HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Babuyan River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Los Baños

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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
UPLB	University of the Philippines Los Baños
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 BABUYAN RIVER

Enrico C. Paringit, Dr. Eng., Asst. Prof. Edwin R. Abucay, and Dr. Cristino L. Tiburan, Jr.

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Los Baños (UPLB). UPLB is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the forty-five (45) river basins in the Southern Luzon region. The university is located in Los Baños in the province of Laguna.

1.2 Overview of the Babuyan River Basin

The Babuyan River Basin is a 27,211-hectare watershed located in Puerto Princesa City, Palawan. It is situated in the northern east portion of the province of Palawan. It covers the barangays of Babuyan, Binduyan, Buenavista, Cabayugan, Langogan, Lucbuan, Macarascas, Maoyon, Marufinas, Maruyogon, New Panggangan, San Rafael, Tagabinit, and Tanabag of Puerto Princesa City. It has an approximate catchment area of 2539.82 square kilometers with an estimated run-off of 168 MCM.

With regards to geology, the basin area has four geological classifications including Basement Complex (Pre-Jurassic), Cretaceous-Paleogene, Oligocene-Miocene, and Undifferentiated (Sedimentary & Metamorphic Rocks). The river basin is generally characterized by moderate to steep slope and elevation more than 300 meters above mean sea level. Babuyan silty clay loam and Tapul clay loam soils can be found in the area. Unclassified soils (rough mountainous land) dominate the area along with hydrosols. Babuyan river basin is predominantly covered with closed forest (broadleaved) followed by open forest (broadleaved) and other wooded land typically composed of shrubs.

Climate Type I and III prevails in the Babuyan River Basin, as well as the larger area of MIMAROPA and Laguna based on the Modified Corona Classification of climate. Type I has two pronounced seasons, dry from November to April, and wet the rest of the year with maximum rain period from June to September. On the other hand, Type III has no very pronounced maximum rain period and with short dry season lasting only from one to three months, during the period from December to February or from March to May.

Babuyan River is the main tributary of Babuyan River Basin. It has an approximate length of 20.68 km and drains towards Honda Bay. The Babuyan river passes through several barangays in Puerto Princesa City including Babuyan, Lucbuan, Maoyon, Marufinas, San Rafael, Tagabinit, and Tanabag. River cruise via a pumpboat in the Babuyan River is among the featured travel itineraries in the city which is a community-based tourism project that aims to support the locals. There is a total of 161, 912 persons residing within the immediate vicinity of the river, with Babuyan being the most-populated barangay in the river basin area, according to the survey conducted by NSO in 2010.

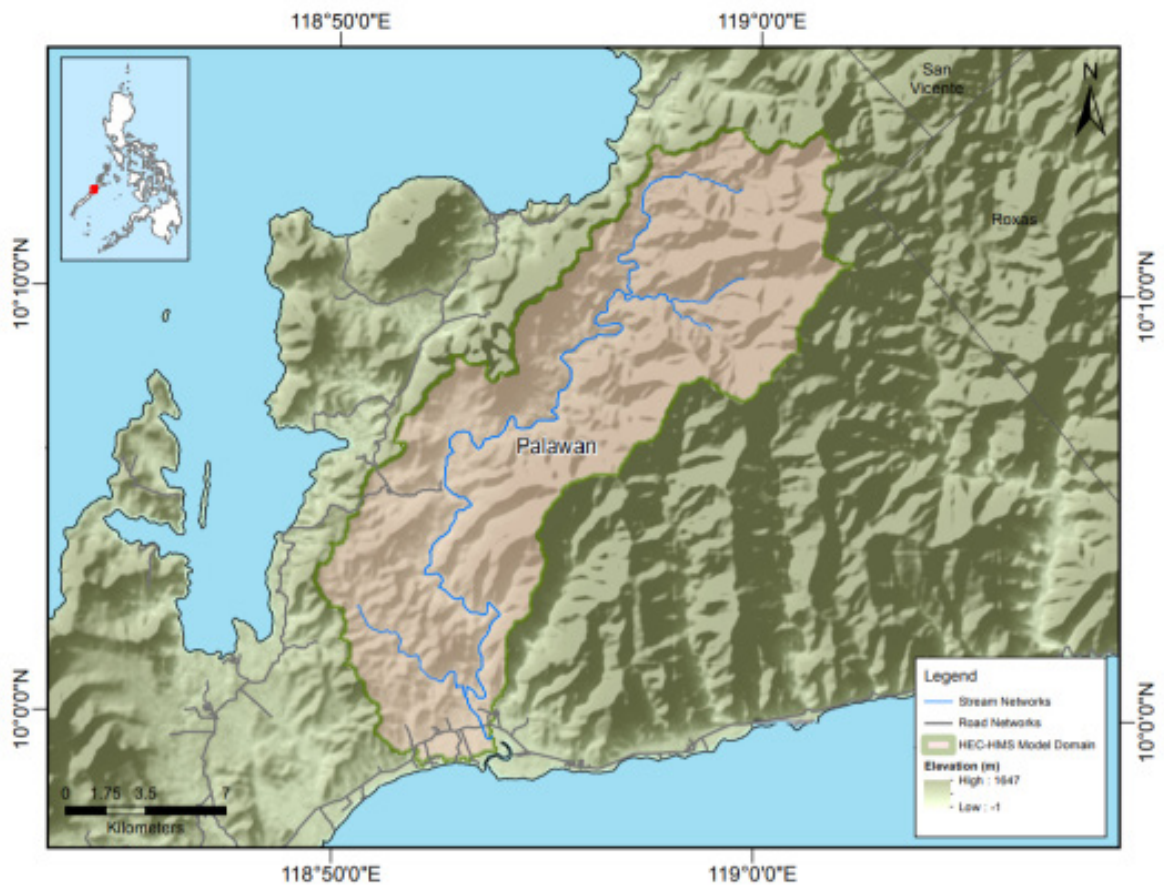

Figure 1. Map of Babuyan River Basin (in brown)

Based on the studies conducted by the Mines and Geosciences Bureau, in terms of flood susceptibility, barangay Babuyan, Lucbuan, and Maoyon have low to high susceptibility. The rest of the barangays do not have problem on flooding. During the field surveys conducted by the PhiL-LiDAR 1 validation team, several notable weather disturbances were found to have caused flooding in 1994 (Norming), 1995 (Pepang), 2007 (Lando), 2013 (Yolanda), 2014 (Ruby), 2015 (Lando), and 2016 (Lawin). The most intensive flooding happened during the flash floods that occurred near the riverside on November 02 – 03, 2013 when Typhoon Yolanda (with international name "Haiyan") hit most of Palawan with intermittent rainfall. For landslides, about 50% of the barangays in the river basin have moderate to high susceptibility.

CHAPTER 2: LIDAR ACQUISITION IN BABUYAN FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Babuyan floodplain in Palawan. These missions were planned for nine (9) 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 are found in Table 1 and Table 2. Figure 2 shows the flight plans and base stations for Babuyan floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK 42A	1000	30	50	200	30	130	5
BLK 42B	1000	30	50	200	30	130	5
BLK 42C	1000	30	50	200	30	130	5
BLK 42D	1000	30	50	200	30	130	5
BLK42E	1000	30	50	200	30	130	5
BLK 42F	1000	30	50	200	30	130	5
BLK 42AA	1200	30	40	150	30	130	5

Table 2. Flight planning parameters for Gemini LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK 42A	600	30	40/48	167/100	50	130	5
BLK 42eA	600/1100	30	40	167	50	130	5
BLK 42eD	1000	30	40	100	50	130	5
BLK 42eE	1000	30	40	100	50	130	5
BLK 42eF	1000	30	40	100	50	130	5
BLK 42 islands	1000/1100	30	40/48	100	50	130	5

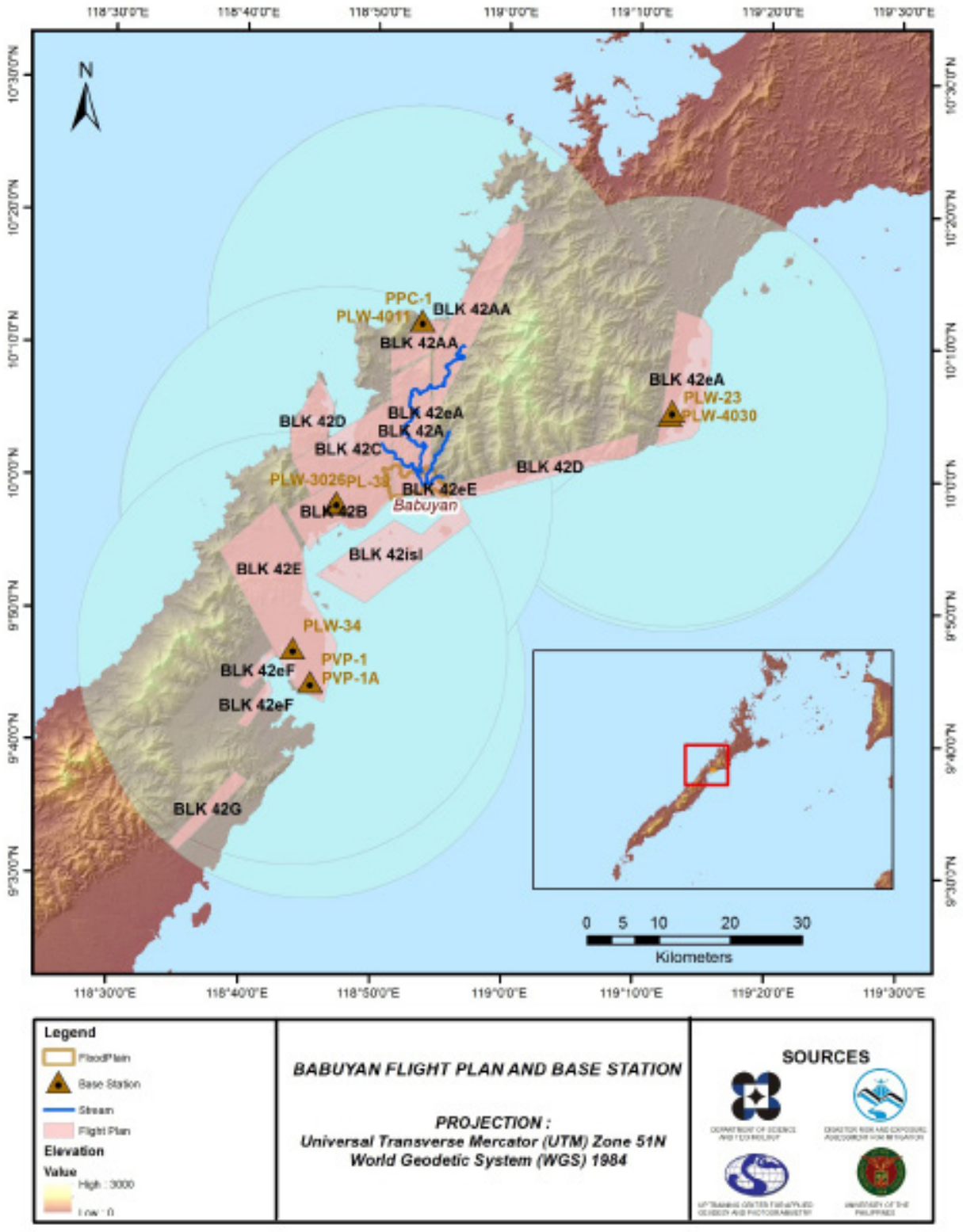

Figure 2. Flight plans and base stations used for Babuyan Floodplain

2.2 Ground Base Station

The project team was able to recover two (2) NAMRIA horizontal ground control points: PLW-23 and PLW-34 which are both of first order accuracy. The project team also re-processed ground control points: PLW-3026, PLW-4011, PLW-4030, PPC-1 and PVP-1A; and established one (1) ground control point: PVP-1A. One (1) NAMRIA benchmark was recovered, PL-38 which is of 1st order accuracy. This benchmark was used as vertical reference point and was also established as ground control points. The certification for the NAMRIA reference points and benchmarks are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (June 6-20, 2015 and November 15-20, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Babuyan floodplain are shown in Figure 2. The list of team members are shown in Annex 4.

Figure 3 to Figure 8 show the recovered NAMRIA reference points within the area. Table 3 to Table 11 show the details about the following NAMRIA control stations and established points, while Table 12 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

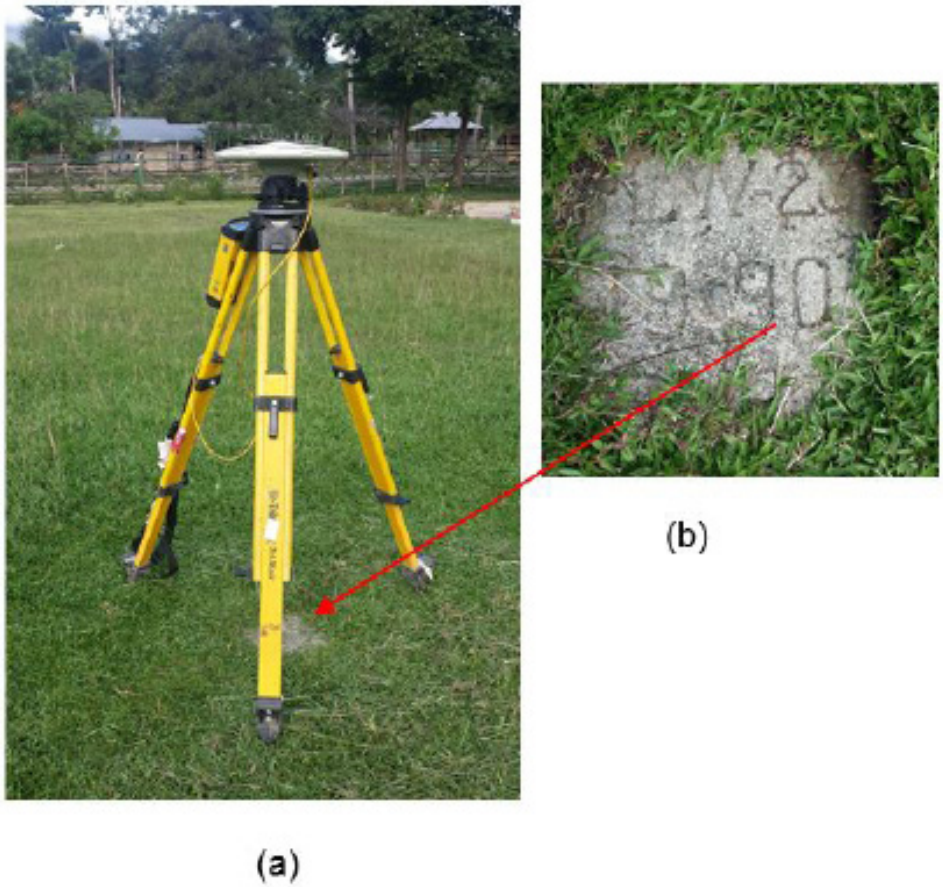

Figure 3. GPS set-up over PLW-23 as recovered at Jolo Elementary School, Puerto Princesa City (a) and NAMRIA reference point PLW-23 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point PLW-23 used as base station for the LiDAR Acquisition.

Station Name	**PLW-23**	
Order of Accuracy	**1st**	
Relative Error (horizontal positioning)	**1:100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10°5'19.52517" North 119°12'33.72062" East 10.427 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	577752.254 meters 1115630.596 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 5'15.04804" North 119° 12' 39.01413" East 61.07260 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	742130.31 meters 1115973.89 meters

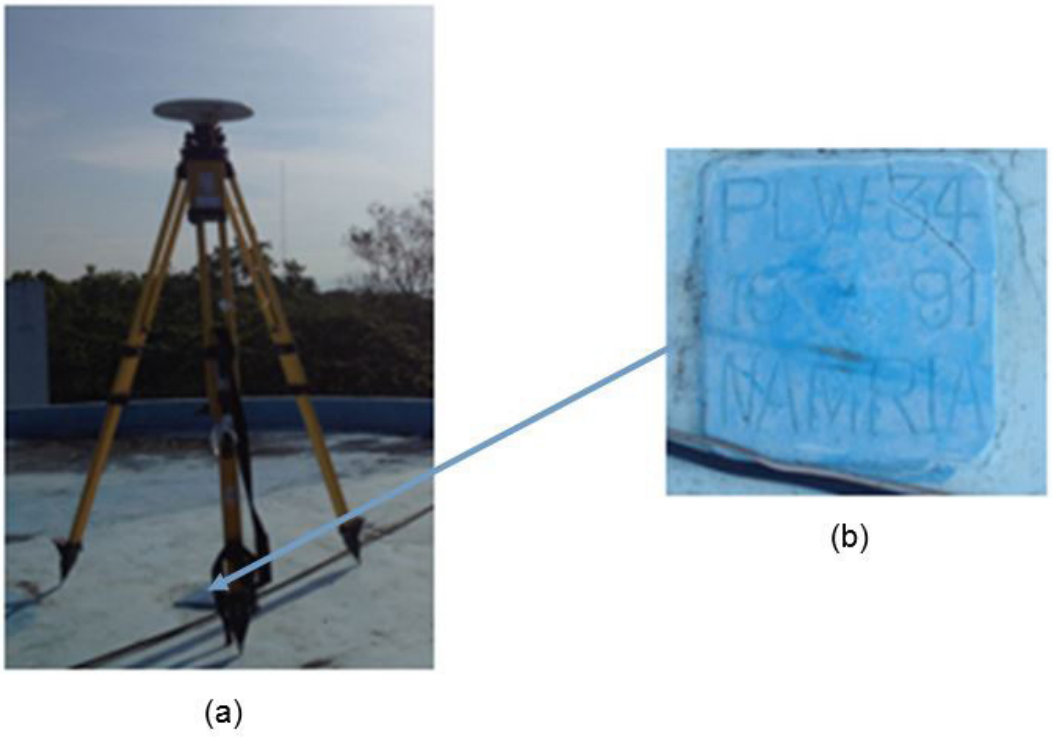

Figure 4. a) GPS set-up over PLW-34 located at the roof deck of the old city hall of Puerto Princesa, Brgy. Sta. Monica, Puerto Princesa City. b) NAMRIA reference point PLW-34 as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point PLW-34 used as base station for the LiDAR acquisition.

Station Name	**PLW-34**	
Order of Accuracy	**1st**	
Relative Error (horizontal positioning)	**1:100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°47'4.34346" North 118°43'50.36738" East 53.76200 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	525304.737 m 1081910.004 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 46'59.90069" North 118° 43' 55.68915" East 103.89600 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	689825.58 m 1082009.99 m

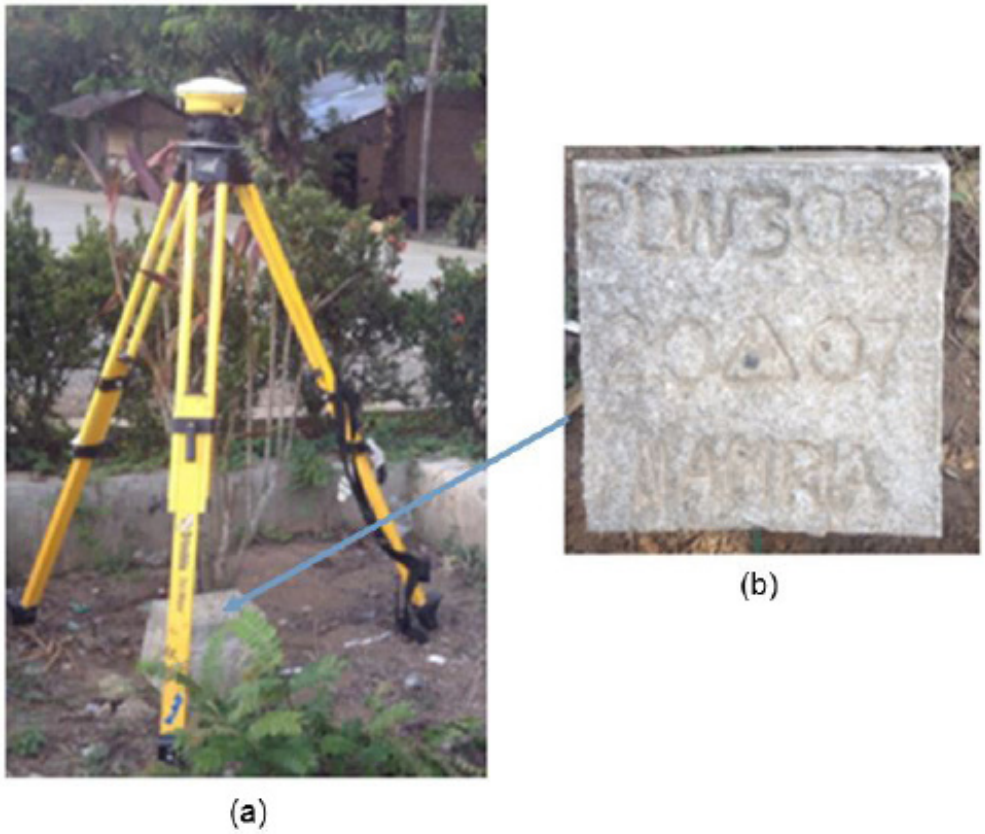

Figure 5. a) GPS set-up over PLW-3026 located at northeast corner of the center island in Salvacion junction, Brgy. Salvacion, Puerto Princesa City. b) NAMRIA reference point PLW-3026 as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point PLW-3026 used as base station for the LiDAR acquisition.

Station Name	**PLW-3026**	
Order of Accuracy	**1st order**	
Relative Error (horizontal positioning)	**1:100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°58'03.41442" North 118°47'09.05751" East 57.363 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°58'07.89863" North 118°47'03.75221" East 7.504 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	695610.418 m 1102427.869 m

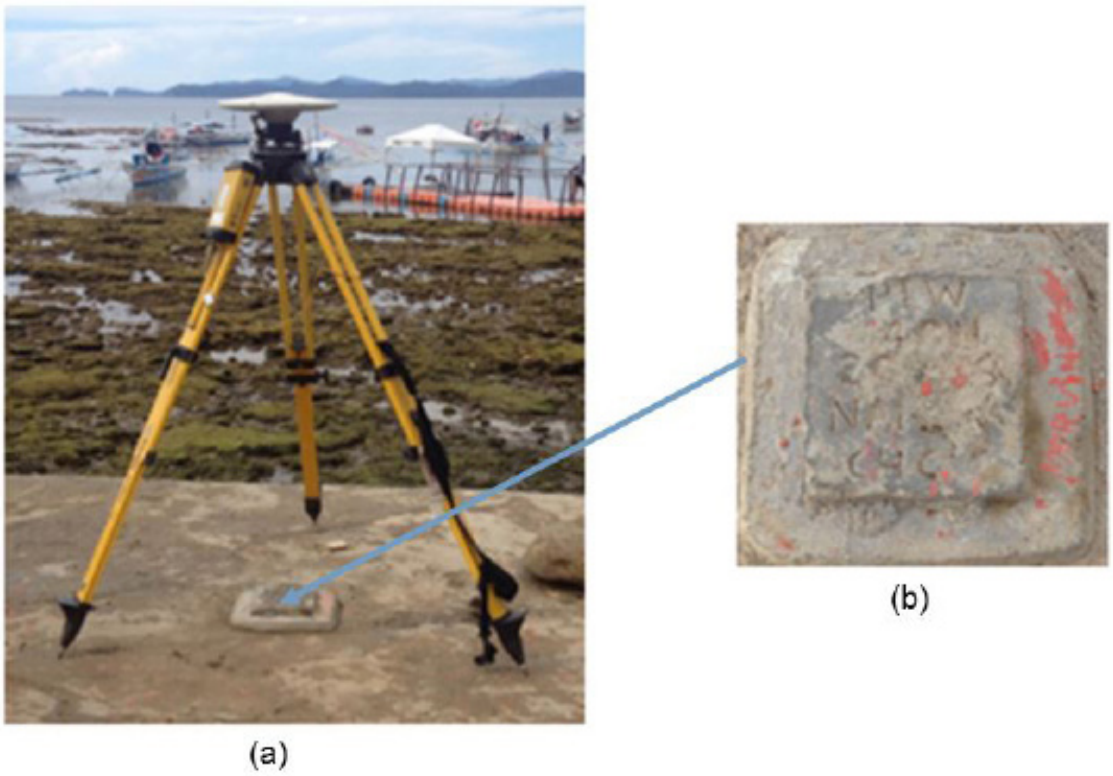

Figure 6. a) GPS set-up over PLW-4011 located infront of A. Susan's Store in Sabang Wharf, Sitio Sabang, Brgy. Cabacungan, Puerto Princesa City. b) NAMRIA reference point PLW-4011 as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point PLW-4011 used as base station for the LiDAR acquisition.

Station Name	**PLW-4011**	
Order of Accuracy	**1st order**	
Relative Error (horizontal positioning)	**1:100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°58'03.41442" North 118°47'09.05751" East 57.363 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°58'07.89863" North 118°47'03.75221" East 7.504 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	695610.418 m 1102427.869 m

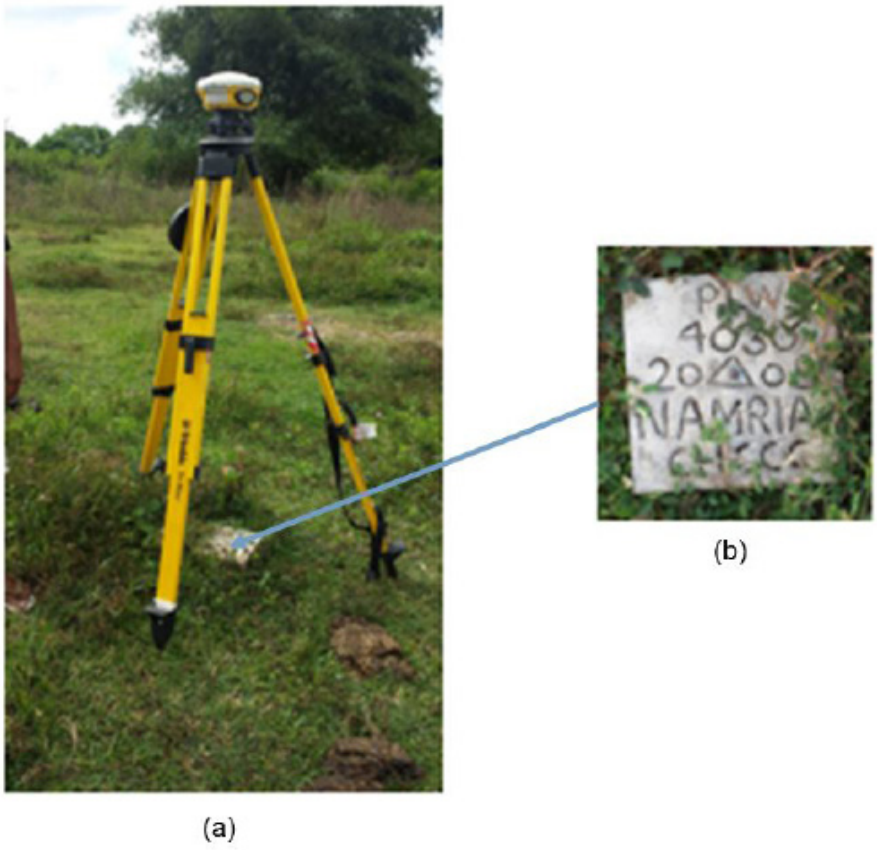

Figure 7. a) GPS set-up over PLW-4030 located beside Jolo Bridge, Roxas, Palawan. b) NAMRIA reference point PLW-4030 as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point PLW-4030 used as base station for the LiDAR acquisition.

Station Name	**PLW-4030**	
Order of Accuracy	**1st order**	
Relative Error (horizontal positioning)	**1:100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10°04'56.95146"North 119°12'22.75168" East 11.183 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10°04'52.47562" North 119°12'28.04576" East 61.835 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	84042.662 m 1116875.986 m

Table 8. Details of the recovered NAMRIA horizontal control point PLW-4030 used as base station for the LiDAR acquisition.

Station Name	PL-38	
Order of Accuracy	1st order	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°57'59.62464" North 118°46'56.29975" East 7.756 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°57'55.14081" North 118°47'01.60525" East 57.615 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	695384.782 m 1102172.433 m

Table 9. Details of the recovered NAMRIA horizontal control point PLW-4030 used as base station for the LiDAR acquisition.

Station Name	PPC-1	
Order of Accuracy	1st order	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10°11'54.83823" North 118°53'26.98215" East 4.002 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10°11'50.30596" North 118°53'32.26682" East 53.609 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	707137.228 m 1127901.415 m

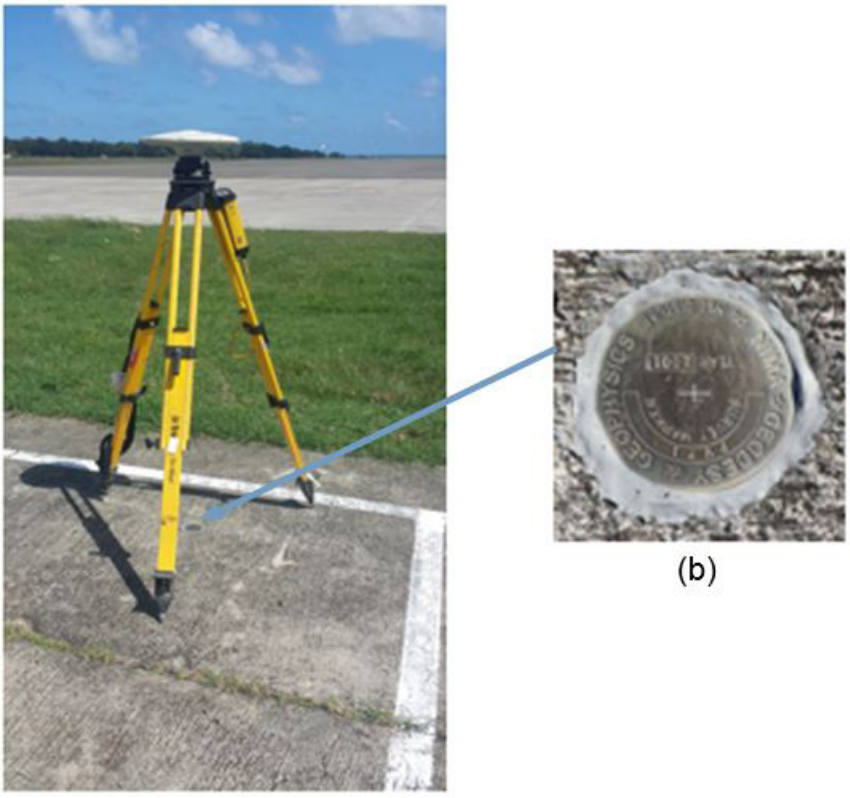

Figure 8. GPS set-up over PVP-1 located on the ground beside Puerto Princesa Airport Fire Station. b) NAMRIA reference point PVP-1 as recovered by the field team.

Table 10. Details of the recovered NAMRIA horizontal control point PVP-1 used as base station for the LiDAR acquisition.

Station Name	**PVP-1**	
Order of Accuracy	**1st order**	
Relative Error (horizontal positioning)	**1:100,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°44'31.66247" North 118°45'13.60677" East 17.172 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°44'27.23233" North 118°45'18.93228" East 61.835 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	33860.371 m 1079760.689 m

Table 11. Details of the recovered NAMRIA horizontal control point PVP-1A used as base station for the LiDAR acquisition.

Station Name	PVP-1A	
Order of Accuracy	1st order	
Relative Error (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°44'32.50133" North 118°45'13.64985" East 17.110 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°44'28.07113" North 118°45'18.97534" East 67.394 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	33862.011 m 1079786.501 m

Table 12. Ground control points used during LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
June 6, 2015	3017P	1BLK42A157A	PLW-34 and PLW-3026
June 7, 2015	3021P	1BLK42BD158A	PLW-34 and PLW-3026
June 7, 2015	3023P	1BLK42BCAL158B	PLW-34 and PLW-3026
June 12, 2015	3041P	1BLK42B163A	PLW-3026 and PL-38
June 13, 2015	3045P	1BLK42BS164A	PLW-4011 and PPC-1
June 13, 2015	3047P	1BLK42Aa164B	PLW-4011 and PPC-1
June 20, 2015	3073P	1BLK42S171A	PLW-3026 and PLW-4011
November 15, 2015	3493G	2BLK42EF319A	PVP-1 and PVP-1A
November 16, 2015	3497G	2BLK42Disl320A	PVP-1 and PVP-1A
November 16, 2015	3499G	2BLK42isl320B	PLW-23 and PLW-4030
November 18, 2015	3505G	2BLK42AEs322A	PLW-23 and PLW-4030
November 18, 2015	3507G	2BLK42islAs322B	PLW-23 and PLW-4030
November 20, 2015	3513G	2BLK42islAs324A	PLW-23 and PLW-4030

2.3 Flight Missions

Thirteen (13) missions were conducted to complete LiDAR data acquisition in Babuyan Floodplain, for a total of thirty nine hours and thirty one minutes (39+31) of flying time for RP-C9122 and RP-C9022. All missions were acquired using Pegasus and Gemini LiDAR systems. Table 13 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 14 presents the actual parameters used during the LiDAR data acquisition.

Table 13. Flight missions for LiDAR data acquisition in Babuyan Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
June 6, 2015	3017P	100.65	178.62	18.84	159.78	792	4	23
June 7, 2015	3021P	139.4	114.91	1.79	113.12	384	2	27
June 7, 2015	3023P	313.41	140.67	6.66	134.01	600	3	49
June 12, 2015	3041P	81.86	115.6	0	115.6	254	2	1
June 13, 2015	3045P	100.11	124.01	1.81	122.2	229	2	27
June 13, 2015	3047P	102.35	185.83	0	185.83	857	3	30
June 20, 2015	3073P	139.4	60.08	0	60.08	173	1	54
November 15, 2015	3493G	29.38	71.47	8.04	63.43	NA	3	45
November 16, 2015	3497G	180.25	97.19	1.03	96.16	NA	2	20
November 16, 2015	3499G	111.35	57.45	0.68	56.77	NA	2	10
November 18, 2015	3505G	106.89	99.41	3.92	95.49	NA	3	35
November 18, 2015	3507G	208.08	86.97	0	86.97	NA	3	0
November 20, 2015	3513G	208.08	59.16	0	59.16	NA	4	10
TOTAL		**1821.21**	**1391.37**	**42.77**	**1348.6**	**3289**	**39**	**31**

Table 14. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
3017P	1000	30	50	200	30	140	5
3021P	1000	30	50	200	30	140	5
3023P	1000	30	50	200	30	140	5
3041P	1000	30	50	200	30	140	5
3045P	1000	30	50	200	30	140	5
3047P	1200	30	40	150	30	140	5
3073P	1000	30	50	200	30	140	5
3493G	1000	30	40	100	50	130	5
3497G	1000	30	40	100	50	130	5
3499G	1000	30	40	100	50	130	5
3505G	600	30	40	167	50	130	5
3507G	1100	30	24	100	50	130	5
3513G	1100	30	24	100	50	130	5

2.4 Survey Coverage

Babuyan floodplain is located in the city of Puerto Princesa, Palawan. The survey covered mostly the city of Puerto Princesa, and municipalities of Roxas and San Vicente. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 15. The actual coverage of the LiDAR acquisition for Babuyan Floodplain is presented in Figure 9.

Table 15. List of municipalities and cities surveyed during Babuyan Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Palawan	Puerto Princesa City	2186.36	646.76	29.58%
	Roxas	1007.30	59.47	5.90%
	San Vicente	870.45	7.21	0.83%
TOTAL		4064.11	713.44	17.55%

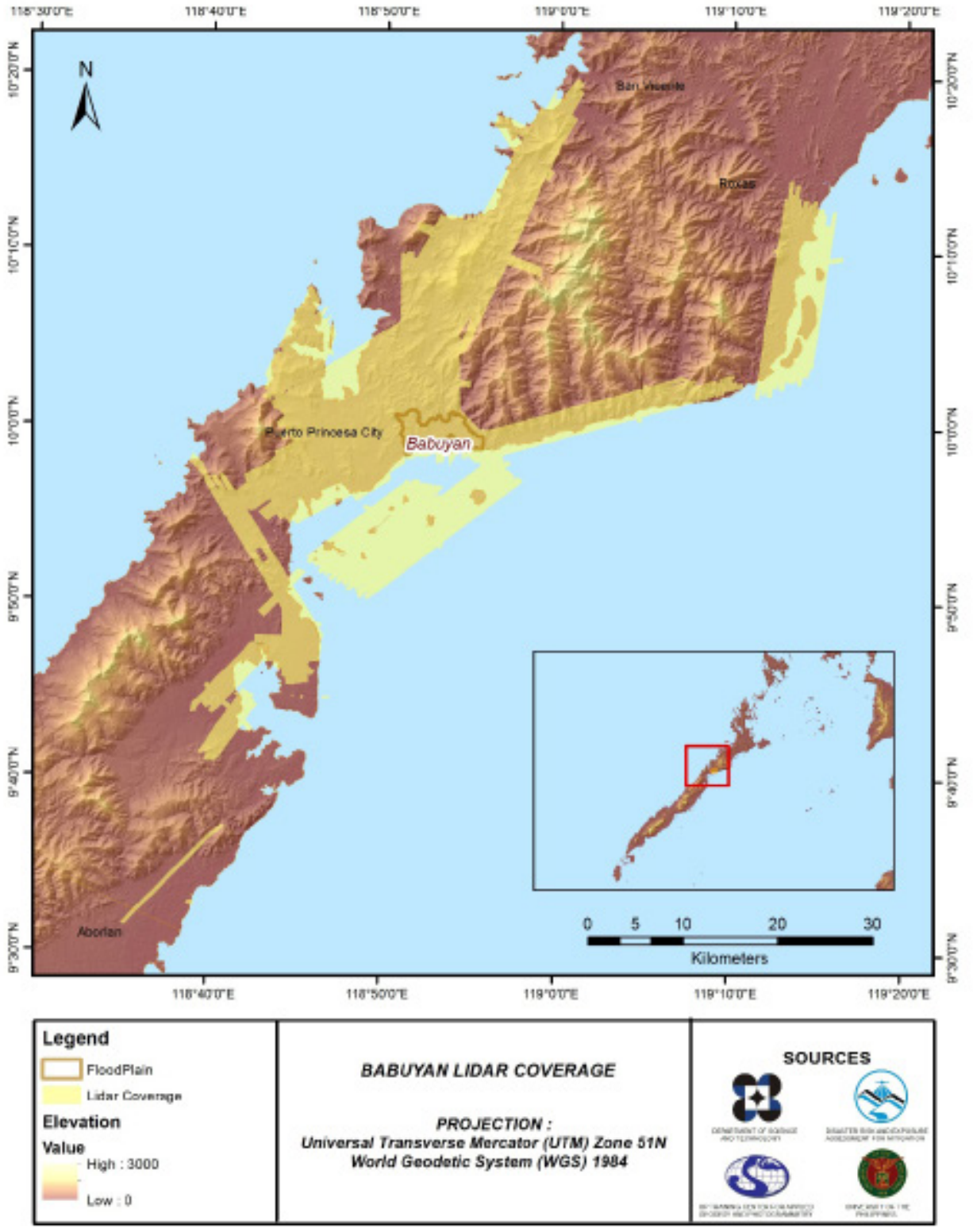

Figure 9. Actual LiDAR data acquisition for Babuyan Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR BABUYAN 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 LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 10.

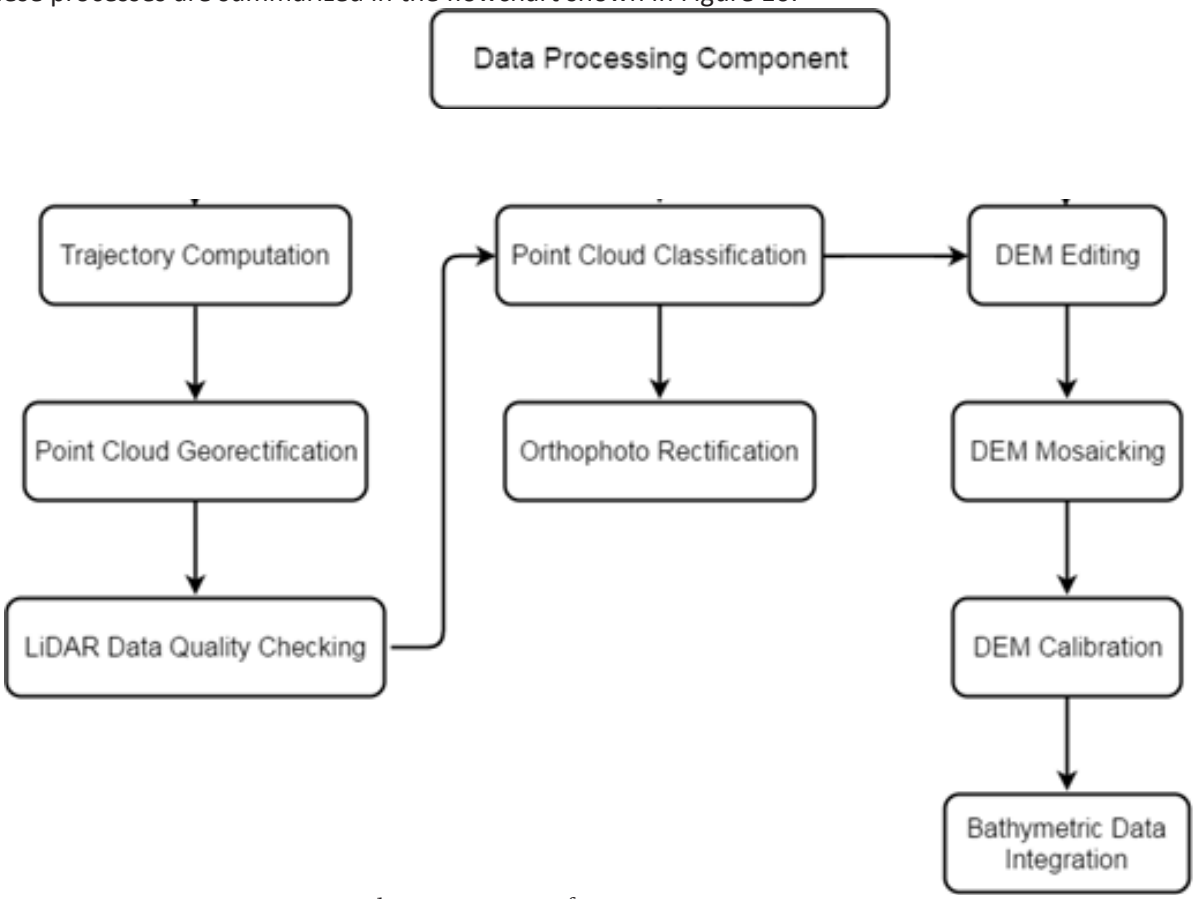

Figure 10. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Babuyan floodplain can be found in Annex 5. Missions flown during the first survey conducted on June 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions acquired during the second survey on November 2015 were flown using the Gemini system over Puerto Princesa City, Palawan.

The Data Acquisition Component (DAC) transferred a total of 176.4 Gigabytes of Range data, 2.36 Gigabytes of POS data, 95.67 Megabytes of GPS base station data, and 200.18 Gigabytes of raw image data to the data server on June 23, 2015 for the first survey and December 8, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Babuyan was fully transferred on January 4, 2016, as indicated on the Data Transfer Sheets for Babuyan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3041P, one of the Babuyan flights, which is the North, East, and Down position RMSE values are shown in Figure 11. 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 June 12, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

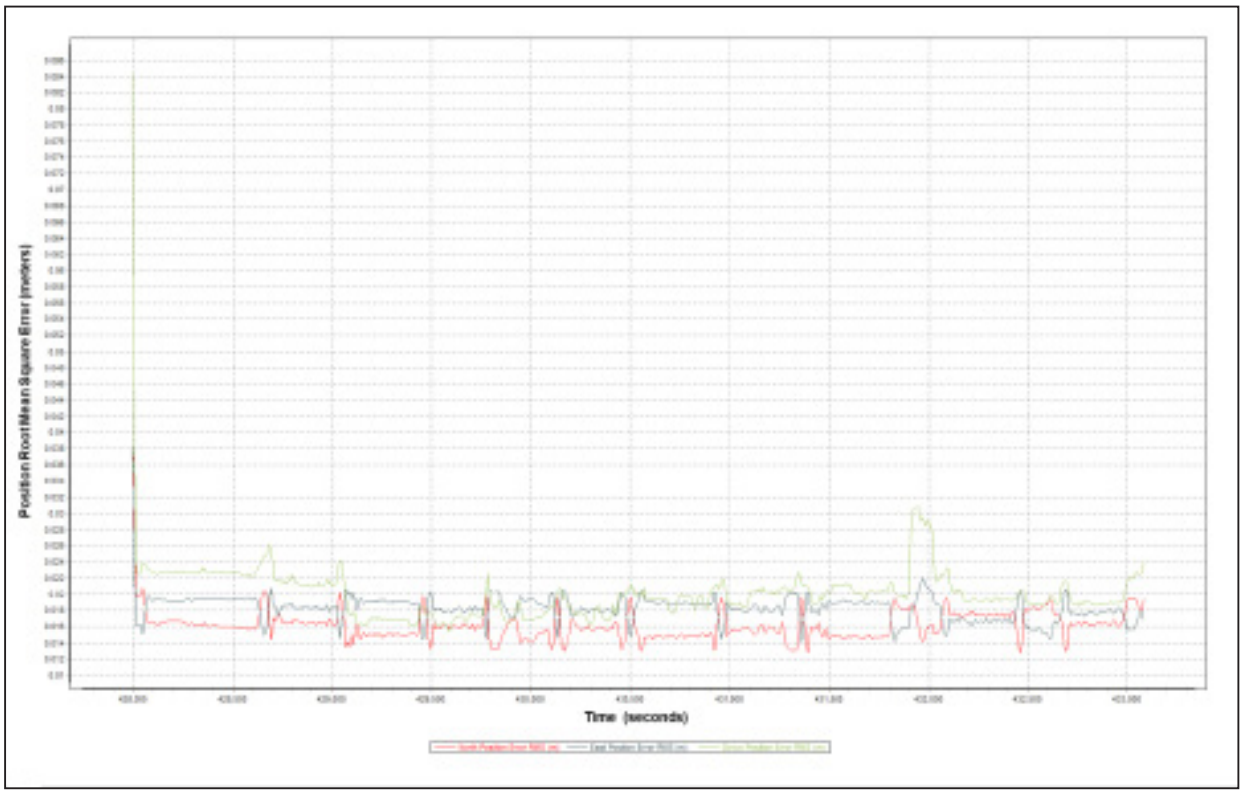

Figure 11. Smoothed Performance Metrics of Babuyan Flight 3041P.

The time of flight was from 428000 seconds to 433000 seconds, which corresponds to morning of June 12, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 11 shows that the North position RMSE peaks at 2.20 centimeters, the East position RMSE peaks at 2.20 centimeters, and the Down position RMSE peaks at 3.20 centimeters, which are within the prescribed accuracies described in the methodology.

Figure 12. Solution Status Parameters of Babuyan Flight 3041P.

The Solution Status parameters of flight 3041P, one of the Babuyan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Babuyan flights is shown in Figure 13.

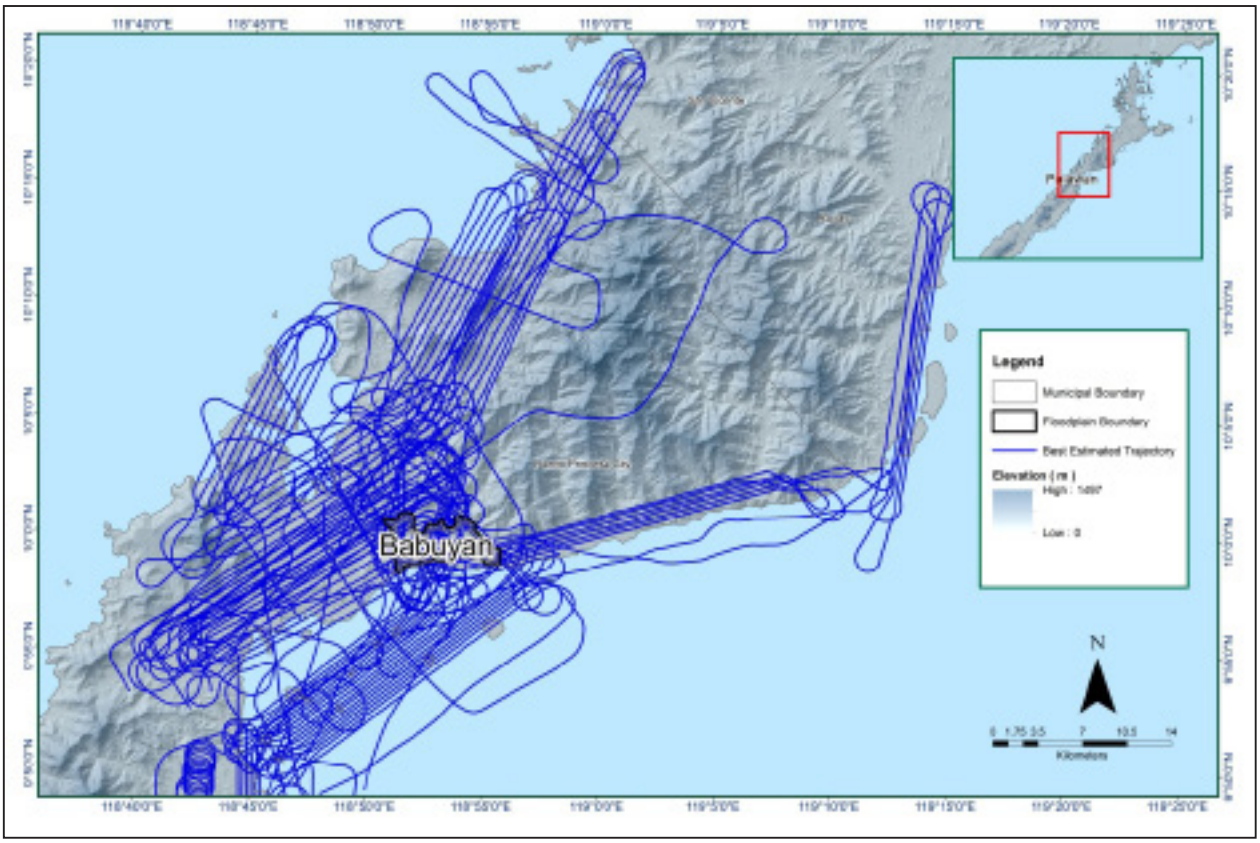

Figure 13. Best Estimated Trajectory for Babuyan Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 247 flight lines, with each flight line containing two channels, since the Pegasus system contains two one channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Babuyan floodplain are given in Table 16.

Table 16. Self-Calibration Results values for Babuyan flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev	(<0.001degrees)	0.000211
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000517
GPS Position Z-correction stdev	(<0.01meters)	0.0022

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Babuyan Floodplain is shown in Figure 14. Boundary of the processed LiDAR data over Caramay Floodplain. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

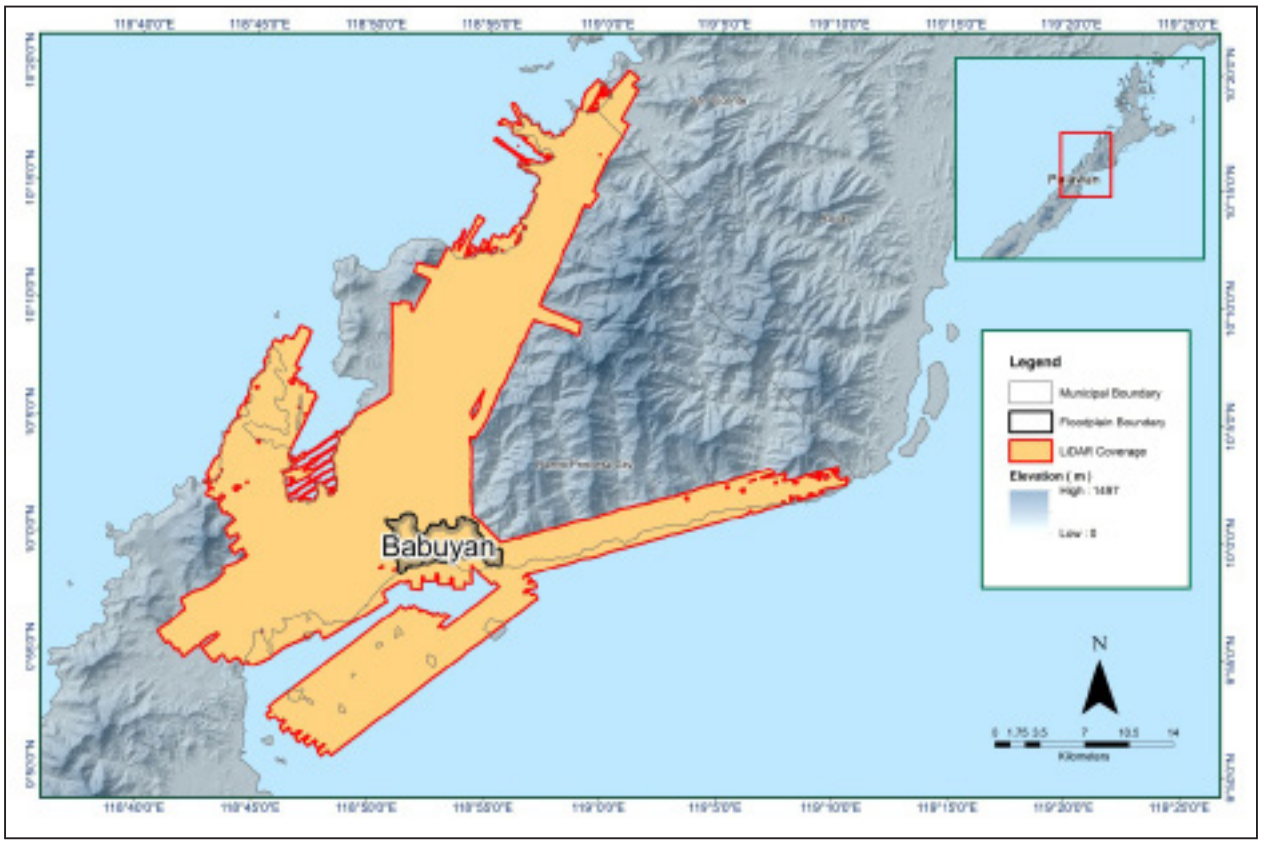

Figure 14. Boundary of the processed LiDAR data over Babuyan Floodplain

The total area covered by the Babuyan missions is 988.25 sq.km that is comprised of seven (7) flight acquisitions grouped and merged into eleven (11) blocks as shown in Table 17.

Table 17. List of LiDAR blocks for Babuyan Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Palawan_Blk42A	3017P	122.52
Palawan_Blk42A_additional	3047P	192.74
Palawan_Blk42B	3021P	142.16
	3023P	
Palawan_Blk42B_additional	3073P	53.32
Palawan_Blk42B_supplement	3045P	115.88
Palawan_Blk42C	3041P	95.86
Palawan_Blk42D	3021P	56.16
Palawan_Reflight_Blk42eD	3497G	74.20
Palawan_Reflight_Blk42eE	3493G	18.47
Palawan_Reflight_eE_additional	3505G	12.20
Palawan_Reflights_Blk42isI	3497G	104.74
	3499G	
	3507G	
	3513G	
TOTAL		988.25 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 15. Since the Gemini system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus system which employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

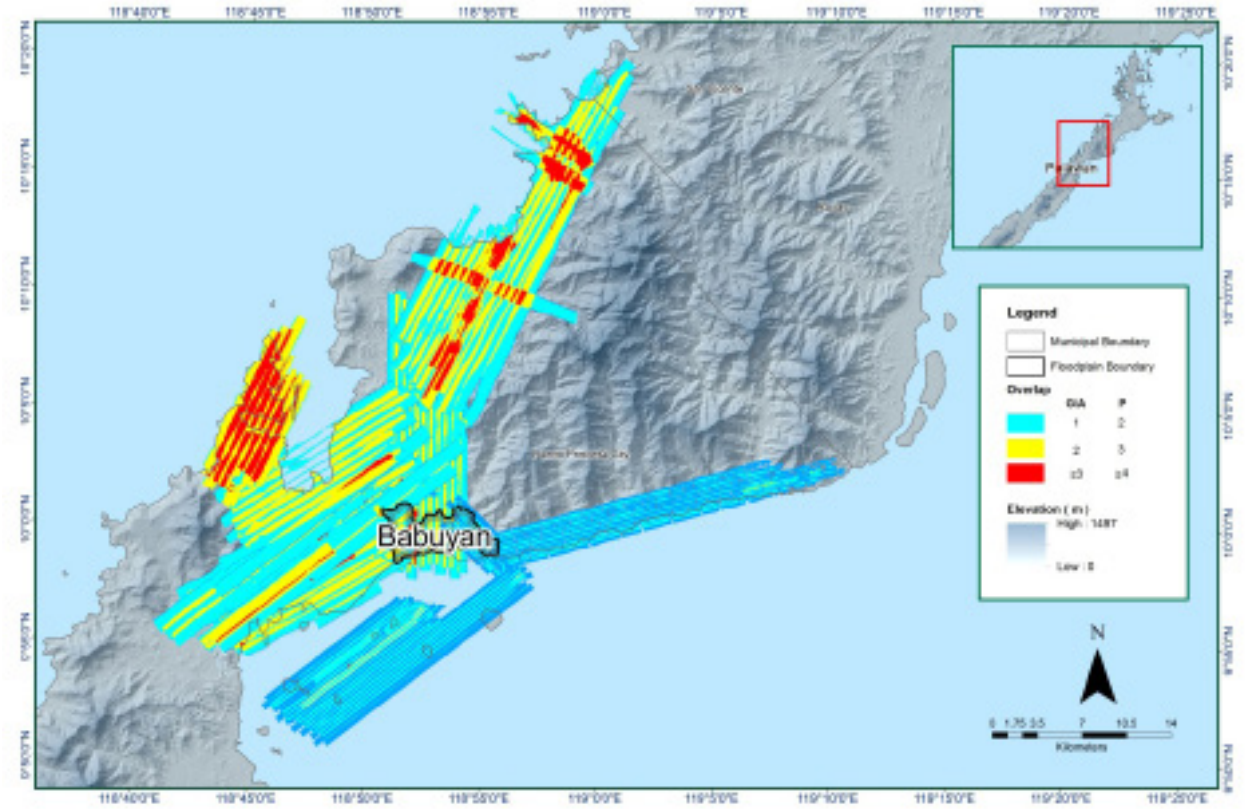

Figure 15. Image of data overlap for Babuyan Floodplain.

The overlap statistics per block for the Babuyan floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 27.46% and 96.78% 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 16. It was determined that all LiDAR data for Babuyan floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.59 points per square meter.

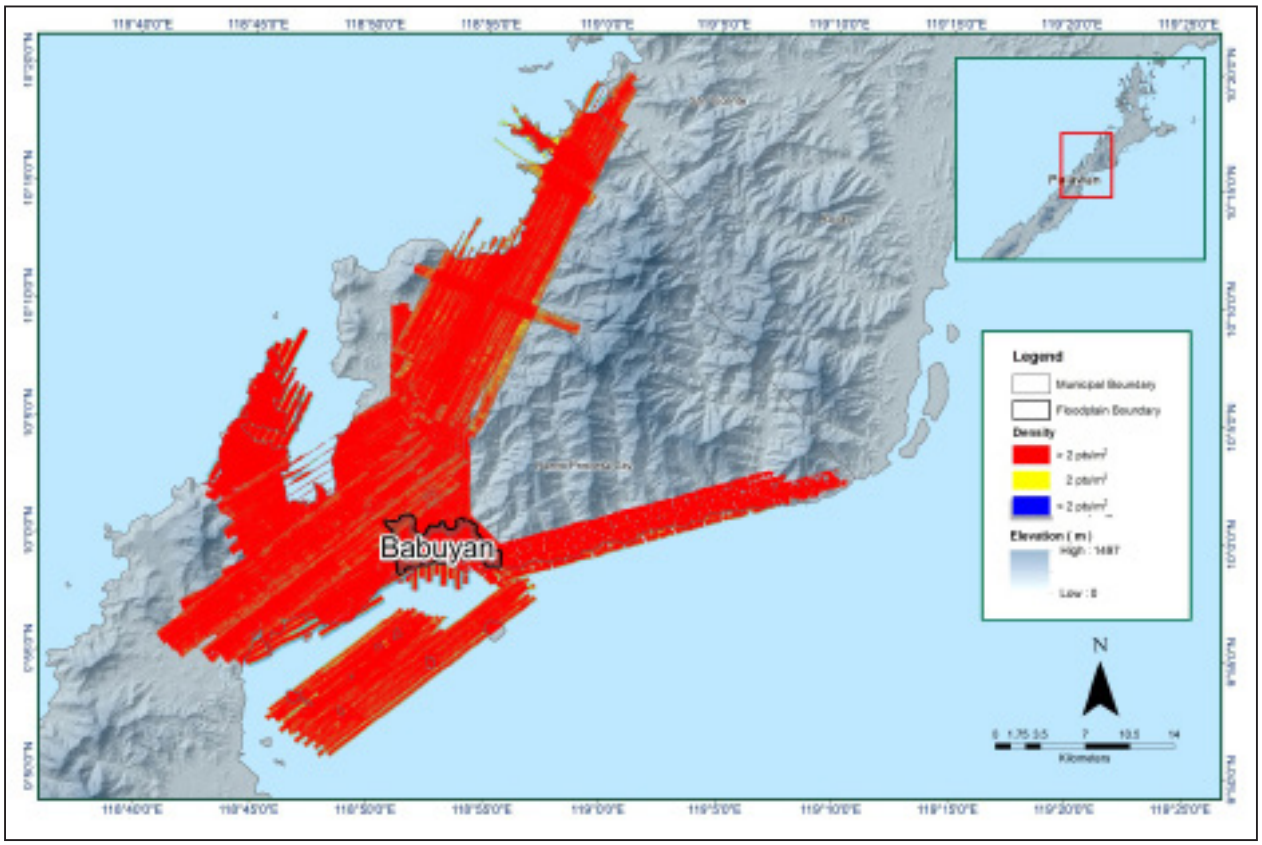

Figure 16. Pulse density map of merged LiDAR data for Babuyan Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. 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.

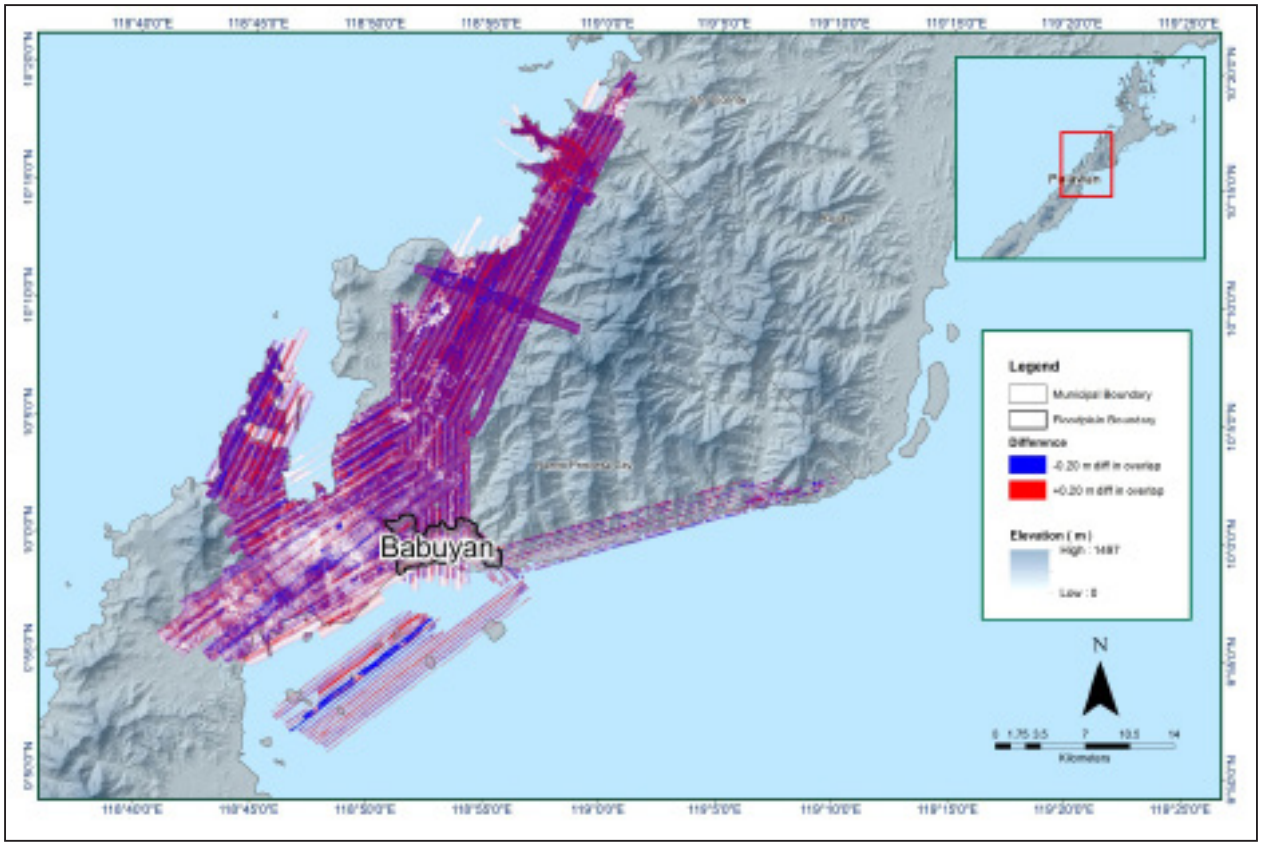

Figure 17. Elevation difference map between flight lines for Babuyan Floodplain.

A screen capture of the processed LAS data from a Babuyan flight 3041P loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

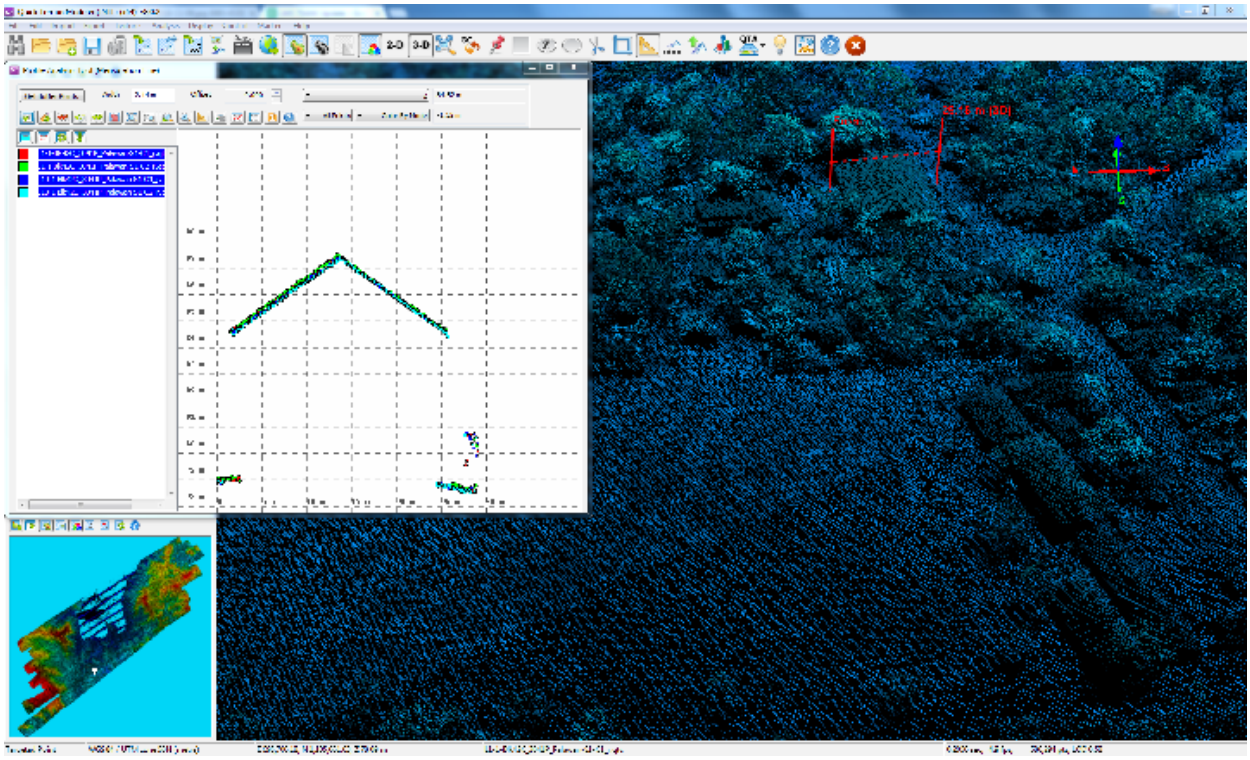

Figure 18. Quality checking for Babuyan flight 3041P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 18. Babuyan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	626,410,073
Low Vegetation	427,891,099
Medium Vegetation	1,147,542,691
High Vegetation	4,729,839,982
Building	41,663,775

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Babuyan floodplain is shown in Figure 19. A total of 1,450 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 18. The point cloud has a maximum and minimum height of 691.88 meters and 42.45 meters.

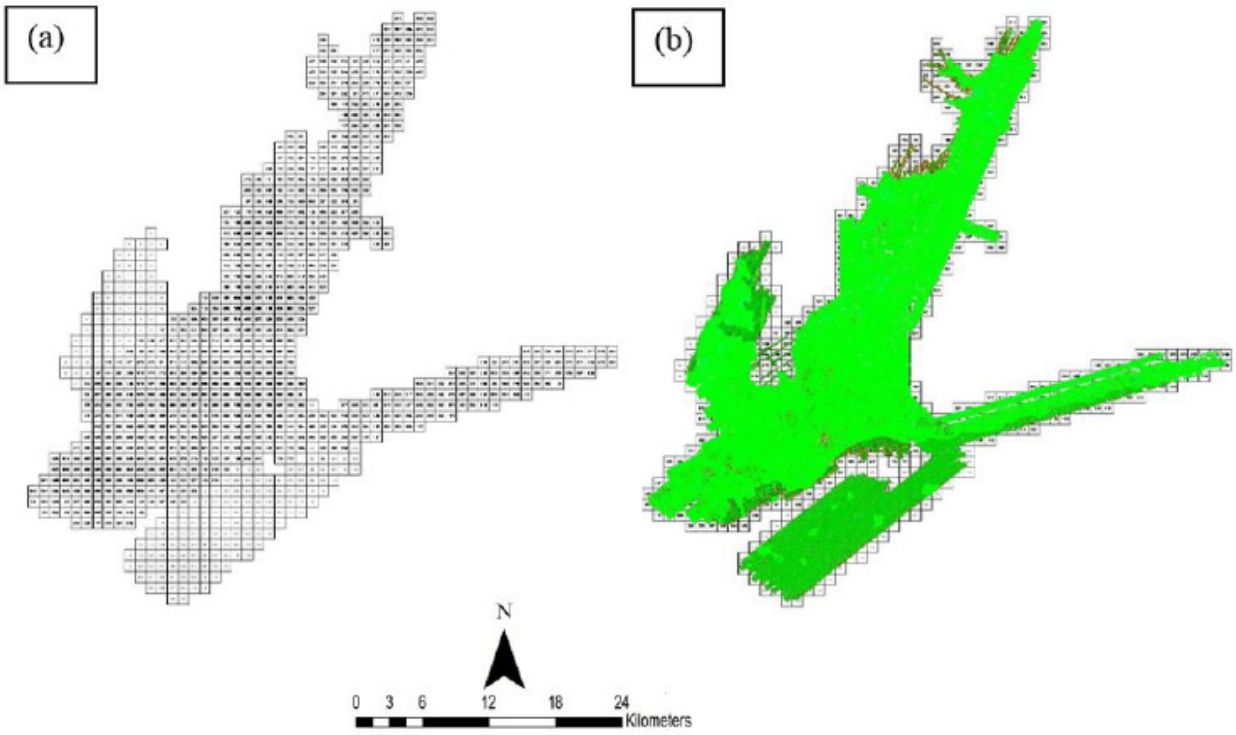

Figure 19. Tiles for Babuyan Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 20. 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.

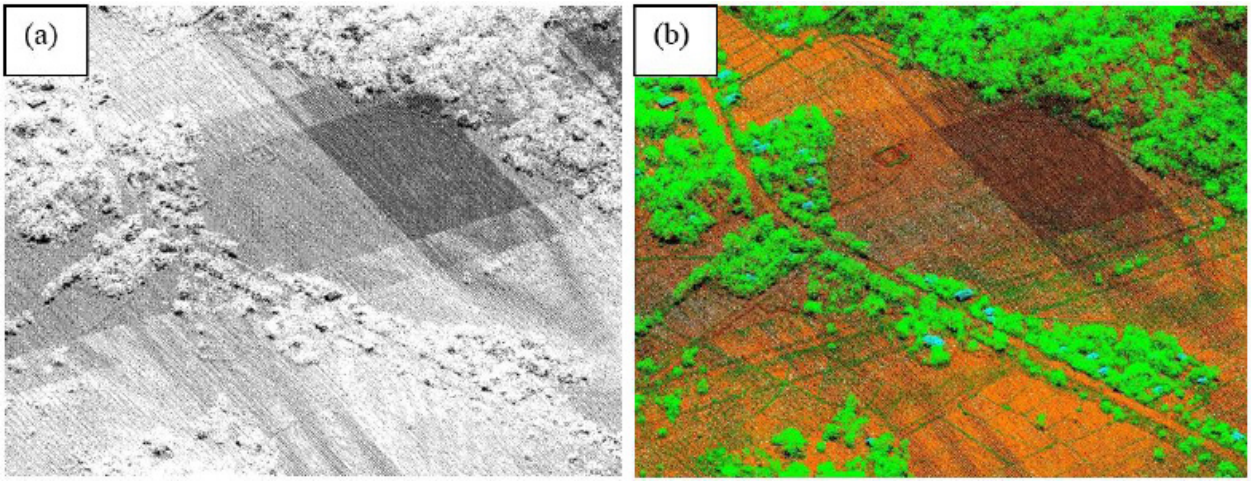

Figure 20. Point cloud before (a) and after (b) classification.

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

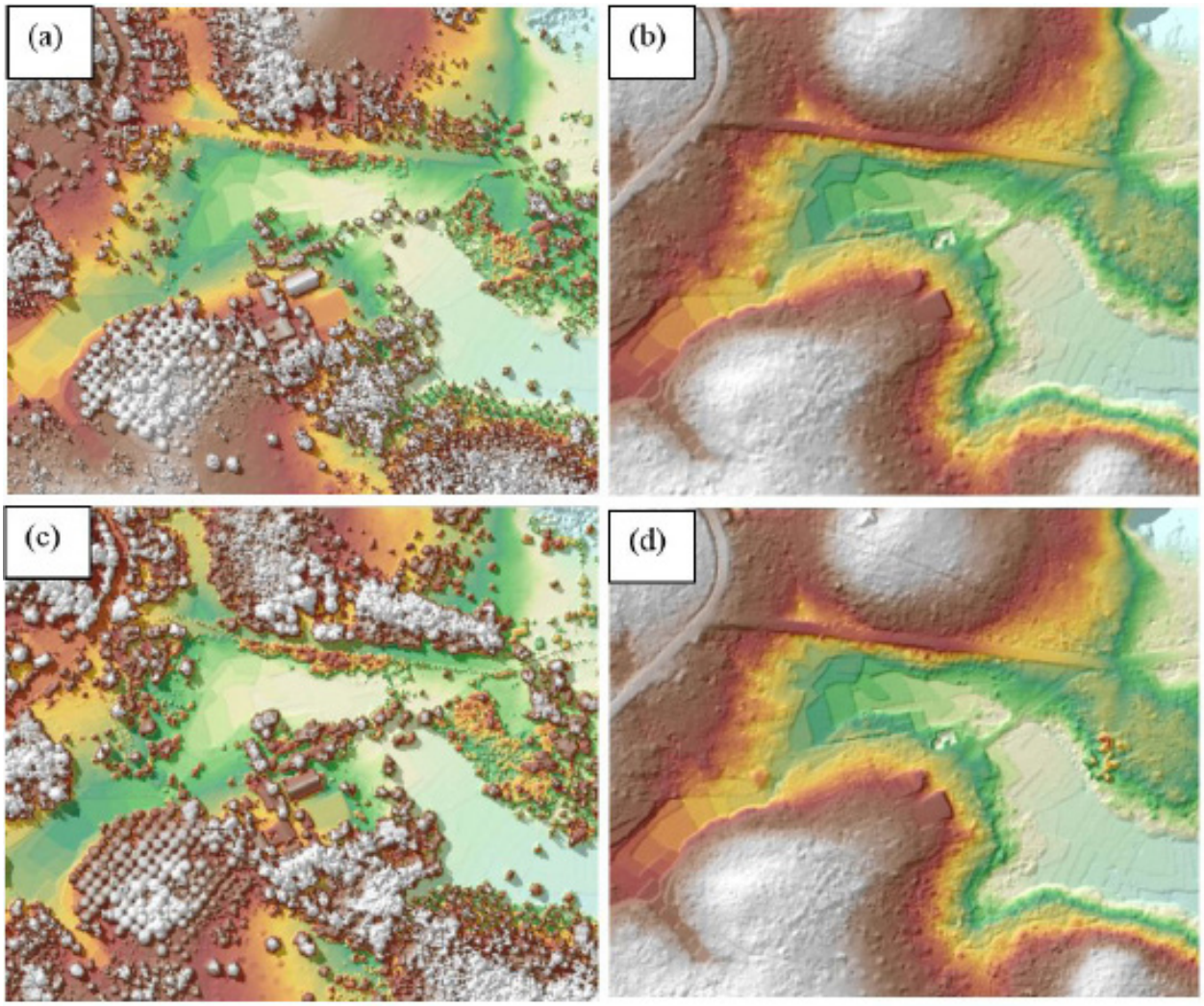

Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Babuyan floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,147 1km by 1km tiles area covered by Babuyan floodplain is shown in Figure 22. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Babuyan floodplain has a total of 569.59 sq.km orthophotogaph coverage comprised of 2,106 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

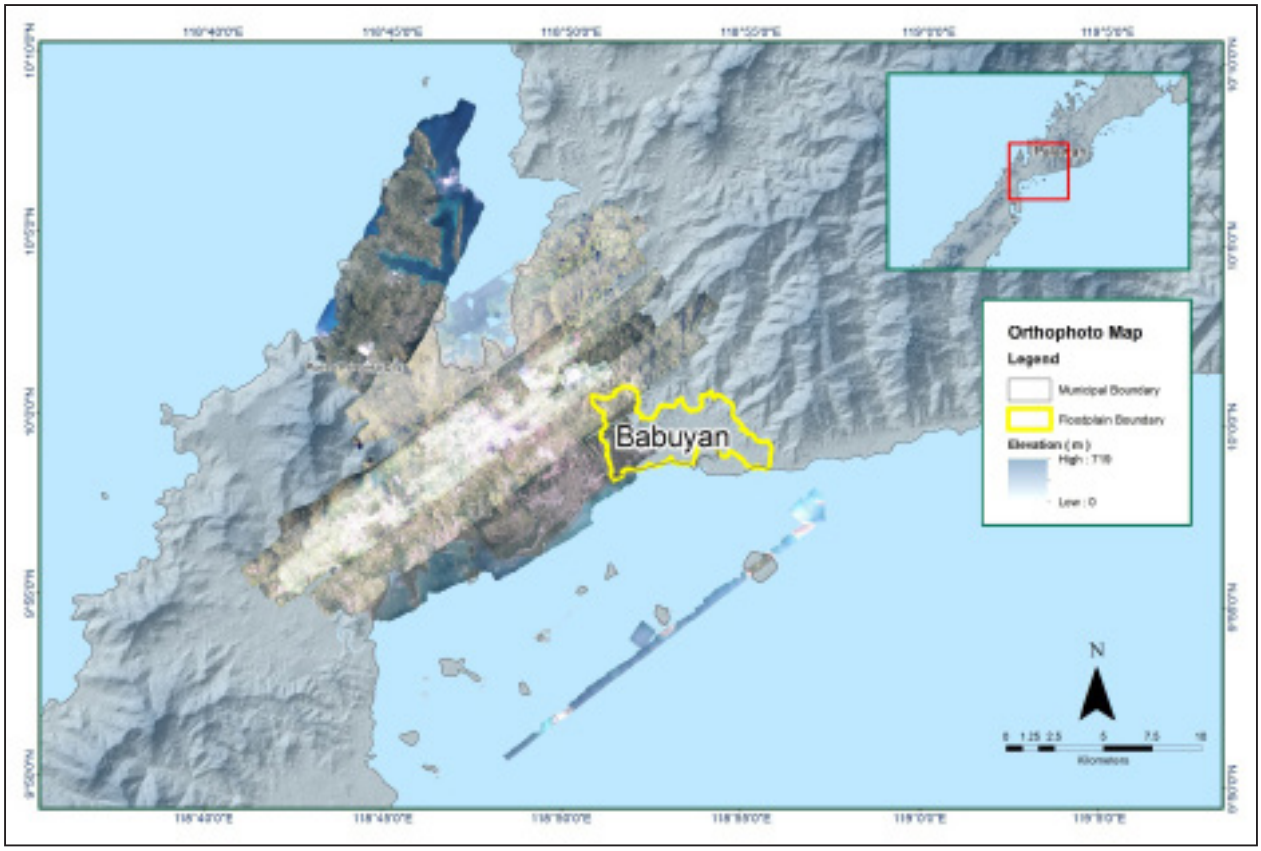

Figure 22. Babuyan floodplain with available orthophotographs

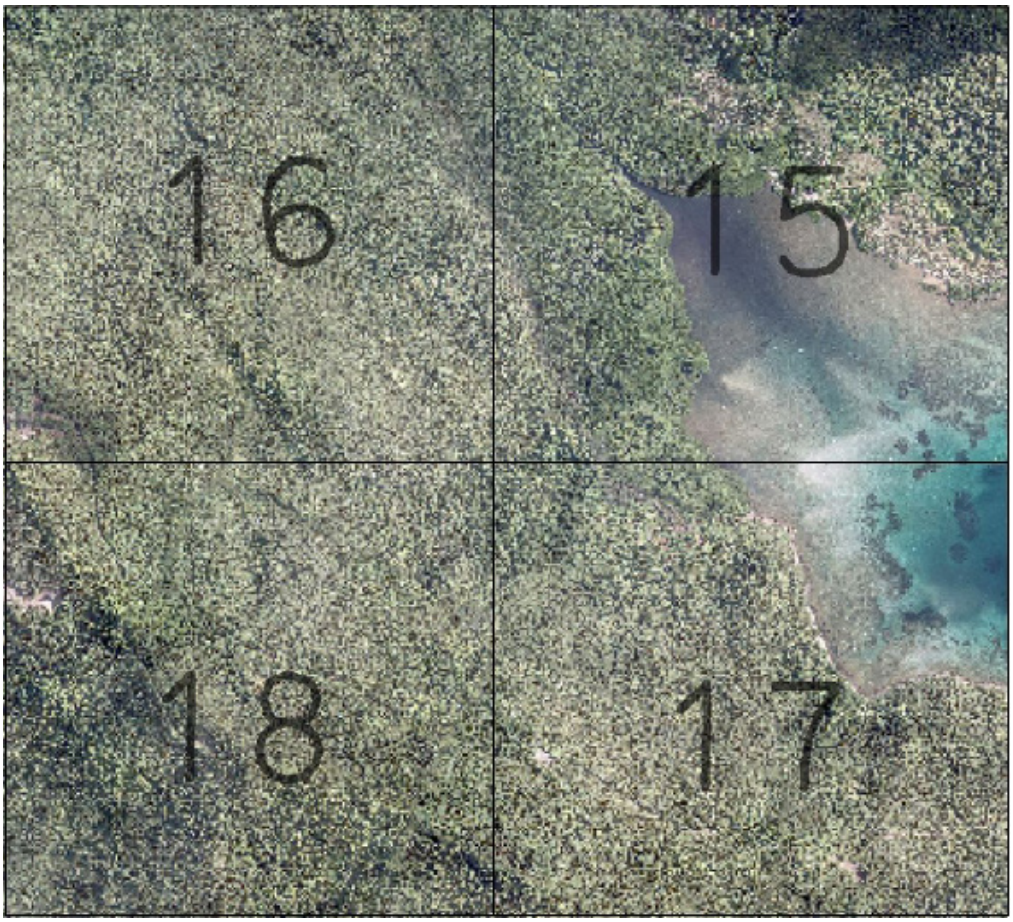

Figure 23. Sample orthophotograph tiles for Babuyan Floodplain

3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for Babuyan flood plain. These blocks are composed of Palawan and Palawan_Reflight blocks with a total area of 988.25 square kilometers. Table 19 shows the name and corresponding area of each block in square kilometers.

