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

LiDAR Surveys and Flood Mapping of Pinacanauan de Ilagan River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Isabela State University (ISU)

APRIL 2017

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

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

E.C. Paringit, and J.P. Floresca, (Eds.). (2017), LiDAR Surveys and Flood Mapping Report of Pinacanauan de Ilagan River, in Enrico C. Paringit, (Ed.), Flood Hazard Mapping of the Philippines using LIDAR, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry – 371pp

For questions/queries regarding this report, contact:

Dr. Januel P. Floresca
Project Leader, PHIL-LIDAR 1 Program
Isabela State University
Echague, Philippines 3309
januelpf@yahoo.com.ph

Enrico C. Paringit, Dr. Eng.
Program Leader, PHIL-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

National Library of the Philippines
ISBN: 978-621-430-040-2

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

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

Dr. Januel P. Floresca and Enrico C. Paringit, Dr. Eng.

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 in 2014 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 methods applied in this report are thoroughly described in a separate publication entitled “FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et. al. 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Isabela State University (ISU). ISU 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 10 river basins in the Cagayan Valley Region. The university is located in Echague in the province of Isabela.

1.2 Overview of the Pinacanauan de Ilagan River Basin

Pinacanauan de Ilagan River Basin (PIRB) is located on the central portion of the province of Isabela. Majority, it consists of two municipalities; San Mariano and Ilagan. Its headwaters are from San Mariano, because of its natural mountainous parts, and it drains to Ilagan where the outlet is located, it is partially covered by Palanan and Benito Soliven. PIRB is a tributary of Cagayan River. It is surrounded by Divilacan, Tumauini, and Delfin Albano on the north; Palanan, and the Pacific Ocean on the east; Quirino, Gamu, Naguilian, Cauayan City, and Angadanan on the west; and San Guillermo, and Dinapigue on the south. Its outlet is located in Ilagan which is approximately 397 kilometres from Metro Manila.

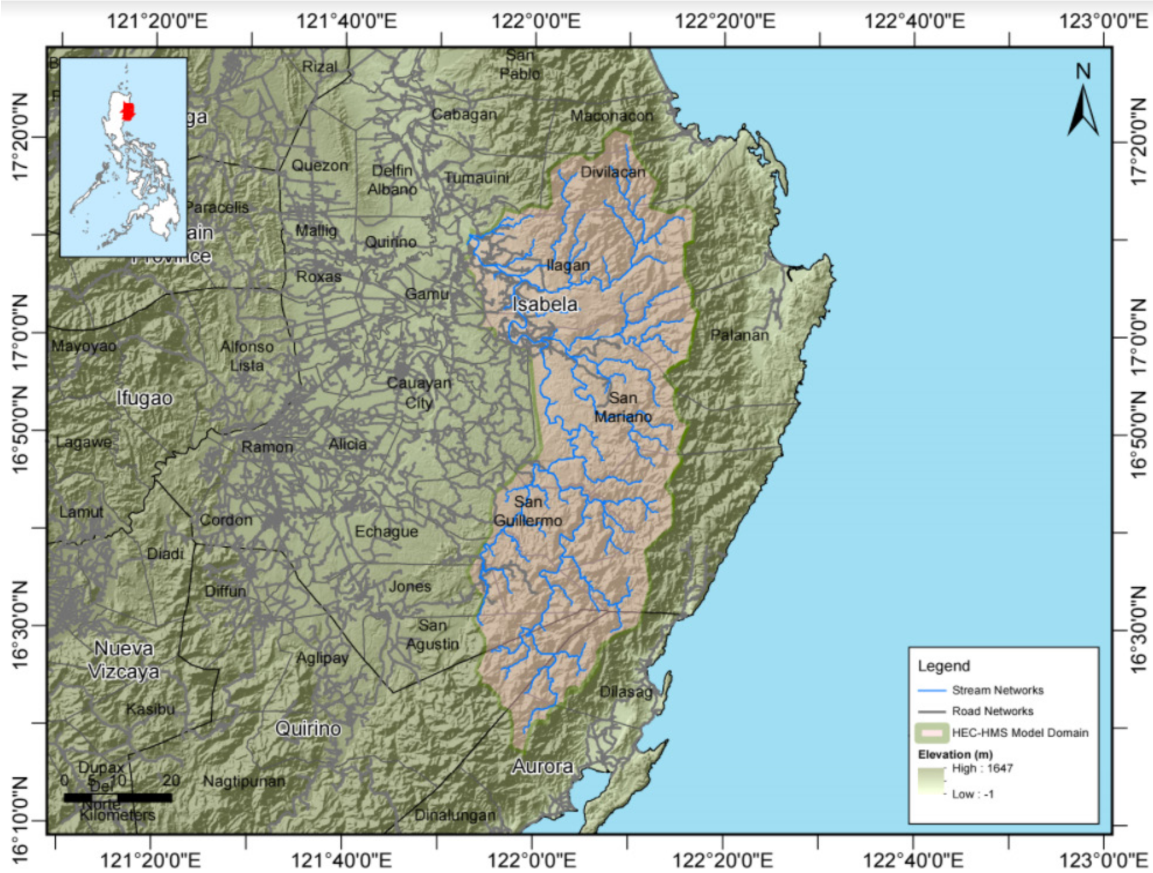


Figure 1. Map of Pinacanauan de Ilagan River Basin (in brown).

Pinacanauan de Ilagan River Basin has two types of climate: Type III and Type IV. Eastern part (mountainous part and the coastal area) falls under Type IV where this type has a more or less evenly distributed rainfall throughout the year. In this type of climate, seasons are not very pronounced; relatively dry from December to April and wet during the rest of the year. Heavy precipitations generally occur from June to November during the southwest monsoon season with October having the heaviest precipitation. The western part, where most of the built-up areas are concentrated, has the third type of climate. These areas experience dry and wet seasons that are not very pronounced. It is relatively dry during the first half of the year and relatively wet during the second half of the year.

Within Pinacanauan de Ilagan River Basin, there are 2 protected areas: The Fuyot Spring and National Park and the Northern Sierra Madre Natural Park. The Fuyot Spring and National Park (FSNP) through the Proclamation No. 327, it was officially established on October 9, 1938 with an approximate area of 819 hectares that extends from the City of Ilagan to the municipality of Tumauini. It is located in the Barangay Santa Victoria and within the rolling hills of Sierra Madre Mountain. The park is known to spelunkers, mountaineers, hikers, and birdwatchers that visit the place and explore its aviary, caves, waterfalls, and peculiar rock formations. The Northern Sierra Madre Natural Park (NSMNP) is the largest protected area in the country and considered as one of the ten (10) hotspots in the world in terms of biodiversity. It covers the midsection of the Sierra Madre Mountain Range and it is within the Sierra Madre Biogeographic Zone which lies on the eastern side of Luzon. It consists of a total area of 359,486 hectares; 287, 861 hectares is land area, and 71,652 hectares of coastline area. It physically extends to the Isabela municipalities of Palanan, Divilacan and Maconacon; including parts of San Mariano, Dinapigue, San Pablo, Cabagan, Tumauini, and the City of Ilagan.

The most devastating typhoons/storms in the history of PIRB are: Typhoon Harurot (internationally known as Imbudo), it happened on July 2003. It caused widespread flooding and power outages in Cagayan Valley for weeks. Nationwide, the storm damaged or destroyed 62,314 houses, causing P4.7 billion (PHP, $86 million USD) in damage, mostly in the Cagayan Valley. There were also 64 deaths in the country. Next is Typhoon Lando (internationally known as Koppu) which happened on Octorber 2015. The storm subsequently made landfall at this strength near Casiguran, Philippines. The storm caused tremendous structural damage in coastal provinces, with thousands of structures damaged or destroyed. Prolonged, heavy rains—peaking at 1,077.8 mm (42.43 in) in Baguio—exacerbated the storm's effects and resulted in widespread flooding. At least 58 people were killed across the country and more than 100,000 others were displaced. Preliminary damage totals, primarily from agriculture, amount to 11 billion pesos (US$235.8 million). Third is Typhoon Lawin (internationally known as Haima) that placed Cagayan, Isabela, Kalinga, Apayao, Northern Abra and Ilocos Norte in signal number 5 last October 2016. The damages caused by by supertyphoon "Lawin" in four affected regions at over P657 million-P581.9 million for infrastructure and P75.8 million for agriculture. The National Disaster Risk Reduction and Management Council (NDRRMC) also said that a total of 29,533 families or 116,826 persons were evacuated in Ilocos Region, Cagayan Valley, Central Luzon and Cordillera Administrative Region (CAR).

http://reliefweb.int/report/philippines/act-alert-12003-philippines-12003-super-typhoon-hits-philippines

http://scinet.dost.gov.ph/union/ShowSearchResult.php?s=2&f=&p=&x=&page=&sid=1&id=Typhoon+harurot+0308+(Imbudo)&Mtype=REPORTS

http://newsinfo.inquirer.net/736370/latest-govt-report-places-lando-damage-at-p11b

http://newsinfo.inquirer.net/830036/typhoon-lawin-damage-p657m

CHAPTER 2: LIDAR DATA ACQUISITION OF THE PINACANAUAN DE ILAGAN FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Ms. Jasmine T. Alviar, Mr. Darryl M. Austria

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).

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Pinacanauan de Ilagan floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Pinacanauan de Ilagan Floodplain in Isabela province. These flight missions were planned for 14 lines and ran for at most four and a half hours (4.5) including take-off, landing and turning time using two sensors – the Gemini and the Pegasus (see Annex 1 for sensor specifications). The flight planning parameters for the LiDAR system are outlined in Table 1 and Table 2. Figure 2, on the other hand, shows the flight plan for Pinacanauan de Ilagan floodplain survey.

Table 1. Flight planning parameters for Gemini LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (Hz)	Scan Frequency (kHz)	Average Speed (kts)	Average Turn Around (Minutes)
BLK 9A	1000	30	40	100	50	130	5
BLK 9B	1000	30	40	100	50	130	5
BLK 9C	1000	30	40	100	50	130	5
CGYR A	1000	30	40	100	50	130	5
CGYR B	1000	30	40	100	50	130	5
CGYR C	1000	30	40	100	50	130	5
CGYR E	1000	30	40	100	50	130	5
CGYR F	1000	30	40	100	50	130	5
CGYR G	1000	30	40	100	50	130	5
CGYR H	1000	30	40	100	50	130	5
CAG 2A	1000	30	40	100	50	130	5
CAG 2B	1000	30	40	100	50	130	5
CAG 2C	1000	30	40	100	50	130	5
CAG 2E	1000	30	40	100	50	130	5
CAG 2G	1000	30	40	100	50	130	5
CAG 2H	1000	30	40	100	50	130	5
CAG 2J	1000	30	40	100	50	130	5

CAG AV	1000	30	40	100	50	130	5
CAG BV	1000	30	40	100	50	130	5
CAG CV	1000	30	40	100	50	130	5
PIN A	1000	30	40	100	50	130	5
PIN B	1000	30	40	100	50	130	5
PIN C	1000	30	40	100	50	130	5

Table 2. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
CAG 11D	1000	30	50	125	50	130	5
CAG 101B	1000	30	50	125	50	130	5
CAG 101C	1000	30	50	125	50	130	5
CAG 101D	1000	30	50	125	50	130	5

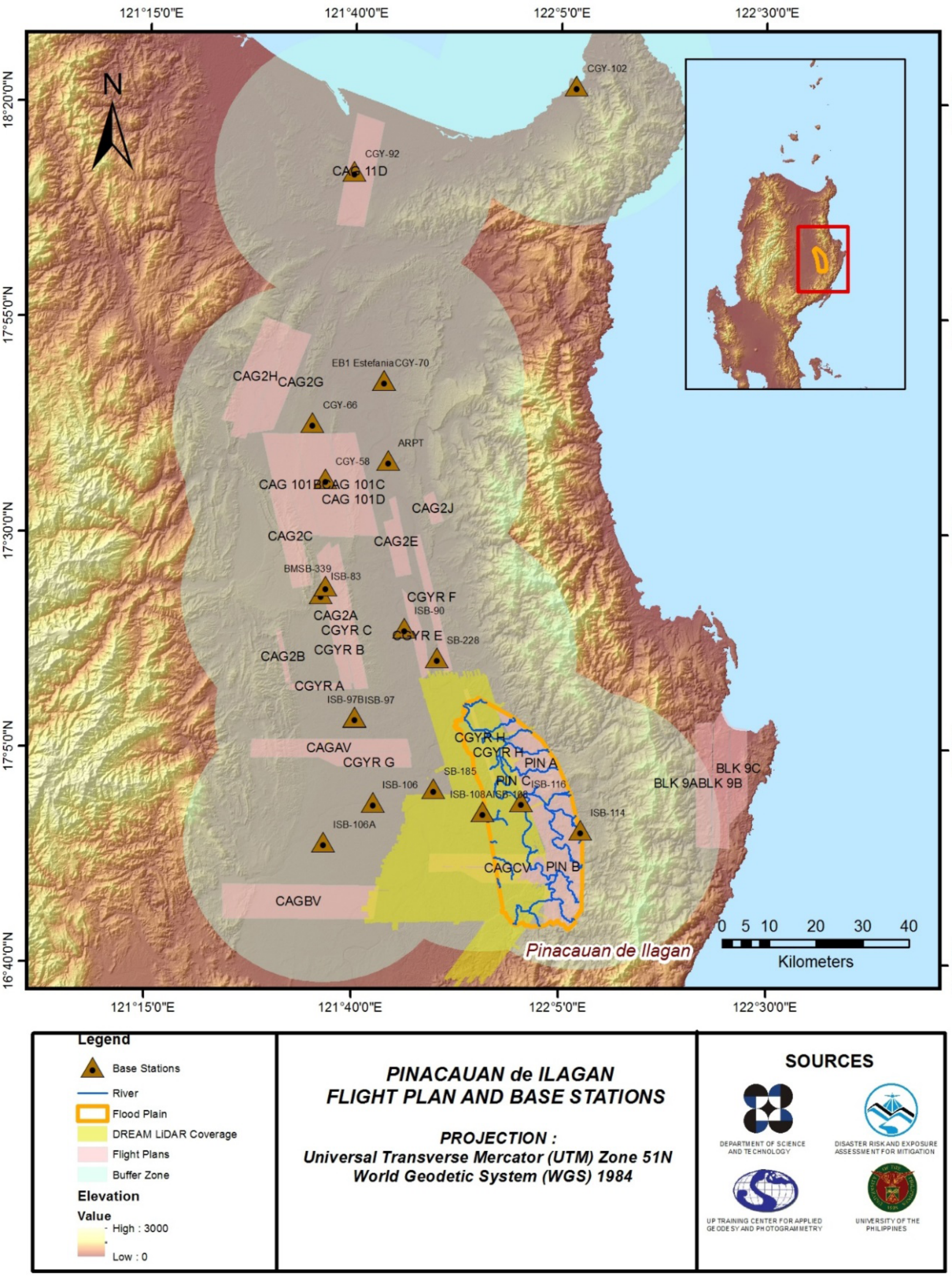


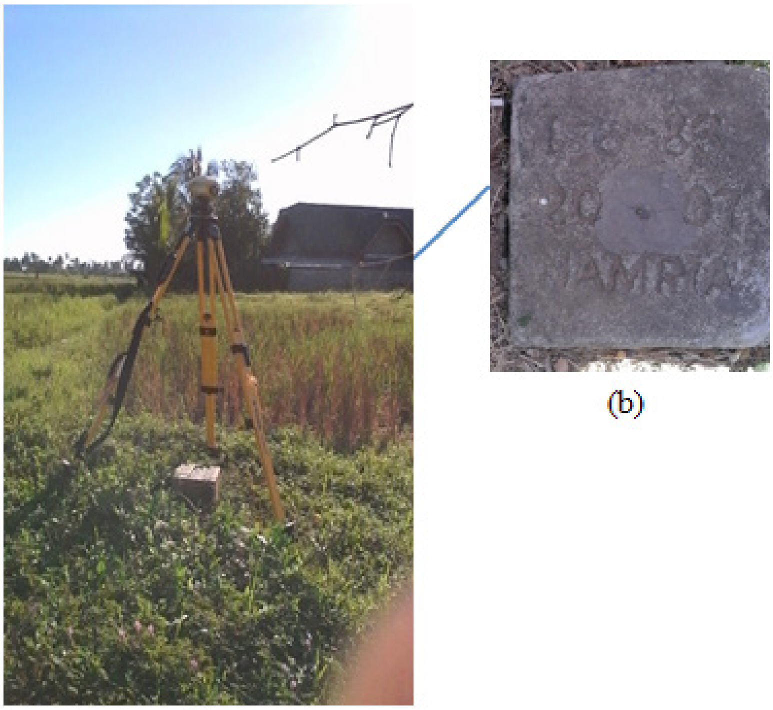
Figure 2. Flight plans and base stations used for Pinacanauan de Ilagan floodplain survey.

2.2 Ground Base Stations

The project team was able to recover twelve (12) NAMRIA horizontal reference points, ISB-83, ISB-90, ISB-97, ISB-106, ISB-108, ISB-114, ISB-116, CGY-58, CGY-66, CGY-70, CGY-92, and CGY-102 which are of second (2^{nd}) order accuracy. NAMRIA vertical reference points SB-185, SB-228, and BMSB-339, were also recovered. The project team also established four (4) ground control points EB1 Estefania, ARPT, ISB-106A, and ISB-108A.

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 from September 4 to 30, 2015, and April 27 to May 18, 2016. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852, TRIMBLE SPS 985, and TRIMBLE SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Pinacanauan de Ilagan floodplain are shown in Figure 2.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Pinacanauan de Ilagan Floodplain LiDAR Survey. Figure 3 to Figure 8 show the recovered NAMRIA reference points within the area of the floodplain, while Table 2 to Table 8 show the details about the following NAMRIA control stations and established points. Table 9, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.



(a) (b)

Figure 3. GPS set-up over ISB-83 (a) located along the National Highway via Quezon, right side direction to Tuguegarao, Cagayan, and NAMRIA reference point ISB-83 (b) as recovered by field team.

Table 3. Details of the recovered NAMRIA horizontal control point ISB-83 used as base station for the LiDAR Acquisition.

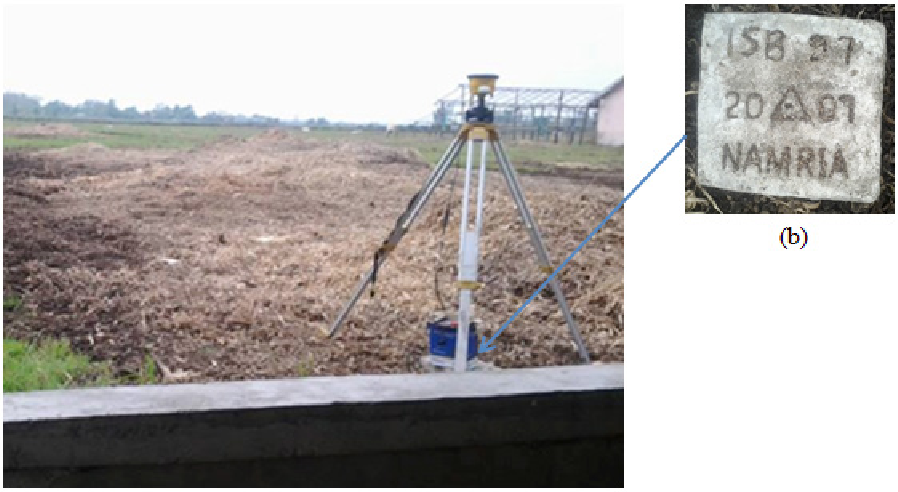
Station Name	ISB-83	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	17° 23’ 6.02040” North
	Longitude	121° 36’ 0.80264” East
	Ellipsoidal Height	131.99400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	563781.983 meters
	Northing	1922803.531meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	17° 23’ 0.02197” North
	Longitude	121° 36’ 5.45806” East
	Ellipsoidal Height	168.56500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	351296.42 meters
	Northing	1922573.55 meters

(a) (b)

Figure 4. GPS set-up over ISB-90 (a) located beside the welcome sign of Barangay Villa Luz, municipality of Delfin Albano, Isabela, and NAMRIA reference point ISB-90 (b) as recovered by field team.

Table 4. Details of the recovered NAMRIA horizontal control point ISB-90 used as base station for the LiDAR data acquisition.

Station Name	ISB-90	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	17° 19’ 10.25017” North
	Longitude	121° 46’ 09.69589” East
	Ellipsoidal Height	35.367 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	581784.952 meters
	Northing	1915619.76 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	17° 19’ 04.27901” North
	Longitude	121° 46’ 14.35585” East
	Ellipsoidal Height	72.554 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	369220.50 meters
	Northing	1915204.01 meters



(a) (b)

Figure 5. GPS set-up over ISB-97 (a) located beside a waiting shed in a vacant lot in Villa Bulusan, Mallig, Isabela, and NAMRIA reference point ISB-97 (b) as recovered by field team.

Table 5. Details of the recovered NAMRIA horizontal control point ISB-97 used as base station for the LiDAR data acquisition.

Station Name	ISB-97	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	17° 08’ 44.15866” North
	Longitude	121° 40’ 11.01238” East
	Ellipsoidal Height	62.259 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	571259.789 meters
	Northing	1896333.662 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	17° 08’ 38.21759” North
	Longitude	121° 40’ 15.68747” East
	Ellipsoidal Height	99.759 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	358498.51 meters
	Northing	1896031.50 meters

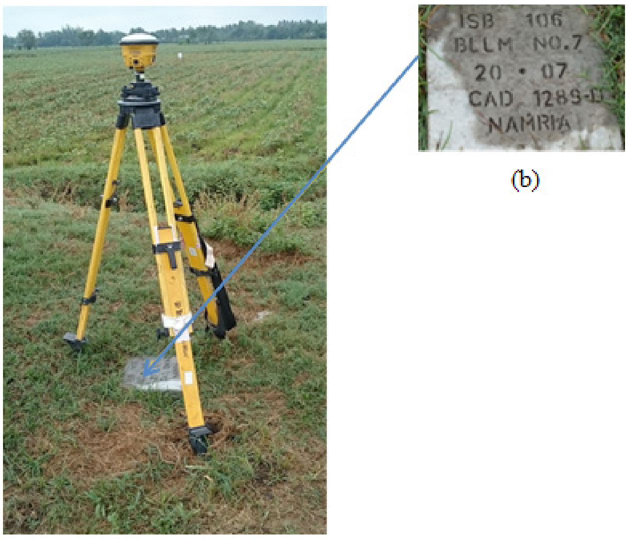
(a)

(b)

Figure 6. GPS set-up over ISB-106 (a) located beside the barangay boundary marker of Pulay, municipality of Luna, Isabela, and NAMRIA reference point ISB-106 (b) as recovered by field team.

Table 6. Details of the recovered NAMRIA horizontal control point ISB-106 used as base station for the LiDAR data acquisition.

Station Name	ISB-106	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	16° 58’ 51.81297” North
	Longitude	121° 42’ 26.76398 ” East
	Ellipsoidal Height	55.38500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	575338.197 meters
	Northing	1878138.936 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	16° 58’ 45.91140” North
	Longitude	121° 42’ 31.45264” East
	Ellipsoidal Height	93.49500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	362389.64 meters
	Northing	1877799.15 meters



(b)

(a)

Figure 7. GPS set-up over ISB-108 (a) located at the corner of the basketball court beside the barangay hall inRizal, municipality of Naguilian, Isabela, and NAMRIA reference point ISB-108 (b) as recovered by field team.

Table 7. Details of the recovered NAMRIA horizontal control point ISB-108 used as base station for the LiDAR data acquisition.

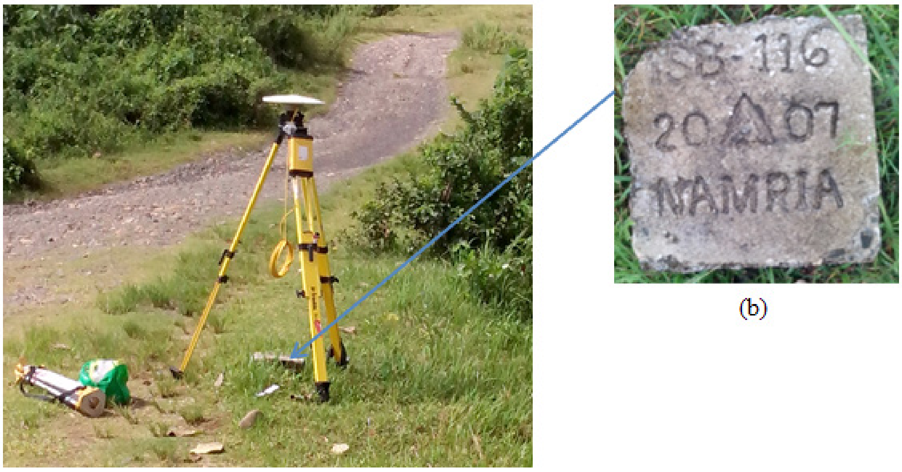
Station Name	ISB-108	
Order of Accuracy	2^{nd}	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	16° 57’ 50.44363” North
	Longitude	121° 55’ 45.03953” East
	Ellipsoidal Height	79.16500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	598963.184 meters
	Northing	1876350.862 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	16° 57’ 44.56307” North
	Longitude	121° 55’ 49.72824” East
	Ellipsoidal Height	117.86300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	385989.32 meters
	Northing	1875770.92 meters

(a) (b)

Figure 8. GPS set-up over ISB-114 (a) in front of Barangay San Jose Day Care Center in San Mariano, Isabela, and NAMRIA reference point ISB-114 (b) as recovered by field team.

Table 8. Details of the recovered NAMRIA horizontal control point ISB-114 used as base station for the LiDAR data acquisition.

Station Name	ISB-114	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	16° 55’ 46.73944” North
	Longitude	122° 7’ 31.95097” East
	Ellipsoidal Height	156.78500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	406848.262 meters
	Northing	1872521.293 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	16° 55’ 40.88179” North
	Longitude	122° 7’ 36.64130” East
	Ellipsoidal Height	196.06400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	406,880.87 meters
	Northing	1,871,865.88 meters



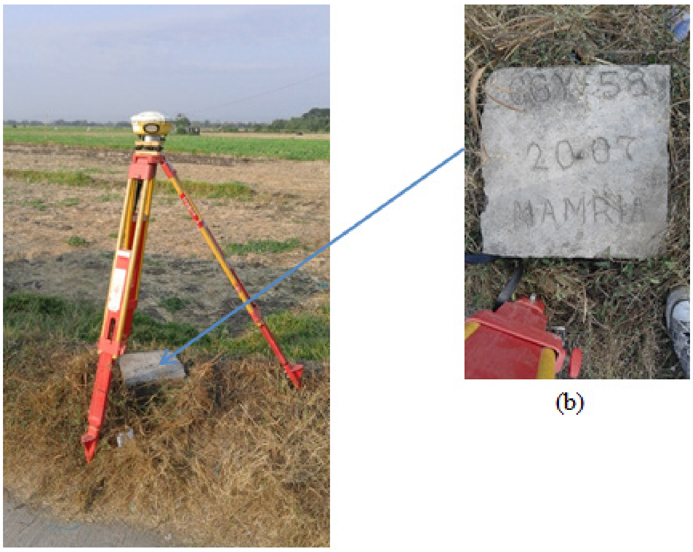
(b)

(a)

Figure 9. GPS set-up over ISB-116 (a) located beside a waiting shed in a vacant lot in Villa Bulusan, Mallig, Isabela, and NAMRIA reference point ISB-116 (b) as recovered by field team.

Table 9. Details of the recovered NAMRIA horizontal control point ISB-116 used as base station for the LiDAR data acquisition.

Station Name	ISB-116	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	16°59’4.21767” North
	Longitude	122°0’23.58158” East
	Ellipsoidal Height	97.639 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	5394202.384 meters
	Northing	1878652.343 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	16° 58’58.33861” North
	Longitude	122° 0’ 28.26808” East
	Ellipsoidal Height	136.459 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	394202.384 meters
	Northing	1878652.343 meters



(a) (b)

Figure 10. GPS set-up over CGY-58 (a) located 15 m. E of the junction of the road leading to barangay. Karilukud, and is situated 10 meters southeast of Barangay. Ubong welcome monument, and NAMRIA reference point CGY-58 (b) as recovered by field team.

Table 10. Details of the recovered NAMRIA horizontal control point CGY-58 used as base station for the LiDAR Acquisition.

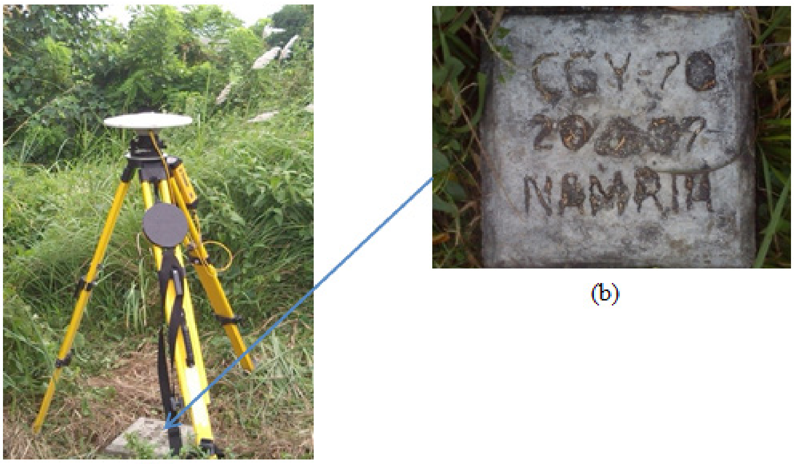
Station Name	CGY-58	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17° 36’ 27.61645” 121° 36’ 25.76184” 40.716 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	564440.235 m 1947447.881 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17° 36’ 21.57004” 121° 36’ 30.39868” 76.590 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	352213.18 m 1947206.45 m

(a) (b)

Figure 11. GPS set-up over CGY-66 (a) located within the compound of Warat barangay. hall, along G. Cusupig St., approximately 15 meters south of the waiting shed, and NAMRIA reference point CGY-66 (b) as recovered by field team.

Table 11. Details of the recovered NAMRIA horizontal control point CGY-66 used as base station for the LiDAR Acquisition.

Station Name	CGY-66	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	17° 42’ 56.12254”
	Longitude	121° 34’ 50.13936”
	Ellipsoidal Height	51.902 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	561584.309 m 1959382.34 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	17° 42’ 50.05073”
	Longitude	121° 34’ 54.76735”
	Ellipsoidal Height	87.364 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	349484.16 m 1959169.01 m



(a) (b)

Figure 12. GPS set-up over CGY-70 (a) located inside Estefania elementary school, and situated 1 meter east of the northeast corner of the basketball court, and NAMRIA reference point CGY-70 (b) as recovered by field team.

Table 12. Details of the recovered NAMRIA horizontal control point CGY-70 used as base station for the LiDAR Acquisition.

Station Name	CGY-70	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	17° 47' 54.79038"
	Longitude	121° 43' 31.26837"
	Ellipsoidal Height	26.859 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	576904.118 m
	Northing	1968617.425 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	17° 47' 48.71170"
	Longitude	121° 43' 35.88859"
	Ellipsoidal Height	62.400 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	364899.00 m
	Northing	1968239.03 m

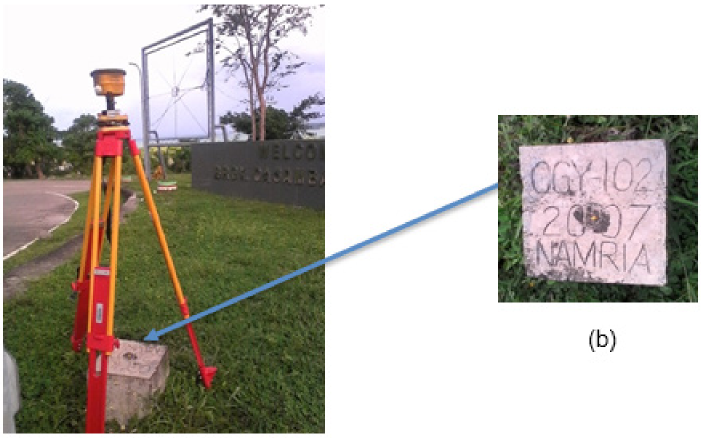
(b)

(a)

Figure 13. GPS set-up over CGY-92 located inside the Lal-lo National High School, about five (5) meters west of the flagpole (a), and CGY-92 (b) as recovered by the field team.

Table 13. Details of the recovered NAMRIA horizontal control point CGY-92 used as base station for the LiDAR acquisition.

Station Name	CGY-92	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	18° 12’ 11.42361”North 121° 39’ 42.14392”East 14.47400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	569996.115 meters 2013373.807 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18° 12’ 5.25321” North 21° 39’ 46.73084” East 48.54000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	358475.41meters 2013059.26 meters



(b)

(a)

Figure 14. GPS set-up over CGY-102 located about two (2) meters from the south corner of the triangular island at the intersection of the national highway and the road to Port Irene in Santa Ana, Cagayan, and CGY-102 (b) as recovered by the field team.

Table 14. Details of the recovered NAMRIA horizontal control point CGY-102 used as base station for the LiDAR acquisition.

Station Name	CGY-102	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	18°22’15.98573” North
	Longitude	122°6’41.74346” East
	Ellipsoidal Height	22.60800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	617476.569 meters
	Northing	2032192.366 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	18°22’9.81367” North
	Longitude	122°6’46.31361” East
	Ellipsoidal Height	57.19500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	406145.45 meters
	Northing	203135134 meters

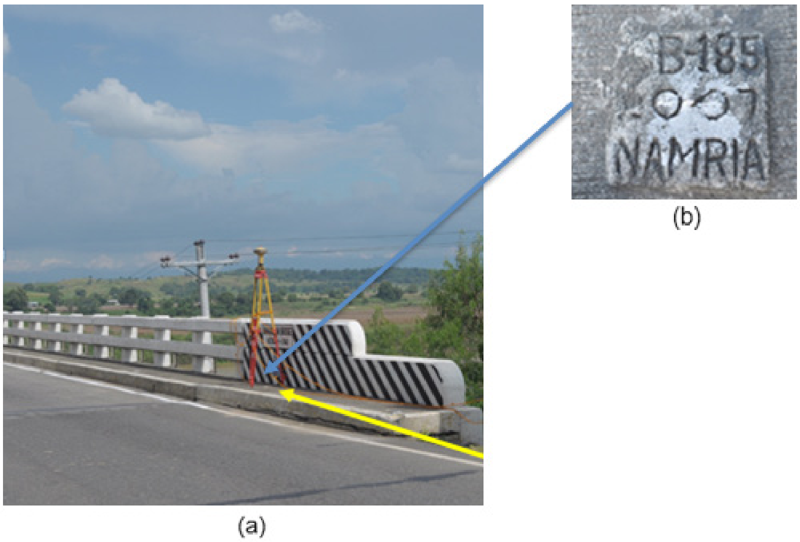
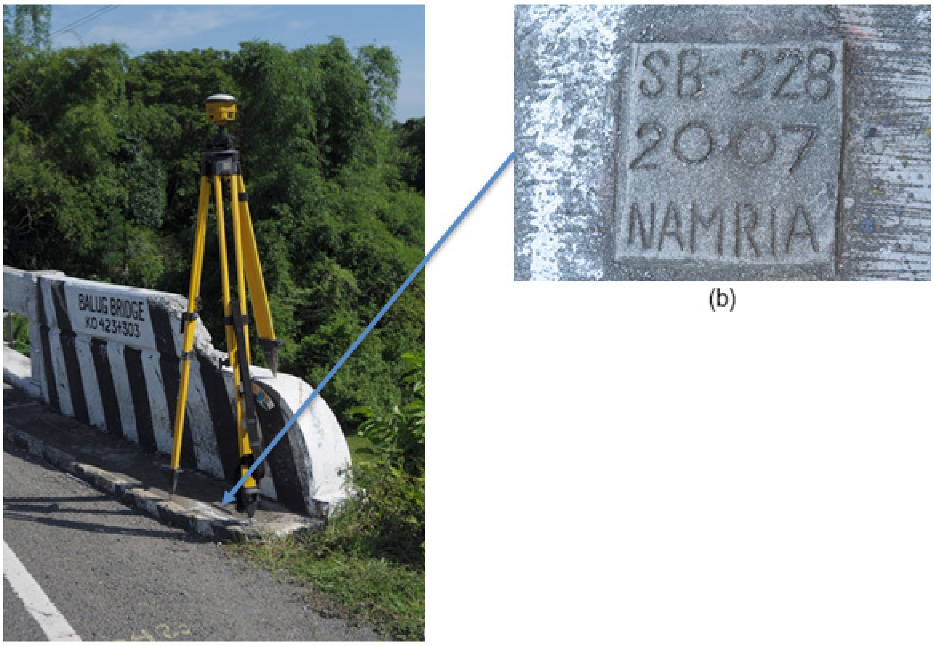


Figure 15. GPS set-up over SB-185 along the national road in Barangay Pallatao, municipality of Naguilian, Isabela, and SB-185 (b) as recovered by the field team.

Table 15. Details of the recovered benchmark SB-185 with reprocessed coordinates.

Station Name	SB-185	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	17°00’28.94757” North
	Longitude	121°49’47.70616” East
	Ellipsoidal Height	57.023 m meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	17° 00’ 23.04956” North
	Longitude	121° 49’ 52.39181” East
	Ellipsoidal Height	95.344 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	375449.061 meters
	Northing	1880702.502 meters

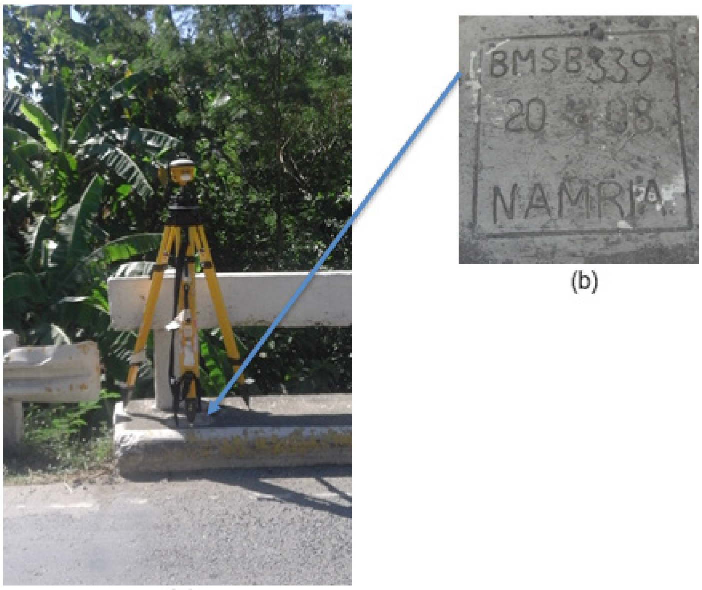


(a) (b)

Figure 16. GPS set-up over SB-228 located at Balug Bridge in Tumauini, Isabela, and SB-228 (b) as recovered by the field team.

Table 16. Details of the recovered benchmark SB-228 with reprocessed coordinates.

Station Name	SB-228	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	17° 15' 43.47469" North
	Longitude	121° 50' 04.02139" East
	Ellipsoidal Height	40.858 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	17° 15' 37.52114" North
	Longitude	121° 50' 08.68575" East
	Ellipsoidal Height	78.384 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	376100.011 meters
	Northing	1908805.967 meters



(a) (b)

Figure 17. GPS set-up over BMSB-339 (a) on a bridge near ISB-83, and NAMRIA vertical reference point BMSB-339 (b) as recovered by field team.

Table 17. Details of the recovered benchmark BMSB-339 used as base station for the LiDAR Acquisition.

Station Name	BMSB-339	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	17° 23’ 59.75074”
	Longitude	121° 36’ 35.34664”
	Ellipsoidal Height	113.774 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting	352327.942 m
	Northing	1924217.595 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	17° 23’ 53.74978”
	Longitude	121° 36’ 40.00077”
	Ellipsoidal Height	150.320 m

Table 18. Details of the established ground control point ARPT.

Station Name	ARPT	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	17° 38’ 35.74536” North
	Longitude	121° 44’ 2.31321” East
	Ellipsoidal Height	27.155 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	17° 38’ 29.70094” North
	Longitude	121° 44’ 6.94633” East
	Ellipsoidal Height	63.218 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	365697.564 meters
	Northing	1951050.094 meters

Table 19. Details of the established ground control point ISB-106A.

Station Name	ISB-106A	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	16° 54’ 11.01828” North 121° 36’ 31.05845” East 78.760 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	16° 54’ 05.12629” North 121° 36’ 35.75422” East 116.877 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	351807.600 meters 1869240.936 meters

Table 20. Details of the established ground control point ISB-108A.

Station Name	ISB-108A	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	16° 57’ 50.14045” North 121° 55’ 45.05570” East 79.099 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	16° 57’ 44.25991” North 121° 55’ 49.74442” East 117.797 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	385989.753 meters 1875761.598 meters

Table 21. Details of the established ground control point EB1-Estefania.

Station Name	EB1-Estefania	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17° 47' 54.71705" North 121° 43' 31.09772" East 13.103 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17° 47' 48.63836" North 121° 43' 35.71795" East 48.643 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	364893.967 meters 1968236.814 meters

Table 22. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 18, 2016	4027G	2PINV139A	ISB-108, ISB-108A
May 17, 2016	4025G	2CAGBV138B	ISB-106, ISB-106A
May 17, 2016	4023G	2CAGABV138A	ISB-106, ISB-106A
May 16, 2016	4021G	2CAGCV137B	ISB-108, ISB-108A
May 16, 2016	4019G	2PINC137A	ISB-108, ISB-108A
May 15, 2016	4017G	2PINA136B	ISB-108, ISB-108A
May 15, 2016	4015G	2PINB136A	ISB-108, ISB-108A
May 7, 2016	4005G	2CAG2ABC128A	BMSB-339, ISB-83
May 1, 2016	3983G	2CAG2CJ122B	ARPT, CGY-70
April 30, 2016	3979G	2CAG2E121B	CGY-58, CGY-66
April 27, 2016	3965G	2CAG2DGH118A	ARPT, CGY-66
November 30, 2015	2914P	1BLK3A334A	CGY-70, CGY-102, CGY-92, EB1-Estefania
November 26, 2015	2898P	1BLK2S330A	CGY-70, CGY-102
November 25, 2015	2894P	1BLK2S329A	CGY-70, EB1-Estefania
September 15, 2015	2732G	2CGYRC258B	SB-228, ISB-90
September 15, 2015	2730G	2BLK9CGYRFG258A	SB-228, ISB-90
September 14, 2015	2728G	2CGYRG257B	SB-228, ISB-90
September 14, 2015	2726G	2CGYRABE257A	SB-228, ISB-90
September 9, 2015	2706G	2BLK9B252A	ISB-114, ISB-116

September 8, 2015	2702G	2BLK9AB251A	ISB-114, SB-185
September 7, 2015	2700G	2CGYRH250A	ISB-97, ISB-97B
September 6, 2015	2696G	2BLKCGYRH249B	ISB-116
September 5, 2015	2690G	2BLK9A248A	ISB-114, ISB-116
September 4, 2015	2686G	2BLK9C247A	ISB-114, ISB-116

2.3 Flight Missions

A total of thirty-four (34) missions were conducted to complete the LiDAR data acquisition in Pinacanauan de Ilagan floodplain. Ten (10) missions under the DREAM Program covered 43.52 square kilometers of the Pinacauan de Ilagan floodplain (see Table 23). Twenty-four (24) missions were conducted under the Phil-LiDAR1 Program for a total of 72 hours and 12 minutes (72+12) of flying time for RP-C9022 and RP-C9122 (See Annex 6). All missions were acquired using the Pegasus and Gemini LiDAR systems. All missions were acquired using both Gemini and Pegasus LiDAR systems. As shown below, the total area of actual coverage per mission and the corresponding flying hours are depicted in Table 24, while the actual parameters used during the LiDAR data acquisition are presented in Table 25.

Table 23. Flight missions under the DREAM Program which covered parts of Pinacanauan de Ilagan floodplain.

Flight Number	Mission Name	Area Surveyed within the Floodplain (km^2)
530P	1CAG171E260A	52.32
533P	1CAG171F261A	45.53
537P	1CAG171G262A	22.64
549P	1CAG171H265A	9.38
551P	1CAG171D265B	53.83
575P	1CAG171K271A	36.60
577P	1CAG171L272A	44.01
834G	2CAG171B340A	42.94
838G	2CAG171C341A	148.94
848G	2CAG171D344B	63.90

Table 24. Flight missions for LiDAR data acquisition in Pinacanauan de Ilagan 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**
May 18, 2016	4027G	381.38	50.40	46.01	4.39	0	2	21
May 17, 2016	4025G	240.76	112.74	0.0	112.74	0	2	34
May 17, 2016	4023G	130.16	246.39	0.0	246.39	0	3	51
May 16, 2016	4021G	134.71	122.80	52.21	70.59	0	2	10
May 16, 2016	4019G	68.08	195.42	180.68	14.74	0	3	34
May 15, 2016	4017G	119.46	113.61	104.68	8.93	0	3	15
May 15, 2016	4015G	193.84	216.13	197.28	18.85	0	4	20
May 7, 2016	4005G	207.32	221.05	0.0	221.05	0	4	5
May 1, 2016	3983G	111.80	76.14	0.0	76.14	0	1	51
April 30, 2016	3979G	49.65	74.80	0.0	74.80	0	1	28
April 27, 2016	3965G	272.73	268.19	0.0	268.19	0	4	35
November 30, 2015	2914P	266.1	190.79	0.0	190.79	54	1	51
November 26, 2015	2898P	123.67	133.89	0.0	133.89	405	1	28
November 25, 2015	2894P	320.26	156.07	0.0	156.07	587	4	35
September 15, 2015	2732G	88.99	201.73	0.0	201.73	273	1	59
September 15, 2015	2730G	180.63	133.39	0.0	133.39	479	3	47
September 14, 2015	2728G	58.05	73.06	0.0	73.06	342	2	11
September 14, 2015	2726G	83.70	114.88	0.0	114.88	434	3	23

September 9, 2015	2706G	102.26	67.70	0.0	67.70	227	2	17
September 8, 2015	2702G	195.35	167.19	0.0	167.19	625	3	59
September 7, 2015	2700G	20.18	77.02	53.30	23.72	324	2	59
September 6, 2015	2696G	20.18	42.89	36.71	6.18	0	3	23
September 5, 2015	2690G	93.09	88.85	0.0	88.85	129	2	17
September 4, 2015	2686G	67.62	91.54	0.0	91.54	250	3	59
TOTAL		3529.97	3236.67	670.87	2565.8	4129	72	12

Table 25. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
4027G	1000	30	40	125	50	130	5
4025G	1000	30	40	125	50	130	5
4023G	1000	30	40	125	50	130	5
4021G	1000	30	40	125	50	130	5
4019G	1000	30	40	125	50	130	5
4017G	1000	30	40	125	50	130	5
4015G	1000	30	40	125	50	130	5
4005G	1000	30	40	125	50	130	5
3983G	1000	30	40	125	50	130	5
3979G	1000	30	40	125	50	130	5
3965G	1000	30	40	125	50	130	5
2914P	1000	30	50	200	30	130	5
2898P	900	30	50	200	30	130	5
2894P	900	30	50	200	30	130	5
2732G	1000	30	40	125	50	130	5
2730G	1000	30	40	125	50	130	5
2728G	1000	30	40	125	50	130	5
2726G	1000	30	40	125	50	130	5

2706G	1000	30	40	125	50	130	5
2702G	1000	30	40	125	50	130	5
2700G	1000	30	40	125	50	130	5
2696G	1000	30	40	125	50	130	5
2690G	1000	30	40	125	50	130	5
2686G	1000	30	40	125	50	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Pinacanauan de Ilagan floodplain (See Annex 7). It is situated within the province of Isabela, with most of it situated within the municipality of San Mariano Sur. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 26. Figure 18, on the other hand, shows the actual coverage of the LiDAR acquisition for the Pinacanauan de Ilagan floodplain.

Table 26. List of municipalities and cities surveyed during Pinacanauan de Ilagan floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed (%)
Isabela	San Mariano	888.15	343.30	38.65
	Palanan	713.18	289.55	40.60
	Ilagan	1311.38	227.02	17.31
	Quezon	233.53	112.96	48.37
	Alicia	172.79	77.29	44.73
	Roxas	120.89	70.02	57.92
	Benito Soliven	290.80	66.25	22.78
	Tumauini	271.26	64.62	23.82
	Ramon	92.83	59.79	64.41
	Santa Maria	116.40	59.76	51.34
	Cabagan	340.26	59.20	17.40
	Cauayan City	276.04	50.82	18.41
	Burgos	74.27	41.59	56.00
	Santiago City	315.10	34.29	10.88
	Gamu	99.64	33.20	33.32
	Delfin Albano	192.53	33.12	17.20
	San Pablo	635.99	30.75	4.83
	Mallig	112.43	23.75	21.12
	San Manuel	82.84	13.73	16.57
	Santo Tomas	60.63	11.41	18.82
	Quirino	130.19	7.30	5.61
	San Guillermo	463.80	4.91	1.06
	San Isidro	58.74	3.48	5.92
	Dinapigue	756.06	3.12	0.41
Cagayan	Solana	238.48	140.15	58.77
	Enrile	161.25	126.20	78.26
	Lal-Lo	760.44	119.95	15.77
	Tuao	161.93	84.43	52.14
	Piat	153.74	37.62	24.47
	Santo Niño	437.82	31.83	7.27
	Camalaniugan	80.92	26.89	33.23
	Tuguegarao City	129.61	23.64	18.24
	Buguey	98.04	12.51	12.76
	Peñablanca	1213.01	8.03	0.66
	Aparri	254.03	7.67	3.02
	Gattaran	557.09	5.11	0.92
	Rizal	166.32	4.24	2.55
Apayao	Conner	775.14	10.42	1.34

Kalinga	Rizal	187.90	135.05	71.87
	Tabuk City	748.12	72.43	9.68
	Pinukpuk	477.11	34.75	7.28
Mountain Province	Paracelis	456.75	56.41	12.35
Ifugao	Alfonso Lista	458.47	20.62	4.50

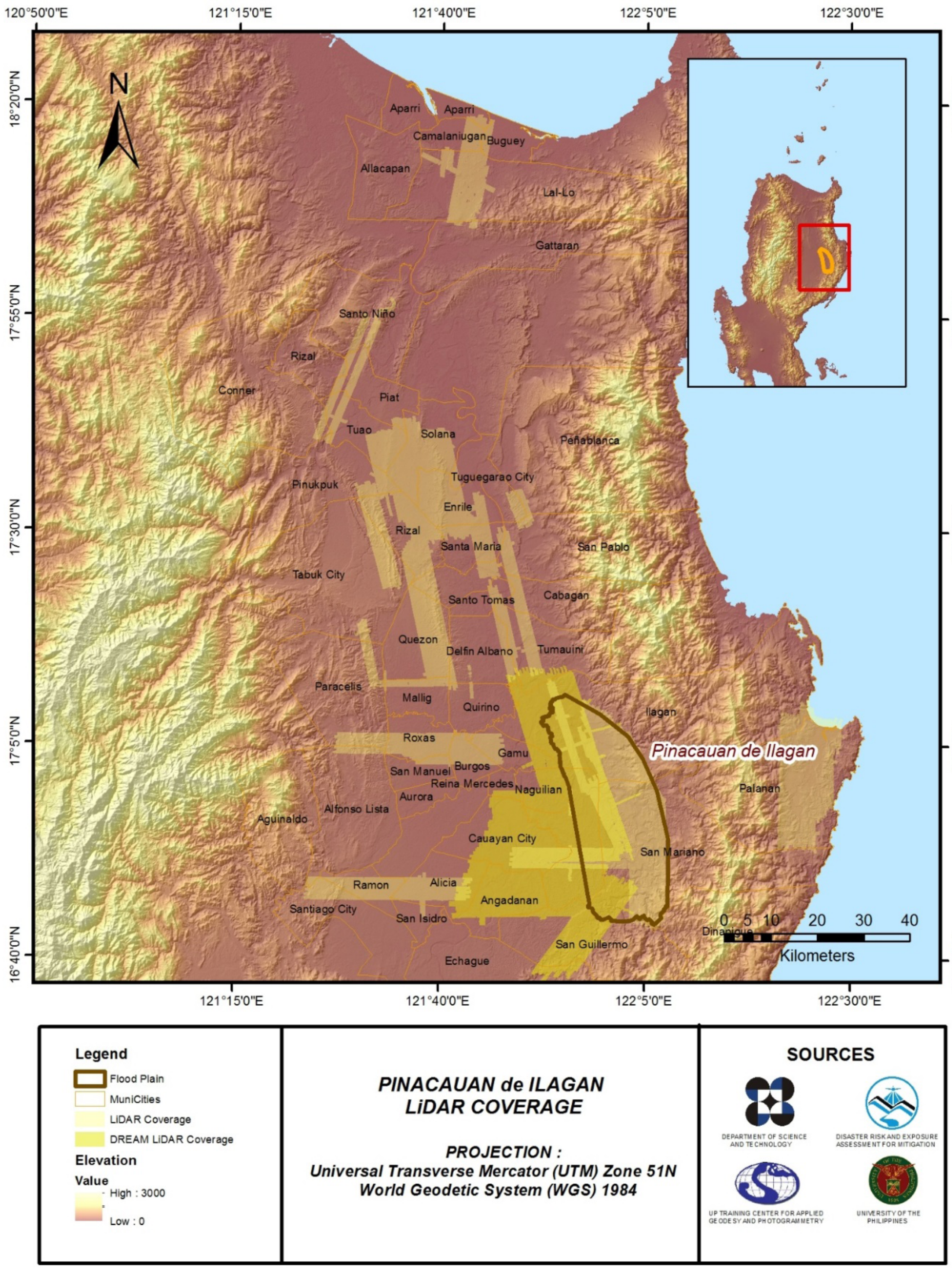


Figure 18. Actual LiDAR survey coverage for Pinacanauan de Ilagan floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE PINACANAUAN DE ILAGAN FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Joida F. Prieto , Engr. Edgardo V. Gubatanga Jr. , Engr. Analyn M. Naldo, Engr. Antonio B. Chua Jr., Maria Tamsyn C. Malabanan , Engr. Don Matthew B. Banatin, Engr. Sheila-Maye F. Santillan

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 19.

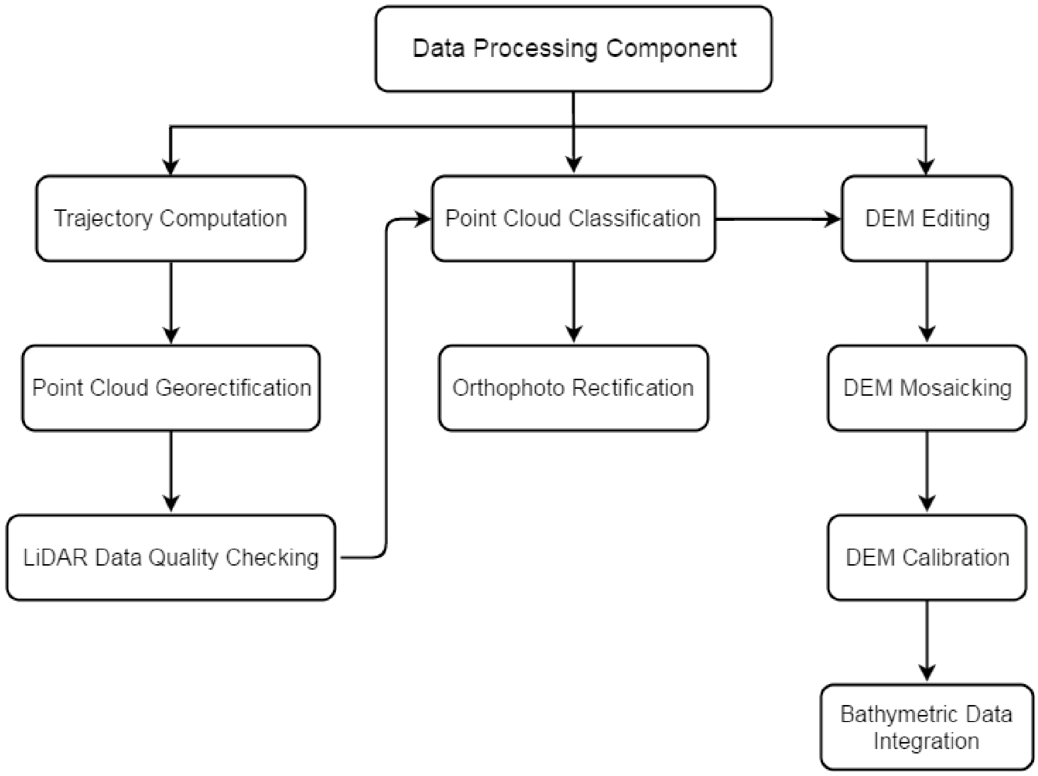


Figure 19. Schematic diagram for the data pre-processing.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Pinacanauan de Ilagan floodplain can be found in Annex 5. Missions flown during the first survey conducted on September 2013 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions acquired during the second survey on May 2016 were flown using the Gemini system over Ilagan City, Isabela.

The Data Acquisition Component (DAC) transferred a total of 621.25 Gigabytes of Range data, 6.11 Gigabytes of POS data, 1131.23 Megabytes of GPS base station data, and 490.64 Gigabytes of raw image data to the data server on September 22, 2013 for the first survey and May 18, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Pinacanauan de Ilagan was fully transferred on June 21, 2016, as indicated on the Data Transfer Sheets for Pinacanauan de Ilagan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 2690G, one of the Pinacanauan de Ilagan flights, which is the North, East, and Down position RMSE values are shown in Figure 20. 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 September 5, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

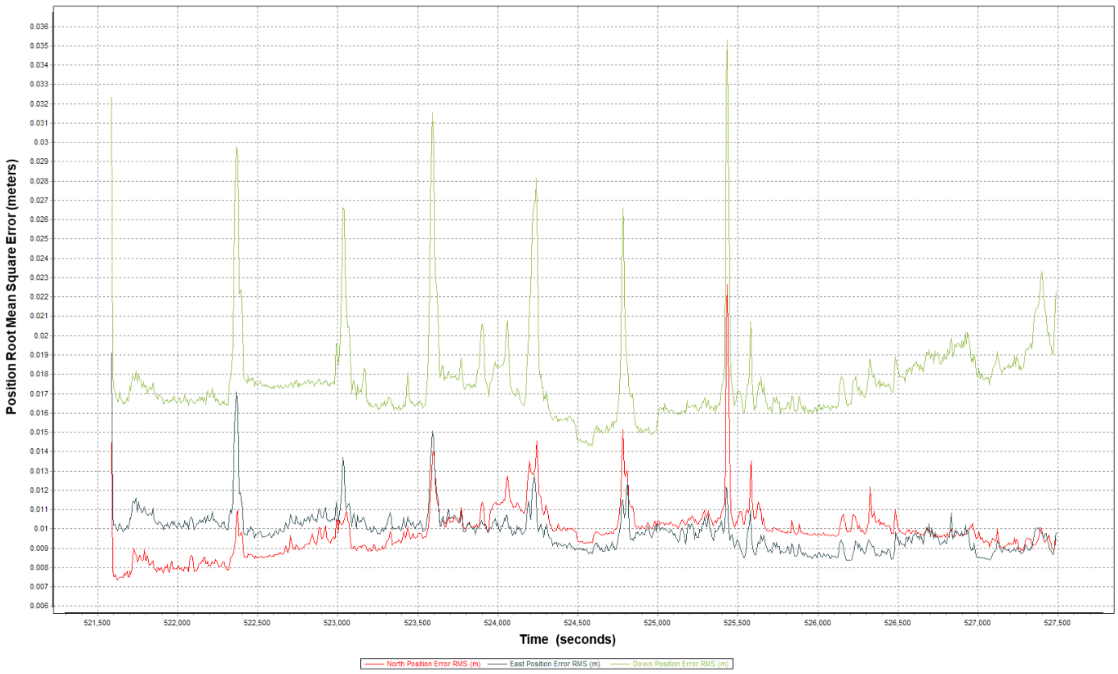


Figure 20. Smoothed Performance Metric Parameters of a Pinacanauan de Ilagan Flight 2690G.

The time of flight was from 521500 seconds to 527500 seconds, which corresponds to morning of September 5, 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 20 shows that the North position RMSE peaks at 2.30 centimeters, the East position RMSE peaks at 1.70 centimeters, and the Down position RMSE peaks at 3.60 centimeters, which are within the prescribed accuracies described in the methodology.

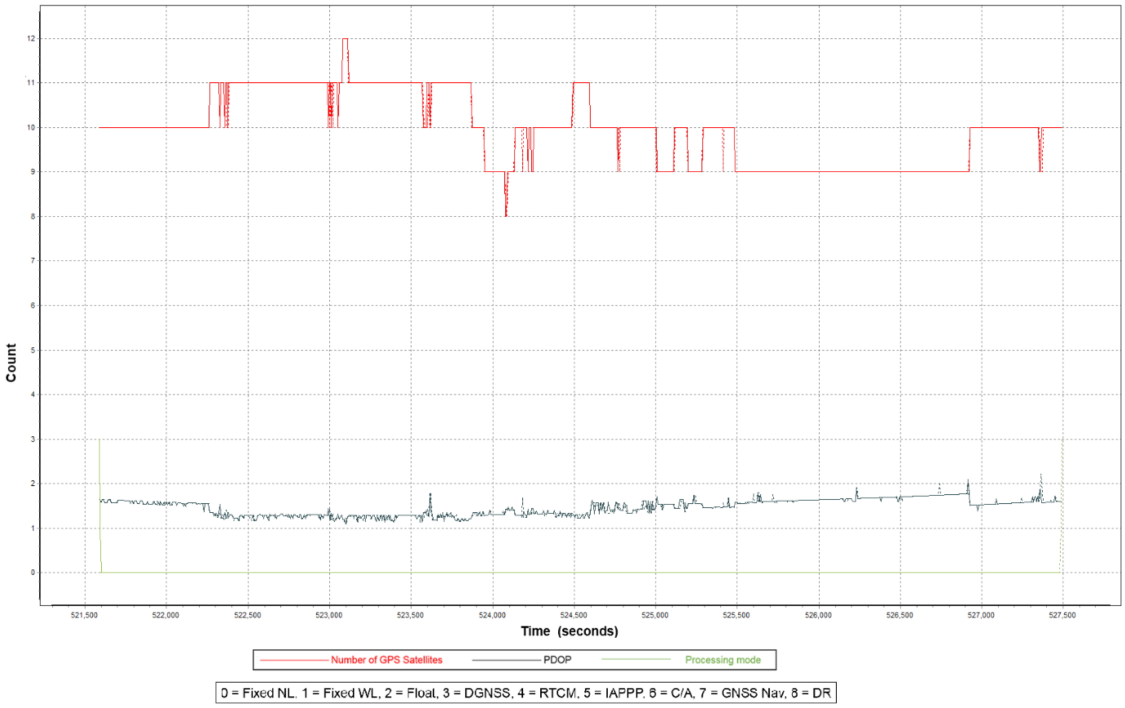


Figure 21. Solution Status Parameters of Pinacanauan de Ilagan Flight 2690G.

The Solution Status parameters of flight 2690G, one of the Pinacanauan de Ilagan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 21. 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 8 and 12. 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 Pinacanauan de Ilagan flights is shown in Figure 22.

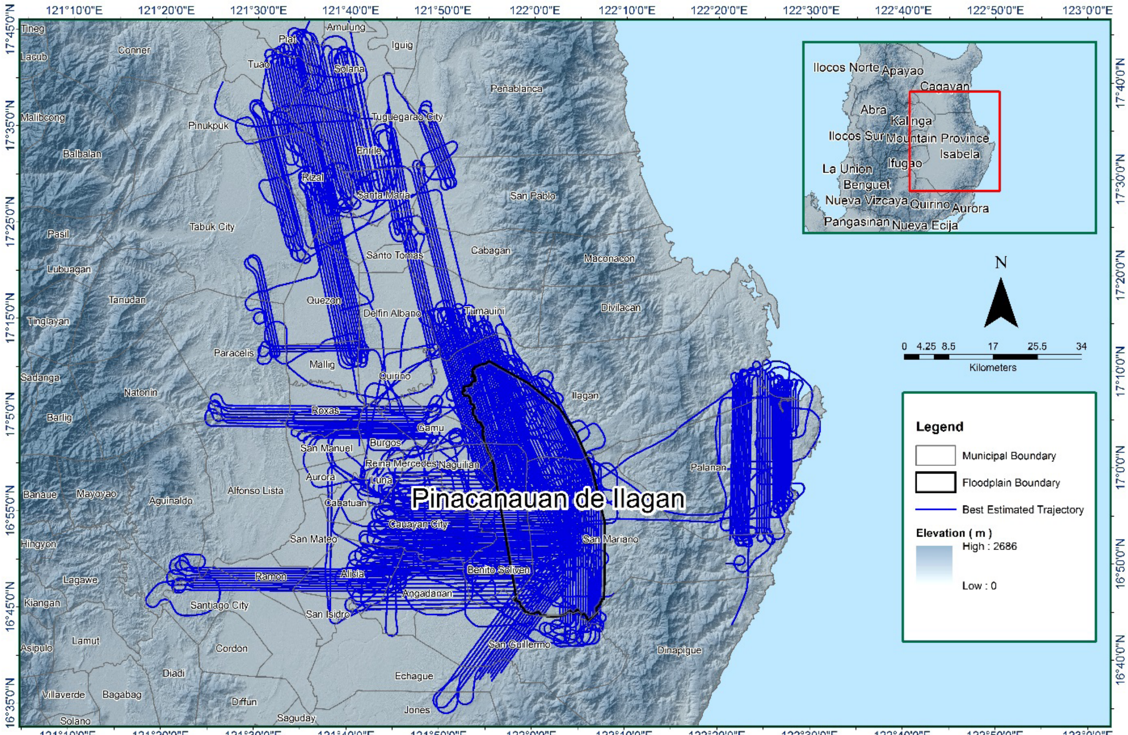


Figure 22. Best Estimated Trajectory of the LiDAR missions conducted over the Pinacanauan de Ilagan Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 371 flight lines, with each flight line containing one channel, since the Gemini system contain one channel only and two channels for the Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over the Pinacanauan de Ilagan floodplain are given in Table 27.

Table 27. Self-calibration Results values for Pinacanauan de Ilagan flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000157
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.000393
GPS Position Z-correction stdev)	<0.01meters	0.0013

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

3.5 LiDAR Quality Checking

The boundary of the processed LiDAR data on top of the SAR Elevation Data over the Pinacanauan de Ilagan Floodplain is shown in Figure 23. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

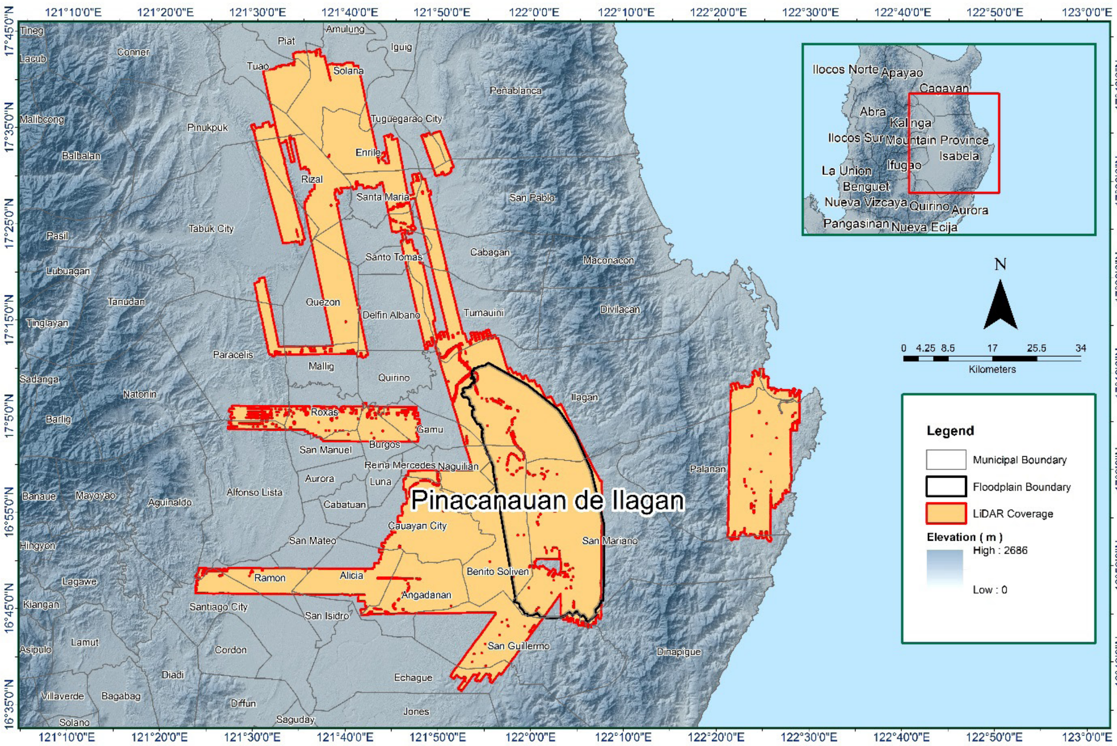


Figure 23. Boundaries of the processed LiDAR data over the Pinacanauan de Ilagan Floodplain.

The total area covered by the Pinacanauan de Ilagan missions is 4021.26 square kilometers (sq. kms.) that is comprised of thirty-six (36) flight acquisitions grouped and merged into thirty-nine (39) blocks as shown in Table 28.

Table 28. List of LiDAR blocks for the Pinacanauan de Ilagan floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Cauayan_Blk171N	4015G	207.86
Cauayan_Blk171M	4017G	111.49
Cauayan_Blk171M_additional	4027G	17.10
Cauayan_Blk171F	4021G	119.90
Cauayan_Blk161LM	4023G 4025G	171.40
Cauayan_Blk161BS	4023G	154.84
Cauayan_Blk171O	4019G 4027G	203.25
Palanan_Blk9A	2690G	120.78
Palanan_CGYR_H	2700G 2696G	53.51
Palanan_CGYR_G	2728G 2730G	85.24
Palanan_CGYR_F	2730G	55.39

Palanan_CGYR_E	2726G	57.68
Palanan_CGYR_C	2726G 2732G	40.98
Palanan_CGYR_A	2726G	20.68
Palanan_Blk9C_additional	2730G	13.46
Palanan_Blk9C	2686G	87.72
Palanan_Blk9B	2702G 2706G	198.03
Cagayan_reflights_Tuguegarao_Cag101D_additional	2914P	16.05
Cagayan_reflights_Tuguegarao_Cag101D	2898P	134.45
Cagayan_reflights_Tuguegarao_Cag101BC	2894P	156.00
Cagayan_reflights_Blk101E	4005G	30.75
Cagayan_reflights_Blk101C	3965G	157.94
Cagayan_reflights_Blk111D	3979G	71.55
Cagayan_reflights_Blk111C	3983G	29.95
Cagayan_reflights_Blk101G	4005G	118.94
Cagayan_reflights_Blk101F	4005G	76.69
Cagayan_reflgihts_Blk101F_additional	3983G	26.17
Cagayan_Blk171G	537P	147.61
Cagayan_Blk171L	577P	97.36
Cagayan_Blk171K	575P	120.15
Cagayan Blk171B_supplement	834P	90.86
Cagayan_Blk171H	545P	203.35
Cagayan_Blk171E	529P	160.53
Cagayan_Blk171F	533P	154.66
Cagayan_Blk171D	547P	150.40
Cagayan_Blk171D_supplement	848P	52.86
Cagayan_Blk171C	838G	178.15
Cauayan_reflights_Blk171P	23728P	49.15
Cauayan_reflights_Blk171Q	23796P	83.38
	TOTAL	**4021.26 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 24. 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.

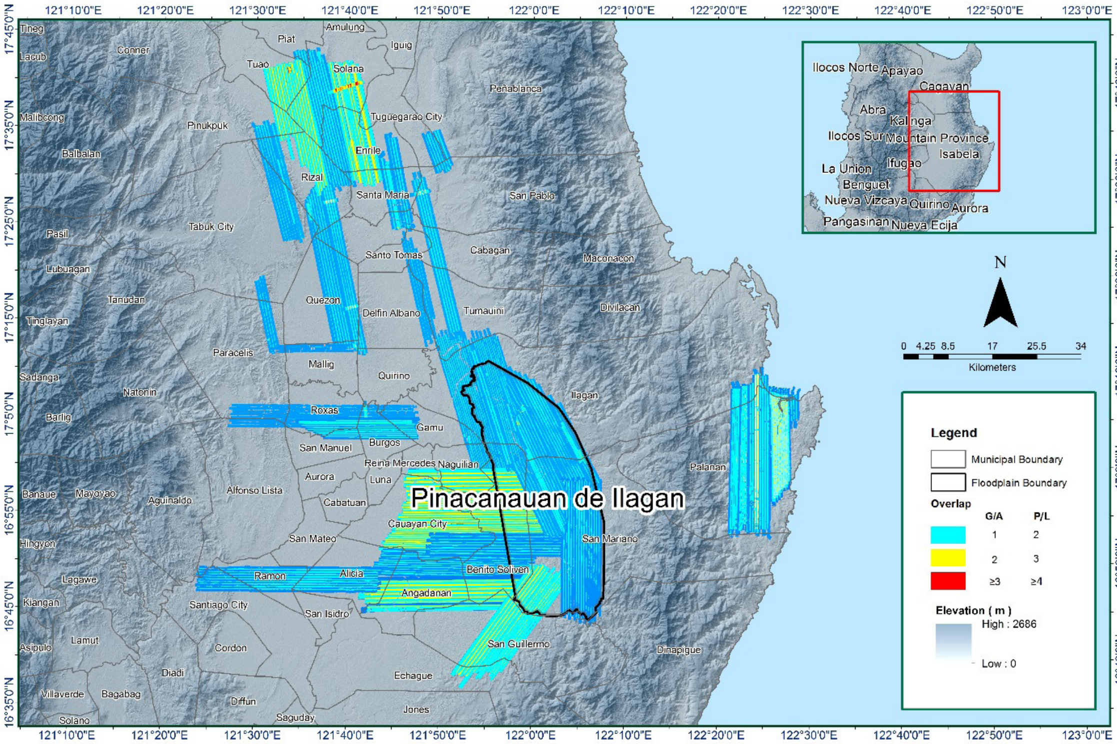


Figure 24. Image of data overlap for Pinacanauan de Ilagan floodplain.

The overlap statistics per block for the Pinacanauan de Ilagan floodplain can be found in the Mission Summary Reports (Annex 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.74% and 80.90% 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 two (2) points per square meter criterion is shown in Figure 25. It was determined that all LiDAR data for the Pinacanauan de Ilagan floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.85 points per square meter.

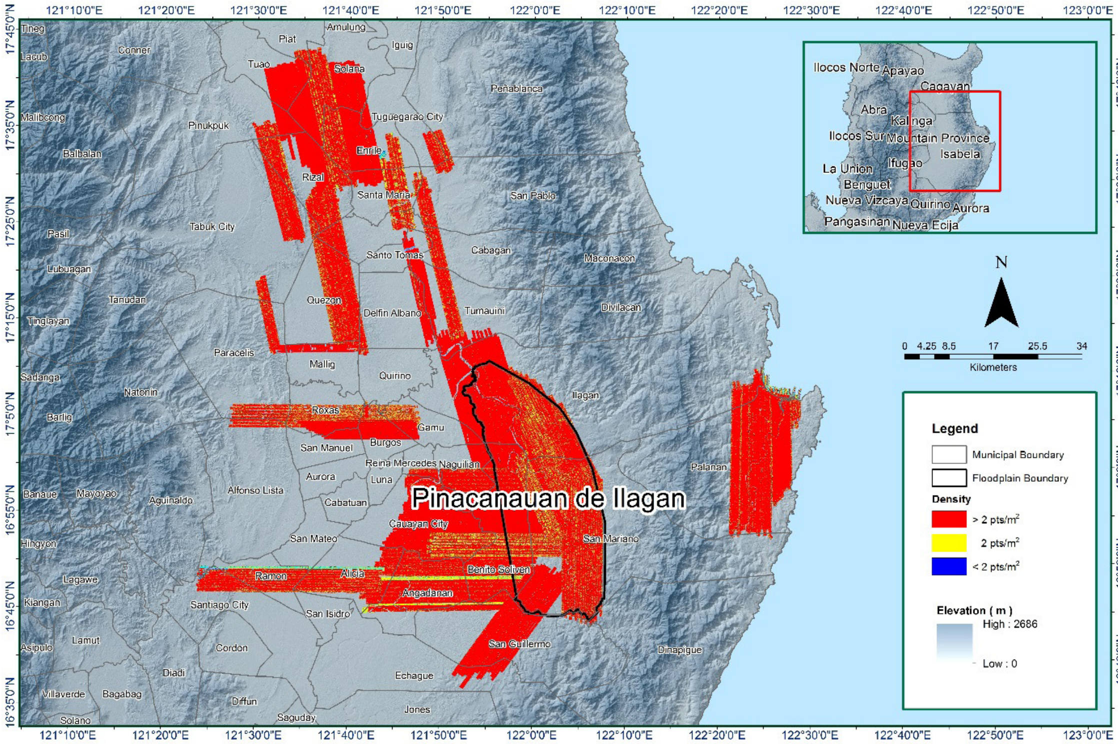


Figure 25. Pulse density map of the merged LiDAR data for Pinacanauan de Ilagan floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 26. 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.

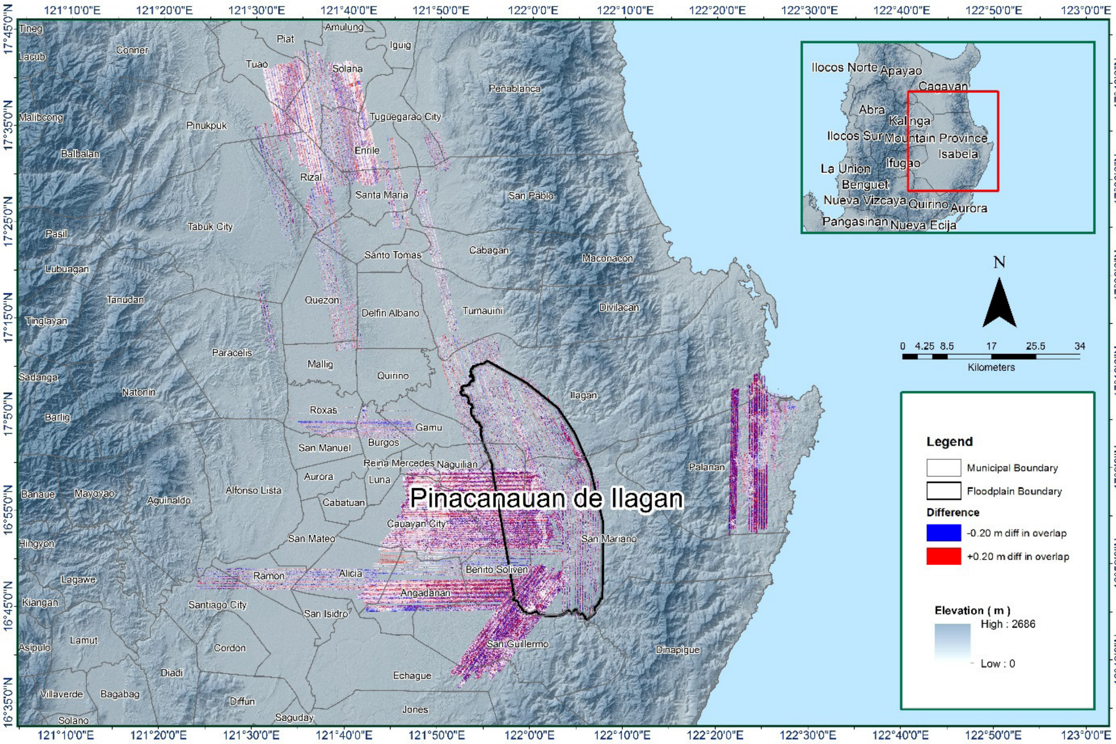


Figure 26. Elevation difference Map between flight lines for the Pinacanauan de Ilagan Floodplain Survey

A screen capture of the processed LAS data from a Pinacanauan de Ilagan flight 2690G loaded in QT Modeler is shown in Figure 27. 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.

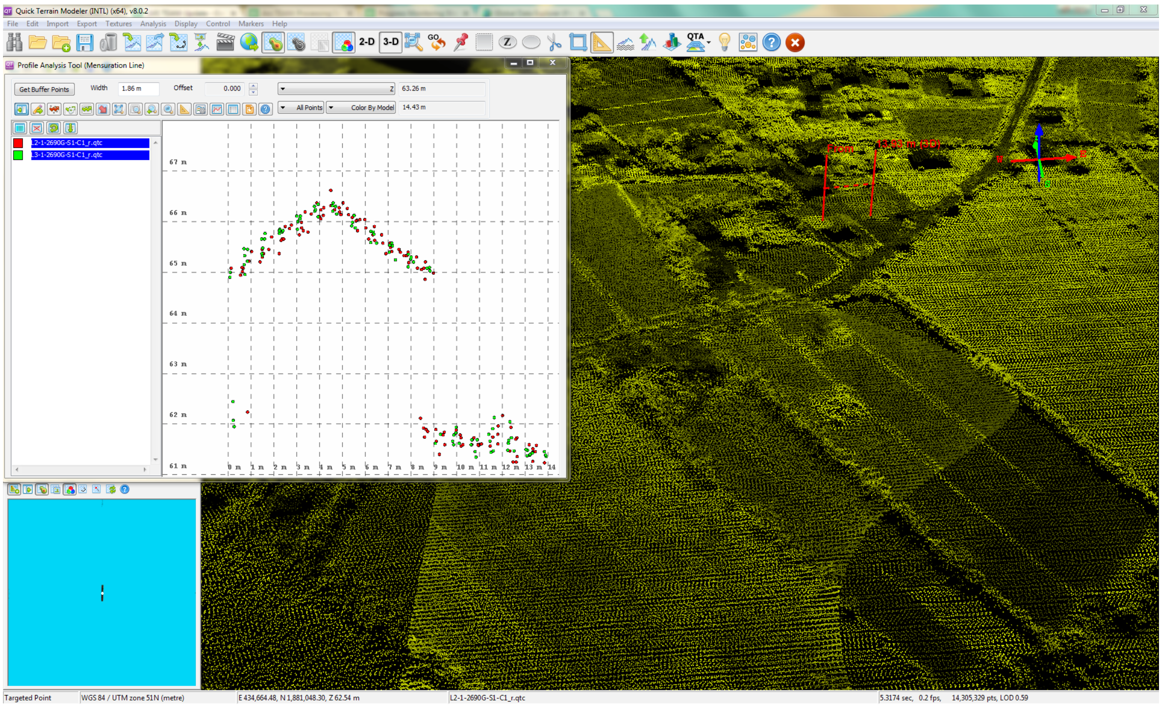


Figure 27. Quality checking for aPinacanauan de Ilagan flight 2690G using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 29. Pinacanauan de Ilagan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	3,544,861,813
Low Vegetation	3,304,668,529
Medium Vegetation	6,020,951,913
High Vegetation	4,225,121,325
Building	105,770,832

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Pinacanauan de Ilagan floodplain is shown in Figure 28. A total of 5,465 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 29. The point cloud has a maximum and minimum height of 703.16 meters and 26.08 meters, respectively.

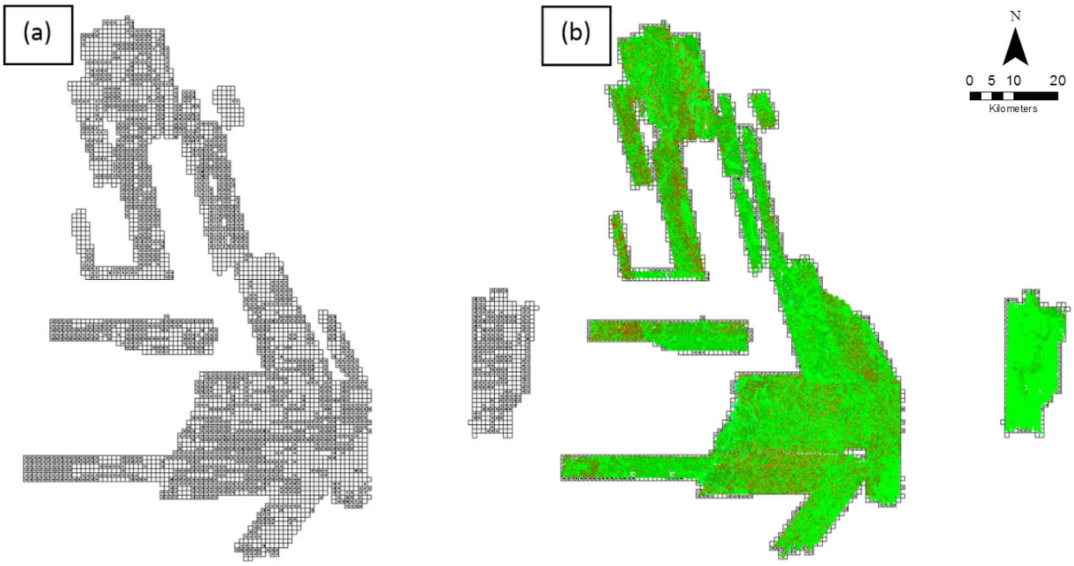


Figure 28. Tiles for Pinacanauan de Ilagan floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 29. The ground points are in orange, while 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 the canopy are classified correctly, due to the density of the LiDAR data.

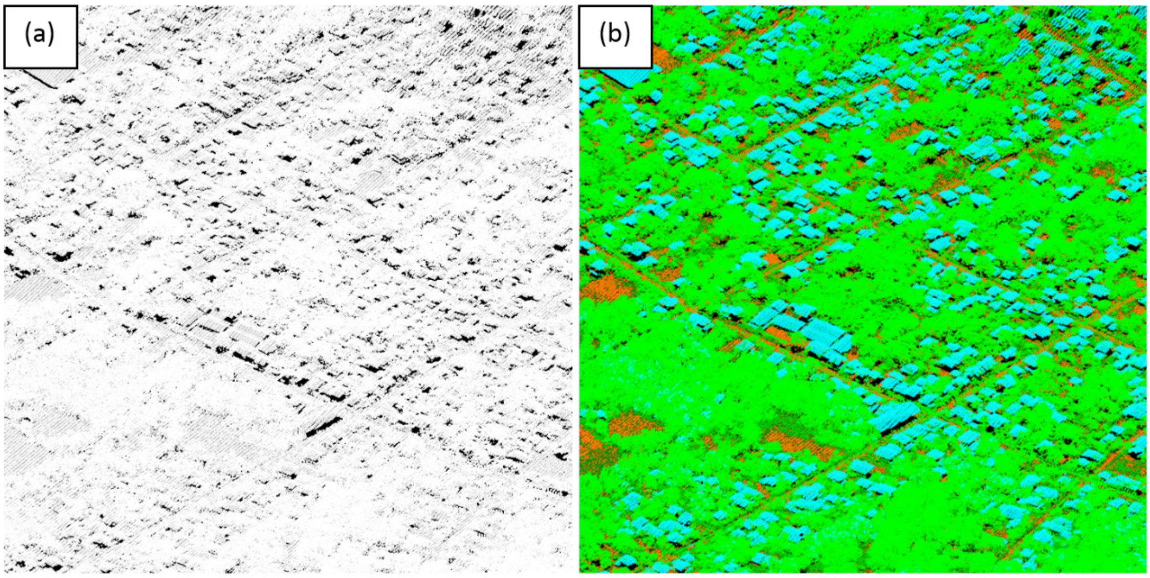


Figure 29. Point cloud before (a) and after (b) classification.

The production of the 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 show in Figure 30. It shows that DTMs are the representation of the bare earth, while on the DSMs, all features are present, such as buildings and vegetation.

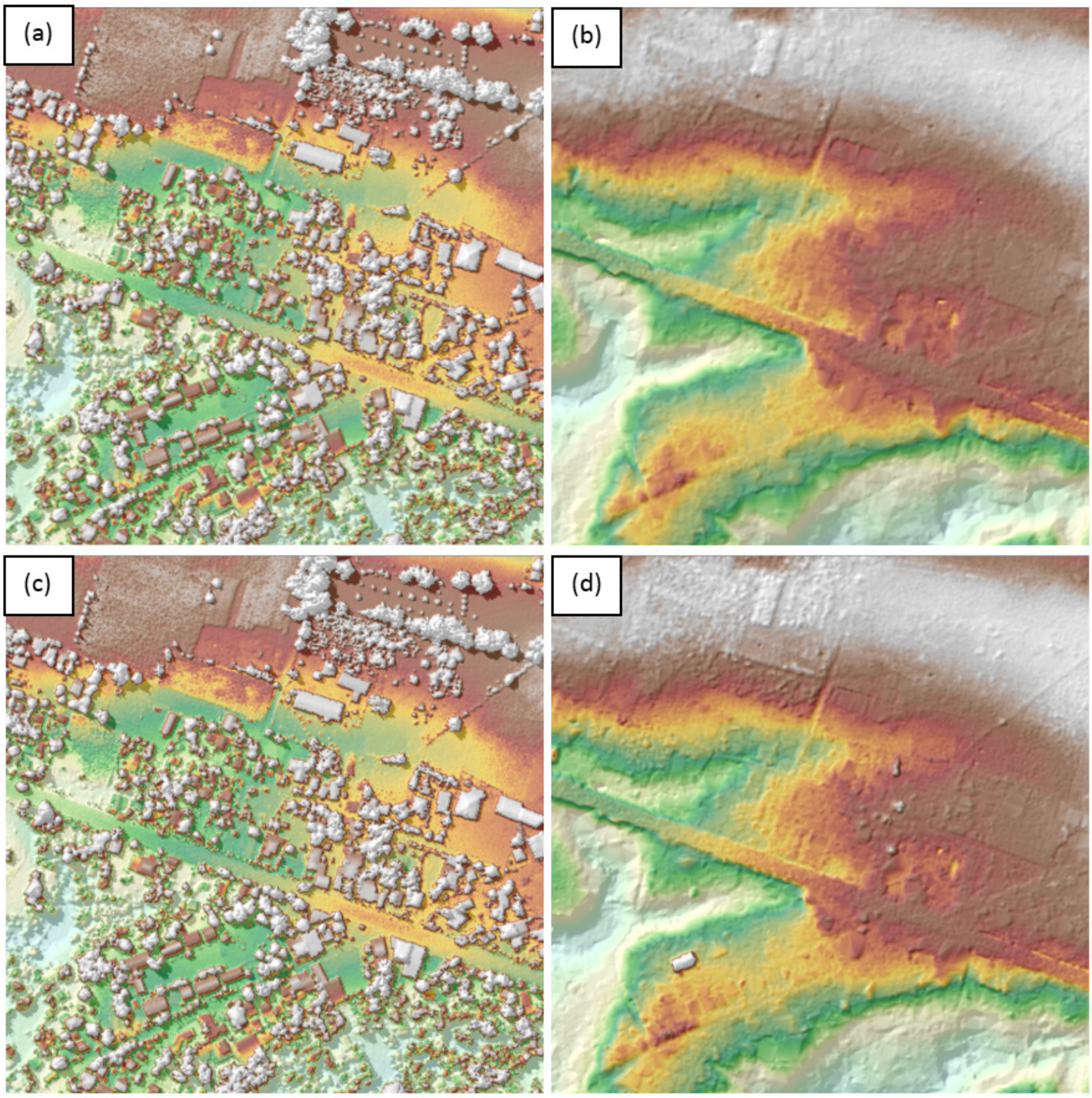


Figure 30. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Pinacanauan de Ilagan floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,778 1km by 1km tiles area covered by Pinacanauan de Ilagan floodplain is shown in Figure 31. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Pinacanauan de Ilagan floodplain has a total of 1,032.08 sq.km orthophotograph coverage comprised of 5,281 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 32.

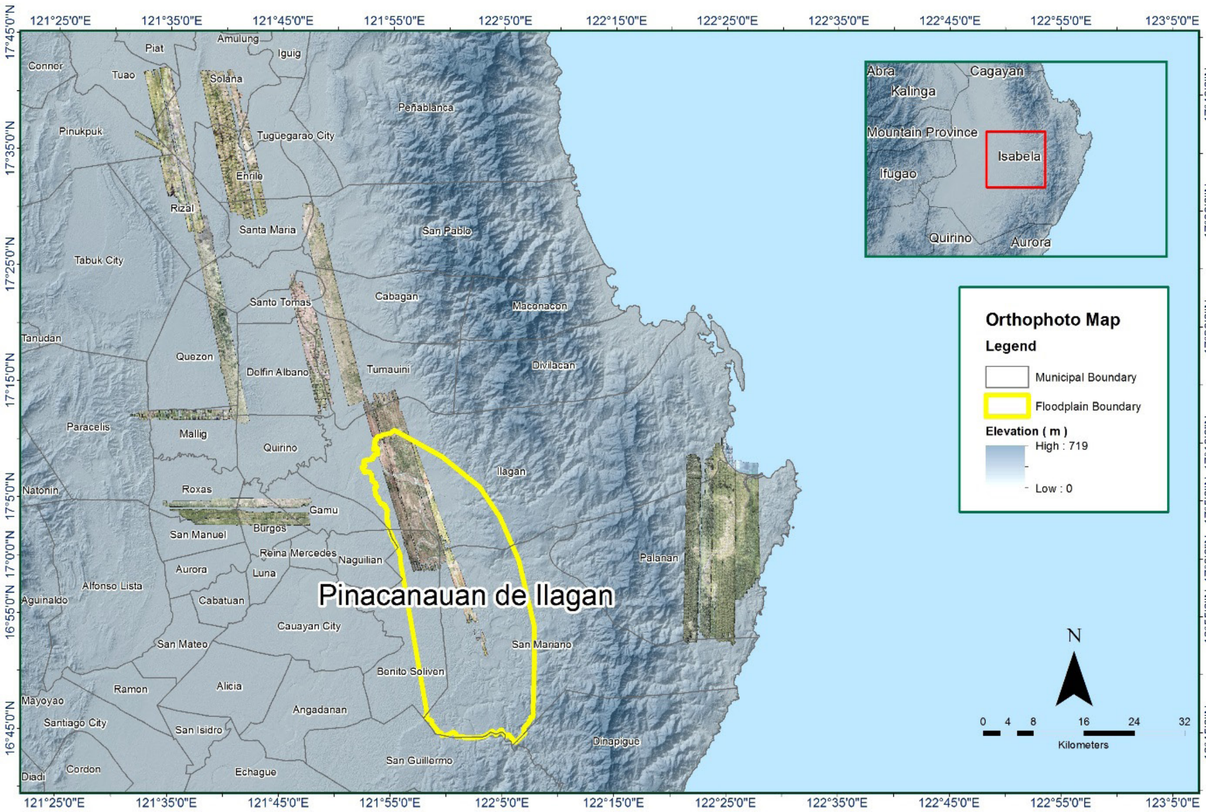


Figure 31. Pinacanauan de Ilagan floodplain with available orthophotographs.

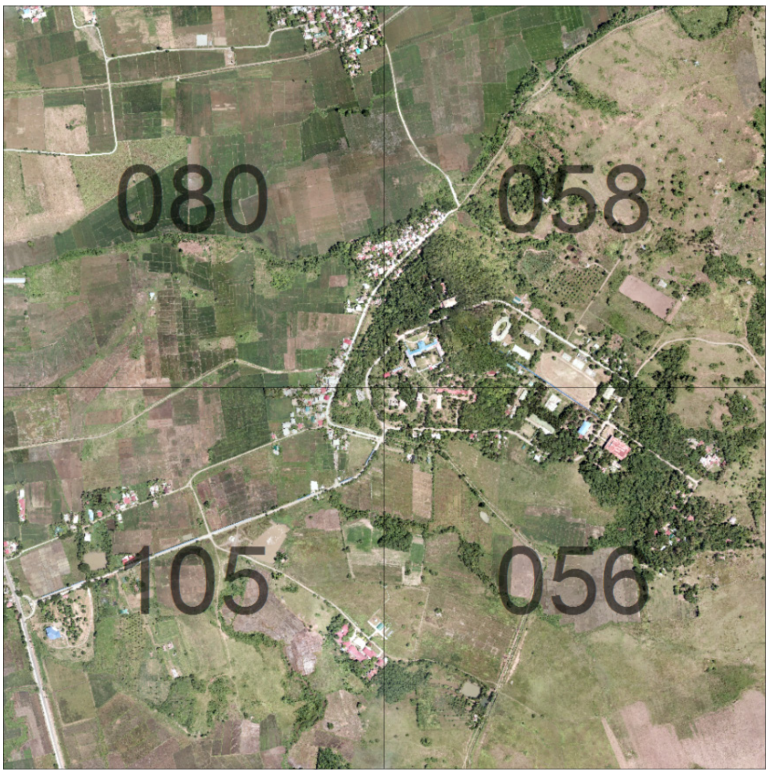


Figure 32. Sample orthophotograph tiles for Pinacanauan de Ilagan floodplain.

3.8 DEM Editing and Hydro-Correction

Thirty-nine (39) mission blocks were processed for Pinacanauan de Ilagan flood plain. These blocks are composed of Cauayan, Palanan, Cagayan_reflights, Cauayan_reflights and Cagayan_reflights_Tugegarao blocks with a total area of 4021.26 square kilometers. Table 30 shows the name and corresponding area of each block in square kilometers.

Table 30. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Cauayan_Blk171N	207.86
Cauayan_Blk171M	111.49
Cauayan_Blk171M_additional	17.10
Cauayan_Blk171F	119.90
Cauayan_Blk171LM	171.40
Cauayan_Blk61BS	154.84
Cauayan_Blk171O	203.25
Palanan_Blk9A	120.78
Palanan_CGYR_H	53.51
Palanan_CGYR_G	85.24
Palanan_CGYR_F	55.39
Palanan_CGYR_E	57.68
Palanan_CGYR_C	40.98
Palanan_CGYR_A	20.68
Palanan_Blk9C_additional	13.46
Palanan_Blk9C	82.72
Palanan_Blk9B	198.03
Cagayan_reflights_Tuguegarao_Cag101D_additional	16.05
Cagayan_reflights_Tuguegarao_Cag101D	134.45
Cagayan_reflights_Tuguegarao_101BC	156.00
Cagayan_reflights_Blk101E	30.75
Cagayan_reflights_Blk101C	157.94
Cagayan_reflights_Blk111D	71.55
Cagayan_reflights_Blk111C	29.95
Cagayan_reflights_Blk101G	118.94
Cagayan_reflights_Blk101F	76.69
Cagayan_reflights_Blk101F_additional	26.17
Cagayan_Blk171G	147.61
Cagayan_Blk171L	97.36
Cagayan_Blk171K	120.15
Cagayan_Blk171Bs	90.86
Cagayan_Blk171H	203.35
Cagayan_Blk171E	160.53
Cagayan_Blk171F	154.66
Cagayan_Blk171D	150.40
Cagayan_Blk171Ds	52.86
Cagayan_Blk171C	178.15

Cauayan_reflights_Blk171P	49.15
Cauayan_reflights_Blk171Q	83.38
TOTAL	**4021.26**

Figure 33 shows portions of a DTM before and after manual editing. As evident in the figure, a road (Figure 33a) has been misclassified and removed during classification process and has to be interpolated to complete the surface (Figure 33b) to allow the correct flow of water. An interpolated ridge (Figure 33c) has been misclassified and removed during classification process and has to be retrieved (Figure 33d) to complete the surface. Another example is a pit (Figure 33e) that has to be interpolated using manual editing to achieve the actual surface (Figure 33f). Lastly the banks (Figure 33g) underwent object retrieval (Figure 33h) to achieve the actual surface.

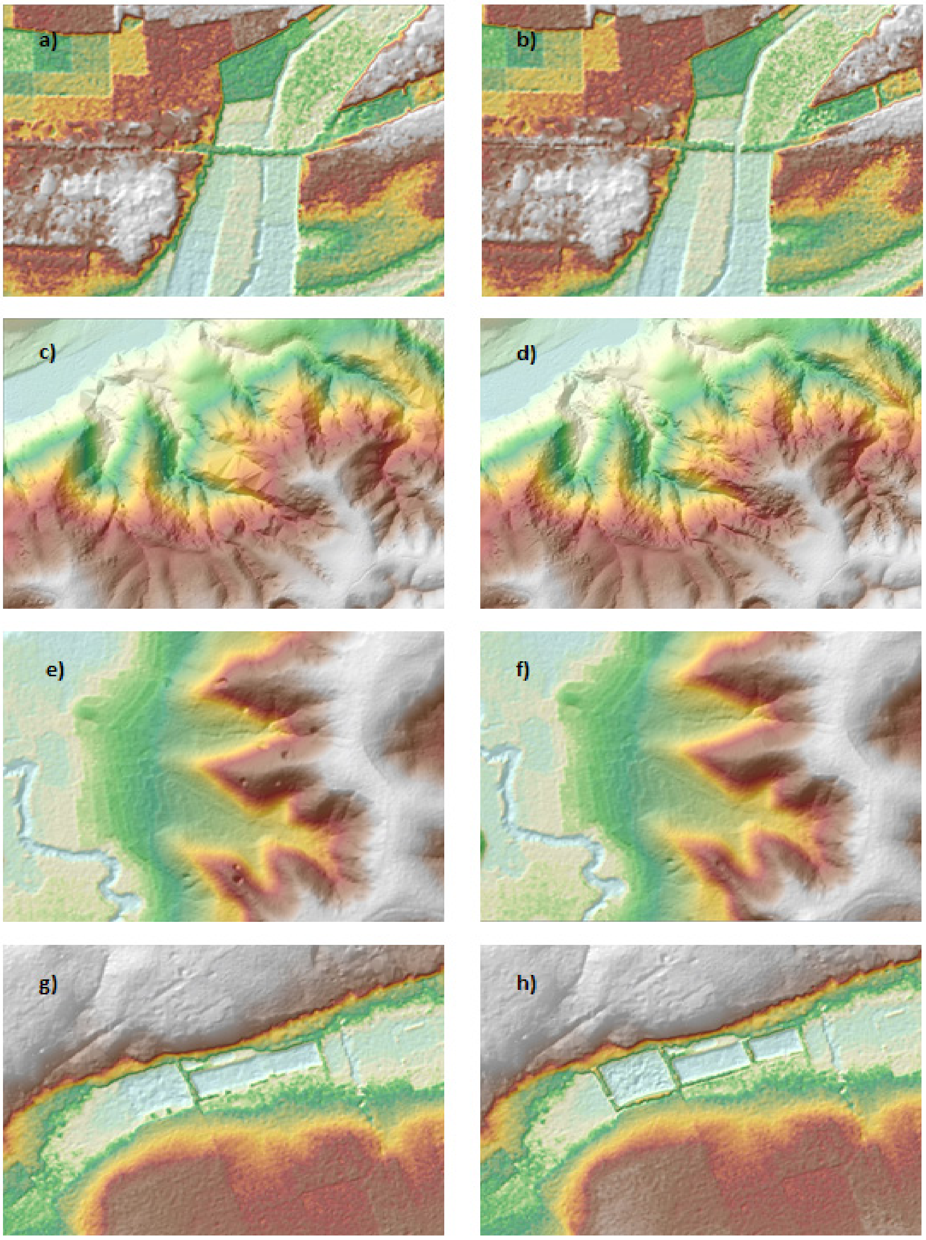


Figure 33. Portions in the DTM of Pinacanauan de Ilagan floodplain – a road before (a) and after (b) manual editing; a ridge before (c) and after object retrieval (d); interpolated pit before (e) and after (f); and banks before (g) and after (h) object retrieval.

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing Cagayan DEM overlapping with the blocks to be mosaicked. Table 31 shows the shift values applied to each LiDAR block during mosaicking.

.

Mosaicked LiDAR DTM for Pinacanauan de Ilagan floodplain is shown in Figure 34. It can be seen that the entire Pinacanauan de Ilagan floodplain is 97.65% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 31. Shift values of each LiDAR block of Pinacanauan de Ilagan Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Cauayan_Blk171N	0.79	-7.14	-4.14
Cauayan_Blk171M	2.96	0.42	-4.21
Cauayan_Blk171M_additional	-5.18	3.15	-5.75
Cauayan_Blk171F	-0.58	-9.50	-4.14
Cauayan_Blk161LM	ongoing		
Cauayan_Blk61BS	ongoing		
Cauayan_Blk171O	-3.97	3.02	-5.46
Palanan_Blk9A	-1.67	0.90	0.33
Palanan_CGYR_H	5.217	14.55	-3.56
Palanan_CGYR_G	ongoing		
Palanan_CGYR_F	ongoing		
Palanan_CGYR_E	ongoing		
Palanan_CGYR_C	ongoing		
Palanan_CGYR_A	ongoing		
Palanan_Blk9C_additional	0.00	0.00	-0.37
Palanan_Blk9C	0.00	0.00	0.00
Palanan_Blk9B	-2.21	-1.22	-168.18
Cagayan_reflights_Tuguegarao_Cag101D_additional	-6.72	-28.80	-5.40
Cagayan_reflights_Tuguegarao_Cag101D	-4.40	1.25	1.90
Cagayan_reflights_Tuguegarao_101BC	-4.78	0.00	0.00
Cagayan_reflights_Blk101E	ongoing		
Cagayan_reflights_Blk101C	ongoing		
Cagayan_reflights_Blk111D	-4.07	4.82	1.90
Cagayan_reflights_Blk111C	ongoing		
Cagayan_reflights_Blk101G	-4.02	2.00	0.21
Cagayan_reflights_Blk101F	-3.92	-1.86	1.32
Cagayan_reflights_Blk101F_additional	ongoing		
Cagayan_Blk171G	-0.65	-0.94	0.23
Cagayan_Blk171L	0.47	1.03	0.03
Cagayan_Blk171K	1.36	0.07	0.03
Cagayan_Blk171Bs	2.00	1.00	0.30
Cagayan_Blk171H	-1.71	-0.89	0.03

Cagayan_Blk171E	ongoing		
Cagayan_Blk171F	ongoing		
Cagayan_Blk171D	ongoing		
Cagayan_Blk171Ds	3.00	2.00	0.30
Cagayan_Blk171C	3.00	1.00	0.27
Cauayan_reflights_Blk171P	0.55	2.38	-3.84
Cauayan_reflights_Blk171Q	-1.11	2.50	-4.03

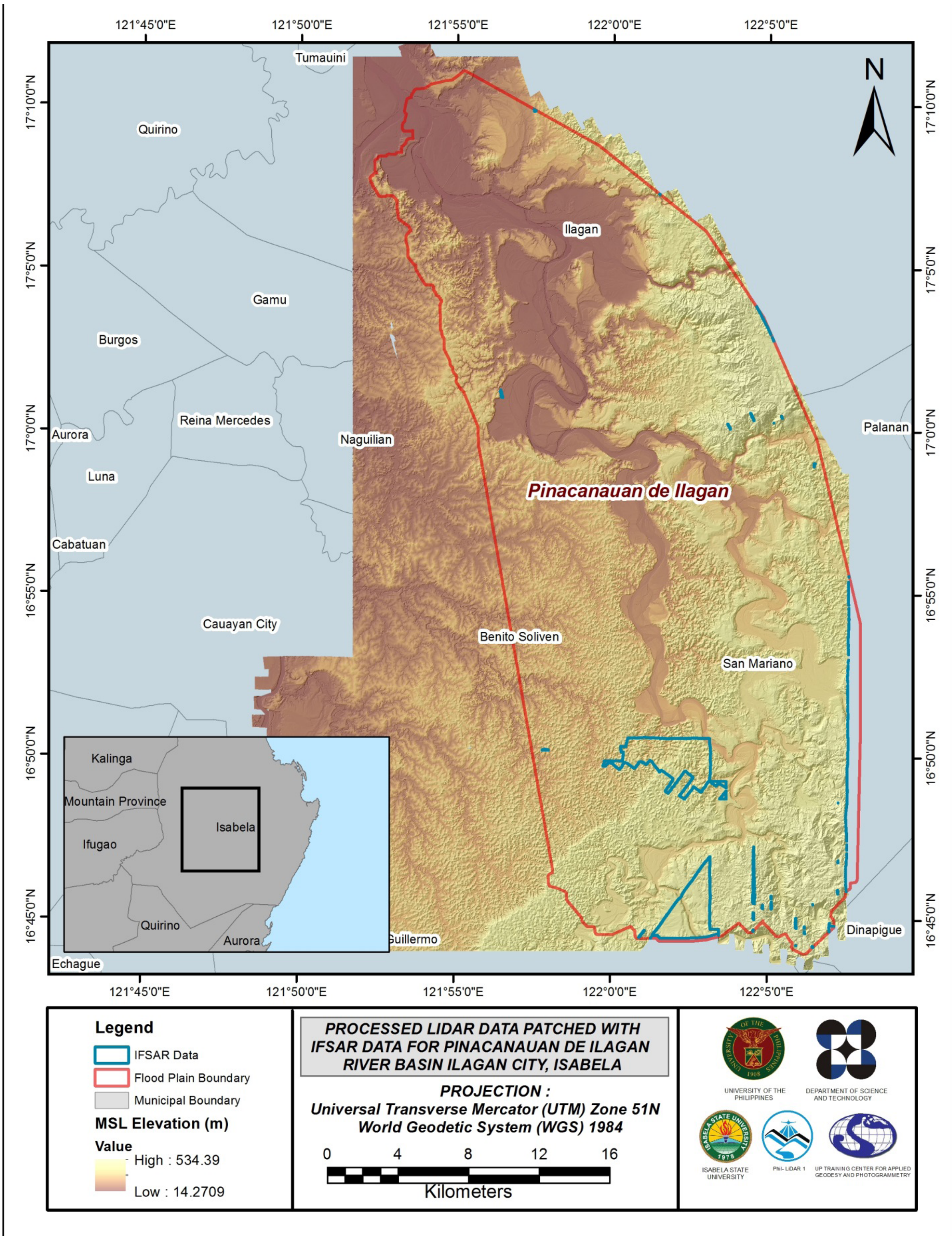


Figure 34. Map of processed LiDAR data for the Pinacanauan de Ilagan Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Pinacanauan de Ilagan to collect points with which the LiDAR dataset is validated is shown in Figure 35, with the validation survey points highlighted in green. A total of 8,676 survey points were gathered for the Pinacanauan de Ilagan floodplain. However, the point dataset was not used for the calibration of the LiDAR data for Pinacanauan de Ilagan because during the mosaicking process, each LiDAR block was referred to the calibrated Cagayan DEM. Therefore, the mosaicked DEM of Pinacanauan de Ilagan can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Pinacanauan de Ilagan LiDAR DTM and ground survey elevation values is shown in Figure 36. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 4.07 meters with a standard deviation of 0.14 meters. Calibration of Pinacanauan de Ilagan LiDAR data was done by subtracting the height difference value, 4.07 meters, to Pinacanauan de Ilagan mosaicked LiDAR data. Table 32 shows the statistical values of the compared elevation values between Pinacanauan de Ilagan LiDAR data and calibration data.

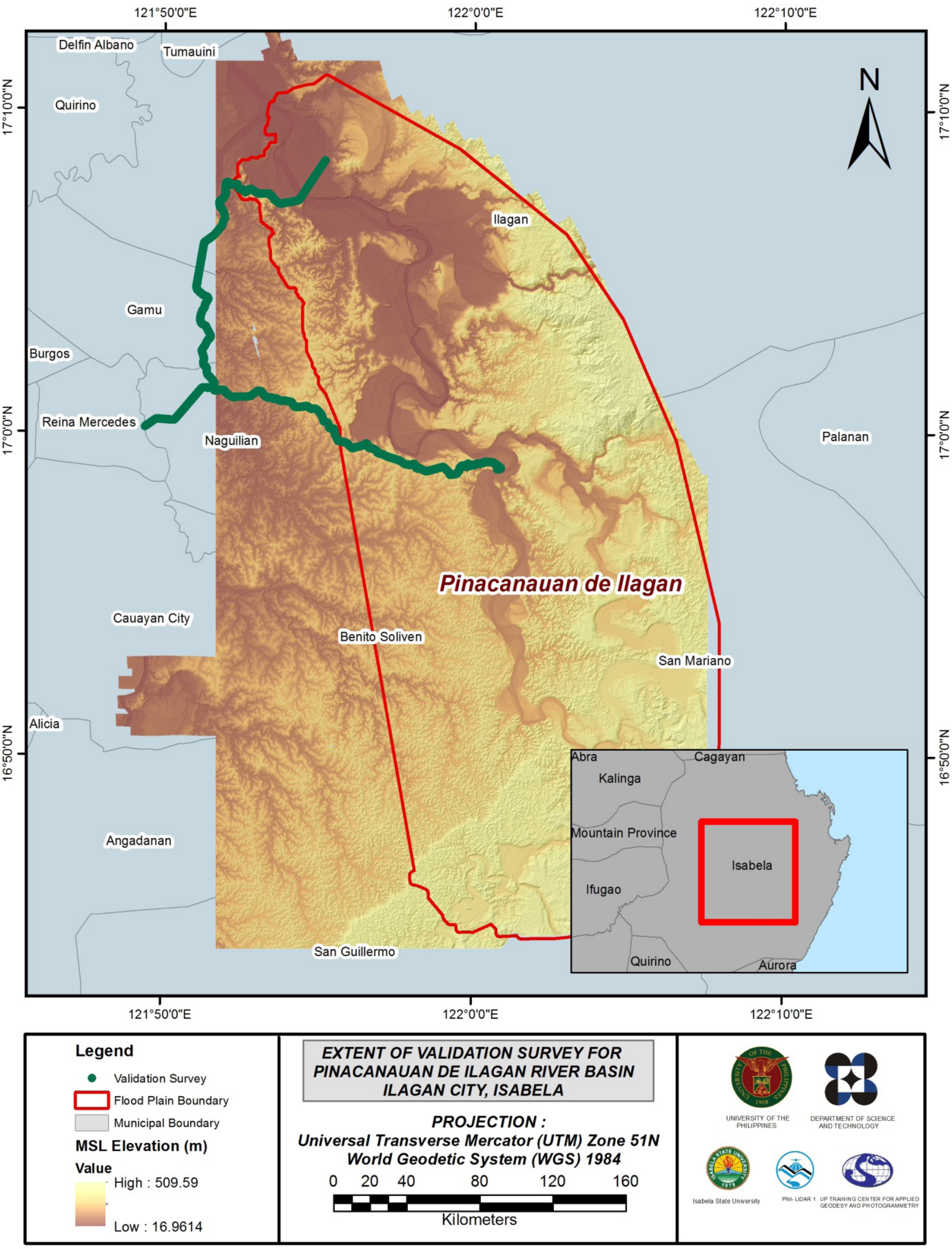


Figure 35. Map of Pinacanauan de Ilagan Floodplain with validation survey points in green.

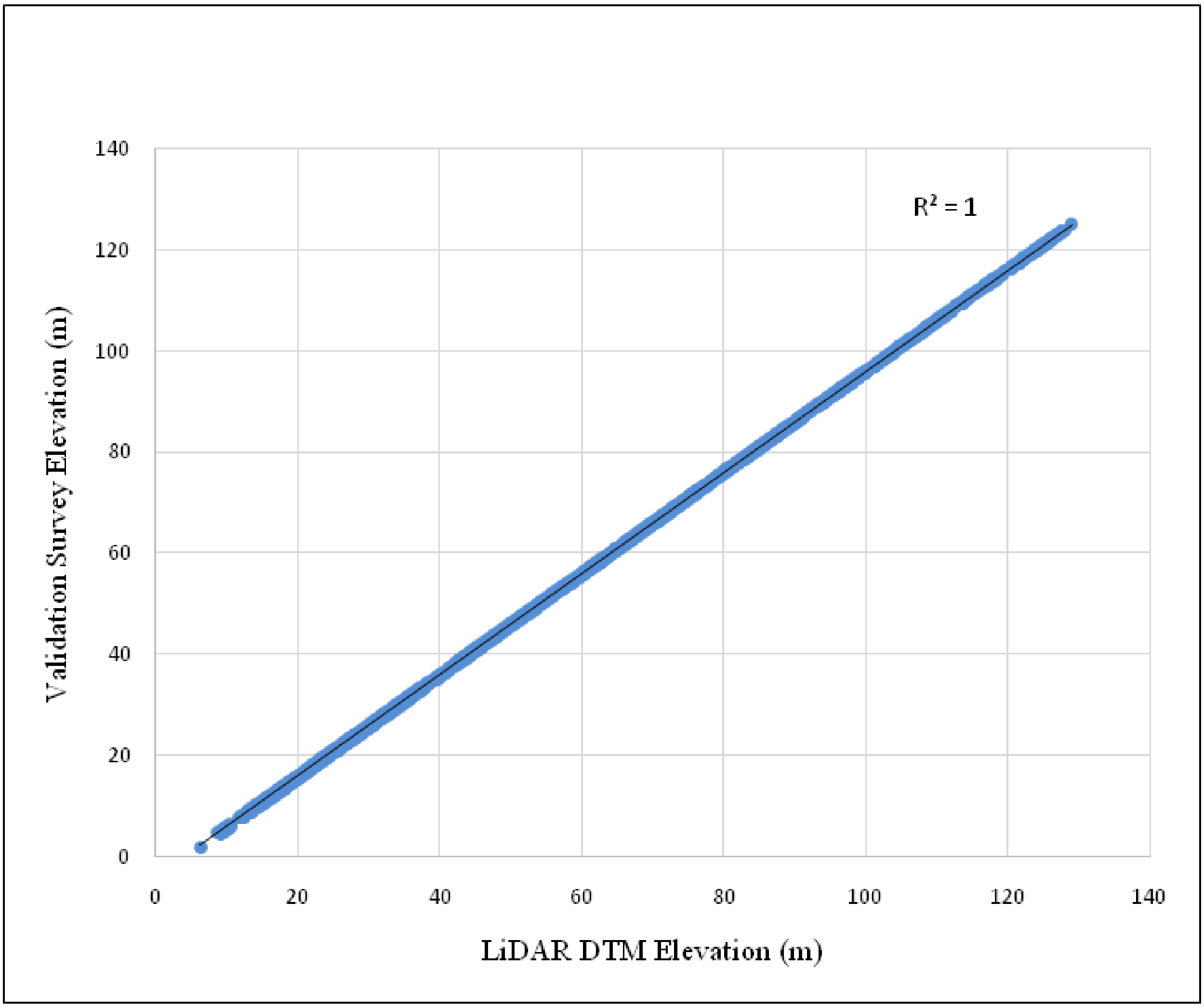


Figure 36. Correlation plot between calibration survey points and LiDAR data.

Table 32. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	4.07
Standard Deviation	0.10
Average	-4.07
Minimum	-4.50
Maximum	-3.77

A total of 4,042 points were used for the validation of calibrated Pinacanauan de Ilagan 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 37. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.16 meters with a standard deviation of 0.16 meters, as shown in Table 33.

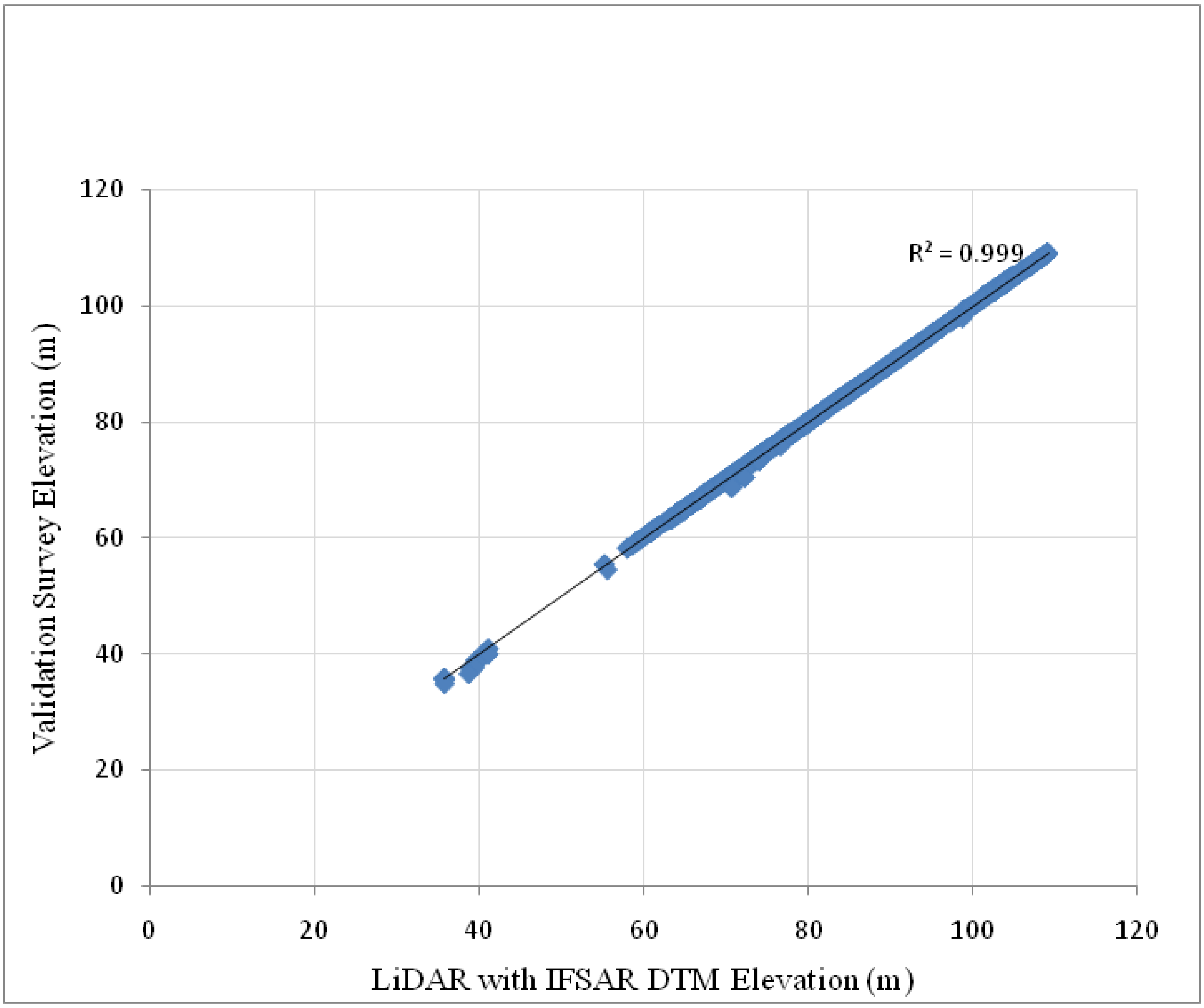


Figure 37. Correlation plot between the validation survey points and the LiDAR with IFSAR data.

Table 33. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.17
Standard Deviation	0.17
Average	-0.02
Minimum	-0.25
Maximum	2.12

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and cross-section data were available for Pinacanauan de Ilagan with 26,003 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.54 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Pinacanauan de Ilagan integrated with the processed LiDAR DEM is shown in Figure 38.

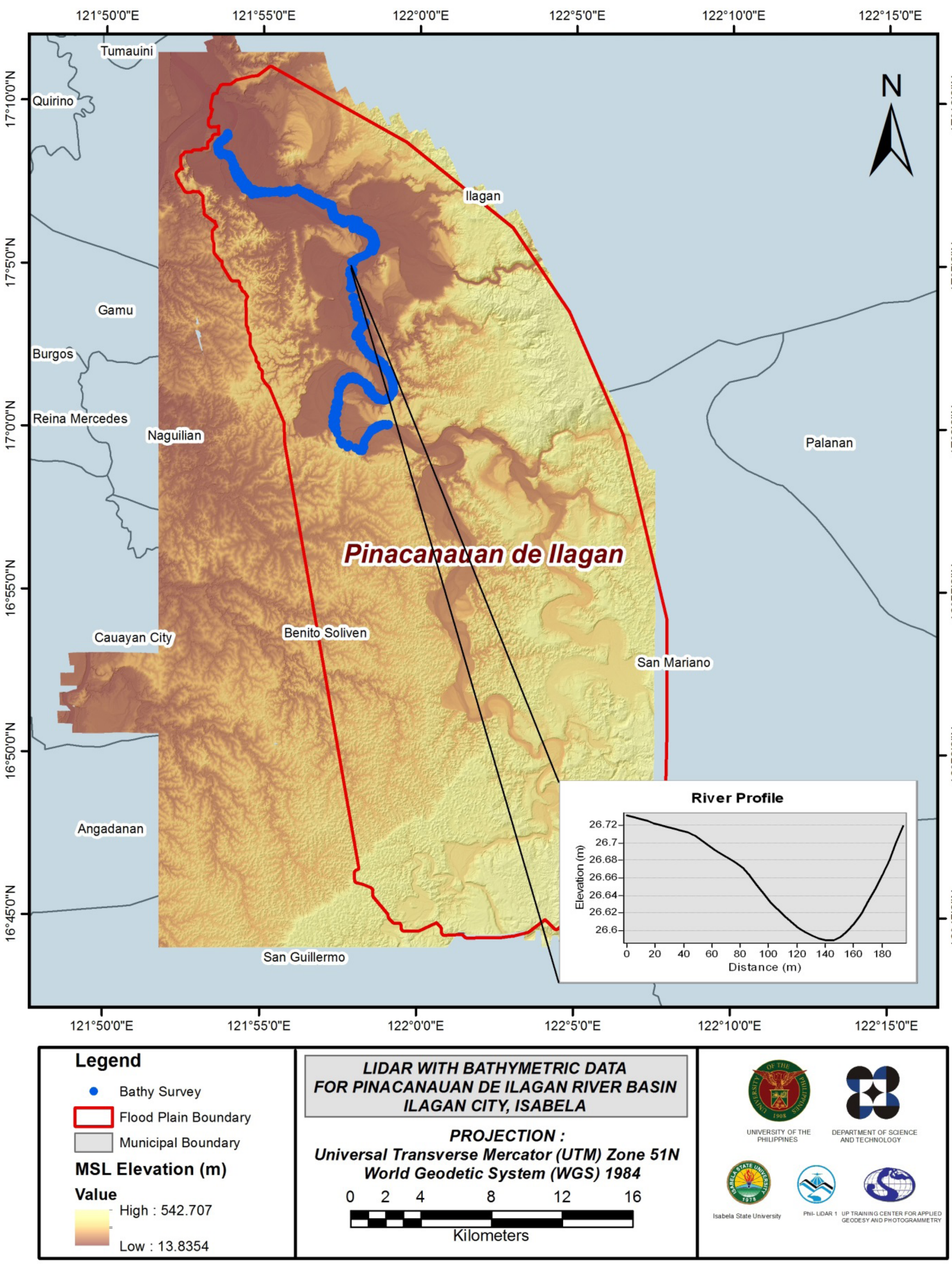


Figure 38. Map of Pinacanauan de Ilagan floodplain with bathymetric survey points in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Pinacanauan de Ilagan floodplain, including its 200 m buffer, has a total area of 840.20 sq km. For this area, a total of 25.0 sq km, corresponding to a total of 2,952 building features, are considered for QC. Figure 39 shows the QC blocks for Pinacanauan de Ilagan floodplain.

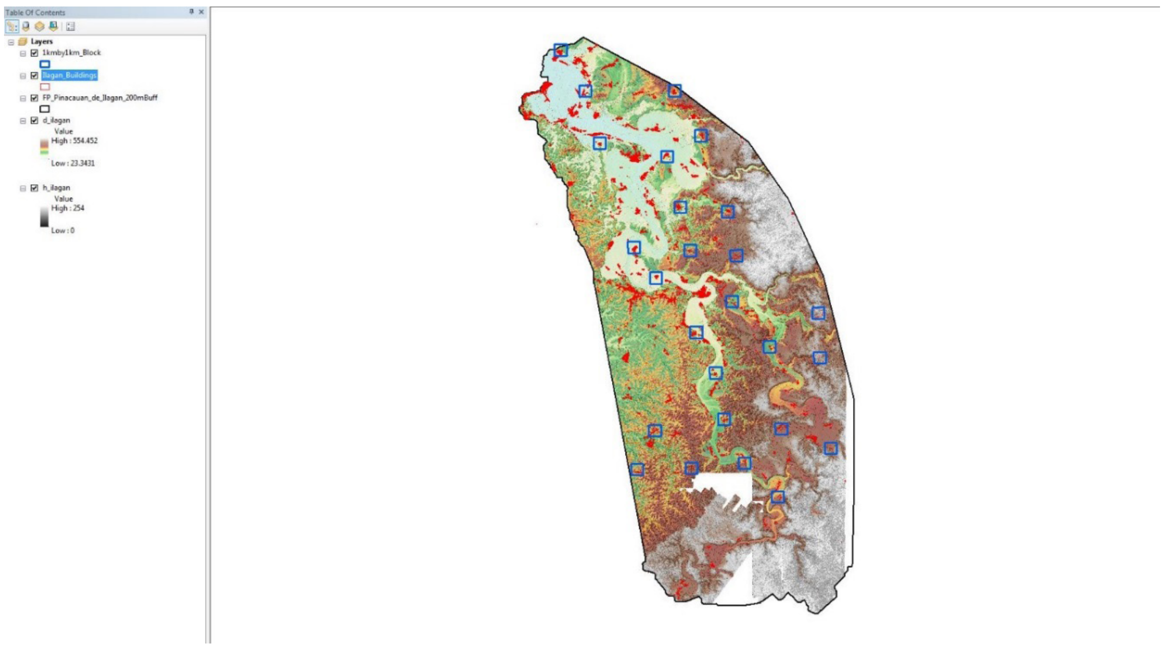


Figure 39. Blocks (in blue) of Pinacanauan de Ilagan building features that was subjected to QC.

Quality checking of Pinacanauan de Ilagan building features resulted in the ratings shown in Table 34.

Table 34. Details of the quality checking ratings for the building features extracted for the Pinacanauan de Ilagan River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Pinacanauan de Ilagan	99.09	100.00	98.41	PASSED

3.12.2 Height Extraction

Height extraction was done for 35,229 building features in Pinacanauan de Ilagan floodplain. Of these building features, 2,591 were filtered out after height extraction, resulting to 32,708 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 10.75 meters.

3.12.3 Feature Attribution

The digitized features were identified using participatory mapping. Stakeholders (preferably barangay officials) were invited in a forum and were given maps of their respective barangays. They attributed first non-residential buildings like barangay hall, schools, churches, commercial buildings, etc. then other building left were then coded as residential. An nDSM was generated using the LiDAR DEMs to extract the heights of the buildings. A minimum height of 2 meters was used to filter out the terrain features that were digitized as buildings. Buildings that were not yet constructed during the time of LiDAR acquisition were noted as new buildings in the attribute table.

Table 35 summarizes the number of building features per type. On the other hand, Table 36 shows the total length of each road type, while Table 37 shows the number of water features extracted per type.

Table 35. Building features extracted for Pinacanauan de Ilagan Floodplain.

Facility Type	No. of Features
Residential	31383
School	578
Market	73
Agricultural/Agro-Industrial Facilities	69
Medical Institutions	44
Barangay Hall	75
Military Institution	7
Sports Center/Gymnasium/Covered Court	60
Telecommunication Facilities	0
Transport Terminal	5
Warehouse	31
Power Plant/Substation	75
NGO/CSO Offices	0
Police Station	2
Water Supply/Sewerage	2
Religious Institutions	80
Bank	3
Factory	0
Gas Station	16
Fire Station	1
Other Government Offices	94
Other Commercial Establishments	110
Total	**32708**

Table 36. Total length of extracted roads for Pinacanauan de Ilagan Floodplain.

Floodplain	**Road Network Length (km)**					**Total**
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Pinacanauan de Ilagan	535.63	26.22	20.06	40.32	0.00	**622.24**

Table 37. Number of extracted water bodies for Pinacanauan de Ilagan Floodplain.

Floodplain	**Water Body Type**					**Total**
	Rivers/ Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Pinacanauan de Ilagan	97	0	0	0	0	**97**

A total of 53 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were completely given the required attributes. All these output features comprise the flood hazard exposure database for the floodplain. This completes the feature extraction phase of the project.

Figure 40 shows the completed Digital Surface Model (DSM) of the Pinacanauan de Ilagan floodplain overlaid with its ground features.

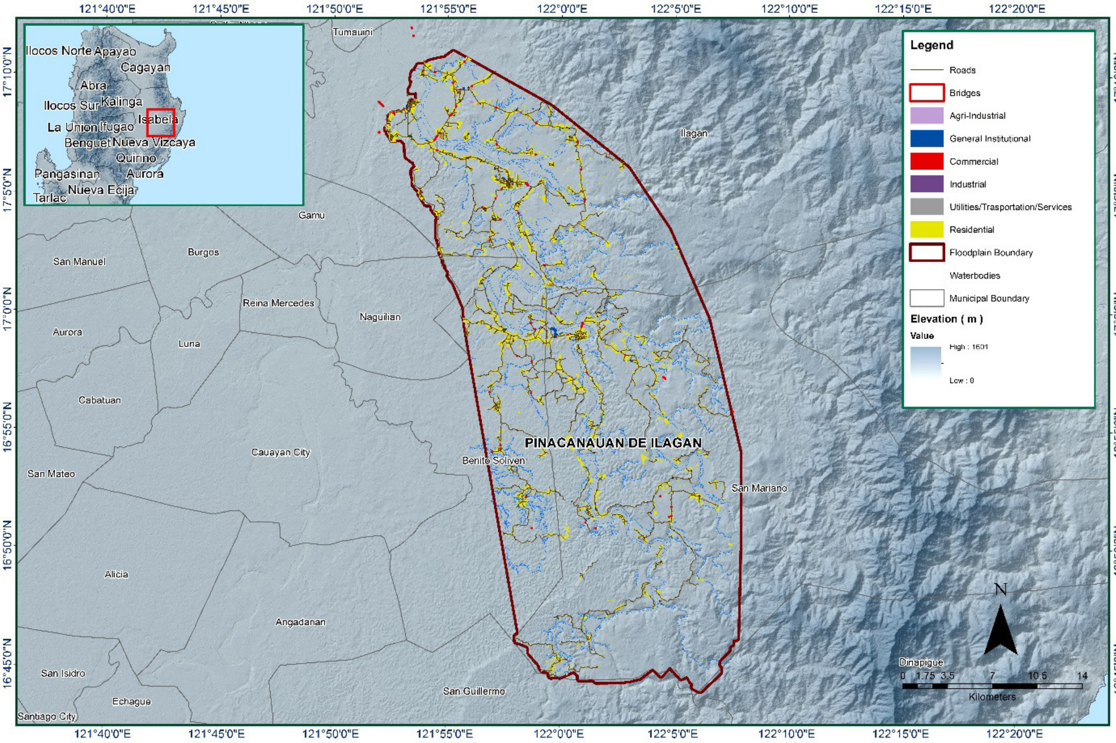


Figure 40. Extracted features of the Pinacanauan de Ilagan Floodplain.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE PINACANAUAN DE ILAGAN RIVER BASIN

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, Ms. Jeline M. Amante, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Engr. Janina Jupiter, Vie Marie Paola M. Rivera

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).

4.1 Summary of Activities

The AB Surveying and Development (ABSD) conducted a field survey in Pinacanauan de Ilagan River on April 20-28, 2016, May 15-17, 2016, May 20, 2016, May 23, 2016, and May 25, 2016. Generally, the scope of work was comprised of (i) initial reconnaissance; (ii) control point survey for the establishment of a control point; (iii) the cross section survey and bridge as-built survey, and water level marking in the Mean Sea Level (MSL) of the Malalam Bridge in Brgy. Alliguigan 2nd, Ilagan, Isabela; (iv) validation points acquisition; and (v) bathymetric survey from the upstream in Brgy. Bangag, Ilagan Isabela to the downstream in Brgy. Maluno Sur, Benito Soliven, Isabela. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVBC on November 3 - December 14, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Pinacanauan de Ilagan River Basin area. Figure 41 illustrates the extent of the entire survey in Pinacanauan de Ilagan River.

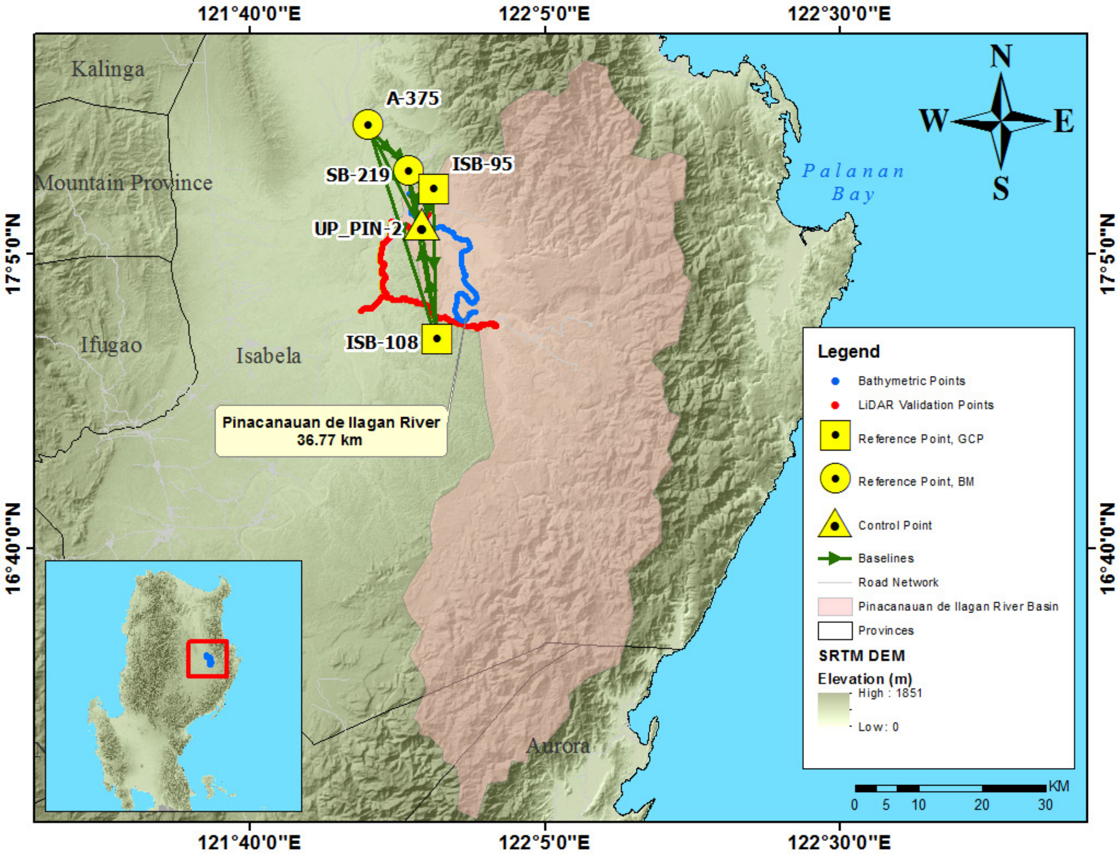


Figure 41. Pinacanauan de Ilagan River Survey Extent

4.2 Control Survey

The GNSS network utilized for the Pinacanauan de Ilagan River Basin is composed of ten (10) loops that was established on December 6, 2016, which occupied the following reference points: A-375, a DPWH established point occupied by DREAM-DVC last March 13-April 7, 2014, in Brgy. Maligaya, Ilagan, Isabela.

Three (3) control points established in the area by NAMRIA were also occupied: ISB-95, a 2nd-order GCP in Brgy. Morado, Ilagan, Isabela; ISB-108, a 2nd-order GCP in Brgy. Danipa, Benito Soliven, Isabela; and SB-219, a 1st-order BM in Brgy. San Juan, Ilagan, Isabela.

One (1) control point established in the area by ABSD was also occupied: UP_PIN-2, located at the approach of Malalam Bridge in Brgy. Alliguigan 2nd, Ilagan, Isabela.

Table 38 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 42 shows the GNSS network established in the Pinacanauan de Ilagan River Survey.

