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

LiDAR Surveys and Flood Mapping of Pinantan River

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

APRIL 2017

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

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

E.C. Paringit and J.R. Sinogaya (eds.) (2017), LiDAR Surveys and Flood Mapping of Pinantan River, Quezon City: University of the Philippines Training Center on Applied Geodesy and Photogrammetry-232pp.

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National Library of the Philippines
ISBN: 978-621-430-111-9

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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
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 PINANTAN RIVER

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1.1 Background of the Phil-LiDAR 1 Program

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

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods described 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) is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 22 river basins in the Western Visayas Region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Pinantan River Basin

The Pinantan River Basin covers the municipalities of Sara and Ajuy in the province of Iloilo located in the north of Panay island. The DENR River Basin Control Office identified the basin to have a drainage area of 134 km2 and an estimated 170 million cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Zerruco River, is part of the twenty-four (24) river systems in Western Visayas Region under the PHIL-LIDAR 1 partner HEI, University of the Philippines Cebu (UP Cebu). The delineated basin and river name is "Pinantan River" according to the RBCO, but the municipal government of Ajuy confirmed that it is known as Zerruco River locally. According to the 2015 national census of NSO, a total of 3,118 persons are residing within the immediate vicinity of the river which is distributed among three (3) barangays, namely, Bakabak in the Municipality of Sara, and Puente Bunglas and Bucana Bunglas in the Municipality of Ajuy (NSO, 2015). According to the Department of Social Welfare and Development (DSWD) the major industries in the Municipality of Ajuy are farming and fishing (www.ugnayan.com, 2016). The Municipality of Ajuy was identified by the Mines and Geosciences Bureau (MGB) as one of the areas in Western Visayas with high risk of flooding (www.manilatimes.net, 2016). Last November, 2013 typhoon Yolanda, internationally known as Haiyan brought massive property damage including 6 casualties and affecting a total of 10,271 families from 34 barangays in the municipality (www.ndrrmc.gov.ph, 2013).

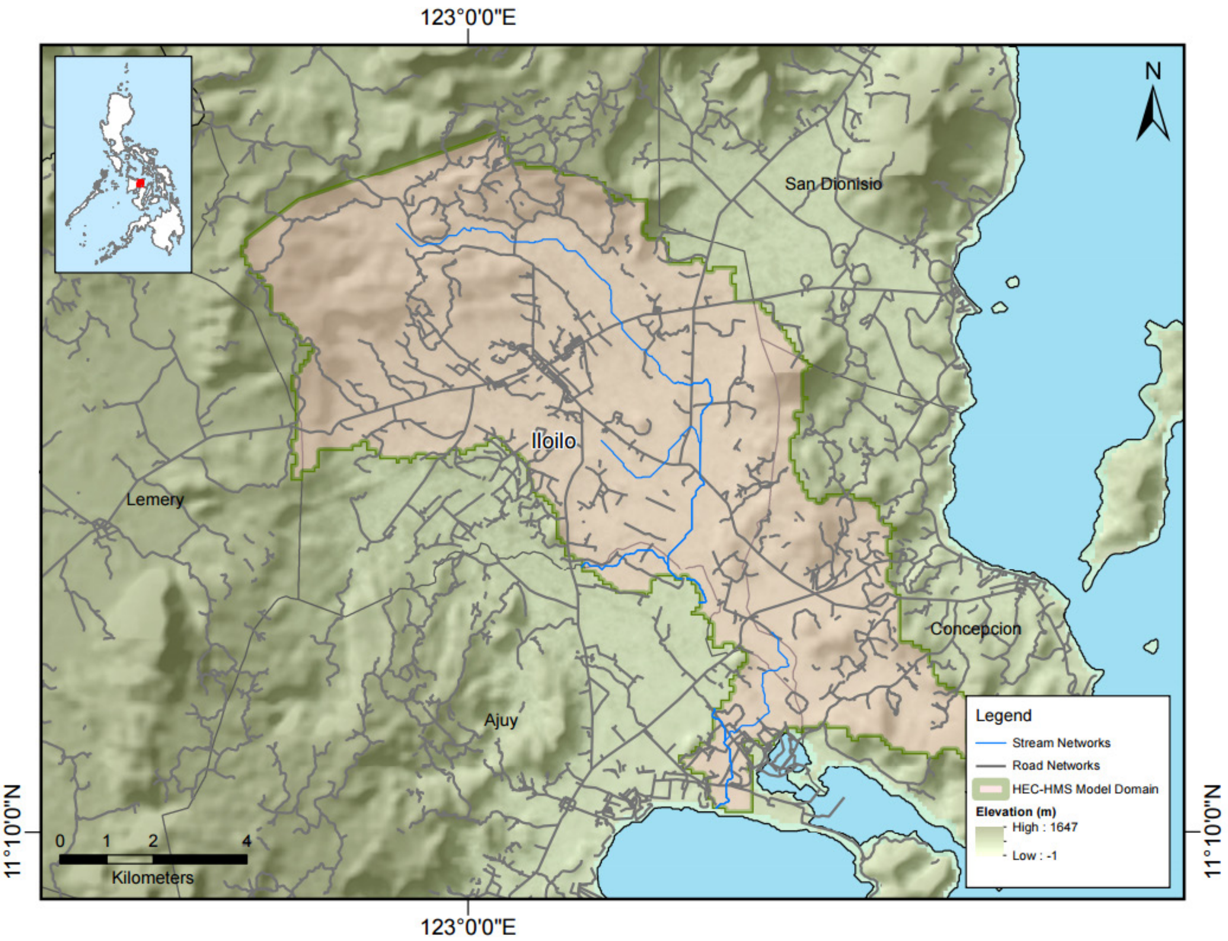

Figure 1. Map of Pinantan River Basin (in brown)

The Pinantan floodplain and drainage area of 119.73 km2 and 152.142 km2 respectively covers the municipalities of Sara, Concepcion and Ajuy. The floodplain is 96.9% covered with LiDAR data which compromises 10 blocks. The LiDAR data was calibrated then mosaicked with an RMSE of -0.3 and then bathy burned. The bathy survey conducted reached a total length of 2.98 km starting from Puente Bunglas Bridge, Bakabak, Sara up to the river mouth with 4696 points surveyed. There are 16982 buildings, 704 km roads, 267 waterbodies and 29 bridges digitized based from the LiDAR data. Feature extraction attribution was conducted and among the building features, 16220 of them are Residential, 335 are schools and 48 are Medical Institutions.

The flood hazard maps produced covers the 62.928 km2, 77.07 km2, 84.40 km2 for the 5-year, 25-year, and 100 year rainfall return period in Ajuy which affects 23 barangays as well as in Concepcion which affects 13 barangays, in San Dionisio which affects 13 barangays, in Sara which affects 37 barangays and in Lemery which affects 6 barangays. A flood depth validation was conducted using 223 randomly generated points which is spread throughout the 6 ranges namely 0m-0.2m, 0.21m-0.5m, 0.51m-1m, 1.01m-2m, 2.10m-5m, 5m+ depth using the 25-yr rainfall flood depth map. It yielded a 0.719m RMSE.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE PINANTAN FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Pinantan floodplain in Iloilo. These missions were planned for 12 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Tables 1 to 3. Figures 1 to 3 shows the flight plan for Pinantan floodplain.

Table 1. 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)
BLK37F	1000	30	50	125	30	120	5
BLK37H	1000	30	50	125	30	120	5
BLK37G	1000	30	50	125	30	120	5
BLK37J	1000	30	50	125	30	120	5

Table 2. 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)
BLK37I	1800	30	40	200	40	130	5
BLK37F	1800	30	50	200	40	130	5
BLK37Q	1800	30	40	200	40	130	5

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

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK37I	1800	30	40	200	40	130	5
BLK37F	1800	30	50	200	40	130	5
BLK37Q	1800	30	40	200	40	130	5

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

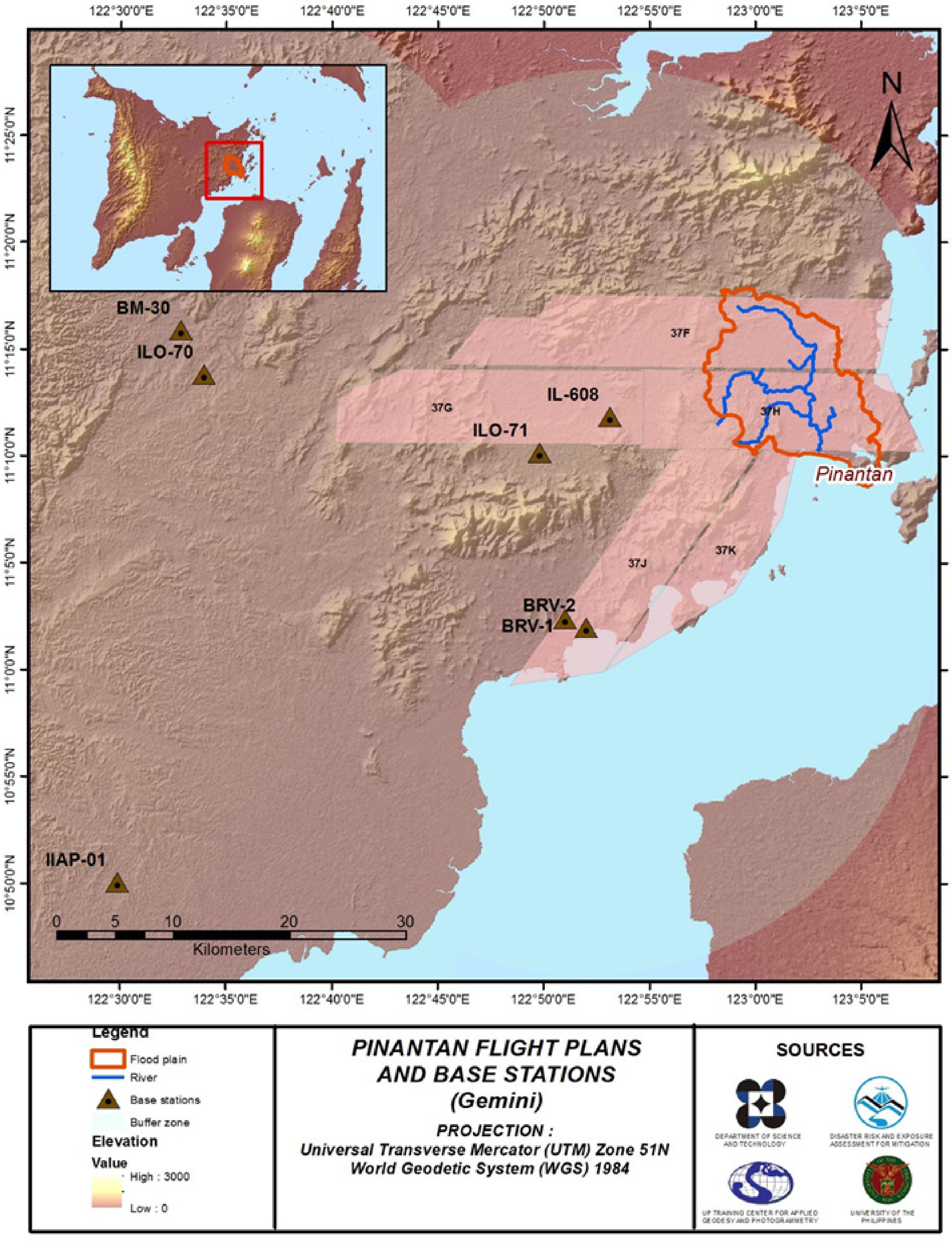


Figure 2. Flight Plan and base stations for Gemini System used for the Pinantan Floodplain survey.

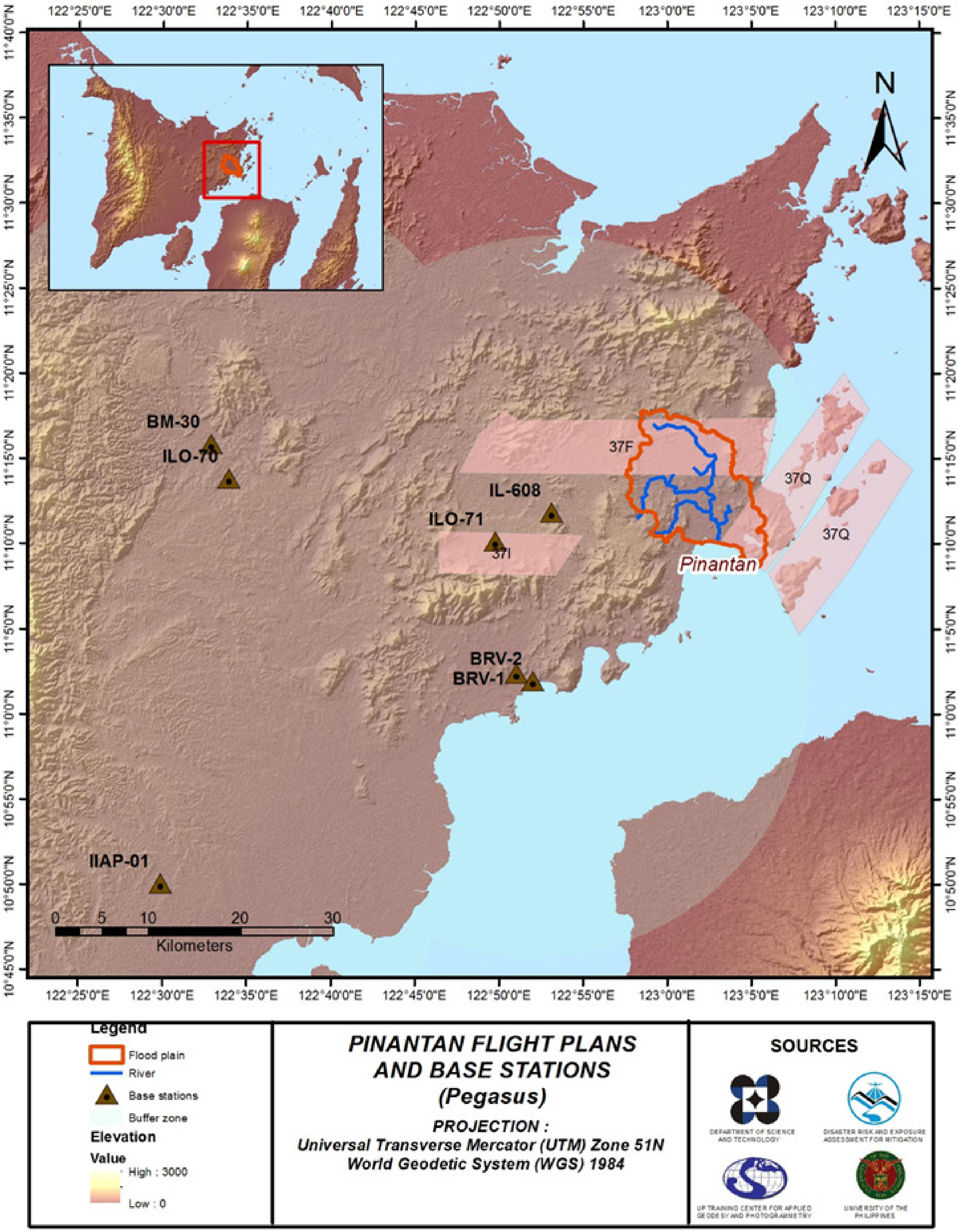


Figure 3. Flight Plan and base stations for Pegasus System used for the Pinantan Floodplain survey.

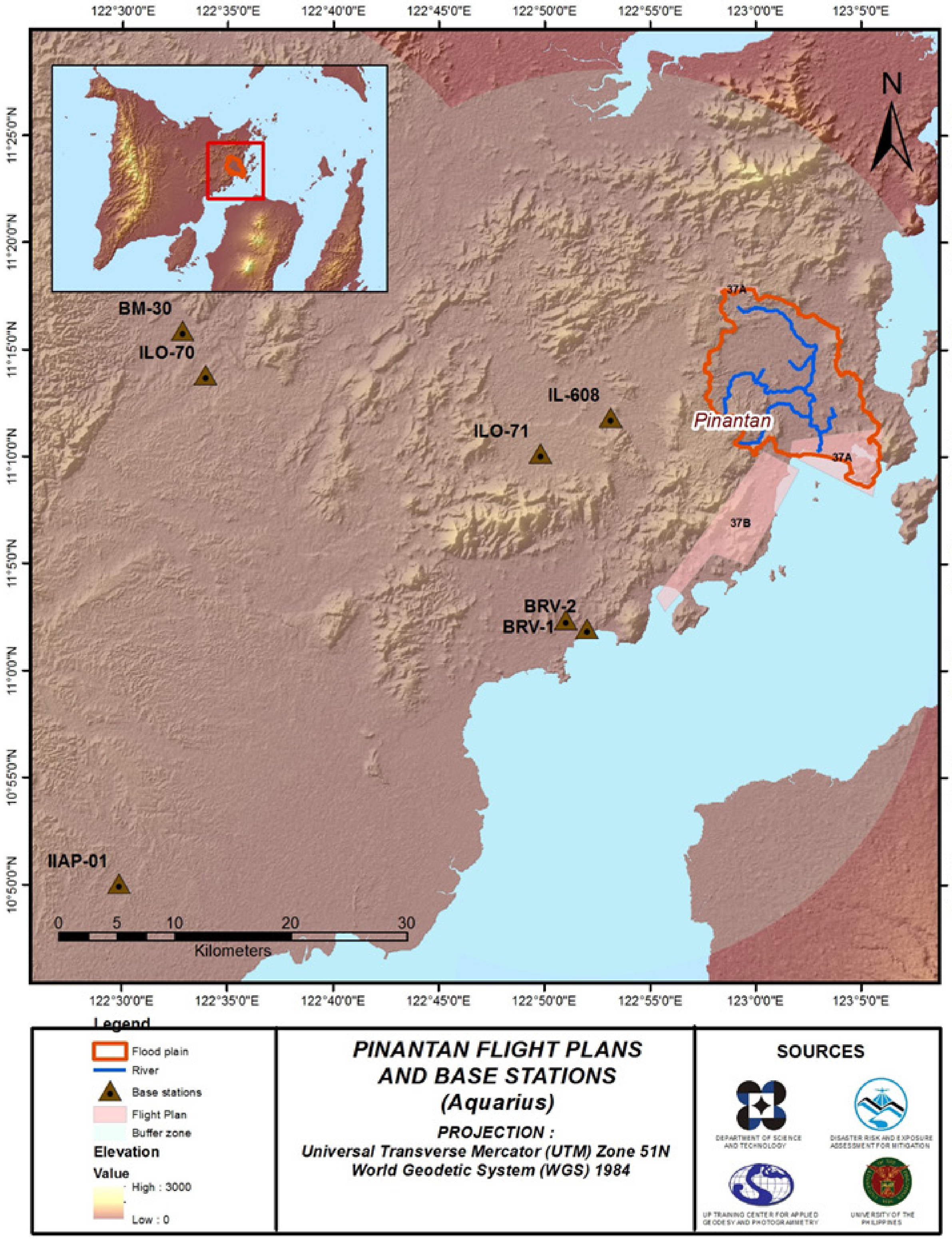


Figure 4. Flight Plan and base stations for Aquarius System used for the Pinantan Floodplain survey.

2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA reference points: ILO-70 and ILO-71 which are of second (2nd) order accuracy, two (2) benchmark points: BMIL-608 and BM-30 which were tied in second 2nd) order accuracy and two (2) established reference points: BRV-1 and BRV-2. The certification for the base station is found in Annex D. The ground control points (GCP) were used as reference point during flight operations using TRIMBLE SPS 852 and TRIMBLE SPS 985, a dual frequency GPS receiver. The ground control points were utilized for the entire duration of the survey (February to March 2015 and October 2016) especially on the days that flight missions were conducted. Flight plans plans and location of base stations used during the aerial LiDAR acquisition in Pinantan floodplain are shown in Figure 2 to Figure 4.

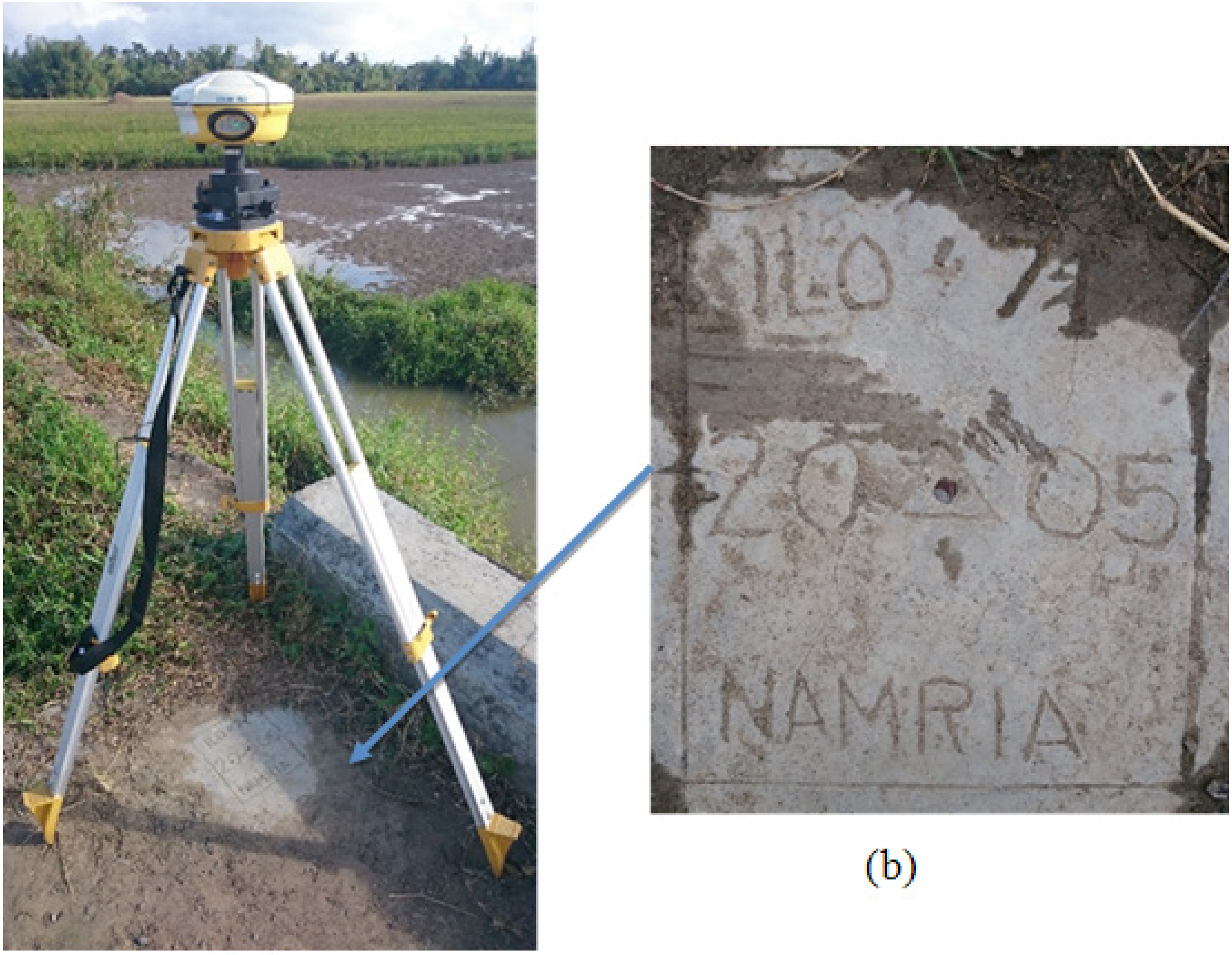
Figure 5 to Figure 10 shows the recovered NAMRIA control station within the area, in addition Table 4 to Table 10 show the details about the following NAMRIA control stations and established points, Table 11 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

Figure 5 to Figure 10 shows the recovered NAMRIA control station within the area, in addition Table 4 to Table 10 show the details about the following NAMRIA control stations and established points, Table 11 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey. The list of team members are found in Annex 4.

Figure 5. NAMRIA reference point ILO-70 as recovered in Barangay Poblacion, Bingawan, Province of Iloilo (a) by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point ILO-70 used as base station for the LiDAR Acquisition.

Station Name	ILO-70	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 13’ 50.08819” 122° 33’56.83732” 76.803 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	452601.273 meters 1241432.381 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 13’45.61545” North 122°34’02.01364” East 133.04 meters



(a)

Figure 6. GPS set-up over ILO-71 as recovered in Barangay Poblacion, San Rafael, Province of Iloilo. (a) NAMRIA reference point ILO-71 (b) as recovered by the field team.

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

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

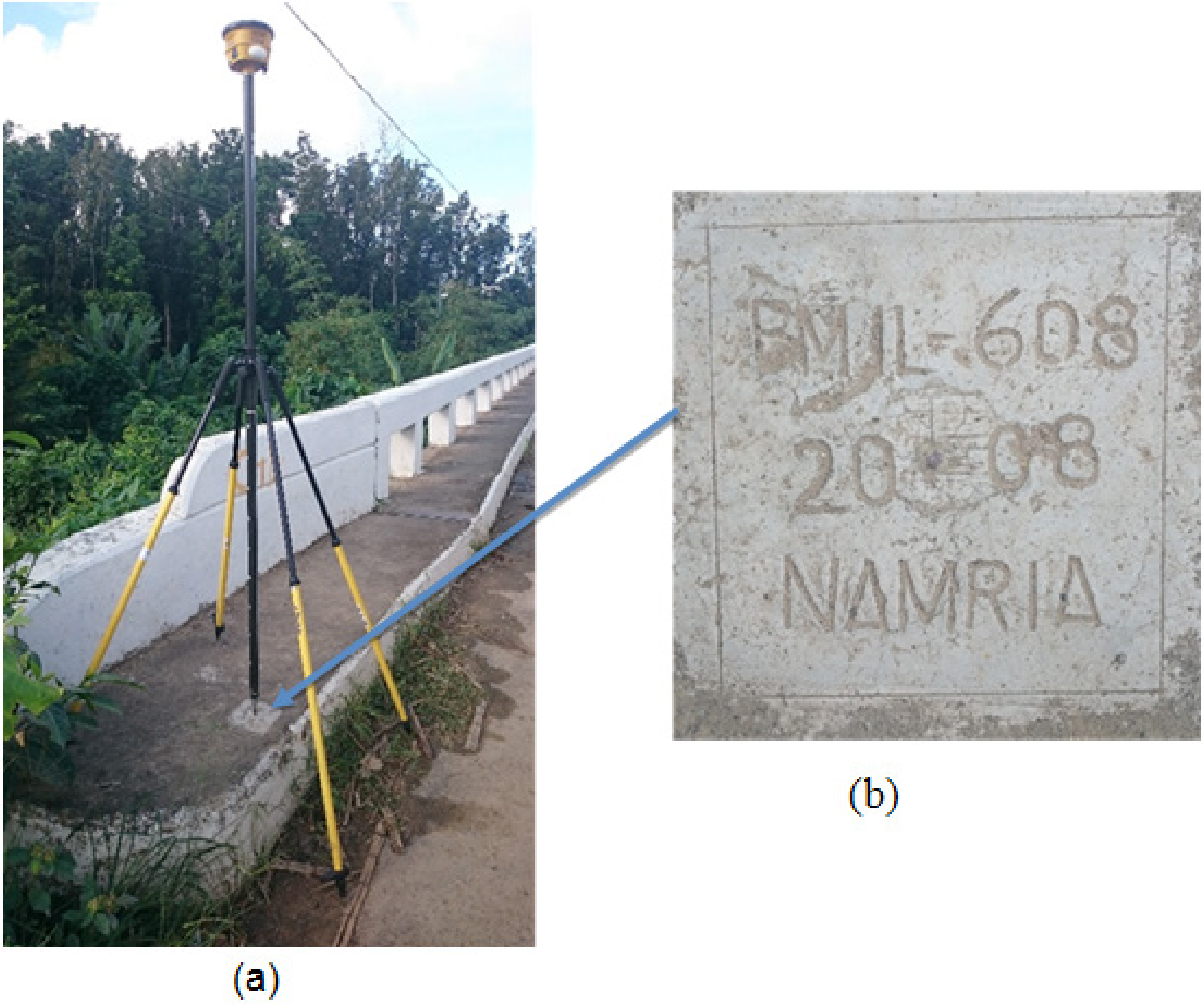
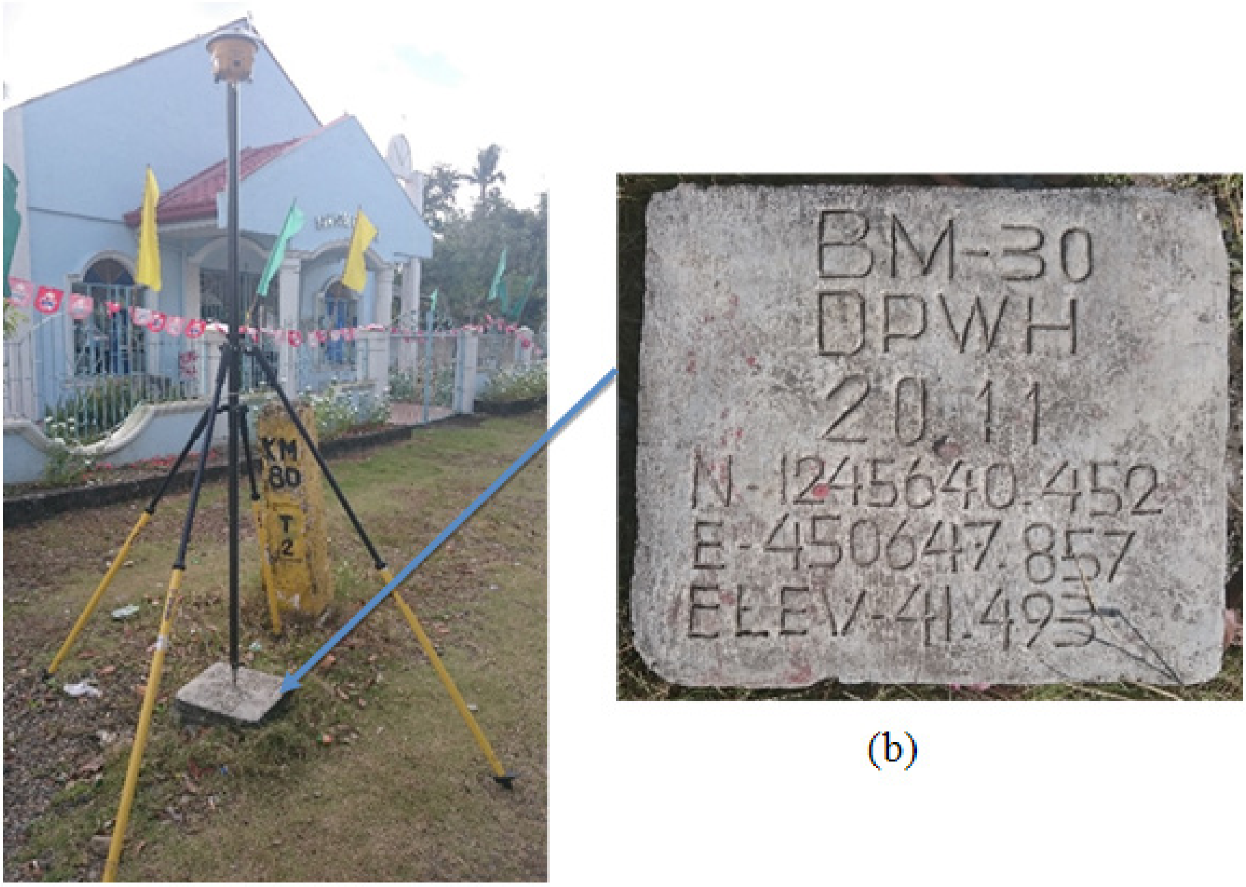


Figure 7. GPS set-up over IL-608 as located in San Rafael, Province of Iloilo (a) NAMRIA reference point IL-608 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point IL-608 GCP used as base station for the LiDAR Acquisition.

Station Name	IL-608	
Order of Accuracy	2ND	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 11’ 55.75853” 122° 53’ 03.09601” 83.941 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone PRS 92)	Easting Northing	487357.226 m 1237888.520 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 11’ 51.32104” 122° 53’ 08.27292” 141.083 m



(a) (b)

Figure 8. GPS set-up over BM-30 as located in Capiz (a) NAMRIA reference point BM-30 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point BM-30 GCP used as base station for the LiDAR Acquisition.

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

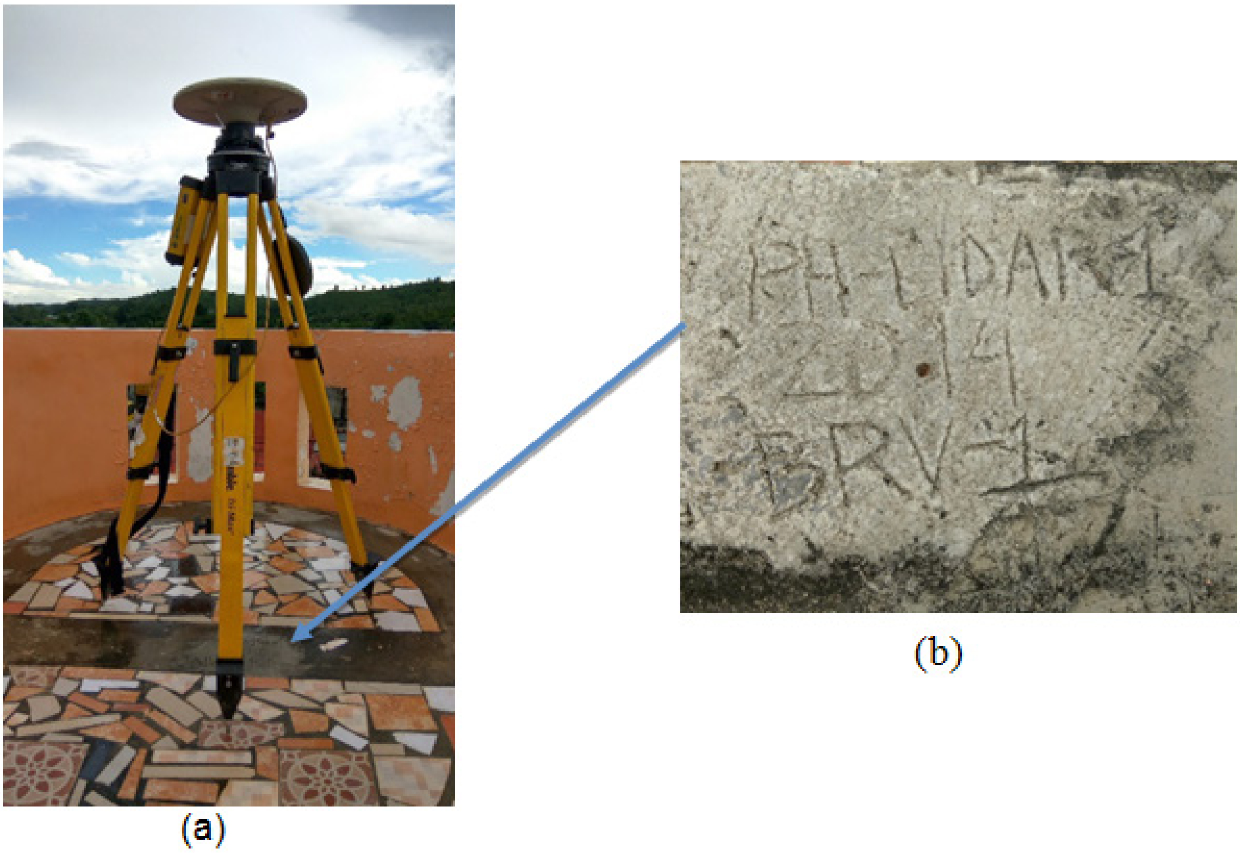
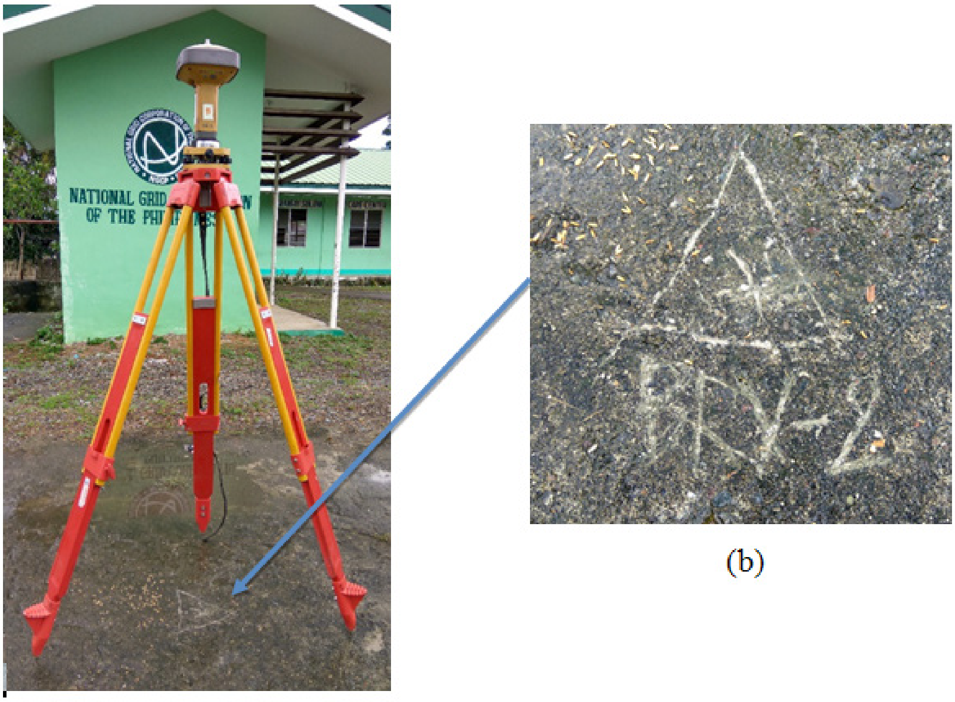


Figure 9. GPS set-up over BRV-1 as located in Municipality of Barotac Viejo, Iloilo (a) NAMRIA reference point BRV-1 (b) as recovered by the field team.

Table 8. Details of the recovered NAMRIA horizontal control point BRV-1 GCP used as base station for the LiDAR Acquisition.

Station Name	BRV-1	
Order of Accuracy	**2ND**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 02’ 23.72962” 122° 51’ 02.09822” 16.296 m
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone PRS 92)	Easting Northing	483679.079 m 1220321 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 2’ 19.32911” 122° 51’ 07.28940” 73.739 m



(b)

(a)

Figure 10. GPS set-up over BRV-2 as located in Municipality of Barotac Viejo, Iloilo (a) NAMRIA reference point BRV-2 (b) as recovered by the field team.

Table 9. Details of recovered NAMRIA horizontal control point BRV-2 GCP used as base station for LiDAR Acquisition.

Station Name	BRV-2	
Order of Accuracy	2ND	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 01’ 58.86503” 122° 52’ 01.23432” 5.276 m
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone PRS 92)	Easting Northing	485473.040 m 1219557.222 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 1’ 54.46766” 122° 52’ 06.42600” 62.776 m

Table 10. Details of IIAP-01 GCP used as base station for the LiDAR Acquisition.

Station Name	IIAP-01	
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° 50’ 08.21923” 122° 29’ 48.82359” 43.390 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone PRS 92)	Easting Northing	445007.365 m 1197773.97 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 50’ 03.83971” 122° 29’ 54.03518” 100.449 m
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	445007.365 m 1197773.97 m

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

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 10, 2015	2542G	2BLK37H041A	ILO-71, BMIL-608
February 10, 2015	2544G	2BLK37F041B	ILO-71, BMIL-608
February 11, 2015	2546G	2BLK37KV042A	ILO-71, BMIL-608
February 13, 2015	2554G	2BLK37J044A	ILO-71, BMIL-608
February 13, 2015	2556G	2BLK37JSG044B	ILO-71, BMIL-608
February 16, 2015	2566G	2BLK37V047A	ILO-71, BMIL-608
February 22, 2015	2601P	1BLKIF053A	ILO-71, IIAP-01
March 5, 2015	2645P	1BLK37Q064A	ILO-70, BM-30
March 6, 2015	2649P	1BLK37Q65A	ILO-70,IIAP-01
October 24, 2016	8509AC	3BLK37A298A	BRV-1, BRV-2
October 24, 2016	8510AC	3BLK37B298B	BRV-1, BRV-2

2.3 Flight Missions

Eleven (11) missions were conducted to complete the LiDAR Data Acquisition in Pinantan Floodplain, for a total of forty-three hours and fifty-nine minutes (43+59) of flying time for RP-C9022, RP-C9122 and RP-C9322. All missions were acquired using the Gemini, Pegasus and Aquarius LiDAR systems. Table 12 shows the total area of actual coverage per mission and the flying length for each mission and Table 13 presents the actual parameters used during the LiDAR data acquisition.

Table 12. Flight missions for the LiDAR data acquisition of the Pinantan Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 10, 2015	2542G	153.37	180.15	87.56	92.59	0	4	23
February 10, 2015	2544G	208.54	220.07	58.2	161.87	1123	4	23
February 11, 2015	2546G	85.54	121.18	3.73	117.45	939	4	23
February 13, 2015	2554G	141.62	133.66	2.52	131.14	0	4	23
February 13, 2015	2556G	161.09	149.6	0	149.6	1194	4	11
February 16, 2015	2566G	161.4	206.69	0.81	205.88	418	3	53
February 22, 2015	2601P	259.0141	175.85	10.45	165.4	505	4	12
March 5, 2015	2645P	125.21	99.02	0	99.02	519	3	14
March 6, 2015	2649P	119.25	70.06	4.78	65.28	206	3	35
October 24, 2016	8509AC	30.44	31.72	19.18	12.54	0	2	53
October 24, 2016	8510AC	50.07	34.66	1.82	32.84	0	4	23
TOTAL		**1495.544**	**1422.66**	**189.05**	**1233.61**	**4904**	**43**	**59**

Table 13. Actual parameters used during the LiDAR data acquisition of the Pinantan Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2542G	800	30	50	125	40	120	5
2544G	800	30	50	125	40	120	5
2546G	800	30	50	125	40	120	5
2554G	800	30	50	125	40	120	5
2556G	800	30	50	125	40	120	5
2566G	800	30	50	125	40	120	5
2601P	1000	30	50	200	40	130	5
2645P	1000	30	50	200	40	130	5
2649P	1000	30	50	200	40	130	5
8509AC	600	30	36	70	50	120	5
8510AC	600	30	36	70	50	120	5

2.4 Survey Coverage

Pinantan floodplain is located in the provinces of Iloilo and Capiz with majority of the floodplain situated within the municipalities of Ajuy and Sara. Municipality of Ajuy is fully covered by the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 14. The actual coverage of the LiDAR acquisition for Pinantan floodplain is presented in Figure 11.

Table 14. List of municipalities and cities surveyed of the Pinantan Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Capiz	Dumarao	228.45	121.93	53
	Pilar	120.51	61.23	51
	Ma-Ayon	192.6	12.74	7
Iloilo	Ajuy	169.66	167.77	99
	Lemery	132.21	118.92	90
	Concepcion	93.82	68.1	73
	Sara	191.04	98.23	51
	Barotac Viejo	187.75	90.66	48
	Balasan	51.11	24.31	48
	Carles	103.84	33.86	33
	San Rafael	78.9	25.5	32
	San Dionisio	108.56	31.33	29
	San Enrique	93.21	15.7	17
	Bingawan	38.34	5.84	15
	Batad	48.05	6.24	13
	Anilao	102.97	3.81	4
	Calinog	132.92	3.9	3
	Estancia	29.44	0.84	3
Total		**2,103.38**	**890.91**	**42.36%**

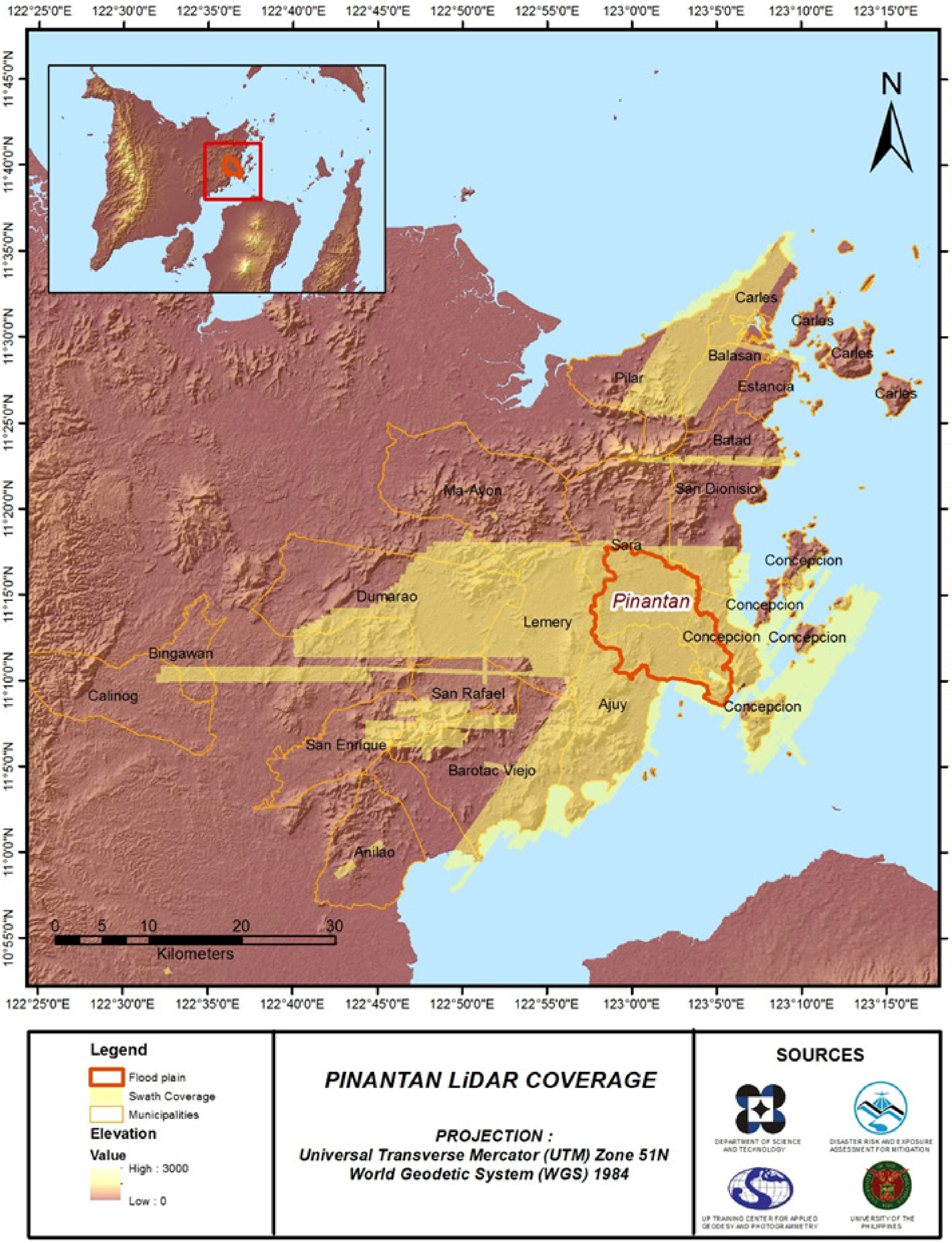


Figure 11. Actual LiDAR survey coverage of the Pinantan Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE PINANTAN FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 12.

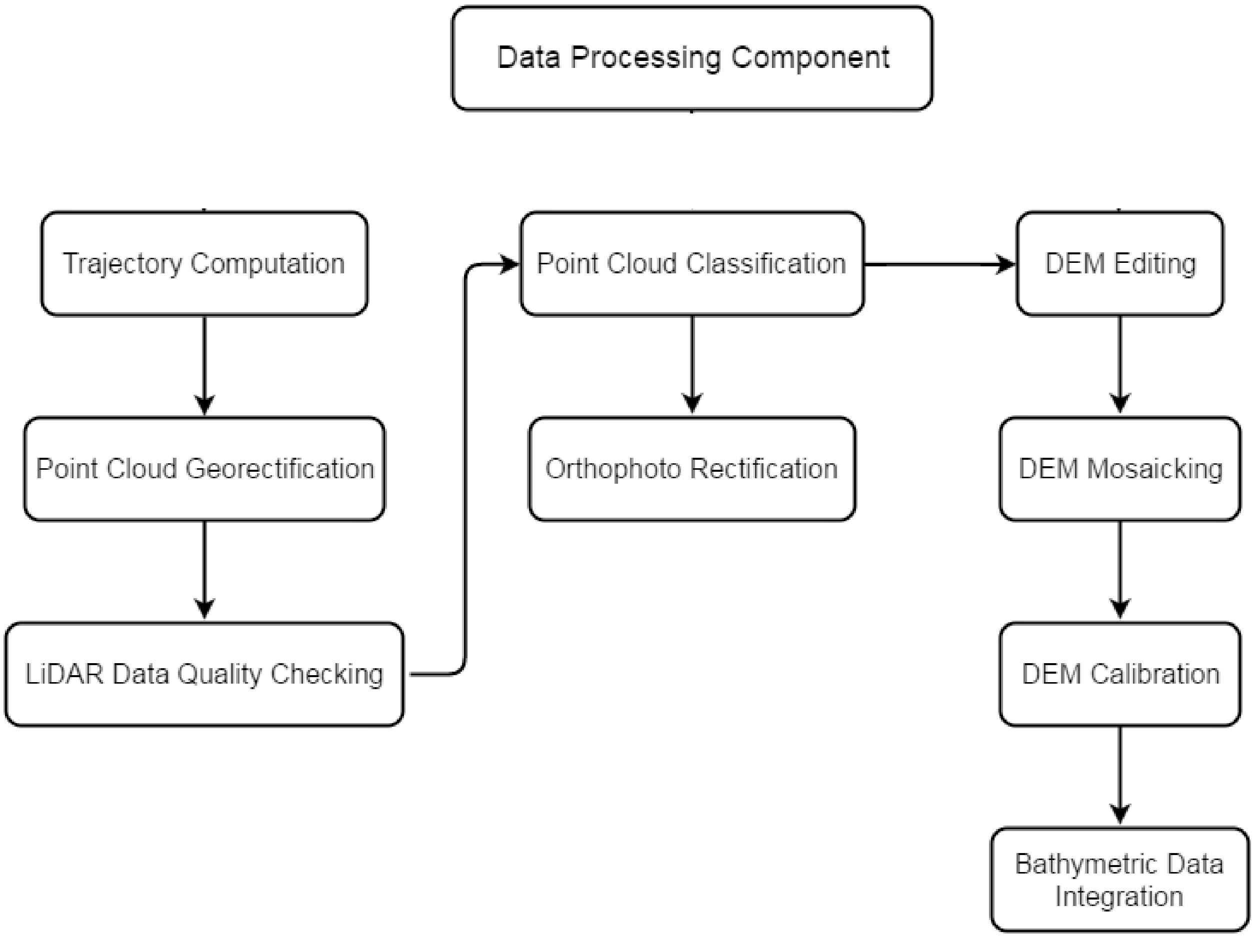

Figure 12. Schematic diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Pinantan floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the first surveys conducted on February 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini and Pegasus systems while missions acquired during the March 2016 were flown using the Gemini system exclusively over Ajuy, Iloilo. The third survey was conducted on October 2016 using the Aquarius system.

The Data Acquisition Component (DAC) transferred a total of 265.08 Gigabytes of Range data, 2.87 Gigabytes of POS data, 266.85 Megabytes of GPS base station data, and 510.00 Gigabytes of raw image data to the data server on February 18, 2015 for the first survey and March 7, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Pinantan was fully transferred on November 22, 2016, as indicated on Annex 5: Data Transfer Sheets for Pinantan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 2544G, one of the Pinantan flights, which is the North, East, and Down position RMSE values are shown 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 on that week fell on February 8, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

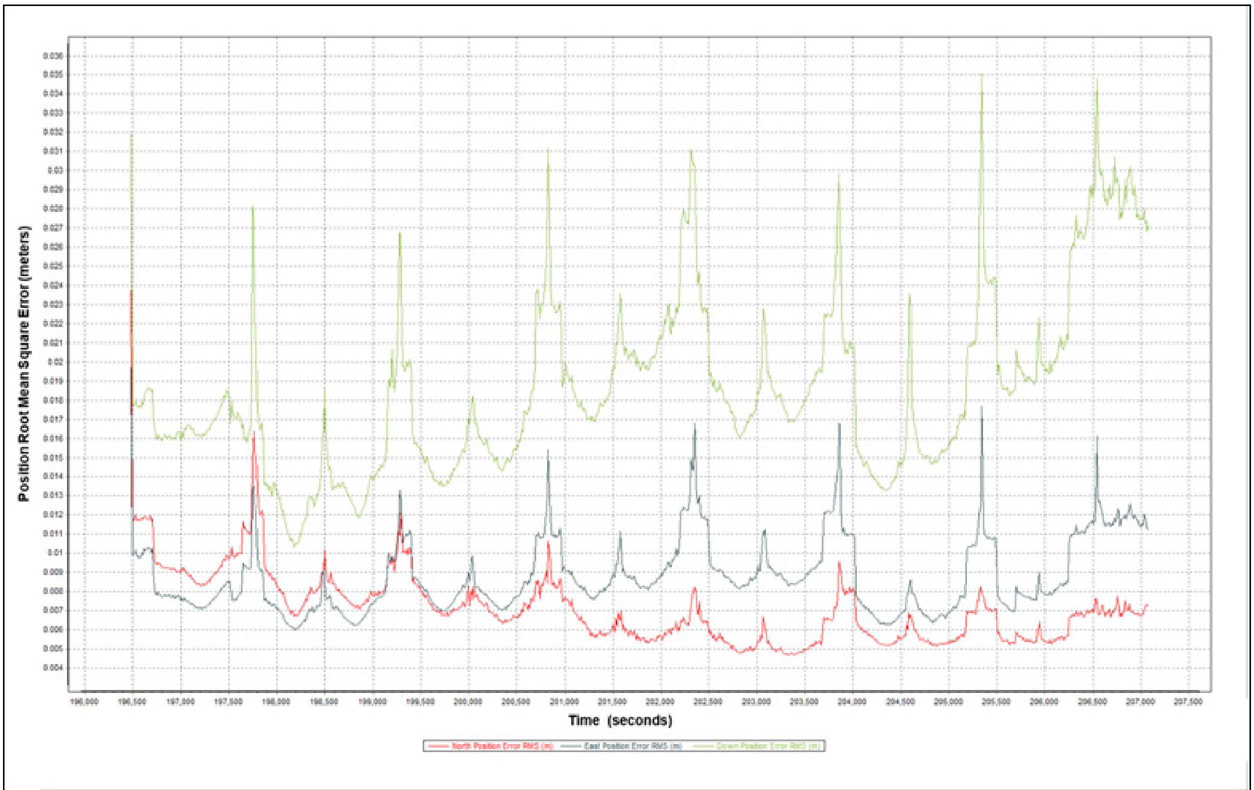

Figure 13. Smoothed Performance Metrics of Pinantan Flight 2544G.

The time of flight was from 196,500 seconds to 207,000 seconds, which corresponds to morning of February 10, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 13 shows that the North position RMSE peaks at 1.60 centimeters, the East position RMSE peaks at 1.80 centimeters, and the Down position RMSE peaks at 3.50 centimeters, which are within the prescribed accuracies described in the methodology.

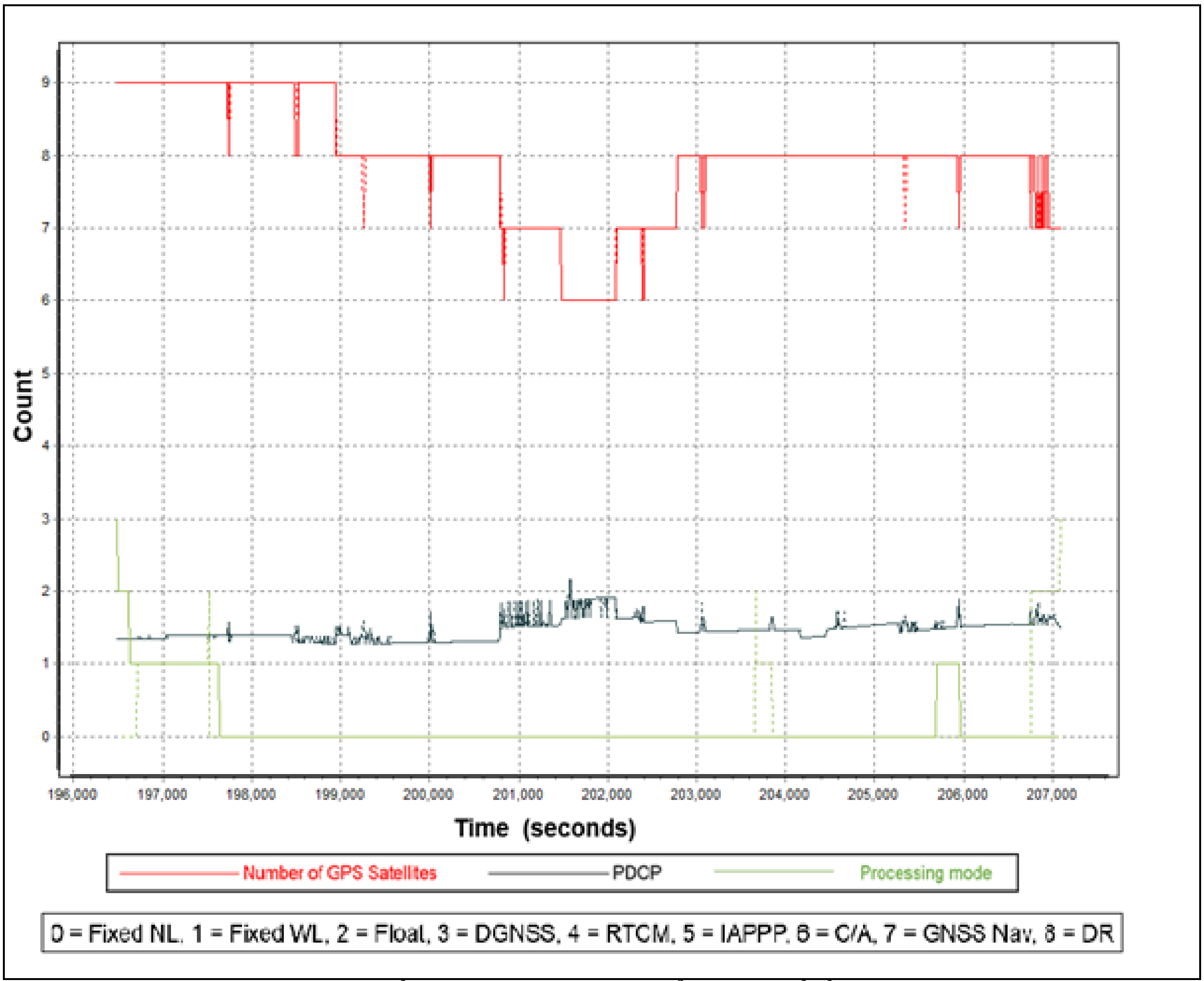

Figure 14. Solution Status Parameters of Pinantan Flight 2544G.

The Solution Status parameters of flight 2544G, one of the Pinantan flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 14. The graphs indicate that the number of satellites during the acquisition did not go down to 5. Most of the time, the number of satellites tracked was between 6 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey with some peaks up to 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Pinantan flights is shown in Figure 15.

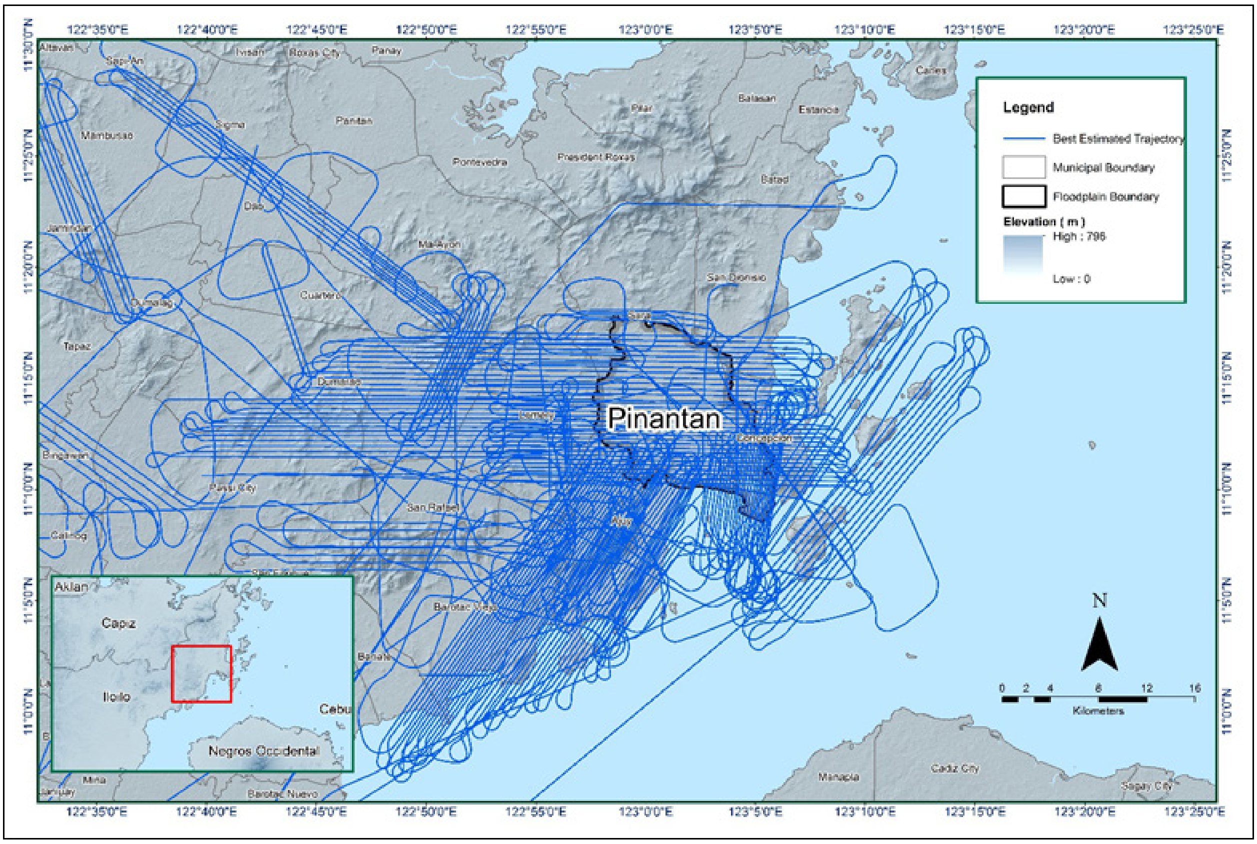

Figure 15. Best Estimated Trajectory of the LiDAR missions conducted over the Pinantan Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 177 flight lines, with each flight line containing one channel for both the Gemini and Aquarius systems and two channels for the Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Pinantan floodplain are given in Table 15.

Table 15. Self-calibration Results values for Pinantan flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	<0.001degrees	0.000591
IMU Attitude Correction Roll and Pitch Correction stdev	<0.001degrees	0.000691
GPS Position Z-correction stdev	<0.01meters	0.0063

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data is shown in Figure 16. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

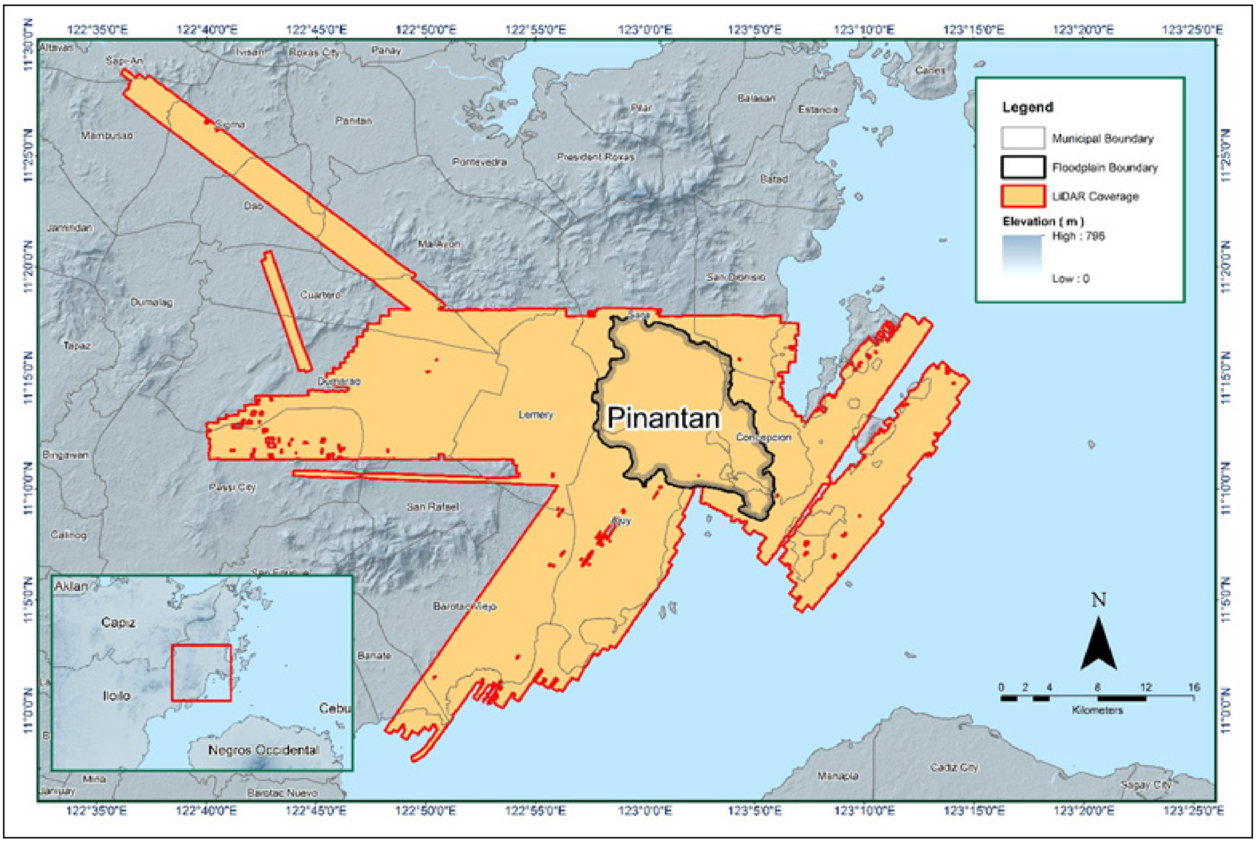

Figure 16. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Pinantan Floodplain.

The total area covered by the Pinantan missions is 1220.29 sq.km that is comprised of thirteen (13) flight acquisitions grouped and merged into ten (10) blocks as shown in Table 16.

Table 16. List of LiDAR blocks for Pinantan Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Iloilo_Blk37F	2544G	104.7
Iloilo_Blk37F_additional1	2544G	179.3
	2601P	
Iloilo_Blk37F_additional2	2566G	40.72
Iloilo_Blk37H	2542G	173.5
Iloilo_Blk37JK	2546G	401.3
	2554G	
	2556G	
Iloilo_Blk37Q	2645P	173.1
	2647P	
	2649P	
Iloilo_reflights_Blk37E	8510AC	6.05
Iloilo_reflights_Blk37K	8509AC	21.89
Iloilo_reflights_Blk37Q	8510AC	29.28
Capiz_Aklan_Blk38J	2792G	90.45
TOTAL		**1220.29 sq.km.**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 17. Since the Gemini and Aquarius-CASI systems both employ one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus system which employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

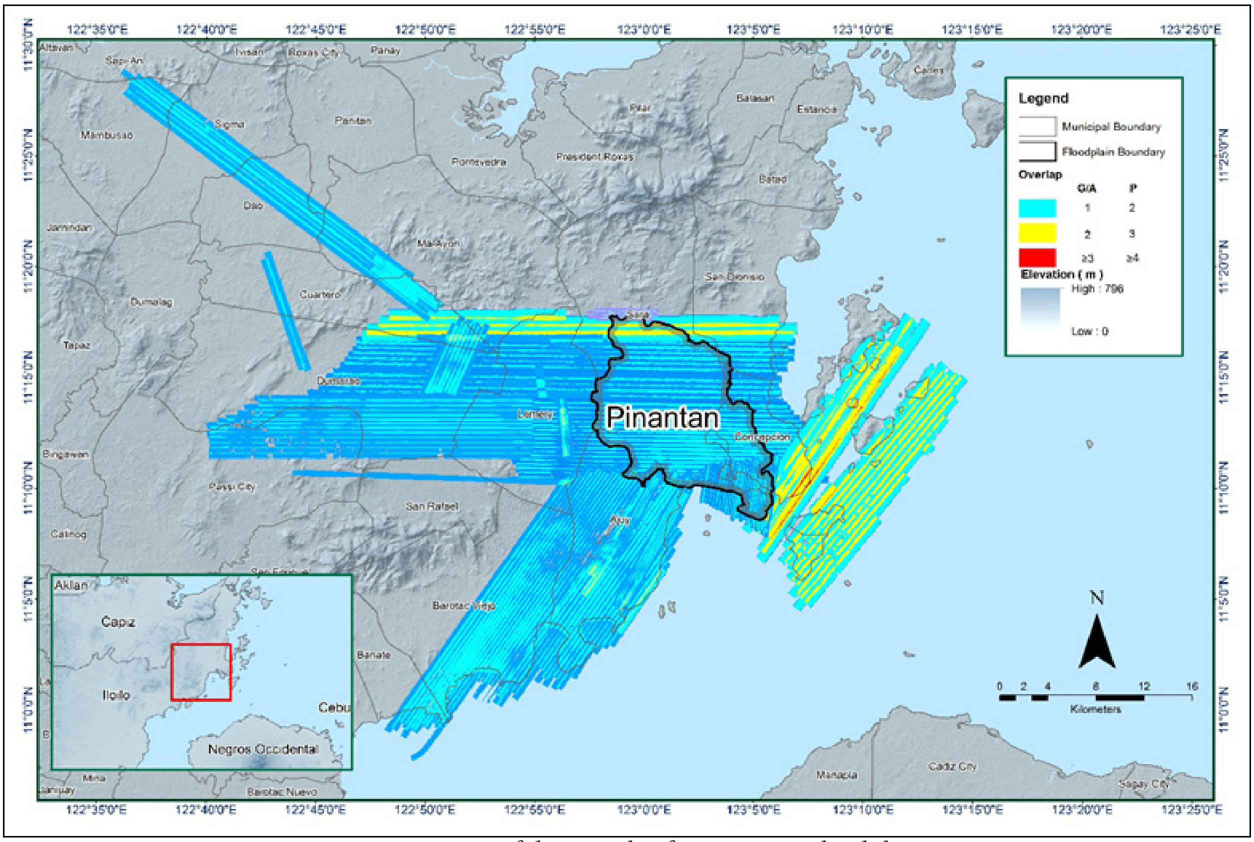

Figure 17. Image of data overlap for Pinantan Floodplain.

The overlap statistics per block for the Pinantan floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 26.80% and 43.43% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 18. It was determined that all LiDAR data for Pinantan floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.48 points per square meter.

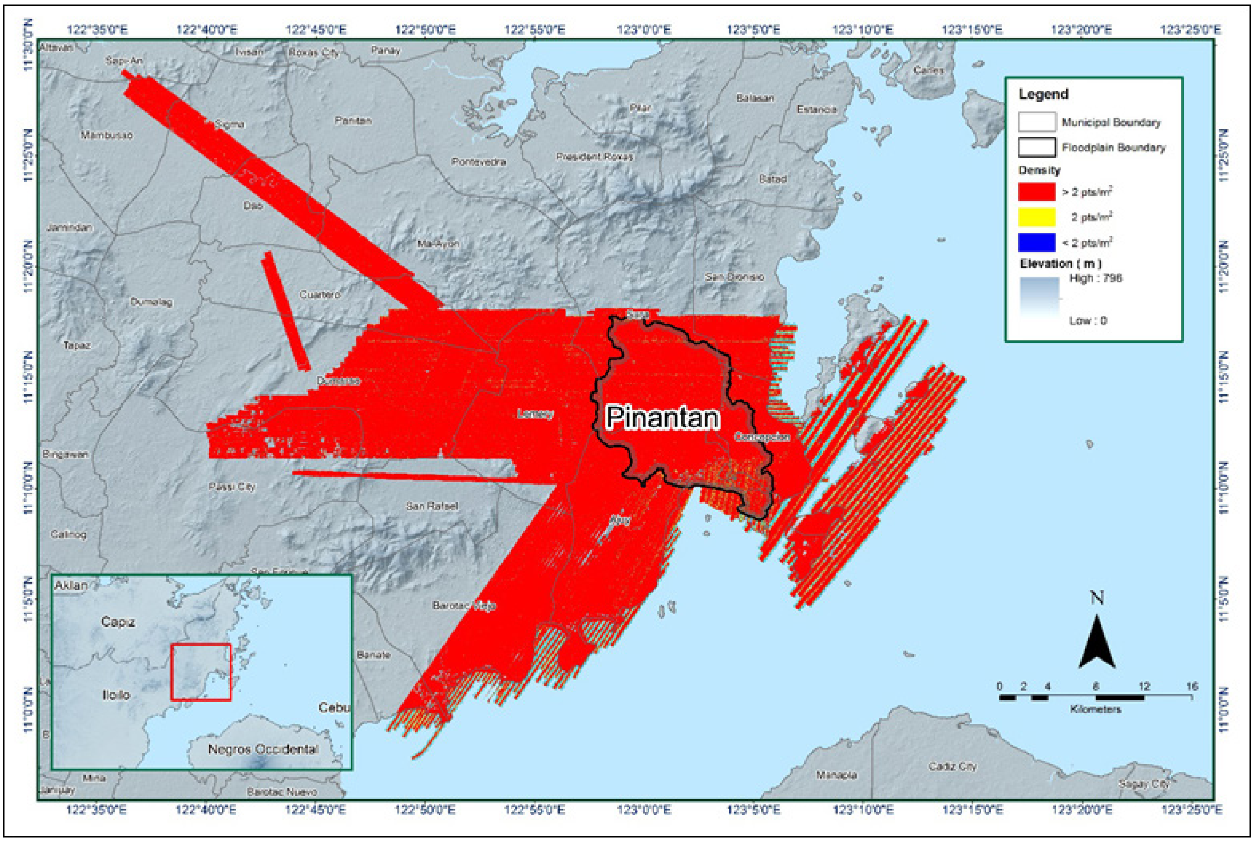

Figure 18. Pulse density map of merged LiDAR data for Pinantan Floodplain.

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

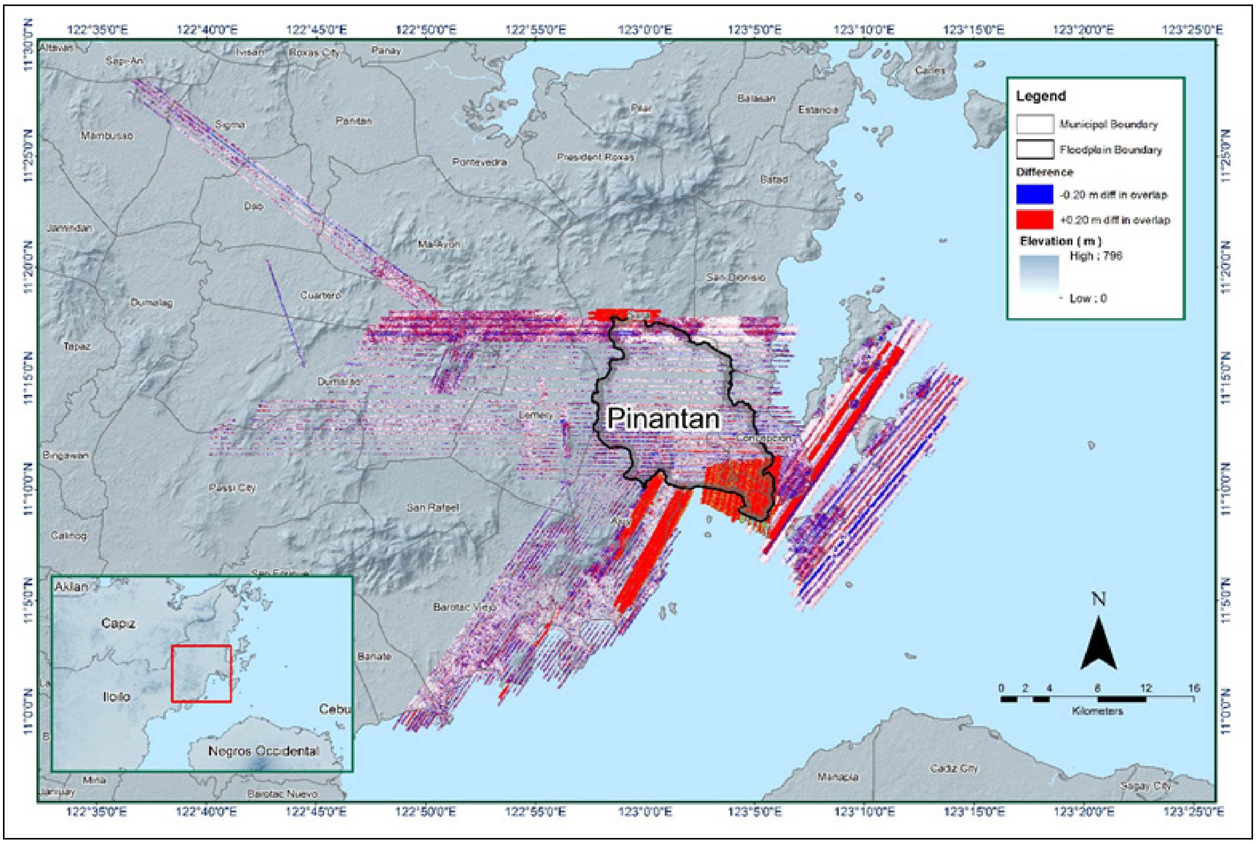

Figure 19. Elevation Difference Map between flight lines for Pinantan Floodplain Survey.

A screen capture of the processed LAS data from a Pinantan flight 2544G loaded in QT Modeler is shown in Figure 20. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

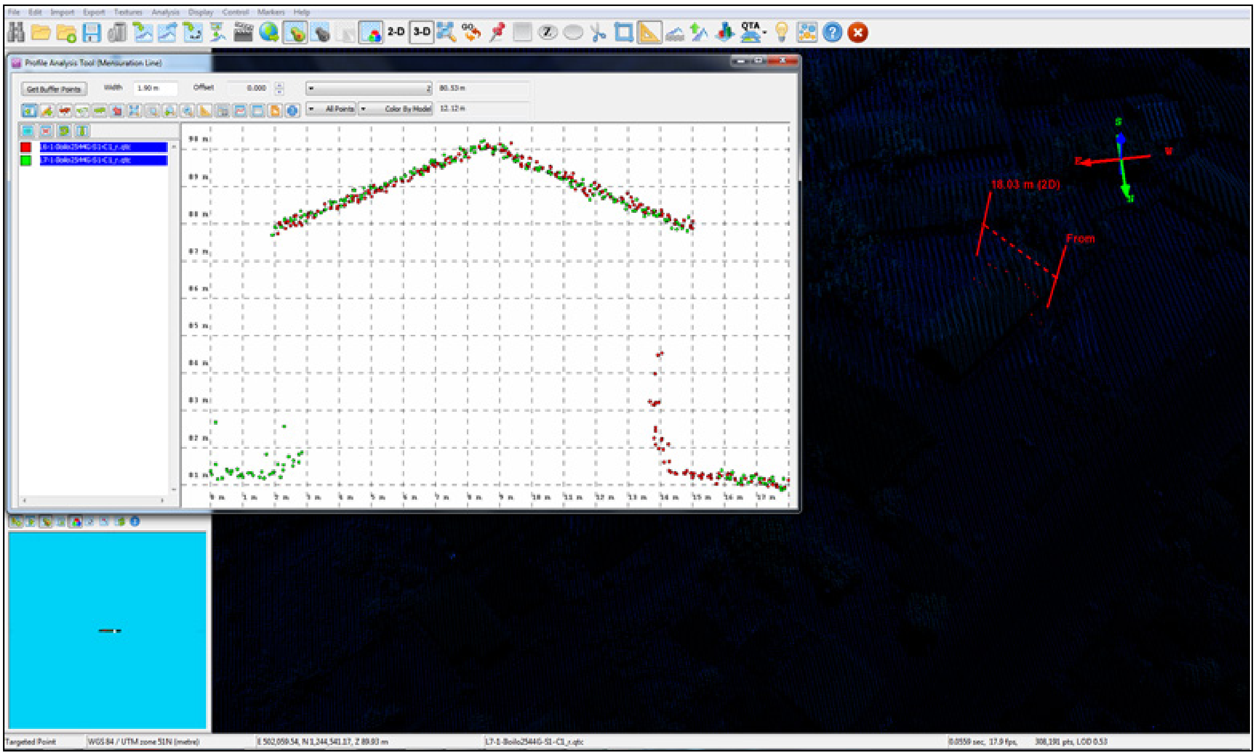

Figure 20. Quality checking for Pinantan flight 2544G using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. Pinantan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	918,730,302
Low Vegetation	975,117,480
Medium Vegetation	2,684,234,983
High Vegetation	1,565,061,016
Building	23,964,266

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Pinantan floodplain is shown in Figure 21. A total of 1,794 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 17. The point cloud has a maximum and minimum height of 734.07 meters and 2.25 meters respectively.

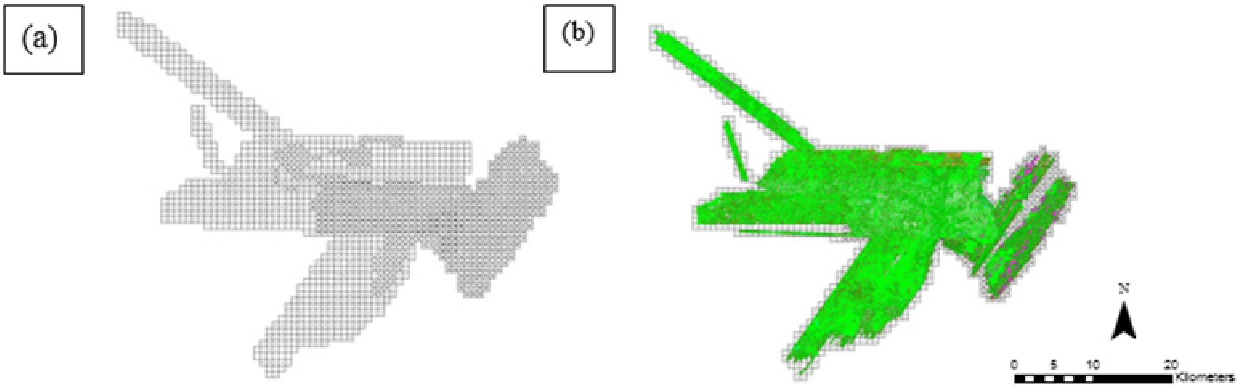

Figure 21. Tiles for Pinantan Floodplain (a) and classification results (b) in TerraScan.

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

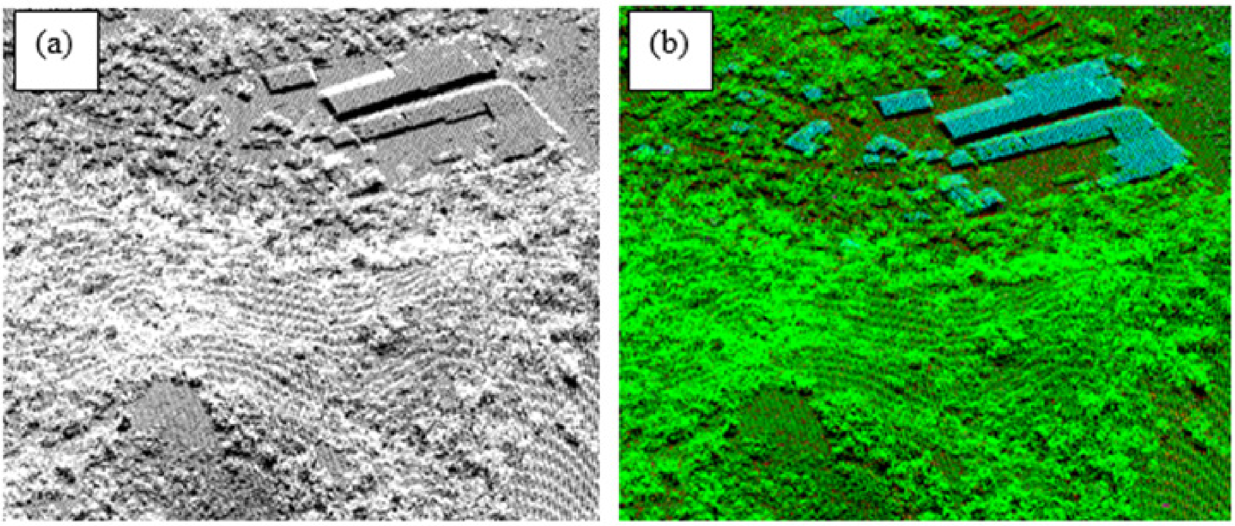

Figure 22. Point cloud before (a) and after (b) classification

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

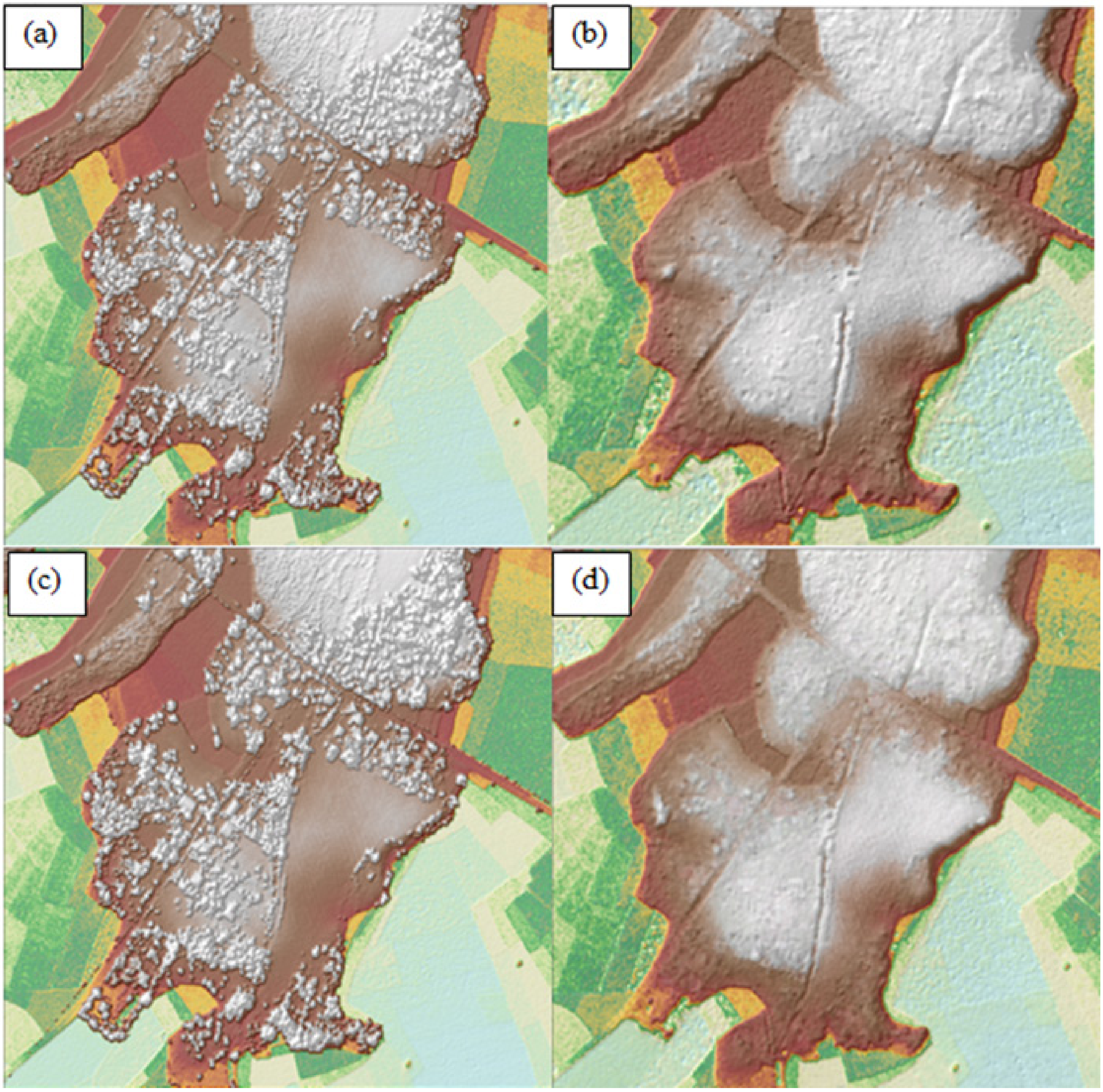

Figure 23. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Pinantan Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 607 1km by 1km tiles area covered by Pinantan floodplain is shown in Figure 24. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Pinantan floodplain has a total of 290.77 sq.km orthophotogaph coverage comprised of 1,614 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 25.