Table 19. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Palawan_Blk42A	122.52
Palawan_Blk42A_additional	192.74
Palawan_Blk42B	142.16
Palawan_Blk42B_additional	53.32
Palawan_Blk42B_supplement	115.88
Palawan_Blk42C	95.86
Palawan_Blk42D	56.16
Palawan_Reflight_Blk42eD	74.20
Palawan_Reflight_Blk42eE	18.47
Palawan_Reflight_eE_additional	12.20
Palawan_Reflights_Blk42isl	104.74
TOTAL	988.25 sq. km

Portions of DTM before and after manual editing are shown in Figure 24. The bridge in Figure 24a would be an impedance to the flow of water along the river and was removed in order to hydrologically correct the river, as done in Figure 24b. Another portion of the DTM presented in Figure 24c shows the part of the river which needed to be filled in order to allow the correct flow of water which resulted to the output in Figure 24d.

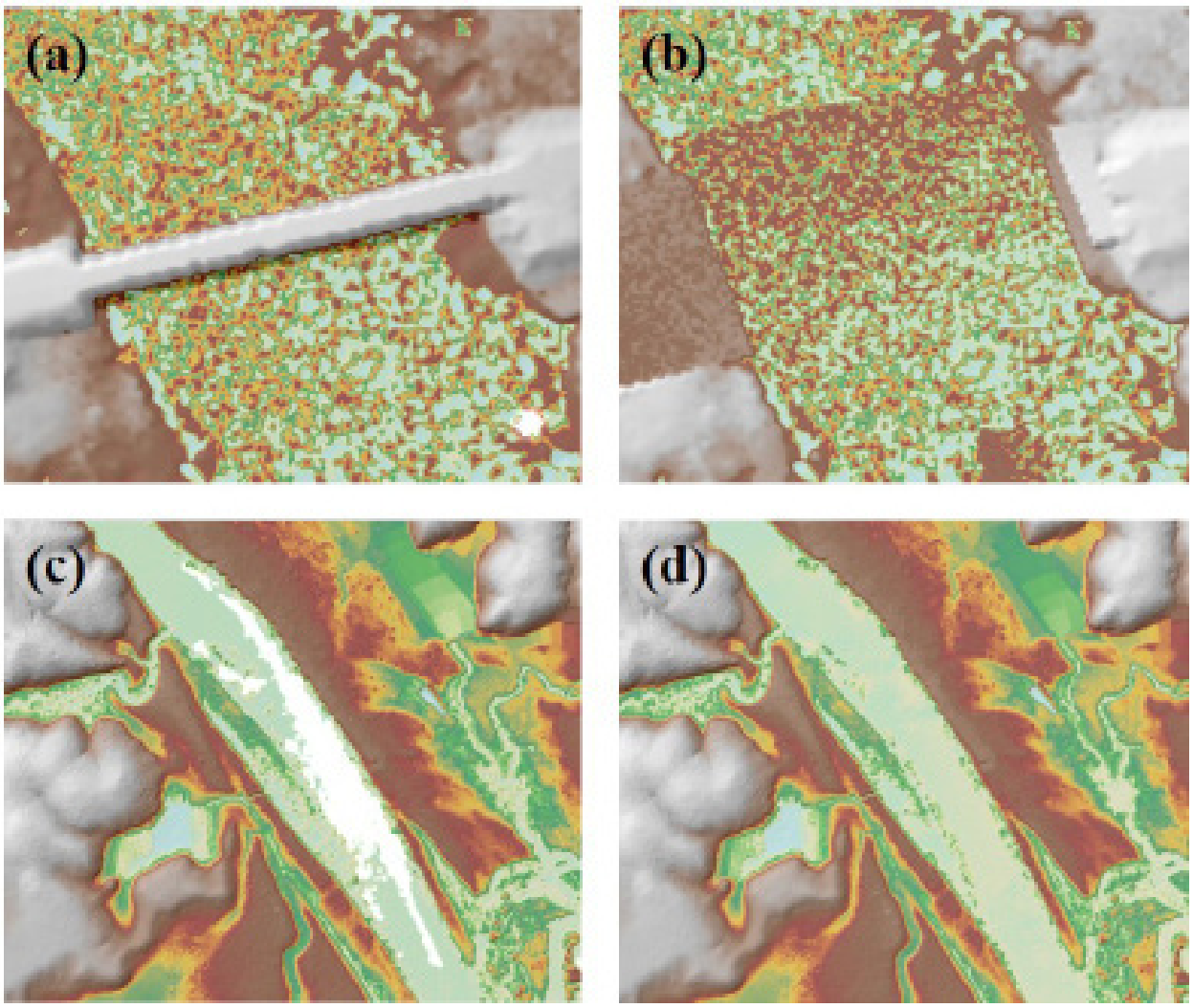

Figure 24. Portions in the DTM of Babuyan Floodplain – a bridge before (a) and and after (b) interpolation process and part of the river with data gap before (c) and after (d) filling data gap.

3.9 Mosaicking of Blocks

Palawan_Blk42A was used as the reference block at the start of mosaicking because it was one of the first data available for mosaicking. Upon inspection of the blocks mosaicked for the Babuyan floodplain, it was concluded that there is no need to adjust the elevation of the DTM for all of the blocks merged. Table 20 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Babuyan floodplain is shown in Figure 25. It can be seen that the entire Babuyan floodplain is 100% covered by LiDAR data.

Table 20. Shift Values of each LiDAR Block of Babuyan Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Palawan_Blk42A	0.00	0.00	0.00
Palawan_Blk42A_additional	0.00	0.00	0.00
Palawan_Blk42B	0.00	0.00	0.00
Palawan_Blk42B_additional	0.00	0.00	0.00
Palawan_Blk42B_supplement	0.00	0.00	0.00
Palawan_Blk42C	0.00	0.00	0.00
Palawan_Blk42D	0.00	0.00	0.00
Palawan_Reflight_Blk42eD	0.54	0.75	0.45
Palawan_Reflight_Blk42eE	0.00	0.00	-0.10
Palawan_Reflight_eE_additional	0.00	0.00	0.00
Palawan_Reflights_Blk42isl	0.00	0.00	

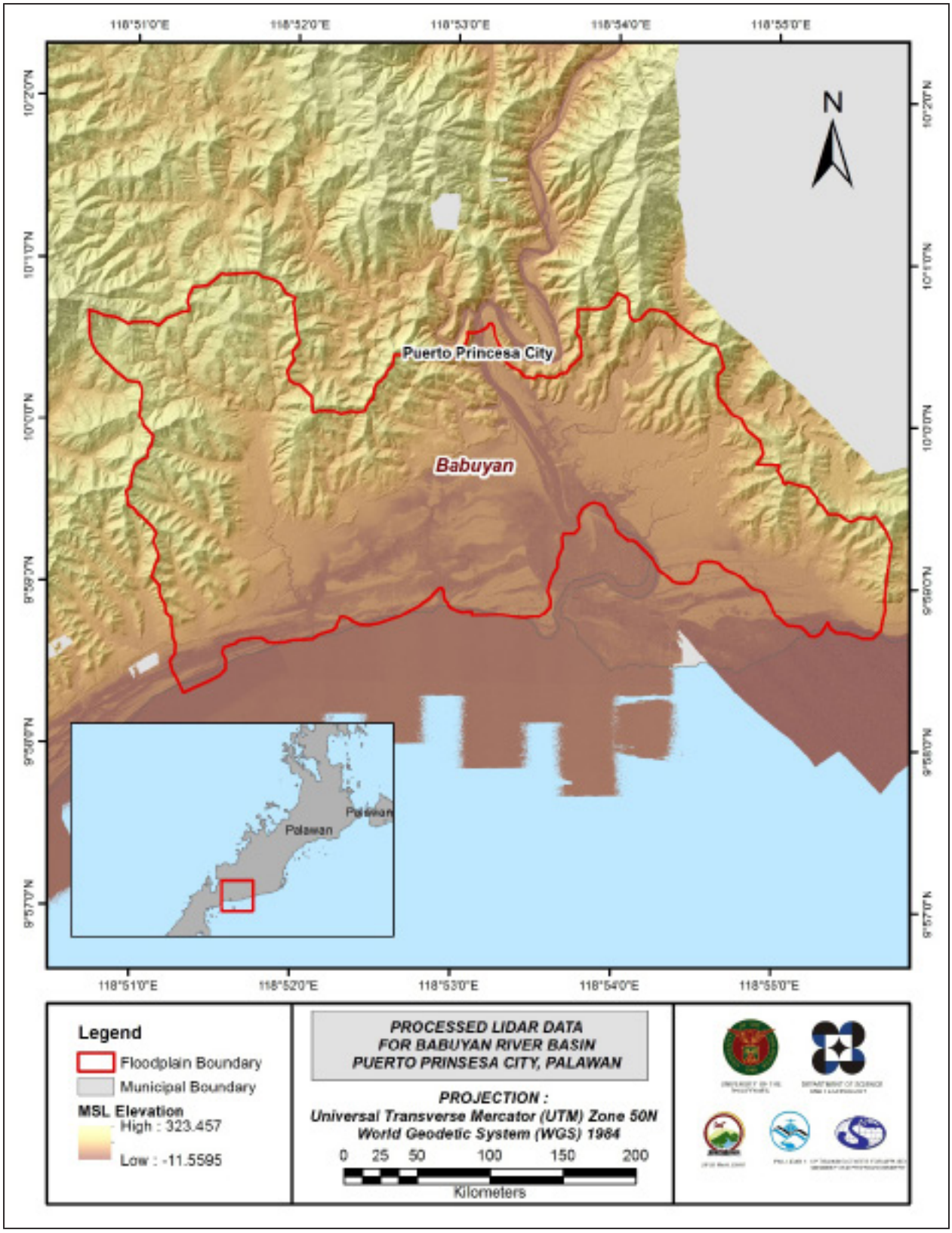

Figure 25. Map of Processed LiDAR Data for Babuyan Floodplain.

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 Babuyan to collect points with which the LiDAR dataset is validated is shown in Figure 26. A total of 2,345 survey points were used for calibration and validation of Babuyan LiDAR data. Random selection of 80% of the survey points, resulting to 1,870 points, were used for calibration.

The good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 27. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 11.08 meters with a standard deviation of 0.23 meters. Calibration of Babuyan LiDAR data was done by adding the height difference value, 11.08 meters, to Babuyan mosaicked LiDAR data. Table 21 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

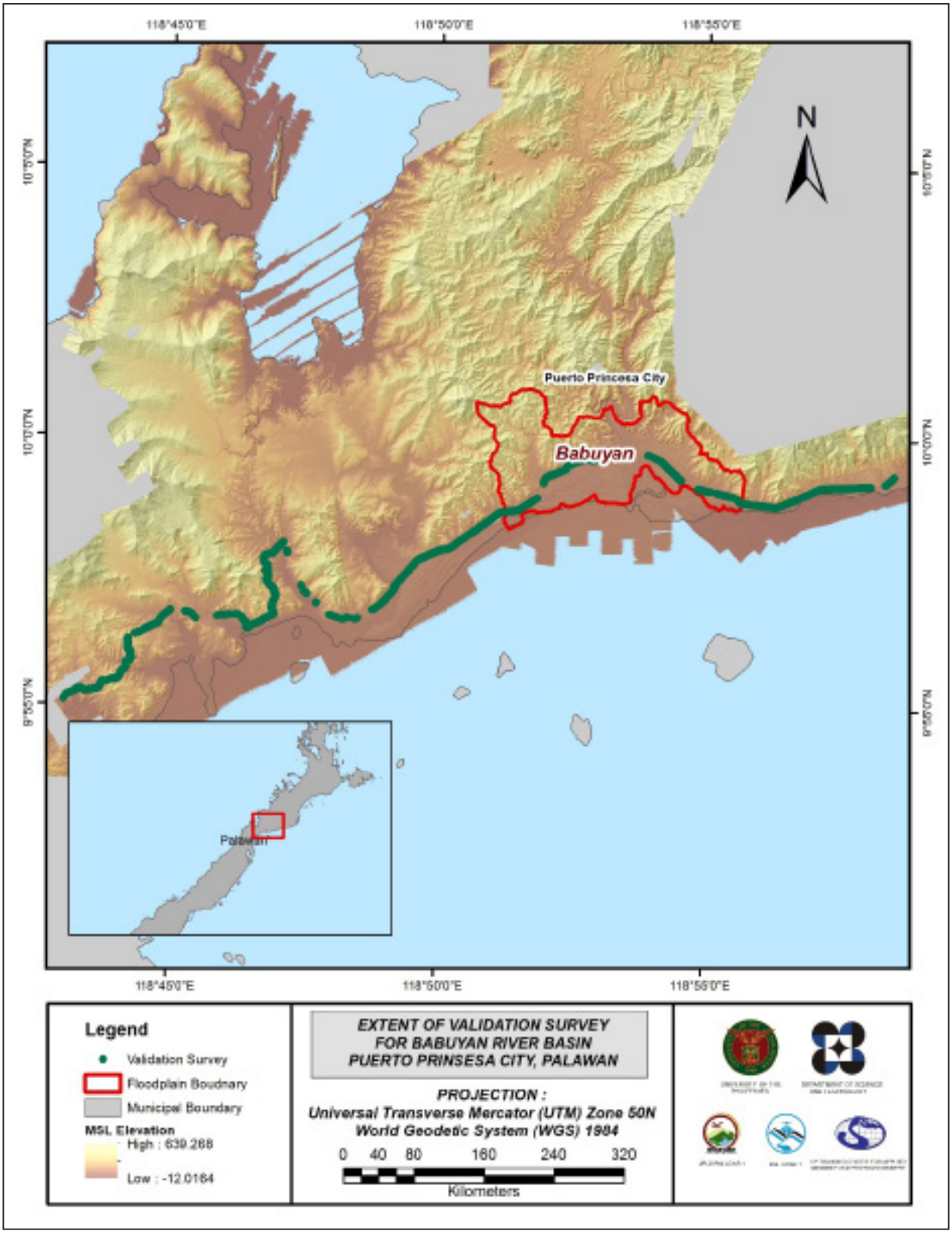

Figure 26. Map of Babuyan Floodplain with validation survey points in green.

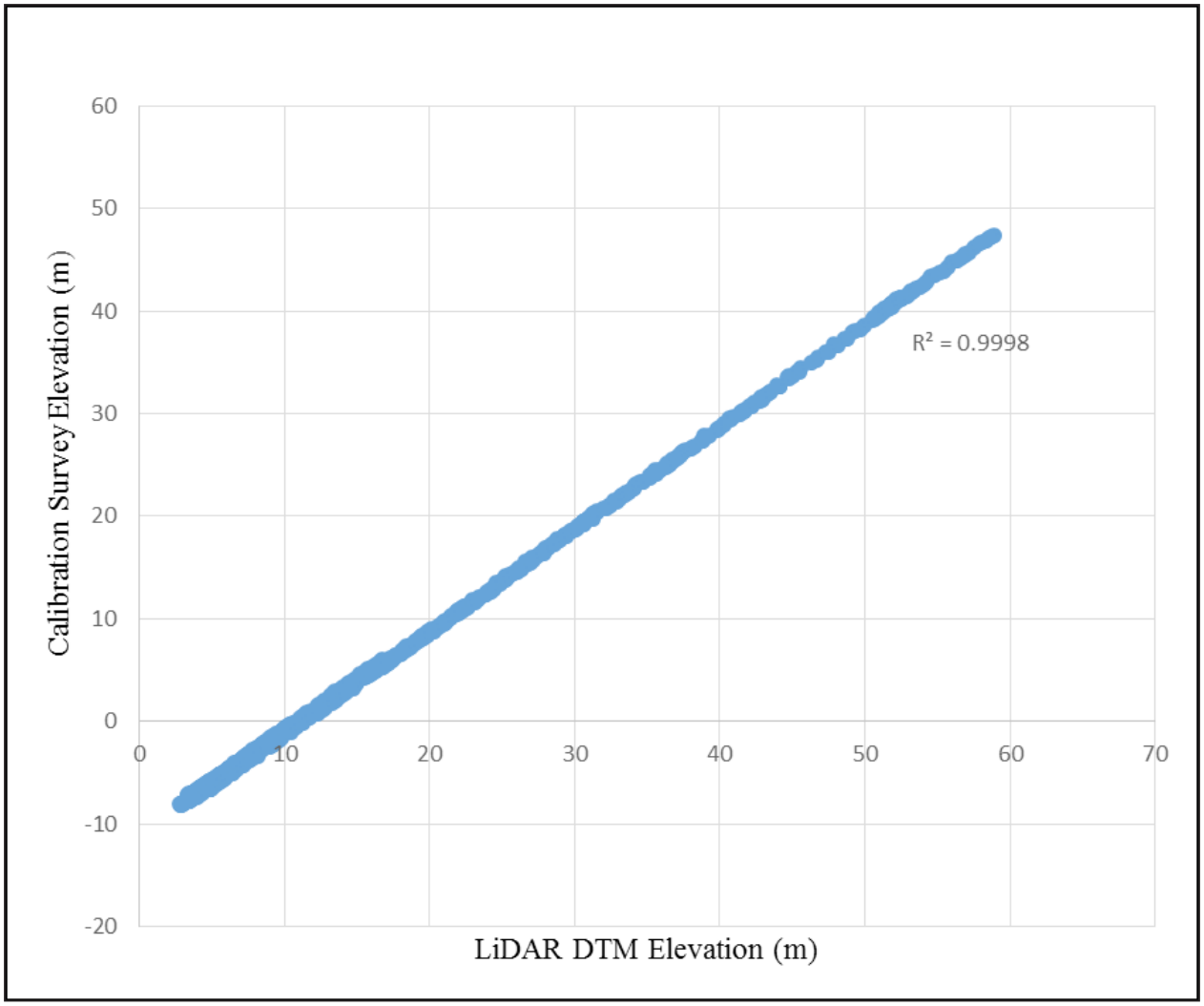

Figure 27. Correlation plot between calibration survey points and LiDAR data.

Table 21. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	11.08
Standard Deviation	0.23
Average	11.07
Minimum	10.62
Maximum	11.52

The remaining 20% of the total survey points, resulting to 472 points, were used for the validation of calibrated Babuyan 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 28. The computed RMSE between the calibrated LiDAR DTM and elevation values is 0.22 meters with a standard deviation of 0.22 meters, as shown in Table 22.

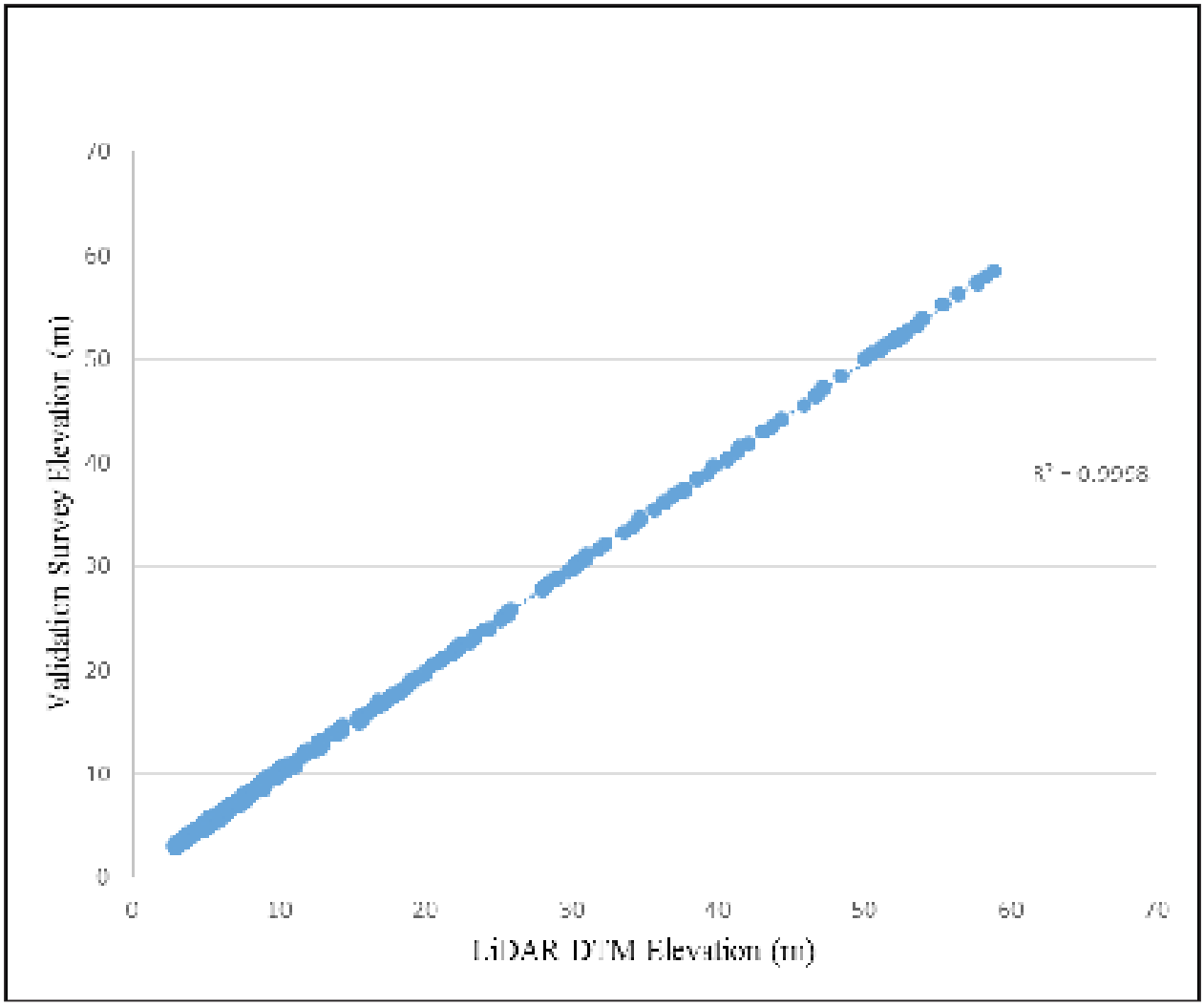

Figure 28. Correlation plot between validation survey points and LiDAR data.

Table 22. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.22
Standard Deviation	0.22
Average	-0.009
Minimum	-0.44
Maximum	0.43

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For the bathymetric data integration, centerline and zigzag points were used. A total of 24,732 points were incorporated, 12,744 points of which are centerlines and he remaining 11,988 points were zigzag points. The output raster surface was produced using Kernel interpolation method. The computed RMSE value for the interpolated surface was 0.68. The extent of the bathymetric survey integrated to the processed LiDAR DEM in Babuyan with a sample of its river profile was shown in Figure 29.

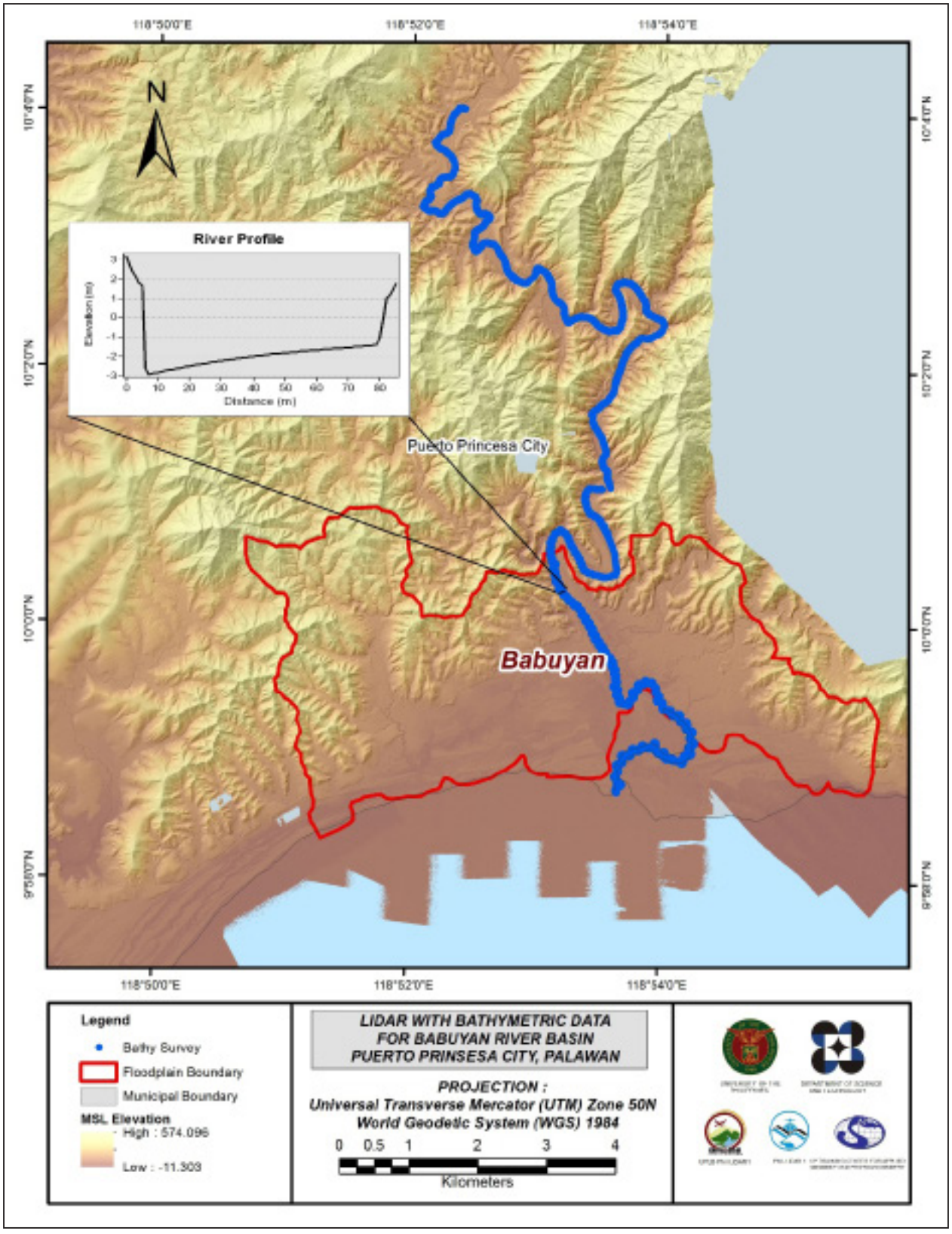

Figure 29. Map of Babuyan Flood Plain with bathymetric survey points shown in blue.

CHAPTER 4: DATA VALIDATION SURVEY AND MEASUREMENTS IN THE BABUYAN RIVER BASIN

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Babuyan River on November 3 to 15, 2015 with its partner HEI, the University of the Philippines Los Baños with the following scope of work; reconnaissance survey to assess the actual condition of the river and recovering of existing control points; control survey for the establishment of control point at the approach of Babuyan River; cross-section, as-built and water level marking on Babuyan Bridge; validation points acquisition along concrete roads and bathymetric survey of Babuyan River. The entire extent of the Babuyan River Basin survey is illustrated in Figure 30.

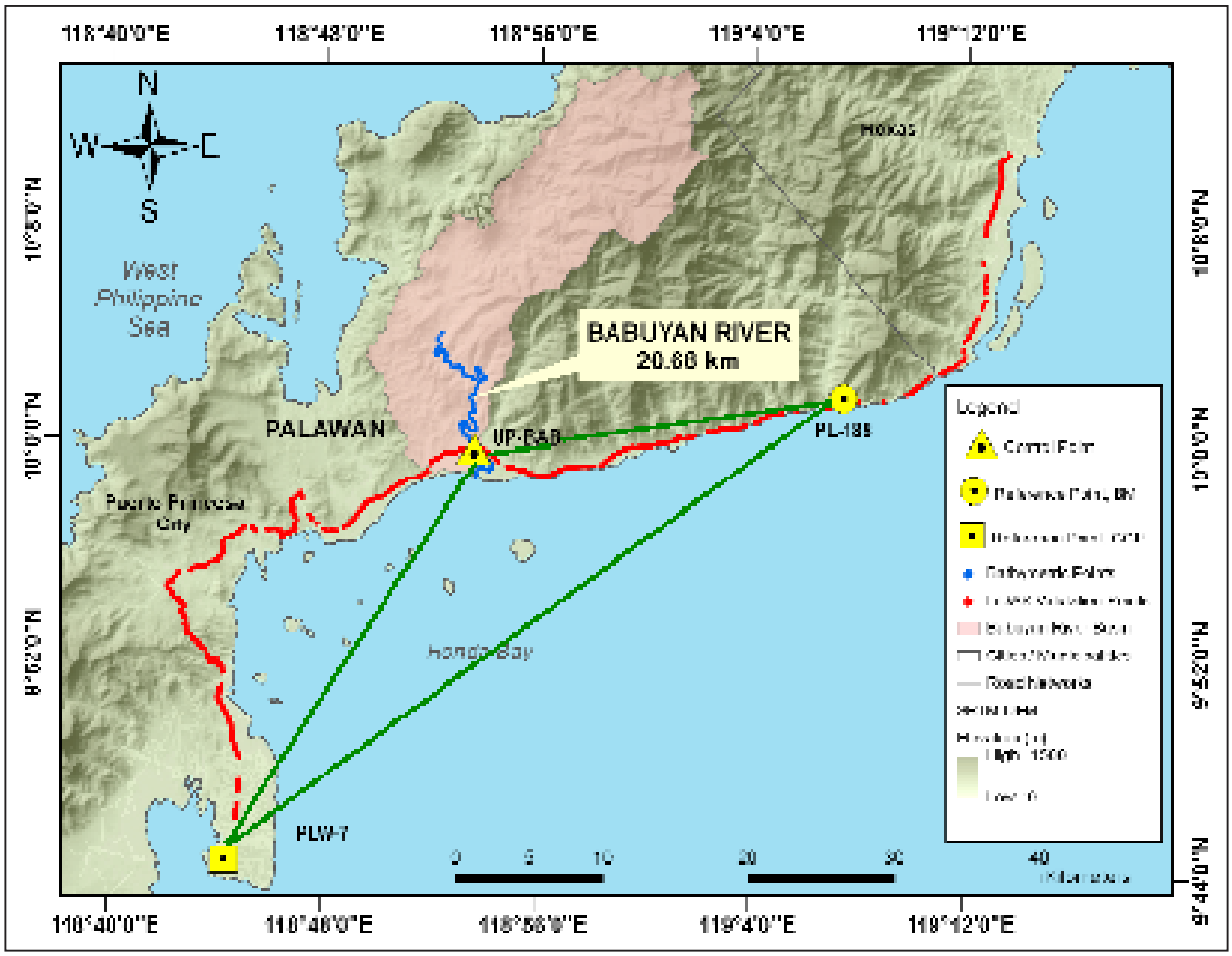


Figure 30. Babuyan River Survey Extent

4.2 Control Survey

The GNSS network used for Babuyan River Basin is composed of eight (8) loops established on November 5, 15 and 17, 2015 occupying the following reference points: MRW-24, a second order GCP in Brgy. Iriron, Municipality of Calintaan; MRW-30, a second order GCP in Bry. Pinagturilan, Municipality of Sta. Cruz; MC-200, a first order BM in Brgy. Magsikap, Municipality of Rizal; and MC-212, also a first order BM in Brgy. Sto. Niño in Rizal.

Three (3) control points were established along the approach of bridges, namely: UP-PIN at Pinamanaan Bridge in Brgy. Mapaya, Municipality of San Jose; UP-ALI at Alipid Bridge in Brgy. Sto. Niño, Municipality of Sablayan; and UP-MOM at Mompong Bridge in Brgy. Lumang Bato, also in Sablayan. The control point established by DPWH, GPS-4, in Brgy. Poblacion, Municipality of Magsaysay; and MC-90, established by NAMRIA, in Brgy. Barahan, Municipality of Sta. Cruz were also occupied to use as a marker for the network.

The summary of reference and control points and its location is summarized in Table 24 while the GNSS network established is in Figure 30.

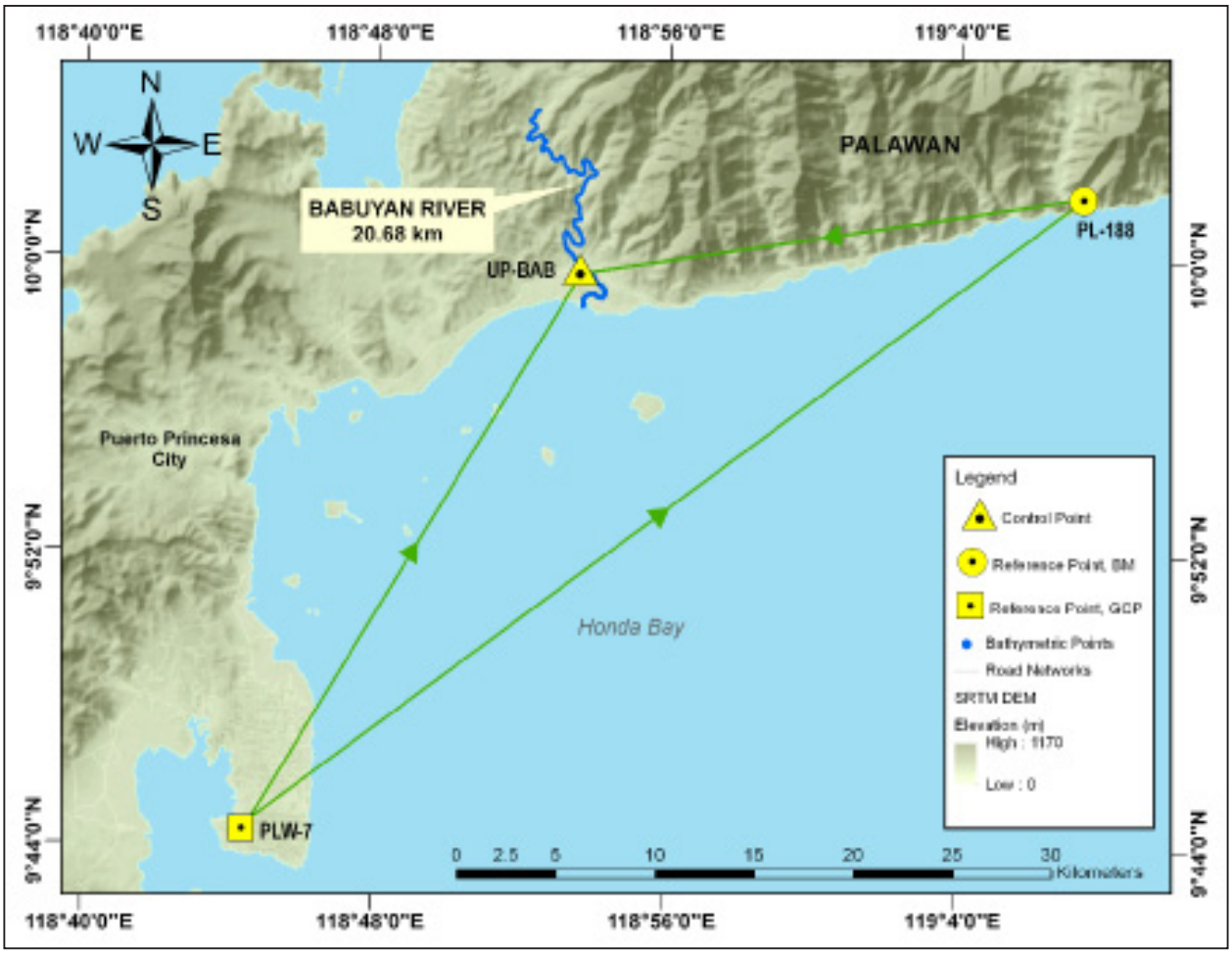


Figure 31. GNSS Network covering Babuyan River

Table 23. List of reference and control points used during the survey in Babuyan River (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
PLW-7	1st order GCP	9°44'25.33347"	118°44'25.60607"	85.742	-	1990
PL-188	1st order BM	-	-	57.865	6.467	2008
UP-BAB	UP Established	-	-	-	-	11-6-2015

The GNSS control points setup in Palawan province are shown in Figure 32 to Figure 34, respectively.

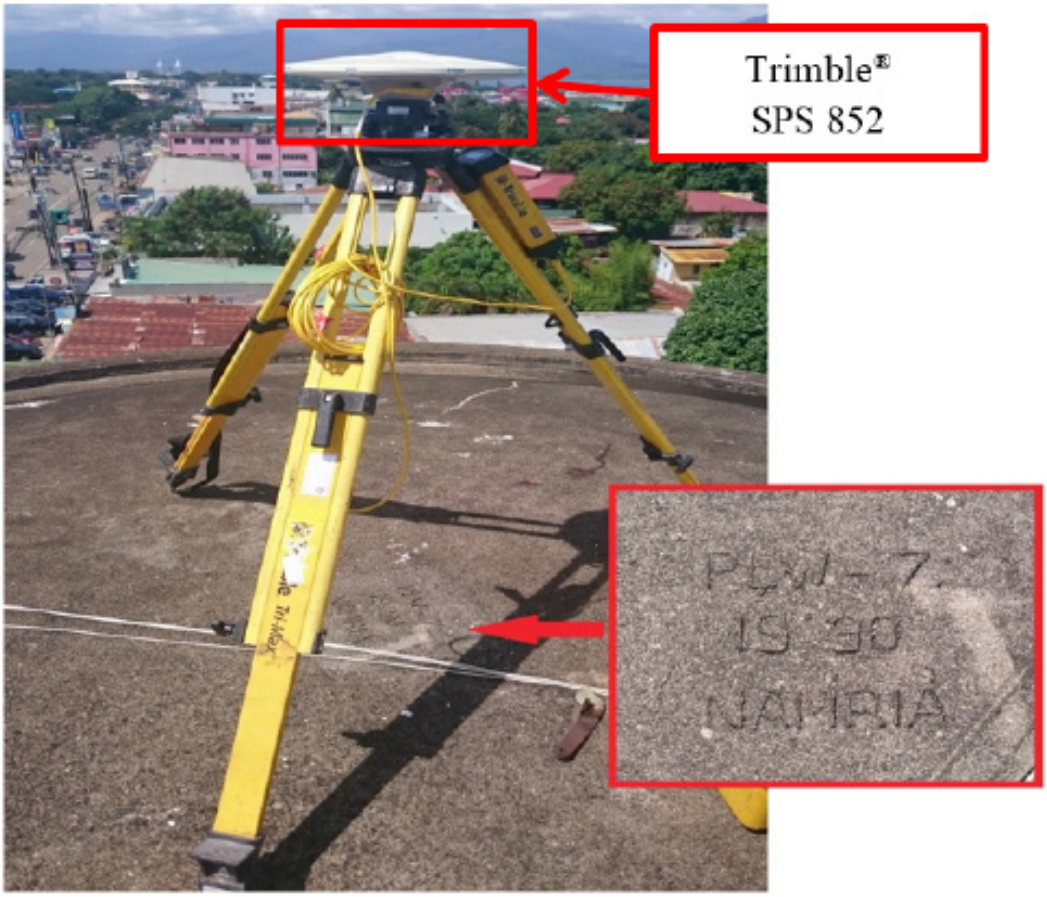


Figure 32. Trimble® SPS 852 GNSS Base setup at PLW-7 at an old water tank inside the Water District compound, Brgy. Maningning, Puerto Prinsesa, Palawan

Figure 33. Trimble® SPS 882 GNSS receiver setup at PL-188 located in Langogan Bridge, Brgy. Langogan, Puerto Prinsesa, Palawan

Figure 34. Trimble® SPS 852 GNSS receiver setup at UP-BAB in Babuyan Bridge, Brgy.Maoyon, Puerto Prinsesa, Palawan

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 used in Babuyan River survey is summarized in Table 24 generated by TBC software.

Table 24. Baseline processing report for Babuyan River Basin static survey

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
PL188 --- UPBAB (B3)	PL188	UPBAB	Fixed	0.003	0.020	261°37'42"	25533.659	-0.319
PLW7 --- UPBAB (B2)	PLW7	UPBAB	Fixed	0.003	0.016	30°40'20"	32806.731	-28.137
PLW7 --- PL188 (B1)	PLW7	PL188	Fixed	0.005	0.016	52°43'22"	52773.818	-27.907

4.4 Network Adjustment

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

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

Where:

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

for each control point. Shown in Table 25 to Table 27 are the results of GNSS network adjustment.

The three (3) control points, PLW-7, PL-188 and UP-BAB were occupied and observed simultaneously to form GNSS LOOP. Coordinates of PLW-7 and elevation value of PL-188 were held fixed during the processing of the control points as presented in Table 25. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 25. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
PL188	Grid				Fixed
PLW7	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 26. The fixed control point PL-188 and PLW-7, has no values for standard elevation and coordinates error, respectively.

Table 26. Adjusted Grid Coordinates

Point ID	Easting	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
PL188	74882.798	0.010	1111141.324	0.008	6.467	?	e
PLW7	32397.249	?	1079651.883	?	35.303	0.055	LL
UPBAB	49529.234	0.009	1107714.961	0.007	6.924	0.062	

The networks are fixed at reference points PLW-7 and PL-188. With the mentioned equation $\sqrt{((x_e)^2 + (y_e)^2)}$ <20cm and $z_e < 10\ cm$ for the horizontal and for the vertical, respectively; the computation for the accuracy for:

a. PLW-7
horizontal accuracy = Fixed
vertical accuracy = 5.5 cm < 10 cm

b. PL-188
horizontal accuracy = √((1.0)² + (0.8)²
= √(1.0 + 0.64)
= 1.28 cm < 20 cm
vertical accuracy = Fixed

c. UP-BAB
horizontal accuracy = √((0.9)² + (0.7)²
= √(0.81 + 0.49)
= 1.14 cm < 20 cm
vertical accuracy = 6.2 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the three (3) occupied control points are within the required accuracy of the program.

Table 27. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
PL188	N10°01'44.89328"	E119°07'24.55714"	57.865	?	e
PLW7	N9°44'25.33347"	E118°44'25.60607"	85.742	0.055	LL
UPBAB	N9°59'43.61069"	E118°53'35.10634"	57.580	0.062	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 27. 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 28. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	MSL Elevation (m)
PLW-7	1st Order GCP	9°44'25.33347"	118°44'25.60607"	85.742	1079652	32397.25	35.303
PL-188	1st Order BM	10°01'44.89328"	119°07'24.55714"	57.865	1111141	74882.8	6.467
UP-BAB	UP Established	9°59'43.61069"	118°53'35.10634"	57.58	1107715	49529.23	6.924

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

Cross-section and bridge as-built surveys were conducted on November 7, 2015 at the upstream side of Babuyan Bridge in Brgy. Maoyon, Puerto Princesa City, Plawan using a GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 35.

Figure 35. Cross–Section Survey in Babuyan Bridge

A total of one hundred thirteen (113) points were obtained for the cross-section with one hundred sixty-two 162 meters in length were acquired using UP-BAB as the GNSS base station. The location map, cross-section diagram, and bridge as-built form are shown in Figure 36 to Figure 38, respectively.

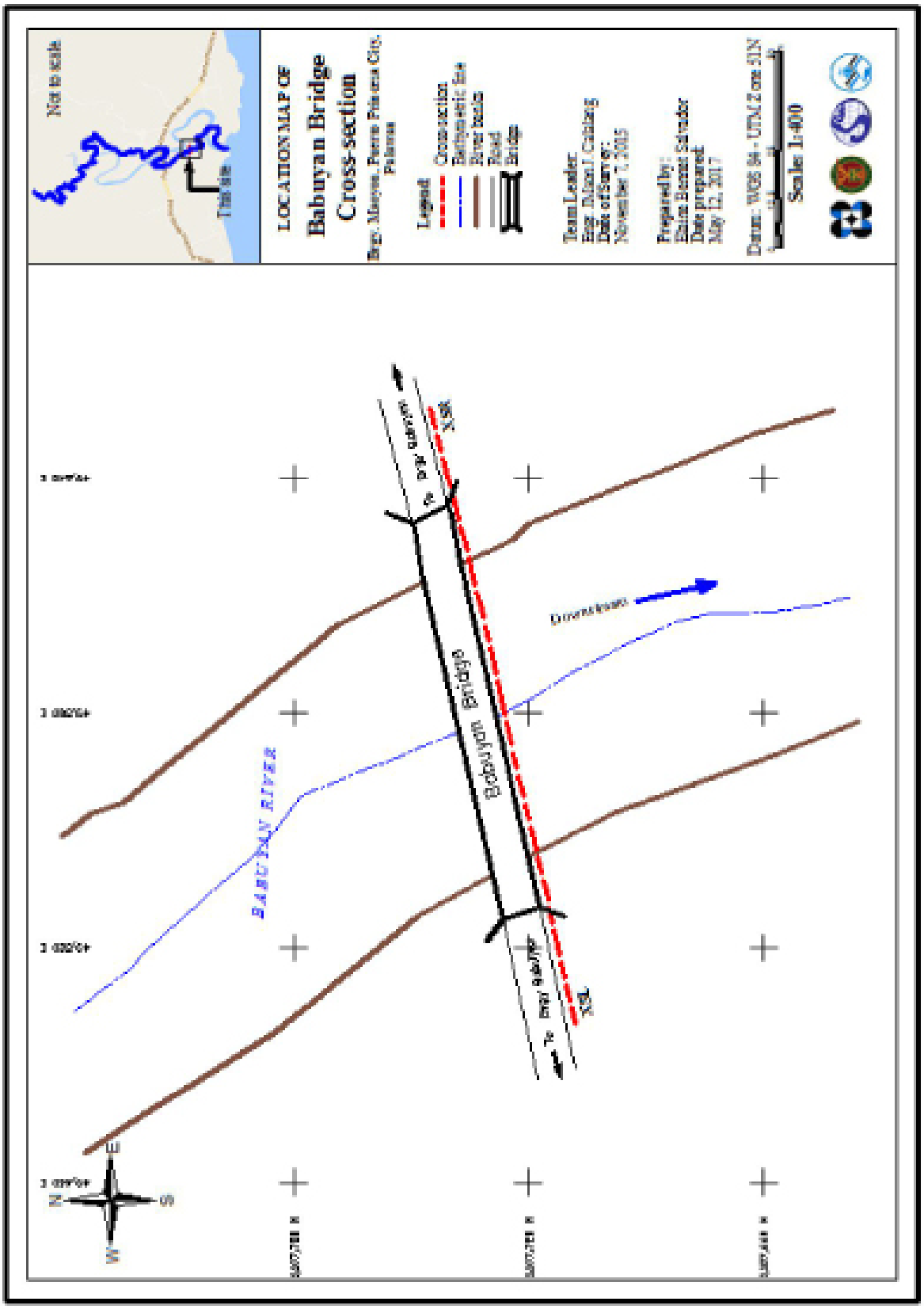


Figure 36. Location Map of Babuyan Bridge River Cross-Section survey

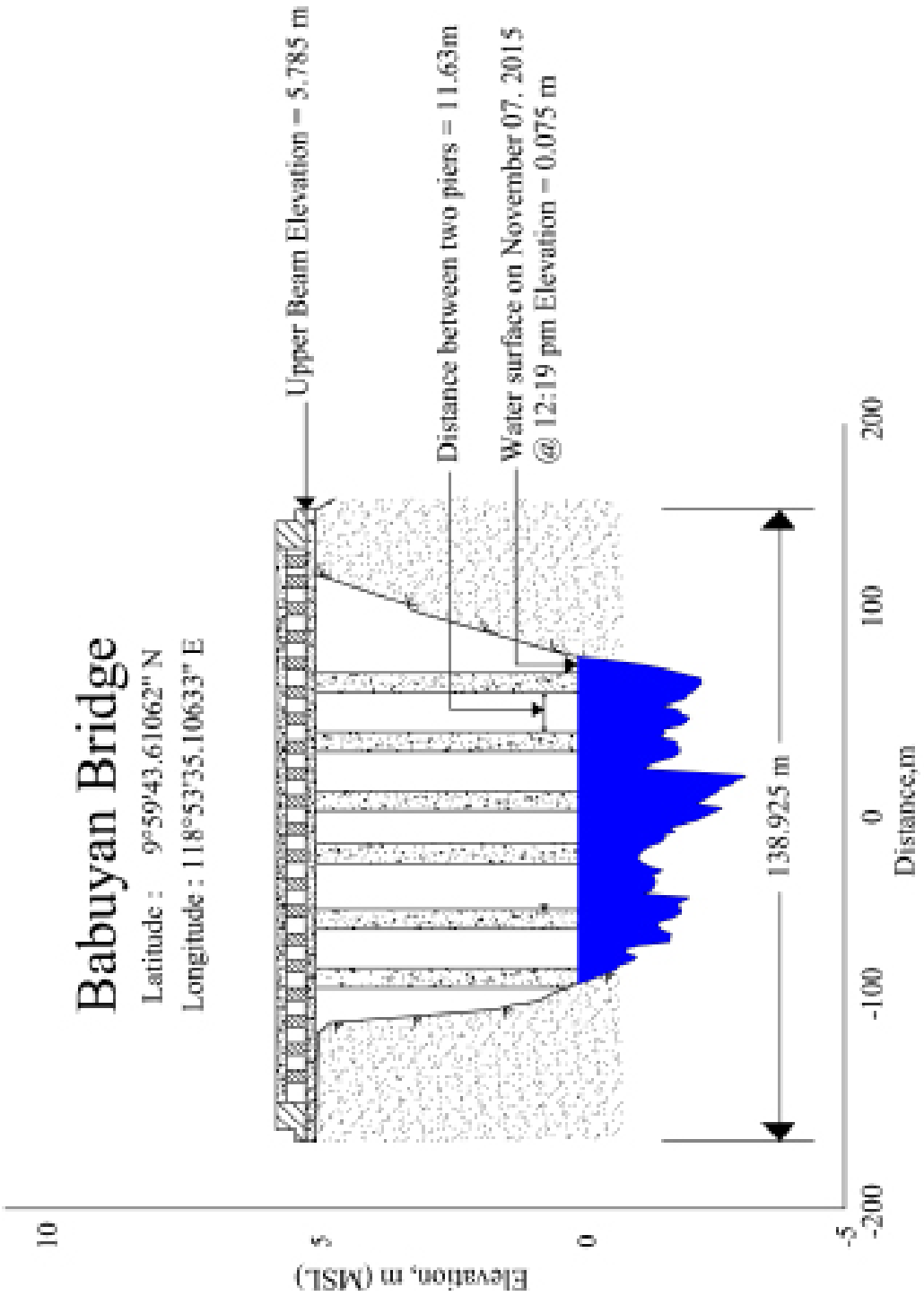


Figure 37. Babuyan Bridge cross-section diagram

Bridge Data Form

Bridge Name: Babuyan Bridge **Date:** November 07, 2015

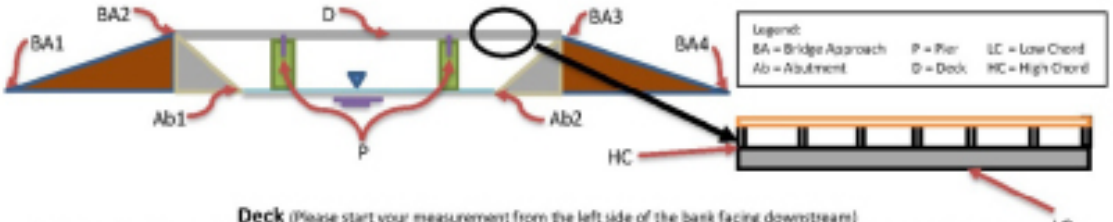
River Name: Babuyan River **Time:** 11:21 pm

Location (Brgy, City, Region): Brgy. Maoyon,Puerto Prinsesa City, Palawan

Survey Team: Team JM

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

Latitude: 9d59'43.61062" N **Longitude:** 118d53'35.10633" E



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

Elevation 5.785 meters **Width:** 7.25 meters **Span (BA3-BA2):** 105.087 meters

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 1	5.854	4.354
2	Pier 3	6.618	5.118
3	Pier 5	6.589	5.089

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	5.725	BA3	114.714	6.902
BA2	9.627	5.785	BA4	138.925	6.643

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

	Station (Distance from BA1)	Elevation
Ab1	31.429	2.024
Ab2	126.426	2.019

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

Shape: Rectangular Columns **Number of Piers:** 6 **Height of column footing:** 5.1

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	24.588	5.854	1.2
Pier 2	39.583	6.079	1.2
Pier 3	54.556	6.618	1.2
Pier 4	69.618	6.392	1.2
Pier 5	84.726	6.589	1.2
Pier 6	99.704	6.806	1.2

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

Figure 38. Bridge as-built form of Babuyan Bridge

Water surface elevation in MSL of Babuyan Bridge was determined using Trimble® SPS 882 in PPK mode survey on November 07, 2015 at 12:19 P.M (Figure 37). This was translated onto marking the bridge's pier using a leveling rod. The marked pier, as shown in Figure 39, shall serve as elevation reference for flow data gathering and depth gauge deployment of the PHIL-LIDAR 1 partner HEI for Babuyan River, the University of the Philippines Los Baños.

Figure 39. Water-level markings on the post of Babuyan Bridge

4.6 Validation Points Acquisition Survey

Validation Points Acquisition survey was conducted on November 6, 9, 10 and 12, 2015 using a survey-grade Trimble® SPS 985 GNSS receiver mounted on a pole measuring 2.3 m which was positioned on the side of the vehicle as shown in Figure 40. It was secured by ropes tied on the windows of the vehicle to ensure that the range pole is steady and upright throughout the extent of the survey.

Figure 40. Validation points acquisition survey set-up for Babuyan River

The surveyed gathered a total of eight thousand five hundred thirteen (8,513) points with an estimated length of 38 km which traversed the concrete roads of Puerto Princesa City starting from Brgy. and travelling down to Brgy. Caramay in the Municipality of Roxas (Figure 41). The control point PL-188 was used as the GNSS base station on November 6 and 9, 2015, UP-BAB on November 10, 2015 and PLW-7 on November 12, 2015.

Figure 41. Validation point acquisition survey of Babuyan River Basin

4.7 Bathymetric Survey

Bathymetric survey of Babuyan River was conducted on November 10 and 12, 2015 utilizing a GNSS Rover receiver, Trimble® SPS 882 in PPK survey technique mounted on top of a pole with Ohmex™ single-beam echo sounder as shown in Figure 42. The survey started from the upstream in Brgy. Tagabinit with coordinates 10°04'02.27021" N 118°52'22.50021" E down to the mouth of the river in Brgy. Babuyan with coordinates 9°58'44.29862" N 118°53'41.49882" E. The control point, UP-BAB, was used as the GNSS base station.

Figure 42. Bathymetric survey equipment set-up in a rented boat in Babuyan River

A total of 24,732 bathymetric points were acquired with an approximate length of 20.68 km as illustrated in the map in Figure 43.

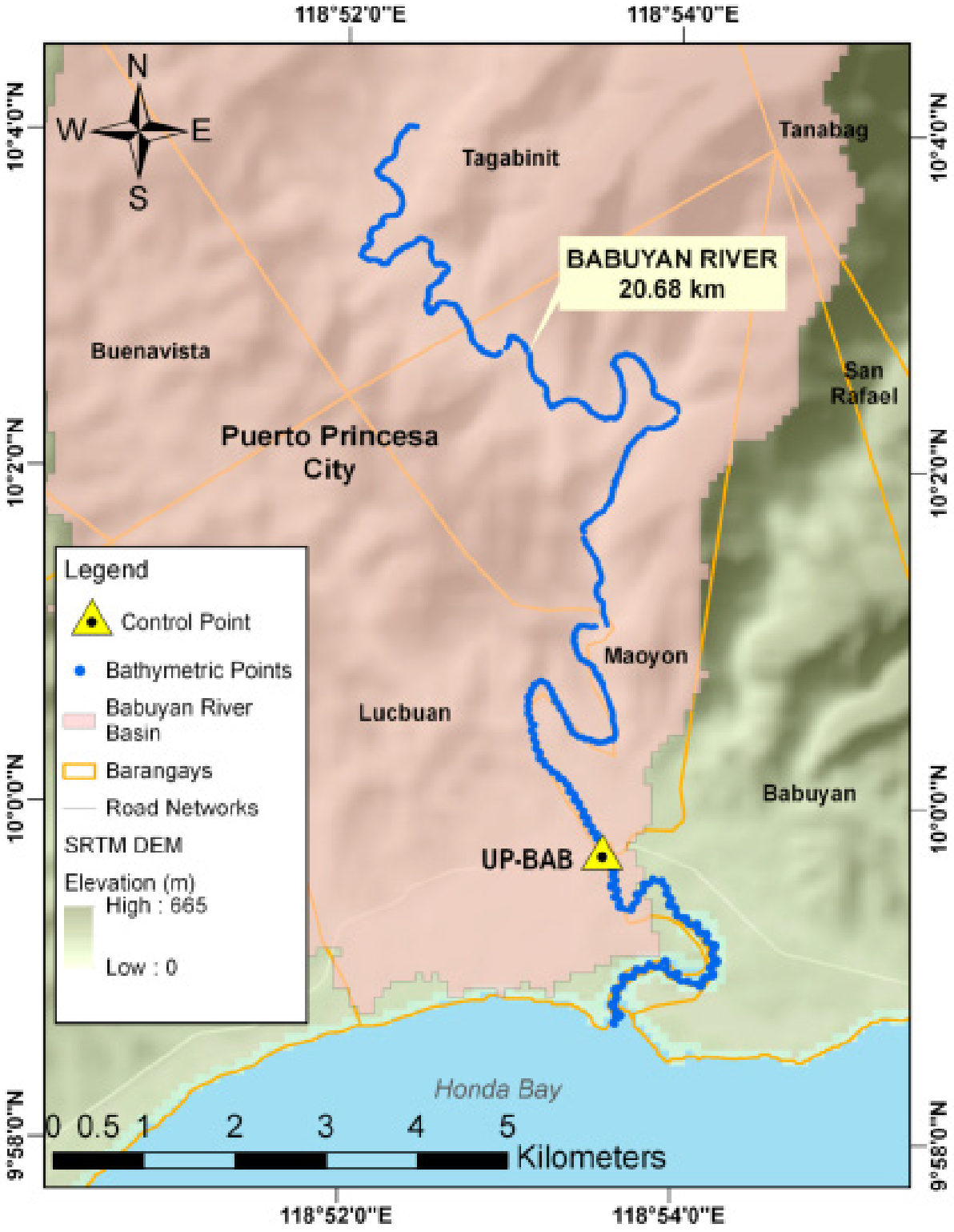


Figure 43. Bathymetric survey of Babuyan River

A CAD drawing was also produced to illustrate the Babuyan River riverbed profile from the upstream in Brgy. Tagabinit down to Brgy. Babuyan as shown in Figure 44. An elevation drop of 16.37 meters with respect to MSL was observed within the approximate distance of 20.68 kilometers. Highest elevation observed was 13.28 m in MSL in the upstream and the lowest elevatin observed was -7.56 m below MSL in the downstream area.

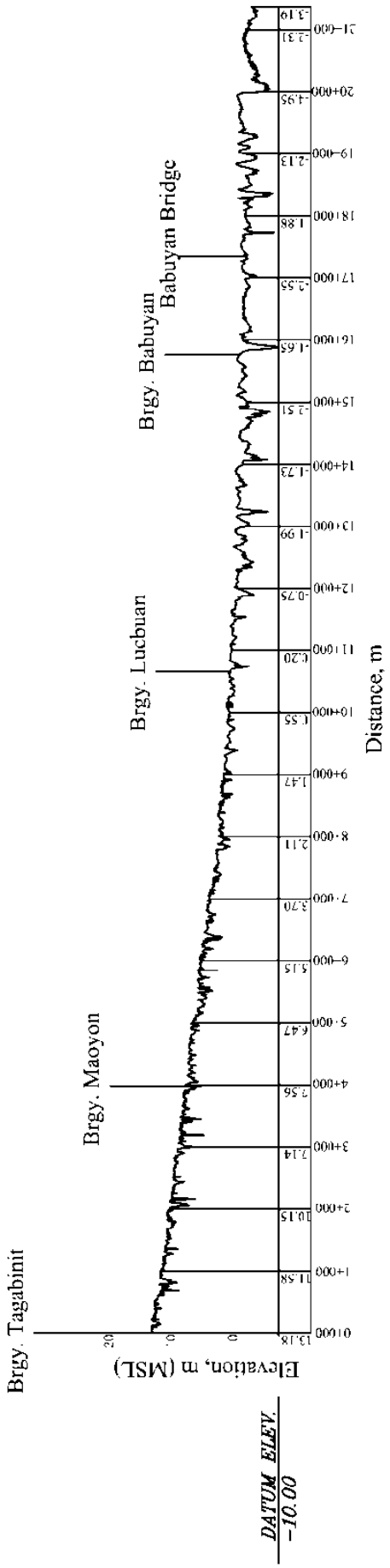


Figure 44. Babuyan riverbed profile from Brgy. Tagabinit down to Brgy. Babuyan

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, Khristoffer Quinton, John Alvin B. Reyes, Alfi Lorenz B. Cura, Angelica T. Magpantay, Maria Michaela A. Gonzales Paulo Joshua U. Quilao, Jayson L. Arizapa, and Kevin M. Manalo

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 Hydrometry and Rating Curves

No gathered rainfall data for Babuyan river basin. The HMS model is not calibrated. The values generated HMS model are by default.

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Puerto Princesa Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station chosen based on its proximity to the Caramay watershed. The extreme values for this watershed were computed based on a 58-year record, with the computed extreme values shown in Table 29.

Table 29. values for Romblon Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	14.8	22	27.3	36.2	49.8	58.8	75.1	88	104.1
5	21.3	31.9	39.7	52.3	73	86.9	112.8	135.4	156.4
10	25.6	38.5	48	63	88.4	105.5	137.8	166.8	191.1
15	28.1	42.2	52.6	69	97	116	151.9	184.5	210.6
20	29.8	44.7	55.9	73.3	103.1	123.4	161.7	196.8	224.3
25	31.1	46.7	58.4	76.5	107.8	129.1	169.3	206.4	234.9
50	35.2	52.9	66.1	86.5	122.2	146.5	192.7	235.8	267.3
100	39.2	59	73.7	96.4	136.5	163.8	216	265	299.6

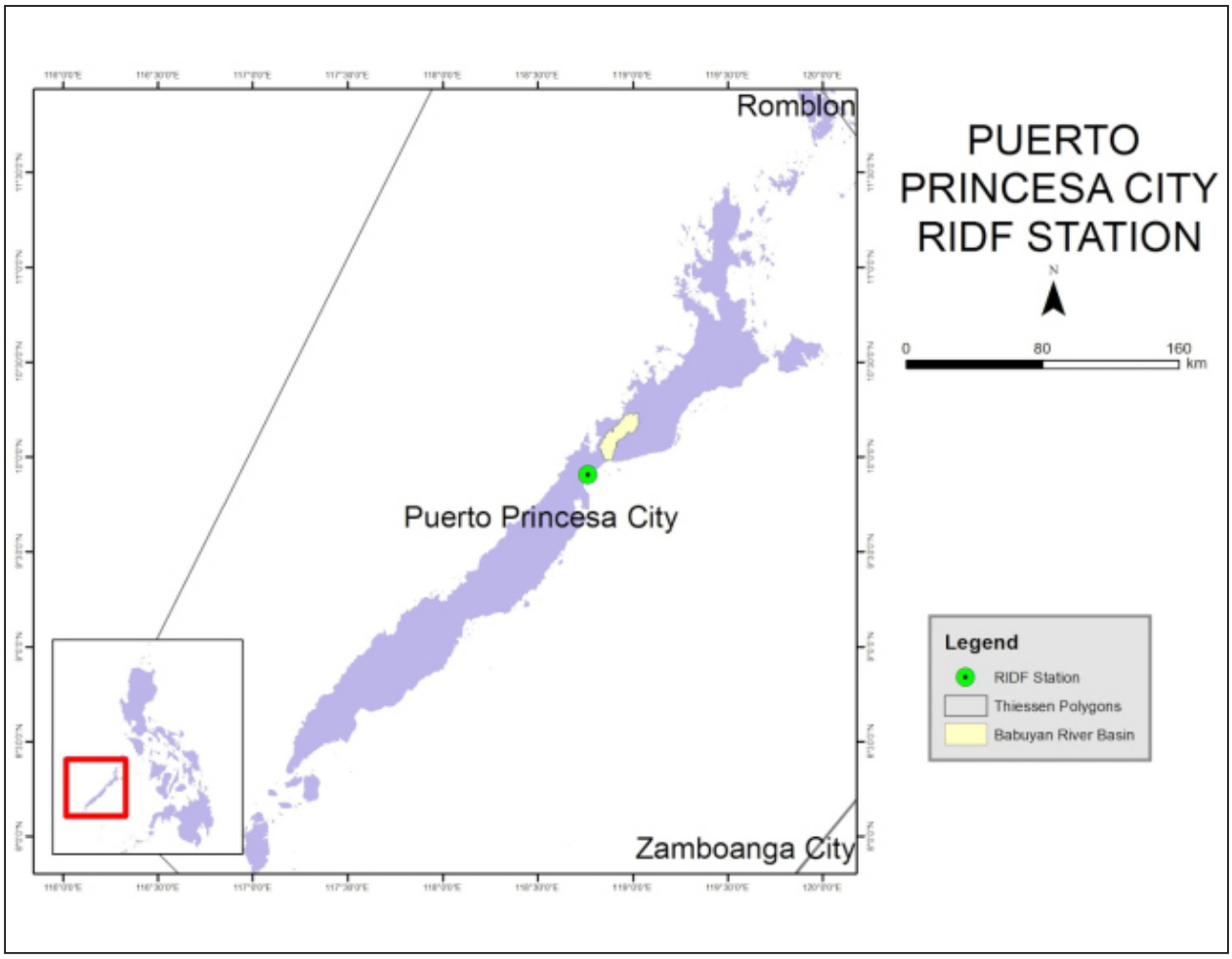


Figure 45. The location map of Babuyan HEC-HMS model used for calibration

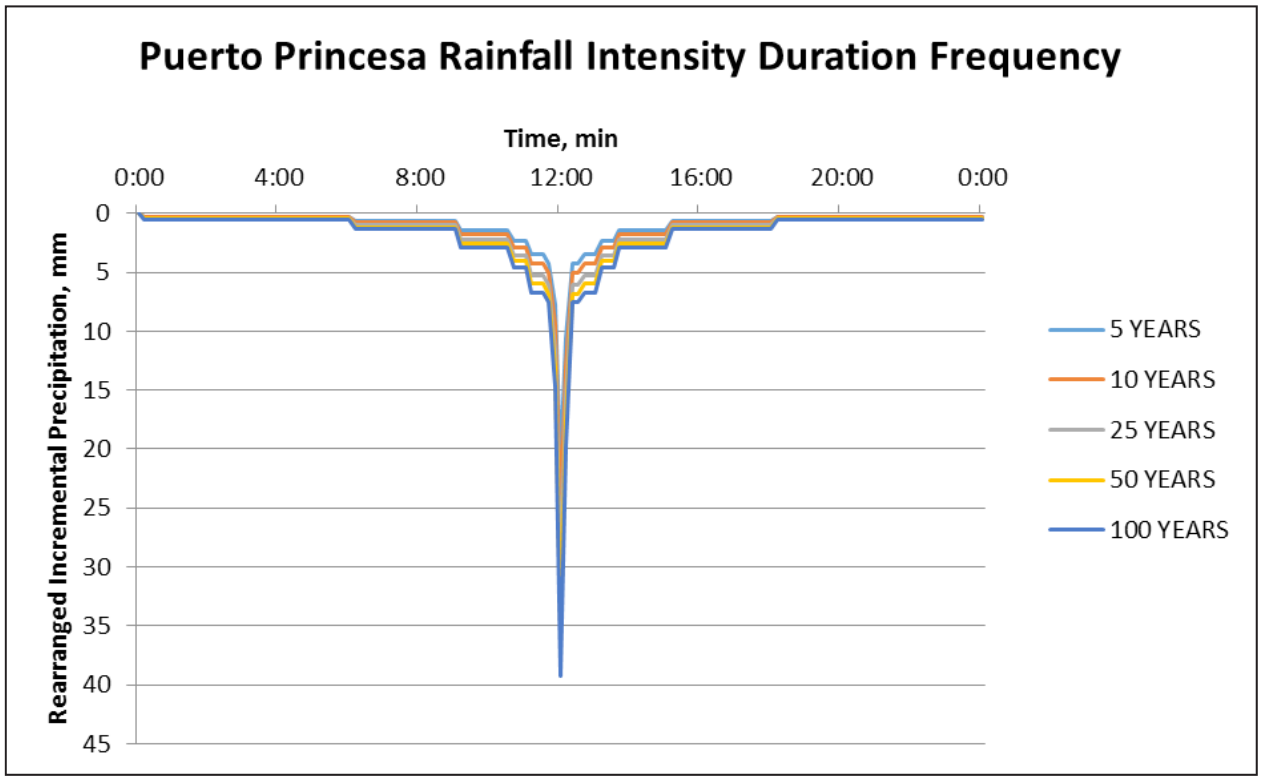


Figure 46. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management under the Department of Agriculture (DA-BSWM). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Babuyan River Basin are shown in Figure 47 and Figure 48, respectively.

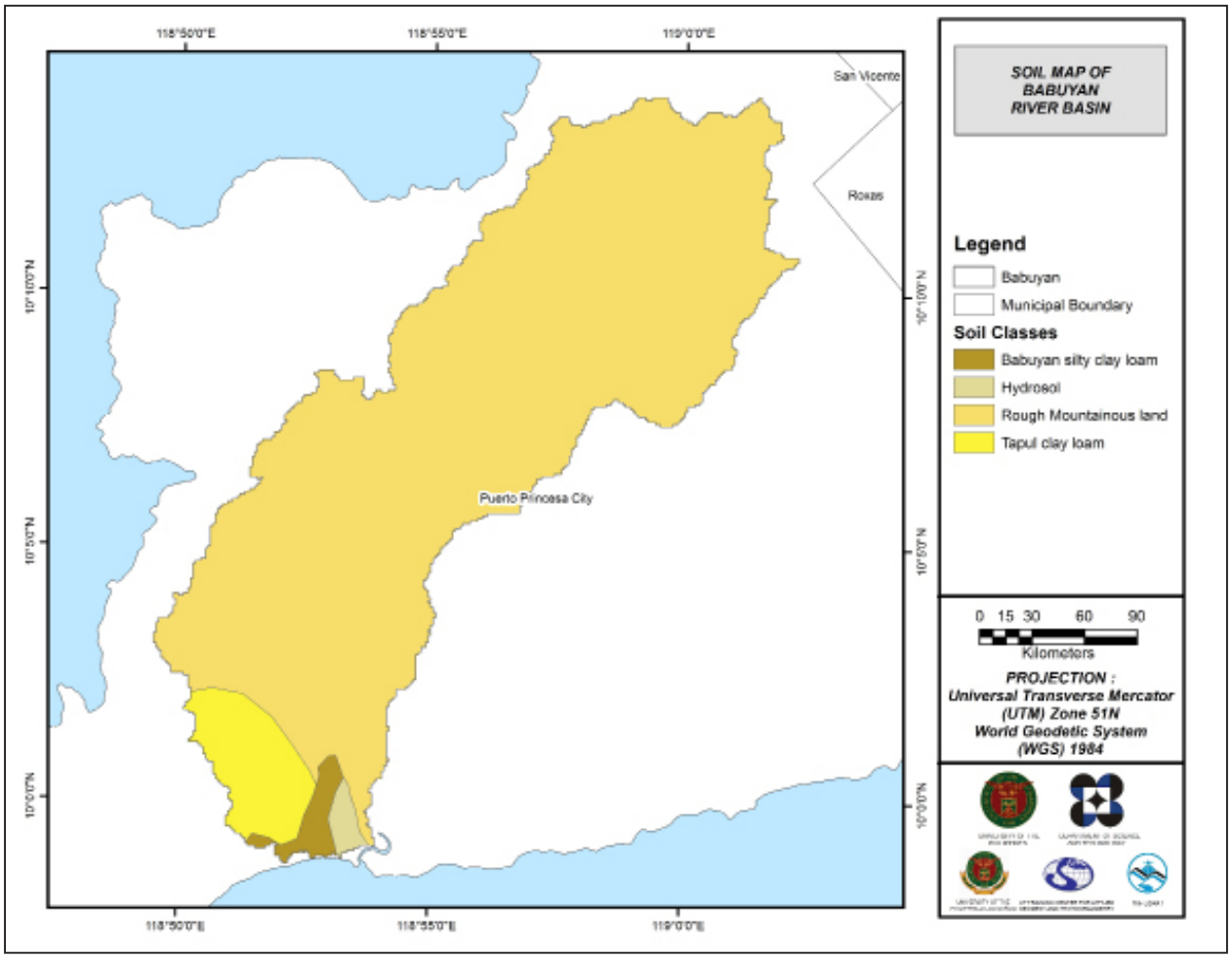


Figure 47. Soil map of Babuyan River Basin used for the estimation of the CN parameter. (Source: DA)

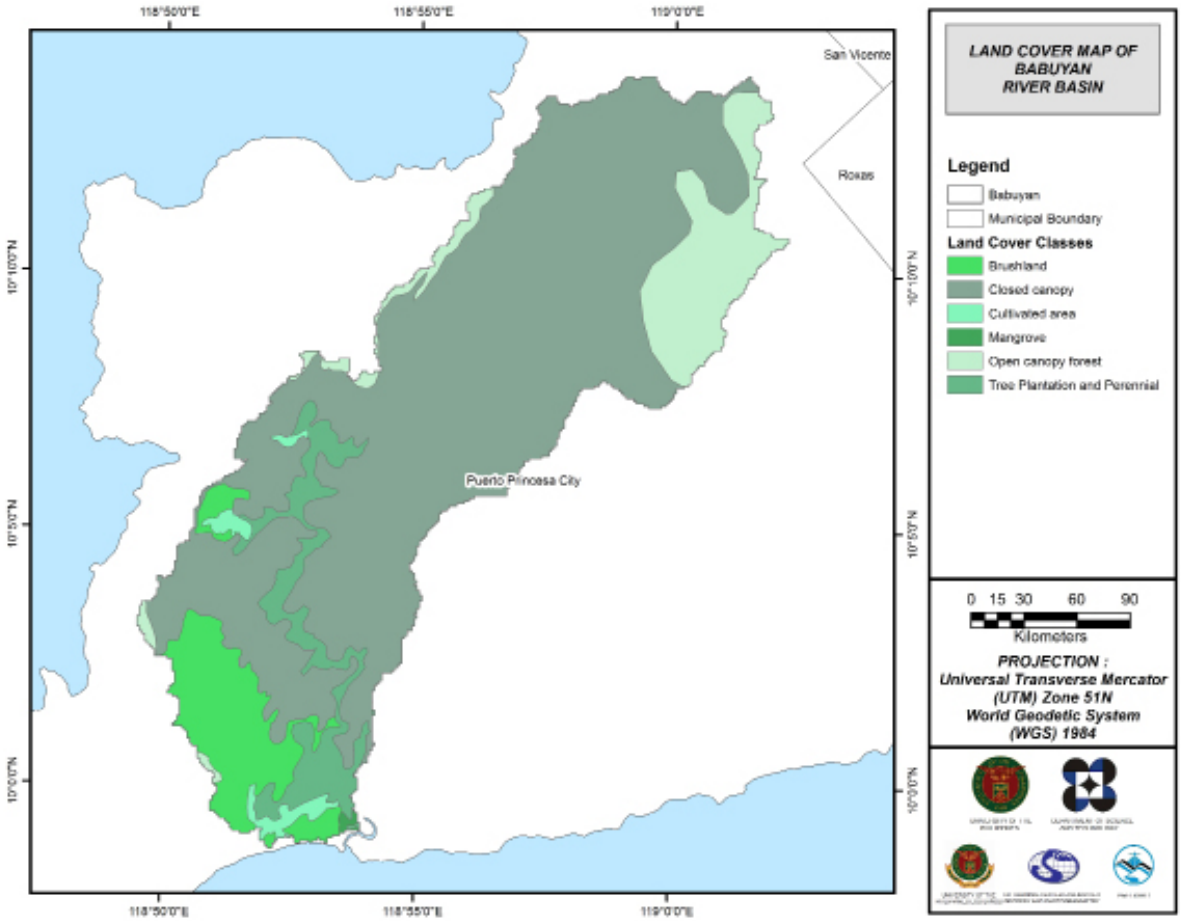


Figure 48. Land cover map of Babuyan River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Babuyan river basin, four (4) soil classes were identified. The river basin area is largely rough mountainous land, with portions of Tapul clay loam, Babuyan silty clay loam, and hydrosol. Moreover, the six (6) land cover types identified were mostly closed canopy, followed by open canopy forest, brushland, tree plantation and perennial, cultivated area, and mangrove.

