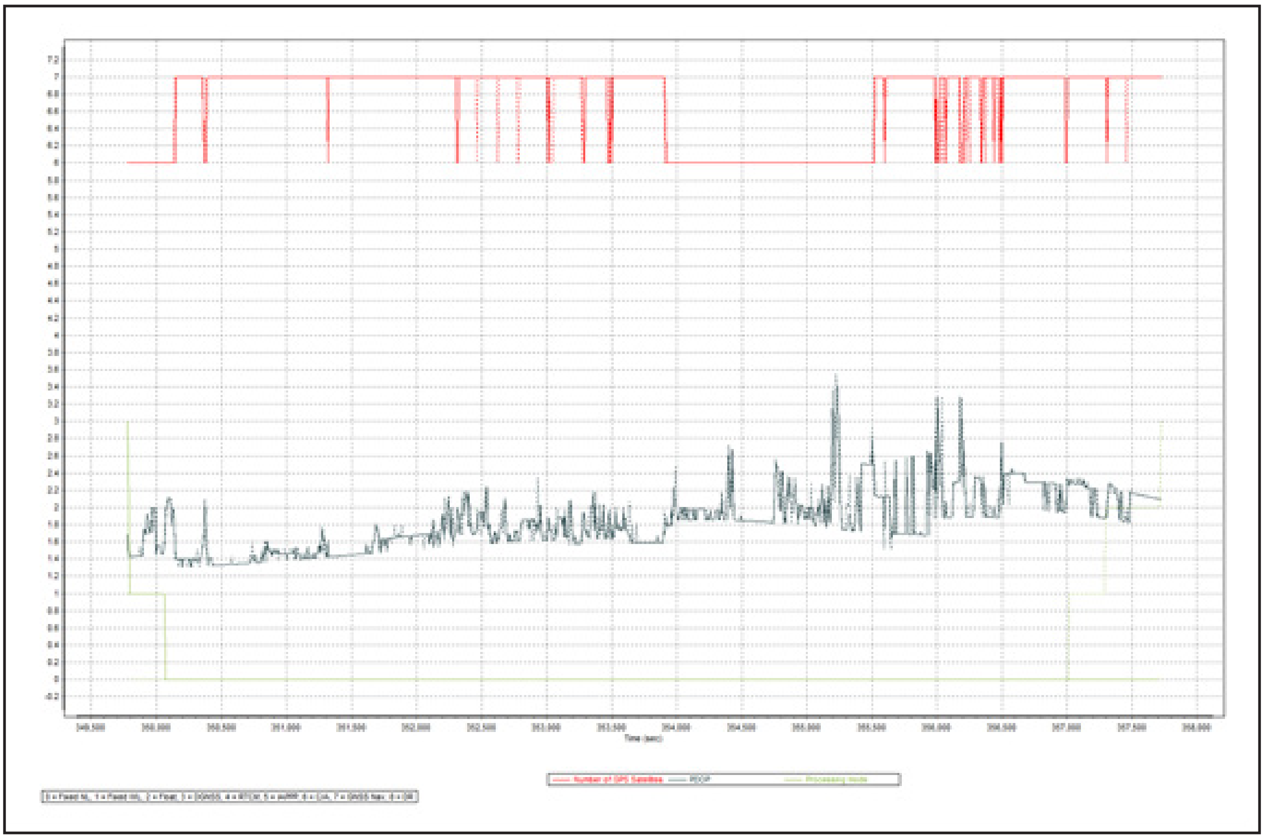


Figure A-8.8. Solution Status

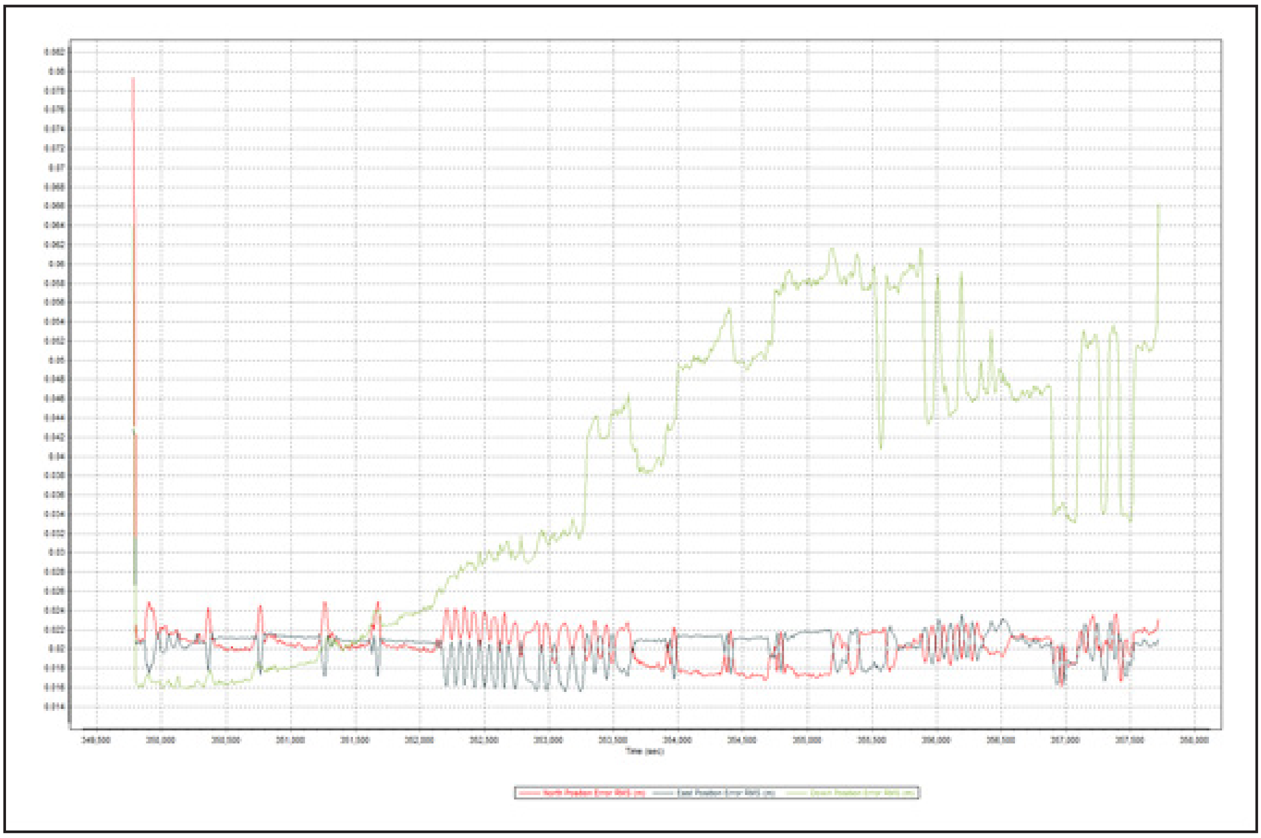


Figure A-8.9. Smoothed Performance Metric Parameters

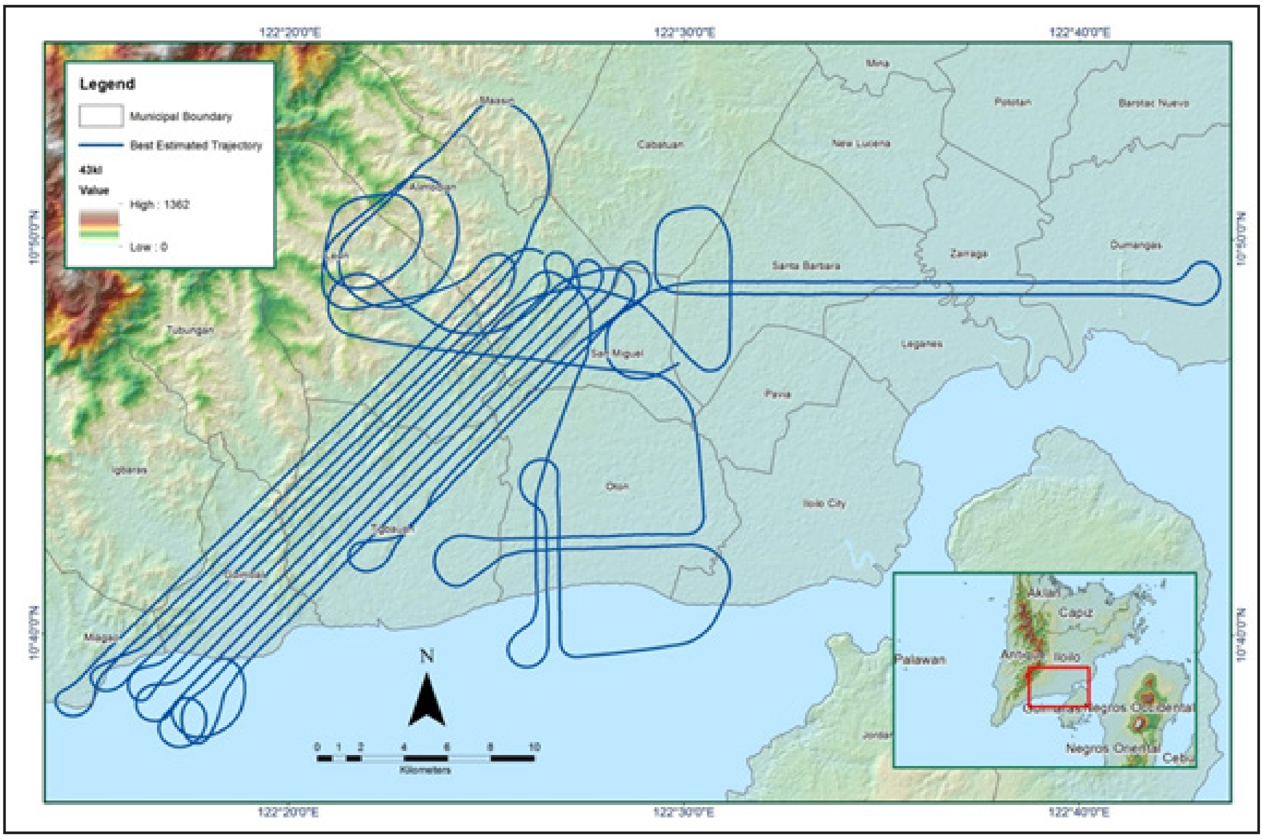


Figure A-8.10. Best Estimated Trajectory

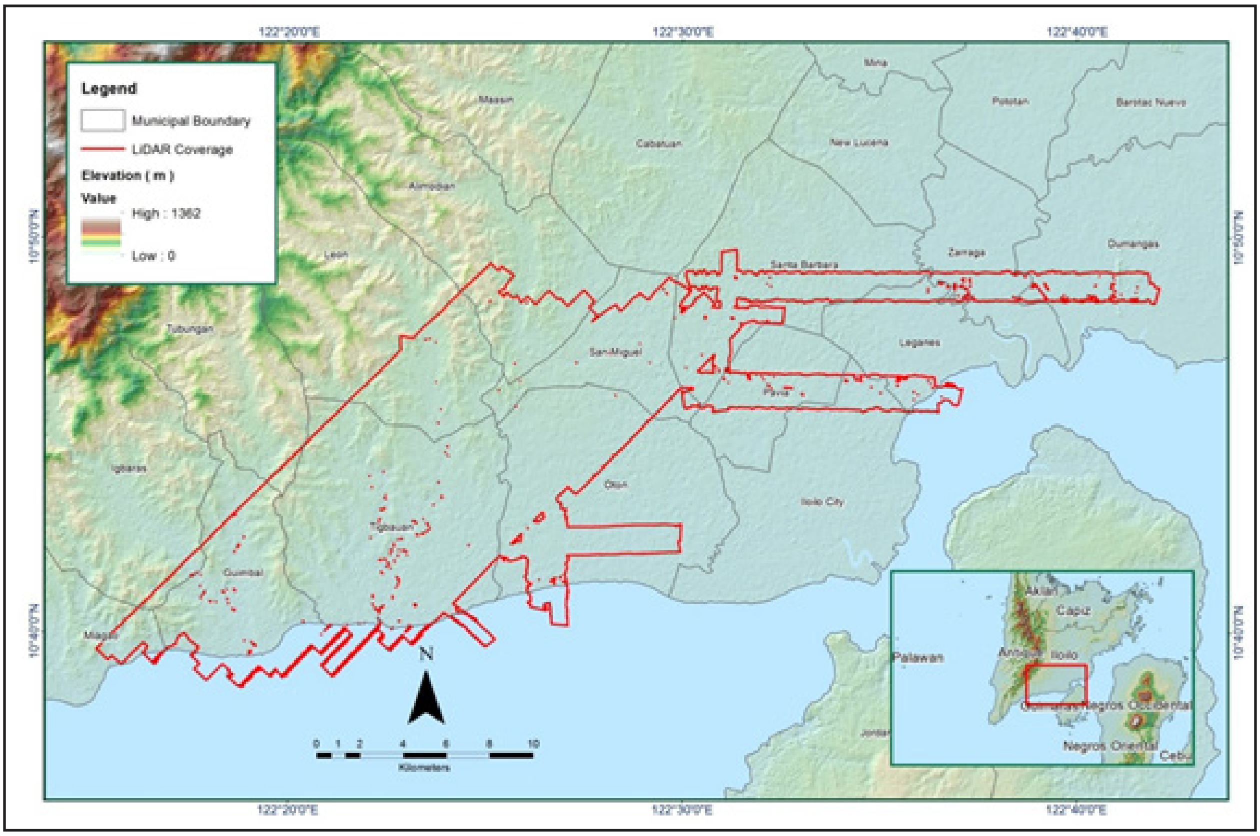


Figure A-8.11. Coverage of LiDAR data

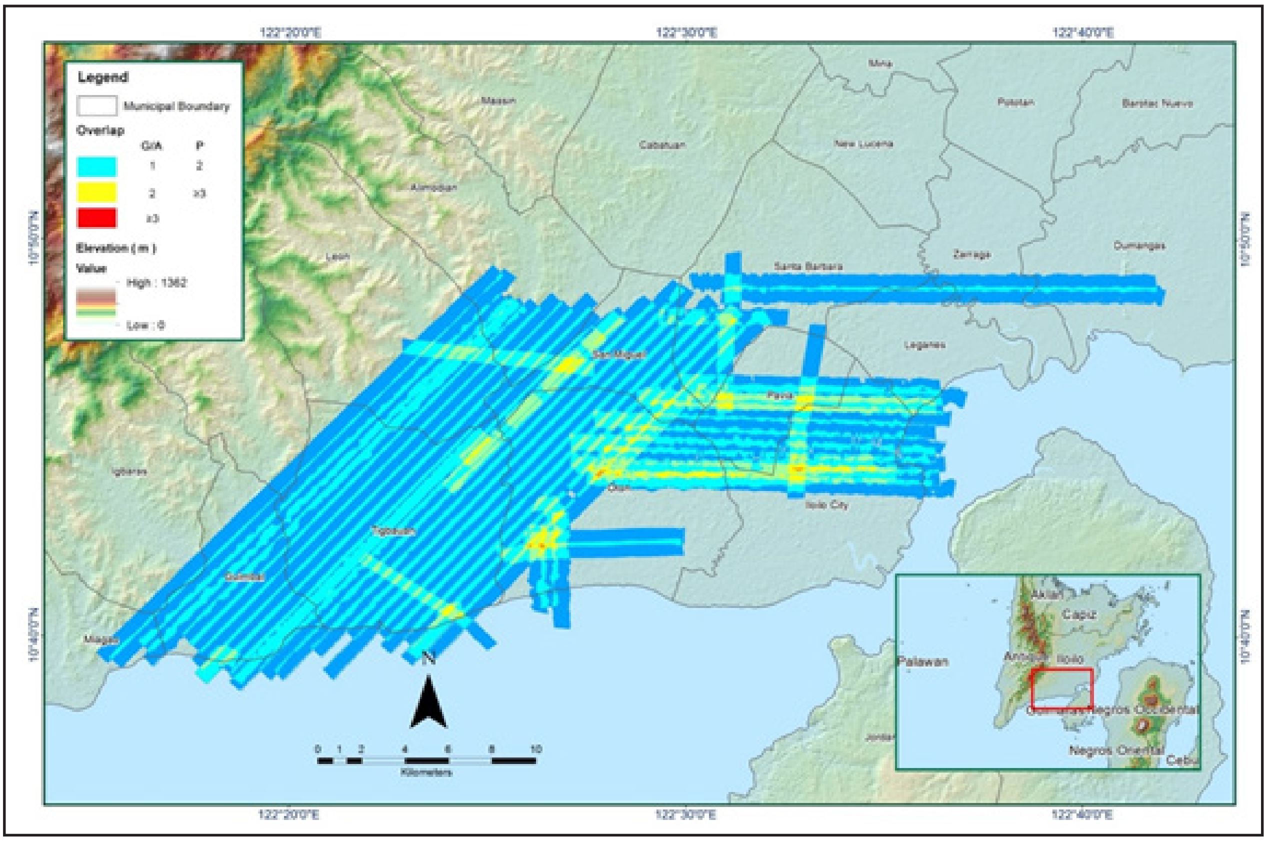


Figure A-8.12. Image of data overlap

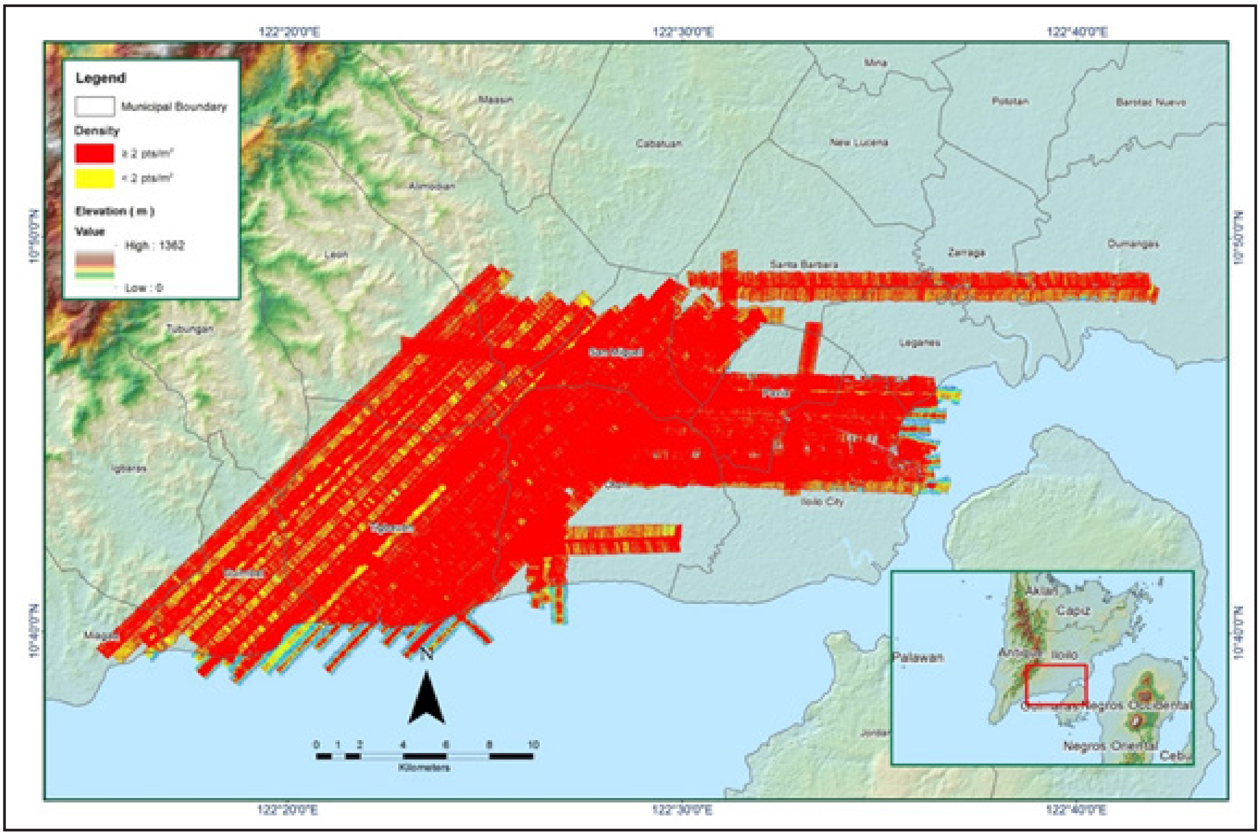


Figure A-8.13. Density map of merged LiDAR data

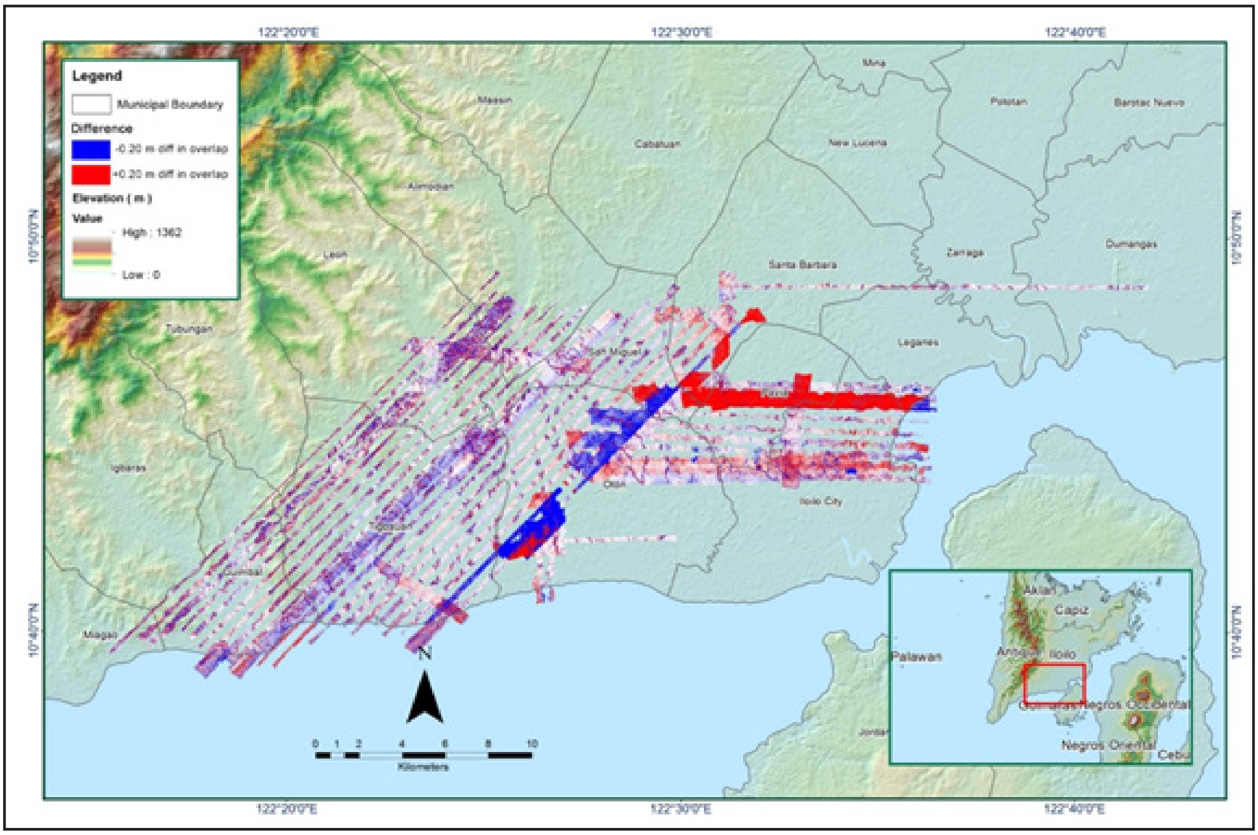


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk43H

Flight Area	Iloilo
Mission Name	Blk43H
Inclusive Flights	2570G
Range data size	21.7 GB
Base data size	14.4 MB
POS	222 MB
Image	48.5 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)	2.31
RMSE for East Position (<4.0 cm)	1.71
RMSE for Down Position (<8.0 cm)	3
Boresight correction stdev (<0.001deg)	0.000267
IMU attitude correction stdev (<0.001deg)	0.000681
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	32.57%
Ave point cloud density per sq.m. (>2.0)	4.43
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	212
Maximum Height	613.99 m
Minimum Height	54.29 m
Classification (# of points)	
Ground	108,534,543
Low vegetation	79,766,900
Medium vegetation	153,063,695
High vegetation	333,632,882
Building	2,427,463
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Krisha Marie Bautista