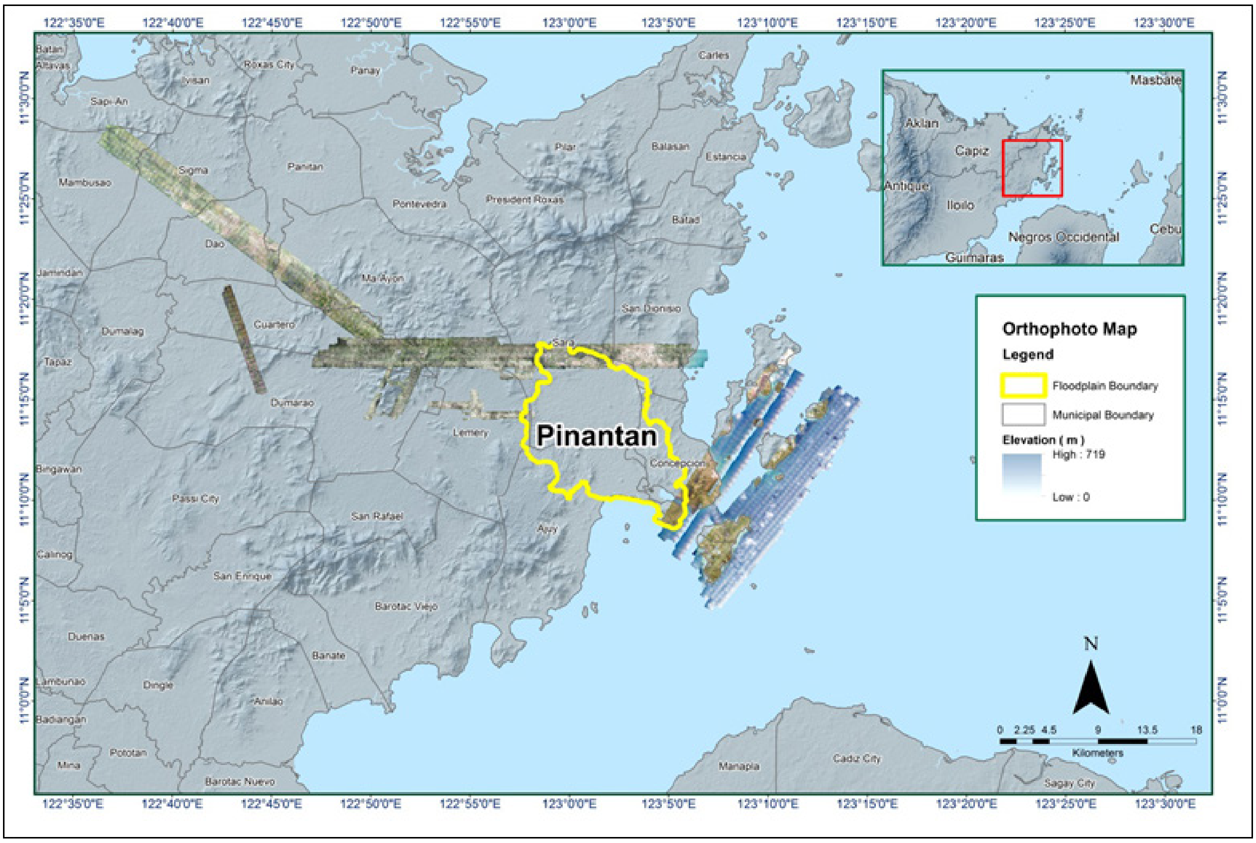

Figure 24. Pinantan Floodplain with available orthophotographs.

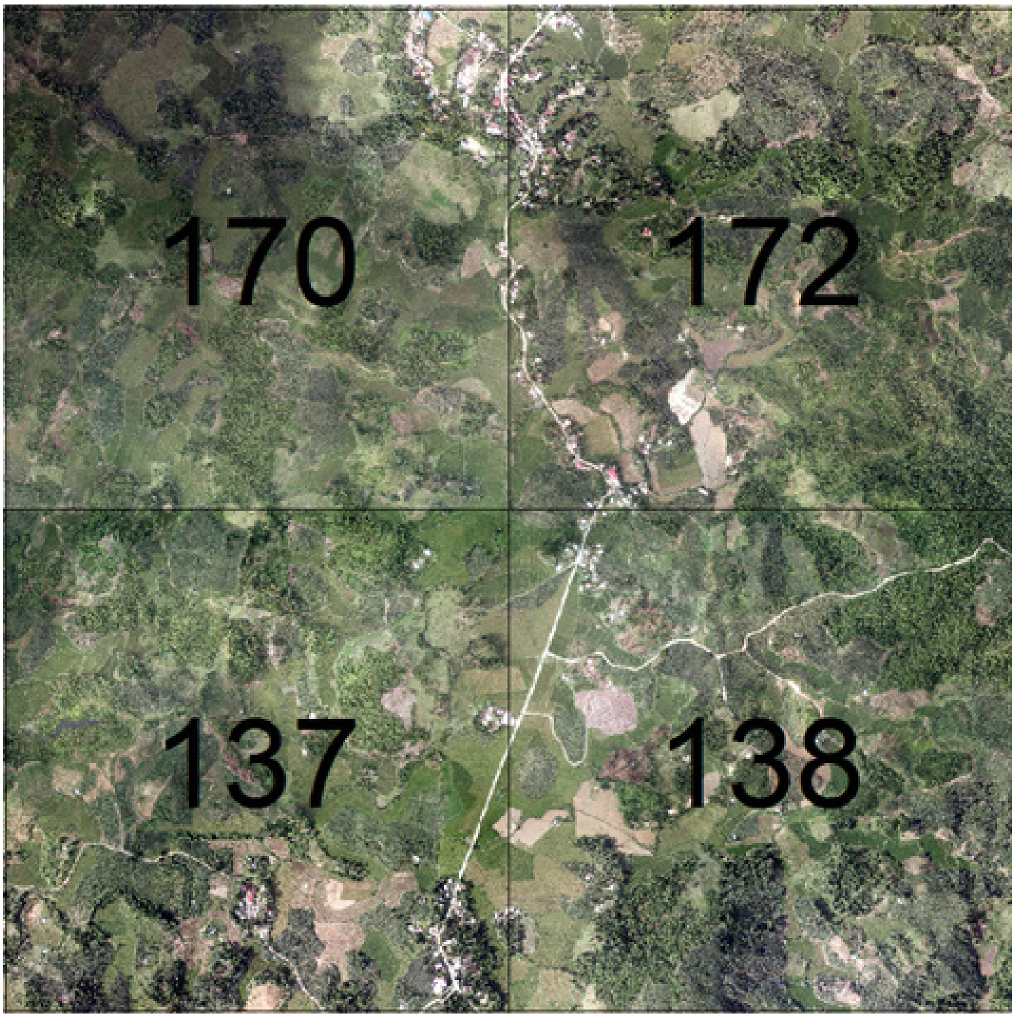

Figure 25. Sample orthophotograph tiles for Pinantan Floodplain.

3.8 DEM Editing and Hydro-Correction

Ten (10) mission blocks were processed for Pinantan flood plain. These blocks are composed of Iloilo blocks with a total area of 1,220.29 square kilometers. Table 18 shows the name and corresponding area of each block in square kilometers.

Table 18. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Iloilo_Blk37F	104.7
Iloilo_Blk37F_additional1	179.3
Iloilo_Blk37F_additional2	40.72
Iloilo_Blk37H	173.5
Iloilo_Blk37JK	401.3
Iloilo_Blk37Q	173.1
Iloilo_Blk37E_reflight	6.05
Iloilo_Blk37K_reflight	21.89
Iloilo_Blk37Q_reflight	29.28
Capiz_Aklan_Blk38J	90.45
TOTAL	**1220.29 sq.km**

Portions of DTM before and after manual editing are shown in Figure 26. It shows that the paddy field (Figure 26a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 26b). The bridges (Figure 265c) would be an impedance to the flow of water along the river and have to be removed (Figure 26d) in order to hydrologically correct the river.

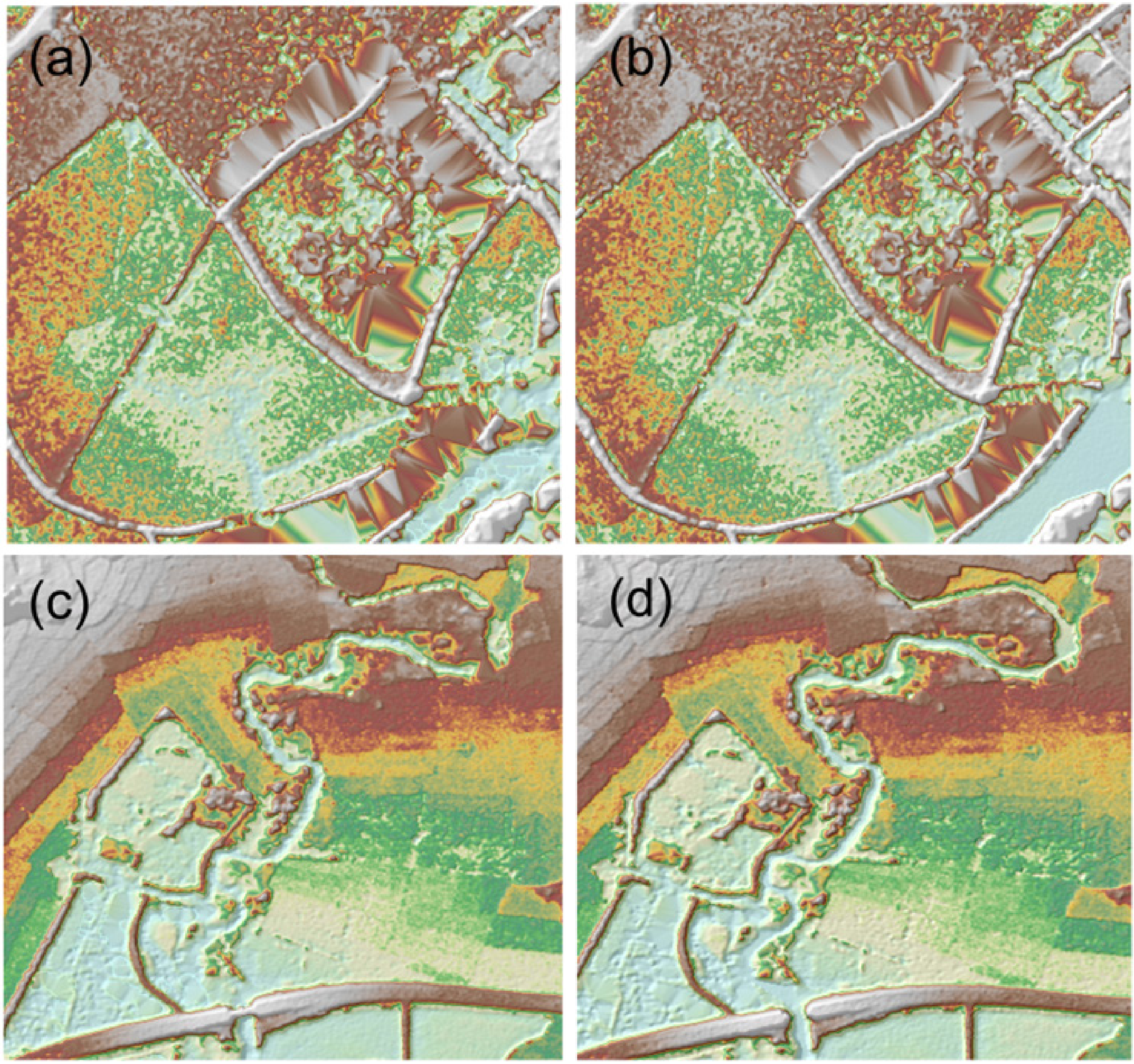

Figure 26. Portions in the DTM of Pinantan floodplain – a paddy field before (a) and after (b) data retrieval; bridges before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

The Calibrated DEM of Jalaur was used as the reference block at the start of mosaicking. Table 19 shows the area of each LiDAR block and the shift values applied during mosaicking.

Mosaicked LiDAR DTM for Pinantan floodplain is shown in Figure 27. It can be seen that the entire Pinantan floodplain is 96.9% covered by LiDAR data.

Table 19. Shift values of each LiDAR block of Pinantan Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Iloilo_Blk37F	0.00	0.00	-0.68
Iloilo_Blk37F_additional1	0.00	0.00	-0.74
Iloilo_Blk37F_additional2	0.00	0.00	-0.52
Iloilo_Blk37H	0.00	0.00	-0.83
Iloilo_Blk37JK	0.00	0.00	-0.82
Iloilo_Blk37Q	0.00	-1.00	-1.20
Iloilo_Blk37E_reflight	0.00	0.00	0.80
Iloilo_Blk37K_reflight	0.00	0.00	0.29
Iloilo_Blk37Q_reflight	0.00	0.00	0.59
Capiz_Aklan_Blk38J	-0.79	2.00	-1.40

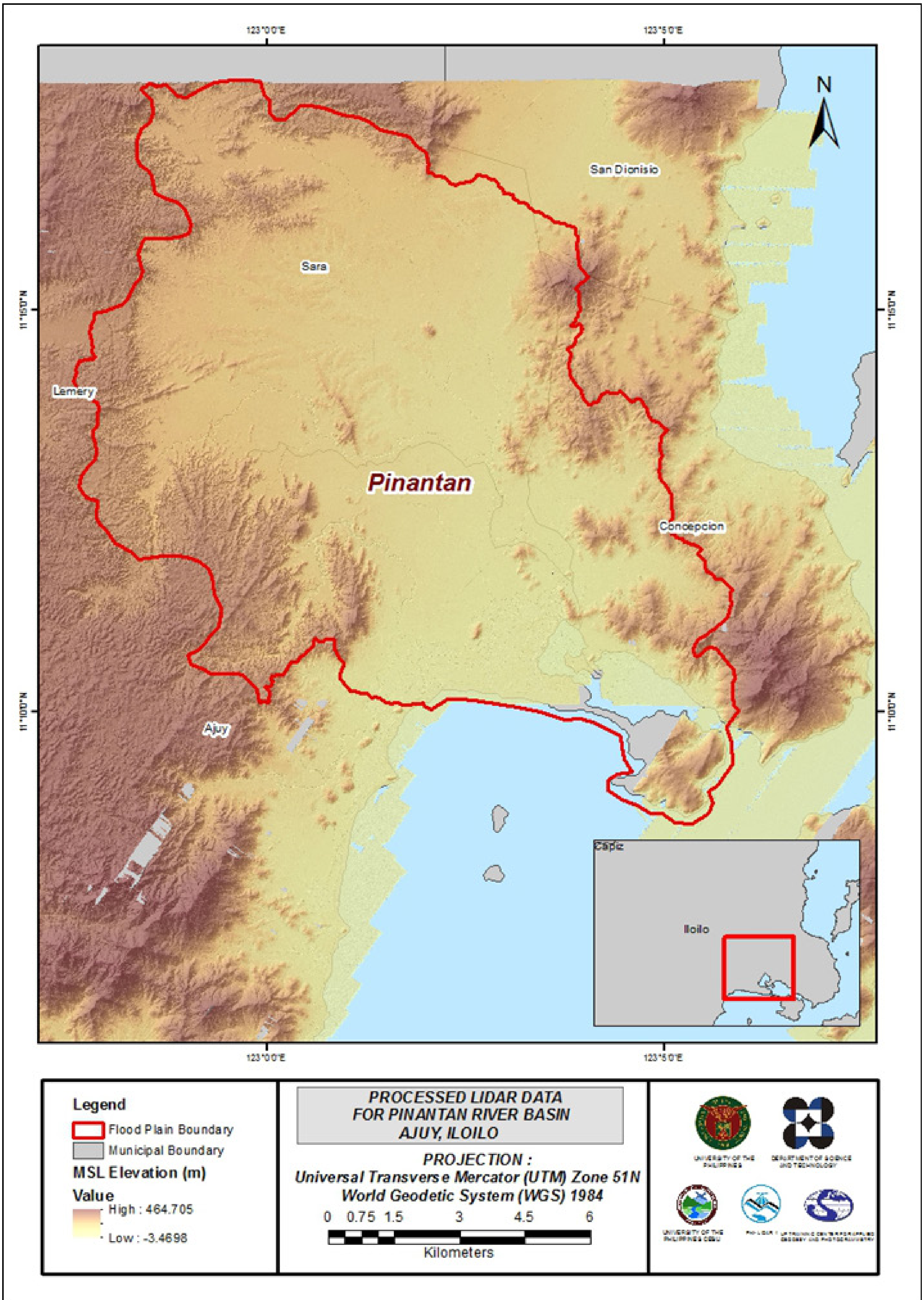

Figure 27. Map of Processed LiDAR Data for Pinantan Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model (DEM)

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Pinantan to collect points with which the LiDAR dataset is validated is shown in Figure 28. A total of 18,528 points were gathered for all the floodplains within the Province of Iloilo wherein the Pinantan is located. However, the point dataset was not used for the calibration of the LiDAR data for Pinantan because during the mosaicking process, each LiDAR block was referred to the calibrated Jalaur DEM. Therefore, the mosaicked DEM of Pinantan can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Jalaur LiDAR DTM and ground survey elevation values is shown in Figure 29. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 1.71 meters with a standard deviation of 0.17 meters. Calibration of Jalaur LiDAR data was done by subtracting the height difference value, 1.71 meters, to Jalaur mosaicked LiDAR data. Table 20 shows the statistical values of the compared elevation values between Jalaur LiDAR data and calibration data. These values were also applicable to the Pinantan DEM.

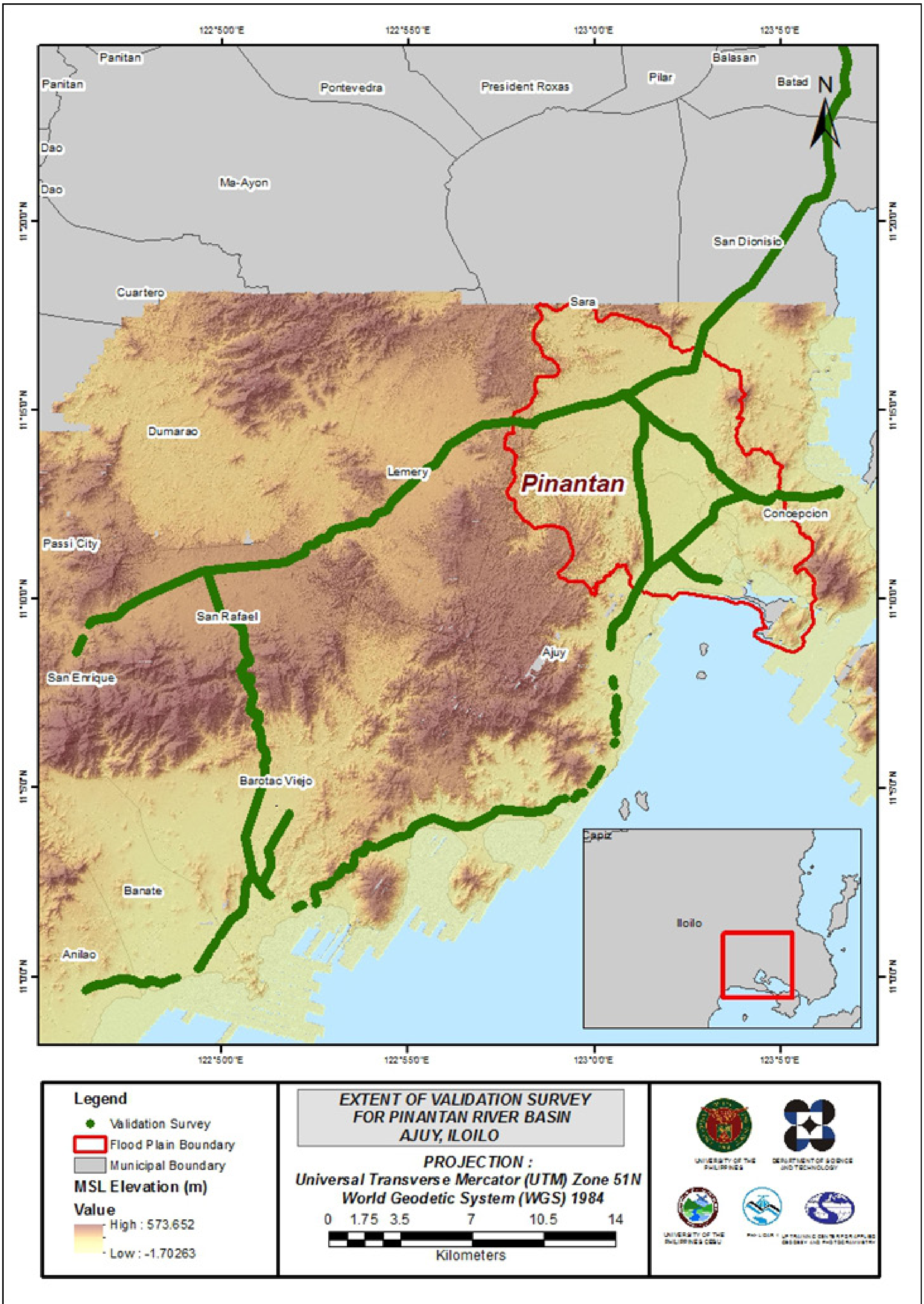

Figure 28. Map of Pinantan Floodplain with validation survey points in green.

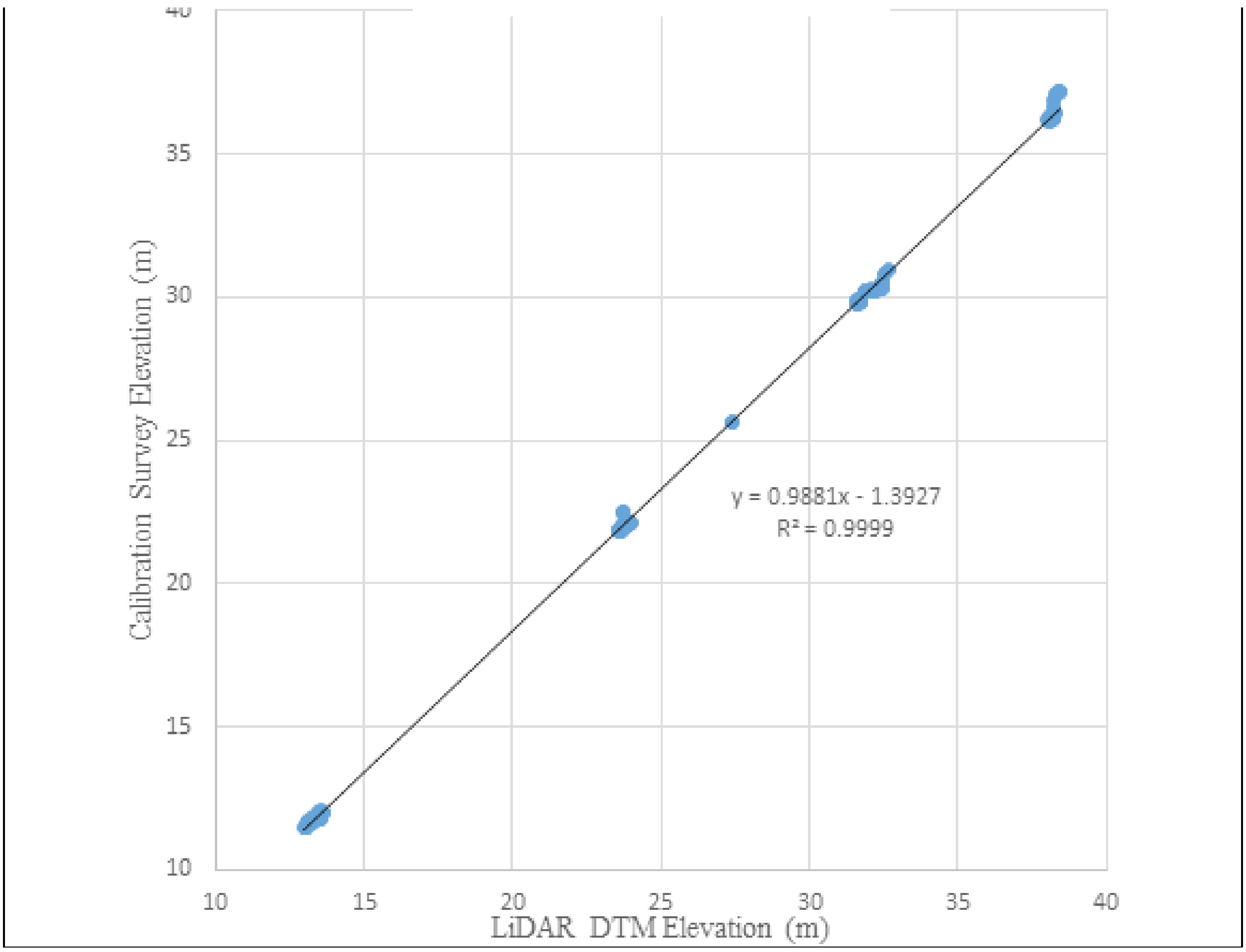

Figure 29. Correlation plot between calibration survey points and LiDAR data.

Table 20. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	1.71
Standard Deviation	0.17
Average	-1.70
Minimum	-2.13
Maximum	-1.16

A total of 2,024 survey points that are within the Pinantan flood plain were used for the validation of the calibrated Pinantan DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 30. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.16 meters with a standard deviation of 0.13 meters, as shown in Table 21.

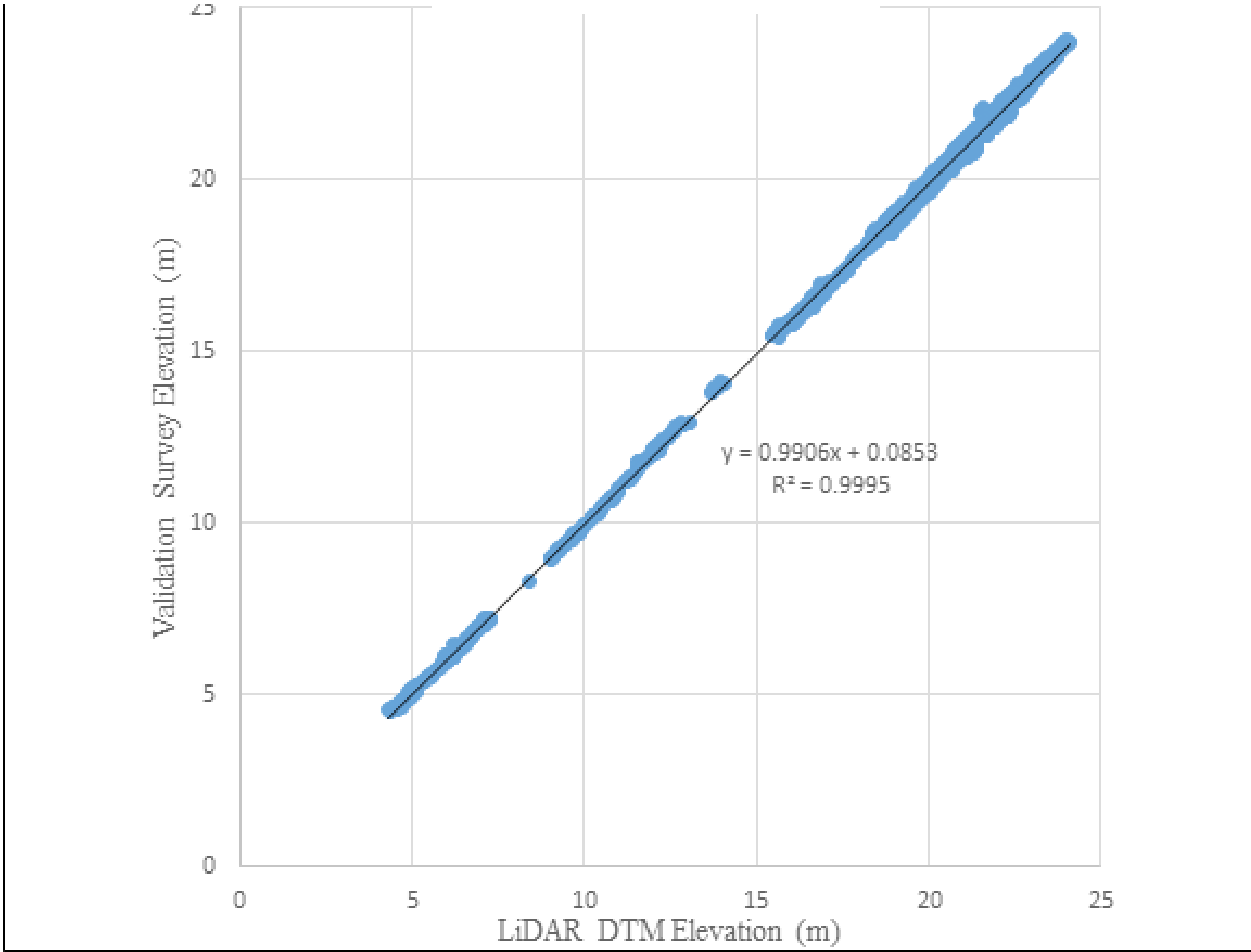

Figure 30. Correlation plot between validation survey points and LiDAR data.

Table 21. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.16
Standard Deviation	0.13
Average	-0.09
Minimum	-0.52
Maximum	-0.09

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Pinantan with 3,144 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of -0.90 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Pinantan integrated with the processed LiDAR DEM is shown in Figure 31.

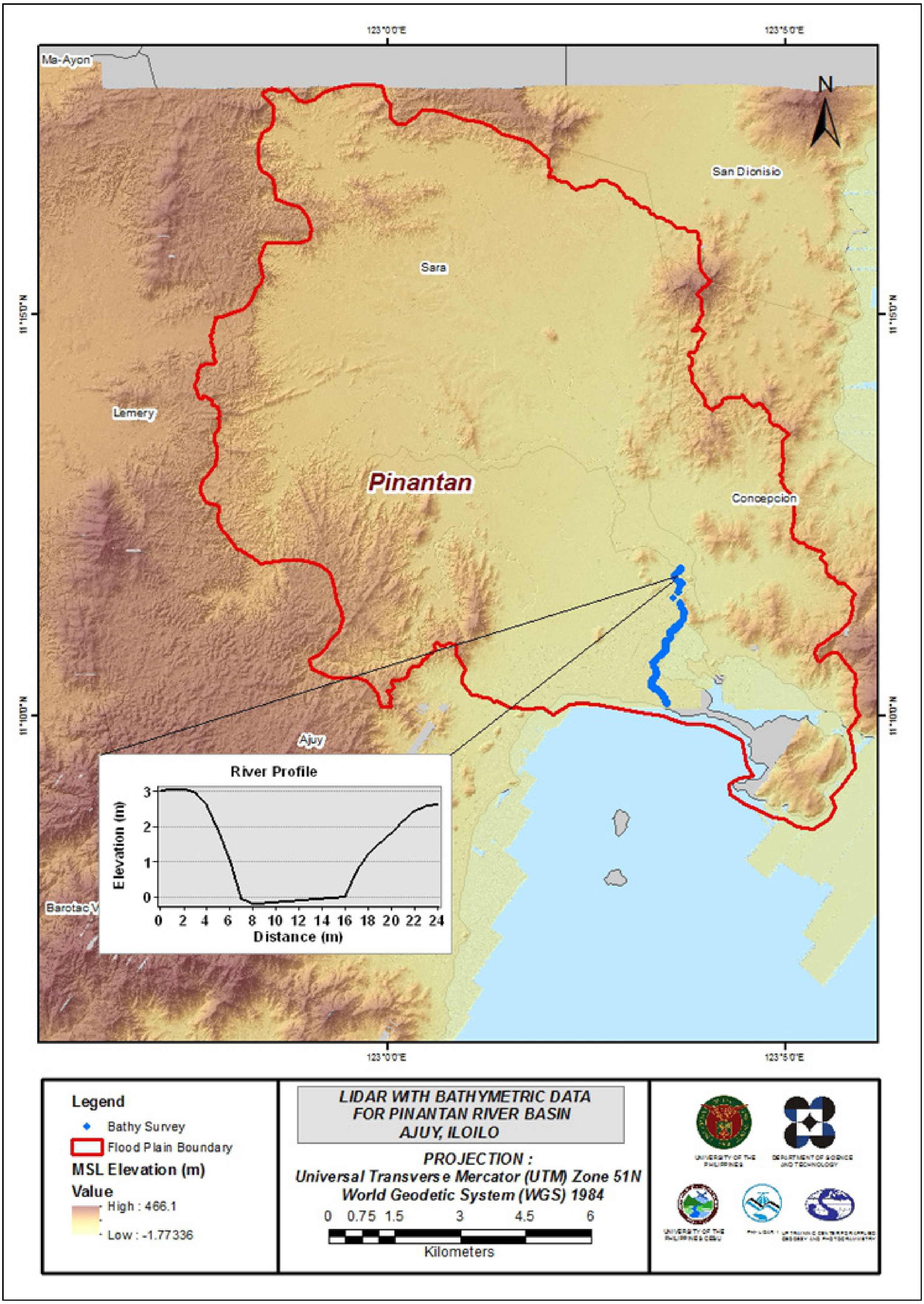

Figure 31. Map of Pinantan Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Pinantan floodplain, including its 200 m buffer, has a total area of 165.53 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 2135 building features, are considered for QC. Figure 32 shows the QC blocks for Pinantan floodplain.

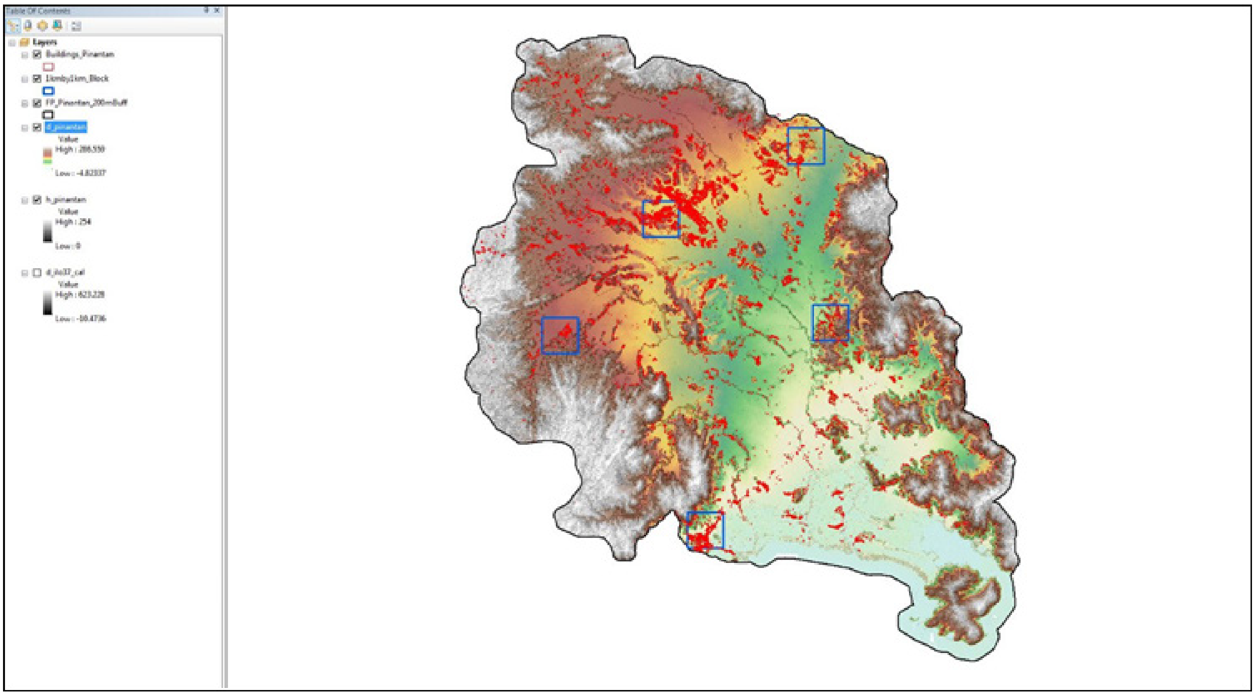

Figure 32. Blocks (in blue) of Pinantan building features that were subjected to QC

Quality checking of Pinantan building features resulted in the ratings shown in Table 22.

Table 22. Quality Checking Ratings for Pinantan Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Pinantan	99.63	99.95	95.13	PASSED

3.12.2 Height Extraction

Height extraction was done for 17,223 building features in Pinantan floodplain. Of these building features, 241 was filtered out after height extraction, resulting to 16,982 buildings with height attributes. The lowest building height is at 2.0 m, while the highest building is at 8.37 m.

3.12.3 Feature Attribution

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

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

Table 23 summarizes the number of building features per type. On the other hand, Table 24 shows the total length of each road type, while Table 25 shows the number of water features extracted per type.

Table 23. Building Features Extracted for Pinantan Floodplain.

Facility Type	No. of Features
Residential	16220
School	335
Market	6
Agricultural/Agro-Industrial Facilities	39
Medical Institutions	48
Barangay Hall	44
Military Institution	4
Sports Center/Gymnasium/Covered Court	18
Telecommunication Facilities	3
Transport Terminal	2
Warehouse	4
Power Plant/Substation	9
NGO/CSO Offices	0
Police Station	8
Water Supply/Sewerage	3
Religious Institutions	95
Bank	3
Factory	2
Gas Station	4
Fire Station	0
Other Government Offices	35
Other Commercial Establishments	79
Total	**16,961**

Table 24. Number of Extracted Road Networks for Pinantan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Pinantan	263.85	0.63	12.89	40	0.09	317.46

Table 25. Number of Extracted Water Bodies for Pinantan Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	Others	
Pinantan	4	0	1	1	260	1	267

A total of 29 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 shows the Digital Surface Model (DSM) of Pinantan floodplain overlaid with its ground features.

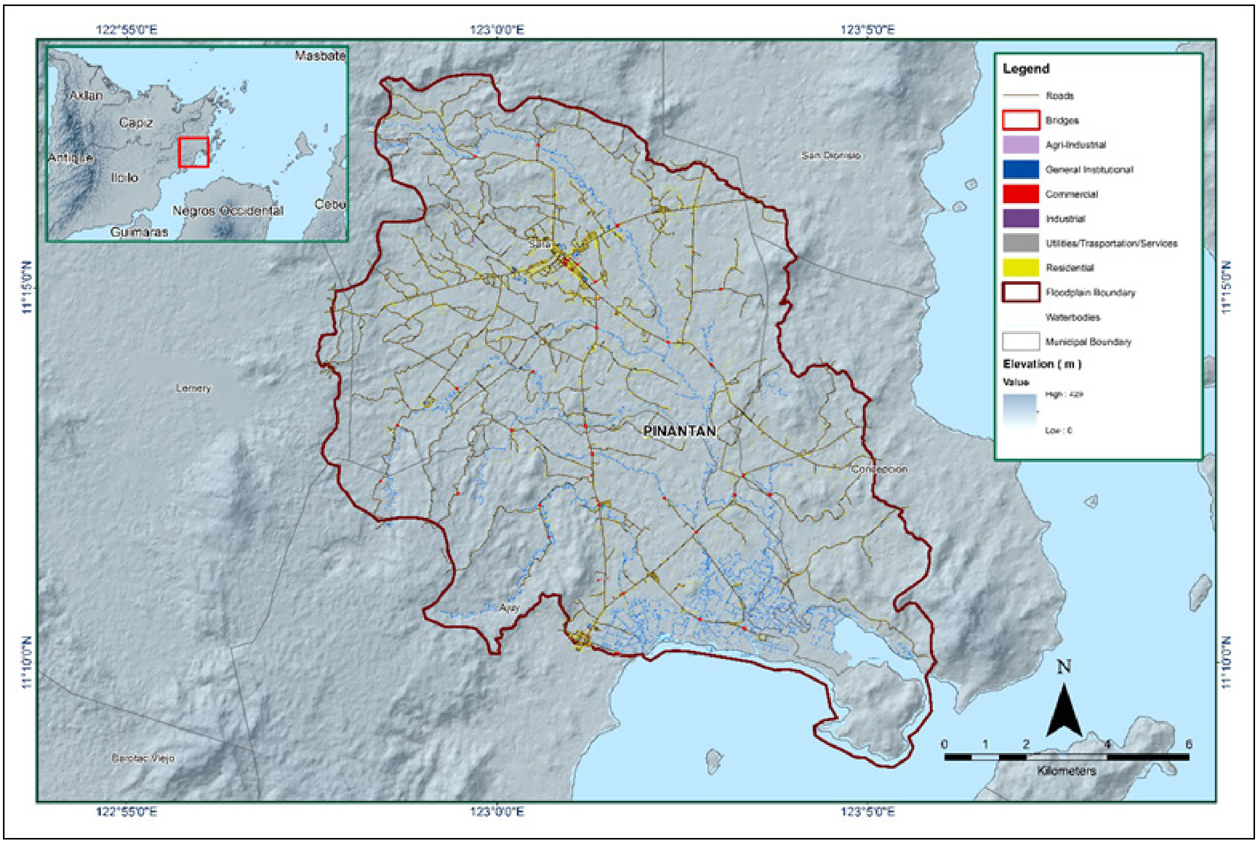

Figure 33. Extracted features for Pinantan Floodplain.

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Zerruco River on September 13-27, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey at Puente Bunglas Bridge in Brgy.Bakabak in the municipality of Sara, Iloilo; validation points acquisition of about 60 km covering the Zerruco River Basin area; and bathymetric survey from its upstream in Brgy. Brgy.Bakabak in the municipality of Sara to the mouth of the river located in Brgy. Bucana Bunglas, in the Municipality of Ajuy, with an approximate length of 5.615 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 34).

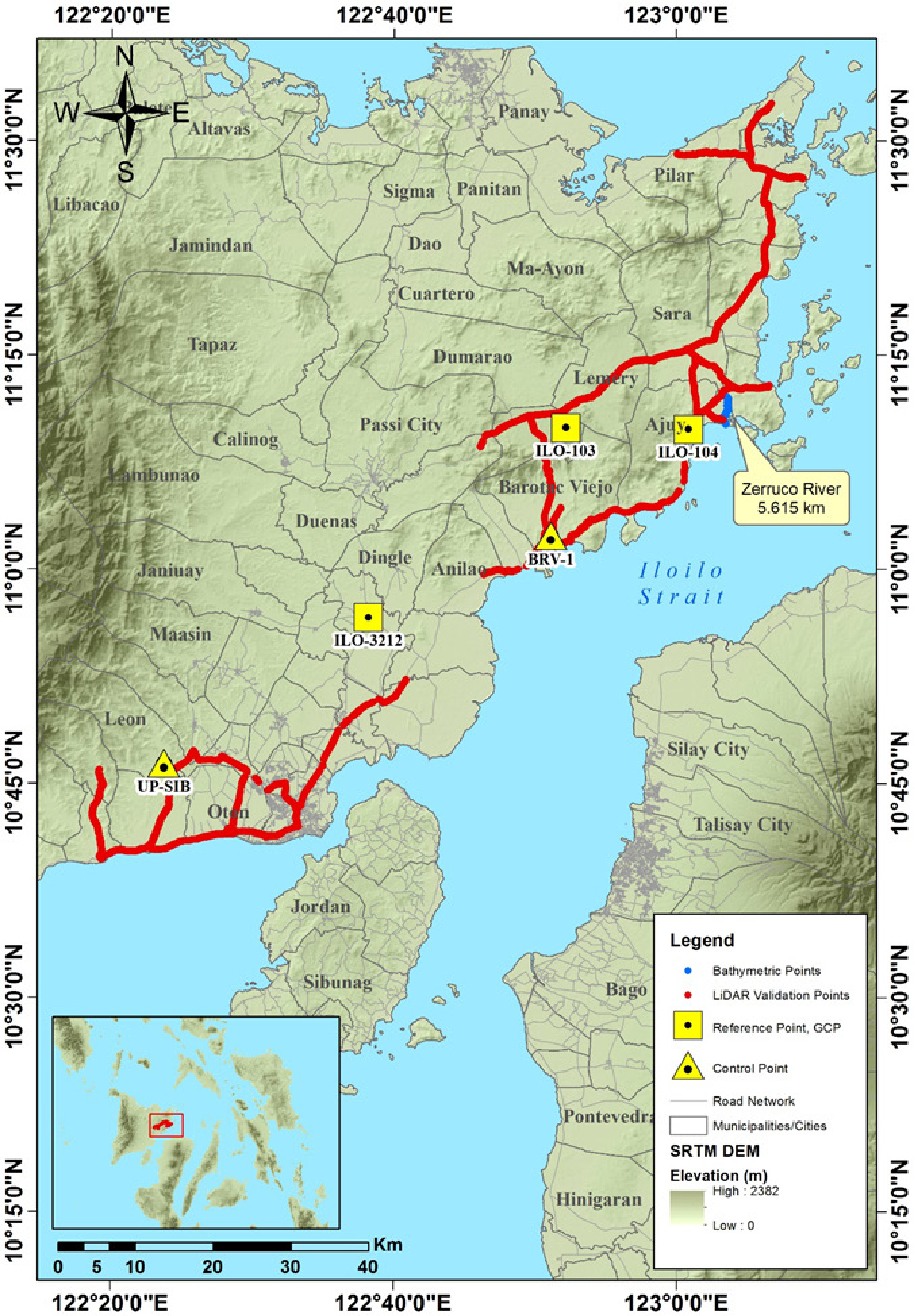


Figure 34. Extent of the bathymetric survey (in blue line) in Pinantan River and the LiDAR data validation survey (in red).

4.2 Control Survey

A GNSS baseline was established on July 22, 2014 occupying the control points ILO-1, a 2nd order GCP in Brgy. Magsaysay Village, Iloilo City; and on October 21, 2015 occupying ILO-66, a 2nd order GCP in Brgy. Dawis, Municipality of Dingle; and IL-391A, a 1st order Benchmark in Brgy. Tabuc-suba, Municipality of Barotac Nuevo; all in the Province of Iloilo as shown in Figure 35.

The GNSS network used for Pinantan River Basin is composed of four (4) loops established on September 14, 15, and 22, 2016 occupying the established control points: UP-SIB, with value fixed from the first survey on 2014 in Sibalom River, located in Brgy. Anonang, Municipality of Leon; and BRV-1., also with coordinates and elevation values from the first batch static in 2014, located in Brgy. Poblacion, Municipality of Barotac Viejo, all in Iloilo. NAMRIA established control points; ILO-103 in Brgy. San Dionisio, Municipality of San Rafael; ILO-104 in Brgy. San Antonio, Municipality of Ajuy; and ILO-3212 in Brgy. San Jose Ward, Municipality of Pototan; were also occupied and used as marker.

The summary of reference and control points and its location is summarized in Table 26 while the GNSS network established is illustrated in Figure 35 and Figure 36.

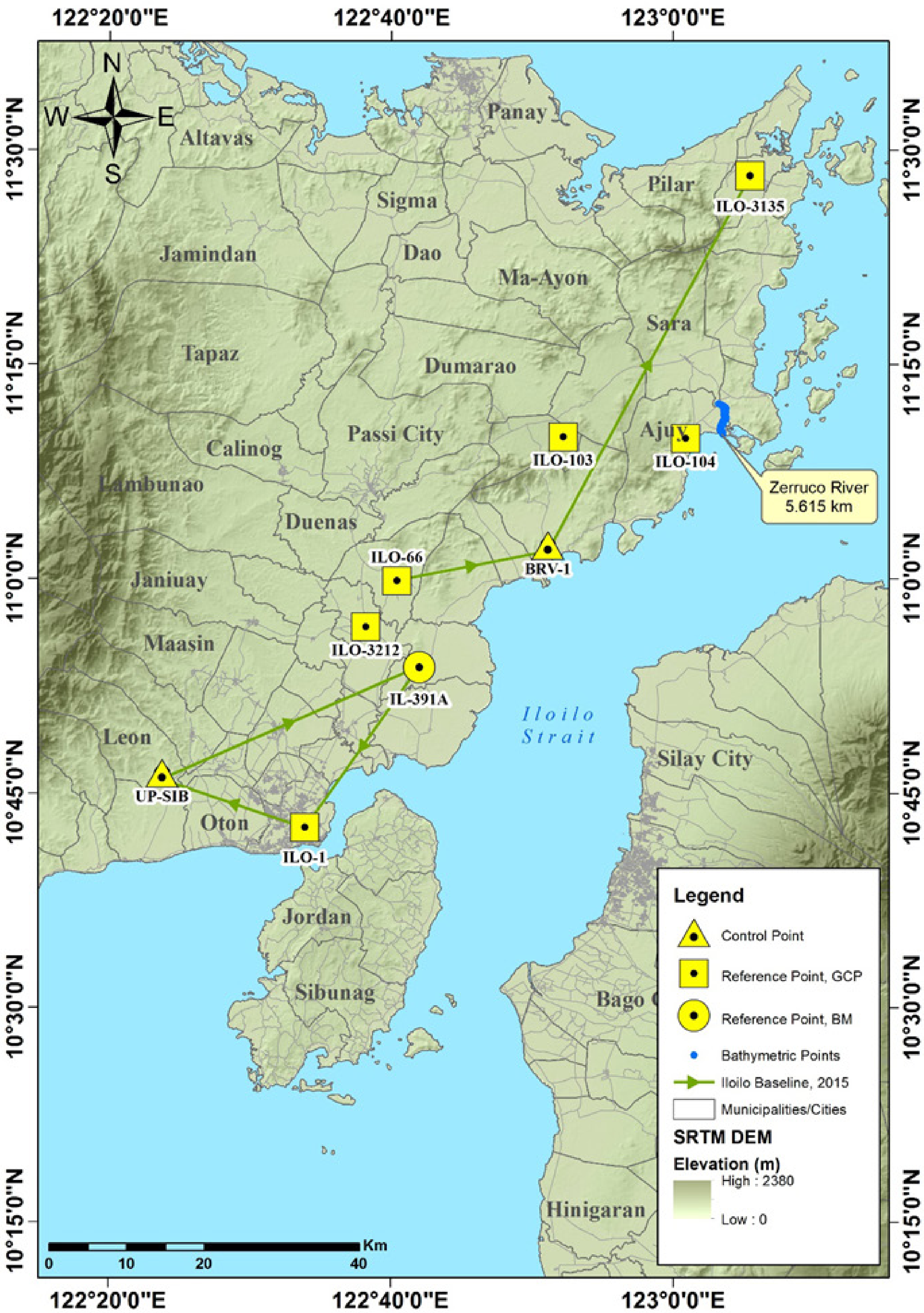


Figure 35. Pinantan RIver Basin 2015 Static Network

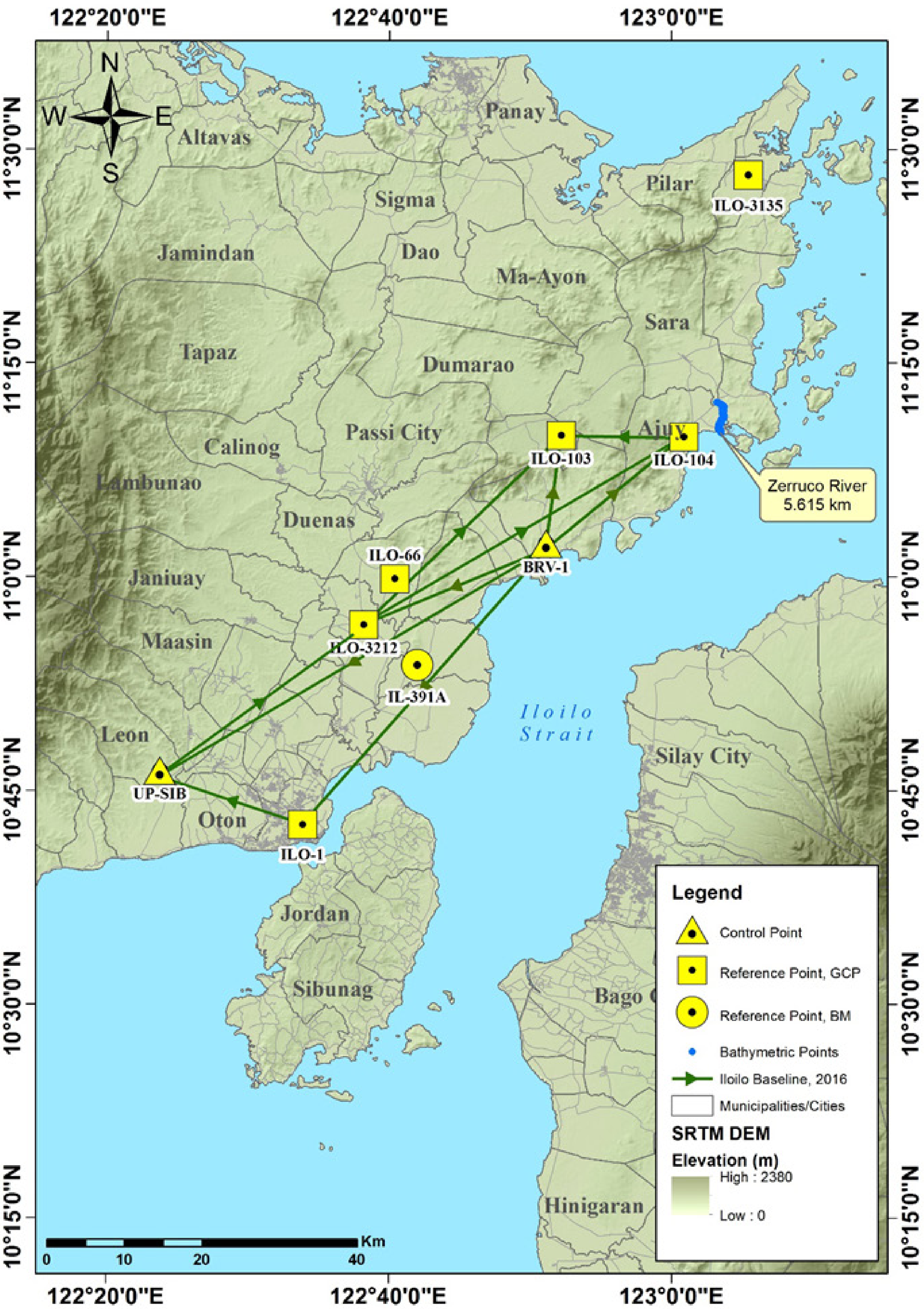


Figure 36. Pinantan River Basin 2016 Static Network

Table 26. List of Reference and Control Points occupied for Pinantan River Survey

(Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
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 Pinantan River are shown in Figure 37 to Figure 41.

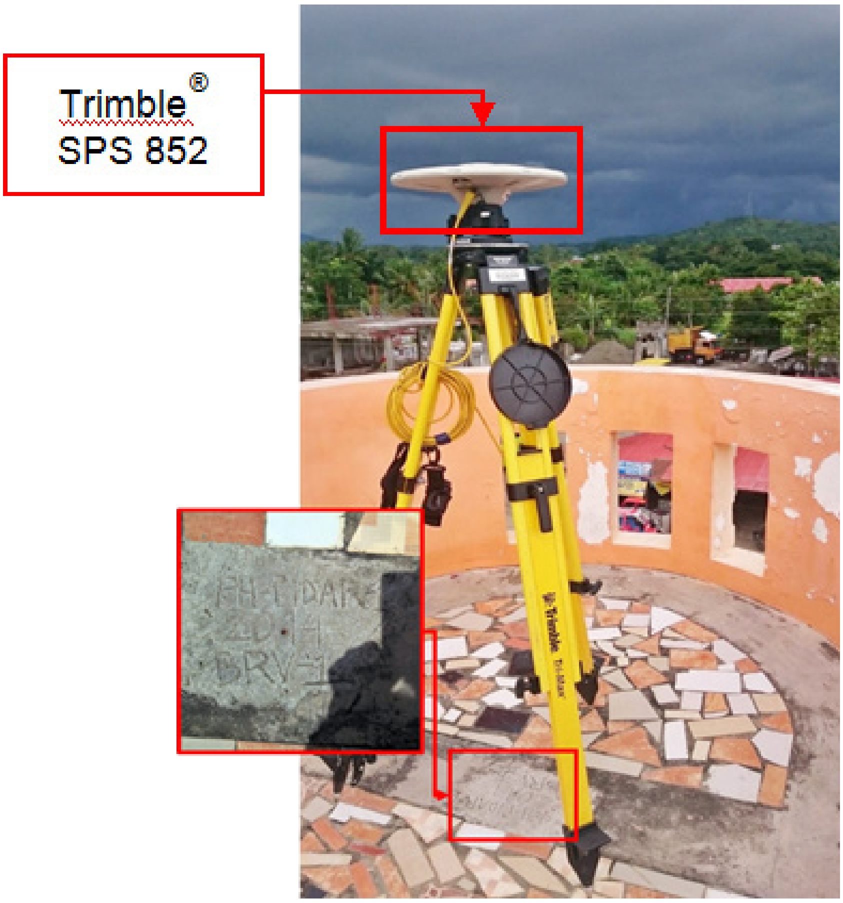


Figure 37. GNSS base set up, Trimble® SPS 852, at BRV-1, situated on top of Hollywood Star Inn in Brgy. Poblacion, Municipality of Barotac Viejo, Iloilo

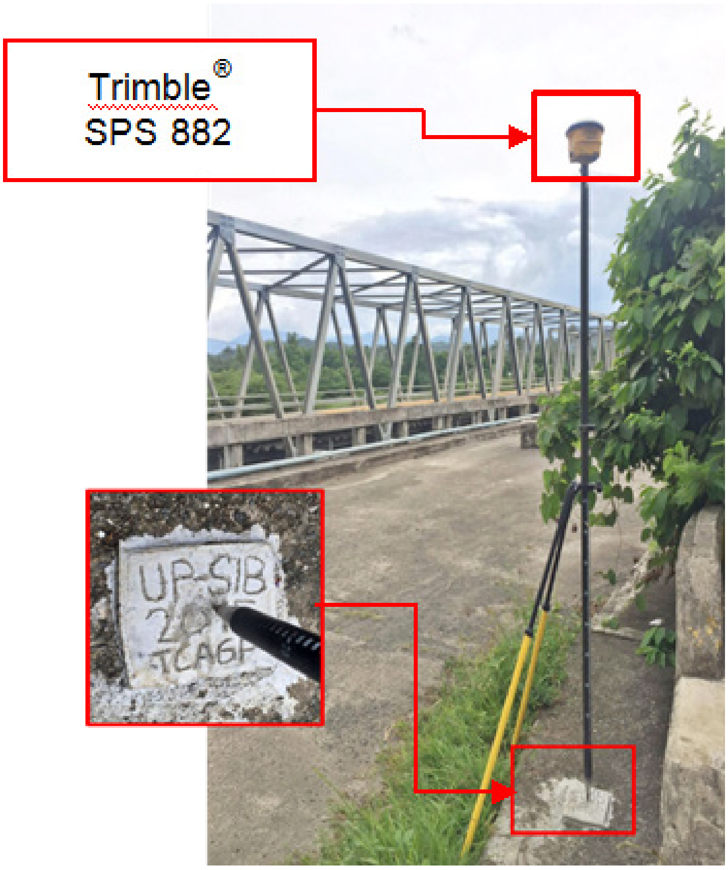


Figure 38. GNSS receiver setup, Trimble® SPS 985, at UP-SIB, located at the approach of Sibalom Bridge in Brgy. Anonang, Municipality of Leon, Iloilo

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

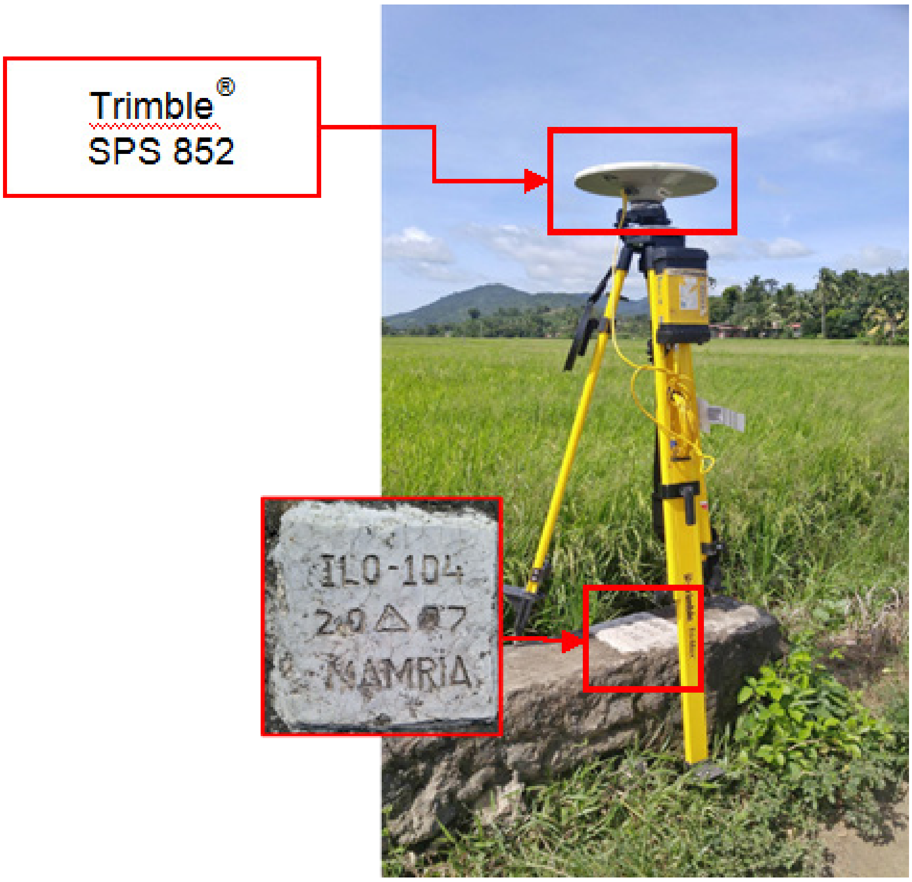


Figure 40. GNSS receiver setup, Trimble® SPS 852, at ILO-104, located along National Highway in Brgy. San Antonio, Municipality of Ajuy, Iloilo

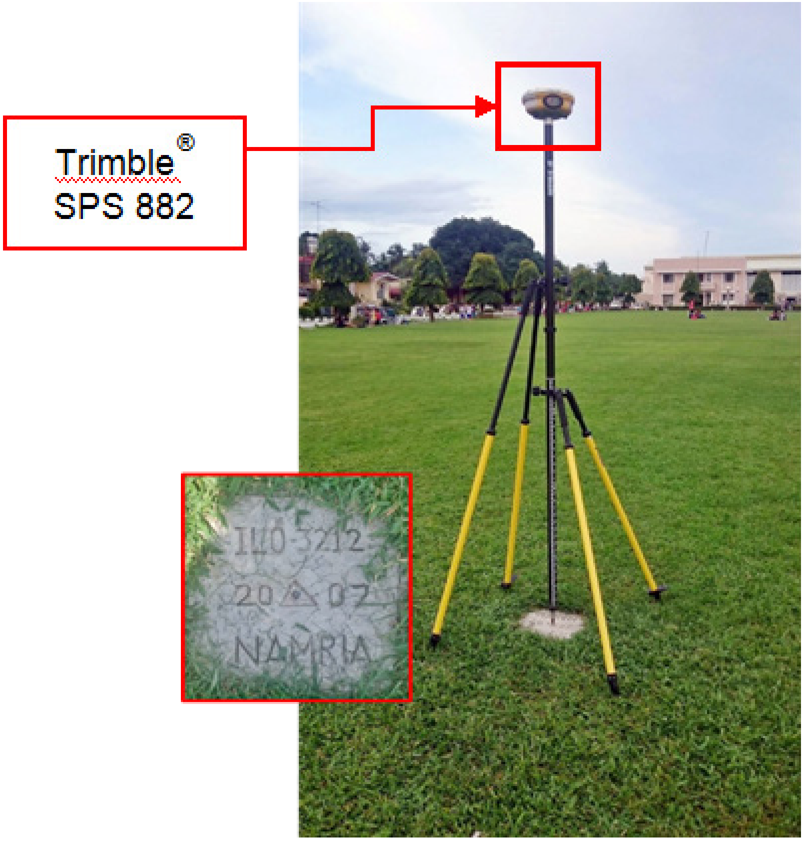


Figure 41. GNSS receiver setup, Trimble® SPS 882, at ILO-3212, located in Pototan Town Plaza in Brgy. San Jose Ward, Municipality of Pototan, Iloilo

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Pinantan River Basin is summarized in Table 27 generated by TBC software.

Table 27. Baseline Processing Summary Report for Pinantan 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

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

4.4 Network Adjustment

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

<20cm and

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. Coordinates and elevation values derived from previous field survey of BRV-1 and UP-SIB; 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 will be computed.

Table 28. Constraints applied to the adjustment 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 have no values for grid and elevation errors.

Table 29. Adjusted grid coordinates for the control points used in the Pinantan River 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, for horizontal and for the vertical; the computation for the accuracy 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 cm < 20 cm
vertical accuracy = 9.9 cm < 10 cm

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

Table 30. Adjusted geodetic coordinates for control points used in the Pinantan 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 result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 31.

Table 31. The reference and control points utilized in the Pinantan 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	10d59'51.74412"	122d40'23.87665"	84.815	1215745.274	464309.479	25.655
ILO-1	2nd order, GCP	10d42'36.46758"	122d33'53.59289"	83.433	1183962.237	452420.308	24.339
IL-391A	1st order, BM	10d53'48.05498"	122d41'59.84121"	71.433	1204571.776	467210.527	12.159
Control Survey on September 14, 15 and 22, 2016							
BRV-1	UP Established	11d02'19.32911"	122d51'07.28940"	73.739	1220262.792	483836.72	14.337
UP-SIB	UP Established	10d46'22.07205"	122d23'46.02739"	112.338	1190922.799	433978.538	55.148
ILO-103	Used as marker	11d09'55.15088"	122d52'11.28672"	207.134	1234262.136	485784.629	147.708
ILO-104	Used as marker	11d09'48.87918"	123d00'52.10858"	68.437	1234066.416	501580.383	8.346
ILO-3212	Used as marker	10d56'37.22766"	122d38'12.48445"	82.417	1209775.371	460315.009	24.148
UP-PAM	UP Established	18°27'29.74599"	121°20'15.06060"	47.728	2041693.715	324445.546	9.580

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

Cross-section and as-built survey were conducted on September 18, 2016 at the downstream side of Puente-Bunglas Bridge in Brgy. Bakabak, Municipality of Sara, Iloilo as shown in Figure 42. A survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique was utilized for this survey as shown in Figure 43.

Figure 42. Puente-Bunglas Bridge facing downstream

Figure 43. As-built survey of Puente-Bunglas Bridge

The cross-sectional line of Puente-Bunglas Bridge is about 124 m with sixty (60) cross-sectional points using the control point ILO-104 as the GNSS base station. The cross-section diagram and the bridge data form are shown in Figure 45 and Figure 46.

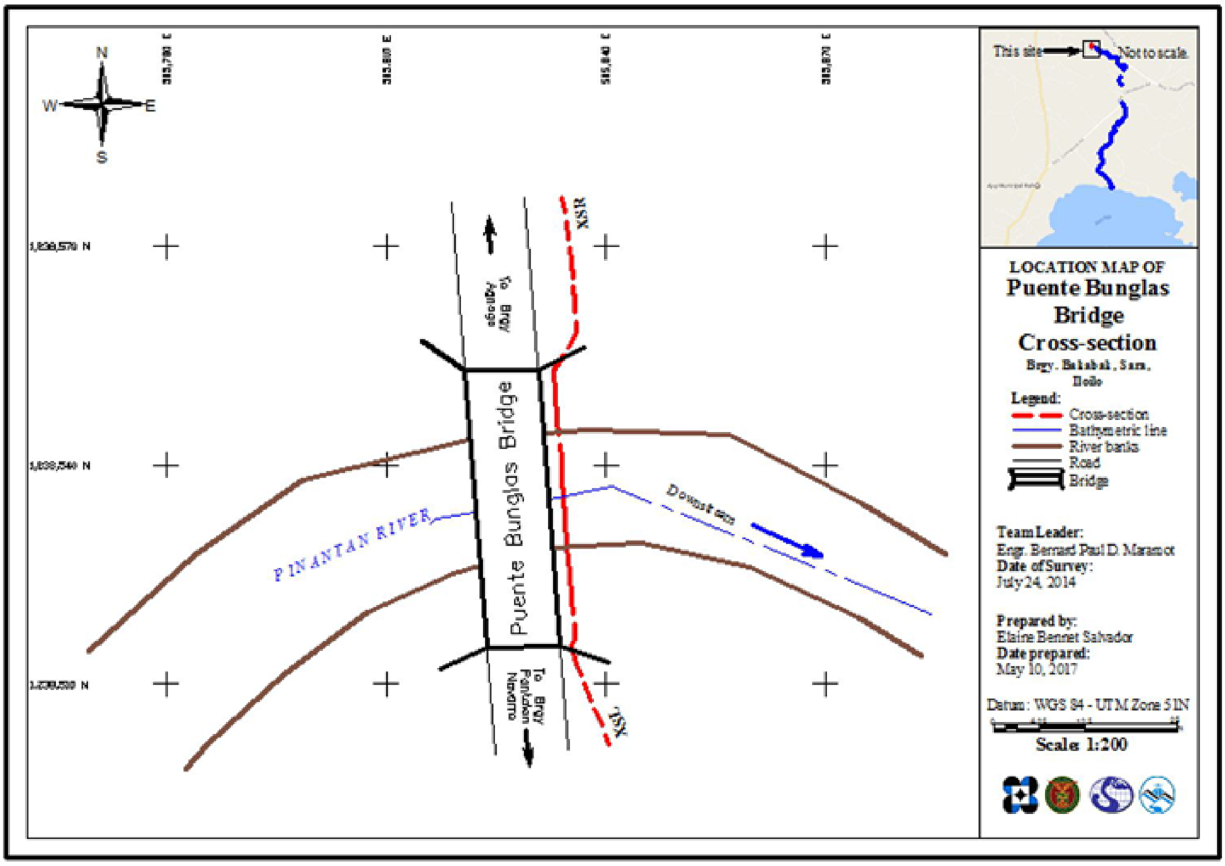


Figure 44. Puente Bunglas Bridge cross-section location map

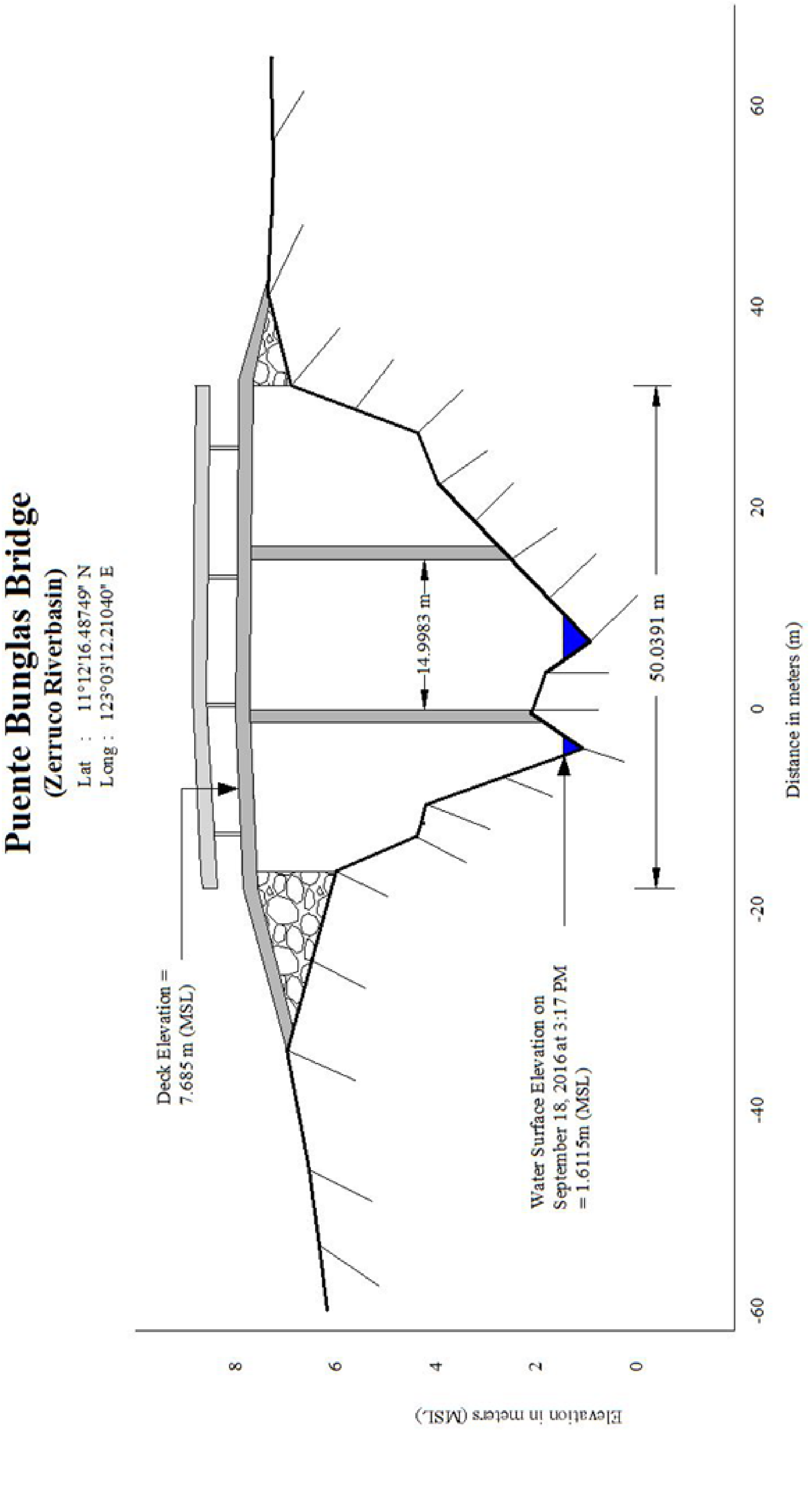


Figure 45. Puente-Bunglas Bridge cross-section diagram

Bridge Data Form

Bridge Name: **Puente Bunglas Bridge** **Date:** **September 18, 2016**

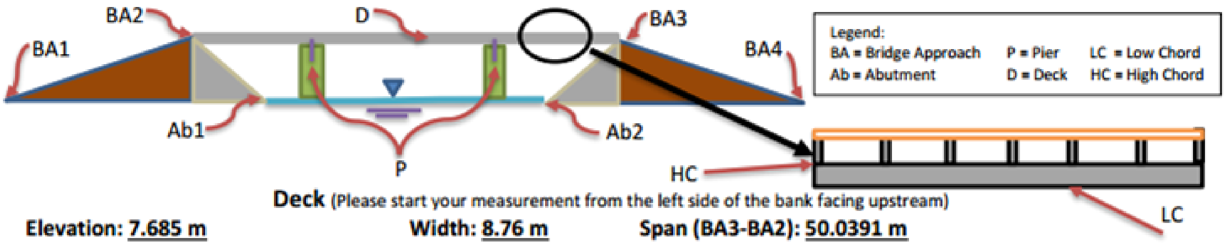
River Name: **Zerruco River** **Time:** **3:17 PM**

Location (Brgy, City,Region): **Brgy. Bakabak, Municipality of Sara, Iloilo**

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

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

Latitude: **11°12'16.48749" N** **Longitude:** **123°03'12.21040" E**



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

Elevation: **7.685 m** **Width:** **8.76 m** **Span (BA3-BA2):** **50.0391 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	6.138 m	BA3	92.675 m	7.622 m
BA2	42.084 m	7.514 m	BA4	124.765 m	7.246 m

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

	Station (Distance from BA1)	Elevation
Ab1	43.792 m	5.961 m
Ab2	92.141 m	6.850 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	59.825 m	7.685 m	1 m
Pier 2	74.823 m	7.657 m	1 m

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

Figure 46. Bridge as-built form of Puente-Bunglas Bridge

Water surface elevation of Pinantan River was determined a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on September 18, 2016 at 3:17 PM with a value of 1.612 m in MSL as shown in Figure 45. This was translated into marking on the bridge's deck using the same technique as shown in Figure 47. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HE responsible for Pinantan River, the University of the Philippines Cebu.

Figure 47. Water-level markings on Puente-Bunglas Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 11-15, 17-19, 2015 and September 19 and 20, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on the roof of a vehicle as shown 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 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with BRV-1 and UP-SIB occupied as GNSS base stations in the conduct of the survey.

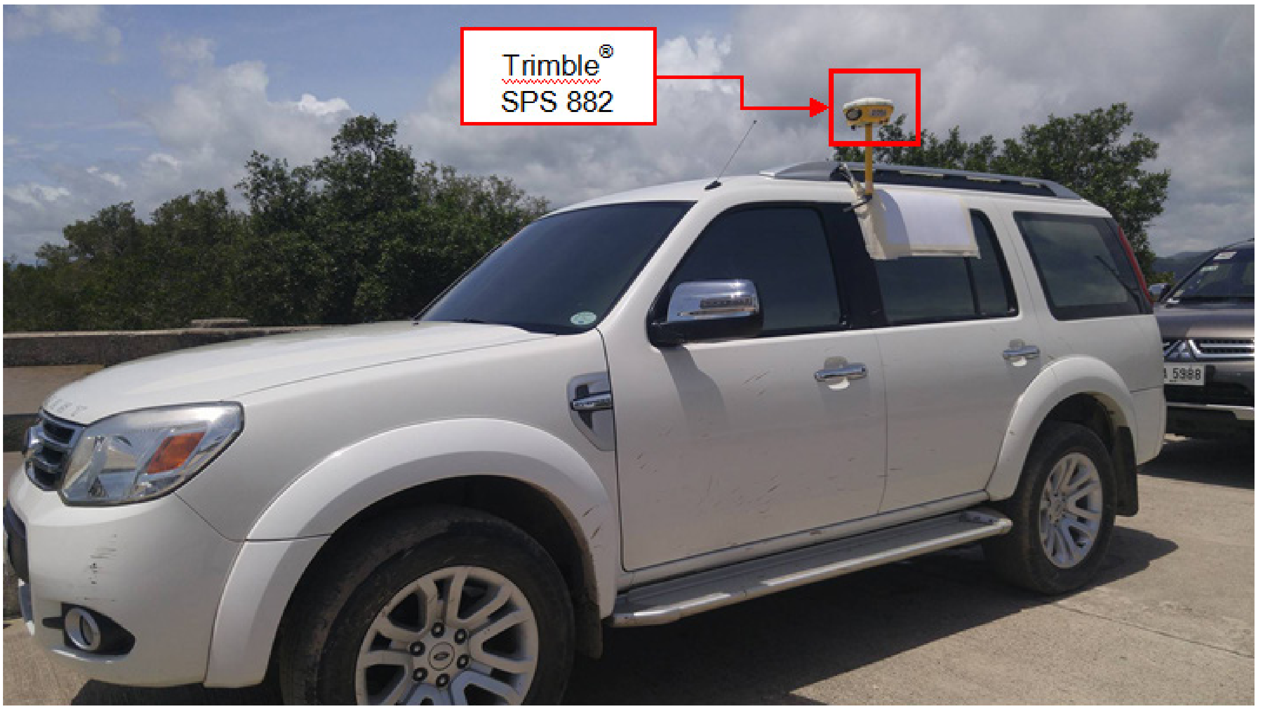


Figure 48. Validation points acquisition survey set up along Pinantan River Basin

The survey started from Sibalom Bridge in Brgy. Anonang, Municipality of Leon; going southwest covering the Municipalities of Guimbal, Miagao, Tigbauan and Tubungan; going southeast covering the Municipalities of Alimodian, Leganes, Oton, Pavia, San Miguel, Santa Barbara and Iloilo City; and going north traversing the Municipalities of Ajuy, Anilao, Balasan, Banate, Barotac Nuevo, Barotac Vieo, Batad, Carles, Dumangas, Estancia, San Dionisio, Sara and Zarraga in Iloilo, and ended in Municipality of Pilar in Capiz. The survey gathered a total of 57,919 points with approximate length of 226 km using BRV-1, UP-SIB and ILO-3135 as GNSS base stations for the entire extent validation points acquisition survey as illustrated in the map in Figure 49.

Figure 49. Validation point acquisition survey of Pinantan River basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on September 16, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as illustrated in Figure 50. The survey started in Brgy. Bucana Bunglas, Municipality of Ajuy, with coordinates 11°11'23.91649"N, 123°03'40.51510"E, and ended at the mouth of the river in the same barangay with coordinates 11°10'08.19807"N, 123°03'30.91204"E.

Figure 50. Manual Bathymetric survey using a Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode in Pinantan River

Figure 51. Manual Bathymetric survey using a Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode in Pinantan River

The bathymetric survey for Pinantan River gathered a total of 5,319 points covering 5.615 km of the river traversing Barangays Bucana Bunglas, Pantalan Navarro, Puente Bunglas,and Rojas in Municipality of Ajuy; and Brgy. Bakabak in Municipality of Sara (Figure 52). A CAD drawing was also produced to illustrate the riverbed profile of Pinantan River. As shown in Figure 53, the highest and lowest elevation has a 59-m difference. The highest elevation observed was -1.039 m above MSL located in Brgy. Bakabak, Municipality of Sara, while the lowest was 2.994 m below MSL located in Brgy. Puente Bunglas, in Municipality of Ajuy. The survey was extended 1.5 km upstream to cover all the flood prone areas.

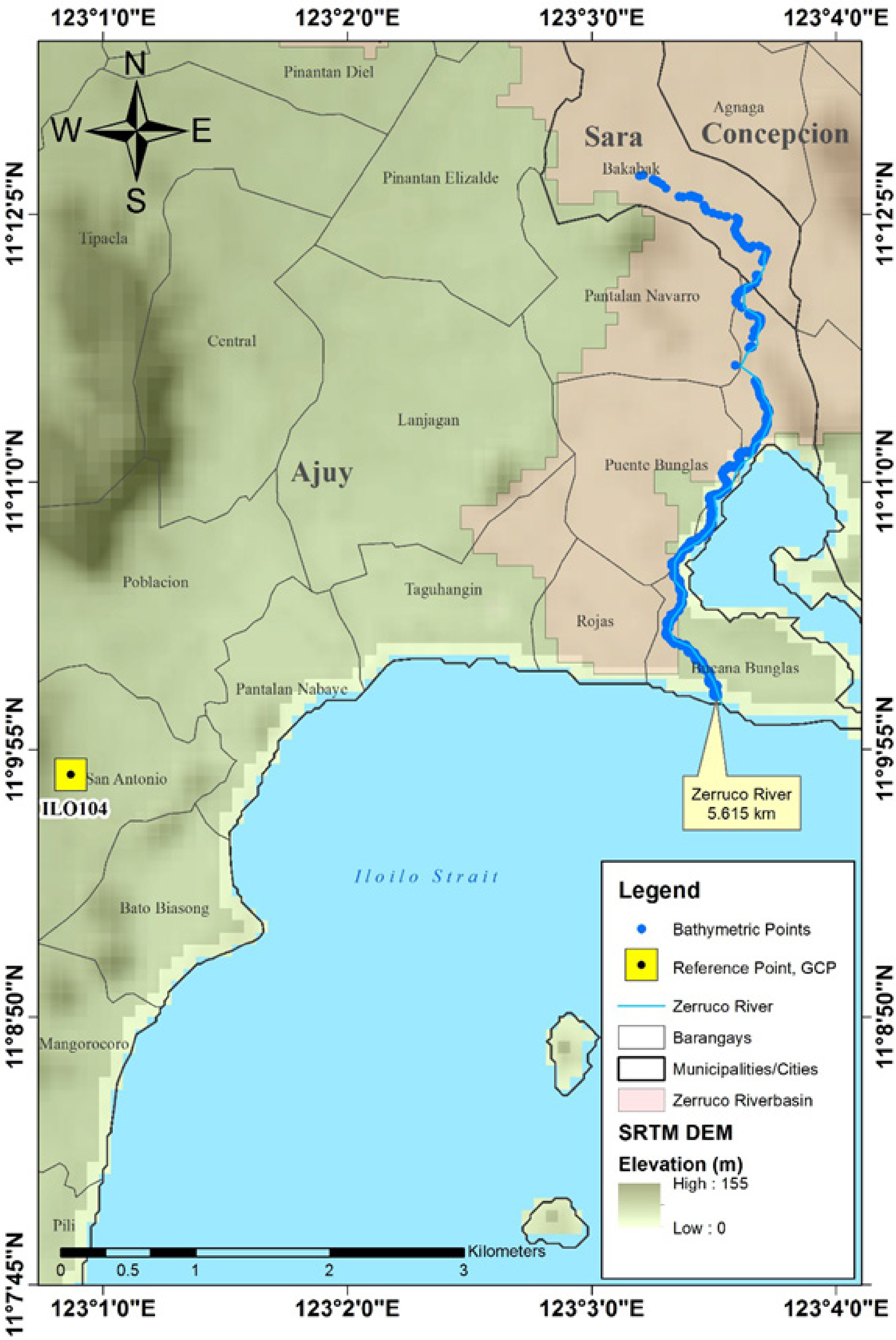


Figure 52. Extent of the Pinantan River Bathymetry Survey

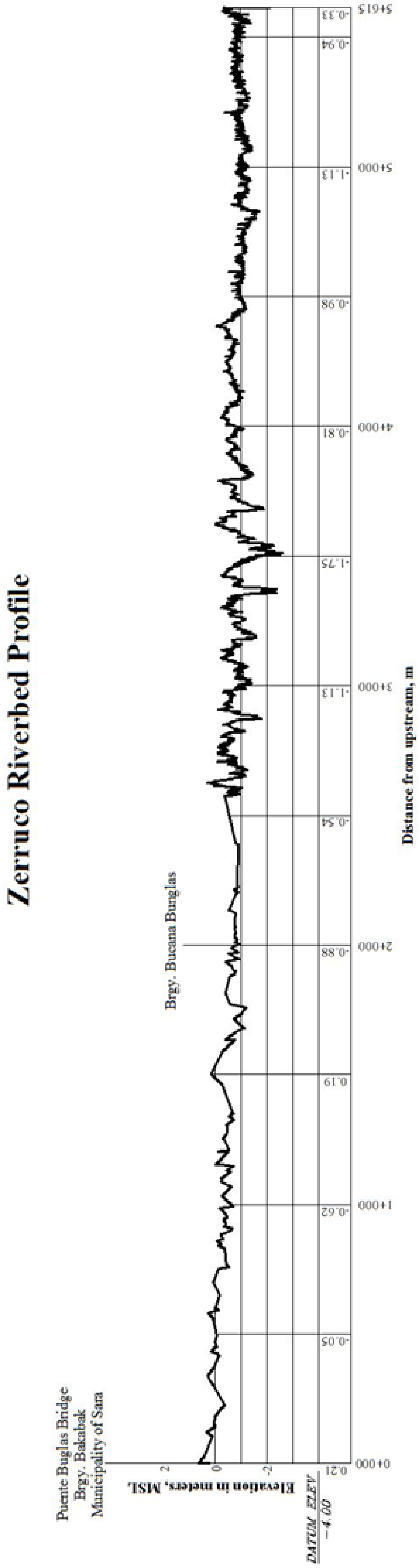


Figure 53. Pinantan riverbed profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

Alfredo Mahar Francisco A. Lagmay, Enrico C. Paringit, Dr. Eng., Christopher Noel L. Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil R. 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

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the UP Cebu Flood Modeling Component (FMC) team. The ARG was installed at Brgy. Pinantan Ghiel, Sagay City, Negros Occidental (Figure 54). The precipitation data collection started from April 16, 2017 at 3:55 AM to 5:55 with a recording interval of 5 minutes.

The total precipitation for this event in Brgy Pinantan Ghiel ARG was 37 mm, with a peak rainfall of 2.40 mm. on April 16, 2017 at 1:15 in the afternoon. The lag time between the peak rainfall and discharge is 1 hour and 5 minutes.

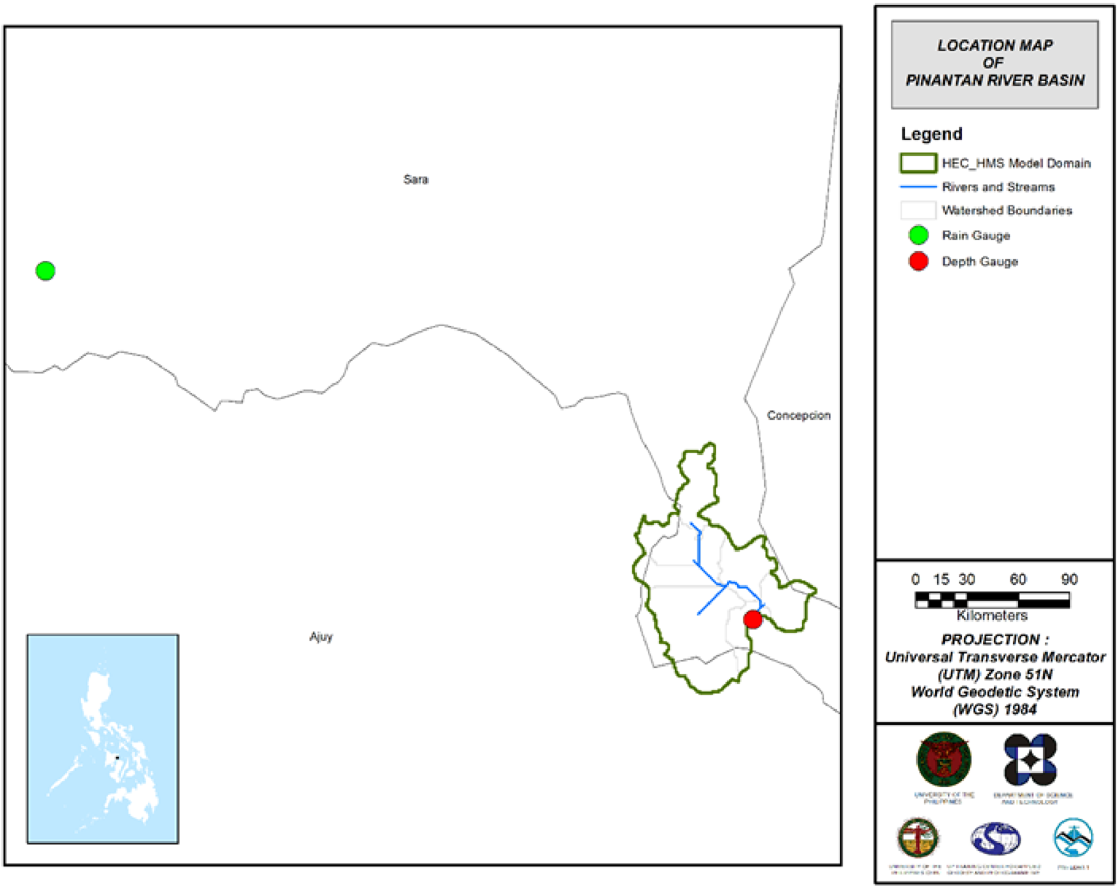


Figure 54. Location map of the Pinantan HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 55) at Puente Bunglas Bridge, Brgy Bakabak, Sara, Iloilo (11°12’13.79”N, 123° 3’12.55”E). It gives the relationship between the observed water levels at Puente Bunglas Bridge and outflow of the watershed at this location.