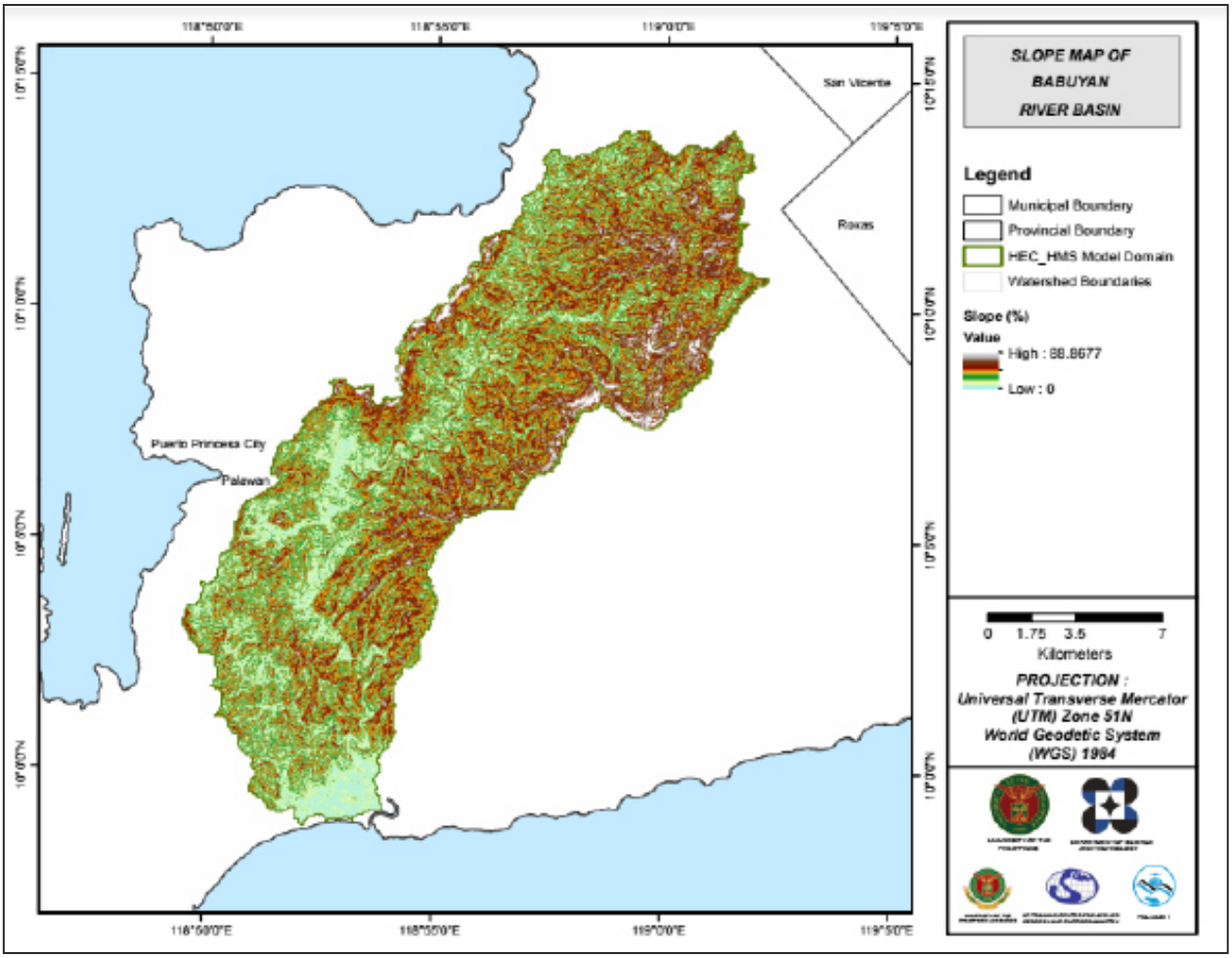


Figure 49. Slope map of Babuyan River Basin

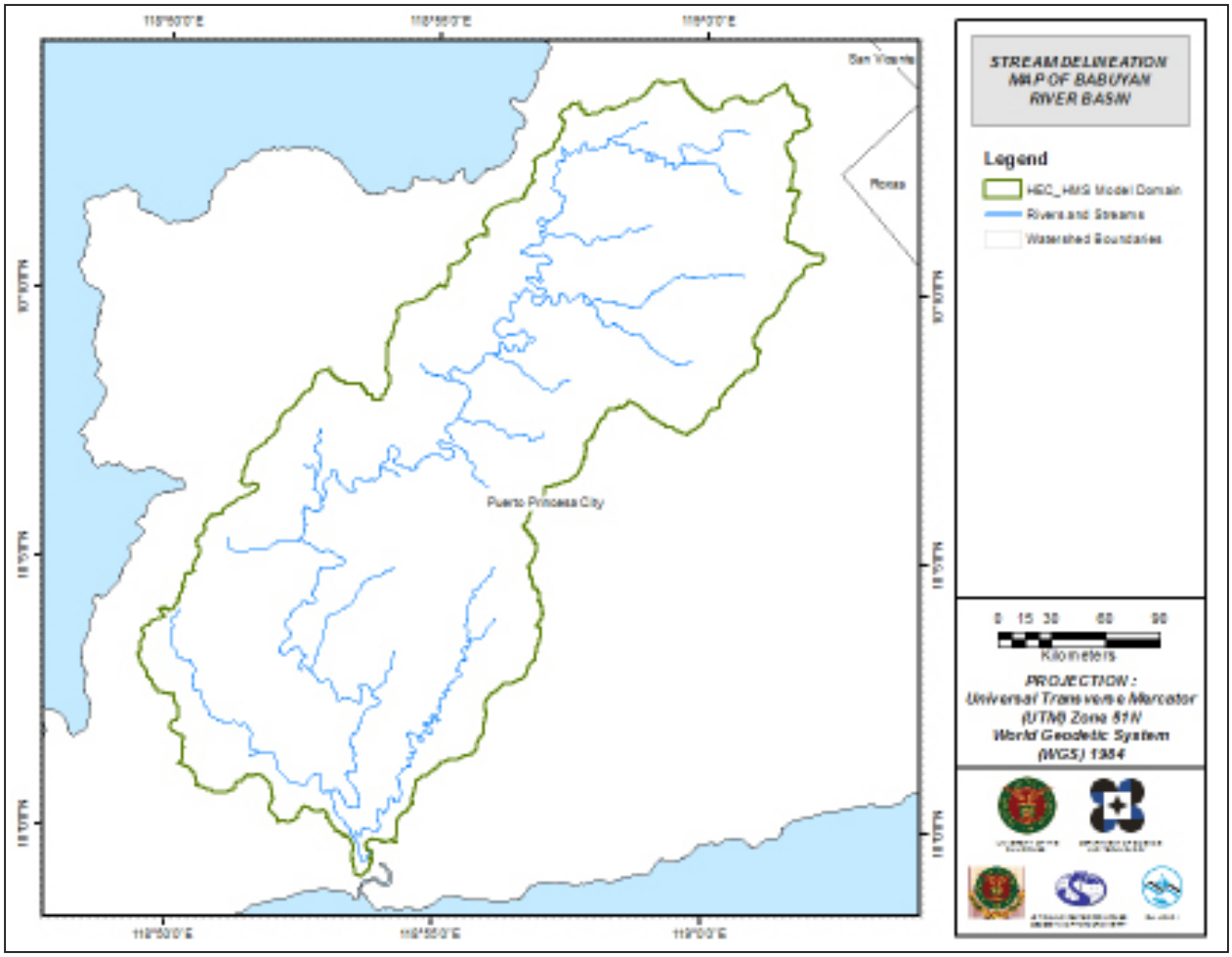


Figure 50. Stream Delineation Map of the Babuyan River Basin

Using SAR-based DEM, the Babuyan basin was delineated and further subdivided into subbasins. The model consists of 46 sub basins, 22 reaches, and 21 junctions. The main outlet is labelled as Babuyan_ outlet. This basin model is illustrated in Figure 51. The basins were identified based on soil and land cover characteristics of the area.

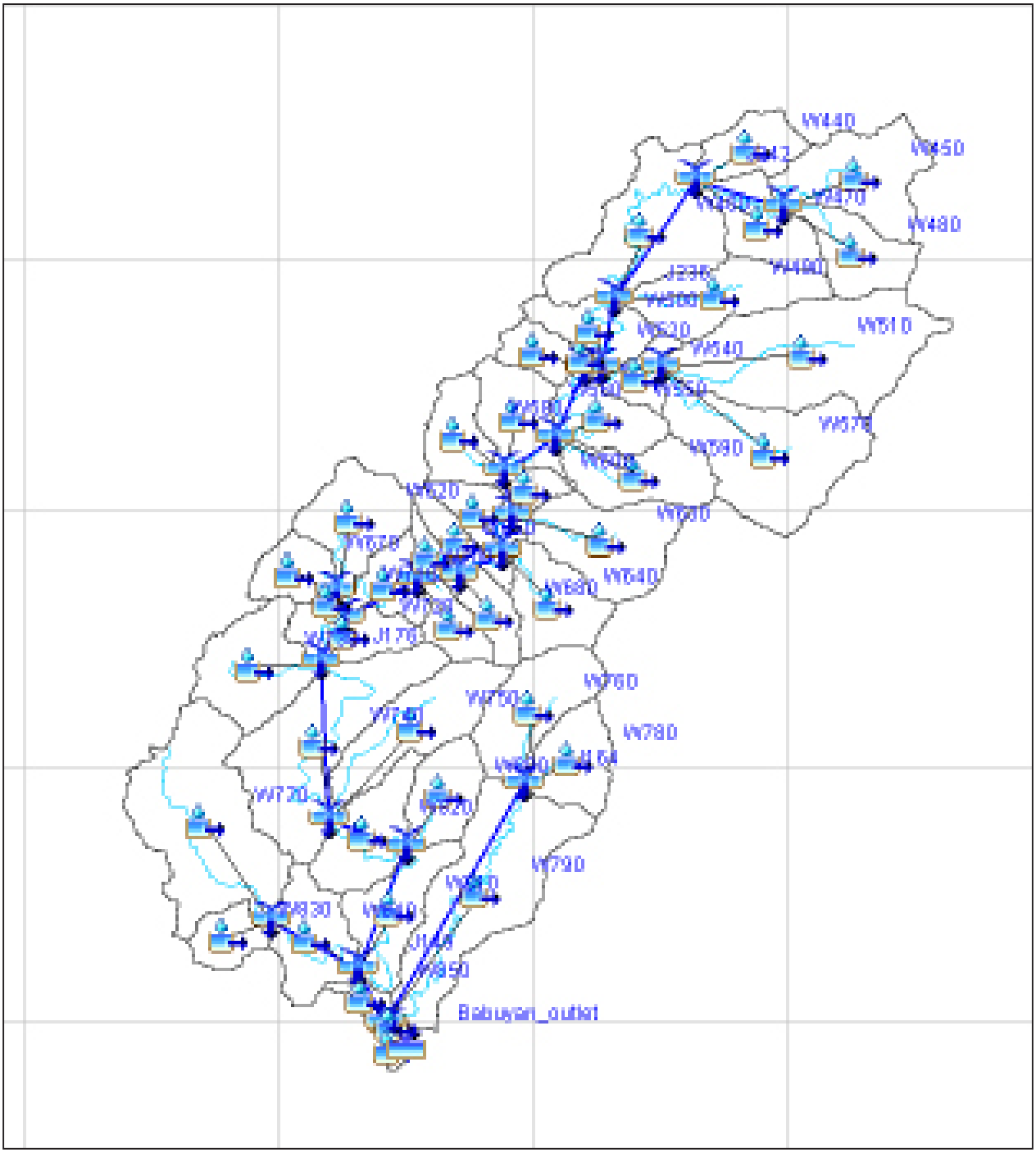


Figure 51. HEC-HMS generated Babuyan River Basin Model.

5.4 Cross-section Data

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

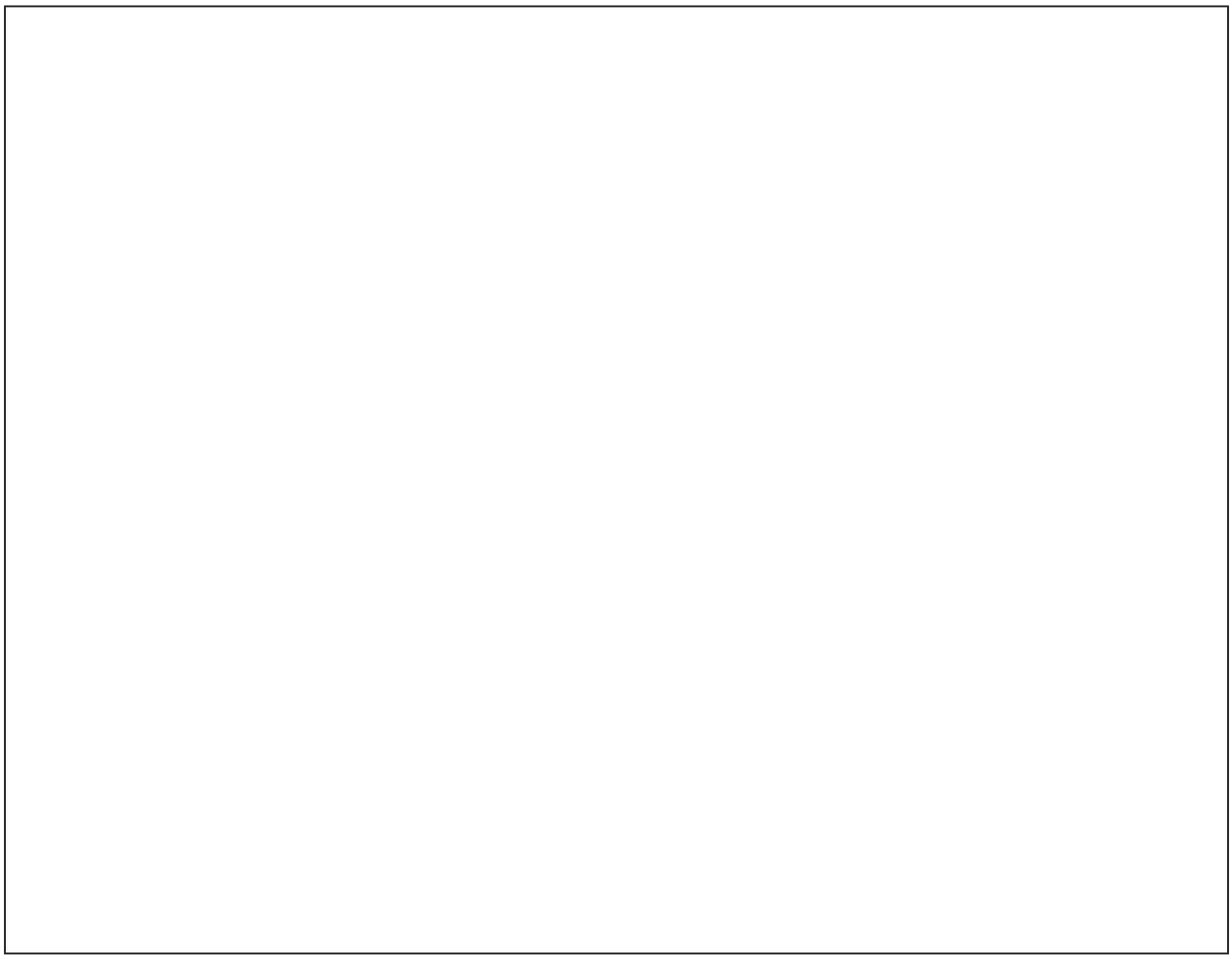


Figure 52. River cross-section of Babuyan River generated through Arcmap HEC GeoRAS tool

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 north of the model to the south, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

Figure 53. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 72.12463 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 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 72433632.00 m2.

There is a total of 54763737.72 m3 of water entering the model. Of this amount, 23061327.29 m3 is due to rainfall while 31702410.43 m3 is inflow from other areas outside the model. 6973149.50 m3 of this water is lost to infiltration and interception, while 29506537.74 m3 is stored by the flood plain. The rest, amounting up to 18284033.95 m3, is outflow.

5.6 HEC-HMS Model Values (Uncalibrated)

Enumerated in Table 30 are the range of values of the parameters in the model.

Table 30. Range of Calibrated Values for Babuyan River

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.0007 - 7
			Curve Number	35 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.03 - 2
			Storage Coefficient (hr)	0.03 - 9

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.0007 to 7mm means that there is no to minimal 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.

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 0.03 hours to 9 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.

5.7 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/ Phil-LiDAR 1 website.

Figure 54. Sample output of Babuyan RAS Model

5.8 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Babuyan floodplain are shown in Figure 55 to Figure 60. The floodplain, with an area of 72.66 sq. km., covers one municipality named Puerto Princesa City. Table 31 shows the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in Babuyan Floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Puerto Princesa City	2186.36	72.45	3.31

Figure 55. 100-year Flood Hazard Map for Babuyan Floodplain overlaid in Google Earth imagery

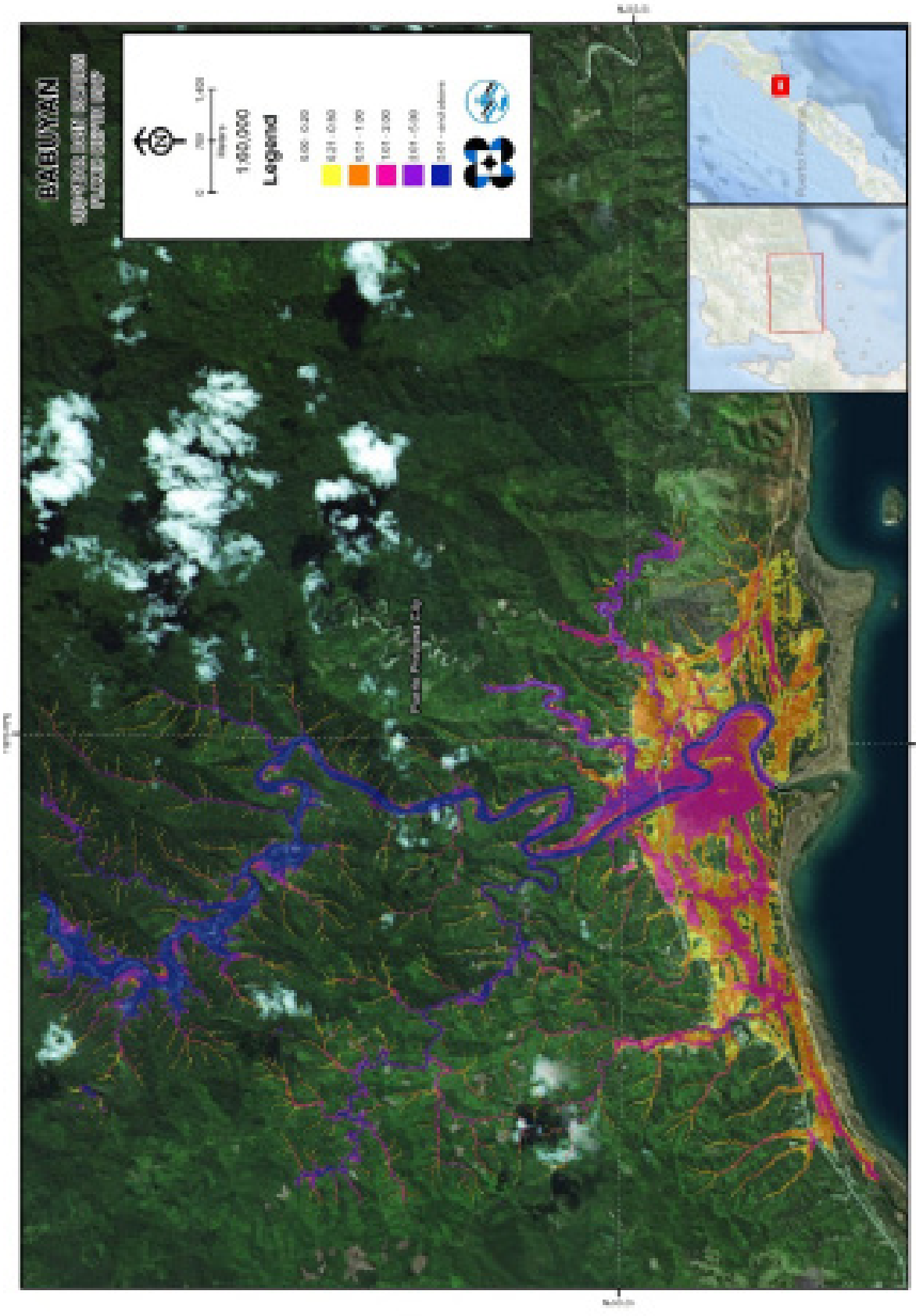


Figure 56. 100-year Flow Depth Map for Babuyan Floodplain overlaid in Google Earth imagery

Figure 57. 25-year Flood Hazard Map for Babuyan Floodplain overlaid in Google Earth imagery

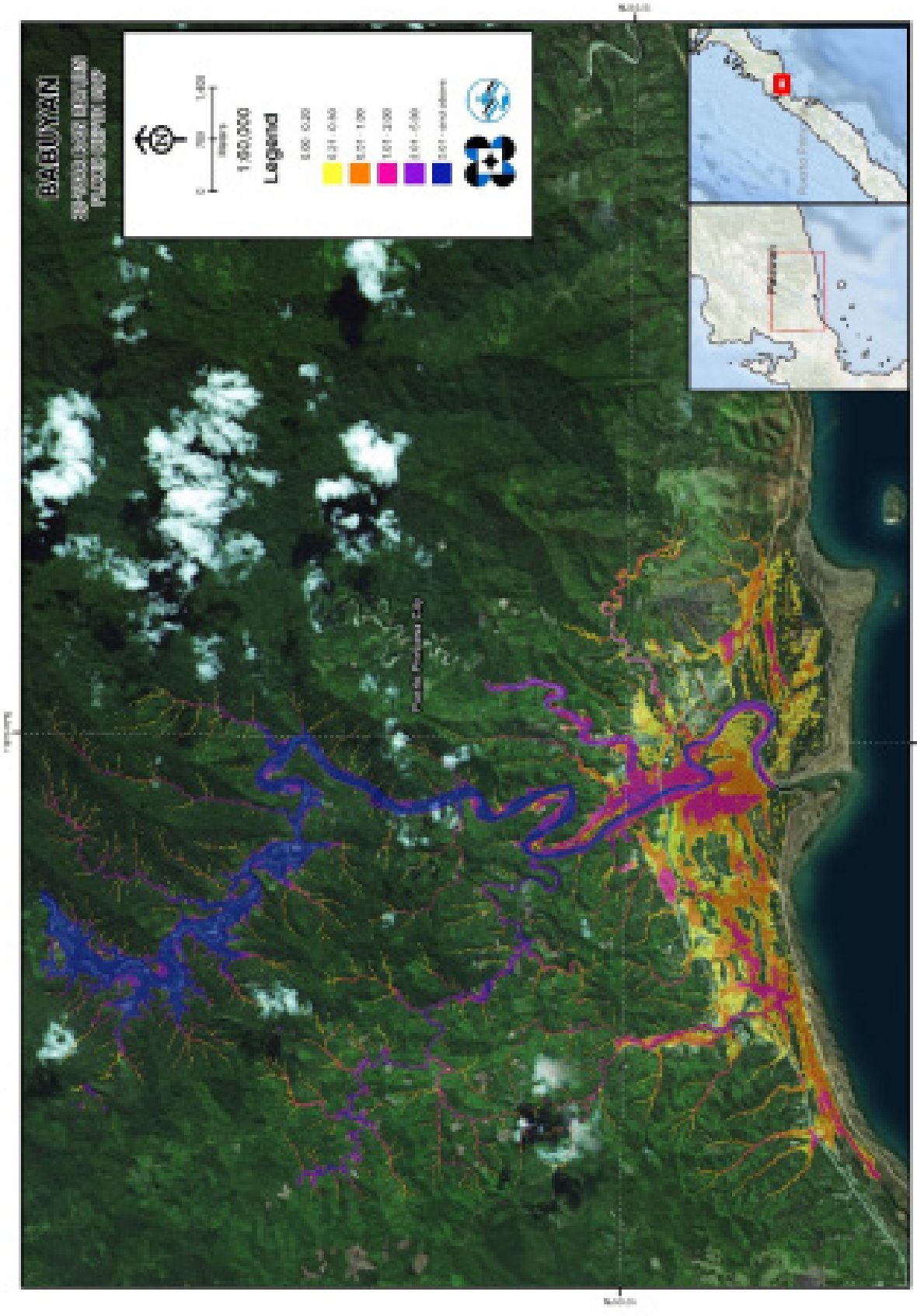


Figure 58. 25-year Flow Depth Map for Babuyan Floodplain overlaid in Google Earth imagery

Figure 59. 5-year Flood Hazard Map for Babuyan Floodplain overlaid in Google Earth imagery

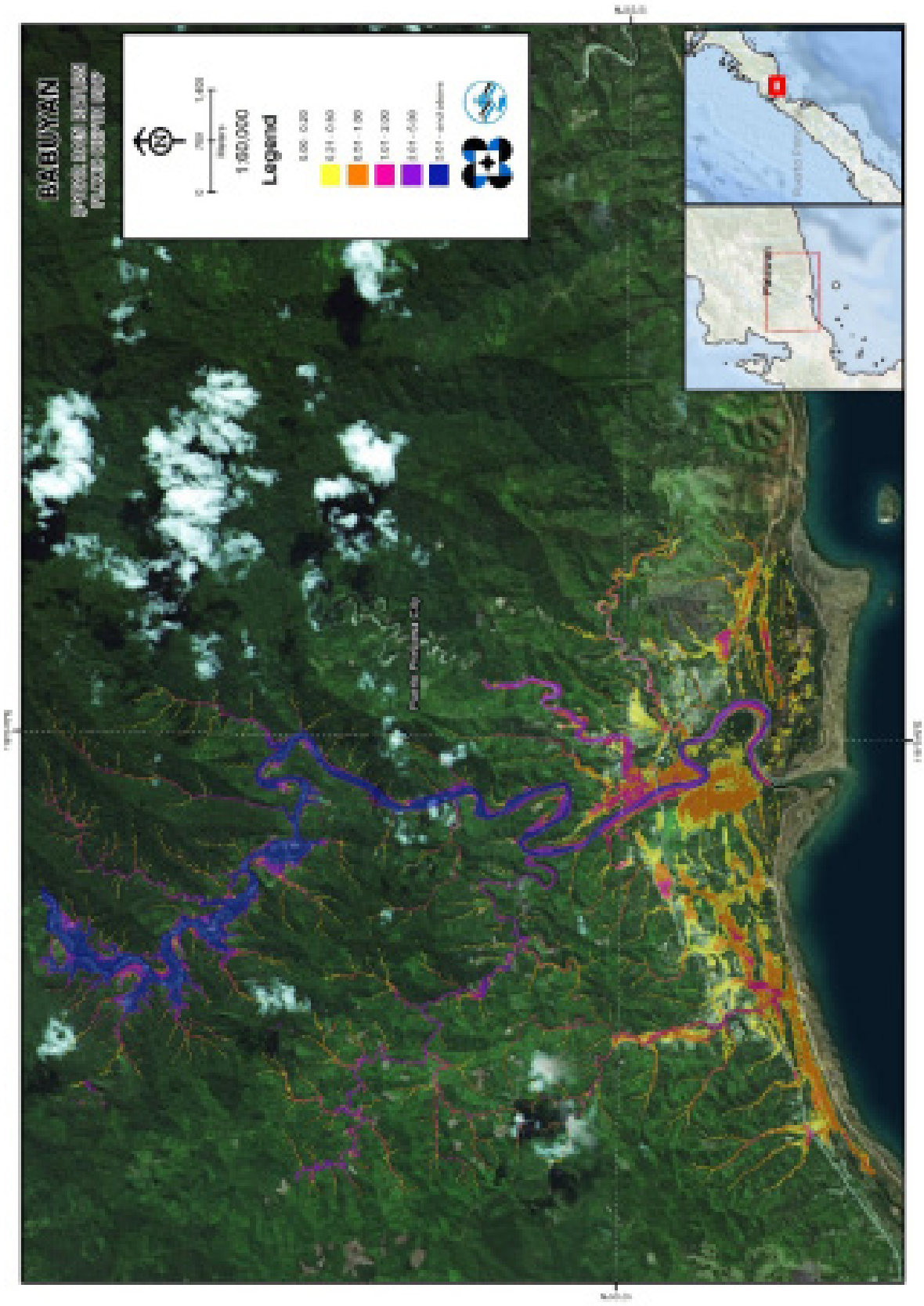


Figure 60. 5-year Flow Depth Map for Babuyan Floodplain overlaid in Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Babuyan River Basin, grouped accordingly by municipality. For the said basin, one (1) municipality consisting of 7 barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 2.72% of the municipality of Puerto Princesa City with an area of 2186.36 sq. km. will experience flood levels of less 0.20 meters, while 0.19% of the area will experience flood levels of 0.21 to 0.50 meters; 0.15%, 0.07%, 0.08%, and 0.1% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Table 32 and Figure 61 depict the areas affected in Puerto Princesa City in square kilometers by flood depth per barangay.

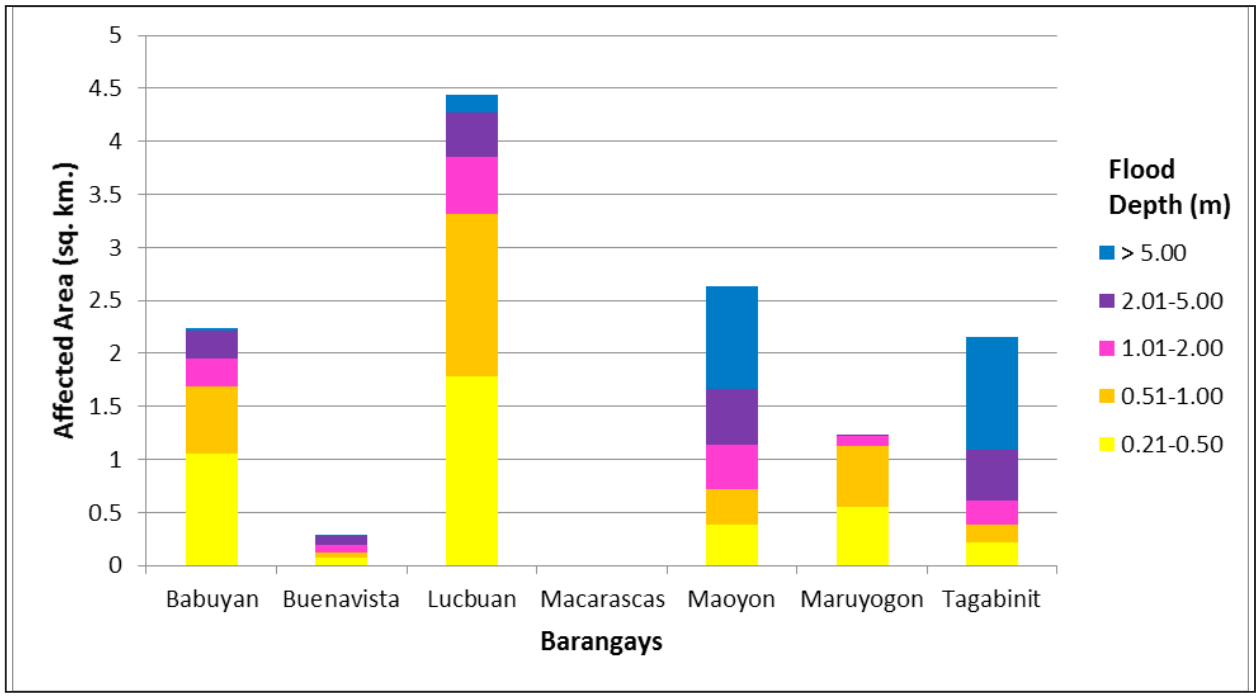


Figure 61. Affected areas in Puerto Princesa City, Palawan during a 5-Year Rainfall Return Period.

Table 32. Affected areas in Puerto Princesa City, Palawan during a 5-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Puerto Princesa City (in sq. km.)						
	Babuyan	Buenavista	Lucbuan	Macarascas	Maoyon	Maruyogon	Tagabinit
0.03-0.20	8.58	2.97	18.63	0.0014	13.16	6.09	10.04
0.21-0.50	1.06	0.073	1.78	0	0.39	0.55	0.22
0.51-1.00	0.63	0.054	1.53	0	0.33	0.58	0.17
1.01-2.00	0.26	0.066	0.54	0	0.42	0.088	0.22
2.01-5.00	0.26	0.087	0.42	0	0.52	0.013	0.48
> 5.00	0.032	0.0037	0.17	0	0.97	0	1.06

For the 25-year return period, 2.56% of the municipality of Puerto Princesa City with an area of 2186.36 sq. km. will experience flood levels of less 0.20 meters, while 0.2% of the area will experience flood levels of 0.21 to 0.50 meters; 0.19%, 0.12%, 0.09%, and 0.16% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Table 33 and Figure 62 depict the areas affected in Puerto Princesa City in square kilometers by flood depth per barangay.

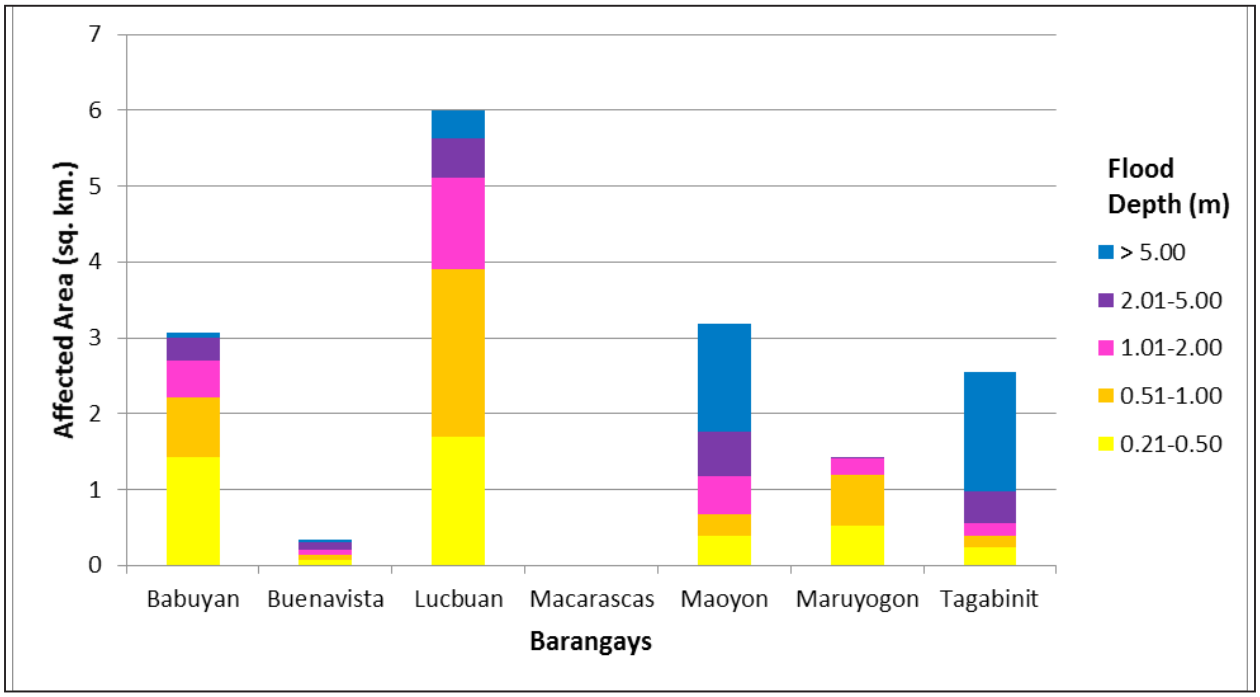


Figure 62. Affected areas in Puerto Princesa City, Palawan during a 25-Year Rainfall Return Period.

Table 33. Affected areas in Puerto Princesa City, Palawan during a 25-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Puerto Princesa City (in sq. km.)						
	Babuyan	Buenavista	Lucbuan	Macarascas	Maoyon	Maruyogon	Tagabinit
0.03-0.20	7.74	2.9	17.09	0.0014	12.61	5.9	9.65
0.21-0.50	1.42	0.077	1.7	0	0.38	0.53	0.23
0.51-1.00	0.8	0.055	2.2	0	0.3	0.66	0.15
1.01-2.00	0.48	0.067	1.21	0	0.49	0.22	0.18
2.01-5.00	0.3	0.11	0.52	0	0.59	0.02	0.41
> 5.00	0.07	0.036	0.36	0	1.42	0	1.57

For the 100-year return period, 2.47% of the municipality of Puerto Princesa City with an area of 2186.36 sq. km. will experience flood levels of less 0.20 meters, while 0.19% of the area will experience flood levels of 0.21 to 0.50 meters; 0.2%, 0.16%, 0.09%, and 0.19% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Table 34 and Figure 63 depict the areas affected in Puerto Princesa City in square kilometers by flood depth per barangay.

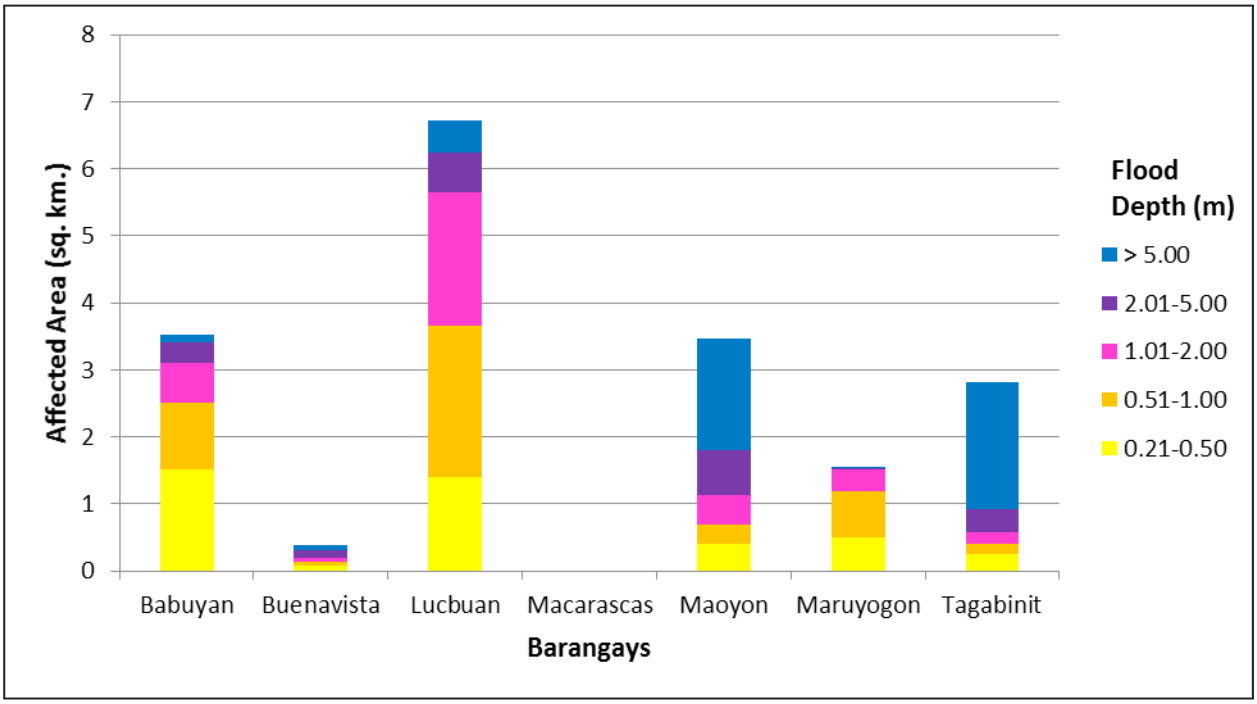


Figure 63. Affected areas in Puerto Princesa City, Palawan during a 100-Year Rainfall Return Period

Table 34. Affected areas in Puerto Princesa City, Palawan during a 100-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Puerto Princesa City (in sq. km.)						
	Babuyan	Buenavista	Lucbuan	Macarascas	Maoyon	Maruyogon	Tagabinit
0.03-0.20	7.28	2.86	16.36	0.0014	12.33	5.79	9.38
0.21-0.50	1.52	0.076	1.4	0	0.4	0.51	0.25
0.51-1.00	0.99	0.055	2.25	0	0.29	0.68	0.15
1.01-2.00	0.59	0.067	1.99	0	0.45	0.32	0.18
2.01-5.00	0.31	0.12	0.6	0	0.67	0.025	0.35
> 5.00	0.12	0.067	0.48	0	1.65	0.0002	1.89

Among the barangays in the municipality of Puerto Princesa City, Buenavista is projected to have the highest percentage of area that will experience flood levels of at 1.14%. On the other hand, Lucbuan posted the percentage of area that may be affected by flood depths of at 1.06%.

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 and through interviews with some residents who have 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 65.

The flood validation consisted of 138 points randomly selected all over the Babuyan flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.72m. Table 35 shows a contingency matrix of the comparison.

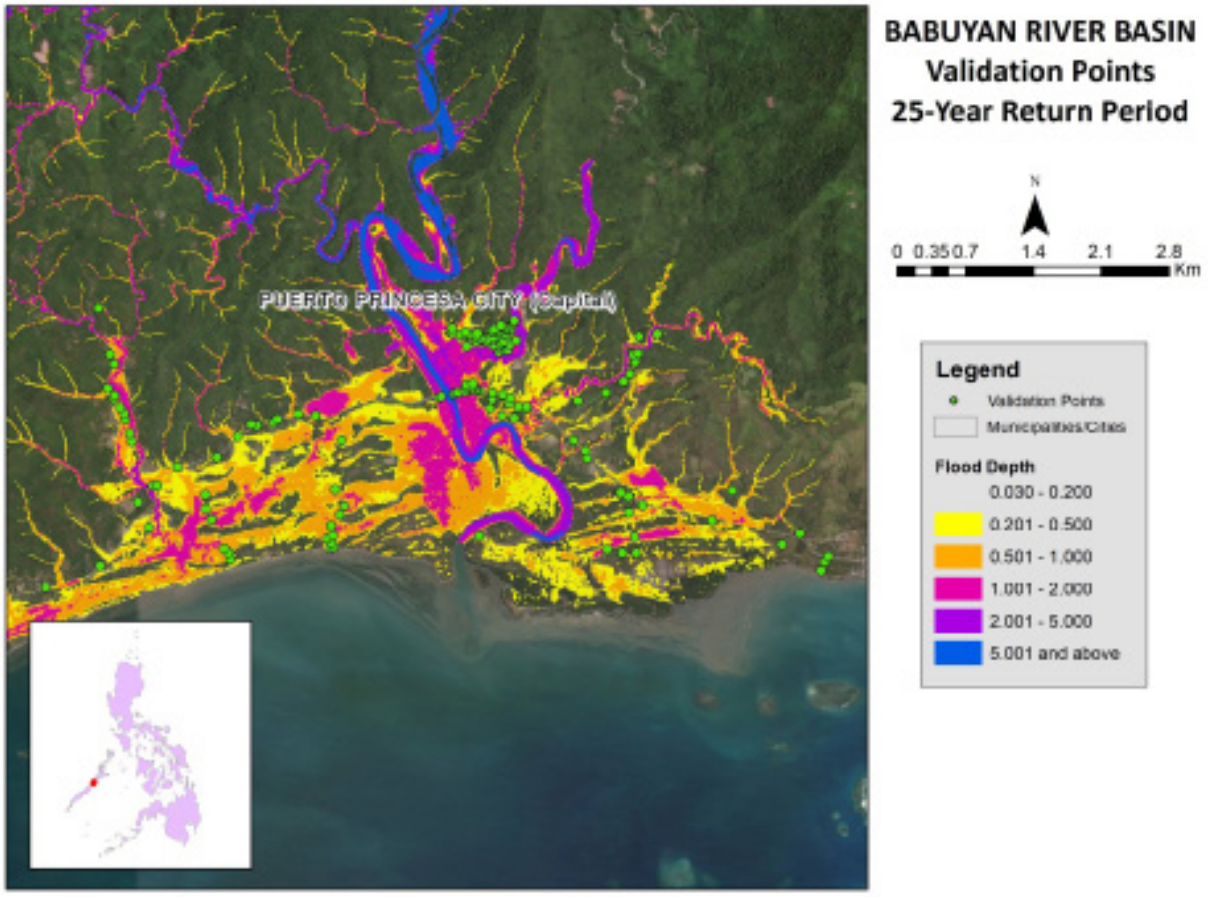


Figure 64. Validation points for 25-year Flood Depth Map of Babuyan Floodplain

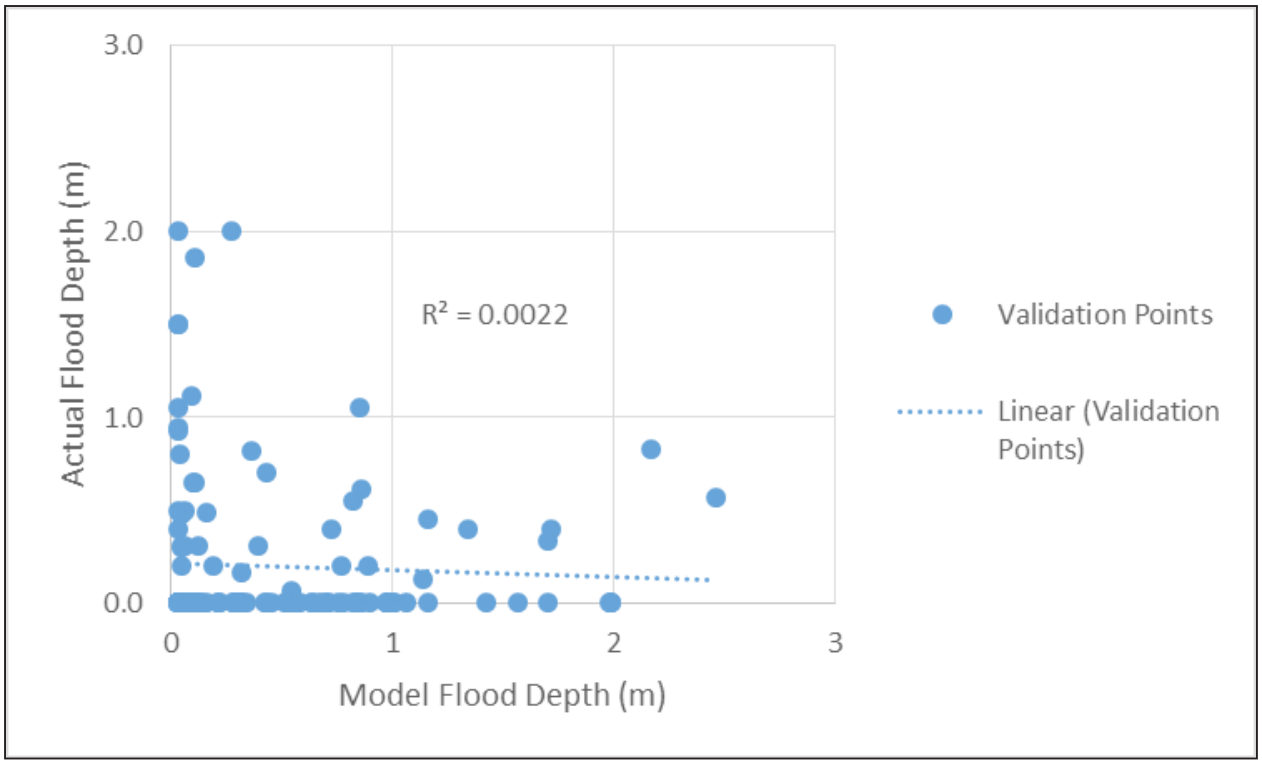


Figure 65. Flood map depth vs. actual flood depth

Table 35. Actual flood vs simulated flood depth at different levels in the Babuyan 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	51	15	27	10	0	0	103
0.21-0.50	10	1	1	4	0	0	16
0.51-1.00	5	2	2	0	2	0	11
1.01-2.00	6	1	1	0	0	0	8
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	72	19	31	14	2	0	138

The overall accuracy generated by the flood model is estimated at 39.13% with 54 points correctly matching the actual flood depths. In addition, there were 27 points estimated one level above and below the correct flood depths while there were 39 points and 16 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 25 points were underestimated in the modelled flood depths of Babuyan. Table 36 depicts the summary of the Accuracy Assessment in the Babuyan River Basin Survey..

Table 36. Summary of Accuracy Assessment in Babuyan River Basin Survey

	No. of Points	%
Correct	54	39.13
Overestimated	59	42.75
Underestimated	25	18.12
Total	138	100.00

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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

www.rappler.com, 2013, Palawan towns in state of calamity, retrieved from <http://www.rappler.com/move-ph/issues/disasters/typhoon-yolanda/43901-palawan-towns-state-calamity>

ANNEXES

Annex 1. Optech Technical Specification of the Pegasus and Gemini Sensors

1. PEGASUS SENSOR

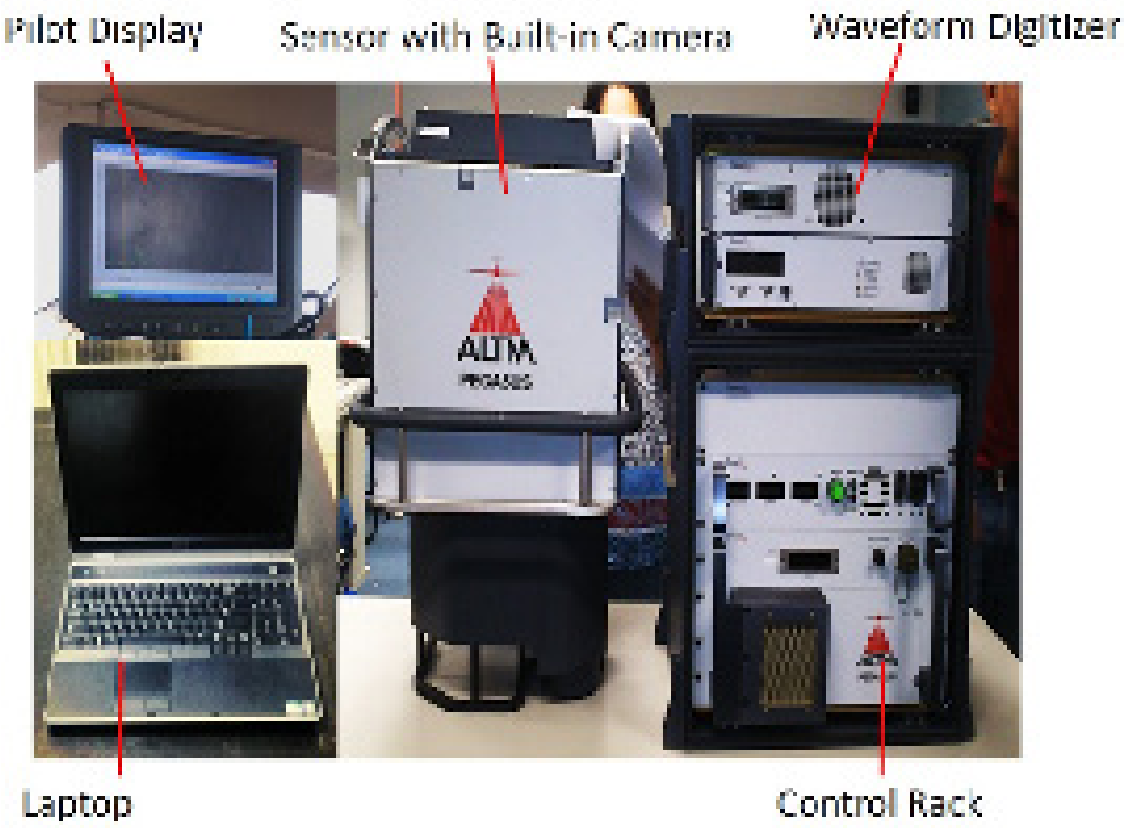


Figure A-1.1 Pegasus Sensor

2. PARAMETERS AND SPECIFICATIONS OF THE PEGASUS SENSOR

Table A-1.1 Parameters and Specifications of the Pegasus Sensor

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

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

1. GEMINI SENSOR

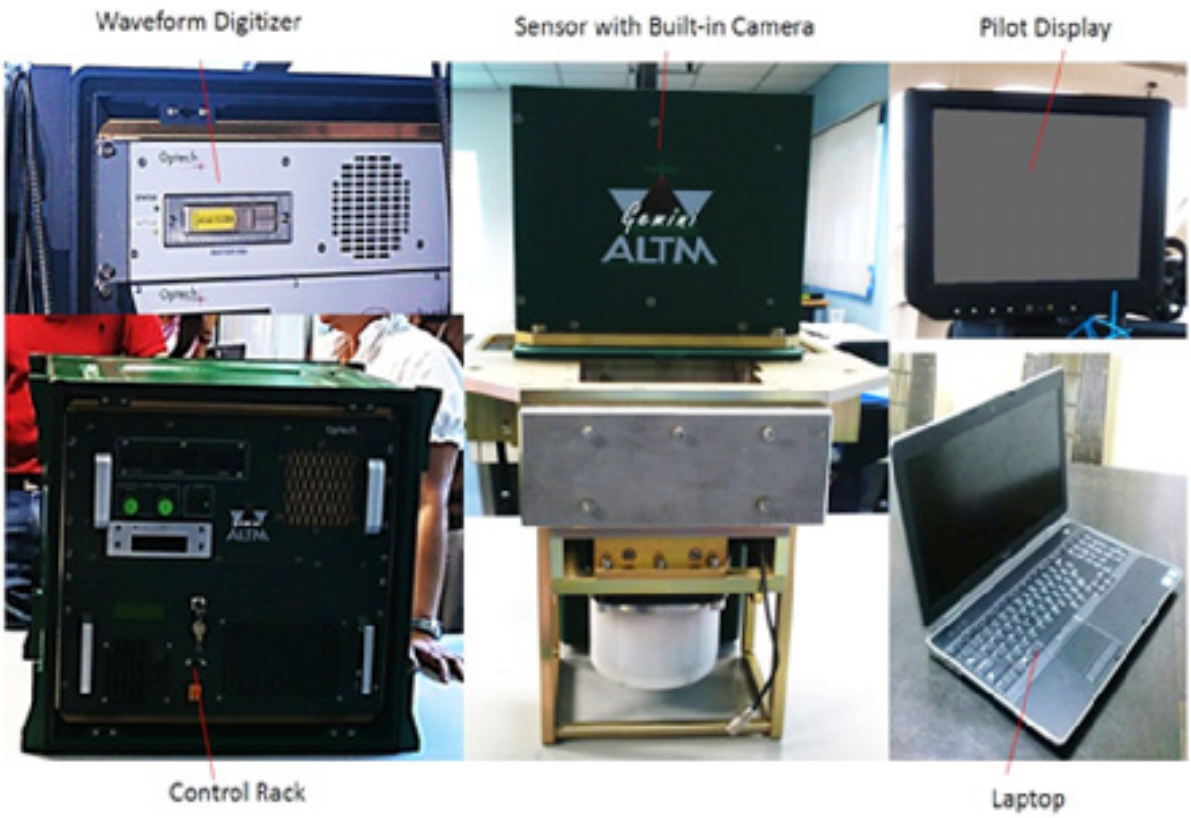


Figure A-1.2 Gemini Sensor

2. PARAMETERS AND SPECIFICATIONS OF THE GEMINI SENSOR

Table A-1.2 Parameters and Specifications of the Gemini Sensor

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

Annex 2. NAMRIA Certificates of Reference Points Used

1. PLW-23

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

December 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: **PALAWAN**		
	Station Name: **PLW-23**		
	Order: **1st**		
Island: **LUZON**	Barangay: **JOLO**		
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **10° 5' 19.52517"**	Longitude: **119° 12' 33.72062"**	Ellipsoidal Hgt:	**10.42700 m.**
	WGS84 Coordinates		
Latitude: **10° 5' 15.04804"**	Longitude: **119° 12' 39.01413"**	Ellipsoidal Hgt:	**61.07260 m.**
	PTM / PRS92 Coordinates		
Northing: **1115630.596 m.**	Easting: **577752.254 m.**	Zone:	**1A**
	UTM / PRS92 Coordinates		
Northing: **1,115,973.89**	Easting: **742,130.31**	Zone:	**50**

Location Description

PLW-23
From the municipality of Roxas, on the intersection at Andres Soriano Memorial Elementary School, travel southwest along the provincial highway for 39.3 kilometers or 1 hour and 25 minutes drive to Jolo elementary School. The station is located inside the compound of Jolo elementary school. It is Northwest 10.00 meters of the school building. Station mark is a cross cut on top of a 0.15 m x 0.012 m in diameter brass rod centered in a 0.30 m x 0.30 m x 1.0 m concrete block, flush with the ground surface and inscribed with station name. Sub-surface mark is a bottle set on concrete block; 68 cm. below station. Reference mark nos. 1,2,3 and 4 are cross cut on top of 0.15 m x 0.01 m in diameter brass rod in a 0.30 m x 0.30 m x 1 meter concrete block, flush with the ground surface, and inscribed with the reference mark numbers and with arrows pointing to the station.

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8088735 I**
T.N.: **2015-3960**

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

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph
ISO 9001:2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 PLW-13

2. PLW-34

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

June 15, 2015

CERTIFICATION

To whom it may concern:

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

Province: **PALAWAN**
Station Name: **PLW-34**
Order: **1st**

Island: **LUZON**
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**
Barangay: **STA. MONICA**
MSL Elevation:

PRS92 Coordinates

Latitude: **9° 47' 4.34345"** Longitude: **118° 43' 50.36738"** Ellipsoidal Hgt: **53.76200 m.**

WGS84 Coordinates

Latitude: **9° 46' 59.90069"** Longitude: **118° 43' 55.68915"** Ellipsoidal Hgt: **103.89600 m.**

PTM / PRS92 Coordinates

Northing: **1081910.004 m.** Easting: **525304.737 m.** Zone: **1A**

UTM / PRS92 Coordinates

Northing: **1,082,009.99** Easting: **689,825.58** Zone: **50**

Location Description

PLW-34
From the wharf of Philippine Ports Authority in Puerto Princesa city, travel eastward on a 2 wheel drive vehicle, along Rizal street up to the National highway for 1.80 kilometers. Turn turn left, travel Northwest along the national highway for 5.50 kilometers up to the cemented road that leads to the City Hall. Turn left and travel alonf the cemented road for 0.75 kilometers up to the station. Station is located on top of the roof deck of the city Mayor's office. Station mark is 4" copper nail with cross cut on top centered in a 30 cm square cement patty, protruding about 1 cm on the semi-circle shaped concrete roofed deck of Puerto Princesa City Hall.

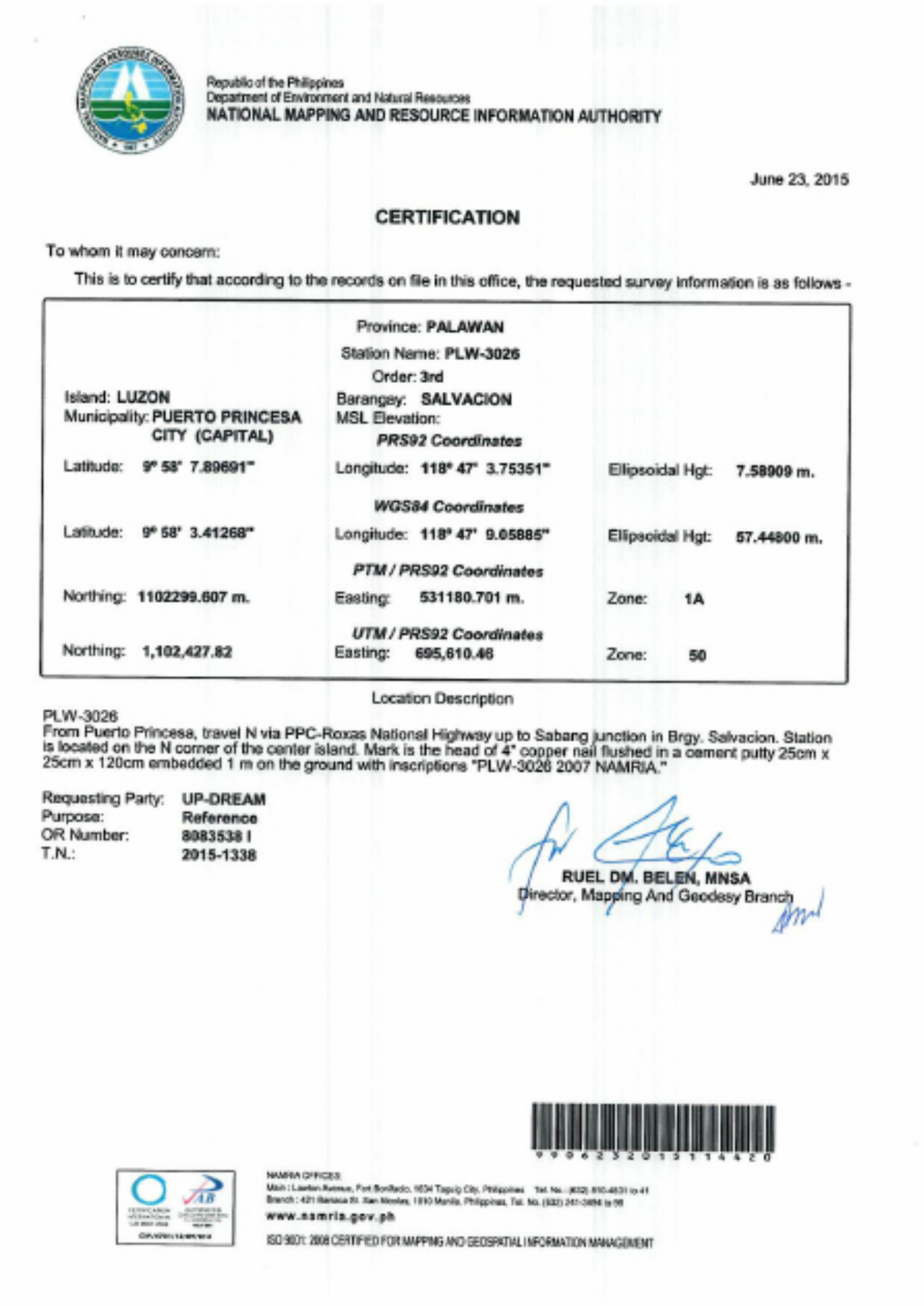
Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8084005 I**
T.N.: **2015-1264**

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

NAMRIA OFFICES
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph
ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2 PLW-34

3. PLW-3026



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

June 23, 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: **PALAWAN**		
	Station Name: **PLW-3026**		
	Order: **3rd**		
Island: **LUZON**	Barangay: **SALVACION**		
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **9° 58' 7.89691"**	Longitude: **118° 47' 3.75351"**	Ellipsoidal Hgt:	**7.58909 m.**
	WGS84 Coordinates		
Latitude: **9° 58' 3.41268"**	Longitude: **118° 47' 9.05885"**	Ellipsoidal Hgt:	**57.44800 m.**
	PTM / PRS92 Coordinates		
Northing: **1102299.607 m.**	Easting: **531180.701 m.**	Zone:	**1A**
	UTM / PRS92 Coordinates		
Northing: **1,102,427.82**	Easting: **695,610.46**	Zone:	**50**

Location Description

PLW-3026
From Puerto Princesa, travel N via PPC-Roxas National Highway up to Sabang junction in Brgy. Salvacion. Station is located on the N corner of the center island. Mark is the head of 4" copper nail flushed in a cement putty 25cm x 25cm x 120cm embedded 1 m on the ground with inscriptions "PLW-3026 2007 NAMRIA."

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8983538 I**
T.N.: **2015-1338**

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

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) 241-3894 to 98
www.namria.gov.ph
ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3 PLW-3026

Annex 3. Baseline Processing Report of Reference Points Used

Vector Components (Mark to Mark)

From:	PLW-34				
Grid		Local		Global	
Easting	689825.571 m	Latitude	N9°47'04.34346"	Latitude	N9°46'59.90069"
Northing	1082009.987 m	Longitude	E118°43'50.36738"	Longitude	E118°43'55.68915"
Elevation	53.466 m	Height	53.762 m	Height	103.896 m

To:	PLW-3026				
Grid		Local		Global	
Easting	695610.418 m	Latitude	N9°58'07.89863"	Latitude	N9°58'03.41442"
Northing	1102427.869 m	Longitude	E118°47'03.75221"	Longitude	E118°47'09.05751"
Elevation	7.024 m	Height	7.504 m	Height	57.363 m

Vector					
ΔEasting	5784.847 m	NS Fwd Azimuth	16°06'56"	ΔX	-3460.453 m
ΔNorthing	20417.882 m	Ellipsoid Dist.	21220.288 m	ΔY	-5939.795 m
ΔElevation	-46.442 m	ΔHeight	-46.258 m	ΔZ	20076.102 m

Standard Errors

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

Figure A-3.1 Baseline Processing Report - A

Vector Components (Mark to Mark)

From:	PLW-34				
Grid		Local		Global	
Easting	689825.571 m	Latitude	N9°47'04.34346"	Latitude	N9°46'59.90069"
Northing	1082009.987 m	Longitude	E118°43'50.36738"	Longitude	E118°43'55.68915"
Elevation	53.466 m	Height	53.762 m	Height	103.896 m

To:	PLW-4011				
Grid		Local		Global	
Easting	707163.027 m	Latitude	N10°11'54.13011"	Latitude	N10°11'49.59791"
Northing	1127879.807 m	Longitude	E118°53'27.82551"	Longitude	E118°53'33.11019"
Elevation	3.616 m	Height	4.146 m	Height	53.754 m

Vector					
ΔEasting	17337.456 m	NS Fwd Azimuth	21°00'21"	ΔX	-11558.541 m
ΔNorthing	45869.821 m	Ellipsoid Dist.	49032.695 m	ΔY	-15476.070 m
ΔElevation	-49.850 m	ΔHeight	-49.616 m	ΔZ	45067.770 m

Figure A-3.2 Baseline Processing Report - B

Vector Components (Mark to Mark)

From:	PLW-23				
Grid		Local		Global	
Easting	84385.264 m	Latitude	N10°05'19.52518"	Latitude	N10°05'15.04804"
Northing	1117566.788 m	Longitude	E119°12'33.72062"	Longitude	E119°12'39.01413"
Elevation	9.470 m	Height	10.427 m	Height	61.073 m

To:	PLW-4030				
Grid		Local		Global	
Easting	84042.662 m	Latitude	N10°04'56.95146"	Latitude	N10°04'52.47562"
Northing	1116875.986 m	Longitude	E119°12'22.75168"	Longitude	E119°12'28.04576"
Elevation	10.228 m	Height	11.183 m	Height	61.835 m

Vector					
ΔEasting	-342.602 m	NS Fwd Azimuth	205°42'51"	ΔX	231.869 m
ΔNorthing	-690.802 m	Ellipsoid Dist.	769.753 m	ΔY	269.625 m
ΔElevation	0.758 m	ΔHeight	0.756 m	ΔZ	-682.686 m

Standard Errors

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

Figure A-3.3 Baseline Processing Report - C

Vector Components (Mark to Mark)

From:	PLW-3026				
Grid		Local		Global	
Easting	695610.414 m	Latitude	N9°58'07.89864"	Latitude	N9°58'03.41443"
Northing	1102427.869 m	Longitude	E118°47'03.75205"	Longitude	E118°47'09.05735"
Elevation	7.058 m	Height	7.537 m	Height	57.396 m

To:	PL-38				
Grid		Local		Global	
Easting	695384.782 m	Latitude	N9°57'59.62464"	Latitude	N9°57'55.14081"
Northing	1102172.433 m	Longitude	E118°46'56.29975"	Longitude	E118°47'01.60525"
Elevation	7.275 m	Height	7.756 m	Height	57.615 m

Vector					
ΔEasting	-225.631 m	NS Fwd Azimuth	221°45'49"	ΔX	177.646 m
ΔNorthing	-255.436 m	Ellipsoid Dist.	340.793 m	ΔY	148.044 m
ΔElevation	0.217 m	ΔHeight	0.219 m	ΔZ	-250.329 m

Standard Errors

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

Figure A-3.4 Baseline Processing Report - D

Vector Components (Mark to Mark)

From:	PLW-34				
Grid		Local		Global	
Easting	689825.571 m	Latitude	N9°47'04.34346"	Latitude	N9°46'59.90069"
Northing	1082009.987 m	Longitude	E118°43'50.36738"	Longitude	E118°43'55.68915"
Elevation	53.466 m	Height	53.762 m	Height	103.896 m

To:	PPC-1				
Grid		Local		Global	
Easting	707137.228 m	Latitude	N10°11'54.83823"	Latitude	N10°11'50.30596"
Northing	1127901.415 m	Longitude	E118°53'26.98215"	Longitude	E118°53'32.26682"
Elevation	3.473 m	Height	4.002 m	Height	53.609 m

Vector					
ΔEasting	17311.657 m	NS Fwd Azimuth	20°58'07"	ΔX	-11534.136 m
ΔNorthing	45891.429 m	Ellipsoid Dist.	49043.798 m	ΔY	-15467.164 m
ΔElevation	-49.993 m	ΔHeight	-49.760 m	ΔZ	45089.156 m

Standard Errors

Vector errors:					
σ ΔEasting	0.017 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.024 m
σ ΔNorthing	0.013 m	σ Ellipsoid Dist.	0.018 m	σ ΔY	0.010 m
σ ΔElevation	0.022 m	σ ΔHeight	0.022 m	σ ΔZ	0.017 m

Figure A-3.5 Baseline Processing Report - E

Vector Components (Mark to Mark)

From:	PLW-7				
Grid		Local		Global	
Easting	32230.670 m	Latitude	N9°44'29.76476"	Latitude	N9°44'25.33347"
Northing	1079722.760 m	Longitude	E118°44'20.28049"	Longitude	E118°44'25.60607"
Elevation	36.677 m	Height	36.867 m	Height	87.116 m

To:	PVP1				
Grid		Local		Global	
Easting	33860.371 m	Latitude	N9°44'31.66247"	Latitude	N9°44'27.23233"
Northing	1079760.689 m	Longitude	E118°45'13.60677"	Longitude	E118°45'18.93228"
Elevation	17.009 m	Height	17.172 m	Height	67.457 m

Vector					
ΔEasting	1629.701 m	NS Fwd Azimuth	87°56'40"	ΔX	-1410.961 m
ΔNorthing	37.929 m	Ellipsoid Dist.	1626.402 m	ΔY	-807.369 m
ΔElevation	-19.668 m	ΔHeight	-19.695 m	ΔZ	54.174 m

Standard Errors

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

Figure A-3.6 Baseline Processing Report - F

Vector Components (Mark to Mark)

From:	PVP1				
Grid		Local		Global	
Easting	33860.371 m	Latitude	N9°44'31.66247"	Latitude	N9°44'27.23233"
Northing	1079760.689 m	Longitude	E118°45'13.60677"	Longitude	E118°45'18.93228"
Elevation	17.009 m	Height	17.172 m	Height	67.457 m

To:	PVP1A				
Grid		Local		Global	
Easting	33862.011 m	Latitude	N9°44'32.50133"	Latitude	N9°44'28.07113"
Northing	1079786.501 m	Longitude	E118°45'13.64985"	Longitude	E118°45'18.97534"
Elevation	16.947 m	Height	17.110 m	Height	67.394 m

Vector					
ΔEasting	1.640 m	NS Fwd Azimuth	2°54'59"	ΔX	0.977 m
ΔNorthing	25.812 m	Ellipsoid Dist.	25.805 m	ΔY	-4.508 m
ΔElevation	-0.063 m	ΔHeight	-0.062 m	ΔZ	25.389 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'02"	σ ΔX	0.000 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.000 m
σ ΔElevation	0.000 m	σ ΔHeight	0.000 m	σ ΔZ	0.000 m

Figure A-3.7 Baseline Processing Report - G

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. The LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
		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)	JASMINE ALVIAR	UP-TCAGP
	SSRS	ENGR. GEROME HIPOLITO	UP-TCAGP
	Research Associate (RA)	GRACE SINADJAN	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
	RA	MARY CATHERINE BALIGUAS	UP-TCAGP
	RA	JONATHAN ALMALVEZ	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. ERIC CACANINDIN	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. MARK LAWRENCE TANGONAN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JUSTIN JOYA	AAC
		CAPT. RANDY LAGCO	AAC

Annex 5. Data Transfer Sheet For Babuyan Floodplain

DATA TRANSFER SHEET
6/23/2015(West Palawan)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	PDS	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	
30-May	2989P	1BLK42E150A	PEGASUS	2.9	NA	9.95	253	55	409	31.5	79.2	4.97	1KB	1KB	101/74/58/79/69/229	na	Z:\DAC\RAW DATA
4-Jun	3009P	1BLK42F155A	PEGASUS	1.63	1235	5.12	166	4.27/20.2	32/154	15.3	na	4.66	1KB	1KB	41/40/76/61	na	Z:\DAC\RAW DATA
6-Jun	3017A	1BLK42A157A	PEGASUS	1.17	334	9.55	259	55.9	400	29.2	na	14.2	1KB	1KB	41/72/40/79/51/07/61	na	Z:\DAC\RAW DATA
7-Jun	3021P	1BLK42BD158A	PEGASUS	980	1082	5.28	139	24.7	193	11.9	na	12.1	1KB	1KB	75/89/32	na	Z:\DAC\RAW DATA
7-Jun	3023P	1BLK42BCAL158B	PEGASUS	1.14	1368	9.2	249	37.4	303	21.9	na	15.1	1KB	1KB	32	na	Z:\DAC\RAW DATA

Received from

Name C. SORIANO
Position RA
Signature

Received by

Name JOMMER MEDINA
Position SENIOR SRS
Signature 6/23/2015

Figure A-5.1. Data Transfer Sheet for Babuyan Floodplain - A

DATA TRANSFER SHEET

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS Output LAS	RAW LAS KML (swath)	LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S) BASE STATION(S)	BASE STATION(S) Base Info (.txt)	OPERATOR LOGS (OPLOG)	FLIGHT PLAN Actual	FLIGHT PLAN KML	SERVER LOCATION
8-Jun-15	3025P	[illegible]	Pegasus	1.04	1365	7.48	187	23.8	246	16.1	NA	7.00	1KB	1KB	1428	na	Z:\DAC\RAW DATA
8-Jun-15	3027P	[illegible]	Pegasus	482	175	5.28	130	15.6	145	10.5	30.2	5.15	1KB	1KB	24	na	Z:\DAC\RAW DATA
11-Jun	3037P	1BLK42UJ162A	Pegasus	1.03	na	13.1	277	45.2	389	21.8	21.7	1.05	1KB	1KB	37/71	na	Z:\DAC\RAW DATA
11-Jun	3039P	1BLK42J162B	Pegasus	868	na	7.09	167	30.4	140/67	17.6	47.6	3.9	1KB	1KB	37/62/68/71	na	Z:\DAC\RAW DATA
12-Jun	3043P	1BLK42B163A	Pegasus	863	na	5.68	120	17	130	11.6	na	8.33	1KB	1KB	58	na	Z:\DAC\RAW DATA
13-Jun	3045P	1BLK42BS164A	Pegasus	589	na	6.01	164	16.7	118	10.6	na	7.09	1KB	1KB	52	na	Z:\DAC\RAW DATA
13-Jun	3047P	1BLK42A164B	Pegasus	1.4	na	15.9	321	65.6	434	10.6	73	5.69	1KB	1KB	114	na	Z:\DAC\RAW DATA
17-Jun	3061P	1BLK42AD168A	Pegasus	1.5	na	16.7	306	30.8	106/162/64	24.4	na	5.03	1KB	1KB	06/66/56	na	Z:\DAC\RAW DATA
* 21-Feb	7814AC	[illegible]	Aquarius	NA	54	91.5	56.1	6.53	31.1/73.6	1.48	na	3.88	1KB	1KB	4	NA	Z:\DAC\RAW DATA

* CALIBRATION FLIGHT

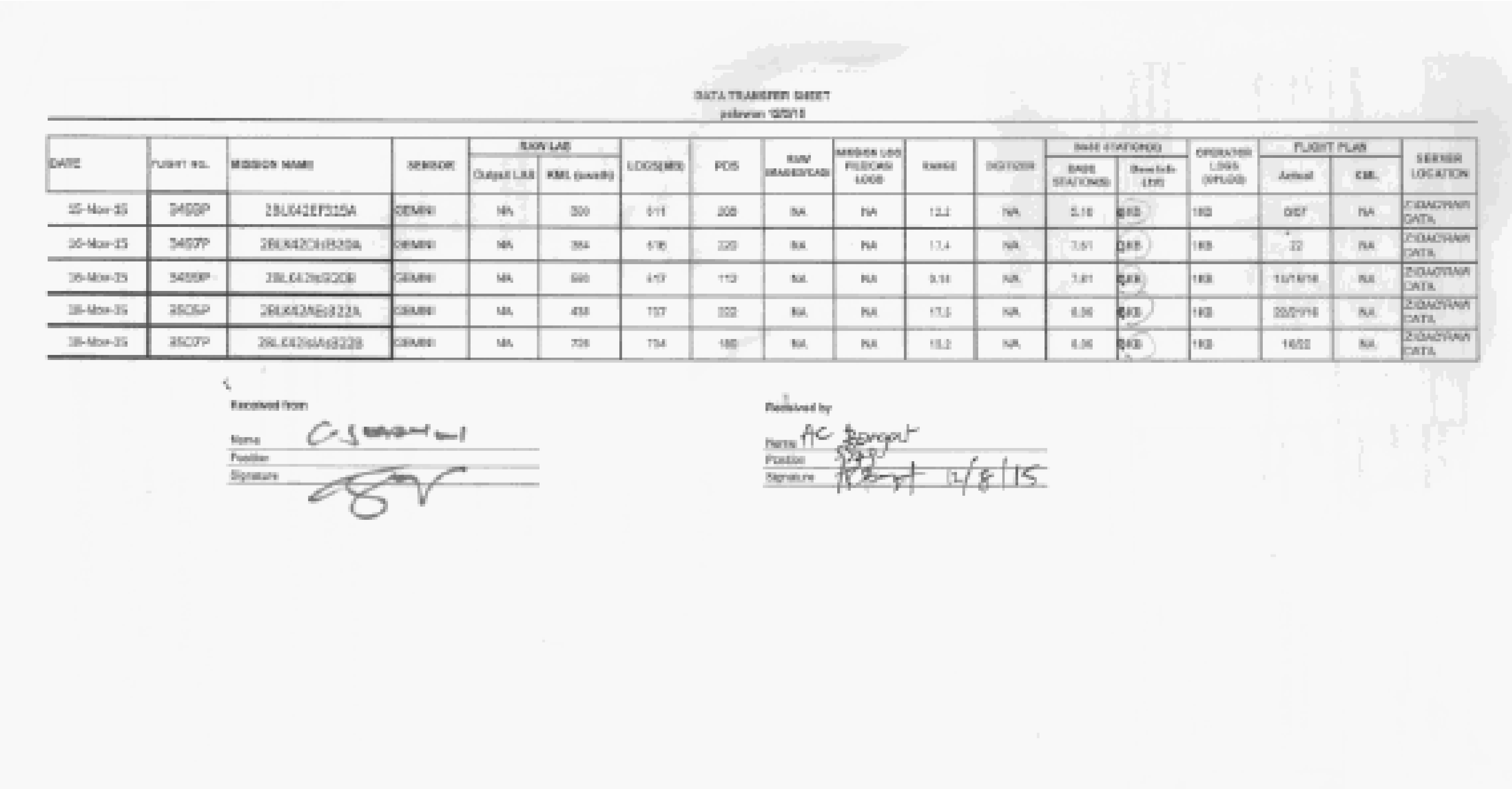
Received from

Name C. JOAQUIN
Position RA
Signature

Received by

Name JOIDA PRIETO 7/13/15
Position SSRS
Signature

Figure A-5.2. Data Transfer Sheet for Babuyan Floodplain - B



DATA TRANSFER SHEET

[illegible] 12/2/15

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	
15-Nov-15	3493P	2BLK42EFS15A	GEMINI	NA	300	[illegible]	208	NA	NA	12.2	NA	5.16	1KB	1KB	[illegible]	NA	Z:\DAC\RAW DATA
16-Nov-15	3497P	2BLK42CbS320A	GEMINI	NA	384	[illegible]	220	NA	NA	17.4	NA	7.51	1KB	1KB	22	NA	Z:\DAC\RAW DATA
16-Nov-15	3499P	2BLK42[illegible]S320B	GEMINI	NA	590	[illegible]	112	NA	NA	9.11	NA	7.81	1KB	1KB	[illegible]	NA	Z:\DAC\RAW DATA
18-Nov-15	3505P	2BLK42AEjS322A	GEMINI	NA	458	737	222	NA	NA	17.3	NA	6.06	1KB	1KB	[illegible]	NA	Z:\DAC\RAW DATA
18-Nov-15	3507P	2BLK42[illegible]S322B	GEMINI	NA	728	734	180	NA	NA	15.2	NA	6.06	1KB	1KB	16/22	NA	Z:\DAC\RAW DATA