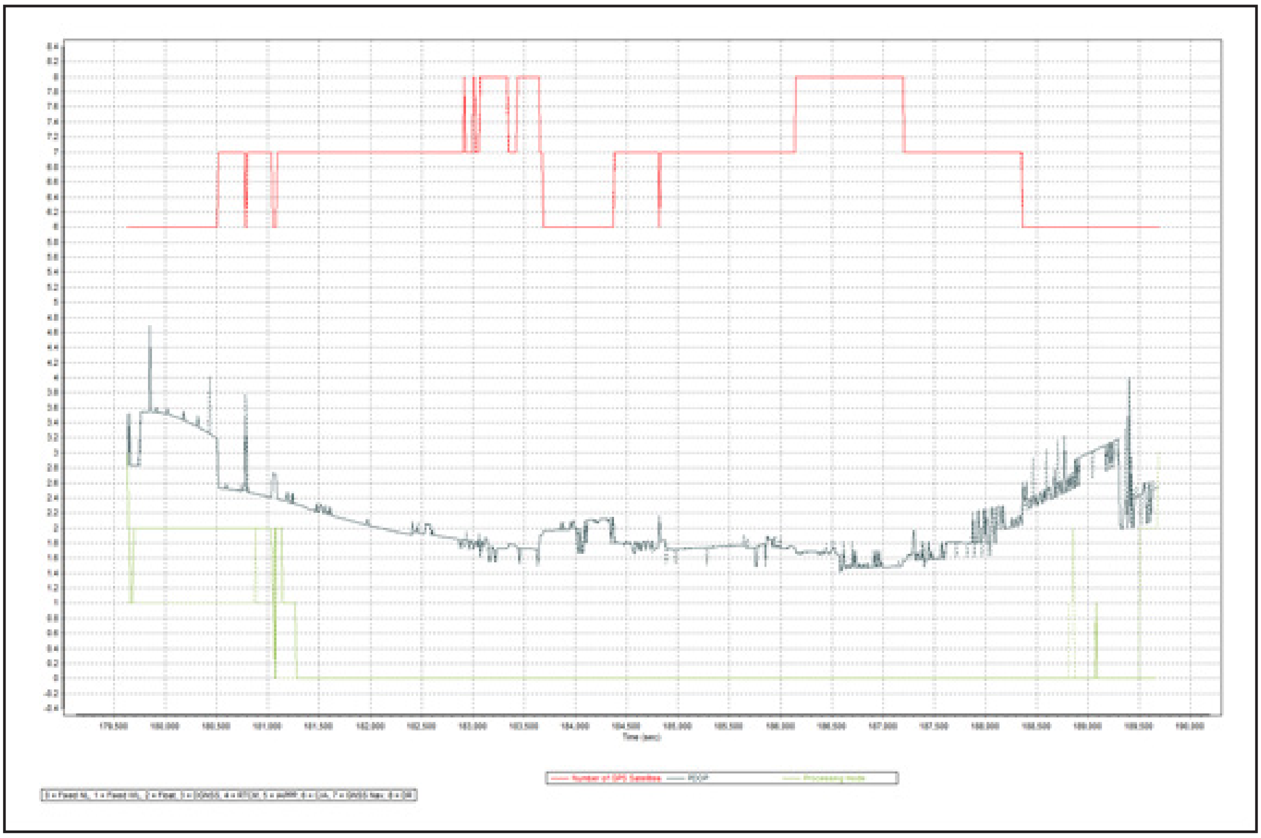


Figure A-8.15. Solution Status

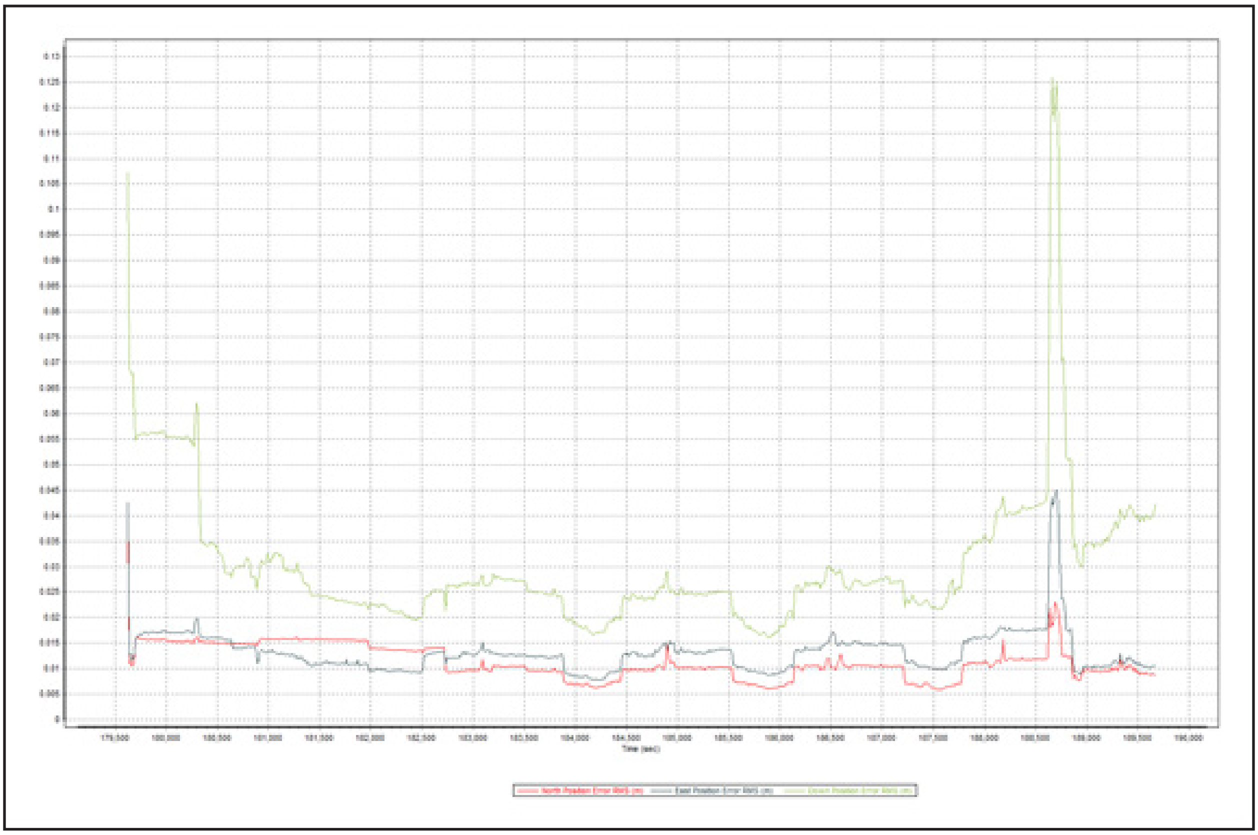


Figure A-8.16. Smoothed Performance Metric Parameters

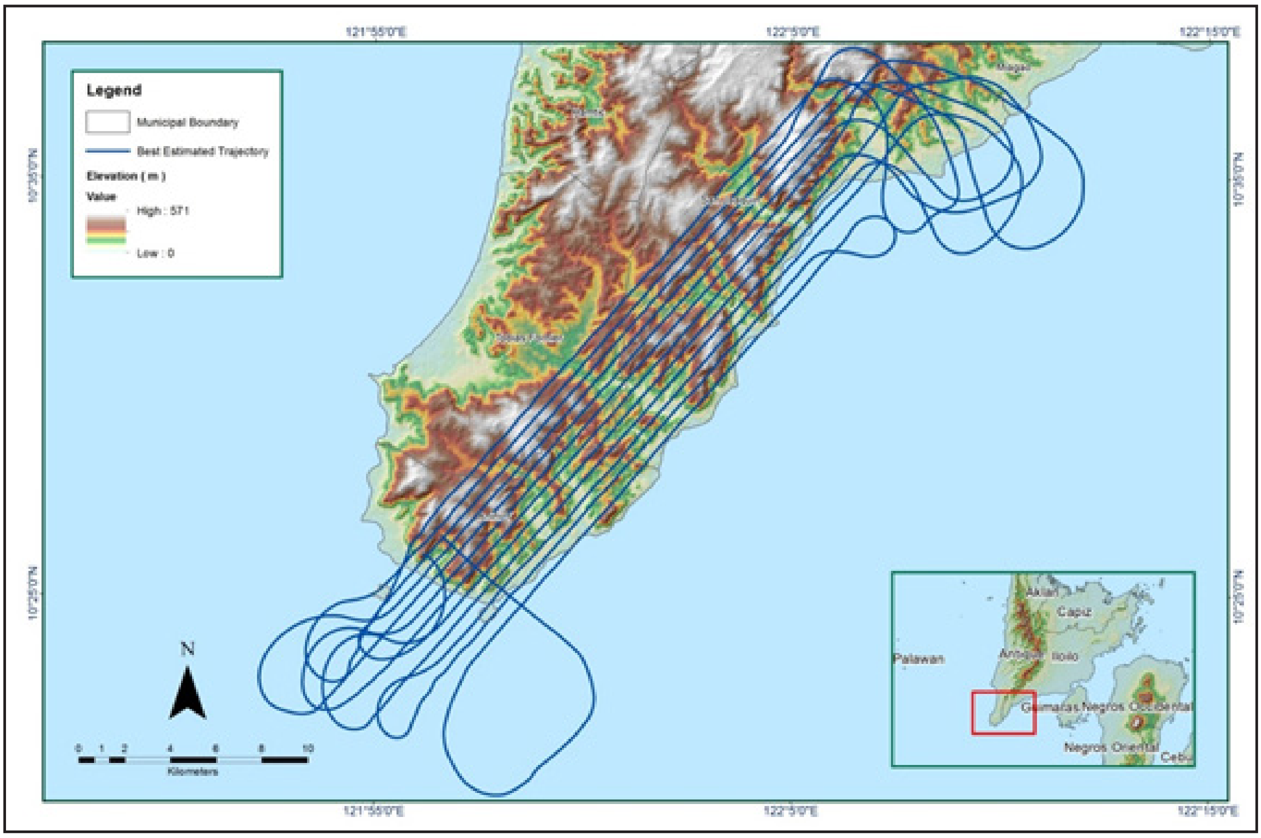


Figure A-8.17. Best Estimated Trajectory

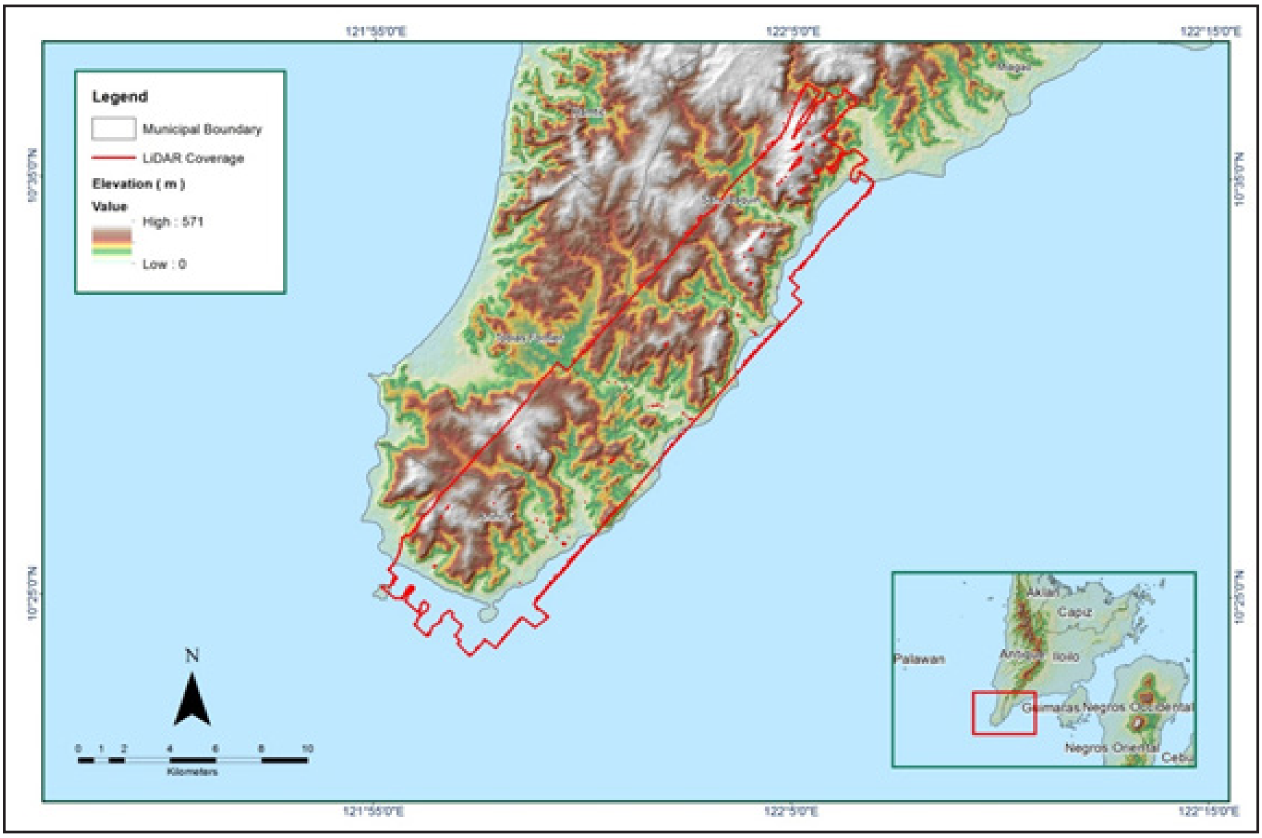


Figure A-8.18. Coverage of LiDAR data

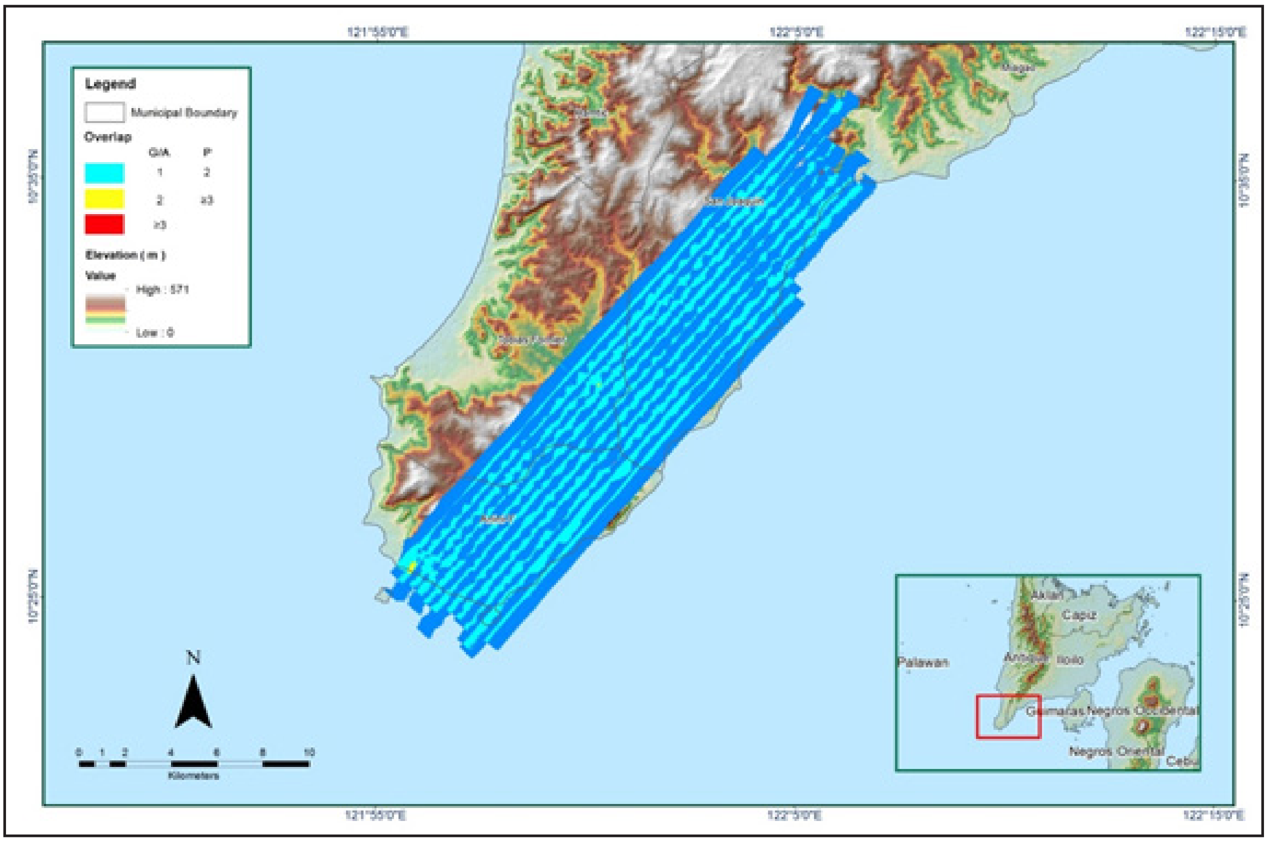


Figure A-8.19. Image of data overlap

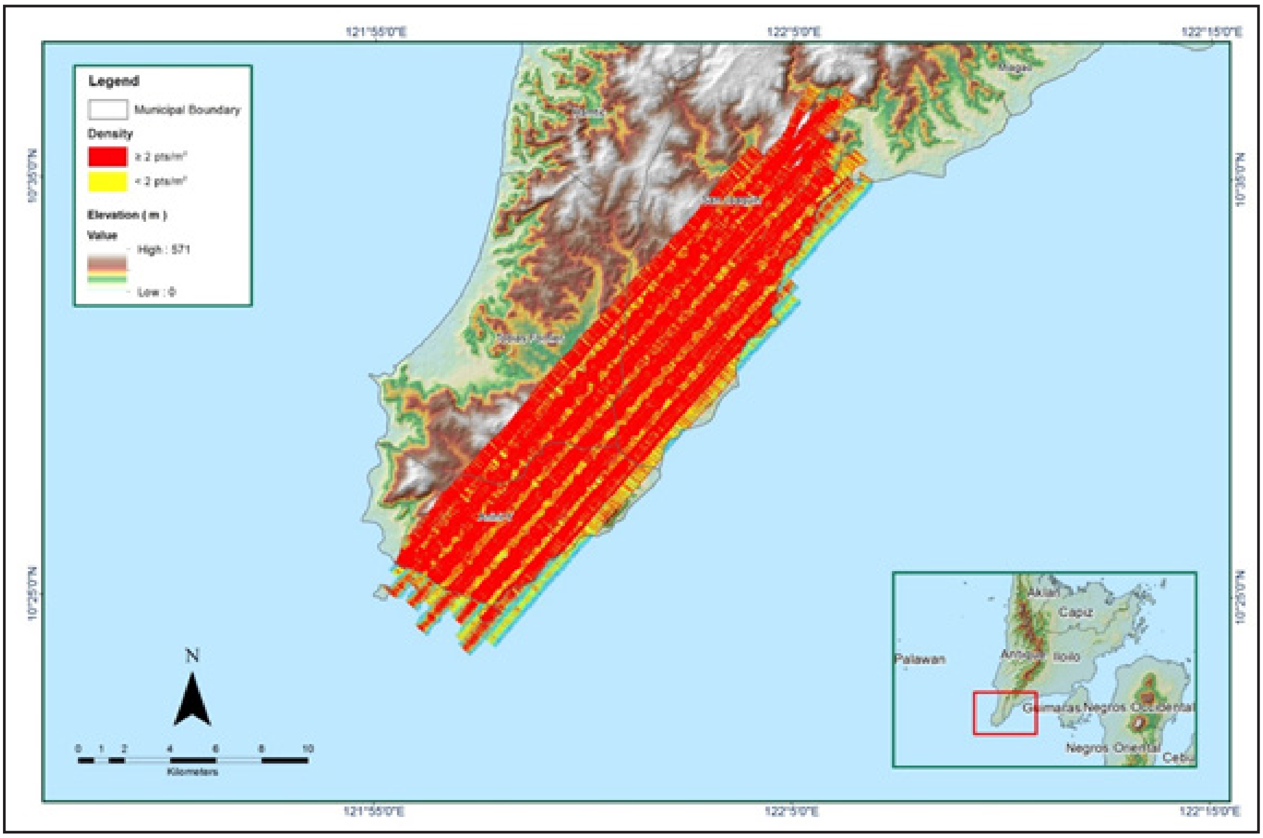


Figure A-8.20. Density map of merged LiDAR data

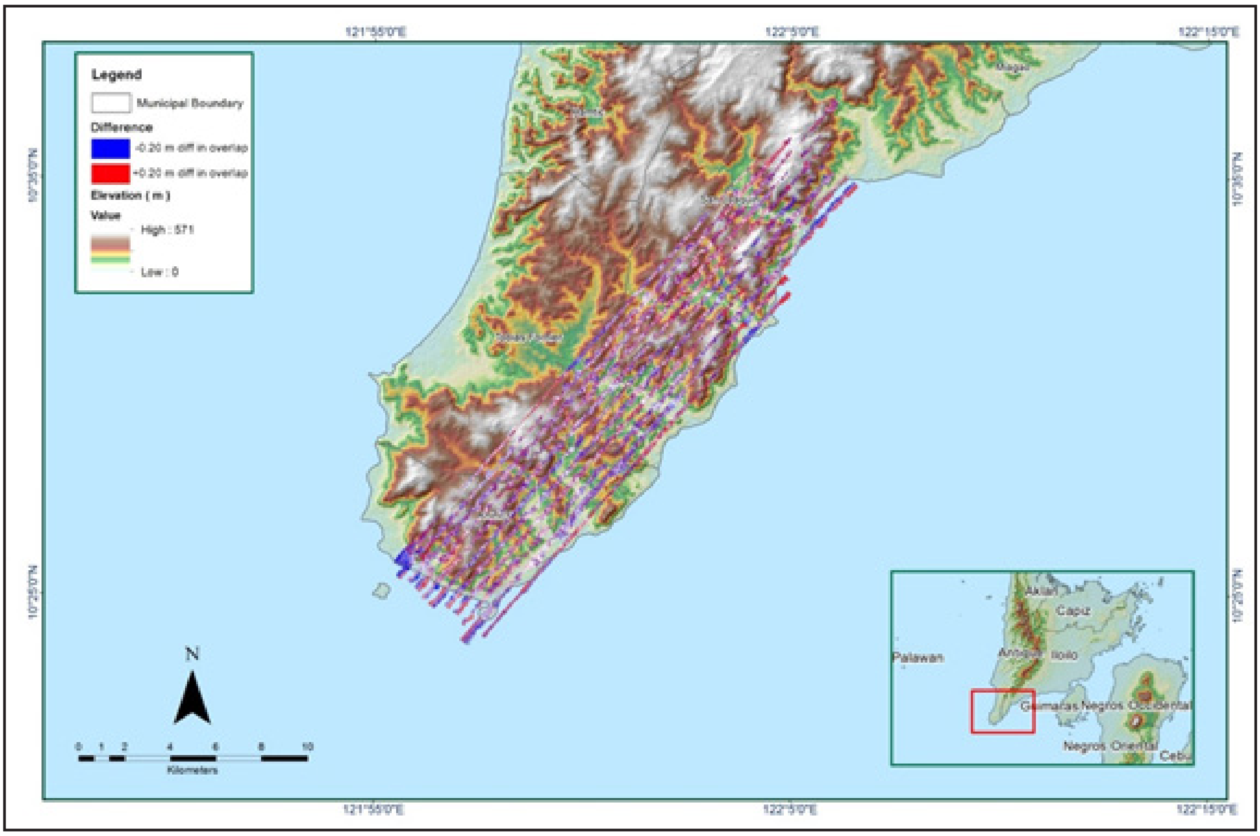


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk43H_Additional

Flight Area	Iloilo
Mission Name	Blk43H_Additional
Inclusive Flights	2570G
Range data size	21.7 GB
Base data size	14.4 MB
POS	222 MB
Image	48.5 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)	2.31
RMSE for East Position (<4.0 cm)	1.71
RMSE for Down Position (<8.0 cm)	3
Boresight correction stdev (<0.001deg)	0.000267
IMU attitude correction stdev (<0.001deg)	0.000681
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	N/A
Ave point cloud density per sq.m. (>2.0)	2.39
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	32
Maximum Height	303.07
Minimum Height	54.15
Classification (# of points)	
Ground	4,896,452
Low vegetation	2,945,541
Medium vegetation	5,105,218
High vegetation	5,769,133
Building	180,519.00
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Krisha Marie Bautista

