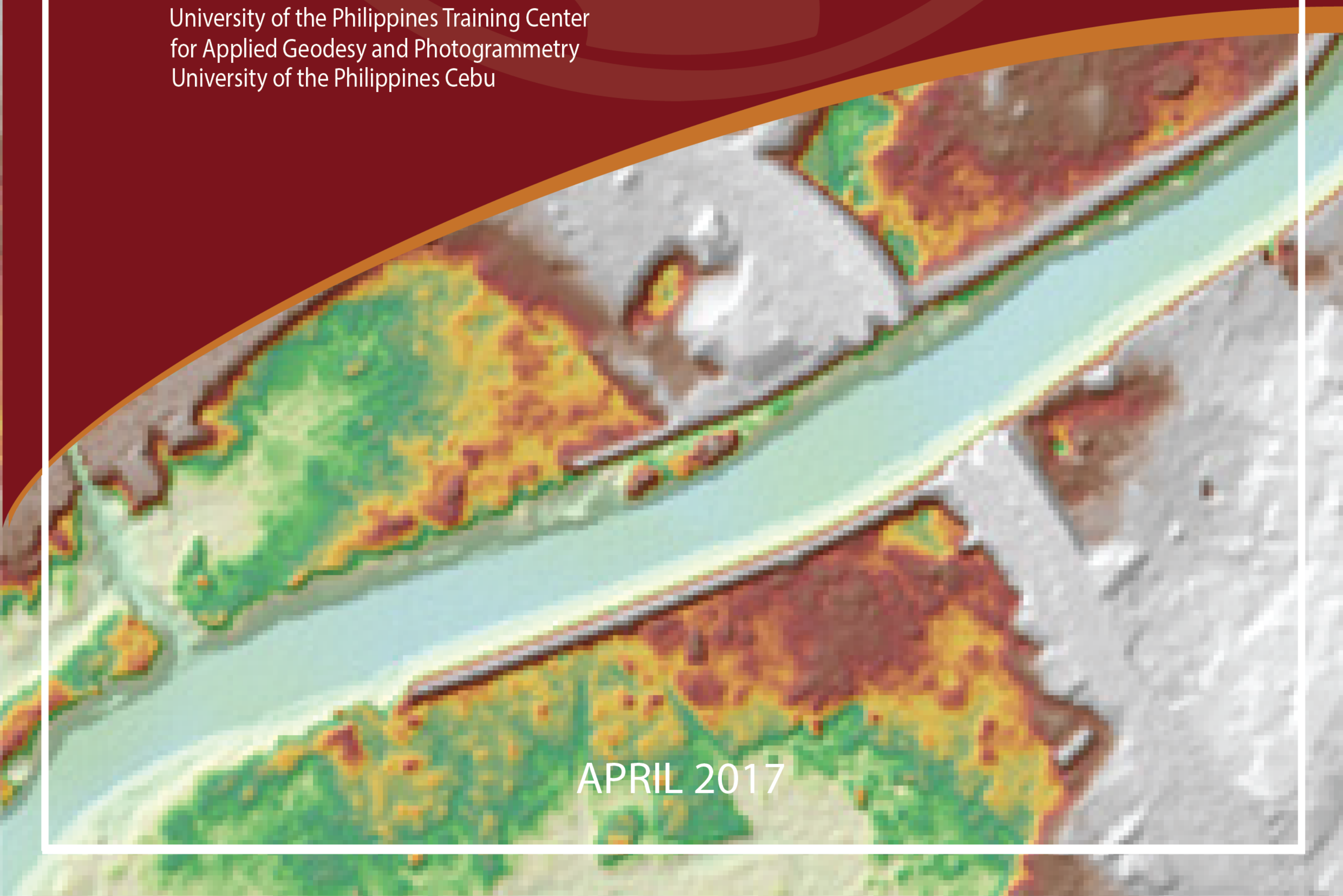
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Barotac River

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



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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND BAROTAC RIVER

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

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program was the University of the Philippines Cebu (UPC). UPC was 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.

2.2 Overview of Barotac River Basin

Barotac River Basin is located in the province of Iloilo which is at the north of Panay Island. The floodplain and drainage area of 119.73 km2 and 106.419 km2 respectively covers the municipalities of San Rafael, Lemery, Ajuy and Barotac Viejo. According to DENR River Basin Control Office (RBCO,2015) it has an approximate a drainage area of 102 km2 and an estimated 130 million cubic meter annual run-off. The floodplain was 96.9% covered with LiDAR data which comprised 18 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 9.05 km starting from Vista Alegre, Barotac Viejo up to the river mouth with 7674 points surveyed. There were 11337 buildings, 314.1 km roads, 461 waterbodies and 9 bridges digitized based from the LiDAR data. Feature Extraction Attribution was conducted and among the building features, 10754 of them were residential, 168 were schools and 31 are medical institutions.

The river basin's main stem, Barotac River is part of the river systems in the Western Visayas Region. It traverses six (6) barangays in Municiality of Barotac Viejo where it also serves as boundary. There is a total of 16,402 people residing within the immediate vicinity of the river which is distributed among the six barangays according to National Statistics Office Census of Population and Housing (NSO, 2010). Primary economic activities in the area are on agricultural production such as coconut, cereal, and sugar, and aquaculture through the cultivation of oysters and fishing. The most recent flooding in the area was caused by Typhoon Lando in October 2015.

The flood hazard map produced covers the 61.4 km2, 68.94 km2, 73.86 km2 for the 5-year, 25-year, and 100 year rainfall return period in Ajuy which affects 4 barangays as well as in Anilao which affects 4 barangays, in Banate which affects 18 barangays, in Barotac Viejo which affects 25 barangays, in Lemery which affects 1 barangay and in San Rafael which affects 3 barangays. A flood depth validation was conducted using 191 randomly generated points which was 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 0.736 m RMSE.

A rating curve was developed at Perfecto Balajadia Bridge, Barotac Viejo, Iloilo, which showed the relationship between the observed water levels at Perfecto Balajadia Bridge and outflow of the watershed at this location. This rating curve equation, expressed as Q = 3E-156e12.277x, was used to compute the river outflow at Perfecto Balajadia Bridge for the calibration of the HEC-HMS model. The resulting outflow was used to simulate the flooded areas using HEC-RAS. The simulated model will be an integral part in determining the real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website.

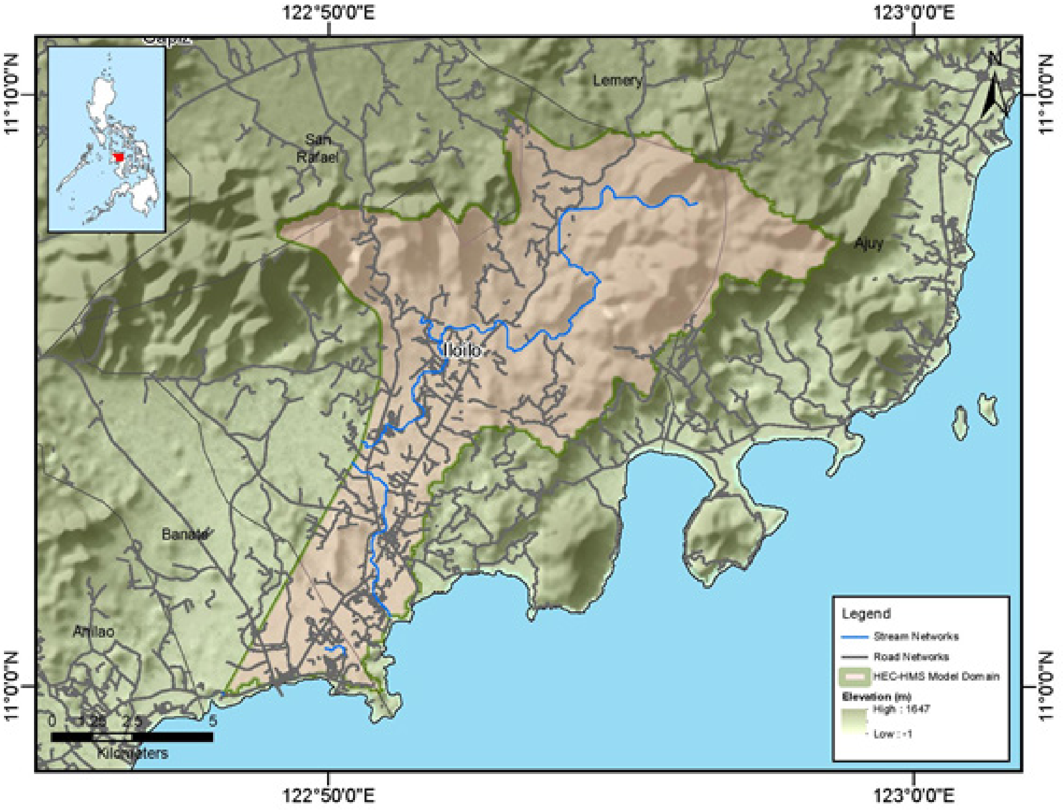

Figure 1. Map of Barotac River (in brown)

CHAPTER 2: LIDAR ACQUISITION IN BAROTAC FLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Barotac Floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Barotac Floodplain in Capiz and 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 Table 1 and Table 2. Figure 2 shows the flight plan and base stations for Barotac floodplain.

Table 1. Flight planning parameters for Gemini LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes
BLK37 A	1000	30	50	100	50	120	5
BLK37 C	1000	30	50	100	50	120	5
BLK37 J	600	30	50	125	50	125	5
BLK37 K	600	30	50	125	50	125	5

Table 2. Flight planning parameters for Pegasus LiDAR System

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes
BLK37 G	1000	30	50	200	50	120	5
BLK37 H	1000	30	50	200	50	120	5

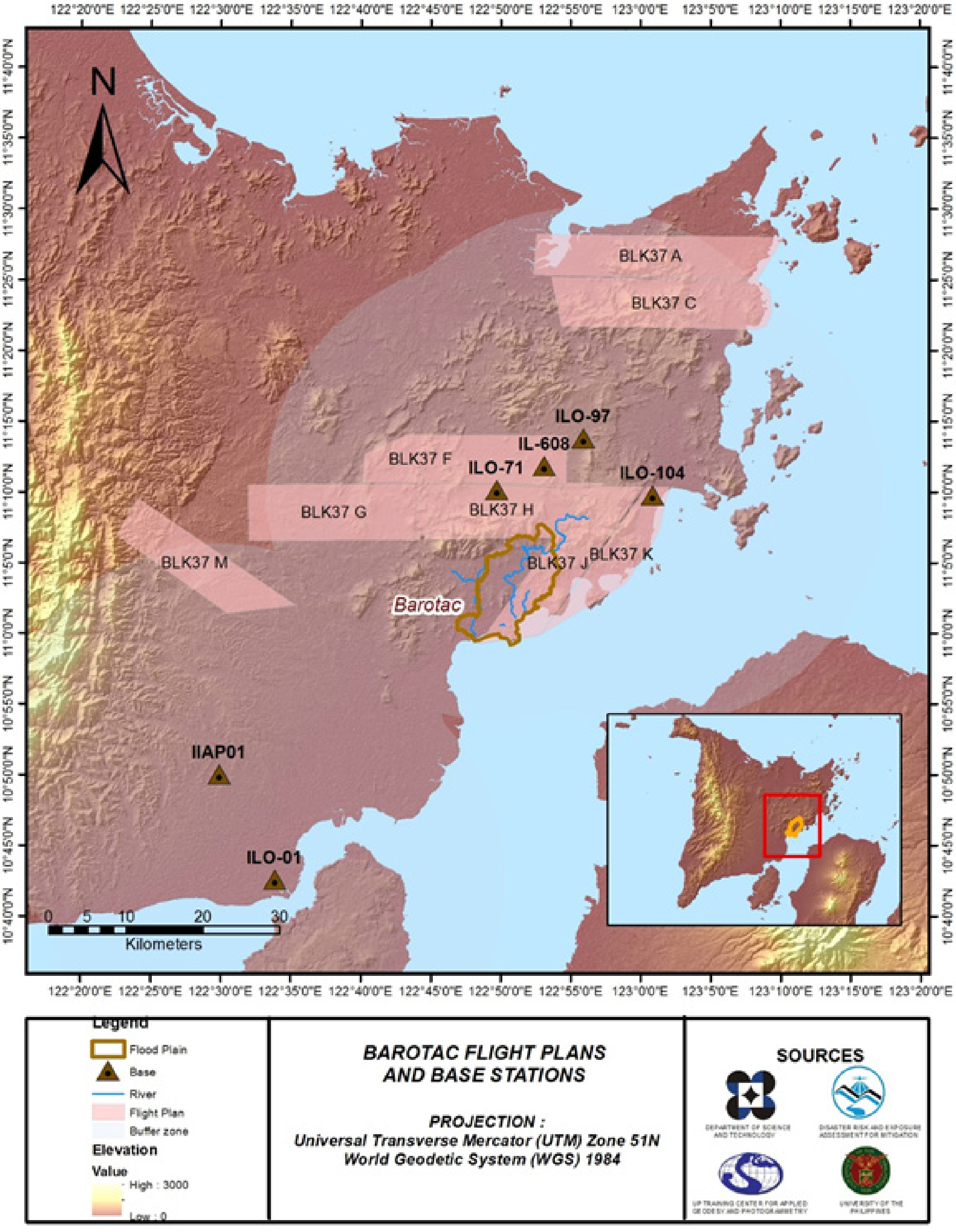


Figure 2. Flight plan and base stations used to cover Barotac Floodplain

2.2 Ground Base Station

The project team recovered three (3) NAMRIA reference points: ILO-71, ILO-01 and ILO-97 which are of second (2nd) order accuracy. The project team also re-established ground control point ILO-104, a NAMRIA reference point of third (3rd) order accuracy. Two (2) NAMRIA benchmarks were recovered: IL-608 and IIAP-01 which are all of second (2nd) accuracy. These benchmarks were used as vertical reference points and were also established as ground control points. The certification for the NAMRIA reference points, benchmarks and base processing reports are found in Annex 2. These were used as base stations during flight operations for the entire duration of the survey (February and September 2016). Base stations were observed using dual frequency GPS receivers, TOPCON GR-5, TRIMBLE SPS 852 and TRIMBLE SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Barotac floodplain are shown in Figure 2.

Figure 3 to Figure 7 show the recovered NAMRIA reference points within the area. Table 3 to Table 8 show the details about the following NAMRIA control stations and established points, while Table 9 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

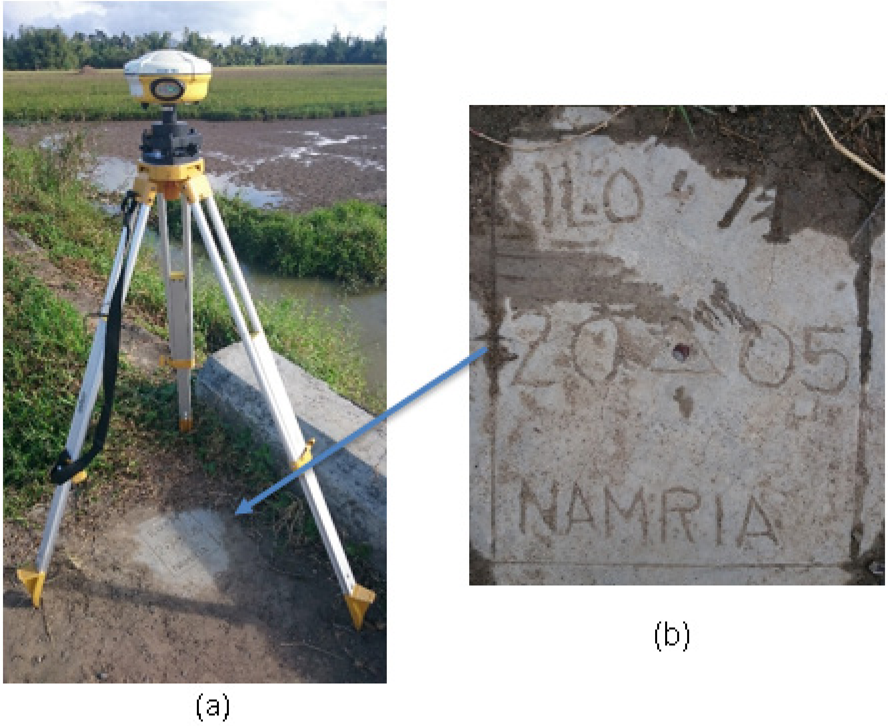
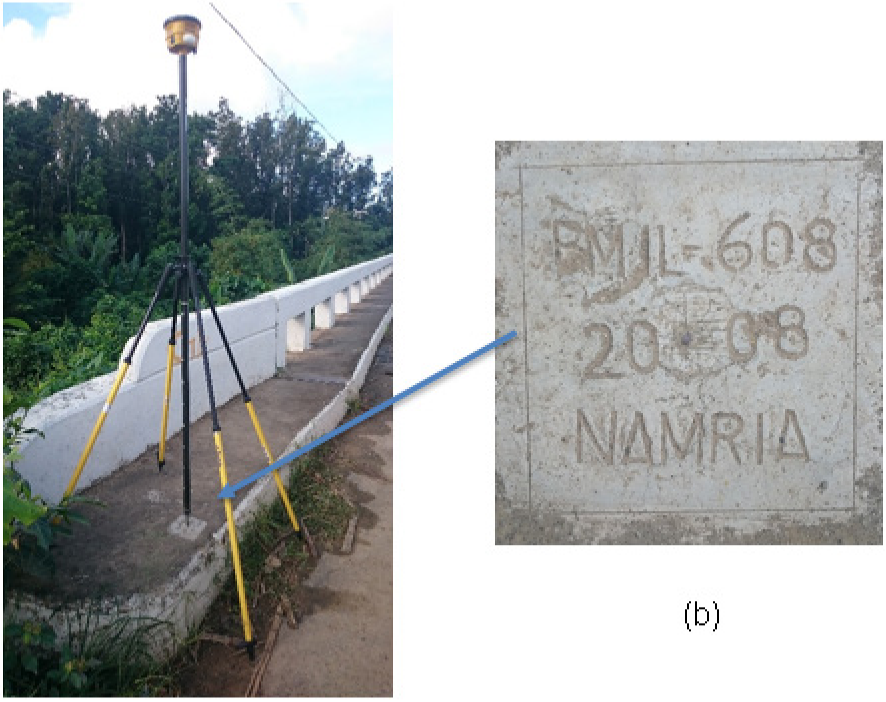


Figure 3. GPS set-up over ILO-71 in Barangay Poblacion, San Rafael, Province of Iloilo (a) and NAMRIA reference point ILO-71 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point ILO-71 used as base station for the LiDAR Acquisition

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



(a) (b)

Figure 4. GPS set-up overIL-608 in San Rafael, Province of Iloilo (a) and NAMRIA reference point IL-608 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point ILO-608 used as base station for the LiDAR acquisition

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

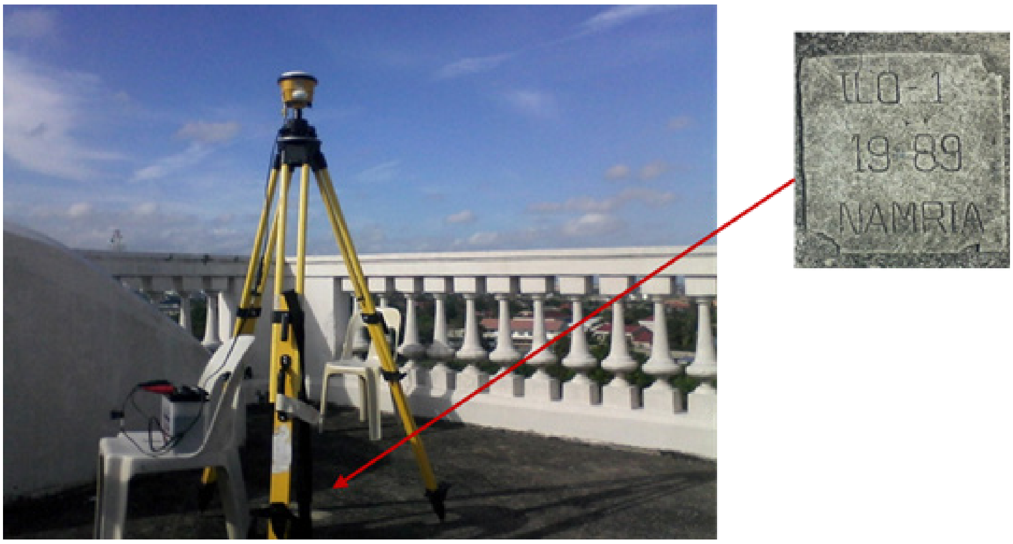


Figure 5. GCP set-up over ILO-1 is located on the roof top of St. Clemente Church Bell Tower in La Paz, Iloilo City (a) and NAMRIA reference point ILO-1 (b) as recovered by the field team

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

Station Name		ILO-1
Order of Accuracy		1st Order
Relative Error (horizontal positioning)		1:50000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10°42'40.74251" 122° 33' 48.38302" 28.93600 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	452244.945m 1184434.202m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 42' 36.40006" 122° 33' 53.60515" 86.45300 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	452261.66m 1184019.63m

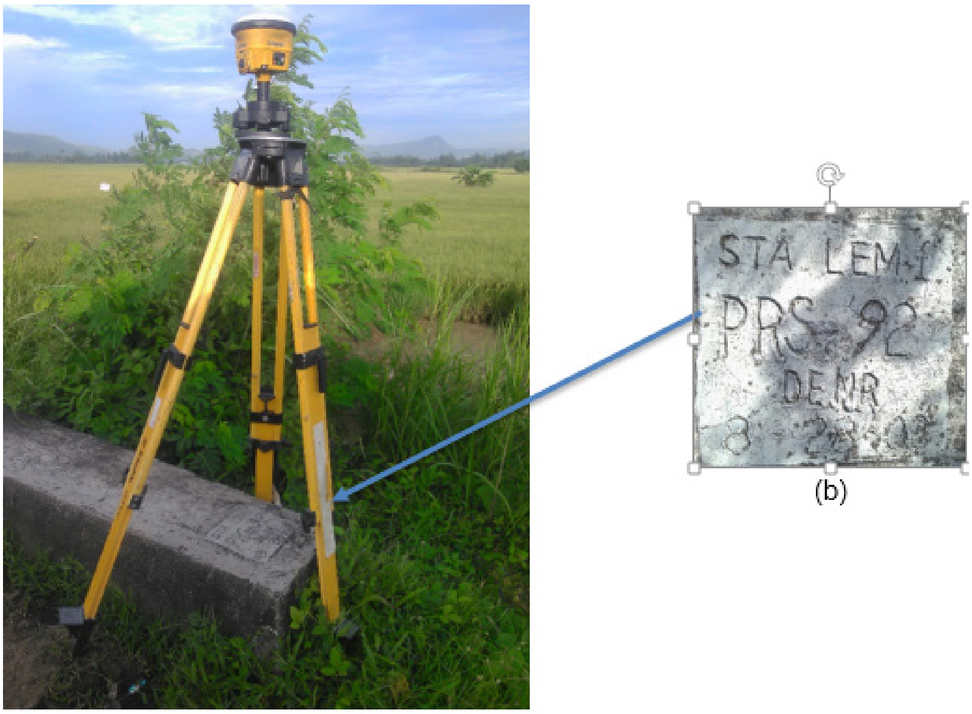


Figure 6. GCP set-up over ILO-97 as located in Brgy. Tabunan, Municipality of Lemery situated in an irrigation canal near the national road (a) and NAMRIA reference point ILO-97 (b) as recovered by the field team

Table 6. Details of ILO-97 GCP used as base station for the LiDAR acquisition

Station Name		ILO-97
Order of Accuracy		2ND
Relative Error (horizontal positioning)		1:50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS92)	Latitude Longitude Ellipsoidal Height	11° 13’ 54.08920” 122° 55’ 50.84966” 88.56000 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone PRS92)	Easting Northing	492442.532 m 1241955.878 m
Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 13’ 49.64749” 122° 55’ 56.02324” 145.73700 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	492445.28 m 1241521.17 m

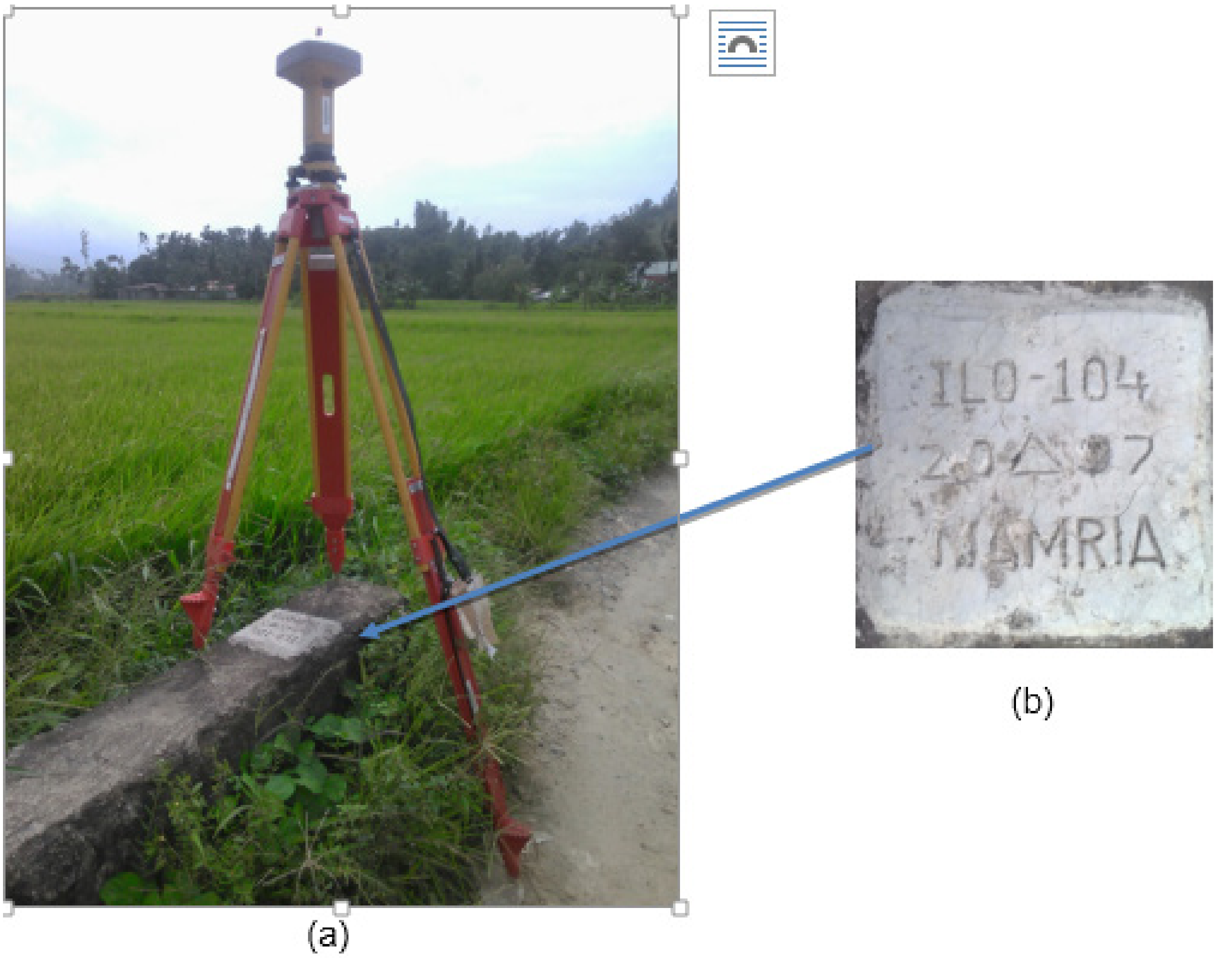


Figure 7. GCP set-up over ILO-104 in Brgy. Poblacion, Municipality of Ajuy situated in an irrigation canal near Ajuy High School (a) and NAMRIA reference point ILO-104 (b) as recovered by the field team

Table 7. Details of ILO-97 GCP used as base station for the LiDAR acquisition

Station Name		ILO-104
Order of Accuracy		2ND
Relative Error (horizontal positioning)		1:50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS92)	Latitude Longitude Ellipsoidal Height	11° 9’ 53.30263” 123° 0’ 46.92545” 11.59700 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone PRS92)	Easting Northing	501423.696 m 1234557.253 m
Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 9’ 48.88466” 123° 0’ 52.10452” 69.13900 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	501423.20 m 1234125.14 m

Table 8. 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 (PRS92)	Latitude Longitude Ellipsoidal Height	10° 50’ 08.21923” 122° 29’ 48.82359” 43.390 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone PRS92)	Easting Northing	445007.365 m 1197773.97 m
Grid 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, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	445007.365 m 1197773.97 m

Table 9. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
Feb. 10, 2015	2546G	2BLK37KV042A	ILO-71 and IL-608
Feb. 13, 2015	2554G	2BLK37J044A	ILO-71 and IL-608
Feb. 13, 2015	2556G	2BLK37JSG044B	ILO-71 and IL-608
Feb. 16, 2015	2568G	2BLK37GSIV047B	ILO-71 and IIAP-01
Feb. 19, 2015	2591P	1BLK37I050B	ILO-71 and IIAP-01
Feb. 22, 2015	2601P	1BLK37IF053A	ILO-71 and IIAP-01
Feb. 25, 2015	2613P	1BLK37IFV056A	ILO-71 and IIAP-01
Mar. 03, 2015	2639P	1BLK37M062B	ILO-01 and IIAP01
Sept. 27, 2015	2778G	2BLK37AC270A	ILO-97(LEM-1) and ILO-104
Sept. 29, 2015	2786G	2BLK37AB272A	ILO-97(LEM-1) and ILO-104
Sept. 29, 2015	2778G	2BLK37BCD272B	ILO-97(LEM-1) and ILO-104

2.3 Flight Missions

Eleven (11) missions were conducted to complete the LiDAR Data Acquisition in Barotac floodplain, for a total of fourty-one hours and twenty-seven minutes (41+27) of flying time for RP-C9022 and RP-C9122. All missions were acquired using the Pegasus and Gemini LiDAR system. Table 10 shows the total area of actual coverage per mission and the flying length for each mission, while Table 11 presents the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions for LiDAR data acquisition in Barotac floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the River Systems (km2)	Area Surveyed Outside the River Systems (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
Feb. 10, 2015	2546G	85.54	121.18	0	121.87	939	4	23
Feb. 13, 2015	2554G	141.62	125.00	29.46	96.00	NA	4	23
Feb. 13, 2015	2556G	161.09	149.60	0	149.60	1194	4	23
Feb. 16, 2015	2568G	161.09	132.27	0	132.27	758	3	41
Feb. 19, 2015	2591P	156.13	210.43	11.64	198.79	674	3	29
Feb. 22, 2015	2601P	186.26	175.70	0.74	174.96	505	3	53
Feb. 25, 2015	2613P	195.02	104.80	7.11	97.69	NA	2	29
Mar. 03, 2015	2639P	121.50	89.95	0	89.95	NA	1	55
Sept. 27, 2015	2778G	176.10	204.34	52.14	152.20	764	4	17
Sept. 29, 2015	2786G	176.10	142.32	47.79	94.53	739	4	17
Sept. 29, 2015	2778G	176.10	182.07	40.18	182.07	930	4	17
TOTAL		1736.55	1637.66	189.06	1489.93	5739	41	27

Table 11. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (AGL) (m)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (kHz)	Speed of Plane (Kts)	Average Turn Time (Minutes)
2546G	600	30	50	125	40	125	5
2554G	600	30	50	125	40	125	5
2556G	600	30	50	125	40	125	5
2568G	800	30	50	125	40	120	5
2591P	1000	30	50	200	30	120	5
2601P	1000	40	50	200	30	120	5
2613P	1000	40	50	200	30	120	5
2639P	1000	40	50	200	30	120	5
2778G	1000	30	30	100	50	120	5
2786G	1000	30	30	100	50	120	5
2788G	800	30	40	125	50	125	5

2.4 Survey Coverage

Barotac floodplain is located in the provinces of Iloilo and Capiz with majority of the floodplain situated within the municipality of San Rafael. Municipalities of Balasan, Estancia and Batad were mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 12. The actual coverage of the LiDAR acquisition for Barotac Floodplain is presented in Figure 8.

Table 12. List of Municipalities/Cities Surveyed in Capiz and Iloilo.

Province	Municipality/ City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
Iloilo	San Rafael	73.9	73.89	100%
	Balasan	51.11	50.49	99%
	Estancia	29.44	28.41	97%
	Batad	48.05	45.05	94%
	Barotac Viejo	187.75	152.94	81%
	San Enrique	93.21	61.69	66%
	Ajuy	169.66	110.56	65%
	Passi City	257.21	152.8	59%
	Lemery	132.21	71.05	54%
	Bingawan	38.34	14.51	38%
	San Dionisio	108.56	39.95	37%
	Banate	51.78	18.84	36%
	Anilao	102.97	24.29	24%
	Calinog	132.92	17.57	13%
	Sara	191.04	21.33	11%
	Dingle	103.12	7.64	7%
	Barotac Nuevo	94.85	2.18	2%
Capiz	Pilar	120.51	70.94	59%
	President Roxas	76.28	34.72	46%
	Dumarao	228.45	67.34	29%
	Cuartero	108.18	18.64	17%
	Pontevedra	95.28	13.68	14%
	Tapaz	515.98	68.11	13%
	Ma-ayon	192.6	11.72	6%

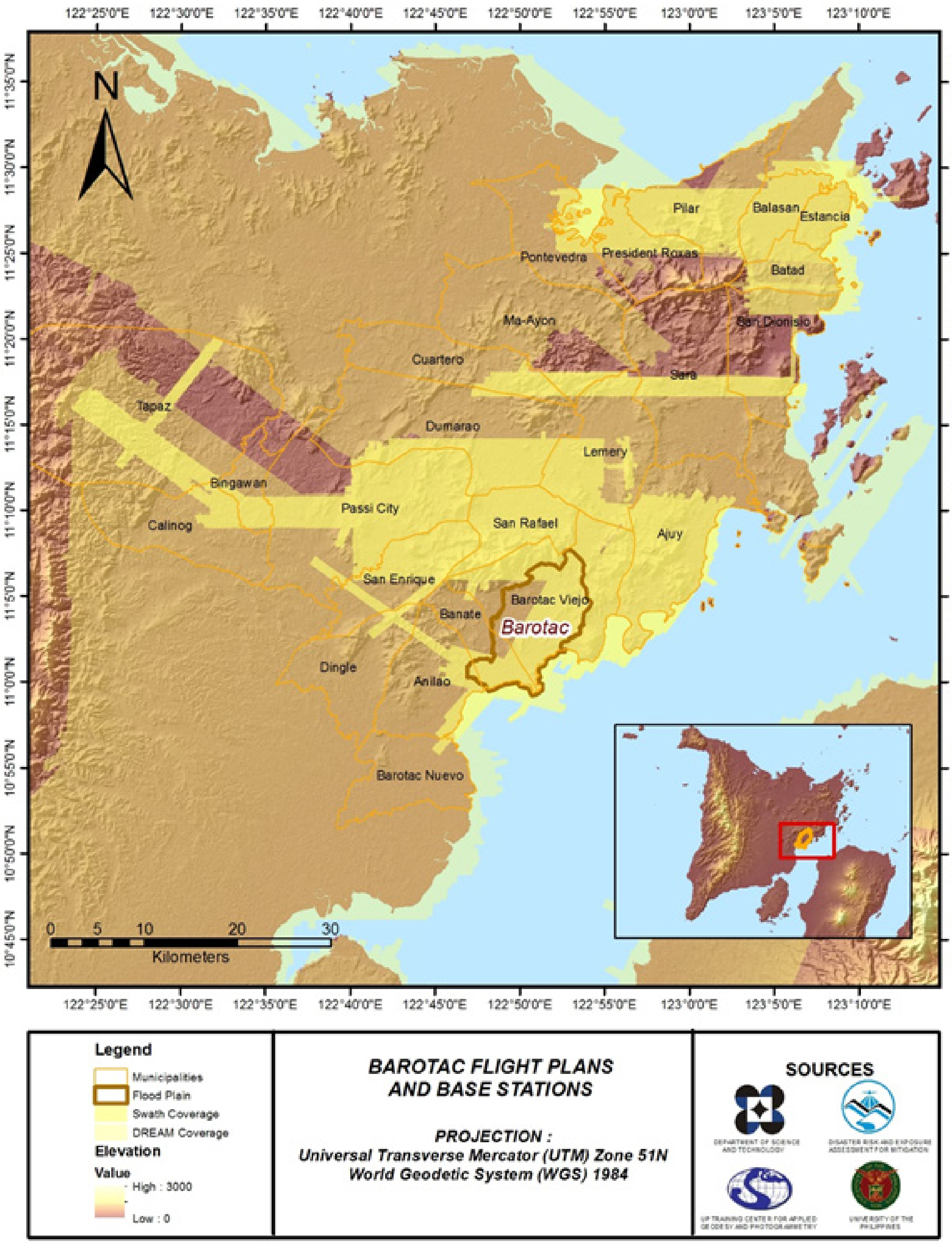


Figure 8. Actual LiDAR survey coverage for Barotac Floodplain

CHAPTER 3: LIDAR DATA PROCESSING FOR BAROTAC 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 Processing

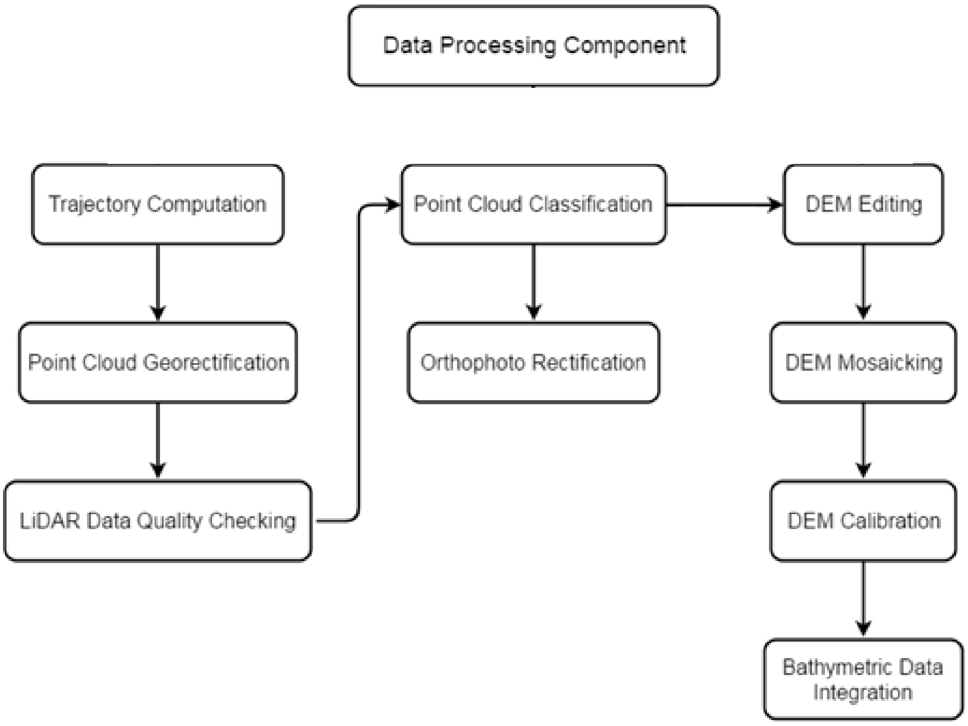


Figure 9. Schematic Diagram for Data Pre-Processing Component

The data transmitted by the Data Acquisition Component were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done in order to obtain the exact location of the LiDAR sensor when the laser was shot. Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were subject for quality checking to ensure that the required accuracies of the program, , were met. These are: minimum point density, vertical and horizontal accuracies. The point clouds were 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 were calibrated. Portions of the river that were barely penetrated by the LiDAR system were replaced by the actual river geometry measured from the field by the Data Validation and Bathymetry Component. LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was 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 9.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Barotac Floodplain can be found in Annex 5. Missions flown during the first survey conducted on May 2013 used both the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini and Pegasus systems while missions acquired during the second survey on March 2014 were flown using the Aquarius system. Missions acquired during the third survey on February 2015 were flown over Barotac Viejo, Iloilo using both Gemini and Pegasus systems again. For the fourth survey on September 2015, only Gemini system was used and for the fifth and last survey on October 2016, only Aquarius system was used. The Data Acquisition Component (DAC) transferred a total of482.49 Gigabytes of Range data, 5.17 Gigabytes of POS data, 418.58 Megabytes of GPS base station data, and 884.35 Gigabytes of raw image data to the data server on June 3, 2013 for the first survey, April 22, 2014 for the second survey, March 23, 2015 for the third survey, November 9 2015 for the fourth survey and November 22, 2016 for the last survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Barotac was fully transferred on November 22, 2016, as indicated on the Data Transfer Sheets for Barotac floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 2613P, one of the Barotac flights, which is the North, East, and Down position RMSE values as shown in Figure 10. 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 25, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

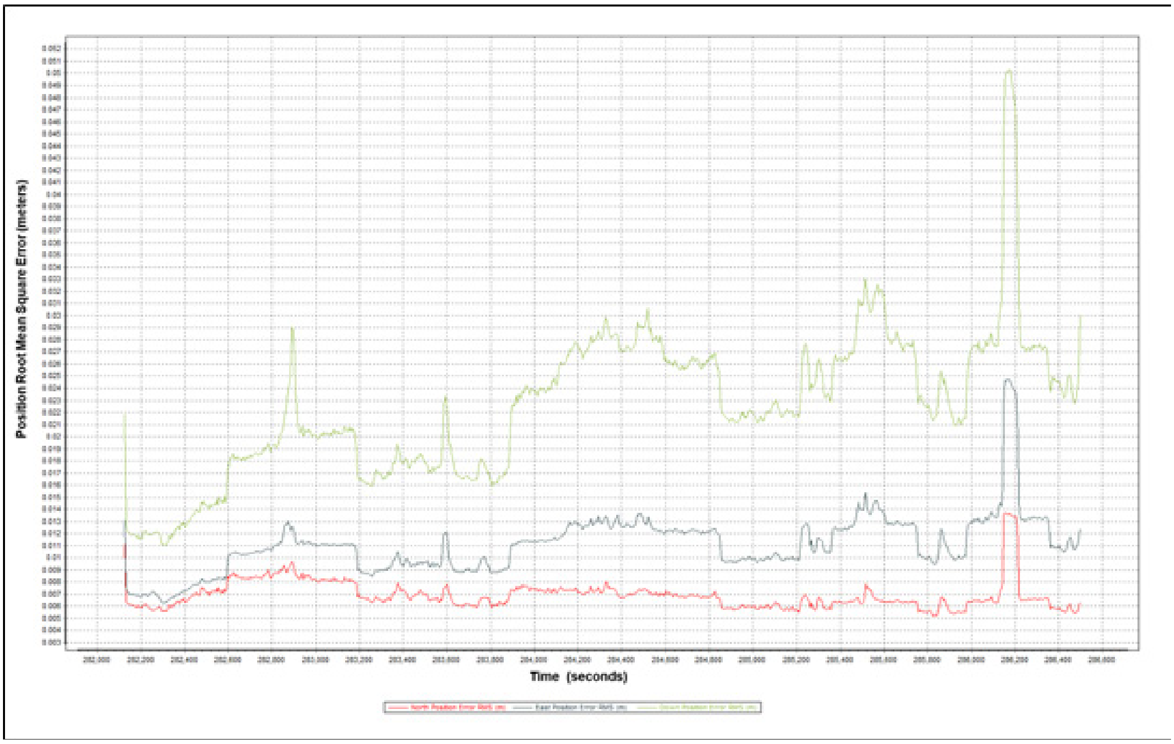


Figure 10. Smoothed Performance Metrics of a Barotac Flight 2613P

The time of flight was from 282100 seconds to 286500 seconds, which corresponds to morning of February 25, 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 started 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 10 shows that the North position RMSE peaks at 0.80 centimeters, the East position RMSE peaks at 1.36 centimeters, and the Down position RMSE peaks at 3.70 centimeters, which are within the prescribed accuracies described in the methodology.

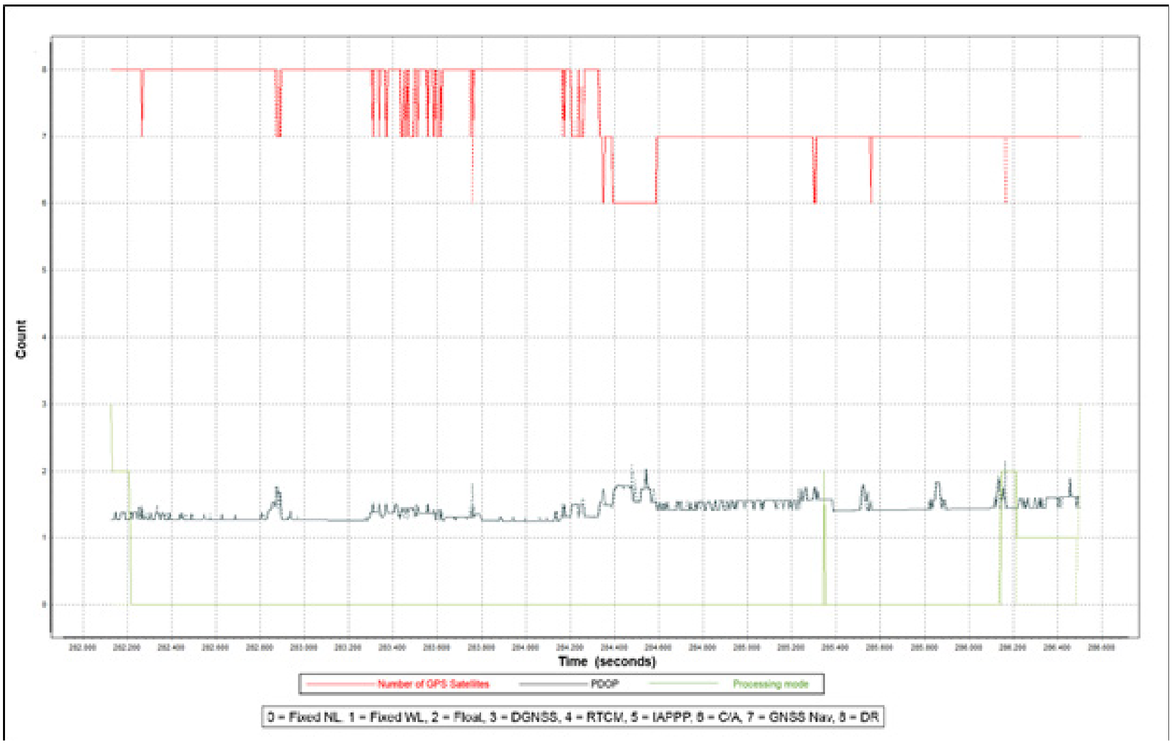


Figure 11. Solution Status Parameters of Barotac Flight 2613P

The Solution Status parameters of flight 2613P,one of the Barotac flights are shown in Figure 11. These parameters are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Most of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Barotac flights is shown in Figure 12.

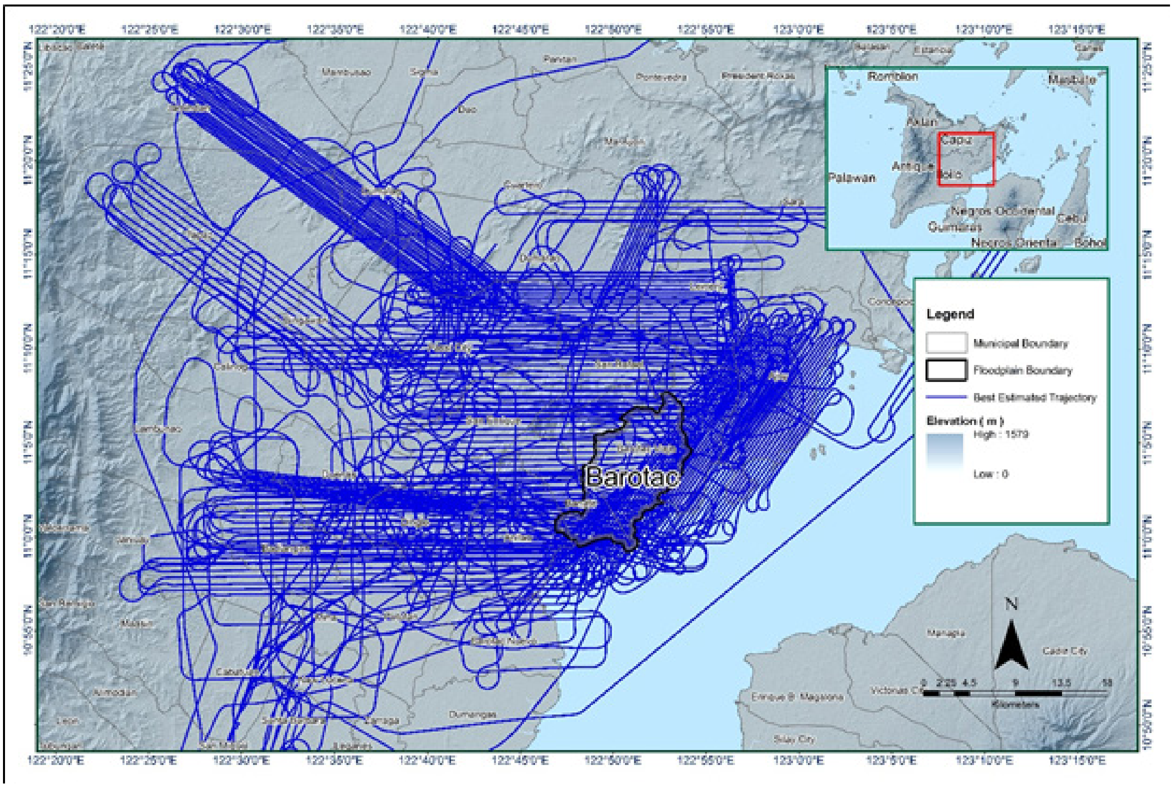


Figure 12. Best estimated trajectory for Barotac Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data consists of 344 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 Barotac floodplain are given in Table 13.

Table 13. Self-Calibration Results values for Barotac flights

Parameter	Computed Value
Boresight Correction stdev(<0.001degrees)	0.000250
IMU Attitude Correction Roll and Pitch Corrections stdev(<0.001degrees)	0.000910
GPS Position Z-correction stdev(<0.01meters)	0.0078

The optimum accuracy was obtained for all Barotac 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 B-5. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

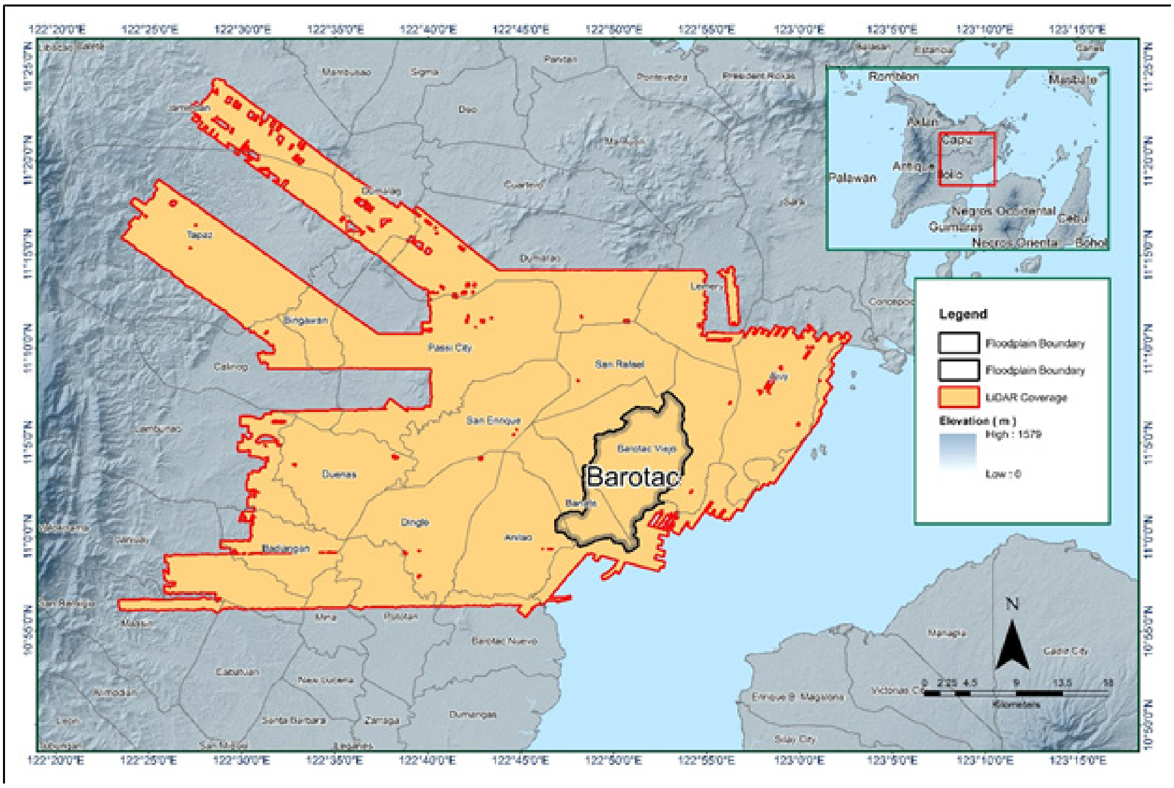


Figure 13. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Barotac Floodplain.

The total area covered by the Barotac missions is 2,365.97 sq.km. This is comprised of twenty seven (27) flight acquisitions grouped and merged into eighteen (18) blocks as shown in Table 14.

Table 14. List of LiDAR blocks for Barotac Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Iloilo_Blk37F_supplement	2634G	21.01
Iloilo_Blk37G	2556G	186.4
	2568G	
Iloilo_Blk37I	2568G	228.1
	2591P	
	2601P	
Iloilo_Blk37I_additional	2613P	25.02
Iloilo_Blk37I_supplement	2601P	72.14
	2613P	
Iloilo_Blk37J_additional	2566G	17.75
Iloilo_Blk37J_supplement	2613P	26.85
Iloilo_Blk37JK	2546G	401.3
	2554G	
	2556G	
Iloilo_Blk37M	2639P	176.4
	2647P	
Aklan_Blk38O	1178A	141.5
	1180A	
Capiz_Aklan_Blk37C	2778G	50.22
Capiz_Aklan_Blk37C_supplement	2778G	85.66
	2788G	
Jalaur_Blk6G	208G	237.86
	217P	
	219P	
	239P	
Jalaur_Blk6H	225P	212.37
	233P	
	237P	
	241P	
	243P	
Jalaur_Blk6H_additional	243P	109.43
Jalaur_Blk6I	227P	321.55
	229P	
	239P	

The overlap data for the merged LiDAR blocks, showing the number of channels that passed through a particular location is shown in Figure 14. Since the Gemini and Aquarius systems both employ one channel, it is expected that an average value of 1 (blue) for areas where there was limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus system which employs two channels, it is expected that an average value of 2 (blue) for areas where there was limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

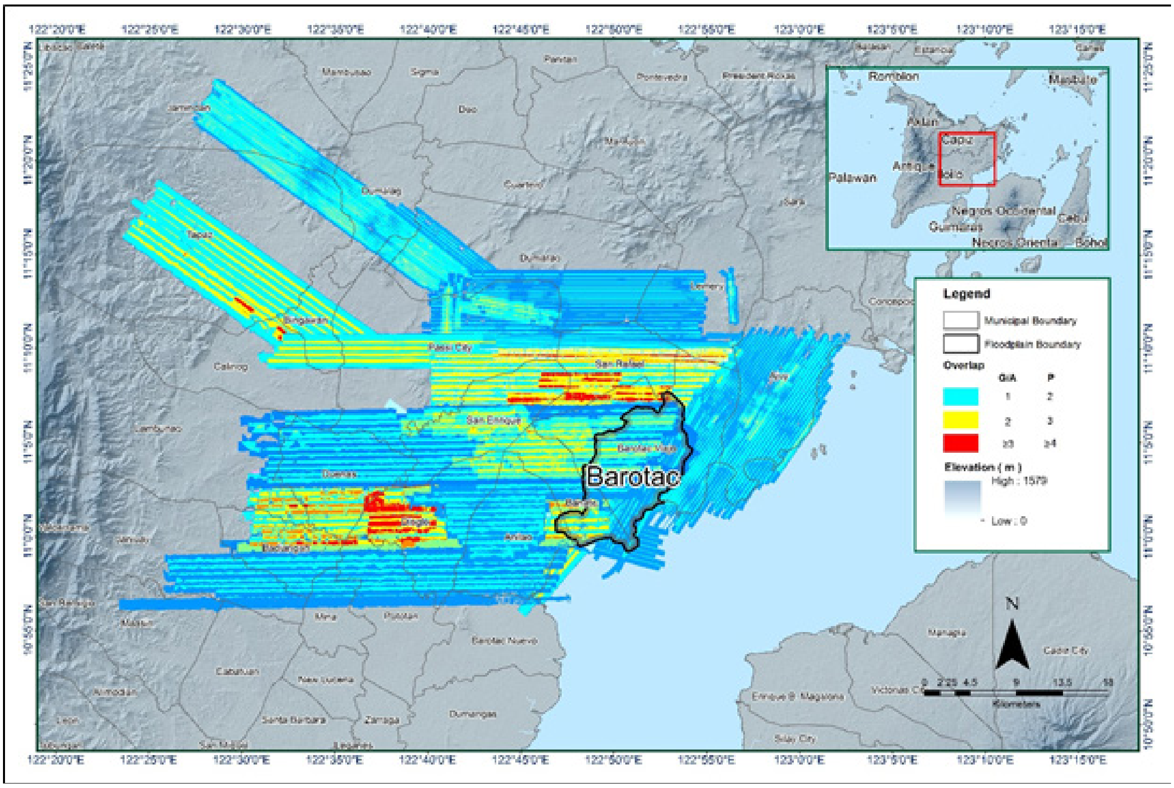


Figure 14. Image of data overlap for Barotac Floodplain

The overlap statistics per block for the Barotac 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 were 29.03% and 78.24% 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 15. It was determined that all LiDAR data for Barotac floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.86 points per square meter.

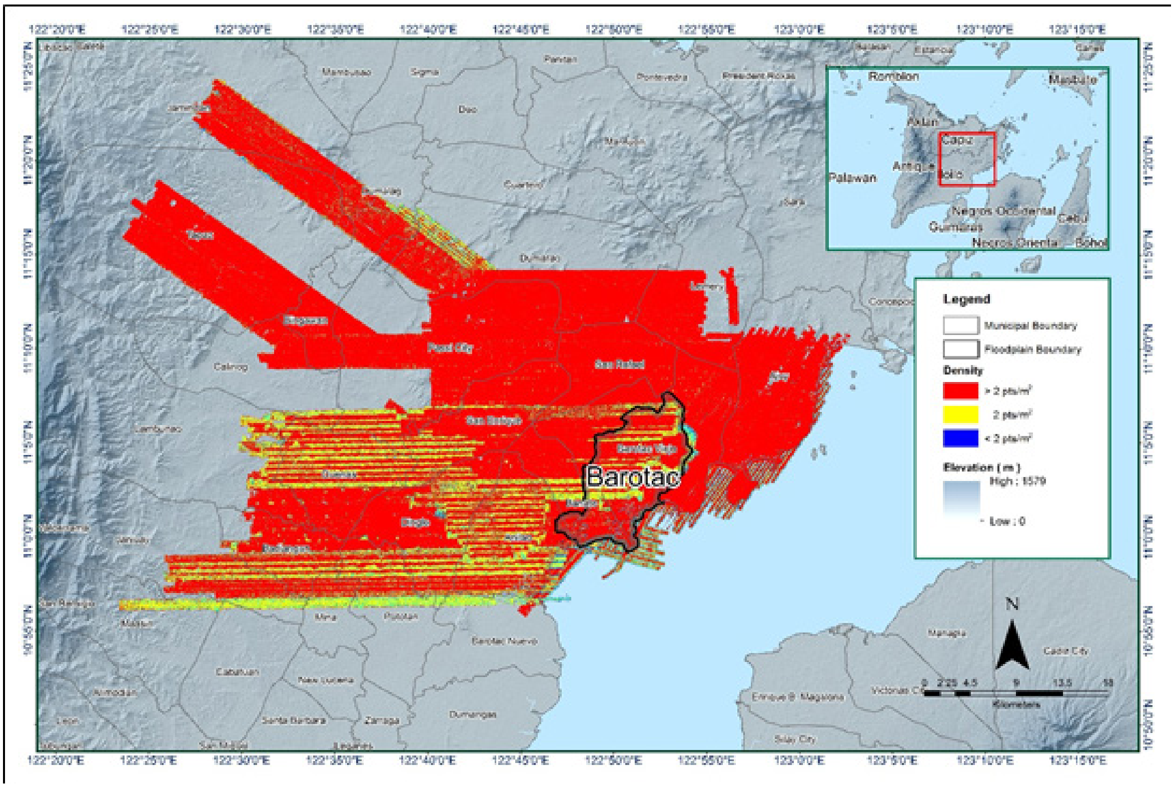


Figure 15. Pulse density map of merged LiDAR data for Barotac Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. 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.

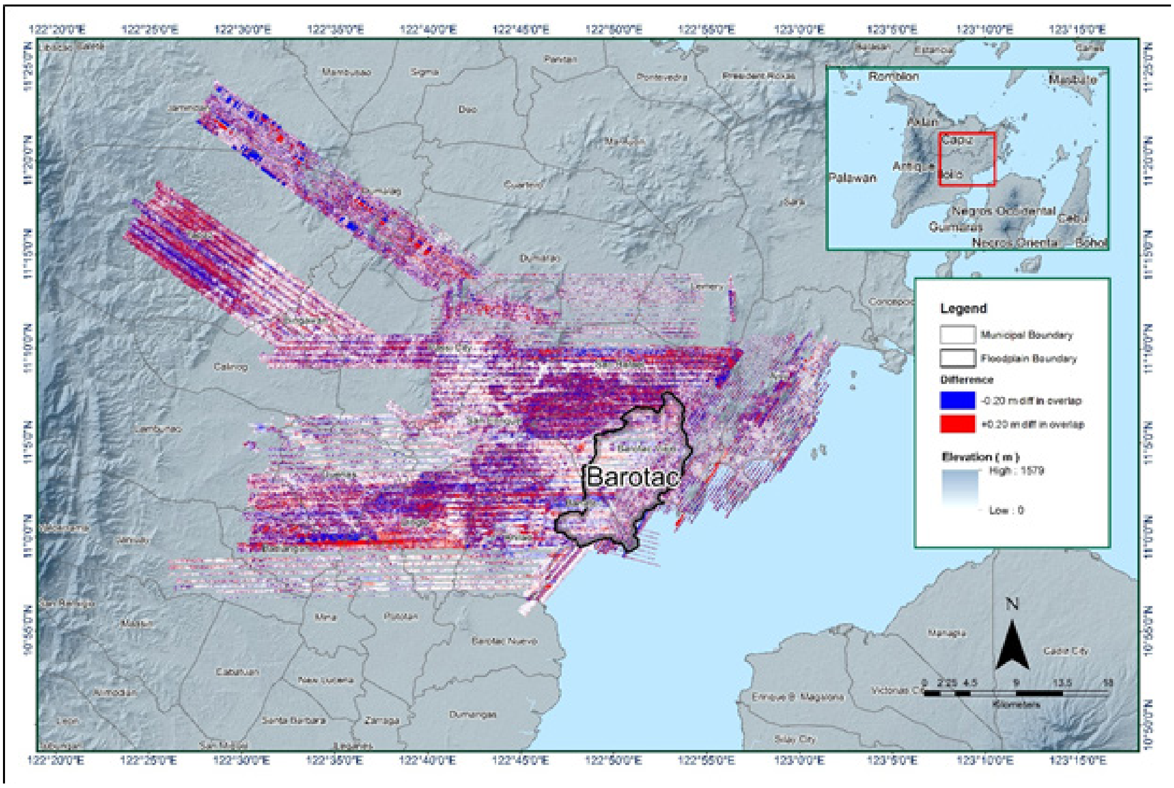


Figure 16. Elevation difference map between flight lines for Barotac floodplain

A screen capture of the processed LAS data from a Barotac flight 2613P loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponded to the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

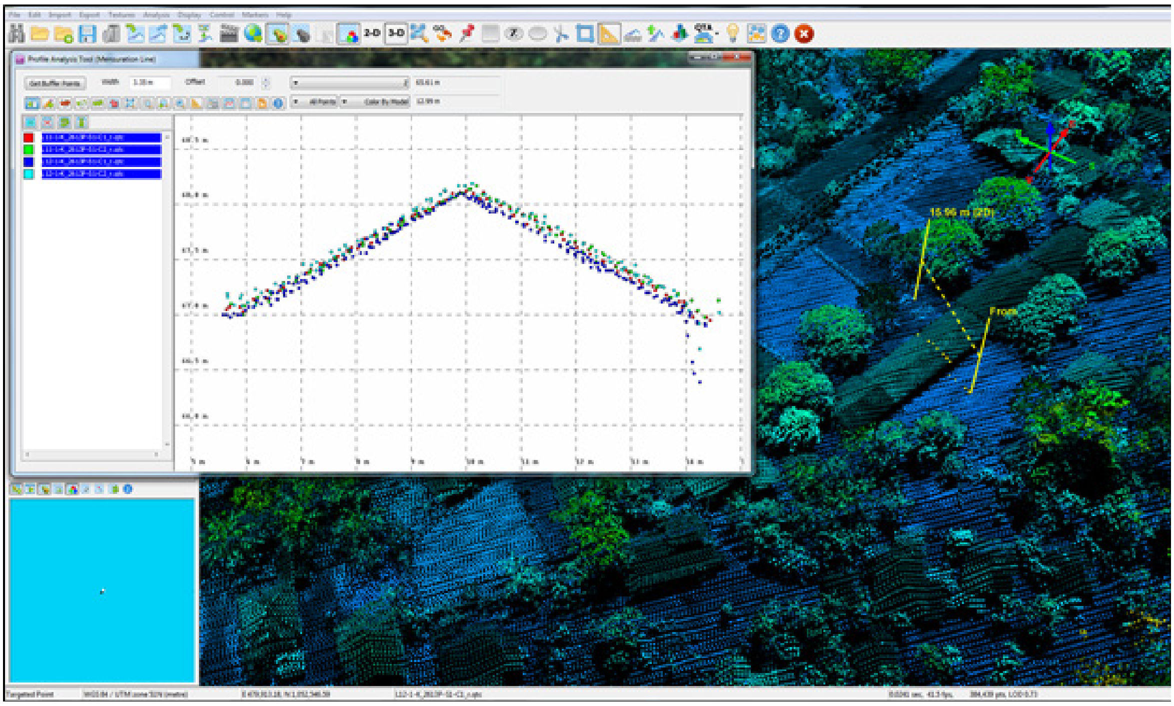


Figure 17. Quality checking for a Barotac flight 2613P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Barotac classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	2,214,477,337
Low Vegetation	1,767,032,842
Medium Vegetation	4,579,870,857
High Vegetation	2,721,254,245
Building	51,223,155

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Barotac floodplain is shown in Figure 18. A total of 3,300 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 15. The point cloud has a maximum and minimum height of 644.85 meters and 50.12 meters respectively.

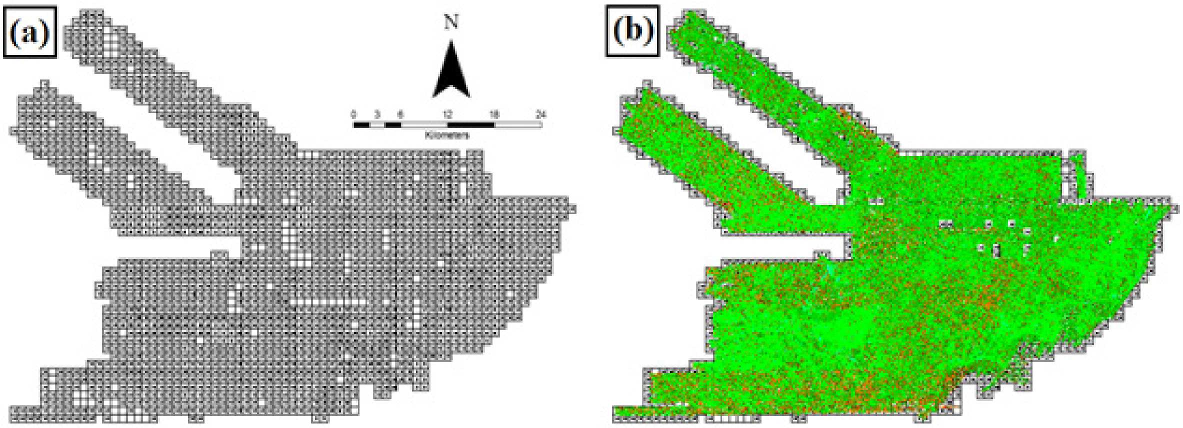


Figure 18. Tiles for Barotac floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 19. 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.

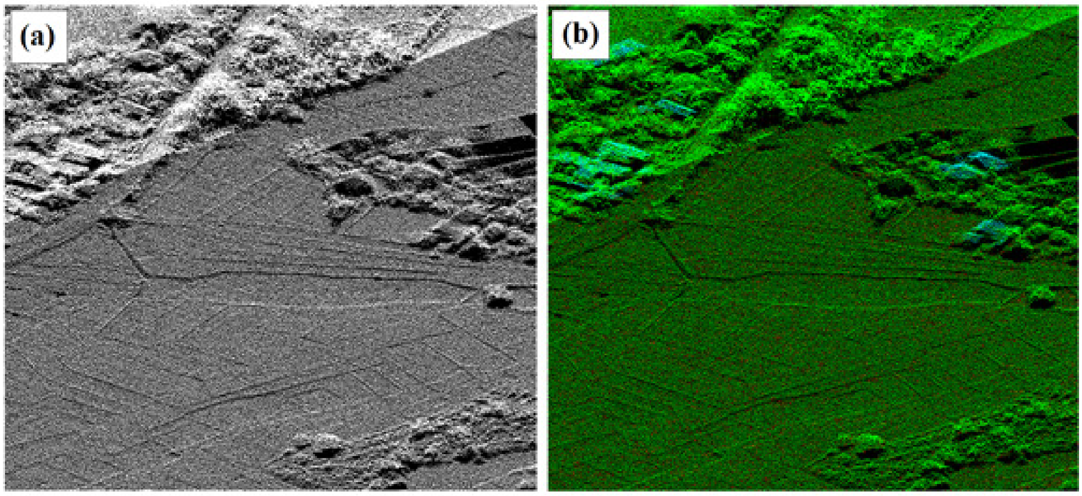


Figure 19. Point cloud before (a) and after (b) classification

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

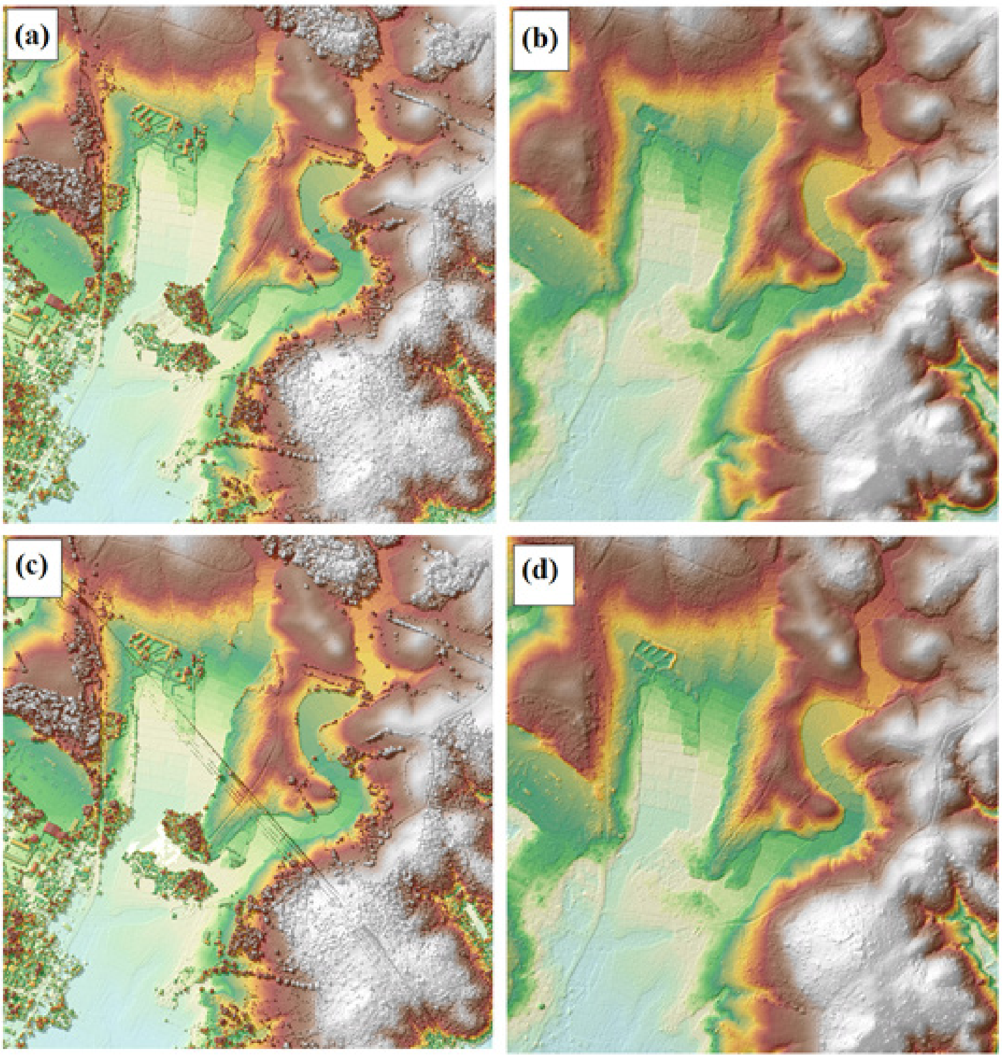


Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Barotac Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 2,403 1km by 1km tiles area covered by Barotac floodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Barotac floodplain has a total of 1,155.34 sq.km orthophotogaph coverage comprised of 8,889 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

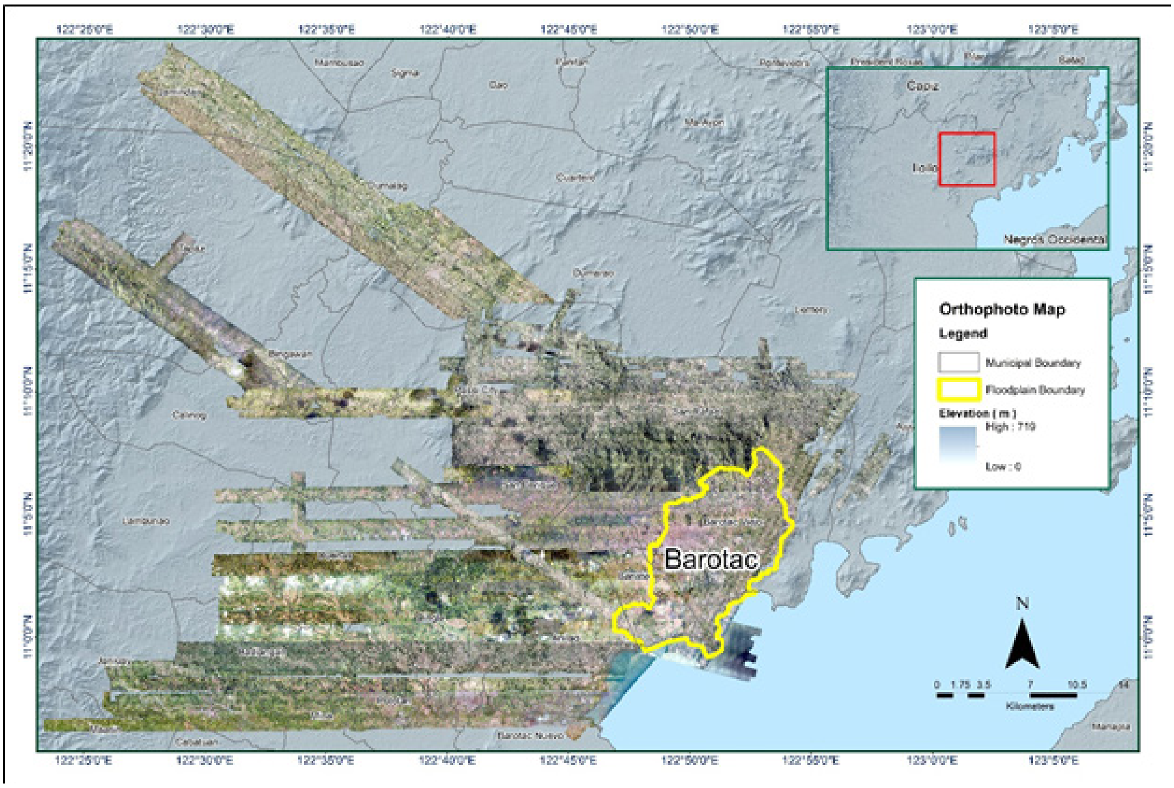


Figure 21. Barotac Floodplain with available orthophotographs

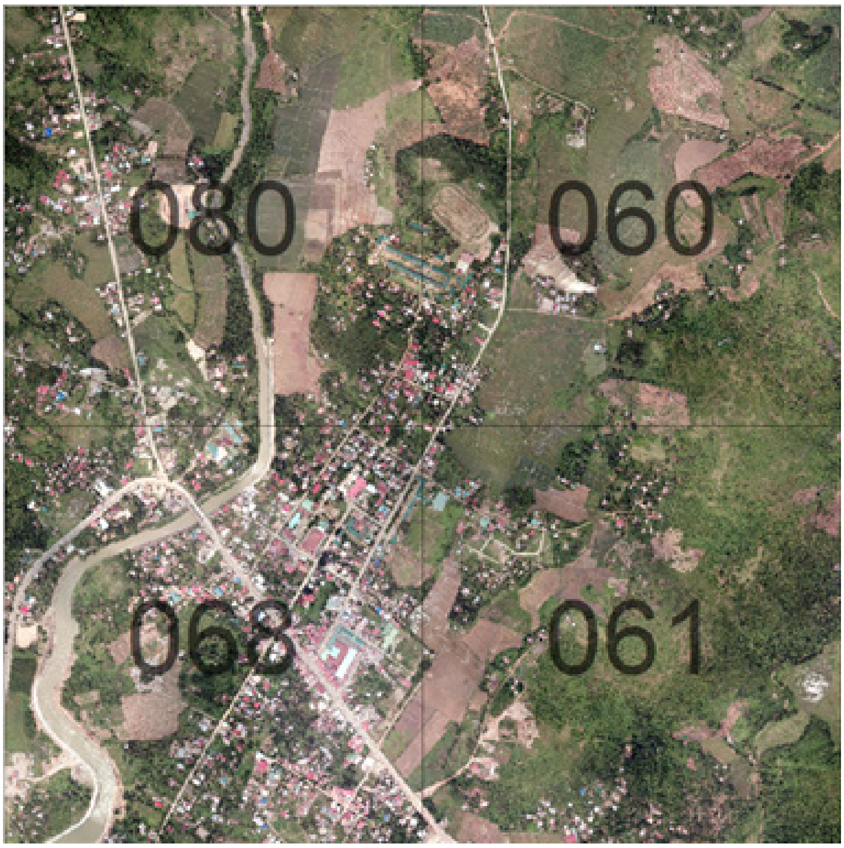


Figure 22. Sample orthophotograph tiles for Barotac Floodplain

3.8 DEM Editing and Hydro-Correction

Eighteen (18) mission blocks were processed for Barotac Floodplain. These blocks are composed of Iloilo and Capiz-Aklan blocks with a total area of 2,365.97 square kilometers. Table 16 shows the name and corresponding area of each block in square kilometers.

Table 16. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
Iloilo_Blk37F_supplement	21.01
Iloilo_Blk37G	186.4
Iloilo_Blk37I	228.1
Iloilo_Blk37I_additional	25.02
Iloilo_Blk37I_supplement	72.14
Iloilo_Blk37J_supplement	26.85
Iloilo_Blk37J_additional	17.75
Iloilo_Blk37JK	401.3
Iloilo_Blk37M	176.4
Aklan_Blk38O	141.5
Capiz_Aklan_Blk37C	50.22
Capiz_Aklan_Blk37C_supplement	85.66
Jalaur_Blk6G	237.86
Jalaur_Blk6H	212.37
Jalaur_Blk6H_additional	109.43
Jalaur_Blk6I	321.55
Iloilo_reflights_Blk37J	8.87
Iloilo_reflights_Blk37P	43.54
TOTAL	2,365.97 sq.km

Portions of DTM before and after manual editing are shown in Figure 23. It shows that the paddy field (Figure 23a) had been misclassified and removed during classification process and had to be retrieved to complete the surface (Figure 23b). The bridges (Figure 23c) would be an impedance to the flow of water along the river and had to be removed (Figure 23d) in order to hydrologically correct the river.

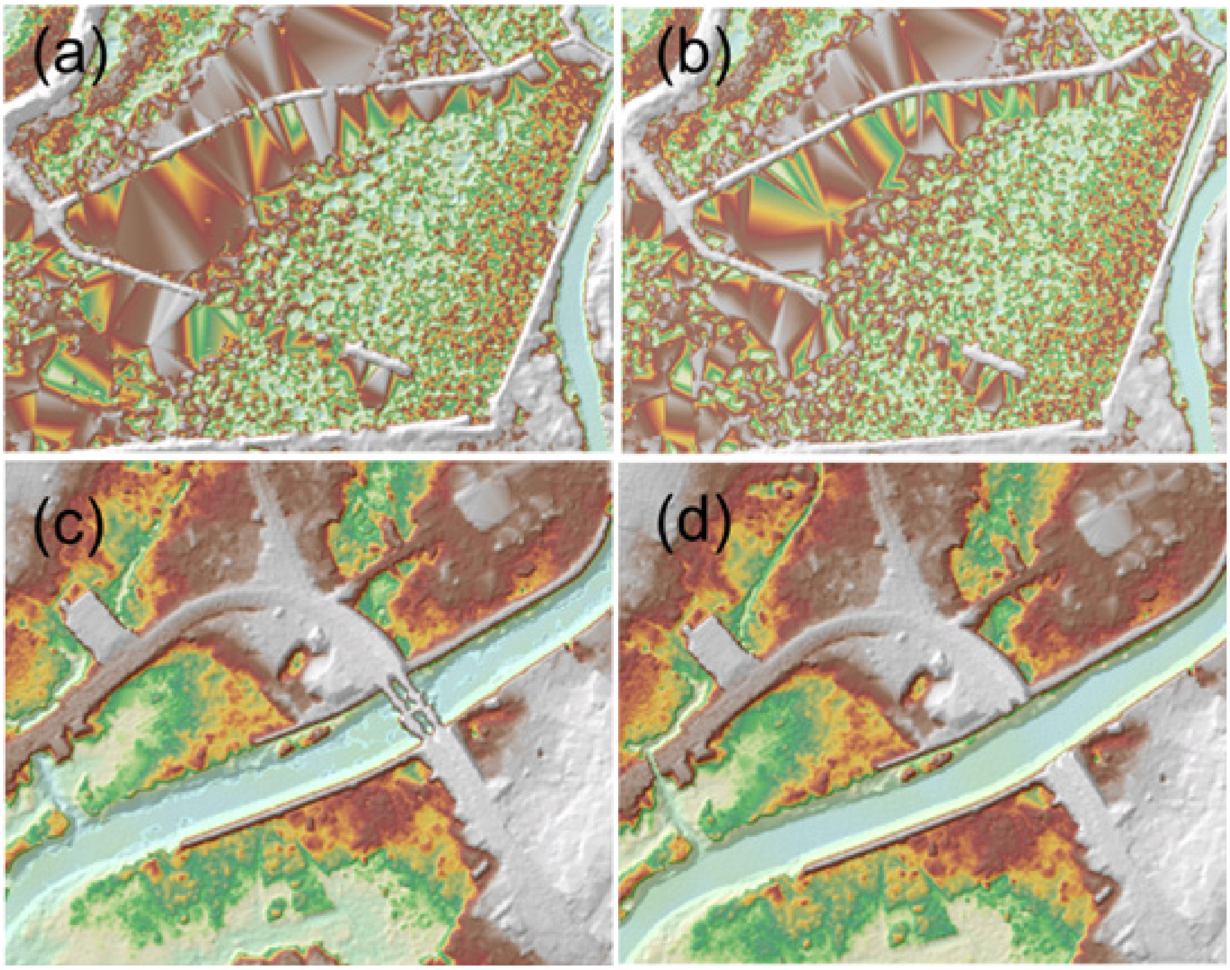


Figure 23. Portions in the DTM of Barotac floodplain – a paddy field before (a) and after (b) data retrieval; bridges before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

The Calibrated DEM of Jalaur was used as the reference block at the start of mosaicking. Table 17 shows the area of each LiDAR block and the shift values applied during mosaicking.

Mosaicked LiDAR DTM for Barotac Floodplain is shown in Figure 24. It can be seen that the entire Barotac Floodplain is 96.9% covered by LiDAR data.

Table 17. Shift Values of each LiDAR Block of Barotac Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Iloilo_Blk37F_ supplement	0.00	0.00	-0.65
Iloilo_Blk37G	0.00	0.00	-0.81
Iloilo_Blk37I	0.00	0.00	-1.13
Iloilo_Blk37I_additional	0.00	0.00	-1.16
Iloilo_Blk37I_ supplement	0.00	0.00	-1.15
Iloilo_Blk37J_ supplement	0.00	0.00	-1.35
Iloilo_Blk37J_additional	0.00	0.00	-0.85
Iloilo_Blk37JK	0.00	0.00	-0.82
Iloilo_Blk37M	0.00	0.00	-1.40
Aklan_Blk38O	-0.21	-0.11	-0.73
CapizAklan_Blk37C	0.00	0.00	-0.82
CapizAklan_Blk37C_ supplement	0.00	0.00	-0.89
Jalaur_Blk6G	0.00	0.00	0.50
Jalaur_Blk6H	0.00	0.00	0.50
Jalaur_Blk6H_additional	0.00	0.00	0.45
Jalaur_Blk6I	0.00	0.00	0.50
Iloilo_reflights_Blk37J	0.00	0.00	0.32
Iloilo_reflights_Blk37P	0.00	0.00	0.23

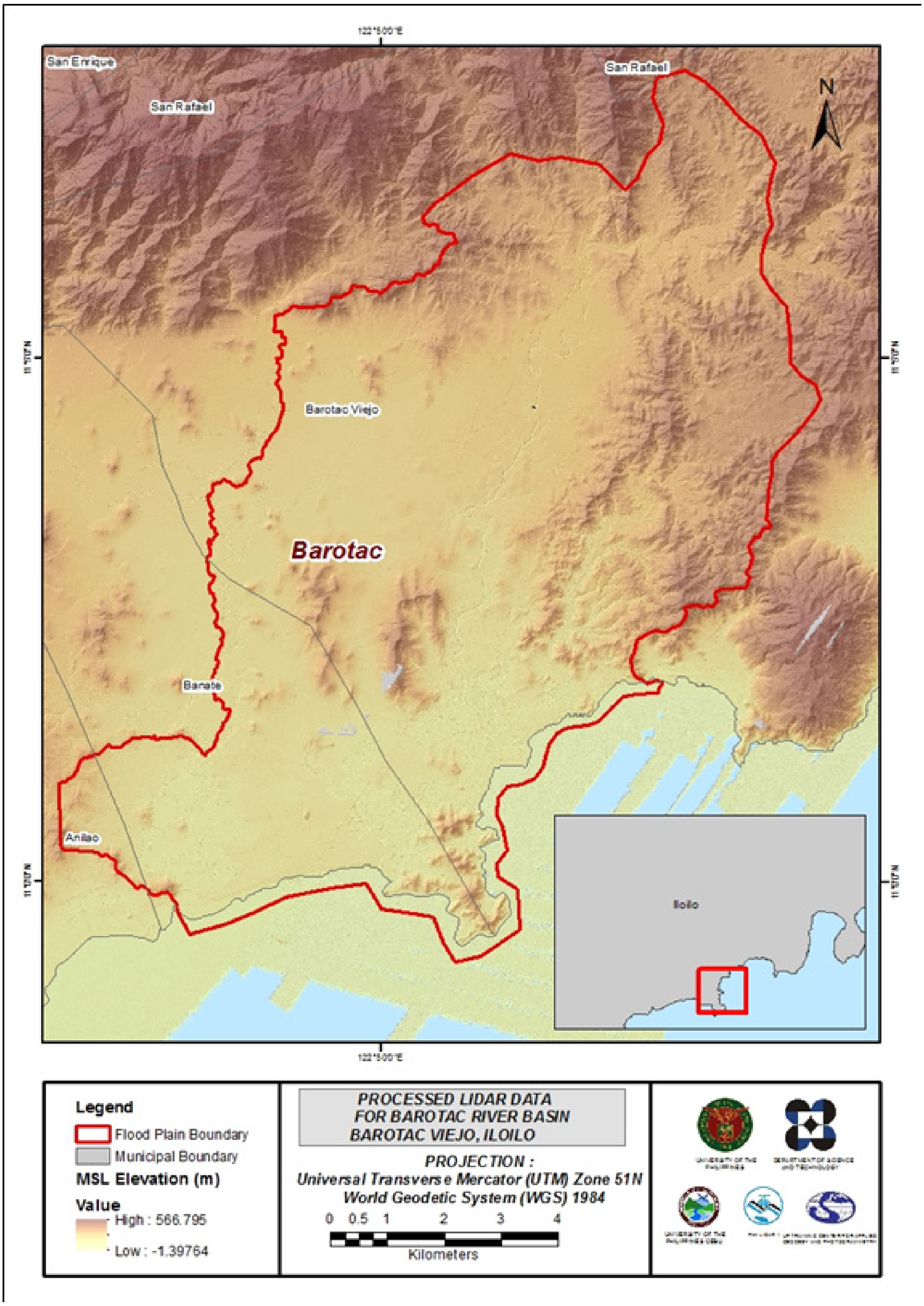


Figure 24. Map of Processed LiDAR Data for Barotac Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Barotac to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 18,528 points were gathered for all the floodplains within the Province of Iloilo wherein the Barotac is located. However, the point dataset was not used for the calibration of the LiDAR data for Barotac because during the mosaicking process, each LiDAR block was referred to the calibrated Jalaur DEM. Therefore, the mosaicked DEM of Barotac 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 26. 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 18 shows the statistical values of the compared elevation values between Jalaur LiDAR data and calibration data. These values were also applicable to the Barotac DEM.

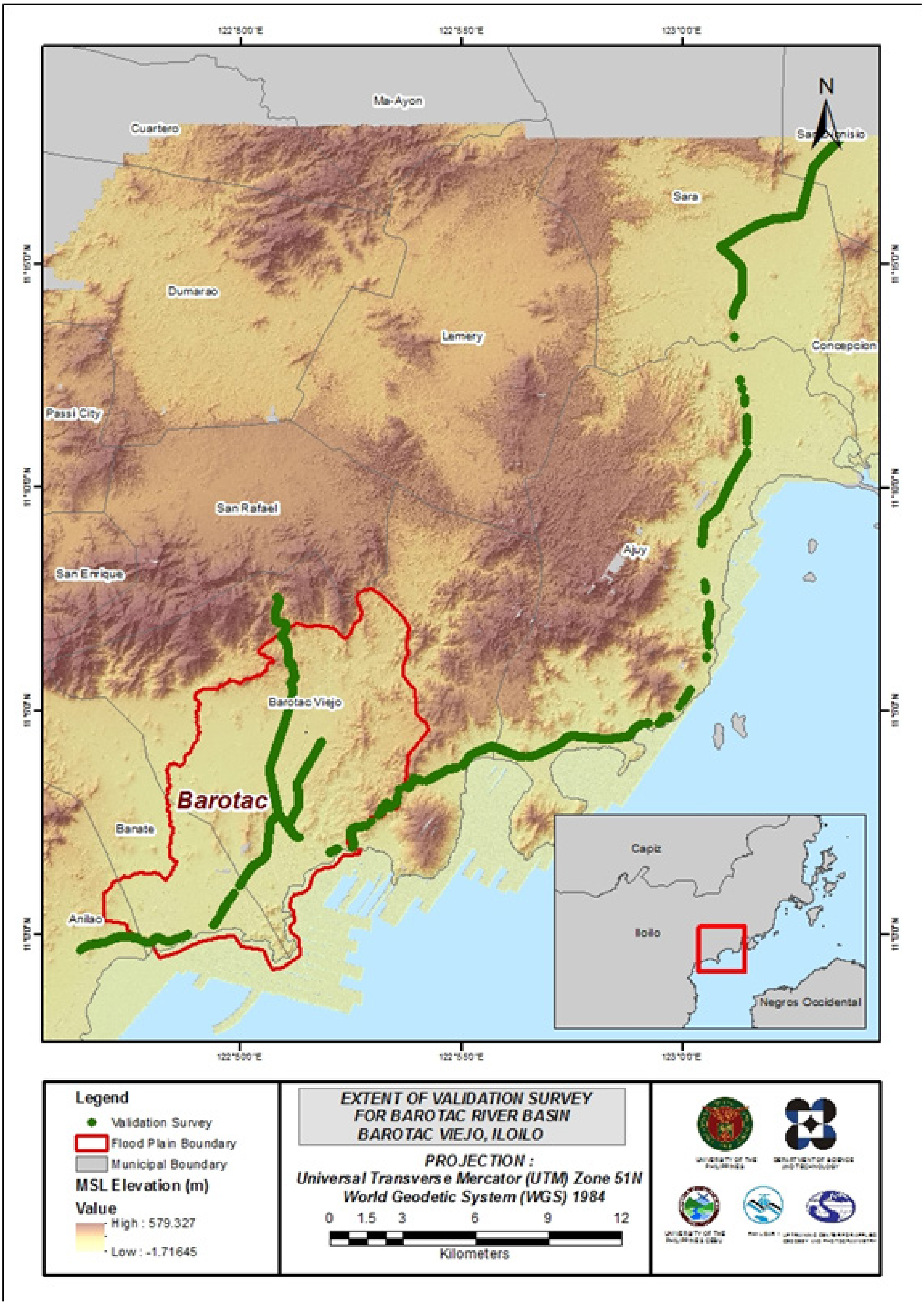


Figure 25. Map of Barotac Floodplain with validation survey points in green

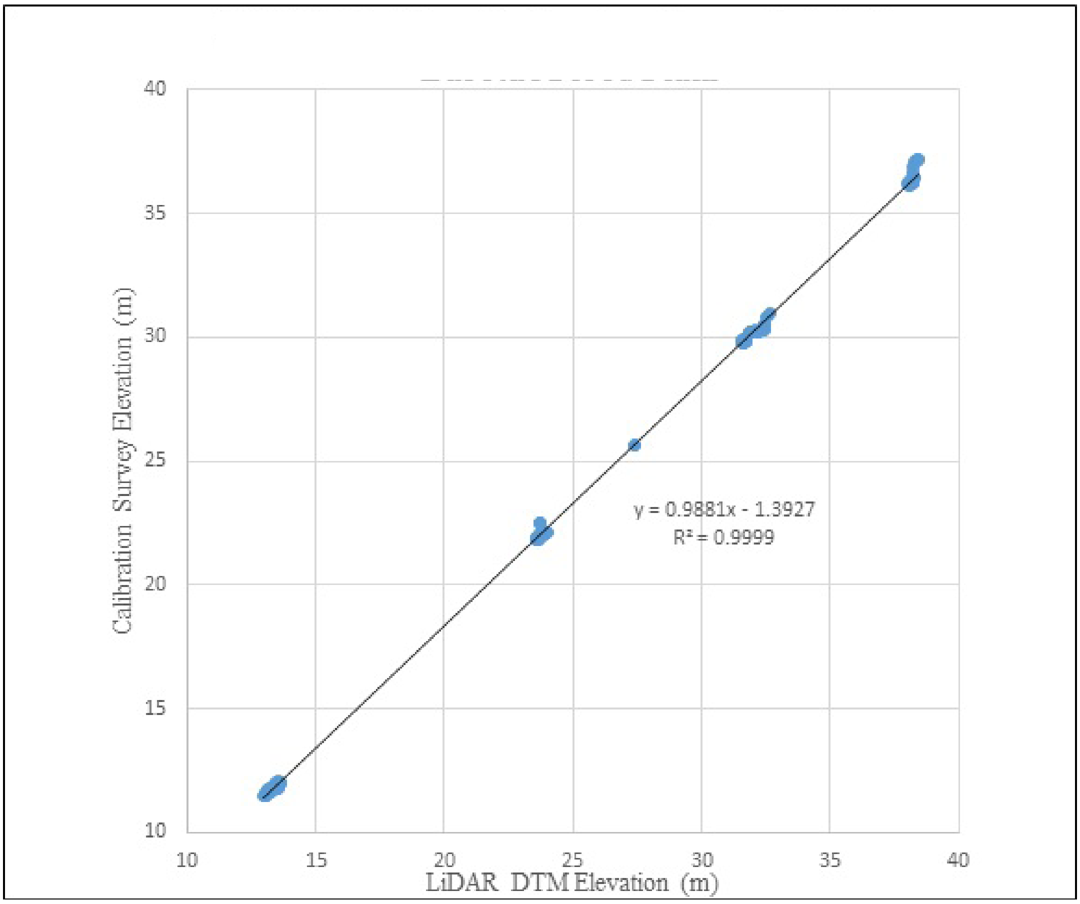


Figure 26. Correlation plot between calibration survey points and LiDAR data

Table 18. 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 7,681 survey points that are within the Barotac flood plain were used for the validation of the calibrated Barotac 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 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.11 meters with a standard deviation of 0.11 meters, as shown in Table 19.