Received from

Name: C. J. [illegible]

Position

Signature

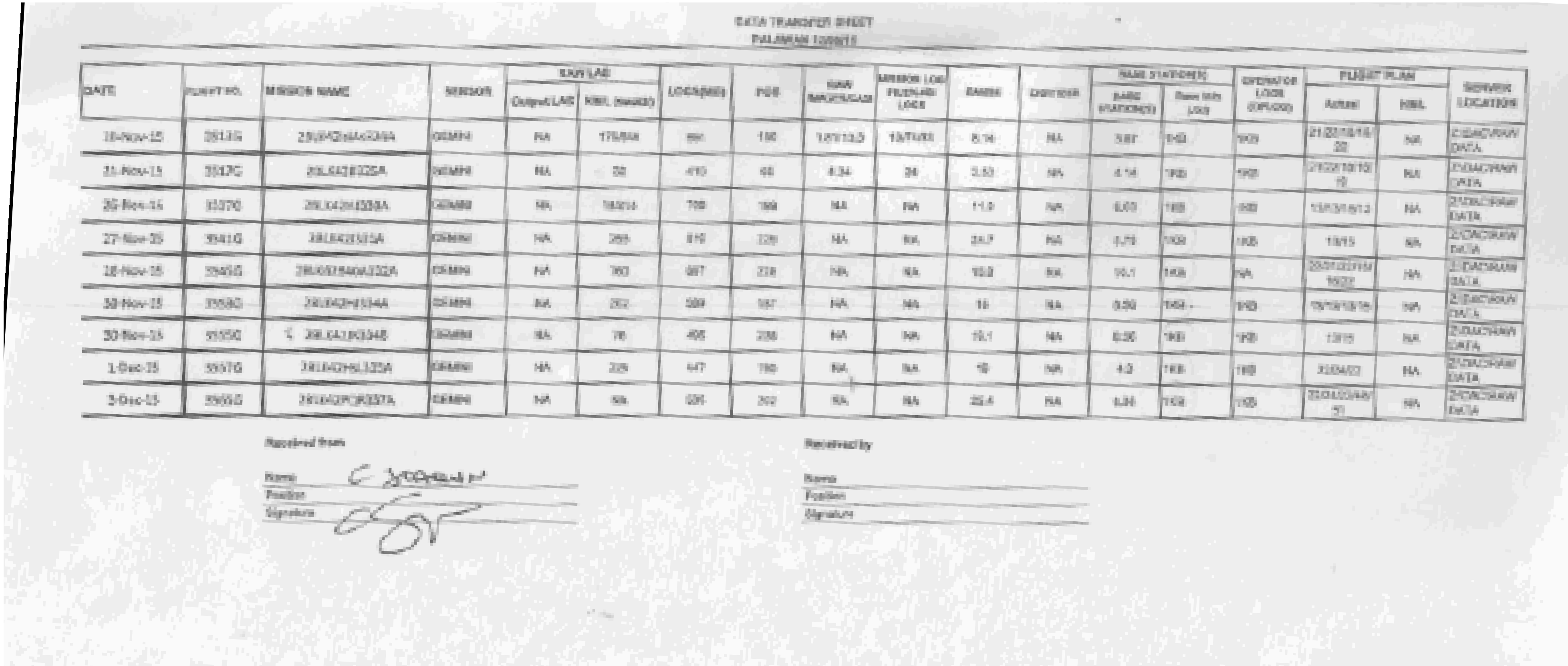
Received by

Name: AC Bongat

Position

Signature 12/8/15

Figure A-5.3. Data Transfer Sheet for Babuyan Floodplain - C



DATA TRANSFER SHEET
PALAWAN [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	
19-Nov-15	3513G	[illegible]	GEMINI	NA	175/NA	[illegible]	190	[illegible]	[illegible]	8.16	NA	5.87	1KB	1KB	21 22 [illegible]	NA	Z:\DAC\RAW DATA
21-Nov-15	3517G	[illegible]	GEMINI	NA	22	410	68	4.34	24	3.53	NA	4.14	1KB	1KB	[illegible]	NA	Z:\DAC\RAW DATA
26-Nov-15	3527G	[illegible]	GEMINI	NA	[illegible]	709	199	NA	NA	11.9	NA	6.03	1KB	1KB	[illegible]	NA	Z:\DAC\RAW DATA
27-Nov-15	3541G	[illegible]	GEMINI	NA	269	819	229	NA	NA	24.7	NA	4.79	1KB	1KB	13/15	NA	Z:\DAC\RAW DATA
28-Nov-15	3545G	[illegible]	GEMINI	NA	160	687	228	NA	NA	10.8	NA	10.1	1KB	NA	[illegible]	NA	Z:\DAC\RAW DATA
30-Nov-15	3553G	[illegible]	GEMINI	NA	262	589	187	NA	NA	19	NA	6.59	1KB	1KB	[illegible]	NA	Z:\DAC\RAW DATA
30-Nov-15	3555G	[illegible]	GEMINI	NA	78	405	238	NA	NA	10.1	NA	6.56	1KB	1KB	13/15	NA	Z:\DAC\RAW DATA
1-Dec-15	3557G	[illegible]	GEMINI	NA	229	447	190	NA	NA	10	NA	4.3	1KB	1KB	[illegible]	NA	Z:\DAC\RAW DATA
3-Dec-15	3565G	[illegible]	GEMINI	NA	NA	226	202	NA	NA	25.4	NA	6.84	1KB	1KB	[illegible]	NA	Z:\DAC\RAW DATA

Received from

Name
Position
Signature

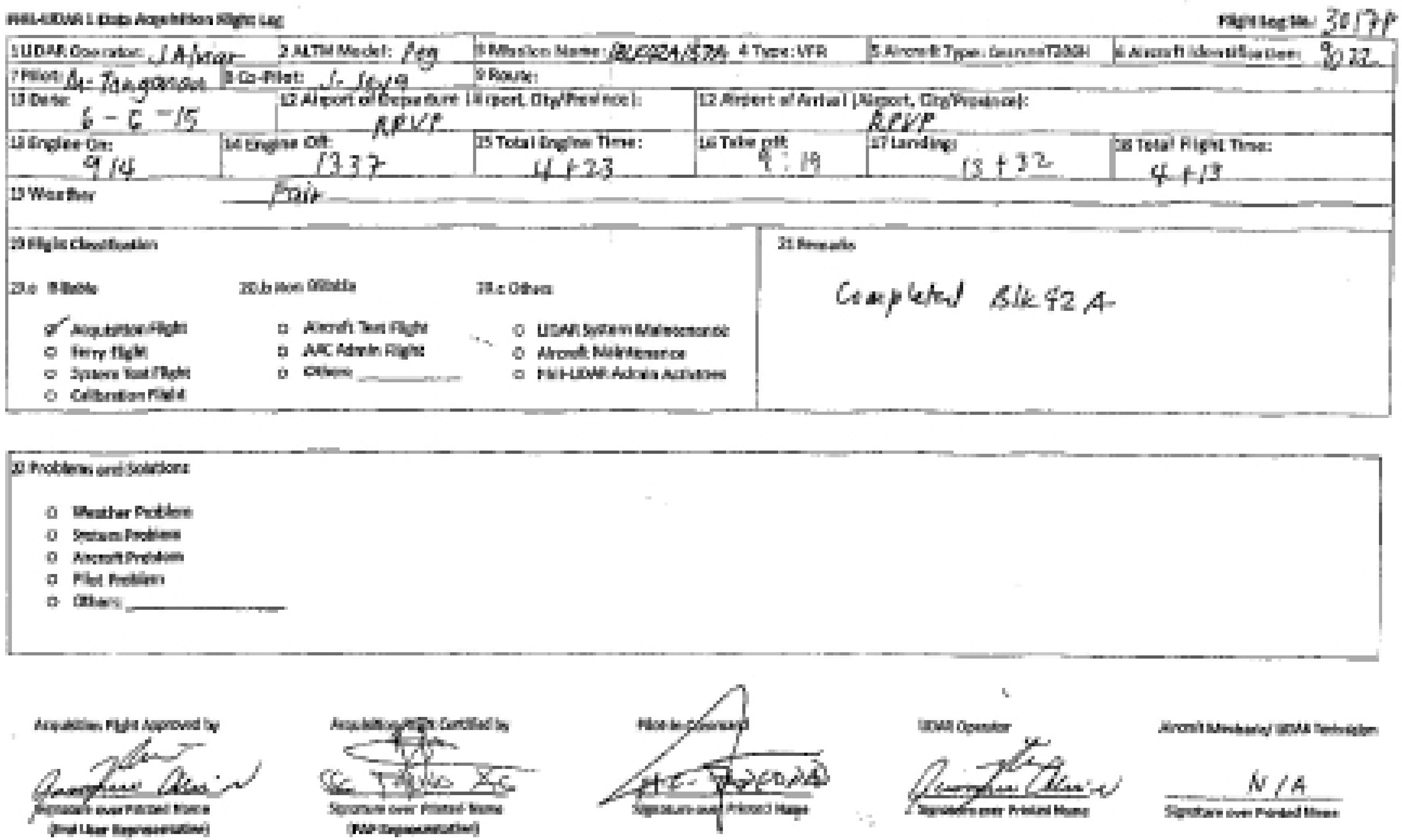
Received by

Name
Position
Signature

Figure A-5.4. Data Transfer Sheet for Babuyan Floodplain - D

Annex 6. Flight Logs

1. Flight Log for 3017P Mission


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3017P

1 LIDAR Operator: J. Alviar
2 ALTM Model: Peg
3 Mission Name:
4 Type: VFR
5 Aircraft Type: Cessna T206H
6 Aircraft Identification: 9022
7 Pilot:
8 Co-Pilot:
9 Route:
10 Date: 6-6-15
12 Airport of Departure (Airport, City/Province): RPVP
12 Airport of Arrival (Airport, City/Province): RPVP
13 Engine On: 914
14 Engine Off: 1337
15 Total Engine Time: 4+23
16 Take off:
17 Landing: 13+32
18 Total Flight Time: 4+13
19 Weather: Fair

20 Flight Classification
20.a Billable
Acquisition Flight
Ferry Flight
System Test Flight
Calibration Flight
20.b Non Billable
Aircraft Test Flight
A/C Admin Flight
Others:
20.c Others
LIDAR System Maintenance
Aircraft Maintenance
Phil-LIDAR Admin Activities

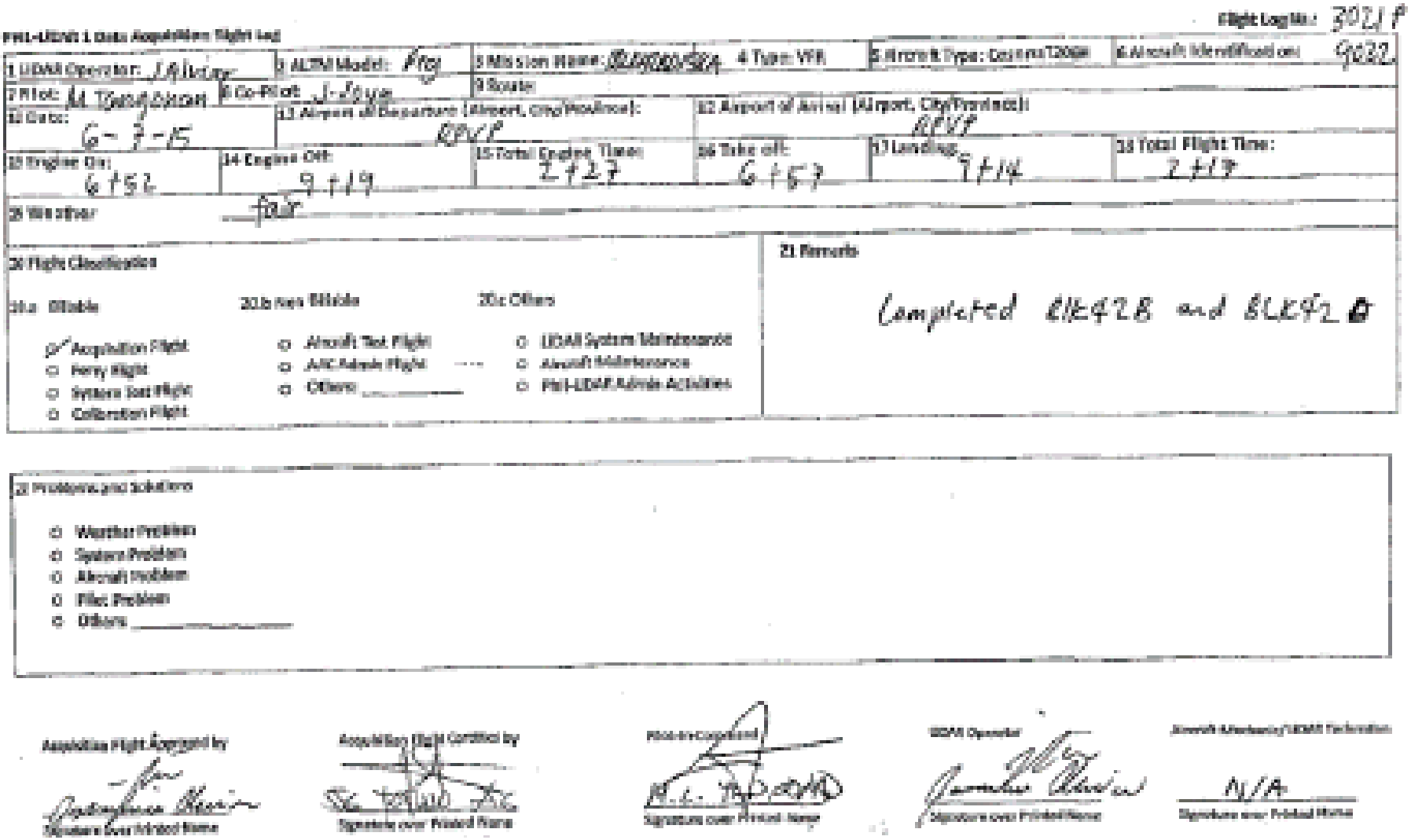
21 Remarks
Completed Blk 42 A

22 Problems and Solutions
Weather Problem
System Problem
Aircraft Problem
Pilot Problem
Others:

Acquisition Flight Approved by — Signature over Printed Name (End User Representative)
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)
Pilot-in-Command — Signature over Printed Name
LIDAR Operator — Signature over Printed Name
Aircraft Mechanic/ LIDAR Technician — N/A — Signature over Printed Name

Figure A-6.1 Flight Log for 3017P Mission

2. Flight Log for 3021P Mission



Flight Log No.: 3021P

PHL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: J.Alviar	2 ALTM Model: Pegasus	3 Mission Name: BLK47B-SEA	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9022	
7 Pilot: M. Tongson	8 Co-Pilot: J. Loyola	9 Route:				
10 Date: 6-7-15	11 Airport of Departure (Airport, City/Province): RPVI		12 Airport of Arrival (Airport, City/Province): RPVI			
13 Engine On: 6:52	14 Engine Off: 9:19	15 Total Engine Time: 2:27	16 Take off: 6:57	17 Landing: 9:14	18 Total Flight Time: 2:17	

19 Weather: fair

20 Flight Classification

20a Mission

- ☑ Acquisition Flight
- ☐ Ferry Flight
- ☐ Systems Test Flight
- ☐ Calibration Flight

20b Non Mission

- ☐ Aircraft Test Flight
- ☐ ATO Admin Flight
- ☐ Others _____

20c Others

- ☐ LIDAR System Maintenance
- ☐ Aircraft Maintenance
- ☐ PHL-LIDAR Admin Activities

21 Remarks: completed BLK47B and BLK47D

22 Problems and Solutions

- ☐ Weather Problem
- ☐ System Problem
- ☐ Aircraft Problem
- ☐ Pilot Problem
- ☐ Others _____

Acquisition Flight Approved by: Signature over Printed Name

Acquisition Flight Certified by: Signature over Printed Name

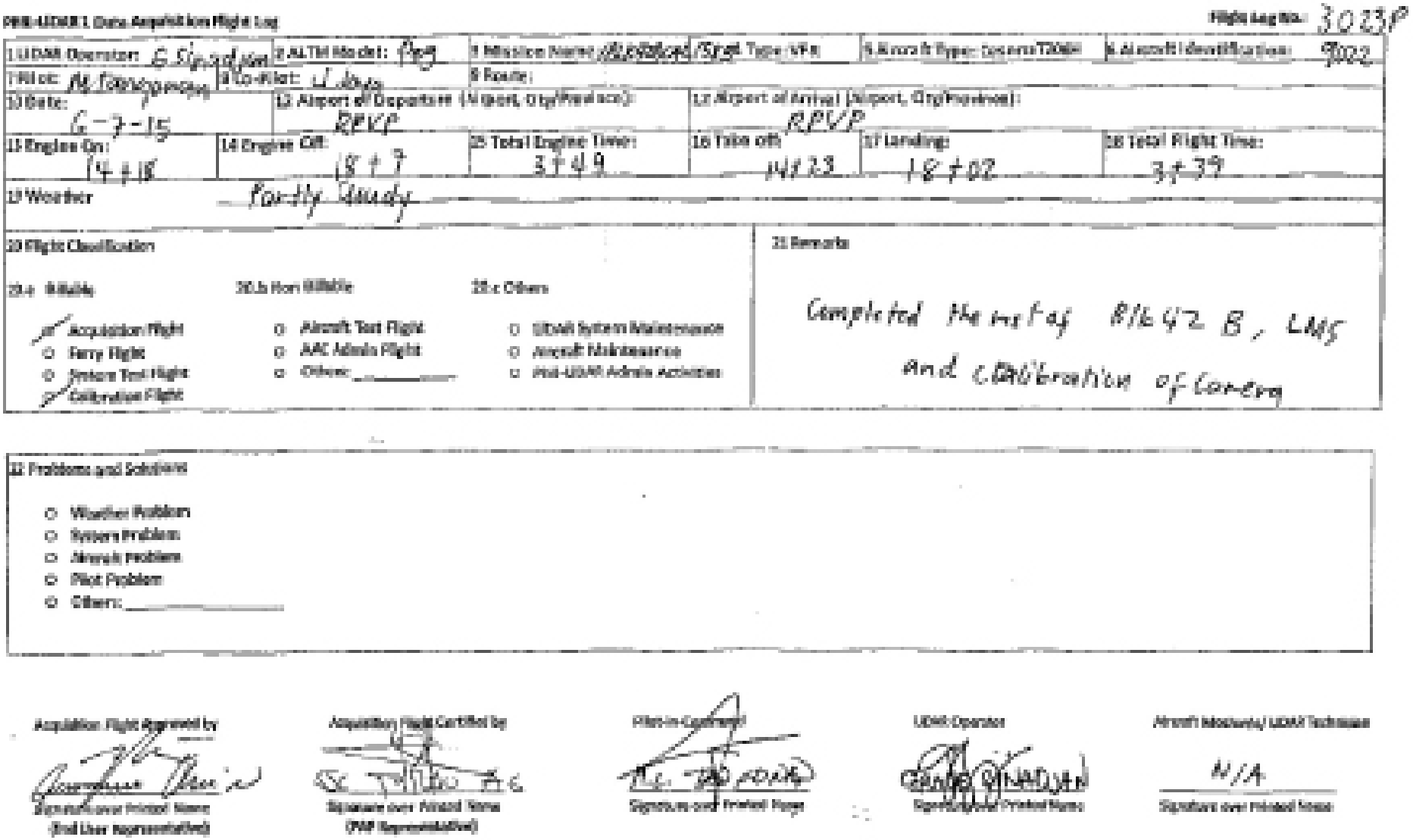
Pilot-in-Command: Signature over Printed Name

LIDAR Operator: Signature over Printed Name

Aircraft Maintenance / LIDAR Technician: N/A — Signature over Printed Name

Figure A-6.2 Flight Log for 3021P Mission

3. Flight Log for 3023P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log — Flight Log No.: 3023P

1 LIDAR Operator: G. Sigmund Gan	2 ALTM Model: Pegasus	3 Mission Name: Blk42B_Strip1	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9022
7 Pilot: M. Tamayo	8 Co-Pilot: J. Abejo	9 Route:			
10 Date: 6-7-15	11 Airport of Departure (Airport, City/Province): REVP		12 Airport of Arrival (Airport, City/Province): REVP		
13 Engine On: 14+18	14 Engine Off: 18+7	15 Total Engine Time: 3+49	16 Take off: 14+23	17 Landing: 18+02	18 Total Flight Time: 3+39
19 Weather: Partly Cloudy					

20 Flight Classification

20.a Billable
- [x] Acquisition Flight
- [ ] Ferry Flight
- [ ] Aircraft Test Flight
- [x] 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 the mission of Blk 42 B, LMS and Calibration of Camera

22 Problems and Solutions
- [ ] Weather Problem
- [ ] System Problem
- [ ] Aircraft Problem
- [ ] Pilot Problem
- [ ] Others: _____

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

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

Pilot-in-Command: Signature over Printed Name

LiDAR Operator: Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: N/A — Signature over Printed Name

Figure A-6.3 Flight Log for 3023P Mission

4. Flight Log for 3041P Mission

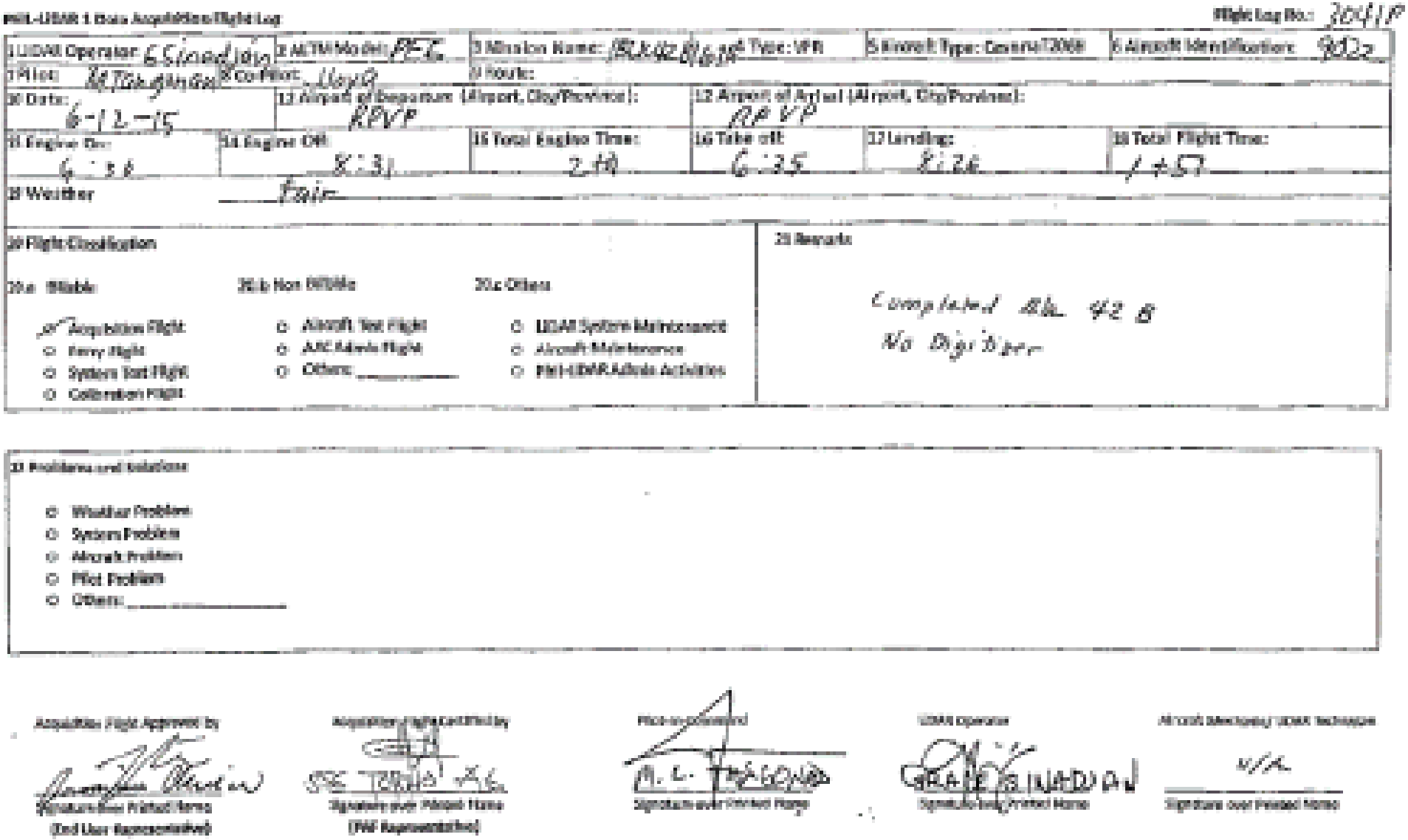
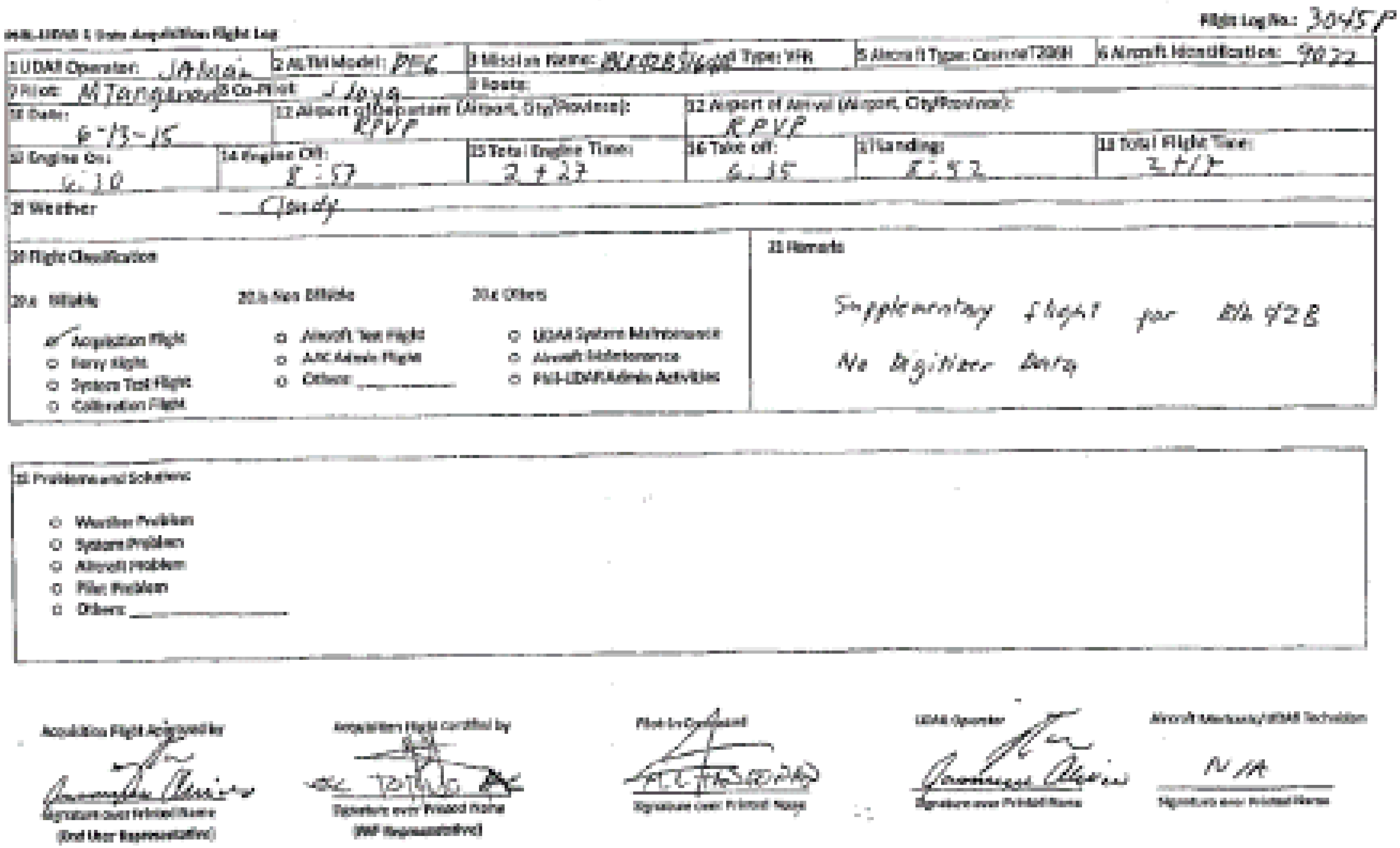


Figure A-6.4 Flight Log for 3041P Mission

5. Flight Log for 3045P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3045P

1 LiDAR Operator: J Alviar
2 ALTM Model: PEG
3 Mission Name: BLK28S
4 Type: VFR
5 Aircraft Type: Cessna T206H
6 Aircraft Identification: 9022
7 Pilot: M Tangonan
8 Co-Pilot: J Loyola
9 Route:
10 Date: 6-13-15
12 Airport of Departure (Airport, City/Province): RPVP
12 Airport of Arrival (Airport, City/Province): RPVP
13 Engine On: 6:10
14 Engine Off: 8:57
15 Total Engine Time: 2+27
16 Take off: 6:15
17 Landing: 8:52
18 Total Flight Time: 2+17
19 Weather: Cloudy

20 Flight Classification
20.a Billable
- ✓ Acquisition Flight
- o Ferry Flight
- o System Test Flight
- o Calibration Flight

20.b Non Billable
- o Aircraft Test Flight
- o A/C Admin Flight
- o Others: ________

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

21 Remarks
Supplementary flight for BLK 28
No digitizer data

22 Problems and Solutions
- o Weather Problem
- o System Problem
- o Aircraft Problem
- o Pilot Problem
- o Others: ________

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

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

Pilot-in-Command
Signature over Printed Name

LiDAR Operator
Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician
N/A
Signature over Printed Name

Figure A-6.5 Flight Log for 3045P Mission

6. Flight Log for 3047P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: L. Paronggao	2 ALTM Model: [illegible]	4 Mission Name: [illegible]	Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 3122
7 Pilot: M. Longalong	8 Co-Pilot: J. Jaca	9 Route:			
10 Date: 6-13-15	11 Airport of Departure (Airport, City/Province): Appc	12 Airport of Arrival (Airport, City/Province): Epcp			
13 Engine On: 14:52	14 Engine Off: 18:26	15 Total Engine Time: 3 + 3.0	16 Take off: 15:21	17 Landing: 18:21	18 Total Flight Time: 3 + 2.0
19 Weather: Cloudy					

20 Flight Classification

20a Billable	20b Non Billable	20c Others
✓ Acquisition Flight	○ Aircraft Test Flight	○ LiDAR System Maintenance
○ Ferry Flight	○ ARC Admin Flight	○ Aircraft Maintenance
○ System Test Flight	○ Others: _____	○ PHIL-LIDAR Admin Activities
○ Calibration Flight		

21 Remarks: Completed Blk 42 Ab (Underground River)

22 Problems and Solutions:

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

Acquisition Flight Approved by: Signature over Printed Name (LiDAR Operator/Pilot)

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

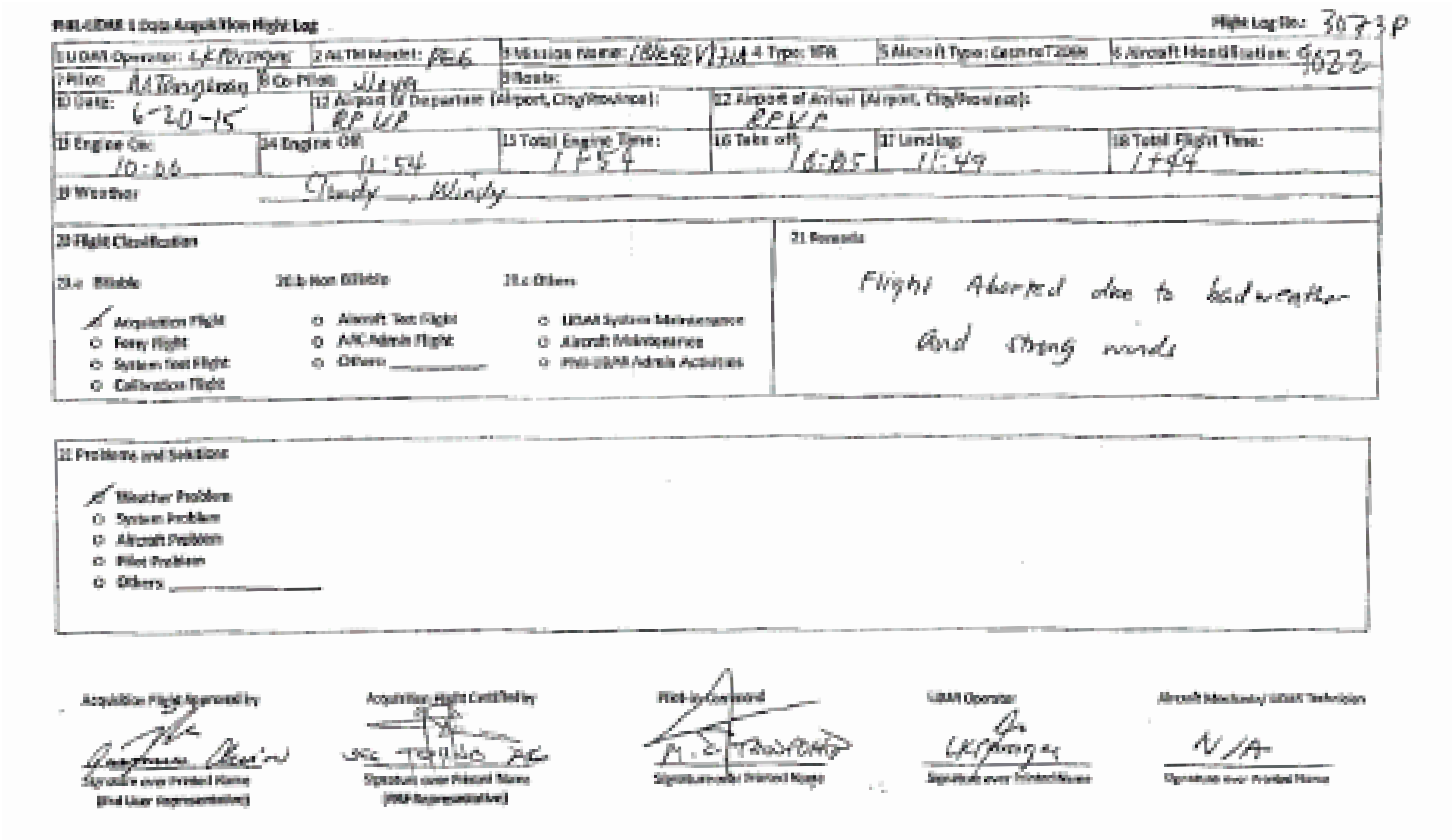
Pilot-in-Command: Signature over Printed Name

LiDAR Operator: Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: N/A — Signature over Printed Name

Figure A-6.6 Flight Log for 3047P Mission

7. Flight Log for 3073P Mission


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3073P

1 LiDAR Operator: LK Paragas | 2 ALTM Model: Peg | 3 Mission Name: 1BLK... | 4 Type: VFR | 5 Aircraft Type: Cessna T206H | 6 Aircraft Identification: 9022

7 Pilot: M Tangonan | 8 Co-Pilot: J Jaya | 9 Route:

10 Date: 6-20-15 | 12 Airport of Departure (Airport, City/Province): RPUP | 12 Airport of Arrival (Airport, City/Province): RPVP

13 Engine On: 10:06 | 14 Engine Off: 11:54 | 15 Total Engine Time: 1+54 | 16 Take off: 10:05 | 17 Landing: 11:49 | 18 Total Flight Time: 1+44

19 Weather: Cloudy, Windy

20 Flight Classification

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

20.b Non Billable
- ○ Aircraft Test Flight
- ○ A/C Admin Flight
- ○ Others: ____

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

21 Remarks

Flight Aborted due to bad weather and strong winds

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

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

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

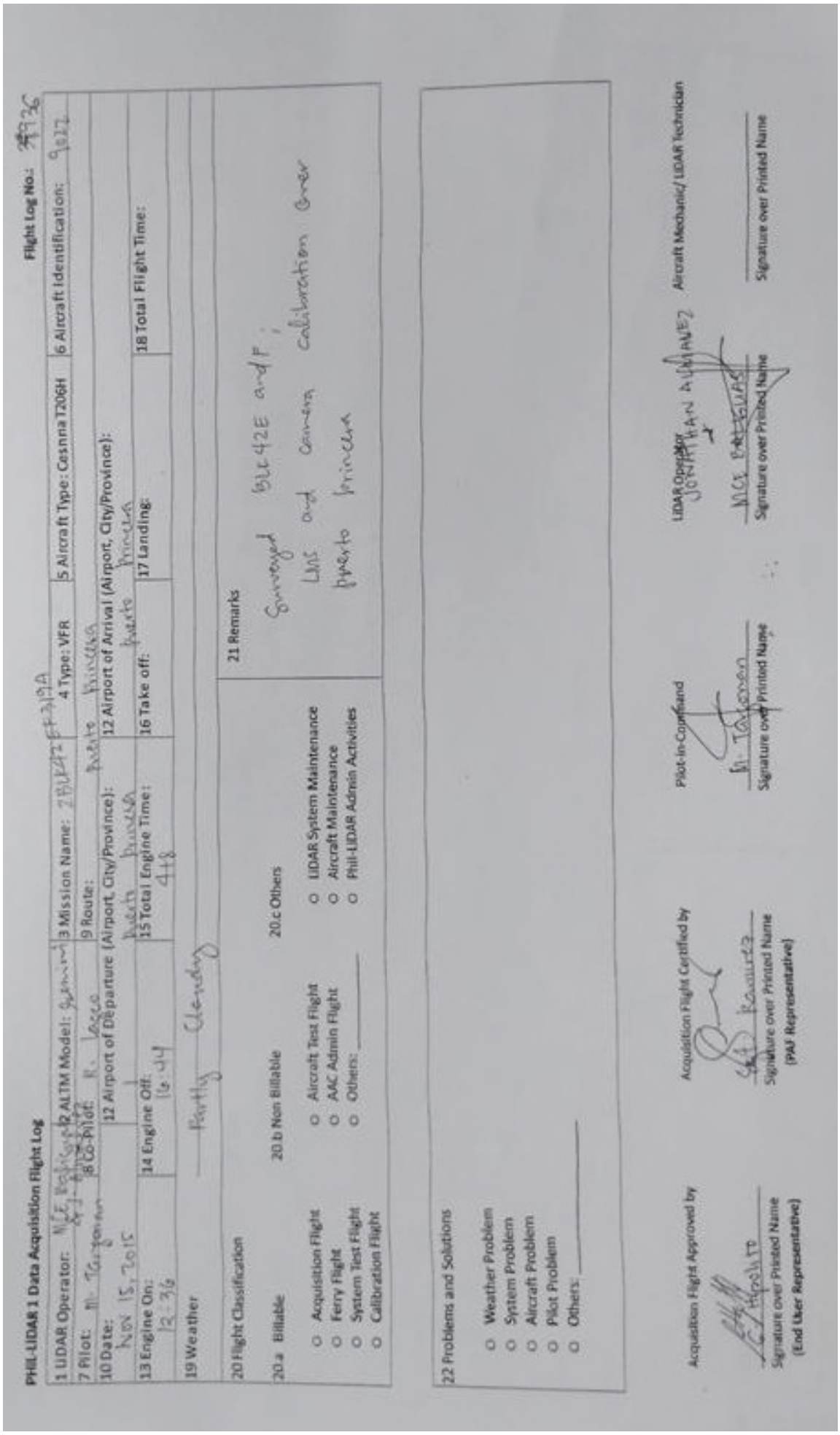
Pilot-in-Command: Signature over Printed Name

LiDAR Operator: LK Paragas — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: N/A — Signature over Printed Name

Figure A-6.7 Flight Log for 3073P Mission

8. Flight Log for 3493G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2936

1 LIDAR Operator: [illegible]	2 ALTM Model: Gemini	3 Mission Name: ZBLK42E_F_A19A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9617
7 Pilot: M. Tolentino	8 Co-Pilot: R. Lasco	9 Route: Basco - Basco			
10 Date: Nov 15, 2015	11 Airport of Departure (Airport, City/Province): Basco Airport, Basco Batanes		12 Airport of Arrival (Airport, City/Province): Basco Airport, Basco Batanes		
13 Engine On: 12:36	14 Engine Off: 16:04	15 Total Engine Time: 4.8	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly Cloudy					

20 Flight Classification

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

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

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

21 Remarks: Surveyed BLK42E and F; LAS and camera calibration over Basco Batanes

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

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

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

Pilot-in-Command
Signature over Printed Name

LiDAR Operator
Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name

Figure A-6.8 Flight Log for 3493G Mission

9. Flight Log for 3497G Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3497G

1 LIDAR Operator: NICE BALIGUAS	2 ALTM Model: Gemini	3 Mission Name: 2BLK42Dis1320A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: JONATHAN ALMALVEZ R. Lagco	9 Route: Puerto Princesa			
10 Date: Nov 16, 2015	12 Airport of Departure (Airport, City/Province): Puerto Princesa		12 Airport of Arrival (Airport, City/Province): Puerto Princesa		
13 Engine On: 7:32	14 Engine Off: 11:17	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time: 3:45
19 Weather: Strong winds					

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: Surveyed 12 lines of BLK42D and 4 lines over the islands; with voids due to tail winds

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

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

Figure A-6.9 Flight Log for 3497G Mission

10. Flight Log for 3499G Mission

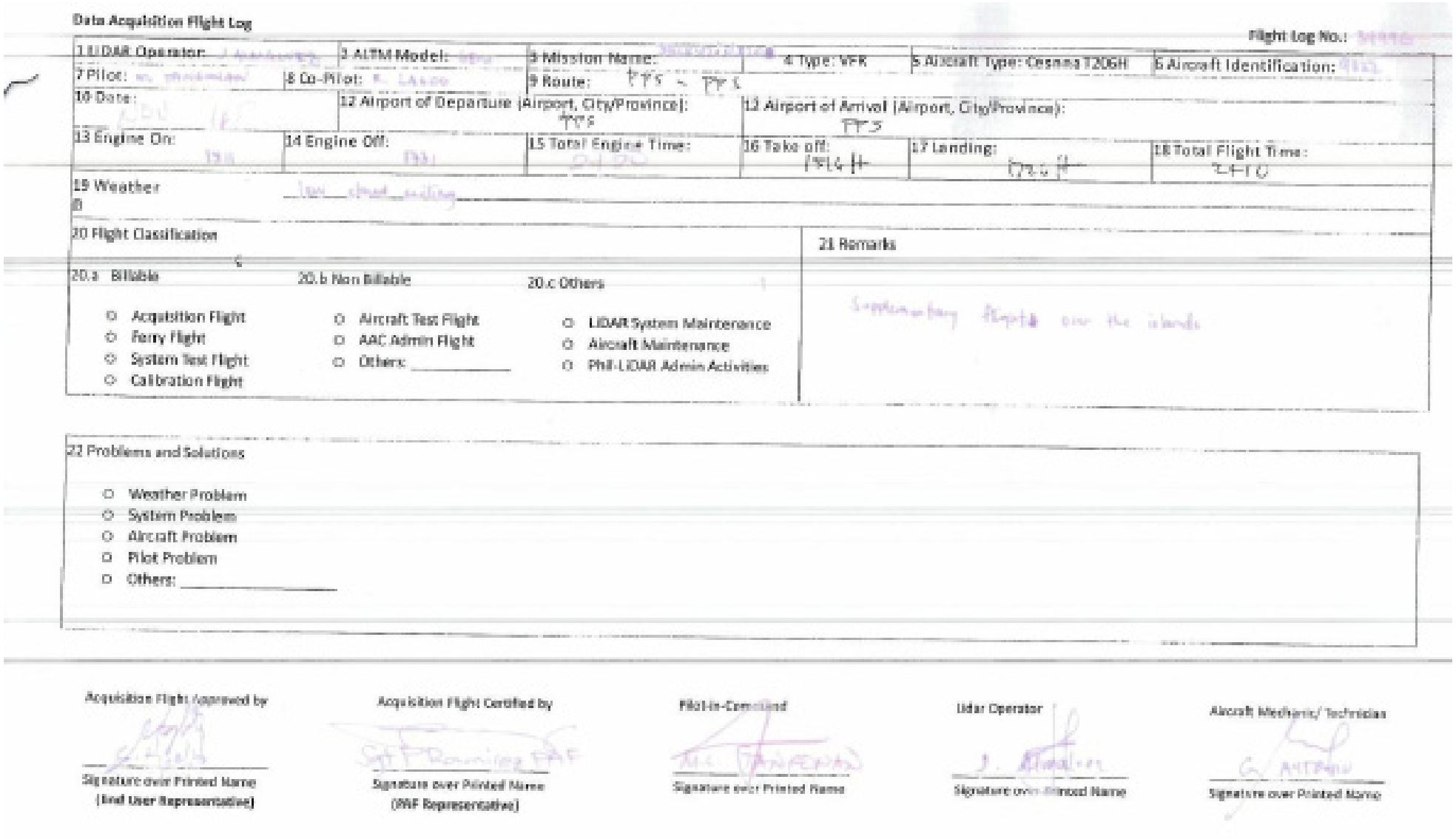
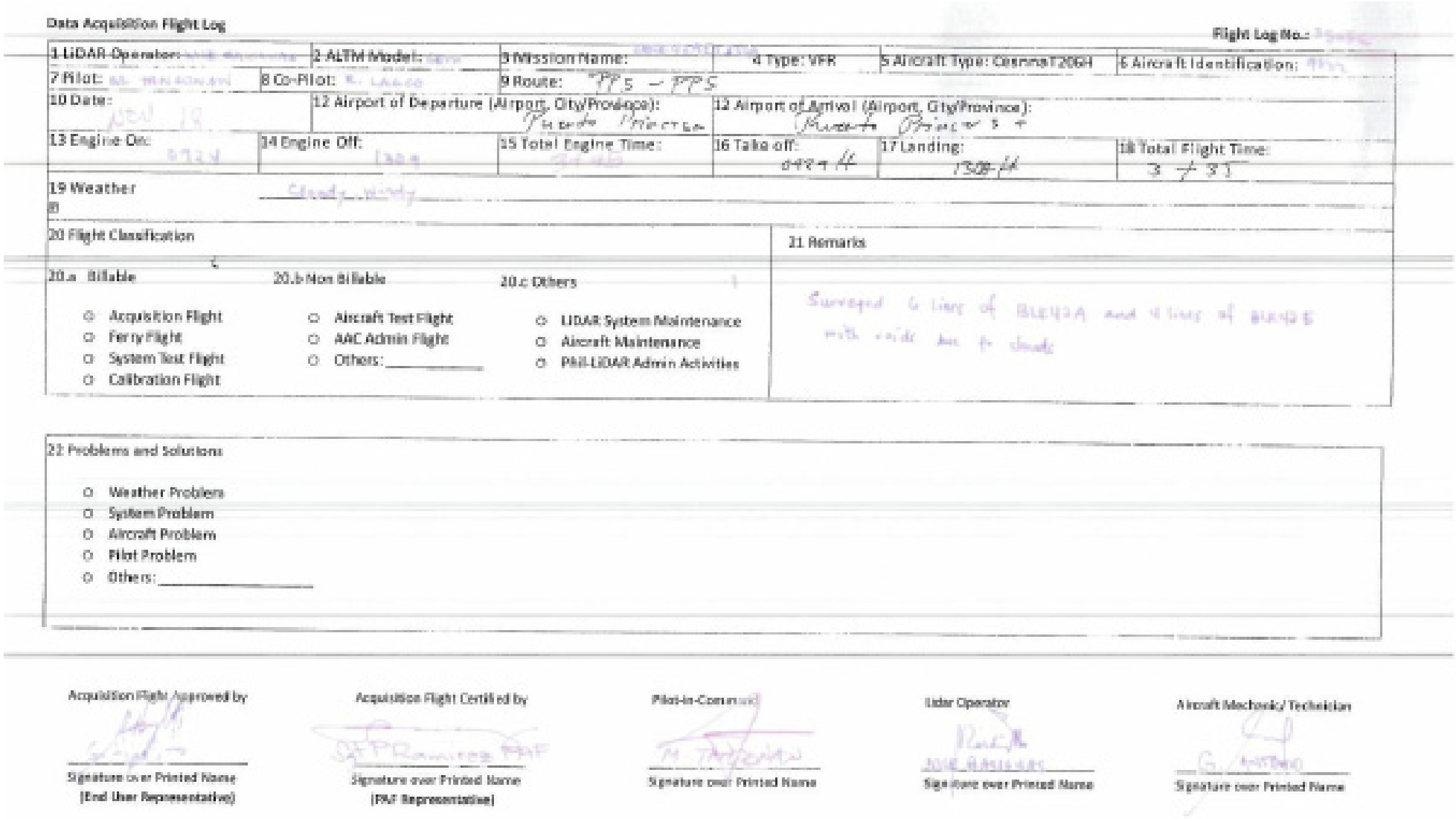


Figure A-6.10 Flight Log for 3499G Mission

11. Flight Log for 3505G Mission



Data Acquisition Flight Log

Flight Log No.:

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

19 Weather

20 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

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

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

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

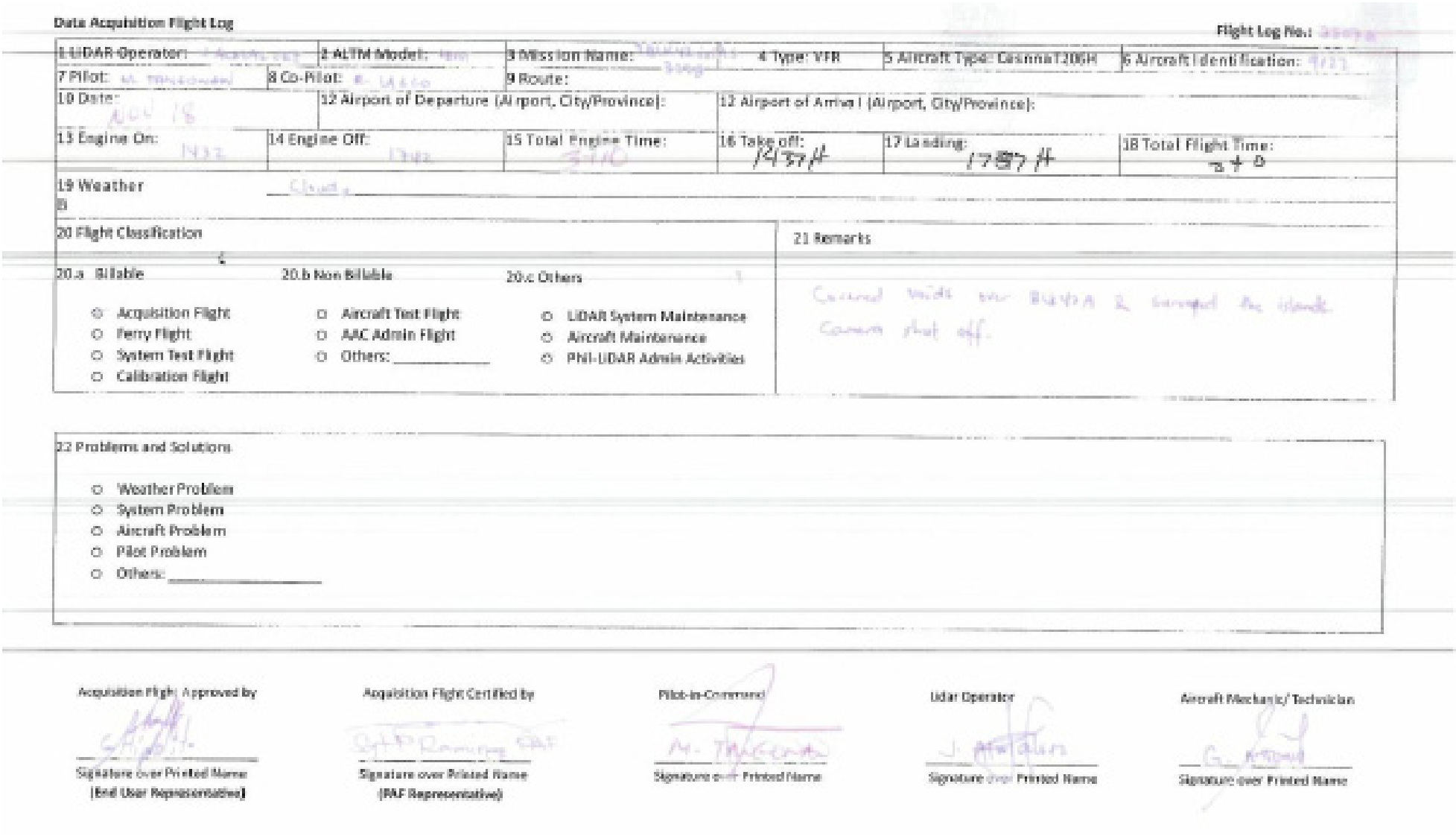
Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Aircraft Mechanic/ Technician
Signature over Printed Name

Figure A-6.11 Flight Log for 3505G Mission

12. Flight Log for 3507G Mission



Data Acquisition Flight Log

Flight Log No.:

1 LiDAR Operator:	2 ALTM Model:	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date:	11 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 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

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

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

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

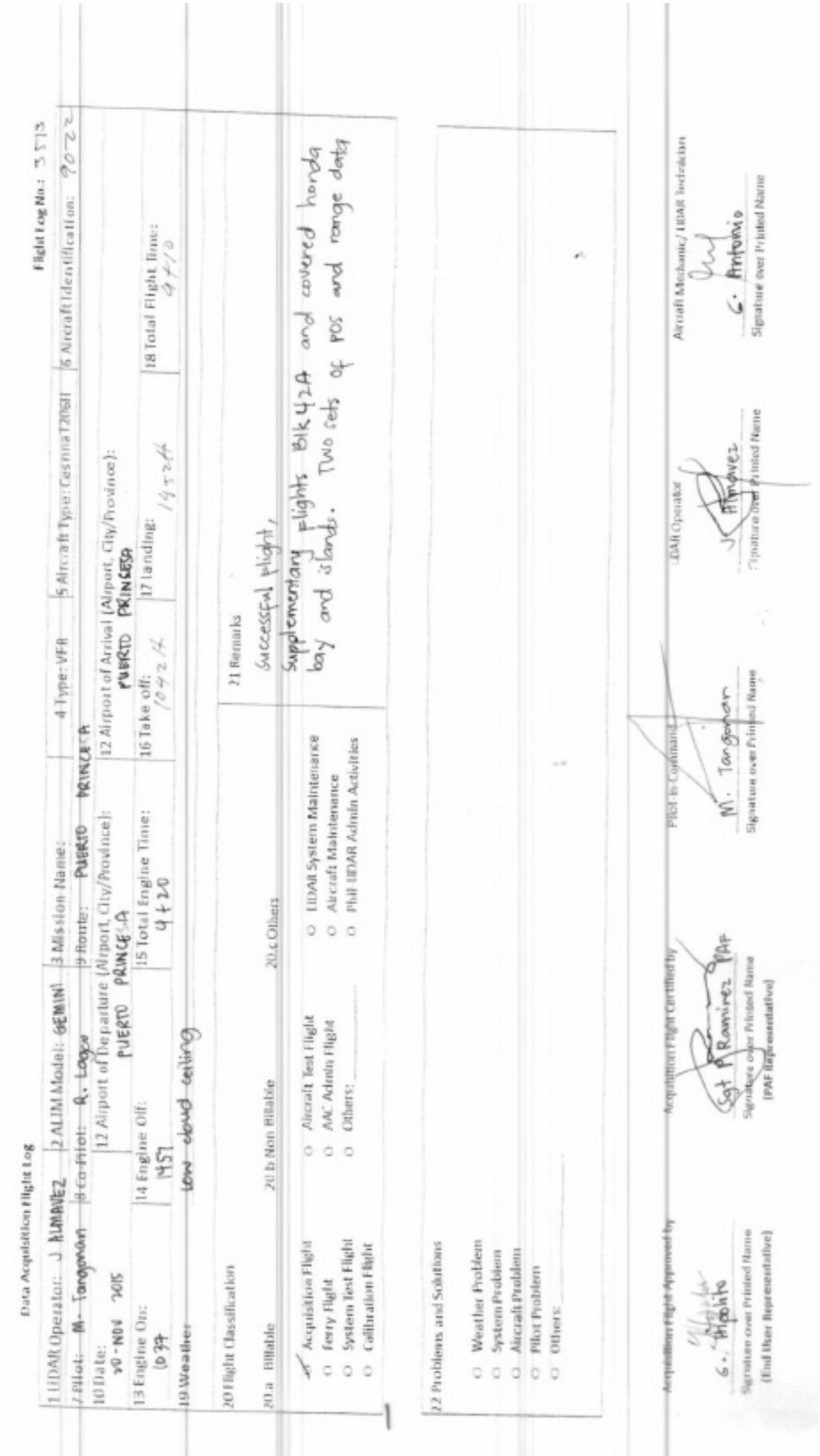
Pilot-in-Command
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Aircraft Mechanic/ Technician
Signature over Printed Name

Figure A-6.12 Flight Log for 3507G Mission

13. Flight Log for 3513G Mission



Data Acquisition Flight Log

Flight Log No.: 3513

1 LIDAR Operator: J. RAMIREZ	2 ALTM Model: GEMINI	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9072
7 Pilot: M. Tangonan	8 Co-Pilot: R. Logo	9 Route: PUERTO PRINCESA			

10 Date: 20-NOV 2015

12 Airport of Departure (Airport, City/Province): PUERTO PRINCESA

12 Airport of Arrival (Airport, City/Province): PUERTO PRINCESA

13 Engine On: 0937

14 Engine Off: 1457

15 Total Engine Time: 4+20

16 Take off: 1042

17 landing: 1432

18 Total Flight Time: 4+10

19 Weather: low cloud ceiling

20 Flight Classification

20.a Billable

20.b Non Billable

20.c Others

21 Remarks: Successful flight, Supplementary flights BIK424 and covered honda bay and islands. Two sets of POS and range data

- ✓ Acquisition Flight
- ○ Ferry Flight
- ○ System Test Flight
- ○ Calibration Flight
- ○ Aircraft Test Flight
- ○ ANC Admin Flight
- ○ Others: _____
- ○ LIDAR System Maintenance
- ○ Aircraft Maintenance
- ○ Phil LIDAR Admin Activities

22 Problems and Solutions

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

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

Acquisition Flight Certified by: Sgt P. Ramirez PAF — Signature over Printed Name (PAF Representative)

Pilot-In-Command: M. Tangonan — Signature over Printed Name

LIDAR Operator: J. Ramirez — Signature over Printed Name

Aircraft Mechanic / LIDAR Technician: G. Antonio — Signature over Printed Name

Figure A-6.13 Flight Log for 3513G Mission

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

FLIGHT STATUS REPORT
PALAWAN
June 6-20, 2015 and November 15-20, 2015

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
3017P	BLK 42A	1BLK42A157A	J Alviar	June 6, 2015	Data acquired in blk 42a 175.55 sq.km
3021P	BLK 42BD	1BLK42BD158A	J Alviar	June 7, 2015	Data acquired; too cloudy in survey areas 118.57 sq.km
3023P	BLK 42BE	1BLK42BCAL158B	G Sinadjan	June 7, 2015	Mission completed; lms and camera calib also conducted 143.49 sq.km
3041P	BLK 42C	1BLK42B163A	G Sinadjan	June 12, 2015	Surveyed blk 42c 116.16 sq.km
3045P	BLK 42BS	1BLK42BS164A	J Alviar	June 13, 2015	Surveyed blk 42b voids, too cloudy 117.78 sq.km
3047P	BLK 42Aa (Subterranean River)	1BLK42Aa164B	L Paragas	June 13, 2015	Surveyed blk 42aa (subterranean river); prf 150, sf 30, fov 40 191.59 sq.km
3073P	BLK 42B, D	1BLK42S171A	L Paragas	June 20, 2015	Surveyed voids in blk 42b and blk 42d; very cloudy 69.08 sq.km
3493G	BLK42 eE,eF	2BLK42EF319A	MCE Baliguas and JM Almalvez	November 15, 2015	Calibration flight; covered voids and gaps on RBs
3497G	BLK42 eD, islands	2BLK42Disl320A	MCE Baliguas and JM Almalvez	November 16, 2015	Voids near mountain of 42eD; moved to islands
3499G	Islands	2BLK42isl320B	JM Almalvez	November 16, 2015	Successful; covered islands
3505G	BLK42 eA,A	2BLK42AEs322A	MCE Baliguas	November 18, 2015	Voids on mountainous part of 42eA; covered 42A voids; Pls use its tie line on 3515 for voids
3507G	BLK42 eA, islands	2BLK42islAs322B	JM Almalvez	November 18, 2015	42eA: Pls use tie line of 3505; 42isl: Pls use tie line of 3499/3515
3513G	BLK42 eA, islands	2BLK42islAs324A	JM Almalvez	November 20, 2015	No tie line on 42eA due to weather, pls use 3505's tie line; finished islands; 2 sets of POS and range data

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No. :	3017P	
Area:	BLK 42A	
Mission Name:	1BLK42A157A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 50	Overlap: 20

LAS

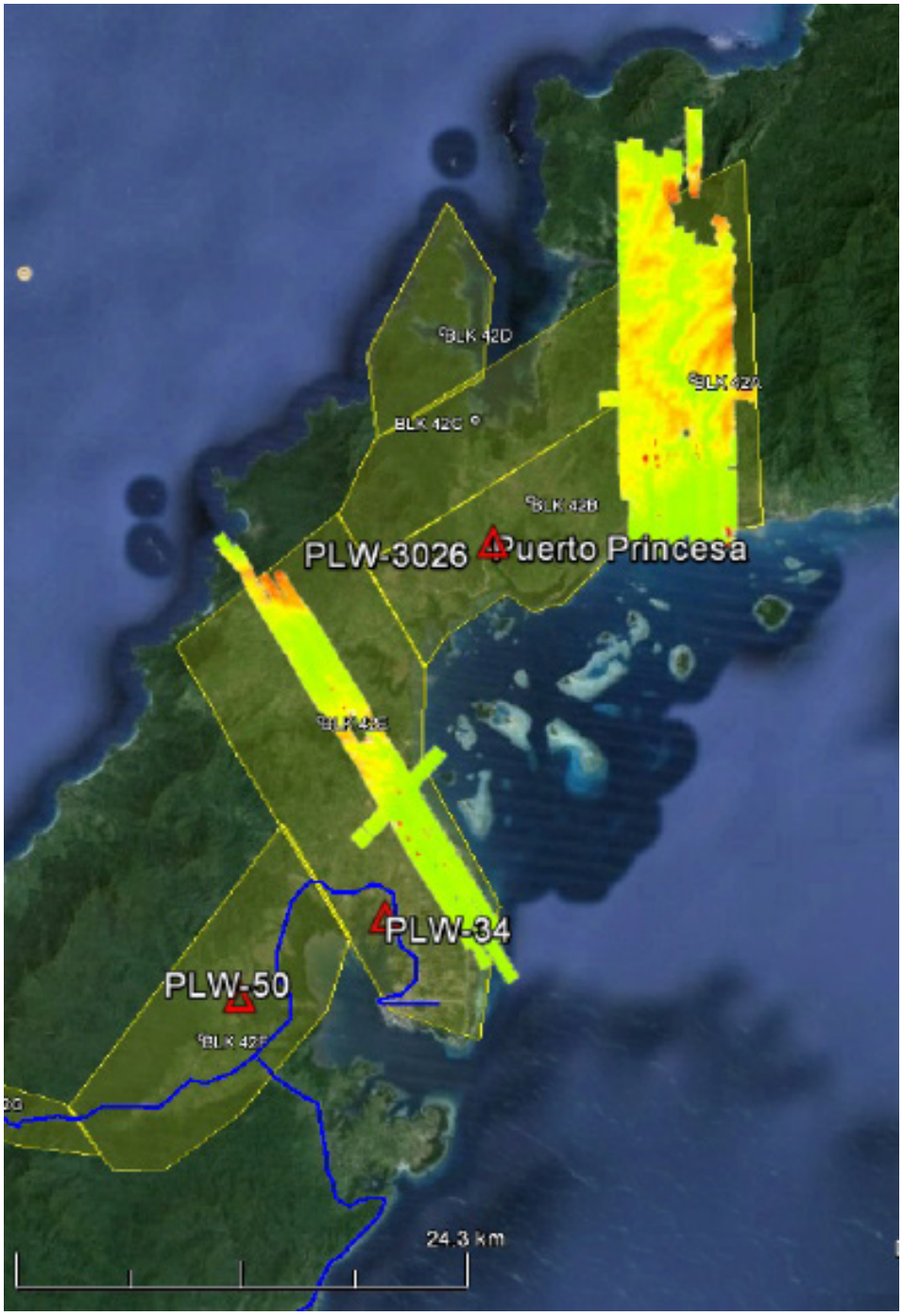


Figure A-7.1. Swath Coverage of Flight No. 3017P

Flight No. :	3021P	
Area:	BLK 42BD	
Mission Name:	1BLK42BD158A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 50	Overlap: 20

LAS

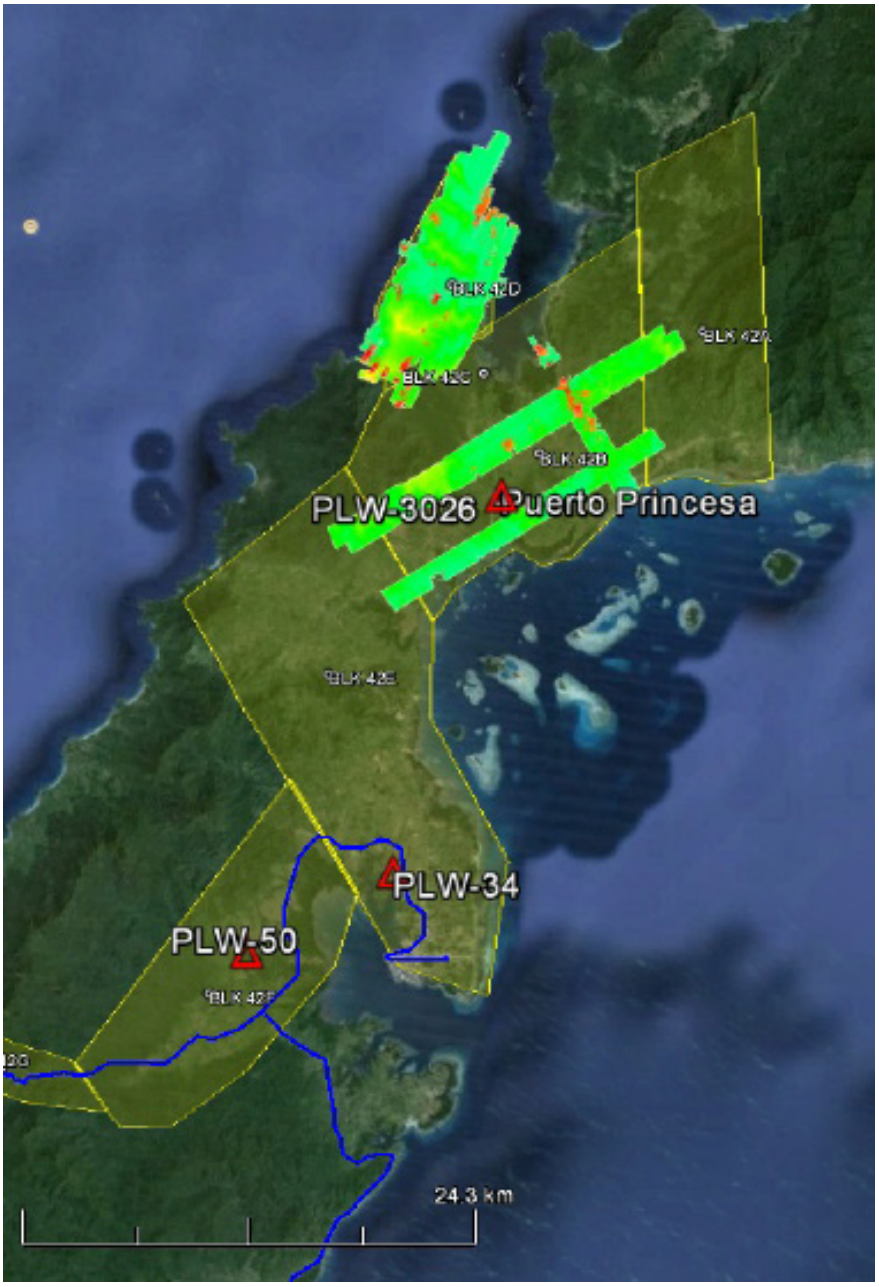


Figure A-7.2. Swath Coverage of Flight No. 3021P

Flight No. :	3023P	
Area:	BLK 42BE	
Mission Name:	1BLK42BCALIB158B	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 50	Overlap: 20

LAS

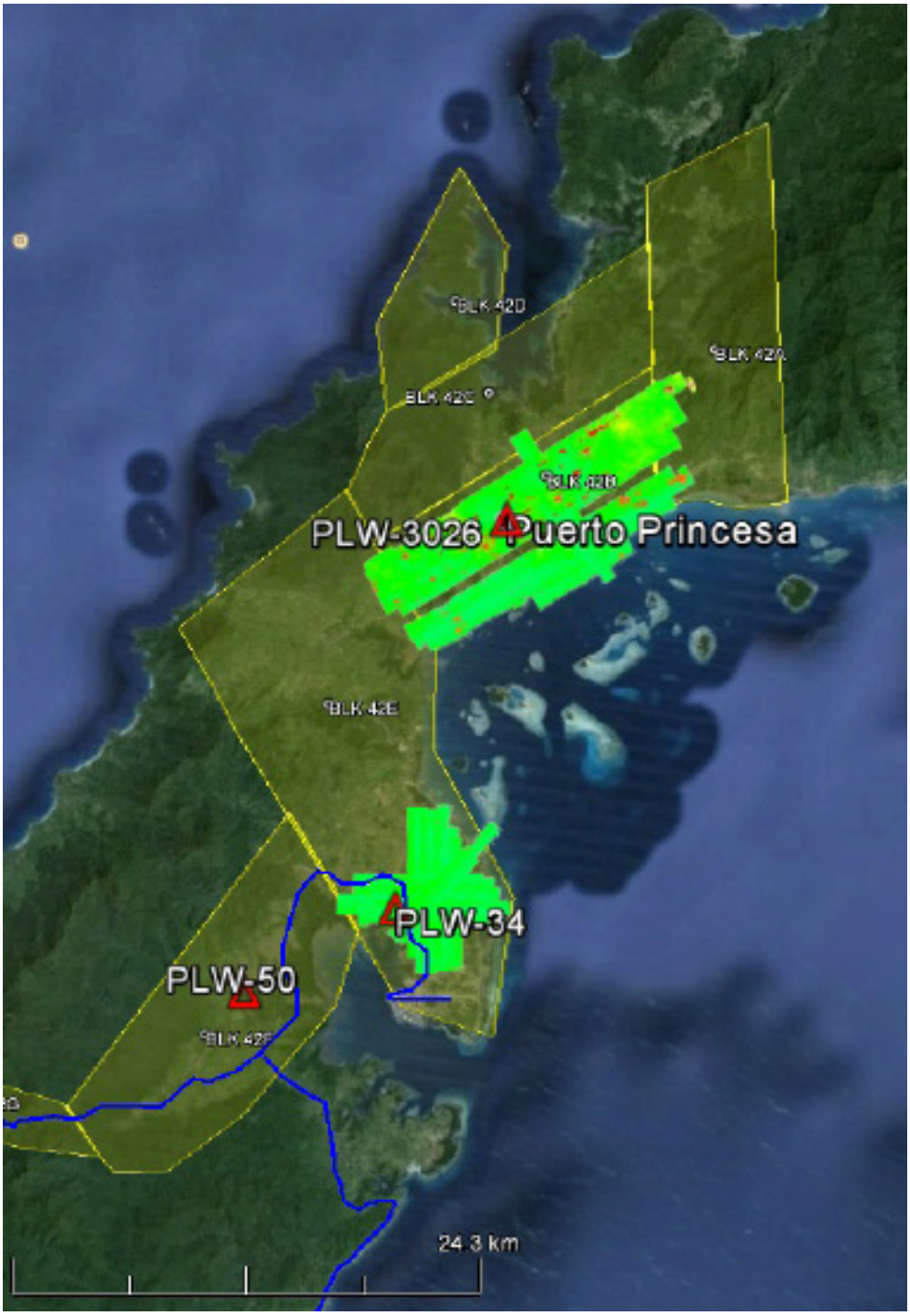


Figure A-7.3. Swath Coverage of Flight No. 3023P

Flight No. :	3041P	
Area:	BLK 42C	
Mission Name:	1BLK42C163A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 50	Overlap: 20

LAS

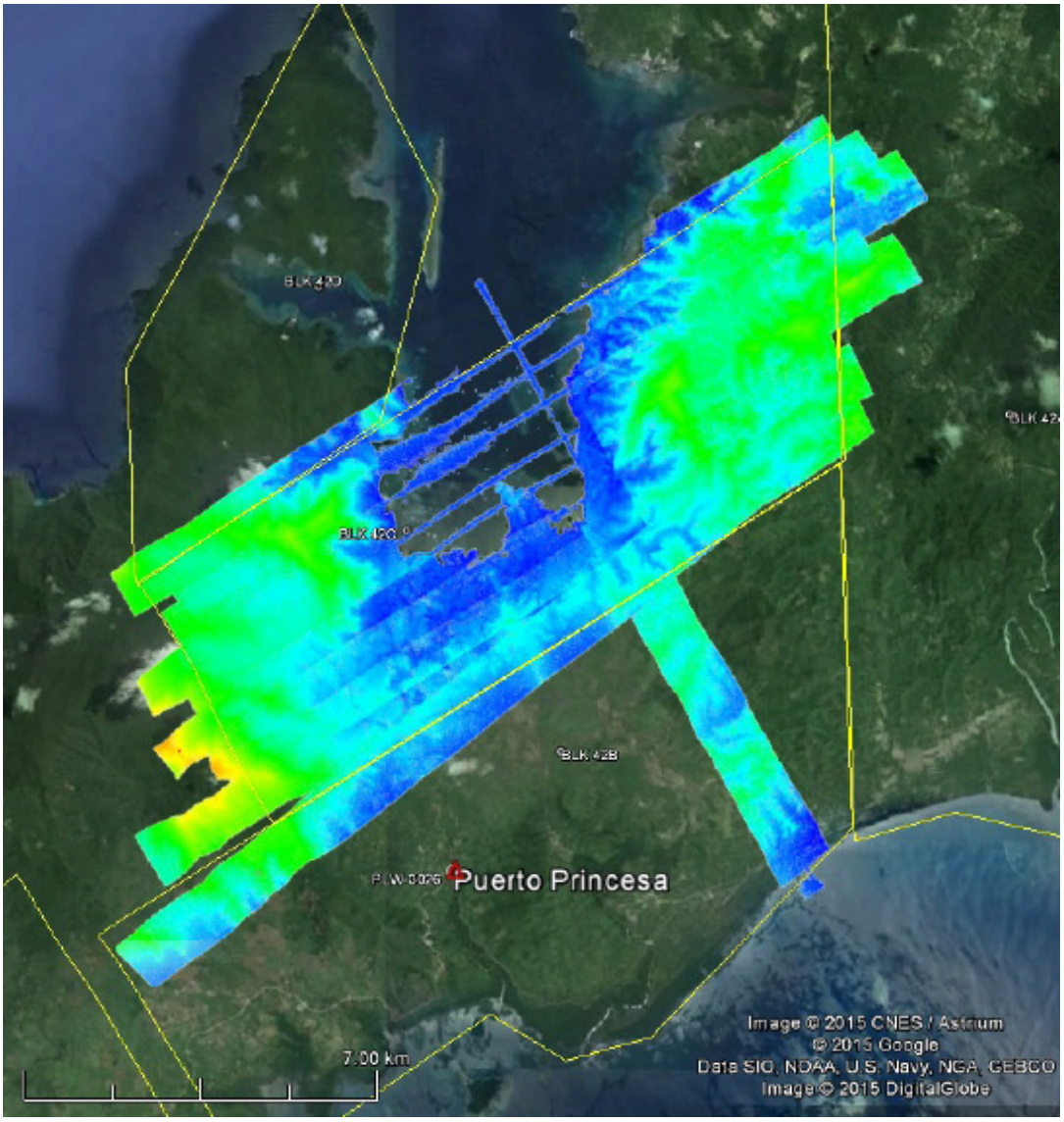


Figure A-7.4. Swath Coverage of Flight No. 3041P

Flight No. : 3045P
Area: BLK 42BS
Mission Name: 1BLK42BS164A
Parameters: Altitude: 1000 Scan Frequency: 30
Scan Angle: 50 Overlap: 20

LAS

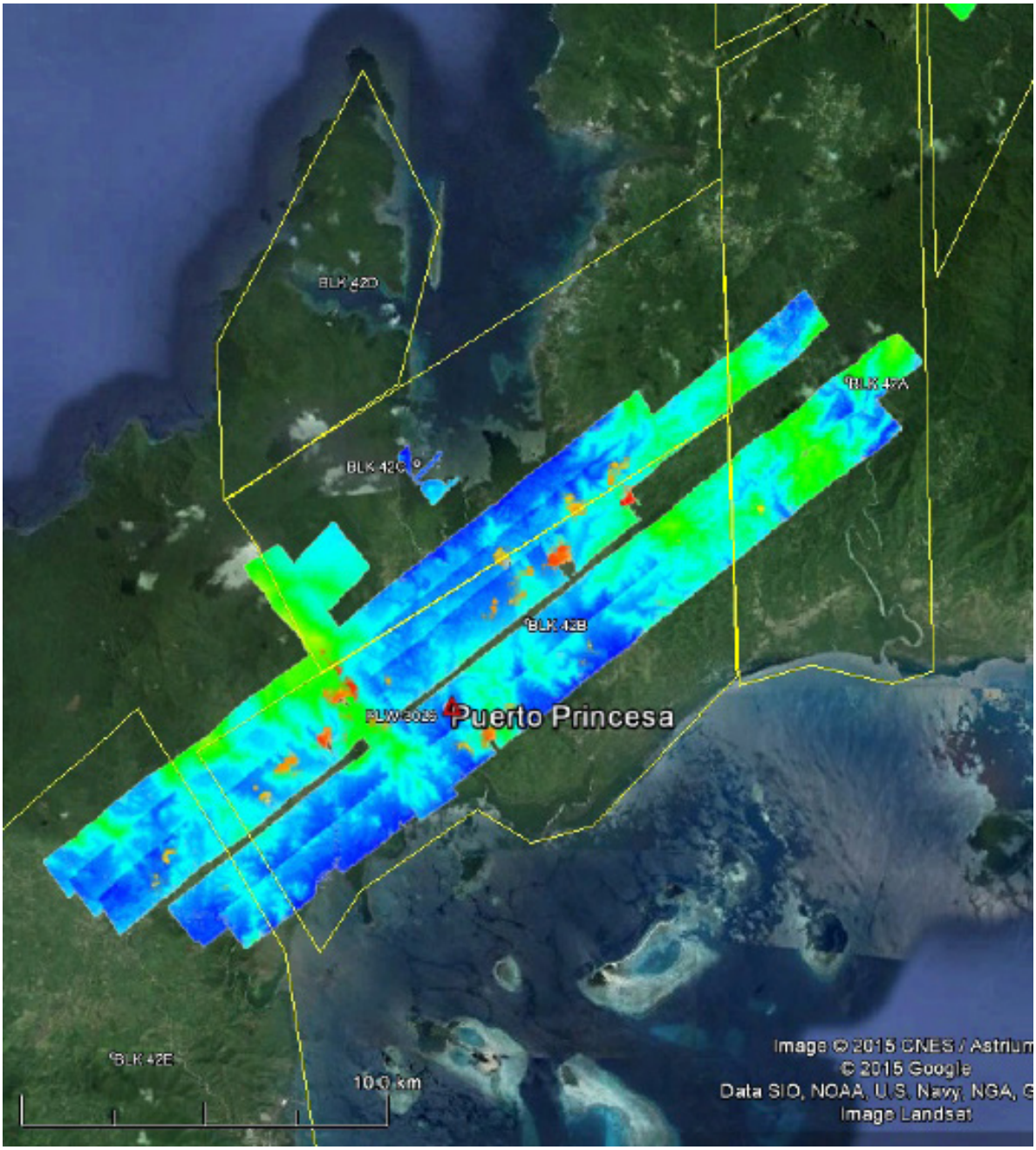


Figure A-7.5. Swath Coverage of Flight No. 3045P

Flight No. :	3047P	
Area:	BLK 42AA	
Mission Name:	1BLK42AA164B	
Parameters:	Altitude: 1200	Scan Frequency: 30
	Scan Angle: 40	Overlap: 20