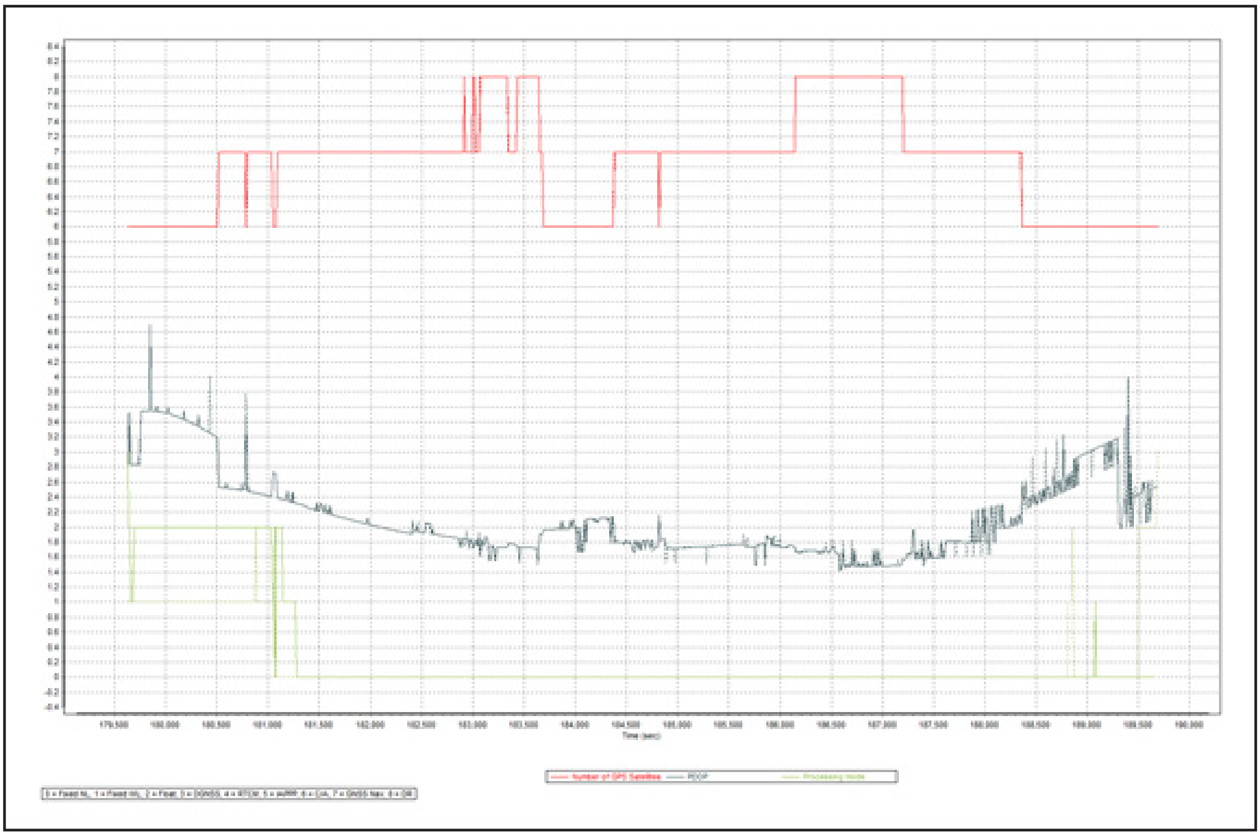


Figure A-8.22. Solution Status

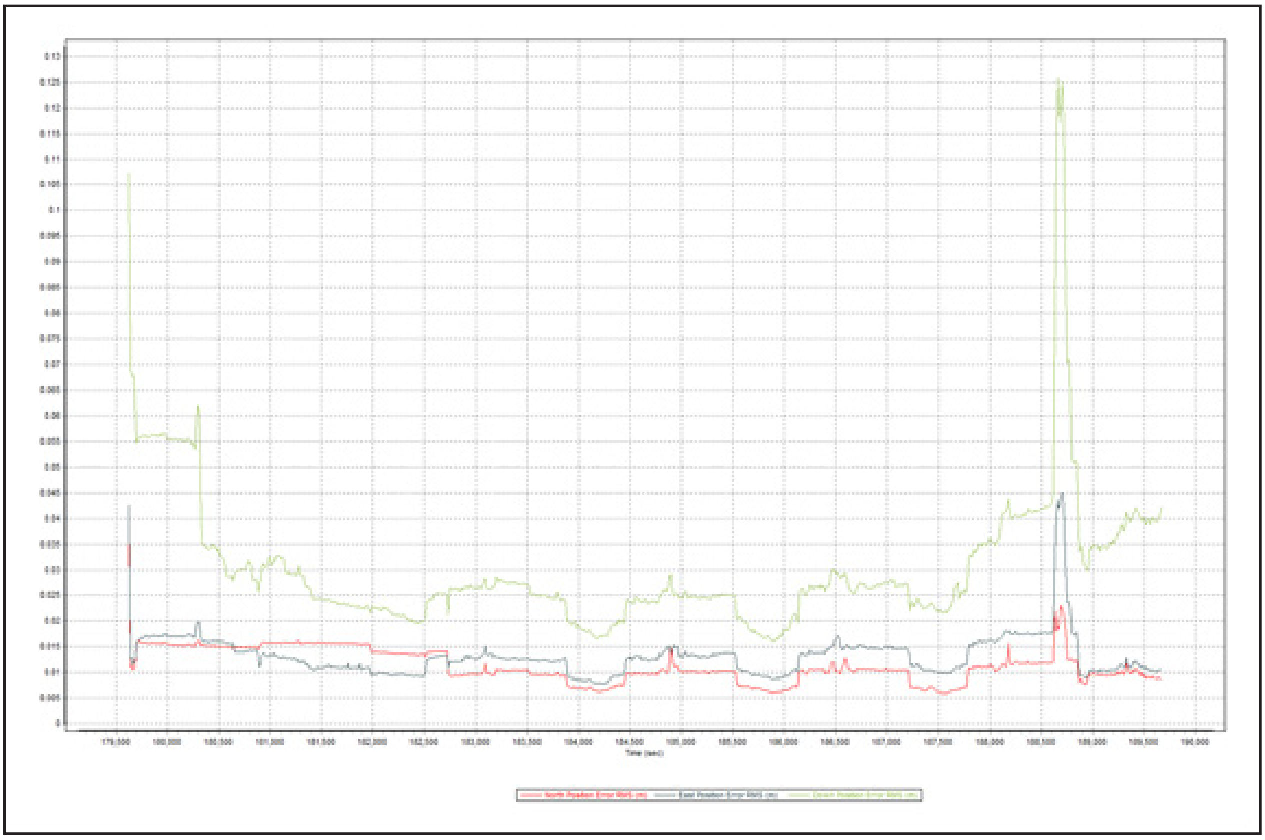


Figure A-8.23. Smoothed Performance Metric Parameters

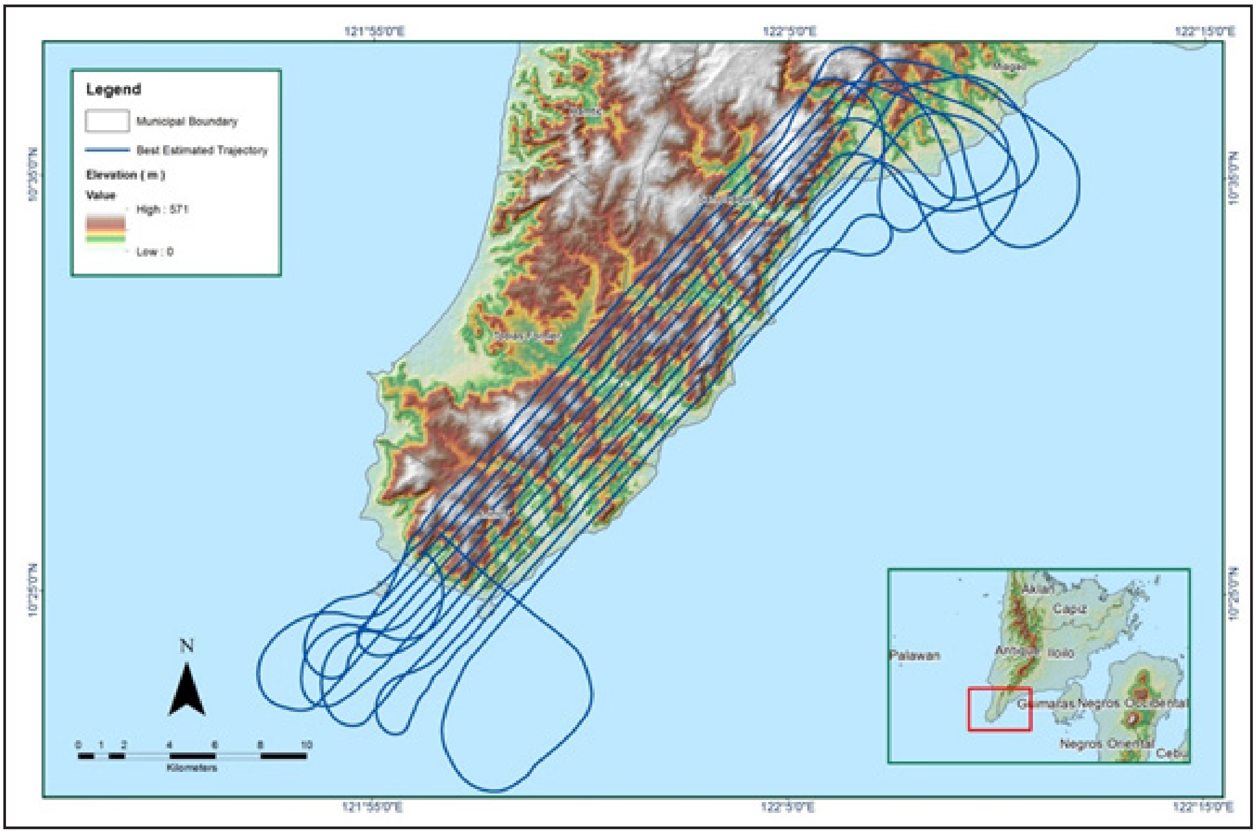


Figure A-8.24. Best Estimated Trajectory

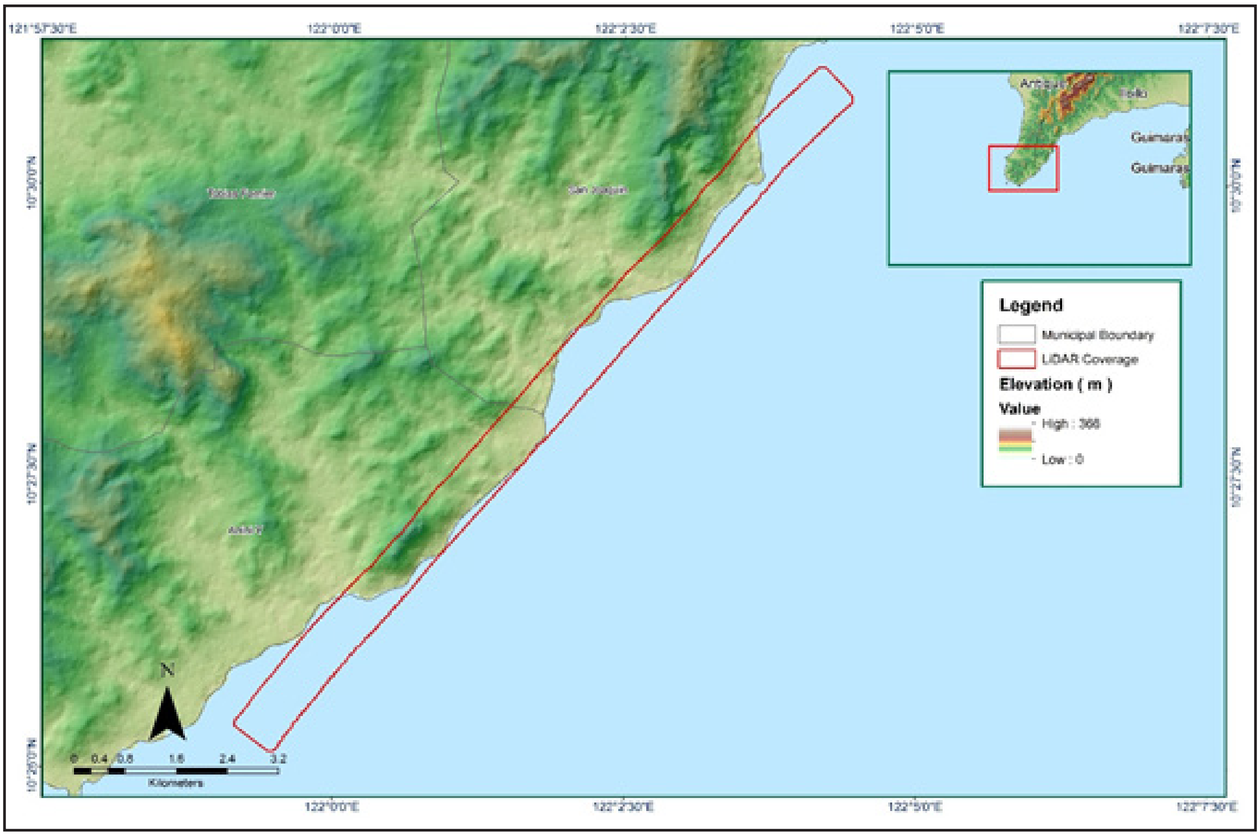


Figure A-8.25. Coverage of LiDAR data

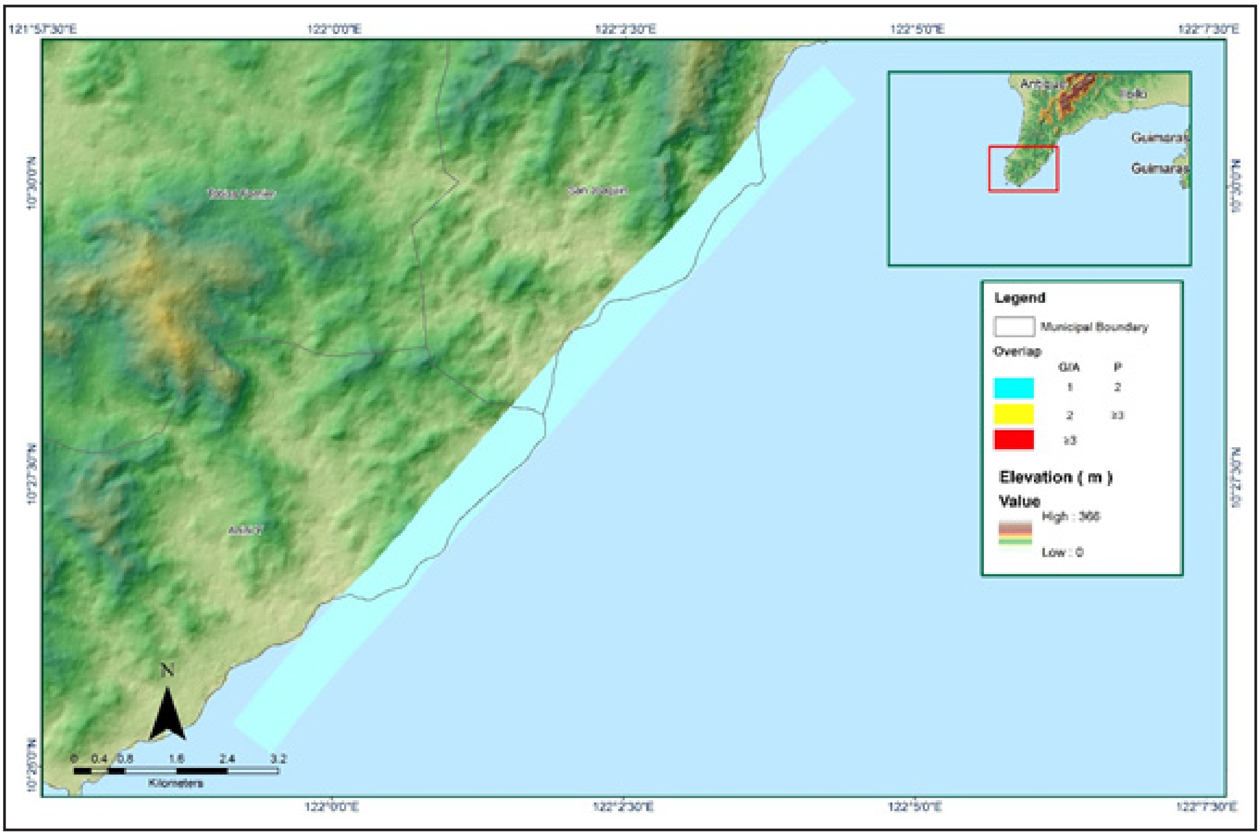


Figure A-8.26. Image of data overlap

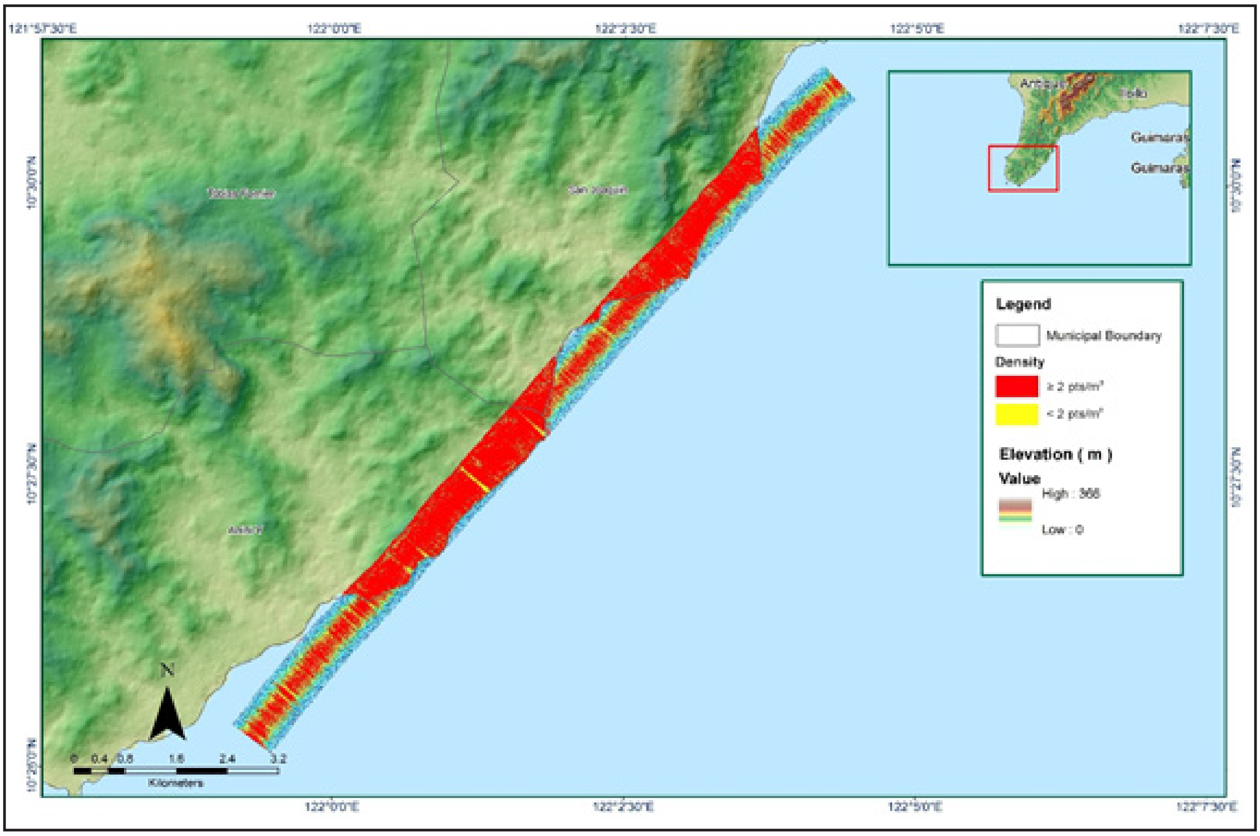


Figure A-8.27. Density map of merged LiDAR data

Table A-8.5. Mission Summary Report for Mission Blk43I

Flight Area	Iloilo
Mission Name	Blk43I
Inclusive Flights	2532G
Range data size	20.8 GB
Base data size	19.1 MB
POS	218 MB
Image	38 GB
Transfer date	February 17, 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)	3.32
RMSE for East Position (<4.0 cm)	2.07
RMSE for Down Position (<8.0 cm)	5.35
Boresight correction stdev (<0.001deg)	0.000222
IMU attitude correction stdev (<0.001deg)	0.000989
GPS position stdev (<0.01m)	0.0023
Minimum % overlap (>25)	34.60%
Ave point cloud density per sq.m. (>2.0)	3.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	236
Maximum Height	601.16 m
Minimum Height	58.56 m
Classification (# of points)	
Ground	86,549,094
Low vegetation	85,709,374
Medium vegetation	89,170,617
High vegetation	205,255,712
Building	6,043,460
Orthophoto	No
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Melissa Fernandez