For Puente Bunglas Bridge, the rating curve is expressed as Q = 4.2201e1.328x [see y formula] as shown in Figure 56.

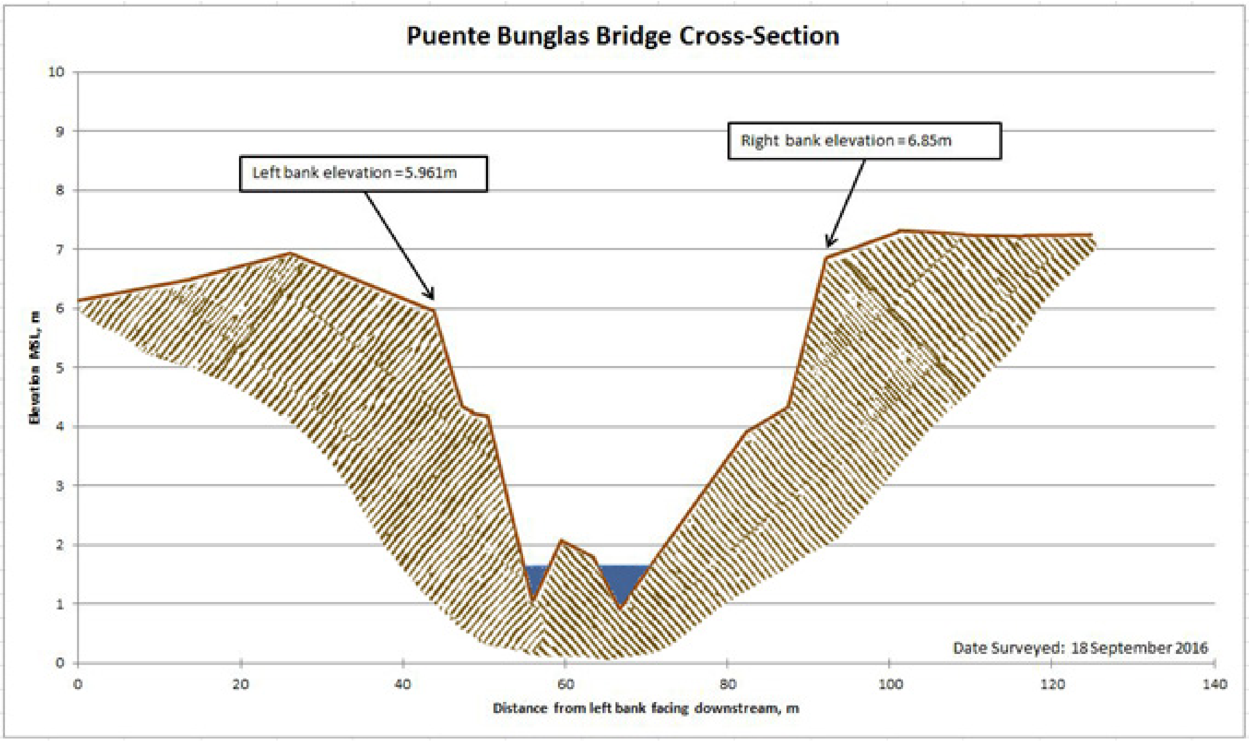


Figure 55. Cross-section plot of Puente-Bunglas Bridge

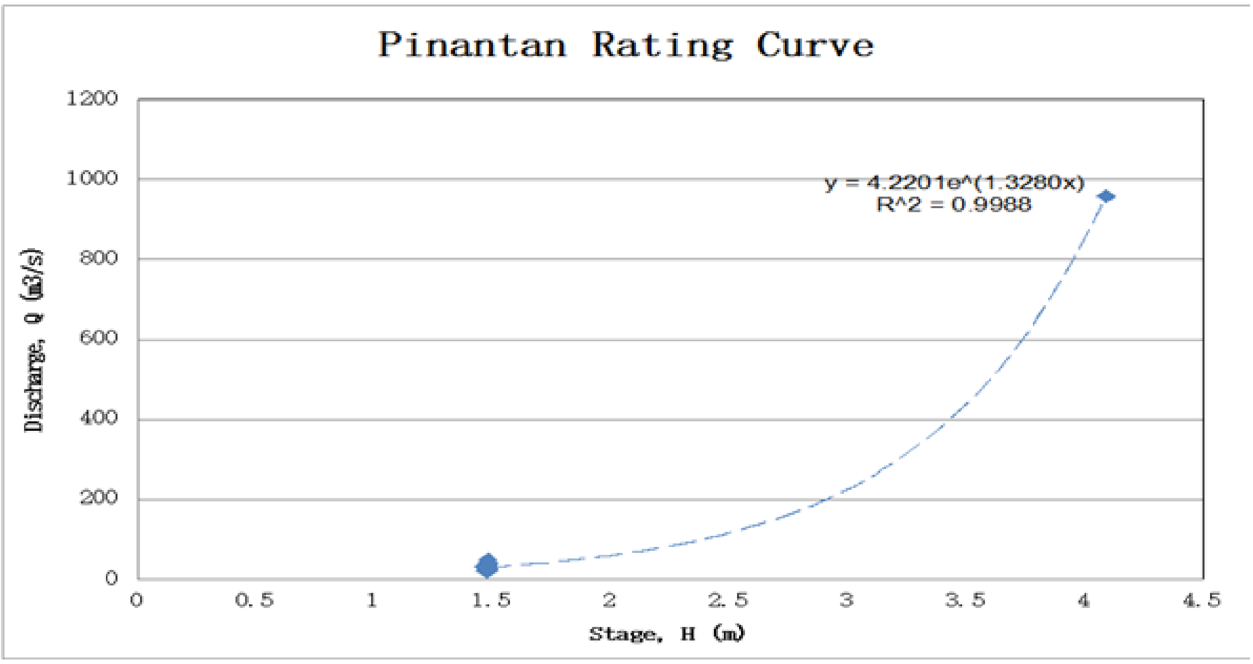


Figure 56. Rating curve at Puente Bunglas Bridge, Paraiso, Sagay City

This rating curve equation was used to compute the river outflow at Puente Bunglas Bridge for the calibration of the HEC-HMS model shown in Figure 4. The total rainfall for this event is 37mm and the peak discharge is 32.751m3 at 2:20 PM, April 16, 2017.

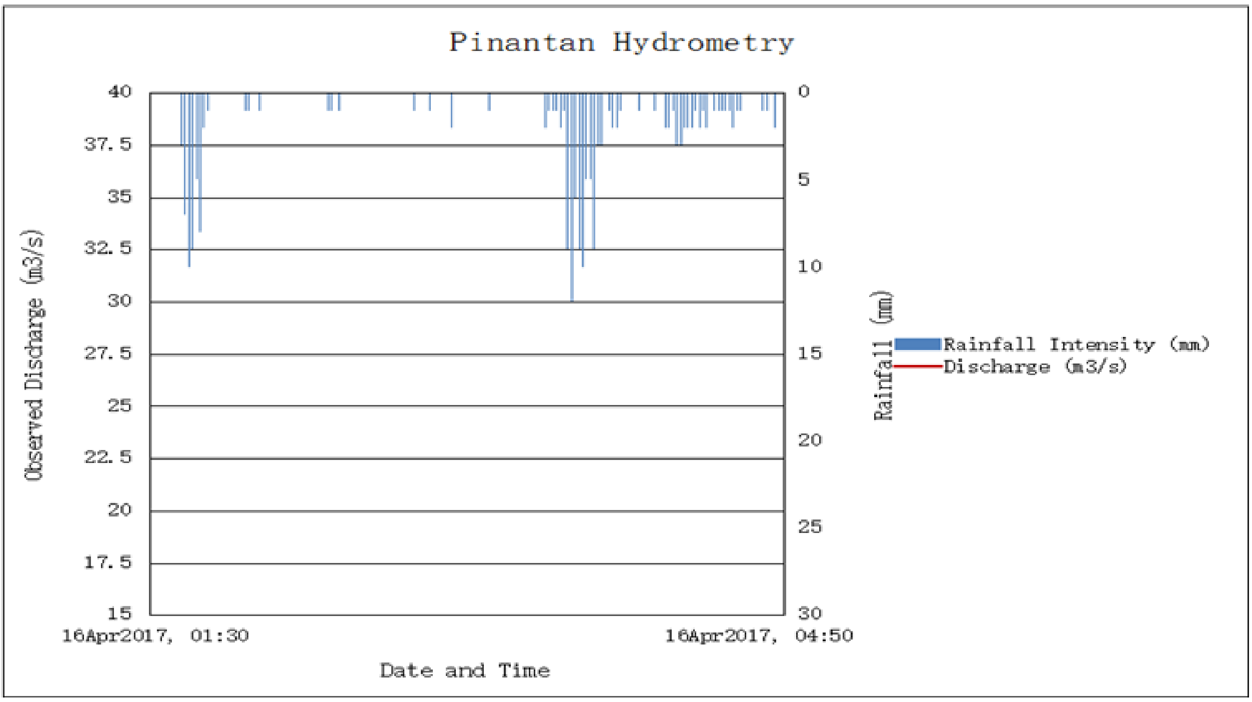


Figure 57. Rainflow and outflow data at Pinantan used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Roxas Rain Gauge (Table 32). The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time (Figure 59). This station chosen based on its proximity to the Pinantan watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 32. RIDF values for Roxas 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	26.6	40.5	51.3	72.1	98	115.5	142.8	165.9	186.2
10	31.3	47.8	60.7	86.2	118	139.4	172.3	200.1	224.6
25	37.4	57	72.5	104	143.1	169.6	209.7	243.4	273
50	41.8	63.8	81.3	117.2	161.8	192	237.4	275.4	308.9
100	46.2	70.5	90	130.2	180.3	214.2	264.9	307.2	344.6

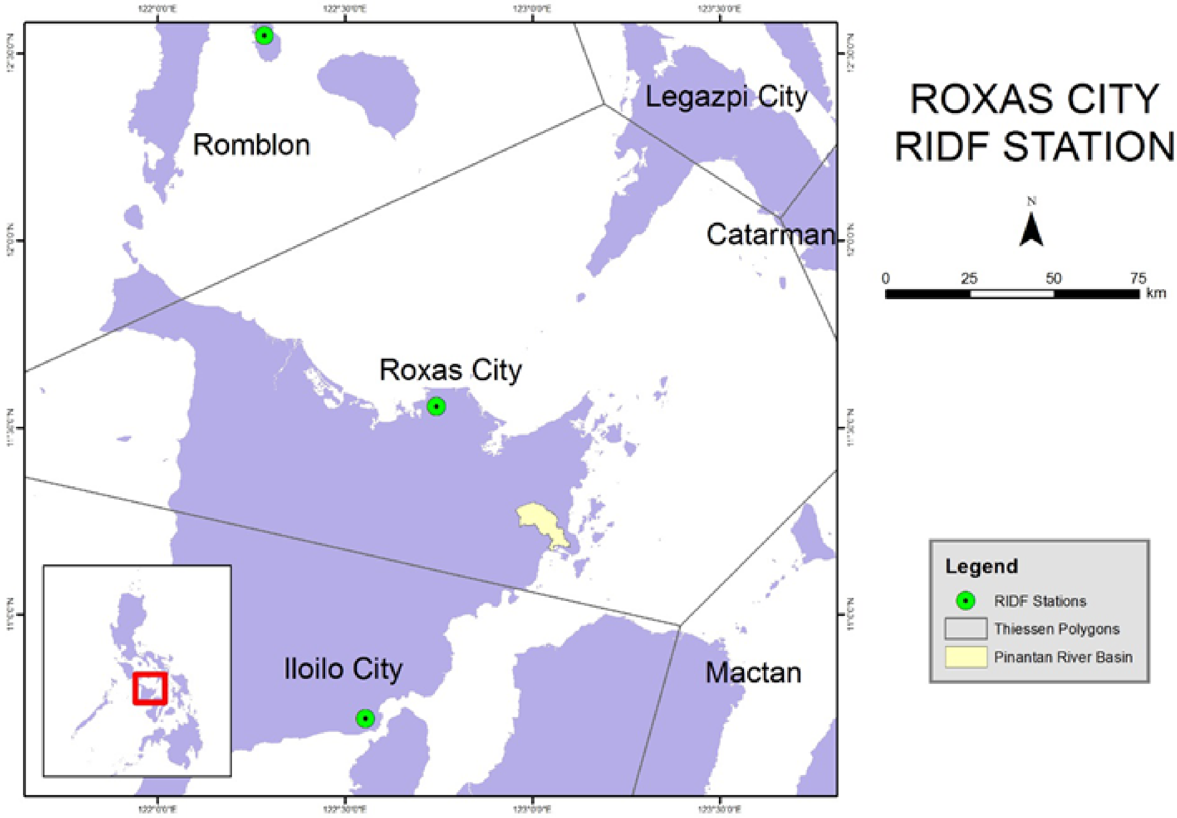


Figure 58. Location of Roxas RIDF Station relative to Pinantan River Basin

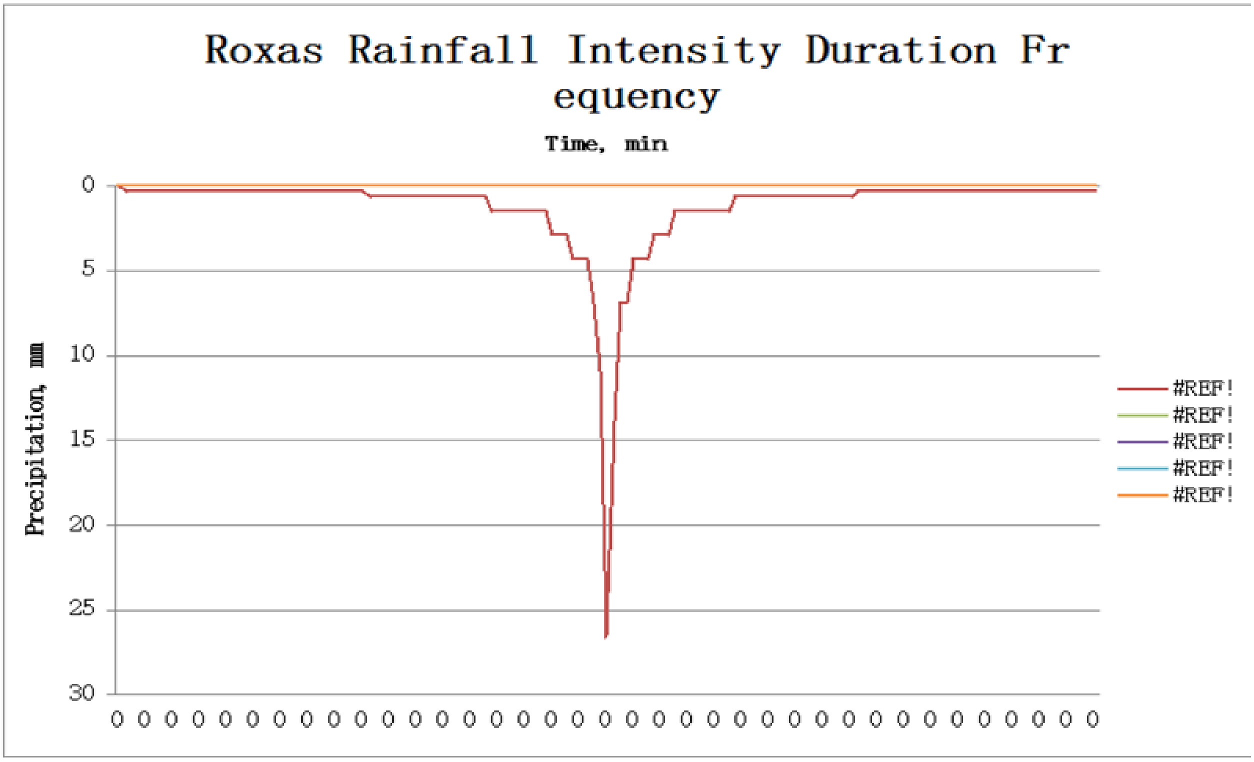


Figure 59. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was taken before 2004 from the Bureau of Soils under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Pinantan River Basin are shown in Figure 60 and Figure 61, respectively.

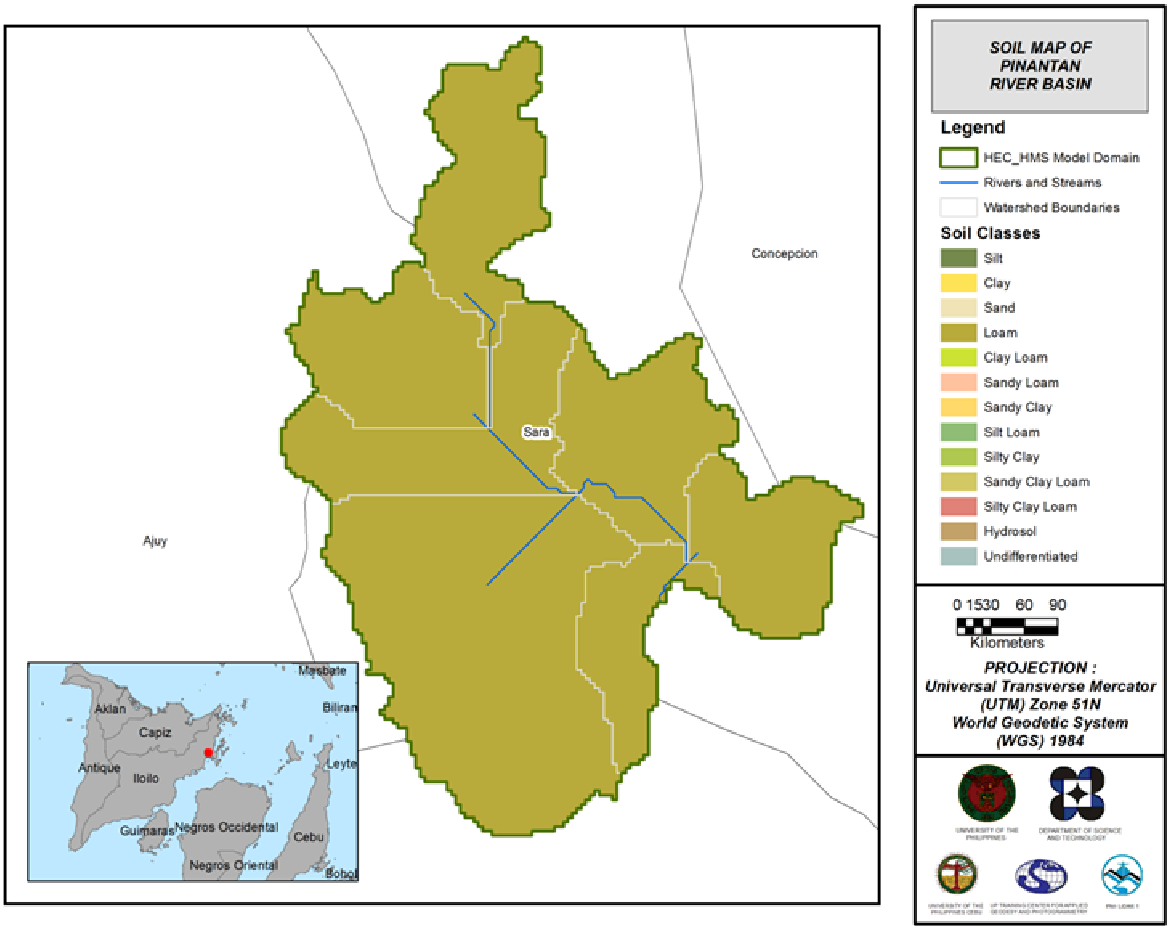


Figure 60. Soil Map of Pinantan River Basin

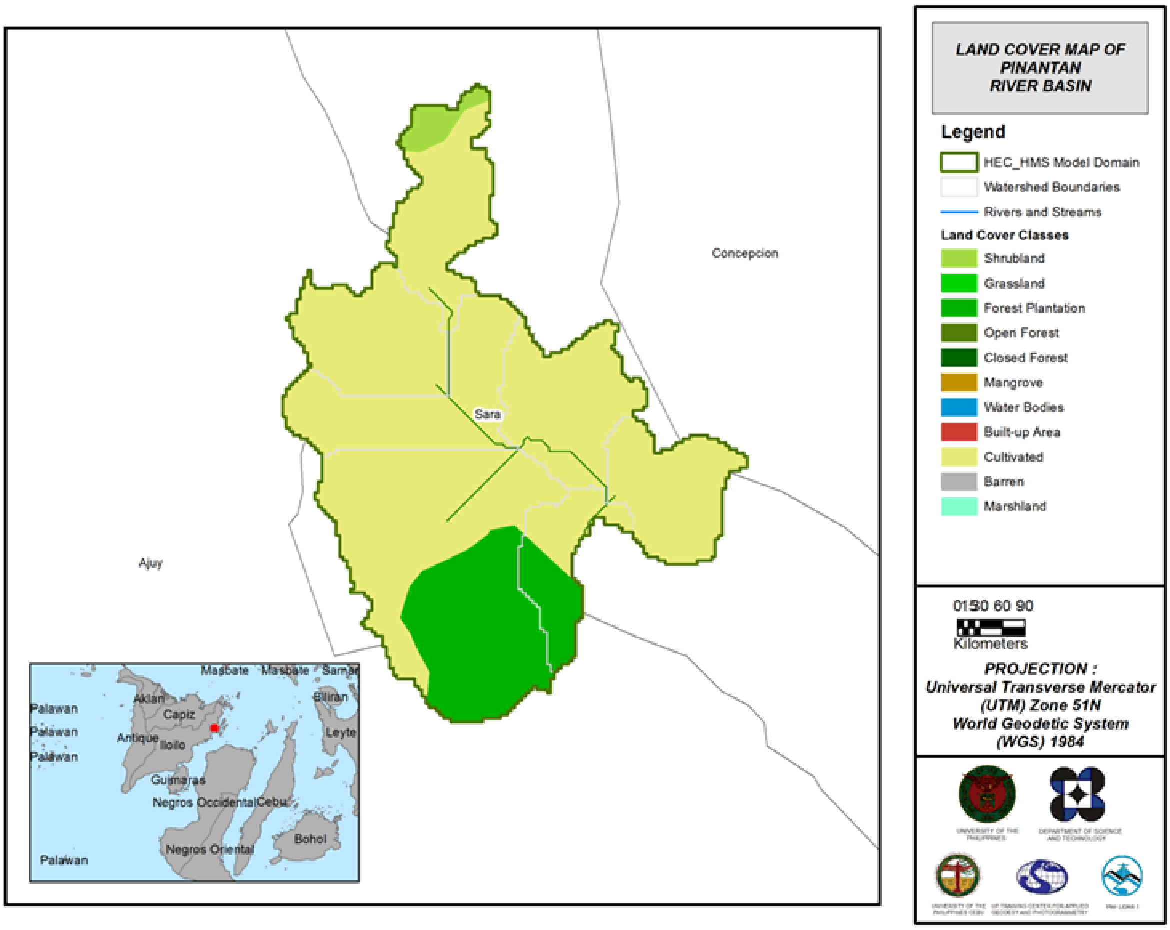


Figure 61. Land Cover Map of Pinantan River Basin (Source: NAMRIA)

For Pinantan, one soil class was identified. This is loam. Moreover, three land cover classes were identified. These are forest plantation, shrubland, and cultivated area.

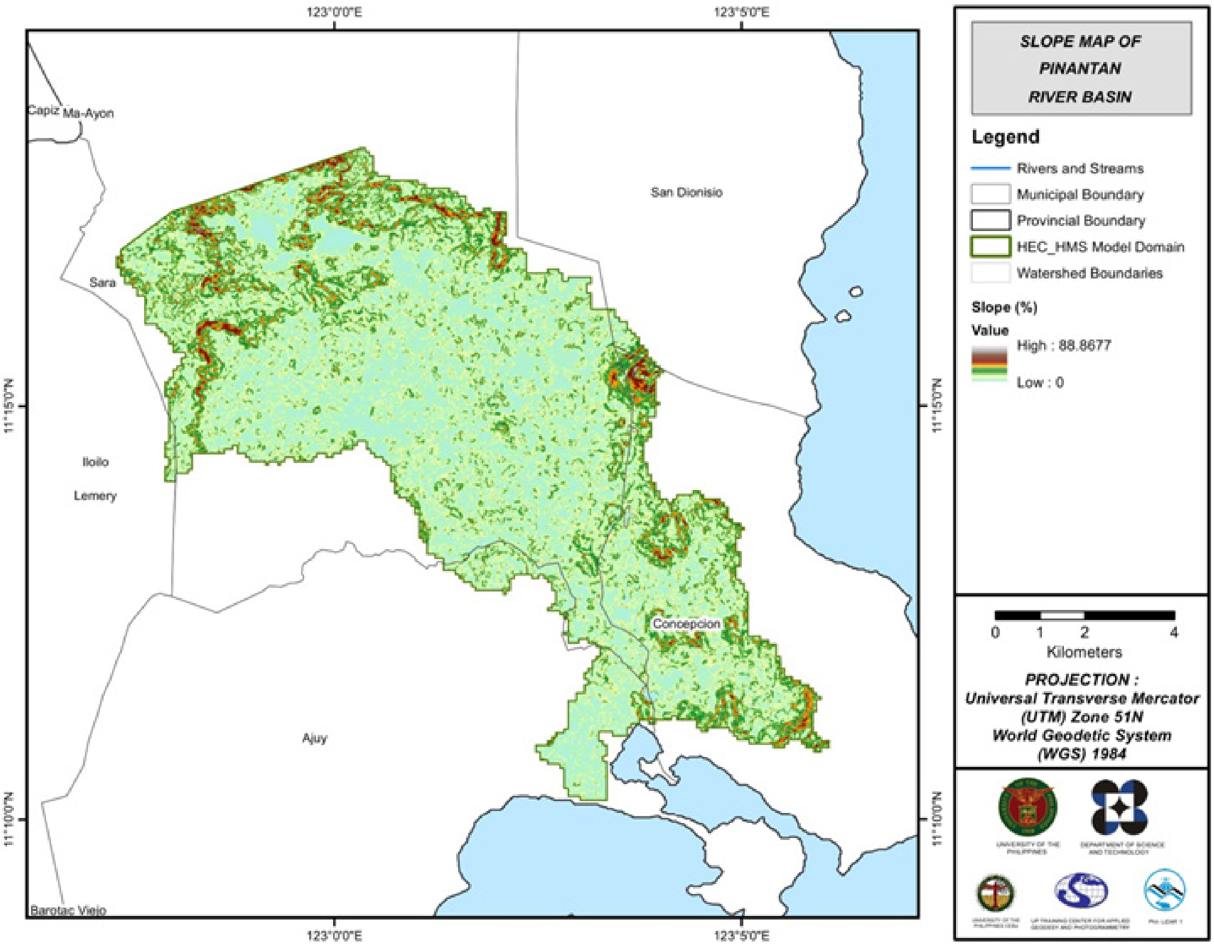


Figure 62. Slope Map of Pinantan River Basin

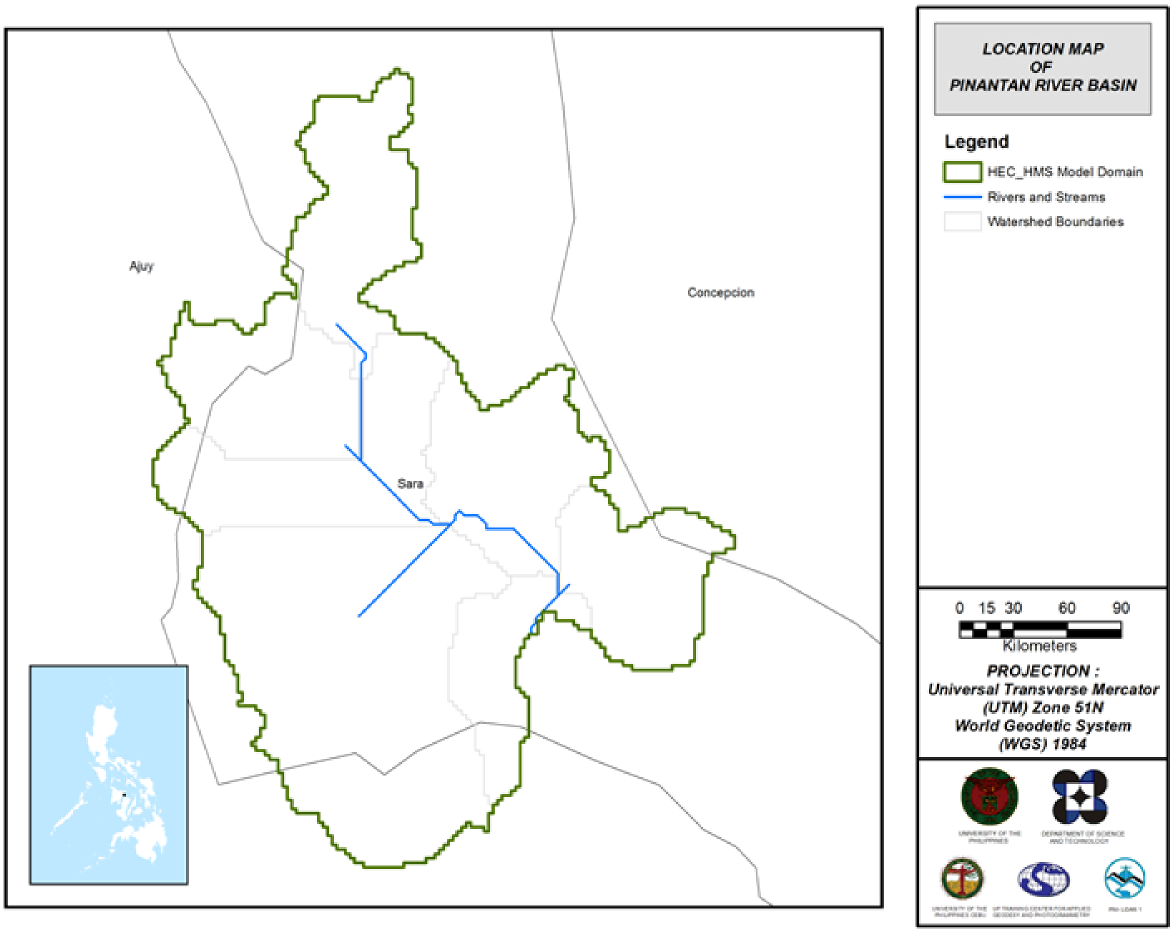


Figure 63. Stream Delineation Map of Pinantan River Basin

Using the SAR-based DEM, the Pinantan basin was delineated and further subdivided into subbasins. The model consists of 7 sub basins, 3 reaches, and 3 junctions as shown in Figure 64. The main outlet is at Puente Bunglas Bridge.

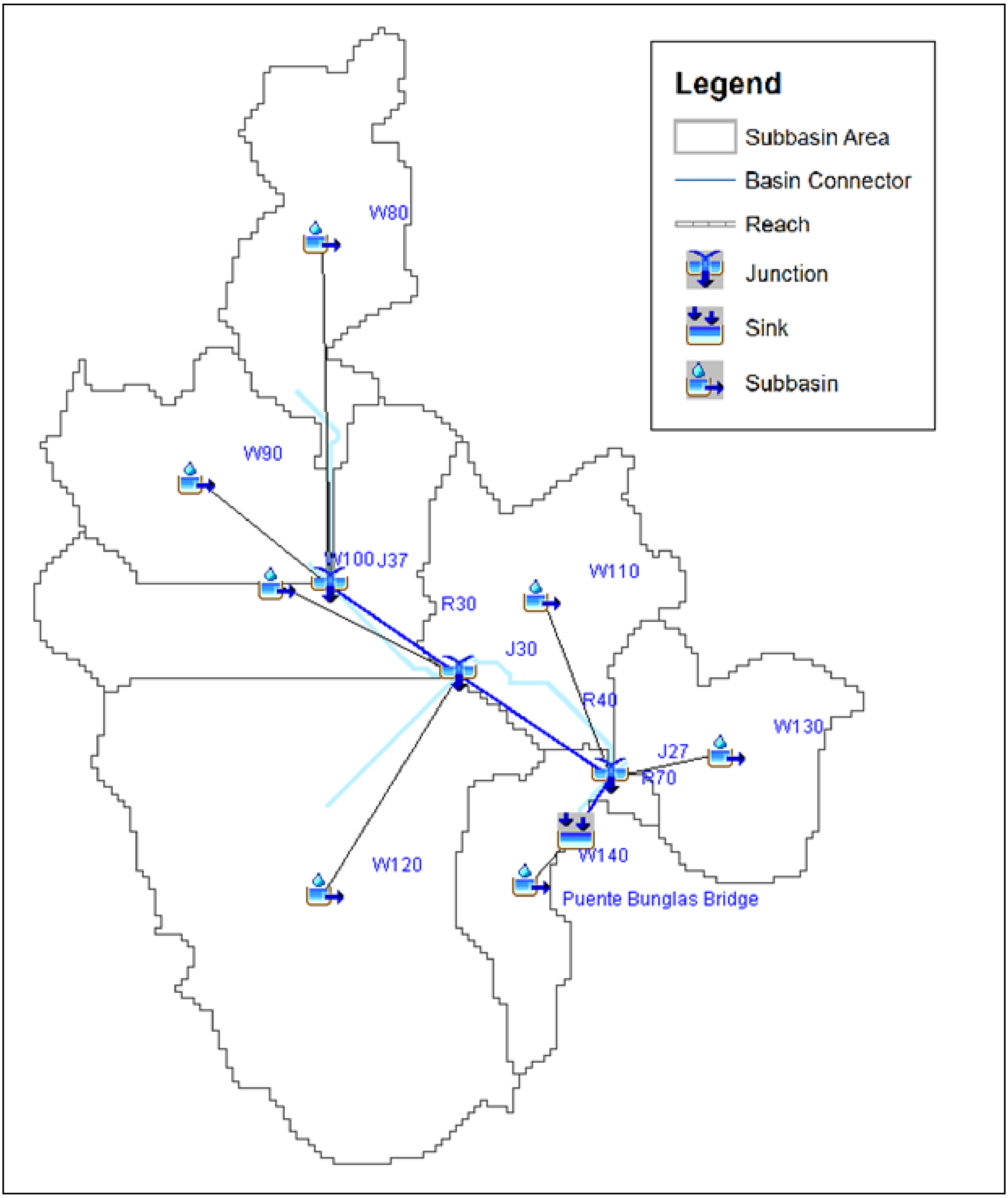


Figure 64. Pinantan River Basin model generated in HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed are crucial in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived using the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS. This is illustrated in Figure 65.

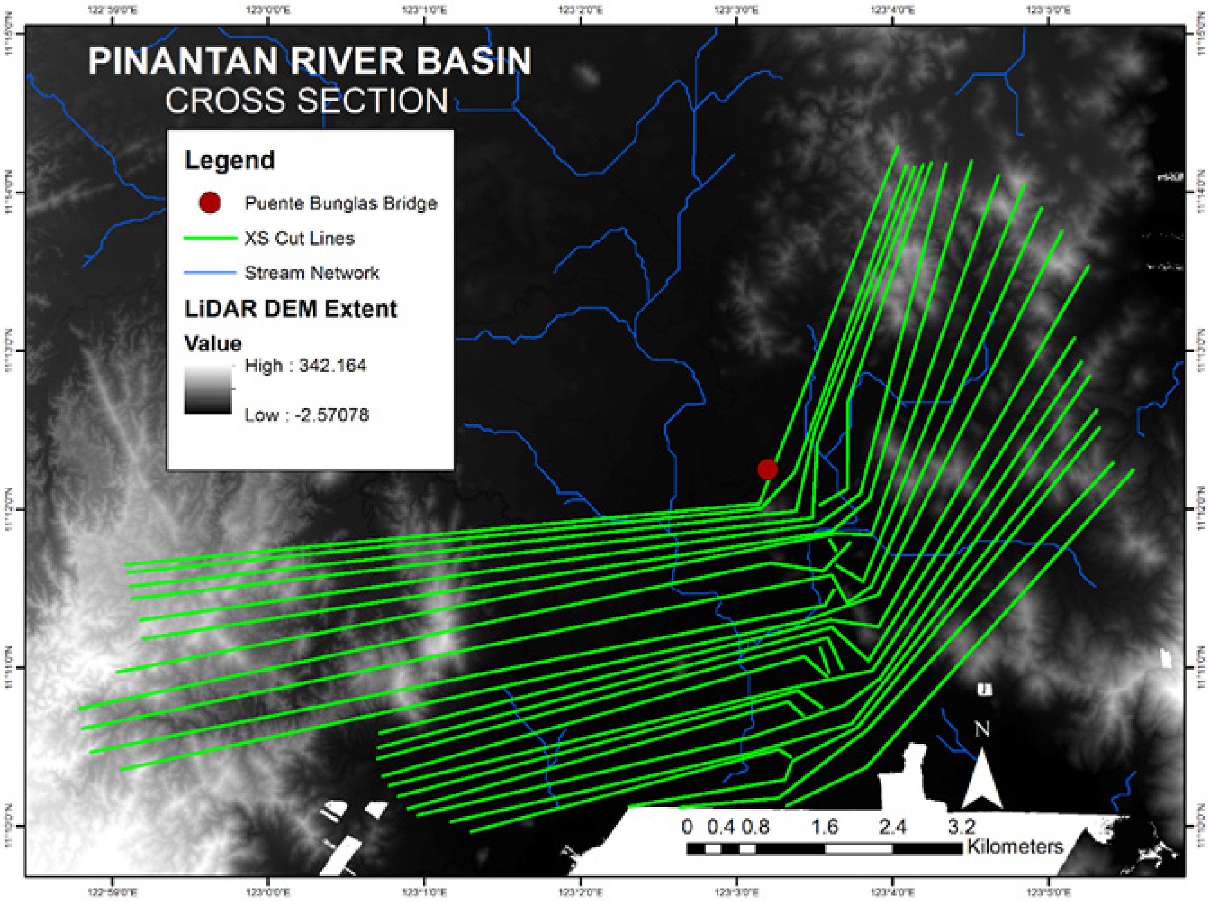


Figure 65. River cross-section of Pinantan River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

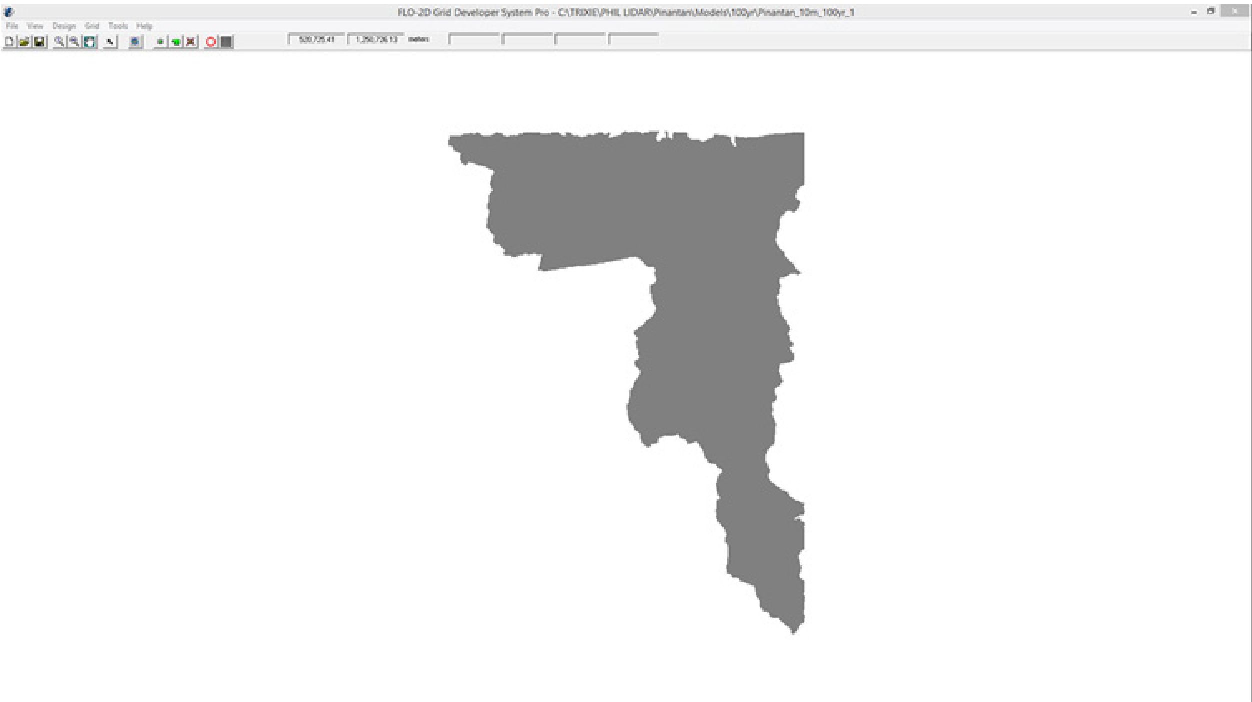


Figure 66. Screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 13.55713 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

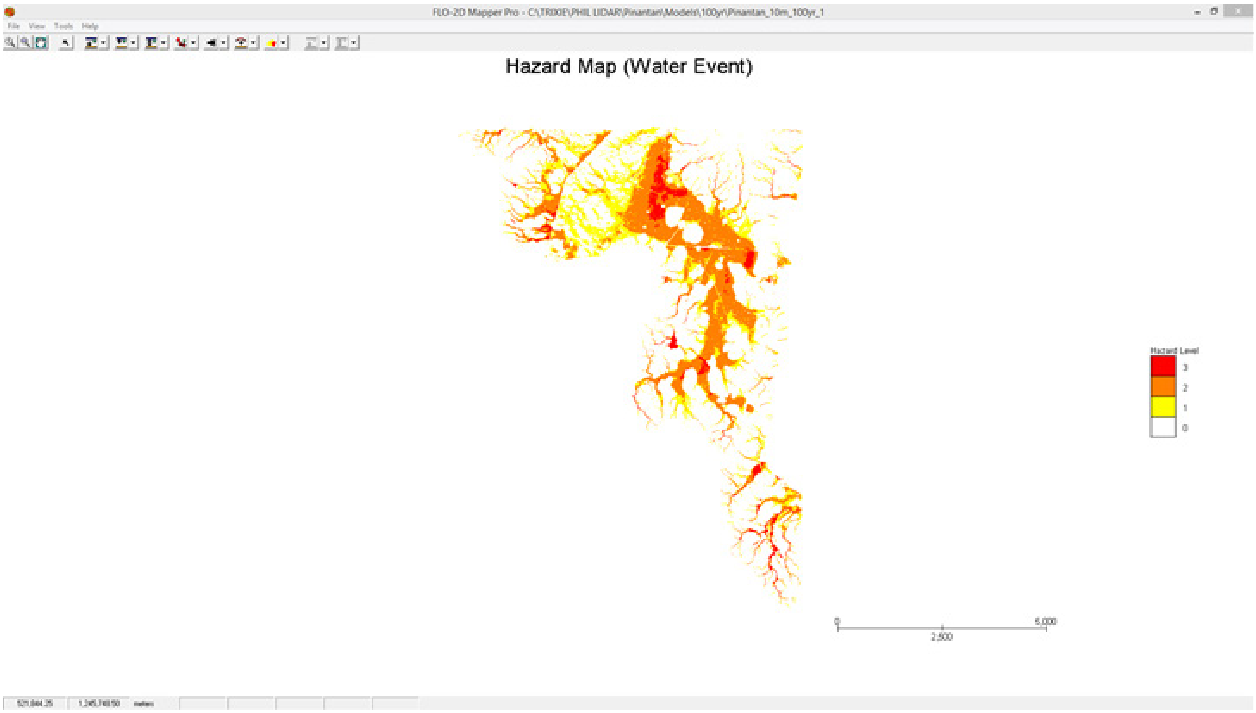


Figure 67. Generated 100-year rain return hazard map from FLO-2D Mapper

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 41 520 800.00 m2.

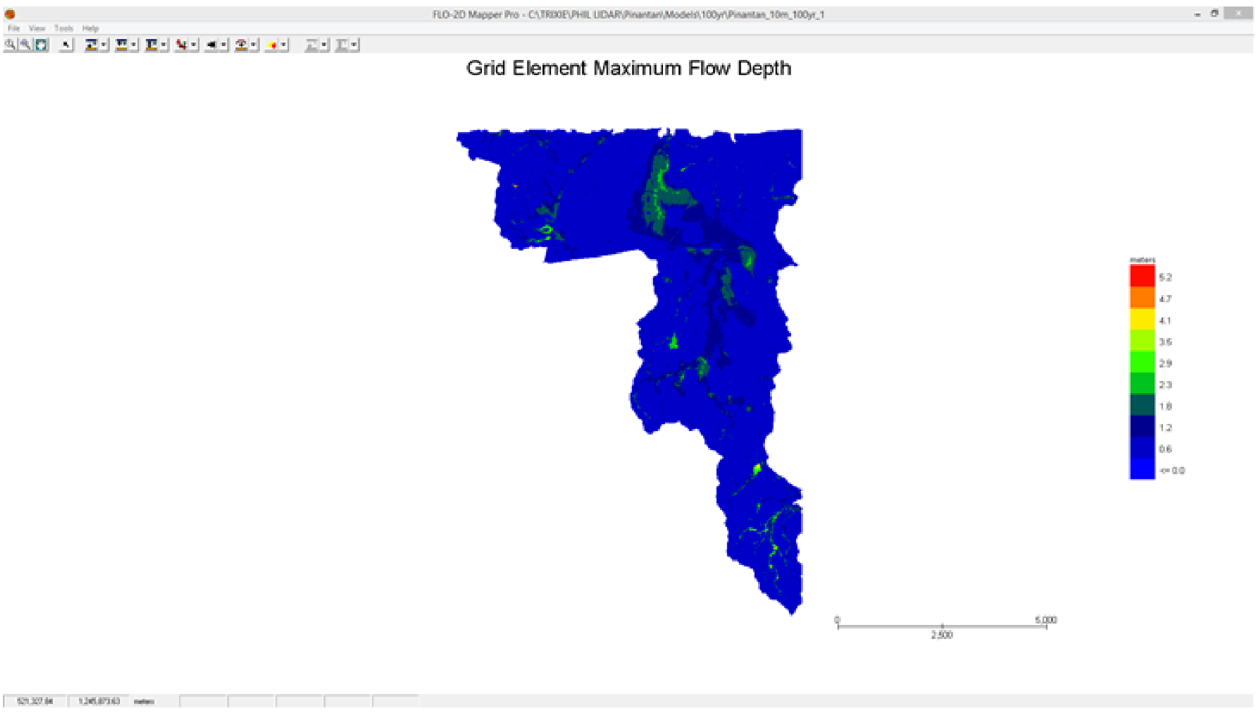


Figure 68. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 13337947.77 m3 of water entering the model. Of this amount, 13337947.77 m3 is due to rainfall while 0.00 m3 is inflow from other areas outside the model. 4069982.25 m3 of this water is lost to infiltration and interception, while 3760365.76 m3 is stored by the flood plain. The rest, amounting up to 5507598.52 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Pinantan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 69 shows the comparison between the two discharge data.

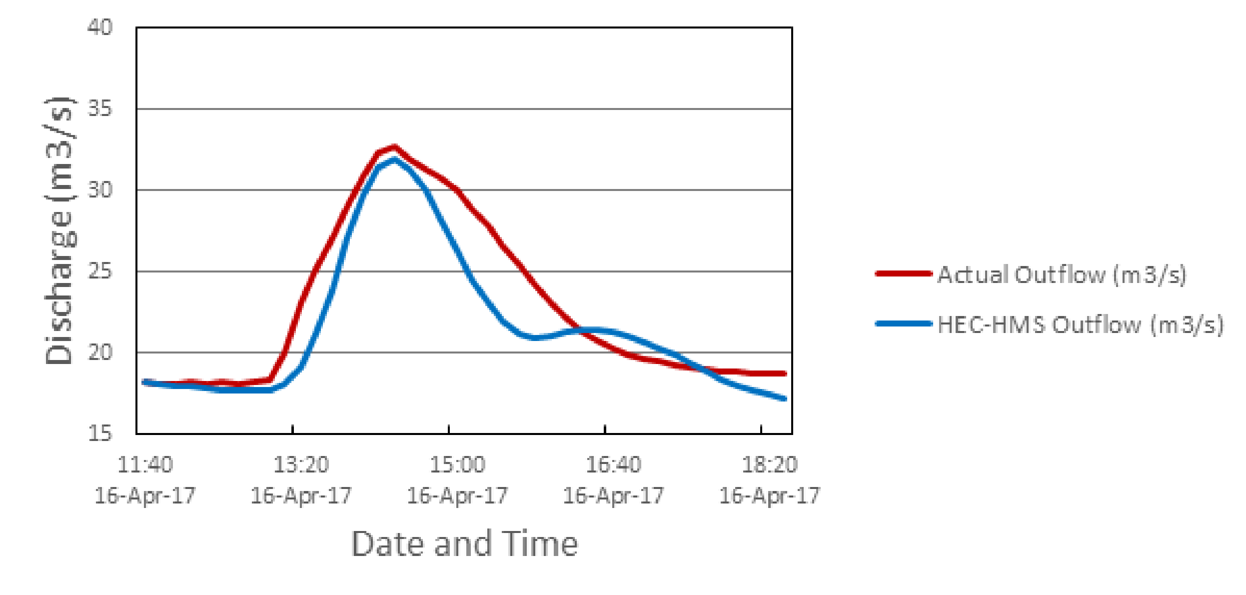


Figure 69. Outflow hydrograph of Pinantan produced by the HEC-HMS model compared with observed outflow

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 Pinantan River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.17-0.4
			Curve Number	99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.73-1.34
			Storage Coefficient (hr)	0.59-1.3
	Baseflow	Recession	Recession Constant	0.5
			Ratio to Peak	0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.005

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.017 mm to 0.4 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Pinantan, the basin mostly consists of cultivated, forest plantations and shrublands, and the soil consists of loam.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.59 hours to 1.34 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.5 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.5 indicates a smoother receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.005 for the Pinantan river basin is lower than the usual Manning's n value in the Philippines (Brunner, 2010).

Table 34. Summary of the Efficiency Test of the Pinantan HMS Model

Accuracy measure	Value
RMSE	1.5
r2	0.8842
NSE	0.99
PBIAS	0.09
RSR	5.76

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 1.5 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.8842.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.99.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 5.76.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.09.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 70) shows the Pinantan outflow using the Roxas Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods from 186.2m3 in a 5-year return period to 344.6m3 for a 100-year return period.

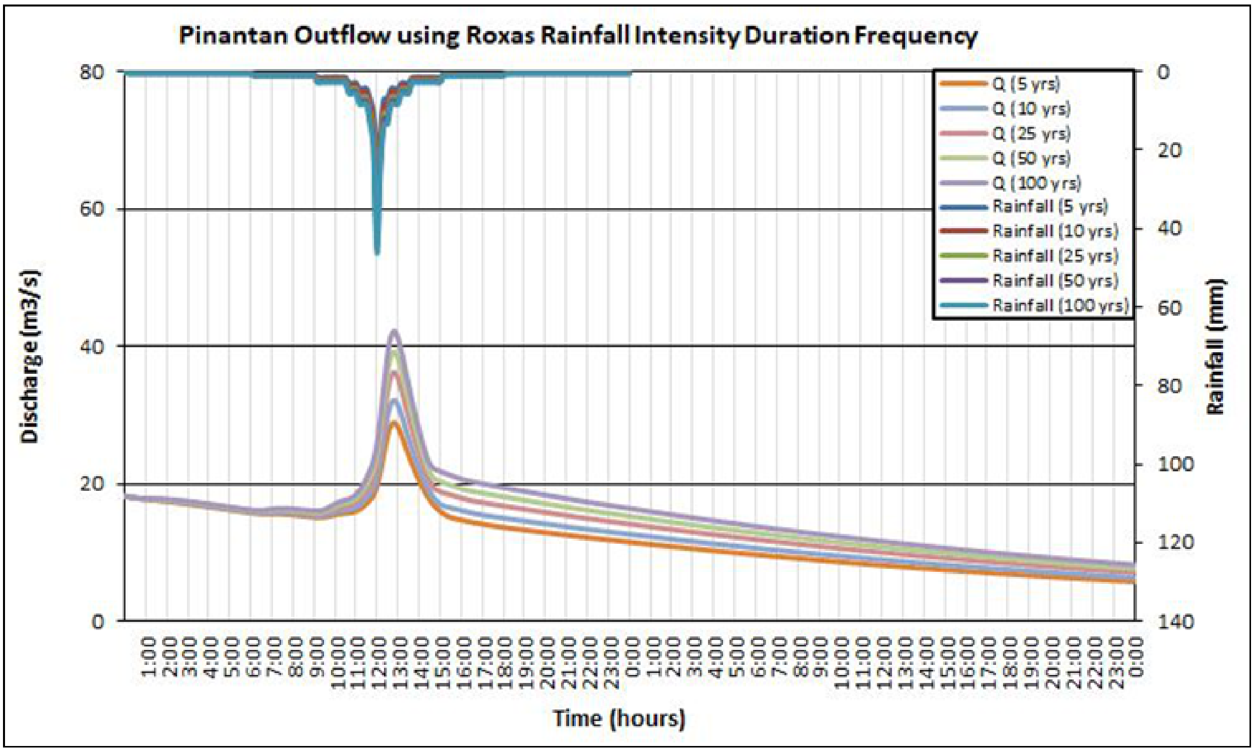


Figure 70. The Outflow hydrograph at the Pinantan Station generated using Aparri RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Pinantan discharge using the Roxas Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 35.

Table 35. Peak values of the Pinantan HEC-HMS Model outflow using the Roxas RIDF 24-hour values.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	186.2	26.6	28.89	50 minutes
10-Year	224.6	31.3	32.12	50 minutes
25-Year	273	37.4	36.19	50 minutes
50-Year	308.9	41.8	39.22	50 minutes
100-Year	344.6	46.2	42.2	50 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Pinantan River using the calibrated HMS event flow is shown in Figure 71.

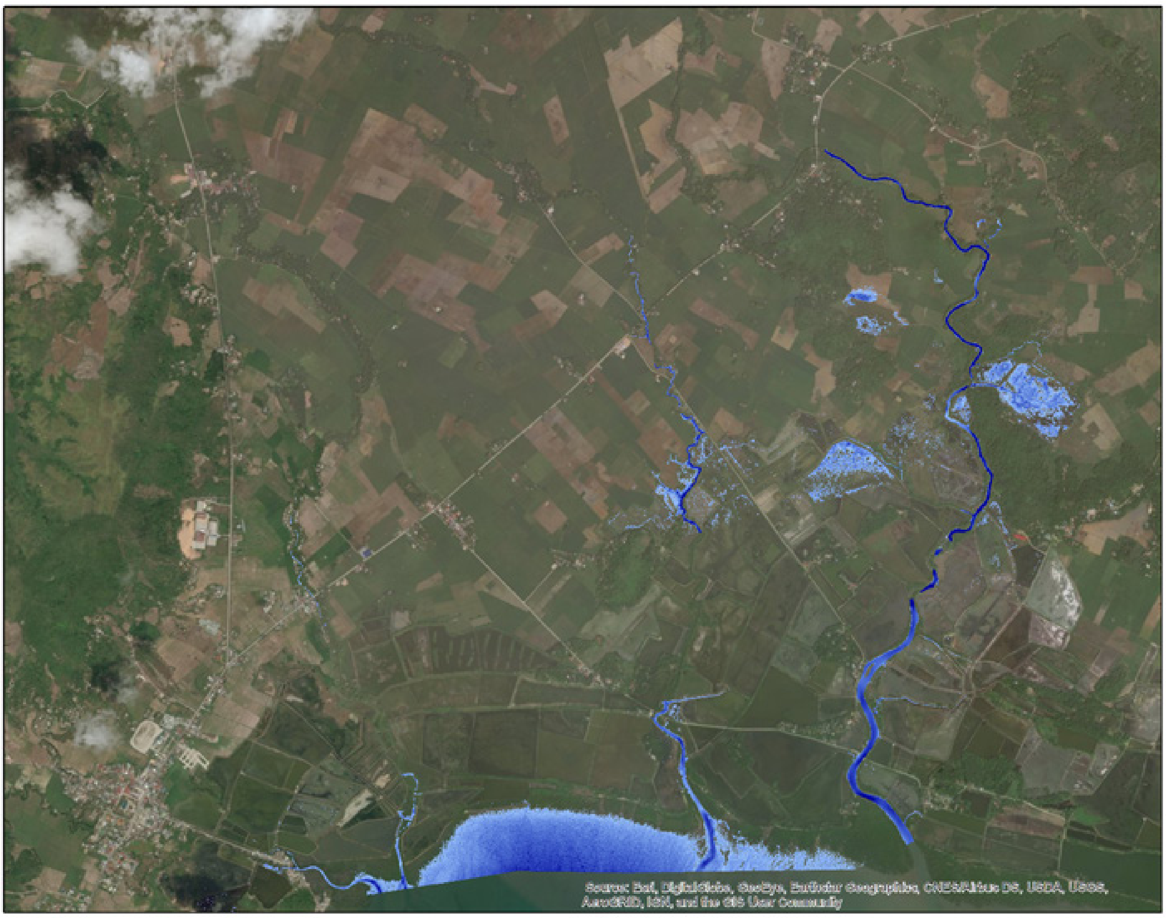


Figure 71. Sample output map of Pinantan RAS Model

5.9 Flood Hazard and Flow Depth

The resulting hazard and flow depth maps have a 10m resolution. Figure 72 to Figure 77 shows the 5-, 25-, and 100-year rain return scenarios of the Pinantan floodplain. The floodplain, with an area of 237.13 sq.km., covers five municipalities namely Ajuy, Concepcion, Lemery, San Dionisio, and Sara.

Table 36. Municipalities affected in Pinantan Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Ajuy	170.884	78.45	45.91
Concepcion	85.803	36.88	42.98
Lemery	149.38	5.23	3.5
San Dionisio	118.5	25.24	21.3
Sara	184.63	89.8	48.64

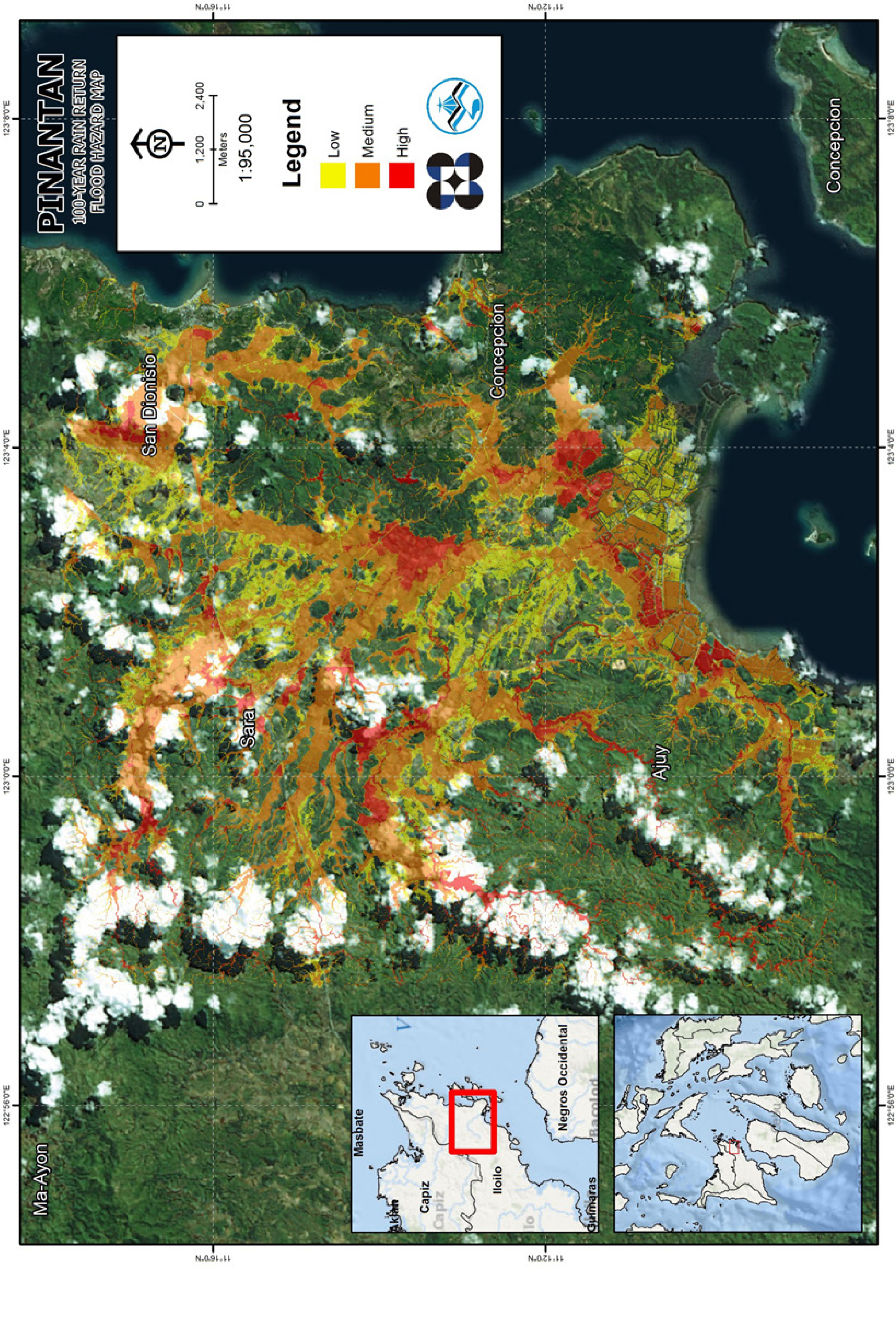


Figure 72. 100-year Flood Hazard Map for Pinantan Floodplain overlaid on Google Earth imagery

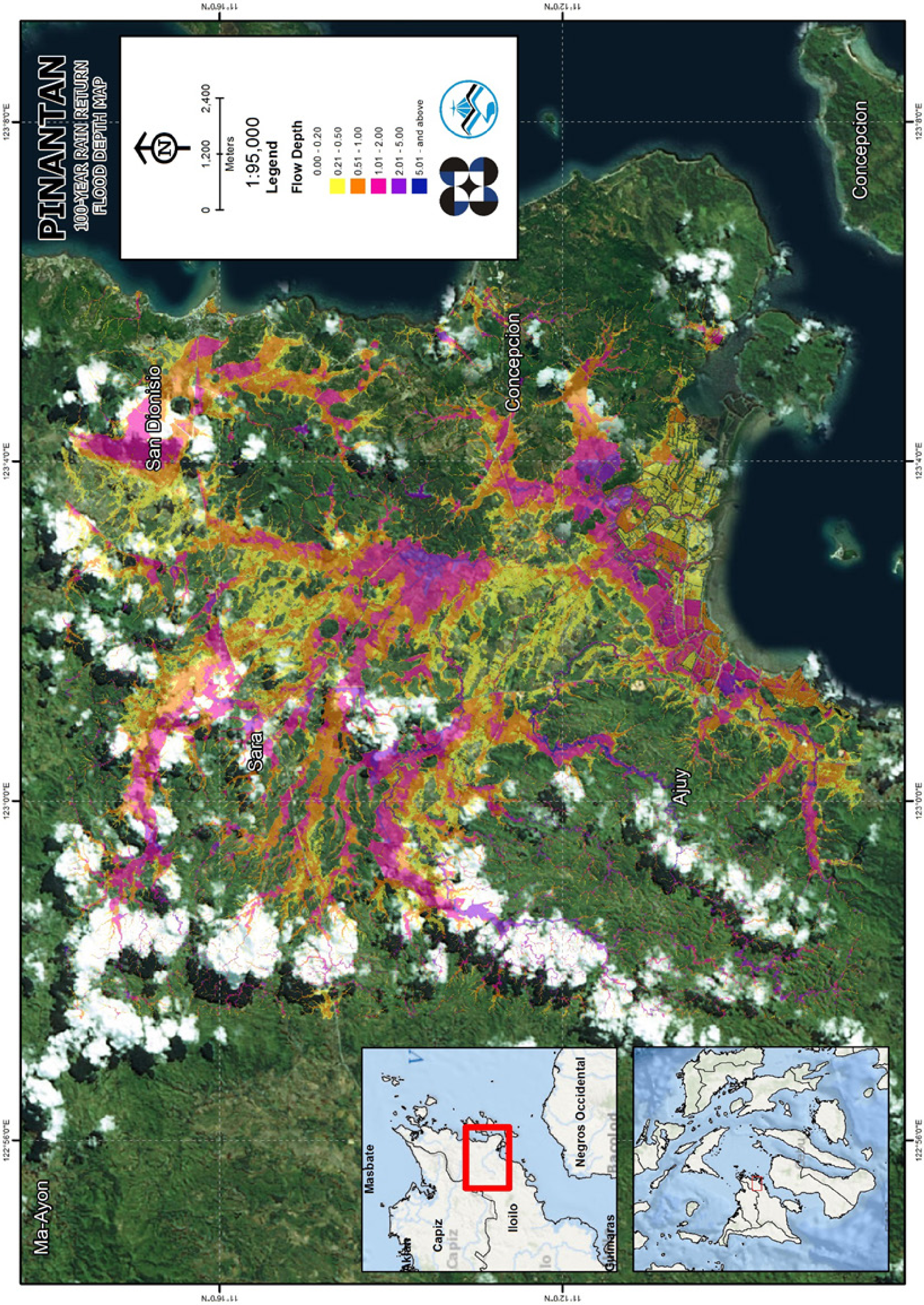


Figure 73. 100-year Flow Depth Map for Pinantan Floodplain overlaid on Google Earth imagery

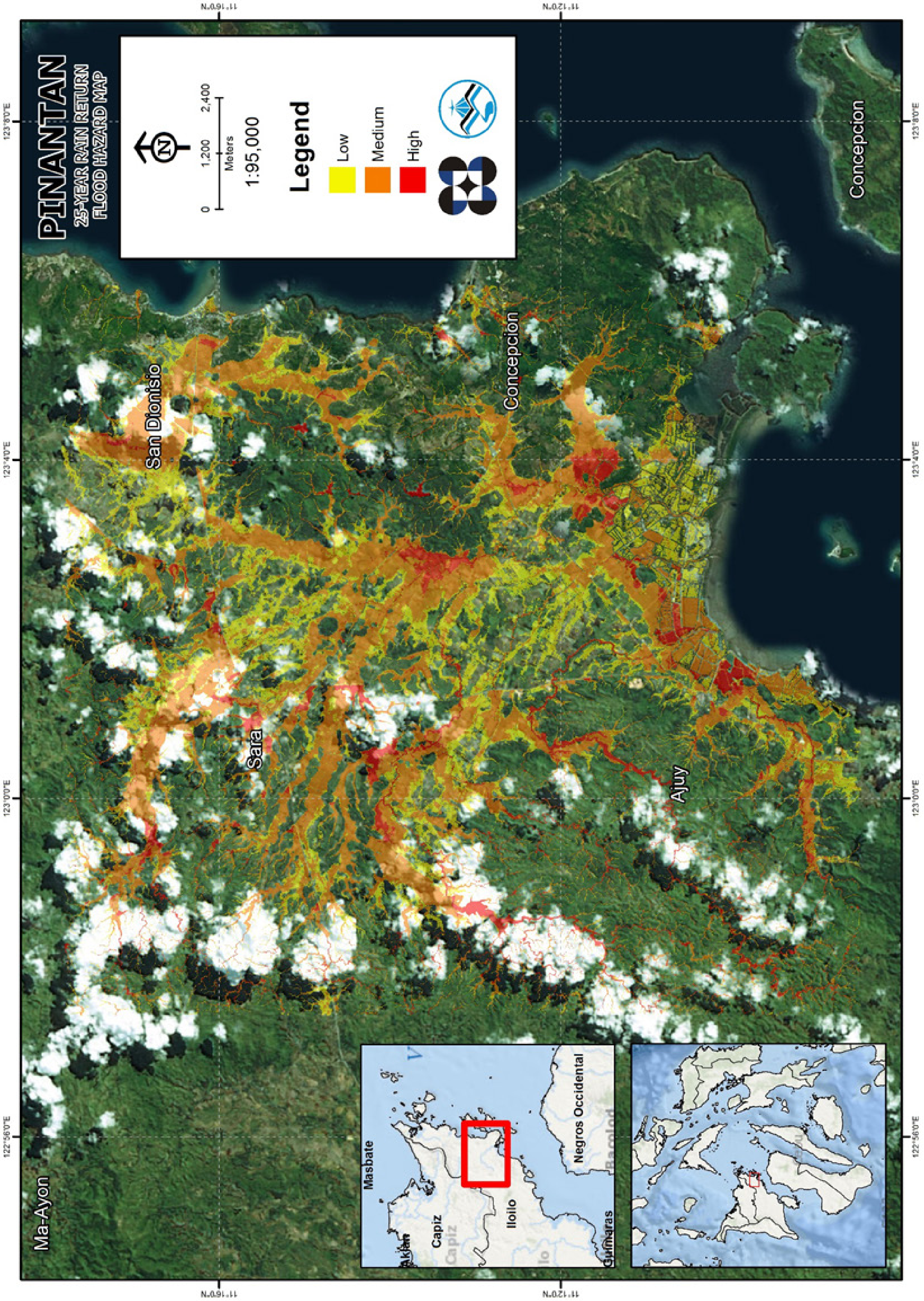


Figure 74. 25-year Flood Hazard Map for Pinantan Floodplain overlaid on Google Earth imagery

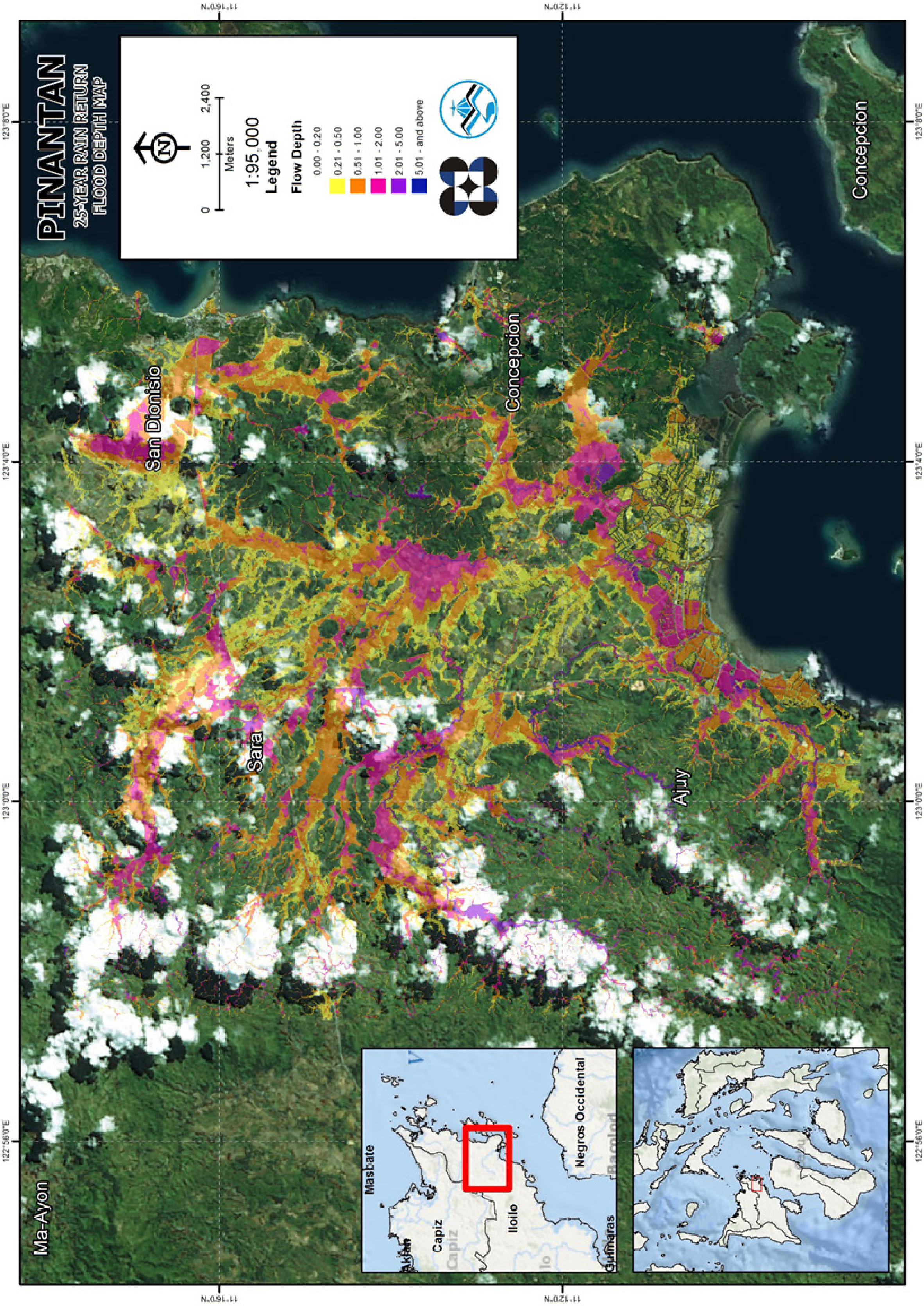


Figure 75. 25-year Flow Depth Map for Pinantan Floodplain overlaid on Google Earth imagery

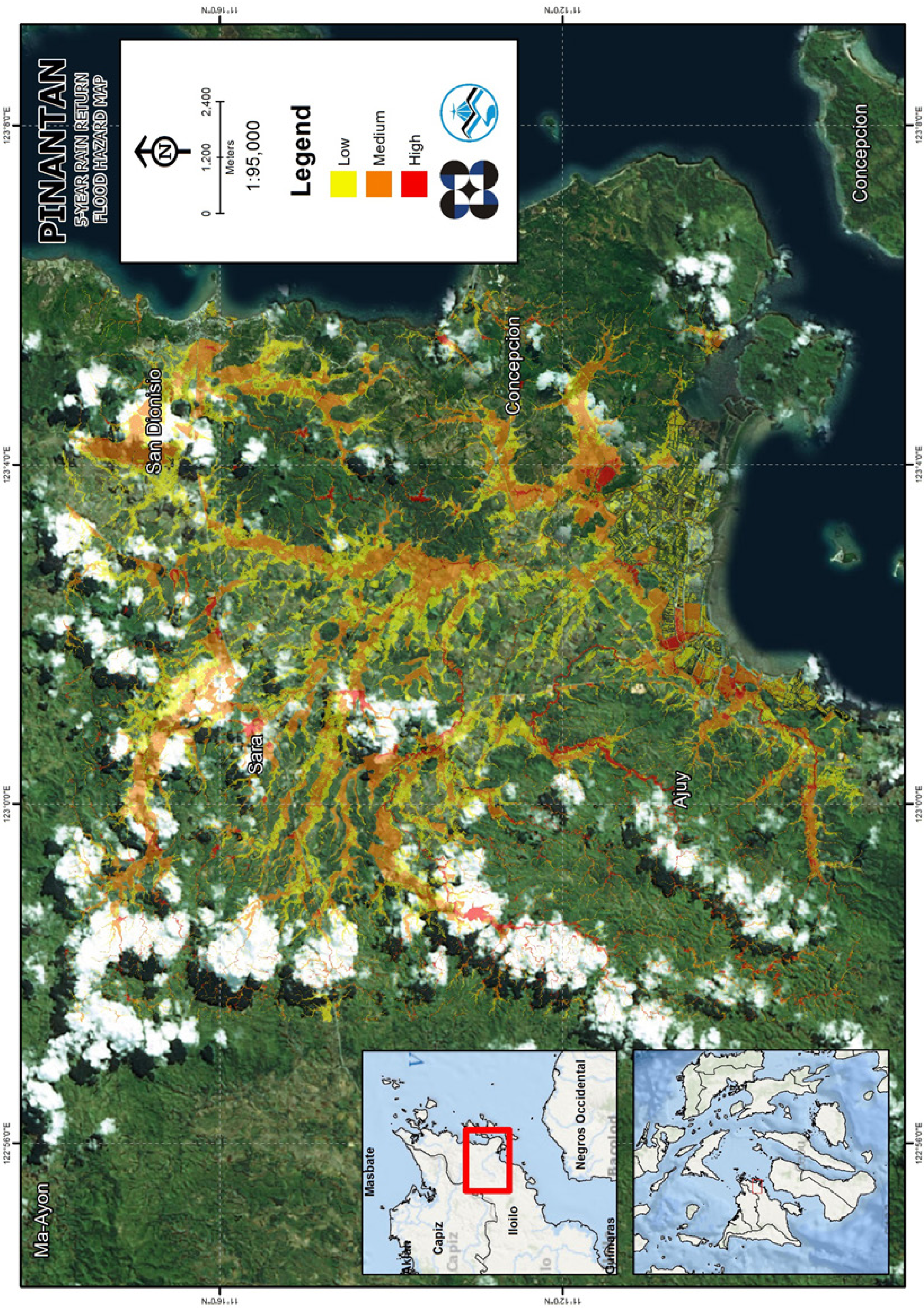


Figure 76. 5-year Flood Hazard Map for Pinantan Floodplain overlaid on Google Earth imagery

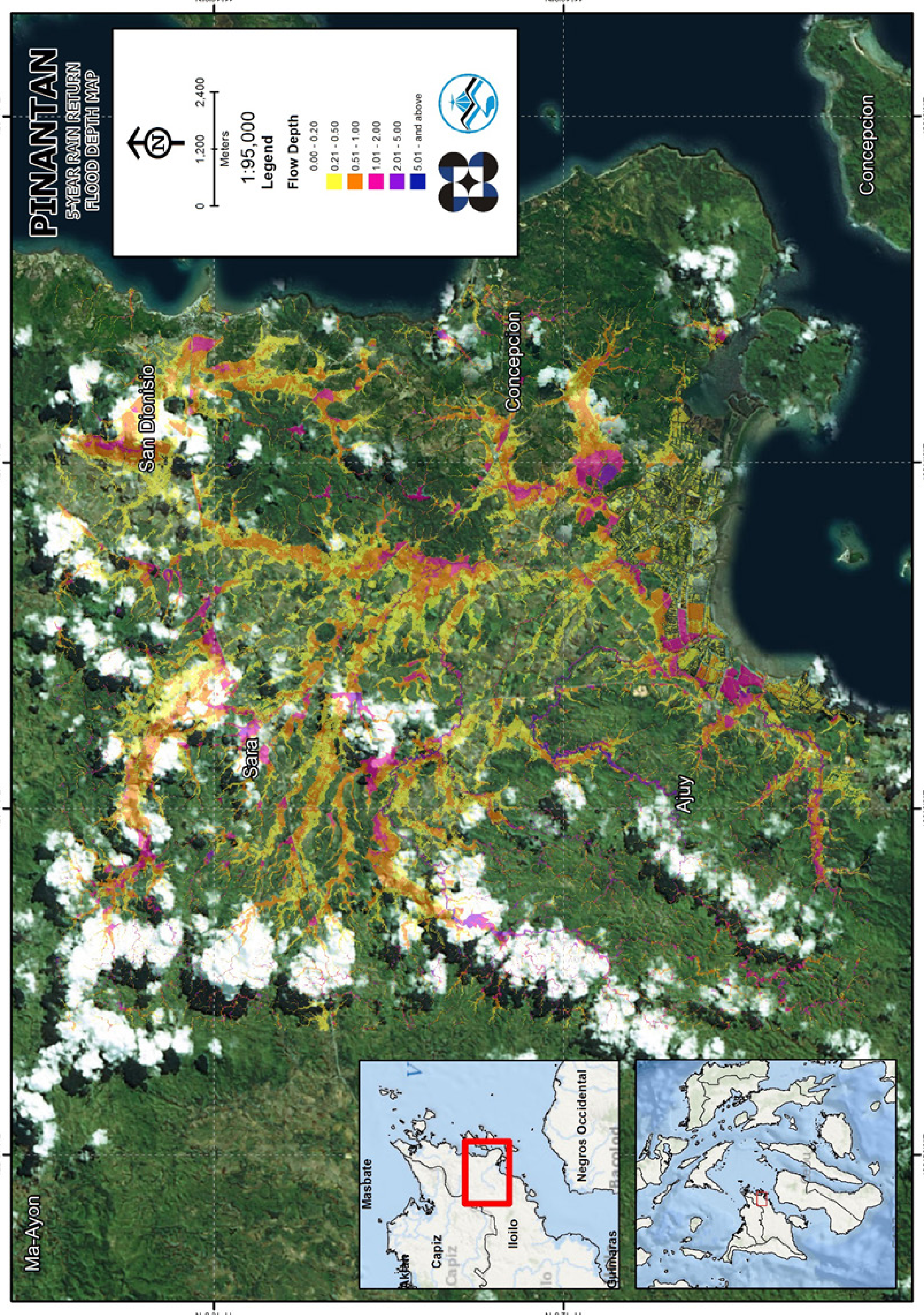


Figure 77. 5-year Flood Depth Map for Pinantan Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Pinantan river basin, grouped by municipality, are listed below. For the said basin, five municipalities consisting of 92 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 35.58% of the municipality of Ajuy with an area of 170.88 sq. km. will experience flood levels of less 0.20 meters. 5.1% of the area will experience flood levels of 0.21 to 0.50 meters while 2.94%, 1.67%, 0.57%, and 0.056% 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 37 and Table 38 are the affected areas in square kilometres by flood depth per barangay.

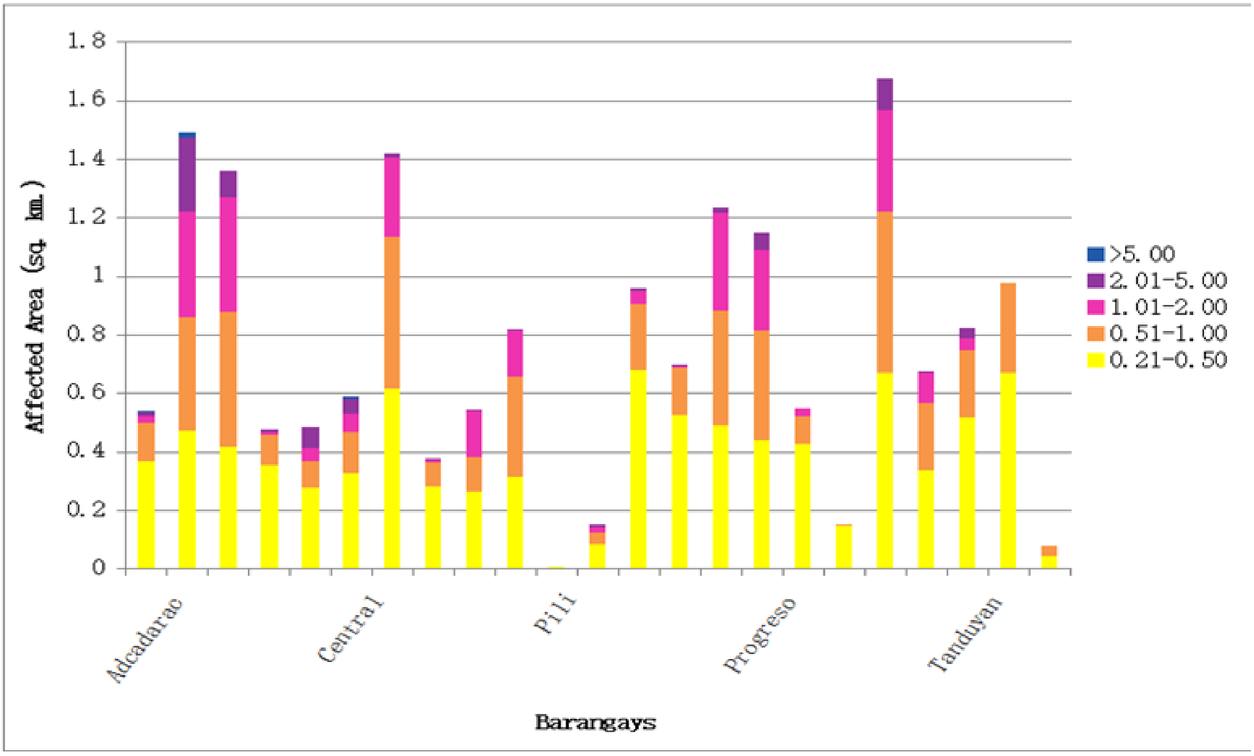


Figure 78. Affected Areas in Ajuy, Iloilo during 5-Year Rainfall Return Period

Table 37. Affected Areas in Ajuy, Iloilo during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ajuy (in sq. km.)											
	Adcadarao	Agbobolo	Badiangan	Bato Biasong	Bucana Bunglas	Central	Lanjagan	Mangorocoro	Pantalan Nabaye	Pantalan Navarro	Pili	Pinantan Diel
0.03-0.20	0.98	12.47	11.09	0.78	1.13	2.09	2.2	1	0.5	1.01	0.07	0.93
0.21-0.50	0.37	0.47	0.42	0.35	0.28	0.33	0.61	0.28	0.26	0.31	0	0.08
0.51-1.00	0.13	0.39	0.46	0.1	0.09	0.14	0.52	0.08	0.12	0.34	0	0.04
1.01-2.00	0.02	0.36	0.39	0.01	0.05	0.06	0.27	0.01	0.16	0.16	0	0.02
2.01-5.00	0.02	0.25	0.09	0.01	0.07	0.05	0.02	0	0	0	0	0.01
> 5.00	0	0.01	0	0	0	0.01	0	0	0	0	0	0

Table 38. Affected Areas in Ajuy, Iloilo during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ajuy (in sq. km.)										
	Pinantan Elizalde	Pinay Espinosa	Poblacion	Progreso	Puente Bunglas	Rojas	San Antonio	Taguhangin	Tanduyan	Tipacla	Tubogan
0.03-0.20	1.57	1.42	2.5	7.58	1.04	0.49	3.45	0.76	2.15	4.5	1.11
0.21-0.50	0.68	0.52	0.49	0.44	0.43	0.14	0.67	0.34	0.52	0.67	0.04
0.51-1.00	0.23	0.16	0.39	0.38	0.09	0.01	0.55	0.23	0.23	0.31	0.04
1.01-2.00	0.04	0.01	0.33	0.28	0.03	0	0.35	0.11	0.04	0.13	0.03
2.01-5.00	0.01	0	0.02	0.06	0	0	0.11	0	0.04	0.18	0.02
> 5.00	0	0	0	0	0	0	0	0	0	0.05	0

For the municipality of Concepcion, with an area of 85.80 sq. km., 33.99% will experience flood levels of less 0.20 meters. 3.89% of the area will experience flood levels of 0.21 to 0.50 meters while 3.53%, 1.39%, and 0.16% 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 39 are the affected areas in square kilometres by flood depth per barangay.