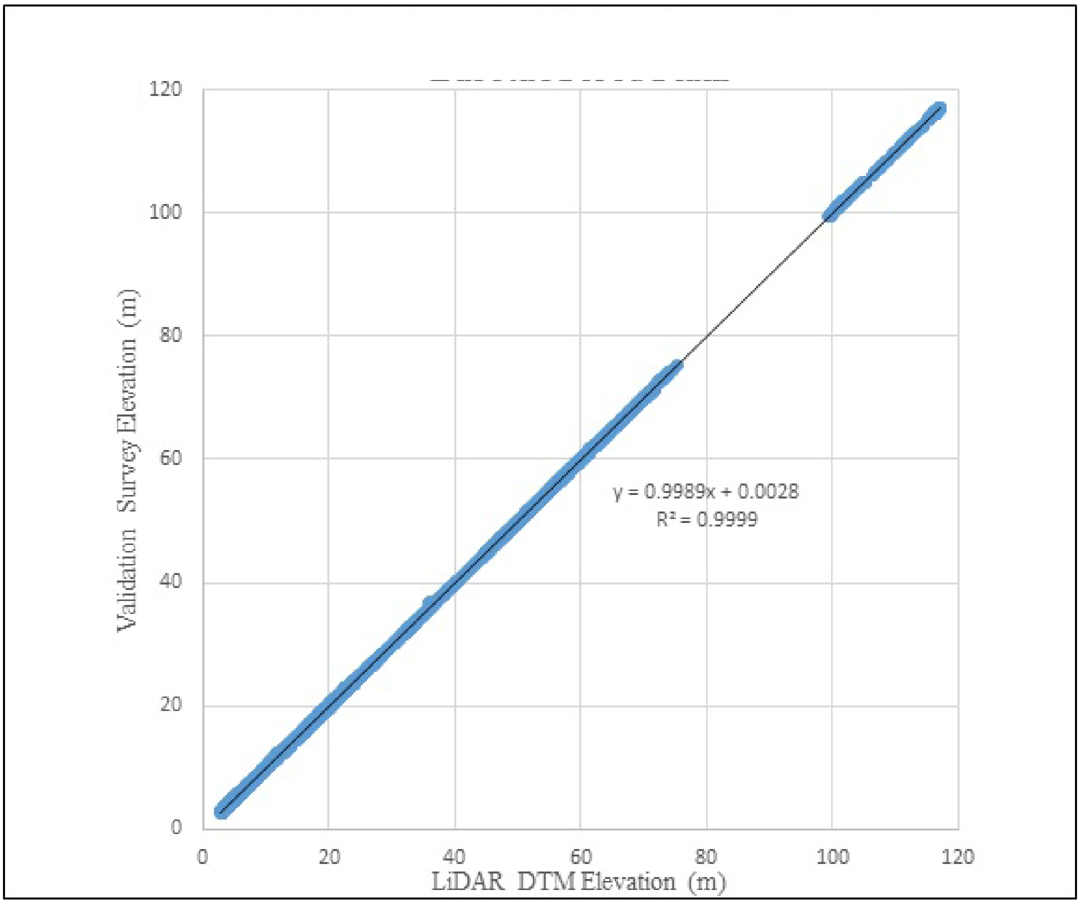


Figure 27. Correlation plot between validation survey points and LiDAR data

Table 19. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.11
Standard Deviation	0.11
Average	-0.02
Minimum	-0.38
Maximum	-0.02

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Barotac with 7674 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 was represented by the computed RMSE value of 0.00003606 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Barotac integrated with the processed LiDAR DEM is shown in Figure 28 .

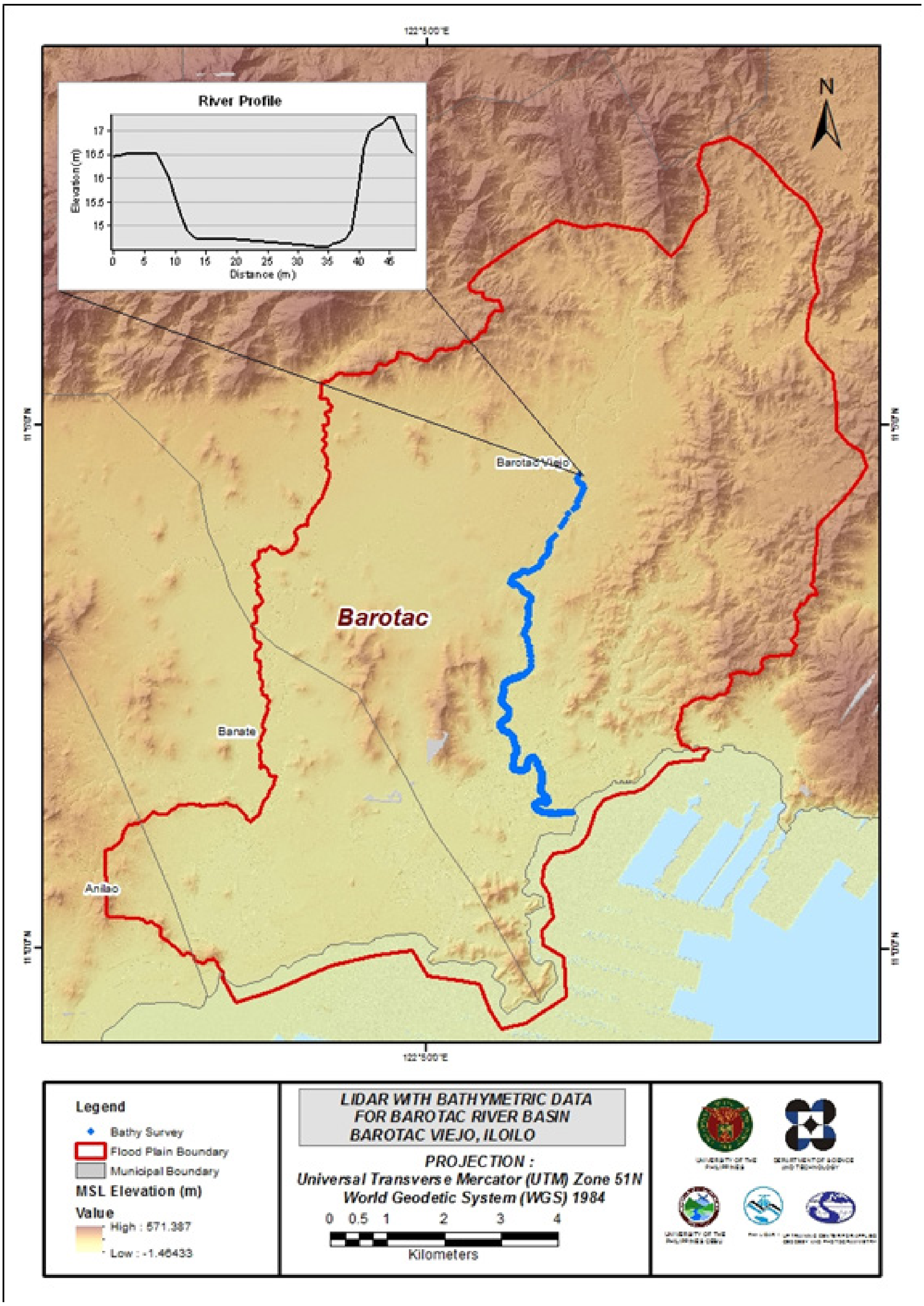


Figure 28. Map of Barotac Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Barotac floodplain, including its 200 m buffer, has a total area of 117.82 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1590 building features, are considered for QC. Figure 29 shows the QC blocks for Barotac floodplain.

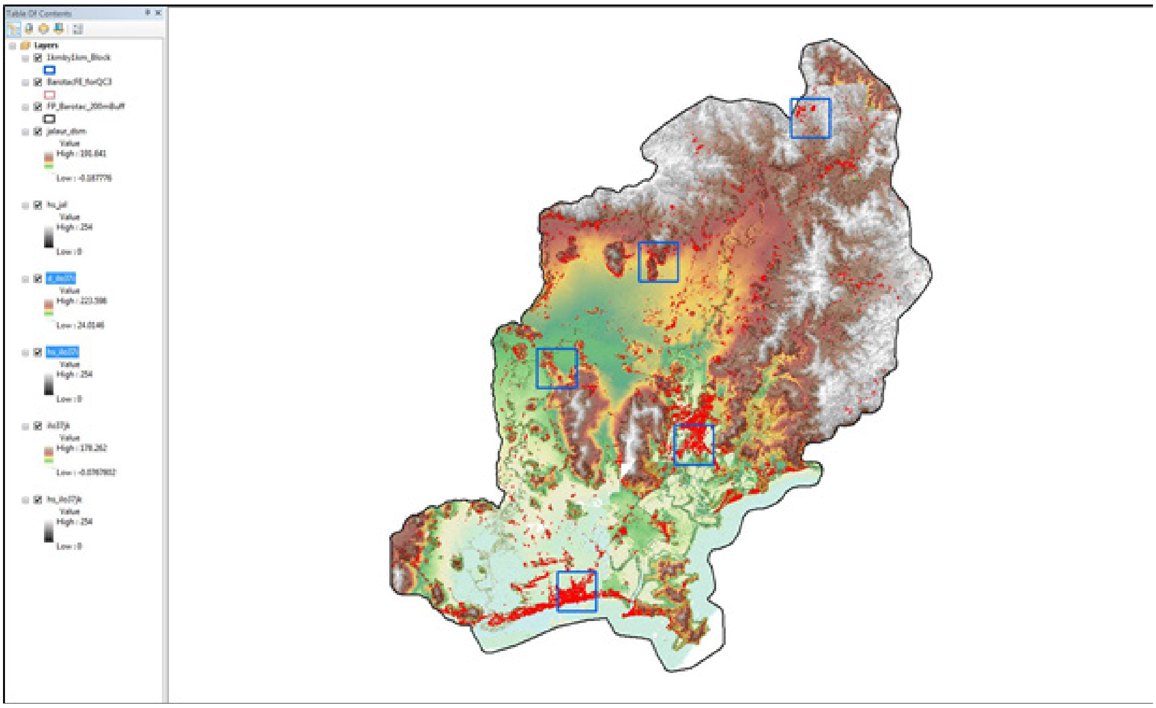


Figure 29. QC blocks for Barotac building features

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

Table 20. Quality Checking Ratings for Barotac Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Barotac	99.37	99.69	93.40	PASSED

3.12.2 Height Extraction

Height extraction was done for 11,434 building features in Barotac floodplain. Of these building features, 97 were filtered out after height extraction, resulting to 11,337 buildings with height attributes. The lowest building height is at 2.0 m, while the highest building is at 10.91 m.

3.12.3Feature 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 included the orthophotographs, Digital Surface Models, existing landmarks, and extracted feature shapefiles. Physical surveys of the barangay were also done by the Phil-LiDAR 1 team after every interview for 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 21 summarizes the number of building features per type. On the other hand, Table 22 shows the total length of each road type, while Table 23 shows the number of water features extracted per type.

Table 21. Building Features Extracted for Barotac Floodplain

Facility Type	No. of Features
Residential	10,754
School	168
Market	17
Agricultural/Agro-Industrial Facilities	108
Medical Institutions	31
Barangay Hall	18
Military Institution	0
Sports Center/Gymnasium/Covered Court	17
Telecommunication Facilities	2
Transport Terminal	0
Warehouse	3
Power Plant/Substation	5
NGO/CSO Offices	3
Police Station	8
Water Supply/Sewerage	1
Religious Institutions	45
Bank	4
Factory	0
Gas Station	10
Fire Station	0
Other Government Offices	33
Other Commercial Establishments	107
Others	3
Total	11,337

Table 22. Total Length of Extracted Roads for Barotac Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/ Municipal Road	Provincial Road	National Road	Others	
Barotac	185.12	16.90	0	112.09	0	314.10

Table 23. Number of Extracted Water Bodies for Barotac Floodplain

Floodplain	Water Body Type						Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	Others	
Barotac	3	387	0	0	71	0	461

A total of 9 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 30 shows the Digital Surface Model (DSM) of Barotac floodplain overlaid with its ground features.

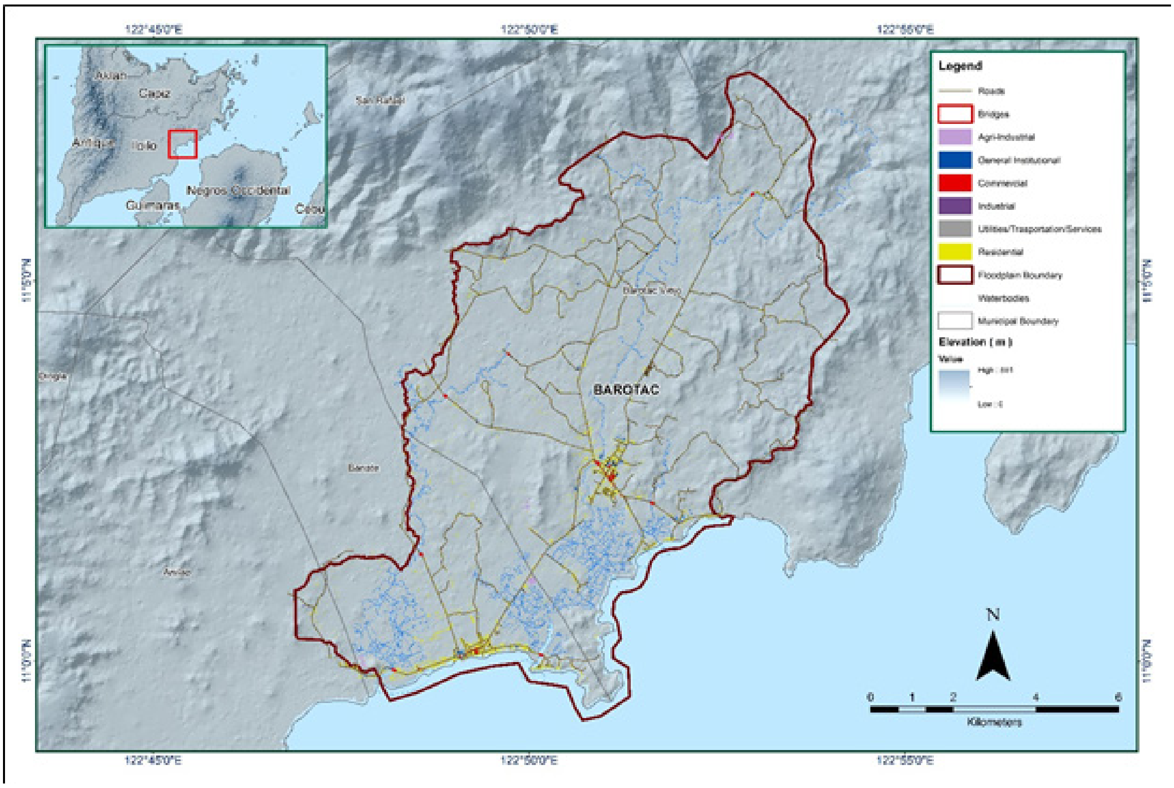


Figure 30. Extracted features for Barotac Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF BAROTAC RIVER BASIN

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in three river basins in Iloilo, including Barotac river basin,on July 22-26, 2014 and October 10 – 21, 2015 with the following scope of work: reconnaissance; cross-section, bridge as-built and water level marking in MSL of Embarcador Bridge;validation point acquisition of about 223.38 km which covers Barotac River Basin; and bathymetric survey from Brgy. San Lucas down to its mouth in Brgy. Sto. Domingo, both in the Municipality of Barotac Viejo, with an estimated length of 8.788 km using Trimble® SPS 882 GNSS PPK survey technique and an OHMEX™ single beam echo sounder. See Figure 31.

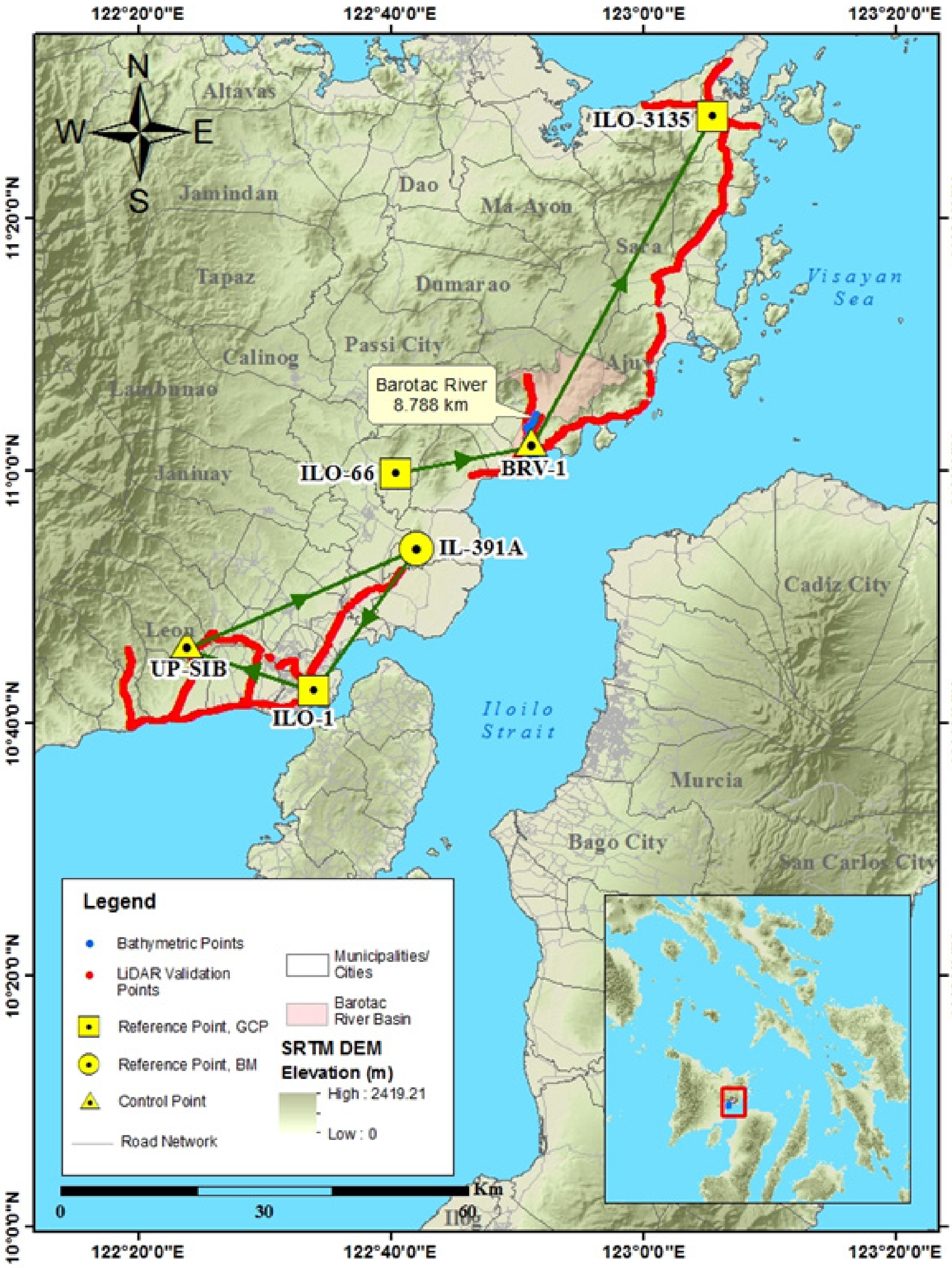


Figure 31. Barotac River Survey Extent

4.2 Control Survey

A GNSS baseline was established on July 22, 2014 occupying the control points ILO-3135, an LMS marker used as GCP in Brgy. Poblacion Sur, Municipality of Balasan.and ILO-66, a 2nd order GCP in Brgy. Camambugan, Municipality of Dingle.

The GNSS network used for Barotac River Basin is composed of only one loop established on October 21, 2015 occupying the reference points; ILO-1, a first order GCP in Brgy. La Paz, Iloilo City and IL-39A, a first order BM in Bry. JT Bretaña in the Municipality of Barotac Nuevo. A control point, UP-SIB, was established along the approach of Sibalom bridge, Brgy. Anonang in the Municipality of Leon.

The summary of reference and control points and their locations is listed in Table 24 while the GNSS network established is illustrated in Figure 32.

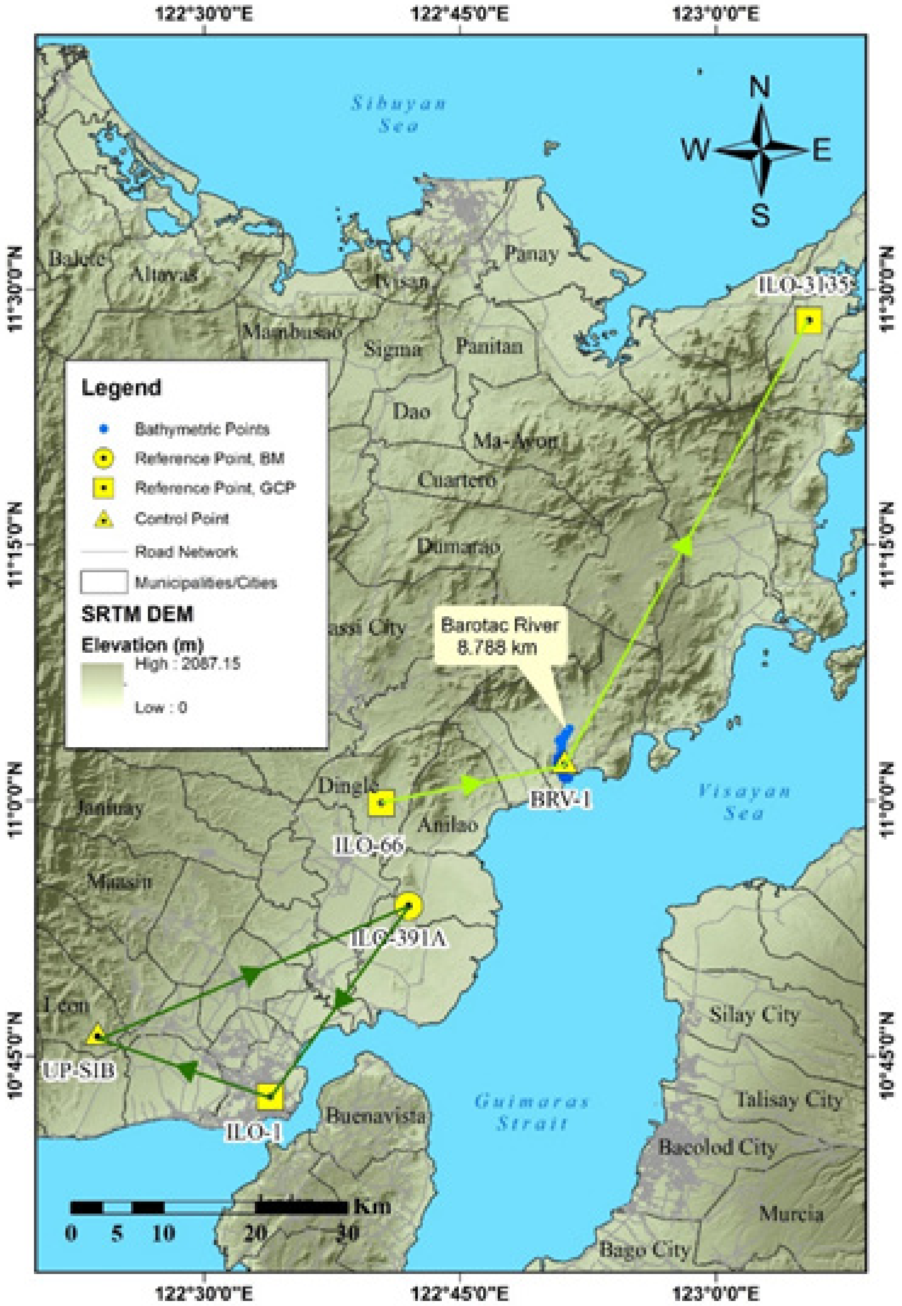


Figure 32. GNSS Network of Barotac River Field Survey.

Table 24. List of Reference and Control points occupied in Barotac River survey
(Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates WGS 84				
		Latitude	Longitude	Ellipsoidal Height, (m)	BM Ortho in MSL (m)	Date Established
Control Survey on July 22-26, 2014						
ILO-66	2nd Order, GCP	10°59'51.7441"N	122°40'23.8767"E	84.815	25.655	2005
ILO-3135	2nd Order, GCP	11°28'10.9134"N	123°05'27.1359"E	67.655	8.0823	2007
BRV-1	UP-established	11°02'19.3210"N	122°51'07.2894"E	74.417	14.337	2014
Control Survey on Oct 10 -21, 2016						
IL-319A	1st order, BM	-	-	70.755	12.159	2012
ILO-1	1st order, GCP	10°42'36.4676"N	122°33'53.5929"E	82.696	-	1989
UP-SIB	UP established	-	-	-	-	2015

The GNSS set-up in the reference points and established control points in Iloilo Survey are shown below on Figure 33 to Figure 38.

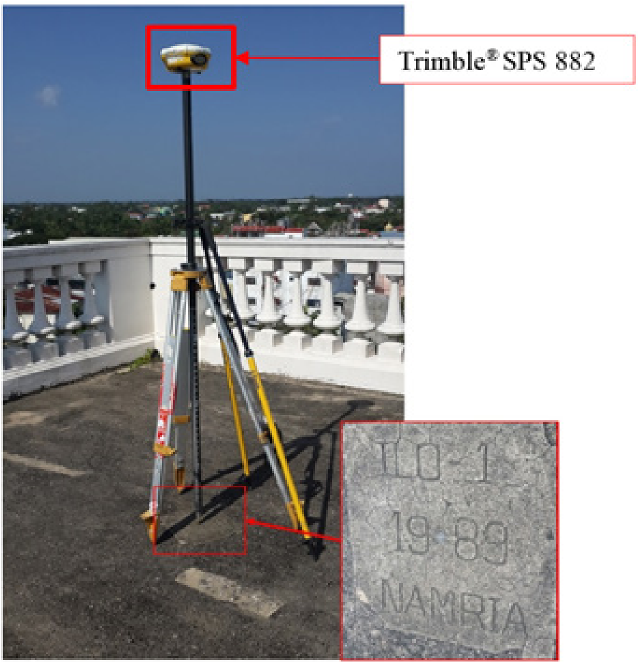


Figure 33. Trimble® SPS 882 set-up at ILO-1 located at the rooftop of St. Clemente Church bell tower, Brgy. La Paz, Iloilo City

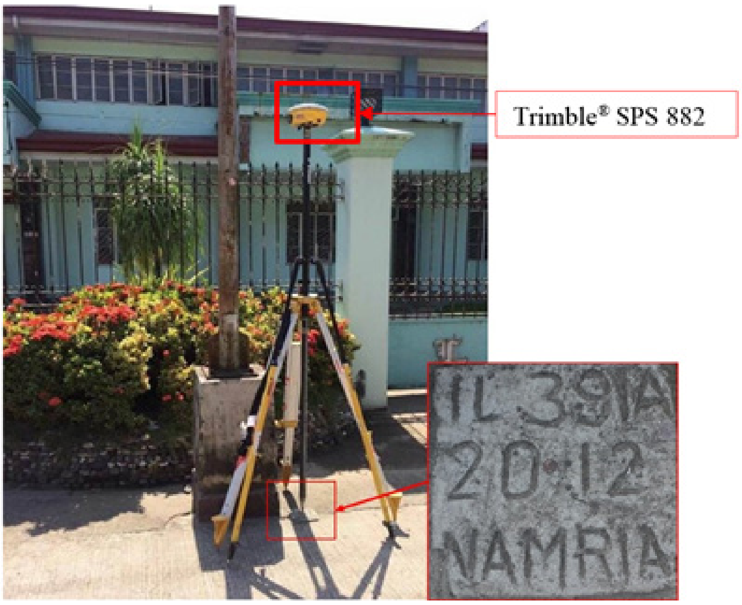


Figure 34. Trimble® SPS 852 set-up at IL-39A located in Brgy. JT Bretaña, Municipality of Barotac Nuevo, Iloilo

Figure 35. Trimble® SPS 882 setup at UP-SIB located at Sibalom Bridge, Brgy. Anonang, Leon, Iloilo

Figure 36. Trimble® SPS 852 setup at BRV-1 located in the rooftop of Hollywood Star Inn, Brgy. Poblacion, Municipality of Barotac Viejo, Iloilo

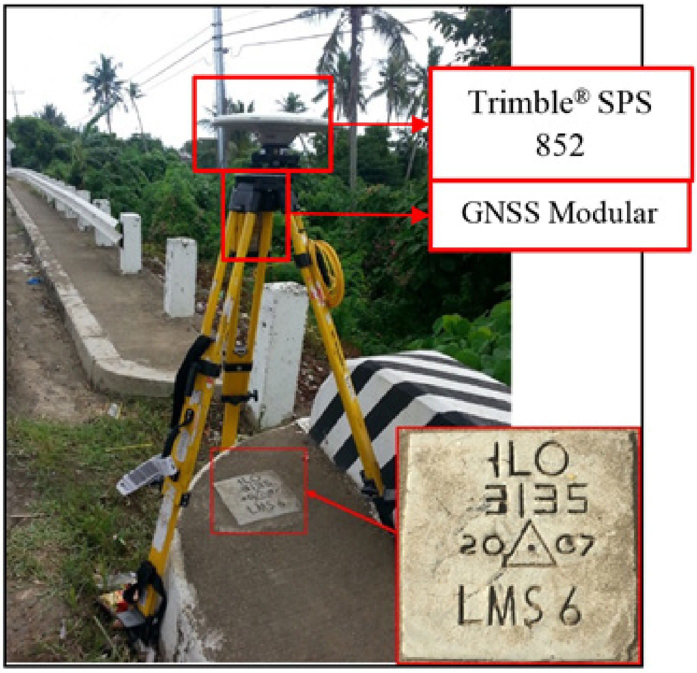


Figure 37. Trimble® SPS 852 setup at ILO-3135 located in Balasan Bridge, Brgy. Poblacion Sur, Municipality of Balasan, Iloilo

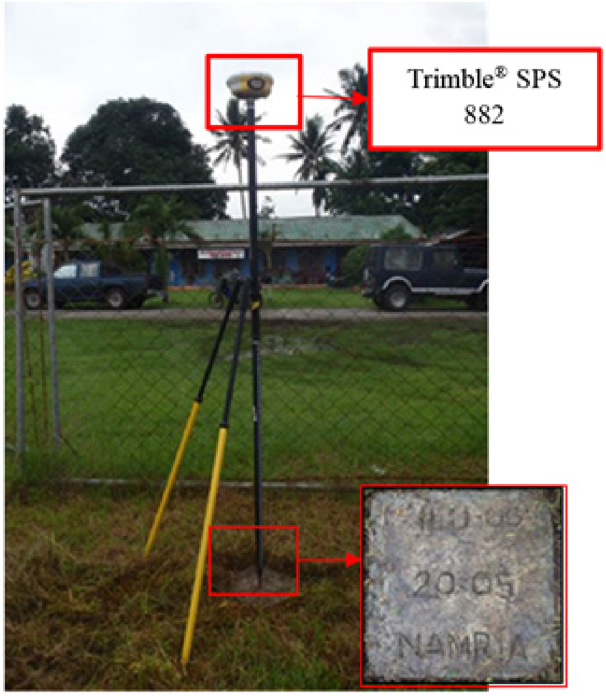


Figure 38. Trimble® SPS 882 setup at ILO-66, located inside Dingle Elementary School, Brgy. Camambugan, Municipality of Dingle, Iloilo

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 Barotac River Basin is summarized in Table 25 generated by TBC software.

Table 25. Baseline Processing Report for Barotac River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
UP-SIB --- ILO-1	10-21-2015	Fixed	0.004	0.020	290°35'49"	19718.694	29.558
ILO-1 --- IL-39A	10-21-2015	Fixed	0.007	0.042	35°35'00"	25376.998	-11.945
UP-SIB --- IL-39A	10-21-2015	Fixed	0.008	0.008	67°33'28"	35939.016	-41.499

As shown in Table 25, a total of four (4) baselines were processed with reference point ILO-1 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates Table 27of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation form:

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

Where:

x^e is the Easting Error,
y^e is the Northing Error, and
z^e is the Elevation Error

for each control point. See the Network Adjustment Report in the next page for

The control point ILO-1 was held fixed during the processing of the control point as presented in Table 26. Through these reference points, the coordinates of the unknown control points was computed.

Table 26. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
IL391A	Grid				Fixed
ILO1	Global	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 27. The fixed control point ILO-1 has no values for standard errors.

Table 27. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
(Meter)	467210.564	0.008	1204571.737	0.009	12.159	?	e
ILO1	452420.308	?	1183962.237	?	24.280	0.067	LL
UPSIB	433978.543	0.006	1190922.753	0.005	55.063	0.069	

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

a. ILO-1
- horizontal accuracy = fixed
- vertical accuracy = 6.7 < 10 cm

b. IL-39A
- horizontal accuracy = $\sqrt{((0.8)^2 + (0.9)^2}$
  = $\sqrt{(0.64 + 0.81)}$
  = 1.20 cm < 20 cm
- vertical accuracy = fixed

c. UP-SIB
- horizontal accuracy = $\sqrt{((0.6)^2 + (0.5)^2}$
  = $\sqrt{(0.36 + 0.25)}$
  = 0.78 cm < 20 cm
- vertical accuracy = 6.9 < 10 cm

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

Table 28. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
L391A	N10°53'48.05371"	E122°41'59.84243"	70.755	?	e
ILO1	N10°42'36.46758"	E122°33'53.59289"	82.696	0.067	LL
UPSIB	N10°46'22.07056"	E122°23'46.02755"	112.253	0.069	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 28. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 28.

Table 29. Reference and Control points used in Balantian River survey (Source: NAMRIA and 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 22-26, 2014							
ILO-66	2nd Order	10°59'51.7441"N	122d40'23.8767"E	84.815	1215745.274	464309.479	25.655
ILO-3135	2nd Order	11°28'10.9134"N	123d05'27.1359"E	67.655	1267916.553	509911.061	8.0823
BRV-1	UP Established	11°02'19.3210"N	122°51'07.2894"E	74.417	1220262.792	483836.720	14.337
Control Survey on Oct 10 -21, 2016							
IL-319A	1st Order, BM	10°53'48.05371"	122°41'59.84243"	70.755	1204572	467210.6	12.159
ILO-1	1st Order, GCP	10°42'36.46758"	122°33'53.59289"	82.696	1183962	452420.3	24.28
UP-SIB	UP Established	10°46'22.07056"	122°23'46.02755"	112.253	1190923	433978.5	55.063

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

Cross-section and as-built survey were conducted on July 22-26, 2014 along the downstream side of the old and new Embarcador Bridges both located in Brgy. Poblacion, Municipality of Barotac Viejo using Trimble® SPS 882 GNSS PPK surveytechnique as shown in Figure 39.

Figure 39. Cross section survey along the downstream side of New Embarcador Bridge, Municipality of Barotac Viejo

A total of twenty-five (25) points with corresponding length of 240.40 meters, and fifteen (15) points with approximate length of 200.9 meters, were gathered from the survey of the Old and New Embarcador Bridge, respectively, using the control point BRV-1 as base station. The cross-section diagrams, bridge data forms for both bridge, and location map are shown in Figure 40 to Figure 44.

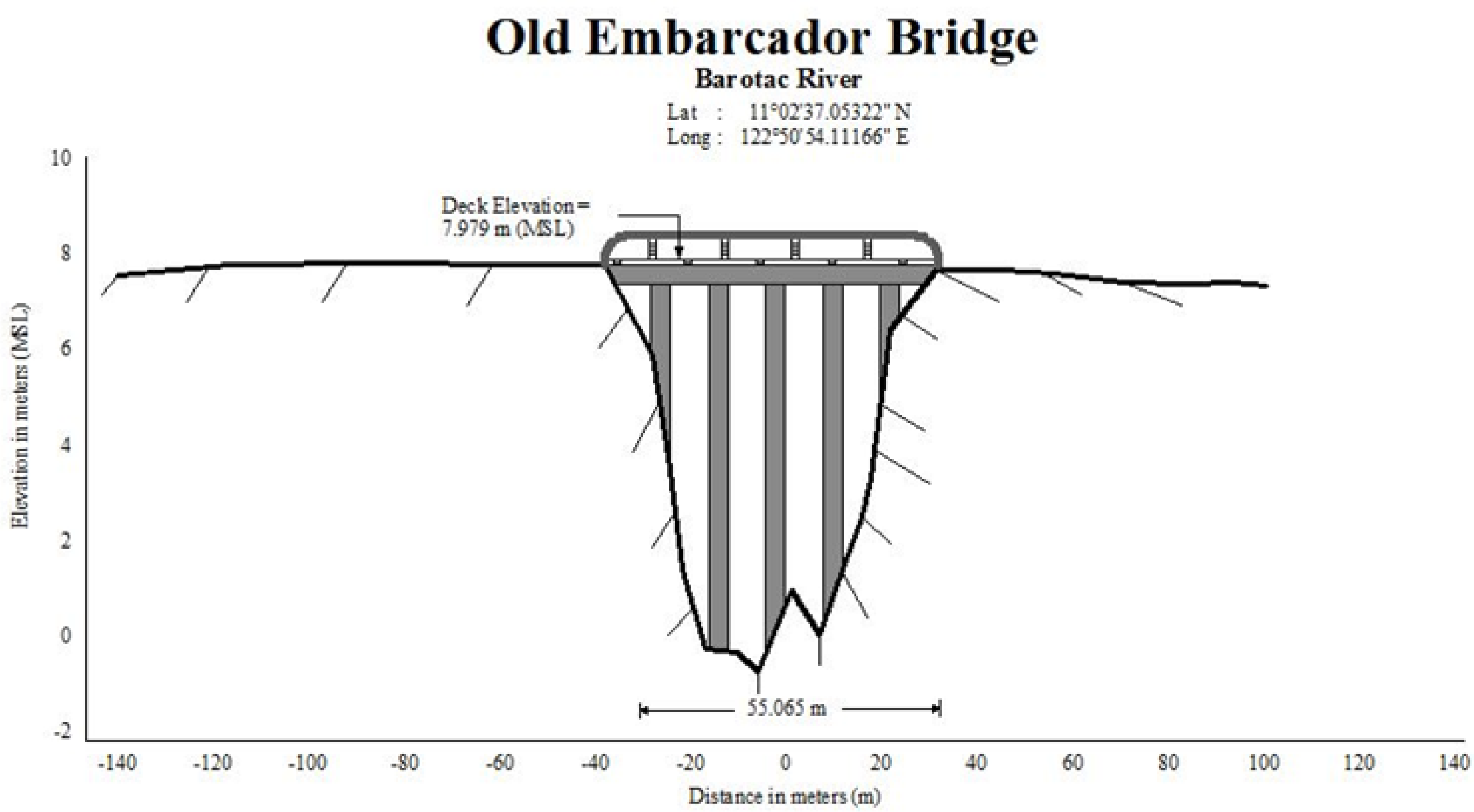


Figure 40. Old Embarcador Bridge cross section diagram

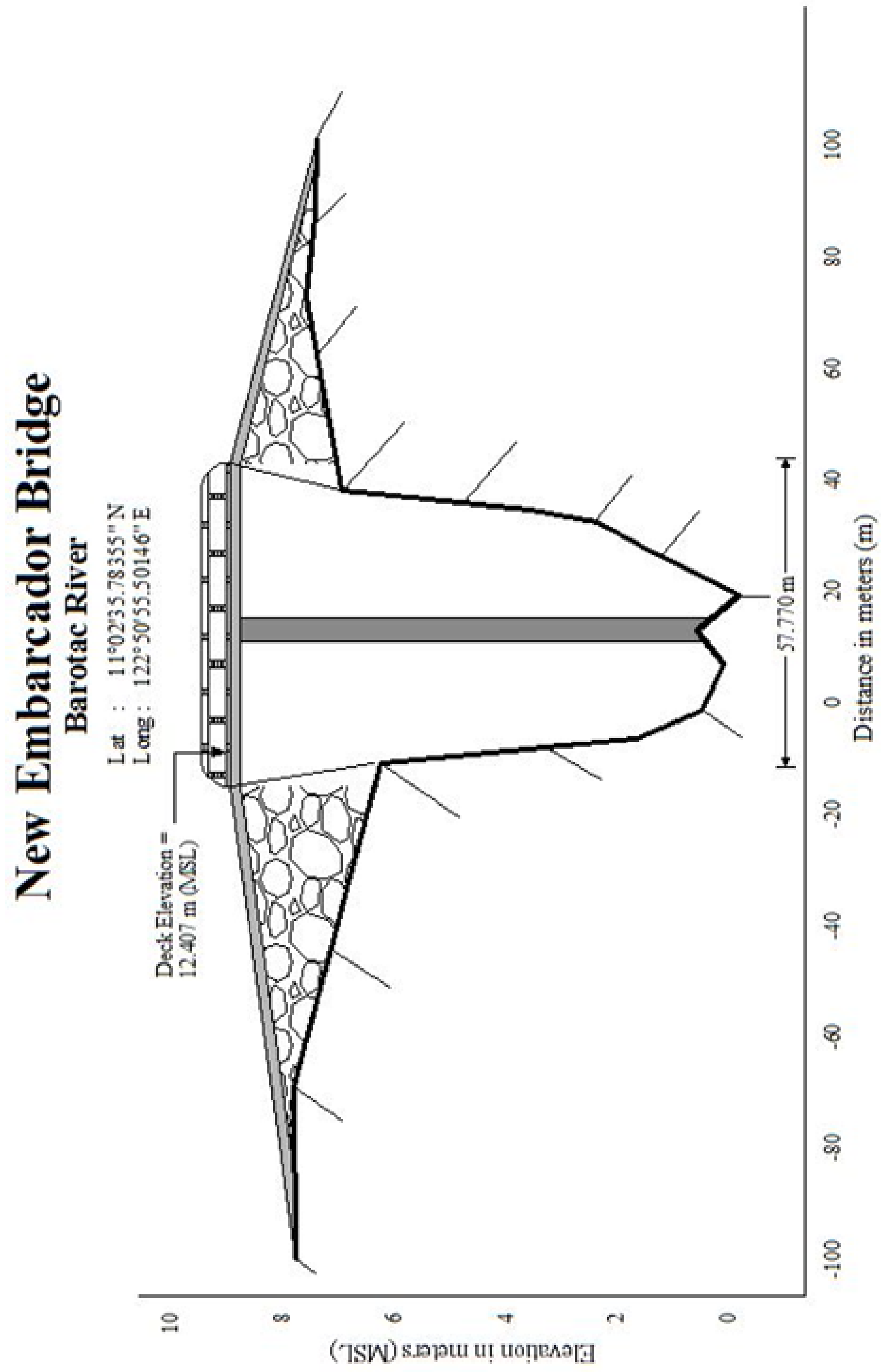
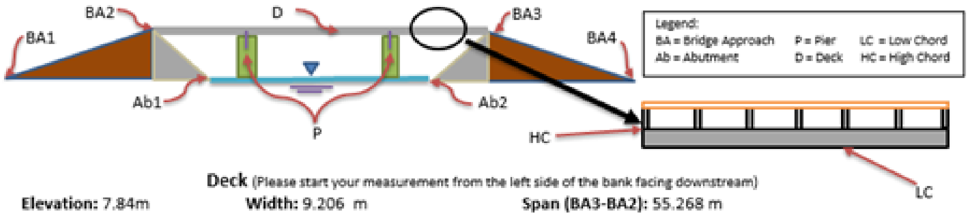


Figure 41. New Embarcador Bridge cross section diagram

Bridge Data Form

Bridge Name: Embarcador Bridge (OLD)	**Date:** July 25, 2014
River Name: Barotac River	**Time:** 11: 30 AM
Location (Brgy, City, Region): San Lucas Barotac Viejo, Iloilo	
Survey Team: DVBC Iloilo Survey Team	
Flow condition: low normal high	**Weather Condition:** fair rainy
Latitude: 11d2'37.05322"N **Longitude:** 122d50'54.1116" E	



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

Elevation: 7.84m **Width:** 9.206 m **Span (BA3-BA2):** 55.268 m

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 1	7.931	9.239
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	5.323 m	**BA3**	306.625 m	7.862 m
BA2	251.560 m	7.979 m	**BA4**	440.319 m	5.530 m

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

	Station (Distance from BA1)	Elevation
Ab1	259.767 m	1.362 m
Ab2	297.523 m	2.463 m

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

Shape: rectangle **Number of Piers:** 5 **Height of column footing:** _______________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	255.250	7.931	
Pier 2	267.318	7.909	
Pier 3	279.140	7.857	
Pier 4	291.176	7.845	
Pier 5	303.210	7.893	
Pier 6			

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

Figure 42. Old Embarcador Bridge Data Form

Bridge Data Form

Bridge Name: Embarcador Bridge (NEW) **Date:** July 25, 2014

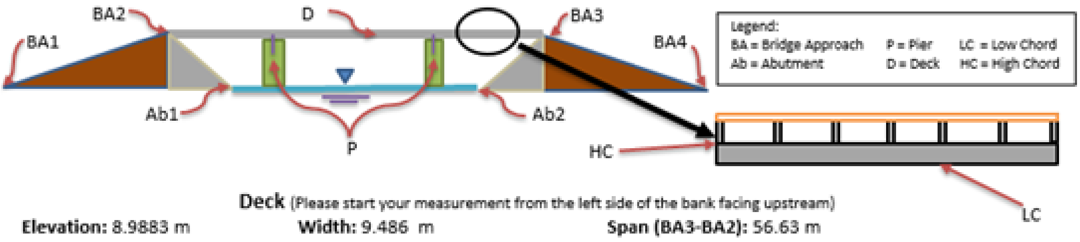
River Name: Barotac River **Time:** 12:00 PM

Location (Brgy, City,Region): San Lucas Barotac Viejo, Iloilo

Survey Team: DVBC Iloilo Survey Team

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

Latitude: 11d2'35.78355"N **Longitude:** 122d50'55.50146" E



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

Elevation: 8.9883 m **Width:** 9.486 m **Span (BA3-BA2):** 56.63 m

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 1	9.2013 m	7.3593 m
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	5.323 m	BA3	306.119 m	9.098 m
BA2	249.831 m	9.088 m	BA4	440.319 m	5.530 m

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

	Station (Distance from BA1)	Elevation
Ab1	141.0401 m	3.5513 m
Ab2	182.0673 m	1.6403 m

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

Shape: cylinder **Number of Piers:** 1 **Height of column footing:** _______________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	162.2017	9.201 m	
Pier 2			
Pier 3			
Pier 4			
Pier 5			
Pier 6			

Figure 43. New Embarcador Bridge Data Form

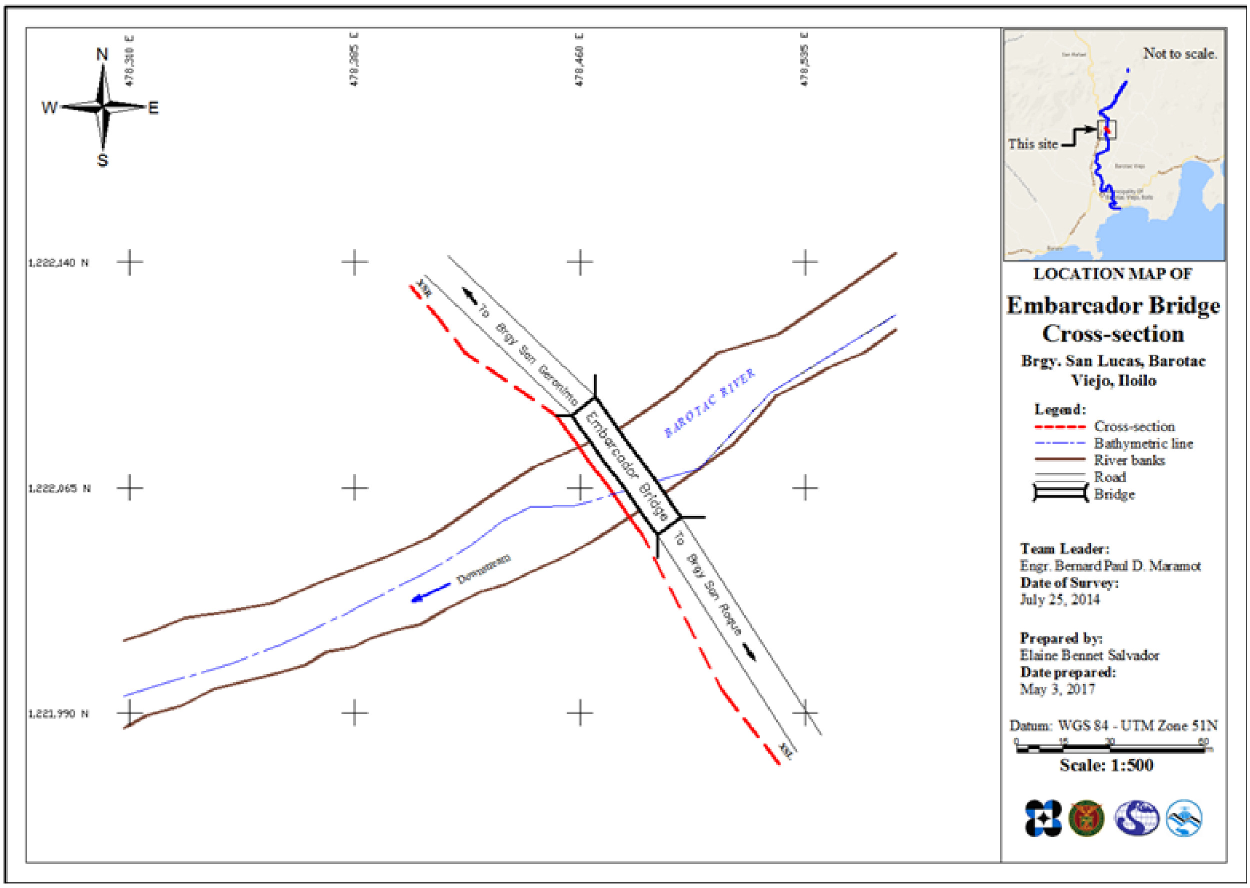


Figure 44. Location map of Embarcador Bridge cross section survey

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 11-14, and 17-19, 2015 using a survey-grade GNSS rover receiver, Trimble® SPS 882, mounted on a pole which was attached in front of a vehicle as shown in Figure 45. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height of 2.53 m was 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 ILO-3135, BRV-1 and UP-SIB occupied as the GNSS base stations all throughout the conduct of the survey.

Figure 45. (A) Set-up of Trimble® SPS 882 attached to a vehicle and (B) Setting up of GNSS base station at BRV-1

The validation points acquisition survey for the Barotac River Basin traversed twenty (20) municipalities and Iloilo City in the Province of Iloilo. The route of the survey aimed to perpendicularly traverse LiDAR flight strips for the basin. A total of 26,620 points with an approximate length of 223.38 km was acquired for the validation points acquisition survey as shown in the map in Figure 46.

Figure 46. Validation Points Acquisition Survey along Iloilo Province

4.7 River Bathymetric Survey

Bathymetric survey of Barotac River was conducted on October 14, 2015 using OHMEXTM and a Trimble® SPS 882 GNSS rover receiver attached to a pole on the side of a boat as shown in Figure 47. The survey began from the Embarcador Bridge in Brgy. Poblacion with coordinates 11°02'36.12343"122°50'53.87001"and ended in the mouth of the river, Brgy. Santo Domingo, with coordinates 11°01'17.43254"122°51'24.35123" both in Municipality of Barotac Viejo.

Figure 47. Bathymetric survey using OHMEXTM echo sounder

Manual bathymetric survey was conducted on October 14, 15 and 16, 2015 using Trimble® SPS 882 GNSS PPK technique as shown in Figure 48. The survey began at the upstream portion of the river in Brgy. San Lucas with coordinates 11°04'31.34403"122°51'28.35973" traversed by foot down to the starting point of bathymetric survey using a boat in Brgy. Poblacion, both in Municipality of Barotac Viejo. The control point BRV-1 was used as GNSS base for the whole bathymetric survey.

Figure 48. Manual Bathymetry using PPK Survey

The processed data were generated into a map using GIS and processed further using CAD for plotting the centerline of the river as illustrated in Figure 49 and Figure 50, respectively. A total 7,674 points with a corresponding length of 8.788 km was acquired for the bathymetric survey from its upstream in Brgy. San Lucas down to its mouth in Brgy. Sto. Domingo. There was an elevation change of about 19.1 m within the 8 km of the 8.788 km acquired data with lowest elevation of -2.9 m located in Brgy. Santo Domingo as illustrated in Figure 50.

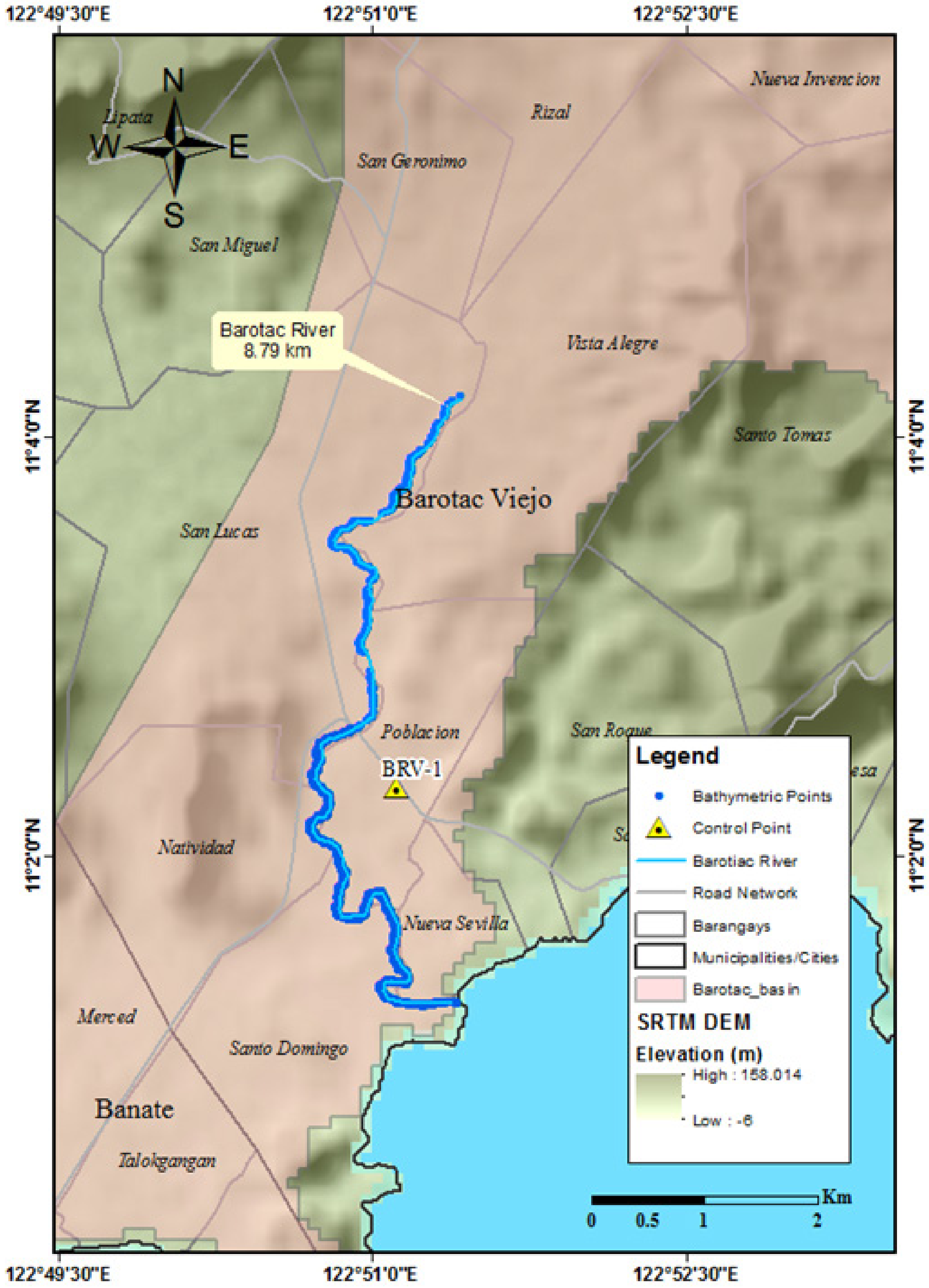


Figure 49. Bathymetric points gathered from Barotac River

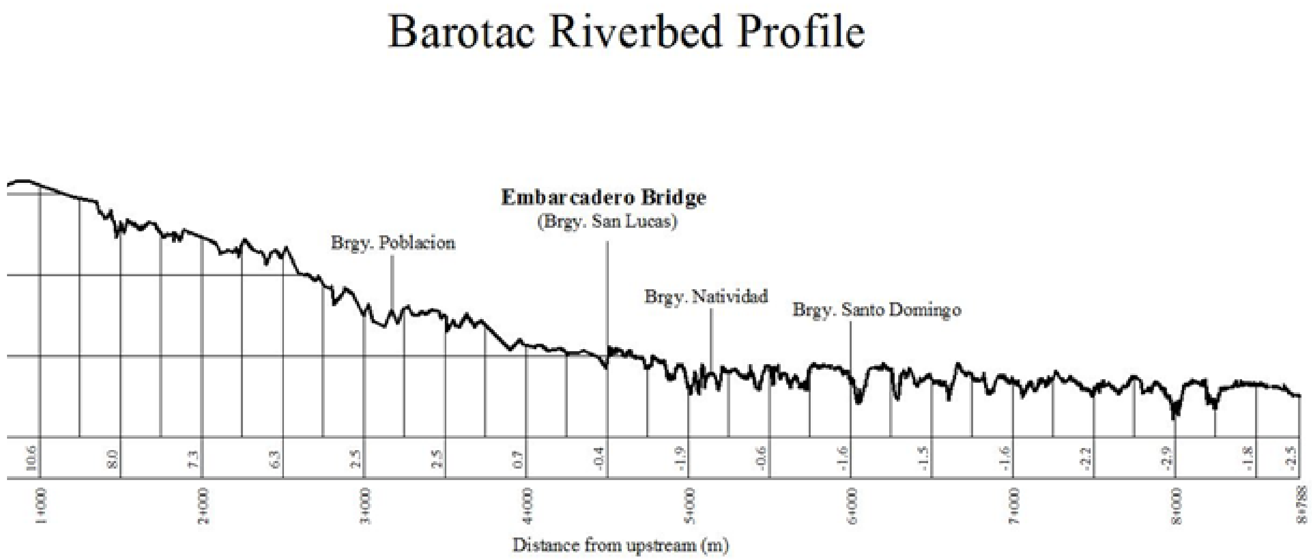


Figure 50. BarotacRiverbed Profile from Brgy. San Lucas, Municipality of Barotac Viejo down to Brgy. Santo Domingo, Municipality of Barotac Viejo

CHAPTER 5 : FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Narvin Clyd Tan, and Marvin Arias

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data that affect the hydrologic cycle of the Barotac river basin were monitored, collected, and analyzed. These include the rainfall, water level, and flow over a certain period of time.

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. Nueva Invencion, Barotac Viejo, Iloilo (Figure 51). The precipitation data collection started from July 27, 2016 at 7:00AM to July 27, 2016 at 12:00 with a recording interval of 5 minutes.

The total precipitation for this event in Brgy. Nueva Invencion ARG was 15 mm, with a peak rainfall of 2mm. on July 27, 2016 at 9:50in the morning. The lag time between the peak rainfall and discharge was 3 hours and 15 minutes.

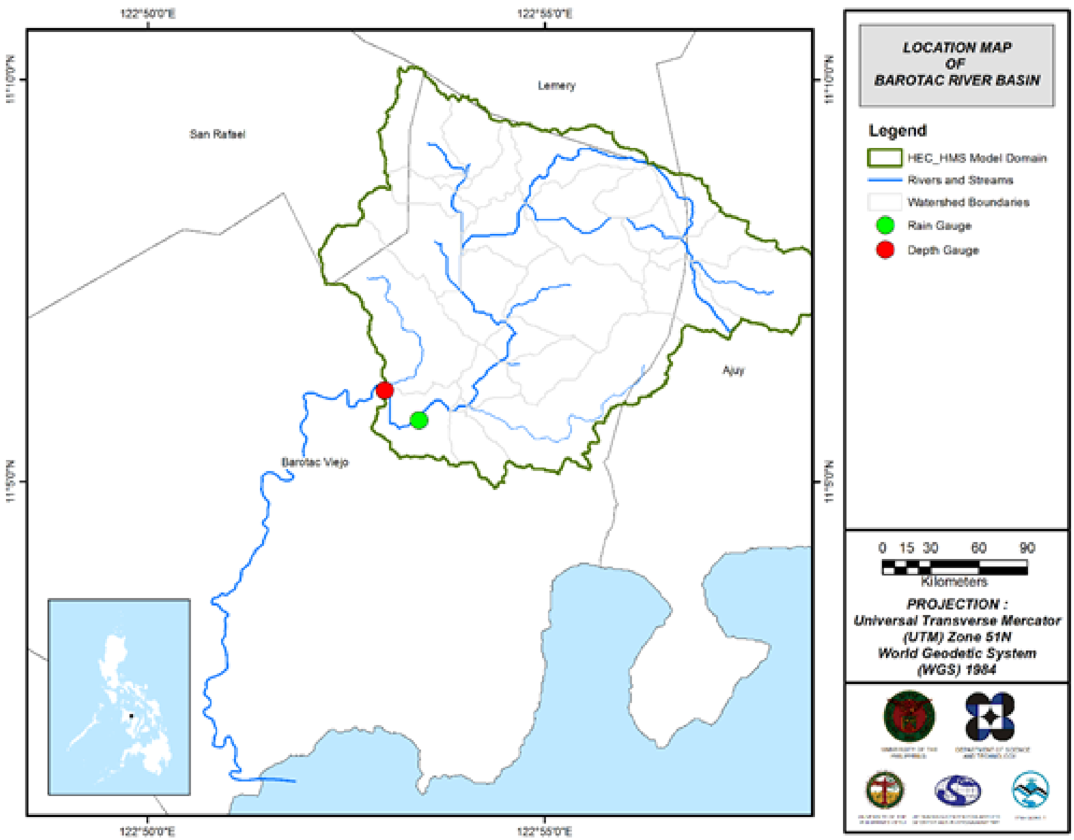


Figure 51. The location map of Barotac HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 52) at Perfecto Balajadia Bridge, Barotac Viejo, Iloilo (11° 6’7.72”N, 122°52’57.21”E) to establish the relationship between the observed water levels (H) at Perfecto Balajadia Bridge and outflow (Q) of the watershed at this location.
For Perfecto Balajadia Bridge, the rating curve is expressed as Q = 3E-156e12.277xas shown in Figure 53.

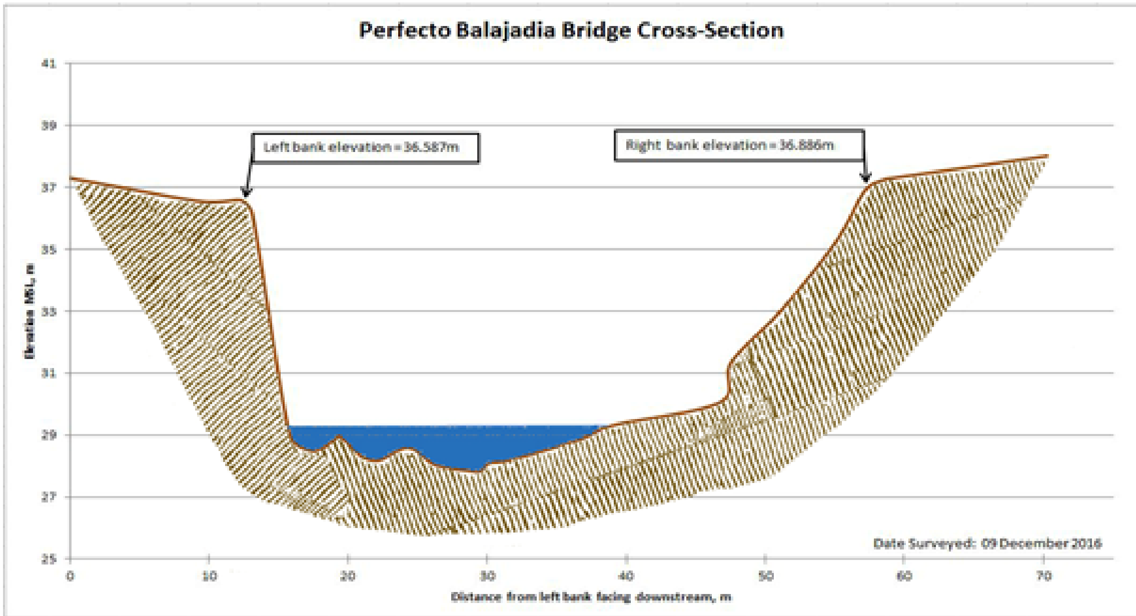


Figure 52. The cross-Section Plot of Perfecto Balajadia Bridge

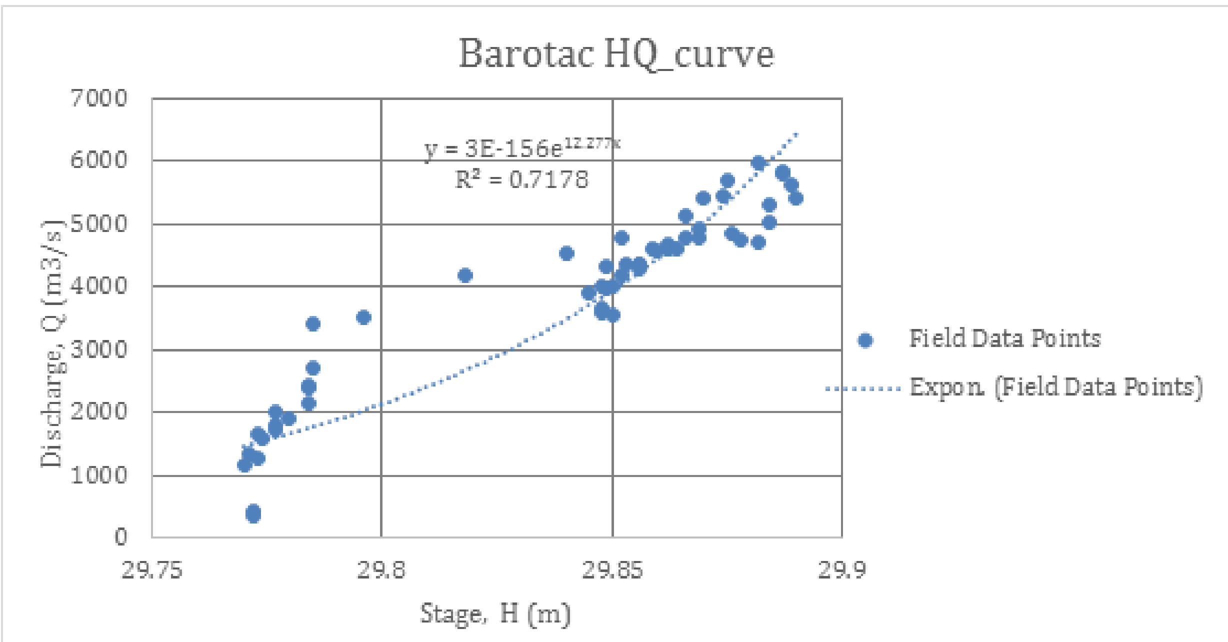


Figure 53. The Rating Curve of the Perfecto BalajadiaBridge in Nueva Invencion, Barotac Viejo

This rating curve equation was used to compute the river outflow at Perfecto Balajadia Bridge for the calibration of the HEC-HMS model shown in Figure 54. The total rainfall for this event is 15mm and the peak discharge is 0.14289m3 at 1:05 PM, July 27, 2016.

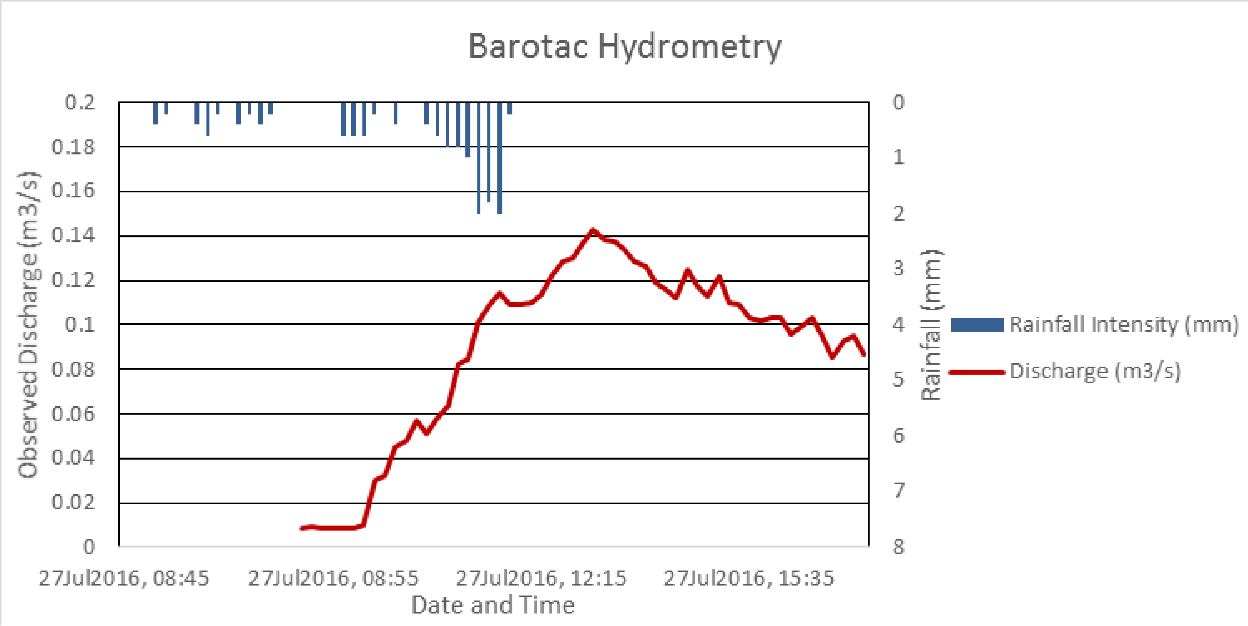


Figure 54. Rainfall and outflow data at Barotac used for modeling

5.2 RIDF Station

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

Table 30. RIDF values for Iloilo Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
5	28.7	39.4	48	59.4	74.9	90	114.7	131.7	165.2
10	33.9	45.6	55.6	68.1	85	103.6	133.6	155.4	198.9
25	40.5	53.5	65.3	79.2	97.6	120.8	157.6	185.3	241.5
50	45.4	59.4	72.4	87.3	107	133.5	175.3	207.4	273.1
100	50.3	65.2	79.5	95.4	116.4	146.2	193	229.4	304.5

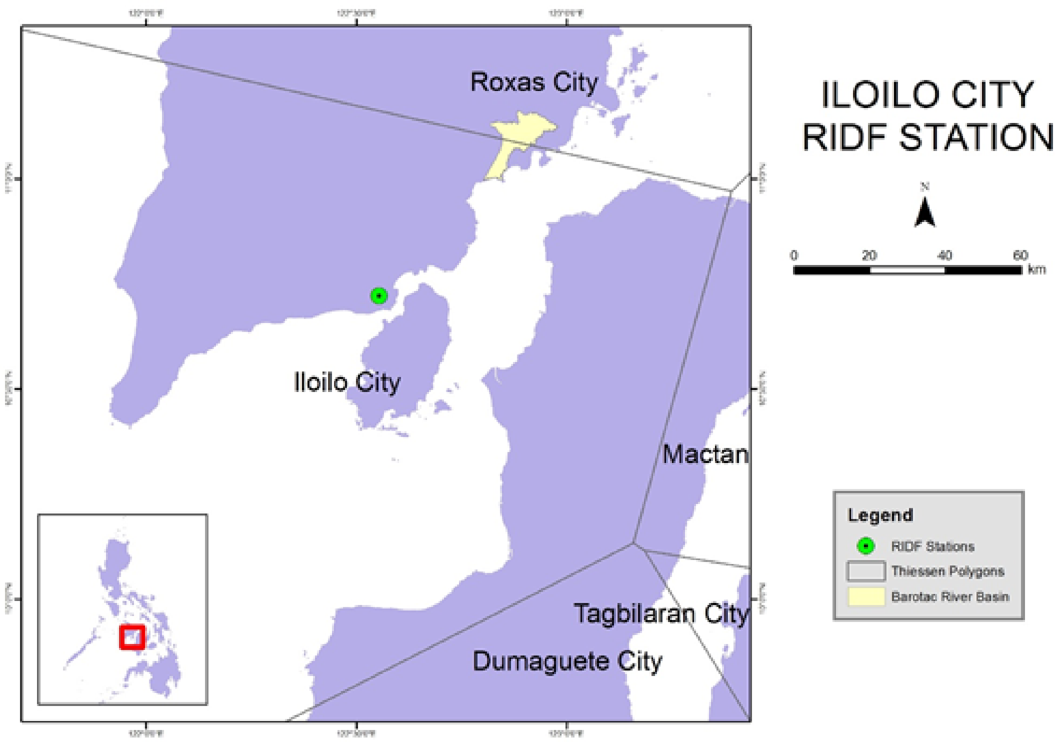


Figure 55. Location of Iloilo RIDF station relative to Barotac River Basin

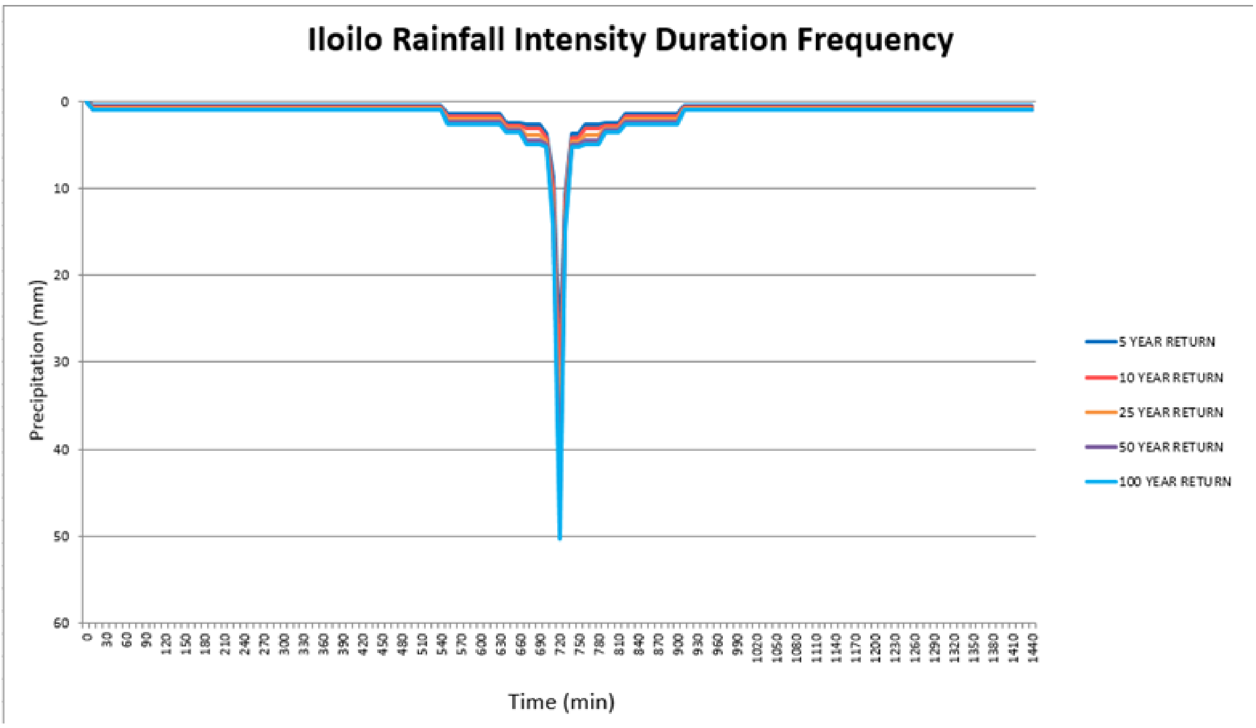


Figure 56. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken in 2004 from the Bureau of Soil and Water Management (BSWM); this is under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Barotac River Basin are shown in Figures 57 and 58, respectively.

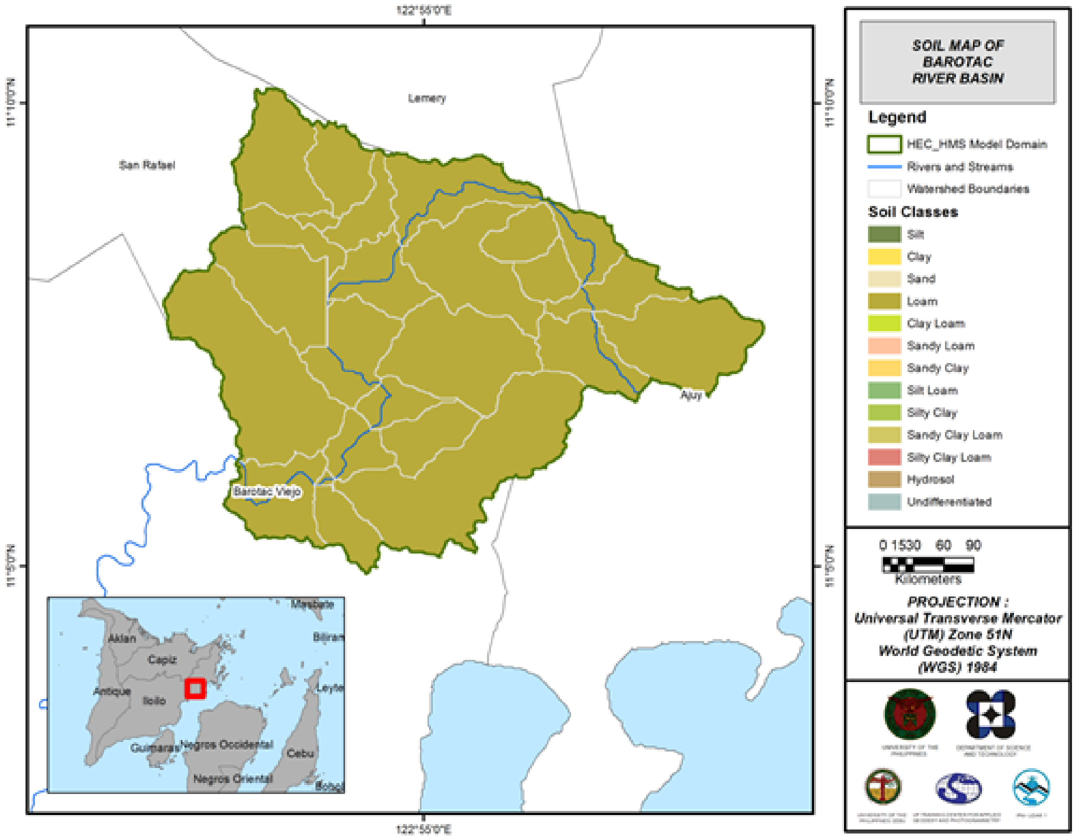


Figure 57. Soil Map of Barotac River Basin

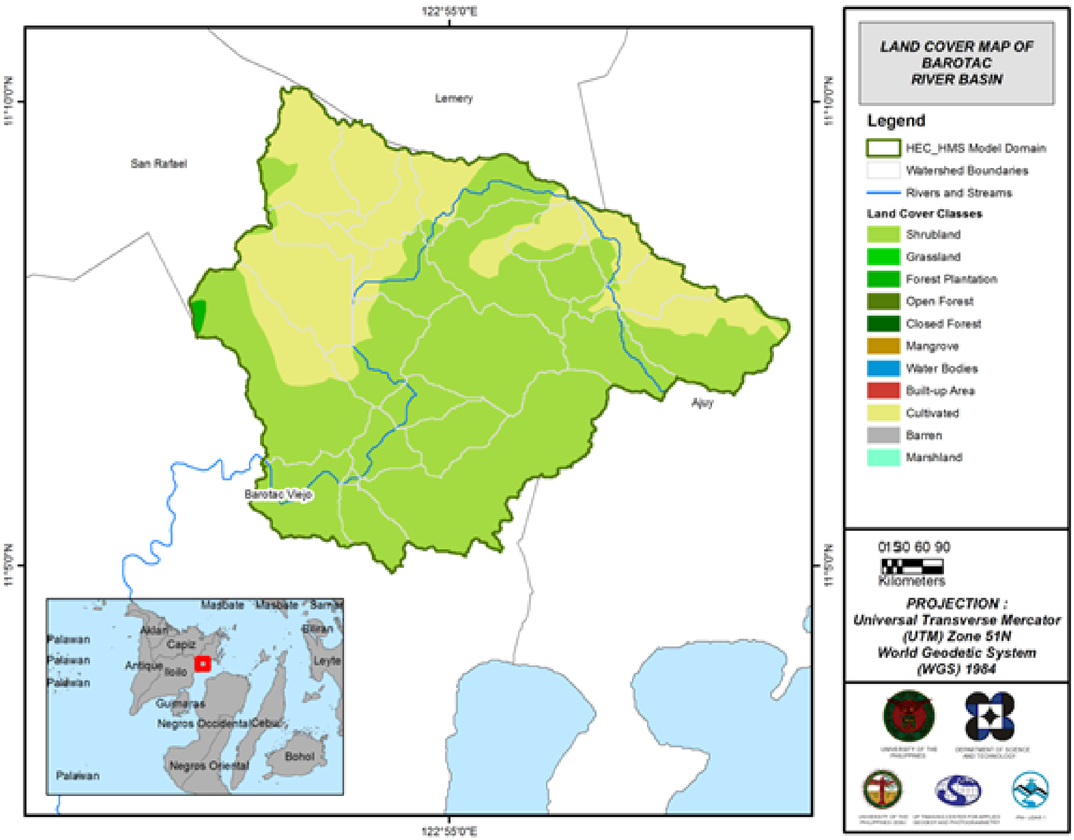


Figure 58. Land Cover Map of Barotac River Basin

For Barotac, one soil class, loam, was identified. Moreover, two land cover classes were identified. These are shrubland, and cultivated area.

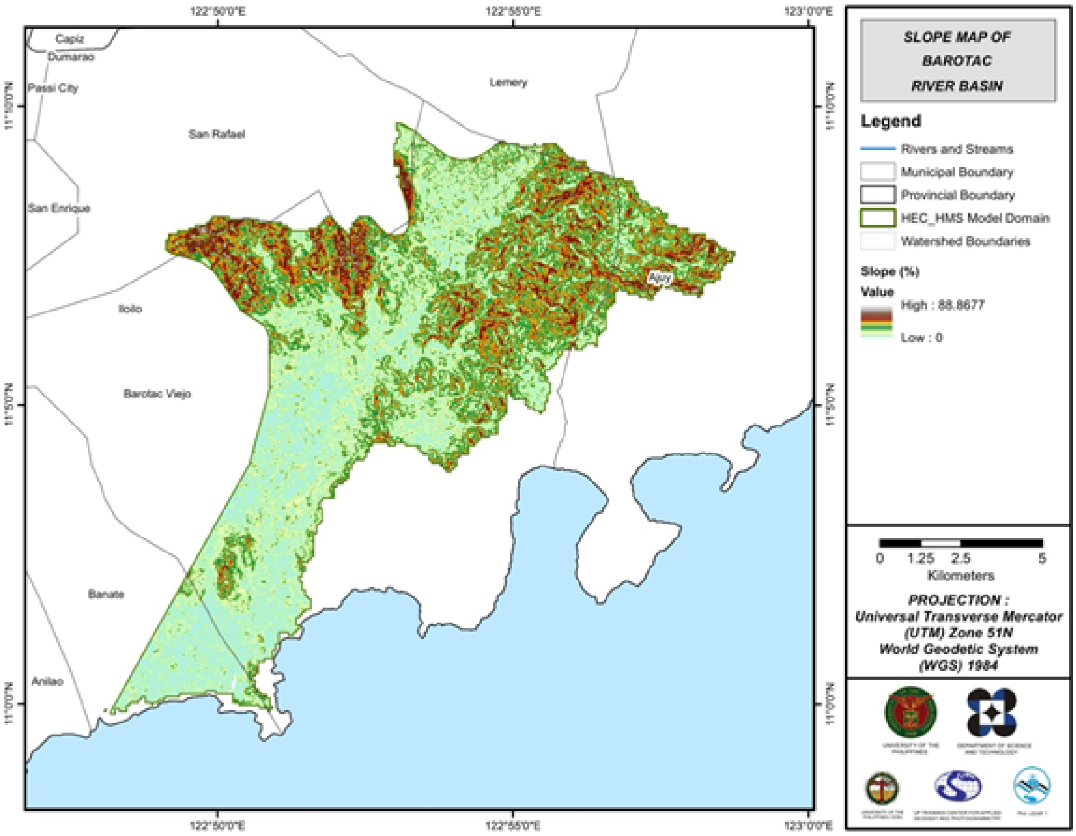


Figure 59. Slope Map of Barotac River Basin

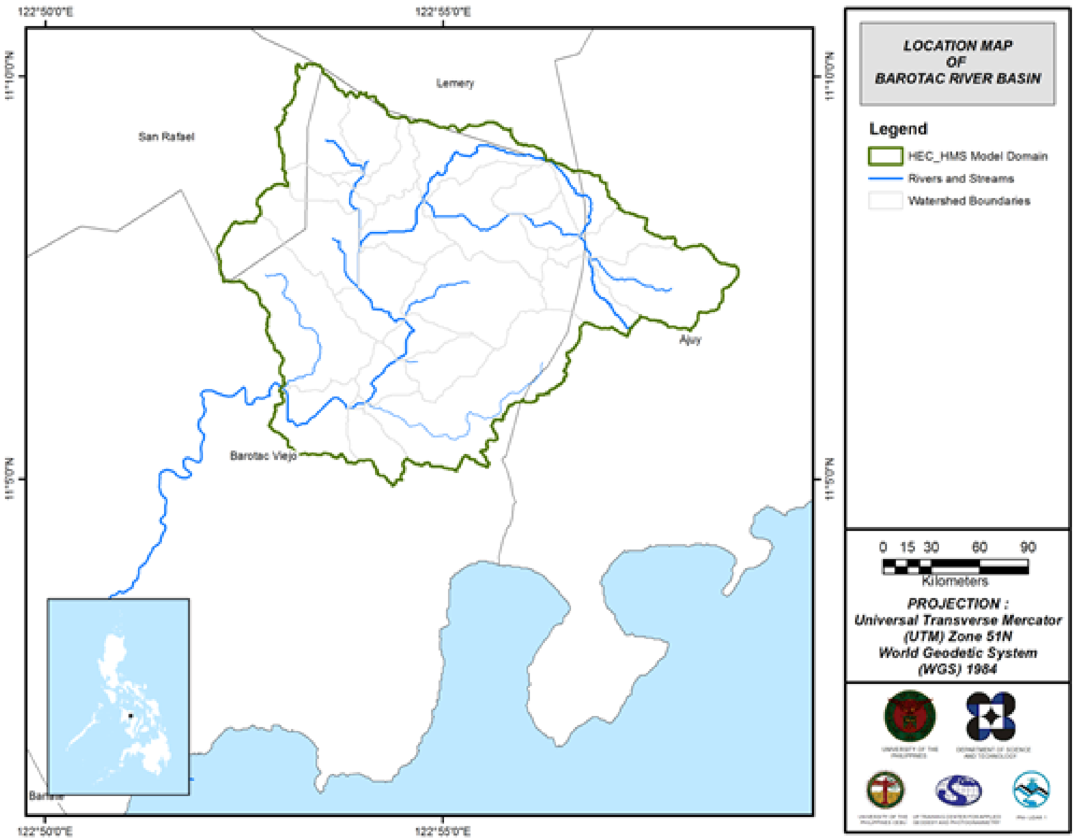


Figure 60. Stream Delineation Map Of Barotac River Basin

Using the SAR-based DEM, the Barotac basin was delineated and further subdivided into sub basins. The model consists of 27 sub basins, 13 reaches, and 13 junctions as shown in Figure 60. The main outlet is at Perfecto Balajadia Bridge.

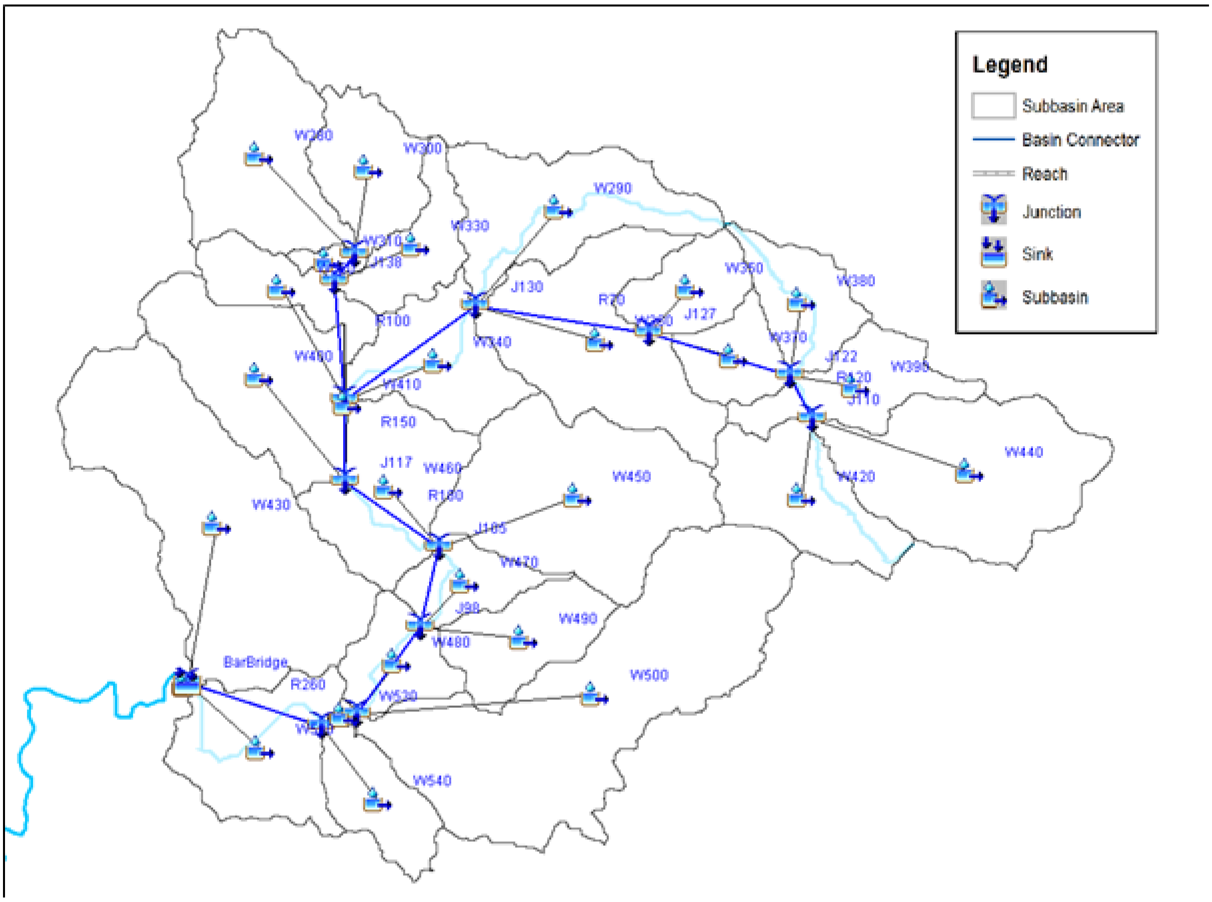


Figure 61. The Barotac river basin model generated using HEC-HMS

5.4 Cross-section Data

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

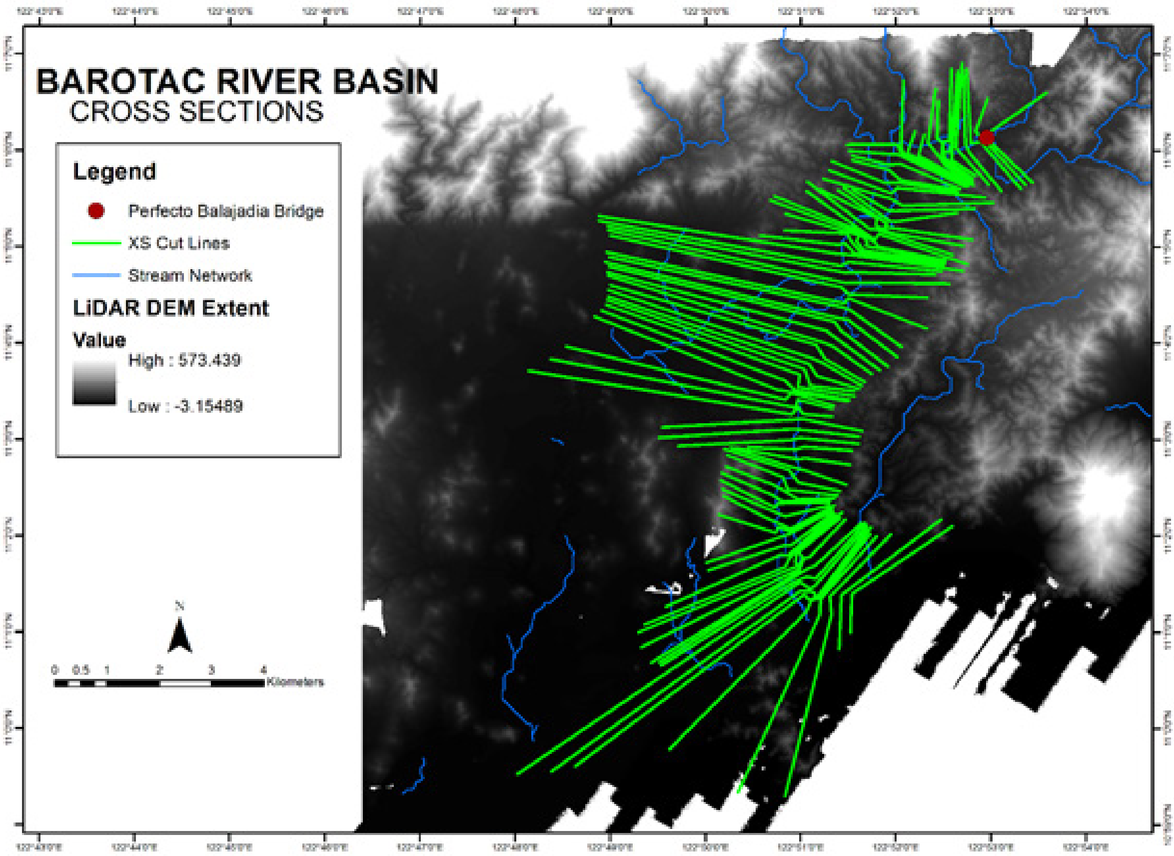


Figure 62. River cross-section of Barotac River generated through Arcmap HEC GeoRAS tool

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.