Table 38. List of reference and control points used during the survey in Pinacanauan de Ilagan River (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establishment
A-375	DPWH	17°15'55.43093"N	121°49'57.14379"E	76.625	36.051	1990
ISB-95	Used as marker	17°10'24.48319"N	121°55'31.82211"E	99.895	58.469	2007
ISB-108	Used as marker	16°57'44.56096"N	121°55'49.72283"E	114.953	72.888	2007
SB-219	Used as marker	17°12'00.00795"N	121°53'22.30250"E	80.861	39.731	2007
UP_PIN-2	Established	17°07'27.19860"N	121°54'32.69181"E	85.77	44.309	5-15-16

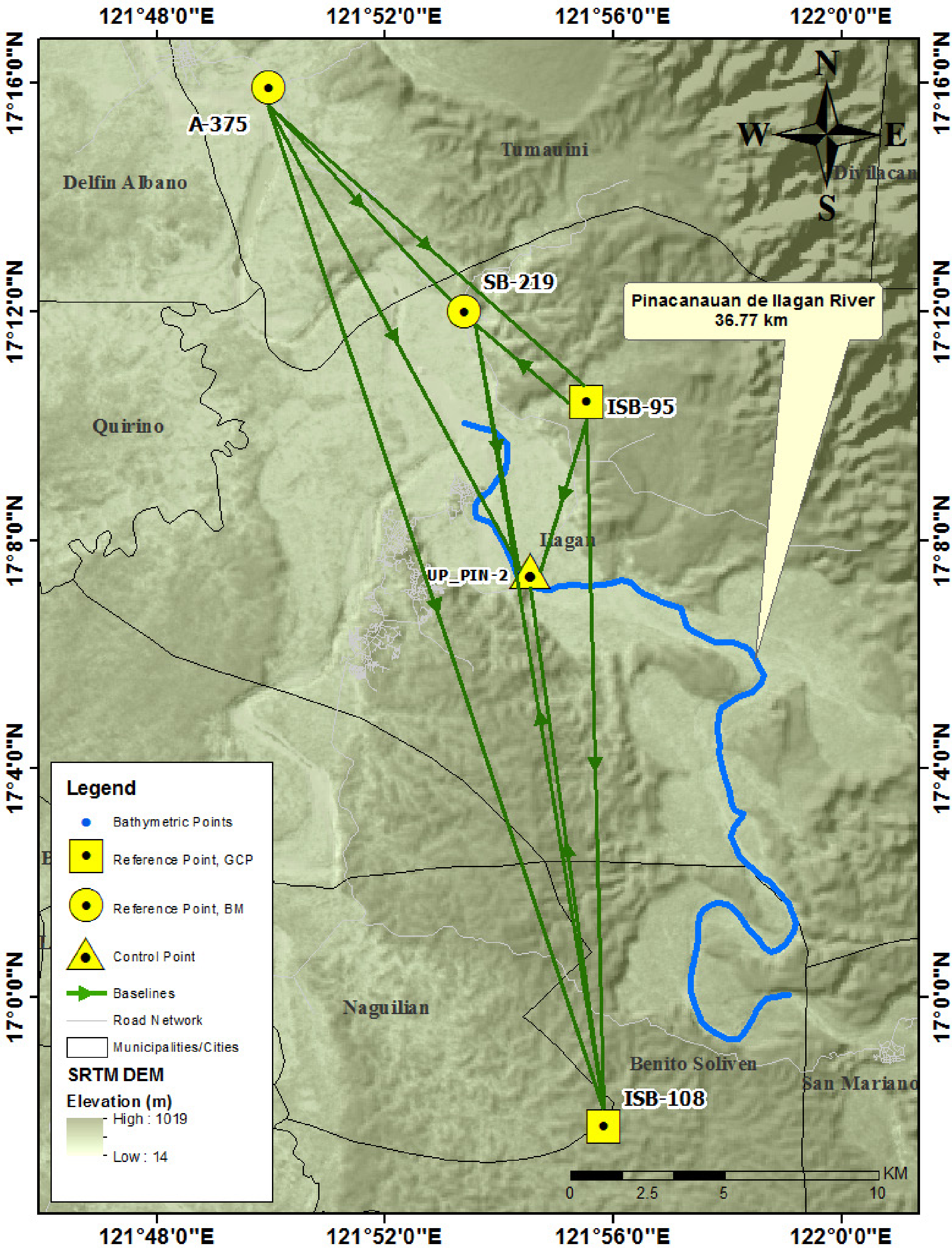


Figure 42. Pinacanauan de Ilagan River Basin Control Survey Extent.

Figure 43 to Figure 47 depict the setup of the GNSS on recovered reference points and established control points in the Pinacanauan de Ilagan River.

Figure 43. GNSS base set up, Trimble® SPS 982, at A-375, located at the approach of Minanga Bridge in Brgy. Maligaya, Ilagan, Isabela.

Figure 44. GNSS receiver set up, Trimble® SPS 882, at ISB-95, located behind a basketball court in Brgy. Morado, Ilagan, Isabela.

Figure 45. GNSS receiver set up, Trimble® SPS 985, at ISB-108, located at the corner of a basketball court in Brgy. San Juan, Ilagan, Isabela.

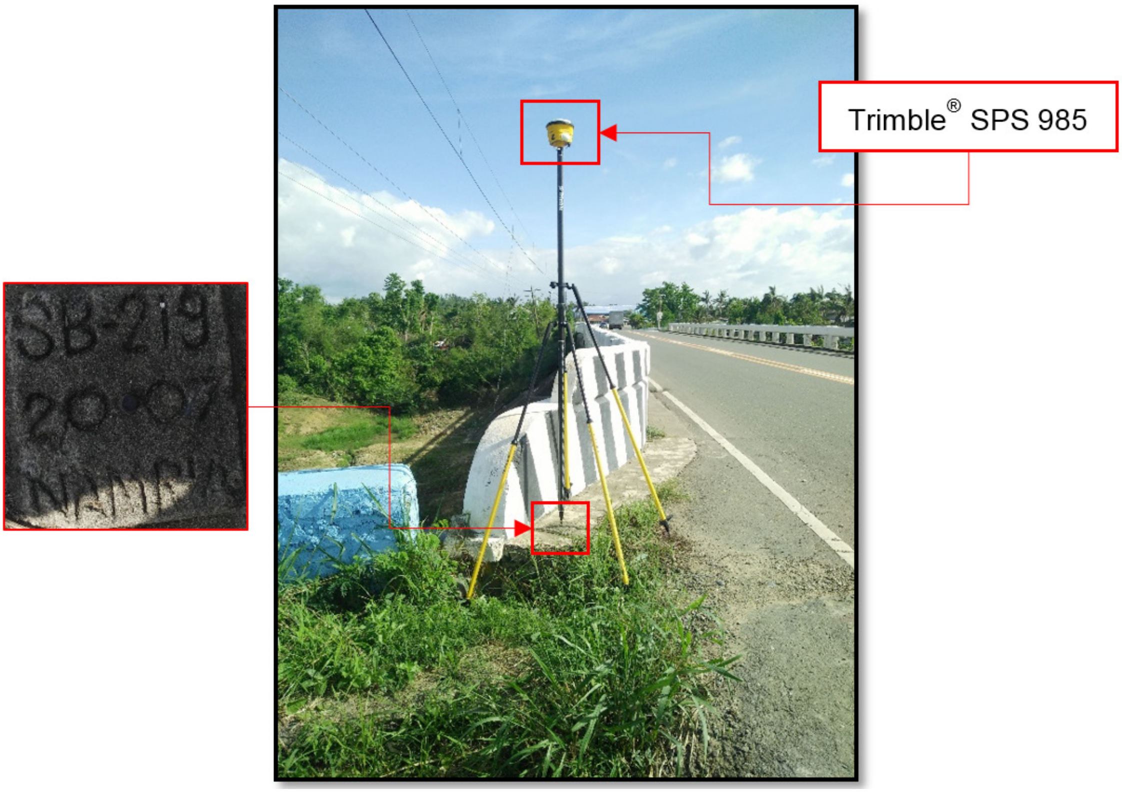


Figure 46. GNSS receiver setup, Trimble® SPS 985, at SB-219, located at the approach of Curillao Bridge in Brgy. San Juan, Ilagan, Isabela.

Figure 47. GNSS receiver set-up, Trimble® SPS 985, at UP_PIN-2, an established control point, located at the approach of Malalam Bridge in Brgy. Alliguigan 2nd, Ilagan, Isabela.

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal or covering of portions of the baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 39 presents the baseline processing results of control points in the Pinacanauan de Ilagan River Basin, as generated by the TBC software.

Table 39. The Baseline processing report for the Pambujan River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (m)
ISB-95 --- UP_PIN-2	12-6-2016	Fixed	0.004	0.016	197°46’54”	5723.415	-14.127
ISB-95--- SB-219	12-6-2016	Fixed	0.003	0.011	307°30’13”	4824.099	-19.036
ISB-95--- ISB-108	12-6-2016	Fixed	0.005	0.024	178°42’05”	23367.262	15.068
A-375 --- SB-219	12-6-2016	Fixed	0.003	0.013	140°02’50”	9440.071	4.241
SB-219 --- UP_PIN-2	12-6-2016	Fixed	0.003	0.016	166°03’59”	8640.850	4.912
ISB-108 --- SB-219	12-6-2016	Fixed	0.004	0.022	350°35’42”	26656.667	-34.101
ISB-108 --- UP_PIN-2	12-6-2016	Fixed	0.004	0.022	352°45’18”	18055.485	-29.192

A-375 --- ISB-108	12-6-2016	Fixed	0.004	0.018	162°43’13”	35117.685	38.315
A-375 --- UP_PIN-2	12-6-2016	Fixed	0.004	0.020	152°27’49”	17618.351	9.155
A-375 --- ISB-95	12-6-2016	Fixed	0.004	0.014	135°48’11”	14187.442	23.274

As shown in Table 39, a total of ten (10) baselines were processed with coordinate and elevation values of A-375 held fixed; it is apparent that all baselines passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, the network adjustment is performed using the TBC software. 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 for each control point; or in equation form:

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

where:

x_e is the Easting Error,
y_e is the Northing Error, and
z_e is the Elevation Error

For complete details, see the Network Adjustment Report shown in Table 40 to Table 42.

The five (5) control points, A-375, ISB-95, ISB-108, SB-219, and UP_PIN-2 were occupied and observed simultaneously to form a GNSS loop. The coordinates and elevation of A-375 was held fixed during the processing of the control points as presented in Table 40. Through this reference point, the coordinates and elevations of the unknown control points will be computed.

Table 40. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
A-375	Grid				Fixed
A-375	Global	Fixed	Fixed		
Fixed = 0.000001(Meter)					

Likewise, 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 41.

Table 41. Adjusted grid coordinates for the control points used in the Pinacanauan de Ilagan River flood plain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
A-375	375900.883	?	1909290.299	?	36.051	?	LLe
ISB-108	386128.463	0.006	1875703.206	0.005	72.888	0.038	
ISB-95	385727.568	0.006	1899061.450	0.006	58.469	0.031	
SB-219	381917.766	0.005	1902018.904	0.005	39.731	0.030	
UP_PIN-2	383949.992	0.006	1893622.490	0.005	44.309	0.035	

The results of the computation for accuracy are as follows:

a. A-375

horizontal accuracy = Fixed

vertical accuracy = Fixed

b. ISB-108

horizontal accuracy = $\sqrt{((0.6)^2 + (0.5)^2}$

= $\sqrt{(0.36 + 0.25)}$

= 0.78 < 20 cm

vertical accuracy = 3.8 < 10 cm

c. ISB-95

horizontal accuracy = $\sqrt{((0.6)^2 + (0.6)^2}$

= $\sqrt{(0.36 + 0.36)}$

= 0.85 < 20 cm

vertical accuracy = 3.1 < 10 cm

d. SB-219

horizontal accuracy = $\sqrt{((0.5)^2 + (0.5)^2}$

= $\sqrt{(0.25 + 0.25)}$

= 0.71 < 20 cm

vertical accuracy = 3.0 < 10 cm

e. UP_PIN-2

horizontal accuracy = $\sqrt{((0.6)^2 + (0.5)^2}$

= $\sqrt{(0.36 + 0.25)}$

= 0.78 < 20 cm

vertical accuracy = 3.5 < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the four (4) occupied control points are within the required precision.

Table 42. Adjusted geodetic coordinates for control points used in the Pinacanauan de Ilagan River Flood Plain validation.

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
A-375	N17°15'55.43093"	E121°'57.14379"	76.625	?	LLe
ISB-108	N16°57'44.56096"	E121°55'49.72283 "	114.953	0.038	
ISB-95	N17°10'24.48319"	E121°55'31.82211"	99.895	0.031	
SB-219	N17°12'00.00795"	E121°53'22.30250"	80.861	0.030	
UP_PIN-2	N17°07'27.19860"	E121°54'32.69181"	85.770	0.035	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 42. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Pinacanauan de Ilagan River GNSS Static Survey are seen in Table 43.

Table 43. The reference and control points utilized in the Pinacanauan de Ilagan River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ell Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
A-375	DPWH	17°15'55.43093"N	121°49'57.14379"E	76.625	1909290.299	375900.883	36.051
ISB-95	Used as marker	17°10'24.48319"N	121°55'31.82211"E	99.895	1899061.45	385727.568	58.469
ISB-108	Used as marker	16°57'44.56096"N	121°55'49.72283"E	114.953	1875703.206	386128.463	72.888
SB-219	Used as marker	17°12'00.00795"N	121°53'22.30250"E	80.861	1902018.904	381917.766	39.731
UP_PIN-2	Established	17°07'27.19860"N	121°54'32.69181"E	85.77	1893622.49	383949.992	44.309

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

The bridge cross-section and as-built survey were conducted on April 22, 2016 at the downstream side of Malalam Bridge in Brgy. Alliguigan 2nd, Ilagan, using a Horizon® Total Station (Figure 48 and Figure 49).

Figure 48. Downstream side of Malalam Bridge.

Figure 49. As-Built Survey of the Malalam Bridge.

The length of the cross-sectional line surveyed at Malalam Bridge is about 740 m. (Figure 52) with two hundred eighty-nine (289) cross-sectional points using the control points UP_PIN-1 and UP_PIN-2 as the GNSS base stations. The location map, cross-section diagram, and the accomplished bridge data form are shown in Figure 51 to Figure 53.

Gathering of random points for the checking of ABSD's bridge cross-section and bridge points data was performed by DVBC on August 25, 2016 using a survey grade GNSS Rover receiver attached to a 2-m pole as seen in Figure 50.

Figure 50. Gathering of random cross-section points along Malalam Bridge.

Linear square correlation (R^2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R^2 value must be within 0.85 to 1. An R^2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R^2 value of 0.869 was obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bridge cross-section data, a computed value of 0.299 was acquired. The computed R^2 and RMSE values are within the accuracy requirement of the program.

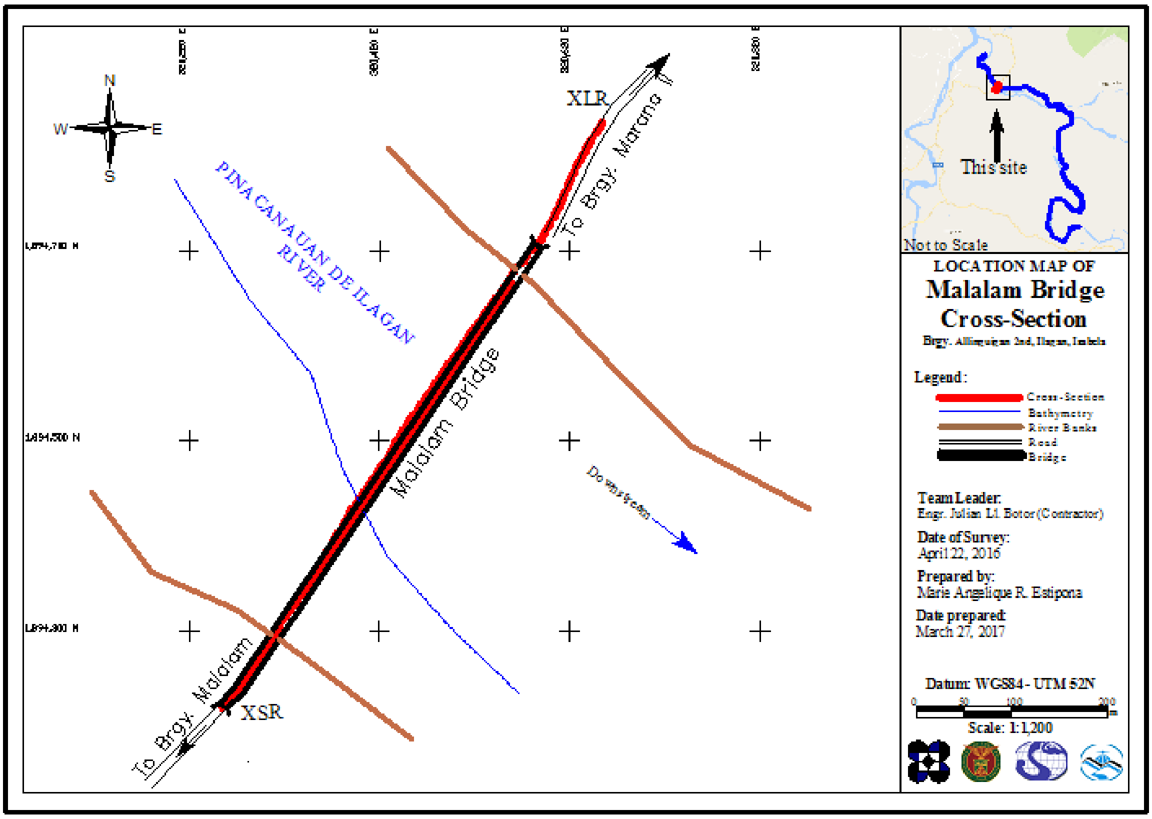


Figure 51. Location map of the Maalam Bridge Cross Section.

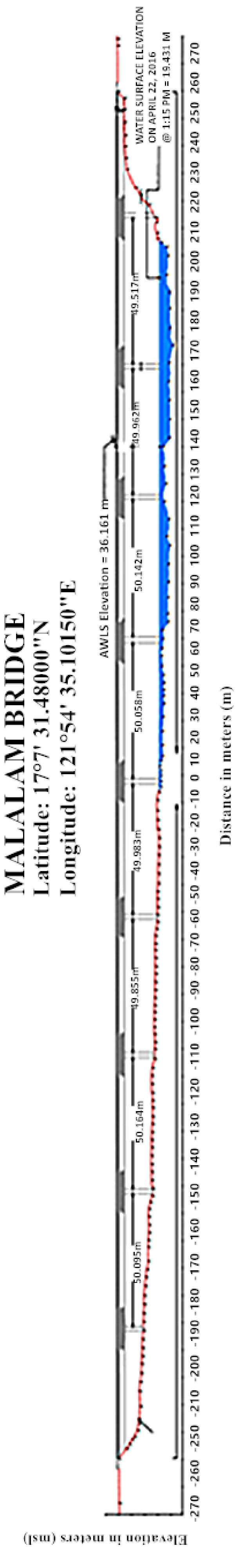


Figure 52. The Maalam Bridge cross-section survey drawn to scale.

Bridge Data Form

Bridge Name: Malalam Bridge

River Name: Pinacanauan de Ilagan River

Location (Brgy, City, Region): Brgy. Allinguigan 2nd, Ilagan, Isabela

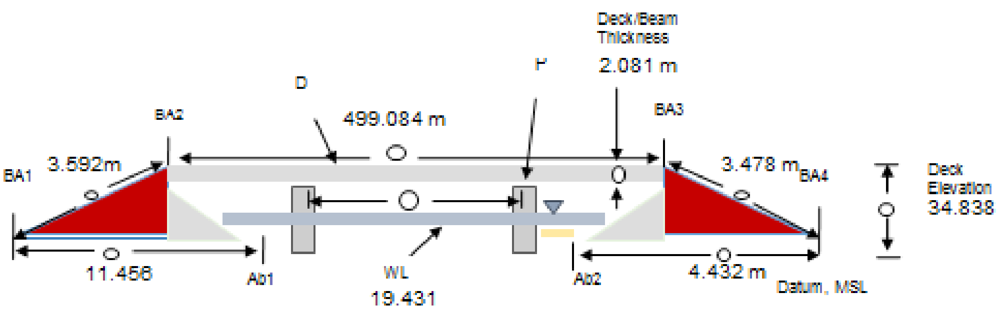
Survey Team: Alpas Nilo

Date and Time: April 22, 2016 at 1:15 pm

Flow Condition: low ✔normal high

Weather Condition: ✔fair rainy

Cross-sectional View (not to scale)



Legend:
BA = Bridge Approach
P = Pier
Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
◯ = Measurement Value

Line Segment	Measurement (m)	Remarks
1. BA1-BA2	3.592 m	
2. BA2-BA3	499.084 m	
3. BA3-BA4	3.478 m	
4. BA1-Ab1	11.456 m	
5. Ab2-BA4	4.432 m	
6. Deck/beam thickness	2.081 m	
7. Deck elevation	34.838 m	

Note: Observer should be facing downstream

Figure 53. The Maalam Bridge as-built survey data.

The water surface elevation of Pinacanauan de Ilagan River was determined using a Horizon® Total Station on April 22, 2016 at 1:15 PM at Malalam Bridge area with a value of 19.431 m in MSL as shown in Figure 52. This was translated into marking on the bridge's pier using the same technique as shown in Figure 54. It now serves as the reference for flow data gathering and depth gauge deployment of the Isabela State University (ISU), the partner HEI responsible for the monitoring of Pinacanauan de Ilagan River.

Figure 54. Water level markings on Maalam Bridge.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted by DVBC on December 9, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached on the rear side of the vehicle as shown in Figure 55. It was secured with cable ties to ensure that it was horizontally and vertically balanced. The antenna heights was 1.985 m and measured from the ground up to the bottom of the antenna mount of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP_PIN-2 occupied as the GNSS base station in the conduct of the survey.

Figure 55. GNSS Receiver Trimble® SPS 882 installed on a vehicle for Ground Validation Survey.

The survey started from Brgy. Marana I, Ilagan, Isabela going southeast along the national highway, covering eight (8) barangays in the Ilagan, four (4) barangays in Gamu, seven (7) barangays in Naguilian, seven (7) barangays in Benito Soliven,and ended in Brgy. Zone I, Municipality of Benito Soliven, Isabela. The survey gathered a total of 2,383 points with approximate length of 47.02 km using UP_PIN-2 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 56.

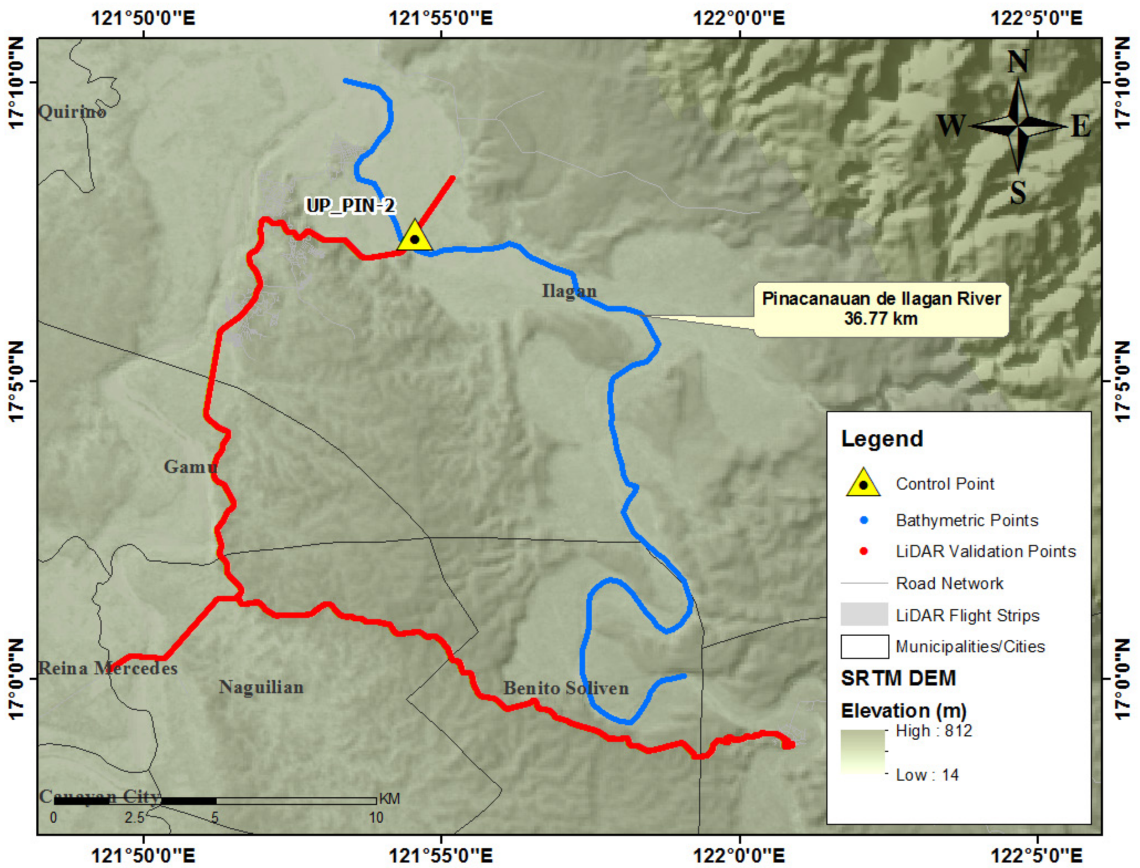


Figure 56. The extent of the LiDAR ground validation survey (in red) for Pinacanauan de Ilagan River Basin.

4.7 River Bathymetric Survey

A bathymetric survey was performed on May 25, 2016 using a single-beam echo sounder. The survey started in Brgy. Bangang, Ilagan, Isabela with coordinates 17° 8’ 59.58406”N, ° 53’ 51.65304”E and ended in Brgy. Santa Barbara, Ilagan, Isabela with coordinates 17° 8’ 24.40694”N, 121° 53’ 34.71180”E. The survey continued in Brgy. Cabeseria 14 & 16, Ilagan, Isabela with coordinates 17° 5’ 52.90112”N, 121° 58’ 29.08812”E and ended in Brgy. Bagumbayan, Ilagan, Isabela with coordinates 17° 5’ 23.78429”N, 121° 58’ 31.70604”E. The survey also continued in Brgy. Cabeseria 9 & 11, Ilagan, Isabela with coordinates 17° 2’ 54.88642”N, 121° 58’ 5.63376”E and ended in Brgy. Yeban Norte, Benito Soliven, Isabela with coordinates 17° 0’ 50.70863”N, 121° 59’ 0.15288”E. Lastly, the survey was continued in Brgy. Maluno Sur, Benito Soliven, Isabela with coordinates 16° 59’ 54.04484”N, 121° 58’ 30.86688”E and ended in Brgy. Maluno Sur, Benito Soliven, Isabela as well with coordinates 17° 0’ 5.01149”N, 121° 59’ 3.20712”E.

Manual bathymetric survey, on the other hand, was executed on April 20-28, 2016 using a Nikon® Total Station as shown in Figure 57. The survey started in Brgy. Santa Barbara, Ilagan, Isabela with coordinates 17° 8’ 22.44962”N, 121° 53’ 37.24152”E and ended in Brgy. Cabeseria 9 & 11, Ilagan, Isabela with coordinates 17° 2’ 55.53600”N, 121° 58’ 5.80800”E. The survey continued in Brgy. Yeban Norte, Benito Soliven, Isabela with coordinates 17° 0’ 52.41600”N, 121° 58’ 42.42000”E and ended in Brgy. Maluno Sur, Benito Soliven, Isabela with coordinates 16° 59’ 22.66800”N, 121° 58’ 15.34800”E. The control point AB-1, AB-5, AB-6, Ab-7, and AB-8 were used as GNSS base stations all throughout the entire survey.

Figure 57. Set-up for the manual bathymetric survey of ABSD along Pinacanauan de Ilagan River.

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on August 26, 2016 using a survey grade GNSS Rover receiver attached to a boat as seen in Figure 58. A map showing the DVBC bathymetric checking points is shown in Figure 60.

Figure 58. Gathering of random bathymetric points along Pinacanauan de Ilagan River.

Linear square correlation (R^2) and RMSE analysis were also performed on the two (2) datasets and a computed R^2 value of 0.985 for the bathymetric data is within the required range for R^2, which is 0.85 to 1. Additionally, an RMSE value of 0.210 for the bathymetric data was obtained. Both the computed R^2 and RMSE values are within the accuracy required by the program.

Overall, the bathymetric survey for Pinacanauan de Ilagan River gathered a total of 27,509 points covering 36.77 km of the river traversing barangays Maraning, Bangag, Capo, Santa Barbara, Maran II, Allinguigan 2nd, Allinguigan 3rd, Sipay, Cadu, Ballacong, Cabeseria 5, Cabeseria 14 & 16, Bagumbayan, Baculod, Centro Poblacion, Cabeseria 17 & 21, Cabeseria 19, Cabeseria 9 & 11, and Cabeseria 7 in the Municipality of Ilagan and among barangays Yeban Norte, Maluno Norte, Yeban Sur, District II, and Maluno Sur in the Municipality of Benito Soliven. To further illustrate this, a CAD drawing of the riverbed profile of the Pinacanauan de Ilagan River was produced. As seen in Figure 61, the highest and lowest elevation has a 17-m difference. The highest elevation observed was 34.944 m above MSL located in Brgy. Bangag, Ilagan, Isabela while the lowest was 17.542 m above MSL located in Brgy. Maluno Sur, Benito Soliven, Isabela.

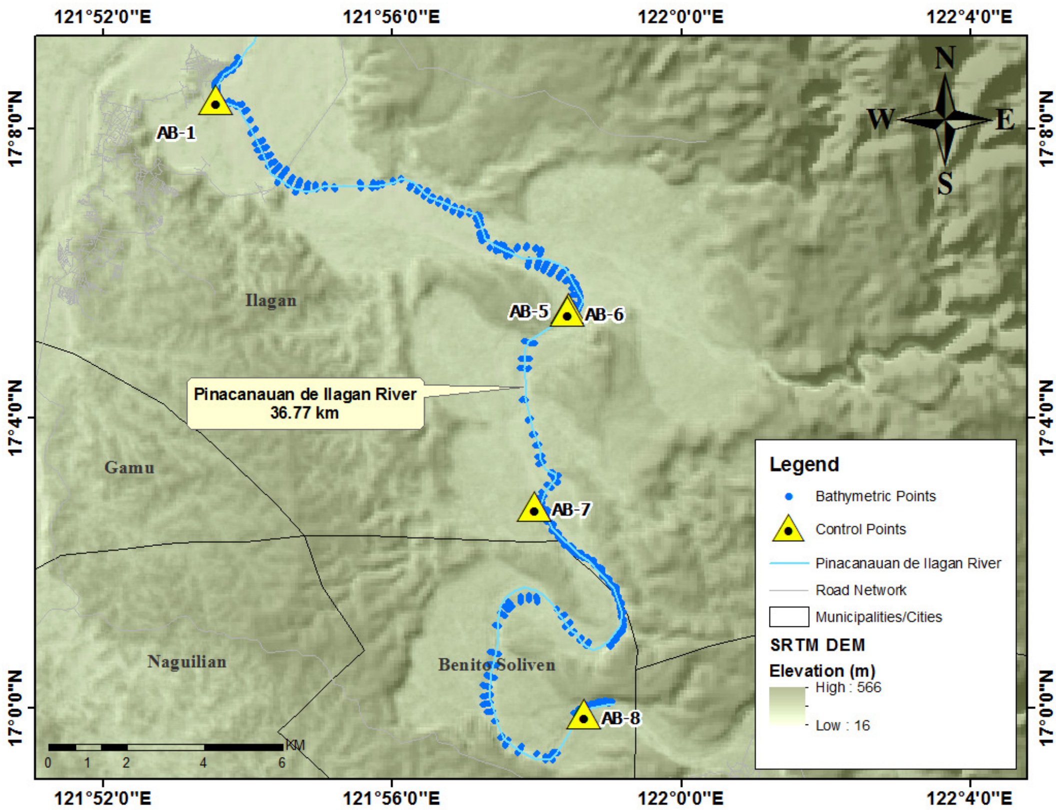


Figure 59. The extent of the Pinacanauan de Ilagan River Bathymetry Survey.

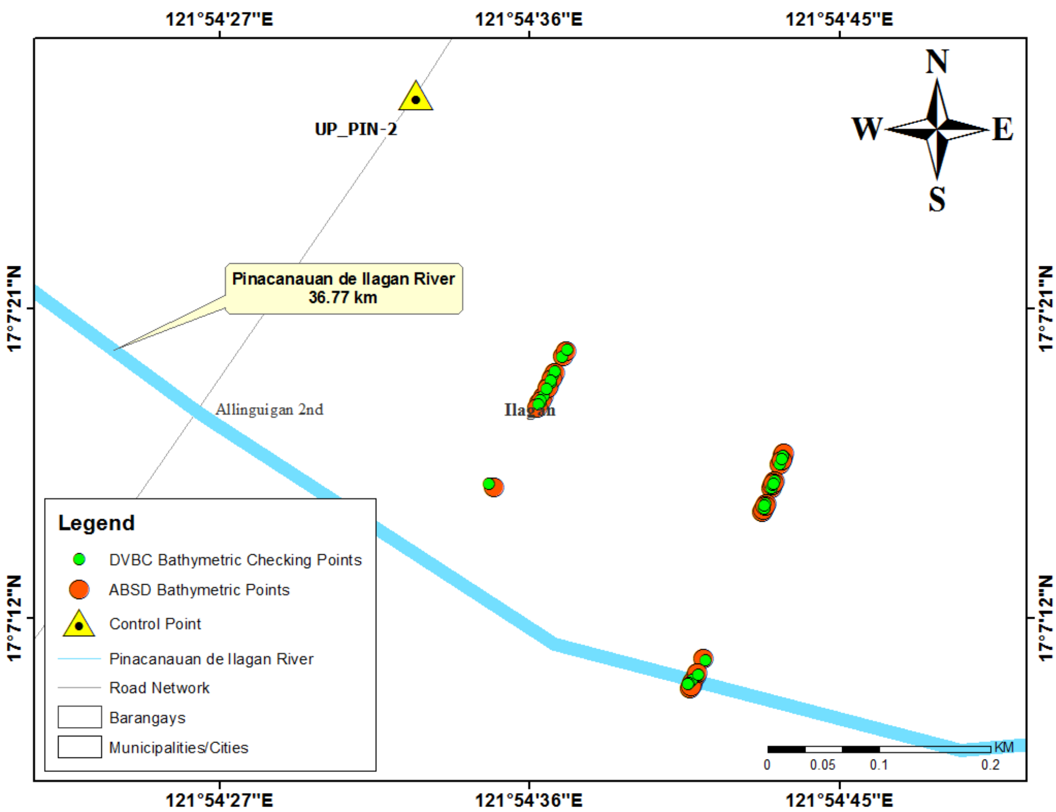


Figure 60. Quality checking points gathered by the DVBC along the Pinacanauan de Ilagan River.

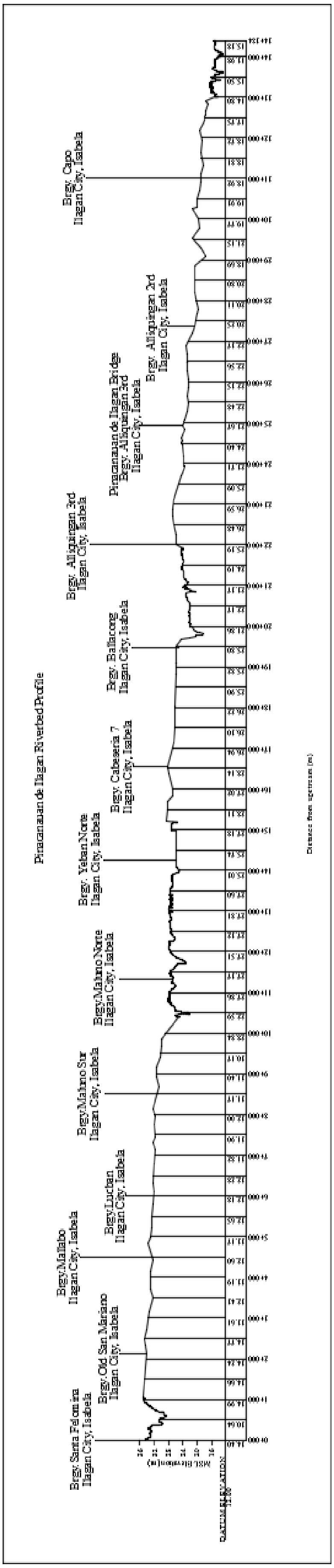


Figure 61. Pinacanauan de Ilagan Riverbed Profile.

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, Mariel Monteclaro

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).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data, such as rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Pinacanauan de Ilagan River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Isabela, including the Pinacauan de Ilagan River basin, was under Signal No. 5 during the landfall of Super Typhoon Lawin last 20 October 2016. The hydrologic data collection covered the period 10:00 A.M. on 19 October 2016 until 12:10 A.M. on 21 October 2016. Hydrologic data include the river velocity, water depth and rain collected from data logging sensors (mechanical velocity meter, depth gauge and rain gauges) in specific time period. Precipitation data was taken from the automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). These were San Mariano Municipal Hall ARG and LGU Compound Ilagan City ARG. The location of the rain gauges is illustrated in Figure 62. Rainfall data were downloaded from the web portal of Philippine E-Science Grid-ASTI (http://repo.pscigrid.gov.ph).

The total precipitation for this event in LGU Compound Ilagan rain gauge was 33.2 mm. It has a peak rainfall of 5.8 mm. on 19 October 2016 at 8:00 P.M.. The lag time between the peak rainfall and discharge is 9 hours and 10 minutes.

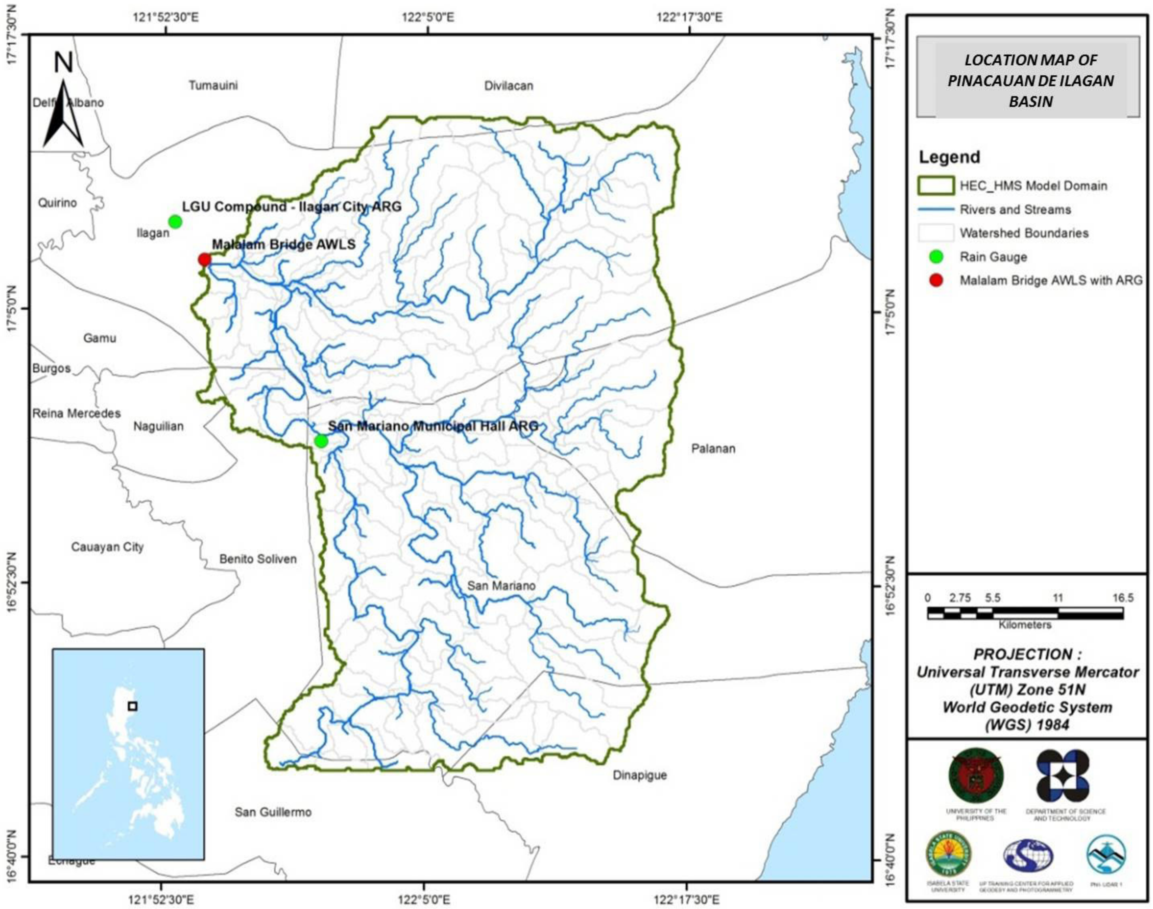


Figure 62. Location Map of the Pinacanauan de Ilagan HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 63 at Pinacanauan de Ilagan Bridge (Malalam Bridge) to establish the relationship between the observed water levels (H) from Pinacanauan de Ilagan Bridge and the outflow (Q) of the watershed at this location.

Super Typhoon Lawin that occurred on 19 to 21 October 2016 contributed to a 34.5889 meter water level rise with peak discharge of 6913.64 m^3/s recorded at 4:10 AM on 20 October 2016 with accumulated rainfall 165.5 mm. These hydrologic data is the actual event of Pinacauan de Ilagan River and inputted to hydrologic modeling. Hydrologic measurements were taken from Malalam Bridge, Malalam, Ilagan, Isabela.

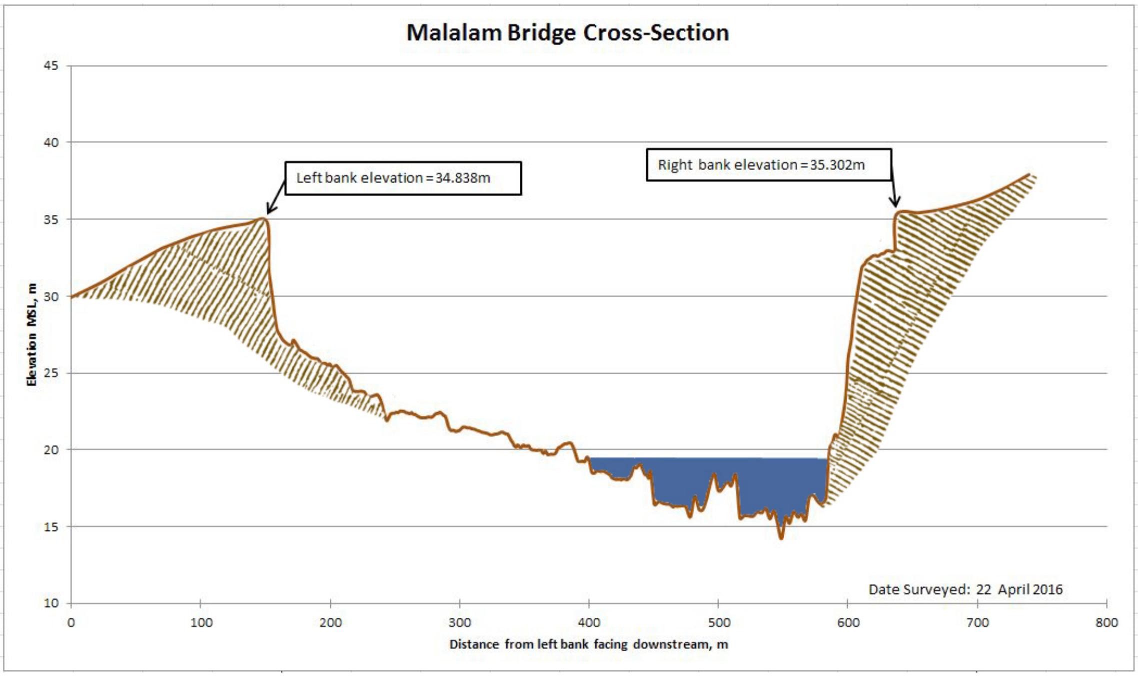


Figure 63. Cross-Section Plot of Pinacanauan de Ilagan Bridge (Malalam Bridge).

The Aunugay River Rating Curve measured at Pateng Bridge is expressed as Q = $28.461e^{0.1588x}$ as shown in Figure 64.

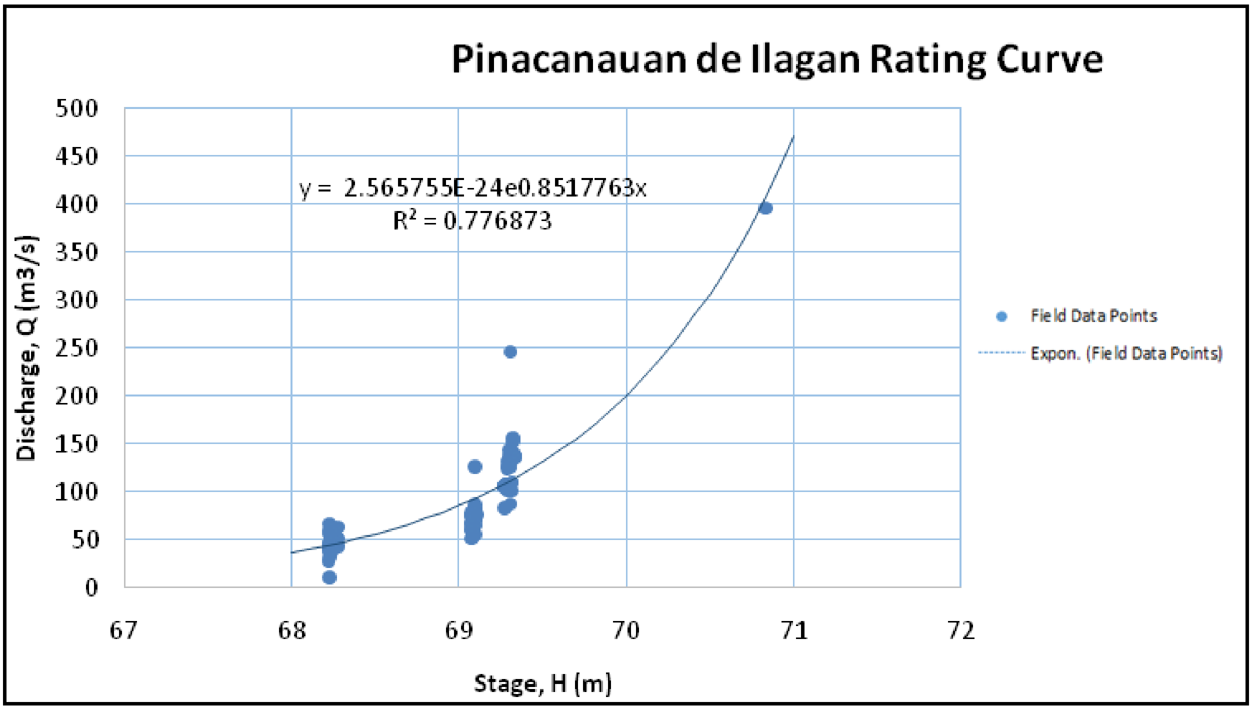


Figure 64. The rating curve at PInacanauan de Ilagan Bridge.

A rating curve was generated for the observed flow and water level. It shows the relationship of the two hydrologic data, expressed in the form of the following equation:

$$Q=a^{nh}$$

where, Q : Discharge (m^3/s),

h : Gauge height (reading from Malalam Bridge AWLS), and

a and n : Constants.

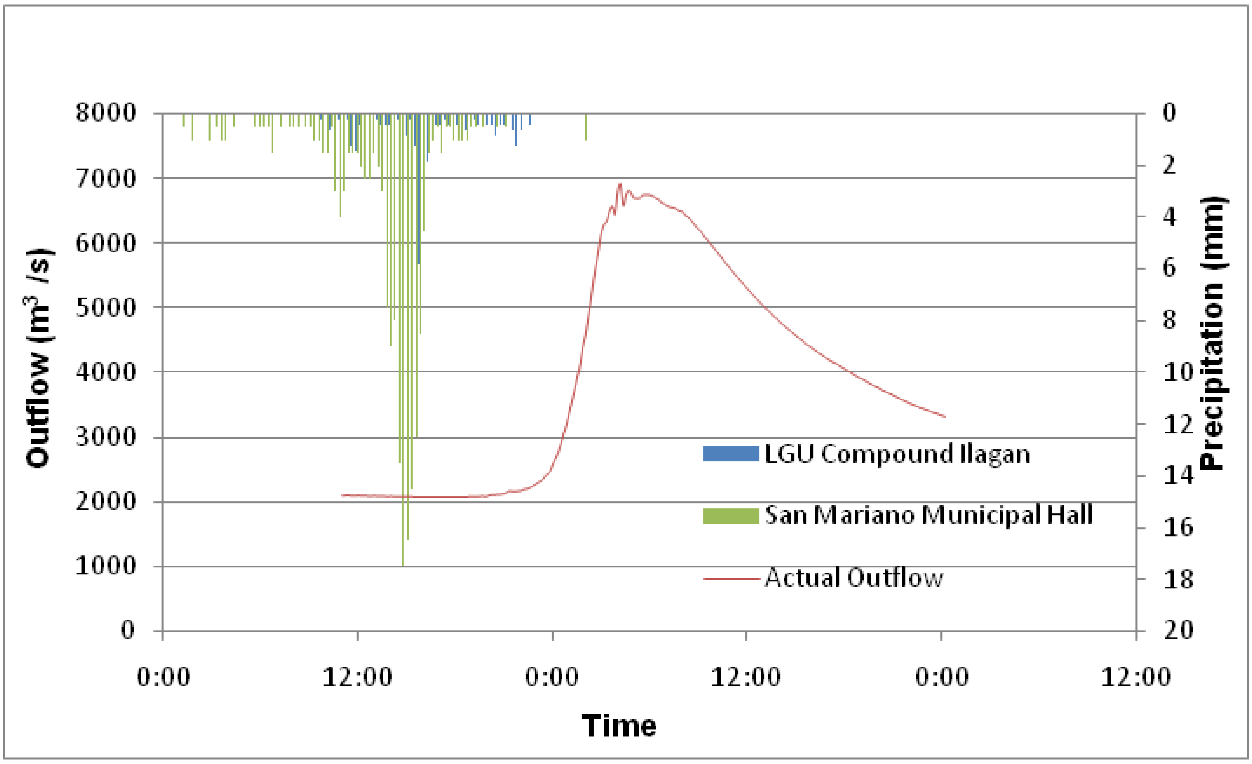


Figure 65. Rainfall and outflow data which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Laoag Rain Gauge (Table 44). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 66). This station was selected based on its proximity to the Pinacanauan de Ilagan watershed. The extreme values for this watershed were computed based on a 37-year record.

Table 44. RIDF values for the Laoag Rain Gauge, as 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	19.7	30.2	38.1	51.9	72.4	86.6	114.7	142.8	168.5
5	28.5	43.3	54.4	73.2	106.7	126.5	167.7	214.9	248
10	34.3	52	65.2	87.3	129.4	152.8	202.8	262.7	300.7
15	37.6	56.9	71.3	95.3	142.2	167.7	222.6	289.6	330.4
20	39.9	60.3	75.5	100.8	151.1	178.1	236.5	308.5	351.2
25	41.7	62.9	78.8	105.1	158	186.1	247.2	323	367.2
50	47.1	71	88.9	118.4	179.3	210.9	280.1	367.8	416.5
100	52.6	79.1	98.9	131.5	200.4	235.4	312.7	412.2	465.5

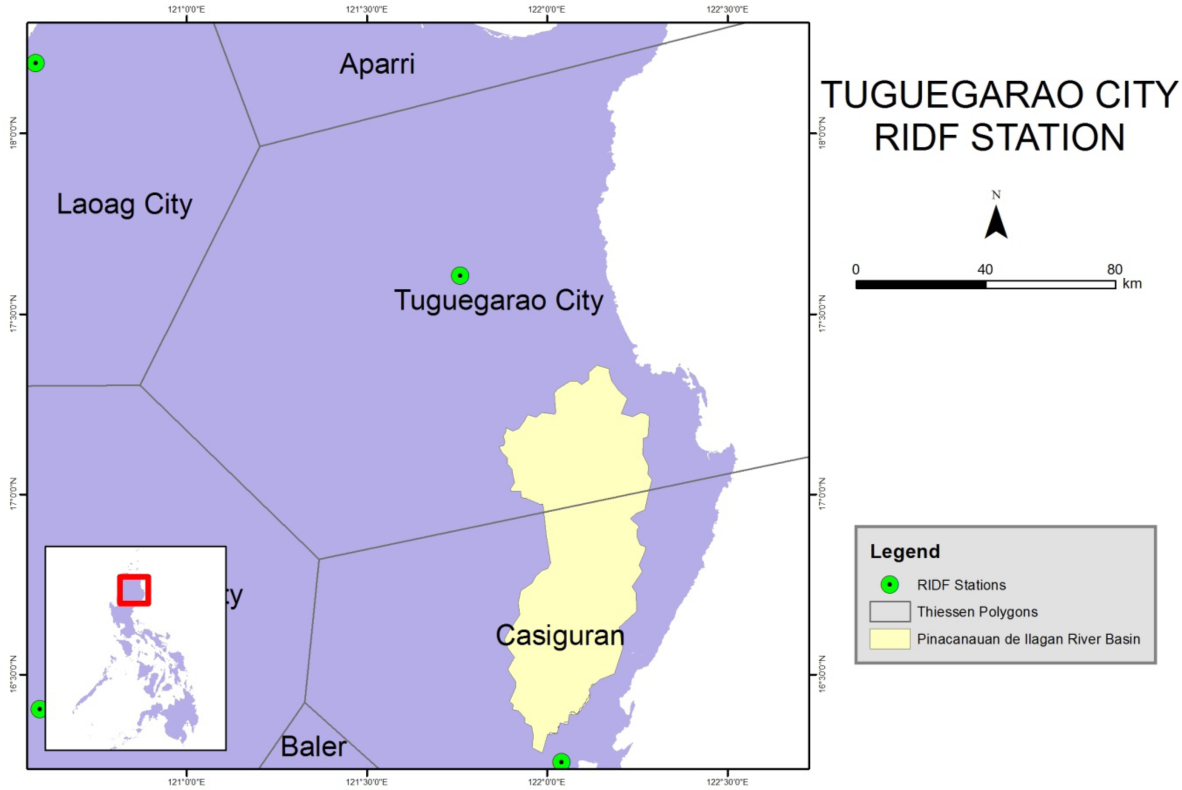


Figure 66. Location of Tuguegarao RIDF Station relative to Pinacanauan de Ilagan River Basin.

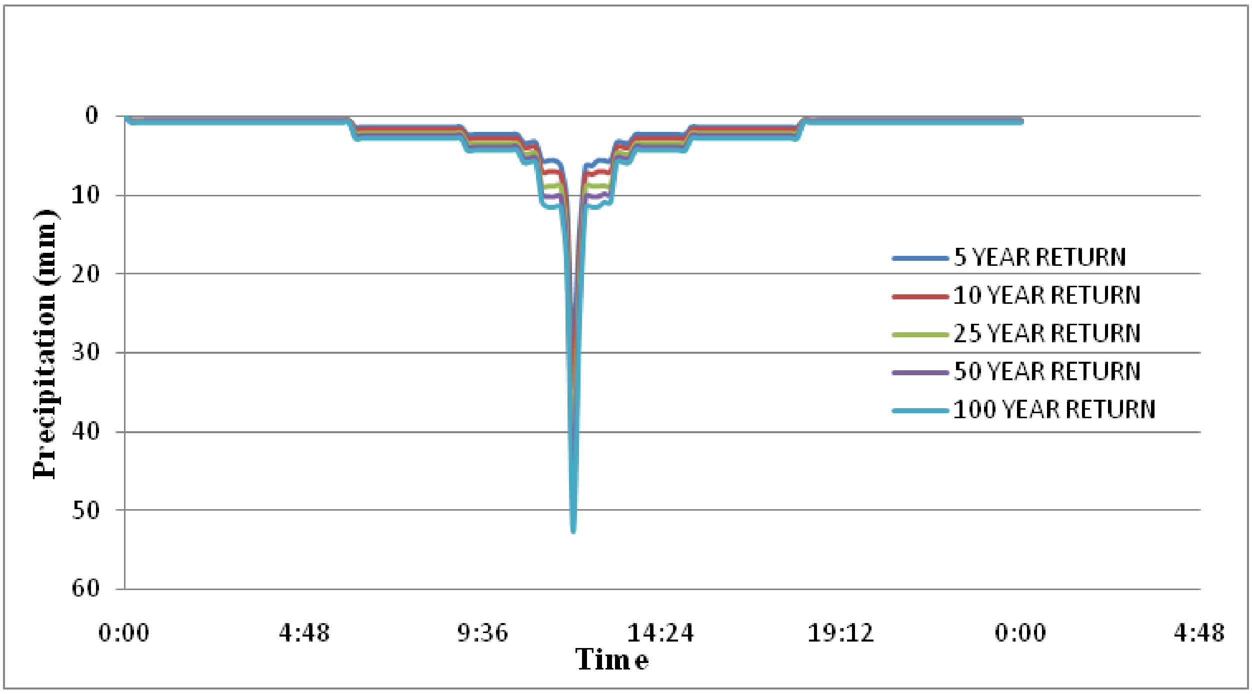


Figure 67. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 from the Bureau of Soils under the Department of Environment and Natural Resources Management. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Pinacanauan de Ilagan River Basin are shown in Figure 68 and Figure 69, respectively.

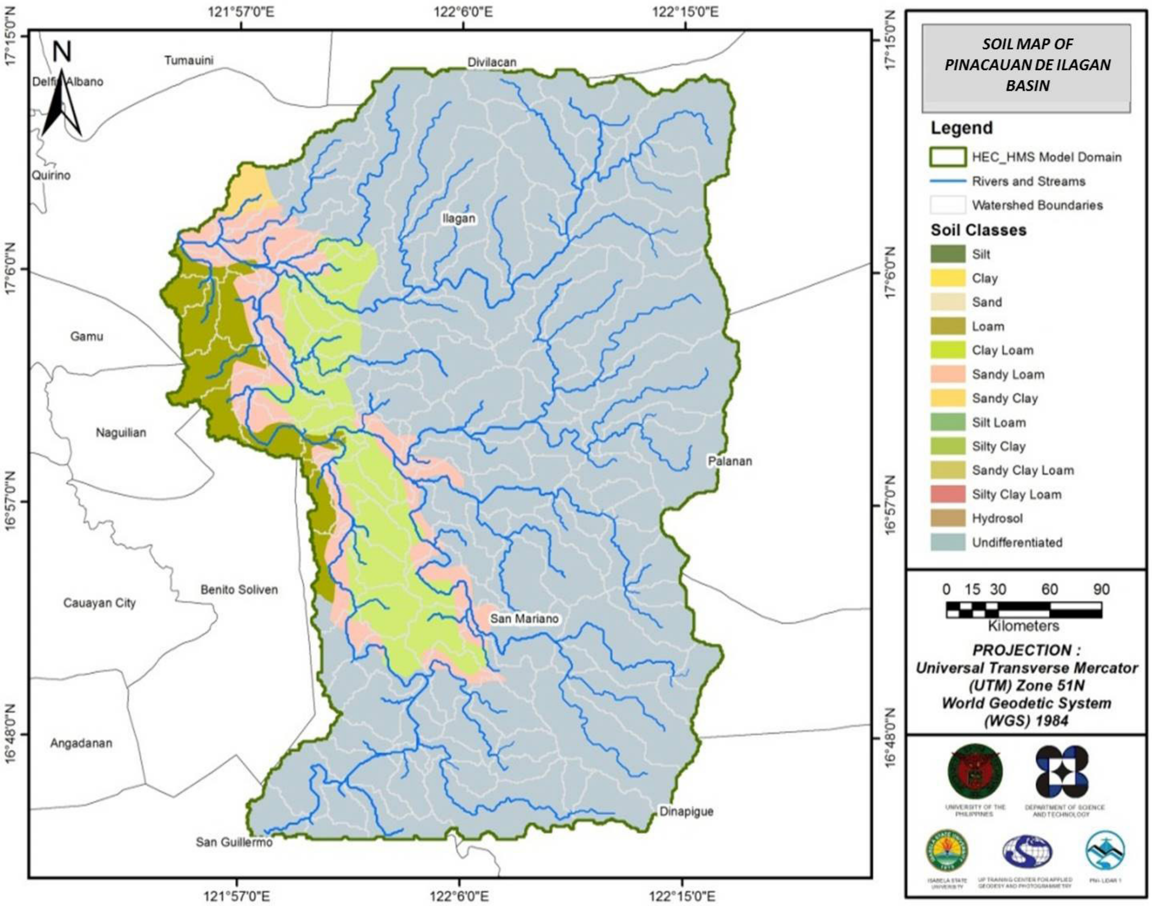


Figure 68. Soil Map of Pinacanauan de Ilagan River Basin.

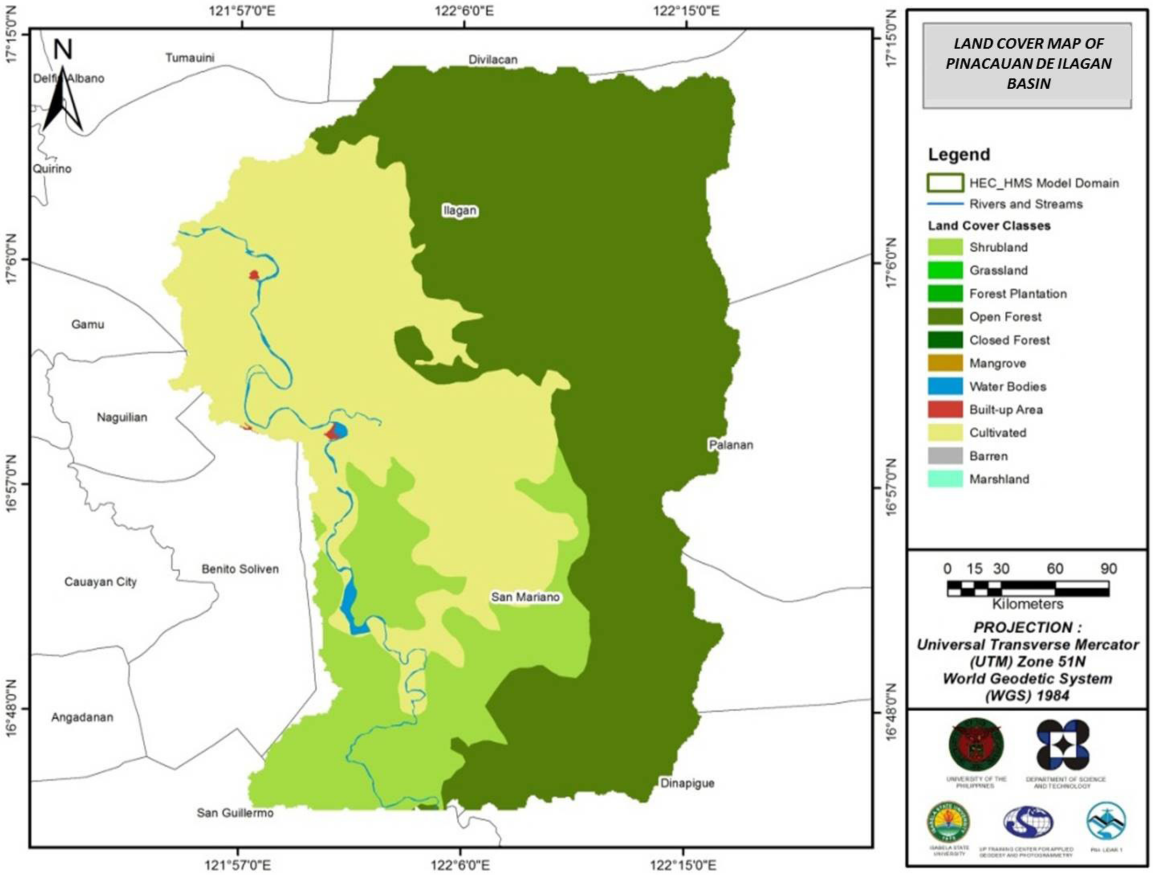


Figure 69. Land Cover Map of Pinacanauan de Ilagan River Basin.

For Pinacauan de Ilagan, thirteen (13) soil classes were identified. These are silt, clay, sand, loam, clay loam, sandy loam, sandy clay, silt loam, silty clay, sandy clay loam, silty clay loam, hydrosol and undifferentiated soil. Moreover, eleven (11) land cover classes were identified. These are shrubland, grassland, forest plantation, open forest, closed forest, mangrove, water bodies, built-up area, cultivated area, barren and marshland.

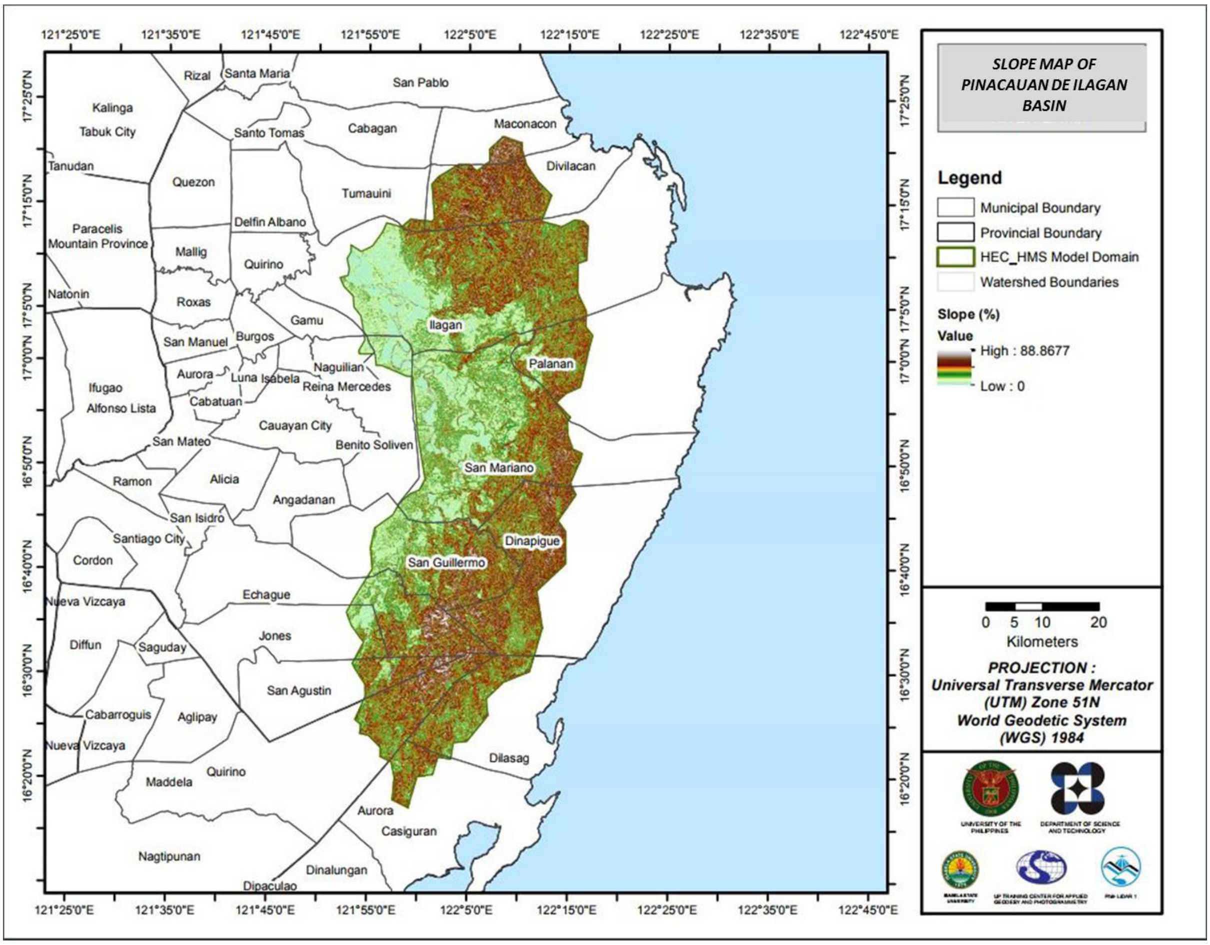


Figure 70. Slope Map of the Pinacanauan de Ilagan River Basin.

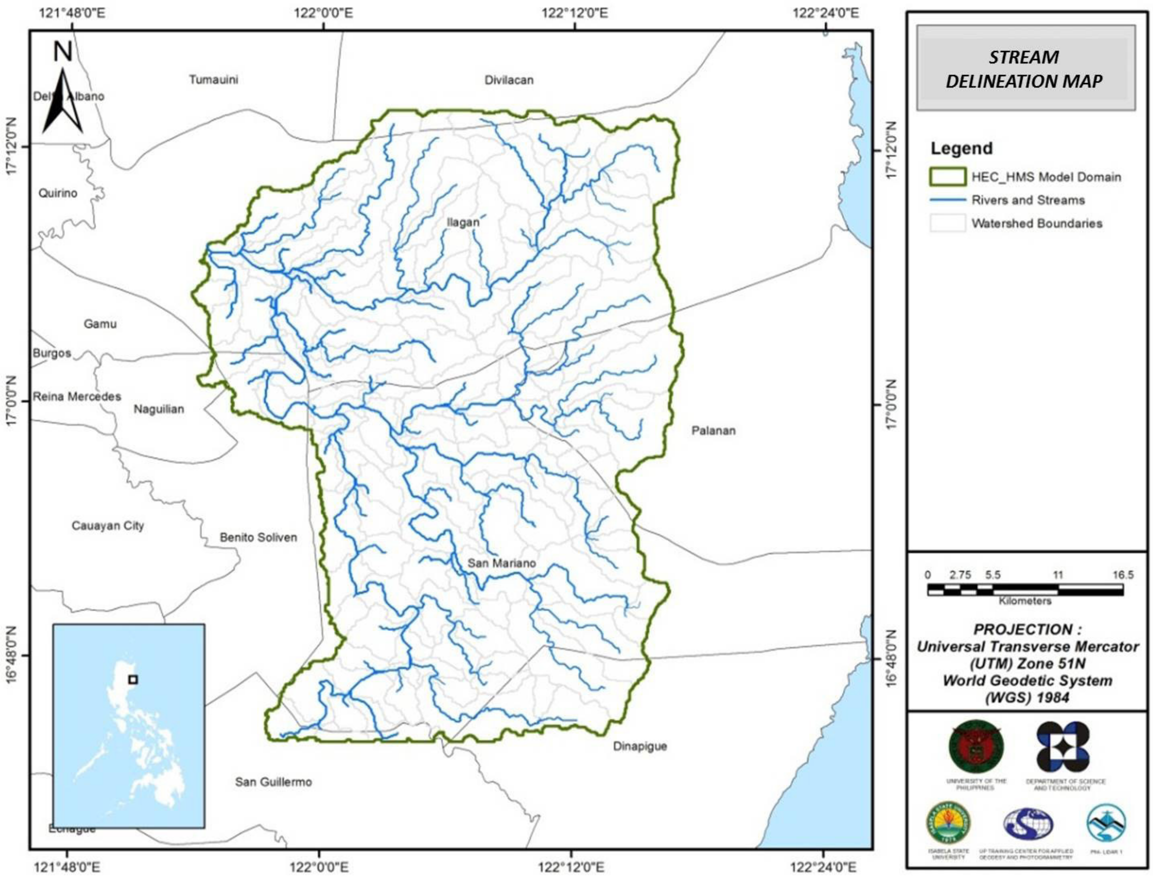


Figure 71. Stream Delineation Map of Pinacanauan de Ilagan River Basin

A drainage system includes the basin boundary, subbasin and the stream networks of the basin. Using ArcMap 10.2 with HEC-GeoHMS version 10.2 extension, the Pinacauan de Ilagan River centerline and SAR-DEM 10m resolution served as primary data, delineating the drainage system of the Pinacauan de Ilagan river basin. The river centerline was digitized starting from upstream towards downstream in Google Earth (2014). Default threshold area used is 140 hectares.

Using the SAR-based DEM, the Pinacauan de Ilagan basin was delineated and further subdivided into subbasins. The Pinacauan de Ilagan basin model consists of 159 subbasins, 79 reaches, and 79 junctions as shown in Figure 72 (See Annex 10). The main outlet is Outlet 1. The basins were identified based on soil and land cover characteristics of the area. Precipitation from the 19-21 October 2016 (Super Typhoon Lawin) was taken from DOST rain gauges. Finally, it was calibrated using data from the Malalam Bridge AWLS.

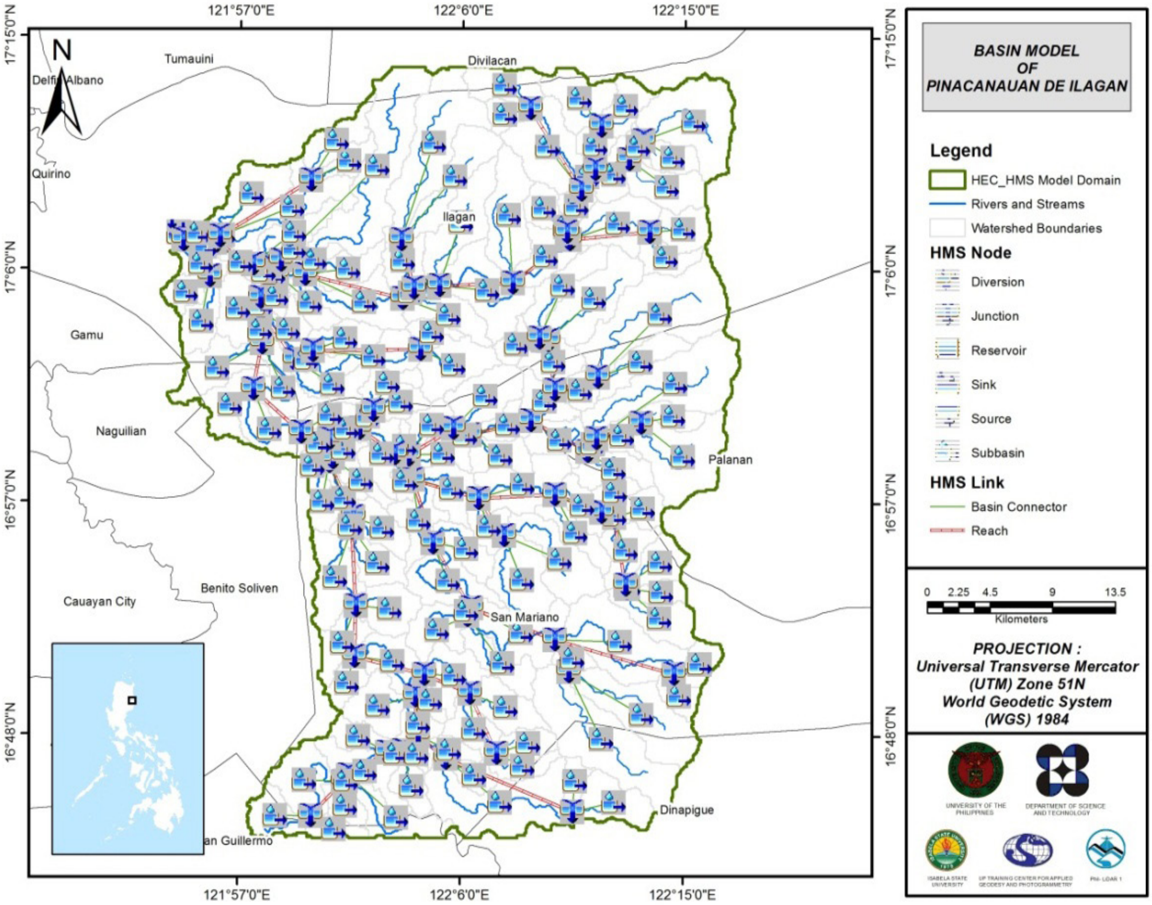


Figure 72. Pinacanauan de Ilagan river basin model generated in HEC-HMS.

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 73).

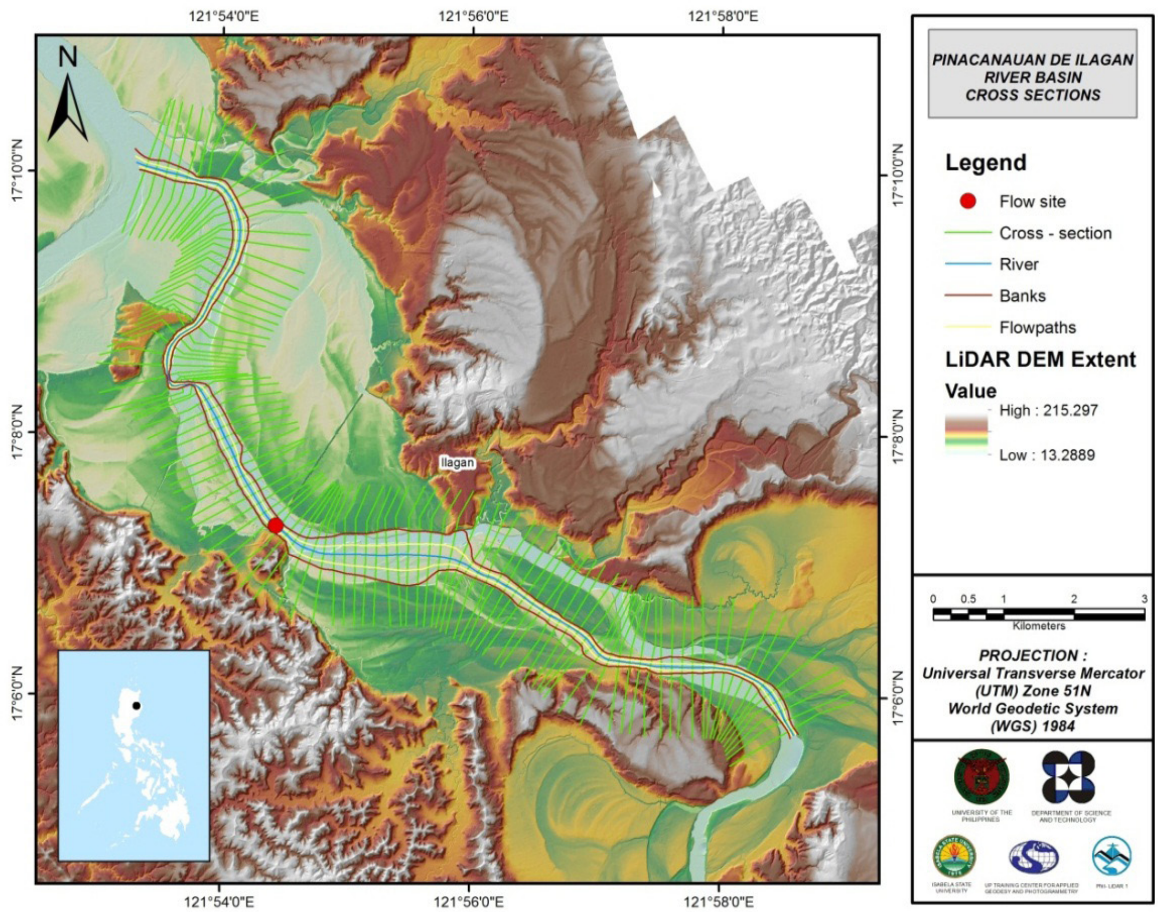


Figure 73. River cross-section of the Pinacanauan de Ilagan River through the HEC GeoRas tool.

5.5 Flo 2D Model

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

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

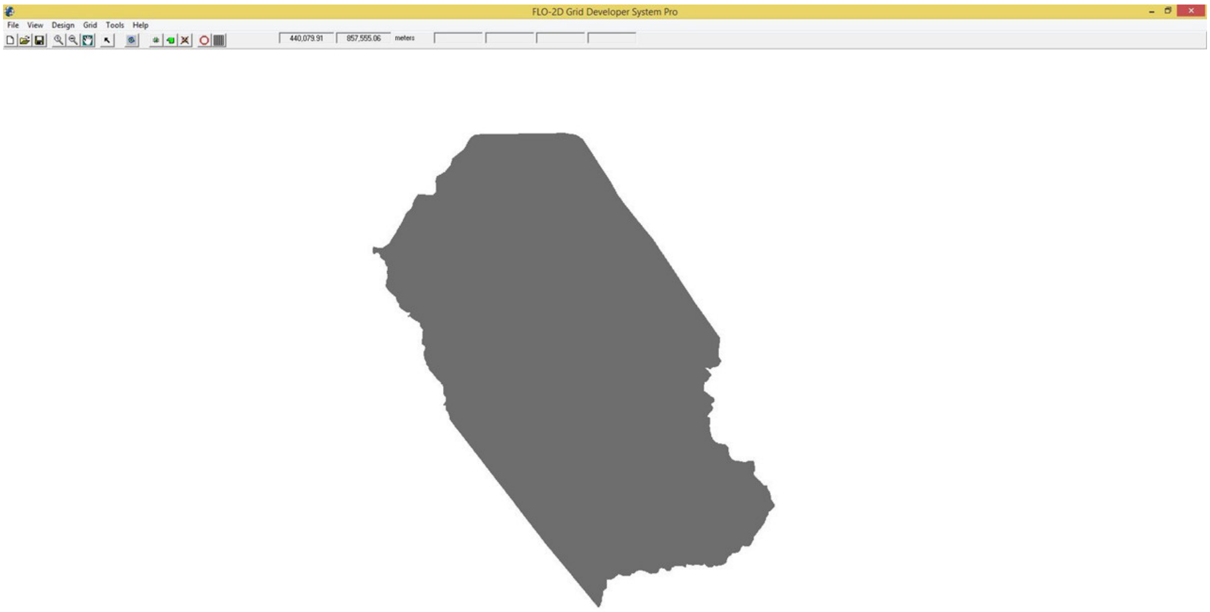


Figure 74. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro).

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 100.06329 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 m^2/s. The generated hazard maps for Pinacanauan de Ilagan are in Figure 78, 80, and 82.

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 63 792 800.00 m^2. The generated flood depth maps for Pinacanauan de Ilagan are in Figure 79, 81, and 83.

There is a total of 465 228 177.98 m^3 of water entering the model. Of this amount, 25 253 779.51 m^3 is due to rainfall while 439 974 398.47 m^3 is inflow from other areas outside the model. 11 329 565.00 m^3 of this water is lost to infiltration and interception, while 24 641 579.81 m^3 is stored by the flood plain. The rest, amounting up to 429 257 024.59 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Pinacanauan de Ilagan HEC-HMS river basin model (See Annex 9), its accuracy was measured against the observed values. Figure 75 shows the comparison between the two discharge data.

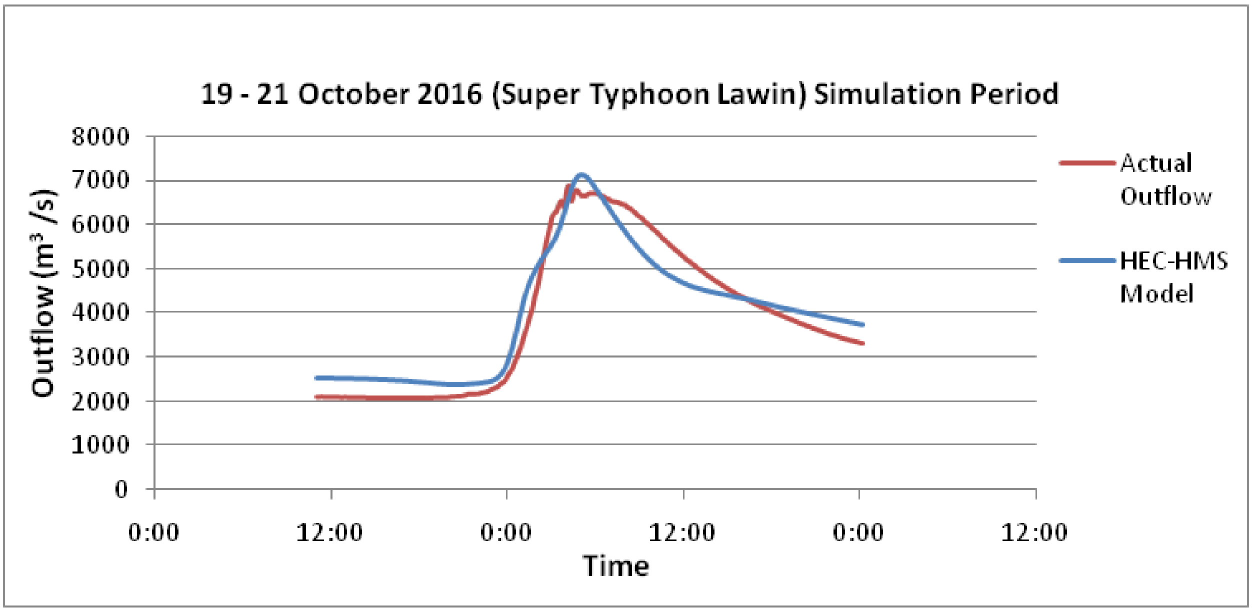


Figure 75. Outflow Hydrograph of Pinacanauan de Ilagan produced by the HEC-HMS model compared with observed outflow.

Table 45 shows the adjusted ranges of values of the parameters used in calibrating the model.

Table 45. Range of calibrated values for the Pinacanauan de Ilagan River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	6.28 - 76
			Curve Number	40 - 89
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02 – 0.57
			Storage Coefficient (hr)	0.04 – 2.04
	Baseflow	Recession	Recession Constant	0.65
			Ratio to Peak	0.3
Reach	Routing	Muskingum-Cunge	Manning’s Coefficient	0.04

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 6.28 mm to 76 mm signifies that there is minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range for the curve number of Pinacanauan de Ilagan River Basin is 40 to 89. For Pinacauan de Ilagan, the basin mostly consists of open forest, cultivated-area and shrubland and the soil mostly consists of undifferentiated soil.

The 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 0.02 hours to 2.04 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.65 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.3 indicates a steep receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.04 corresponds to the common roughness in Pinacanauan de Ilagan watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

Table 46. Summary of the Efficiency Test of the Pinacanauan de Ilagan HMS Model

Accuracy measure	Value
RMSE	423.10
r^2	0.9557
NSE	0.93
PBIAS	-2.35
RSR	0.26

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 423.10 (m^3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9557.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here the optimal value is 1. The model attained an efficiency coefficient of 0.93.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -2.35.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.26.

5.7 Calculated Outflow hydrographys and Discharge Values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 76) shows the Pinacanauan de Ilagan outflow using the Tuguegarao Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results show increasing outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

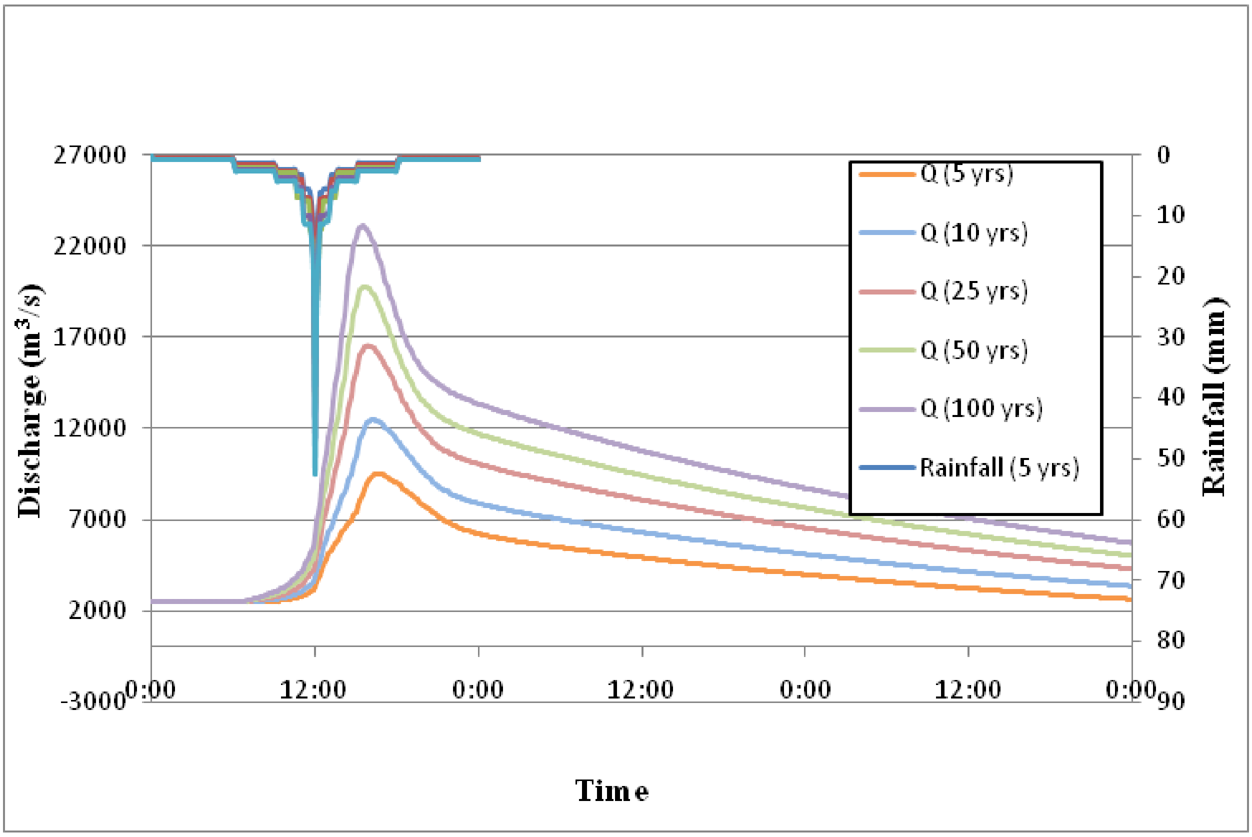


Figure 76. The Outflow hydrograph at the Pinacanauan de Ilagan Station, generated using the Tuguegarao RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Pinacanauan de Ilagan discharge using the Tuguegarao Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 47

Table 47. The peak values of the Pinacanauan de Ilagan HEC-HMS Model outflow using the Maasin RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	248	28.5	9,519.10	4 hours, 40 minutes
10-Year	300.7	34.3	12,460.90	4 hours, 20 minutes
25-Year	367.2	41.7	16,526.70	3 hours, 50 minutes
50-Year	416.5	47.1	19,787.0	3 hours, 40 minutes
100-Year	465.5	52.6	23,085.7	3 hours, 30 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. Figure 77 shows a generated sample map of the Pinacanauan de Ilagan River using the calibrated HMS base flow.

Figure 77. Sample output map of the Pinacanauan de Ilagan RAS Model.

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 78 to Figure 83 show the 5-, 25-, and 100-year rain return scenarios of the Pinacanauan de Ilagan floodplain. The floodplain, with an area of 566.21 sq. km., covers 16 municipalities from three provinces. Table 48 shows the percentage of area affected by flooding per municipality.

Table 48. Municipalities affected in Pinacanauan de Ilagan floodplain.

Province	Municipality	Total Area	Area Flooded	% Flooded
Abra	San Quintin	62.29	44.19	70.94%
Abra	Bangued	123.75	30.88	24.96%
Abra	Langiden	98.70	87.67	88.82%
Abra	Pidigan	58.13	45.00	77.41%
Ilocos Norte	Nueva Era	619.00	3.54	0.57%
Ilocos Sur	Bantay	71.06	71.06	100.00%
Ilocos Sur	Caoayan	21.20	20.08	94.73%
Ilocos Sur	Magsingal	78.90	75.66	95.90%
Ilocos Sur	Narvacan	97.18	0.30	0.31%
Ilocos Sur	San Ildefonso	13.21	13.21	100.00%
Ilocos Sur	San Juan	59.88	42.08	70.28%
Ilocos Sur	San Vicente	12.20	12.20	100.00%
Ilocos Sur	Santa Catalina	10.83	8.09	74.65%
Ilocos Sur	Santa	57.20	35.91	62.78%
Ilocos Sur	Santo Domingo	50.36	50.36	99.99%
Ilocos Sur	Vigan City	24.01	23.44	97.66%

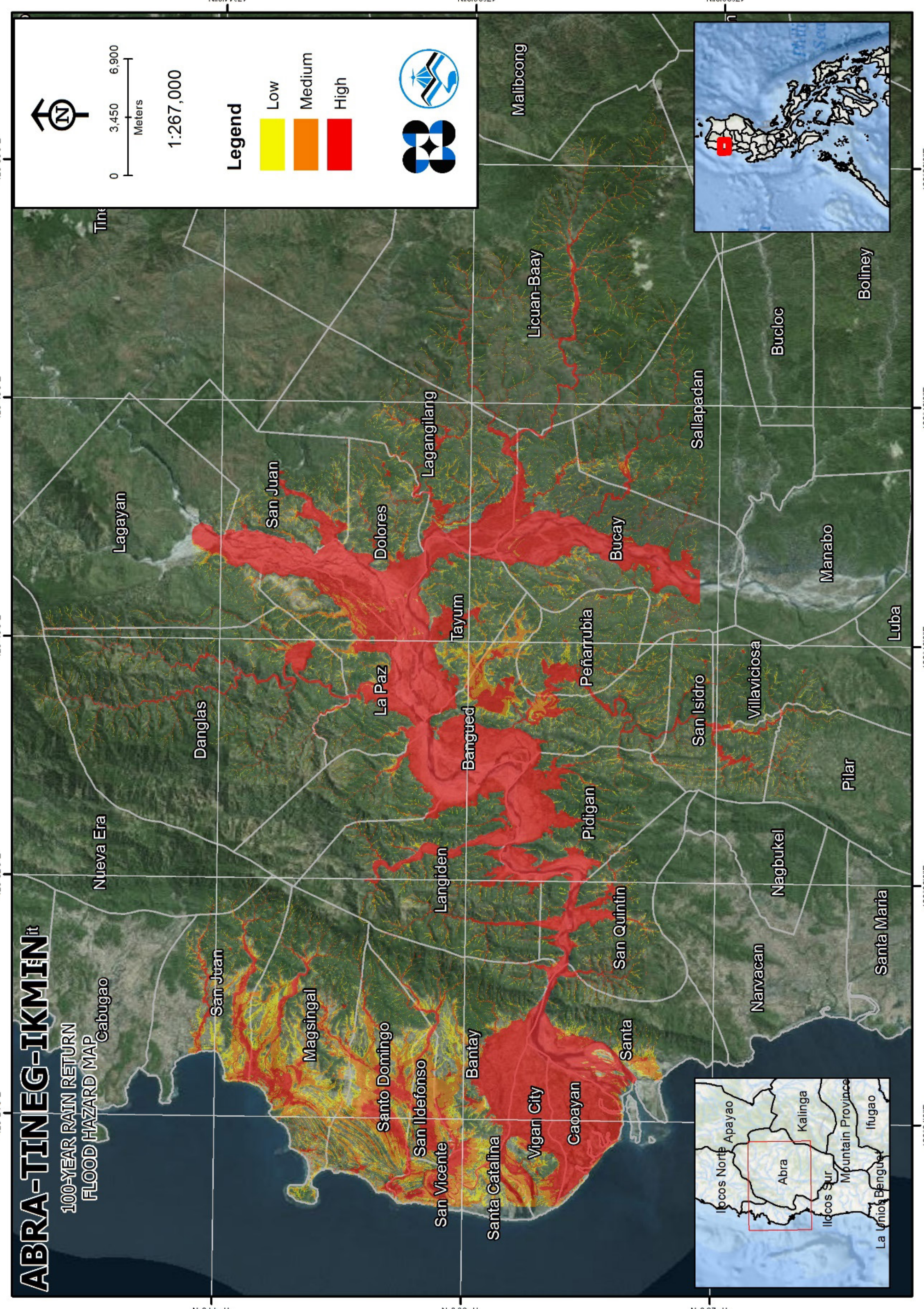


Figure 78. A 100-year Flood Hazard Map for Pinacanauan de Ilagan Floodplain overlaid on Google Earth imagery

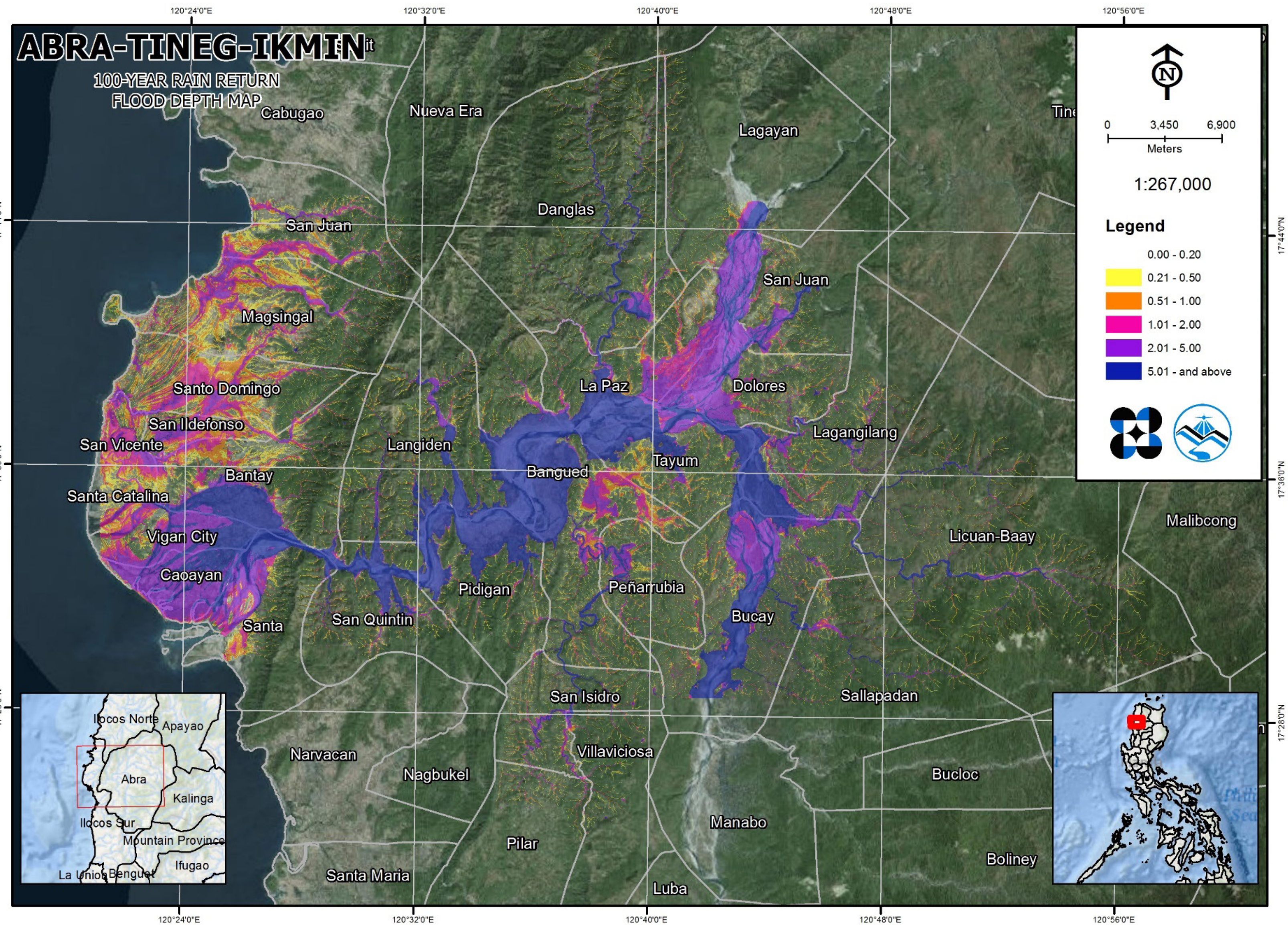


Figure 79. A 100-year Flow Depth Map for Pinacanauan de Ilagan Floodplain overlaid on Google Earth imagery

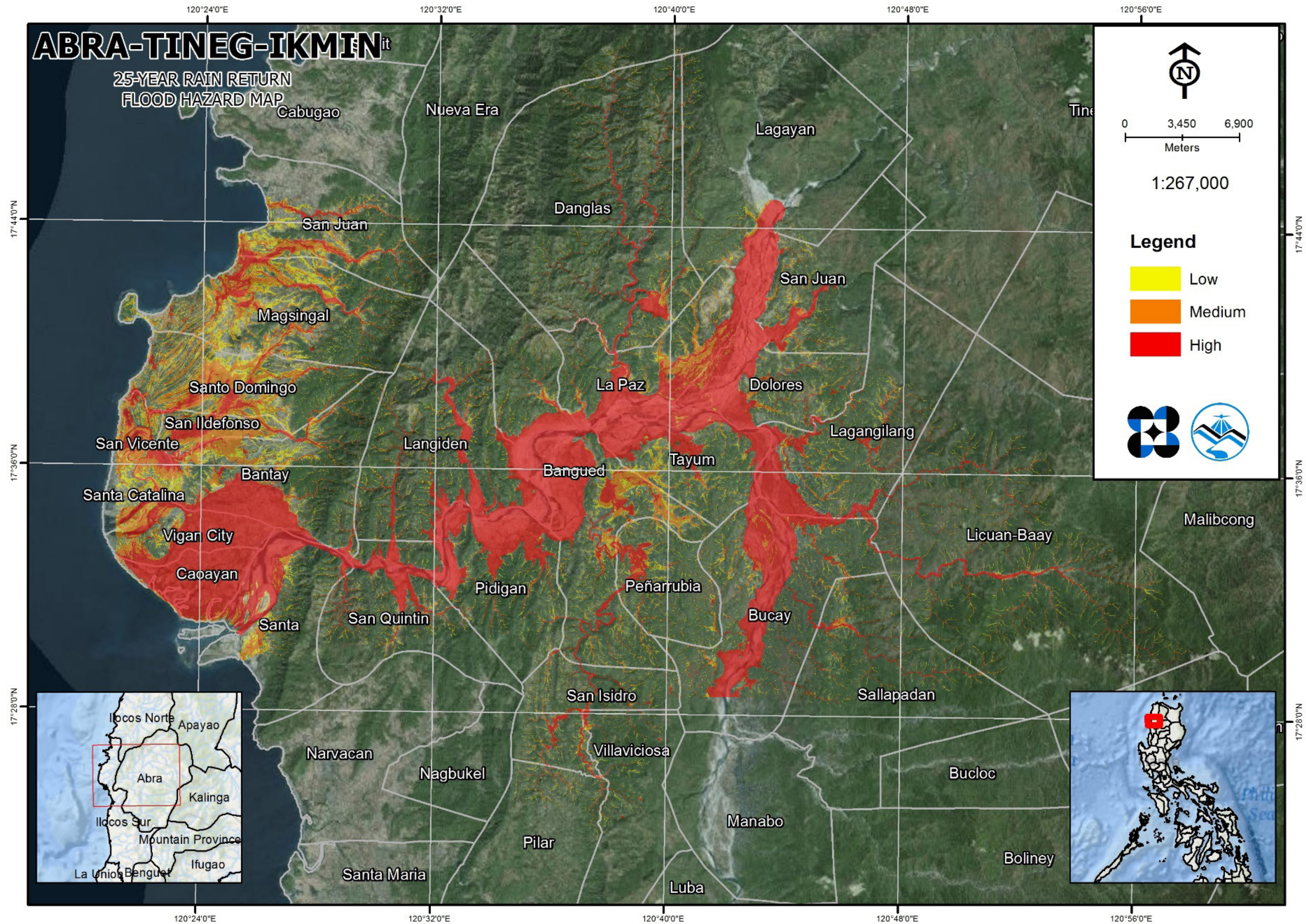


Figure 80. A 25-year Flood Hazard Map for Pinacanauan de Ilagan Floodplain overlaid on Google Earth imagery

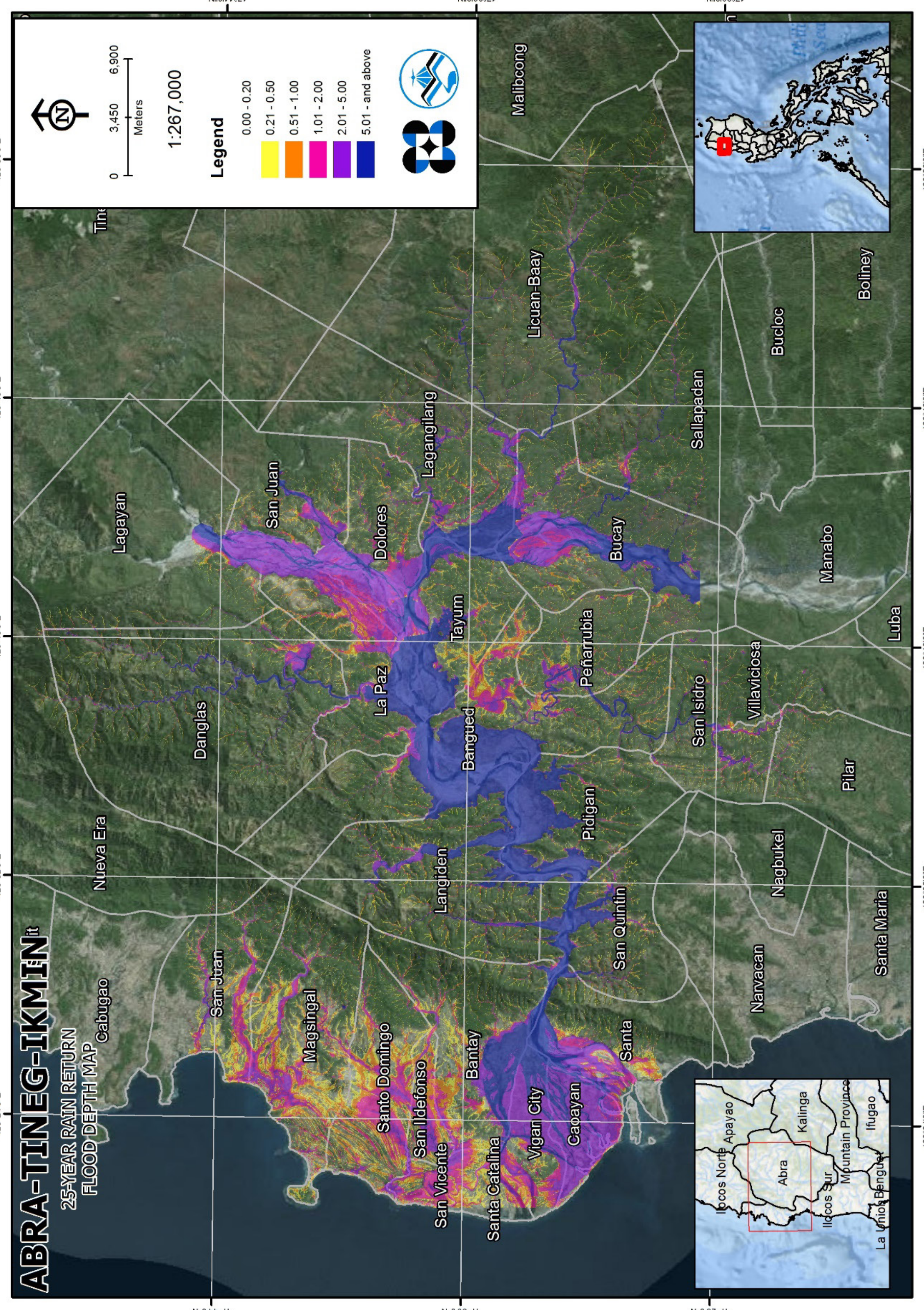


Figure 81. A 25-year Flow Depth Map for Pinacanauan de Ilagan Floodplain overlaid on Google Earth imagery

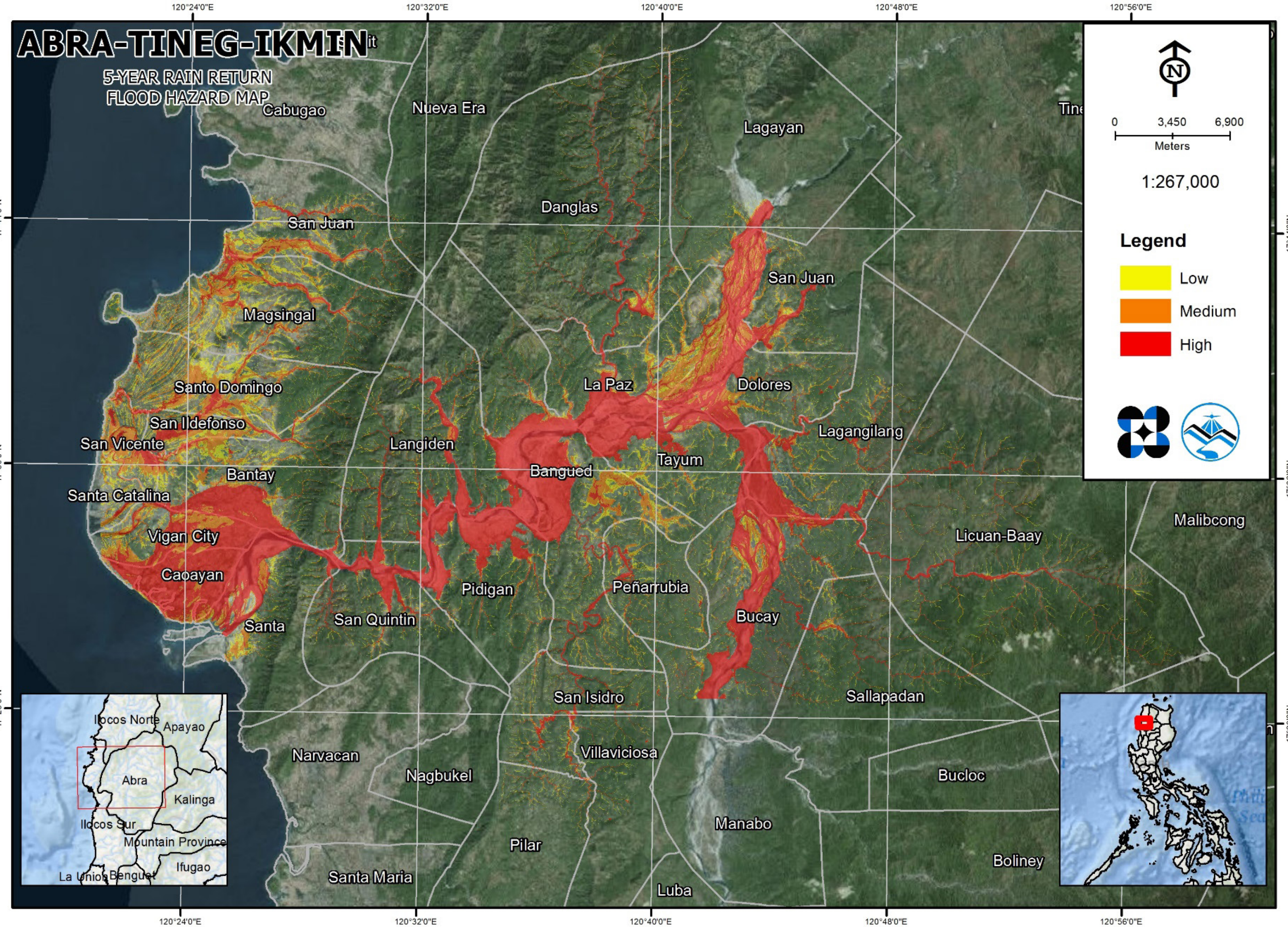


Figure 82. A 5-year Flood Hazard Map for Pinacanauan de Ilagan Floodplain overlaid on Google Earth imagery

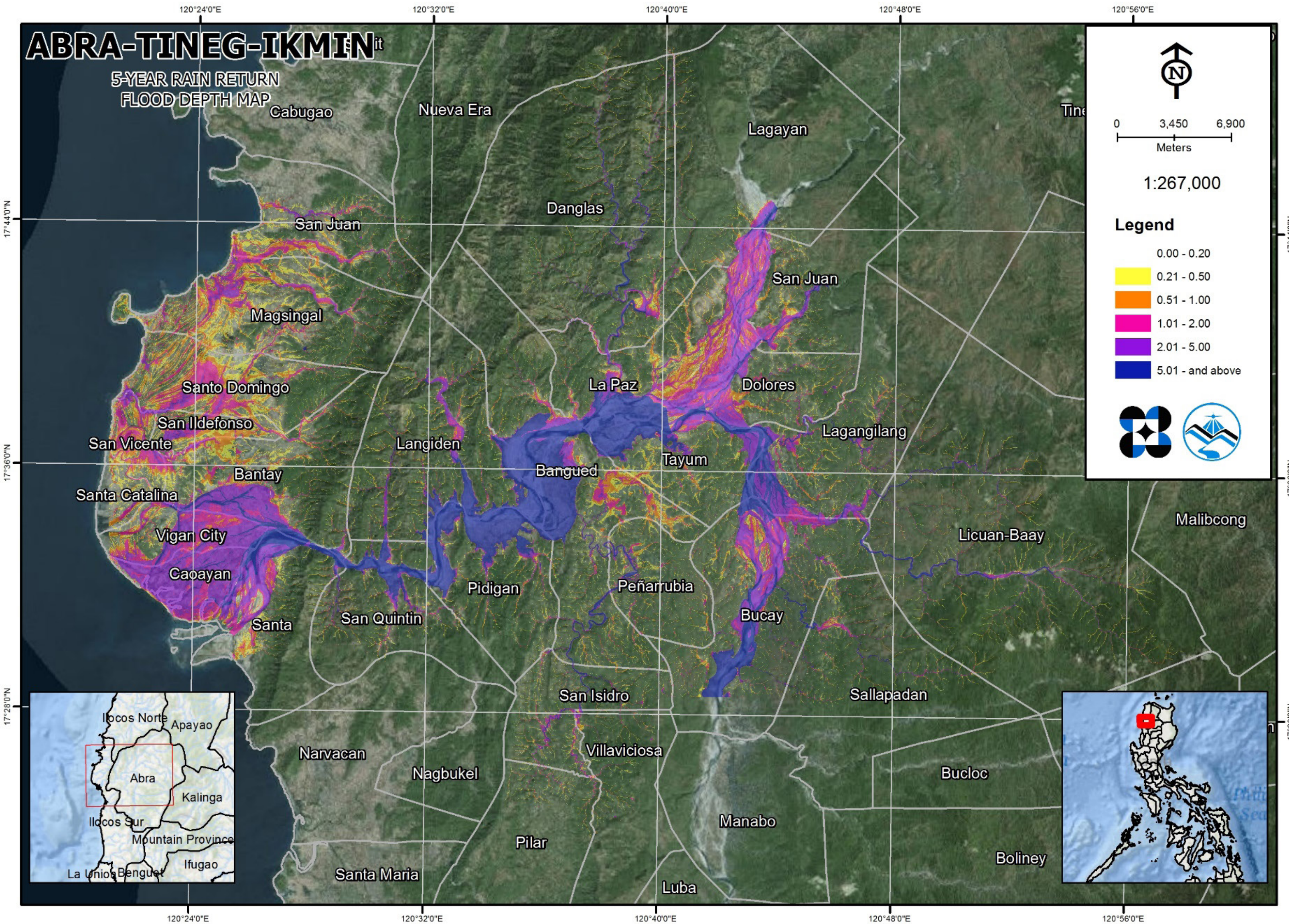


Figure 83. A 5-year Flood Depth Map for Pinacanauan de Ilagan Floodplain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Pinacanauan de Ilagan River Basin, grouped accordingly by municipality. For the said basin, ___ municipalities consisting of ___ barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

<insert Affected Areas part>

Among the barangays in the municipality of Hinundayan, Cabulisan and Navalita are projected to have the highest percentage of area that will experience flood levels at 5.3%. Meanwhile, Bugho posted the second highest percentage of area that may be affected by flood depths at 4.15%.

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

Table 49. Area covered by each warning level with respect to the rainfall scenarios.

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	81.42	79.64	79.16
Medium	102.41	99.92	100.51
High	226.15	288.35	317.94

Of the 131 identified Educational Institutions in Pinacanauan de Ilagan flood plain, 11 were assessed to be exposed to low, 17 to medium, and 16 to high level flooding during the 5-year scenario. In the 25-year scenario, 8 were assessed to be exposed to low, 12 to medium, and 42 to high level flooding. In the 100-year scenario, 7 were assessed to be exposed to low, 5 to medium, and 54 to high level flooding. See Annex 12 for a detailed enumeration of schools in the Pinacanauan de Ilagan floodplain.

Of the 30 identified Medical Institutions in Pinacanauan de Ilagan flood plain, 2 were assessed to be exposed to low, 1 to medium, and 1 to high level flooding in the 5-year scenario. In the 25-year scenario, 3 were assessed to be exposed to low, 3 to medium, and 1 to high level flooding. In the 100-year scenario, 5 were assessed to be exposed to low, 3 to medium, and 3 to high level flooding. See Annex 13 for a detailed enumeration of hospitals and clinics in the Pinacanauan de Ilagan floodplain.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there is a need to perform validation survey work. Field personnel gather 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 will then go to the specified points identified in a river basin and will gather data regarding the actual flood level in each location. Data gathering can be done through a local DRRM office to obtain maps or situation reports about the past flooding events or interview some residents with knowledge of or have had experienced flooding in a particular area.

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 84.

The flood validation consists of 135 points randomly selected all over the Pinacanauan de Ilagan flood plain. Comparing it with the flood depth of the nearest storm event, the map has an RMSE value of 1.13m. The validation points are found in Annex 11.

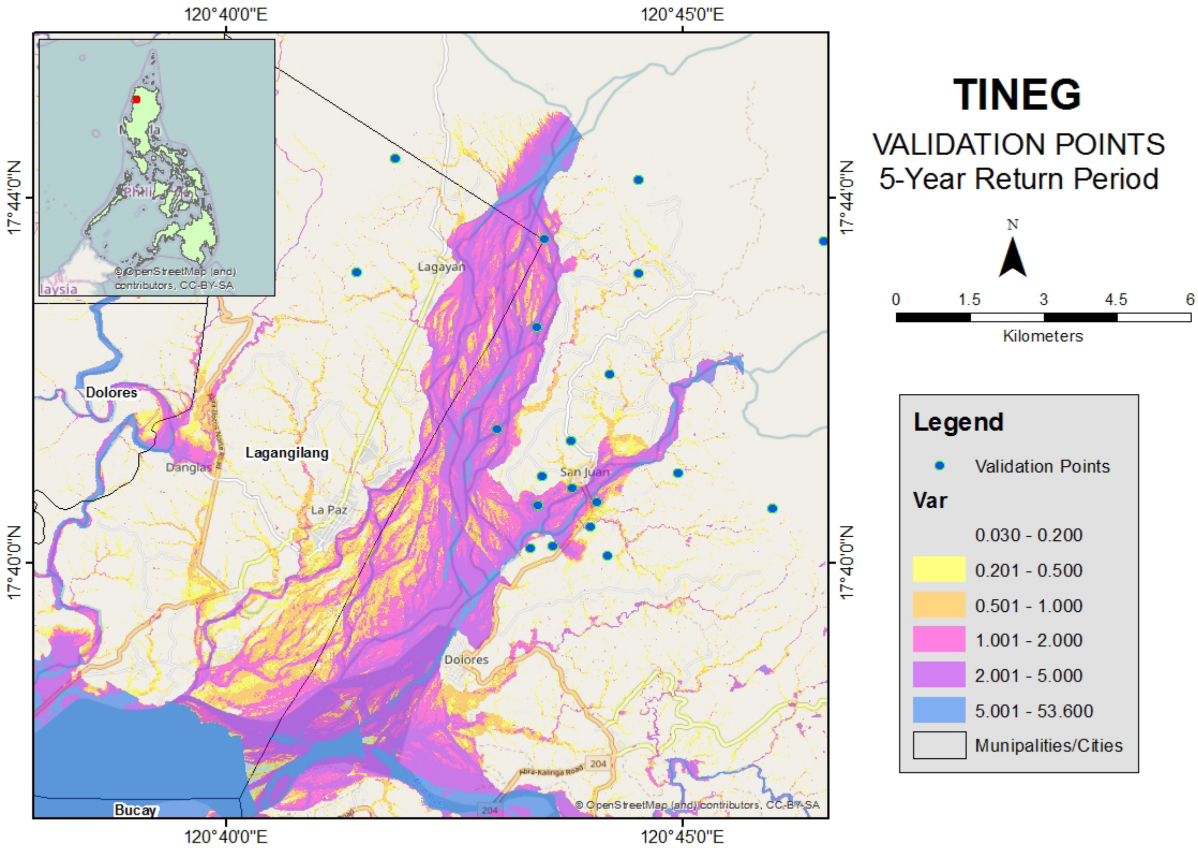


Figure 84. Validation Points for a 5-year Flood Depth Map of the Pinacanauan de Ilagan Floodplain.

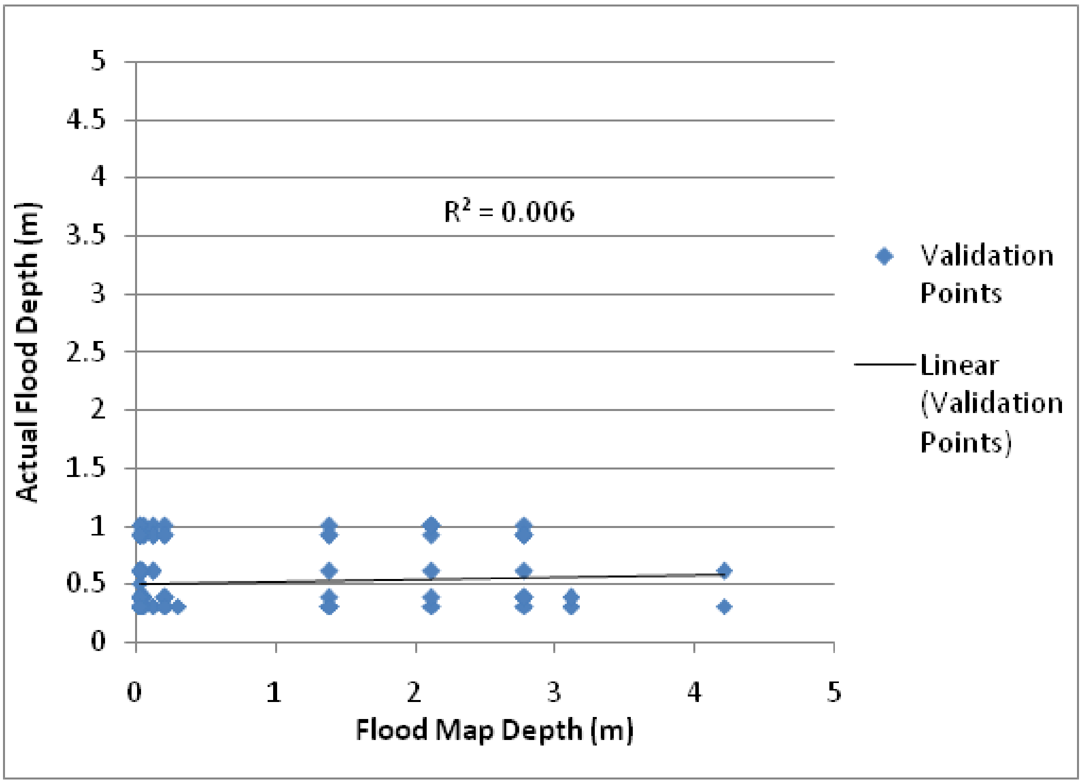


Figure 85. Flood depth map vs actual flood depth.

Table 50. Actual Flood Depth versus Simulated Flood Depth at different levels in the Pinacanauan de Ilagan River Basin.

PINACANAUAN DE ILAGAN BASIN		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
Actual Flood Depth (m)	0-0.20	0	0	0	0	0	0	0
	0.21-0.50	56	9	0	6	15	0	86
	0.51-1.00	30	3	0	4	12	0	49
	1.01-2.00	0	0	0	0	0	0	0
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	86	12	0	10	27	0	135

On the whole, the overall accuracy generated by the flood model is estimated at 6.67%, with 9 points correctly matching the actual flood depths. In addition, there were 63 points estimated one level above and below the correct flood depths while there were 48 points and 15 points estimated two levels above and below, and three or more levels above and below the correct flood depth. A total of 37 points were overestimated while a total of 89 points were underestimated in the modelled flood depths of Pinacanauan de Ilagan. Table 51 depicts the summary of the Accuracy Assessment in the Pinacanauan de Ilagan River Basin Flood Depth Map.

Table 51. Summary of the Accuracy Assessment in the Pinacanauan de Ilagan River Basin Survey.

	No. of Points	%
Correct	9	6.67
Overestimated	37	27.41
Underestimated	89	65.93
Total	135	100

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LiDAR Sensors used in the Pinacanauan de Ilagan Floodplain Survey

1. GEMINI SENSOR

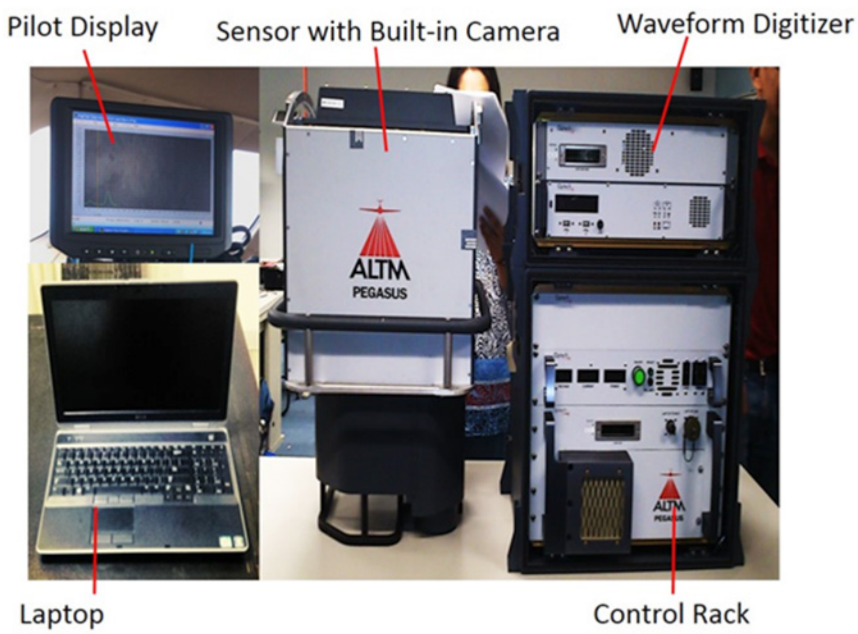


Figure A-1.1 Gemini Sensor

Table A-1.1 Parameters and Specifications of Gemini Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
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

2. PEGASUS SENSOR

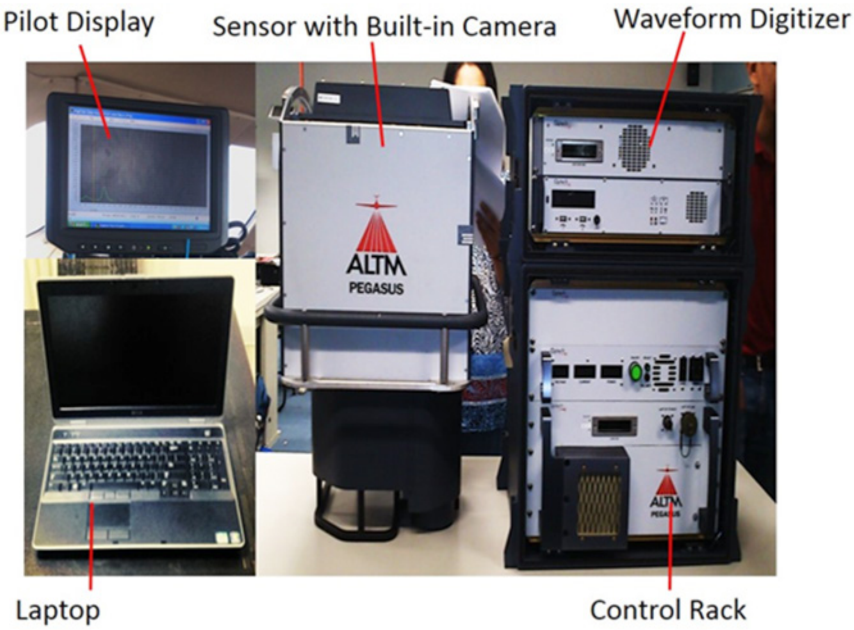


Figure A-1.2 Pegasus Sensor

Table A-1.2 Parameters and Specifications of Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)

Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

Annex 2. NAMRIA certification of reference points used in the LiDAR survey

1. ISB-83

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

December 12, 2013

CERTIFICATION

To whom it may concern:

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

Province: **ISABELA**
Station Name: **ISB-83**
Order: **2nd**

Island: **LUZON**
Municipality: **QUEZON**
Barangay: **MINAGBAG**

	PRS92 Coordinates	
Latitude: **17° 23' 6.02040"**	Longitude: **121° 36' 0.80264"**	Ellipsoidal Hgt: **131.99400 m.**
	WGS84 Coordinates	
Latitude: **17° 23' 0.02197"**	Longitude: **121° 36' 5.45806"**	Ellipsoidal Hgt: **168.56500 m.**
	PTM Coordinates	
Northing: **1922803.531 m.**	Easting: **563781.983 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,922,573.55**	Easting: **351,296.42**	Zone: **51**

Location Description

ISB-83
Station is located along the Nat'l Highway via Quezon, right side directioin to Tuguegarao Cagayan Province, beside the Km. post mark. Approx. 41.0 Km. from Tuguegarao and 8.0 Km. from Quezon Town Proper to the station. Station is marked by a 4 in. copper nail, set at the center of a 0.30 m x 0.30 m x 1.20 m concrete block, 0.20 m above the ground surface with inscriptions, "ISB-83, 2007, NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8794925 A**
T.N.: **2013-1570**

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

9912122013163628

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

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

Figure A-2.1. ISB-83

2. ISB-90

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

October 10, 2013

CERTIFICATION

To whom it may concern:

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

Province: **ISABELA**
Station Name: **ISB-90**
Order: **2nd**

Island: **LUZON**
Municipality: **DELFIN ALBANO (MAGSAYSAY)**
Barangay: **VILLA LUZ**

	PRS92 Coordinates	
Latitude: **17° 19' 10.25017"**	Longitude: **121° 46' 9.69589"**	Ellipsoidal Hgt: **35.36700 m.**
	WGS84 Coordinates	
Latitude: **17° 19' 4.27901"**	Longitude: **121° 46' 14.35585"**	Ellipsoidal Hgt: **72.55400 m.**
	PTM Coordinates	
Northing: **1915619.76 m.**	Easting: **581784.952 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,915,204.01**	Easting: **369,220.50**	Zone: **51**

Location Description

ISB-90

Station is locted at the boundary of Brgy. Villa Luz and Brgy. Rizal, along the road, right side going to Brgy. Villa Luz, near boundary mark and Meralco post. Approx. 30 Km. from Mallig Town Proper to the station, travel time tooks 1.50 hrs. Station is marked by a 0.10 m x 0.005 m copper nail, set in the center of a 0.30 m x 0.30 m x 1.20 m concrete block, set 0.20 m above the ground surface with inscriptions, "ISB-90, 2007, NAMRIA".

Requesting Party: **NATIONWIDE DREAM PROGRAM**
Pupose: **Reference**
OR Number: **3947014 B**
T.N.: **2013-1073**

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

9 9 1 0 1 0 2 0 1 3 1 3 1 3 1 0

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

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

Figure A-2.2. ISB-90

3. ISB-97

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

December 05, 2013

CERTIFICATION

To whom it may concern:

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

Province: **ISABELA**
Station Name: **ISB-97**
Order: **2nd**

Island: **LUZON** Municipality: **MALLIG**		Barangay: **VILLA BULUSAN**
	PRS92 Coordinates	
Latitude: **17° 8' 44.15866"**	Longitude: **121° 40' 11.01238"**	Ellipsoidal Hgt: **62.25900 m.**
	WGS84 Coordinates	
Latitude: **17° 8' 38.21795"**	Longitude: **121° 40' 15.68747"**	Ellipsoidal Hgt: **99.75900 m.**
	PTM Coordinates	
Northing: **1896333.662 m.**	Easting: **571259.789 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,896,031.50**	Easting: **358,498.51**	Zone: **51**

Location Description

ISB-97

Station is beside the waiting shed of Brgy. Bulusan along the Brgy. Road. Station is marked by 0.10 m x 0.005 m diameter brass rod set in a 0.30 m x 0.30 m x 1.20 m concrete block, set in 0.20 m above the ground surface with inscriptions, "ISB-97, 2007, NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8794880 B**
T.N.: **2013-1521**

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

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

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

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

Figure A-2.3. ISB-97

4. ISB-106

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

May 17, 2016

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: **ISABELA**	
	Station Name: **ISB-106**	
	Order: **2nd**	
Island: **LUZON**	Barangay: **PULAY**	
Municipality: **LUNA**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **16° 58' 51.81297"**	Longitude: **121° 42' 26.76398"**	Ellipsoidal Hgt: **55.38500 m.**
	WGS84 Coordinates	
Latitude: **16° 58' 45.91140"**	Longitude: **121° 42' 31.45264"**	Ellipsoidal Hgt: **93.49500 m.**
	PTM / PRS92 Coordinates	
Northing: **1878138.936 m.**	Easting: **575338.197 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **1,877,799.15**	Easting: **362,389.64**	Zone: **51**

Location Description

ISB-106

Station is located beside the brgy. boundary marker, NE side. From Cabatuan going to Cauayan Nat'l Road, it is approx. 2 Km. to the bridge, additional 1.0 Km. to the intersection road of Brgy. Nambanga at left side, turn to the said intersection road going straight ahead, passing the Brgy. Nambanga and Conception then the Brgy. Pulay. The station is beside the irrigation canal and boudary marker. Station is marked by a 0.10 m x 0.005 m diameter brass rod set in a 0.30 m x 0.30 m x 1.20 m concrete block, embedded in the ground with 0.20 m above the ground surface, with inscriptions, "ISB-106, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8090370 I**
T.N.: **2016-1115**

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

9 9 0 5 1 7 2 0 1 6 1 0 0 0 0 6

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

CIP/4701/12/09/814

Figure A-2.4. ISB-106

5. ISB-108

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

May 17, 2016

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: **ISABELA**
Station Name: **ISB-108**
Order: **2nd**

Island: **LUZON**	Barangay: **RIZAL**		
Municipality: **NAGUILIAN**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **16º 57' 50.44363"**	Longitude: **121º 55' 45.03953"**	Ellipsoidal Hgt:	**79.16500 m.**
	WGS84 Coordinates		
Latitude: **16º 57' 44.56307"**	Longitude: **121º 55' 49.72824"**	Ellipsoidal Hgt:	**117.86300 m.**
	PTM / PRS92 Coordinates		
Northing: **1876350.862 m.**	Easting: **598963.184 m.**	Zone:	**3**
	UTM / PRS92 Coordinates		
Northing: **1,875,770.92**	Easting: **385,989.32**	Zone:	**51**

Location Description

ISB-108

Station is located NW corner of the basketball court beside the house of Brgy. Capt. R. Biado. E of the Brgy. Community Center of Brgy. Rizal, more or less 200 m to the basketball court. From San Manuel Isabela junction road travel E along the Provincial Road to the Mun. of Benito Soliven, approx. 13 Km. to the Benito Sokiven high School, upon reaching the Pump Gas Station, turn right to the intersection Brgy. Road, going to Brgy. Rizal, and additional travel approx. 7.0 Km. to the Brgy. Rizal, encouter the juction of Brgy. Road, move to the left, no more than 100 m to the basketball court. Station is marked by 0.10 m x 0.005 m diameter brass rod centered on a 0.30 m x 0.30 m putty, flushed is a concrete pavement of basketball court with inscriptions, "ISB-108, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8090370 I**
T.N.: **2016-1114**

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

9 9 0 5 1 7 2 0 1 6 0 9 5 9 4 7

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.5. ISB-108

6. ISB-114

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

September 21, 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: **ISABELA**	
	Station Name: **ISB-114**	
	Order: **2nd**	
Island: **LUZON**	Barangay: **SAN JOSE**	
Municipality: **SAN MARIANO**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **16° 55' 46.73944"**	Longitude: **122° 7' 31.95097"**	Ellipsoidal Hgt: **156.78500 m.**
	WGS84 Coordinates	
Latitude: **16° 55' 40.88179"**	Longitude: **122° 7' 36.64130"**	Ellipsoidal Hgt: **196.06400 m.**
	PTM / PRS92 Coordinates	
Northing: **1872521.293 m.**	Easting: **406848.262 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,871,865.88**	Easting: **406,880.87**	Zone: **51**

Location Description

ISB-114

Station is located beside the waiting shed E side, N of San Jose Day Care Center and the brgy. basketball court which is near to the Brgy. Health Center and the San Jose Brgy. Hall, GMAC Office. Opposite NE of the station is the rice mill. Station is marked by a 0.10 m x 0.005 m diameter brass rod set in a 0.30 m x 0.30 m x 1.20 m concrete block embedded to the ground, 0.20 m ground surface with inscriptions, "ISB-114, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8087355 I**
T.N.: **2015-2814**

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.6. ISB-114

7. ISB-116

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

September 11, 2013

CERTIFICATION

To whom it may concern:

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

Province: **ISABELA**
Station Name: **ISB-116**
Order: **2nd**

Island: **LUZON**
Municipality: **SAN MARIANO**
Barangay: **ZONE I (POB.)**

PRS92 Coordinates

Latitude: **16° 59' 4.21767"**	Longitude: **122° 0' 23.58158"**	Ellipsoidal Hgt: **97.63900 m.**

WGS84 Coordinates

Latitude: **16° 58' 58.33861"**	Longitude: **122° 0' 28.26808"**	Ellipsoidal Hgt: **136.45900 m.**

PTM Coordinates

Northing: **1878652.343 m.**	Easting: **394202.384 m.**	Zone: **4**

UTM Coordinates

Northing:	Easting:	Zone:

Location Description

ISB-116

Station is located on the summit of a bridge which is overlooking the town proper of San Mariano on the E part, and Brgy. Felomina on the W part. From the Mun. Bldg., travel sW about 400 m to high school campus, along Provincial Road leading to Poblacion. Station is marked by a 0.10 m x 0.005 m diameter copper nail set in a 0.30 m x 0.30 m x 1.20 m concrete block embedded to the ground, 0.20 m ground surface with inscriptions, "ISB-116, 2007, NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **3946815 B**
T.N.: **2013-0878**

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

9909112013163348

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

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

Figure A-2.7. ISB-116

8. CGY-58

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

October 22, 2013

CERTIFICATION

To whom it may concern:

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

	Province: **CAGAYAN**	
	Station Name: **CGY-58**	
	Order: **2nd**	
Island: **LUZON**		Barangay: **UBONG**
Municipality: **SOLANA**		
	PRS92 Coordinates	
Latitude: **17° 36' 27.61645"**	Longitude: **121° 36' 25.76184"**	Ellipsoidal Hgt: **40.71600 m.**
	WGS84 Coordinates	
Latitude: **17° 36' 21.57004"**	Longitude: **121° 36' 30.39868"**	Ellipsoidal Hgt: **76.59000 m.**
	PTM Coordinates	
Northing: **1947447.881 m.**	Easting: **564440.235 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,947,206.45**	Easting: **352,213.18**	Zone: **51**

Location Description

CGY-58
Is located 15 m. E of the junction of the road leading to Brgy. Ubong and the road leading to Brgy. Karilukud. It is situated 10 m. SE of Brgy. Ubong welcome monument. Mark is the head of a 3 in. copper nail set flushed on top of a standard concrete monument, with inscriptions "CGY-58 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **3947072 B**
T.N.: **2013-1136**

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

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

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

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

Figure A-2.8. CGY-58

9. CGY-66

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

October 29, 2013

CERTIFICATION

To whom it may concern:

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

	Province: **CAGAYAN**	
	Station Name: **CGY-66**	
Island: **LUZON**	Order: **2nd**	Barangay: **WARAT**
Municipality: **PIAT**		
	PRS92 Coordinates	
Latitude: **17° 42' 56.12254"**	Longitude: **121° 34' 50.13936"**	Ellipsoidal Hgt: **51.90200 m.**
	WGS84 Coordinates	
Latitude: **17° 42' 50.05073"**	Longitude: **121° 34' 54.76735"**	Ellipsoidal Hgt: **87.36400 m.**
	PTM Coordinates	
Northing: **1959382.34 m.**	Easting: **561584.309 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,959,169.01**	Easting: **349,484.16**	Zone: **51**

Location Description

CGY-66
Is located within the compound of Warat Brgy. Hall, along G. Cusupig St., approx. 15 m. S of the waiting shed. Mark is the head of a 3 in. copper nail set flushed on top of a standard concrete monument, with inscriptions "CGY-66 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **3947072 B**
T.N.: **2013-1167**

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

9 9 1 0 2 9 2 0 1 3 1 2 3 3 0 1

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

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

Figure A-2.9. CGY-66

10 CGY-70

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

November 05, 2013

CERTIFICATION

To whom it may concern:

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

	Province: **CAGAYAN**	
	Station Name: **CGY-70**	
Island: **LUZON**	Order: **2nd**	Barangay: **ESTEFANIA**
Municipality: **AMULUNG**		
	PRS92 Coordinates	
Latitude: **17° 47' 54.79038"**	Longitude: **121° 43' 31.26837"**	Ellipsoidal Hgt: **26.85900 m.**
	WGS84 Coordinates	
Latitude: **17° 47' 48.71170"**	Longitude: **121° 43' 35.88859"**	Ellipsoidal Hgt: **62.40000 m.**
	PTM Coordinates	
Northing: **1968617.425 m.**	Easting: **576904.118 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,968,239.03**	Easting: **364,899.00**	Zone: **51**

Location Description

CGY-70
Is located inside Estefania Elem. School campus. It is situated 1 m. E of the NE corner of the basketball court. Mark is the head of a 3 in. copper nail set flushed on top of a standard concrete monument, with inscriptions "CGY-70 2007 NAMRIA".