Table 39. Affected areas in Concepcion, Iloilo during a 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Concepcion (in sq. km.)												
	Aglosong	Agnaga	Bacjawan Norte	Bacjawan Sur	Batiti	Calamigan	Jamul-Awon	Macalbang	Niño	Nipa	Plandico	Poblacion	Tamis-Ac
0.03-0.20	4.75	0.77	1.99	2.62	1.96	2.79	2.08	6.74	1.13	1.24	1.78	0.41	0.91
0.21-0.50	0.62	0.32	0.16	0.21	0.36	0.26	0.12	0.76	0.09	0.02	0.17	0.04	0.22
0.51-1.00	0.51	0.29	0.14	0.12	0.32	0.12	0.16	1.01	0.05	0.01	0.11	0.03	0.15
1.01-2.00	0.18	0.16	0.01	0.08	0.07	0.11	0.04	0.33	0.01	0	0.05	0.01	0.15
2.01-5.00	0	0.01	0	0.02	0	0.01	0.01	0.03	0	0	0	0	0.05
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0

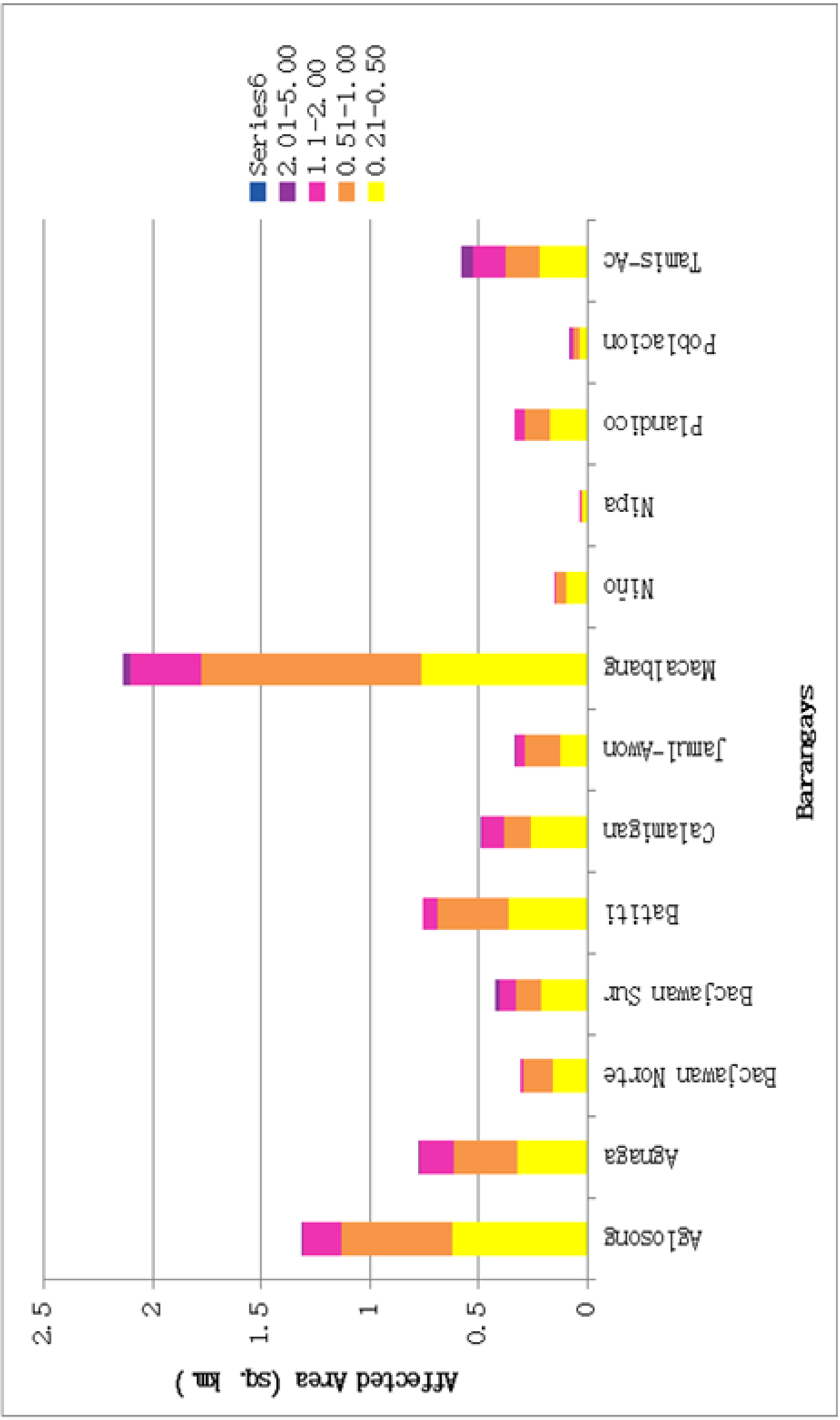


Figure 79. Affected Areas in Concepcion, Iloilo during 5-Year Rainfall Return Period

For the municipality of Lemery, with an area of 149.38 sq. km., 3.07% will experience flood levels of less 0.20 meters. 0.23% of the area will experience flood levels of 0.21 to 0.50 meters while 0.12%, 0.066%, 0.016%, and 0.00007% 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 40 are the affected areas in square kilometres by flood depth per barangay.

Table 40. Affected Areas in Lemery, Iloilo during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lemery (in sq. km.)					
	Agpipili	Almeñana	Cabantohan	Dapdapan	Nagsulang	Velasco
0.03-0.20	0.27	0.68	2.32	0.17	0.15	0.99
0.21-0.50	0.01	0.08	0.12	0.01	0.01	0.11
0.51-1.00	0.01	0.02	0.1	0	0.01	0.05
1.01-2.00	0	0.01	0.04	0	0	0.04
2.01-5.00	0	0	0.01	0	0	0.01
> 5.00	0	0	0	0	0	0

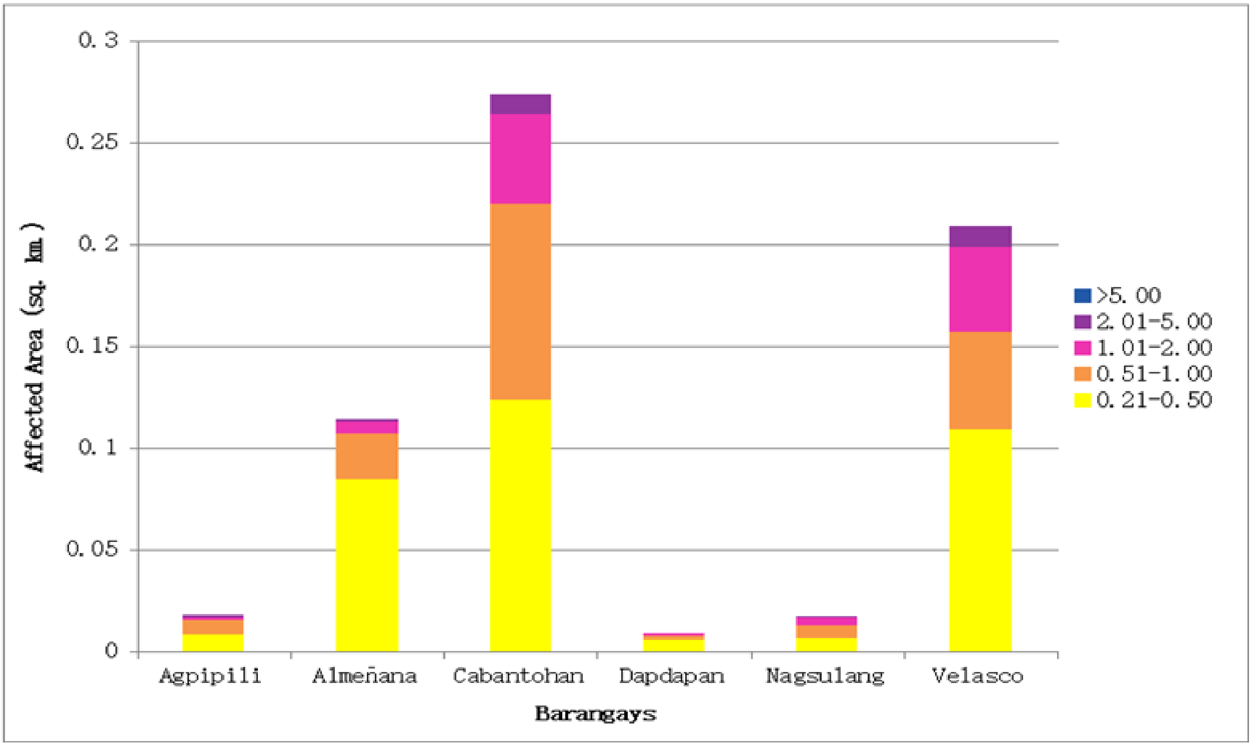


Figure 80. Affected Areas in Lemery, Iloilo during 5-Year Rainfall Return Period

For the municipality of San Dionisio, with an area of 118.50 sq. km., 15.39% will experience flood levels of less 0.20 meters. 3.38% of the area will experience flood levels of 0.21 to 0.50 meters while 2.12%, 0.39%, and 0.016% 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 41 are the affected areas in square kilometres by flood depth per barangay.

Table 41. Affected Areas in San Dionisio, Iloilo during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Dionisio (in sq. km.)												
	Bondulan	Capinang	Dugman	Moto	Nipa	Pangi	Pase	Poblacion	San Nicolas	Santol	Siempreviva	Tiabas	Tuble
0.03-0.20	1.44	1.39	3.35	3.04	0.93	0.43	0.99	0.88	0.2	0.57	0.98	2.68	1.36
0.21-0.50	0.92	0.09	1	0.55	0.1	0.04	0.22	0.11	0	0.23	0.35	0.09	0.31
0.51-1.00	0.84	0.08	0.5	0.11	0.01	0.02	0.09	0.09	0	0.14	0.28	0.05	0.29
1.01-2.00	0.06	0.03	0.09	0.03	0	0	0.01	0.09	0	0	0.06	0.02	0.08
2.01-5.00	0	0.01	0	0	0	0	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0

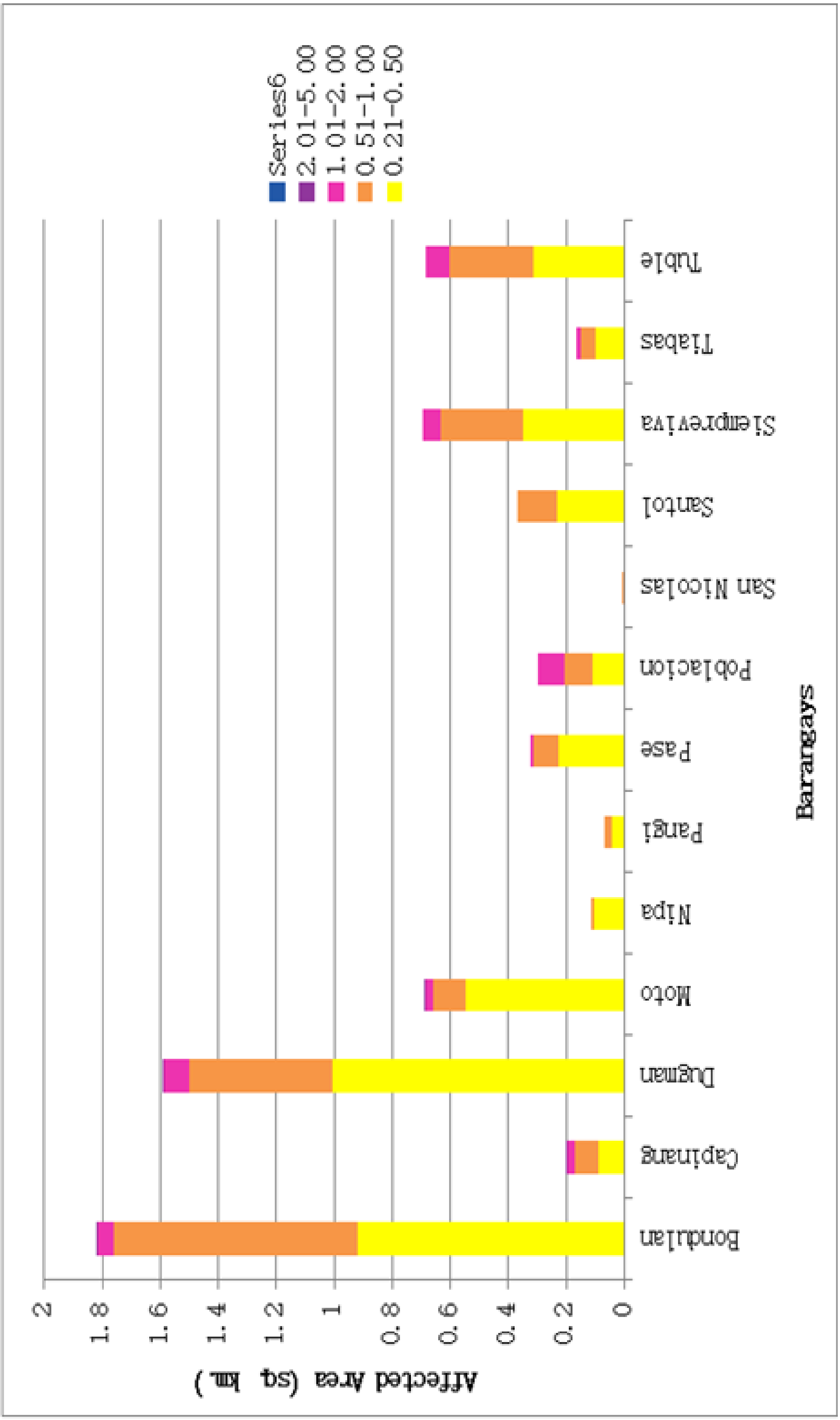


Figure 81. Affected Areas in San Diosio, Iloilo during 5-Year Rainfall Return Period

For the municipality of Sara, with an area of 184.63 sq. km., 33.16% will experience flood levels of less 0.20 meters. 7.44% of the area will experience flood levels of 0.21 to 0.50 meters while 5.90%, 1.71%, 0.41%, and 0.41% 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 42 to Table 44 are the affected areas in square kilometres by flood depth per barangay.

Table 42. Affected Areas in Sara, Iloilo during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sara (in sq. km.)												
	Aguirre	Aldeguer	Alibayog	Anoring	Apelo	Apologista	Aposaga	Arante	Ardemil	Aspera	Aswe-Pabriaga	Bagaygay	Bakabak
0.03-0.20	2.91	2.49	1.07	1.03	1.72	0.67	0.73	4.05	0.24	0.7	0.76	0.73	3.07
0.21-0.50	0.24	0.65	0.42	0.28	0.21	0.35	0.34	0.27	0.01	0.17	0.79	0.16	0.69
0.51-1.00	0.3	0.35	0.32	0.21	0.13	0.29	0.29	0.28	0.01	0.16	0.59	0.47	0.95
1.01-2.00	0.11	0.15	0.06	0.22	0.05	0.1	0.02	0.07	0.01	0.03	0.06	0.11	0.39
2.01-5.00	0.02	0.04	0	0.04	0.01	0.06	0.01	0.02	0	0	0	0	0.03
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 43. Affected Areas in Sara, Iloilo during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sara (in sq. km.)													
	Batitao	Bato	Castor	Crespo	Devera	Domingo	Ferraris	Gildore	Improgo	Labigan	Lanciola	Malapaya	Padios	Pasig
0.03-0.20	1.15	1.95	2.32	2.71	1.19	5.19	0.94	0.95	2.82	1.35	1.89	4.26	0.72	0.63
0.21-0.50	0.66	0.18	0.21	1.02	0.41	0.31	0.89	0.27	0.16	0.59	0.47	0.36	0.32	0.13
0.51-1.00	0.29	0.23	0.15	0.71	0.34	0.28	0.56	0.27	0.13	0.55	0.05	0.45	0.37	0.06
1.01-2.00	0.02	0.11	0.06	0.04	0.16	0.13	0.06	0.15	0.08	0.16	0	0.21	0.03	0.01
2.01-5.00	0.02	0.01	0	0.01	0	0.06	0.02	0.05	0.05	0.02	0	0.02	0	0
> 5.00	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0

Table 44. Affected Areas in Sara, Iloilo during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Poblacion Ilawod	Poblacion Ilaya	Poblacion Market	Posadas	Preciosa	Salcedo	San Luis	Tentay	Villahermosa	Zerrudo
0.03-0.20	0.64	0.34	0.4	1.87	2.24	0.76	1.21	1.87	1.24	2.4
0.21-0.50	0.28	0.07	0.08	0.3	0.26	0.43	0.54	0.34	0.51	0.39
0.51-1.00	0.13	0.06	0.14	0.13	0.21	0.2	0.51	0.21	0.31	0.2
1.01-2.00	0.03	0.01	0.09	0.03	0.08	0.02	0.01	0.15	0.02	0.12
2.01-5.00	0	0	0	0.01	0.02	0.01	0	0.17	0	0.04
> 5.00	0	0	0	0	0	0	0	0.01	0	0

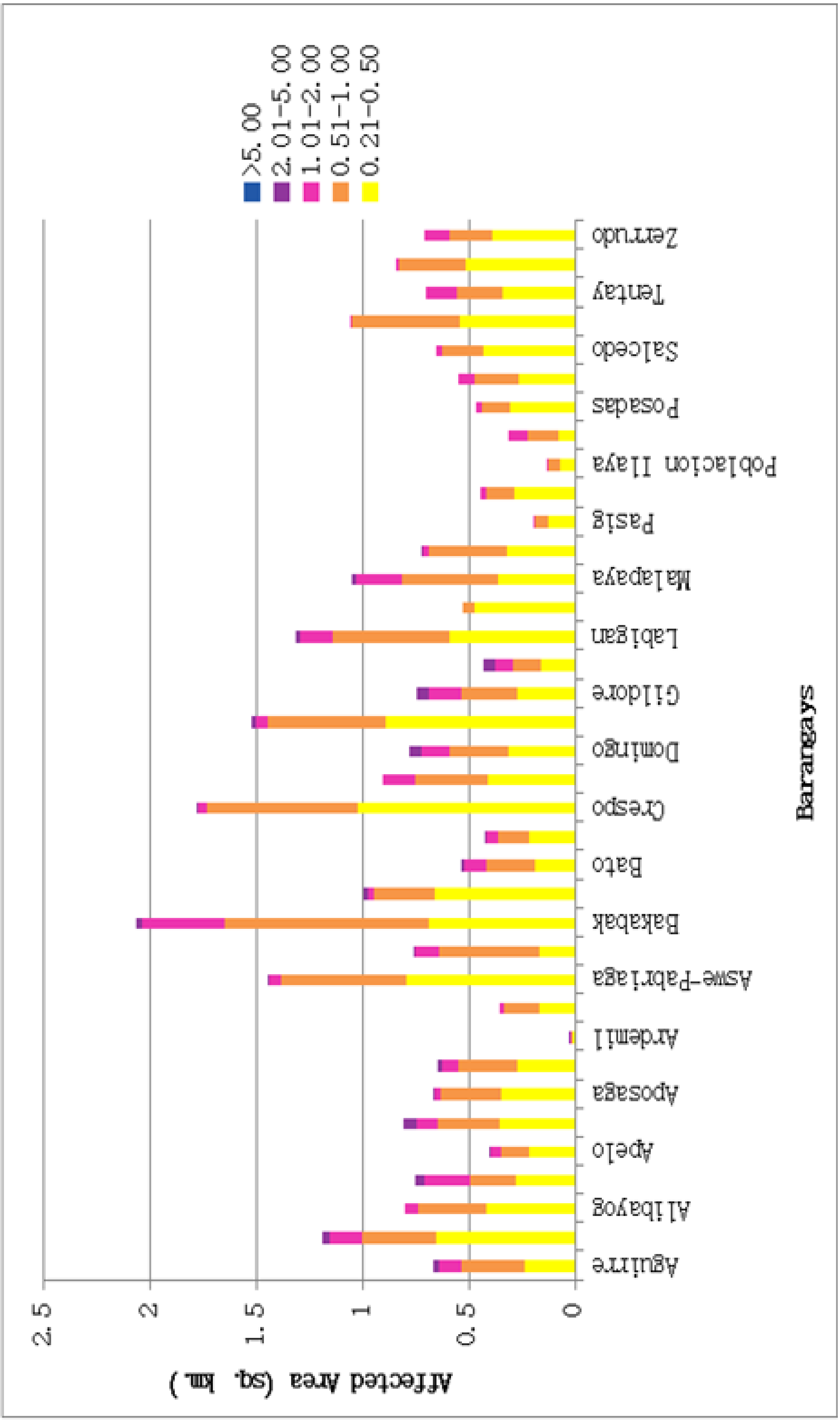


Figure 82. Affected Areas Sara, Iloilo during 5-Year Rainfall Return Period

For the 25-year return period, 32.54% of the municipality of Ajuy with an area of 170.88 sq. km. will experience flood levels of less 0.20 meters. 5.35% of the area will experience flood levels of 0.21 to 0.50 meters while 4.22%, 2.82%, 0.89%, and 0.1% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 45 and Table 46 are the affected areas in square kilometres by flood depth per barangay.

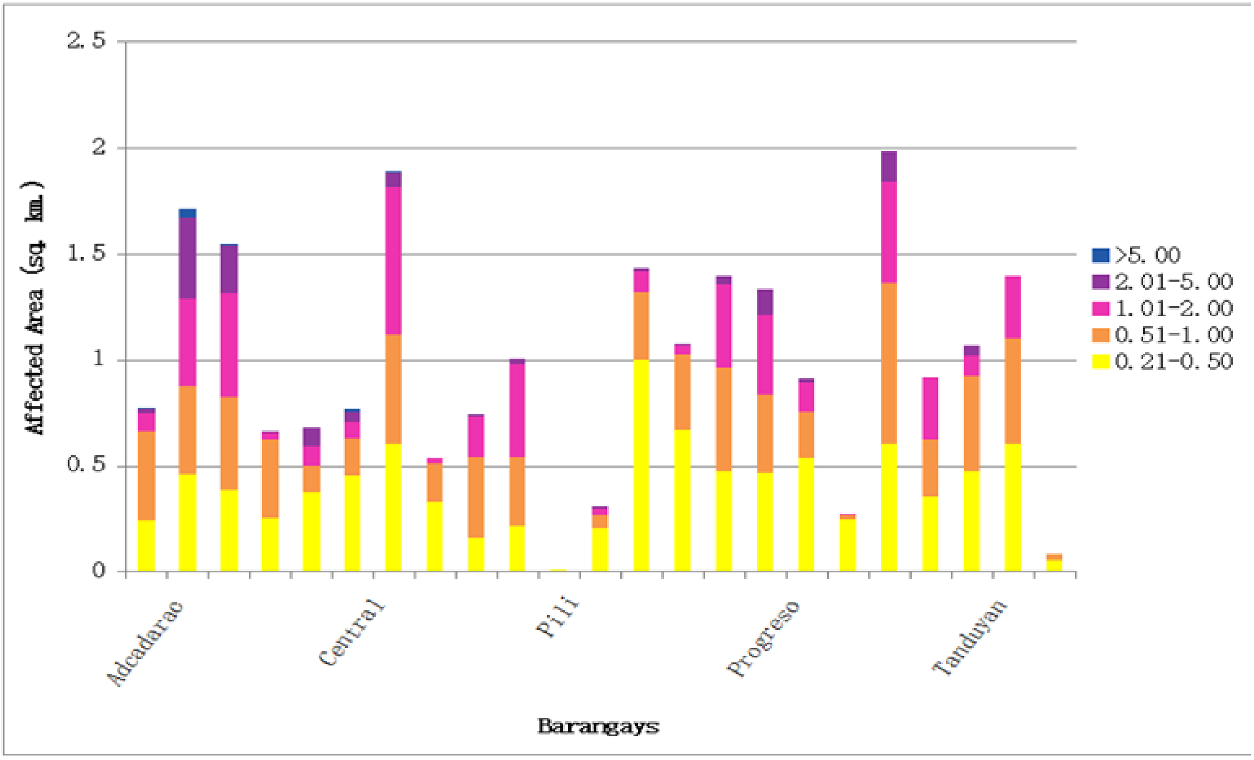


Figure 83. Affected Areas in Ajuy, Iloilo during 25-Year Rainfall Return Period

Table 45. Affected Areas in Ajuy, Iloilo during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ajuy (in sq. km.)											
	Adcadarao	Agbobolo	Badiangan	Bato Biasong	Bucana Bunglas	Central	Lanjagan	Mangorocoro	Pantalan Nabaye	Pantalan Navarro	Pili	Pinantan Diel
0.03-0.20	0.74	12.25	10.91	0.59	0.94	1.91	1.73	0.84	0.3	0.82	0.06	0.77
0.21-0.50	0.24	0.46	0.38	0.25	0.37	0.45	0.6	0.33	0.16	0.22	0.01	0.2
0.51-1.00	0.42	0.41	0.44	0.37	0.13	0.17	0.52	0.18	0.38	0.32	0	0.06
1.01-2.00	0.09	0.41	0.49	0.03	0.1	0.07	0.7	0.02	0.19	0.44	0	0.03
2.01-5.00	0.02	0.38	0.22	0.01	0.09	0.05	0.07	0	0.01	0.03	0	0.01
> 5.00	0.01	0.04	0	0	0	0.01	0	0	0	0	0	0

Table 46. Affected Areas in Ajuy, Iloilo during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ajuy (in sq. km.)										
	Pinantan Elizalde	Pinay Espinosa	Poblacion	Progreso	Puente Bunglas	Rojas	San Antonio	Taguhangin	Tanduyan	Tipacla	Tubogan
0.03-0.20	1.1	1.04	2.34	7.4	0.68	0.37	3.14	0.52	1.9	4.16	1.09
0.21-0.50	1	0.66	0.47	0.46	0.53	0.25	0.6	0.35	0.47	0.61	0.05
0.51-1.00	0.32	0.36	0.49	0.38	0.22	0.02	0.76	0.27	0.45	0.49	0.04
1.01-2.00	0.1	0.04	0.39	0.38	0.14	0	0.47	0.3	0.09	0.29	0.04
2.01-5.00	0.01	0	0.04	0.11	0.01	0	0.14	0	0.05	0.21	0.03
> 5.00	0	0	0	0	0	0	0.01	0	0.01	0.08	0

For the municipality of Concepcion, with an area of 85.80 sq. km., 32.87% will experience flood levels of less 0.20 meters. 3.25% of the area will experience flood levels of 0.21 to 0.50 meters while 4.29%, 2.11%, 0.35%, and 0.0001 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 kilometres by flood depth per barangay.

Table 47. Affected areas in Concepcion, Iloilo during a 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Concepcion (in sq. km.)												
	Aglosong	Agnaga	Bacjawan Norte	Bacjawan Sur	Batiti	Calamigan	Jamul-Awon	Macalbang	Niño	Nipa	Plandico	Poblacion	Tamis-Ac
0.03-0.20	4.6	0.63	1.95	2.49	1.88	2.71	2.04	6.61	1.11	1.23	1.73	0.39	0.83
0.21-0.50	0.52	0.27	0.14	0.25	0.25	0.24	0.11	0.46	0.1	0.02	0.18	0.04	0.2
0.51-1.00	0.66	0.34	0.17	0.16	0.43	0.19	0.15	1.17	0.06	0.01	0.13	0.03	0.19
1.01-2.00	0.27	0.28	0.04	0.11	0.15	0.08	0.1	0.57	0.01	0	0.07	0.02	0.2
2.01-5.00	0.02	0.02	0	0.03	0	0.06	0.01	0.07	0	0	0	0	0.07
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0

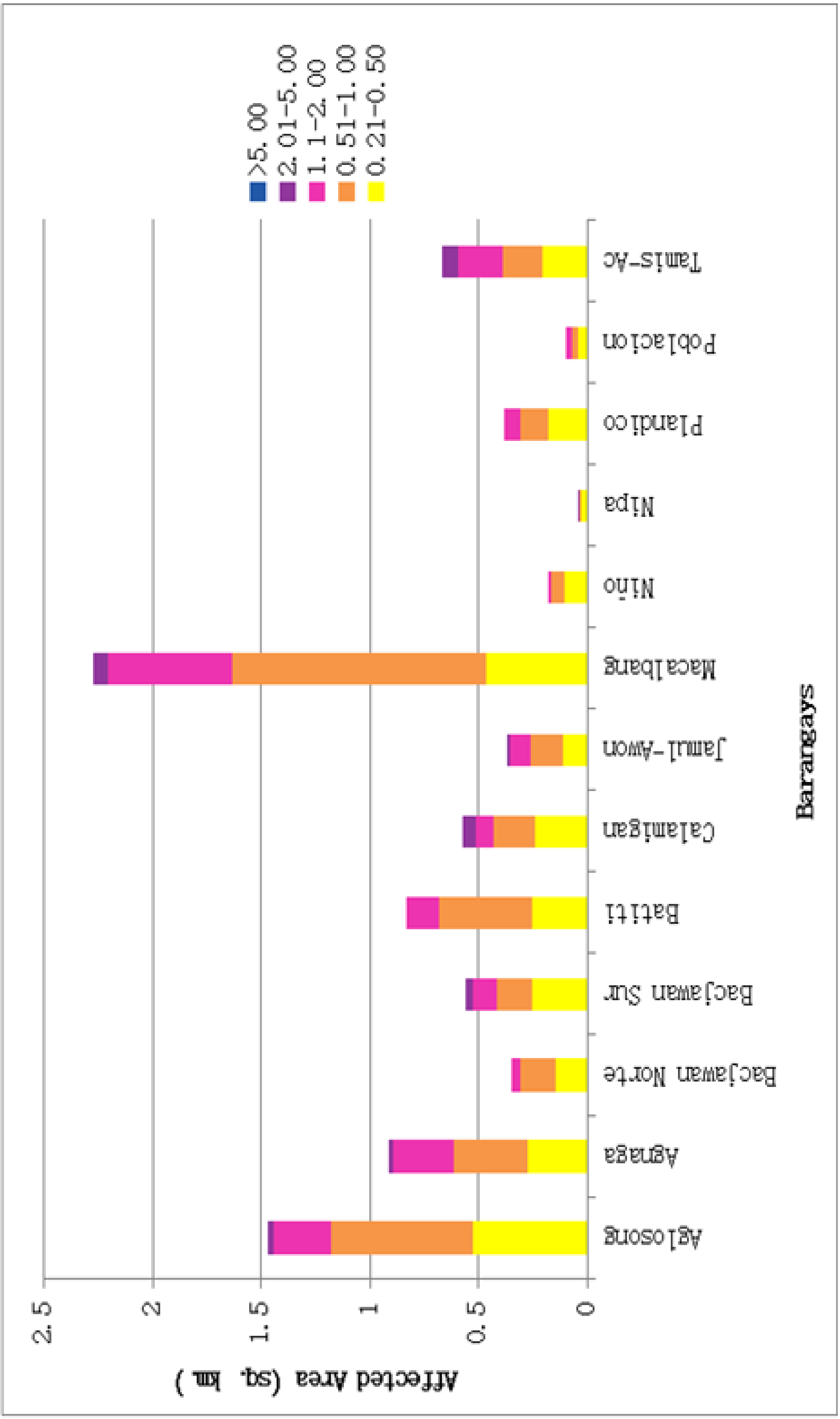


Figure 84. Affected Areas Concepcion, Iloilo during 5-Year Rainfall Return Period

For the municipality of Lemery, with an area of 149.38 sq. km., 3.01% will experience flood levels of less 0.20 meters. 0.22% of the area will experience flood levels of 0.21 to 0.50 meters while 0.16%, 0.089%, 0.027%, and 0.0001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 48 are the affected areas in square kilometres by flood depth per barangay.

Table 48. Affected Areas in Lemery, Iloilo during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lemery (in sq. km.)					
	Agpipili	Almeñana	Cabantohan	Dapdapan	Nagsulang	Velasco
0.03-0.20	0.27	0.66	2.29	0.17	0.15	0.95
0.21-0.50	0.01	0.08	0.11	0.01	0.01	0.11
0.51-1.00	0.01	0.03	0.11	0	0.01	0.07
1.01-2.00	0	0.01	0.06	0	0	0.05
2.01-5.00	0	0	0.01	0	0	0.02
> 5.00	0	0	0	0	0	0

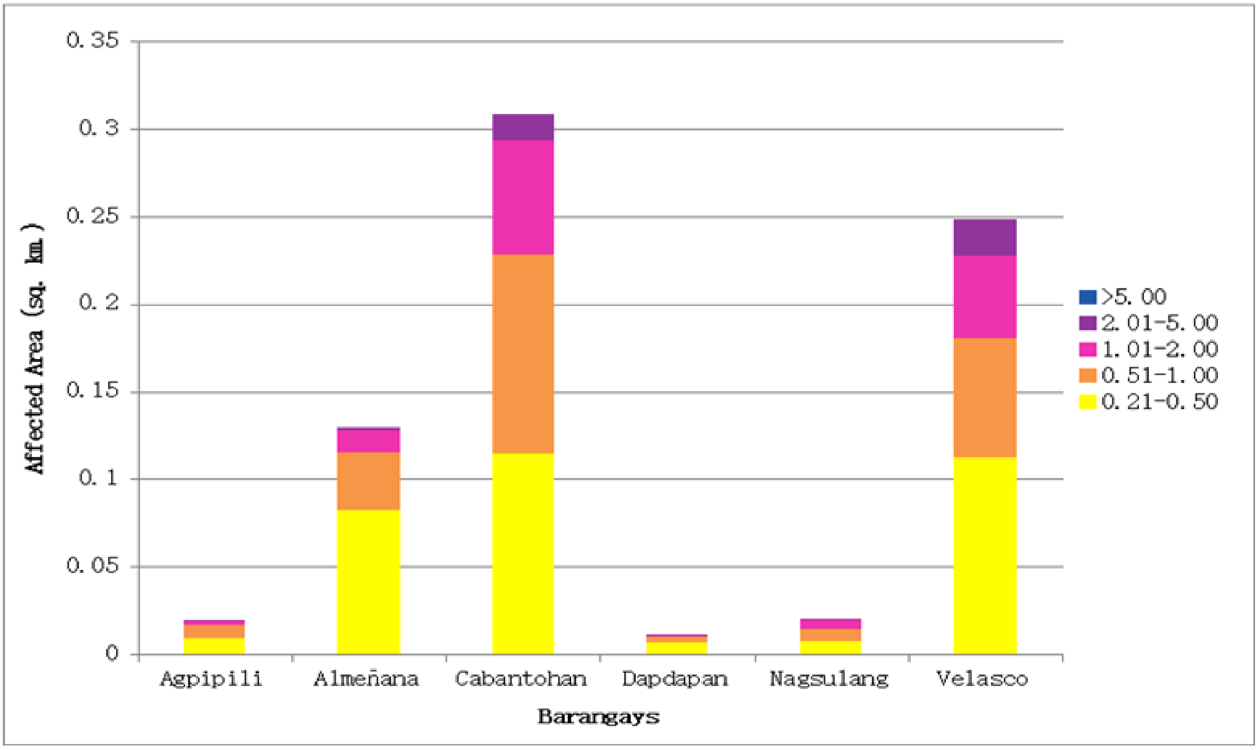


Figure 85. Affected Areas in Lemery, Iloilo during 25-Year Rainfall Return Period

For the municipality of San Dionisio, with an area of 118.50 sq. km., 14.08% will experience flood levels of less 0.20 meters. 3.12% of the area will experience flood levels of 0.21 to 0.50 meters while 2.88%, 1.20%, 0.020%, and 0.0002% 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 kilometres by flood depth per barangay.

Table 49. Affected Areas in San Dionisio, Iloilo during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Dionisio (in sq. km.)												
	Bondulan	Capinang	Dugman	Moto	Nipa	Pangi	Pase	Poblacion	San Nicolas	Santol	Siempreviva	Tiabas	Tuble
0.03-0.20	1.21	1.35	2.91	2.81	0.9	0.42	0.91	0.85	0.2	0.44	0.87	2.64	1.18
0.21-0.50	0.51	0.09	1.03	0.69	0.11	0.04	0.25	0.1	0	0.16	0.25	0.11	0.35
0.51-1.00	1.31	0.06	0.57	0.17	0.02	0.03	0.13	0.11	0	0.27	0.41	0.06	0.26
1.01-2.00	0.22	0.08	0.43	0.05	0	0	0.02	0.12	0	0.06	0.15	0.03	0.25
2.01-5.00	0	0.01	0	0	0	0	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0

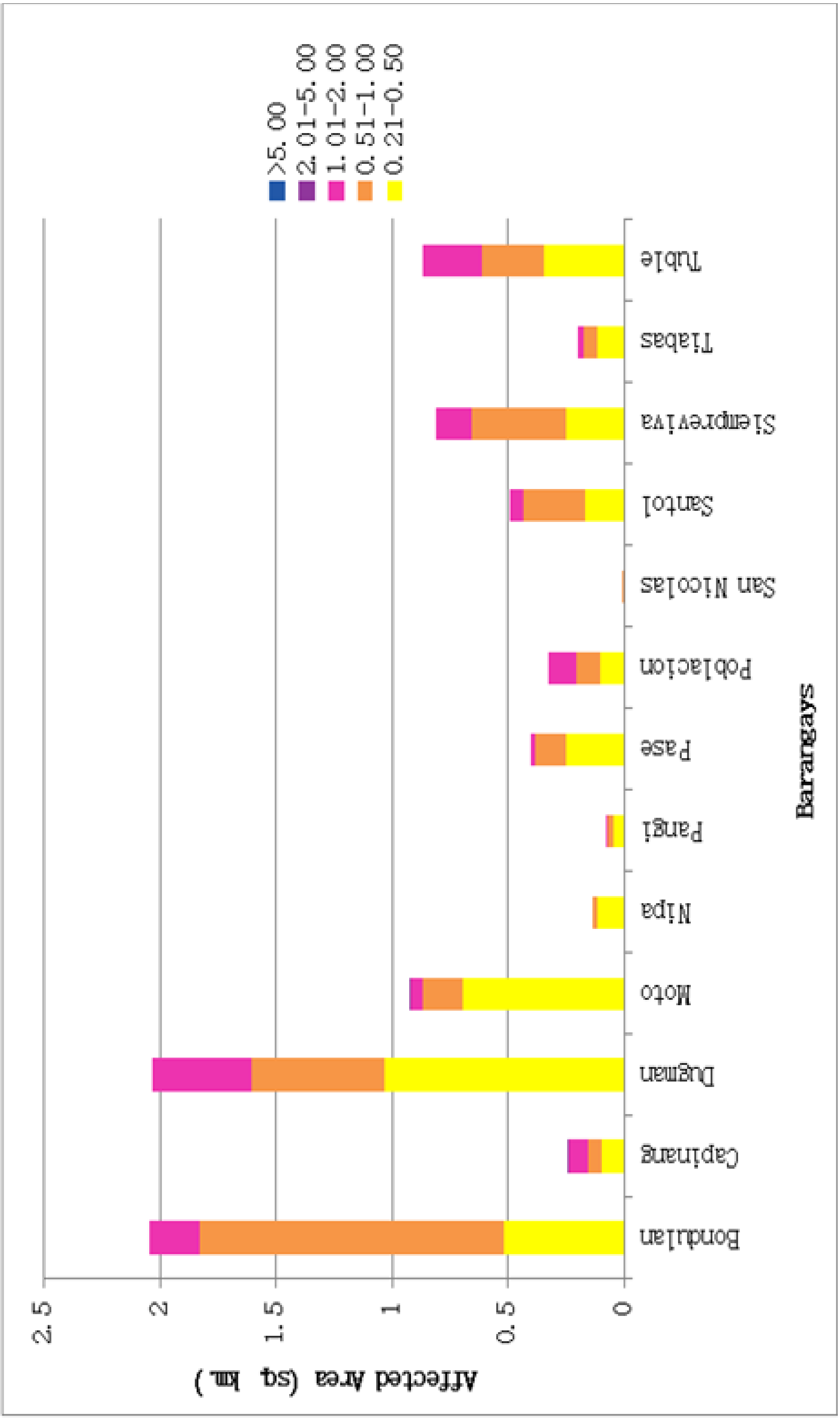


Figure 86. Affected Areas in San Diosio, Iloilo during 25-Year Rainfall Return Period

For the municipality of Sara, with an area of 184.63 sq. km., 29.60% will experience flood levels of less 0.20 meters. 6.16% of the area will experience flood levels of 0.21 to 0.50 meters while 8.04%, 4.17%, 0.63%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 to Table 52 are the affected areas in square kilometres by flood depth per barangay.

Table 50. Affected Areas in Sara, Iloilo during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sara (in sq. km.)												
	Aguirre	Aldeguer	Alibayog	Anoring	Apelo	Apologista	Aposaga	Arante	Ardemil	Aspera	Aswe-Pabriaga	Bagaygay	Bakabak
0.03-0.20	2.85	2.19	0.95	0.85	1.66	0.55	0.62	3.98	0.24	0.66	0.57	0.65	2.74
0.21-0.50	0.18	0.68	0.21	0.29	0.16	0.16	0.28	0.24	0.01	0.07	0.44	0.08	0.53
0.51-1.00	0.3	0.56	0.56	0.27	0.2	0.49	0.4	0.31	0.01	0.25	0.93	0.26	0.8
1.01-2.00	0.21	0.2	0.15	0.31	0.09	0.19	0.08	0.14	0.01	0.07	0.26	0.48	0.99
2.01-5.00	0.04	0.06	0	0.06	0.01	0.09	0.01	0.03	0	0	0	0.01	0.09
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 51. Affected Areas in Sara, Iloilo during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sara (in sq. km.)													
	Batitao	Bato	Castor	Crespo	Devera	Domingo	Ferraris	Gildore	Improgo	Labigan	Lanciola	Malapaya	Padios	Pasig
0.03-0.20	0.72	1.88	2.26	2.33	0.76	5.09	0.49	0.86	2.72	1.16	1.14	4.16	0.58	0.61
0.21-0.50	0.64	0.15	0.2	0.85	0.57	0.26	0.53	0.09	0.19	0.23	1.05	0.3	0.18	0.1
0.51-1.00	0.64	0.21	0.16	1.14	0.47	0.31	0.78	0.3	0.12	0.83	0.22	0.4	0.5	0.09
1.01-2.00	0.13	0.21	0.12	0.15	0.3	0.23	0.64	0.36	0.13	0.41	0	0.42	0.18	0.01
2.01-5.00	0.03	0.02	0.01	0.01	0	0.09	0.03	0.07	0.08	0.03	0	0.03	0	0
> 5.00	0	0	0	0	0	0.01	0	0.02	0	0	0	0	0	0

Table 52. Affected Areas in Sara, Iloilo during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Poblacion Ilawod	Poblacion Ilaya	Poblacion Market	Posadas	Preciosa	Salcedo	San Luis	Tentay	Villahermosa	Zerrudo
0.03-0.20	0.45	0.33	0.36	1.78	2.18	0.45	0.94	1.71	1.05	2.13
0.21-0.50	0.27	0.04	0.04	0.3	0.18	0.31	0.42	0.3	0.43	0.44
0.51-1.00	0.29	0.08	0.09	0.22	0.31	0.56	0.63	0.32	0.51	0.34
1.01-2.00	0.06	0.02	0.21	0.04	0.12	0.09	0.28	0.15	0.09	0.2
2.01-5.00	0	0	0	0.01	0.03	0.01	0	0.26	0	0.04
> 5.00	0	0	0	0	0	0	0	0.02	0	0

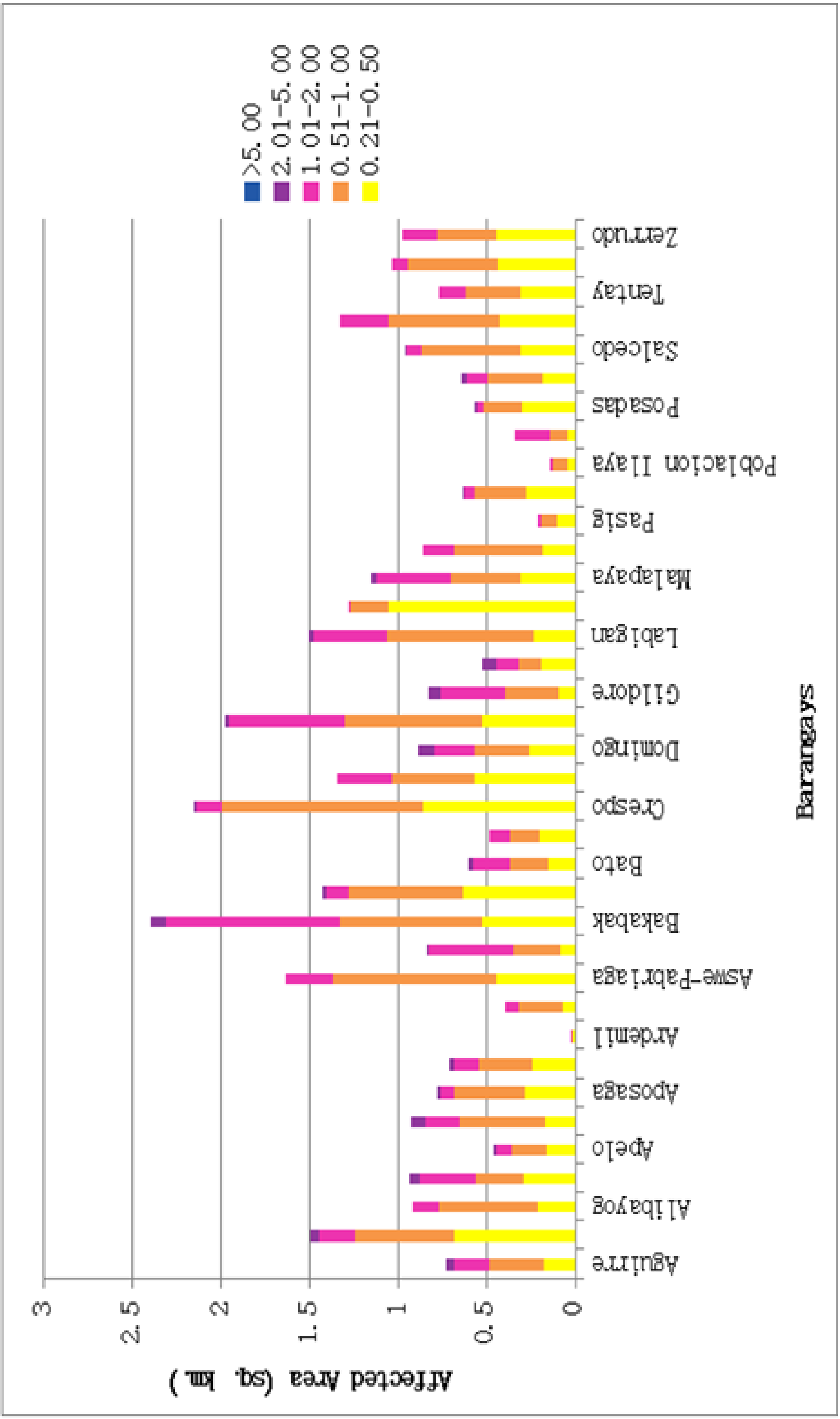


Figure 87. Affected Areas in Sara, Iloilo during 25-Year Rainfall Return Period

For the 100-year return period, 30.87% of the municipality of Ajuy with an area of 170.88 sq. km. will experience flood levels of less 0.20 meters. 5.21% of the area will experience flood levels of 0.21 to 0.50 meters while 4.49%, 3.89%, 1.31%, and 0.14% 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 53 and Table 54 are the affected areas in square kilometres by flood depth per barangay.

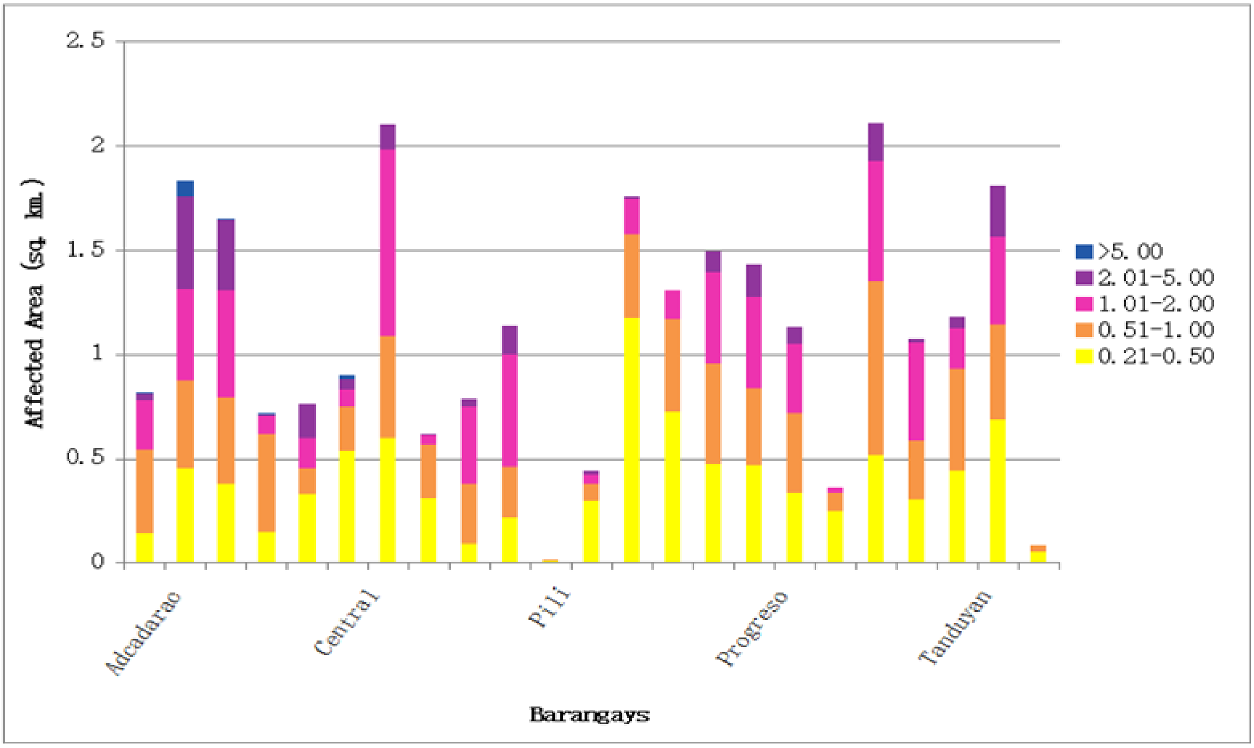


Figure 88. Affected Areas in Ajuy, Iloilo during 100-Year Rainfall Return Period

Table 53. Affected Areas in Ajuy, Iloilo during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ajuy (in sq. km.)											
	Adcadarao	Agbobolo	Badiangan	Bato Biasong	Bucana Bunglas	Central	Lanjagan	Mangorocoro	Pantalan Nabaye	Pantalan Navarro	Pili	Pinantan Diel
0.03-0.20	0.7	12.13	10.8	0.54	0.86	1.78	1.52	0.76	0.26	0.69	0.06	0.64
0.21-0.50	0.14	0.45	0.38	0.15	0.33	0.54	0.6	0.31	0.09	0.21	0.01	0.3
0.51-1.00	0.4	0.43	0.41	0.47	0.13	0.21	0.49	0.26	0.29	0.25	0	0.08
1.01-2.00	0.24	0.43	0.52	0.09	0.14	0.08	0.89	0.04	0.37	0.54	0	0.05
2.01-5.00	0.03	0.45	0.34	0.01	0.17	0.05	0.12	0	0.04	0.13	0	0.02
> 5.00	0.01	0.07	0.01	0	0	0.02	0	0	0	0	0	0

Table 54. Affected Areas in Ajuy, Iloilo during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Ajuy (in sq. km.)										
	Pinantan Elizalde	Pinay Espinosa	Poblacion	Progreso	Puente Bunglas	Rojas	San Antonio	Taguhangin	Tanduyan	Tipacla	Tubogan
0.03-0.20	0.77	0.8	2.24	7.3	0.46	0.29	3.01	0.36	1.79	3.94	1.08
0.21-0.50	1.17	0.72	0.47	0.46	0.33	0.24	0.52	0.31	0.44	0.69	0.05
0.51-1.00	0.4	0.44	0.48	0.37	0.38	0.09	0.83	0.28	0.49	0.46	0.04
1.01-2.00	0.17	0.14	0.43	0.44	0.34	0.02	0.58	0.47	0.2	0.42	0.04
2.01-5.00	0.01	0	0.1	0.15	0.08	0	0.18	0.02	0.06	0.24	0.03
> 5.00	0	0	0	0.01	0	0	0.01	0	0.01	0.1	0.01

For the municipality of Concepcion, with an area of 85.80 sq. km., 32.20% will experience flood levels of less 0.20 meters. 2.97% of the area will experience flood levels of 0.21 to 0.50 meters while 4.35%, 2.80%, 0.66%, and 0.0002 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 kilometres by flood depth per barangay.

Table 55. Affected areas in Concepcion, Iloilo during a 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Concepcion (in sq. km.)												
	Aglosong	Agnaga	Bacjawan Norte	Bacjawan Sur	Batiti	Calamigan	Jamul-Awon	Macalbang	Niño	Nipa	Plandico	Poblacion	Tamis-Ac
0.03-0.20	4.51	0.58	1.92	2.4	1.84	2.67	2.02	6.52	1.09	1.23	1.7	0.38	0.78
0.21-0.50	0.46	0.2	0.15	0.27	0.21	0.21	0.11	0.42	0.1	0.03	0.18	0.04	0.19
0.51-1.00	0.67	0.37	0.16	0.2	0.43	0.23	0.14	1.07	0.08	0.01	0.14	0.04	0.21
1.01-2.00	0.38	0.36	0.07	0.13	0.24	0.1	0.13	0.71	0.01	0	0.09	0.03	0.16
2.01-5.00	0.05	0.04	0	0.04	0.01	0.07	0.01	0.17	0	0	0	0	0.16
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0

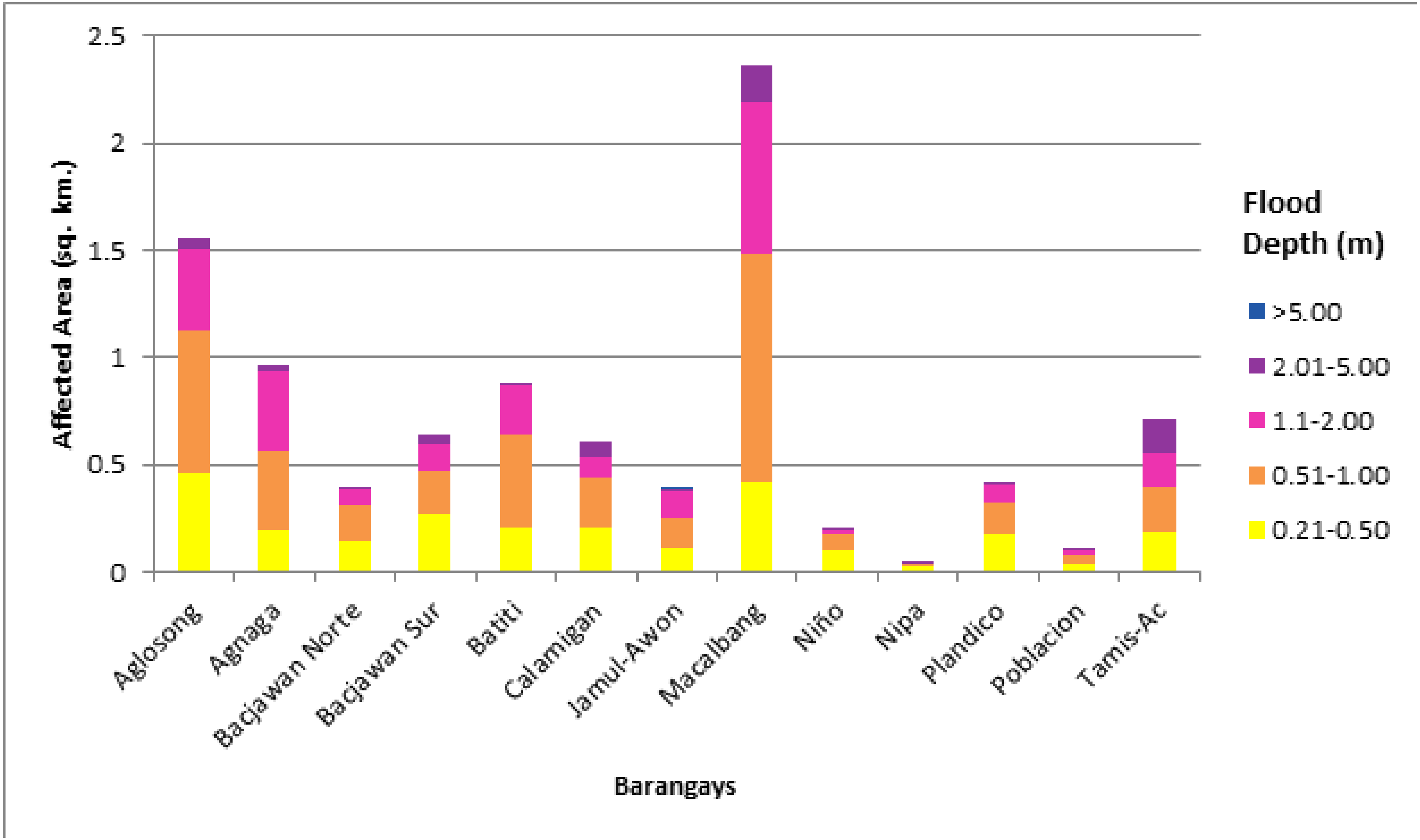


Figure 89. Affected Areas in Concepcion, Iloilo during 100-Year Rainfall Return Period

For the municipality of Lemery, with an area of 149.38 sq. km., 3.01% will experience flood levels of less 0.20 meters. 0.22% of the area will experience flood levels of 0.21 to 0.50 meters while 0.16%, 0.089%, 0.027%, and 0.0001% 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 kilometres by flood depth per barangay.

Table 56. Affected Areas in Lemery, Iloilo during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Lemery (in sq. km.)					
	Agpipili	Almeñana	Cabantohan	Dapdapan	Nagsulang	Velasco
0.03-0.20	0.27	0.65	2.27	0.17	0.15	0.93
0.21-0.50	0.01	0.07	0.1	0.01	0.01	0.11
0.51-1.00	0.01	0.04	0.13	0	0.01	0.08
1.01-2.00	0	0.02	0.07	0	0.01	0.05
2.01-5.00	0	0	0.02	0	0	0.03
> 5.00	0	0	0	0	0	0

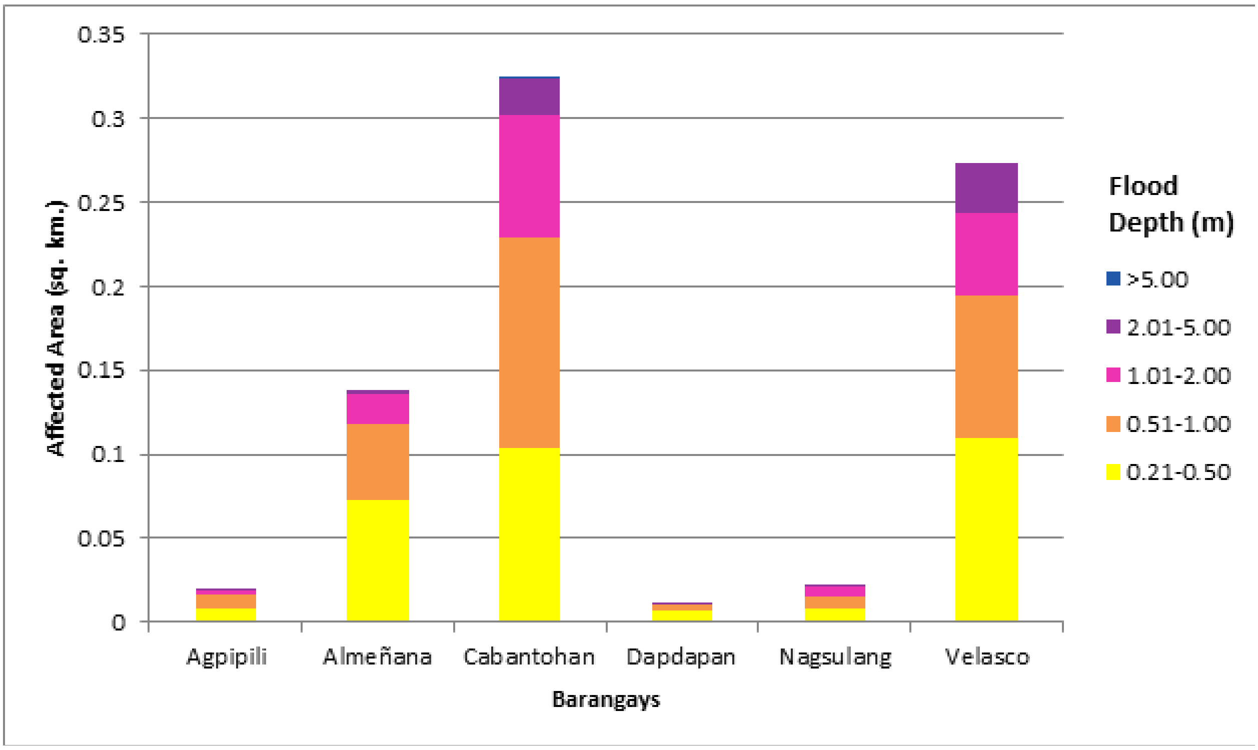


Figure 90. Affected Areas in Lemery, Iloilo during 100-Year Rainfall Return Period

For the municipality of San Dionisio, with an area of 118.50 sq. km., 13.37% will experience flood levels of less 0.20 meters. 2.88% of the area will experience flood levels of 0.21 to 0.50 meters while 3.05%, 1.97%, 0.033%, and 0.0002% 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 kilometres by flood depth per barangay.

Table 57. Affected Areas in San Dionisio, Iloilo during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Dionisio (in sq. km.)												
	Bondulan	Capinang	Dugman	Moto	Nipa	Pangi	Pase	Poblacion	San Nicolas	Santol	Siempreviva	Tiabas	Tuble
0.03-0.20	1.14	1.32	2.63	2.66	0.89	0.41	0.86	0.83	0.19	0.41	0.82	2.62	1.06
0.21-0.50	0.32	0.1	1.03	0.69	0.11	0.04	0.25	0.09	0	0.1	0.17	0.13	0.37
0.51-1.00	1.32	0.06	0.6	0.3	0.05	0.03	0.16	0.11	0	0.25	0.43	0.06	0.23
1.01-2.00	0.47	0.11	0.67	0.07	0	0.01	0.04	0.14	0	0.17	0.25	0.04	0.38
2.01-5.00	0	0.01	0.01	0	0	0	0	0	0	0	0	0	0.01
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0

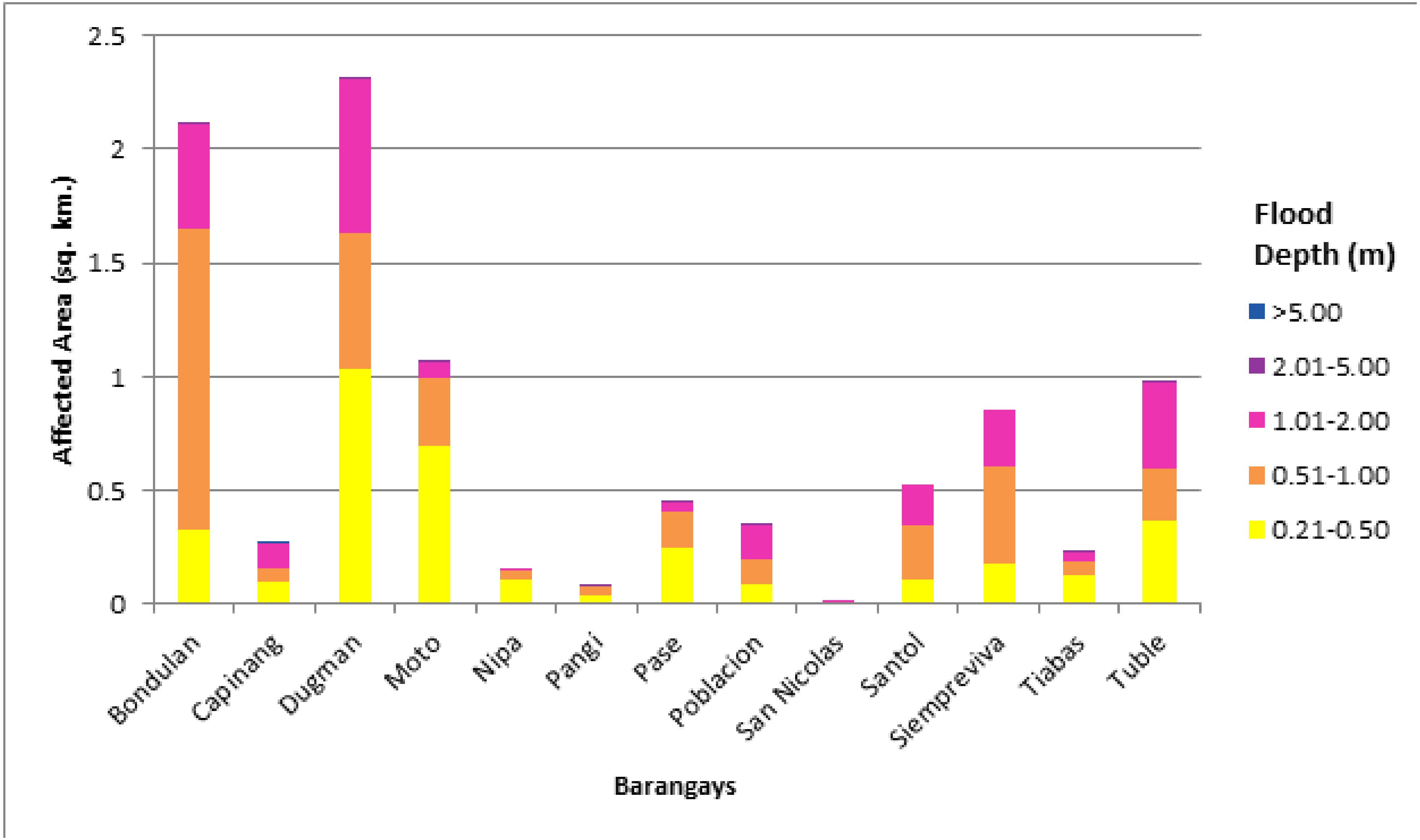


Figure 91. Affected Areas in San Dionisio, Iloilo during 100-Year Rainfall Return Period

For the municipality of Sara, with an area of 184.63 sq. km., 27.89% will experience flood levels of less 0.20 meters. 5.36% of the area will experience flood levels of 0.21 to 0.50 meters while 7.85%, 6.32%, 1.79%, and 0.04% 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 58 to Table 60 are the affected areas in square kilometres by flood depth per barangay.

Table 58. Affected Areas in Sara, Iloilo during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sara (in sq. km.)												
	Aguirre	Aldeguer	Alibayog	Anoring	Apelo	Apologista	Aposaga	Arante	Ardemil	Aspera	Aswe-Pabriaga	Bagaygay	Bakabak
0.03-0.20	2.82	1.99	0.88	0.78	1.63	0.5	0.59	3.94	0.23	0.64	0.5	0.61	2.56
0.21-0.50	0.16	0.73	0.16	0.23	0.14	0.11	0.23	0.22	0.01	0.05	0.25	0.06	0.49
0.51-1.00	0.25	0.64	0.56	0.35	0.21	0.38	0.35	0.29	0	0.18	0.91	0.19	0.58
1.01-2.00	0.28	0.26	0.27	0.33	0.12	0.36	0.21	0.2	0.01	0.18	0.53	0.57	1.12
2.01-5.00	0.07	0.07	0	0.1	0.02	0.12	0.01	0.04	0	0	0.01	0.04	0.38
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 59. Affected Areas in Sara, Iloilo during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sara (in sq. km.)													
	Batitao	Bato	Castor	Crespo	Devera	Domingo	Ferraris	Gildore	Improgo	Labigan	Lanciola	Malapaya	Padios	Pasig
0.03-0.20	0.5	1.86	2.19	2.16	0.61	5.02	0.32	0.83	2.67	1.11	0.72	4.1	0.51	0.61
0.21-0.50	0.59	0.13	0.23	0.71	0.43	0.26	0.3	0.05	0.19	0.13	1.14	0.27	0.12	0.08
0.51-1.00	0.67	0.17	0.18	1.19	0.63	0.28	0.64	0.16	0.13	0.77	0.52	0.38	0.33	0.11
1.01-2.00	0.36	0.27	0.14	0.41	0.42	0.29	1.01	0.49	0.14	0.52	0.03	0.49	0.47	0.02
2.01-5.00	0.03	0.06	0.01	0.02	0	0.11	0.19	0.15	0.11	0.13	0	0.06	0.01	0
> 5.00	0	0	0	0	0	0.01	0	0.02	0	0	0	0.01	0	0

Table 60. Affected Areas in Sara, Iloilo during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Poblacion Ilawod	Poblacion Ilaya	Poblacion Market	Posadas	Preciosa	Salcedo	San Luis	Tentay	Villahermosa	Zerrudo
0.03-0.20	0.33	0.33	0.34	1.73	2.14	0.28	0.81	1.62	0.97	2.04
0.21-0.50	0.28	0.03	0.04	0.28	0.15	0.23	0.4	0.29	0.33	0.39
0.51-1.00	0.33	0.08	0.06	0.27	0.32	0.52	0.5	0.34	0.62	0.4
1.01-2.00	0.1	0.03	0.25	0.04	0.16	0.37	0.56	0.19	0.16	0.27
2.01-5.00	0.02	0	0.01	0.01	0.04	0.01	0	0.29	0	0.05
> 5.00	0	0	0	0	0	0	0	0.02	0	0.01

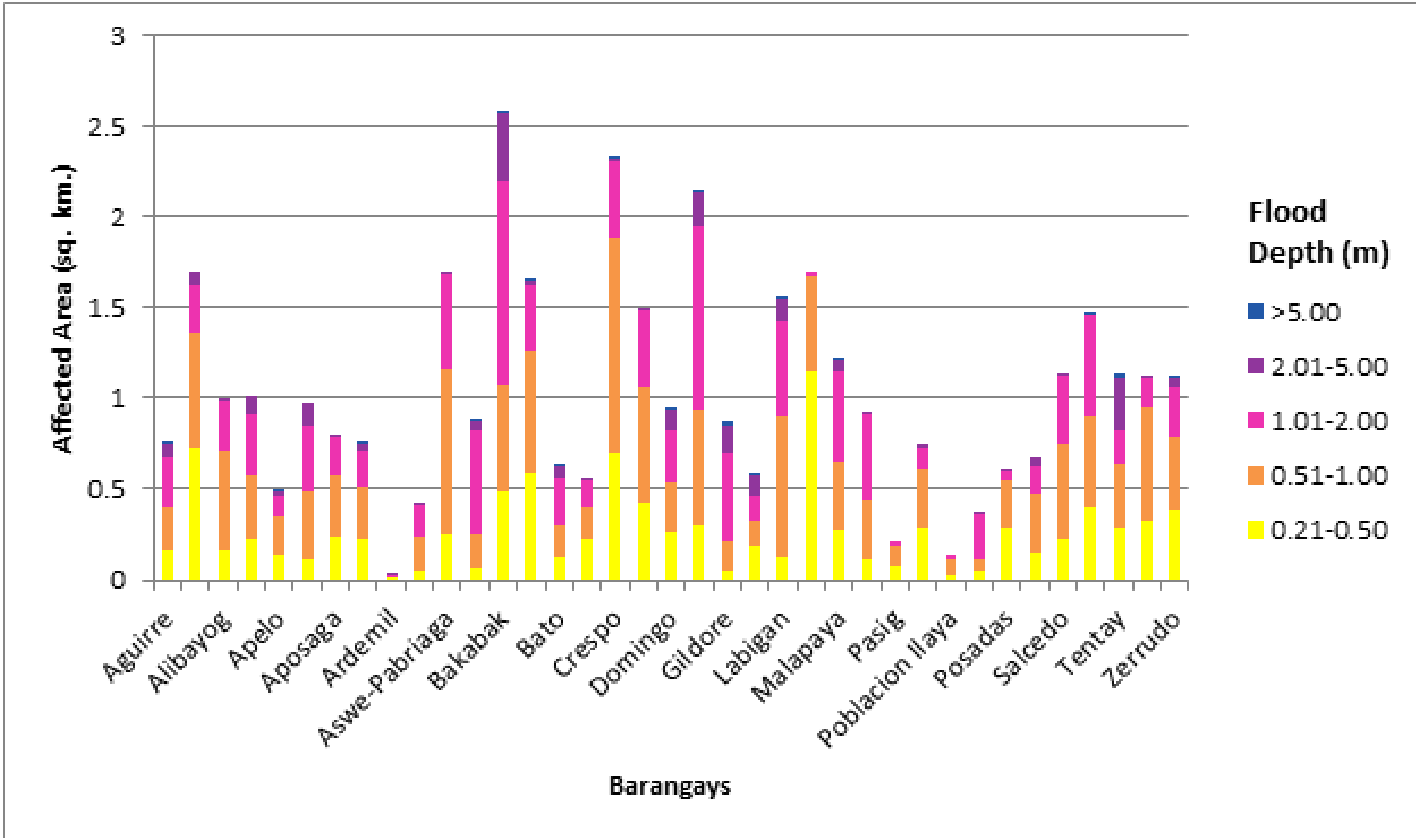


Figure 92. Affected Areas in Sara, Iloilo during 100-Year Rainfall Return Period

Among the barangays in the municipality of Ajuy, Agbobolo is projected to have the highest percentage of area that will experience flood levels at 8.17%. Meanwhile, Badiangan posted the second highest percentage of area that may be affected by flood depths at 7.29%.

Among the barangays in the municipality of Concepcion, Macalbang is projected to have the highest percentage of area that will experience flood levels at 10.35%. Meanwhile, Aglosong posted the second highest percentage of area that may be affected by flood depths at 7.07%.

Among the barangays in the municipality of Lemery, Cabantohan is projected to have the highest percentage of area that will experience flood levels at 1.74%. Meanwhile, Velcaso posted the second highest percentage of area that may be affected by flood depths at 0.80%.

Among the barangays in the municipality of San Dionisio, Dugman is projected to have the highest percentage of area that will experience flood levels at 4.17%. Meanwhile, Bondulan posted the second highest percentage of area that may be affected by flood depths at 7.07%.

Among the barangays in the municipality of Sara, Domingo is projected to have the highest percentage of area that will experience flood levels at 3.24%. Meanwhile, Crespo posted the second highest percentage of area that may be affected by flood depths at 2.43%.

Moreover, the generated flood hazard maps for the Pinantan Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps - "Low", "Medium", and "High" - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr).

Table 61. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	31.13	28.32	25.99
Medium	28.04	41.36	46.58
High	4.27	8.22	12.81
TOTAL	**63.44**	**77.9**	**85.38**

Of the ninety-two (92) identified Education Institute in the Pinantan Flood plain, 11 schools were assessed to be exposed to the low level flooding during a 5 year scenario, while 6 schools were assessed to be exposed to medium level flooding, and 1 school was assessed to be exposed to the high level flooding in the same scenario. In the 25 year scenario, 12 schools were assessed to be exposed to the low level flooding scenario, while 12 schools were assessed to be exposed to medium level flooding, and 1 school was assessed to be exposed to the high level flooding in the same scenario. . In the 100 year scenario, 13 schools were assessed to be exposed to the low level flooding scenario, while 15 schools were assessed to be exposed to medium level flooding, and 1 school was assessed to be exposed to the high level flooding in the same scenario. This educational institution is Eucharistic King Academy, which is located at Barangay Anoring. The educational institutions exposed to flooding are shown in Annex 12.

Of the thirty-seven (37) Medical Institutions identified in Pinantan Floodplain, 5 were assessed to be exposed to the low level flooding during a 5 year scenario, while 1 was assessed to be exposed to the medium level flooding scenario. In the 25 year scenario, 5 were assessed to be exposed to the low level flooding scenario, while 3 were assessed to be exposed to the medium level flooding scenario. In the 100 year scenario, 7 were assessed to be exposed to the low level flooding scenario, while 4 were assessed to be exposed to the medium level flooding scenario. The medical institutions exposed to flooding are found in Annex 13.

5.11 Flood Validation

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

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

The validation personnel went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events and interview of some residents with knowledge of or have had experienced flooding in a particular area. The flood validation points were obtained on February 8, 2017.

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 93.

The flood validation consists of 115 points randomly selected all over the Pinantan floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 2.57m. Table 62 shows a contingency matrix of the comparison.

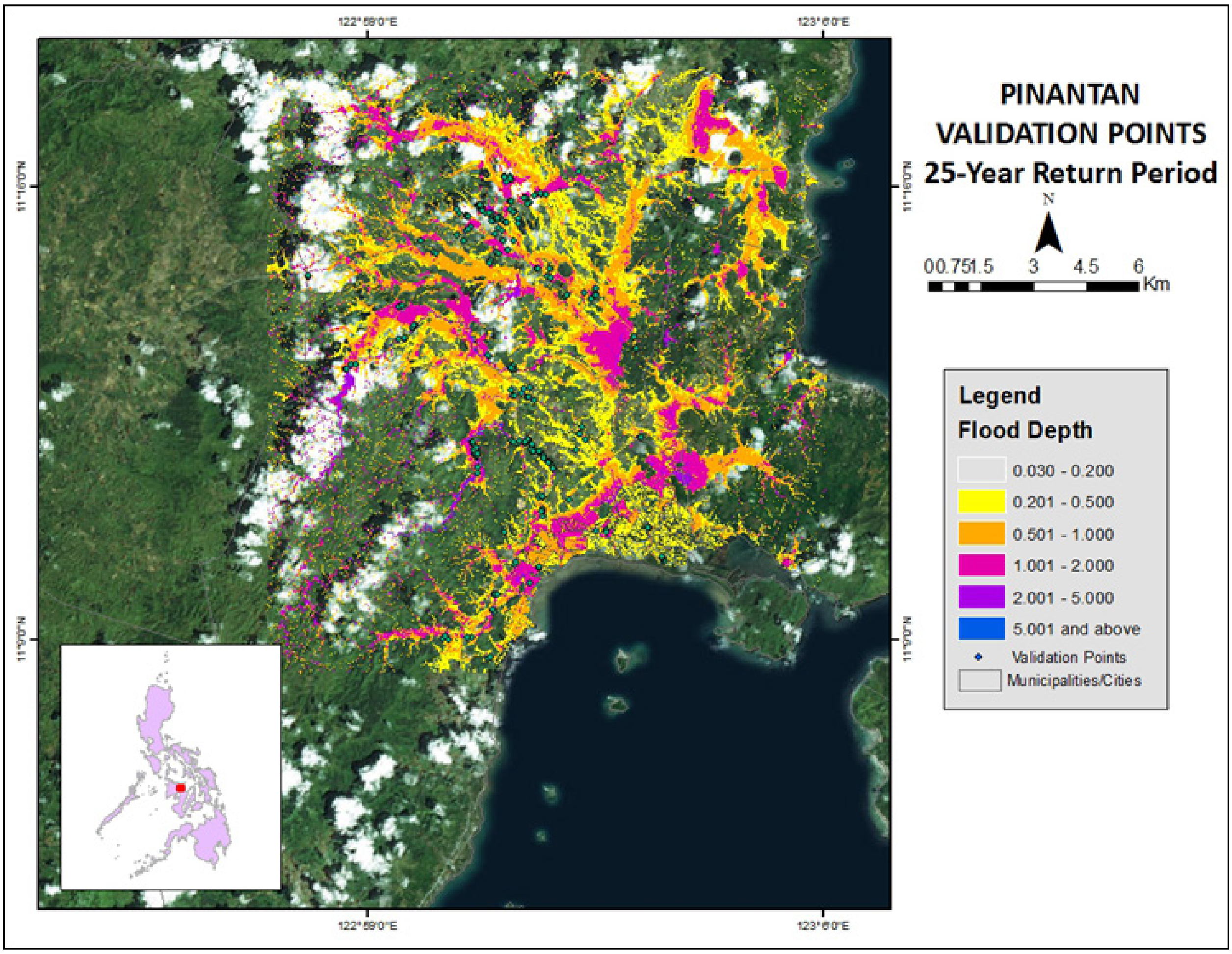


Figure 93. Pinantan Flood Validation Points

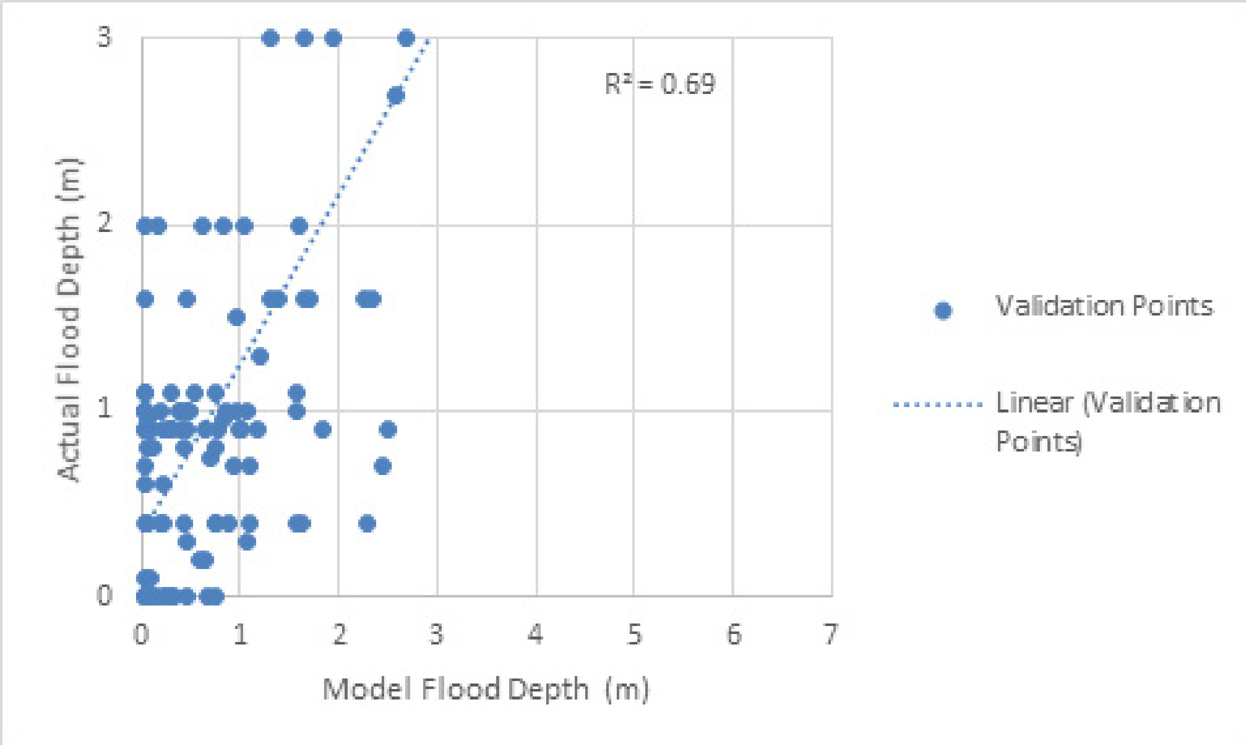


Figure 94. Flood map depth vs. actual flood depth

Table 62. Actual flood vs simulated flood depth at different levels in the Pinantan 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	12	5	4	0	0	0	21
0.21-0.50	3	3	3	4	1	0	14
0.51-1.00	18	12	9	6	2	0	47
1.01-2.00	5	2	5	8	2	0	22
2.01-5.00	0	0	0	3	4	0	7
> 5.00	0	0	0	0	1	3	4
Total	38	22	21	21	10	3	115

The overall accuracy generated by the flood model is estimated at 33.91% with 39 points correctly matching the actual flood depths. In addition, there were 28 points estimated one level above and below the correct flood depths while there were 30 points and 6 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 49 points were underestimated in the modelled flood depths of Pinantan. Table 63 depicts the summary of the Accuracy Assessment in the Pinantan River Basin Survey.

Table 63. Summary of the Accuracy Assessment in the Pinantan River Basin Survey

	No. of Points	%
Correct	39	33.91
Overestimated	27	23.48
Underestimated	49	42.61
Total	**115**	**100.00**

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ANNEXES

Annex 1. Optech Technical Specification of the Sensors Used in the Pinantan LiDAR Data Acquisition Surveys

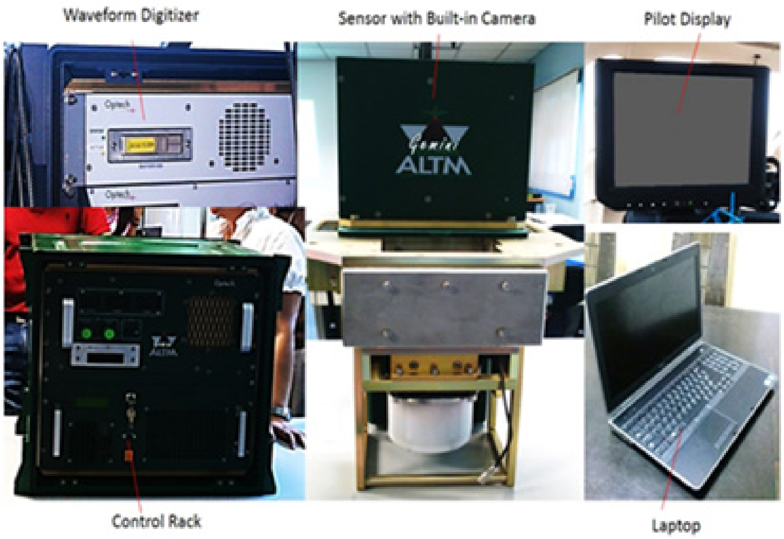


Figure A-1.1. Parameters and Specification of Gemini Sensor

Table A-1.1. Parameters and Specification of Gemini Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM);
220-channel dual frequency GPS/ GNSS/Galileo/L-Band receiver	Programmable, 0-75 ˚
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	-10°C to +35°C
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-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

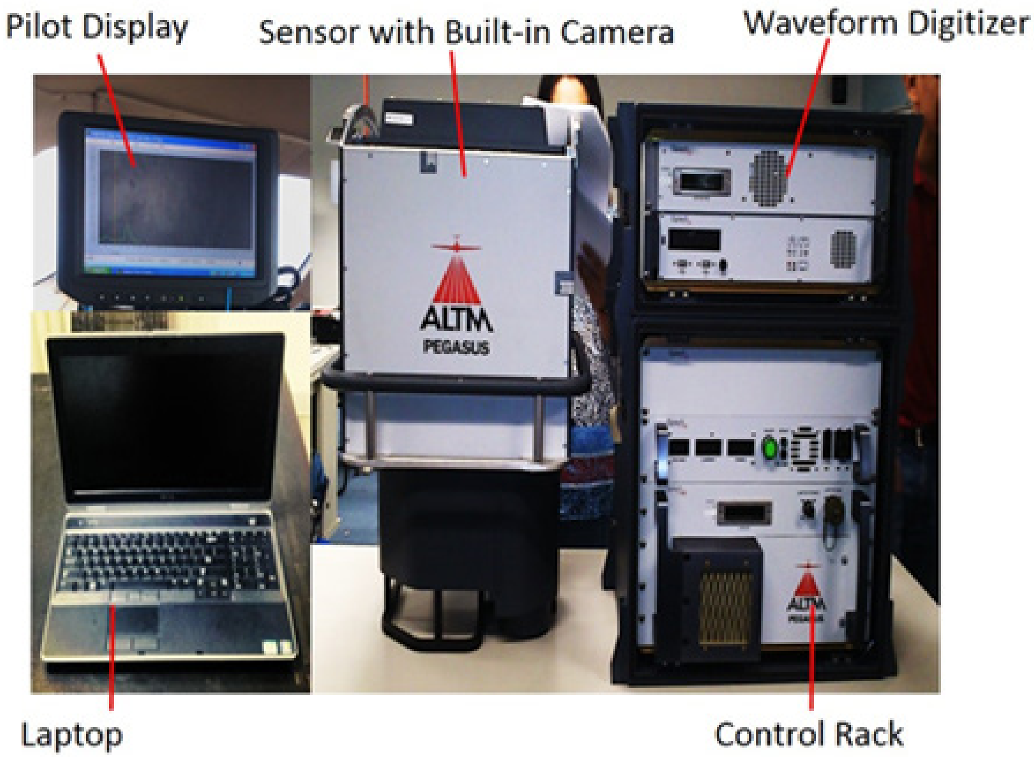


Figure A-1.2. Parameters and Specification of Pegasus Sensor

Table A-1.2. Parameters and Specification of Pegasus Sensor

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

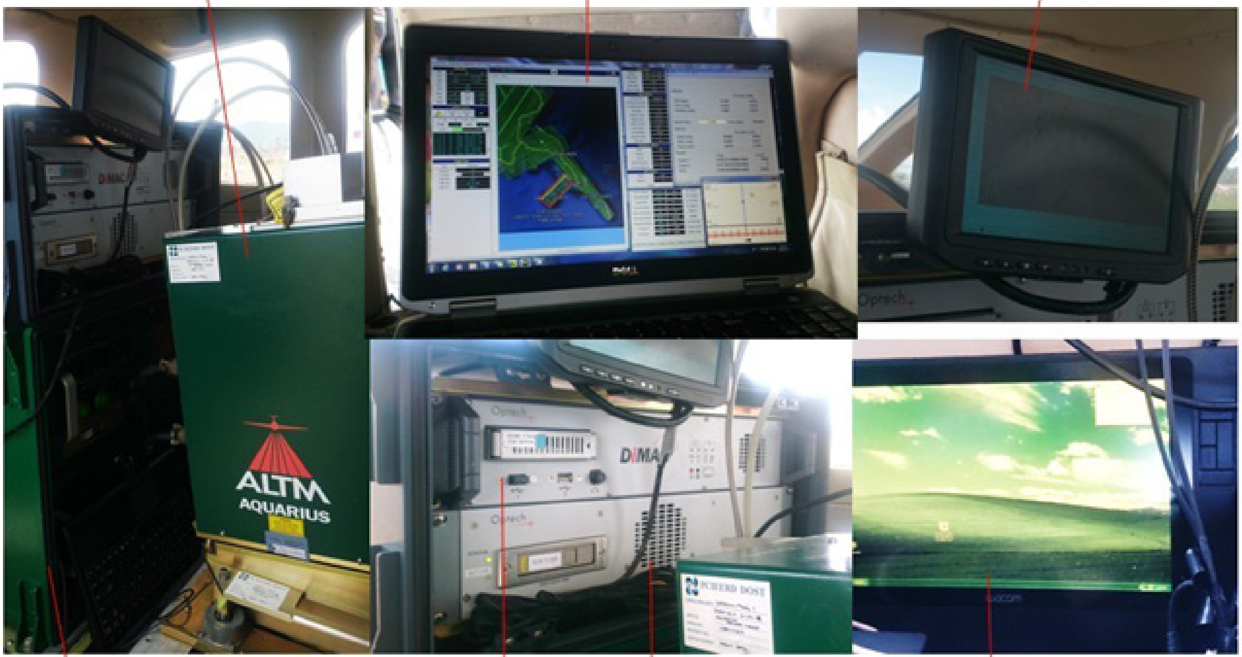


Figure A-1.3. Parameters and Specification of Aquarius Sensor

Table A-1.3. Parameters and Specification of Aquarius Sensor

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

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

1. ILO-70

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

July 07, 2015

CERTIFICATION

To whom it may concern:

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

Province: **ILOILO**
Station Name: **ILO-70**
Order: **2nd**

Island: **VISAYAS**	Barangay: **POBLACION**	
Municipality: **BINGAWAN**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **11° 13' 50.08819"**	Longitude: **122° 33' 56.83732"**	Ellipsoidal Hgt: **76.80300 m.**
	WGS84 Coordinates	
Latitude: **11° 13' 45.61545"**	Longitude: **122° 34' 2.01364"**	Ellipsoidal Hgt: **133.08400 m.**
	PTM / PRS92 Coordinates	
Northing: **1241867.057 m.**	Easting: **452584.677 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,241,432.38**	Easting: **452,601.27**	Zone: **51**

Location Description

ILO-70
Is located on the land property of Mayor Ted Peter Plagata, 50 m. SE of the cell site tower. The said tower is W of the cockpit arena. It is also situated at the intersection of a ricefield dike about 20 m. S of the Smart cell site gate. Mark is the head of a 4 in. concrete nail embedded and centered on a 30 cm. x 30 cm. concrete monument, with inscriptions "ILO-70 2005 NAMRIA".