LAS

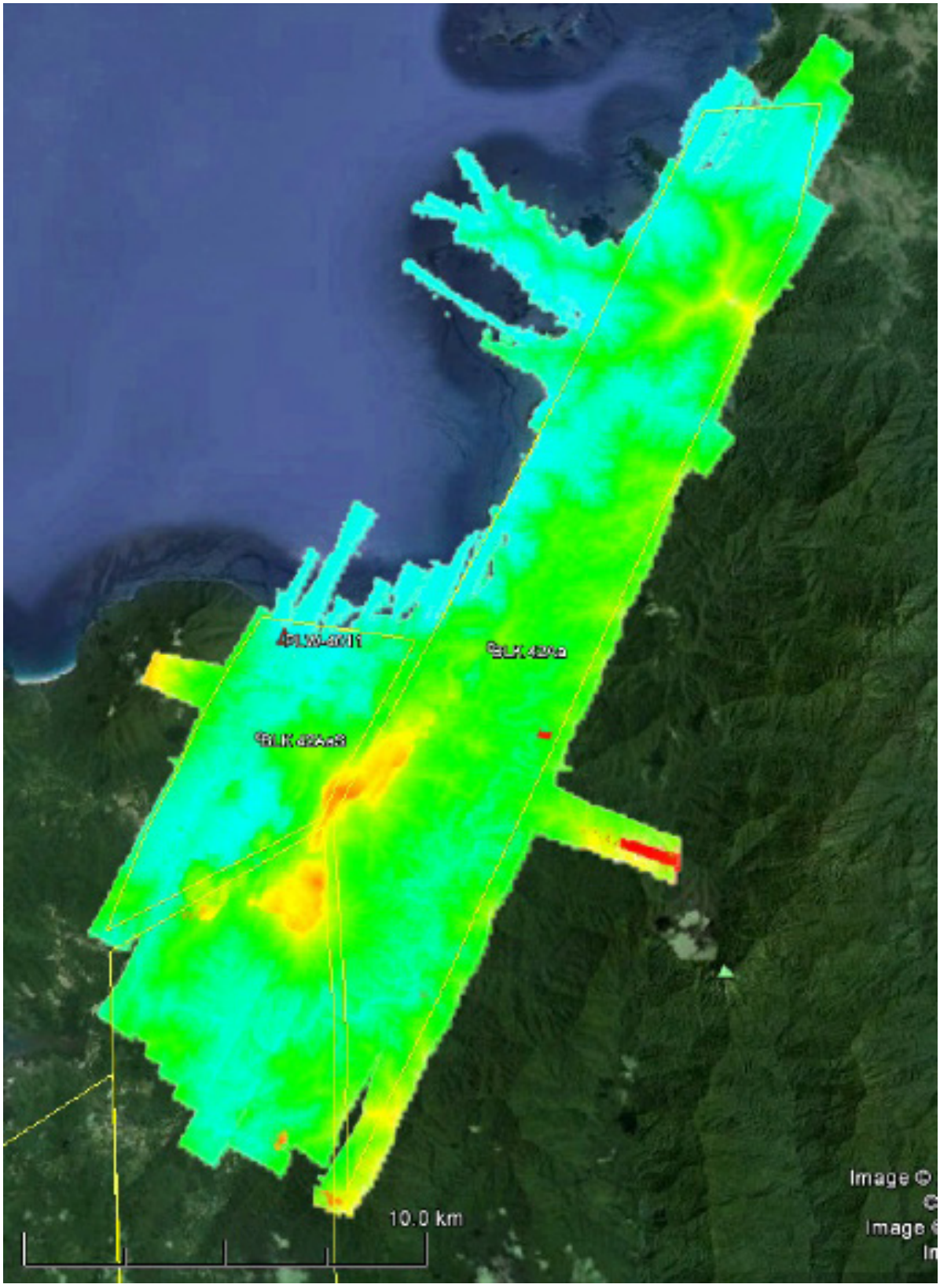


Figure A-7.6. Swath Coverage of Flight No. 3047P

Flight No. :	3073P	
Area:	BLK 42B, BLK 42D	
Mission Name:	1BLK42S171A	
Parameters:	Altitude: 1000	Scan Frequency: 30
	Scan Angle: 50	Overlap: 20

LAS

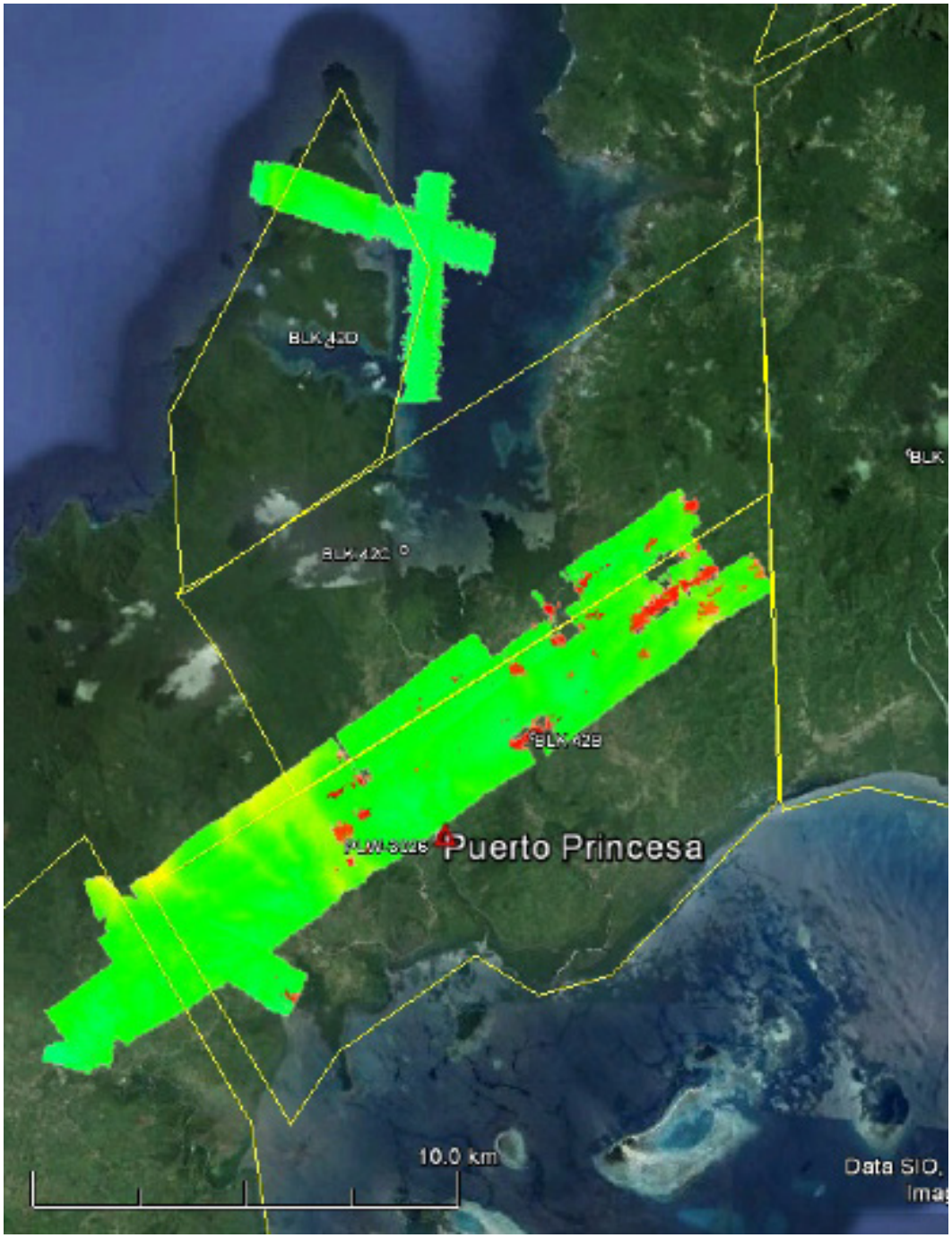


Figure A-7.7. Swath Coverage of Flight No. 3073P

Flight No. :	3493G	
Area:	BLK42 eE,eF	
Mission Name:	2BLK42EF319A	
Parameters:	Altitude: 1000	Scan Frequency: 50
	Scan Angle: 40	Overlap: 30

SWATH

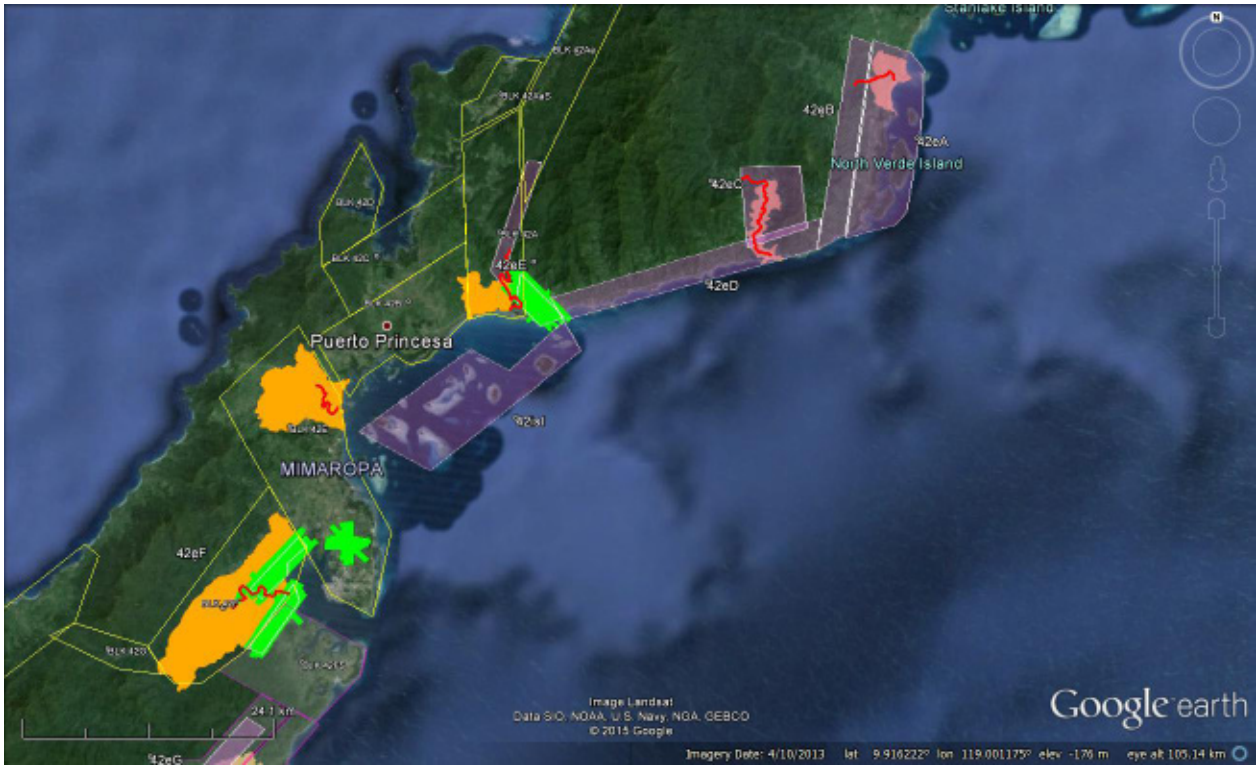


Figure A-7.8. Swath Coverage of Flight No. 3493G

Flight No. :	3497G	
Area:	BLK42 eD, islands	
Mission Name:	2BLK42Disl320A	
Parameters:	Altitude: 1000	Scan Frequency: 50
	Scan Angle: 40	Overlap: 30

SWATH

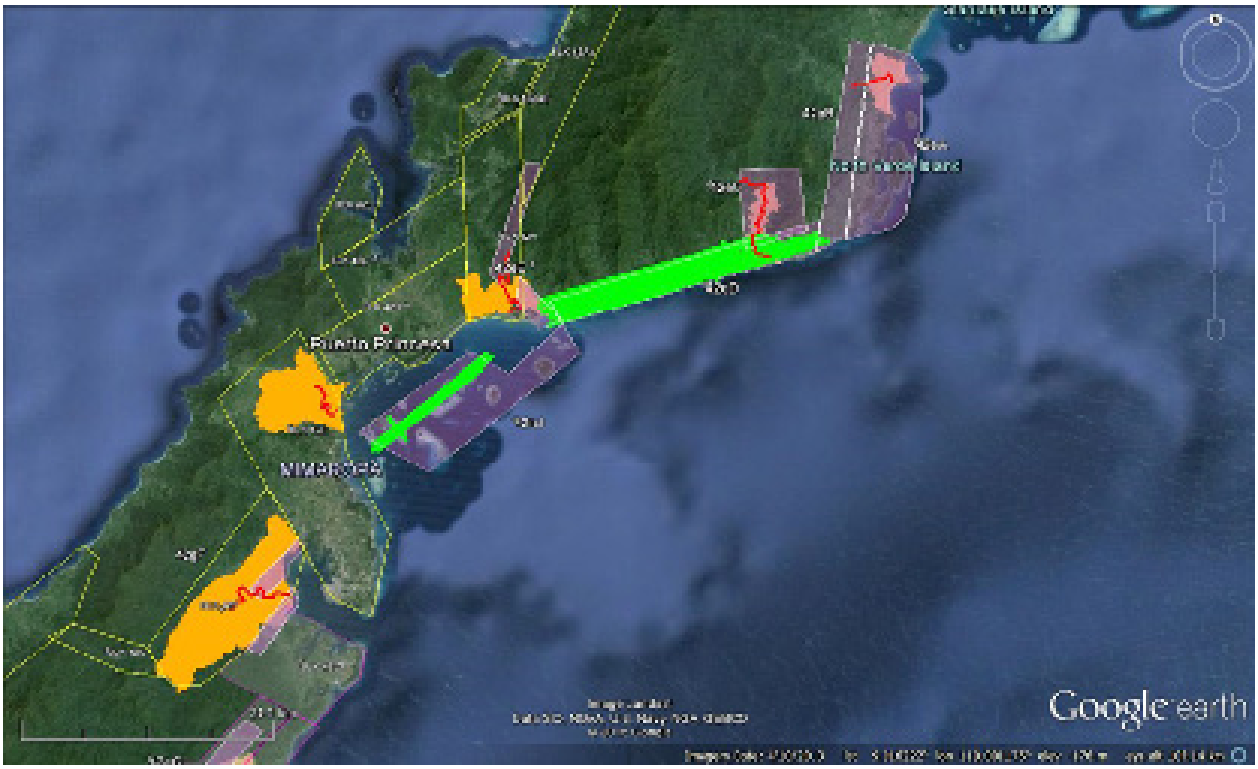


Figure A-7.9. Swath Coverage of Flight No. 3497G

Flight No.:	3499G	
Area:	BLK42 islands	
Mission Name:	2BLK42isl320B	
Parameters:	Altitude: 1000	Scan Frequency: 50
	Scan Angle: 40	Overlap: 30

SWATH

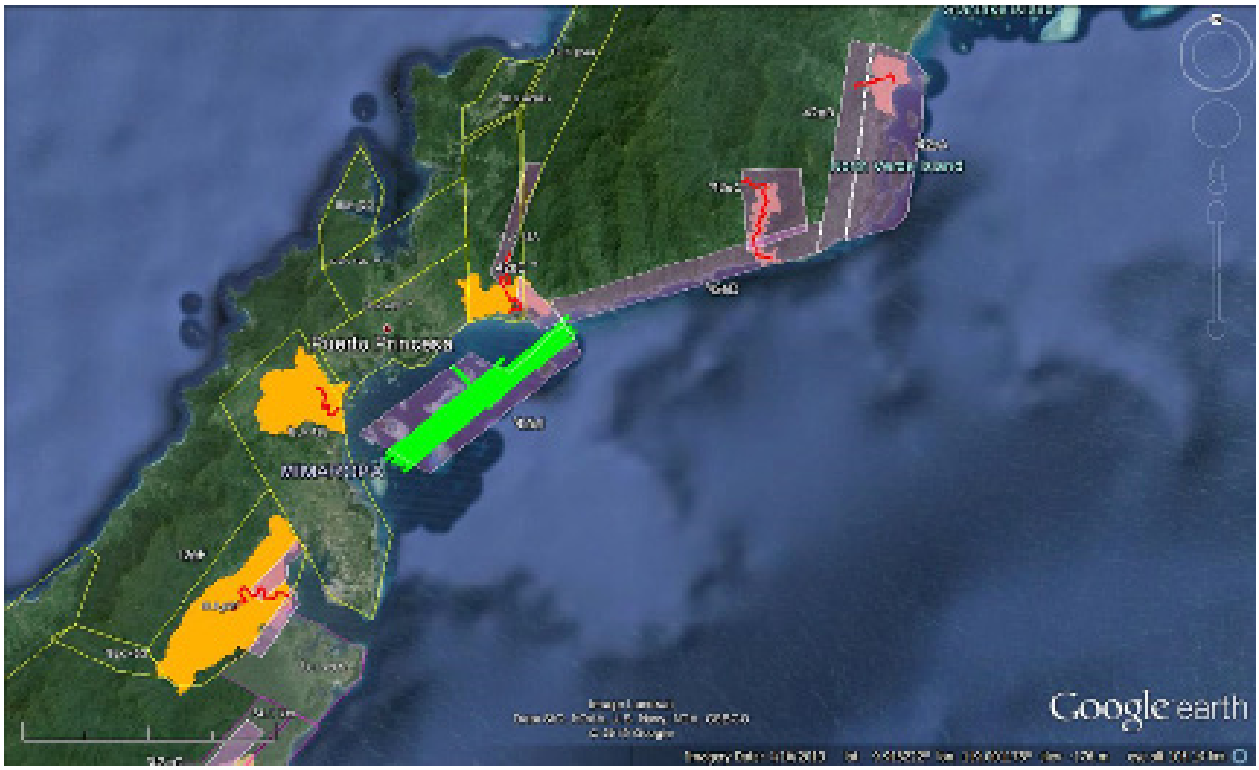


Figure A-7.10. Swath Coverage of Flight No. 3499G

Flight No. : 3505G
Area: BLK42 eA,A
Mission Name: 2BLK42AEs322A
Parameters: Altitude: 600 Scan Frequency: 50
Scan Angle: 40 Overlap: 30

SWATH

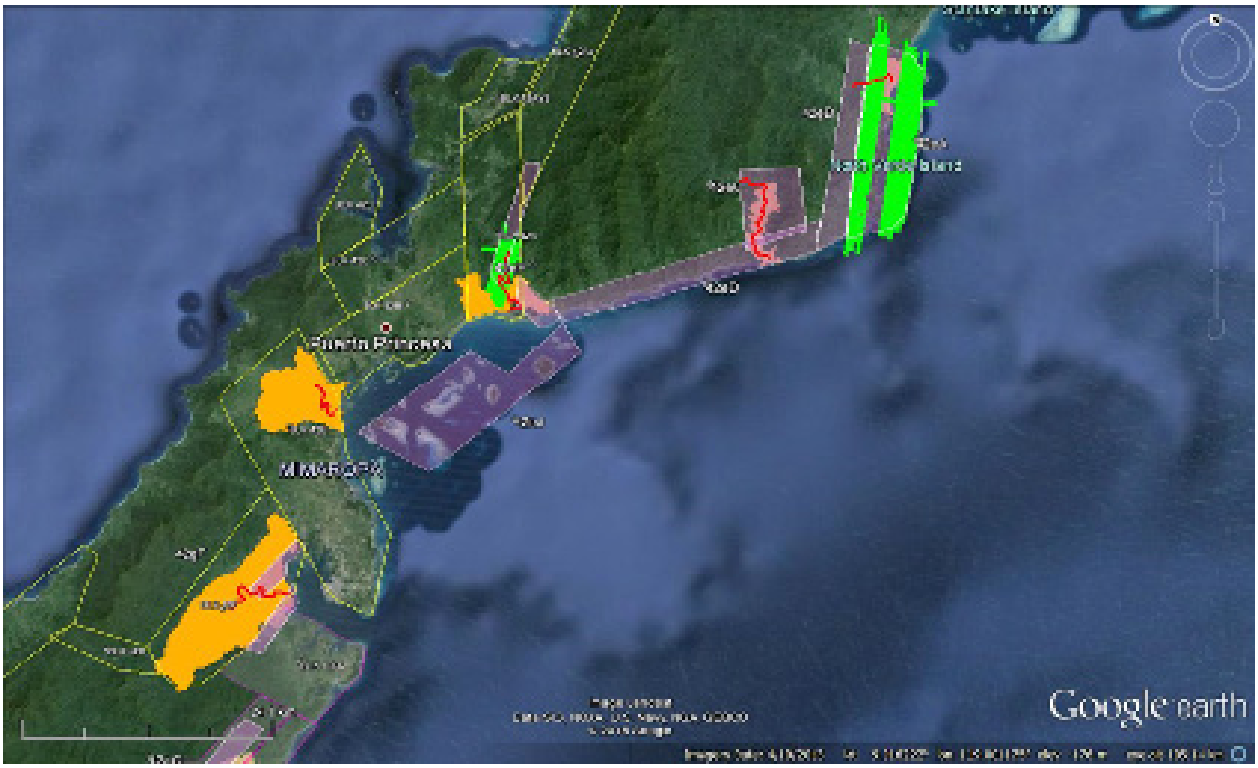


Figure A-7.11. Swath Coverage of Flight No. 3505G

Flight No. :	3507G	
Area:	BLK42 eA, islands	
Mission Name:	2BLK42islAs322B	
Parameters:	Altitude: 1100	Scan Frequency: 50
	Scan Angle: 24	Overlap: 30

SWATH

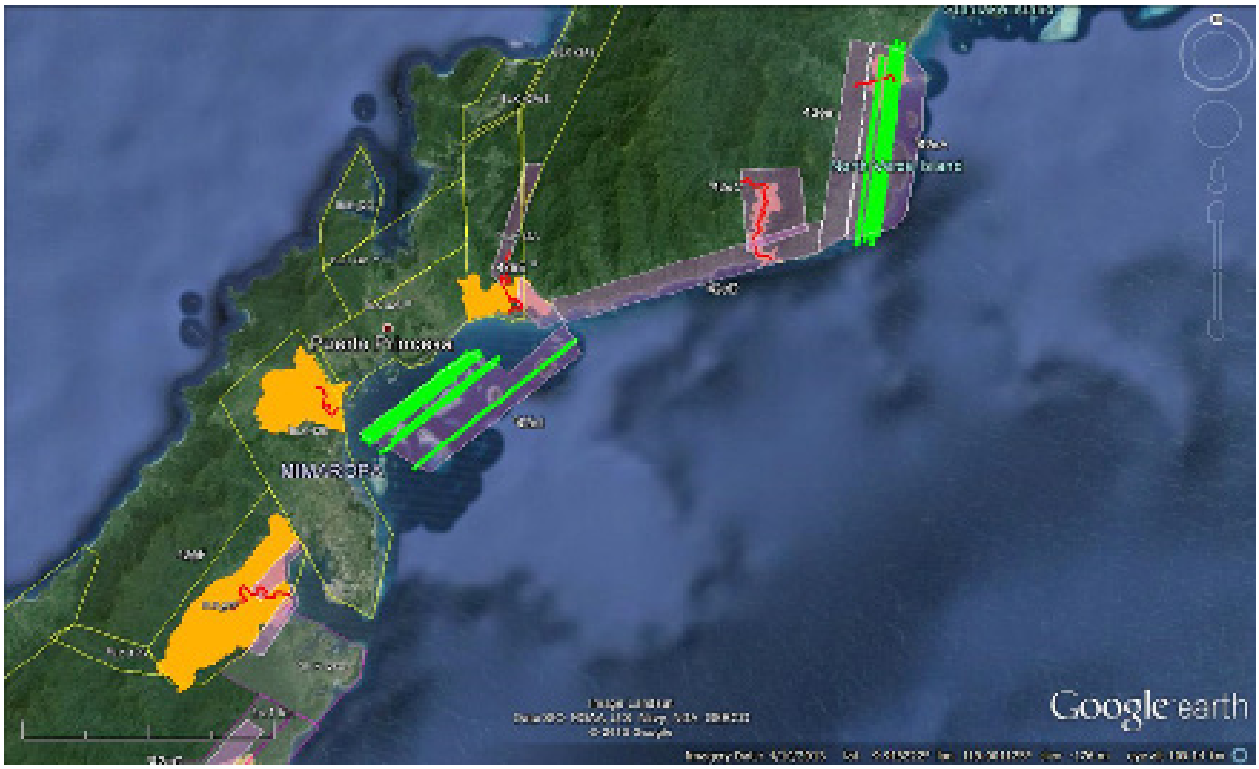


Figure A-7.12. Swath Coverage of Flight No. 3507G

Flight No. :	3513G	
Area:	BLK42 eA, islands	
Mission Name:	2BLK42islAs324A	
Parameters:	Altitude: 1100	Scan Frequency: 50
	Scan Angle: 30	Overlap: 24

SWATH

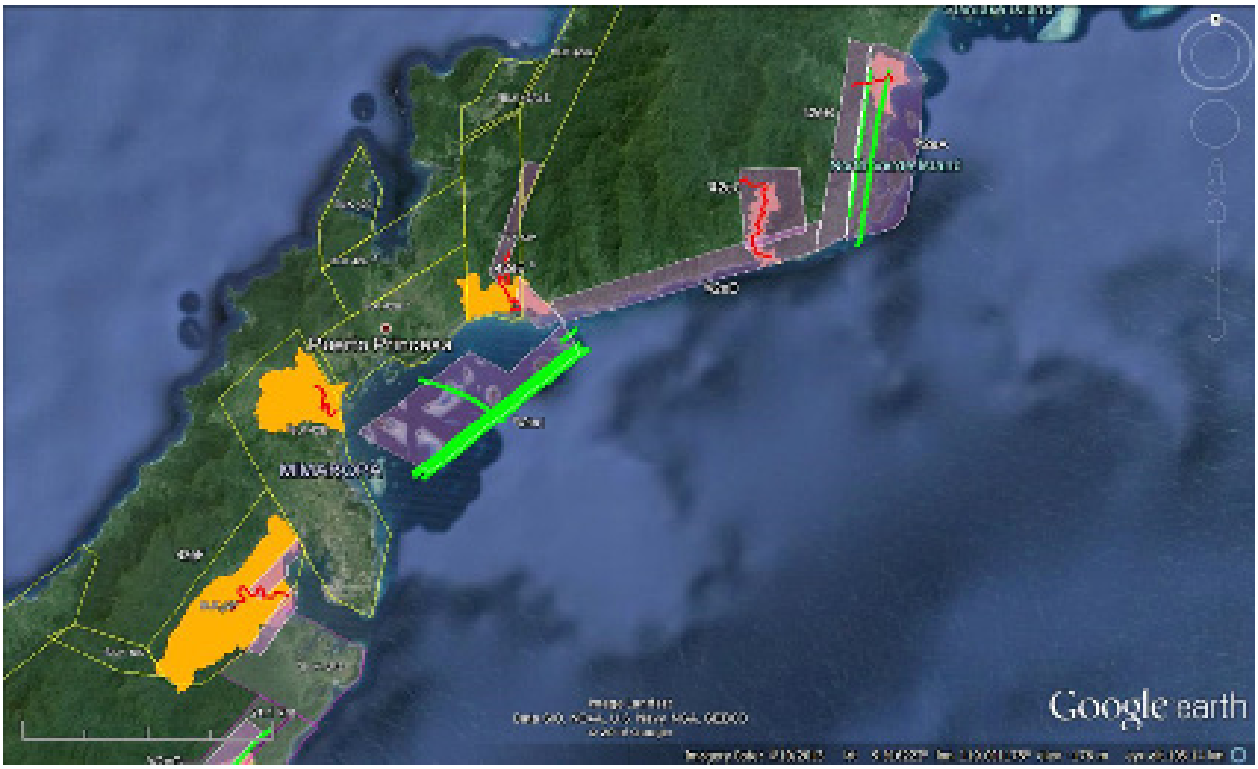


Figure A-7.13. Swath Coverage of Flight No. 3513G

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Block 42Aa

Flight Area	West Palawan
Mission Name	Block 42Aa
Inclusive Flights	3047P
Range data size	19.60 GB
POS	221 MB
Image	53.50 GB
Transfer date	July 13, 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)	1.95
RMSE for East Position (<4.0 cm)	2.40
RMSE for Down Position (<8.0 cm)	3.20
Boresight correction stdev (<0.001deg)	0.000368
IMU attitude correction stdev (<0.001deg)	0.0.000215
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	55.41
Ave point cloud density per sq.m. (>2.0)	3.80
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	270
Maximum Height	1081.76 m
Minimum Height	49.91 m
Classification (# of points)	
Ground	75,662,152
Low vegetation	20,625,024
Medium vegetation	88,392,700
High vegetation	1,217,118,601
Building	6,450,621
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Antonio Chua Jr., Engr. Gladys Mae Apat

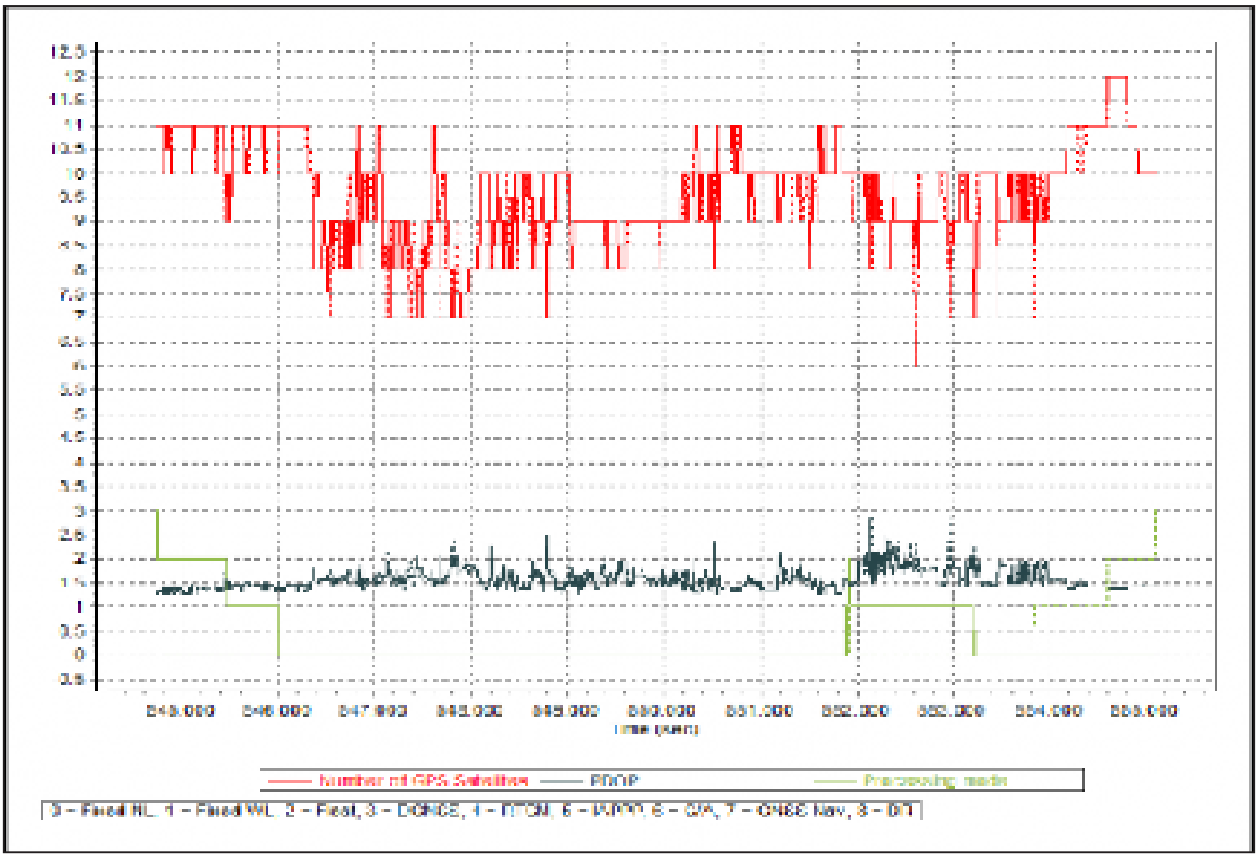


Figure A-8.1. Solution Status

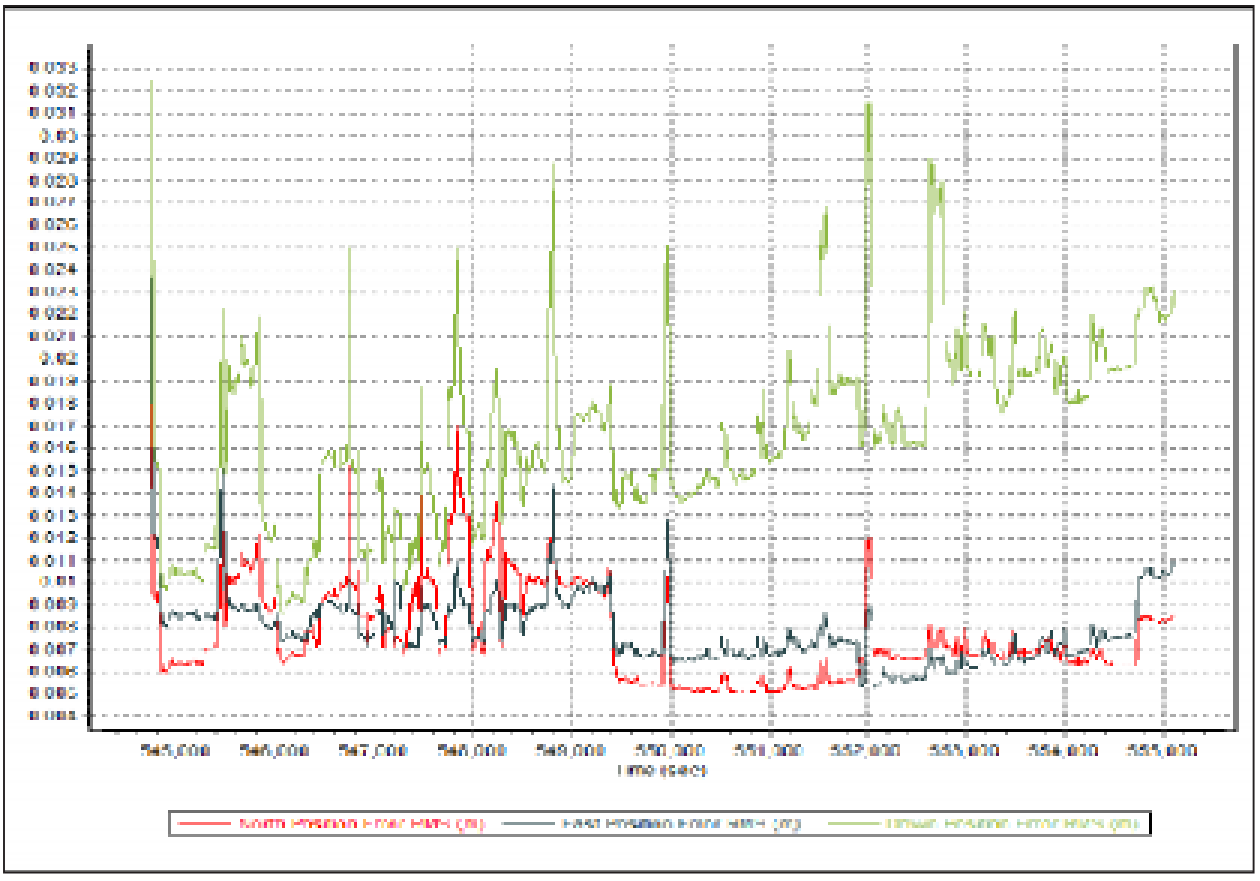


Figure A-8.2. Smoothed Performance Metric Parameters

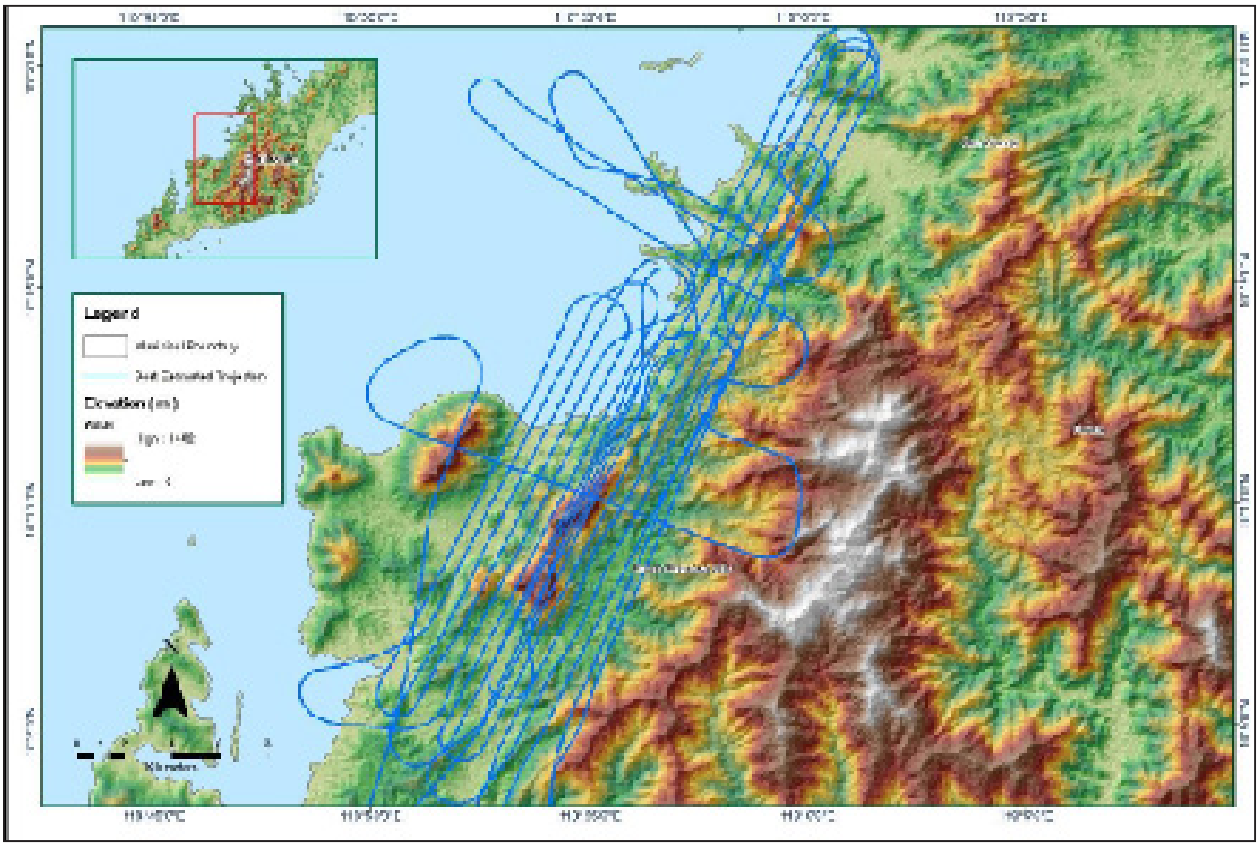


Figure A-8.3. Best Estimated Trajectory

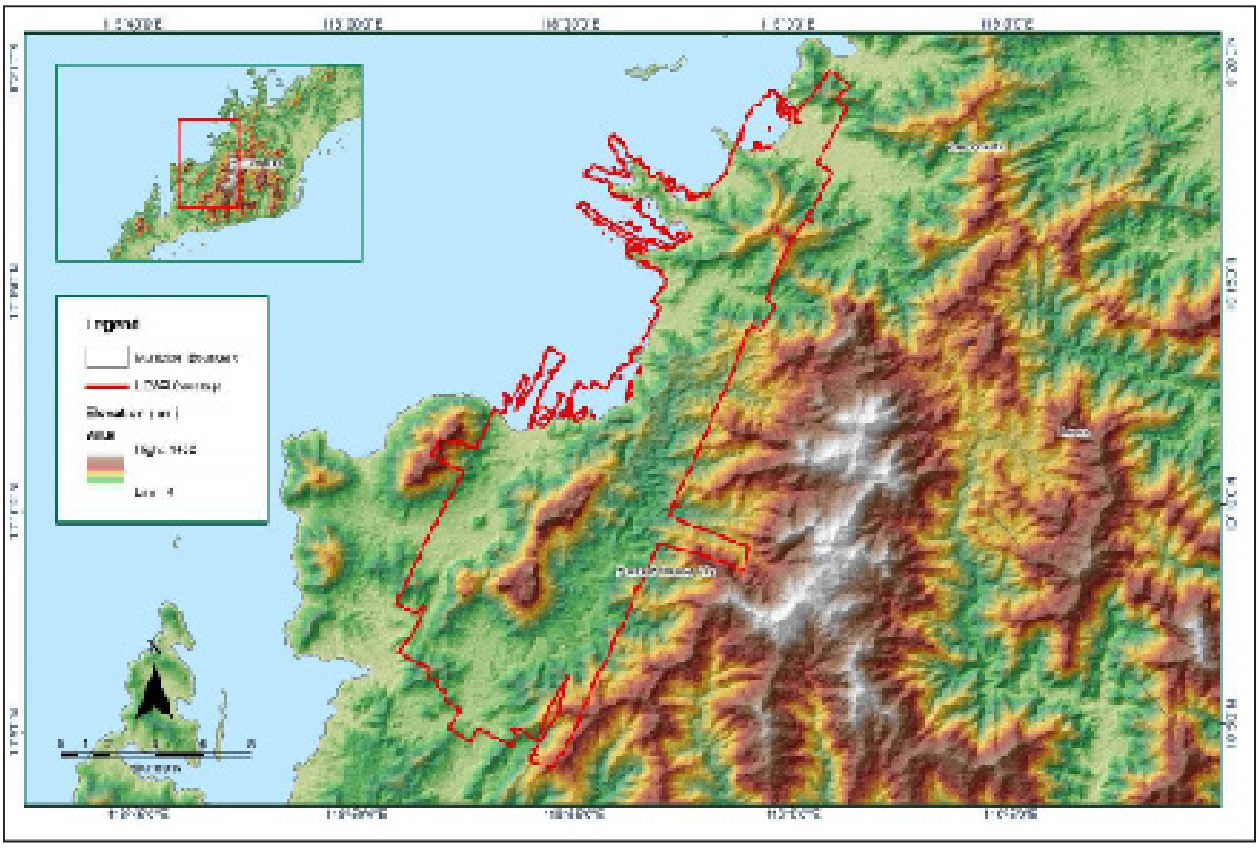


Figure A-8.4. Coverage of LiDAR data

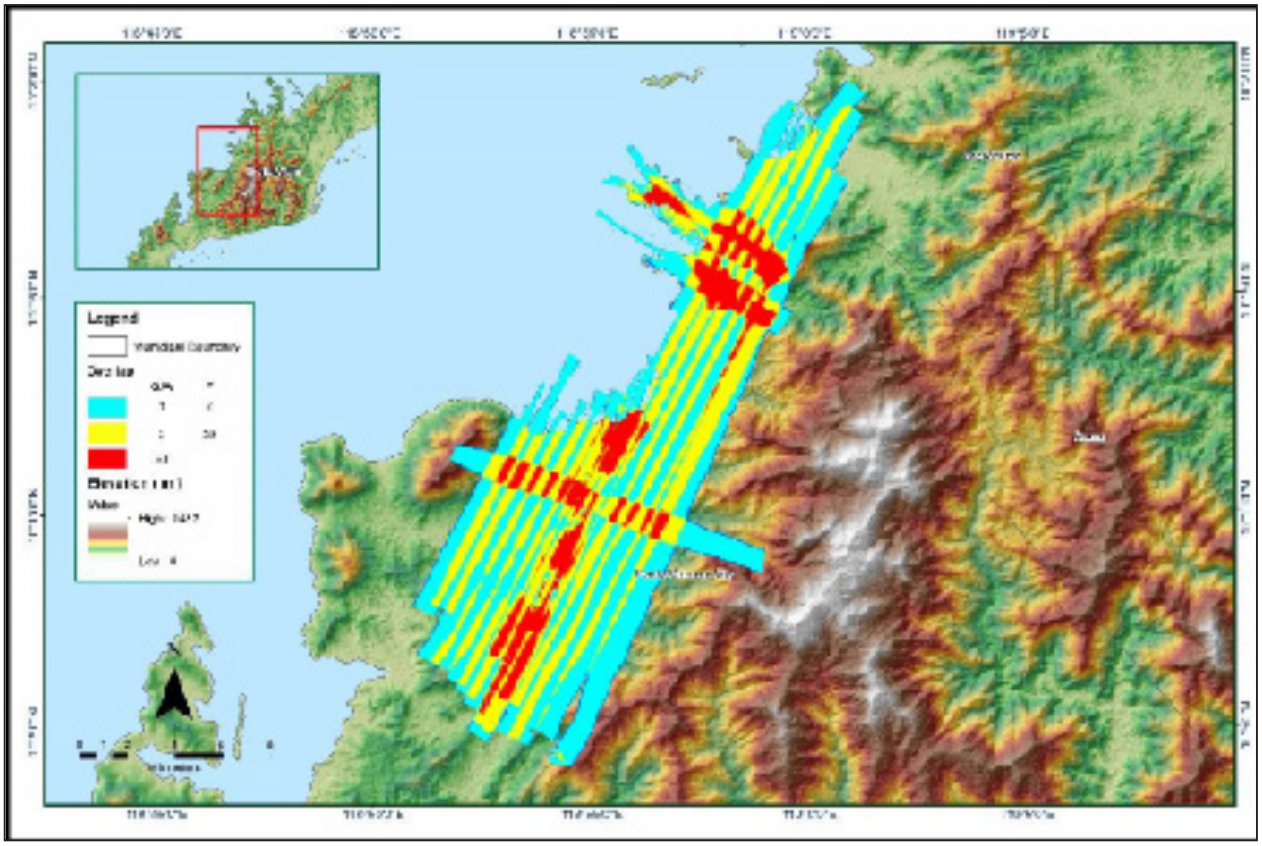


Figure A-8.5. Image of data overlap

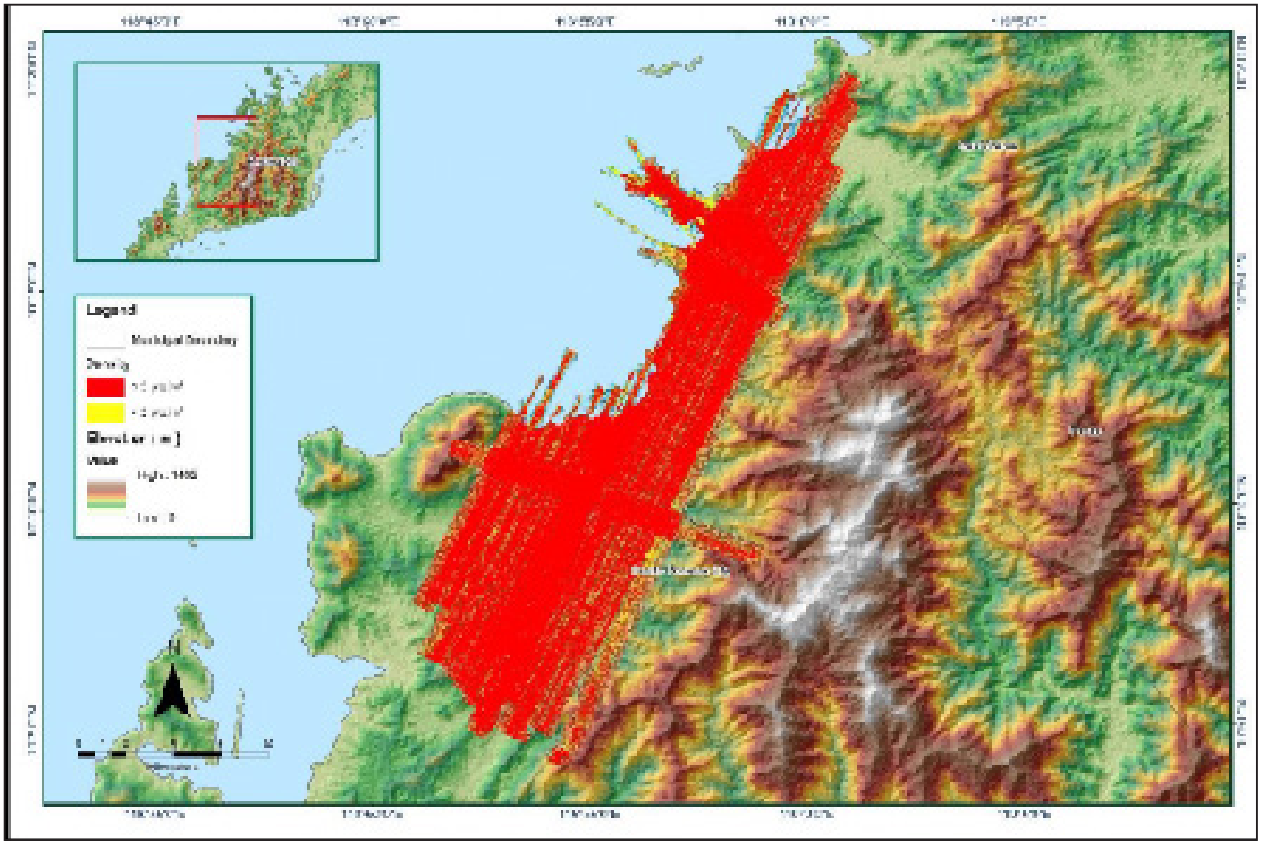


Figure A-8.6. Density map of merged LiDAR data

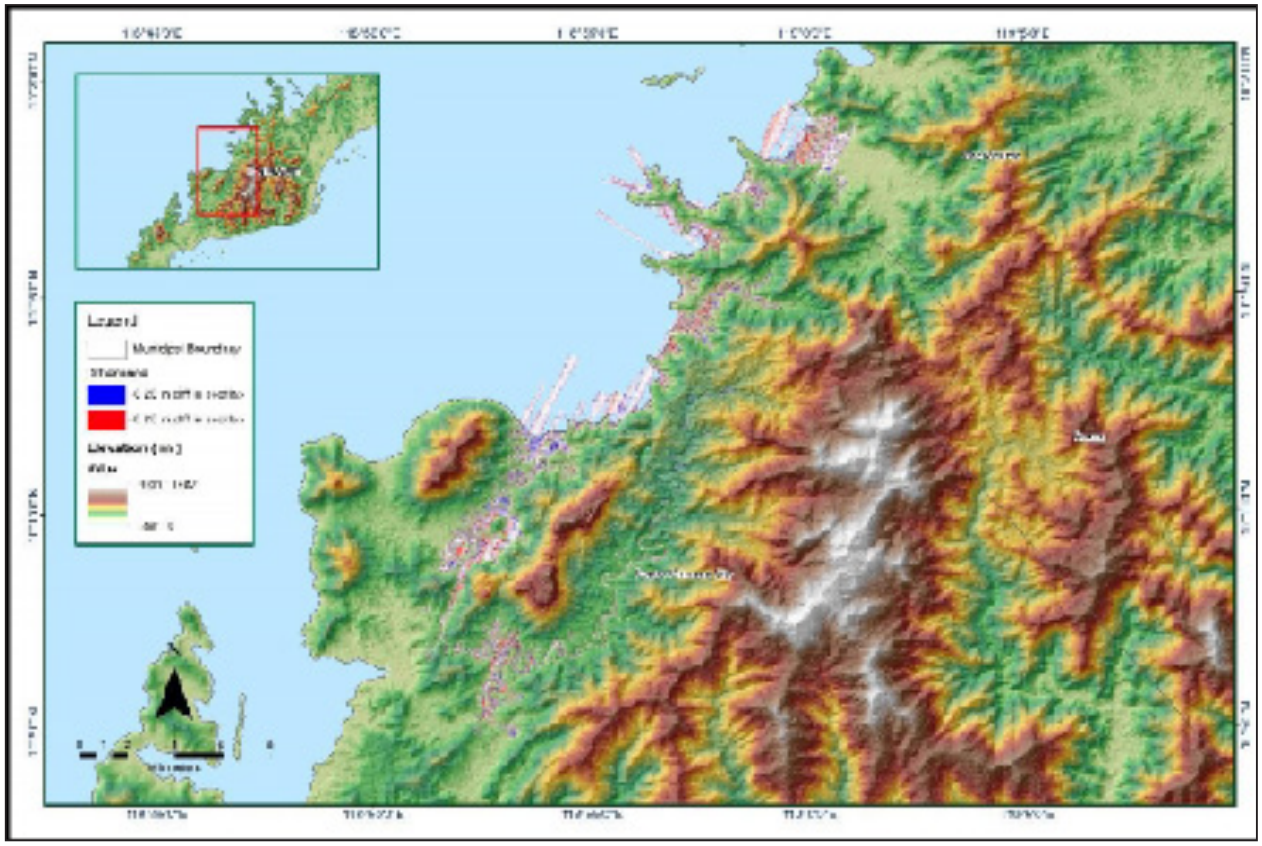


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Block 42A

Flight Area	West Palawan
Mission Name	Block 42A
Inclusive Flights	3017P
Range data size	23.20 GB
POS	256 MB
Image	55.80 GB
Transfer date	July 23, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.70
RMSE for East Position (<4.0 cm)	2.65
RMSE for Down Position (<8.0 cm)	7.0
Boresight correction stdev (<0.001deg)	0.000219
IMU attitude correction stdev (<0.001deg)	0.0.000206
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	43.05
Ave point cloud density per sq.m. (>2.0)	4.97
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	167
Maximum Height	691.88 m
Minimum Height	49.73 m
Classification (# of points)	
Ground	123,911,999
Low vegetation	53,331,766
Medium vegetation	135,405,339
High vegetation	972,312,453
Building	4,714,315
Orthophoto	Yes
Processed by	Engr. Abigail Joy Ching, Engr. Merven Matthew Natino, Engr. Mark Sueden Lyle Magtalas

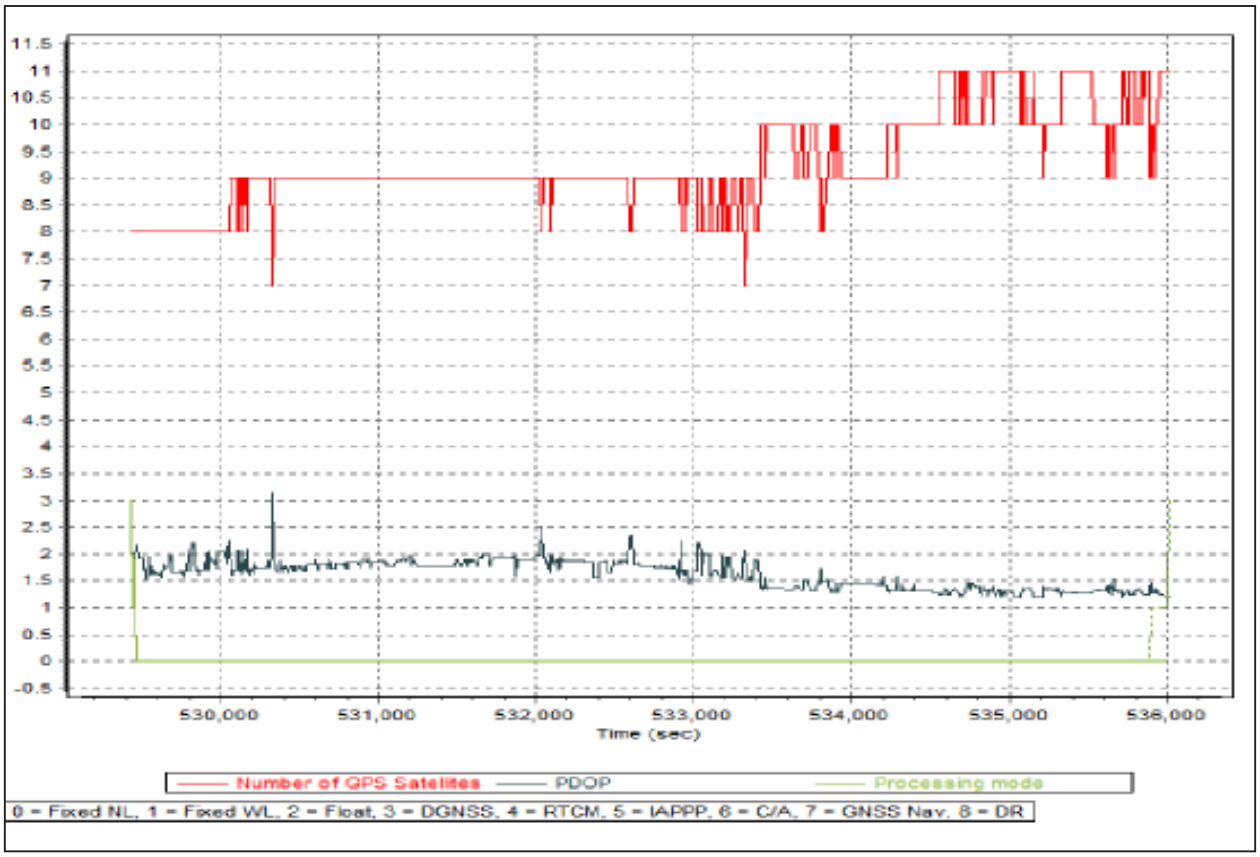


Figure A-8.8. Solution Status

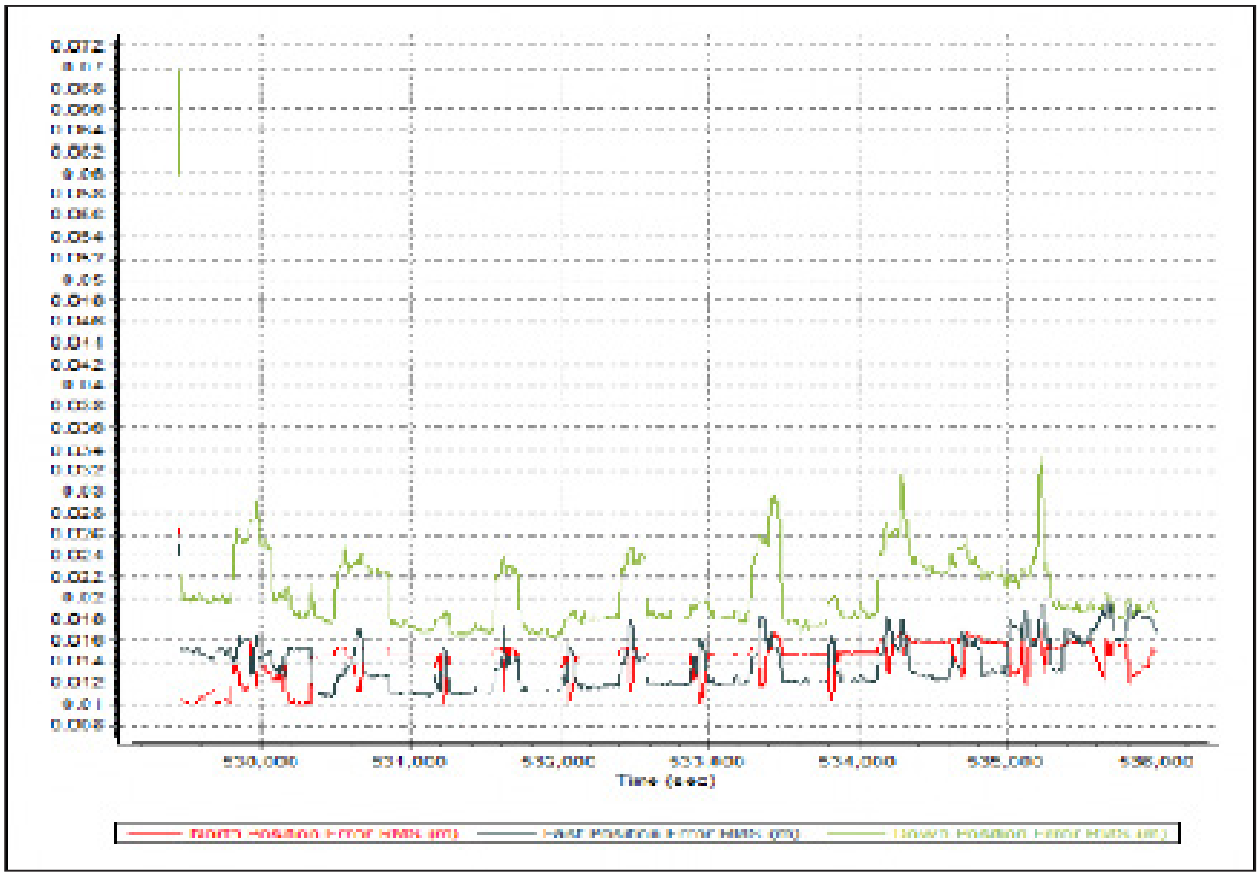


Figure A-8.9. Smoothed Performance Metric Parameters

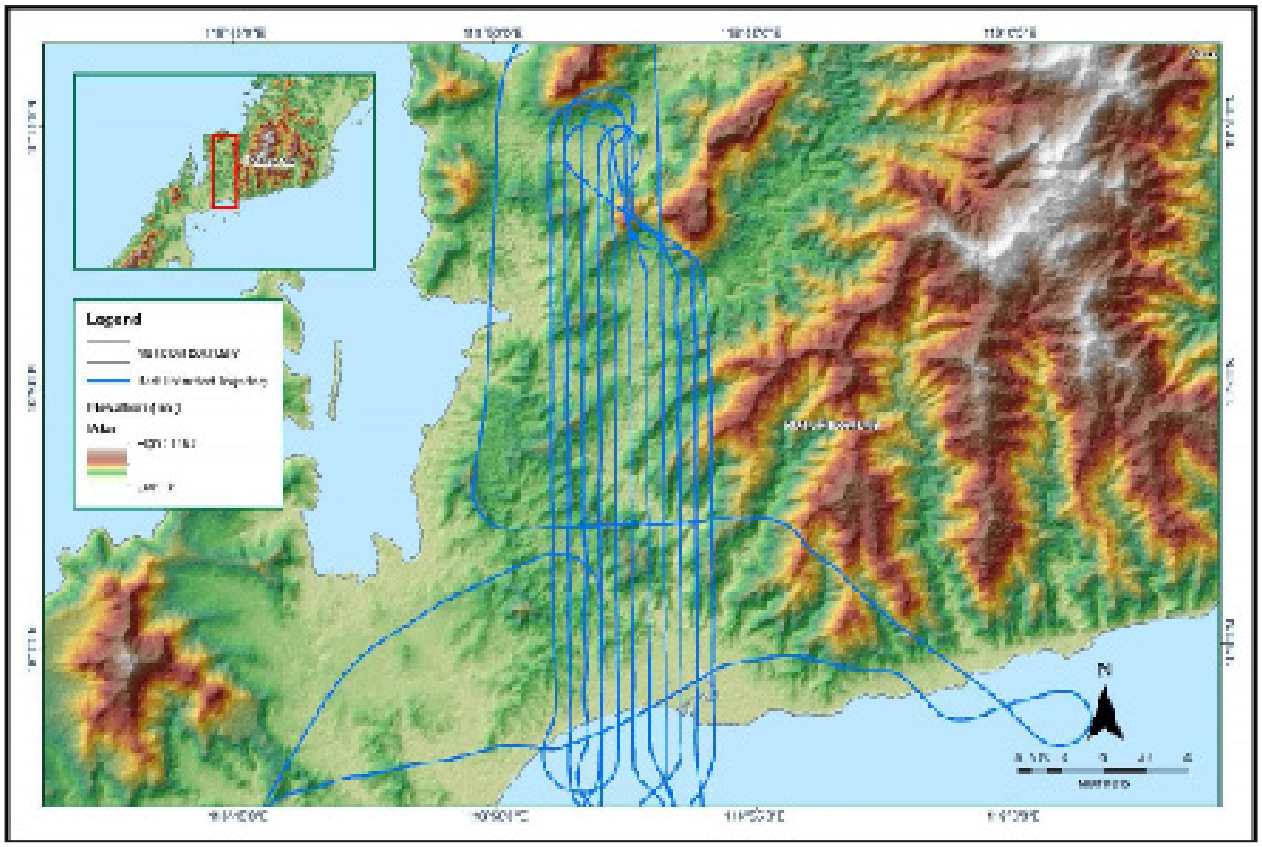


Figure A-8.10. Best Estimated Trajectory

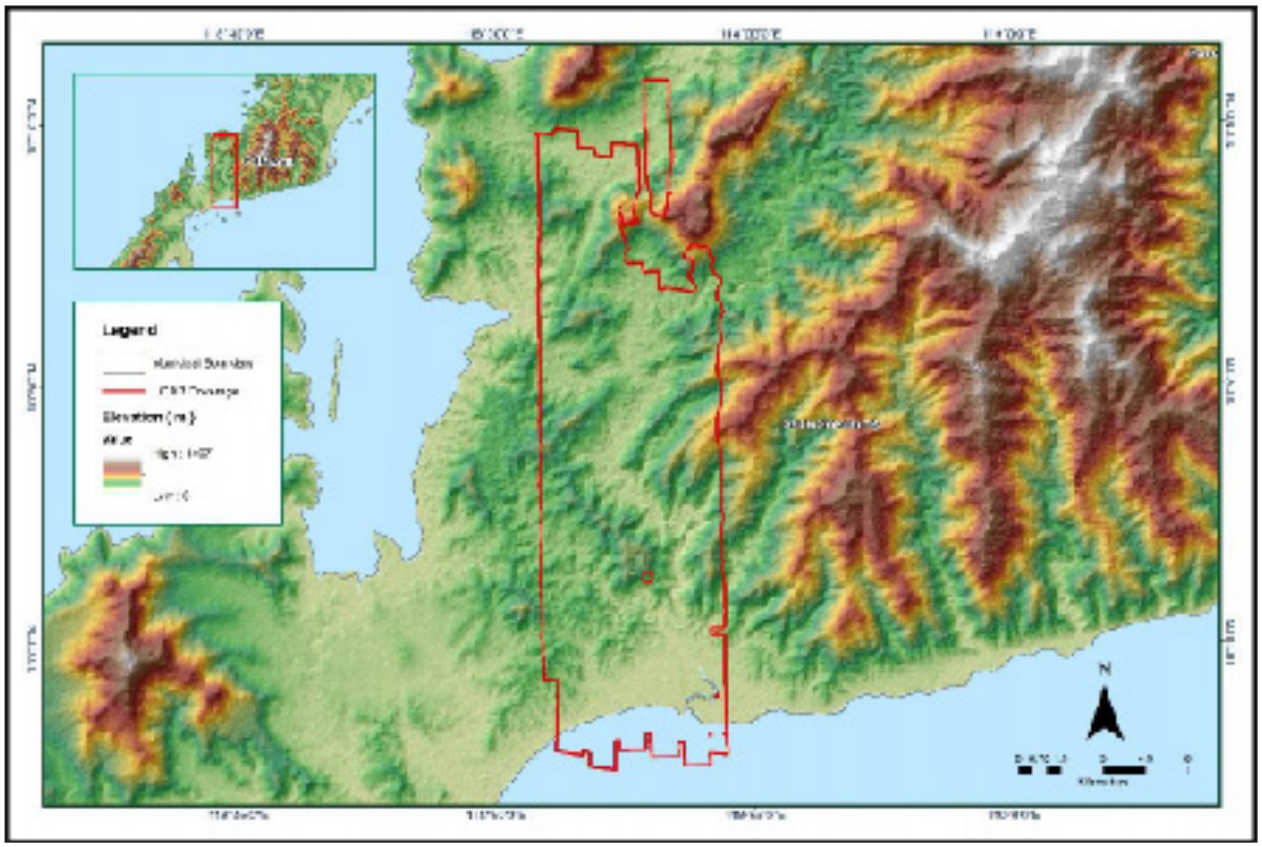


Figure A-8.11. Coverage of LiDAR data

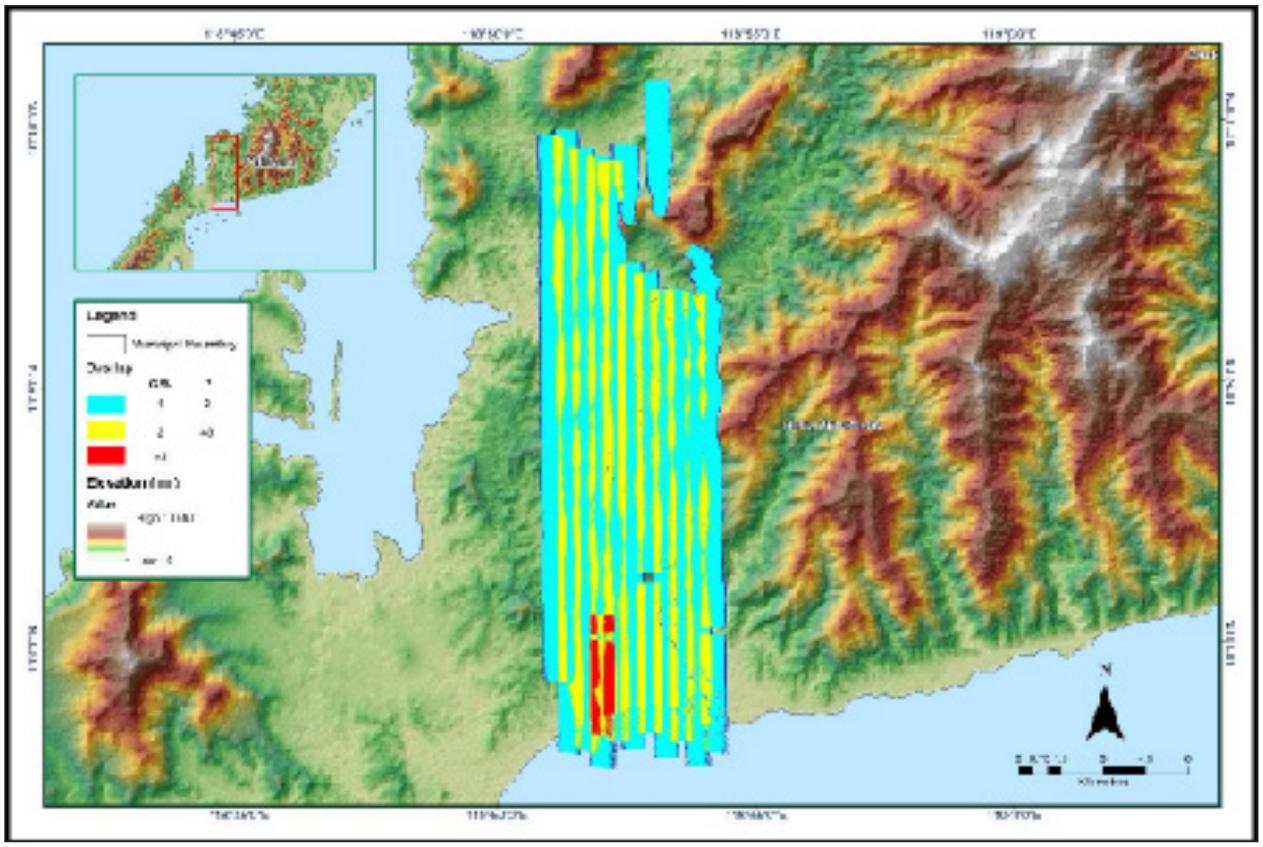


Figure A-8.12. Image of data overlap

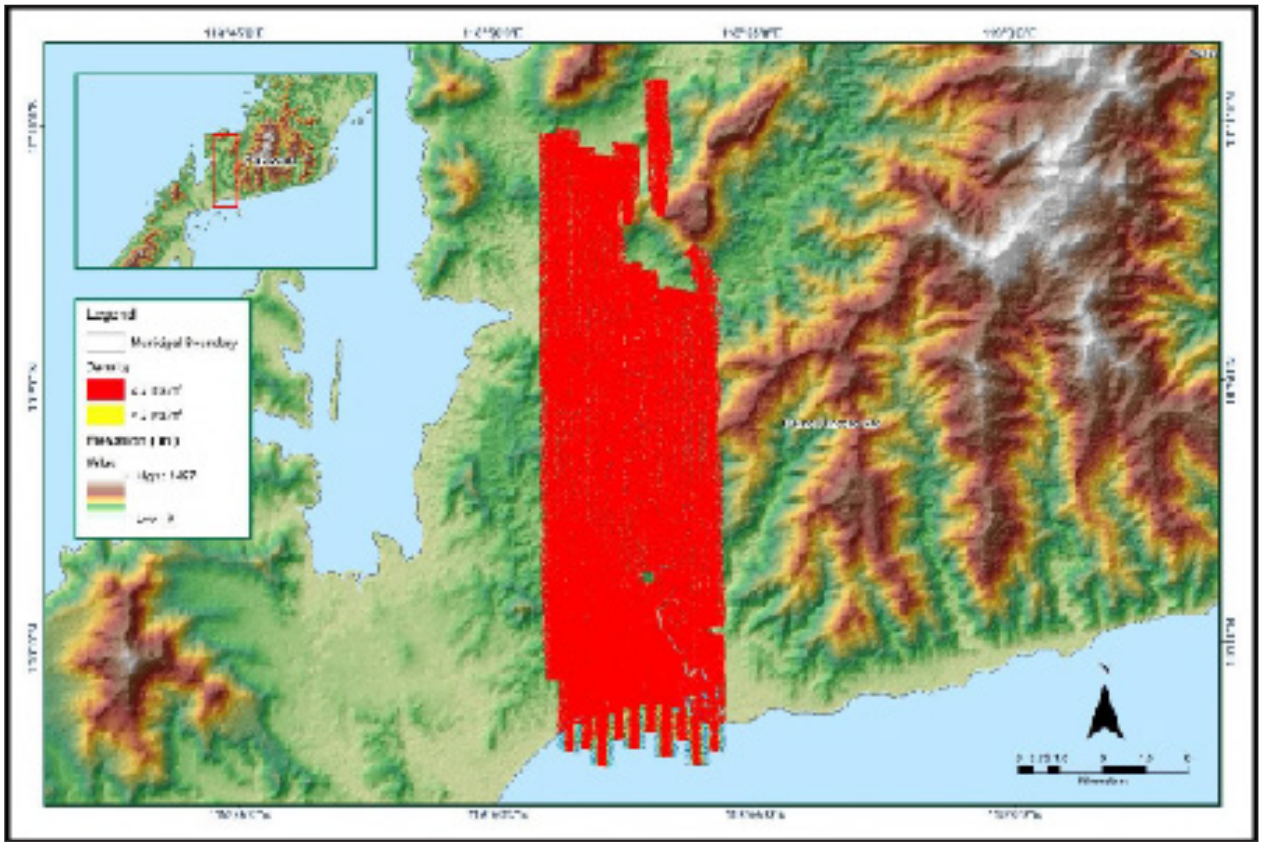


Figure A-8.13. Density map of merged LiDAR data

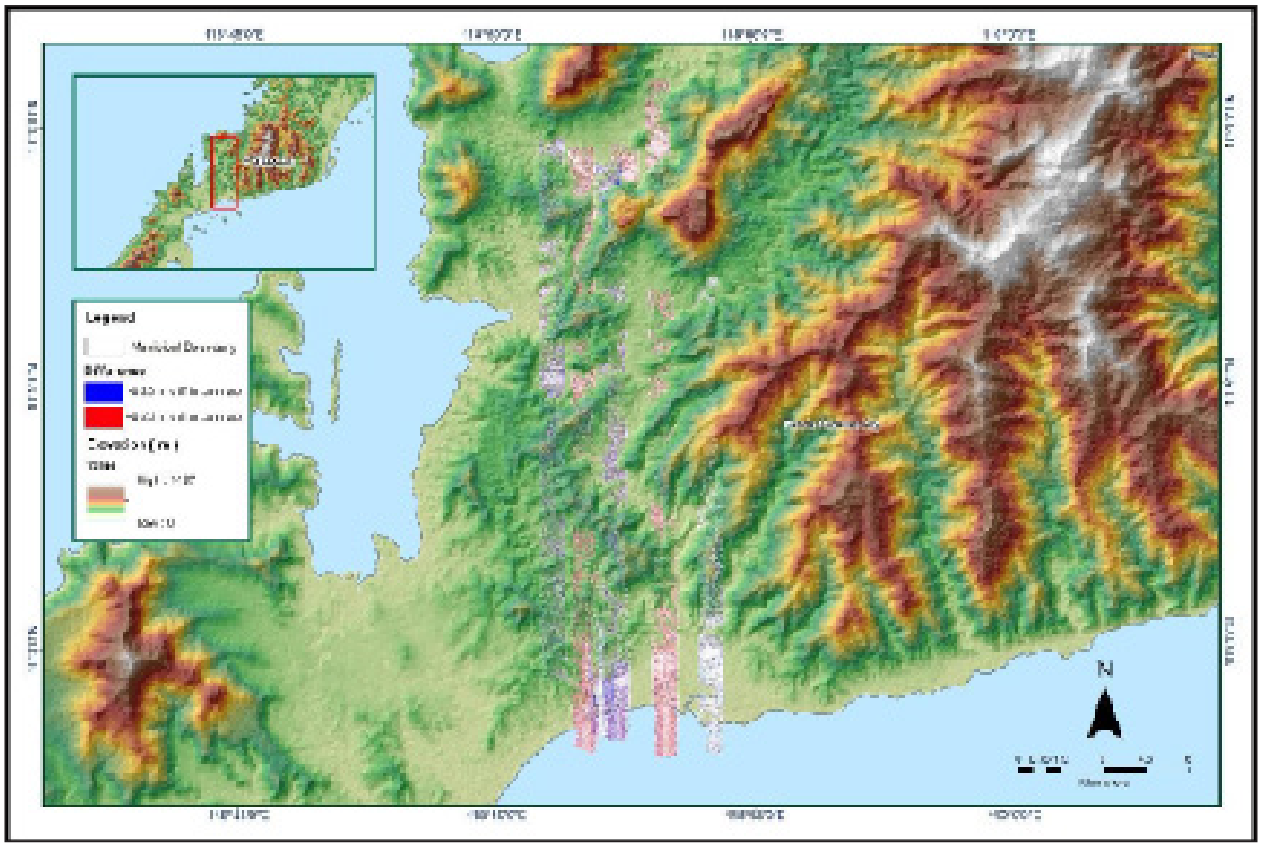


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Block 42B

Flight Area	West Palawan
Mission Name	Block 42B
Inclusive Flights	3021P & 3023P
Range data size	33.80 GB
POS	388 MB
Image	62.10 GB
Transfer date	June 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)	1.15
RMSE for East Position (<4.0 cm)	1.60
RMSE for Down Position (<8.0 cm)	2.70
Boresight correction stdev (<0.001deg)	0.000249
IMU attitude correction stdev (<0.001deg)	0.0.003542
GPS position stdev (<0.01m)	0.0099
Minimum % overlap (>25)	61.51
Ave point cloud density per sq.m. (>2.0)	4.60
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	187
Maximum Height	531.87 m
Minimum Height	51.45 m
Classification (# of points)	
Ground	127,193,781
Low vegetation	117,846,397
Medium vegetation	277,341,672
High vegetation	665,966,968
Building	3,365,152
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Jennifer Saguran, Aljon Rei Araneta , Engr. Mark Sueden Lyle Magtalas