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **3947129 B**
T.N.: **2013-1200**

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

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

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

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

Figure A-2.10. CGY-70

11. CGY-92

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

October 29, 2013

CERTIFICATION

To whom it may concern:

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

	Province: **CAGAYAN**	
	Station Name: **CGY-92**	
Island: **LUZON**	Order: **2nd**	Barangay: **POBLACION**
Municipality: **LAL-LO**		
	PRS92 Coordinates	
Latitude: **18° 12' 11.42361"**	Longitude: **121° 39' 42.14392"**	Ellipsoidal Hgt: **14.47400 m.**
	WGS84 Coordinates	
Latitude: **18° 12' 5.25321"**	Longitude: **121° 39' 46.73084"**	Ellipsoidal Hgt: **48.54000 m.**
	PTM Coordinates	
Northing: **2013373.807 m.**	Easting: **569996.115 m.**	Zone: **3**
	UTM Coordinates	
Northing: **2,013,059.26**	Easting: **358,475.41**	Zone: **51**

Location Description

CGY-92
Is located inside the Lal-lo Nat'l. High School, about 5 m. W of the flagpole. Said school is 95 m. E of the Tuguegarao-Aparri nat'l. road, between Km Posts 562 and 563 and about 40 m. N of Lal-lo Mun. Hall. Mark is the head of a copper nail centered and flushed on a 30 cm. x 30 cm. cement putty, with inscriptions "CGY-92 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **3947103 B**
T.N.: **2013-1171**

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

9 9 1 0 2 9 2 0 1 3 1 2 4 7 0 7

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

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

Figure A-2.11. CGY-92

12. CGY-102

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: **CAGAYAN**
Station Name: **CGY-102**
Order: **2nd**

Island: **LUZON**
Municipality: **SANTA ANA**
Barangay: **CASAMBALANGAN**
MSL Elevation:

		PRS92 Coordinates			
Latitude:	**18° 22' 15.98573"**	Longitude:	**122° 6' 41.74346"**	Ellipsoidal Hgt:	**22.60800 m.**
		WGS84 Coordinates			
Latitude:	**18° 22' 9.81367"**	Longitude:	**122° 6' 46.31361"**	Ellipsoidal Hgt:	**57.19500 m.**
		PTM / PRS92 Coordinates			
Northing:	**2032192.366 m.**	Easting:	**617476.569 m.**	Zone:	**3**
		UTM / PRS92 Coordinates			
Northing:	**2,031,351.34**	Easting:	**406,145.45**	Zone:	**51**

Location Description

CGY-102
From Gonzaga, travel along the nat'l. highway to Santa Ana. Station is located about 2 m. from the S corner of the triangular isalnd at the intersection of the nat'l. highway and the road to Port Irene. Mark is the head of a copper nail centered and flushed on a 30 cm. x 30 cm. concrete monument, with inscriptions "CGY-102 2007 NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8088735 I**
T.N.: **2015-3961**

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

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

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

CIP/4701/12/09/814

Figure A-2.12. CGY-102

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

1. SB-185

Table A-3.1. SB-185

Baseline observation:	SB-185 --- ISB-114 (B1)
Processed:	10/16/2015 7:56:46 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.003 m
Vertical precision:	0.018 m
RMS:	0.004 m
Maximum PDOP:	2.043
Ephemeris used:	Broadcast
Antenna model:	No phase table corrections applied.
Processing start time:	9/8/2015 12:05:19 AM (GPS Time)
Processing stop time:	9/8/2015 4:11:53 AM (GPS Time)
Processing duration:	04:06:34
Processing interval:	1 second
Vector Components (Mark to Mark)	

From:	ISB-114				
Grid		Local		Global	
Easting	406880.868 m	Latitude	N16°55’46.73941”	Latitude	N16°55’40.88179”
Northing	1871865.877 m	Longitude	E122°07’31.95100”	Longitude	E122°07’36.64130”
Elevation	153.190 m	Height	156.785 m	Height	196.064 m
To:	SB-185				
Grid		Local		Global	
Easting	375449.061 m	Latitude	N17°00’28.94757”	Latitude	N17°00’23.04956”
Northing	1880702.502 m	Longitude	E121°49’47.70616”	Longitude	E121°49’52.39181”
Elevation	53.963 m	Height	57.023 m	Height	95.344 m

2. SB-228

Table A-3.2. SB-228

Project information		Coordinate System	
Name:	C:\Users\Windows User\Documents \Business Center - HCE\ISB-90 to SB-228.vce	Name:	UTM
		Datum:	PRS 92
Size:	239 KB	Zone:	51 North (123E)
Modified:	10/14/2015 5:41:41 PM (UTC:8)	Geoid:	EGMPH
Time zone:	China Standard Time	Vertical datum:	
Reference number:			
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ISB-90 --- SB-228 B (B1)	ISB-90	SB-228 B	Fixed	0.005	0.025	132°33'27"	9396.688	5.491
ISB-90 --- SB-228 A (B2)	ISB-90	SB-228 A	Fixed	0.004	0.022	132°33'27"	9396.683	5.497

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

ISB-90 - SB-228 B (1:54:36 PM-5:03:16 PM) (S1)

Baseline observation:	ISB-90 --- SB-228 B (B1)
Processed:	10/14/2015 5:37:09 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.005 m
Vertical precision:	0.025 m
RMS:	0.003 m
Maximum PDOP:	3.350
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	9/14/2015 1:54:39 PM (Local: UTC+8hr)
Processing stop time:	9/14/2015 5:03:16 PM (Local: UTC+8hr)
Processing duration:	03:08:37
Processing interval:	1 second

1

3. BMSB-339

Table A-3.3. BM-339

Vector Components (Mark to Mark)

From:	ISB-83				
Grid		Local		Global	
Easting	351296.425 m	Latitude	N17°23'06.02040"	Latitude	N17°23'00.02197"
Northing	1922573.548 m	Longitude	E121°36'00.80264"	Longitude	E121°36'05.45806"
Elevation	129.048 m	Height	131.994 m	Height	168.565 m

To:	BMSB-339				
Grid		Local		Global	
Easting	352327.942 m	Latitude	N17°23'59.75074"	Latitude	N17°23'53.74978"
Northing	1924217.595 m	Longitude	E121°36'35.34664"	Longitude	E121°36'40.00077"
Elevation	110.884 m	Height	113.774 m	Height	150.320 m

Vector					
ΔEasting	1031.518 m	NS Fwd Azimuth	31°41'12"	ΔX	-600.533 m
ΔNorthing	1644.047 m	Ellipsoid Dist.	1941.105 m	ΔY	-969.664 m
ΔElevation	-18.164 m	ΔHeight	-18.220 m	ΔZ	1570.818 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.004 m
σ ΔElevation	0.004 m	σ ΔHeight	0.004 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000072263		
Y	-0.0000074380	0.0000153827	
Z	-0.0000014802	0.0000027219	0.0000024417

4. ARPT

Table A-3.4. ARPT

Standard Errors

Vector errors:					
σ ΔEasting	0.001 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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000127245		
Y	-0.0000196861	0.0000358238	
Z	-0.0000069331	0.0000122190	0.0000056523

Vector Components (Mark to Mark)

From:	CGY-66				
Grid		Local		Global	
Easting	349484.163 m	Latitude	N17°42'56.12254"	Latitude	N17°42'50.05073"
Northing	1959169.007 m	Longitude	E121°34'50.13937"	Longitude	E121°34'54.76735"
Elevation	48.886 m	Height	51.902 m	Height	87.364 m

To:	ARPT				
Grid		Local		Global	
Easting	365697.564 m	Latitude	N17°38'35.74536"	Latitude	N17°38'29.70094"
Northing	1951050.094 m	Longitude	E121°44'02.31321"	Longitude	E121°44'06.94633"
Elevation	24.276 m	Height	27.155 m	Height	63.218 m

Vector					
ΔEasting	16213.401 m	NS Fwd Azimuth	116°10'06"	ΔX	-15115.447 m
ΔNorthing	-8118.914 m	Ellipsoid Dist.	18135.300 m	ΔY	-6491.935 m
ΔElevation	-24.610 m	ΔHeight	-24.747 m	ΔZ	-7633.540 m

5. ISB-106A

Table A-3.5. ISB-106A

Vector Components (Mark to Mark)

From:	ISB-106				
Grid		Local		Global	
Easting	362389.644 m	Latitude	N16°58'51.81297"	Latitude	N16°58'45.91140"
Northing	1877799.149 m	Longitude	E121°42'26.76398"	Longitude	E121°42'31.45264"
Elevation	52.328 m	Height	55.384 m	Height	93.495 m

To:	ISB-106A				
Grid		Local		Global	
Easting	351807.600 m	Latitude	N16°54'11.01828"	Latitude	N16°54'05.12629"
Northing	1869240.936 m	Longitude	E121°36'31.05845"	Longitude	E121°36'35.75422"
Elevation	75.115 m	Height	78.760 m	Height	116.877 m

Vector					
ΔEasting	-10582.045 m	NS Fwd Azimuth	230°39'33"	ΔX	7626.723 m
ΔNorthing	-8558.212 m	Ellipsoid Dist.	13611.659 m	ΔY	7684.012 m
ΔElevation	22.787 m	ΔHeight	23.375 m	ΔZ	-8250.473 m

Standard Errors

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000345465		
Y	-0.0000543060	0.0000931383	
Z	-0.0000190463	0.0000317184	0.0000131143

6. ISB-108A

Table A-3.6. ISB-108A

Vector Components (Mark to Mark)

From:	ISB-108				
Grid		Local		Global	
Easting	385989.325 m	Latitude	N16°57'50.44363"	Latitude	N16°57'44.56307"
Northing	1875770.918 m	Longitude	E121°55'45.03953"	Longitude	E121°55'49.72824"
Elevation	75.798 m	Height	79.165 m	Height	117.863 m

To:	ISB-108A				
Grid		Local		Global	
Easting	385989.753 m	Latitude	N16°57'50.14045"	Latitude	N16°57'44.25991"
Northing	1875761.598 m	Longitude	E121°55'45.05570"	Longitude	E121°55'49.74442"
Elevation	75.732 m	Height	79.099 m	Height	117.797 m

Vector					
ΔEasting	0.427 m	NS Fwd Azimuth	177°03'41"	ΔX	-1.811 m
ΔNorthing	-9.320 m	Ellipsoid Dist.	9.332 m	ΔY	2.001 m
ΔElevation	-0.066 m	ΔHeight	-0.066 m	ΔZ	-8.933 m

7. EB1-Estefania

Table A-3.8. EB1-Estefania

Vector Components (Mark to Mark)

From:	CGY-70				
Grid		Local		Global	
Easting	364899.007 m	Latitude	N17°47'54.79039"	Latitude	N17°47'48.71170"
Northing	1968239.034 m	Longitude	E121°43'31.26836"	Longitude	E121°43'35.88859"
Elevation	10.038 m	Height	13.000 m	Height	48.540 m

To:	EB1 Estefania				
Grid		Local		Global	
Easting	364893.967 m	Latitude	N17°47'54.71705"	Latitude	N17°47'48.63836"
Northing	1968236.814 m	Longitude	E121°43'31.09772"	Longitude	E121°43'35.71795"
Elevation	10.141 m	Height	13.103 m	Height	48.643 m

Vector					
ΔEasting	-5.040 m	NS Fwd Azimuth	245°50'10"	ΔX	3.861 m
ΔNorthing	-2.220 m	Ellipsoid Dist.	5.508 m	ΔY	3.312 m
ΔElevation	0.103 m	ΔHeight	0.103 m	ΔZ	-2.116 m

Standard Errors

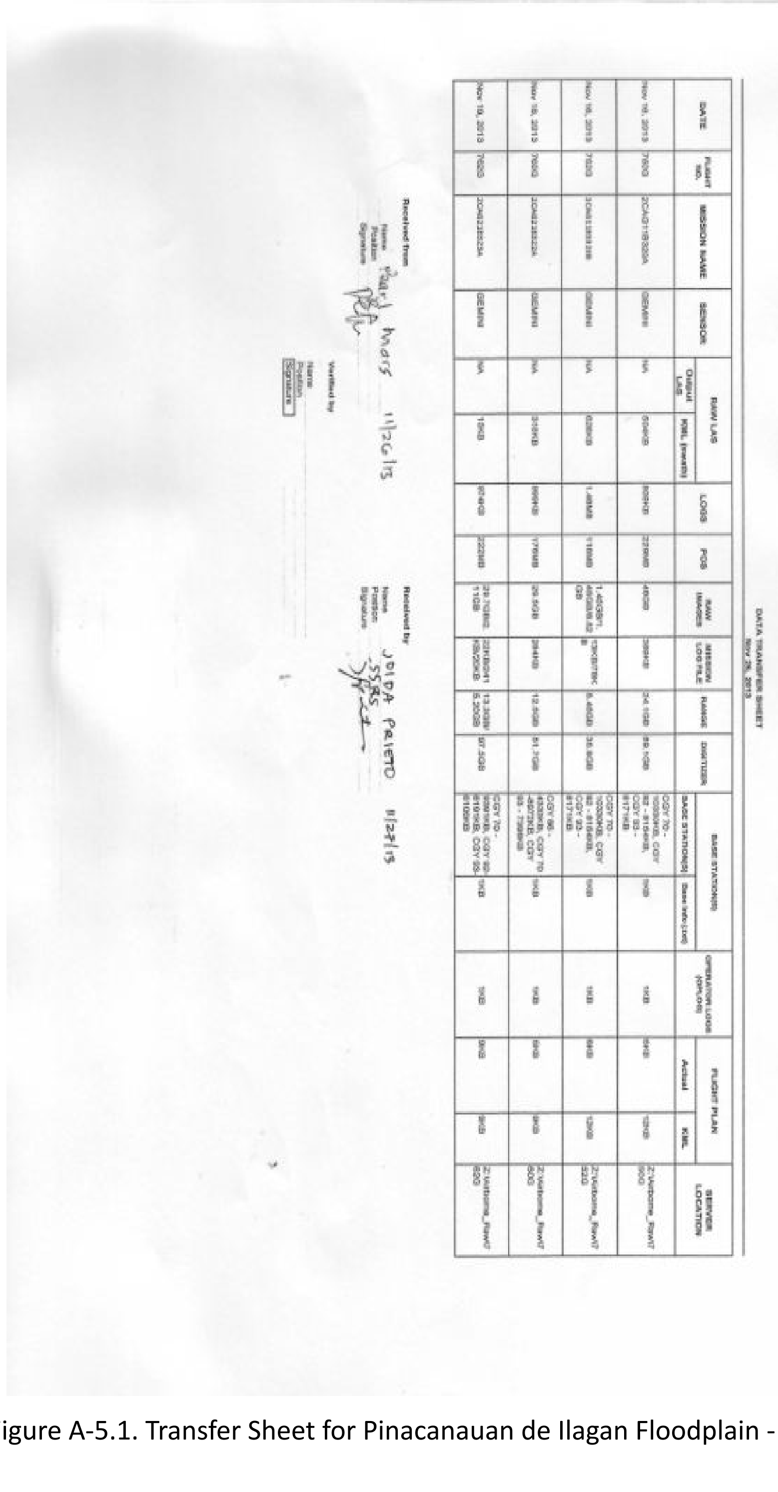
Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'13"	σ ΔX	0.001 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

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
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUñA	UP-TCAGP
		ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	AUBREY MATIRA - PAGADOR	UP-TCAGP
	SSRS	JASMINE ALVIAR	UP-TCAGP
	SSRS	ENGR. GEROME HIPOLITO	UP-TCAGP
	SSRS	ENGR. IRO NIEL ROXAS	UP-TCAGP
	Research Associate (RA)	KRISTINE JOY ANDAYA	UP-TCAGP
	RA	ENGR. KENNETH QUISADO	UP-TCAGP
	RA	ENGR. GRACE SINADJAN	UP-TCAGP
	RA	ENGR. FRANK NICOLAS ILEJAY	UP-TCAGP
	RA	SANDRA POBLETE	UP-TCAGP
	RA	JONATHAN ALMALVEZ	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. GEF SORIANO	UP-TCAGP
	RA	FOR. MA. REMEDIOS VILLANUEVA	UP-TCAGP
	RA	DARRYL AUSTRIA	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
		SSG. ERWIN DELOS SANTOS	PAF
		SSG. DIOSCORRO SOBERANO	PAF
		SSG. JOHN ERIC CACANINDIN	PAF
	Pilot	CAPT. SHERWIN ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. FERDINAND DE OCAMPO	AAC
		CAPT. JERICO JECIEL	AAC
		CAPT. JEROME MOONEY	AAC

Annex 5. Data Transfer Sheet for Pinacanauan de Ilagan Floodplain



DATA TRANSFER SHEET
Nov 26, 2013

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Nov 18, 2013	760G	2CAG11B320A	GEMINI	NA	504KB	805KB	229MB	48GB	389KB	24.1GB	89.1GB	CGY 70 - 10330KB, CGY 92 - 8164KB, CGY 93 - 8171KB	1KB	1KB	5KB	12KB	Z:\Airborne_Raw\760G
Nov 18, 2013	762G	[illegible]	GEMINI	NA	628KB	1.48MB	116MB	1.45GB/1.45GB/6.62GB	13KB/78KB	6.46GB	35.8GB	CGY 70 - 10330KB, CGY 92 - 8164KB, CGY 93 - 8171KB	1KB	1KB	6KB	12KB	Z:\Airborne_Raw\762G
Nov 19, 2013	760G	[illegible]	GEMINI	NA	316KB	899KB	176MB	29.5GB	284KB	12.5GB	51.7GB	CGY 66 - 4339KB, CGY 70 - 8972KB, CGY 93 - 7399KB	1KB	1KB	9KB	9KB	Z:\Airborne_Raw\760G
Nov 19, 2013	762G	[illegible]	GEMINI	NA	15KB	974KB	222MB	29.7GB/2.11GB	22KB/241KB/20KB	13.3GB/5.20GB	97.5GB	CGY 70 - 9391KB, CGY 92 - 8191KB, CGY 93 - 8109KB	1KB	1KB	9KB	9KB	Z:\Airborne_Raw\762G

Received from
Name Pearl Mars 11/26/13
Position
Signature

Received by
Name JOIDA PRIETO 11/27/13
Position SSRS
Signature

Verified by
Name
Position
Signature

Figure A-5.1. Transfer Sheet for Pinacanauan de Ilagan Floodplain - A

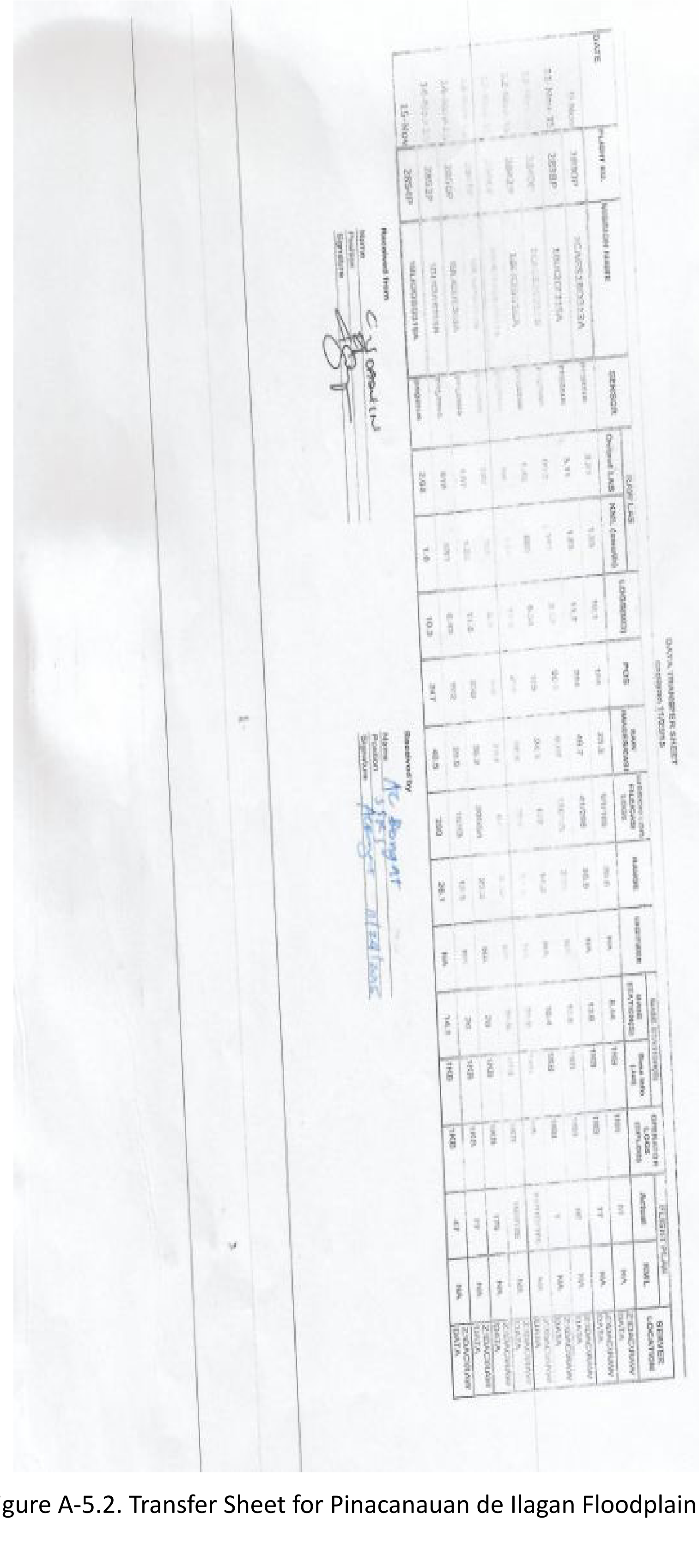


Figure A-5.2. Transfer Sheet for Pinacanauan de Ilagan Floodplain - B

DATA TRANSFER SHEET
cagayan2 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	
18-Nov	2866P	1BLK2G322A	pegasus	2.33	na	11.8	266	34.7	258	22.5	na	15.8	1KB	1KB	129	NA	Z:\DAC\RAW DATA
18-Nov	2868P	1BLK2H322B	pegasus	1.87	na	7.24	157	27.7	207	18	na	15.9	1KB	1KB	74	NA	Z:\DAC\RAW DATA
19-Nov	2870P	1BLK21AB323A	pegasus	2.11	na	11.8	295	23.2	211	22.5	na	10.3	1KB	1KB	48	NA	Z:\DAC\RAW DATA
20-Nov	2874P	1BLK21C324A	pegasus	1.22	na	8.12	195	7.3	80	12	na	10.8	1KB	1KB	57/90	NA	Z:\DAC\RAW DATA
21-Nov	2880P	1BLK2HS325A	pegasus	1.76	na	12.2	231	30	240/1	17.7	na	11.4	1KB	1KB	84/76/74	NA	Z:\DAC\RAW DATA

Received from

Name Chris Joaquin
Position
Signature

Received by

Name AC Bongat 12/4/15
Position
Signature

Figure A-5.3. Transfer Sheet for Pinacanauan de Ilagan Floodplain - C

DATA TRANSFER SHEET
21/09/2016 TUGUEGARAO

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
4/27/2016	3965G	2CAG2DSH118A	GEMINI	NA	367	585	251	NA	NA	28.2	NA	9.67	1KB	1KB	252	NA	Z:\DAC\RAWDATA
4/28/2016	3971G	2BLK3CAG2MQR119A	GEMINI	NA	193	559	252	NA	NA	21	NA	9.78	1KB	1KB	65.1	NA	Z:\DAC\RAWDATA
4/29/2016	3973G	2CAG2GSHS120A	GEMINI	NA	740	662	274	NA	NA	28.6	NA	9.24	1KB	1KB	506	NA	Z:\DAC\RAWDATA
4/30/2016	3977G	2CAG2FG121A	GEMINI	NA	392/99.5/404/107	767	255	NA	NA	29.4	NA	12.1	1KB	1KB	NA	NA	Z:\DAC\RAWDATA
4/30/2016	3979G	2CAG2E121B	GEMINI	NA	99.5	193	71.1	NA	NA	7.37	NA	12.1	1KB	1KB	67.2	NA	Z:\DAC\RAWDATA
5/1/2016	3981G	2CAG2I122A	GEMINI	NA	404	730	263	NA	NA	30.2	NA	8.23	1KB	1KB	23.2/20.6/276/129	NA	Z:\DAC\RAWDATA
5/1/2016	3983G	2CAG2CJ122B	GEMINI	NA	107	220	103	NA	NA	8.25	NA	8.23	1KB	1KB	72.4	NA	Z:\DAC\RAWDATA
5/3/2016	3989G	2BLK3CAG2QSR124A	GEMINI	NA	136/319	514	245	NA	NA	17.1	NA	14.6	1KB	1KB	NA	NA	Z:\DAC\RAWDATA
5/3/2016	3991G	2BLK3CAG2MNSQS124B	GEMINI	NA	204	228	143	NA	NA	8.65	NA	14.6	1KB	1KB	137	NA	Z:\DAC\RAWDATA
5/4/2016	3993G	2BLK3CAG2LMNQR125A	GEMINI	NA	435	161	244	NA	NA	21.2	NA	8.65	1KB	1KB	294	NA	Z:\DAC\RAWDATA
5/5/2016	3997G	2BLK3CAG2NO126A	GEMINI	NA	353	691	272	NA	NA	26.4	NA	13.9	1KB	1KB	239	NA	Z:\DAC\RAWDATA
5/5/2016	3999G	2CAG2P126B	GEMINI	NA	151	290	137	NA	NA	11.6	NA	13.9	1KB	1KB	102	151	Z:\DAC\RAWDATA
5/6/2016	4001G	2BLK3CAG2MRS127A	GEMINI	NA	208	459	245	NA	NA	16.1	NA	9.35	1KB	1KB	138	NA	Z:\DAC\RAWDATA
5/7/2016	4005G	2CAG2ABC128A	GEMINI	NA	316	NA	257	NA	NA	24	NA	8.88	1KB	1KB	215	NA	Z:\DAC\RAWDATA
5/8/2016	4009G	2CAG2K129A	GEMINI	NA	132	286	118	NA	NA	10	NA	5.85	1KB	1KB	114	NA	Z:\DAC\RAWDATA

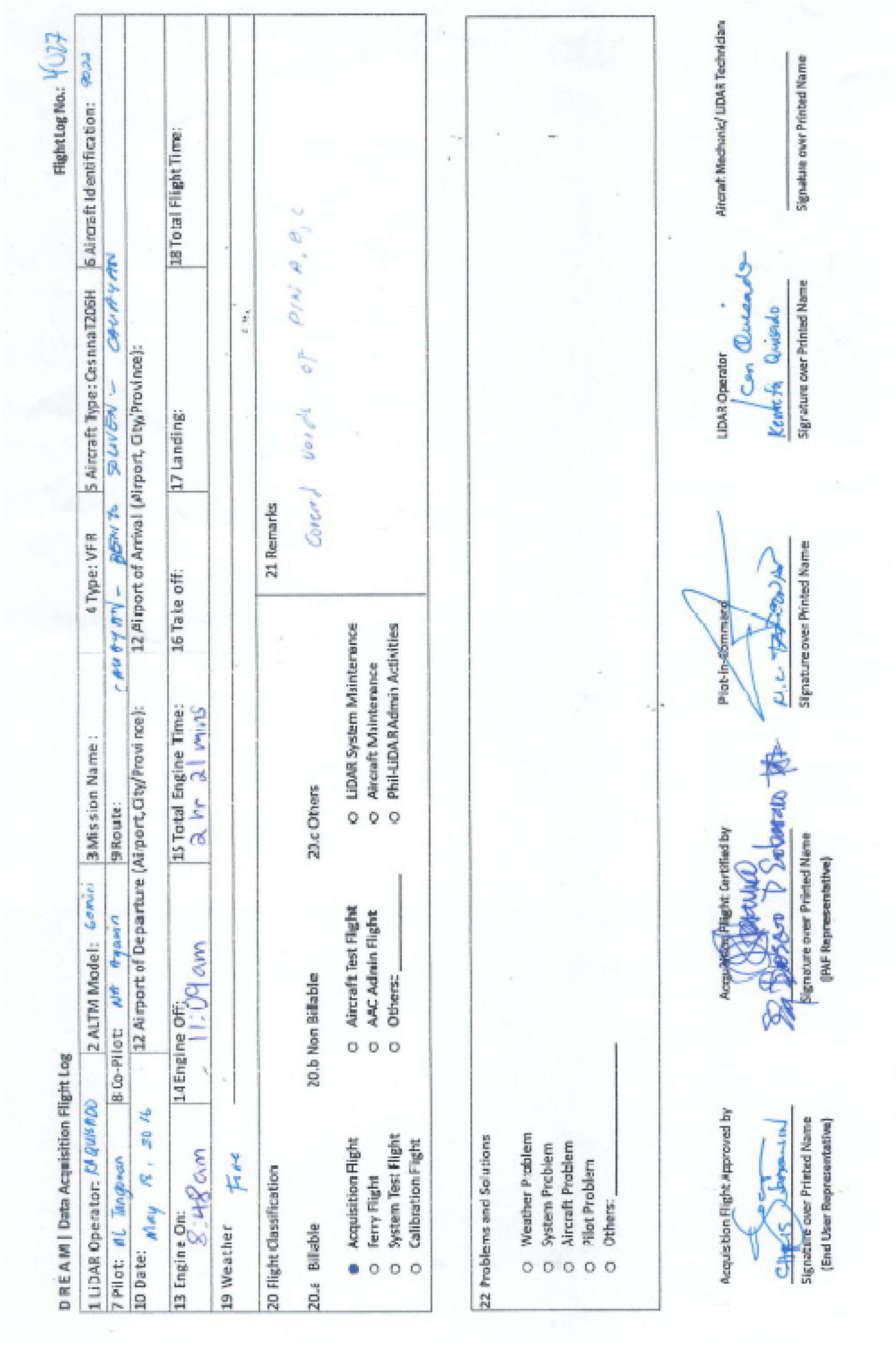
Name DARRYL AUSTRIA
Position R.A.
Signature

Name AC Bongat
Position SSRS
Signature 9/21/16

Figure A-5.4. Transfer Sheet for Pinacanauan de Ilagan Floodplain - D

Annex 6. Flight logs for the flight missions

1. Flight Log for 4027G



DREAM | Data Acquisition Flight Log

Flight Log No.: 4027

1 LiDAR Operator: KA Quisado	2 ALTM Model: Gemini	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: RL Tangonan	8 Co-Pilot: NA Ayanin	9 Route: Cauayan – Benito Soliven – Cauayan			
10 Date: May 18, 2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 8:48am	14 Engine Off: 11:09am	15 Total Engine Time: 2 hr 21 mins	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fine					

20 Flight Classification

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

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

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

21 Remarks

Covered voids of PIN A, B, C

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

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

Acquisition Flight Certified by: Diosdado D Sabarrato — Signature over Printed Name (PAF Representative)

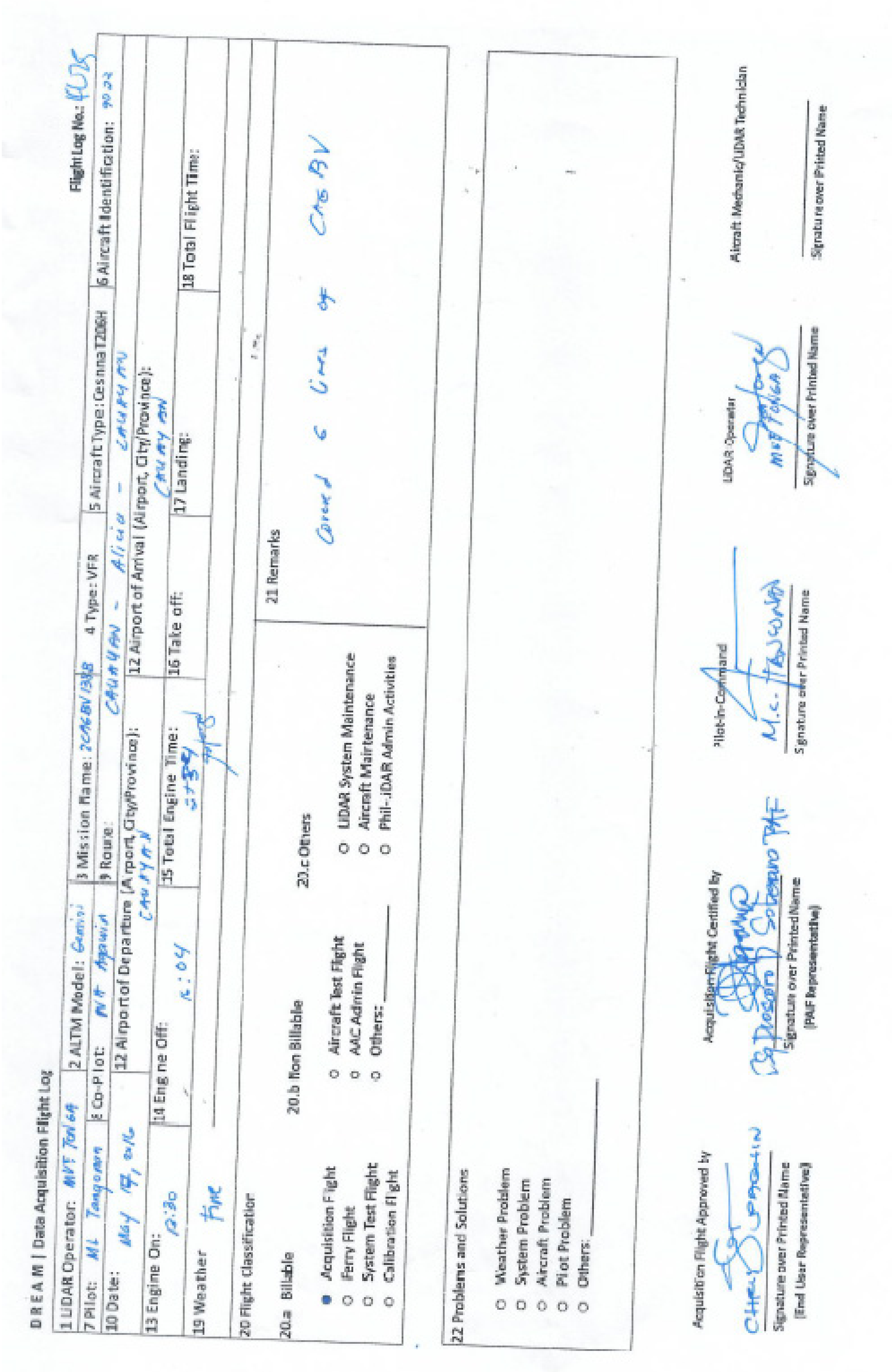
Pilot-in-Command: R.L. Tangonan — Signature over Printed Name

LIDAR Operator: Kenneth Quisado — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician — Signature over Printed Name

Figure A-6.1. Flight Log for Mission 4027G

2. Flight Log for 4025G


DREAM | Data Acquisition Flight Log

1 LiDAR Operator: MVT Tonga	2 ALTM Model: Gemini	3 Mission Name: 2CAGBV138B	4 Type: VFR	5 Aircraft Type: Cesnna T206H
7 Pilot: ML Tangonan	8 Co-Pilot: NA Aguin	9 Route: Cauayan - Alicia - Cauayan		6 Aircraft Identification: 9022
10 Date: May 17, 2016	12 Airport of Departure (Airport, City/Province): Cauayan		12 Airport of Arrival (Airport, City/Province): Cauayan	
13 Engine On: 12:30	14 Engine Off: 16:04	15 Total Engine Time: 3+34	16 Take off:	17 Landing:
19 Weather: Fine				18 Total Flight Time:

Flight Log No.: 4025

20 Flight Classification

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

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

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

21 Remarks

Covered 6 lines of CAGBV

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

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

Acquisition Flight Certified by: Sgt Diosdado Sotomayor PAF — Signature over Printed Name (PAF Representative)

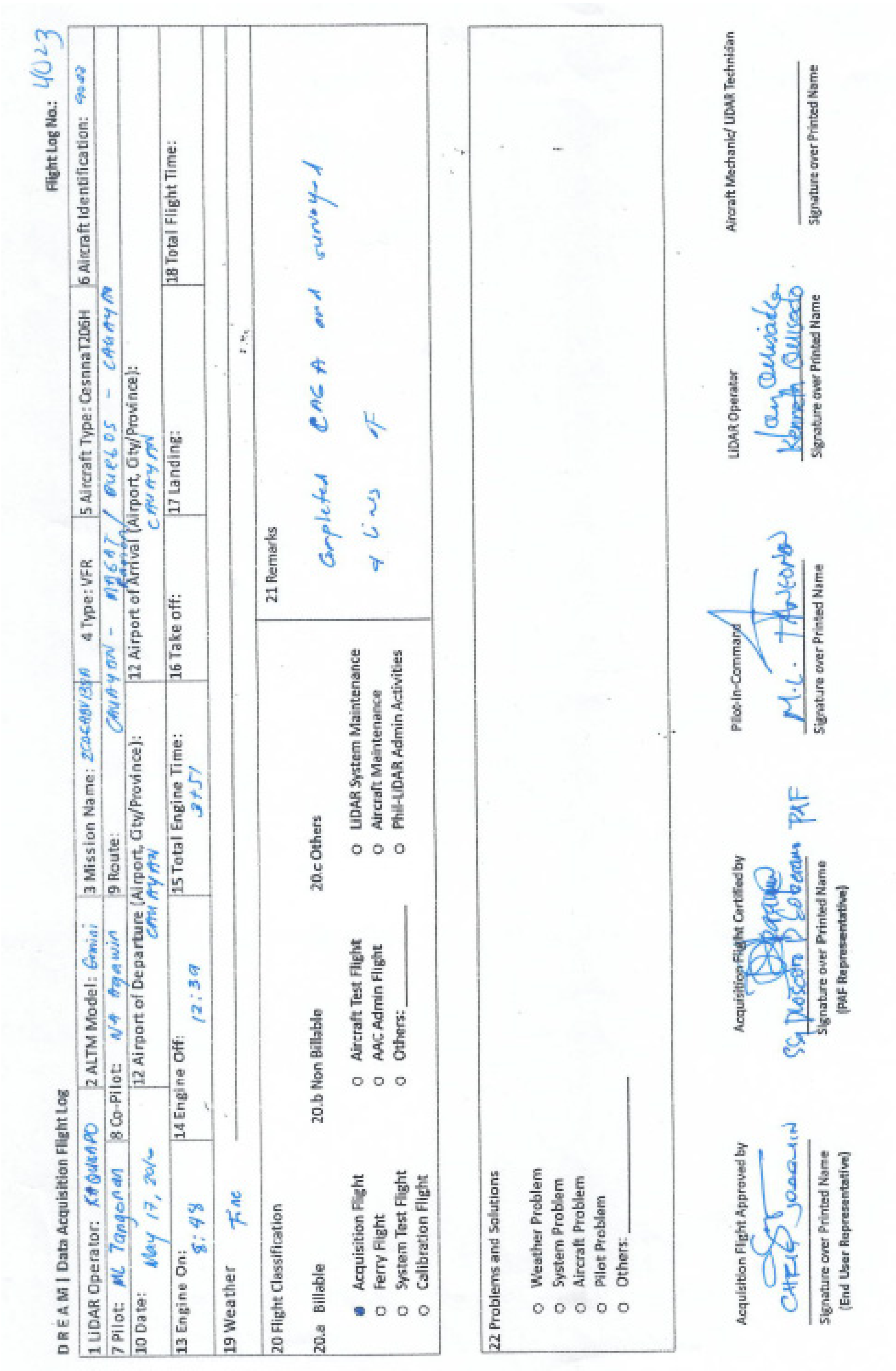
Pilot-in-Command: M.C. Tangonan — Signature over Printed Name

LiDAR Operator: MVT Tonga — Signature over Printed Name

Aircraft Mechanic/LiDAR Technician — Signature over Printed Name

Figure A-6.2. Flight Log for Mission 4025G

3. Flight Log for 4023G



DREAM | Data Acquisition Flight Log — Flight Log No.: 4023

1 LiDAR Operator: KB Gunapo	2 ALTM Model: Gemini	3 Mission Name: 2CAGBV138A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: MC Tangonan	8 Co-Pilot: NA Agawin	9 Route: Cauayan - Magat / Buegos - Cauayan			
10 Date: May 17, 2016	12 Airport of Departure (Airport, City/Province): Cauayan		12 Airport of Arrival (Airport, City/Province): Cauayan		
13 Engine On: 8:48	14 Engine Off: 12:39	15 Total Engine Time: 3+51	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fine					

20 Flight Classification

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

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

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

21 Remarks

Completed CAG A and surveyed 4 lines of

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

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

Acquisition Flight Certified by: SSg Dioscoro Cobarrubias PAF — Signature over Printed Name (PAF Representative)

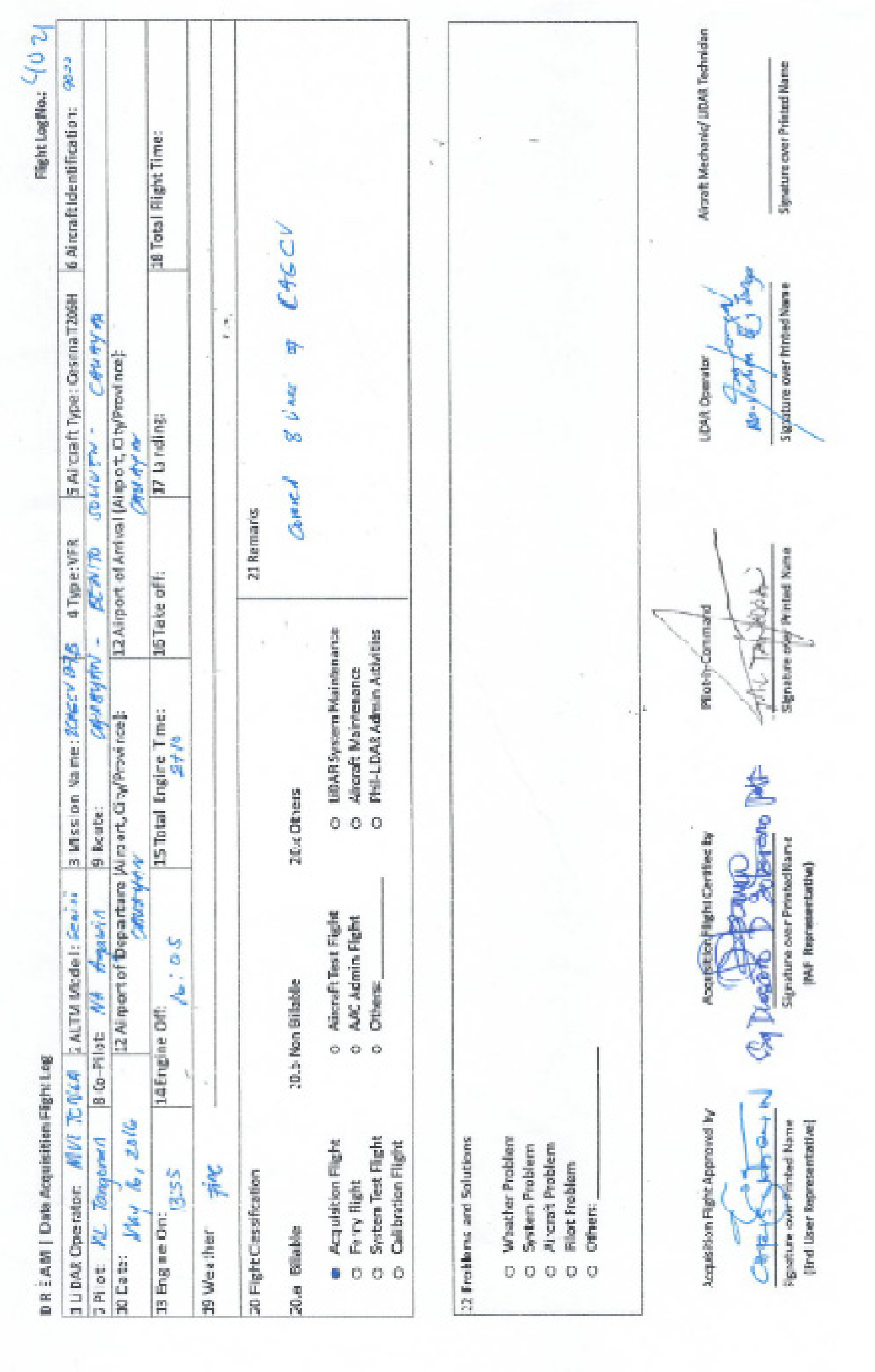
Pilot-in-Command: M.C. Tangonan — Signature over Printed Name

LiDAR Operator: Kenneth Quisado — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician — Signature over Printed Name

Figure A-6.3. Flight Log for Mission 4023G

4. Flight Log for 4021G



DREAM | Data Acquisition Flight Log

Flight Log No.: 4021

1 LiDAR Operator: MVI Tonga
2 ALTM Model: Gemini
3 Mission Name: 2BAGCV 137B
4 Type: VFR
5 Aircraft Type: Cessna T206H
6 Aircraft Identification: 9022
7 Pilot: RL Tongcuan
8 Co-Pilot: NM Angalim
9 Route: Cauayan - Benito Soliven - Cauayan
10 Date: May 16, 2016
12 Airport of Departure (Airport, City/Province): Cauayan
12 Airport of Arrival (Airport, City/Province): Cauayan
13 Engine On: 1355
14 Engine Off: 16:05
15 Total Engine Time: 2+10
16 Take off:
17 Landing:
18 Total Flight Time:
19 Weather: fine
20 Flight Classification
20.a Billable
- Acquisition Flight
- Ferry Flight
- System Test Flight
- Calibration Flight

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

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

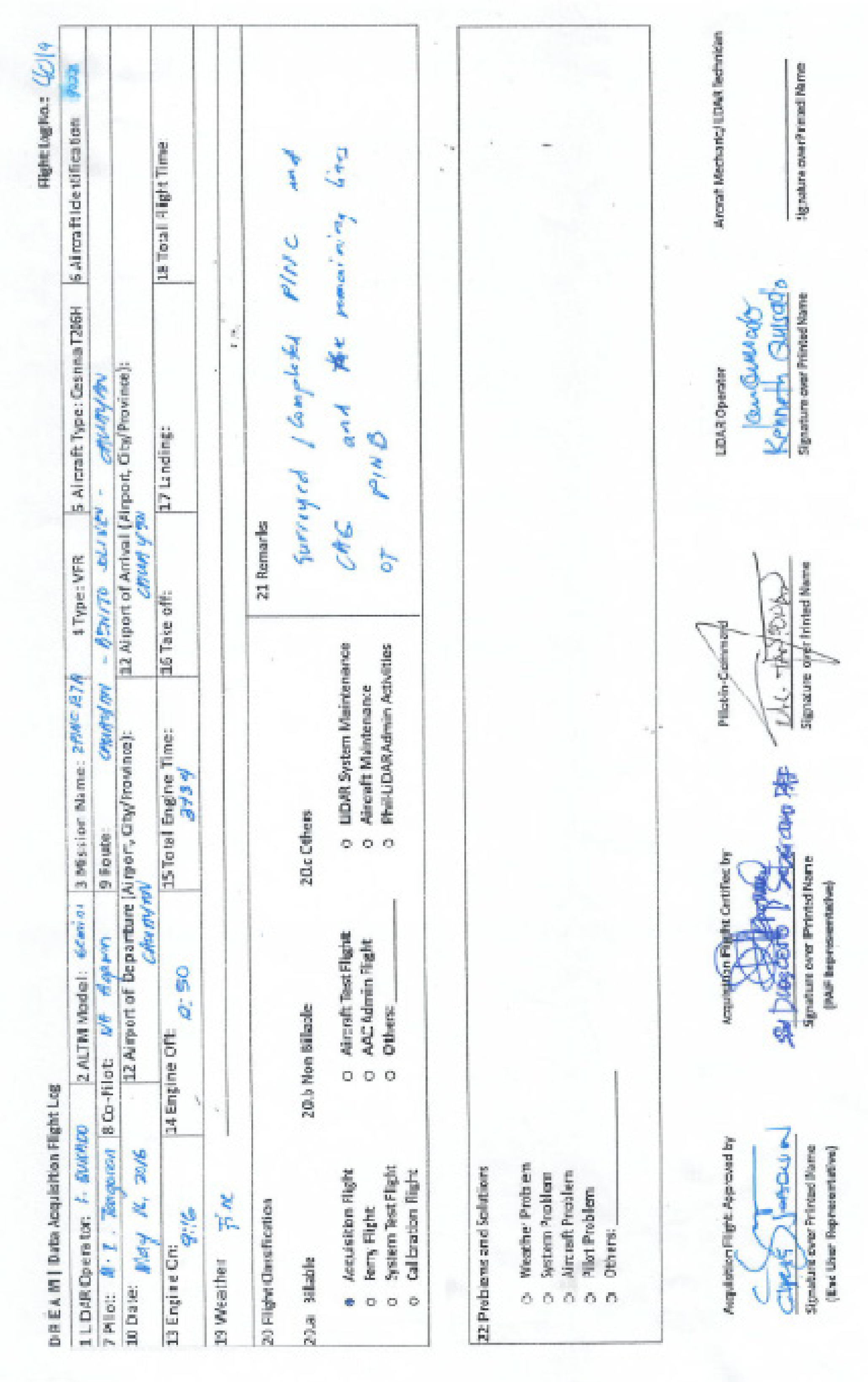
21 Remarks: Covered 8 lines of CAGCV

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-6.4. Flight Log for Mission 4021G

5. Flight Log for 4019G



DREAM | Data Acquisition Flight Log

Flight Log No.: 4019

1 LiDAR Operator: F. Quisado	2 ALTM Model: Gemini	3 Mission Name: 2BWC137A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. T. Tangonan	8 Co-Pilot: NF Agapin	9 Route: Cauayan - Benito Soliven - Cauayan			
10 Date: May 16, 2016	12 Airport of Departure (Airport, City/Province): Cauayan		12 Airport of Arrival (Airport, City/Province): Cauayan		
13 Engine On: 9:16	14 Engine Off: 0:50	15 Total Engine Time: 3+34	16 Take off:	17 Landing:	18 Total Flight Time
19 Weather: Fine					

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 / Completed PINC and CAG and the remaining lines of PINB

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)

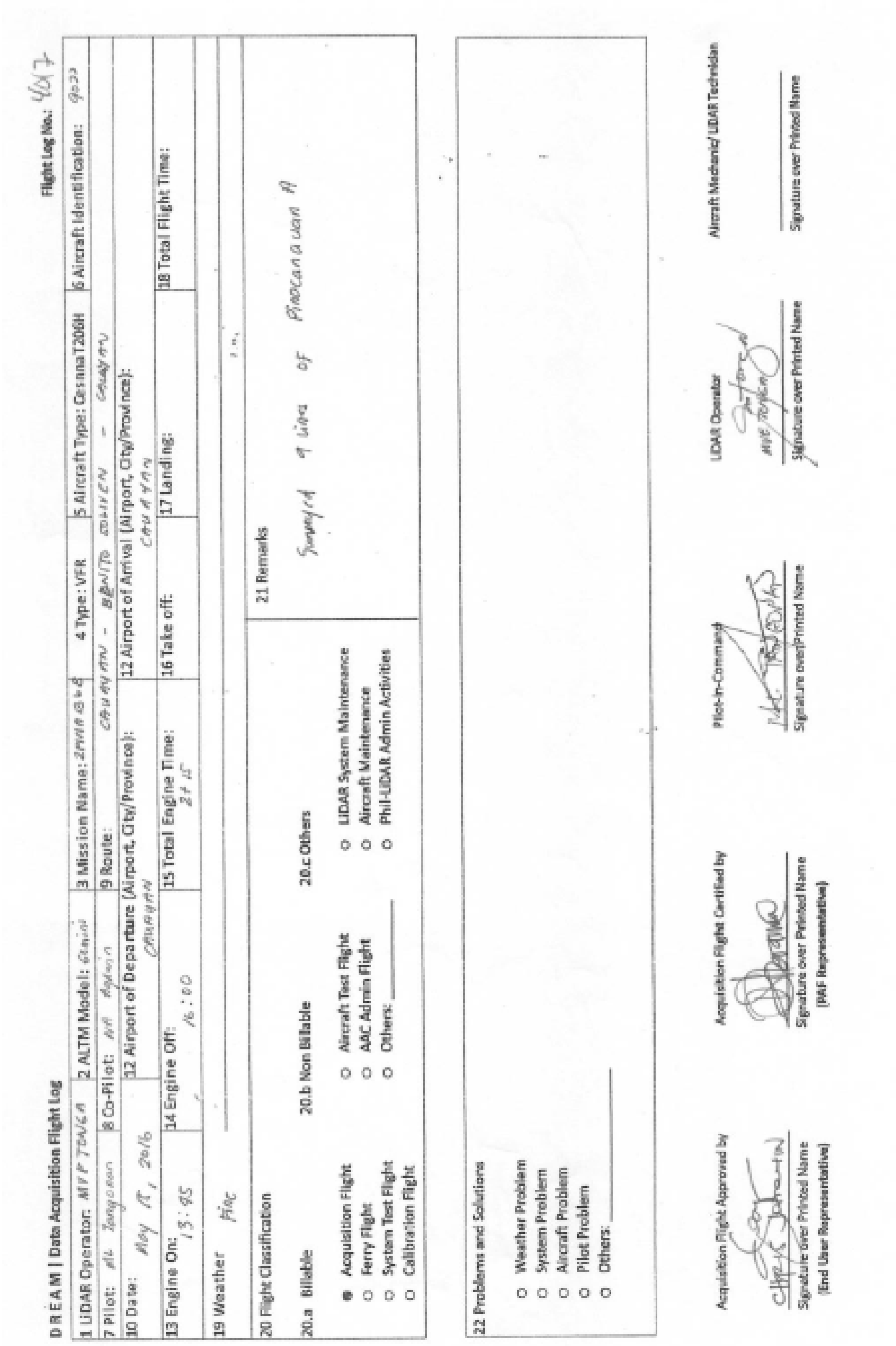
Pilot-in-Command: Signature over Printed Name

LiDAR Operator: Kenneth Quisado, Signature over Printed Name

Aircraft Mechanic/LiDAR Technician: Signature over Printed Name

Figure A-6.5. Flight Log for Mission 4019G

6. Flight Log for 4017G



DREAM | Data Acquisition Flight Log

Flight Log No.: 4017

1 LiDAR Operator: MVF Tonga	2 ALTM Model: Gemini	3 Mission Name: 2MNA 16	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: AL Tangonan	8 Co-Pilot: AR Aglanan	9 Route: Cauayan - Benito Soliven - Cauayan			
10 Date: May 17, 2016	12 Airport of Departure (Airport, City/Province): Cauayan		12 Airport of Arrival (Airport, City/Province): Cauayan		
13 Engine On: 13:45	14 Engine Off: 16:00	15 Total Engine Time: 2+15	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fine					

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 9 lines of Pinacanauan R

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)

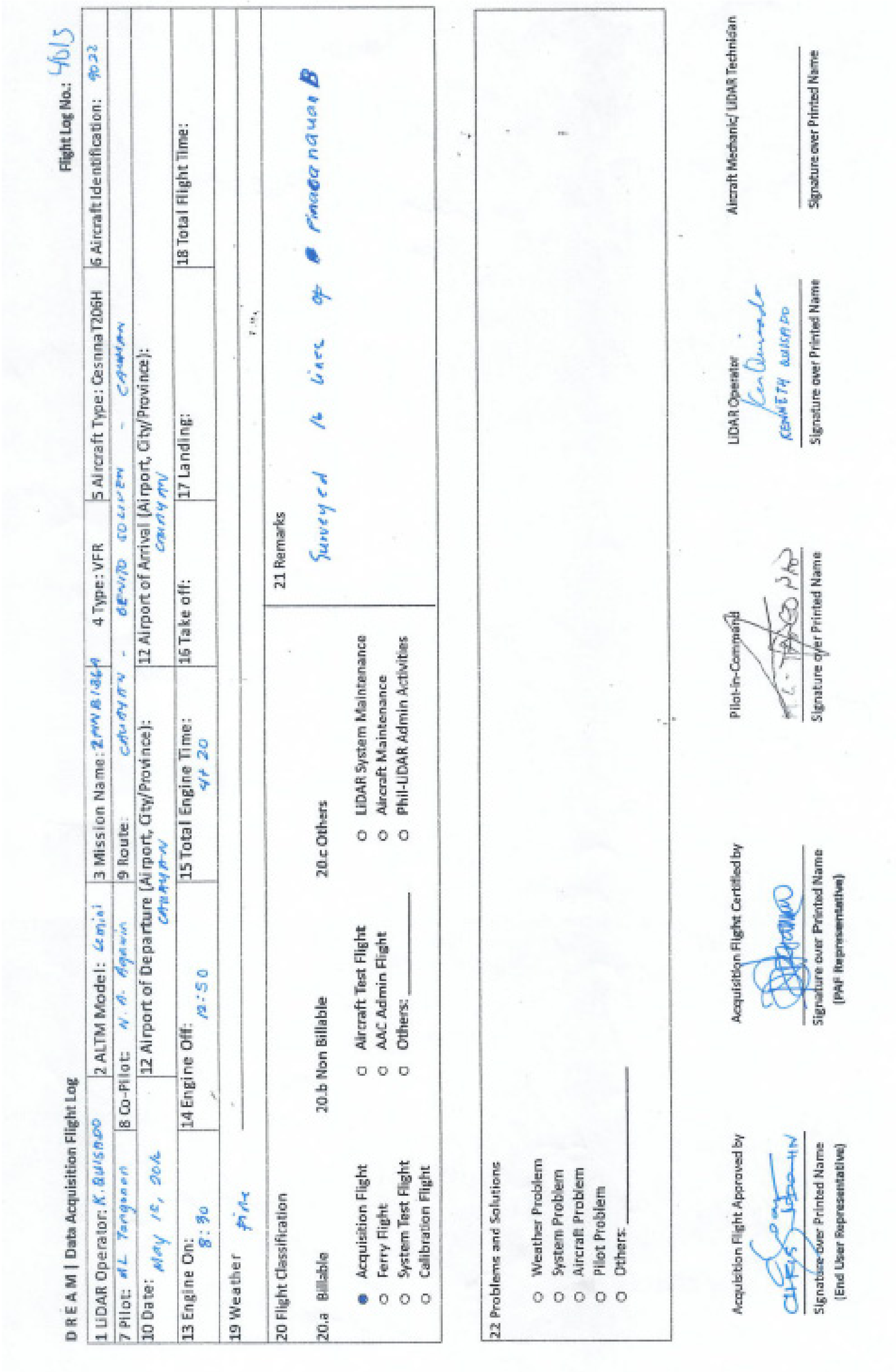
Pilot-in-Command: Signature over Printed Name

LiDAR Operator: MVF Tonga, Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: Signature over Printed Name

Figure A-6.6. Flight Log for Mission 4017G

7. Flight Log for 4015G


DREAM | Data Acquisition Flight Log

Flight Log No.: 4015

1 LiDAR Operator: K. Bulisado	2 ALTM Model: Gemini	3 Mission Name: 2PNB186A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: AL Tangonan	8 Co-Pilot: N. A. Aganin	9 Route: Cauayan - Benito Soliven - Cauayan			
10 Date: May 12, 2016	12 Airport of Departure (Airport, City/Province): Cauayan		12 Airport of Arrival (Airport, City/Province): Cauayan		
13 Engine On: 8:30	14 Engine Off: 12:50	15 Total Engine Time: 4+20	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: fine					

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 16 lines of Pinacanauan B

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

Acquisition Flight Approved by
Chris [signature]
Signature over Printed Name
(End User Representative)

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

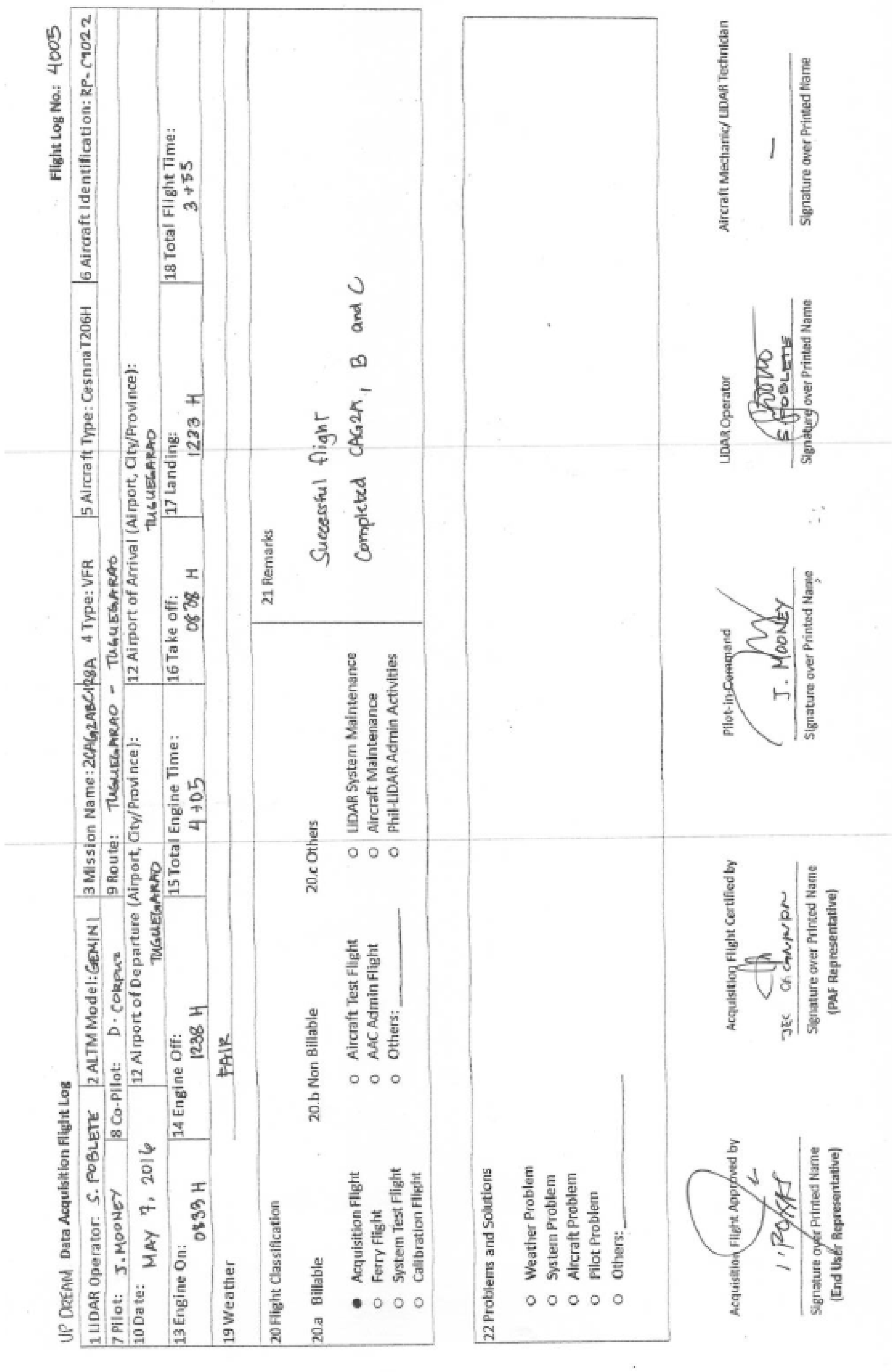
Pilot-in-Command
[signature]
Signature over Printed Name

LiDAR Operator
Kenneth Bulisado
Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name

Figure A-6.7. Flight Log for Mission 4015G

8. Flight Log for 4005G



UP DREAM Data Acquisition Flight Log

Flight Log No.: 4005

1 LIDAR Operator: S. POBLETE	2 ALTM Model: GEMINI	3 Mission Name: 2BLG2ABC128A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORPUZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: MAY 7, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 0833 H	14 Engine Off: 1238 H	15 Total Engine Time: 4+05	16 Take off: 0838 H	17 Landing: 1233 H	18 Total Flight Time: 3+55
19 Weather: FAIR					

20 Flight Classification

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

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

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

21 Remarks

Successful flight
Completed CAG2A, B and C

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

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

Acquisition Flight Certified by: 2LT CF CAMINDAN — Signature over Printed Name (PAF Representative)

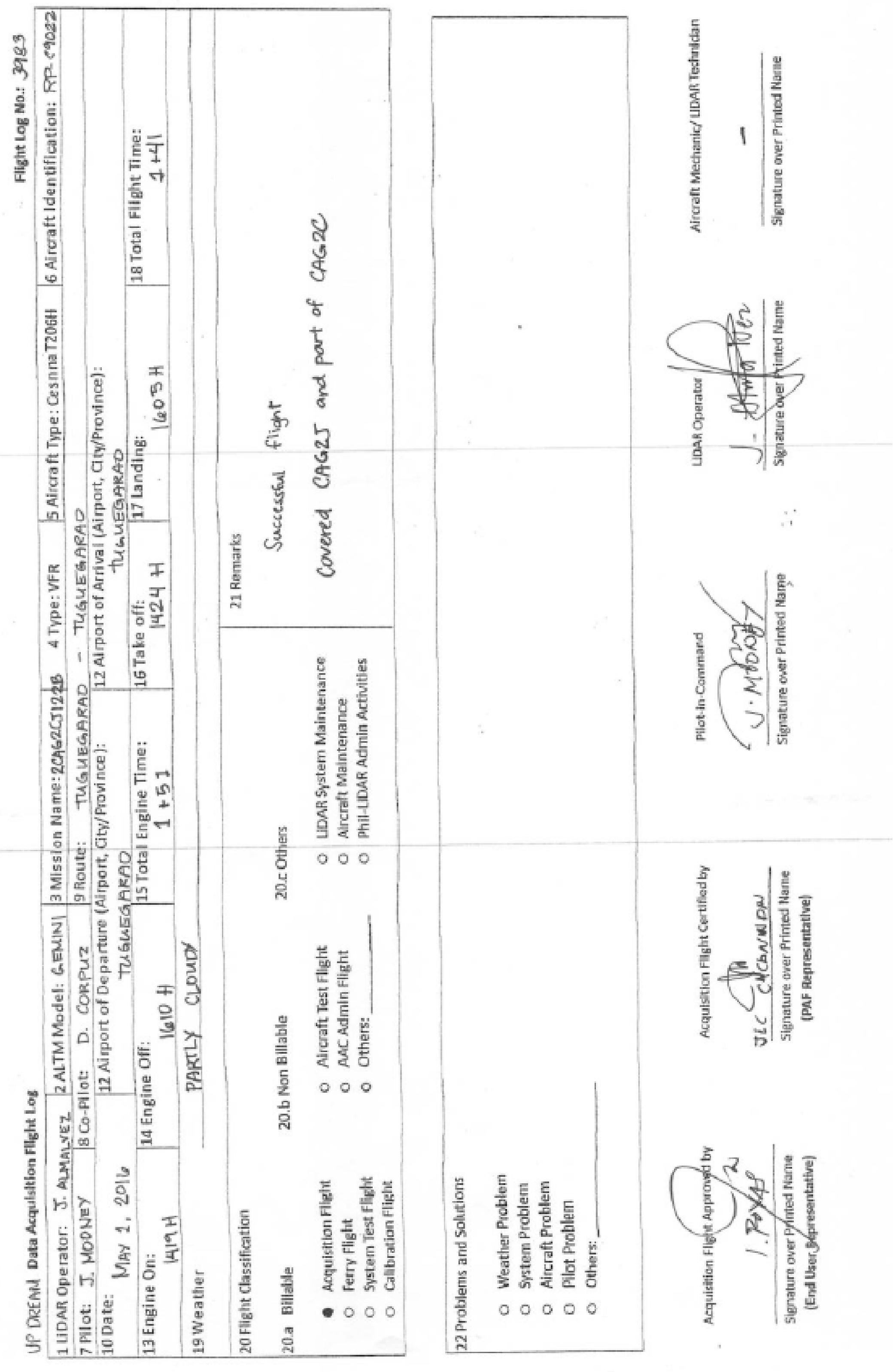
Pilot-in-Command: J. MOONEY — Signature over Printed Name

LIDAR Operator: S. POBLETE — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician — Signature over Printed Name

Figure A-6.8. Flight Log for Mission 4005G

9. Flight Log for 3983G



UP DREAM Data Acquisition Flight Log

Flight Log No.: 3983

1 LIDAR Operator: J. ALMALVEZ	2 ALTM Model: GEMINI	3 Mission Name: 2CAG2CJ122B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORPUZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: MAY 1, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 1419 H	14 Engine Off: 1610 H	15 Total Engine Time: 1+51	16 Take off: 1424 H	17 Landing: 1605 H	18 Total Flight Time: 1+41
19 Weather	PARTLY CLOUDY				

20 Flight Classification

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

21 Remarks

Successful flight

Covered CAG2J and part of CAG2C

22 Problems and Solutions

○ Weather Problem
○ System Problem
○ Aircraft Problem
○ Pilot Problem
○ Others: ____

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
I. ROXAS	JLC CALANDON	J. MOONEY	J. ALMALVEZ	
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 Mission 3983G

10. Flight Log for 3979G

UP DREAM **Data Acquisition Flight Log**

Flight Log No.: 3979

1 LiDAR Operator: J. ALMALVEZ / P. ARCEO	2 ALTM Model: GEMINI	3 Mission Name: 2CAG2E121B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORPUZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: APRIL 30, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 1934 H	14 Engine Off: 1602 H	15 Total Engine Time: 1 + 28	16 Take off: 1439 H	17 Landing: 1557 H	18 Total Flight Time: 1 + 18
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

Successful flight

Covered CAG2E

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

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

Acquisition Flight Certified by: ??C CAPANGPAN — Signature over Printed Name (PAF Representative)

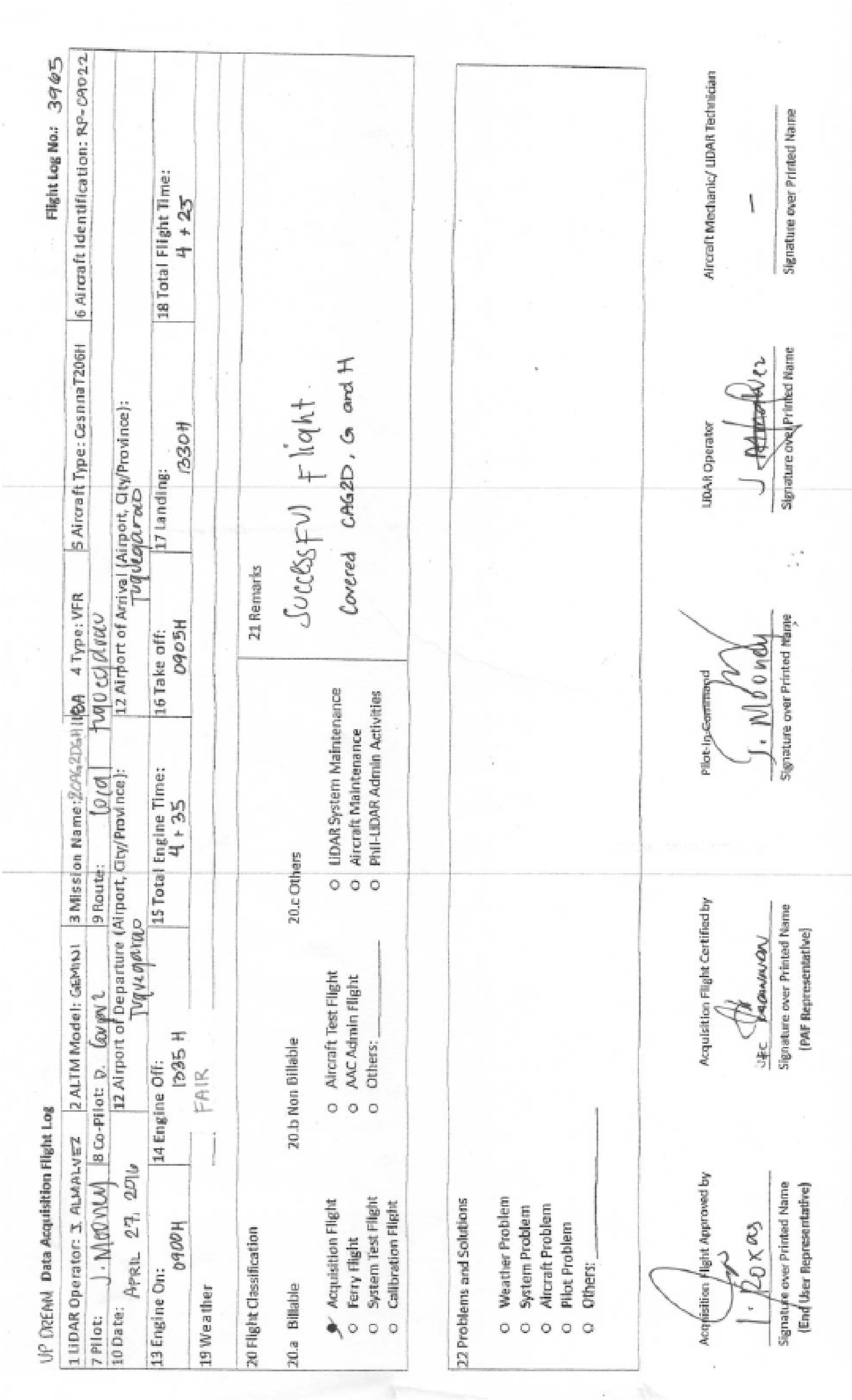
Pilot-in-Command: J. MOONEY — Signature over Printed Name

LIDAR Operator: [illegible] — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: — — Signature over Printed Name

Figure A-6.10. Flight Log for Mission 3979G

11. Flight Log for 3965G



UP DREAM Data Acquisition Flight Log

Flight Log No.: 3965

1 LiDAR Operator: J. ALMALVEZ | 2 ALTM Model: GEMINI | 3 Mission Name: 2CAG2DGH118A | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: RP-C9022

7 Pilot: J. Mooney | 8 Co-Pilot: D. Cayari | 9 Route: Local Tuguegarao

10 Date: APRIL 27, 2016 | 12 Airport of Departure (Airport, City/Province): Tuguegarao | 12 Airport of Arrival (Airport, City/Province): Tuguegarao

13 Engine On: 0900H | 14 Engine Off: 1335 H | 15 Total Engine Time: 4 + 35 | 16 Take off: 0905H | 17 Landing: 1330H | 18 Total Flight Time: 4 + 25

19 Weather: FAIR

20 Flight Classification

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

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

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

21 Remarks

Successful Flight.

Covered CAG2D, G and H

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

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

Acquisition Flight Certified by: 1LT/C Pagaduan — Signature over Printed Name (PAF Representative)

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

LiDAR Operator: J. Almalvez — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: – — Signature over Printed Name

Figure A-6.11. Flight Log for Mission 3965G

12. Flight Log for 2732G

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2732

1 LiDAR Operator: JP ALAMBAN	2 ALTM Model: Gemini	3 Mission Name: 2CGYRC258B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: A. Lim	8 Co-Pilot: D. [illegible]	9 Route: Cauayan			
10 Date: 9/15/2015	12 Airport of Departure (Airport, City/Province): Cauayan City, Isabela		12 Airport of Arrival (Airport, City/Province): Cauayan City, Isabela		
13 Engine On: 1407H	14 Engine Off: 1606H	15 Total Engine Time: 1:59	16 Take off: 1412H	17 Landing: 1601H	18 Total Flight Time: 1:57
19 Weather	fair				

20 Flight Classification

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

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

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

21 Remarks

Successful flight; completed CGYRC

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
G. Alfelor	CHARISMA NAVARRO	A. LIM	JP ALAMBAN	G. ANTONIO
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-6.12. Flight Log for Mission 2732G

13. Flight Log for 2730G

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2730

1 LIDAR Operator: JS Gonzales	2 ALTM Model: Gemini	3 Mission Name: 2BLK9CGHRFG258A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: A. Lim	8 Co-Pilot: D. Cabusel	9 Route: Cauayan, Palanan			
10 Date: 9/15/2015	12 Airport of Departure (Airport, City/Province): Cauayan City, Isabela		12 Airport of Arrival (Airport, City/Province): Cauayan City, Isabela		
13 Engine On: 0818H	14 Engine Off: 1205H	15 Total Engine Time: 3:47	16 Take off: 0823H	17 Landing: 1200H	18 Total Flight Time: 3:37
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Supplementary flight over Palanan; successful flight

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
G. Hipolito	Charisma Navarro	A. Lim		G. Antonio
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-6.13. Flight Log for Mission 2730G

14. Flight Log for 2728G

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2728

1 LIDAR Operator: JP Alamban	2 ALTM Model: Gemini	3 Mission Name: 2CGYRG257B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: A. Lim	8 Co-Pilot: D. Cabuhat	9 Route: Cauayan			
10 Date: 9/14/2015	12 Airport of Departure (Airport, City/Province): Cauayan City, Isabela		12 Airport of Arrival (Airport, City/Province): Cauayan City, Isabela		
13 Engine On: 1357H	14 Engine Off: 1608H	15 Total Engine Time: 2:11	16 Take off: 1402H	17 Landing: 1603H	18 Total Flight Time: 2:01
19 Weather	Fair				

20 Flight Classification

20.a Billable	20.b Non Billable	20.c Others
☒ Acquisition Flight	o Aircraft Test Flight	o LIDAR System Maintenance
o Ferry Flight	o AAC Admin Flight	o Aircraft Maintenance
o System Test Flight	o Others: ____________	o Phil-LIDAR Admin Activities
o Calibration Flight		

21 Remarks

Successful flight; surveyed CGYRG

22 Problems and Solutions

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
G. Hipolito	Charisma M. Navarro	A. Lim	JP Alamban	G. Antonio
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-6.14. Flight Log for Mission 2728G

15. Flight Log for 2726G

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2726

1 LIDAR Operator: JS Gonzales	2 ALTM Model: Gemini	3 Mission Name: 2CGYRABE257A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: A. Lim	8 Co-Pilot: D. Cabaral	9 Route: Cauayan			
10 Date: 9/14/2015	12 Airport of Departure (Airport, City/Province): Cauayan City, Isabela		12 Airport of Arrival (Airport, City/Province): Cauayan City, Isabela		
13 Engine On: 0819H	14 Engine Off: 1142H	15 Total Engine Time: 3:23	16 Take off: 0824H	17 Landing: 1137H	18 Total Flight Time: 3:13
19 Weather: Fair but partly 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 AAC Admin Flight
- o Others: ____________

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

21 Remarks

Successful flight; surveyed CGYRA

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
G. Hipolito	Charisma Navarro	A. Lim	JP Alamban; Jonathan Gonzales	G. Antonio
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-6.15. Flight Log for Mission 2726G

16. Flight Log for 2706G

PHIL-LIDAR 1 Data Acquisition Flight Log — Flight Log No.: 2706

1 LIDAR Operator: JP Alambra	2 ALTM Model: Gemini	3 Mission Name: 2BLK9B252A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: A. Lim	8 Co-Pilot: D. Alfelor	9 Route: Palanan, Isabela			
10 Date: 9/9/2015	12 Airport of Departure (Airport, City/Province): Cauayan City, Isabela		12 Airport of Arrival (Airport, City/Province): Cauayan City, Isabela		
13 Engine On: 0815H	14 Engine Off: 1032H	15 Total Engine Time: 2:17	16 Take off: 0820H	17 Landing: 1027H	18 Total Flight Time: 2:07
19 Weather: Fair					

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 AAC Admin Flight
- o Others: ____________

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

21 Remarks

Successful flight; completed BLK9B

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
G. Hipolito	Cathrylann M. Navarro	A. Lim	JP Alambra	G. Antonio
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.16. Flight Log for Mission 2706G

17. Flight Log for 2702G

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2702

1 LIDAR Operator: U Gonzales	2 ALTM Model: Gemini	3 Mission Name: 2BLK9AB251A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: A. Lim	8 Co-Pilot: D. Gubat	9 Route: Palanan, Isabela			
10 Date: 9/8/2015	12 Airport of Departure (Airport, City/Province): Cauayan City, Isabela		12 Airport of Arrival (Airport, City/Province): Cauayan City, Isabela		
13 Engine On: 0900H	14 Engine Off: 1259H	15 Total Engine Time: 3:59	16 Take off: 0905H	17 Landing: 1254H	18 Total Flight Time: 3:49
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 AAC Admin Flight
- o Others: ____________

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

21 Remarks

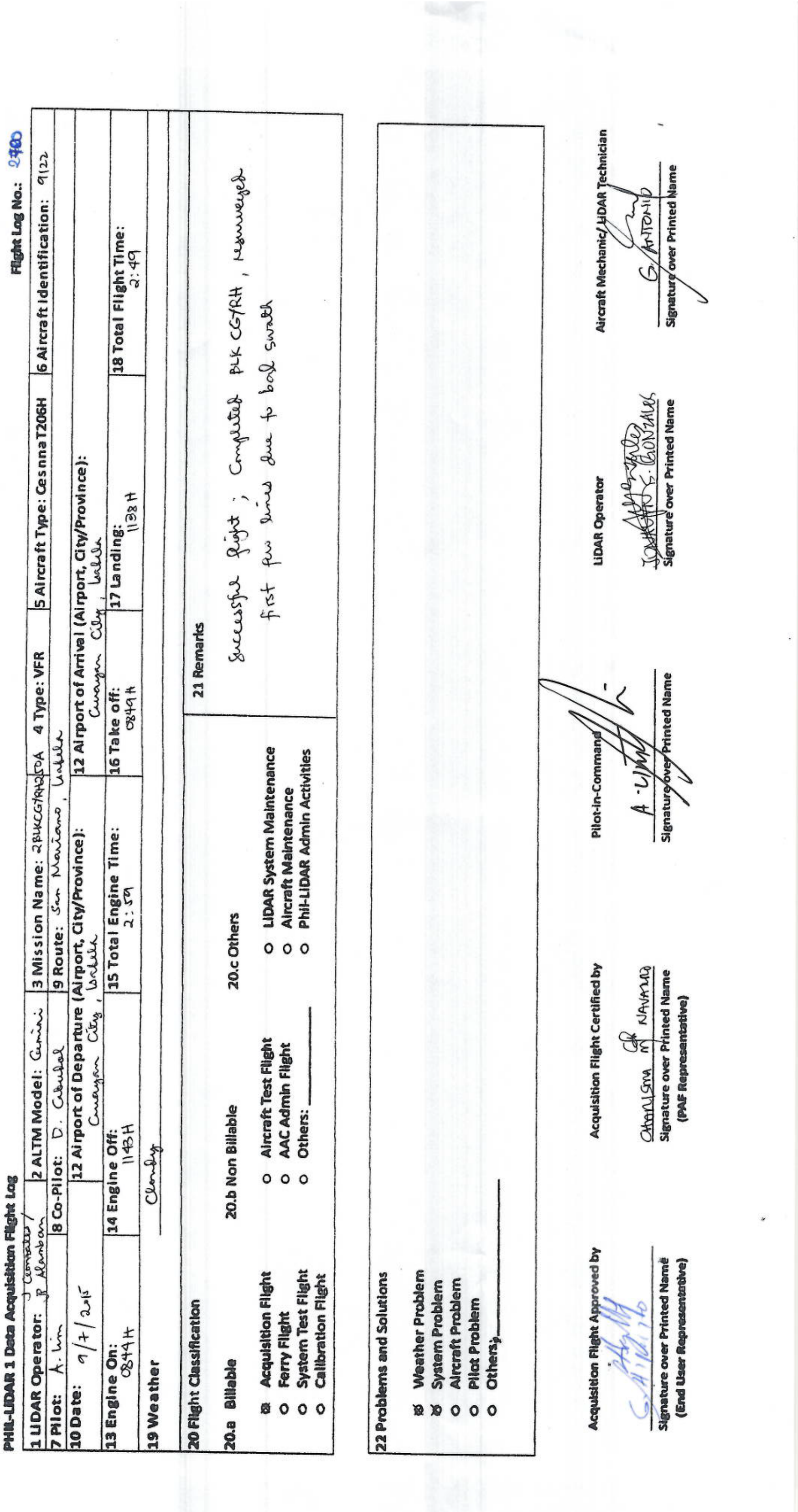
Successful flight; Completed BLK9A and surveyed BLK9B

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
G. Hipolito	CHARLIGMA M NAVARRO	A [signature]	JOHALYN C. GONZALES	G. ANTONIO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.17. Flight Log for Mission 2702G

18. Flight Log for 2700G


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2700

1 LiDAR Operator: J Gonzales / R Alambon	2 ALTM Model: Gemini	3 Mission Name: 2BLKCG/RH	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: A. Lim	8 Co-Pilot: D. Cabildo	9 Route: San Mariano, Isabela			
10 Date: 9/7/2015	12 Airport of Departure (Airport, City/Province): Cauayan City, Isabela		12 Airport of Arrival (Airport, City/Province): Cauayan City, Isabela		
13 Engine On: 0844H	14 Engine Off: 1143H	15 Total Engine Time: 2:59	16 Take off: 0849H	17 Landing: 1138H	18 Total Flight Time: 2:49
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 AAC Admin Flight
- o Others:

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

21 Remarks

Successful flight; Completed BLK CG/RH, resurveyed first few lines due to bad swath

22 Problems and Solutions
- ☒ Weather Problem
- ☒ 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 — A. Lim — Signature over Printed Name

LiDAR Operator — J. Gonzales — Signature over Printed Name

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

Figure A-6.18. Flight Log for Mission 2700G

Annex 7. Flight status reports

PALANAN AND CASIGURAN (BLK 9 & 11) WITH REFLIGHTS GEMINI STATUS REPORT
September 4-15, 2015; November 25-30, 2015; April 27-May 15, 2016

Table A-7.1. Flight Status Report

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2686G	BLK 9C	2BLK9C247A	JS GONZALES JP ALAMBAN	4-Sep-15	Mission successful; Covered BLK9C
2690G	BLK 9A	2BLK9A248A	JS GONZALES JP ALAMBAN	5-Sep-15	Mission successful; Surveyed BLK9A
2696G	CGYR H	2CGYRH249B	JP ALAMBAN	6-Sep-15	Test/troubleshooting flight for PDOP 99; For checking of POS data only
2700G	CGYR H	2CGYRH250A	JS GONZALES JP ALAMBAN	7-Sep-15	Completed CGYRH; First few lines resurveyed due to bad swath
2702G	BLK 9A,B	2BLK9AB251A	JS GONZALES	8-Sep-15	Successful; Completed BLK9A and surveyed BLK9B; DiOps error message though camera is triggering normally
2706G	BLK 9B	2BLK9B252A	JP ALAMBAN	9-Sep-15	Completed BLK9B
2710G	BLK 11A	2BLK11A253A	JS GONZALES	10-Sep-15	Successful; Start survey of BLK11A
2718G	BLK 11A	2BLK11A255A	JP ALAMBAN	12-Sep-15	Successful; Completed BLK11A
2726G	CGYR A,B,E	2CGYRABE257A	JS GONZALES	14-Sep-15	Some gaps on CGYRA; May use A as tie line of CGYRB
2728G	CGYR G	2CGYRG257B	JP ALAMBAN	14-Sep-15	Successful
2730G	BLK 9, CGYR G,F	2BLK9CGYRFG258A	JS GONZALES	15-Sep-15	Supplementary flight over Palanan; CGYR G has no tie line due to maximized air time
2732G	CGYR C	2CGYRC258B	JP ALAMBAN	15-Sep-15	Successful
2894P	BLK 101BCS	1BLK2S329A	KJ ANDAYA	NOV 25	SURVEYED GAPS WEST OF TUGUEGARAO 158.09 SQ.KM
2898P	BLK 101DS	1BLK2S330A	K QUISADO	NOV 26	SURVEYED GAPS WEST OF TUGUEGARAO 142.98 SQ.KM.
2914P	BLK 11DS, CAG 101DS	1BLK3A334A	K QUISADO	NOV 30	SURVEYED CAG11D AND CAG 101DS (ONE STRIP) 214.57 SQ.KM

3965G	CAG2H, CAG2G	2CAG2DGH118A	J. ALMALVEZ	April 27, 2016	Covered CAG2D,G and H
3979G	CAG2E	2CAG2E121B	J. ALMALVEZ and P. ARCEO	April 30, 2016	Covered CAG2E
3983G	CAG2C, CAG2J	2CAG2CJ122B	J. ALMALVEZ	May 1, 2016	Covered CAG2J and part of CAG2C
4005G	CAG2A, CAG2B, CAG2C	2CAG2ABC128A	S. POBLETE	May 7, 2016	Completed CAG2A, B and C
4015G	Pinacanauan de Ilagan FP	2PINB136A	K. QUISADO	MAY 15	SURVEYED PIN B 207.42 SQ.KM
4017G	Pinacanauan de Ilagan FP	2PINA136B	V. TONGA	MAY 15	SURVEYED PIN A 112.31 SQ.KM
4019G	Pinacanauan de Ilagan FP	2PINC137A	K. QUISADO	MAY 16	SURVEYED PIN C 176 SQ.KM
4021G	Pinacanauan de Ilagan FP	2CAGCV137B	V. TONGA	MAY 16	SURVEYED CAGCV 117.19 SQ.KM
4023G	Cagayan FP	2CAGABV138A	K. QUISADO	MAY 17	SURVEYED CAGBV 164.35 SQ.KM.
4025G	Cagayan FP	2CAGBV138B	V. TONGA	MAY 17	SURVEYED CAGBV 169.36 SQ.KM.
4027G	Voids of Pinacanauan	2PINV139A	K. QUISADO	MAY 18	SURVEYED VOIDS 25 SQ.KM.
4015G	Pinacanauan de Ilagan FP	2PINB136A	K. QUISADO	MAY 15	SURVEYED PIN B 207.42 SQ.KM

SWATH PER FLIGHT MISSION

Flight No. :	2686
Area:	BLK 9C
Mission Name:	2BLK9C247A
Altitude:	1200
Scan Frequency:	50
Scan Angle:	18
Total Area Surveyed:	91.53 sq km

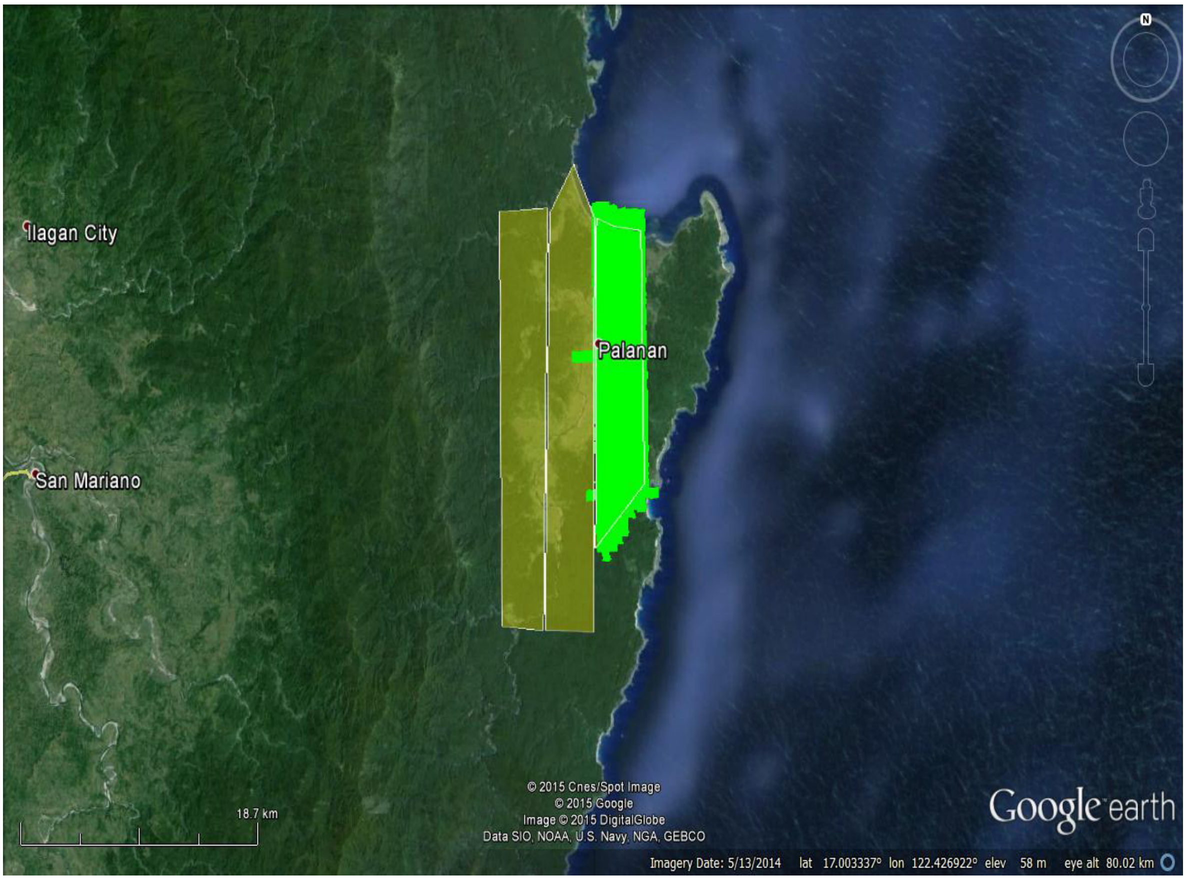


Figure A-7.1. Swath for Flight No. 2686

Flight No. : 2690
Area: BLK 9A
Mission Name: 2BLK9A248A
Altitude: 1200, 900
Scan Frequency: 50, 40
Scan Angle: 18, 25
Total Area Surveyed: 88.85 sq km

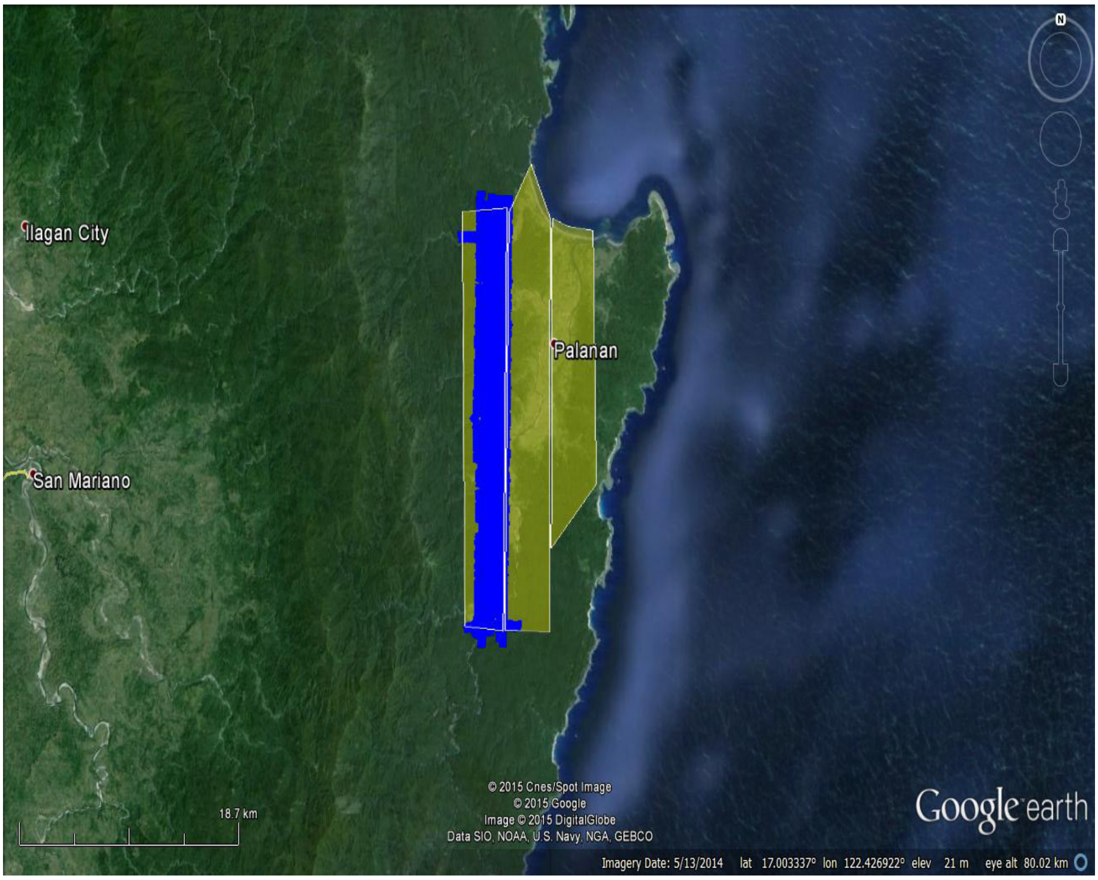


Figure A-7.2. Swath for Flight No. 2690

Flight No. :	2700
Area:	CGYR H
Mission Name:	2CGYRH250A
Altitude:	900
Scan Frequency:	40
Scan Angle:	25
Total Area Surveyed:	60.02 sq km

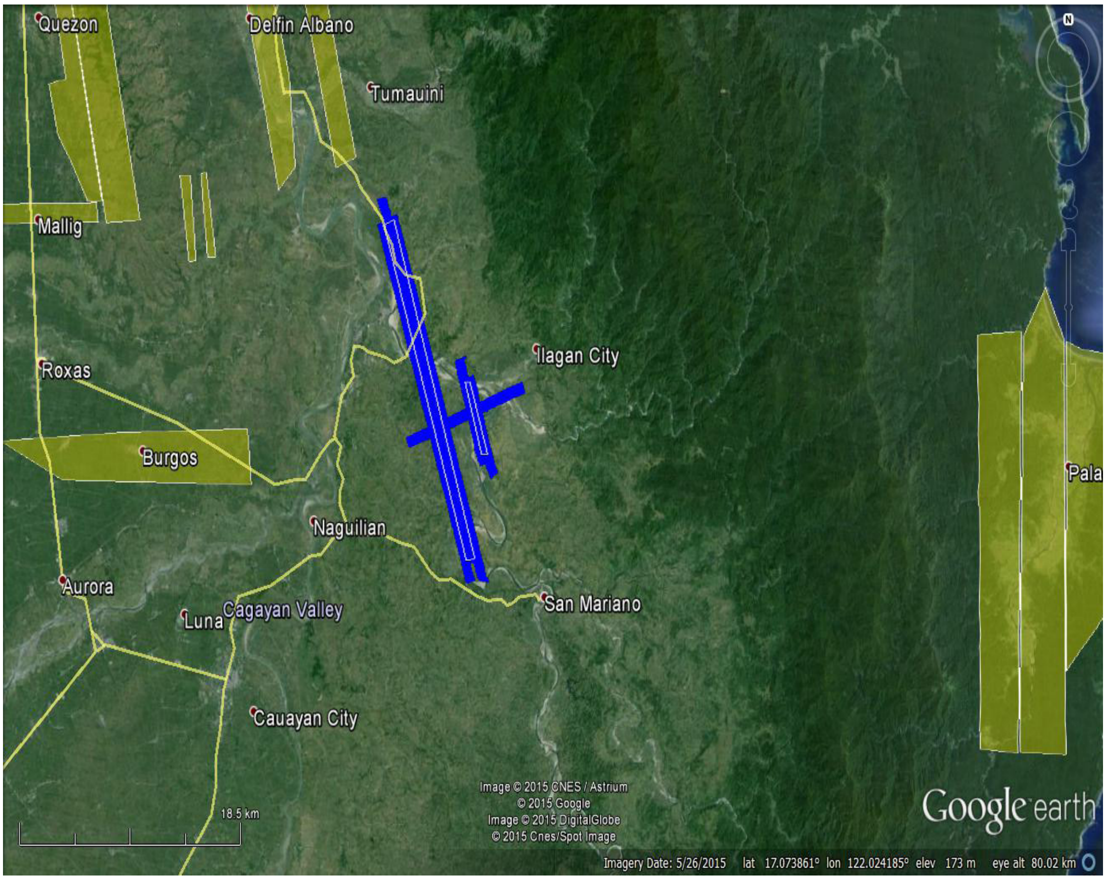


Figure A-7.3. Swath for Flight No. 2700

Flight No. : 2702
Area: BLK 9A,B
Mission Name: 2BLK9AB251A
Altitude: 1200, 900
Scan Frequency: 50, 40
Scan Angle: 18, 25
Total Area Surveyed: 166.88 sq km

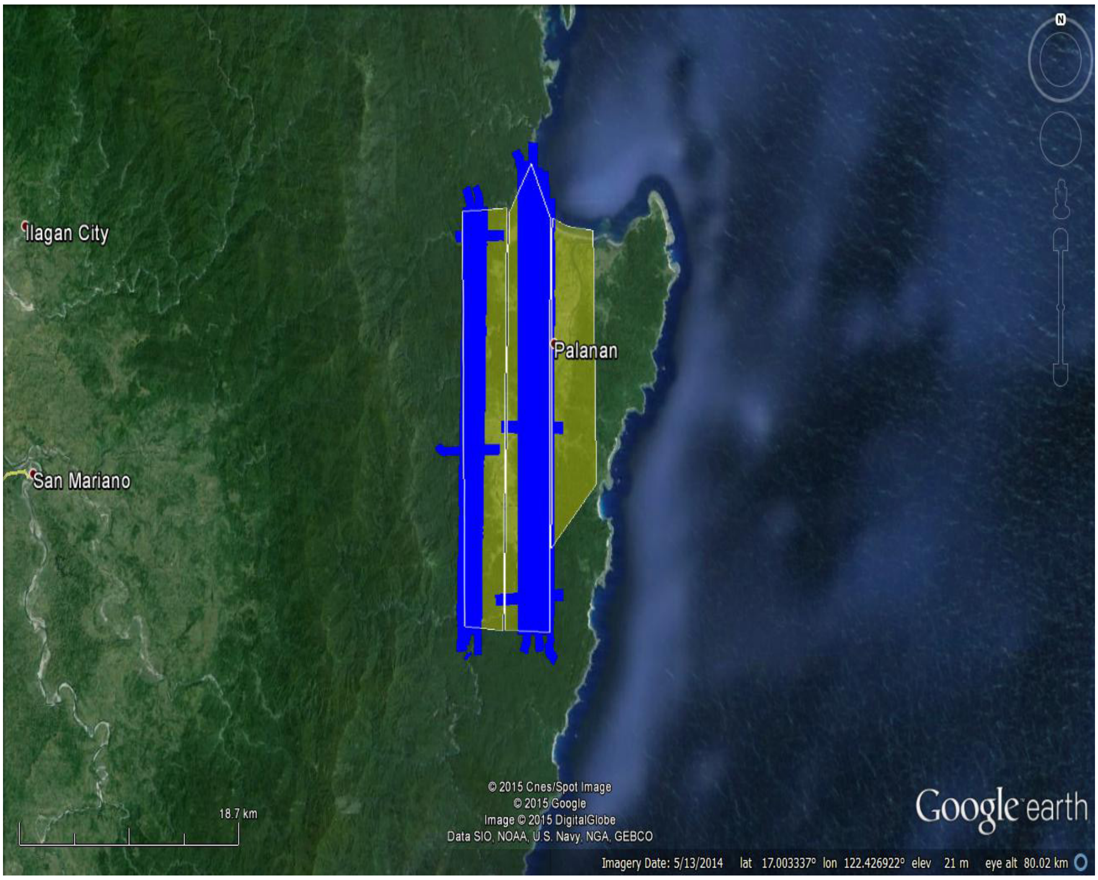


Figure A-7.4. Swath for Flight No. 2702

Flight No. :	2706
Area:	BLK 9B
Mission Name:	2BLK9B252A
Altitude:	900
Scan Frequency:	40
Scan Angle:	25
Total Area Surveyed:	67.99 sq km

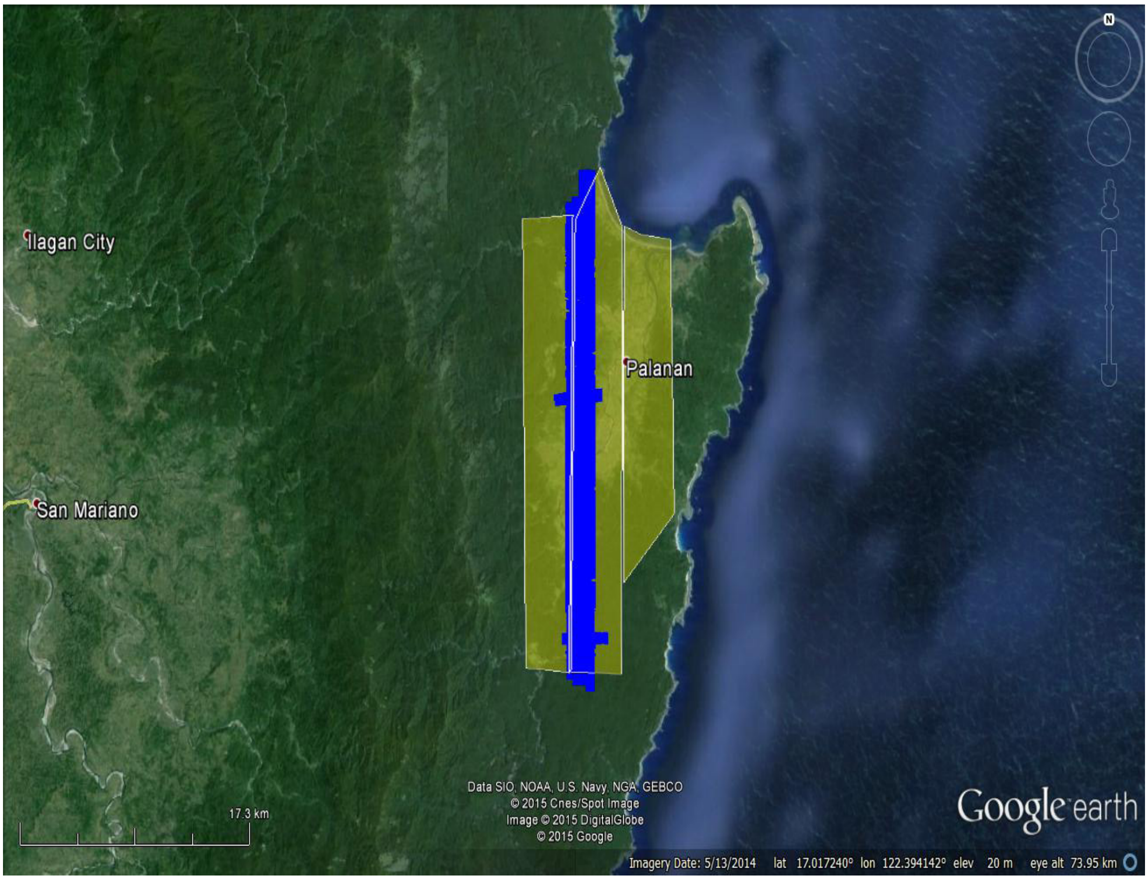


Figure A-7.5. Swath for Flight No. 2706

Flight No. :	2710
Area:	BLK 11A
Mission Name:	2BLK11A253A
Altitude:	900
Scan Frequency:	40
Scan Angle:	25
Total Area Surveyed:	29.28 sq km

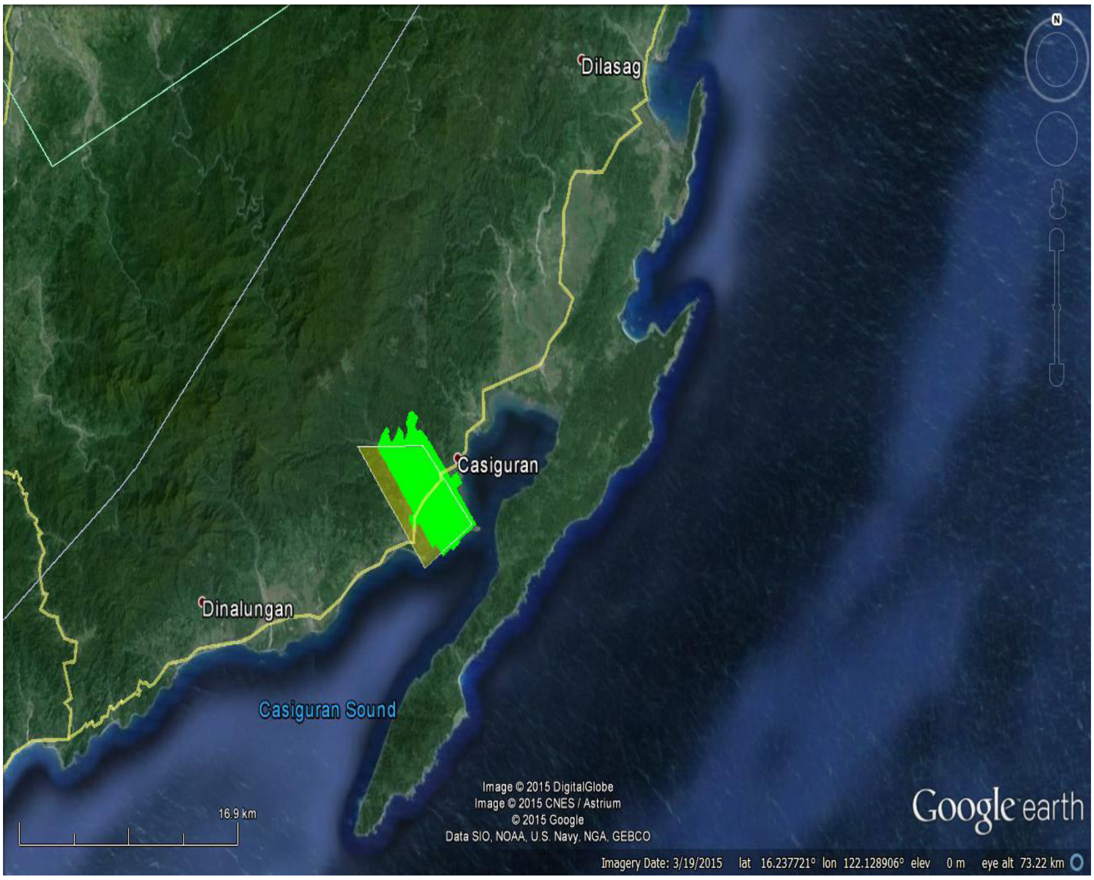


Figure A-7.6. Swath for Flight No. 2710

Flight No. :	2718
Area:	BLK 11A
Mission Name:	2BLK11A255A
Altitude:	900
Scan Frequency:	40
Scan Angle:	25
Total Area Surveyed:	26.47 sq km

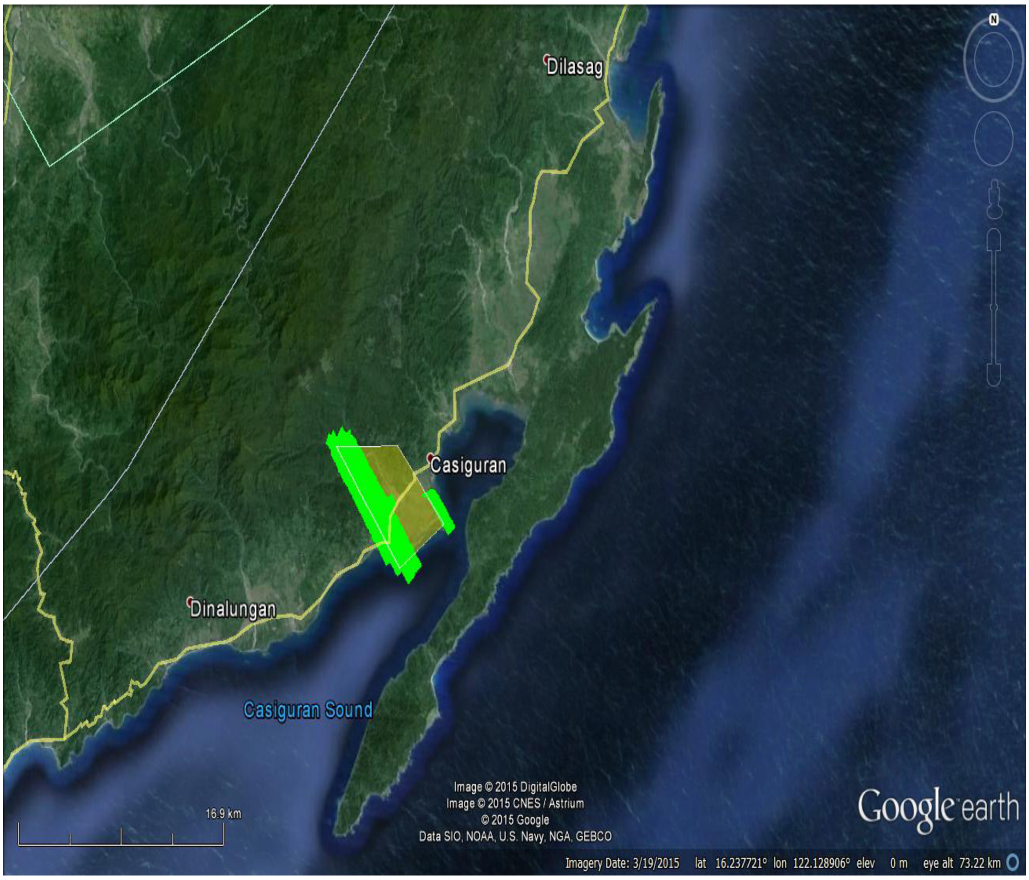


Figure A-7.7. Swath for Flight No. 2718

Flight No. :	2726
Area:	CGYR A,B,E
Mission Name:	2CGYRABE257A
Altitude:	900, 700
Scan Frequency:	40
Scan Angle:	25
Total Area Surveyed:	96.33 sq km

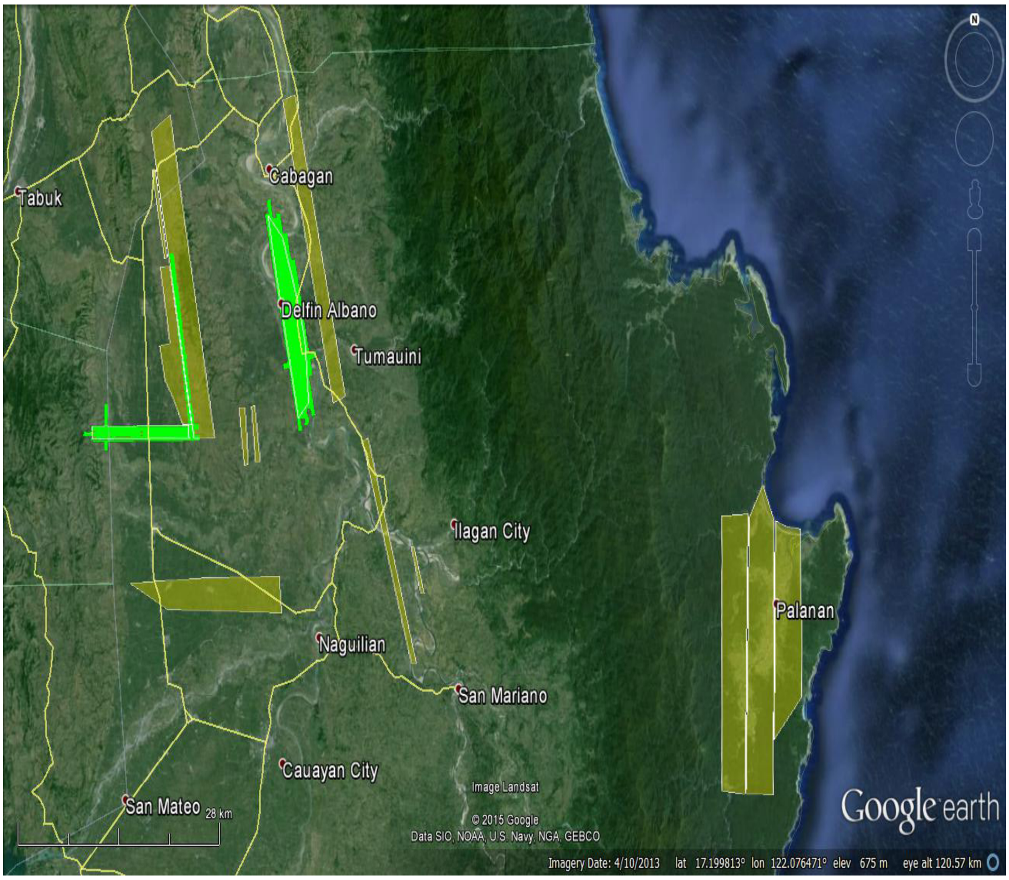


Figure A-7.8. Swath for Flight No. 2726

Flight No. :	2728
Area:	CGYR G
Mission Name:	2CGYRG257B
Altitude:	700
Scan Frequency:	40
Scan Angle:	25
Total Area Surveyed:	73.06 sq km

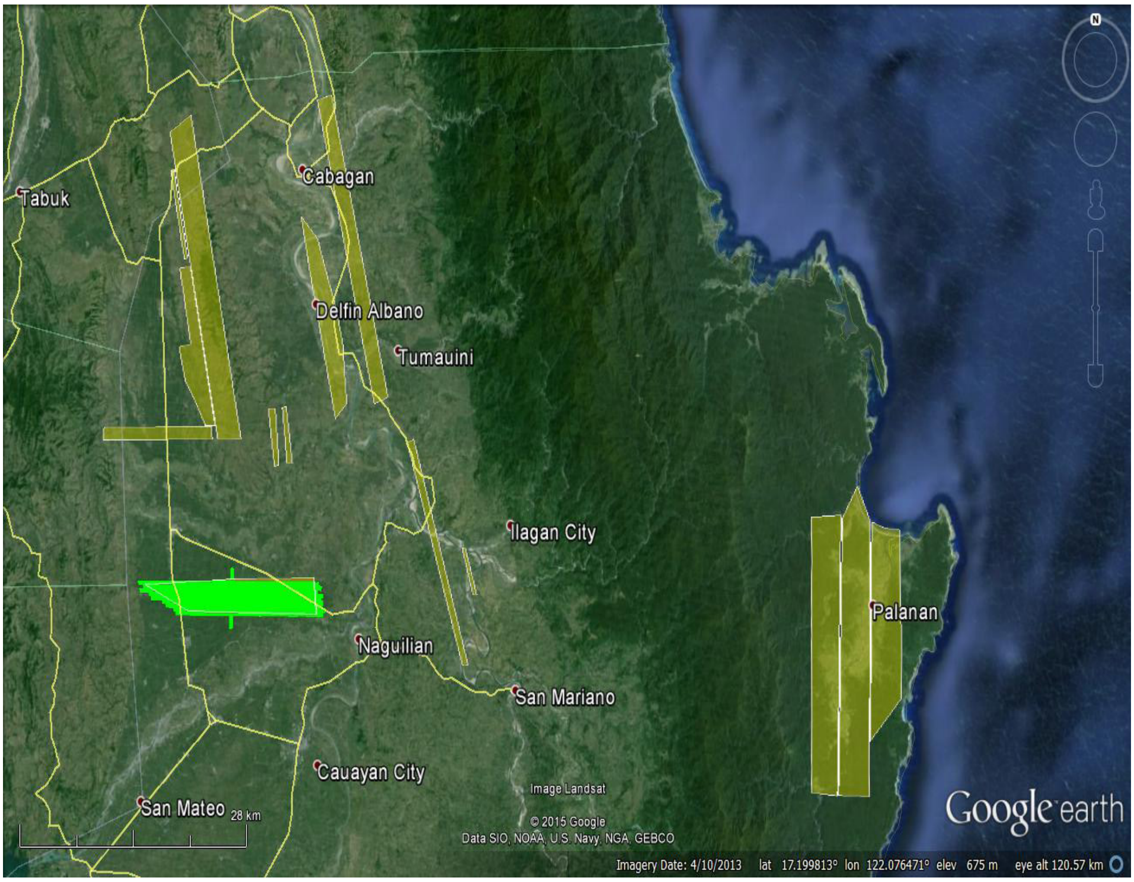


Figure A-7.9. Swath for Flight No. 2728

Flight No. :	2730
Area:	BLK 9, CGYR F,G
Mission Name:	2BLK9CGYRFG258A
Altitude:	1200
Scan Frequency:	50
Scan Angle:	18
Total Area Surveyed:	133.39 sq km

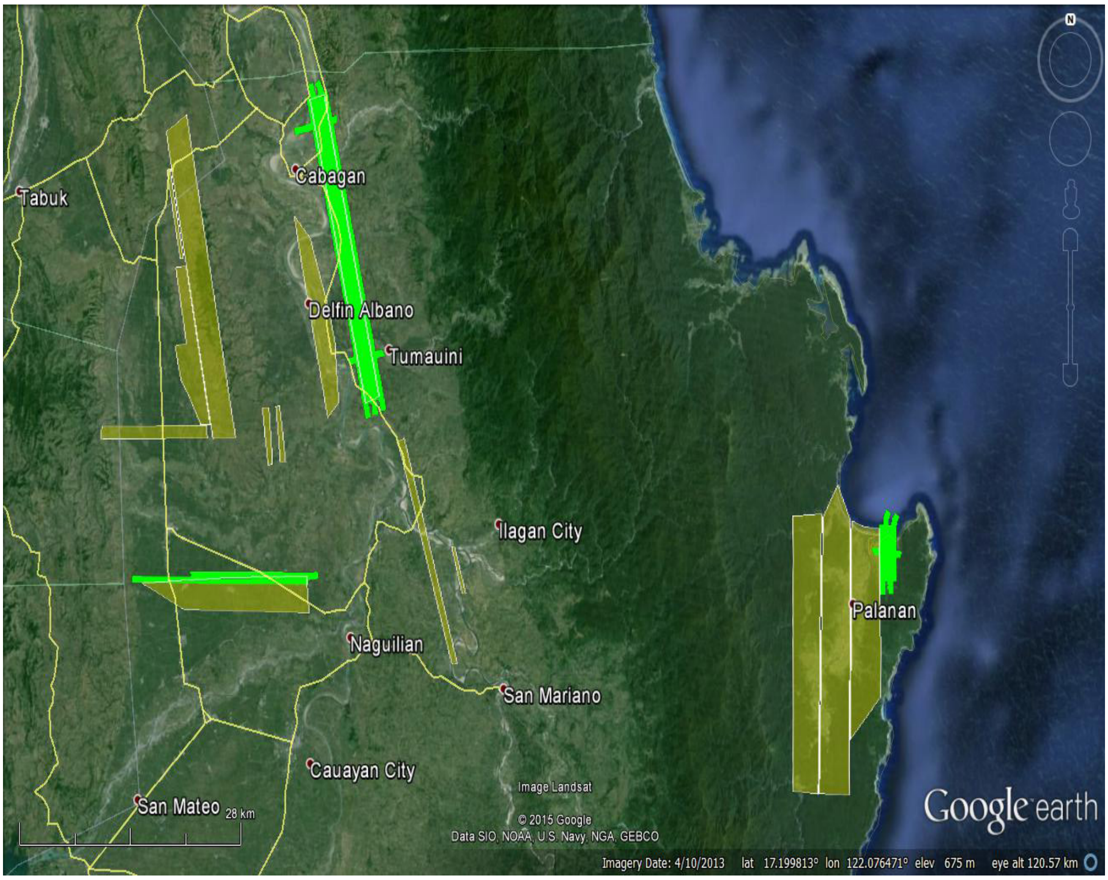


Figure A-7.10. Swath for Flight No. 2730

Flight No. :	2732
Area:	CGYR C
Mission Name:	2CGYRC258B
Altitude:	1200
Scan Frequency:	50
Scan Angle:	18
Total Area Surveyed:	84.45 sq km

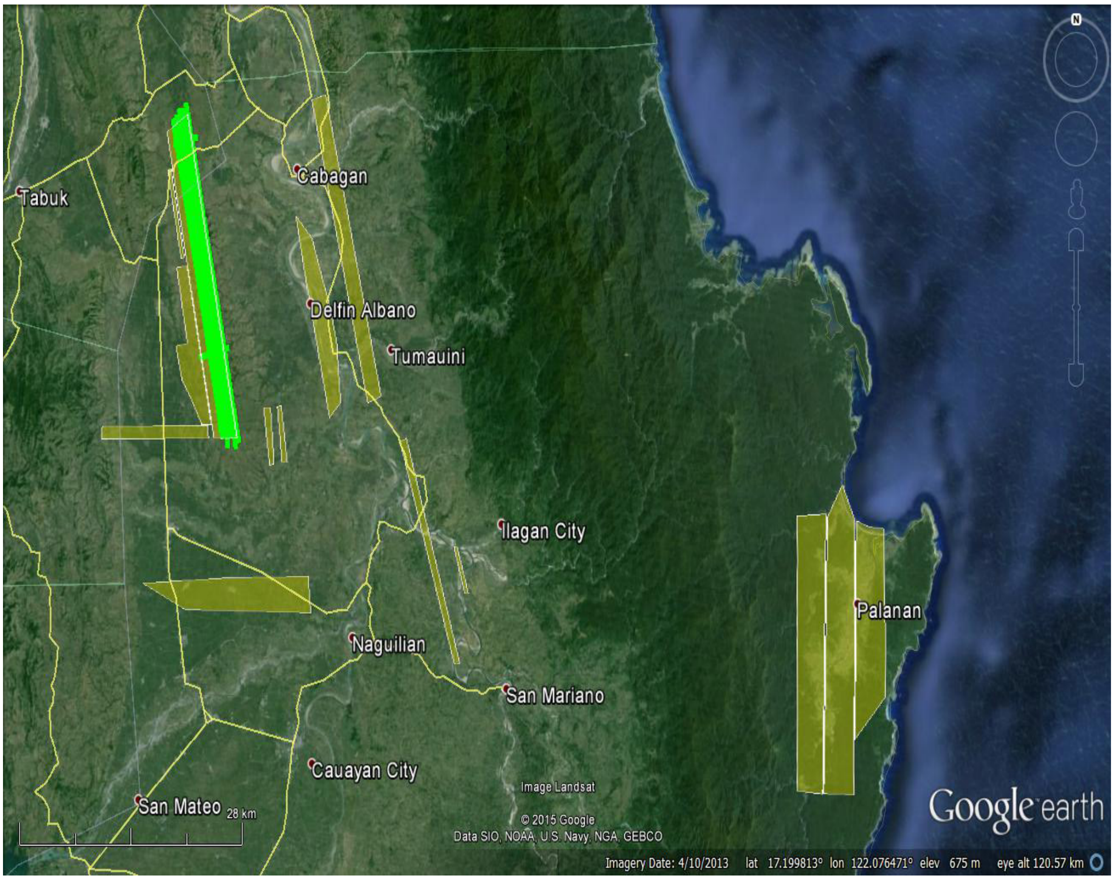


Figure A-7.11. Swath for Flight No. 2732

Flight No. :	2898P
Area:	CAG 101D
Mission Name:	1BLK2S330A
Parameters:	PRF 200 SF 30 FOV 50

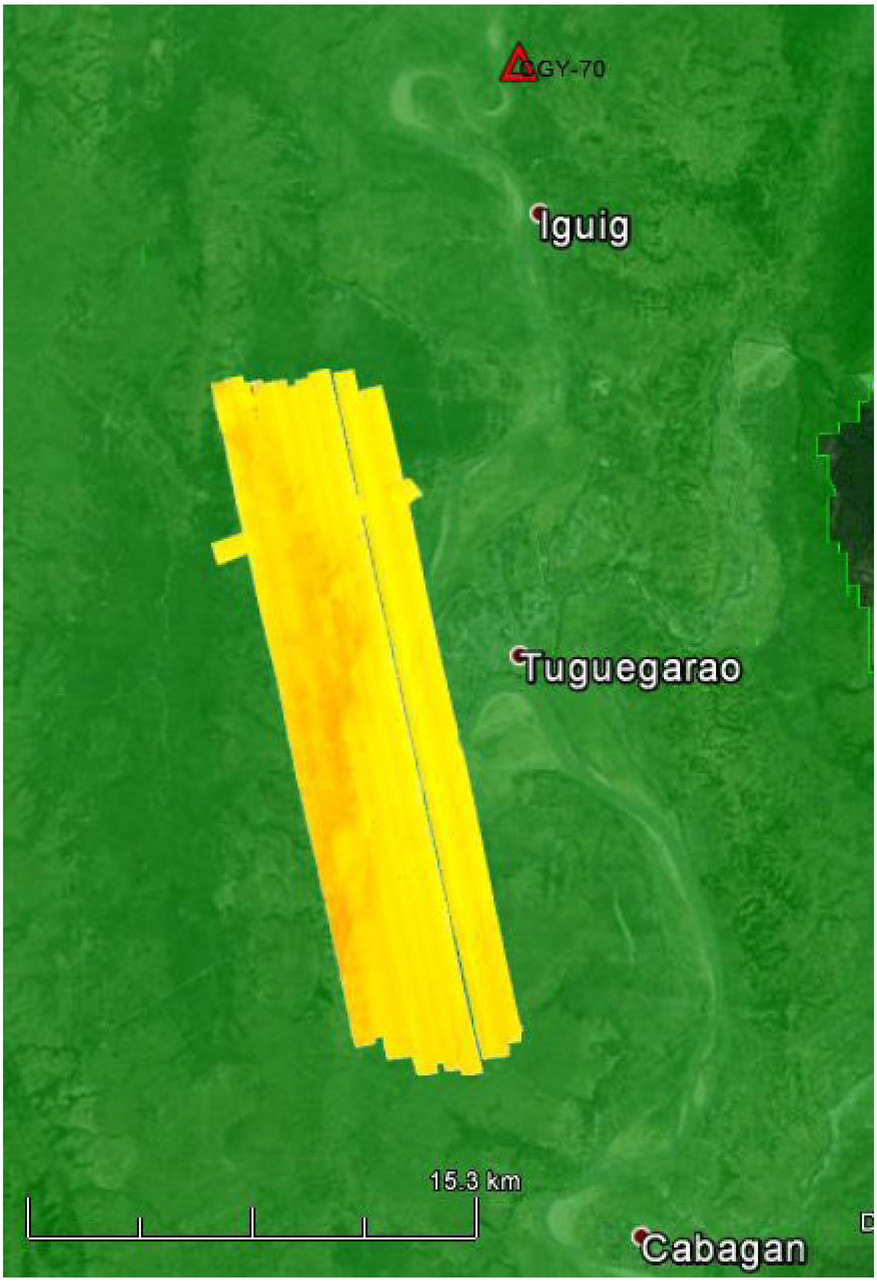


Figure A-7.12. Swath for Flight No. 2898P

Flight No. :	2914P
Area:	BLK 11
Mission Name:	1BLK3A334A
Parameters:	PRF 200 SF 30 FOV 50

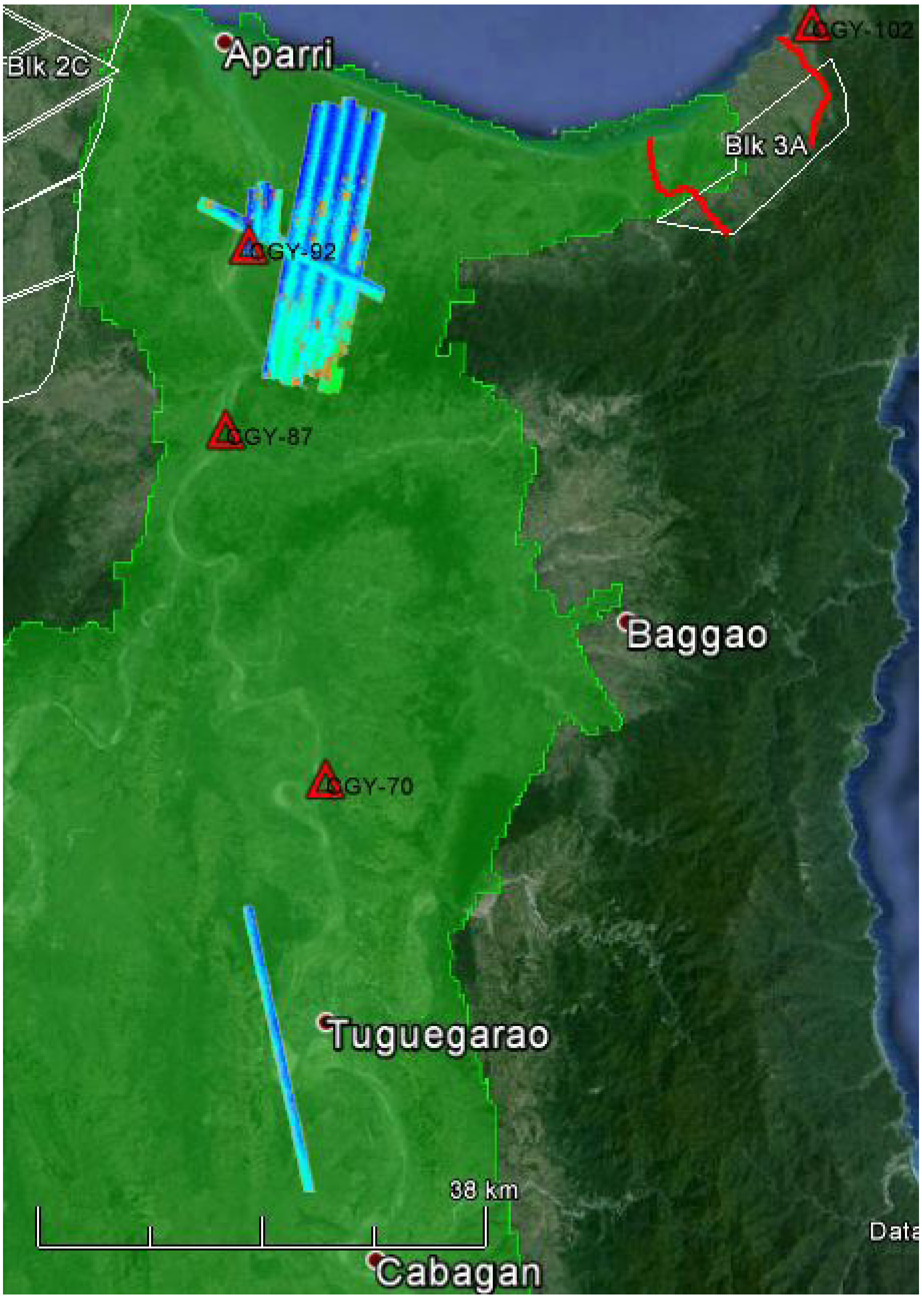


Figure A-7.13. Swath for Flight No. 2914P

FLIGHT NO.:	3965G
AREA:	CAG2H, CAG2G
MISSION NAME:	2CAG2DGH118A

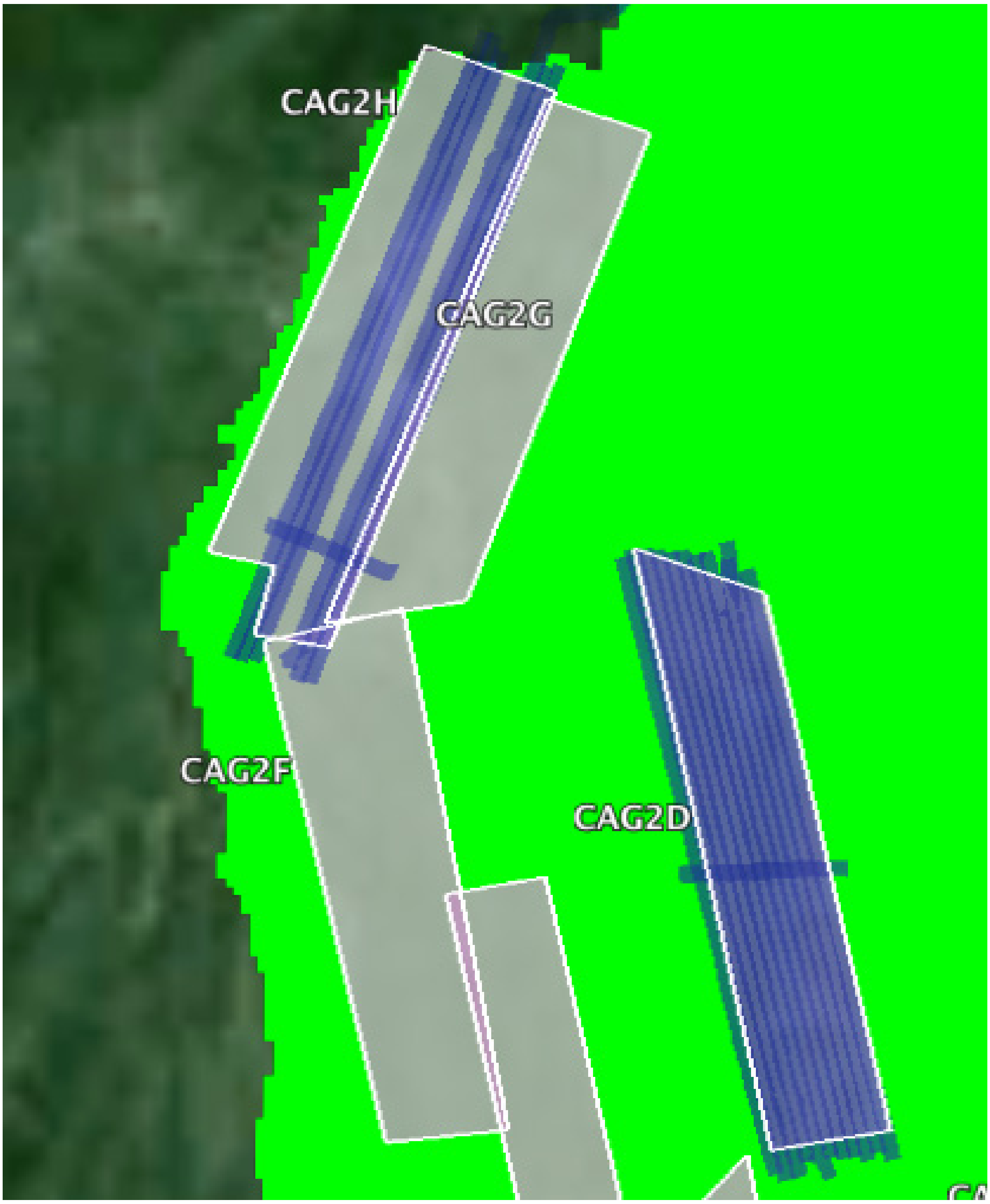


Figure A-7.14. Swath for Flight No. 3965G

FLIGHT NO.: 3979G
AREA: CAG2E
MISSION NAME: 2CAG2E121B

Figure A-7.15. Swath for Flight No. 3979G

FLIGHT NO.: 3983G
AREA: CAG2C, CAG2J
MISSION NAME: 2CAG2CJ122B

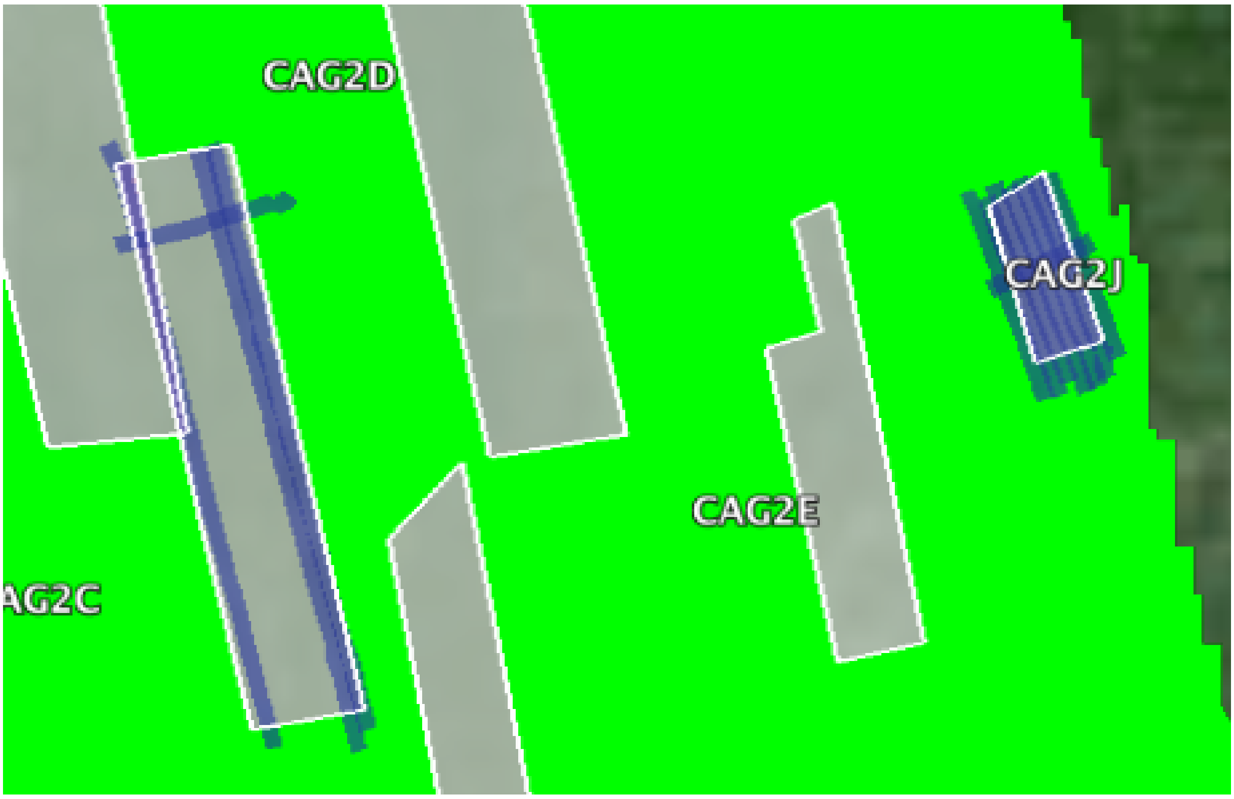


Figure A-7.16. Swath for Flight No. 3983G

FLIGHT NO.: 4005G
AREA: CAG2, CAG2B, CAG2C
MISSION NAME: 2CAG2ABC128A

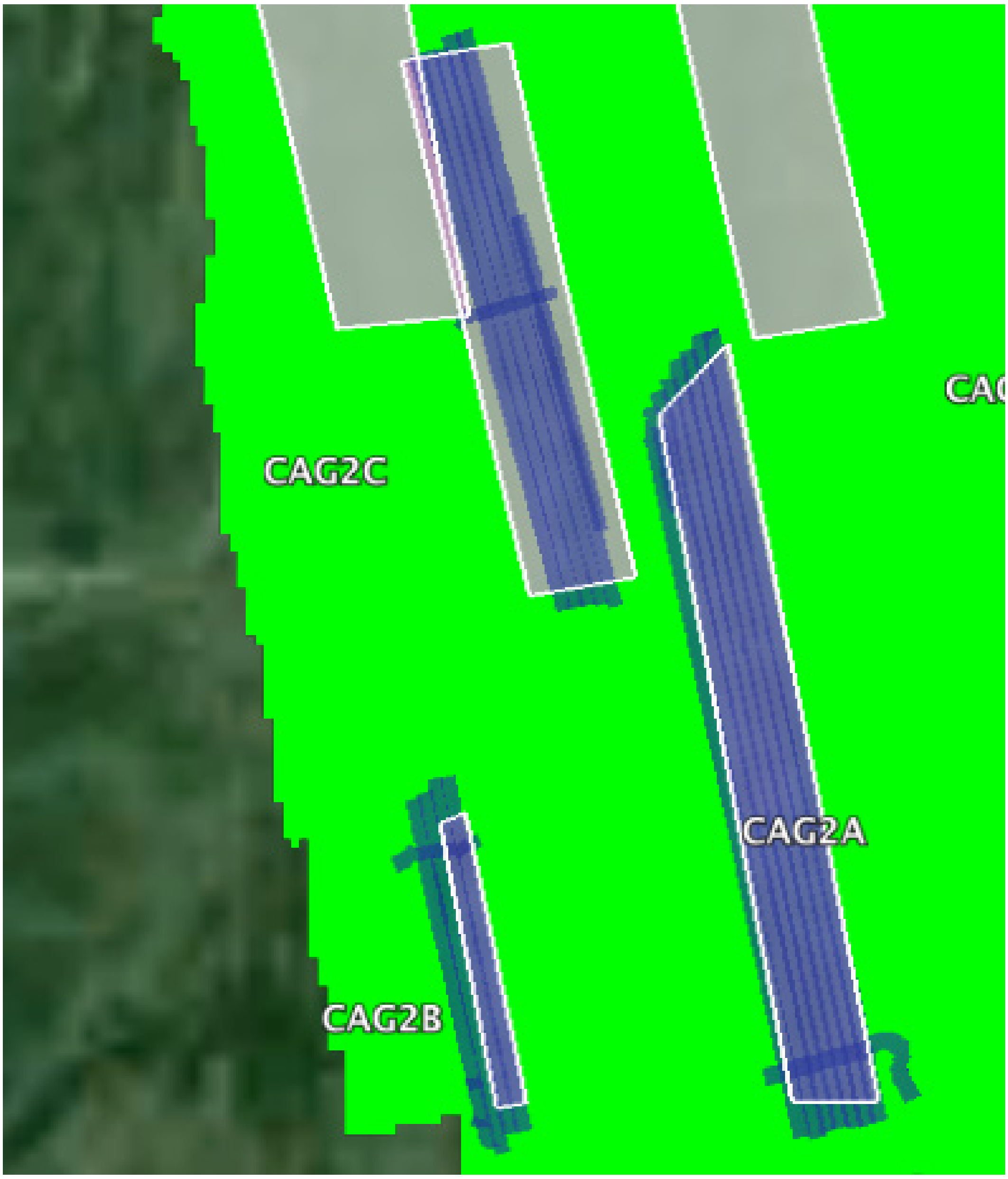


Figure A-7.17. Swath for Flight No. 4005G

Flight No. :	4015G	
Area:	PIN B	
Mission Name:	2PINB136A	
Parameters:	PRF 100	SF 50
SCAN ANGLE	20	
Flying Height:	1000 M	