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8083657 I**
T.N.: **2015-1500**

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

9 9 0 7 0 7 2 0 1 5 1 5 0 5 2 9

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. ILO-70

2. ILO-71

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

June 15, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **ILOILO**	
	Station Name: **ILO-71**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **POBLACION (SITIO ILOCO)**	
Municipality: **SAN RAFAEL**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **11° 10' 14.95277"**	Longitude: **122° 49' 43.05170"**	Ellipsoidal Hgt: **114.27700 m.**
	WGS84 Coordinates	
Latitude: **11° 10' 10.51756"**	Longitude: **122° 49' 48.23144"**	Ellipsoidal Hgt: **171.35000 m.**
	PTM / PRS92 Coordinates	
Northing: **1235227.808 m.**	Easting: **481282.443 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,234,795.46**	Easting: **481,289.00**	Zone: **51**

Location Description

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

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

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

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

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. ILO-71

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

1. ILO-70 and BM-30

Table A-3.1. ILO-70 and BM-30

Vector Components (Mark to Mark)

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

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

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

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

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

2. ILO-71 and BMIL-608

Table A-3.2. ILO-71 and BMIL-608

Vector Components (Mark to Mark)

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

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

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

Standard Errors

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

3. BRV-1 and BRV-2

Table A-3.3. BRV-1 and BRV-2

Vector Components (Mark to Mark)

From:	BRV-1				
Grid		Local		Global	
Easting	483679.079 m	Latitude	N11°02'23.72962"	Latitude	N11°02'19.32911"
Northing	1220321.718 m	Longitude	E122°51'02.09822"	Longitude	E122°51'07.28940"
Elevation	14.337 m	Height	16.296 m	Height	73.739 m

To:	BRV-2				
Grid		Local		Global	
Easting	485473.040 m	Latitude	N11°01'58.86503"	Latitude	N11°01'54.46766"
Northing	1219557.222 m	Longitude	E122°52'01.23432"	Longitude	E122°52'06.42600"
Elevation	3.306 m	Height	5.276 m	Height	62.776 m

Vector					
ΔEasting	1793.961 m	NS Fwd Azimuth	113°03'10"	ΔX	-1581.340 m
ΔNorthing	-764.496 m	Ellipsoid Dist.	1950.839 m	ΔY	-860.194 m
ΔElevation	-11.031 m	ΔHeight	-11.020 m	ΔZ	-751.884 m

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000006492		
Y	-0.0000003781	0.0000012105	
Z	-0.0000001169	0.0000002315	0.0000002114

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, DR.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. LOVELYN ASUNCION ENGR. GEROME HIPOLITO ENGR. IRO NIEL ROXAS	UP-TCAGP
	Research Associate (RA)	PAULINE JOANNE ARCEO VERLINA TONGA REGINA FELISMINO MARY CATHERINE ELIZABETH BALIGUAS RENAN PUNTO MA. REMEDIOS VILLANUEVA KRISTINE ANDAYA	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN KENNETH QUISADO IRO NIEL ROXAS SANDRA POBLETE	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. LEE JAY PUNZALAN SSG. DAVE GUMBAN	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JACKSON JAVIER CAPT. JEFFREY ALAJAR CAPT. BRYAN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. NEIL ACHILLES AGAWIN CAPT. ALBERT LIM CAPT. HOYA	AAC

Annex 5. Data Transfer Sheet for Pinantan Floodplain

DATA TRANSFER SHEET
7/3/2014(Iloilo)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
25-Feb-15	2602G	2BLK43B056A	GEMINI	NA	278	402	167	8.44	61	5.95	NA	9.49	1KB	1KB	12	17	Z:\DAC\RAW DATA
26-Feb-15	2606G	2BLK43BV057A	GEMINI	NA	739	932	208	22.5	92	12.6	NA	9.26	1KB	1KB	12	18	Z:\DAC\RAW DATA
27-Feb-15	2610G	2BLK43BV058A	GEMINI	NA	100	190	173	2.88	25	2.95	NA	8.94	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
5-Mar-15	2634G	2BLK37FV064A	GEMINI	NA	298	532	170	14.6	122	5.2	NA	22.7	1KB	1KB	8	13	Z:\DAC\RAW DATA
5-Mar-15	2636G	2BLK43OS064B	GEMINI	NA	468	770	205	23.2	106	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. JOAQUIN
Position
Signature

Received by
Name Angelo Carlo Bongat
Position SSRS
Signature

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

DATA TRANSFER SHEET

03/23/2015(Iloilo-peg)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
14-Feb-15	2569P	1BLK43DO45A	pegasus	1.20	840	6.06	196	10.8	30/48	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	26.4	251	19.1	na	17.2	1KB	1KB	77/18	na	Z:\DAC\RAW DATA
17-Feb-15	2581P	1BLK43MNO48A	pegasus	2.06	1.35	9.99	253	34.3	265	21.4	na	20.2	1KB	1KB	76/77/21	na	Z:\DAC\RAW DATA
17-Feb-15	2583P	1BLK43DO48B	pegasus	1.11	716	6.58	170	14	127	11.4	na	20.2	1KB	1KB	96/70	na	Z:\DAC\RAW DATA
18-Feb-15	2585P	1BLK43EFO49A	pegasus	2.91	1.71	9.97	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	130	19.9	16/71	17.4	na	7.48	1KB	1KB	1/92/77	na	Z:\DAC\RAW DATA
19-Feb-15	2589P	1BLK43EFDO50A	pegasus	1.2	739	7.78	417	17.3	131	12.3	na	16.7	1KB	1KB	86/77/120/121	na	Z:\DAC\RAW DATA
19-Feb-15	2591P	1BLK37IO50B	pegasus	5.55	1.02	9.47	199	49.9	343	25.3	na	9.75	1KB	1KB	64	na	Z:\DAC\RAW DATA
20-Feb-15	2593P	1BLK43BDGO51A	pegasus	3.14	1.01	7.62	213	27	218	18.3	na	11	1KB	1KB	114	na	Z:\DAC\RAW DATA
21-Feb-15	2597P	1BLK43NO52A	pegasus	2.09	1.29	6.69	257	37.9	274	21	na	11.5	1KB	1KB	52	na	Z:\DAC\RAW DATA
22-Feb-15	2601P	1BLK37IFVO53A	pegasus	2.13	1.27	9.06	225	32.2	256	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

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

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

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	28	206	13	1.36	10.7	1KB	1KB	19	19	Z:\DAC\RAW DATA
16-Feb-15	2568G	2BLK37GSIV047B	gemini	na	952	1.34	222	46.8	383	21.9	2.12	6.61	1KB	1KB	7/4	15/12	Z:\DAC\RAW DATA
17-Feb-15	2570G	2BLK43H048A	gemini	na	1078	1.43	222	48.5	342	21.7	3.4	14.4	1KB	1KB	3	3	Z:\DAC\RAW DATA
19-Feb-15	2578G	2BLK43GV050A	gemini	na	586	891	184	8.07	67.8	19.4	na	11.1	1KB	1KB	7	na	Z:\DAC\RAW DATA
19-Feb-15	2580G	2BLK43F050B	gemini	na	740	990	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	254	106	6.84	57.4	4.65	ns	11	1KB	1KB	6	13	Z:\DAC\RAW DATA
21-Feb-15	2586G	2BLK43A052A	gemini	na	613	670	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	94.4/628	12.1	na	17	1KB	1KB	5	10	Z:\DAC\RAW DATA
23-Feb-15	2594G	2BLK43C054A	gemini	na	856	1.05	240	28.2	17.2/163	16.3	na	11.6	1KB	1KB	6	14	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position FA
Signature [signature]

Received by

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

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

DATA TRANSFER SHEET
ILOILO 11/14/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
October 23, 2016	8507AC	3BLK37C297A	AQUA CASI	NA	198	686	206	NA	NA	8.18	NA	134	1KB	1KB	16	NA	Z:\DAC\RAW DATA
October 24, 2016	8509AC	3BLK37A298A	AQUA CASI	NA	105	311	204	NA	NA	5.27	NA	127	1KB	1KB	8	20	Z:\DAC\RAW DATA
October 24, 2016	8510AC	3BLK37B298B	AQUA CASI	NA	116	642	160	NA	NA	5.11	NA	127	1KB	1KB	23	NA	Z:\DAC\RAW DATA
October 25, 2016	8511AC	3BLK43KJ299A	AQUA CASI	NA	92	337	217	NA	NA	4.91	NA	71.7	1KB	1KB	9	NA	Z:\DAC\RAW DATA
October 26, 2016	8513AC	3BLK43D300A	AQUA CASI	NA	316	664	244	NA	NA	13.2	NA	208	1KB	1KB	66	NA	Z:\DAC\RAW DATA
October 26, 2016	8514AC	3BLK43G300B	AQUA CASI	NA	41	127	142	NA	NA	2.7	NA	208	1KB	1KB	6	NA	Z:\DAC\RAW DATA
October 27, 2016	8515AC	3BLK43K301A	AQUA CASI	NA	156	273	189	NA	NA	3.35	NA	104	1KB	1KB	5	NA	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature

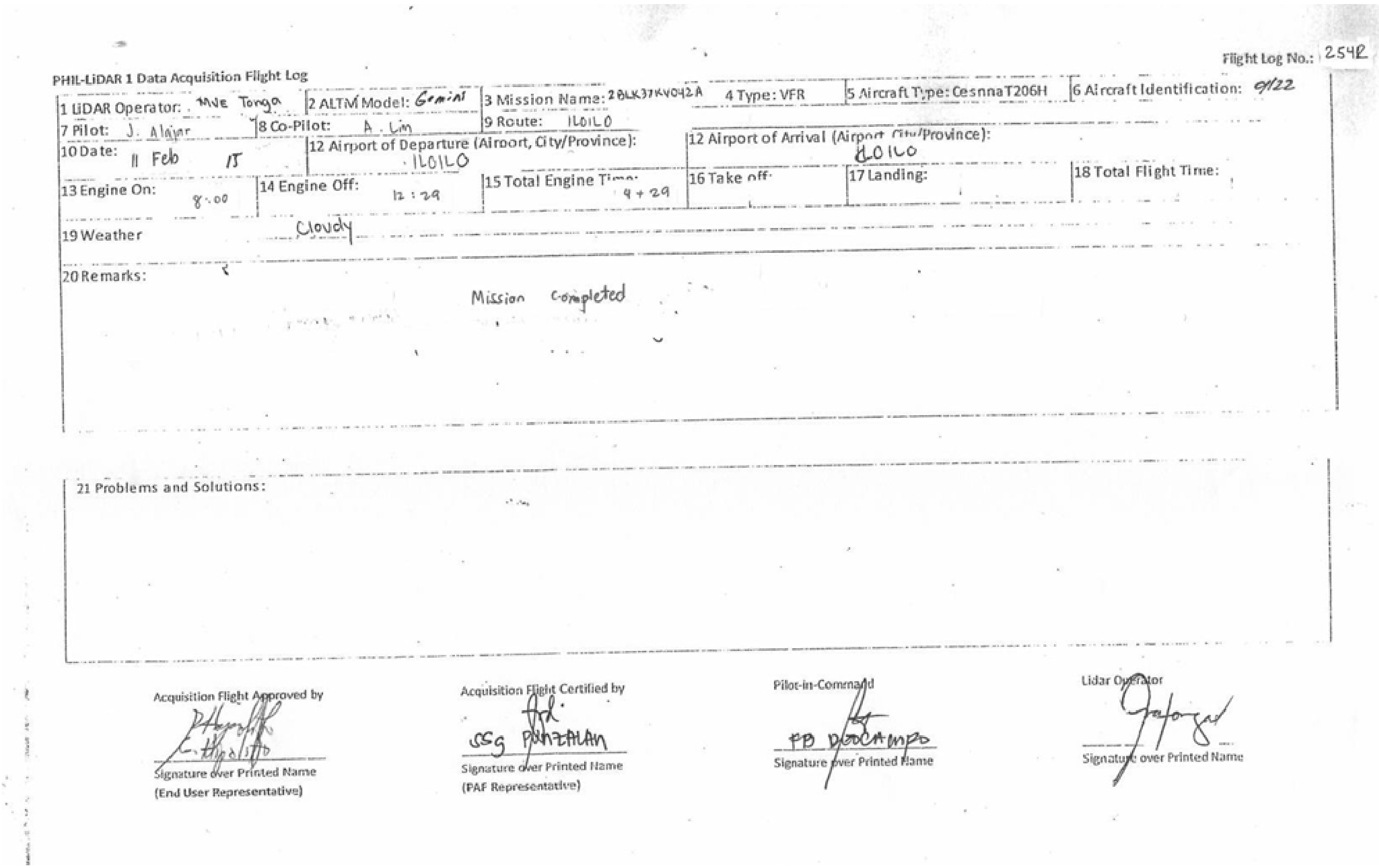
Received by

Name AC Bongat
Position SSRS
Signature 11/22/16

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

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for Mission 2542G



Flight Log No.: 2542

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK37KV042A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: ILOILO			
10 Date: 11 Feb 15	12 Airport of Departure (Airport, City/Province): ILOILO		12 Airport of Arrival (Airport, City/Province): ILOILO		
13 Engine On: 8:00	14 Engine Off: 12:29	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Mission completed					
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 PANTALAN Signature over Printed Name (PAF Representative)	FB DOCAMPO Signature over Printed Name	Signature over Printed Name

Figure A-6.1. Flight Log for Mission 2542G

2. Flight Log for 2544G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2544G

1 LiDAR Operator: RAC FELISMINO	2 ALTM Model: GEMINI	3 Mission Name: 2BLK37F 041B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. ALAJAR	8 Co-Pilot: J A. LIM	9 Route: ILOILO			
10 Date: 10 Feb 15	12 Airport of Departure (Airport, City/Province): ILOILO		12 Airport of Arrival (Airport, City/Province): ILOILO		
13 Engine On: 14:09	14 Engine Off: 18:32	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Mission Completed					
21 Problems and Solutions:					

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

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

Pilot-in-Command: FB DOCAMPO — Signature over Printed Name

Lidar Operator: RAC FELISMINO — Signature over Printed Name

Figure A-6.2. Flight Log for Mission 2544G

3. Flight Log for 2546G Mission

Flight Log No.: 2546

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK37KV042A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: ILOILO			
10 Date: 11 Feb 15	12 Airport of Departure (Airport, City/Province): ILOILO		12 Airport of Arrival (Airport, City/Province): ILOILO		
13 Engine On: 8:00	14 Engine Off: 12:23	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Mission completed for BLK37 K and covered voids of BLK37'A

21 Problems and Solutions:

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

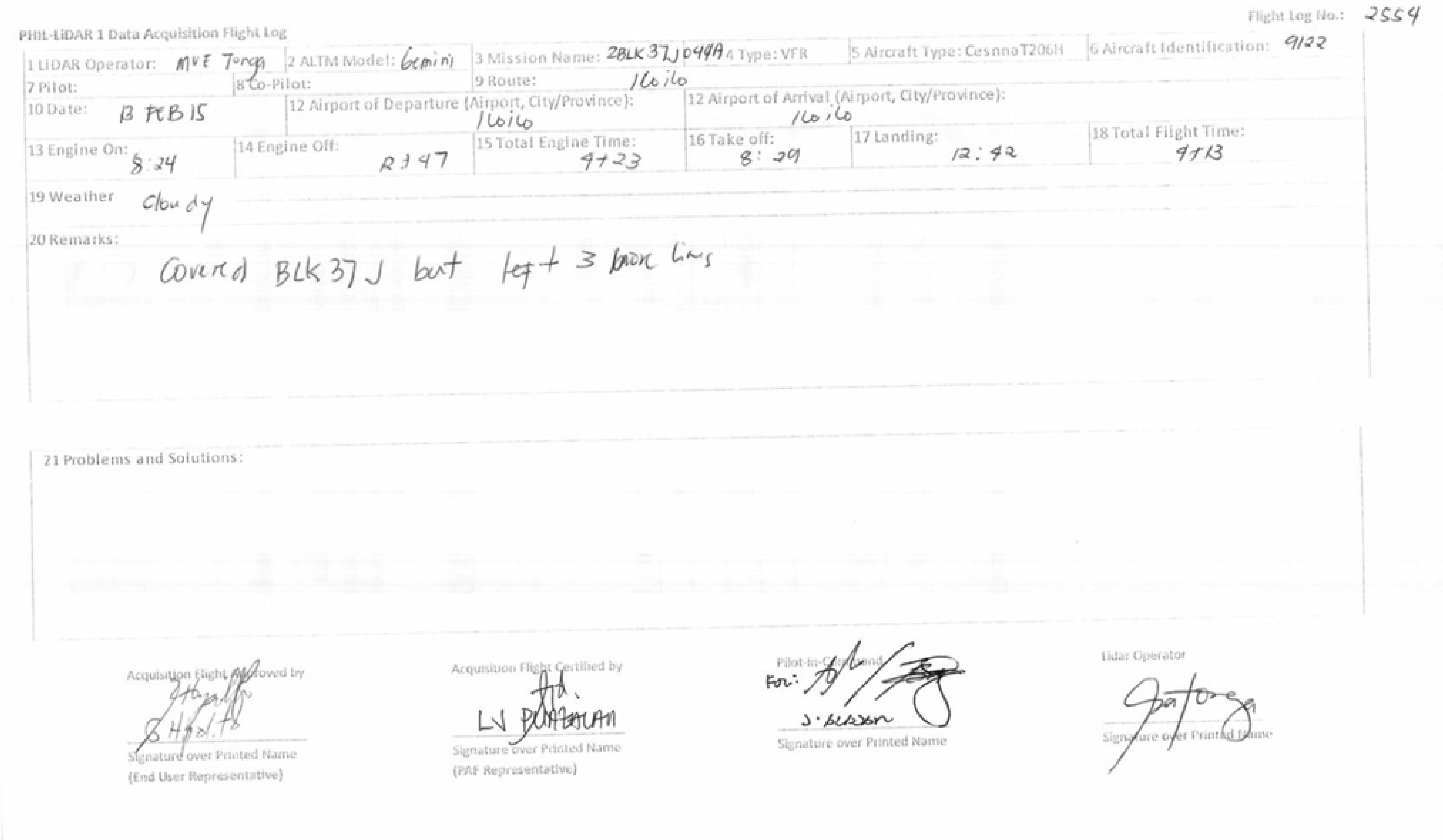
Acquisition Flight Certified by
SSG Pantalan
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
PB Docampo
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.3. Flight Log for Mission 2546G

4. Flight Log for 2554G Mission


Flight Log No.: 2554

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: MVE Tongo	2 ALTM Model: Gemini	3 Mission Name: 2BLK37J049A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot:	8 Co-Pilot:	9 Route: Iloilo			
10 Date: 13 FEB 15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province): Iloilo		
13 Engine On: 8:24	14 Engine Off: 2347	15 Total Engine Time: 4+23	16 Take off: 8:29	17 Landing: 12:42	18 Total Flight Time: 4+13

19 Weather: Cloudy

20 Remarks: Covered BLK 37J but left 3 block lines

21 Problems and Solutions:

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

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

Pilot-in-Command — For: J. [illegible] — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 2554G

5. Flight Log for 2556G Mission

Flight Log No.: 2556

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: RA FELISMINO	2 ALTM Model: Gemini	3 Mission Name: 2BLK37JSG044B	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: 13 FEB 15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province): Iloilo		
13 Engine On: 14:10	14 Engine Off: 18:33	15 Total Engine Time: 4+23	16 Take off: 14:15	17 Landing: 18:28	18 Total Flight Time: 4+13
19 Weather: Cloudy					
20 Remarks: Covered the remaining lines of BLK37J and surveyed 22 lines of BLK37G					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. Hipolito	LJ Punzalan	For: J. Alajar	rafelismino
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.5. Flight Log for Mission 2556G

6. Flight Log for 2566G Mission

Flight Log No.: 2566

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: RA Felizmino	2 ALTM Model: Gemini	3 Mission Name: 2BLK37V047A	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: 16 FEB 15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province): Iloilo		
13 Engine On: 8:43	14 Engine Off: 12:54	15 Total Engine Time: 4+11	16 Take off: 8:48	17 Landing: 12:49	18 Total Flight Time: 4+01
19 Weather: cloudy					
20 Remarks: Covered voids of BLK 37					
21 Problems and Solutions:					

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

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

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

Lidar Operator: [signature] — Signature over Printed Name

Figure A-6.6. Flight Log for Mission 2566G

7. Flight Log for 2601P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2601

1 LiDAR Operator: KJ Andaya	2 ALTM Model: Pegasus	3 Mission Name: 1BLK37IF053A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 02-22-2015	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1328	14 Engine Off: 1721	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	fair				

20 Remarks:

Completed BLK 37F and covered voids.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[signature]	LJ [signature]	C. Alfonso III	KS Andaya
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.7. Flight Log for Mission 2601P

8. Flight Log for 2645P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2645

1 LiDAR Operator: KJ ANDAYA	2 ALTM Model: Pegasus	3 Mission Name: 1BLK37Q064A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 03 - 05 - 15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 4+12	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	cloudy				

20 Remarks:

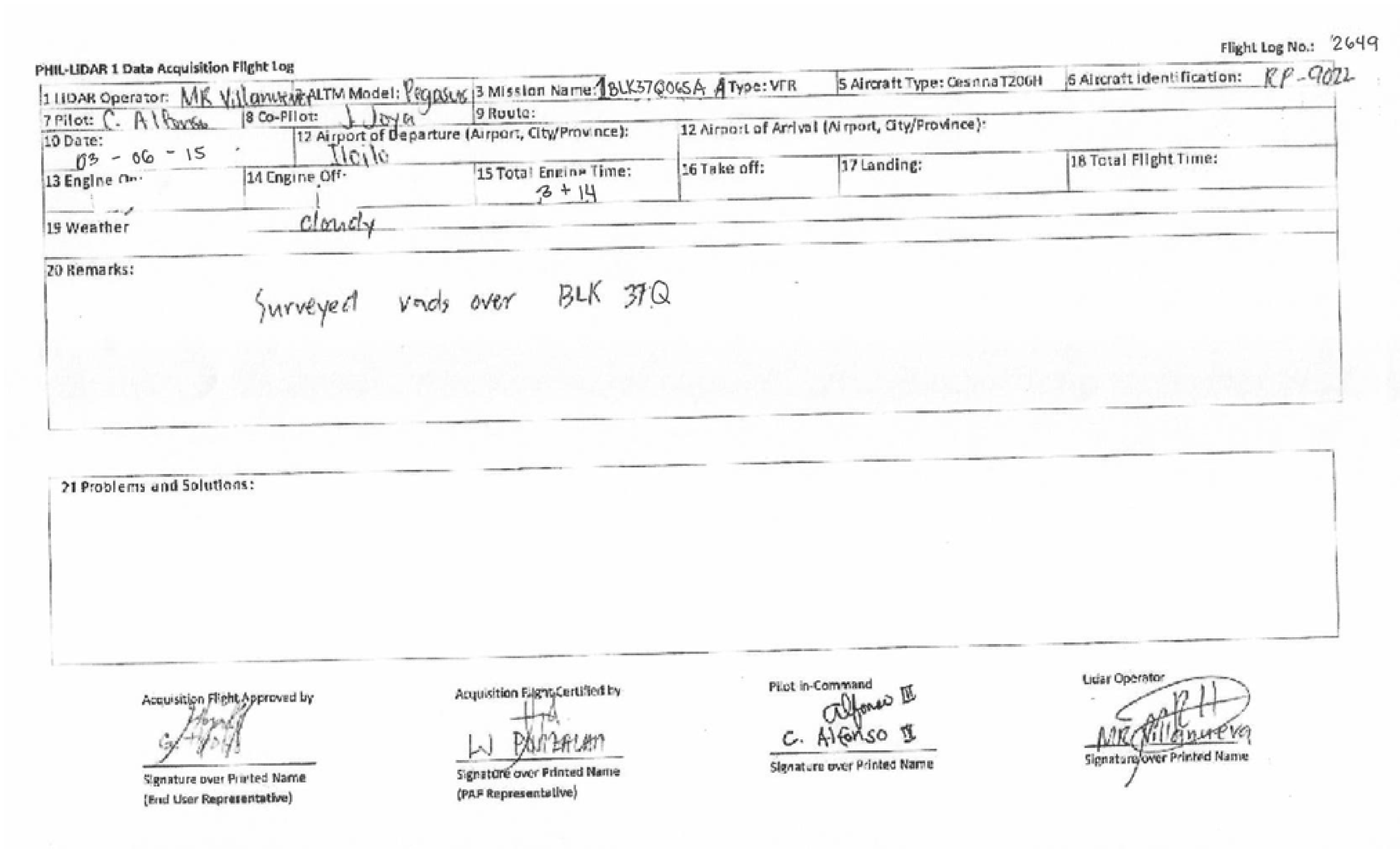
Surveyed 8 lines over BLK 37Q

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[signature]	L. J. Pantalan	C. Alfonso II	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-6.8. Flight Log for Mission 2645P

9. Flight Log for 2649P Mission


Flight Log No.: 2649

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: MR Villanueva	2 ALTM Model: Pegasus	3 Mission Name: 1BLK37Q065A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 03-06-15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 3+14	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	cloudy				

20 Remarks:

Surveyed voids over BLK 37Q

21 Problems and Solutions:

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

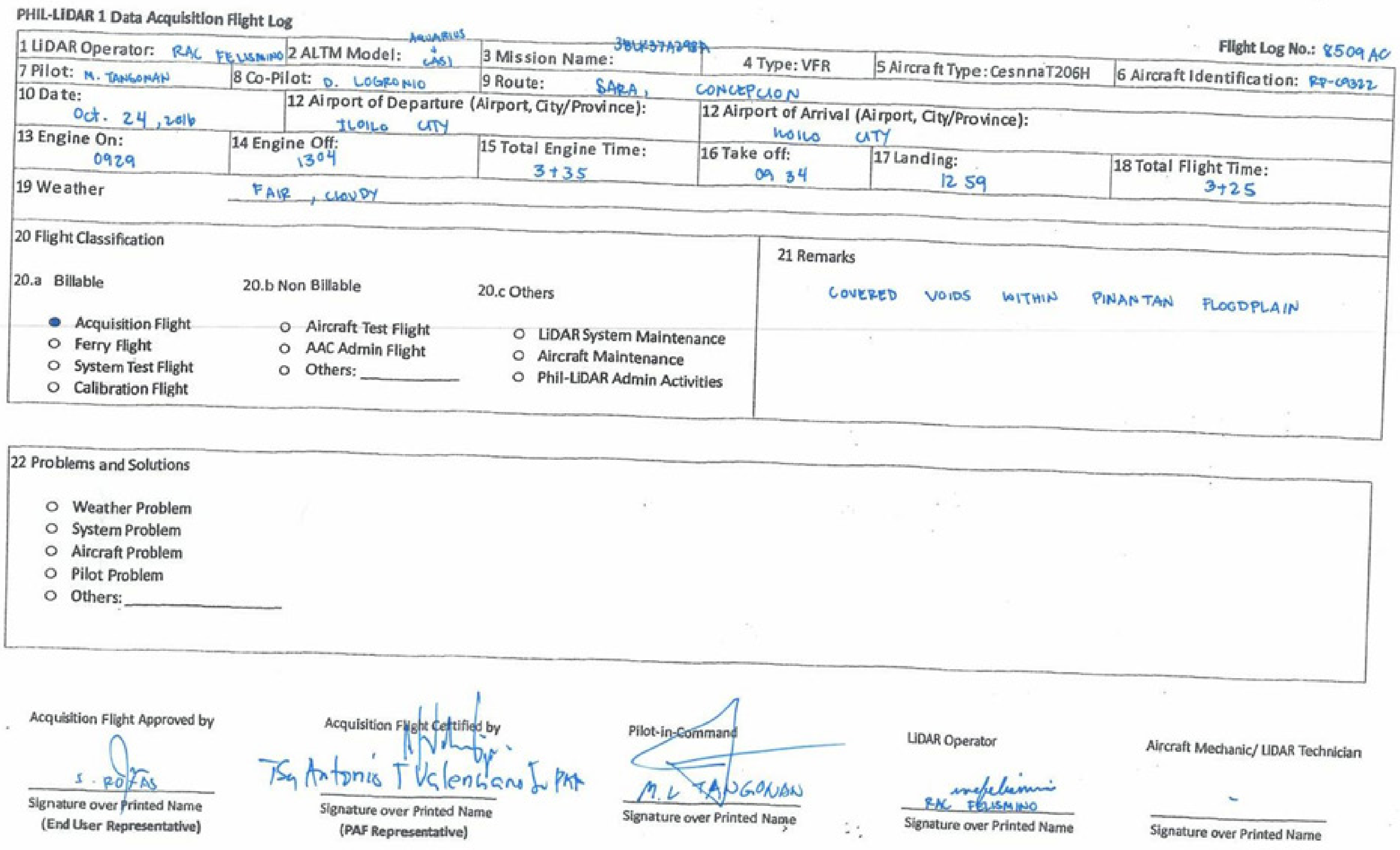
Acquisition Flight Certified by
W. Punzalan
Signature over Printed Name
(PAF Representative)

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

Lidar Operator
MR Villanueva
Signature over Printed Name

Figure A-6.9. Flight Log for Mission 2649P

10. Flight Log for 8509AC Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 8509AC

1 LiDAR Operator: RAC FELISMINO	2 ALTM Model: AQUARIUS + CASI	3 Mission Name: 3BLK37A298A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: M. TANGONAN	8 Co-Pilot: D. LOGRONIO	9 Route: SARA, CONCEPCION			
10 Date: Oct. 24, 2016	12 Airport of Departure (Airport, City/Province): ILOILO CITY		12 Airport of Arrival (Airport, City/Province): ILOILO CITY		
13 Engine On: 0929	14 Engine Off: 1304	15 Total Engine Time: 3+35	16 Take off: 09 34	17 Landing: 12 59	18 Total Flight Time: 3+25
19 Weather: FAIR, CLOUDY					

20 Flight Classification

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

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

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

21 Remarks

COVERED VOIDS WITHIN PINANTAN FLOODPLAIN

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

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

Acquisition Flight Certified by: TSg Antonio T Valenciano Jr PAF — Signature over Printed Name (PAF Representative)

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

LiDAR Operator: RAC FELISMINO — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: — Signature over Printed Name

Figure A-6.10. Flight Log for Mission 8509AC

11. Flight Log for 8510AC Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 8510AC

1 LiDAR Operator: MS REYES	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK37B298B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: M. TANGONAN	8 Co-Pilot: D. LOGRONIO	9 Route: SARA, CONCEPCION			
10 Date: OCT. 24, 2016	12 Airport of Departure (Airport, City/Province): ILOILO INTERNATIONAL AIRPORT		12 Airport of Arrival (Airport, City/Province): ILOILO INTERNATIONAL AIRPORT		
13 Engine On: 14 37	14 Engine Off: 17 30	15 Total Engine Time: 2+53	16 Take off: 14 42	17 Landing: 17 25	18 Total Flight Time: 2+43
19 Weather: CLOUDY					

20 Flight Classification

20.a Billable	20.b Non Billable	20.c Others
● Acquisition Flight	○ Aircraft Test Flight	○ LiDAR System Maintenance
○ Ferry Flight	○ AAC Admin Flight	○ Aircraft Maintenance
○ System Test Flight	○ Others: ________	○ Phil-LiDAR Admin Activities
○ Calibration Flight		

21 Remarks

COVERED VOIDS

22 Problems and Solutions

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
I. ROXAS	TSg Antonio T Valenciano Jr PAF	M. C. TANGONAN	MS REYES	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.11. Flight Log for Mission 8510AC

Annex 7. Flight Status Reports

CAPIZ, ANTIQUE, AND ILOILO
February - March 2015 and October 2016

Table A-7.1. Flight Status Report

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2542G	BLK37H	2BLK37H041A	MVE TONGA	10 FEB 15	Mission completed
2544G	BLK37F	2BLK37F041B	RA FELISMINO	10 FEB 15	Mission completed
2546G	BLK37J	2BLK37KV042A	MVE TONGA	11 FEB 15	Mission completed for BLK37K, covered voids of BLK 37H
2554G	BLK 37J	2BLK37J044A	MVE TONGA	13 FEB 15	Unfinished, with voids
2556G	BLK 37G, 37J	2BLK37JSG044B	RA FELISMINO	13 FEB 15	Finish BLK37J, voids in 37G
2566G	BLK 37	2BLK37V047A	RA FELISMINO	16 FEB 15	Covered voids of Block 37
2601P	BLK 37I, 37F	1BLK37IF053A	KJ ANDAYA	22 FEB 15	Finished BLK37F and covered voids
2645P	BLK 37Q	1BLK37Q064A	KJ ANDAYA	05 MAR 15	Surveyed 8 lines over BLK 37Q
2649P	BLK 37Q	1BLK37Q065A	MR VILLANUEVA	06 MAR 15	Surveyed 4 lines over BLK 37Q
8509AC	BLK37A	3BLK37A298A	RA FELISMINO	24 OCT 16	Covered voids within Pinantan Floodplain
8510AC	BLK37B, Pinantan FP	3BLK37B298B	MS REYES	24 OCT 16	Covered voids over BLK37B and Pinantan Flood

LAS BOUNDARIES PER MISSION FLIGHT

Flight No. : 2542G
Area: BLK 37H
Base: ILO-71 & IL-608
Mission Name: 2BLK37H041A
Total Area Surveyed: 180.154 sq km

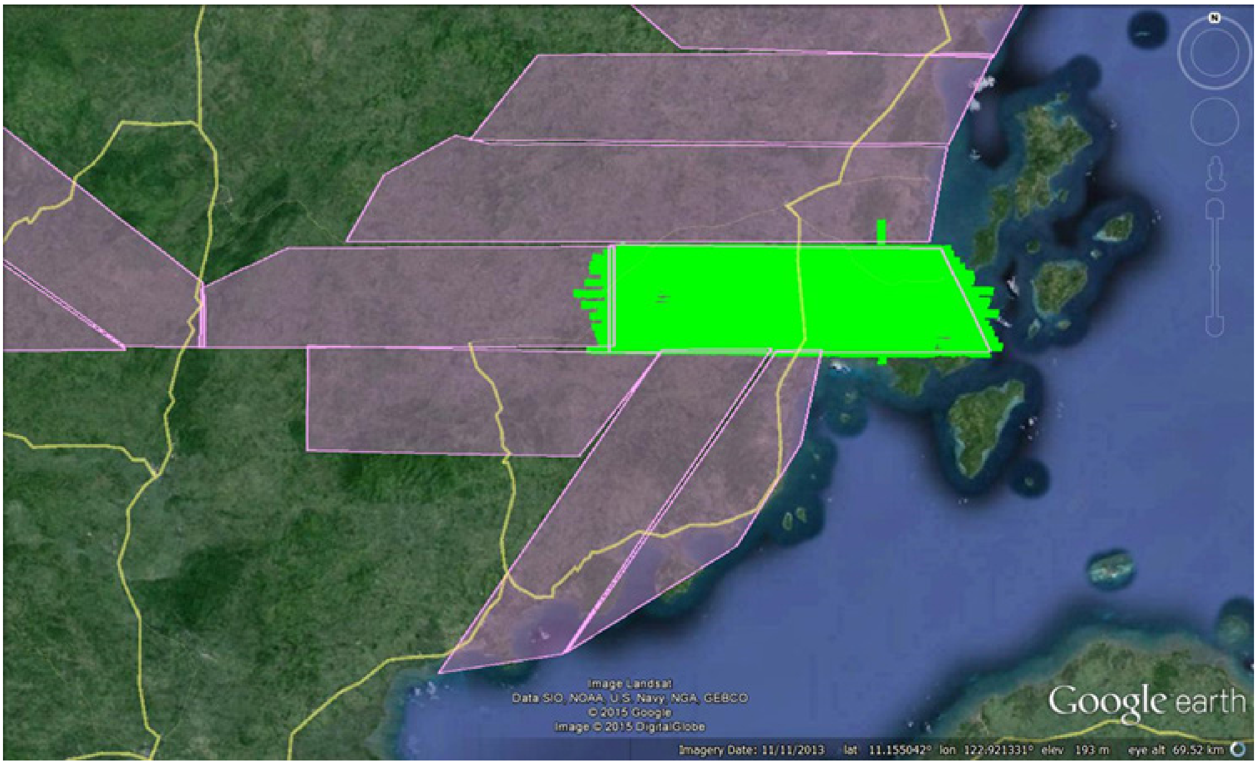


Figure A-7.1. Swath for Flight No. 2542G

Flight No.: 2544G
Area: BLK 37F
Base: ILO-71 & IL-608
Mission Name: 2BLK37F041B
Total Area Surveyed: 220.069 sq km

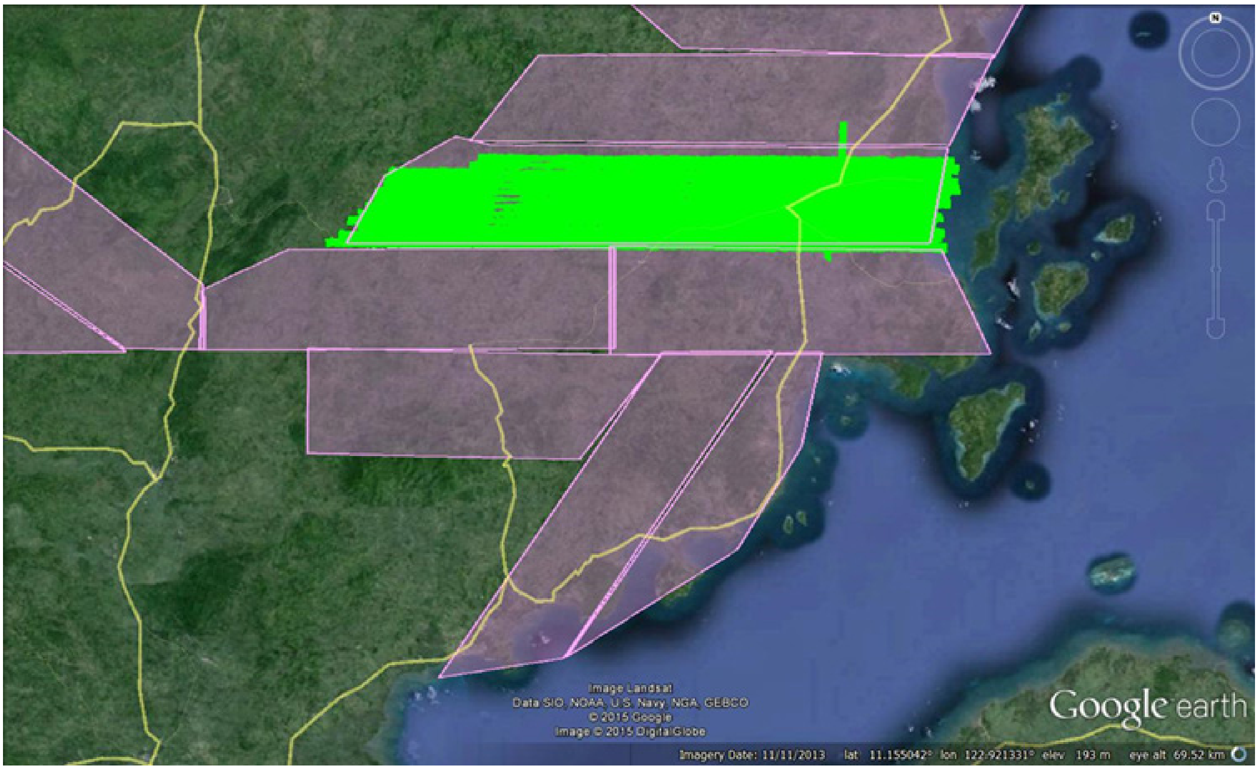


Figure A-7.2. Swath for Flight No. 2544G

Flight No. : 2546G
Area: BLK 37K
Base: ILO-71 & IL-608
Mission Name: 2BLK37KV042A
Total Area Surveyed: 121.182 sq km

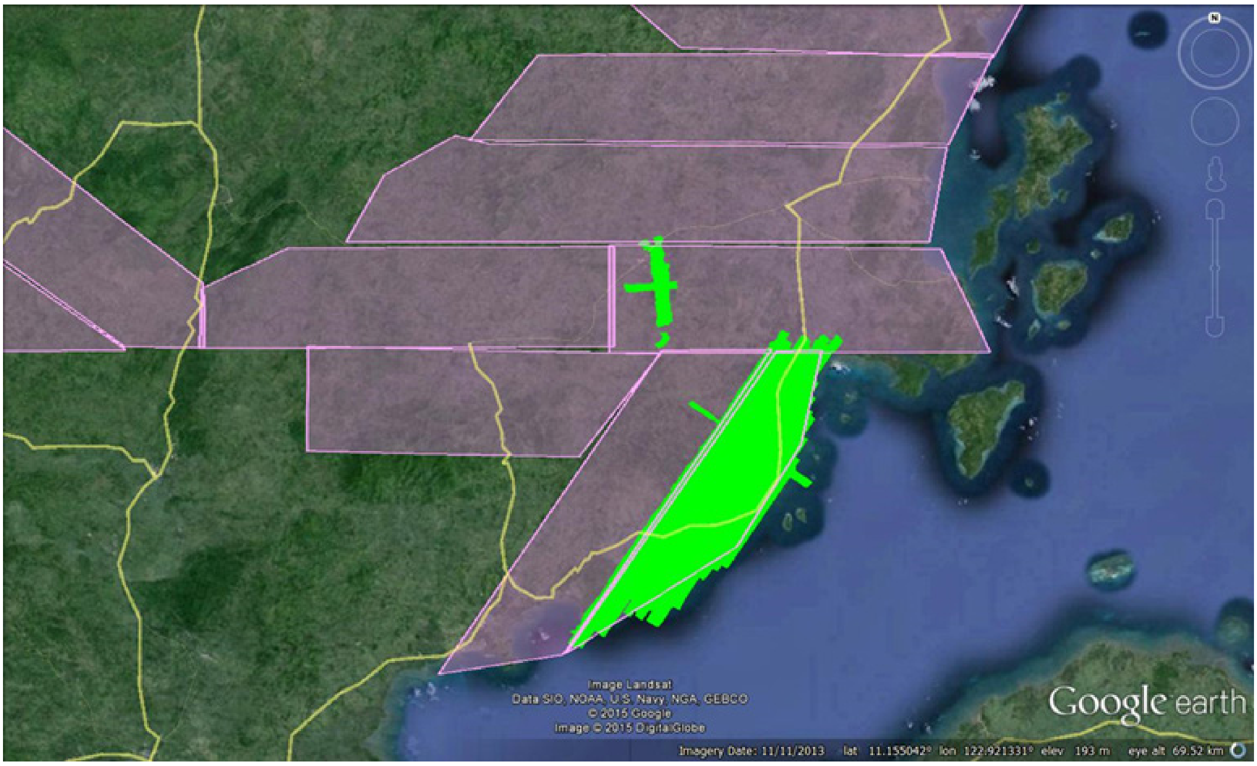


Figure A-7.3. Swath for Flight No. 2546G

Flight No. : 2554G
Area: BLK 37J
Base: ILO-71 & IL-608
Mission Name: 2BLK37J044A
Total Area Surveyed: 127.347 sq km

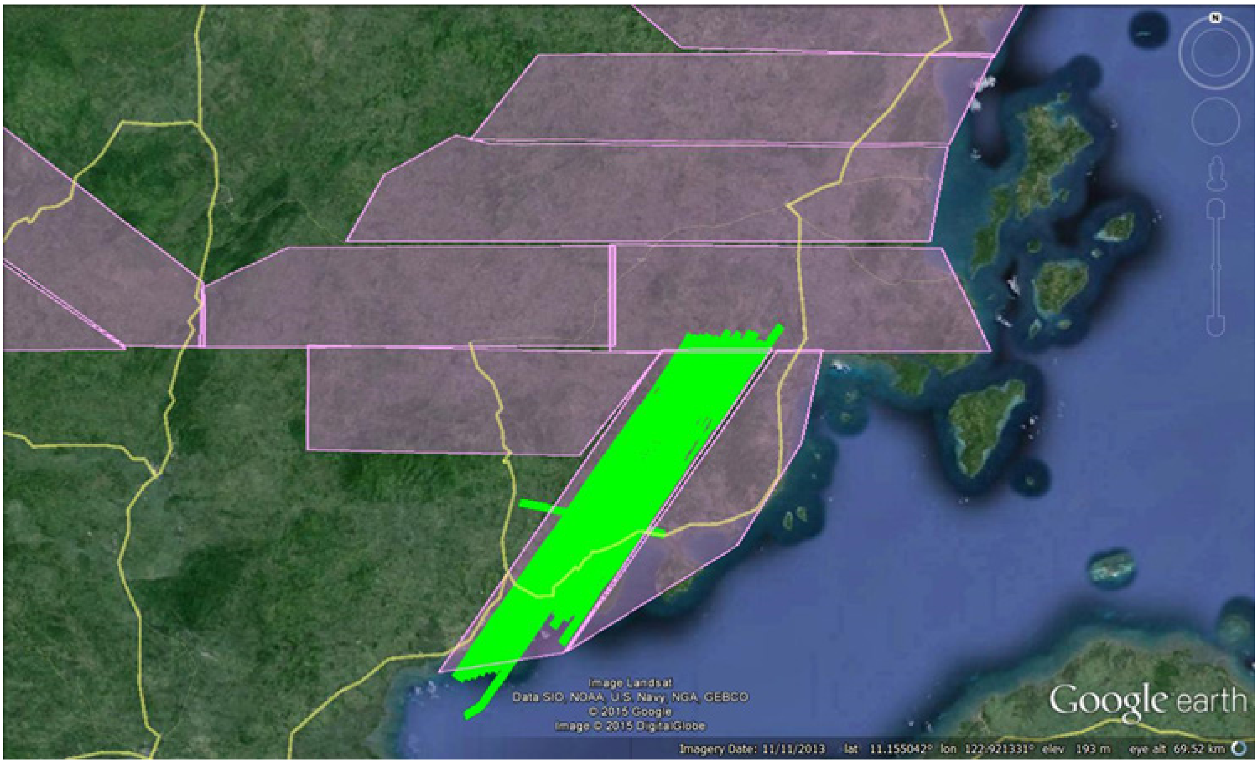


Figure A-7.4. Swath for Flight No. 2554G

Flight No. : 2556G
Area: BLK 37J, 37G
Base: ILO-71 & IL-608
Mission Name: 2BLK37JSG044B
Total Area Surveyed: 182.072 sq km

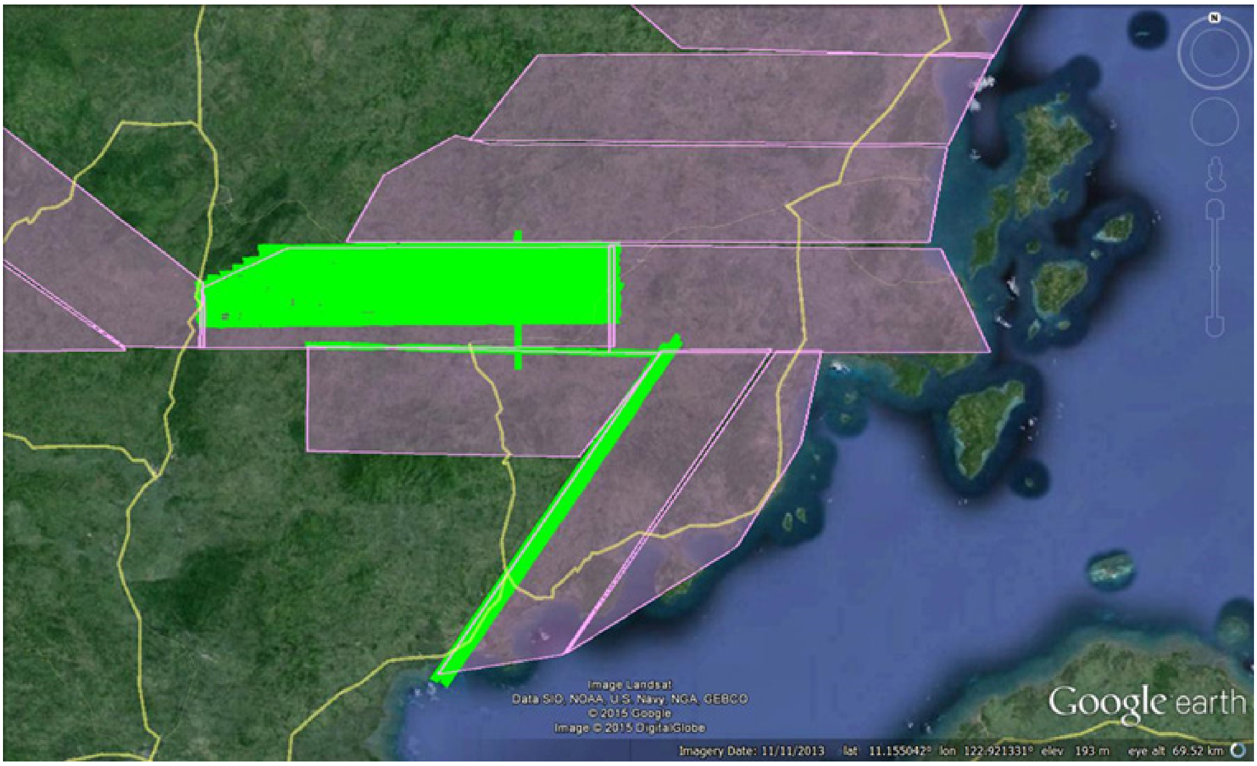


Figure A-7.5. Swath for Flight No. 2556G

Flight No. : 2566G
Area: BLK 37F,H,J,K voids
Mission Name: 2BLK37V047A
Total Area Surveyed: 65.8297 sq km

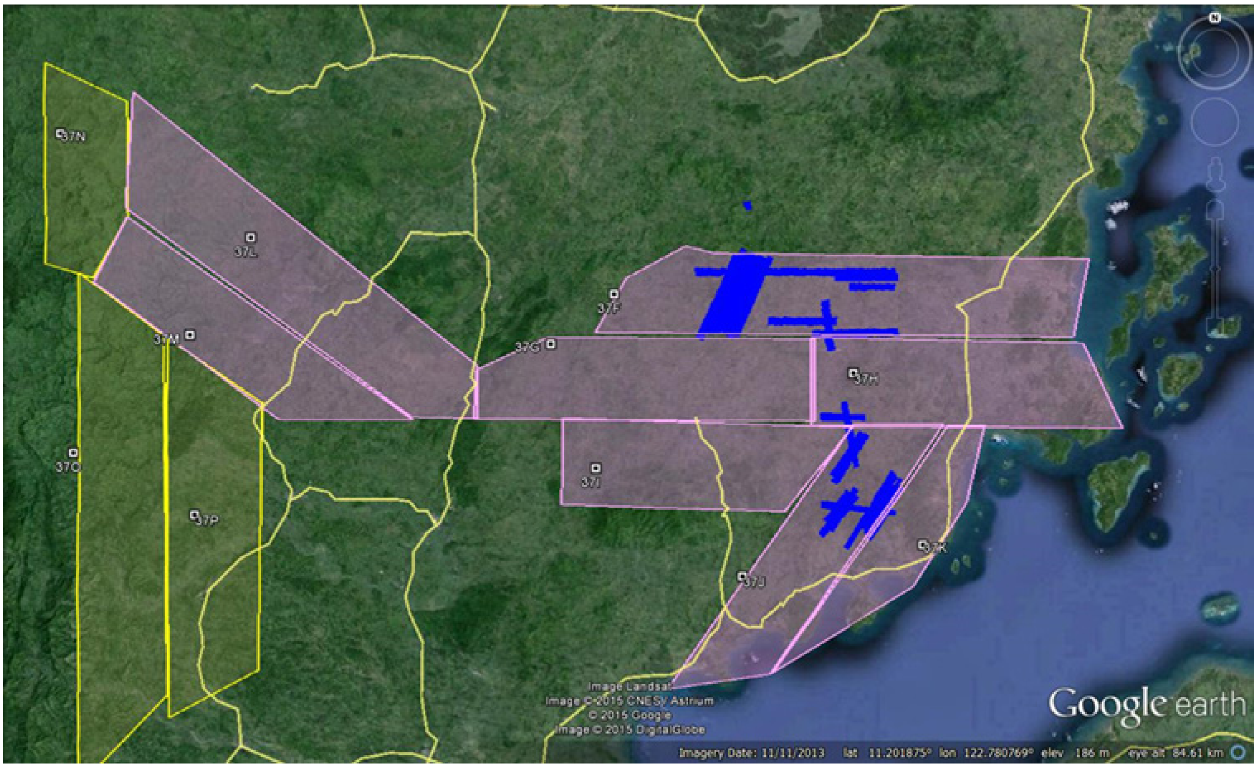


Figure A-7.6. Swath for Flight No. 2566G

Flight No. : 2601P
Area: BLK 37I, 37F, voids
Mission Name: 1BLK37IFV053A
Total Area Surveyed: 175.699 sq km

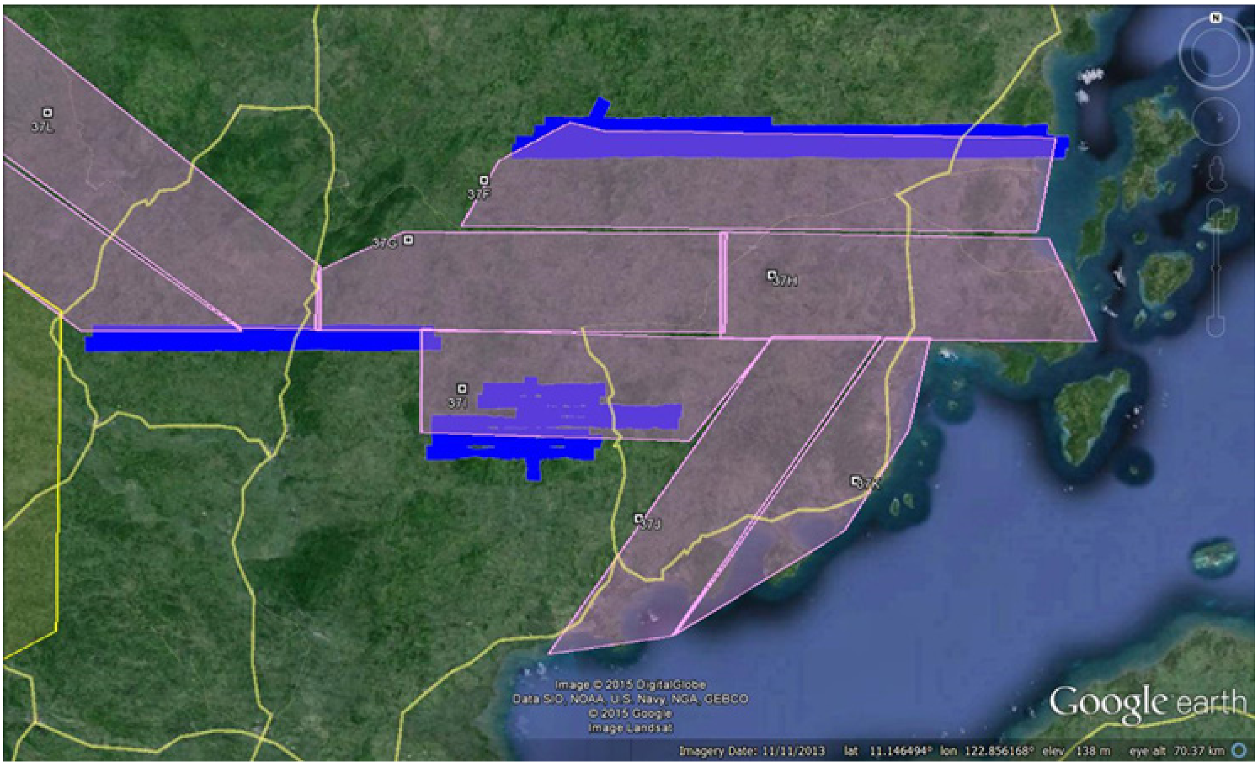


Figure A-7.7. Swath for Flight No. 2601P

Flight No. : 2645P
Area: BLK 37Q
Mission Name: 1BLK37Q064A
Total Area Surveyed: 98.8552 sq km

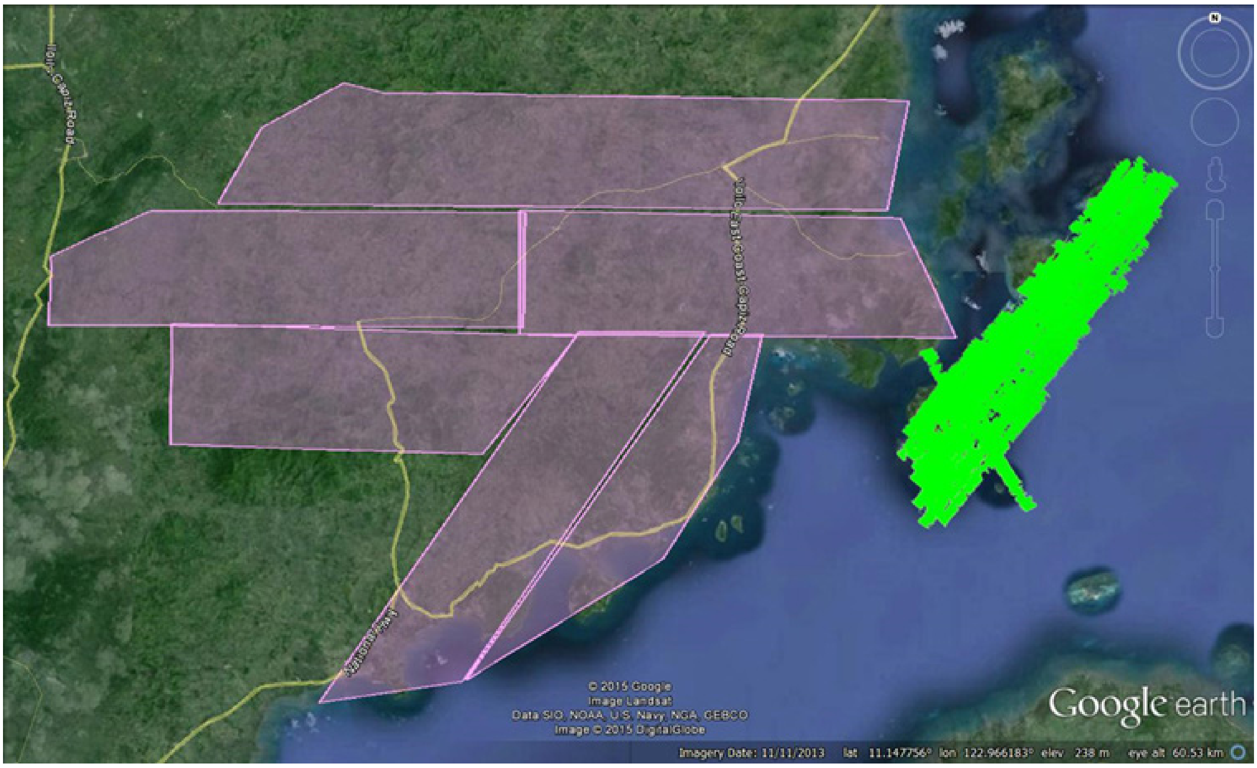


Figure A-7.8. Swath for Flight No. 2645P

Flight No. : 2649P
Area: BLK 37Q
Mission Name: 1BLK37Q065A
Total Area Surveyed: 70.0025 sq km

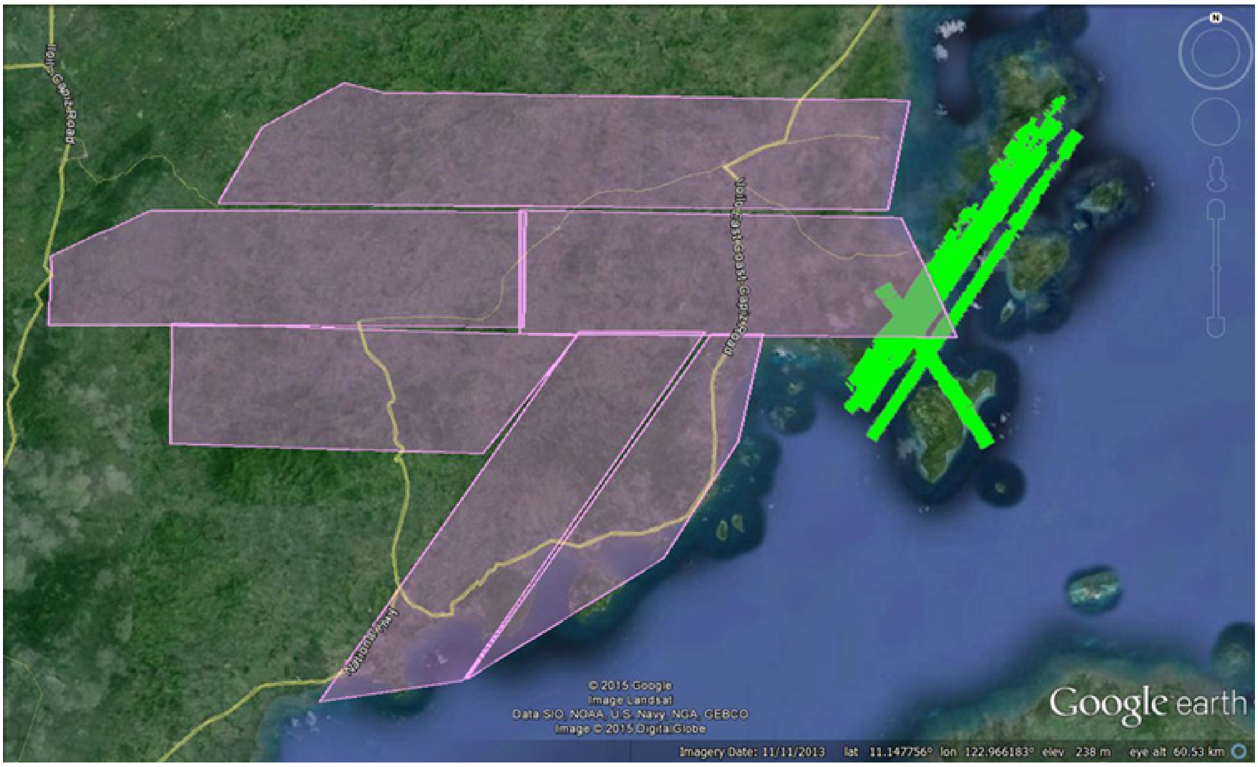


Figure A-7.9. Swath for Flight No. 2649P

FLIGHT NO:	8509AC
MISSION NAME:	3BLK37A298A
AREA:	BLK37A
	29.25km2

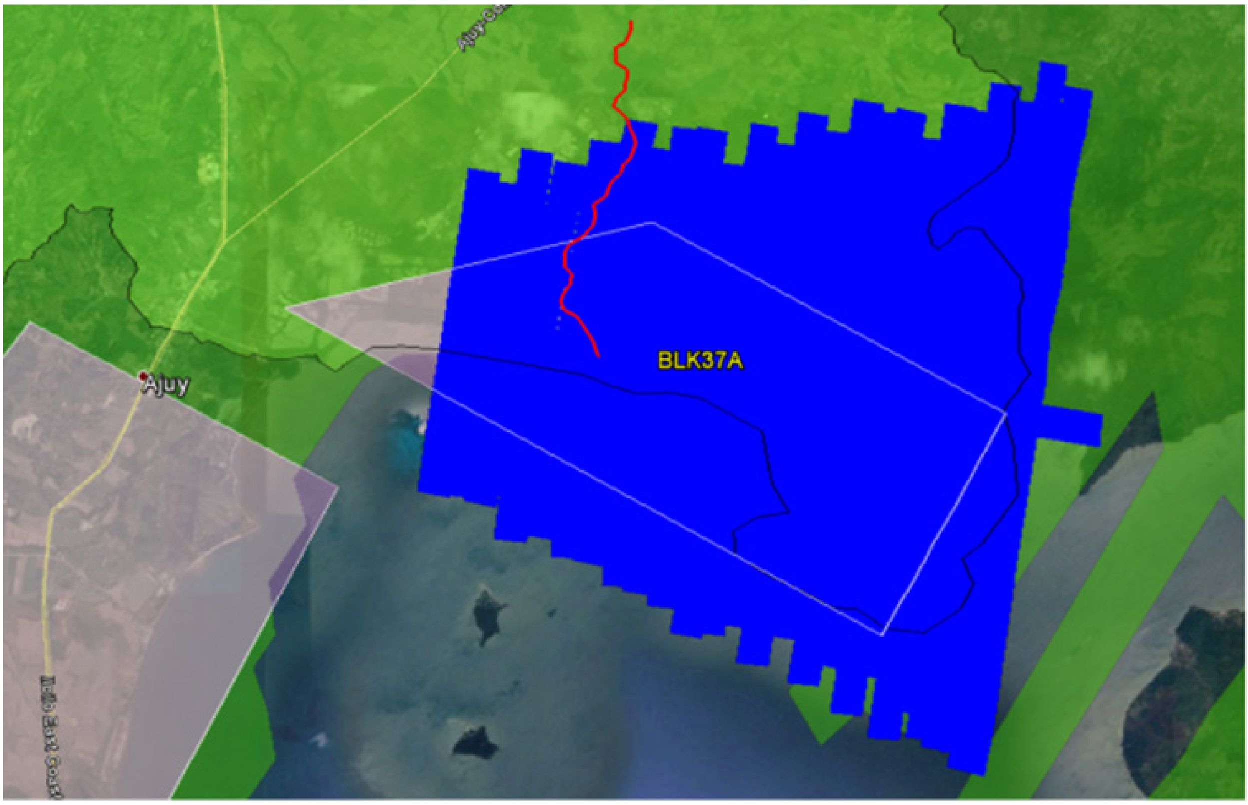


Figure A-7.10. Swath for Flight No. 8509AC

FLIGHT NO:	8510AC
MISSION NAME:	3BLK37B298B
AREA:	BLK37B, Pinantan FP
	25.57km2

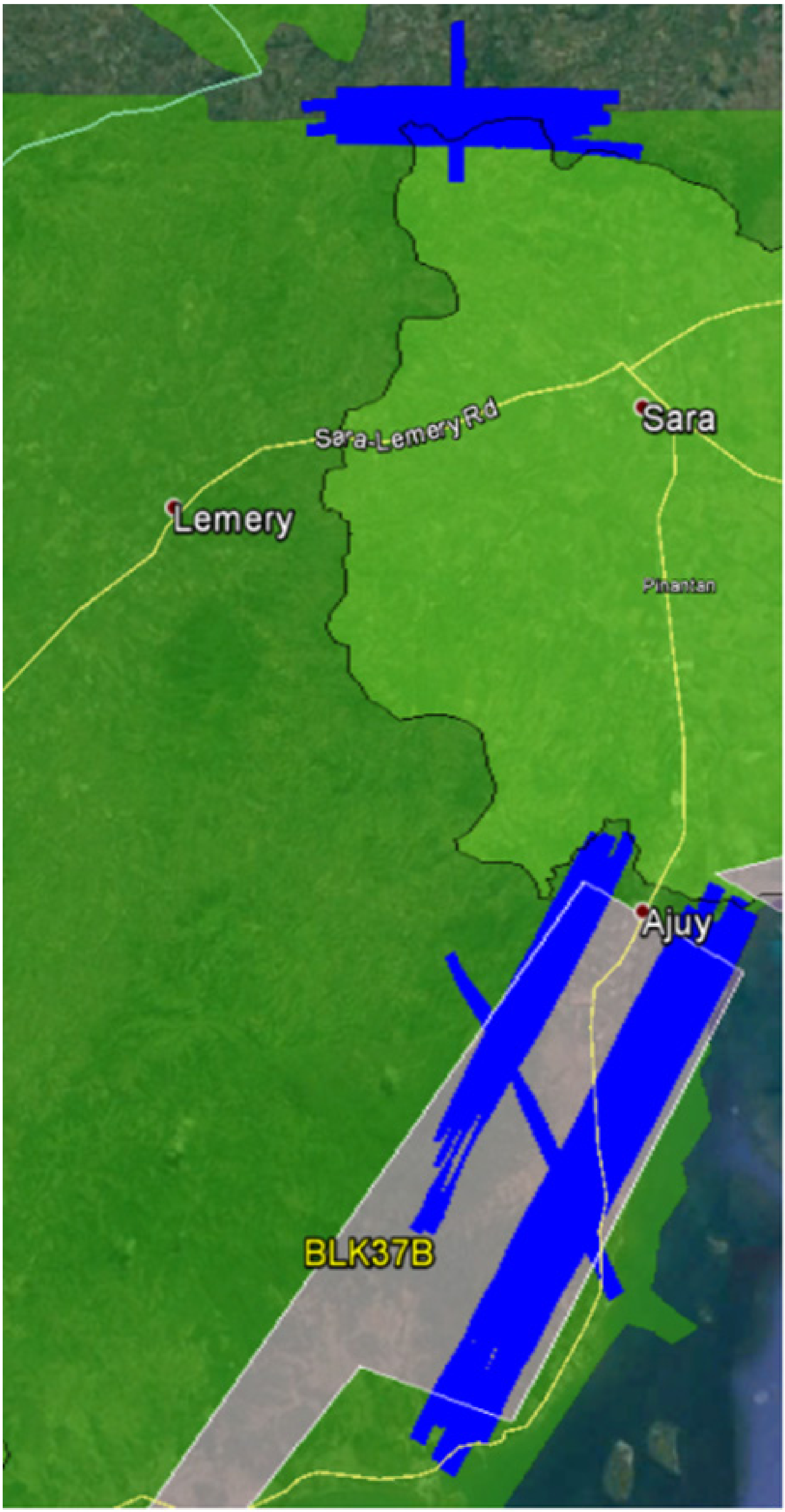


Figure A-7.11. Swath for Flight No. 8510AC

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk37F

Flight Area	Iloilo
Mission Name	Blk37F
Inclusive Flights	2544G, 2601P
Range data size	55.2 GB
POS data size	433 MB
Base data size	34.3 MB
Image	104.3 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)	1.64
RMSE for East Position (<4.0 cm)	1.77
RMSE for Down Position (<8.0 cm)	3.51
Boresight correction stdev (<0.001deg)	0.000591
IMU attitude correction stdev (<0.001deg)	0.003272
GPS position stdev (<0.01m)	0.0063
Minimum % overlap (>25)	19.03%
Ave point cloud density per sq.m. (>2.0)	4.50
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	158
Maximum Height	734.07
Minimum Height	60.11
Classification (# of points)	
Ground	54,352,246
Low vegetation	89,442,575
Medium vegetation	228,991,667
High vegetation	65,949,441
Building	1,352,639
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Jommer Medina, Engr. Mark Joshua Salvacion, Ryan James Nicholai Dizon

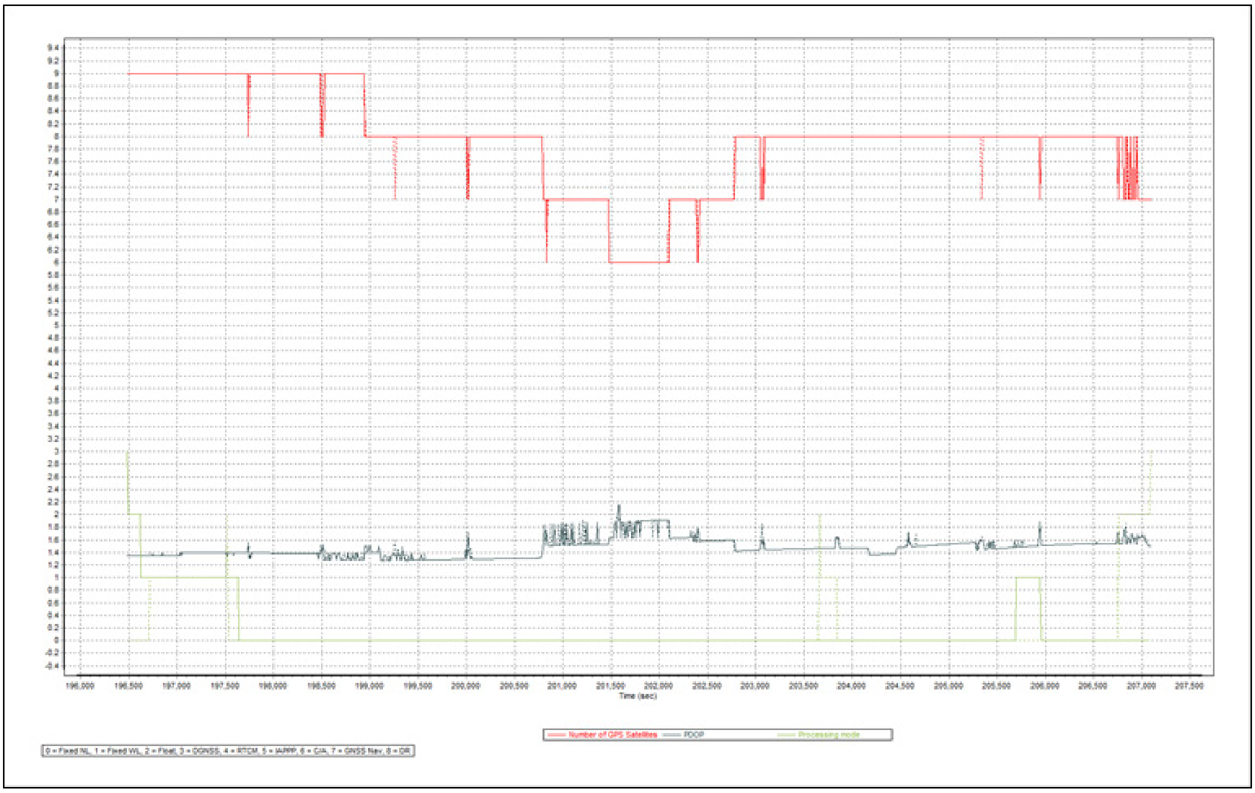


Figure A-8.1. Solution Status

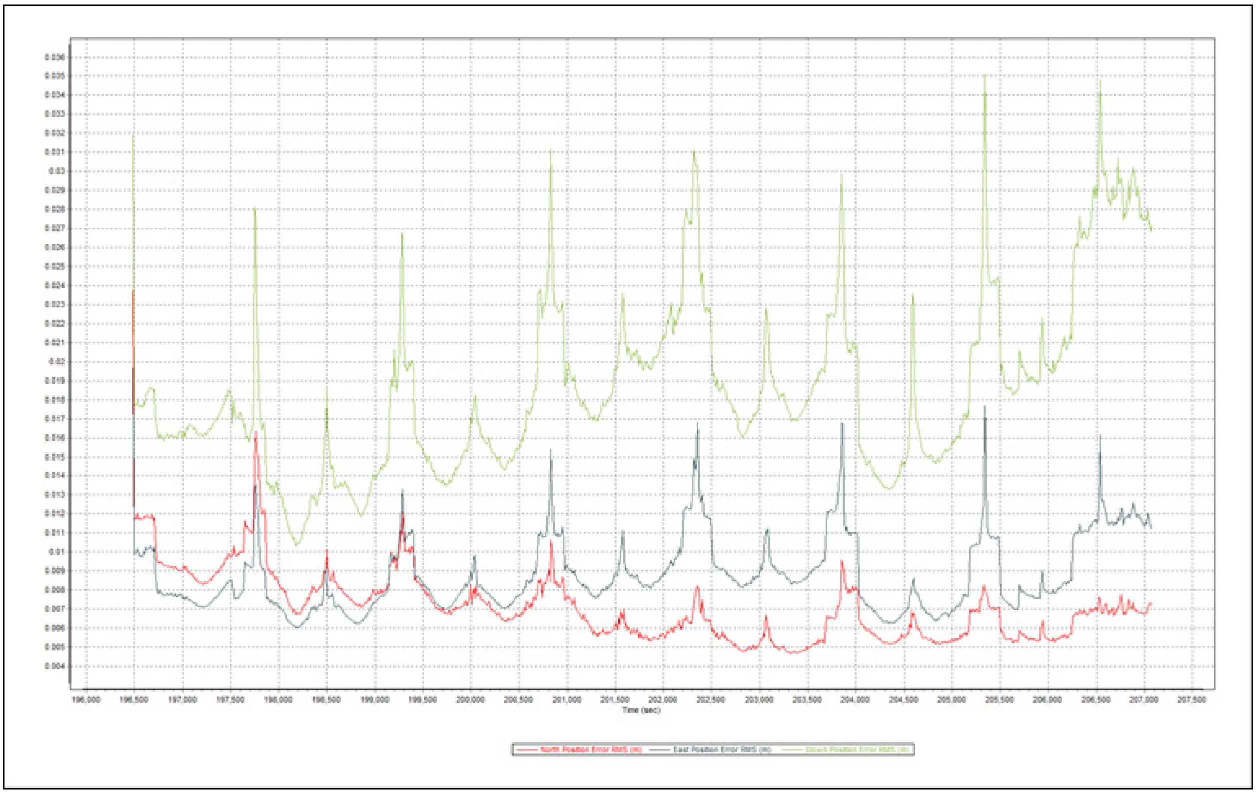


Figure A-8.2. Smoothed Performance Metrics Parameters

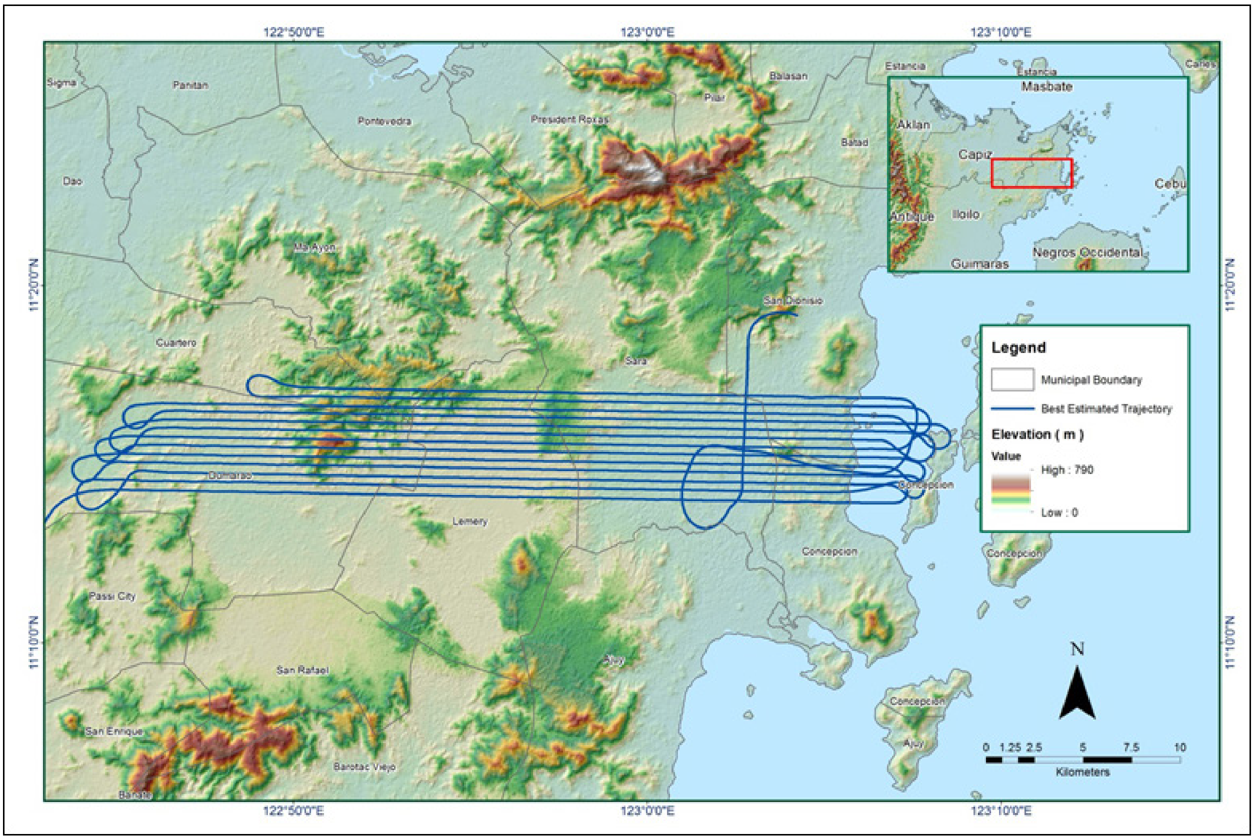


Figure A-8.3. Best Estimated Trajectory

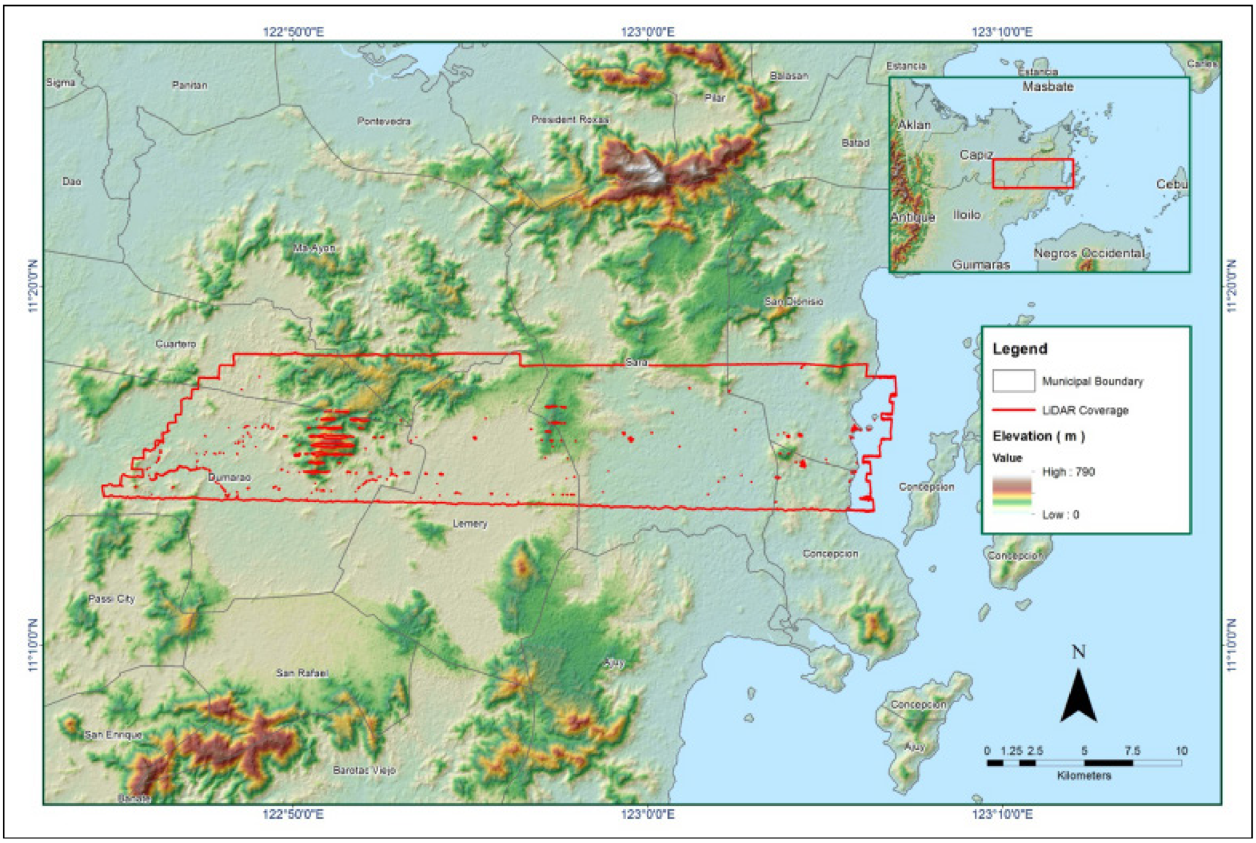


Figure A-8.4. Coverage of LiDAR data

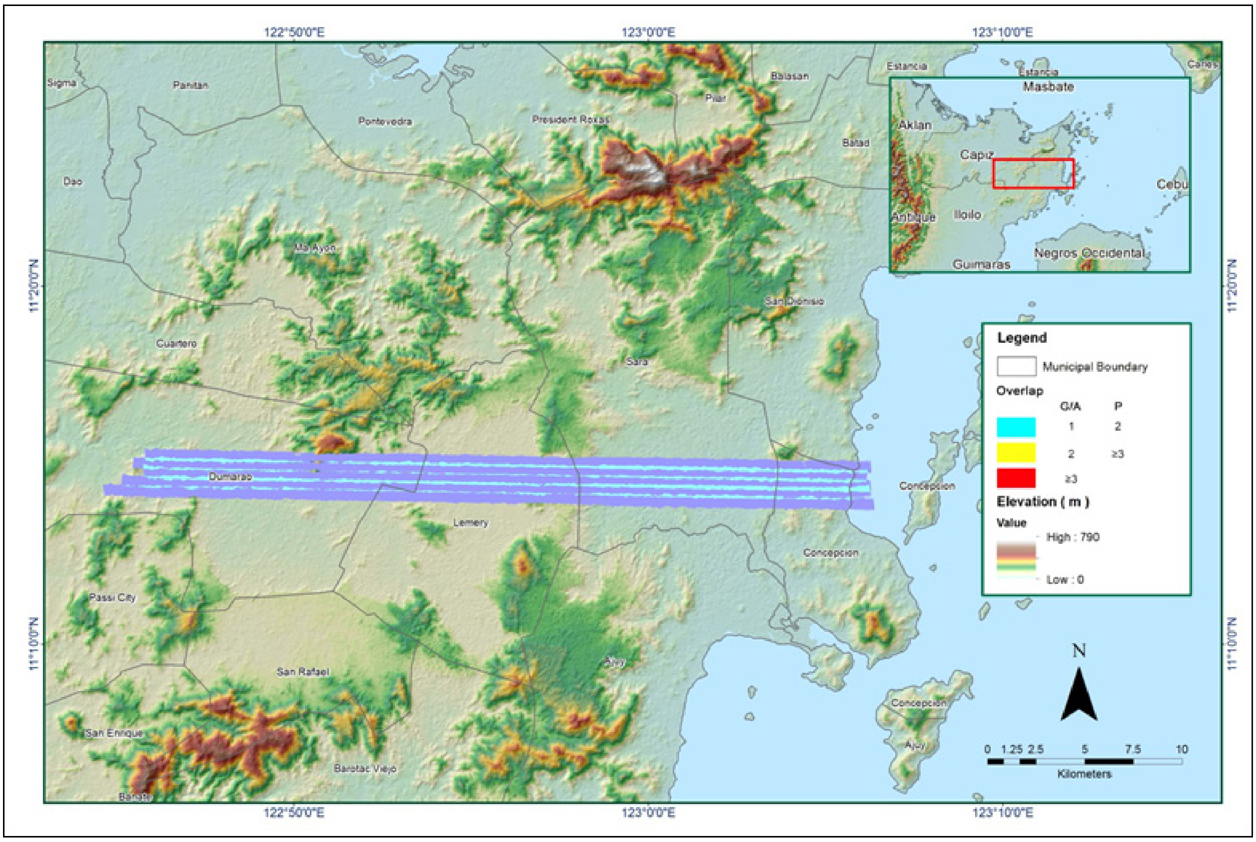


Figure A-8.5. Image of Data Overlap

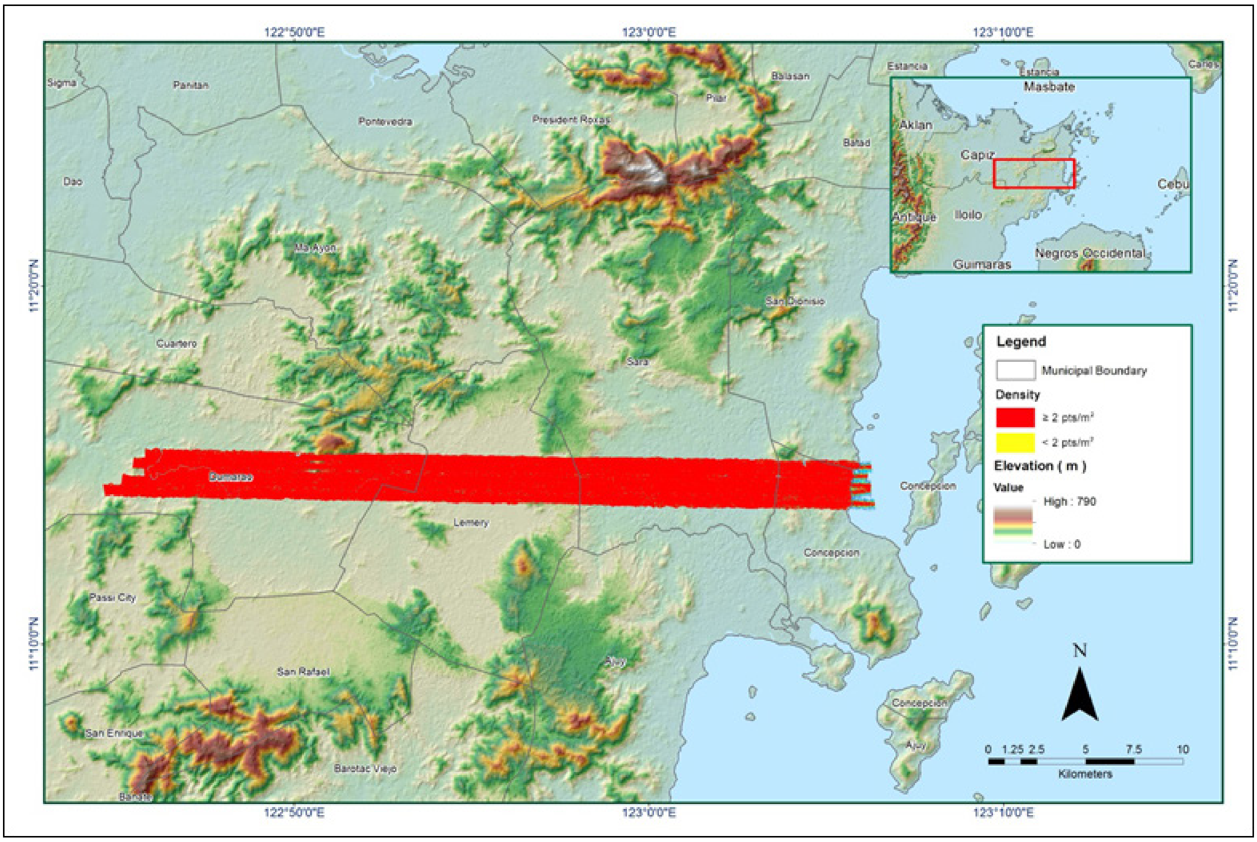


Figure A-8.6. Density map of merged LiDAR data

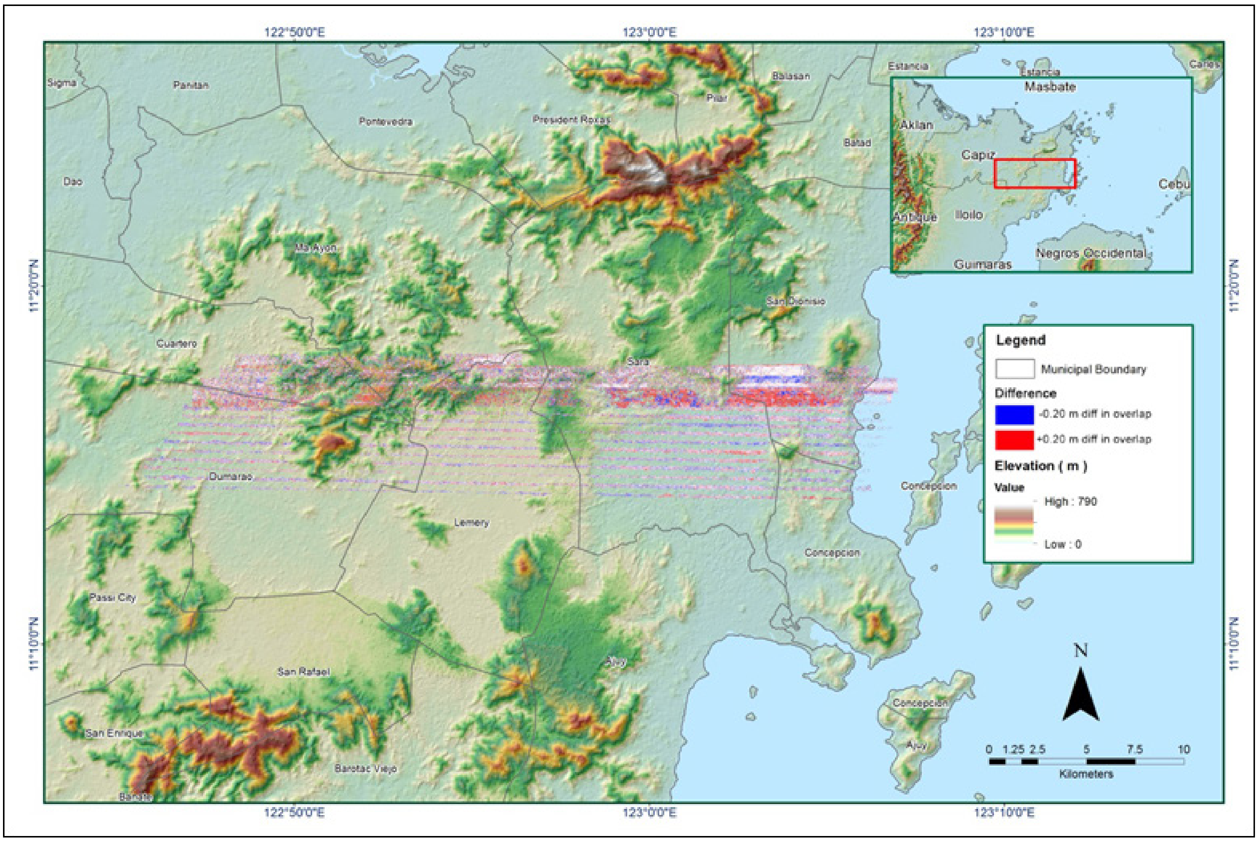


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk37F_additional1

Flight Area	Iloilo
Mission Name	Blk37F_additional1
Inclusive Flights	2544G, 2601P
Range data size	55.2 GB
POS data size	433 MB
Base data size	34.3 MB
Image	104.3 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)	1.64
RMSE for East Position (<4.0 cm)	1.77
RMSE for Down Position (<8.0 cm)	3.51
Boresight correction stdev (<0.001deg)	0.000209
IMU attitude correction stdev (<0.001deg)	0.002256
GPS position stdev (<0.01m)	0.002
Minimum % overlap (>25)	27.82%
Ave point cloud density per sq.m. (>2.0)	4.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	223
Maximum Height	258.19
Minimum Height	63.70
Classification (# of points)	
Ground	33,663,994
Low vegetation	20,083,337
Medium vegetation	33,186,779
High vegetation	62,500,449
Building	390,277
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Jommer Medina, Engr. Chelou Prado