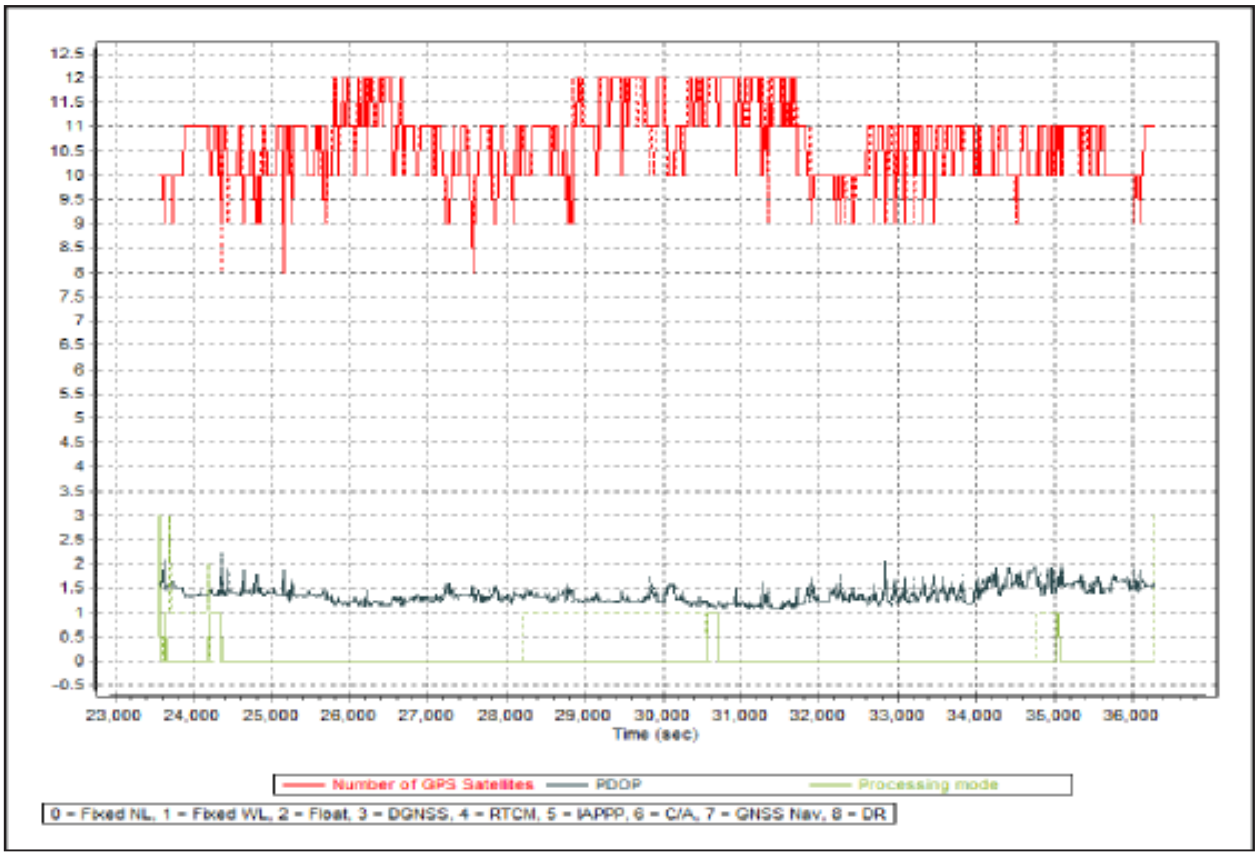


Figure A-8.15. Solution Status

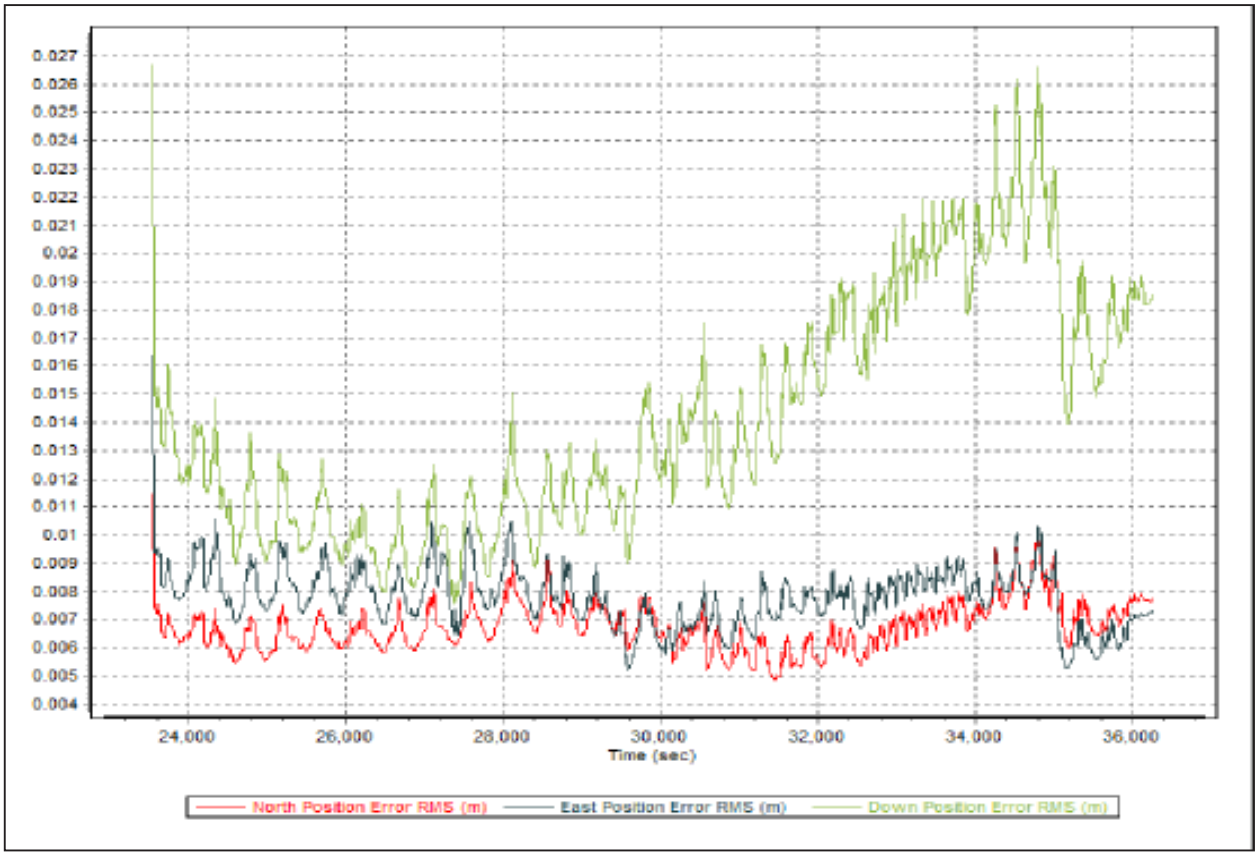


Figure A-8.16. Smoothed Performance Metric Parameters

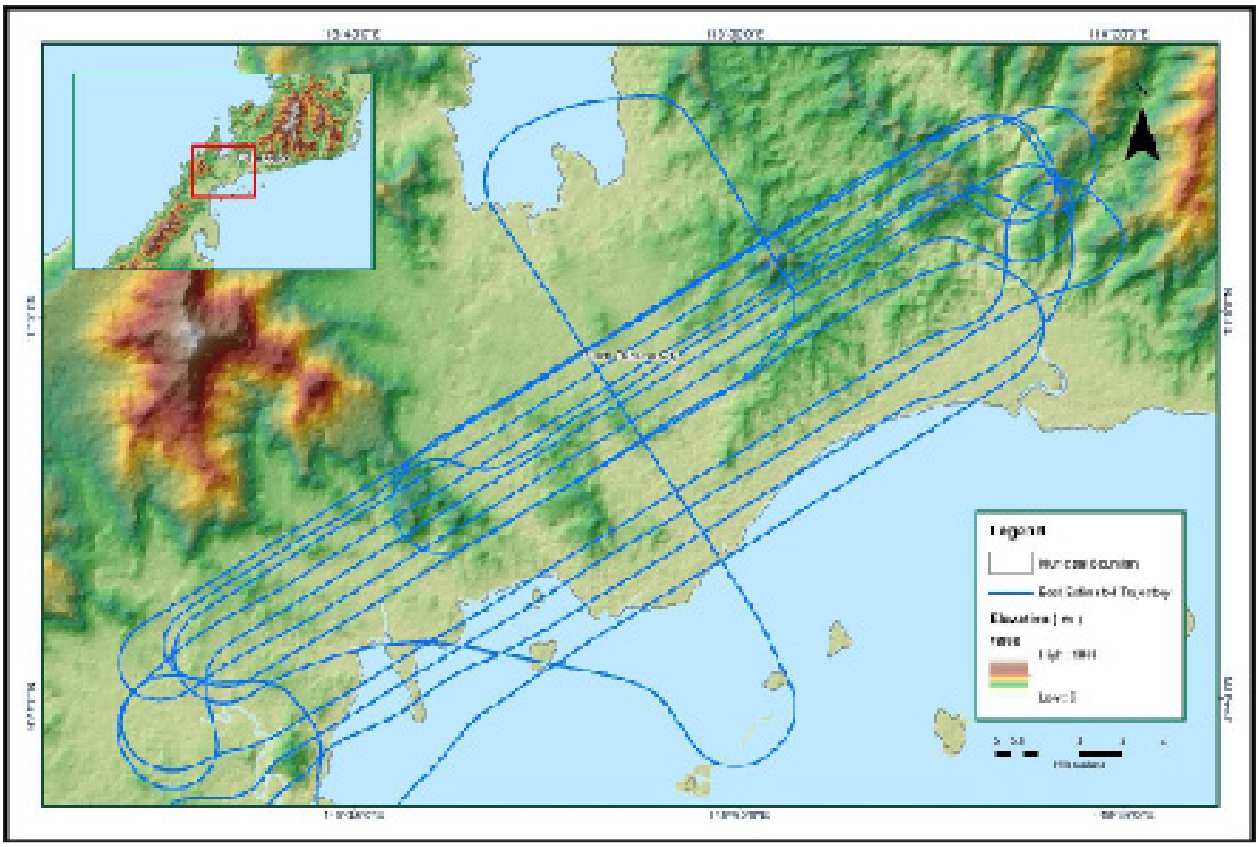


Figure A-8.17. Best Estimated Trajectory

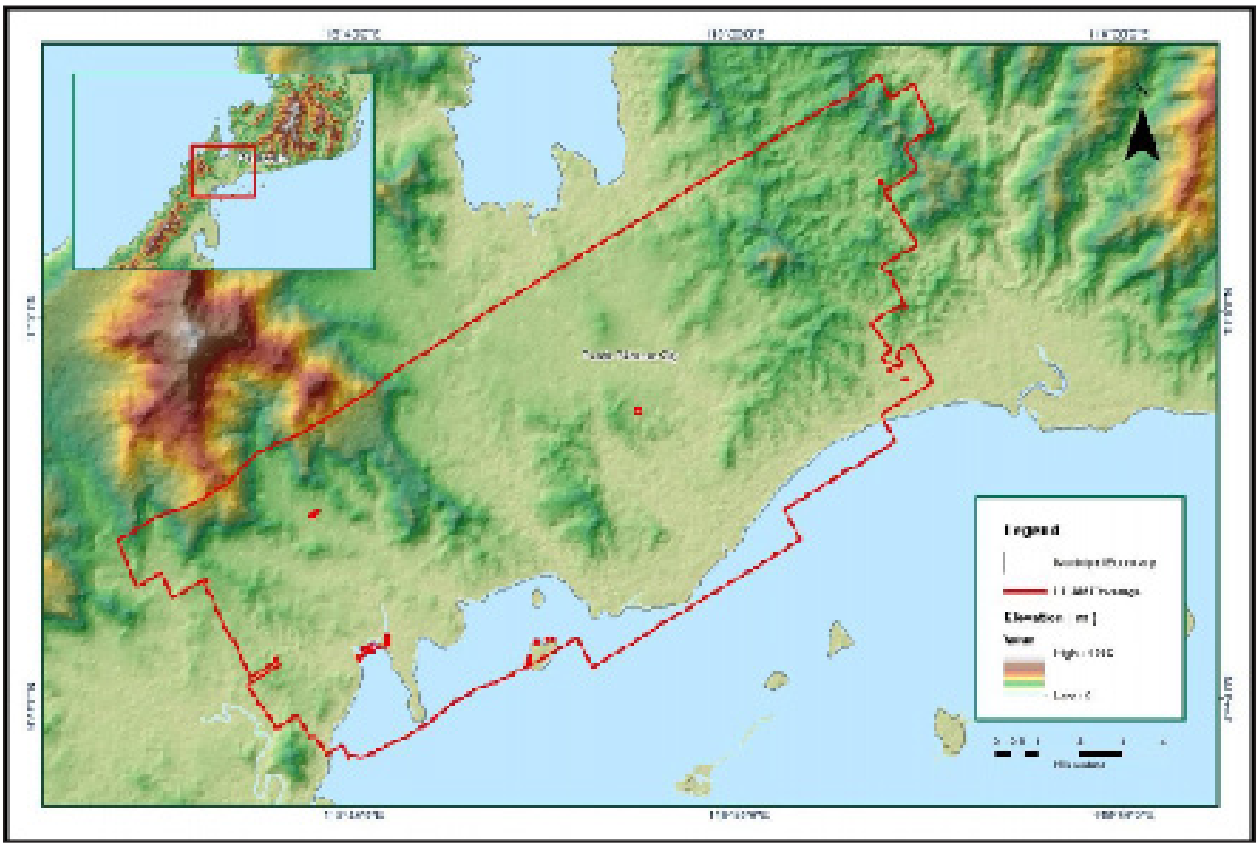


Figure A-8.18. Coverage of LiDAR data

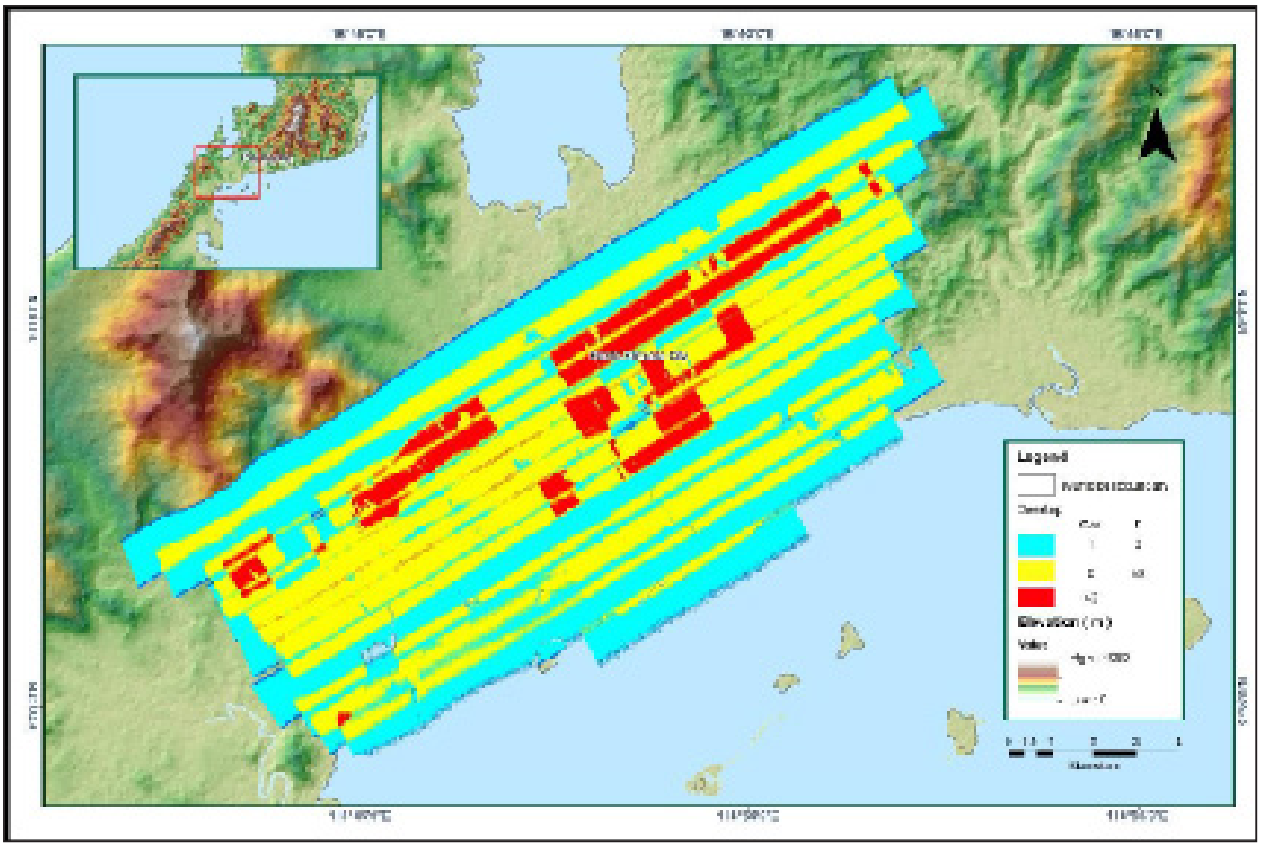


Figure A-8.19. Image of data overlap

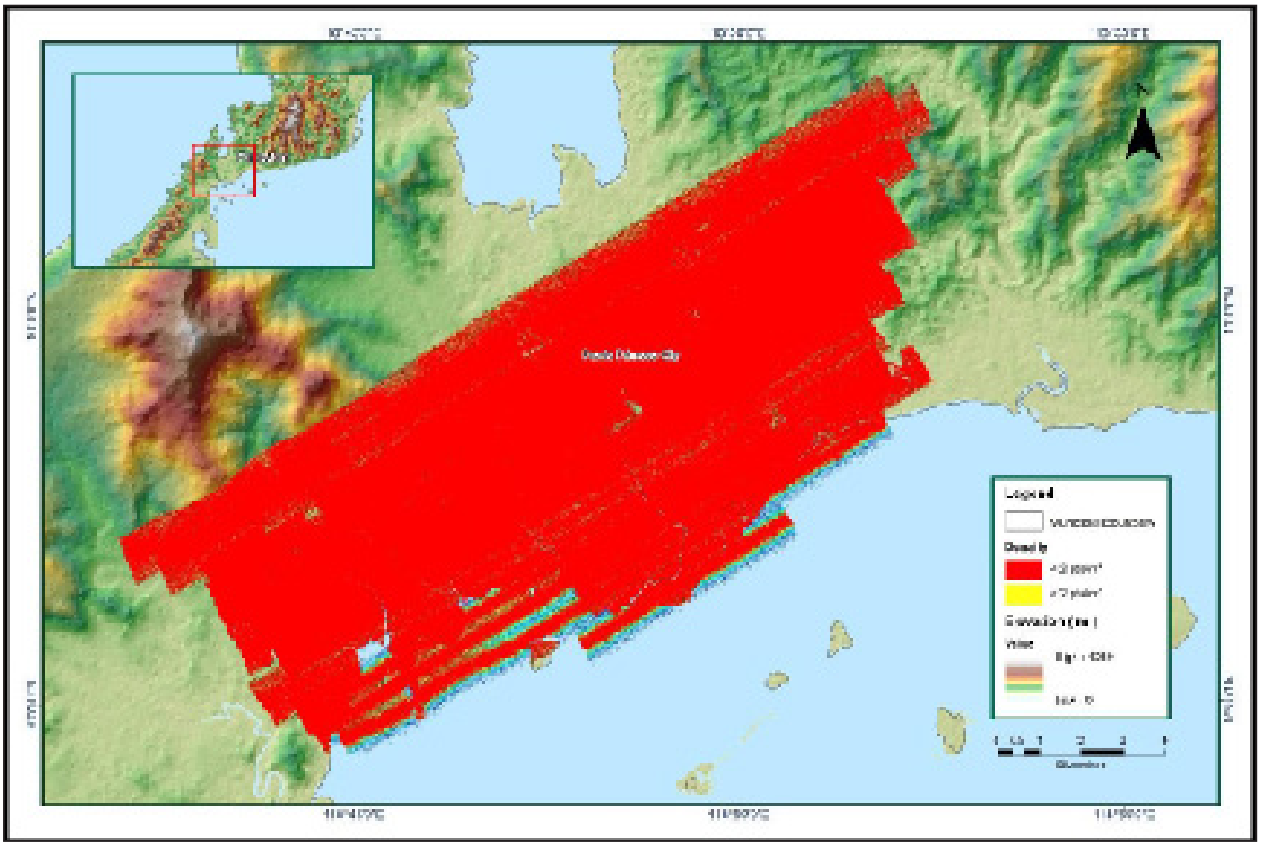


Figure A-8.20. Density map of merged LiDAR data

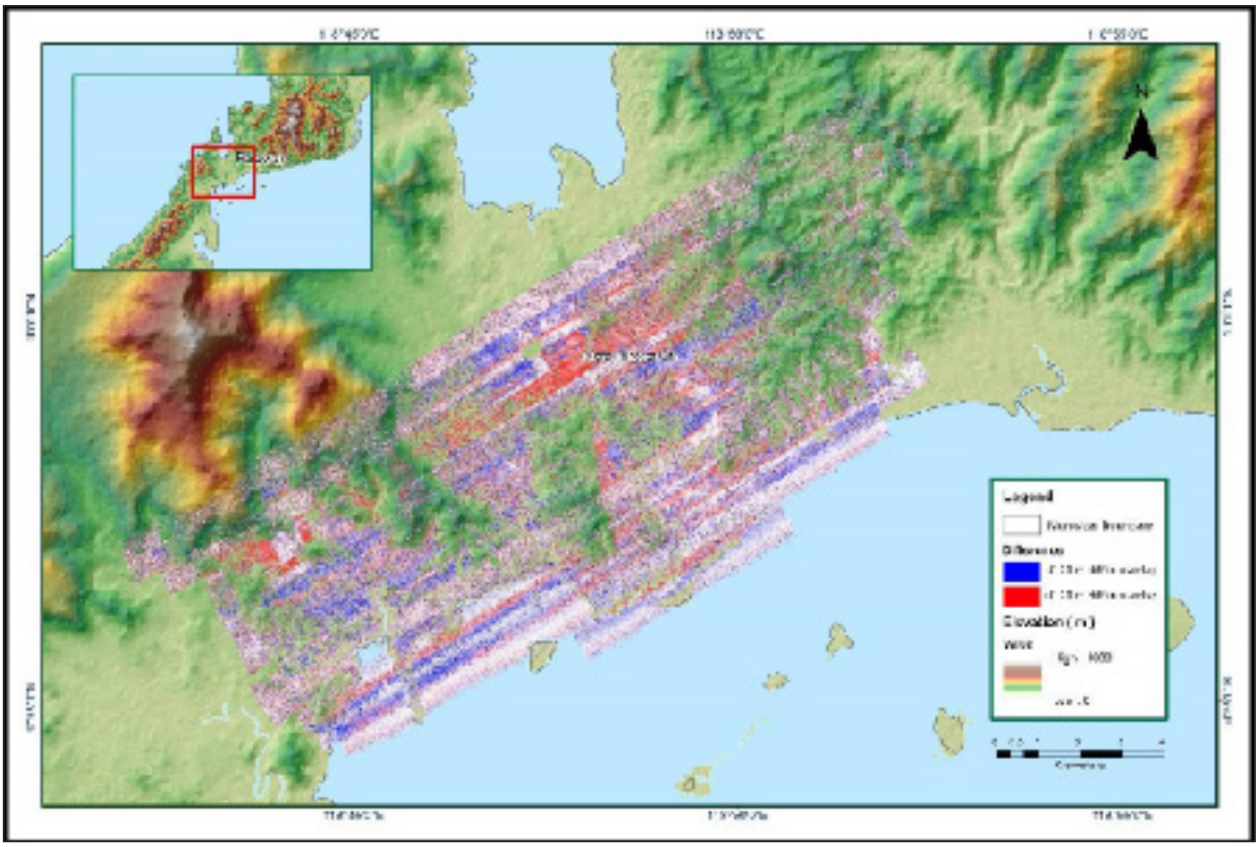


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Block 42B Additional

Flight Area	West Palawan
Mission Name	Block 42B Additional
Inclusive Flights	3073P
Range data size	7.10 GB
POS	107 MB
Image	12.30 GB
Transfer date	August 5, 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)	1.06
RMSE for East Position (<4.0 cm)	1.65
RMSE for Down Position (<8.0 cm)	2.90
Boresight correction stdev (<0.001deg)	0.000070
IMU attitude correction stdev (<0.001deg)	0.0.003542
GPS position stdev (<0.01m)	0.0015
Minimum % overlap (>25)	23.89
Ave point cloud density per sq.m. (>2.0)	3.56
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	92
Maximum Height	440.57 m
Minimum Height	52.38 m
Classification (# of points)	
Ground	41,429,226
Low vegetation	29,503,758
Medium vegetation	83,889,950
High vegetation	177,852,098
Building	1,986,175
Orthophoto	Yes
	Engr. Abigail Ching, Engr. Velina Angela Bemida, Alex John Escobido

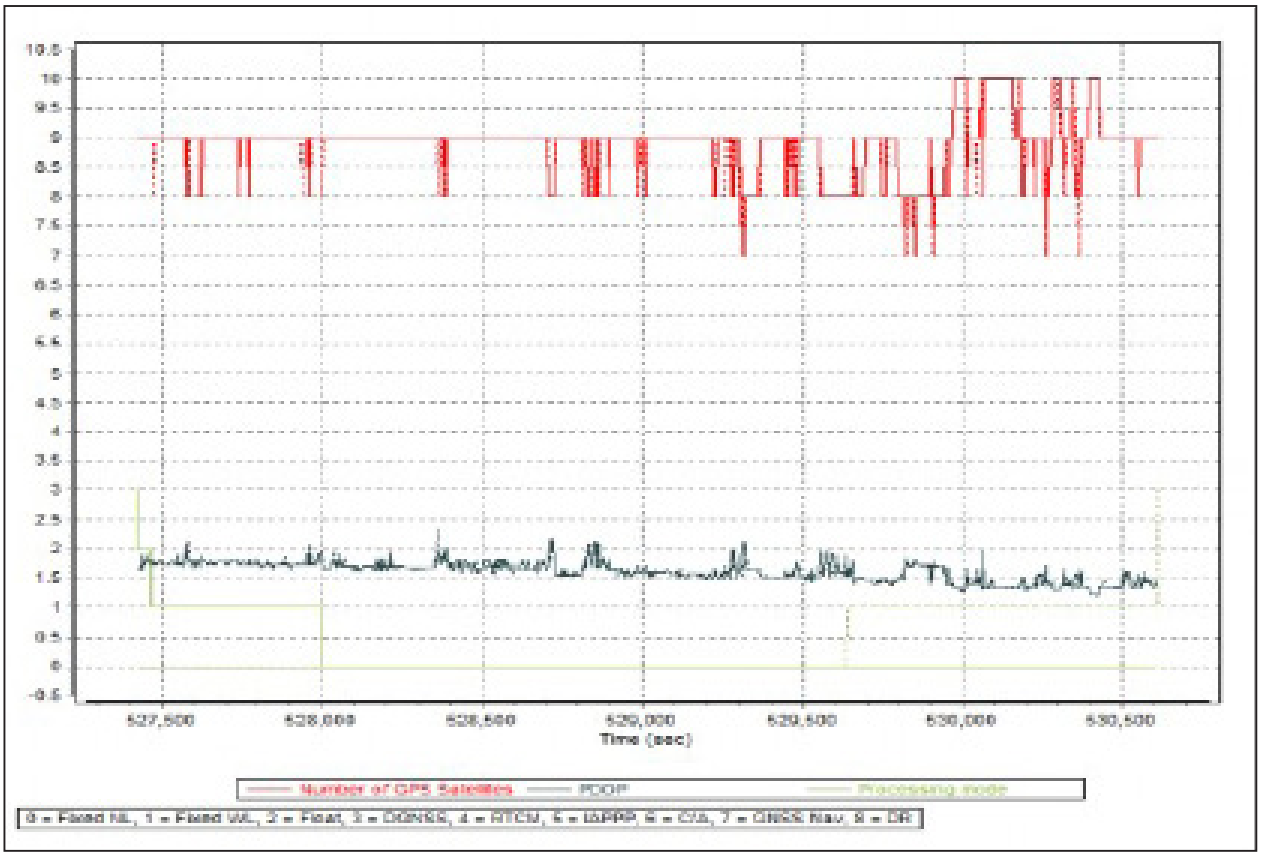


Figure A-8.22. Solution Status

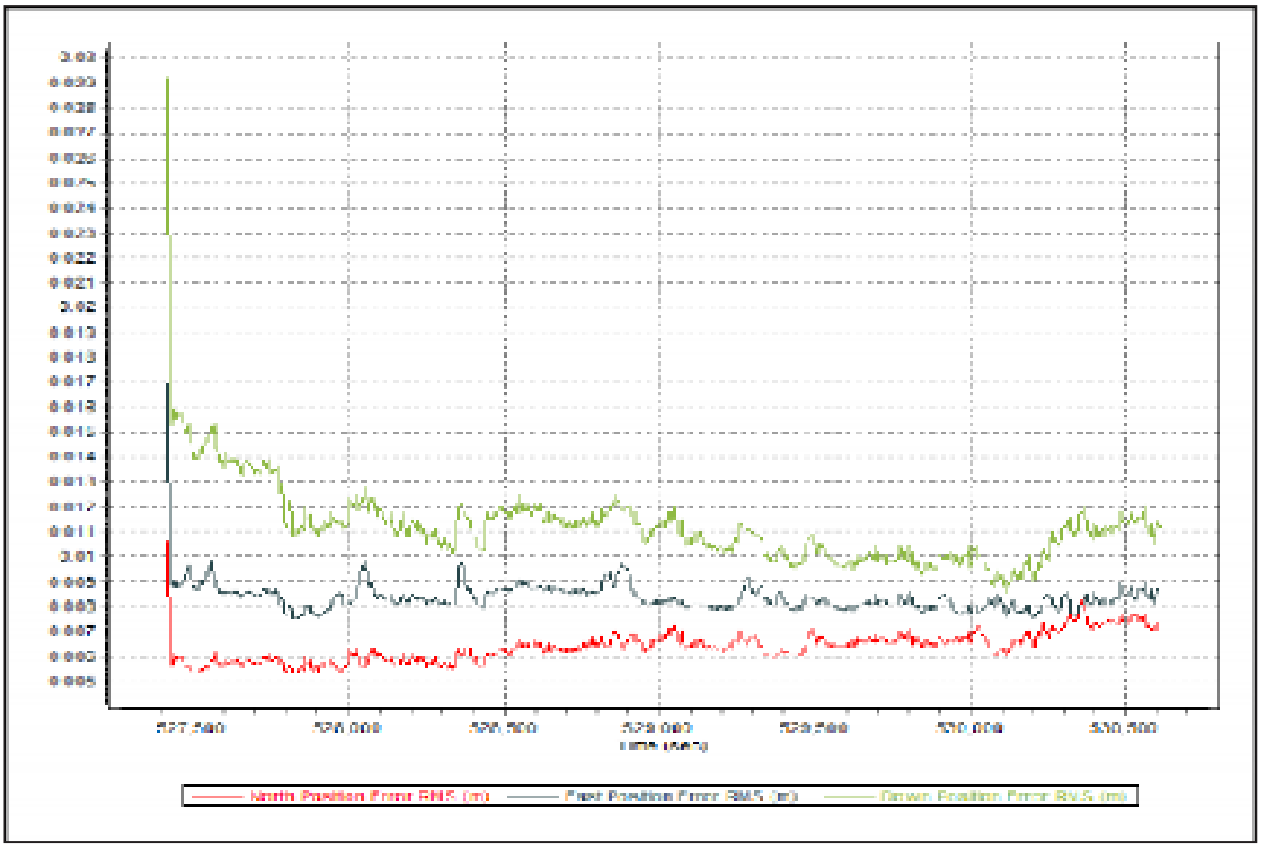


Figure A-8.23. Smoothed Performance Metric Parameters

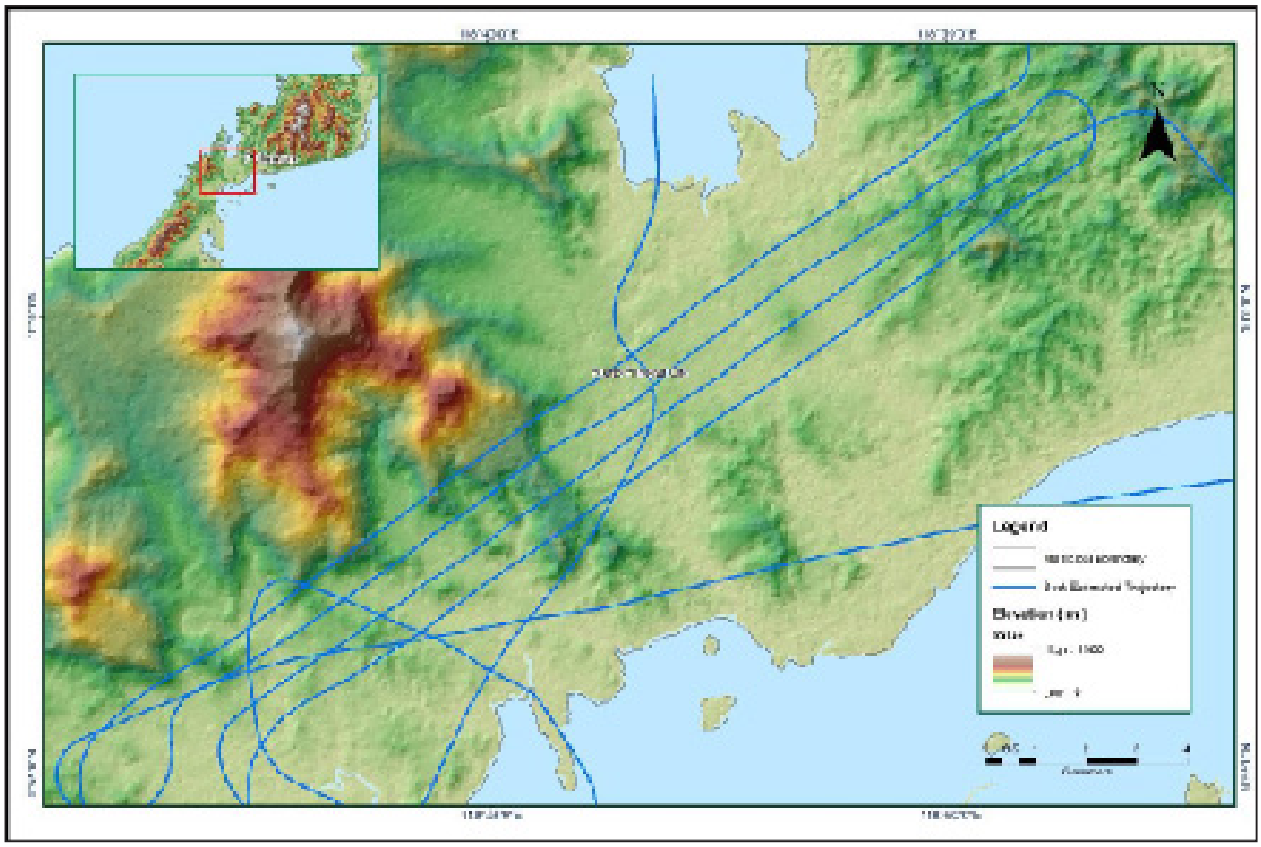


Figure A-8.24. Best Estimated Trajectory

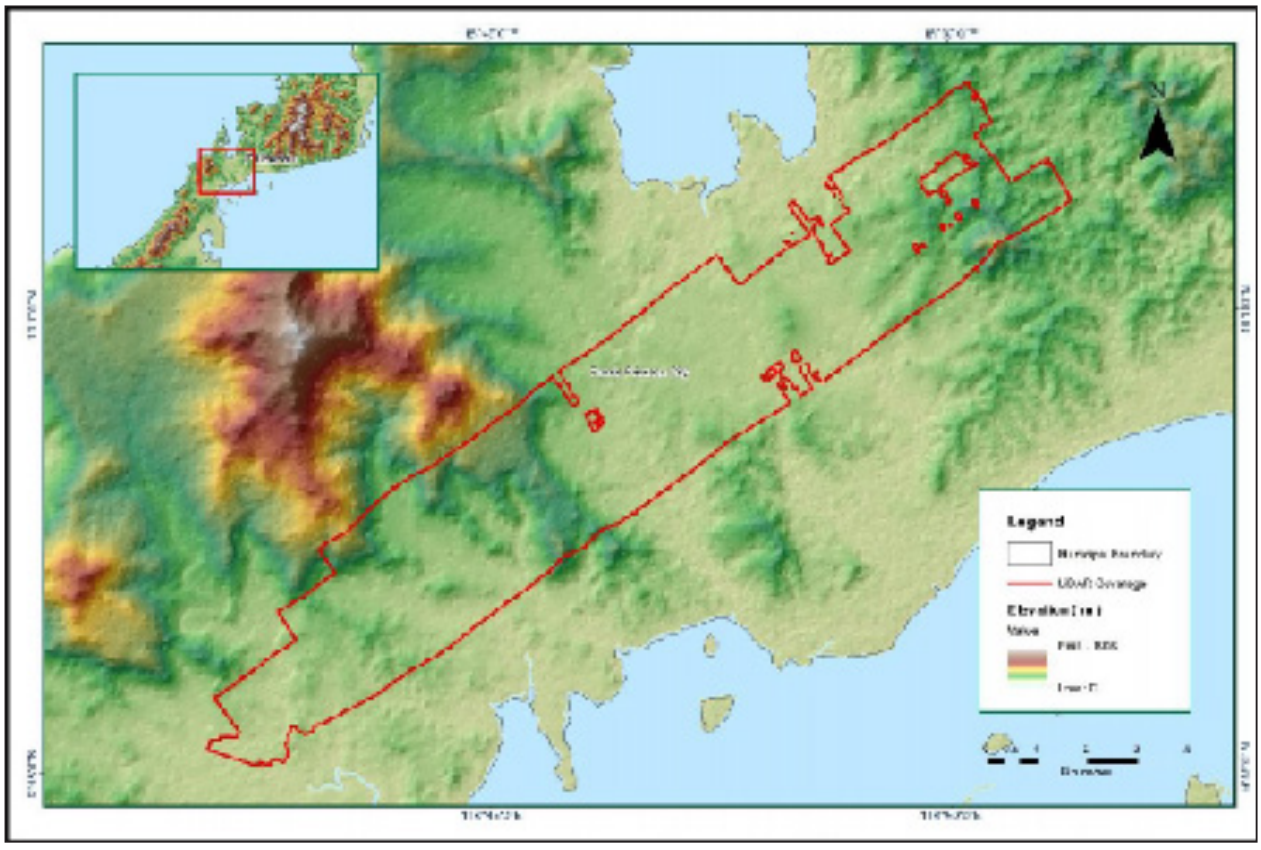


Figure A-8.25. Coverage of LiDAR data

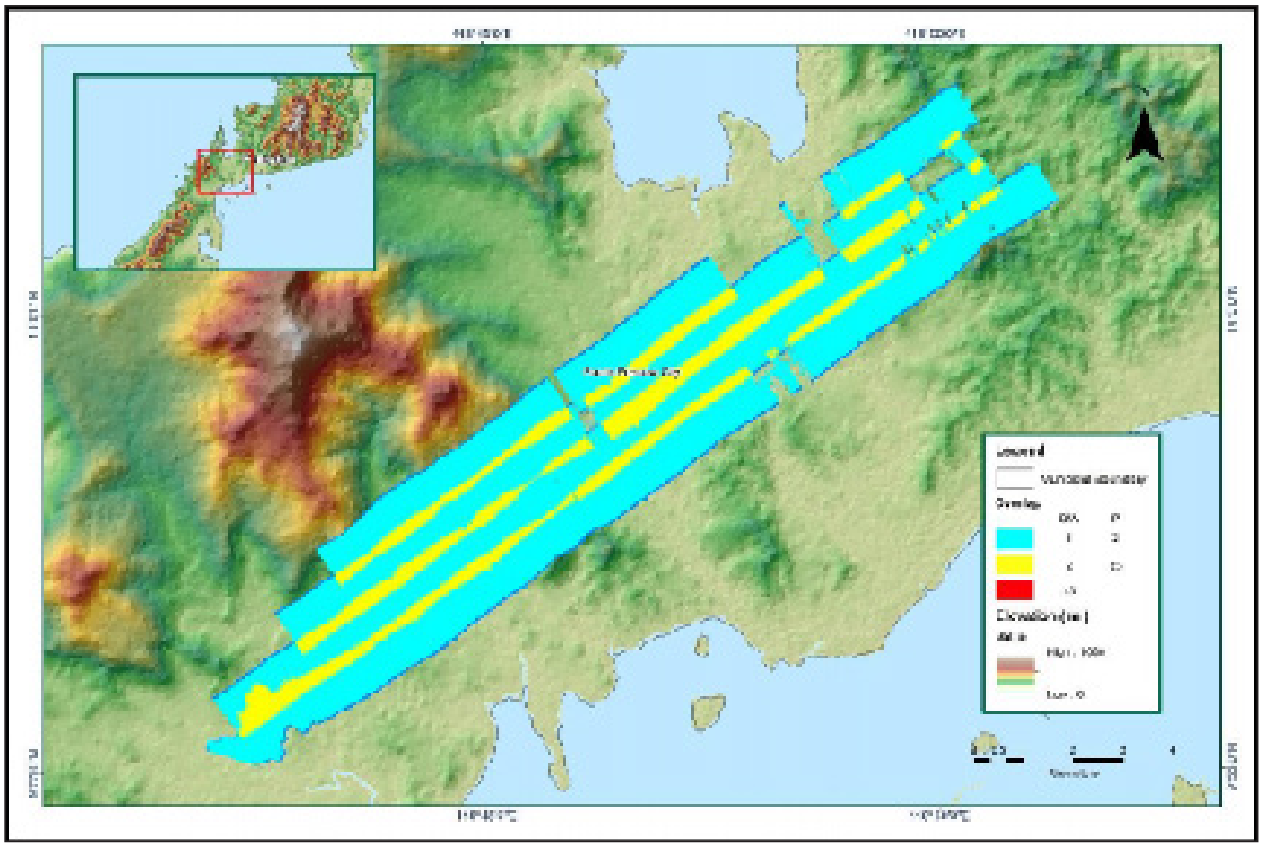


Figure A-8.26. Image of data overlap

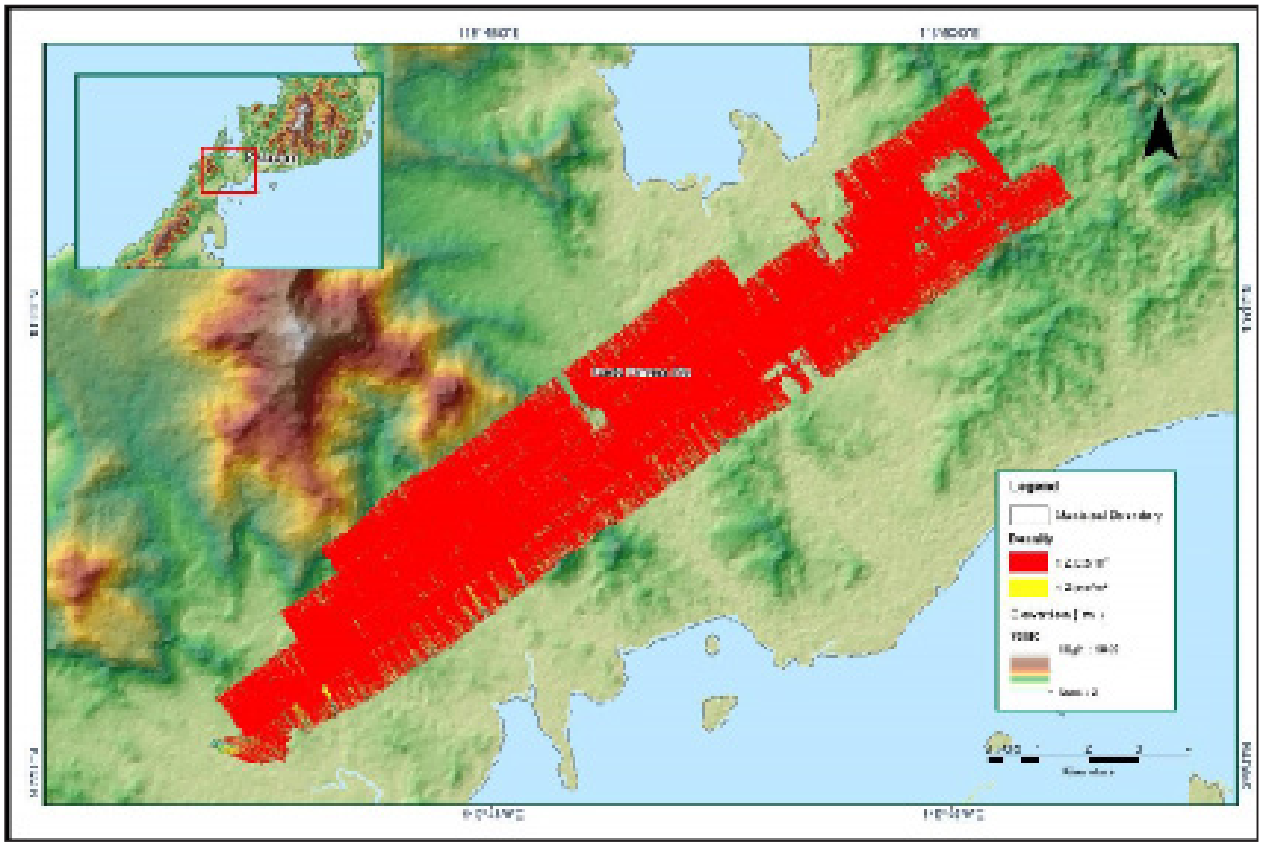


Figure A-8.27. Density map of merged LiDAR data

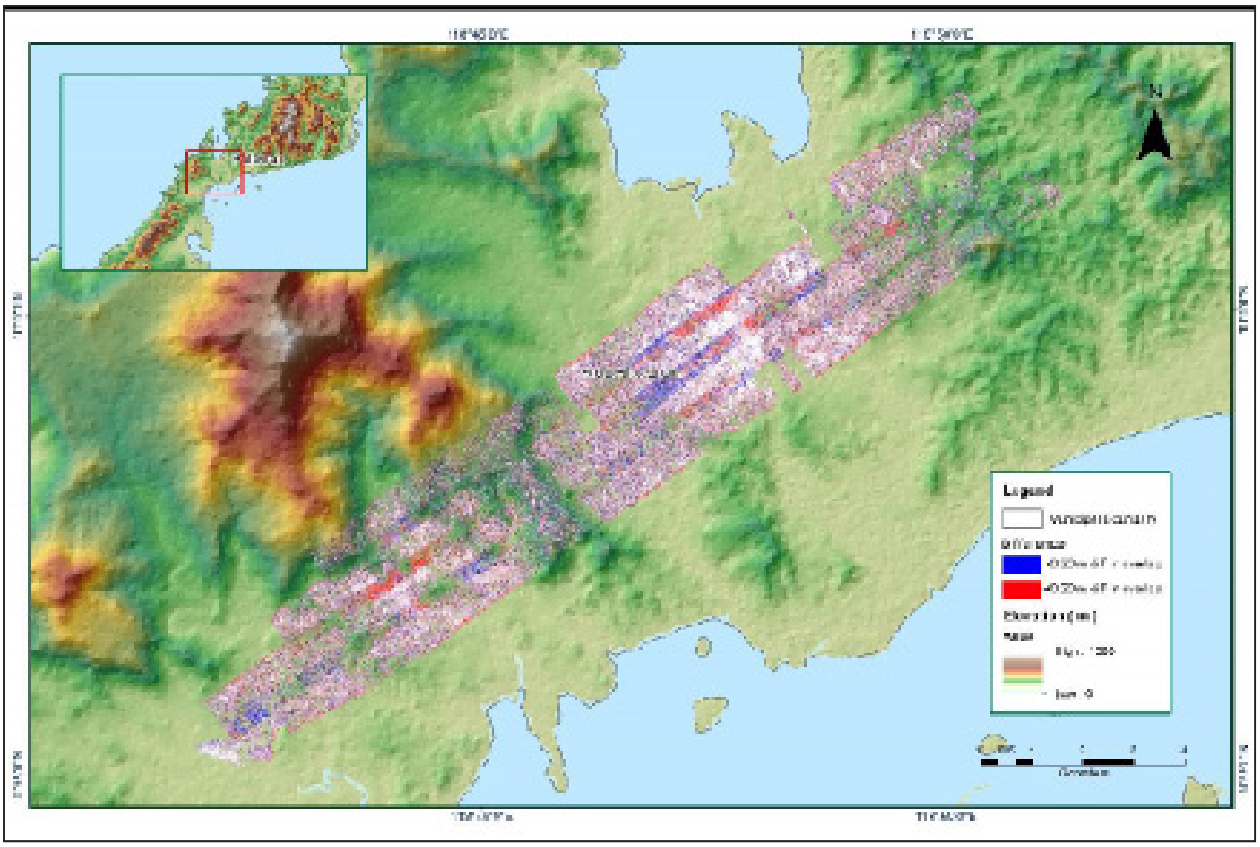


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Block 42C

Flight Area	West Palawan
Mission Name	Block 42C
Inclusive Flights	3041P
Range data size	11.50 GB
POS	122 MB
Image	17.00 GB
Transfer date	July 13, 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)	3.90
RMSE for East Position (<4.0 cm)	3.80
RMSE for Down Position (<8.0 cm)	8.50
Boresight correction stdev (<0.001deg)	0.000211
IMU attitude correction stdev (<0.001deg)	0.0.000165
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	48.63
Ave point cloud density per sq.m. (>2.0)	3.65
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	146
Maximum Height	723.79 m
Minimum Height	50.93 m
Classification (# of points)	
Ground	50,396,287
Low vegetation	30,060,050
Medium vegetation	94,316,490
High vegetation	511,637,374
Building	2,121,355
Orthophoto	Yes
Processed by	Engr. Abigail Joy Ching, Engr. Melanie Hingpit, Alex John Escobido

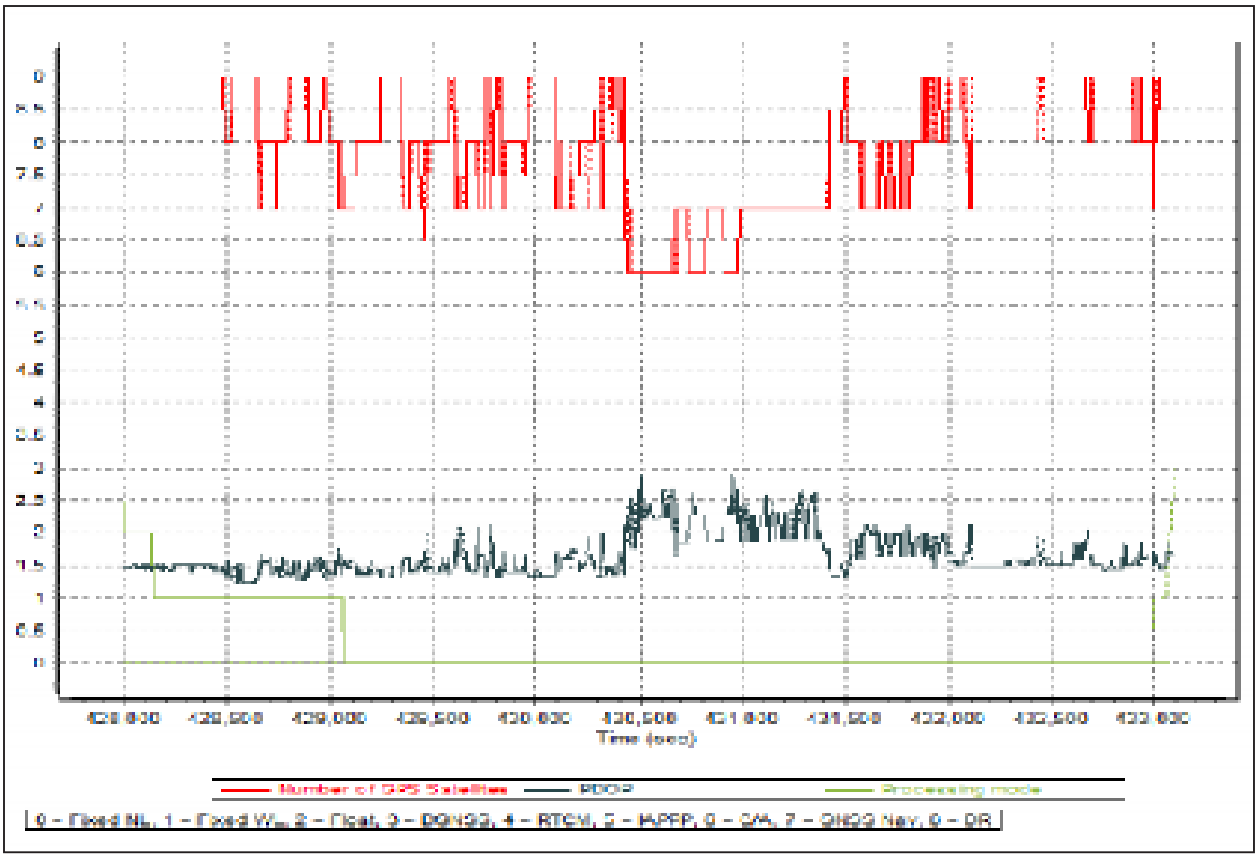


Figure A-8.29. Solution Status

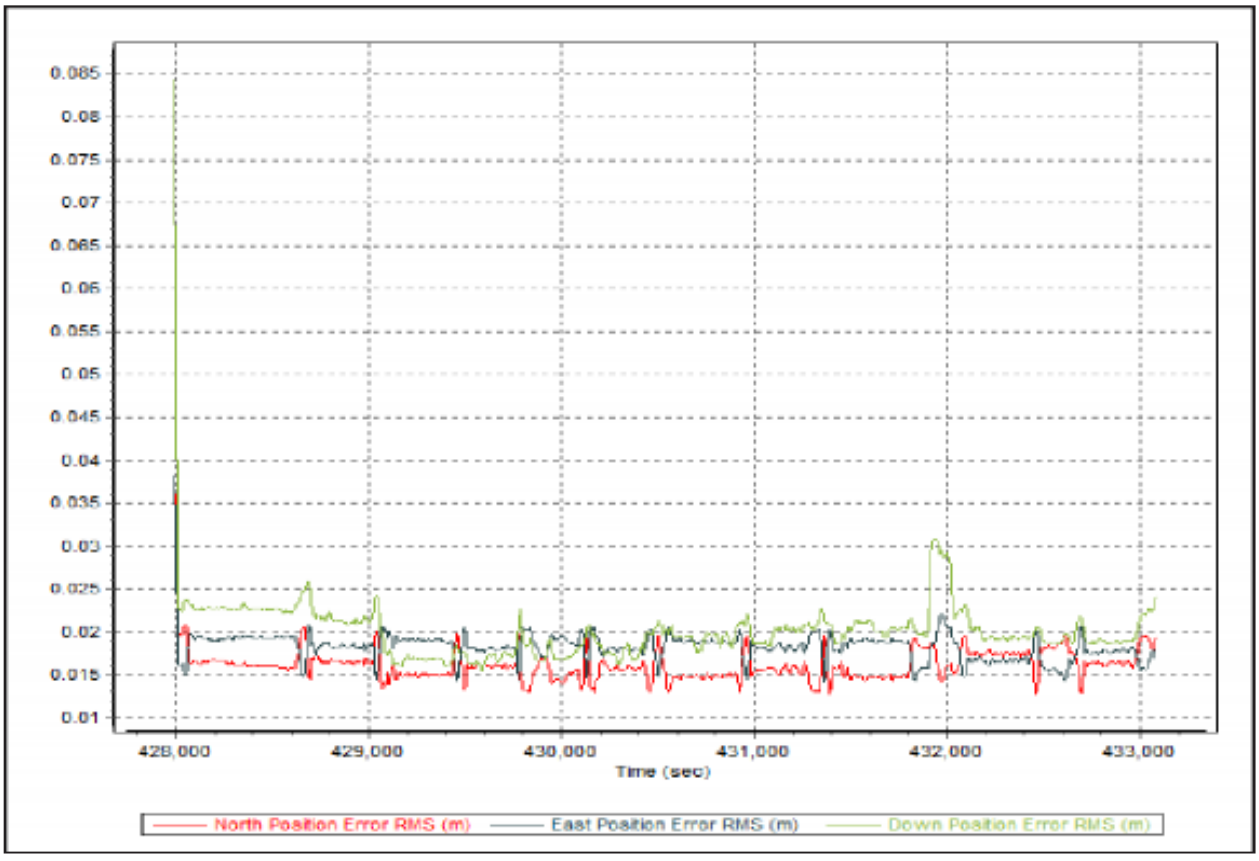


Figure A-8.30. Smoothed Performance Metric Parameters

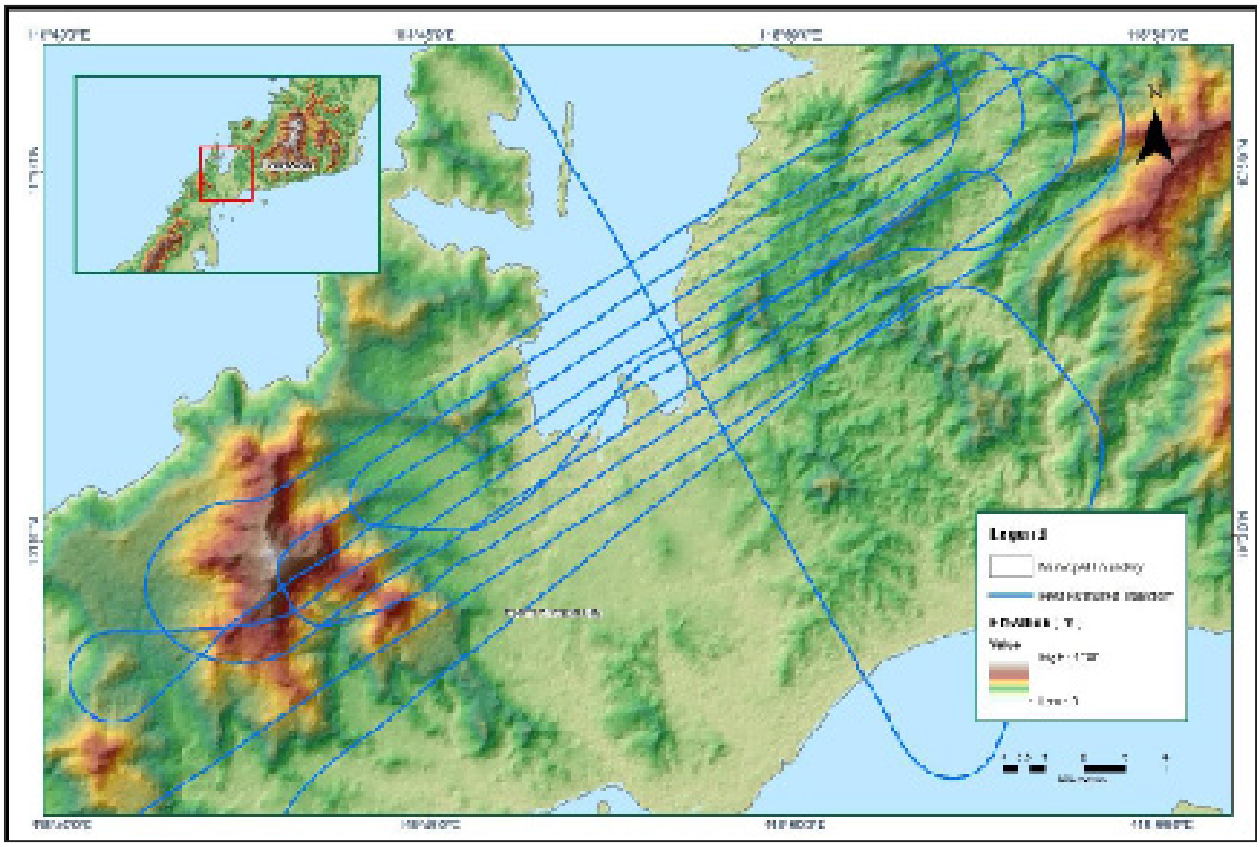


Figure A-8.31. Best Estimated Trajectory

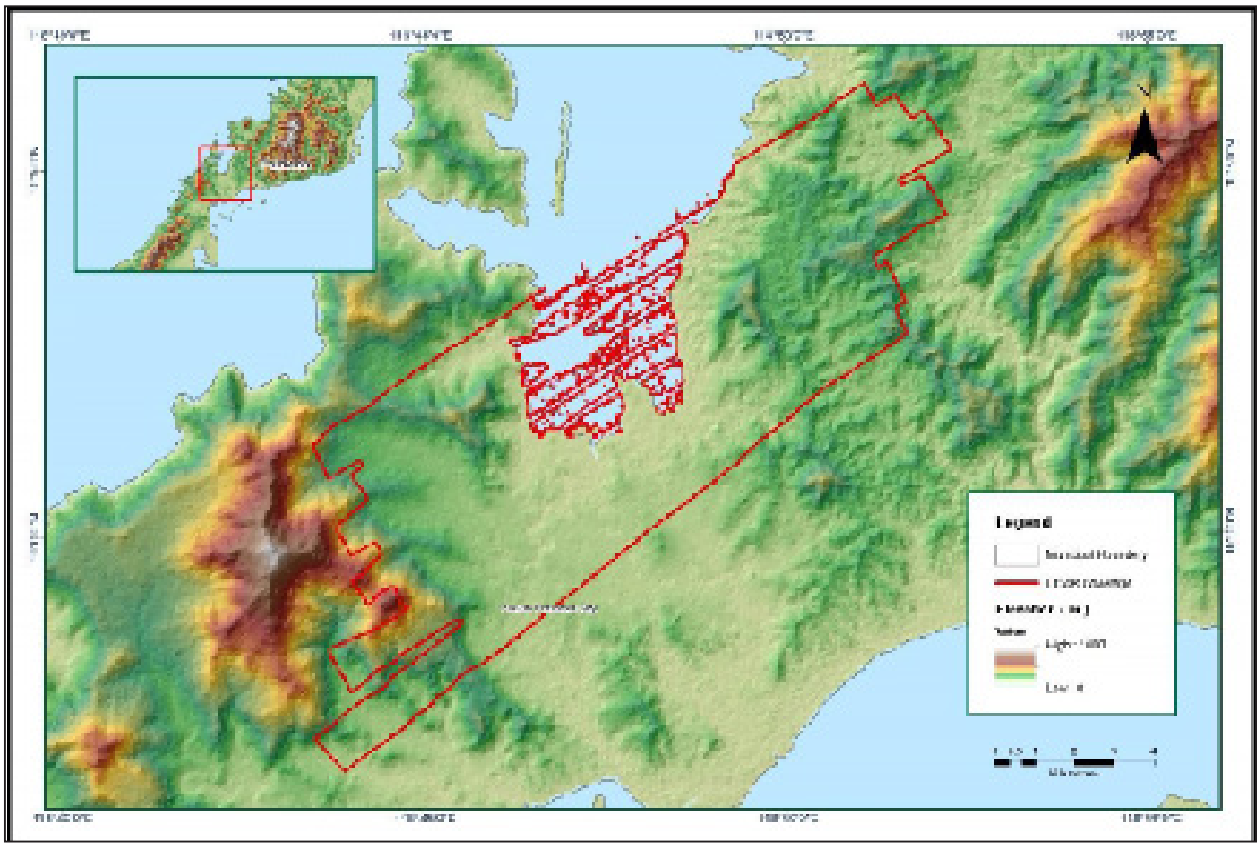


Figure A-8.32. Coverage of LiDAR data

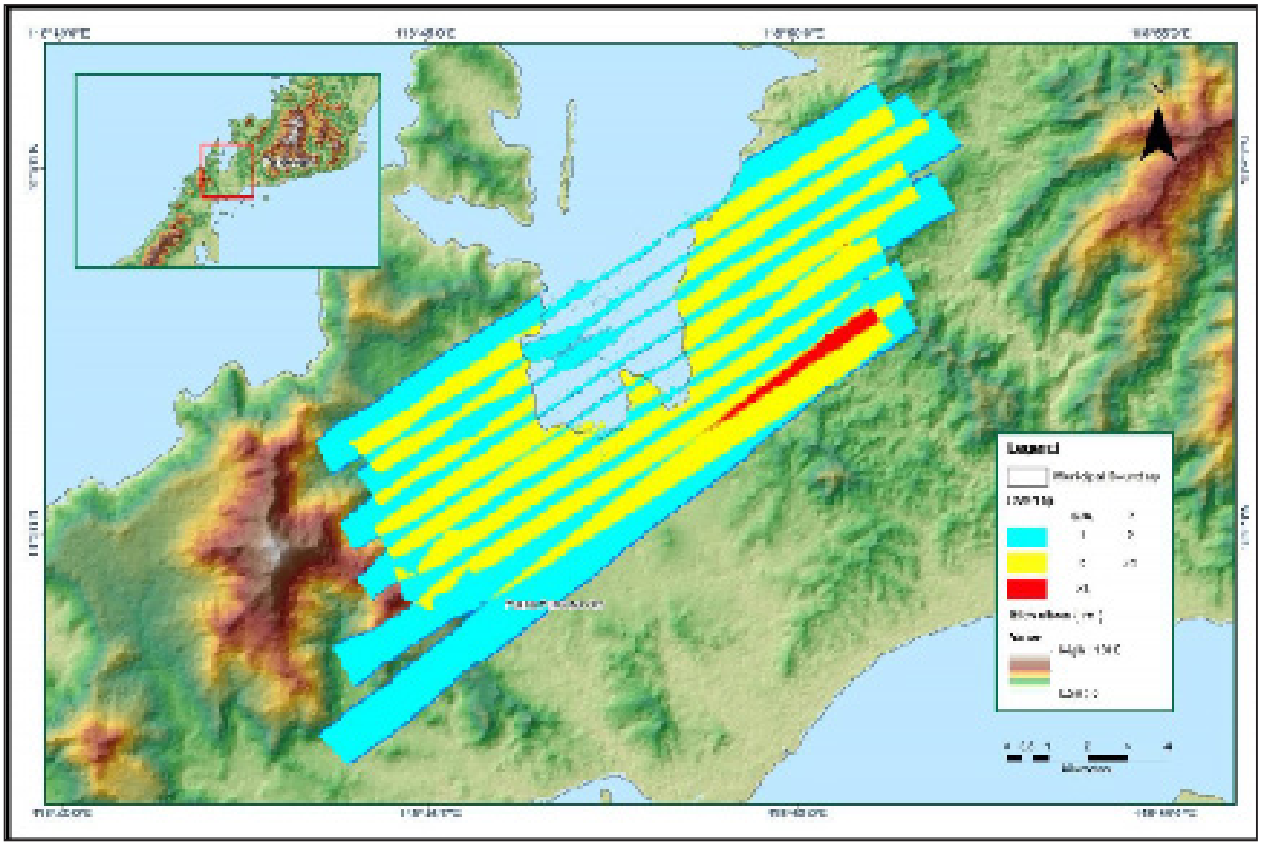


Figure A-8.33. Image of data overlap

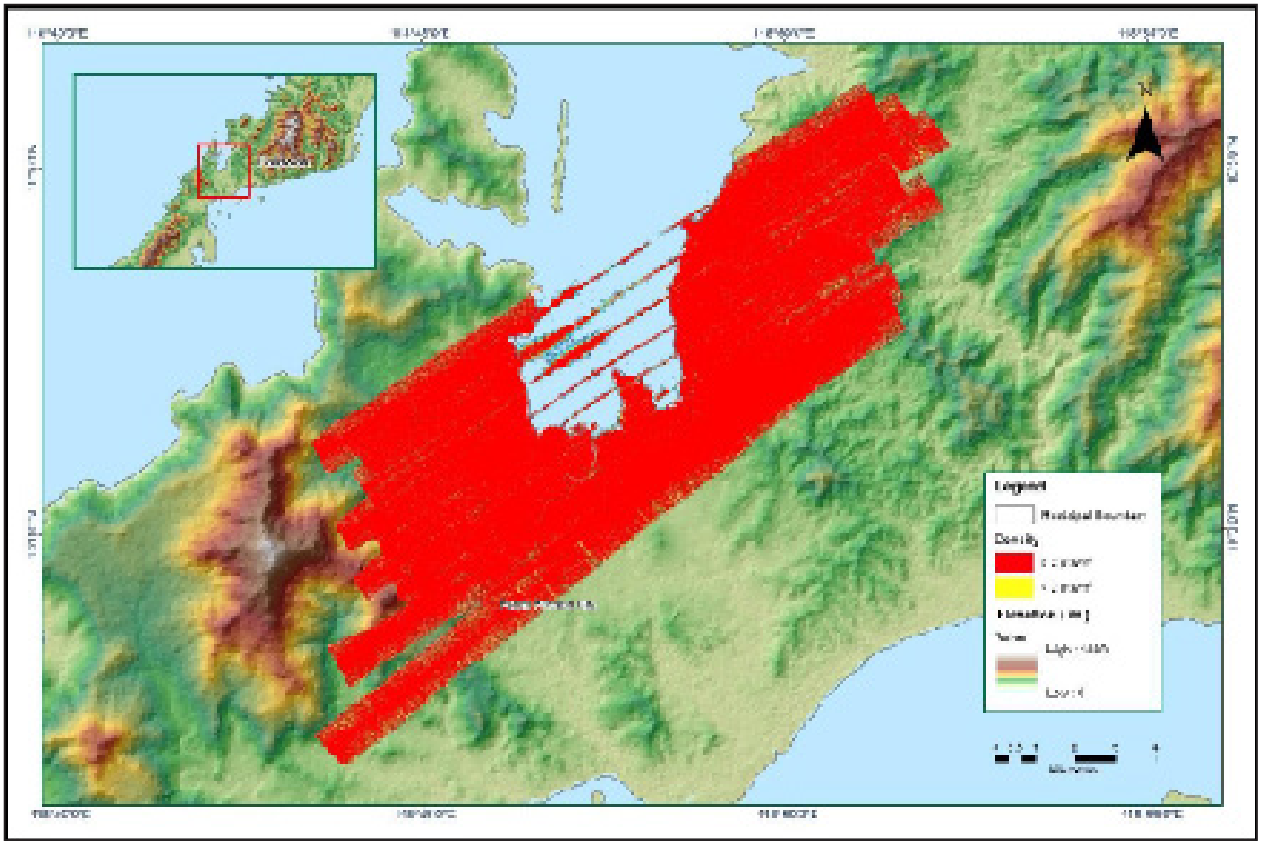


Figure A-8.34. Density map of merged LiDAR data

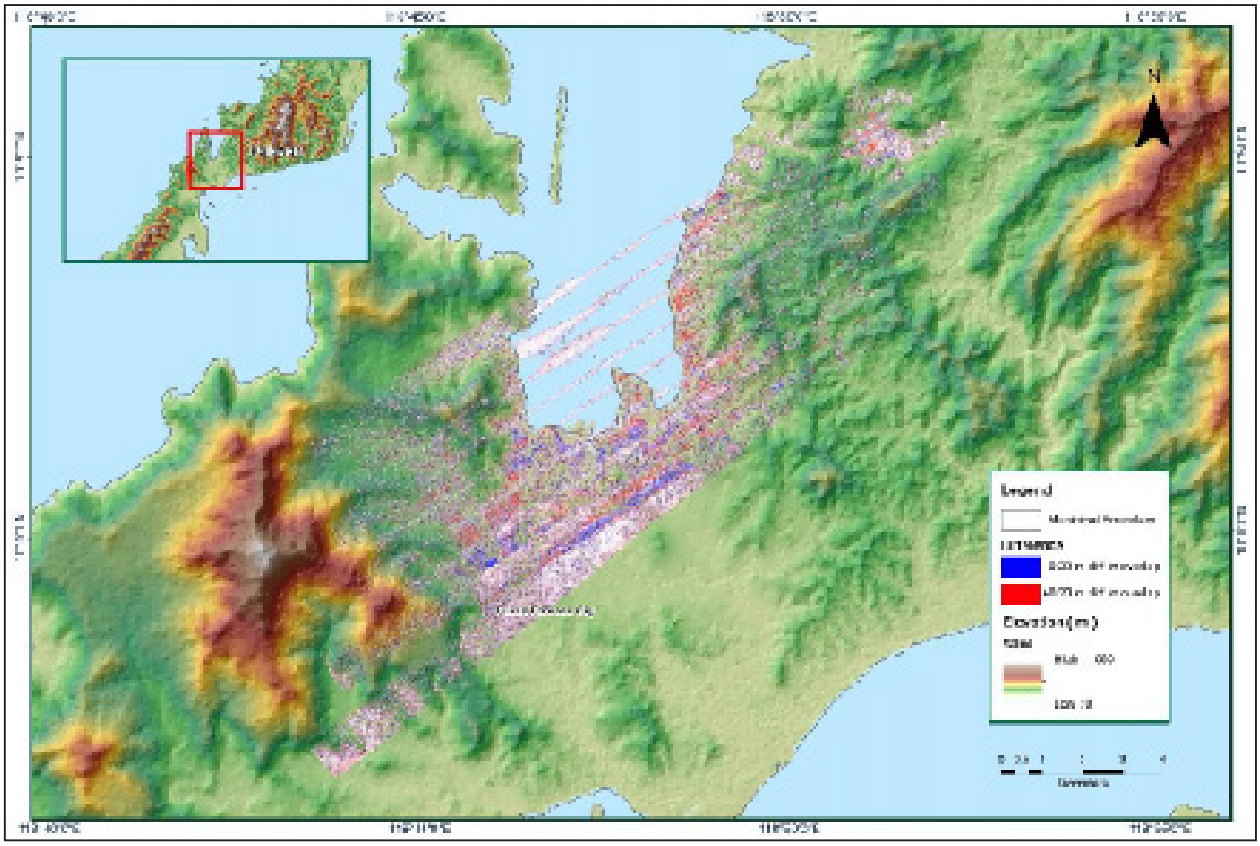


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Block 42D

Flight Area	West Palawan
Mission Name	Block 42D
Inclusive Flights	3021P
Range data size	11.90 GB
POS	139 MB
Image	24.70 GB
Transfer date	June 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)	1.40
RMSE for East Position (<4.0 cm)	1.60
RMSE for Down Position (<8.0 cm)	2.90
Boresight correction stdev (<0.001deg)	0.001186
IMU attitude correction stdev (<0.001deg)	0.0.000342
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	96.78
Ave point cloud density per sq.m. (>2.0)	6.51
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	90
Maximum Height	1191.83 m
Minimum Height	48.8 m
Classification (# of points)	
Ground	34,337,350
Low vegetation	45,301,387
Medium vegetation	74,425,435
High vegetation	493,041,213
Building	11,873,530
Orthophoto	Yes
Processed by	Engr. Regis Guhiting, Engr. Velina Angela Bemida, Engr. Ma. Ailyn Olanda

