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

LiDAR Surveys and Flood Mapping of Cañas River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Mapua Institute of Technology

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND CAÑAS RIVER

Enrico C. Paringit, Dr. Eng., Dr. Francis Aldrine A. Uy, and Engr. Fibor Tan

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 a sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for a 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through the DOST. The methods applied in this report are thoroughly described in a separate publication entitled "Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods" (Paringit, et. al., 2017), available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the Mapua Institute of Technology (MIT). MIT is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the twenty-six (26) river basins in the Southern Luzon region. The university is located in Manila City in Metro Manila.

1.2 Overview of the Cañas River Basin

The Cañas River Basin is one the major river basins of the Cavite province. It is located in the eastern part of the province of Cavite, which lies close to the border of Manila. It covers the Municipalities of Trece Martires City and Indang; the eastern parts of the Municipality of Tanza; the western portions of the Municipalities of Rosario, General Trias and Amadeo; and a small portion of Tagaytay City. The Department of Environment and Natural Resources River Basin Control Office (DENR – RBCO) identified the basin to have a drainage area of 210 km2, and an estimated annual runoff of 336 million cubic meters (MCM) (RBCO, 2015).

The main river channel of the basin, the Cañas River, passes through the Lubluban River in General Trias, and traverses back to its point of origin in Kaybagal, Tagaytay City. It serves as an eastern boundary for the Municipality of Tanza to the neighboring districts, General Trias and Rosario. It is part of the twenty-six (26) river systems in the Southern Luzon Region.

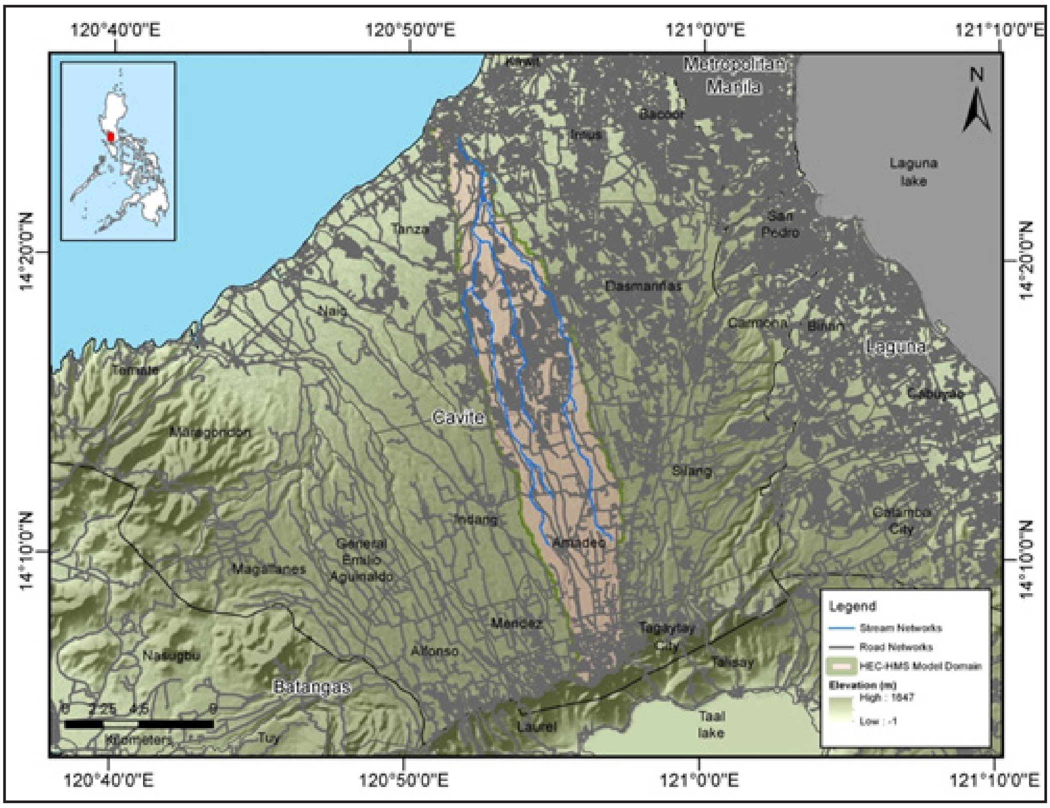


Figure 1. Location map of the Cañas River Basin (in brown)

According to the 2015 national census of the National Statistics Office (NSO), the total population of residents within the immediate vicinity of the river is 50,717 persons. This population is distributed among two (2) barangays in General Trias City – San Juan II and Tejero; and four (4) barangays in Rosario – Tejeros Convention, Wawa I, Wawa II, and Sapa I.