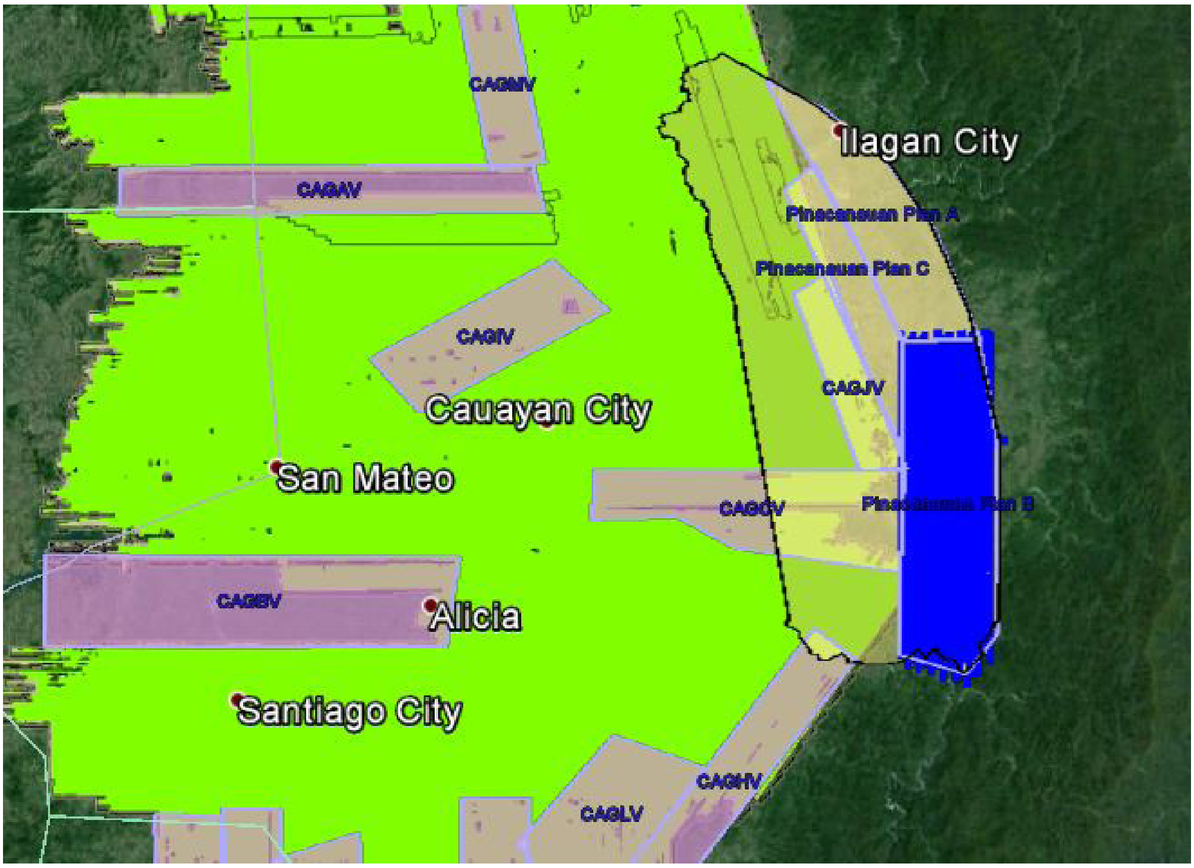


Figure A-7.18. Swath for Flight No. 4015G

Flight No. :	4017G	
Area:	PIN A	
Mission Name:	2PINA136B	
Parameters:	PRF 100	SF 50
SCAN ANGLE	20	
Flying Height:	1000 M	

Figure A-7.19. Swath for Flight No. 4017G

Flight No. :	4019G
Area:	PIN C
Mission Name:	2PINC137A
Parameters:	PRF 100 SF 50
SCAN ANGLE	20
Flying Height:	1000 M

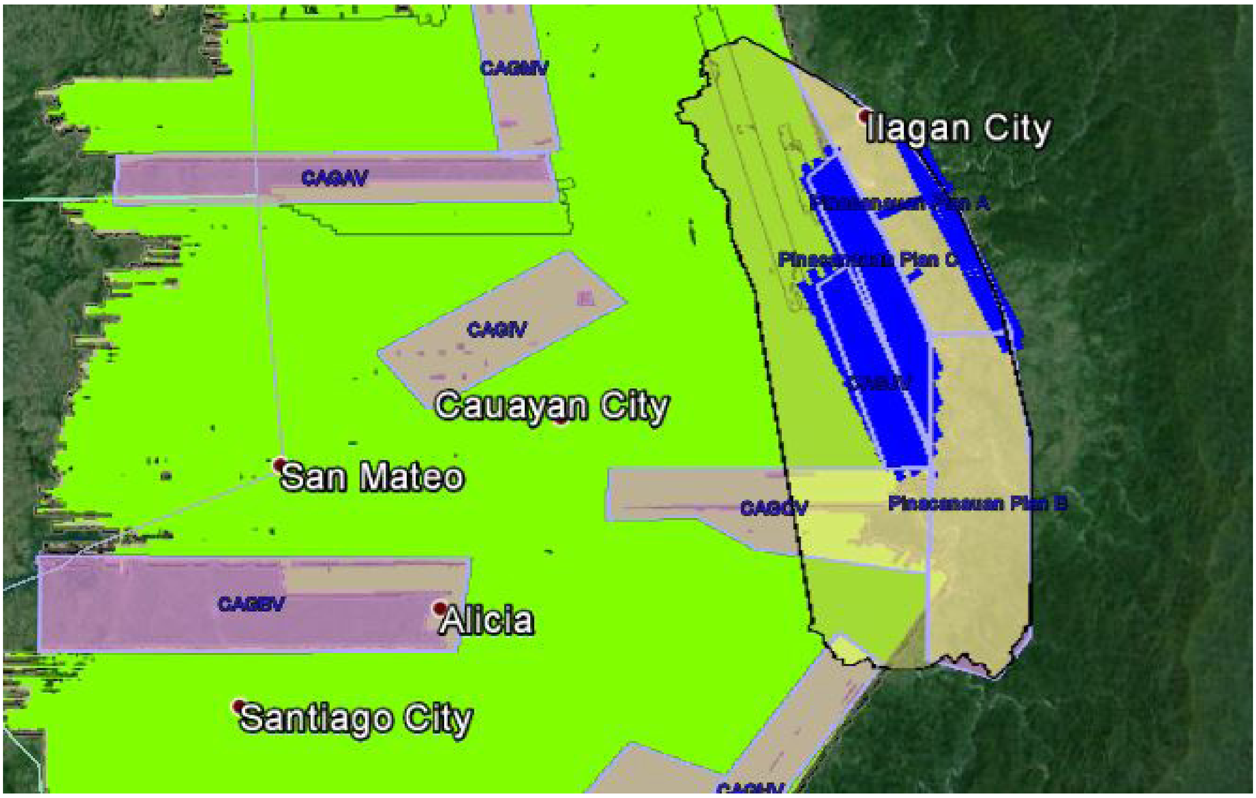


Figure A-7.20. Swath for Flight No. 4019G

Flight No. :	4021G	
Area:	CAG CV	
Mission Name:	2CAGCV137B	
Parameters:	PRF 100	SF 50
SCAN ANGLE	20	
Flying Height:	1000 M	

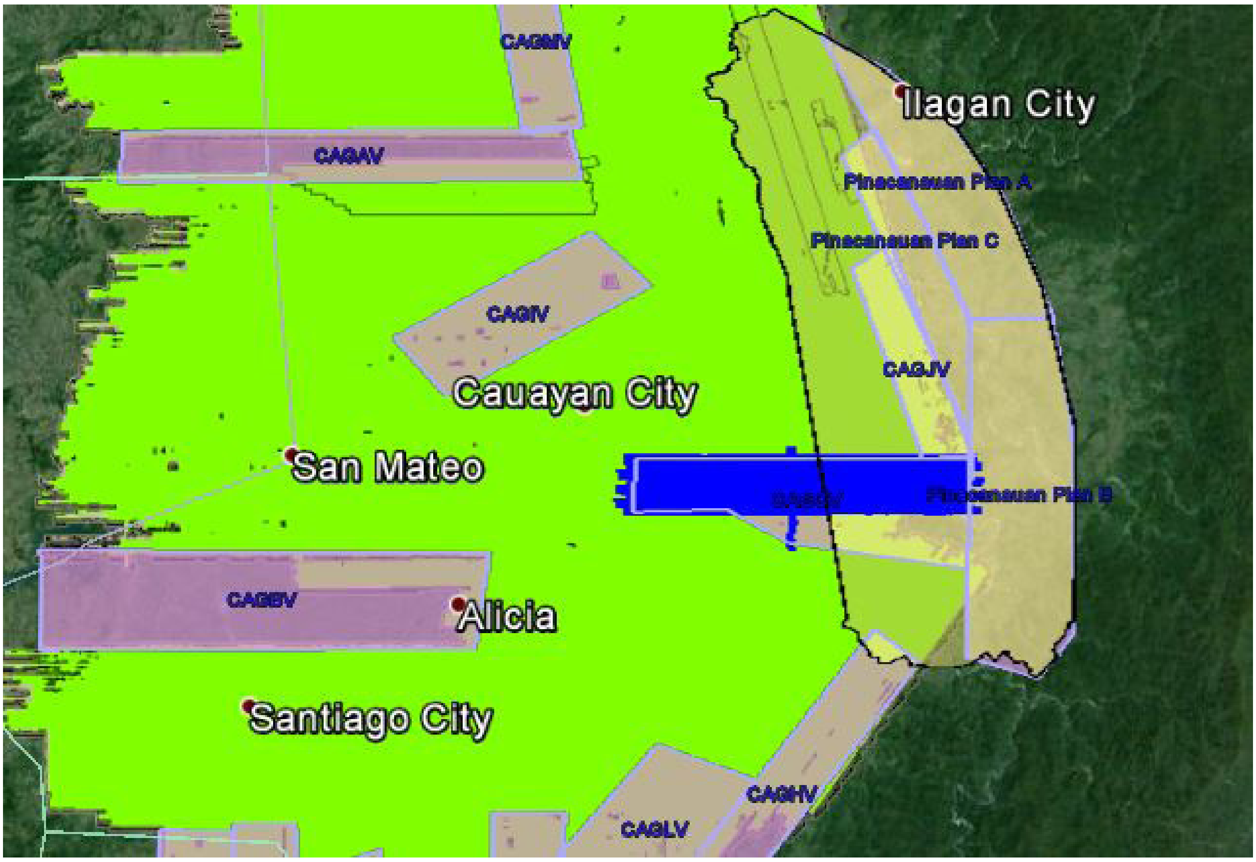


Figure A-7.21. Swath for Flight No. 4021G

Flight No. :	4023G	
Area:	CAG AB	
Mission Name:	2CAGABV138A	
Parameters:	PRF 100	SF 50
SCAN ANGLE	20	
Flying Height:	1000 M	

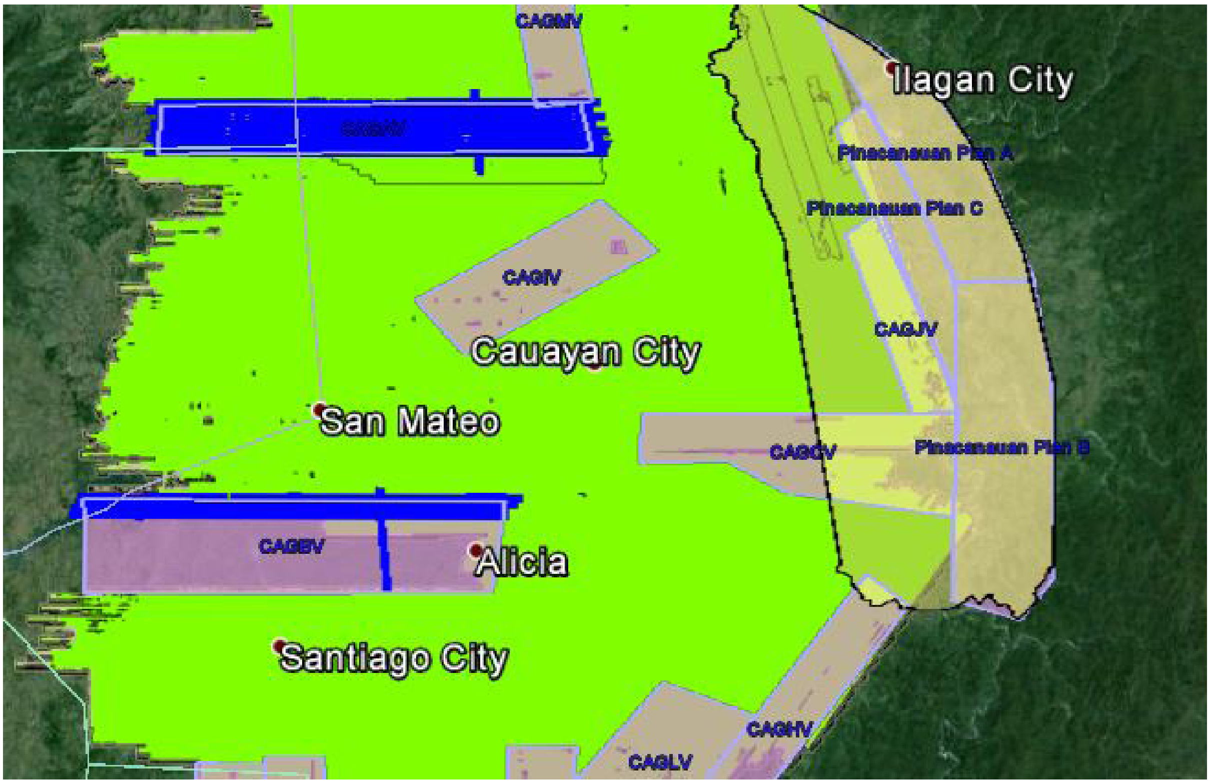


Figure A-7.22. Swath for Flight No. 4023G

Flight No. :	4025G	
Area:	CAG B	
Mission Name:	2CAGBV138B	
Parameters:	PRF 100	SF 50
SCAN ANGLE	20	
Flying Height:	1000 M	

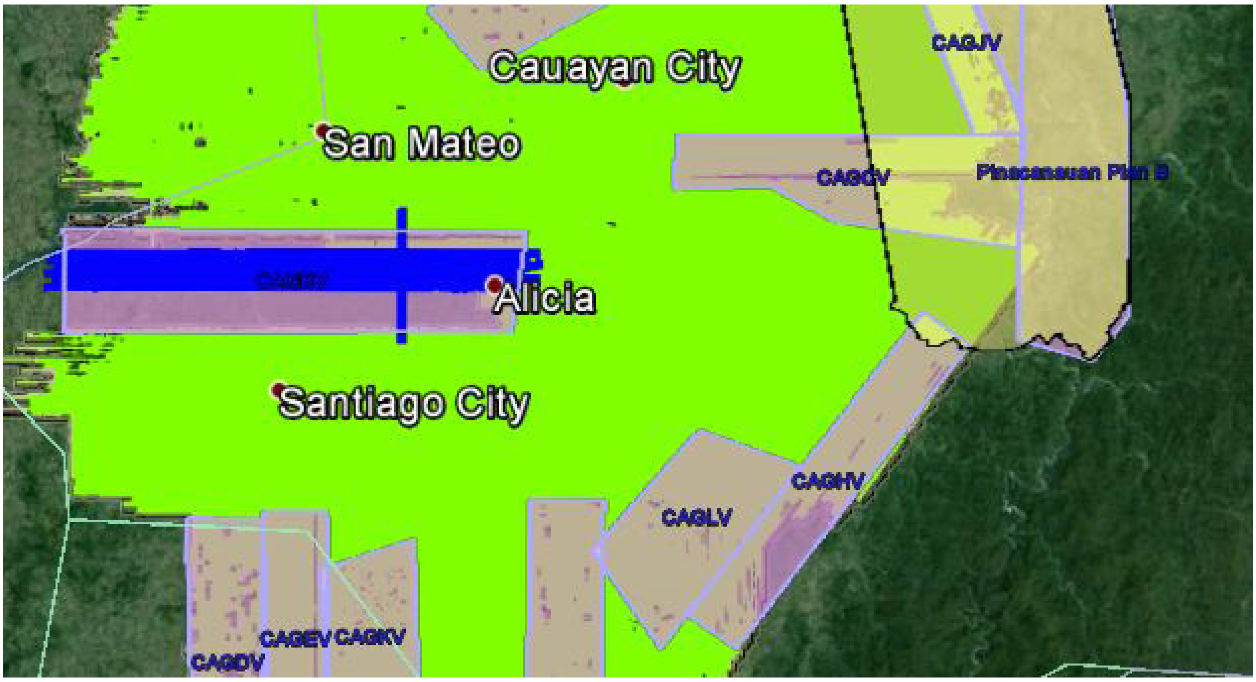


Figure A-7.23. Swath for Flight No. 4025G

Flight No. :	4027G	
Area:	PIN VOIDS	
Mission Name:	2PINV139A	
PRF:	100	SF 50
SCAN ANGLE:	20	
Flying Height:	1000 M	

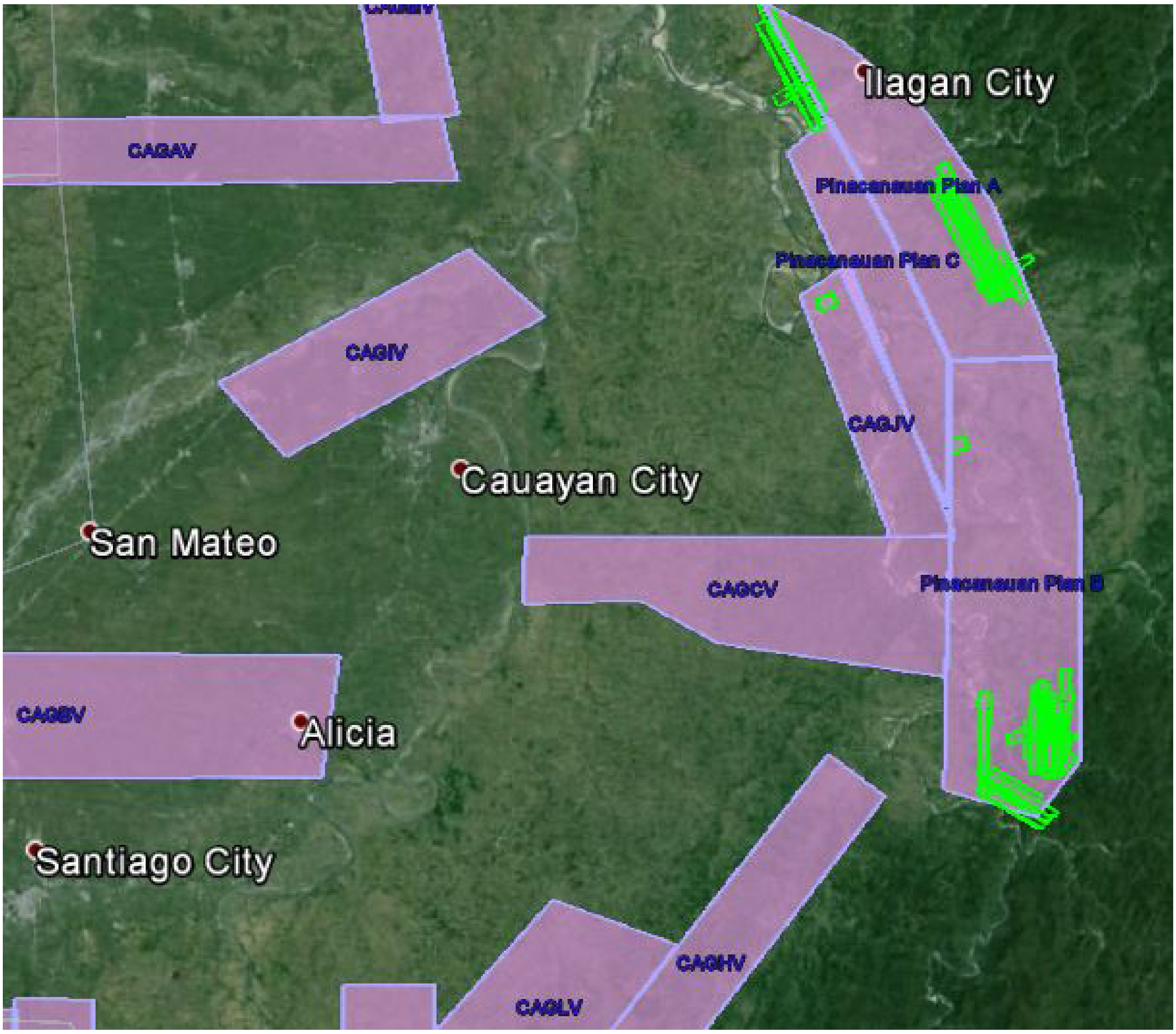


Figure A-7.24. Swath for Flight No. 4027G

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk171N

Flight Area	Cauayan
Mission Name	Blk171N
Inclusive Flights	4015G
Range data size	24.1 GB
POS data size	259 MB
Base data size	15.1 MB
Image	n/a
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	5.3
Boresight correction stdev (<0.001deg)	0.000157
IMU attitude correction stdev (<0.001deg)	0.000393
GPS position stdev (<0.01m)	0.0013
Minimum % overlap (>25)	26.86
Ave point cloud density per sq.m. (>2.0)	3.63
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	235
Maximum Height	617.93
Minimum Height	7.44
Classification (# of points)	
Ground	150,394,932
Low vegetation	88,227,376
Medium vegetation	218,079,957
High vegetation	280,823,064
Building	518,117
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Chelou Prado, Engr. Monalyne Rabino

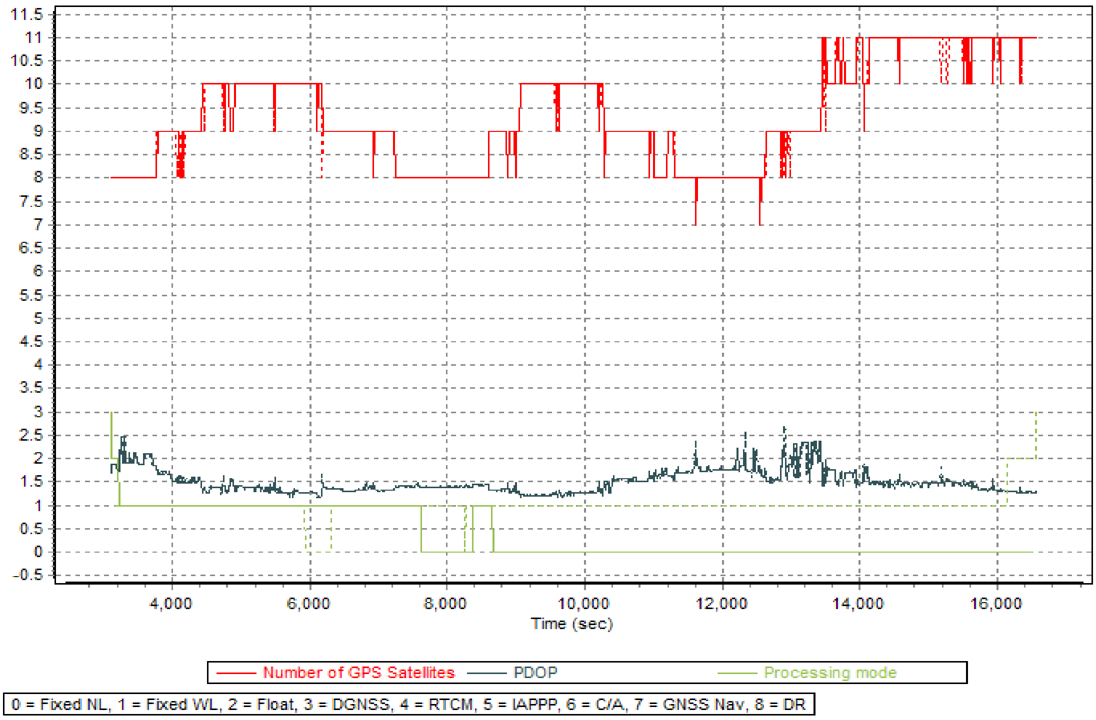


Figure A-8.1. Solution Status

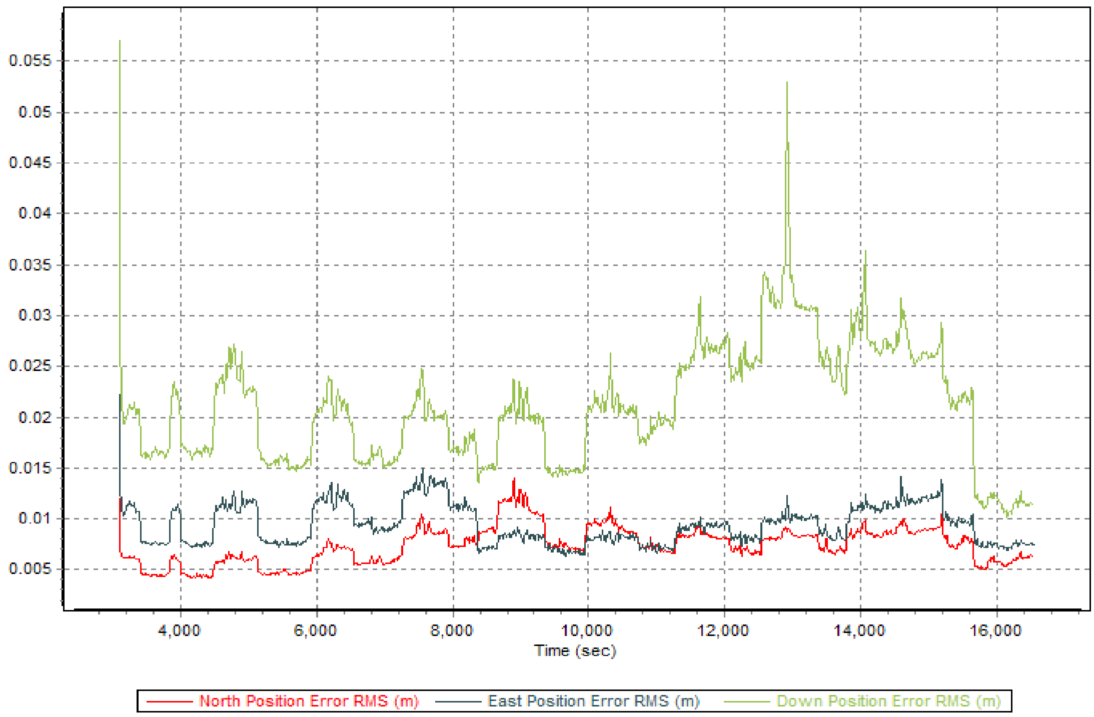


Figure A-8.2. Smoothed Performance Metrics Parameters

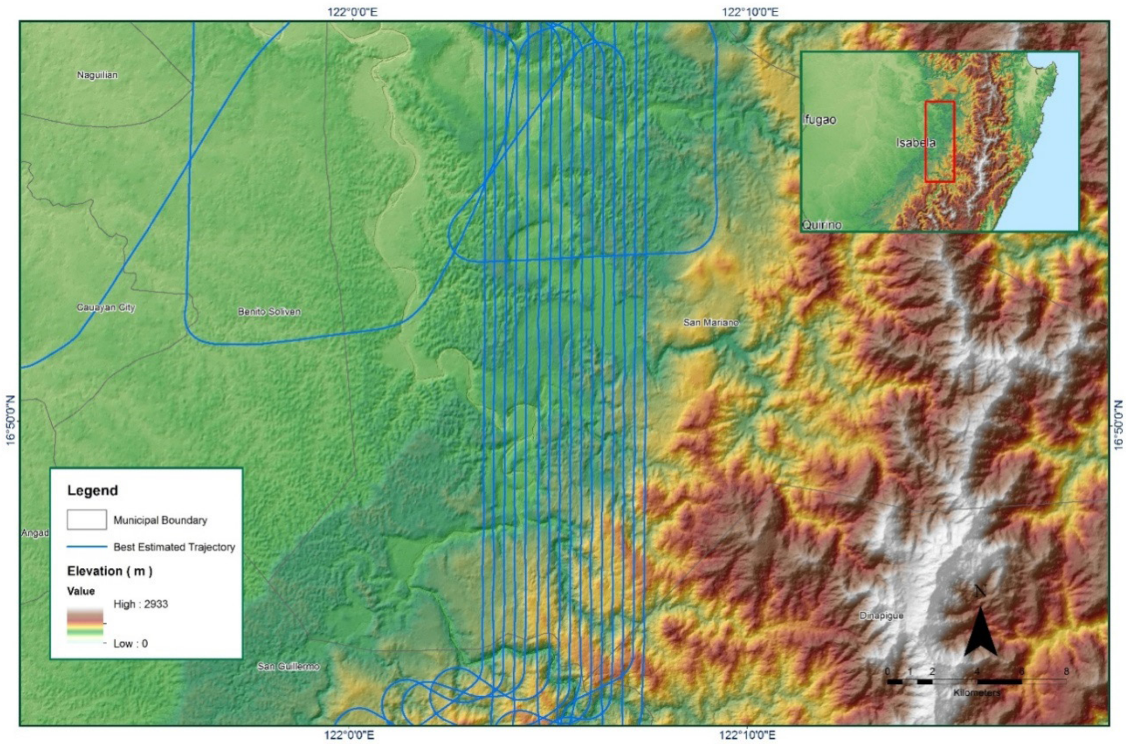


Figure A-8.3. Best Estimated Trajectory

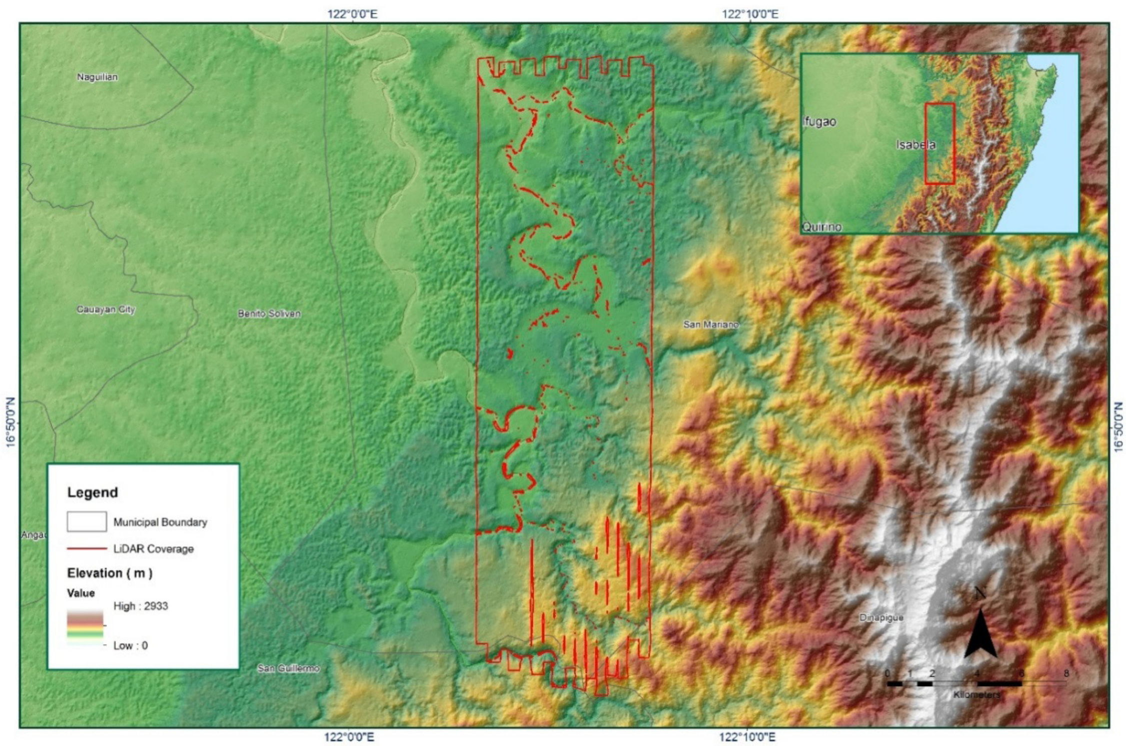


Figure A-8.4 Coverage of LiDAR data

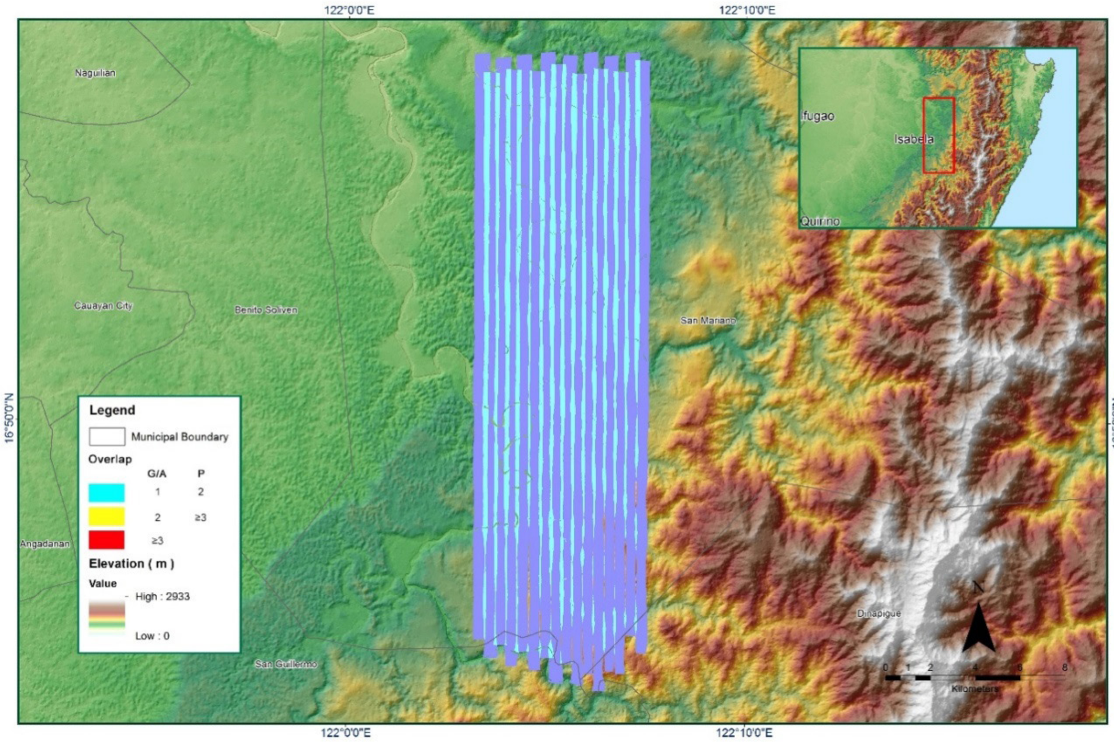


Figure A-8.5. Image of data overlap

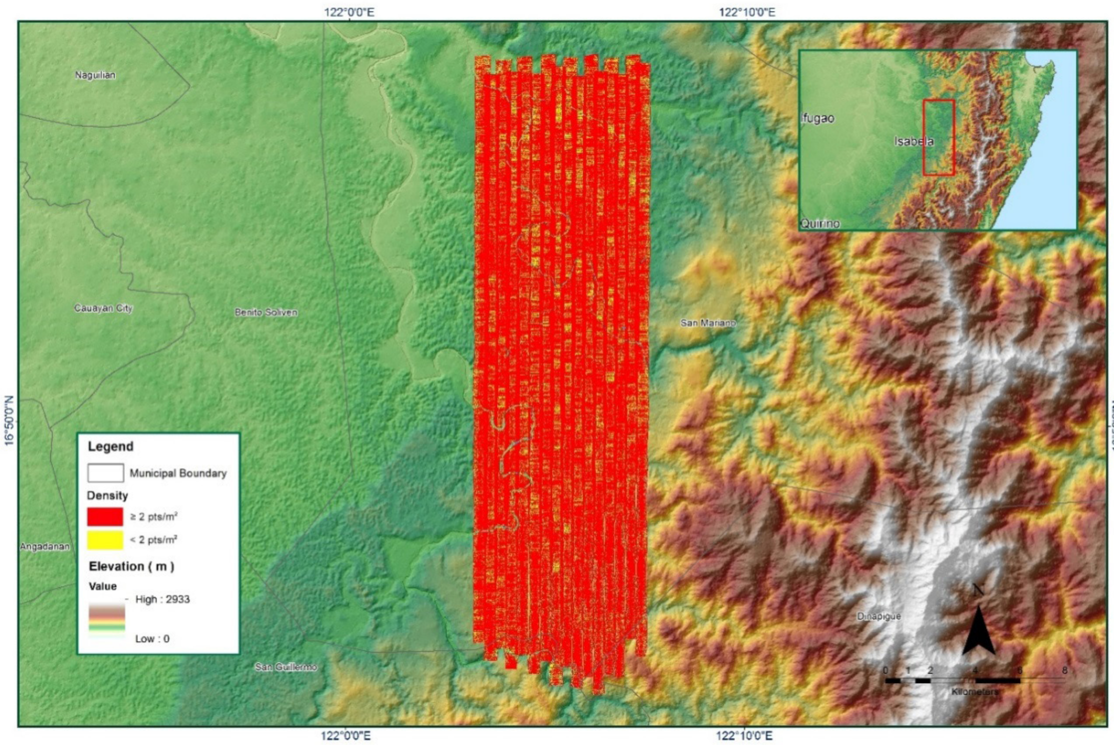


Figure A-8.6. Density map of merged LiDAR data

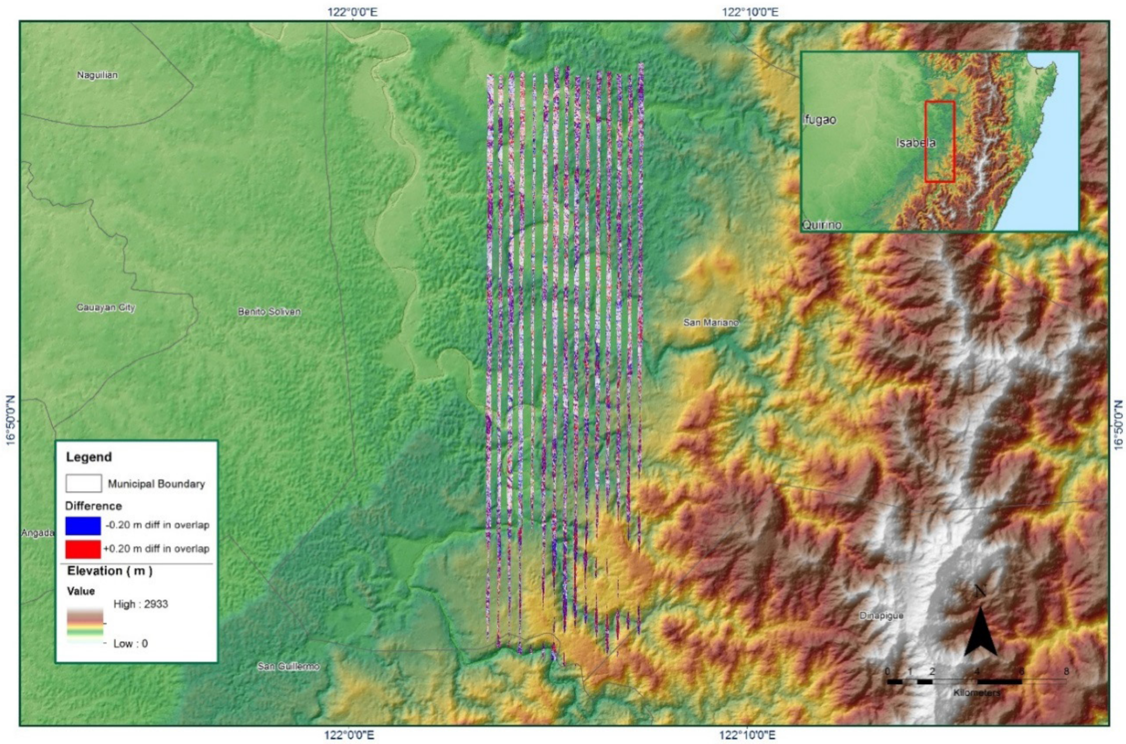


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk171M

Flight Area	Cauayan
Mission Name	Blk171M
Inclusive Flights	4017G
Range data size	11.6 GB
POS data size	126 MB
Base data size	15.1 MB
Image	n/a
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.1
RMSE for East Position (<4.0 cm)	2.9
RMSE for Down Position (<8.0 cm)	5.3
Boresight correction stdev (<0.001deg)	0.000182
IMU attitude correction stdev (<0.001deg)	0.000439
GPS position stdev (<0.01m)	0.0040
Minimum % overlap (>25)	24.92
Ave point cloud density per sq.m. (>2.0)	3.07
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	152
Maximum Height	537.17 m
Minimum Height	81.31 m
Classification (# of points)	
Ground	94,443,003
Low vegetation	55,555,927
Medium vegetation	114,633,783
High vegetation	71,710,448
Building	125,380
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Edgardo Gubatanga Jr., Engr. Monalyne Rabino

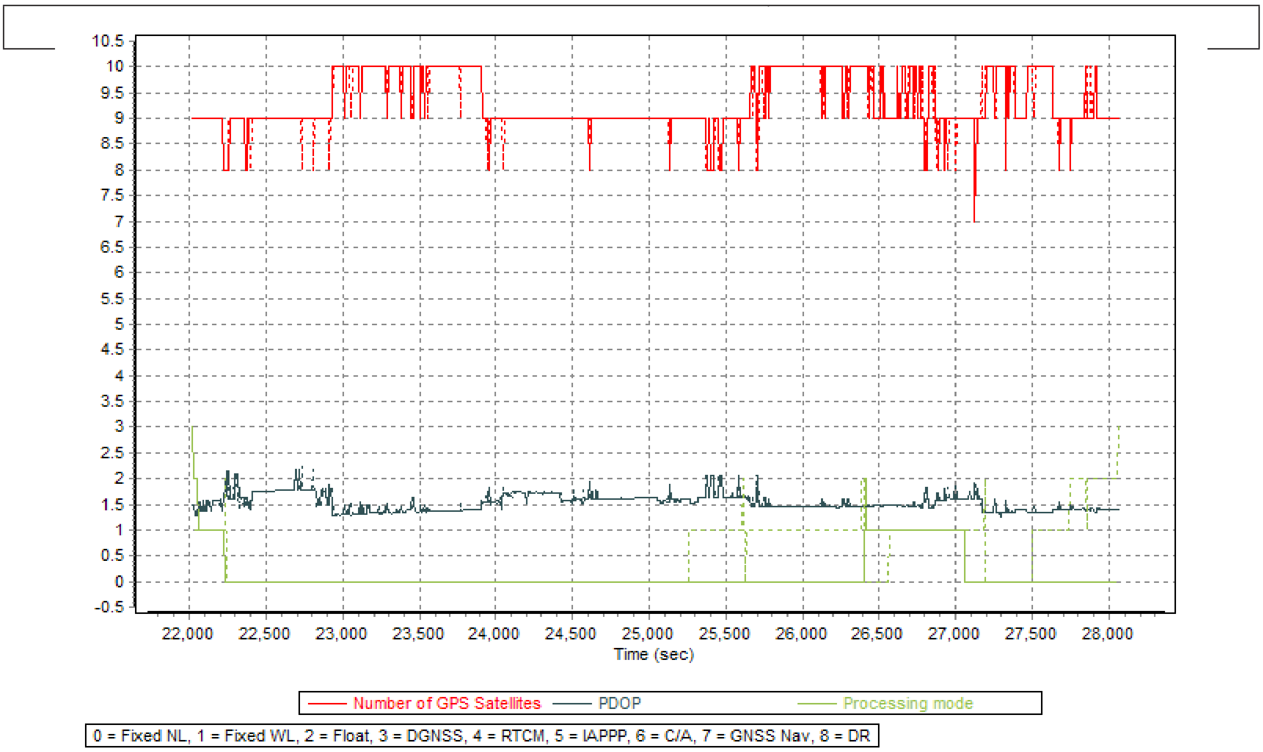


Figure A-8.8. Solution Status

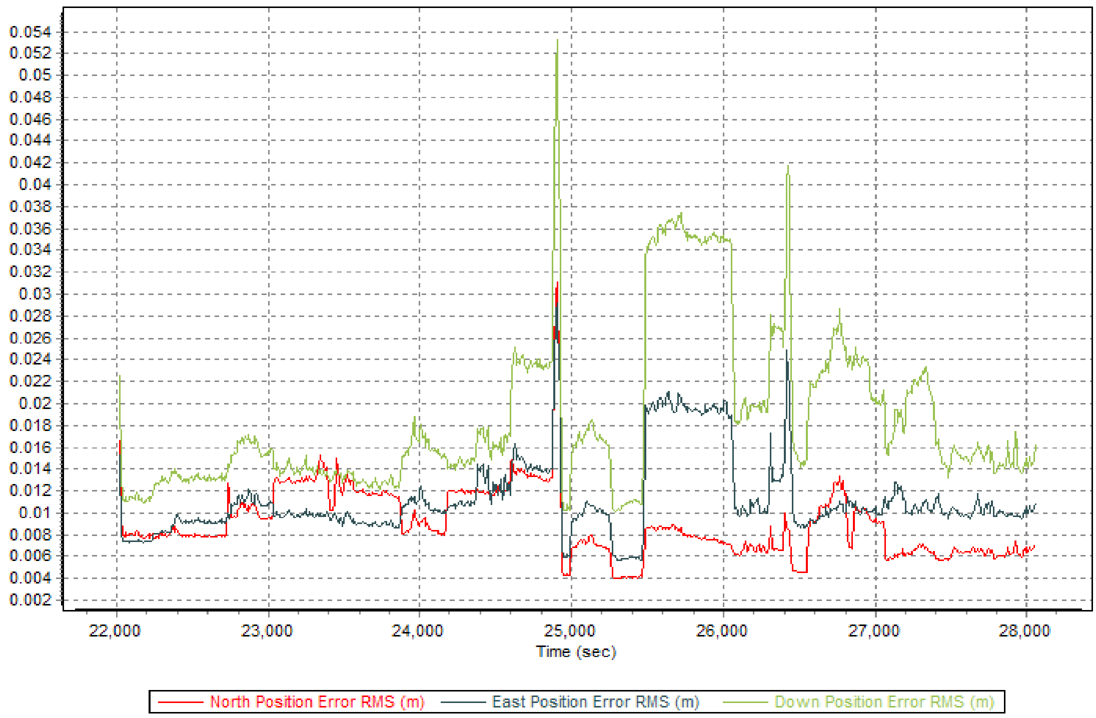


Figure A-8.9. Smoothed Performance Metrics Parameters

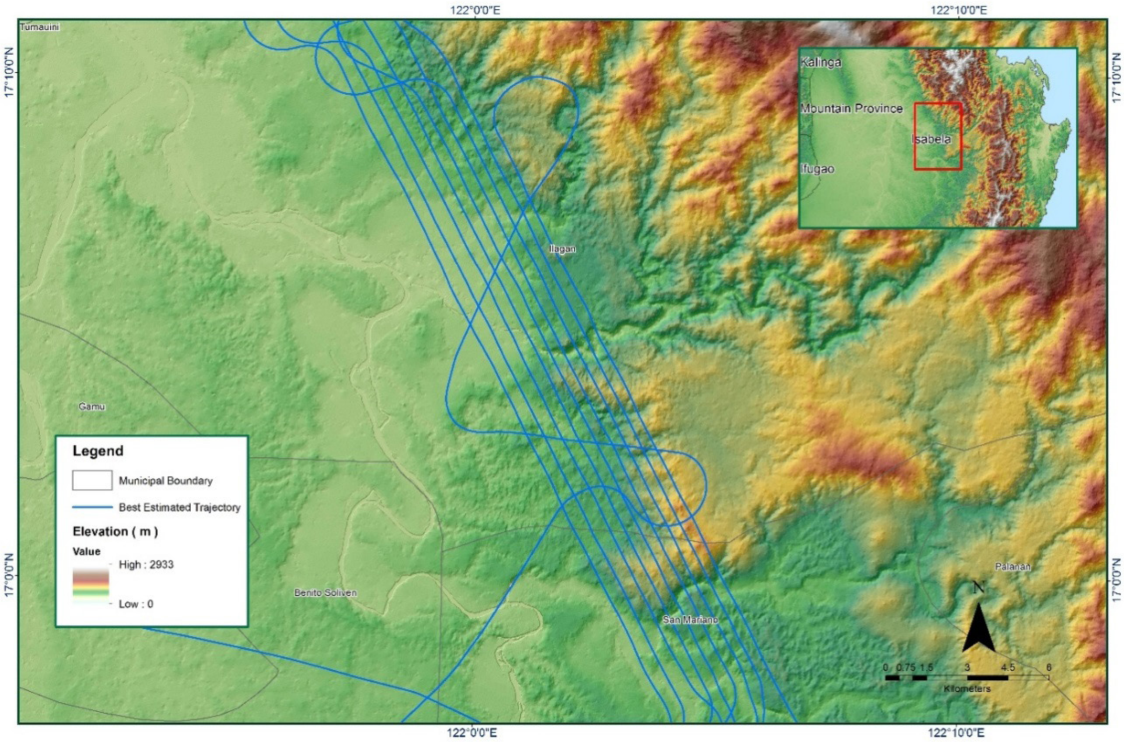


Figure A-8.10. Best Estimated Trajectory

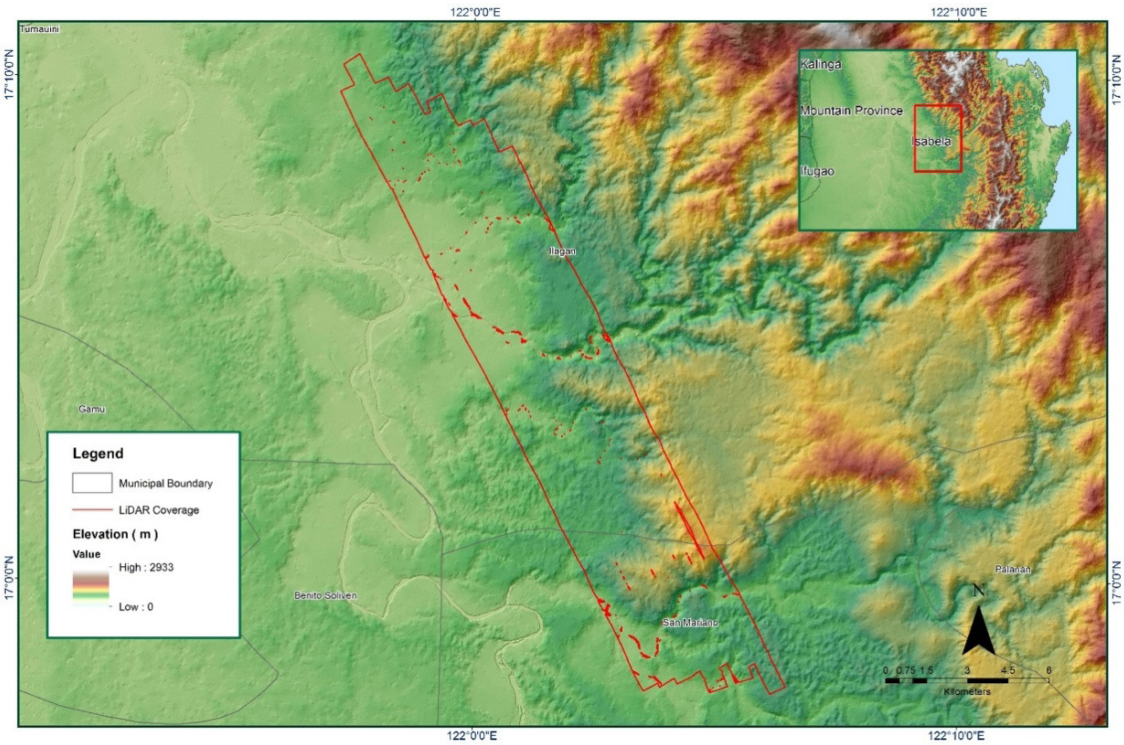


Figure A-8.11. Coverage of LiDAR data

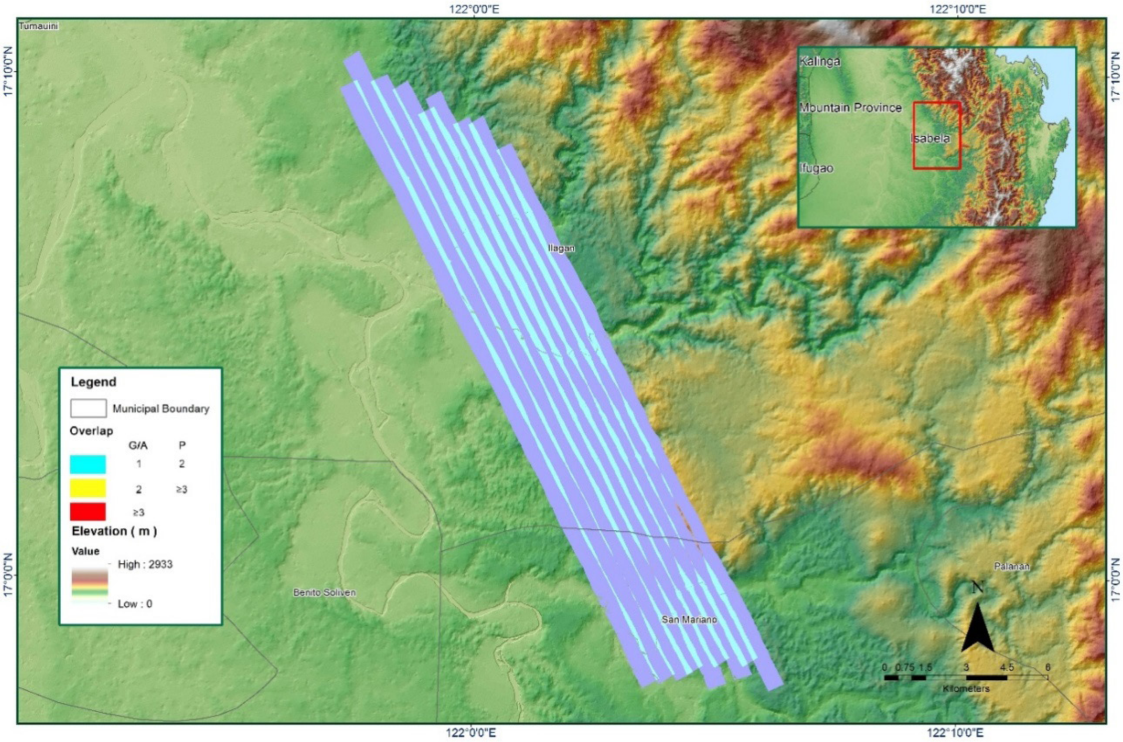


Figure A-8.12. Image of data overlap

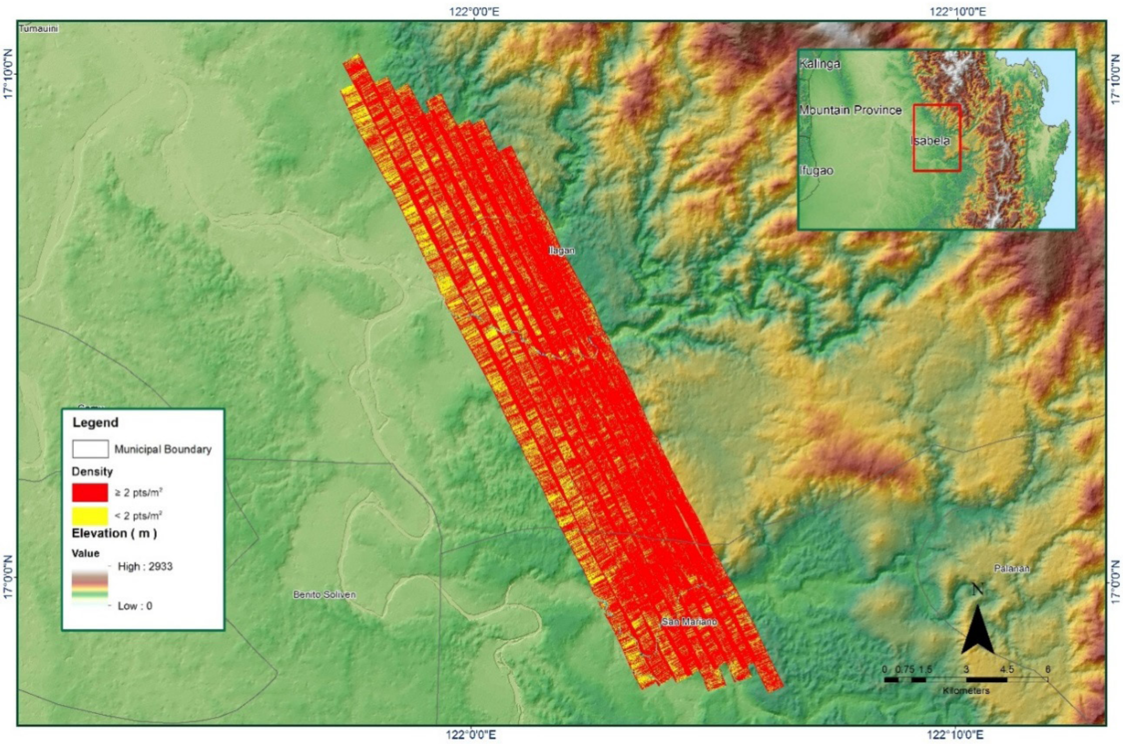


Figure A-8.13. Density map of merged LiDAR data

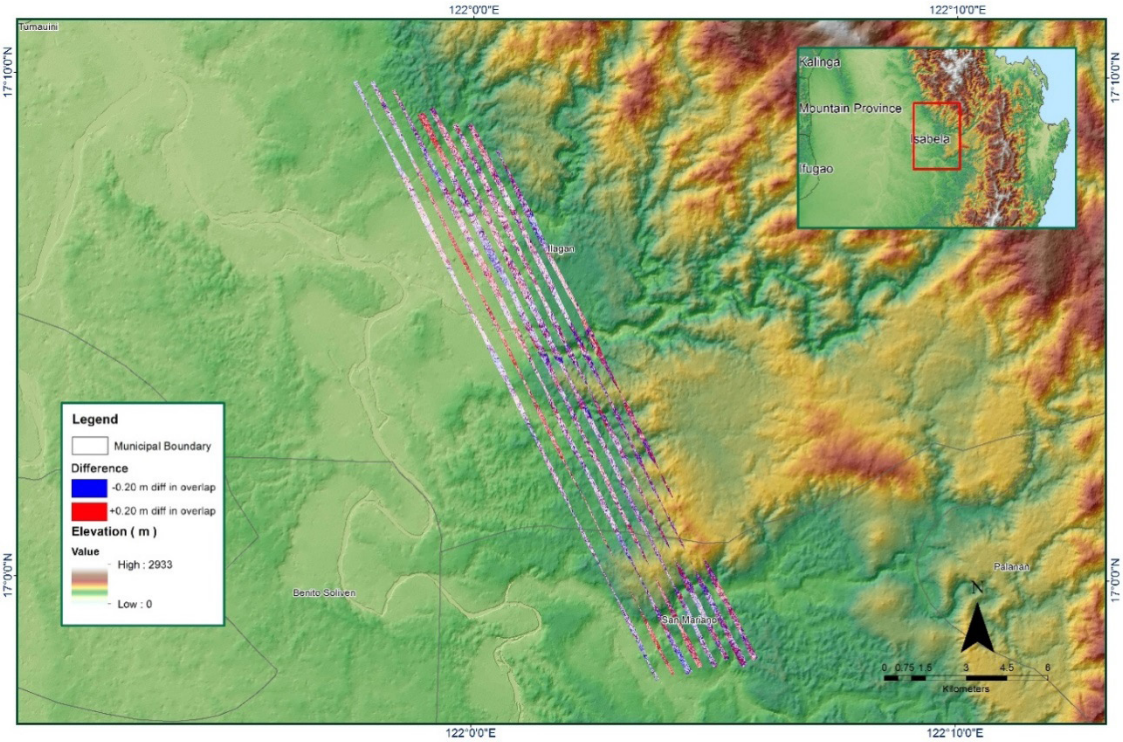


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk171M_additional

Flight Area	Cauayan
Mission Name	Blk171M_additional
Inclusive Flights	4027G
Range data size	6.34 GB
POS data size	133 MB
Base data size	4.87 MB
Image	n/a
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.0
RMSE for Down Position (<8.0 cm)	2.8
Boresight correction stdev (<0.001deg)	0.003941
IMU attitude correction stdev (<0.001deg)	0.001080
GPS position stdev (<0.01m)	0.0315
Minimum % overlap (>25)	8.73
Ave point cloud density per sq.m. (>2.0)	4.54
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	37
Maximum Height	605.80 m
Minimum Height	180.81 m
Classification (# of points)	
Ground	7,099,576
Low vegetation	4,815,779
Medium vegetation	23,046,261
High vegetation	111,058,076
Building	1,282,952
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Erica Erin Elazegui, Engr. Melissa Fernandez

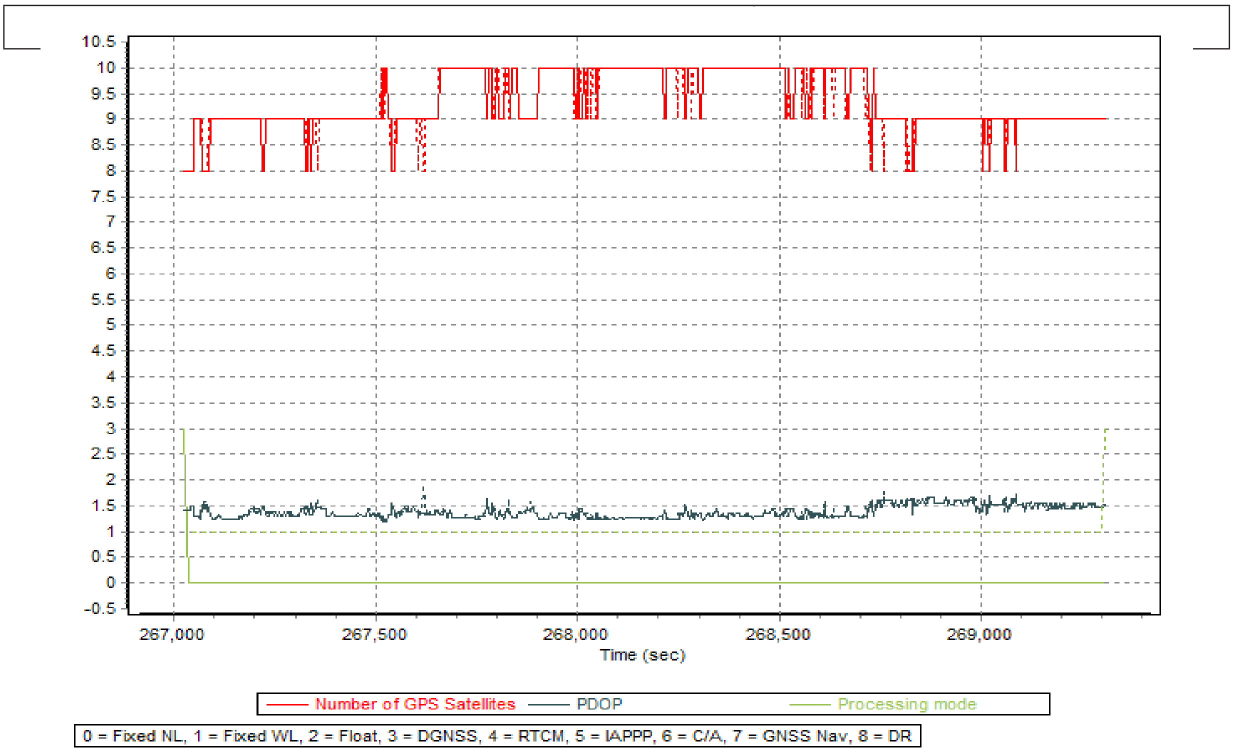


Figure A-8.15. Solution Status

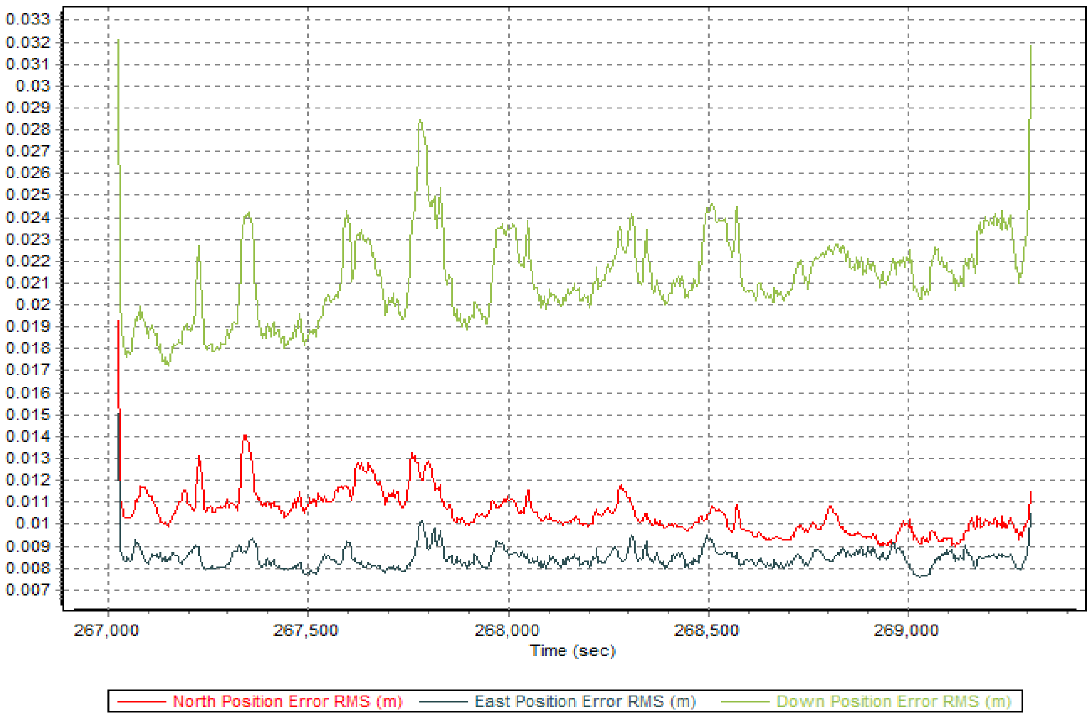


Figure A-8.16. Smoothed Performance Metrics Parameters

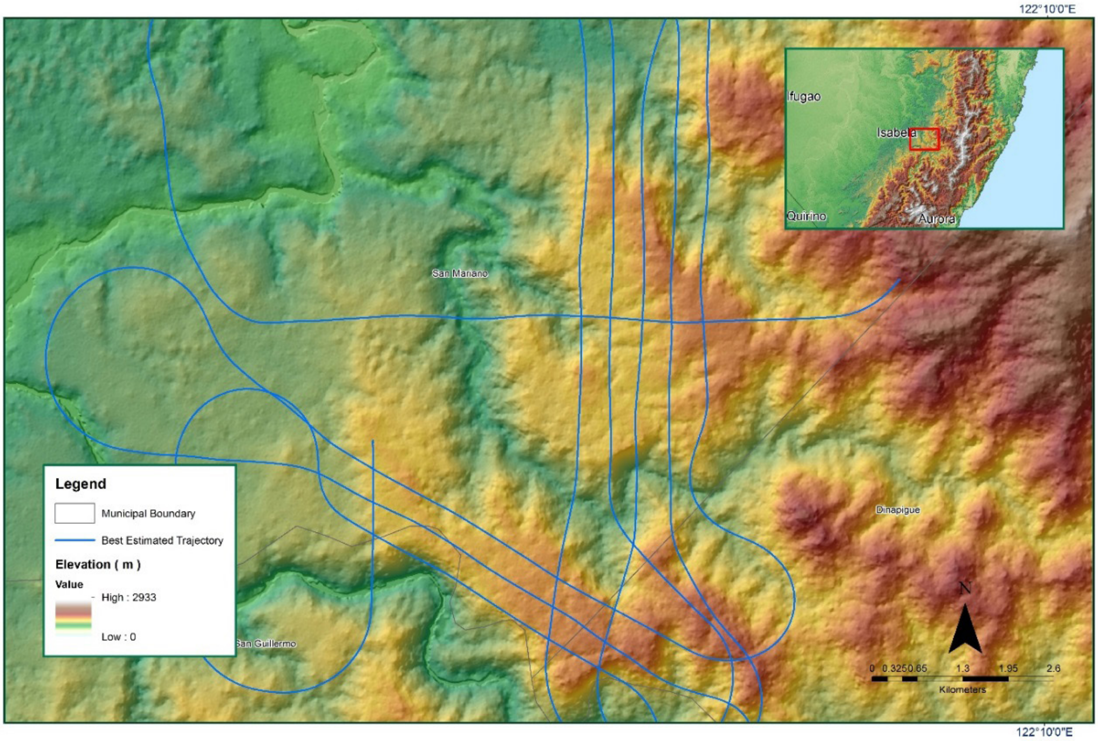


Figure A-8.17. Best Estimated Trajectory

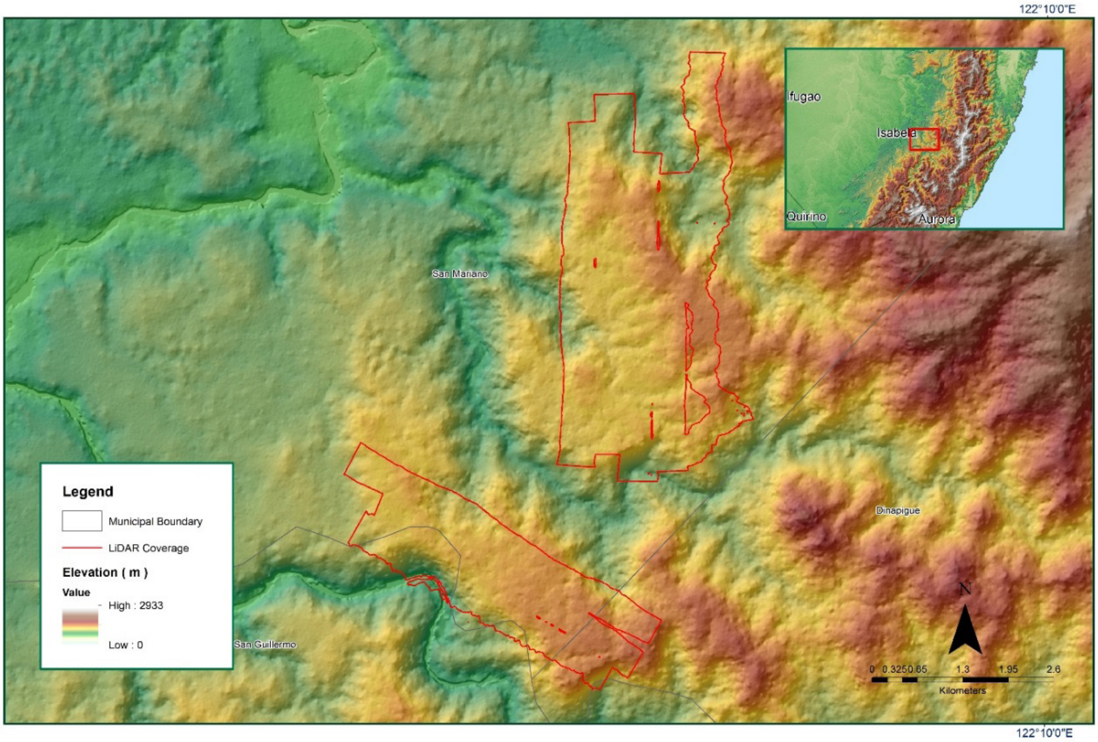


Figure A-8.18. Coverage of LiDAR data

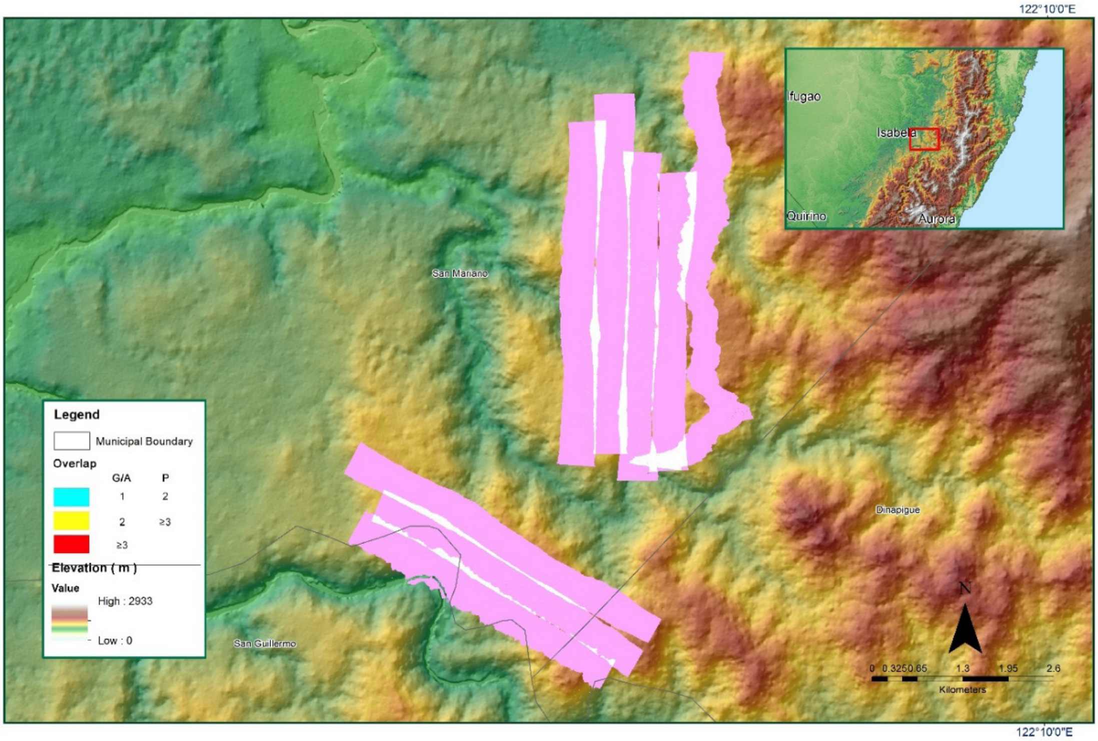


Figure A-8.19. Image of data overlap

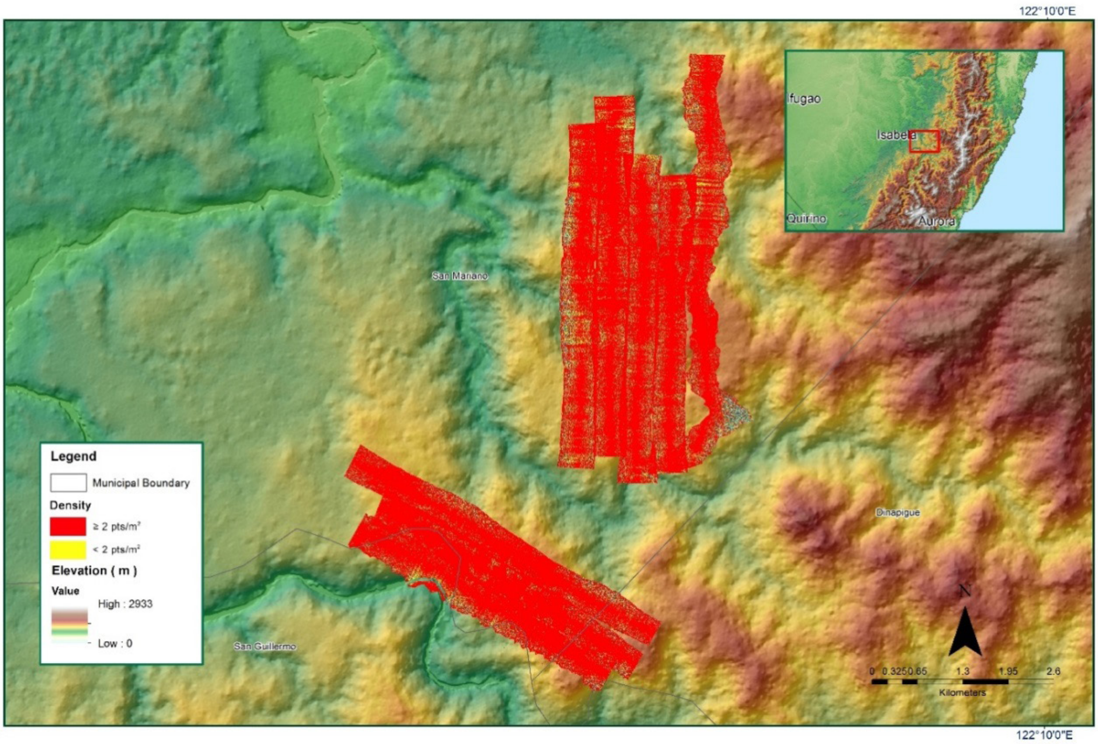


Figure A-8.20. Density map of merged LiDAR data

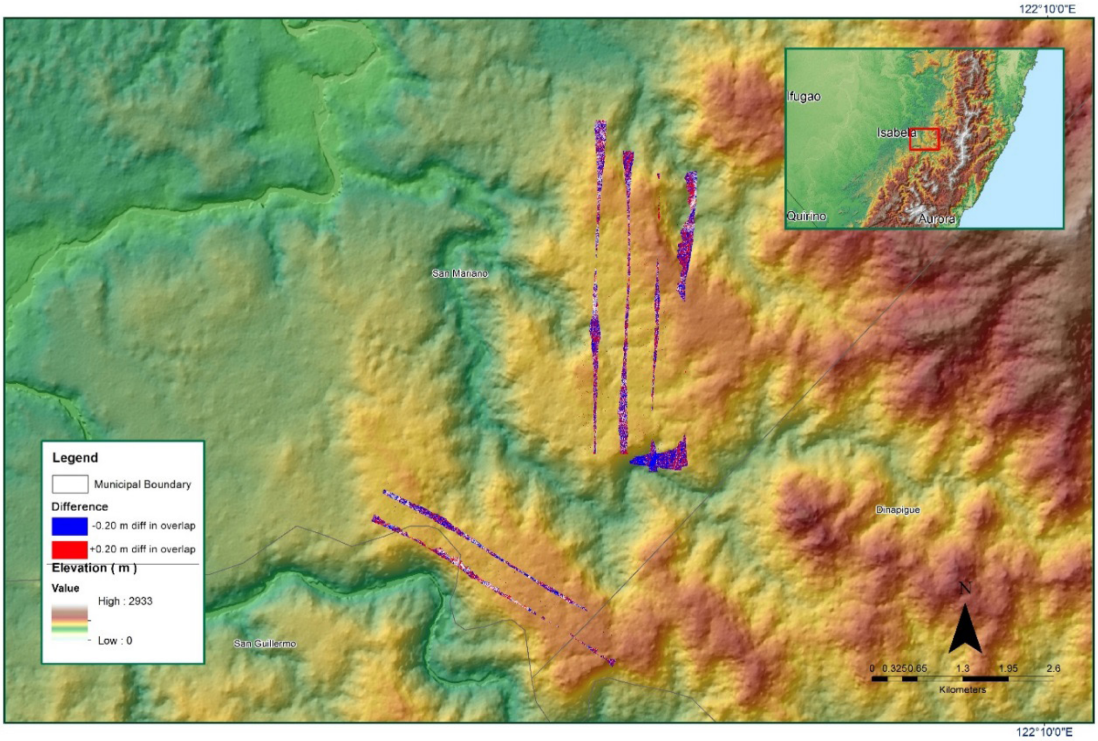


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk171F

Flight Area	Cauayan
Mission Name	Blk171F
Inclusive Flights	4021G
Range data size	11.3 GB
POS data size	123 MB
Base data size	12.5 MB
Image	n/a
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.1
RMSE for East Position (<4.0 cm)	2.3
RMSE for Down Position (<8.0 cm)	4.9
Boresight correction stdev (<0.001deg)	0.000190
IMU attitude correction stdev (<0.001deg)	0.000284
GPS position stdev (<0.01m)	0.0102
Minimum % overlap (>25)	24.25
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	156
Maximum Height	270.24 m
Minimum Height	77.95 m
Classification (# of points)	
Ground	92,740,519
Low vegetation	58,191,360
Medium vegetation	116,112,631
High vegetation	56,633,194
Building	98,892
Orthophoto	No
Processed by	Engr. Kenneth Solidum, Engr. Jovelle Anjeanette Canlas, Engr. Vincent Louise Azucena

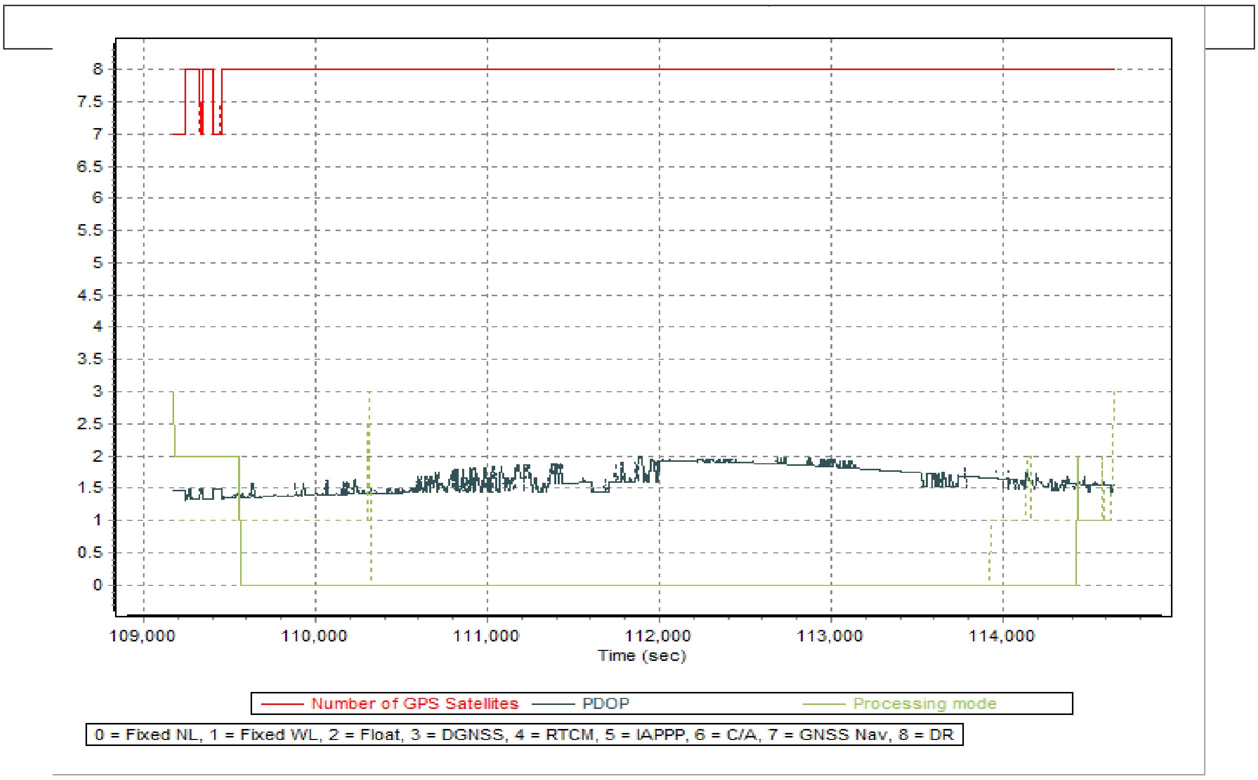


Figure A-8.22. Solution Status

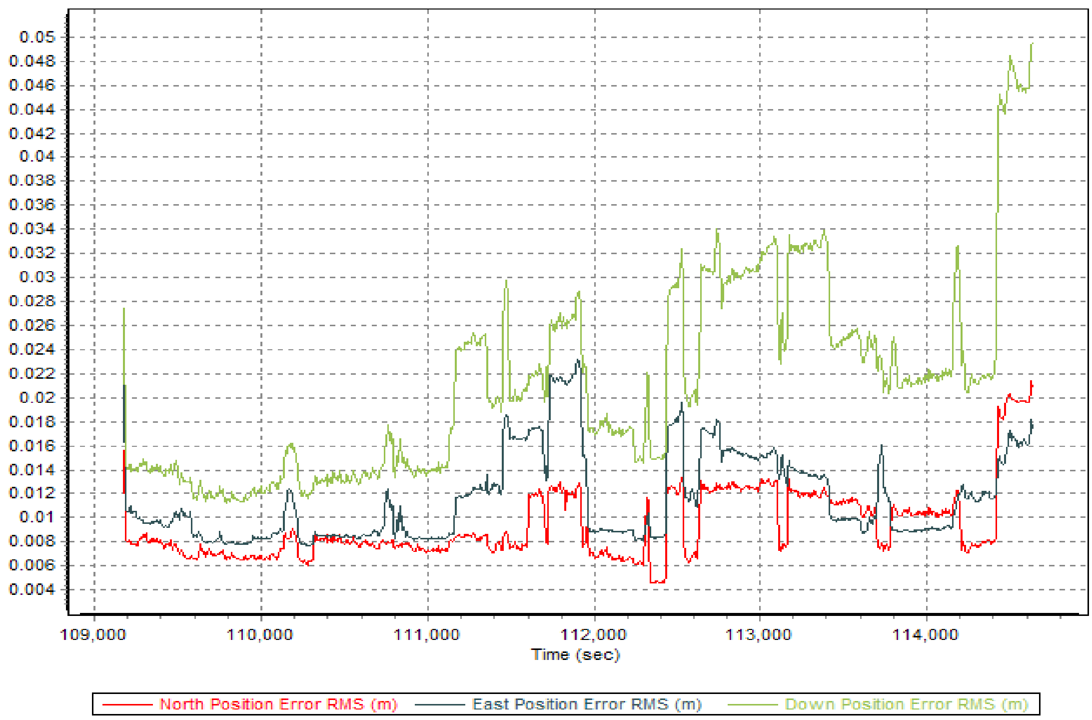


Figure A-8.23. Smoothed Performance Metrics Parameters

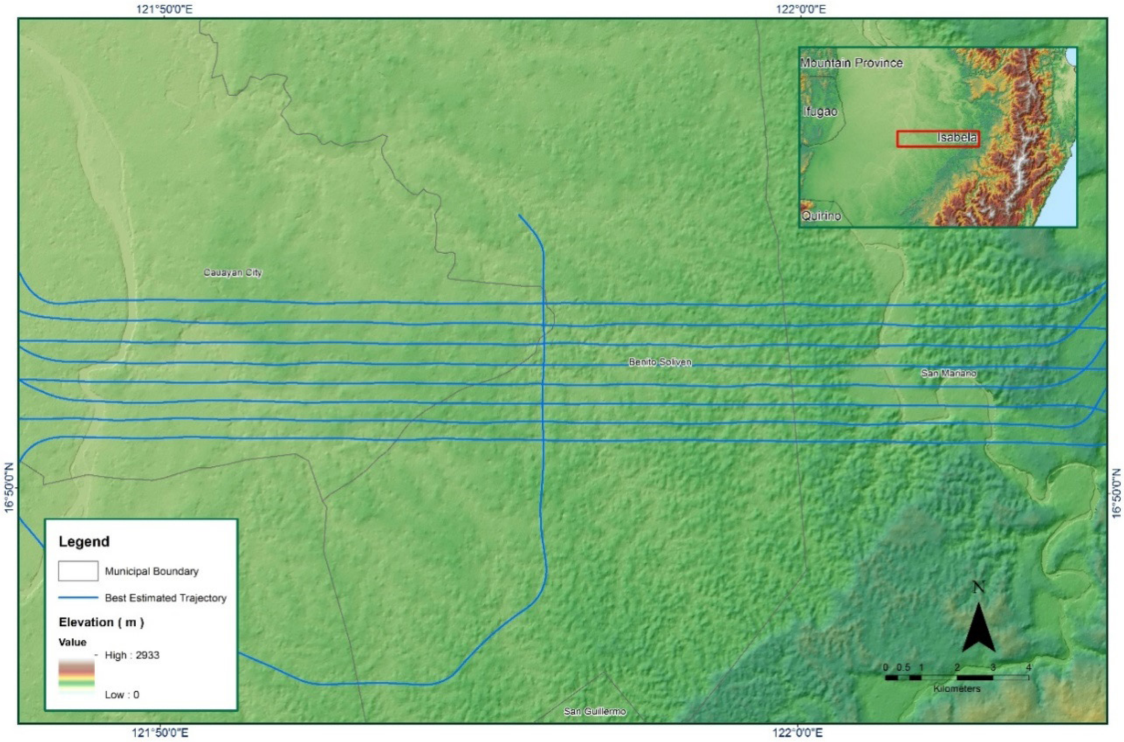


Figure A-8.24. Best Estimated Trajectory

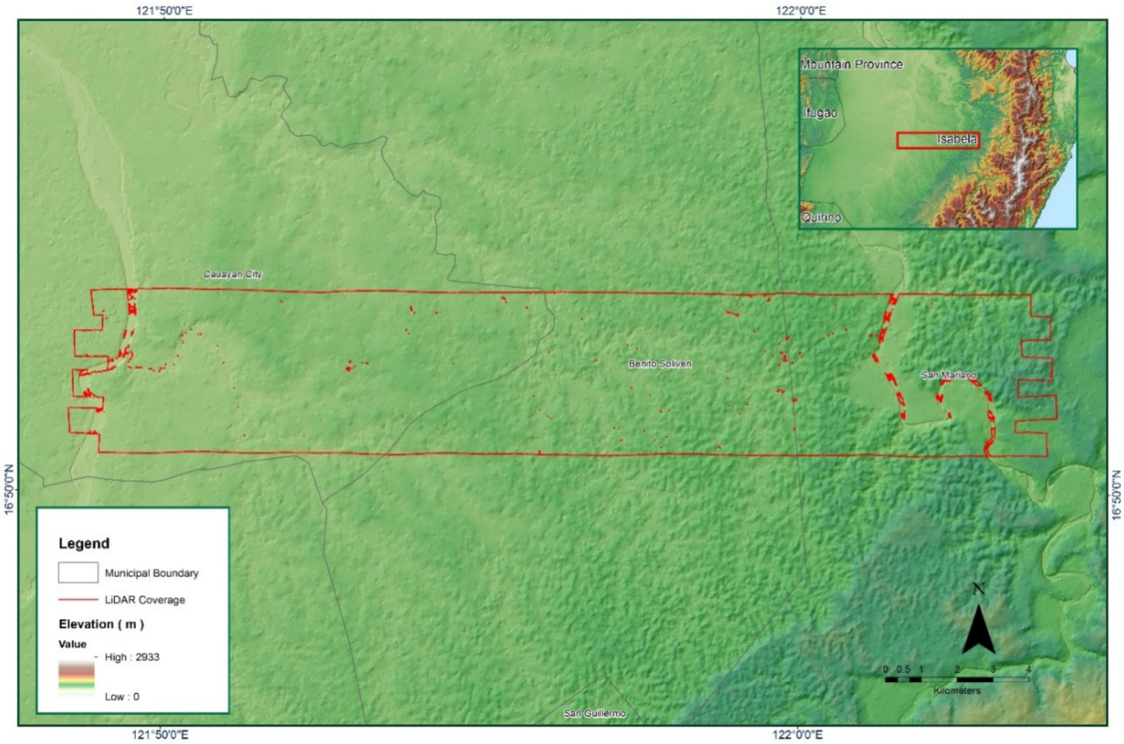


Figure A-8.25. Coverage of LiDAR data

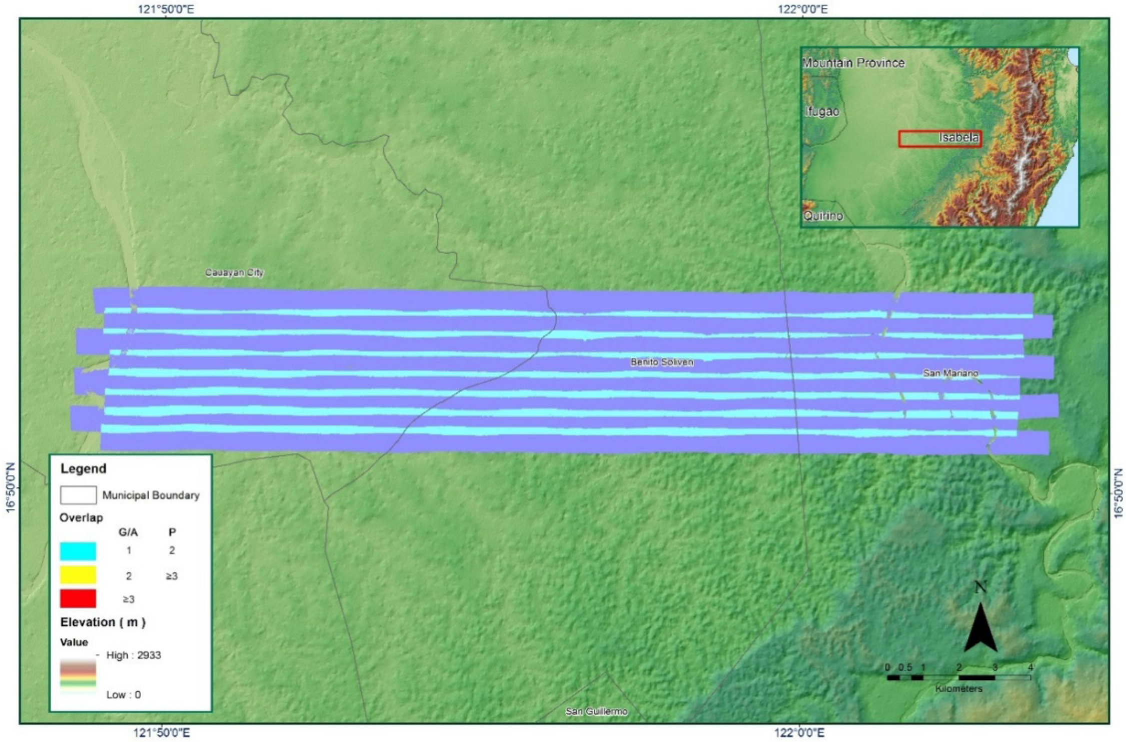


Figure A-8.26. Image of data overlap

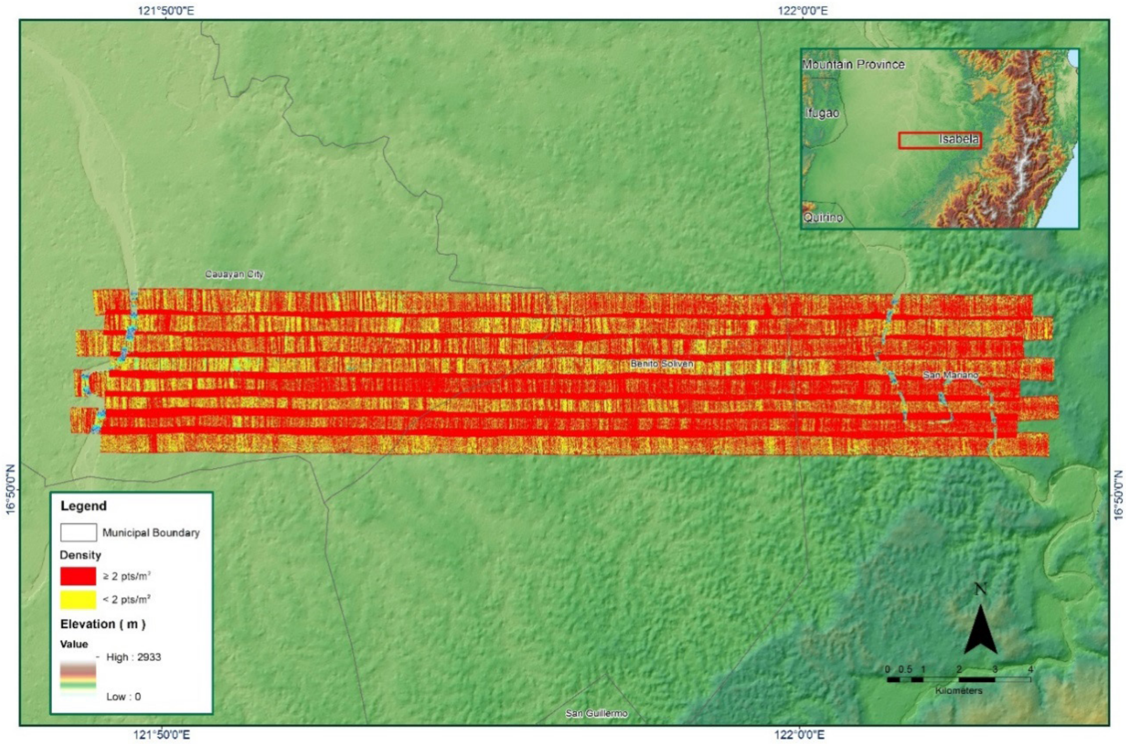


Figure A-8.27. Density map of merged LiDAR data

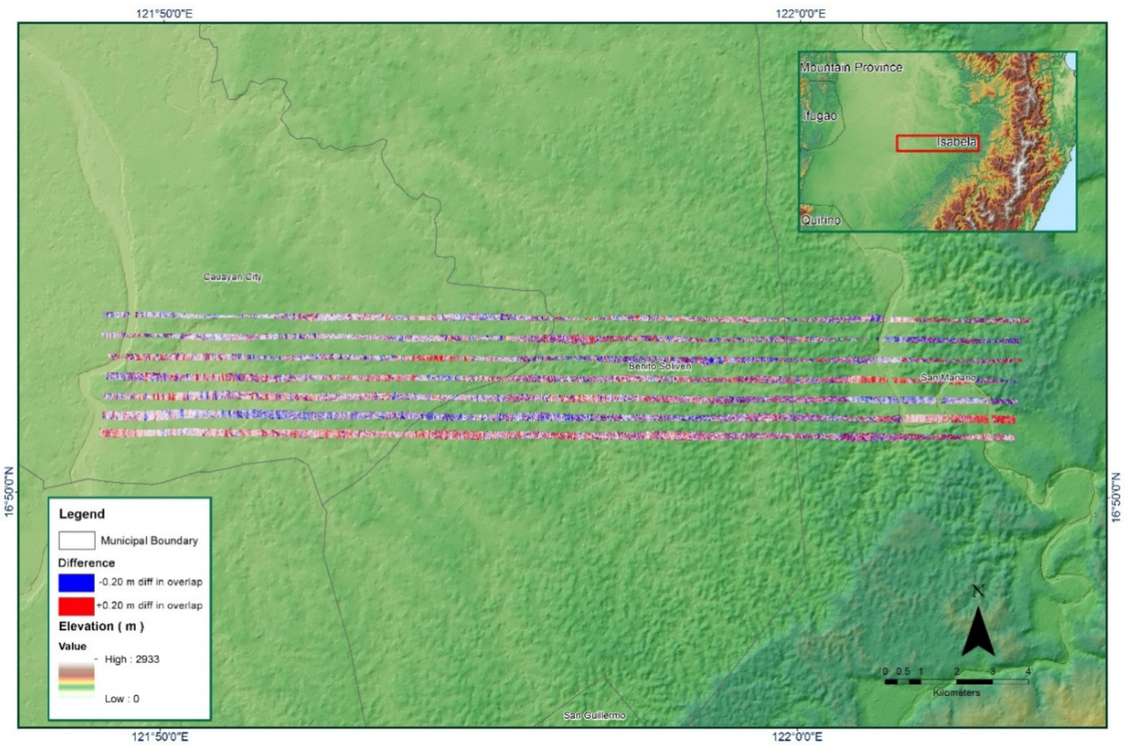


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk161LM

Flight Area	Cauayan
Mission Name	Blk161LM
Inclusive Flights	4023G,4025G
Range data size	12.1 GB
POS data size	145 MB
Base data size	13.2 MB
Image	n/a
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	3.6
Boresight correction stdev (<0.001deg)	0.001103
IMU attitude correction stdev (<0.001deg)	0.007658
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	36.41
Ave point cloud density per sq.m. (>2.0)	3.06
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	217
Maximum Height	395.29 m
Minimum Height	101.07 m
Classification (# of points)	
Ground	91,651,326
Low vegetation	106,368,499
Medium vegetation	244,378,060
High vegetation	52,948,267
Building	942,421
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Velina Angela Bemida, Engr. Monalyne Rabino

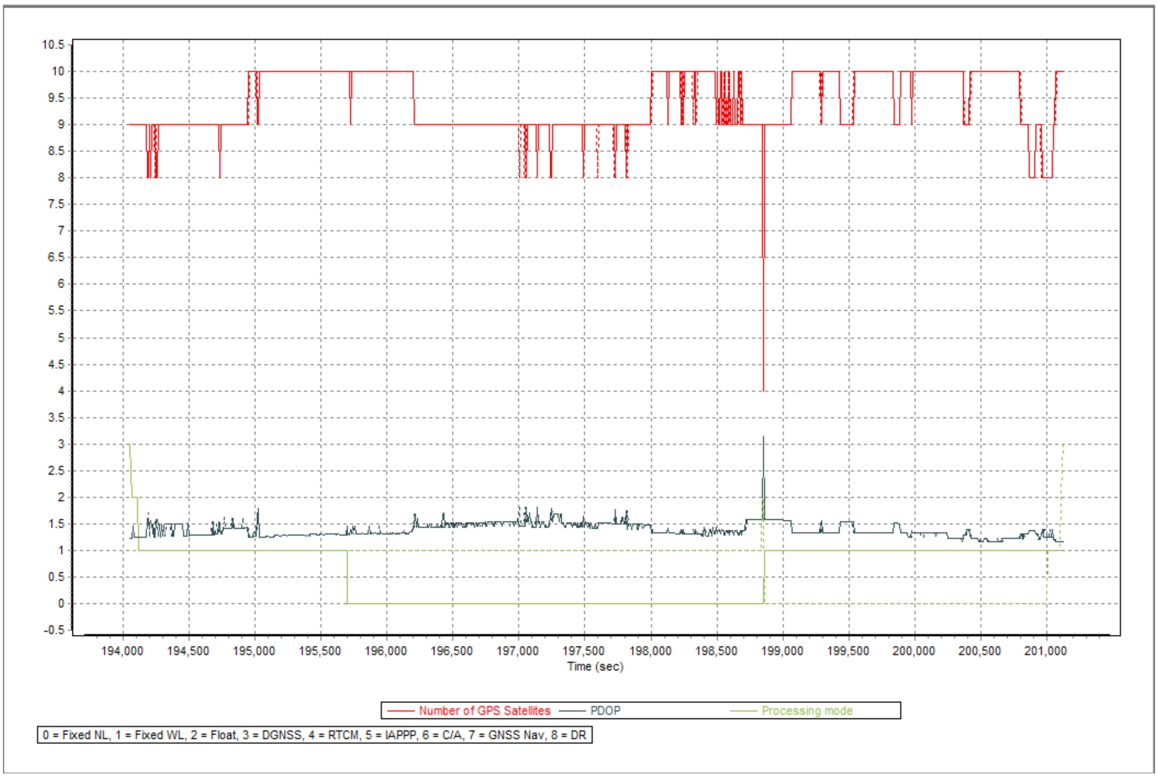


Figure A-8.29. Solution Status

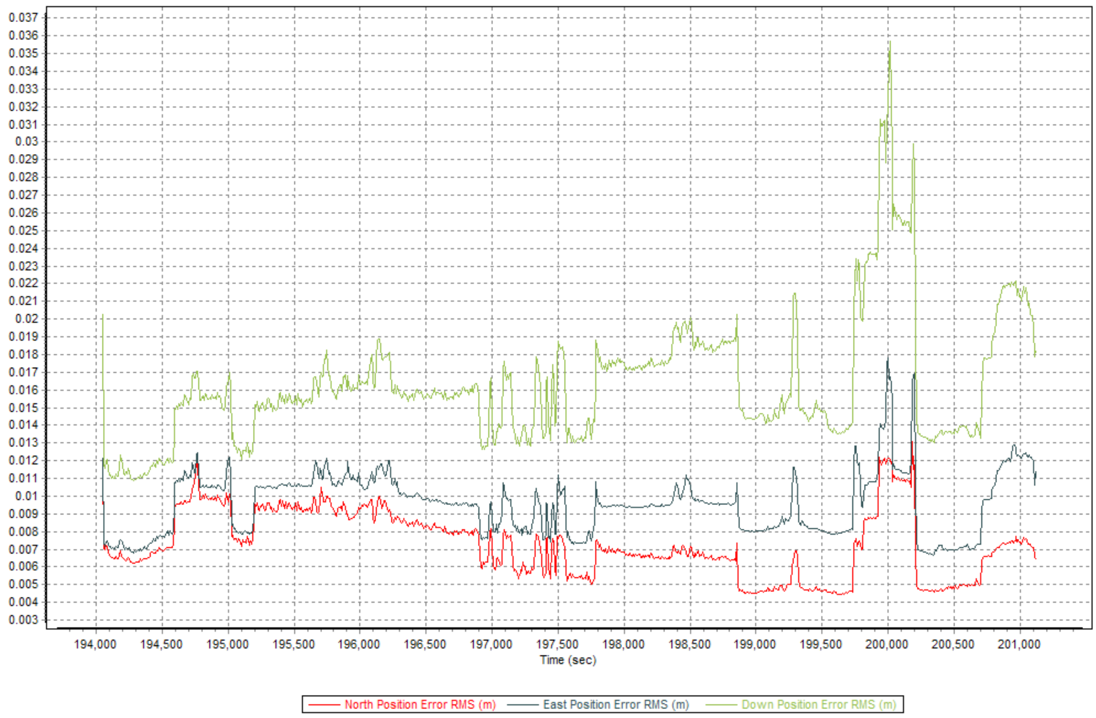


Figure A-8.30. Smoothed Performance Metrics Parameters

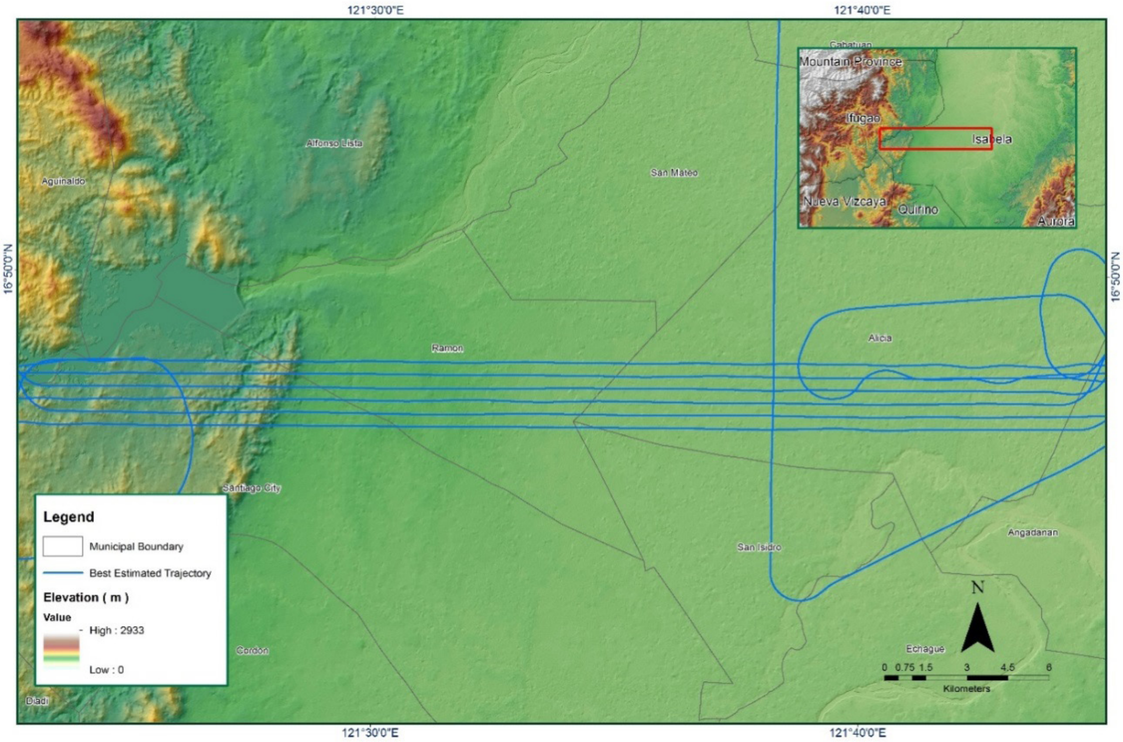


Figure A-8.31. Best Estimated Trajectory

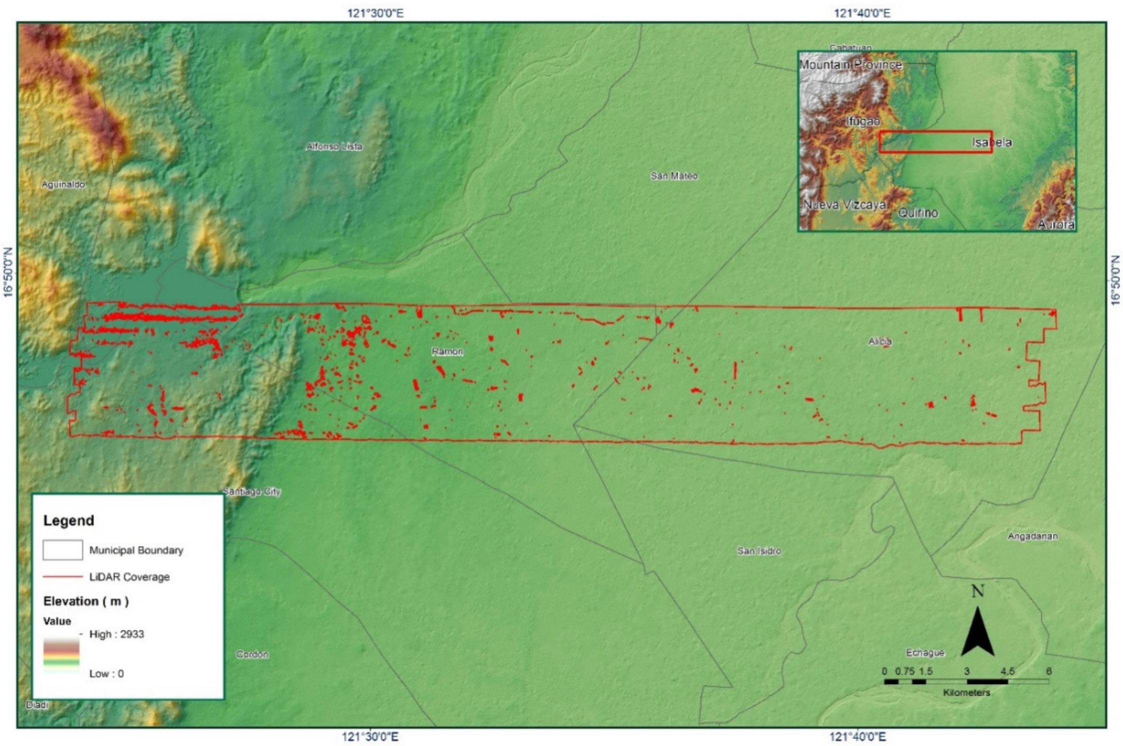


Figure A-8.32. Coverage of LiDAR data

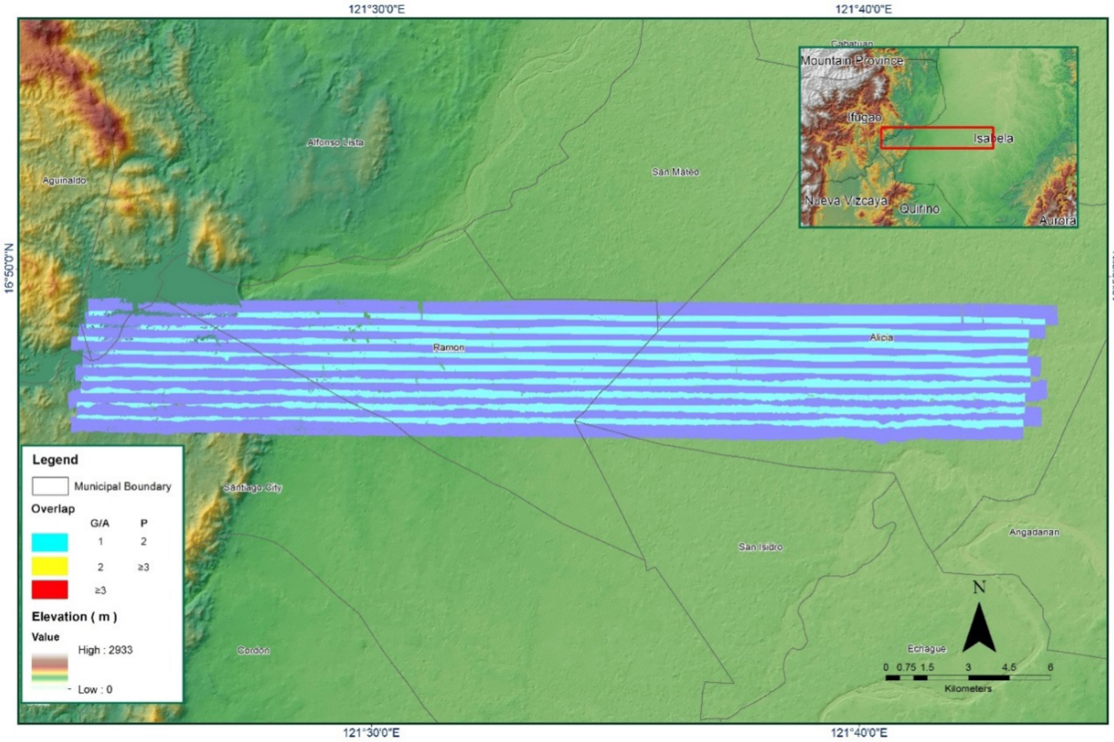


Figure A-8.33. Image of data overlap

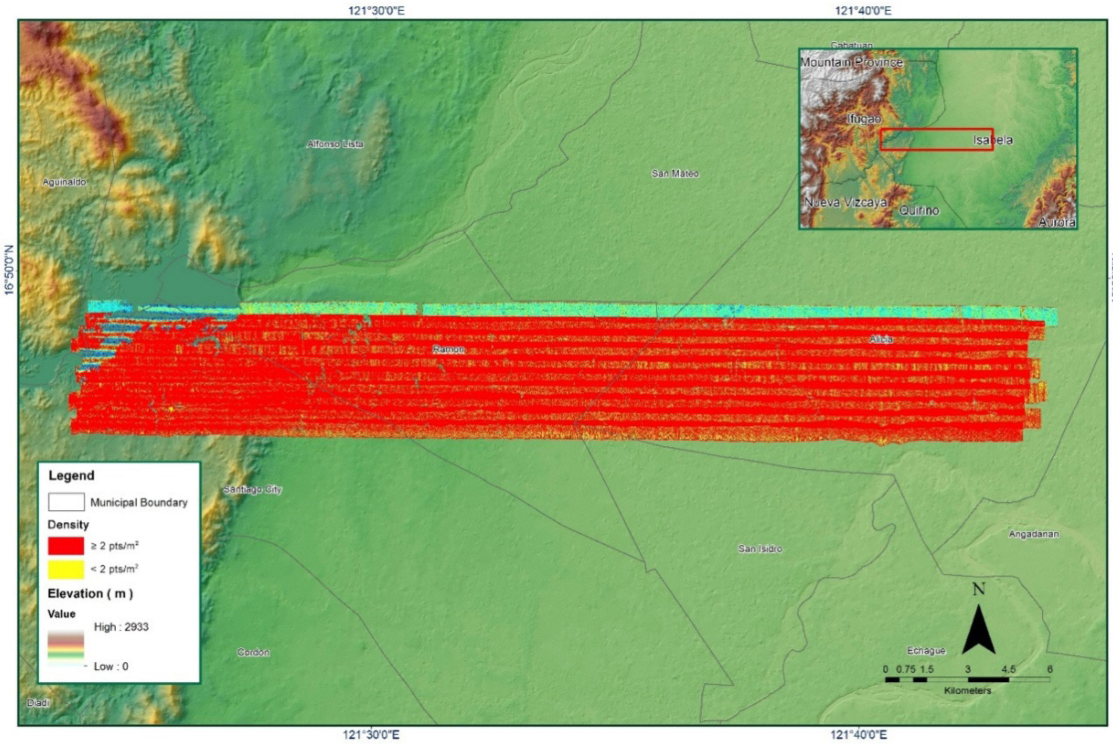


Figure A-8.34. Density map of merged LiDAR data

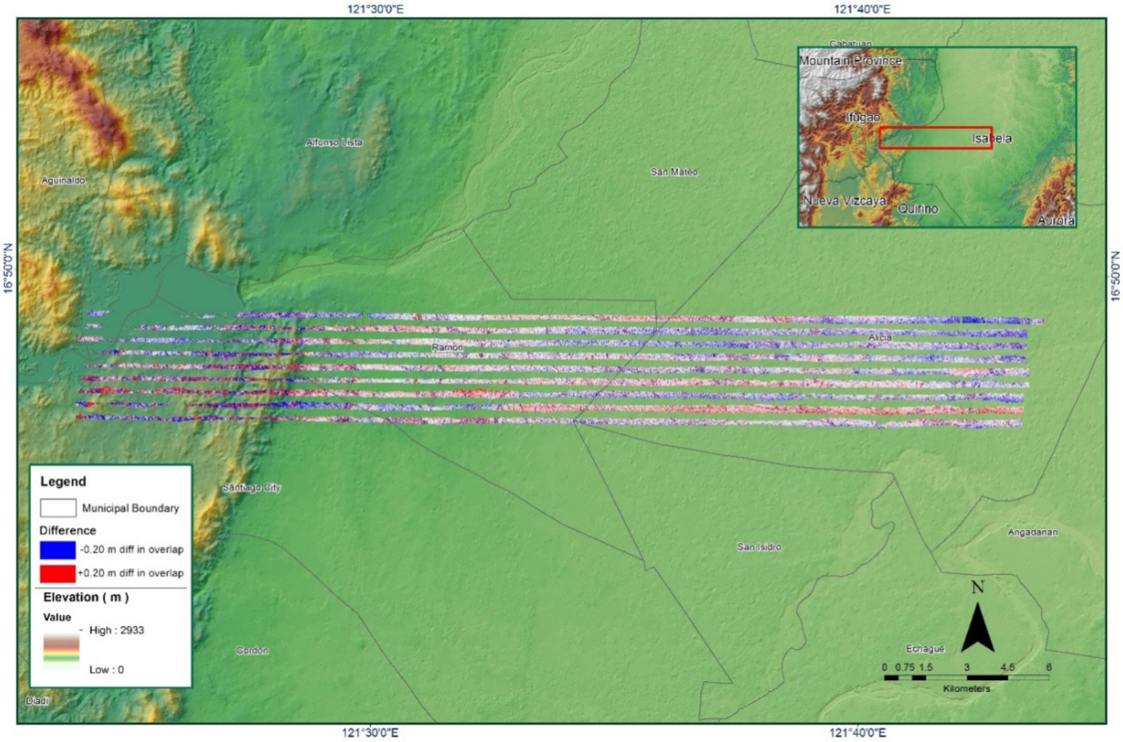


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk61BS

Flight Area	Cauayan
Mission Name	Blk61BS
Inclusive Flights	4023G
Range data size	23.5 GB
POS data size	227 MB
Base data size	13.2 MB
Image	n/a
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	5.1
Boresight correction stdev (<0.001deg)	n/a
IMU attitude correction stdev (<0.001deg)	n/a
GPS position stdev (<0.01m)	n/a
Minimum % overlap (>25)	5.04
Ave point cloud density per sq.m. (>2.0)	2.35
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	194
Maximum Height	414.46 m
Minimum Height	78.77 m
Classification (# of points)	
Ground	123,046,950
Low vegetation	62,299,966
Medium vegetation	103,415,839
High vegetation	35,239,939
Building	579,860
Orthophoto	No
Processed by	Engr. Don Matthew Banatin, Engr. Harmond Santos, Engr. Gladys Mae Apat

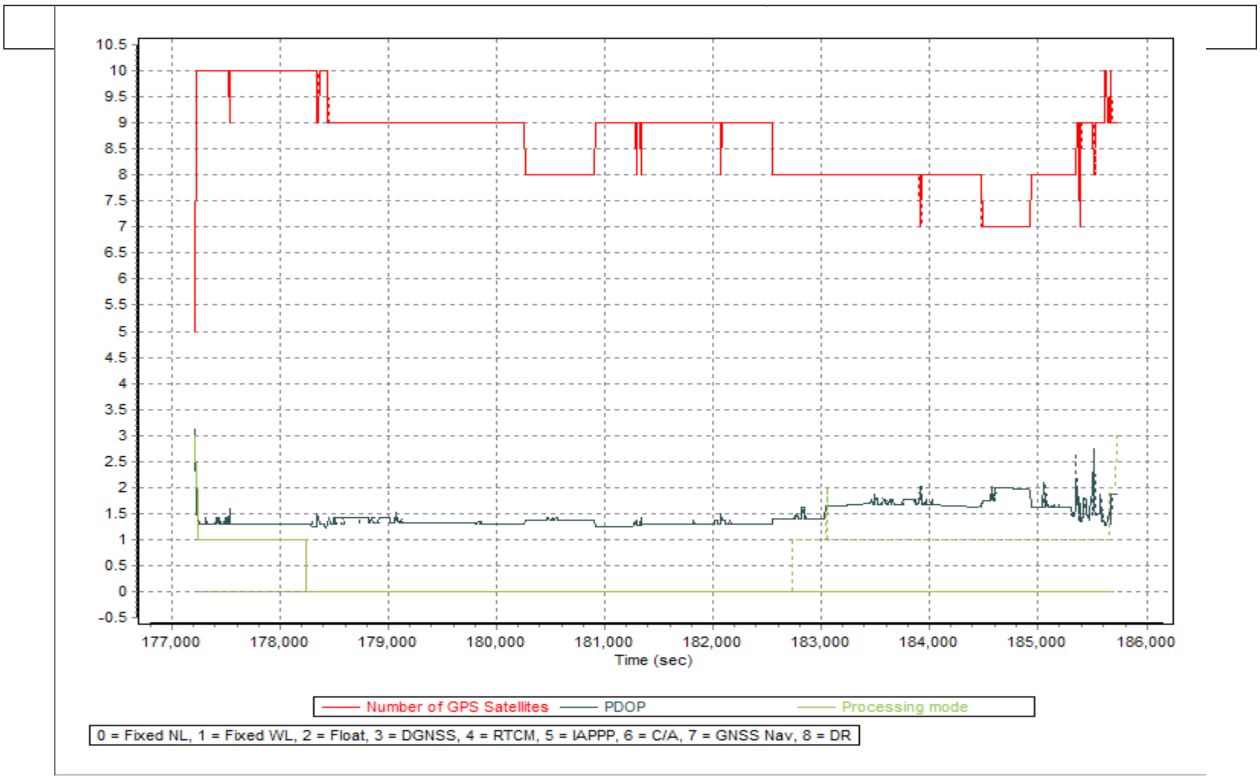


Figure A-8.36. Solution Status

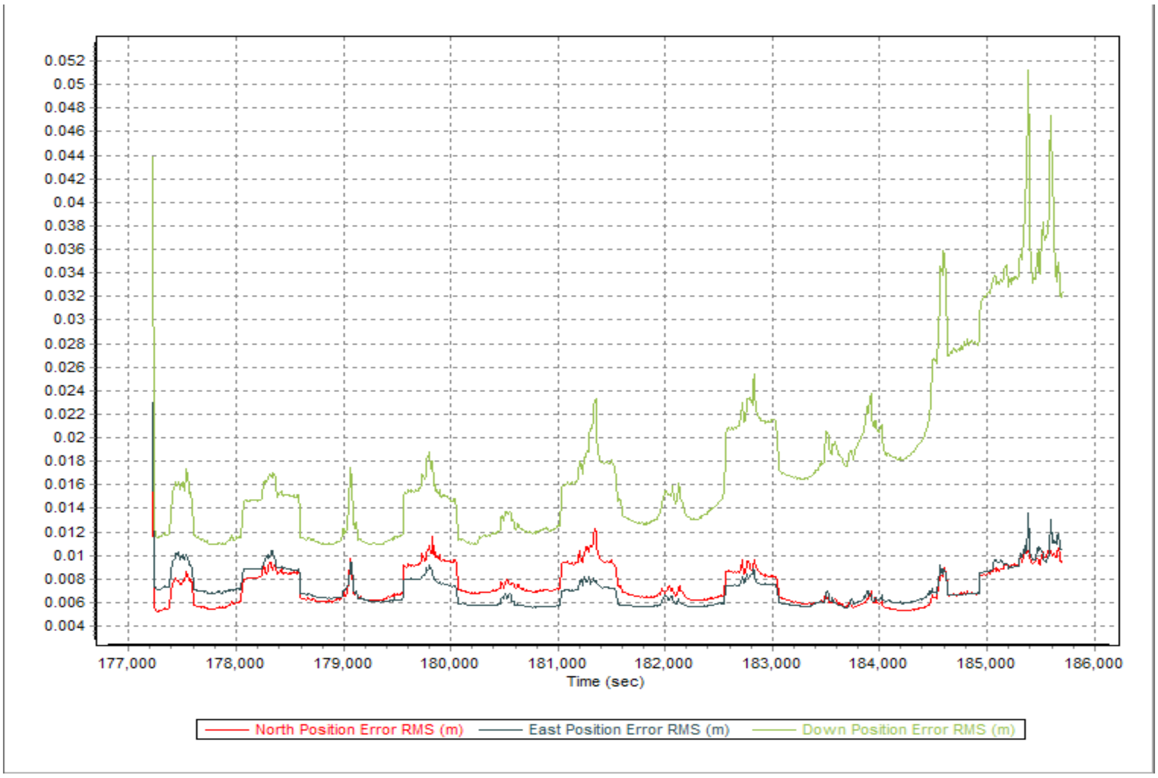


Figure A-8.37. Smoothed Performance Metrics Parameters

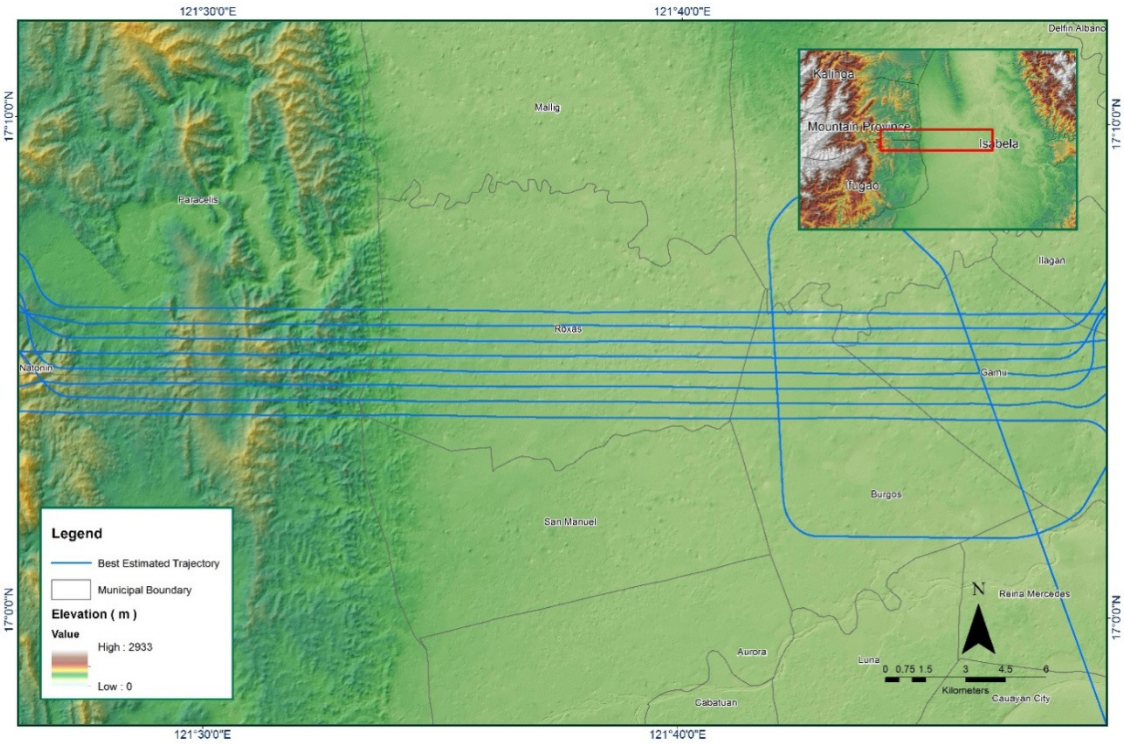


Figure A-8.38. Best Estimated Trajectory

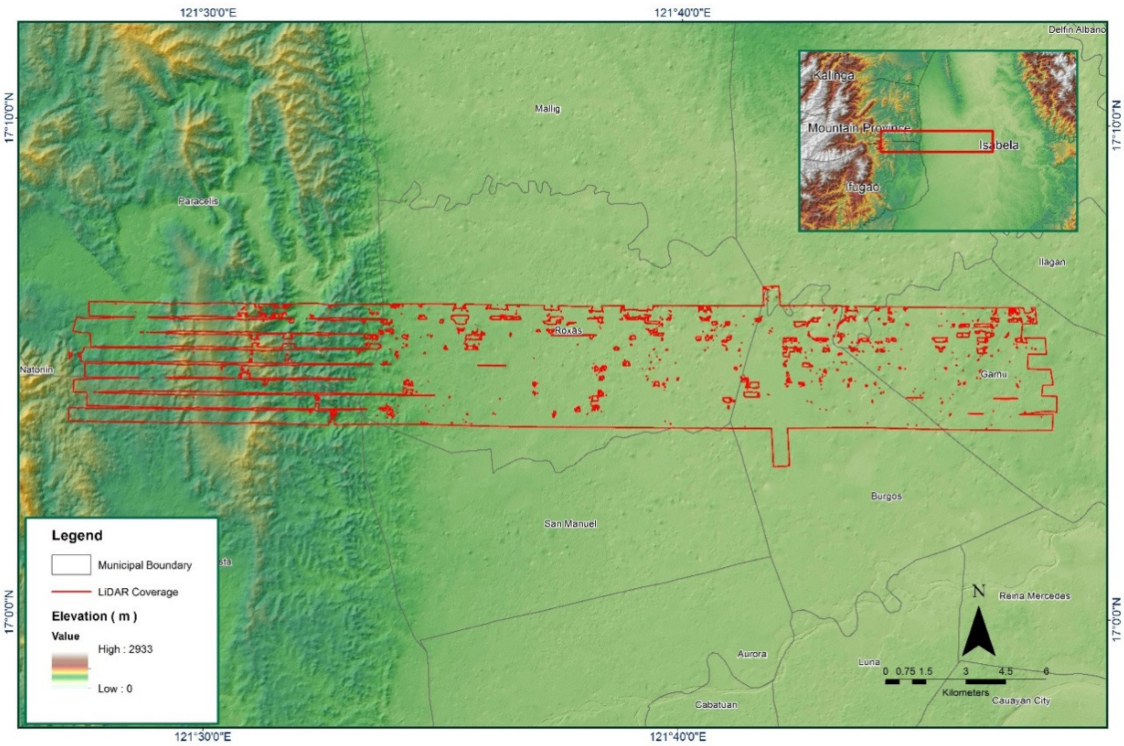


Figure A-8.39. Coverage of LiDAR data

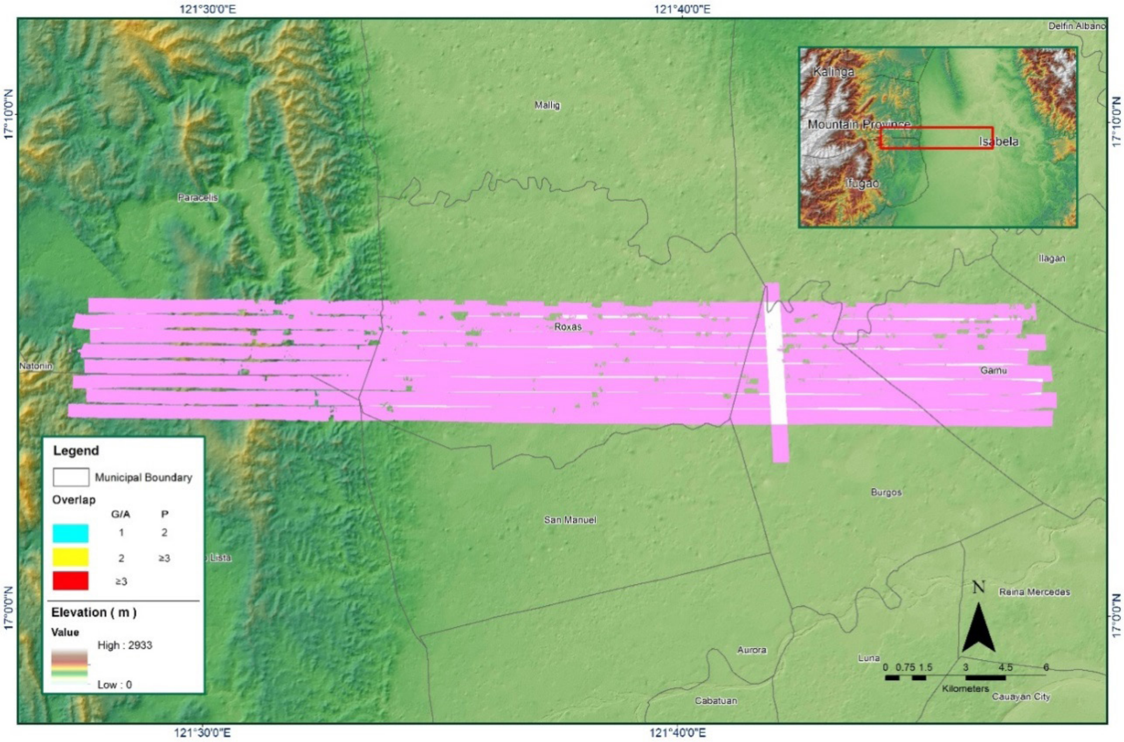


Figure A-8.40. Image of data overlap

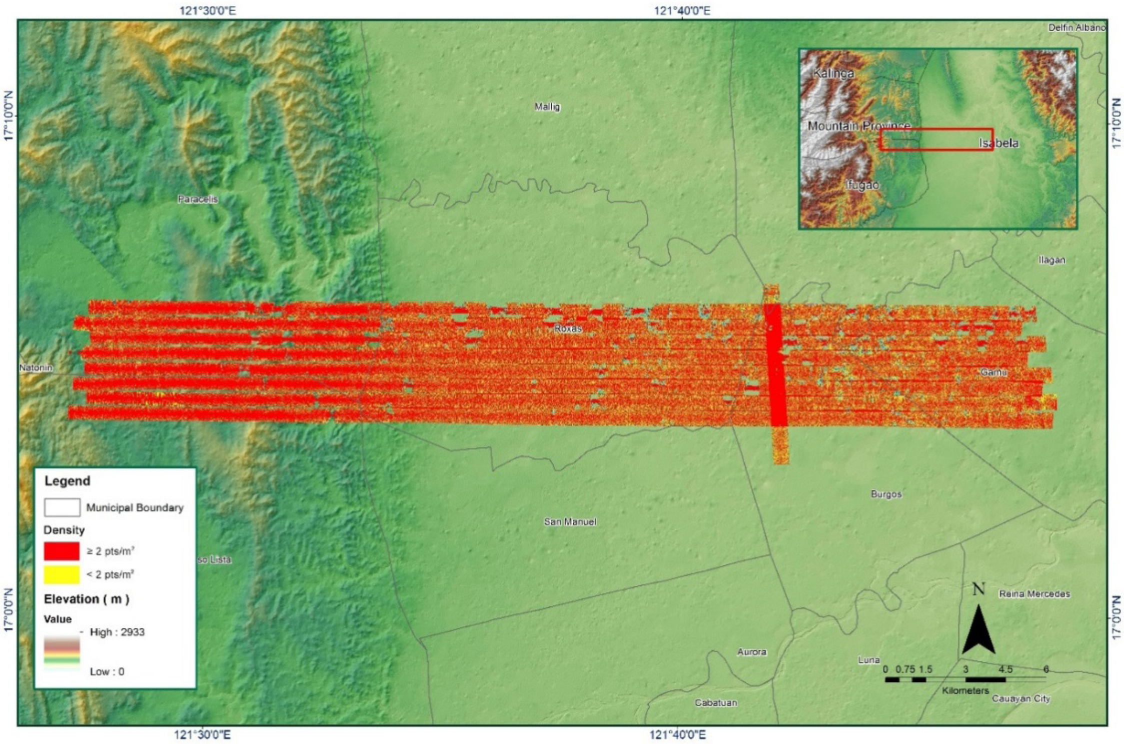


Figure A-8.41. Density map of merged LiDAR data

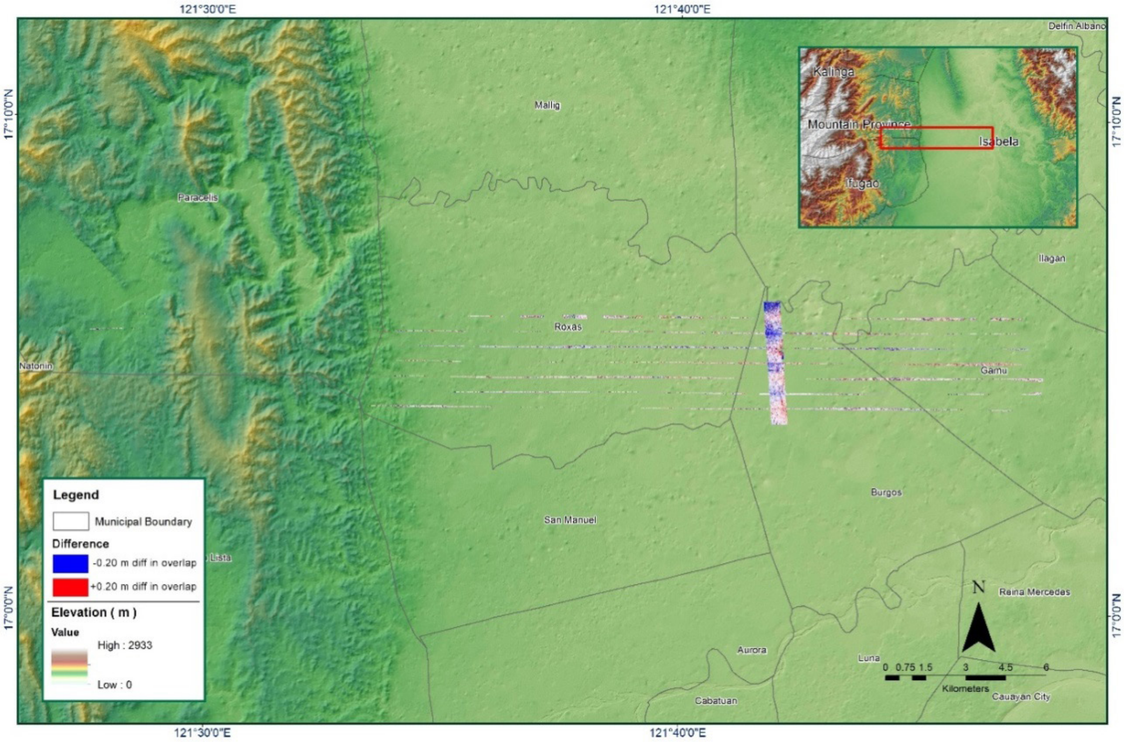


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk171O

Flight Area	Cauayan
Mission Name	Blk171O
Inclusive Flights	4019G, 4027G
Range data size	19.5 GB
POS data size	215 MB
Base data size	12.5 MB
Image	n/a
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000246
IMU attitude correction stdev (<0.001deg)	0.001338
GPS position stdev (<0.01m)	0.0016
Minimum % overlap (>25)	27.75
Ave point cloud density per sq.m. (>2.0)	3.20
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	296
Maximum Height	540.95 m
Minimum Height	57.35 m
Classification (# of points)	
Ground	117,841,690
Low vegetation	116,121,850
Medium vegetation	233,848,095
High vegetation	154,601,291
Building	1,025,828
Orthophoto	No
Processed by	Engr. Sheila Maye Santillan, Aljon Rei Araneta, Jovy Narisma