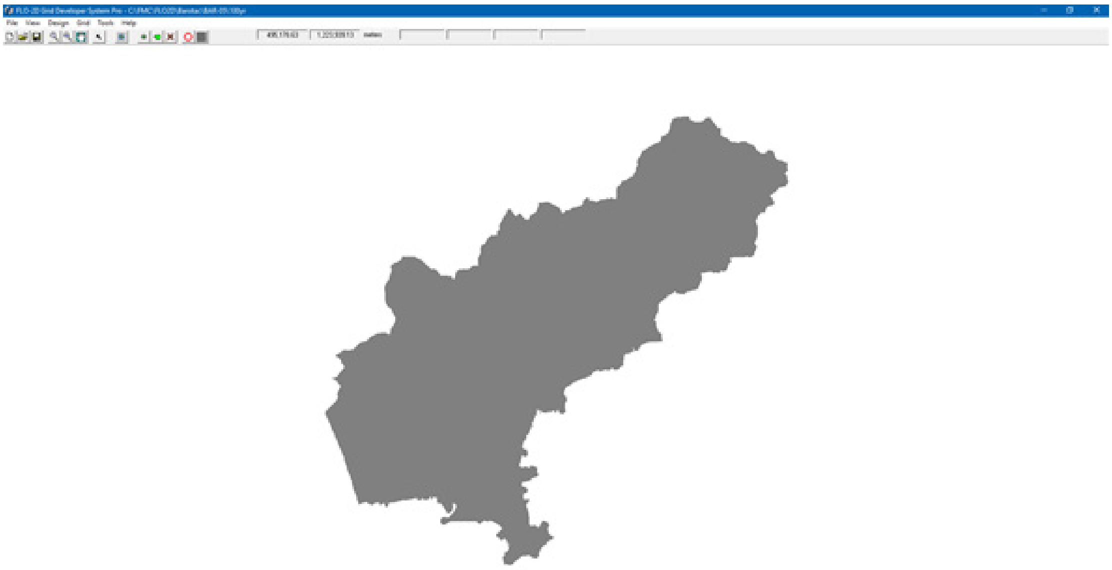


Figure 63. A screenshot of sub catchment with the computational area to be modeled in FLO-2D GDS Pro (Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 25.78375 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.The generated hazard maps for Barotac are in Figures 69, 71, and 68.

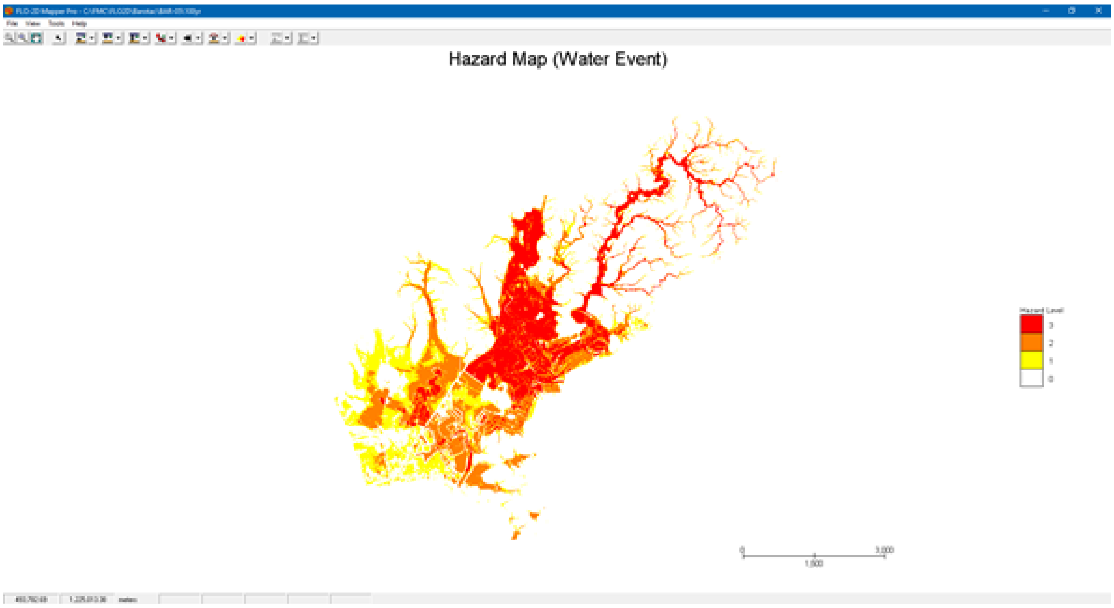


Figure 64. Generated 100-year rain return hazard map from FLO-2D Mapper

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 36034000.00m2.The generated flood depth maps for Barotac are in Figures 70, 72, and 74.

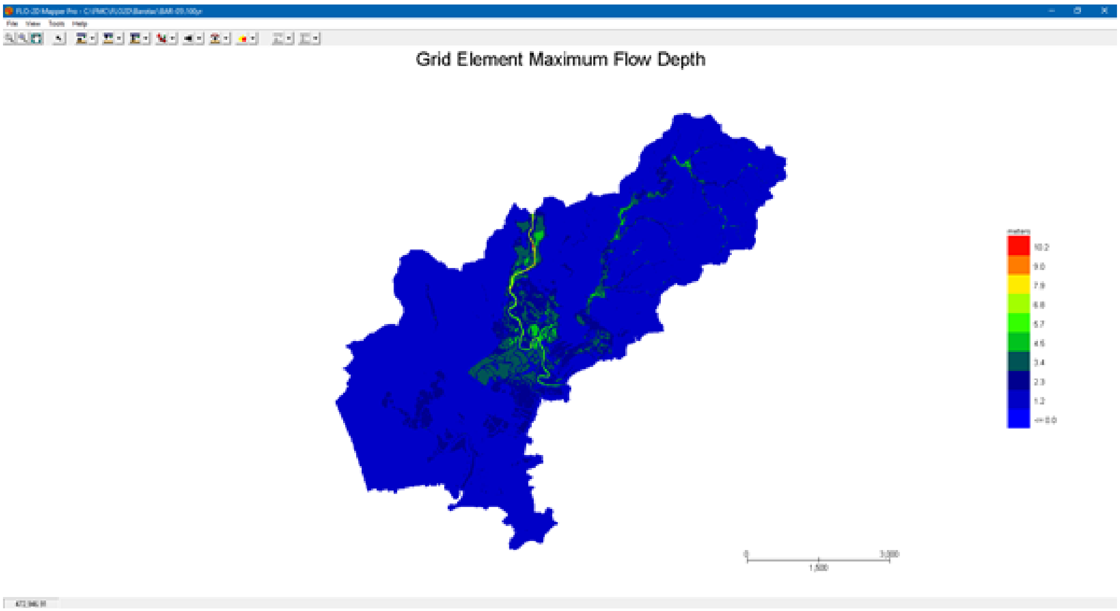


Figure 65. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 34429025.71m3 of water entering the model. Of this amount, 12726793.84m3 is due to rainfall while 21702231.87m3 is inflow from other areas outside the model.4802789.50m3of this water is lost to infiltration and interception, while 9196925.51m3 is stored by the flood plain. The rest, amounting up to 20429314.94 m3,is outflow.

5.6 Results of HMS Calibration

After calibrating the Barotac HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 66 shows the comparison between the two discharge data.

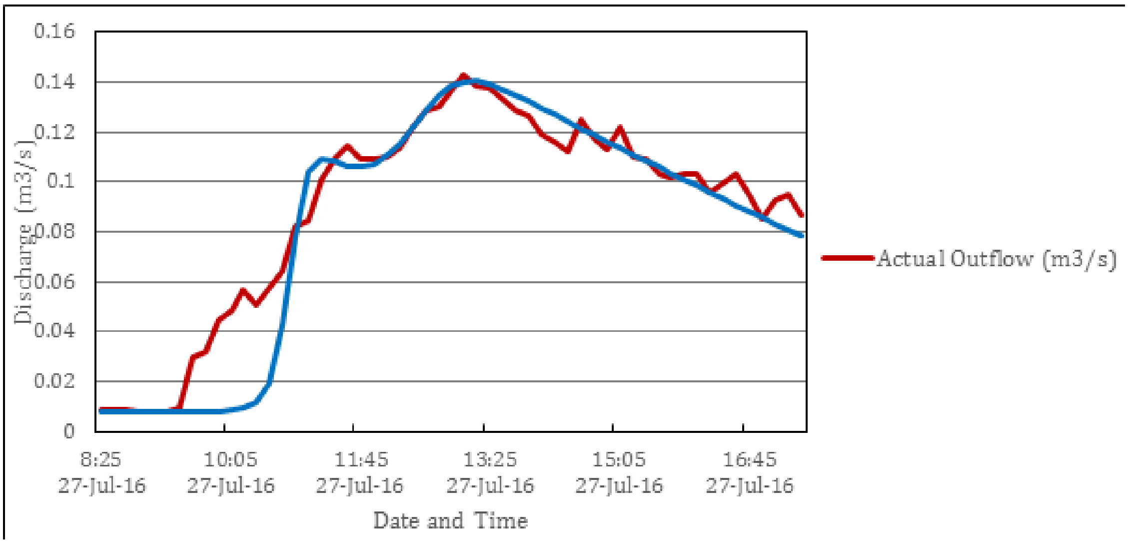


Figure 66. Outflow Hydrograph of Barotac produced by the HEC-HMS model compared with observed outflow

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

Table 31. Range of Calibrated Values for Barotac River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	5.1-20.7
			Curve Number	35.4-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.07-5
			Storage Coefficient (hr)	0.3-18.8
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.0001
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0001-0.0026

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 5.1mm to 20.7mm 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 35.4 to 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, Personal Comunnication, 2012). For Barotac, the basin mostly consists of shrublands, forest plantation and cultivated areas, 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 0.07 hours to 5 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 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.0001 indicates a much steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.0001 to 0.0026for the Barotac river basin is lower than the usual Manning's n value in the Philippines (Brunner, 2010).

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

Accuracy Measure	Value
RMS Error	0.0
r2	0.9651
NSE	0.87
RSR	0.36
PBIAS	5.83

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.0 (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 0.9651.

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 0.87.

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 5.83.

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 0.36.

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 67) shows the Barotac outflow using the Iloilo Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods from 165.2m3 in a 5-year return period to 304.5m3 for a 100-year return period.

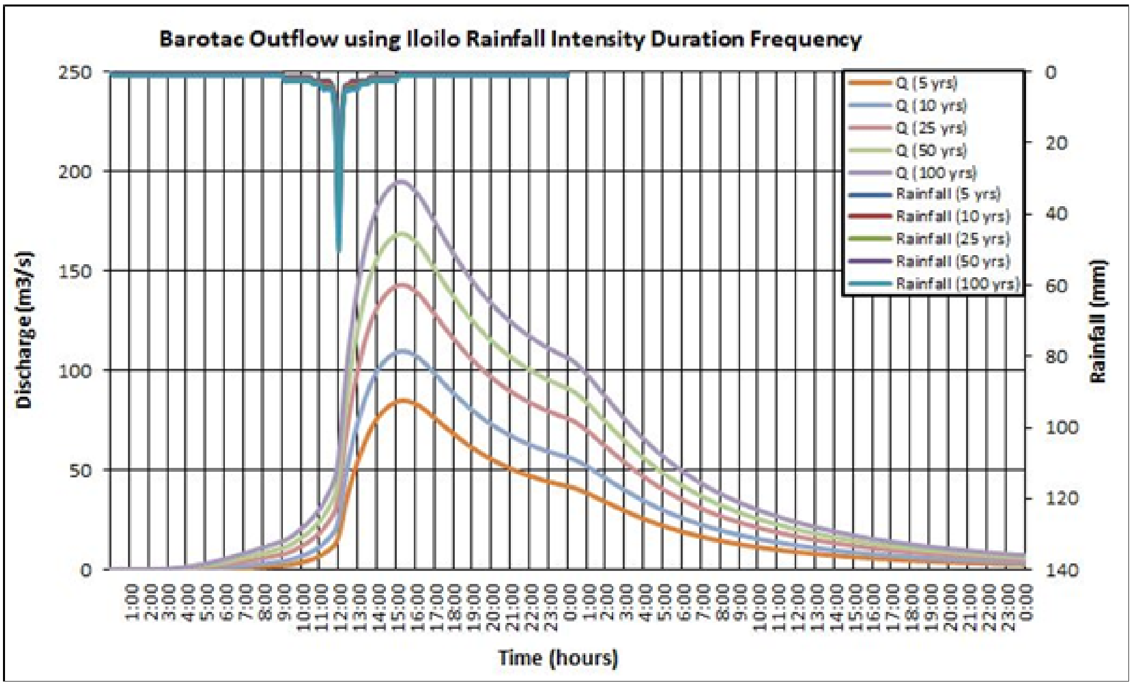


Figure 67. Outflow hydrograph at Barotac Station generated using Iloilo RIDF simulated in HEC-HMS

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

Table 33. Peak values of the Barotac HEC-HMS Model outflow using the Iloilo RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	165.2	28.7	84.88	3 hours, 20 minutes
10-Year	198.9	33.9	109.84	3 hours, 20 minutes
25-Year	241.5	40.5	143.11	3 hours, 20 minutes
50-Year	273.1	45.4	168.69	3 hours, 20 minutes
100-Year	304.5	50.3	194.87	3 hours, 20 minutes

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Barotac River using the calibrated HMS event flow is shown in Figure 68.

Figure 68. Sample output of Barotac RAS Model

5.9 Flood Hazard and Flow Depth Map

Figure to Figure show the 5-, 25-, and 100-year rain return scenarios of the Barotac floodplain. The floodplain, with an area of 243.695sq. km., covers sevenmunicipalitesnamely Ajuy, Anilao, Banate, Barotac Viejo, Lemery, San Enrique, and San Rafael. Table 34 shows the percentage of area affected by flooding per municipality.

Table 34. Municipalities affected in Barotac floodplain

Municipality	Total Area	Area Flooded	% Flooded
Ajuy	170.88	8.553315	5.005
Anilao	101.869	9.907	9.725
Banate	55.127	49.99	90.67
Barotac Viejo	180.585	166.09	91.976
Lemery	149.382	0.6178	0.4135
San Enrique	105.44	0.005562	0.00527
San Rafael	84.014	8.5149	10.135

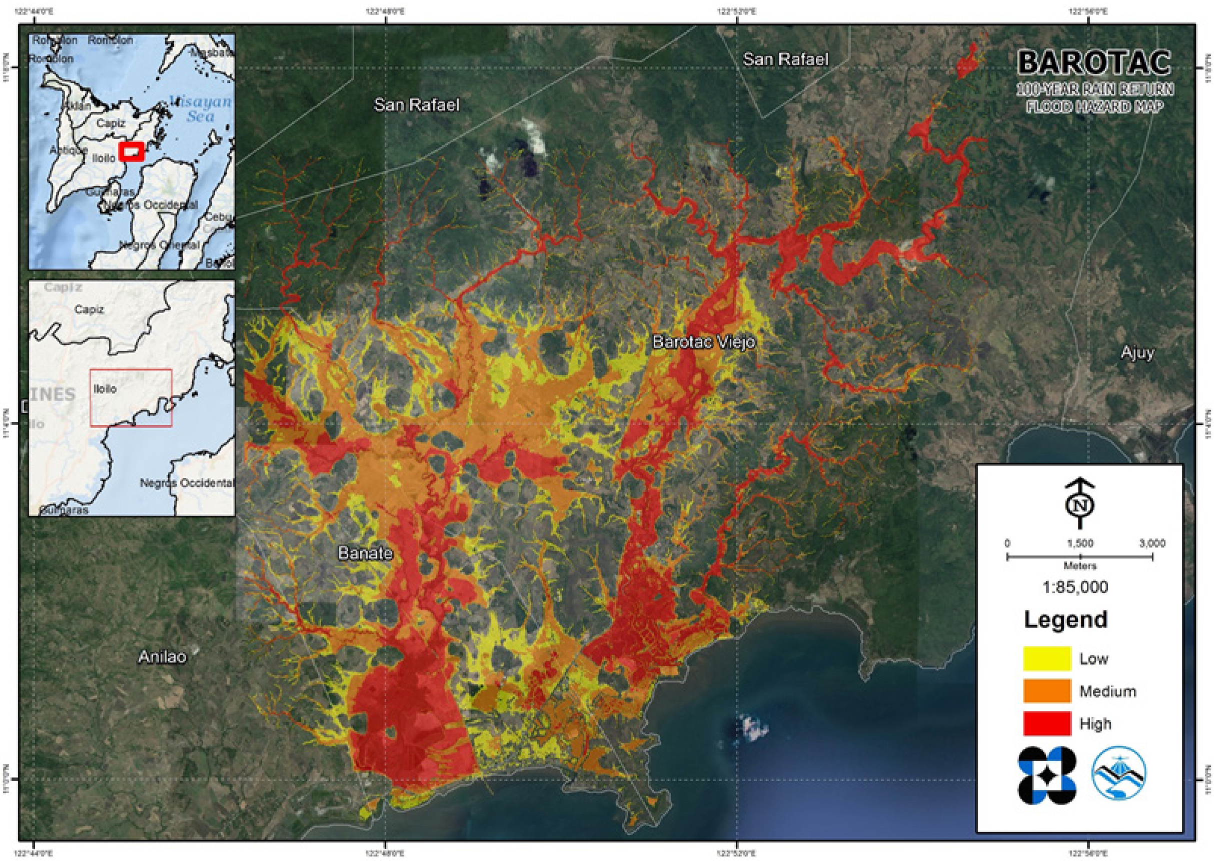


Figure 69. A 100-year Flood Hazard Map for Barotac Floodplain overlaid on Google Earth imagery

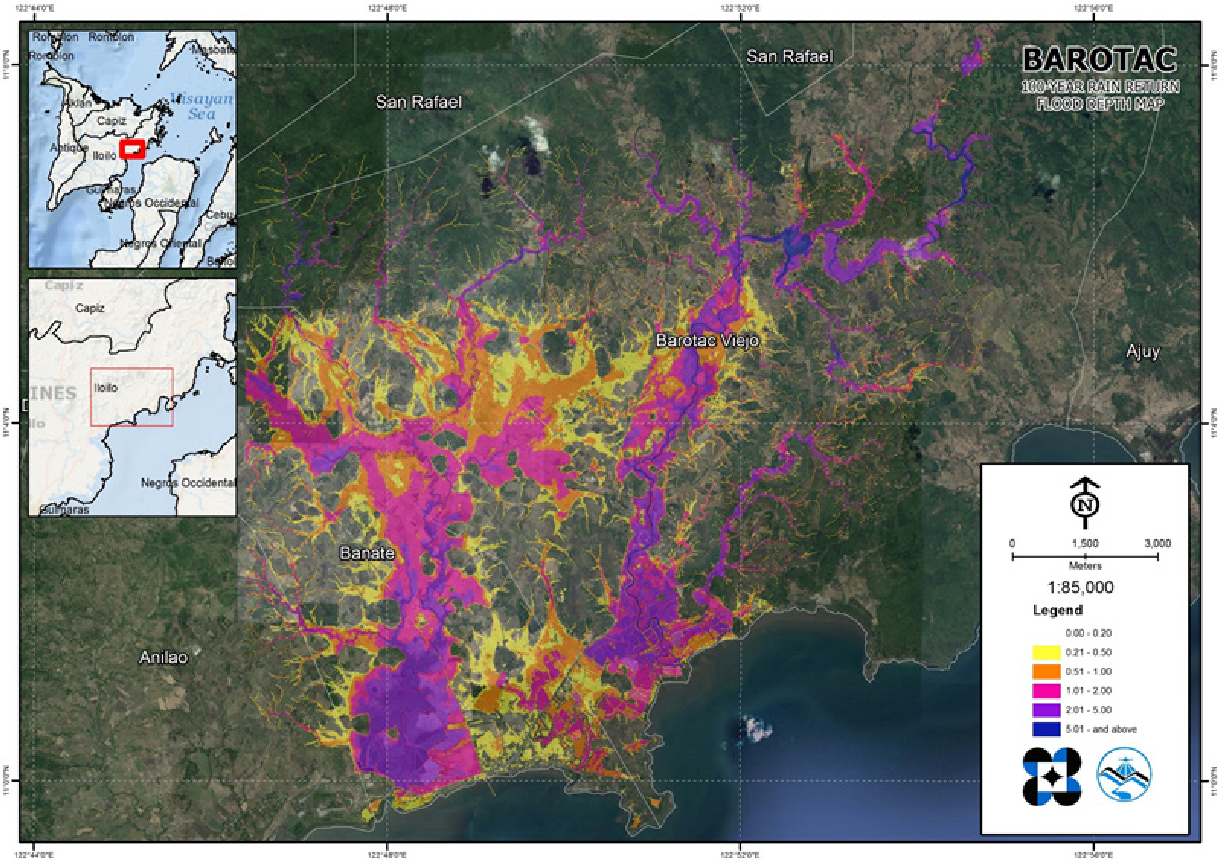


Figure 70. A 100-year Flow Depth Map for Barotac Floodplain overlaid on Google Earth imagery

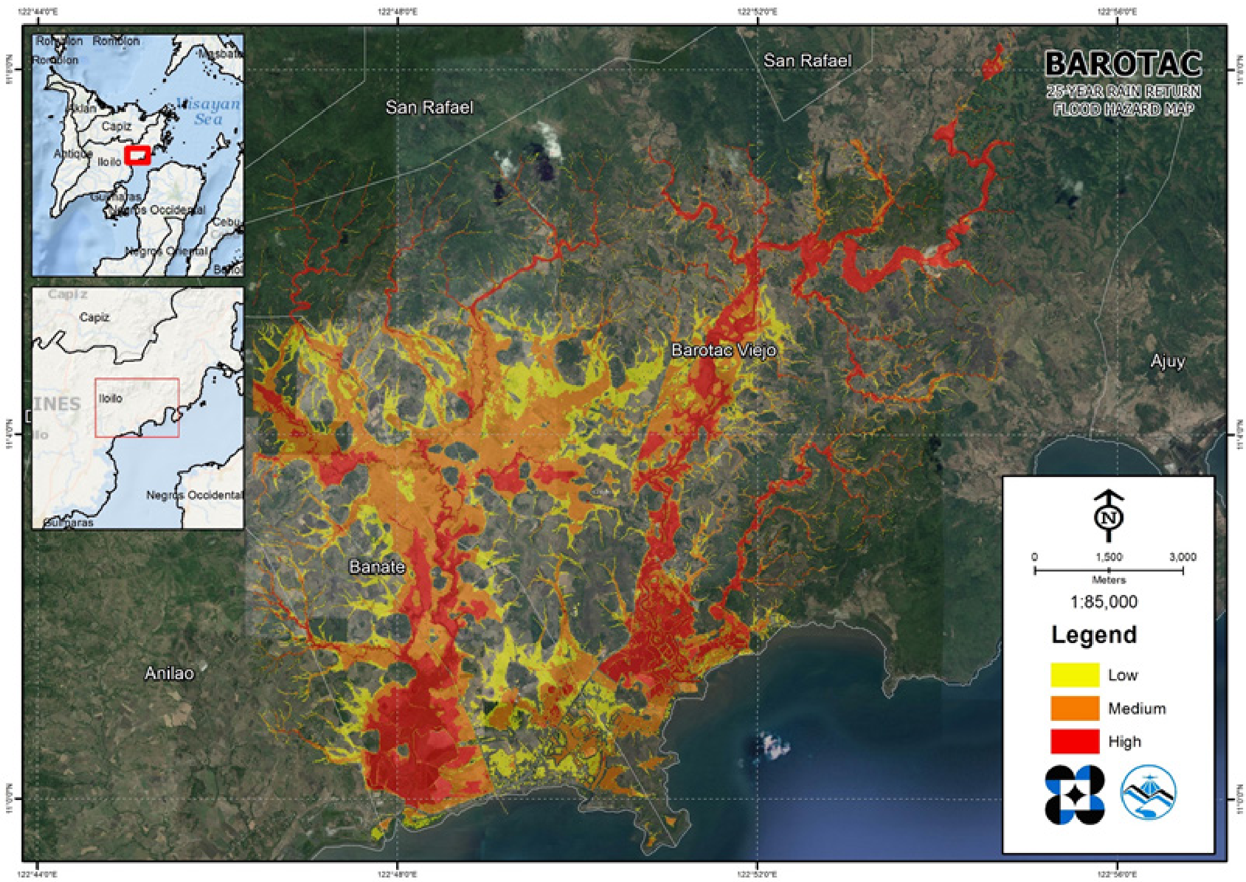


Figure 71. A 25-year Flood Hazard Map for Barotac Floodplainoverlaid on Google Earth imagery

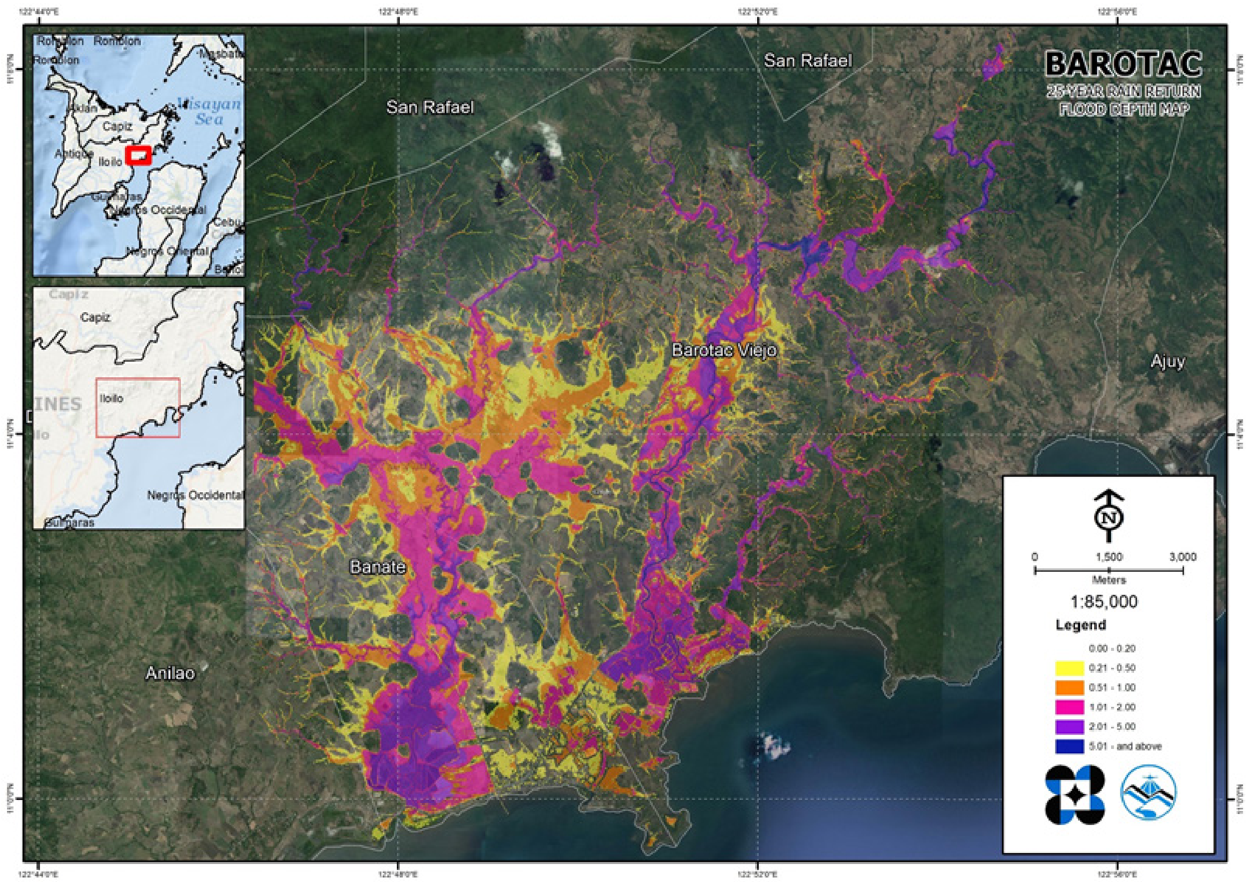


Figure 72. A 25-year Flow Depth Map for Barotac Floodplain overlaid on Google Earth imagery

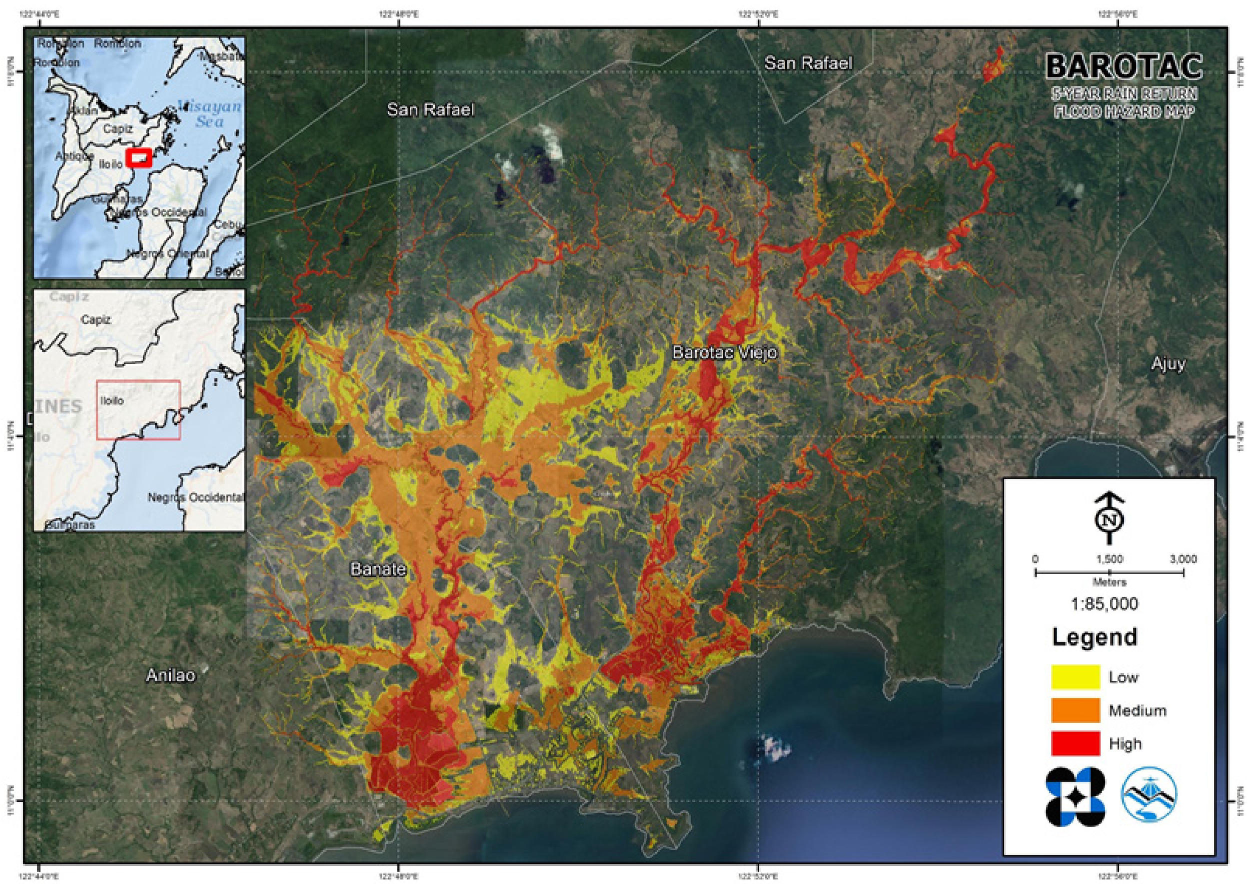


Figure 73. A 5-year Flood Hazard Map for Barotac Floodplain overlaid on Google Earth imagery

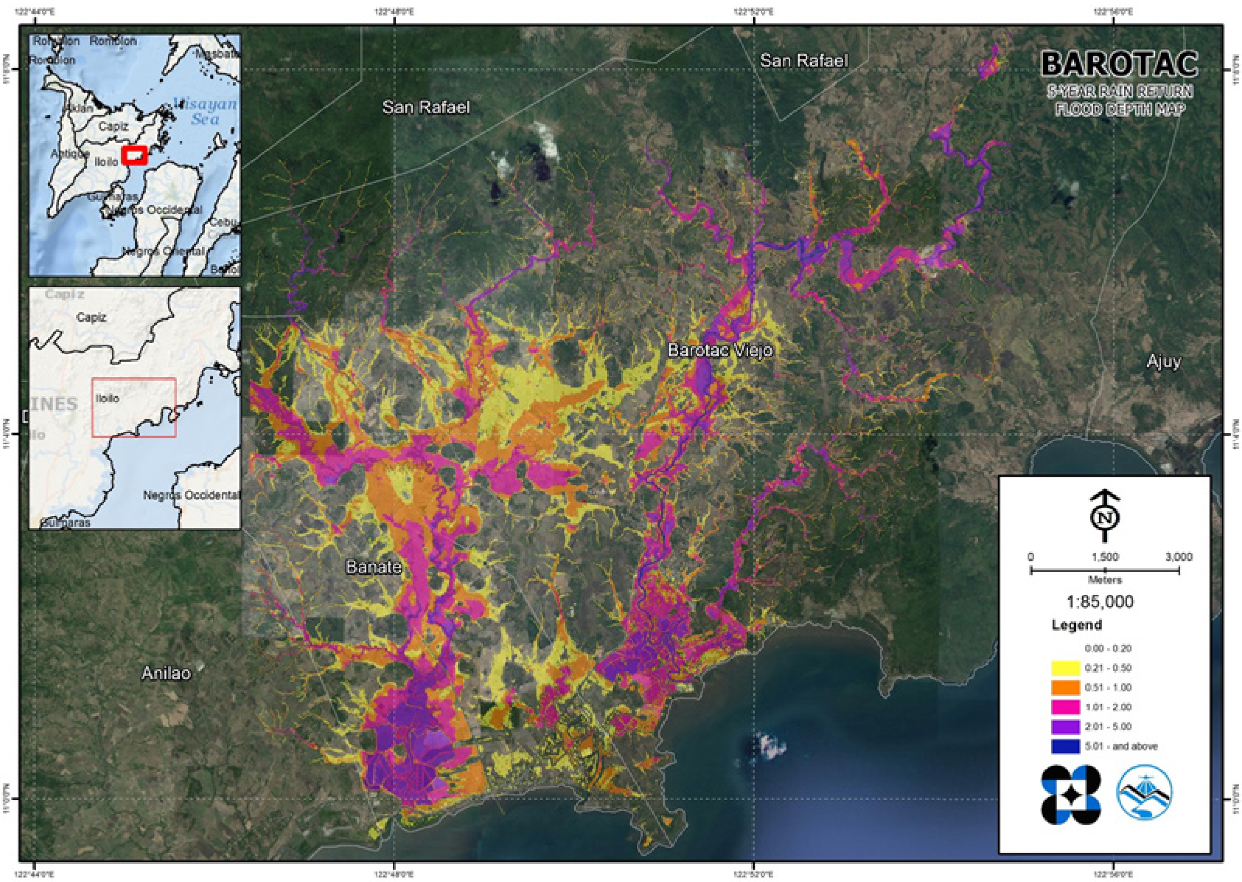


Figure 74. A 5-year Flood Depth Map for Barotac Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Barotac river basin, grouped by municipality, are listed below. For the said basin, seven municipalities consisting of 58 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 4.71% of the municipality of Ajuy with an area of 170.88 sq. km. will experience flood levels of less 0.20 meters. 0.13% of the area will experience flood levels of 0.21 to 0.50 meters while 0.06%, 0.04%, 0.05%, and 0.003%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 35 are the affected areas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Ajuy, Iloilo during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Ajuy (sq. km.)			
	Luca	Pili	Progreso	Santo Rosario
0.03-0.20	0.39	5.95	1.3	0.23
0.21-0.50	0.014	0.19	0.069	0.01
0.51-1.00	0.011	0.094	0.034	0.0038
1.01-2.00	0.0067	0.069	0.031	0.00015
2.01-5.00	0.011	0.1	0.014	0
> 5.00	0	0.018	0.00092	0

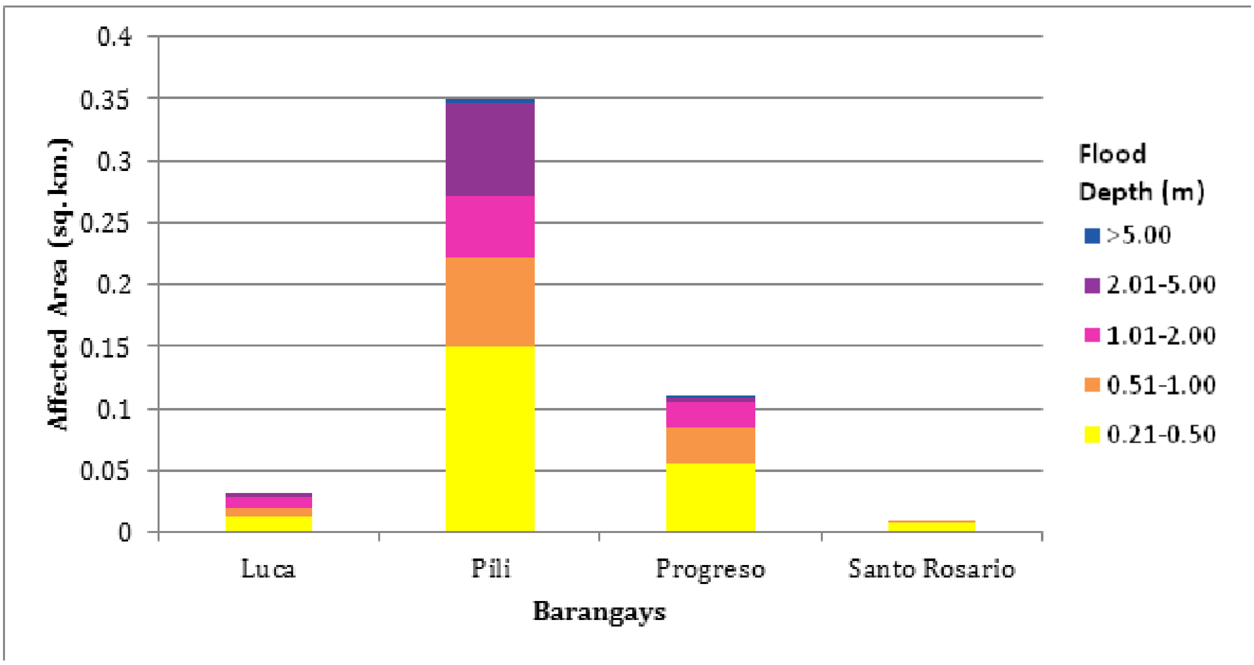


Figure 75. Affected Areas in Ajuy, Iloilo during 5-Year Rainfall Return Period

For the municipality of Anilao, with an area of 101.87 sq. km., 8.75% will experience flood levels of less 0.20 meters. 0.55% of the area will experience flood levels of 0.21 to 0.50 meters while 0.24%, 0.15%, and 0.03% 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 36 are the affected areas in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Anilao, Iloilo during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Anilao (sq. km.)			
	Cag-An	Dangula-An	Guipis	Manganese
0.03-0.20	3.31	1.71	2.01	1.51
0.21-0.50	0.3	0.28	0.075	0.046
0.51-1.00	0.16	0.12	0.041	0.029
1.01-2.00	0.14	0.042	0.031	0.01
2.01-5.00	0.055	0.0049	0.011	0
> 5.00	0.0001	0	0	0

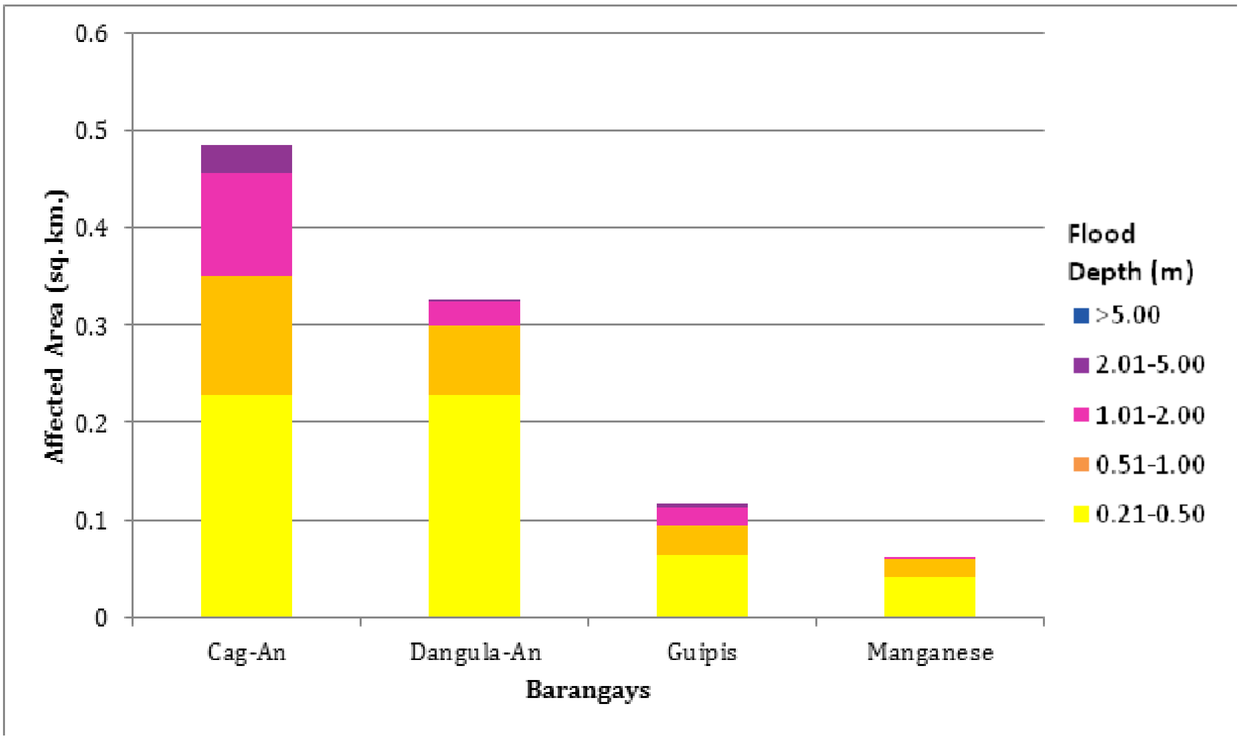


Figure 76. Affected Areas in Anilao, Iloilo during 5-Year Rainfall Return Period

For the municipality of Banate, with an area of 55.127 sq. km., 52.37% will experience flood levels of less 0.20 meters. 11.66% of the area will experience flood levels of 0.21 to 0.50 meters while 11.35%, 10.48%, 4.81%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 are the affected areas in square kilometers by flood depth per barangay.

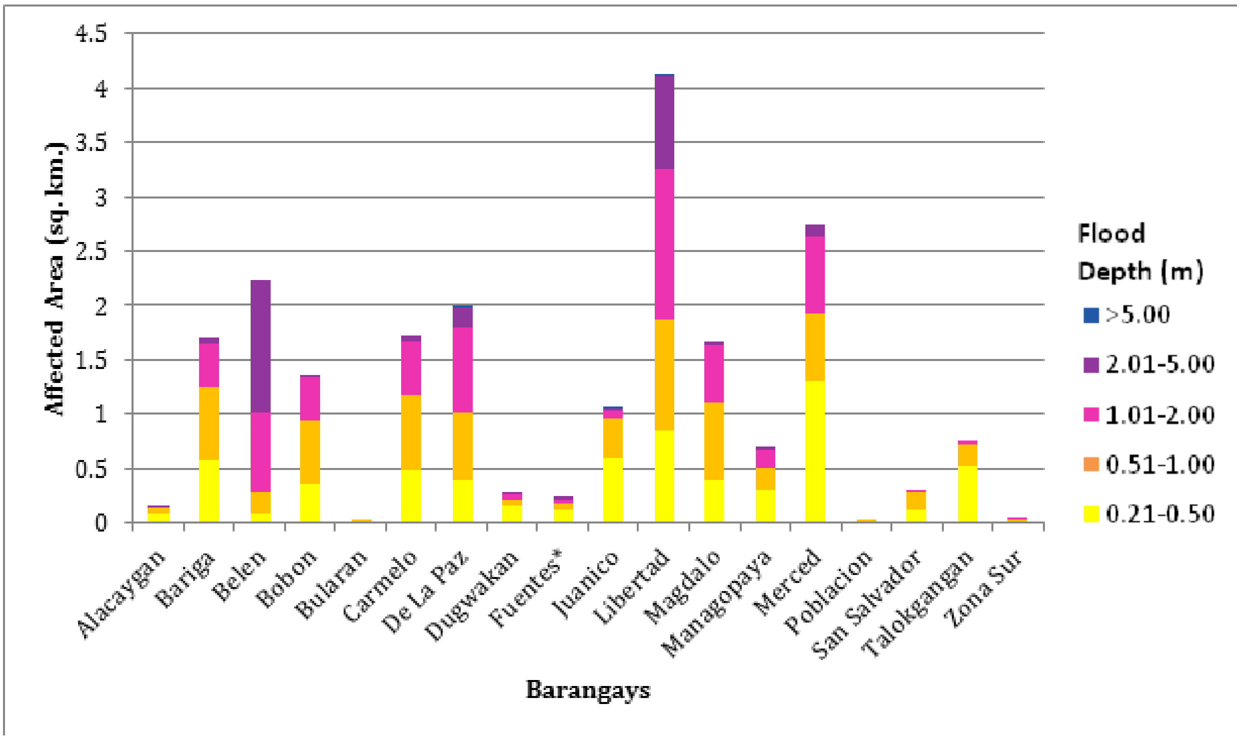


Figure 77. Affected Areas in Banate, Iloilo during 5-Year Rainfall Return Period.

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

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Banate (sq. km.)									
	Alacaygan	Bariga	Belen	Bobon	Bularan	Carmelo	De La Paz	Dugwakan	Fuentes	Juanico
0.03-0.20	0.086	2.62	0.31	0.74	0.094	0.76	4.58	1.67	0.46	1.55
0.21-0.50	0.12	0.39	0.027	0.24	0.021	0.42	0.34	0.19	0.14	0.59
0.51-1.00	0.046	0.68	0.053	0.58	0.0015	0.26	0.48	0.11	0.072	0.36
1.01-2.00	0.11	0.66	0.26	0.53	0	0.84	1.07	0.061	0.089	0.077
2.01-5.00	0.012	0.17	1.98	0.1	0	0.69	0.34	0.02	0.061	0.026
> 5.00	0	0	0	0	0	0	0.01	0	0	0.0048
Affected area (sq. km.) by flood depth (m.)	**Affected Barangays in Banate (sq. km.)**									
	Libertad	**Magdalo**	**Manago-paya**	**Merced**	**Poblacion**	**San Salvador**	**Talokgangan**	**Zona Sur**		
0.03-0.20	**2.59**	**1.64**	**4.18**	**3.76**	**0.11**	**1.09**	**1.13**	**0.068**		
0.21-0.50	**0.85**	**0.4**	**0.31**	**1.3**	**0.019**	**0.13**	**0.53**	**0.012**		
0.51-1.00	**1.02**	**0.71**	**0.19**	**0.63**	**0.00013**	**0.16**	**0.2**	**0.027**		
1.01-2.00	**1.38**	**0.52**	**0.17**	**0.7**	**0**	**0.0066**	**0.027**	**0.0013**		
2.01-5.00	**0.86**	**0.041**	**0.033**	**0.11**	**0**	**0**	**0**	**0**		
> 5.00	0.0001	0	0	0	0	0	0	0		

For the municipality of Barotac Viejo, with an area of 180.59 sq. km., 71.18% will experience flood levels of less 0.20 meters. 6.74% of the area will experience flood levels of 0.21 to 0.50 meters while 5.83%, 5.19%, 2.76%, and 0.27% 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 38 are the affected areas in square kilometers by flood depth per barangay.

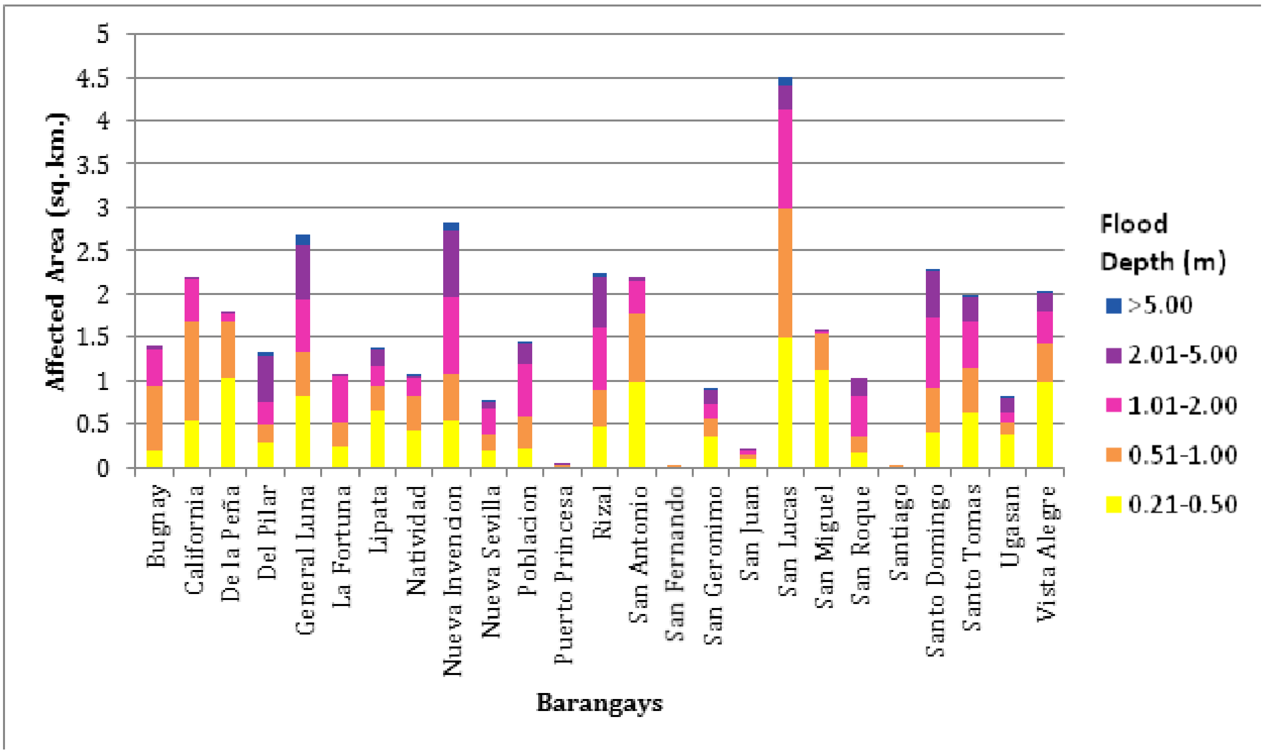


Figure 78. Affected Areas in Banate, Iloilo during 5-Year Rainfall Return Period

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

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Barotac Viejo (sq. km.)									
	Bugnay	California	De la Peña	Del Pilar	General Luna	La Fortuna	Lipata	Natividad	Nueva Invencion	Nueva Sevilla
0.03-0.20	0.16	0.46	0.55	8.57	18.77	2.19	14.76	2.75	13.14	0.29
0.21-0.50	0.18	0.55	1.03	0.28	0.81	0.23	0.66	0.41	0.53	0.18
0.51-1.00	0.75	1.13	0.65	0.21	0.52	0.29	0.27	0.41	0.54	0.21
1.01-2.00	0.43	0.48	0.088	0.26	0.6	0.53	0.25	0.21	0.9	0.29
2.01-5.00	0.051	0.0054	0.0087	0.53	0.63	0.0017	0.18	0.021	0.76	0.079
> 5.00	0	0	0	0.045	0.11	0	0.0029	0.0053	0.096	0.00031
	Poblacion	Puerto Princesa	Rizal	San Antonio	San Fernando	San Geronimo	San Juan	San Lucas	San Miguel	San Roque
0.03-0.20	1.35	0.4	11.94	4.84	0.079	2.3	0.86	5.51	2.54	3.5
0.21-0.50	0.22	0.011	0.48	0.99	0.0026	0.36	0.096	1.49	1.12	0.16
0.51-1.00	0.37	0.0056	0.41	0.79	0.0018	0.2	0.056	1.5	0.42	0.2
1.01-2.00	0.59	0.003	0.72	0.36	0	0.16	0.028	1.12	0.028	0.47
2.01-5.00	0.23	0.0011	0.57	0.058	0	0.16	0.00098	0.3	0.0004	0.21
> 5.00	0.02	0	0.067	0	0	0.01	0	0.084	0	0
	Santiago	Santo Domingo	Santo Tomas	Ugasan	Vista Alegre					
0.03-0.20	0.02	2.23	15.07	9.54	6.72					
0.21-0.50	0.0001	0.41	0.63	0.37	0.99					
0.51-1.00	0.000056	0.51	0.52	0.14	0.43					
1.01-2.00	0	0.81	0.53	0.13	0.38					
2.01-5.00	0	0.52	0.29	0.16	0.2					
> 5.00	0	0.0042	0.021	0.022	0.0063					

For the municipality of Lemery with an area of 149.382 sq. km., 0.10% will experience flood levels of less 0.20 meters. 0.01% of the area will experience flood levels of 0.21 to 0.50 meters while 0.001%, and 0.0003%,of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 39 Affected Areas in Lemery, Iloilo during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Lemery (sq. km.)	
	Nasapahan	San Jose Moto
0.03-0.20	0.000011	0.6
0.21-0.50	0	0.015
0.51-1.00	0	0.0016
1.01-2.00	0	0.00043
2.01-5.00	0	0
> 5.00	0	0

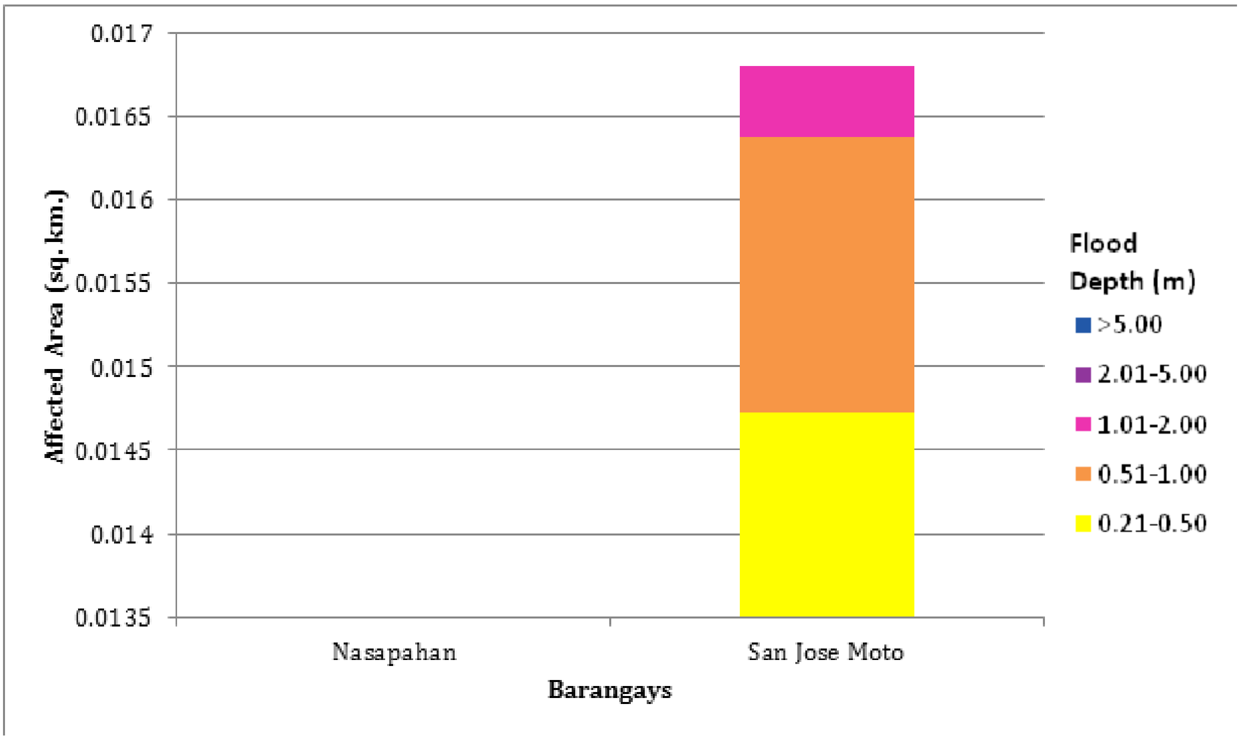


Figure 79. Affected Areas in Lemery, Iloilo during 5-Year Rainfall Return Period

For the municipality of San Enrique with an area of 105.44 sq. km., 0.005% will experience flood levels of less 0.20 meters. Listed in Table 40 are the affected areas in square kilometers by flood depth per barangay.

Table 40 Affected Areas in San Enrique, Iloilo during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in San Enrique (sq. km.)
	San Antonio
0.03-0.20	0.0056
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

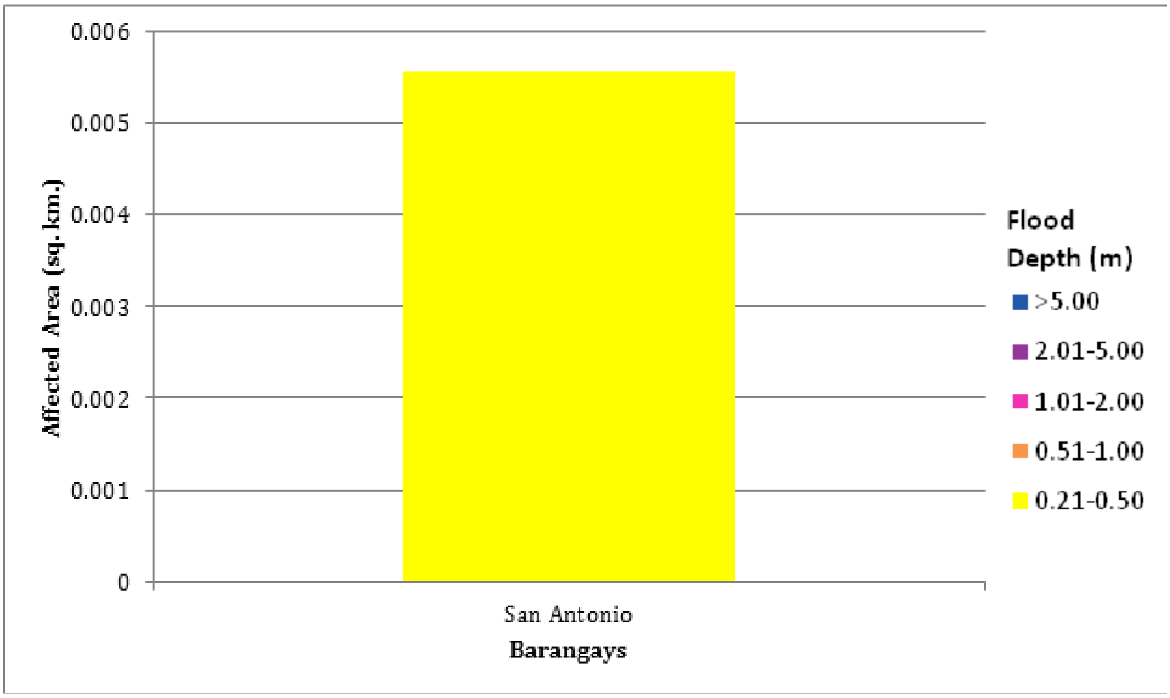


Figure 80. Affected Areas in San Enrique, Iloilo during 5-Year Rainfall Return Period

For the municipality of San Rafael, with an area of 84.01 sq. km., 9.76% 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 0.09%, 0.039%, and 0.015% 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 kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in San Rafael (sq. km.)			
	Aripdip	Ilongbukid	San Dionisio	San Florentino
0.03-0.20	0.001	1.28	3.82	3.09
0.21-0.50	0	0.026	0.1	0.067
0.51-1.00	0	0.012	0.041	0.022
1.01-2.00	0	0.0063	0.018	0.0079
2.01-5.00	0	0.0007	0.0052	0.0064
> 5.00	0	0	0	0

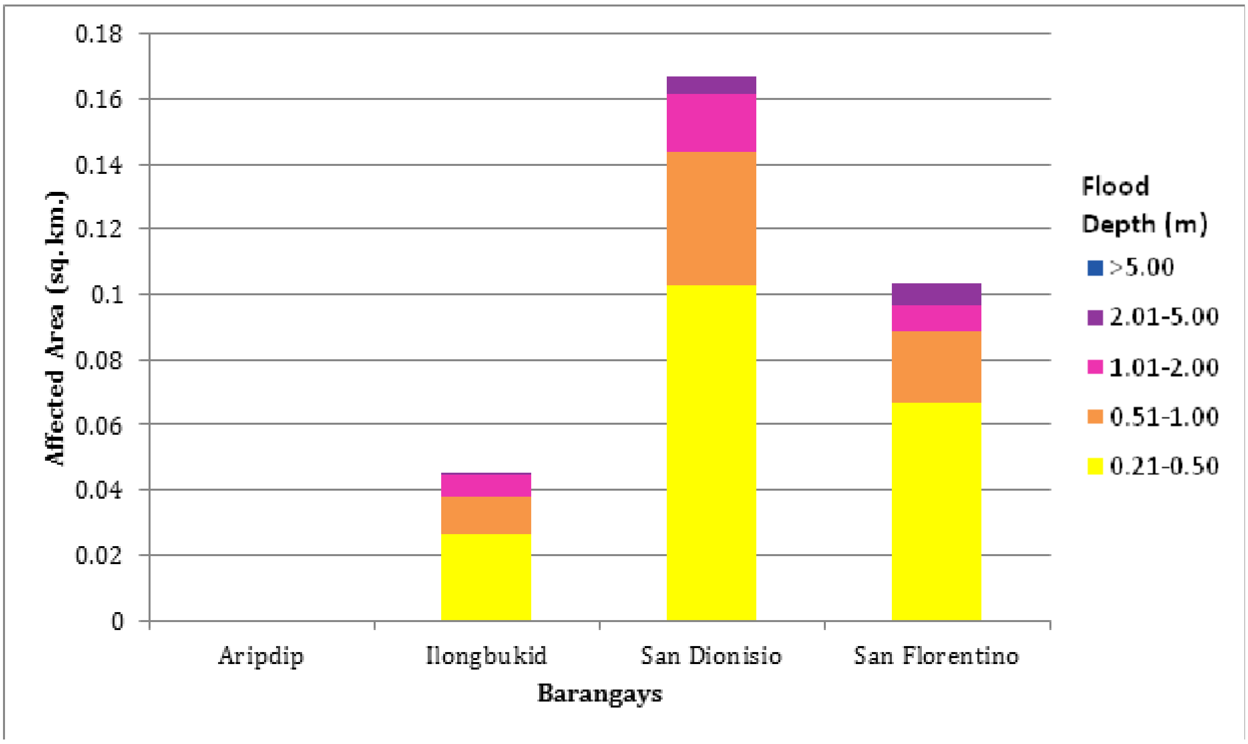


Figure 81. Affected Areas in Rafael, Iloilo during 5-Year Rainfall Return Period

For the 25-year return period, 4.65% of the municipality of Ajuy with an area of 170.88 sq. km. will experience flood levels of less 0.20 meters. 0.15% of the area will experience flood levels of 0.21 to 0.50 meters while 0.08%, 0.05%, 0.06%, and

0.007%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 are the affected areas in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Ajuy, Iloilo during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Ajuy (sq. km.)			
	Luca	Pili	Progreso	Santo Rosario
0.03-0.20	0.4	6.01	1.32	0.23
0.21-0.50	0.014	0.18	0.061	0.0089
0.51-1.00	0.0094	0.083	0.034	0.003
1.01-2.00	0.0064	0.057	0.025	0
2.01-5.00	0.0088	0.092	0.0097	0
> 5.00	0	0.011	0.00062	0

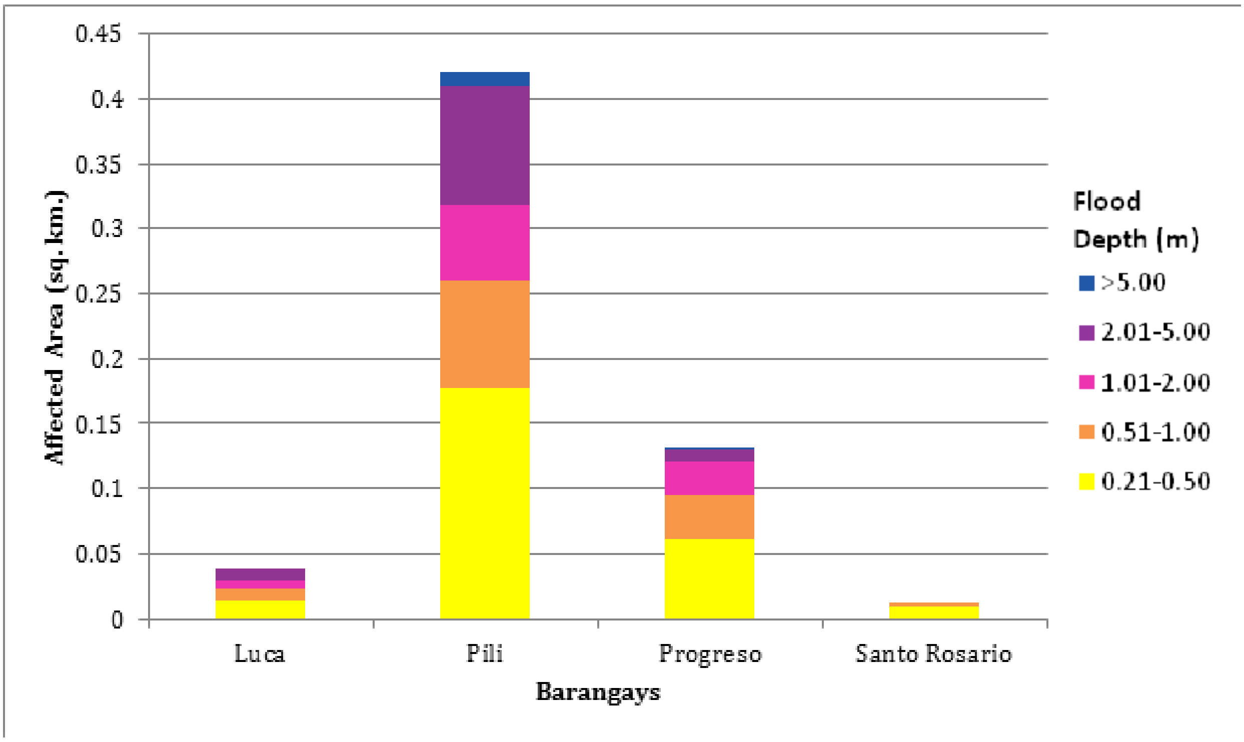


Figure 82. Affected Areas in Ajuy, Iloilo during 25-Year Rainfall Return Period

For the municipality of Anilao, with an area of 101.87 sq. km., 8.55% will experience flood levels of less 0.20 meters. 0.64% of the area will experience flood levels of 0.21 to 0.50 meters while 0.3%, 0.19%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 43 are the affected areas in square kilometers by flood depth per barangay.

Table 43 Affected Areas in Anilao, Iloilo during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Anilao (sq. km.)			
	Cag-An	Dangula-An	Guipis	Manganese
0.03-0.20	3.39	1.77	2.03	1.52
0.21-0.50	0.27	0.26	0.07	0.044
0.51-1.00	0.14	0.1	0.038	0.026
1.01-2.00	0.13	0.032	0.024	0.005
2.01-5.00	0.042	0.0038	0.0084	0
> 5.00	0.0001	0	0	0

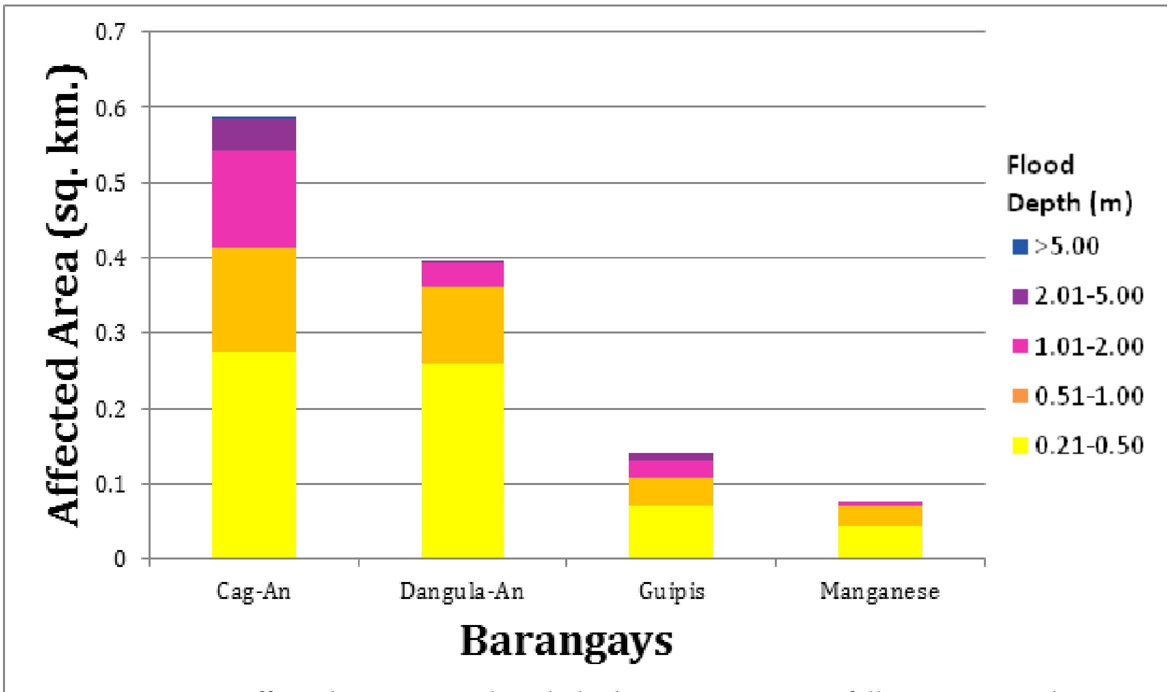


Figure 83. Affected Areas in Anilao, Iloilo during 25-Year Rainfall Return Period

For the municipality of Banate, with an area of 55.127 sq. km., 47.97% will experience flood levels of less 0.20 meters. 11.41% of the area will experience flood levels of 0.21 to 0.50 meters while 10.44%, 14.10%, 6.75%, and 0.021% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas in square kilometers by flood depth per barangay.

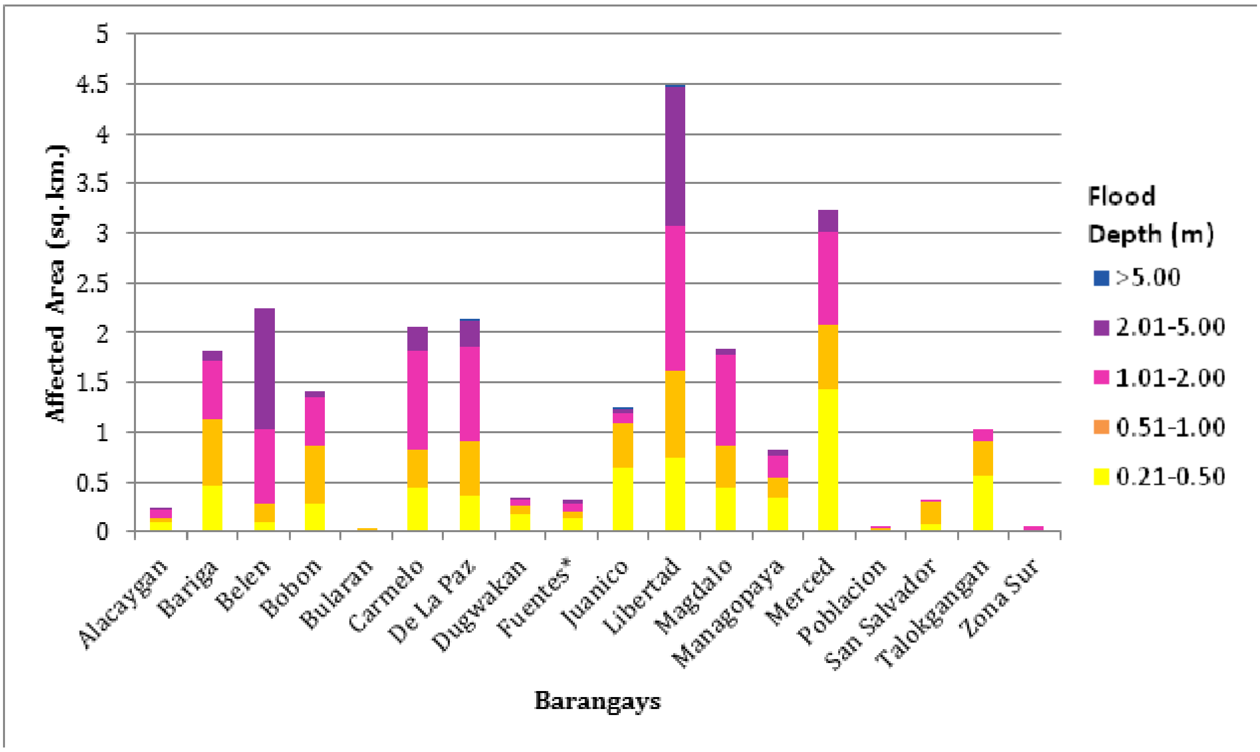


Figure 84. Affected Areas in Banate, Iloilo during 25-Year Rainfall Return Period

Table 44. Affected Areas in Banate, Iloilo during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Banate (sq. km.)									
	Alacaygan	**Bariga**	**Belen**	**Bobon**	**Bularan**	**Carmelo**	**De La Paz**	**Dugwakan**	**Fuentes***	Juanico
0.03-0.20	0.16	2.7	0.39	0.78	0.098	0.9	4.69	1.73	0.5	1.39
0.21-0.50	0.086	0.46	0.09	0.28	0.017	0.44	0.36	0.17	0.13	0.65
0.51-1.00	0.053	0.68	0.2	0.57	0.0009	0.37	0.54	0.088	0.078	0.44
1.01-2.00	0.078	0.58	0.74	0.5	0	0.99	0.96	0.057	0.071	0.11
2.01-5.00	0.0023	0.11	1.22	0.058	0	0.24	0.27	0.012	0.039	0.028
> 5.00	0	0	0	0	0	0	0.0055	0	0	0.0051

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Banate (sq. km.)									
	Libertad	**Magdalo**	**Managopaya**	**Merced**	**Poblacion**	**San Salvador**	**Talokgangan**	**Zona Sur**		
0.03-0.20	2.23	1.48	4.06	3.27	0.1	1.07	0.86	0.051		
0.21-0.50	0.74	0.44	0.34	1.44	0.024	0.08	0.56	0.0036		
0.51-1.00	0.88	0.43	0.21	0.63	0.0079	0.21	0.35	0.018		
1.01-2.00	1.45	0.9	0.21	0.94	0.0021	0.025	0.12	0.034		
2.01-5.00	1.41	0.062	0.056	0.22	0	0	0	0		
> 5.00	0.0008	0	0	0	0	0	0	0		

For the municipality of Barotac Viejo, with an area of 180.59 sq. km., 68.57% will experience flood levels of less 0.20 meters. 6.50% of the area will experience flood levels of 0.21 to 0.50 meters while 6.12%, 6.15%, 4.08%, and 0.56% 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 are the affected areas in square kilometers by flood depth per barangay.

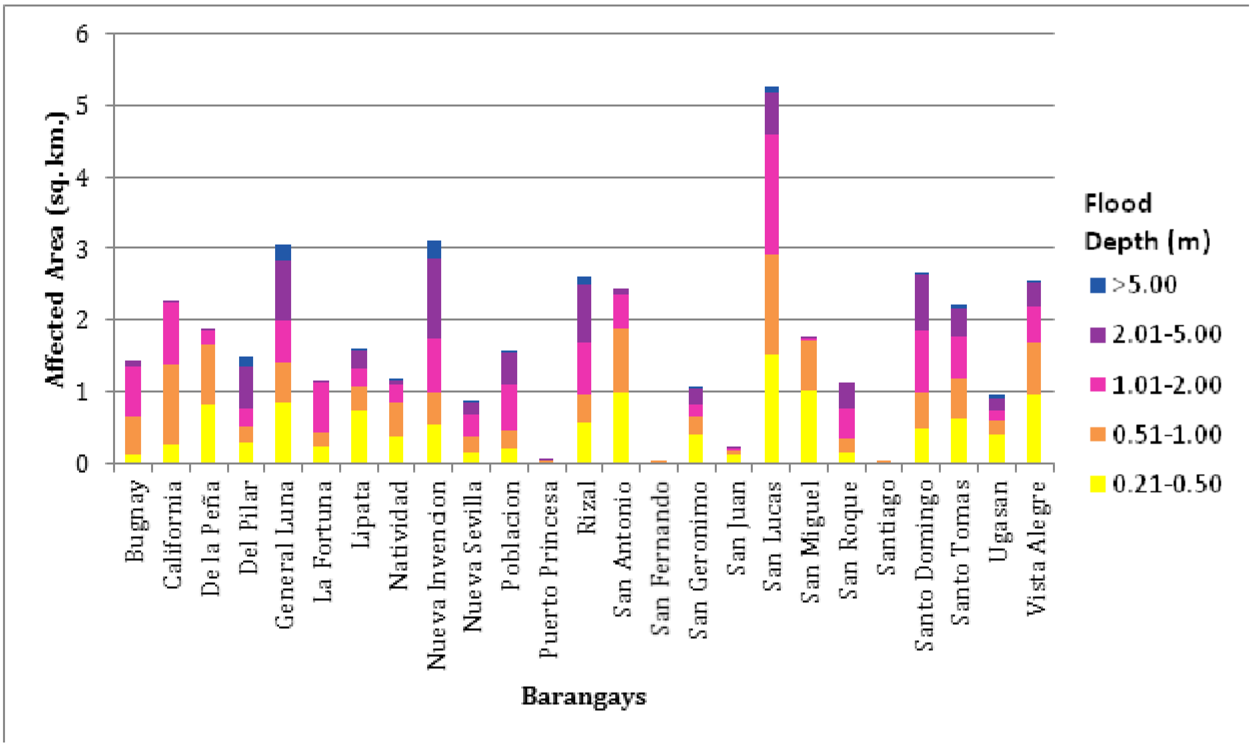


Figure 85. Affected Areas in Barotac Viejo, Iloilo during 25-Year Rainfall Return Period

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

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Barotac Viejo (sq. km.)									
	Bugnay	California	De la Peña	Del Pilar	General Luna	La Fortuna	Lipata	Natividad	Nueva Invencion	Nueva Sevilla
0.03-0.20	0.13	0.39	0.47	8.41	18.39	2.09	14.53	2.64	12.85	0.21
0.21-0.50	0.11	0.26	0.83	0.28	0.84	0.24	0.73	0.38	0.54	0.13
0.51-1.00	0.54	1.12	0.84	0.22	0.55	0.18	0.34	0.46	0.45	0.23
1.01-2.00	0.7	0.85	0.18	0.24	0.6	0.72	0.26	0.26	0.74	0.31
2.01-5.00	0.081	0.015	0.011	0.6	0.85	0.017	0.25	0.051	1.12	0.15
> 5.00	0	0	0	0.14	0.22	0	0.011	0.0085	0.26	0.0008
	Poblacion	Puerto Princesa	Rizal	San Antonio	San Fernando	San Geronimo	San Juan	San Lucas	San Miguel	San Roque
0.03-0.20	1.22	0.4	11.58	4.6	0.078	2.14	0.83	4.75	2.36	3.42
0.21-0.50	0.19	0.013	0.55	0.99	0.0032	0.39	0.1	1.5	1.01	0.15
0.51-1.00	0.25	0.0061	0.41	0.9	0.0021	0.26	0.069	1.43	0.68	0.19
1.01-2.00	0.67	0.0037	0.72	0.46	0	0.16	0.037	1.67	0.042	0.42
2.01-5.00	0.43	0.0016	0.8	0.089	0	0.23	0.003	0.58	0.0014	0.36
> 5.00	0.028	0	0.11	0	0	0.014	0	0.096	0	0
	Santiago	Santo Domingo	Santo Tomas	Ugasan	Vista Alegre					
0.03-0.20	0.02	1.85	14.84	9.41	6.19					
0.21-0.50	0.0001	0.49	0.63	0.41	0.96					
0.51-1.00	0.000056	0.51	0.53	0.18	0.71					
1.01-2.00	0	0.84	0.59	0.14	0.5					
2.01-5.00	0	0.79	0.4	0.18	0.35					
> 5.00	0	0.012	0.049	0.046	0.017					

For the municipality of Lemery with an area of 149.382 sq. km., 0.40% will experience flood levels of less 0.20 meters. 0.012% of the area will experience flood levels of 0.21 to 0.50 meters while 0.002%, and 0.0004%,of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 46 are the affected areas in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Lemery (sq. km.)	
	Nasapahan	San Jose Moto
0.03-0.20	0.000011	0.6
0.21-0.50	0	0.017
0.51-1.00	0	0.0022
1.01-2.00	0	0.00053
2.01-5.00	0	0
> 5.00	0	0

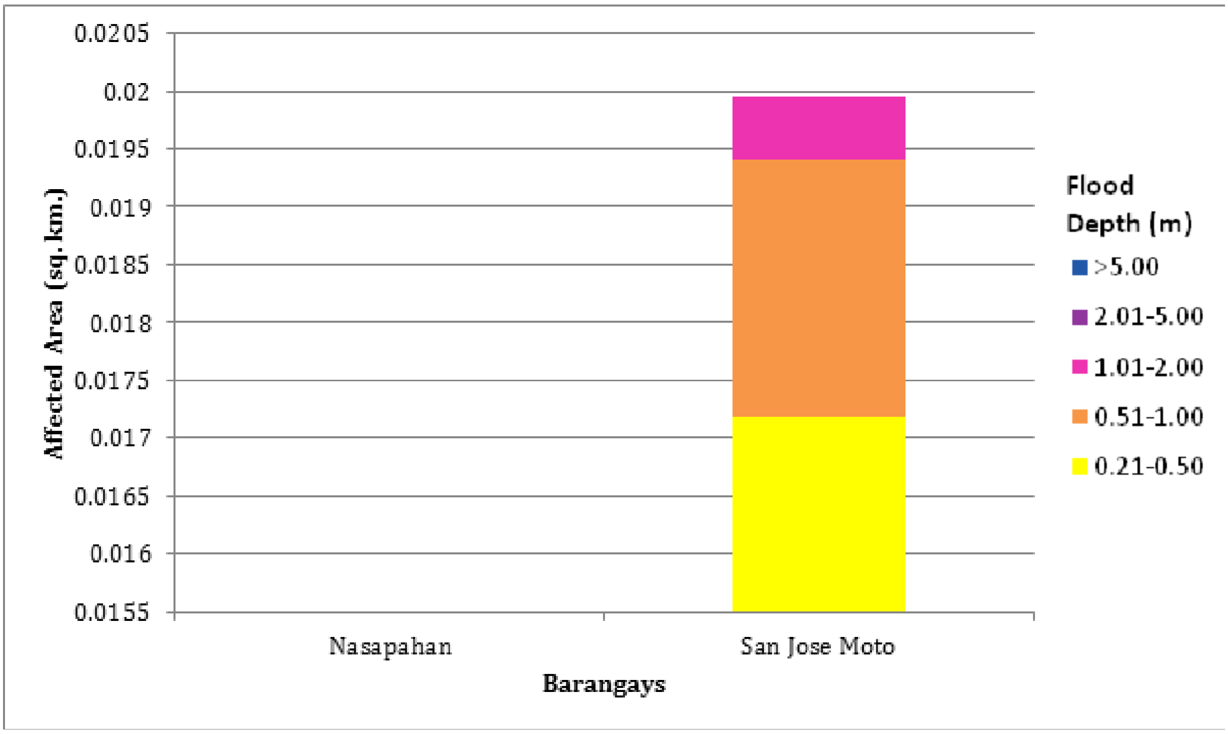


Figure 86. Affected Areas in Lemery, Iloilo during 25-Year Rainfall Return Period

For the municipality of San Enrique with an area of 105.44 sq. km., 0.005% will experience flood levels of less 0.20 meters. Listed in Table 47 are the affected areas in square kilometers by flood depth per barangay.

Table 47. Affected Areas in San Enrique, Iloilo during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in San Enrique (sq. km.)
	San Antonio
0.03-0.20	0.0056
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

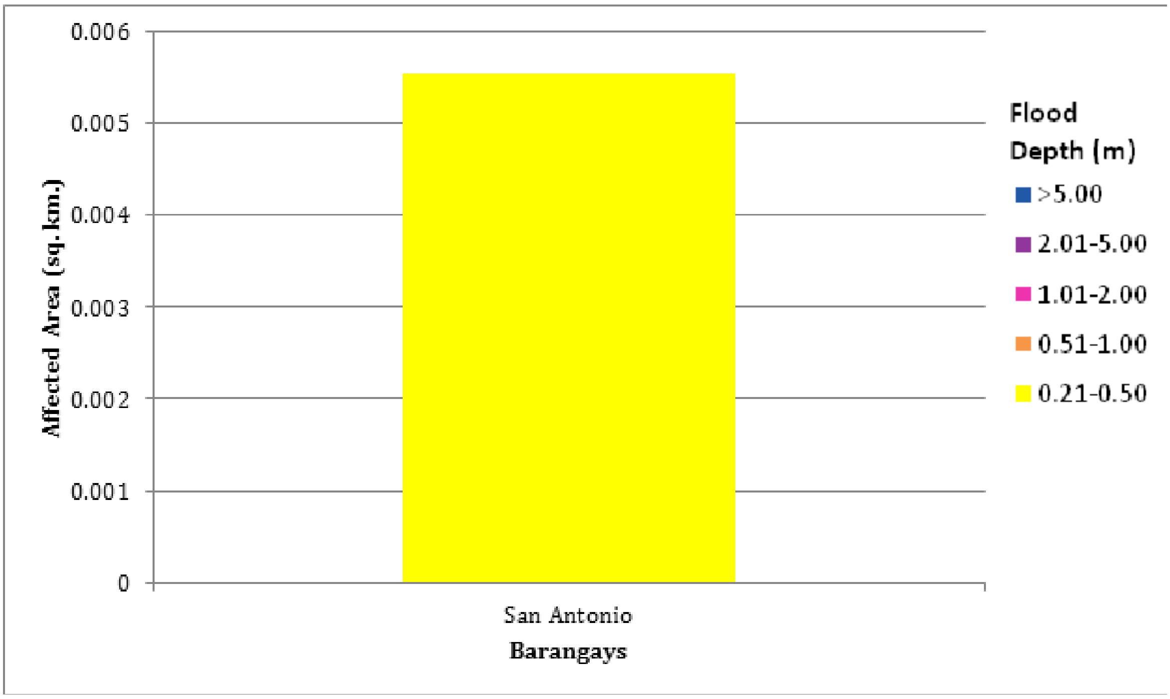


Figure 87. Affected Areas in San Enrique, Iloilo during 25-Year Rainfall Return Period

For the municipality of San Rafael, with an area of 84.01 sq. km., 9.67% will experience flood levels of less 0.20 meters. 0.28% of the area will experience flood levels of 0.21 to 0.50 meters while 0.11%, 0.053%, 0.02, 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 48 are the affected areas in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in San Rafael (sq. km.)			
	Aripdip	Ilongbukid	San Dionisio	San Florentino
0.03-0.20	0.001	1.27	3.79	3.07
0.21-0.50	0	0.03	0.12	0.081
0.51-1.00	0	0.014	0.052	0.026
1.01-2.00	0	0.0089	0.022	0.013
2.01-5.00	0	0.0018	0.0088	0.0082
> 5.00	0	0	0	0.0002

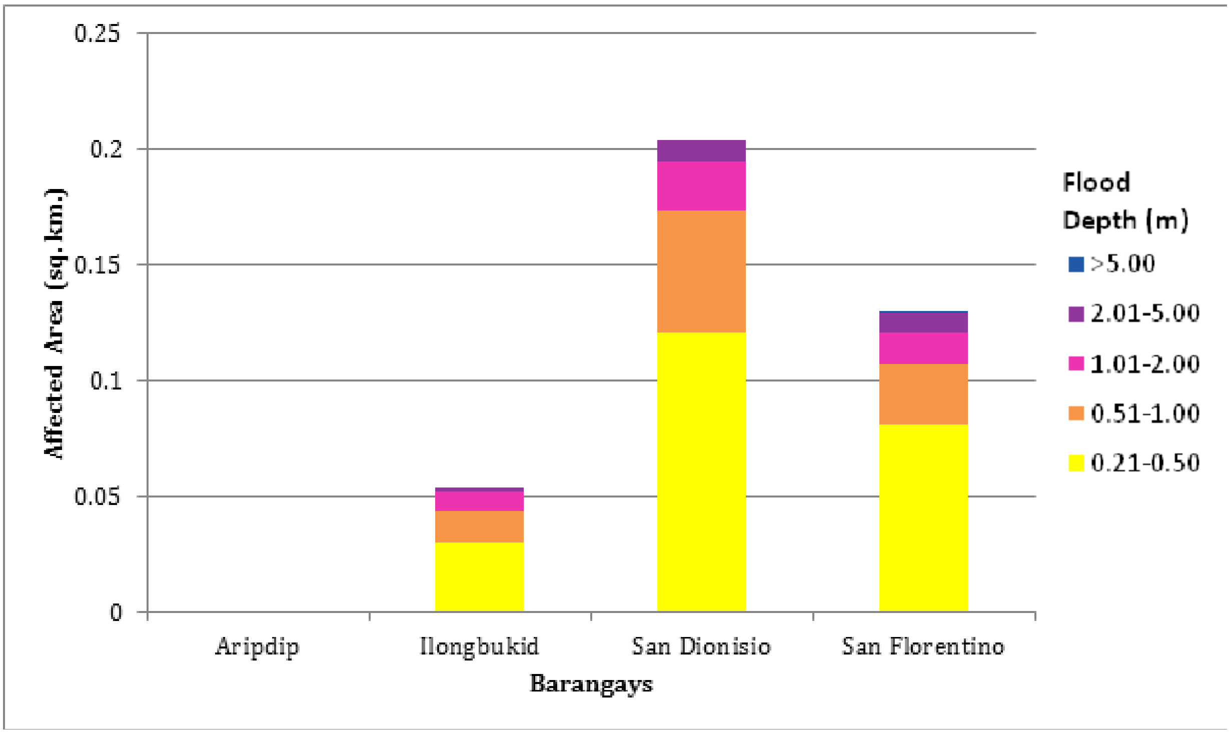


Figure 88. Affected Areas in Rafael, Iloilo during 25-Year Rainfall Return Period

For the 100-year return period, 4.61% of the municipality of Ajuy with an area of 170.88 sq. km. will experience flood levels of less 0.20 meters. 0.17% of the area will experience flood levels of 0.21 to 0.50 meters while 0.08%, 0.06%, 0.07%, and 0.01%of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 49 are the affected areas in square kilometers by flood depth per barangay.

Table 49. Affected Areas in Ajuy, Iloilo during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Ajuy (sq. km.)			
	Luca	Pili	Progreso	Santo Rosario
0.03-0.20	0.39	5.95	1.3	0.23
0.21-0.50	0.014	0.19	0.069	0.01
0.51-1.00	0.011	0.094	0.034	0.0038
1.01-2.00	0.0067	0.069	0.031	0.00015
2.01-5.00	0.011	0.1	0.014	0
> 5.00	0	0.018	0.00092	0

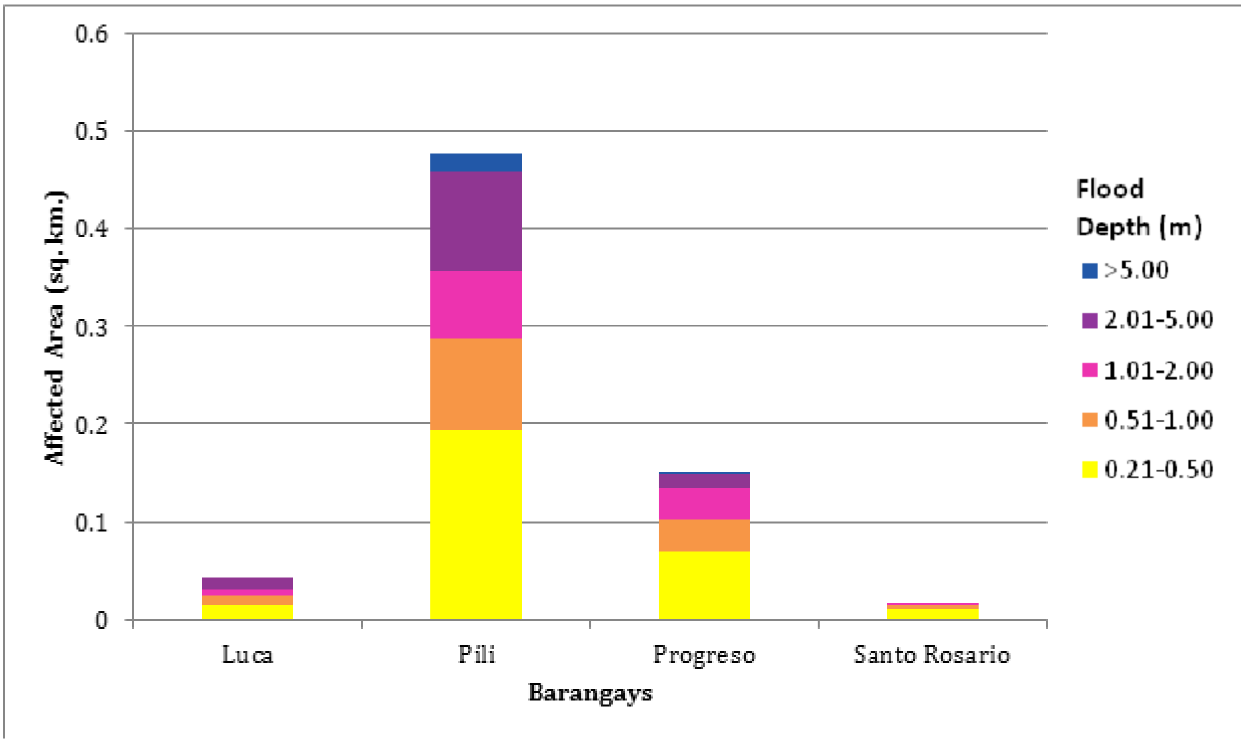


Figure 89. Affected Areas in Ajuy, Iloilo during 100-Year Rainfall Return Period

For the municipality of Anilao, with an area of 101.87 sq. km., 8.39% will experience flood levels of less 0.20 meters. 0.69% of the area will experience flood levels of 0.21 to 0.50 meters while 0.35%, 0.22%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 50 are the affected areas in square kilometers by flood depth per barangay.