The predominant economic activity in General Trias City is agriculture, specifically farming of rice, fruit trees, and vegetables. Recently, agricultural lands in the area have been converted into non-agricultural territories for private and commercial purposes. This is part of the city's strategy to focus on real estate development and industry (Source: http://generaltrias.gov.ph/about-general-trias/profile-of-the-municipality/).

The province of Cavite is constantly burdened by typhoons and heavy rains every year. This causes the river tributaries to overflow, resulting in the flooding of communities residing near the rivers, or on low-lying areas. Flooding is considered to be one of the most destructive natural disasters that may affect a community, causing damages to infrastructure and the loss of life. In 2006, Cavite and other neighboring provinces were hit by Typhoon Milenyo. The typhoon brought about millions' worth of damages to the province, and claimed the lives of many locals.

In December 2016, Typhoon Nina (internationally known as Nock-Ten) made landfall in the Philippines, bringing torrential rains and strong winds. The province of Cavite was placed under Signal No. 3 by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) due to expectations of floods and landslides in the area (Source: http://www.rappler.com/nation/special-coverage/weather-alert/156614-20161226-typhoon-nina-pagasa-forecast-2am).

These occurrences make it imperative to find ways to mitigate damages that are caused by these disasters. One of the means that this can be done is through the development of a highly accurate digital elevation model of the earth's surface using LiDAR technology. This technology is applied to flood modeling of river basins to produce high resolution flood hazard maps that can be used by local government units (LGUs) in the planning and development of disaster preparedness and mitigation. The high-resolution flood hazard maps would enable LGU administrators to identify areas that face high risks of flooding under extreme weather conditions, and consequently create emergency plans before disasters strike.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE CAÑAS FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Acuna, Engr. Gerome Hipolito, Engr. Grace B. Sinadjan, and Jonalyn S. Gonzales

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Cañas Floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in Cavite. These missions were planned for ten (10) lines that ran for at most three (3) hours, including take-off, landing, and turning time. The Pegasus and Leica ALS-80 HP LiDAR systems were used for the mission (See Annex 1 for the sensor specifications). The flight planning parameters for the Pegasus and the Leica ALS-80 HP LiDAR systems are found in Table 1 and Table 2, respectively. Figure 2 illustrates the flight plan for the Cañas floodplain survey.

Table 1. Flight planning parameters for the Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK18B	1000	30	50	200	50	130	5
BLK18C	1000	30	50	200	50	130	5
BLK18D	1000	30	50	200	50	130	5
BLK18A	1000/1100	30	50	200	50	130	5
BLK18X	1200	30	50	200	50	130	5
BLK18CF	1100	30	50	200	50	130	5

Table 2. Flight planning parameters for the Leica ALS-80 HP LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK18A	1500	30	45	128	42	130	5
BLK18B	1500	30	45	128	42	130	5