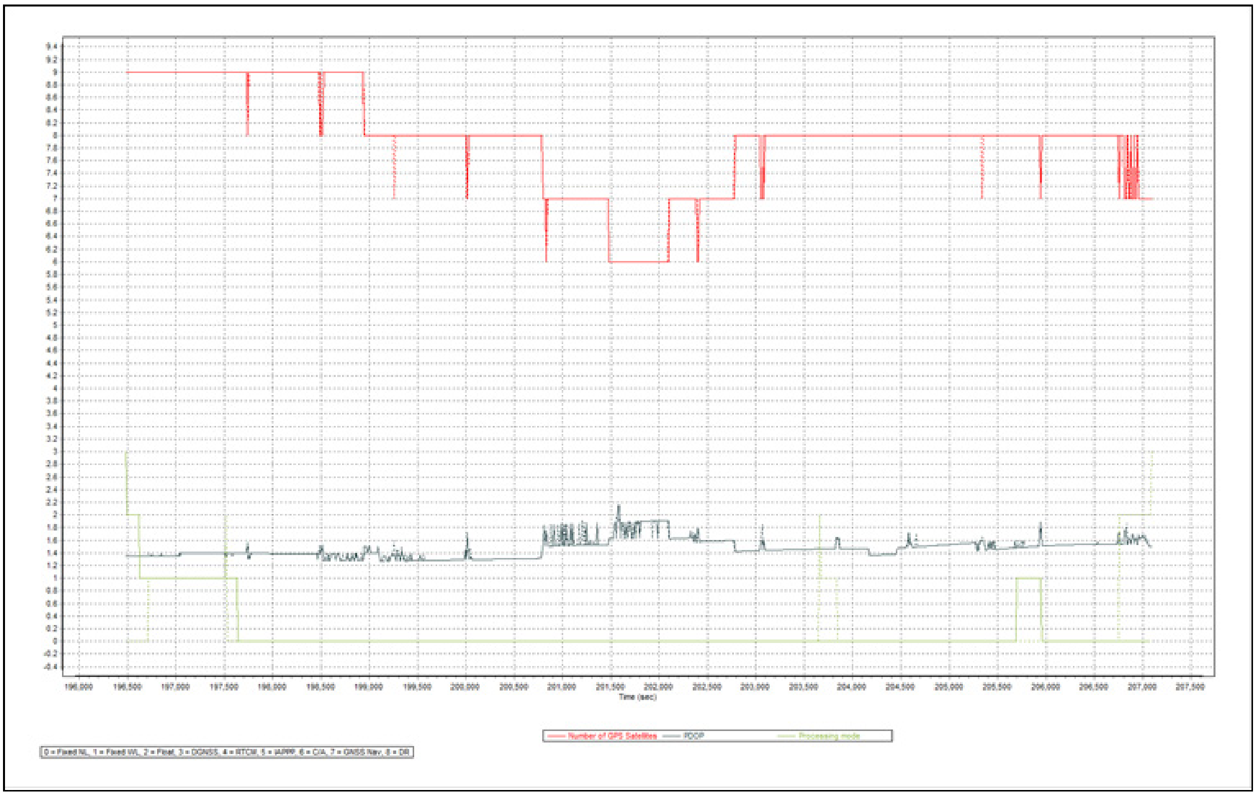


Figure A-8.8. Solution Status Parameters

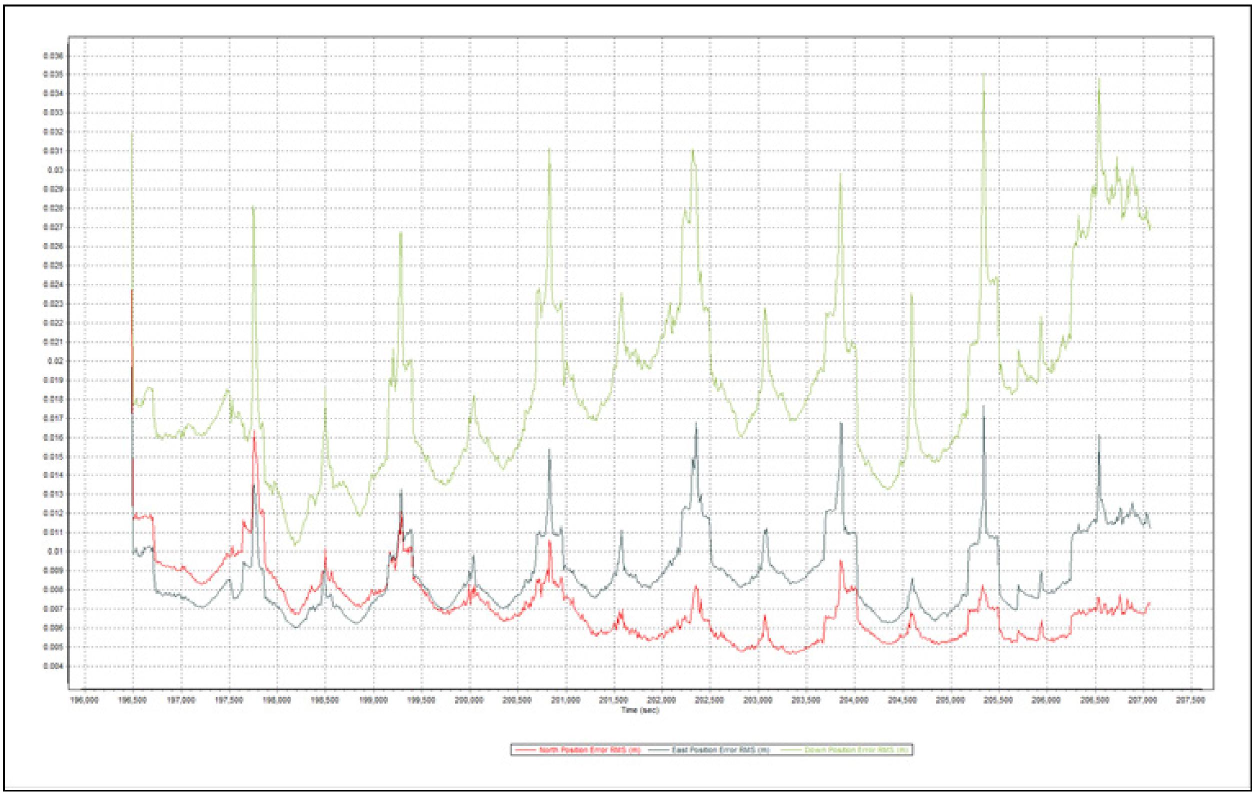


Figure A-8.9. Smoothed Performance Metrics Parameters

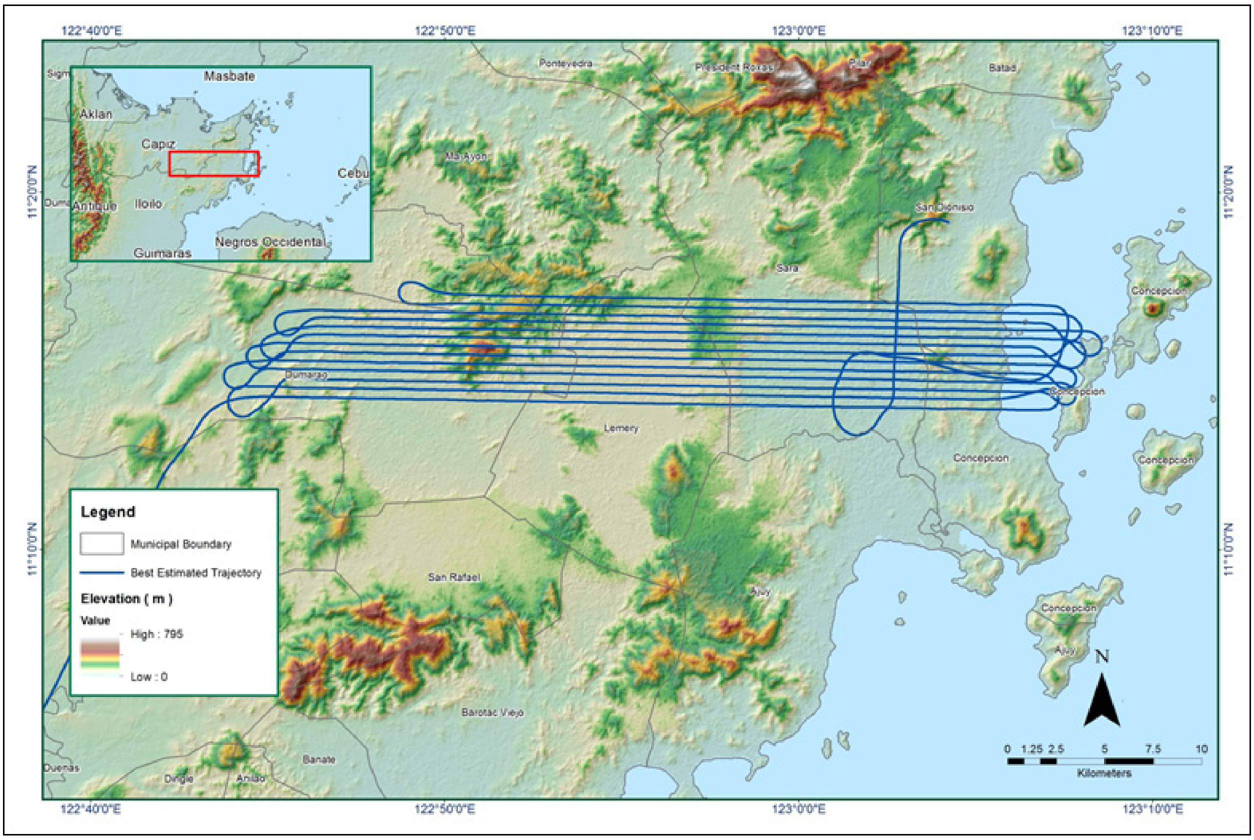


Figure A-8.10. Best Estimated Trajectory

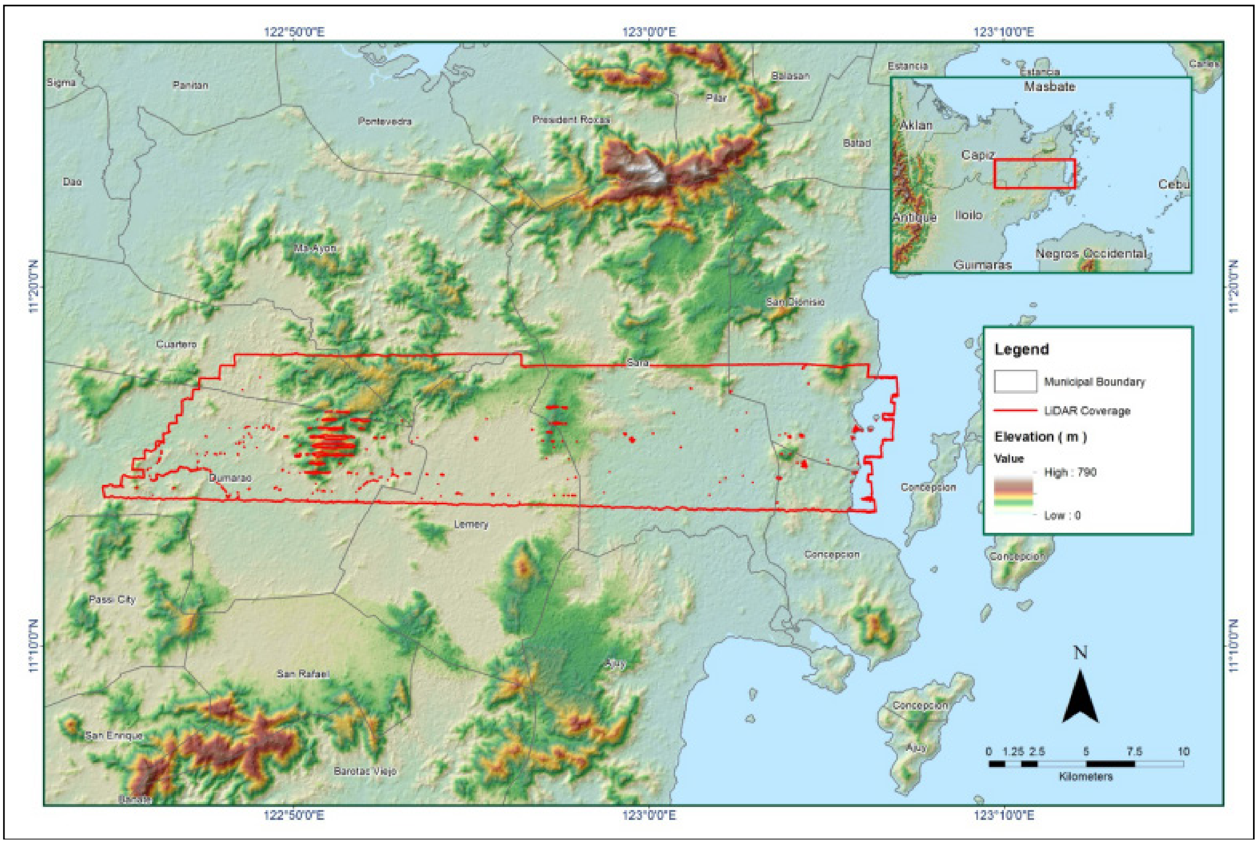


Figure A-8.11. Coverage of LiDAR data

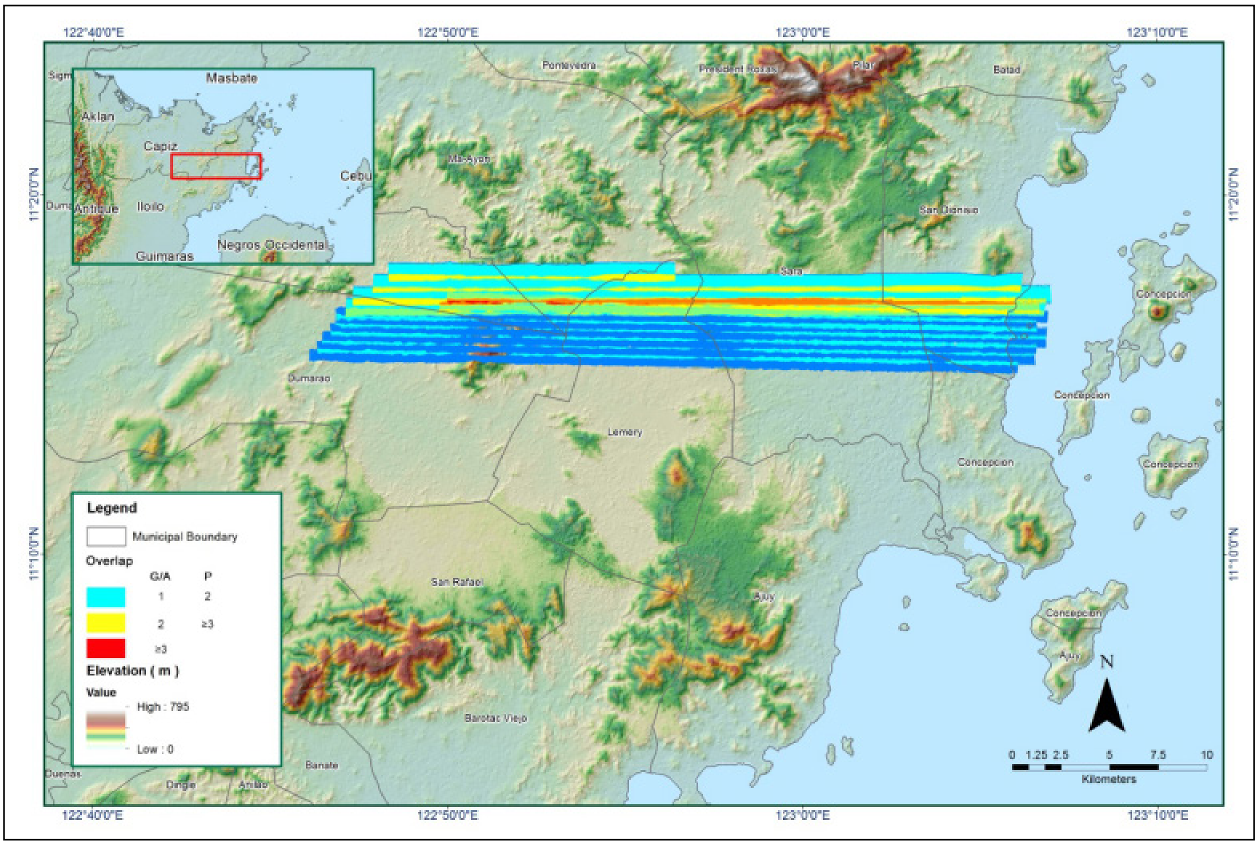


Figure A-8.12. Image of Data Overlap

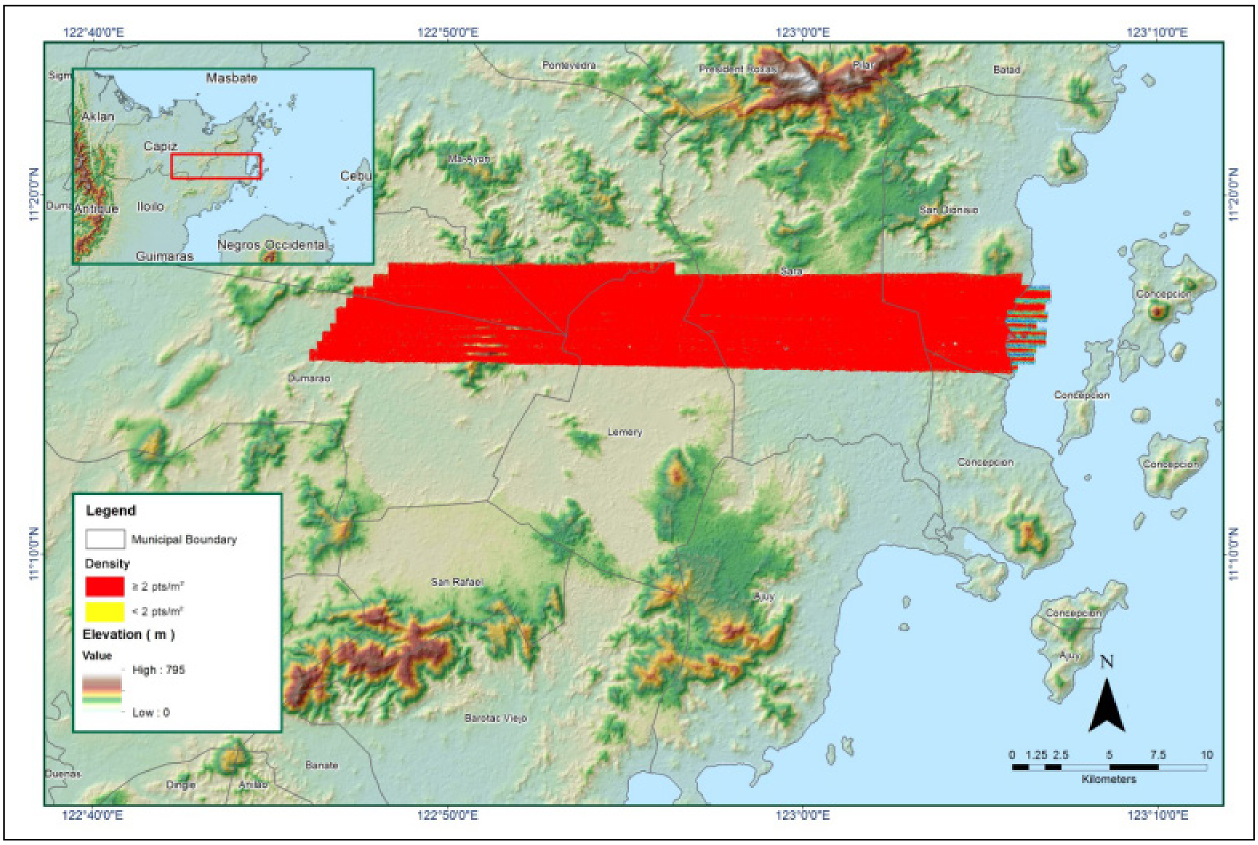


Figure A-8.13. Density map of merged LiDAR data

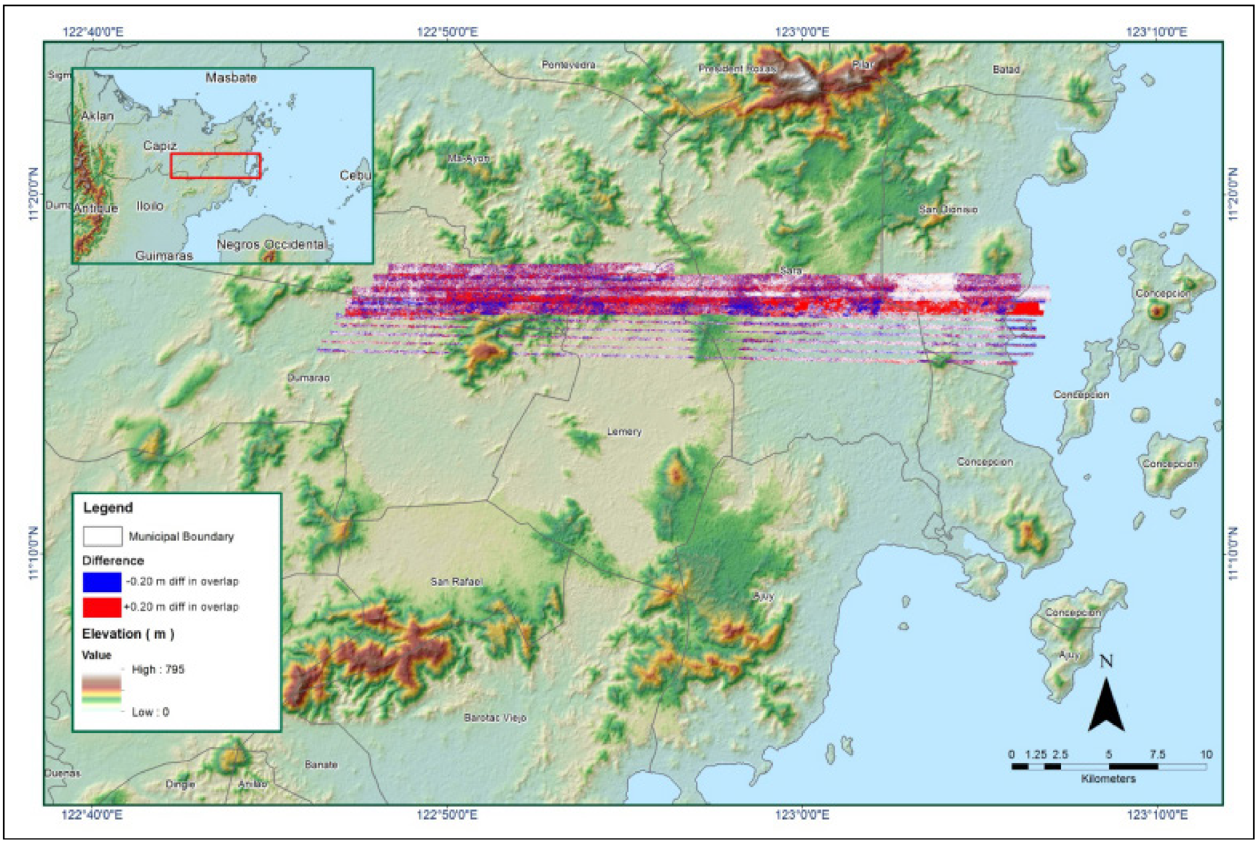


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk37F_additional2

Flight Area	Iloilo
Mission Name	Blk37F_additional2
Inclusive Flights	2566G
Range data size	13 GB
POS data size	209 MB
Base data size	10.7 MB
Image	28 GB
Transfer date	March 23, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.33
RMSE for East Position (<4.0 cm)	1.565
RMSE for Down Position (<8.0 cm)	2.58
Boresight correction stdev (<0.001deg)	0.001069
IMU attitude correction stdev (<0.001deg)	0.532029
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	26.80%
Ave point cloud density per sq.m. (>2.0)	5.28
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	92
Maximum Height	120.20 m
Minimum Height	568.01 m
Classification (# of points)	
Ground	8,434,991
Low vegetation	23,215,965
Medium vegetation	103,075,975
High vegetation	49,410,182
Building	176,635
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Engr. Krisha Marie Bautista

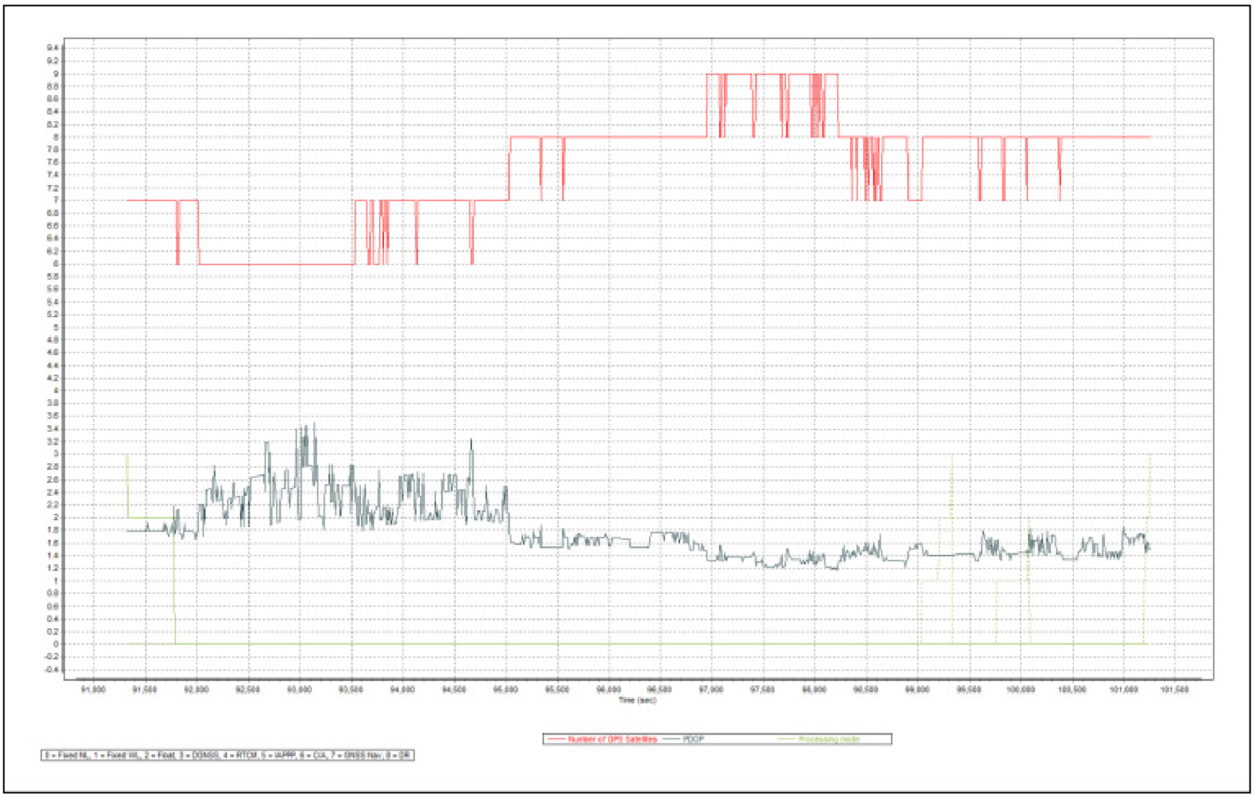


Figure A-8.15. Solution Status

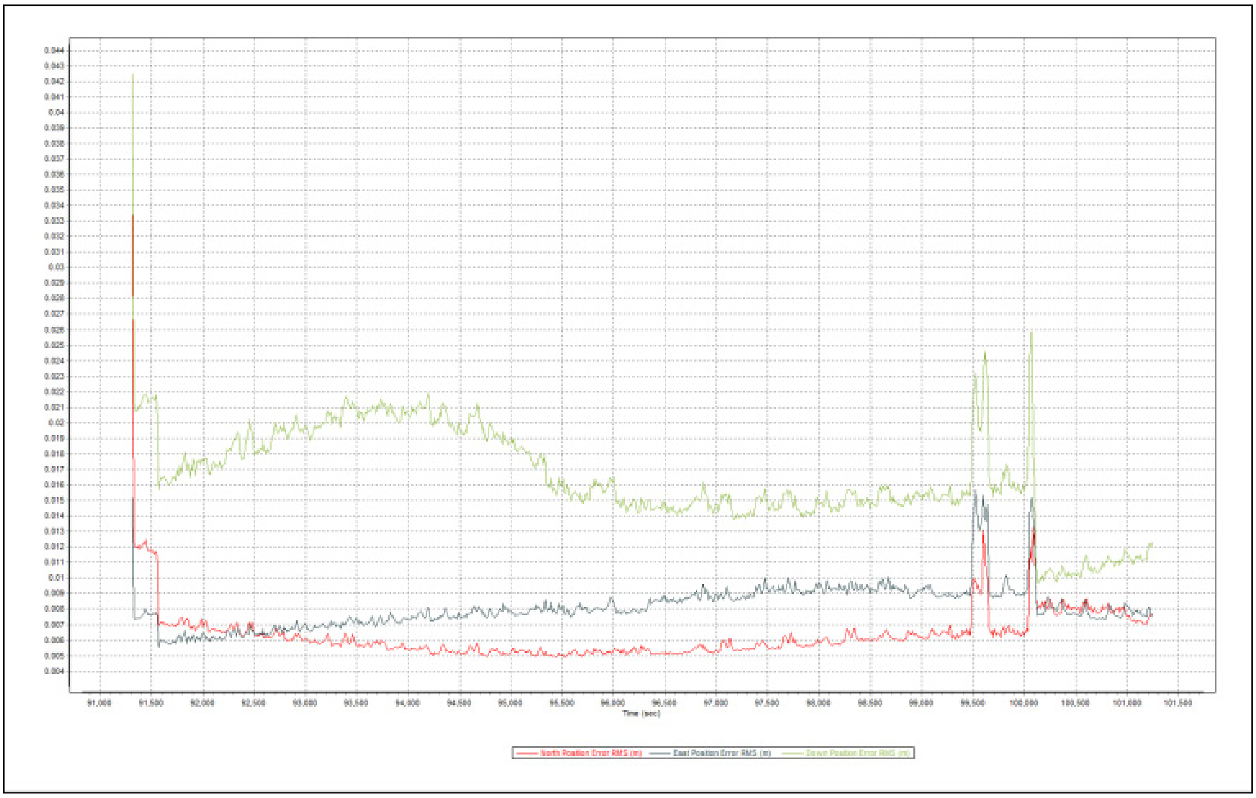


Figure A-8.16. Smoothed Performance Metric Parameters

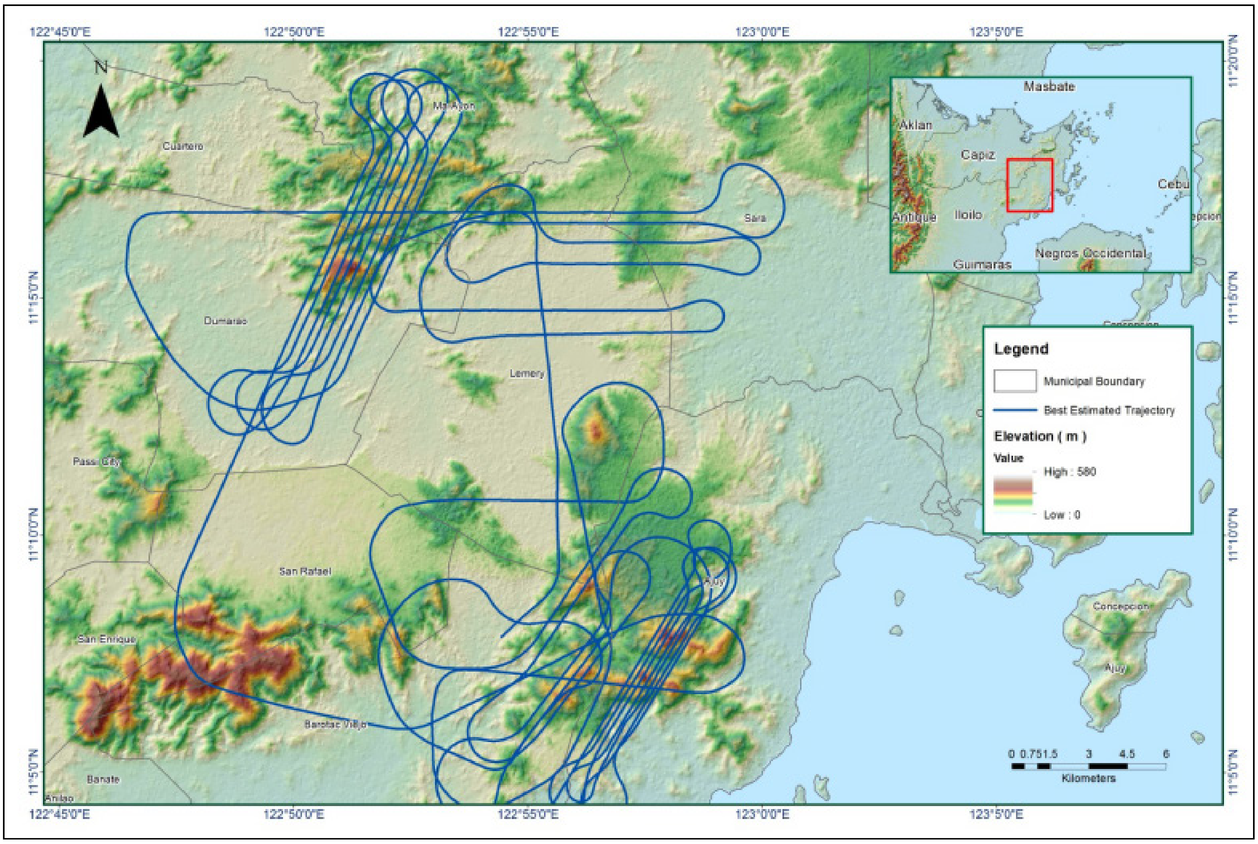


Figure A-8.17. Best Estimated Trajectory

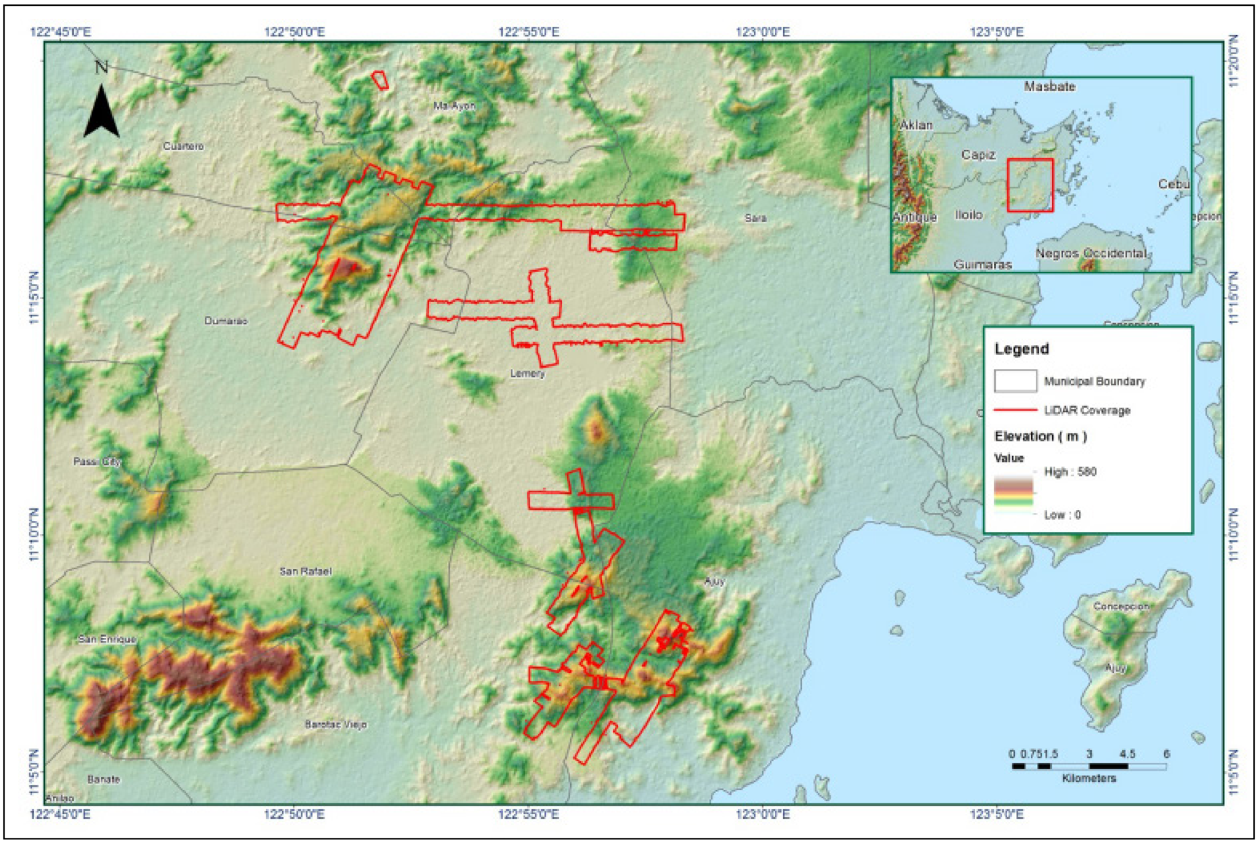


Figure A-8.18. Coverage of LiDAR data

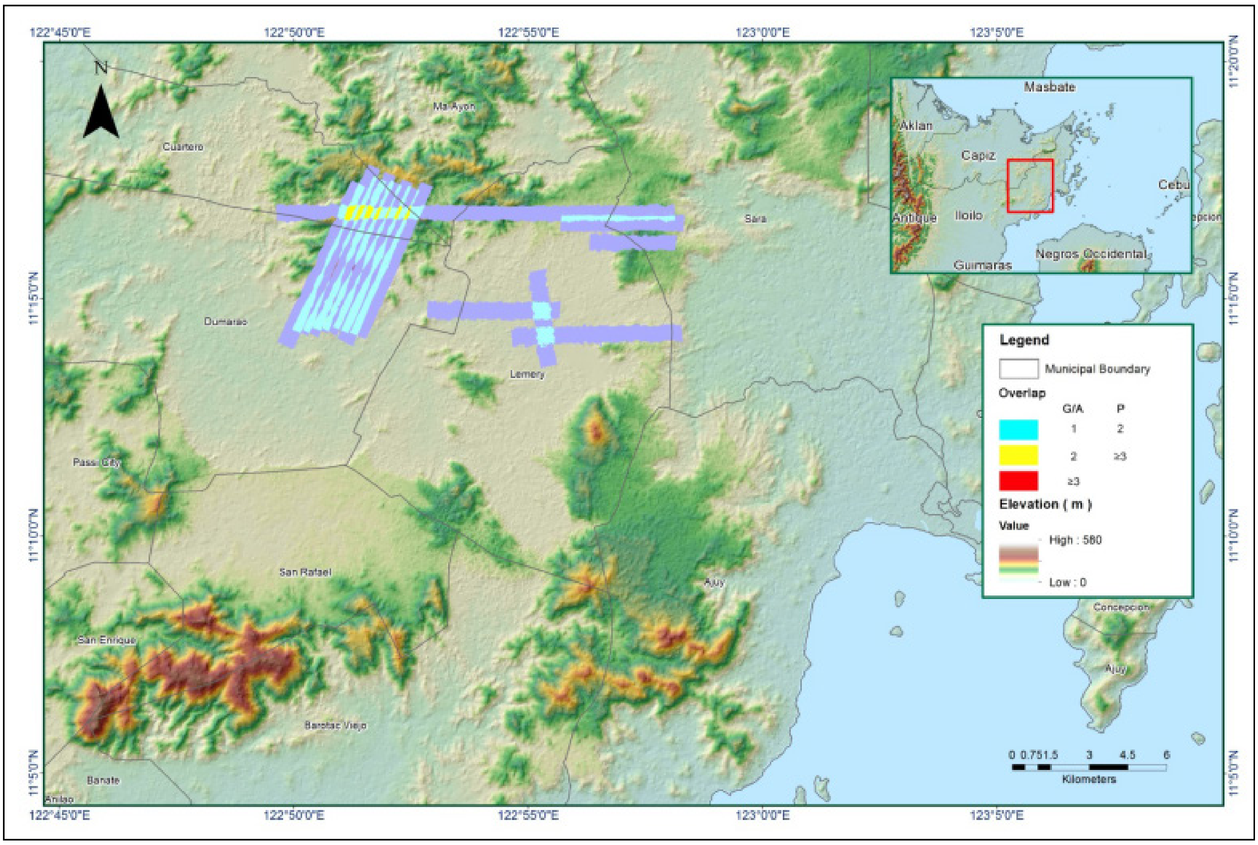


Figure A-8.19. Image of Data Overlap

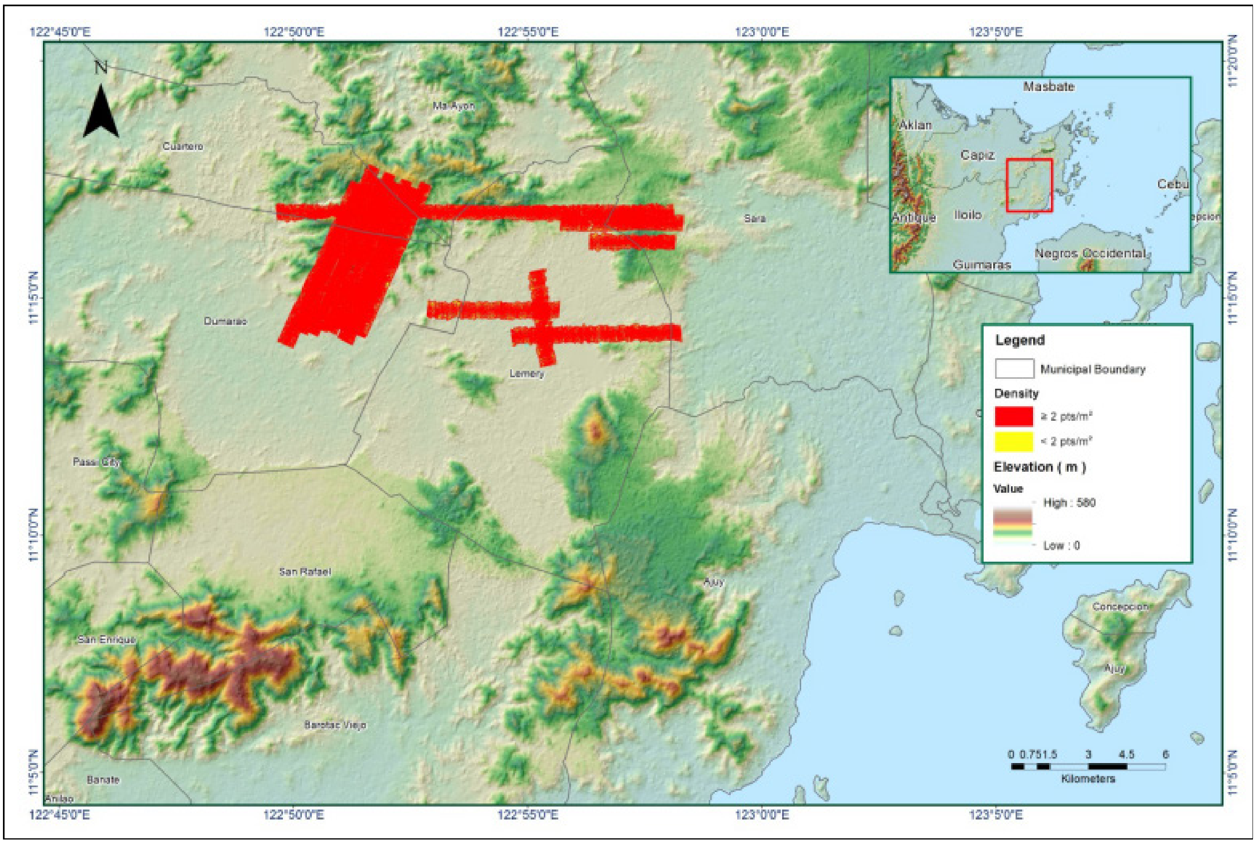


Figure A-8.20. Density map of merged LiDAR data

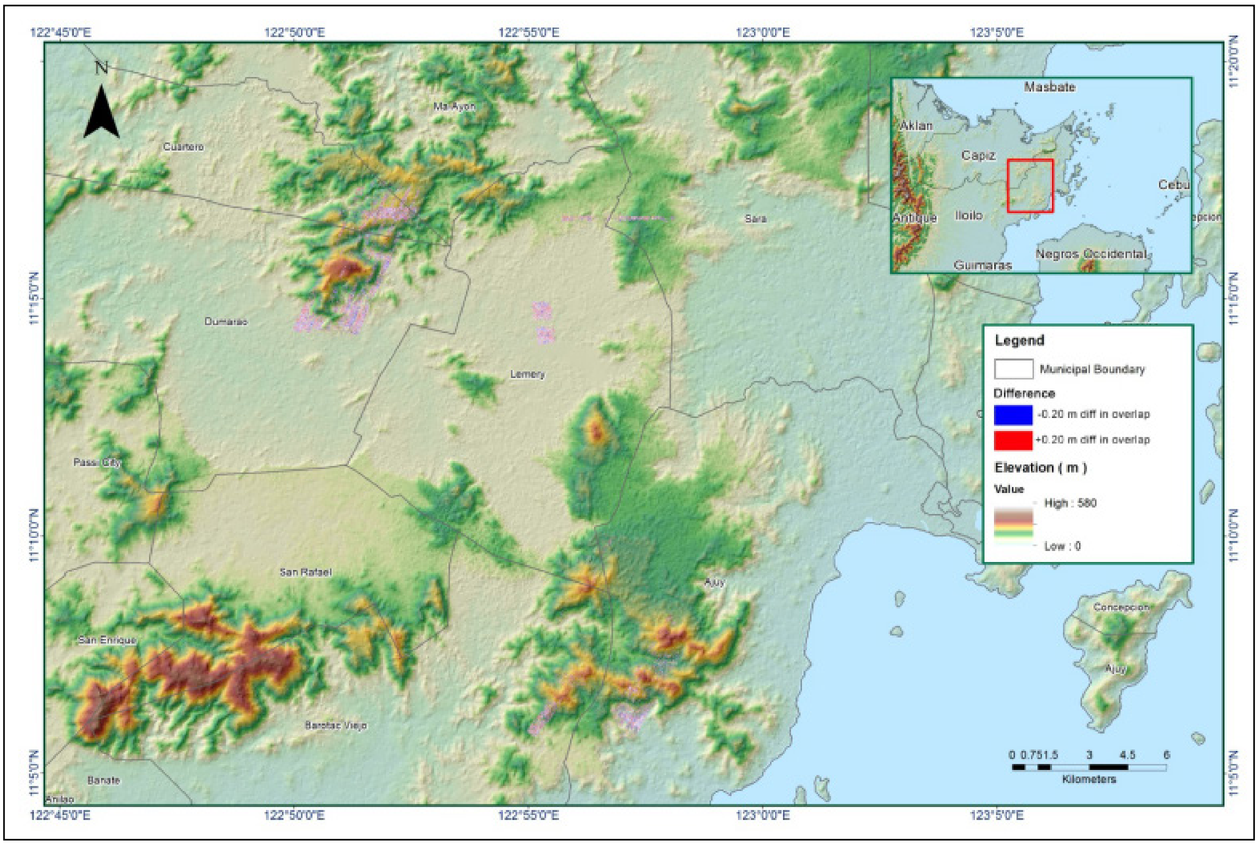


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk37H

Flight Area	Iloilo
Mission Name	Blk37H
Inclusive Flights	2542G
Range data size	34.5 GB
POS data size	274 MB
Base data size	16.6 MB
Image	85.2 GB
Transfer date	February 17, 2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.49
RMSE for East Position (<4.0 cm)	3.15
RMSE for Down Position (<8.0 cm)	4.73
Boresight correction stdev (<0.001deg)	0.007773
IMU attitude correction stdev (<0.001deg)	0.072669
GPS position stdev (<0.01m)	0.0188
Minimum % overlap (>25)	40.10%
Ave point cloud density per sq.m. (>2.0)	5.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	231
Maximum Height	695.16 m
Minimum Height	50.43
Classification (# of points)	
Ground	89,013,593
Low vegetation	145,375,969
Medium vegetation	494,759,424
High vegetation	184,454,693
Building	3,043,940
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Mark Joshua Salvacion, Engr. Krisha Marie Bautista

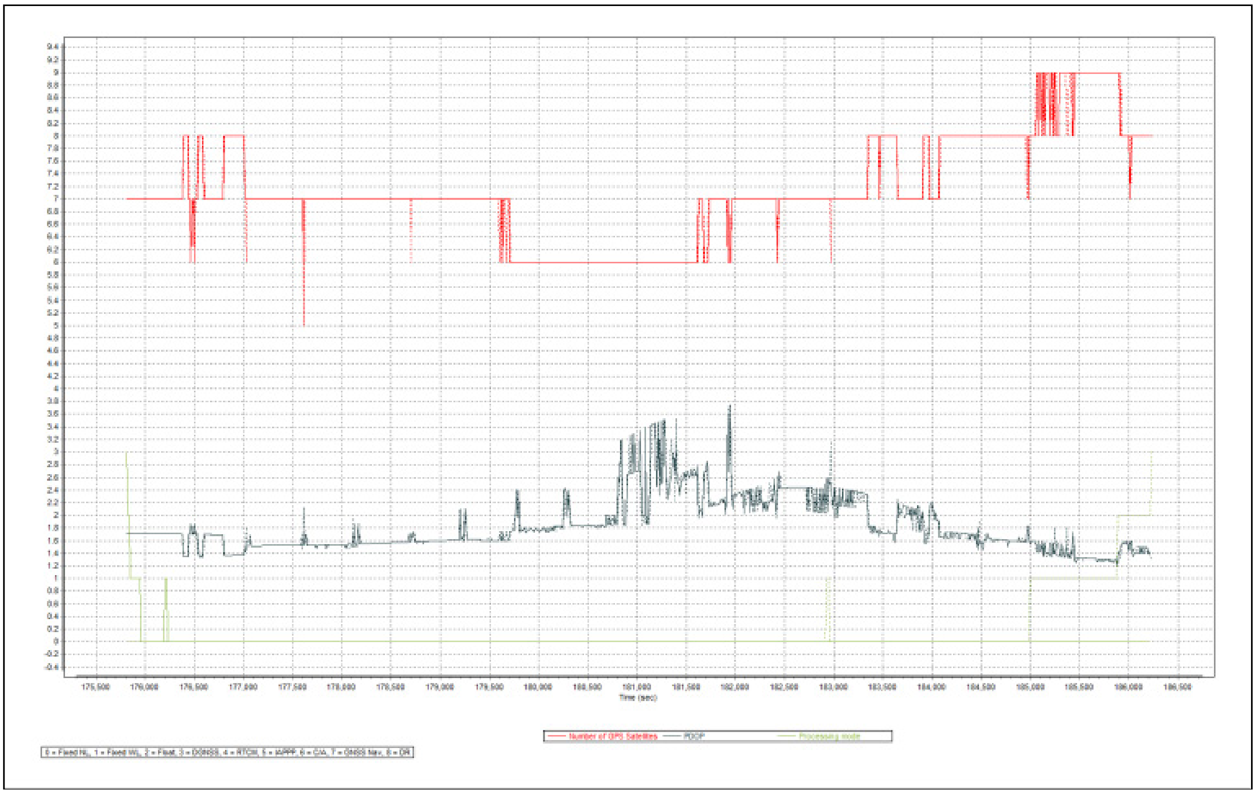


Figure A-8.22. Solution Status

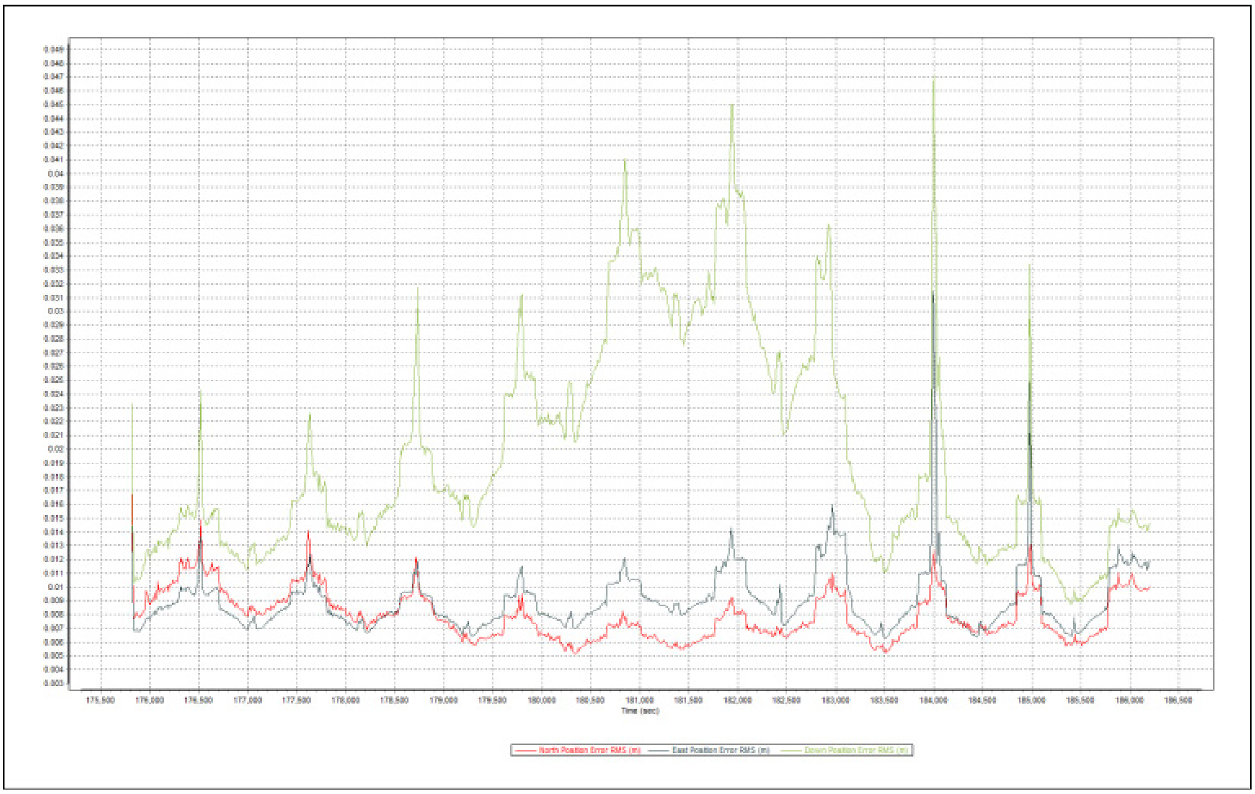


Figure A-8.23. Smoothed Performance Metric Parameters

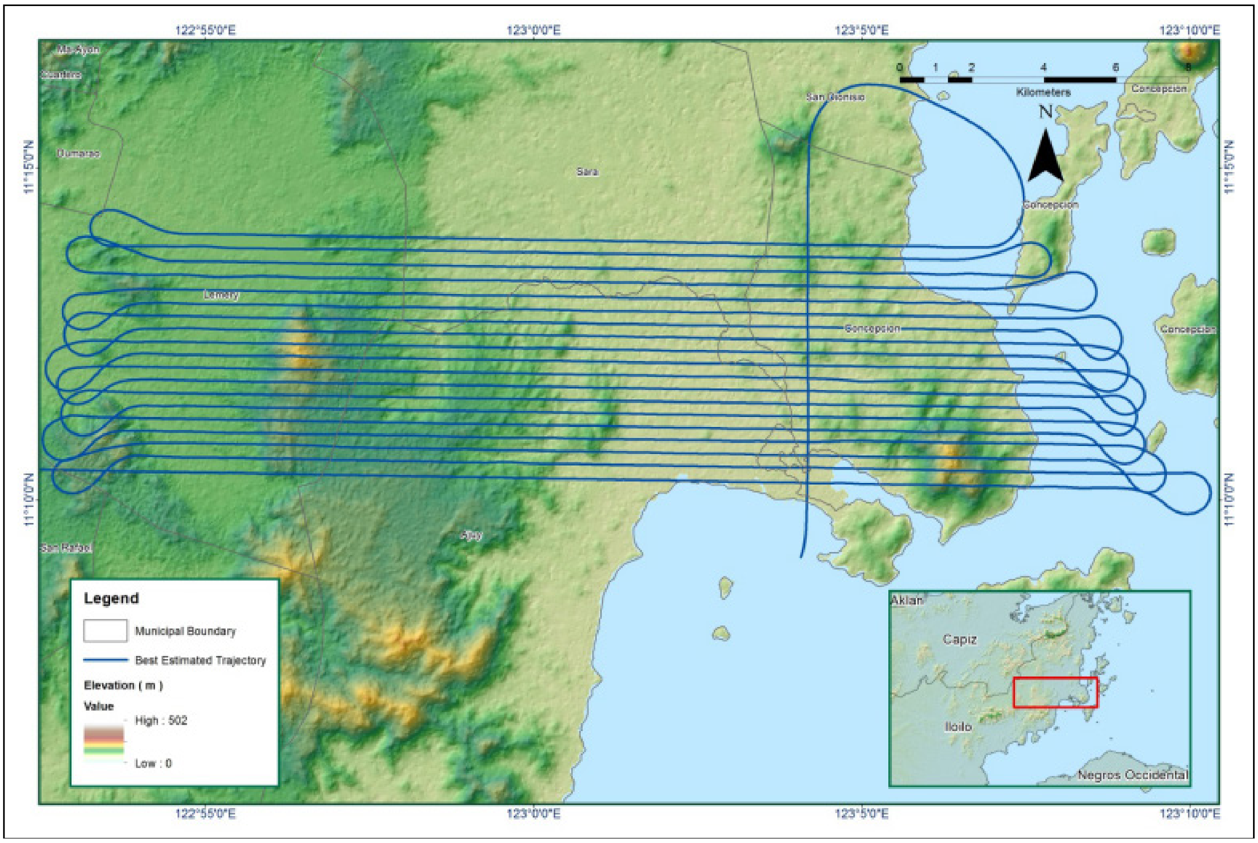


Figure A-8.24. Best Estimated Trajectory

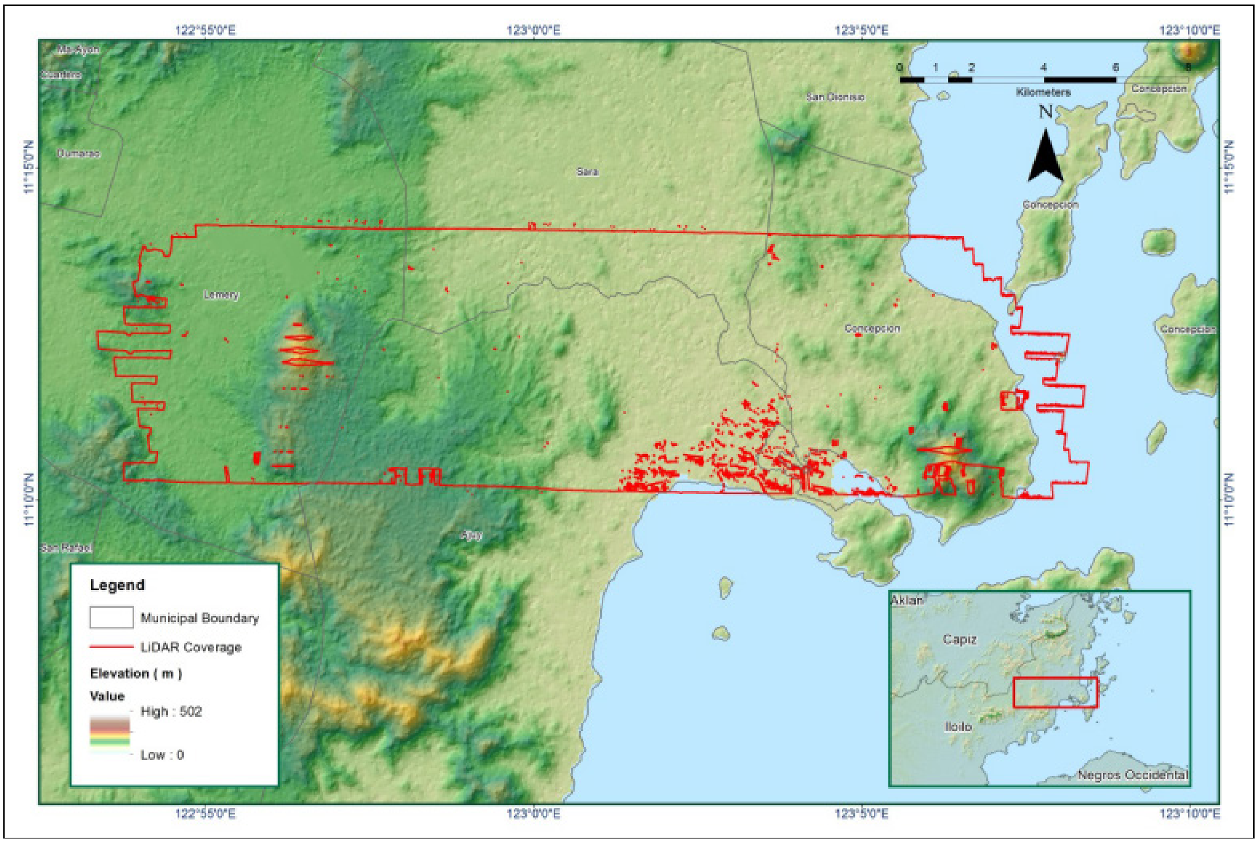


Figure A-8.25. Coverage of LiDAR data

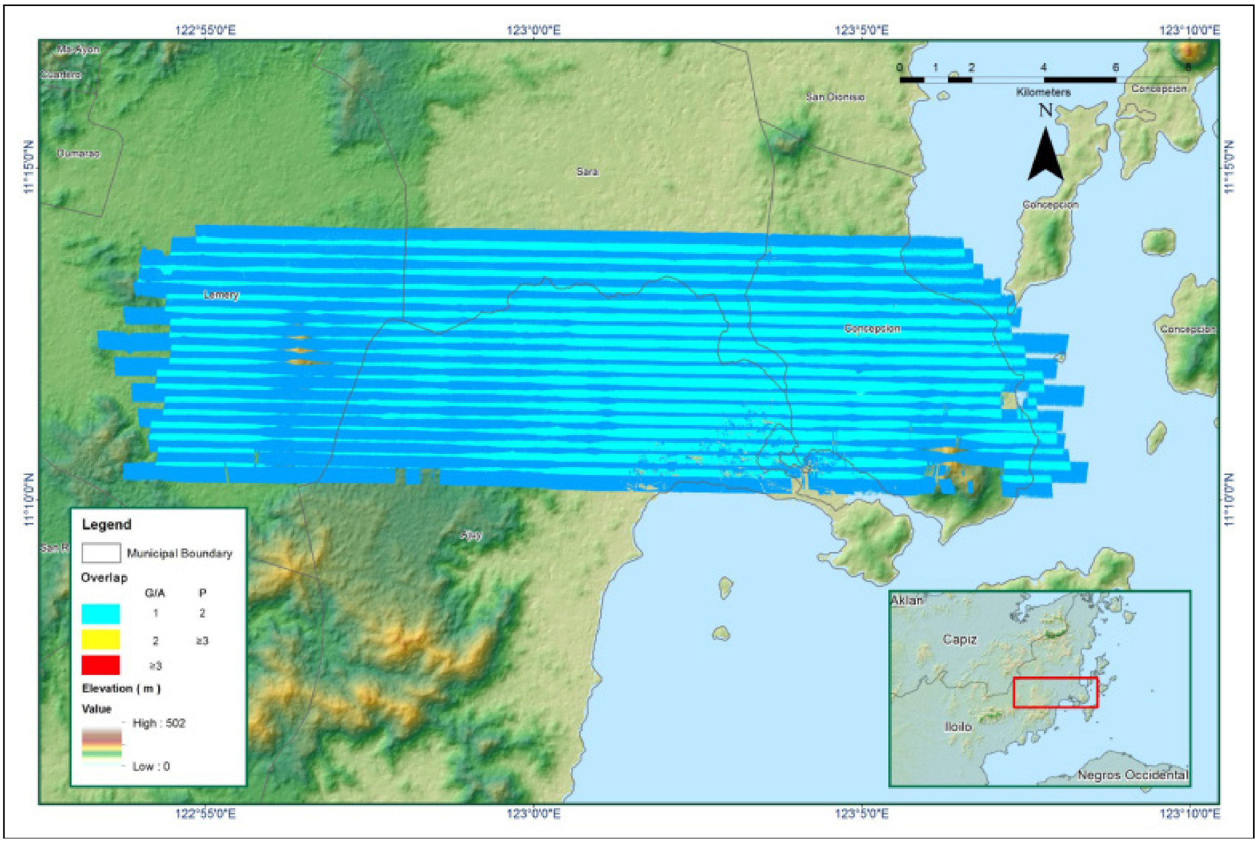


Figure A-8.26. Image of Data Overlap

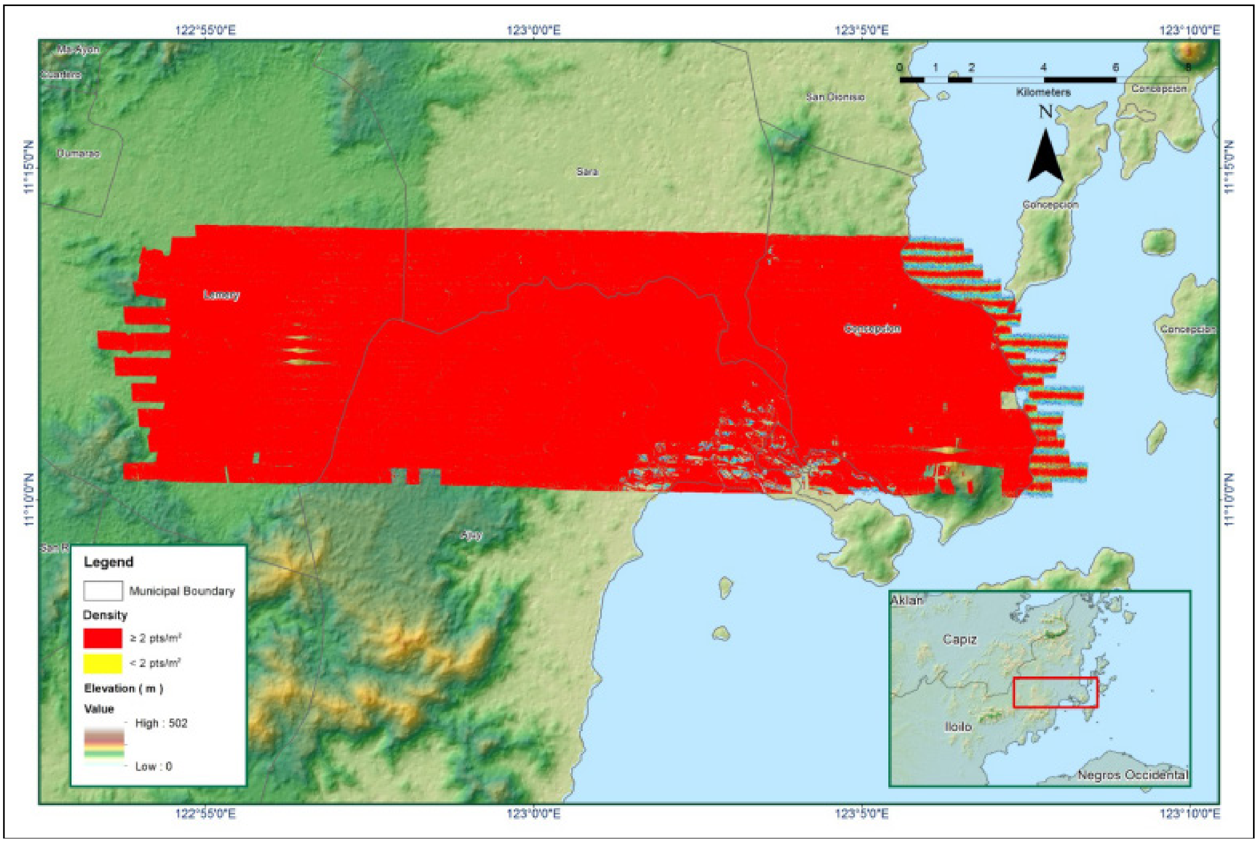


Figure A-8.27. Density map of merged LiDAR data

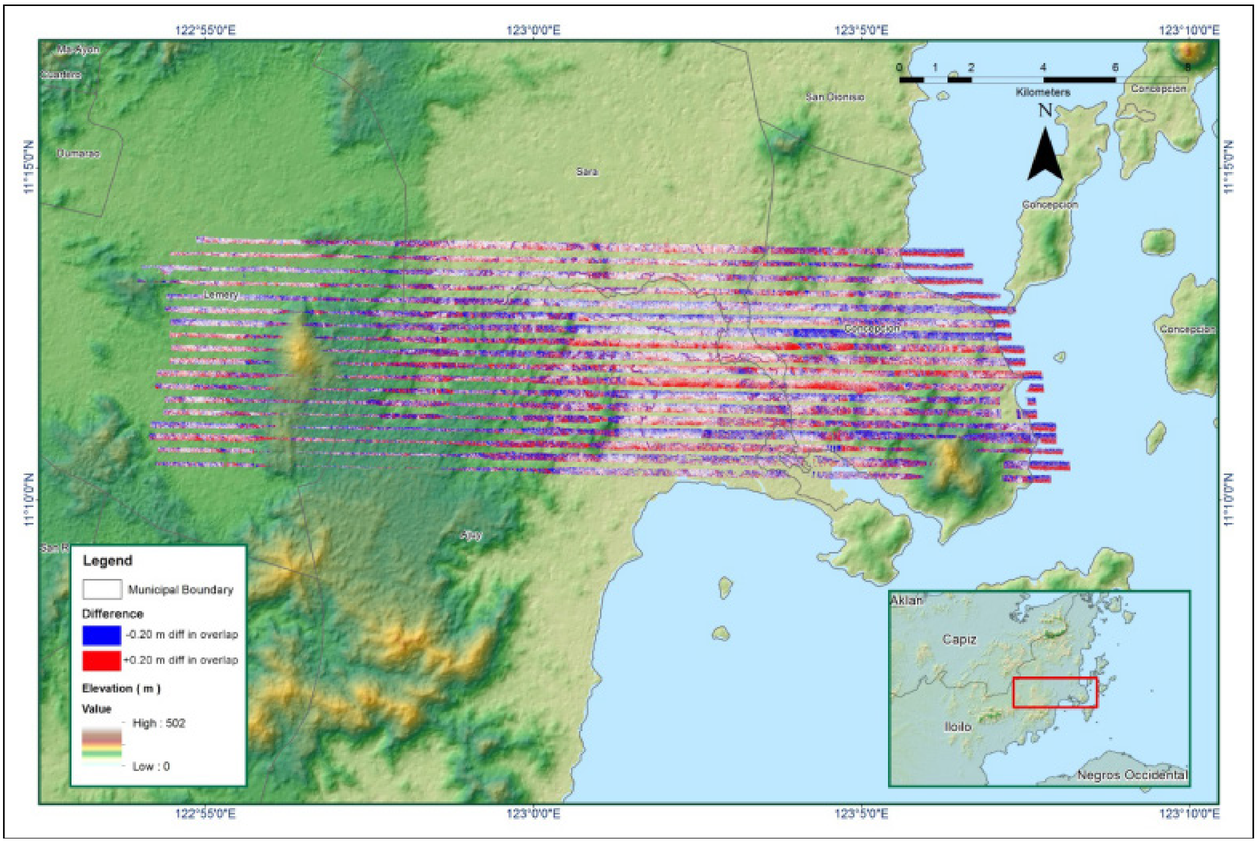


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk37JK

Flight Area	Iloilo
Mission Name	Blk37JK
Inclusive Flights	2544G, 2556G, 2546G
Range data size	93.5 GB
POS data size	678 MB
Base data size	45.1 MB
Image	208.1 GB
Transfer date	February 17, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.66
RMSE for East Position (<4.0 cm)	1.68
RMSE for Down Position (<8.0 cm)	5.17
Boresight correction stdev (<0.001deg)	0.000239
IMU attitude correction stdev (<0.001deg)	0.004494
GPS position stdev (<0.01m)	0.0123
Minimum % overlap (>25)	36.99%
Ave point cloud density per sq.m. (>2.0)	5.63
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	564
Maximum Height	535.68 m
Minimum Height	58.02 m
Classification (# of points)	
Ground	321,104,634
Low vegetation	303,553,251
Medium vegetation	958,590,516
High vegetation	604,654,304
Building	6,369,594
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Mark Joshua Salvacion, Kathryn Claudyn Zarate