Table 50. Affected Areas in Anilao, Iloilo during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Anilao (sq. km.)			
	Cag-An	Dangula-An	Guipis	Manganese
0.03-0.20	3.31	1.71	2.01	1.51
0.21-0.50	0.3	0.28	0.075	0.046
0.51-1.00	0.16	0.12	0.041	0.029
1.01-2.00	0.14	0.042	0.031	0.01
2.01-5.00	0.055	0.0049	0.011	0
> 5.00	0.0001	0	0	0

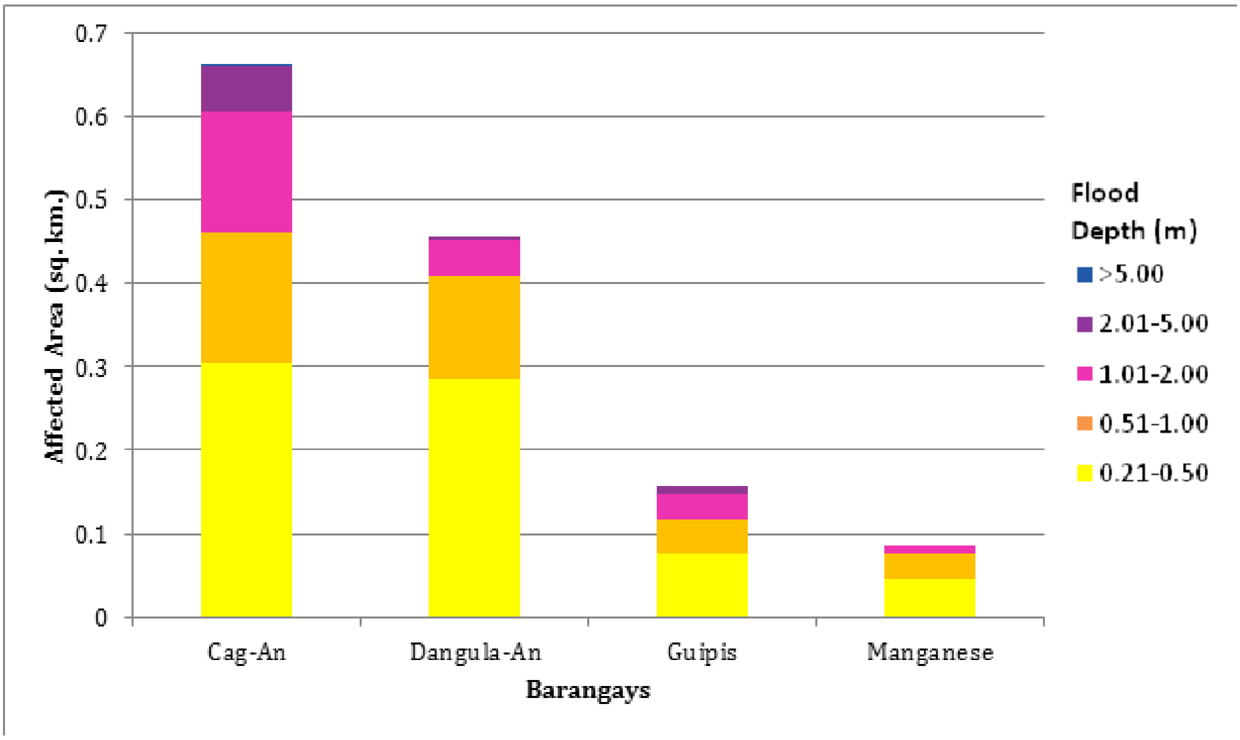


Figure 90. Affected Areas in Anilao, Iloilo during 100-Year Rainfall Return Period

For the municipality of Banate, with an area of 55.127 sq. km., 44.81% will experience flood levels of less 0.20 meters. 11% of the area will experience flood levels of 0.21 to 0.50 meters while 9.68%, 14.37%, 10.83%, and 0.035% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 51 are the affected areas in square kilometers by flood depth per barangay.

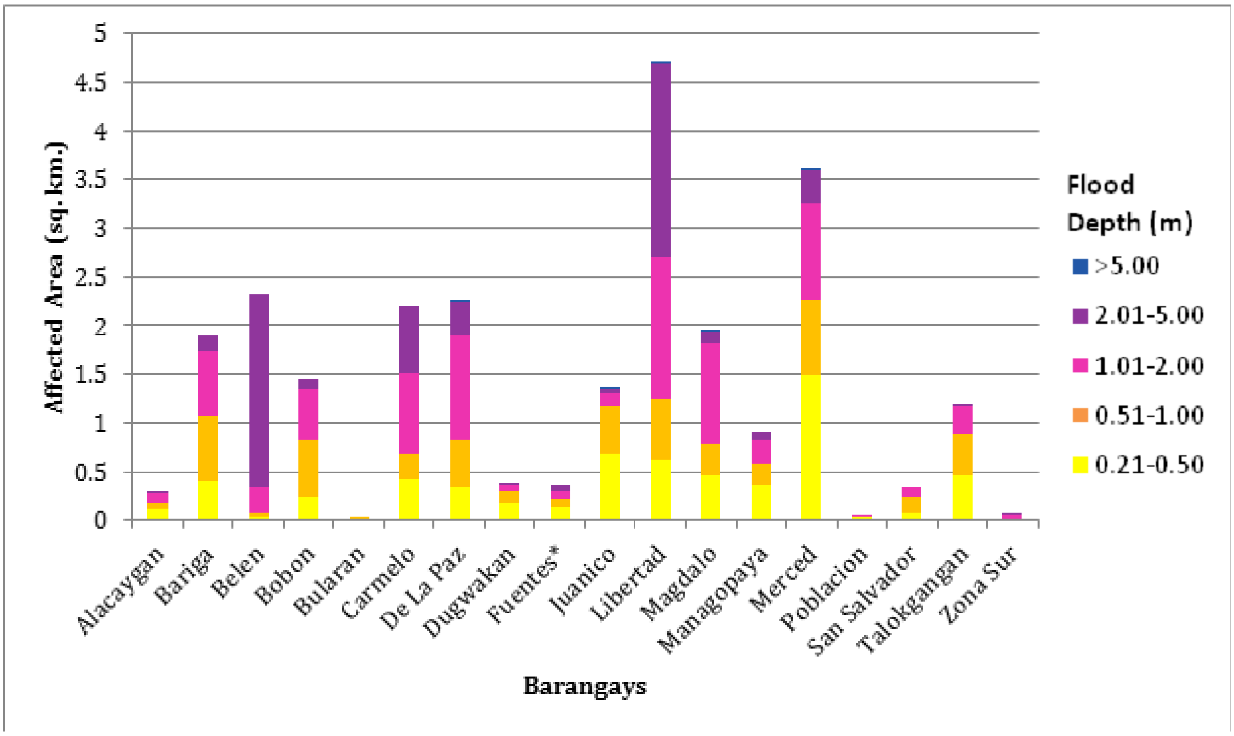


Figure 91. Affected Areas in Banate, Iloilo during 100-Year Rainfall Return Period

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

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Banate (sq. km.)									
	Alacaygan	Bariga	Belen	Bobon	Bularan	Carmelo	De La Paz	Dugwakan	Fuentes*	Juanico
0.03-0.20	0.086	2.62	0.31	0.74	0.094	0.76	4.58	1.67	0.46	1.26
0.21-0.50	0.12	0.39	0.027	0.24	0.021	0.42	0.34	0.19	0.14	0.68
0.51-1.00	0.046	0.68	0.053	0.58	0.0015	0.26	0.48	0.11	0.072	0.49
1.01-2.00	0.11	0.66	0.26	0.53	0	0.84	1.07	0.061	0.089	0.15
2.01-5.00	0.012	0.17	1.98	0.1	0	0.69	0.34	0.02	0.061	0.029
> 5.00	0	0	0	0	0	0	0.01	0	0	0.0053
	Affected Barangays in Banate (sq.km.)									
	Libertad	Magdalo	Managopaya	Merced	Poblacion	San Salva-dor	Talokgangan	Zona Sur		
0.03-0.20	2.01	1.37	3.98	2.89	0.086	1.04	0.7	0.039		
0.21-0.50	0.61	0.46	0.35	1.49	0.035	0.078	0.46	0.012		
0.51-1.00	0.63	0.32	0.23	0.78	0.0061	0.16	0.43	0.0061		
1.01-2.00	1.45	1.04	0.23	0.99	0.0081	0.1	0.29	0.04		
2.01-5.00	1.99	0.12	0.086	0.34	0	0	0.0066	0.011		
> 5.00	0.0034	0.0002	0	0.0001	0	0	0	0		

For the municipality of Barotac Viejo, with an area of 180.59 sq. km., 66.94% will experience flood levels of less 0.20 meters. 6.20% of the area will experience flood levels of 0.21 to 0.50 meters while 6.28%, 6.64%, 5.05%, and 0.89% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 52 are the affected areas in square kilometers by flood depth per barangay.

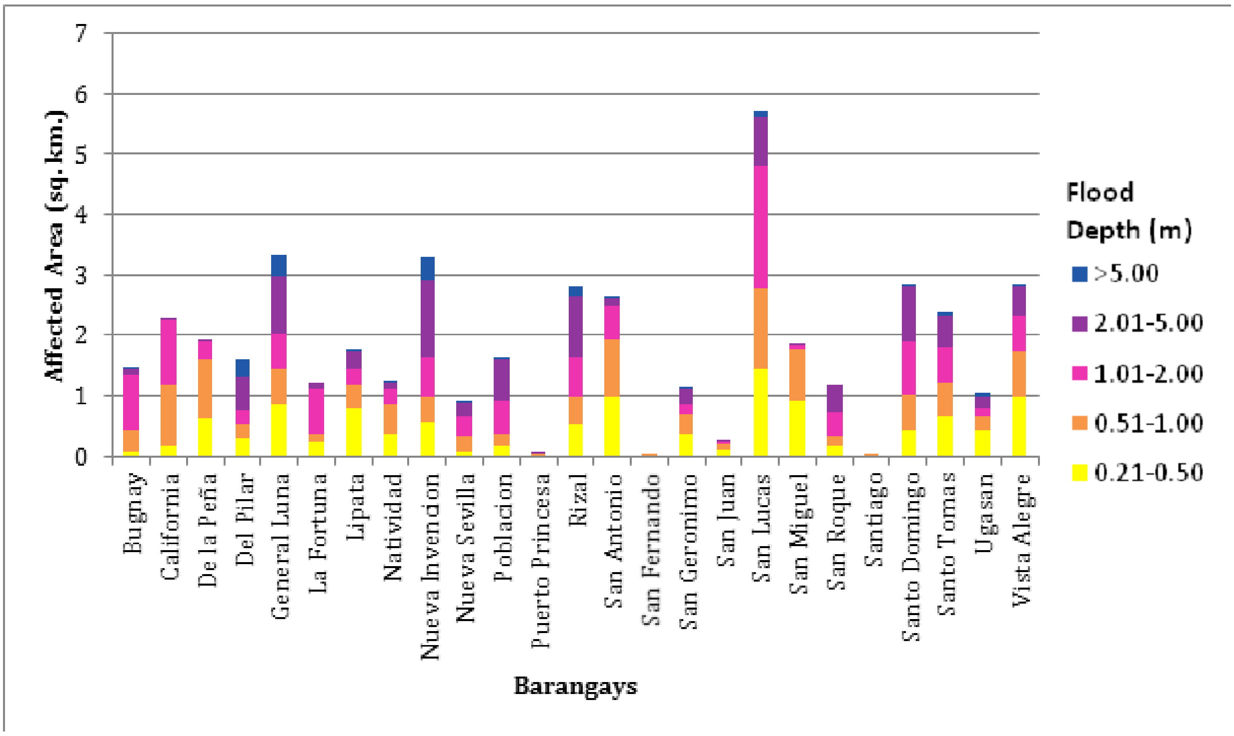


Figure 92. Affected Areas in Barotac Viejo, Iloilo during 100-Year Rainfall Return Period

Table 52 Affected Areas in Barotac Viejo, Iloilo during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Barotac Viejo (sq. km.)									
	Bugnay	**California**	**De la Peña**	**Del Pilar**	**General Luna**	**La Fortuna**	**Lipata**	**Natividad**	**Nueva Invencion**	**Nueva Sevilla**
0.03-0.20	0.13	0.35	0.43	8.3	18.12	2.03	14.36	2.57	12.65	0.17
0.21-0.50	0.065	0.16	0.62	0.3	0.87	0.25	0.78	0.35	0.55	0.079
0.51-1.00	0.36	1.01	0.98	0.22	0.57	0.13	0.4	0.51	0.44	0.26
1.01-2.00	0.91	1.07	0.28	0.25	0.6	0.72	0.26	0.24	0.64	0.3
2.01-5.00	0.11	0.031	0.013	0.54	0.94	0.11	0.3	0.12	1.28	0.23
> 5.00	0.0005	0	0	0.29	0.35	0	0.03	0.012	0.4	0.0009
	Poblacion	**Puerto Princesa**	**Rizal**	**San Anto-nio**	**San Fernando**	**San Geron-imo**	**San Juan**	**San Lucas**	**San Miguel**	**San Roque**
0.03-0.20	1.16	0.39	11.38	4.43	0.078	2.06	0.81	4.31	2.26	3.36
0.21-0.50	0.16	0.014	0.53	0.97	0.0033	0.36	0.11	1.44	0.92	0.15
0.51-1.00	0.2	0.0069	0.45	0.95	0.0025	0.33	0.078	1.34	0.86	0.18
1.01-2.00	0.56	0.0042	0.64	0.56	0	0.18	0.045	2.04	0.058	0.39
2.01-5.00	0.68	0.0019	1.04	0.12	0	0.26	0.0035	0.8	0.0032	0.44
> 5.00	0.033	0.000002	0.15	0.0003	0	0.018	0	0.1	0	0
	Santiago	**Santo Domingo**	**Santo Tomas**	**Ugasan**	Vista Alegre					
0.03-0.20	0.02	1.66	14.66	9.31	5.88					
0.21-0.50	0.0001	0.44	0.64	0.44	0.97					
0.51-1.00	0.000056	0.57	0.55	0.2	0.75					
1.01-2.00	0	0.89	0.6	0.15	0.59					
2.01-5.00	0	0.91	0.52	0.2	0.49					
> 5.00	0	0.02	0.081	0.068	0.042					

For the municipality of Lemery with an area of 149.382 sq. km., 0.40% will experience flood levels of less 0.20 meters. 0.013% of the area will experience flood levels of 0.21 to 0.50 meters while 0.002%, and 0.0006%,of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 53 are the affected areas in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in Lemery (sq. km.)	
	Nasapahan	San Jose Moto
0.03-0.20	0.000011	0.59
0.21-0.50	0	0.019
0.51-1.00	0	0.0033
1.01-2.00	0	0.00083
2.01-5.00	0	0
> 5.00	0	0

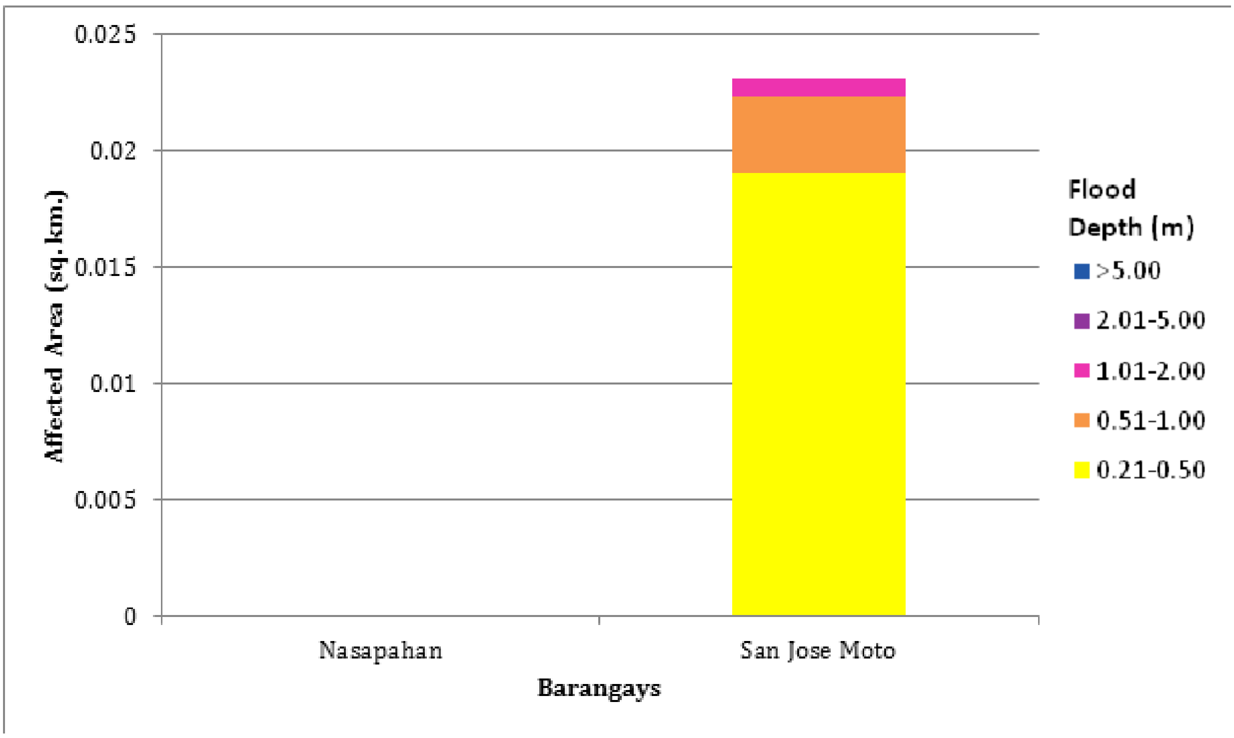


Figure 93. Affected Areas in Lemery, Iloilo during 100-Year Rainfall Return Period

For the municipality of San Enrique with an area of 105.44 sq. km., 0.005% will experience flood levels of less 0.20 meters. Listed in Table 54 are the affected areas in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in San Enrique (sq. km.)
	San Antonio
0.03-0.20	0.0056
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

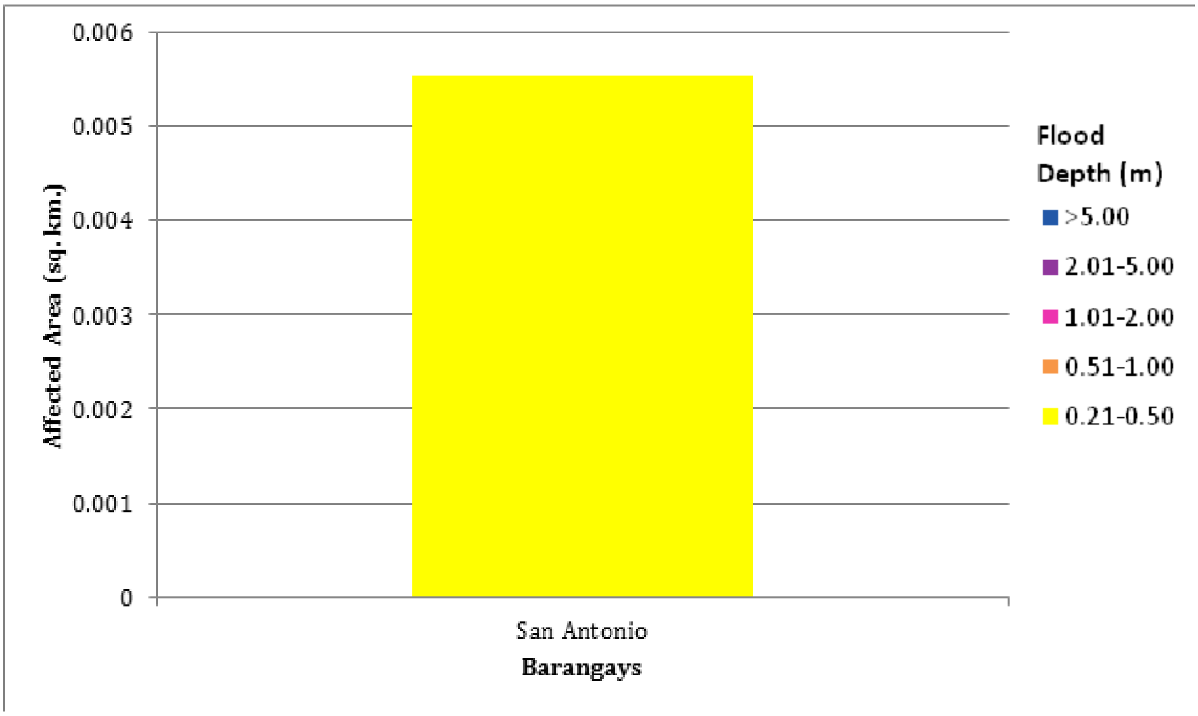


Figure 94. Affected Areas in San Enrique, Iloilo during 100-Year Rainfall Return Period

For the municipality of San Rafael, with an area of 84.01 sq. km., 9.61% will experience flood levels of less 0.20 meters. 0.30% of the area will experience flood levels of 0.21 to 0.50 meters while 0.13%, 0.064%, 0.03, and 0.0005% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 55 are the affected areas in square kilometers by flood depth per barangay.

Table 55. Affected Areas in San Rafael, Iloilo during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (m.)	Affected Barangays in San Rafael (sq. km.)			
	Aripdip	Ilongbukid	San Dionisio	San Florentino
0.03-0.20	0.001	1.26	3.76	3.05
0.21-0.50	0	0.034	0.13	0.088
0.51-1.00	0	0.015	0.062	0.032
1.01-2.00	0	0.01	0.027	0.017
2.01-5.00	0	0.0026	0.011	0.01
> 5.00	0	0	0	0.0004

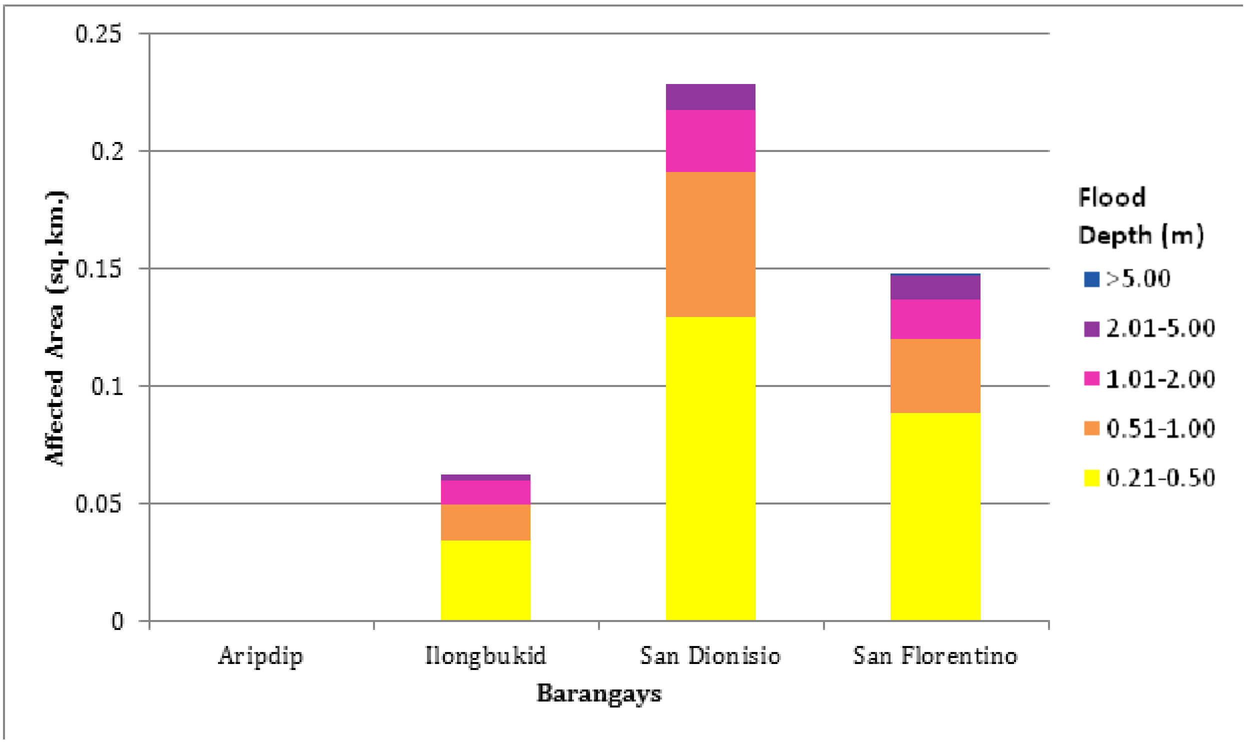


Figure 95. Affected Areas in Rafael, Iloilo during 100-Year Rainfall Return Period

Among the barangays in the municipality of AJuy, Piliis projected to have the highest percentage of area that will experience flood levels at 3.76%. Meanwhile, Progreso posted the second highest percentage of area that may be affected by flood depths at 0.85%.

Among the barangays in the municipality of Anilao, Cag-An is projected to have the highest percentage of area that will experience flood levels at 3.90%. Meanwhile, Dangula posted the second highest percentage of area that may be affected by flood depths at 2.13%.

Among the barangays in the municipality of Banate, De La Paz is projected to have the highest percentage of area that will experience flood levels at 12.37%. Meanwhile, Libertad posted the second highest percentage of area that may be affected by flood depths at 12.16%.

Among the barangays in the municipality of Barotac Viejo, General Luna is projected to have the highest percentage of area that will experience flood levels at 11.88%. Meanwhile, Dangula posted the second highest percentage of area that may be affected by flood depths at 9.44%.

Among the barangays in the municipality of Lemery, San Jose is projected to have the highest percentage of area that will experience flood levels at 0.41%. Meanwhile, Nasapahan posted the second highest percentage of area that may be affected by flood depths at 7.36367E-06.

Among the barangays in the municipality of San Enrique, San Antonio is projected to have the highest percentage of area that will experience flood levels at 0.005%.

Among the barangays in the municipality of San Rafael, San Dionisio is projected to have the highest percentage of area that will experience flood levels at 4.75%. Meanwhile, San Florentino posted the second highest percentage of area that may be affected by flood depths at 3.81%.

Moreover, the generated flood hazard maps for the Barotac 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 56. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	19.17	18.68	18.08
Medium	27.28	28.58	28.40
High	14.96	21.70	27.41
Total	**61.41**	**68.96**	**73.89**

Of the forty-one (41) identified Education Institutions in the Barotac Flood plain, 6 schools were assessed to be exposed to the low level flooding during a 5 year scenario while 4 schools were assessed to be exposed to medium flooding in the same scenario. In the 25 year scenario, 6 schools were assessed to be exposed to the low level flooding while 4 schools were assessed to be exposed to medium flooding in the same scenario. In the 100 year scenario, 4 schools were assessed to be exposed to the low level flooding scenario, 7 schools were assessed to be exposed to the medium level flooding scenario, and 1 school was assessed to be exposed to the medium level flooding scenario..

Nineteen (19) Medical Institutions were identified in Barotac Floodplain, 1 medical institution was assessed to be exposed to the low level flooding during a 5 year scenario, 1was assessed to be exposed to the medium level flooding, while 1 medical institution was assessed to be exposed to high flooding in the same scenario. In the 25 year scenario, 1 medical institution was assessed to be exposed to the medium level flooding while 2medical institutions were assessed to be exposed to high flooding in the same scenario.. In the 100 year scenario, 2medical institutions were assessed to be exposed to the low level flooding scenario, 1medical institution was assessed to be exposed to the medium level flooding scenario, and 1 medical institution was assessed to be exposed to the high level flooding scenario..

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there was 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 or interview some residents with knowledge of or have had experienced flooding in a particular area.

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 97.

The flood validation consists of 191 points randomly selected all over the Barotac flood plain (Figure 96). Comparing it with the flood depth map of the nearest storm event, the maphas an RMSE value of 0.736m. Table 57 shows a contingency matrix of the comparison.

The validation points data were obtained on February 8, 2017.

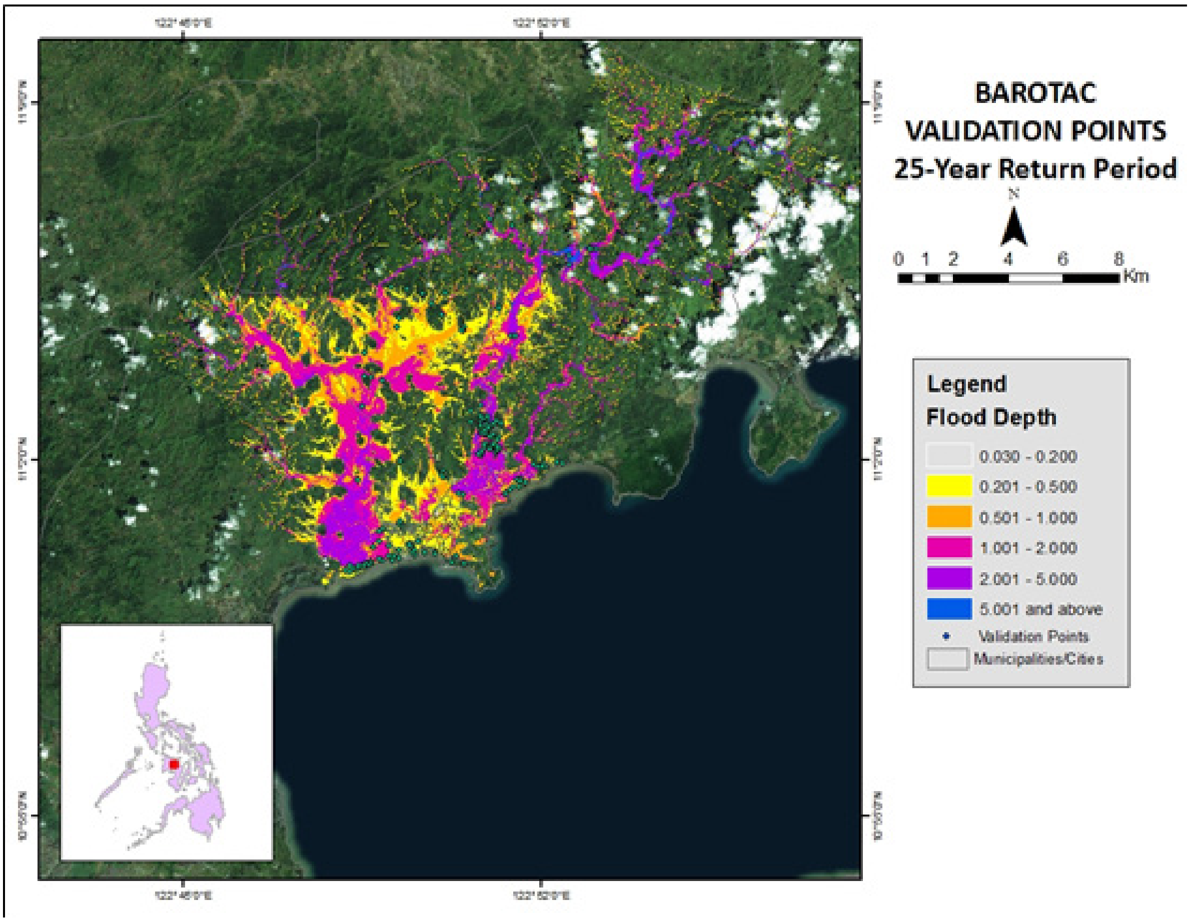


Figure 96. Validation points for 25-year Flood Depth Map of Barotac Floodplain

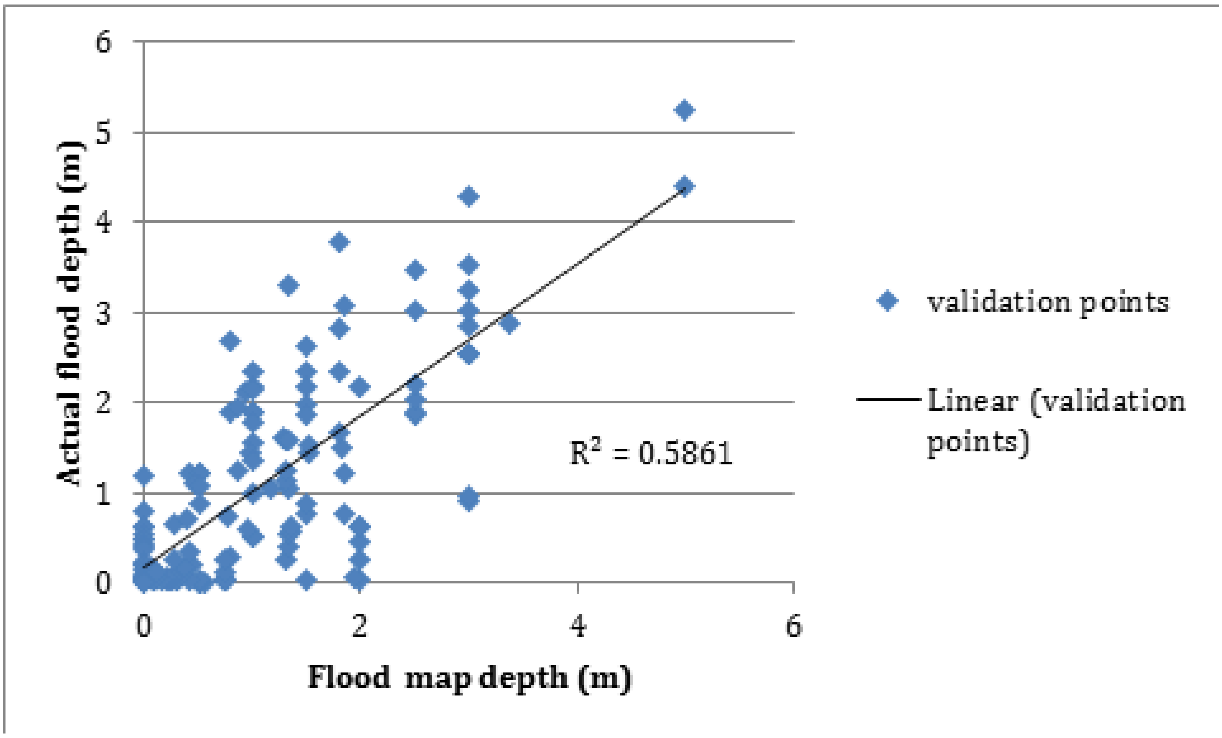


Figure 97. Flood map depth vs actual flood depth

Table 57 Actual Flood Depth vs Simulated Flood Depth in Barotac at different levels in the Barotac 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	29	14	8	15	24	1	91
0.21-0.50	7	2	4	4	1	0	18
0.51-1.00	4	3	3	8	2	0	20
1.01-2.00	1	5	9	14	2	0	31
2.01-5.00	0	0	5	10	13	1	29
> 5.00	0	0	0	1	1	0	2
Total	41	24	29	52	43	2	191

On the whole, The overall accuracy generated by the flood model is estimated at 31.94%, with 61 points correctly matching the actual flood depths. In addition, there were 59 points estimated one level above and below the correct flood depths while there were 29 points and 17 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 84 points were overestimated while a total of 46 points were underestimated in the modelled flood depths of Barotac.Table 58 depicts the summary of the Accuracy Assessment in the Barotac River Basin Survey.

Table 58. Summary of Accuracy Assessment in the Barotac River Basin Survey

	No. of Points	%
Correct	61	31.94
Overestimated	84	43.98
Underestimated	46	24.08
Total	191	100

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1.

OPTECH TECHNICAL SPECIFICATION OF THE PEGASUS SENSOR

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

OPTECH TECHNICAL SPECIFICATION OF THE GEMINI SENSOR

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

OPTECH TECHNICAL SPECIFICATION OF THE D-8900 AERIAL DIGITAL CAMERA

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

Annex 2. NAMRIA CERTIFICATES OF REFERENCE POINTS USED

1. ATQ-18

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

March 02, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **ANTIQUE**	
	Station Name: **ATQ-18**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **CUBAY**	
Municipality: **BARBAZA**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **11° 11' 58.67081"**	Longitude: **122° 2' 22.83300"**	Ellipsoidal Hgt: **10.90200 m.**
	WGS84 Coordinates	
Latitude: **11° 11' 54.16068"**	Longitude: **122° 2' 28.01549"**	Ellipsoidal Hgt: **65.96100 m.**
	PTM / PRS92 Coordinates	
Northing: **1238579.674 m.**	Easting: **395119.157 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,238,146.15**	Easting: **395,155.87**	Zone: **51**

Location Description

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

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

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

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

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

2. ATQ-22

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

March 02, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **ANTIQUE**	
	Station Name: **ATQ-22**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **CONCEPCION**	
Municipality: **BELISON**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **10° 49' 46.66618"**	Longitude: **121° 58' 11.90221"**	Ellipsoidal Hgt: **12.25000 m.**
	WGS84 Coordinates	
Latitude: **10° 49' 42.24271"**	Longitude: **121° 58' 17.11770"**	Ellipsoidal Hgt: **68.02200 m.**
	PTM / PRS92 Coordinates	
Northing: **1197676.056 m.**	Easting: **387365.279 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,197,256.85**	Easting: **387,404.70**	Zone: **51**

Location Description

ATQ-22

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

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

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

9 9 0 3 0 2 2 0 1 5 1 3 0 9 5 8

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. ILO-97

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

October 28, 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-97 (LEM-1)**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **TABUNAN**	
Municipality: **LEMERY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **11° 13' 54.08920"**	Longitude: **122° 55' 50.84966"**	Ellipsoidal Hgt: **88.56000 m.**
	WGS84 Coordinates	
Latitude: **11° 13' 49.64749"**	Longitude: **122° 55' 56.02324"**	Ellipsoidal Hgt: **145.73700 m.**
	PTM / PRS92 Coordinates	
Northing: **1241955.878 m.**	Easting: **492442.632 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,241,521.17**	Easting: **492,445.28**	Zone: **51**

Location Description

ILO-97 (LEM-1)
From Iloilo City, travel NE to the Mun. of Lemery. Then from the town proper, go to Brgy. Tabunan along the Lemery-Sara Nat'l. Rd. Station is located on the headwall of an irrigation gate at the left side going to Sara. It is situated about 50 m. from a Duhat tree, 200 m. from the welcome arch of Pob. Lemery and about 210 m. and 300 m. NW of Km. Post No. 89 and Total Gas Station, respectively. Mark is the head of a 4 in. copper nail set flushed and centered on a 20 cm. x 20 cm. cement putty, with inscriptions "STA. LEM 1 PRS 92 DENR 08-282003".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8088472 I**
T.N.: **2015-3528**

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

9 9 1 0 2 8 2 0 1 5 1 3 4 9 5 6

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

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ILO-71 --- IL-608 (B1)	ILO-71	IL-608	Fixed	0.003	0.011	62°57'29"	6813.760	-30.336
ILO-71 --- IL-608 (B2)	ILO-71	IL-608	Fixed	0.004	0.012	62°57'28"	6813.751	-30.334
ILO-71 --- IL-608 (B3)	ILO-71	IL-608	Fixed	0.005	0.011	62°57'29"	6813.700	-30.384

Acceptance Summary

Processed	Passed	Flag	Fail
3	3	0	0

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

5. IIAP-01

Baseline Processing Report

Processing Summary

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

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

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

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

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

Standard Errors

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

6. ILO-104

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

October 28, 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-104**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **POBLACION**	
Municipality: **AJUY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **11° 9' 53.30263"**	Longitude: **123° 0' 46.92545"**	Ellipsoidal Hgt: **11.59700 m.**
	WGS84 Coordinates	
Latitude: **11° 9' 48.88466"**	Longitude: **123° 0' 52.10452"**	Ellipsoidal Hgt: **69.13900 m.**
	PTM / PRS92 Coordinates	
Northing: **1234557.253 m.**	Easting: **501423.696 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,234,125.14**	Easting: **501,423.20**	Zone: **51**

Location Description

ILO-104
From Iloilo City, travel NE to the Mun. of Ajuy. Then from the town proper, travel SW to Ajuy Nat'l. High School for about 1 km. Station is located on the headwall of an irrigation gate, at the left side of the road leading to the said school about 90 m. from the provincial road. Mark is the head of a 4 in. copper nail set flushed on top of a 30 cm. x 30 cm. concrete monument protruding 20 cm. above the ground, with inscriptions "ILO-104 2007 NAMRIA".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8088472 I**
T.N.: **2015-3527**

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

9 9 1 0 2 8 2 0 1 5 1 3 4 9 4 1

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

Annex 3 Baseline Processing Reports of Control Points Used in the LiDAR Survey

This river basin has no Baseline Processing Report

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. GEROME HIPOLITO	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELYN ASUNCION	UP-TCAGP
	Research Associate (RA)	MA. VERLINA TONGA	UP-TCAGP
	RA	REGINA FELISMINO	UP-TCAGP
	RA	KRISTINE ANDAYA	UP-TCAGP
	RA	REMEDIOS VILLANUEVA	UP-TCAGP
	RA	MARY CATHERINE BALIGUAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	KENNETH QUISADO	UP-TCAGP
	RA	JONATHAN ALMALVEZ	UP-TCAGP
	RA	IRO NIEL ROXAS	UP-TCAGP

Annex 5. DATA TRANSFER SHEET FOR BAROTAC FLOODPLAIN

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 RA
Signature

Received by

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

DATA TRANSFER SHEET

[illegible]

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	1BLK43JD045A	pegasus	1.26	940	6.96	196	10.5	30/48	14.4	na	10.5	1KB	1KB	76	na	Z:\DAC\RAW DATA
16-Feb-15	2579P	1BLK43JM047B	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	1BLK43MN048A	pegasus	2.06	1.35	9.59	253	34.3	265	21.4	na	20.3	1KB	1KB	76/71/21	na	Z:\DAC\RAW DATA
17-Feb-15	2583P	1BLK43JD048B	pegasus	1.11	716	6.56	170	14	127	11.4	na	20.2	1KB	1KB	96/70	na	Z:\DAC\RAW DATA
18-Feb-15	2585P	1BLK43EF049A	pegasus	2.91	1.71	9.97	263	43	314	27.8	na	14.3	1KB	1KB	95/117	na	Z:\DAC\RAW DATA
18-Feb-15	2587P	1BLK43ED049B	pegasus	1.7	1.02	5.55	130	19.9	90/71	17.4	na	7.48	1KB	1KB	140/77	na	Z:\DAC\RAW DATA
19-Feb-15	2589P	1BLK43EFD050A	pegasus	1.2	739	7.74	417	17.3	153	12.3	na	16.7	1KB	1KB	[illegible] 1	na	Z:\DAC\RAW DATA
19-Feb-15	2591P	1BLK37I050B	pegasus	5.55	1.03	9.47	199	49.9	343	26.3	na	9.75	1KB	1KB	64	na	Z:\DAC\RAW DATA
20-Feb-15	2595P	1BLK43BDG051A	pegasus	3.14	1.81	7.62	213	27	218	16.3	na	11	1KB	1KB	116	na	Z:\DAC\RAW DATA
21-Feb-15	2597P	1BLK43N052A	pegasus	2.09	1.29	9.69	257	37.9	274	21	na	11.5	1KB	1KB	52	na	Z:\DAC\RAW DATA
22-Feb-15	2601P	1BLK37IFV053A	pegasus	2.13	1.37	9.86	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

DATA TRANSFER SHEET
7/3/2014(Iloilo)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
25-Feb-15	2602G	2BLK43B056A	GEMINI	NA	278	402	167	8.44	61	5.95	NA	9.49	1KB	1KB	12	17	Z:\DAC\RAW DATA
26-Feb-15	2606G	2BLK43BV057A	GEMINI	NA	739	932	208	22.5	92	12.6	NA	9.26	1KB	1KB	12	18	Z:\DAC\RAW DATA
27-Feb-15	2610G	2BLK43BV058A	GEMINI	NA	100	190	173	2.88	25	2.95	NA	8.94	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
5-Mar-15	2634G	2BLK37FV064A	GEMINI	NA	298	532	170	14.6	12[illegible]	5.2	NA	22.7	1KB	1KB	8	13	Z:\DAC\RAW DATA
5-Mar-15	2636G	2BLK43OS064B	GEMINI	NA	468	770	205	23.2	105	5.05	NA	22.7	1KB	1KB	8	18	Z:\DAC\RAW DATA
6-Mar-15	2638G	2BLK43OS065A	GEMINI	NA	581	894	234	27.5	[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 Carlo Bragat
Position
Signature

DATA TRANSFER SHEET
Capiz-Aklan 10/9/15

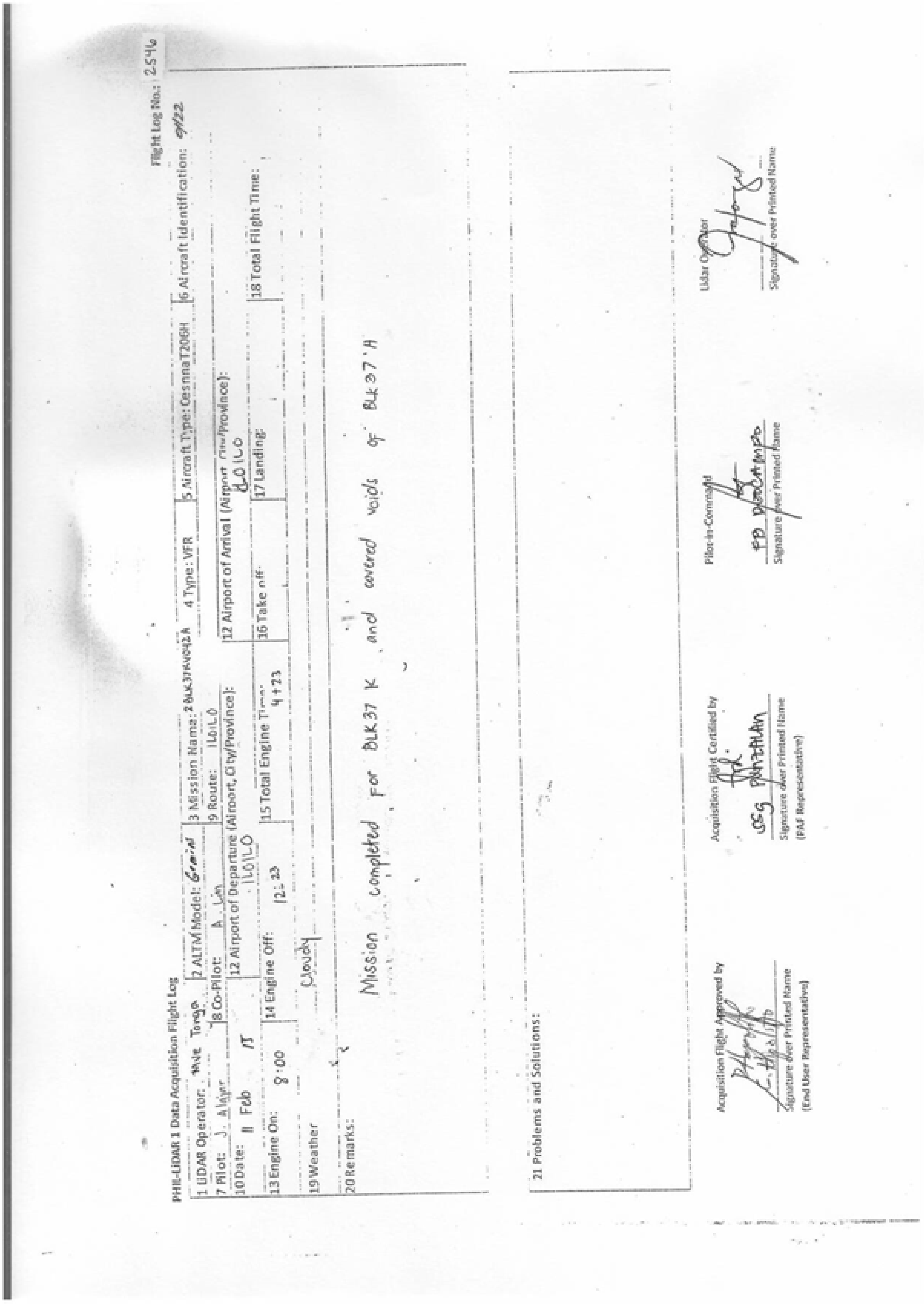
DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
23-Sep	2762G	2CALIBBLK38K266A	gemini	na	220	896	243	40.4	311	17.8	na	75.4	1KB	1KB	43	na	Z:\DAC\RAW DATA
24-Sep	2766G	2BLK38C267A	gemini	na	1019	1.18	243	34.9	254	28.8	na	82.8	1KB	1KB	27	na	Z:\DAC\RAW DATA
24-Sep	2768G	2BLK38G267B	gemini	na	403	790	185	34.9/4.65	254/37	17.3	na	82.8	1KB	1KB	29	na	Z:\DAC\RAW DATA
25-Sep	2770G	2BLK38BDVES268A	gemini	na	638	1	245	56.7	451	29.8	na	83.1	1KB	1KB	29	na	Z:\DAC\RAW DATA
25-Sep	2772G	2BLK38GS268B	gemini	na	883	948	186	40.9	314	20.6	na	83.1	1KB	1KB	28	na	Z:\DAC\RAW DATA
26-Sep	2774G	2BLK38ES269A	gemini	na	620/85	0.99	255	21.7/20.6	208/180	26.3	na	74.3	1KB	1KB	9	na	Z:\DAC\RAW DATA
26-Sep	2776G	2BLK38J269B	gemini	na	97/15	661	84.2	7.74	39	5.16	na	74.3	1KB	1KB	19	na	Z:\DAC\RAW DATA
30-Sep	2790G	2BLK38BSF273A	gemini	na	1318	1.5	258	57.4	272	28.1	na	93.5	1KB	1KB	30	na	Z:\DAC\RAW DATA
30-Sep	2792G	2BLK37IJ273B	Pegasus	212	555	791	190	11.4/22.7	90/215	21.6	na	93.5	1KB	1KB	21	na	Z:\DAC\RAW DATA

Received from
Name C. Joaquin
Position RA
Signature

Received by
Name Irish R. Cortez 10/9/15
Position RA
Signature

Annex 6. FLIGHT LOGS

1. Flight Log for 2546G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2546

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK37KV042A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: ILOILO			
10 Date: 11 Feb 17	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 BLK37K and covered voids of BLK37'A

21 Problems and Solutions:

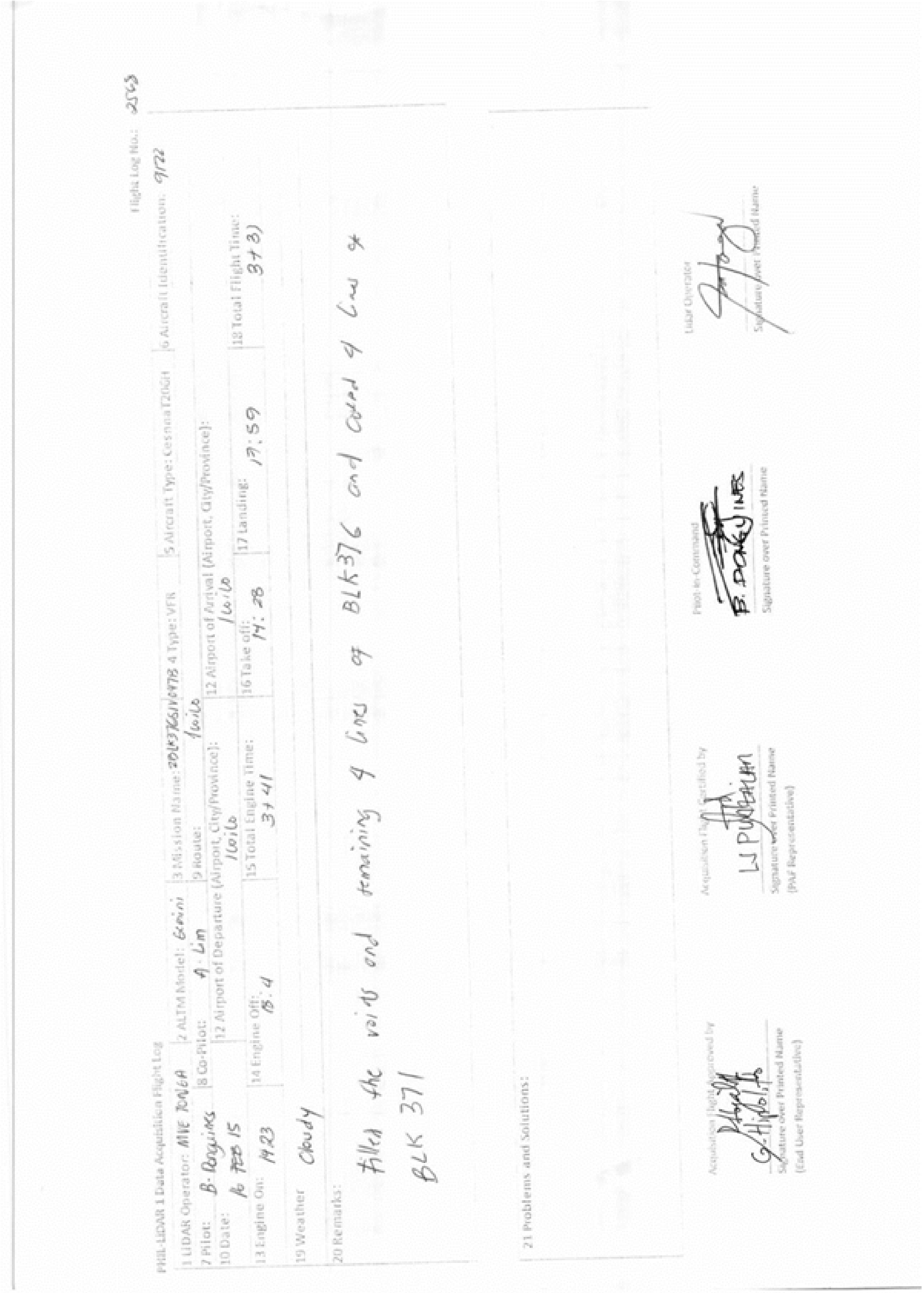
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

2. Flight Log for 2568G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2568

1 LIDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK37GS1V047B	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: B. Dongiines	8 Co-Pilot: A. Lim	9 Route: Iloilo			
10 Date: Feb 15	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province): Iloilo		
13 Engine On: 1423	14 Engine Off: 18:4	15 Total Engine Time: 3+41	16 Take off: 14:28	17 Landing: 17:59	18 Total Flight Time: 3+31
19 Weather: Cloudy					

20 Remarks:

Filled the voids and remaining 4 lines of BLK376 and covered 4 lines of BLK 371

21 Problems and Solutions:

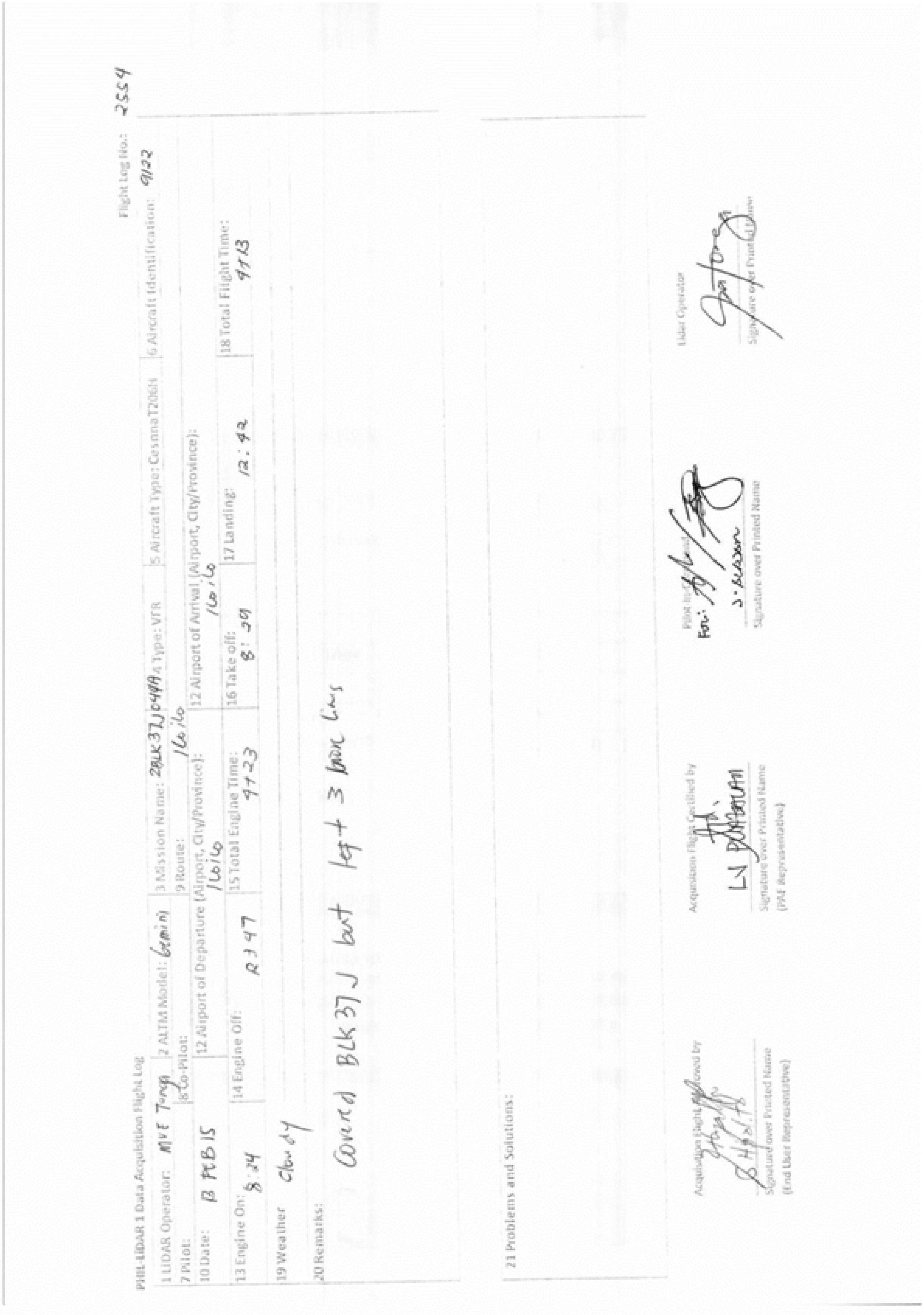
Acquisition Flight Approved by: G. Hipolito — Signature over Printed Name (End User Representative)

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

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

Lidar Operator: Signature over Printed Name

3. Flight Log for 2554G Mission



4. Flight Log for 2556G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2556

1 LIDAR Operator: RA FELISMINO	2 ALTM Model: Gemini	3 Mission Name: 2BLK37JS6044B	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:					

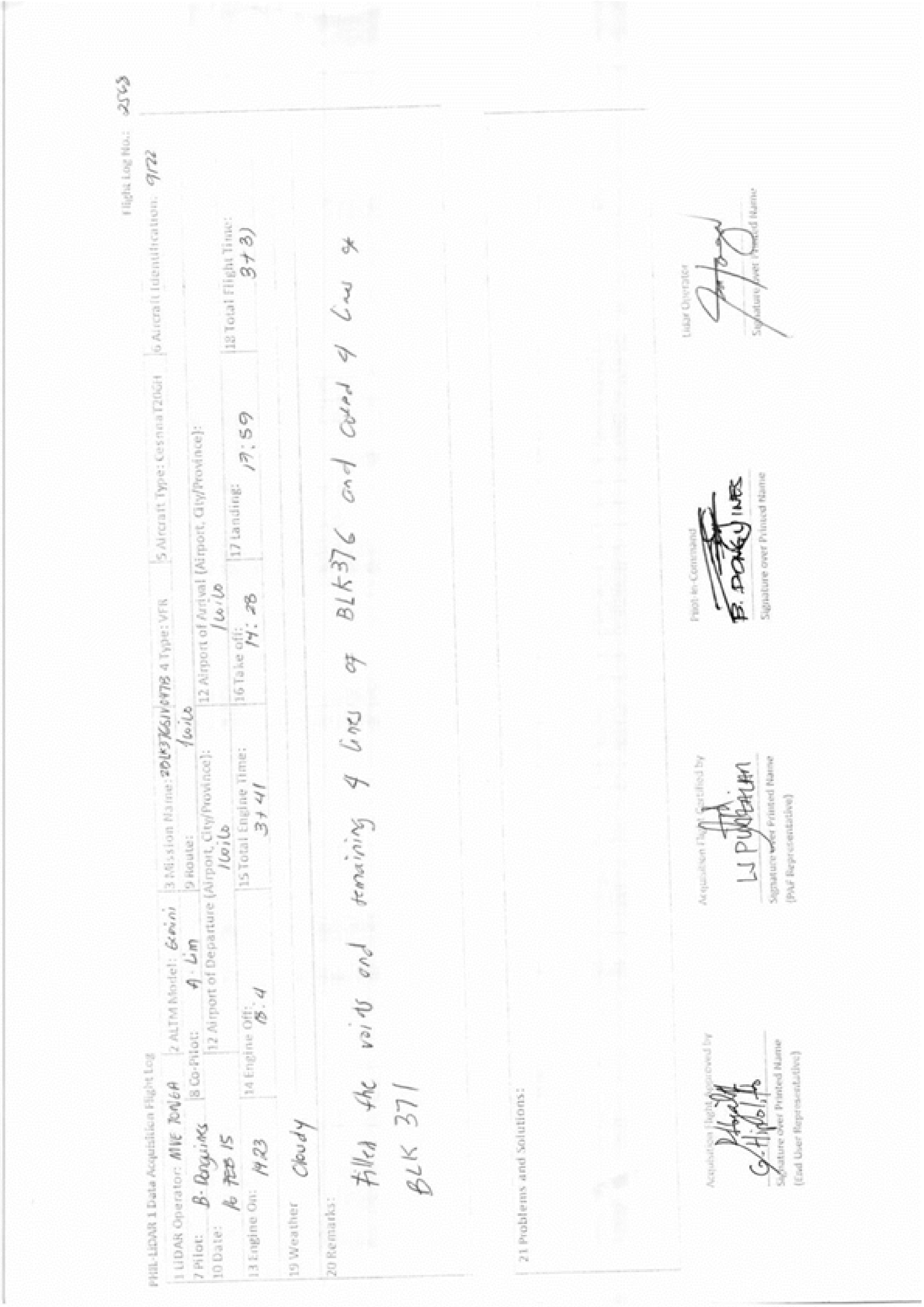
Acquisition Flight Approved by
C. Hipolito
Signature over Printed Name
(End User Representative)

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

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

Lidar Operator
rafelismino
Signature over Printed Name

5. Flight Log for 2568G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log — Flight Log No.: 2568

1 LiDAR Operator: MVE JONGEA	2 ALTM Model: Gemini	3 Mission Name: 2BLK37GS14047B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: B. Dongiines	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: 14:23	14 Engine Off: 18:4	15 Total Engine Time: 3+41	16 Take off: 14:28	17 Landing: 17:59	18 Total Flight Time: 3+31

19 Weather: Cloudy

20 Remarks:

Filled the voids and remaining 4 lines of BLK37G and covered 4 lines of BLK 37I

21 Problems and Solutions:

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

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

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

Lidar Operator: Signature over Printed Name

6. Flight Log for 2591P Mission

Flight Log No.: 2591

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: KJ Andaya	2 ALTM Model: Pegasus	3 Mission Name: 1BLK37I050B	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: 02 - 19 - 2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1410	14 Engine Off: 1739	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: fair					
20 Remarks: Completed BLK 37I.					
21 Problems and Solutions:					

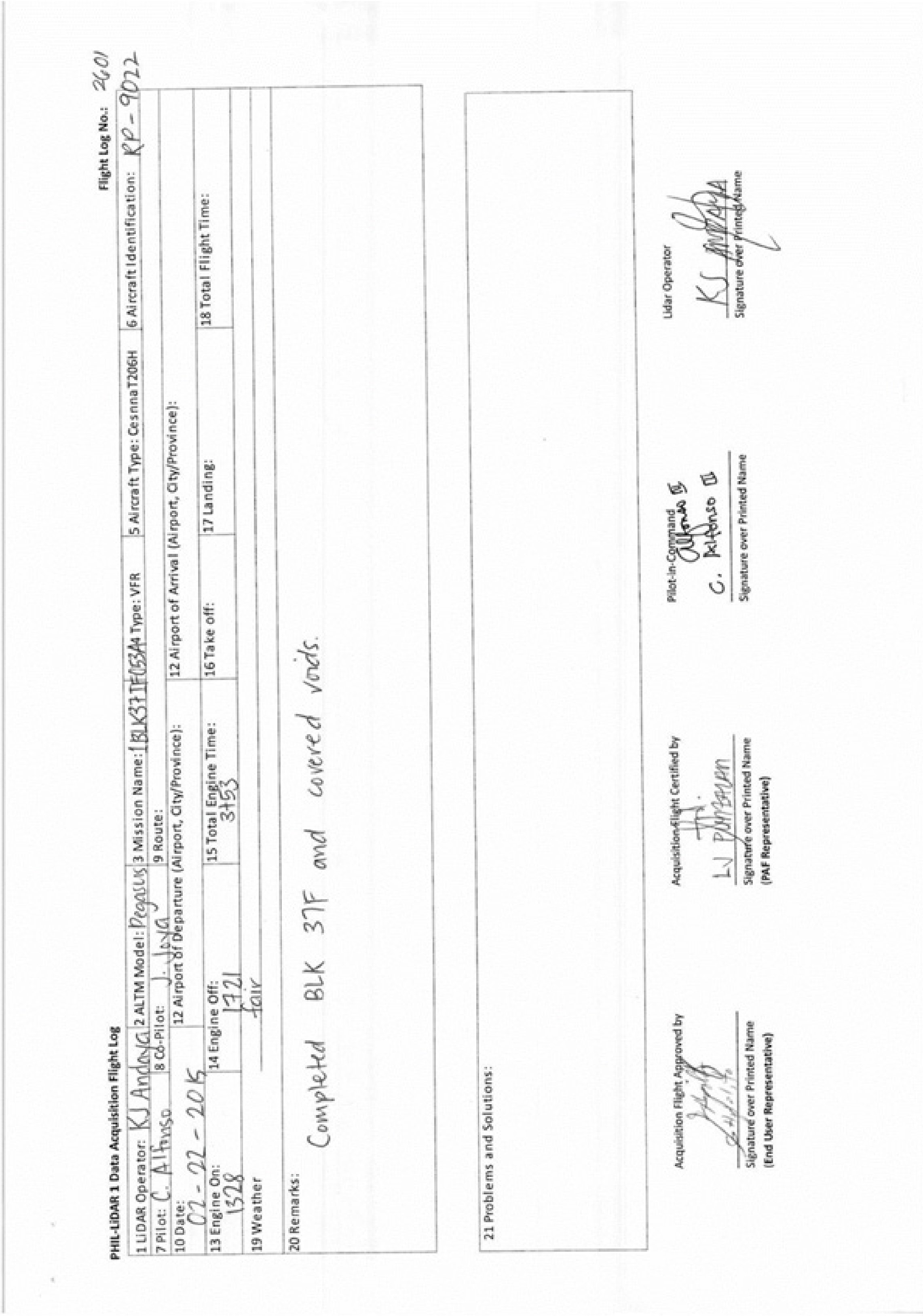
Acquisition Flight Approved by
Signature over Printed Name
(End User Representative)

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

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

Lidar Operator
KJ Andaya
Signature over Printed Name

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: Cesnna T206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Jaya	9 Route:			
10 Date: 02-22-2016	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 — Signature over Printed Name (End User Representative)

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

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

Lidar Operator — KS Andaya — Signature over Printed Name

8. Flight Log for 2613P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2613

1 LiDAR Operator: MK Villanueva	2 ALTM Model: Pegasus	3 Mission Name: 1BLK37IFV056A	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: 02-25-2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1333	14 Engine Off: 1602	15 Total Engine Time: 2+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks:

Surveyed voids over BLK 37I and 37F.

21 Problems and Solutions:

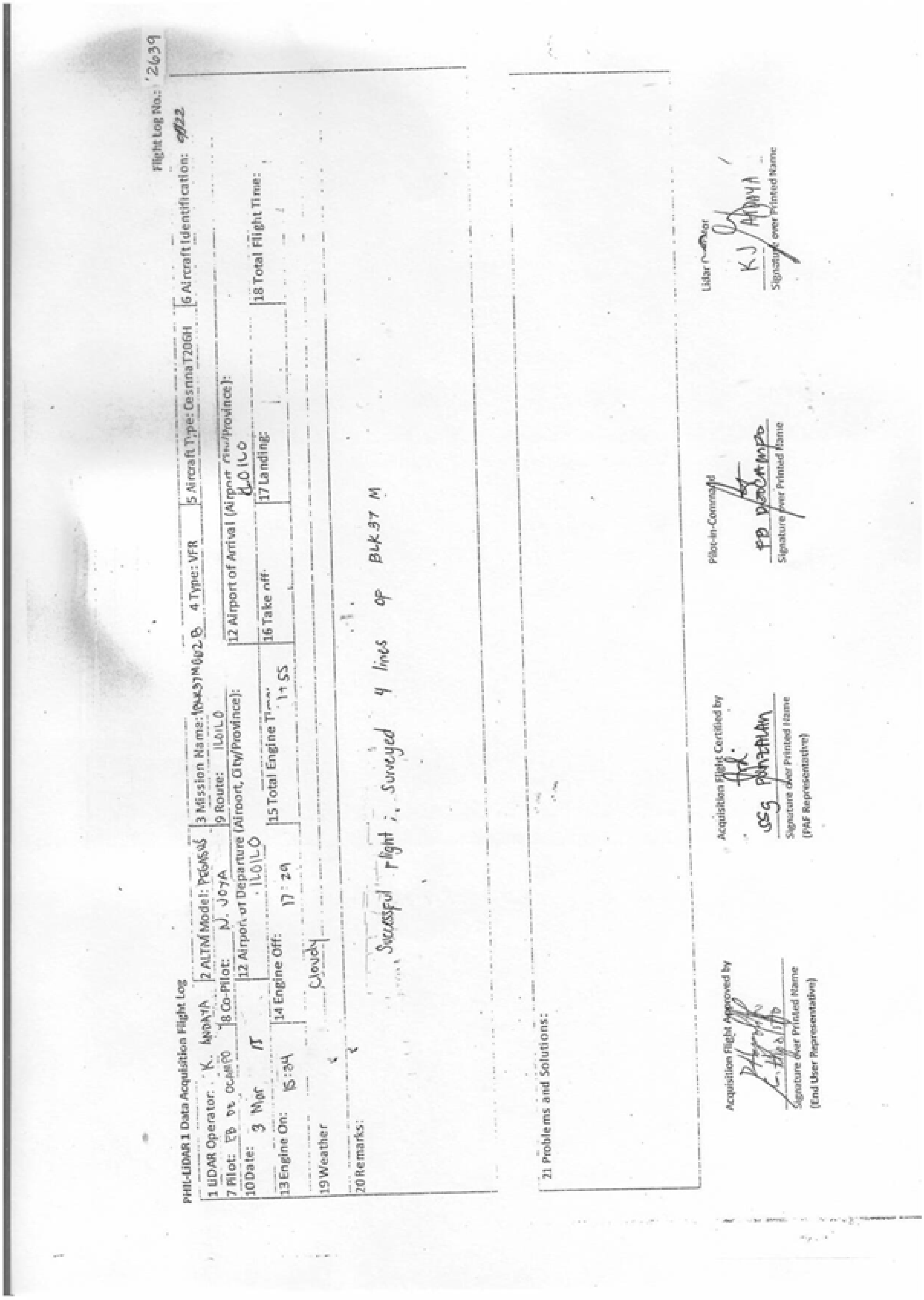
Acquisition Flight Approved by: Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: L. Paraguan — Signature over Printed Name (PAF Representative)

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

Lidar Operator: MK Villanueva — Signature over Printed Name

9. Flight Log for 2639P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2639

1 LiDAR Operator: K. ANDAYA	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK37M062B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: FB De Ocampo	8 Co-Pilot: N. JOYA	9 Route: ILOILO			
10 Date: 3 Mar 15	12 Airport of Departure (Airport, City/Province): ILOILO		12 Airport of Arrival (Airport, City/Province): ILOILO		
13 Engine On: 15:34	14 Engine Off: 17:29	15 Total Engine Time: 1+55	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Successful flight; Surveyed 4 lines of BLK37M					
21 Problems and Solutions:					

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

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

Pilot-in-Command: FB DeOCAMPO, Signature over Printed Name

Lidar Operator: KJ ANDAYA, Signature over Printed Name

10. Flight Log for 2778G Mission

Data Acquisition Flight Log

Flight Log No.: 2778G

1 LiDAR Operator: MCE BALIGUAS	2 ALTM Model: GEM	3 Mission Name: 2BLK37AC270A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: A. LIM	8 Co-Pilot: J. VECIEL	9 Route:			
10 Date: 27 SEPT 15	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0623	14 Engine Off: 1040	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Cloudy / Scattered rainshowers				

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

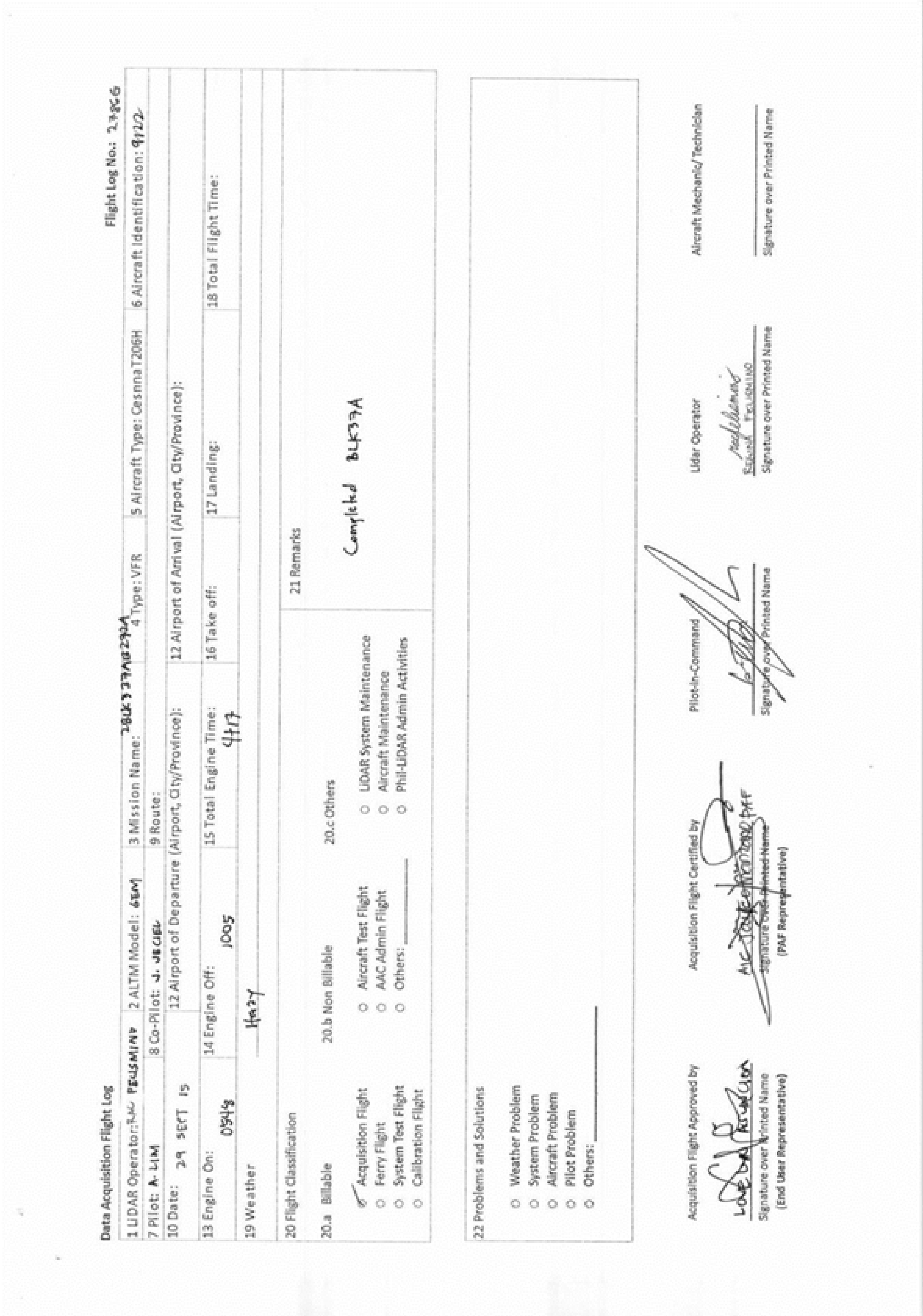
Covered 9 lines over BLK37C & 10 lines over BLK37A; POS turning red.

22 Problems and Solutions

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	MCE BALIGUAS Signature over Printed Name	Signature over Printed Name

11. Flight Log for 2786G Mission



Data Acquisition Flight Log

Flight Log No.: 2786G

1 LiDAR Operator: R.M. FELISMINO	2 ALTM Model: GEM	3 Mission Name: 2BLK37A272A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: A. LIM	8 Co-Pilot: J. JECIEL	9 Route:			
10 Date: 29 SEPT 15	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0548	14 Engine Off: 1005	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Hazy					

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

Completed BLK37A

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Signature over Printed Name (End User Representative)	A1C [signature] PAF Signature over Printed Name (PAF Representative)	Signature over Printed Name	REGINA FELISMINO Signature over Printed Name	Signature over Printed Name

12. Flight Log for 2788G Mission

Data Acquisition Flight Log — **Flight Log No.:** 2788G

1 LIDAR Operator: MCE BALILUAS	2 ALTM Model: GEM	3 Mission Name: 1BLK39BCD272B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: A. LIM	8 Co-Pilot: J. JECIEL	9 Route:			
10 Date: 29 SEPT 15	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1059	14 Engine Off: 1516	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Hazy					

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

Completed BLK37B & BLK37C and covered 4 lines over BLK37D.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
LOVELYN ASUNCION	[signature]	B. Lim	MCE BALILUAS	
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

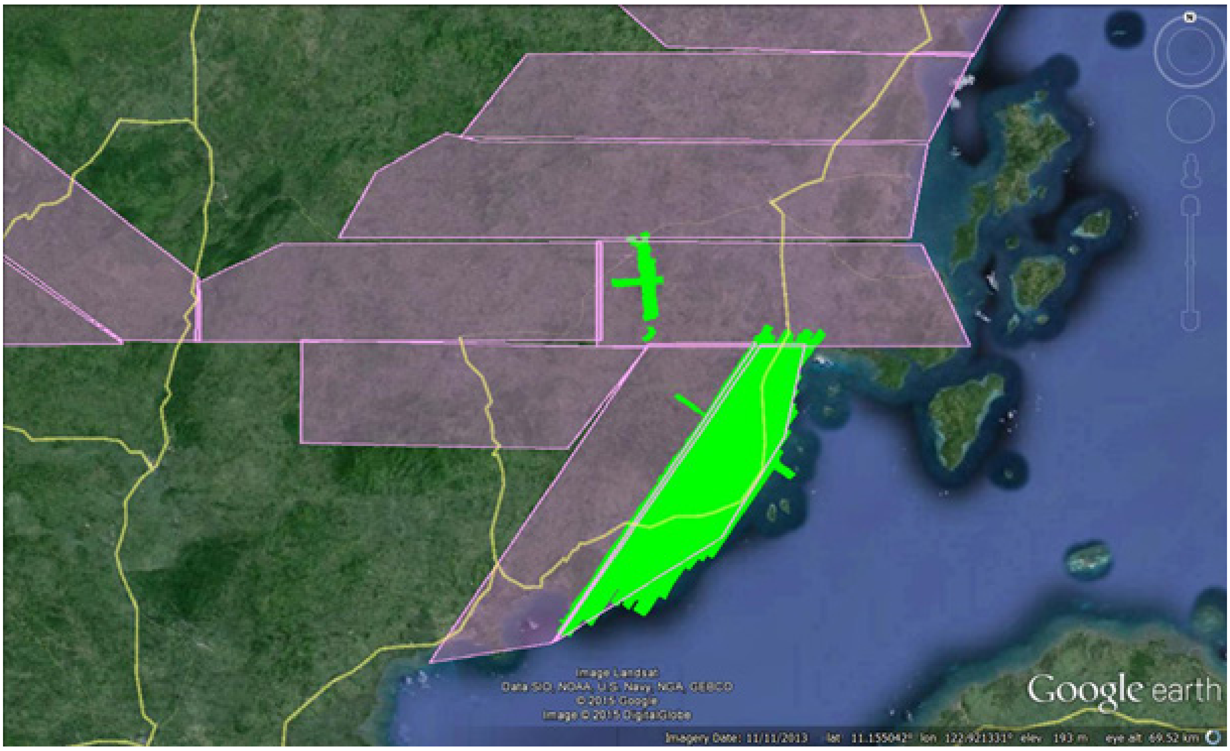
Annex 7. Flight Status Report

Table A-7.1 Flight Status Report

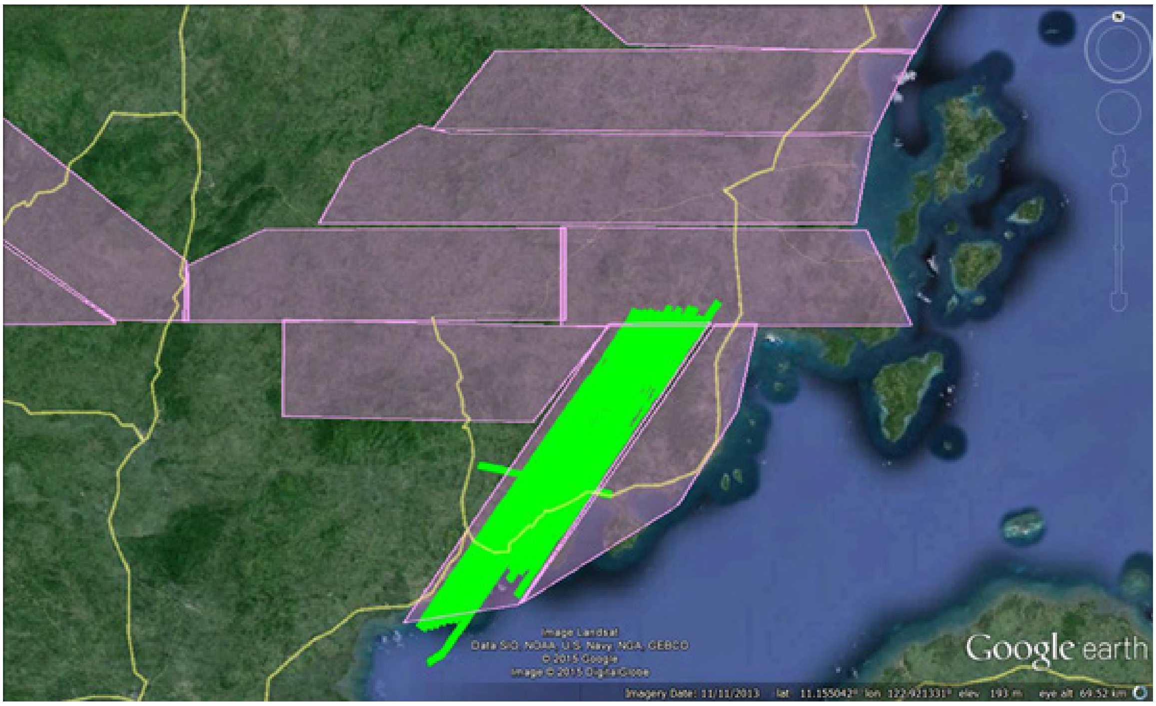
FLIGHT STATUS REPORT BAROTAC (February & September, 2015)					
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2546G	BLK37J	2BLK37K-V042A	MVE TONGA	FEB 11, 2015	Mission completed for BLK37K, covered voids of BLK 37H
2554G	BLK 37J	2BLK37J044A	MVE TONGA	FEB. 13, 2015	Unfinished, with voids
2556G	BLK 37G, 37J	2BLK37JSG044B	RA FELISMINO	FEB. 13, 2015	Finish BLK37J, voids in 37G
2568G	BLK 37G, 37I	2BLK37GSIV047B	MVE TONGA	FEB 16, 2015	Filled the voids and remaining 4 lines of BLK37G and covered 4 lines of BLK37I
2591P	BLK 37I	1BLK37I050B	KJ ANDAYA	FEB 19, 2015	Finished BLK 37I but with voids
2601P	BLK 37I, 37F	1BLK37IF053A	KJ ANDAYA	FEB 22, 2015	Finished BLK37F and covered voids
2613P	Near BLK 37	1BLK37IFV056A	MR VILLANUEVA	FEB. 25, 2015	Surveyed voids over BLK 37I and old swath
2639P	BLK 37M	1BLK37M062B	KJ ANDAYA	MAR. 03,2015	Surveyed 4 lines of BLK 37M
2778G	BLKs37 A & C	2BLK37AC270A	MCE BALIGUAS	SEPT. 27, 2015	Covered BLKs37 A & C, changed of altitudes because of cloud build up. Restarted ALTM twice, POS turning red. Bright images captured in most of the lines. No digitizer
2786G	BLKs37 A & C	2BLK37AB272A	RA FELISMINO	SEPT. 29, 2015	Covered several lines of BLK37A and one line from C but lots of voids due to clouds. No images on the last line No digitizer.
2788G	BLKs37 B, C & D	2BLK37BCD272B	RA FELISMINO	SEPT. 30, 2015	Completed BLK38B and few lines of BLK38F. Changed of altitudes because of clouds and high terrain

LAS BOUNDARIES PER MISSION FLIGHT

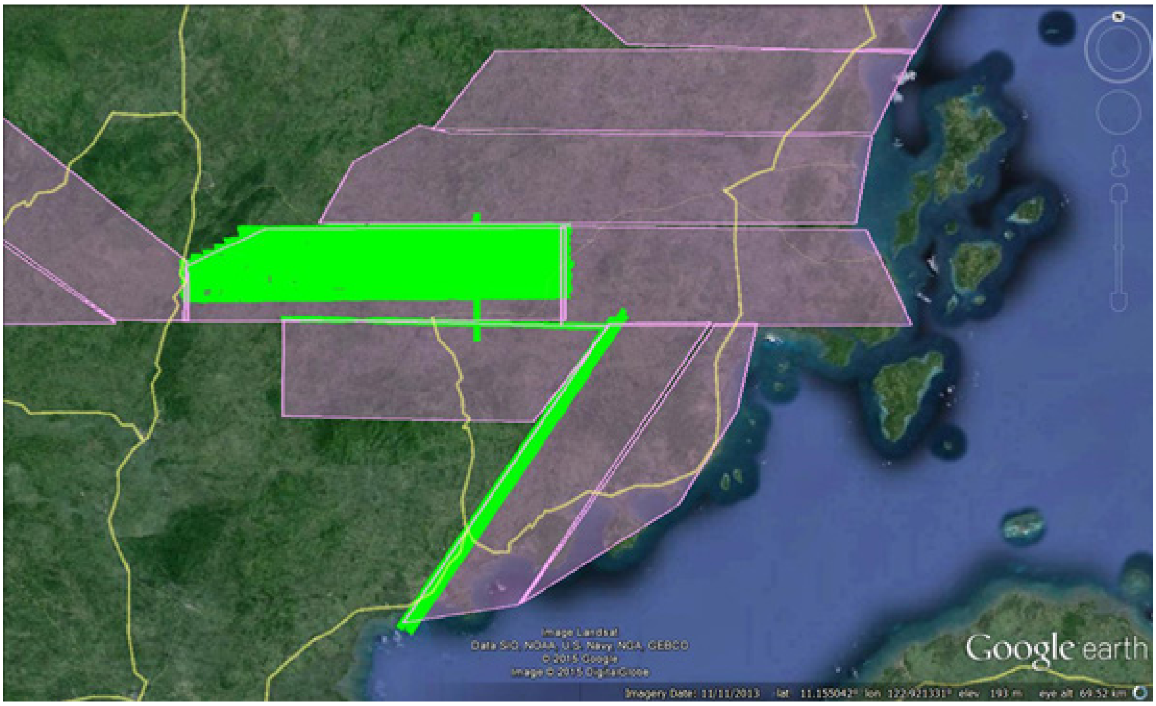
Flight No. : 2546G
Area: BLK 37K
Base: ILO-71 & IL-608
Mission Name: 2BLK37KV042A
Total Area Surveyed: 121.182 sq km



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

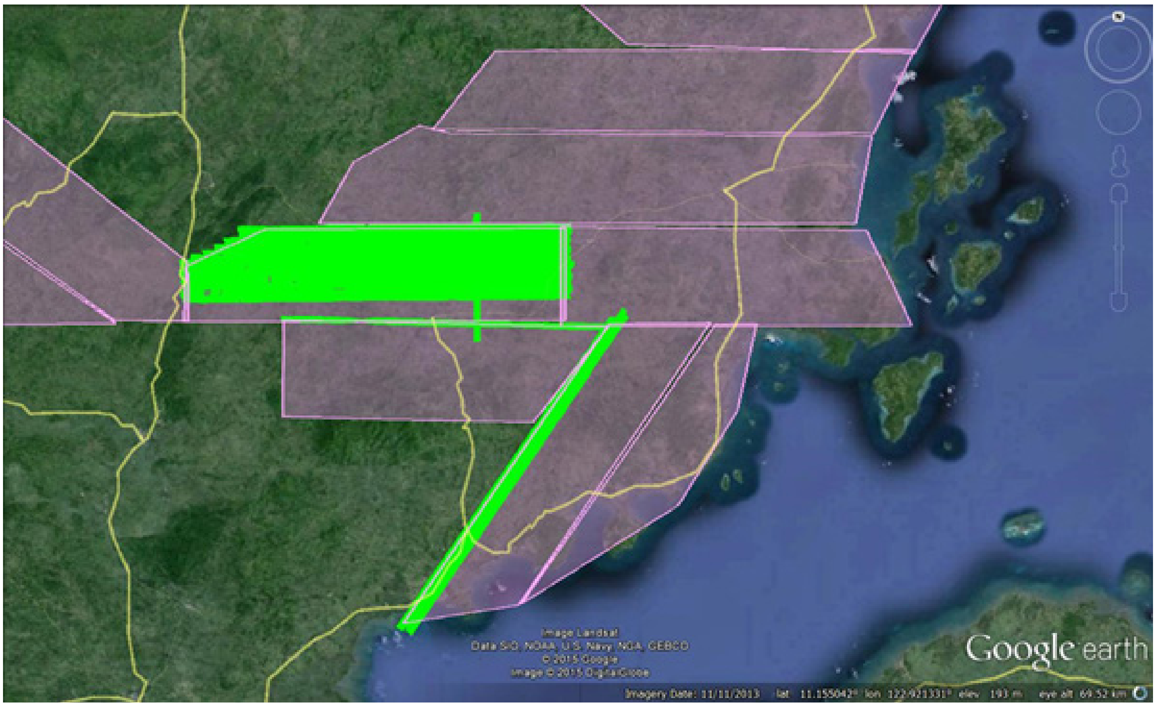


Flight No. : 2556G
Area: BLK 37J, 37G Base: ILO-71 & IL-608
Mission Name: 2BLK37JSG044B
Total Area Surveyed: 182.072 sq km

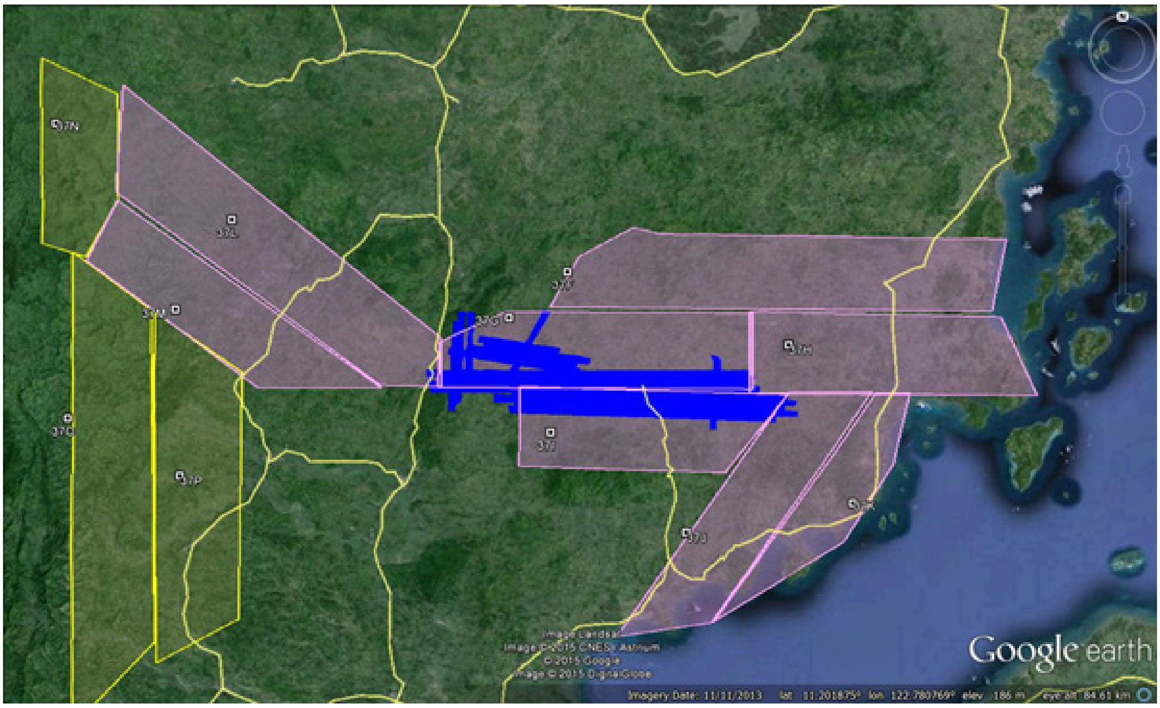


Flight No. : 2556G
Area: BLK 37J, 37G
Mission Name: 2BLK37JSG044B
Total Area Surveyed: 182.072 sq km

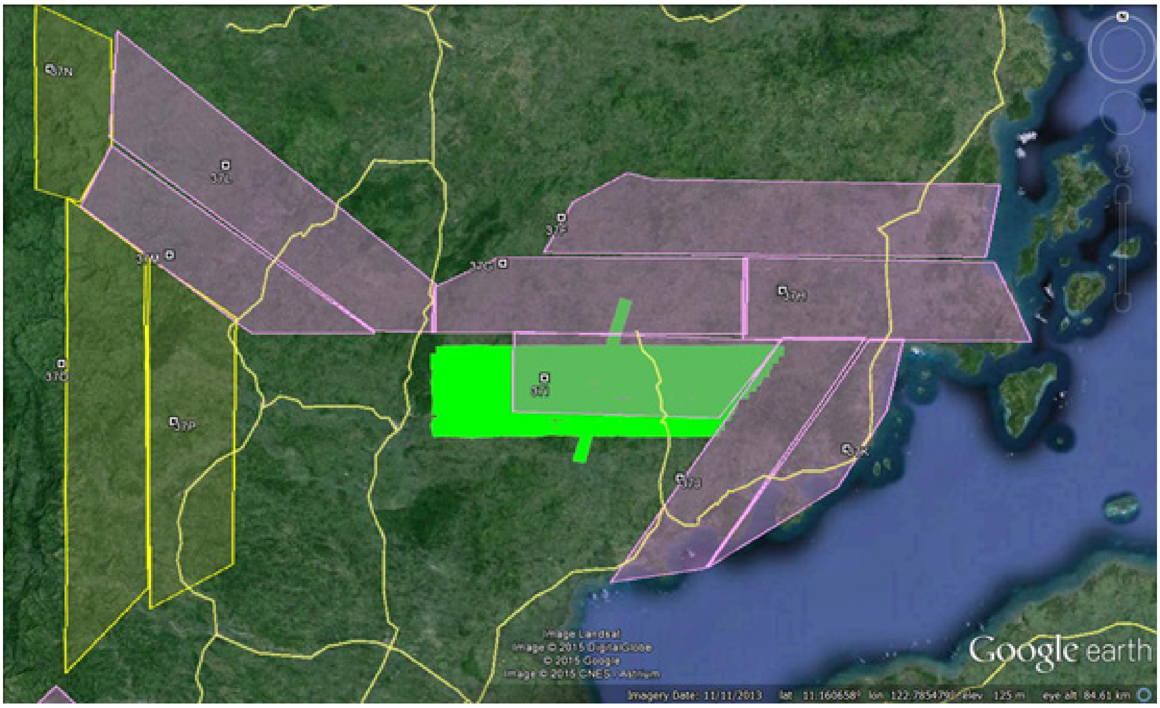
Base: ILO-71 & IL-608



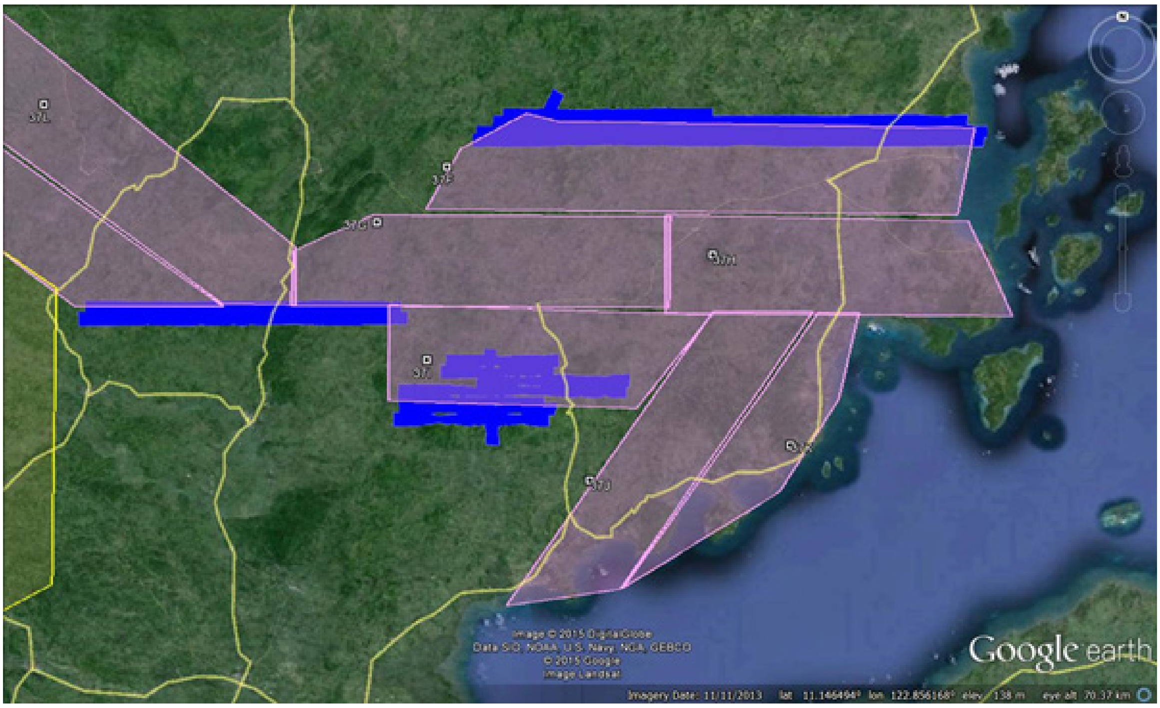
Flight No. : 2568G
Area: BLK 37G, 37I
Mission Name: 2BLK37GSIV047B
Total Area Surveyed: 132.274 sq km