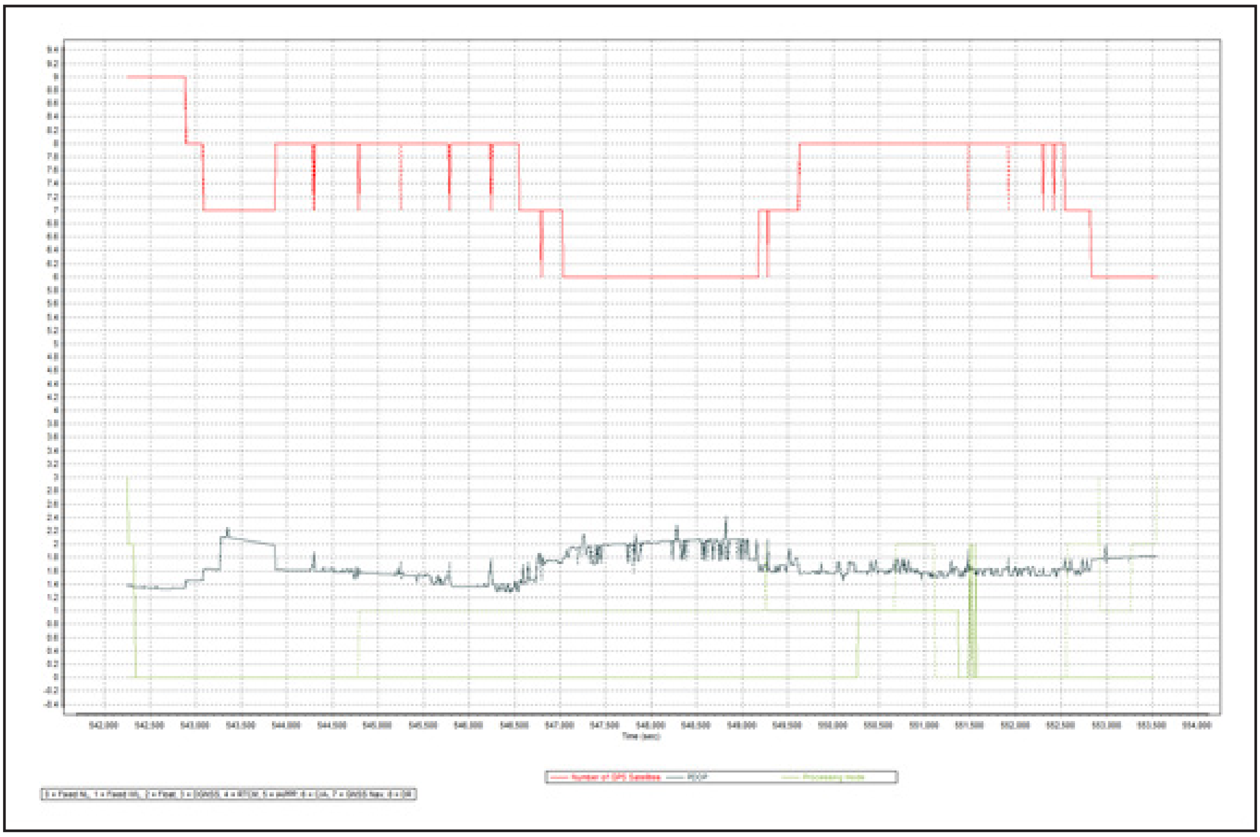


Figure A-8.28. Solution Status

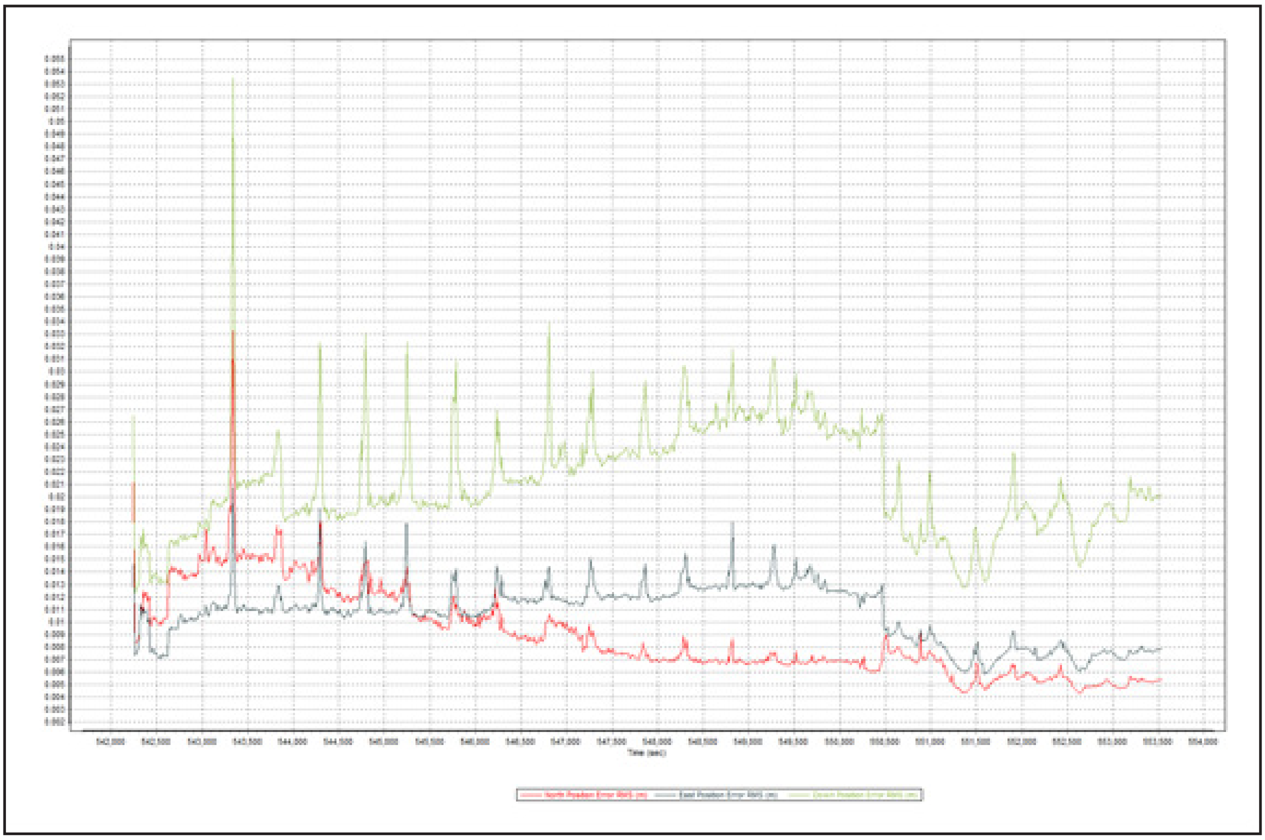


Figure A-8.29. Smoothed Performance Metric Parameters

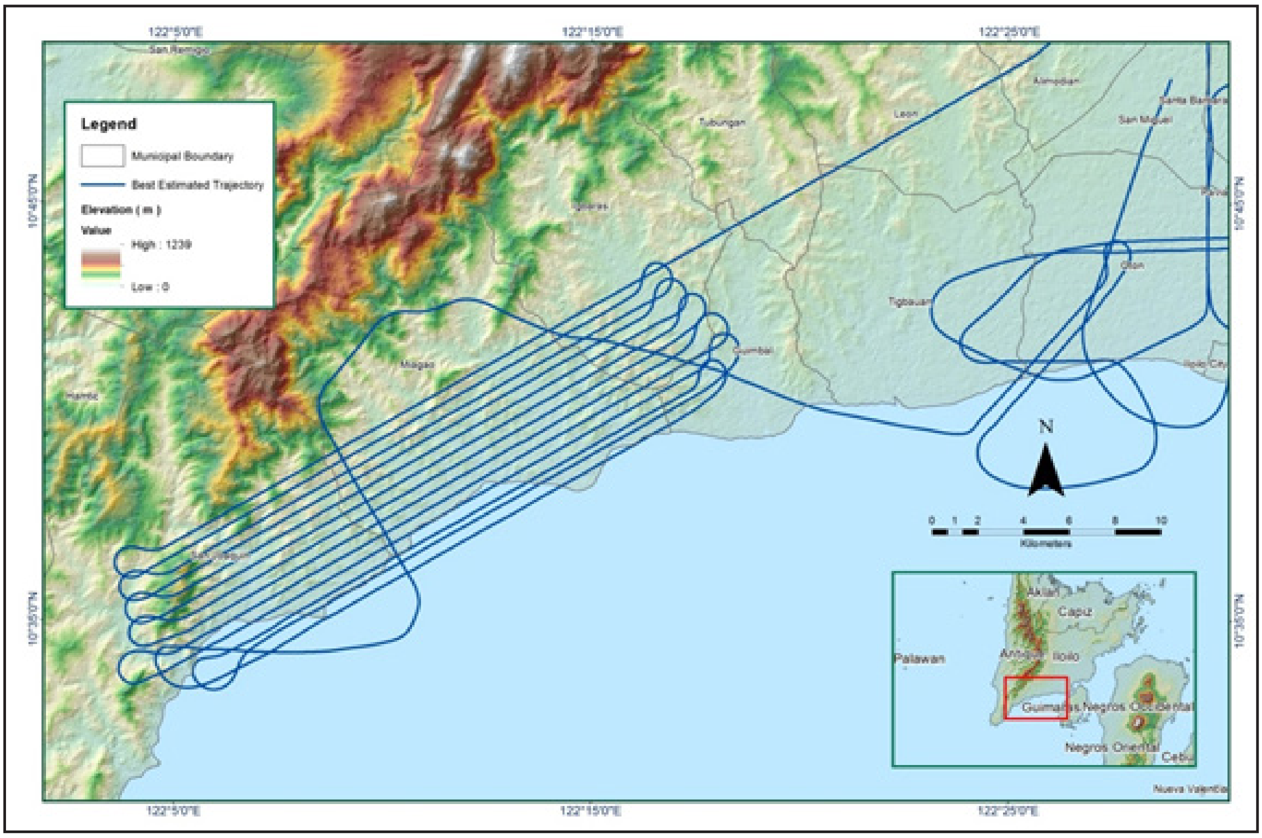


Figure A-8.30. Best Estimated Trajectory

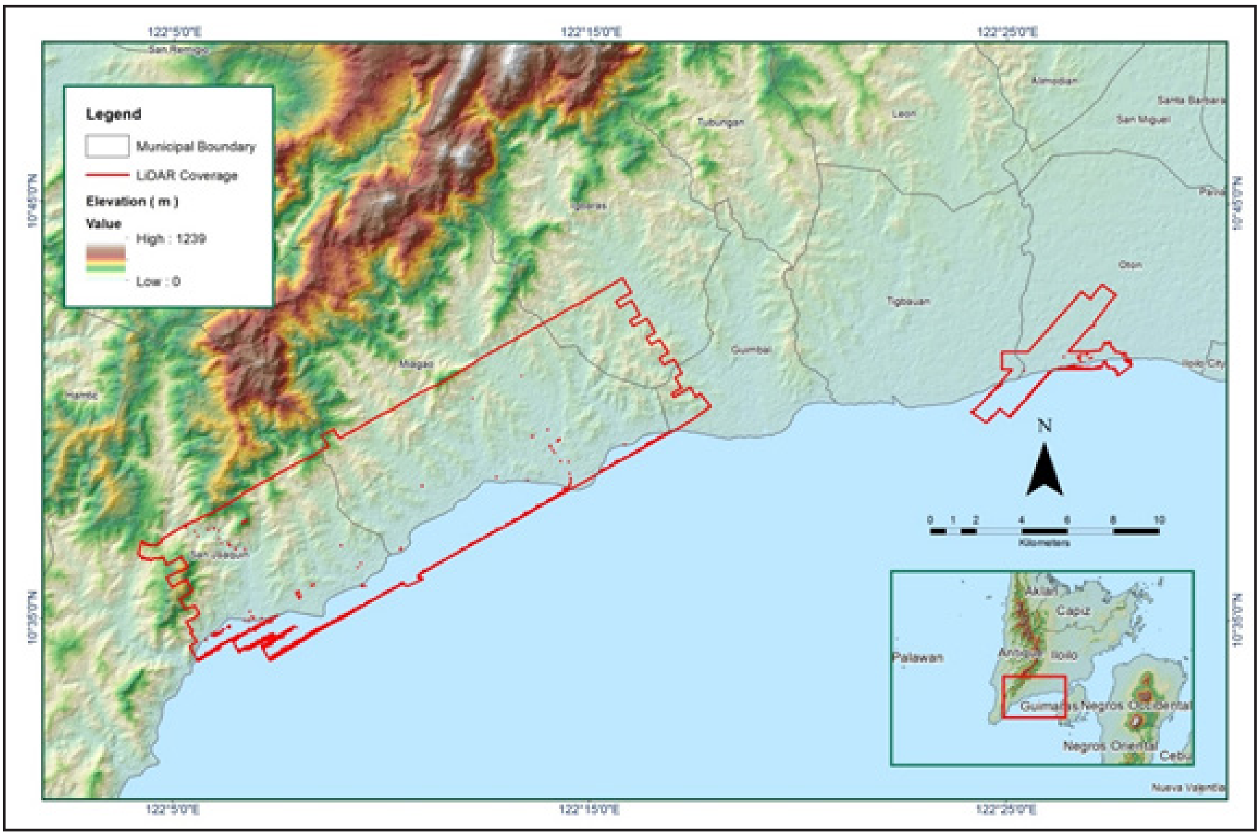


Figure A-8.31. Coverage of LiDAR data

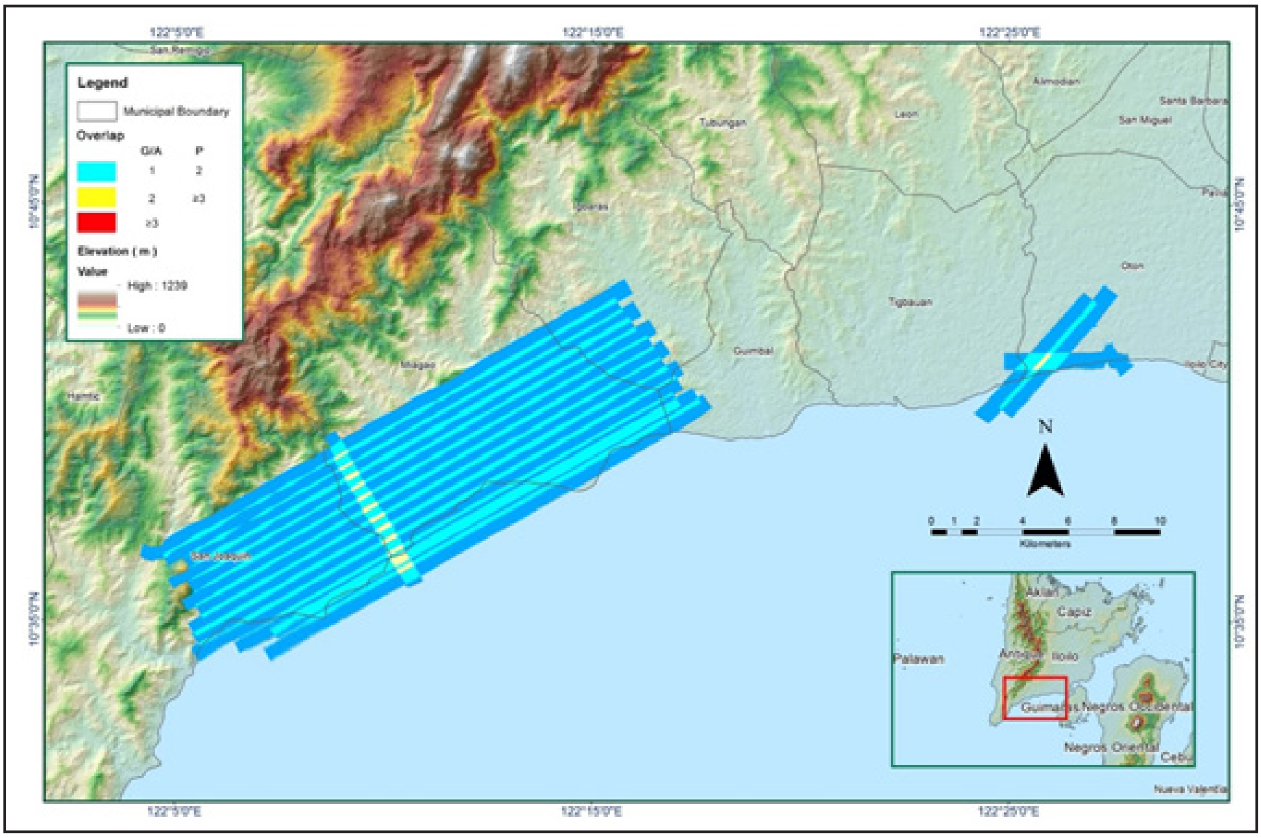


Figure A-8.32. Image of data overlap

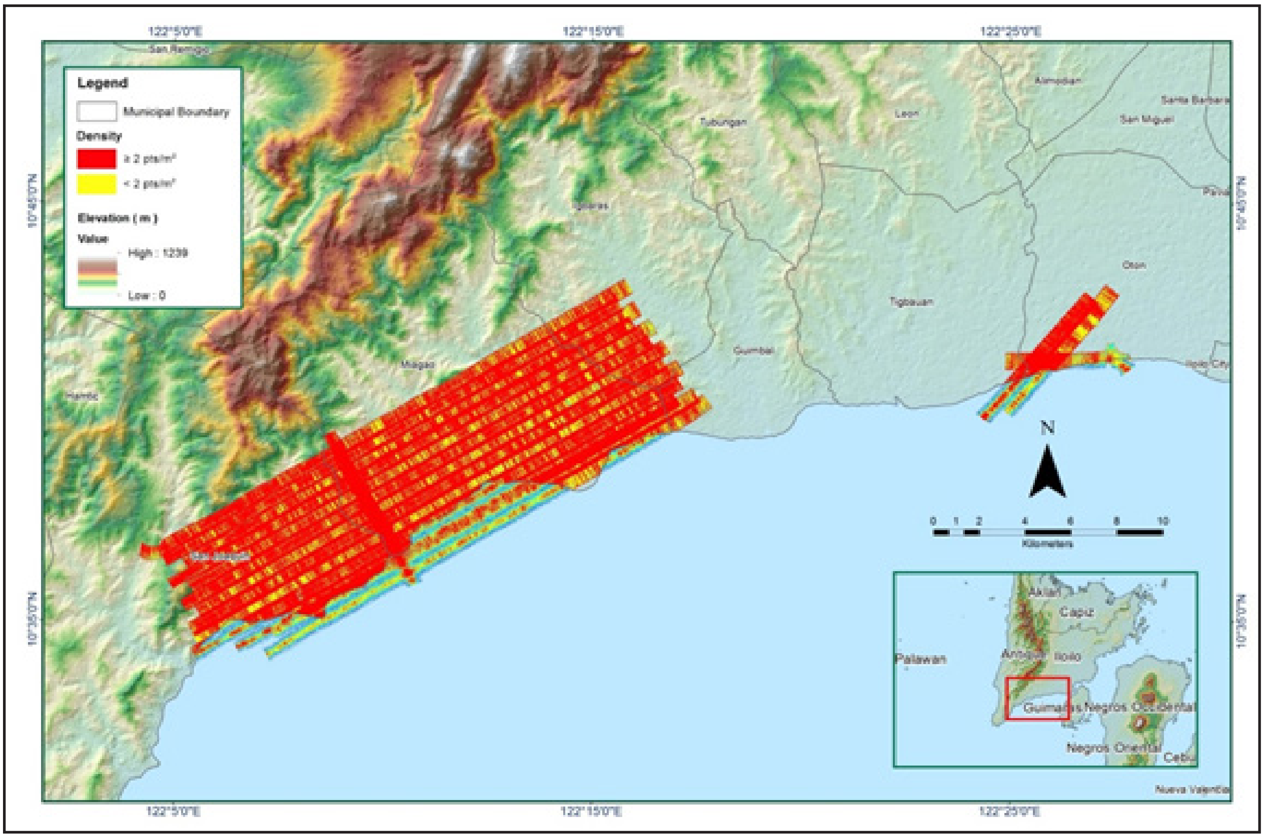


Figure A-8.33. Density map of merged LiDAR data

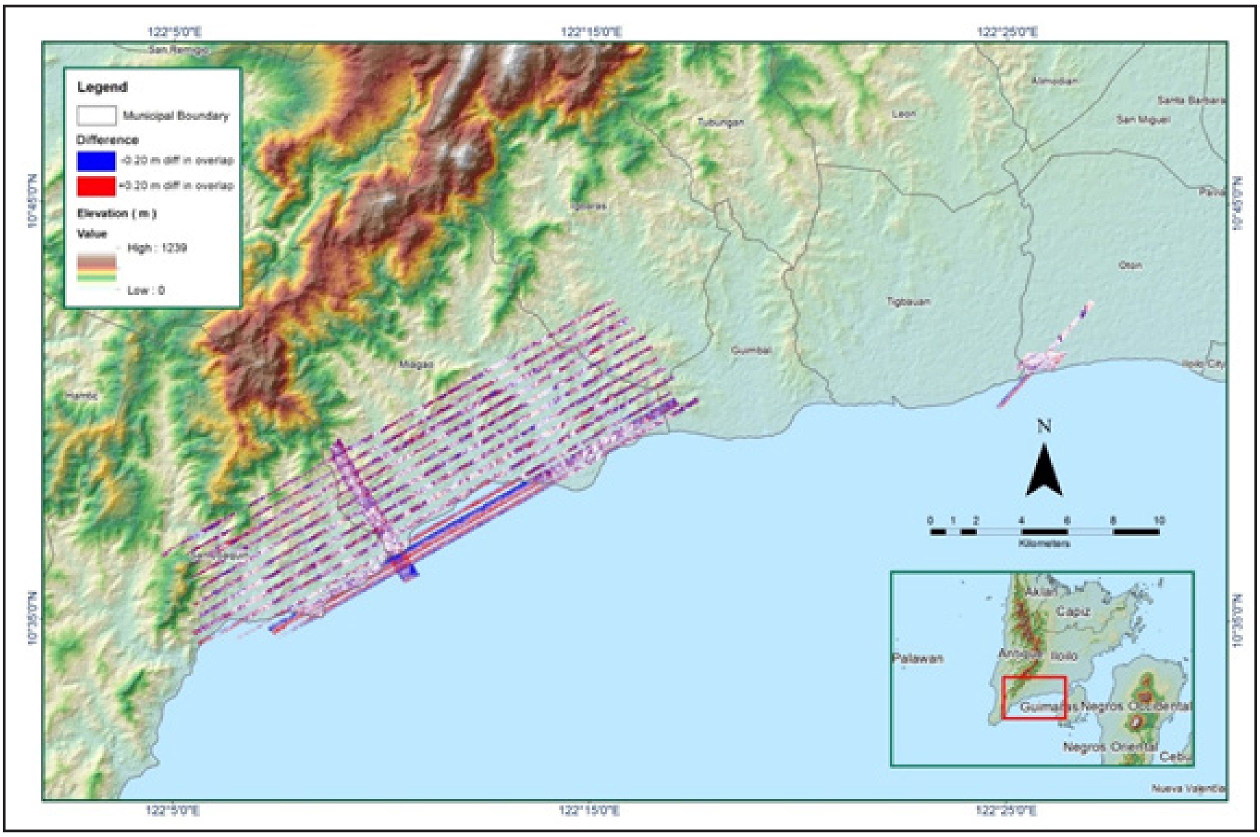


Figure A-8.34.Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk43G

Flight Area	Iloilo
Mission Name	Blk43G
Inclusive Flights	2558G
Range data size	27.3 GB
Base data size	10.5 MB
POS	241 MB
Image	42.2 GB
Transfer date	February 17, 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)	0.000687
IMU attitude correction stdev (<0.001deg)	0.001634
GPS position stdev (<0.01m)	0.0092
Minimum % overlap (>25)	20.84%
Ave point cloud density per sq.m. (>2.0)	3.41
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	246
Maximum Height	627.30 m
Minimum Height	96.23 m
Classification (# of points)	
Ground	60,476,294
Low vegetation	52,354,260
Medium vegetation	178,194,040
High vegetation	289,810,980
Building	1,744,342
Orthophoto	No
Processed by	Engr. Analyn Naldo, Aljon Rie Araneta, Kathryn Claudyn Zarate

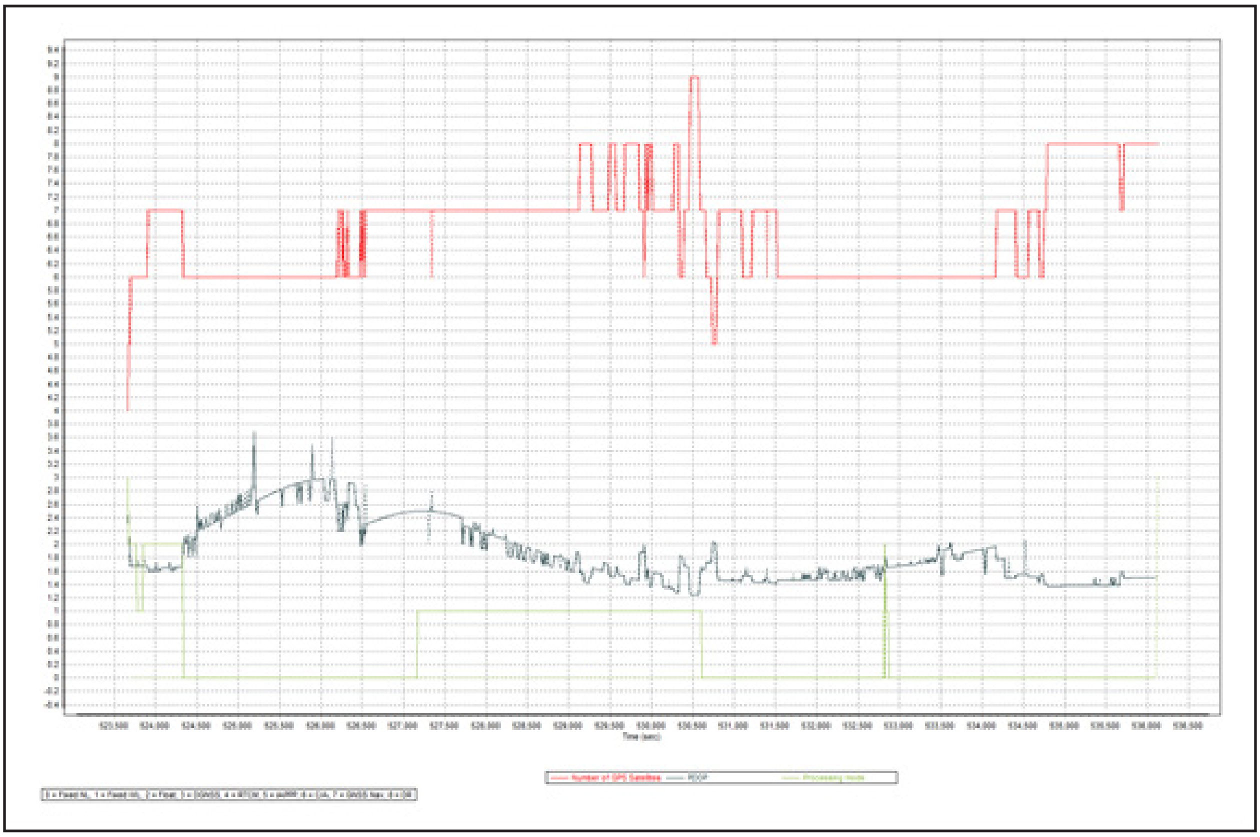


Figure A-8.35. Solution Status

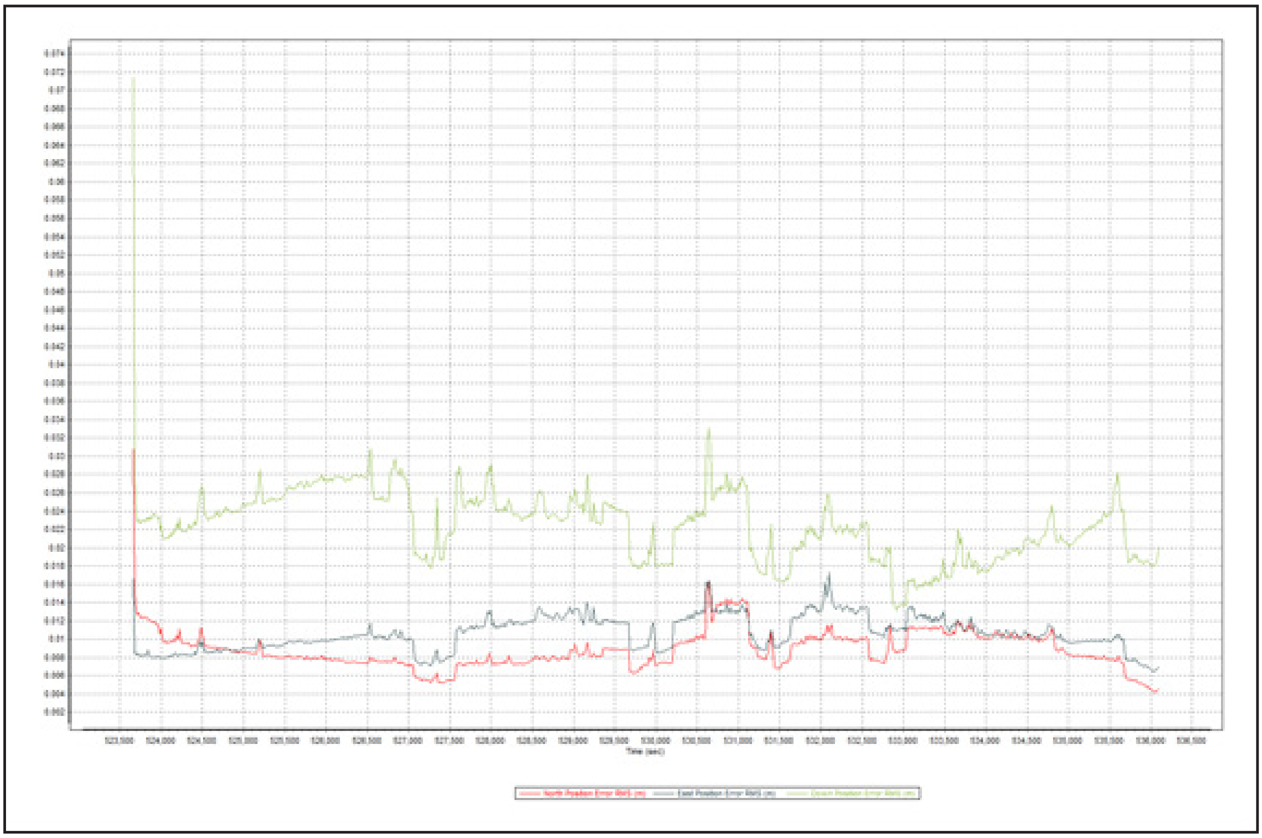


Figure A-8.36. Smoothed Performance Metric Parameters

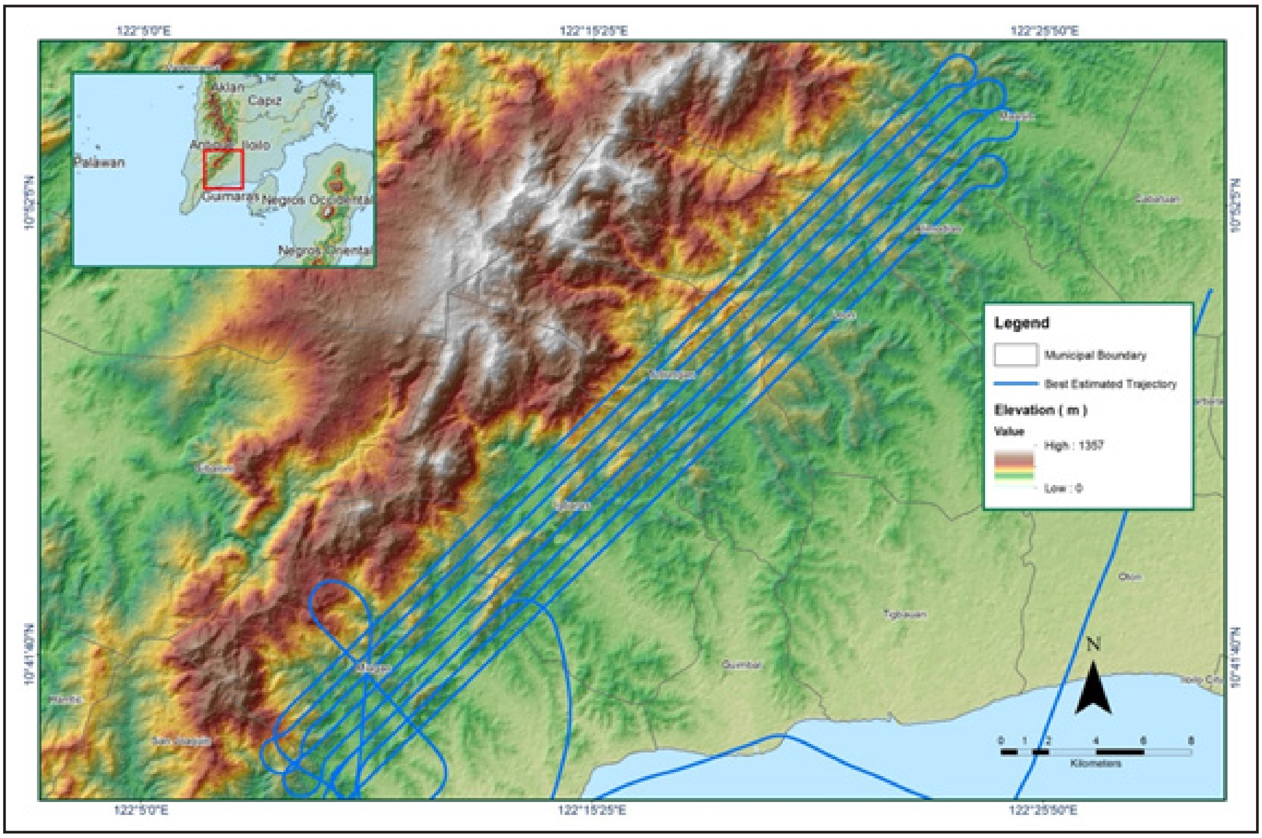


Figure A-8.37. Best Estimated Trajectory

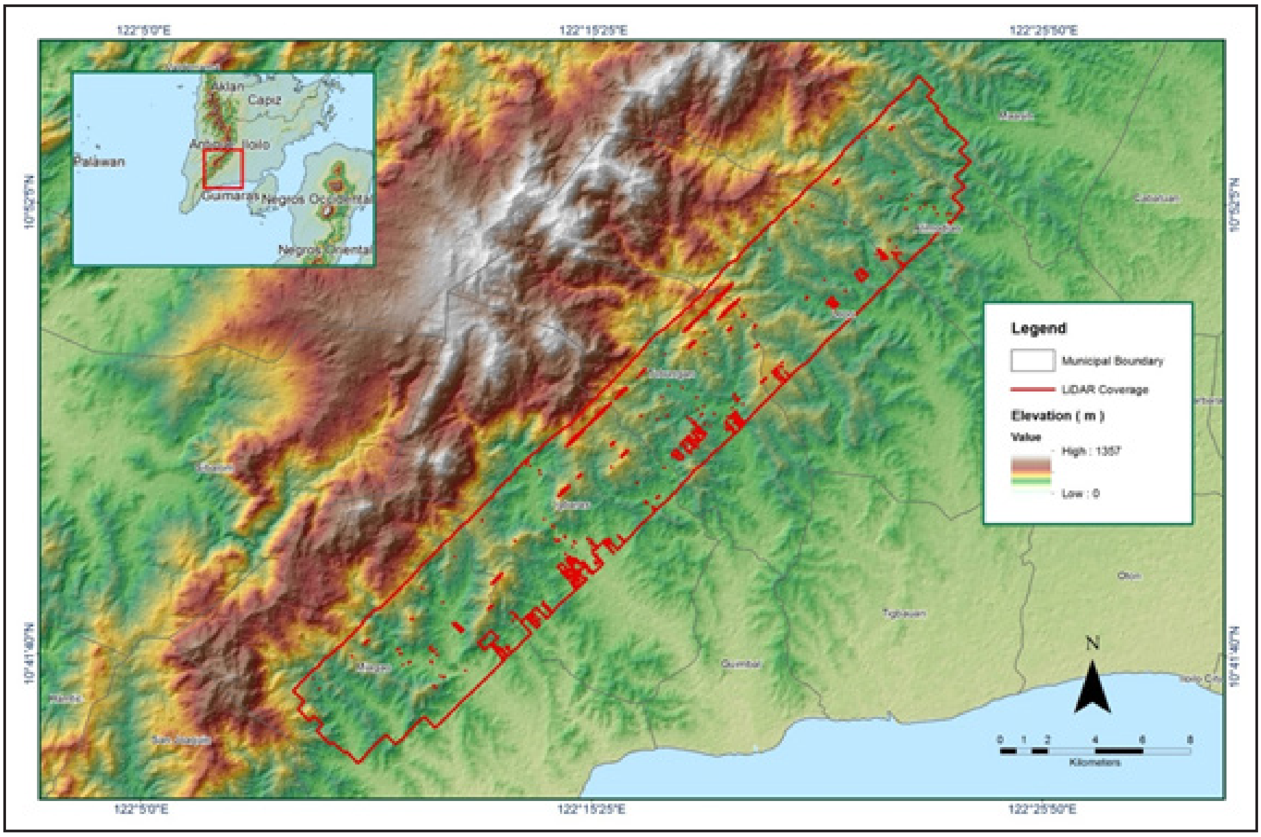


Figure A-8.38. Coverage of LiDAR data

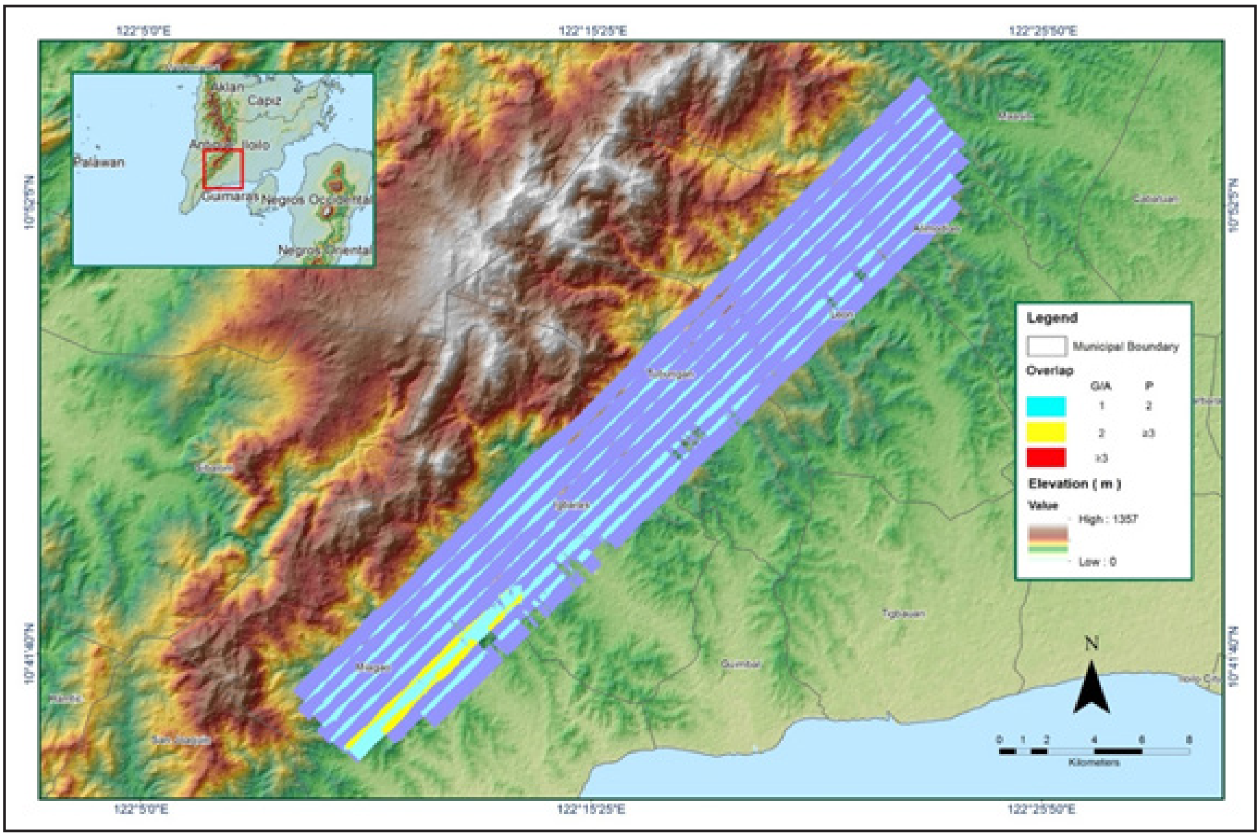


Figure A-8.39. Image of data overlap

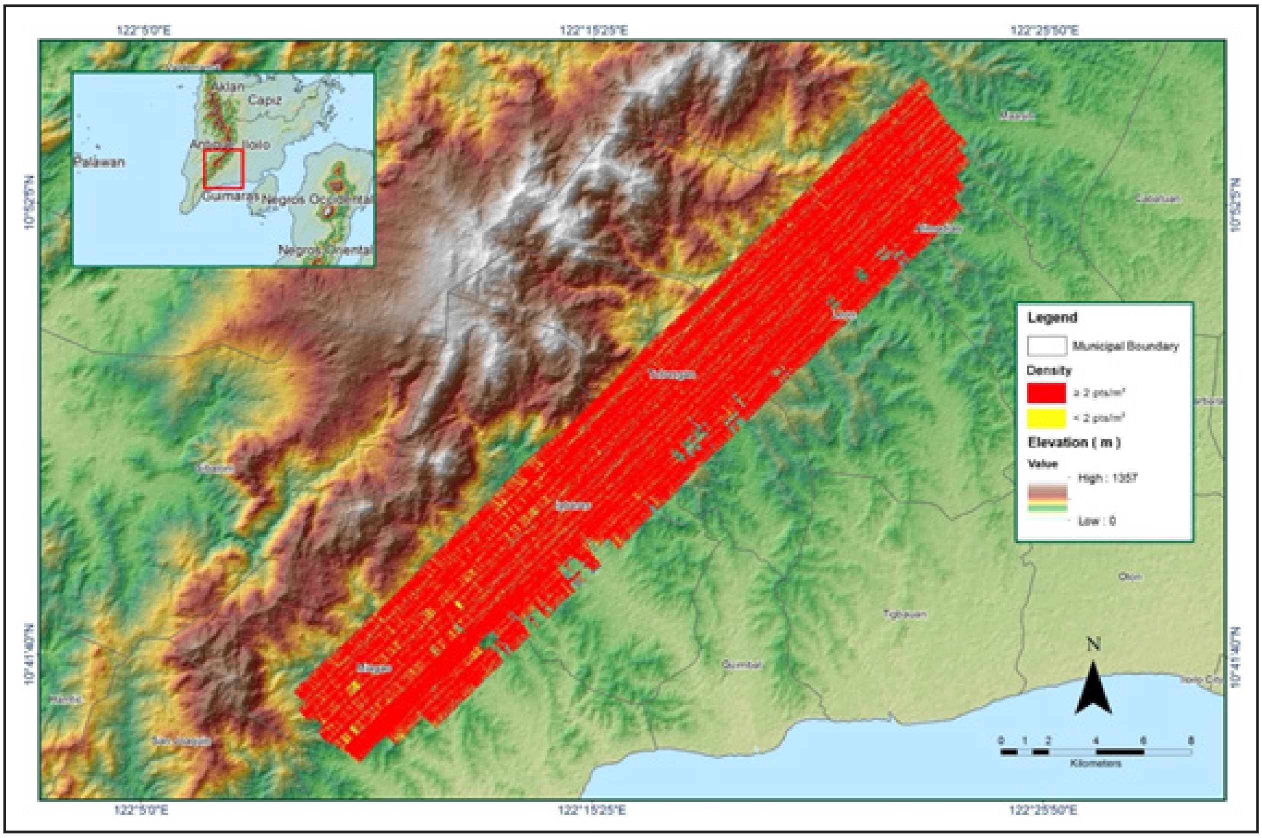


Figure A-8.40. Density map of merged LiDAR data

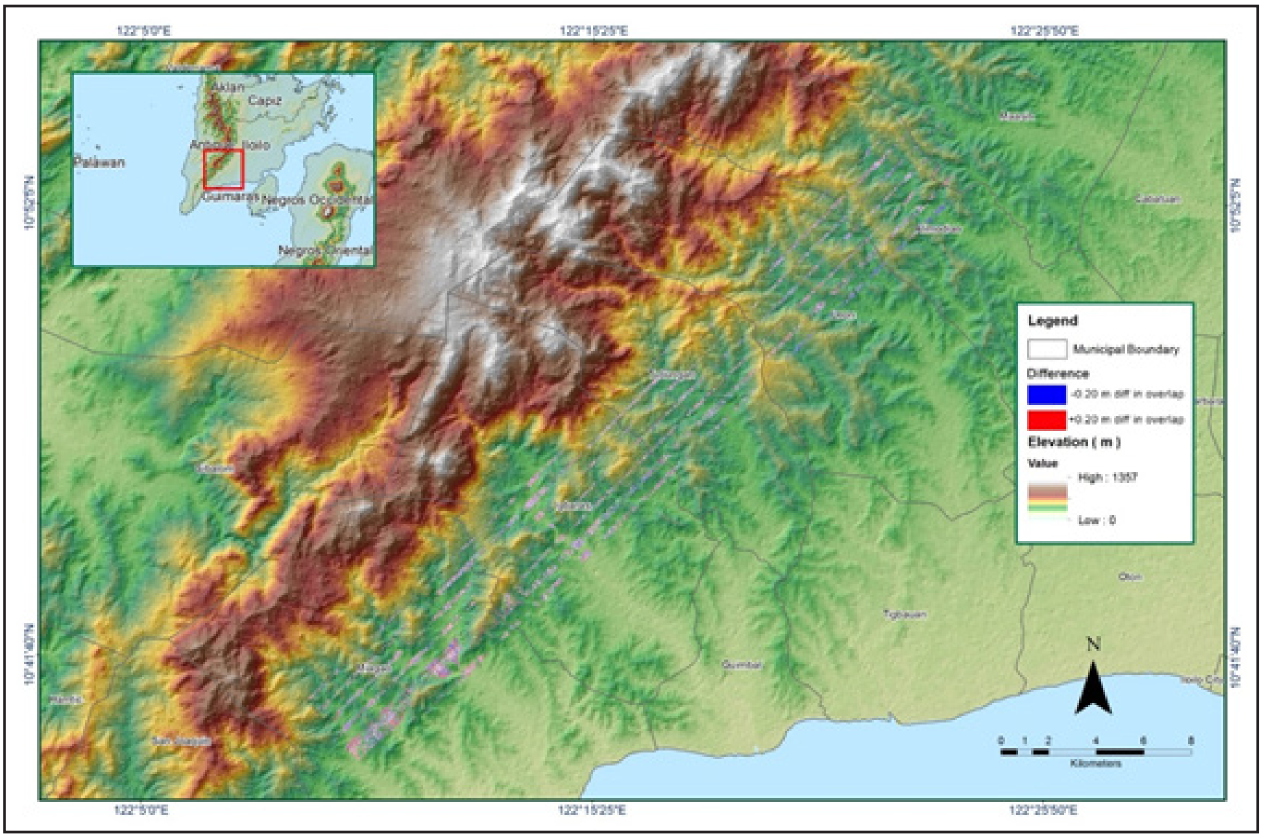


Figure A-8.41. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk43G_additional