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

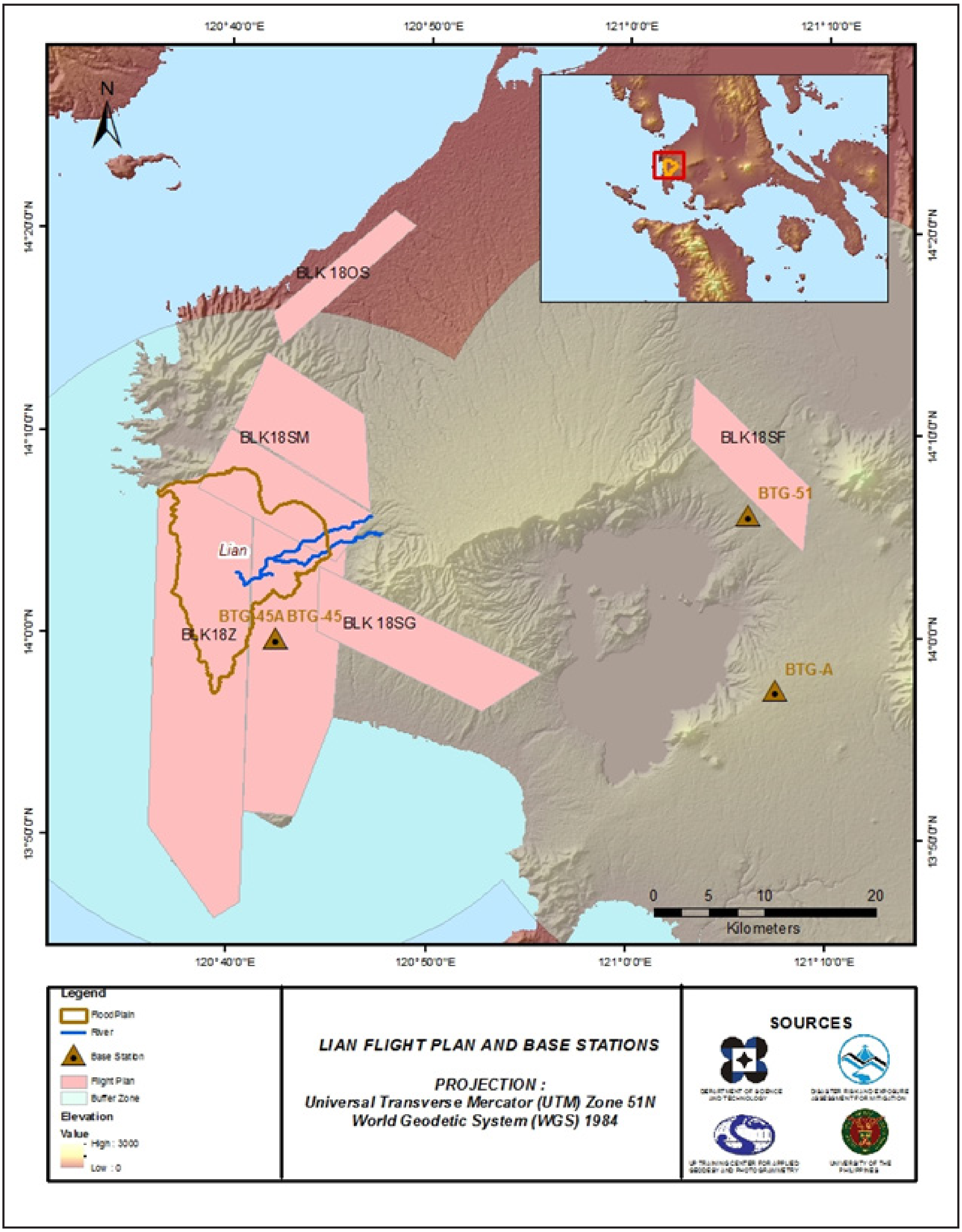
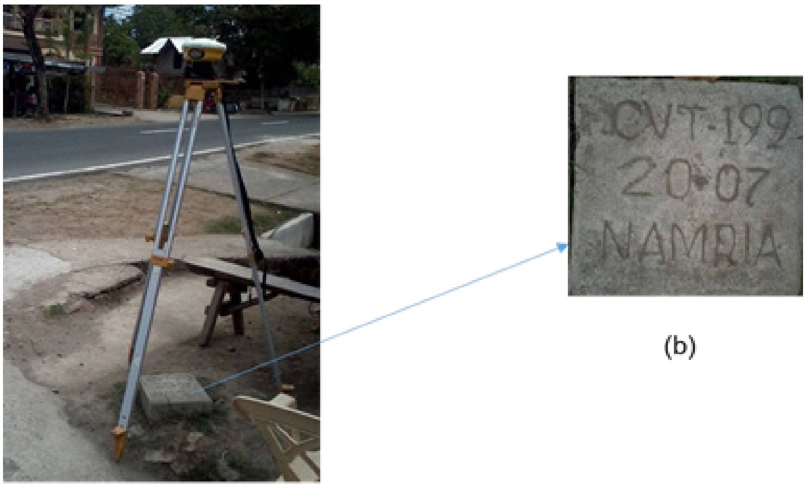