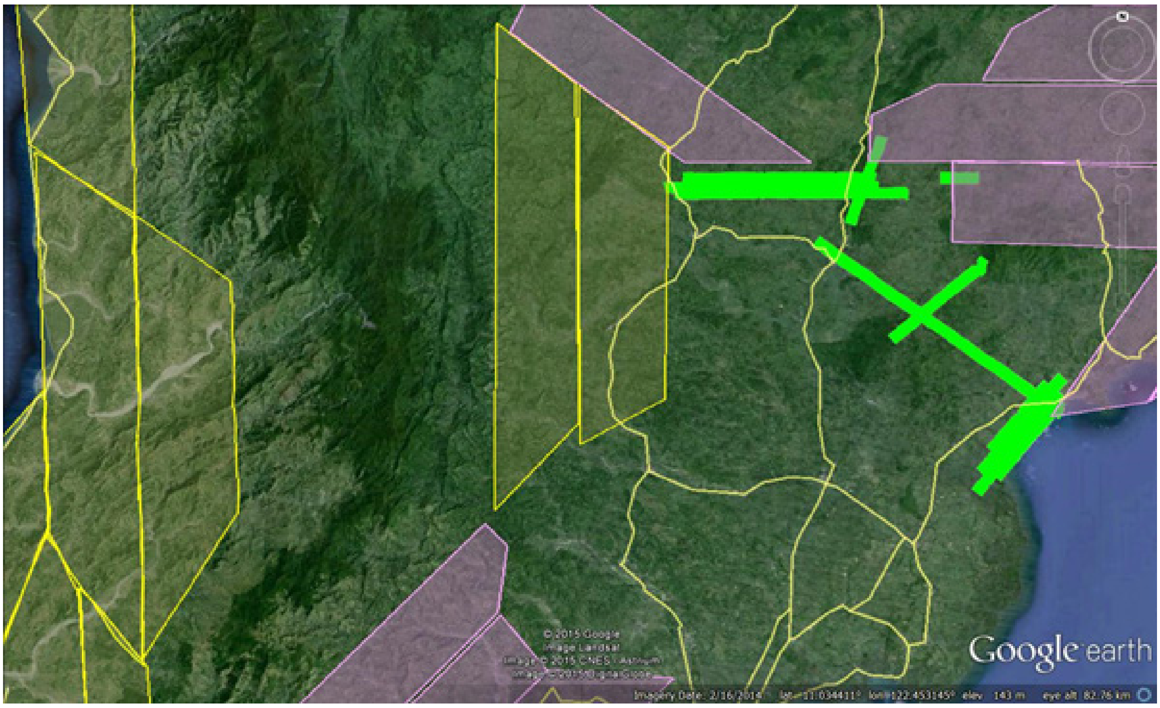
Flight No. : 2591P
Area: BLK 37I
Mission Name: 1BLK37FIV050B
Total Area Surveyed: 210.432 sq km



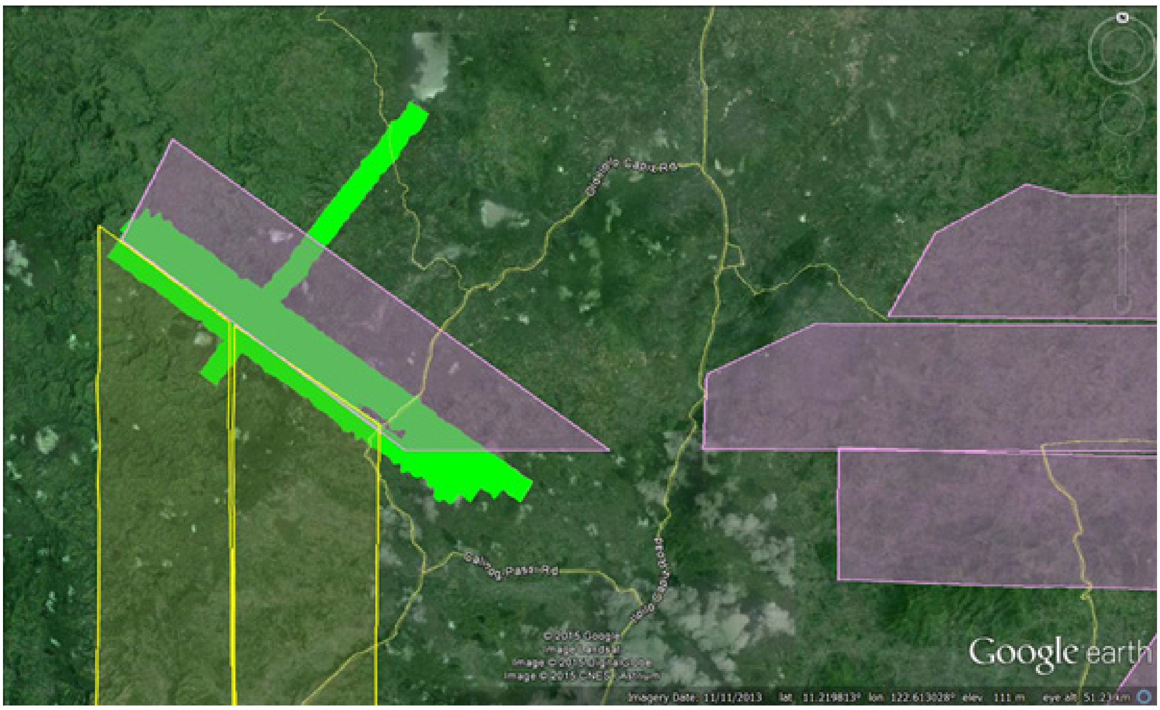
Flight No. : 2601P
Area: BLK 37I, 37F, voids
Mission Name: 1BLK37IFV053A
Total Area Surveyed: 175.699 sq km



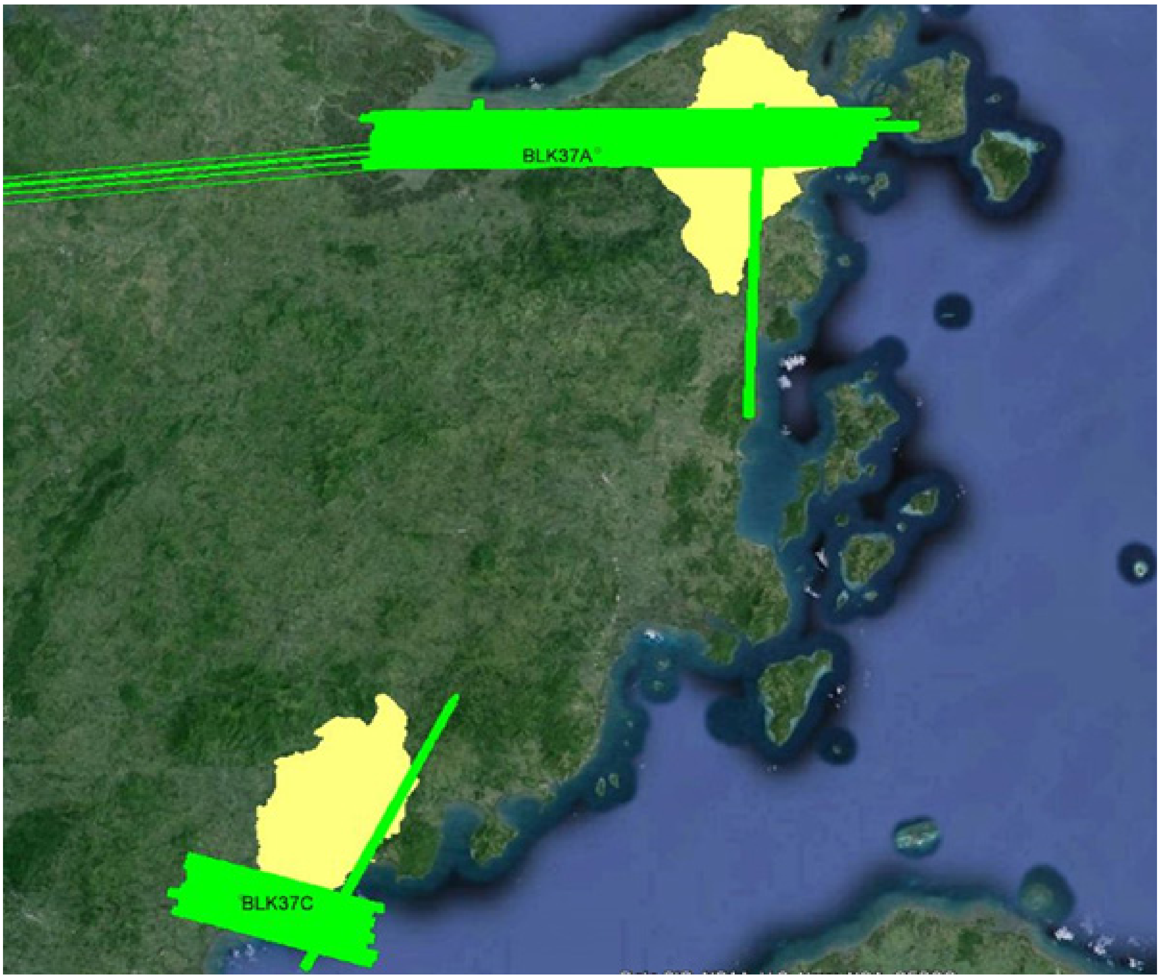
Flight No. : 2613P
Area: Near BLK37
Mission Name: 1BLK37IFV056A
Total Area Surveyed: 104.8 sq km



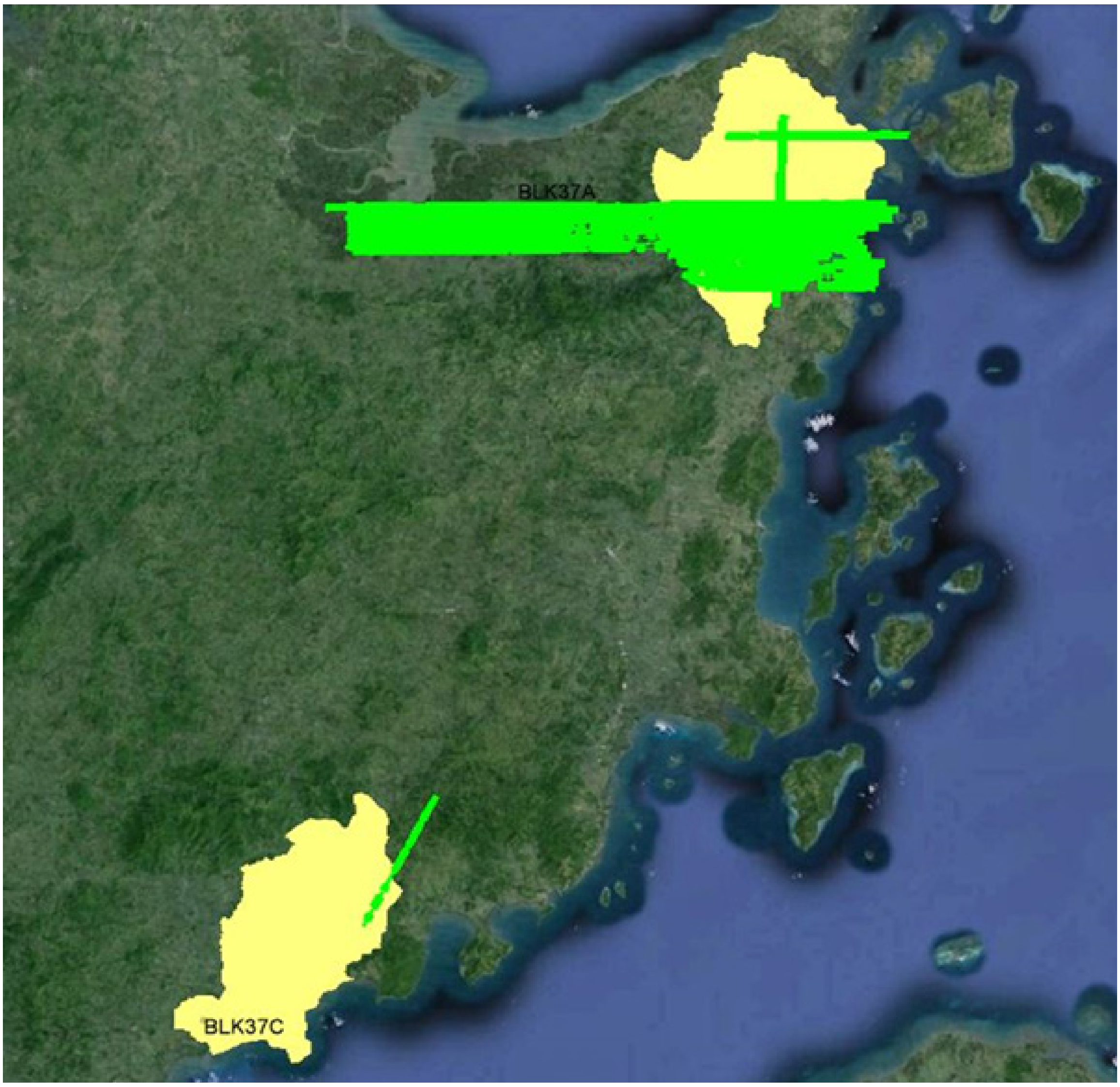
Flight No. : 2639P
Area: BLK 37M
Mission Name: 1BLK37M062B
Total Area Surveyed: 90.0761 sq km



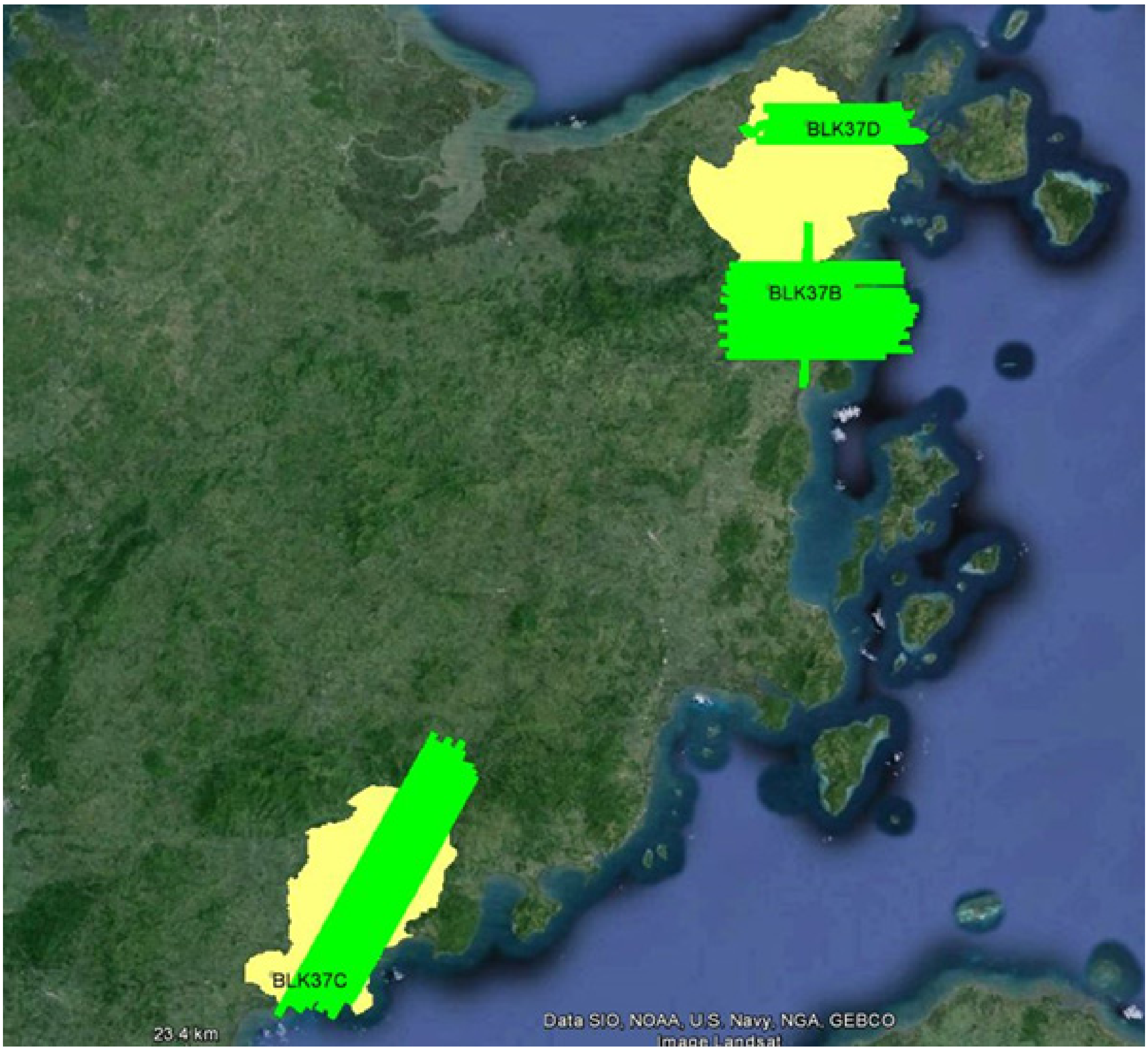
Flight No. :	2778G
Area:	BLKs37 A & C
Mission Name:	2BLK37AC270A
Parameters:	FOR BLK37C: Alt: 1000m; Scan Fz: 50; Scan angle: 15; PRF: 100
	FOR BLK37A: Alt: 850m; Scan Fz: 50; Scan angle: 20; PRF: 125
Area surveyed:	187.46 sq km.



Flight No. : 2786G
Area: BLKs37 A & C
Mission Name: 2BLK37AB272A
Parameters: Alt: 1000m; Scan Fz: 50; Scan angle: 15; PRF: 100
Area surveyed: 131.32 sq km.



Flight No. :	2788G
Area:	BLKs37 B, C & D
Mission Name:	2BLK37BCD272B
Parameters:	Alt: 800m; Scan Fz: 50; Scan angle: 20; PRF: 125
Area surveyed:	178.88 sq km.



Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk37I

Flight Area	Iloilo
Mission Name	Blk37I
Inclusive Flights	2591P, 2568G, 2601P
Range data size	93.3 GB
POS	659 MB
Image	119.9 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)	1.44
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.39
Boresight correction stdev (<0.001deg)	0.001057
IMU attitude correction stdev (<0.001deg)	0.003876
GPS position stdev (<0.01m)	0.0078
Minimum % overlap (>25)	44.38%
Ave point cloud density per sq.m. (>2.0)	4.67
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	285
Maximum Height	644.85 m
Minimum Height	83.10 m
Classification (# of points)	
Ground	224,157,743
Low vegetation	233,880,601
Medium vegetation	751,526,042
High vegetation	357,115,031
Building	5,885,387
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Antonio Chua, Jr., Engr. Krisha Marie Bautista

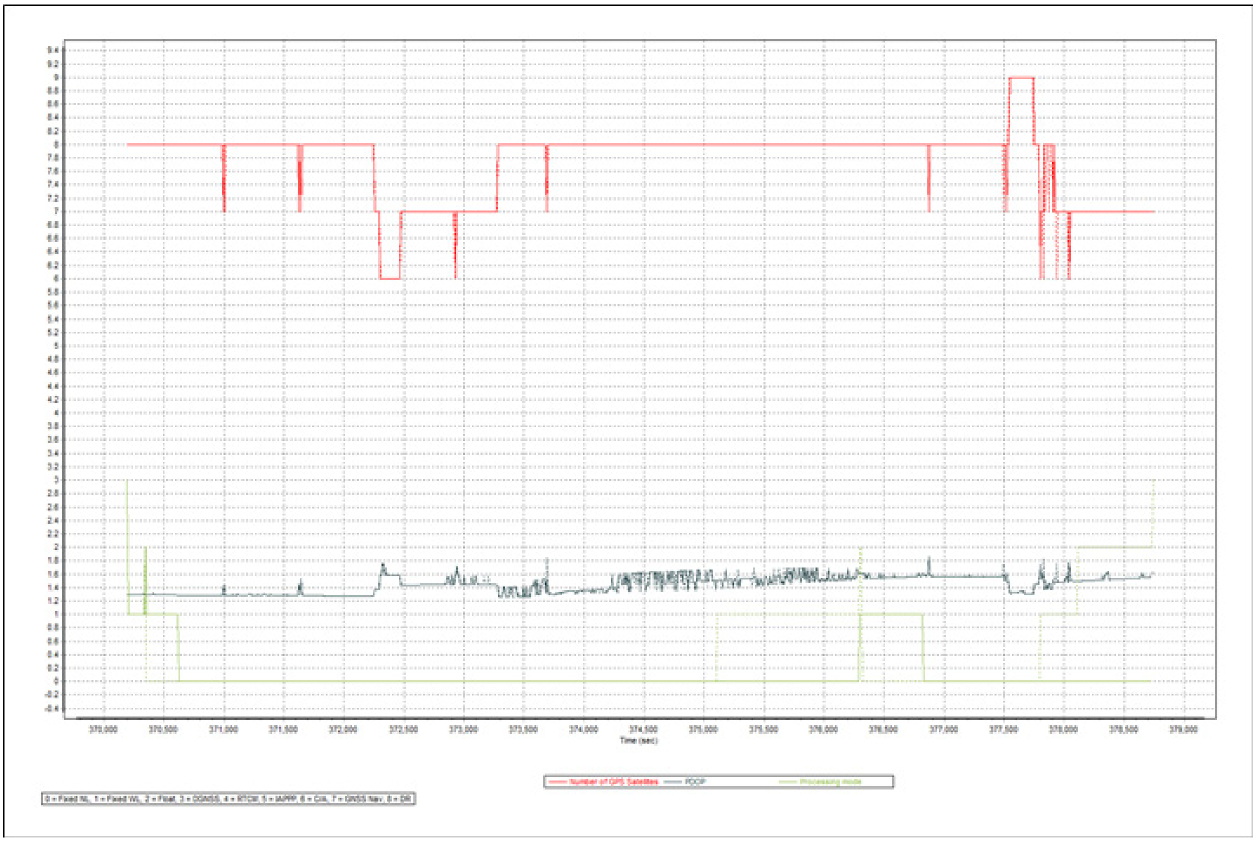


Figure A-8.1. Solution Status

Figure A-8.2. Smoothed Performance Metric Parameters

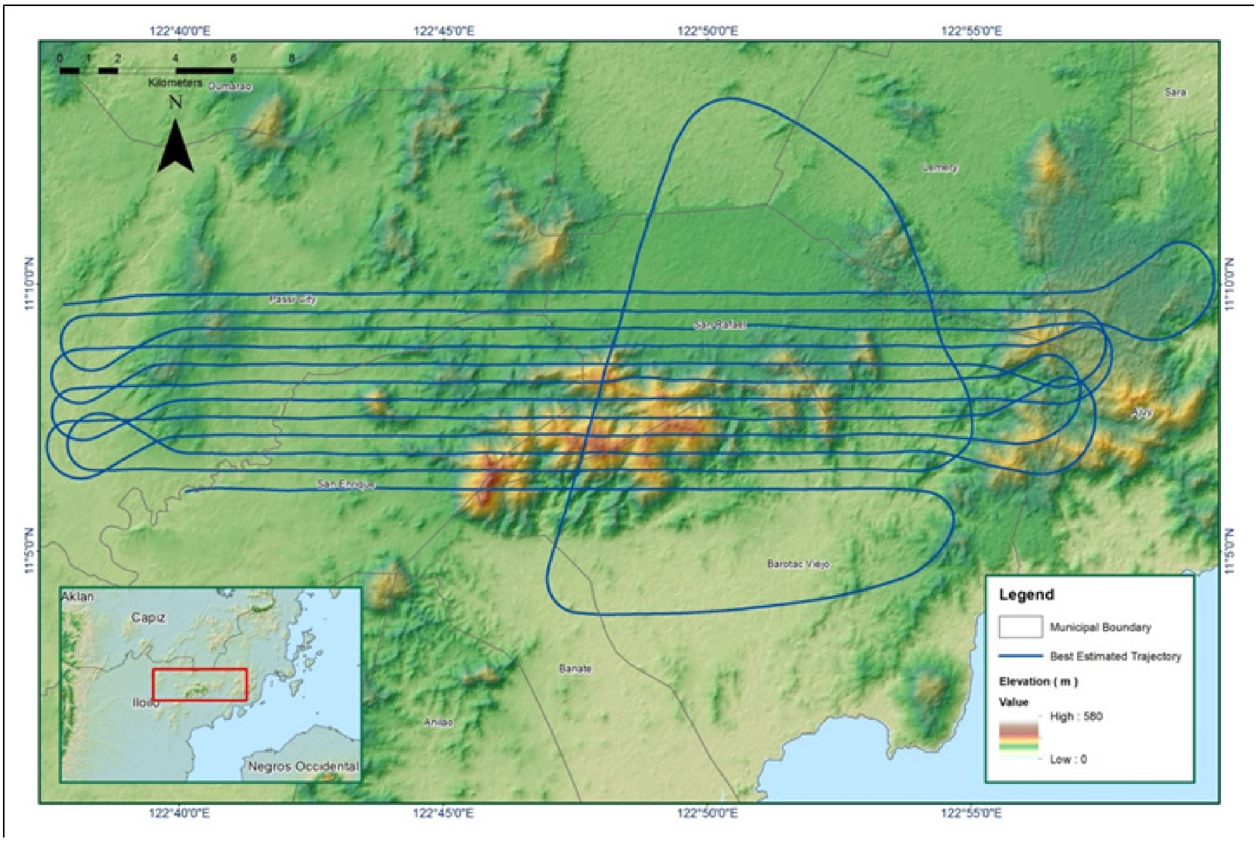


Figure A-8.3. Best Estimated Trajectory

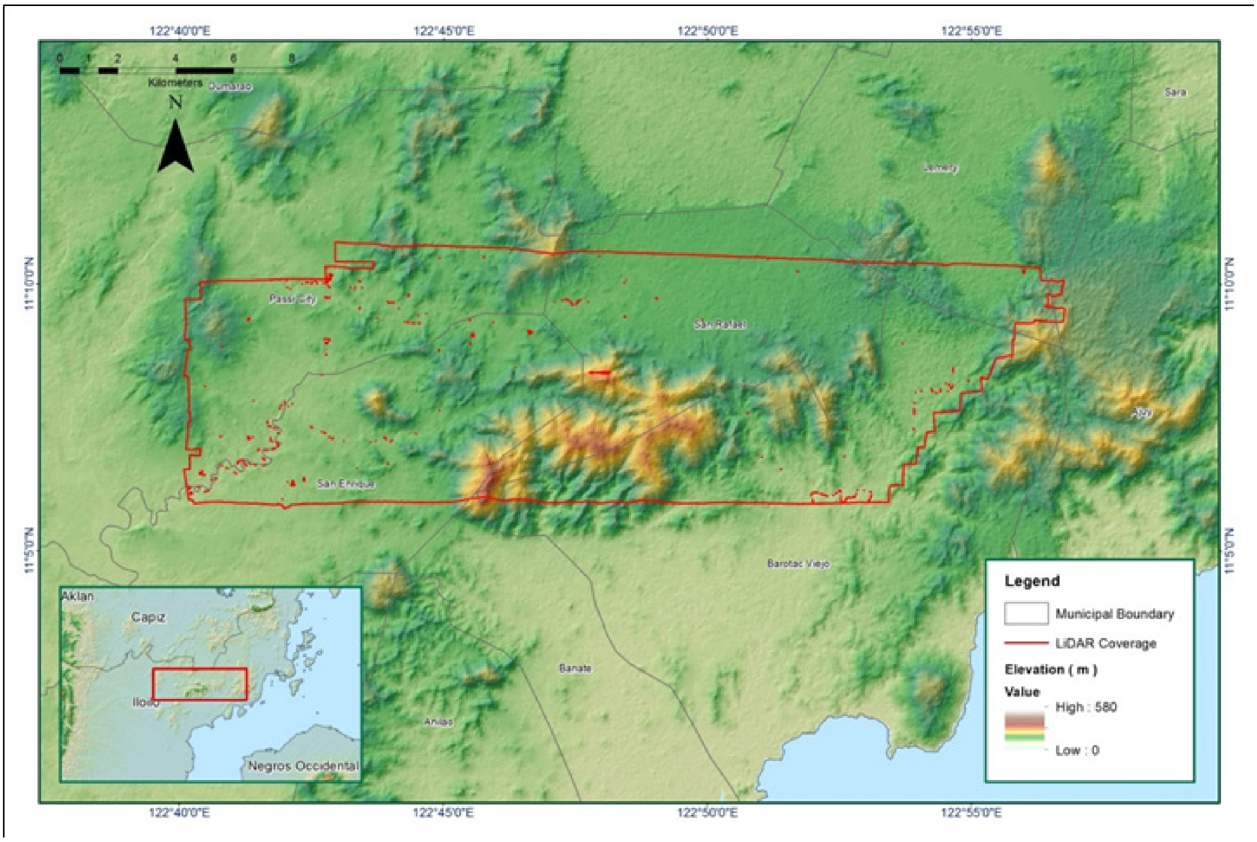


Figure A-8.4. Coverage of LiDAR data

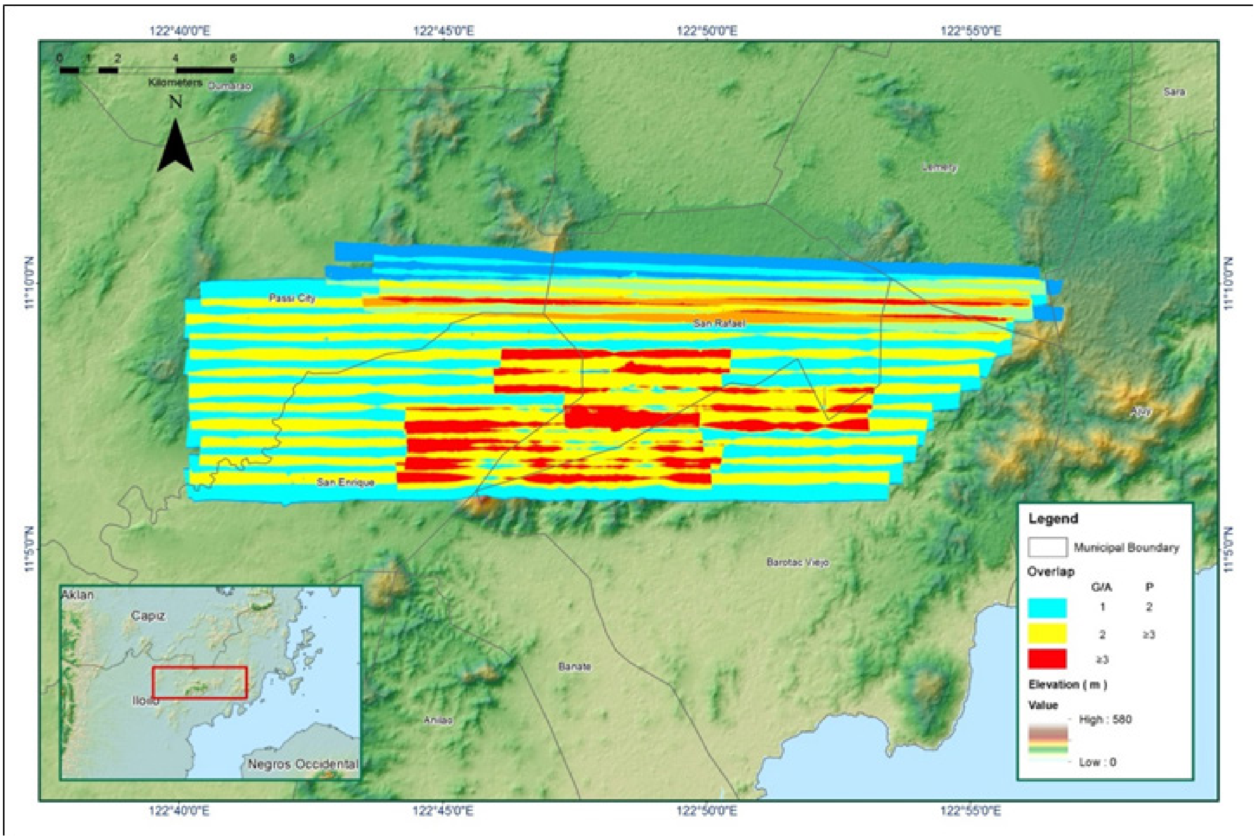


Figure A-8.5. Image of data overlap

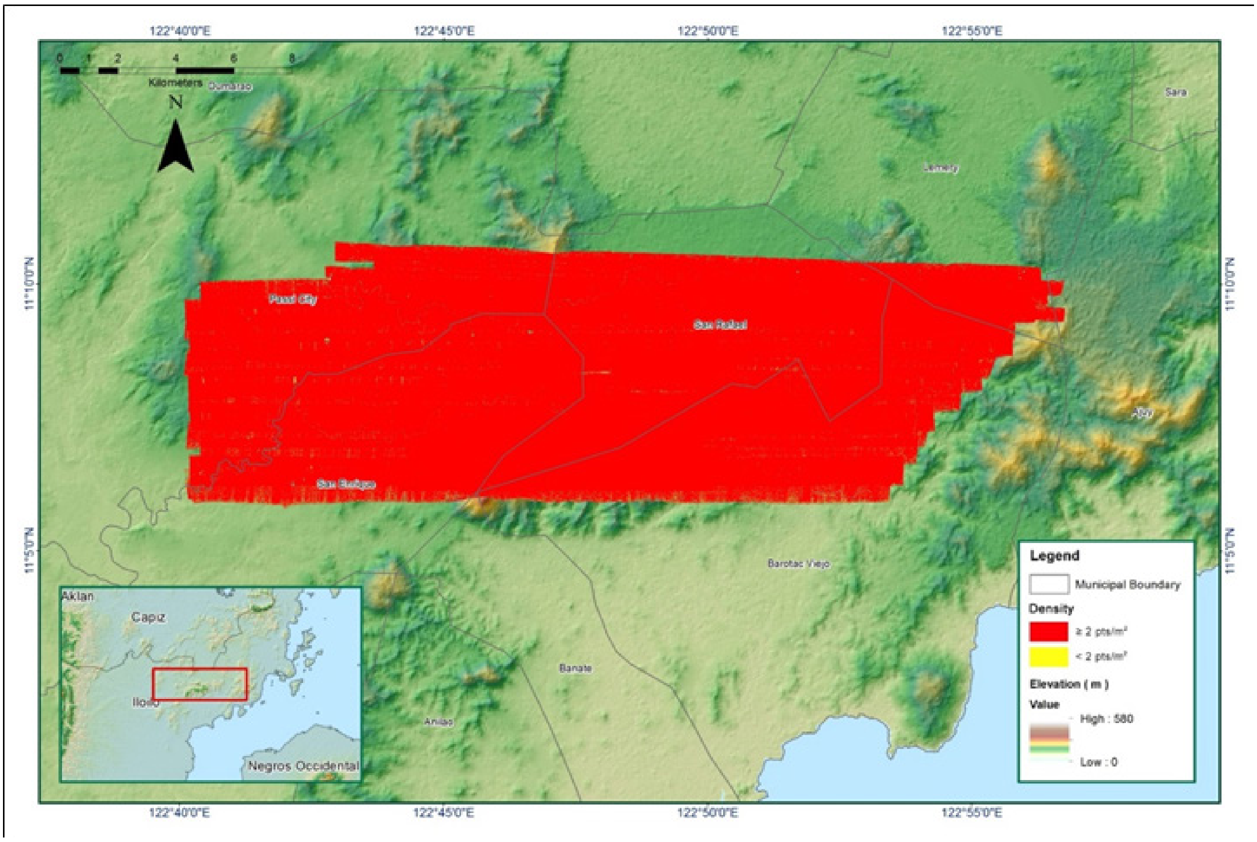


Figure A-8.6. Density map of merged LiDAR data

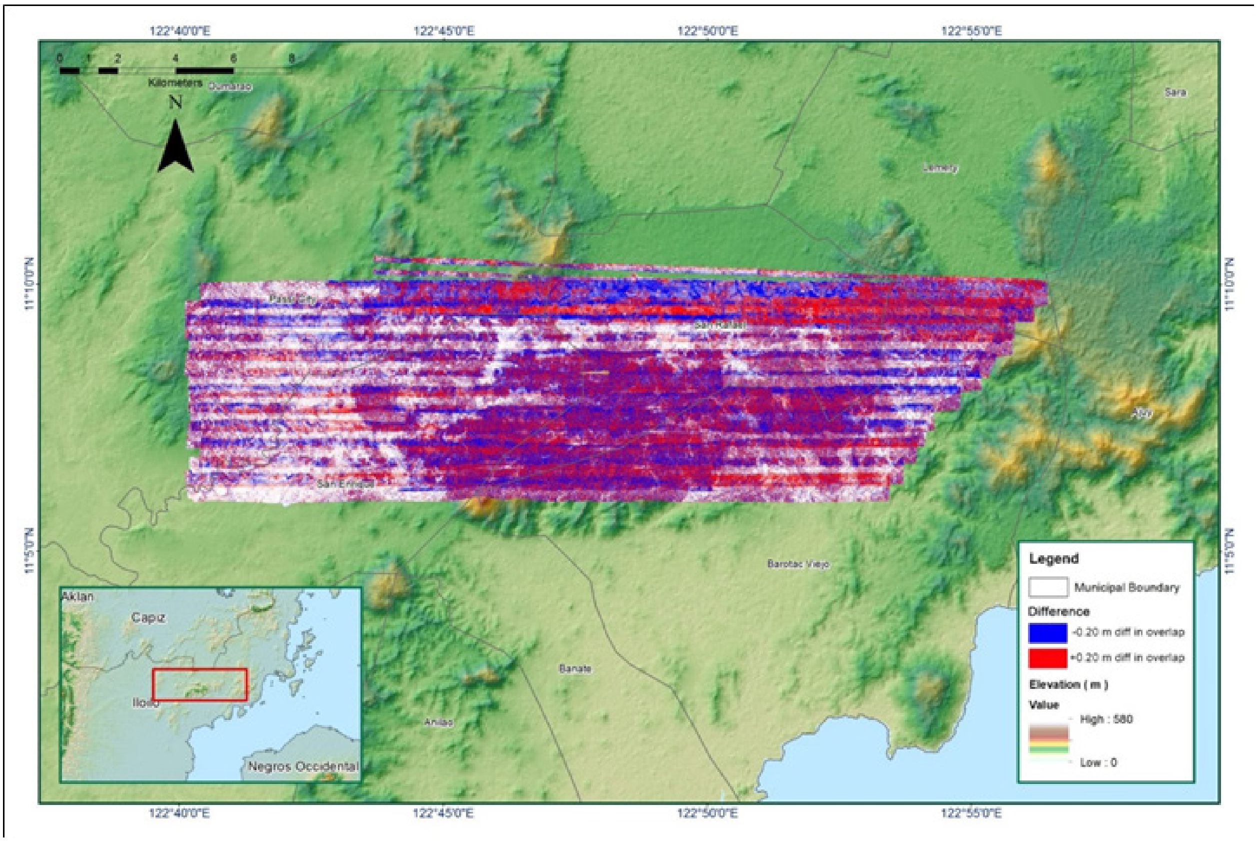


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk37I_Additional

Flight Area	Iloilo
Mission Name	Blk 37I_Additional
Inclusive Flights	2613P
Range data size	10 GB
POS	151 MB
Base data size	166 MB
Image	17.6 MB
Transfer date	February 25, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.375
RMSE for East Position (<4.0 cm)	2.475
RMSE for Down Position (<8.0 cm)	5.055
Boresight correction stdev (<0.001deg)	0.000290
IMU attitude correction stdev (<0.001deg)	0.000865
GPS position stdev (<0.01m)	0.0099
Minimum % overlap (>25)	NA
Ave point cloud density per sq.m. (>2.0)	2.1
Elevation difference between strips (<0.20 m)	No
Number of 1km x 1km blocks	62
Maximum Height	325.13
Minimum Height	60.60
Classification (# of points)	
Ground	30,668,264
Low vegetation	14,403,528
Medium vegetation	22,919,417
High vegetation	27,824,513
Building	1,478,994
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Edgardo Gubatanga Jr., Engr. Gladys Mae Apat

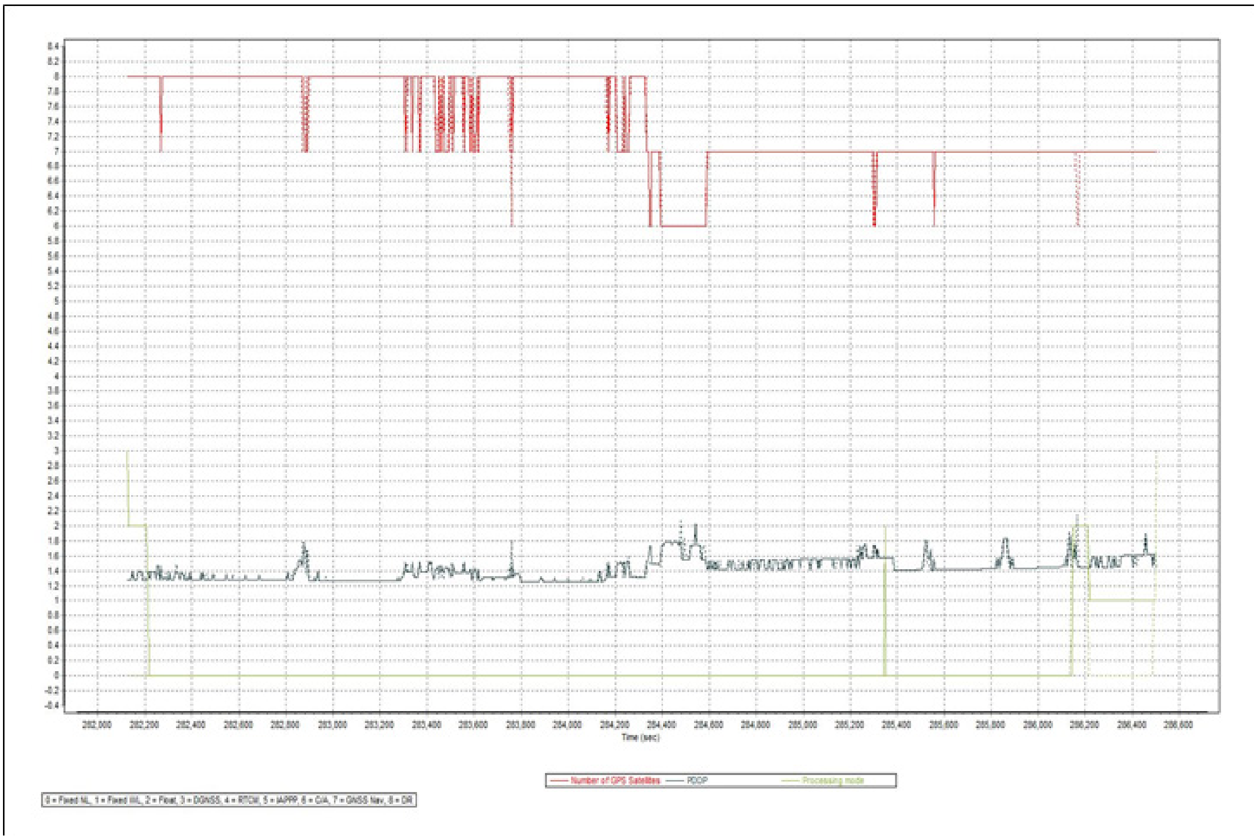


Figure A-8.8. Solution Status

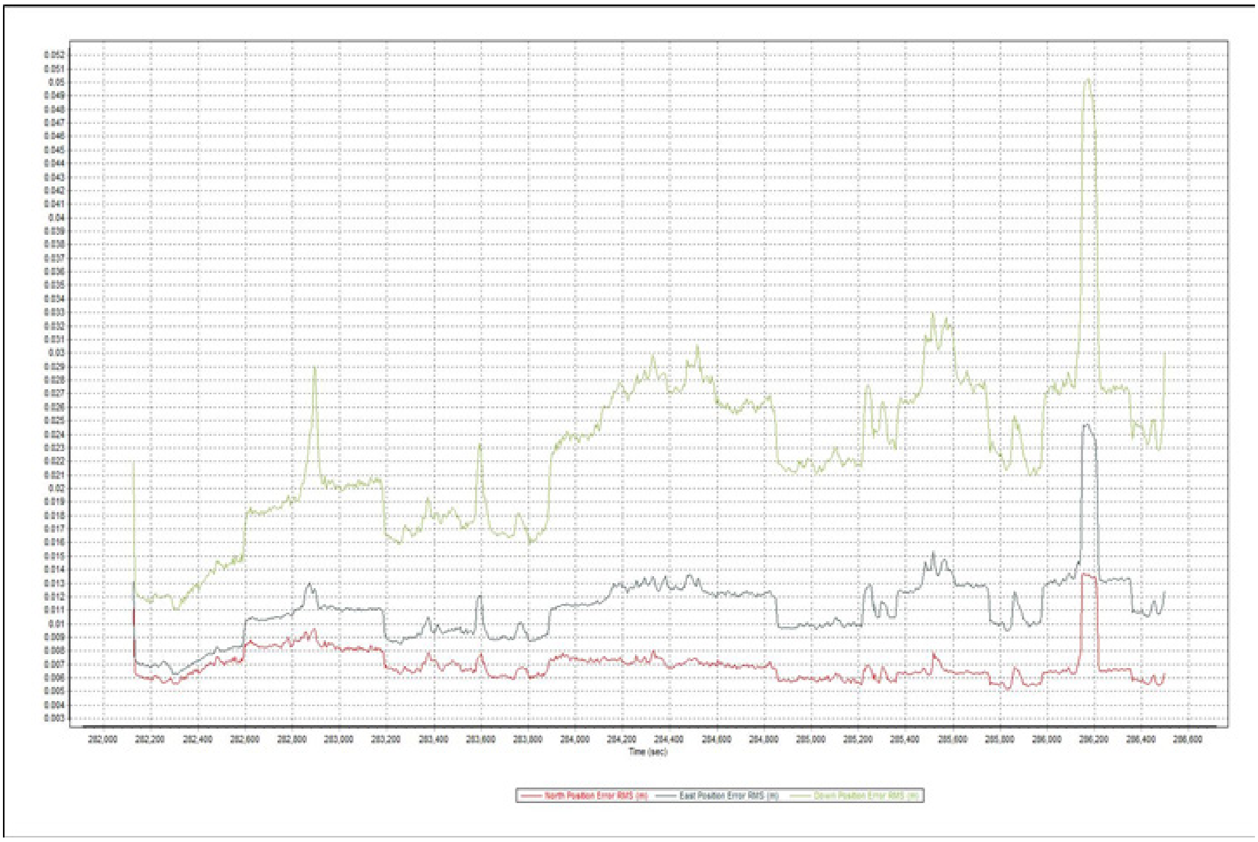


Figure A-8.9. Smoothed Performance Metric Parameters

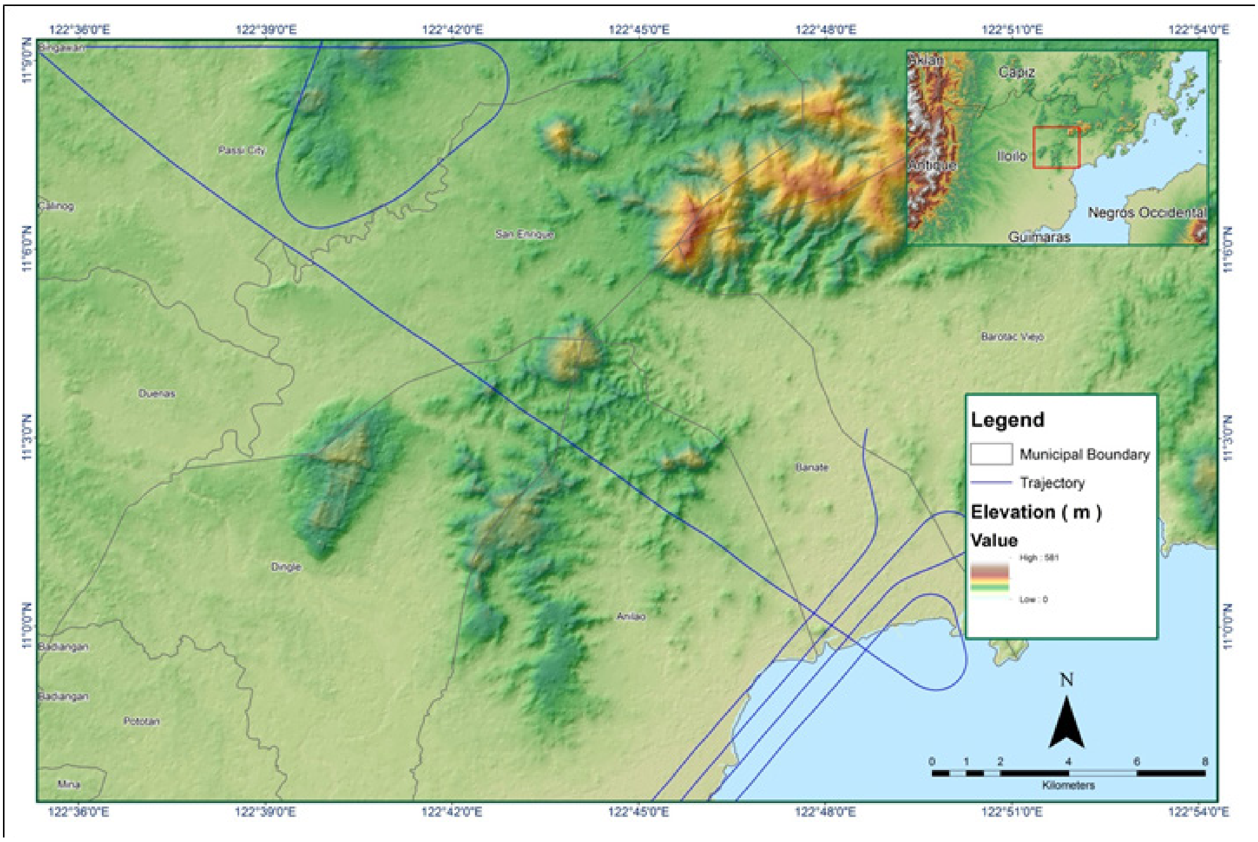


Figure A-8.10. Best Estimated Trajectory

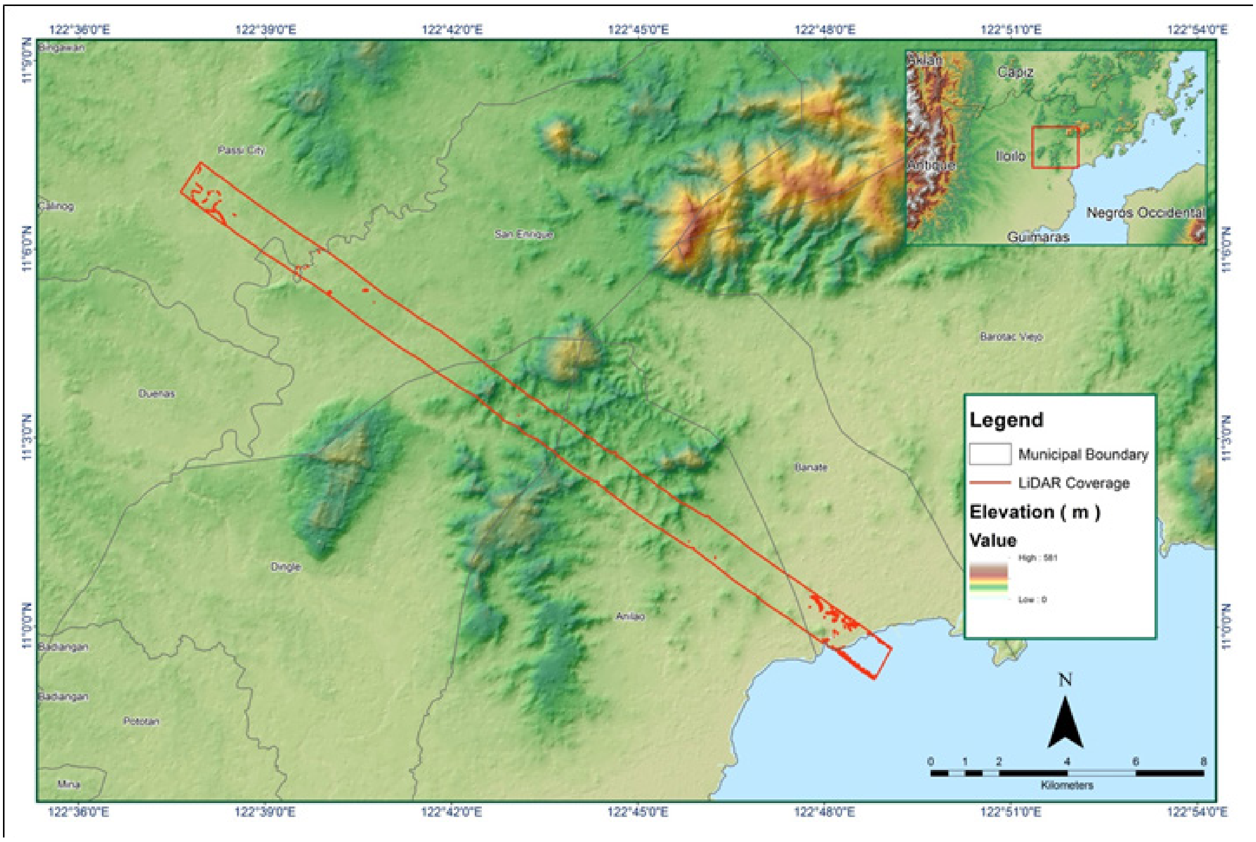


Figure A-8.11. Coverage of LiDAR data

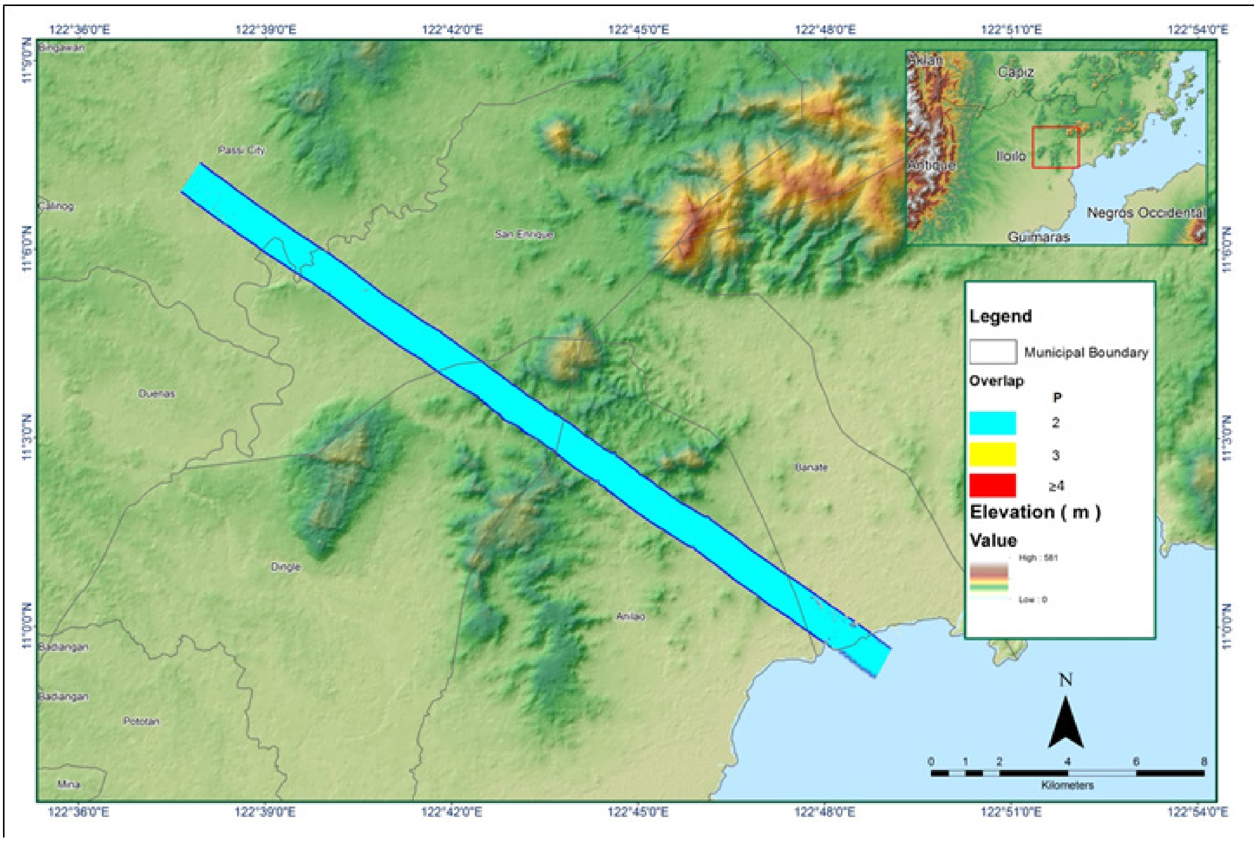


Figure A-8.12. Image of data overlap

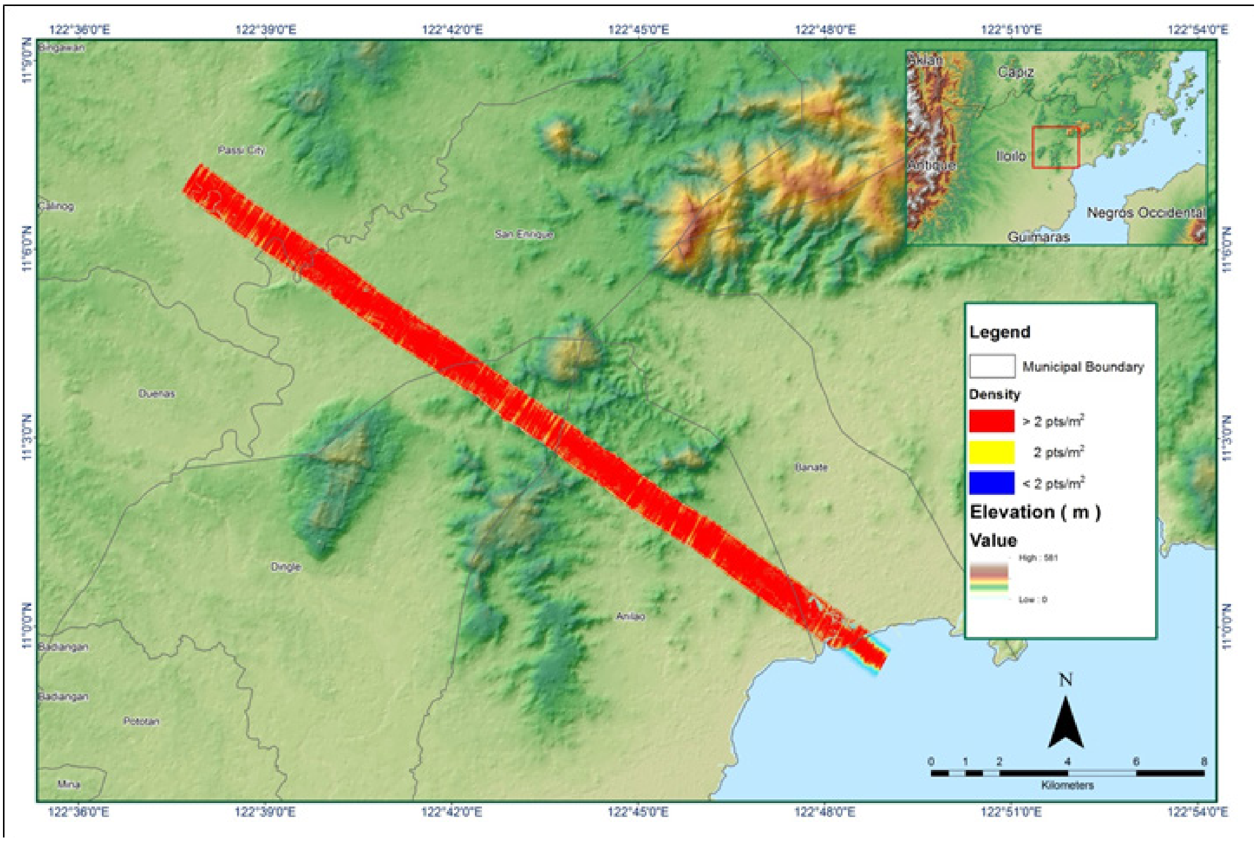


Figure A-8.13. Density map of merged LiDAR data

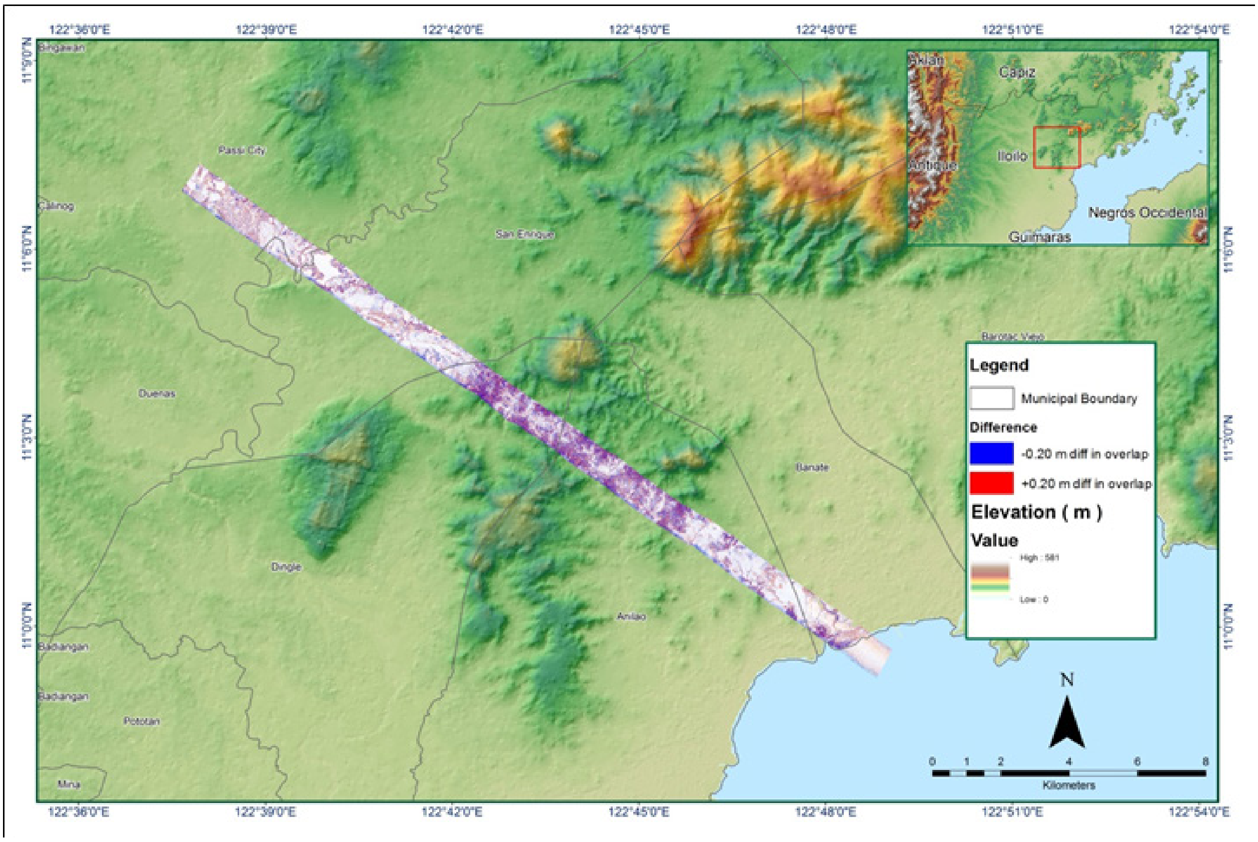


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk37J_supplement

Flight Area	Iloilo
Mission Name	Blk37J_supplement
Inclusive Flights	2613P
Range data size	10 GB
POS	151 MB
Image	17.6 GB
Transfer date	July 07, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.97
RMSE for East Position (<4.0 cm)	1.54
RMSE for Down Position (<8.0 cm)	3.3
Boresight correction stdev (<0.001deg)	0.000418
IMU attitude correction stdev (<0.001deg)	0.000466
GPS position stdev (<0.01m)	0.0104
Minimum % overlap (>25)	36.94%
Ave point cloud density per sq.m. (>2.0)	1.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	47
Maximum Height	147.77 m
Minimum Height	60.18 m
Classification (# of points)	
Ground	31,011,874
Low vegetation	23,398,742
Medium vegetation	13,493,180
High vegetation	15,258,674
Building	909,625
Orthophoto	YES
Processed by	Engr. Kenneth Solidum, Engr. Melanie Hingpit, Engr. Sueden Lyle Magtalas

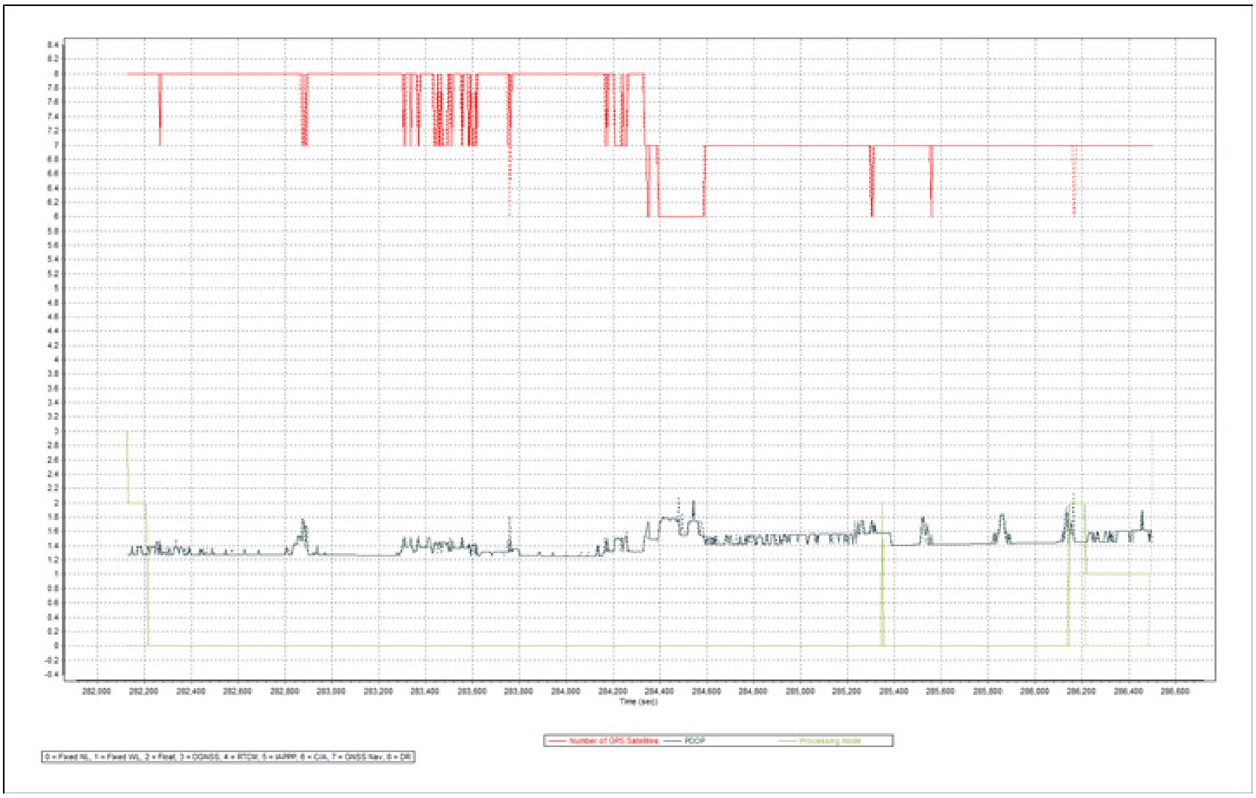


Figure A-8.15. Solution Status

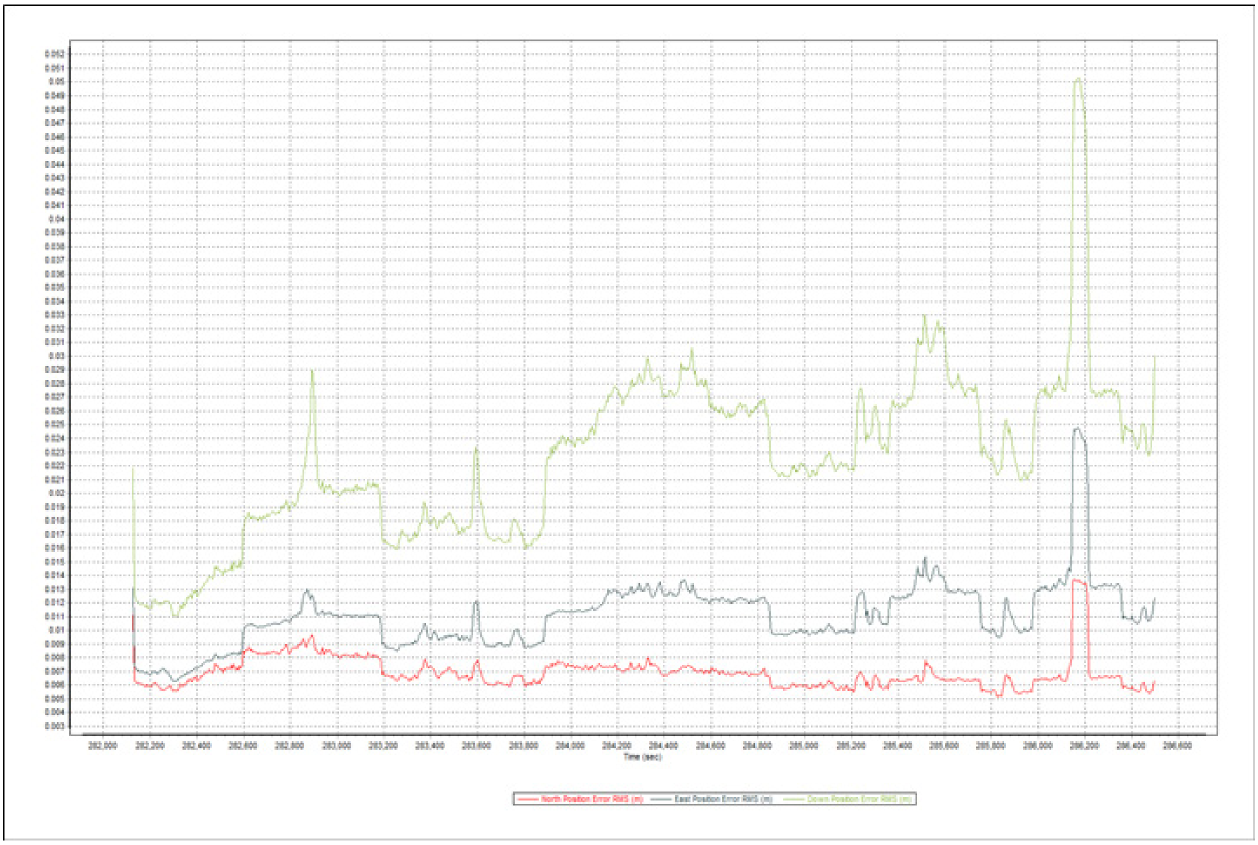


Figure A-8.16. Smoothed Performance Metric Parameters

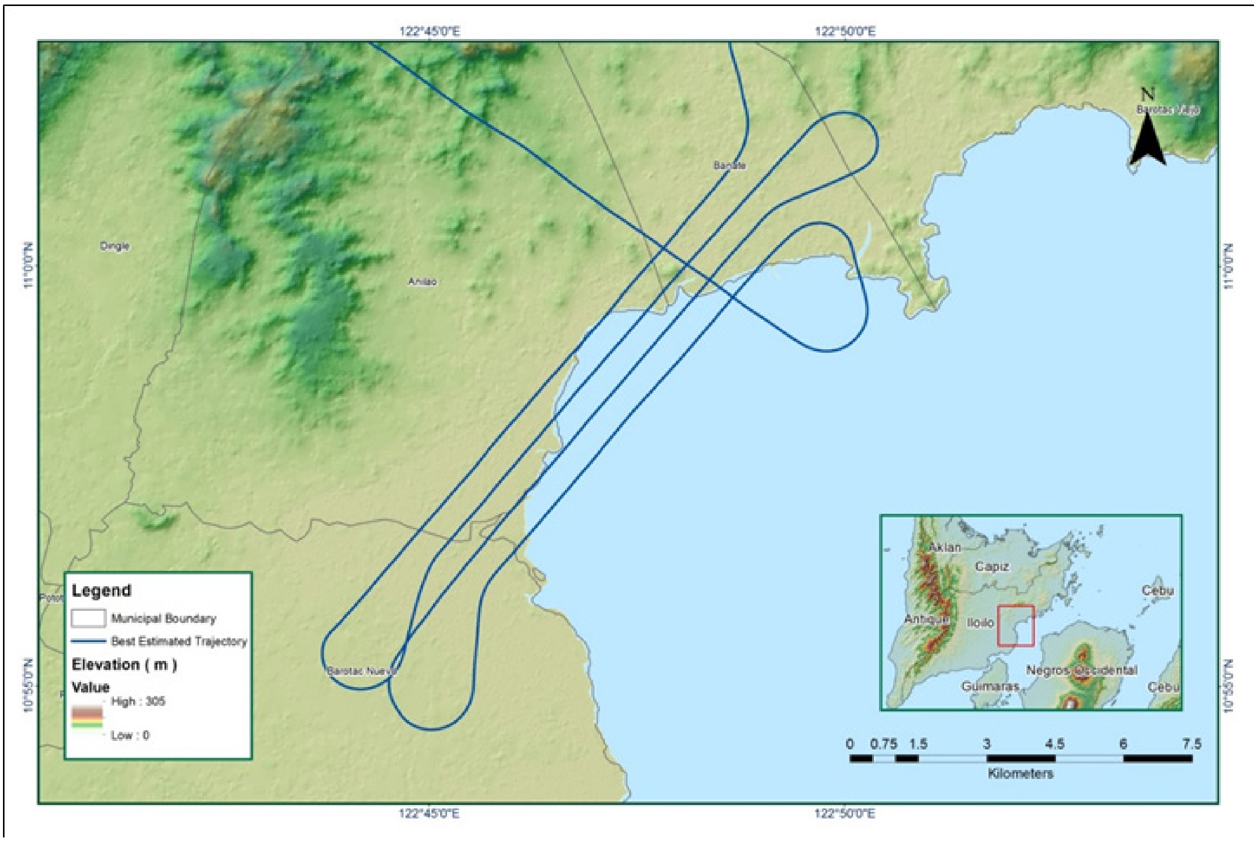


Figure A-8.17. Best Estimated Trajectory

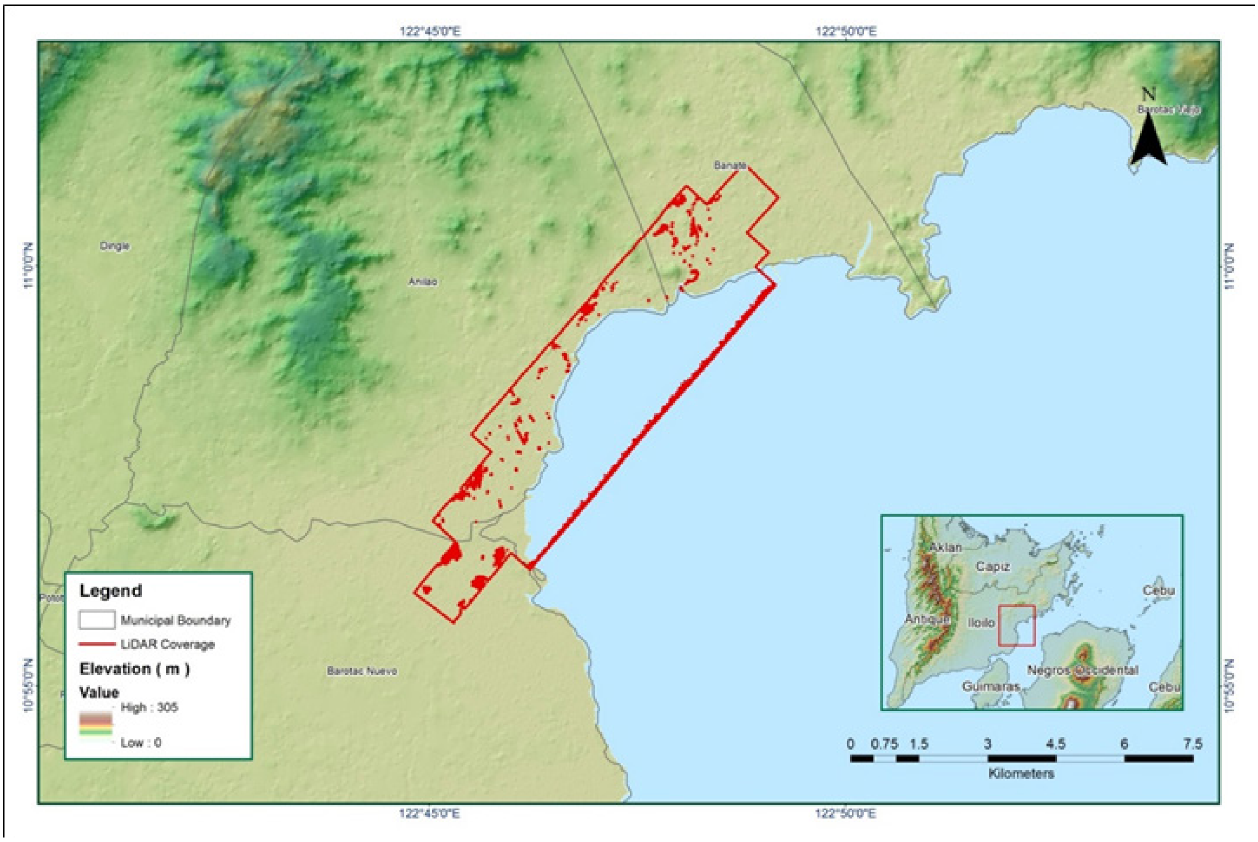


Figure A-8.18. Coverage of LiDAR data

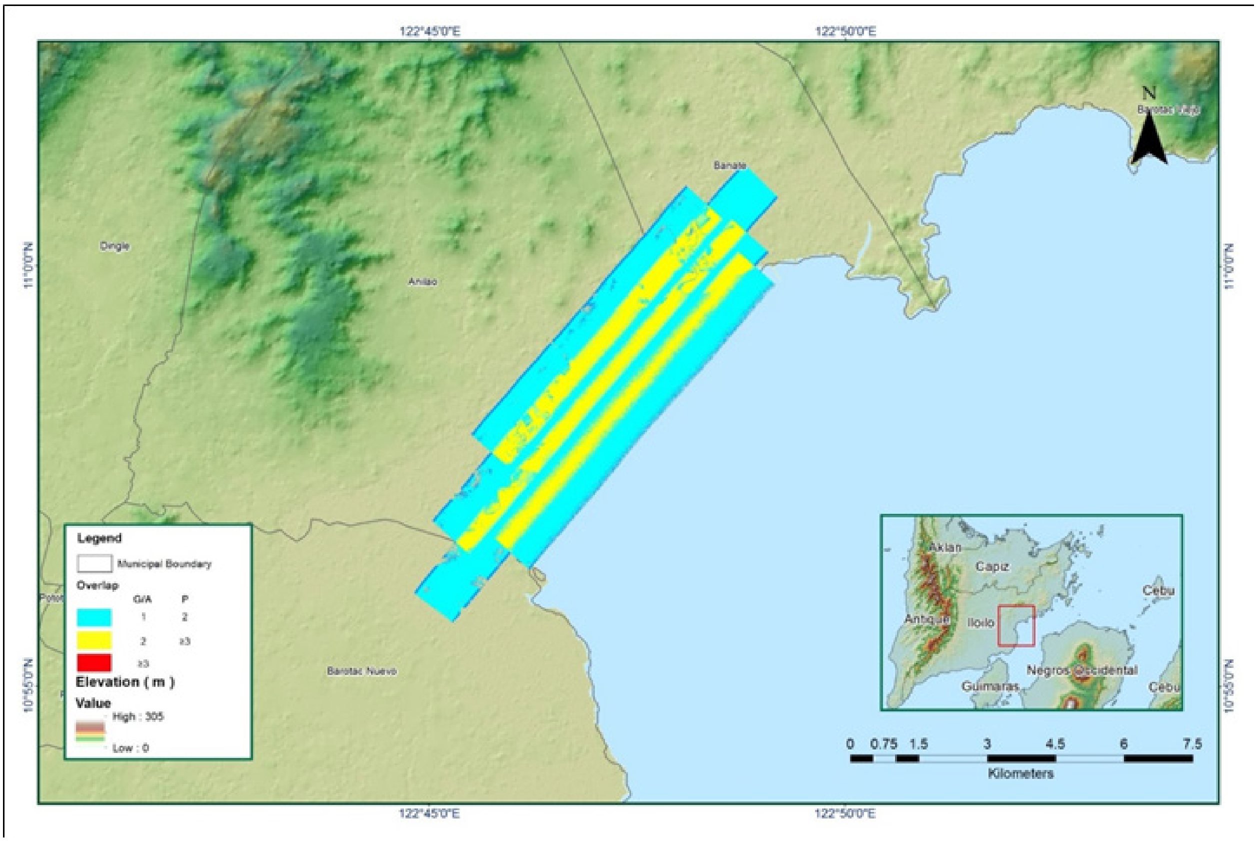


Figure A-8.19. Image of data overlap

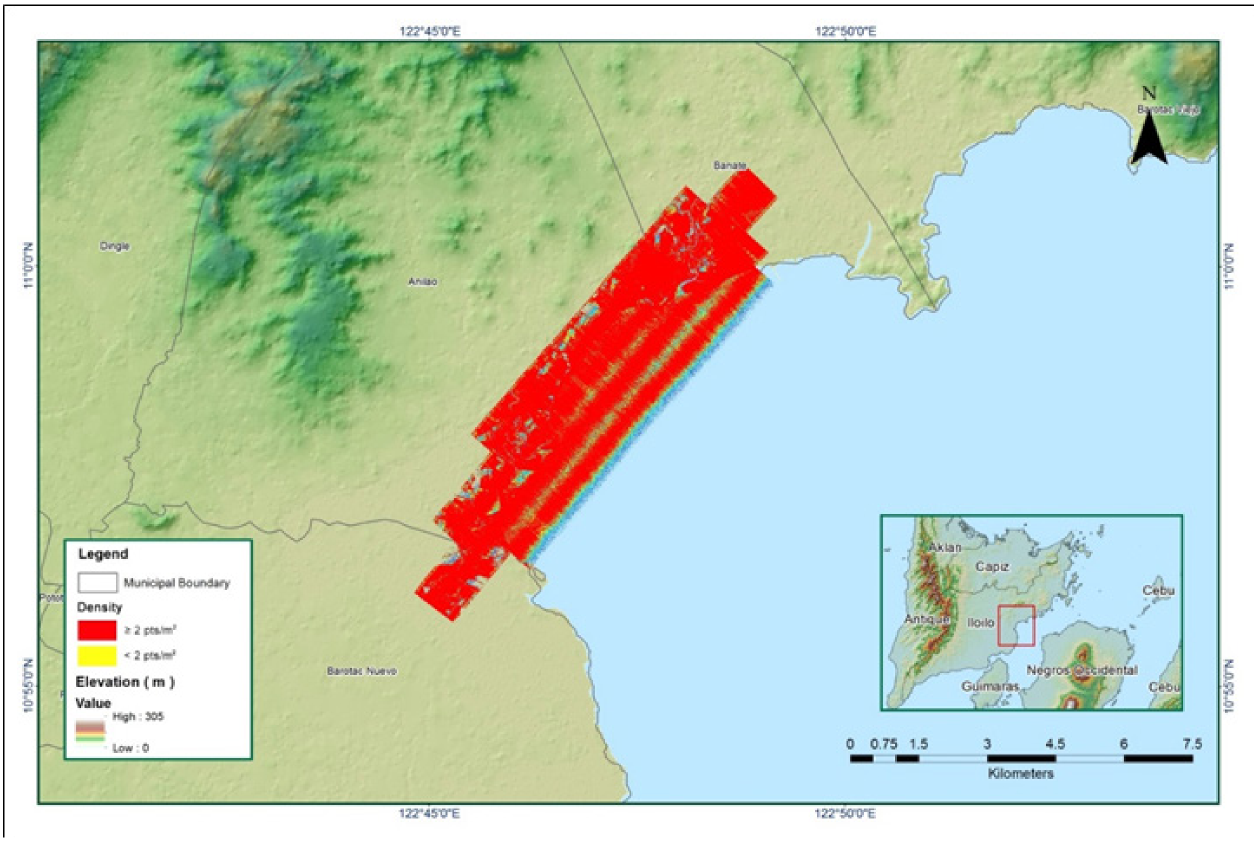


Figure A-8.20. Density map of merged LiDAR data

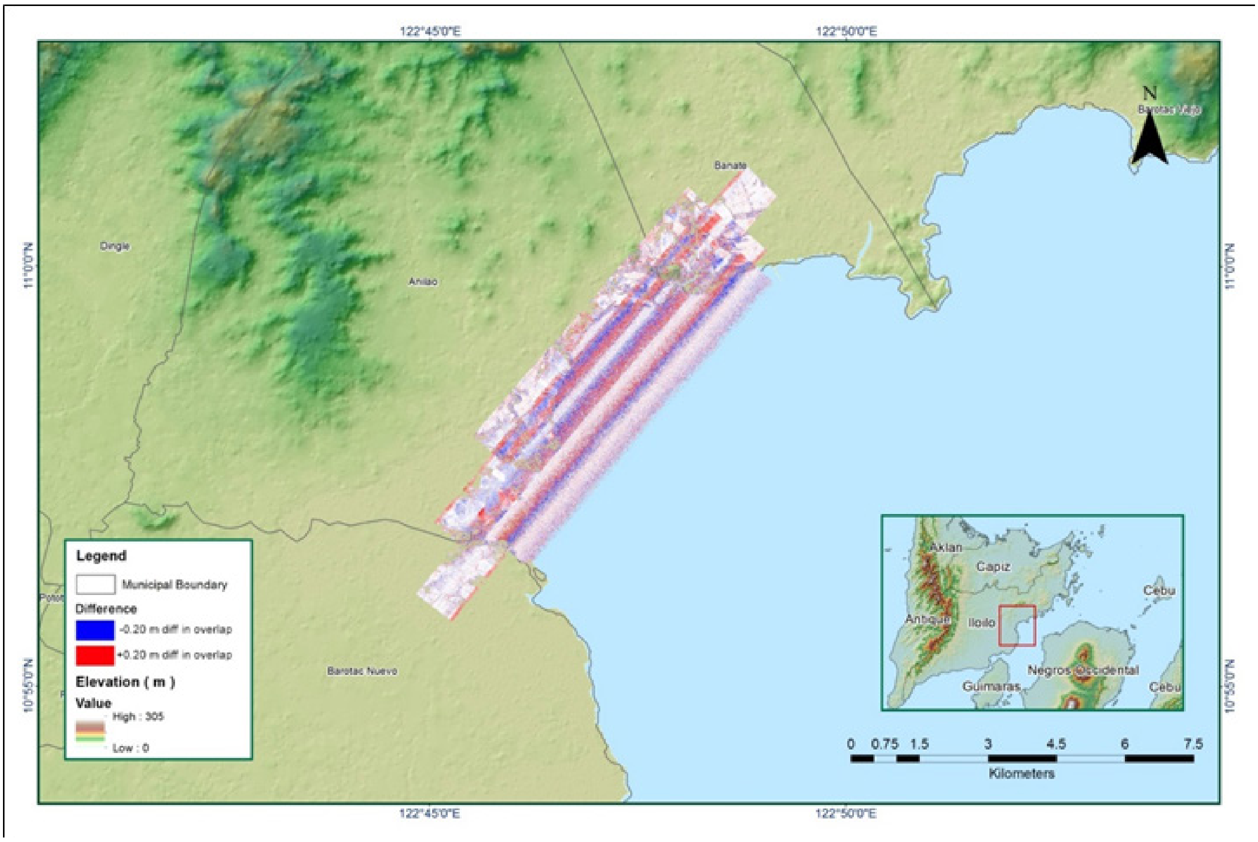


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk37G

Flight Area	Iloilo
Mission Name	Blk37G
Inclusive Flights	2568G, 2556G
Range data size	54.4 GB
POS	437 MB
Image	120.9 GB
Transfer date	March 23, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.17
RMSE for East Position (<4.0 cm)	1.62
RMSE for Down Position (<8.0 cm)	3.68
Boresight correction stdev (<0.001deg)	0.000386
IMU attitude correction stdev (<0.001deg)	0.004513
GPS position stdev (<0.01m)	0.0058
Minimum % overlap (>25)	37.09%
Ave point cloud density per sq.m. (>2.0)	5.98
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	226
Maximum Height	473.68 m
Minimum Height	97.55 m
Classification (# of points)	
Ground	126,832,205
Low vegetation	175,151,275
Medium vegetation	548,299,043
High vegetation	162,212,862
Building	1,390,962
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Sheila-Maye Santillan, Engr. Edgardo Gubatanga, Jr., Engr. Krisha Marie Bautista