Flight Area	Iloilo
Mission Name	Blk43G_additional
Inclusive Flights	2550G, 2558G, 2578G, 2593P
Range data size	82.2 GB
Base data size	38.2 MB
POS	847 MB
Image	116.97 GB
Transfer date	March 23, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.92
RMSE for East Position (<4.0 cm)	1.38
RMSE for Down Position (<8.0 cm)	2.67
Boresight correction stdev (<0.001deg)	0.000872
IMU attitude correction stdev (<0.001deg)	0.00273
GPS position stdev (<0.01m)	0.018
Minimum % overlap (>25)	29.07%
Ave point cloud density per sq.m. (>2.0)	4.37
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	287
Maximum Height	1475.44 m
Minimum Height	93.85 m
Classification (# of points)	
Ground	203,299,702
Low vegetation	125,600,493
Medium vegetation	348,926,496
High vegetation	593,034,772
Building	2,309,980
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Kenneth Solidum, Engr. Anton Chua, Jr., Jovy Narisma

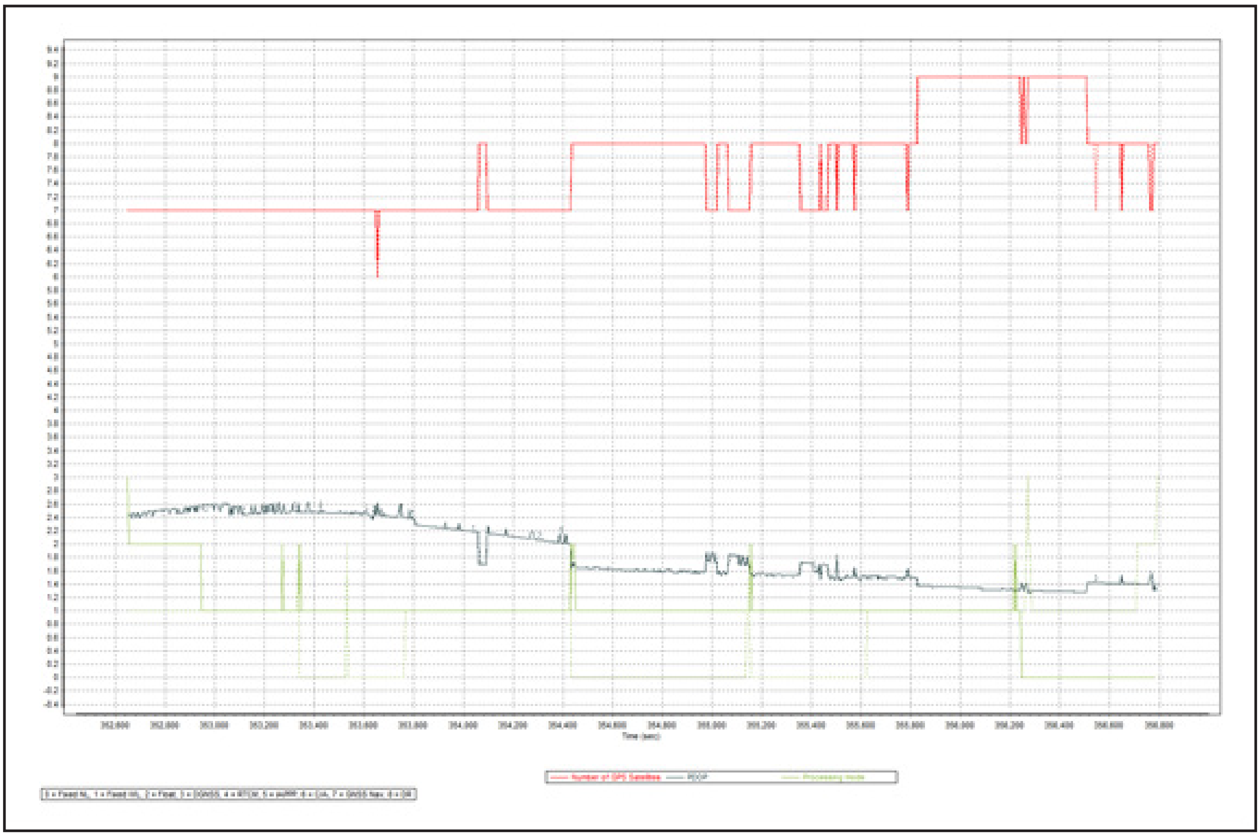


Figure A-8.42. Solution Status

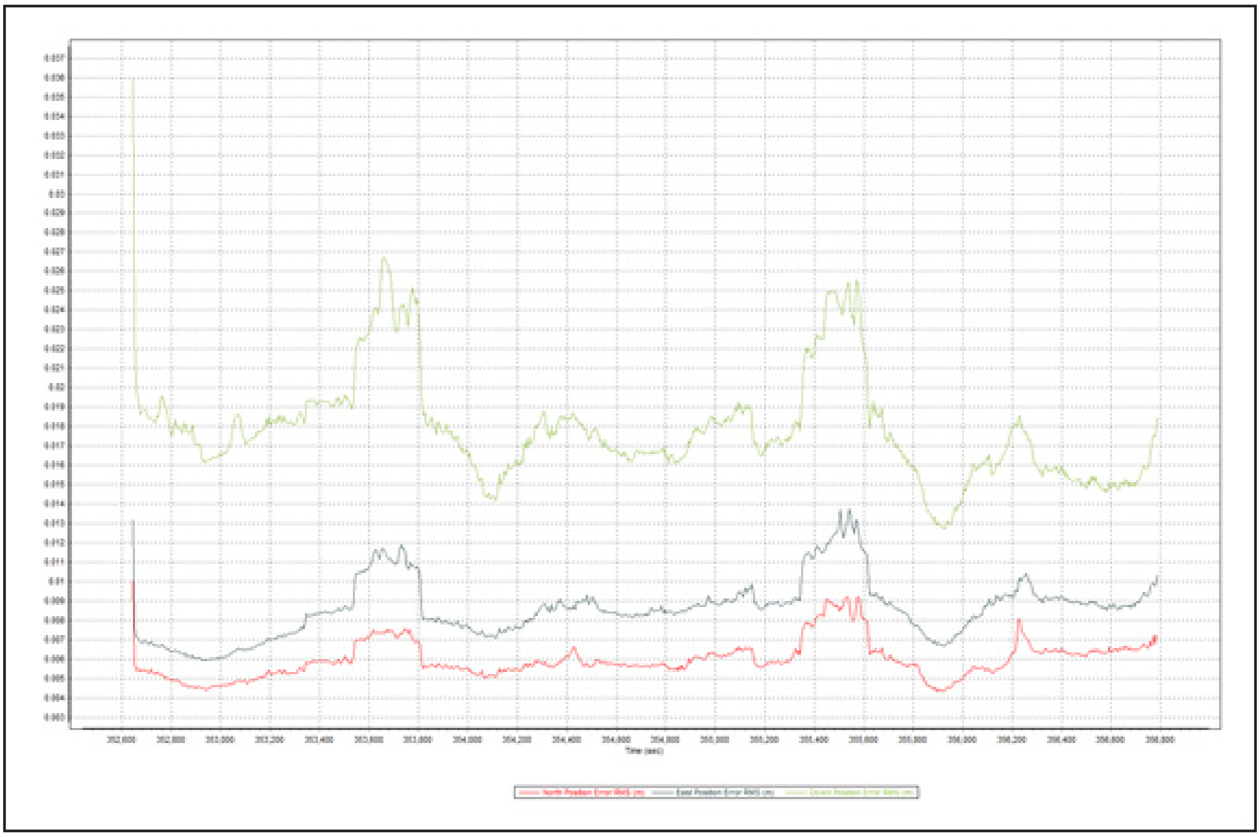


Figure A-8.43. Smoothed Performance Metric Parameters

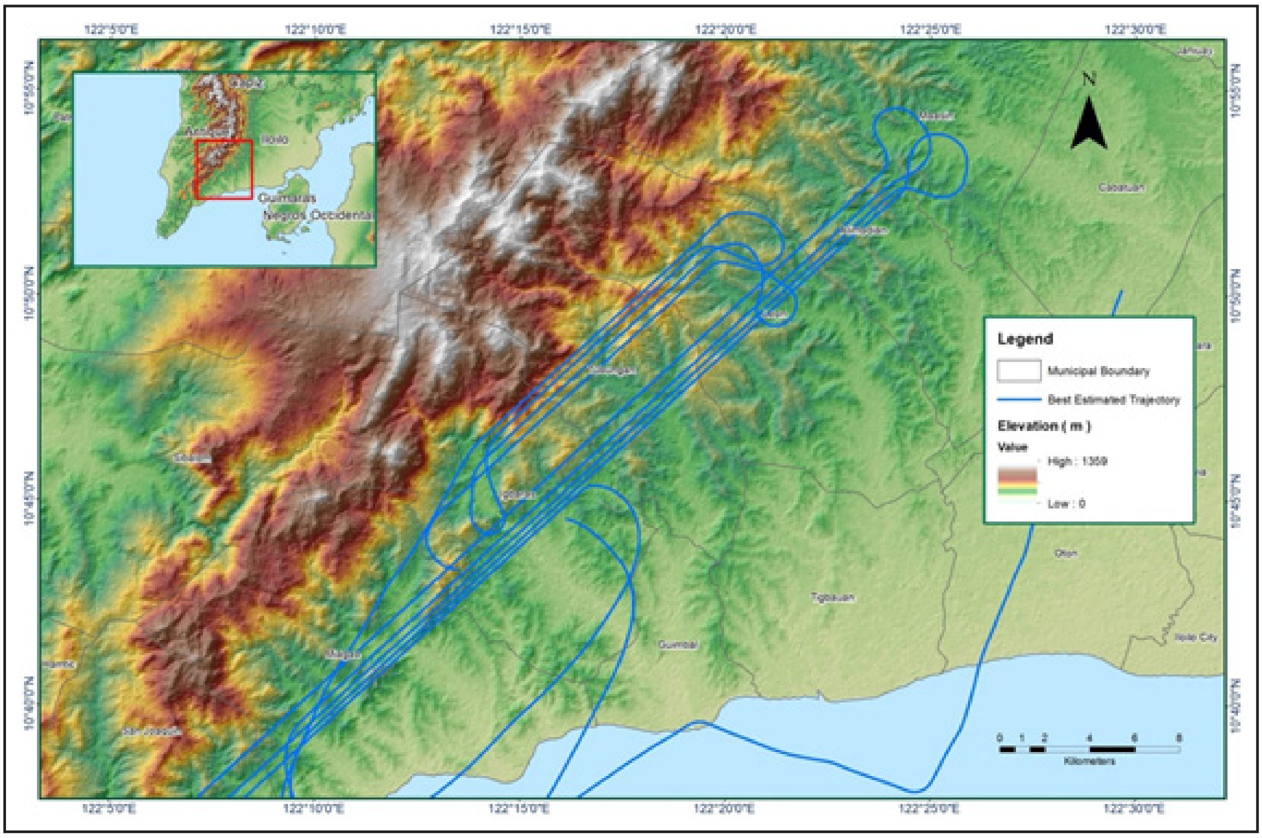


Figure A-8.44. Best Estimated Trajectory

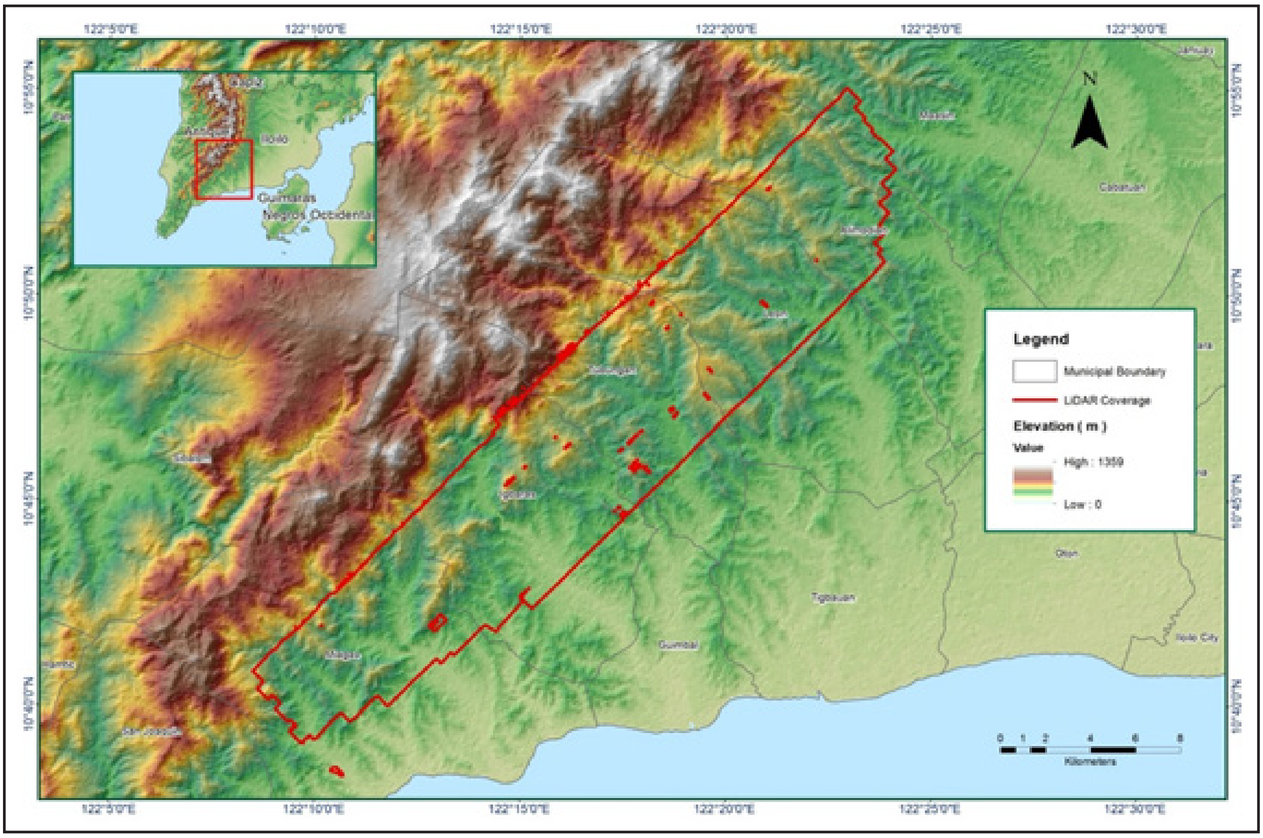


Figure A-8.45. Coverage of LiDAR data

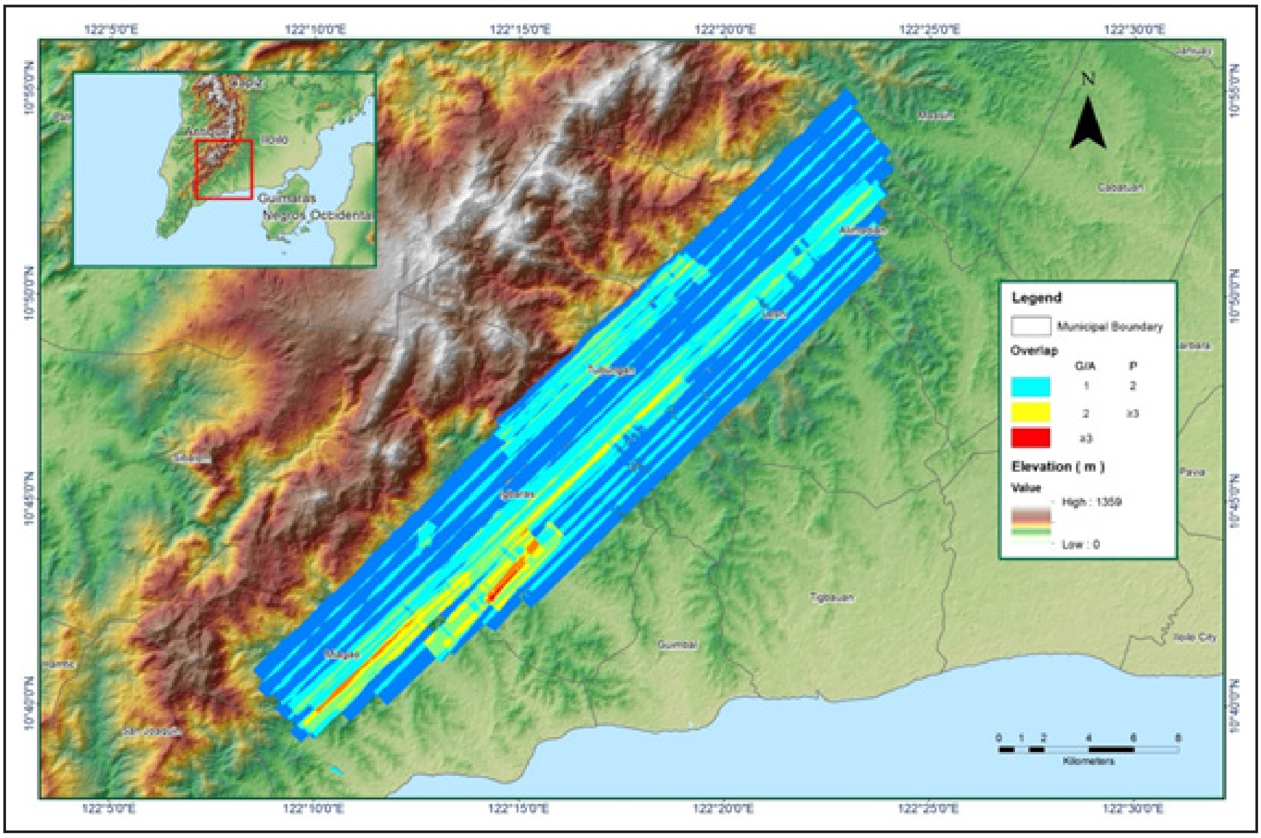


Figure A-8.46. Image of data overlap

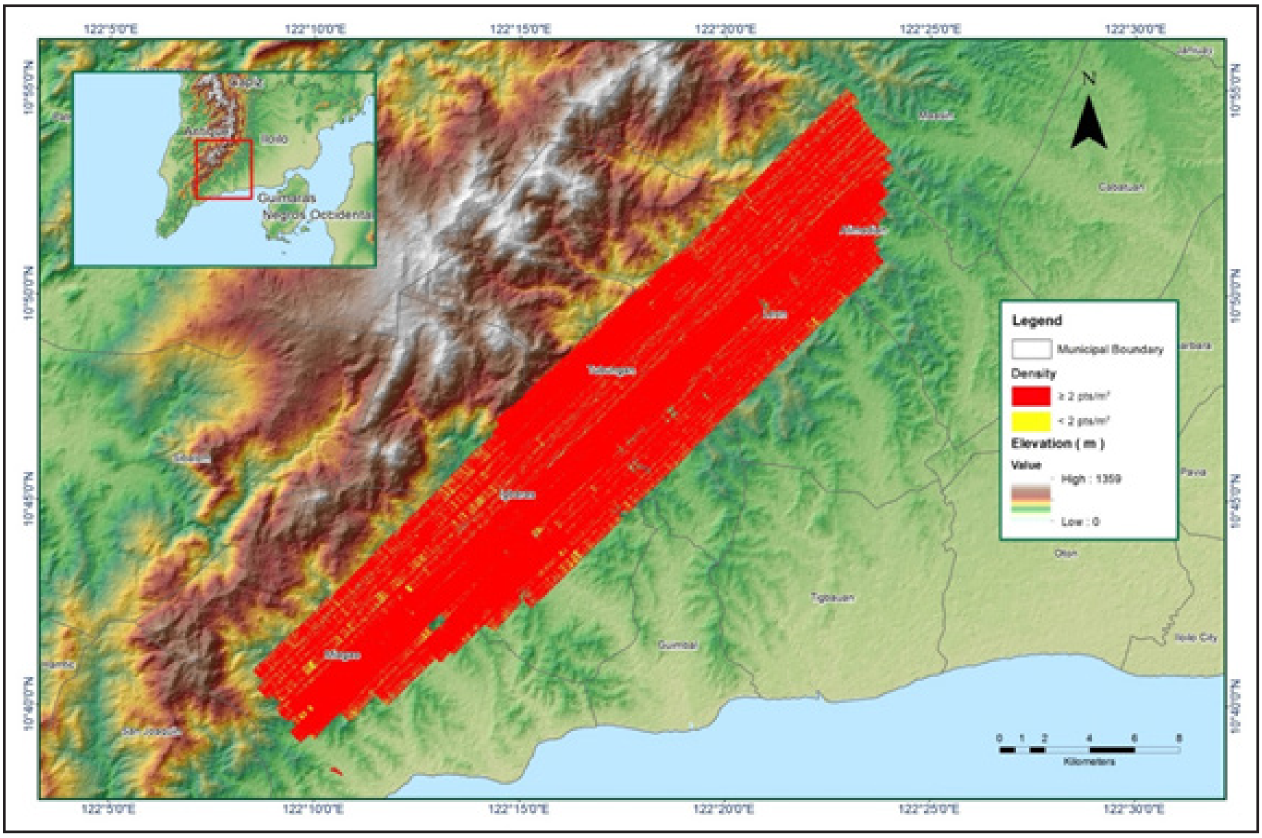


Figure A-8.47. Density map of merged LiDAR data

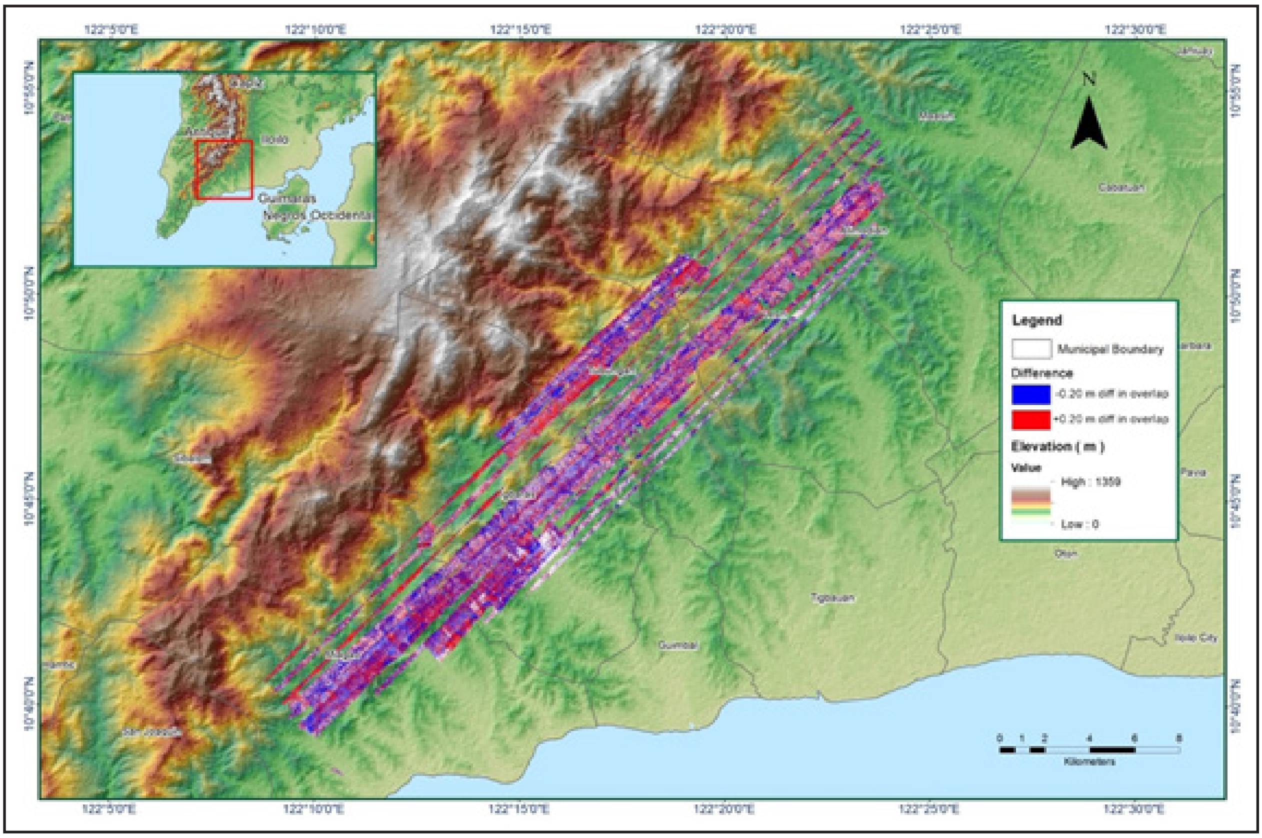


Figure A-8.48. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk37O

Flight Area	Iloilo
Mission Name	Blk37O
Inclusive Flights	2617P
Range data size	34.5 GB
Base data size	18.7 MB
POS	260 MB
Image	55.2 GB
Transfer date	July 07, 2015
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)	3.55
RMSE for East Position (<4.0 cm)	3.78
RMSE for Down Position (<8.0 cm)	6.81
Boresight correction stdev (<0.001deg)	0.000218
IMU attitude correction stdev (<0.001deg)	0.001128
GPS position stdev (<0.01m)	0.0074
Minimum % overlap (>25)	34.53%
Ave point cloud density per sq.m. (>2.0)	4.13
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	331
Maximum Height	114.96 m
Minimum Height	566.58 m
Classification (# of points)	
Ground	385,064,706
Low vegetation	146,093,396
Medium vegetation	460,050,051
High vegetation	448,593,461
Building	3,093,173
Orthophoto	No
Processed by	Engr. Regis Guhiting, Aljon Rie Araneta, Engr. Krisha Marie Bautista