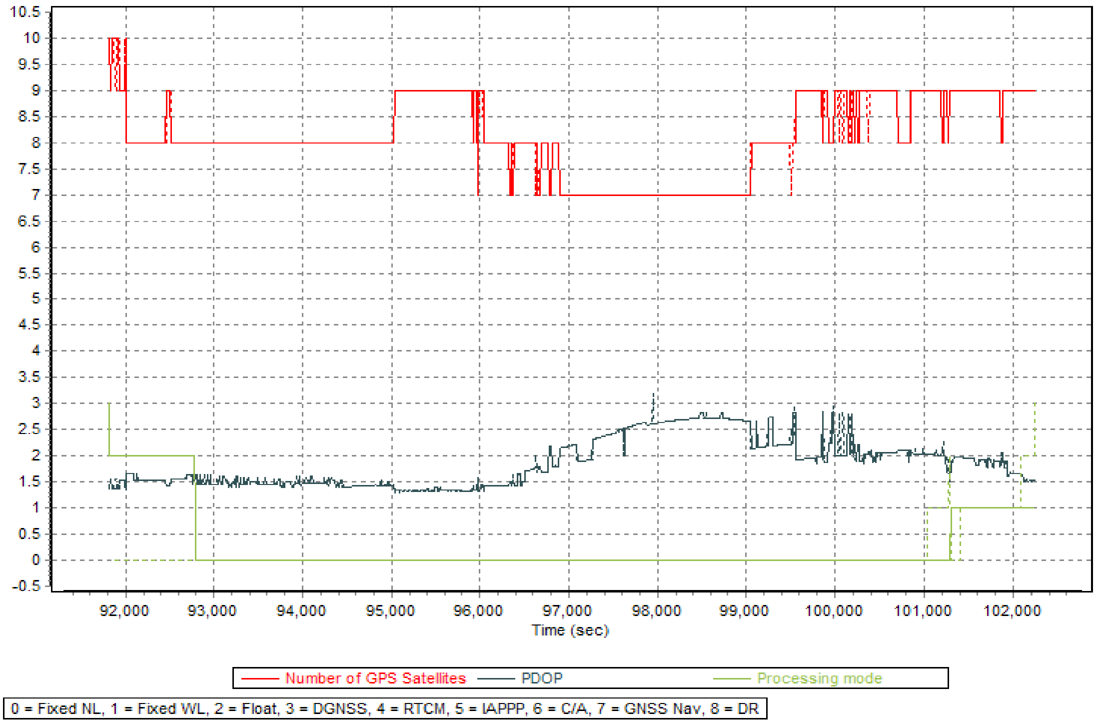


Figure A-8.43. Solution Status

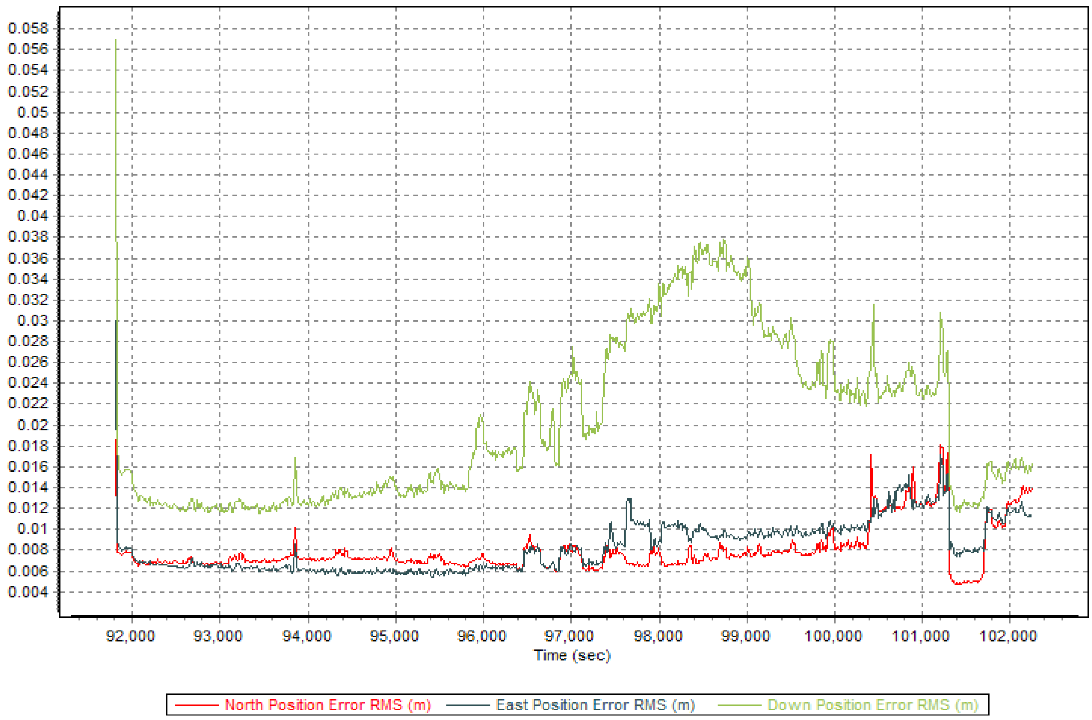


Figure A-8.44. Smoothed Performance Metrics Parameters

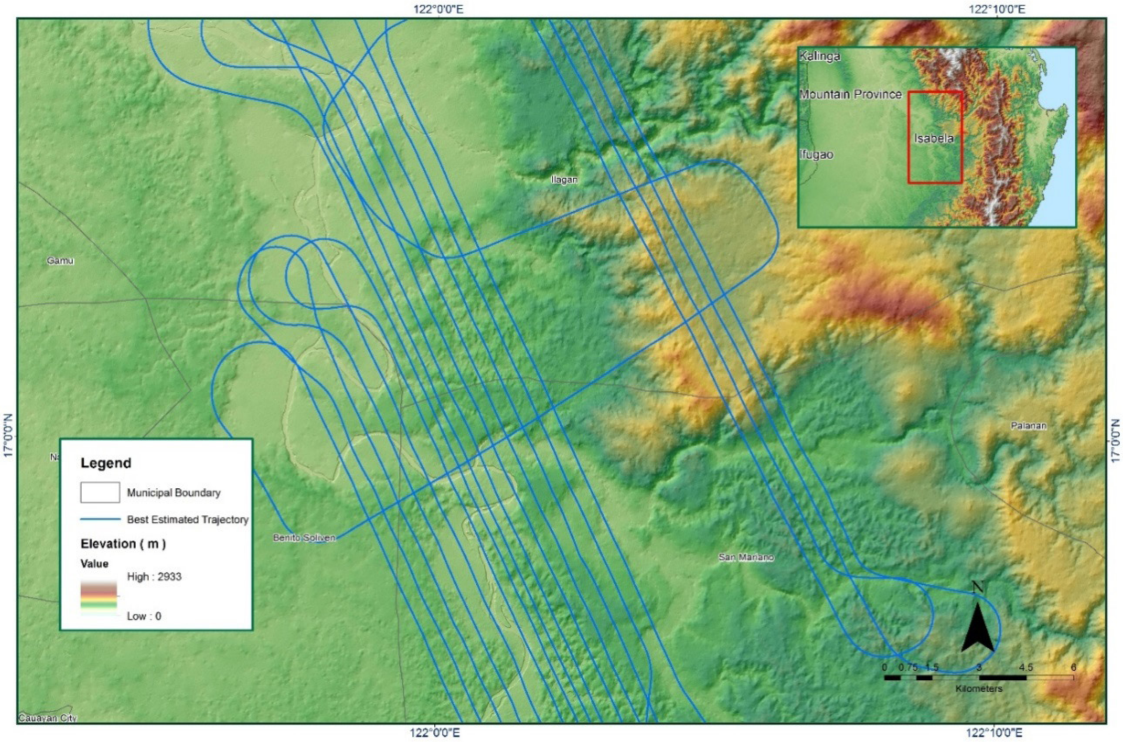


Figure A-8.45. Best Estimated Trajectory

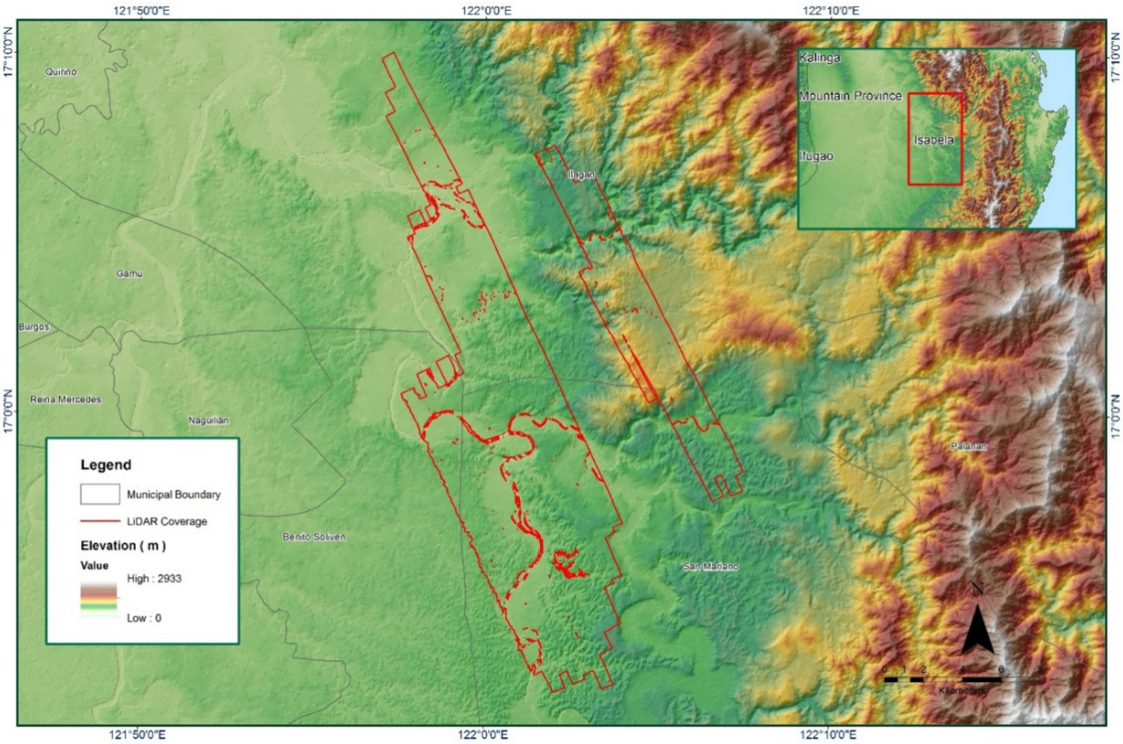


Figure A-8.46. Coverage of LiDAR data

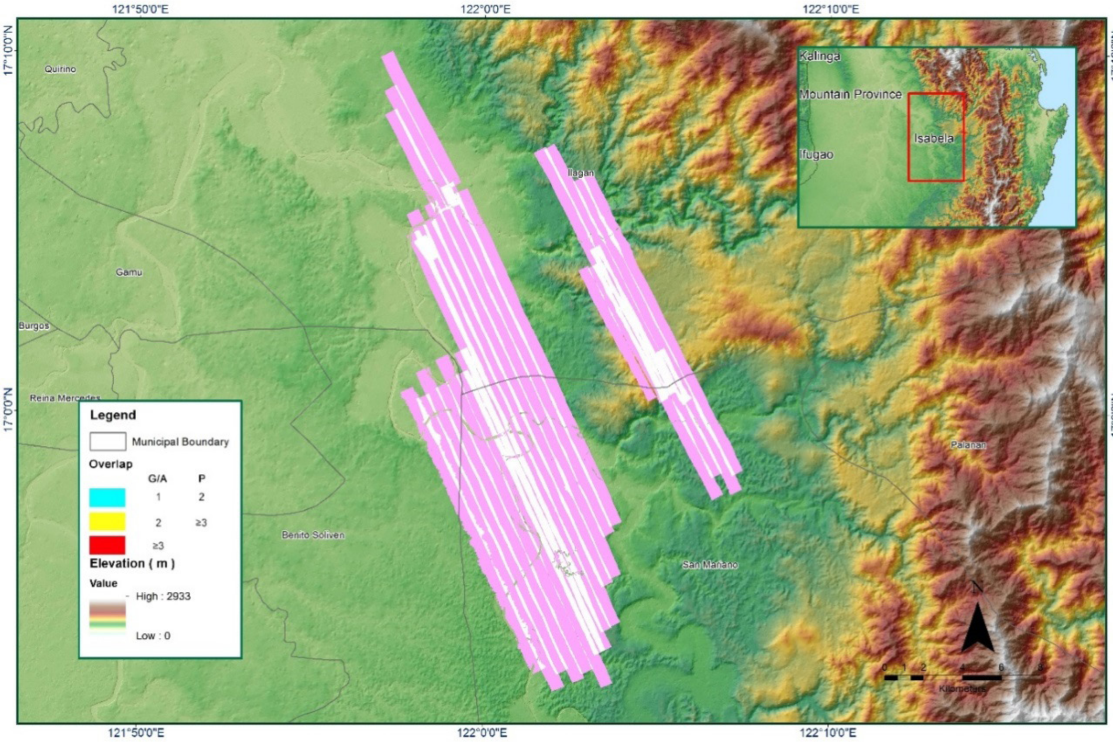


Figure A-8.47. Image of data overlap

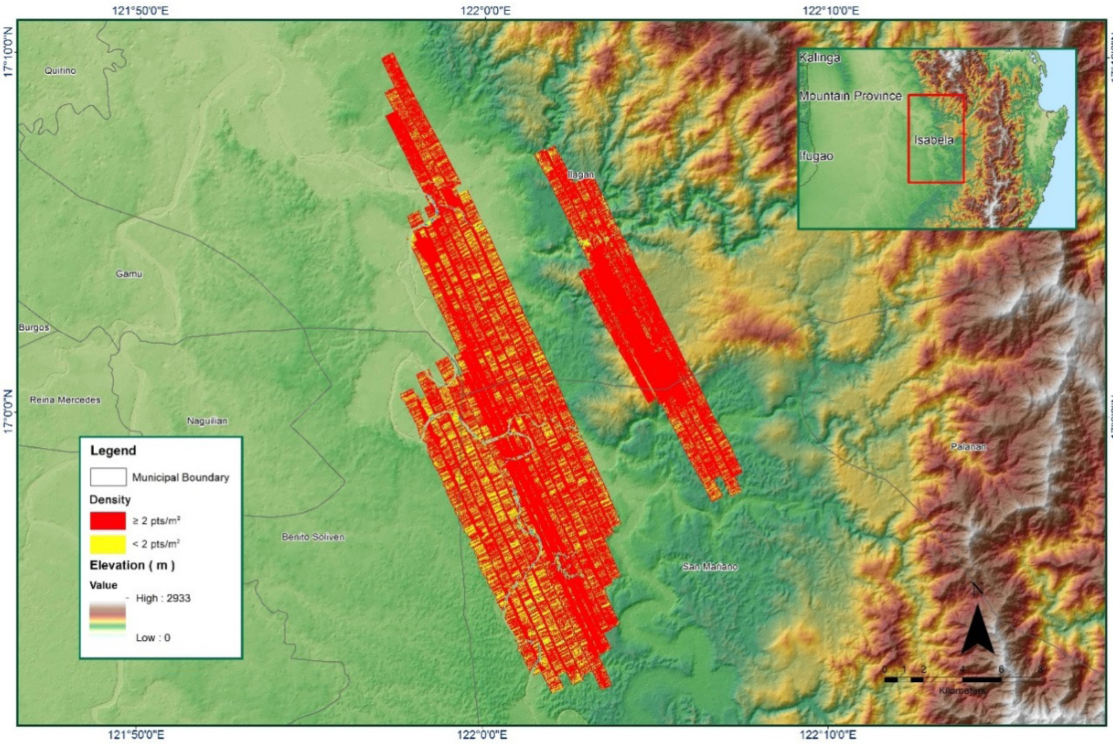


Figure A-8.48. Density map of merged LiDAR data

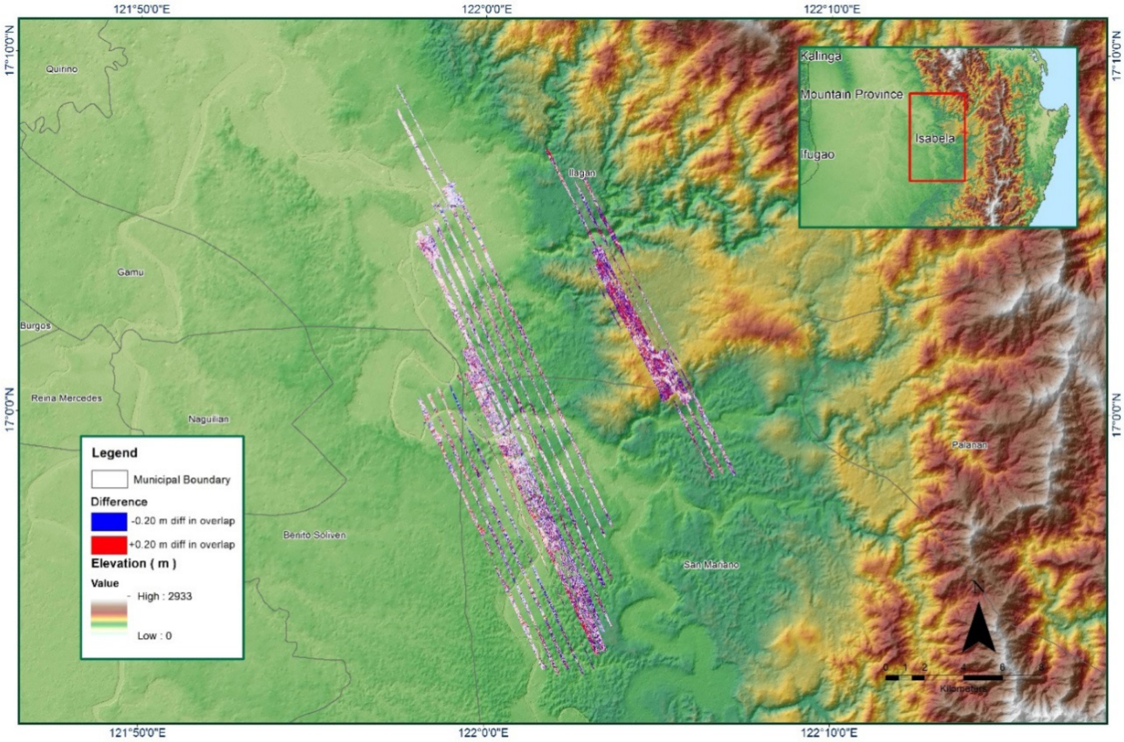


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk171P

Flight Area	Cauayan Reflights
Mission Name	Blk171P
Inclusive Flights	23728P
Range data size	8.23 GB
Base data size	34.3 MB
POS	92.8 MB
Image	NA
Transfer date	February 27, 2017
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)	1.03
RMSE for East Position (<4.0 cm)	1.10
RMSE for Down Position (<8.0 cm)	2.04
Boresight correction stdev (<0.001deg)	0.000352
IMU attitude correction stdev (<0.001deg)	0.000630
GPS position stdev (<0.01m)	0.0013
Minimum % overlap (>25)	37.11
Ave point cloud density per sq.m. (>2.0)	4.34
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	86
Maximum Height	371.67 m
Minimum Height	69.30 m
Classification (# of points)	
Ground	107,950,649
Low vegetation	80,129,947
Medium vegetation	147,500,790
High vegetation	56,637,804
Building	8,307,144
Ortophoto	No
Processed by	Engr. Irish Cortez, Engr. Harmond Santos, Engr. Gladys Mae Apat

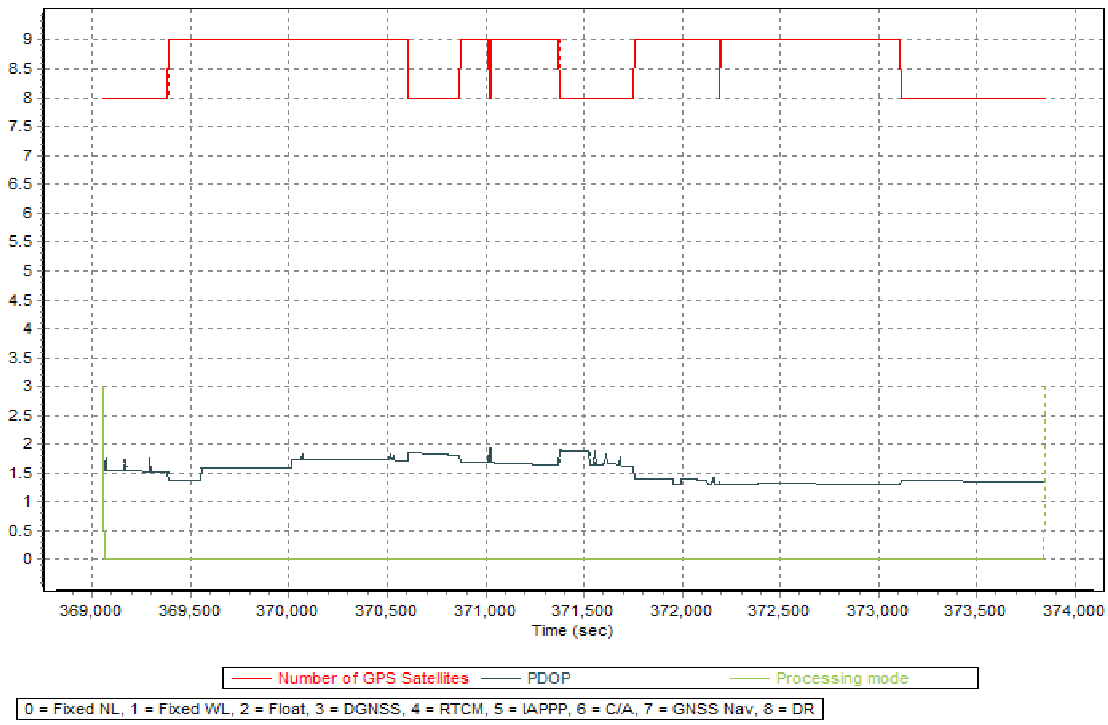


Figure A-8.50. Solution Status

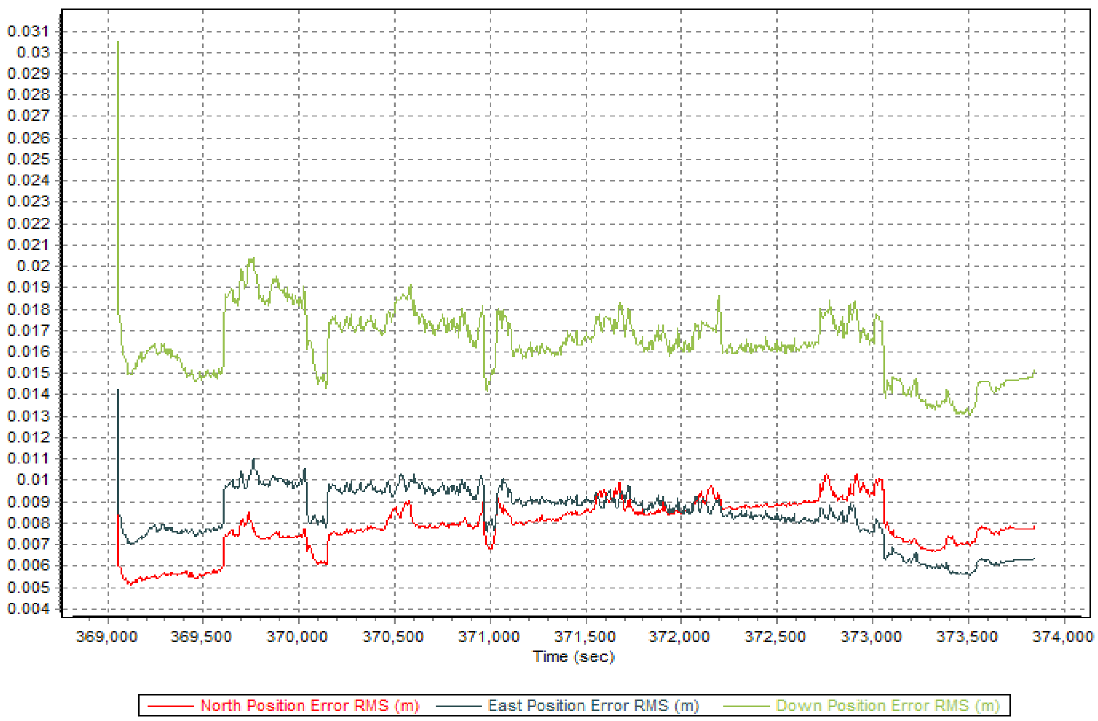


Figure A-8.51. Smoothed Performance Metrics Parameters

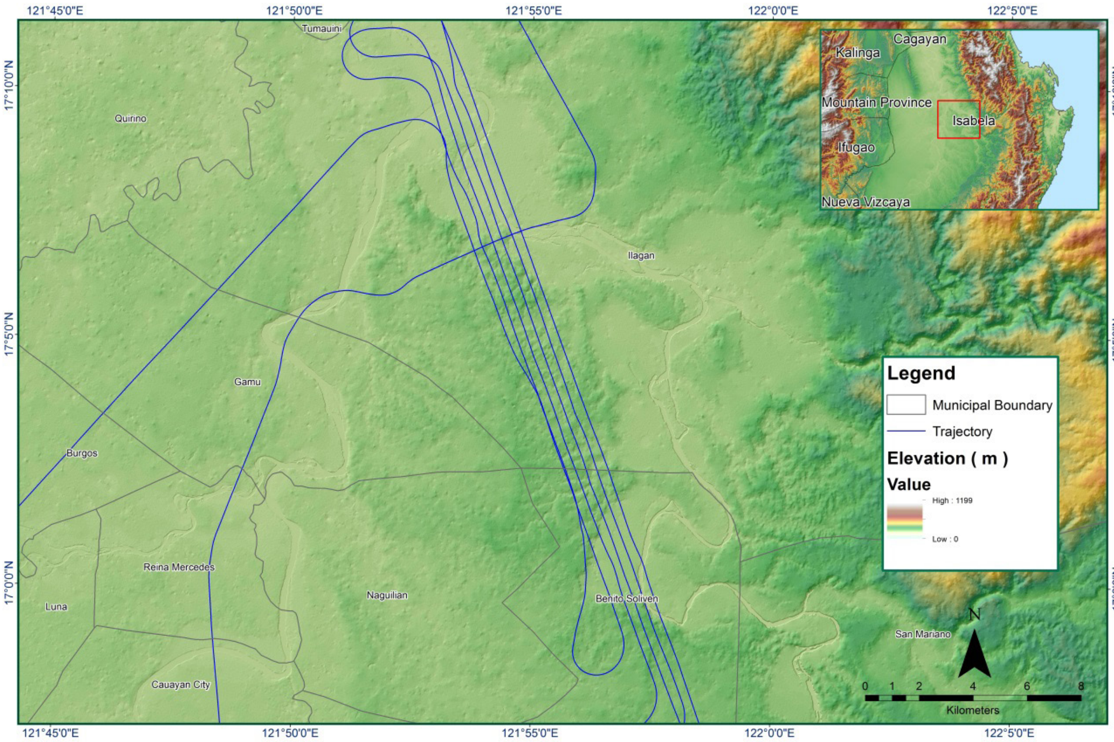


Figure A-8.52. Best Estimated Trajectory

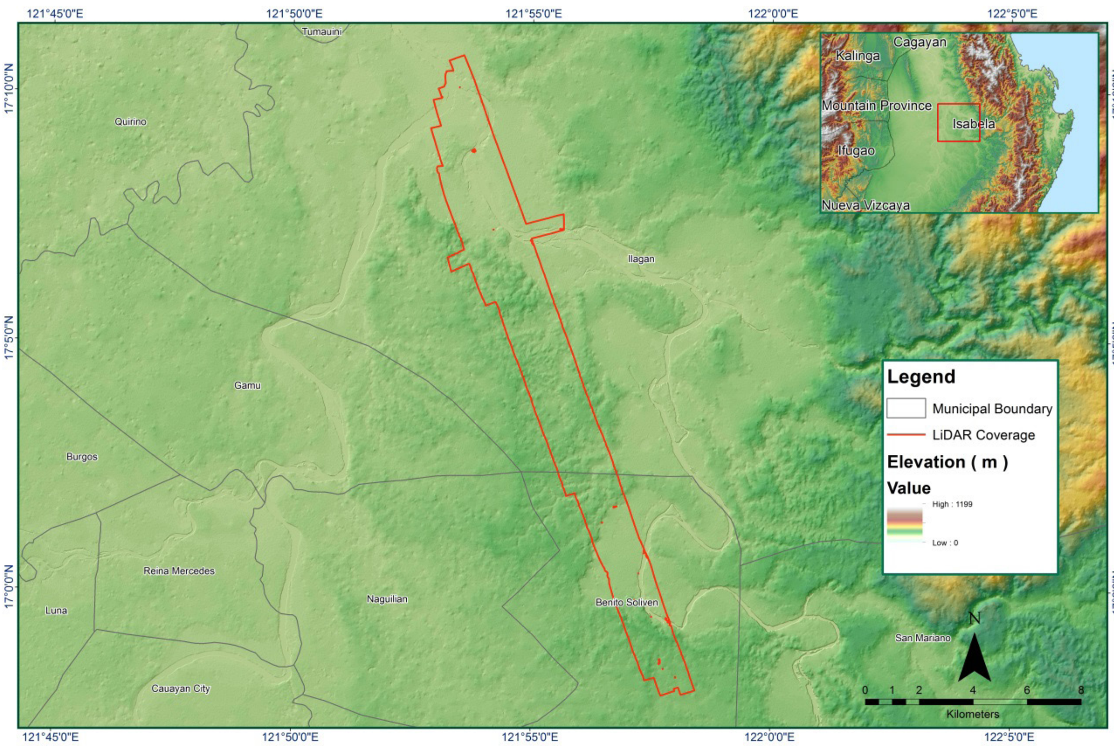


Figure A-8.53. Coverage of LiDAR data

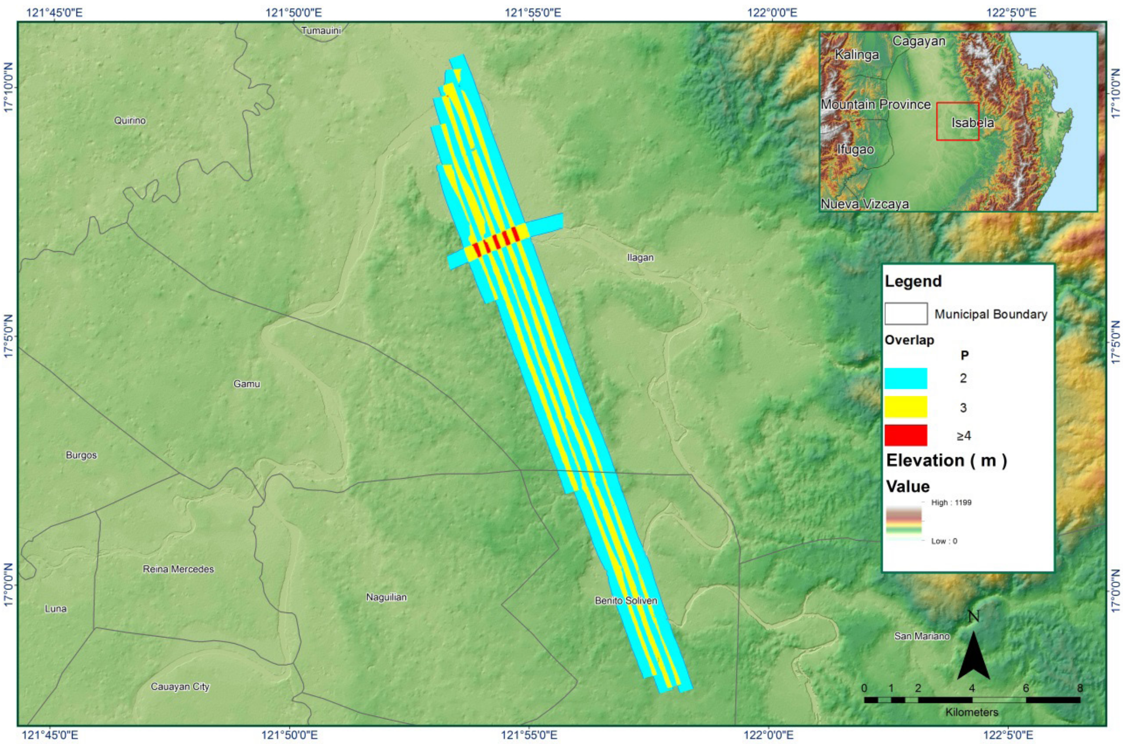


Figure A-8.54. Image of data overlap

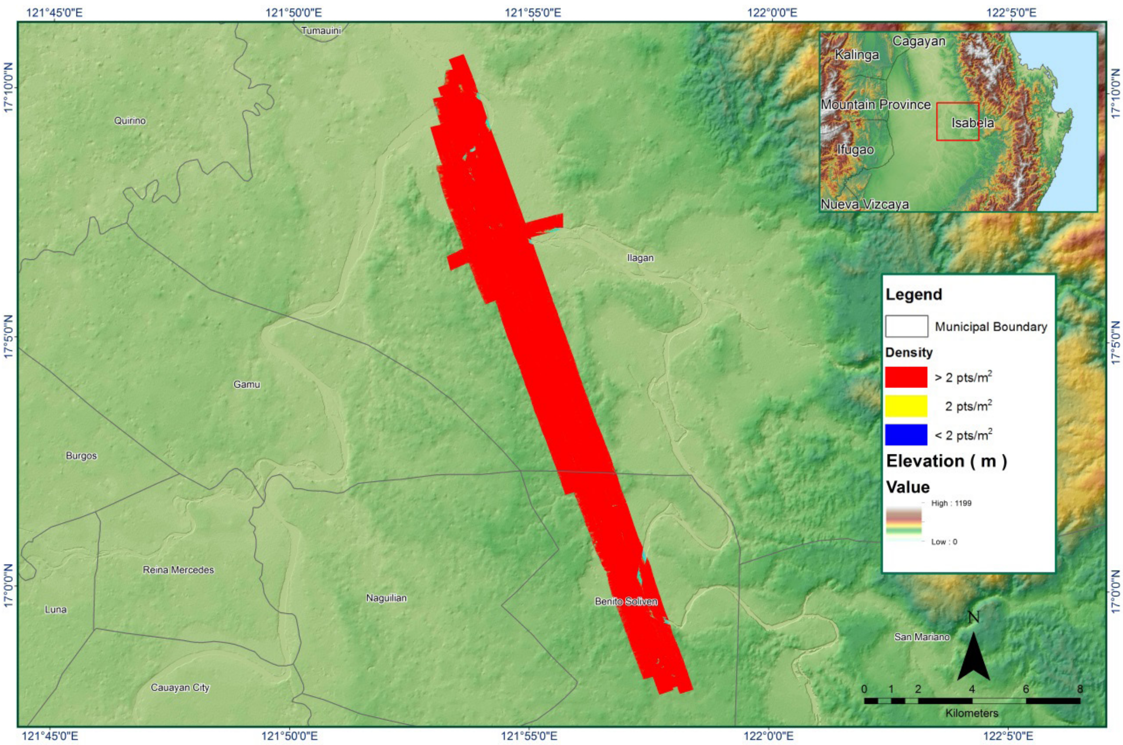


Figure A-8.55. Density map of merged LiDAR data

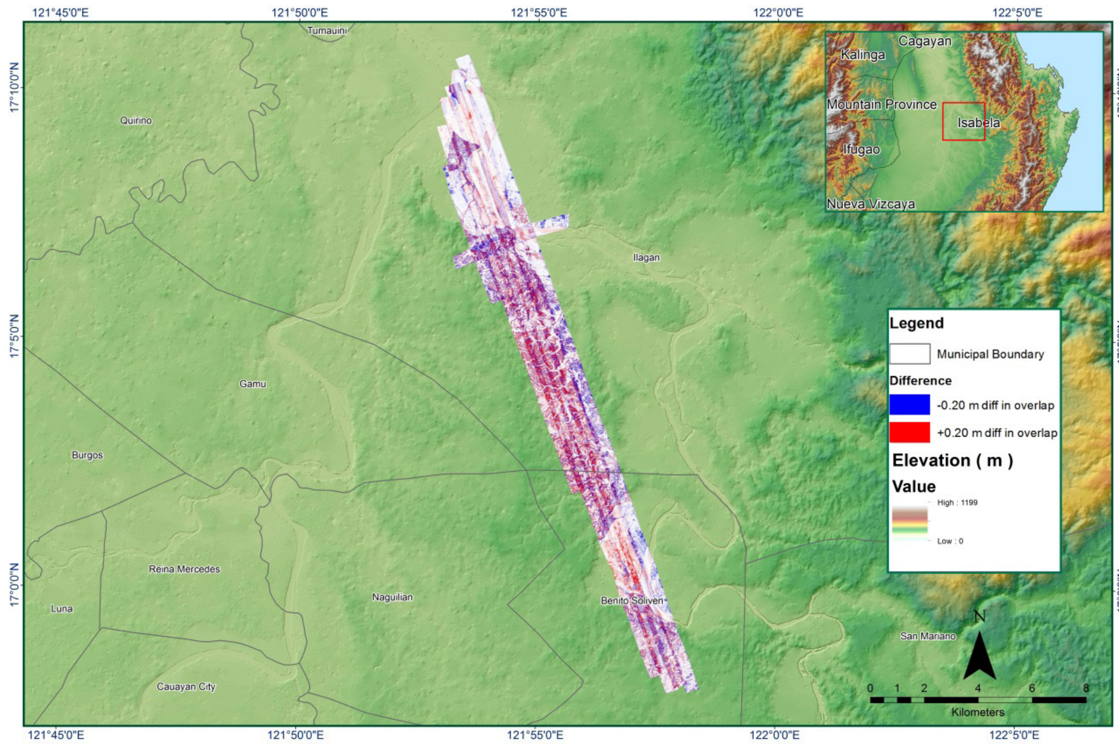


Figure A-8.56. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission Blk171Q

Flight Area	Cauayan_Reflights
Mission Name	Blk171Q
Inclusive Flights	23796P
Range data size	7.4 GB
POS	122 MB
Base data size	44.8 MB
Image	NA
Transfer date	April 7, 2017
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.45
RMSE for East Position (<4.0 cm)	1.57
RMSE for Down Position (<8.0 cm)	3.35
Boresight correction stdev (<0.001deg)	0.000141
IMU attitude correction stdev (<0.001deg)	0.001033
GPS position stdev (<0.01m)	0.0117
Minimum % overlap (>25)	24.59%
Ave point cloud density per sq.m. (>2.0)	2.23
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	144
Maximum Height	290.92 m
Minimum Height	68.33 m
Classification (# of points)	
Ground	94587143
Low vegetation	57222816
Medium vegetation	120057041
High vegetation	44217933
Building	2908800
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Gladys Mae Apat

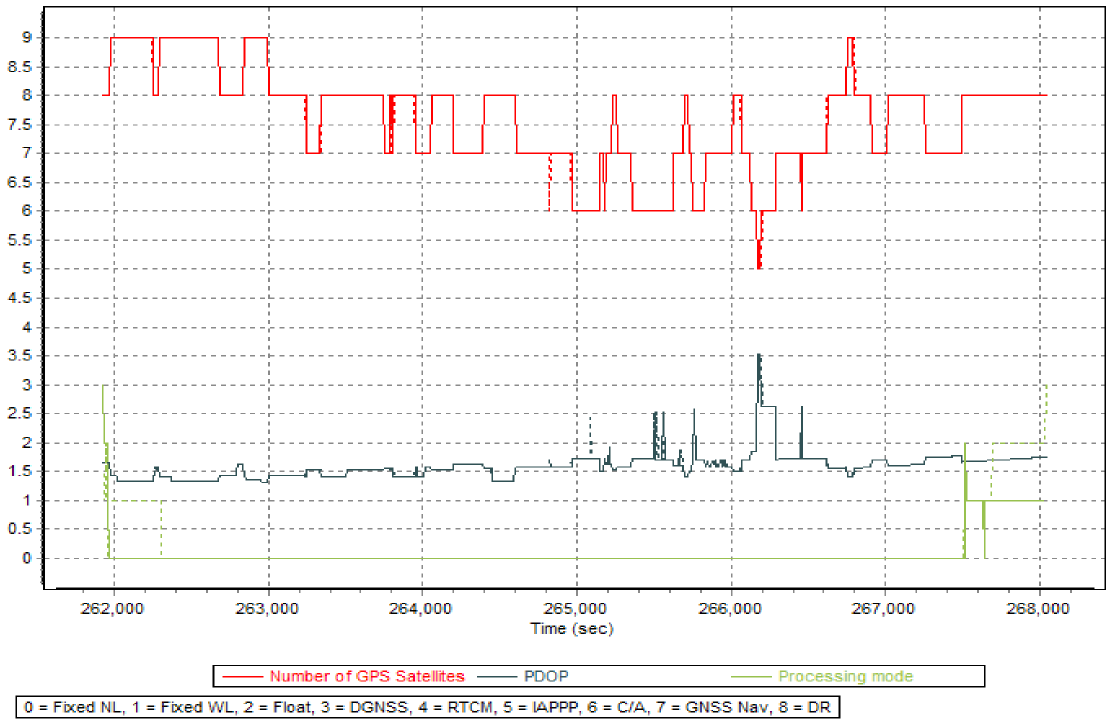


Figure A-8.57. Solution Status

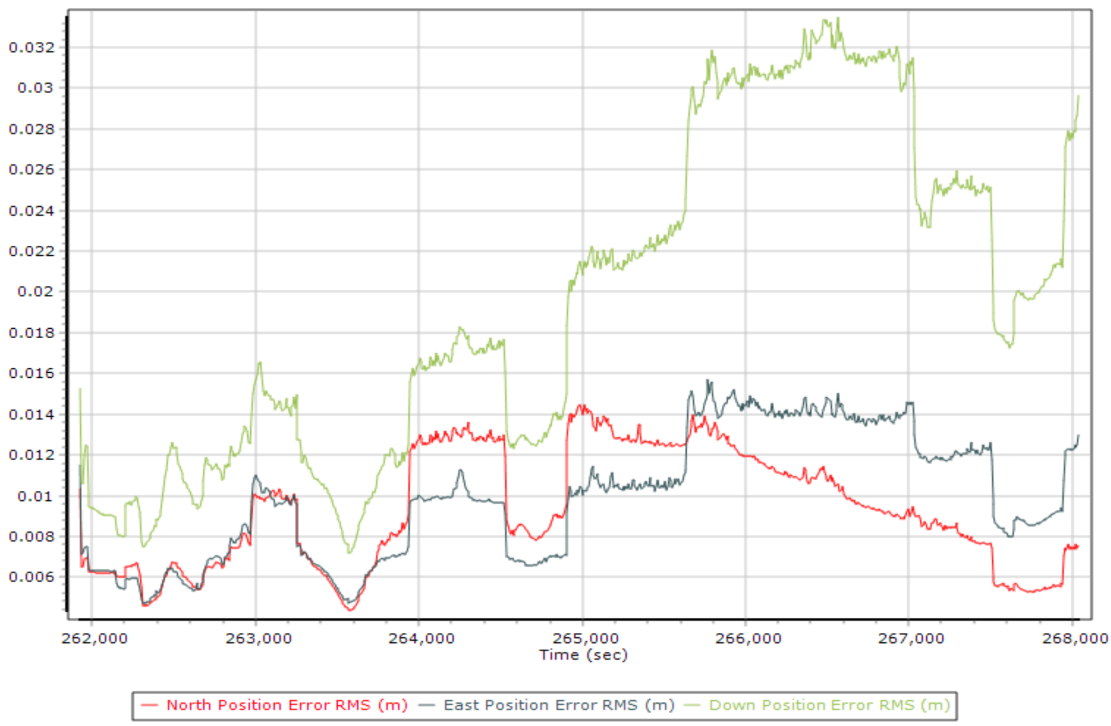


Figure A-8.58. Smoothed Performance Metric Parameters

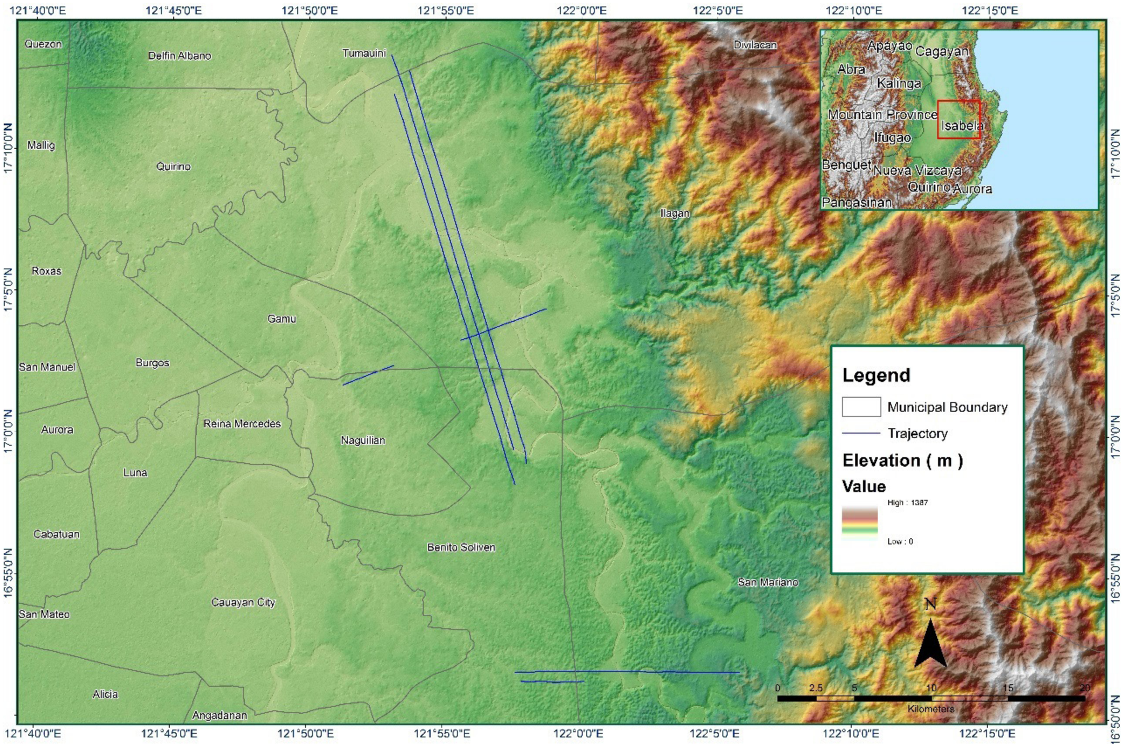


Figure A-8.59. Best Estimated Trajectory

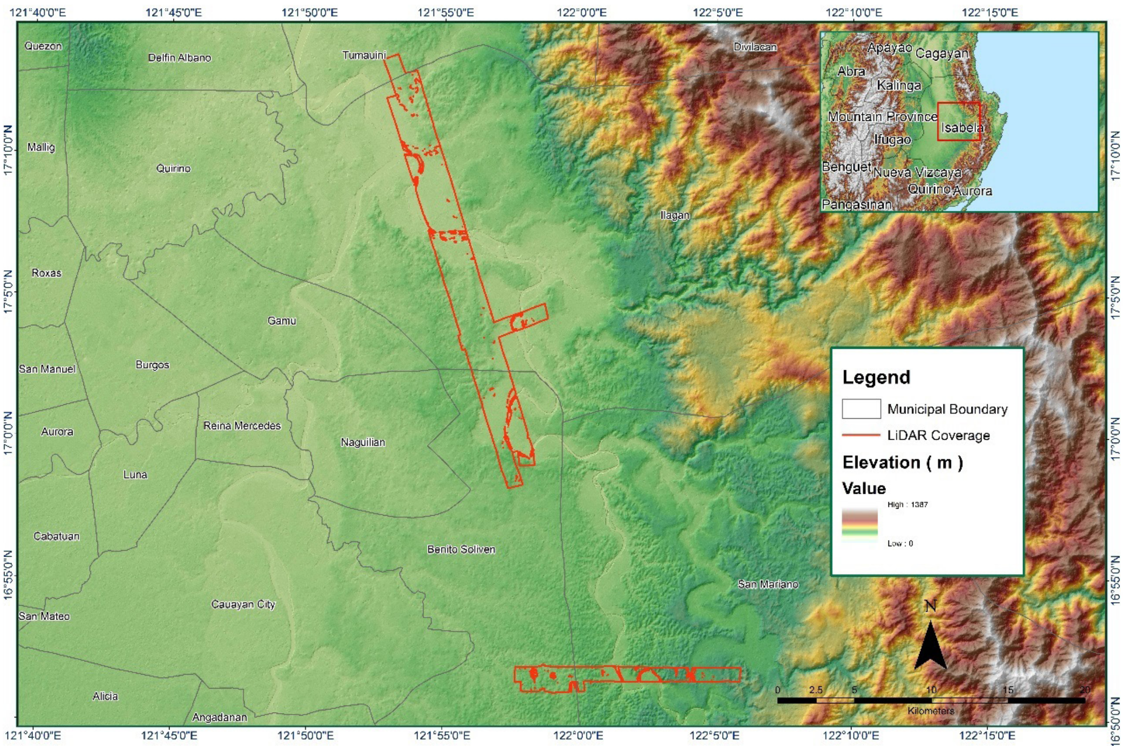


Figure A-8.60. Coverage of LiDAR Data

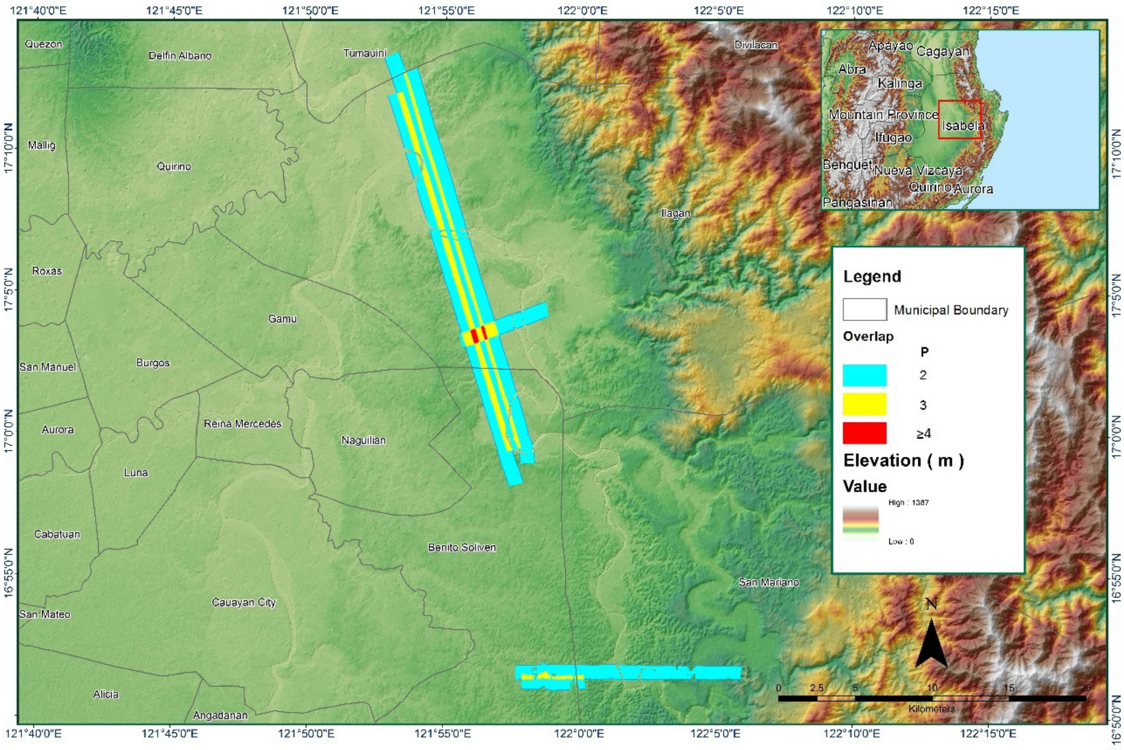


Figure A-8.61. Image of data overla

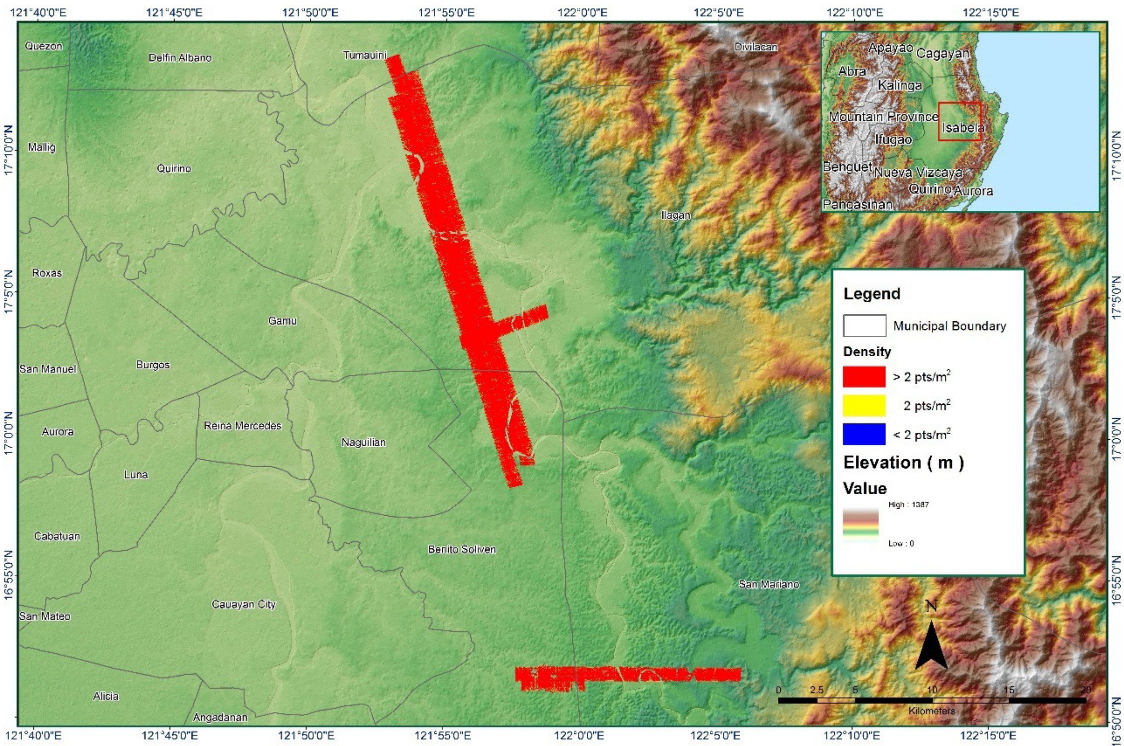


Figure A-8.62**. Density map of merged LiDAR data**

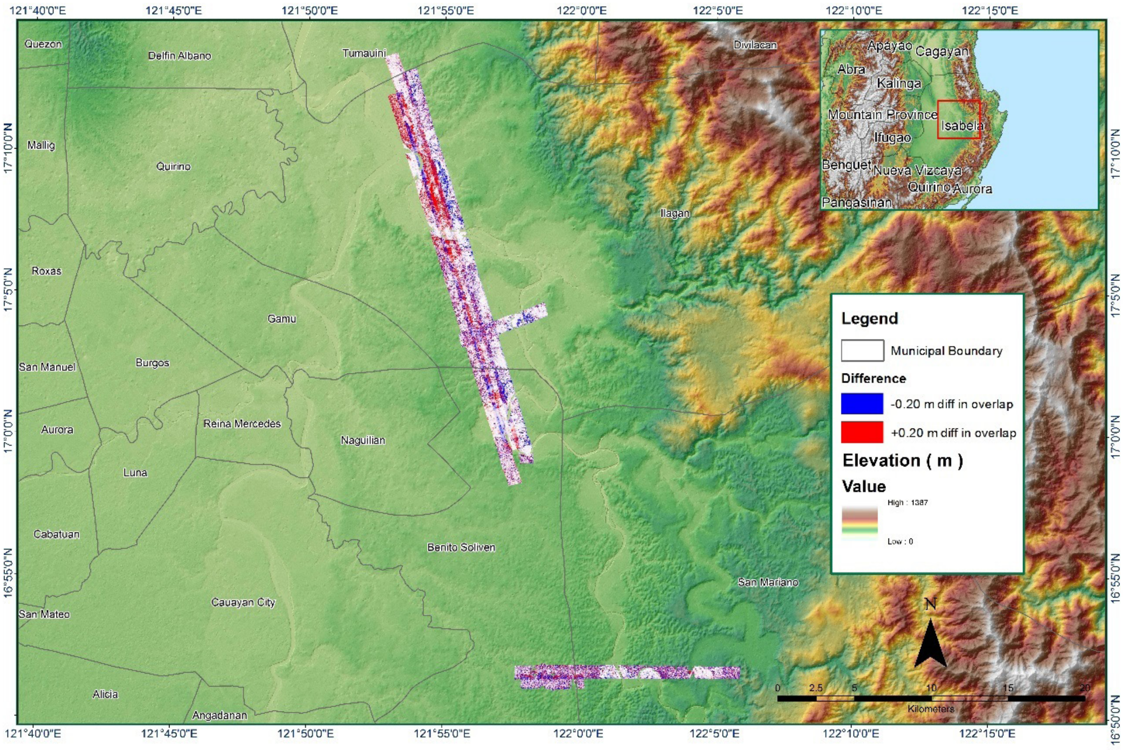


Figure A-8.63. Elevation difference between flight lines

Table A-8.10. Mission Summary Report for Mission Blk9A

Flight Area	Palanan
Mission Name	Blk 9A
Inclusive Flights	2690G, 2702G
Range data size	36.3 GB
POS	384 MB
Image	54.41 GB
Transfer date	10/5/15
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)	2.3
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.5
Boresight correction stdev (<0.001deg)	0.000173
IMU attitude correction stdev (<0.001deg)	0.049046
GPS position stdev (<0.01m)	-
Minimum % overlap (>25)	71.78%
Ave point cloud density per sq.m. (>2.0)	5.54
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	155
Maximum Height	534.83 m
Minimum Height	54.43 m
Classification (# of points)	
Ground	33,821,718
Low vegetation	24,079,115
Medium vegetation	85,089,427
High vegetation	577,986,986
Building	2,074,659
Orthophoto	Yes
Processed by	Engr. Sheila Maye Santilan, Engr. Chelou Prado, Engr. Ma. Ailyn Olanda

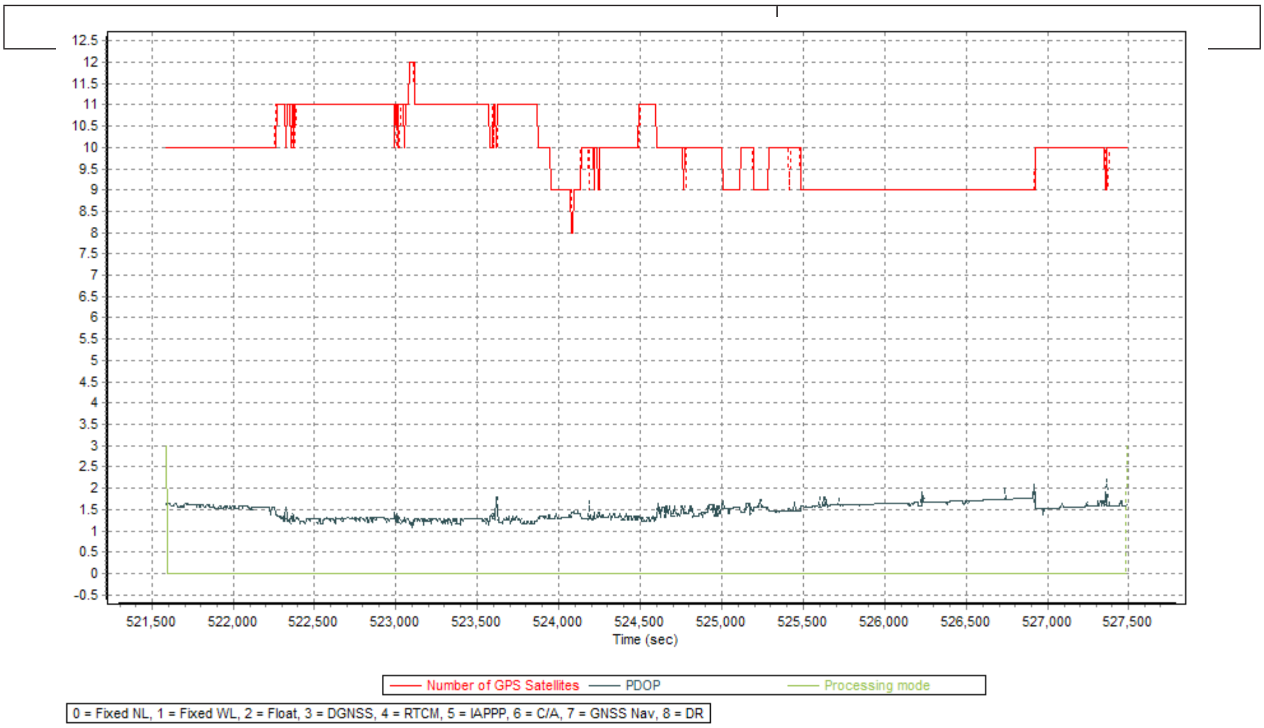


Figure A-8.64. Solution Status

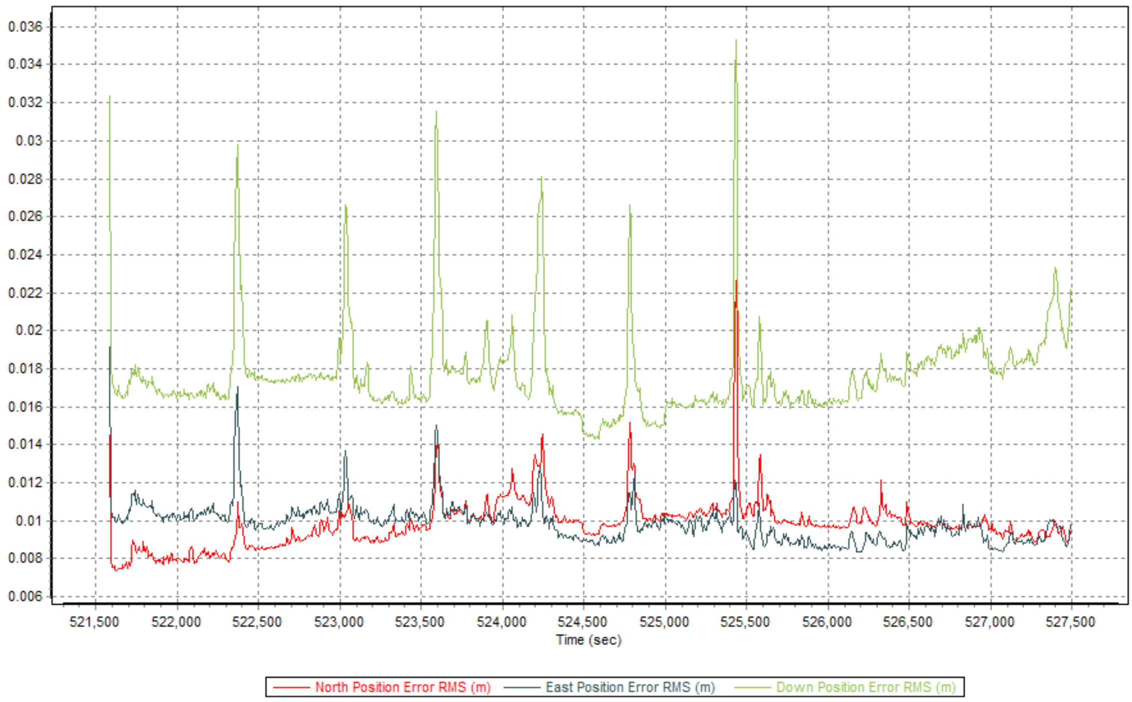


Figure A-8.65. Smoothed Performance Metrics Parameters

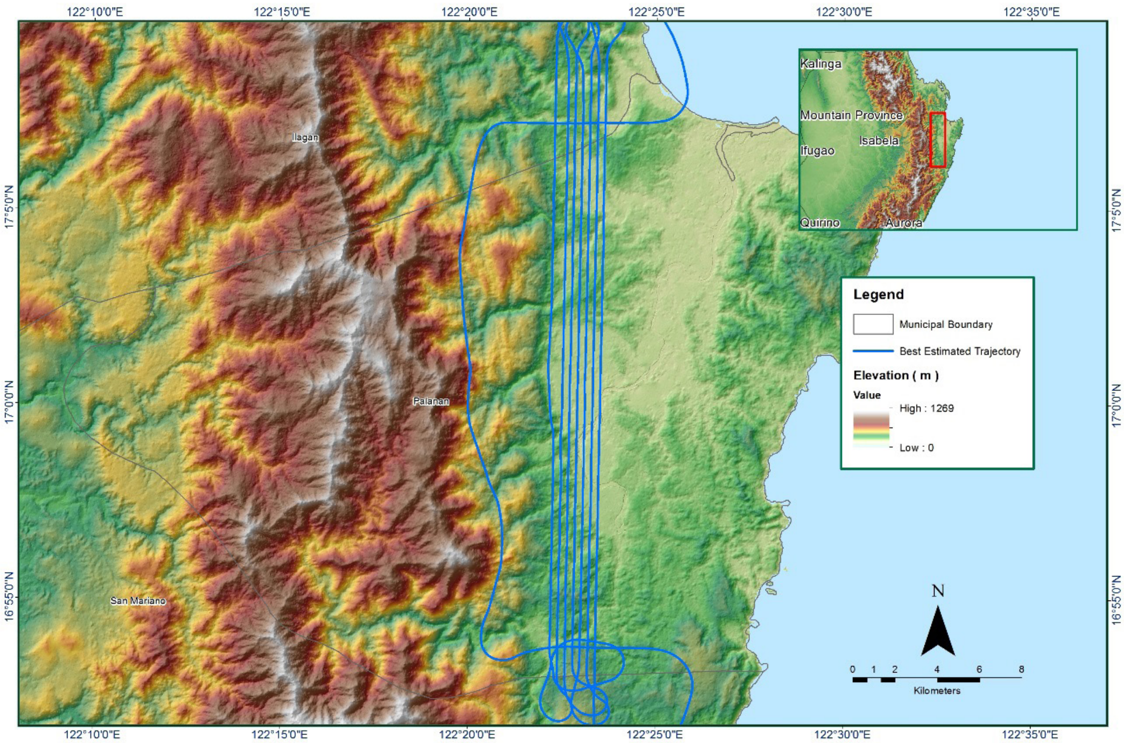


Figure A-8.66. Best Estimated Trajectory

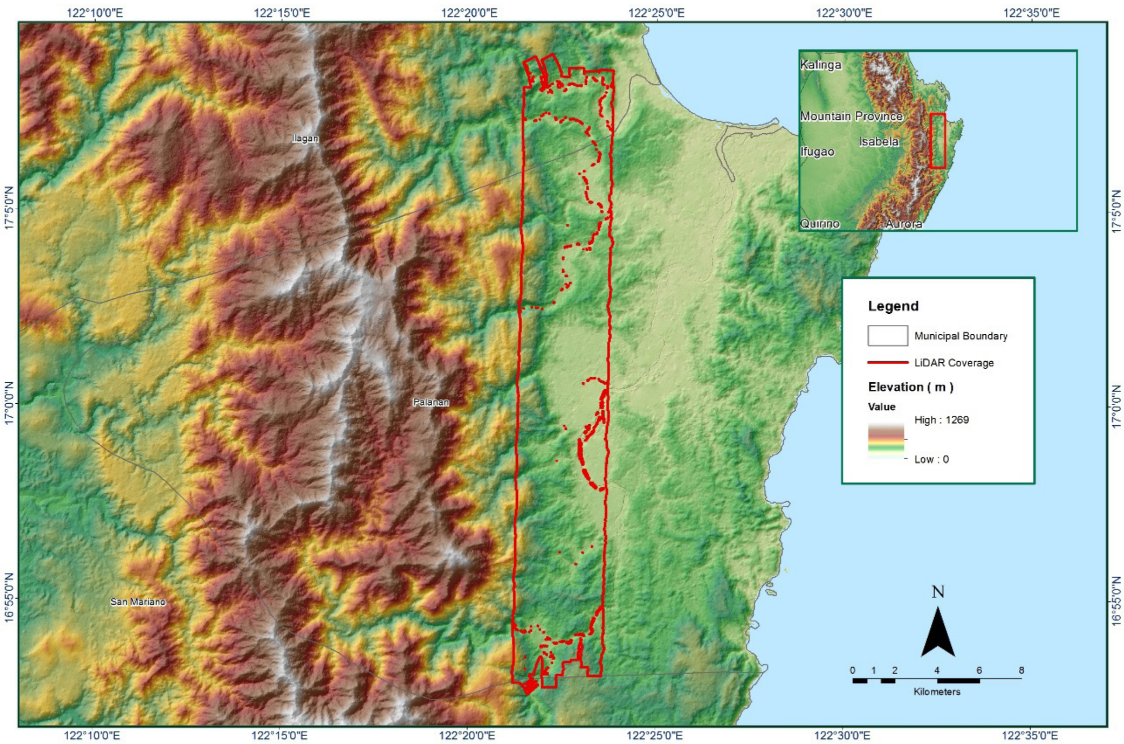


Figure A-8.67. Coverage of LiDAR data

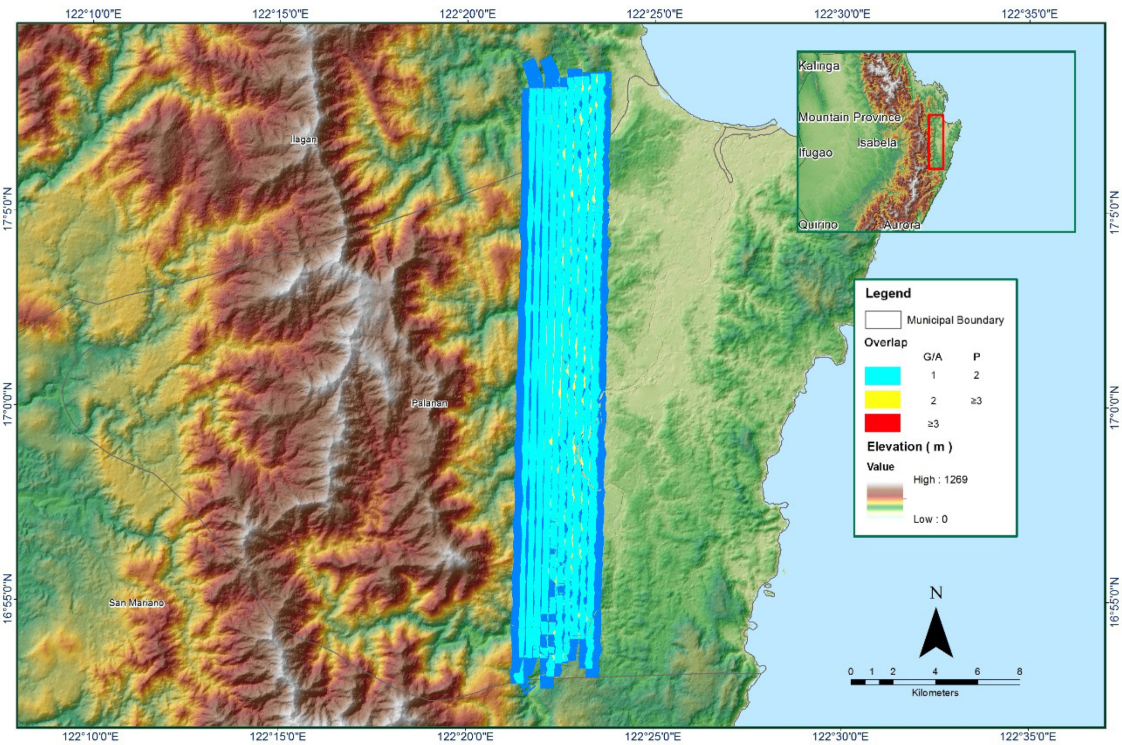


Figure A-8.68. Image of data overlap

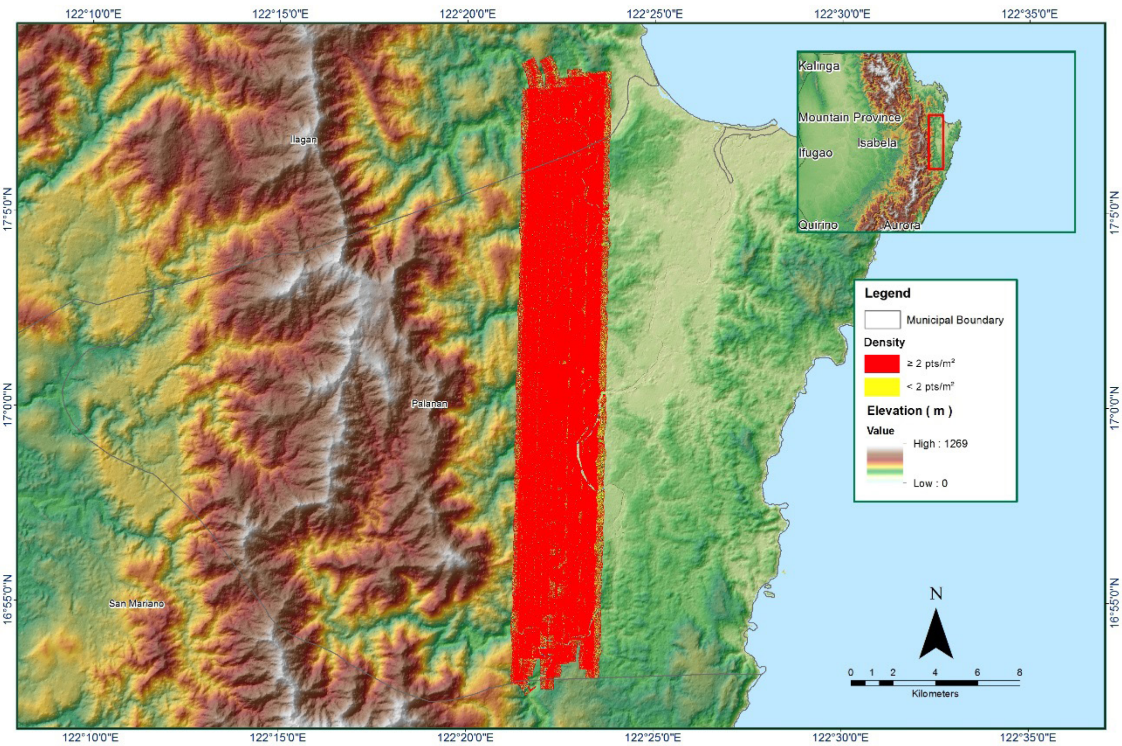


Figure A-8.69. Density map of merged LiDAR data

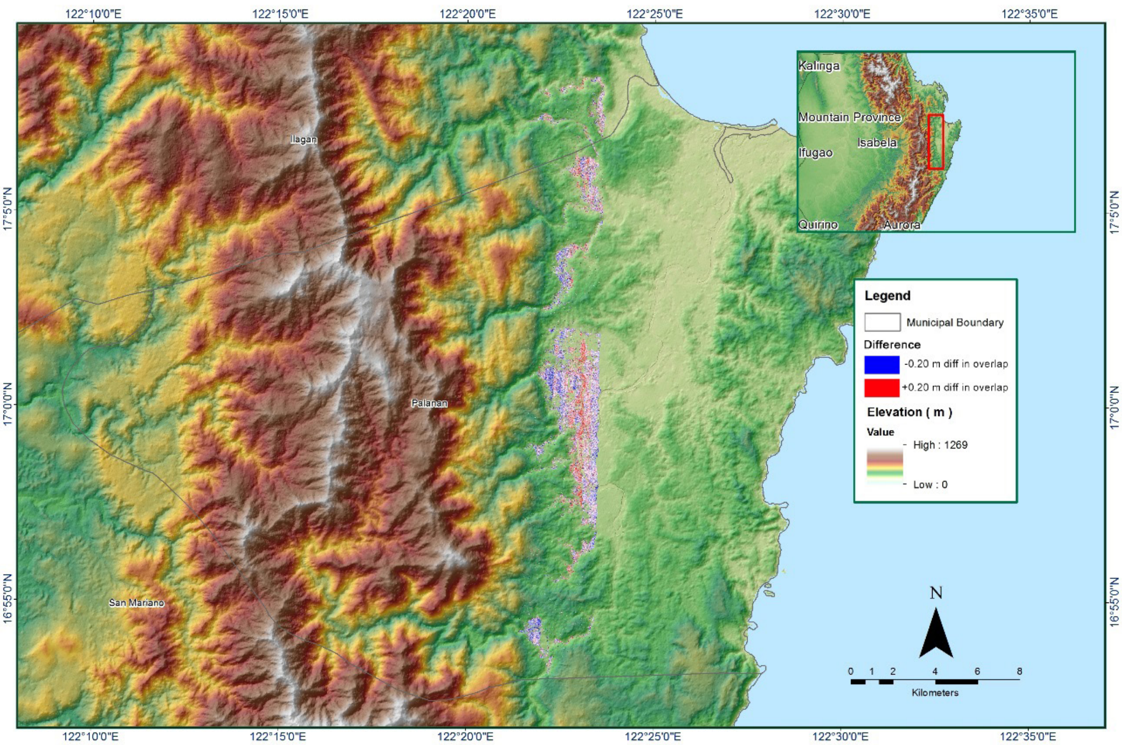


Figure A-8.70. Elevation difference between flight lines

Table A-8.11. Mission Summary Report for Mission CGYR H

Flight Area	Palanan
Mission Name	CGYR H
Inclusive Flights	2700G
Range data size	12.5 GB
POS	149 MB
Image	23.7 GB
Transfer date	10/5/15
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	0.9
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	0.000010
IMU attitude correction stdev (<0.001deg)	0.002749
GPS position stdev (<0.01m)	0.0019
Minimum % overlap (>25)	24.70%
Ave point cloud density per sq.m. (>2.0)	3.91
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	104
Maximum Height	168.07 m
Minimum Height	64.78 m
Classification (# of points)	
Ground	24,197,645
Low vegetation	26,214,503
Medium vegetation	129,971,249
High vegetation	19,553,285
Building	69,781
Orthophoto	Yes
Processed by	Engr. Sheila Maye Santillan, Engr. Melanie Hingpit, Jovy Narisma

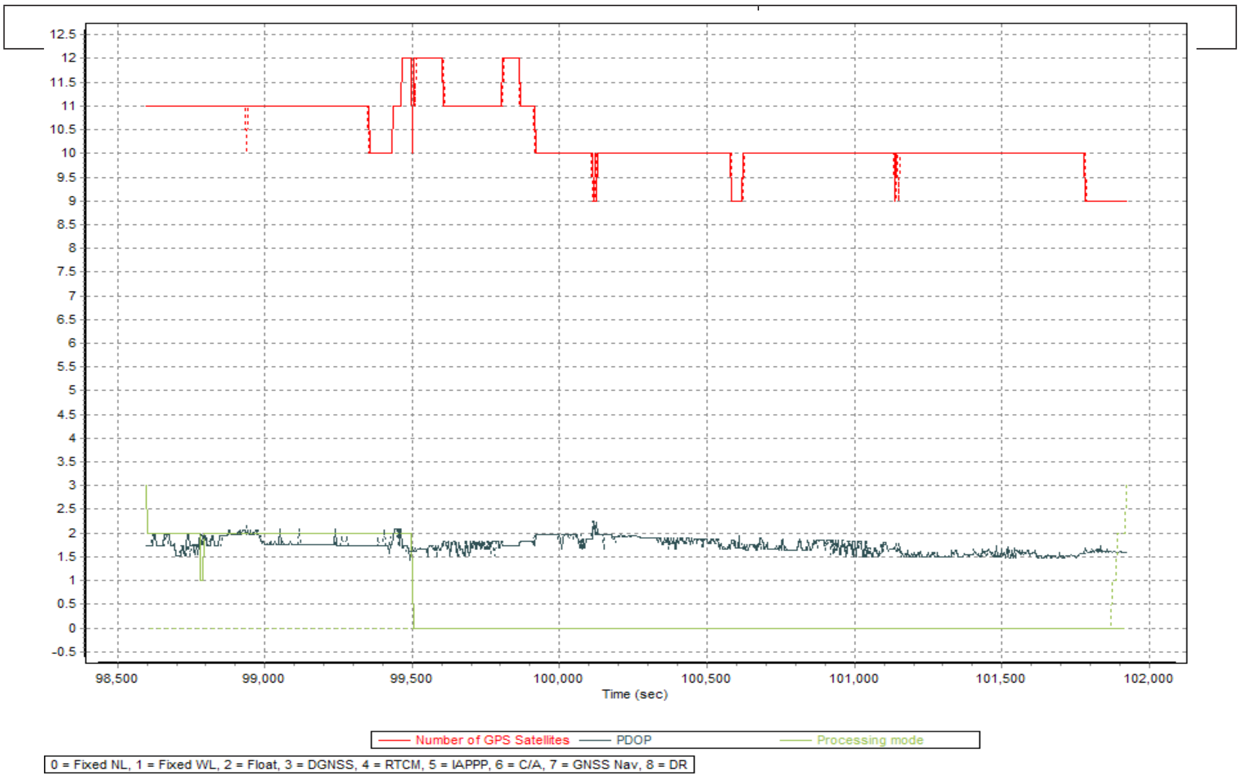


Figure A-8.71. Solution Status

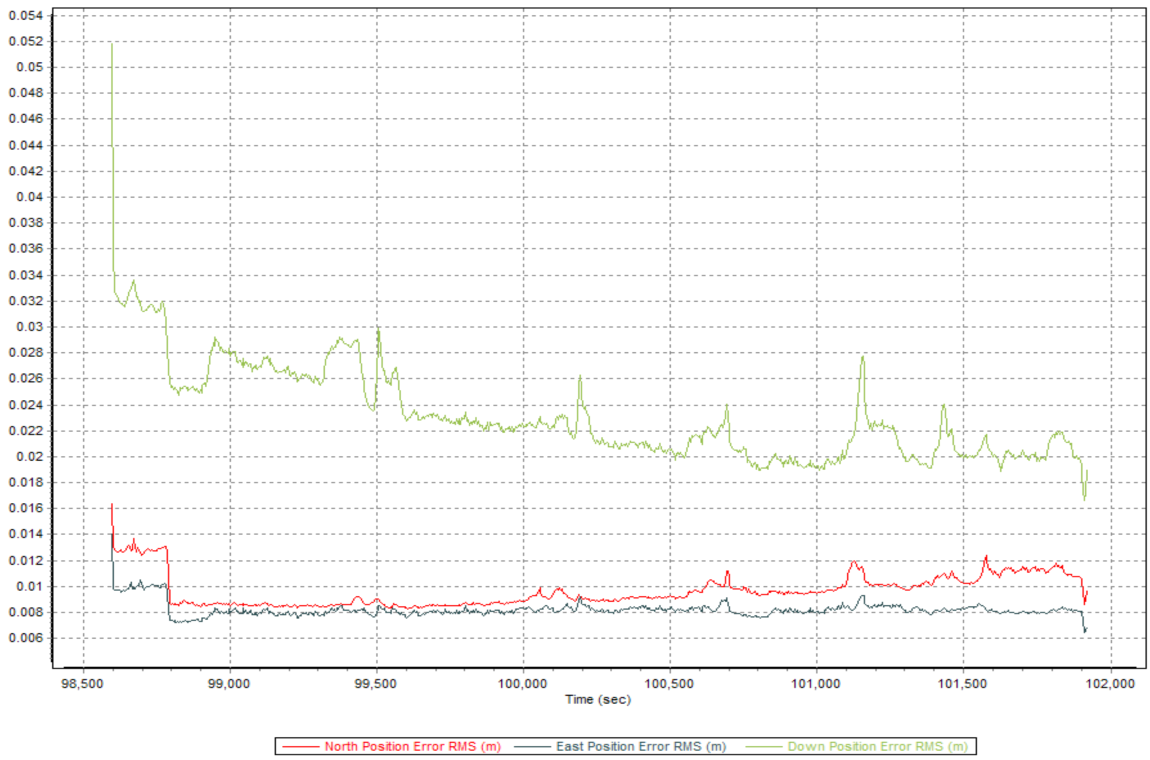


Figure A-8.72. Smoothed Performance Metrics Parameters

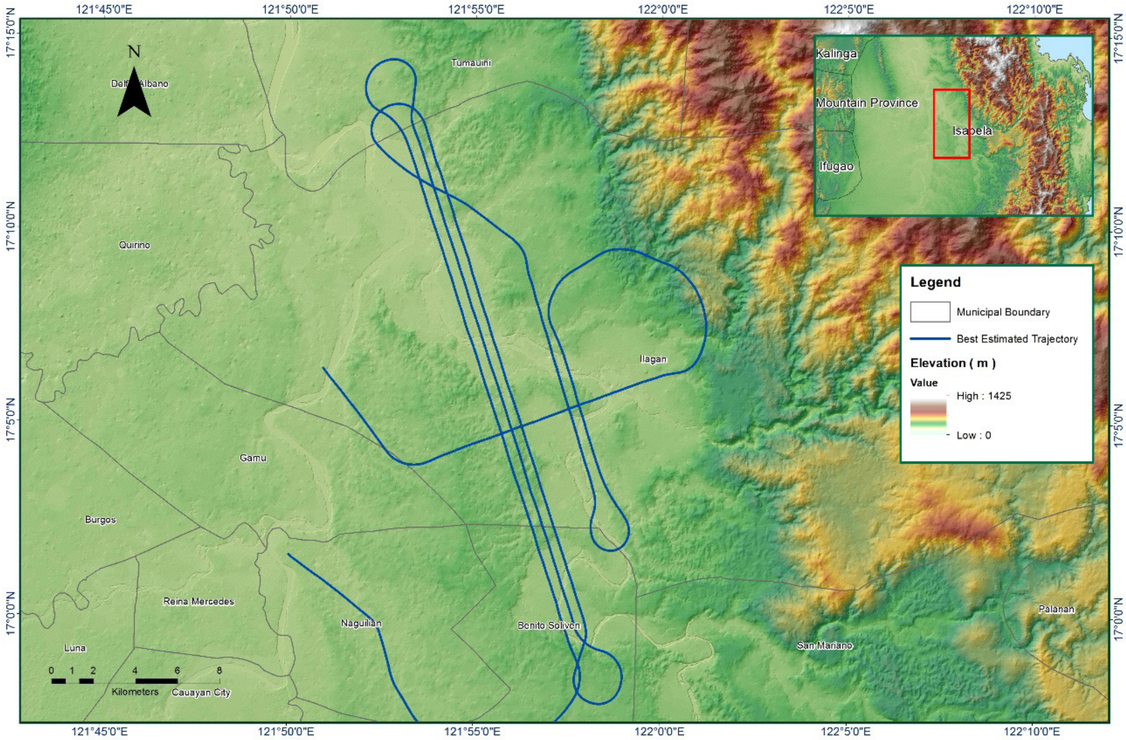


Figure A-8.73. Best Estimated Trajectory

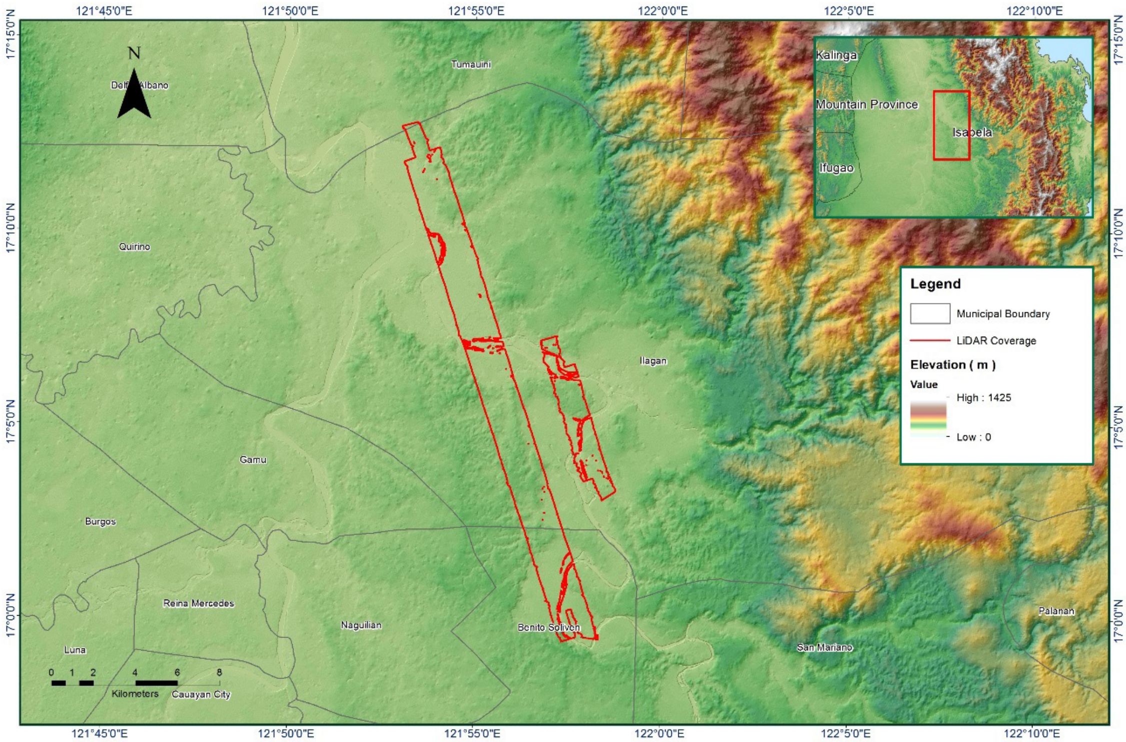


Figure A-8.74. Coverage of LiDAR data

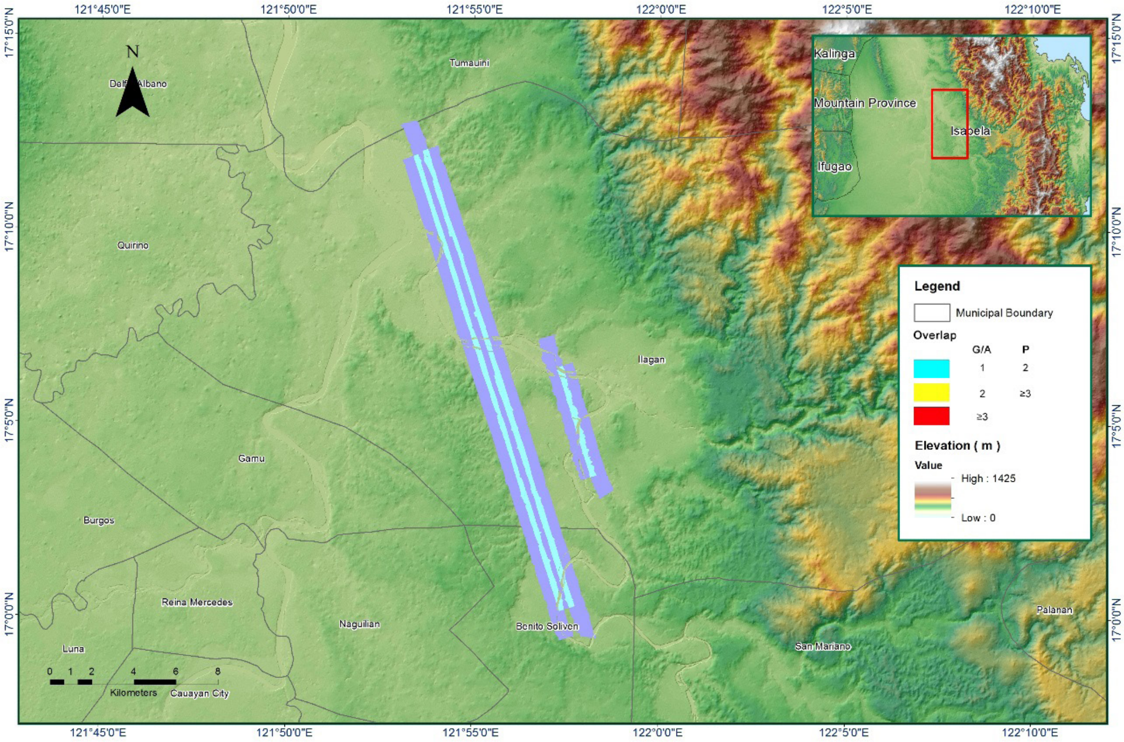


Figure A-8.75. Image of data overlap

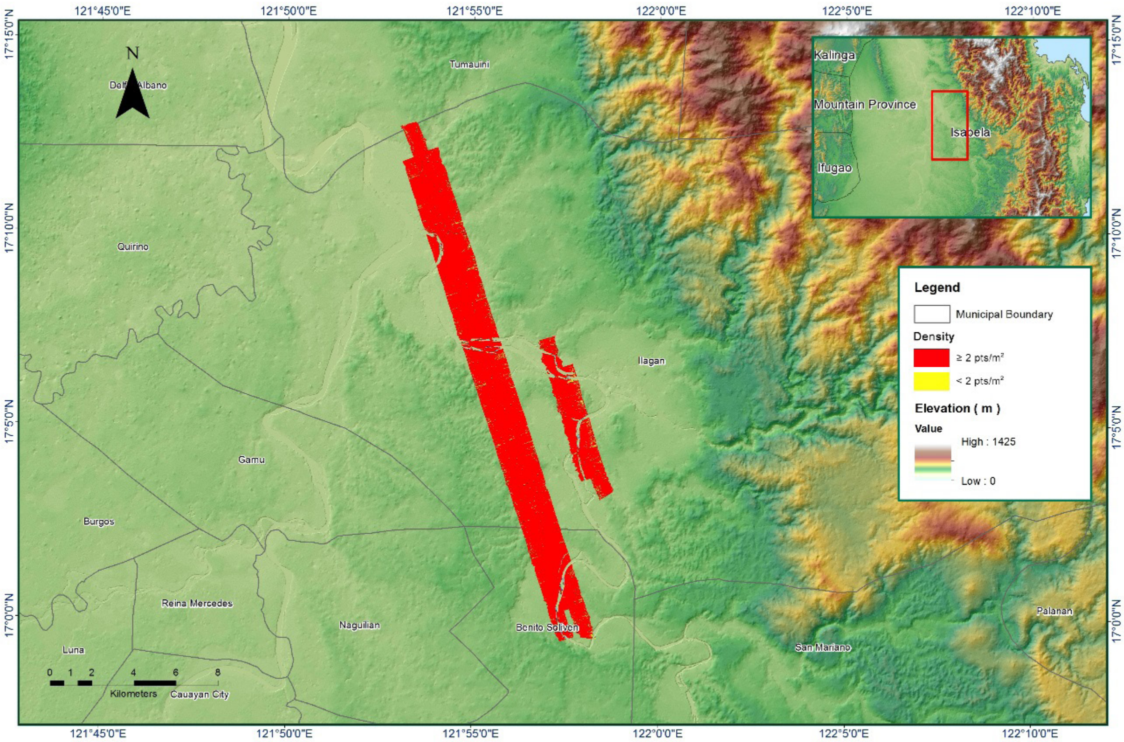


Figure A-8.76. Density map of merged LiDAR data

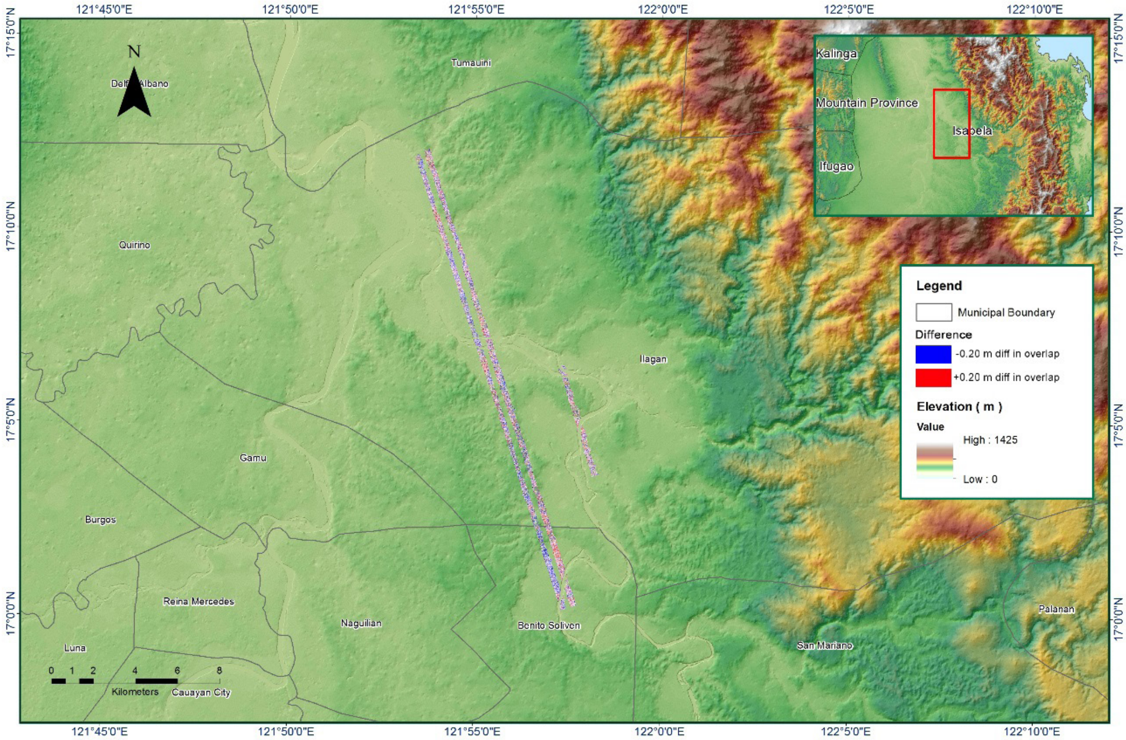


Figure A-8.77. Elevation difference between flight lines

Table A-8.12. Mission Summary Report for Mission CGYR G

Flight Area	Palanan
Mission Name	CGYR G
Inclusive Flights	2728G, 2730G
Range data size	28.5 GB
POS	319 MB
Image	52.5 GB
Transfer date	10/5/15
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)	1.4
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000012
IMU attitude correction stdev (<0.001deg)	0.001879
GPS position stdev (<0.01m)	0.0136
Minimum % overlap (>25)	45.76%
Ave point cloud density per sq.m. (>2.0)	5.43
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	123
Maximum Height	286.26 m
Minimum Height	79.45 m
Classification (# of points)	
Ground	88,280,475
Low vegetation	120,396,708
Medium vegetation	223,955,820
High vegetation	22,470,885
Building	2,354,457
Orthophoto	Yes
Processed by	Engr. Analayn Naldo, Engr. Jennifer Saguran, Engr. Merven Matthew Natino, Kathryn Claudyn Zarate

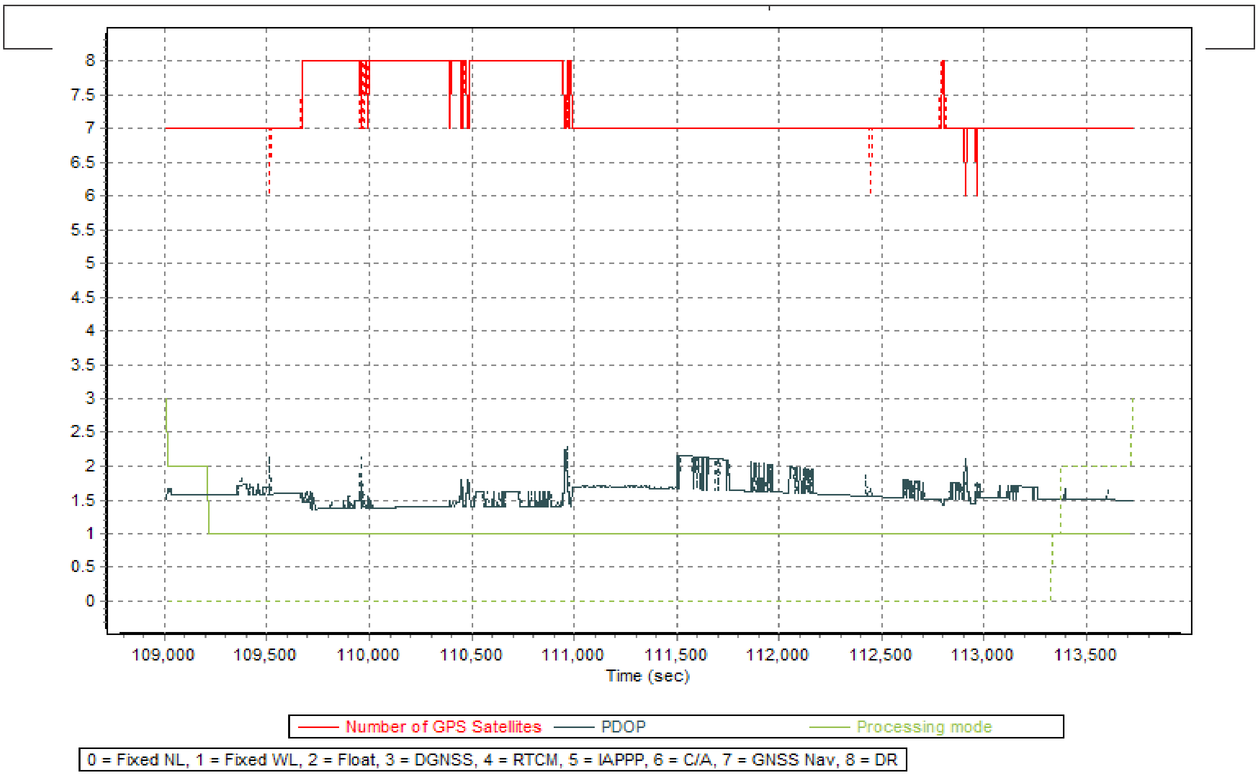


Figure A-8.78. Solution Status

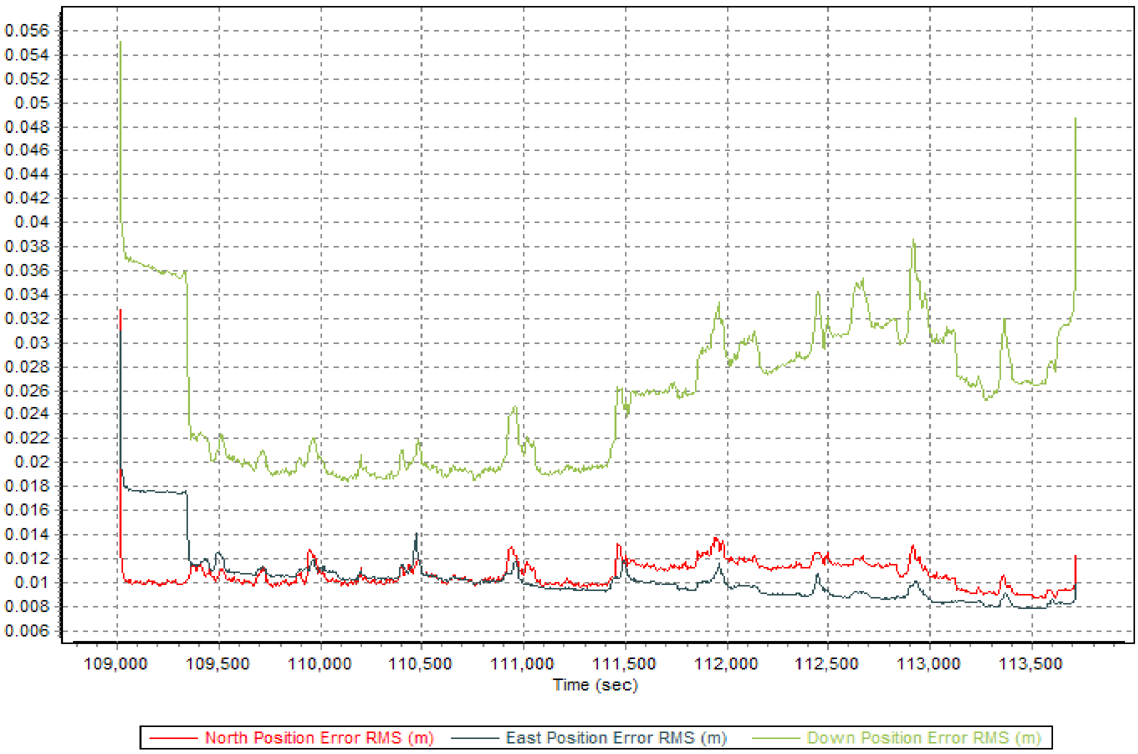


Figure A-8.79. Smoothed Performance Metrics Parameters

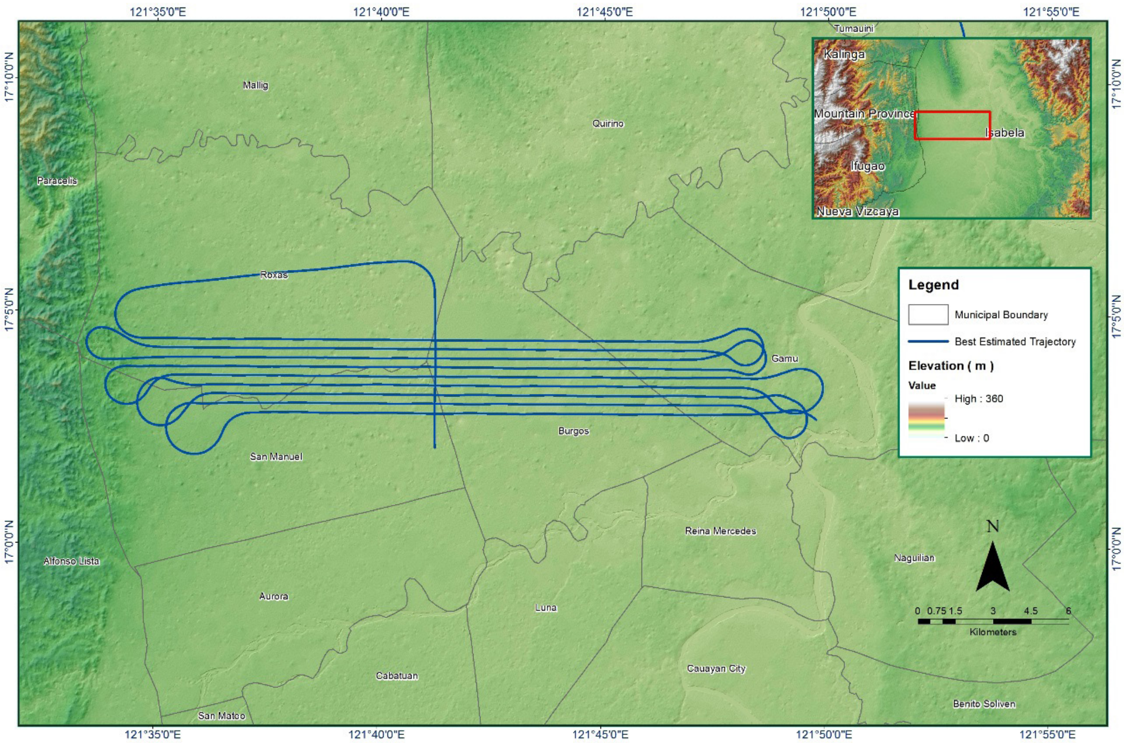


Figure A-8.80. Best Estimated Trajectory

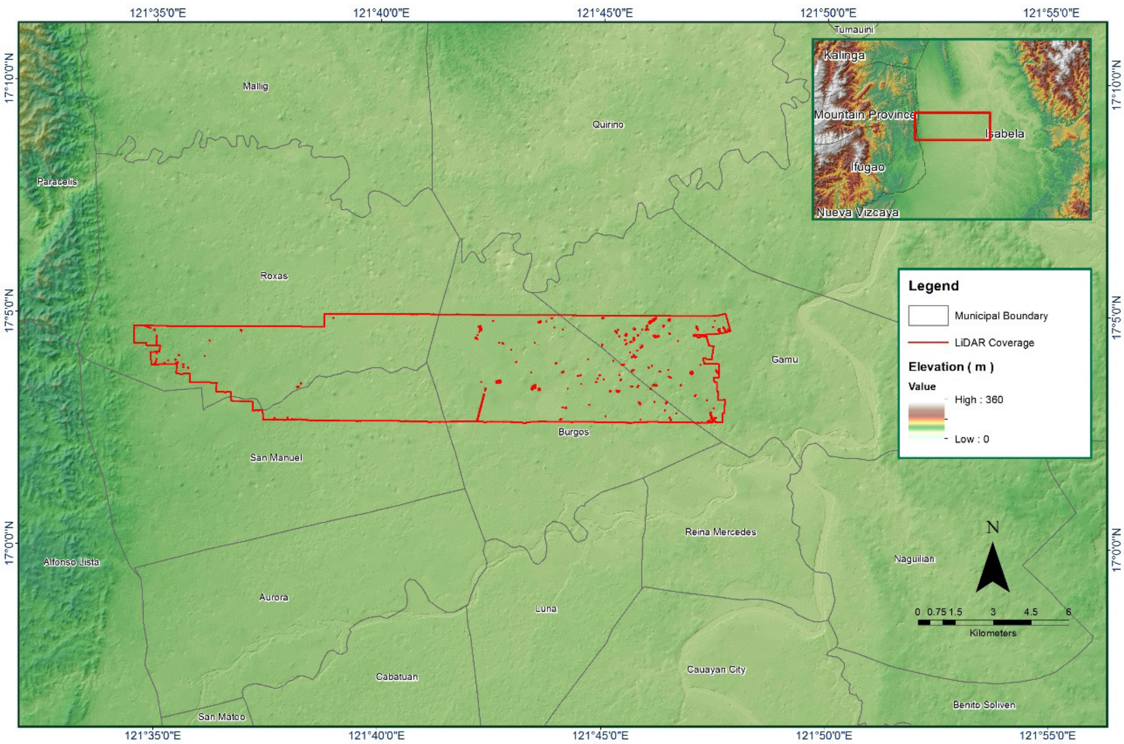


Figure A-8.81. Coverage of LiDAR data

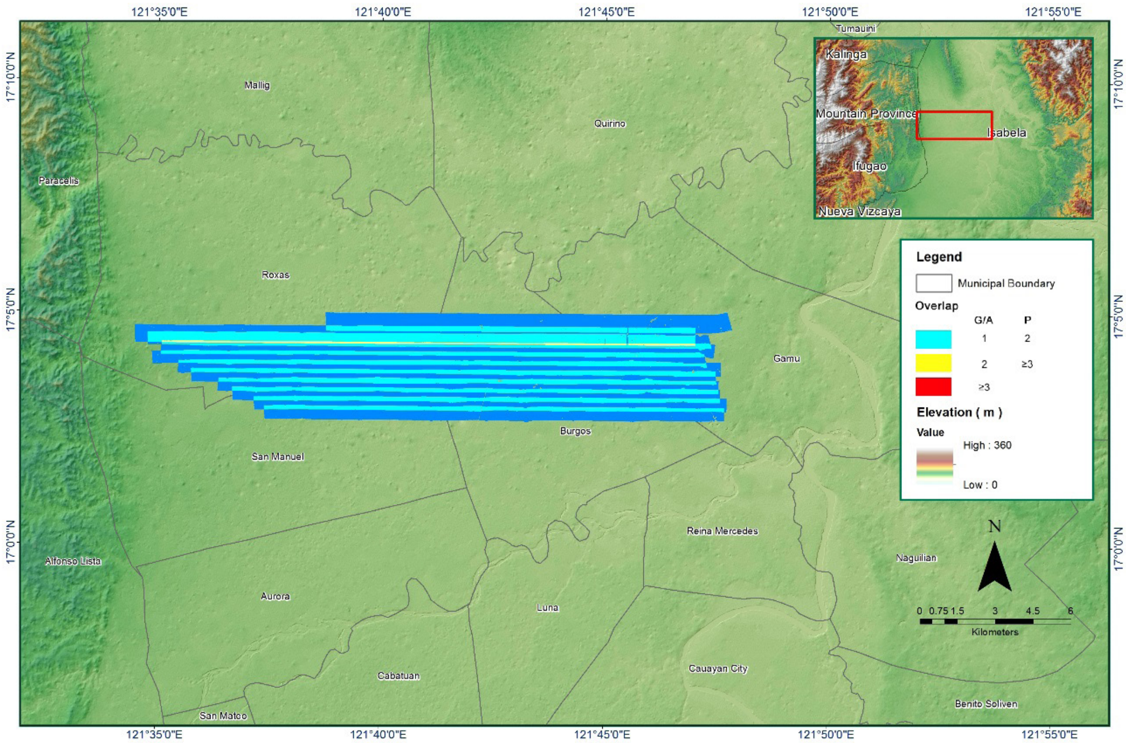


Figure A-8.82. Image of data overlap

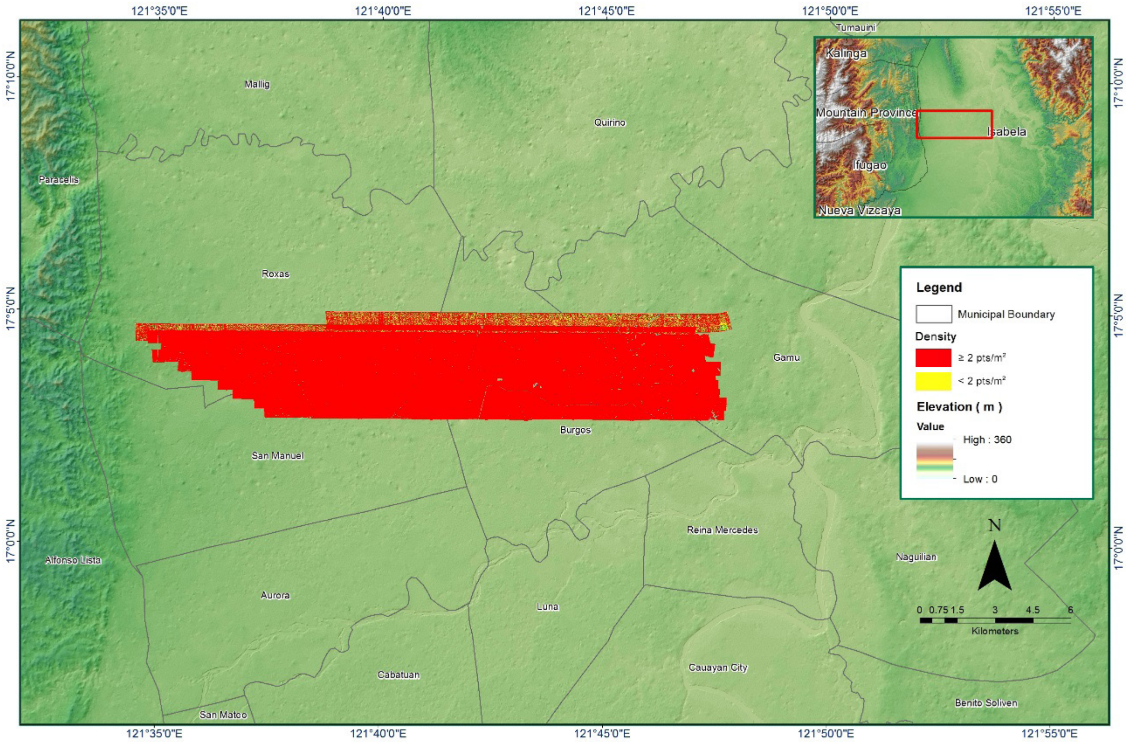


Figure A-8.83. Density map of merged LiDAR data

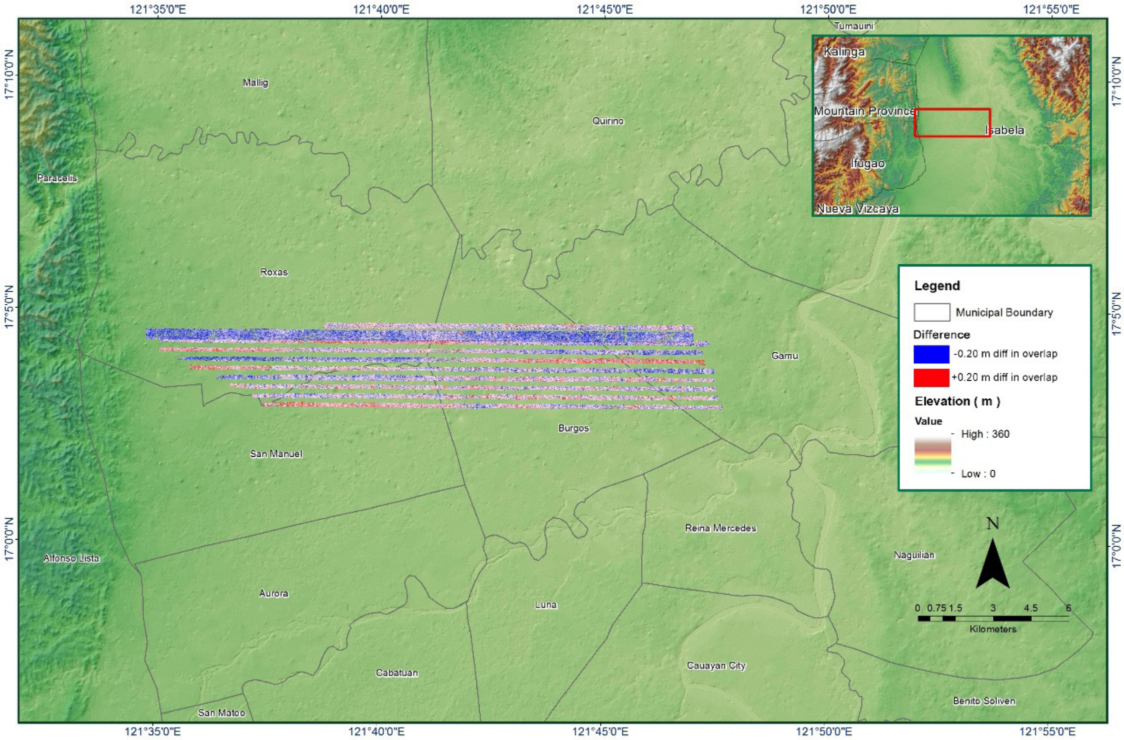


Figure A-8.84. Elevation difference between flight lines

Table A-8.13. Mission Summary Report for Mission CGYR F

Flight Area	Palanan
Mission Name	CGYR F
Inclusive Flights	2730G
Range data size	14.4 GB
POS	211 MB
Image	31.2 GB
Transfer date	10/5/15
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)	1.3
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	3.5
Boresight correction stdev (<0.001deg)	0.000016
IMU attitude correction stdev (<0.001deg)	0.001174
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	30.17%
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	142
Maximum Height	180.53 m
Minimum Height	52.84 m
Classification (# of points)	
Ground	53,230,092
Low vegetation	70,172,503
Medium vegetation	119,414,323
High vegetation	22,935,335
Building	896,369
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Merven Matthew Natino, Maria Tamsyn Malabanan

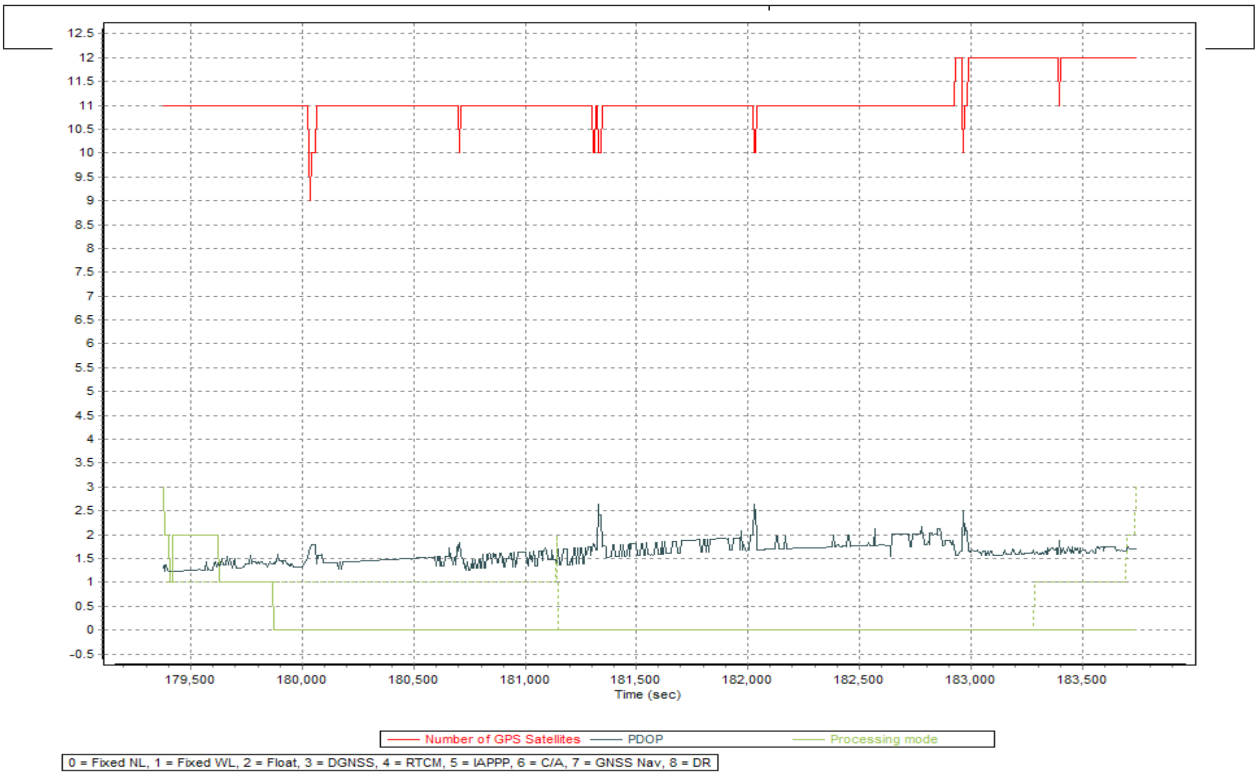


Figure A-8.85. Solution Status

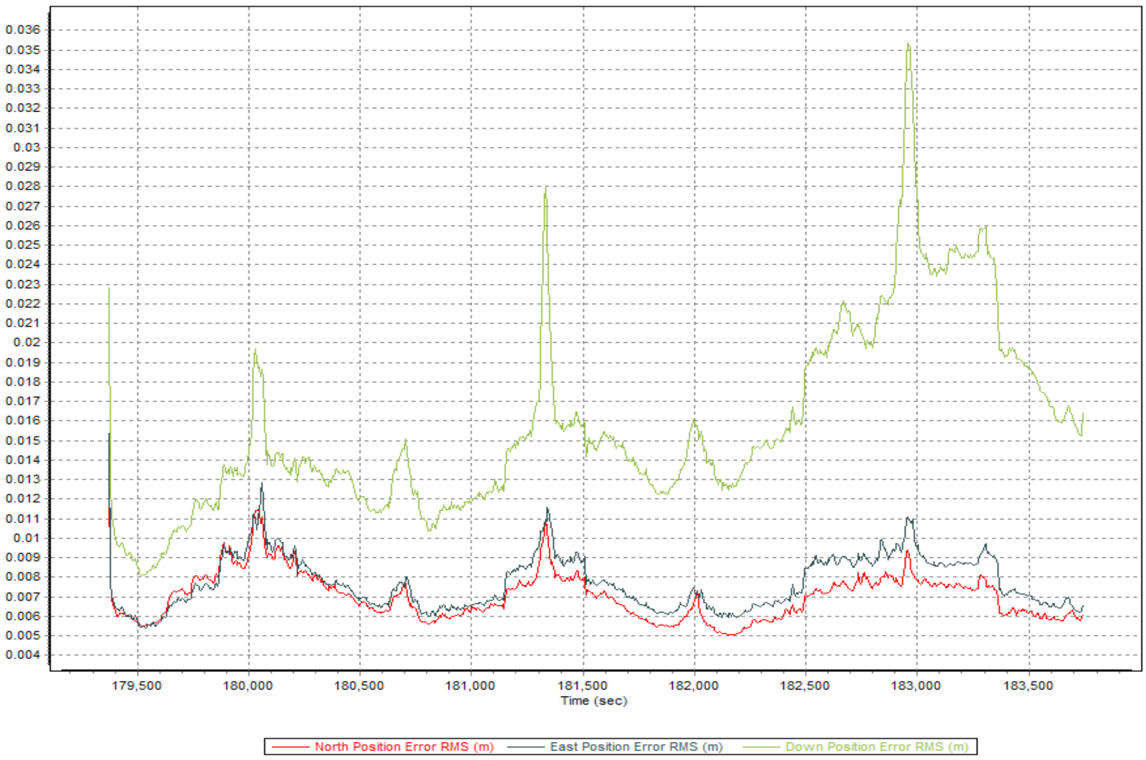


Figure A-8.86. Smoothed Performance Metrics Parameters

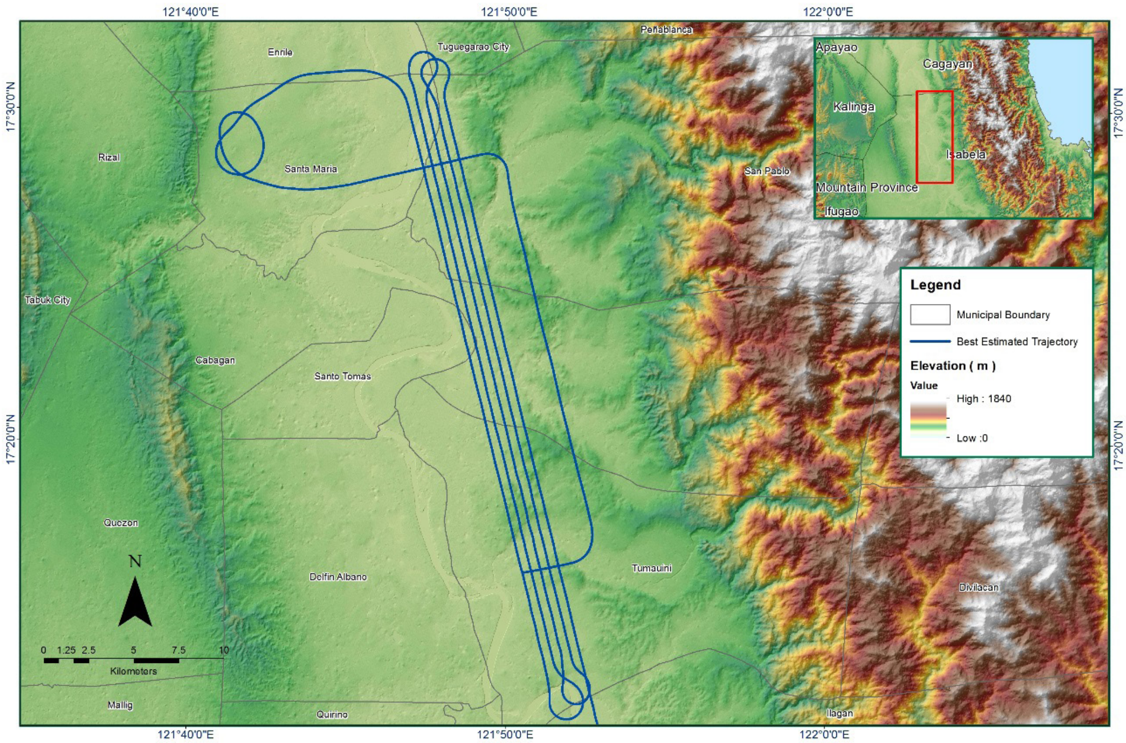


Figure A-8.87. Best Estimated Trajectory

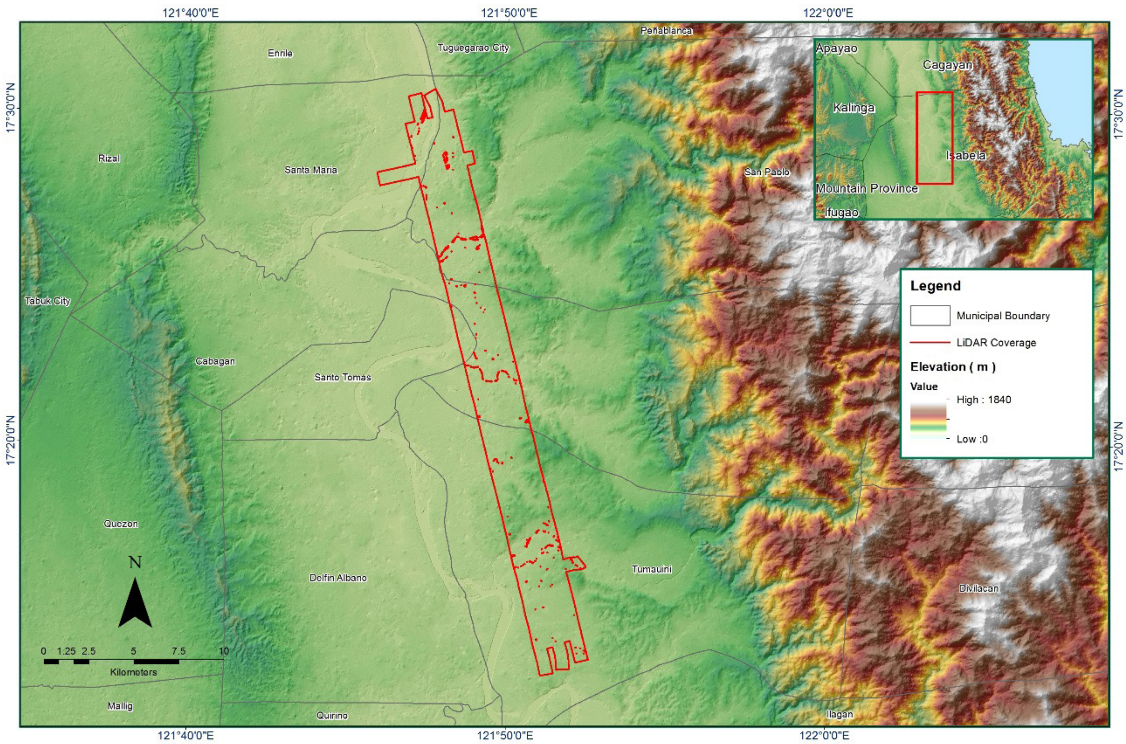


Figure A-8.88. Coverage of LiDAR data

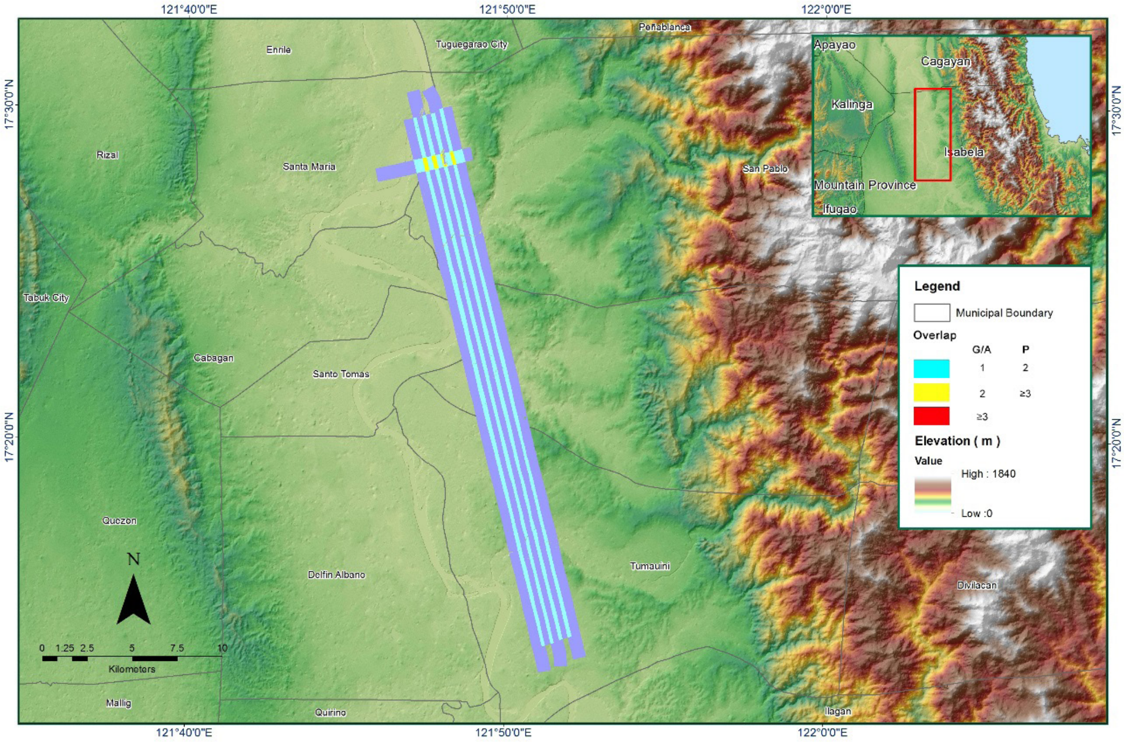


Figure A-8.89. Image of data overlap

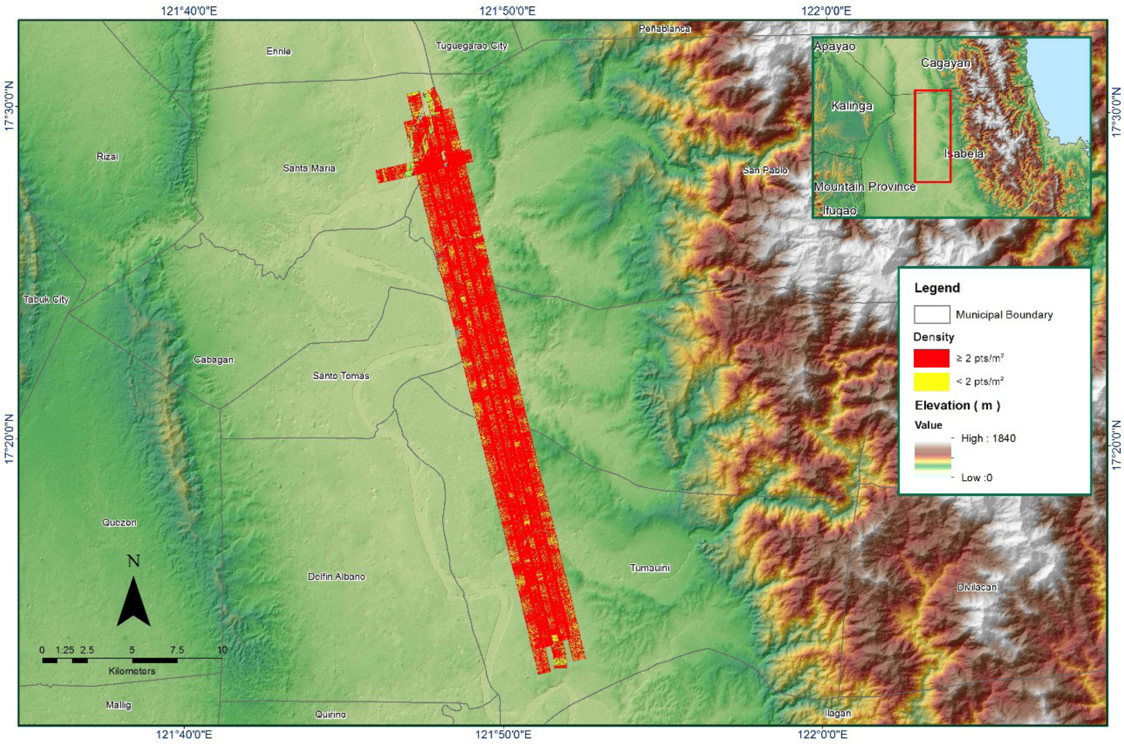


Figure A-8.90. Density map of merged LiDAR data

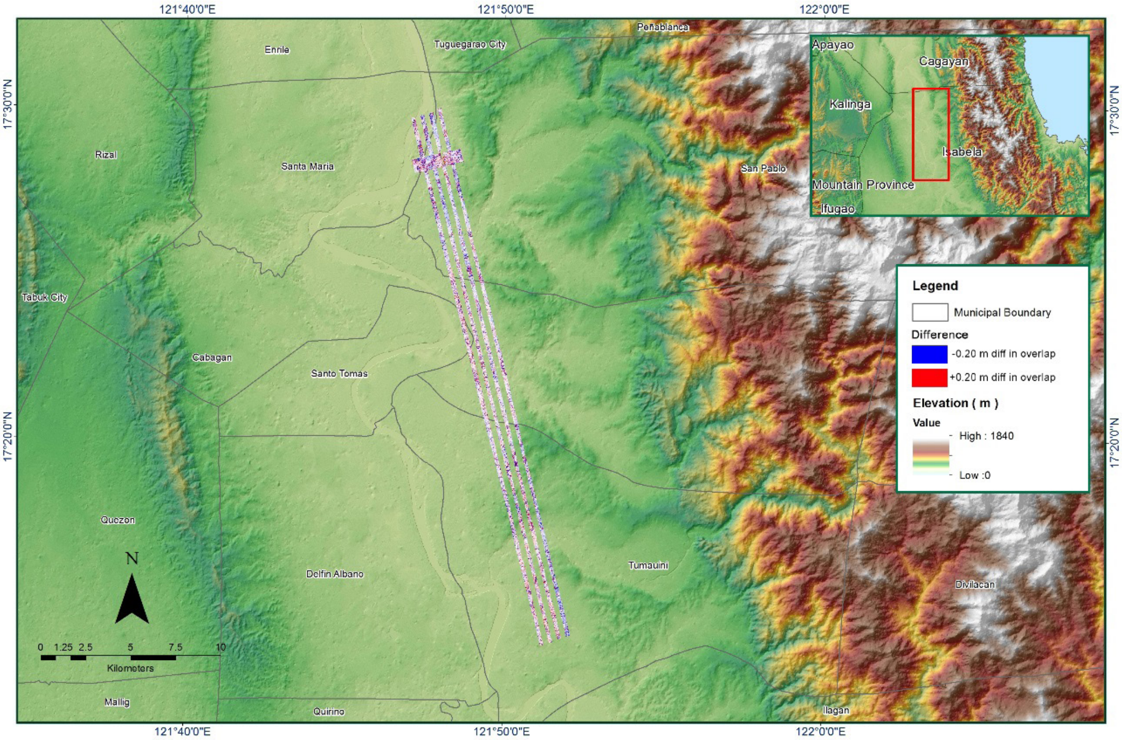


Figure A-8.91. Elevation difference between flight lines

Table A-8.14. Mission Summary Report for Mission CGYR E

Flight Area	Palanan
Mission Name	CGYR E
Inclusive Flights	2726G
Range data size	19.5 GB
POS	171 MB
Image	27.55 GB
Transfer date	10/5/15
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.1
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	4.9
Boresight correction stdev (<0.001deg)	-
IMU attitude correction stdev (<0.001deg)	-
GPS position stdev (<0.01m)	-
Minimum % overlap (>25)	7.79%
Ave point cloud density per sq.m. (>2.0)	5.21
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	90
Maximum Height	237.60 m
Minimum Height	28.51 m
Classification (# of points)	
Ground	37,680,246
Low vegetation	34,250,785
Medium vegetation	197,875,377
High vegetation	28,349,609
Building	70,807
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Edgardo Gubatanga Jr., Kathryn Claudyn Zarate