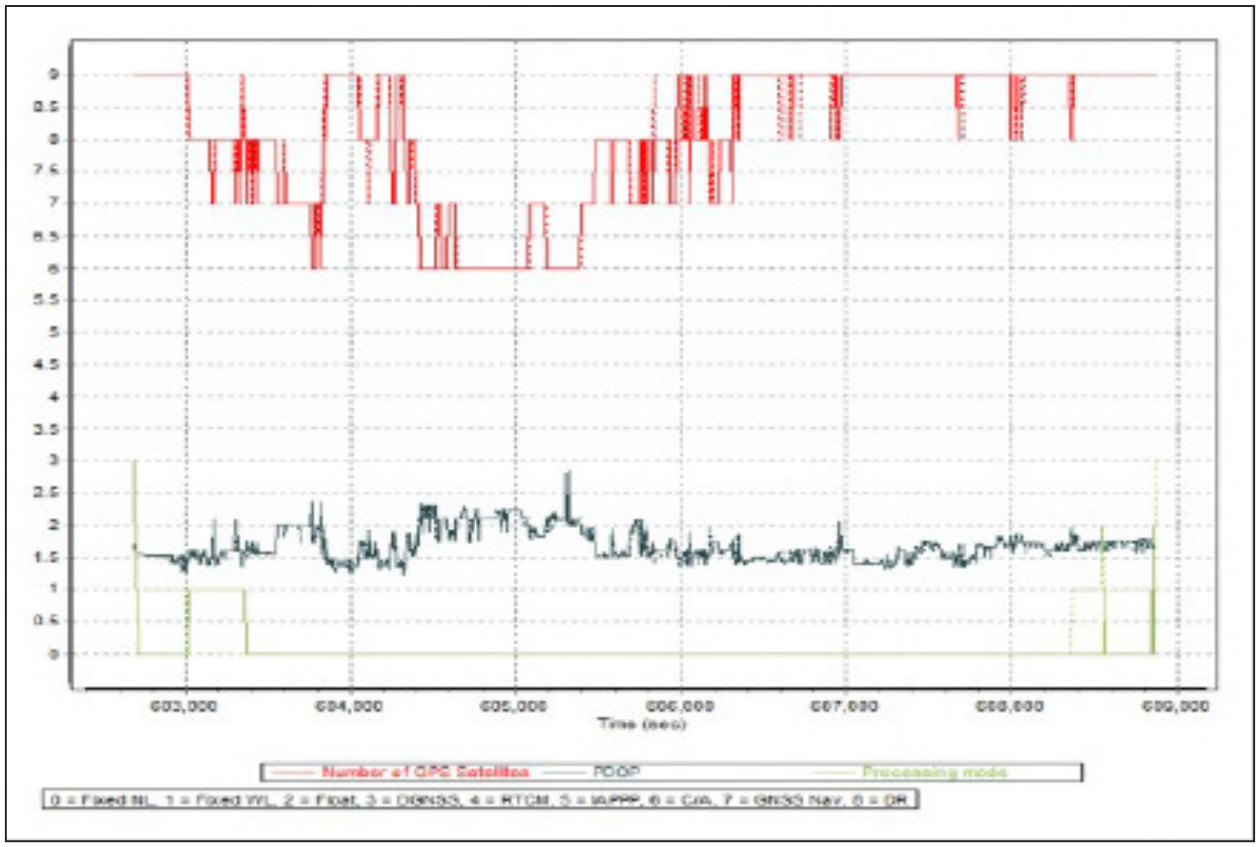


Figure A-8.36. Solution Status

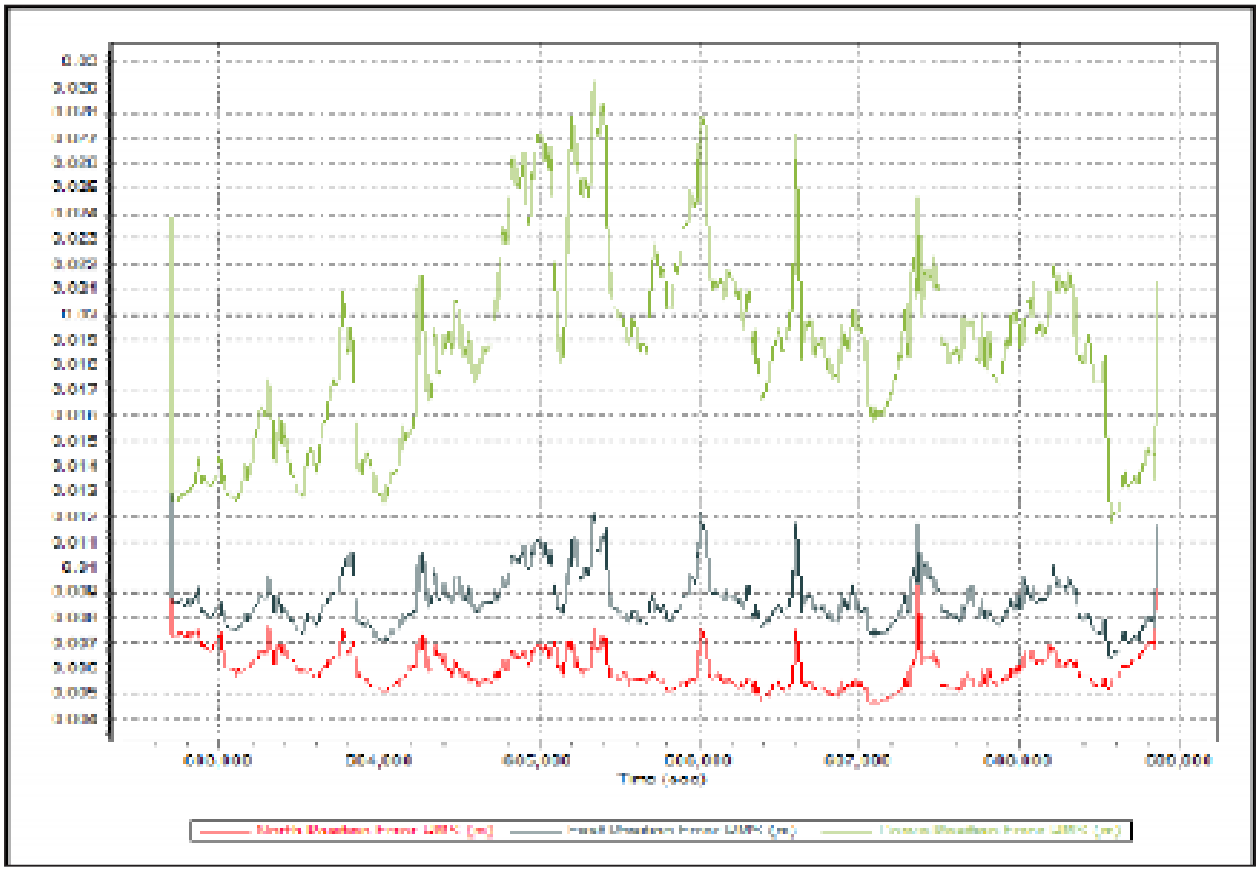


Figure A-8.37. Smoothed Performance Metric Parameters

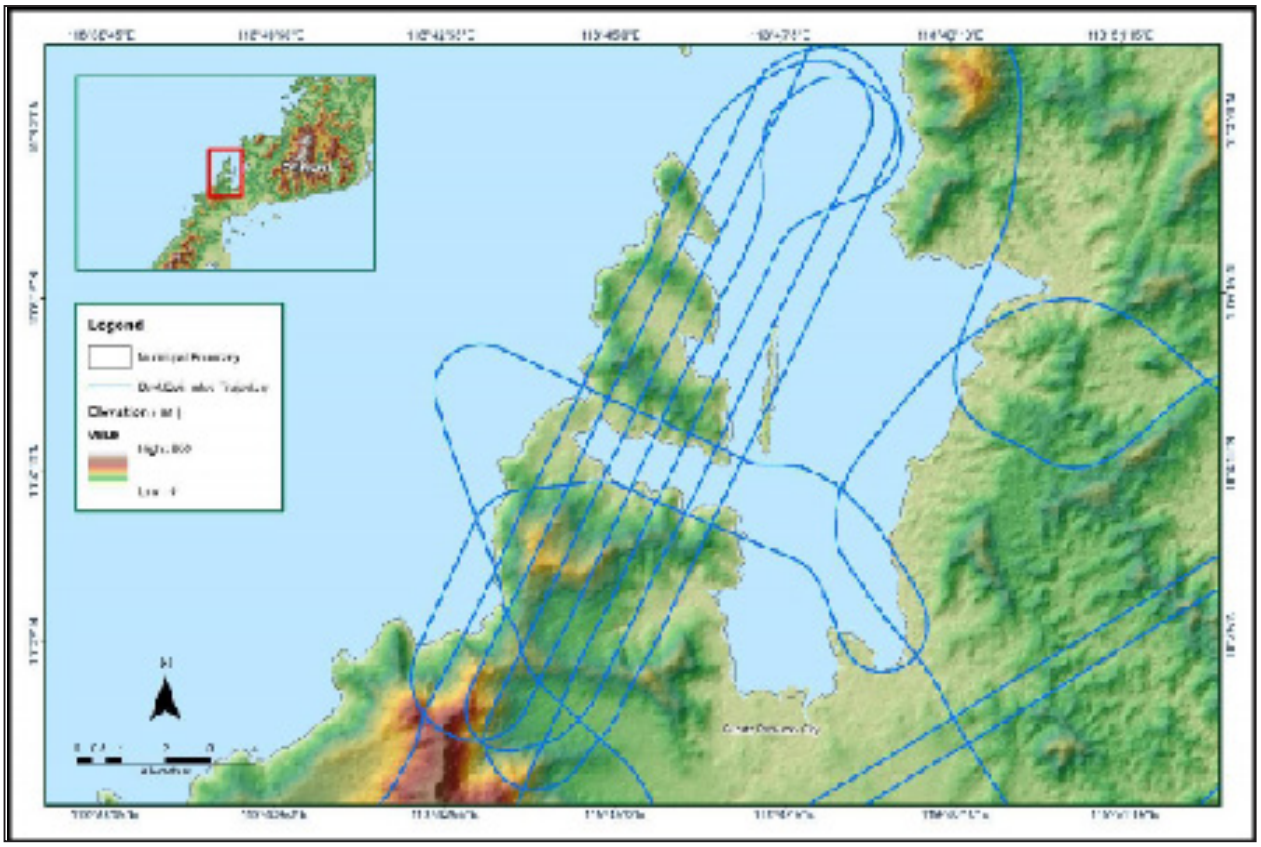


Figure A-8.38. Best Estimated Trajectory

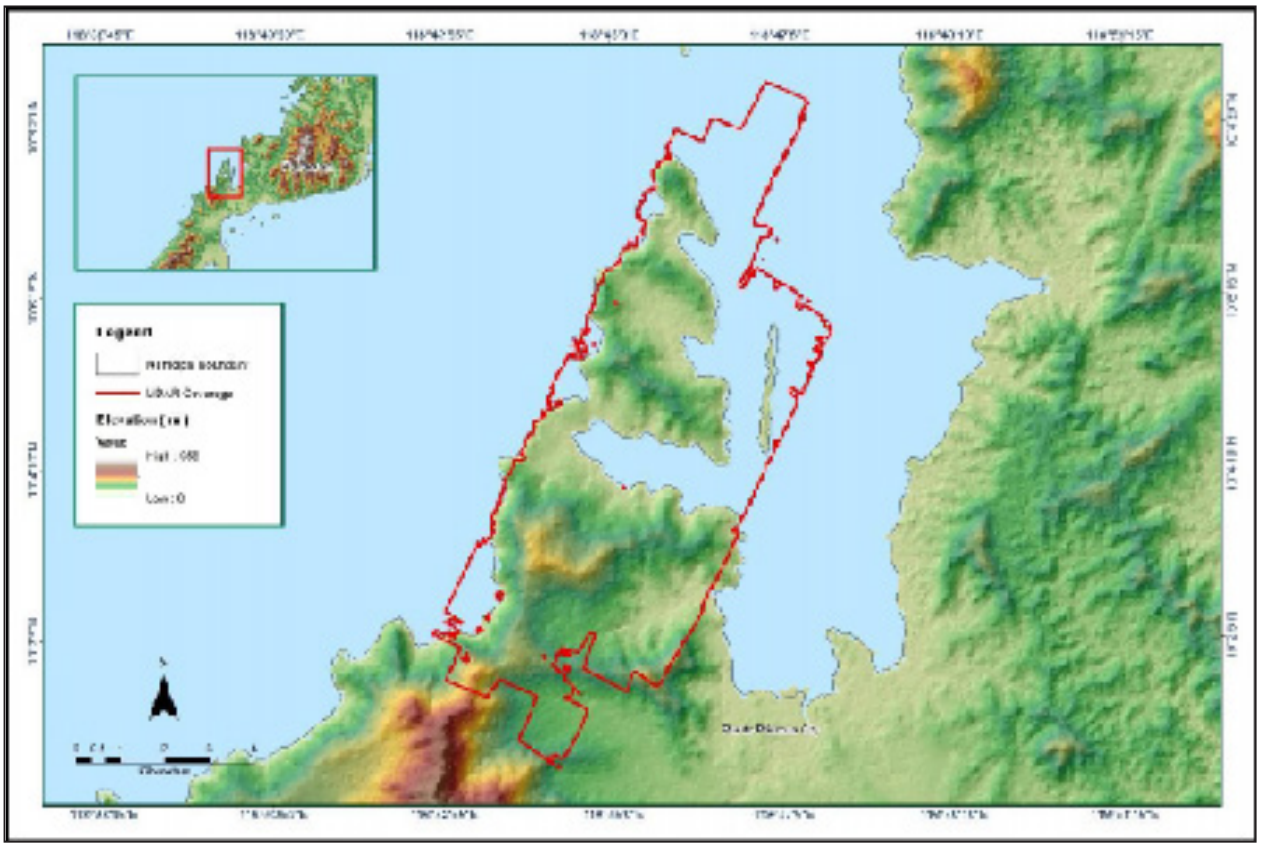


Figure A-8.39. Coverage of LiDAR data

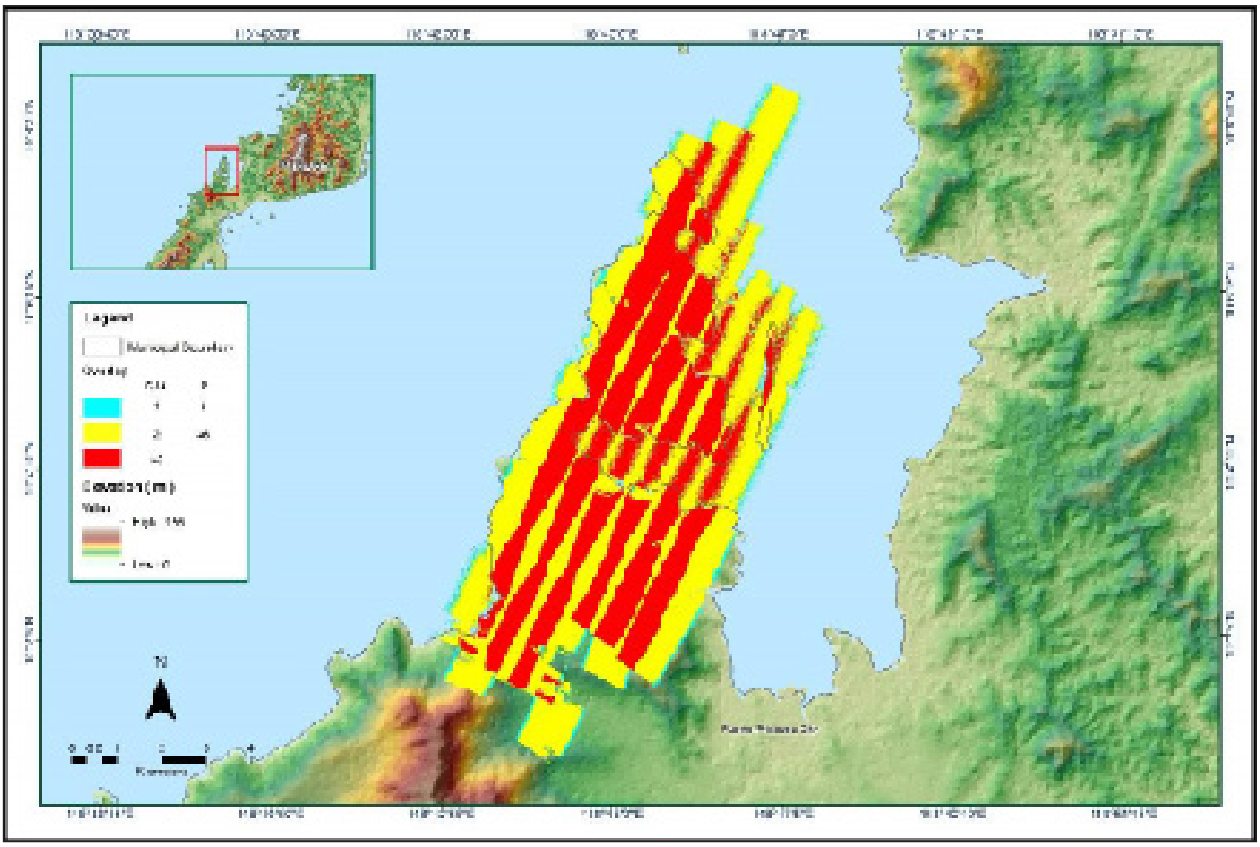


Figure A-8.40. Image of data overlap

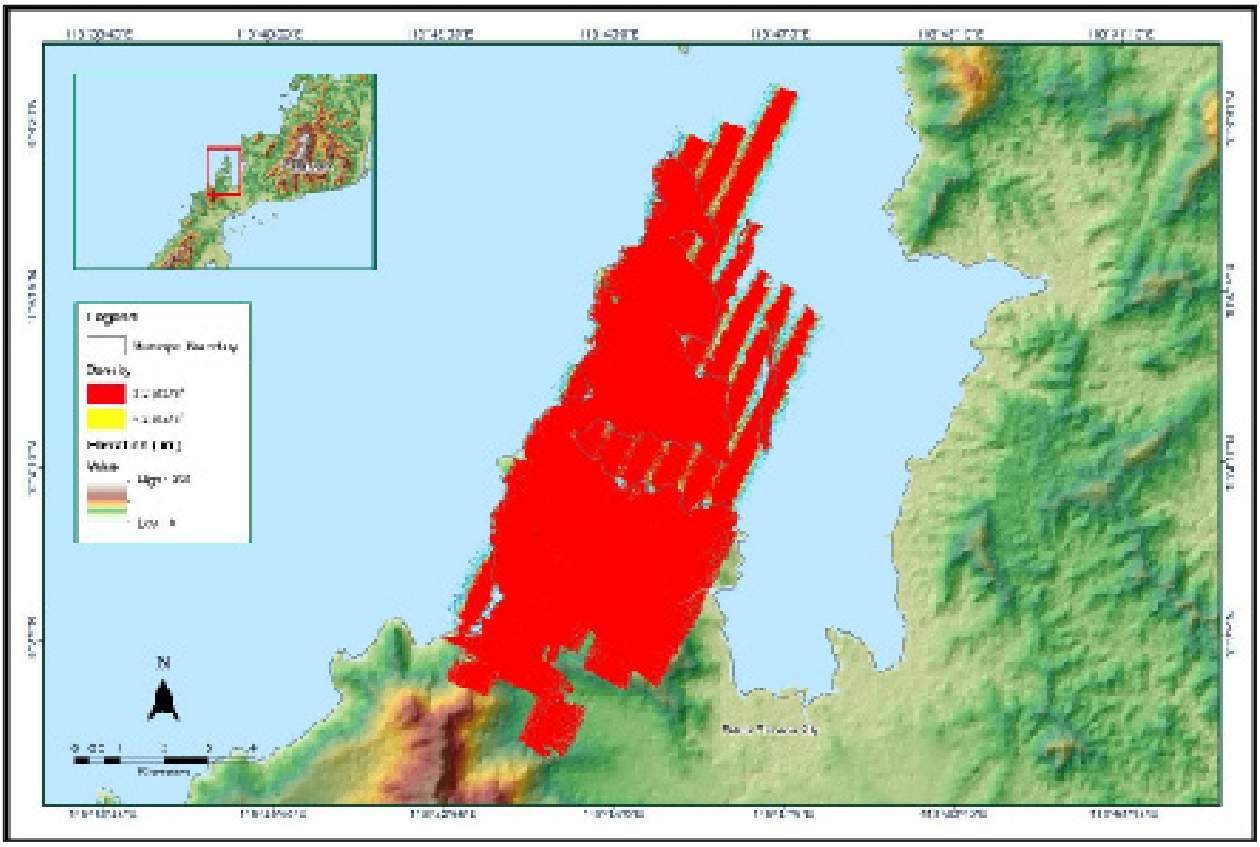


Figure A-8.41. Density map of merged LiDAR data

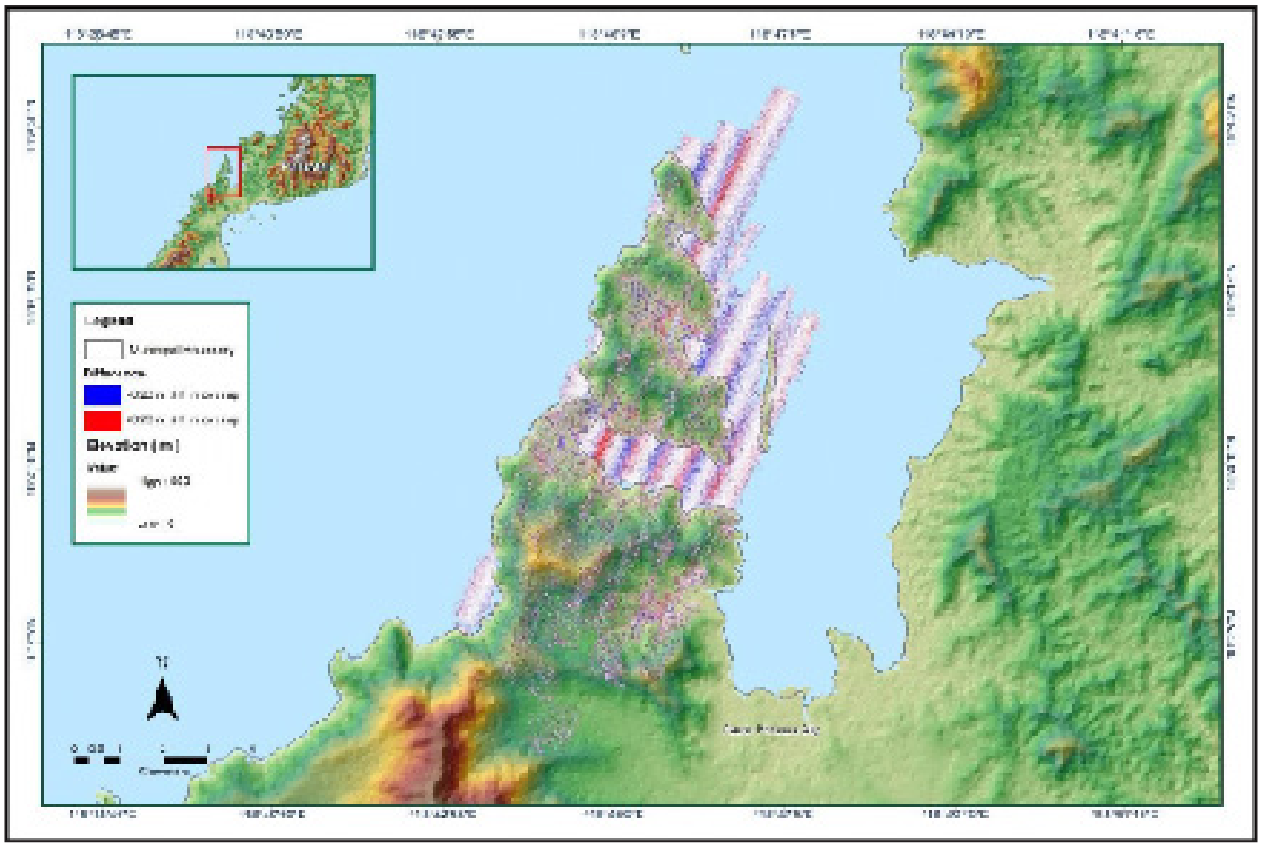


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Block 42B Supplement

Flight Area	West Palawan
Mission Name	Block 42B Supplement
Inclusive Flights	3045P
Range data size	10.50 GB
POS	144MB
Image	15.70 GB
Transfer date	June 13, 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)	1.95
RMSE for East Position (<4.0 cm)	2.30
RMSE for Down Position (<8.0 cm)	3.70
Boresight correction stdev (<0.001deg)	0.000249
IMU attitude correction stdev (<0.001deg)	0.0.003542
GPS position stdev (<0.01m)	0.0099
Minimum % overlap (>25)	27.46
Ave point cloud density per sq.m. (>2.0)	2.81
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	177
Maximum Height	428.28 m
Minimum Height	42.45 m
Classification (# of points)	
Ground	92,670,052
Low vegetation	67,814,293
Medium vegetation	141,295,150
High vegetation	319,882,750
Building	4,546,105
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Merven Matthew nation, Kathryn Claudyn Zarate

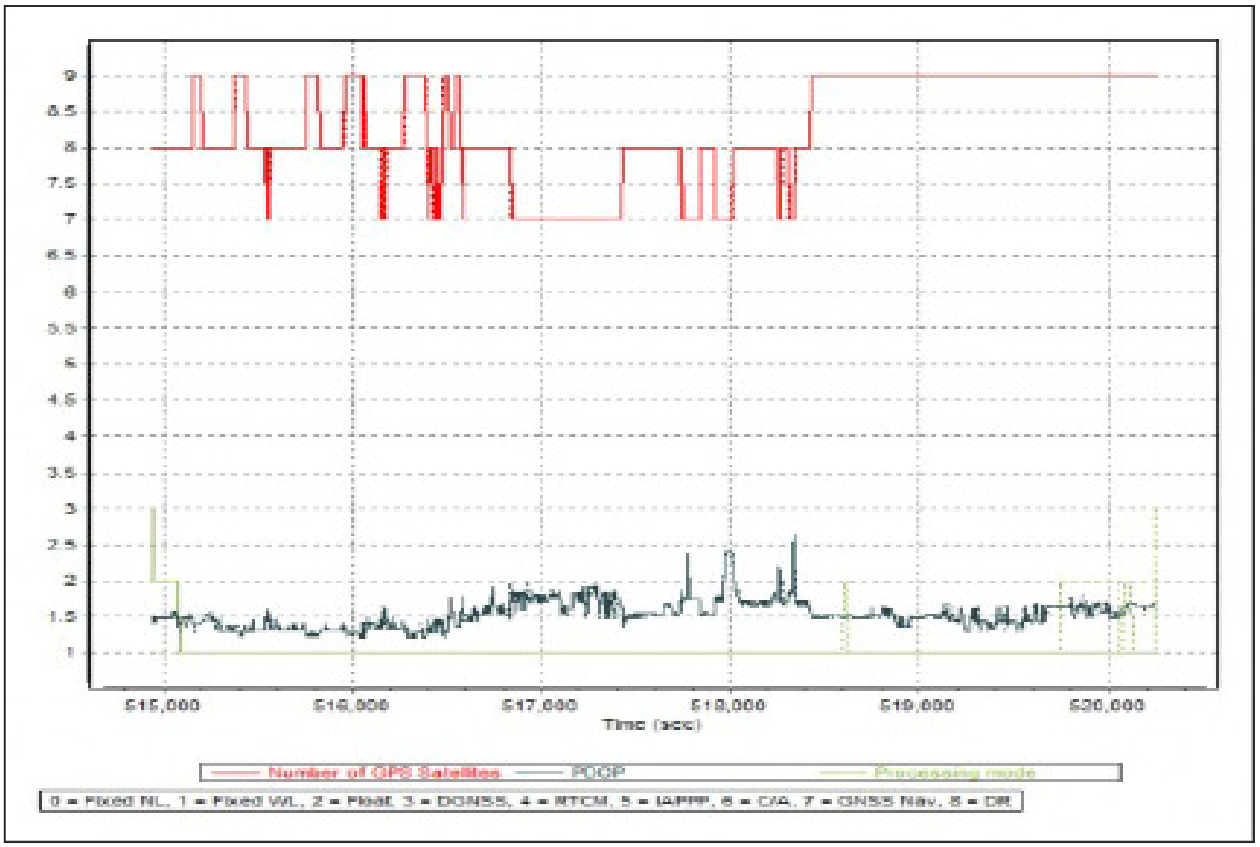


Figure A-8.43. Solution Status

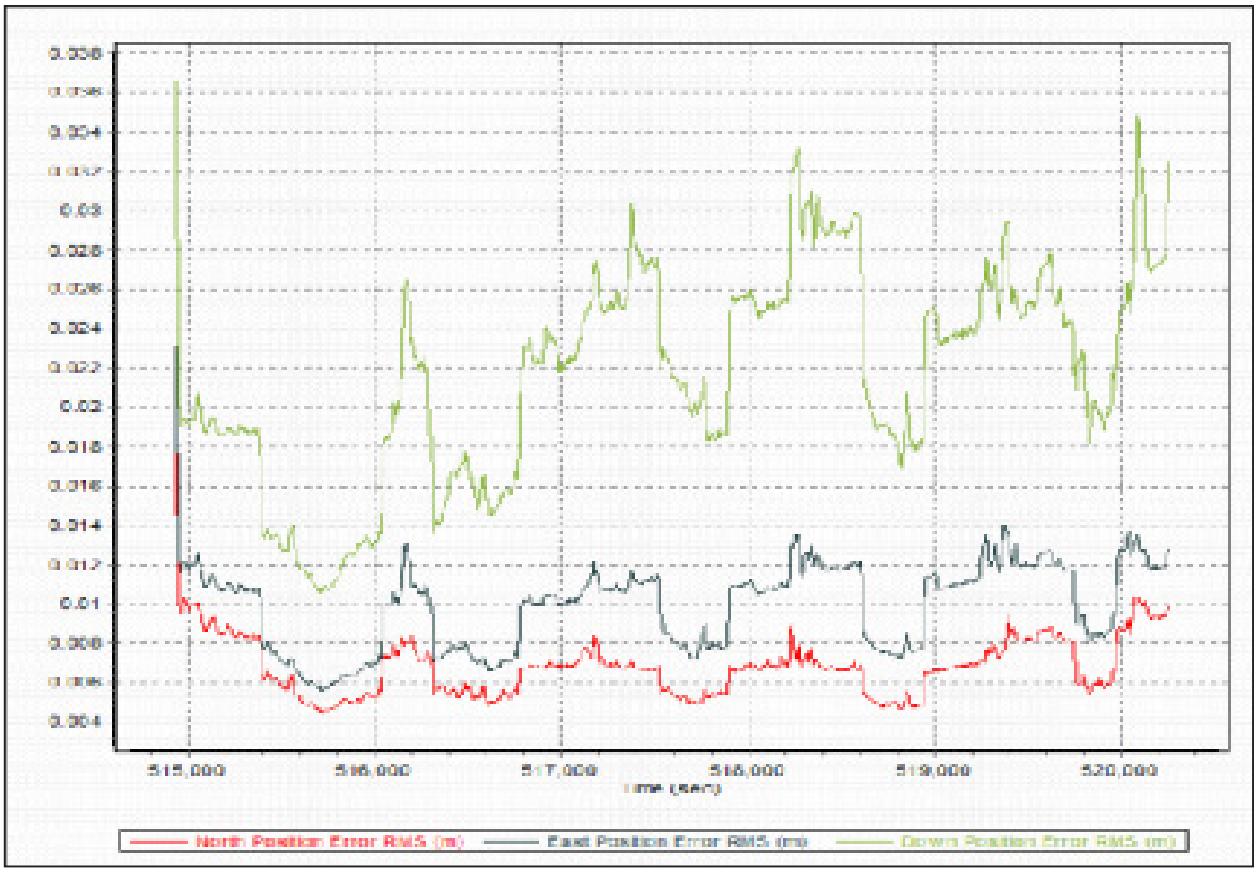


Figure A-8.44. Smoothed Performance Metric Parameters

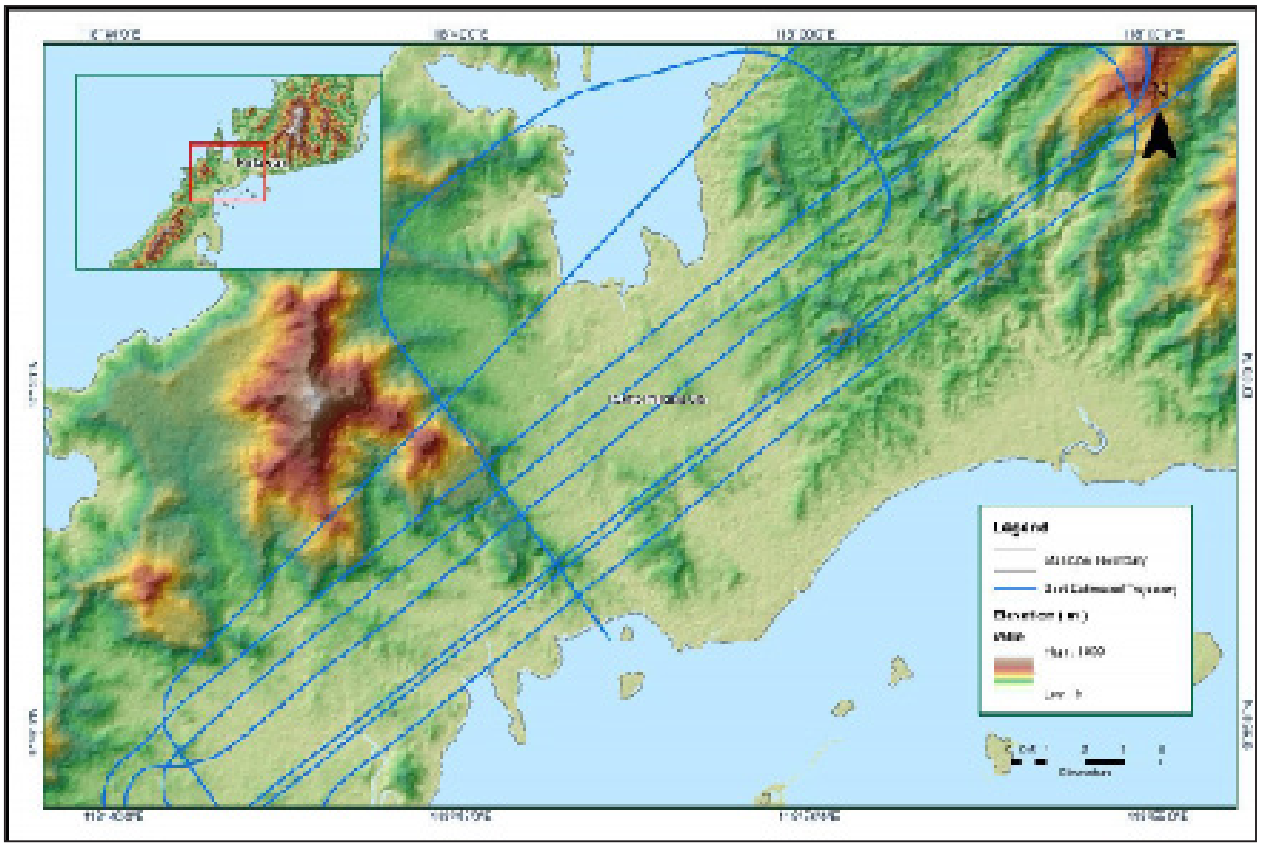


Figure A-8.45. Best Estimated Trajectory

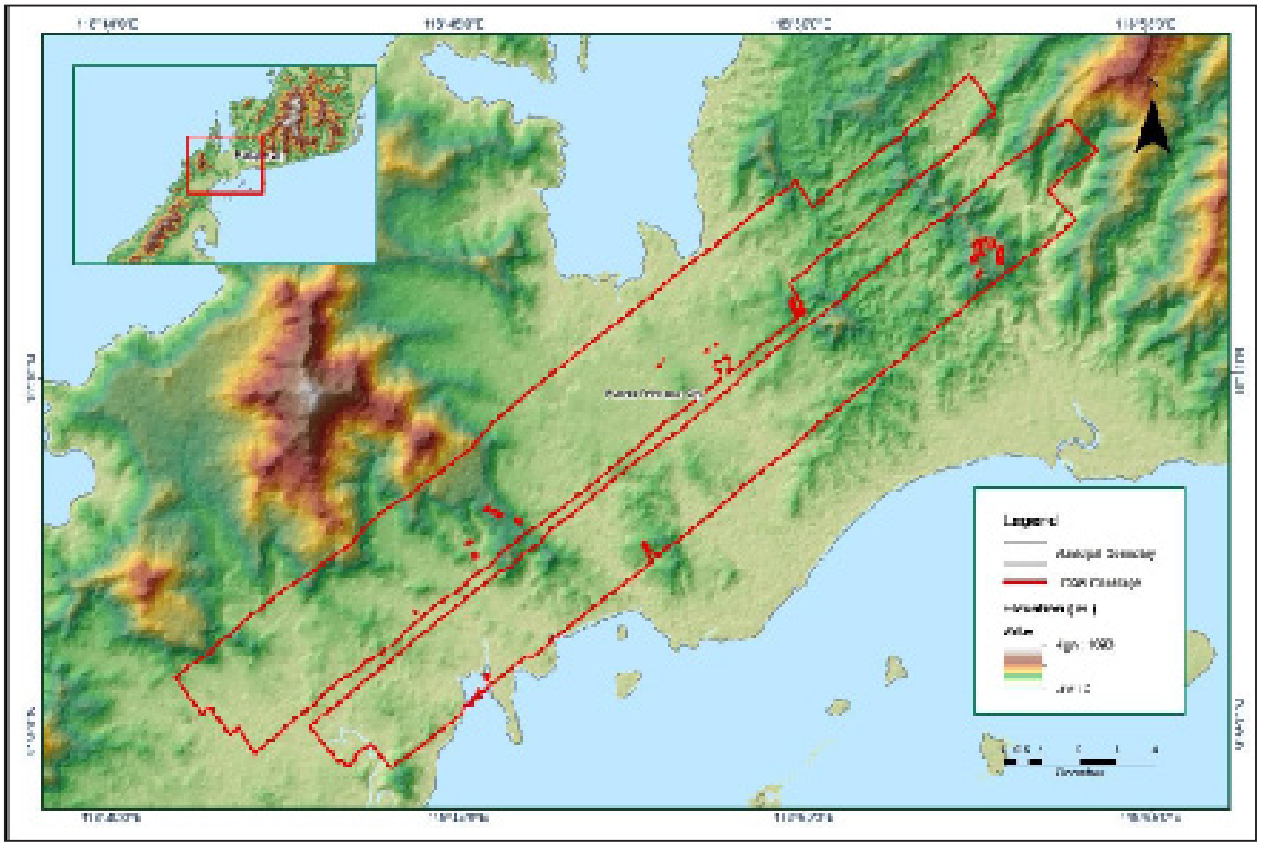


Figure A-8.46. Coverage of LiDAR data

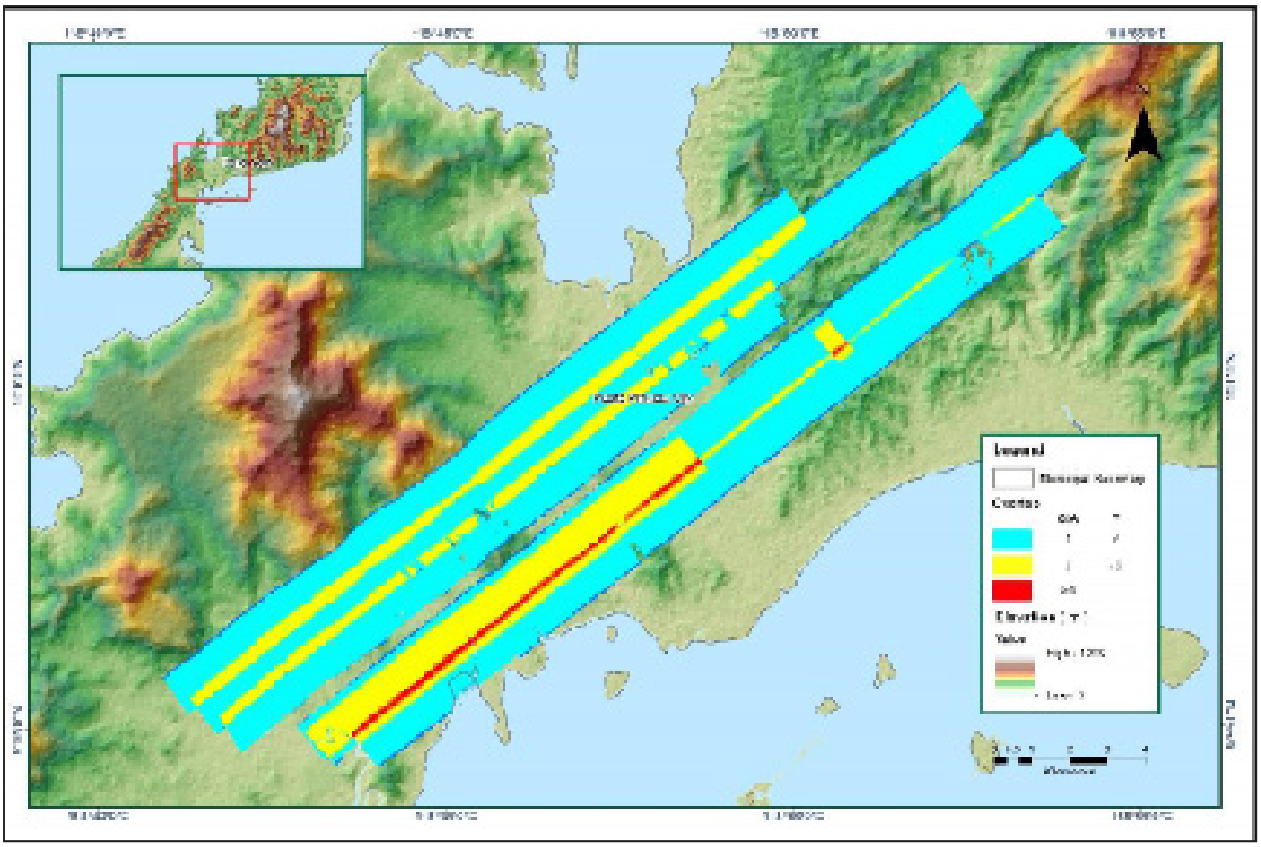


Figure A-8.47. Image of data overlap

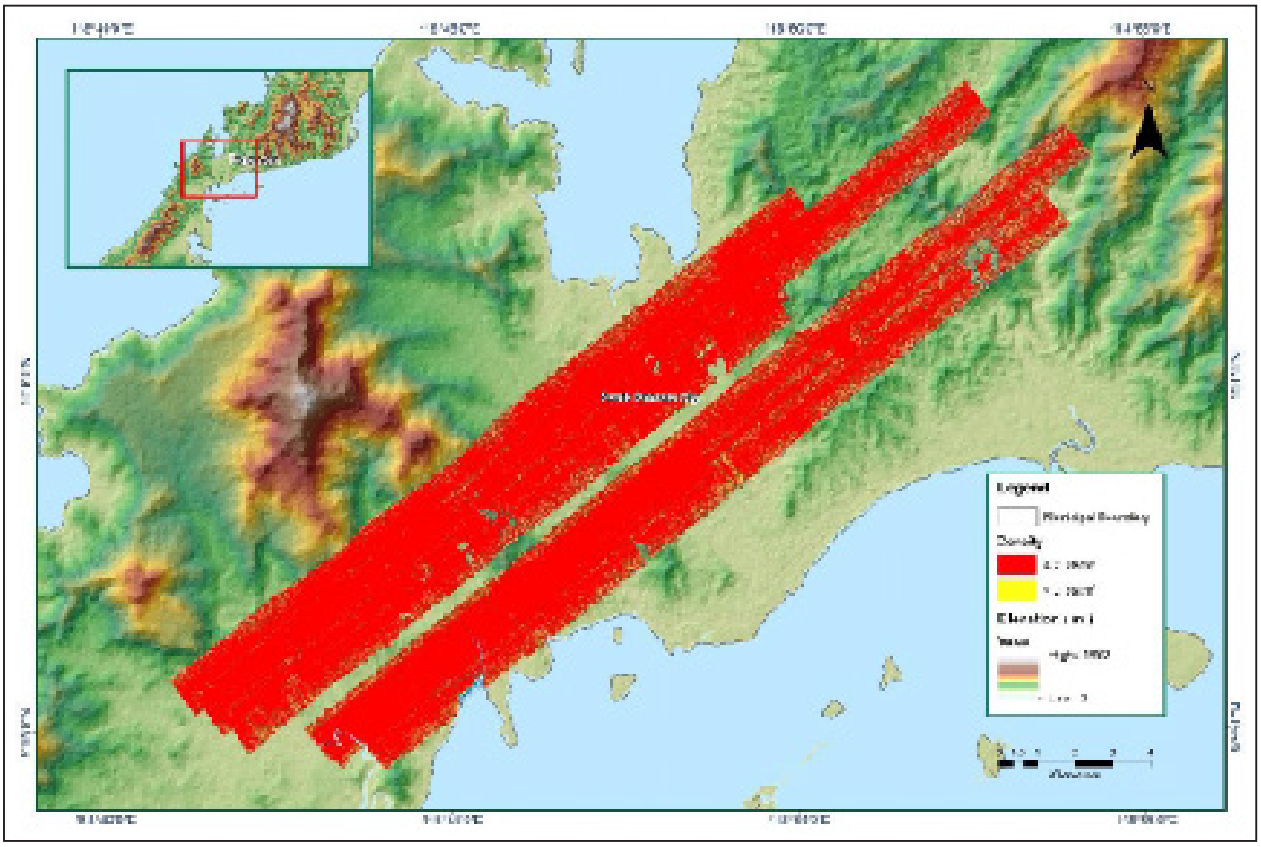


Figure A-8.48. Density map of merged LiDAR data

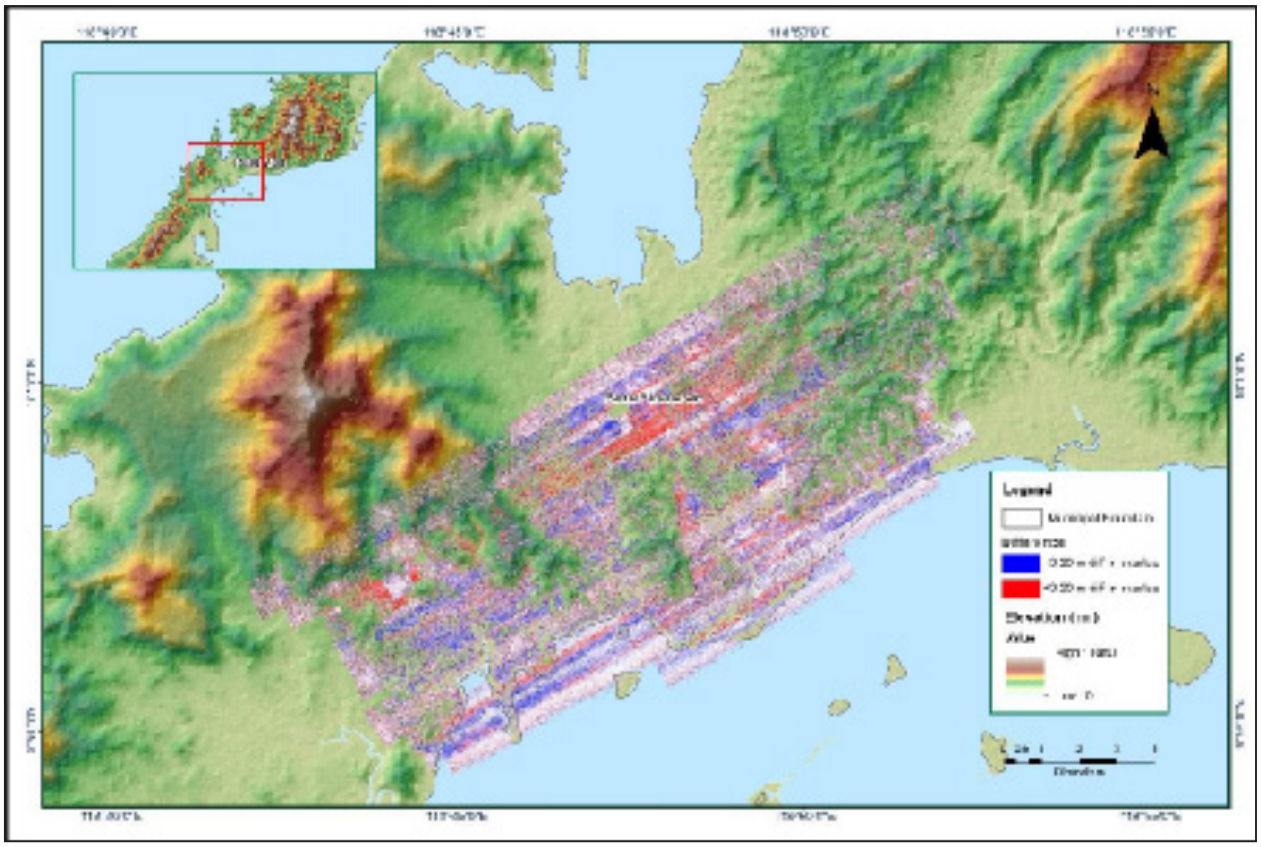


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk42eD

Flight Area	Palawan Reflights
Mission Name	Blk42eD
Inclusive Flights	3493G
Range data size	13.2 GB
Base data size	5.16 MB
POS	208 MB
Image	NA
Transfer date	December 8, 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)	1.51
RMSE for East Position (<4.0 cm)	2.13
RMSE for Down Position (<8.0 cm)	3.58
Boresight correction stdev (<0.001deg)	0.020137
IMU attitude correction stdev (<0.001deg)	0.037835
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	32.14%
Ave point cloud density per sq.m. (>2.0)	6.35
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	117
Maximum Height	655.63 m
Minimum Height	51.32 m
Classification (# of points)	
Ground	30,227,181
Low vegetation	16,386,156
Medium vegetation	76,491,030
High vegetation	265,788,221
Building	5,414,882
Ortophoto	No
Processed by	Engr. Regis Guhiting, Engr. Edgardo Gubatanga Jr., Marie Denise Bueno

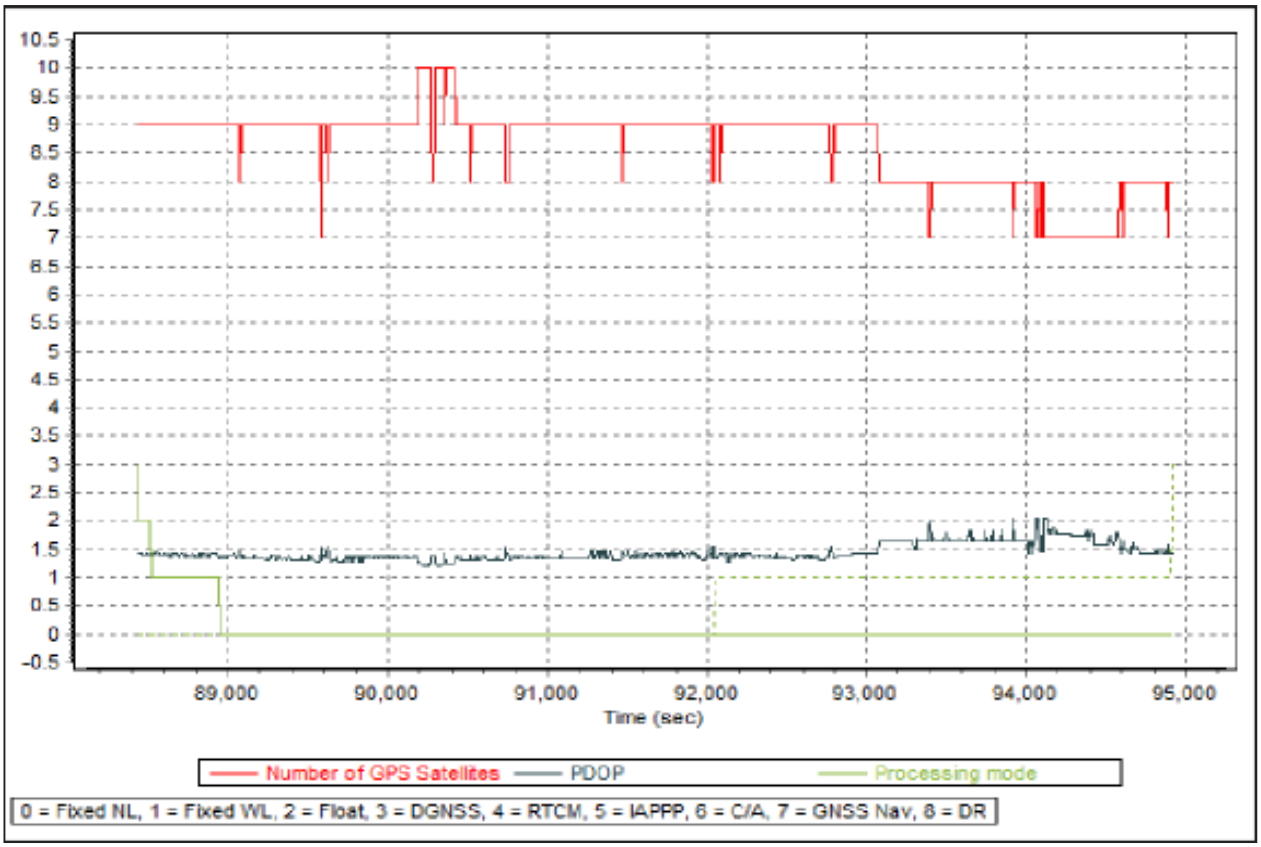


Figure A-8.50. Solution Status

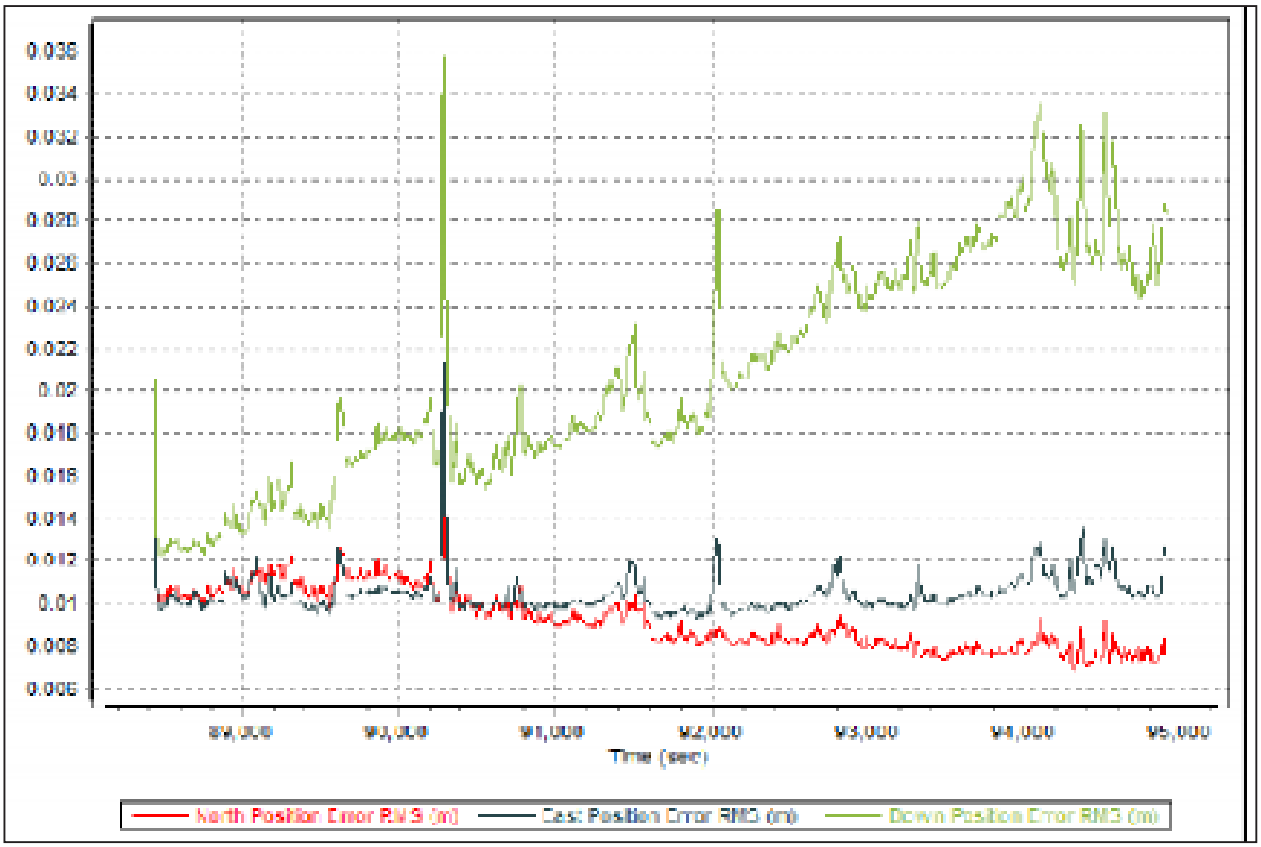


Figure A-8.51. Smoothed Performance Metric Parameters

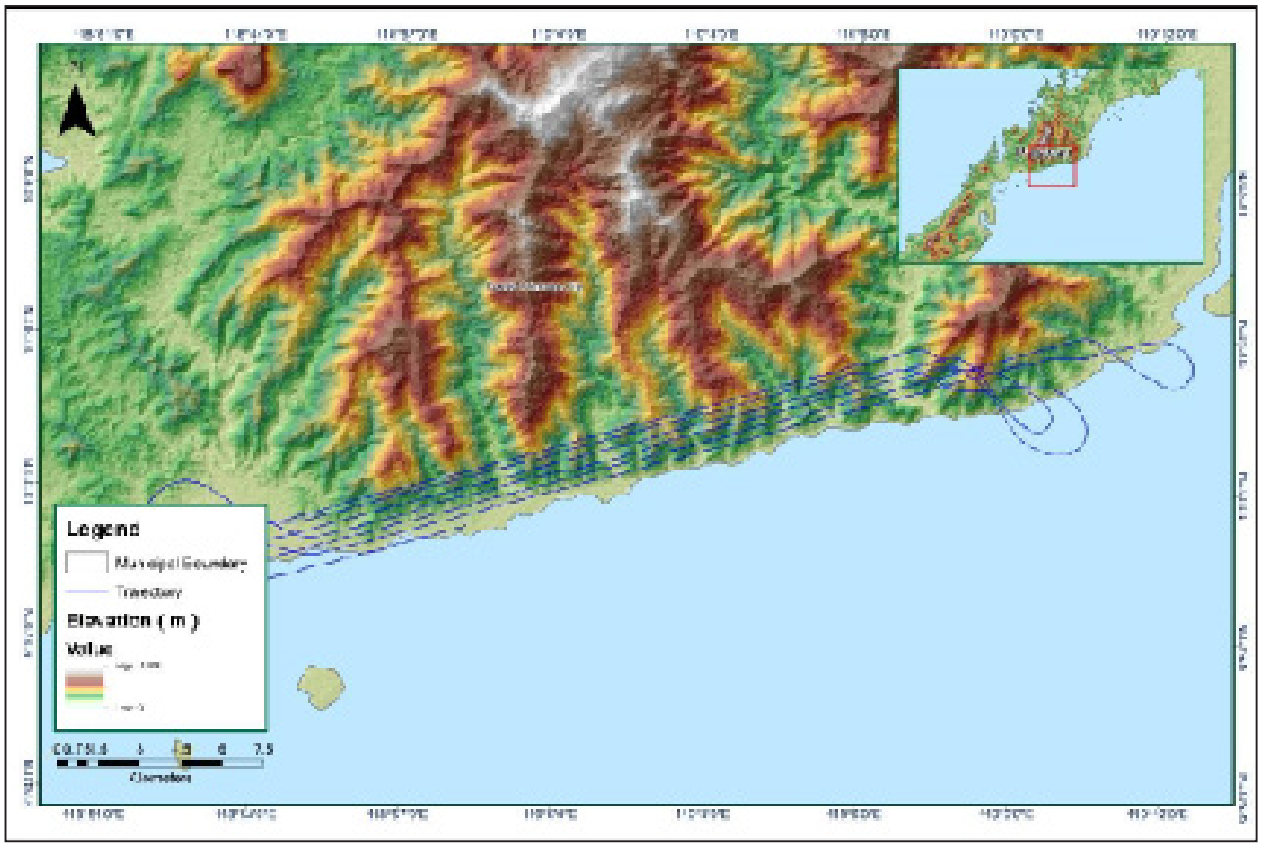


Figure A-8.52. Best Estimated Trajectory

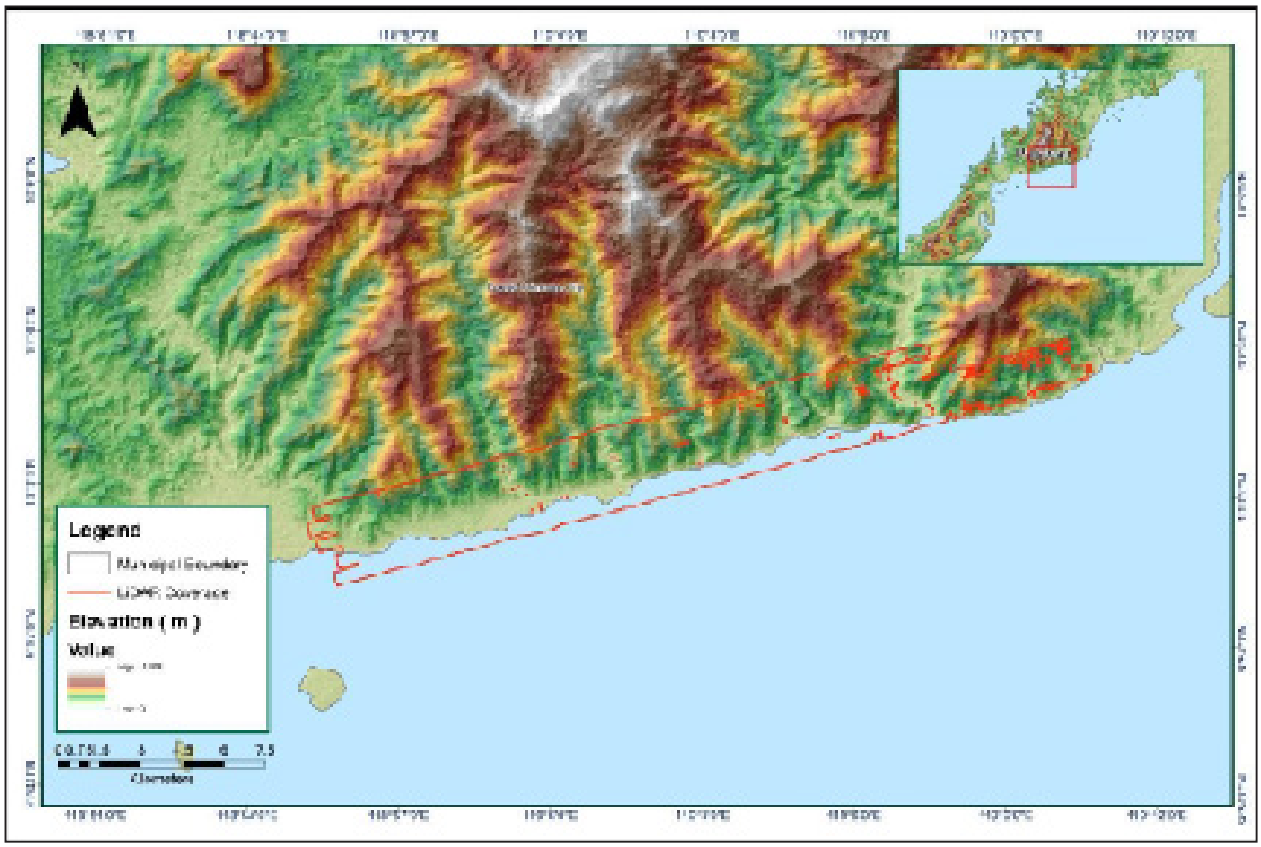


Figure A-8.53. Coverage of LiDAR data

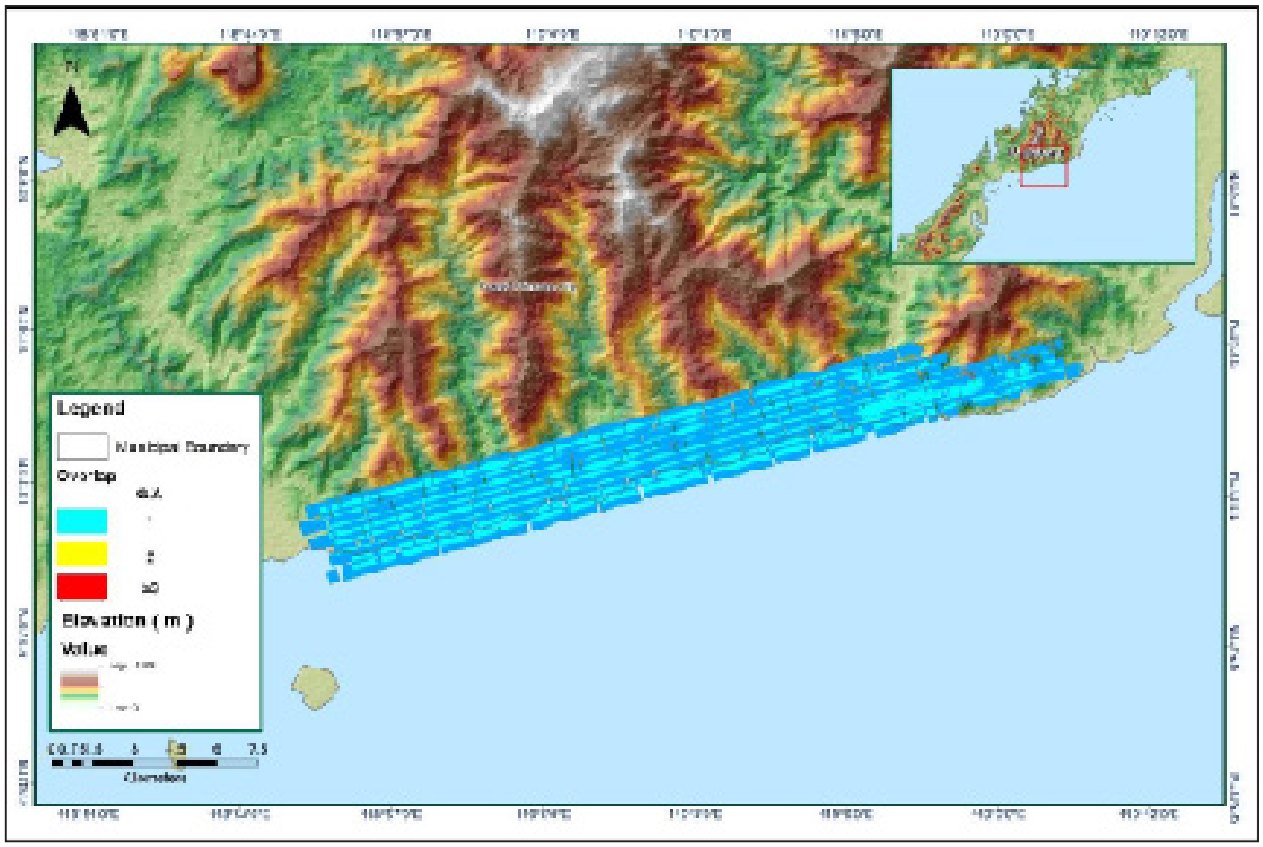


Figure A-8.54. Image of data overlap

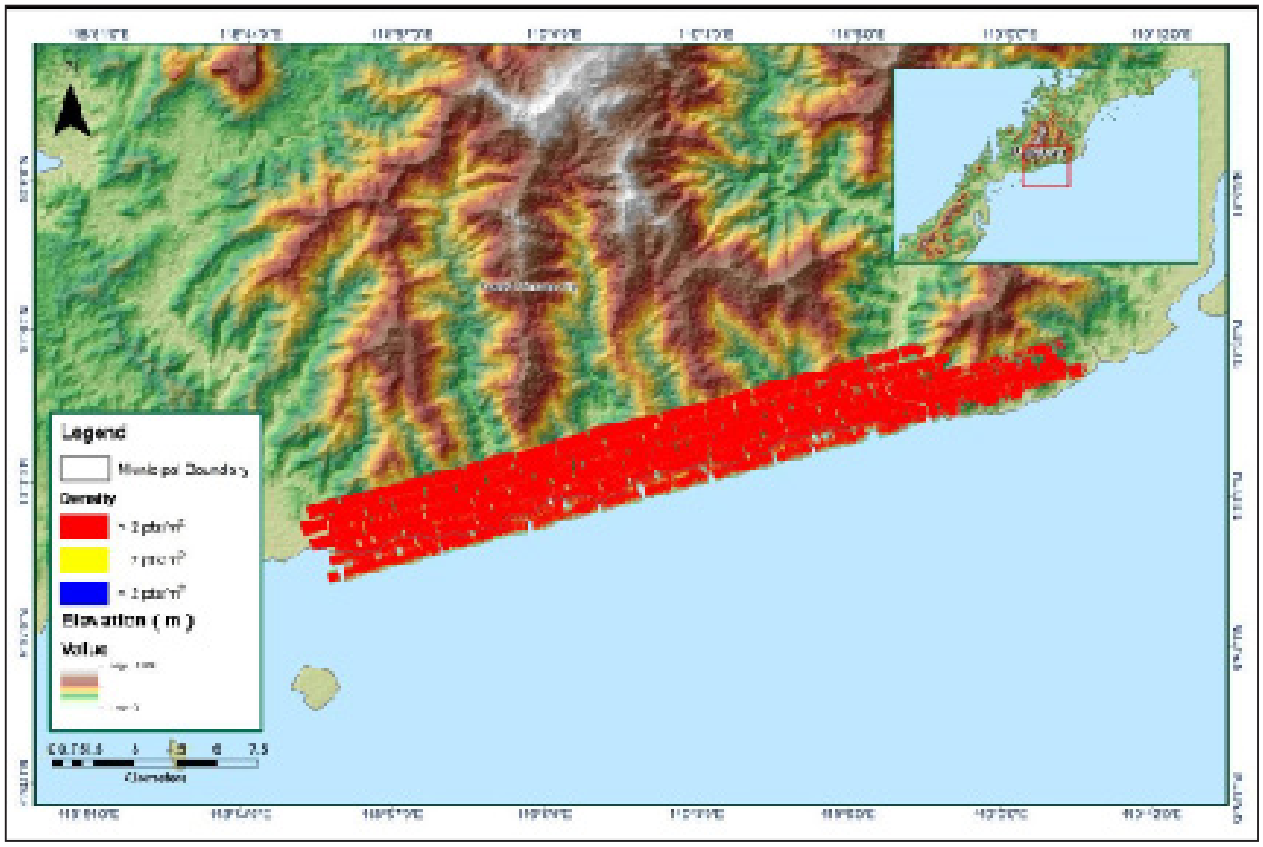


Figure A-8.55. Density map of merged LiDAR data

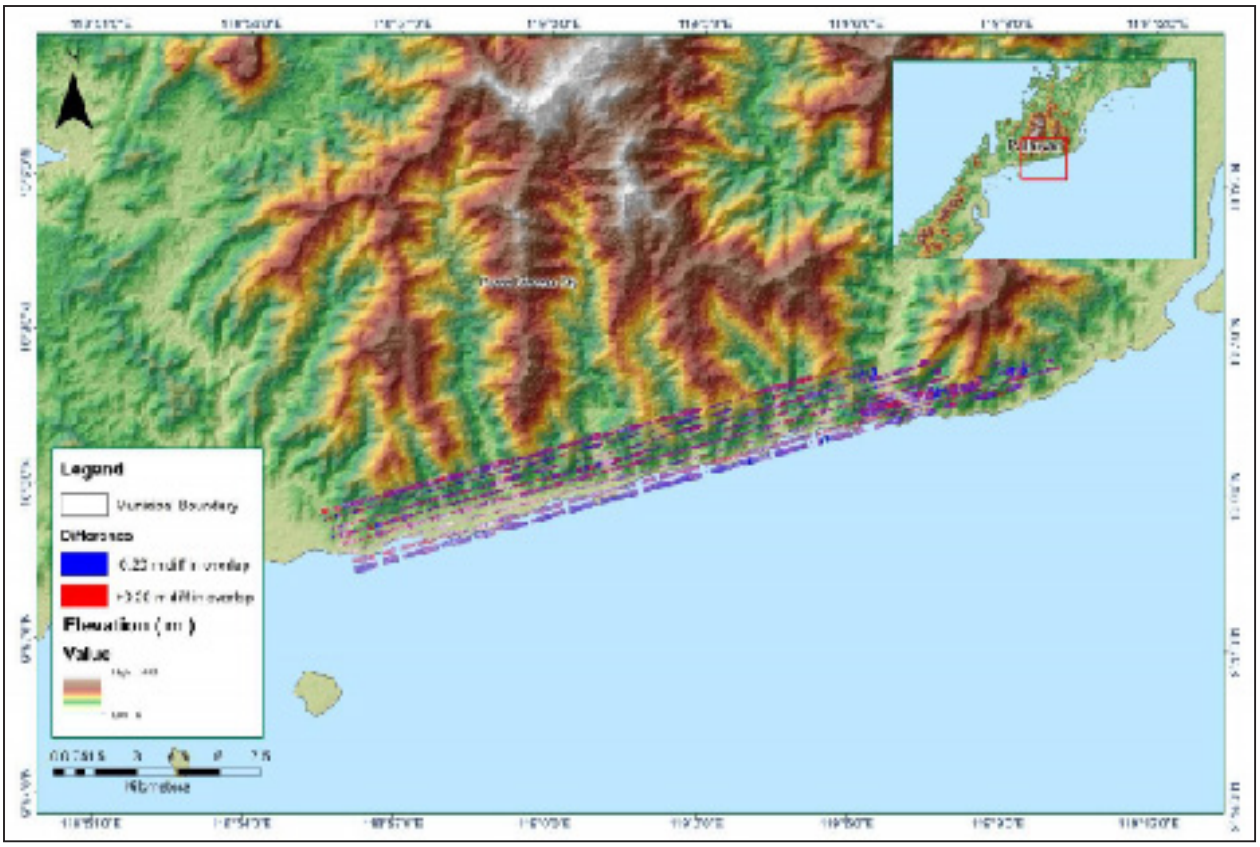


Figure A-8.56. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission Blk42eE

Flight Area	Palawan Reflights
Mission Name	Blk42eE
Inclusive Flights	3493G
Range data size	13.2 GB
Base data size	5.16 MB
POS	208 MB
Image	NA
Transfer date	December 8, 2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.31
RMSE for East Position (<4.0 cm)	1.20
RMSE for Down Position (<8.0 cm)	3.37
Boresight correction stdev (<0.001deg)	0.005354
IMU attitude correction stdev (<0.001deg)	0.003248
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	39.34%
Ave point cloud density per sq.m. (>2.0)	4.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	34
Maximum Height	317.78 m
Minimum Height	2.89 m
Classification (# of points)	
Ground	6,594,561
Low vegetation	7,877,605
Medium vegetation	31,879,859
High vegetation	37,079,890
Building	416,796
Ortophoto	No
Processed by	Engr. Regis Guhiting, Engr. Chelou Prado, Engr. Elainne Lopez