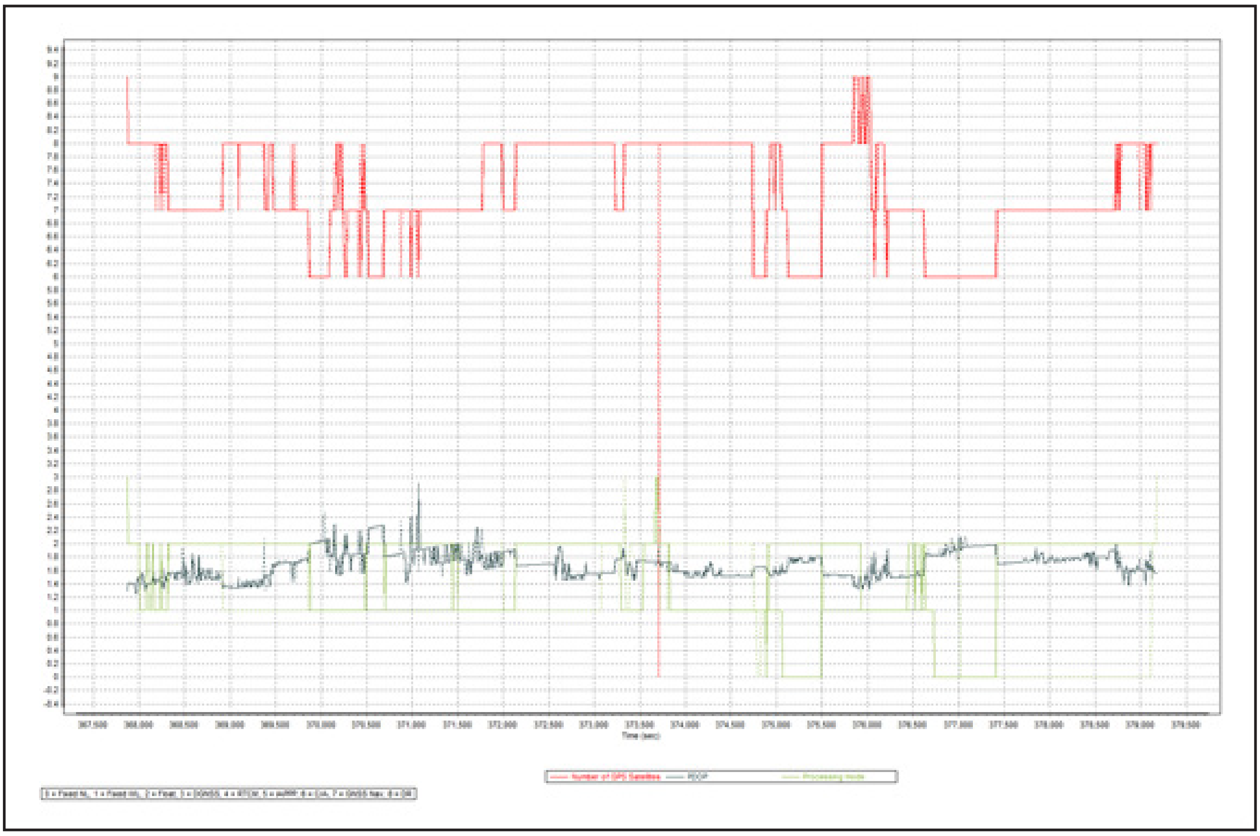


Figure A-8.49. Solution Status

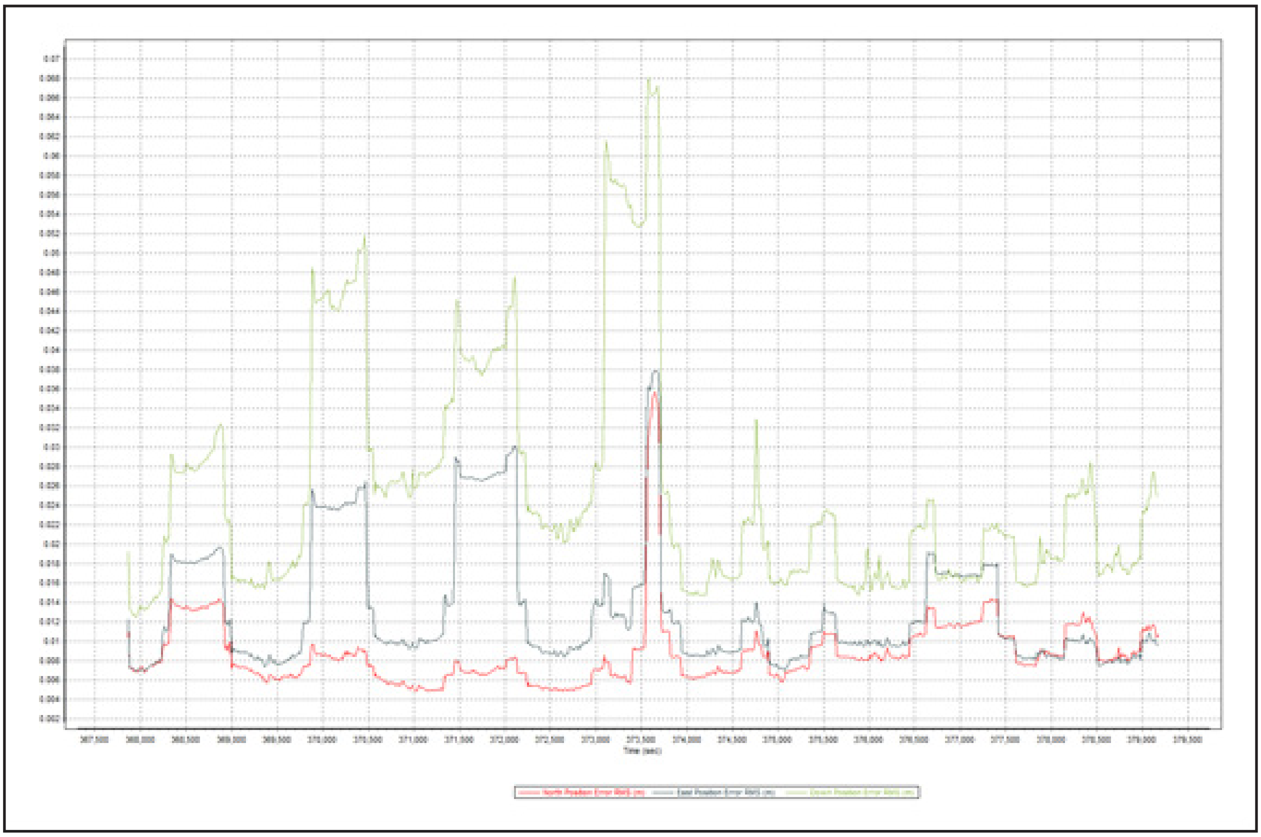


Figure A-8.50. Smoothed Performance Metric Parameters

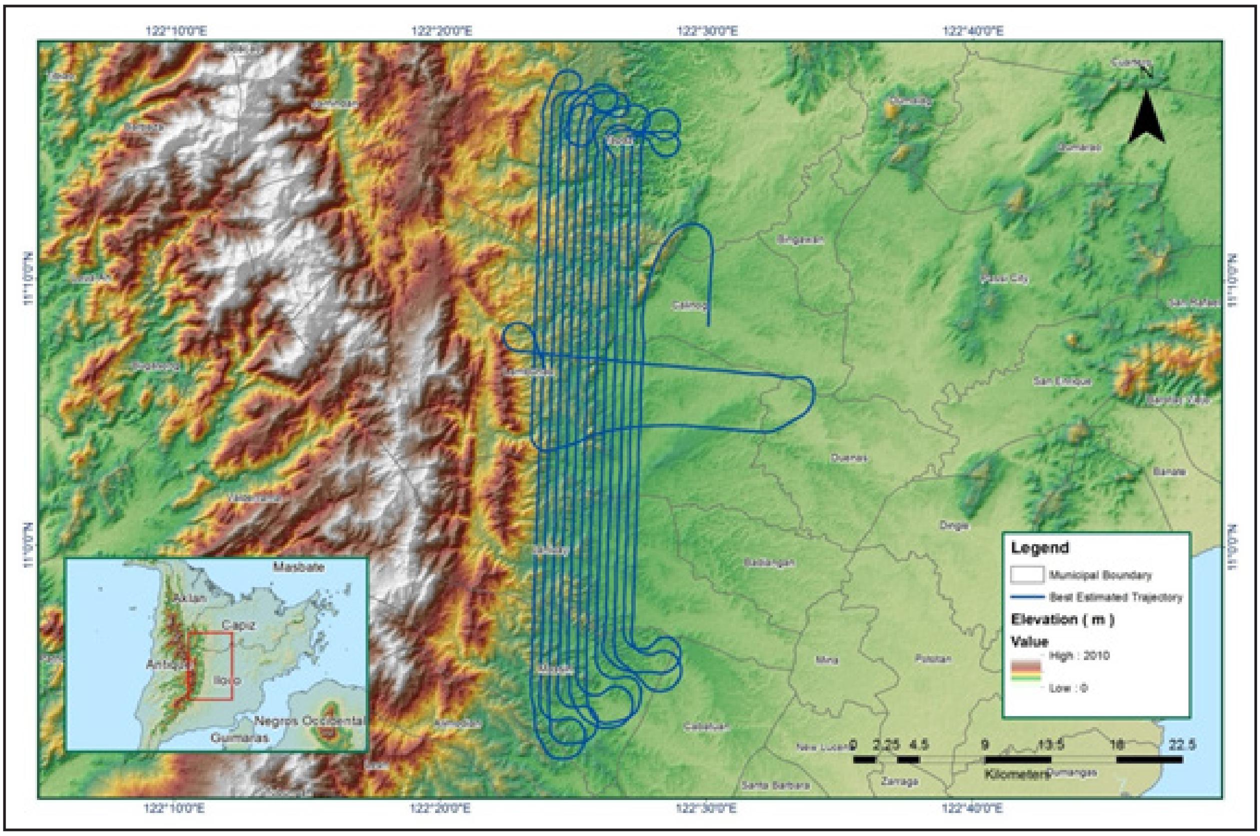


Figure A-8.51. Best Estimated Trajectory

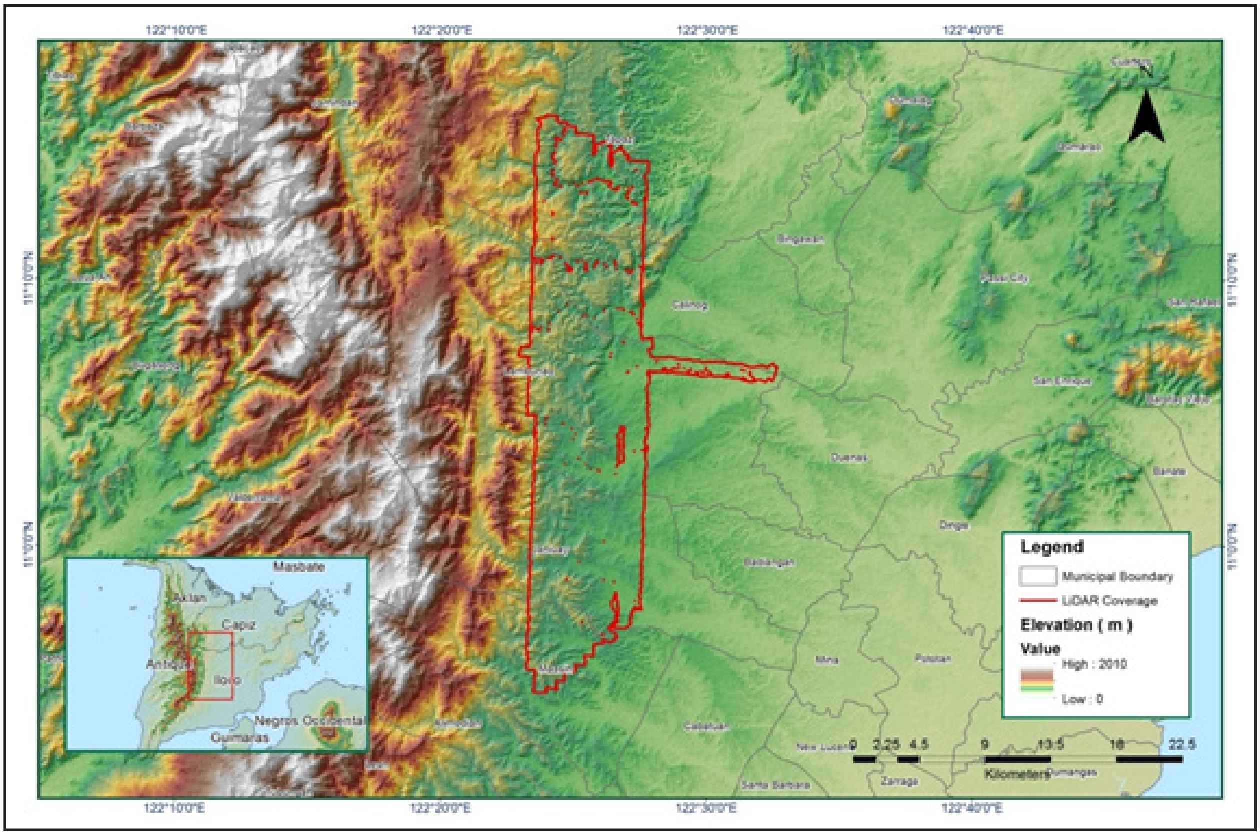


Figure A-8.52. Coverage of LiDAR data

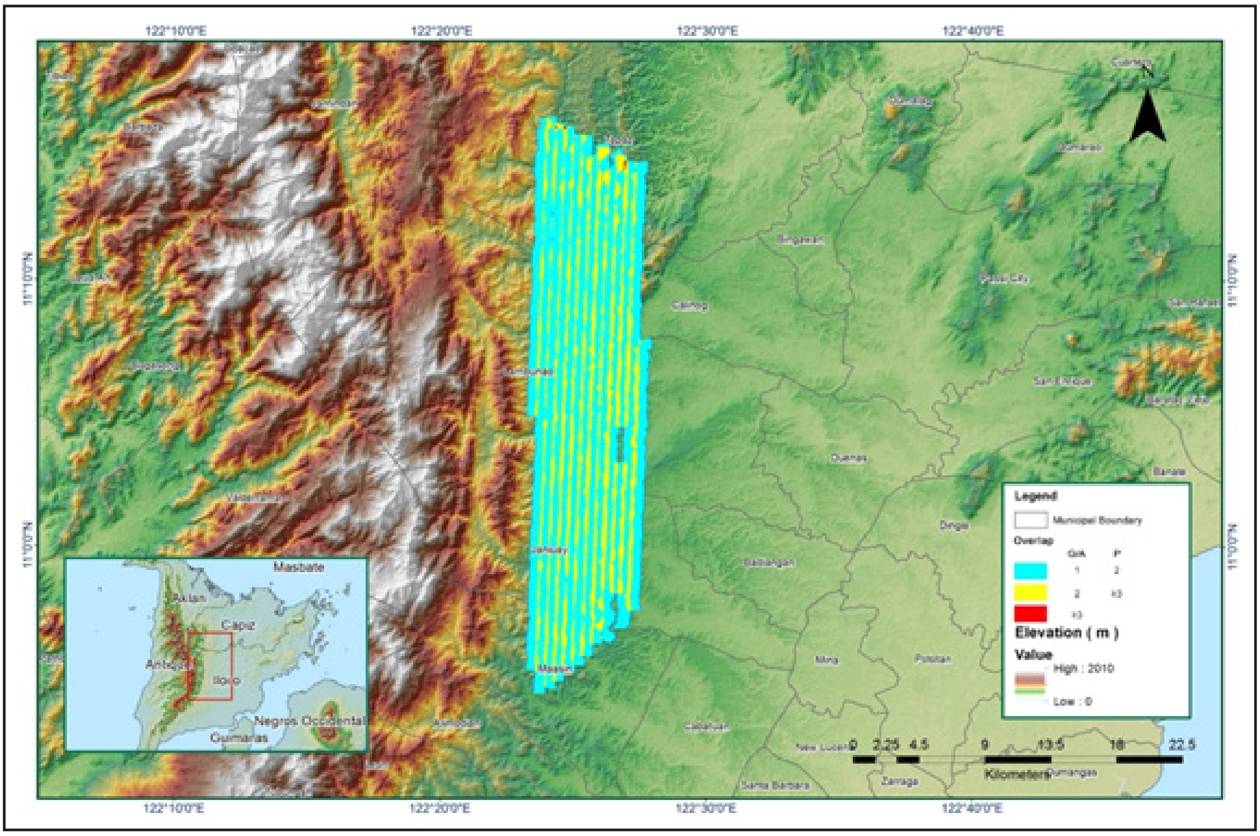


Figure A-8.53. Image of data overlap

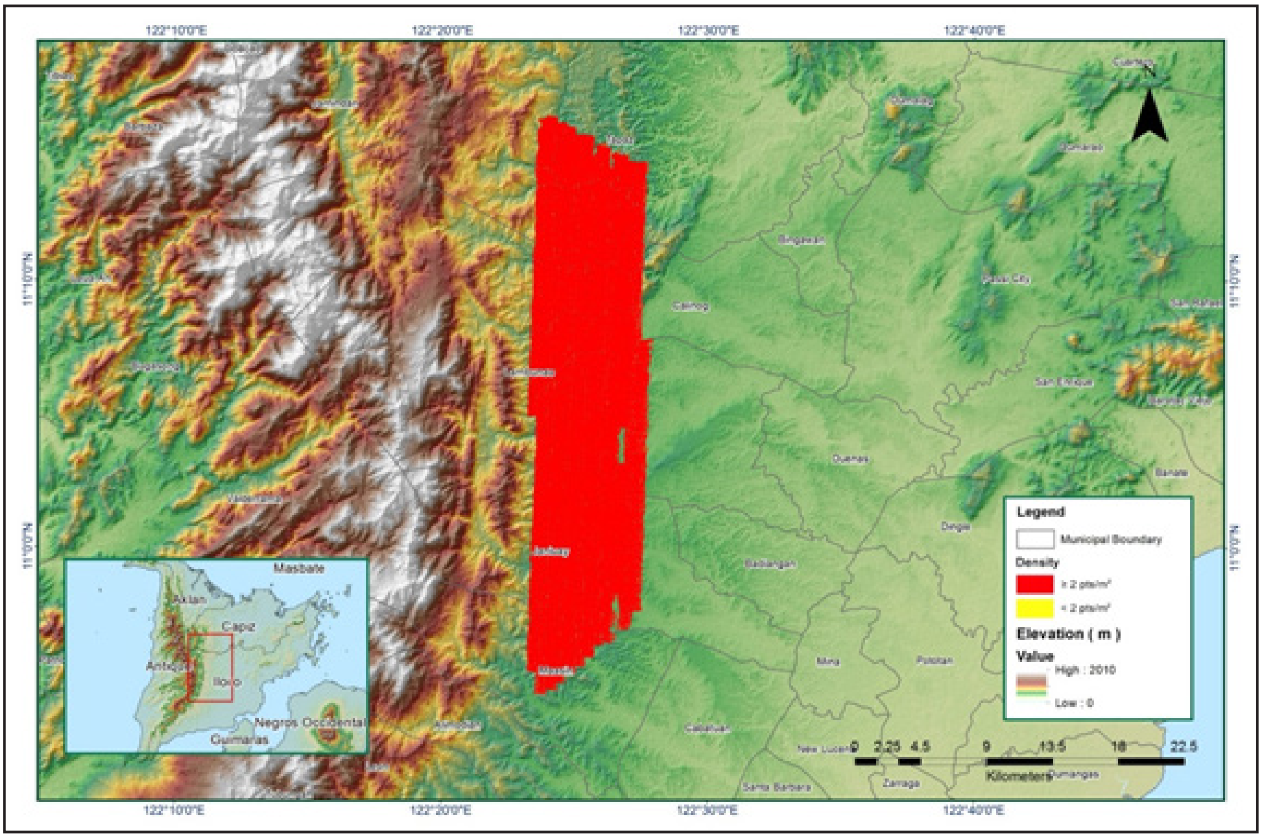


Figure A-8.54. Density map of merged LiDAR data

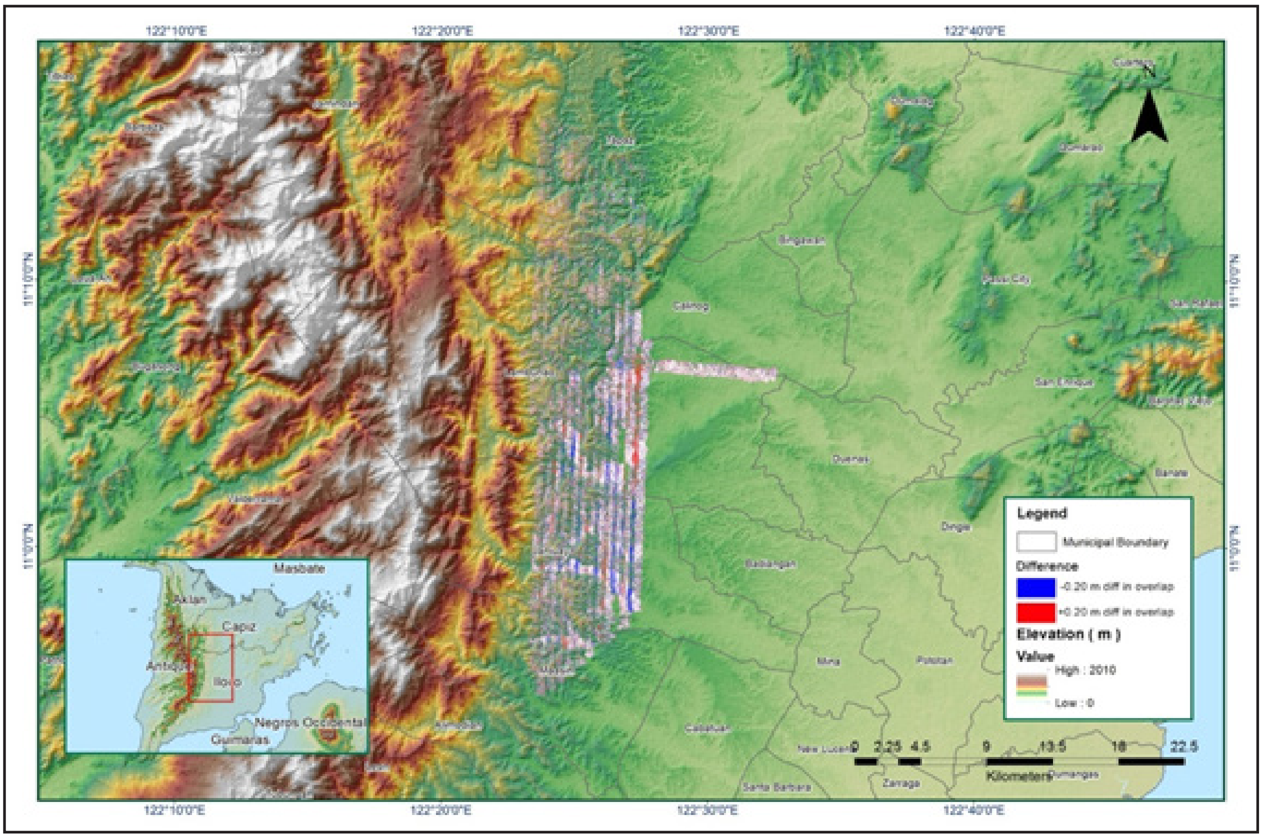


Figure A-8.55. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission Blk37P

Flight Area	Iloilo
Mission Name	Blk37P
Inclusive Flights	2621P
Range data size	27.3 GB
Base data size	15.5 MB
POS	245 MB
Image	48.1 GB
Transfer date	July 07, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.48
RMSE for East Position (<4.0 cm)	1.86
RMSE for Down Position (<8.0 cm)	3.18
Boresight correction stdev (<0.001deg)	0.000295
IMU attitude correction stdev (<0.001deg)	0.00084
GPS position stdev (<0.01m)	0.0011
Minimum % overlap (>25)	43.40%
Ave point cloud density per sq.m. (>2.0)	3.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	266
Maximum Height	473.01 m
Minimum Height	102.13
Classification (# of points)	
Ground	321,747,586
Low vegetation	243,851,479
Medium vegetation	318,431,696
High vegetation	632,590,369
Building	5,683,008
Orthophoto	No
Processed by	Engr. Abigail Joy Ching, Engr. Edgardo Gubatanga, Jr., Engr. Melissa Fernandez