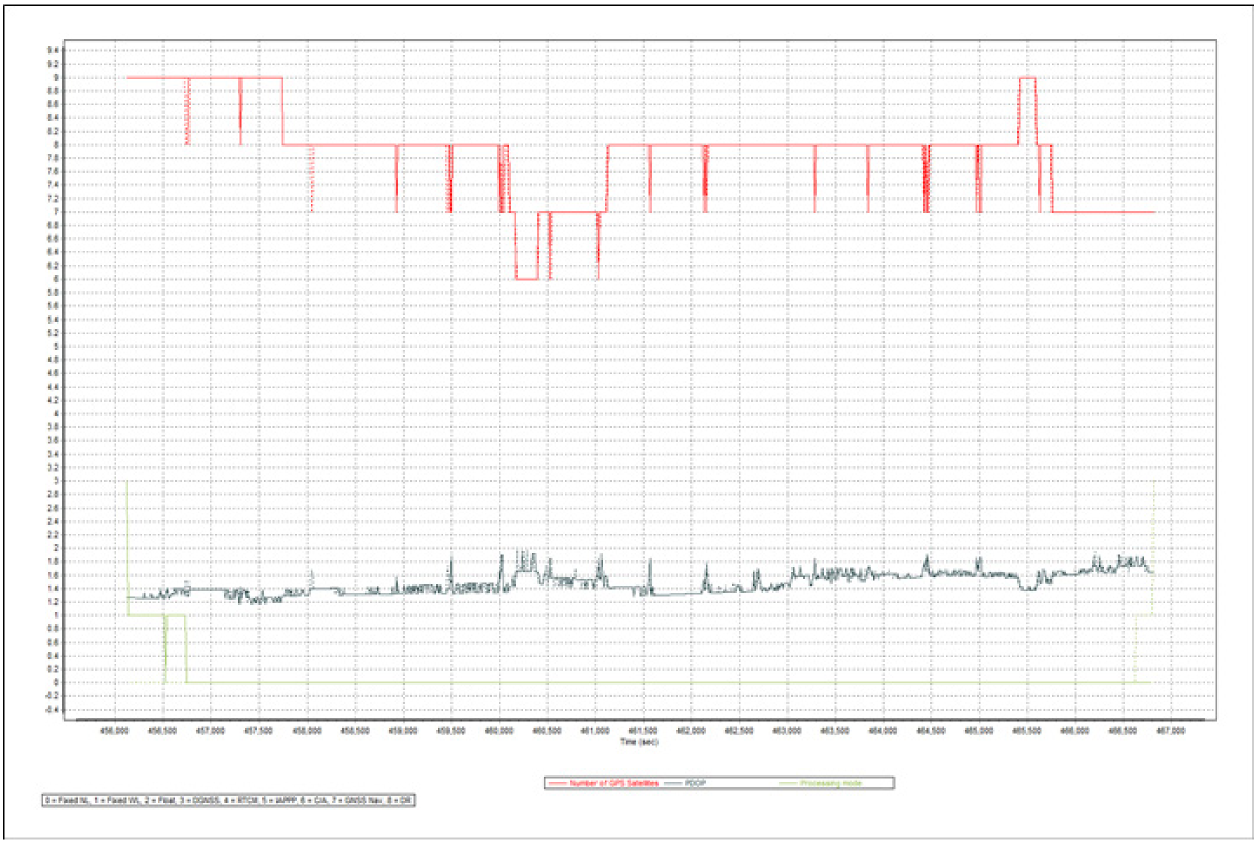


Figure A-8.22. Solution Status

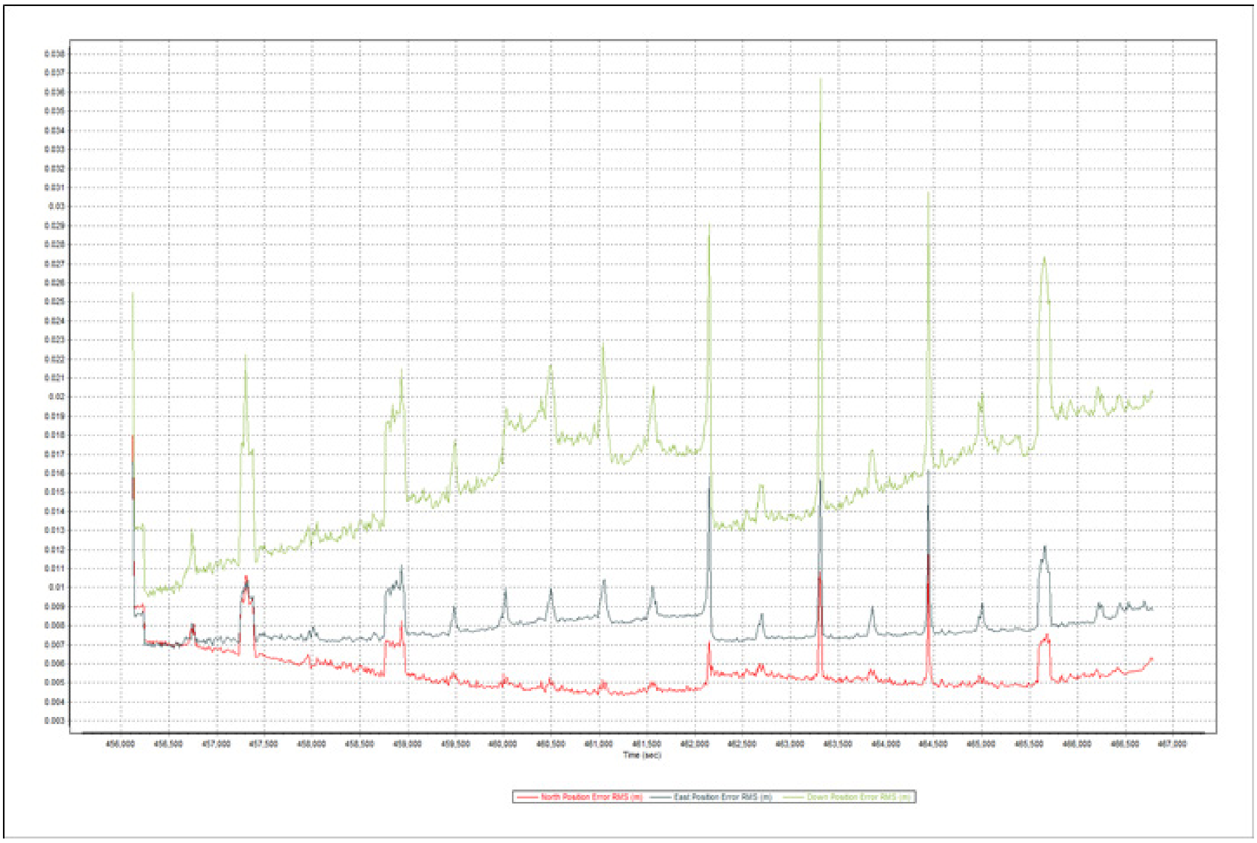


Figure A-8.23. Smoothed Performance Metric Parameters

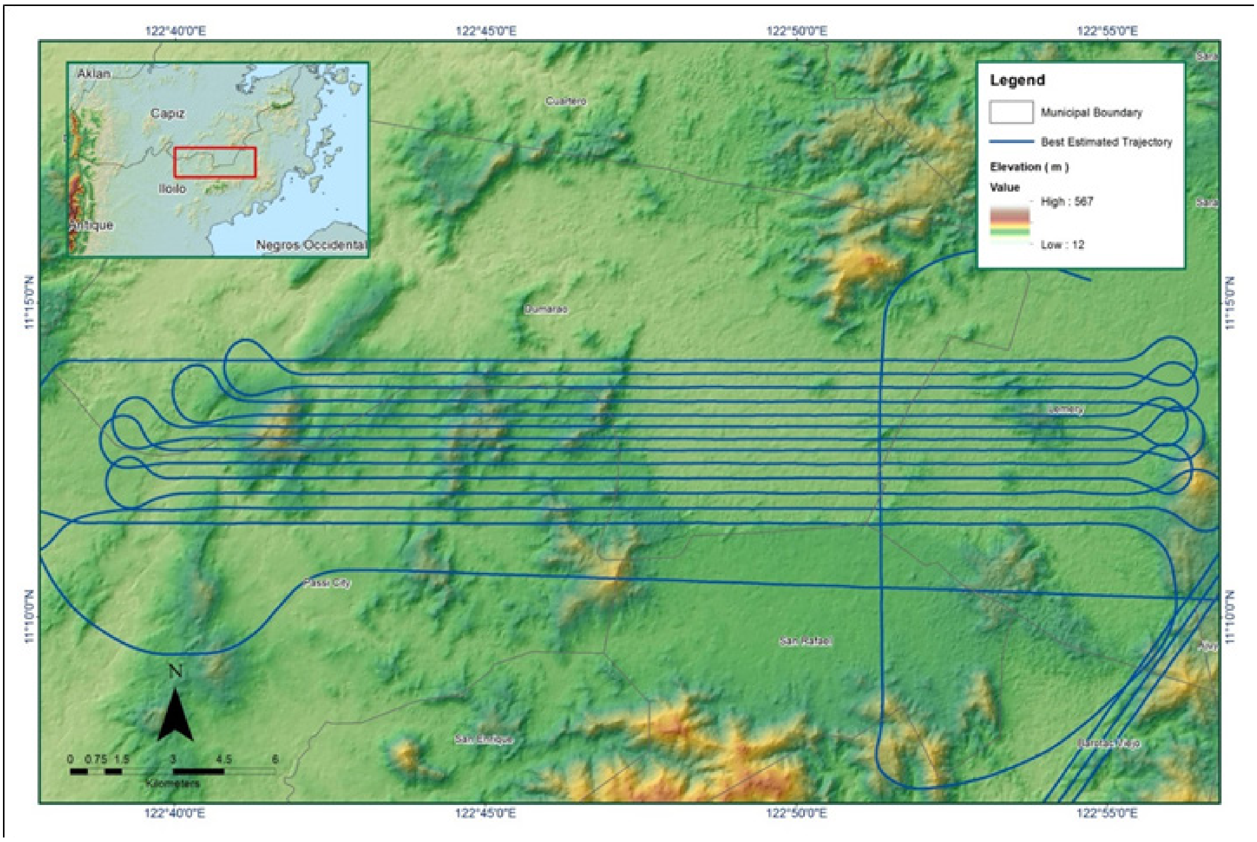


Figure A-8.24. Best Estimated Trajectory

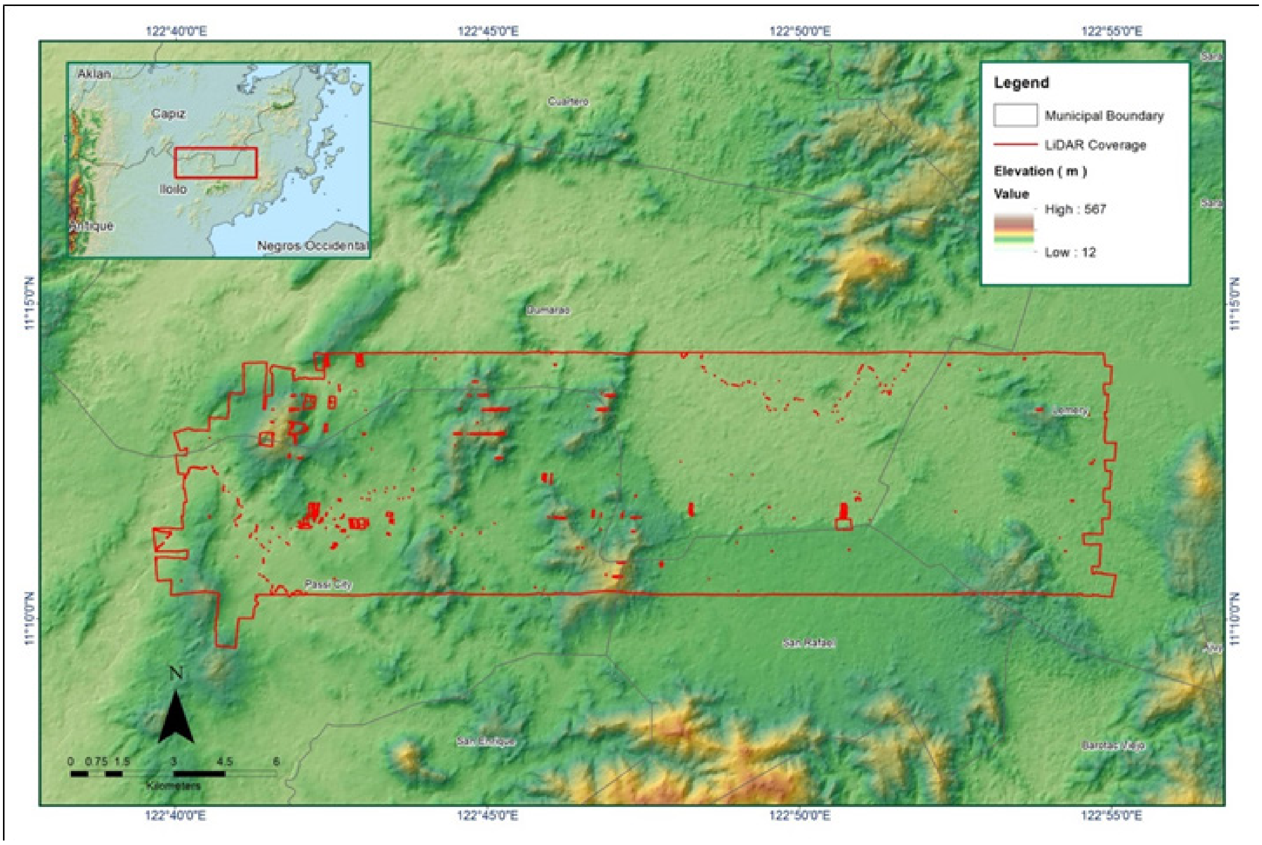


Figure A-8.25. Coverage of LiDAR data

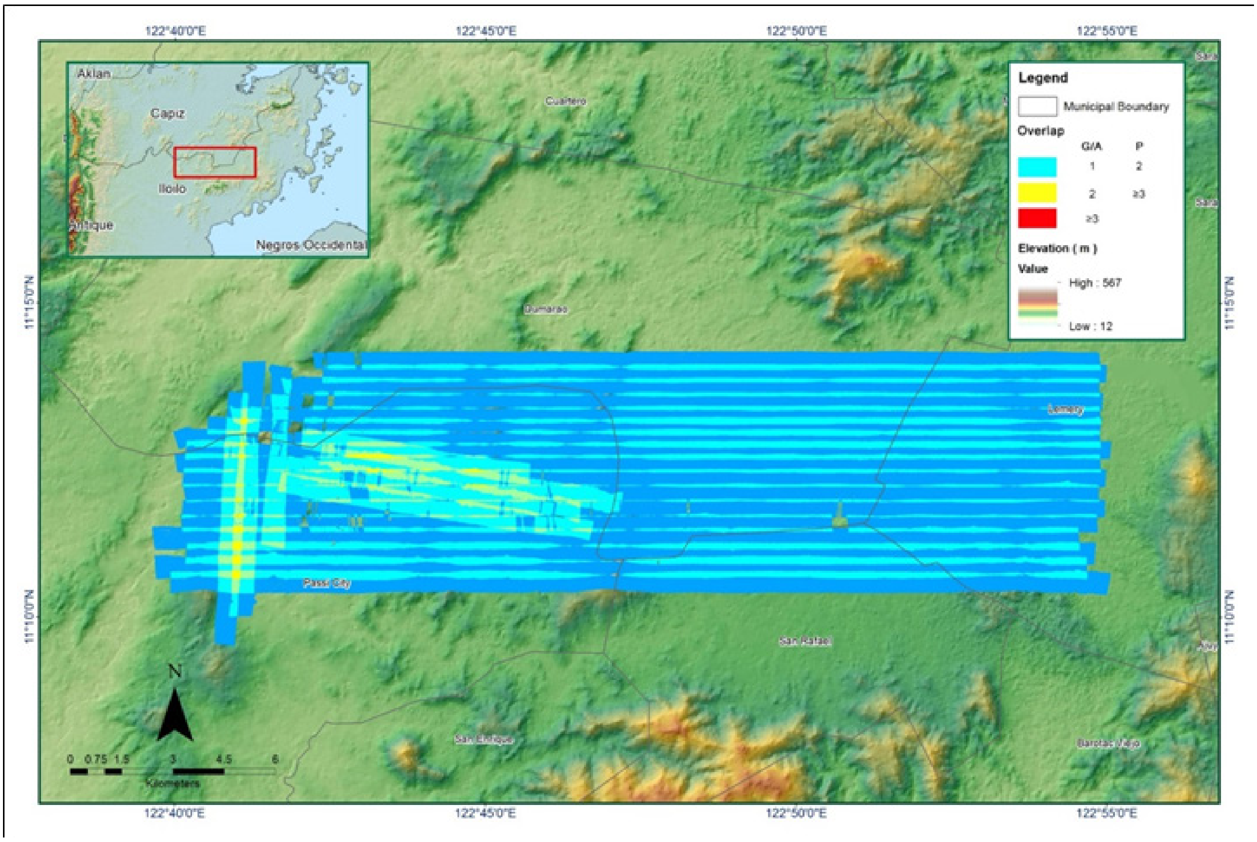


Figure A-8.26. Image of data overlap

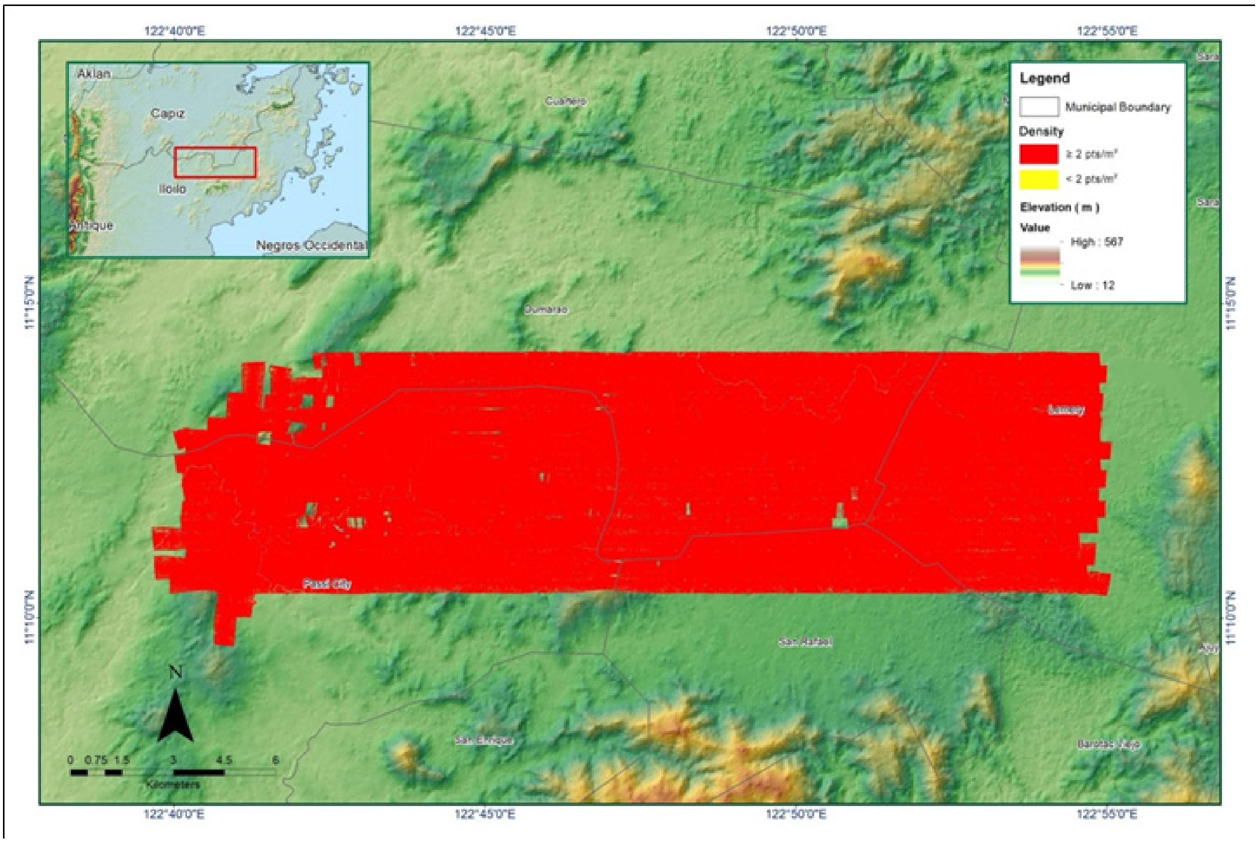


Figure A-8.27. Density map of merged LiDAR data

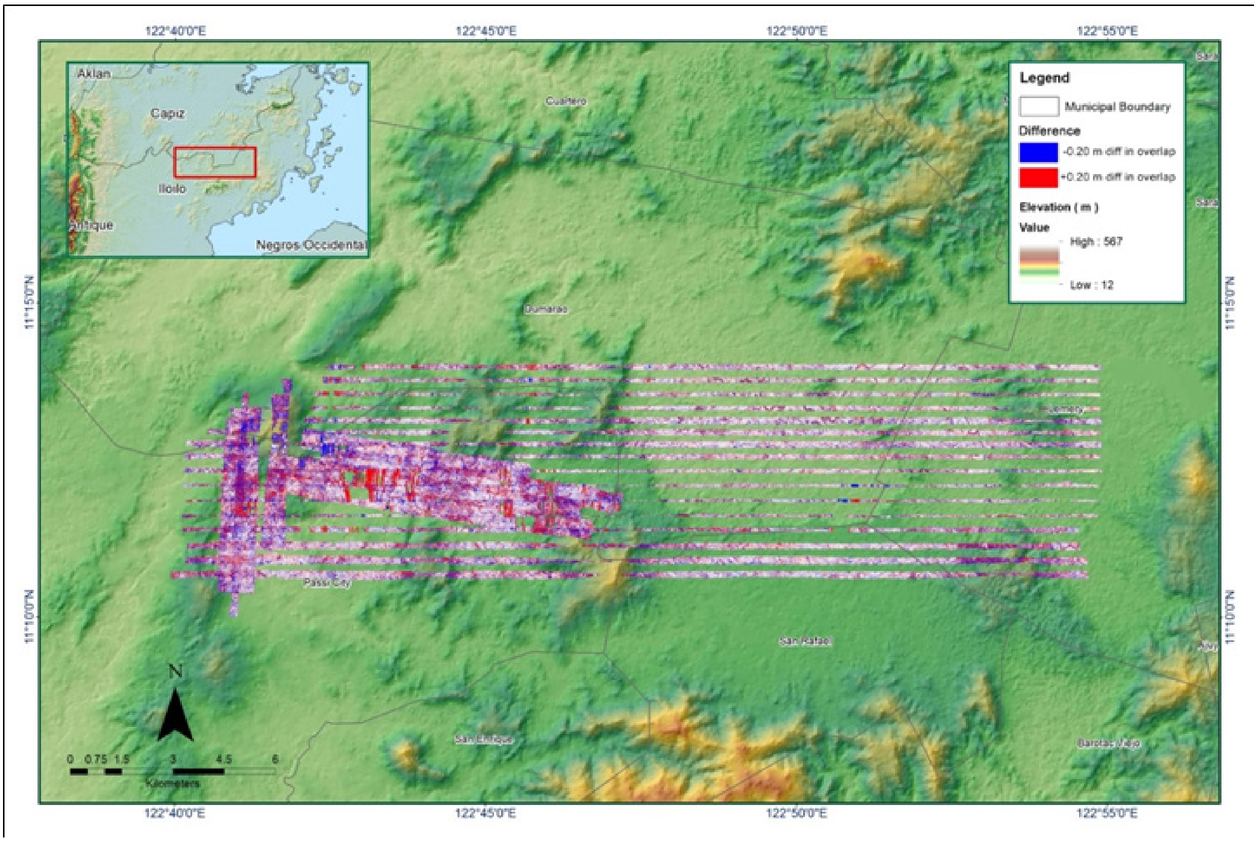


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk37J_additional

Flight Area	Iloilo
Mission Name	Blk37J_additional
Inclusive Flights	2566G
Range data size	13 GB
POS	209 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)	49.52%
Ave point cloud density per sq.m. (>2.0)	8.52
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	55
Maximum Height	362.11 m
Minimum Height	91.85 m
Classification (# of points)	
Ground	8,460,493
Low vegetation	7,013,332
Medium vegetation	54,125,450
High vegetation	79,263,211
Building	955,450
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Melissa Fernandez

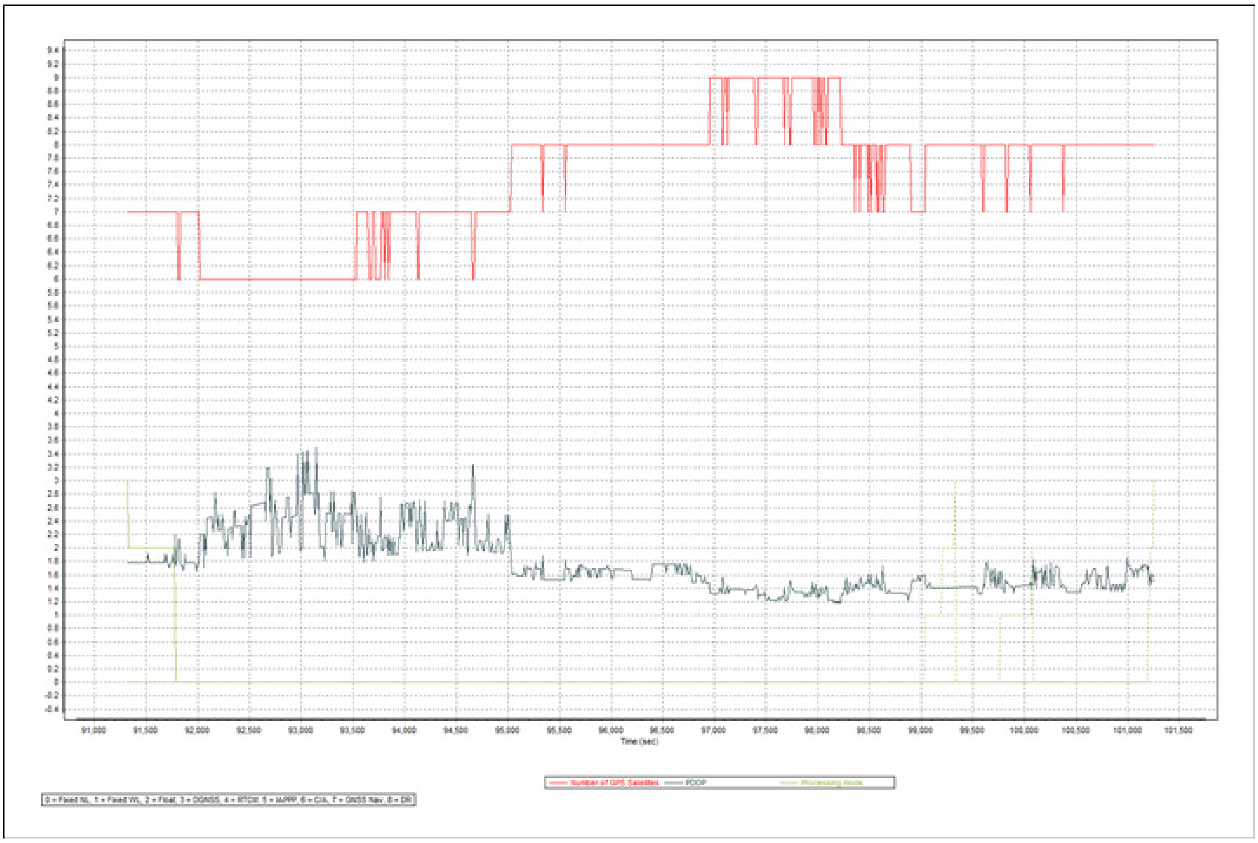


Figure A-8.29. Solution Status

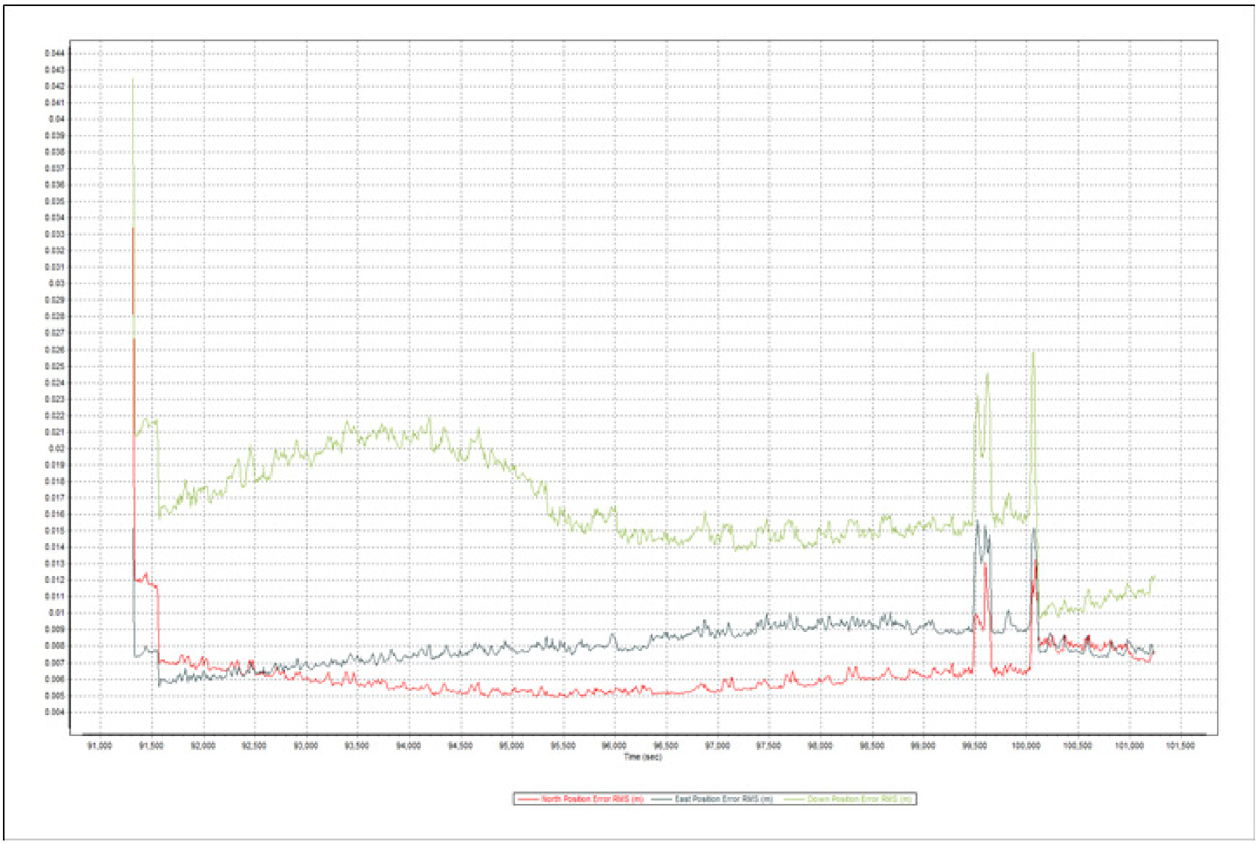


Figure A-8.30. Smoothed Performance Metric Parameters

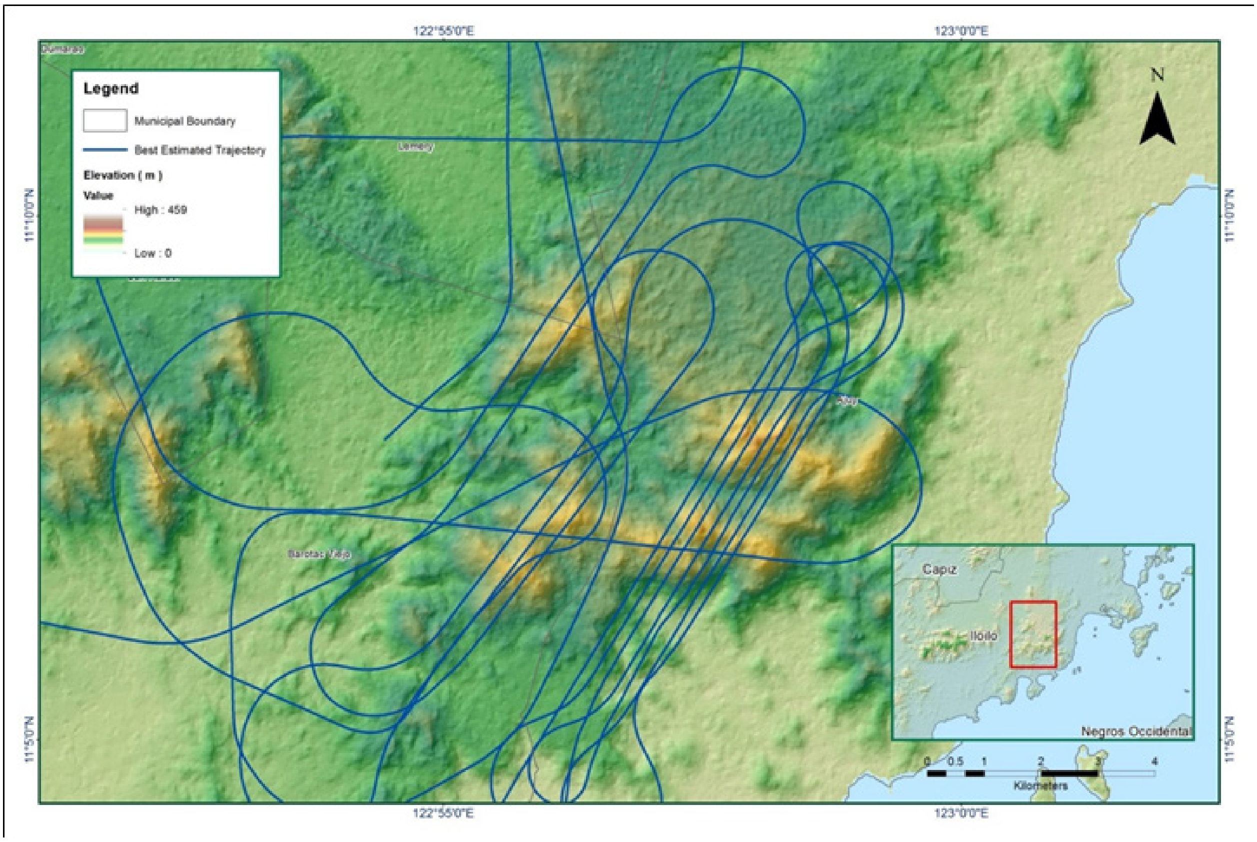


Figure A-8.31. Best Estimated Trajectory

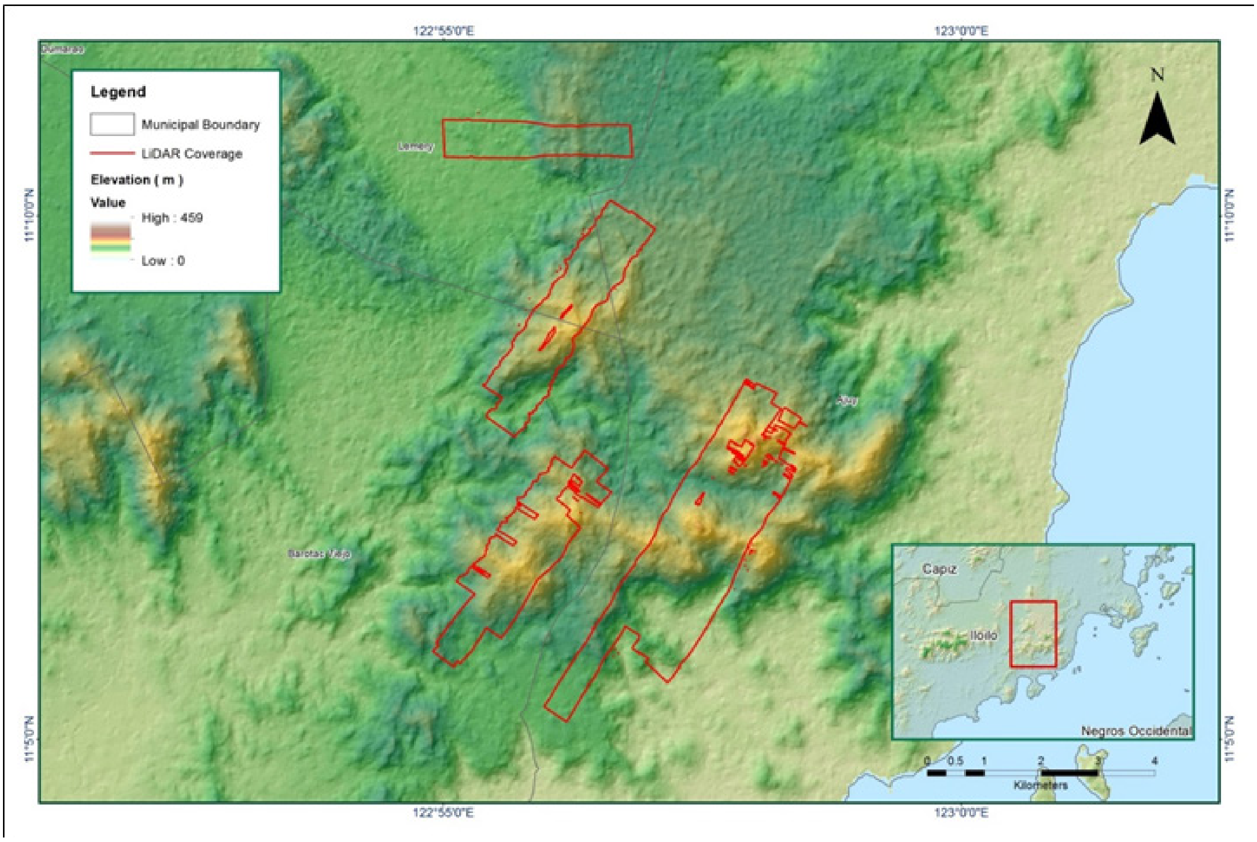


Figure A-8.32. Coverage of LiDAR data

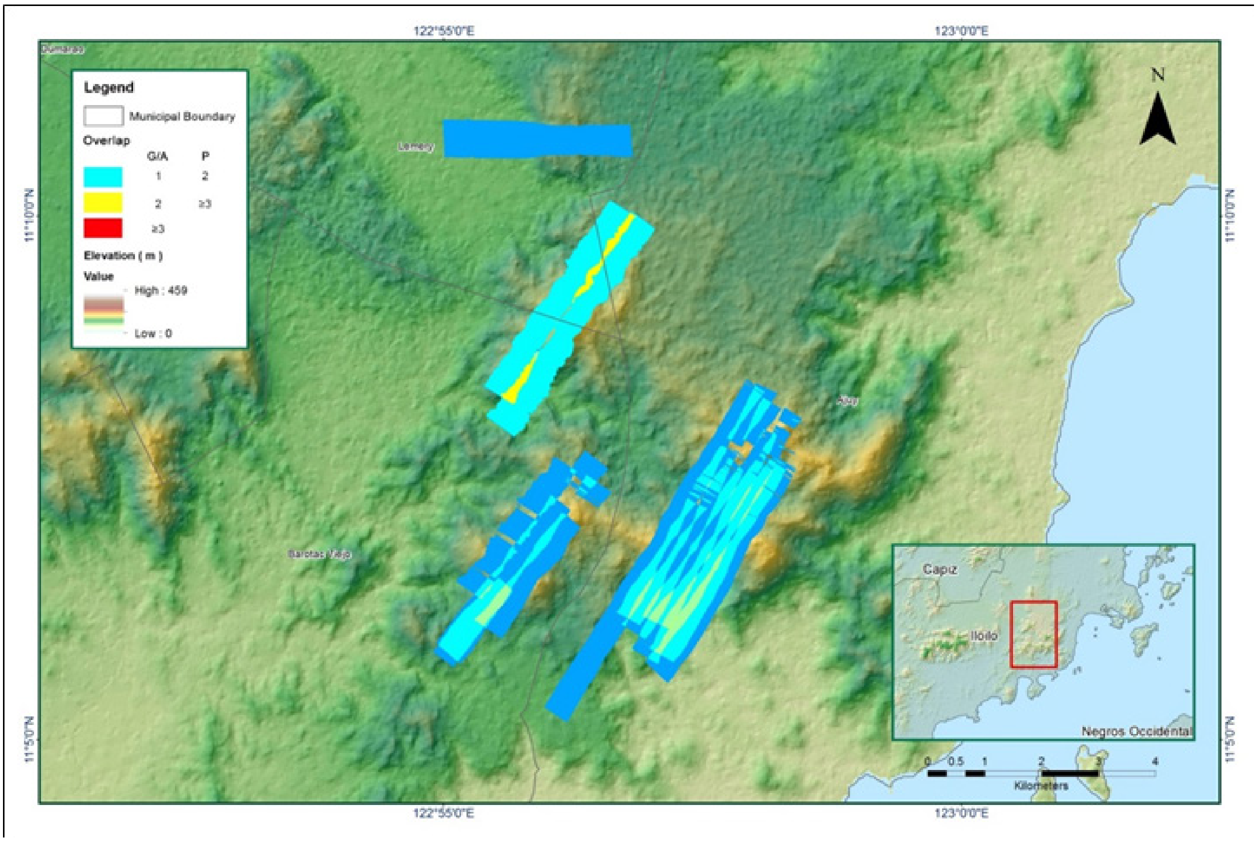


Figure A-8.33. Image of data overlap

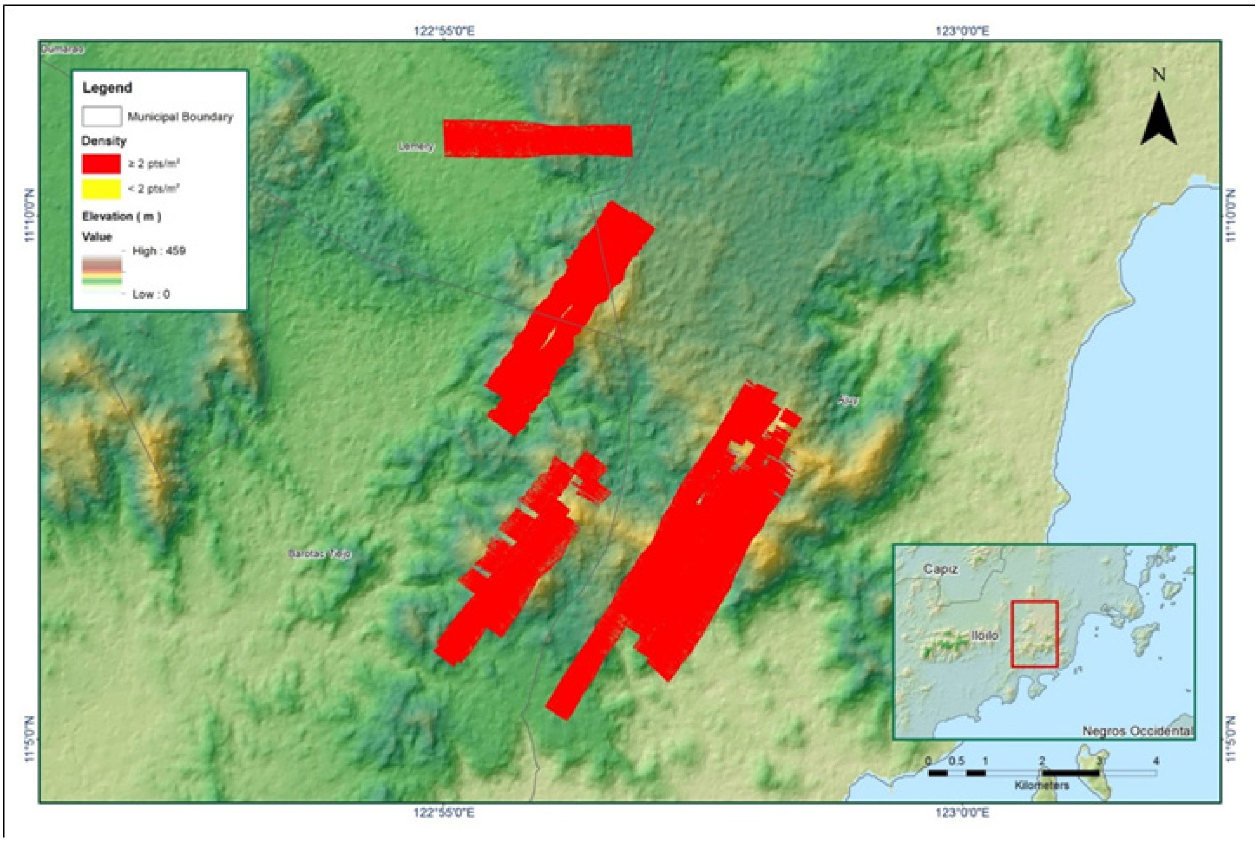


Figure A-8.34. Density map of merged LiDAR data

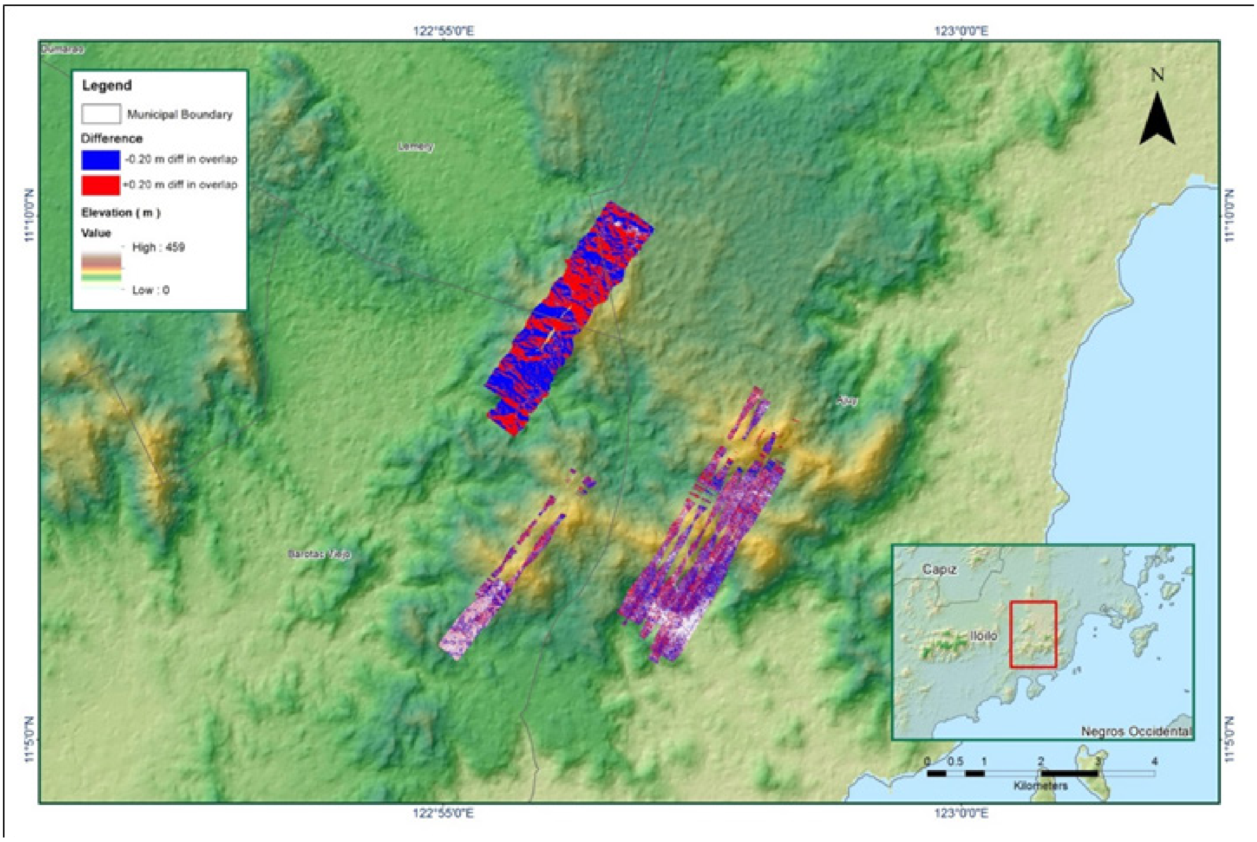


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk37M

Flight Area	Iloilo
Mission Name	Blk37M
Inclusive Flights	2639P, 2647P
Range data size	25.89 GB
POS	349 MB
Image	81.44 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)	13.23
RMSE for East Position (<4.0 cm)	8.95
RMSE for Down Position (<8.0 cm)	42.8
Boresight correction stdev (<0.001deg)	0.000207
IMU attitude correction stdev (<0.001deg)	0.000348
GPS position stdev (<0.01m)	0.001
Minimum % overlap (>25)	33.61%
Ave point cloud density per sq.m. (>2.0)	2.99
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	229
Maximum Height	536.70 m
Minimum Height	88.87 m
Classification (# of points)	
Ground	300,368,355
Low vegetation	85,956,177
Medium vegetation	239,189,039
High vegetation	395,809,877
Building	5,683,008
Orthophoto	Yes
Procesed by	Engr. Angelo Carlo Bongat, Engr. Edgardo Gubatanga, Jr., Maria Tamsyn Malabanan,

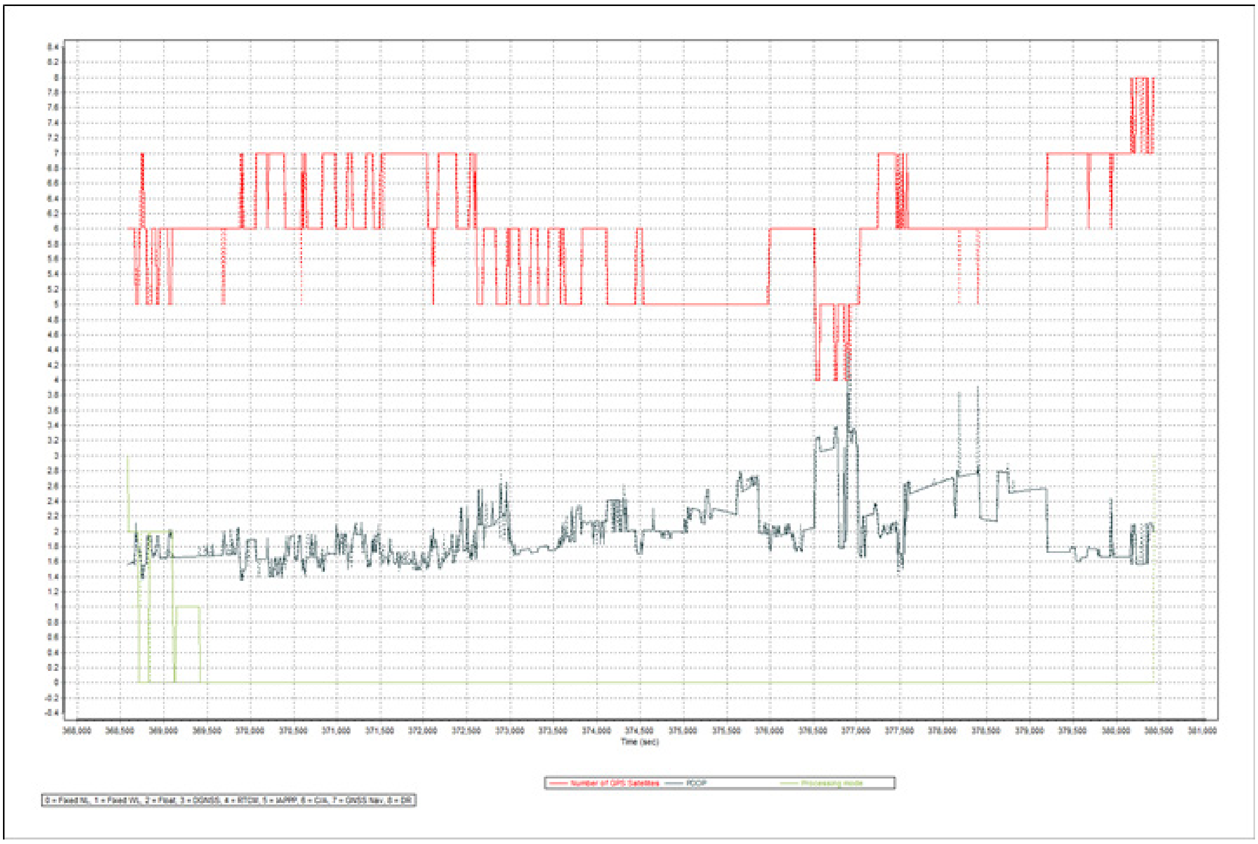


Figure A-8.36. Solution Status

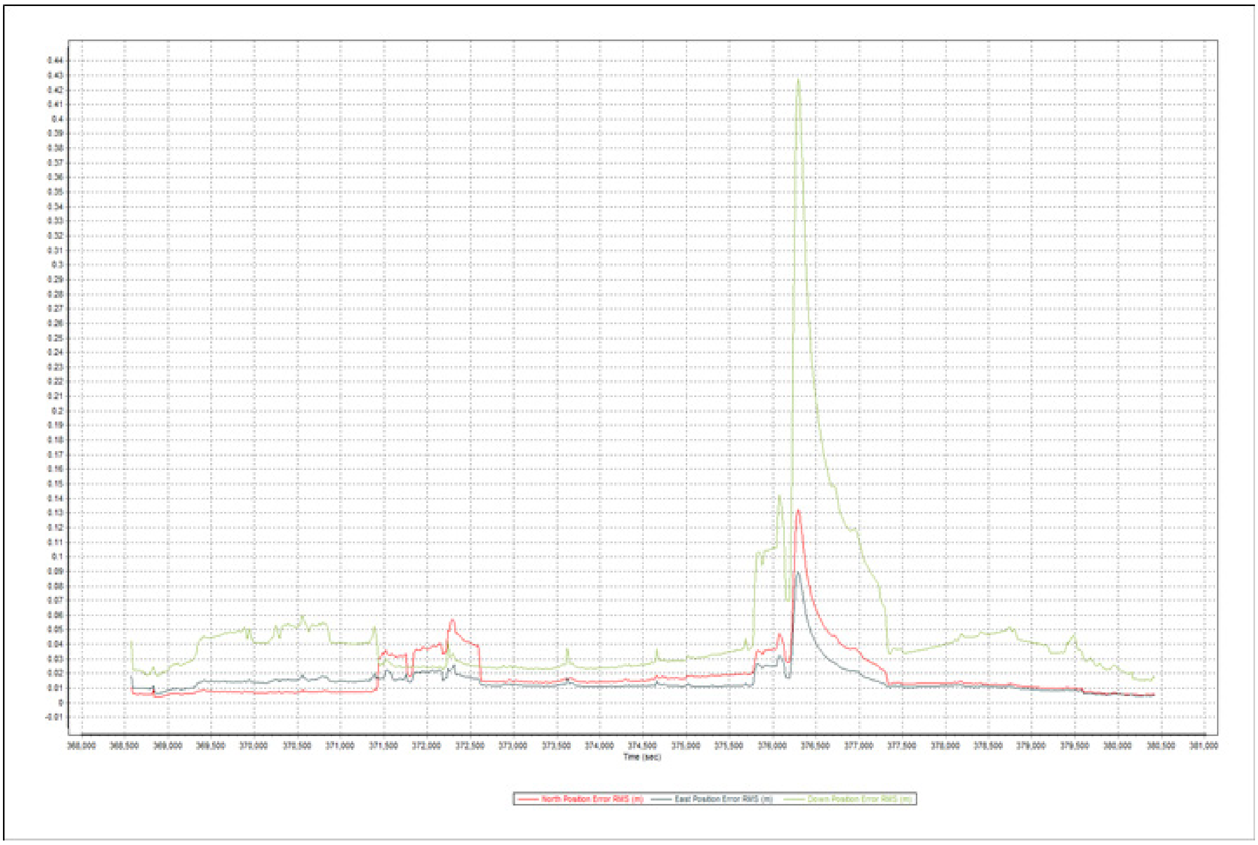


Figure A-8.37. Smoothed Performance Metric Parameters

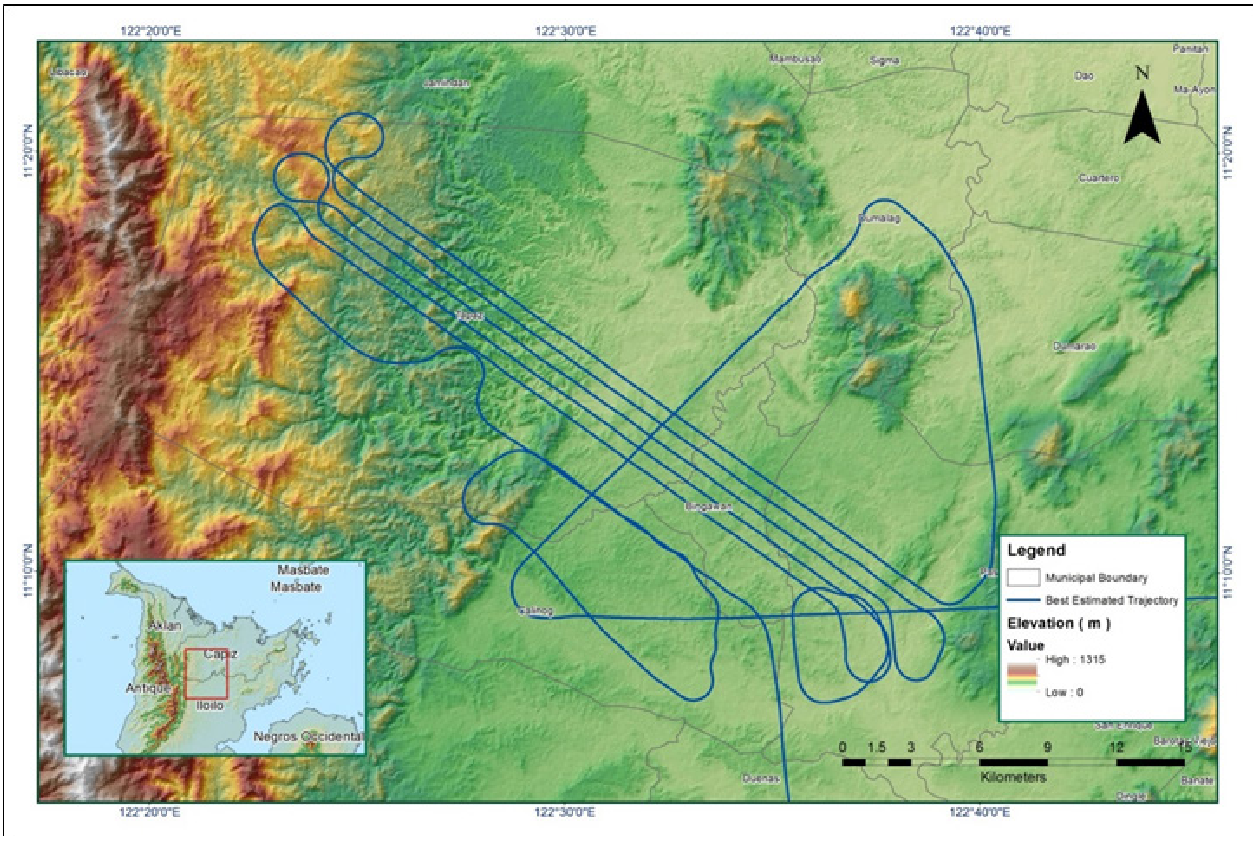


Figure A-8.38. Best Estimated Trajectory

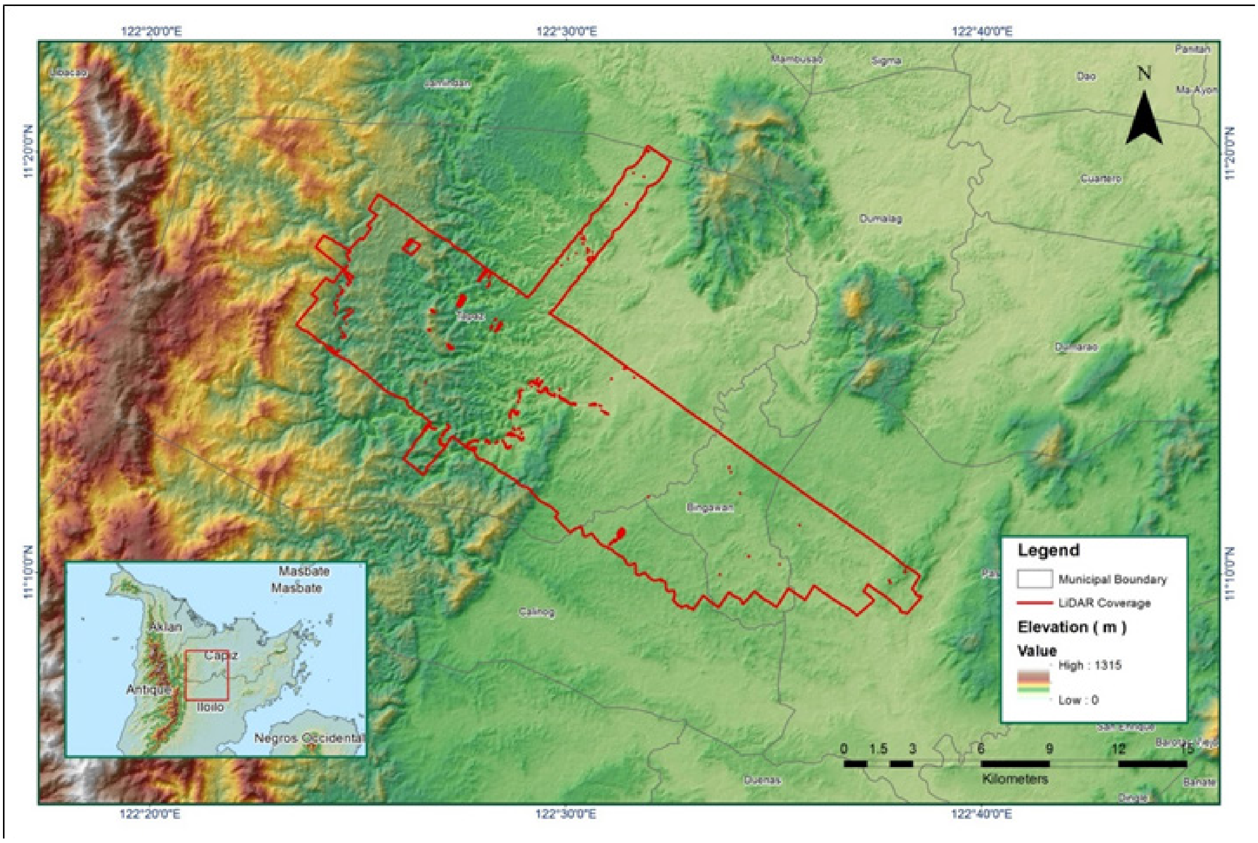


Figure A-8.39. Coverage of LiDAR data

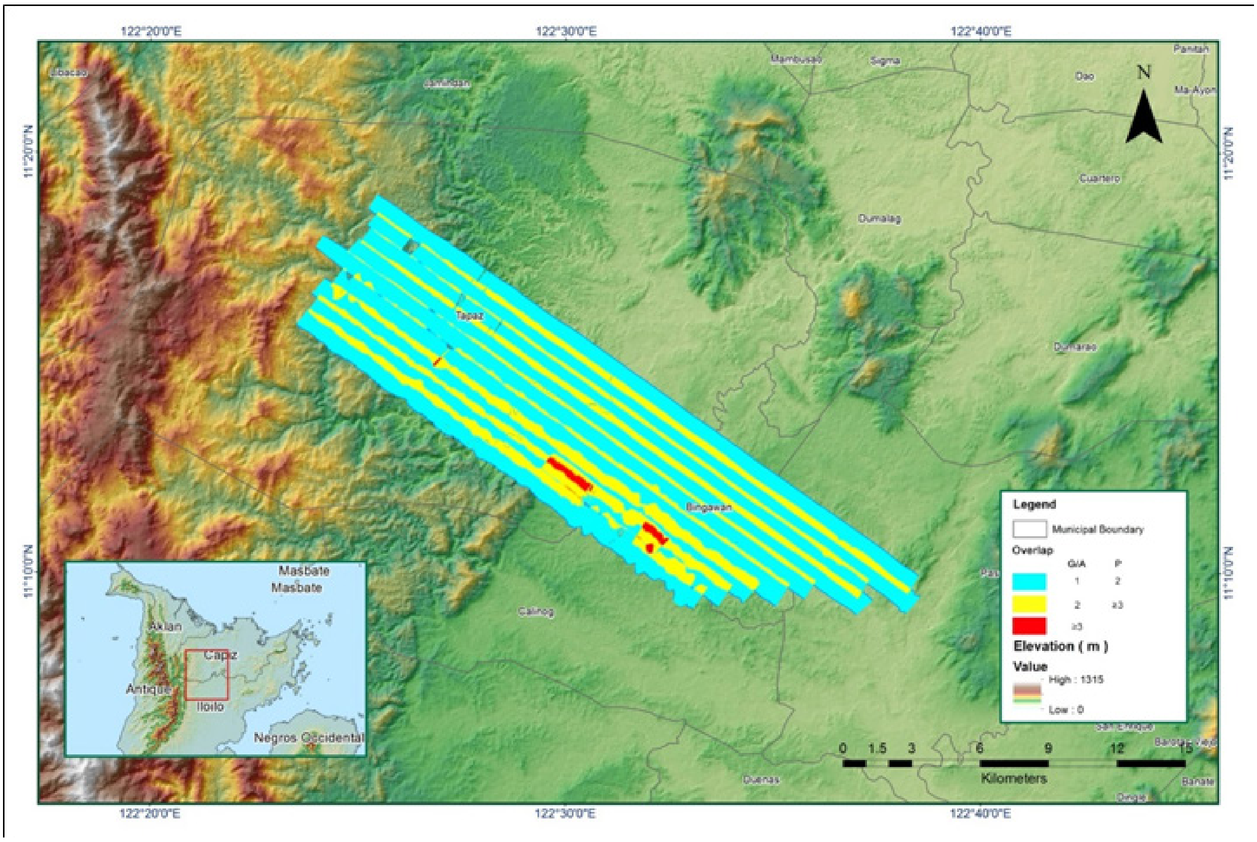


Figure A-8.40. Image of data overlap

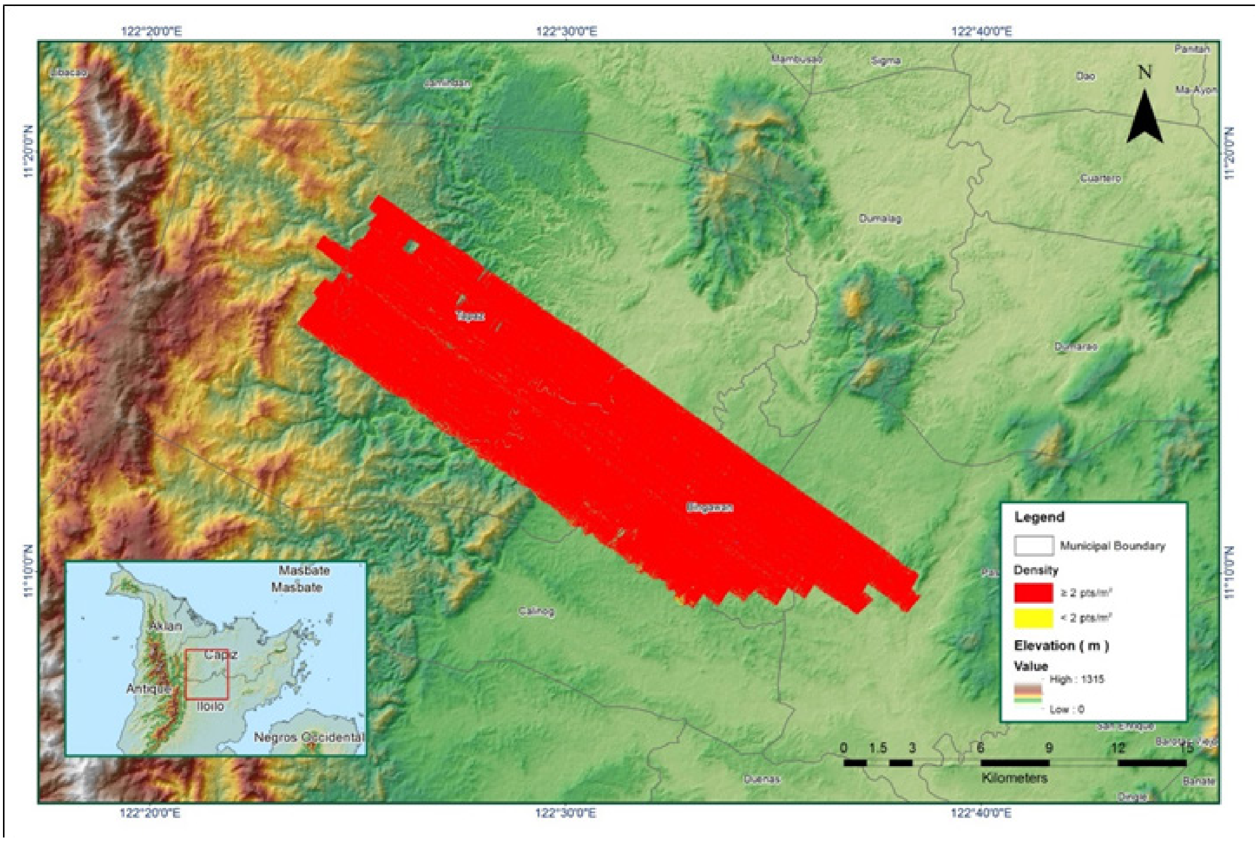


Figure A-8.41. Density map of merged LiDAR data

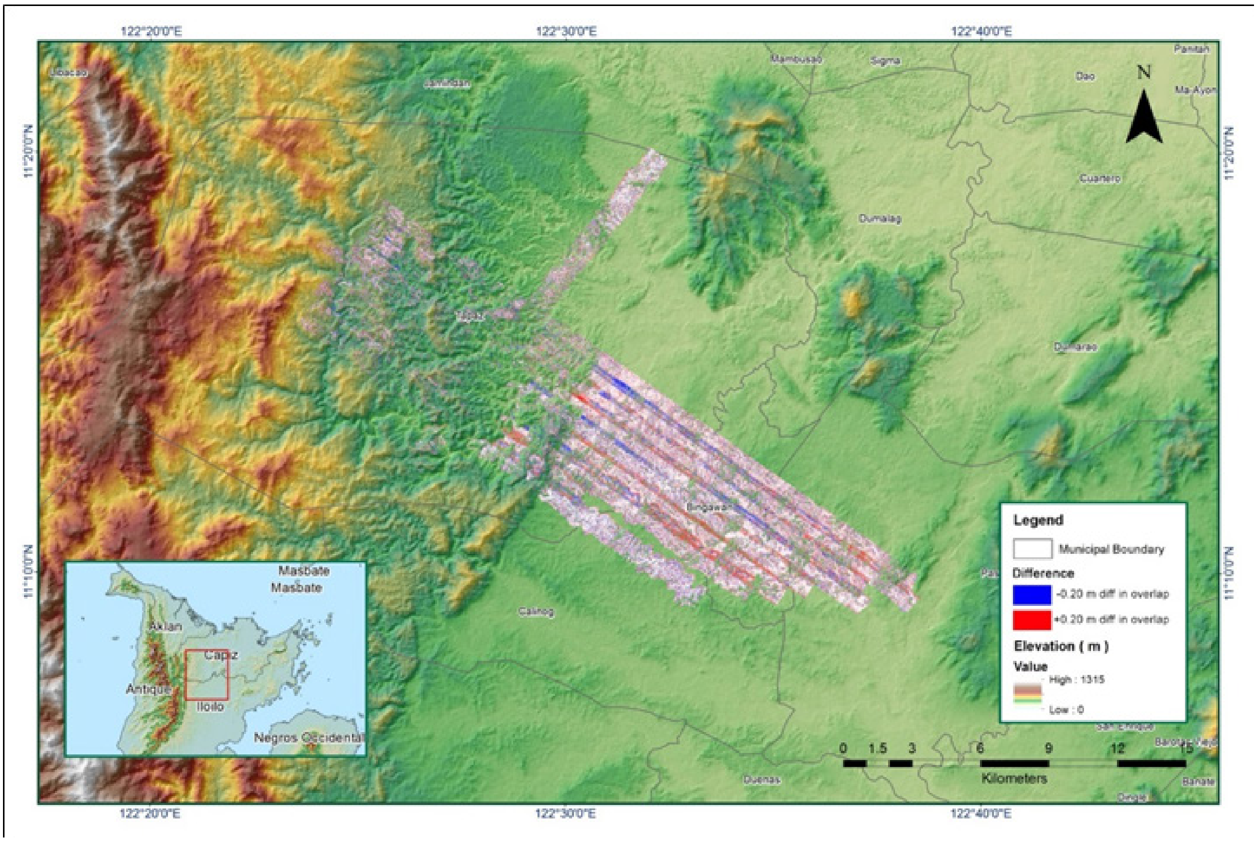


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk37JK

Flight Area	Iloilo
Mission Name	Blk37JK
Inclusive Flights	2544G, 2556G, 2546G
Range data size	93.5 GB
POS	678 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

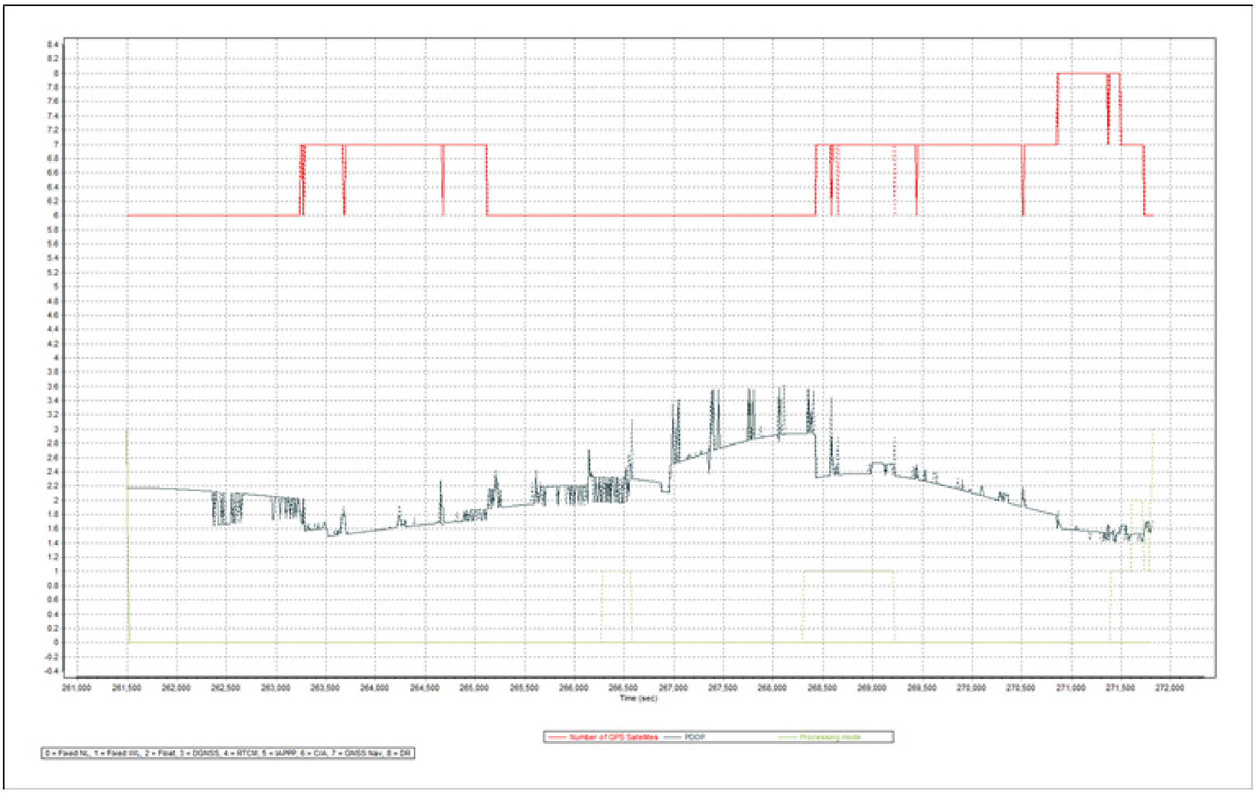


Figure A-8.43. Solution Status

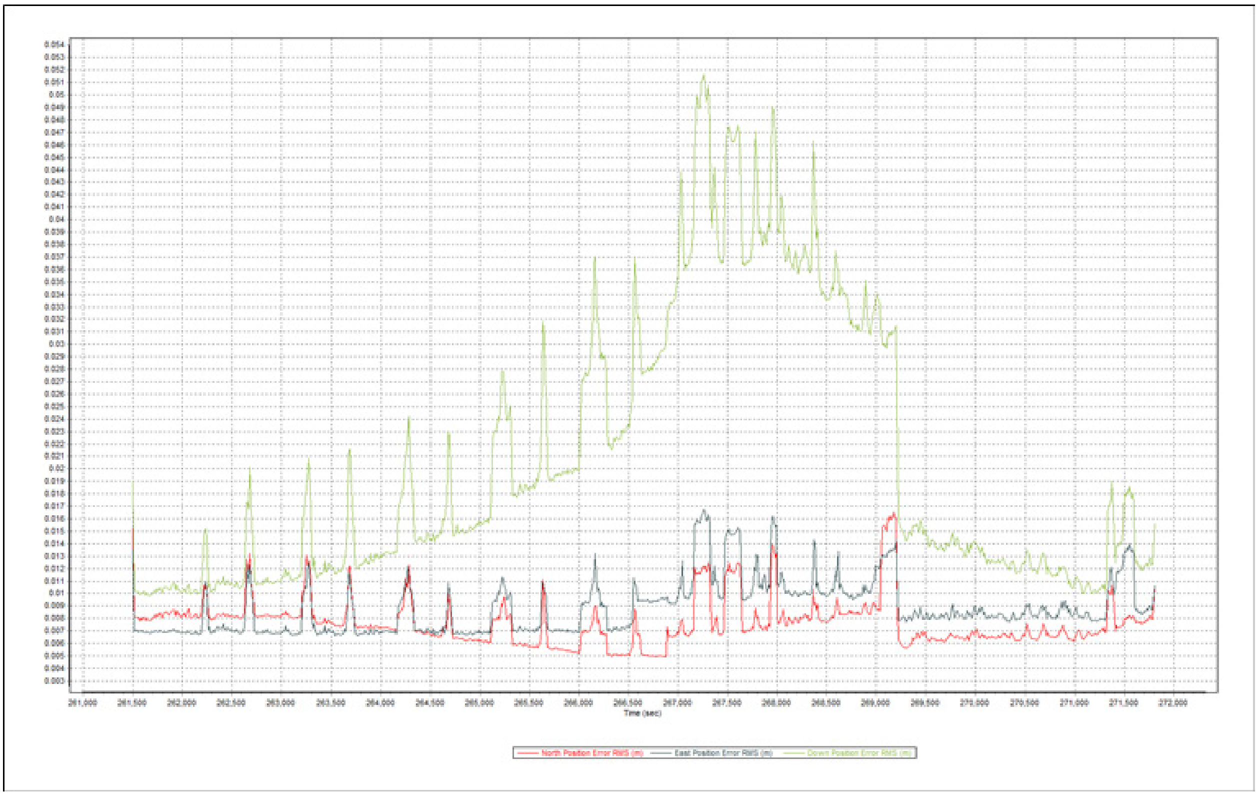


Figure A-8.44. Smoothed Performance Metric Parameters

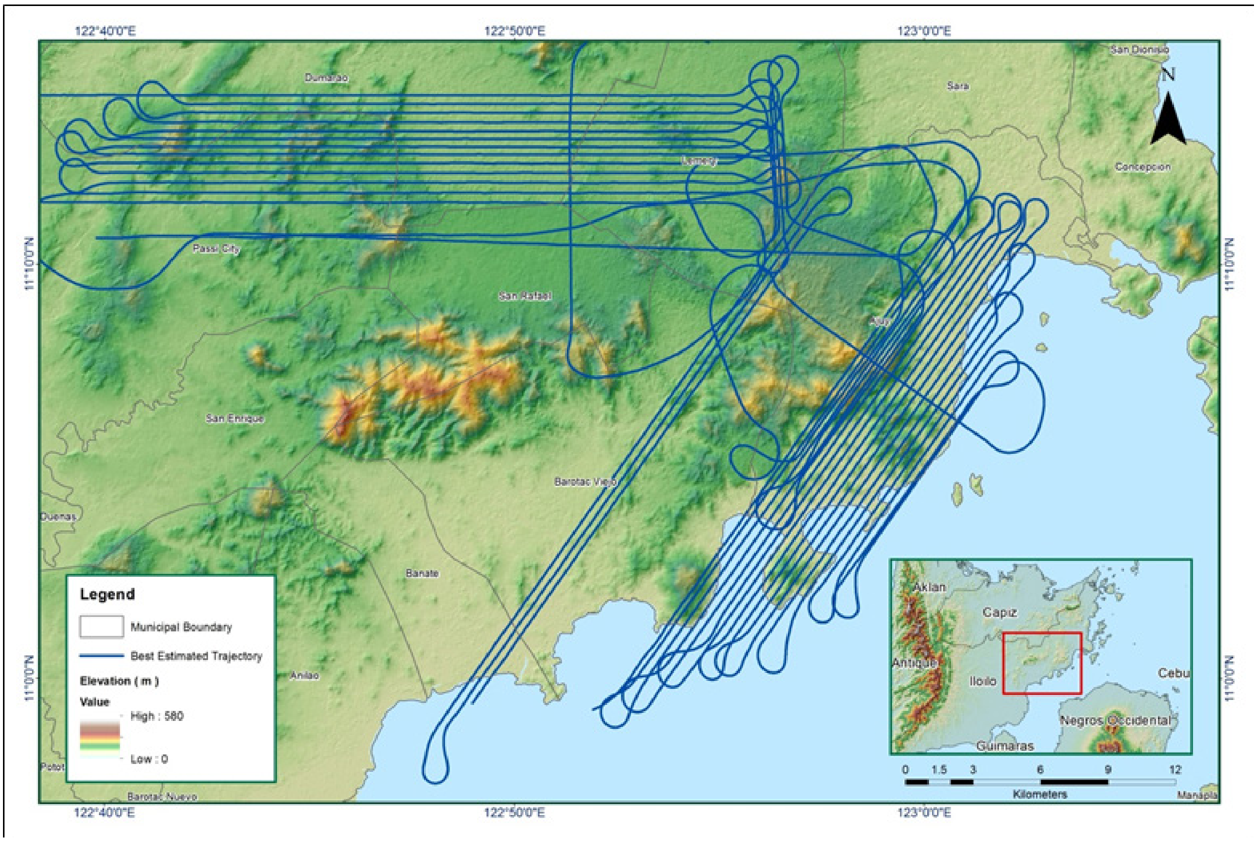


Figure A-8.45. Best Estimated Trajectory

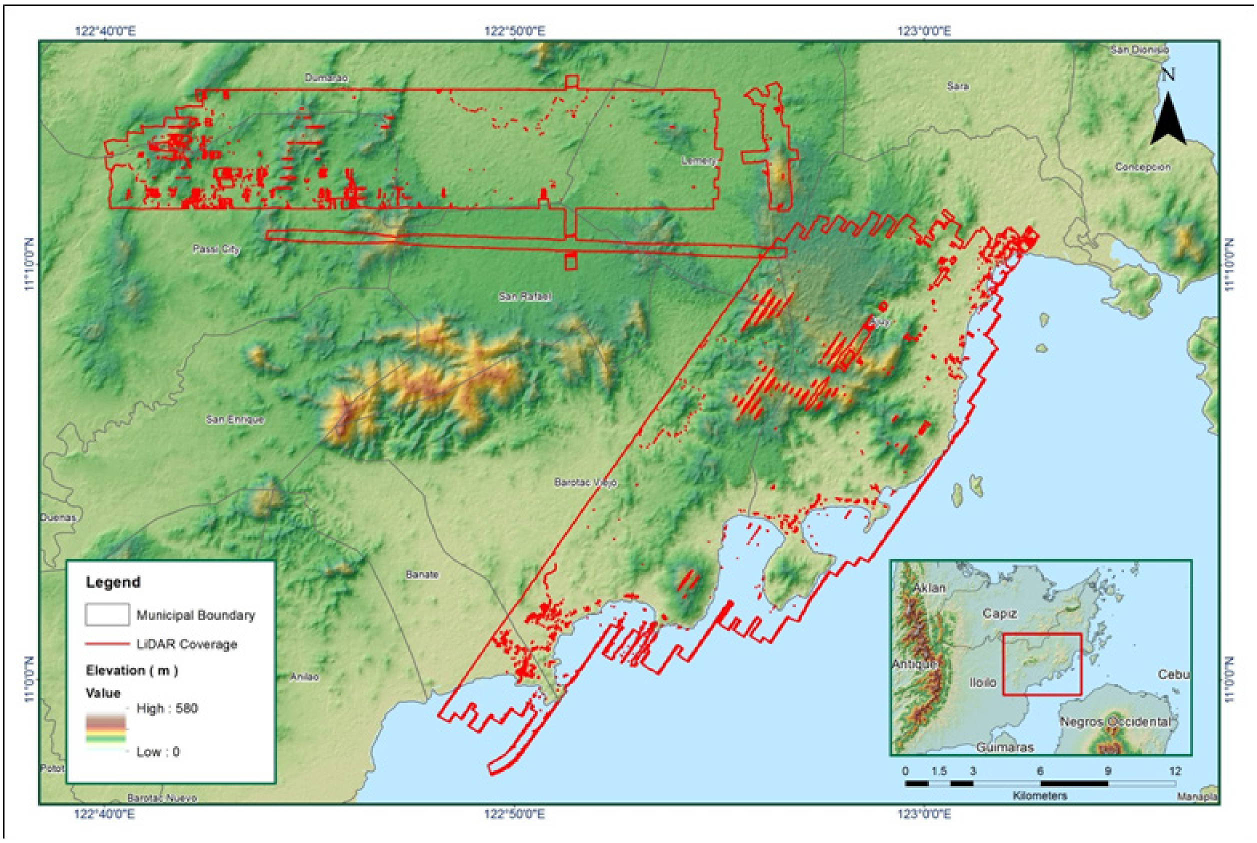


Figure A-8.46. Coverage of LiDAR data

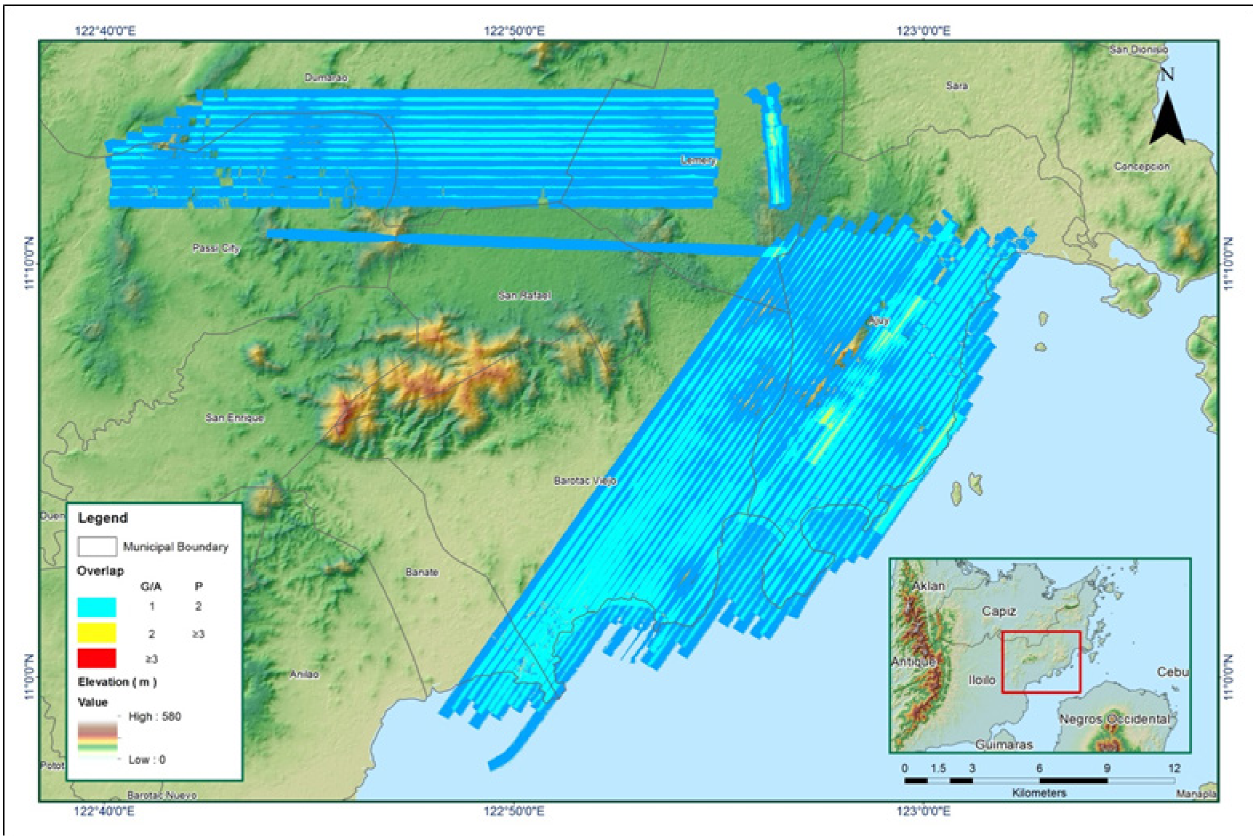


Figure A-8.47. Image of data overlap

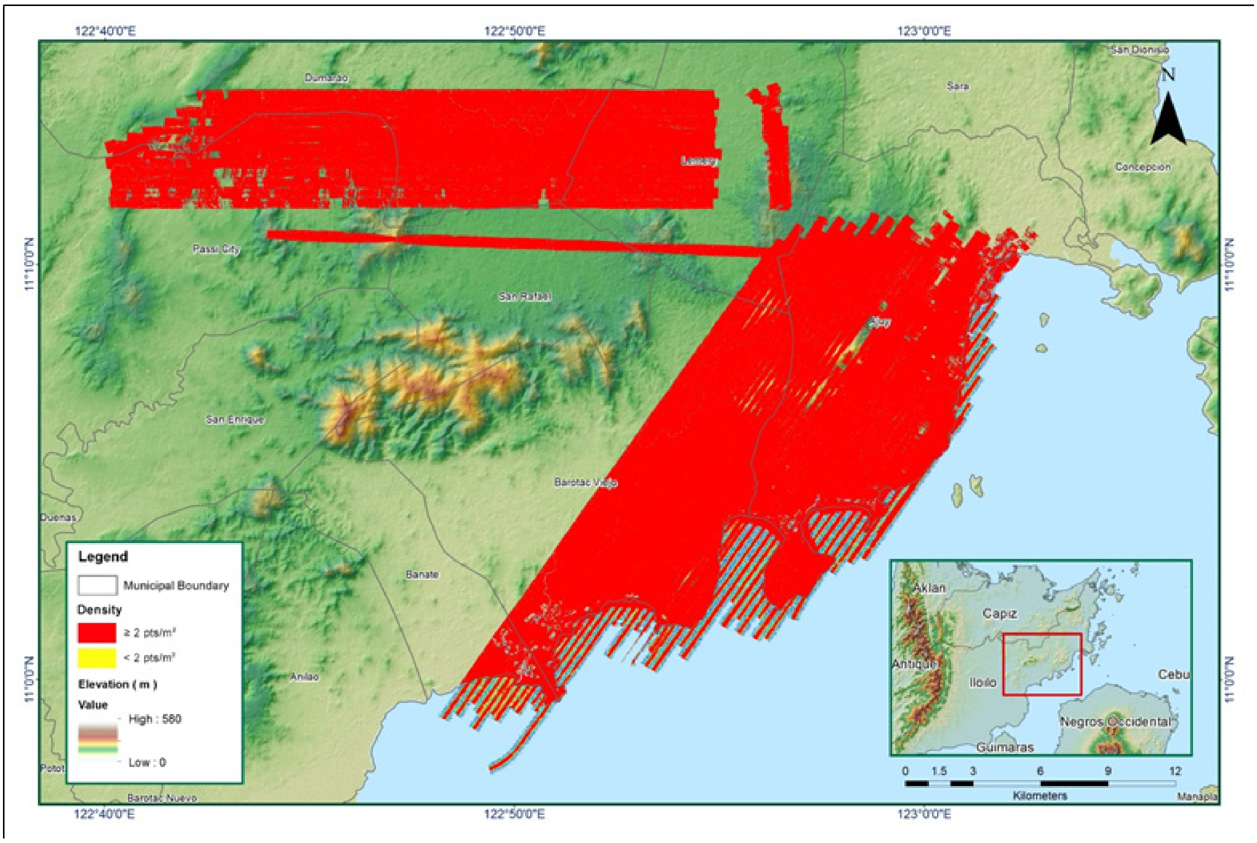


Figure A-8.48. Density map of merged LiDAR data

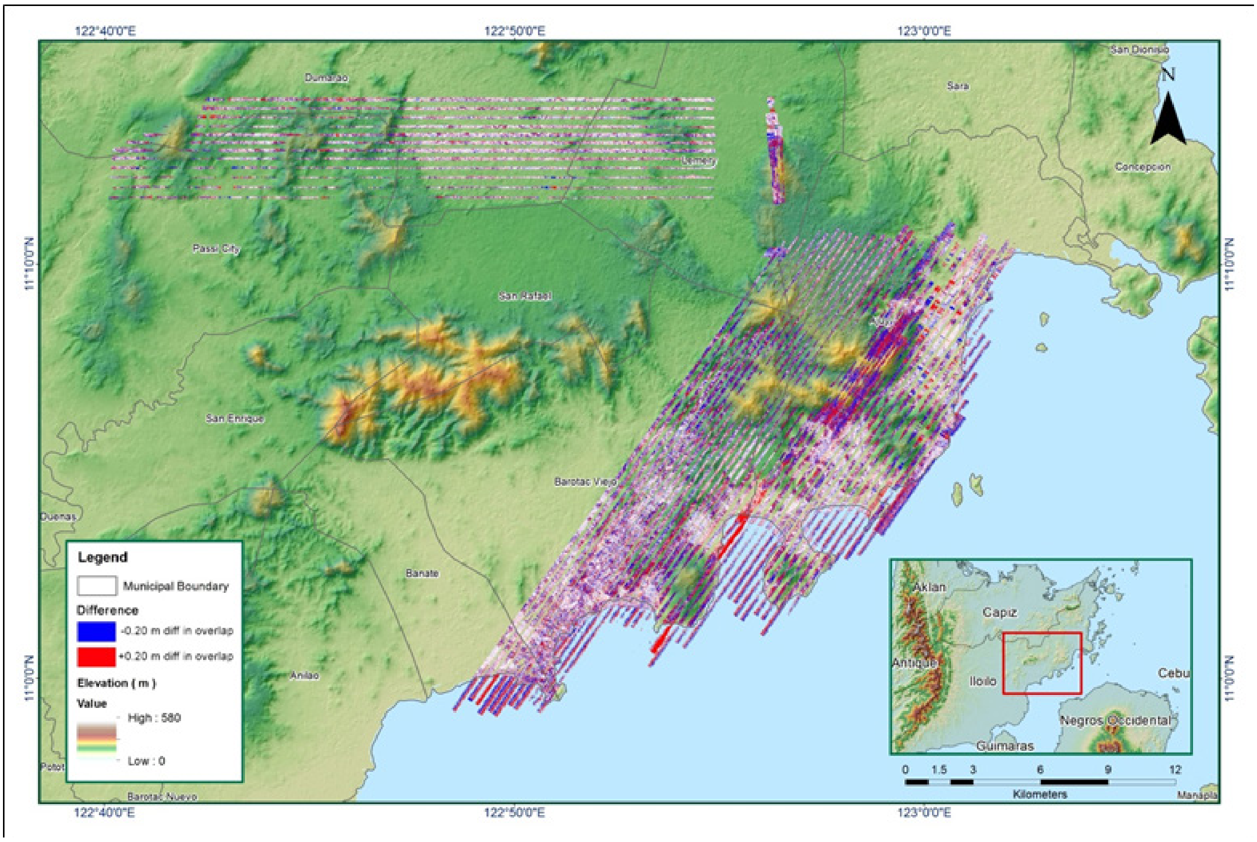


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk37I_supplement

Flight Area	Iloilo
Mission Name	Blk37I_supplement
Inclusive Flights	2601P, 2613P
Range data size	30.7 GB
POS	376 MB
Image	49.8 GB
Transfer date	July 07, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.97
RMSE for East Position (<4.0 cm)	1.54
RMSE for Down Position (<8.0 cm)	3.3
Boresight correction stdev (<0.001deg)	0.00029
IMU attitude correction stdev (<0.001deg)	0.000865
GPS position stdev (<0.01m)	0.0099
Minimum % overlap (>25)	37.62%
Ave point cloud density per sq.m. (>2.0)	3.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	99
Maximum Height	362.11m
Minimum Height	91.85m
Classification (# of points)	
Ground	86,120,324
Low vegetation	64,370,386
Medium vegetation	110,314,612
High vegetation	141,057,514
Building	3,208,017
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Antonio Chua Jr., Engr. Gladys Mae Apat