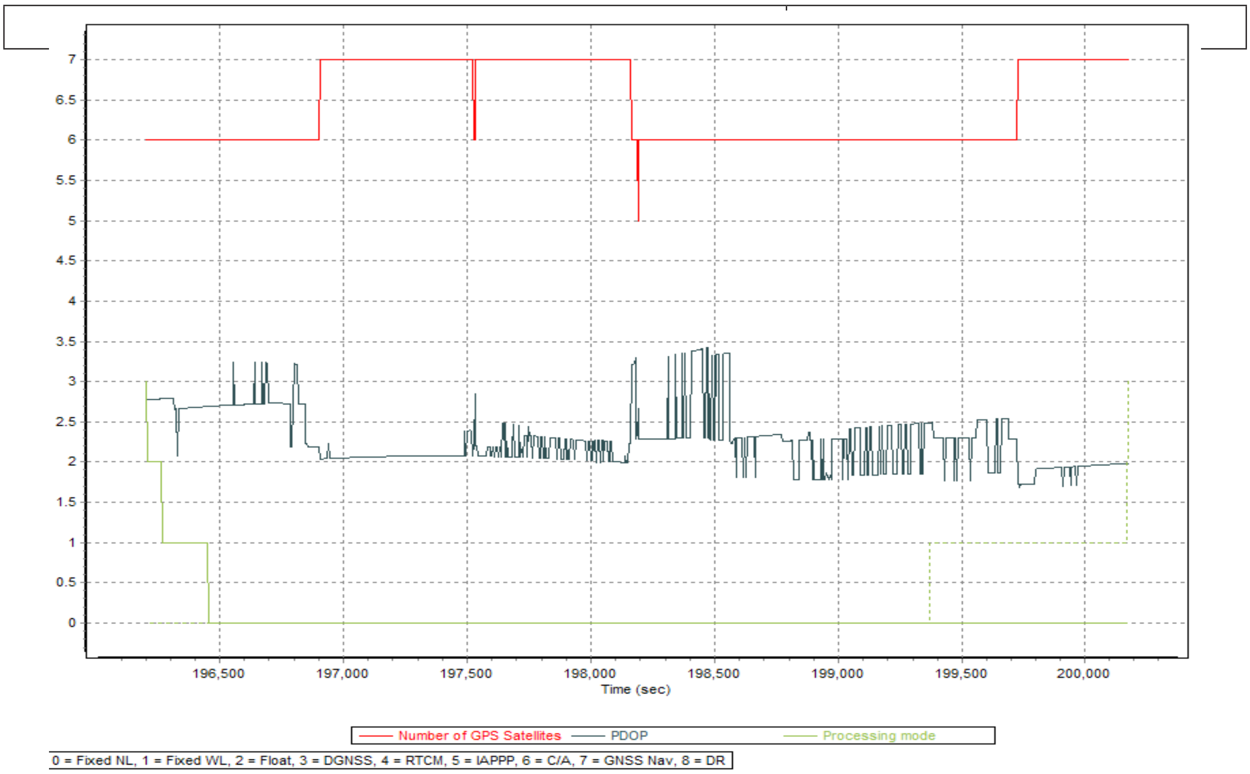


Figure A-8.92. Solution Status

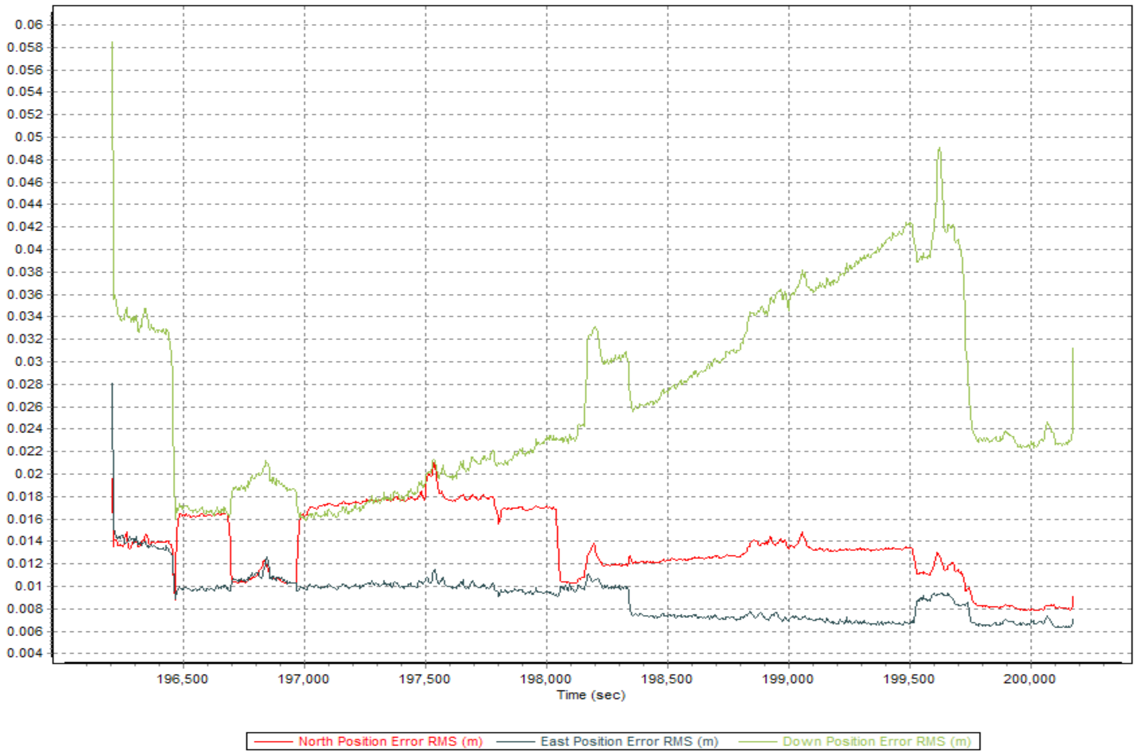


Figure A-8.93. Smoothed Performance Metrics Parameters

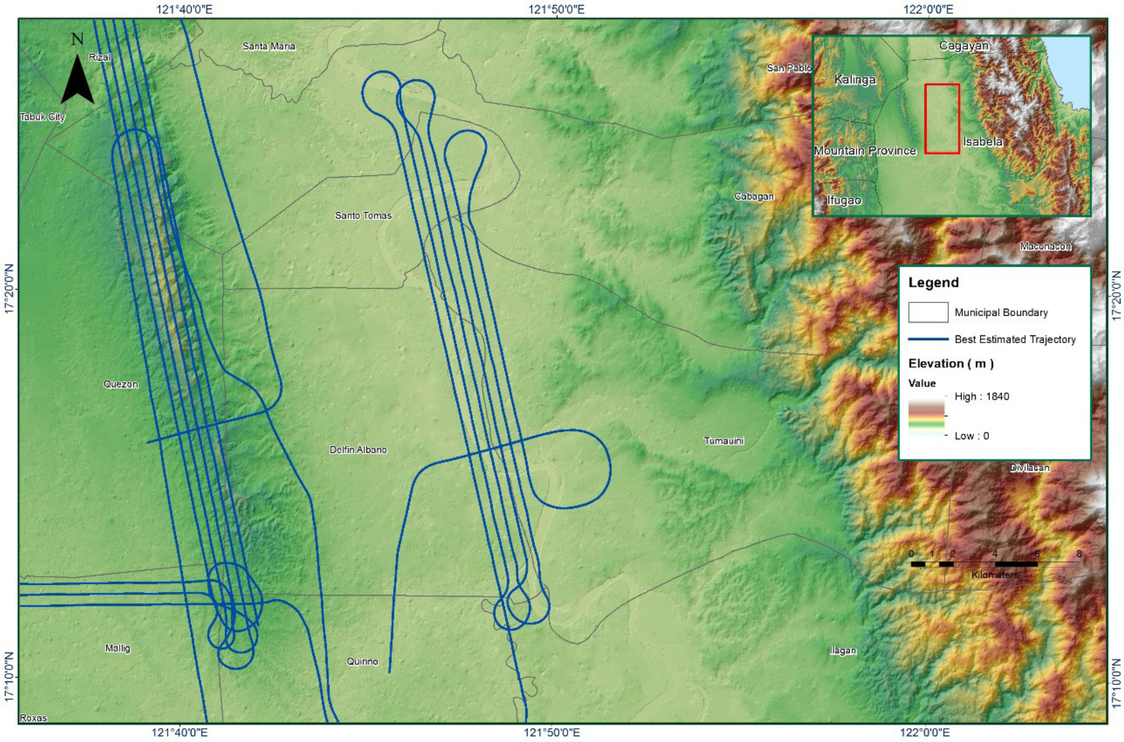


Figure A-8.94. Best Estimated Trajectory

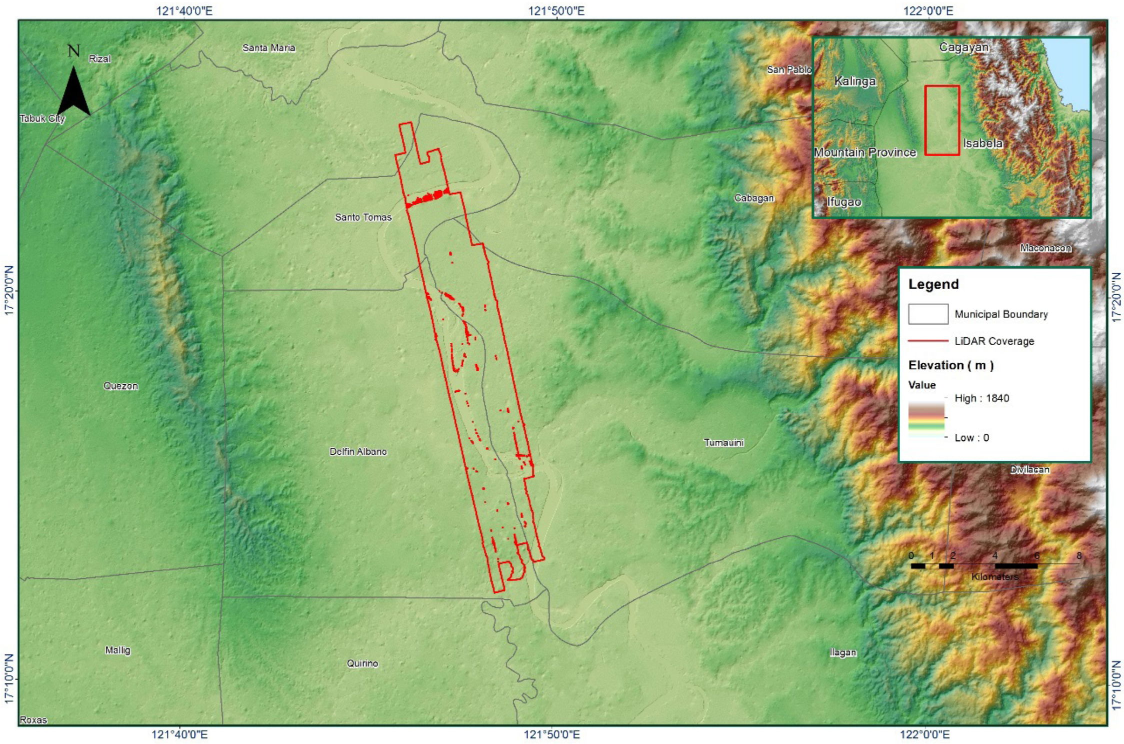


Figure A-8.95. Coverage of LiDAR data

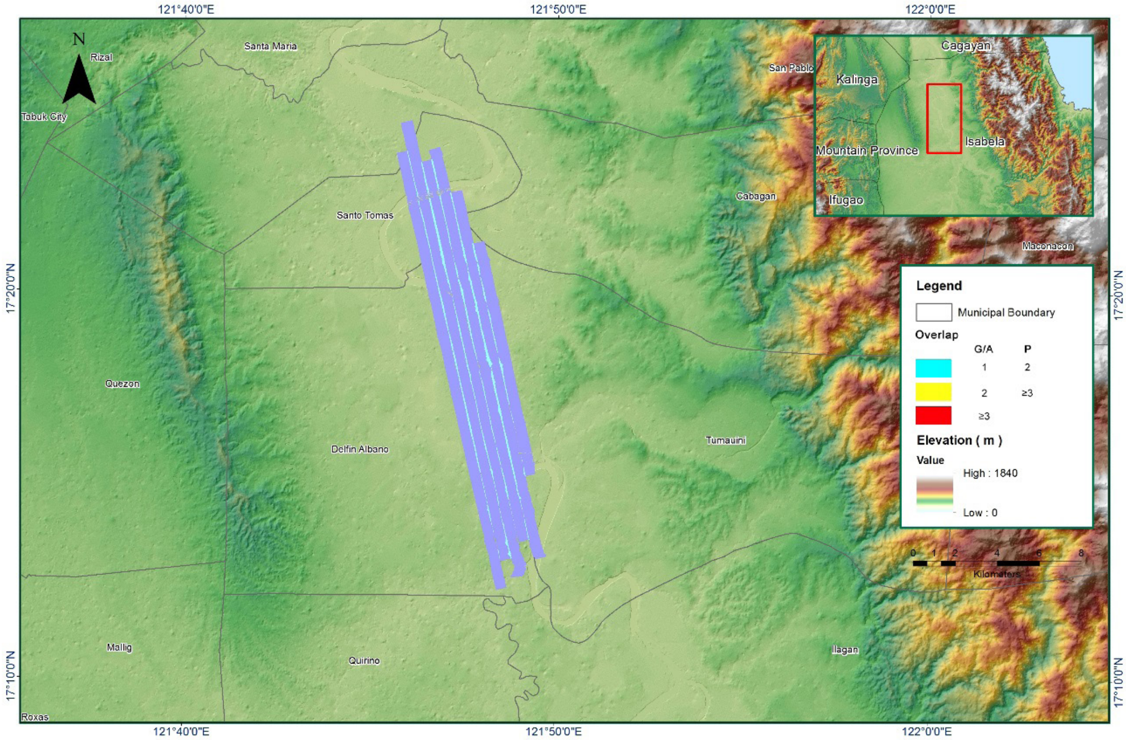


Figure A-8.96. Image of data overlap

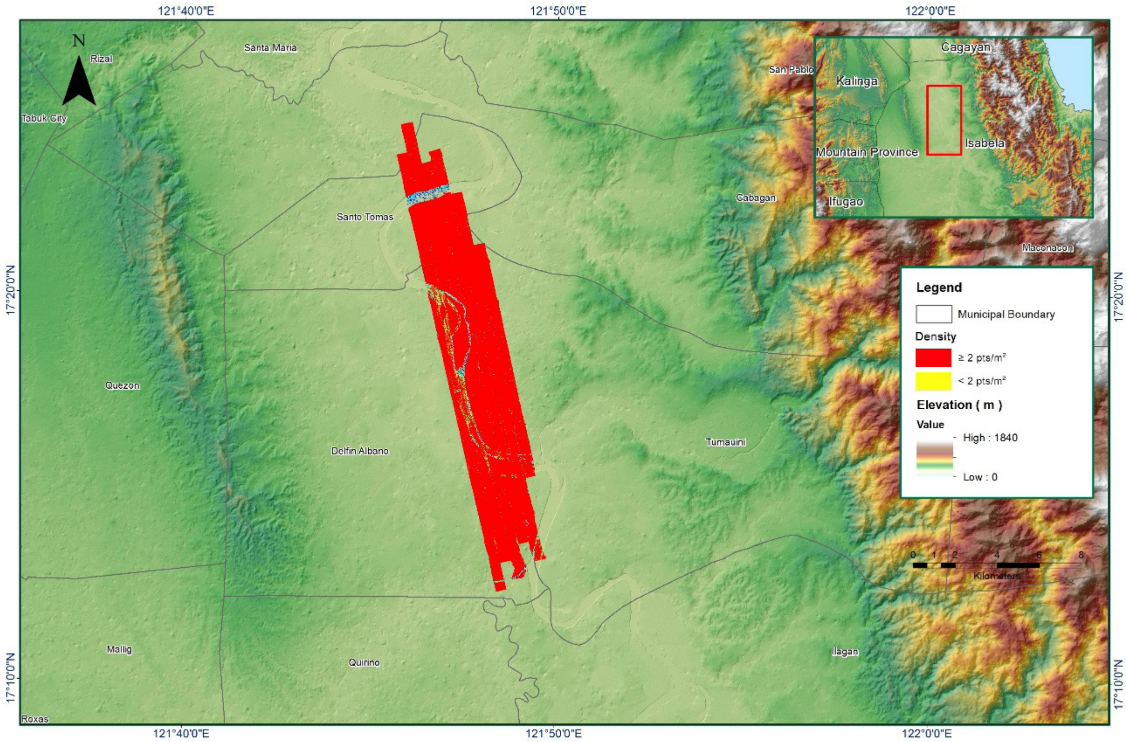


Figure A-8.97. Density map of merged LiDAR data

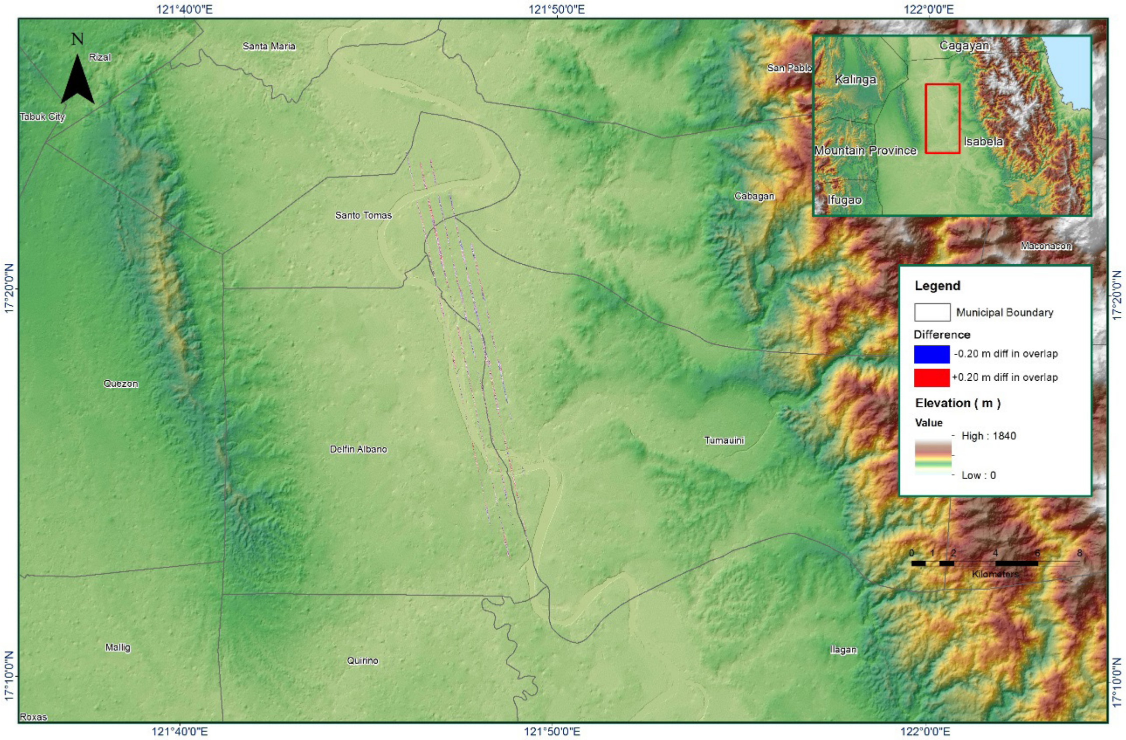


Figure A-8.98. Elevation difference between flight lines

Table A-8.15. Mission Summary Report for Mission CGYR C

Flight Area	Palanan
Mission Name	CGYR C
Inclusive Flights	2732G
Range data size	10 GB
POS	104 MB
Image	138 GB
Transfer date	10/5/15
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.1
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	4.9
Boresight correction stdev (<0.001deg)	0.000016
IMU attitude correction stdev (<0.001deg)	0.000456
GPS position stdev (<0.01m)	0.0116
Minimum % overlap (>25)	31.50%
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	127
Maximum Height	410.81 m
Minimum Height	55.37 m
Classification (# of points)	
Ground	76,533,828
Low vegetation	49,166,218
Medium vegetation	100,542,285
High vegetation	66,380,613
Building	959,622
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Christy Lubiano, Maria Tamsyn Malabanan

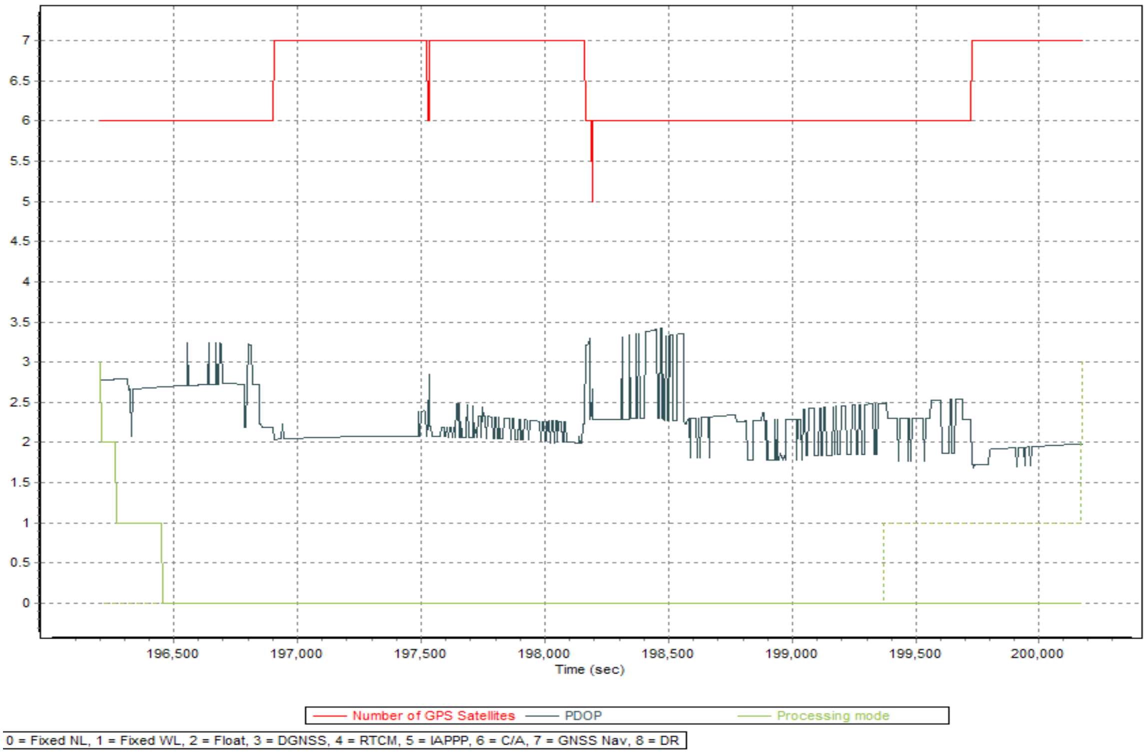


Figure A-8.99. Solution Status

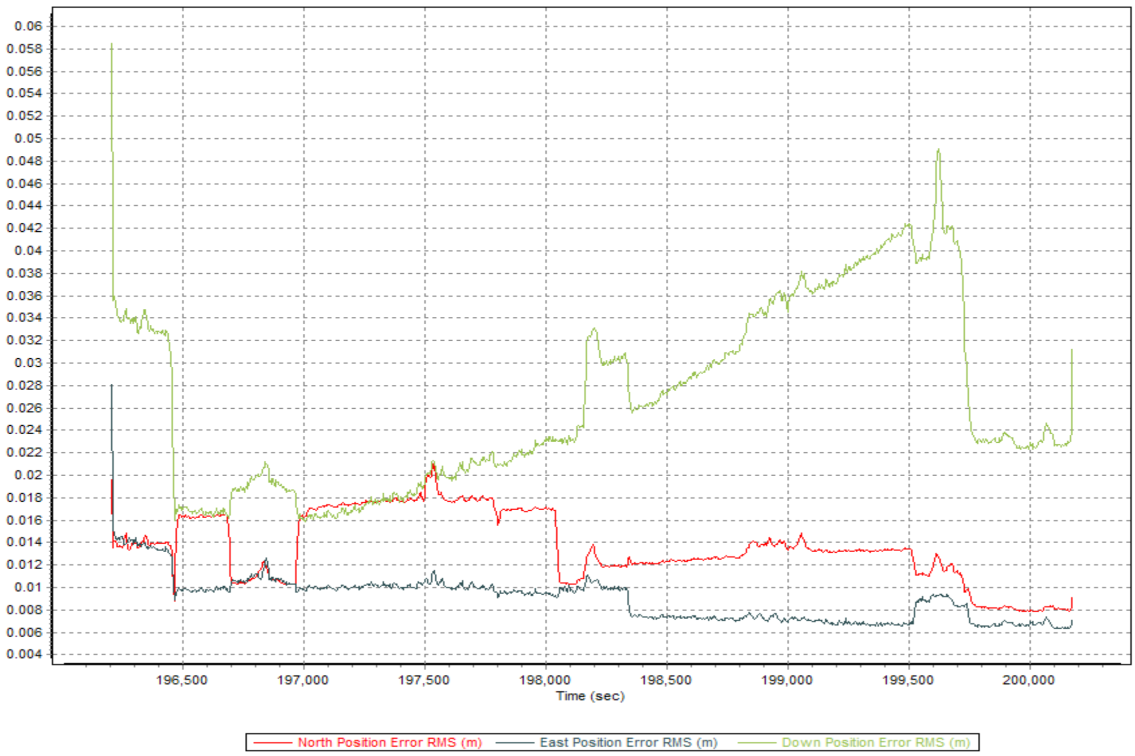


Figure A-8.100. Smoothed Performance Metric Parameters

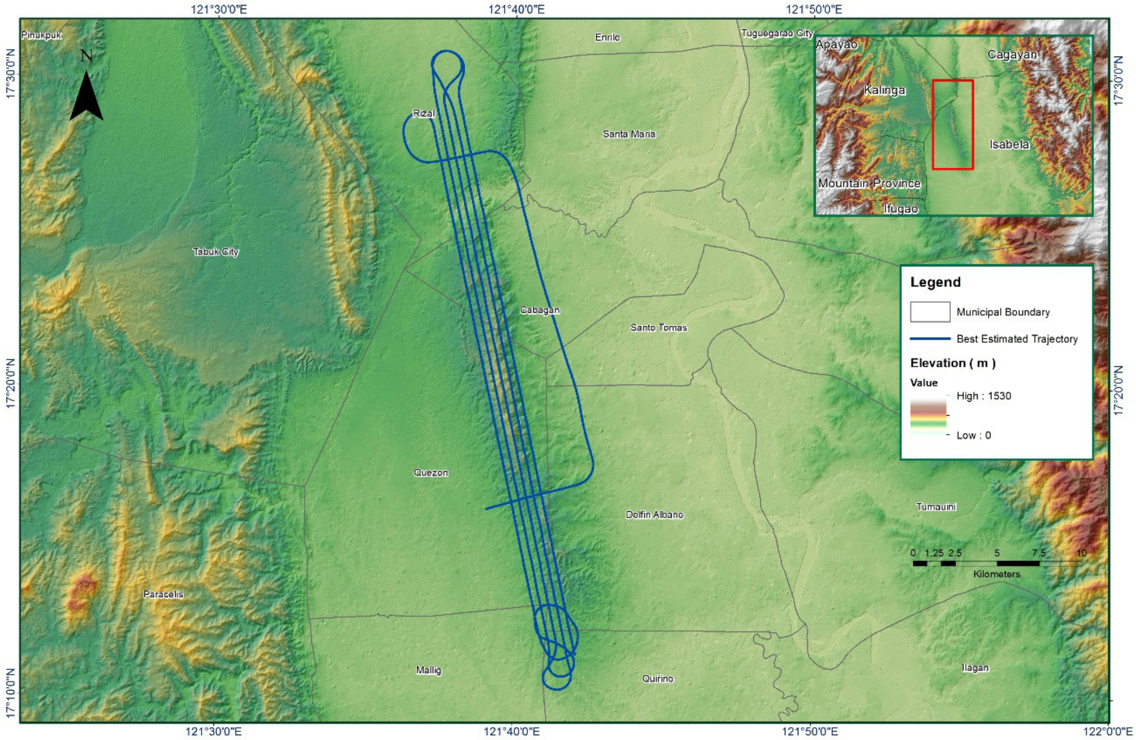


Figure A-8.101. Best Estimated Trajectory

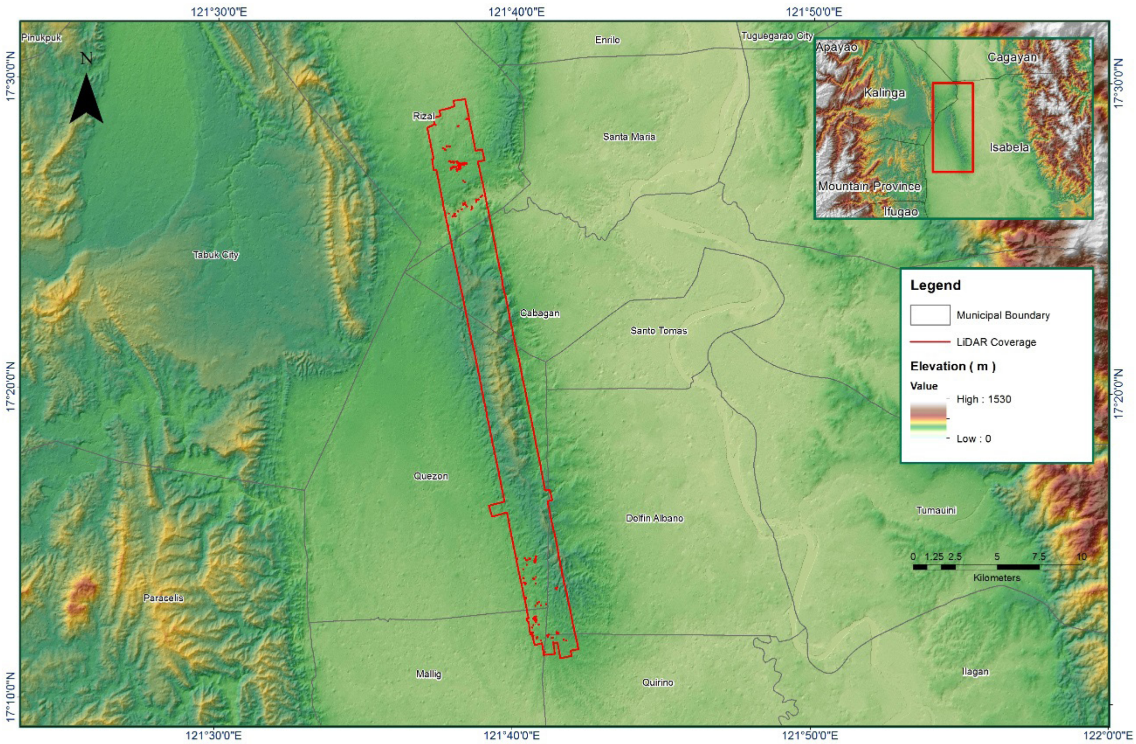


Figure A-8.102. Coverage of LiDAR Data

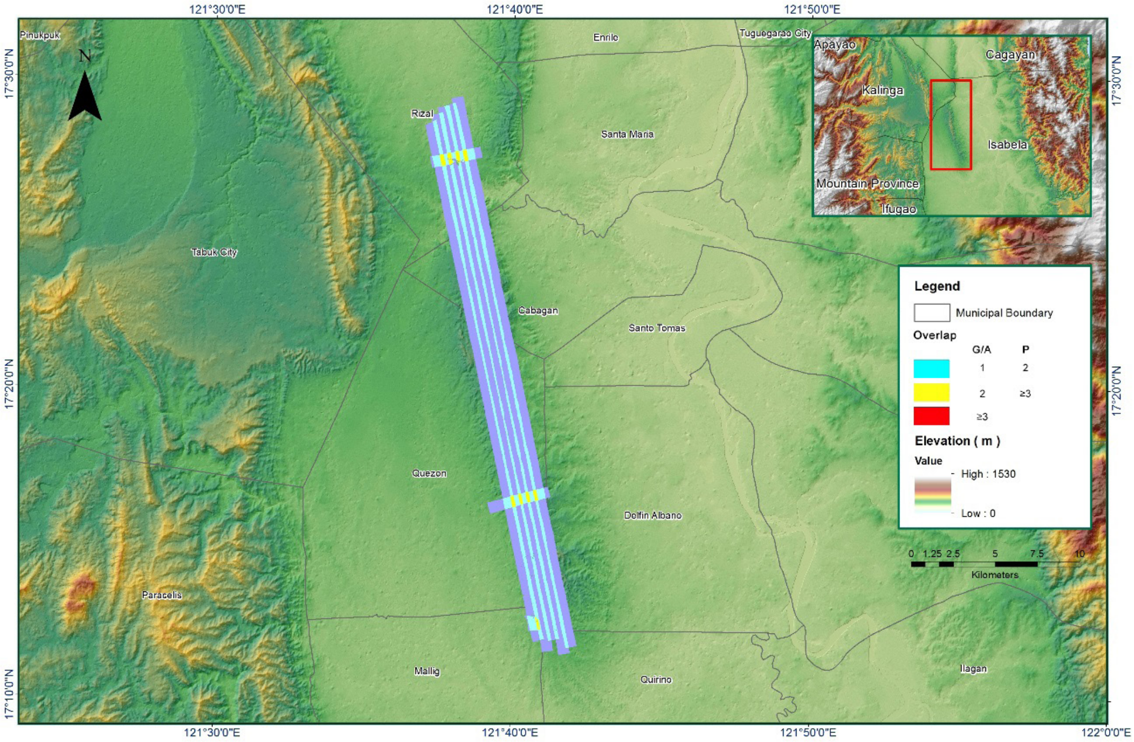


Figure A-8.103. Image of data overlap

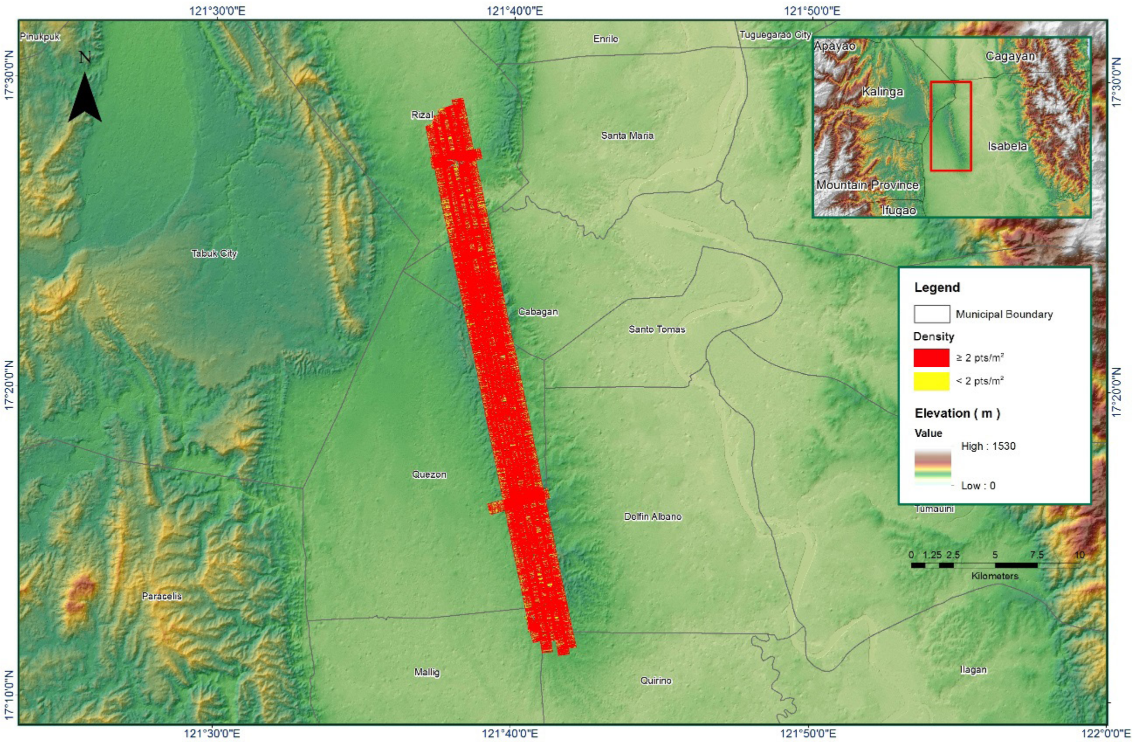


Figure A-8.104. **Density map of merged LiDAR data**

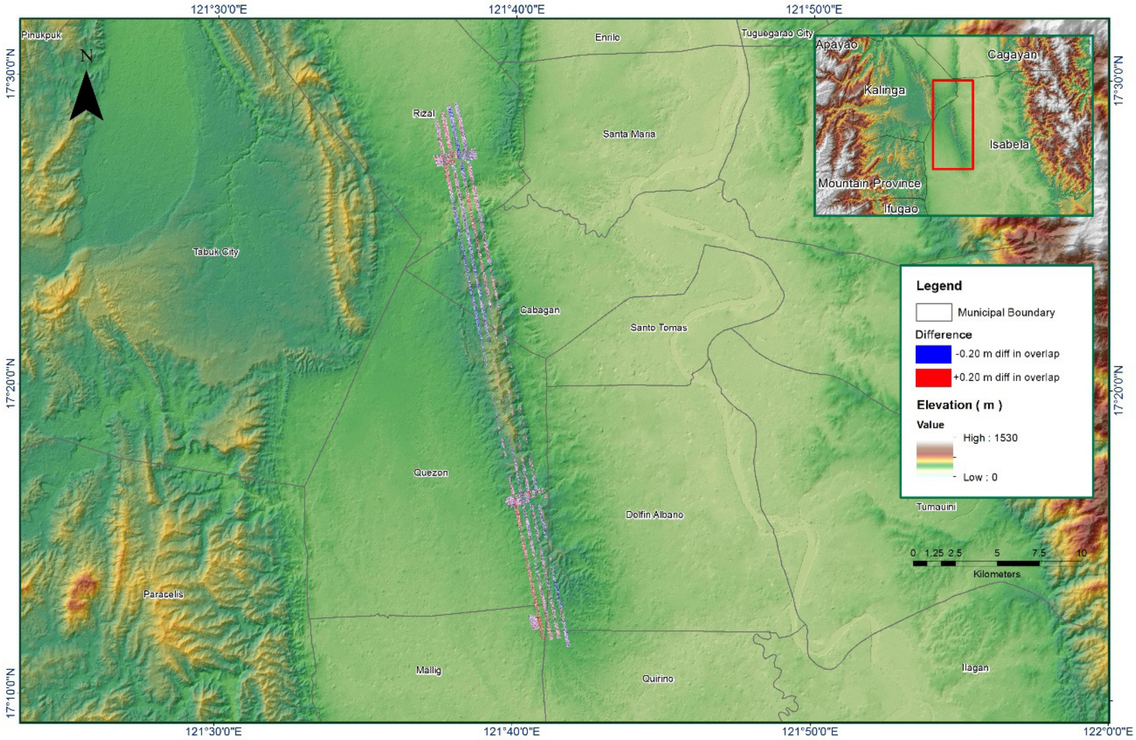


Figure A-8.105. Elevation difference between flight lines

Table A-8.16. Mission Summary Report for Mission CGYR A

Flight Area	Palanan
Mission Name	CGYR A
Inclusive Flights	2726G
Range data size	19.5 GB
POS	171 MB
Image	27.55 GB
Transfer date	10/5/15
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)	1.8
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	2.8
Boresight correction stdev (<0.001deg)	0.000016
IMU attitude correction stdev (<0.001deg)	0.030263
GPS position stdev (<0.01m)	0.0112
Minimum % overlap (>25)	1.93%
Ave point cloud density per sq.m. (>2.0)	6.02
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	49
Maximum Height	338.89 m
Minimum Height	52.12 m
Classification (# of points)	
Ground	10,703,830
Low vegetation	12,038,330
Medium vegetation	81,001,011
High vegetation	13,644,594
Building	103,402
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Edgardo Gubatanga Jr., Engr. Krisha Marie Bautista

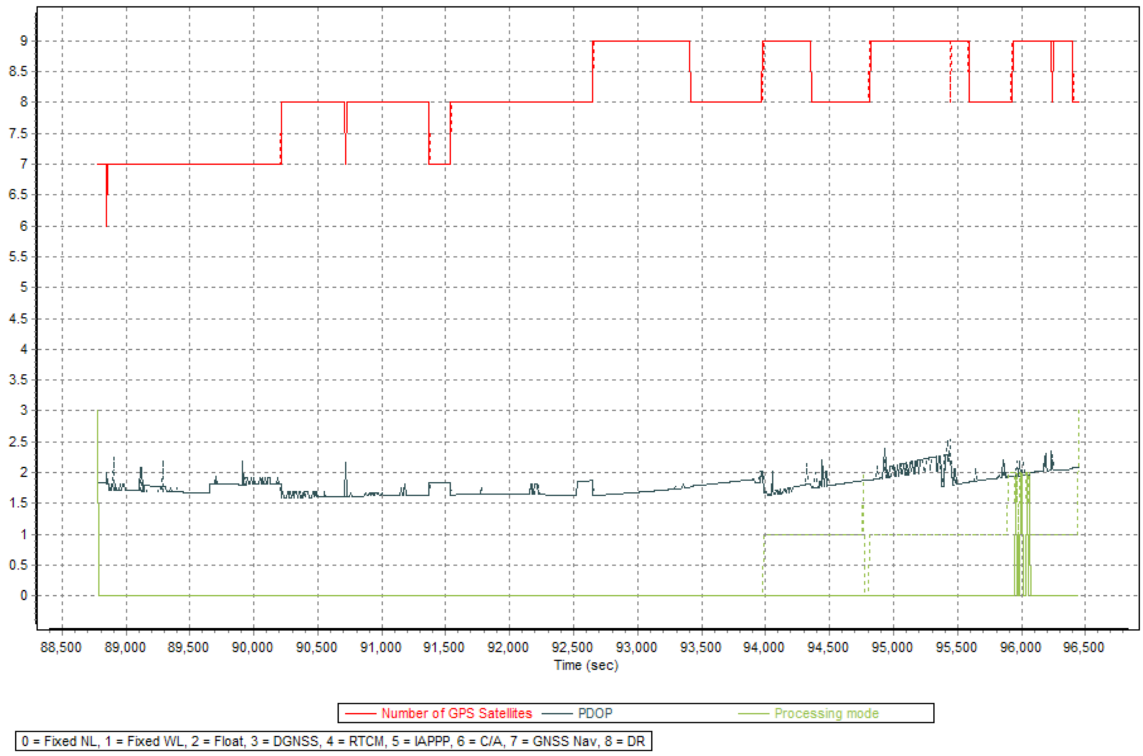


Figure A-8.106. Solution Status

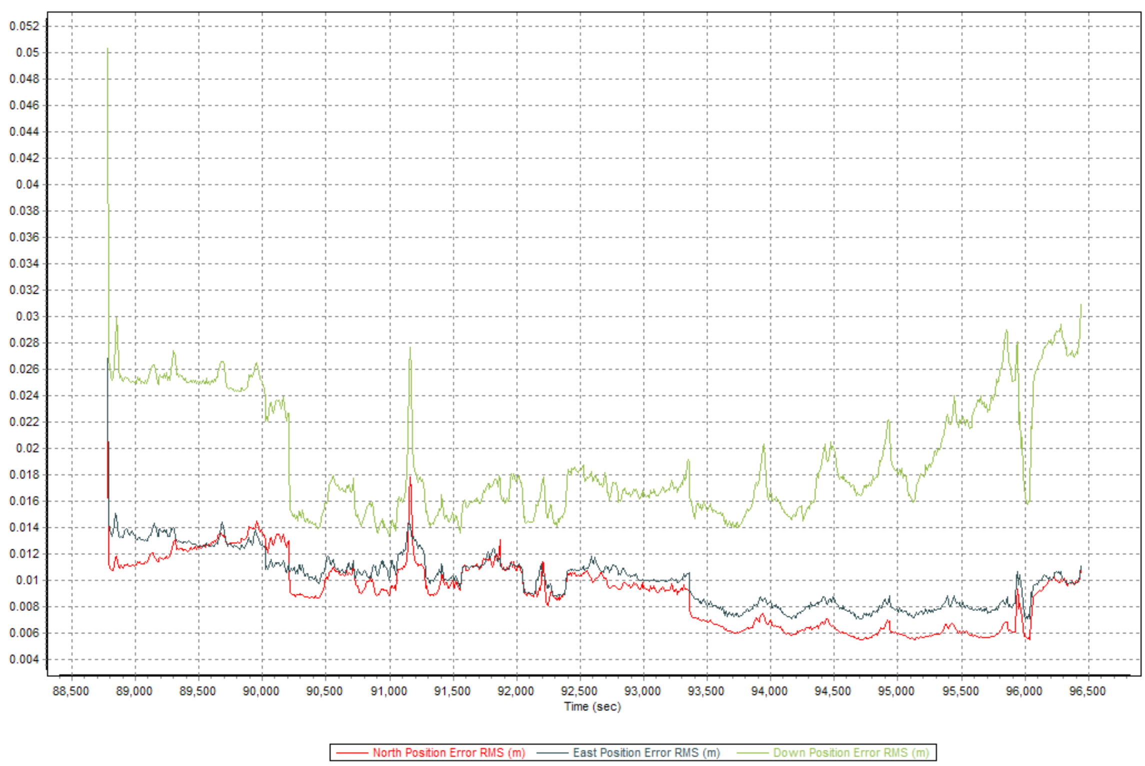


Figure A-8.107. Smoothed Performance Metric Parameters

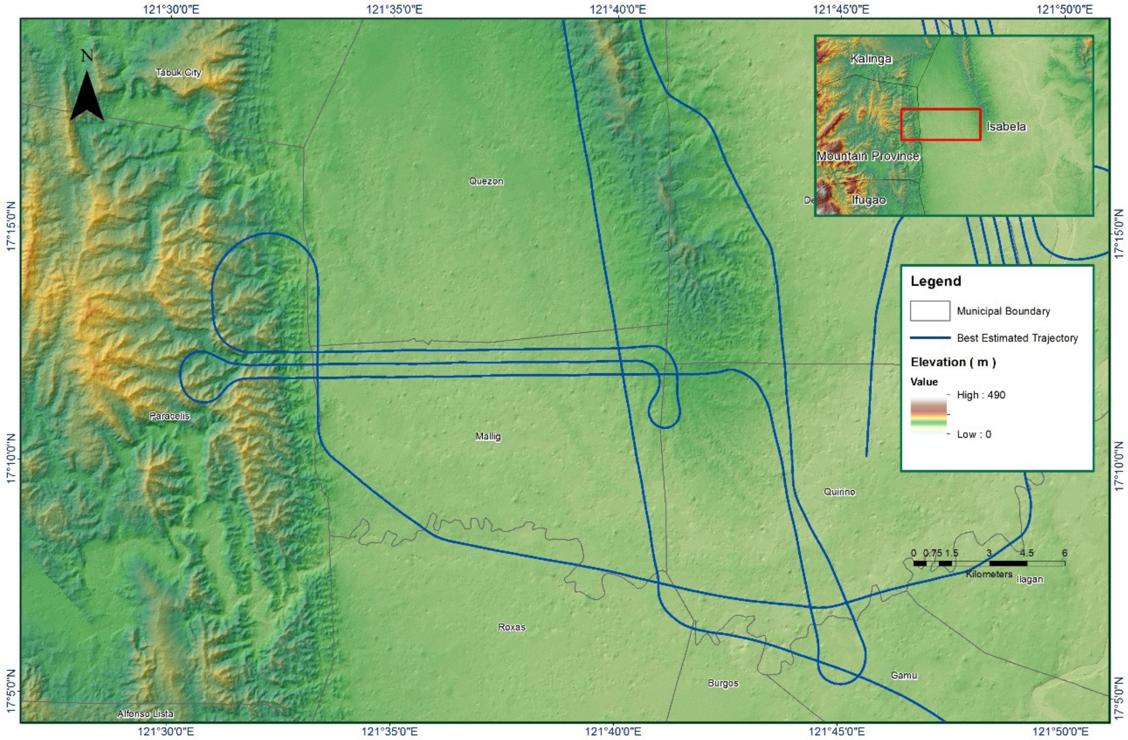


Figure A-8.108. Best Estimated Trajectory

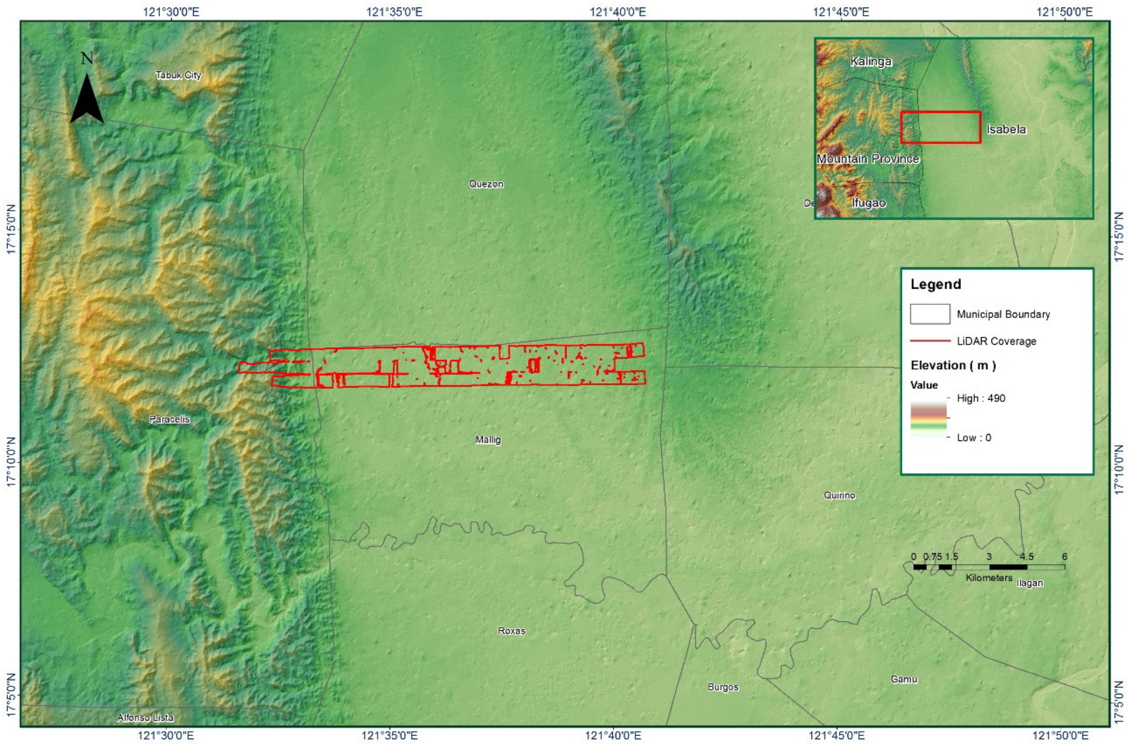


Figure A-8.109. Coverage of LiDAR Data

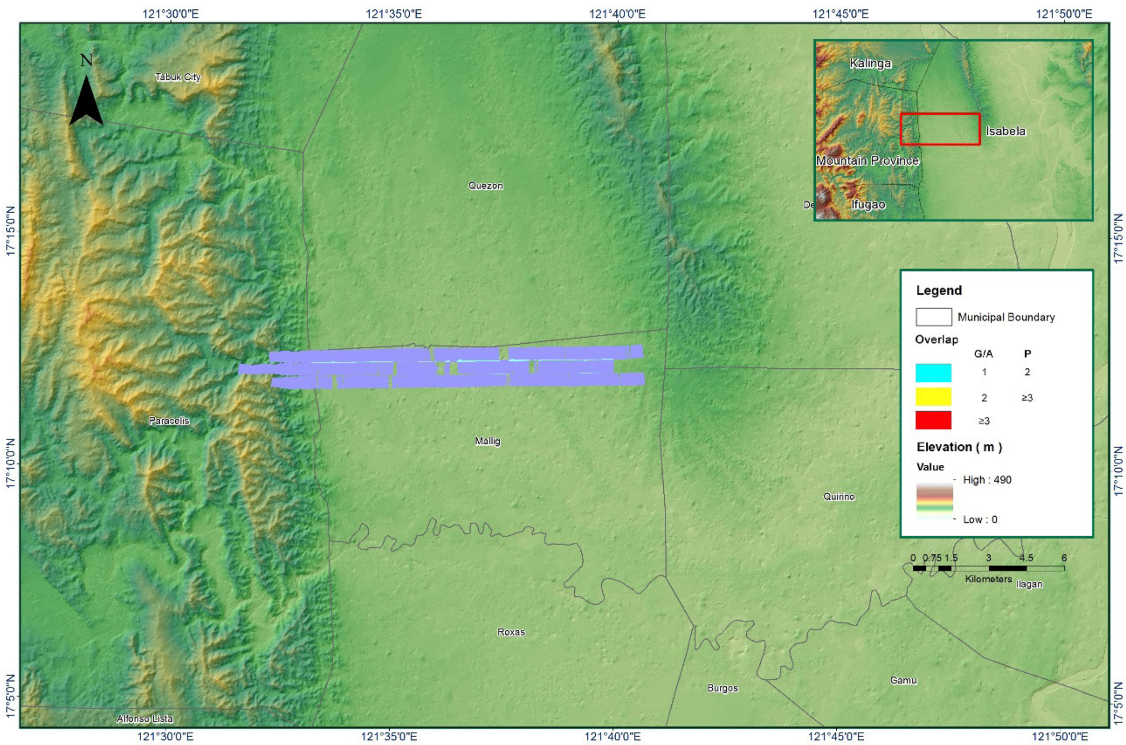


Figure A-8.110. Image of data overlap

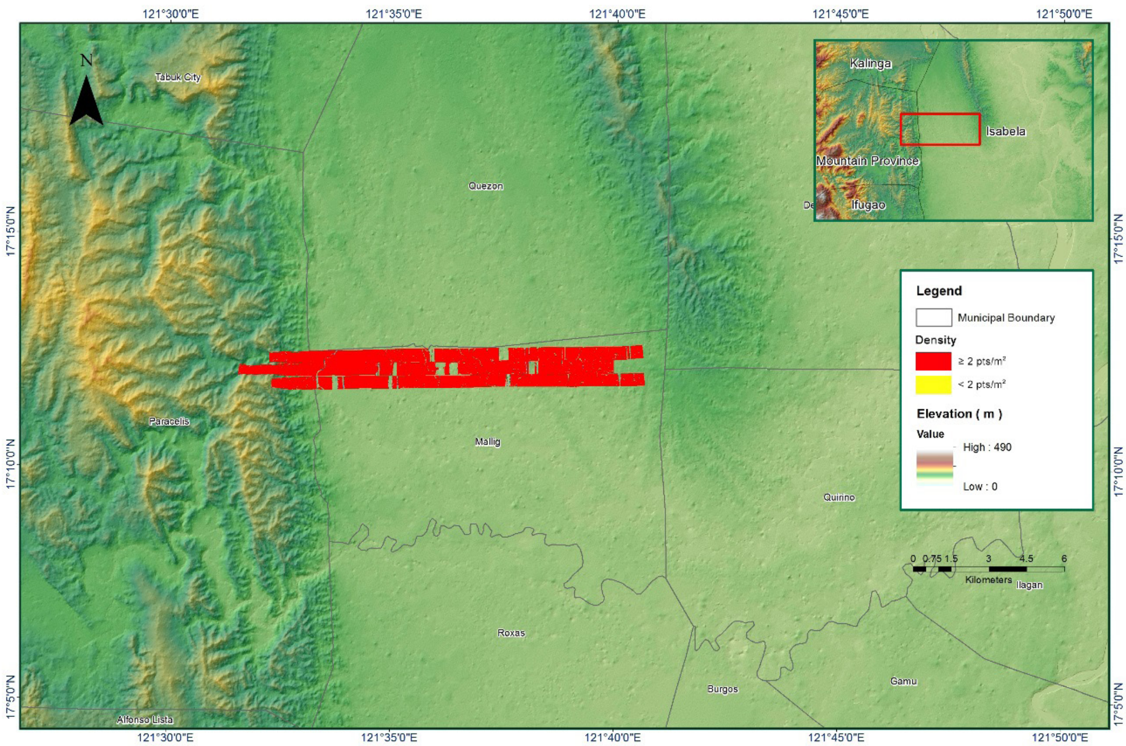


Figure A-8.111**. Density map of merged LiDAR data**

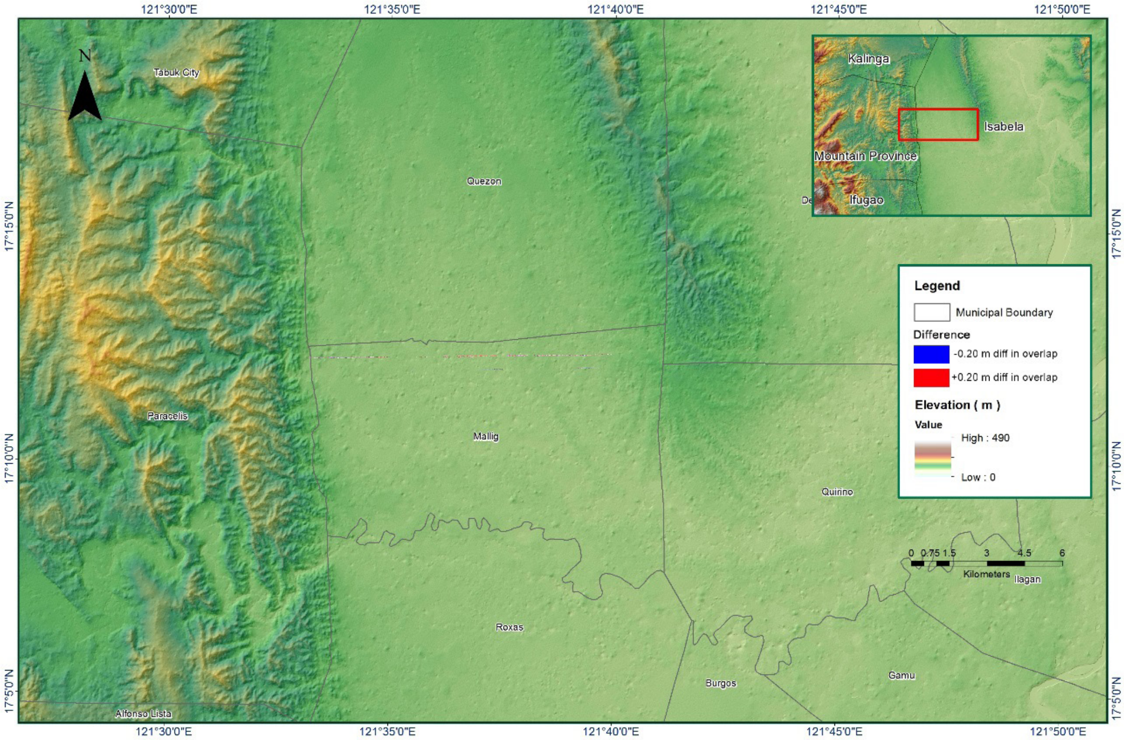


Figure A-8.112. Elevation difference between flight lines

Table A-8.17. Mission Summary Report for Mission Blk9C_additional

Flight Area	Palanan
Mission Name	Blk 9C_additional
Inclusive Flights	2730G
Range data size	14.4 GB
POS	211 MB
Image	31.2 GB
Transfer date	10/5/15
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.4
RMSE for East Position (<4.0 cm)	2.1
RMSE for Down Position (<8.0 cm)	3.6
Boresight correction stdev (<0.001deg)	0.000013
IMU attitude correction stdev (<0.001deg)	0.001507
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	23.05%
Ave point cloud density per sq.m. (>2.0)	3.18
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	26
Maximum Height	253.33
Minimum Height	38.12
Classification (# of points)	
Ground	5,973,775
Low vegetation	4,122,554
Medium vegetation	11,762,632
High vegetation	16,445,083
Building	45,407
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Jovelle Anjeanette Canlas, Kathryn Claudyn Zarate

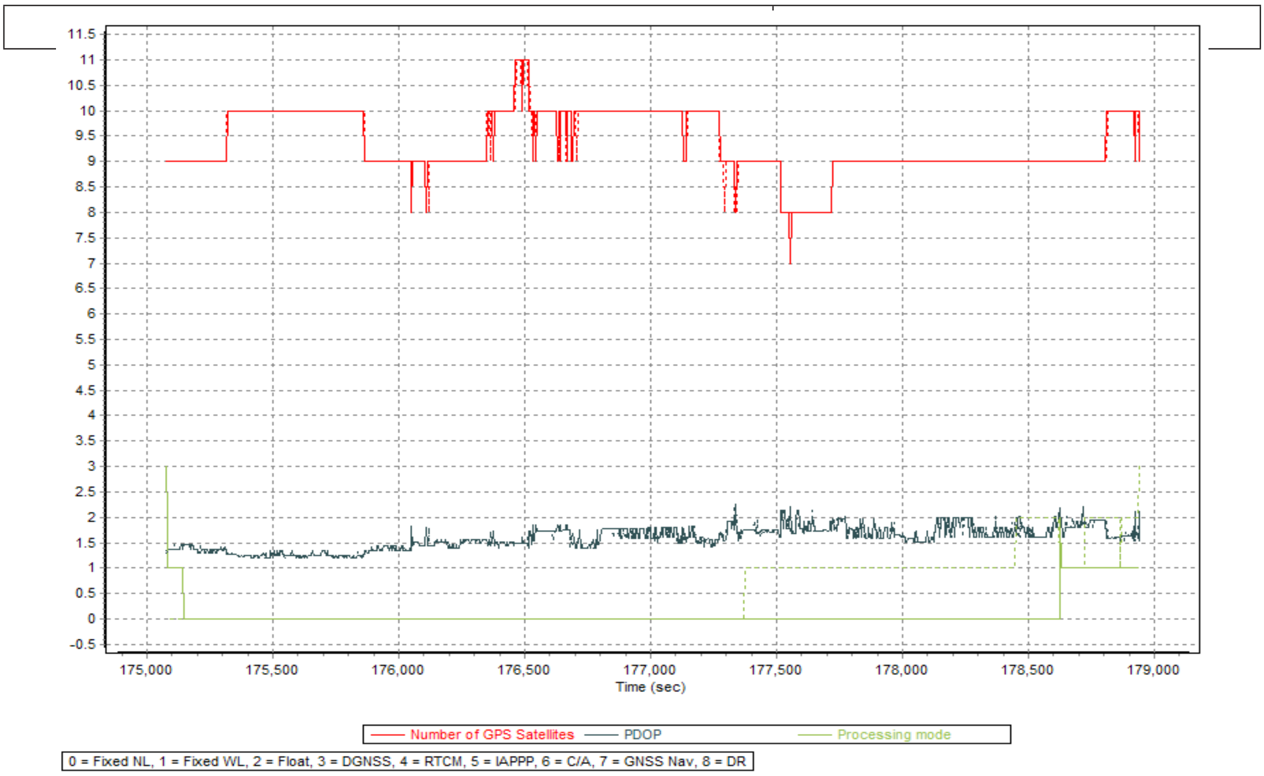


Figure A-8.113. Solution Status

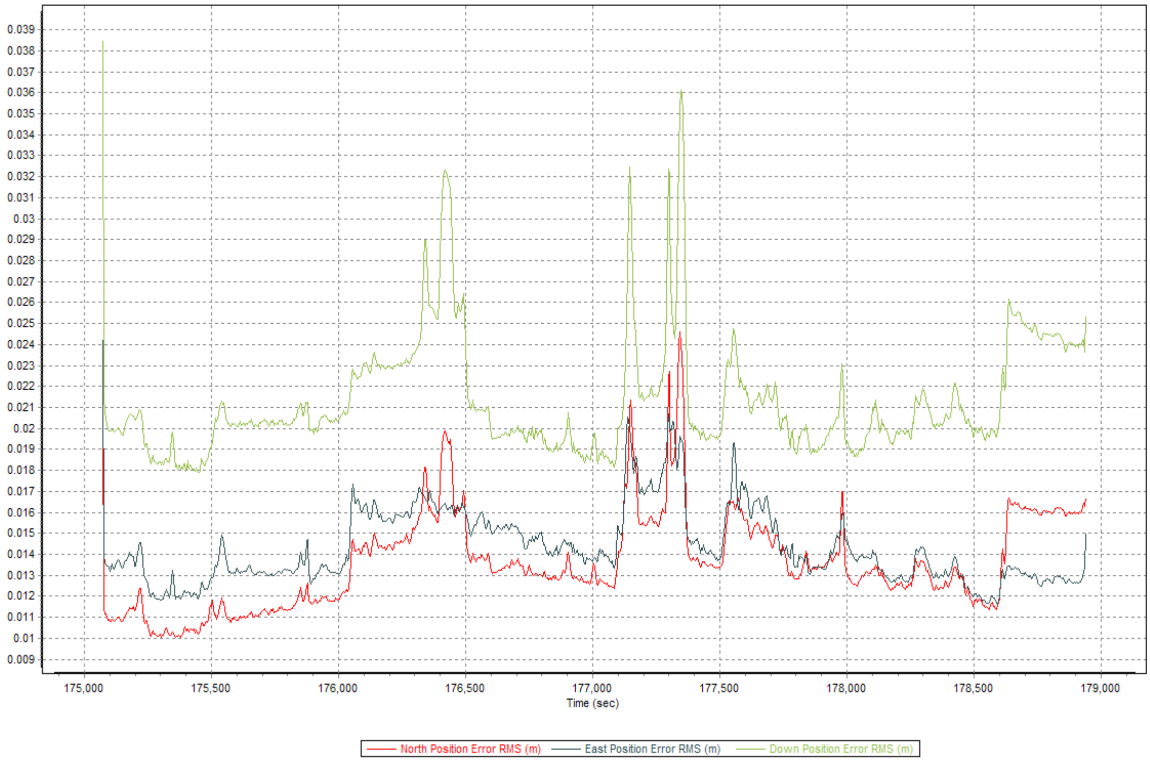


Figure A-8.114. Smoothed Performance Metrics Parameters

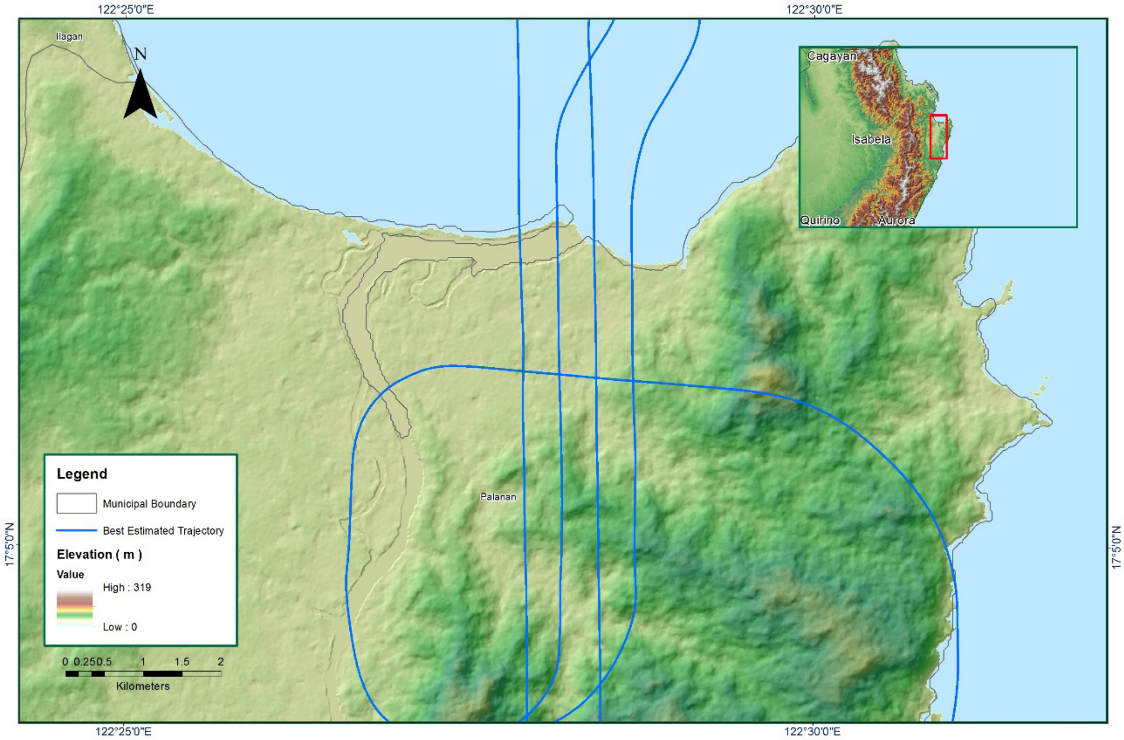


Figure A-8.115. Best Estimated Trajectory

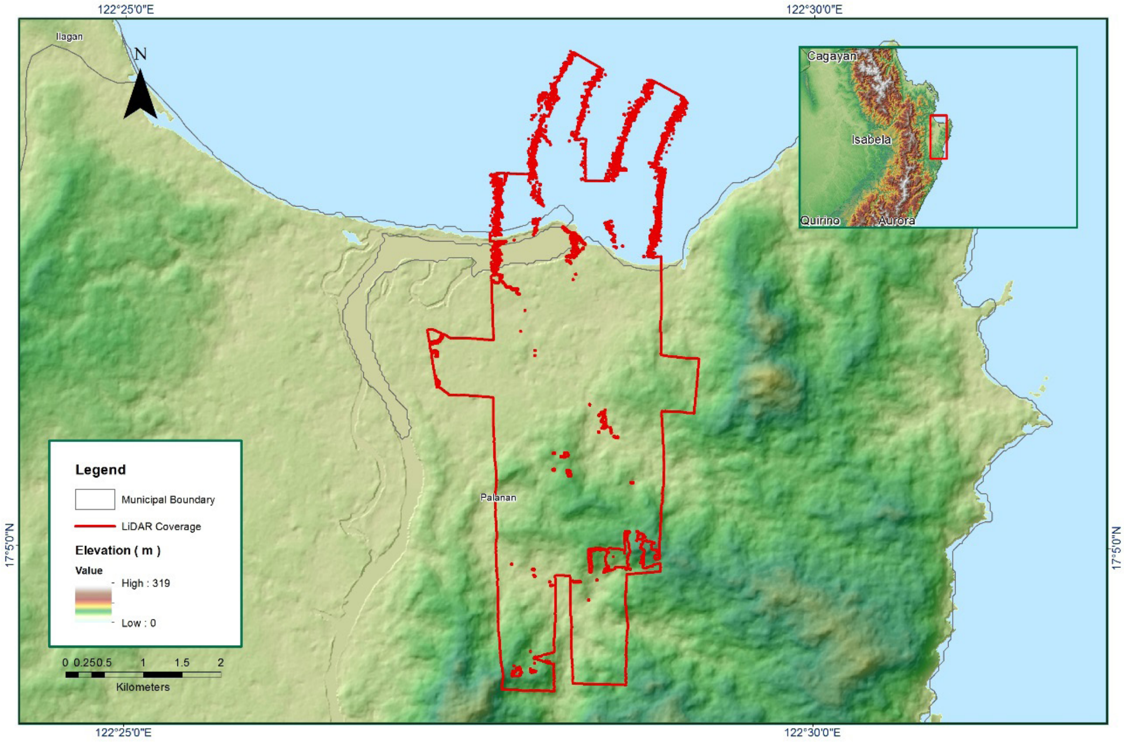


Figure A-8.116 Coverage of LiDAR data

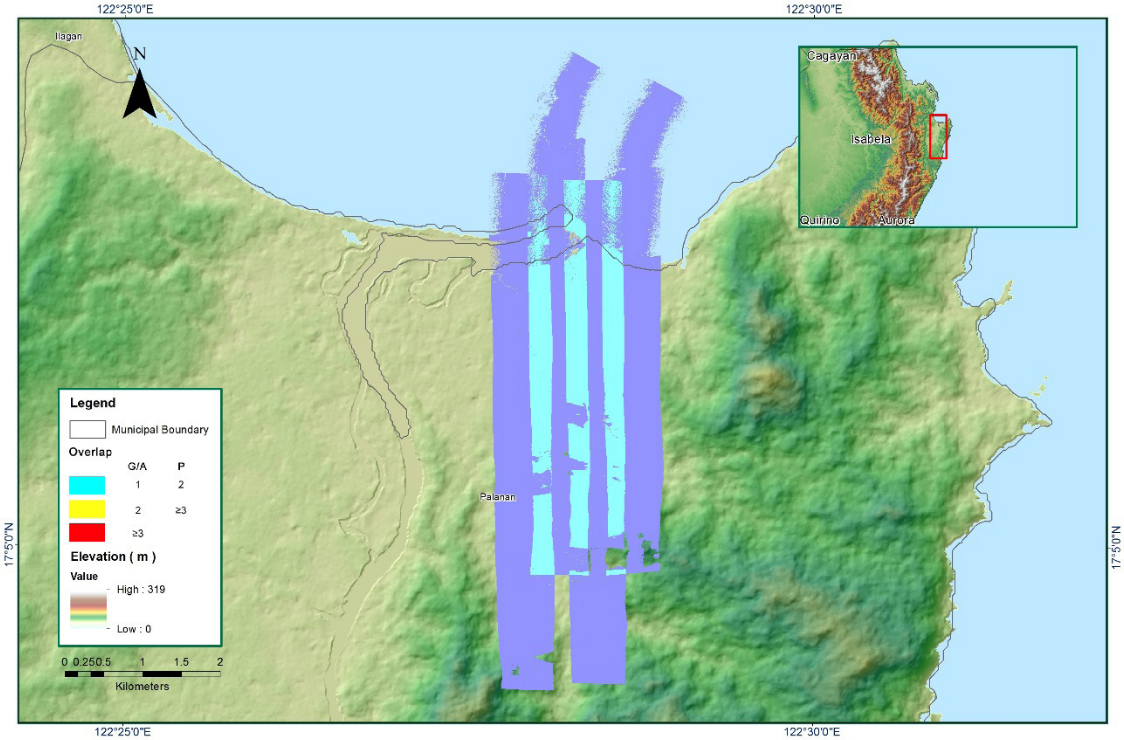


Figure A-8.117. Image of data overlap

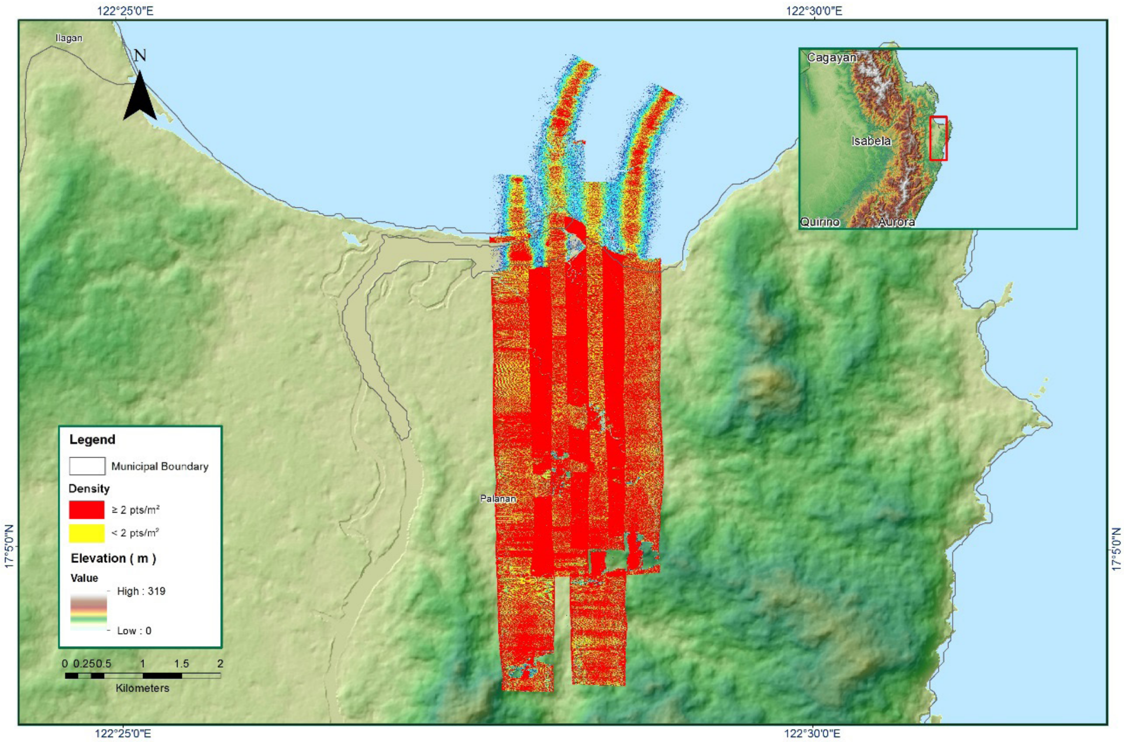


Figure A-8.118. Density map of merged LiDAR data

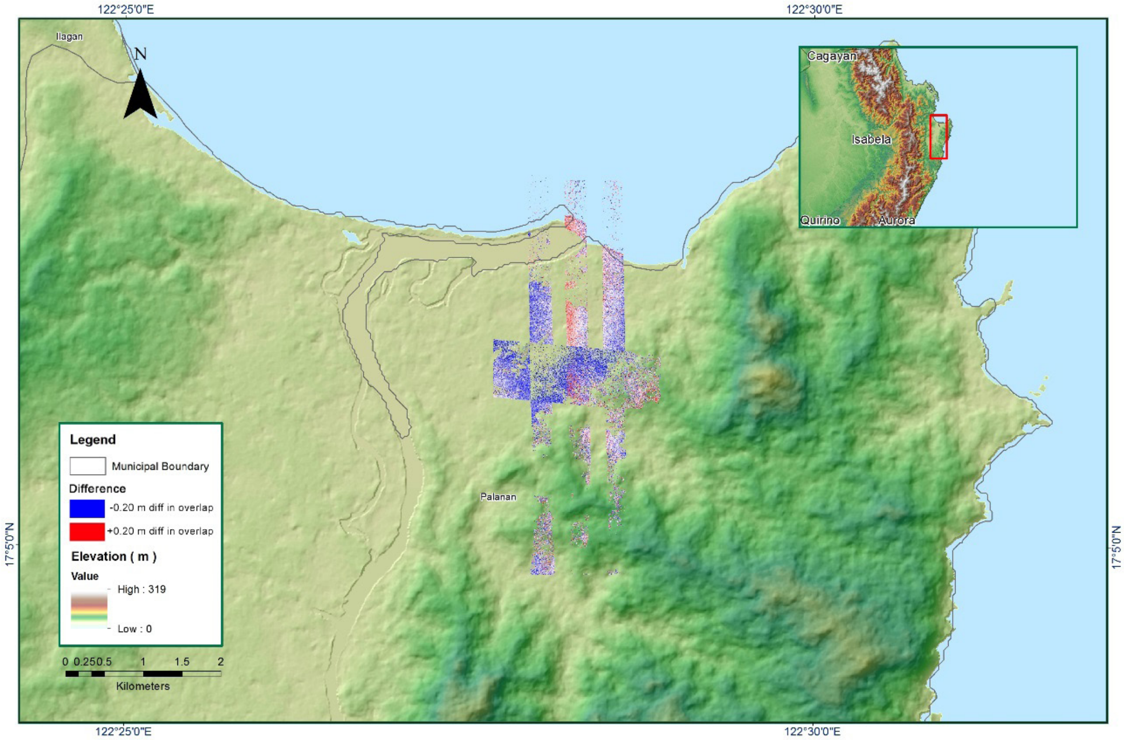


Figure A-8.119. Elevation difference between flight lines

Table A-8.18. Mission Summary Report for Mission Blk 9C

Flight Area	Palanan
Mission Name	Blk 9C
Inclusive Flights	2686G
Range data size	19.6 GB
POS	230 MB
Image	13.6 GB
Transfer date	10/5/15
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)	2.3
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.5
Boresight correction stdev (<0.001deg)	0.000016
IMU attitude correction stdev (<0.001deg)	0.001292
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	80.90%
Ave point cloud density per sq.m. (>2.0)	6.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	114
Maximum Height	305.22 m
Minimum Height	38.03 m
Classification (# of points)	
Ground	32,427,001
Low vegetation	37,721,817
Medium vegetation	110,646,645
High vegetation	368,270,681
Building	4,464,003
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Antonio Chua Jr., Engr. Krisha Marie Bautista

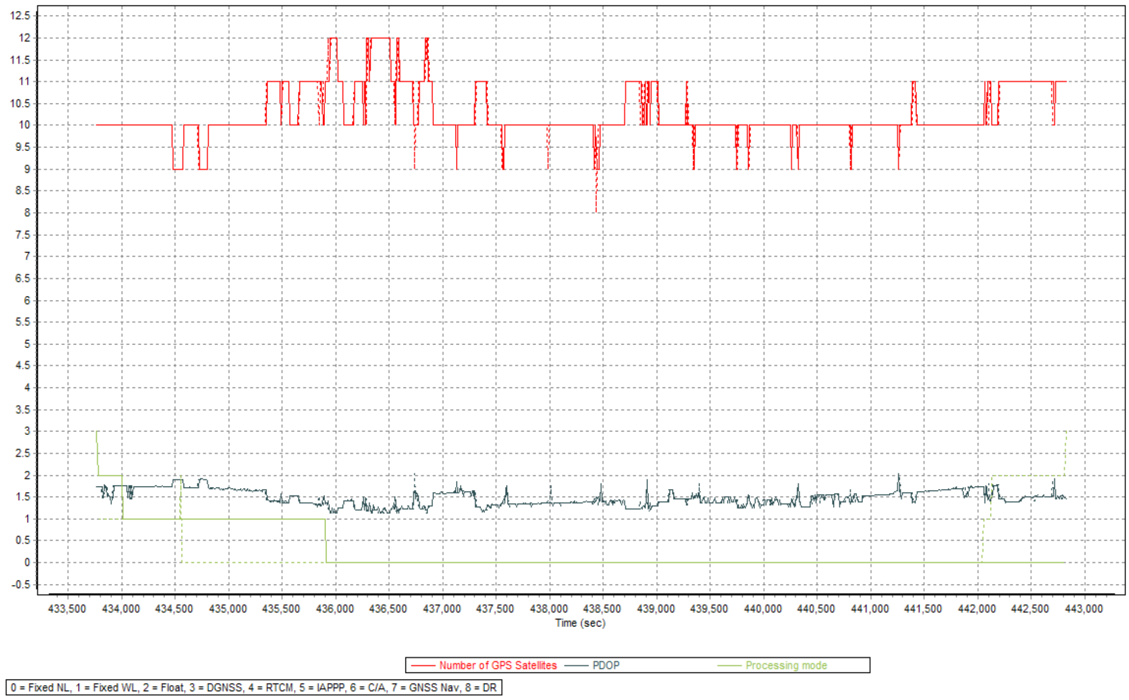


Figure A-8.120. Solution Status

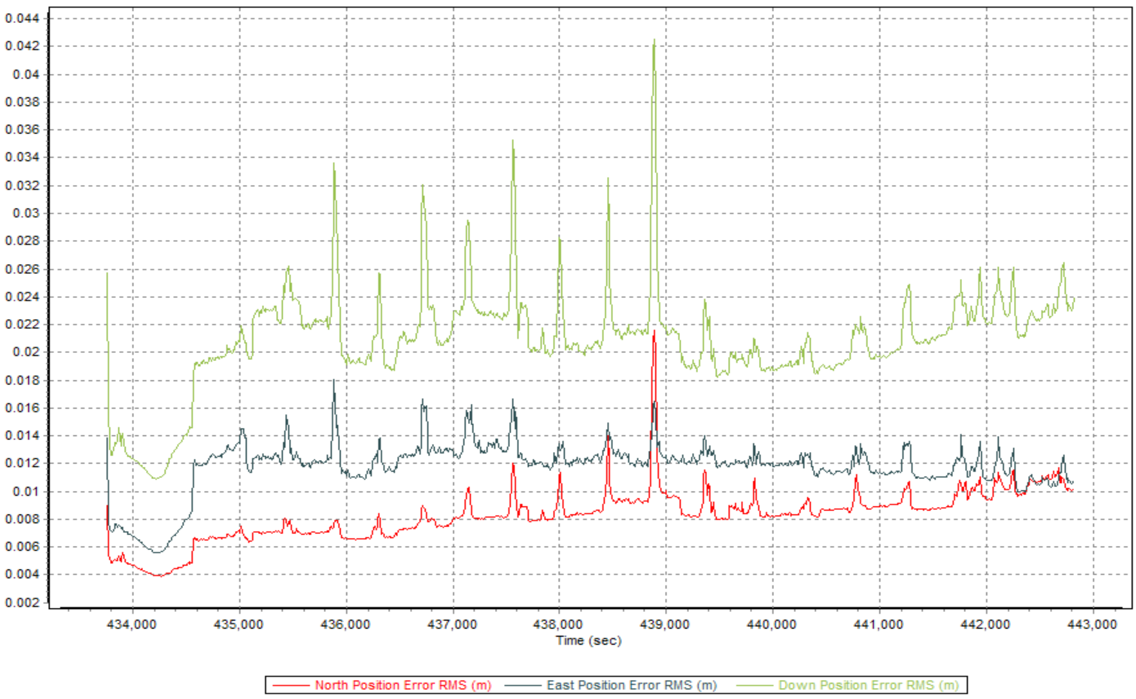


Figure A-8.121. Smoothed Performance Metrics Parameters

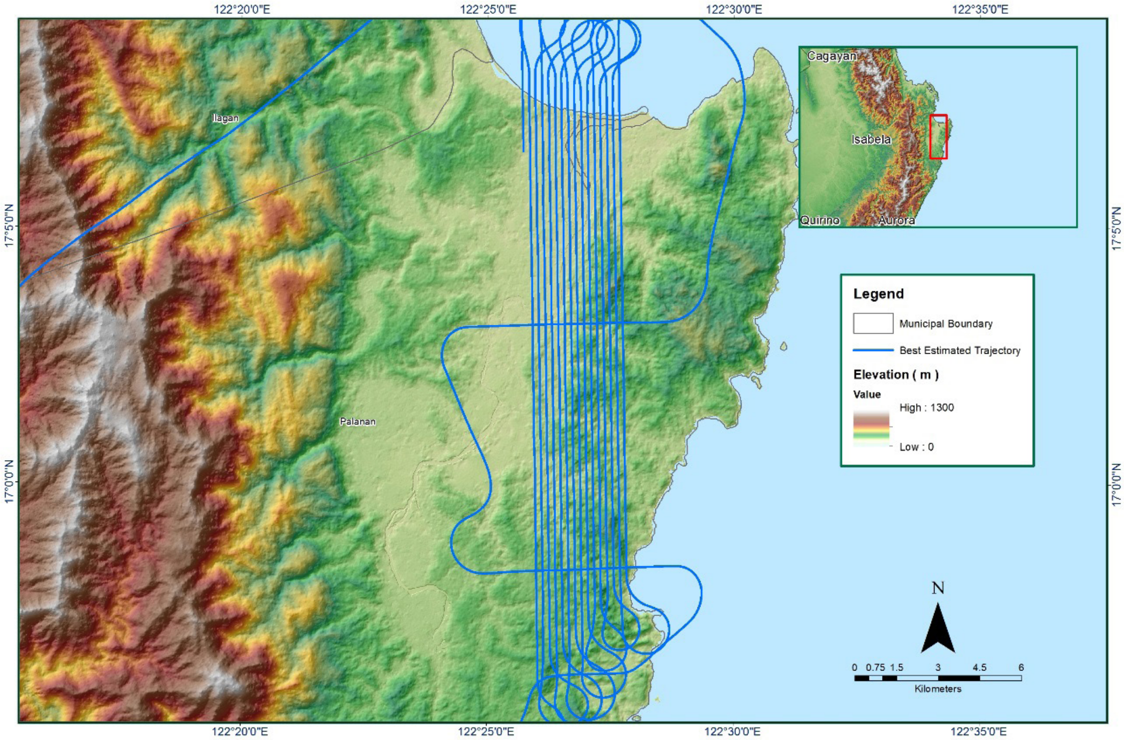


Figure A-8.122. Best Estimated Trajectory

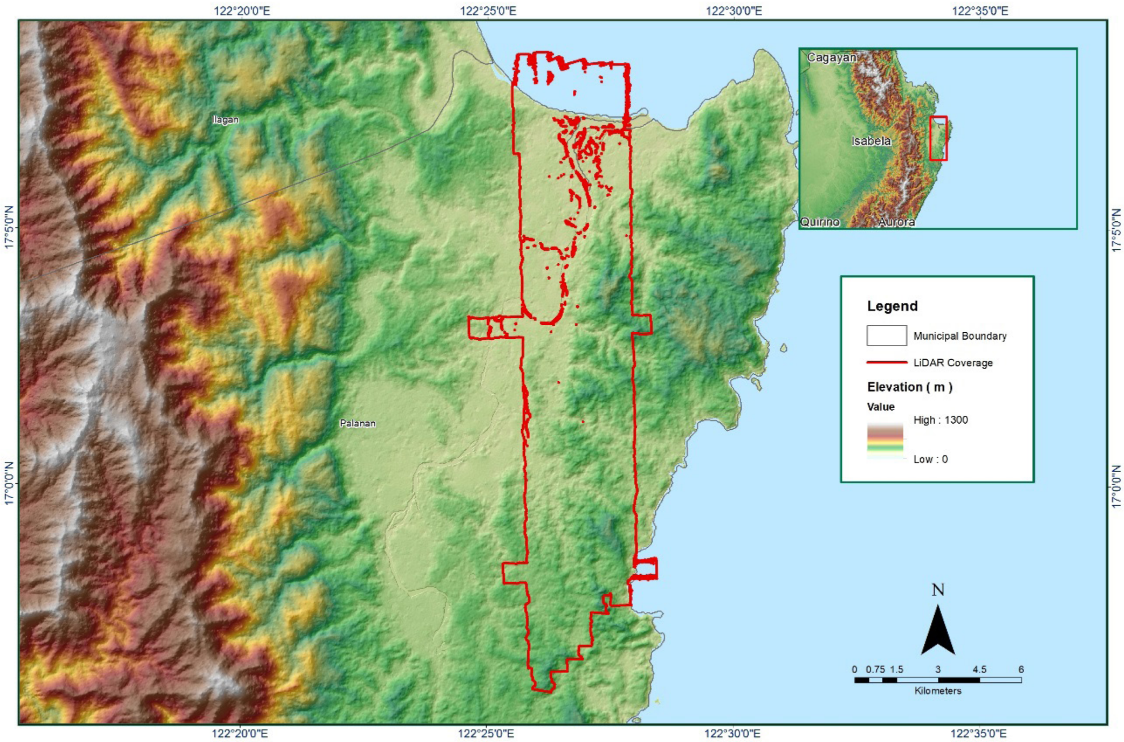


Figure A-8.123. Coverage of LiDAR data

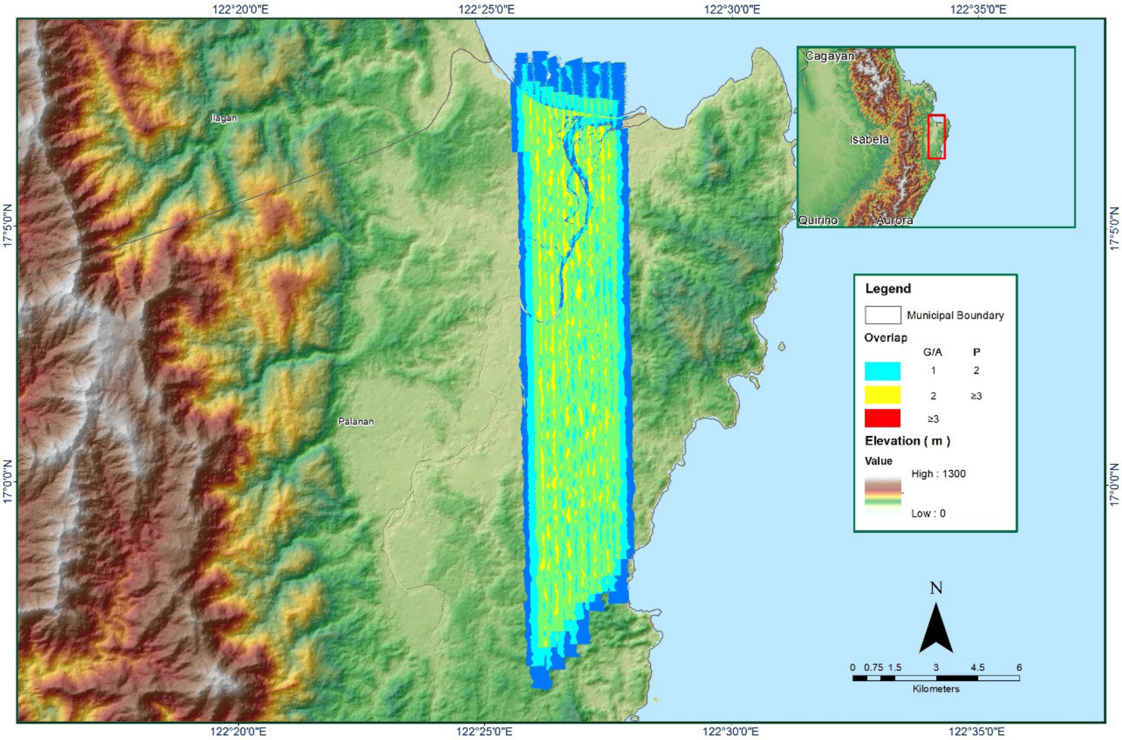


Figure A-8.124. Image of data overlap

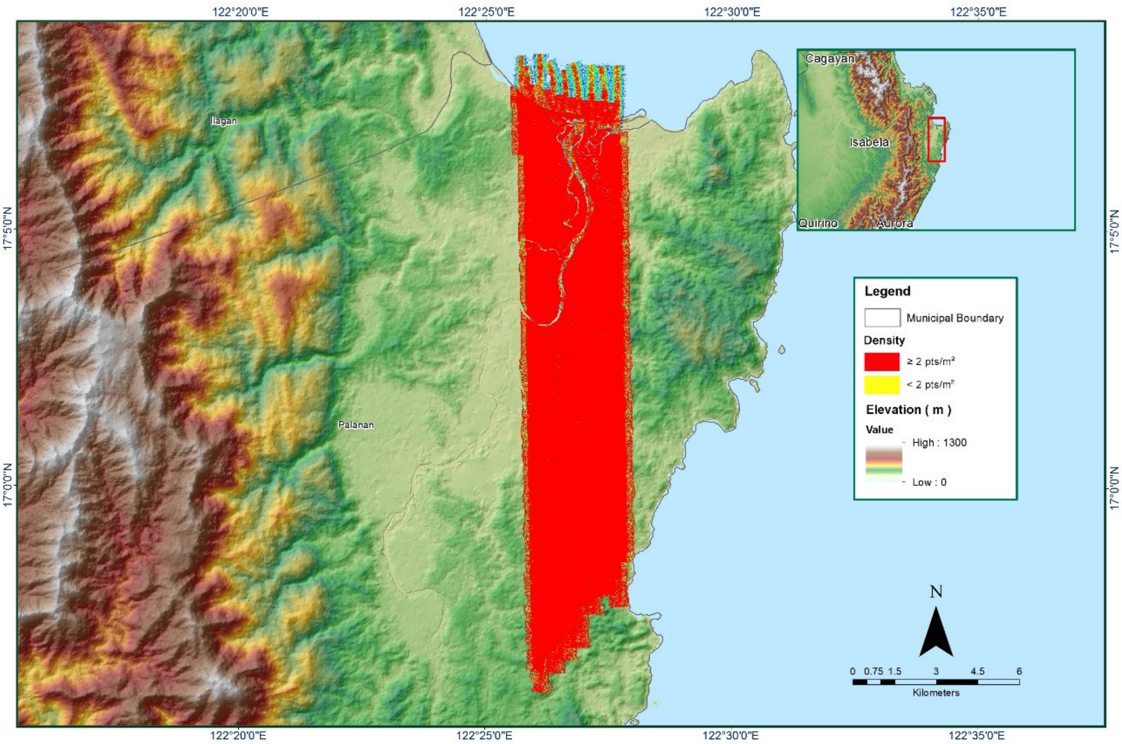


Figure A-8.125. Density map of merged LiDAR data

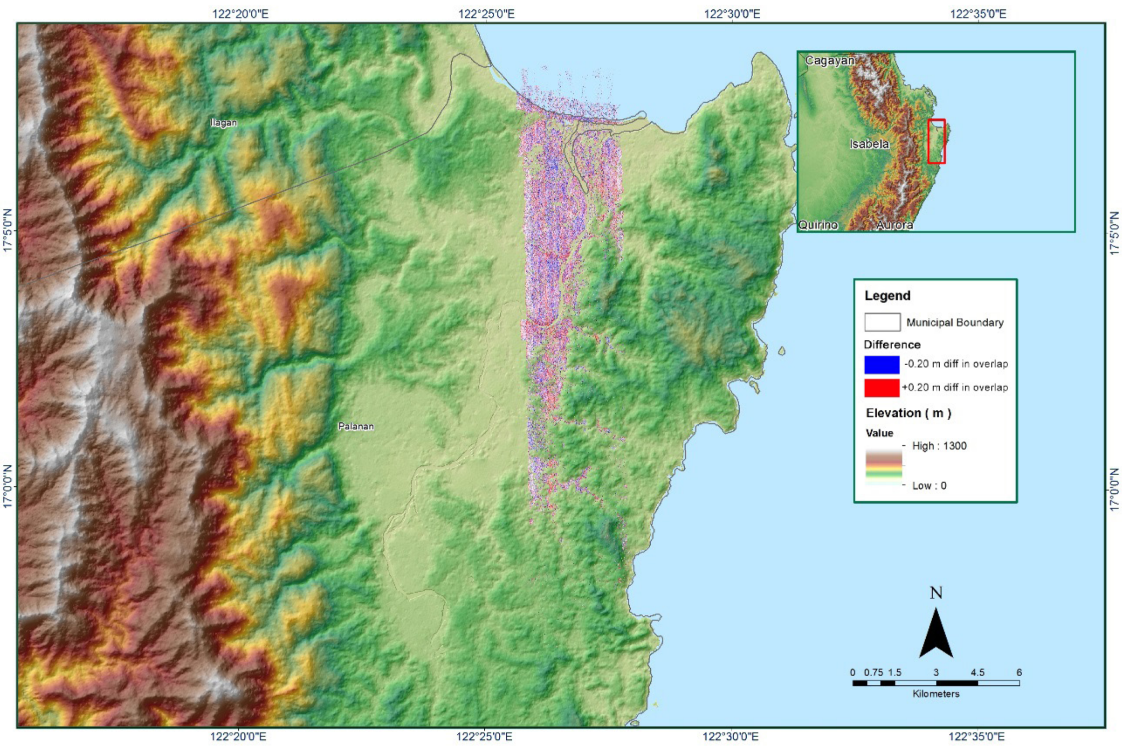


Figure A-8.126. Elevation difference between flight lines

Table A-8.19. Mission Summary Report for Mission Blk9B

Flight Area	Palanan
Mission Name	Blk 9B
Inclusive Flights	2702G, 2706G
Range data size	32.41 GB
POS	334 MB
Image	59.7 GB
Transfer date	10/5/15
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)	1.6
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000013
IMU attitude correction stdev (<0.001deg)	0.001632
GPS position stdev (<0.01m)	0.0253
Minimum % overlap (>25)	54.19%
Ave point cloud density per sq.m. (>2.0)	5.29
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	287
Maximum Height	703.16 m
Minimum Height	31.31 m
Classification (# of points)	
Ground	58,881,933
Low vegetation	43,838,207
Medium vegetation	186,980,397
High vegetation	831,308,545
Building	4,182,154
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr Velina Angela Bemida, Kathryn Claudyn Zarate

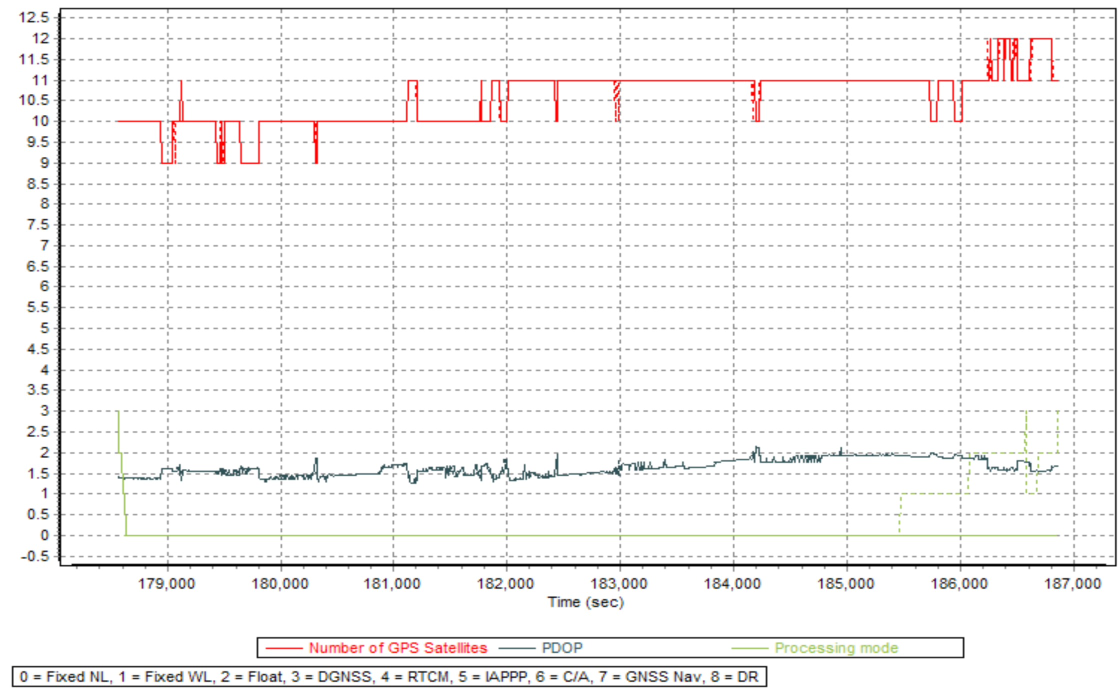


Figure A-8.127. Solution Status

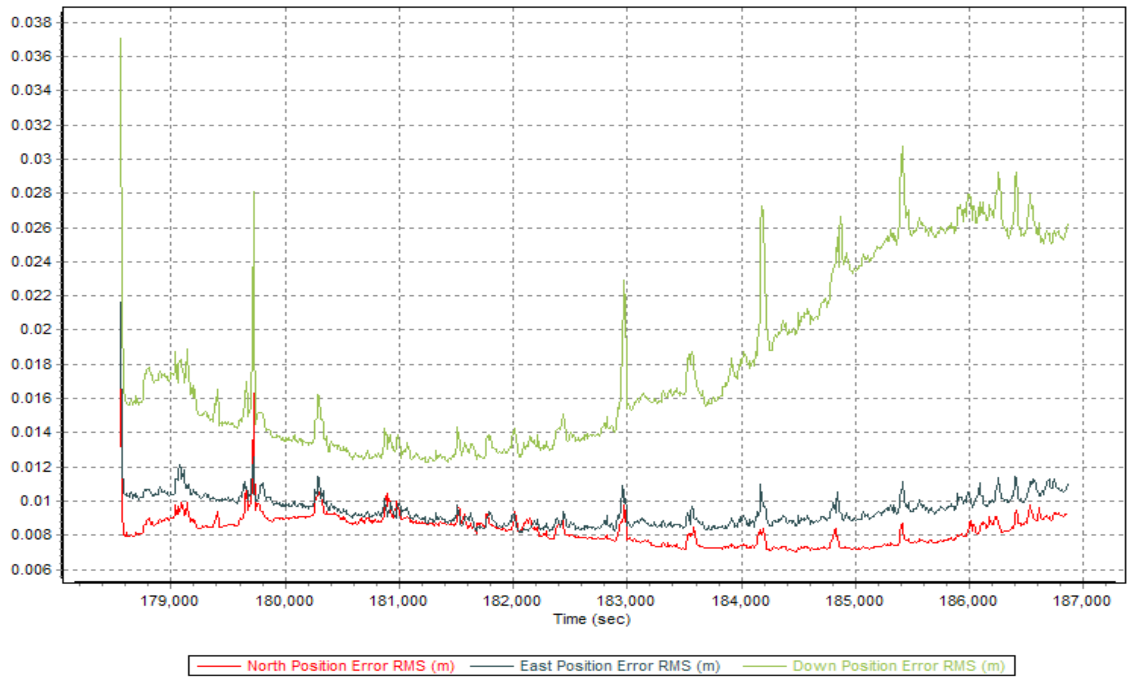


Figure A-8.128. Smoothed Performance Metrics Parameters

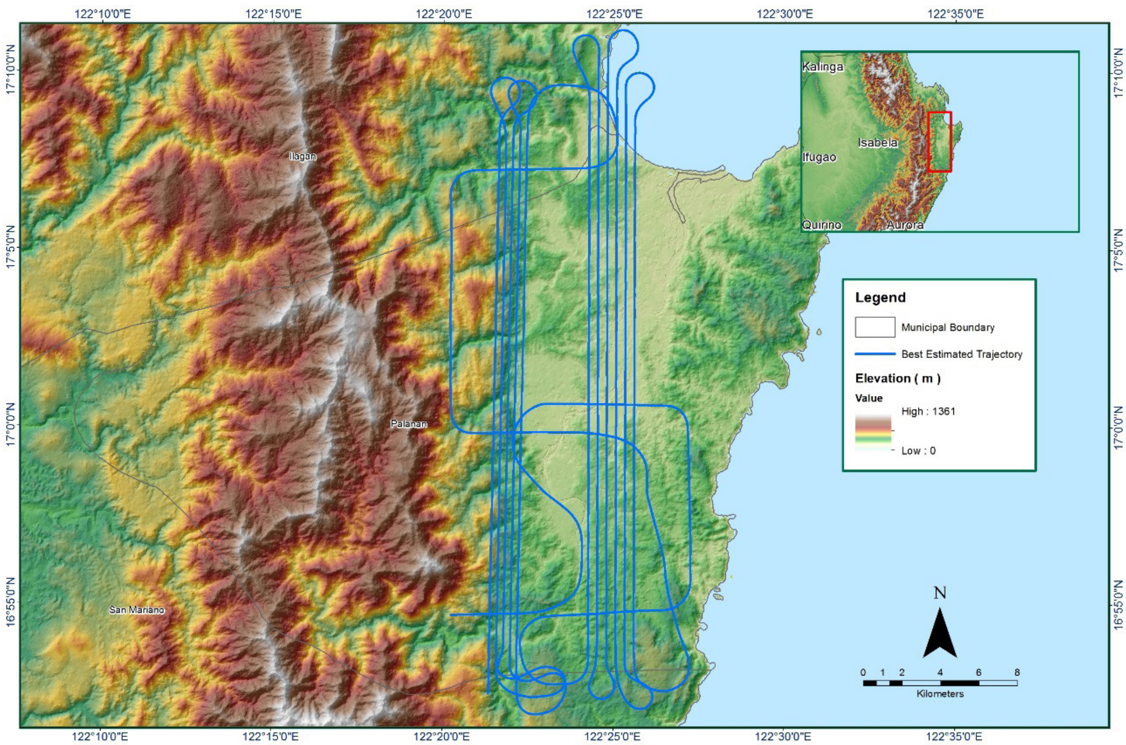


Figure A-8.129. Best Estimated

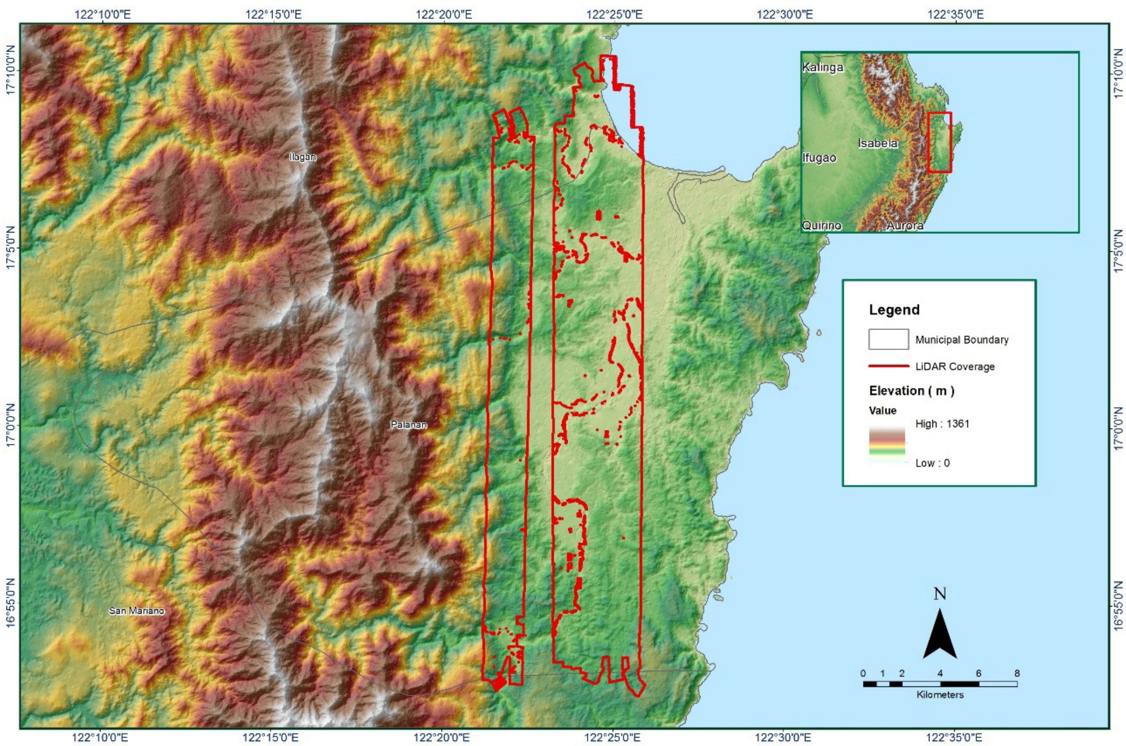


Figure A-8.130. Coverage of LiDAR data

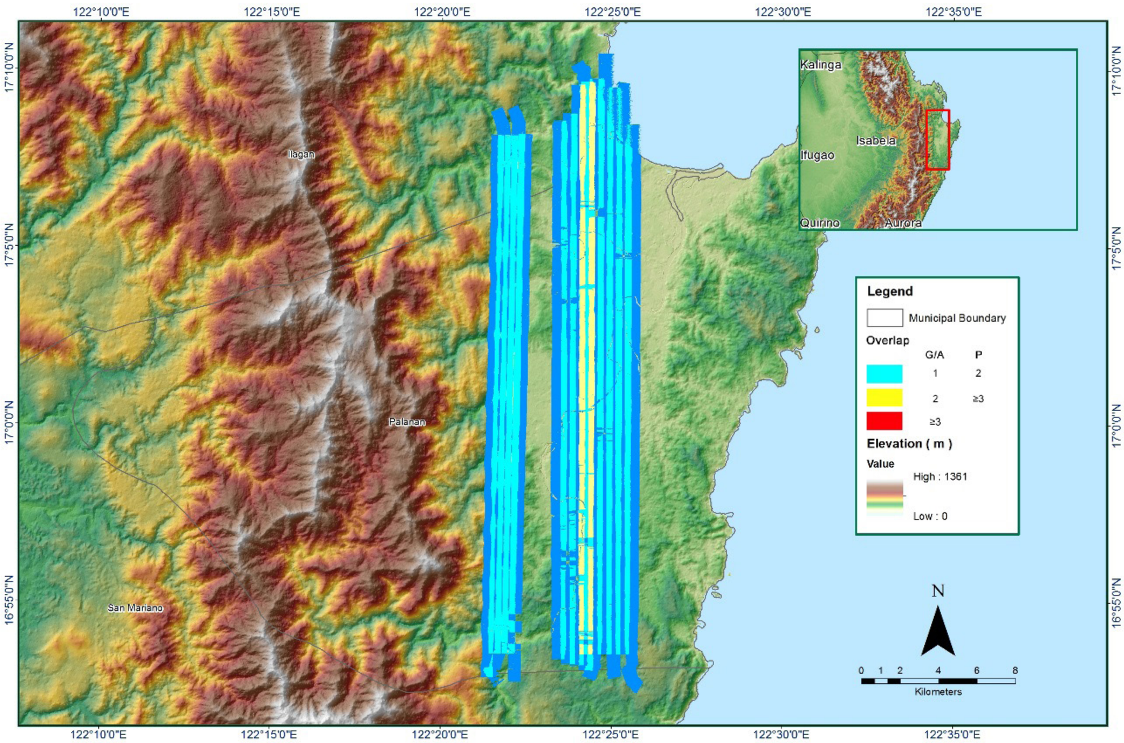


Figure A-8.131. Image of data overlap

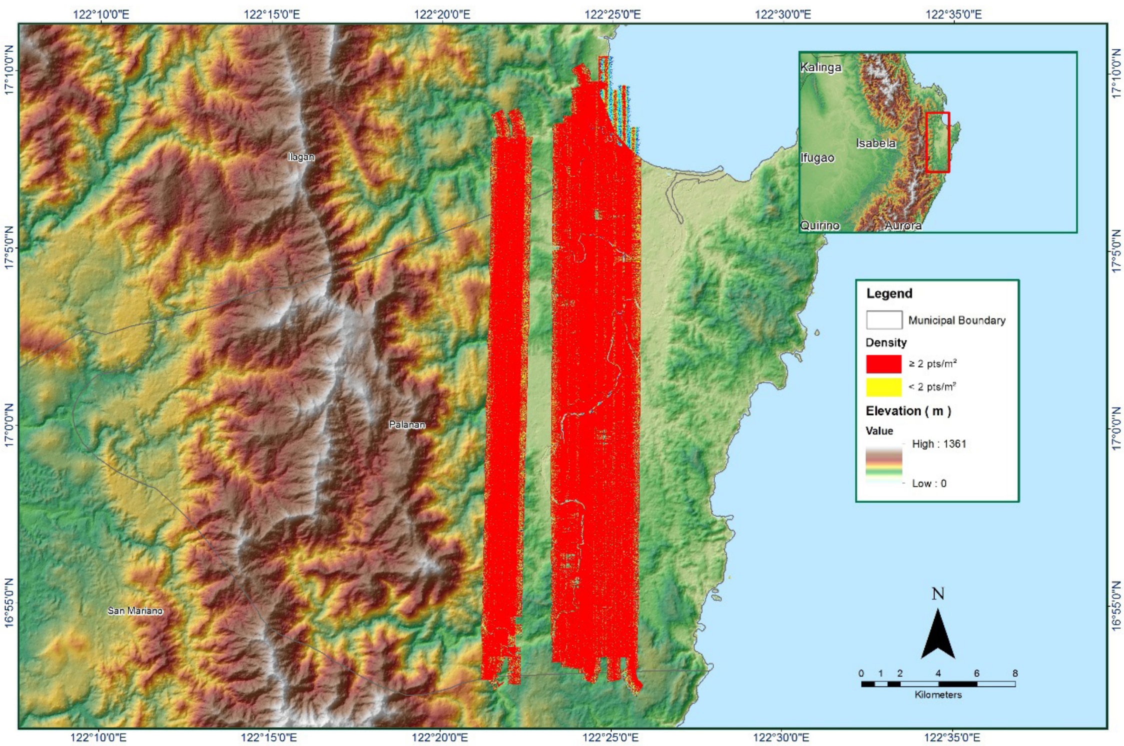


Figure A-8.132. Density map of merged LiDAR data

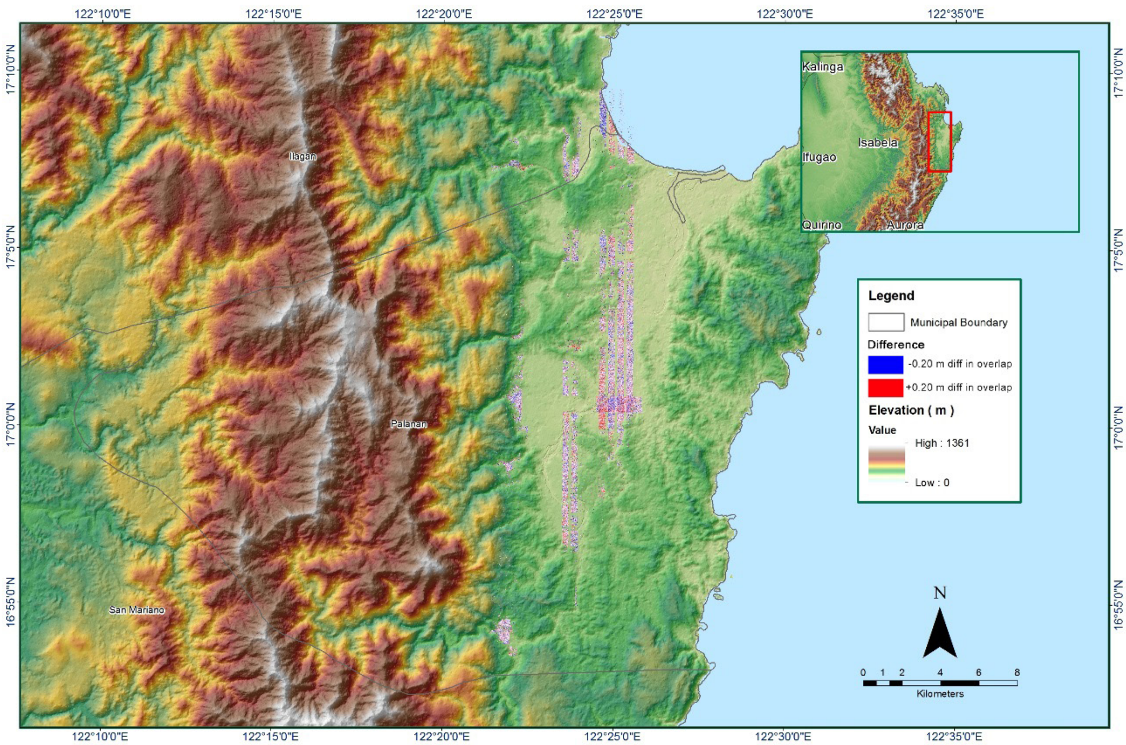


Figure A-8.133. Elevation difference between flight lines

Table A-8.20. Mission Summary Report for Mission Blk171F

Flight Area	Cagayan Reflights Tuguegarao
Mission Name	Blk 101D_additional
Inclusive Flights	2914P
Range data size	17.1 GB
POS data size	190 MB
Base data size	97.1 MB
Image	3.48 MB
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)	0.96
RMSE for East Position (<4.0 cm)	1.0
RMSE for Down Position (<8.0 cm)	1.7
Boresight correction stdev (<0.001deg)	0.018665
IMU attitude correction stdev (<0.001deg)	0.088343
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	N/A
Ave point cloud density per sq.m. (>2.0)	2.27
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	50
Maximum Height	120.6
Minimum Height	25.77
Classification (# of points)	
Ground	39052107
Low vegetation	23028006
Medium vegetation	14721848
High vegetation	13621357
Building	1924633
Orthophoto	No
Processed by	Engr. Sheila,Maye Santillan, Engr. Harmond Santos, Engr. Krisha Marie Bautista

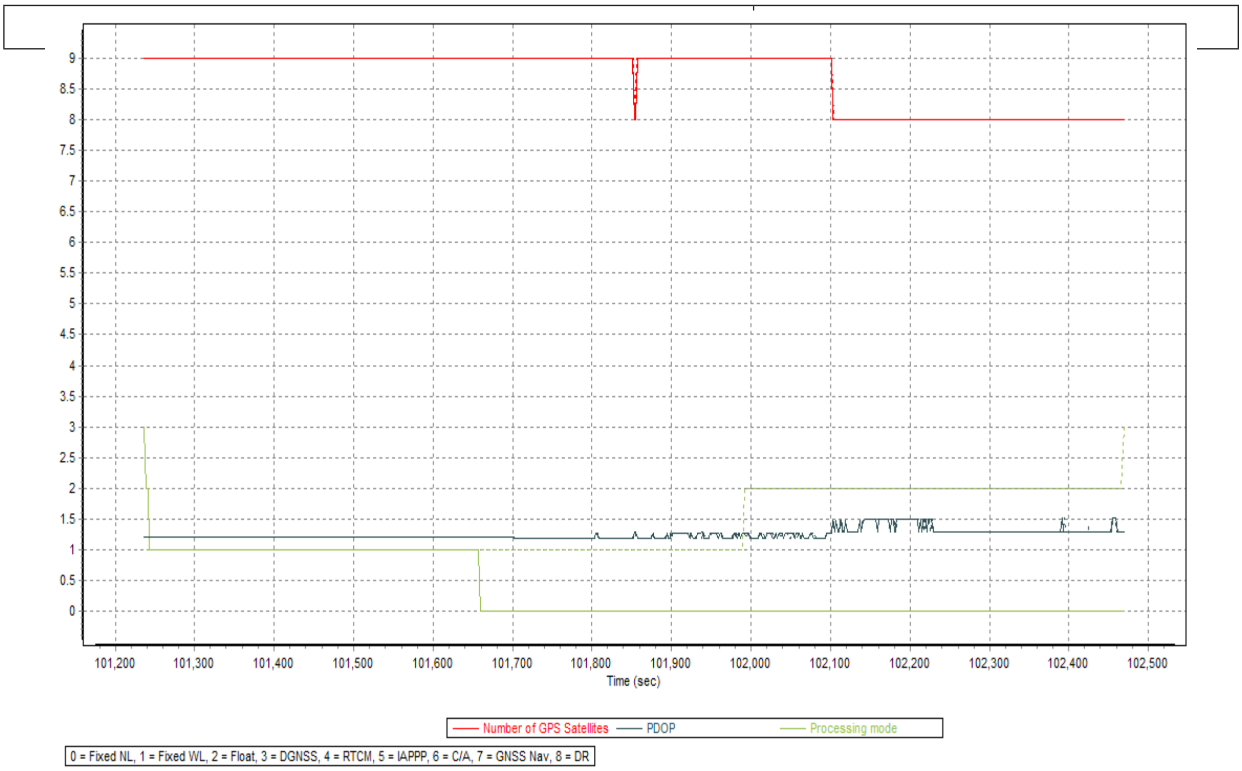


Figure A-8.134. Solution Status

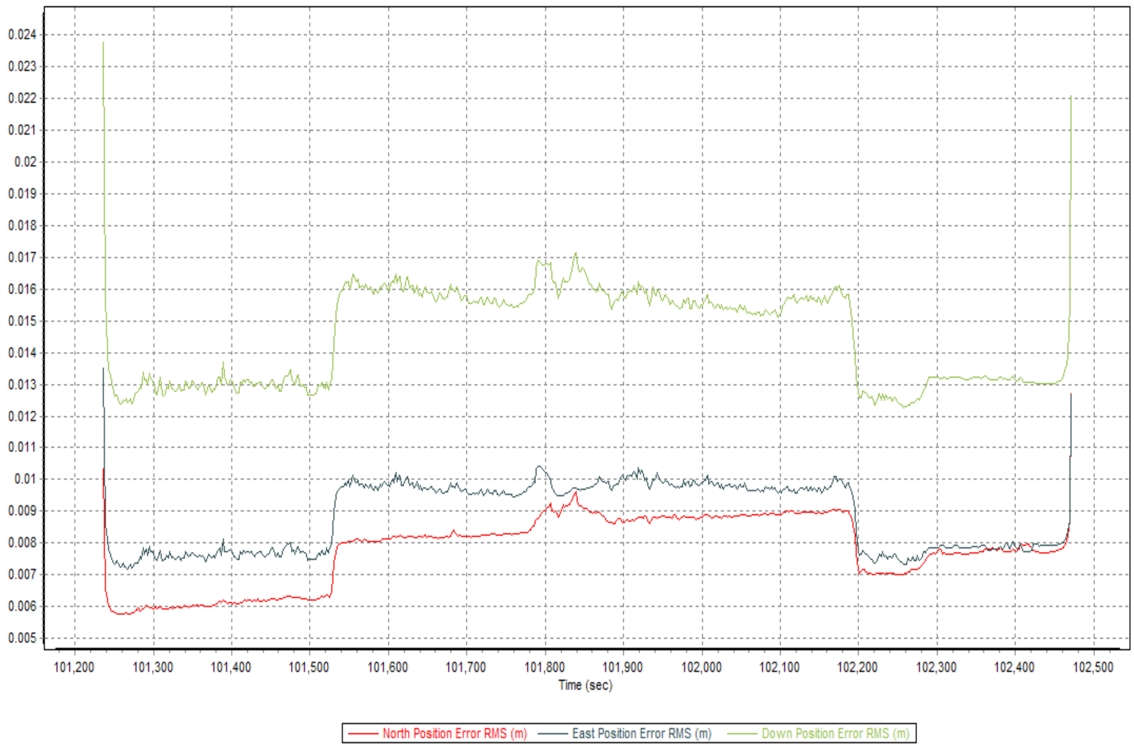


Figure A-8.135. Smoothed Performance Metrics Parameters

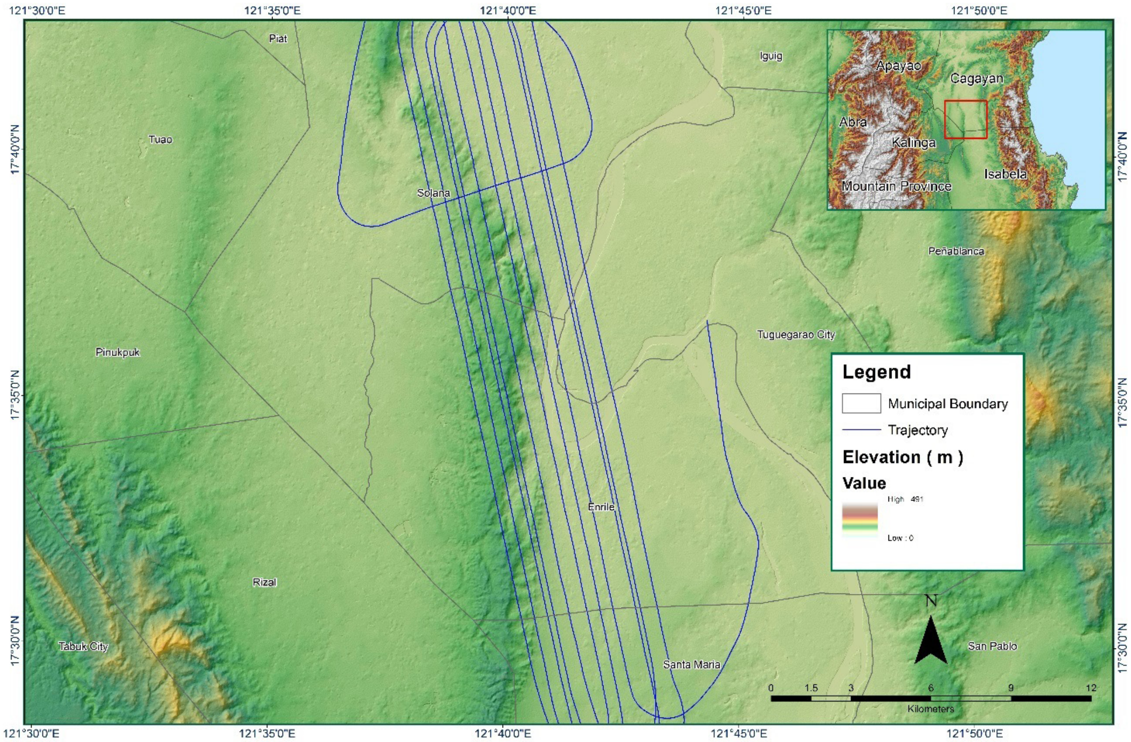


Figure A-8.136. Best Estimated Trajectory

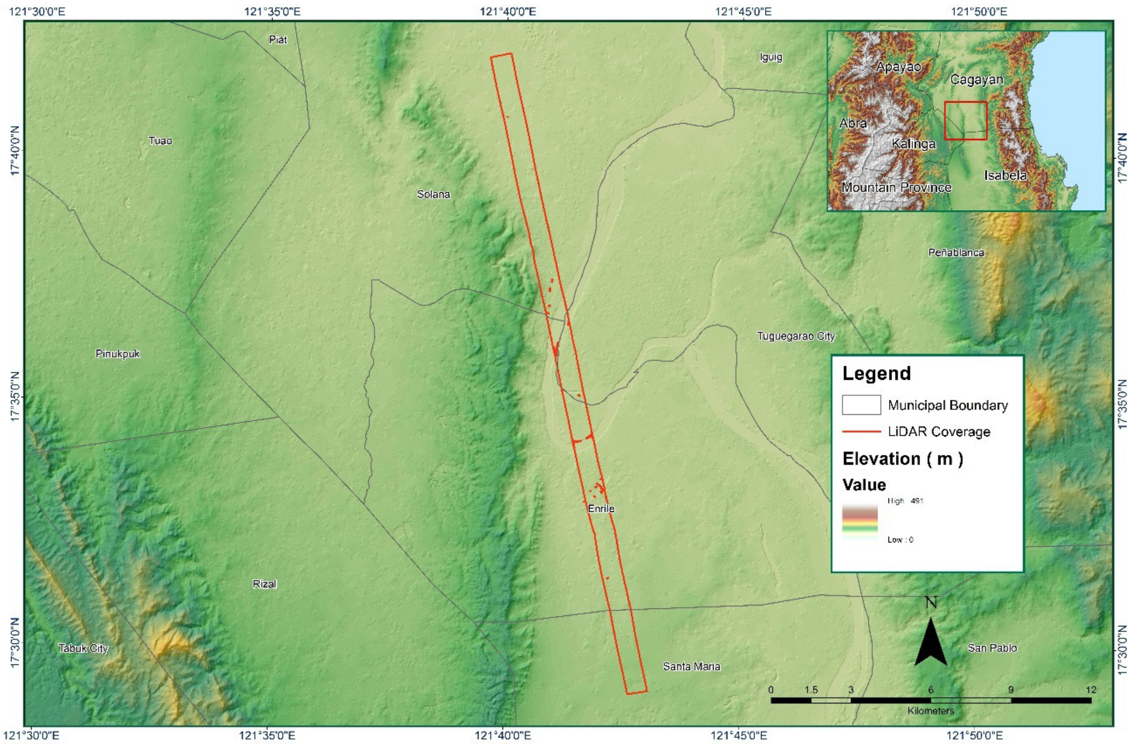


Figure A-8.137. Coverage of LiDAR data

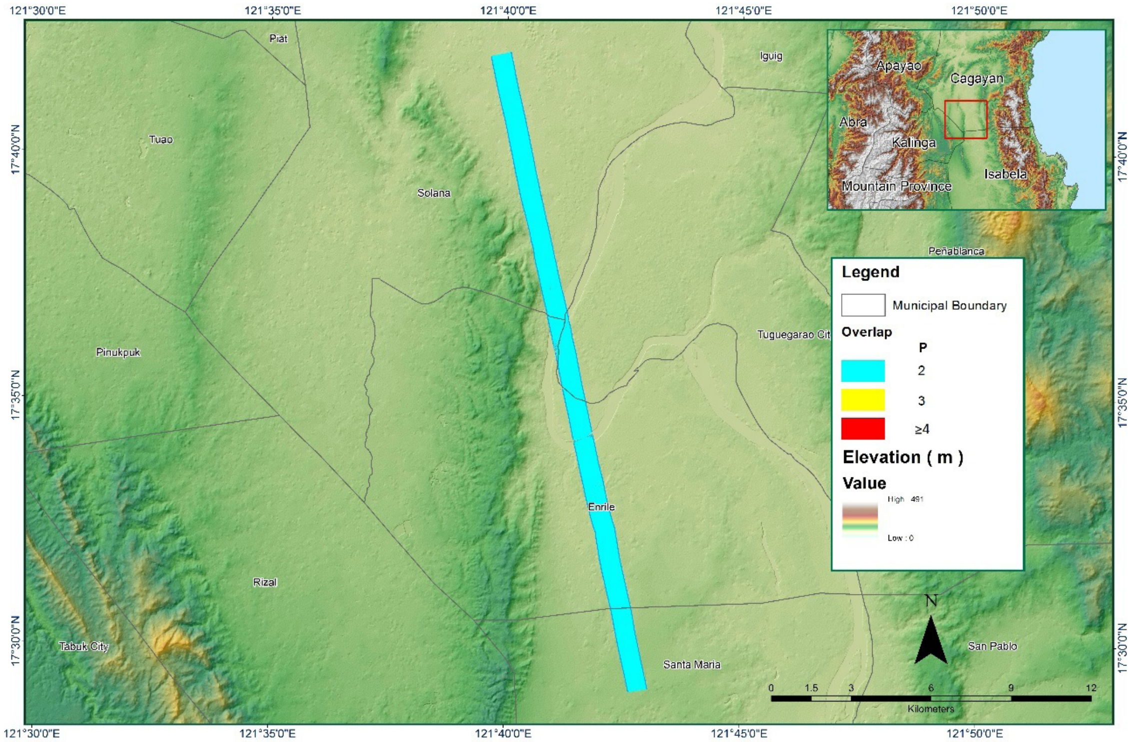


Figure A-8.138. Image of data overlap

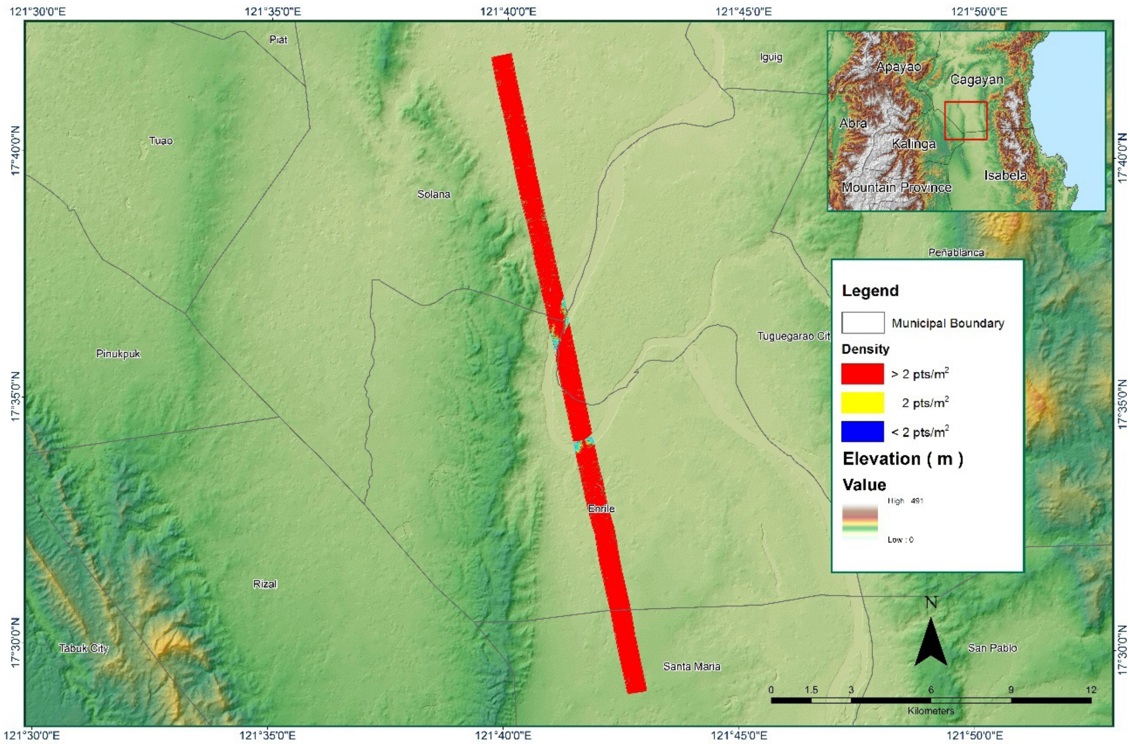


Figure A-8.139. Density map of merged LiDAR data

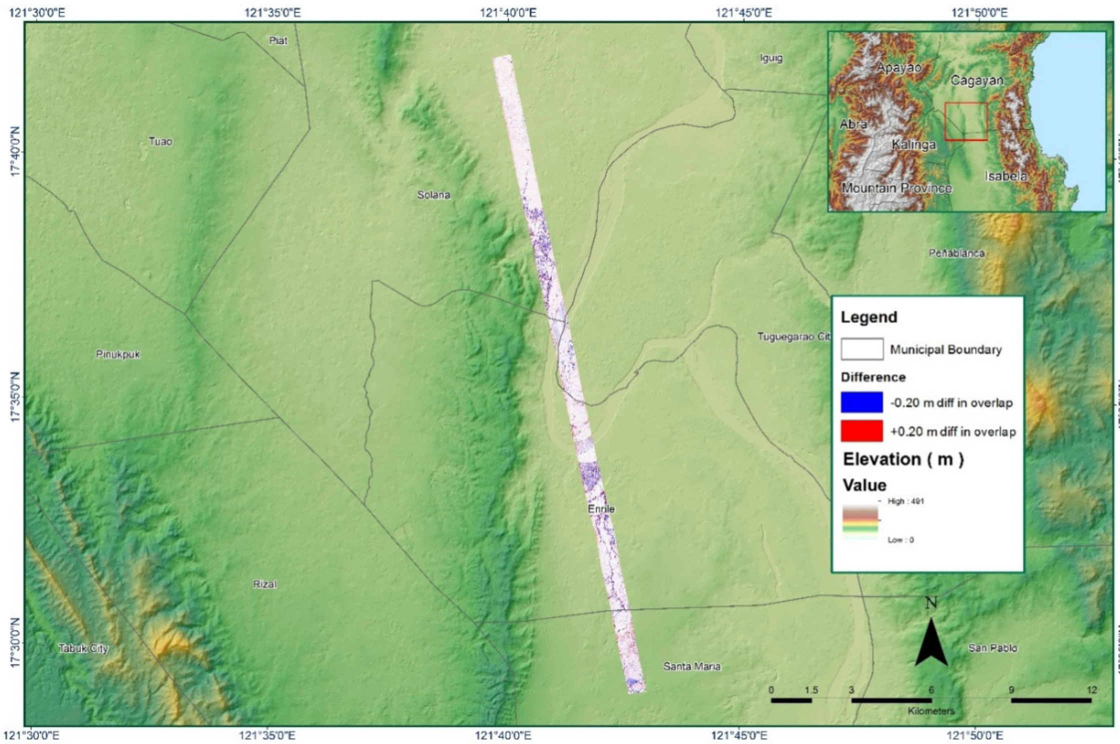


Figure A-8.140. Elevation difference between flight lines

Table A-8.21. Mission Summary Report for Mission Blk101D

Flight Area	Cagayan Reflights Tuguegarao
Mission Name	Blk 101D
Inclusive Flights	2898P
Range data size	19.2 GB
POS data size	167 MB
Base data size	62.2 MB
Image	25.9 MB
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)	2.3
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	4.8
Boresight correction stdev (<0.001deg)	0.000367
IMU attitude correction stdev (<0.001deg)	0.001668
GPS position stdev (<0.01m)	0.0103
Minimum % overlap (>25)	4.27%
Ave point cloud density per sq.m. (>2.0)	2.68
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	172
Maximum Height	725.31
Minimum Height	0
Classification (# of points)	
Ground	291287573
Low vegetation	161982049
Medium vegetation	160438293
High vegetation	158956026
Building	13582654
Orthophoto	yes
Processed by	Eng. Jennifer Saguran, Engr. Merven Mattew Natino, Marie Denise Bueno