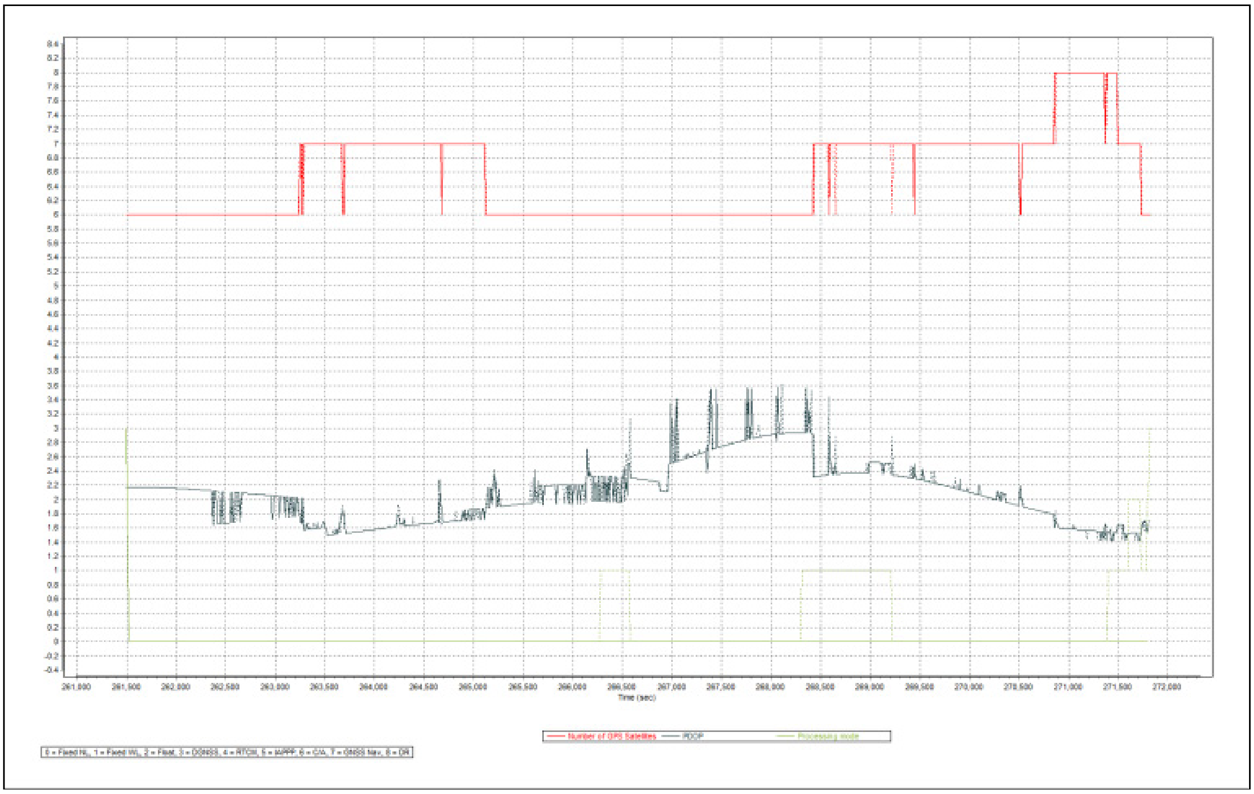


Figure A-8.29. Solution Status

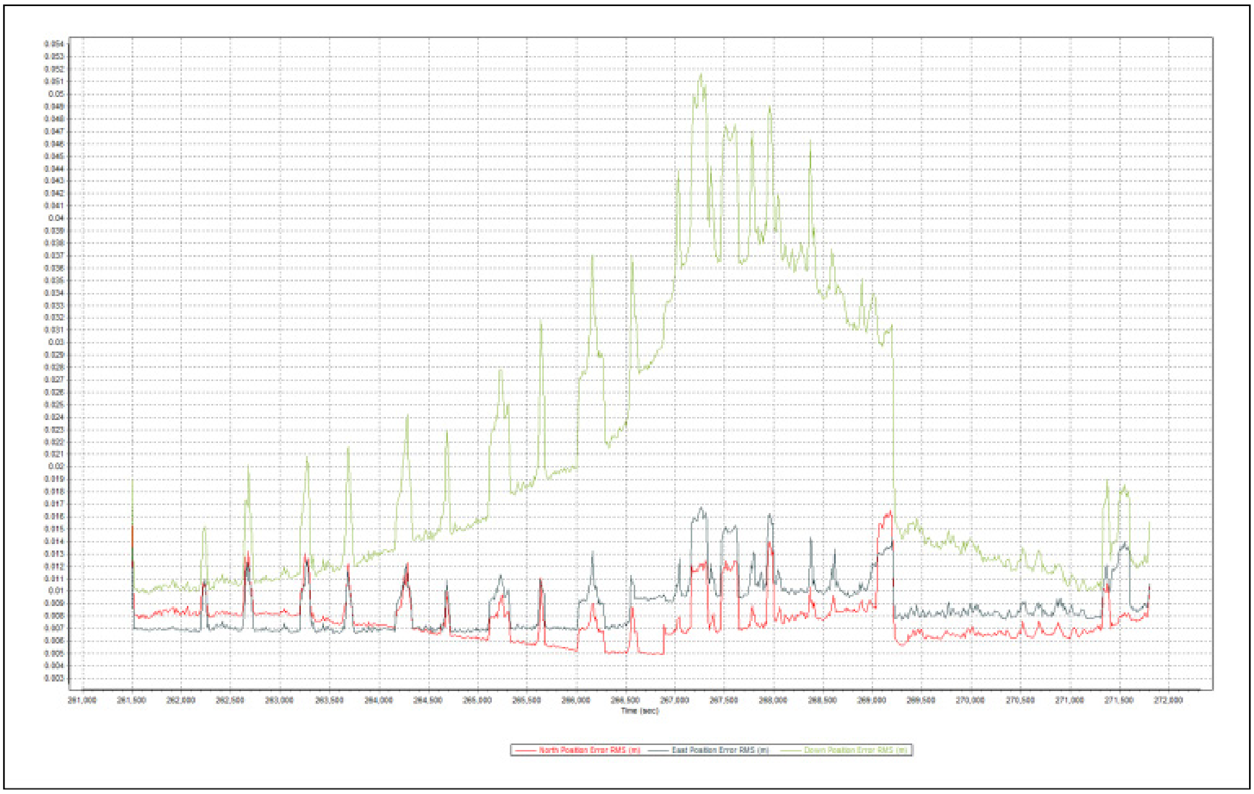


Figure A-8.30. Smoothed Performance Metric Parameters

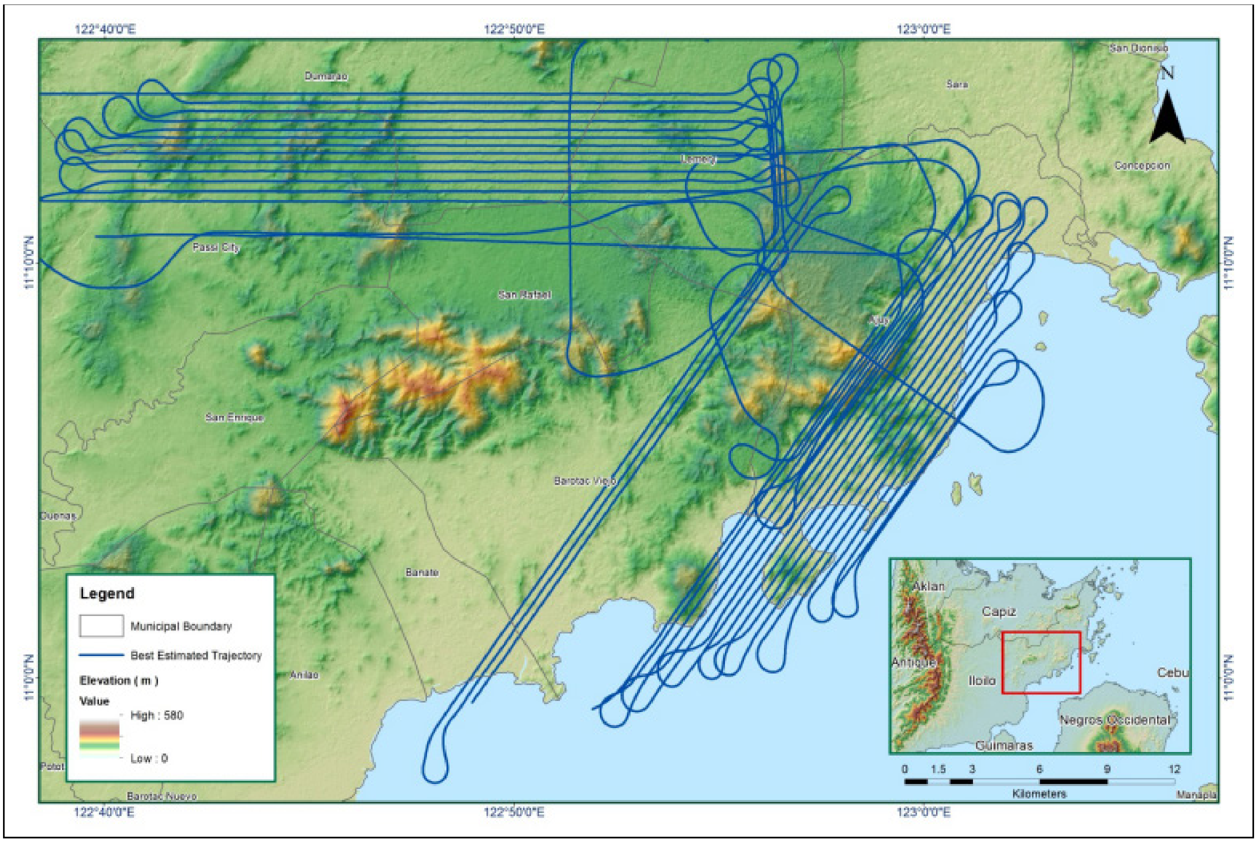


Figure A-8.31. Best Estimated Trajectory

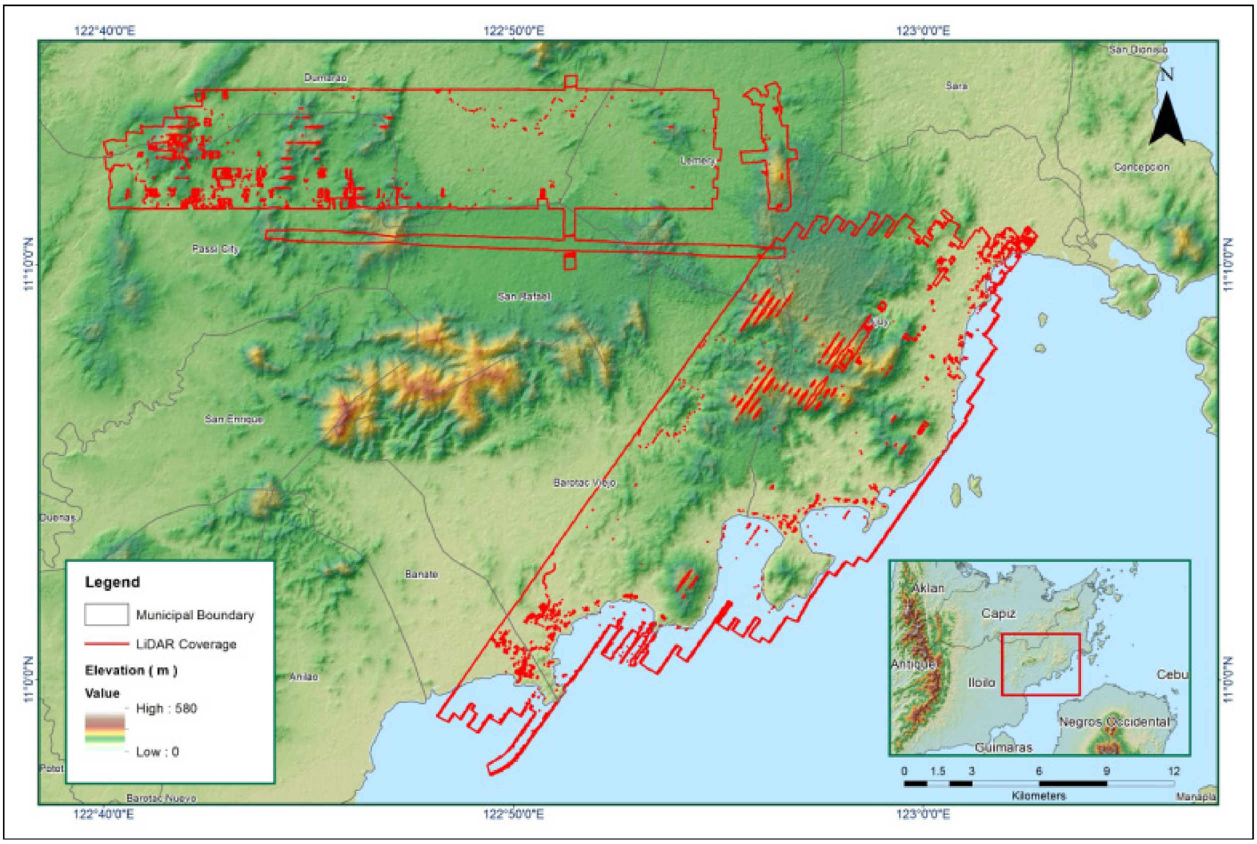


Figure A-8.32. Coverage of LiDAR data

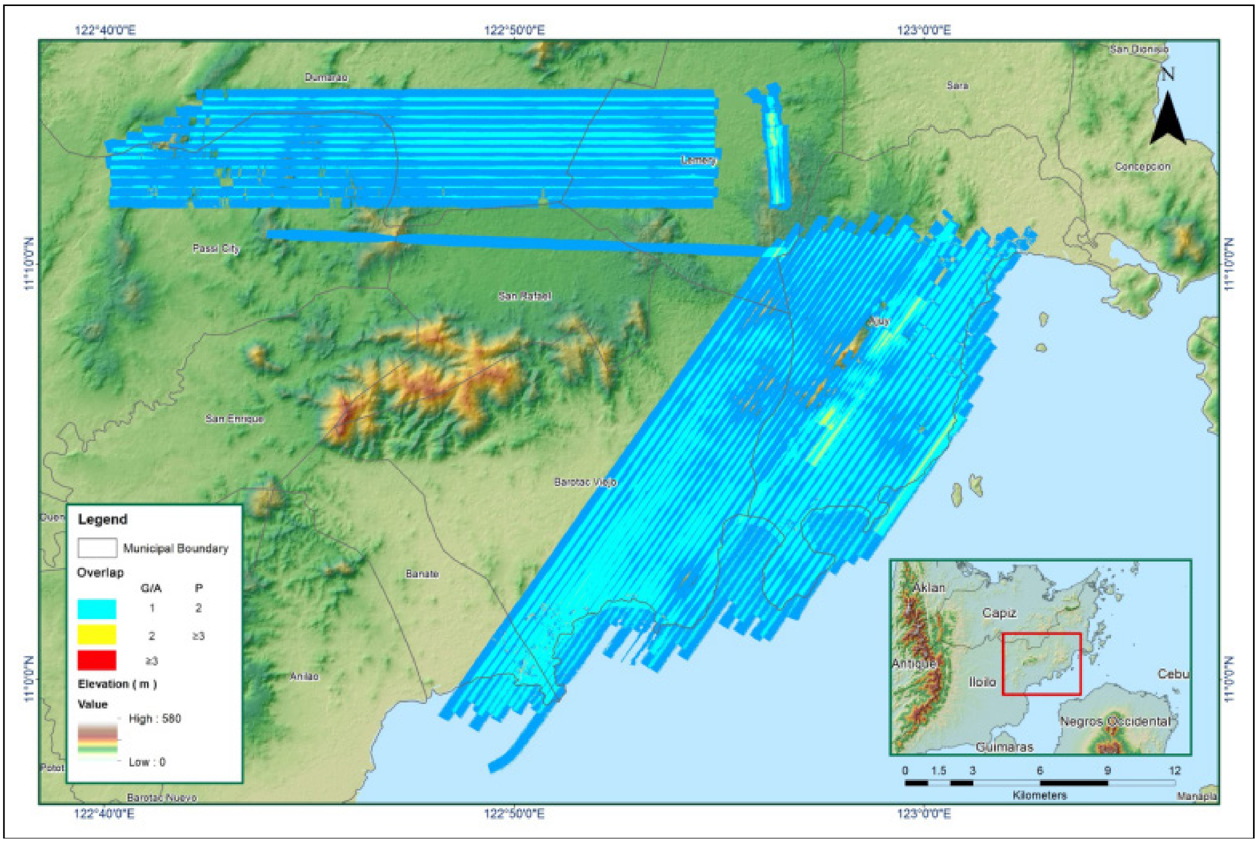


Figure A-8.33. Image of Data Overlap

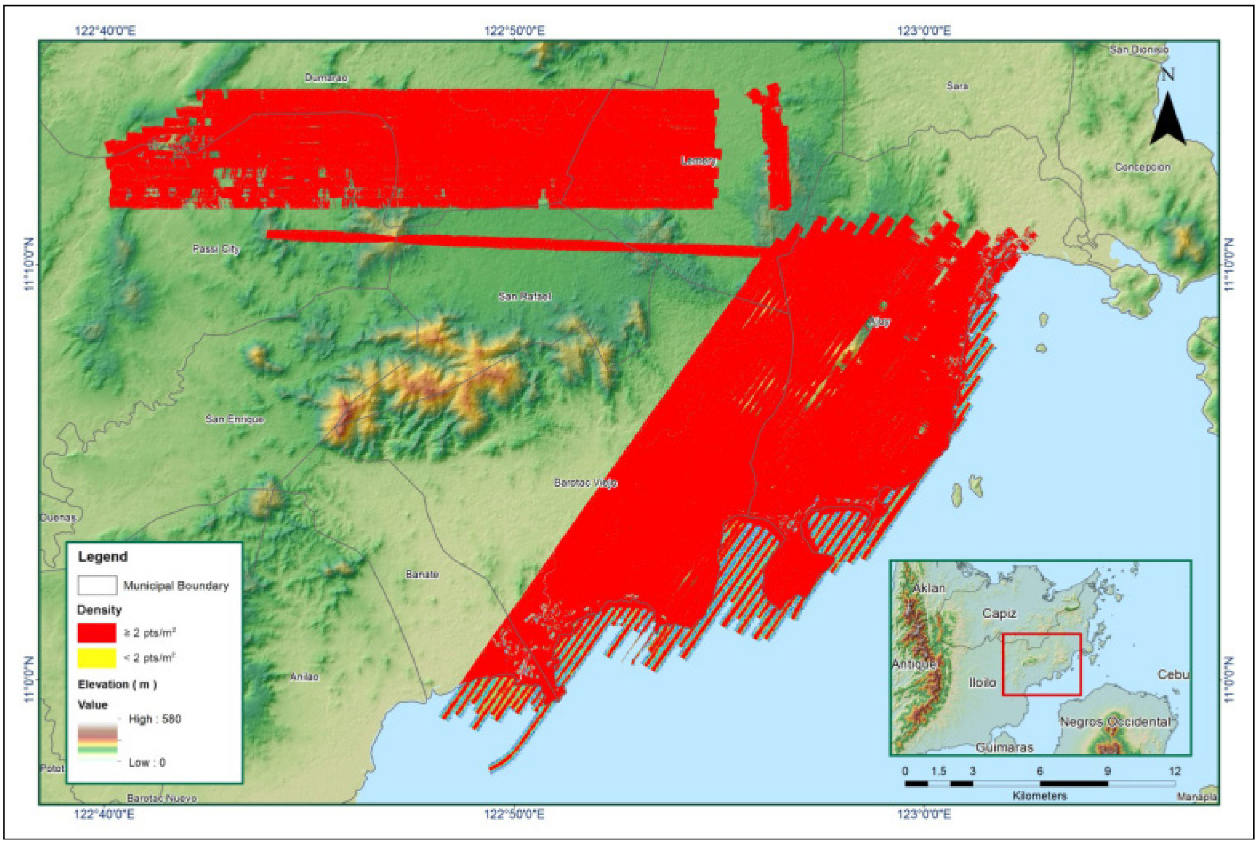


Figure A-8.34. Density map of merged LiDAR data

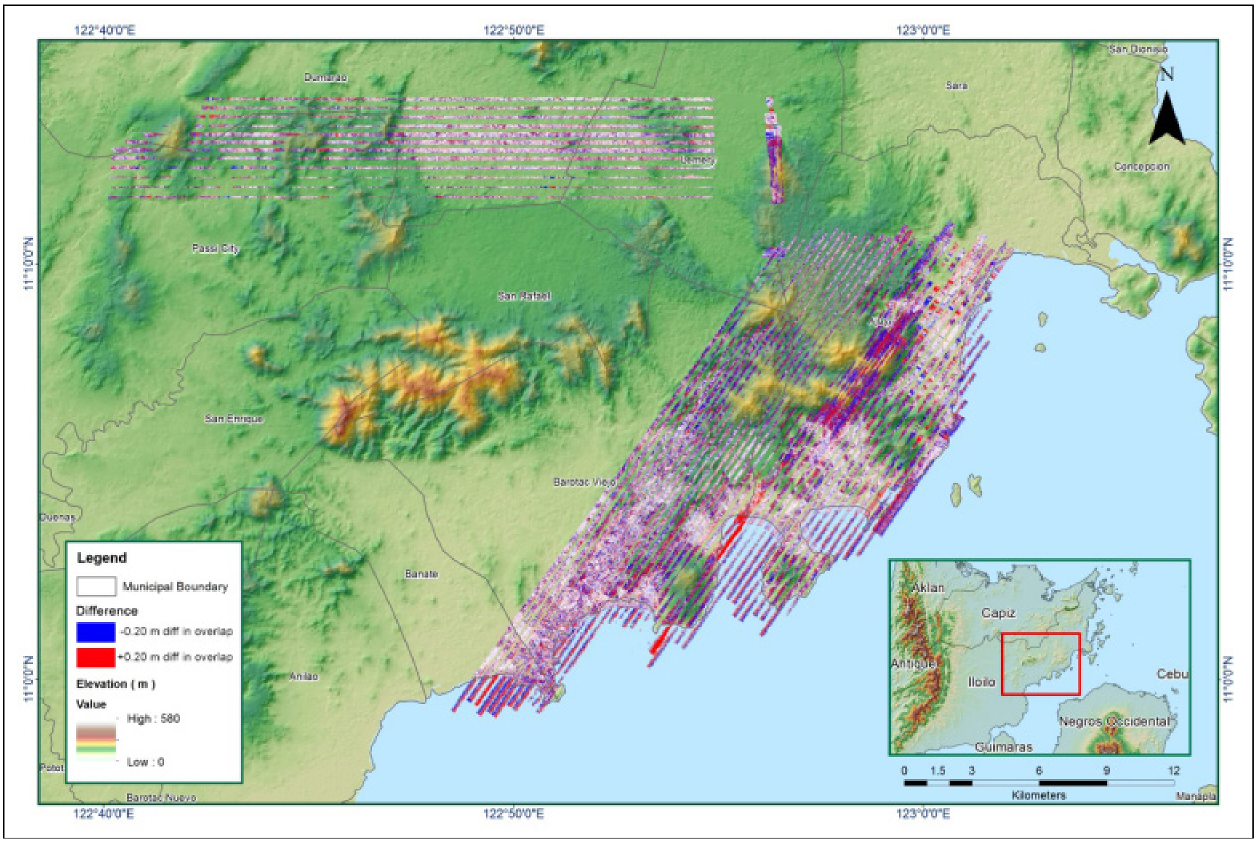


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk37Q

Flight Area	Iloilo
Mission Name	Blk37Q
Inclusive Flights	2645P, 2647P, 2649P
Range data size	44 GB
POS data size	700 MB
Base data size	65.5 MB
Image	122.4 GB
Transfer date	July 07, 2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.14
RMSE for East Position (<4.0 cm)	2.44
RMSE for Down Position (<8.0 cm)	5.4
Boresight correction stdev (<0.001deg)	0.000496
IMU attitude correction stdev (<0.001deg)	0.002611
GPS position stdev (<0.01m)	0.001
Minimum % overlap (>25)	43.43%
Ave point cloud density per sq.m. (>2.0)	2.86
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	258
Maximum Height	581.60 m
Minimum Height	50.96 m
Classification (# of points)	
Ground	146,277,156
Low vegetation	176,372,738
Medium vegetation	222,753,602
High vegetation	195,610,886
Building	4,585,646
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Edgardo Gubatanga Jr., Engr. Sueden Lyle Magtalas

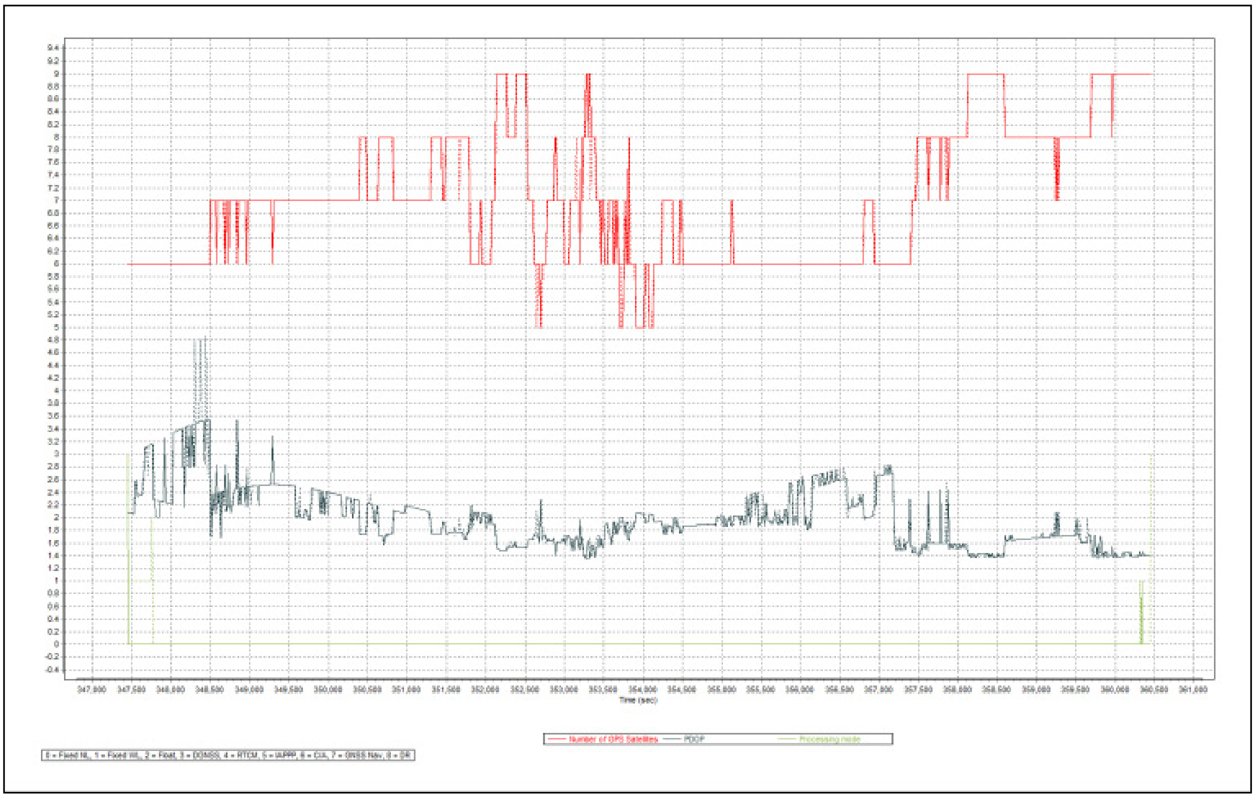


Figure A-8.36. Solution Status

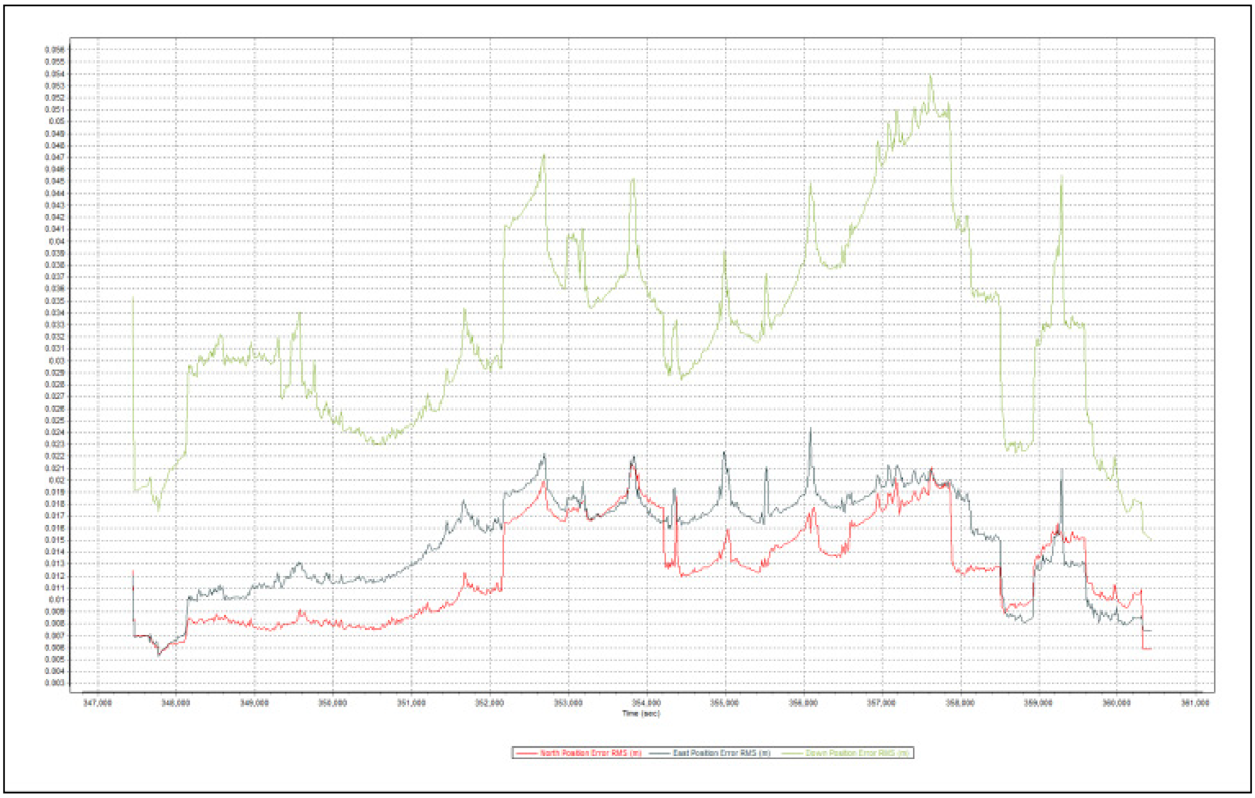


Figure A-8.37. Smoothed Performance Metric Parameters

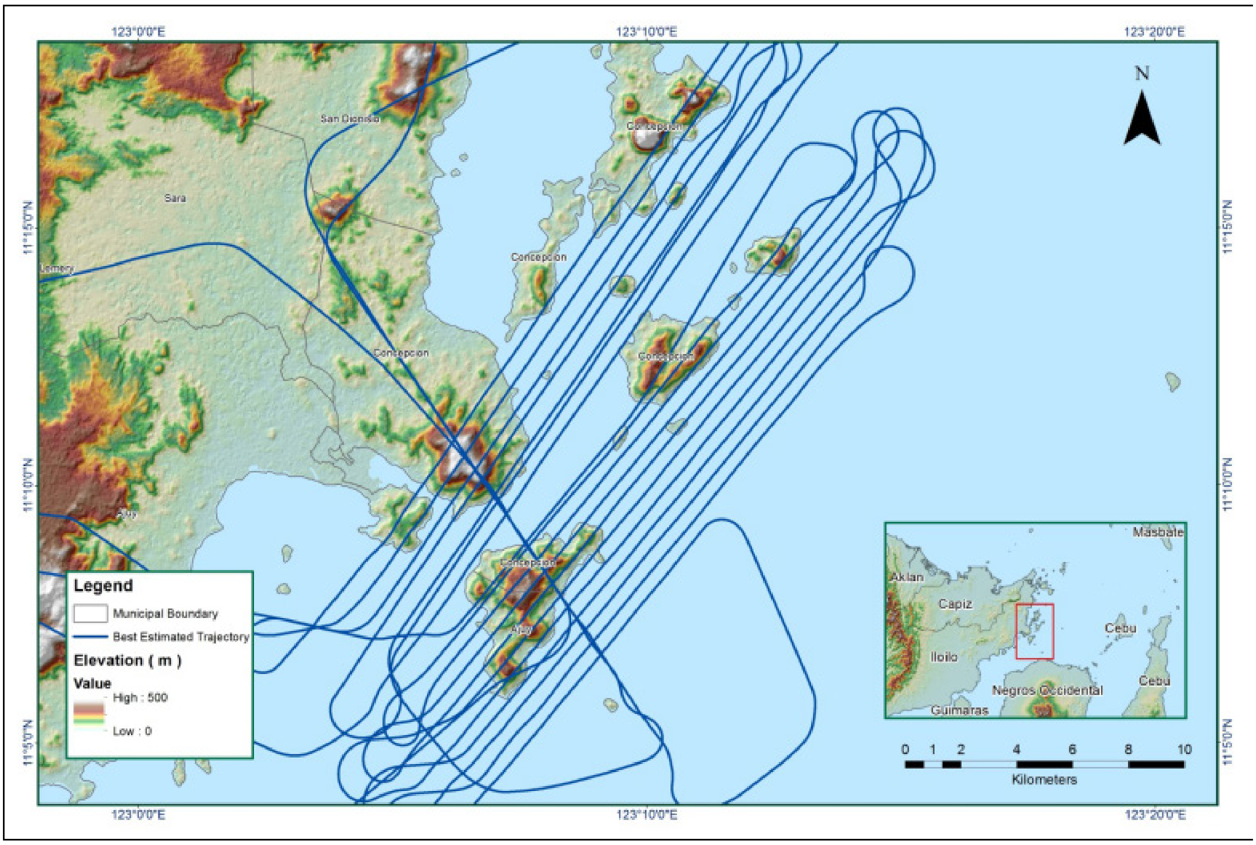


Figure A-8.38. Best Estimated Trajectory

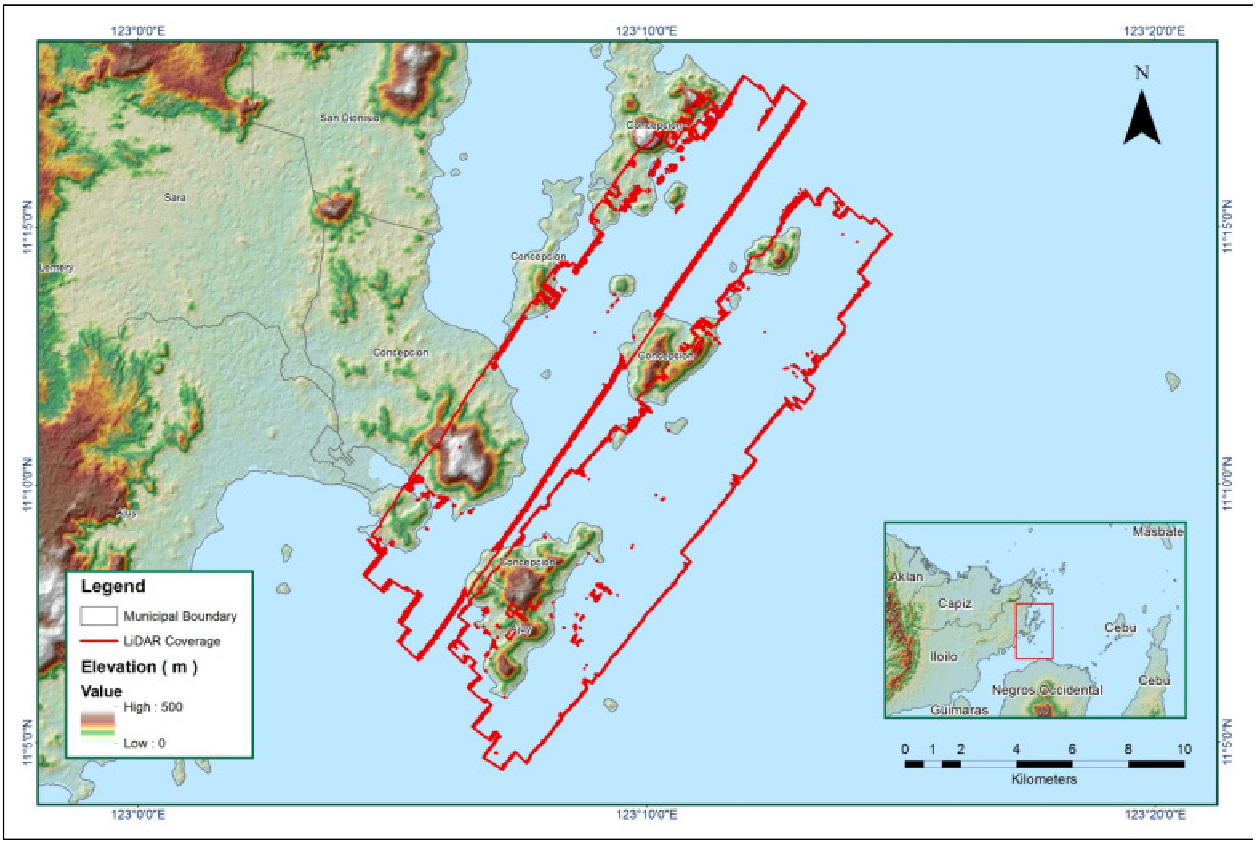


Figure A-8.39. Coverage of LiDAR data

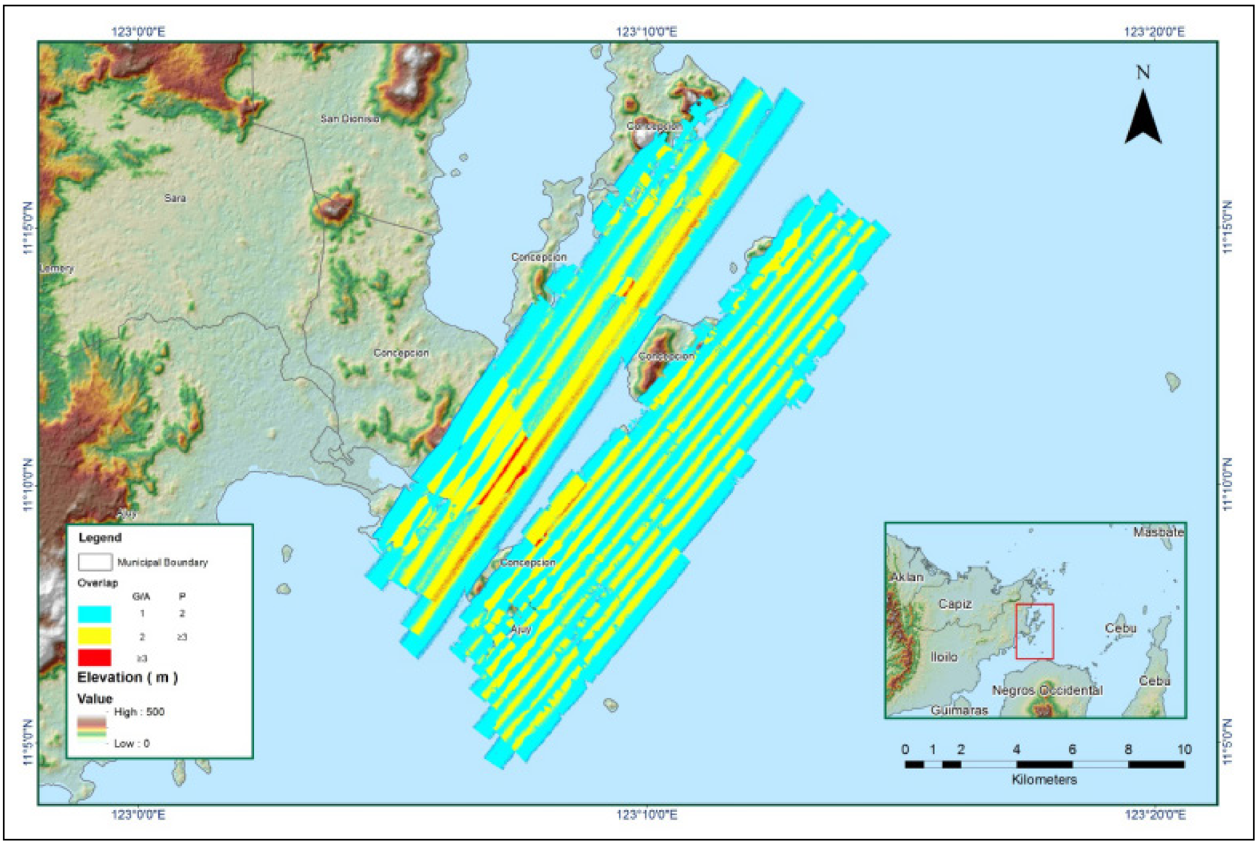


Figure A-8.40. Image of Data Overlap

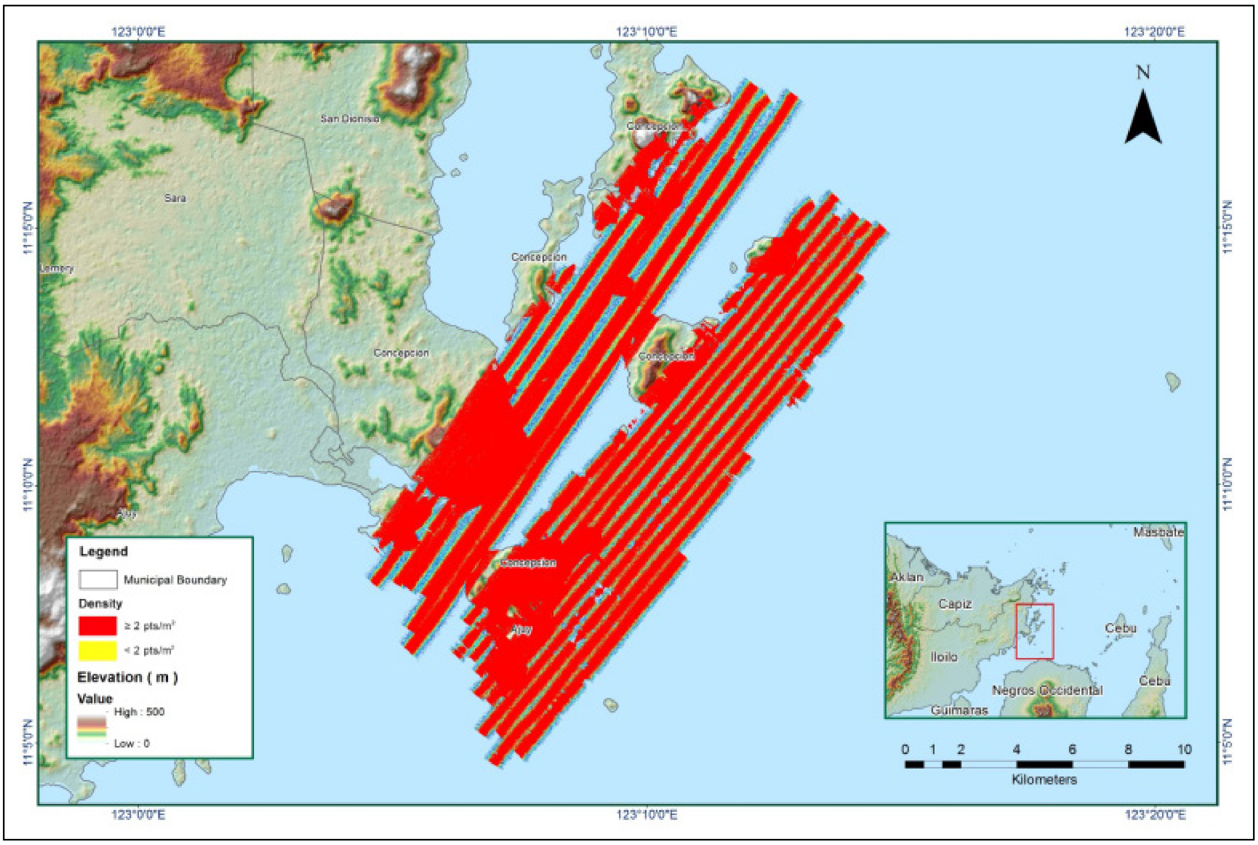


Figure A-8.41. Density map of merged LiDAR data

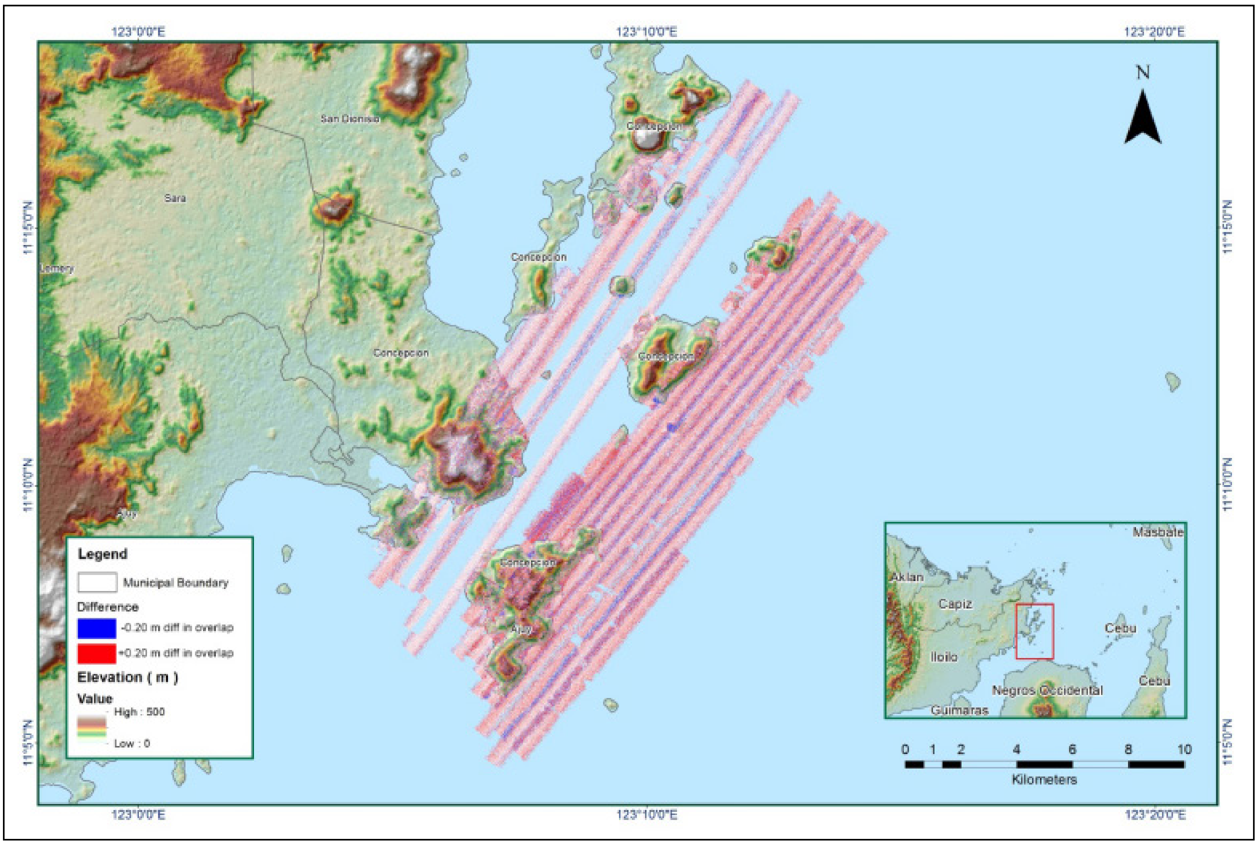


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk38J

Flight Area	Capiz_Aklan
Mission Name	Blk38J
Inclusive Flights	2776G, 2792G
Range data size	26.76 GB
POS	274.2 MB
Image	19.14 MB
Transfer date	October 9, 2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.89
RMSE for East Position (<4.0 cm)	1.95
RMSE for Down Position (<8.0 cm)	13.52
Boresight correction stdev (<0.001deg)	0.000850
IMU attitude correction stdev (<0.001deg)	0.050557
GPS position stdev (<0.01m)	0.0224
Minimum % overlap (>25)	33.11
Ave point cloud density per sq.m. (>2.0)	5.38
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	157
Maximum Height	866.70 m
Minimum Height	58.85 m
Classification (# of points)	
Ground	45,769,140
Low vegetation	59,681,799
Medium vegetation	246,340,757
High vegetation	125,887,319
Building	719,193
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Melanie Hingpit, Engr. Gladys Mae Apat

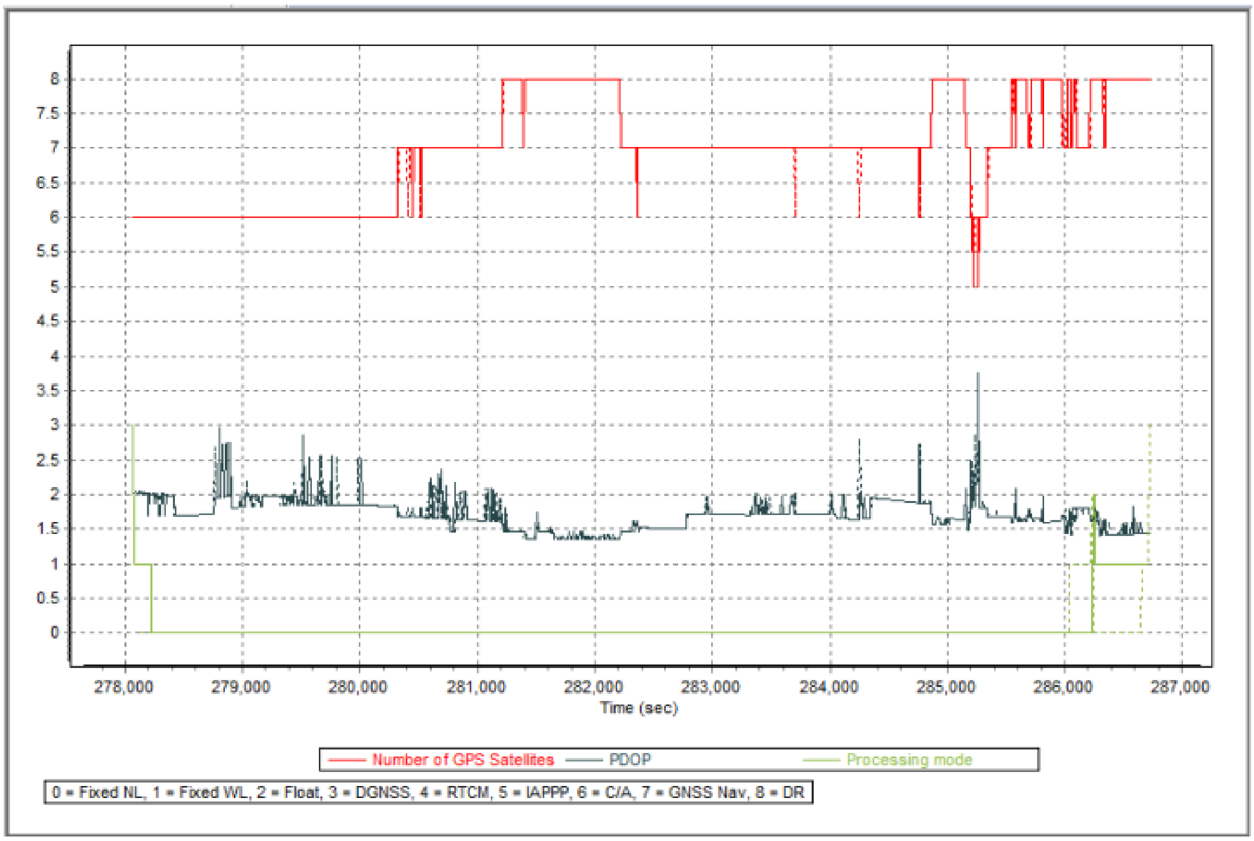


Figure A-8.43. Solution Status

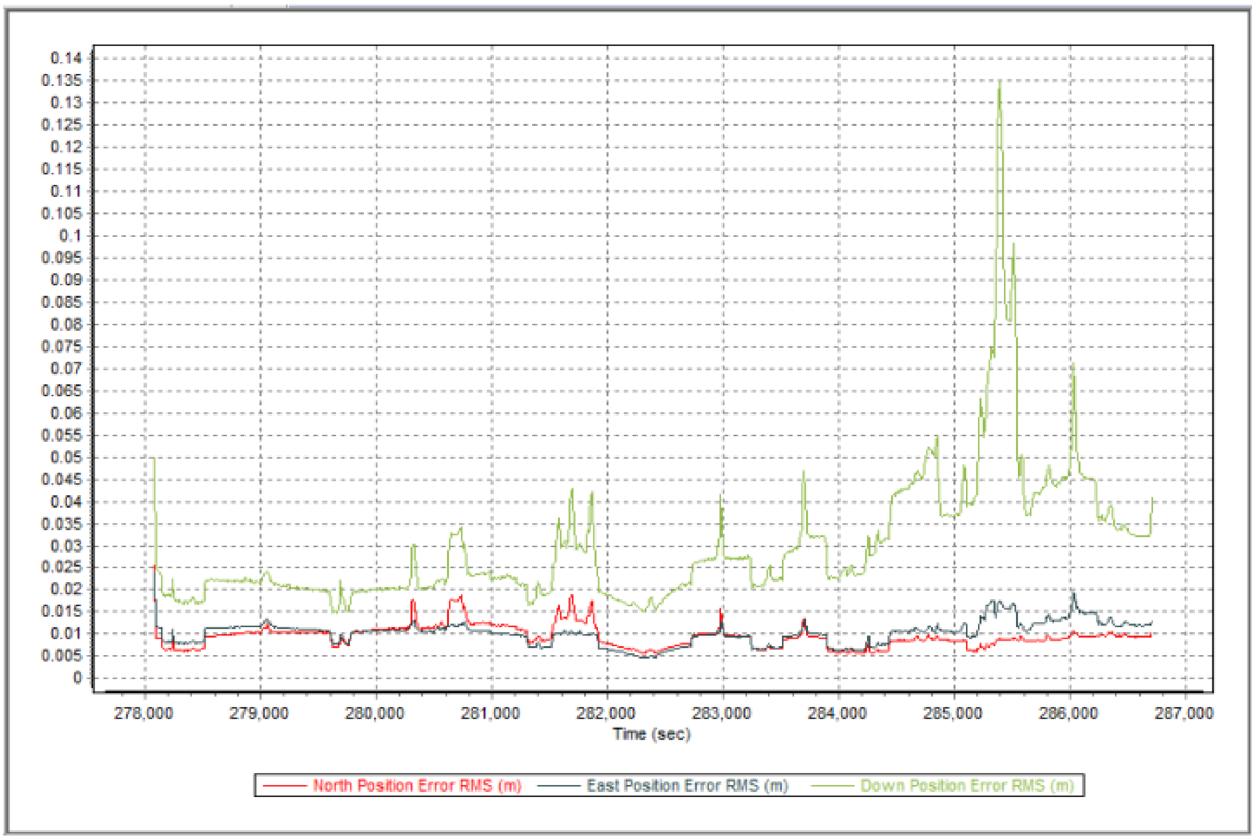


Figure A-8.44. Smoothed Performance Metric Parameters

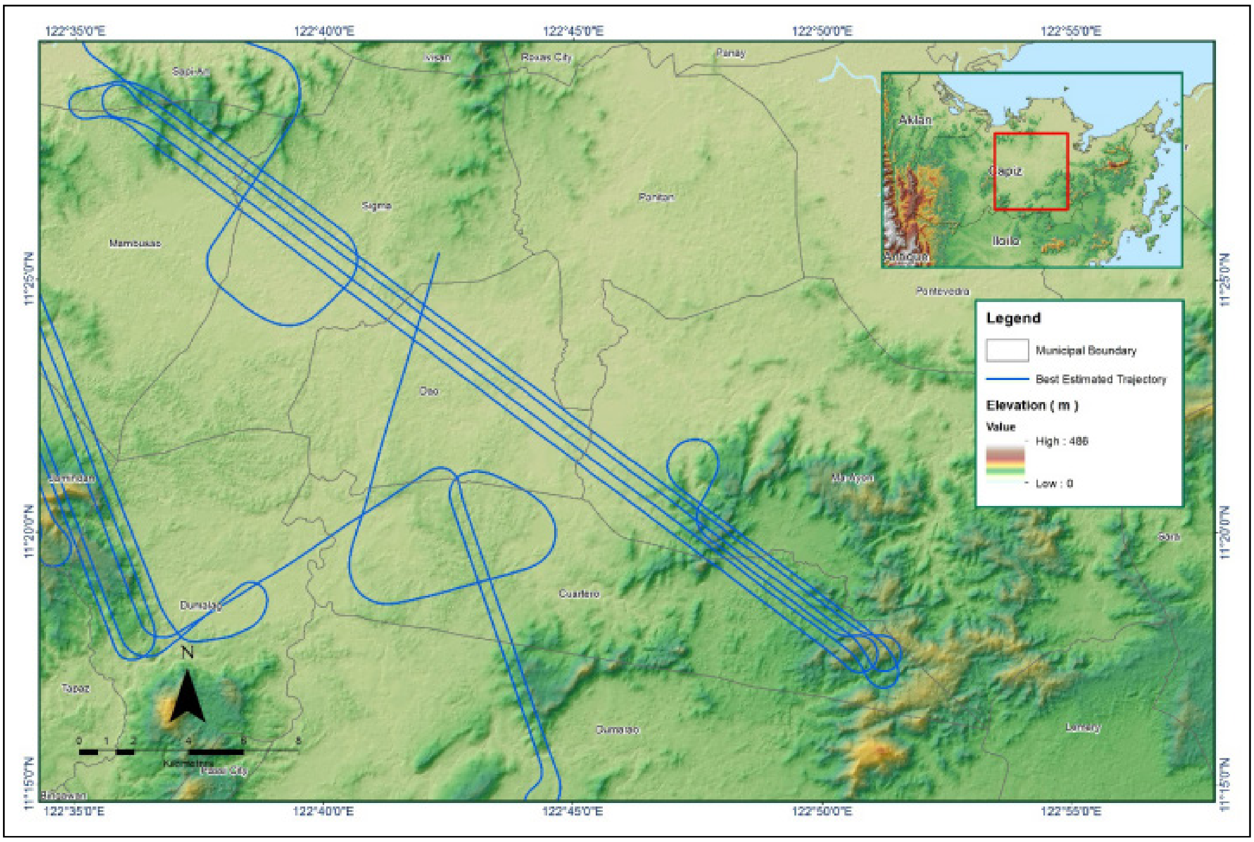


Figure A-8.45. Best Estimated Trajectory

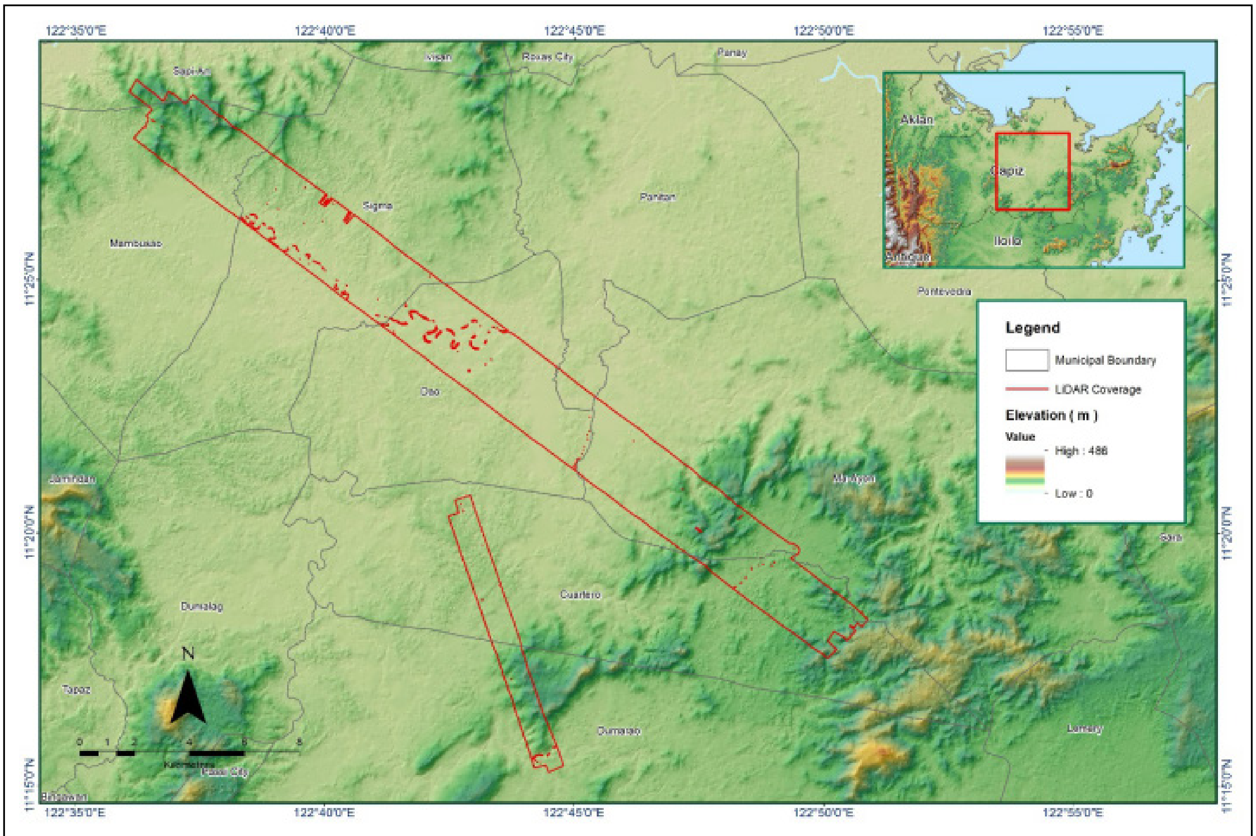


Figure A-8.46. Coverage of LiDAR data

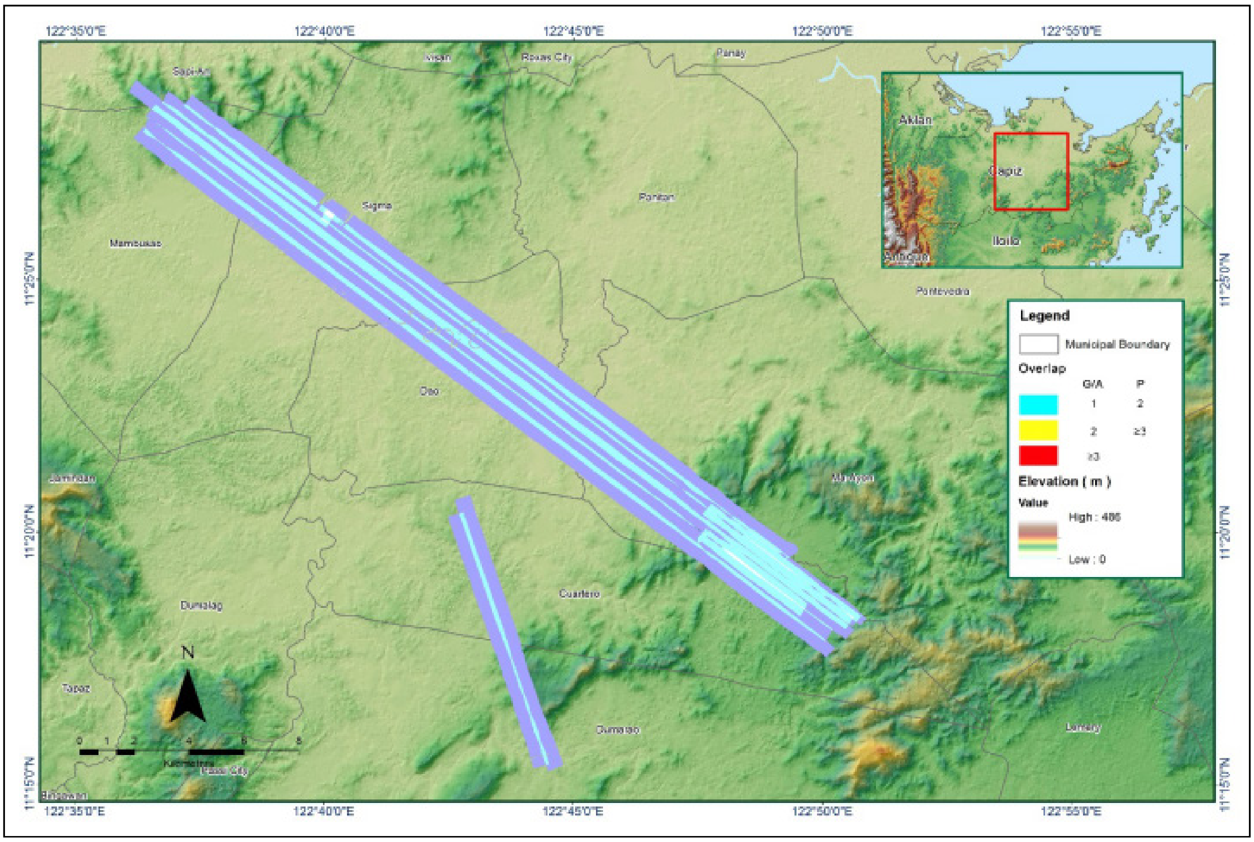


Figure A-8.47. Image of Data Overlap

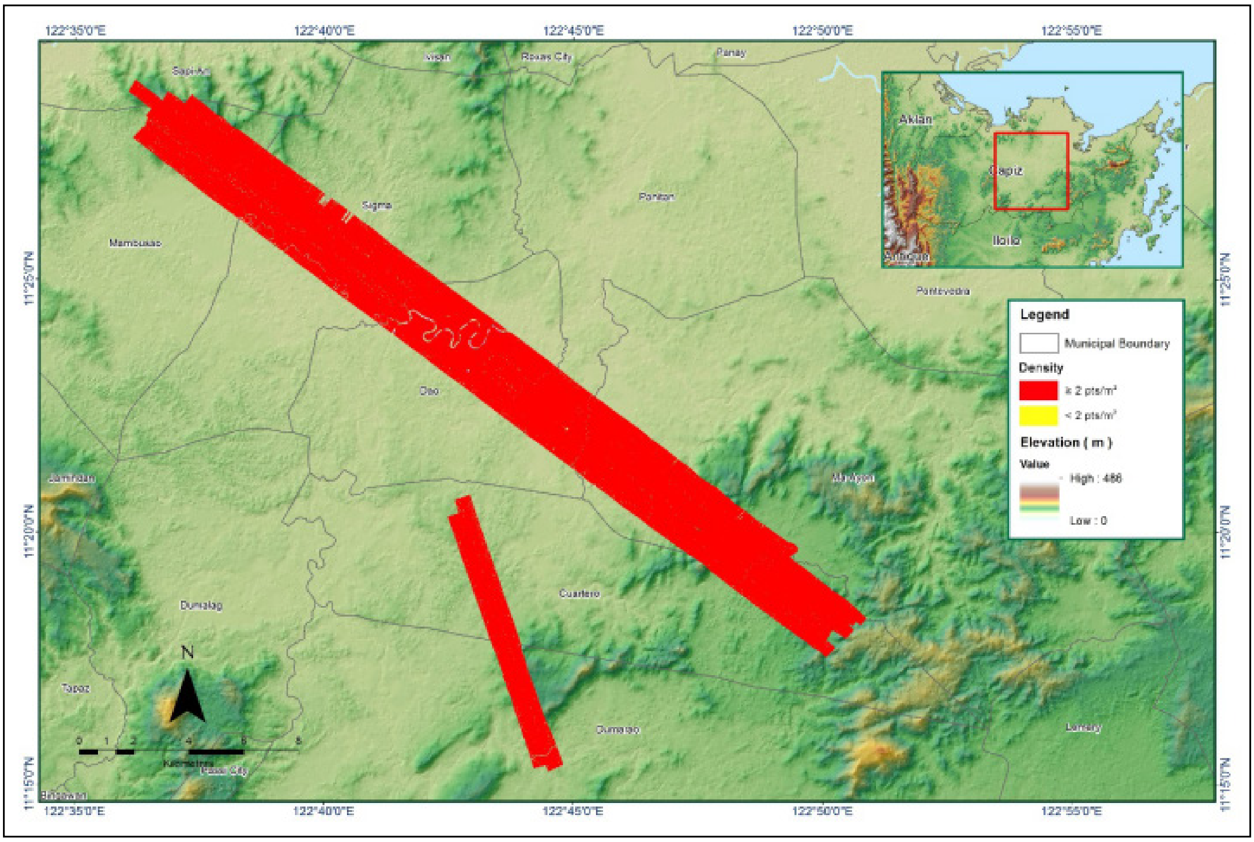


Figure A-8.48. Density map of merged LiDAR data

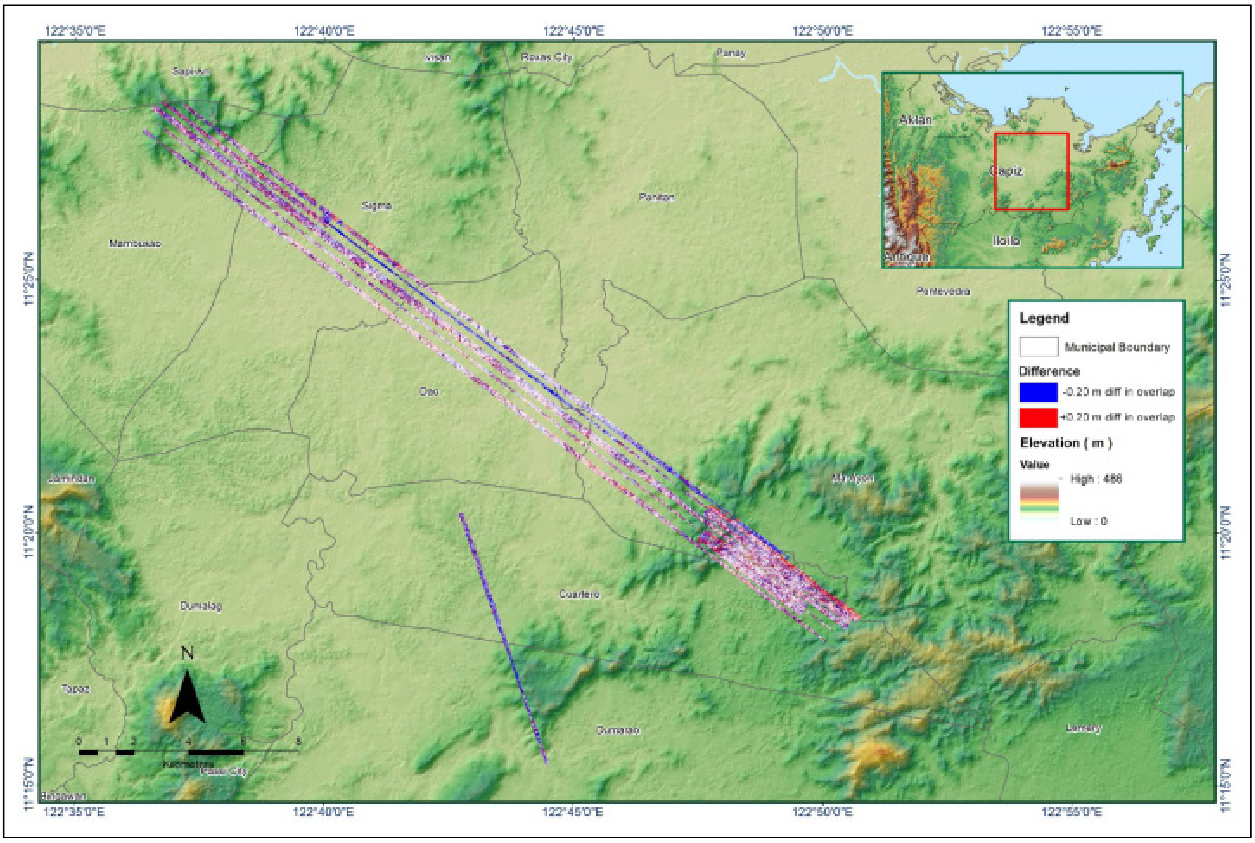


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk37Q

Flight Area	Iloilo
Mission Name	Blk37Q
Inclusive Flights	2645P, 2647P, 2649P
Range data size	44 GB
POS data size	700 MB
Base data size	65.5 MB
Image	122.4 GB
Transfer date	July 07, 2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.14
RMSE for East Position (<4.0 cm)	2.44
RMSE for Down Position (<8.0 cm)	5.4
Boresight correction stdev (<0.001deg)	0.000496
IMU attitude correction stdev (<0.001deg)	0.002611
GPS position stdev (<0.01m)	0.001
Minimum % overlap (>25)	43.43%
Ave point cloud density per sq.m. (>2.0)	2.86
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	258
Maximum Height	581.60 m
Minimum Height	50.96 m
Classification (# of points)	
Ground	146,277,156
Low vegetation	176,372,738
Medium vegetation	222,753,602
High vegetation	195,610,886
Building	4,585,646
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Edgardo Gubatanga Jr., Engr. Sueden Lyle Magtalas

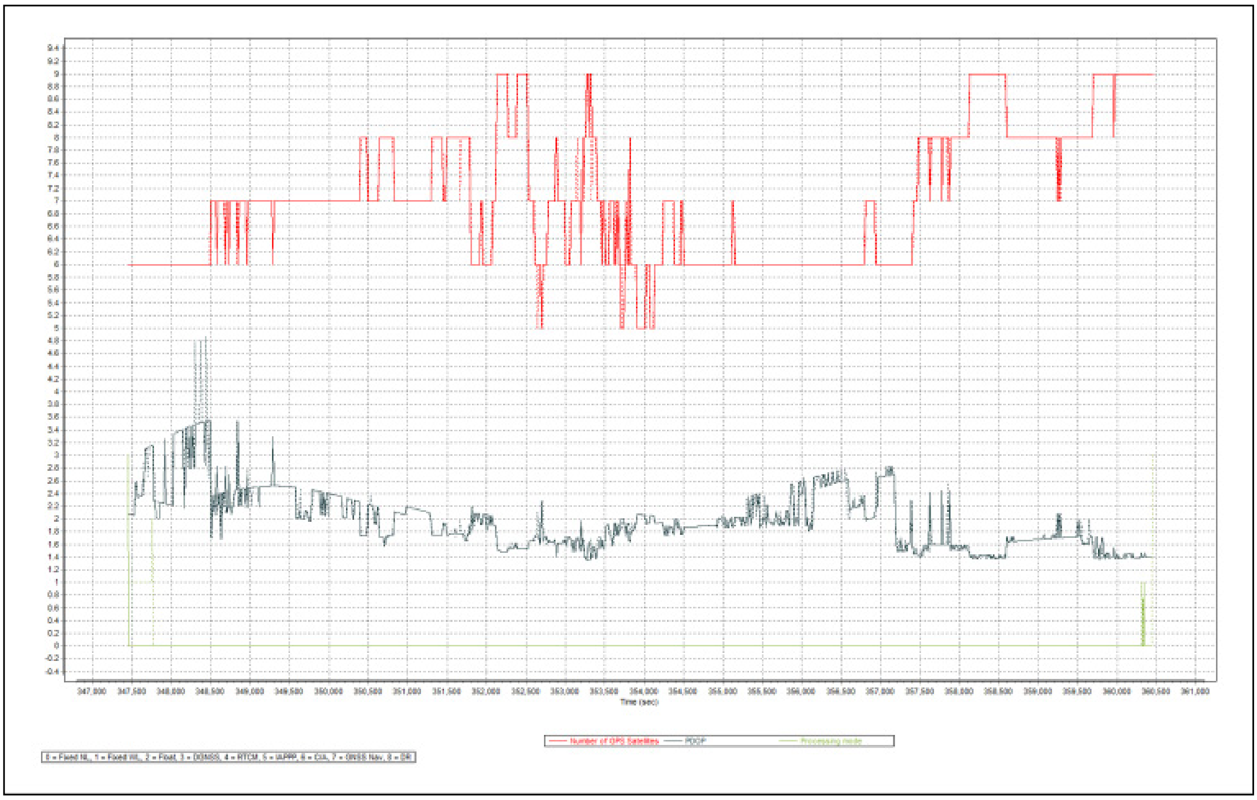


Figure A-8.50. Solution Status

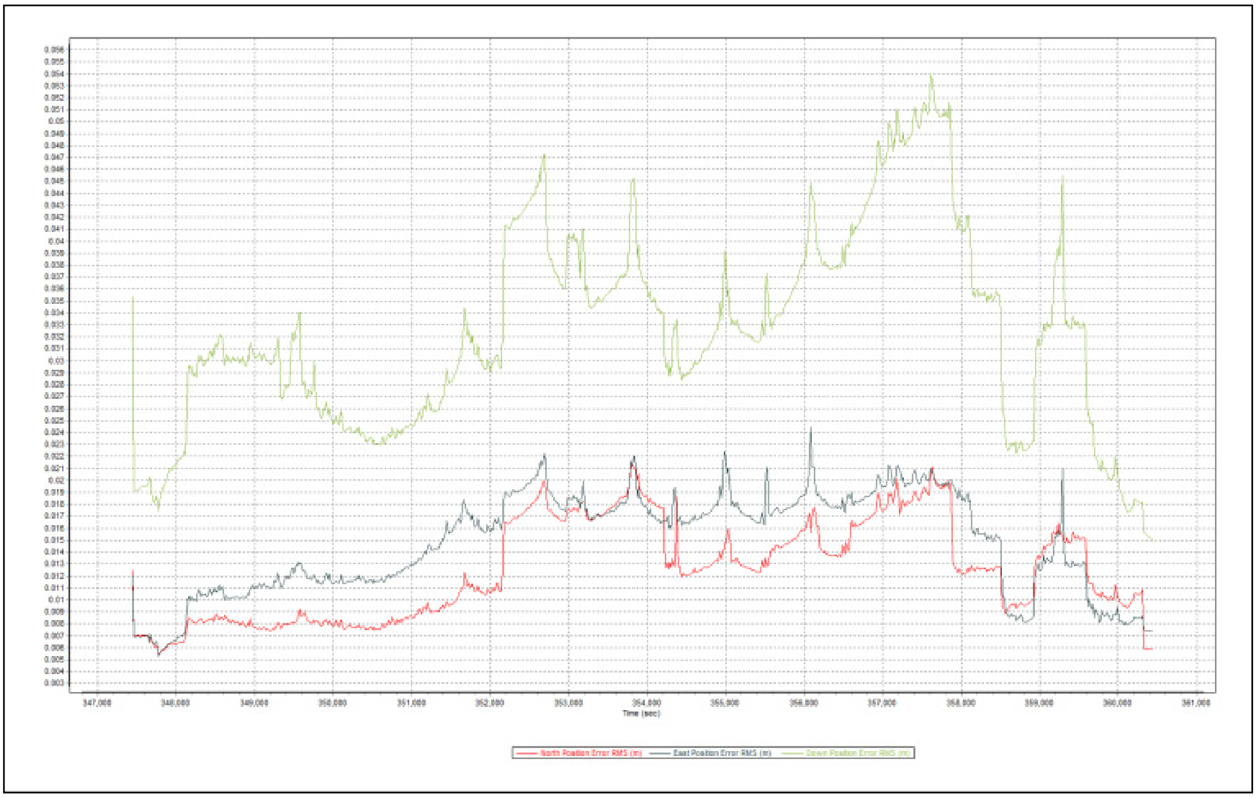


Figure A-8.51. Smoothed Performance Metric Parameters

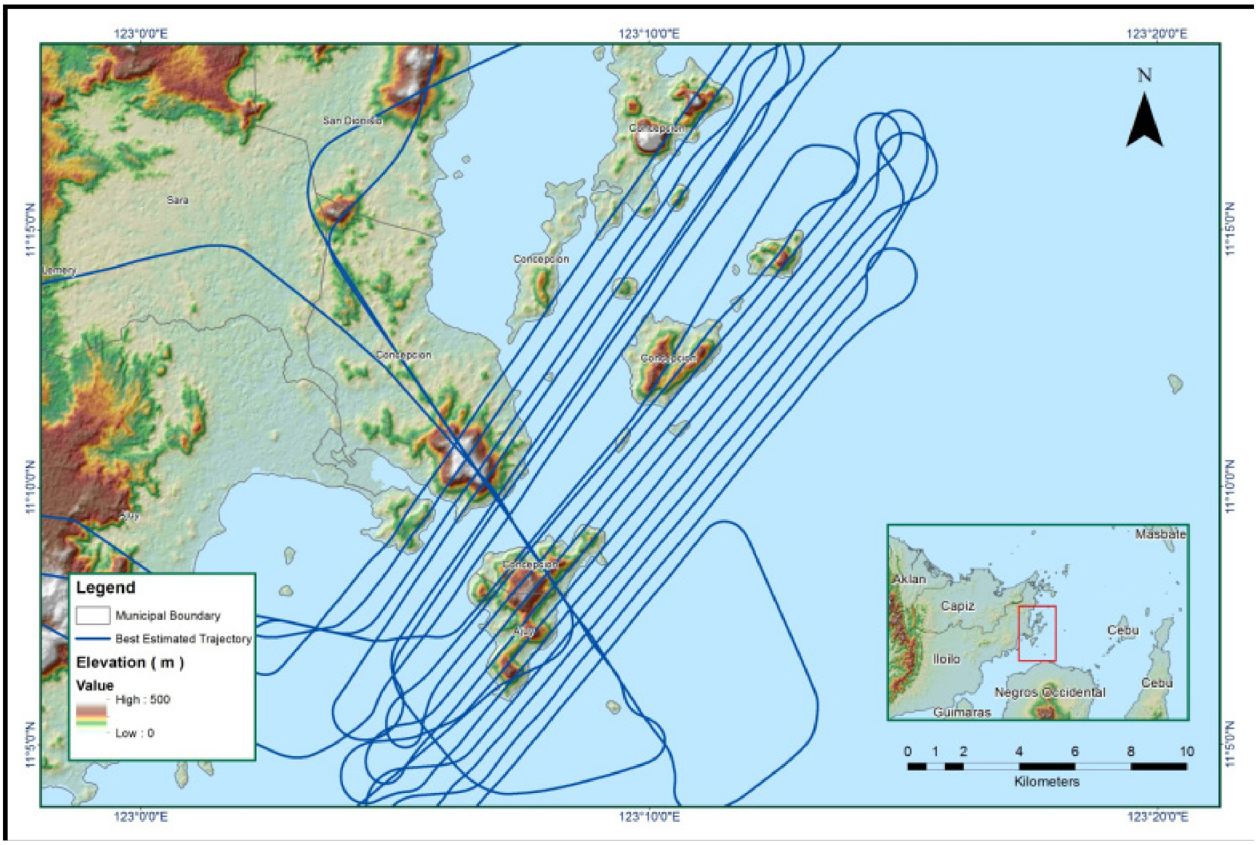


Figure A-8.52. Best Estimated Trajectory

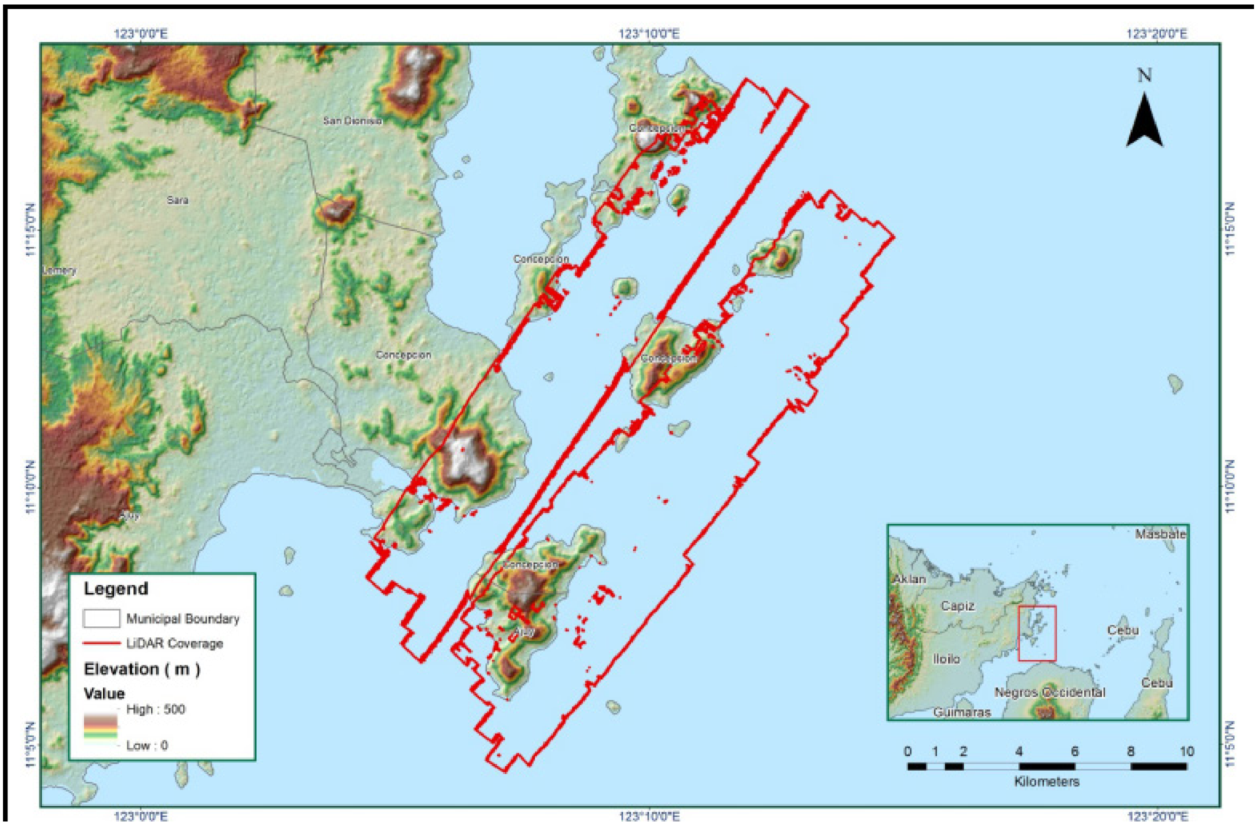


Figure A-8.53. Coverage of LiDAR data

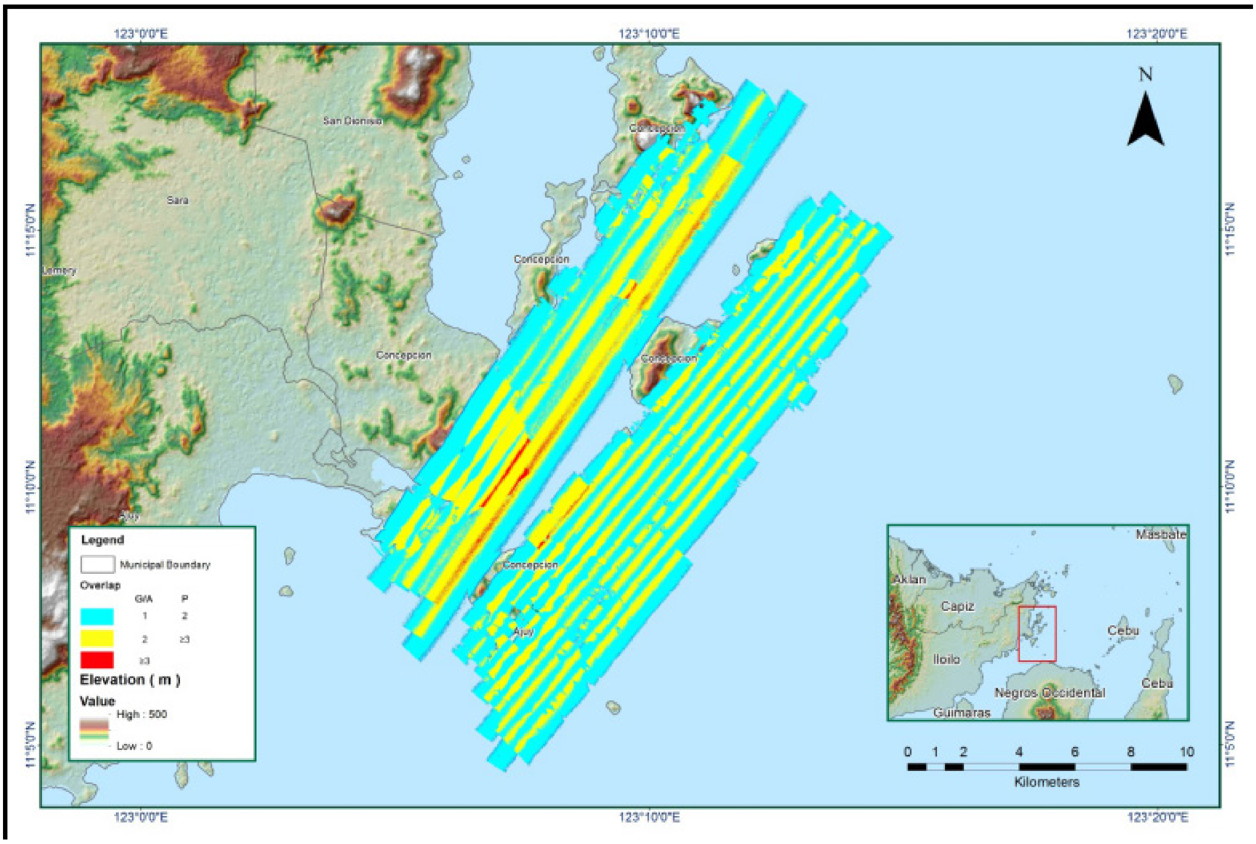


Figure A-8.54. Image of Data Overlap

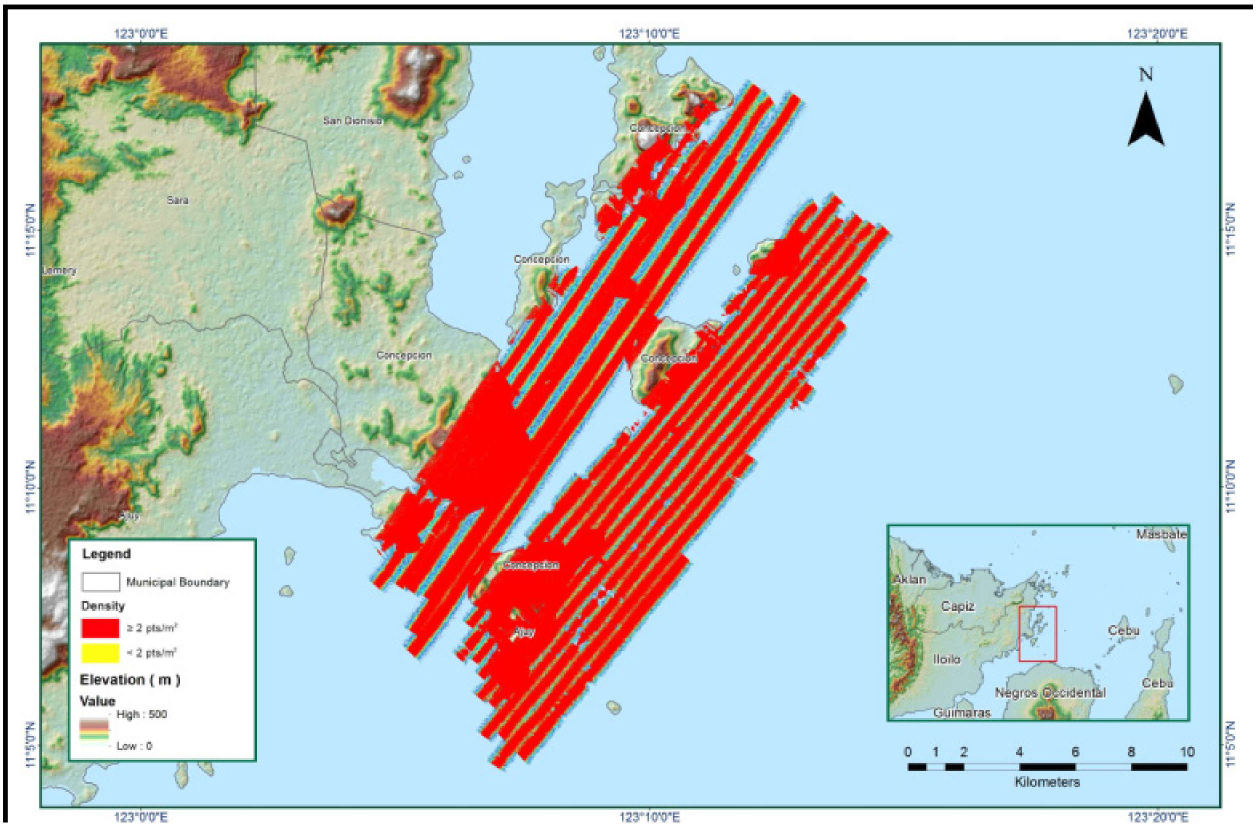


Figure A-8.55. Density map of merged LiDAR data

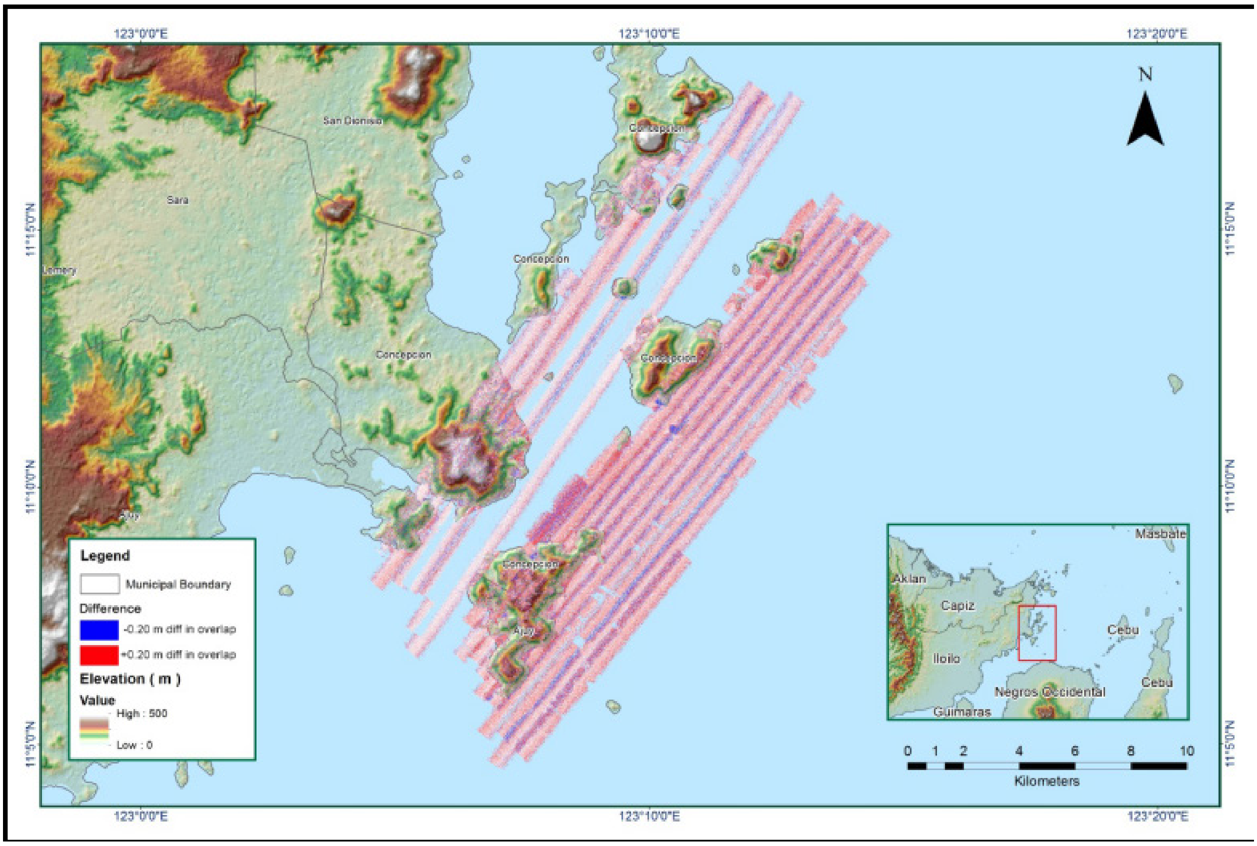


Figure A-8.56. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission Blk37E

Flight Area	Iloilo Reflights
Mission Name	Blk37E
Inclusive Flights	8510AC
Range data size	5.11 GB
Base data size	127 MB
POS	642 MB
Image	NA
Transfer date	October 24, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.79
RMSE for East Position (<4.0 cm)	1.29
RMSE for Down Position (<8.0 cm)	2.63
Boresight correction stdev (<0.001deg)	0.001146
IMU attitude correction stdev (<0.001deg)	0.001475
GPS position stdev (<0.01m)	0.0112
Minimum % overlap (>25)	18.46
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	14
Maximum Height	320.78
Minimum Height	100.89
Classification (# of points)	
Ground	7,247,296
Low vegetation	3,072,147
Medium vegetation	5,790,099
High vegetation	7,292,331
Building	283,749
Ortophoto	None
Processed by	Engr. Jommer Medina, Engr. Melanie Hingpit, Engr. Wilbert Ian San Juan