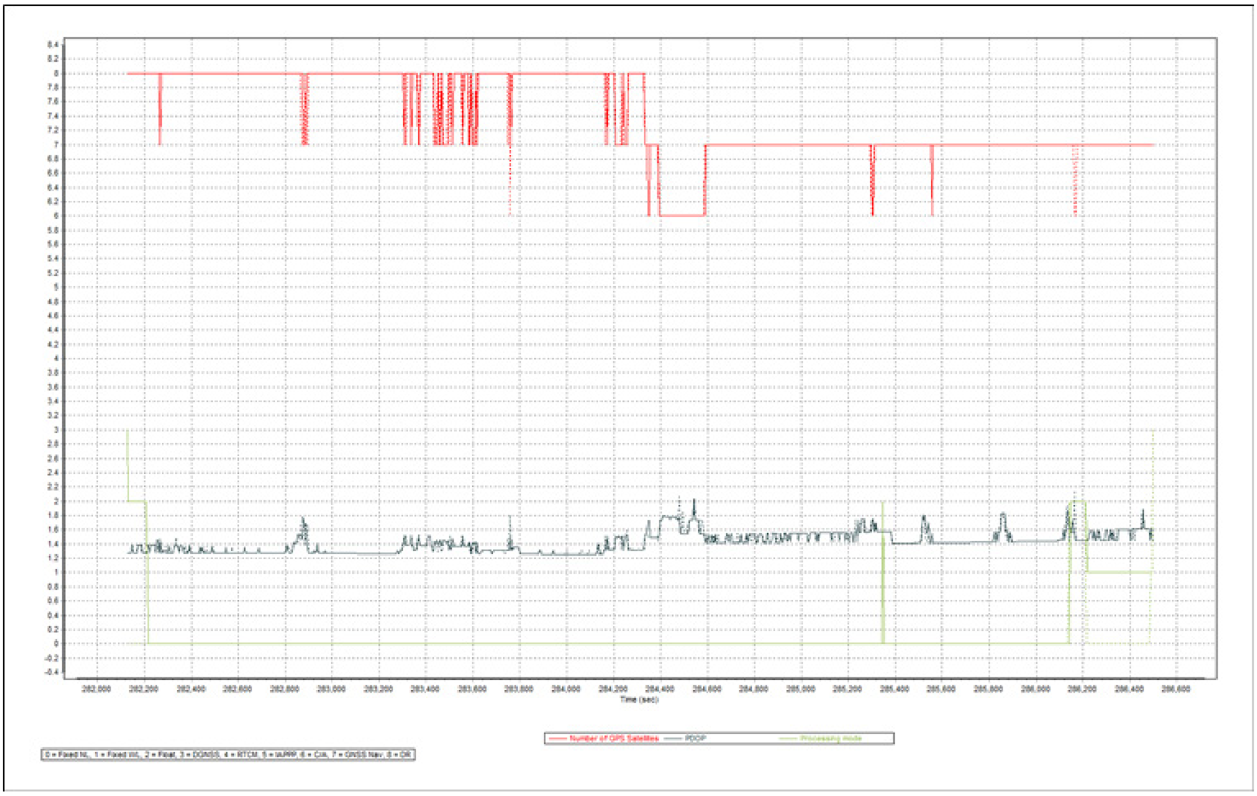


Figure A-8.50. Solution Status

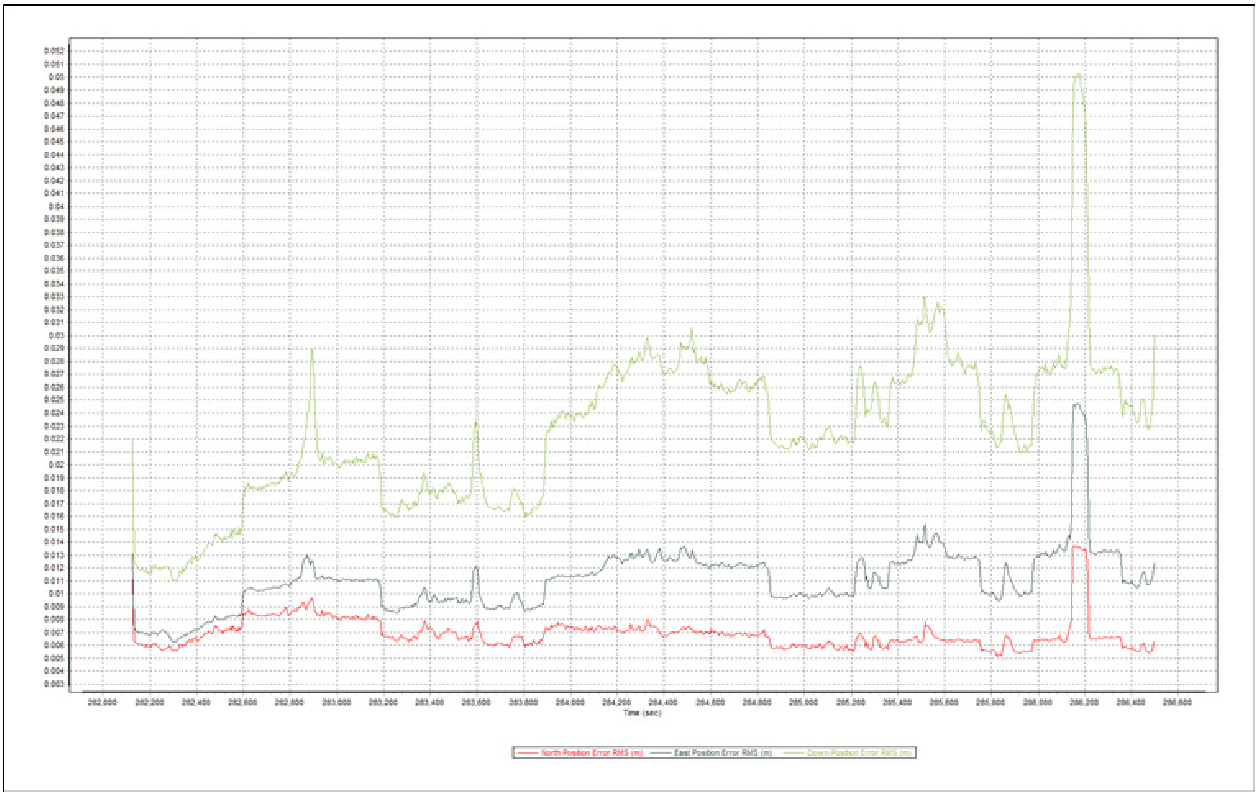


Figure A-8.51. Smoothed Performance Metric Parameters

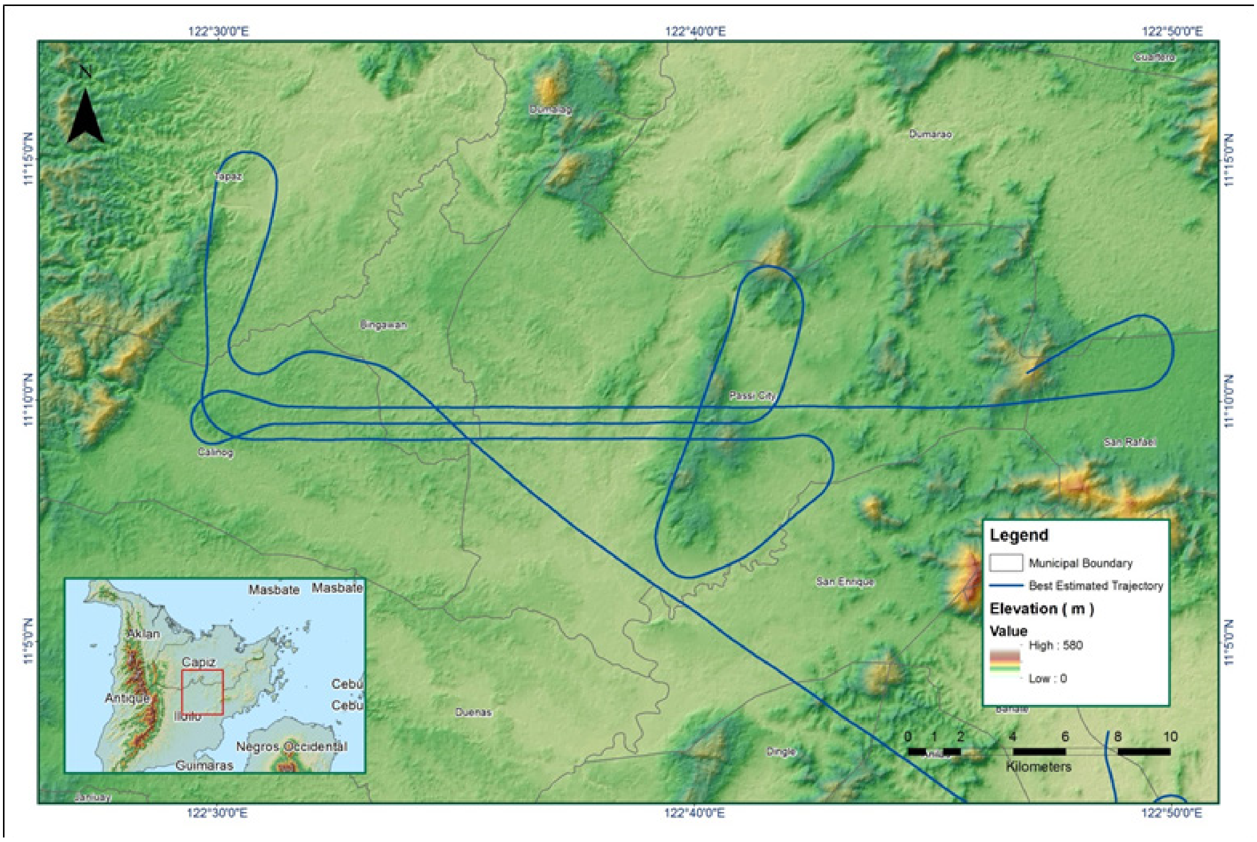


Figure A-8.52. Best Estimated Trajectory

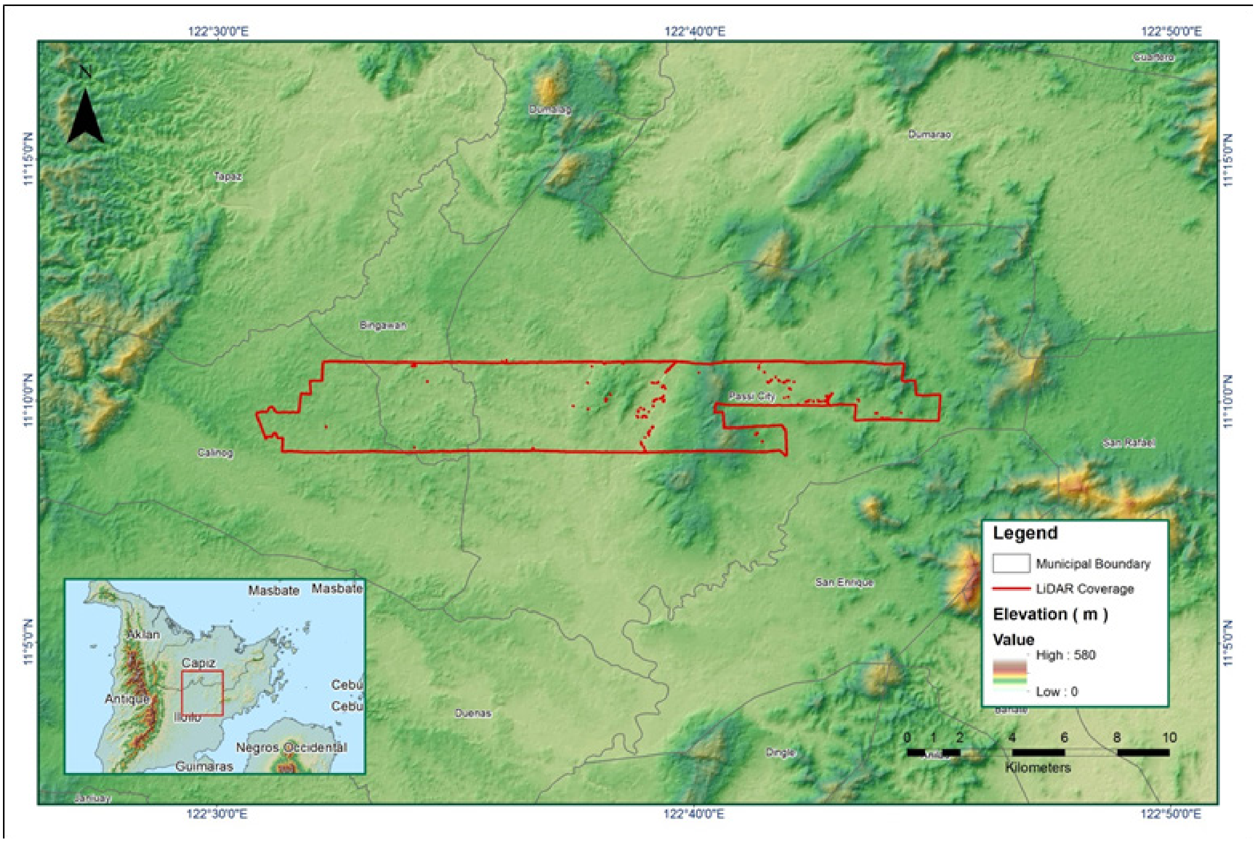


Figure A-8.53. Coverage of LiDAR data

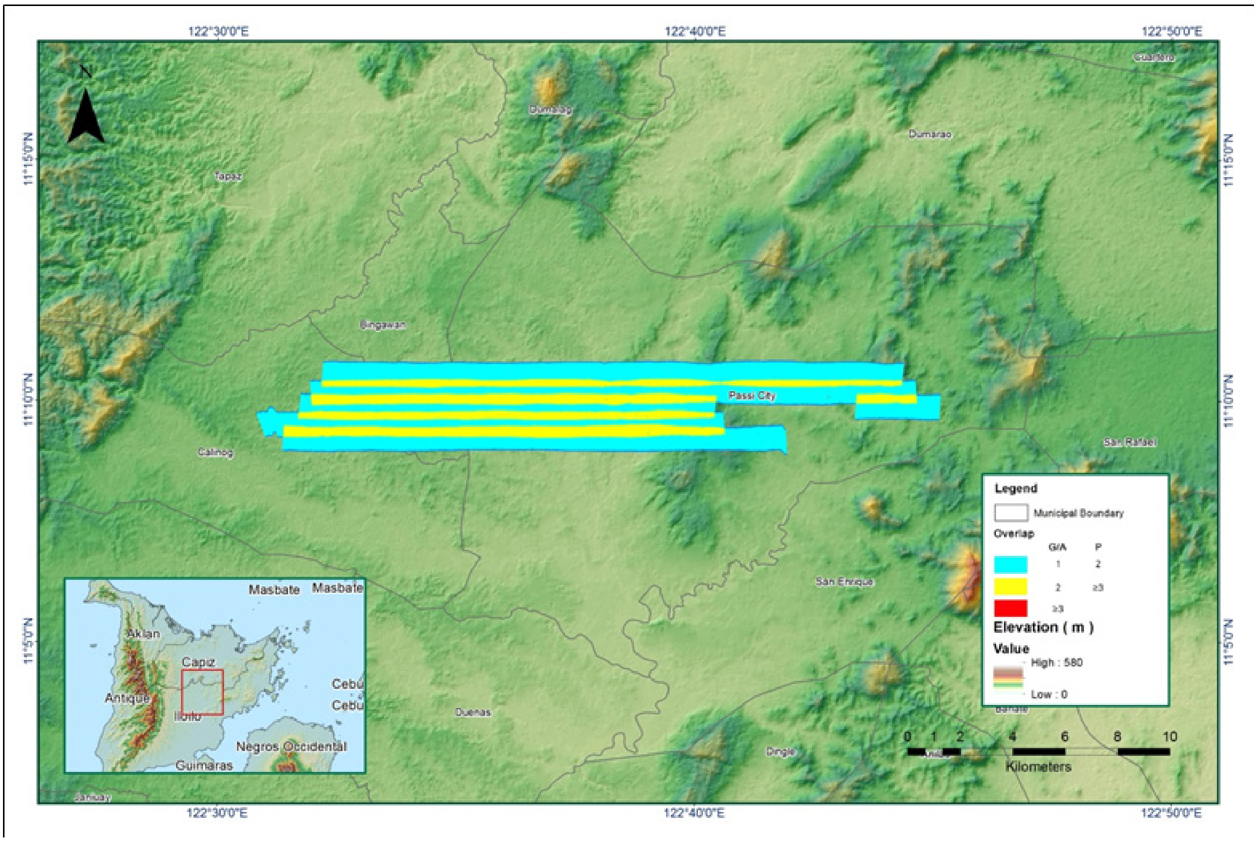


Figure A-8.54. Image of data overlap

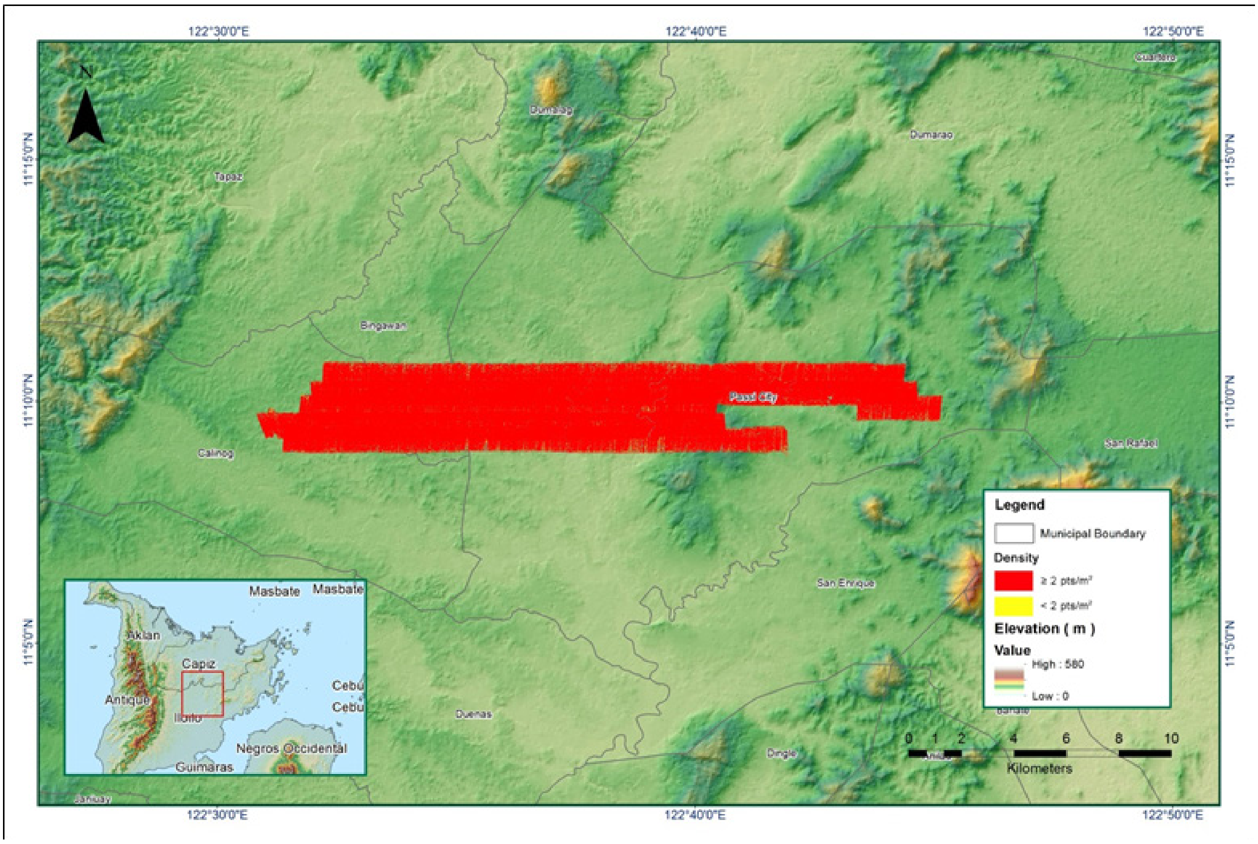


Figure A-8.55. Density map of merged LiDAR data

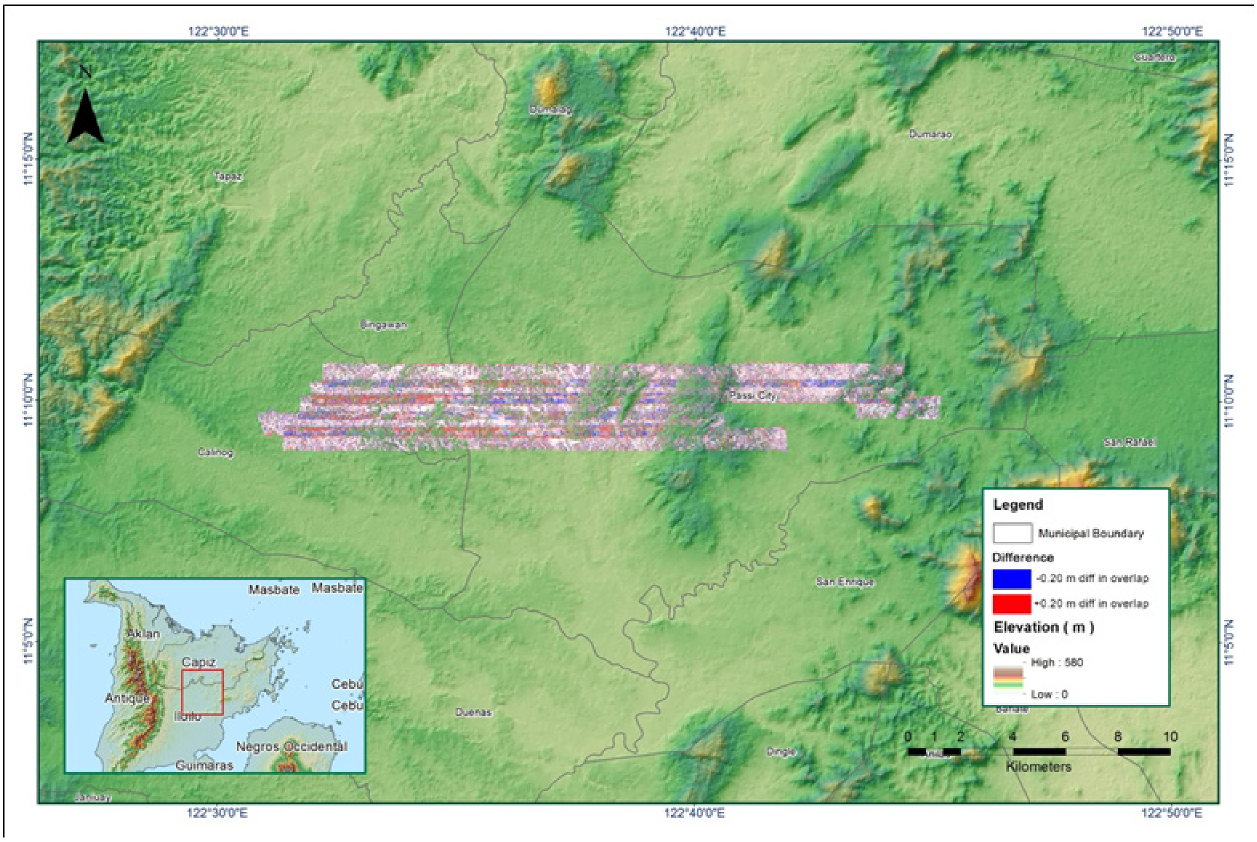


Figure A-8.56. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission Blk37F_supplement

Flight Area	Iloilo
Mission Name	Blk37F_supplement
Inclusive Flights	2634G
Range data size	5.20 GB
POS	170 MB
Image	14.6 GB
Transfer date	July 07, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.94
RMSE for East Position (<4.0 cm)	1.14
RMSE for Down Position (<8.0 cm)	3.02
Boresight correction stdev (<0.001deg)	0.000604
IMU attitude correction stdev (<0.001deg)	0.03
GPS position stdev (<0.01m)	0.000611
Minimum % overlap (>25)	20.13%
Ave point cloud density per sq.m. (>2.0)	1.87
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	42
Maximum Height	303.21 m
Minimum Height	74.98 m
Classification (# of points)	
Ground	13,550,169
Low vegetation	3,037,333
Medium vegetation	9,508,155
High vegetation	8,449,394
Building	57,981
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Mark Joshua Salvacion, Engr. Gladys Mae Apat

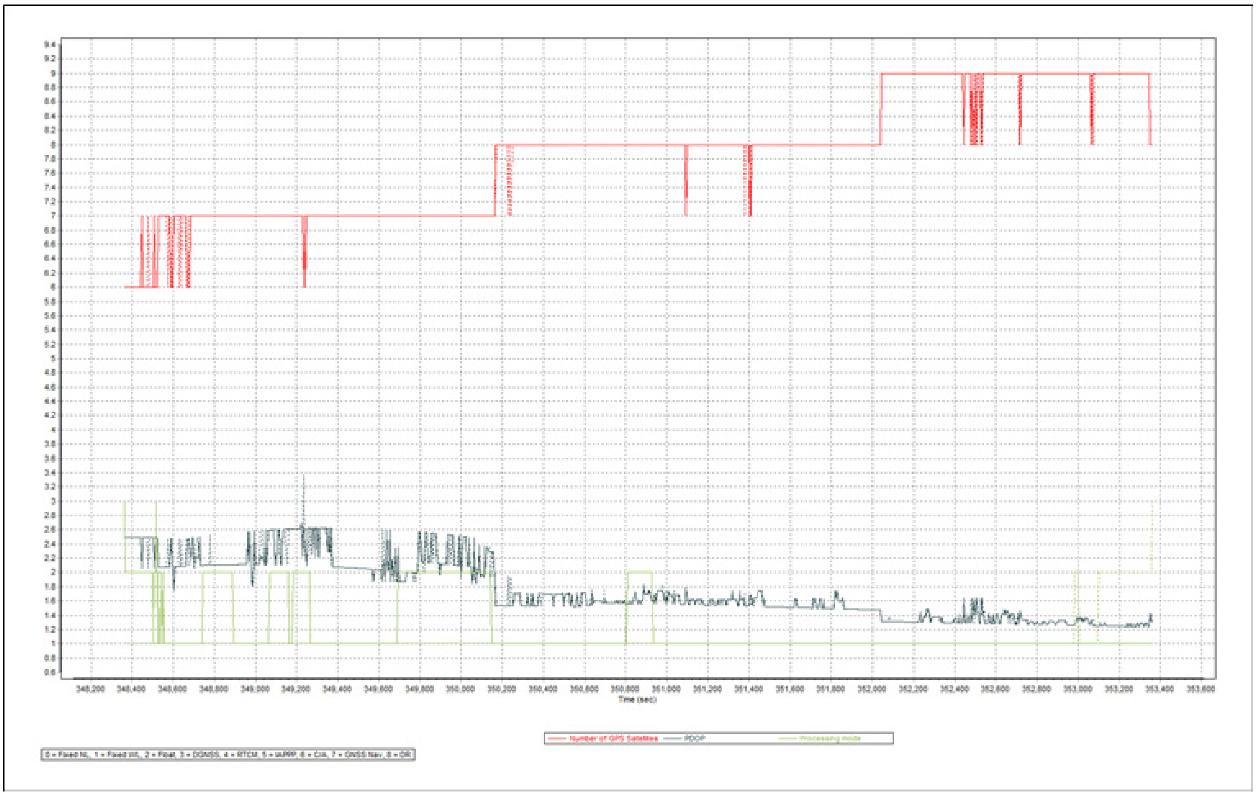


Figure A-8.57. Solution Status

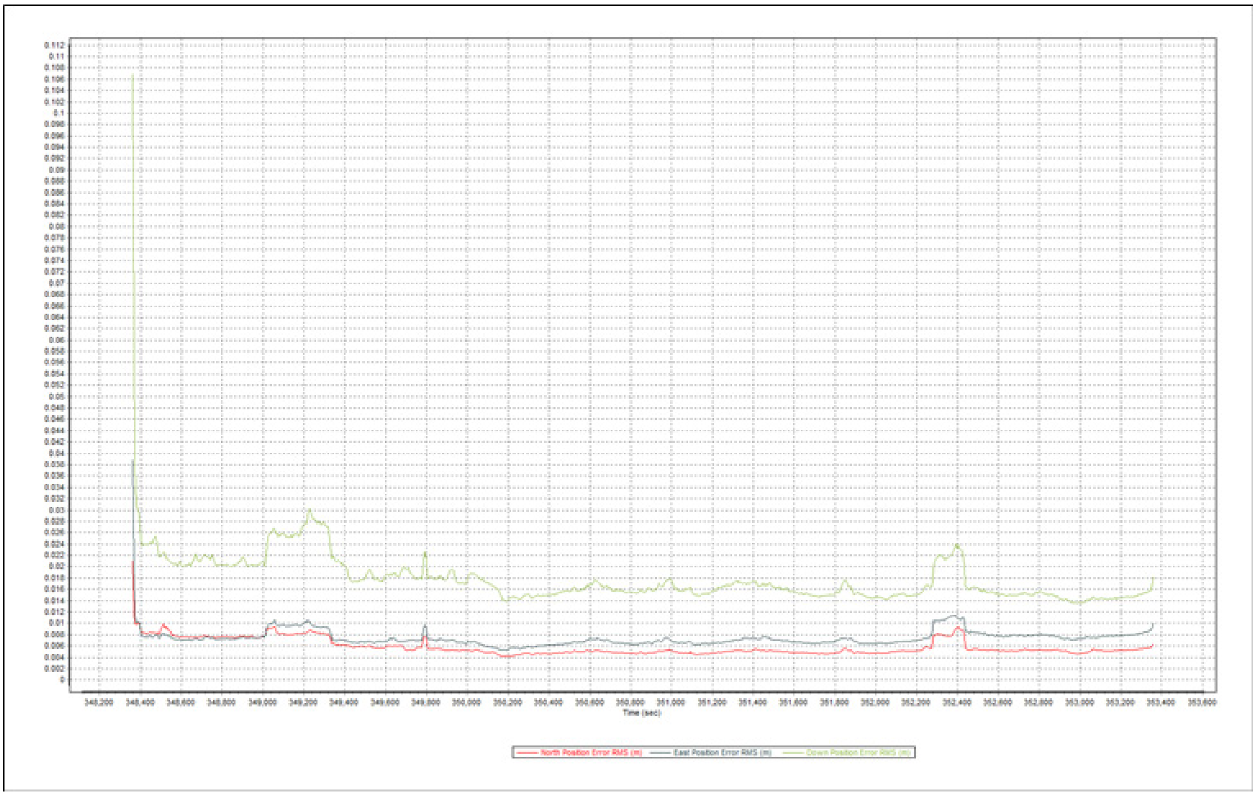


Figure A-8.58. Smoothed Performance Metric Parameters

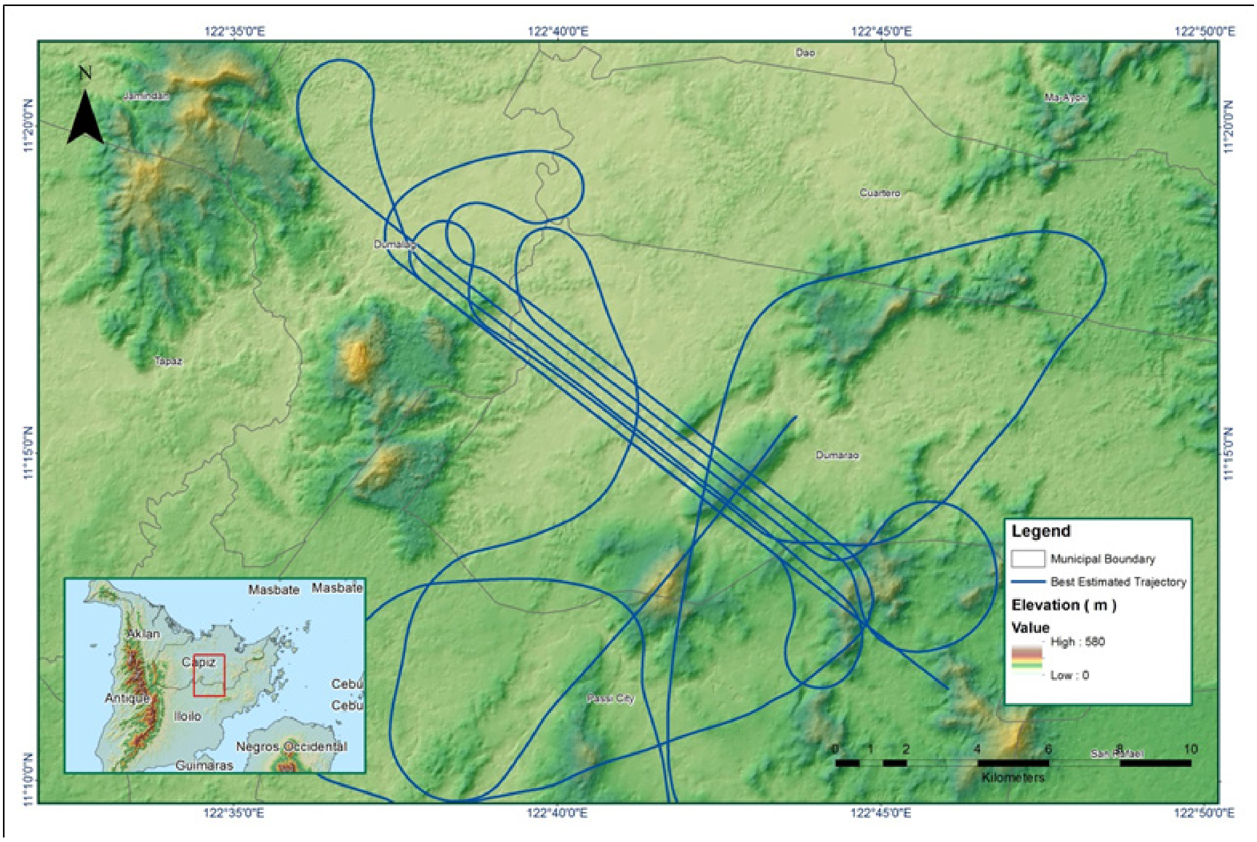


Figure A-8.59. Best Estimated Trajectory

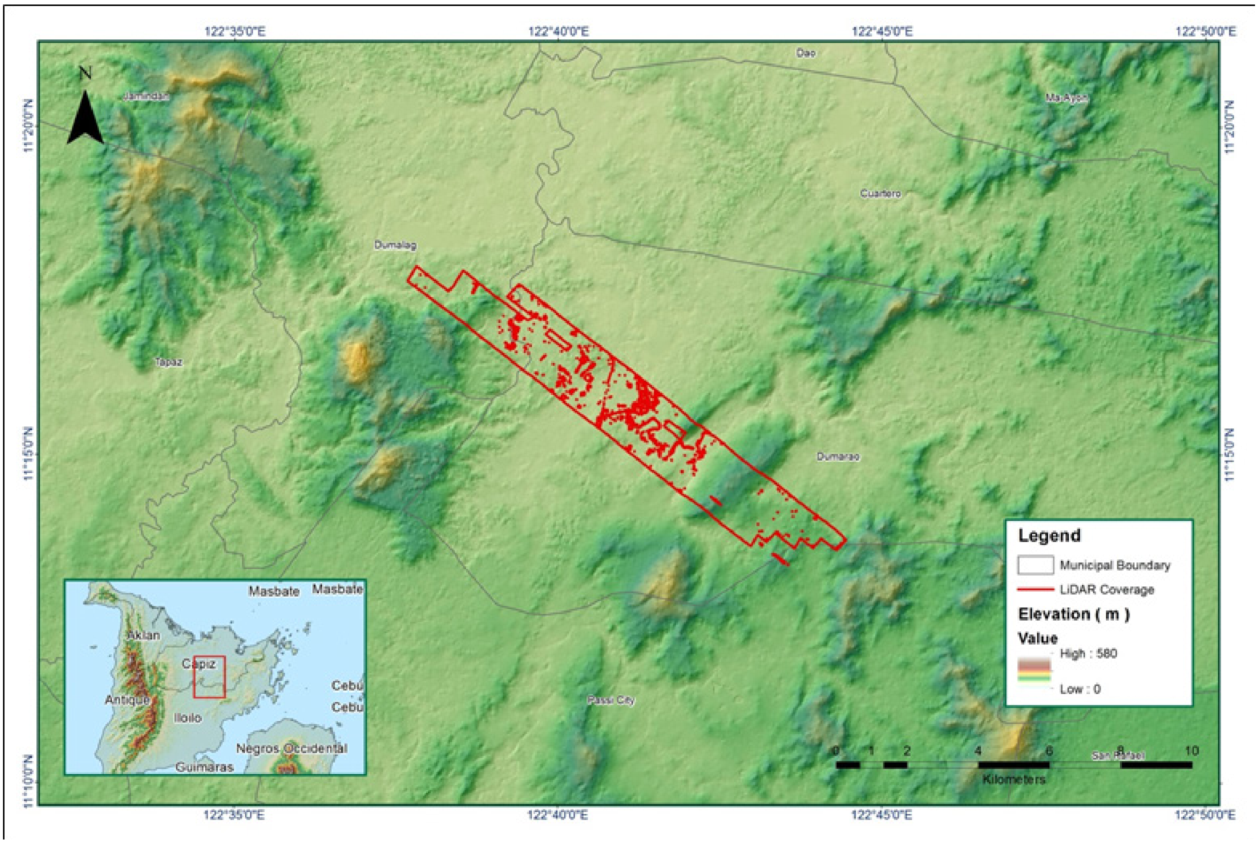


Figure A-8.60. Coverage of LiDAR data

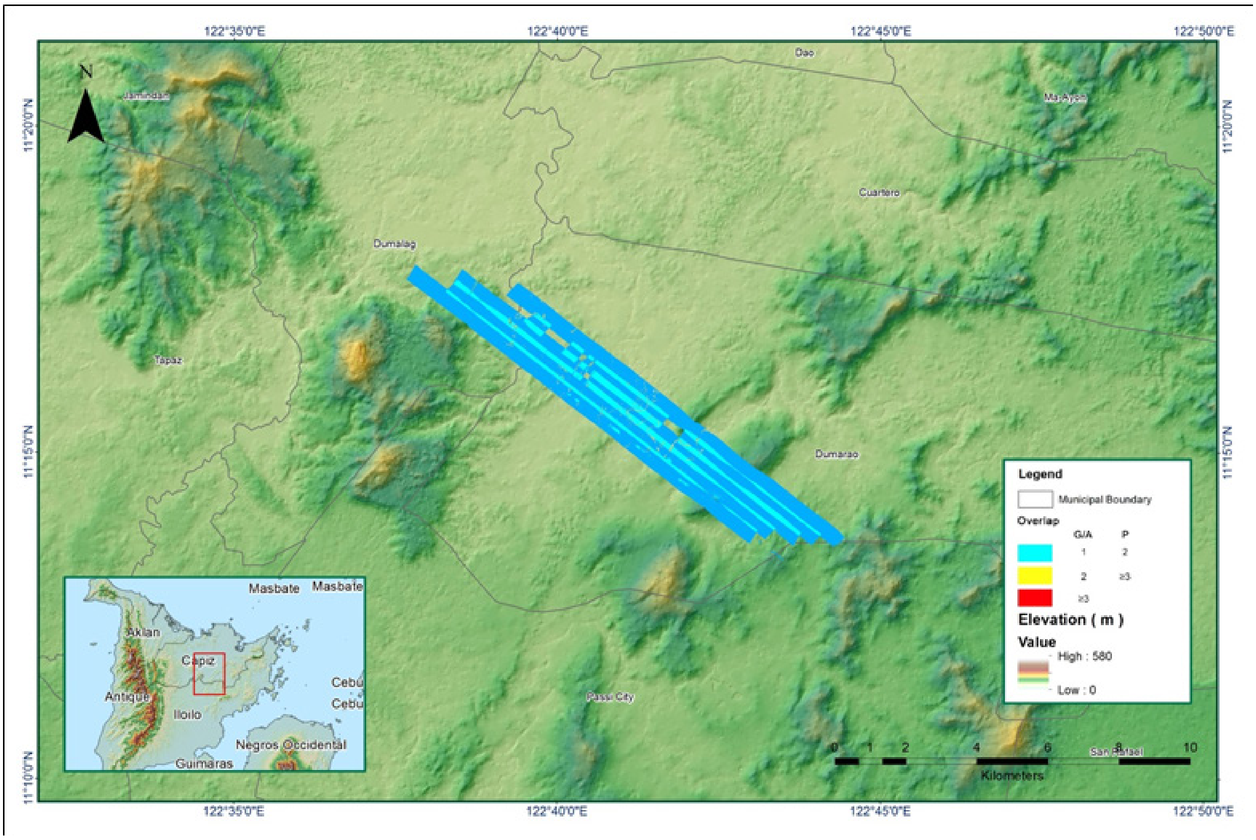


Figure A-8.61. Image of data overlap

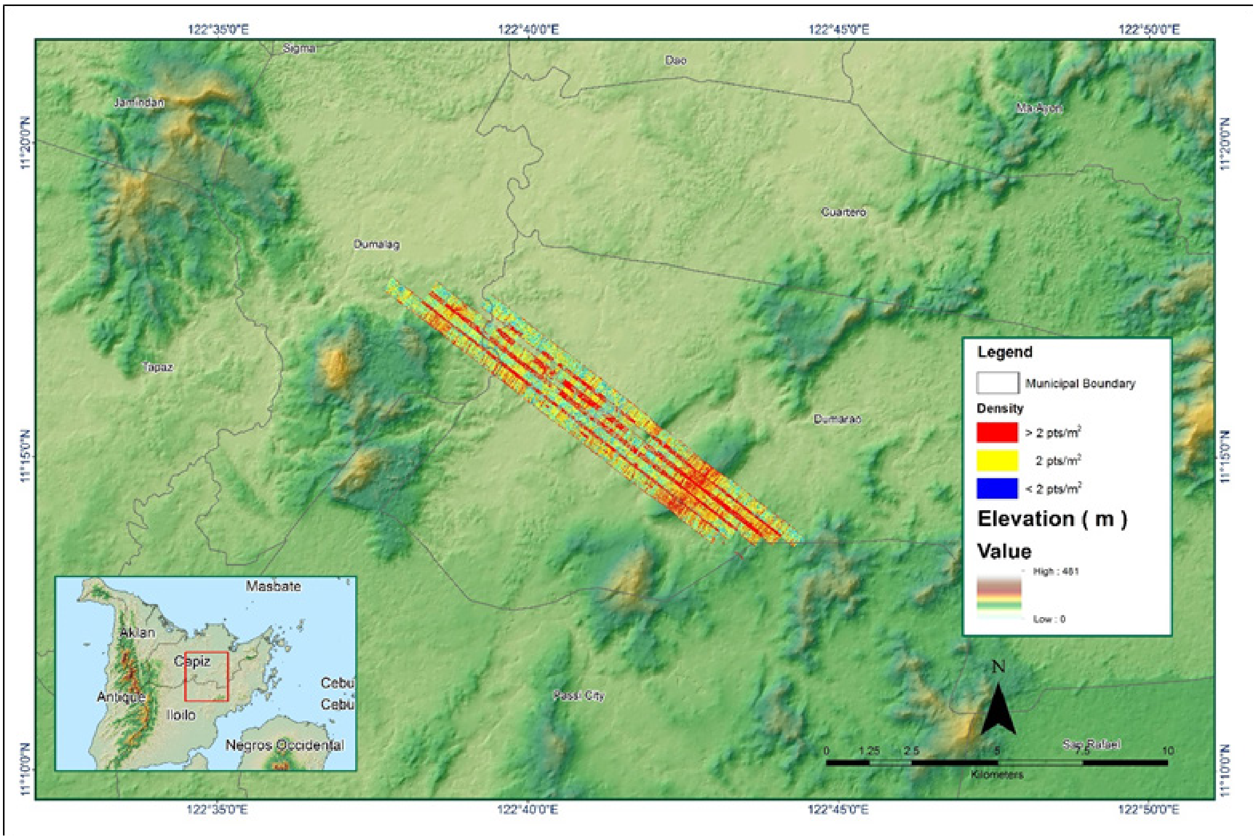


Figure A-8.62. Density map of merged LiDAR data

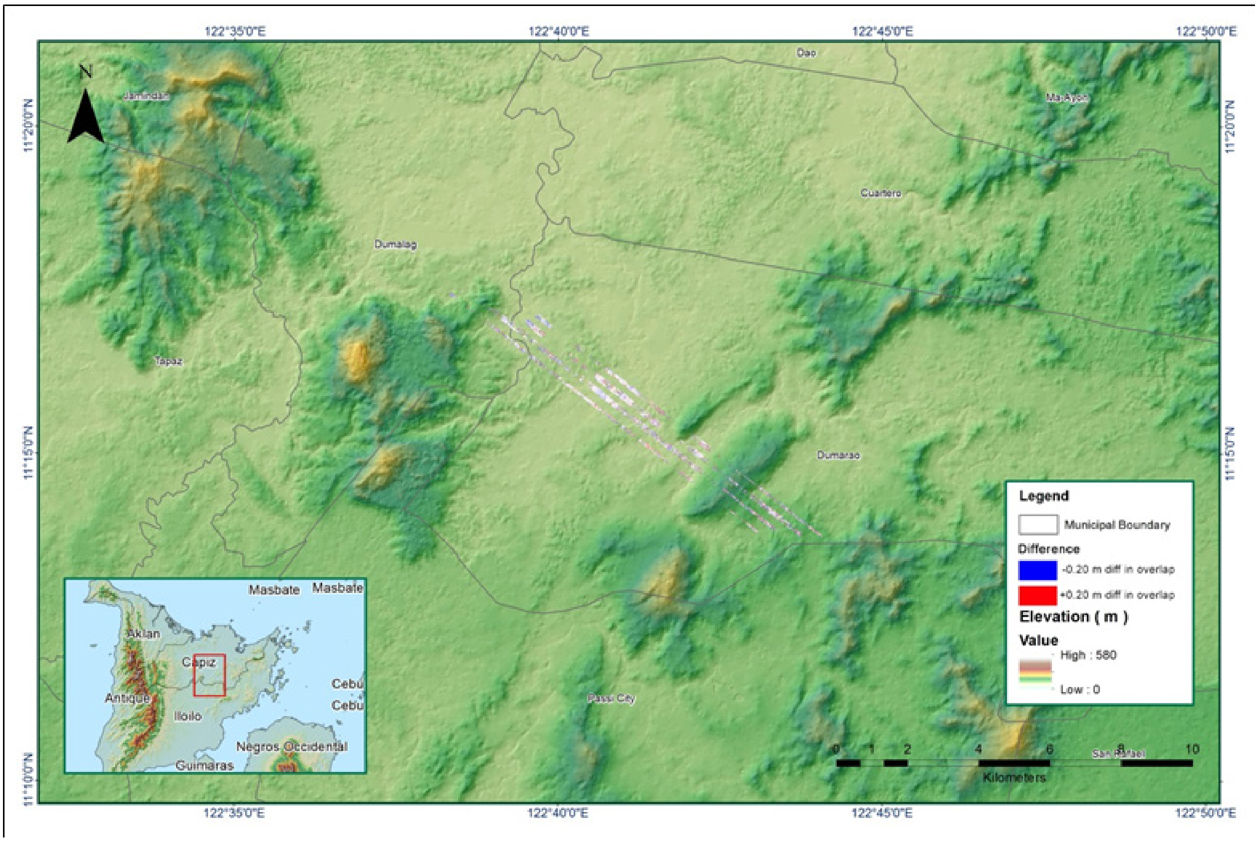


Figure A-8.63. Elevation difference between flight lines

Table A-8.10. Mission Summary Report for Mission Blk38O

Flight Area	Aklan
Mission Name	Blk38O
Inclusive Flights	1178A, 1180A
Mission Name	3BLK38O065A
Range data size	26.28 GB
POS	361 MB
Image	118 GB
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	4.0
Boresight correction stdev (<0.001deg)	0.000314
IMU attitude correction stdev (<0.001deg)	0.001087
GPS position stdev (<0.01m)	0.0093
Minimum % overlap (>25)	78.24%
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	205
Maximum Height	531.05 m
Minimum Height	67.16 m
Classification (# of points)	
Ground	186089611
Low vegetation	193161826
Medium vegetation	752839451
High vegetation	159342539
Building	4115819
Orthophoto	Yes
Processed by	Victoria Rejuso, Engr. Mark Joshua Salvacion, Engr. Ma. Ailyn Olanda

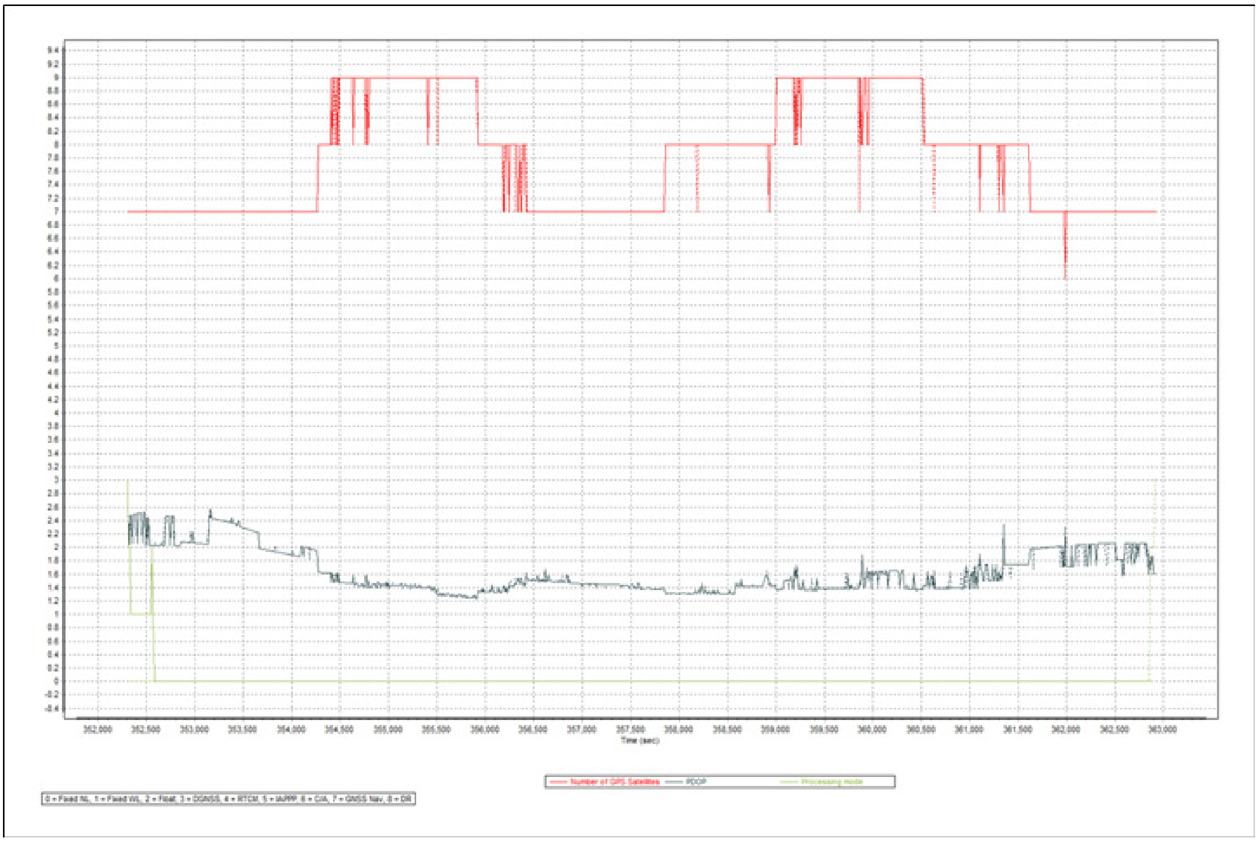


Figure A-8.64. Solution Status

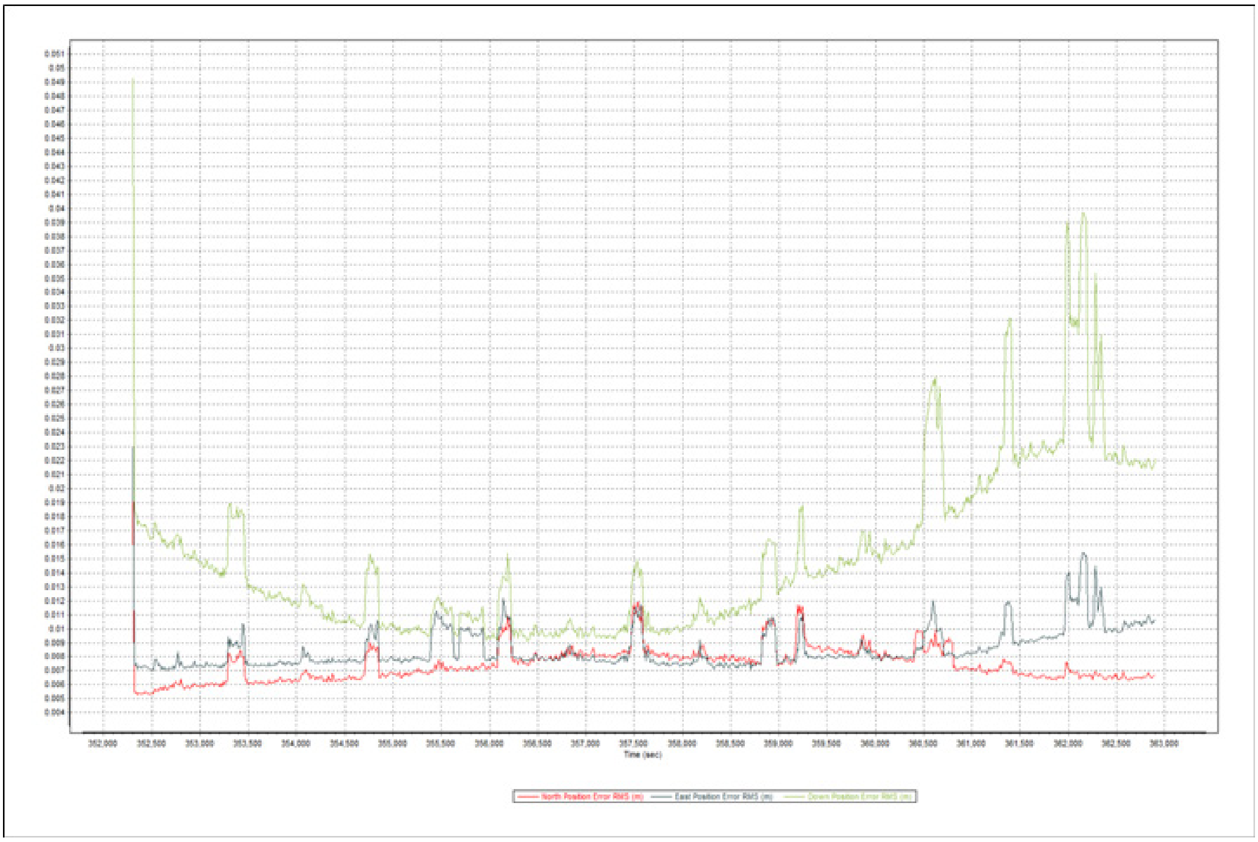


Figure A-8.65. Smoothed Performance Metric Parameters

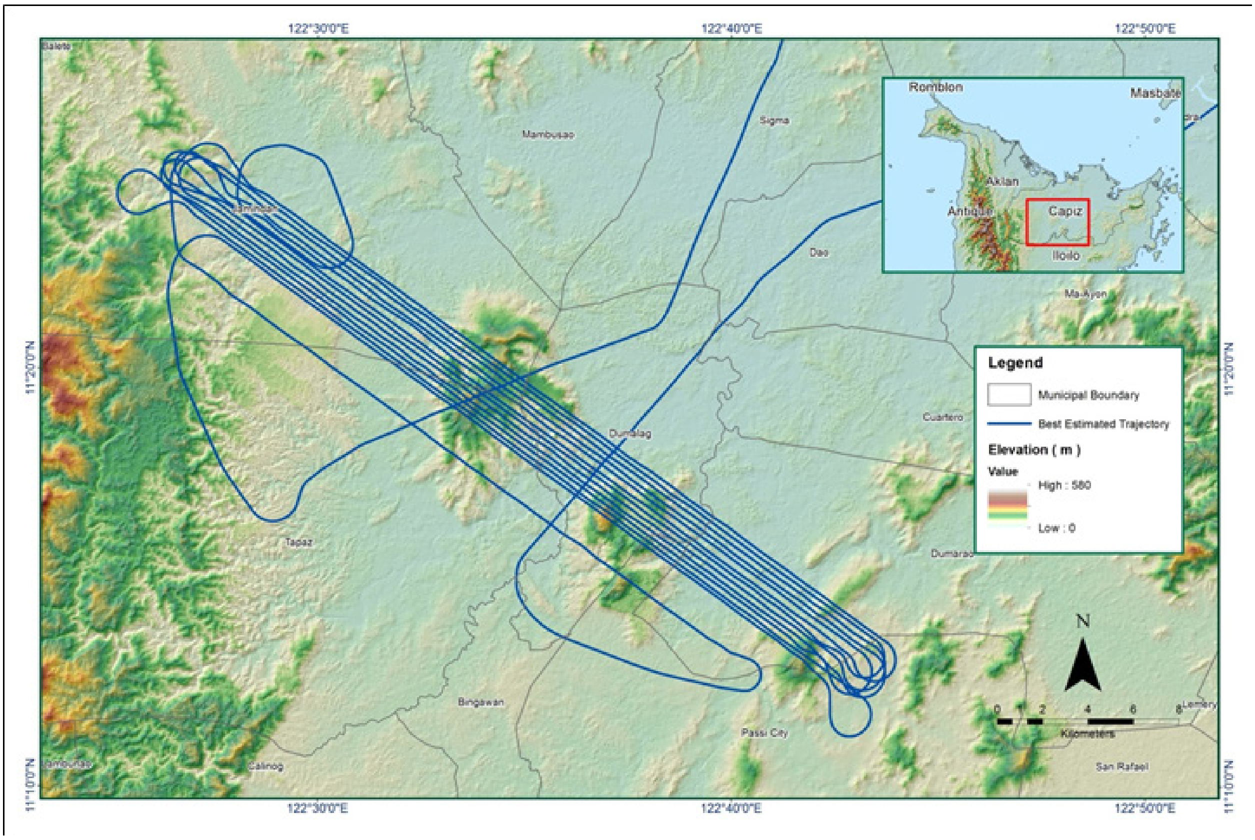


Figure A-8.66. Best Estimated Trajectory

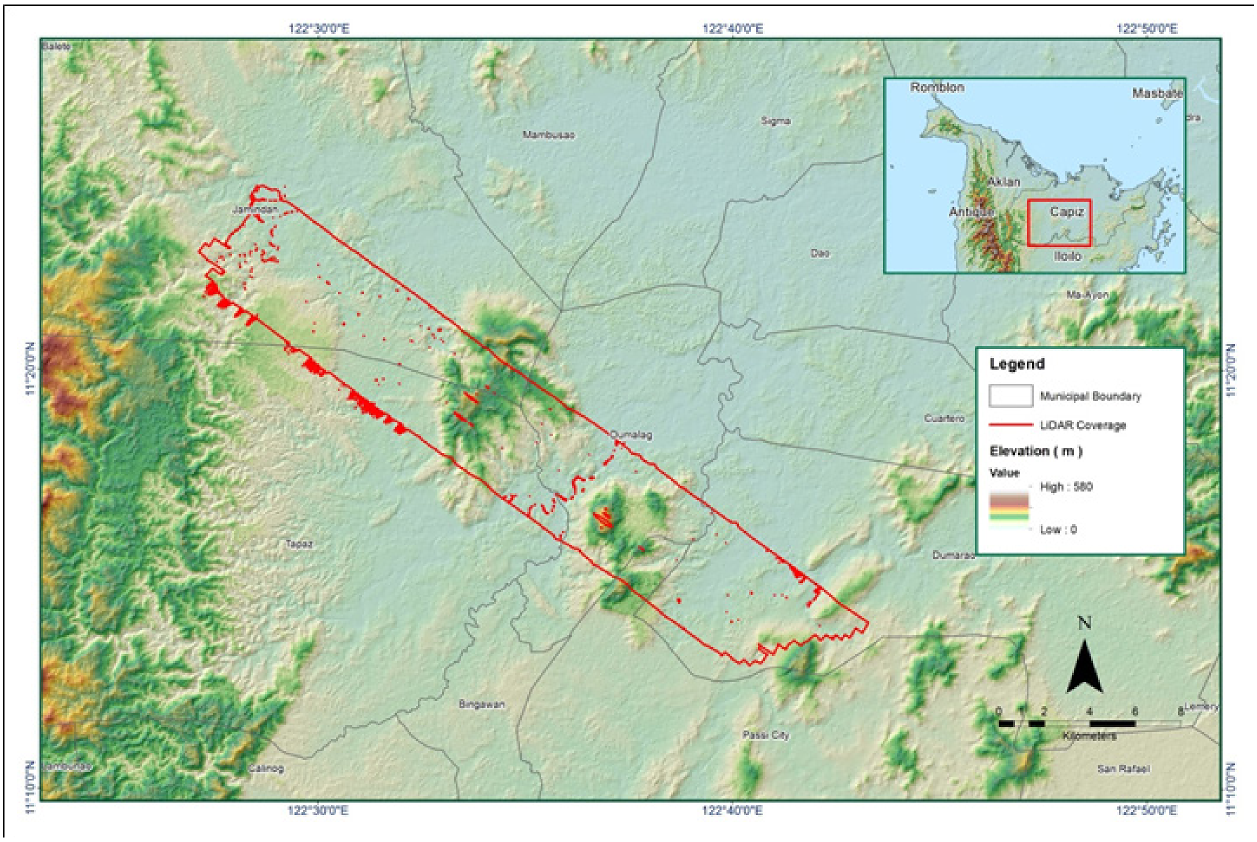


Figure A-8.67. Coverage of LiDAR data

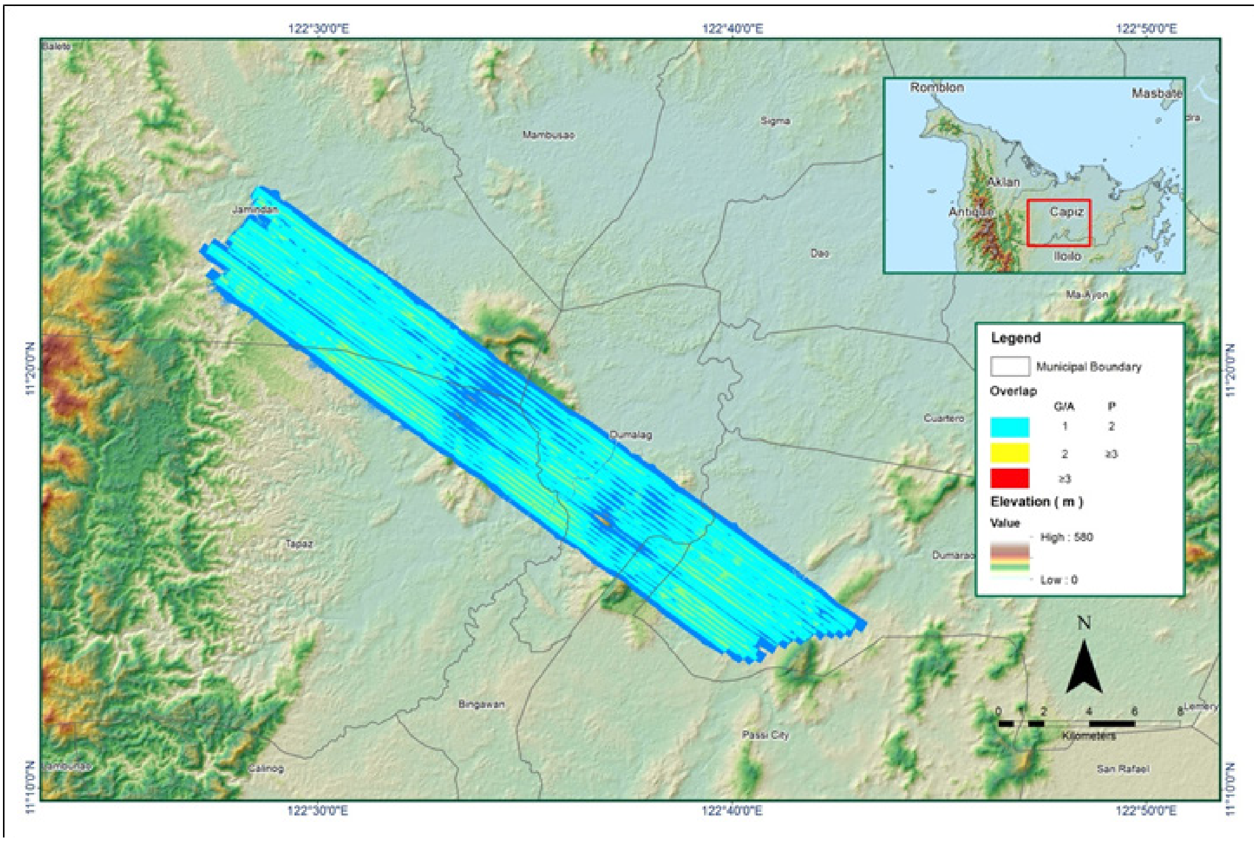


Figure A-8.68. Image of data overlap

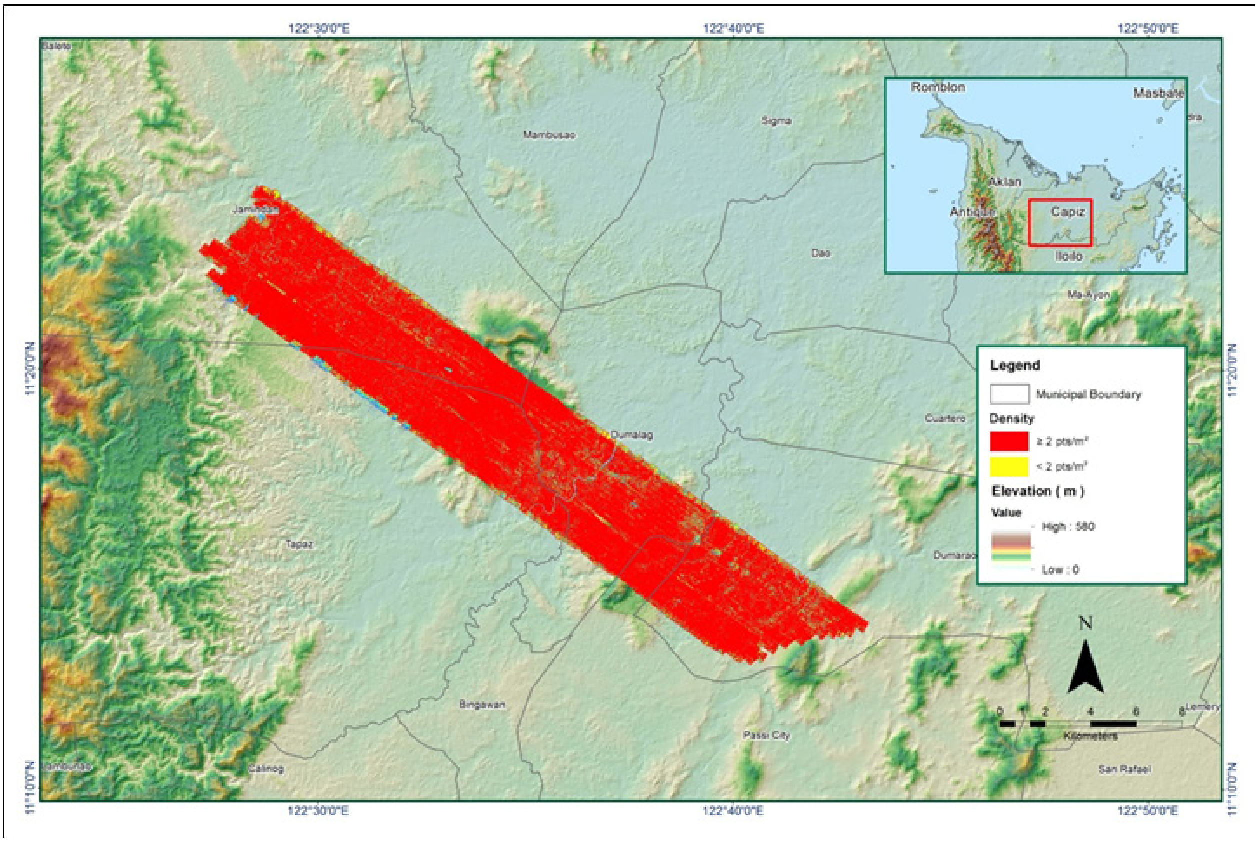


Figure A-8.69. Density map of merged LiDAR data

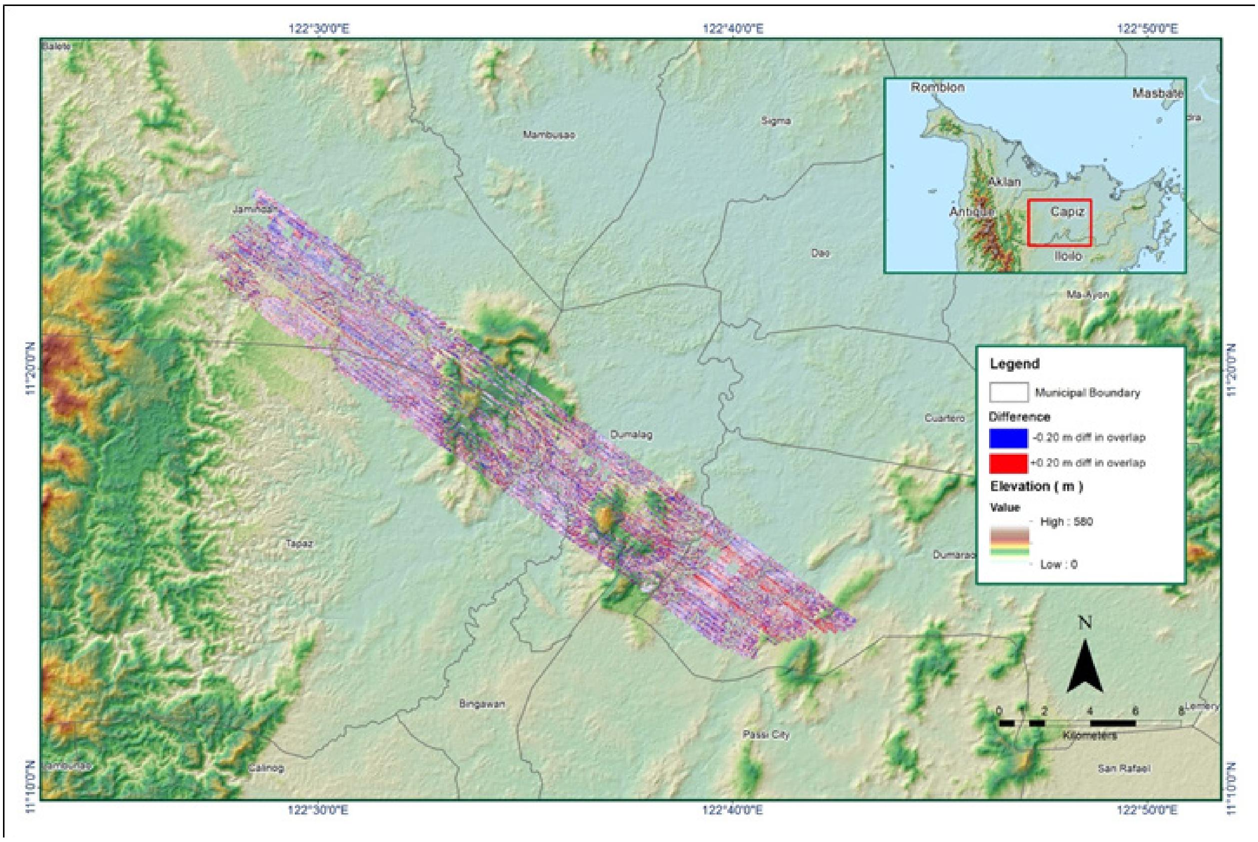


Figure A-8.70. Elevation difference between flight lines

Table A-8.11. Mission Summary Report for Mission Blk37C

Flight Area	Capiz_Aklan
Mission Name	Blk37C
Inclusive Flights	2778G, 2786G, 2788G
Range data size	29.3 GB
POS	242 MB
Image	53.8 GB
Transfer date	November 9, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.457
RMSE for East Position (<4.0 cm)	1.337
RMSE for Down Position (<8.0 cm)	3.085
Boresight correction stdev (<0.001deg)	0.002184
IMU attitude correction stdev (<0.001deg)	0.004448
GPS position stdev (<0.01m)	0.0245
Minimum % overlap (>25)	10.42
Ave point cloud density per sq.m. (>2.0)	2.79
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	75
Maximum Height	221.38 m
Minimum Height	59.31 m
Classification (# of points)	
Ground	22,016,818
Low vegetation	15,151,021
Medium vegetation	64,535,156
High vegetation	20,589,829
Building	365,616
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Edgardo Gubatanga, Jr., Maria Tamsyn Malabanan

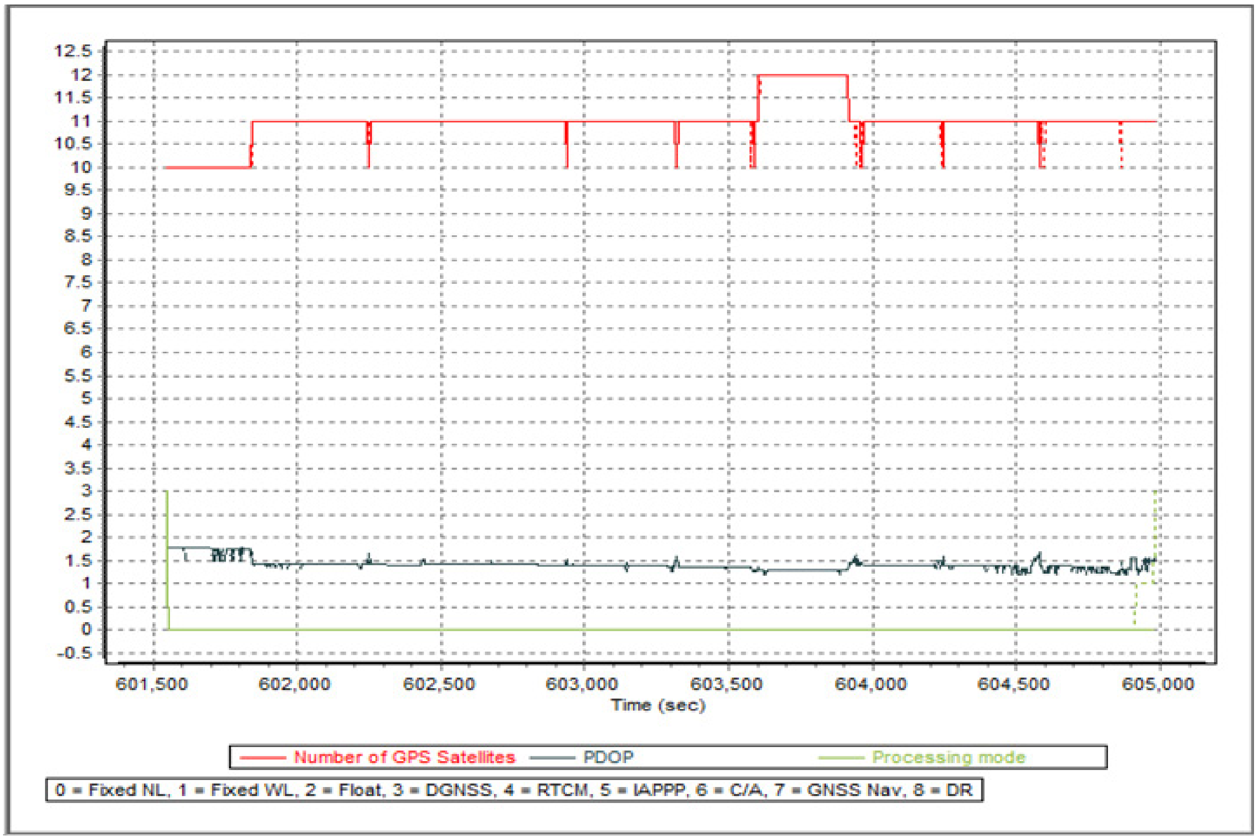


Figure A-8.71. Solution Status

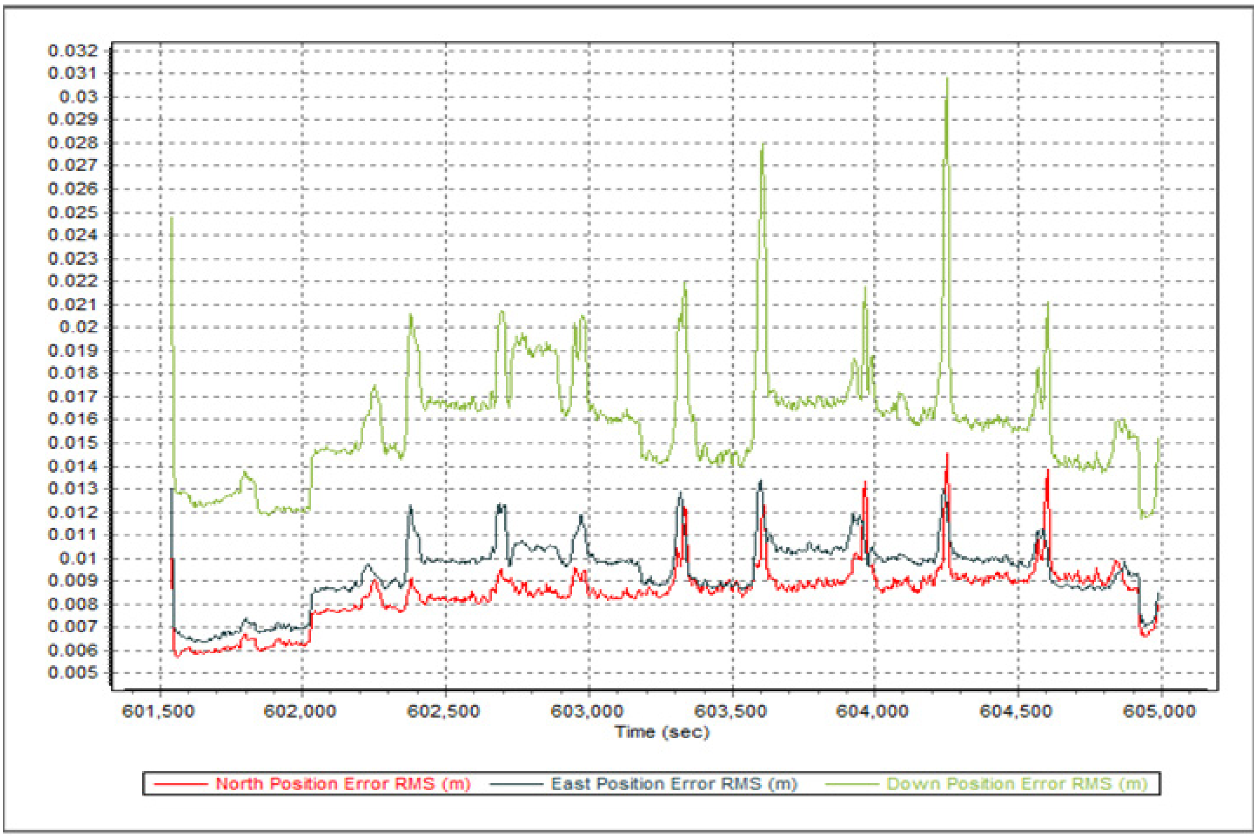


Figure A-8.72. Smoothed Performance Metric Parameters

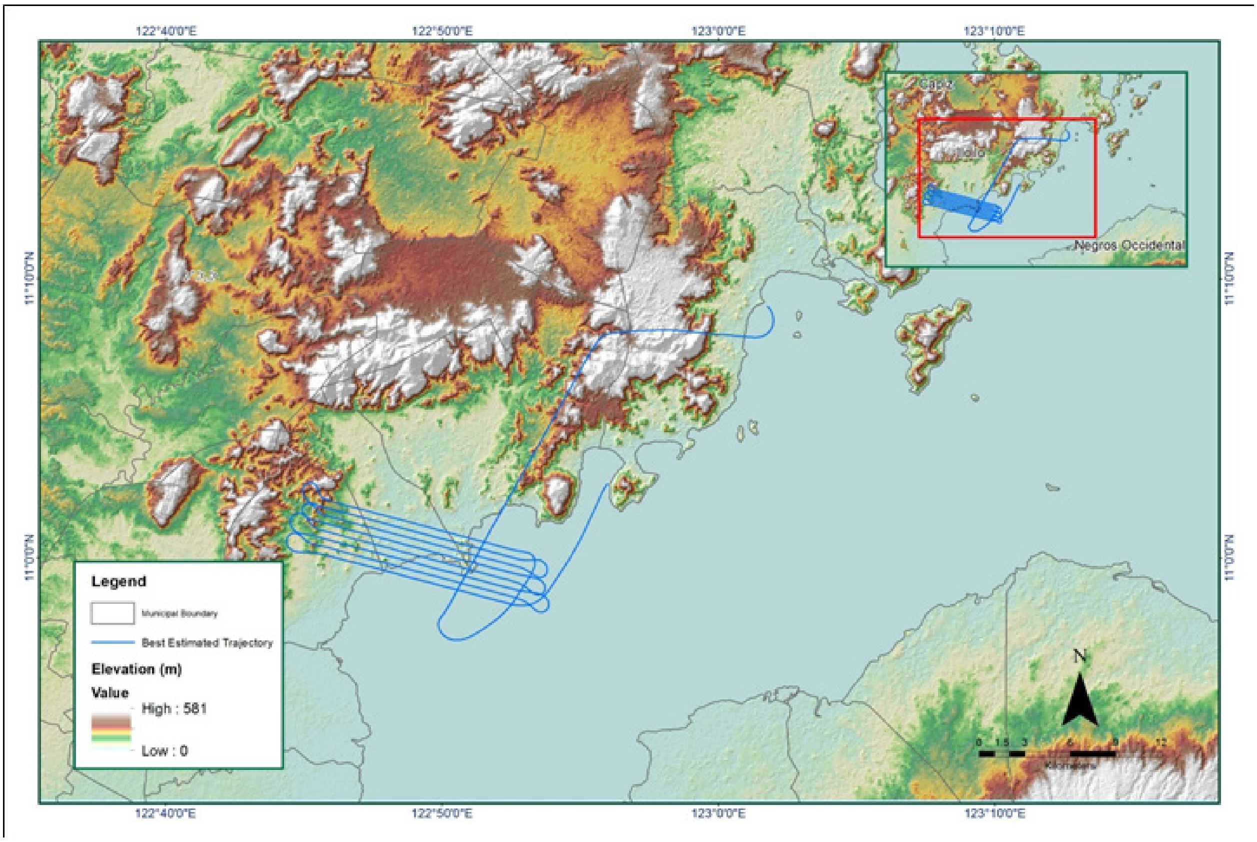


Figure A-8.73. Best Estimated Trajectory

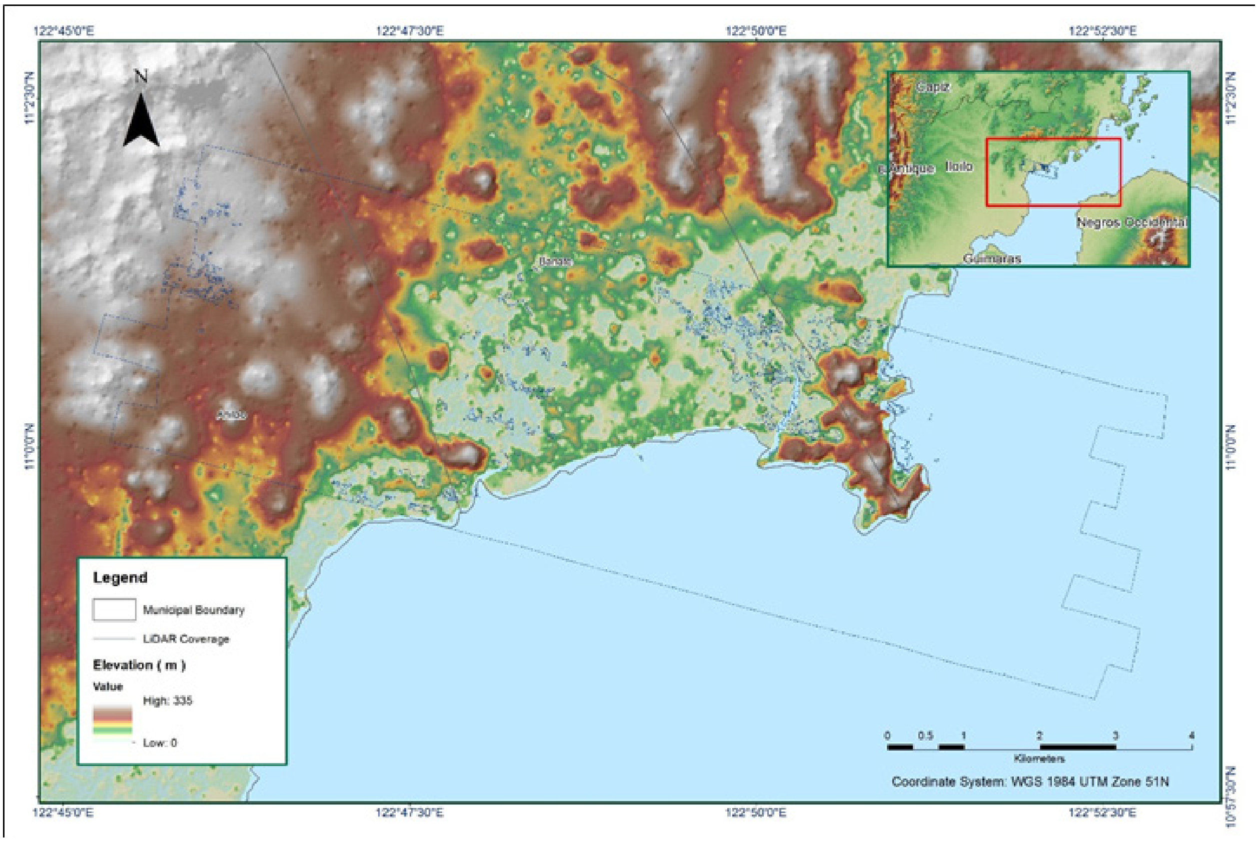


Figure A-8.74. Coverage of LiDAR data

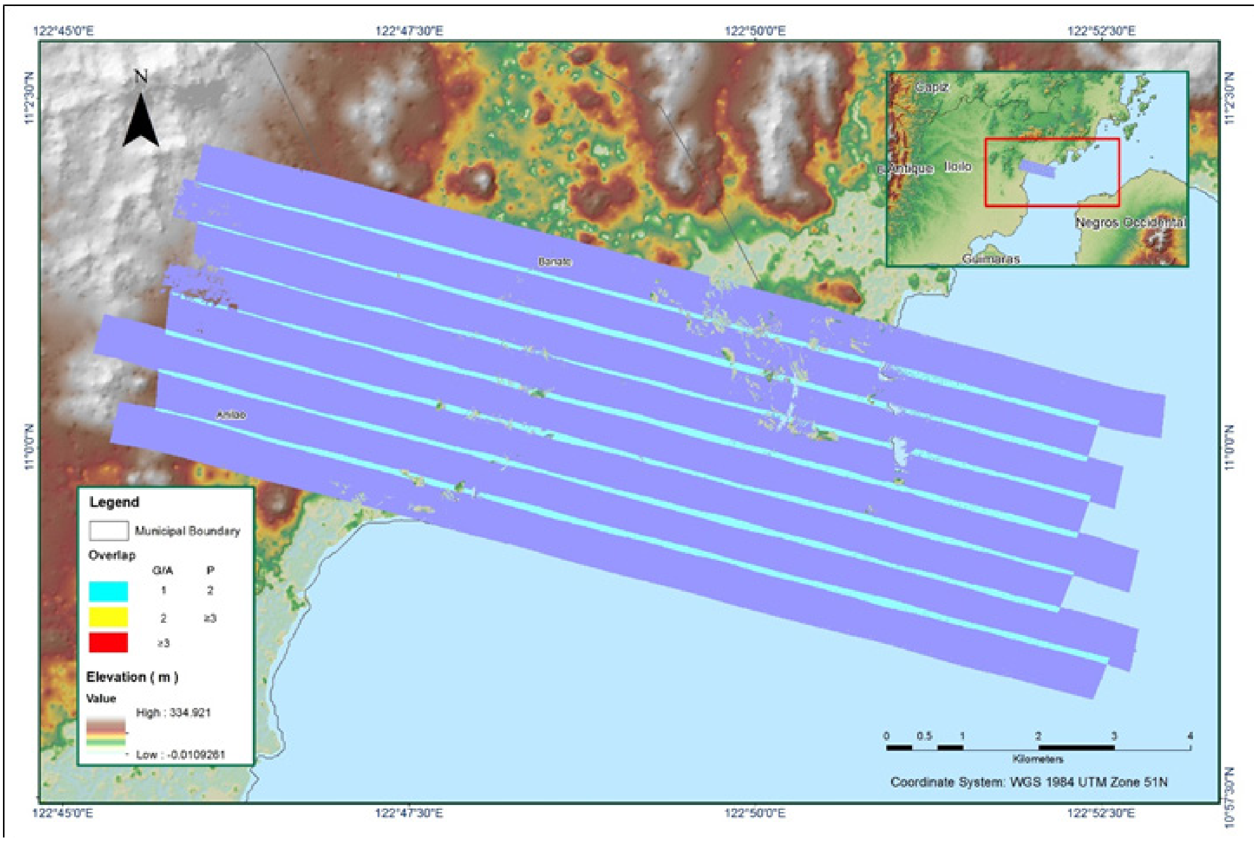


Figure A-8.75. Image of data overlap

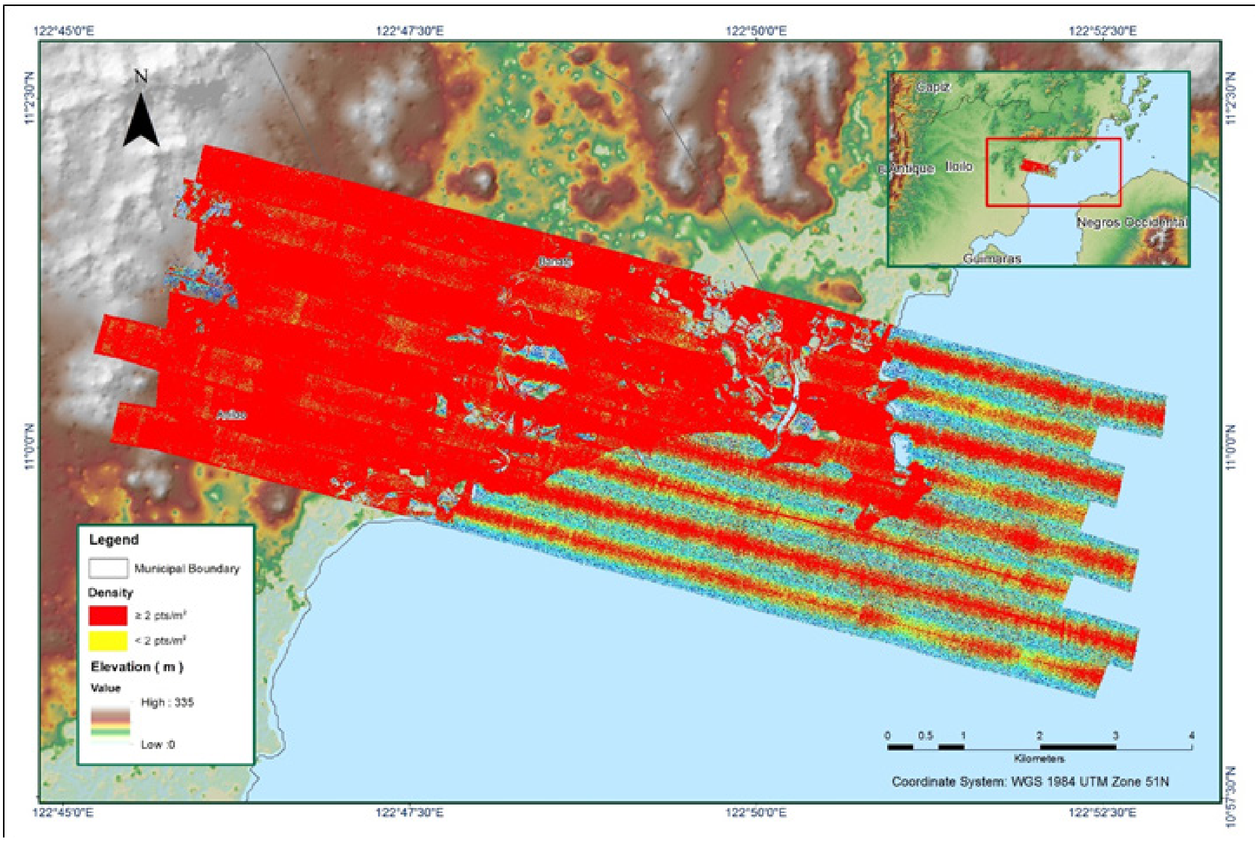


Figure A-8.76. Density map of merged LiDAR data

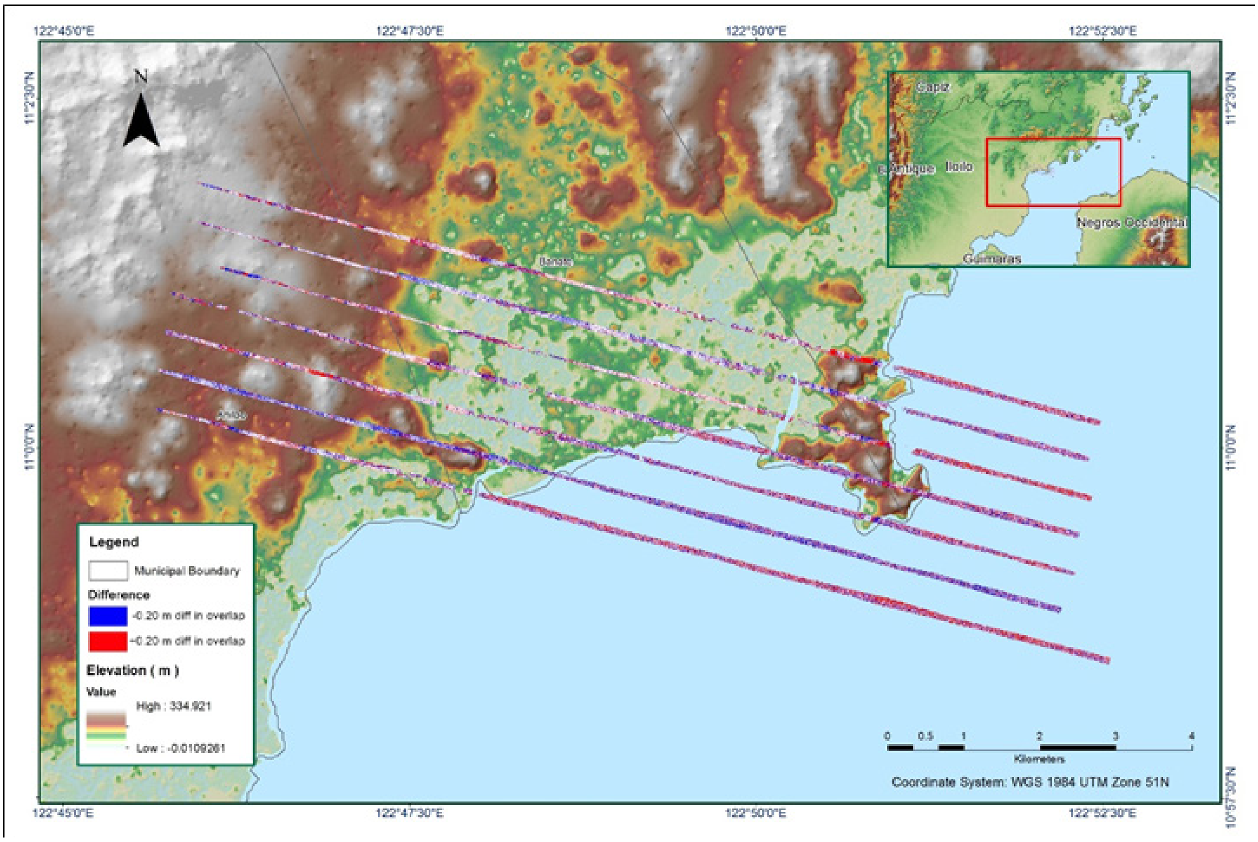


Figure A-8.77. Elevation difference between flight lines

Table A-8.12. Mission Summary Report for Mission Blk37C_supplement

Flight Area	Capiz_Aklan
Mission Name	Blk37C_supplement
Inclusive Flights	2788G
Range data size	30.7 GB
POS	255 MB
Image	59.1 GB
Transfer date	November, 9, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.146
RMSE for East Position (<4.0 cm)	1.877
RMSE for Down Position (<8.0 cm)	4.286
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	35.82
Ave point cloud density per sq.m. (>2.0)	4.85
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	128
Maximum Height	352.86 m
Minimum Height	59.18 m
Classification (# of points)	
Ground	31,017,268
Low vegetation	35,074,945
Medium vegetation	229,774,600
High vegetation	79,178,626
Building	580,373
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Ma. Joanne Balaga, Jovy Narisma