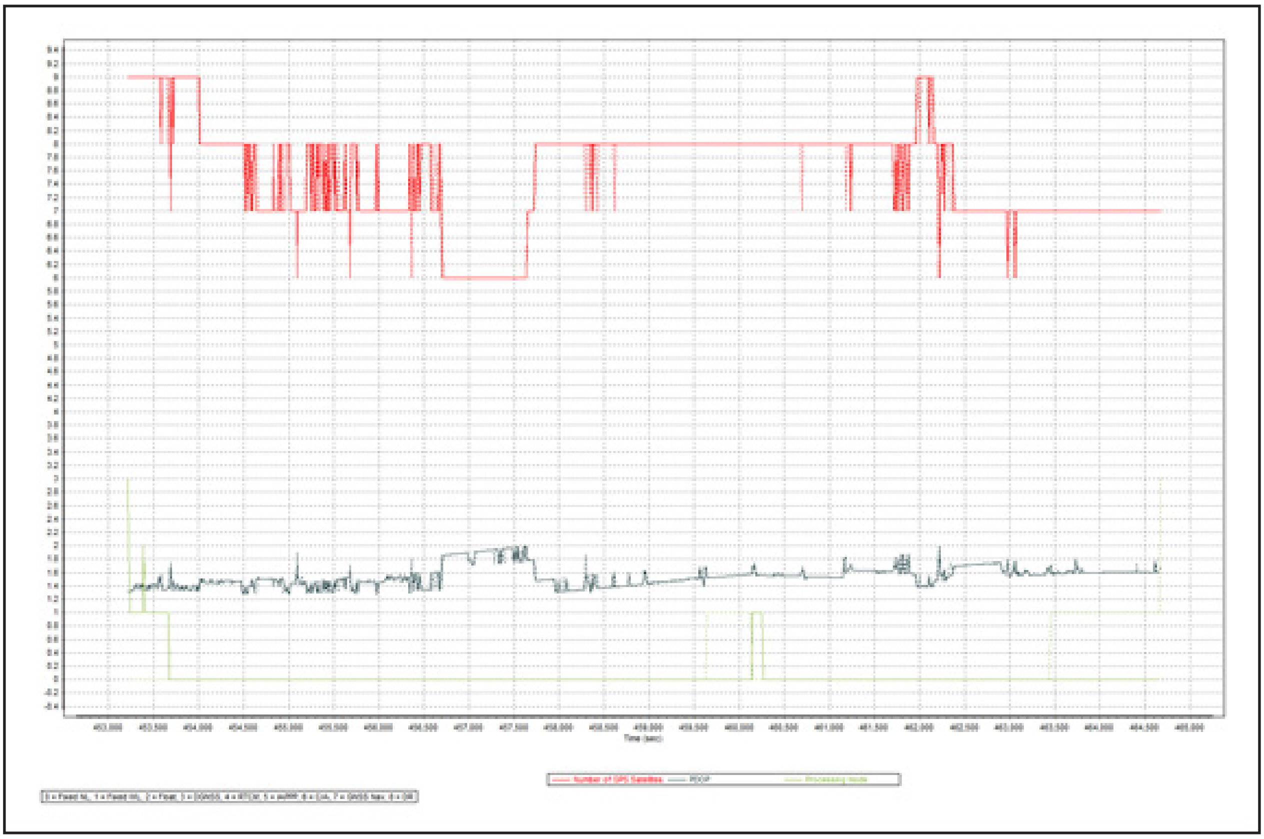


Figure A-8.56. Solution Status

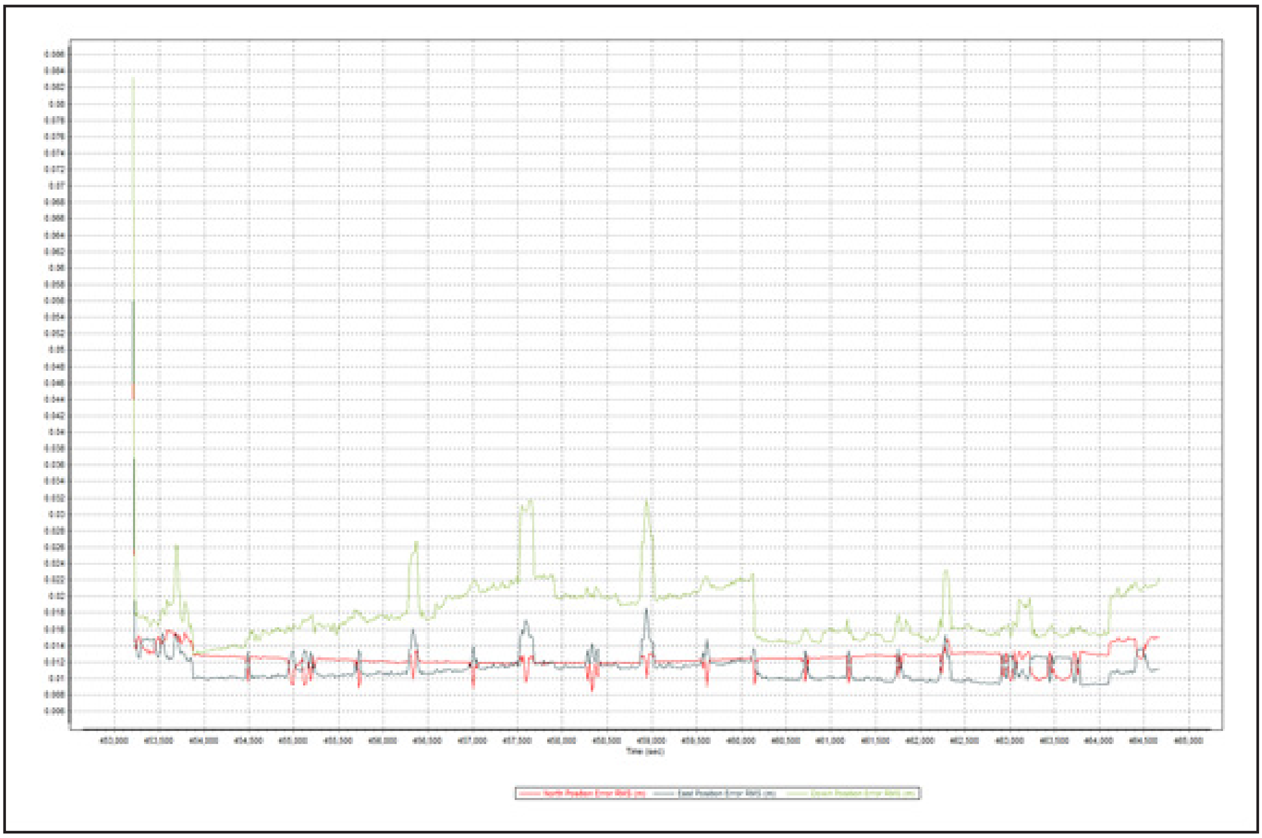


Figure A-8.57. Smoothed Performance Metric Parameters

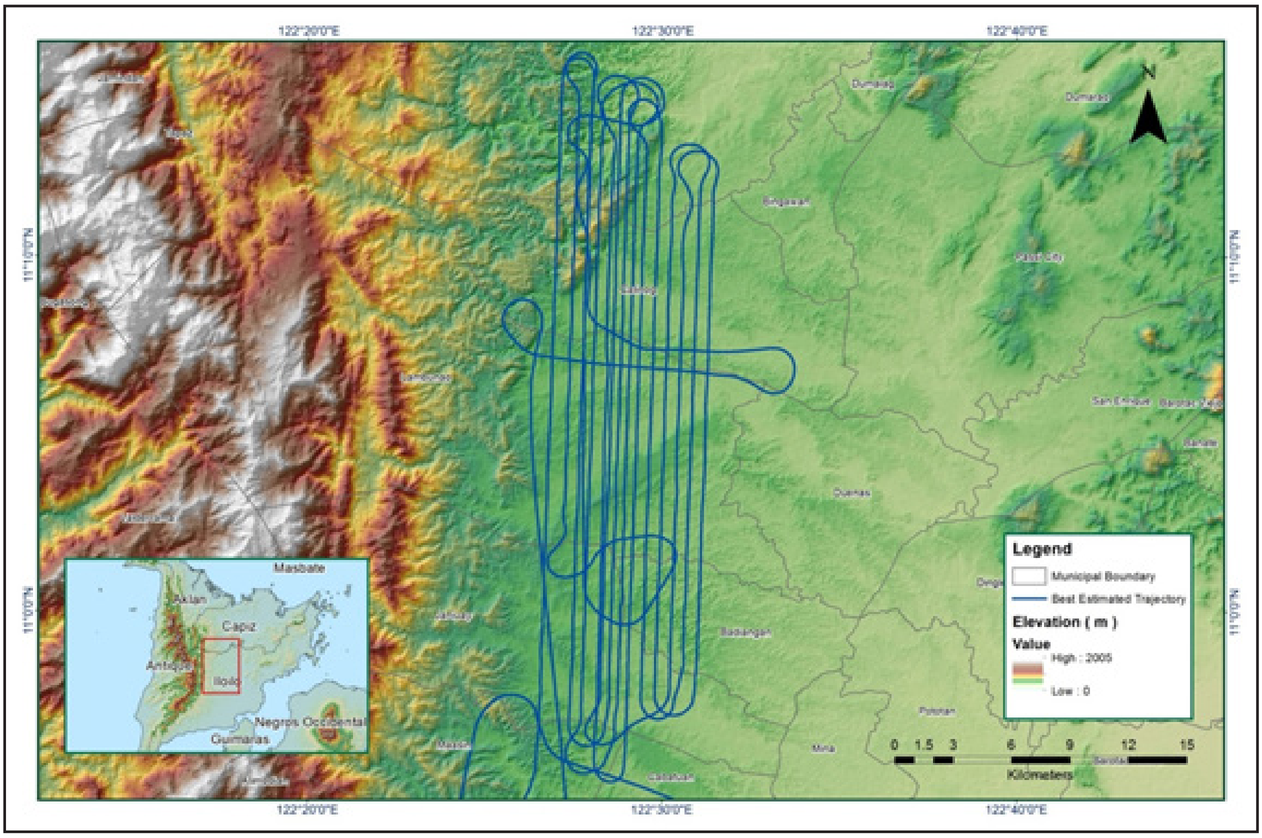


Figure A-8.58. Best Estimated Trajectory

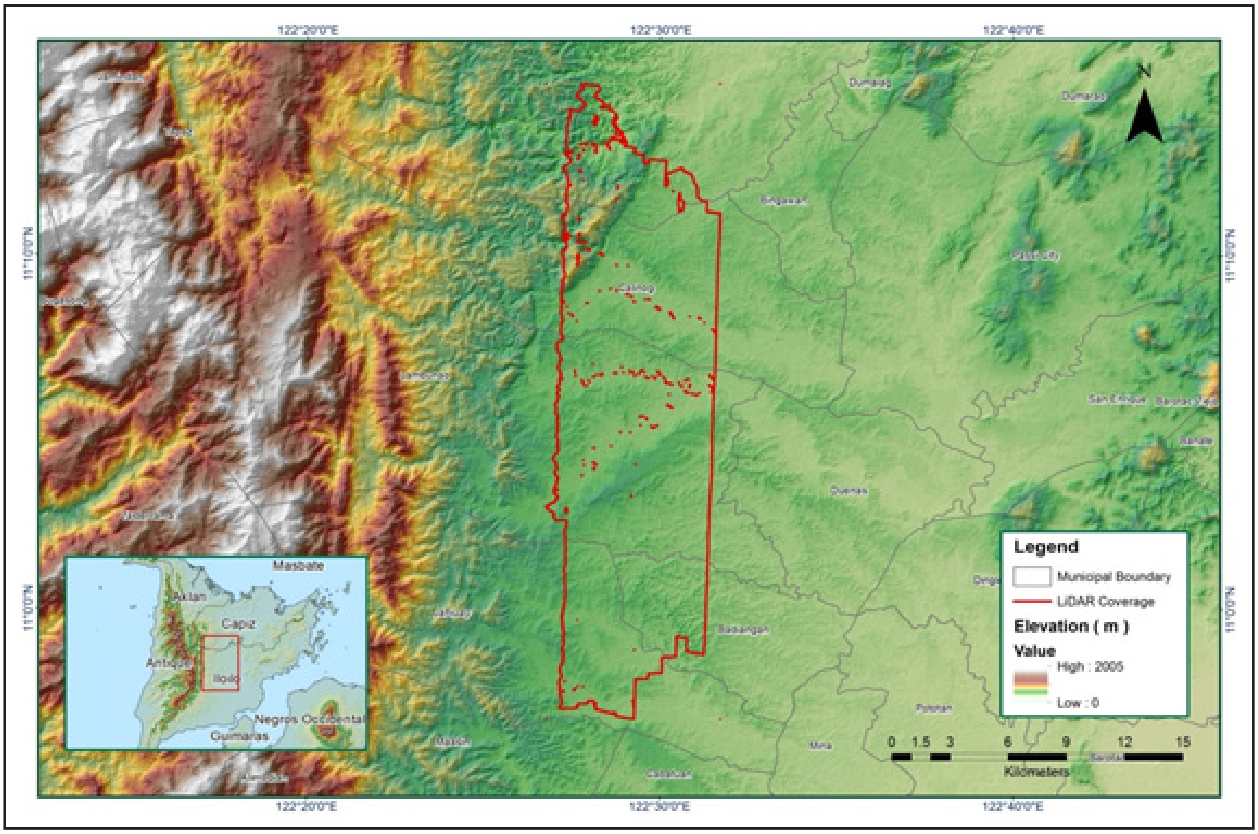


Figure A-8.4. Coverage of LiDAR data

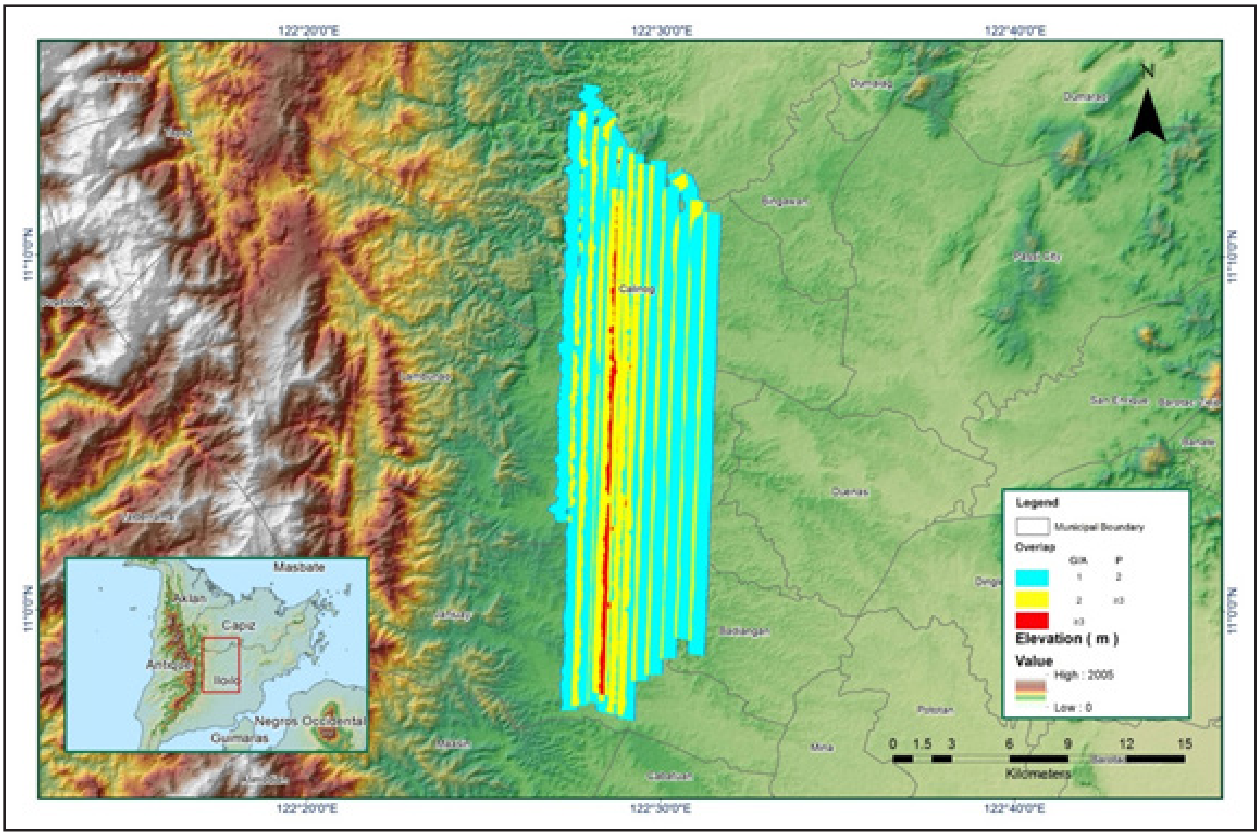


Figure A-8.60. Image of data overlap

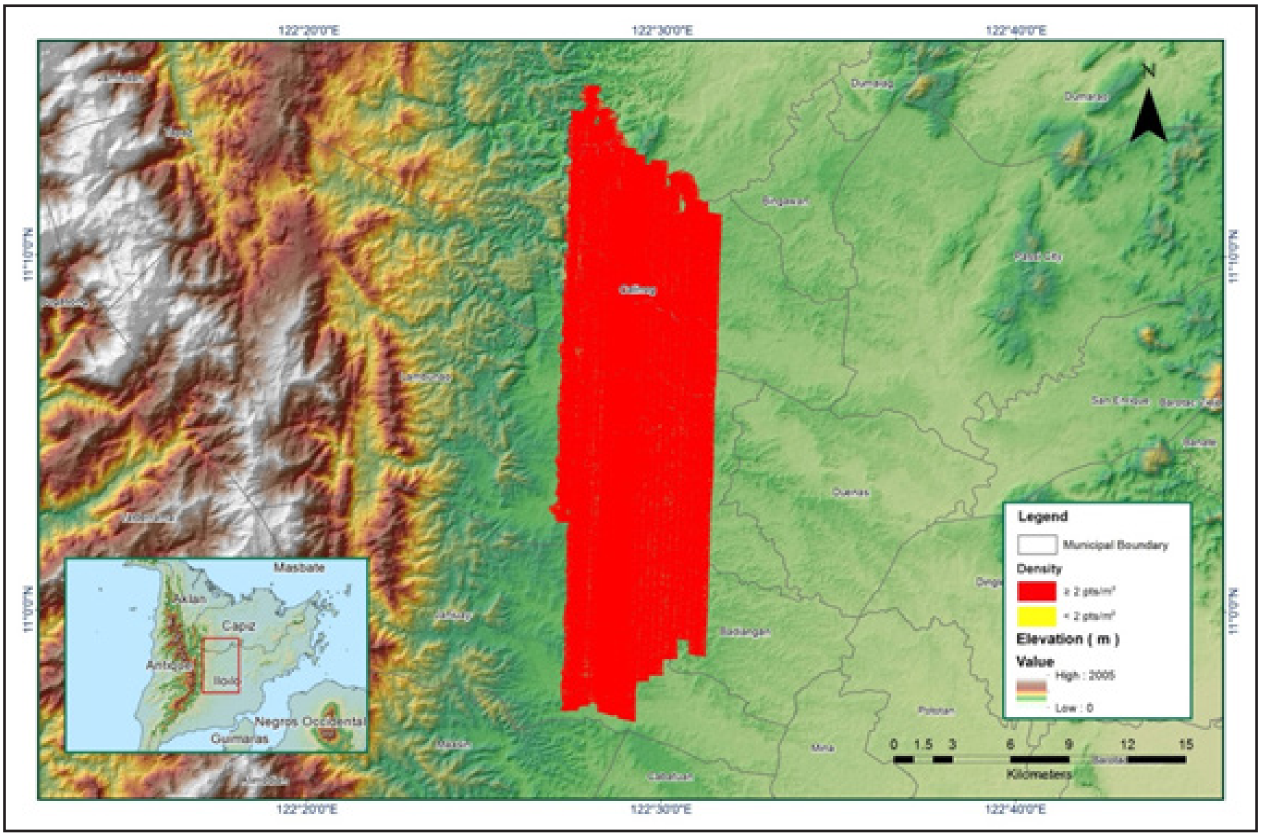


Figure A-8.61. Density map of merged LiDAR data

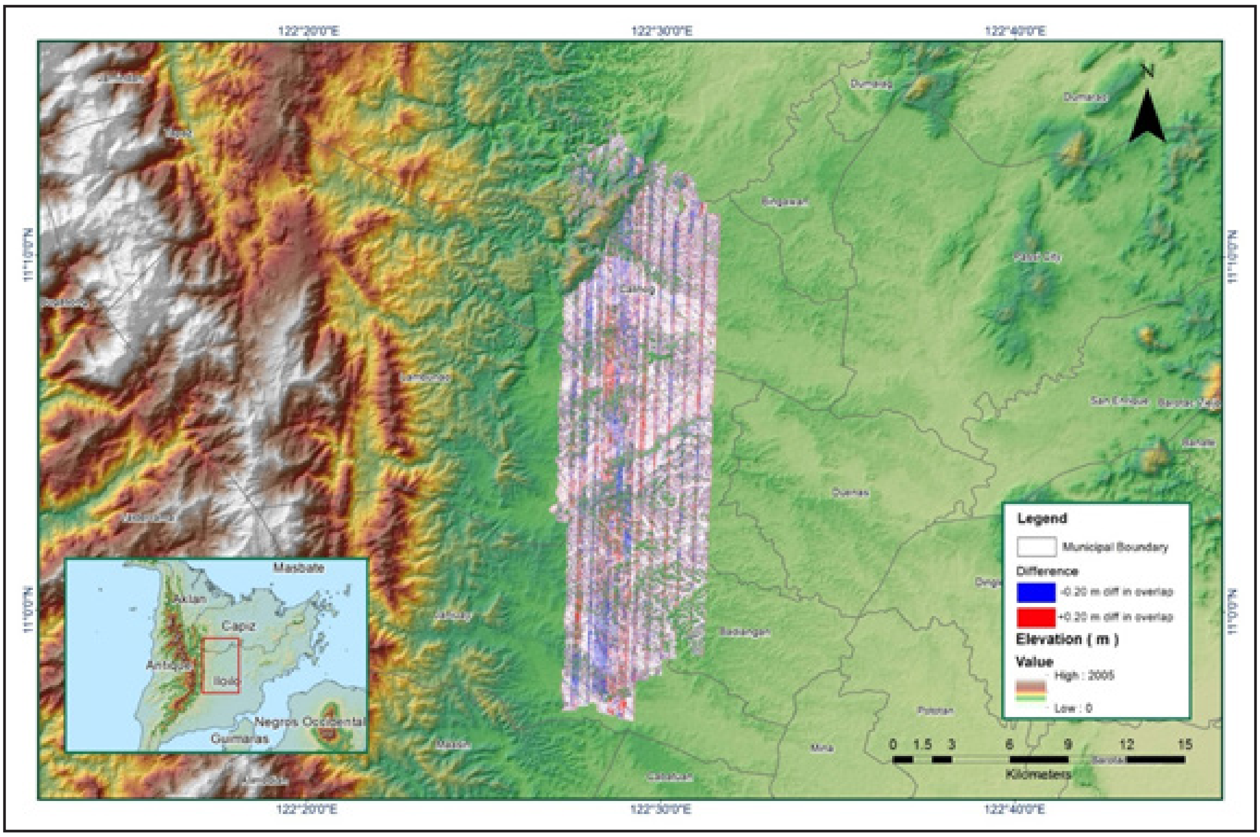


Figure A-8.62. Elevation difference between flight lines

Table A-8.10. Mission Summary Report for Mission Blk43B_additional

Flight Area	Iloilo_Antique
Mission Name	Blk43B_additional
Inclusive Flights	1274A, 1282A, 1290A
Range data size	33.47 GB
POS	744 MB
Image	83.5 GB
Transfer date	April 18, 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)	2.223
RMSE for East Position (<4.0 cm)	2.17
RMSE for Down Position (<8.0 cm)	3.835
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	0.000845
GPS position stdev (<0.01m)	0.0186
Minimum % overlap (>25)	45.20%
Ave point cloud density per sq.m. (>2.0)	3.76
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	60
Maximum Height	105.28
Minimum Height	58.00
Classification (# of points)	
Ground	8,786,829
Low vegetation	14,421,926
Medium vegetation	34,824,267
High vegetation	1,249,090
Building	336,920
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Aljon Rei Araneta