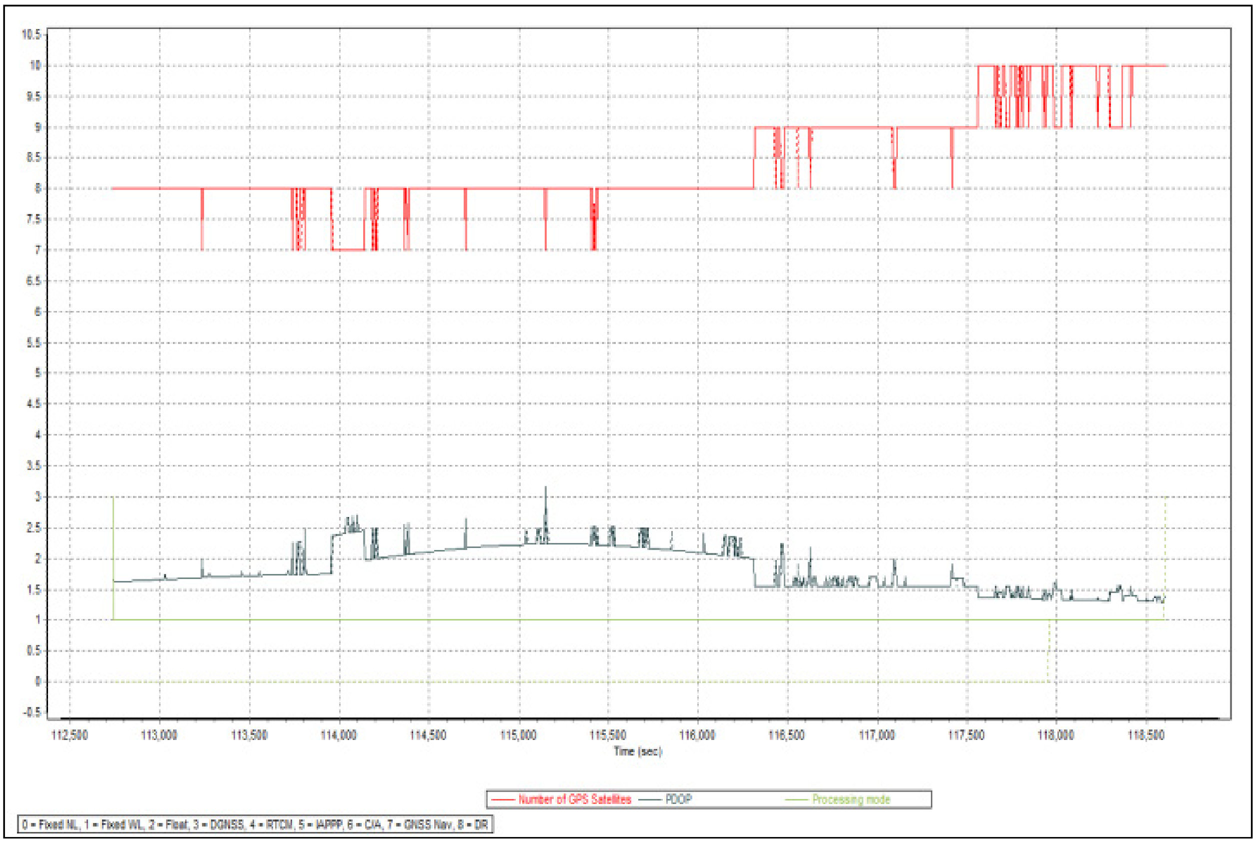


Figure A-8.57. Solution Status

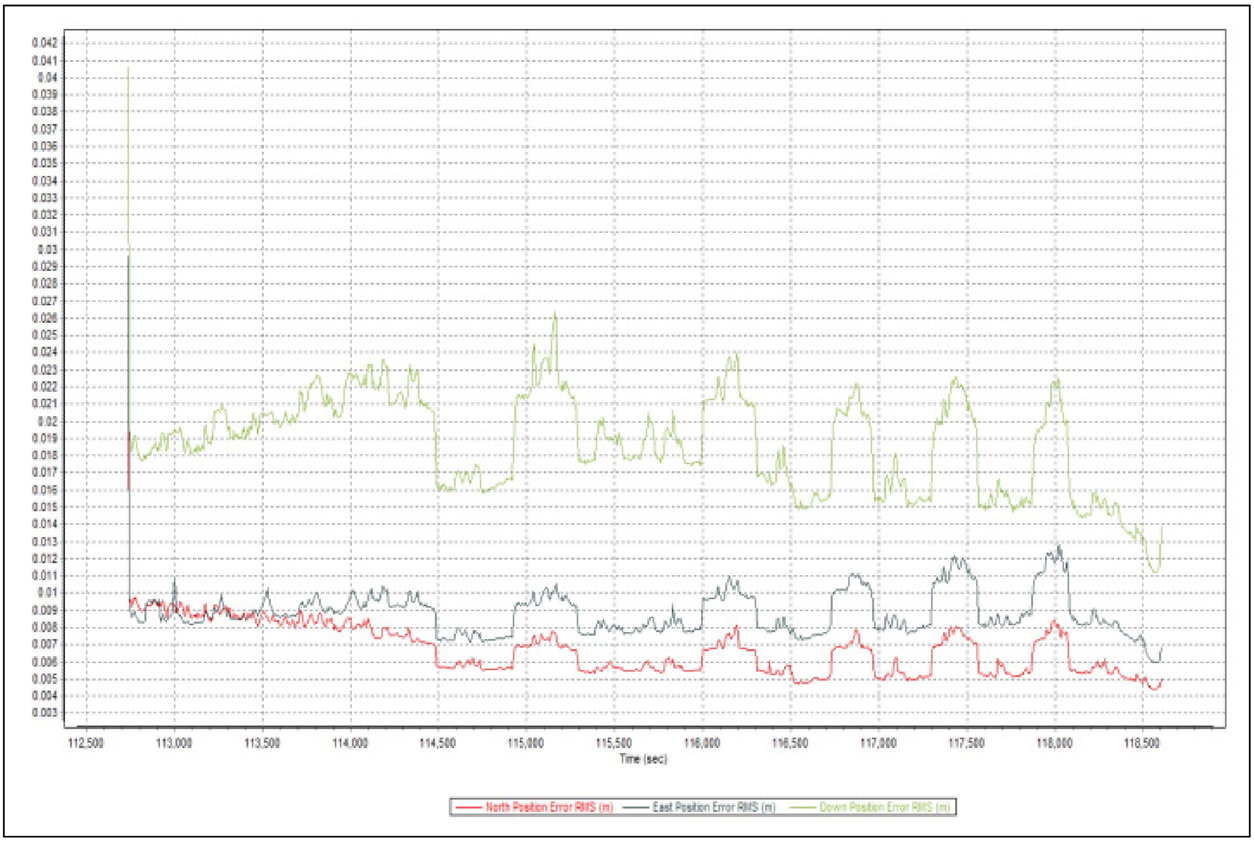


Figure A-8.58. Smoothed Performance Metric Parameters

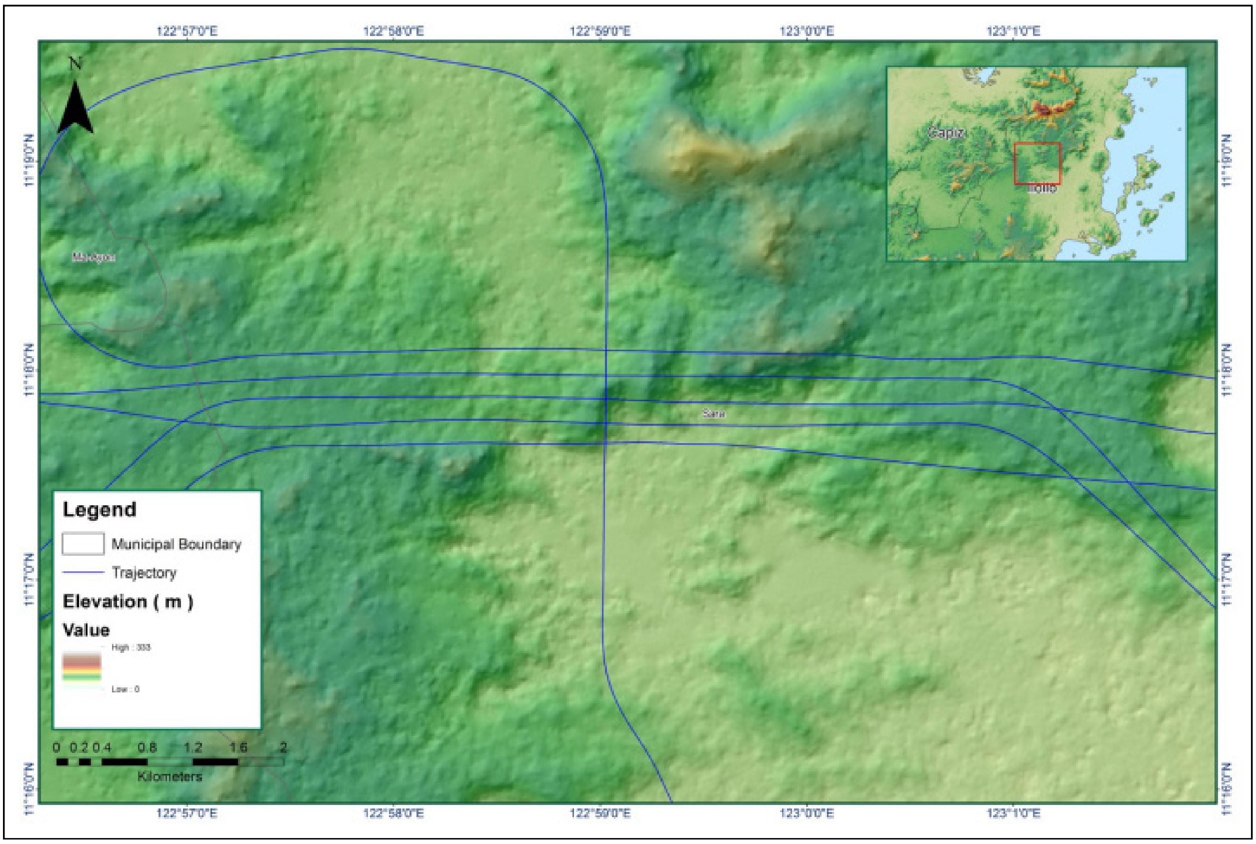


Figure A-8.59. Best Estimated Trajectory

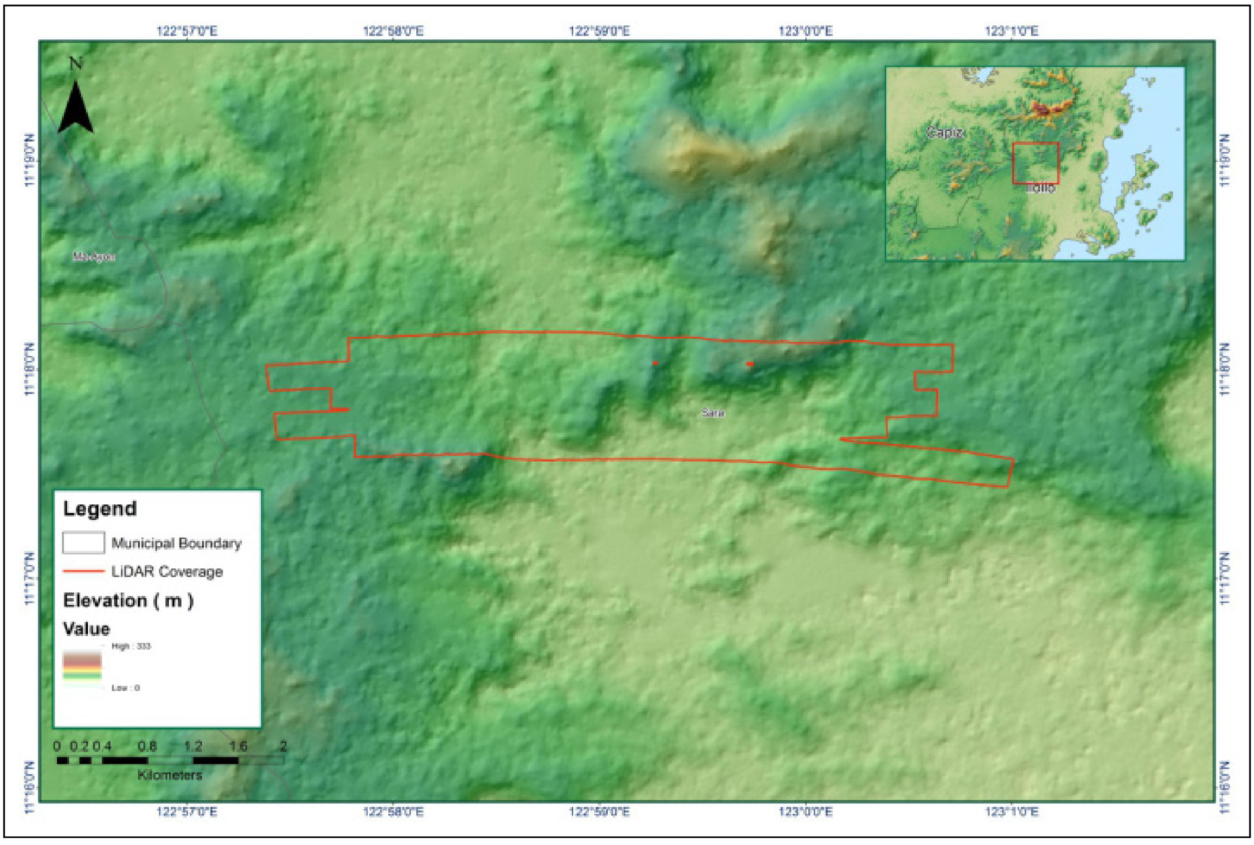


Figure A-8.60. Coverage of LiDAR data

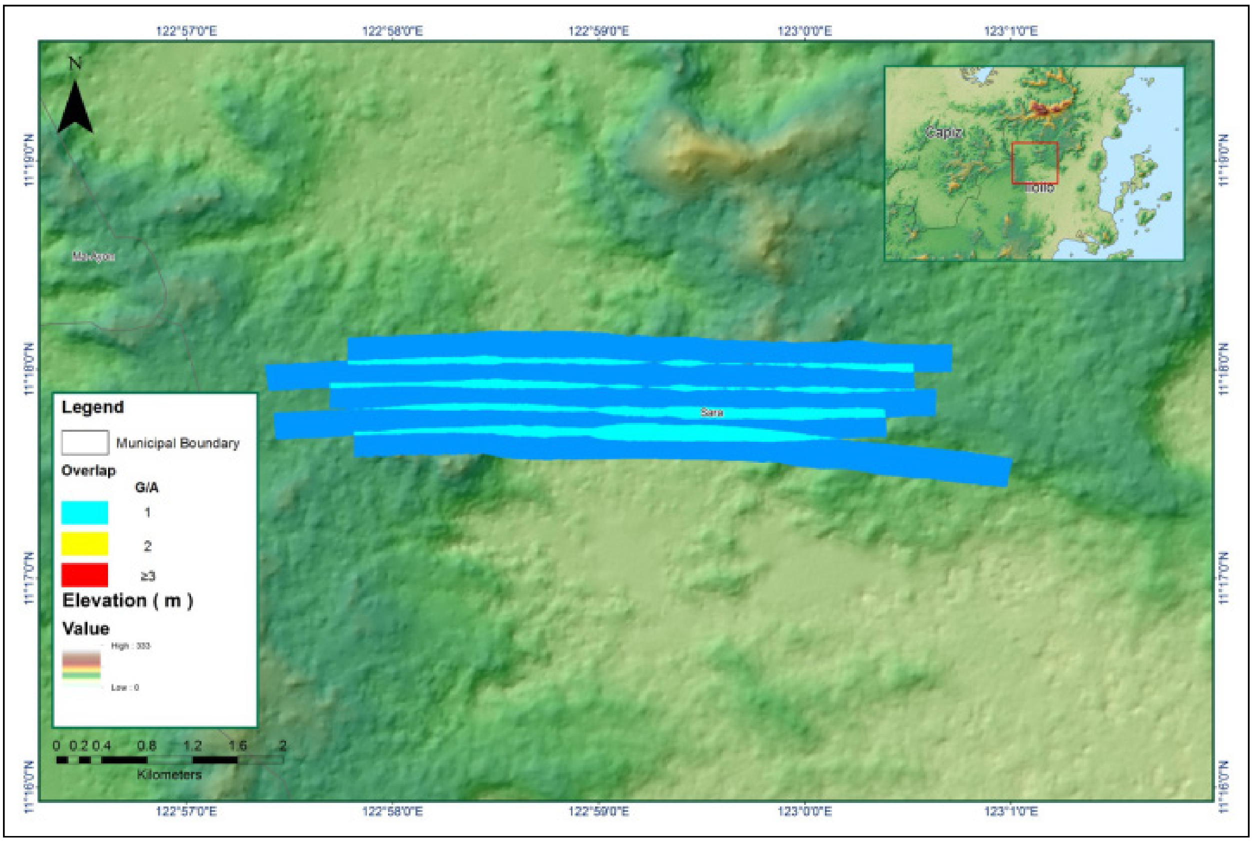


Figure A-8.61. Image of Data Overlap

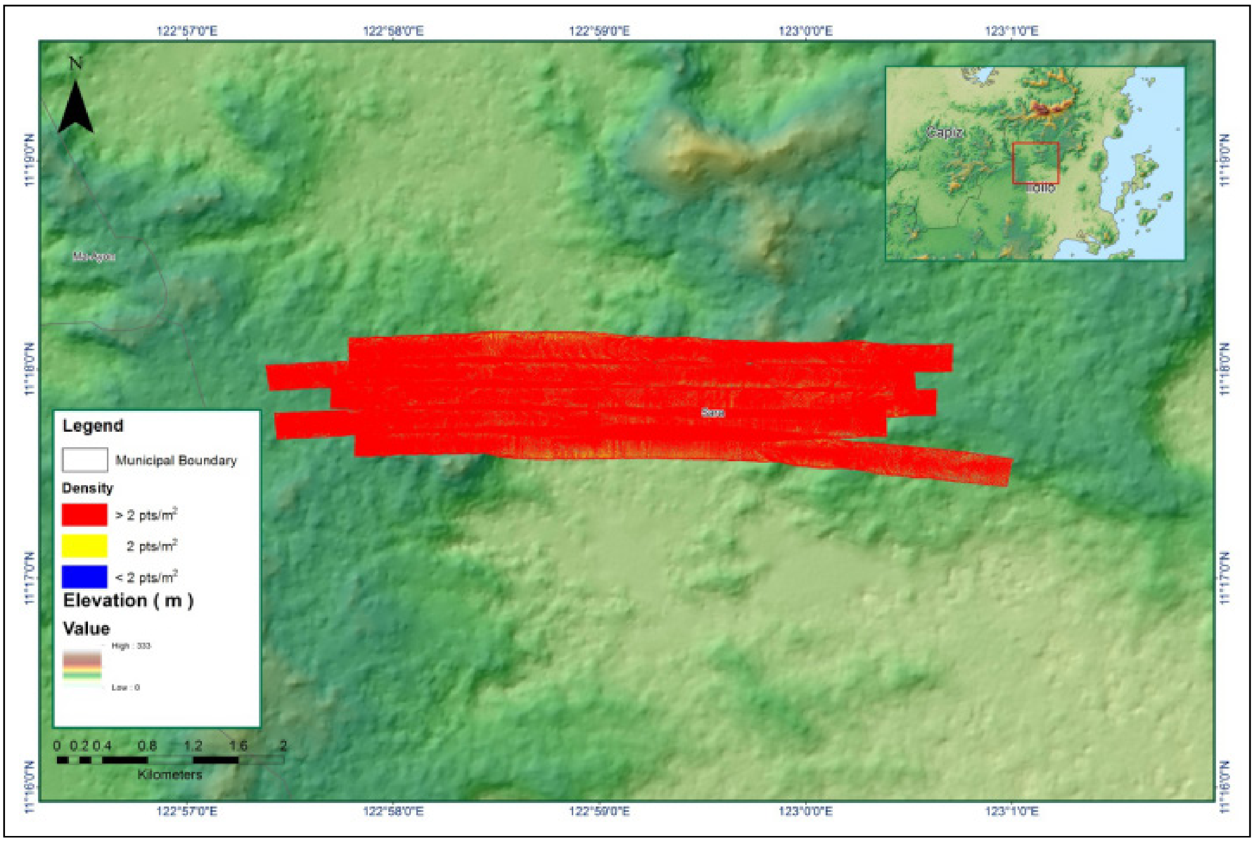


Figure A-8.62. Density map of merged LiDAR data

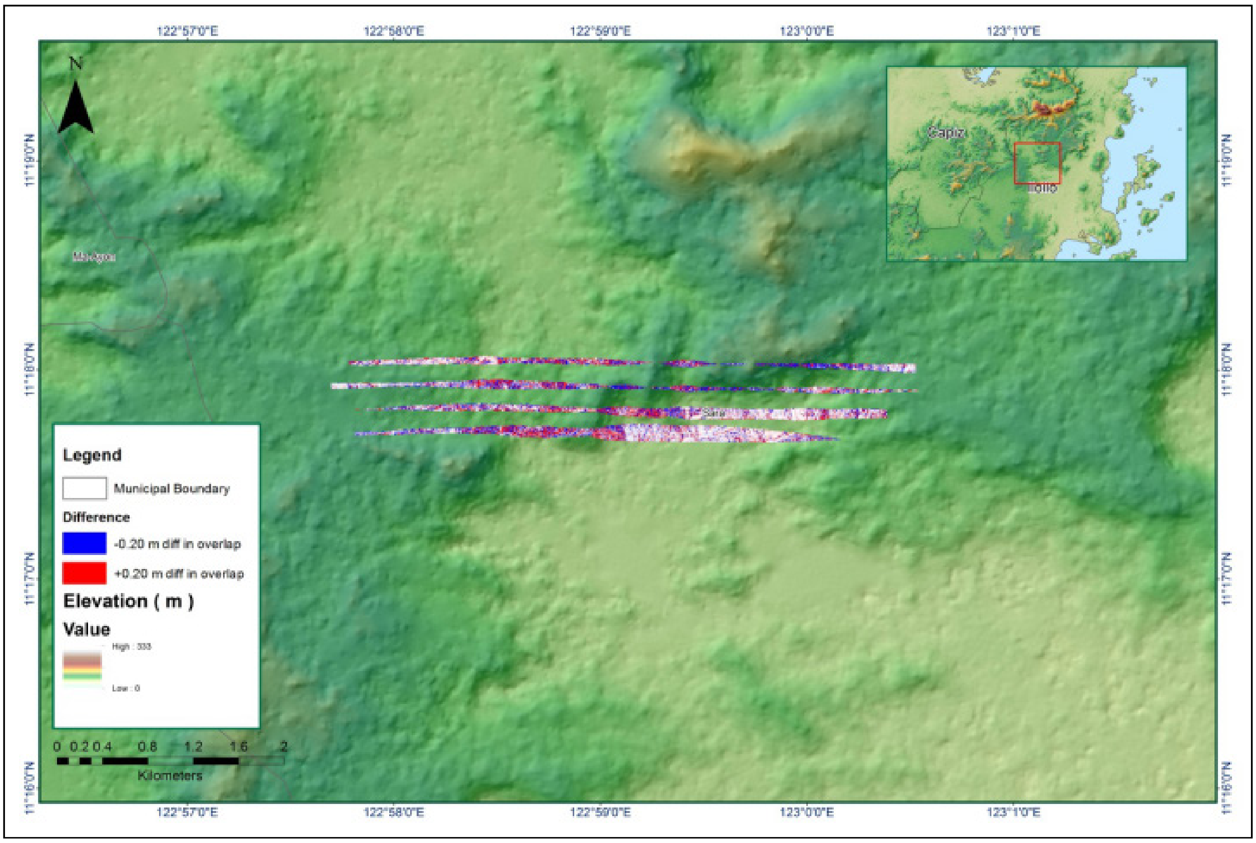


Figure A-8.63. Elevation difference between flight lines

Table A-8.10. Mission Summary Report for Mission Blk37Q

Flight Area	Iloilo Reflights
Mission Name	Blk37Q
Inclusive Flights	8509AC
Range data size	5.27 GB
POS	204 MB
Base data size	127 MB
Image	NA
Transfer date	October 24, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.49
RMSE for East Position (<4.0 cm)	2.06
RMSE for Down Position (<8.0 cm)	3.44
Boresight correction stdev (<0.001deg)	0.000633
IMU attitude correction stdev (<0.001deg)	0.002346
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	32.31
Ave point cloud density per sq.m. (>2.0)	3.47
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	45
Maximum Height	346.06
Minimum Height	52.18
Classification (# of points)	
Ground	22,923,306
Low vegetation	21,287,136
Medium vegetation	2,0931,093
High vegetation	3,0276,841
Building	1,219,306
Orthophoto	No
Processed by	Engr. Sheila Maye Santillan, Engr. Christy Lubiano, Maria Tamsyn Malabanan

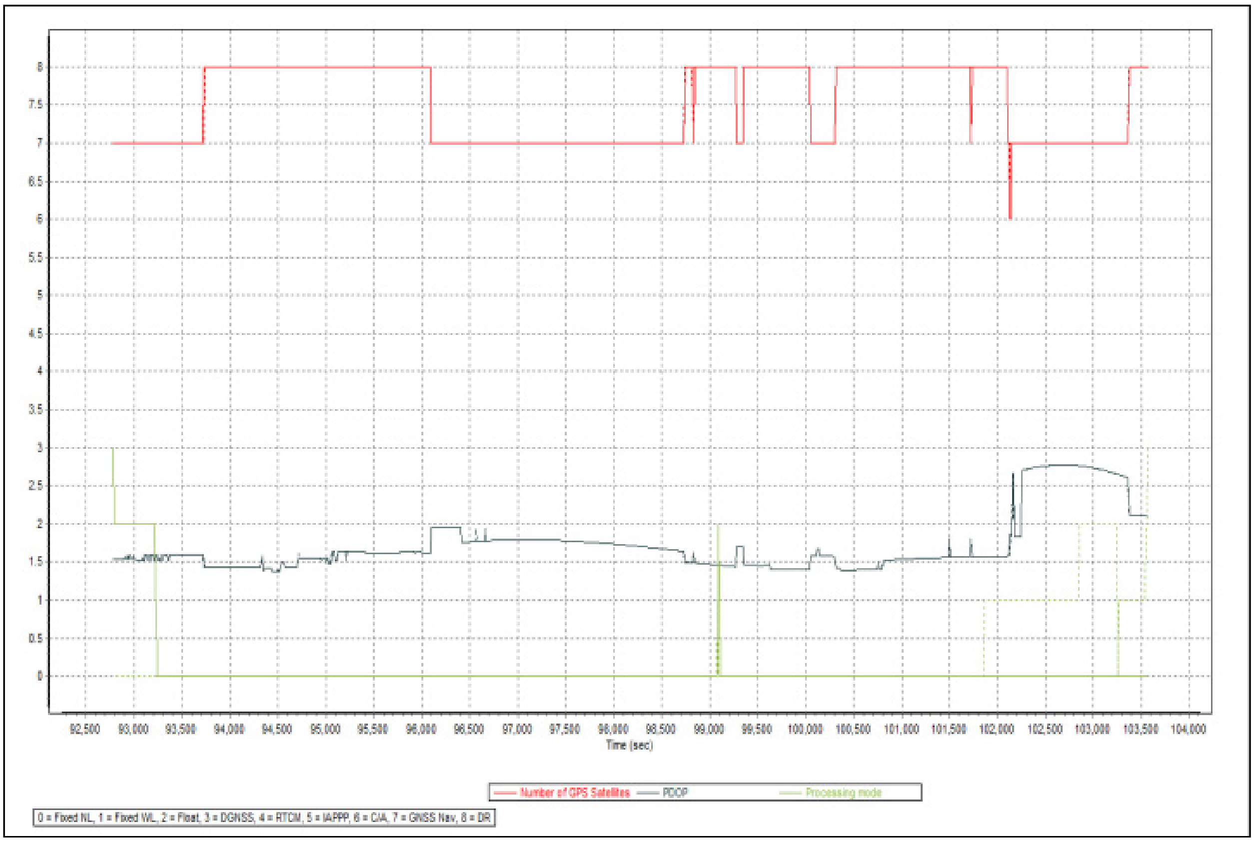


Figure A-8.64. Solution Status

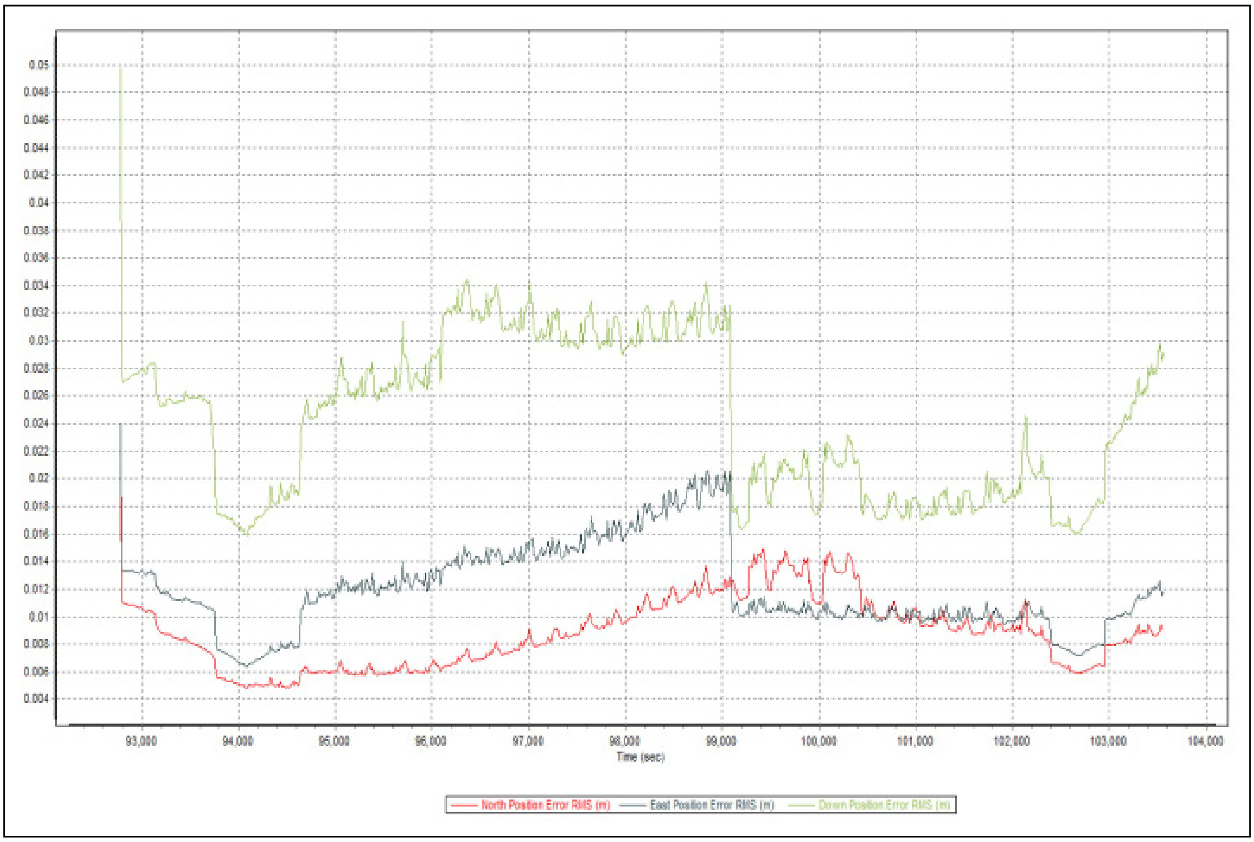


Figure A-8.65. Smoothed Performance Metric Parameters

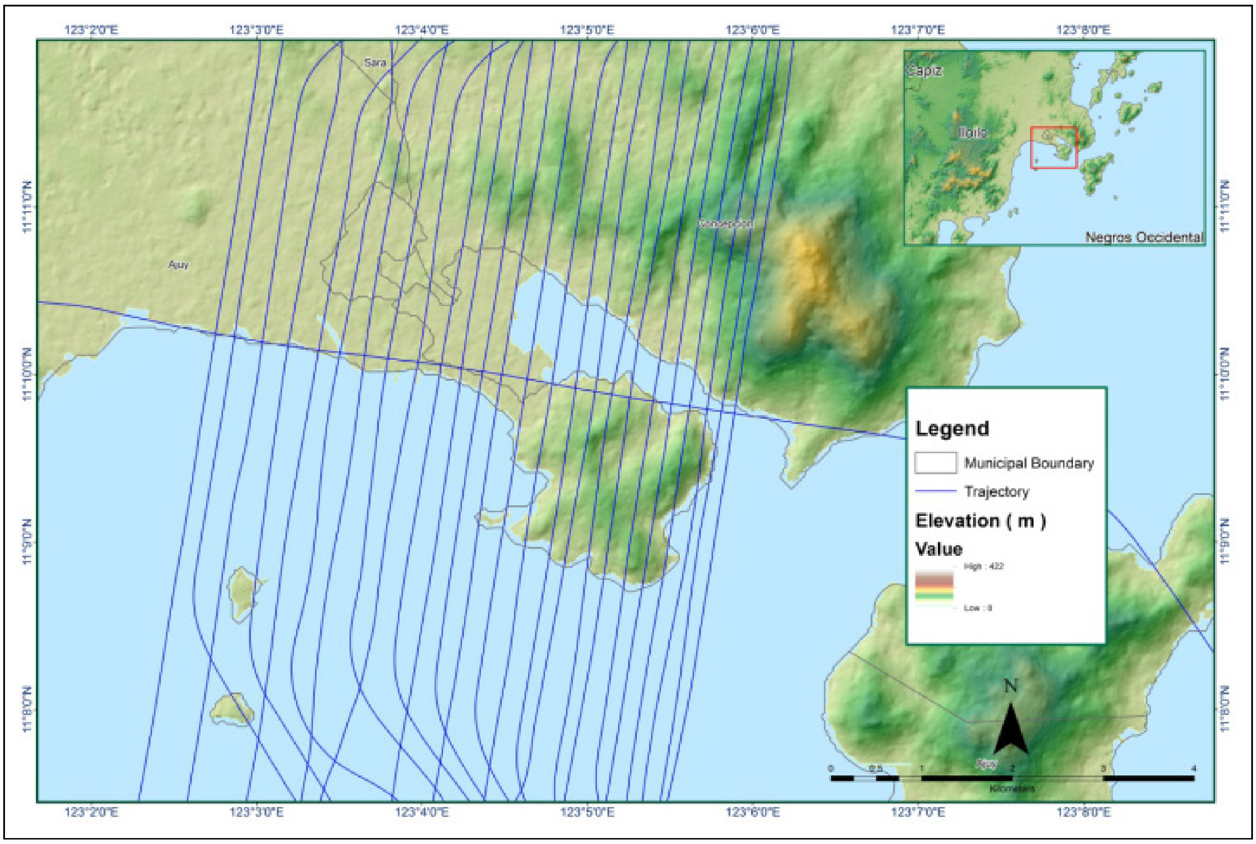


Figure A-8.66. Best Estimated Trajectory

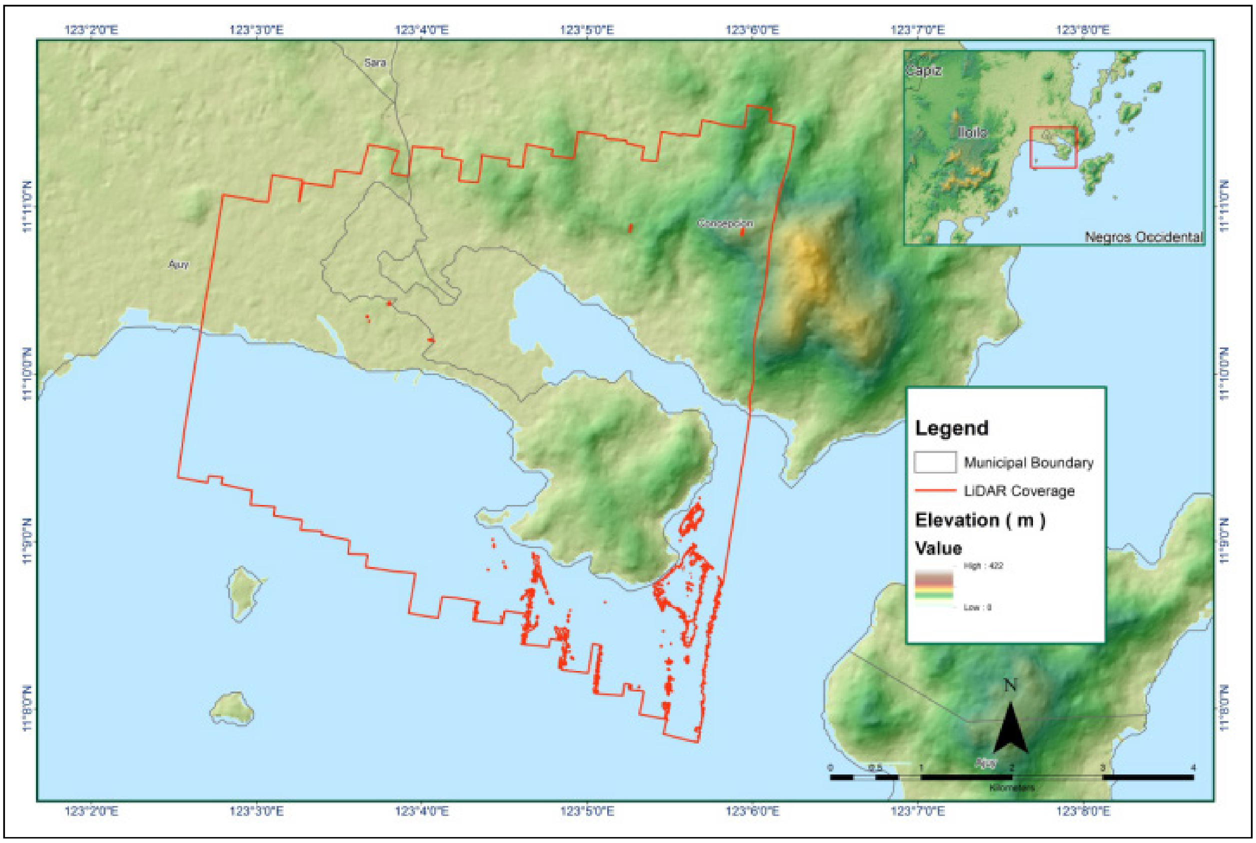


Figure A-8.67. Coverage of LiDAR data

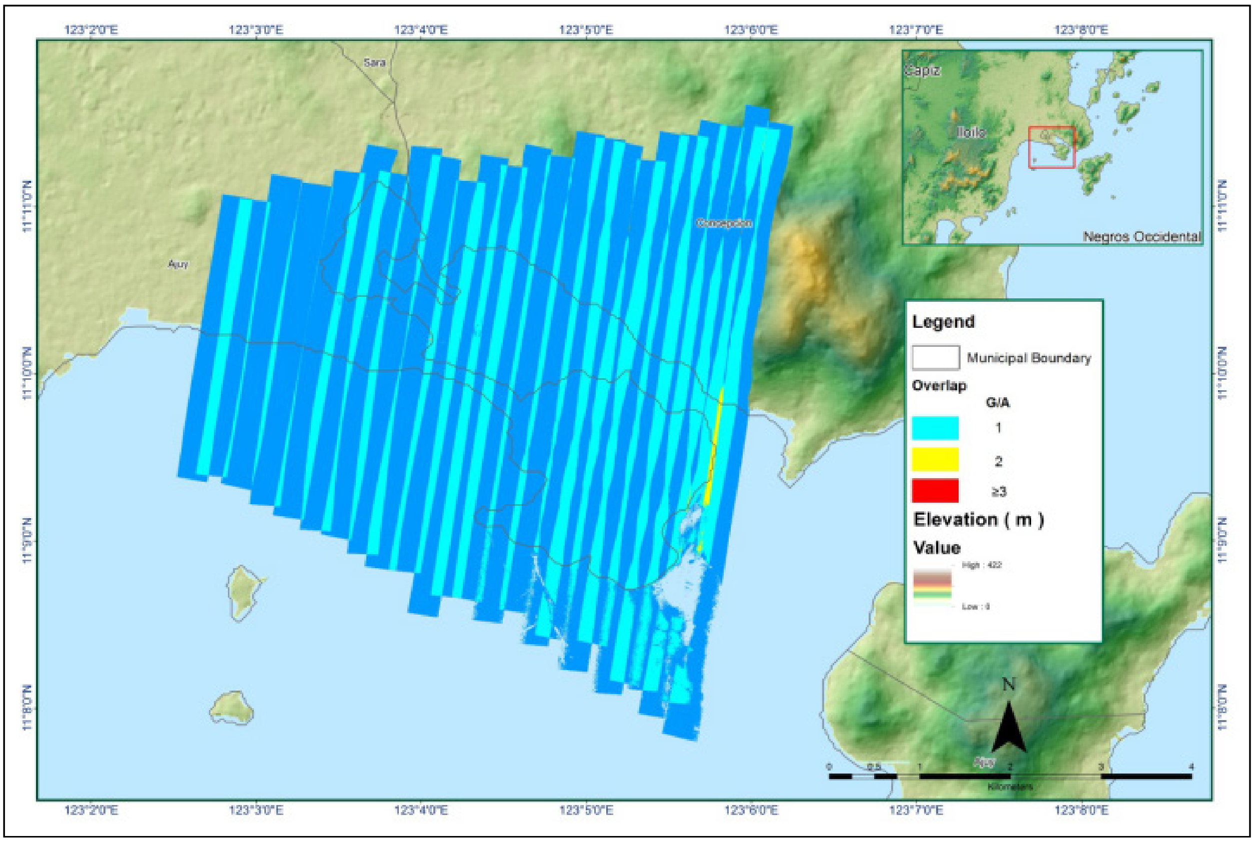


Figure A-8.68. Image of Data Overlap

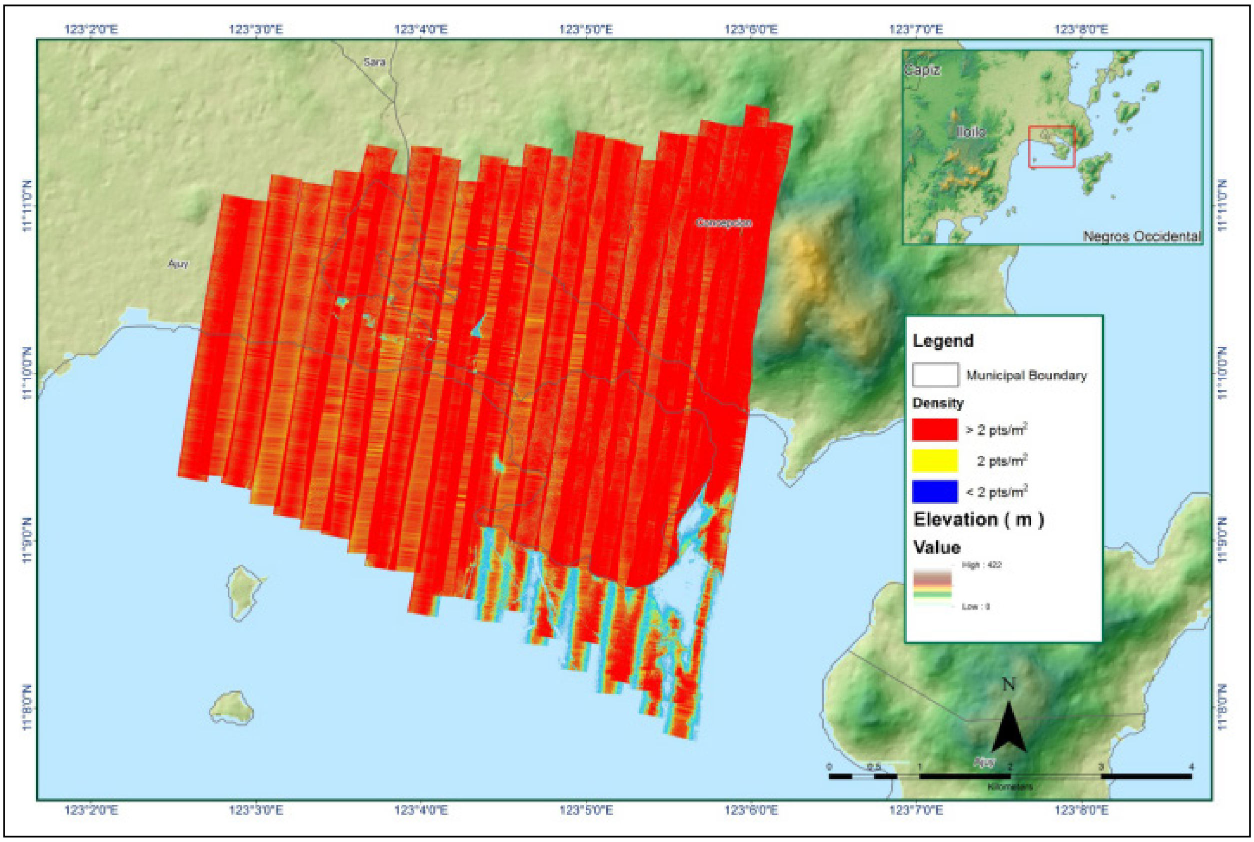


Figure A-8.69. Density map of merged LiDAR data

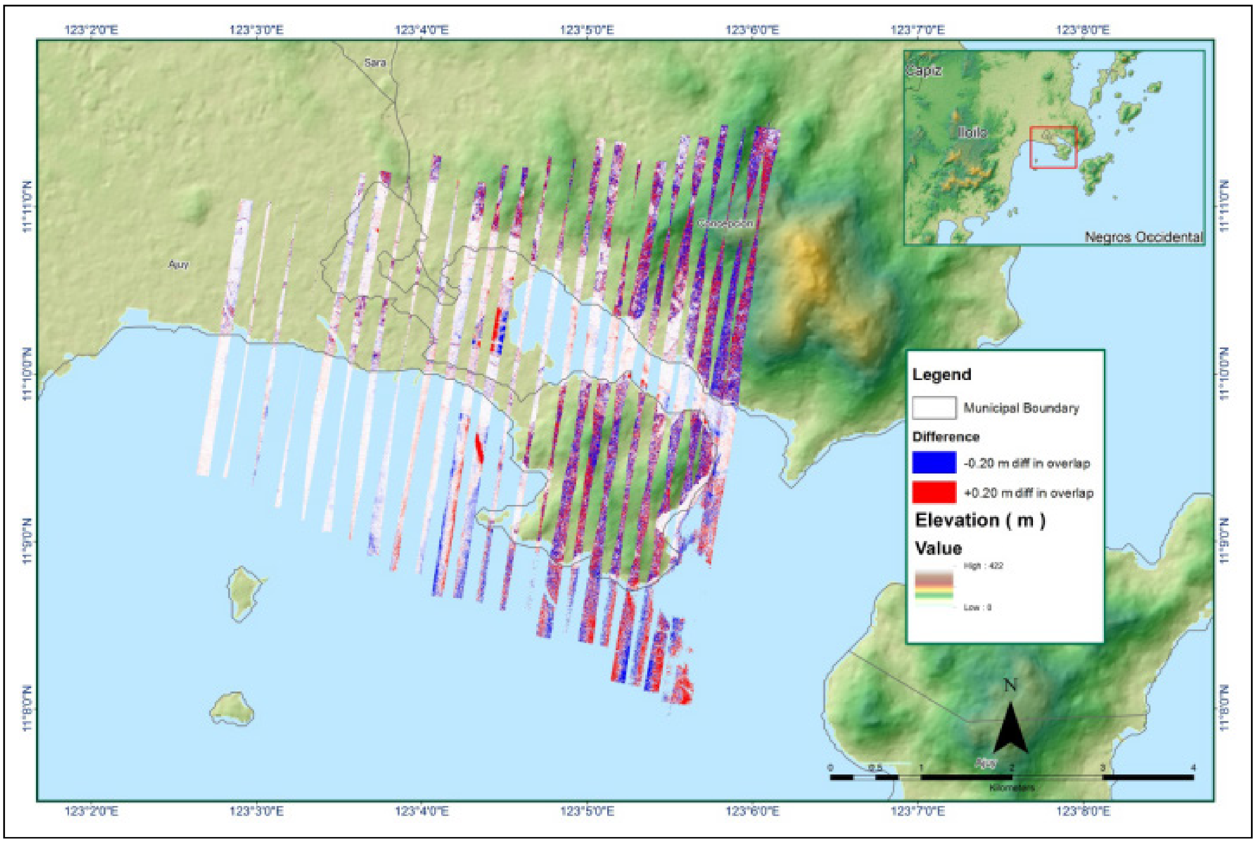


Figure A-8.70. Elevation difference between flight lines

Table A-8.11. Mission Summary Report for Mission Blk37K

Flight Area	Iloilo Reflights
Mission Name	Blk37K
Inclusive Flights	8510AC
Range data size	5.11 GB
POS	160 MB
Base data size	127 MB
Image	NA
Transfer date	October 24, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	0.82
RMSE for North Position (<4.0 cm)	1.27
RMSE for East Position (<4.0 cm)	2.21
RMSE for Down Position (<8.0 cm)	
Boresight correction stdev (<0.001deg)	0.001780
IMU attitude correction stdev (<0.001deg)	0.002797
GPS position stdev (<0.01m)	0.0134
Minimum % overlap (>25)	36.62
Ave point cloud density per sq.m. (>2.0)	4.40
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	52
Maximum Height	474.44
Minimum Height	57
Classification (# of points)	
Ground	14045874
Low vegetation	16368281
Medium vegetation	19424510
High vegetation	38926290
Building	1917633
Orthophoto	None
Processed by	

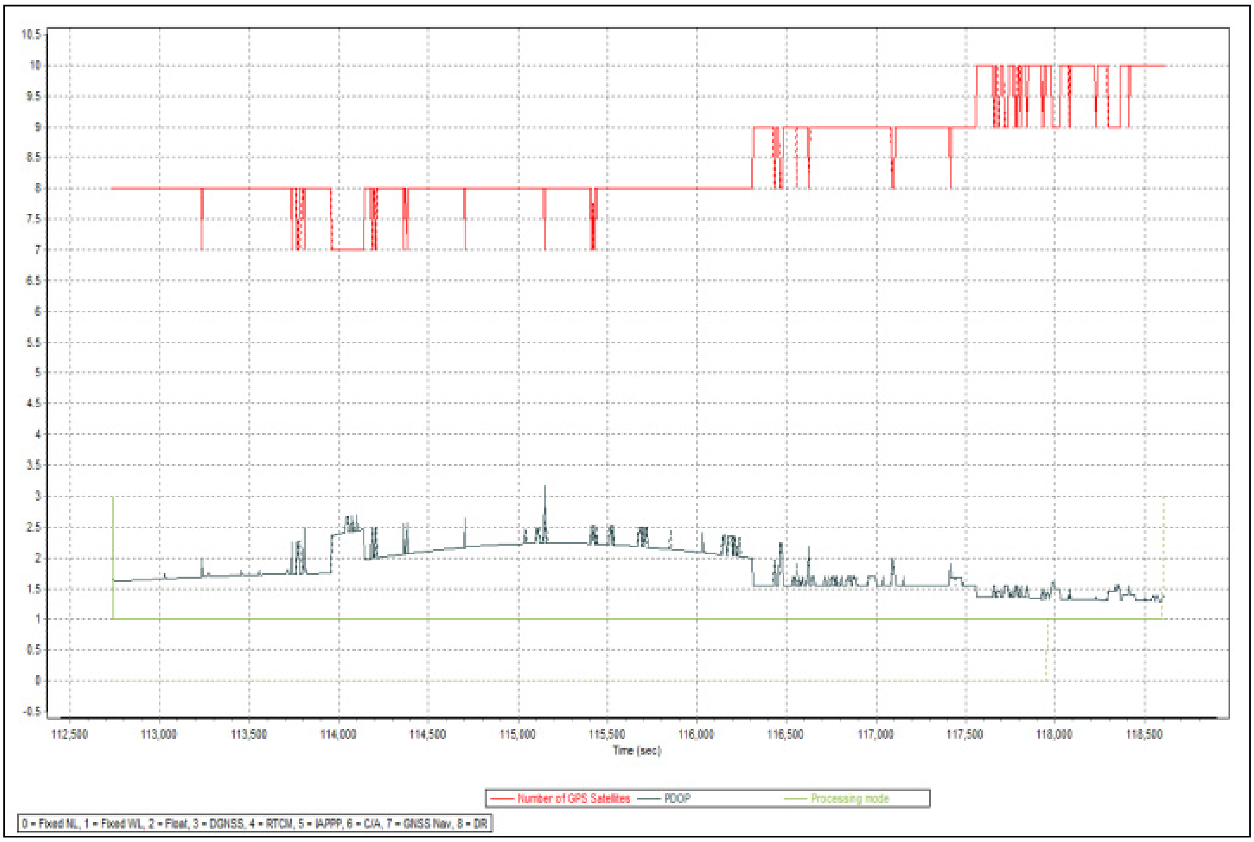


Figure A-8.71. Solution Status

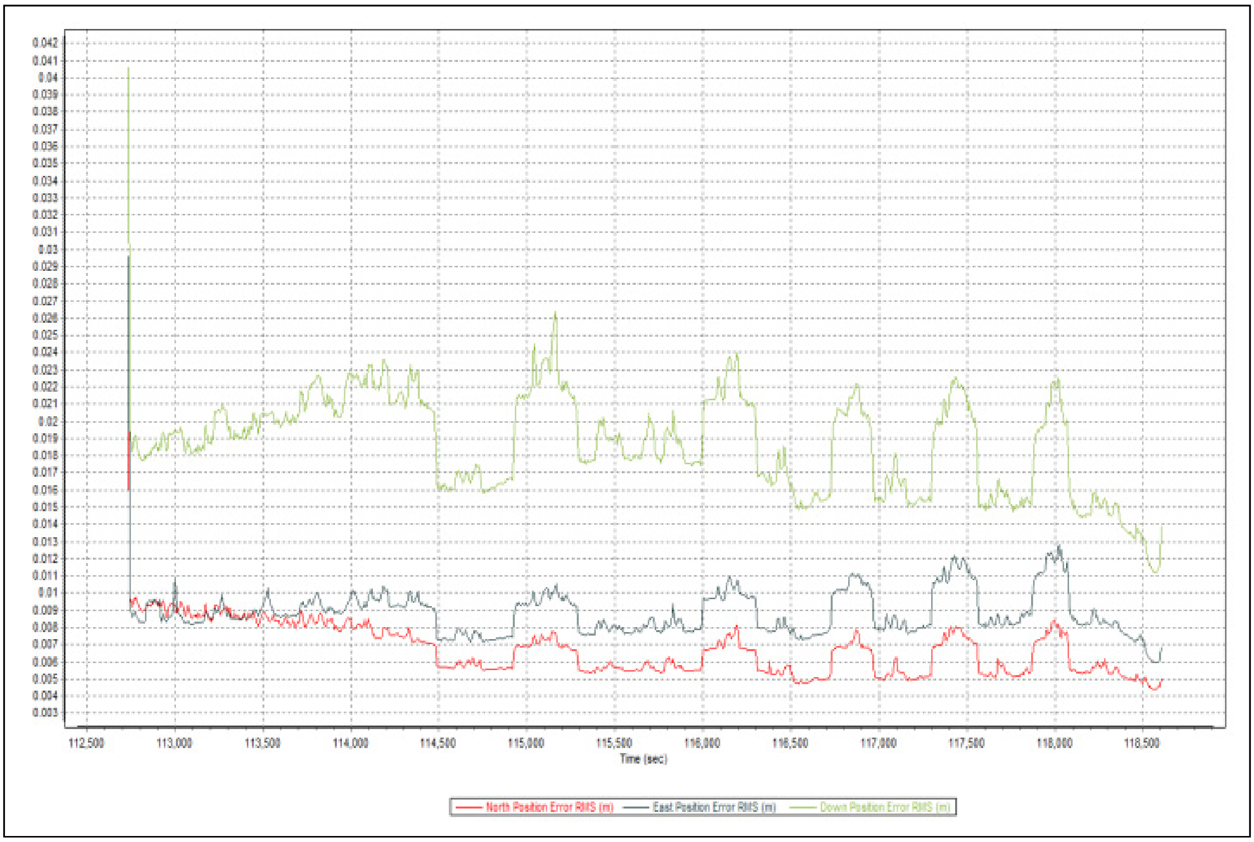


Figure A-8.72. Smoothed Performance Metric Parameters

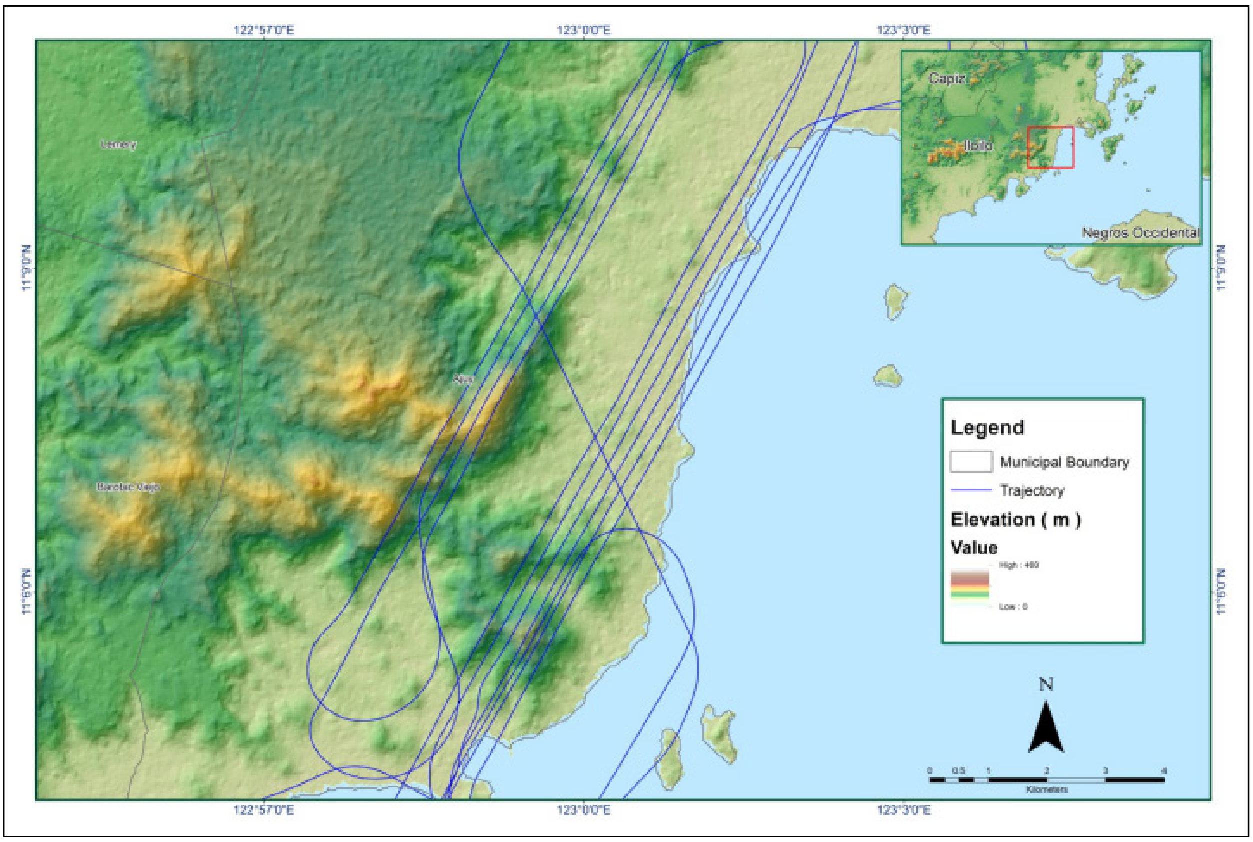


Figure A-8.73. Best Estimated Trajectory

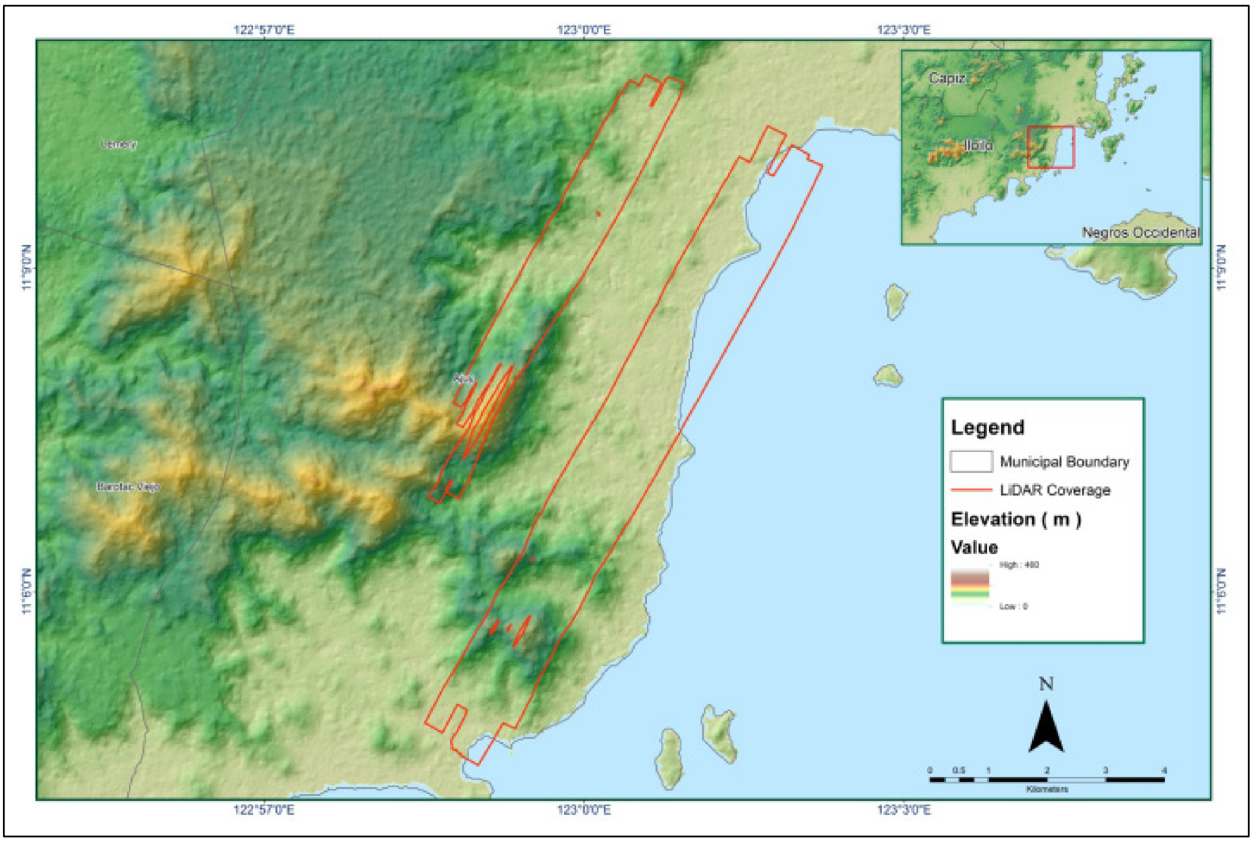


Figure A-8.74. Coverage of LiDAR data

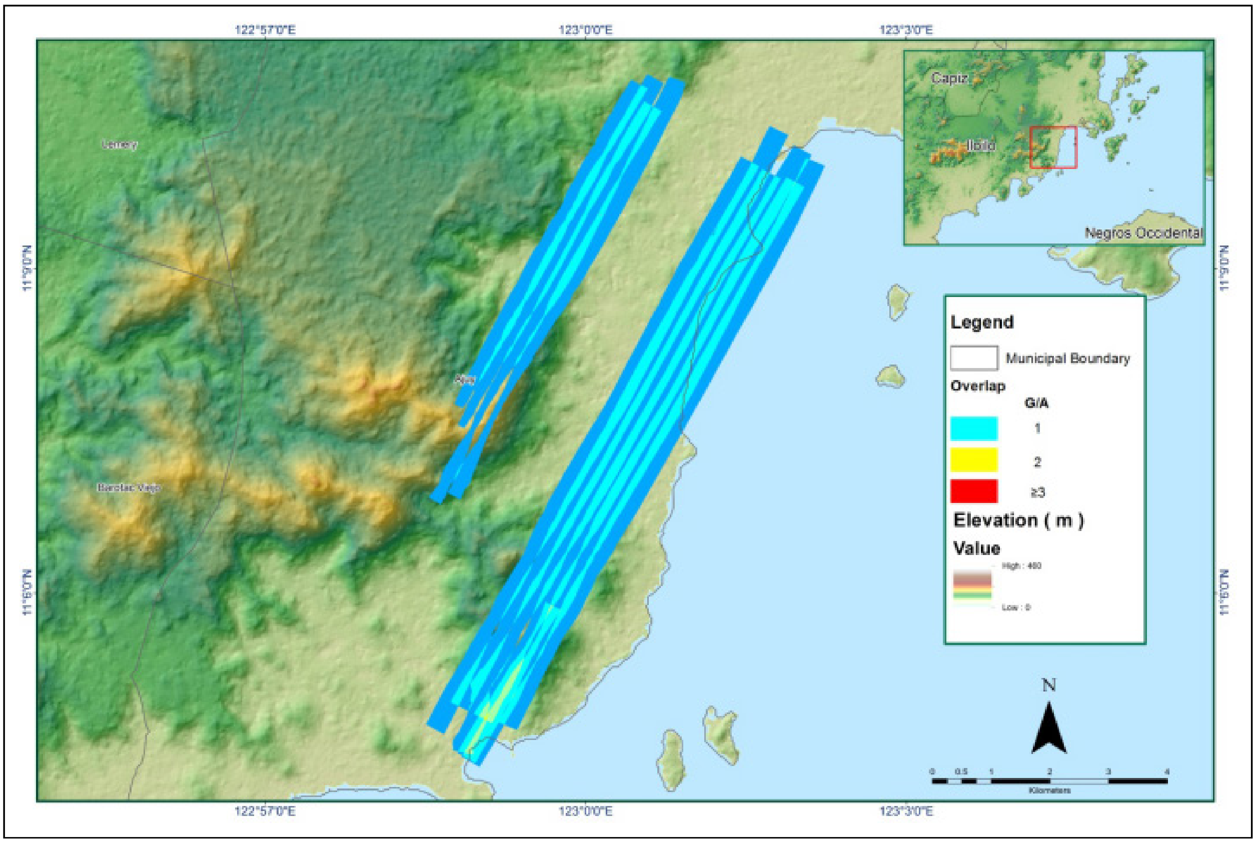


Figure A-8.75. Image of Data Overlap

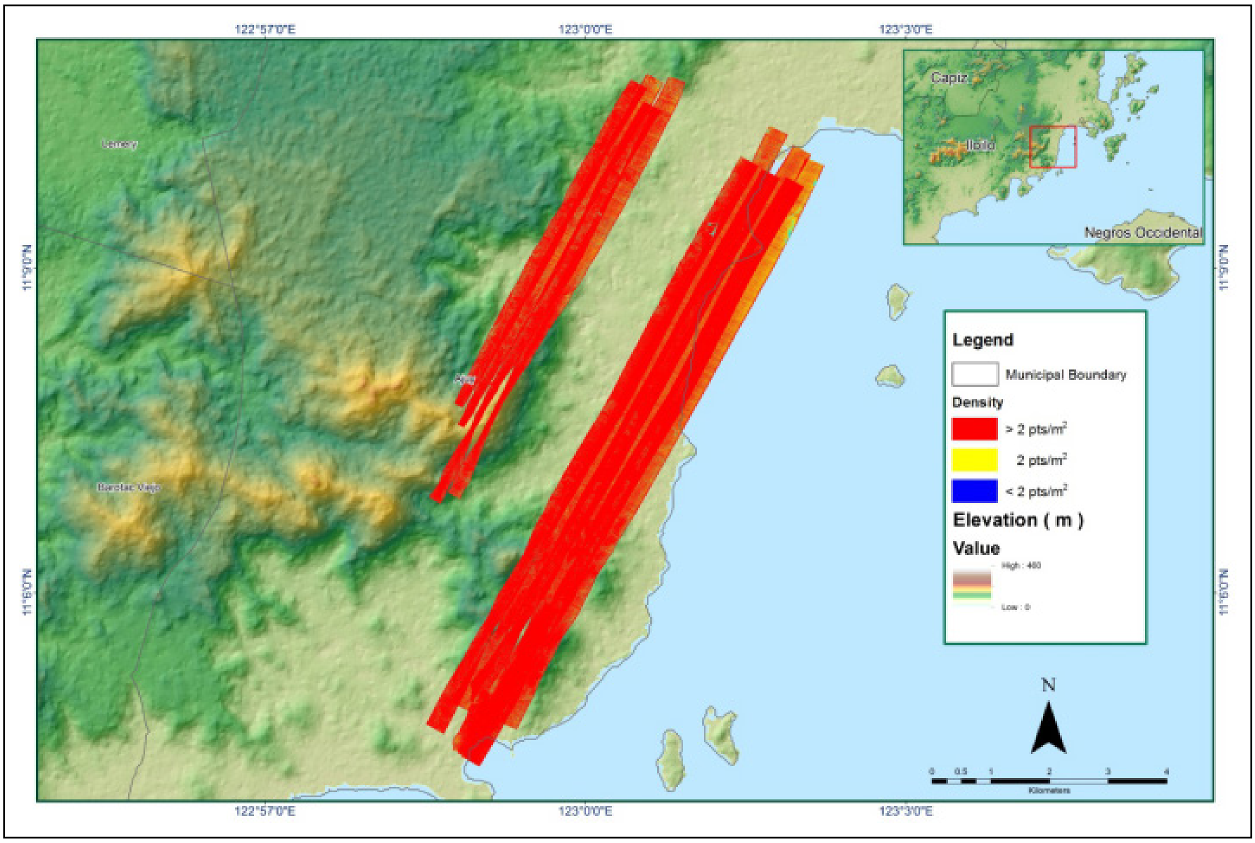


Figure A-8.76. Density map of merged LiDAR data

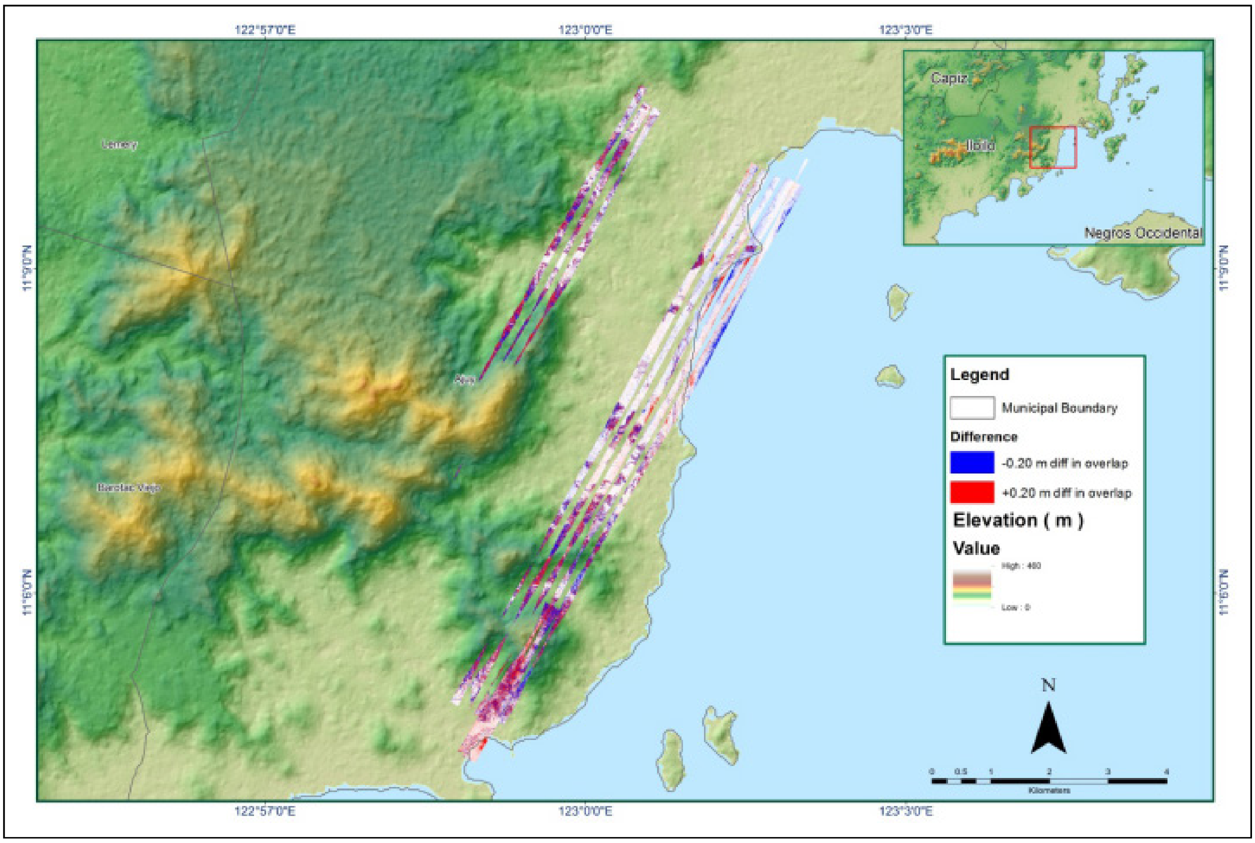


Figure A-8.77. Elevation difference between flight lines

Annex 9. Pinantan Model Basin Parameters

Table A-9.1. Pinantan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W100	0.1775	99	0	0.91603	0.72599	Discharge	2.4206	0.5	Ratio to Peak	0.5
W110	0.1775	99	0	0.94797	0.59374	Discharge	2.1763	0.5	Ratio to Peak	0.5
W120	0.18168	99	0	1.11363	0.60905	Discharge	6.288	0.5	Ratio to Peak	0.5
W130	0.1775	99	0	0.81928	0.66452	Discharge	1.7875	0.5	Ratio to Peak	0.5
W140	0.18497	99	0	0.83509	0.65888	Discharge	1.2576	0.5	Ratio to Peak	0.5
W80	0.39502	99	0	1.33934	1.2065	Discharge	2.1969	0.5	Ratio to Peak	0.5
W90	0.1775	99	0	0.73658	0.71024	Discharge	2.0593	0.5	Ratio to Peak	0.5

Annex 10. Pinantan Model Reach Parameters

Table A-10.1. Pinantan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R30	Automatic Fixed Interval	257.99	0.0147719	0.005	Trapezoid	12.5	1
R40	Automatic Fixed Interval	372.13	0.0174012	0.005	Trapezoid	12.5	1
R70	Automatic Fixed Interval	111.92	5.79E-02	0.005	Trapezoid	12.5	1

Annex 11. Pinantan Field Validation Points

Table A-11.1. Pinantan Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	11.01223	123.0079	0.03	0	0.001	-	
2	11.01267	123.0373	0.03	0	0.001	-	
3	11.07674	123.0147	0.03	0	0.001	-	
4	11.02962	122.9968	0.04	0	0.002	-	
5	11.04585	123.0217	0.3	0	0.09	-	
6	11.00313	123.0061	0.03	0	0.001	-	
7	11.03308	123.018	0.03	0	0.001	-	
8	11.00117	123.0381	0.13	0	0.017	-	
9	11.01003	123.02	0.49	1	0.26	Yolanda	5-Year
10	11.08771	123.0176	1.85	0.9	0.903	Frank	100-year
11	11.08364	123.0446	0.29	0.9	0.372	Yolanda	5-Year
12	11.02853	123.0235	0.31	0.9	0.348	Frank	100-year
13	11.08738	123.0418	1.01	0.9	0.012	Yolanda	5-Year
14	11.08993	123.0595	0.22	3	7.728	Yolanda	5-Year
15	11.04467	123.03	0.04	0.7	0.436	Yolanda	5-Year
16	11.04102	123.0592	0.03	3	8.821	Yolanda	5-Year
17	11.07567	123.0207	0.44	3	6.554	Yolanda	5-Year
18	11.08896	123.0418	0.03	1.1	1.145	Yolanda	5-Year
19	11.0027	123.0202	0.1	0.9	0.64	Yolanda	5-Year
20	11.00305	123.0159	0.03	0.1	0.005	Yolanda	5-Year
21	11.07951	123.0557	0.12	3	8.294	Undang	5-Year
22	11.0877	123.052	0.82	0.95	0.017	Yolanda	5-Year
23	10.99944	123.059	0.2	3	7.84	Yolanda	5-Year
24	11.00237	123.0273	0.64	4.5	14.9	Yolanda	5-Year
25	11.08286	123.0197	0.45	0	0.202	-	
26	10.99955	123.0186	0.77	0.9	0.017	Frank	100-year
27	11.04606	123.0142	0.11	0.8	0.476	Yolanda	5-Year
28	11.07548	123.0339	0.03	1.6	2.465	Yolanda	5-Year
29	11.10998	123.0281	1.1	0.7	0.16	Yolanda	5-Year
30	11.08084	123.028	2.45	0.7	3.063	Yolanda	5-Year
31	11.11231	123.0084	0.74	1.1	0.13	Auring	5-Year
32	11.08792	123.0128	0.18	2.25	4.285	Undang	5-Year
33	11.03269	123.0067	0.46	0.9	0.194	Frank	100-year
34	11.0454	123.0276	0.56	4.5		Yolanda	5-Year
35	11.04005	123.0209	0.32	0	0.102	-	
36	11.0246	123.0267	0.45	1.6	1.323	Yolanda	5-Year
37	11.04151	122.995	0.13	6.9		Yolanda	5-Year
38	11.00512	123.0002	0.05	0.9	0.722	Yolanda	5-Year
39	11.06059	123.0143	0.17	6		Yolanda	5-Year
40	11.00674	123.0169	0.65	0.9	0.063	Yolanda	5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
41	11.0005	123.0191	0.08	0.1	0	Undang	5-Year
42	11.02458	123.0532	0.64	0.2	0.194	Frank	100-year
43	11.04655	123.0264	0.16	2	3.386	Yolanda	5-Year
44	10.99675	123.0513	0.23	0.9	0.449	Yolanda	5-Year
45	11.02701	123.0294	0.66	3	5.476	Yolanda	5-Year
46	11.00294	123.0199	0.4	1	0.36	Milenyo	5-Year
47	11.00202	123.0419	0.19	1	0.656	Frank	100-year
48	11.02547	123.0182	1.06	1	0.004	Frank	100-year
49	11.0056	123.0387	0.59	6	29.268	Yolanda	5-Year
50	11.04933	123.004	0.42	0.4	0	Yolanda	5-Year
51	11.01049	123.0368	0.39	1	0.372	Yolanda	5-Year
52	11.00655	123.0278	1.57	0.4	1.369	Frank	100-year
53	11.04001	123.0162	0.55	1.1	0.302	Yolanda	5-Year
54	11.00497	123.0152	1.38	1.6	0.048	Yolanda	5-Year
55	11.03224	123.0261	1.05	2	0.903	Yolanda	5-Year
56	11.03103	123.0113	0.03	0	0.001	-	
57	11.01327	123.024	0.61	2	1.932	Ruping	5-Year
58	11.00364	123.0291	1.57	1	0.325	Frank	100-year
59	11.00517	122.9918	0.95	1	0.003	Yolanda	5-Year
60	11.00367	122.9679	1.59	2	0.168	Frank	100-year
61	11.05104	123.0084	0.74	0.4	0.116	Yolanda	5-Year
62	11.02789	123.015	1.71	1.6	0.012	Yolanda	5-Year
63	11.07413	123.0248	0.06	0.95	0.792	Yolanda	5-Year
64	11.02677	123.0178	1.18	0.9	0.078	Undang	5-Year
65	11.00194	123.0097	0.41	0.9	0.24	Yolanda	5-Year
66	11.02665	123.0156	2.49	0.9	2.528	Frank	100-year
67	10.99995	123.0169	0.29	1.1	0.656	Yolanda	5-Year
68	10.99923	123.0197	0.87	1	0.017	Milenyo	5-Year
69	11.03165	123.0136	1.32	1.6	0.078	Yolanda	5-Year
70	11.03095	123.0276	0	0.4	0.16	Frank	100-year
71	11.02582	123.0188	0.03	1	0.941	Yolanda	5-Year
72	11.03225	123.0118	0.95	1.5	0.303	Frank	100-year
73	11.00186	123.0587	0.1	0.8	0.49	Yolanda	5-Year
74	11.02336	123.009	0.88	0.4	0.23	Yolanda	5-Year
75	10.99912	122.9913	0	1	1	Yolanda	5-Year
76	11.03053	123.0248	1.21	1.3	0.008	Yolanda	5-Year
77	11.04056	122.9947	0.44	6	30.914	Yolanda	5-Year
78	11.0006	123.0281	0.03	2	3.881	Yolanda	5-Year
79	10.99877	123.022	4.41	6	2.528	Yolanda	5-Year
80	11.04112	123.0305	0.03	10.5		Yolanda	5-Year
81	10.99795	123.011	1.47	7.5	36.361	Yolanda	5-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Valid-ation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
82	11.0311	123.0262	0.03	4.5	19.981	Yolanda	5-Year
83	10.99903	123.0148	1.65	1.6	0.002	Yolanda	5-Year
84	11.00979	123.0242	0.55	4.5	15.602	Yolanda	5-Year
85	11.03135	123.0108	0.29	7.5	51.984	Yolanda	5-Year
86	10.99771	123.0152	0	1.6	2.56	Yolanda	5-Year
87	11.04171	123.0205	0.51	3.75	10.498	Yolanda	5-Year
88	11.0374	123.0221	0	6	36	Yolanda	5-Year
89	11.03125	123.0238	5.55	6	0.202	Yolanda	5-Year
90	11.03101	123.0162	2.17	3.2	1.061	Frank	100-year
91	11.02223	123.0104	3.23	6.9	13.469	Yolanda	5-Year
92	11.03587	123.0144	0	1.6	2.56	Yolanda	5-Year
93	11.02652	123.0256	5.66	12	40.196	Yolanda	5-Year
94	11.08448	123.0145	2.25	1.6	0.423	Yolanda	5-Year
95	11.0682	123.0245	0.09	6	34.928	Yolanda	5-Year
96	11.06017	123.0212	1.31	4.5	10.176	Yolanda	5-Year
97	11.06959	123.0099	2.59	2.7	0.012	Ondoy	5-Year
98	11.07691	123.0202	0.03	6	35.641	Yolanda	5-Year
99	10.99876	123.0104	3.4	6.9	12.25	Yolanda	5-Year
100	11.03595	123.0102	0.82	6.9	36.966	Yolanda	5-Year
101	11.03753	123.0207	0.03	6	35.641	Yolanda	5-Year
102	11.03802	123.0106	1.94	3	1.124	Yolanda	5-Year
103	10.99941	123.0262	0.03	4.5	19.981	Yolanda	5-Year
104	11.03489	123.011	1.74	7.5	33.178	Yolanda	5-Year
105	11.0009	122.9911	0.03	6.75	45.158	Yolanda	5-Year
106	11.03532	123.0112	6	6	0	Yolanda	5-Year
107	11.04518	123.0254	2.73	7.5	22.753	Yolanda	5-Year
108	11.0353	123.0284	0.03	7.5	55.801	Yolanda	5-Year
109	11.03869	123.011	0	3.75	14.063	Yolanda	5-Year
110	11.03189	123.0102	0	6.9	47.61	Yolanda	5-Year
111	11.0311	123.0103	0	6.9	47.61	Yolanda	5-Year
112	11.03517	123.0242	0	6	36	Yolanda	5-Year
113	11.0365	123.0256	0	6	36	Yolanda	5-Year
114	11.04829	123.03	2.46	7.5	25.402	Yolanda	5-Year
115	11.02188	123.0223	0.03	6	35.641	Yolanda	5-Year

Annex 12. Educational Institutions affected by flooding in Pinantan Floodplain

Table A-12.1. Educational Institutions in Ajuy, Iloilo affected by flooding in Pinantan Floodplain

Iloilo				
Ajuy				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Adcadarao Elementary School	Adcadarao			
Bucana Bunglas Day Care Center	Bucana Bunglas			
Bucana Bunglas Primary School	Bucana Bunglas			
Tamis-ac Elementary School	Bucana Bunglas			
Central Day Care Center	Central			Low
Patricio Alcantara Memorial Elementary School	Central			
Lanjagan Day Care Center	Lanjagan	Low	Low	Low
Lanjagan Primary School	Lanjagan	Low	Medium	Medium
Taguhangin Day Care Center	Lanjagan		Low	Low
Valentine Dignadice Memorial Elementary School	Lanjagan	Low	Medium	Medium
Pinantan Diel Barangay Day Care Center	Pinantan Diel			
Pinantan Elizalde Barangay Day Care Center	Pinantan Elizalde			
Alejo Posadas Memorial Elementary School	Poblacion	Low	Medium	Medium
Precious Gym Learning Center	Poblacion	Low	Medium	Medium
Barangay Pantalan Navarro Daycare Center	Puente Bunglas			
Pantalan Navarro Elementary School	Puente Bunglas			
Rojas Day Care Center	Rojas			
Barangay Adcadarao Daycare Center	Tanduyan			
Barangay Tanduyan Day Care Center	Tanduyan			

Table A-12.2. Educational Institutions in Concepcion, Iloilo affected by flooding in Pinantan Floodplain

Iloilo				
Concepcion				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Calamigan Day Care Center	Agnaga			
Calamigan Elementary School	Agnaga			
Maria Lourdes Chapel	Agnaga	Medium	Medium	Medium
Batiti Day Care Center	Batiti	Medium	Medium	Medium
Batiti Learning Center	Batiti			
Jamul-awon Day Care Center	Batiti			
Jamul-awon Elem. School	Jamul-Awon			
Liboron Primary School	Macalbang			
Macalbang Elementary School	Macalbang			
Sitio Kasantulan Day Care Center	Macalbang			
Nino Plandico Elementary School	Niño			
Nino Plandico Preparatory School	Niño			
Plandico Barangay Day Care Center	Plandico			
Tamis-ac Barangay Health Center	Tamis-Ac			
Tamis-ac Day Care Center	Tamis-Ac			
Tamis-ac Elementary School	Tamis-Ac			

Table A-12.3. Educational Institutions in Sara, Iloilo affected by flooding in Pinantan Floodplain

Iloilo				
Sara				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Aldeguer Barangay Day Care Center	Aldeguer			
Devera Barangay Day Care Center	Aldeguer			
Alibayog Barangay Day Care Center	Alibayog			
Anoring Barangay Day Care Center	Anoring		Low	Low
Eucharistic King Academy	Anoring	High	High	High
Ilaya Elementary School	Anoring	Medium	Medium	Medium
Northern Iloilo Polytechnic State College - Victorino Salcedo,Sara Campus	Anoring	Medium	Medium	Medium
Sara Central Elementary School	Anoring	Low	Low	Low
Sara Fundamental Christian Baptist School	Anoring	Medium	Medium	Medium
Juaneza Elementary School	Aposaga			
Alfredo Sanson Memorial Elementary School	Aspera			
Sara National High School	Aspera			
Antonio Yusay Primary School	Aswe-Pabriaga			
Aswe-Pabriaga Day Care Center	Aswe-Pabriaga			
Kalahi Day Care	Aswe-Pabriaga	Low	Low	Medium
Agnaga Day Care Center	Bakabak			
Bakabak Elem. School	Bakabak			
Brgy. Bakabak Day Care Center	Bakabak	Medium	Medium	Medium
Dominggo Y. Sobrimonte Memorial School	Bakabak			
Puente Bunglas Elementary School	Bakabak			
Sto. Nino Chapel	Bakabak			
Barangay Batitao Daycare Center	Batitao		Medium	Medium
Tentay Primary School	Batitao	Low	Low	Low
Crespo Day Care Center	Crespo			
Crespo Elem. School	Crespo			
Hugo T. Apelo Memorial Elementary School	Devera	Low	Medium	Medium
Domingo Day Care Center	Domingo			
Barangay Zerrudo Daycare Center	Ferraris			
Purfication Salcedo Gustillo Memorial Elementary School	Ferraris			
Barangay Gildore Daycare Center	Gildore			
Barangay Labigan Daycare Center	Gildore			
Labigan Primary School	Gildore			
Lanciola Day Care Center	Lanciola			
Malapaya Elementary School	Malapaya			
Malapaya National High School	Malapaya			
Seventh Day Adventist Church	Malapaya			
Padios Day Care Center	Padios			

Table A-12.4. Educational Institutions in Sara, Iloilo affected by flooding in Pinantan Floodplain

Iloilo				
Sara				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Sara Central Elementary School	Poblacion Ilawod	Low	Low	Low
BJIT School	Poblacion Market			
San Juan Academy	Poblacion Market			
Sara Central Elementary School	Poblacion Market			
Zerrudo Learning School	Poblacion Market			
Posadas Barangay Day Care Center	Posadas			
Preciosa Day Care Center	Preciosa			Low
Brgy. Salcedo Elem. School	Salcedo			
Barangay San Luis Daycare Center	San Luis	Low	Low	Medium
San Luis Elementary School	San Luis			Low
San Luis National High School	San Luis		Low	Low
Improgo Primary School	Tentay			Low
Tentay Primary School	Tentay	Low	Low	Low
Apelo Elementary School	Villahermosa		Low	Low
Arante Day Care Center	Villahermosa			
Villahermosa Day Care Center	Villahermosa			
Barangay Ferraris Daycare Center	Zerrudo			
Ferraris Elementary School	Zerrudo			
Pinay Espinosa Barangay Day Care Center	Zerrudo		Low	Medium
Pinay Espinosa Elementary School	Zerrudo			

Annex 13. Health Institutions affected by flooding in Pinantan Floodplain

Table A-13.1. Health Institutions in Ajuy, Iloilo affected by flooding in Pinantan Floodplain

Iloilo				
Ajuy				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Central Barangay Health Center	Central			
Lanjagan Health Station	Lanjagan			
Taguhangin Health Center	Lanjagan			
Pantalan Nabaye Barangay Health Center	Pantalan Nabaye			
Barangay Puente Bunglas Health Center	Pantalan Navarro			
Pinantan Elizalde Barangay Health Center	Pinantan Elizalde			
Pinantan Diel Barangay Health Center	Pinay Espinosa			Low
Pinay Espinosa Barangay Health Center	Pinay Espinosa			
Future Poblacion Barangay Health Center	Poblacion			
Barangay Pantalan Navarro Health Center	Puente Bunglas	Low	Low	Low
Rojas Health Center	Rojas			
Taguhangin Health Center	Taguhangin		Low	Low
Adcadarao Health Center	Tanduyan			

Table A-13.2. Health Institutions in Concepcion, Iloilo affected by flooding in Pinantan Floodplain

Iloilo				
Concepcion				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Batiti Health Center	Batiti	Medium	Medium	Medium
Jamul-awon Health Center	Batiti			
Calamigan Heatlh Center	Calamigan			Low
Macalbang Barangay Health Center	Macalbang			
Nino Health Center	Niño			Low
Plandico Barangay Health Center	Plandico			

Table A-13.3. Health Institutions in Sara, Iloilo affected by flooding in Pinantan Floodplain

Iloilo				
Sara				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Alibayog Barangay Health Center	Alibayog			
Anoring Barangay Health Center	Anoring			
Dra. Erlinda Penaflor Clinic	Anoring	Low	Medium	Medium
Sara District Hospital	Anoring	Low	Medium	Medium
Barangay Health Center	Aswe-Pabriaga	Low	Low	Medium
Barangay Bagaygay Health Center	Bagaygay			
Castor Barangay Day Care Center	Castor			
Crespo Health Center	Crespo			
Devera Barangay Health Center	Devera			
Sara District Hospital	Devera			
Barangay Zerrudo Health Center	Ferraris			
Barangay Labigan Health Center	Gildore			
Padios Health Center	Padios			
Sara Health Center	Poblacion Market			
Salcedo Health Center	Salcedo	Low	Low	Low
Barangay San Luis Health Center	San Luis		Low	Low
Arante Barangay Health Center	Villahermosa			
Barangay Ferraris Health Center	Zerrudo			

Annex 14. UPC Phil-LiDAR 1 Team Composition

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