Figure 2. Flight plans and base stations used to cover the Cañas floodplain

2.2 Ground Base Stations

The field team for this undertaking was able to recover three (3) NAMRIA ground control points: CVT-199, CVT-194, and BTG-45, which are of second (2nd) order accuracy. The field team also established four (4) ground control points – PB-1, BTG-45A, GC-1, and GC-2; and re-processed two (2) NAMRIA reference points – CVT-3051 and CVT-3123. The certifications for the base stations are found in Annex 2, while the baseline processing reports for the re-processed ground control points and established points are available in Annex 3. These were used as the base stations during the flight operations for the entire duration of the survey, held on January 26-February 28, 2014; August 18, 2015; May 7, 2016; and June 16, 2016. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 985 and TOPCON GR5. The flight plans and the locations of the base stations used during the aerial LiDAR acquisition in the Cañas floodplain are presented in Figure 2. The composition of the project team is shown in Annex 4.

Figure 3 to Figure 7 exhibit the recovered NAMRIA reference points and established points within the area. Table 3 to Table 11 provide the details about the NAMRIA control stations, and Table 12 lists all the ground control points occupied during the acquisition, together with the dates of utilization during the survey.



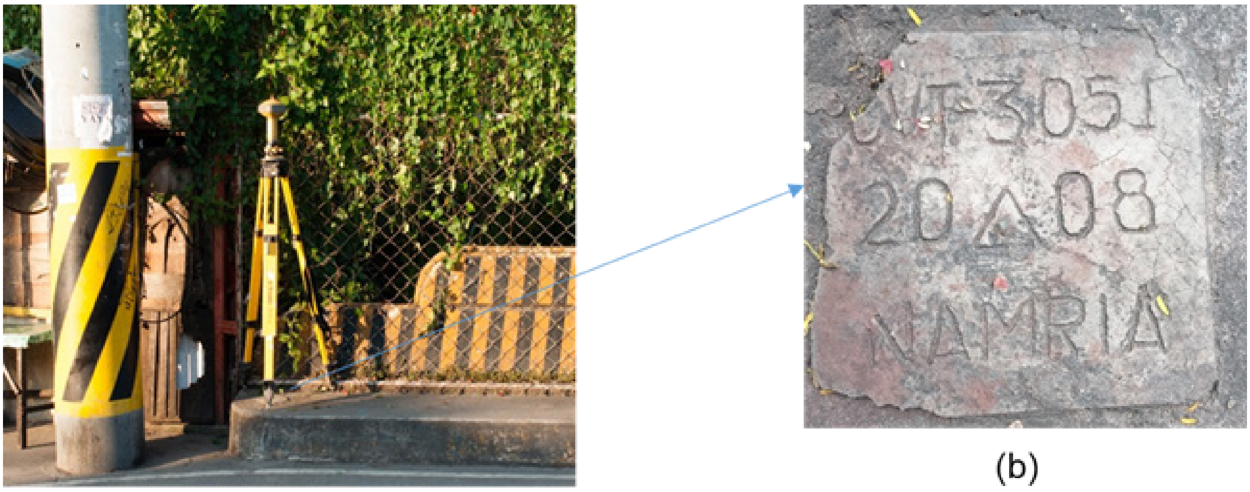
(b)

(a)

Figure 3. (a) GPS set-up over CVT-199 found near the basketball covered court of Barangay Calumpang Lejos; and (b) NAMRIA reference point CVT-199, as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point CVT-199, used as a base station for the LiDAR acquisition