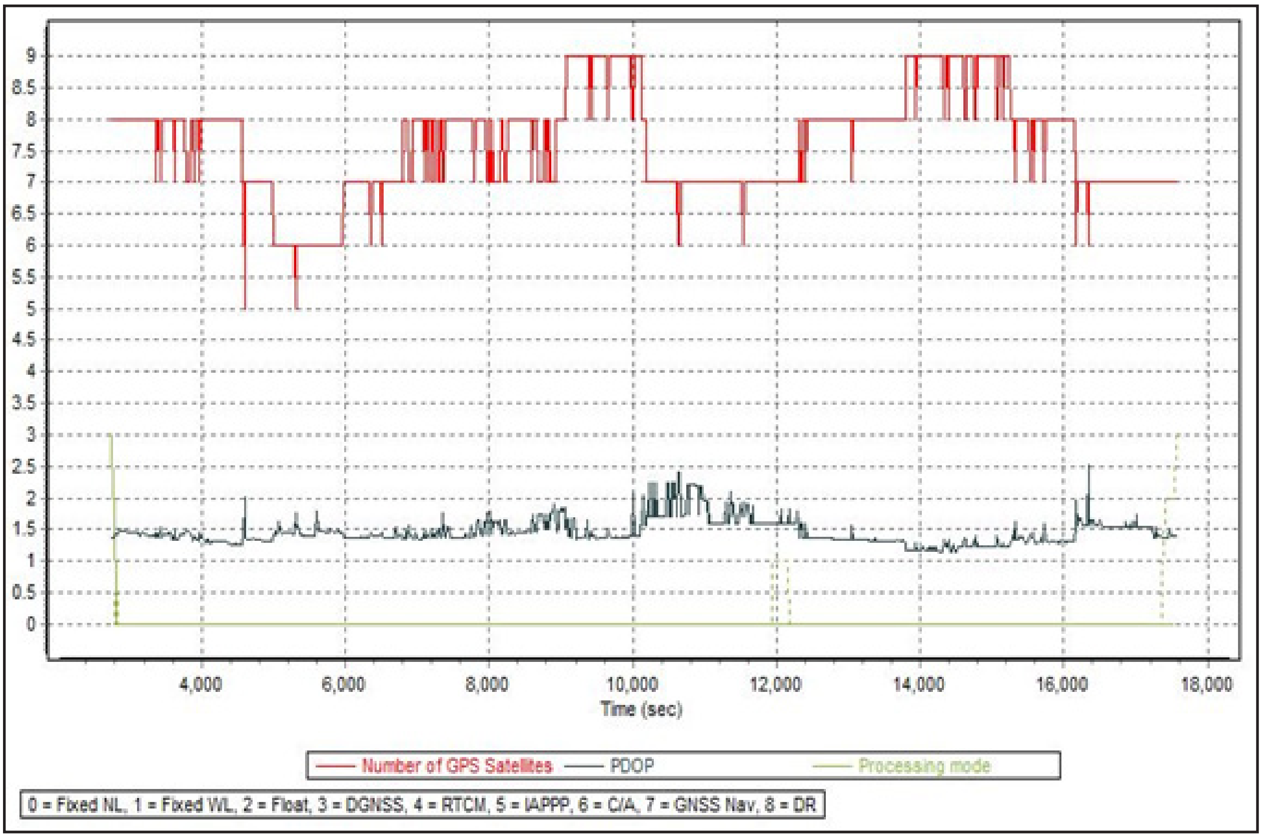


Figure A-8.63. Solution Status

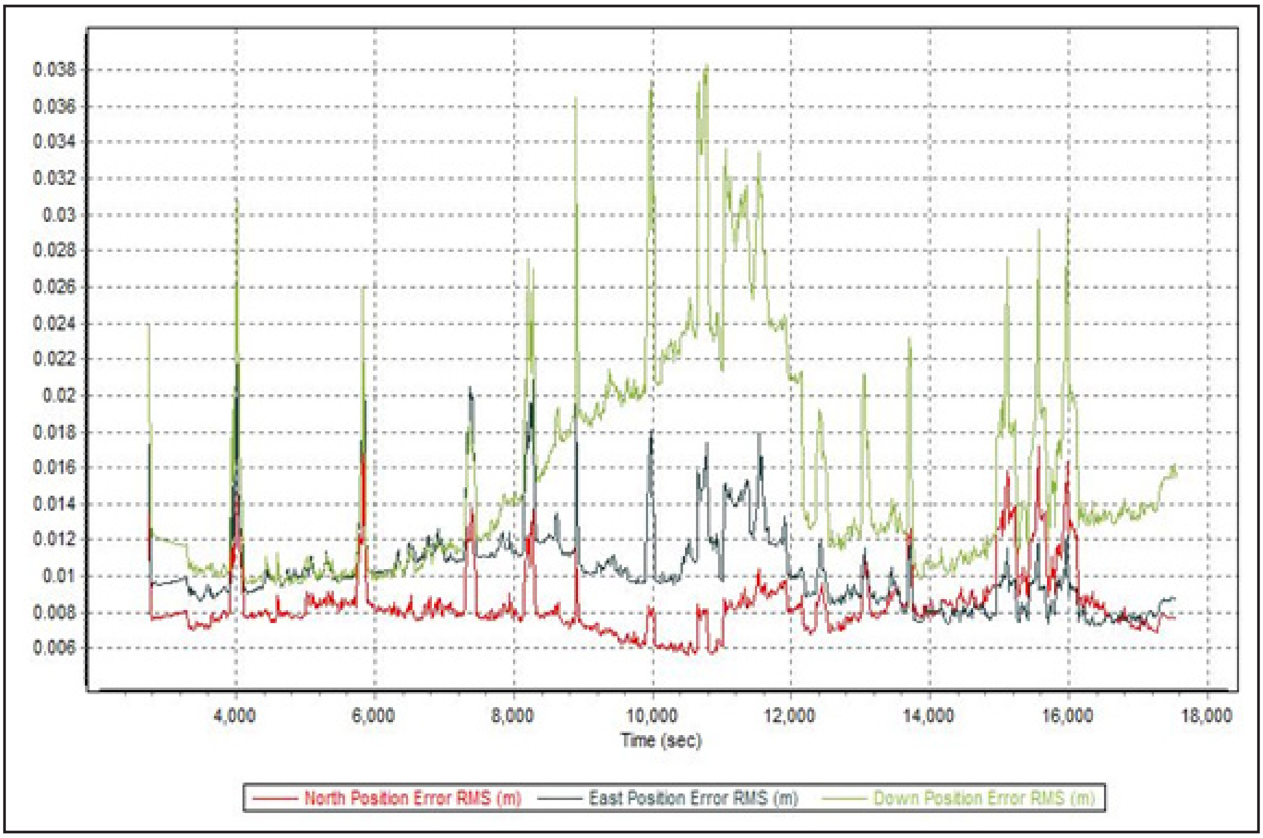


Figure A-8.64. Smoothed Performance Metric Parameters

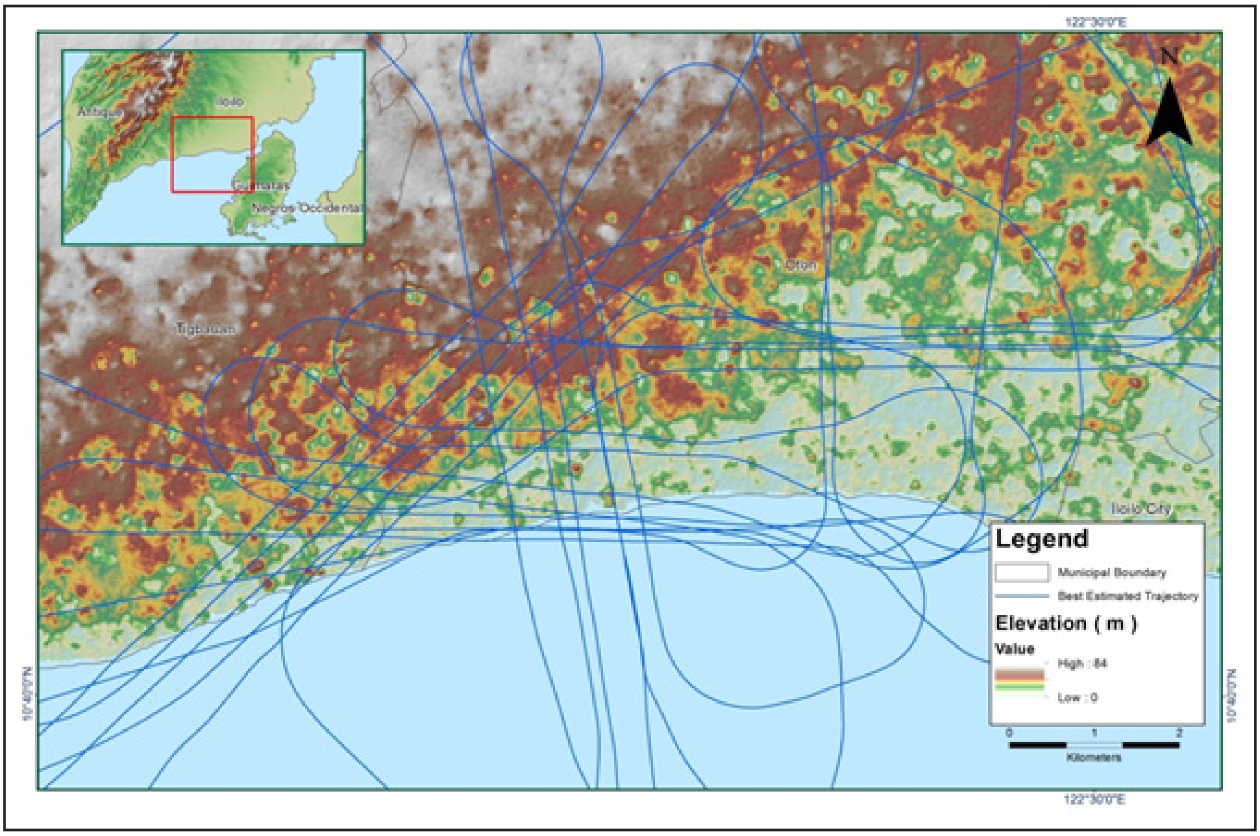


Figure A-8.65. Best Estimated Trajectory

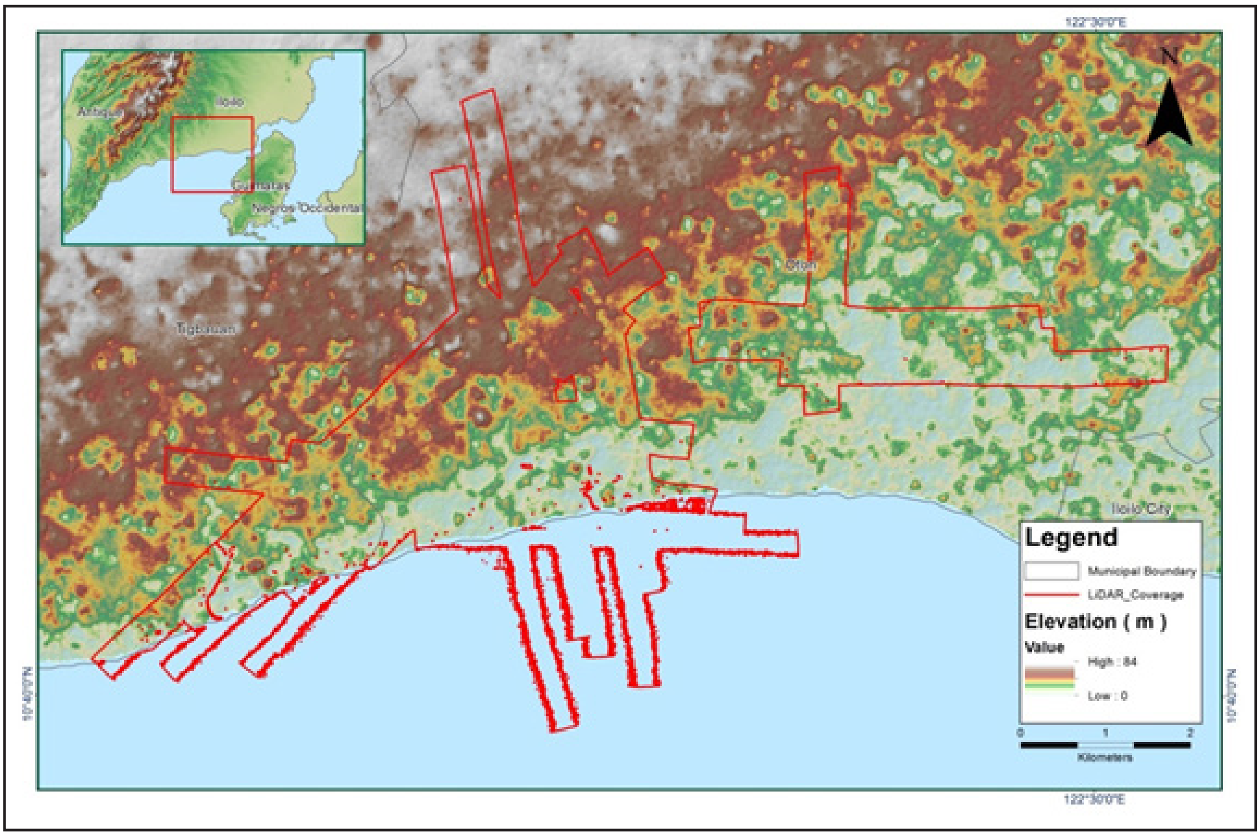


Figure A-8.66. Coverage of LiDAR data

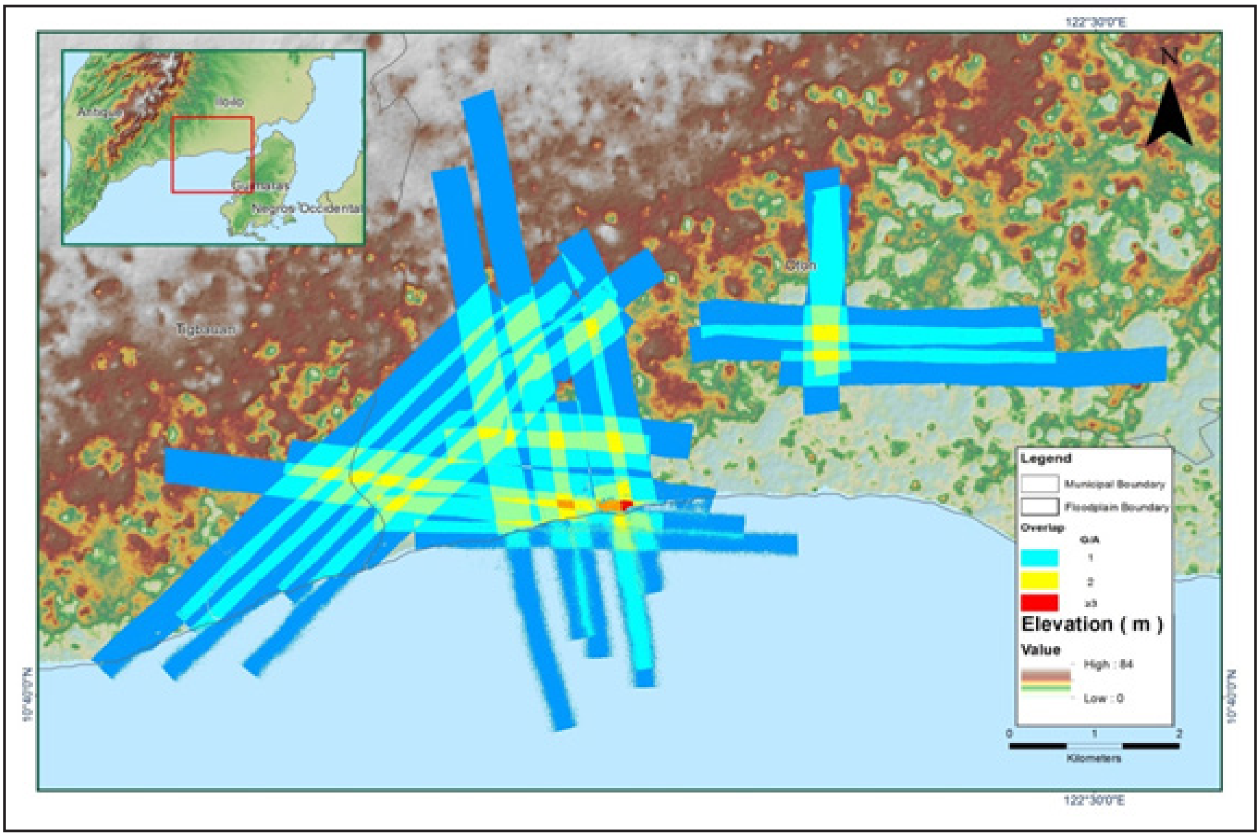


Figure A-8.67. Image of data overlap

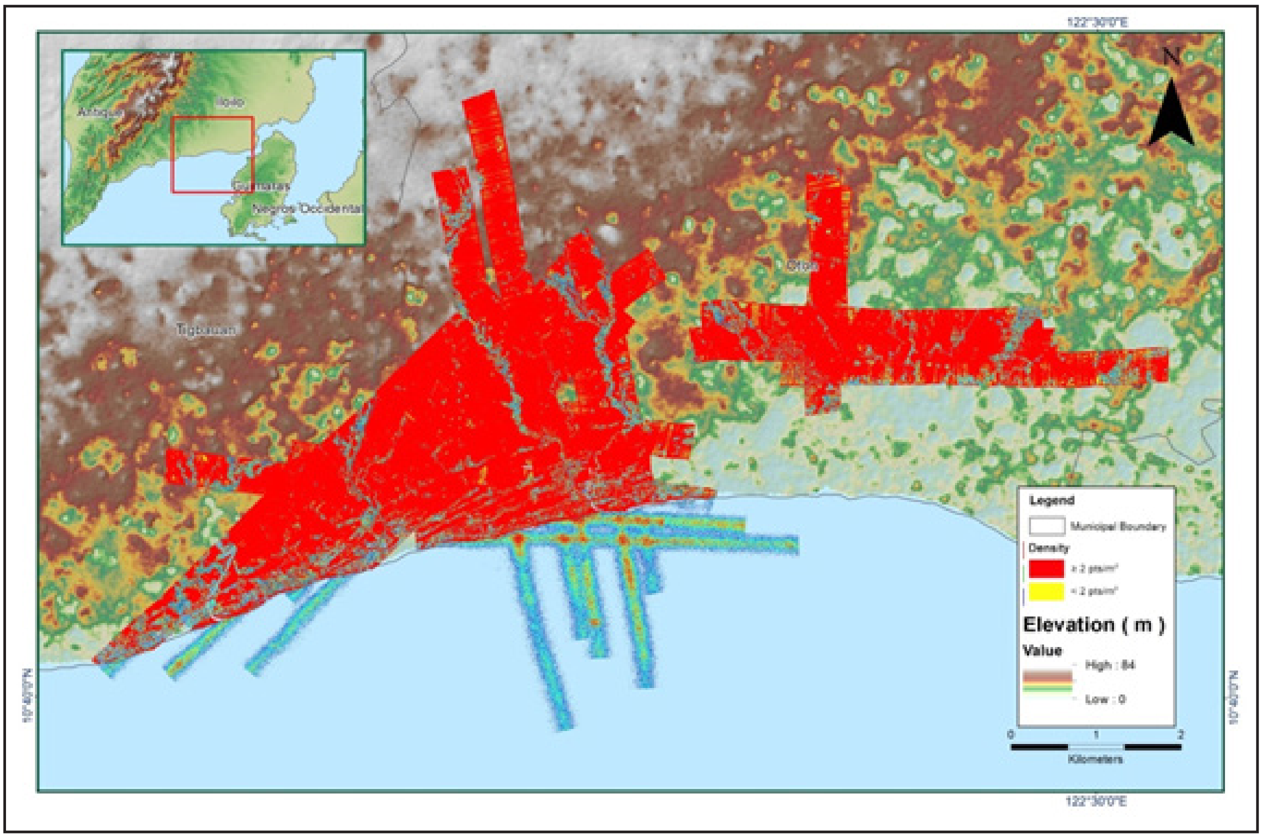


Figure A-8.68. Density map of merged LiDAR data

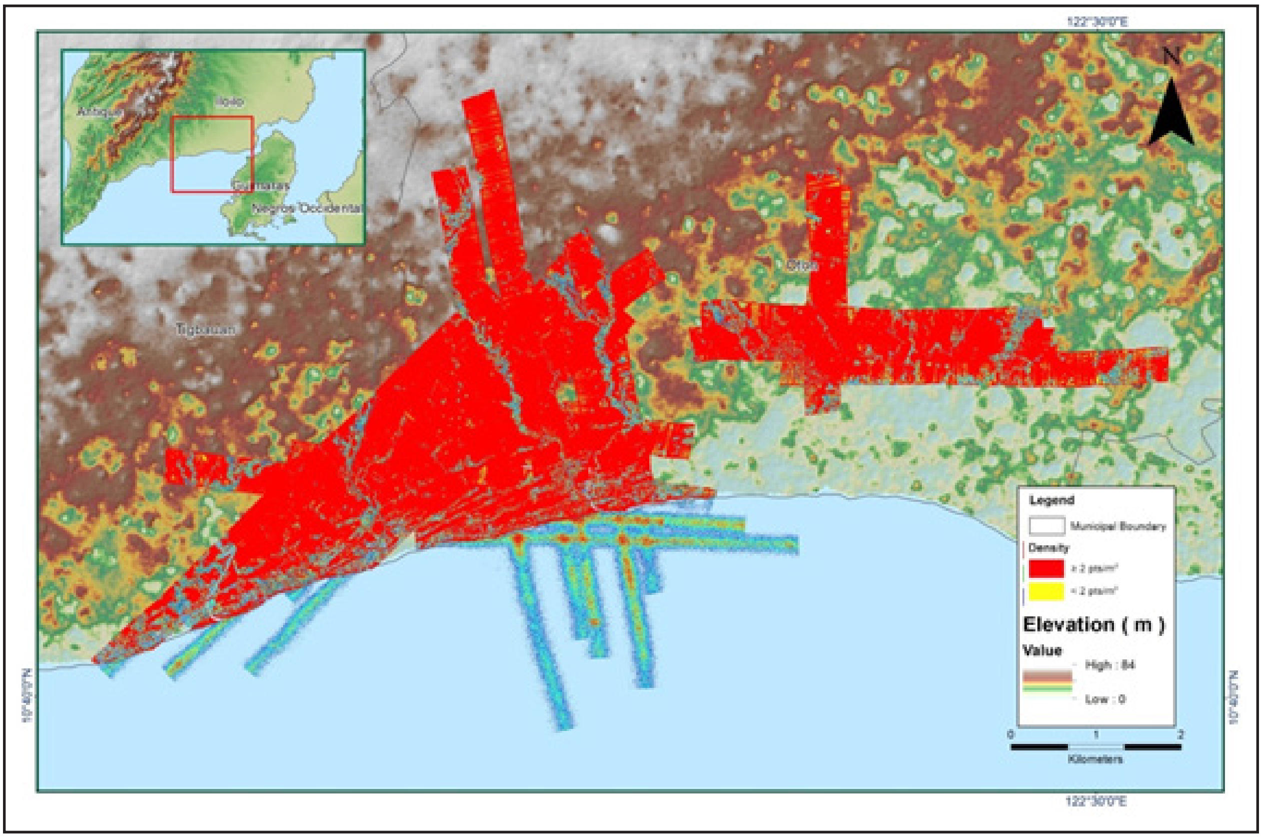


Figure A-8.68. Density map of merged LiDAR data

ANNEX 9. Sibalom Model Basin Parameters

Table A-9.1. Cangaranan Model Basin Parameters

Basin Number	Curve Number Loss			Clark Unit Hydrograph Transform		Recession Base flow				
	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. Sibalom Model Reach Parameters

Table A-10.1. Sibalom Model Reach Parameters

Reach	Muskingum-Cunge Channel Routing						
Number	Time Step Method	Length (m)	Slope (m/m)	Manning's n	Shape	Width (m)	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. Sibalom Field Validation Points

Table A-11.1. Sibalom Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event/ Date	Date	Rain Return/ Scenario
	Lat	Long						
1	10.6786	122.3783	1.31	3	1.69	Frank	June 21-22, 2008	25-Year
2	10.70285	122.3585	1.69	0	-1.69			25-Year
3	10.77682	122.3864	1.67	0	-1.67			25-Year
4	10.67842	122.3769	5.86	7.5	1.64	Frank	June 21-22, 2008	25-Year
5	10.78139	122.3859	3.78	2.2	-1.58	Frank	June 21-22, 2008	25-Year
6	10.67931	122.3792	0.93	2.5	1.57	Frank	June 21-22, 2008	25-Year
7	10.78047	122.397	4.51	3	-1.51	Frank	June 21-22, 2008	25-Year
8	10.67851	122.379	1.57	3	1.43	Frank	June 21-22, 2008	25-Year
9	10.676	122.3733	1.07	2.44	1.37	Frank	June 21-22, 2008	25-Year
10	10.76039	122.3581	3.85	2.5	-1.35	Frank	June 21-22, 2008	25-Year
11	10.77212	122.3899	0.08	1.4	1.32	Undang	30991	25-Year
12	10.67184	122.3836	1.3	0	-1.3			25-Year
13	10.77891	122.3858	0	1.3	1.3	Frank	June 21-22, 2008	25-Year
14	10.67462	122.3722	3.21	2	-1.21	Frank	June 21-22, 2008	25-Year
15	10.6744	122.3809	0.08	1.25	1.17	Frank	June 21-22, 2008	25-Year
16	10.67815	122.3785	1.83	3	1.17	Frank	June 21-22, 2008	25-Year
17	10.67135	122.3836	1.16	0	-1.16			25-Year
18	10.67769	122.3781	1.39	2.5	1.11	Frank	June 21-22, 2008	25-Year
19	10.67431	122.3733	1.08	0	-1.08			25-Year
20	10.77784	122.3863	1.08	0	-1.08			25-Year
21	10.6734	122.4007	1.02	0	-1.02			25-Year
22	10.67731	122.3768	0	1	1	Frank	June 21-22, 2008	25-Year
23	10.73749	122.3634	6.49	5.5	-0.99	Frank	June 21-22, 2008	25-Year
24	10.77879	122.3856	2.28	1.3	-0.98	Frank	June 21-22, 2008	25-Year
25	10.77991	122.3895	0.04	1	0.96	Frank	June 21-22, 2008	25-Year
26	10.67643	122.3744	1.54	2.5	0.96	Frank	June 21-22, 2008	25-Year

27	10.67504	122.4034	0.25	1.2	0.95	Frank	June 21-22, 2008	25-Year
28	10.77673	122.3866	4.92	4	-0.92	Frank	June 21-22, 2008	25-Year
29	10.67136	122.381	1.1	0.2	-0.9	Frank	June 21-22, 2008	25-Year
30	10.6731	122.3733	0	0.9	0.9	Frank	June 21-22, 2008	25-Year
31	10.67341	122.3961	0.88	0	-0.88			25-Year
32	10.67647	122.3733	2.38	1.5	-0.88	Frank	June 21-22, 2008	25-Year
33	10.77989	122.3824	1.07	0.2	-0.87	Undang	30991	25-Year
34	10.67485	122.3893	0.03	0.9	0.87	Frank	June 21-22, 2008	25-Year
35	10.6715	122.3736	0.24	1.1	0.86	Frank	June 21-22, 2008	25-Year
36	10.67709	122.3772	0.94	1.8	0.86	Frank	June 21-22, 2008	25-Year
37	10.677	122.3751	1.64	2.5	0.86	Frank	June 21-22, 2008	25-Year
38	10.67484	122.3737	0.85	1.7	0.85	Frank	June 21-22, 2008	25-Year
39	10.78251	122.3927	0.55	1.4	0.85	Frank	June 21-22, 2008	25-Year
40	10.74684	122.4008	0.08	0.9	0.82	Frank	June 21-22, 2008	25-Year
41	10.675	122.373	0.98	1.8	0.82	Frank	June 21-22, 2008	25-Year
42	10.71952	122.3666	0.09	0.9	0.81	Frank	June 21-22, 2008	25-Year
43	10.67901	122.378	1.2	2	0.8	Frank	June 21-22, 2008	25-Year
44	10.67498	122.4022	0.41	1.2	0.79	Frank	June 21-22, 2008	25-Year
45	10.6778	122.3782	1.71	2.5	0.79	Frank	June 21-22, 2008	25-Year
46	10.77743	122.3867	0.98	0.2	-0.78	Frank	June 21-22, 2008	25-Year
47	10.67301	122.3882	1.05	0.3	-0.75	Frank	June 21-22, 2008	25-Year
48	10.67161	122.3939	0.72	0	-0.72			25-Year
49	10.77948	122.3966	3.69	3	-0.69	Frank	June 21-22, 2008	25-Year
50	10.67338	122.4004	0.68	0	-0.68			25-Year
51	10.6772	122.3756	1.53	2.2	0.67	Frank	June 21-22, 2008	25-Year
52	10.67182	122.3736	0.47	1.1	0.63	Frank	June 21-22, 2008	25-Year
53	10.67397	122.4018	0.59	1.2	0.61	Frank	June 21-22, 2008	25-Year

54	10.6769	122.3748	1.9	2.5	0.6	Frank	June 21-22, 2008	25-Year
55	10.77176	122.3895	1.9	1.3	-0.6	Undang	30991	25-Year
56	10.67276	122.3876	0.86	0.3	-0.56	Frank	June 21-22, 2008	25-Year
57	10.67144	122.395	0.55	0	-0.55			25-Year
58	10.67086	122.3788	0.56	1.1	0.54	Frank	June 21-22, 2008	25-Year
59	10.67191	122.3854	0.92	0.4	-0.52	Frank	June 21-22, 2008	25-Year
60	10.67497	122.4005	0.51	0	-0.51			25-Year
61	10.67199	122.3983	0.49	0	-0.49			25-Year
62	10.67771	122.3768	1.52	2	0.48	Frank	June 21-22, 2008	25-Year
63	10.67027	122.3862	0.43	0.9	0.47	Yolanda	41586	25-Year
64	10.67379	122.4005	0.73	1.2	0.47	Frank	June 21-22, 2008	25-Year
65	10.79262	122.3909	0.84	1.3	0.46	Frank	June 21-22, 2008	25-Year
66	10.67317	122.3734	0.84	1.3	0.46	Frank	June 21-22, 2008	25-Year
67	10.66986	122.3762	0.46	0	-0.46			25-Year
68	10.79666	122.395	0.45	0	-0.45			25-Year
69	10.67181	122.396	0.42	0	-0.42			25-Year
70	10.67307	122.3887	0.72	0.3	-0.42	Frank	June 21-22, 2008	25-Year
71	10.67149	122.3743	0.52	0.9	0.38	Frank	June 21-22, 2008	25-Year
72	10.67198	122.3969	0.53	0.9	0.37	Yolanda	41586	25-Year
73	10.67144	122.391	0.47	0.1	-0.37	Frank	June 21-22, 2008	25-Year
74	10.77223	122.3606	0.37	0	-0.37			25-Year
75	10.6726	122.3728	0.75	1.1	0.35	Frank	June 21-22, 2008	25-Year
76	10.67736	122.3747	3.35	3	-0.35	Frank	June 21-22, 2008	25-Year
77	10.67261	122.3896	0.34	0	-0.34			25-Year
78	10.76175	122.4027	0.31	0	-0.31			25-Year
79	10.67262	122.3957	0.47	0.2	-0.27	Yolanda	41586	25-Year
80	10.67067	122.3798	0.56	0.3	-0.26	Frank	June 21-22, 2008	25-Year
81	10.77769	122.3894	0.26	0	-0.26			25-Year
82	10.70823	122.3921	0.04	0.3	0.26	Frank	June 21-22, 2008	25-Year
83	10.67221	122.3927	0.76	0.5	-0.26	Frank	June 21-22, 2008	25-Year
84	10.77295	122.3907	0.04	0.3	0.26	Frank	June 21-22, 2008	25-Year

85	10.77362	122.3908	0.05	0.3	0.25	Frank	June 21-22, 2008	25-Year
86	10.70037	122.3892	0.24	0	-0.24			25-Year
87	10.67419	122.3759	0.09	0.3	0.21	Frank	June 21-22, 2008	25-Year
88	10.67474	122.3796	0.2	0	-0.2			25-Year
89	10.774	122.3882	0.2	0	-0.2			25-Year
90	10.77863	122.3894	0.3	0.1	-0.2	Frank	June 21-22, 2008	25-Year
91	10.67671	122.3739	1.8	2	0.2	Frank	June 21-22, 2008	25-Year
92	10.78204	122.3858	2.01	2.2	0.19	Frank	June 21-22, 2008	25-Year
93	10.67201	122.3964	0.71	0.9	0.19	Yolanda	41586	25-Year
94	10.67283	122.3804	0.19	0	-0.19			25-Year
95	10.66995	122.3802	0.19	0	-0.19			25-Year
96	10.67345	122.3893	0.11	0.3	0.19	Frank	June 21-22, 2008	25-Year
97	10.77232	122.3915	0.18	0	-0.18			25-Year
98	10.67102	122.3762	0.17	0	-0.17			25-Year
99	10.67724	122.3766	1.17	1	-0.17	Frank	June 21-22, 2008	25-Year
100	10.67456	122.4009	0.46	0.3	-0.16	Frank	June 21-22, 2008	25-Year
101	10.7806	122.387	0.16	0	-0.16			25-Year
102	10.71405	122.3956	0.14	0.3	0.16	Frank	June 21-22, 2008	25-Year
103	10.78129	122.3914	0.14	0.3	0.16	Yolanda	41586	25-Year
104	10.7762	122.39	0.15	0	-0.15			25-Year
105	10.70217	122.3982	0.14	0	-0.14			25-Year
106	10.78765	122.3937	1.04	0.9	-0.14	Frank	June 21-22, 2008	25-Year
107	10.78069	122.3836	0.13	0	-0.13			25-Year
108	10.77464	122.388	0.13	0	-0.13			25-Year
109	10.76043	122.3576	1.03	0.9	-0.13	Frank	June 21-22, 2008	25-Year
110	10.67255	122.3723	1.22	1.1	-0.12	Frank	June 21-22, 2008	25-Year
111	10.67352	122.3732	1.09	1.2	0.11	Frank	June 21-22, 2008	25-Year
112	10.67126	122.3726	0.8	0.9	0.1	Frank	June 21-22, 2008	25-Year
113	10.78011	122.3822	0.3	0.2	-0.1	Undang	30991	25-Year
114	10.67345	122.3931	1.34	1.25	-0.09	Frank	June 21-22, 2008	25-Year
115	10.78225	122.3868	0.07	0	-0.07			25-Year
116	10.6713	122.3874	0.84	0.9	0.06	Frank	June 21-22, 2008	25-Year
117	10.77716	122.3895	0.06	0	-0.06			25-Year

118	10.76683	122.3662	0.06	0	-0.06			25-Year
119	10.6758	122.3858	0.06	0	-0.06			25-Year
120	10.67252	122.3836	0.06	0	-0.06			25-Year
121	10.6784	122.3816	0.06	0	-0.06			25-Year
122	10.70179	122.3542	0.06	0	-0.06			25-Year
123	10.72219	122.3706	0.05	0	-0.05			25-Year
124	10.75807	122.3682	0.05	0	-0.05			25-Year
125	10.67445	122.3783	0.06	0.01	-0.05	Frank	June 21-22, 2008	25-Year
126	10.7354	122.3598	0.04	0	-0.04			25-Year
127	10.78778	122.3896	0.03	0	-0.03			25-Year
128	10.67	122.3752	0.03	0	-0.03			25-Year
129	10.67623	122.381	0.03	0	-0.03			25-Year
130	10.76766	122.3994	0.03	0	-0.03			25-Year
131	10.78117	122.3911	0.03	0	-0.03			25-Year
132	10.77843	122.3872	0.03	0	-0.03			25-Year
133	10.77534	122.3898	0.03	0	-0.03			25-Year
134	10.70019	122.3903	0.03	0	-0.03			25-Year
135	10.67498	122.3748	0.03	0	-0.03			25-Year
136	10.73275	122.3587	0.03	0	-0.03			25-Year
137	10.6899	122.3967	0.03	0	-0.03			25-Year
138	10.68469	122.3629	0.03	0	-0.03			25-Year
139	10.76149	122.3661	0.03	0	-0.03			25-Year
140	10.67271	122.391	0.17	0.2	0.03	Frank	June 21-22, 2008	25-Year
141	10.78102	122.3833	0.03	0	-0.03			25-Year
142	10.70941	122.3605	0.03	0	-0.03			25-Year
143	10.70386	122.3527	0.03	0	-0.03			25-Year
144	10.68797	122.3639	0.03	0	-0.03			25-Year
145	10.77619	122.3868	3.98	4	0.02	Frank	June 21-22, 2008	25-Year
146	10.67234	122.3752	0.09	0.1	0.01	Frank	June 21-22, 2008	25-Year
147	10.67101	122.394	0.31	0.3	-0.01	Frank	June 21-22, 2008	25-Year

ANNEX 12. Educational Institutions Affected by Flooding in Sibalom Floodplain

Table A-12.1. Educational Institutions Affected by Flooding in the Sibalom Floodplain

Iloilo				
Leon				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Anonang Elementary School	Anonang			
Anonang Elementary School Stage	Anonang	Low	Low	Low
Barangay Anonang Daycare Center	Anonang			
Ambulong Day Care Center	Avanzada			
Bayag Elementary School	Bayag Sur			
Nagba Day Care Center	Bayag Sur			
Nagba Day Care Center (Old)	Bayag Sur	Medium	Medium	Medium
Nagba Learning Center	Bayag Sur			
Isian Barangay Day Care Center	Isian Norte			
Isian Norte Elementary School	Isian Norte			
Barangay Jamog Gines Daycare Center	Jamog Gines			
Lanagbangi Elem. School	Nagbangi	Low	Medium	Medium
Omambong Elementary School	Omambong			
En Akorre School	Poblacion			
Iloilo Science and Technology University - Leon Campus	Poblacion			
Lanagbangi Elem. School	Poblacion			
Leon Central Elementary School	Poblacion			
Leon Holy Family Learning Center	Poblacion			
Leon National High School	Poblacion			
Poblacion Day Care Center	Poblacion			
St. Catherine Parochial School	Poblacion			
Tigbauan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Alupidian Barangay Day Care Center	Alupidian			
Bagacay Elementary School	Bagacay			
Bagacay National High School	Bagacay			
Baguingin Barangay Day Care Center (Sition Lino Flores)	Baguingin			
Lino Flores Elementary School	Baguingin			

Namocon Elementary School	Baguingin	Medium	Medium	Medium
Bagumbayan Day Care Center	Bagumbayan			
Bagumbayan Elementary School	Bagumbayan			
Bangkal Day Care Center	Bangkal			Medium
Olo-Barroc Elementary School	Bangkal			
Tigbauan Central Elementary School	Barangay 2			
Tigbauan National High School	Barangay 3			
Tigbauan National High School	Barangay 4			
Tigbauan National High School Grand Stand	Barangay 4			
Wisdom School	Barangay 5			
Queen of Heaven Mission School	Barangay 8	Low	Low	Medium
St. Therese MTC Colleges	Barangay 8			
Queen of Heaven Mission School	Barangay 9	Low	Low	Medium
Barosong Barangay Day Care Center	Barosong			
Barosong Elementary School	Barosong			
Barosong National High School	Barosong			
Binaluian Elementary School	Binaliuan Mayor			
Binaluian Mayor Barangay Day Care Center	Binaliuan Mayor		Low	Low
Binaluian National High School	Binaliuan Mayor			
Binaluian National High School Covered Court	Binaliuan Mayor			
Binaluian Menor Barangay Day Care Center	Binaliuan Menor			
Bagumbayan Elementary School	Bitas			
Bitas Barangay Day Care Center	Bitas			
Canabuan Elementary School	Canabuan			
Canbuan Barangay Day Care Center	Canabuan			
Cordova Elementary School	Cordova Norte	Low	Low	Low
Cordova National High School	Cordova Norte	Low	Low	Low
Cordova Sur Barangay Day Care Center	Cordova Sur			
MCB Holy Spirit Total Learning School Inc.	Cordova Sur			
Barangay Danao Daycare Center	Danao			
Danao Elementary School	Danao			
Dapdap Day Care Center	Dapdap			
Dapdap National High School	Dapdap			

Dorong-An Elementary School	Dorong-An			
GETROPES Learning Center Inc.	Dorong-An			
Wisdom School	Dorong-An			Low
Barangay Isauan Day Care Center	Isawan			
Jamog Day Care Center	Jamog			
Jamog Elem. School	Jamog			
Old Day Care Center	Jamog			
Danao Elementary School	Lanag			
Linobayan Day Care Center	Linobayan			
Barangay Lubog Day Care Center	Lubog			
Lubog Primary School	Lubog			
Namocon Elementary School	Namocon	Low	Medium	Medium
Holy Spirit Christian School	Napnapan Norte			
Napnapan Norte Barangay Day Care Center 2	Napnapan Norte			
Napnapan Norte Christian Learning Center	Napnapan Norte			
Napnapan Elementary School	Napnapan Sur		Low	Medium
Napnapan National High School	Napnapan Sur		Low	Medium
Parara Norte Day Care Center	Parara Norte	Low	Medium	High
Mayor Eugenio Torrento Elementary School	Parara Sur			
Parara National High School	Parara Sur	Low	Low	Low
Sermon Day Care Center	Sermon			
St. Therese MTC Colleges	Tan Pael			
Barangay Taro Daycare Center	Taro			

ANNEX 13. Medical Institutions Affected by Flooding in Sibalom Floodplain

Table A-13.1. Medical Institutions Affected by Flooding in the Sibalom Floodplain

Iloilo				
Leon				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Barasan Day Care Center	Barasan		Low	Low
Bayag Norte Health Center	Bayag Sur			
Biri Sur Sub-station Health Center	Biri Sur	Low	Low	Low
Municipal Health Center	Poblacion			
Tigbauan				
Baguingin Barangay Health Center	Baguingin			
Venus T. Toledo M.D.	Barangay 2			
Barosong Barangay Health Center	Barosong			
Binaluian Mayor Barangay Health Center	Binaliuan Mayor	Medium	Medium	Medium
Cordova Sur Barangay Health Center	Cordova Sur			
Dapdap Health Center	Dapdap			
Dorong-an Health Center	Dorong-An			
Parara Sur Barangay Health Center	Parara Sur			