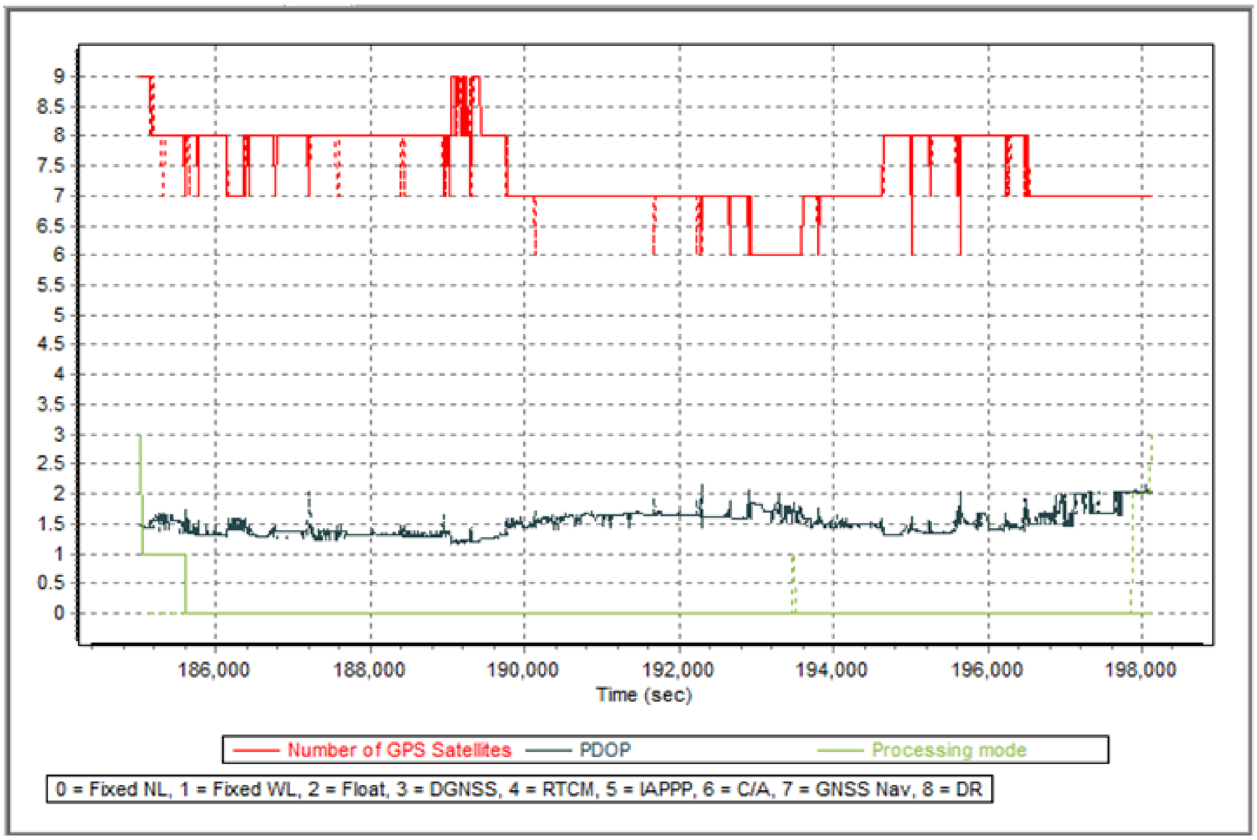


Figure A-8.78. Solution Status

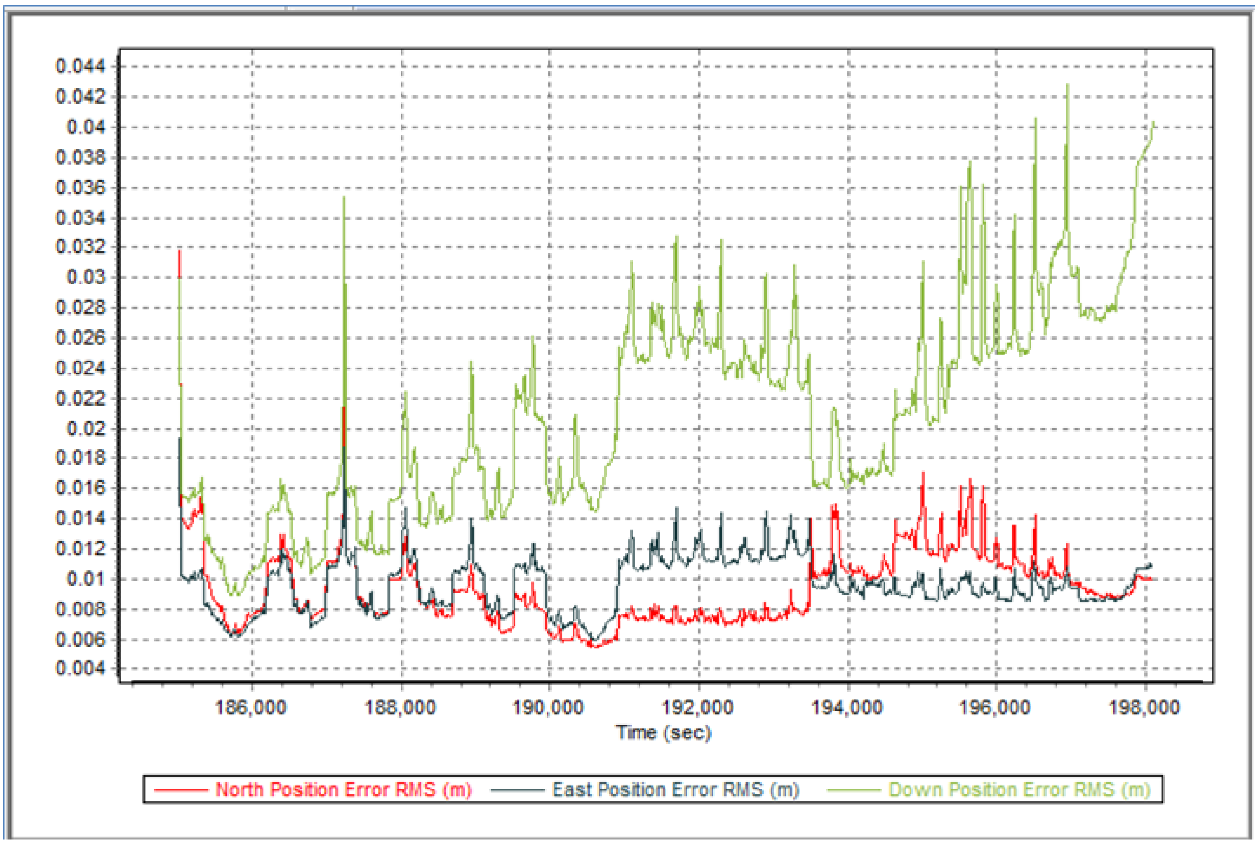


Figure A-8.79. Smoothed Performance Metric Parameters

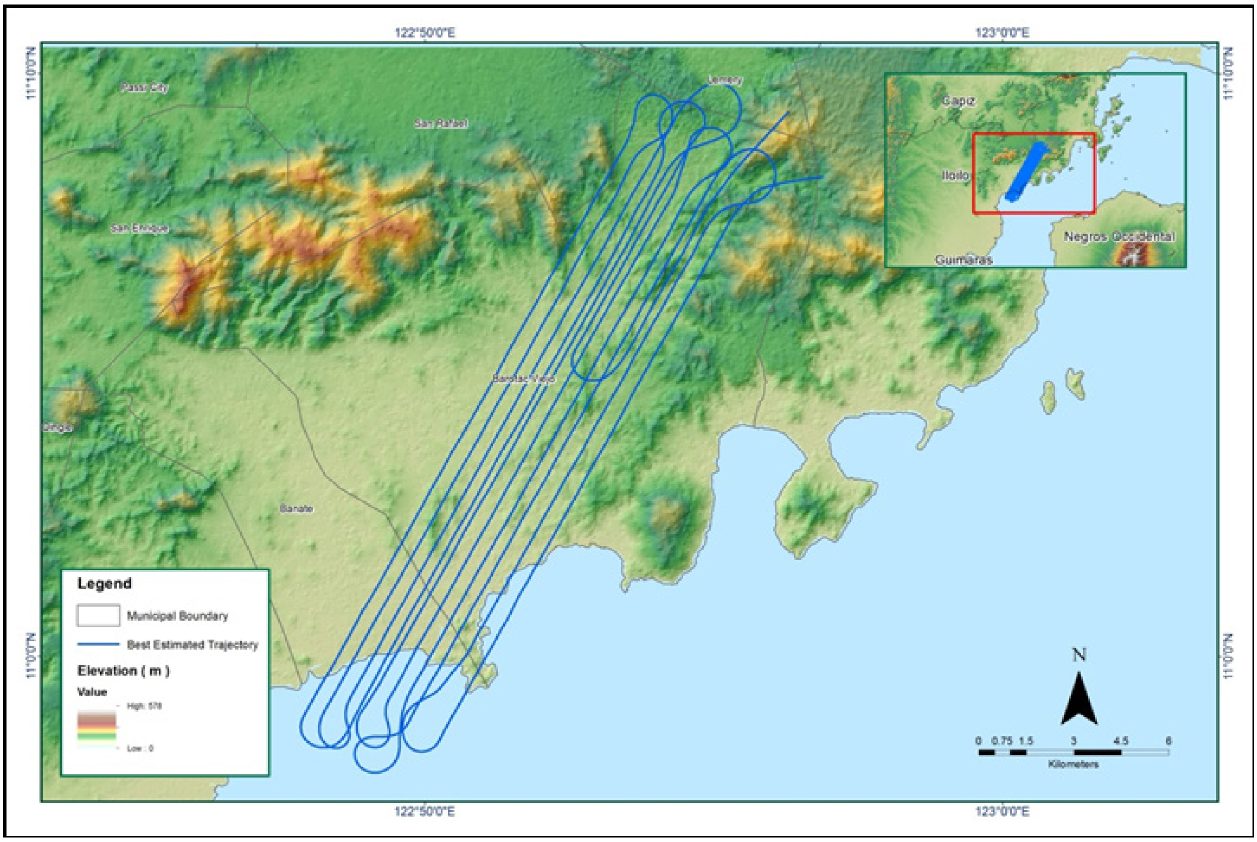


Figure A-8.80. Best Estimated Trajectory

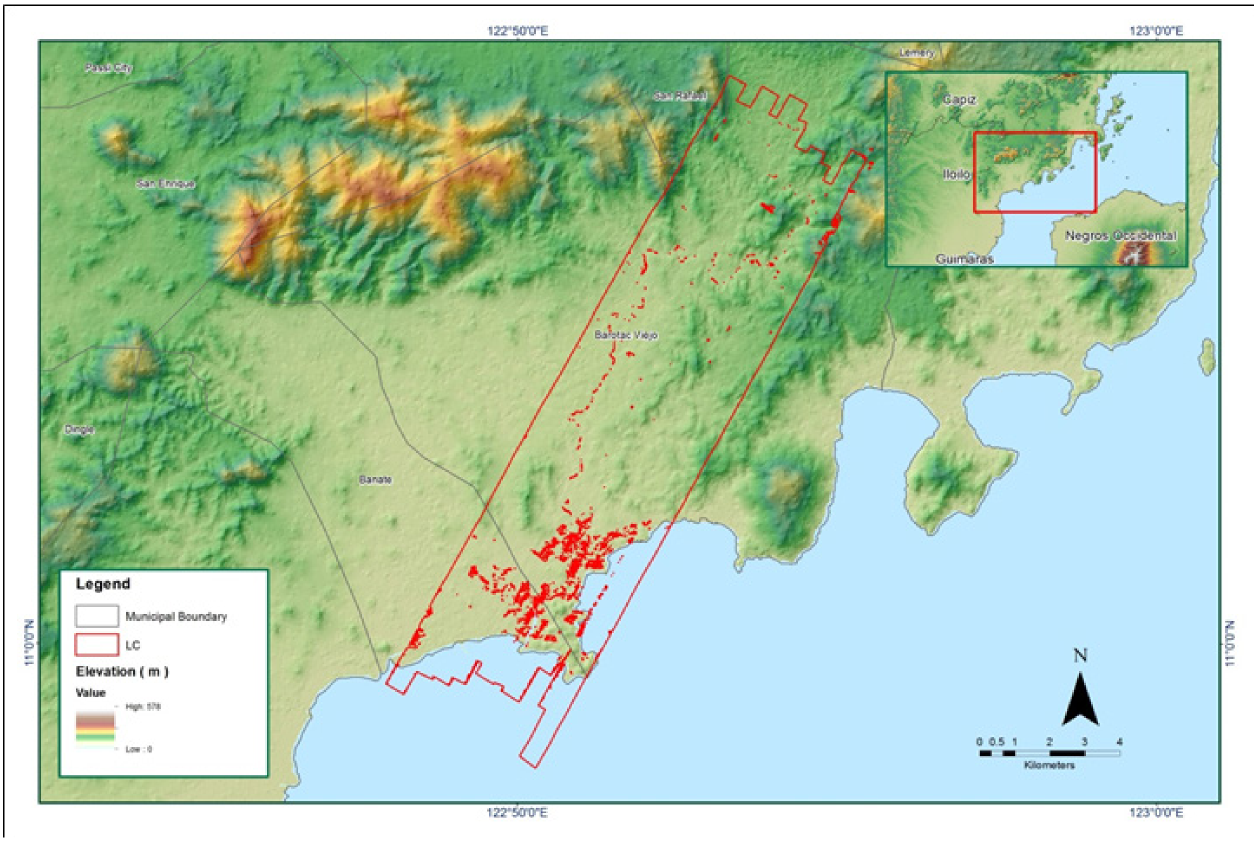


Figure A-8.81. Coverage of LiDAR data

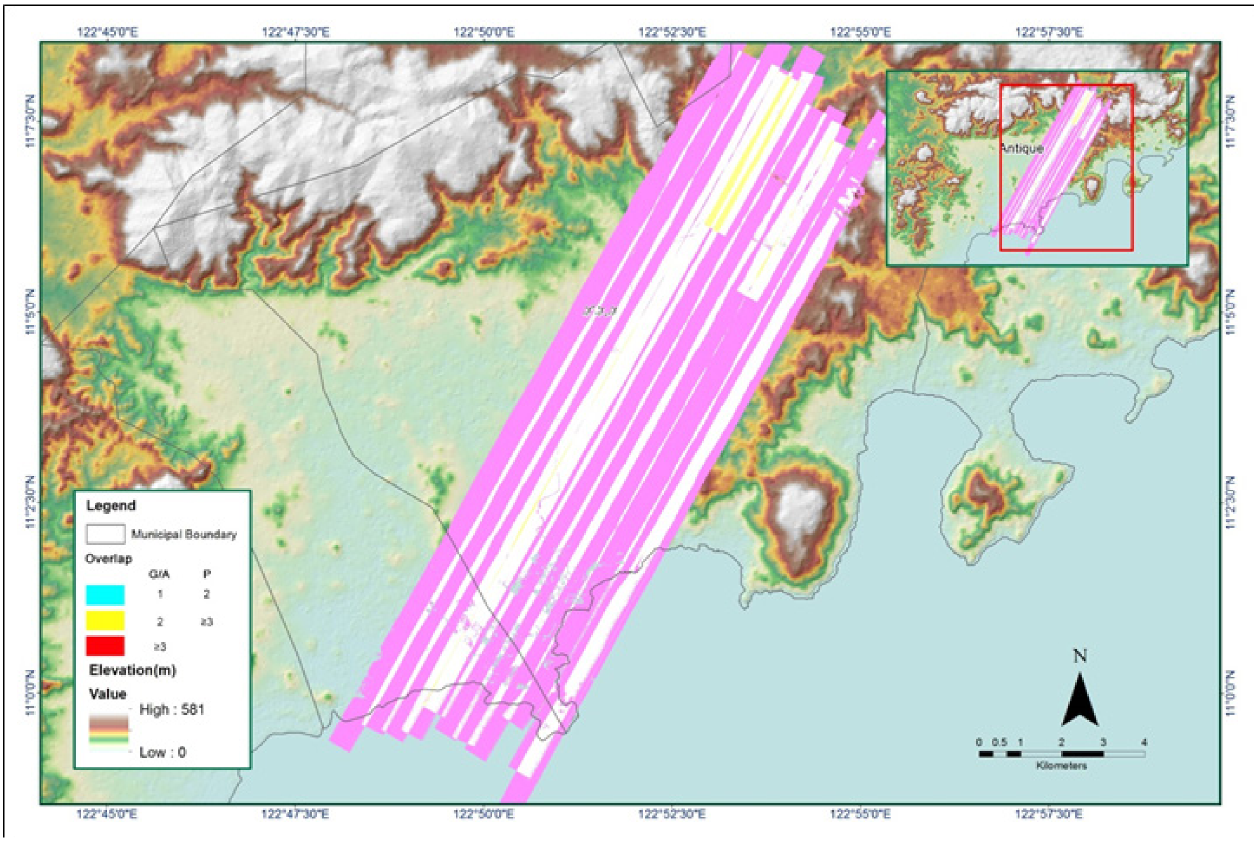


Figure A-8.82. Image of data overlap

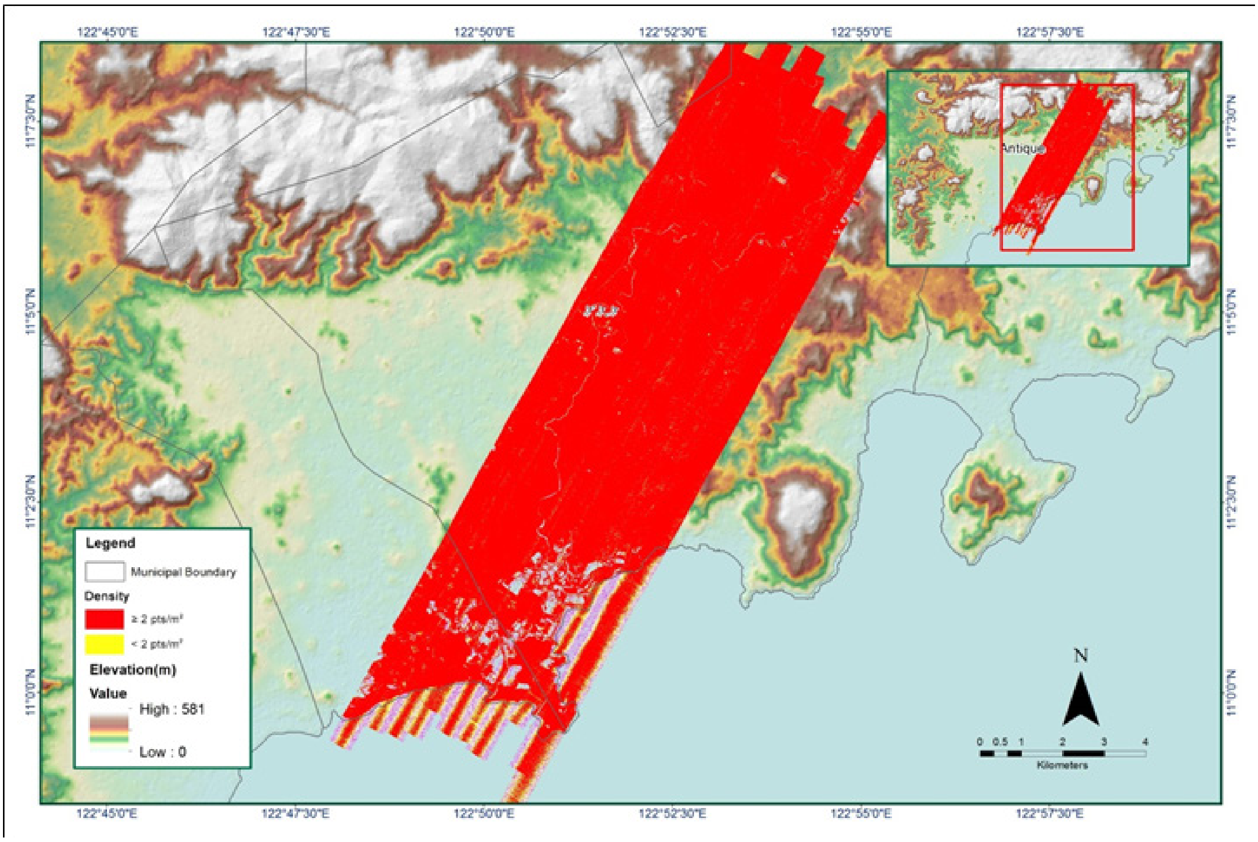


Figure A-8.83. Density map of merged LiDAR data

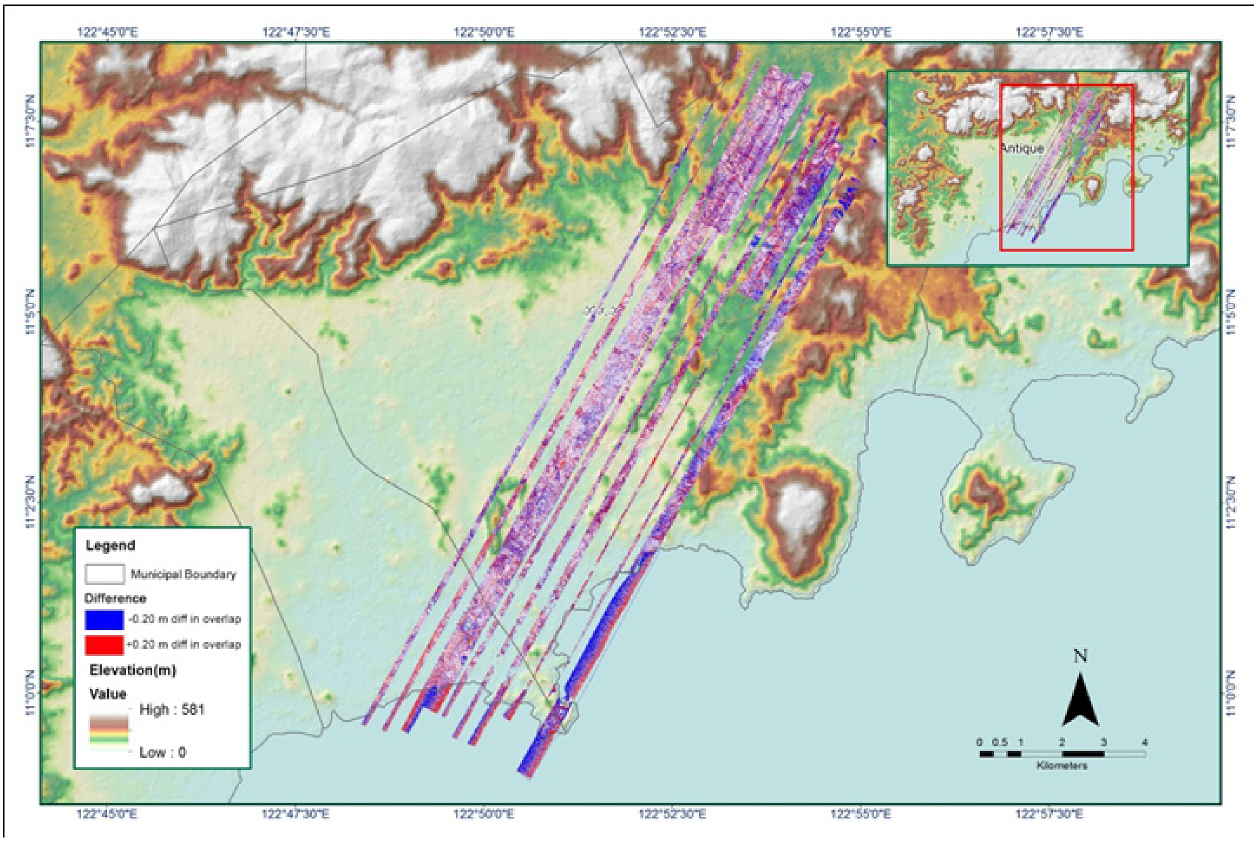


Figure A-8.84. Elevation difference between flight lines

Table A-8.13. Mission Summary Report for Mission Blk37P

Flight Area	Iloilo Reflights
Mission Name	Blk37P
Inclusive Flights	8507AC
Range data size	8.18 GB
Base data size	134 MB
POS	206 MB
Image	NA
Transfer date	October 23, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	Yes
RMSE for East Position (<4.0 cm)	Yes
RMSE for Down Position (<8.0 cm)	Yes
Boresight correction stdev (<0.001deg)	0.000315
IMU attitude correction stdev (<0.001deg)	0.000546
GPS position stdev (<0.01m)	0.0084
Minimum % overlap (>25)	30.27
Ave point cloud density per sq.m. (>2.0)	4.43
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	73
Maximum Height	357.42 m
Minimum Height	10.01 m
Classification (# of points)	
Ground	40,505,140
Low vegetation	22,749,958
Medium vegetation	43,777,702
High vegetation	101,728,247
Building	4,890,355
Ortophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Chelou Prado, Engr. Gladys Mae Apat

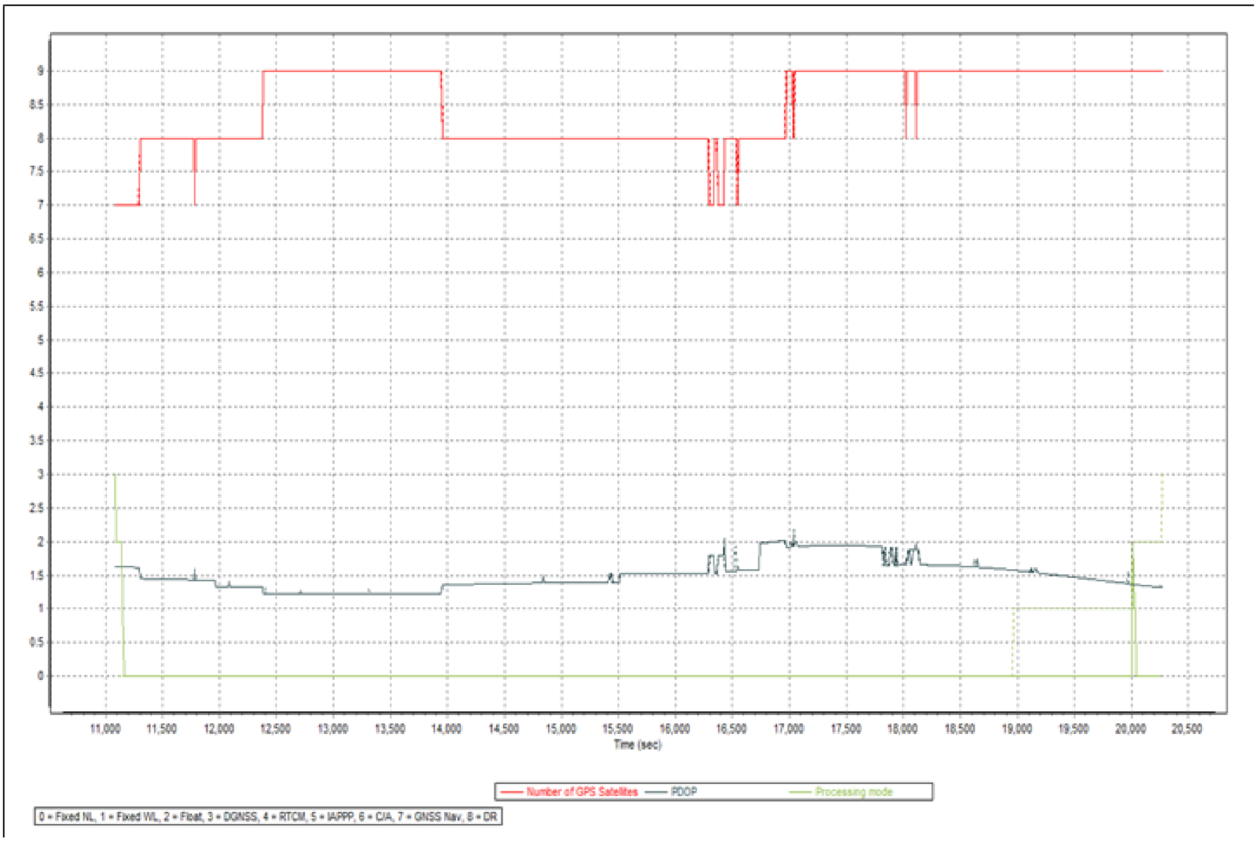


Figure A-8.85. Solution Status

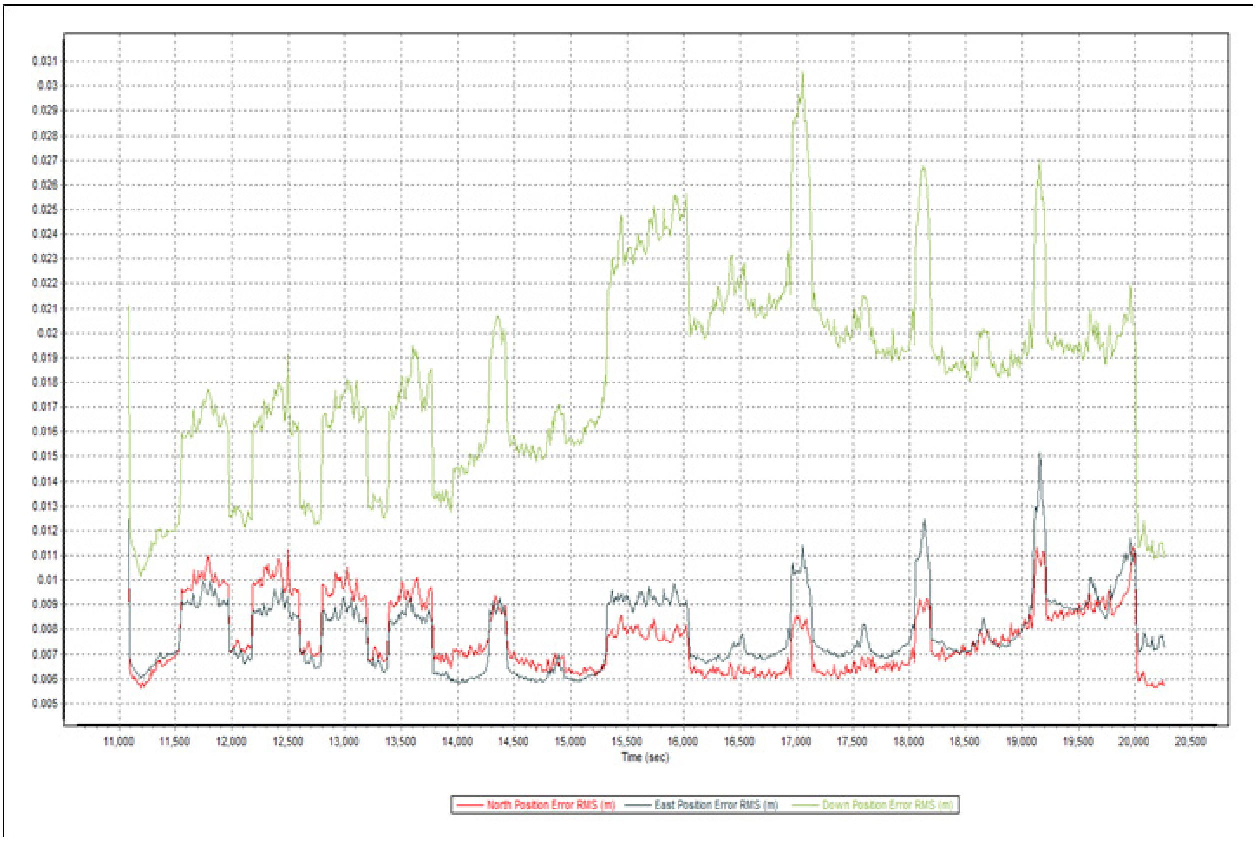


Figure A-8.86. Smoothed Performance Metric Parameters

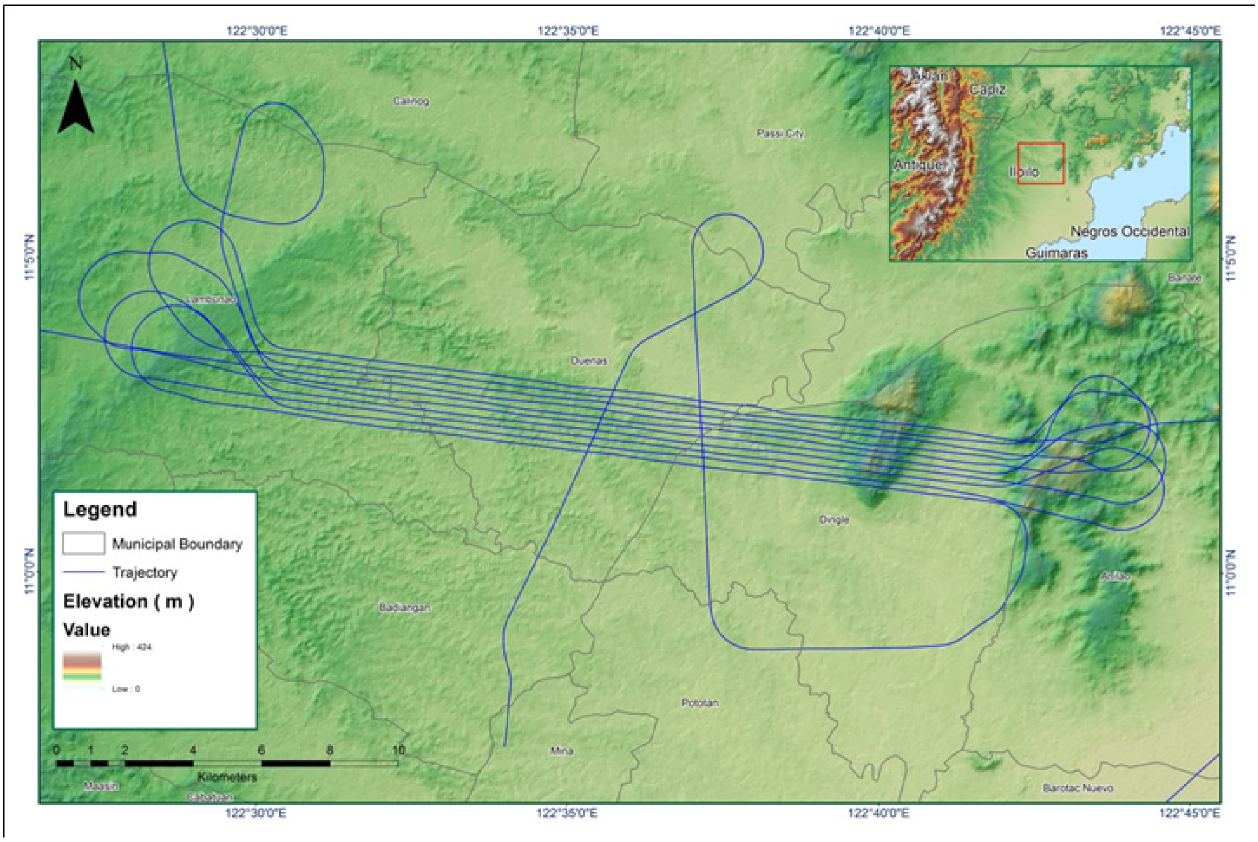


Figure A-8.87. Best Estimated Trajectory

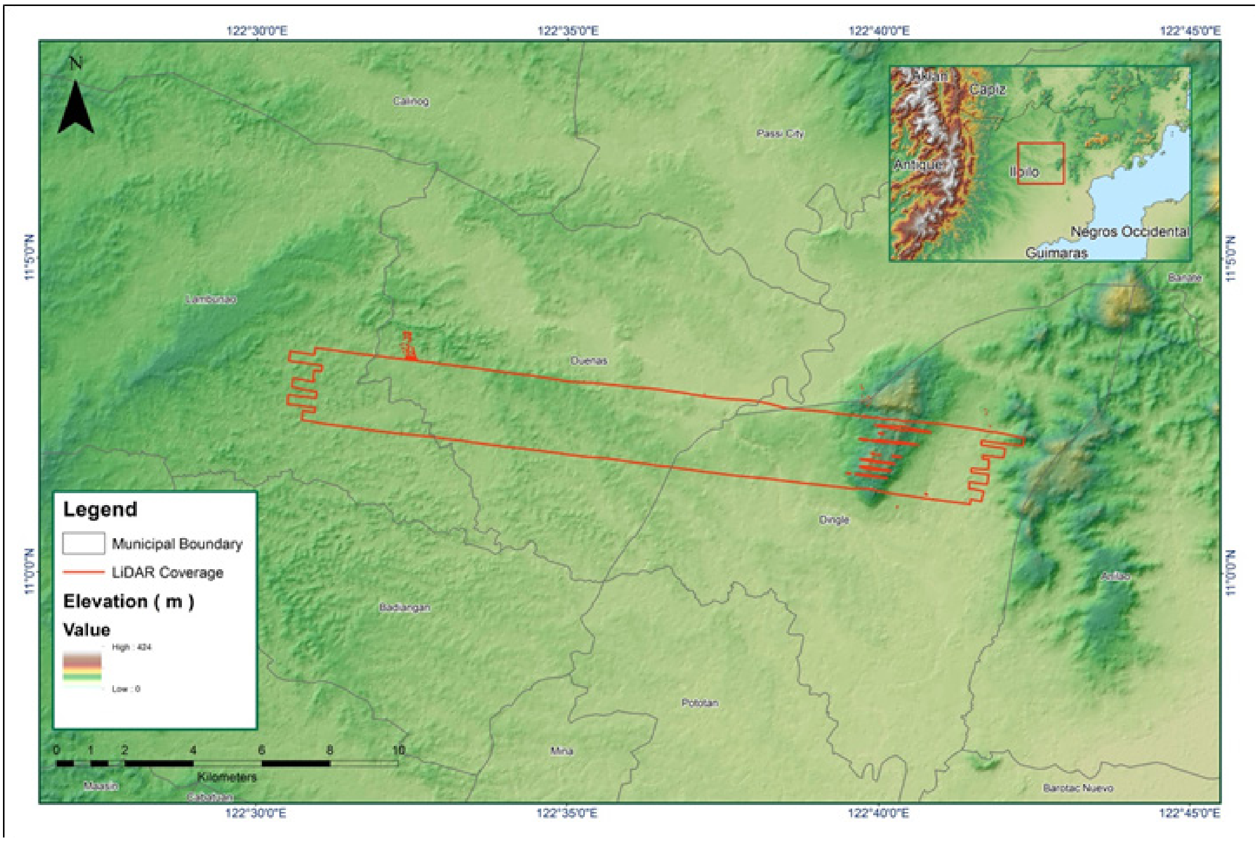


Figure A-8.88. Coverage of LiDAR data

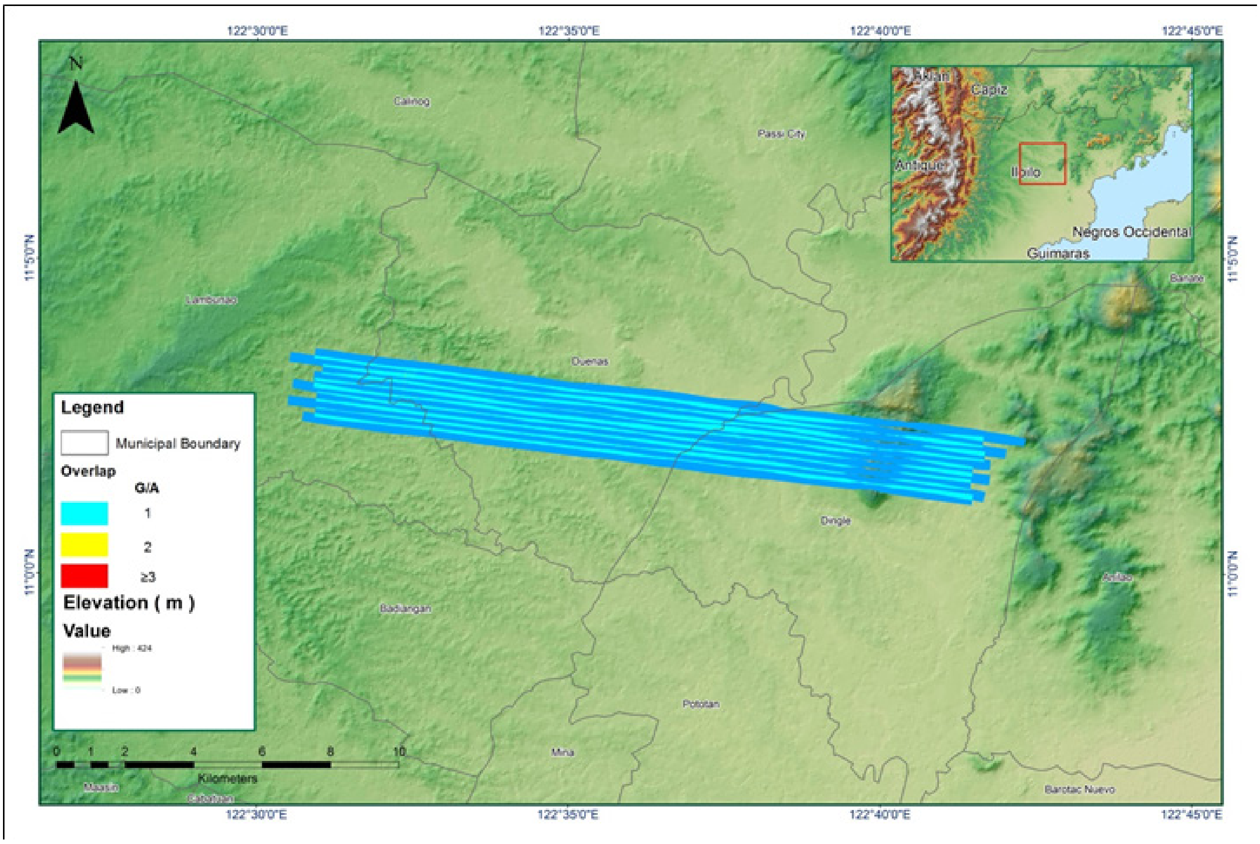


Figure A-8.89. Image of data overlap

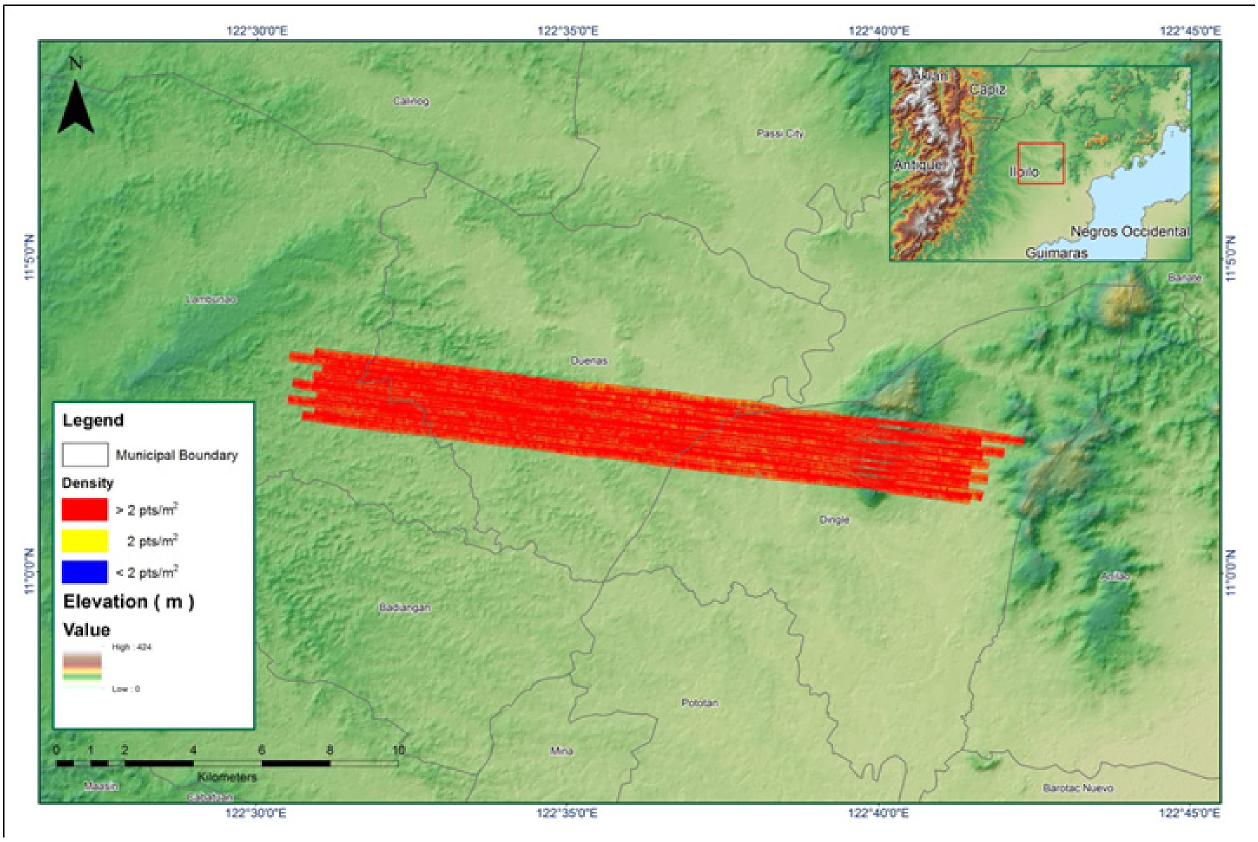


Figure A-8.90. Density map of merged LiDAR data

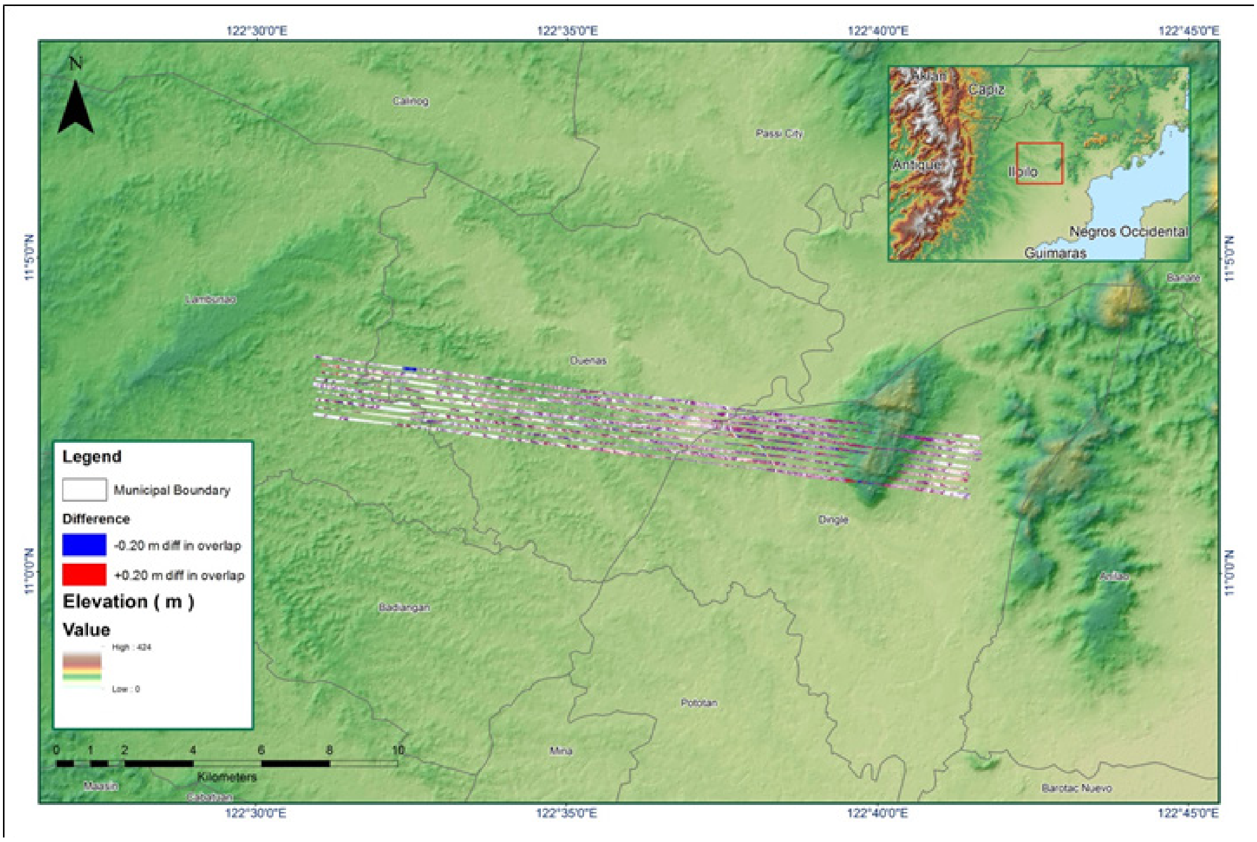


Figure A-8.91. Elevation difference between flight lines

Table A-8.14. Mission Summary Report for Mission Blk37J

Flight Area	Iloilo Reflights
Mission Name	Blk37J
Inclusive Flights	8507AC
Range data size	8.18 GB
POS	206 MB
Base data size	134 MB
Image	NA
Transfer date	October 23, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	1.14
RMSE for North Position (<4.0 cm)	1.51
RMSE for East Position (<4.0 cm)	3.05
RMSE for Down Position (<8.0 cm)	
Boresight correction stdev (<0.001deg)	0.000540
IMU attitude correction stdev (<0.001deg)	0.001007
GPS position stdev (<0.01m)	0.0096
Minimum % overlap (>25)	40.24
Ave point cloud density per sq.m. (>2.0)	3.68
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	20
Maximum Height	195.94
Minimum Height	58.57
Classification (# of points)	
Ground	12,109,985
Low vegetation	5,645,580
Medium vegetation	5,575,631
High vegetation	6,920,203
Building	654,632
Orthophoto	None
Processed by	Engr. Kenneth Solidum, Engr. Edgardo Gubatanga Jr., Engr. Gladys Mae Apat

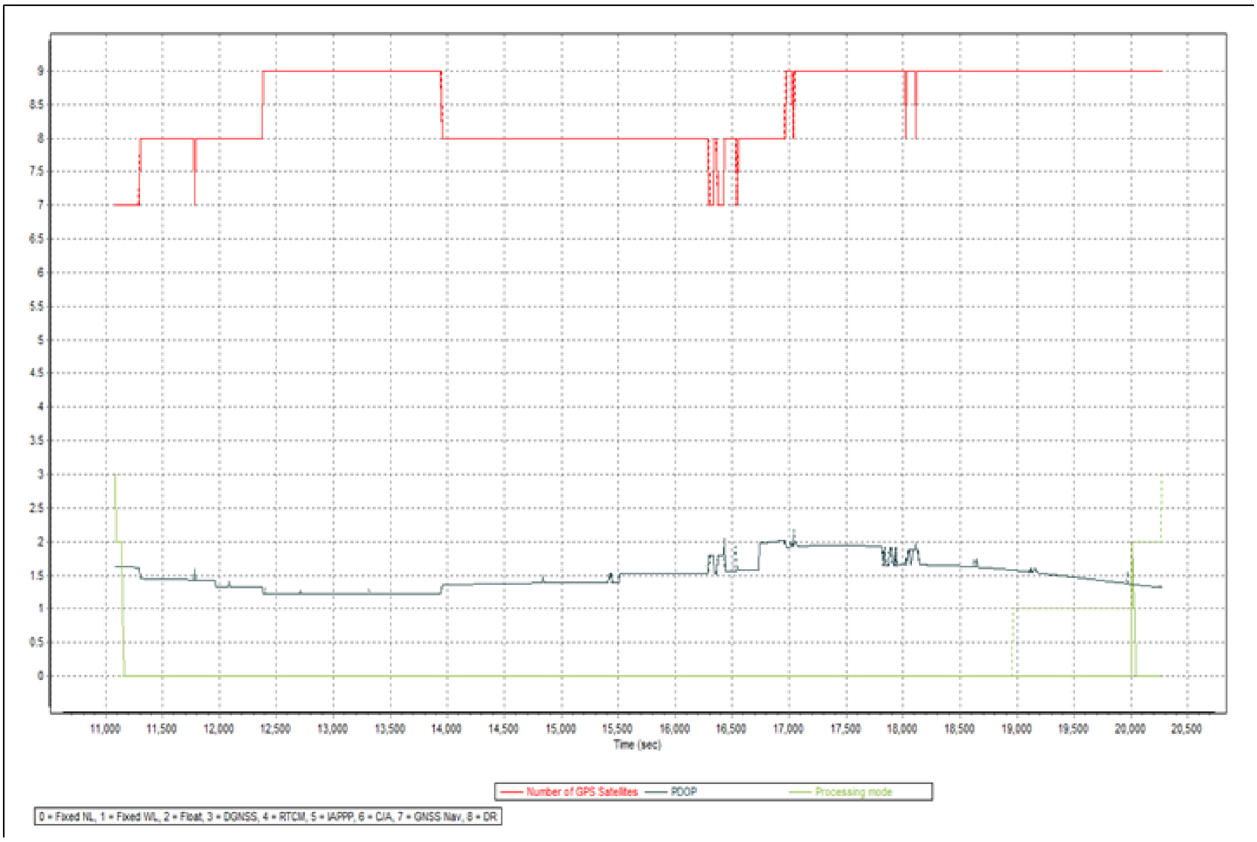


Figure A-8.92. Solution Status

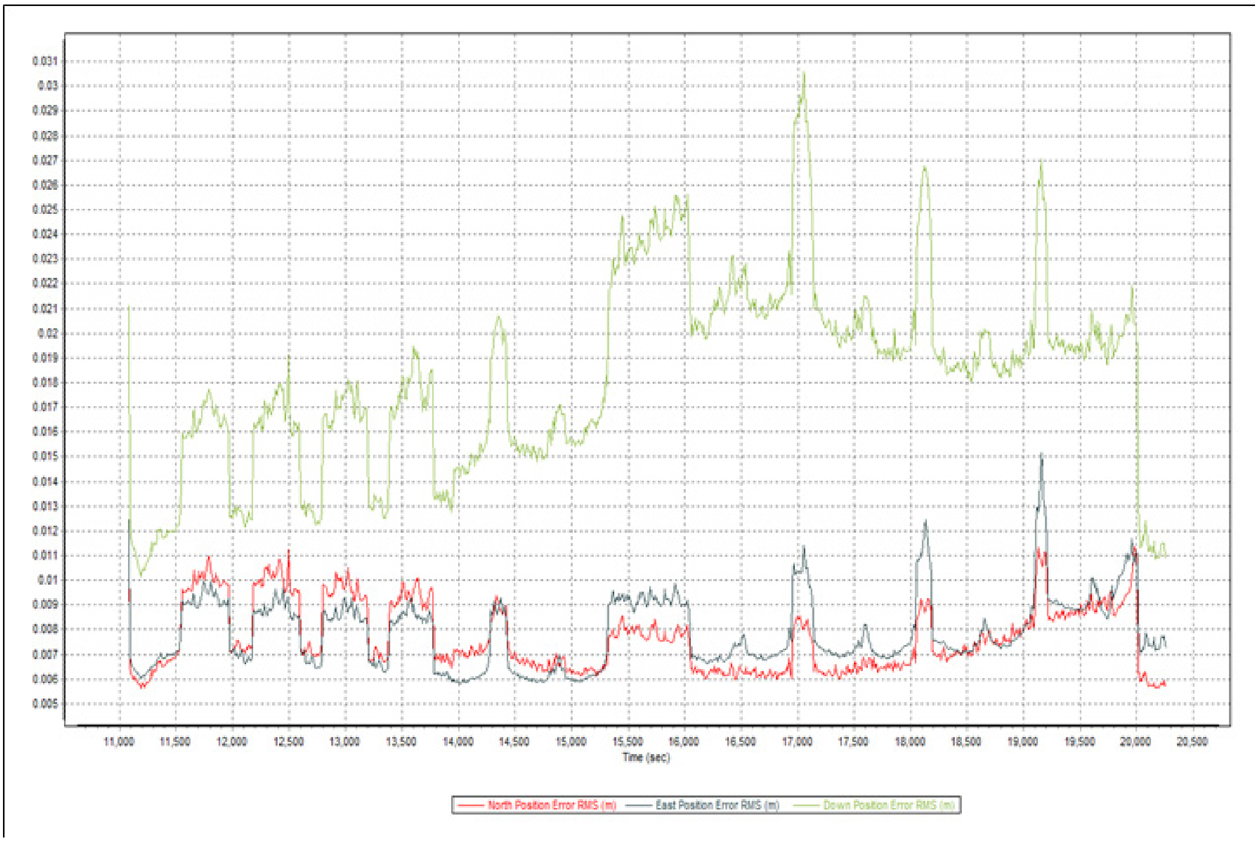


Figure A-8.93. Smoothed Performance Metric Parameters

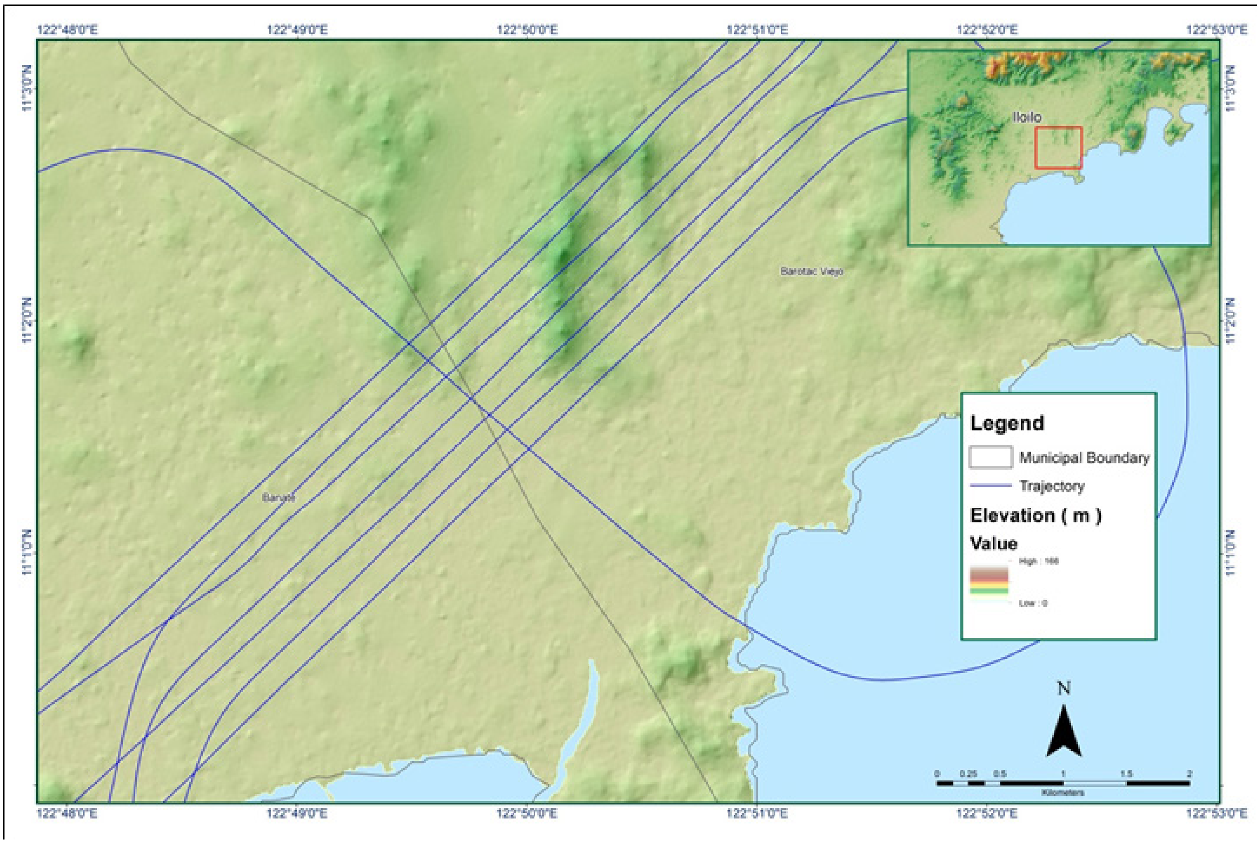


Figure A-8.94. Best Estimated Trajectory

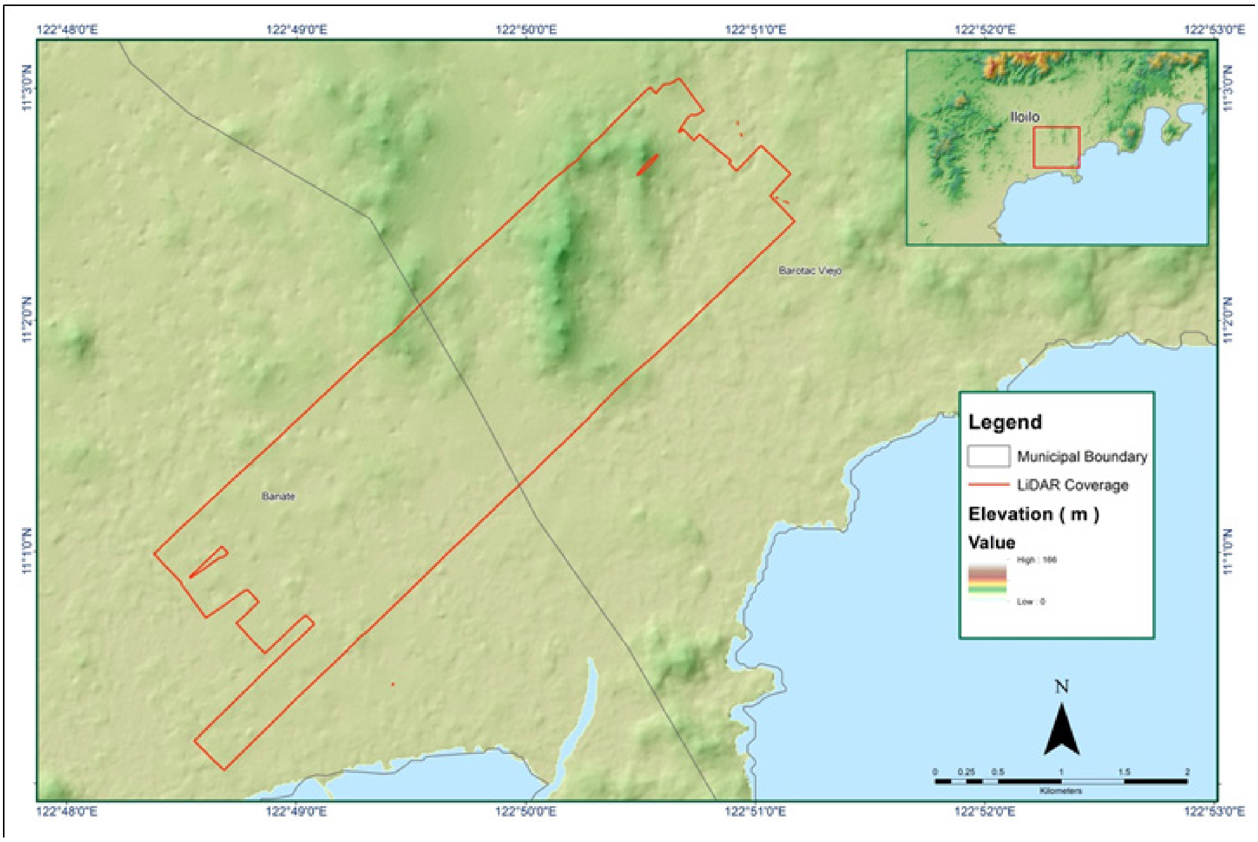


Figure A-8.95. Coverage of LiDAR data

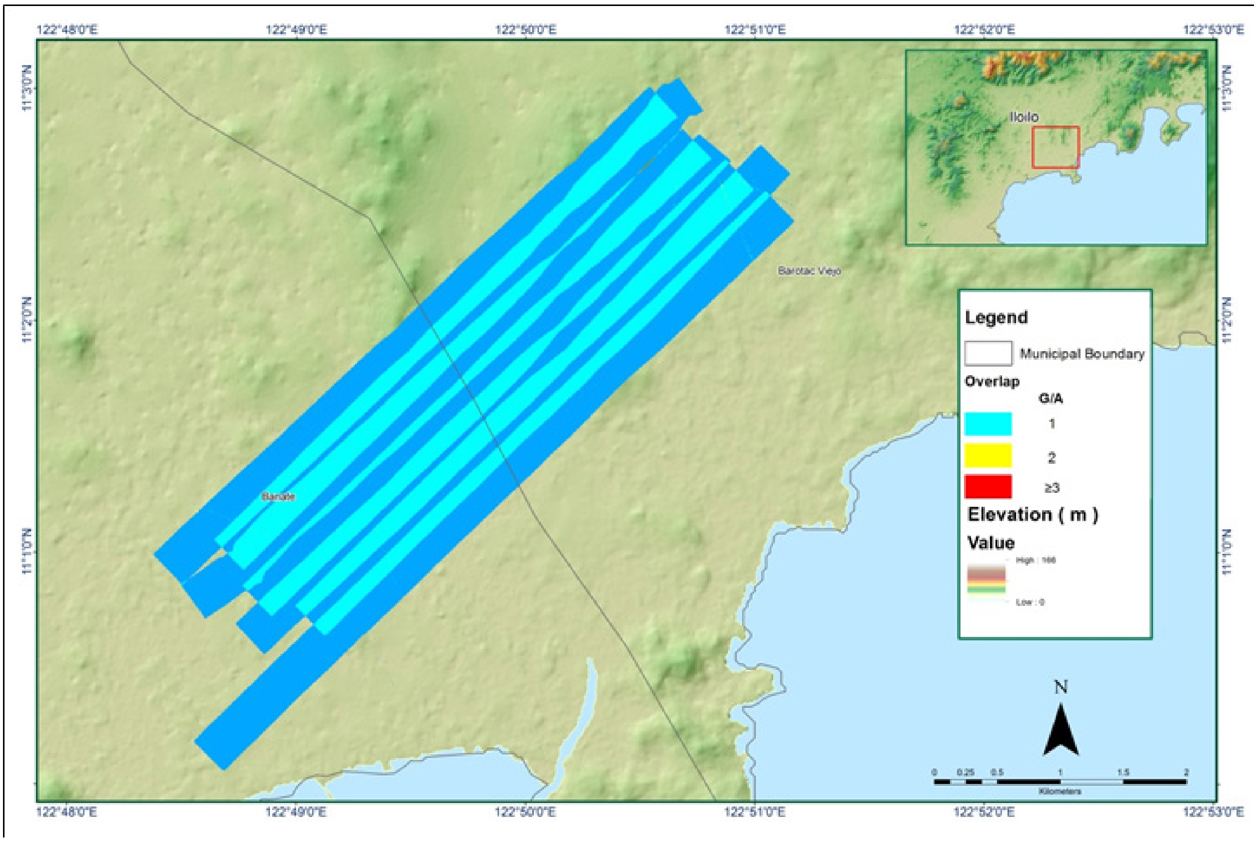


Figure A-8.96. Image of data overlap

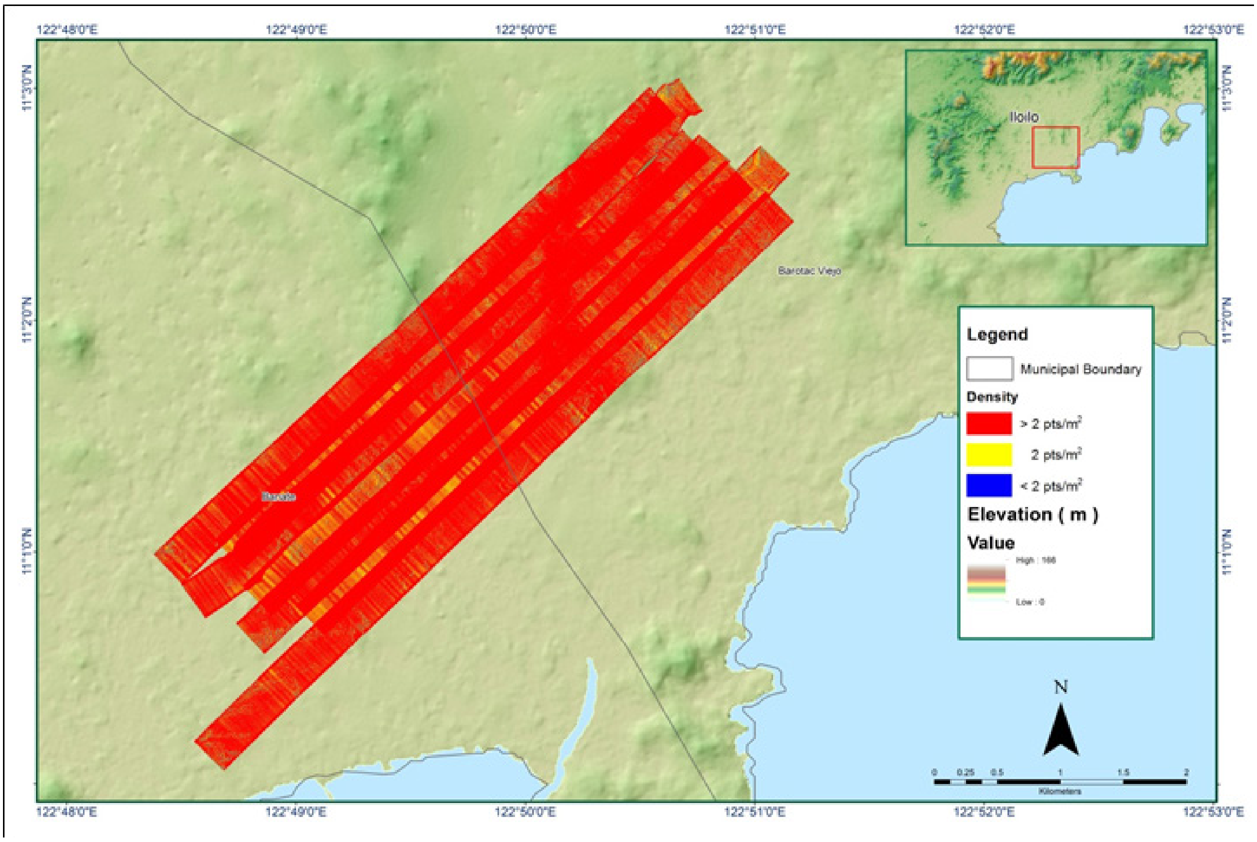


Figure A-8.97. Density map of merged LiDAR data

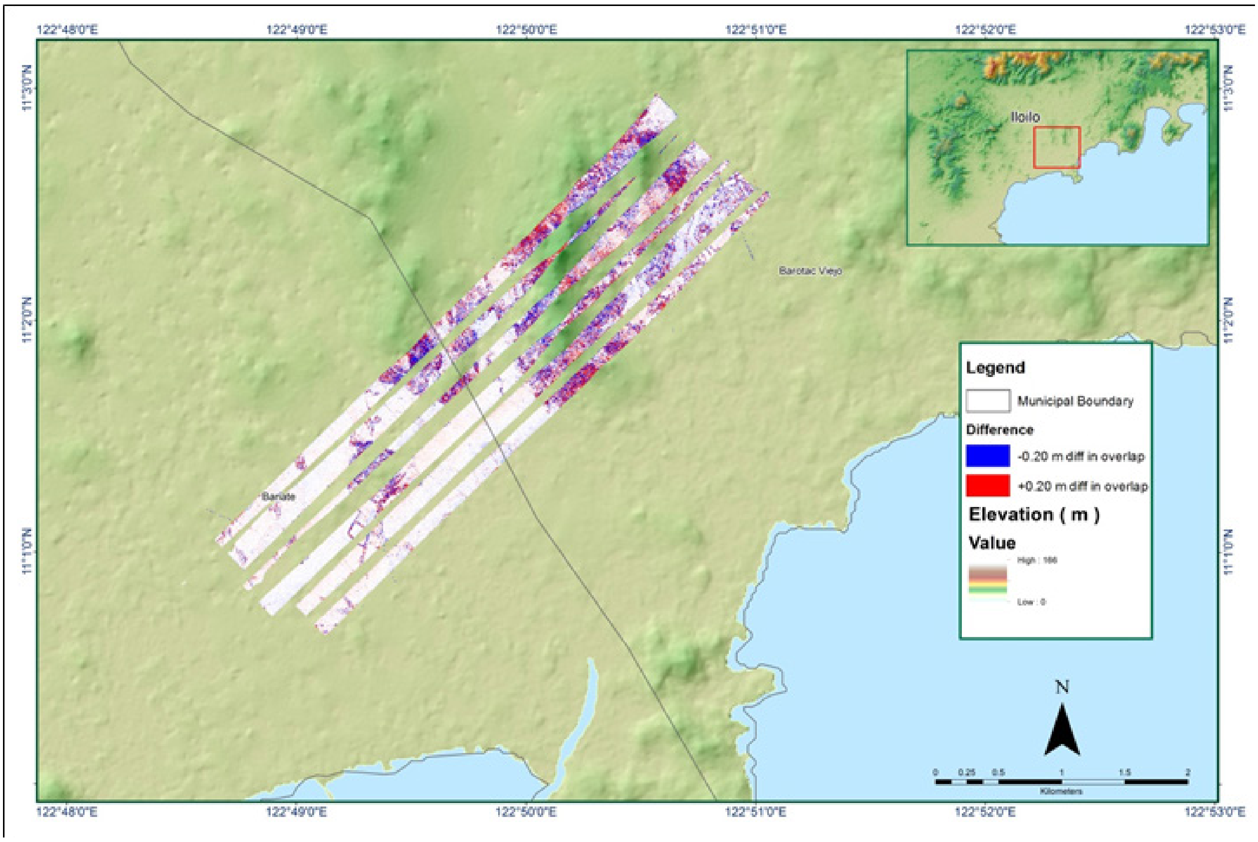


Figure A-8.98. Elevation difference between flight lines

Annex 9. Barotac Basin Model Parameters

Table A-9.1 Barotac 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
W280	8.7619	87.626	0	2.7033	6.6714	Discharge	0.000178639	1	Ratio to Peak	0.0001
W290	8.5578	56.429	0	1.2876	8.2887	Discharge	1.05E-05	1	Ratio to Peak	0.0001
W300	7.1707	75.9	0	2.06	4.5848	Discharge	0.000348278	1	Ratio to Peak	0.0001
W310	7.6132	76.433	0	0.1533	2.1594	Discharge	1.23E-07	1	Ratio to Peak	0.0001
W320	6.0455	69.945	0	0.28039	1.745	Discharge	0.0010394	1	Ratio to Peak	0.0001
W330	7.9812	76.399	0	2.1424	4.1828	Discharge	0.000227497	1	Ratio to Peak	0.0001
W340	9.4025	84.892	0	4.9302	9.0855	Discharge	0.000161782	1	Ratio to Peak	0.0001
W350	10.122	35.418	0	1.0624	4.0214	Discharge	0.000142936	1	Ratio to Peak	0.0001
W360	17.134	44.75	0	1.9749	8.5313	Discharge	0.000350715	1	Ratio to Peak	0.0001
W370	16.911	45.029	0	1.4858	6.4188	Discharge	0.000628376	1	Ratio to Peak	0.0001
W380	7.7246	56.102	0	0.74227	4.8164	Discharge	0.000571662	1	Ratio to Peak	0.0001

W390	8.3118	55.355	0	1.2316	6.1795	Discharge	0.000943838	1	Ratio to Peak	0.0001
W400	6.2713	64.179	0	0.34631	4.8639	Discharge	0.000299489	1	Ratio to Peak	0.0001
W410	5.1809	99	0	0.39703	3.4731	Discharge	4.43E-06	1	Ratio to Peak	0.0001
W420	20.067	41.395	0	1.1893	5.1379	Discharge	0.000457553	1	Ratio to Peak	0.0001
W430	15.111	47.4	0	2.9391	12.697	Discharge	0.000226598	1	Ratio to Peak	0.0001
W440	10.642	89.329	0	4.3839	3.1518	Discharge	0.000188961	1	Ratio to Peak	0.0001
W450	20.637	40.8	0	2.1122	9.1244	Discharge	0.000141969	1	Ratio to Peak	0.0001
W460	10.07	35.647	0	0.56888	1.72	Discharge	0.00052177	1	Ratio to Peak	0.0001
W470	20.637	40.8	0	1.1523	4.9781	Discharge	0.000162068	1	Ratio to Peak	0.0001
W480	20.637	40.8	0	1.2141	5.245	Discharge	0.000280602	1	Ratio to Peak	0.0001
W490	20.637	40.8	0	1.1482	4.9601	Discharge	0.000169366	1	Ratio to Peak	0.0001
W500	20.637	40.8	0	4.3358	18.731	Discharge	0.000166874	1	Ratio to Peak	0.0001
W510	20.637	40.8	0	0.0753765	0.32562	Discharge	3.04E-05	1	Ratio to Peak	0.0001
W520	20.637	40.8	0	2.803	12.109	Discharge	0.000231868	1	Ratio to Peak	0.0001
W530	20.637	40.8	0	0.48641	2.1013	Discharge	0.000405387	1	Ratio to Peak	0.0001
W540	20.637	40.8	0	1.5037	6.4962	Discharge	0.000429026	1	Ratio to Peak	0.0001

Annex 10. Barotac Model Reach Parameters

Table A-10.1 Barotac Model Reach

Reach Number	MuskingumCunge Channel Routing							
	Time Step	Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R30	Automatic interval	Fixed	422.84	0.0070526	0.002267	Trapezoid	27	1
R70	Automatic interval	Fixed	2561.8	0.0133743	0.001521	Trapezoid	27	1
R80	Automatic interval	Fixed	1990.2	0.0141727	0.0015139	Trapezoid	27	1
R100	Automatic interval	Fixed	1507	0.0029403	0.0025956	Trapezoid	27	1
R110	Automatic interval	Fixed	2217.8	0.0037547	0.0010033	Trapezoid	27	1
R120	Automatic interval	Fixed	614.26	0.014499	0.001009	Trapezoid	27	1
R150	Automatic interval	Fixed	934.14	0.0065817	0.00043755	Trapezoid	27	1
R180	Automatic interval	Fixed	1561	0.0022154	0.00093366	Trapezoid	27	1
R190	Automatic interval	Fixed	1243	0.0077067	0.00065802	Trapezoid	27	1
R210	Automatic interval	Fixed	7.0711	0.0023349	0.00092237	Trapezoid	27	1
R230	Automatic interval	Fixed	1447.2	0.0031464	0.0001	Trapezoid	27	1
R240	Automatic interval	Fixed	449.71	0.0020222	0.00042684	Trapezoid	27	1
R260	Automatic interval	Fixed	2681.5	0.0041197	0.00042684	Trapezoid	27	1

Annex 11. Barotac Field Validation Points

Table A-11.1 Barotac Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return/ Scenario
	Lat	Long					
0	11.0122275	122.8209459	0.16	0.38	0.048	Yolanda	5-Year
1	11.01266587	122.8203257	0.25	0.28	0.001	Yolanda	5-Year
2	11.07673934	122.8413791	0.03	0.75	0.518	Frank	100-Year
3	11.02962465	122.8346646	0.03	0	0.001		
4	11.04585489	122.8437635	0.04	0	0.002		
5	11.00313318	122.8319138	0.25	0.75	0.250	Yolanda	5-Year
6	11.03307951	122.820822	0.11	0.11	0.000	Frank	100-Year
7	11.00116547	122.8202398	0.06	0	0.004	Yolanda	5-Year
8	11.01003419	122.8136837	0.03	0.31	0.078	Yolanda	5-Year
9	11.08770544	122.8280643	0.03	0.5	0.221	Yolanda	5-Year
10	11.08363828	122.8529895	0.03	0.1	0.005	Frank	100-Year
11	11.02852536	122.8342067	0.14	0	0.020		
12	11.08738393	122.8280774	0	0.5	0.250	Yolanda	5-Year
13	11.08992966	122.8178225	0.03	0	0.001		
14	11.04467392	122.8536422	0.03	0	0.001	Yolanda	5-Year
15	11.04101947	122.8527029	0.13	0.7366	0.368	Yolanda	5-Year
16	11.07567103	122.8411895	0.03	0.75	0.518	Frank	100-Year
17	11.08896289	122.8227645	0.2	0	0.040		
18	11.00269809	122.8321889	0.03	0.75	0.518	Yolanda	5-Year
19	11.0030488	122.8286304	0.03	0.25	0.048	Yolanda	5-Year
20	11.07951131	122.8201827	0.03	0	0.001		
21	11.08770052	122.8278931	0	0.5	0.250	Yolanda	5-Year
22	10.99943702	122.8414286	0.03	0	0.001		
23	11.00236502	122.8254285	0.07	0	0.005		
24	11.08286499	122.8530331	0.03	0.1	0.005	Frank	100-Year
25	10.99955355	122.8373469	0.03	0	0.001		
26	11.04605855	122.8522567	0.03	0	0.001	Yolanda	5-Year
27	11.07547581	122.840798	0.03	0.75	0.518	Frank	100-Year
28	11.1099753	122.8574113	0.03	0	0.001		
29	11.08083736	122.8340991	0.03	0	0.001		
30	11.11230532	122.8498422	0.03	0	0.001		
31	11.08792004	122.835365	0.04	0	0.002		
32	11.03269294	122.8717429	0.29	0.8	0.260	Frank	100-Year
33	11.04539826	122.8536252	0.05	0.32	0.073	Yolanda	5-Year
34	11.04004625	122.8509171	1.77	1	0.593	Frank	100-Year
35	11.02459695	122.8592843	0.27	2	2.993	Frank	100-Year
36	11.04150881	122.8511118	0.17	0.0762	0.009	Yolanda	5-Year
37	11.00512039	122.8243691	0.23	0	0.053	Yolanda	5-Year
38	11.06058959	122.8091817	0.6	0.9652	0.133	Frank	100-Year

39	11.00674011	122.8266237	0.39	0	0.152		
40	11.00049946	122.8181374	0.07	0.12	0.003	Yolanda	5-Year
41	11.02458468	122.8576433	0.5	1	0.250	Frank	100-Year
42	11.04654782	122.8465433	0.21	0	0.044		
43	10.99674781	122.8042745	0.43	0	0.185	Frank	100-Year
44	11.0270132	122.8596241	1	1	0.000	Frank	100-Year
45	11.00294184	122.8245805	0.06	0.2	0.020	Frank	100-Year
46	11.00201777	122.8183777	0.03	0.31	0.078	Yolanda	5-Year
47	11.02546985	122.8612838	0.63	2	1.877	Frank	100-Year
48	11.00559834	122.8236801	0.1	0	0.010	Yolanda	5-Year
49	11.04932604	122.8436237	0.03	0	0.001		
50	11.01049125	122.8147384	0.7	0.39	0.096	Frank	100-Year
51	11.00654589	122.8139404	0.75	0.78	0.001	Frank	100-Year
52	11.04000729	122.8525813	0.03	0	0.001		
53	11.00497012	122.8118526	1.12	1.32	0.040	Frank	100-Year
54	11.03223531	122.8735122	0.07	0.25	0.032	Frank	100-Year
55	11.03102767	122.8681509	0.37	0	0.137		
56	11.01326542	122.820615	0.65	0.28	0.137	Yolanda	5-Year
57	11.00363504	122.8254773	0.06	0	0.004		
58	11.00516833	122.817055	0.03	0.23	0.040	Marce	5-Year
59	11.00366899	122.8204153	0.03	0.15	0.014	Frank	100-Year
60	11.051042	122.8469951	0.87	0.5	0.137	Frank	100-Year
61	11.02789106	122.8347701	0.03	0.1	0.005	Yolanda	5-Year
62	11.07413344	122.786963	0.2	0.4318	0.054	Frank	100-Year
63	11.0267679	122.8068666	0.58	1.3462	0.587	Yolanda	5-Year
64	11.00193792	122.8388242	0.47	3	6.401	Yolanda	5-Year
65	11.02665192	122.858677	0.5	1	0.250	Frank	100-Year
66	10.99995092	122.8112341	1.04	1.33	0.084	Ruping	5-Year
67	10.99923173	122.8111349	0.41	1.33	0.846	Ruping	5-Year
68	11.03164558	122.8662044	0.04	1.5	2.132	Frank	100-Year
69	11.03094837	122.8666879	1.21	0.5	0.504	Frank	100-Year
70	11.0258227	122.8615659	0.61	2	1.932	Frank	100-Year
71	11.03225042	122.8673891	0.78	0	0.608		
72	11.0018551	122.8171044	0.03	0.42	0.152	Yolanda	5-Year
73	11.02335728	122.8564483	1.88	0.8	1.166	Frank	100-Year
74	10.99912292	122.8087417	1.57	1.32	0.063	Frank	100-Year
75	11.03053205	122.8666695	0.46	2	2.372	Frank	100-Year
76	11.04056172	122.8502406	0.54	0	0.292		
77	11.00060456	122.8148905	1.43	0.97	0.212	Frank	100-Year
78	10.99876922	122.8095092	1.52	1.51	0.000	Frank	100-Year
79	11.04111609	122.8497928	0.03	0.2032	0.030	Yolanda	5-Year
80	10.99795236	122.80538	1.6	1.28	0.102	Frank	100-Year
81	11.03110475	122.866608	0	0.5	0.250	Frank	100-Year
82	10.99903049	122.8103716	0.54	1.33	0.624	Ruping	5-Year
83	11.00978573	122.8139481	0.35	0.42	0.005	Yolanda	5-Year

84	11.03135468	122.8668801	0	2	4.000	Frank	100-Year
85	10.99770659	122.8067595	1.23	1.32	0.008	Frank	100-Year
86	11.04171467	122.8483329	3.48	2.5	0.960	Frank	100-Year
87	11.03739661	122.8516712	1.98	1.5	0.230	Frank	100-Year
88	11.03124867	122.8657059	0.89	1.5	0.372	Frank	100-Year
89	11.03101463	122.8655085	0.77	1.5	0.533	Frank	100-Year
90	11.0222303	122.8551524	2.67	0.8	3.497	Frank	100-Year
91	11.03586992	122.8521283	0.49	0	0.240	Yolanda	5-Year
92	11.02651594	122.8596981	0	1	1.000	Frank	100-Year
93	11.08447643	122.8309557	0.49	0	0.240		
94	11.0682027	122.8089892	0.62	0	0.384		
95	11.06016958	122.8113771	1.09	0.4572	0.400	Yolanda	5-Year
96	11.06959492	122.8002888	0.62	1.3462	0.527	Yolanda	5-Year
97	11.07690723	122.8195778	0.62	0	0.384		
98	10.99876224	122.8043589	1.04	1.16	0.014	Frank	100-Year
99	11.03594666	122.8516653	1.19	0	1.416	Yolanda	5-Year
100	11.03753013	122.8524111	0.77	1.85	1.166	Yolanda	5-Year
101	11.03801883	122.8504314	1.85	1.5	0.123	Frank	100-Year
102	10.99940699	122.8095425	1.44	1.51	0.005	Frank	100-Year
103	11.03489442	122.8471531	2.02	2.5	0.230	Frank	100-Year
104	11.00089753	122.8138355	2.11	0.94	1.369	Frank	100-Year
105	11.03531859	122.8467563	1.9	2.5	0.360	Frank	100-Year
106	11.04518466	122.8465207	0.05	1.9304	3.536	Yolanda	5-Year
107	11.03530123	122.8474779	2.19	2.5	0.096	Frank	100-Year
108	11.03869274	122.8489422	2.18	1	1.392	Frank	100-Year
109	11.03189308	122.8641703	1.9	1	0.810	Frank	100-Year
110	11.03109806	122.8670407	0	2	4.000	Frank	100-Year
111	11.03517337	122.8463891	0	2.5	6.250	Frank	100-Year
112	11.03650158	122.8519985	0.25	1.32	1.145	Yolanda	5-Year
113	11.04828625	122.8467487	1.07	0.5	0.325	Frank	100-Year
114	11.0218826	122.8412337	1.22	0.5	0.518	Frank	100-Year
115	11.03677531	122.8498836	2.35	1.5	0.723	Frank	100-Year
116	10.99855836	122.808589	0	1.93	3.725	Frank	100-Year
117	11.04439864	122.847349	3.29	1.3208	3.878	Frank	100-Year
118	10.99861935	122.8043986	0	1.16	1.346	Frank	100-Year
119	11.04659073	122.8490548	2.53	3	0.221	Frank	100-Year
120	11.03817836	122.851063	2.61	1.5	1.232	Frank	100-Year
121	11.03628275	122.8474941	1.56	1	0.314	Frank	100-Year
122	10.99714227	122.8028444	1.21	0.41	0.640	Frank	100-Year
123	11.04431552	122.84619	2.87	3.3782	0.258	Frank	100-Year
124	11.03591363	122.8518475	0	0	0.000	Yolanda	5-Year
125	10.99869823	122.8071018	1.59	1.34	0.063	Frank	100-Year
126	11.03641813	122.8520663	0	1.16	1.346	Yolanda	5-Year
127	11.05933082	122.8149339	1.24	0.8636	0.142	Yolanda	5-Year
128	11.04215598	122.8487505	0	2.5	6.250	Frank	100-Year

129	11.04397064	122.8498398	4	1.321	7.177	Yolanda	5-Year
130	11.04188013	122.8469475	2.84	3	0.026	Frank	100-Year
131	11.04231527	122.8483	1.86	2.5	0.410	Frank	100-Year
132	11.04347542	122.846798	3.07	1.8542	1.478	Frank	100-Year
133	11.0441735	122.8486472	2.33	1.8	0.281	Frank	100-Year
134	11.04672974	122.8482389	3.24	3	0.058	Frank	100-Year
135	11.04742232	122.849116	3.01	3	0.000	Frank	100-Year
136	11.04336883	122.8473094	0	1.016	1.032	Yolanda	5-Year
137	11.04599915	122.847137	1.89	1	0.792	Frank	100-Year
138	11.03707485	122.8531005	1.51	1.83	0.102	Yolanda	5-Year
139	11.03662162	122.8524916	0	1.2	1.440	Yolanda	5-Year
140	11.04611088	122.8470258	0	1	1.000	Frank	100-Year
141	11.04337393	122.849012	1.68	1.79	0.012	Frank	100-Year
142	11.04686348	122.8478197	0	3	9.000	Frank	100-Year
143	11.04435657	122.8490247	2.82	1.8	1.040	Frank	100-Year
144	11.04469746	122.847032	0	0.56	0.314	Yolanda	5-Year
145	11.04205677	122.8472648	0	3	9.000	Frank	100-Year
146	11.0450444	122.8509633	3.03	2.5	0.281	Frank	100-Year
147	11.04505875	122.8488184	3.79	1.8	3.960	Frank	100-Year
148	11.04210964	122.8484114	0	2.5	6.250	Frank	100-Year
149	11.0450291	122.8493104	2.16	1.5	0.436	Frank	100-Year
150	11.03743079	122.8479498	2.34	1	1.796	Frank	100-Year
151	11.04432019	122.8500596	0	2.5	6.250	Frank	100-Year
152	11.03852038	122.8482325	2.14	1	1.300	Frank	100-Year
153	11.03750129	122.8525779	1.22	1.85	0.397	Yolanda	5-Year
154	11.04753283	122.8468825	1.36	1	0.130	Yolanda	5-Year
155	11.04471133	122.8486279	0	2	4.000	Frank	100-Year
156	11.03825845	122.8511062	0	1.5	2.250	Frank	100-Year
157	11.07363859	122.8568737	0.9	3	4.410	Yolanda	5-Year
158	11.0222711	122.8396608	2.16	2	0.026	Yolanda	5-Year
159	11.05099653	122.8082724	1.94	0.8636	1.159	Yolanda	5-Year
160	11.10232294	122.8832122	4.29	3	1.664	Frank	100-Year
161	11.1022126	122.8829528	2.55	3	0.203	Frank	100-Year
162	11.10258947	122.8824966	3.53	3	0.281	Frank	100-Year
163	11.10215804	122.8844578	5.25	5	0.063	Frank	100-Year
164	11.10233742	122.8832058	0	3	9.000	Frank	100-Year
165	11.04314803	122.8483813	3.72	6	5.198	Frank	100-Year
166	11.10227272	122.8832669	0	3	9.000	Frank	100-Year
167	11.10256022	122.8824728	0	3	9.000	Frank	100-Year
168	11.10252806	122.8825923	0	3	9.000	Frank	100-Year
169	11.10235567	122.8831614	0	3	9.000	Frank	100-Year
170	11.04347027	122.8489085	0	1.79	3.204	Frank	100-Year
171	11.10227889	122.8829651	0	3	9.000	Frank	100-Year
172	11.10231723	122.8830818	0	3	9.000	Frank	100-Year
173	11.10231229	122.8830329	0	3	9.000	Frank	100-Year

174	11.04424452	122.8500142	0	2.5	6.250	Frank	100-Year
175	11.04425197	122.8500237	0	2.5	6.250	Frank	100-Year
176	11.10223391	122.8831267	0	3	9.000	Frank	100-Year
177	11.10240613	122.8826536	0	3	9.000	Frank	100-Year
178	11.10227913	122.8828485	0	3	9.000	Frank	100-Year
179	11.10217976	122.8845037	4.39	5	0.372	Frank	100-Year
180	11.10225814	122.8831971	0	3	9.000	Frank	100-Year
181	11.10227519	122.8831229	0	3	9.000	Frank	100-Year
182	11.04322499	122.8485113	0	6	36.000	Frank	100-Year
183	11.10229158	122.883464	0	3	9.000	Frank	100-Year
184	11.04415929	122.8499427	0	1.321	1.745	Yolanda	5-Year
185	11.10228047	122.8833766	0	3	9.000	Frank	100-Year
186	11.04392608	122.8496648	0	1.321	1.745	Yolanda	5-Year
187	11.10239404	122.8827561	0	3	9.000	Frank	100-Year
188	11.09716802	122.8756844	0.03	2	3.881	Frank	100-Year
189	11.10000999	122.8759651	8.98	2	48.720	Frank	100-Year
190	11.07392109	122.8584378	0.95	3	4.203	Yolanda	5-Year

Annex 12. Educational Institutions Affected by flooding in Barotac Floodplain

Table A-12.1 Educational Institutions Affected in Barotac Floodplain

Iloilo				
Anilao				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Barangay Dugwakan Daycare Center	Dangula-An	Low	Low	Low
Dugwakan Primary School	Dangula-An			
Dugwakan Primary School Stage	Dangula-An			
Banate				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Barangay Belen Daycare Center	Belen	Low	Medium	Medium
Serafin Madrid Elementary School	Fuentes*			
Serafin Madrid Elementary School Stage	Fuentes*			
Banate Central School	Poblacion			
Talokgangan Elementary School	Talokgangan	Low	Low	Low
Barotac Viejo				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Barangay Bugnay Day Care Center	Bugnay		Low	Low
California Day Care Center	California			
California Primary School	California			
La Fortuna Day Care Center	La Fortuna		Low	Low
La Fortuna Elem. School	La Fortuna			
Lipata Day Care Center	Lipata			
Lipata Elementary School	Lipata			
St. Paul School	Natividad			
Nueva Invencion Barangay Day Care Center	Nueva Invencion	Medium	High	High
Nueva Invencion Elementary School	Nueva Invencion			
Nueva Sevilla Barangay Day Care Center	Nueva Sevilla	Low	Low	Medium
Nueva Sevilla Elementary School	Nueva Sevilla	Medium	Medium	Medium
Btac. Viejo National High School	Poblacion			
Raul O.V. Causing Memorial School	Poblacion			
Raul OV. Causing Memorial School	Poblacion			
Rizal Day Care Center	Rizal			

Rizal Elementary School	Rizal			
San Geronimo Church	San Geronimo			
San Geronimo Day Care Center	San Geronimo			
San Geronimo Primary School	San Geronimo			
Barangay San Juan Daycare Center	San Juan	Medium	Medium	Medium
San Juan Elementary School	San Juan	Low	Low	Medium
San Juan Elementary School Stage	San Juan	Low	Low	Medium
San Lucas Day Care Center	San Lucas	Medium	Medium	Medium
San Lucas Elementary School	San Lucas			
San Miguel Day Care Center	San Miguel			
San Miguel Elementary School	San Miguel			
Santo Domingo Elementary School	Santo Domingo			
Barangay Santo Tomas Daycare Center	Santo Tomas			
Santo Tomas Elementary School	Santo Tomas			
SitioTarog Barangay Santo Tomas Daycare Center	Santo Tomas			
Barangay Vista Alegre Daycare Center	Vista Alegre			
Vista Alegre Elementary School	Vista Alegre			

Annex 13. Health Institutions affected by flooding in Barotac Floodplain

Table A-13.1 Medical Institutions Affected in Barotac Flood Plain

Iloilo				
Banate				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Banate Health Center	Dangula-An			Low
Barotac Viejo				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Barangay Bugnay Health Center	Bugnay			
California Health Center	California			Low
La Fortuna Health Center	La Fortuna			
Lipata Health Center	Lipata			
Nueva Invencion Barangay Health Center	Nueva Invencion	Medium	High	High
Nueva Sevilla Barangay Health Center	Nueva Sevilla	Low	Medium	Medium
Barotac Viejo Health Center	Poblacion			
Don Ramon Tugbang Medical Center, Inc.	Poblacion			
Municipal Health Center	Poblacion			
Rizal Barangay Health Center	Rizal			
Rizal Old Barangay Health Center	Rizal			
San Geronimo Health Center	San Geronimo			
Barangay San Juan Health Station	San Juan			
Barotac Viejo District Hospital	San Lucas	High	High	High
San Lucas Barangay Health Center	San Lucas			
San Miguel Barangay Health Center	San Miguel			
Barangay Santo Tomas Health Center	Santo Tomas			
Barangay Vista Alegre Health Center	Vista Alegre			

Annex 14. UPC Phil-LiDAR 1 Team Composition

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