Station Name	CVT-199	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 14' 16.32329" North 120° 50' 40.63536" East 166.20100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 3 PRS 92)	Easting Northing	1574493.218 meters 483231.789 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 14' 10.97763" North 120° 50' 45.56096" East 210.38600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS1992)	Easting Northing	267, 428.74 meters 1,575,012.80 meters



(b)

(a)

Figure 4. (a) GPS set-up over CVT-3051 in a concrete bridge leading to Manggahan, 70 m SE of Jetti Gas Station, and about 250 m from Gen. Trias Poblacion; and (b) NAMRIA reference point CVT-3051, as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point CVT-3051, with processed coordinates used as a base station for the LiDAR acquisition

Station Name	**CVT-3051**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 22’ 58.33330” North 120° 52’ 44.06059”East 21.122 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 22’52.95639” North 120° 52’ 48.97372 East” 64.983 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	271276.565 meters 1591024.612 meters

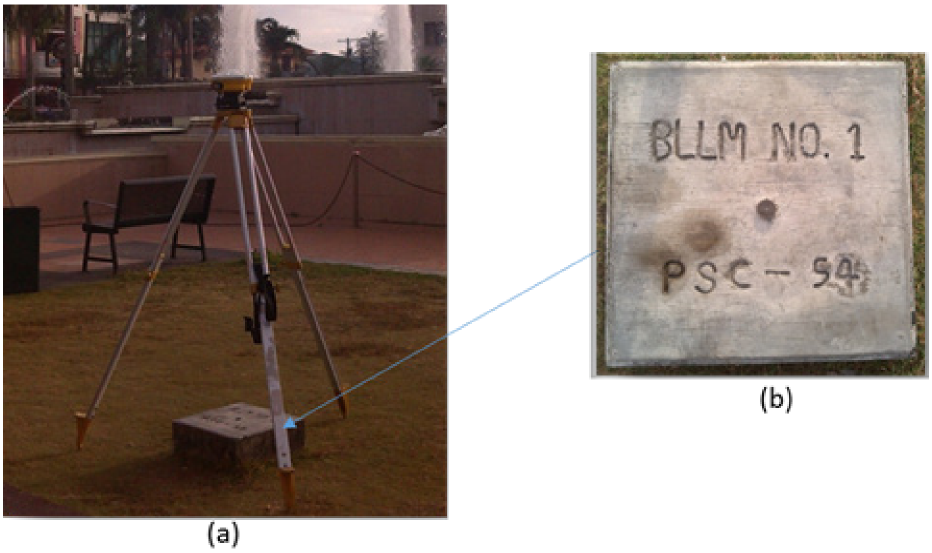
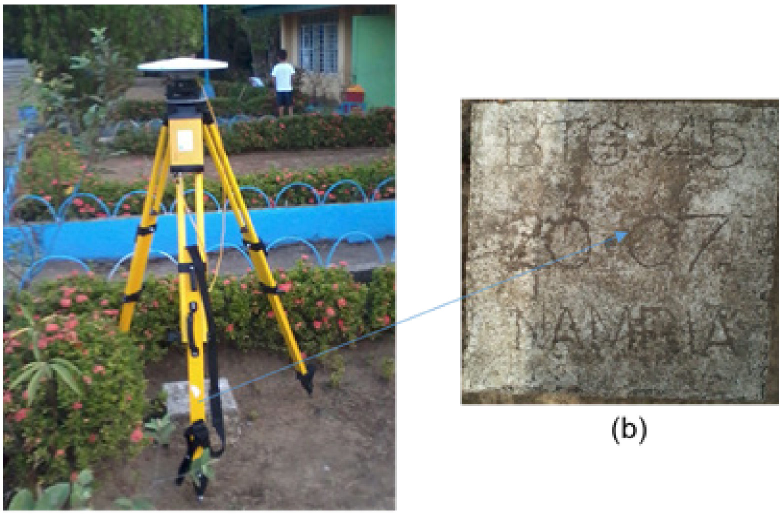


Figure 5. (a) GPS set-up over CVT-194 (BLLM NO.1 PSC-94) near the Municipal Hall of Gen. Trias, Cavite; and (b) NAMRIA reference point CVT-194, as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point CVT-194, used as a base station for the LiDAR acquisition