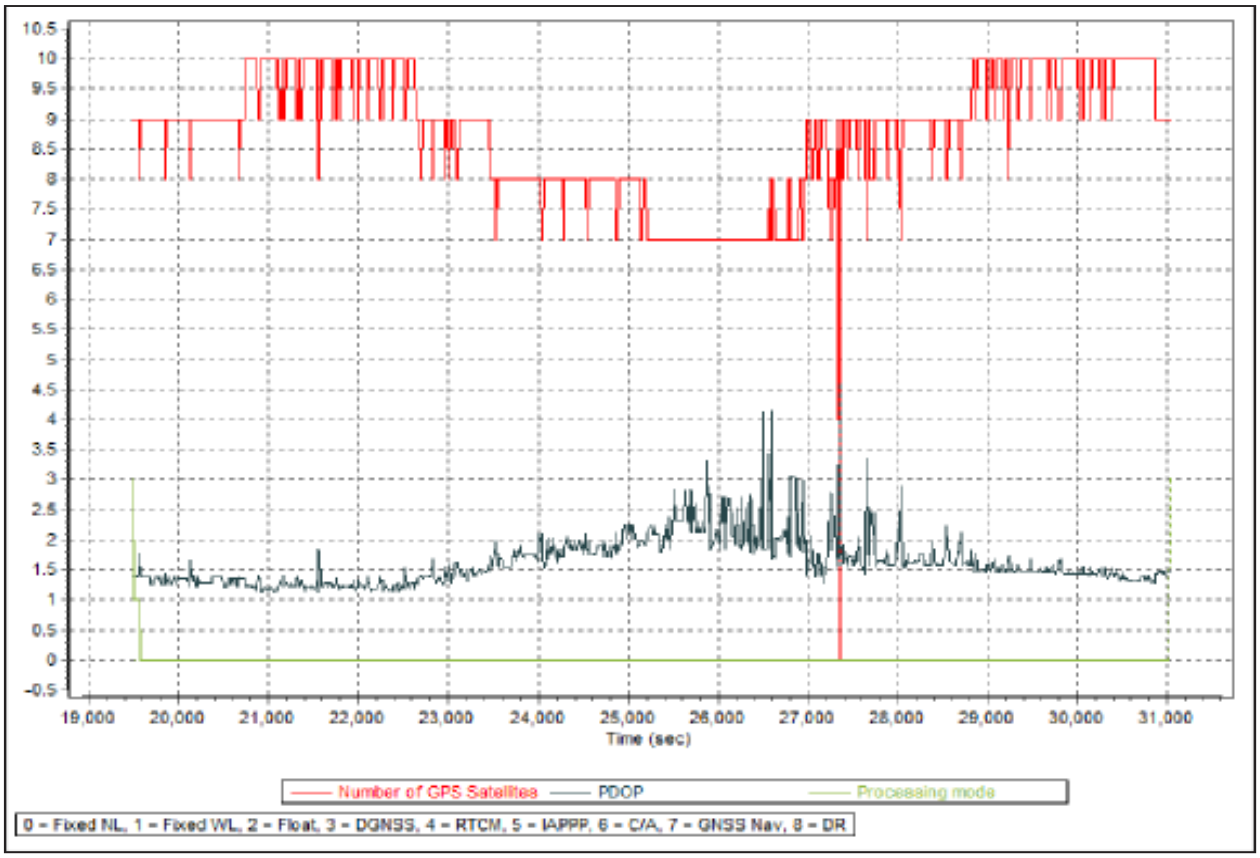


Figure A-8.57. Solution Status

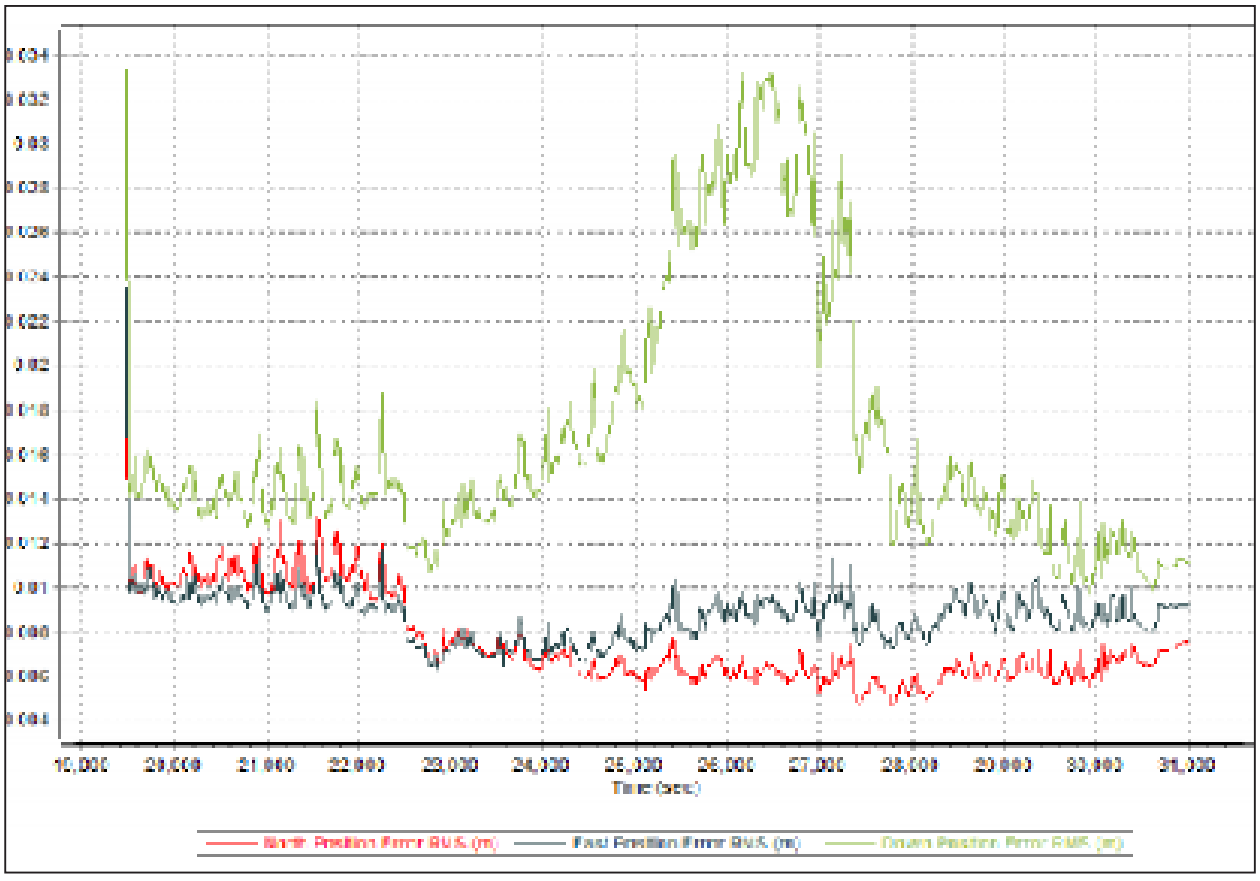


Figure A-8.58. Smoothed Performance Metric Parameters

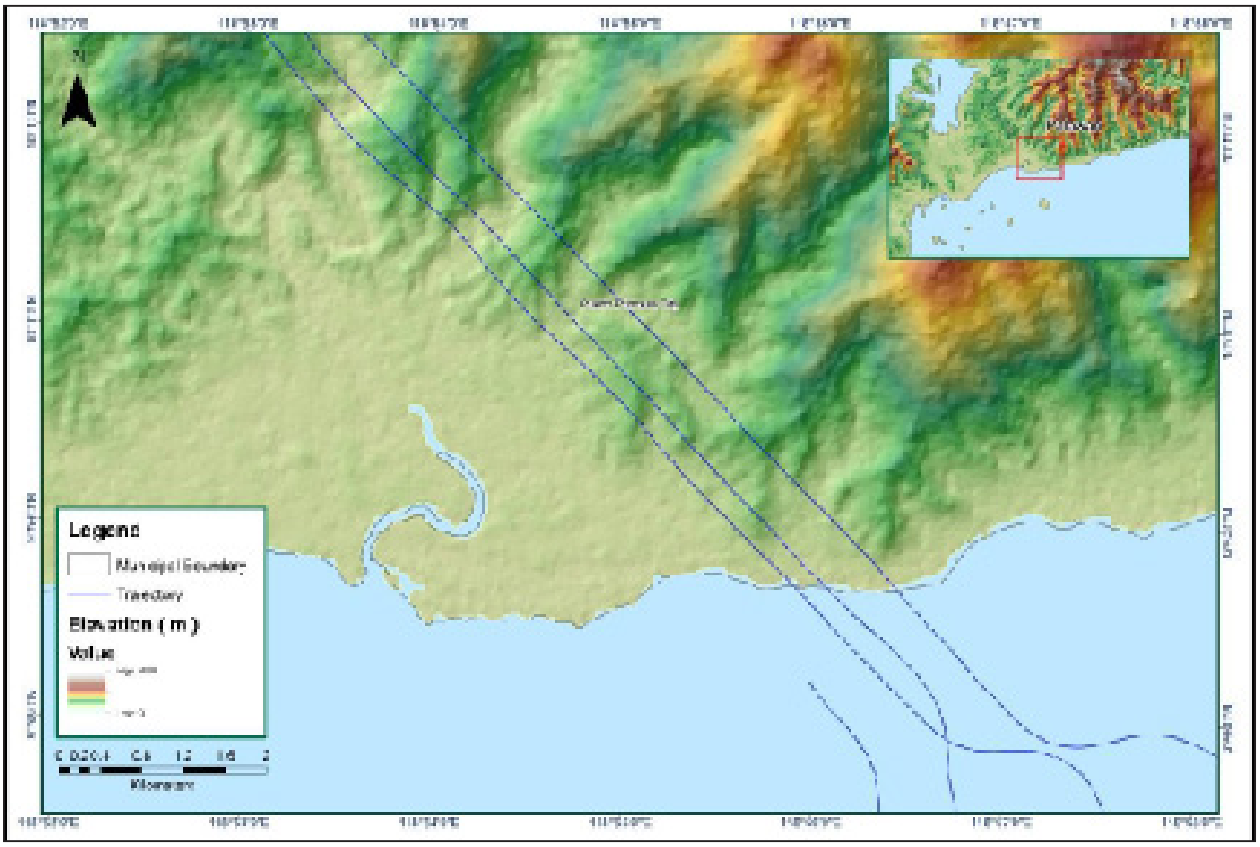


Figure A-8.59. Best Estimated Trajectory

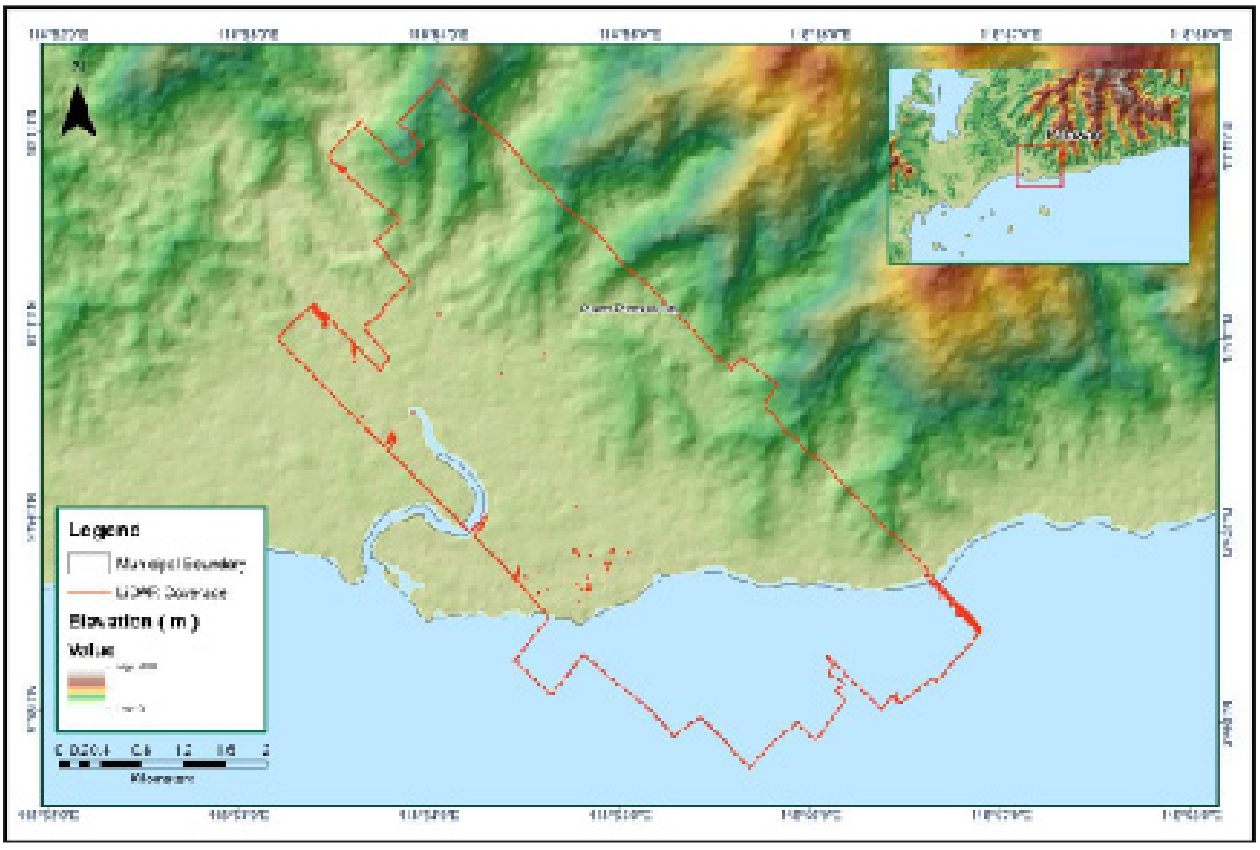


Figure A-8.60. Coverage of LiDAR data

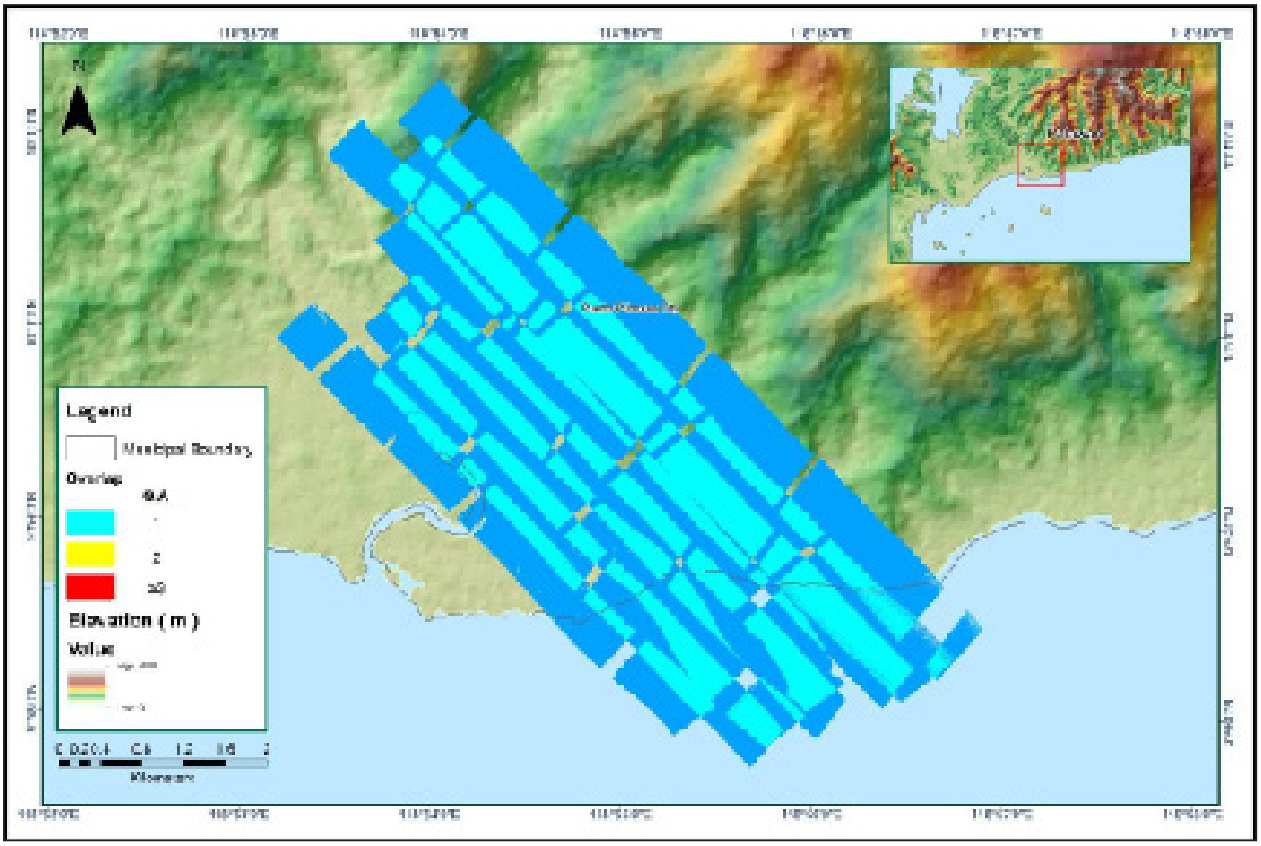


Figure A-8.61. Image of data overlap

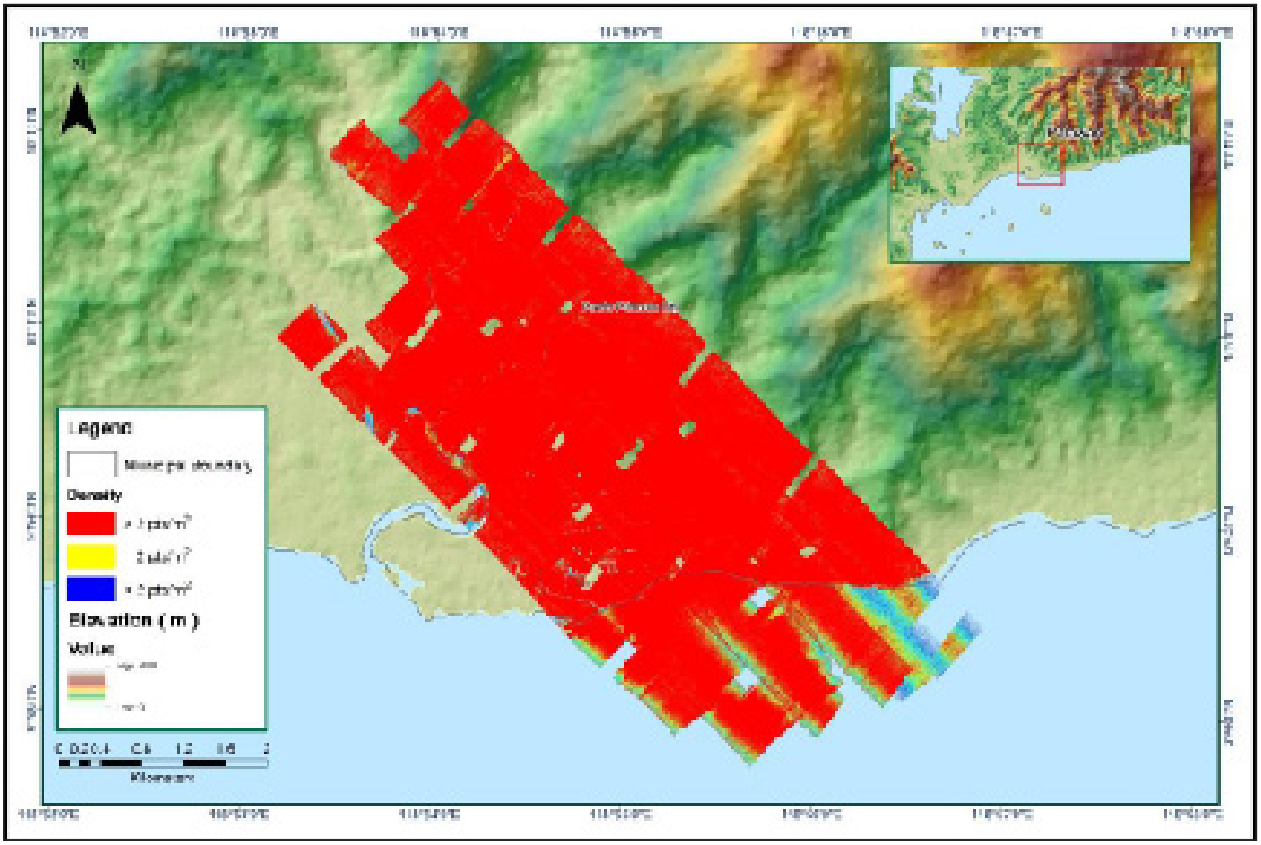


Figure A-8.62. Density map of merged LiDAR data

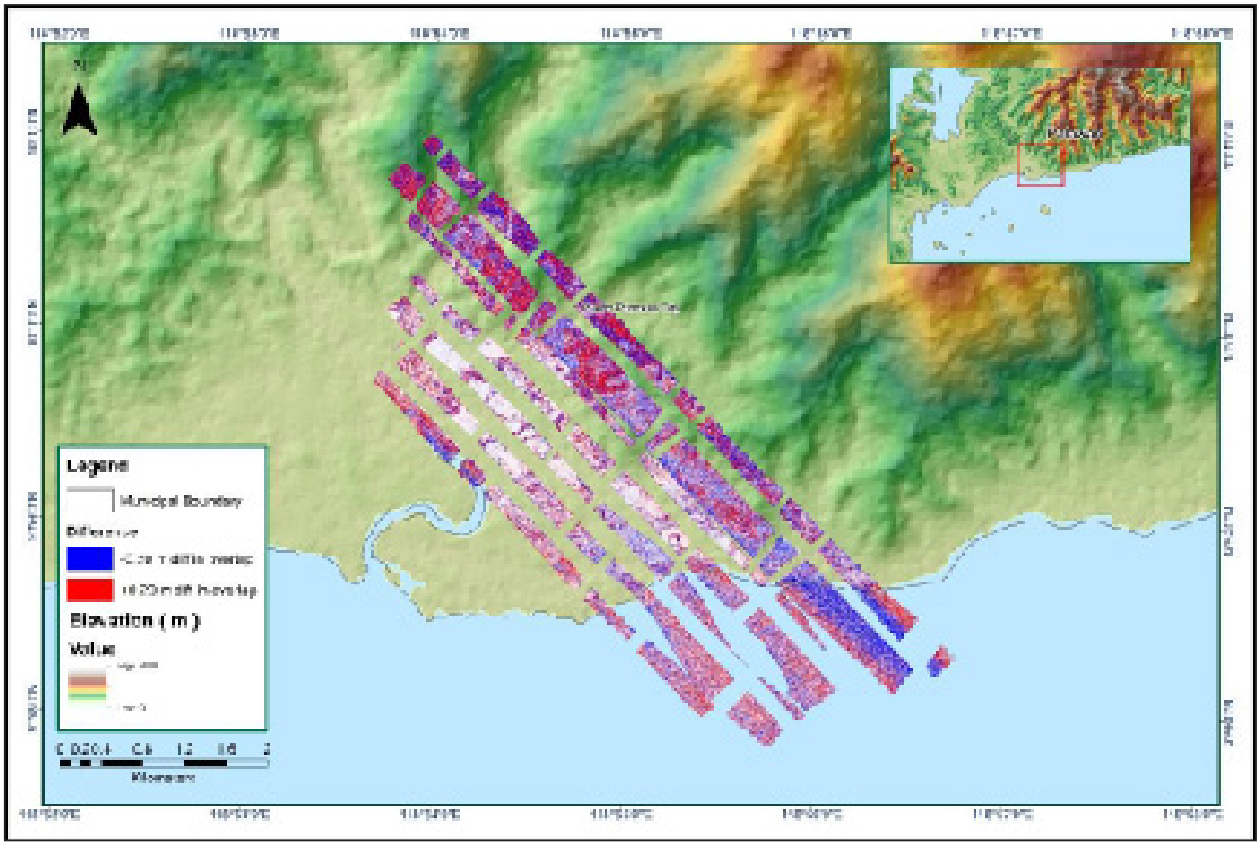


Figure A-8.63. Elevation difference between flight lines

Table A-8.10. Mission Summary Report for Mission Blk42eE_additional

Flight Area	Palawan Reflights
Mission Name	Blk42eE_additional
Inclusive Flights	3505G
Range data size	17.5 GB
Base data size	8.09 MB
POS	222 MB
Image	NA
Transfer date	December 8, 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)	1.52
RMSE for East Position (<4.0 cm)	1.72
RMSE for Down Position (<8.0 cm)	4.29
Boresight correction stdev (<0.001deg)	0.007009
IMU attitude correction stdev (<0.001deg)	0.316639
GPS position stdev (<0.01m)	0.0289
Minimum % overlap (>25)	31.24%
Ave point cloud density per sq.m. (>2.0)	6.45
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	26
Maximum Height	398.37 m
Minimum Height	2.75 m
Classification (# of points)	
Ground	2,645,643
Low vegetation	2,145,514
Medium vegetation	9,174,098
High vegetation	49,611,536
Building	486,145
Ortophoto	No
Processed by	Engr. Regis Guhiting, Engr. Ma.Joanne Balaga, Engr. Ma.Ailyn Olanda

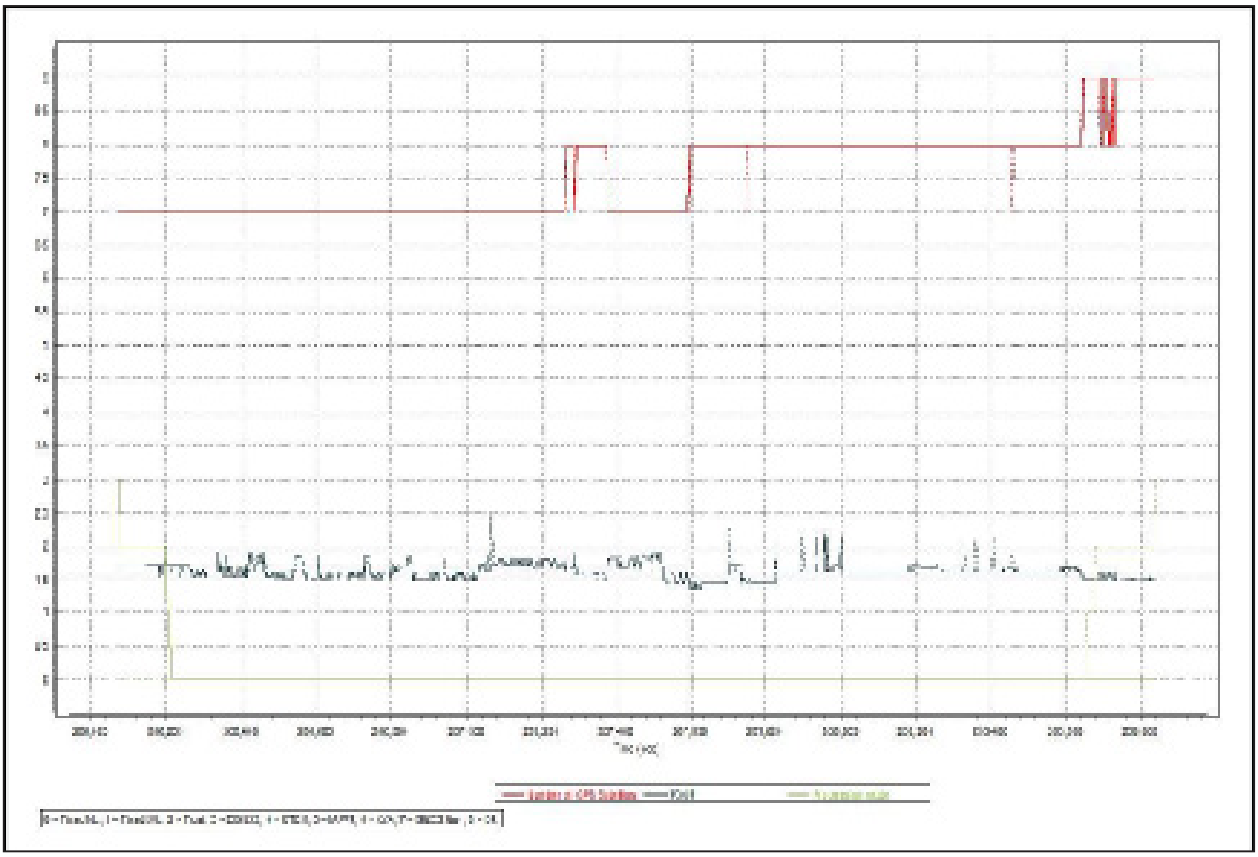


Figure A-8.64. Solution Status

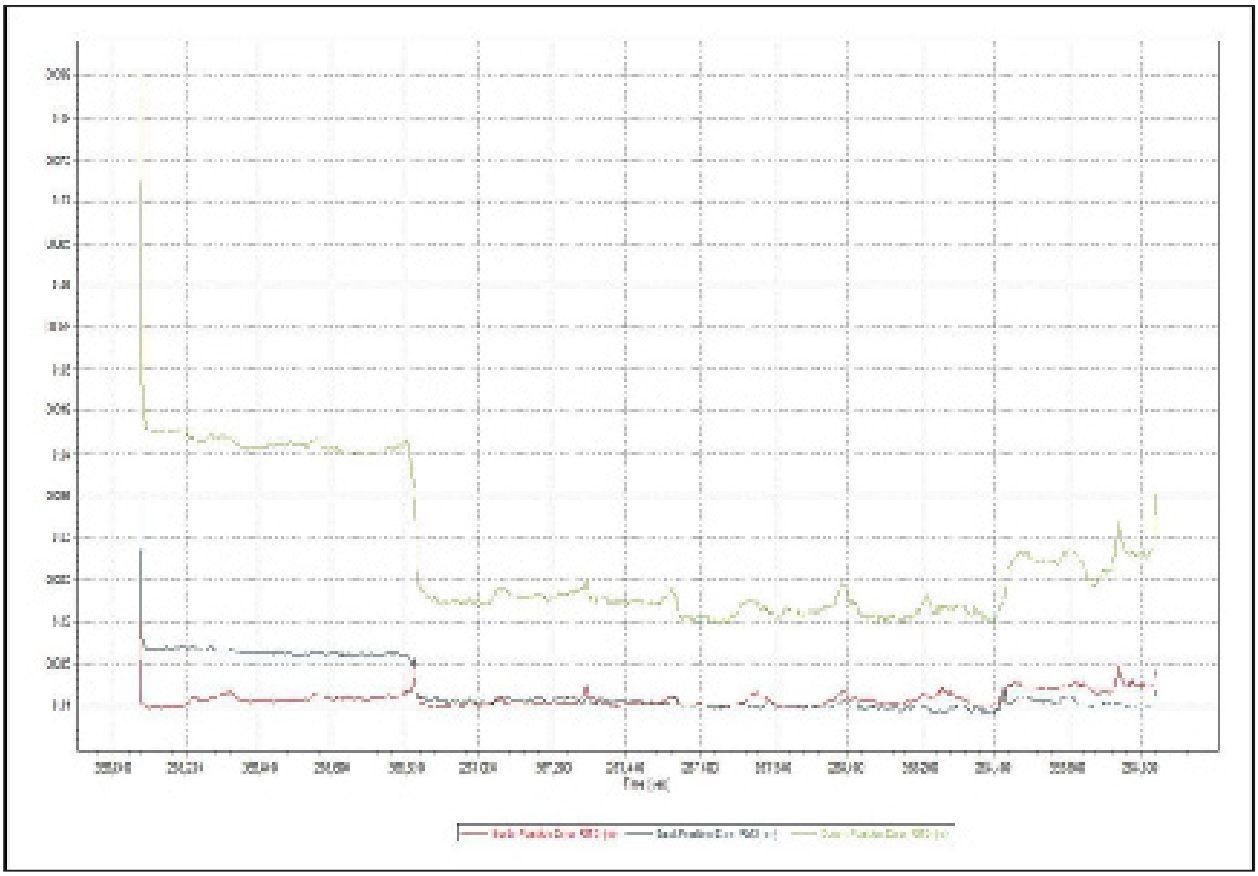


Figure A-8.65. Smoothed Performance Metric Parameters

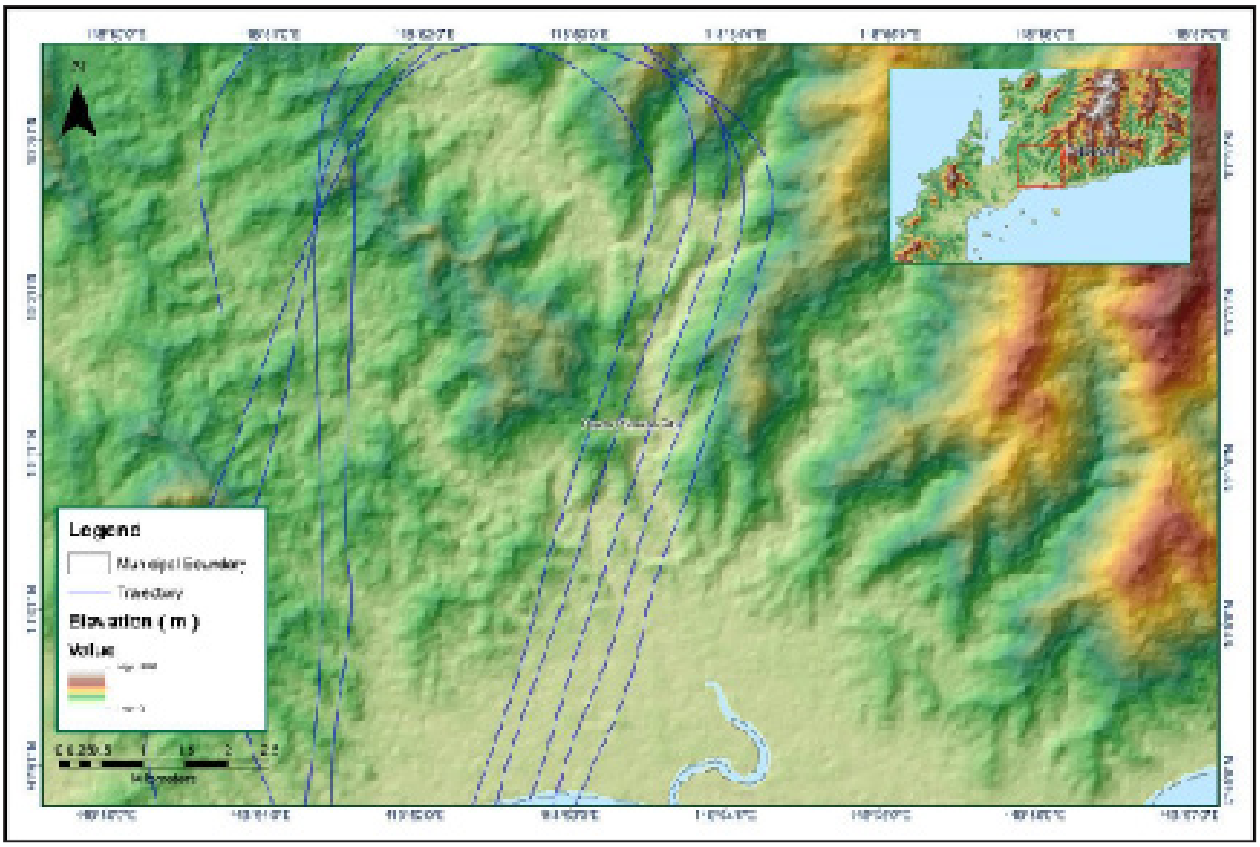


Figure A-8.66. Best Estimated Trajectory

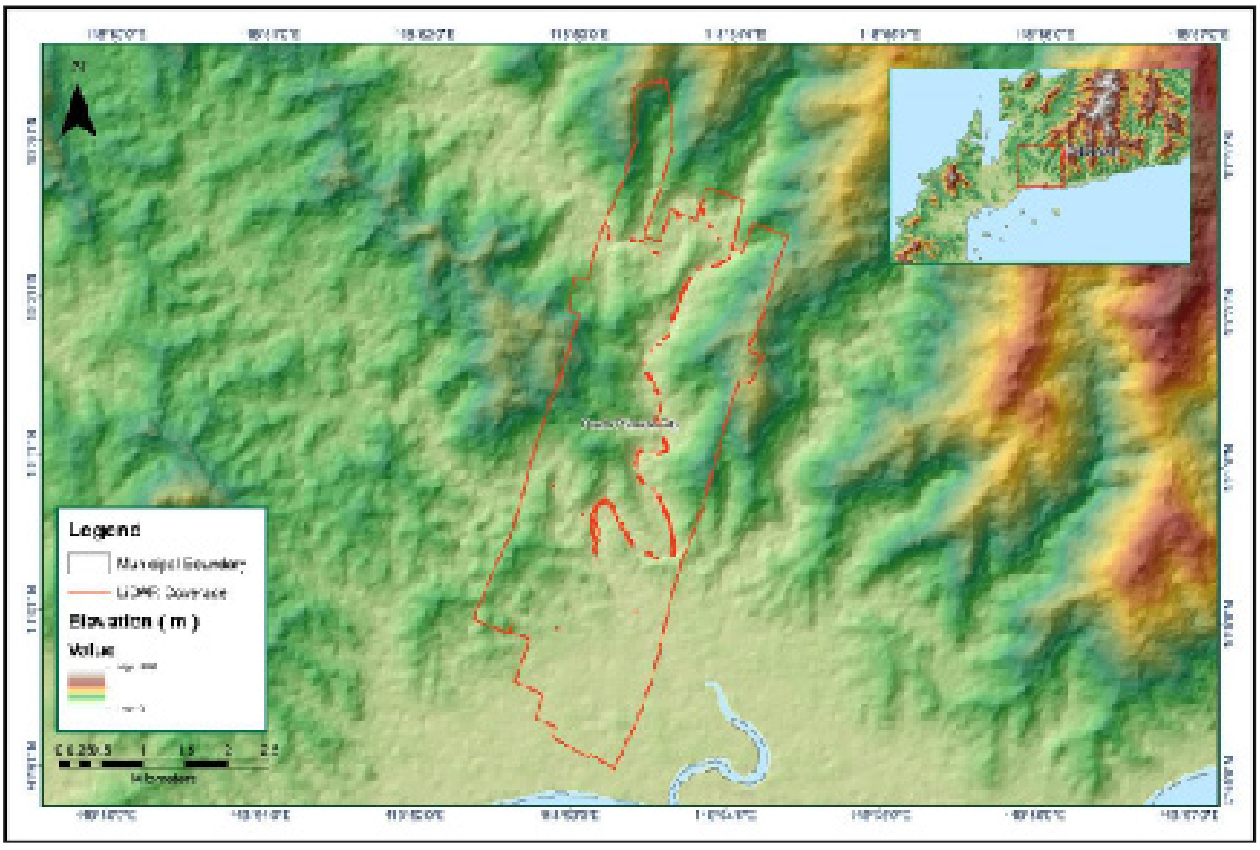


Figure A-8.67. Coverage of LiDAR data

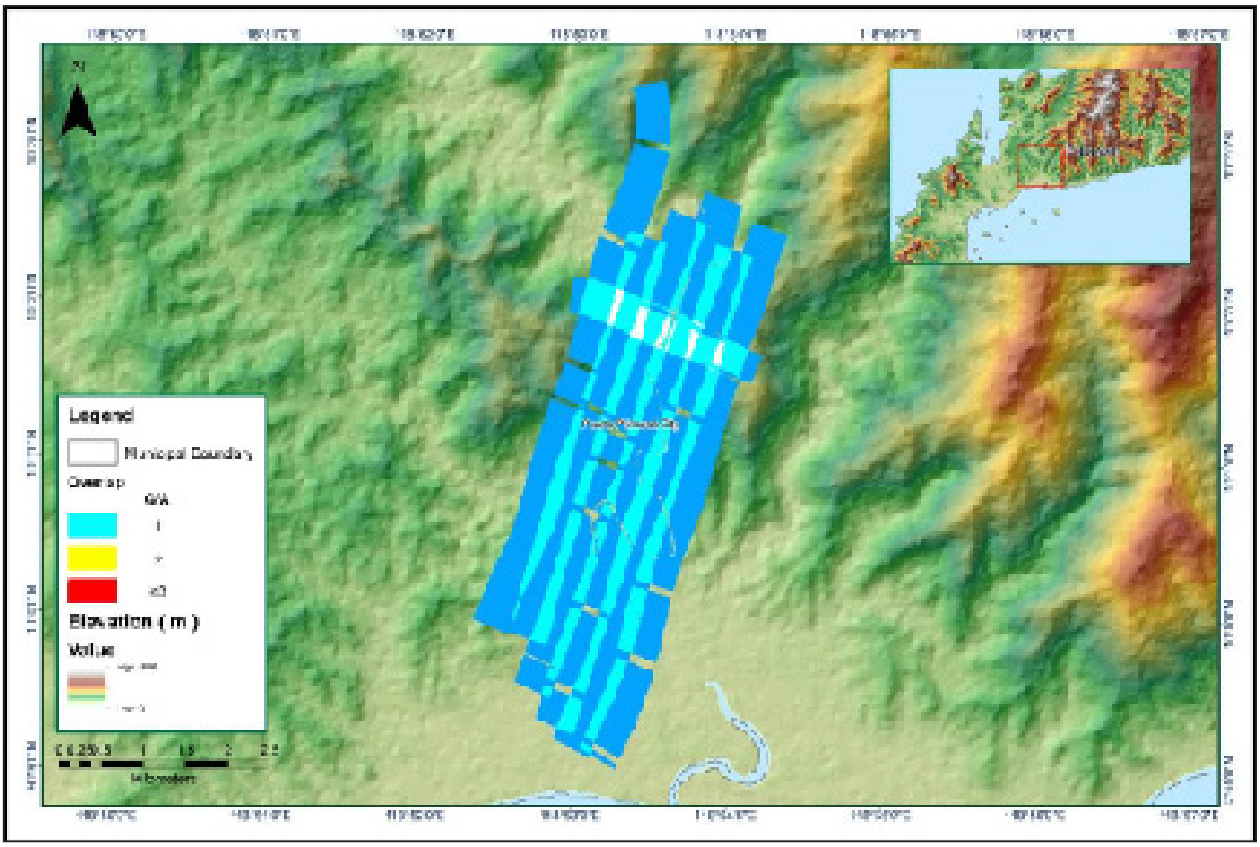


Figure A-8.68. Image of data overlap

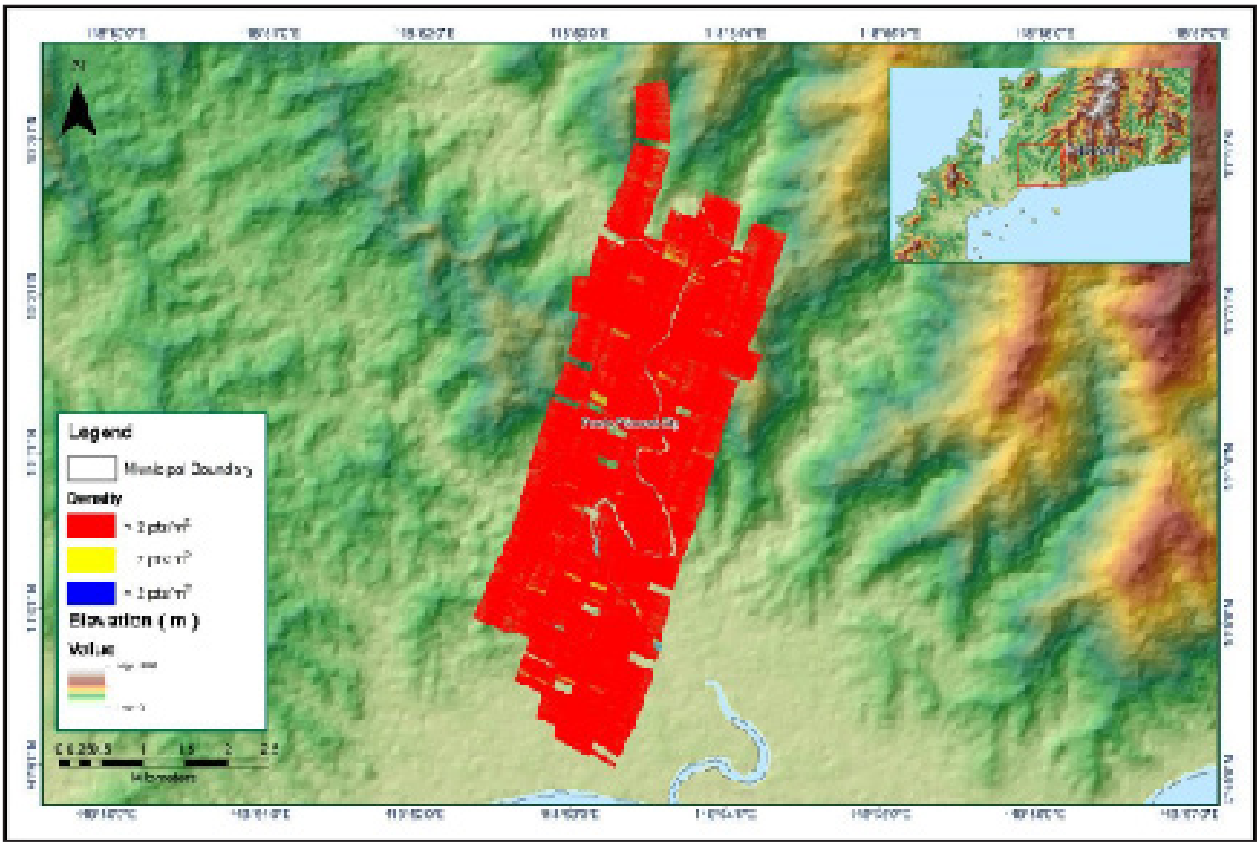


Figure A-8.69. Density map of merged LiDAR data

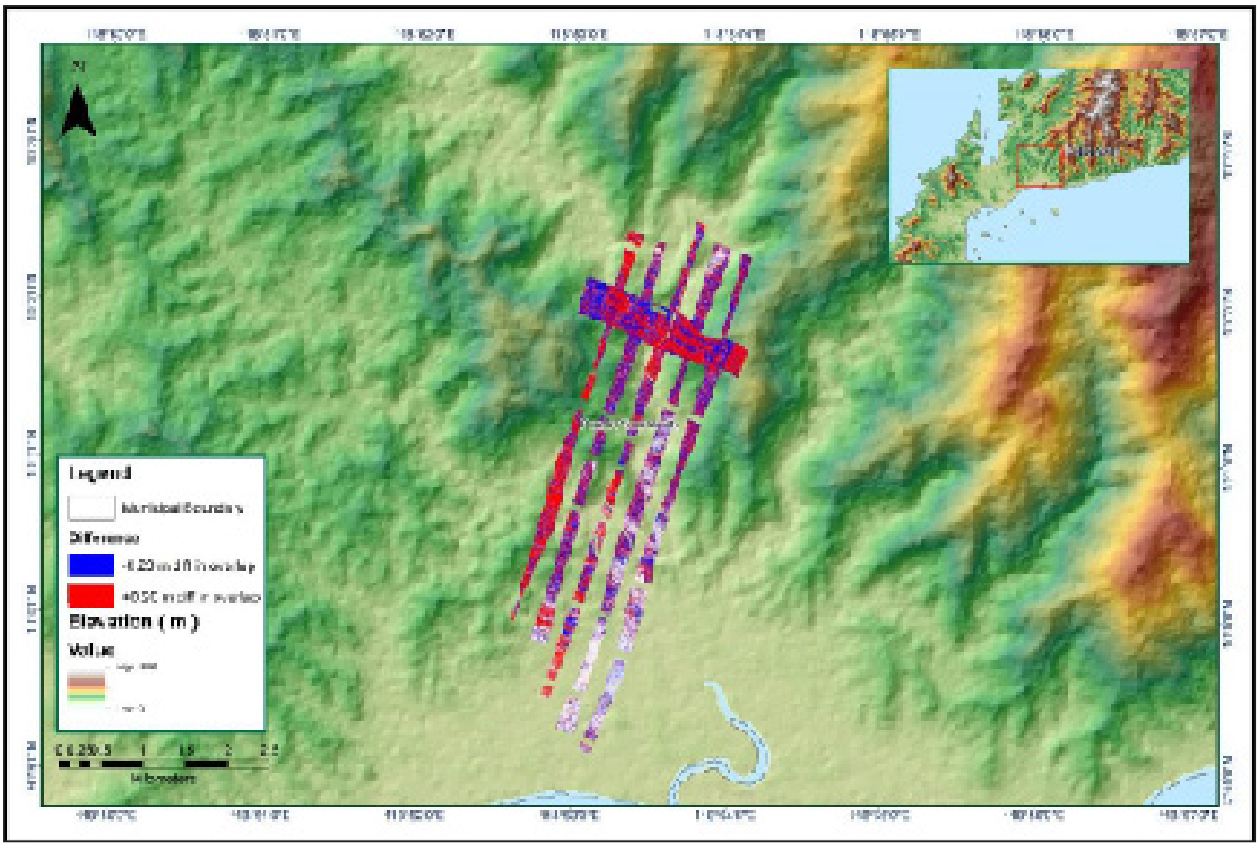


Figure A-8.70. Elevation difference between flight lines

Table A-8.11. Mission Summary Report for Mission Blk42isl

Flight Area	Palawan Reflights
Mission Name	Blk42isl
Inclusive Flights	3497G, 3499G, 3507G
Range data size	39.76 GB
Base data size	20.86 MB
POS	608 MB
Image	NA
Transfer date	December 8, 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)	2.51
RMSE for East Position (<4.0 cm)	2.24
RMSE for Down Position (<8.0 cm)	3.72
Boresight correction stdev (<0.001deg)	0.002718
IMU attitude correction stdev (<0.001deg)	0.007351
GPS position stdev (<0.01m)	0.0031
Minimum % overlap (>25)	42.72%
Ave point cloud density per sq.m. (>2.0)	3.03
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	144
Maximum Height	99.14 m
Minimum Height	50.81 m
Classification (# of points)	
Ground	41,203,649
Low vegetation	35,941,452
Medium vegetation	132,405,119
High vegetation	12,239,761
Building	85,719
Ortophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Chelou Prado, Engr. Elainne Lopez

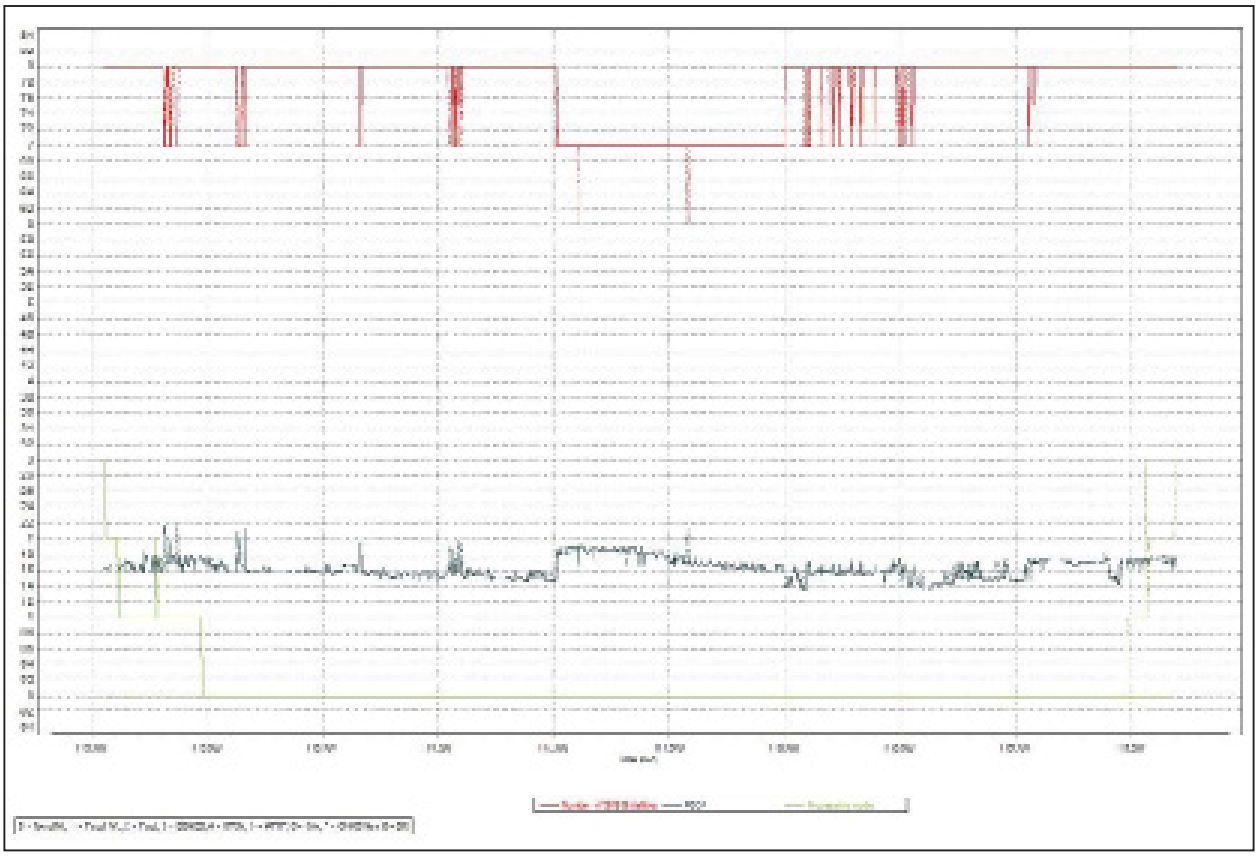


Figure A-8.71. Solution Status

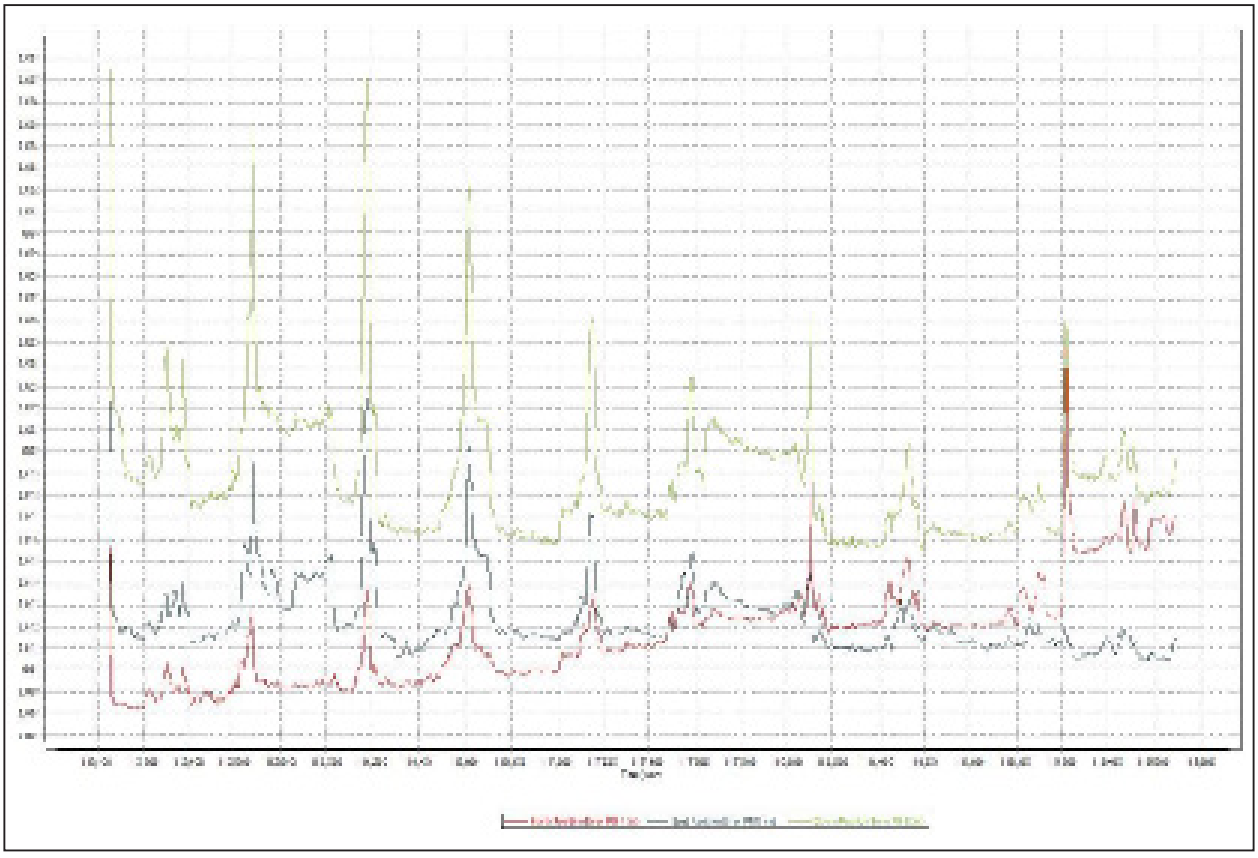


Figure A-8.72. Smoothed Performance Metric Parameters

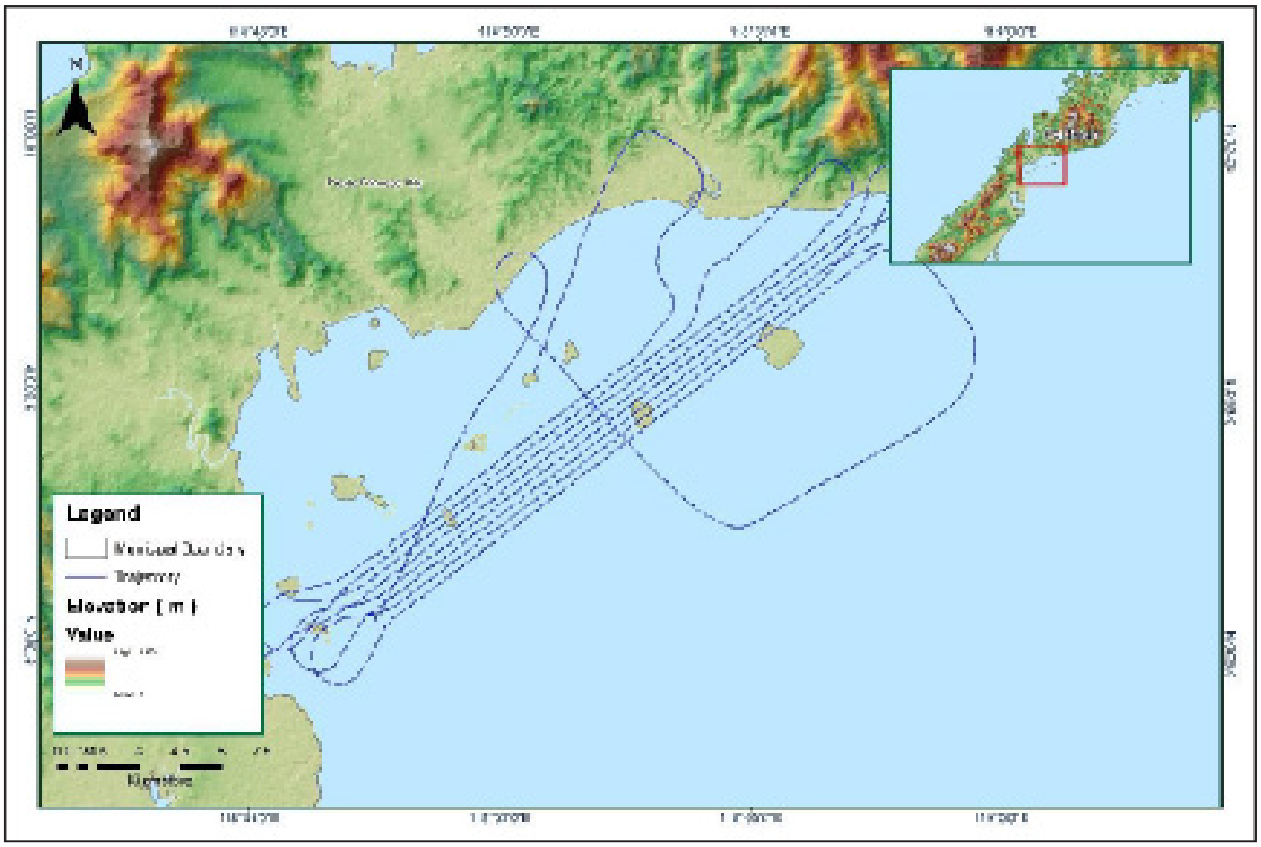


Figure A-8.73. Best Estimated Trajectory

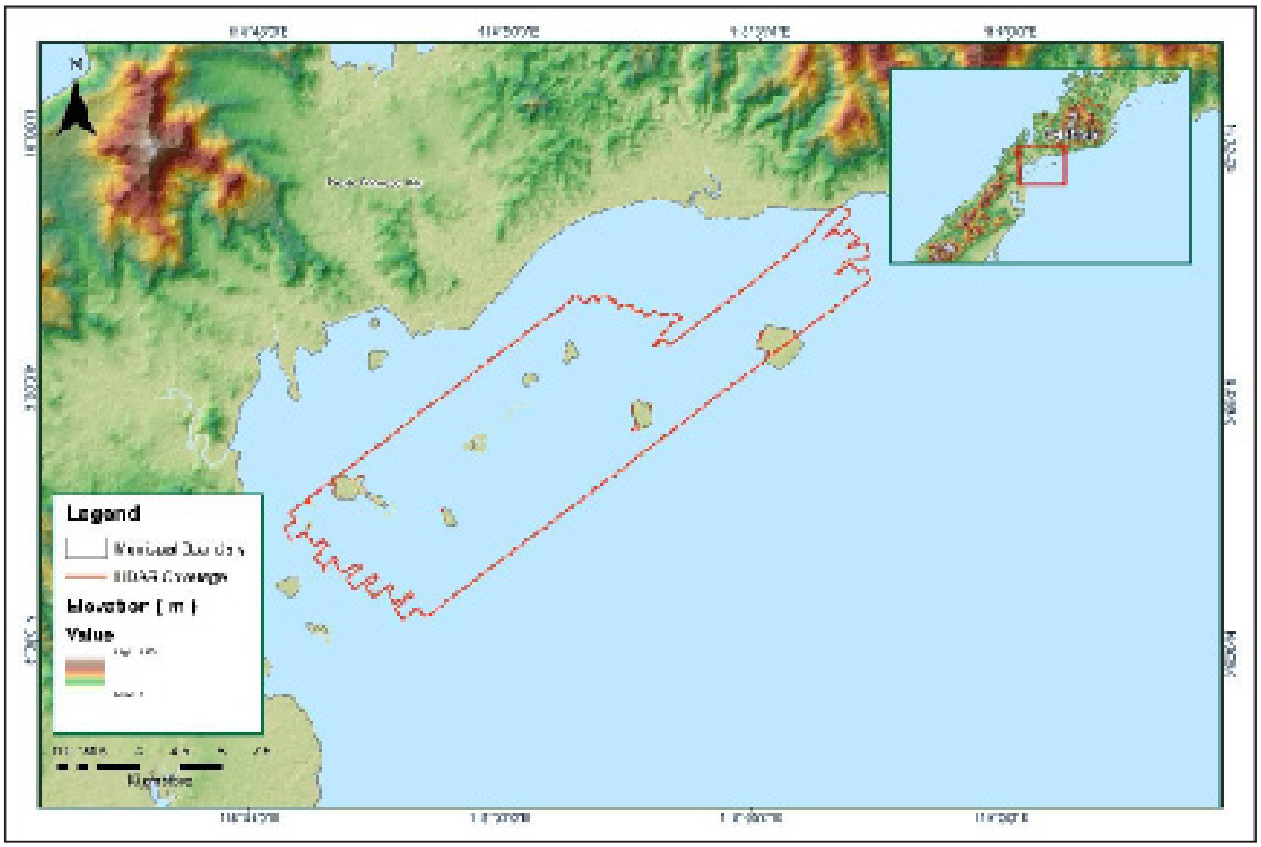


Figure A-8.74. Coverage of LiDAR data

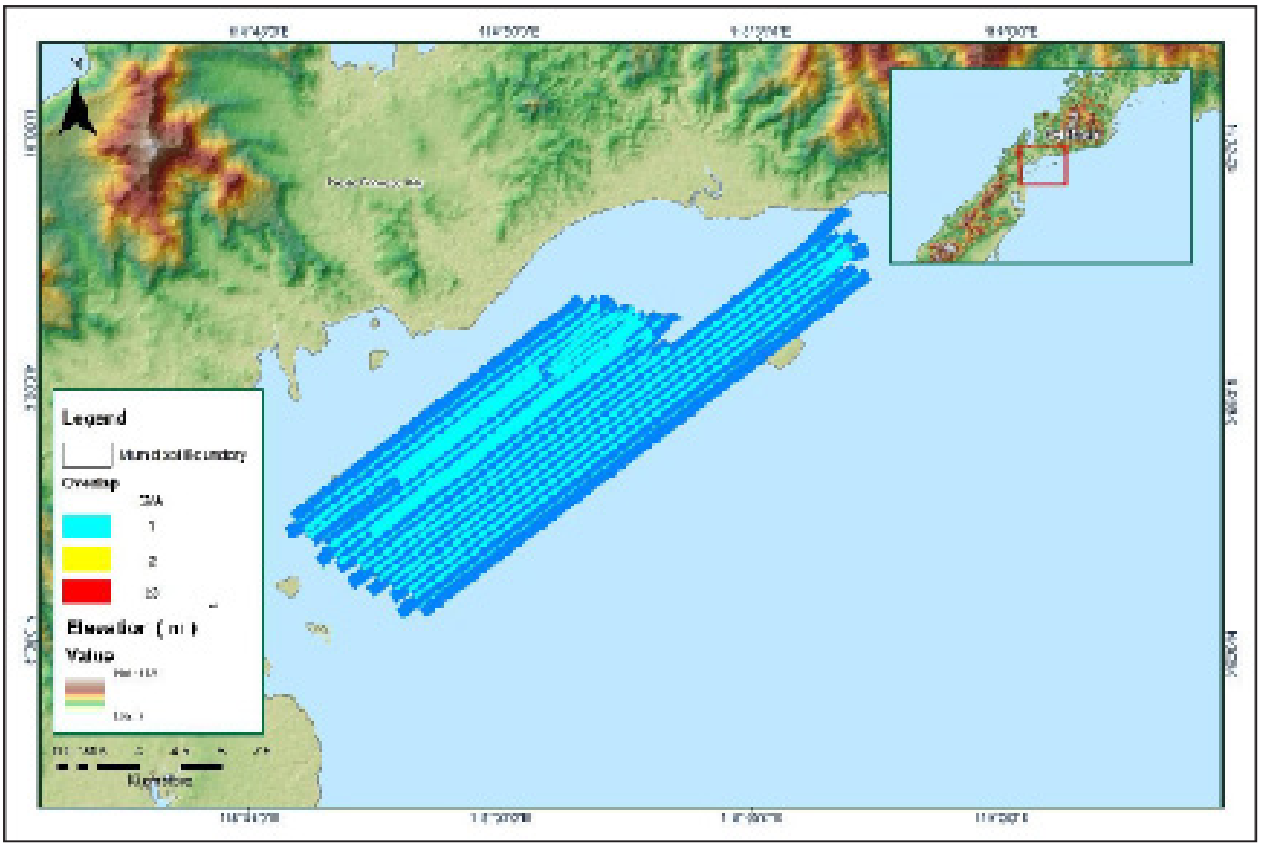


Figure A-8.75. Image of data overlap

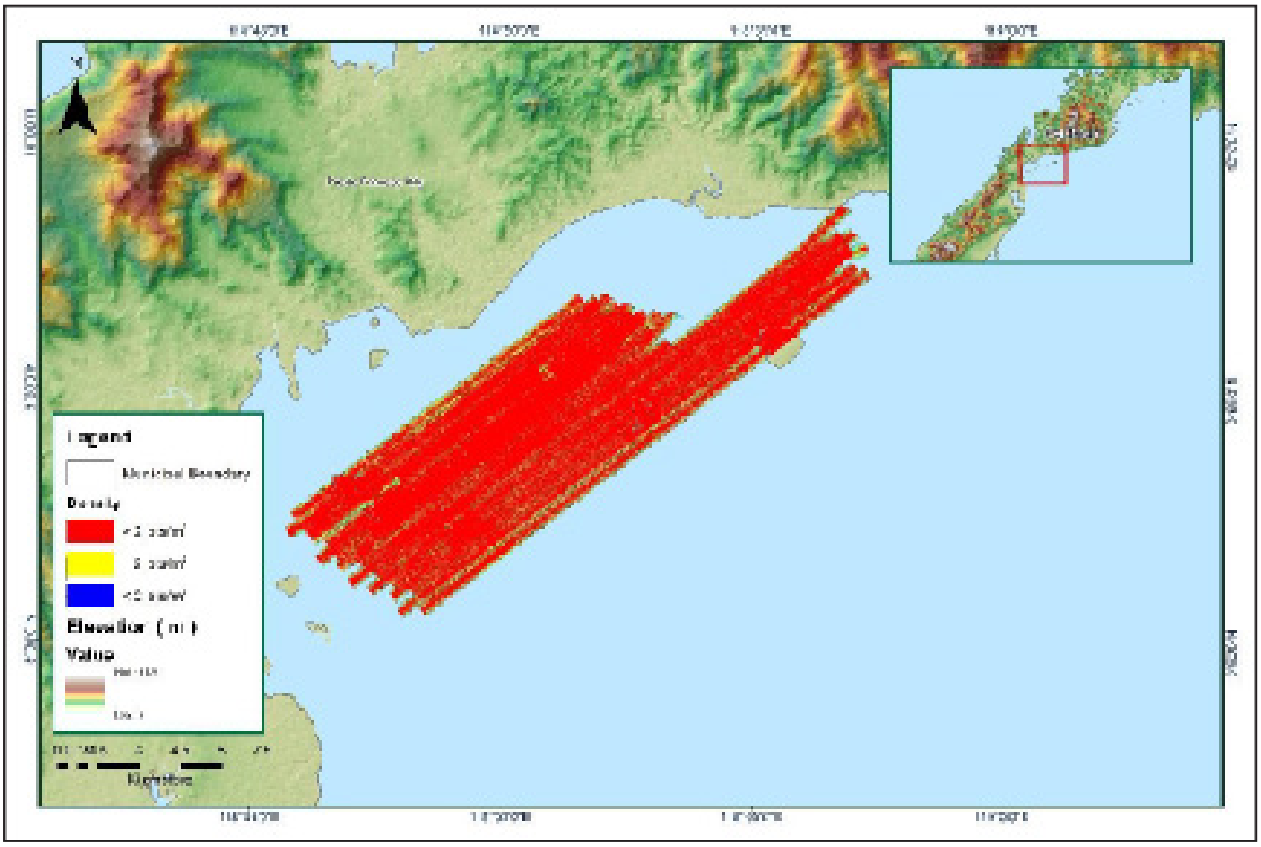


Figure A-8.76. Density map of merged LiDAR data

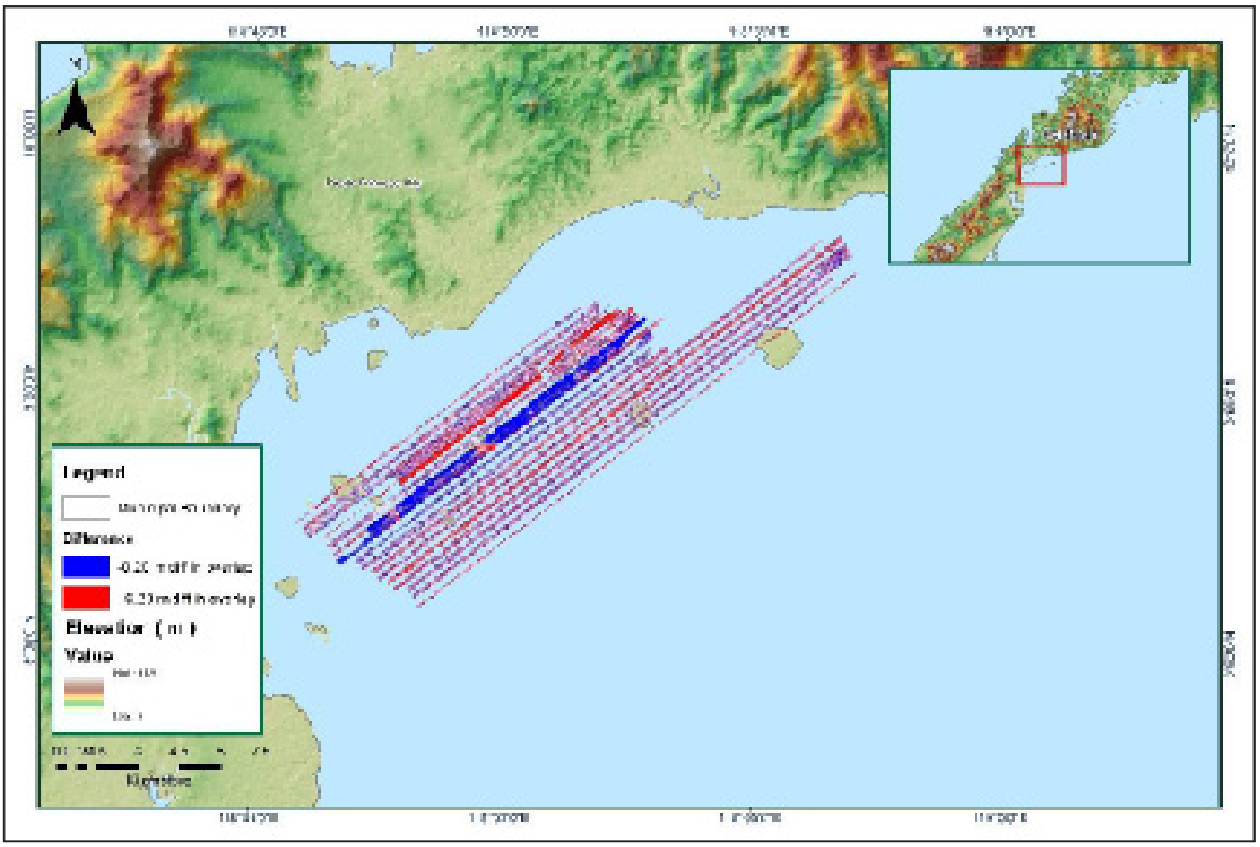


Figure A-8.77. Elevation difference between flight lines

Annex 9. Babuyan Model Basin Parameters

Table A-9.1. Babuyan Model Basin Parameters

Sub-basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform	
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)
W440	0.1718	48.978	0	0.033333	0.033333
W450	0.25072	49.494	0	0.033333	0.033333
W460	0.10245	38.212	0	0.033333	0.088716
W470	0.26082	38.259	0	0.033333	0.033333
W480	0.16203	35.767	0	0.033333	0.033333
W490	0.263	39.935	0	0.033333	0.049891
W500	0.25379	40.576	0	0.033333	3.0325
W510	0.16411	51.371	0	0.033333	0.033333
W520	0.16965	87.12	0	0.033333	0.033333
W530	0.23359	45.001	0	0.033333	0.033333
W540	0.15639	47.473	0	0.033333	0.033333
W550	0.26358	41.126	0	0.033333	0.049107
W560	0.12372	60.847	0	0.033333	0.033333
W570	0.16412	46.662	0	0.033333	0.11576
W580	0.10927	48.248	0	0.033333	0.033333
W590	0.12144	48.944	0	0.033333	0.033333
W600	0.082718	52.229	0	0.033333	0.033333
W610	0.26132	42.061	0	0.033333	0.033333
W620	0.23646	45.553	0	0.033333	0.033333
W630	0.074852	57.538	0	0.033333	0.033333
W640	0.20123	35.528	0	0.033333	0.033333
W650	0.013859	54.961	0	0.033333	0.033333
W660	0.075324	70.497	0	0.033333	0.033333
W670	0.10942	38.019	0	0.033333	0.033333
W680	0.10154	53.098	0	0.033333	0.033333
W690	0.085058	68.426	0	0.033333	0.033333
W700	0.23834	50.761	0	0.033333	0.033333
W710	0.10042	58.126	0	0.033333	0.033333
W720	0.093625	71.763	0	0.033333	0.033333
W730	0.085618	38.758	0	0.033333	0.051753
W740	0.18422	45.242	0	0.033333	0.10301
W750	0.17937	52.042	0	0.033333	0.089332
W760	0.091276	43.37	0	0.033333	0.033333
W770	0.15964	46.276	0	0.033333	0.079583
W780	0.17555	62.344	0	0.033333	0.033333
W790	0.11111	52.784	0	0.033333	0.29641
W800	0.000701	53.447	0	0.033333	0.033333
W810	0.23644	42.266	0	0.033333	0.17069

Sub-basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform	
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)
W820	0.000789	56.458	0	0.033333	0.033333
W830	0.00768	59.4	0	0.033333	0.033333
W840	0.18817	60.079	0	0.033333	0.033333
W850	0.002742	99	0	0.033333	0.033333
W880	6.538	66.015	0	2.2053	3.5991

Annex 10. Babuyan Model Reach Parameters

Table A-10.1. Babuyan Model Reach Parameters

Reach Number				
	Length (m)	Slope (M/M)	Shape	Side Slope (xH:1V)
R100	3000.5	0.020529	Trapezoid	1
R120	6593.4	0.004969	Trapezoid	1
R150	2524.2	0.002232	Trapezoid	1
R170	1837.5	0.005355	Trapezoid	1
R190	2363.8	0.000666	Trapezoid	1
R200	1983.1	0.002175	Trapezoid	1
R220	2880.1	0.005626	Trapezoid	1
R270	970.83	0.010771	Trapezoid	1
R280	4268.6	0.002877	Trapezoid	1
R290	2130.2	0.001399	Trapezoid	1
R30	4496.9	0.030203	Trapezoid	1
R340	9619.3	0.001843	Trapezoid	1
R360	4038.6	0.000484	Trapezoid	1
R390	4306.2	0.011425	Trapezoid	1
R400	6876.2	0.001127	Trapezoid	1
R410	1897.2	0.001631	Trapezoid	1
R420	14832	0.008533	Trapezoid	1
R430	1244.5	0.005363	Trapezoid	1
R50	8102.2	0.009273	Trapezoid	1
R70	5714.6	0.002544	Trapezoid	1
R90	729.12	0.022853	Trapezoid	1
R900	181.42	0.015515	Trapezoid	1

Annex 11. Babuyan Field Validation Data

Table A-11.1. Babuyan Field Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
1	9.97766130400	118.85618310000	0	0.03	-0.03			25-Year
2	9.97924865600	118.92812620000	0	0.09	-0.09			25-Year
3	9.98007116600	118.92843290000	0	0.07	-0.07			25-Year
4	9.97967822400	118.86126230000	0	0.03	-0.03			25-Year
5	9.98053853900	118.92879330000	0	0.04	-0.04			25-Year
6	9.98026700000	118.87331000000	0.31	0.05	0.26	Lando	Nov. 2007	25-Year
7	9.98086600000	118.91097000000	0	0.04	-0.04			25-Year
8	9.98087210000	118.90968000000	0.4	0.03	0.37	Lando	Oct. 2015	25-Year
9	9.98118110000	118.90833000000	0.61	0.86	-0.25	Lando	Oct. 2015	25-Year
10	9.98086900000	118.87314000000	0	0.42	-0.42			25-Year
11	9.98164303300	118.92447020000	0	0.06	-0.06			25-Year
12	9.98131700000	118.88256000000	0.3	0.05	0.25	Lando	Nov. 2007	25-Year
13	9.98124500000	118.87273000000	0.4	0.72	-0.32	Lawin	Oct. 2016	25-Year
14	9.98143600000	118.88289000000	0.65	0.1	0.55	Lando	Nov. 2007	25-Year
15	9.98178300000	118.88269000000	0.2	0.19	0.01	Lando	Nov. 2007	25-Year
16	9.98233360000	118.91080000000	0.45	1.16	-0.71	Lando	Oct. 2015	25-Year
17	9.98263828200	118.92618680000	0	0.03	-0.03			25-Year
18	9.98218000000	118.88233000000	0.55	0.82	-0.27	Lando	Nov. 2007	25-Year
19	9.98240101100	118.89640580000	2	0.27	1.73	Norming	1994	25-Year
20	9.98246900000	118.88282000000	0.2	0.77	-0.57	Lawin	Aug. 2016	25-Year
21	9.98340700000	118.88265000000	0.2	0.89	-0.69	Lando	Nov. 2007	25-Year
22	9.98321349700	118.86573770000	0	0.28	-0.28			25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
23	9.98389572000	118.91799270000	0	0.29	-0.29			25-Year
24	9.98399800000	118.87159000000	0.13	1.14	-1.01	Yolanda	Nov. 2013	25-Year
25	9.98463210000	118.91027000000	0	0.43	-0.43			25-Year
26	9.98440000000	118.88348000000	0	0.05	-0.05			25-Year
27	9.98526553800	118.91156470000	0	0.03	-0.03			25-Year
28	9.98497200000	118.87106000000	0.17	0.32	-0.15	Yolanda	Nov. 2013	25-Year
29	9.98520100000	118.88390000000	0	0.56	-0.56			25-Year
30	9.98606150000	118.91022000000	0	0.03	-0.03			25-Year
31	9.98556738600	118.86472780000	0	0.05	-0.05			25-Year
32	9.98645126400	118.90952900000	0	0.03	-0.03			25-Year
33	9.98663592100	118.91985140000	0	0.03	-0.03			25-Year
34	9.98623500000	118.87103000000	0	0.03	-0.03			25-Year
35	9.98674500000	118.88301000000	0	0.54	-0.54			25-Year
36	9.98706555900	118.86618550000	0	0.51	-0.51			25-Year
37	9.98708681900	118.86654890000	0	0.67	-0.67			25-Year
38	9.98885153700	118.86838210000	0	0.03	-0.03			25-Year
39	9.98964402800	118.90637100000	1.5	0.03	1.47	Lando	Nov. 2007	25-Year
40	9.98972236700	118.87207800000	0	0.04	-0.04			25-Year
41	9.99035275300	118.90622380000	2	0.03	1.97	Lando	Nov. 2007	25-Year
42	9.99128966300	118.90513770000	1.5	0.03	1.47	Lando	Nov. 2007	25-Year
43	9.99128300000	118.88369000000	0.31	0.39	-0.08	Lando	Nov. 2007	25-Year
44	9.99117273200	118.86415010000	0	0.45	-0.45			25-Year
45	9.99164081100	118.87399260000	0	0.21	-0.21			25-Year
46	9.99190613400	118.86397240000	0	0.71	-0.71			25-Year
47	9.99264099300	118.87579800000	0	0.03	-0.03			25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
48	9.99276428200	118.87527940000	0	0.03	-0.03			25-Year
49	9.99291117400	118.87728850000	0	0.03	-0.03			25-Year
50	9.99338200000	118.89965000000	0.95	0.03	0.92	Yolanda	Nov. 2013	25-Year
51	9.99327740500	118.87765550000	0	0.04	-0.04			25-Year
52	9.99358300000	118.89855000000	0.48	0.05	0.43	Norving	1997	25-Year
53	9.99322656200	118.86357740000	0	1.01	-1.01			25-Year
54	9.99360471600	118.88123280000	0	0.84	-0.84			25-Year
55	9.99375200000	118.87966000000	0.07	0.54	-0.47	Rainfall		25-Year
56	9.99423700000	118.90062000000	0.93	0.03	0.9	Yolanda	Nov. 2013	25-Year
57	9.99382432400	118.86345360000	0	0.64	-0.64			25-Year
58	9.99432500000	118.89745000000	0.65	0.11	0.54	Pepang	1995	25-Year
59	9.99439900000	118.90080000000	0.7	0.43	0.27	Yolanda	Nov. 2013	25-Year
60	9.99440500000	118.90003000000	0.49	0.16	0.33		1995	25-Year
61	9.99476772800	118.89922440000	0	0.03	-0.03			25-Year
62	9.99433333300	118.86312380000	0	0.71	-0.71			25-Year
63	9.99495290000	118.90555000000	0.31	0.12	0.19	Norming	1994	25-Year
64	9.99509679800	118.89760790000	0	0.03	-0.03			25-Year
65	9.99522958100	118.89927310000	0	0.58	-0.58			25-Year
66	9.99526249600	118.89265920000	0	1.99	-1.99			25-Year
67	9.99535032500	118.89287510000	0	1.98	-1.98			25-Year
68	9.99553013400	118.89861870000	0	0.56	-0.56			25-Year
69	9.99570490000	118.90817000000	1.05	0.03	1.02	Norming	1994	25-Year
70	9.99514727700	118.86252560000	0	0.11	-0.11			25-Year
71	9.99560890200	118.89406440000	0	0.34	-0.34			25-Year
72	9.99570467700	118.89765360000	0	0.03	-0.03			25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
73	9.99567602100	118.89422970000	0	0.03	-0.03			25-Year
74	9.99572524800	118.89449410000	0	0.03	-0.03			25-Year
75	9.99543943200	118.86259490000	0	0.22	-0.22			25-Year
76	9.99584832900	118.89521500000	0	0.09	-0.09			25-Year
77	9.99587085500	118.89506750000	0	0.03	-0.03			25-Year
78	9.99588900000	118.89644000000	0	0.32	-0.32			25-Year
79	9.99592198800	118.89616350000	0	1.16	-1.16			25-Year
80	9.99594736800	118.89596470000	0	0.09	-0.09			25-Year
81	9.99618220200	118.89518000000	0	1.57	-1.57			25-Year
82	9.99622436200	118.89588740000	0	0.78	-0.78			25-Year
83	9.99623289500	118.89571110000	0	1.06	-1.06			25-Year
84	9.996417533	118.8952239	0	1.42	-1.42			25-Year
85	9.996097662	118.8619826	0	0.28	-0.28			25-Year
86	9.996535454	118.8958088	0	0.75	-0.75			25-Year
87	9.9967351	118.90976	0.31	0.06	0.25	Lando	Oct. 2015	25-Year
88	9.9973976	118.91037	0.5	0.03	0.47	Lando	Oct. 2015	25-Year
89	9.9985699	118.91086	0.5	0.06	0.44	Lando	Oct. 2015	25-Year
90	9.998362871	118.8625432	0	0.07	-0.07			25-Year
91	9.9992313	118.91069	1.12	0.09	1.03	Lando	Oct. 2015	25-Year
92	9.9993645	118.91117	1.86	0.11	1.75			25-Year
93	9.999522	118.89829	0.4	1.72	-1.32	Yolanda	Nov. 2013	25-Year
94	9.999655207	118.898759	0	1.7	-1.7			25-Year
95	9.999705	118.89906	0.4	1.34	-0.94	Yolanda	Nov. 2013	25-Year
96	9.999282996	118.8621804	0	0.1	-0.1			25-Year
97	9.999926874	118.8982466	0	0.9	-0.9			25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
98	9.999993069	118.8952531	0	0.03	-0.03			25-Year
99	10.00007606	118.8983229	0	0.97	-0.97			25-Year
100	10.000124	118.89779	0.49	0.04	0.45	Lando	Nov. 2007	25-Year
101	10.00018229	118.8992155	0	0.63	-0.63			25-Year
102	10.000283	118.89857	0	1	-1			25-Year
103	10.00029829	118.8984304	0	0.98	-0.98			25-Year
104	10.00046784	118.8987231	0	0.97	-0.97			25-Year
105	10.00045227	118.8970401	0	0.07	-0.07			25-Year
106	10.000472	118.89614	0	0.11	-0.11			25-Year
107	10.000518	118.89984	0.83	2.17	-1.34	Yolanda	Nov. 2013	25-Year
108	10.00056297	118.8977533	0	0.06	-0.06			25-Year
109	10.00065161	118.8965731	0	0.07	-0.07			25-Year
110	10.000668	118.89722	0	0.12	-0.12			25-Year
111	10.00070194	118.8964566	0	0.16	-0.16			25-Year
112	10.00075512	118.8979309	0	0.14	-0.14			25-Year
113	10.00092	118.91123	0.8	0.04	0.76	Norming	1994	25-Year
114	10.00081498	118.897719	0	0.13	-0.13			25-Year
115	10.00088924	118.8961388	0	0.11	-0.11			25-Year
116	10.001146	118.91295	0.2	0.05	0.15			25-Year
117	10.00099007	118.8990049	0	0.85	-0.85			25-Year
118	10.001067	118.89467	0.82	0.36	0.46	Yolanda	Nov. 2013	25-Year
119	10.0010907	118.8955538	0	0.03	-0.03			25-Year
120	10.001133	118.89878	1.05	0.85	0.2		Oct. 2005	25-Year
121	10.00117533	118.8962354	0	0.09	-0.09			25-Year
122	10.00121908	118.8939127	0	0.69	-0.69			25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
123	10.00127941	118.8950939	0	0.21	-0.21			25-Year
124	10.00131423	118.897718	0	0.32	-0.32			25-Year
125	10.00132656	118.8982565	0	0.03	-0.03			25-Year
126	10.00144772	118.8975671	0	0.03	-0.03			25-Year
127	10.00146711	118.8989668	0	0.82	-0.82			25-Year
128	10.00151206	118.8981076	0	0.53	-0.53			25-Year
129	10.001546	118.89932	0.34	1.7	-1.36	Yolanda	Nov. 2013	25-Year
130	10.00155838	118.8977876	0	0.03	-0.03			25-Year
131	10.00165802	118.8990225	0	0.86	-0.86			25-Year
132	10.001658	118.89388	0	0.84	-0.84			25-Year
133	10.00172703	118.8988633	0	0.3	-0.3			25-Year
134	10.001799	118.8986	0	0.09	-0.09			25-Year
135	10.00191297	118.8984332	0	0.31	-0.31			25-Year
136	10.00219917	118.8996392	0	1.99	-1.99			25-Year
137	10.002374	118.89966	0.57	2.46	-1.89	Yolanda	Nov. 2013	25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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