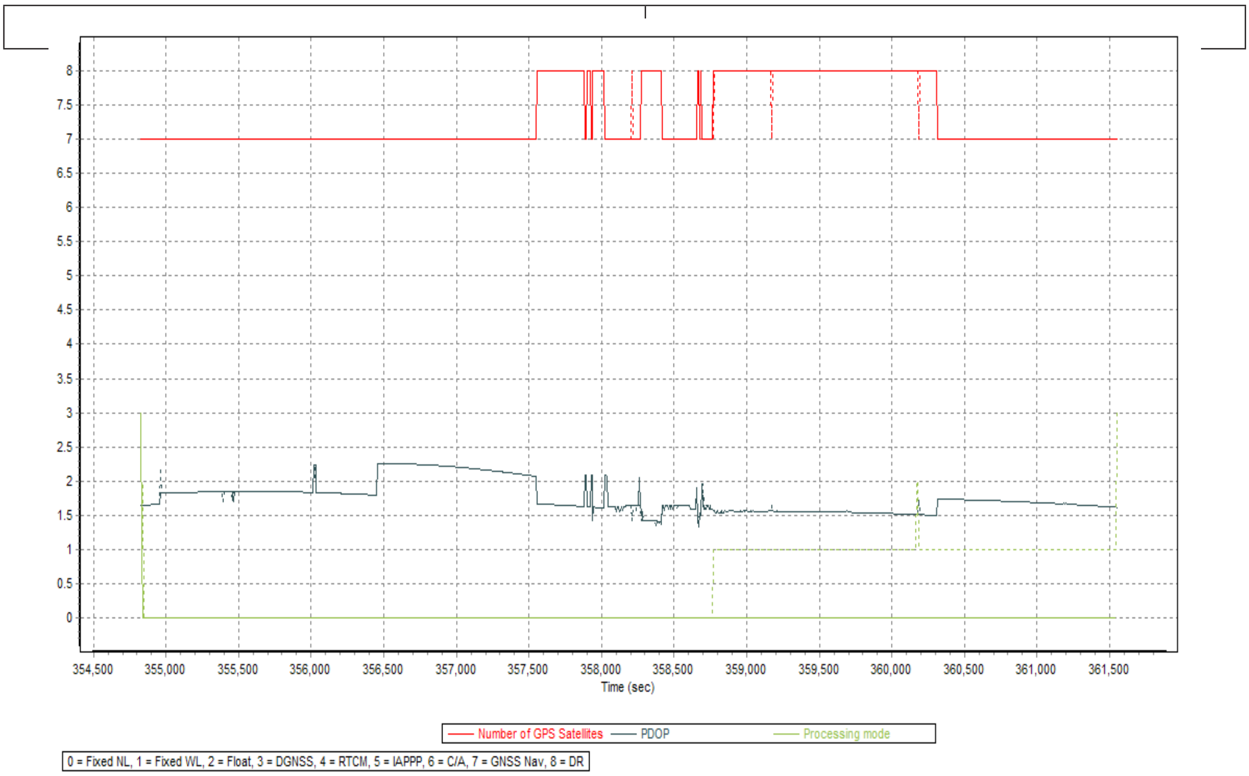


Figure A-8.141. Solution Status

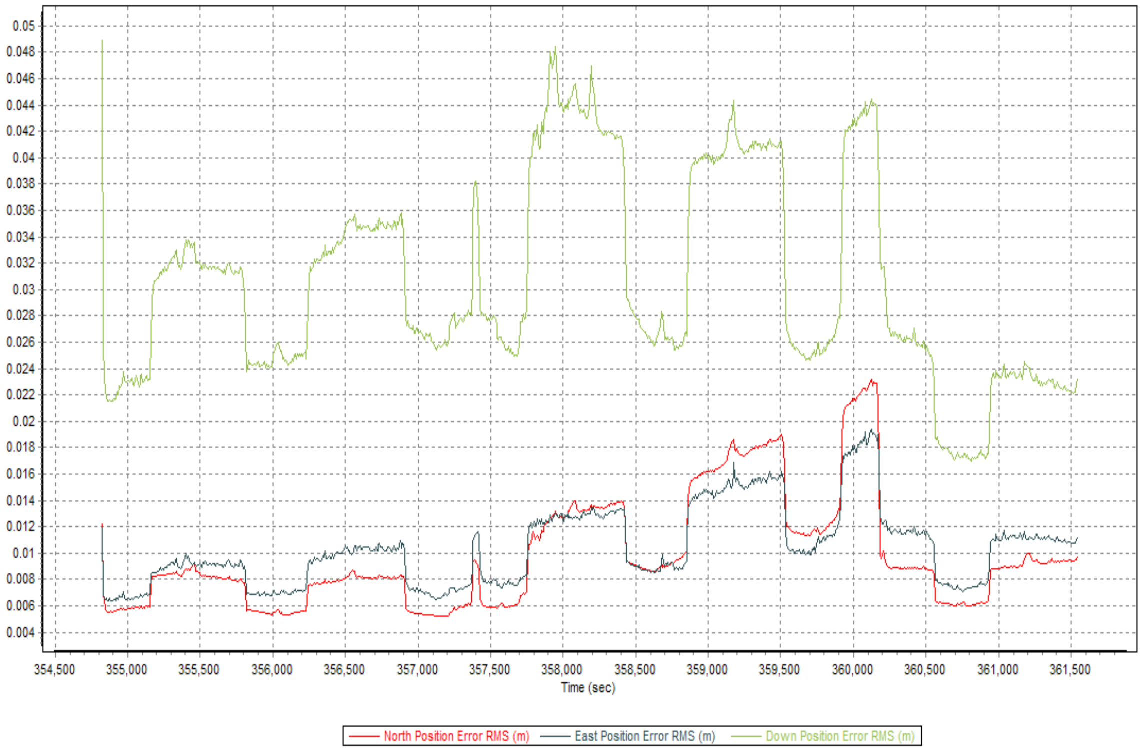


Figure A-8.142. Smoothed Performance Metrics Parameters

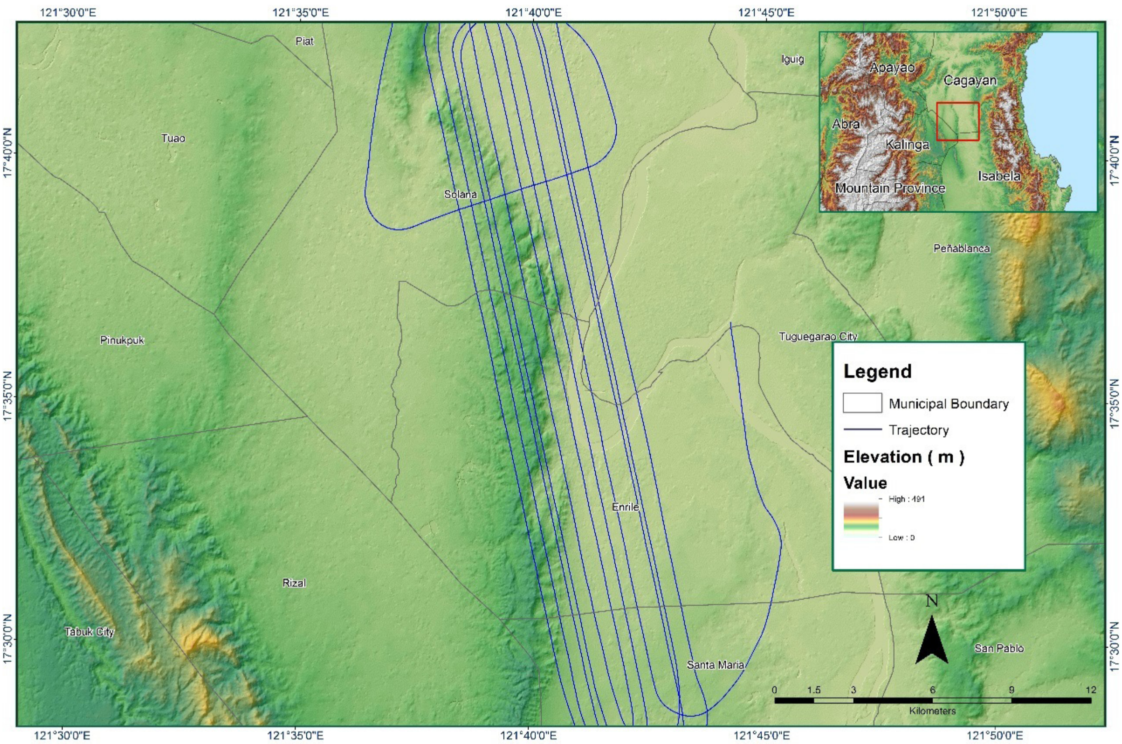


Figure A-8.143. Best Estimated Trajectory

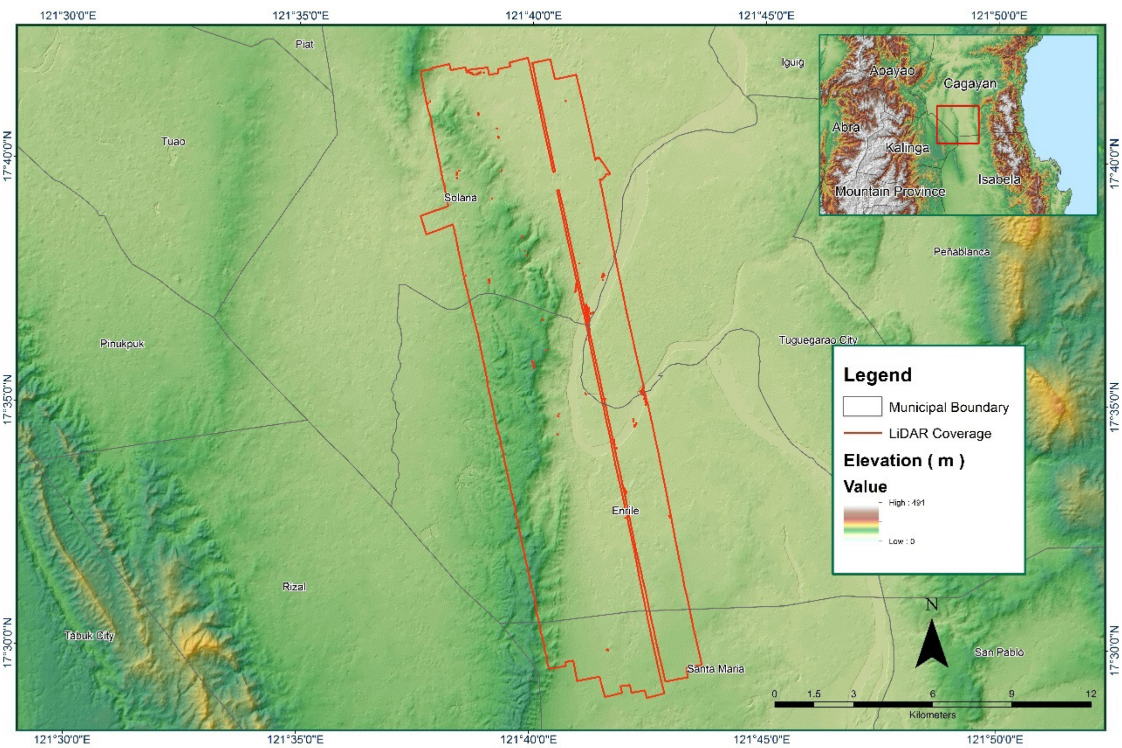


Figure A-8.144. Coverage of LiDAR data

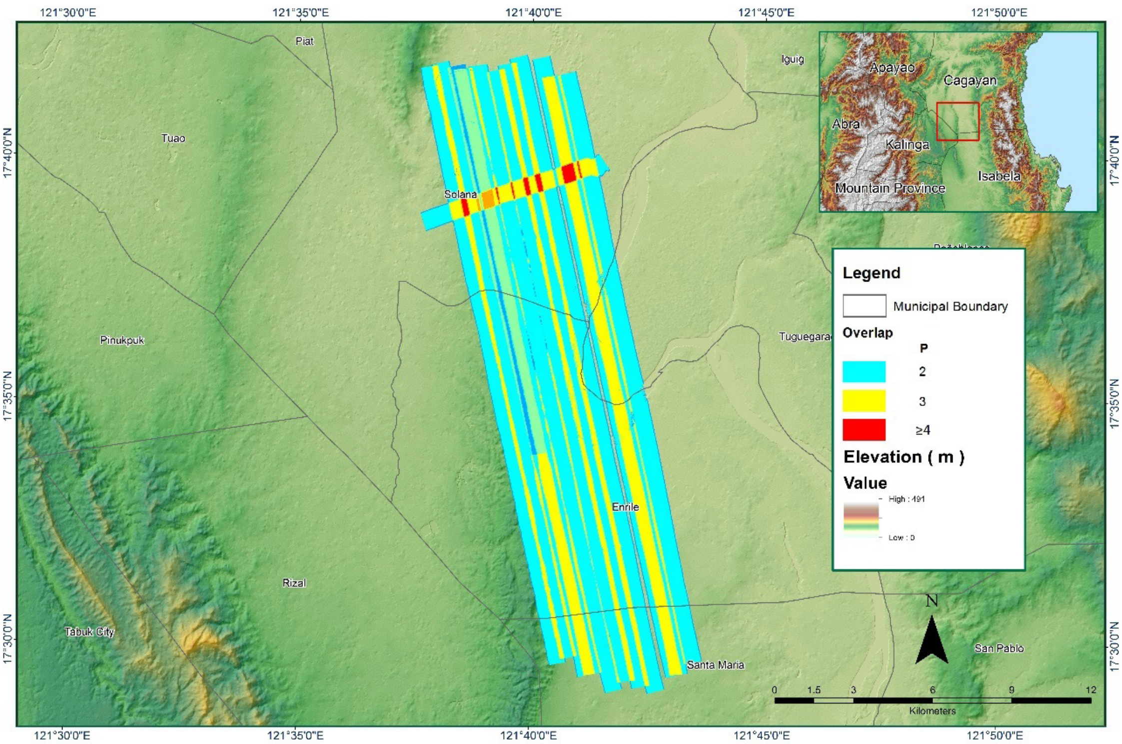


Figure A-8.145. Image of data overlap

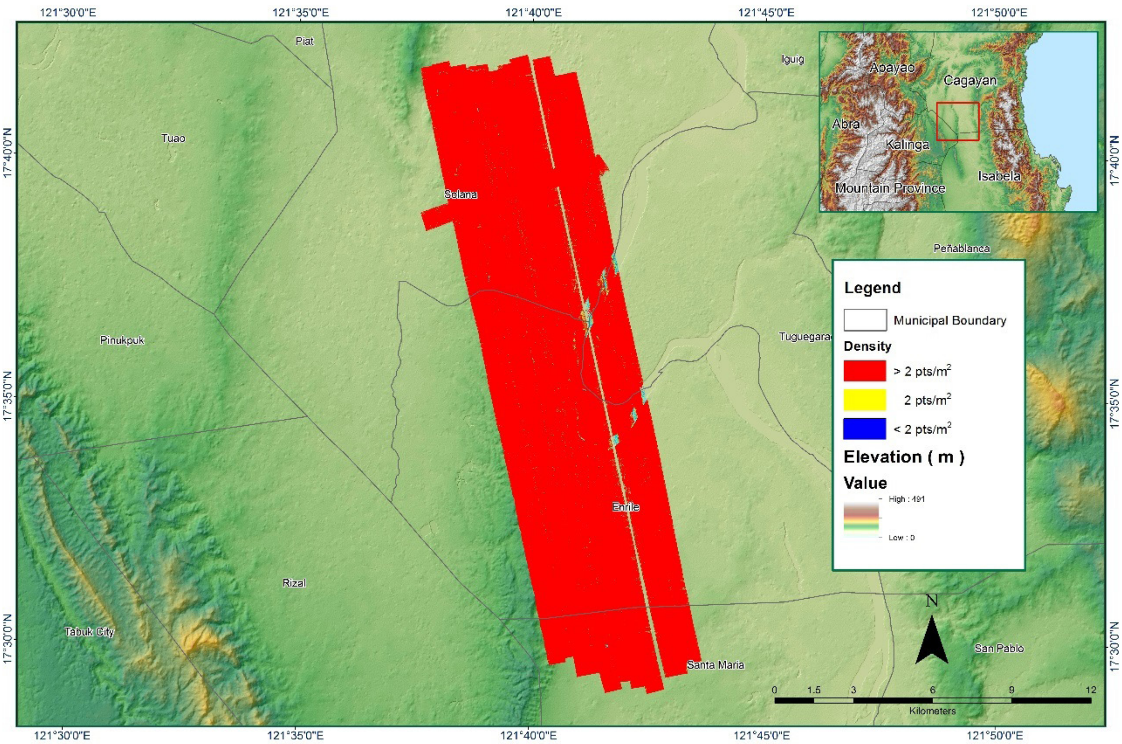


Figure A-8.146. Density map of merged LiDAR data

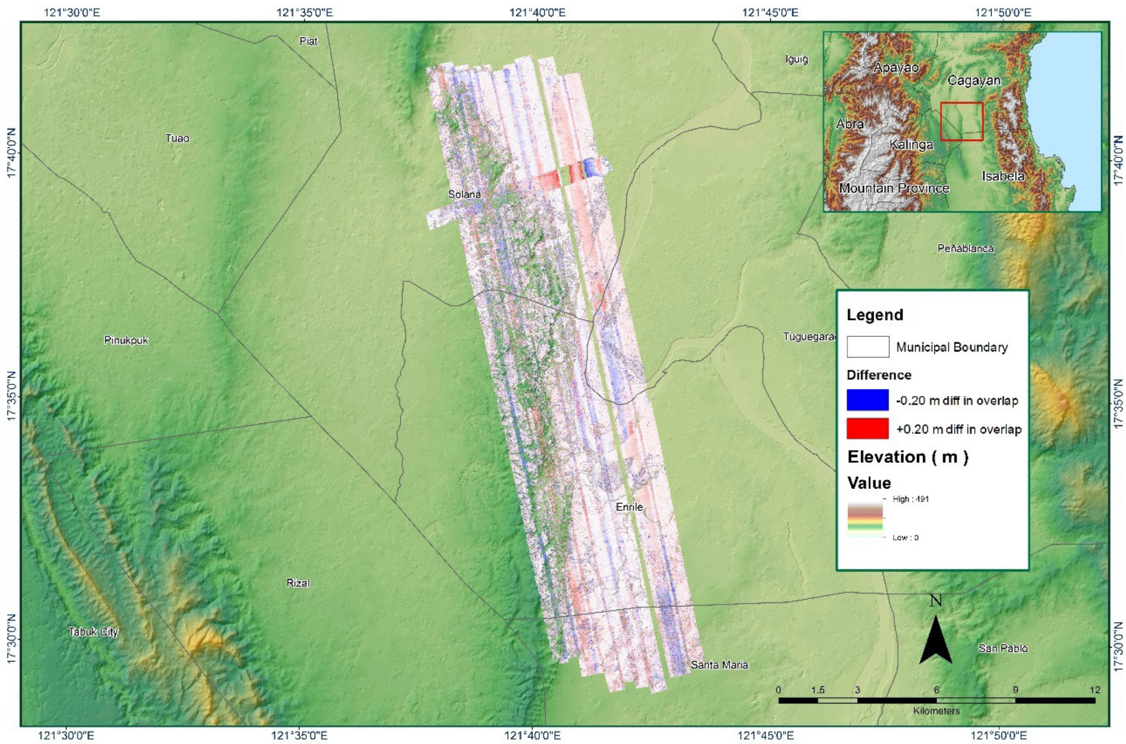


Figure A-8.147. Elevation difference between flight lines

Table A-8.22. Mission Summary Report for Mission Blk101BC

Flight Area	Cagayan Reflights Tuguegarao
Mission Name	Blk 101BC
Inclusive Flights	2894P
Range data size	22.3 GB
POS data size	215 MB
Base data size	8.95 MB
Image	36.8 MB
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)	1.78
RMSE for East Position (<4.0 cm)	2.0
RMSE for Down Position (<8.0 cm)	6.1
Boresight correction stdev (<0.001deg)	0.000375
IMU attitude correction stdev (<0.001deg)	0.001590
GPS position stdev (<0.01m)	0.0011
Minimum % overlap (>25)	15.71%
Ave point cloud density per sq.m. (>2.0)	2.71
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	201
Maximum Height	203.83
Minimum Height	68.32
Classification (# of points)	
Ground	313089108
Low vegetation	275731421
Medium vegetation	283015013
High vegetation	110292514
Building	8245649
Orthophoto	Yes
Processed by	Engr. Abigail Ching, Engr. Mark Joshua Salvacion, Jovy Narisma

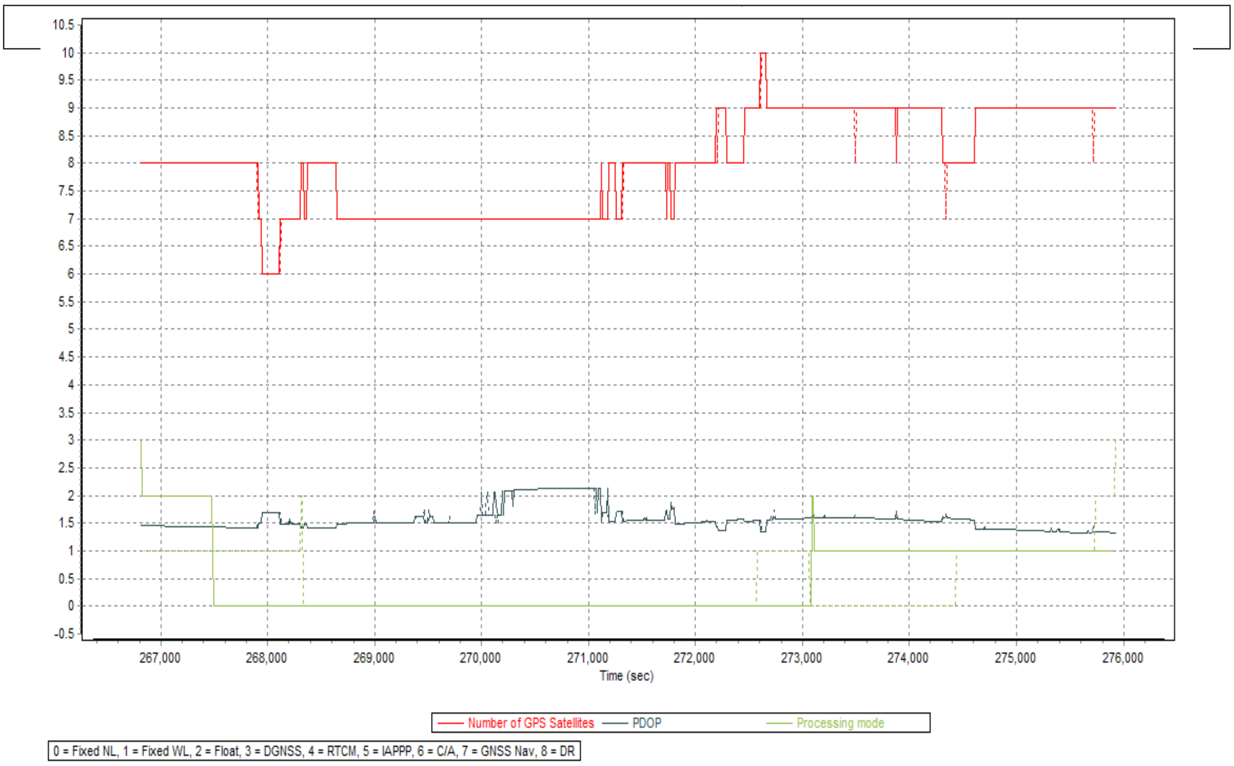


Figure A-8.148. Solution Status

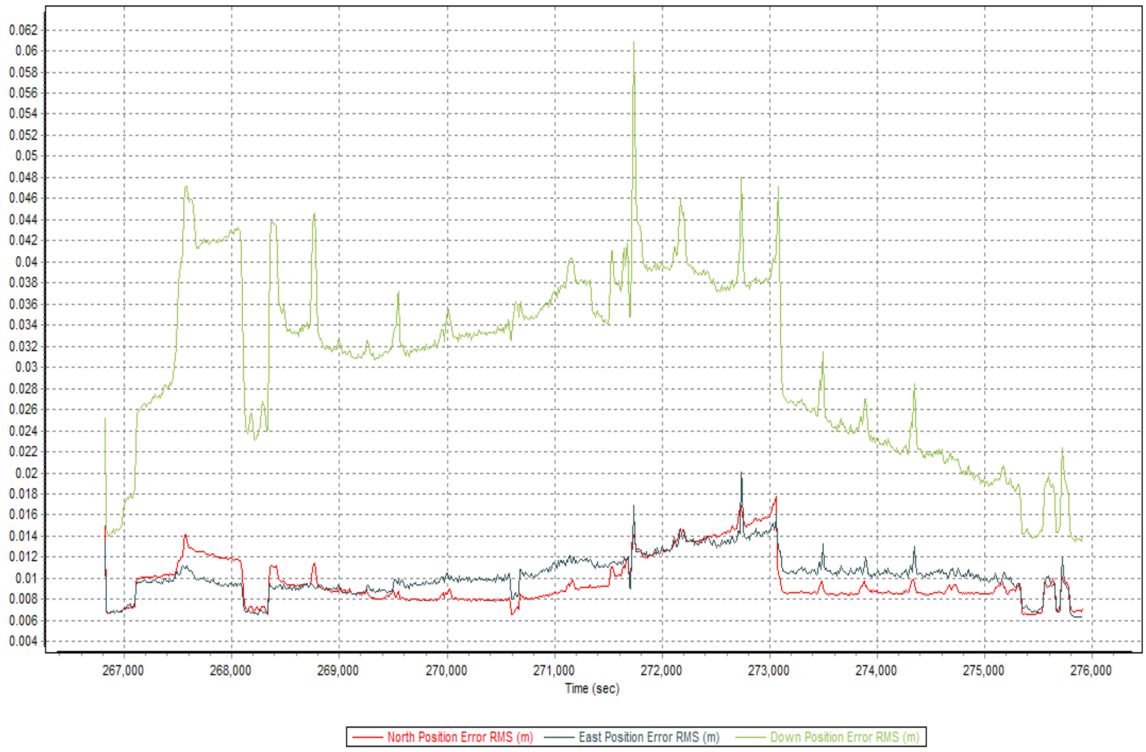


Figure A-8.149. Smoothed Performance Metrics Parameters

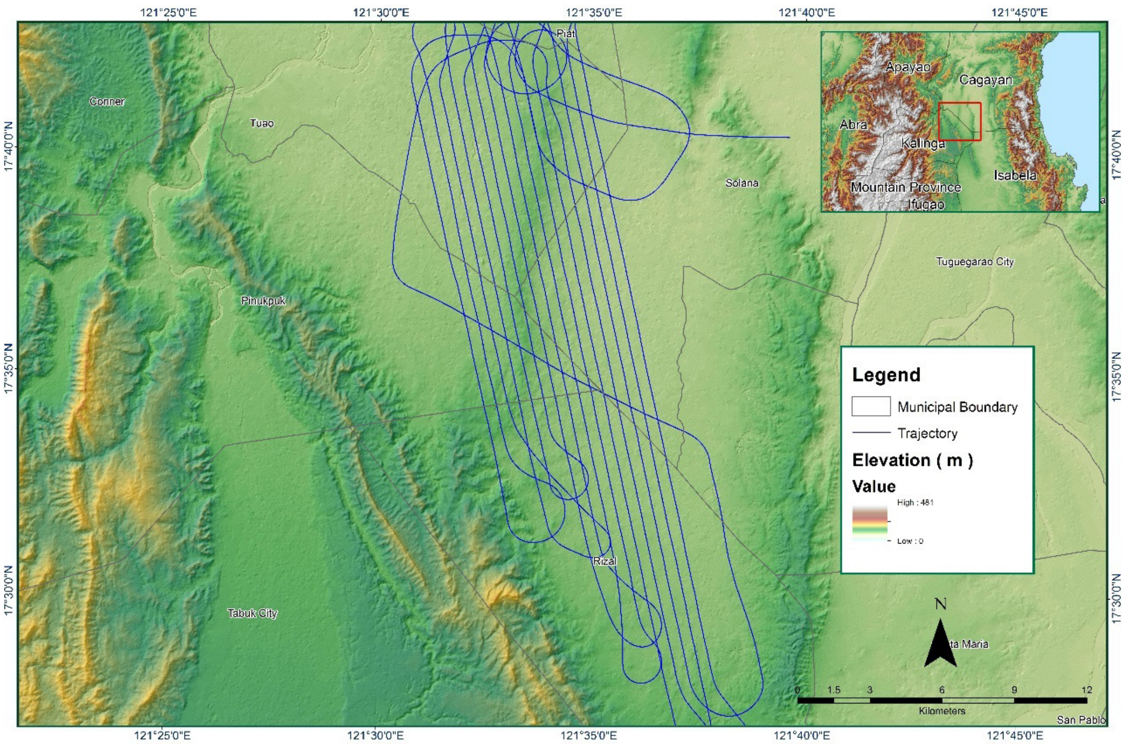


Figure A-8.150. Best Estimated Trajectory

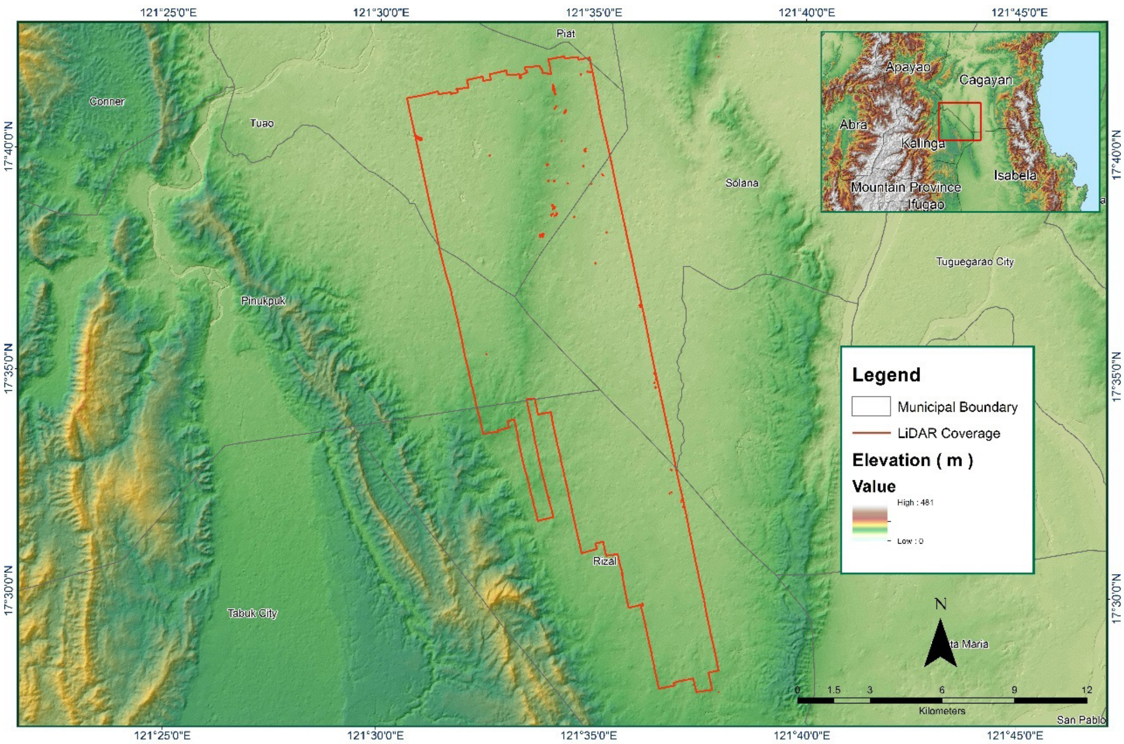


Figure A-8.151. Coverage of LiDAR data

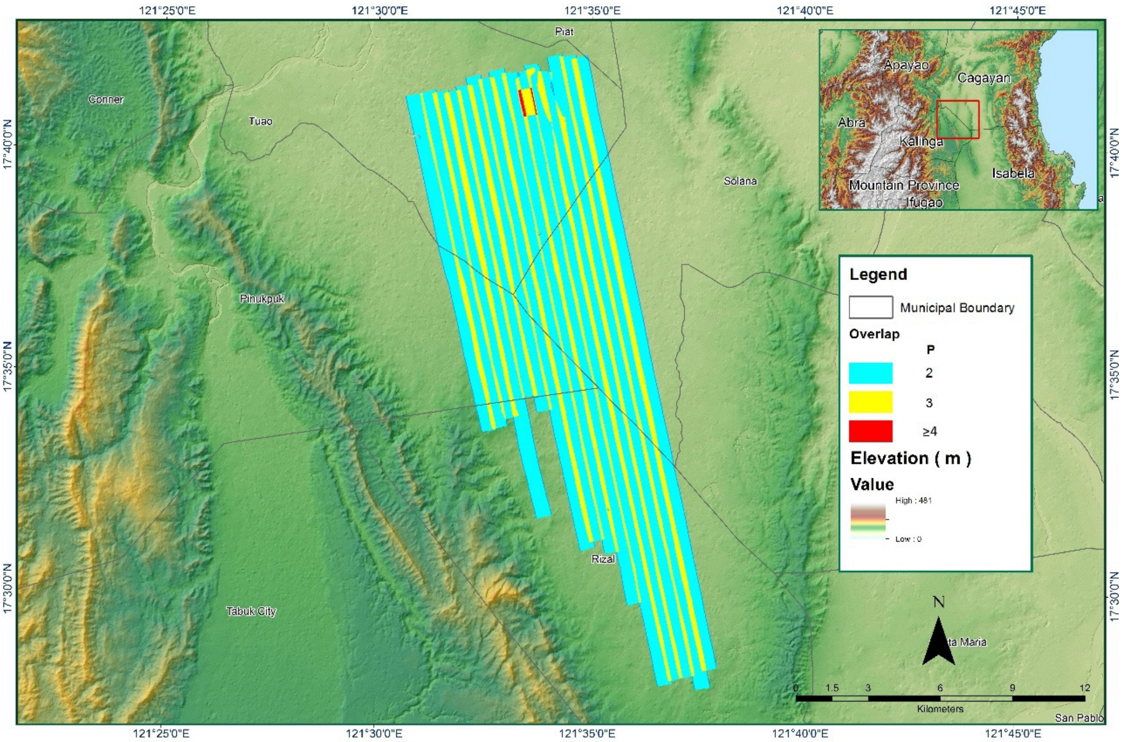


Figure A-8.152. Image of data overlap

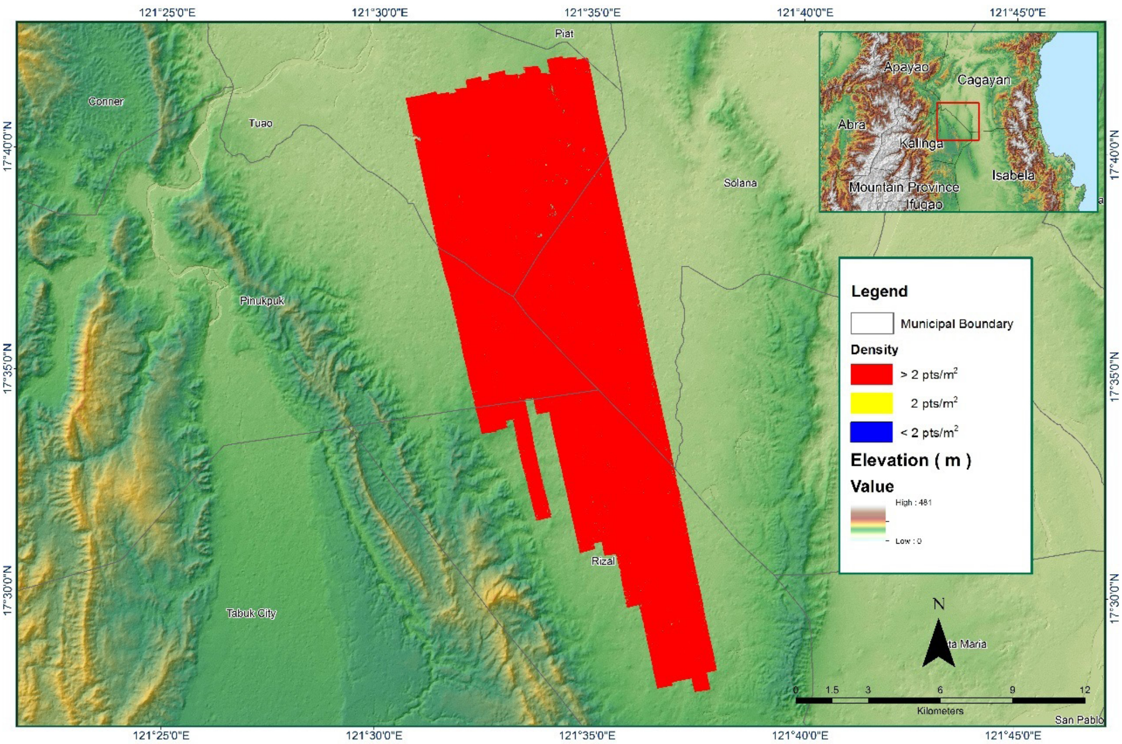


Figure A-8.153. Density map of merged LiDAR data

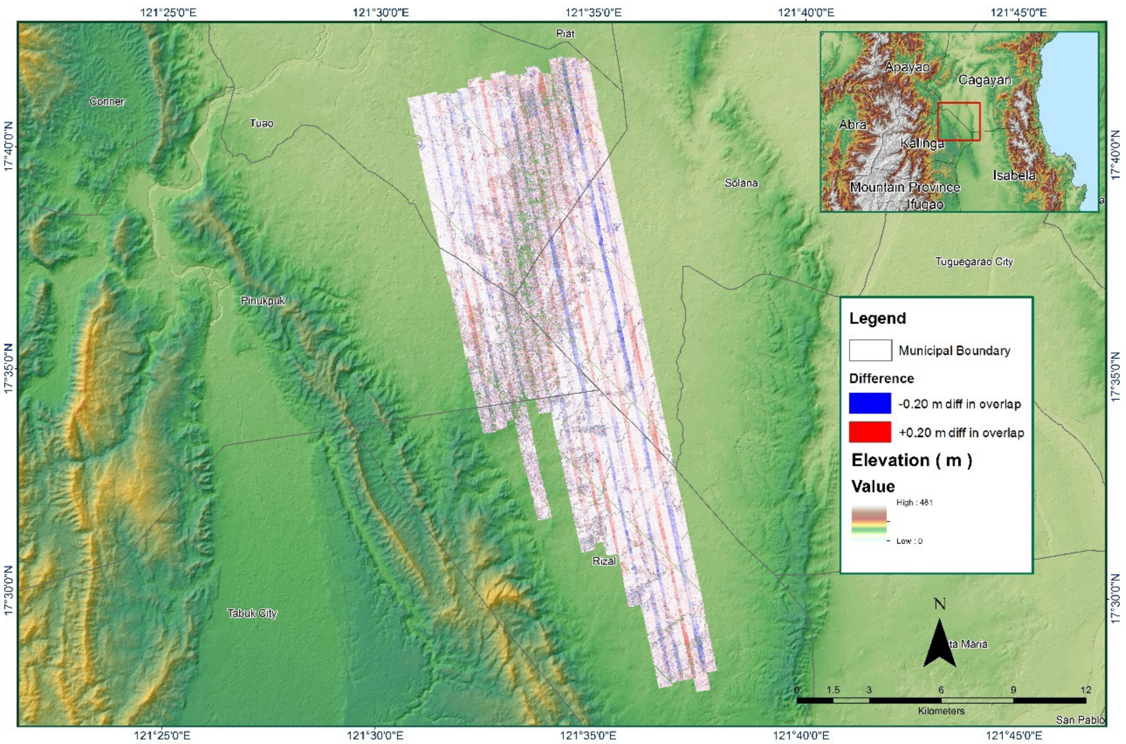


Figure A-8.154. Elevation difference between flight lines

Table A-8.23. Mission Summary Report for Mission Cagayan_Reflights_Blk101E

Flight Area	Cagayan_Reflights
Mission Name	Cagayan_Reflights_Blk101E
Inclusive Flights	4005G
Range data size	24 GB
POS data size	257 MB
Base data size	8.88 MB
Image	n/a
Transfer date	January 06, 2014
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)	1.3
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	4.7
Boresight correction stdev (<0.001deg)	0.016255
IMU attitude correction stdev (<0.001deg)	0.024433
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	13.82
Ave point cloud density per sq.m. (>2.0)	3.42
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	53
Maximum Height	499.44 m
Minimum Height	121.67 m
Classification (# of points)	
Ground	28,593,527
Low vegetation	12,140,350
Medium vegetation	32,360,954
High vegetation	30,043,954
Building	27,544
Orthophoto	No
Processed by	Engr. Sheila Maye Santillan, Engr. Chelou Prado, Engr. Karl Adrian Vergara

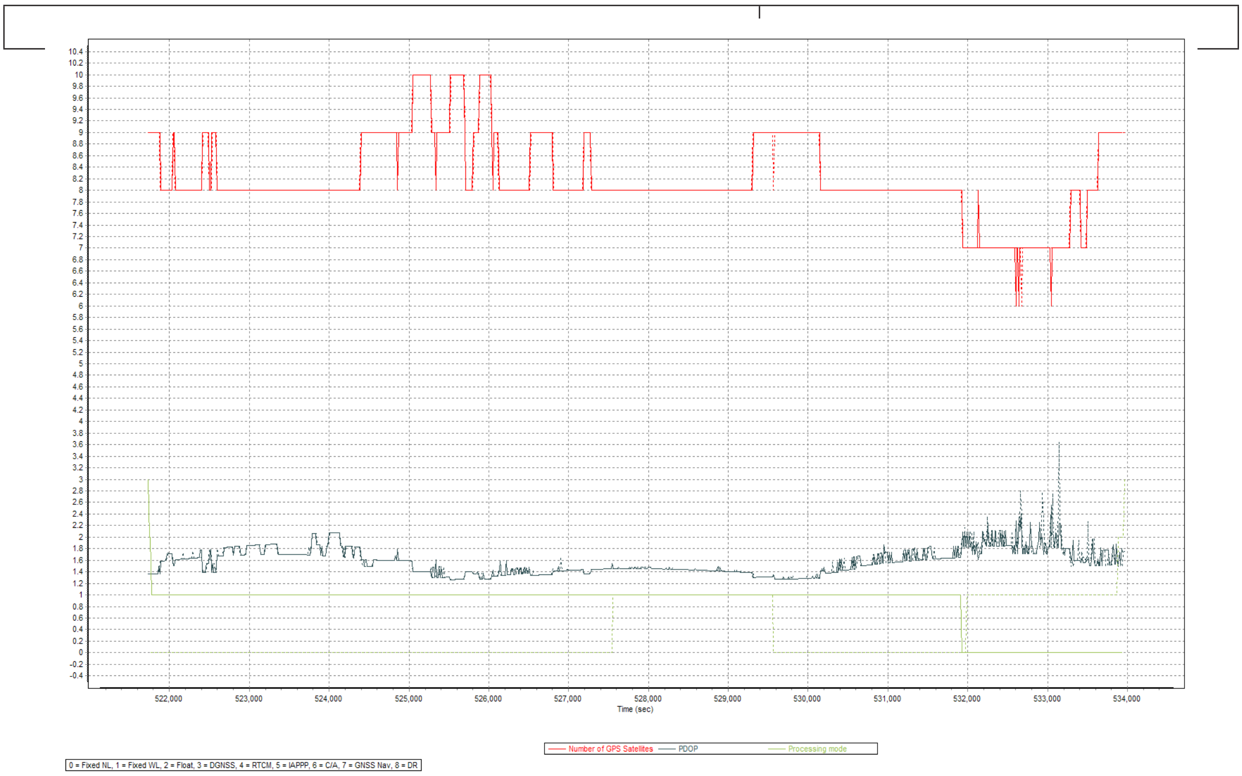


Figure A-8.155. Solution Status

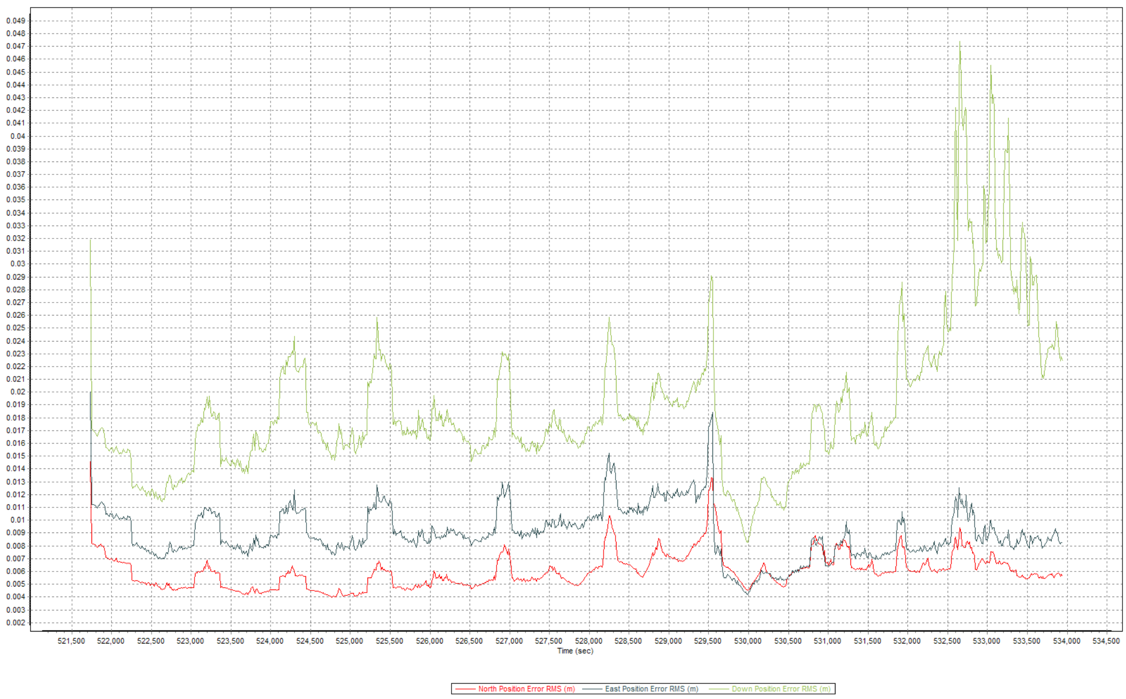


Figure A-8.156. Smoothed Performance Metrics Parameters

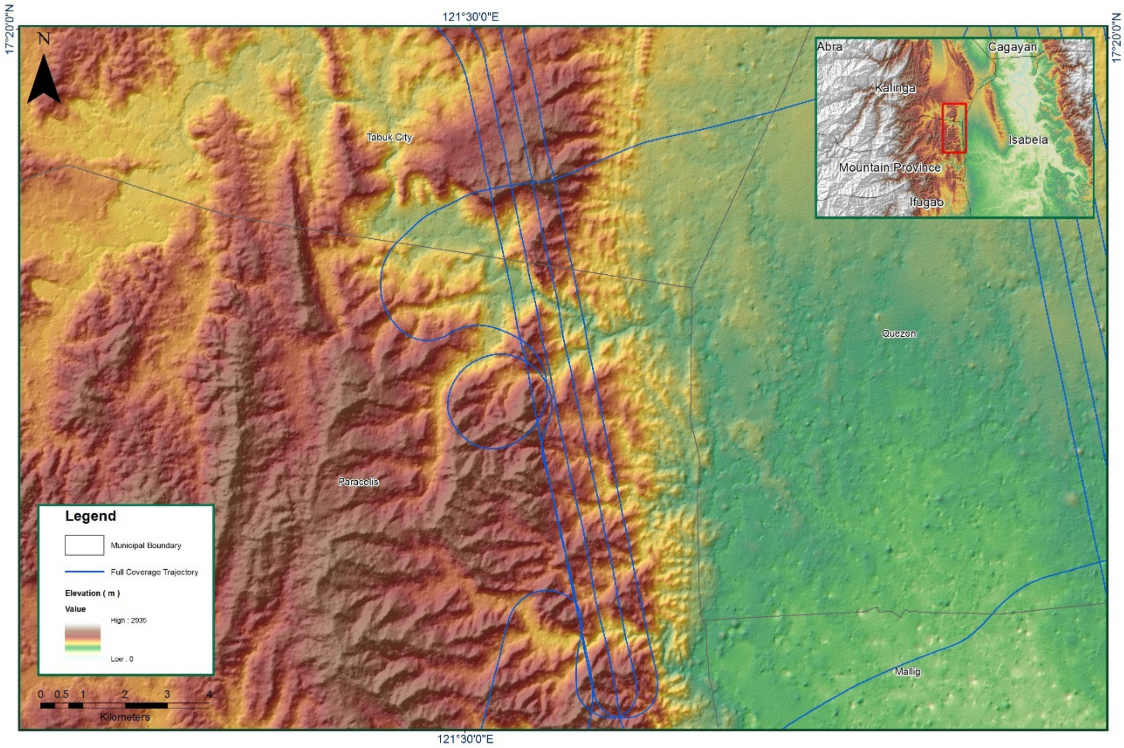


Figure A-8.157. Best Estimated Trajectory

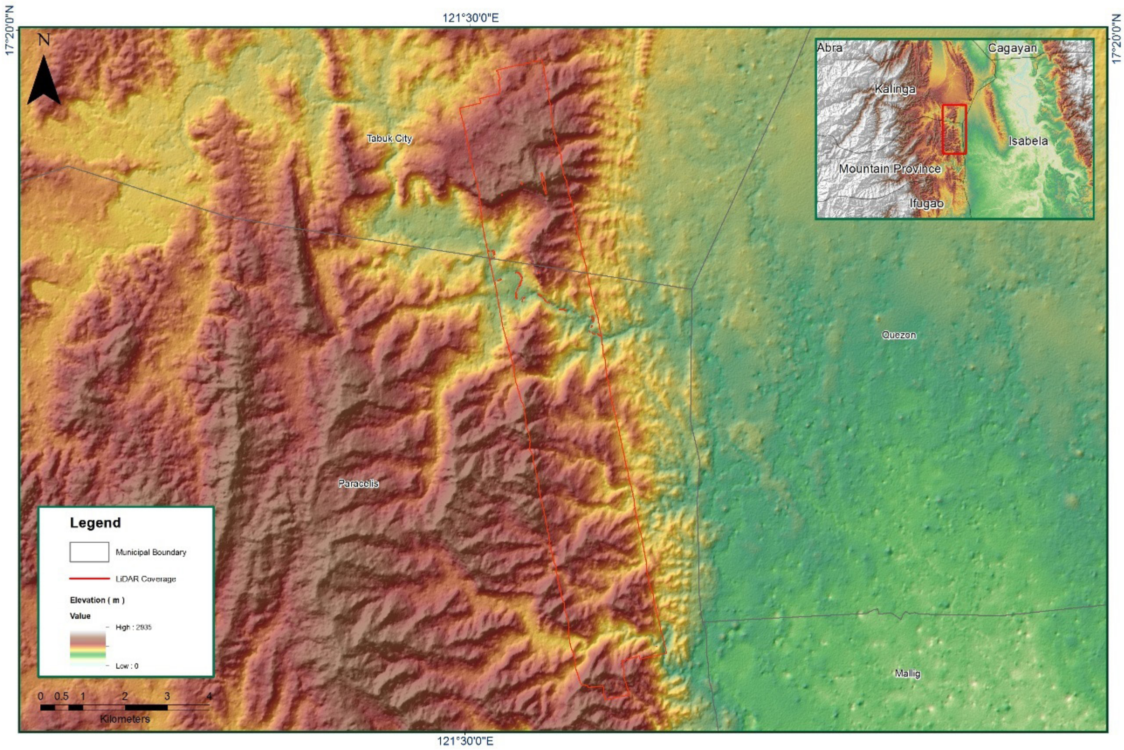


Figure A-8.158. Coverage of LiDAR data

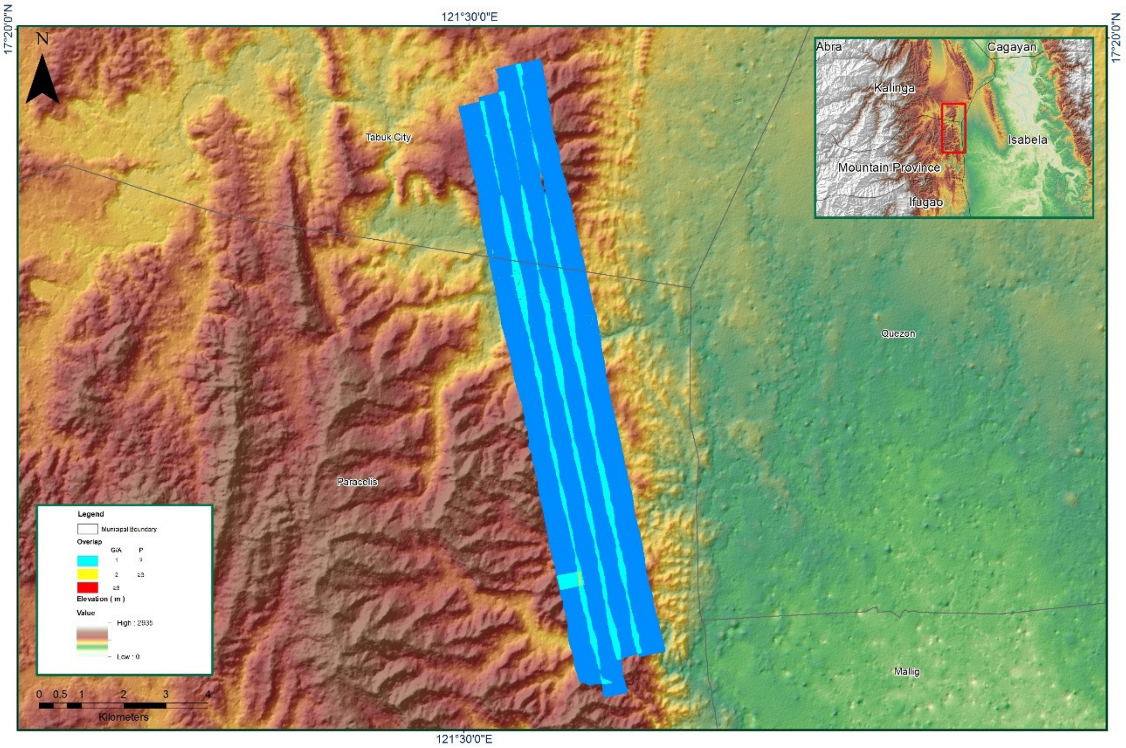


Figure A-8.159. Image of data overlap

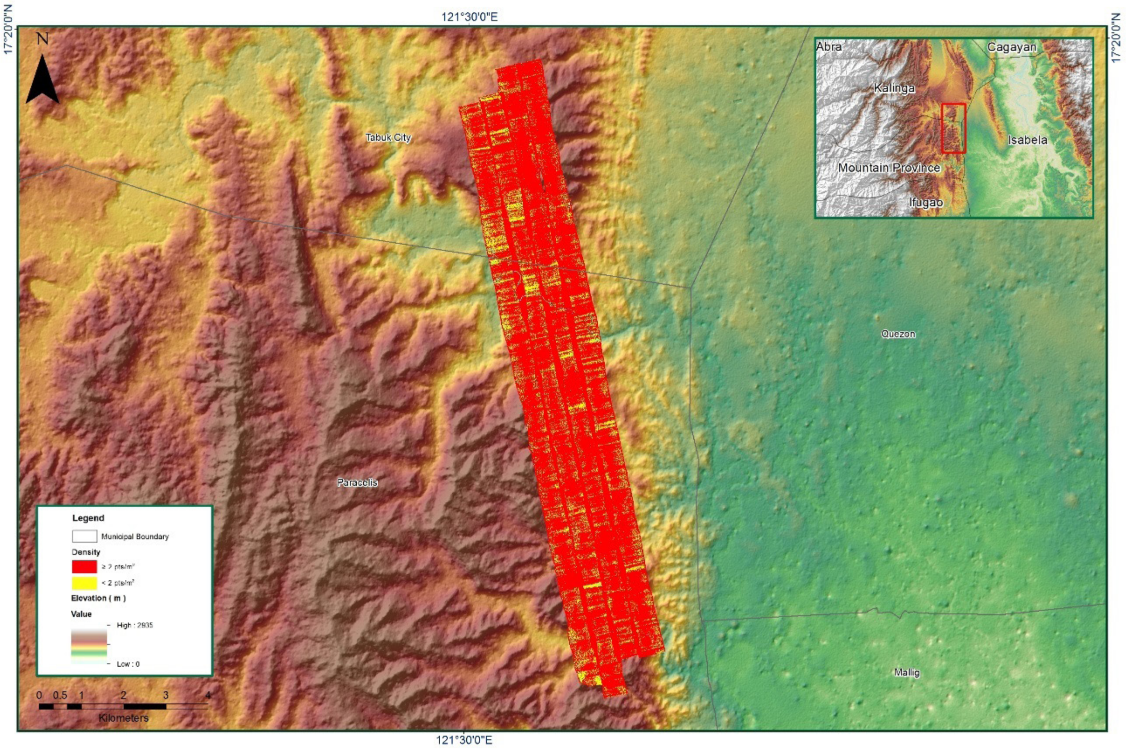


Figure A-8.160. Density map of merged LiDAR data

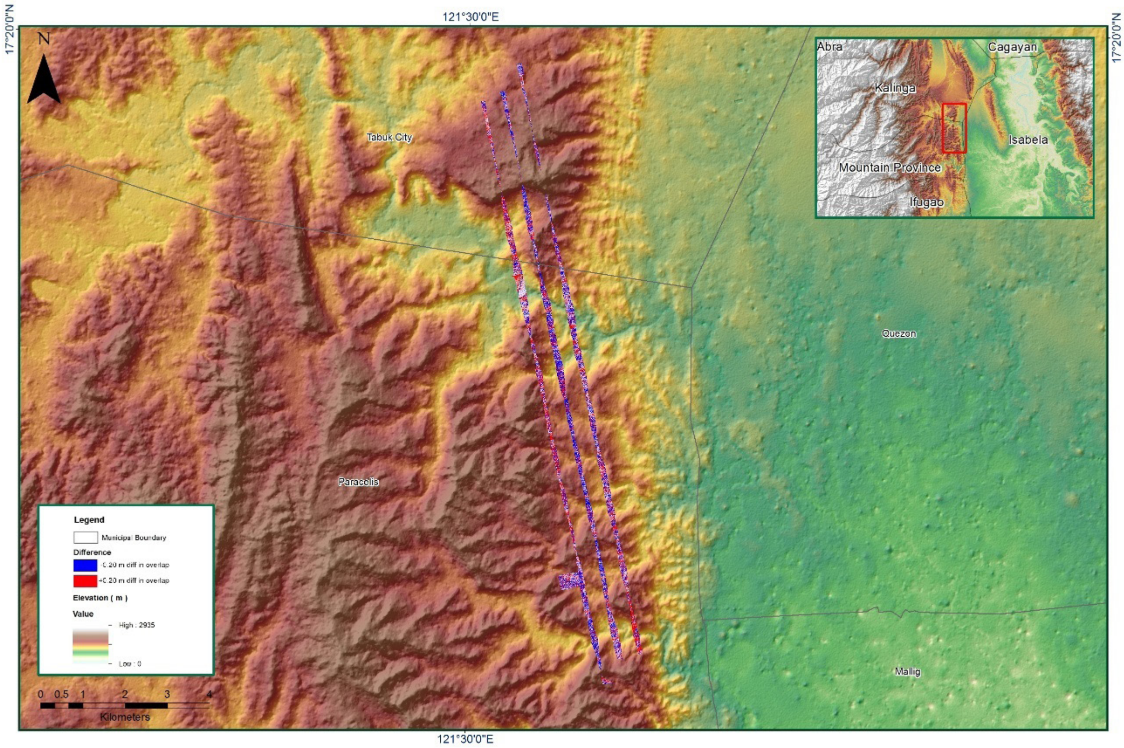


Figure A-8.161. Elevation difference between flight lines

Table A-8.24. Mission Summary Report for Mission Cagayan_Reflights_BLK101C

Flight Area	Cagayan_Reflights
Mission Name	Cagayan_Reflights_BLK101C
Inclusive Flights	3965G
Range data size	28.2 GB
POS data size	251 MB
Base data size	9.67 MB
Image	n/a
Transfer date	June 21,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	0.002582
IMU attitude correction stdev (<0.001deg)	0.006977
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	36.06
Ave point cloud density per sq.m. (>2.0)	3.15
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	199
Maximum Height	290.35 m
Minimum Height	56.28 m
Classification (# of points)	
Ground	142,642,886
Low vegetation	108,911,951
Medium vegetation	199,800,032
High vegetation	34,718,112
Building	262,912
Orthophoto	No
Processed by	Engr. James Kevin Dimaculangan, Engr. Mark Joshua Salvacion, Engr. Vincent Louise Azucena

Figure A-8.162. Solution Status

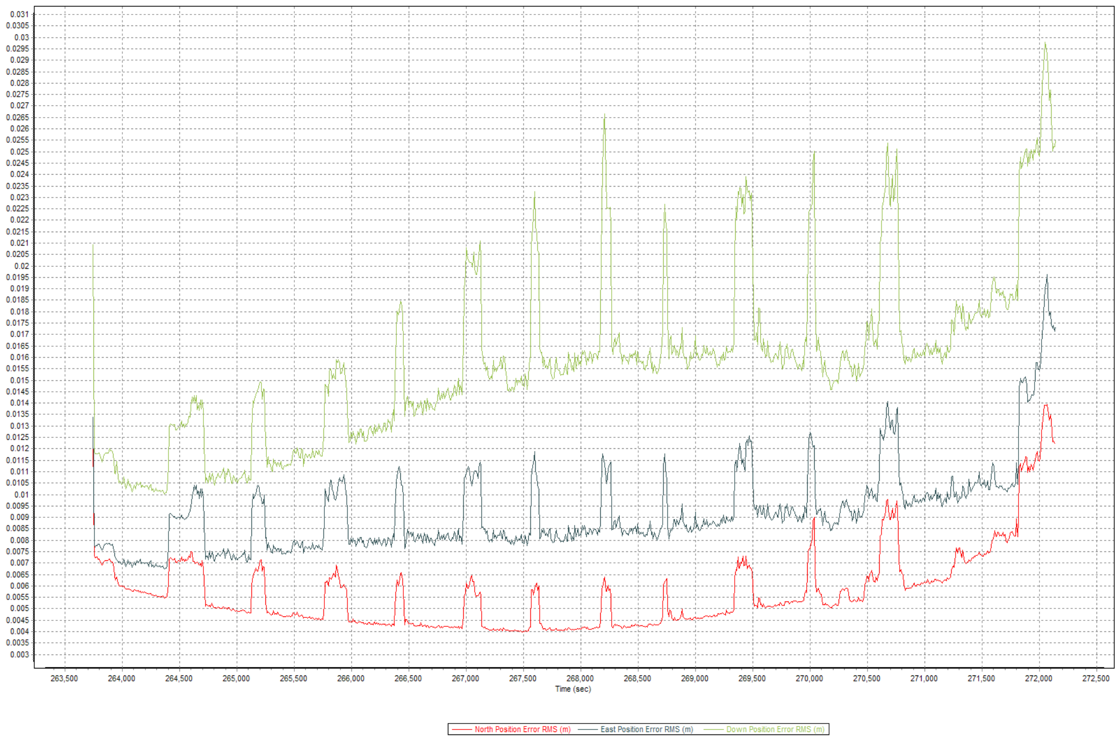


Figure A-8.163. Smoothed Performance Metrics Parameters

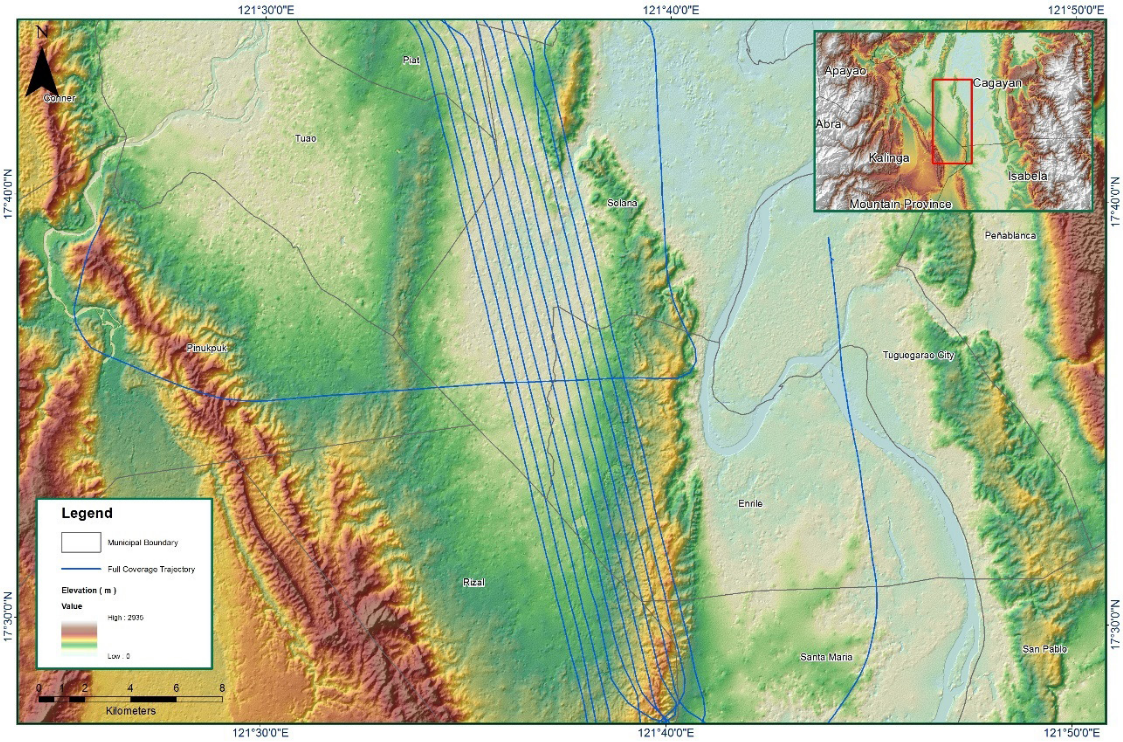


Figure A-164. Best Estimated Trajectory

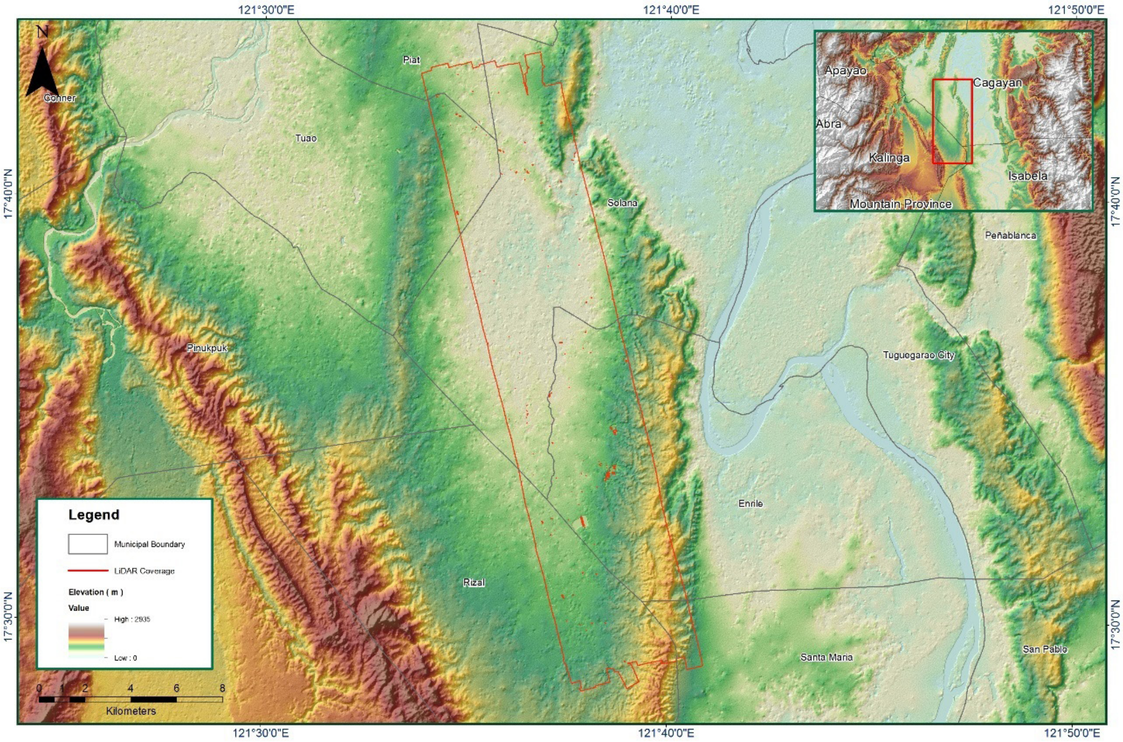


Figure A-8.165. Coverage of LiDAR data

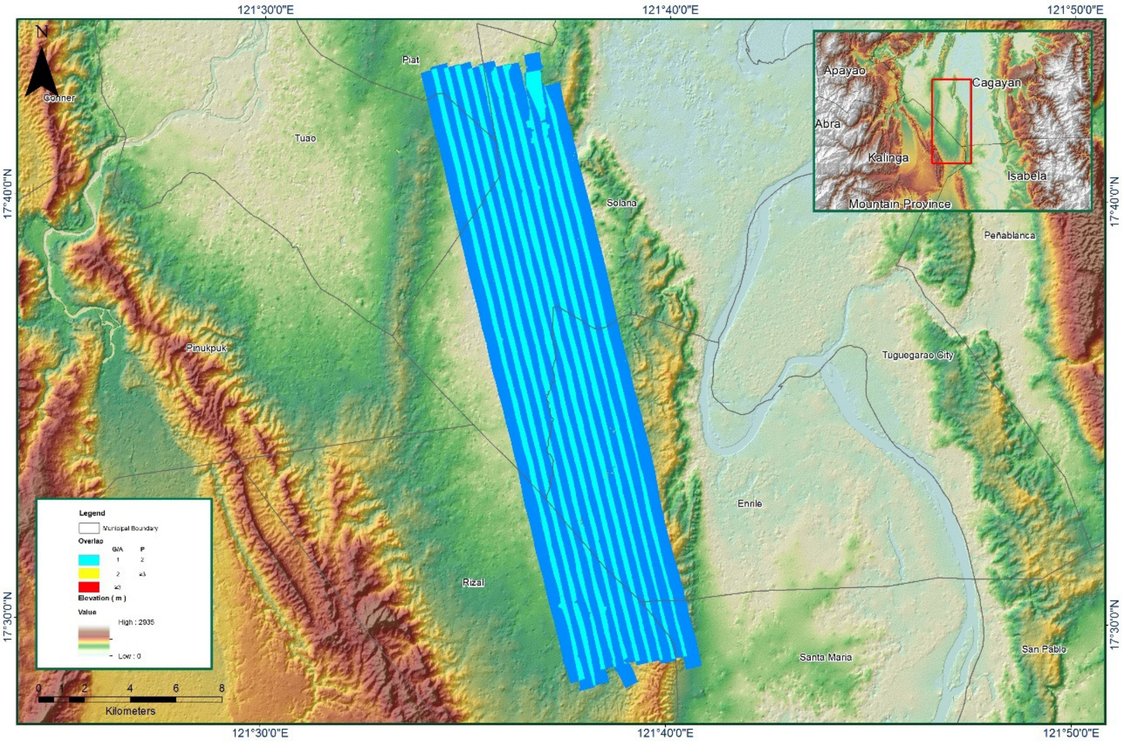


Figure A-8.166. Image of data overlap

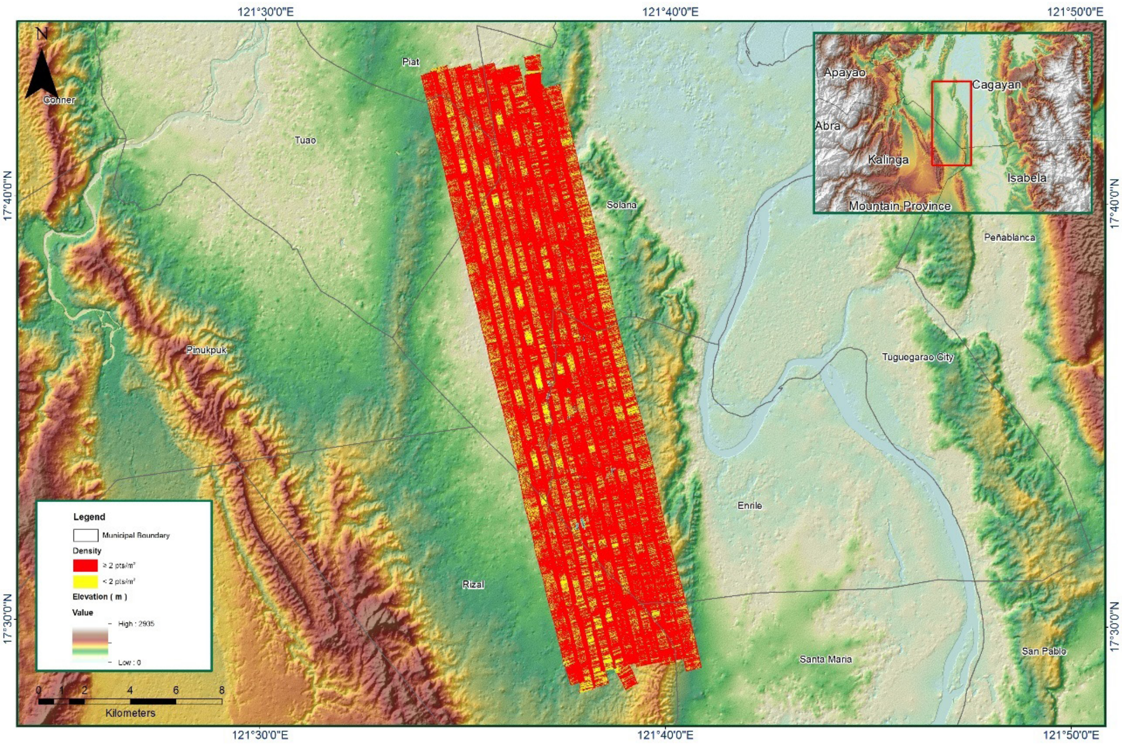


Figure A-8.167. Density map of merged LiDAR data

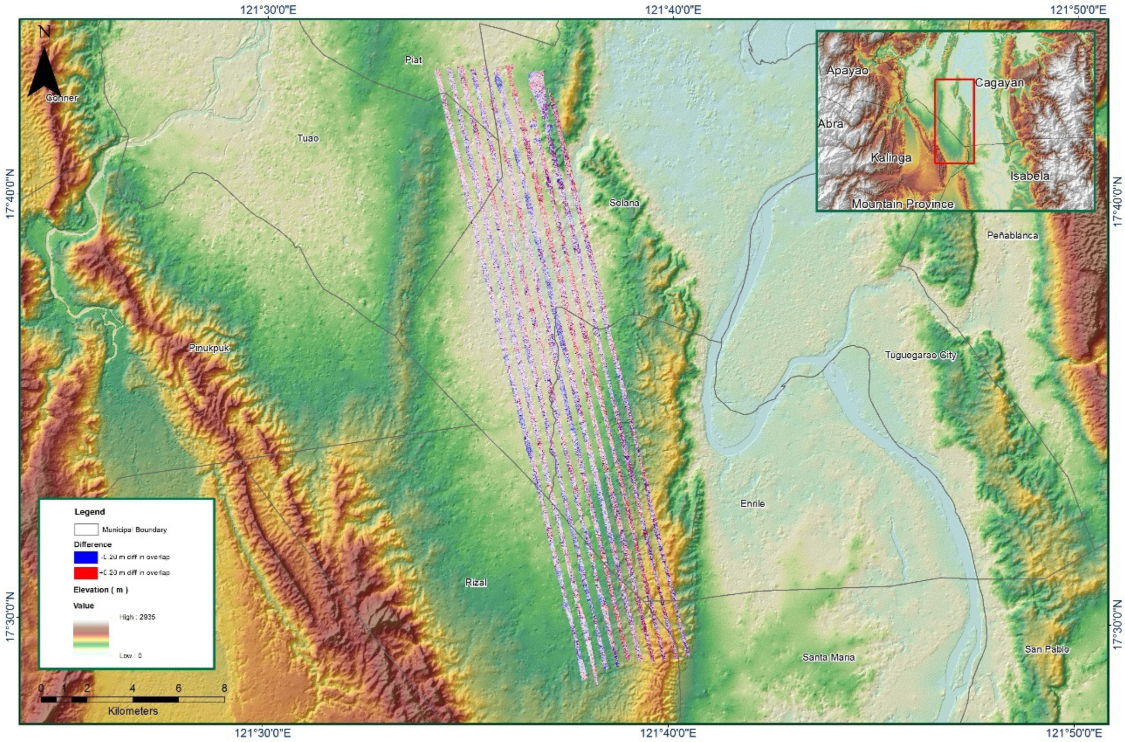


Figure A-8.168. Elevation difference between flight lines

Table A-8.25. Mission Summary Report for Mission Cagayan_Reflights_Blk111C

Flight Area	Cagayan_Reflights
Mission Name	Cagayan_Reflights_Blk111C
Inclusive Flights	3983G
Range data size	8.25 GB
POS data size	103 MB
Base data size	8.23 MB
Image	n/a
Transfer date	January 06, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	2.1
Boresight correction stdev (<0.001deg)	0.000251
IMU attitude correction stdev (<0.001deg)	0.000550
GPS position stdev (<0.01m)	0.0106
Minimum % overlap (>25)	31.09
Ave point cloud density per sq.m. (>2.0)	3.52
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	47
Maximum Height	222.31 m
Minimum Height	72.95 m
Classification (# of points)	
Ground	19,578,344
Low vegetation	21,944,581
Medium vegetation	40147622.00
High vegetation	20,453,844
Building	57,491
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Velina Angela Bemida, Jovy Narisma

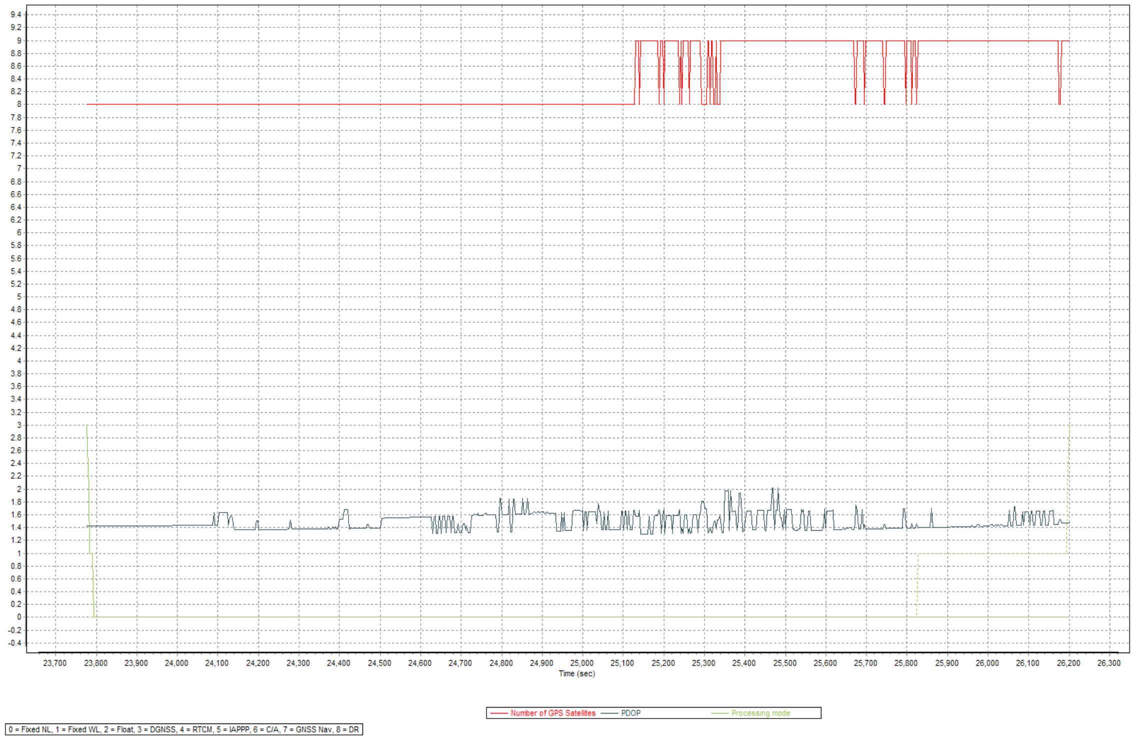


Figure A-8.169. Solution Status

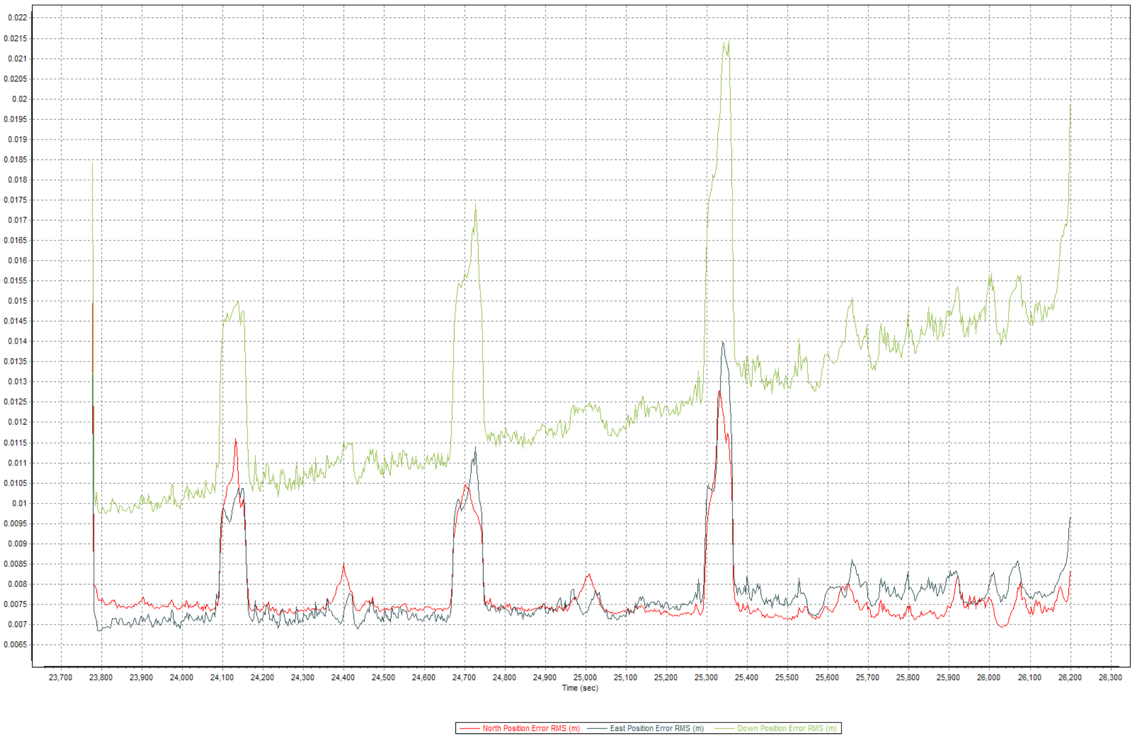


Figure A-8.170. Smoothed Performance Metric Parameters

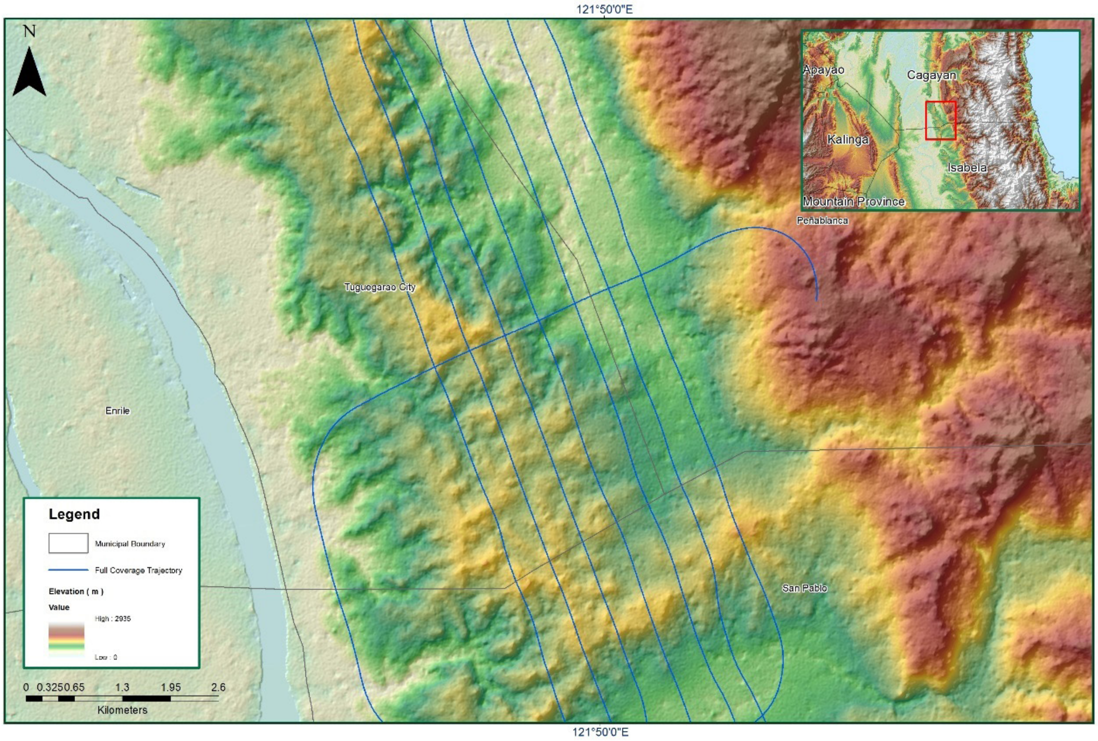


Figure A-8.171. Best Estimated Trajectory

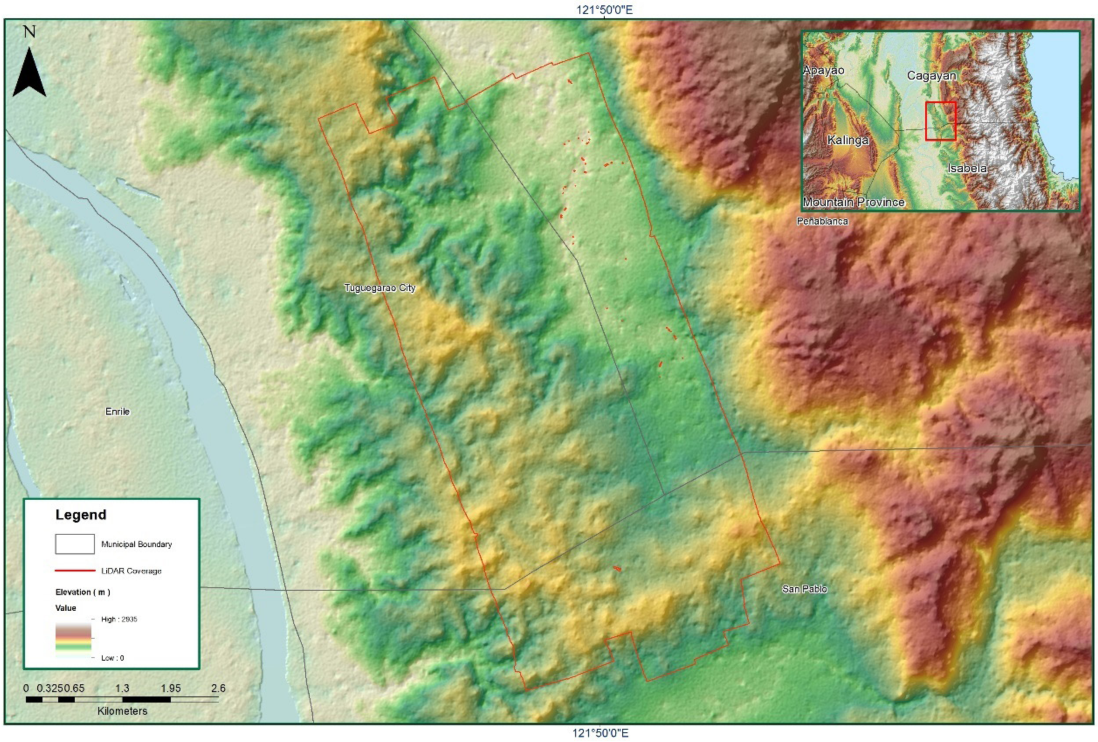


Figure A-8.172. Coverage of LiDAR Data

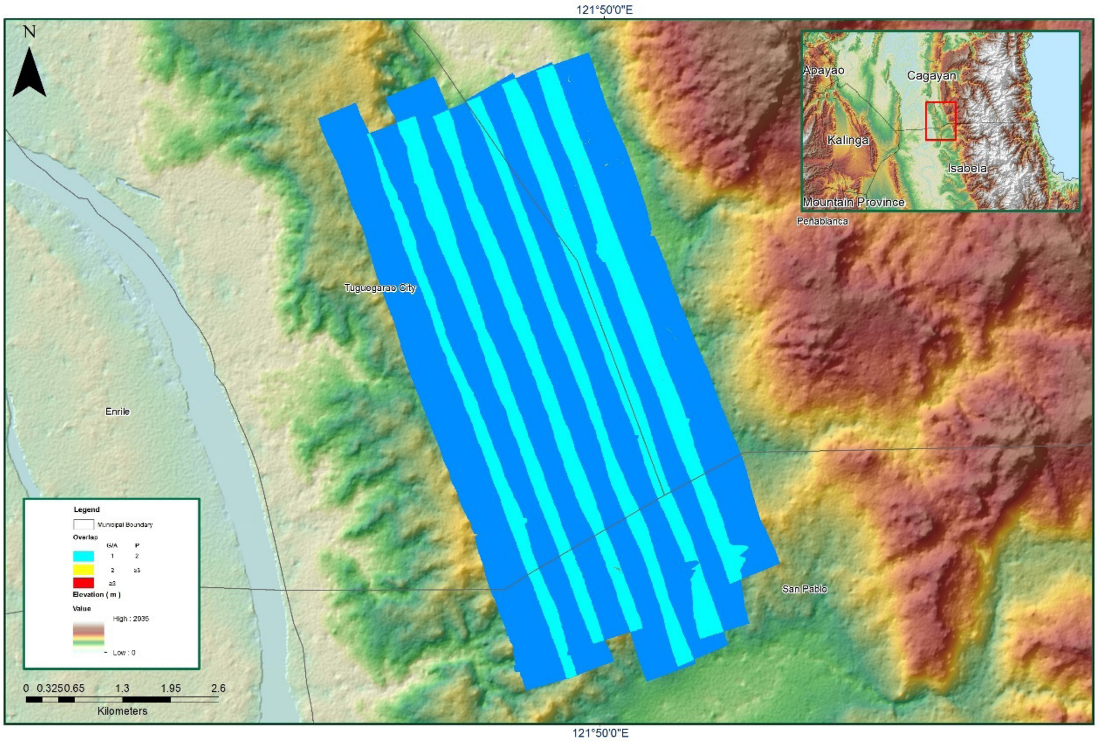


Figure A-8.173. Image of data overlap

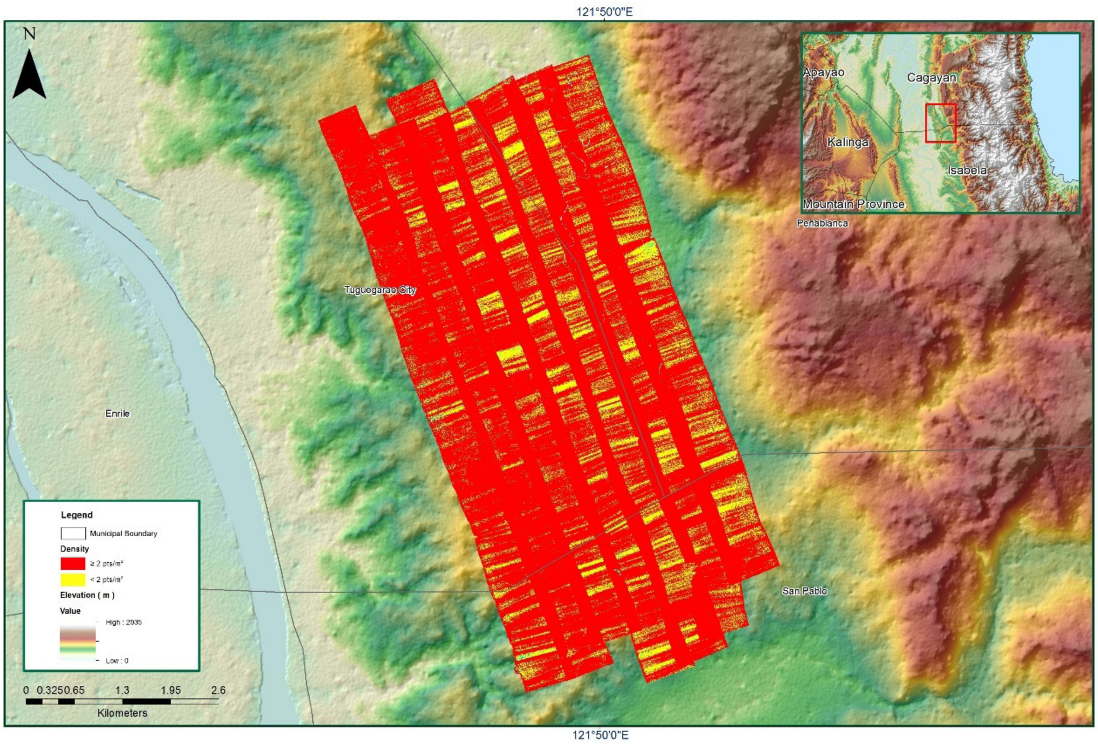


Figure A-8.174**. Density map of merged LiDAR data**

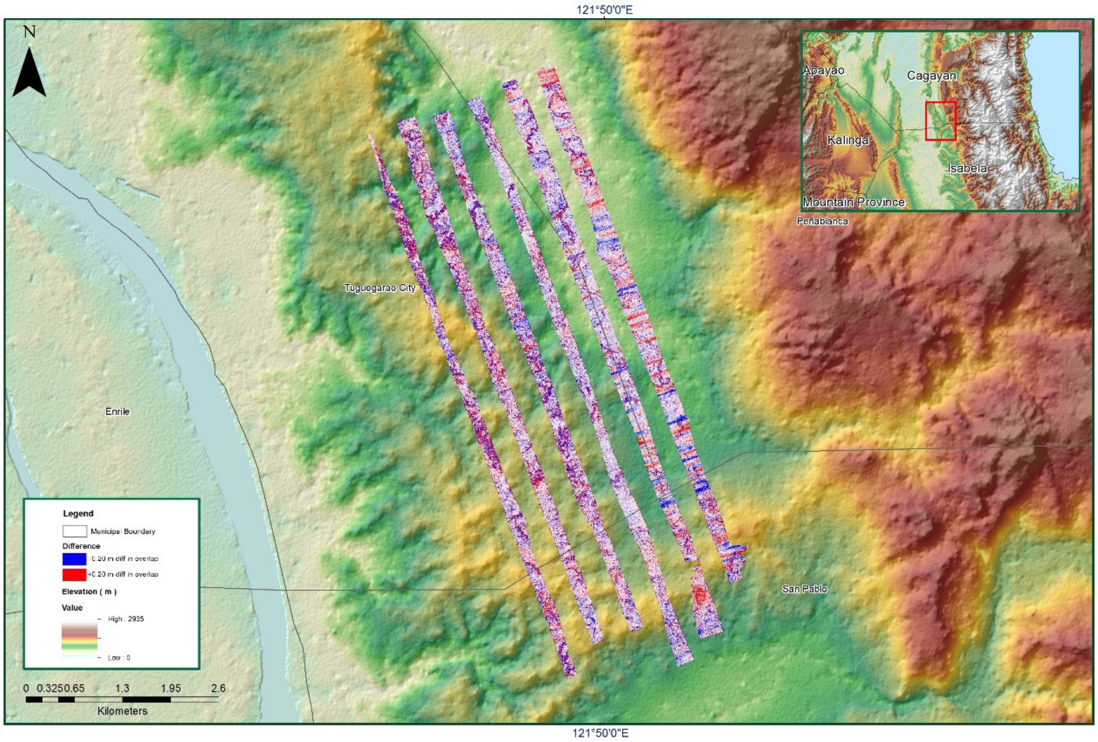


Figure A-8.175. Elevation difference between flight lines

Table A-8.26. Mission Summary Report for Mission Cagayan_Reflights_Blk101G

Flight Area	Cagayan_Reflights
Mission Name	Cagayan_Reflights_Blk101G
Inclusive Flights	4005G
Range data size	24 GB
POS data size	257 MB
Base data size	8.88 MB
Image	n/a
Transfer date	January 06, 2014
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)	1.3
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	4.7
Boresight correction stdev (<0.001deg)	0.000349
IMU attitude correction stdev (<0.001deg)	0.000722
GPS position stdev (<0.01m)	0.0016
Minimum % overlap (>25)	26.18
Ave point cloud density per sq.m. (>2.0)	3.22
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	164
Maximum Height	290.27 m
Minimum Height	95.11 m
Classification (# of points)	
Ground	82,454,668
Low vegetation	96,056,800
Medium vegetation	165668847.00
High vegetation	33,217,399
Building	140,387
Orthophoto	No
Processed by	Engr. Sheila Maye Santillan, Aljon Rei Araneta, Jovy Narisma

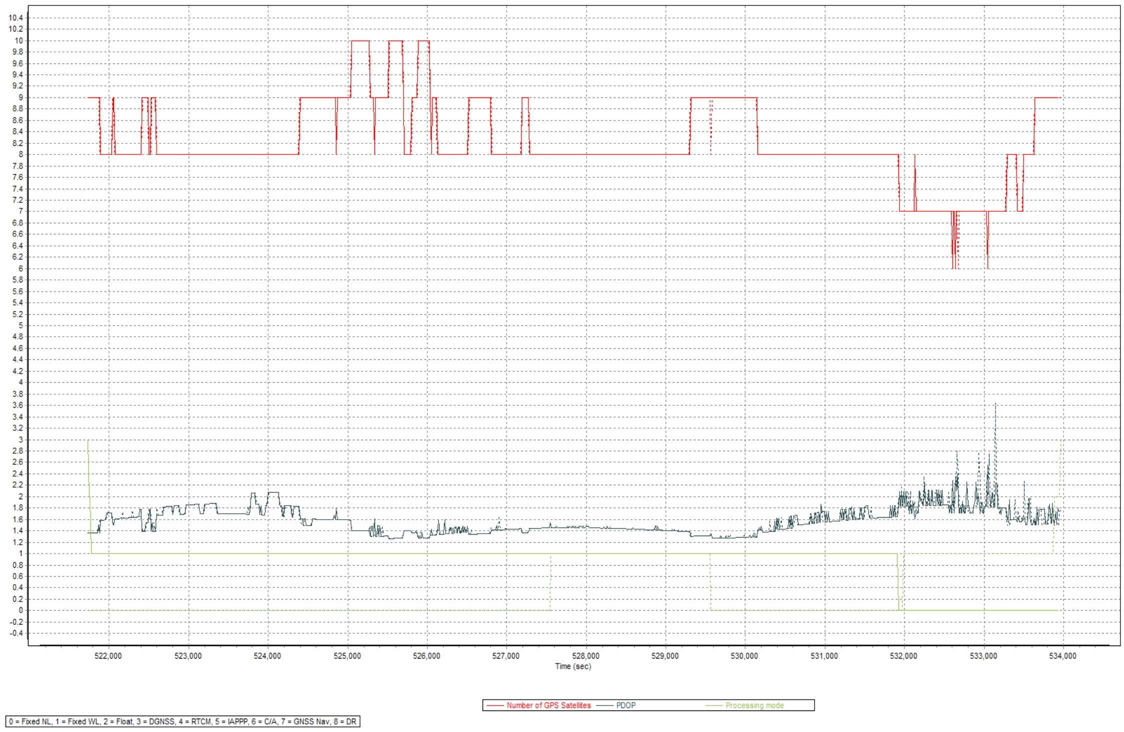


Figure A-8.176. Solution Status

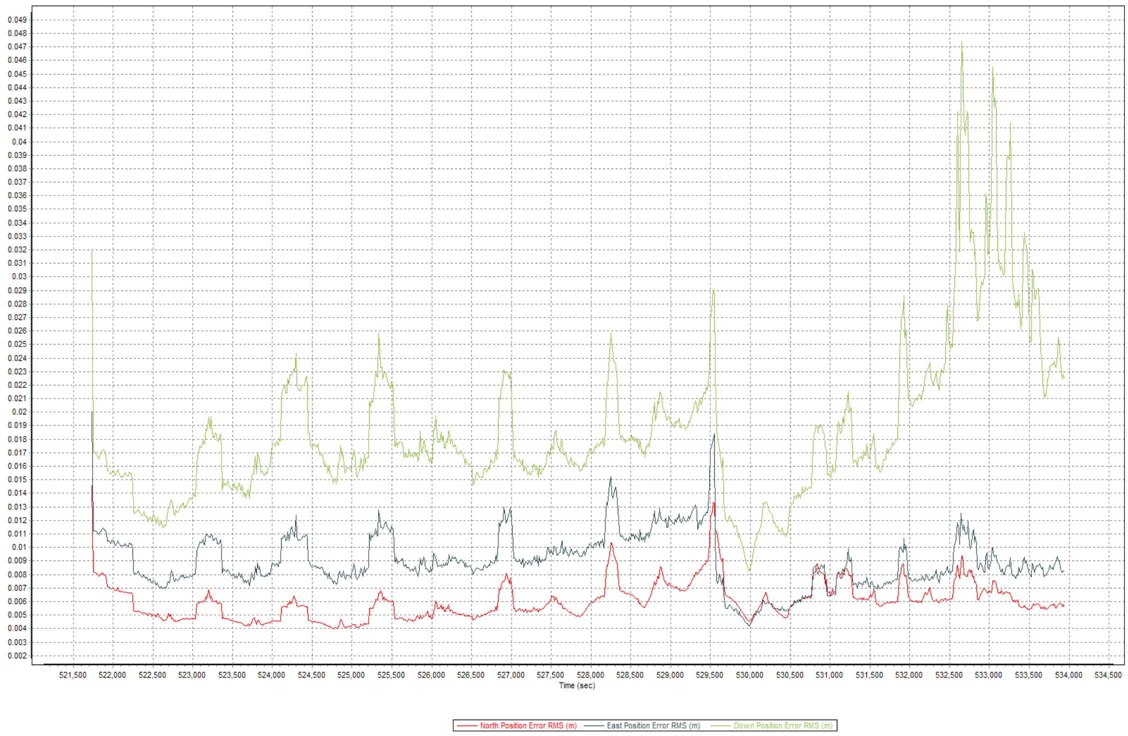


Figure A-8.177. Smoothed Performance Metrics Parameters

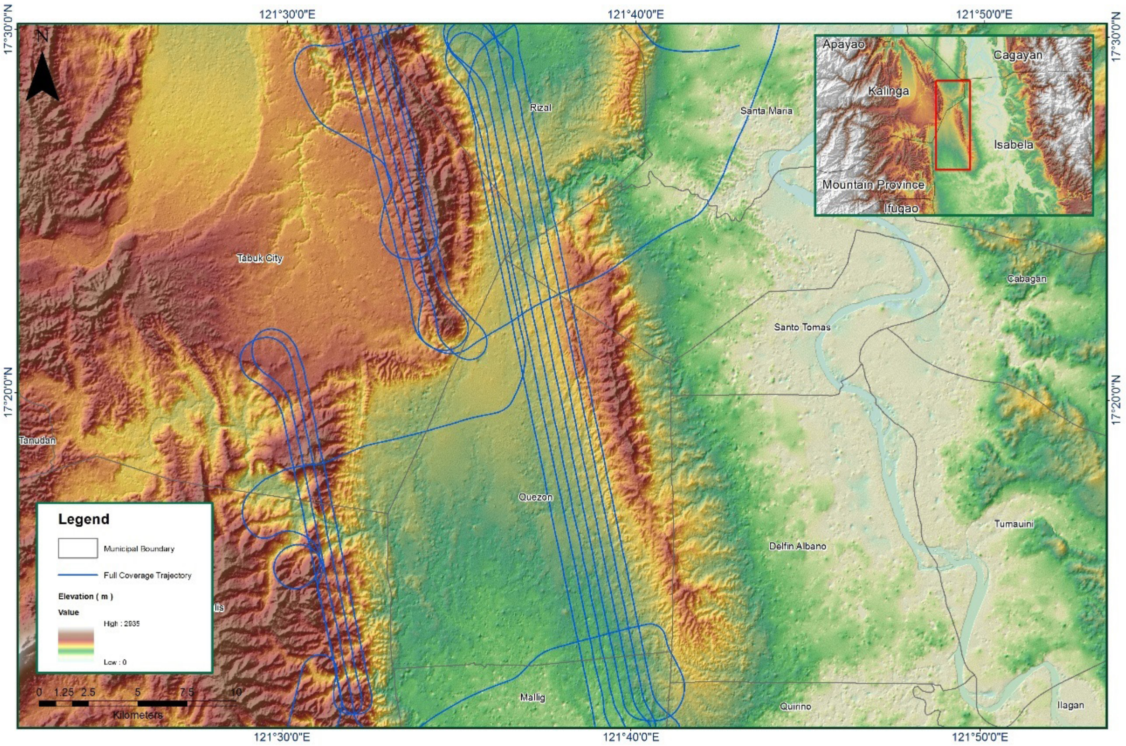


Figure A-8.178. Best Estimated Trajectory

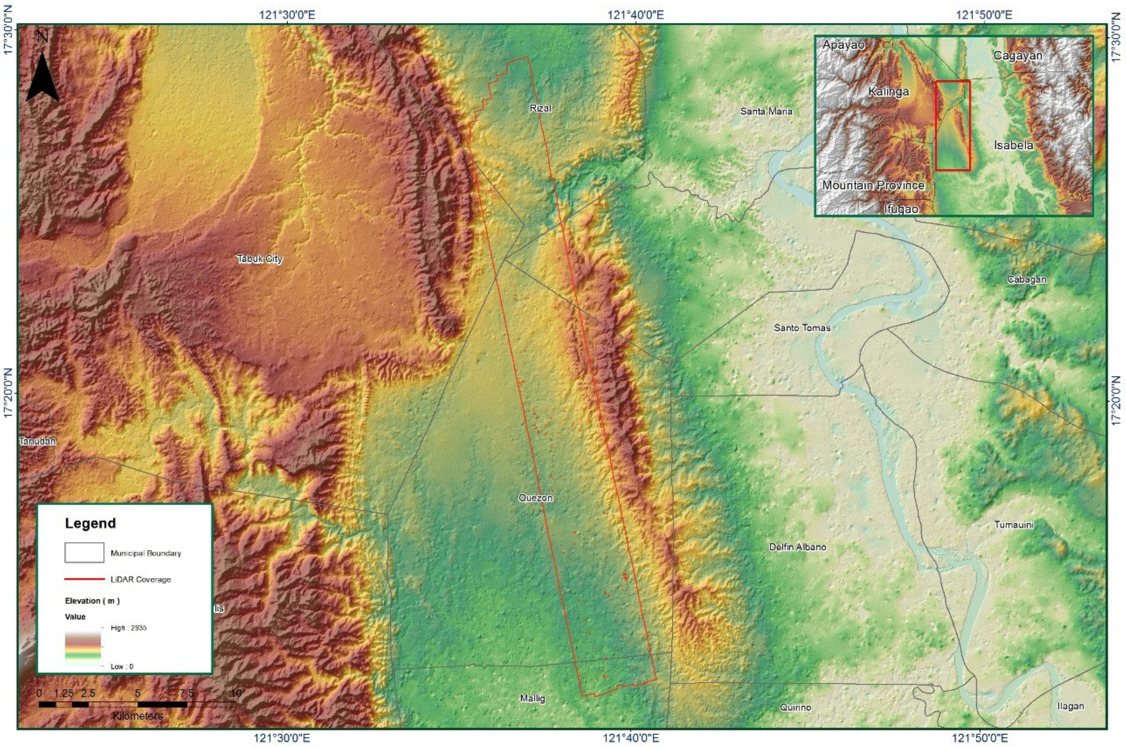


Figure A-8.179. Coverage of LiDAR data

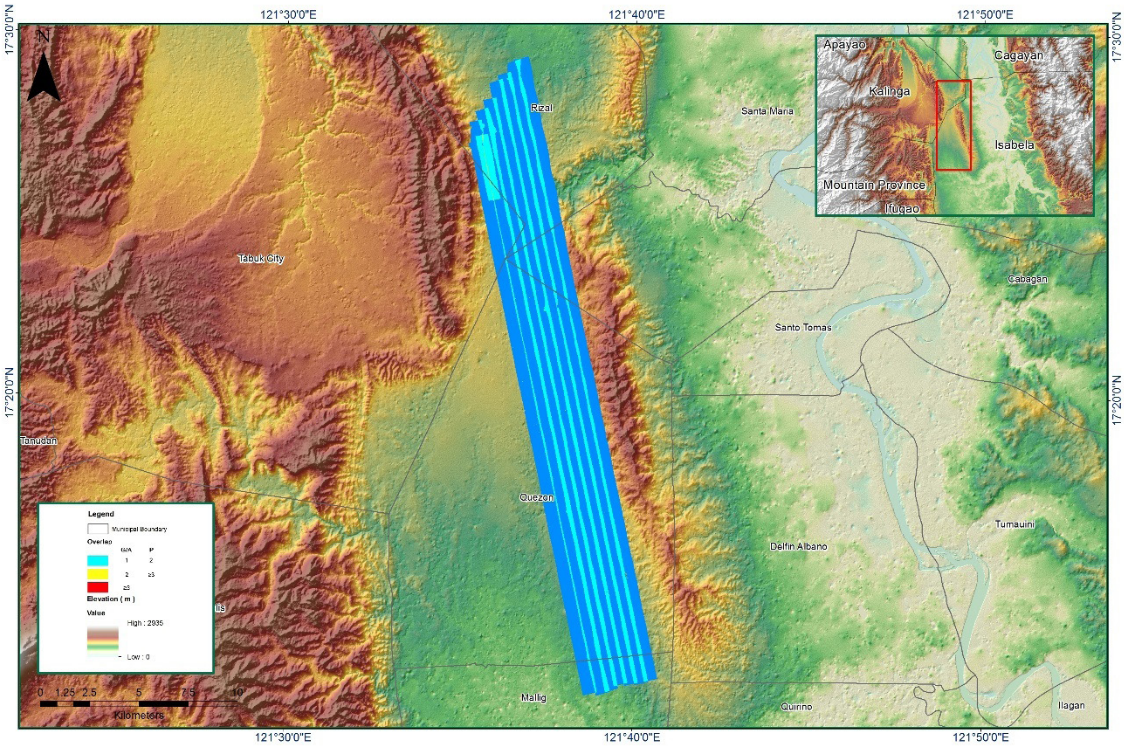


Figure A-8.180. Image of data overlap

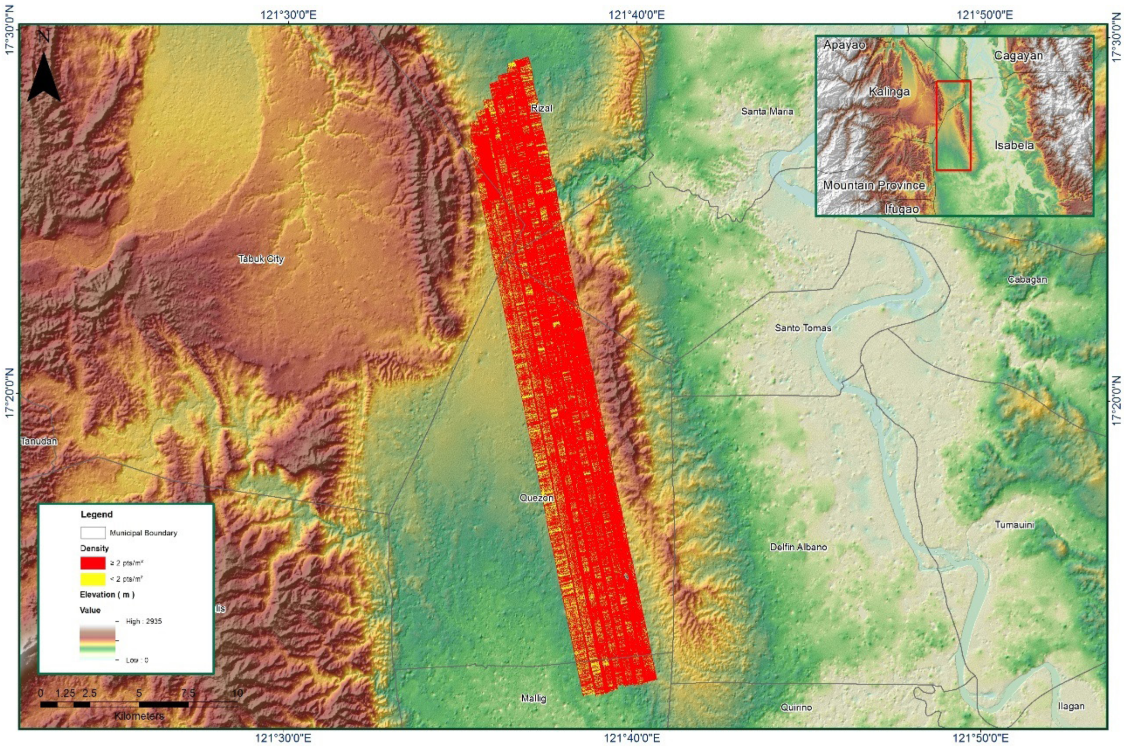


Figure A-8.181. Density map of merged LiDAR data

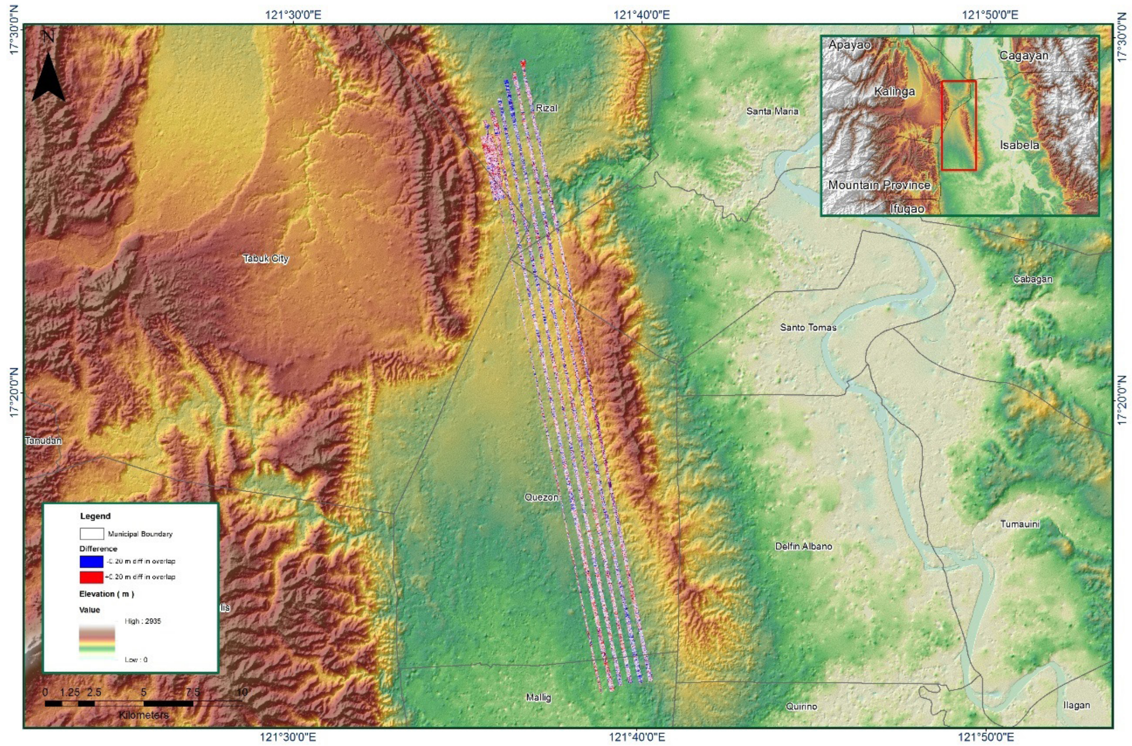


Figure A-8.182. Elevation difference between flight lines

Table A-8.27. Mission Summary Report for Mission Cagayan_Reflights_Blk101F

Flight Area	Cagayan_Reflights
Mission Name	Cagayan_Reflights_Blk101F
Inclusive Flights	3983G 4005G
Range data size	32.25 GB
POS data size	360 MB
Base data size	17.11
Image	n/a
Transfer date	January 06, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	4.7
Boresight correction stdev (<0.001deg)	0.024495
IMU attitude correction stdev (<0.001deg)	0.070417
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	19.73
Ave point cloud density per sq.m. (>2.0)	3.47
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	111
Maximum Height	508.69 m
Minimum Height	106.59 m
Classification (# of points)	
Ground	54,471,407
Low vegetation	46,073,333
Medium vegetation	104,292,050
High vegetation	55,096,408
Building	217,225
Orthophoto	No
Processed by	Engr. Sheila Maye Santillan, Engr. Jovelle Anjeanette Canlas, Jovy Narisma

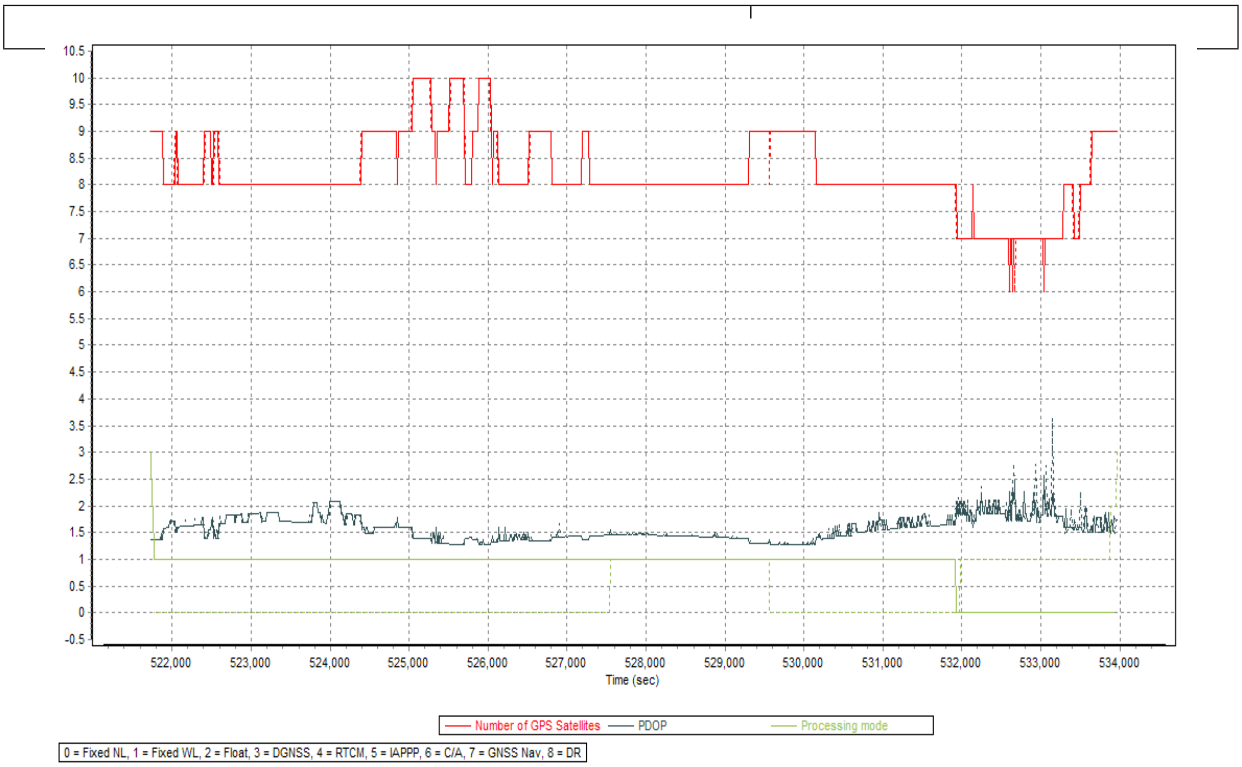


Figure A-8.183. Solution Status

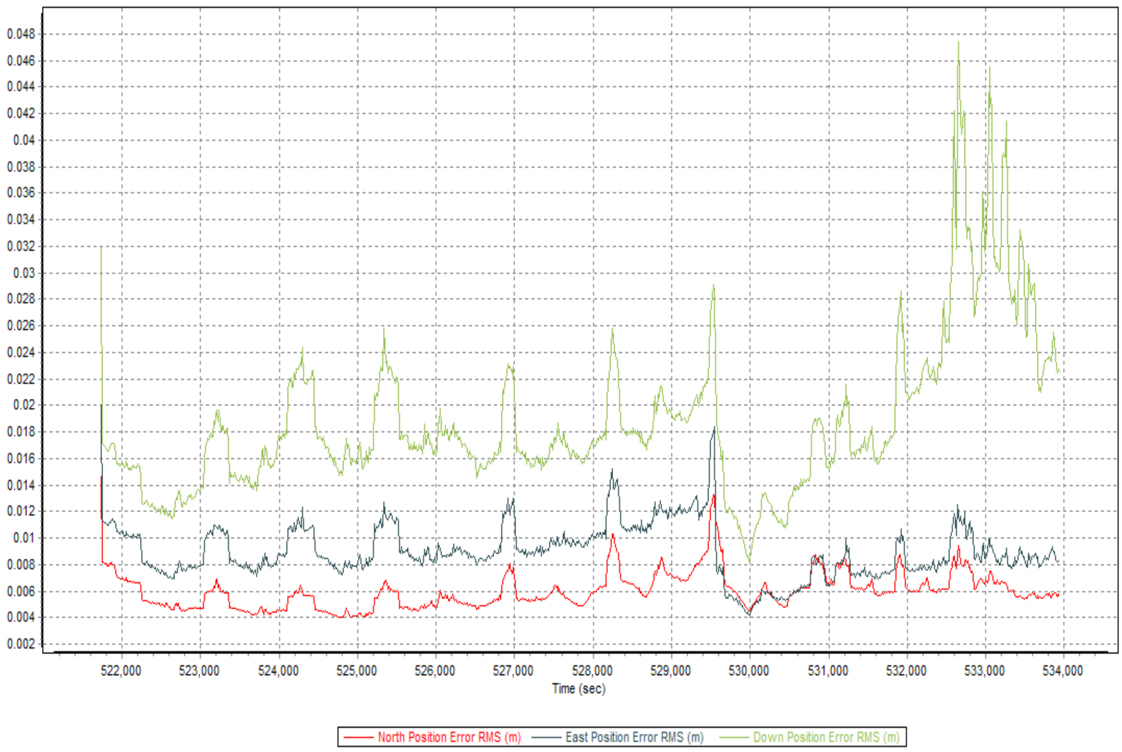


Figure A-8.184. Smoothed Performance Metrics Parameters

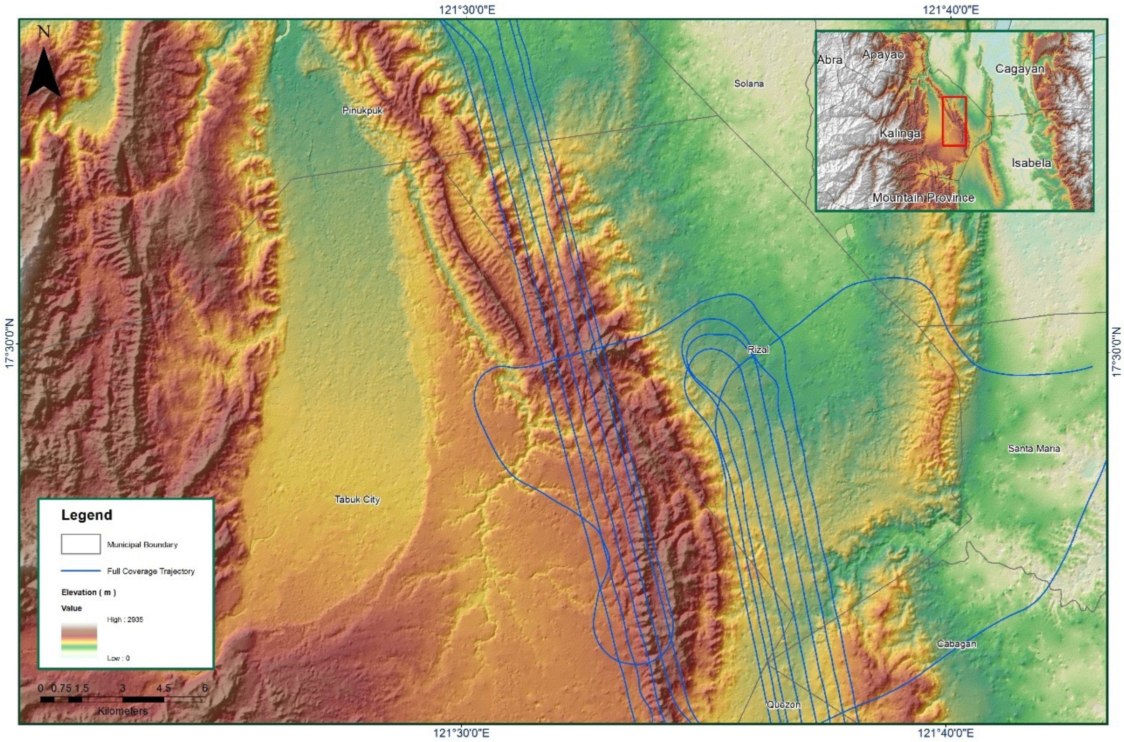


Figure A-8.185. Best Estimated Trajectory

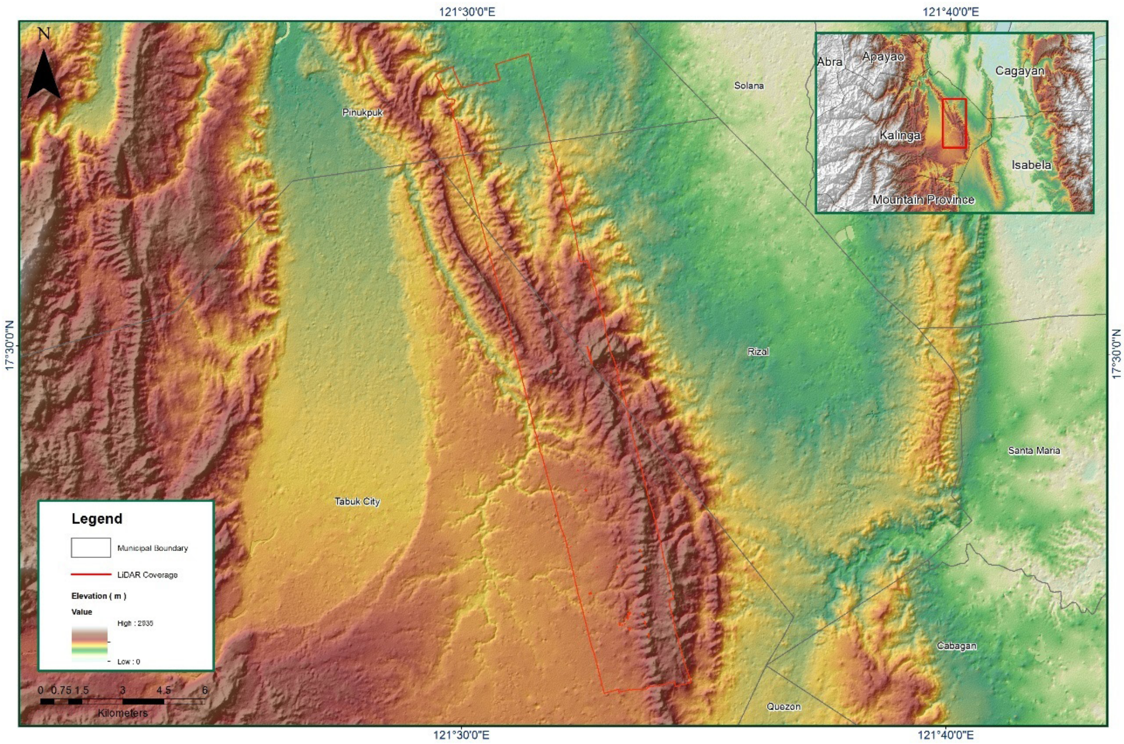


Figure A-8.186. Coverage of LiDAR data

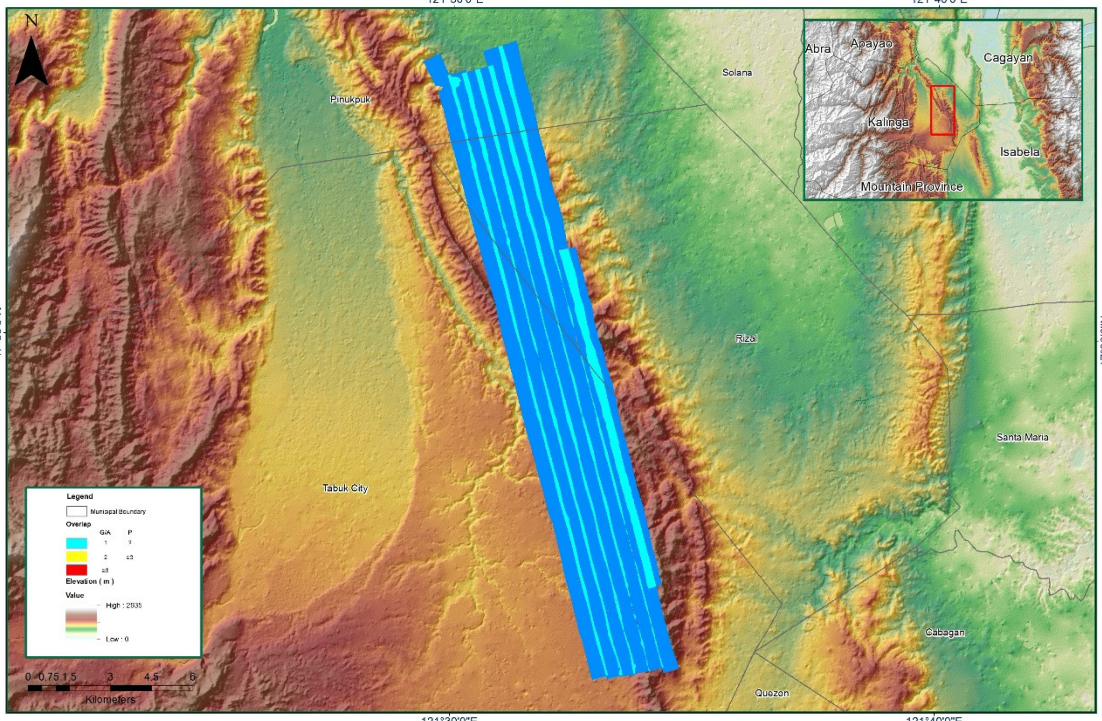


Figure A-8.187. Image of data overlap

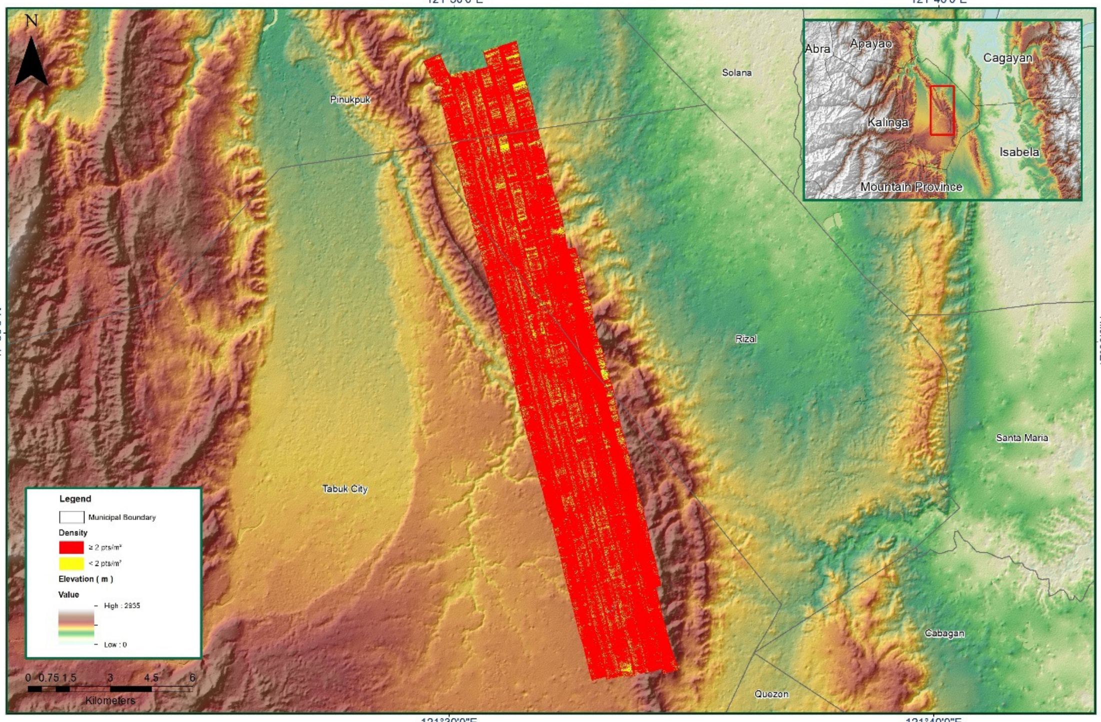


Figure A-8.188. Density map of merged LiDAR data

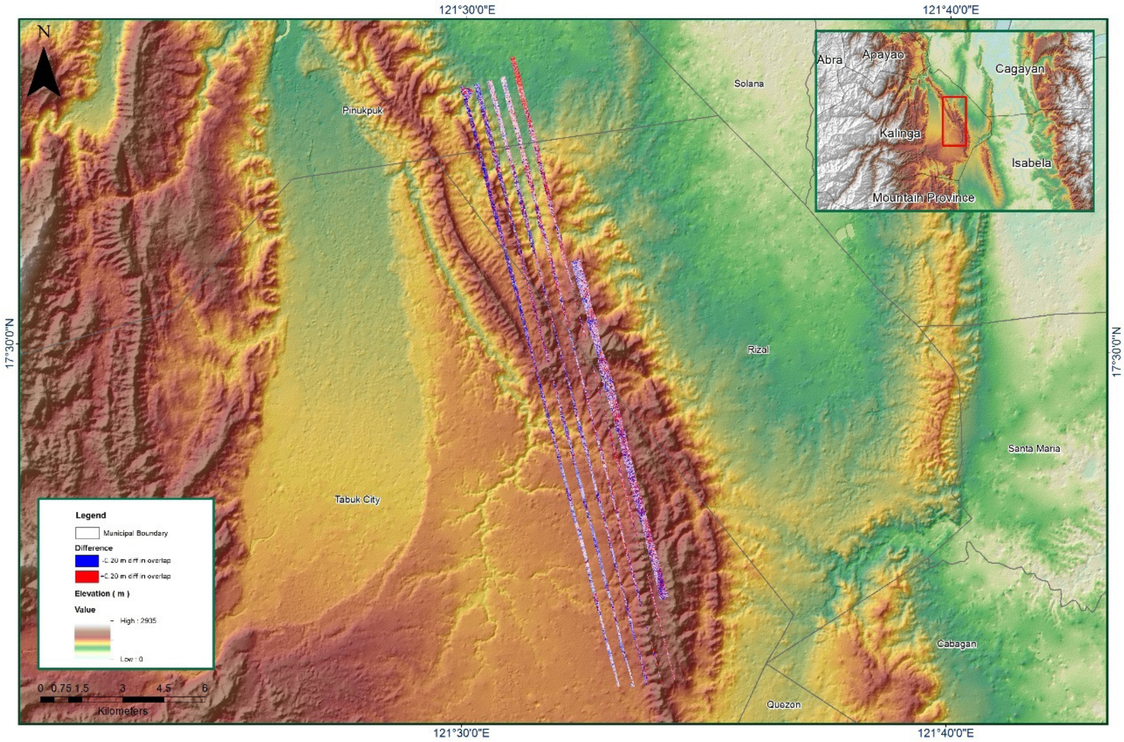


Figure A-8.189. Elevation difference between flight lines

Table A-8.28. Mission Summary Report for Mission Cagayan_Reflights_Blk111D

Flight Area	Cagayan_Reflights
Mission Name	Cagayan_Reflights_Blk111D
Inclusive Flights	3979G
Range data size	7.57 GB
POS data size	71.1 MB
Base data size	12.1
Image	n/a
Transfer date	January 06, 2014
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)	2.0
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	2.1
Boresight correction stdev (<0.001deg)	0.000776
IMU attitude correction stdev (<0.001deg)	0.000303
GPS position stdev (<0.01m)	0.0309
Minimum % overlap (>25)	31.78
Ave point cloud density per sq.m. (>2.0)	2.86
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	100
Maximum Height	143.27 m
Minimum Height	53.14 m
Classification (# of points)	
Ground	38,108,782
Low vegetation	45,773,687
Medium vegetation	96,102,397
High vegetation	15,794,629
Building	481,574
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Christy Lubiano, Engr. Karl Adrian Vergara

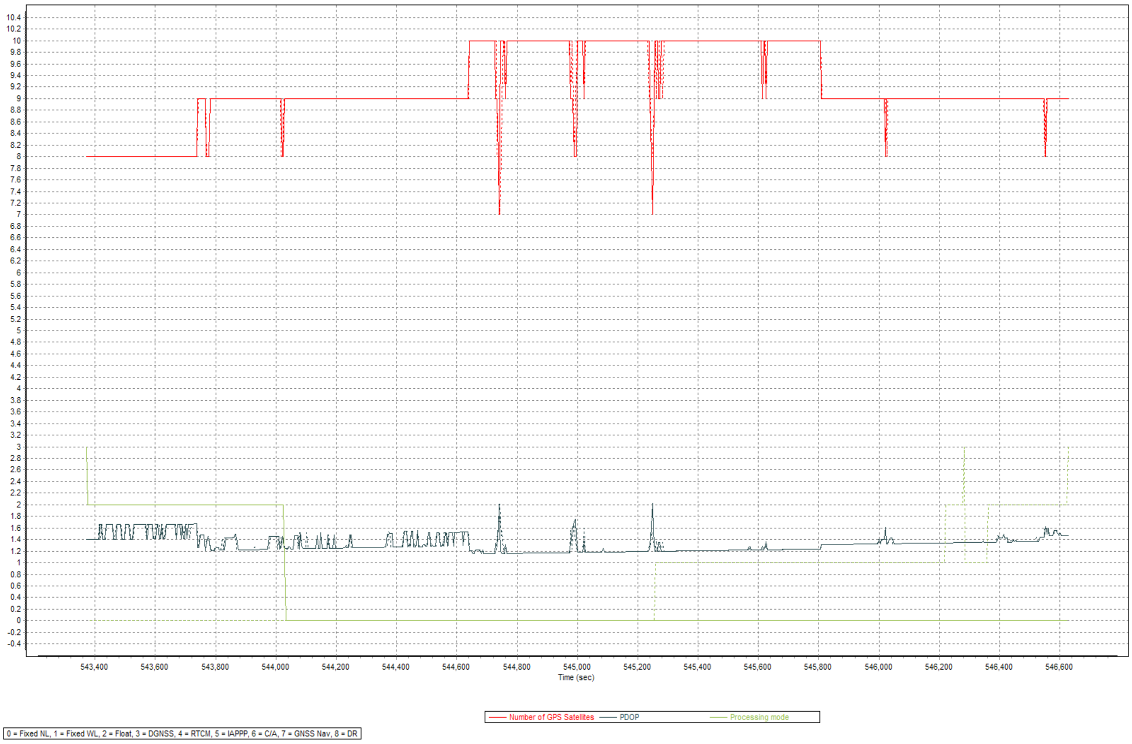


Figure A-8.190. Solution Status

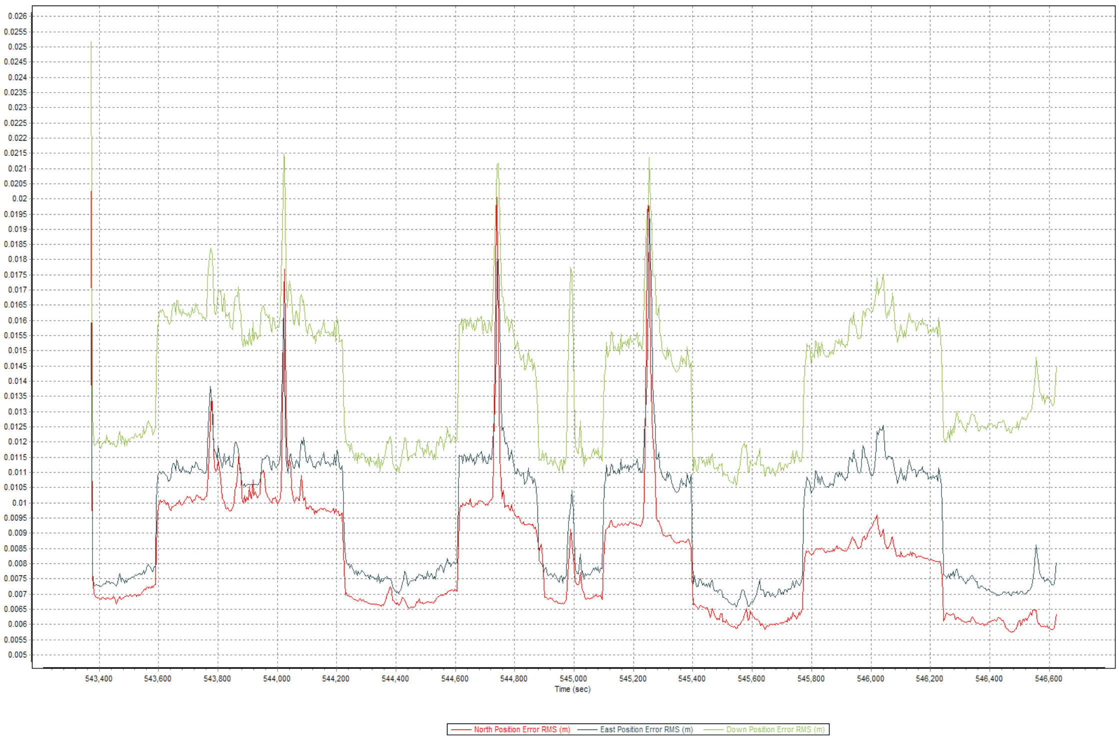


Figure A-8.191. Smoothed Performance Metrics Parameters

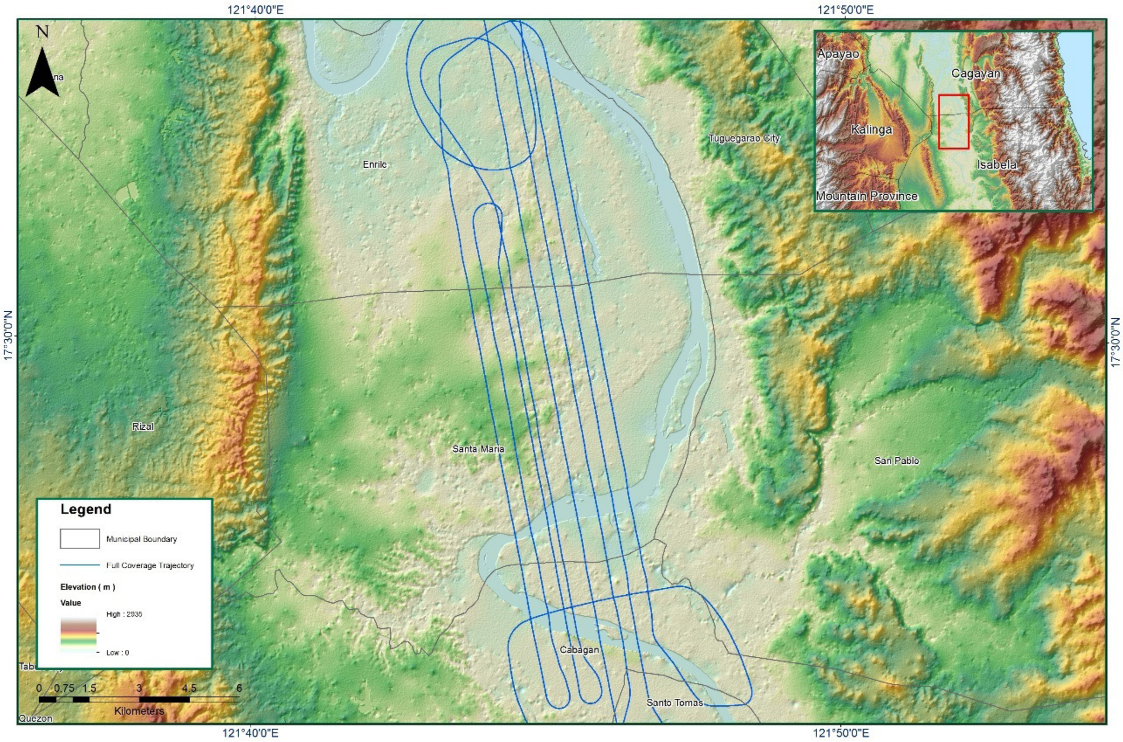


Figure A-8.192. Best Estimated Trajectory

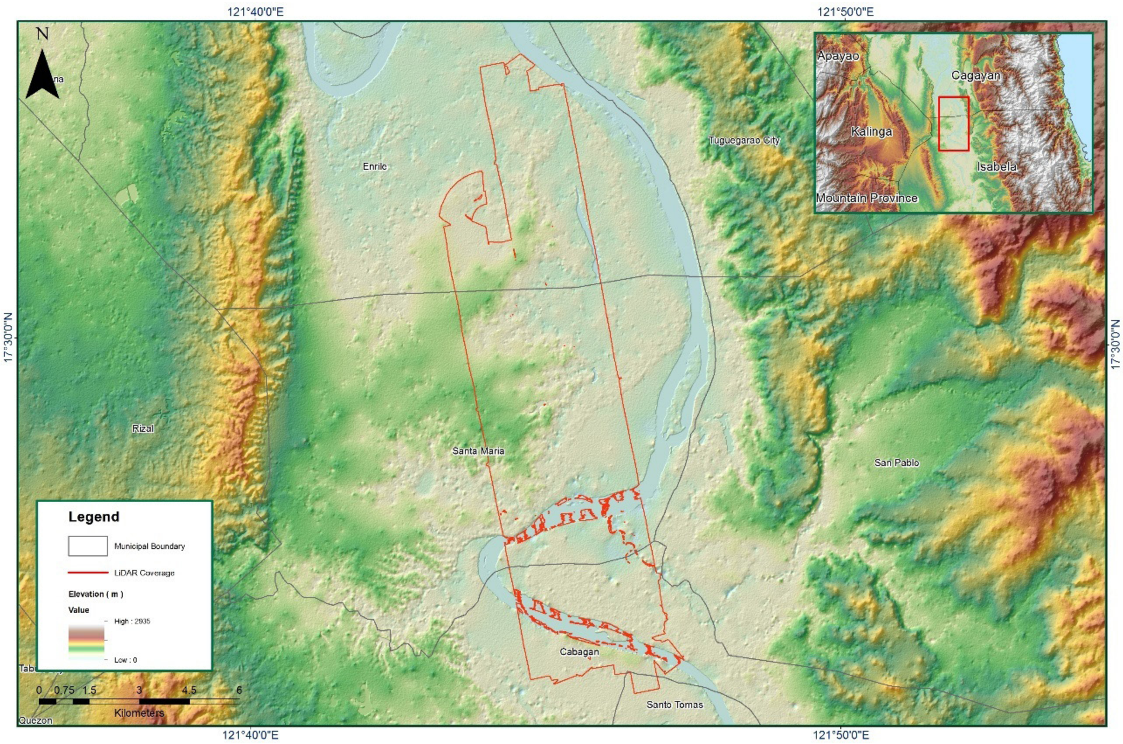


Figure A-8.193. Coverage of LiDAR data

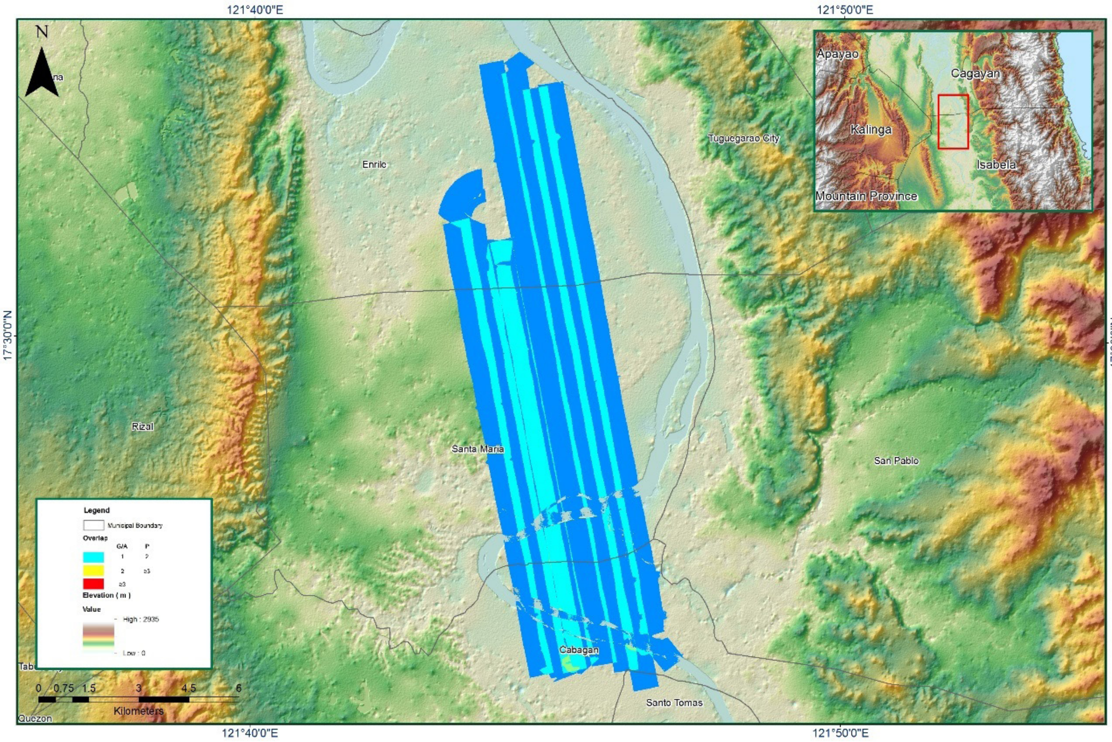


Figure A-8.194. Image of data overlap

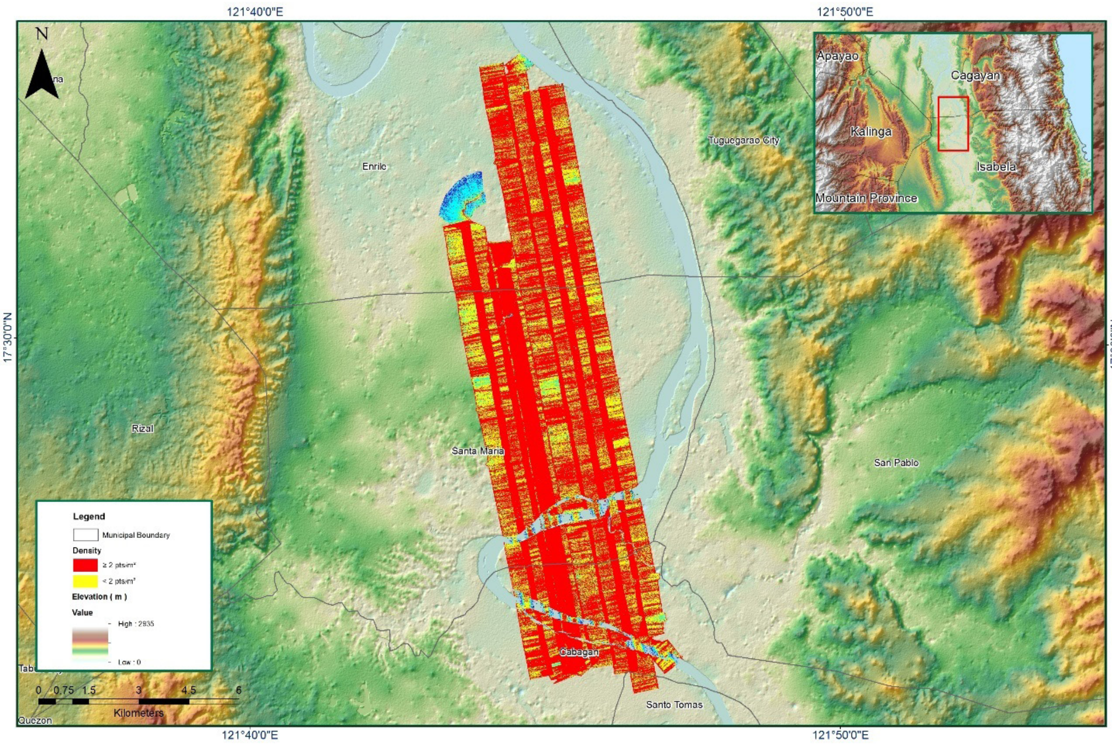


Figure A-8.195. Density map of merged LiDAR data

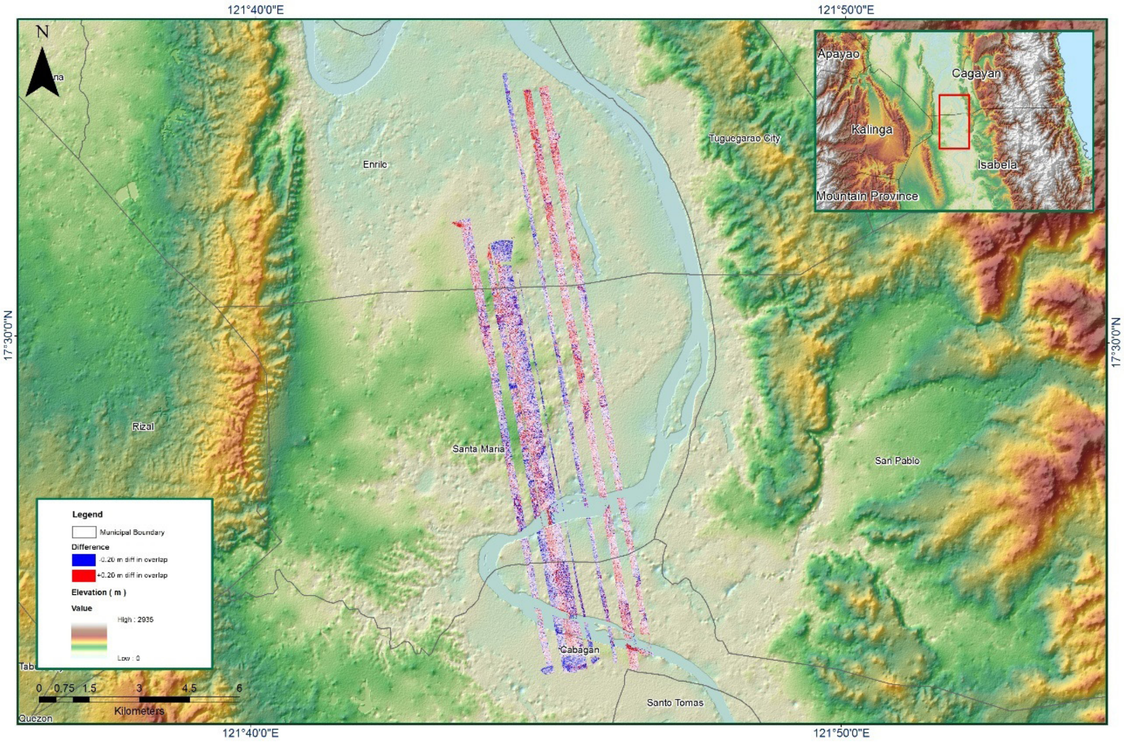


Figure A-8.196. Elevation difference between flight lines

Table A-8.29. Mission Summary Report for Mission CGY_Reflights_Blk101FAddi

Flight Area	Cagayan_Reflights
Mission Name	Cagayan_Reflights_Blk101F_Additional
Inclusive Flights	3983G
Range data size	8.25 GB
POS data size	103 MB
Base data size	8.23 MB
Image	n/a
Transfer date	January 06, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	4.7
Boresight correction stdev (<0.001deg)	0.024495
IMU attitude correction stdev (<0.001deg)	0.070417
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	8.18
Ave point cloud density per sq.m. (>2.0)	3.14
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	56
Maximum Height	492.74 m
Minimum Height	106.19 m
Classification (# of points)	
Ground	24,689,748
Low vegetation	10,988,096
Medium vegetation	28,075,595
High vegetation	16,875,653
Building	25,164
Orthophoto	No
Processed by	Engr. Sheila Maye Santillan, Engr. Jovelle Anjeanette Canlas, Engr. Vincent Louise Azucena

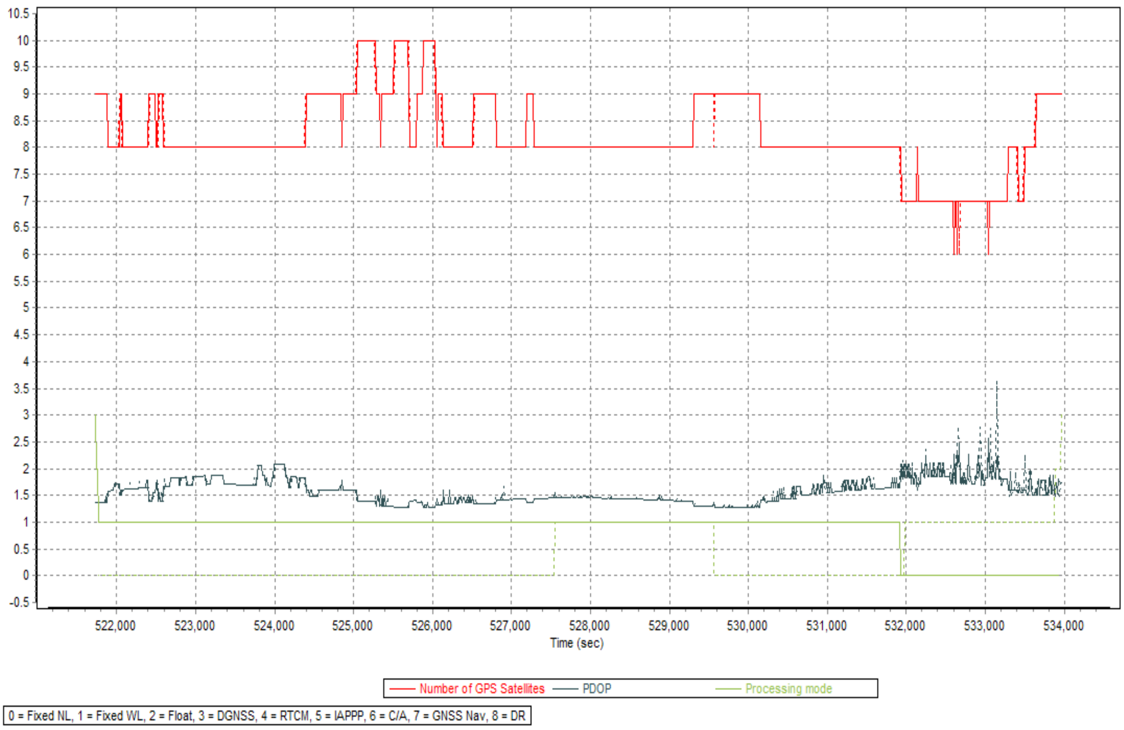


Figure A-8.197. Solution Status

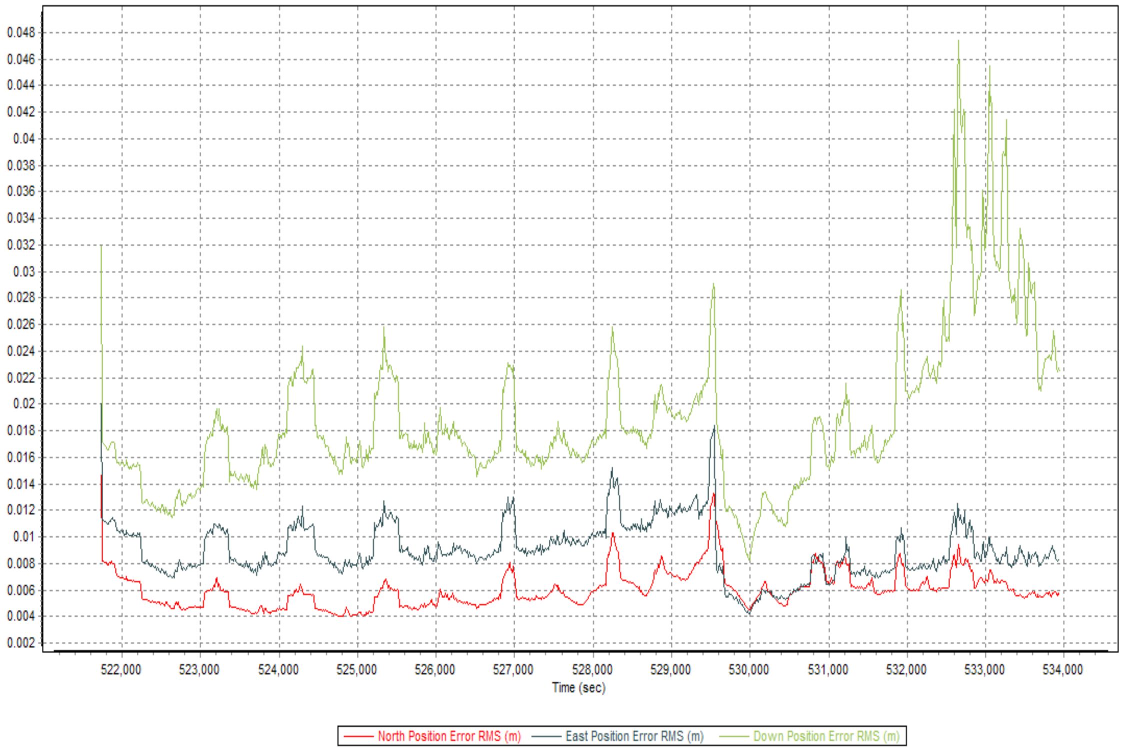


Figure A-8.198. Smoothed Performance Metrics Parameters

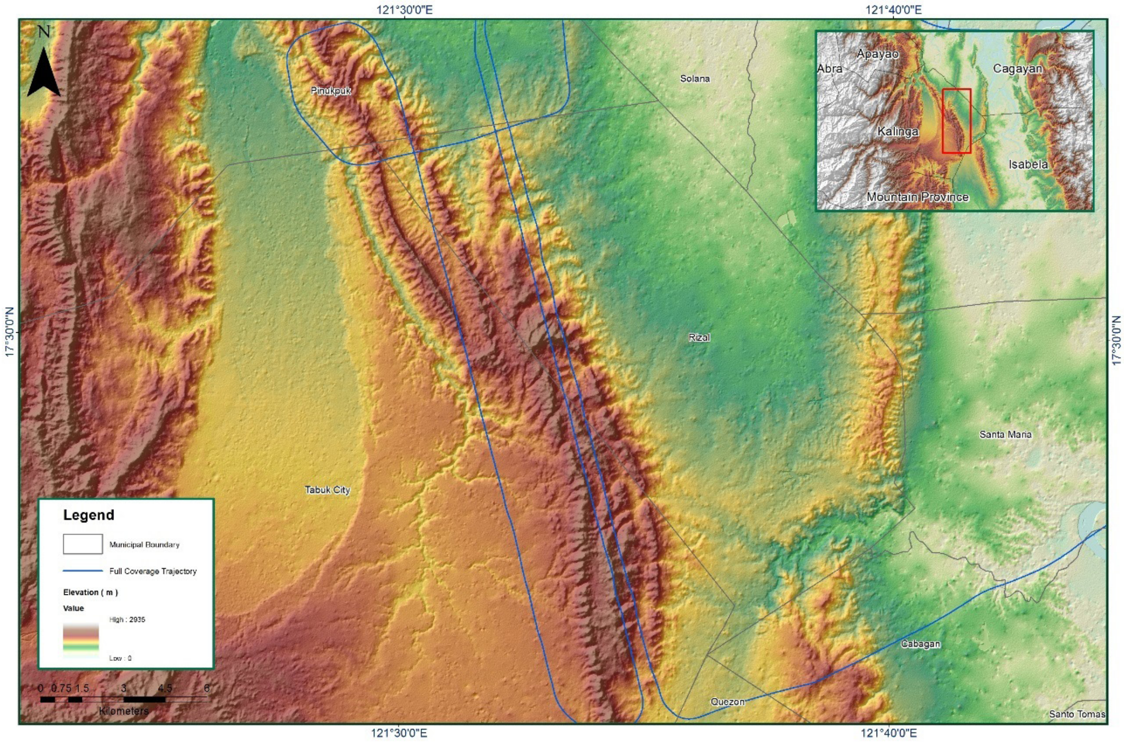


Figure A-8.199. Best Estimated Trajectory

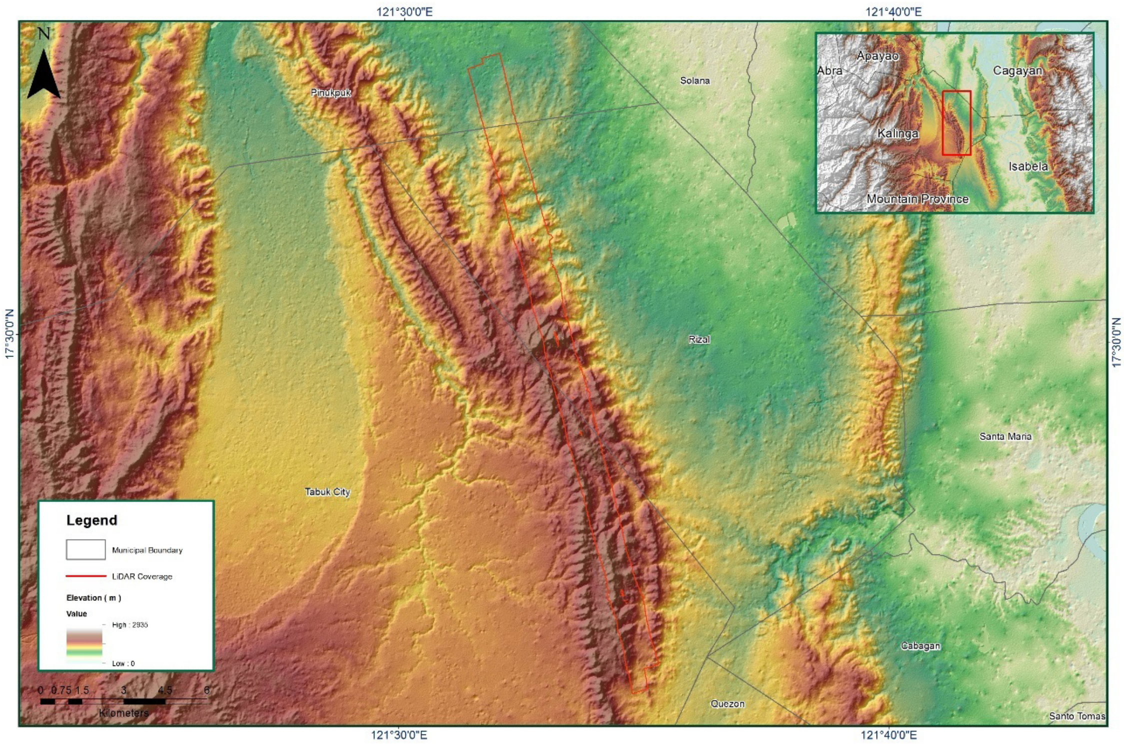


Figure A-8.200. Coverage of LiDAR data

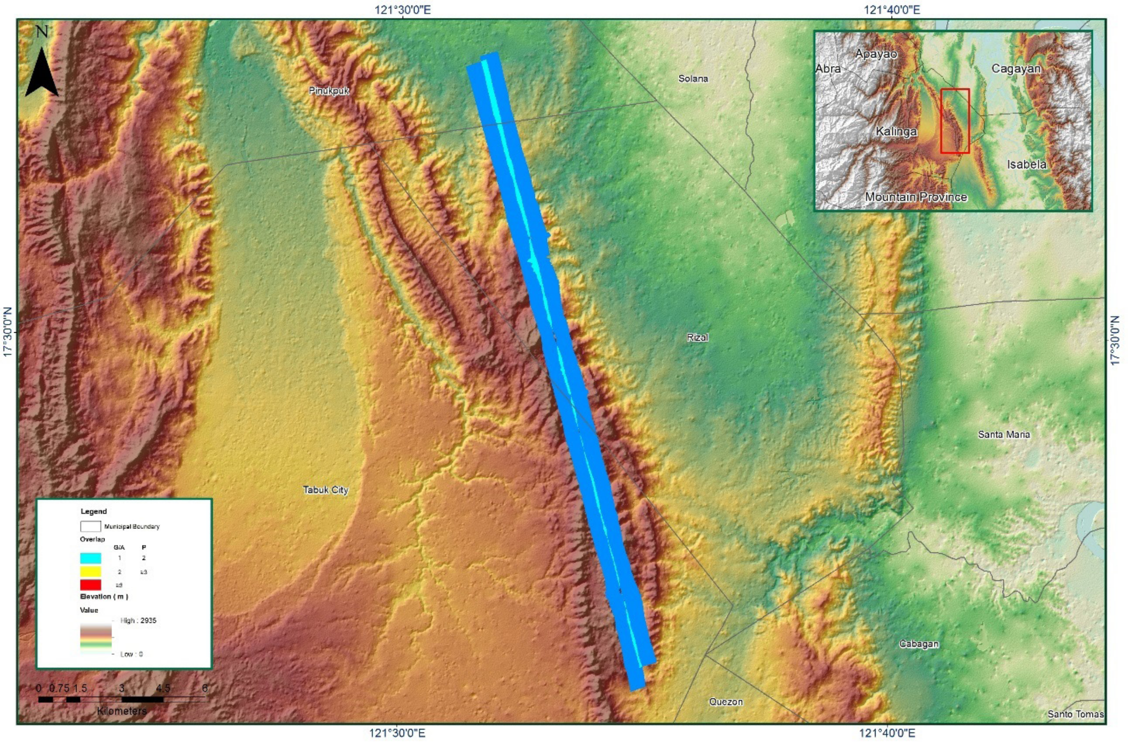


Figure A-8.201. Image of data overlap

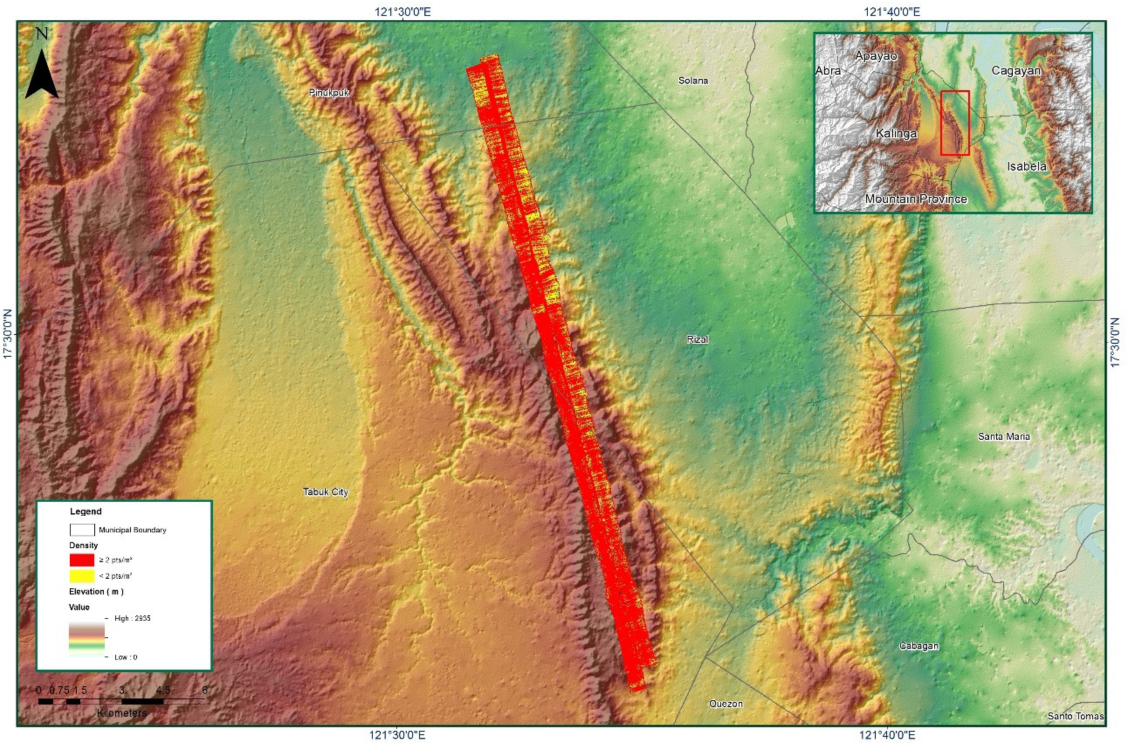


Figure A-8.202. Density map of merged LiDAR data

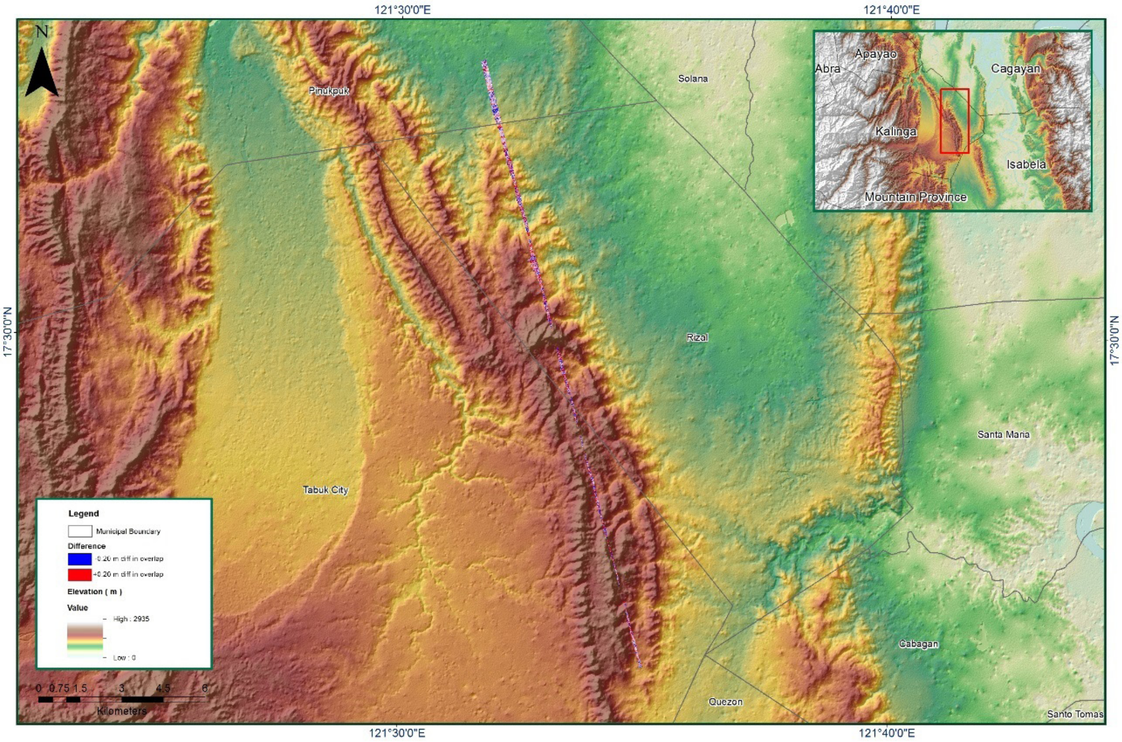


Figure A-8.203. Elevation difference between flight lines

Table A-8.30. Mission Summary Report for Mission Cagayan_reflights_Blk3E

Flight Area	Cagayan
Mission Name	Cagayan_reflights_Blk3E
Inclusive Flights	4001G
Range data size	16.1 GB
POS data size	245 MB
Base data size	9.35 MB
Image	NA
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	4.0
Boresight correction stdev (<0.001deg)	0.042939
IMU attitude correction stdev (<0.001deg)	0.015915
GPS position stdev (<0.01m)	0.0028
Minimum % overlap (>25)	39.43%
Ave point cloud density per sq.m. (>2.0)	4.48
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	56
Maximum Height	1137.78 m
Minimum Height	36.97 m
Classification (# of points)	
Ground	7,027,759
Low vegetation	1,038,007
Medium vegetation	9,626,843
High vegetation	115,006,003
Building	78,814
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Harmond Santos, Engr. Gladys Mae Apat,

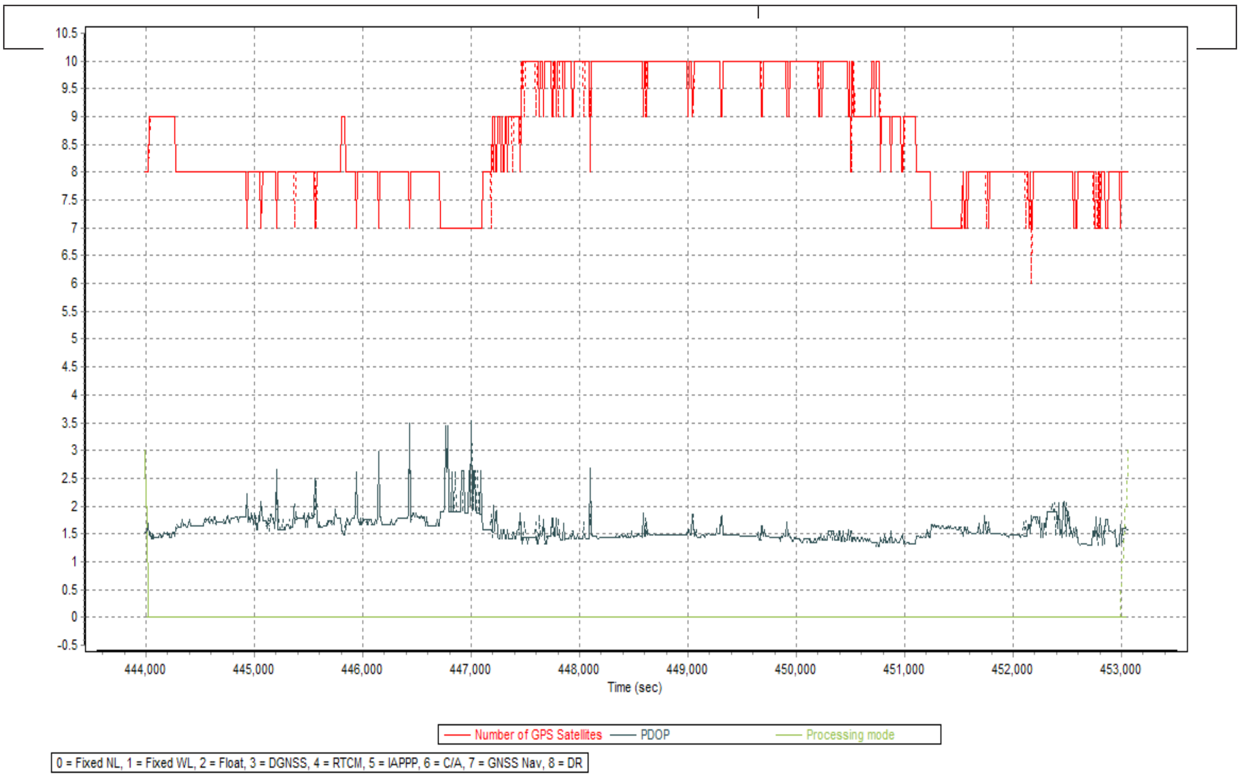


Figure A-8.204. Solution Status

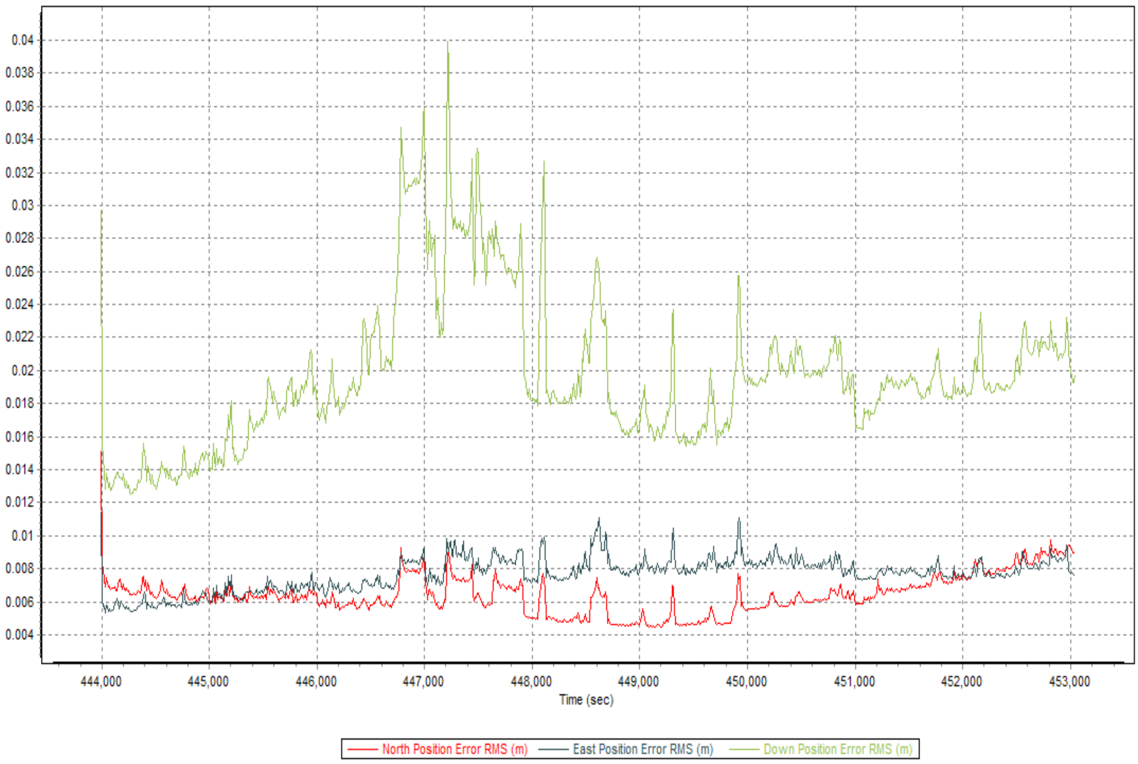


Figure A-8.205. Smoothed Performance Metrics Parameters

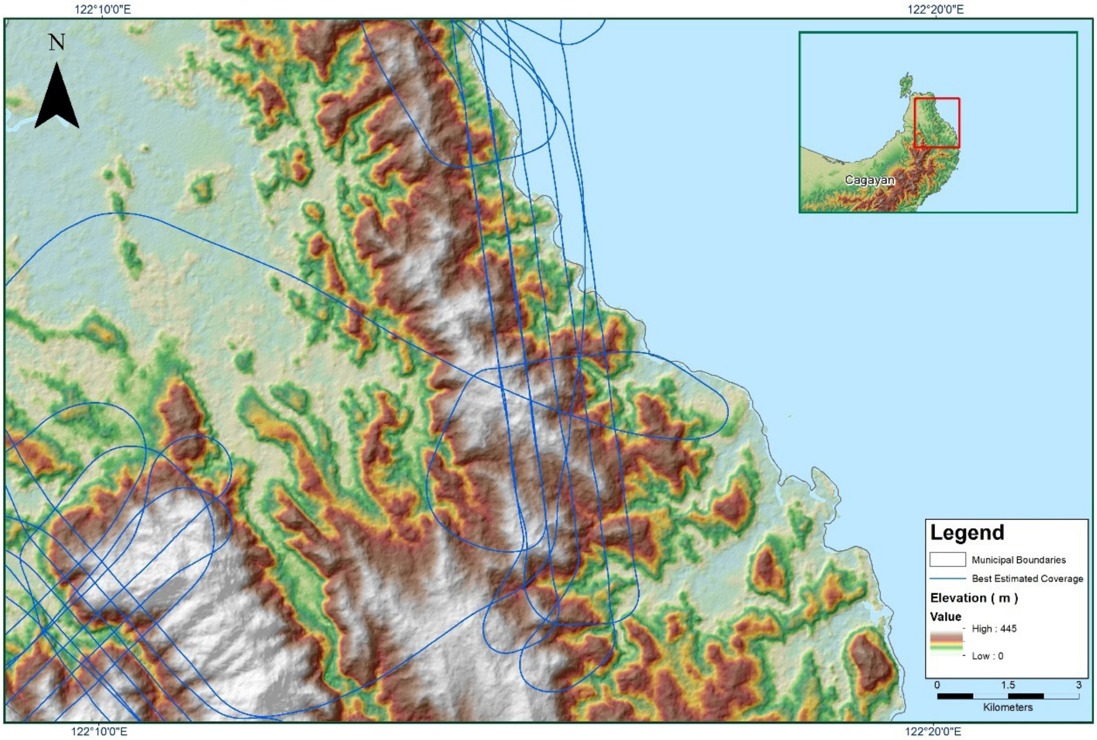


Figure A-8.206. Best Estimated Trajectory

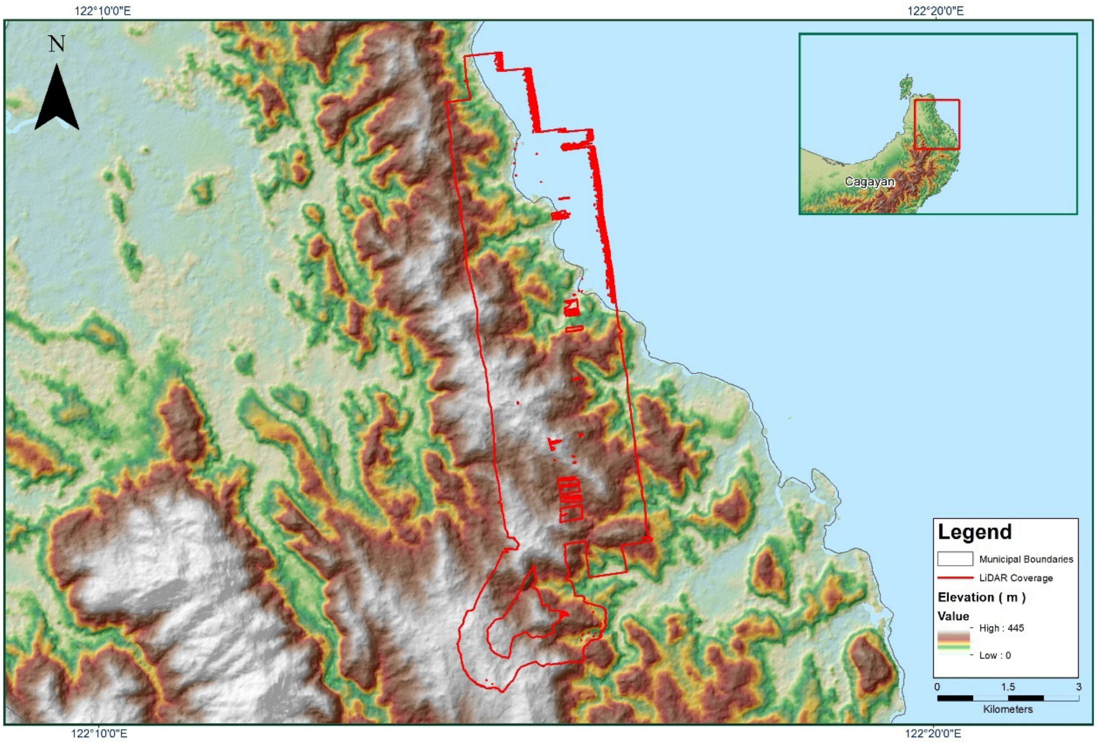


Figure A-8.207. Coverage of LiDAR data

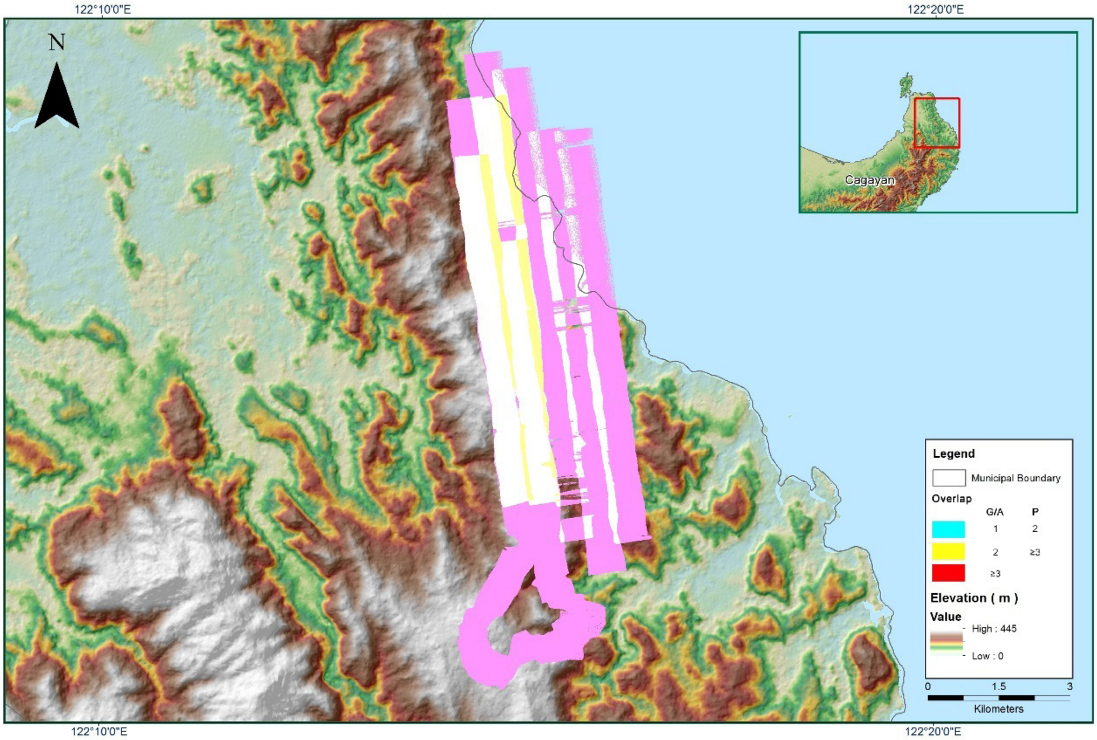


Figure A-8.208. Image of data overlap

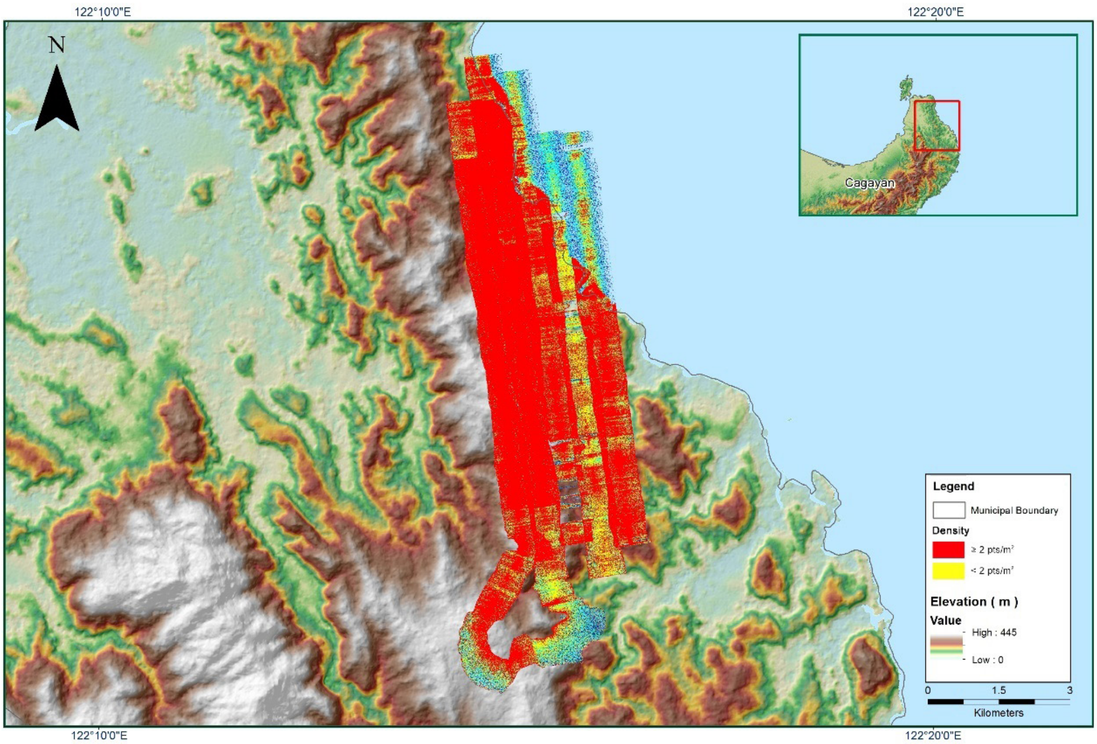


Figure A-8.209. Density map of merged LiDAR data

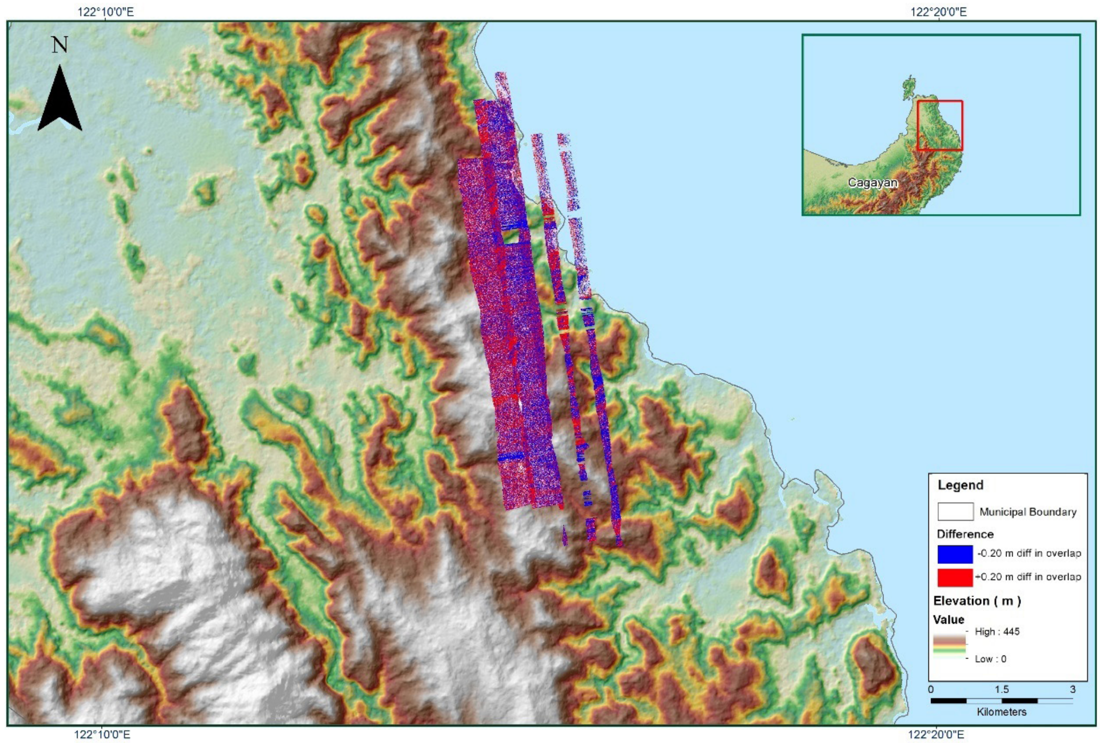


Figure A-8.210. Elevation difference between flight lines

Table A-8.31. Mission Summary Report for Mission Cagayan_reflights_Blk3D

Flight Area	Cagayan
Mission Name	Cagayan_reflights_Blk3D
Inclusive Flights	4001G
Range data size	16.1 GB
POS data size	245 MB
Base data size	9.35 MB
Image	NA
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	4.0
Boresight correction stdev (<0.001deg)	0.001846
IMU attitude correction stdev (<0.001deg)	0.0027
GPS position stdev (<0.01m)	0.007490
Minimum % overlap (>25)	40.87%
Ave point cloud density per sq.m. (>2.0)	3.10
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	48
Maximum Height	384.55 m
Minimum Height	36.47 m
Classification (# of points)	
Ground	9,410,752
Low vegetation	3,773,495
Medium vegetation	18,571,059
High vegetation	4,495,3057
Building	60,141
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Harmond Santos, Engr. Gladys Mae Apat

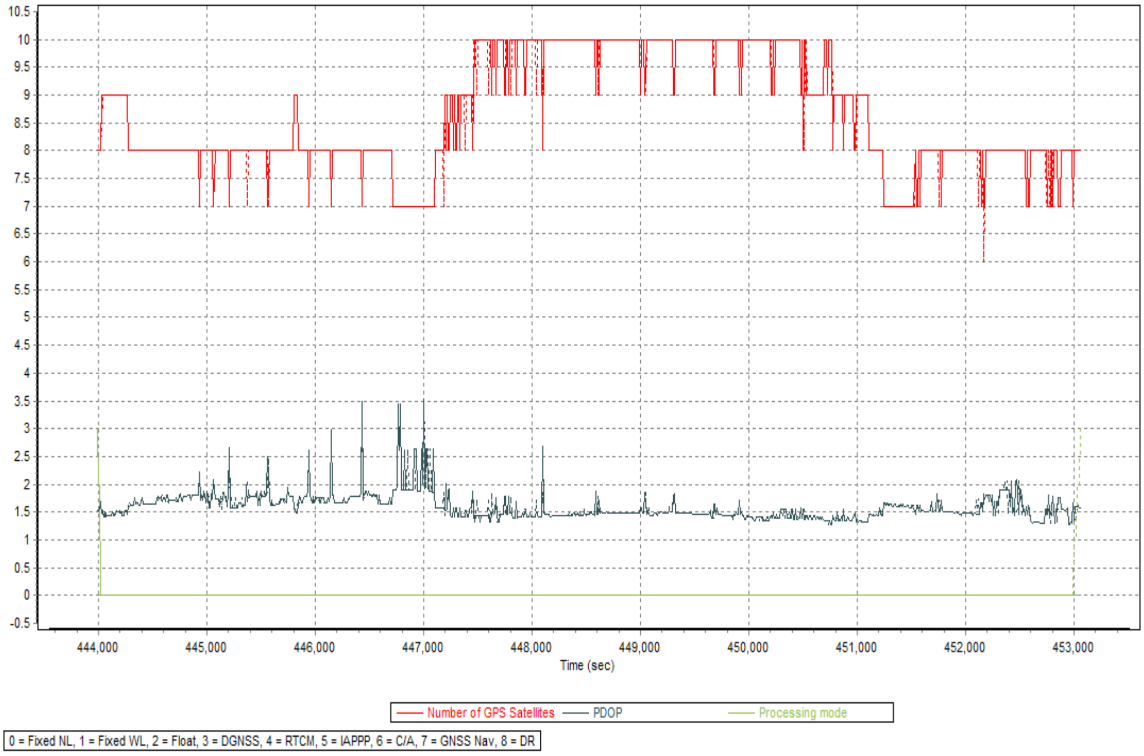


Figure A-8.211. Solution Status

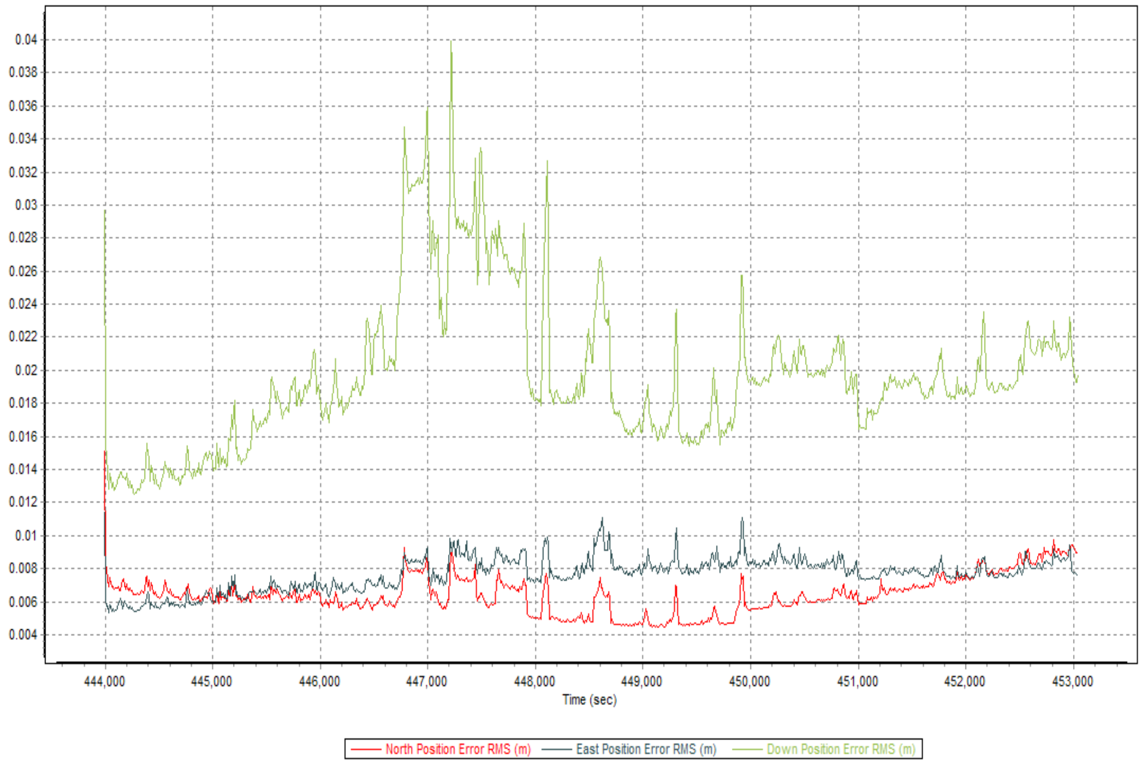


Figure A-8.212. Smoothed Performance Metric Parameters

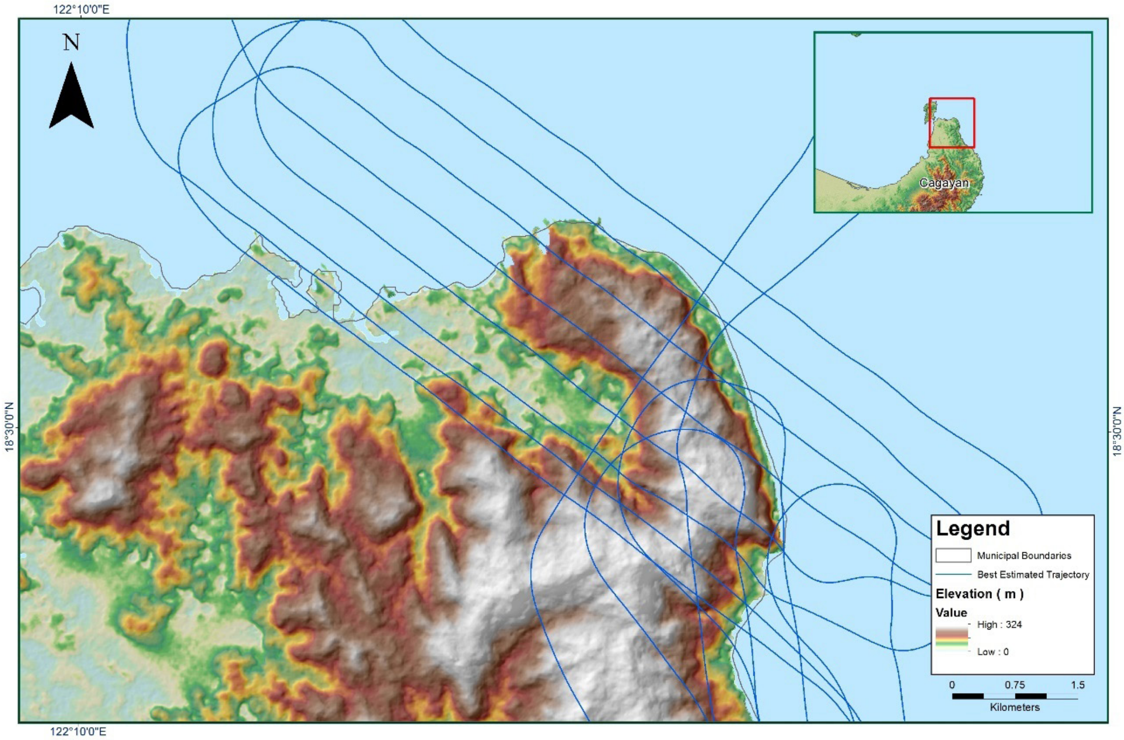


Figure A-8.213. Best Estimated Trajectory

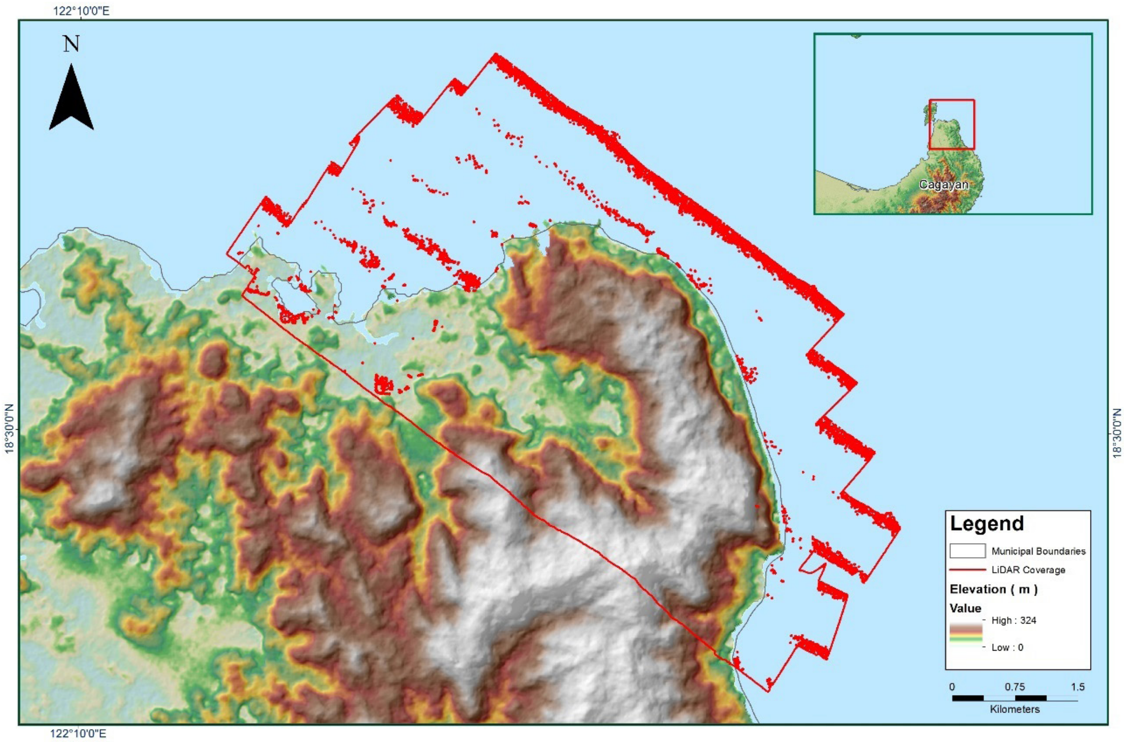


Figure A-8.214. Coverage of LiDAR Data

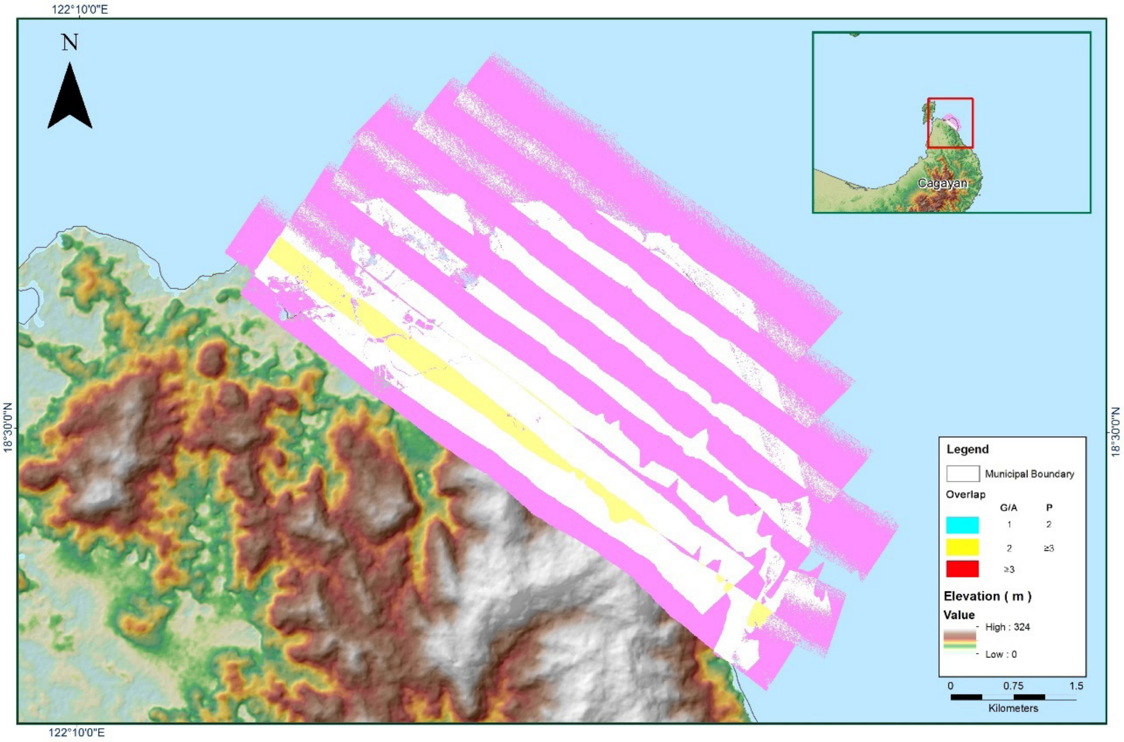


Figure A-8.215. Image of data overlap

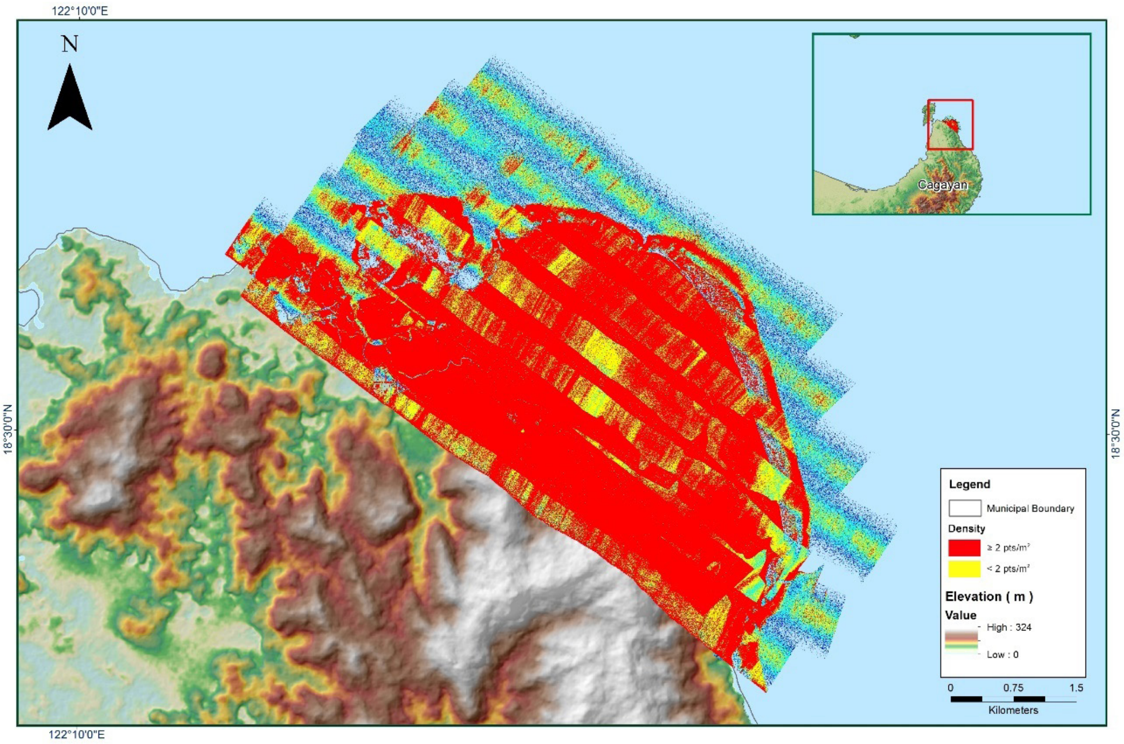


Figure A-8.216**. Density map of merged LiDAR data**

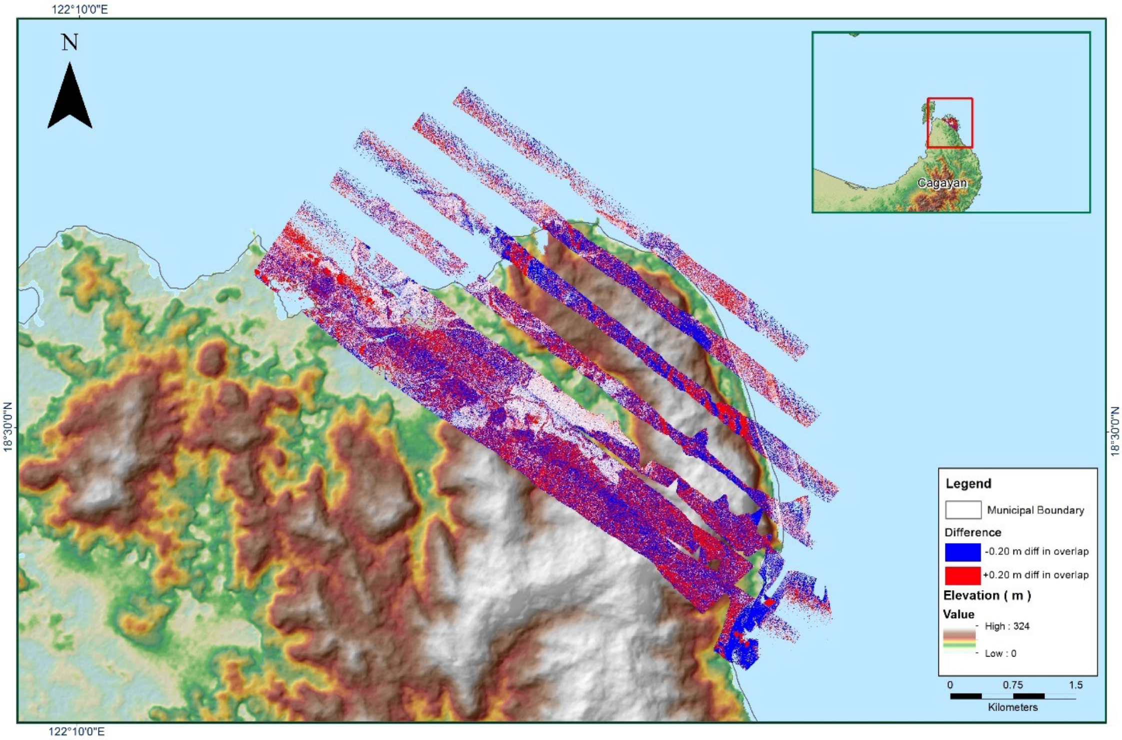


Figure A-8.217. Elevation difference between flight lines

Table A-8.32. Mission Summary Report for Mission Cagayan_reflights_Blk3A

Flight Area	Cagayan
Mission Name	Cagayan_reflights_Blk3A
Inclusive Flights	3971G, 3991G, 4001G
Range data size	45.75 GB
POS data size	640 MB
Base data size	33.73 MB
Image	NA
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.5
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	2.4
Boresight correction stdev (<0.001deg)	0.000876
IMU attitude correction stdev (<0.001deg)	0.015089
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	42.36%
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	156
Maximum Height	526.96 m
Minimum Height	39.41 m
Classification (# of points)	
Ground	70,619,413
Low vegetation	72,372,299
Medium vegetation	199,312,514
High vegetation	122,546,677
Building	5,607,920
Orthophoto	No
Processed by	Engr. Don Matthew Banatin, Engr. Christy Lubiano, Engr. Karl Adrian Vergara

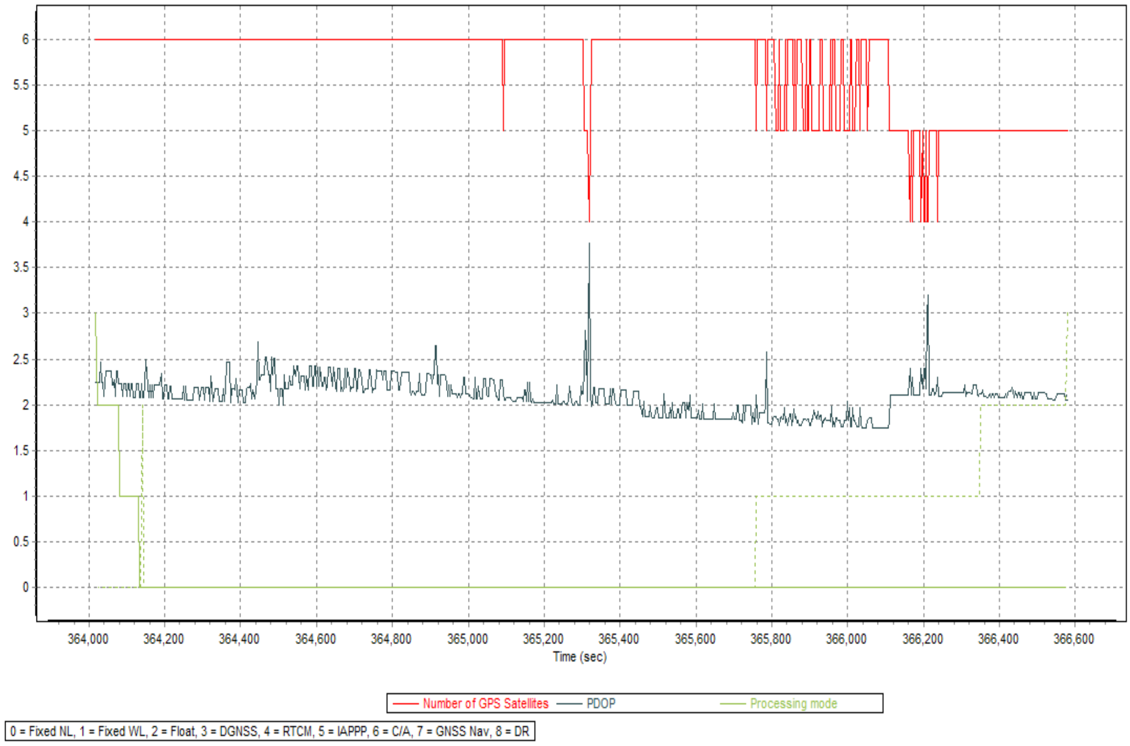


Figure A-8.218. Solution Status

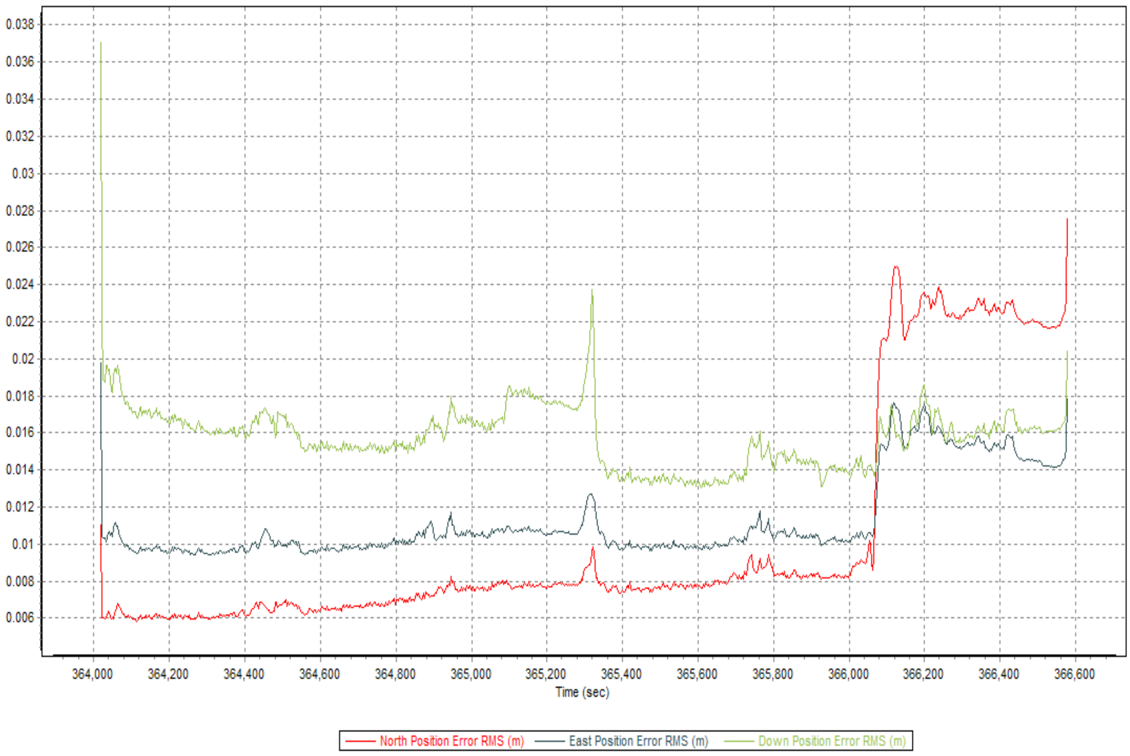


Figure A-8.219. Smoothed Performance Metric Parameters

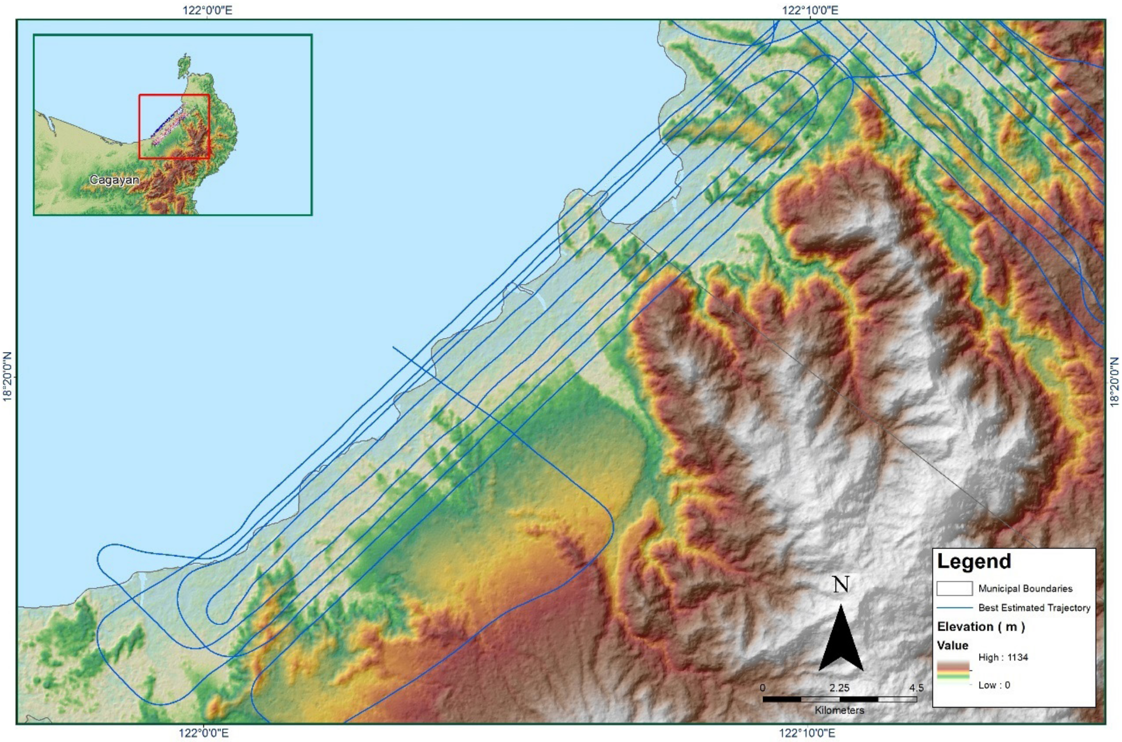


Figure A-8.220. Best Estimated Trajectory

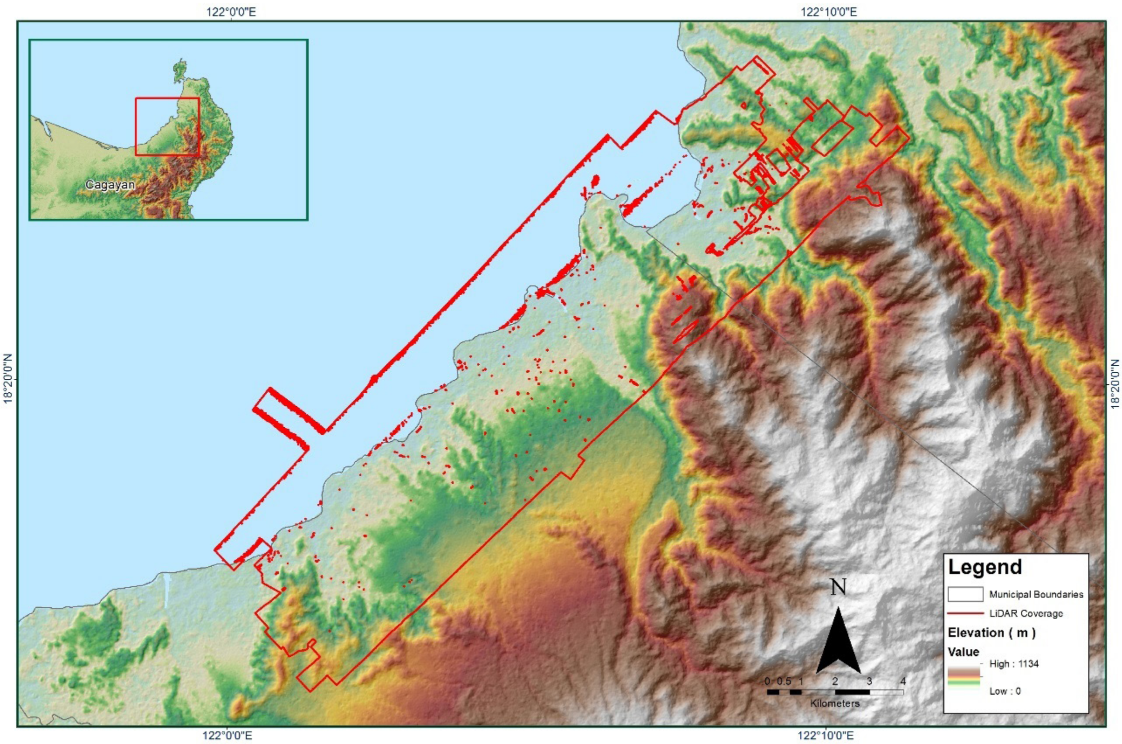


Figure A-8.221. Coverage of LiDAR Data

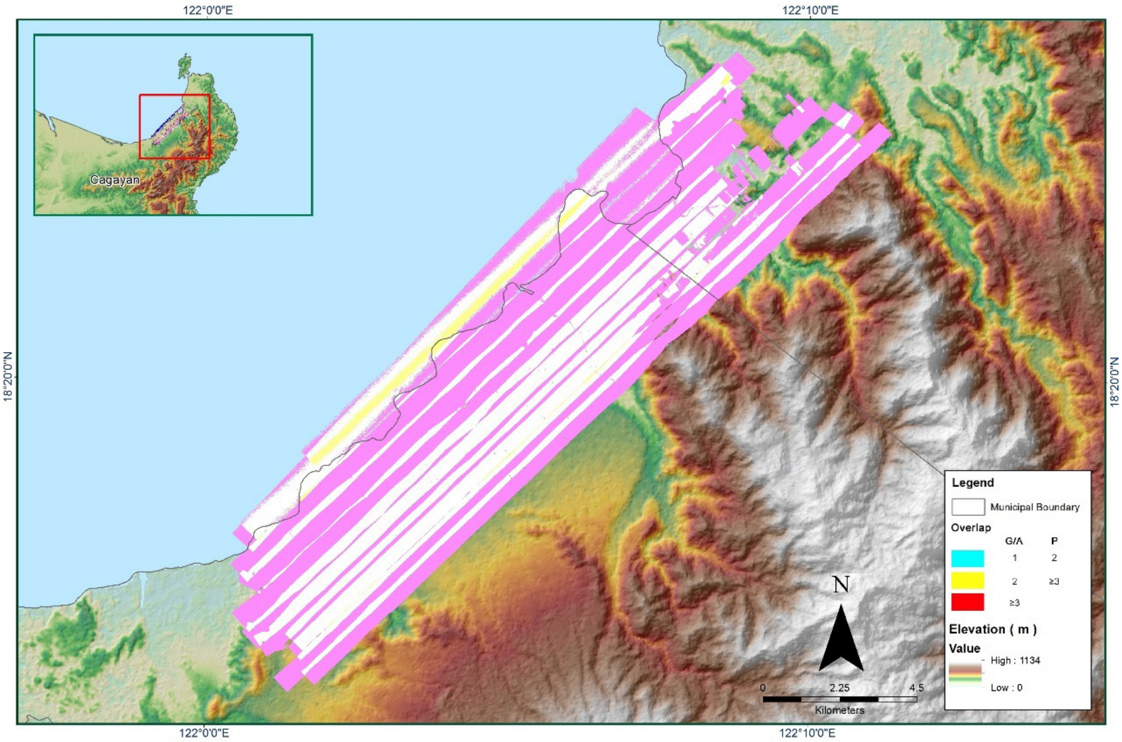


Figure A-8.222. Image of data overlap

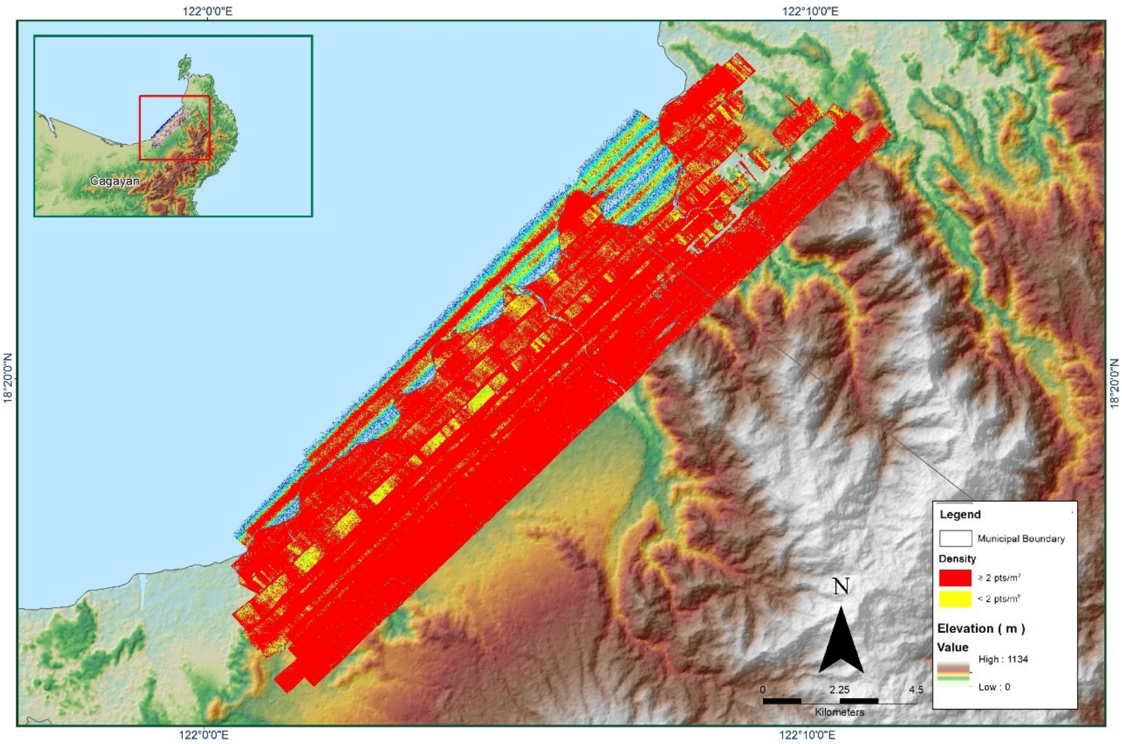


Figure A-8.223. **Density map of merged LiDAR data**

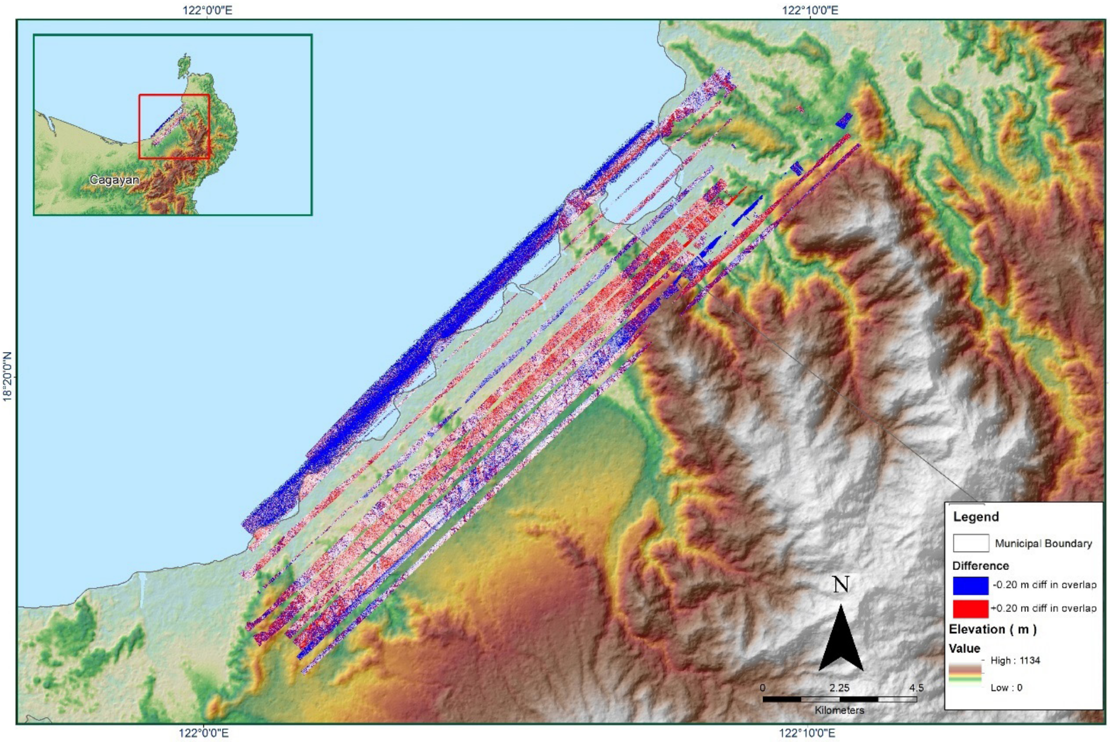


Figure A-8.224. Elevation difference between flight lines

Table A-8.33. Mission Summary Report for Mission Cagayan_reflights_Blk3C

Flight Area	Cagayan
Mission Name	Cagayan_reflights_Blk3C
Inclusive Flights	3991G, 3971G, 3989G
Range data size	46.75 GB
POS data size	640 MB
Base data size	38.98 MB
Image	NA
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	0.000342
IMU attitude correction stdev (<0.001deg)	0.000718
GPS position stdev (<0.01m)	0.0014
Minimum % overlap (>25)	44.96%
Ave point cloud density per sq.m. (>2.0)	5.54
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	211
Maximum Height	801.02 m
Minimum Height	37.68 m
Classification (# of points)	
Ground	64,955,431
Low vegetation	70,520,039
Medium vegetation	182,653,450
High vegetation	495,888,734
Building	7,863,830
Orthophoto	No
Processed by	Engr. Regis Guhiting, Engr. Harmond Santos, Engr. Gladys Mae Apat

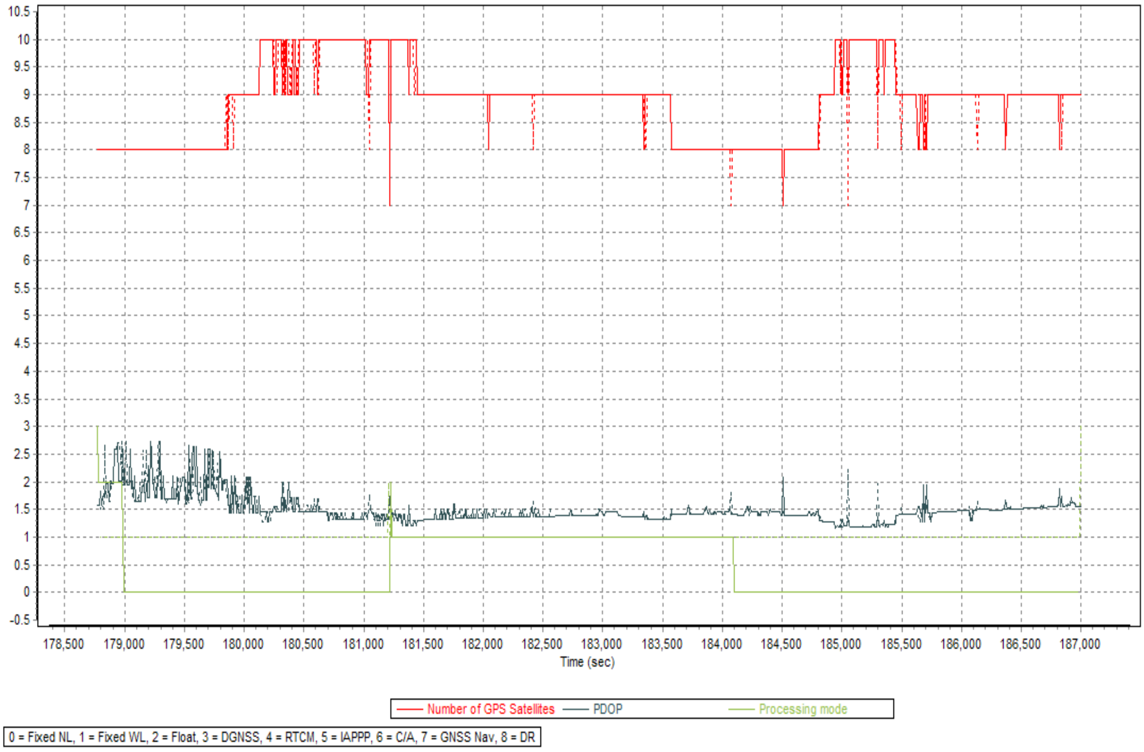


Figure A-8.225. Solution Status

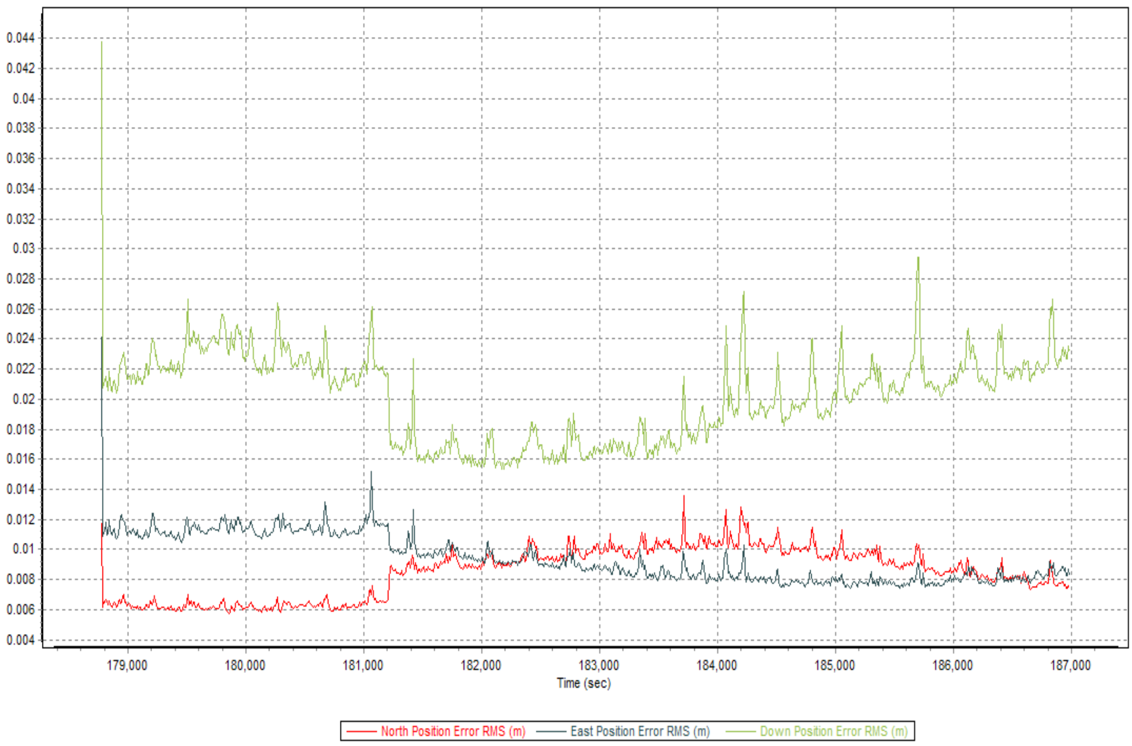


Figure A-8.226. Smoothed Performance Metric Parameters

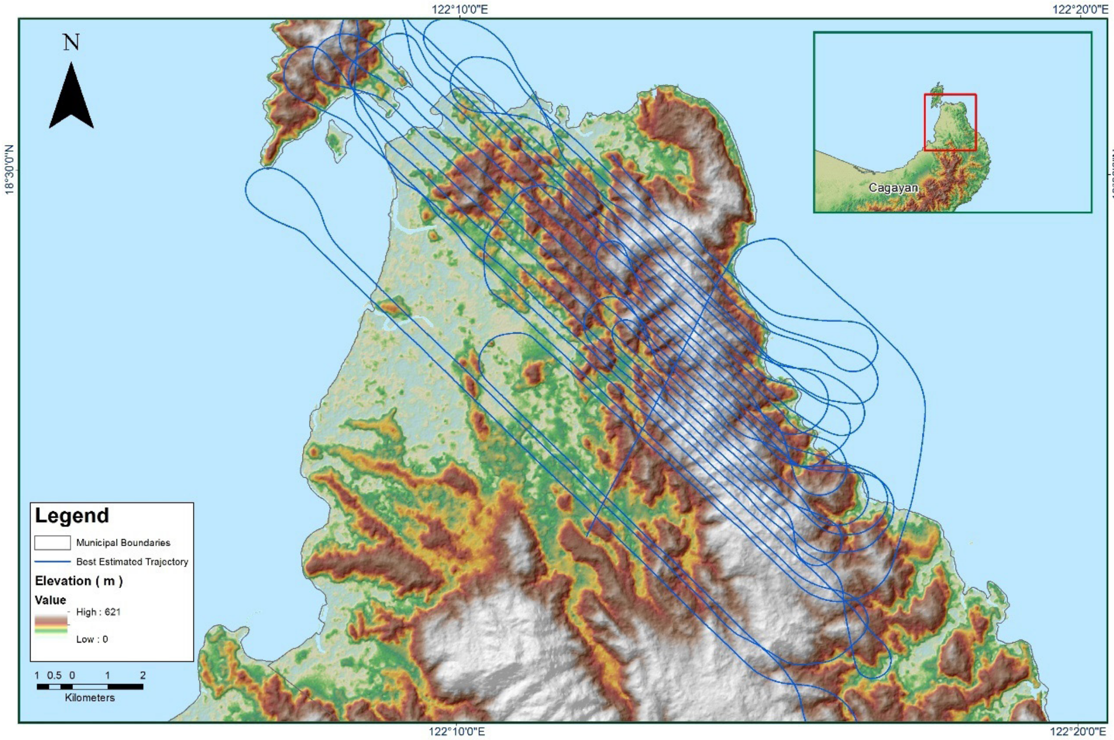


Figure A-8.227. Best Estimated Trajectory

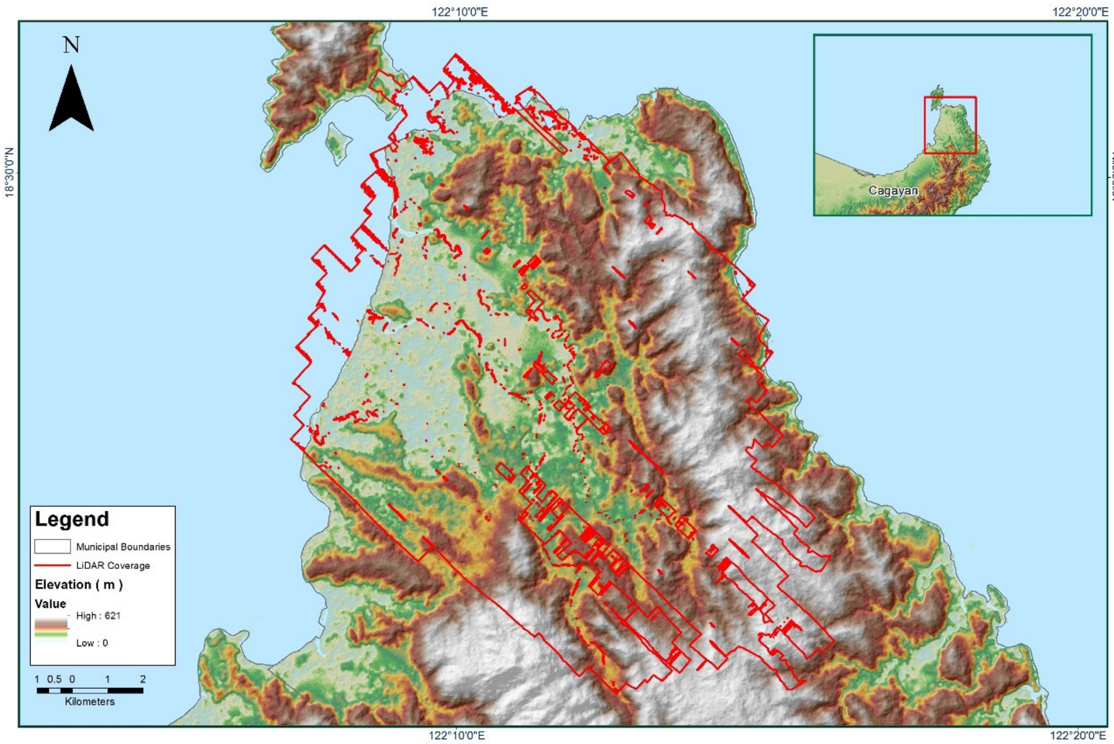


Figure A-8.228. Coverage of LiDAR Data

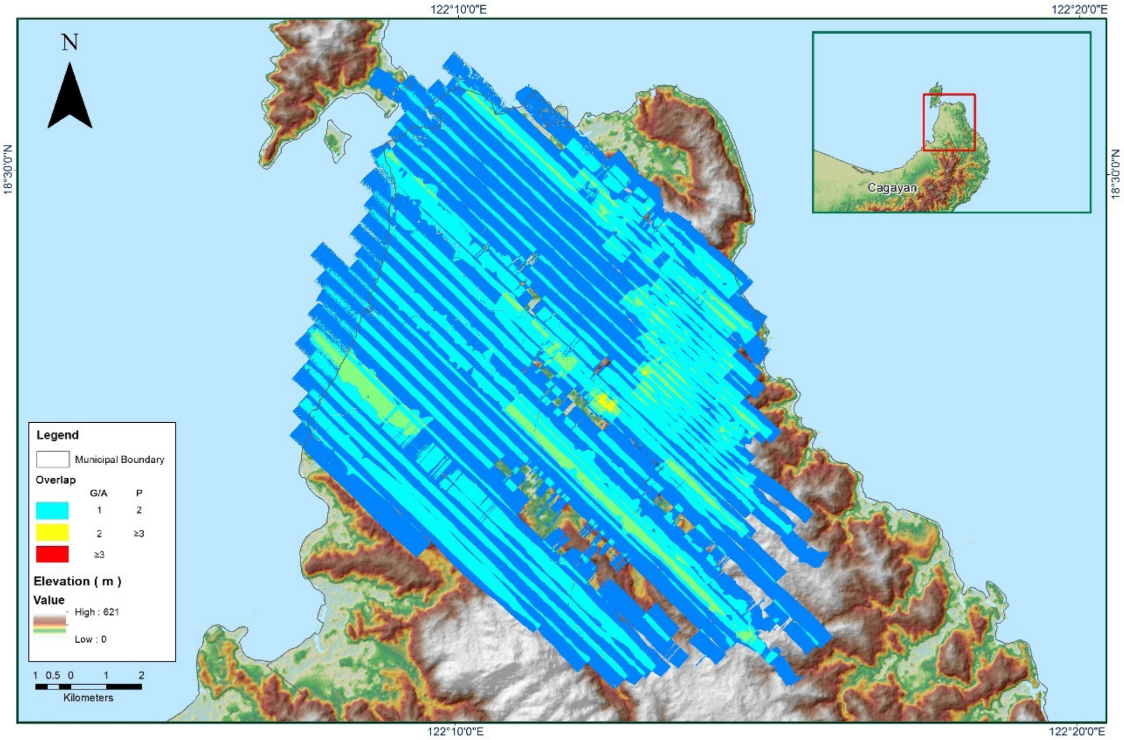


Figure A-8.229. Image of data overlap

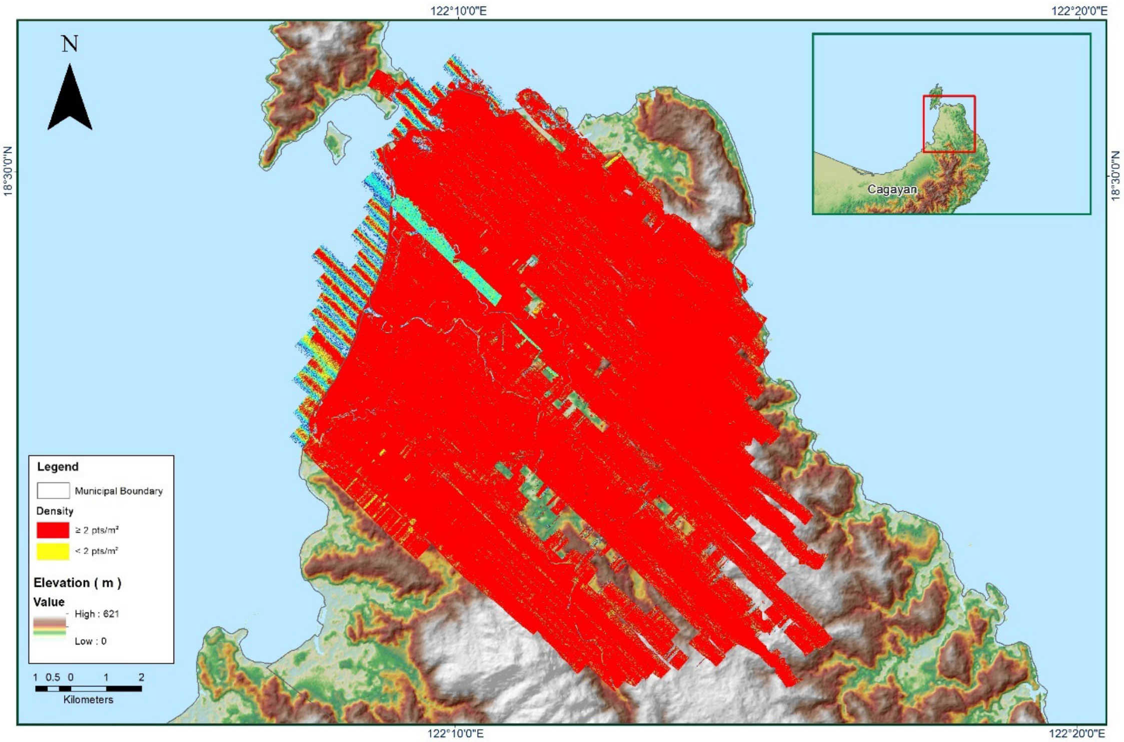


Figure A-8.230. **Density map of merged LiDAR data**

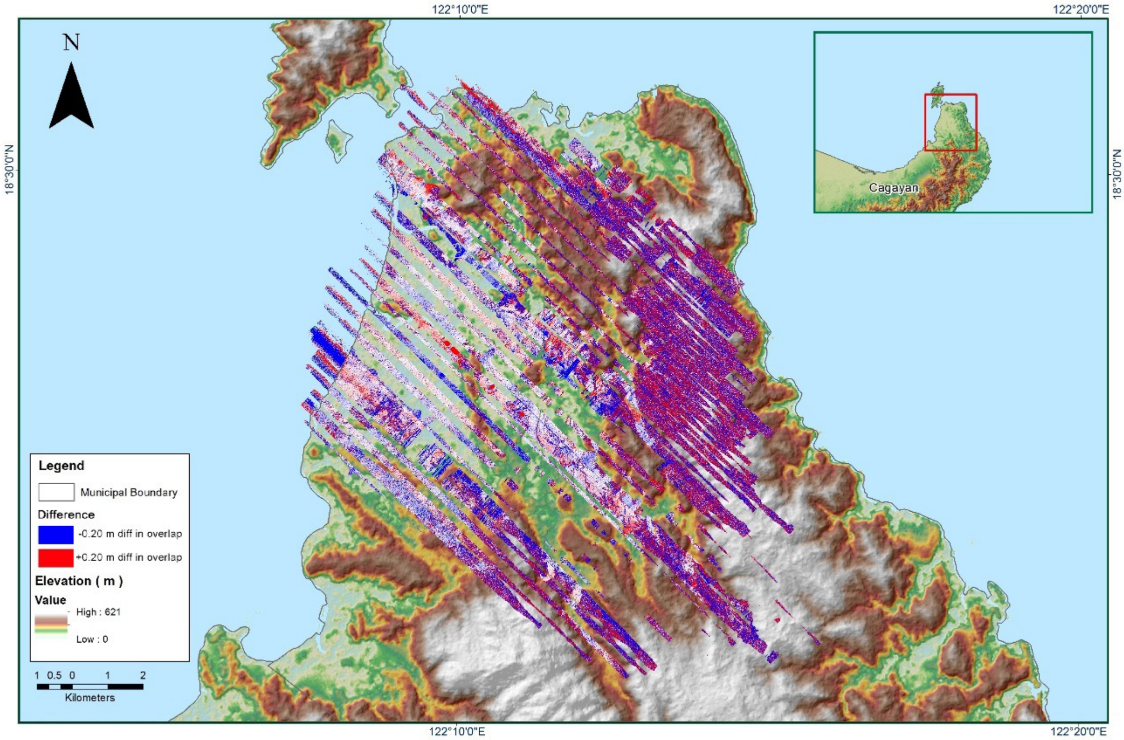


Figure A-8.231. Elevation difference between flight lines

Annex 9. Pinacanauan de Ilagan Model Basin Parameters

Table A-9.1. Pinacanauan de Ilagan Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1600	34	60	0	0.14275	0.51254	Discharge	18.589	0.65	Ratio to Peak	0.3
W1610	22.095	69.689	0	0.44002	1.5799	Discharge	67.526	0.65	Ratio to Peak	0.3
W1620	29.932	62.925	0	0.29245	1.05	Discharge	54.398	0.65	Ratio to Peak	0.3
W1630	33.87	60	0	0.0567248	0.20366	Discharge	7.9261	0.65	Ratio to Peak	0.3
W1640	33.87	60	0	0.22244	0.79866	Discharge	48.432	0.65	Ratio to Peak	0.3
W1650	33.87	60	0	0.17728	0.63652	Discharge	36.487	0.65	Ratio to Peak	0.3
W1660	33.87	60	0	0.16607	0.59626	Discharge	22.841	0.65	Ratio to Peak	0.3
W1670	33.87	60	0	0.12857	0.46163	Discharge	14.1880	0.65	Ratio to Peak	0.3
W1680	33.87	60	0	0.10342	0.37133	Discharge	8.7889	0.65	Ratio to Peak	0.3
W1690	28.419	64.126	0	0.18012	0.6467	Discharge	17.800	0.65	Ratio to Peak	0.3
W1700	33.87	60	0	0.085401	0.30662	Discharge	4.8197	0.65	Ratio to Peak	0.3
W1710	33.87	60	0	0.0874653	0.31404	Discharge	10.2681	0.65	Ratio to Peak	0.3
W1720	33.87	60	0	0.12814	0.46008	Discharge	12.3390	0.65	Ratio to Peak	0.3
W1730	32.8001473	60.765	0	0.20918	0.75105	Discharge	27.5378530	0.65	Ratio to Peak	0.3
W1740	33.87	60	0	0.14013	0.50314	Discharge	21.251	0.65	Ratio to Peak	0.3
W1750	17.313	74.582	0	0.11424	0.41015	Discharge	9.7381	0.65	Ratio to Peak	0.3

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1760	33.87	60	0	0.0475855	0.17085	Discharge	2.5023	0.65	Ratio to Peak	0.3
W1770	17.498	74.38	0	0.27409	0.98411	Discharge	31.741	0.65	Ratio to Peak	0.3
W1780	33.87	60	0	0.10193	0.36598	Discharge	7.8275	0.65	Ratio to Peak	0.3
W1790	12.756	79.93	0	0.16256	0.58366	Discharge	24.173	0.65	Ratio to Peak	0.3
W1800	33.87	60	0	0.22203	0.79719	Discharge	33.418	0.65	Ratio to Peak	0.3
W1810	33.632	60.166	0	0.23781	0.85385	Discharge	31.988	0.65	Ratio to Peak	0.3
W1820	33.87	60	0	0.19145	0.68739	Discharge	26.478	0.65	Ratio to Peak	0.3
W1830	33.87	60	0	0.0942682	0.33846	Discharge	15.914	0.65	Ratio to Peak	0.3
W1840	23.382	68.48	0	0.18472	0.66322	Discharge	4.1048	0.65	Ratio to Peak	0.3
W1850	33.87	60	0	0.10769	0.38664	Discharge	10.8228	0.65	Ratio to Peak	0.3
W1860	33.87	60	0	0.0477343	0.17139	Discharge	1.15871	0.65	Ratio to Peak	0.3
W1870	33.87	60	0	0.109431	0.3929	Discharge	12.2774	0.65	Ratio to Peak	0.3
W1880	22.449	69.353	0	0.0635732	0.22825	Discharge	0.83822	0.65	Ratio to Peak	0.3
W1890	20.679	71.07	0	0.23986	0.86121	Discharge	14.1880	0.65	Ratio to Peak	0.3
W1900	33.87	60	0	0.16457	0.59086	Discharge	18.576	0.65	Ratio to Peak	0.3
W1910	17.156	74.754	0	0.17251	0.61938	Discharge	8.9862	0.65	Ratio to Peak	0.3
W1920	20.842	70.908	0	0.19224	0.69022	Discharge	3.3652	0.65	Ratio to Peak	0.3
W1930	19.924	71.828	0	0.17548	0.63004	Discharge	6.6071	0.65	Ratio to Peak	0.3

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W1940	16.899	75.038	0	0.0922069	0.33106	Discharge	15.507	0.65	Ratio to Peak	0.3
W1950	24.89	67.116	0	0.16132	0.57921	Discharge	3.4145	0.65	Ratio to Peak	0.3
W1960	17.401	74.486	0	0.1383	0.49654	Discharge	5.3251	0.65	Ratio to Peak	0.3
W1970	8.0207	86	0	0.1491	0.53534	Discharge	15.4330315	0.65	Ratio to Peak	0.3
W1980	18.415	73.395	0	0.0767966	0.27573	Discharge	1.4669	0.65	Ratio to Peak	0.3
W1990	20.297	71.4521739	0	0.0543543	0.19515	Discharge	1.41757	0.65	Ratio to Peak	0.3
W2000	7.2726	87	0	0.15779	0.56653	Discharge	10.6010	0.65	Ratio to Peak	0.3
W2010	14.355	77.968	0	0.11729	0.42113	Discharge	7.7412	0.65	Ratio to Peak	0.3
W2020	14.328	78	0	0.17525	0.62921	Discharge	9.8244	0.65	Ratio to Peak	0.3
W2030	14.328	78	0	0.2597	0.93243	Discharge	14.718	0.65	Ratio to Peak	0.3
W2040	33.87	60	0	0.2219	0.79672	Discharge	18.946	0.65	Ratio to Peak	0.3
W2050	33.87	60	0	0.23255	0.83494	Discharge	36.376	0.65	Ratio to Peak	0.3
W2060	33.87	60	0	0.31501	1.131	Discharge	36.228	0.65	Ratio to Peak	0.3
W2070	27.917	64.535	0	0.0607207	0.21801	Discharge	3.1803	0.65	Ratio to Peak	0.3
W2080	14.328	78	0	0.0220927	0.0793217	Discharge	1.12173	0.65	Ratio to Peak	0.3
W2090	33.87	60	0	0.31367	1.1262	Discharge	66.823	0.65	Ratio to Peak	0.3
W2100	16.904	75.0321958	0	0.26028	0.9345	Discharge	19.143	0.65	Ratio to Peak	0.3
W2110	10.922	82.305	0	0.19363	0.6952	Discharge	25.861	0.65	Ratio to Peak	0.3

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W2120	25.021	67	0	0.0733623	0.2634	Discharge	0.1355937	0.65	Ratio to Peak	0.3
W2130	22.7	69.116	0	0.15868	0.56971	Discharge	18.157	0.65	Ratio to Peak	0.3
W2140	20.303	71.446	0	0.16127	0.57902	Discharge	2.5146	0.65	Ratio to Peak	0.3
W2150	12.443	80.325	0	0.23158	0.83145	Discharge	13.2882	0.65	Ratio to Peak	0.3
W2160	8.1185	86	0	0.10372	0.37239	Discharge	15.1248639	0.65	Ratio to Peak	0.3
W2170	33.87	60	0	0.11817	0.42428	Discharge	8.7643	0.65	Ratio to Peak	0.3
W2180	33.87	60	0	0.0294697	0.10581	Discharge	0.71495	0.65	Ratio to Peak	0.3
W2190	33.601	60.189	0	0.17202	0.6176	Discharge	15.248	0.65	Ratio to Peak	0.3
W2200	15.273	76.885	0	0.29037	1.0426	Discharge	25.529	0.65	Ratio to Peak	0.3
W2210	12.966	79.666	0	0.26893	0.96558	Discharge	21.2142547	0.65	Ratio to Peak	0.3
W2220	14.856	77.372	0	0.12193	0.43777	Discharge	7.7781	0.65	Ratio to Peak	0.3
W2230	14.605	77.6695157	0	0.21198	0.76109	Discharge	21.633	0.65	Ratio to Peak	0.3
W2240	24.346	67.601	0	0.17424	0.62559	Discharge	24.9862253	0.65	Ratio to Peak	0.3
W2250	6.2787	89	0	0.0566161	0.20327	Discharge	2.5146	0.65	Ratio to Peak	0.3
W2260	33.87	60	0	0.15384	0.55233	Discharge	17.492	0.65	Ratio to Peak	0.3
W2270	33.87	60	0	0.31279	1.123	Discharge	55.852	0.65	Ratio to Peak	0.3
W2280	30.961	62.132	0	0.12481	0.44812	Discharge	9.8860	0.65	Ratio to Peak	0.3
W2290	17.335	74.557	0	0.21522	0.77272	Discharge	17.405	0.65	Ratio to Peak	0.3

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W2300	8.8396	85	0	0.19473	0.69916	Discharge	14.5825	0.65	Ratio to Peak	0.3
W2310	22.2214577	69.569	0	0.0966992	0.34719	Discharge	13.6580	0.65	Ratio to Peak	0.3
W2320	16.908	75.028	0	0.10806	0.38798	Discharge	9.2574	0.65	Ratio to Peak	0.3
W2330	14.328	78	0	0.074243	0.26656	Discharge	11.1803190	0.65	Ratio to Peak	0.3
W2340	21.239	70.517	0	0.13363	0.47978	Discharge	24.937	0.65	Ratio to Peak	0.3
W2350	19.996	71.75521	0	0.0692811	0.24875	Discharge	2.3667	0.65	Ratio to Peak	0.3
W2360	33.87	60	0	0.10204	0.36637	Discharge	9.7627	0.65	Ratio to Peak	0.3
W2370	14.328	78	0	0.10041	0.3605	Discharge	11.0817	0.65	Ratio to Peak	0.3
W2380	33.87	60	0	0.12384	0.44463	Discharge	9.2080	0.65	Ratio to Peak	0.3
W2390	15.993	76.055	0	0.32895	1.1811	Discharge	19.784	0.65	Ratio to Peak	0.3
W2400	15.114	77.07	0	0.0994698	0.35714	Discharge	12.8937	0.65	Ratio to Peak	0.3
W2410	23.862	68.04	0	0.20783	0.74619	Discharge	15.951	0.65	Ratio to Peak	0.3
W2420	7.0683	88	0	0.1444	0.51846	Discharge	7.7042	0.65	Ratio to Peak	0.3
W2430	8.4411	86	0	0.0730863	0.26241	Discharge	4.8074	0.65	Ratio to Peak	0.3
W2440	14.328	78	0	0.0444228	0.1595	Discharge	1.5778	0.65	Ratio to Peak	0.3
W2450	12.135	80.719	0	0.16099	0.57804	Discharge	18.404	0.65	Ratio to Peak	0.3
W2460	12.563	80.173	0	0.12361	0.44381	Discharge	6.2127	0.65	Ratio to Peak	0.3
W2470	7.2815	87	0	0.12099	0.43441	Discharge	5.0293	0.65	Ratio to Peak	0.3

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W2480	33.87	60	0	0.0695987	0.24989	Discharge	1.9476	0.65	Ratio to Peak	0.3
W2490	33.87	60	0	0.22687	0.81455	Discharge	43.0818246	0.65	Ratio to Peak	0.3
W2500	14.328	78	0	0.14219	0.51052	Discharge	14.6318	0.65	Ratio to Peak	0.3
W2510	24.284	67.657	0	0.1255	0.45058	Discharge	5.2512	0.65	Ratio to Peak	0.3
W2520	21.726	70.044	0	0.0892217	0.32034	Discharge	3.3405	0.65	Ratio to Peak	0.3
W2530	33.87	60	0	0.13637	0.48963	Discharge	16.296	0.65	Ratio to Peak	0.3
W2540	16.506	75.476	0	0.0766675	0.27527	Discharge	2.0955	0.65	Ratio to Peak	0.3
W2550	7.1448	88	0	0.14061	0.50485	Discharge	8.3575	0.65	Ratio to Peak	0.3
W2560	16.588	75.384	0	0.16268	0.58408	Discharge	10.1079	0.65	Ratio to Peak	0.3
W2570	15.243	76.92	0	0.22709	0.81535	Discharge	10.2928	0.65	Ratio to Peak	0.3
W2580	19.017	72.761	0	0.20519	0.73672	Discharge	10.1695	0.65	Ratio to Peak	0.3
W2590	17.06	74.86	0	0.18221	0.65419	Discharge	18.354	0.65	Ratio to Peak	0.3
W2600	23.899	68.006	0	0.27586	0.99046	Discharge	19.1926754	0.65	Ratio to Peak	0.3
W2610	17.258	74.642	0	0.16608	0.59629	Discharge	28.438	0.65	Ratio to Peak	0.3
W2620	41.937	54.7785366	0	0.18274	0.6561	Discharge	12.6349	0.65	Ratio to Peak	0.3
W2630	43.748743	53.729	0	0.20645	0.74123	Discharge	14.4592	0.65	Ratio to Peak	0.3
W2640	33.87	60	0	0.10676	0.38331	Discharge	7.6549	0.65	Ratio to Peak	0.3
W2650	33.87	60	0	0.0463265	0.16633	Discharge	1.29430	0.65	Ratio to Peak	0.3

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W2660	33.87	60	0	0.076482	0.2746	Discharge	11.3036	0.65	Ratio to Peak	0.3
W2670	16.985	74.943	0	0.0463417	0.16639	Discharge	0.86287	0.65	Ratio to Peak	0.3
W2680	17.835	74.0143946	0	0.17201	0.61759	Discharge	14.5578	0.65	Ratio to Peak	0.3
W2690	33.87	60	0	0.14683	0.52718	Discharge	18.367	0.65	Ratio to Peak	0.3
W2700	14.328	78	0	0.12067	0.43327	Discharge	11.3899	0.65	Ratio to Peak	0.3
W2710	25.622	66.473	0	0.22587	0.81095	Discharge	30.780	0.65	Ratio to Peak	0.3
W2720	33.349	60.369	0	0.51475	1.8482	Discharge	28.746	0.65	Ratio to Peak	0.3
W2730	17.3669882	74.523	0	0.19664	0.70601	Discharge	15.088	0.65	Ratio to Peak	0.3
W2740	14.867	77.36	0	0.19572	0.70273	Discharge	13.9785	0.65	Ratio to Peak	0.3
W2750	14.338	77.988	0	0.18355	0.65902	Discharge	30.274	0.65	Ratio to Peak	0.3
W2760	19.913	71.8400891	0	0.36921	1.3256	Discharge	27.673	0.65	Ratio to Peak	0.3
W2770	33.87	60	0	0.1184	0.42509	Discharge	14.706	0.65	Ratio to Peak	0.3
W2780	33.87	60	0	0.01667	0.0367724	Discharge	0.1109403	0.65	Ratio to Peak	0.3
W2790	33.87	60	0	0.13046	0.4684	Discharge	20.5979198	0.65	Ratio to Peak	0.3
W2800	33.87	60	0	0.0917338	0.32936	Discharge	8.3822	0.65	Ratio to Peak	0.3
W2810	19.373	72.392	0	0.18235	0.65472	Discharge	19.353	0.65	Ratio to Peak	0.3
W2820	34.378	59.64	0	0.32355	1.1617	Discharge	16.629	0.65	Ratio to Peak	0.3
W2830	75.912	40.091	0	0.1019	0.36585	Discharge	0.40678	0.65	Ratio to Peak	0.3

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W2840	15.389	76.75	0	0.25509	0.91587	Discharge	18.552	0.65	Ratio to Peak	0.3
W2850	38.758	56.723	0	0.32145	1.1542	Discharge	30.730	0.65	Ratio to Peak	0.3
W2860	41.099	55.278	0	0.23567	0.84614	Discharge	15.815	0.65	Ratio to Peak	0.3
W2870	54.509	48.239	0	0.12877	0.46234	Discharge	7.4330	0.65	Ratio to Peak	0.3
W2880	16.897	75.04	0	0.23222	0.83375	Discharge	20.265	0.65	Ratio to Peak	0.3
W2890	54.476	48.254	0	0.22269	0.79956	Discharge	9.7504	0.65	Ratio to Peak	0.3
W2900	30.542	62.4522523	0	0.21894	0.7861	Discharge	20.524	0.65	Ratio to Peak	0.3
W2910	36.087	58.467	0	0.27477	0.98652	Discharge	48.617	0.65	Ratio to Peak	0.3
W2920	33.87	60	0	0.0791849	0.28431	Discharge	10.6873	0.65	Ratio to Peak	0.3
W2930	33.87	60	0	0.0805257	0.28912	Discharge	9.4299	0.65	Ratio to Peak	0.3
W2940	28.956	63.694	0	0.12825	0.46046	Discharge	5.4361	0.65	Ratio to Peak	0.3
W2950	35.377	58.948	0	0.22972	0.82479	Discharge	44.167	0.65	Ratio to Peak	0.3
W2960	53.0778024	48.904	0	0.34521	1.2394	Discharge	20.4623256	0.65	Ratio to Peak	0.3
W2970	20.654	71.095	0	0.1201	0.43122	Discharge	10.2558	0.65	Ratio to Peak	0.3
W2980	44.503	53.304	0	0.1752481	0.62921	Discharge	19.760	0.65	Ratio to Peak	0.3
W2990	36.227	58.3728037	0	0.30517	1.0957	Discharge	64.543	0.65	Ratio to Peak	0.3
W3000	47.6244197	51.613	0	0.0930069	0.33393	Discharge	3.9199	0.65	Ratio to Peak	0.3
W3010	55.03	48	0	0.34024	1.2216	Discharge	10.9215	0.65	Ratio to Peak	0.3

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W3020	34.001732	59.904	0	0.10899	0.39132	Discharge	10.8352	0.65	Ratio to Peak	0.3
W3030	52.528	49.164	0	0.17656	0.63393	Discharge	8.5794	0.65	Ratio to Peak	0.3
W3040	49.134	51	0	0.0524417	0.18829	Discharge	1.5532	0.65	Ratio to Peak	0.3
W3050	54.798	48.107	0	0.22267	0.79947	Discharge	11.7473	0.65	Ratio to Peak	0.3
W3060	52.695	49.084	0	0.2808	1.0081869	Discharge	22.028	0.65	Ratio to Peak	0.3
W3070	52.985	48.947	0	0.20317	0.72945	Discharge	15.618	0.65	Ratio to Peak	0.3
W3080	40.116	55.876	0	0.15951	0.5727	Discharge	8.7150	0.65	Ratio to Peak	0.3
W3090	55.03	48	0	0.56696	2.0356	Discharge	24.912	0.65	Ratio to Peak	0.3
W3100	36.954	57.889	0	0.12028	0.43184	Discharge	10.4407	0.65	Ratio to Peak	0.3
W3110	55.03	48	0	0.0336764	0.12091	Discharge	0.27119	0.65	Ratio to Peak	0.3
W3120	55.03	48	0	0.19889	0.71408	Discharge	9.886015	0.65	Ratio to Peak	0.3
W3130	37.683	57.412	0	0.35795	1.2852	Discharge	56.592	0.65	Ratio to Peak	0.3
W3140	33.87	60	0	0.0992753	0.35644	Discharge	7.7412	0.65	Ratio to Peak	0.3
W3150	33.87	60	0	0.11818	0.42431	Discharge	21.966	0.65	Ratio to Peak	0.3
W3160	55.03	48	0	0.44751	1.6067	Discharge	15.951	0.65	Ratio to Peak	0.3
W3170	55.03	48	0	0.25134	0.9024	Discharge	7.8275	0.65	Ratio to Peak	0.3
W3180	47.526	51.665	0	0.35706	1.282	Discharge	20.142	0.65	Ratio to Peak	0.3

Annex 10. Pinacanauan de Ilagan Model Reach Parameters

Table A-10.1. Pinacanauan de Ilagan Model Reach Parameters

Reach Number	MuskingumCunge Channel Routing						
	Time Step Method	Length (m)	Slope	Man-ning's n	Shape	Width	Side Slope
R1000	Automatic Fixed Interval	6757.1	0.0054757	0.04	Trapezoid	407.372	0.593
R1020	Automatic Fixed Interval	5312.2	0.0109182	0.04	Trapezoid	407.372	0.593
R1030	Automatic Fixed Interval	4751.4	0.0012628	0.04	Trapezoid	407.372	0.593
R1040	Automatic Fixed Interval	1059.3	0.0377599	0.04	Trapezoid	407.372	0.593
R1060	Automatic Fixed Interval	855.52	0.001	0.04	Trapezoid	407.372	0.593
R1090	Automatic Fixed Interval	4093.2	0.0109939	0.04	Trapezoid	407.372	0.593
R110	Automatic Fixed Interval	4306.1	0.0146303	0.04	Trapezoid	407.372	0.593
R1100	Automatic Fixed Interval	6870	0.0030568	0.04	Trapezoid	407.372	0.593
R1140	Automatic Fixed Interval	5970.4	0.0164143	0.04	Trapezoid	407.372	0.593
R1160	Automatic Fixed Interval	310.27	0.001	0.04	Trapezoid	407.372	0.593
R1180	Automatic Fixed Interval	7769.6	0.0023167	0.04	Trapezoid	407.372	0.593
R120	Automatic Fixed Interval	8527.8	0.0216937	0.04	Trapezoid	407.372	0.593
R1200	Automatic Fixed Interval	12173	0.0028752	0.04	Trapezoid	407.372	0.593
R1220	Automatic Fixed Interval	764.65	0.0052312	0.04	Trapezoid	407.372	0.593
R1250	Automatic Fixed Interval	9850.6	0.0058879	0.04	Trapezoid	407.372	0.593
R1260	Automatic Fixed Interval	4252.9	0.001	0.04	Trapezoid	407.372	0.593
R1290	Automatic Fixed Interval	3222.1	0.0148972	0.04	Trapezoid	407.372	0.593
R130	Automatic Fixed Interval	2049.8	0.0039028	0.04	Trapezoid	407.372	0.593
R1300	Automatic Fixed Interval	13370	0.0251307	0.04	Trapezoid	407.372	0.593
R1320	Automatic Fixed Interval	8405.8	0.0022604	0.04	Trapezoid	407.372	0.593
R1340	Automatic Fixed Interval	6757.1	0.0088796	0.04	Trapezoid	407.372	0.593
R1350	Automatic Fixed Interval	2034.2	0.001	0.04	Trapezoid	407.372	0.593
R1390	Automatic Fixed Interval	3570	0.002521	0.04	Trapezoid	407.372	0.593
R1400	Automatic Fixed Interval	2096.6	0.0052466	0.04	Trapezoid	407.372	0.593
R1420	Automatic Fixed Interval	1128.2	0.0088641	0.04	Trapezoid	407.372	0.593
R1440	Automatic Fixed Interval	6400	0.0198436	0.04	Trapezoid	407.372	0.593
R1450	Automatic Fixed Interval	3927	0.0099312	0.04	Trapezoid	407.372	0.593
R1480	Automatic Fixed Interval	3494.7	0.001	0.04	Trapezoid	407.372	0.593
R150	Automatic Fixed Interval	3466.2	0.0066355	0.04	Trapezoid	407.372	0.593
R1510	Automatic Fixed Interval	658.18	0.0121547	0.04	Trapezoid	407.372	0.593

R1550	Automatic Fixed Interval	8095.5	0.001	0.04	Trapezoid	407.372	0.593
R1560	Automatic Fixed Interval	15881	0.0167499	0.04	Trapezoid	407.372	0.593
R190	Automatic Fixed Interval	722.44	0.001	0.04	Trapezoid	407.372	0.593
R220	Automatic Fixed Interval	620.54	0.0354531	0.04	Trapezoid	407.372	0.593
R230	Automatic Fixed Interval	7519.1	0.0308549	0.04	Trapezoid	407.372	0.593
R240	Automatic Fixed Interval	11076	0.009209	0.04	Trapezoid	407.372	0.593
R250	Automatic Fixed Interval	604.95	0.001	0.04	Trapezoid	407.372	0.593
R260	Automatic Fixed Interval	2551	0.001568	0.04	Trapezoid	407.372	0.593
R290	Automatic Fixed Interval	3366.2	0.001	0.04	Trapezoid	407.372	0.593
R310	Automatic Fixed Interval	1256.7	0.001	0.04	Trapezoid	407.372	0.593
R320	Automatic Fixed Interval	1112.6	0.0062918	0.04	Trapezoid	407.372	0.593
R330	Automatic Fixed Interval	733.46	0.001	0.04	Trapezoid	407.372	0.593
R340	Automatic Fixed Interval	2193.9	0.001	0.04	Trapezoid	407.372	0.593
R360	Automatic Fixed Interval	4274.9	0.0032749	0.04	Trapezoid	407.372	0.593
R380	Automatic Fixed Interval	6021	0.001	0.04	Trapezoid	407.372	0.593
R410	Automatic Fixed Interval	5531.6	0.0173548	0.04	Trapezoid	407.372	0.593
R430	Automatic Fixed Interval	2247.2	0.0062301	0.04	Trapezoid	407.372	0.593
R440	Automatic Fixed Interval	2397.7	0.001	0.04	Trapezoid	407.372	0.593
R450	Automatic Fixed Interval	1119	0.001	0.04	Trapezoid	407.372	0.593
R460	Automatic Fixed Interval	10305	0.0062106	0.04	Trapezoid	407.372	0.593
R480	Automatic Fixed Interval	908.76	0.001	0.04	Trapezoid	407.372	0.593
R500	Automatic Fixed Interval	9781.8	0.0030669	0.04	Trapezoid	407.372	0.593
R540	Automatic Fixed Interval	711.41	0.0126509	0.04	Trapezoid	407.372	0.593
R560	Automatic Fixed Interval	2776.8	0.001	0.04	Trapezoid	407.372	0.593
R590	Automatic Fixed Interval	5544.5	0.0028857	0.04	Trapezoid	407.372	0.593
R600	Automatic Fixed Interval	2156.3	0.0027826	0.04	Trapezoid	407.372	0.593
R610	Automatic Fixed Interval	11364	0.0182149	0.04	Trapezoid	407.372	0.593
R660	Automatic Fixed Interval	4547.6	0.0219898	0.04	Trapezoid	407.372	0.593
R670	Automatic Fixed Interval	4108.8	0.0124124	0.04	Trapezoid	407.372	0.593
R70	Automatic Fixed Interval	2300.4	0.0086941	0.04	Trapezoid	407.372	0.593
R700	Automatic Fixed Interval	8139.6	0.001	0.04	Trapezoid	407.372	0.593
R730	Automatic Fixed Interval	3911.4	0.0094594	0.04	Trapezoid	407.372	0.593
R750	Automatic Fixed Interval	2262.8	0.0309357	0.04	Trapezoid	407.372	0.593
R780	Automatic Fixed Interval	1369.6	0.0014603	0.04	Trapezoid	407.372	0.593

R790	Automatic Fixed Interval	4904.6	0.0063206	0.04	Trapezoid	407.372	0.593
R80	Automatic Fixed Interval	3632.4	0.0066073	0.04	Trapezoid	407.372	0.593
R800	Automatic Fixed Interval	2996.2	0.0020025	0.04	Trapezoid	407.372	0.593
R820	Automatic Fixed Interval	4328.2	0.0117833	0.04	Trapezoid	407.372	0.593
R830	Automatic Fixed Interval	2466.6	0.0012163	0.04	Trapezoid	407.372	0.593
R840	Automatic Fixed Interval	8443.4	0.001	0.04	Trapezoid	407.372	0.593
R860	Automatic Fixed Interval	8246.1	0.0115206	0.04	Trapezoid	407.372	0.593
R870	Automatic Fixed Interval	1354	0.0103397	0.04	Trapezoid	407.372	0.593
R880	Automatic Fixed Interval	3510.3	0.0014244	0.04	Trapezoid	407.372	0.593
R890	Automatic Fixed Interval	4911.1	0.0054978	0.04	Trapezoid	407.372	0.593
R900	Automatic Fixed Interval	2920.9	0.0020541	0.04	Trapezoid	407.372	0.593
R910	Automatic Fixed Interval	385.55	0.001	0.04	Trapezoid	407.372	0.593
R940	Automatic Fixed Interval	1701.9	0.0029379	0.04	Trapezoid	407.372	0.593
R970	Automatic Fixed Interval	2504.2	0.0019966	0.04	Trapezoid	407.372	0.593
R990	Automatic Fixed Interval	6158.6	0.0056831	0.04	Trapezoid	407.372	0.593