Station Name	SMR-56	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 23’ 15.01186” North 120° 52’ 43.52184” East 18.337 meters
Grid Coordinates Philippine Transverse Mercator Zone 3 (PTM Zone 3 PRS 92)	Easting Northing	486924.253 meters 1591045.311 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14°23 ’9.63386” North 120° 52’ 48.43458” East 62.184 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	271265.13 meters 1591537.44 meters



(a) (b)

Figure 6. (a) GPS set-up over BTG-45 inside Santiago De Guzman Elementary School of Barangay Malibu, Tuy, Batangas Province; and (b) NAMRIA reference point BTG-45, as recovered by the field team

Table 6. Details of the recovered NAMRIA horizontal control point BTG-45, used as a base station for the LiDAR acquisition

Station Name	BTG-45	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 59' 52.18294" North 120° 42' 18.96476" East 48.43000 meters
Grid Coordinates Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	468159.677 meters 1547952.281 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 59' 46.88216" North 120° 42' 23.91169" East 92.94300 meters

(a) (b)

Figure 7. (a) GPS set-up over PB-1, as established in an elevated traffic island in Daang Hari Road, Imus, Cavite; and (b) reference point PB-1, as established by the field team

Table 7. Details of the established horizontal control point PB-1 with processed coordinates, used as a base station for the LiDAR acquisition

Station Name	PB-1	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 23' 19.56635" North 120° 58' 04.29835"East 87.568 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 23'19.56635" North 120° 58' 04.29835" East 87.568 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	280881.093 meters 1591688.776 meters

Table 8. Details of the established reference point BTG-45A with processed coordinates, used as a base station for the LiDAR acquisition

Station Name	BTG-45A	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 59' 51.95603" North 120° 42' 18.98286 " East 49.08900 meters
Grid Coordinates Philippine Transverse Mercator Zone 5 (PTM Zone 3 PRS 92)	Easting Northing	252126.100 meters 1548584.818 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 59' 46.65526" North 120° 42' 23.92980" East 93.60200 meters

Table 9. Details of the established reference point GC-1 with processed coordinates, used as a base station for the LiDAR acquisition

Station Name	GC-1	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 22' 02.99339" North 120° 55' 39.25400" East 37.855 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 21'57.62404" North 120° 55' 44.43458"East 81.878 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	276510.990 meters 1589275.842 meters

Table 10. Details of the established reference point GC-2 with processed coordinates, used as a base station for the LiDAR acquisition

Station Name	GC-2	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 22' 03.22135" North 120° 55' 39.22621" East 38.103 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 21'57.85198" North 120° 55' 44.14039" East 82.125 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	276510.220 meters 1589282.856 meters

Table 11. Details of the recovered NAMRIA horizontal control point CVT-3123 with processed coordinates, used as a base station for the LiDAR acquisition

Station Name	CVT-3123	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	14° 14' 15.59521" North 120° 50' 41.86474" East 167.527 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	14° 14'10.24962" North 120° 50' 46.79435" East 211.713 meters
Grid Coordinates Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	267465.517 meters 1574990.072 meters

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

Date Surveyed	Flight Number	Mission Name	Ground Control Points
26 January 2014	1031P	1BLK18C026A	PB-1 and CVT-194
29 January 2014	1043P	1BLK18AS029A	PB-1 and CVT-194
3 February 2014	1063P	1BLK18D034A	PB-1 and CVT-194
22 February 2014	1139P	1BLK18X53A	BTG-45 and BTG-45A
28 February 2014	1039P	1BLK18B028A	PB-1 and CVT-194
18 August 2015	3309P	1BLK18AsS230A	CVT-199 and CVT-3051
7 May 2016	10144L	4BLK18ABS128A	CVT-199 and CVT-3123
16 June 2016	23462P	1BLK18CFS168A	GC-1 and GC-2

2.3 Flight Missions

A total of eight (8) flight missions were conducted to complete the LiDAR data acquisition in the Cañas floodplain, for a total of twenty-five hours and fifty-three minutes (25+53) of flying time for RP-C9022 and RP-C9522. All missions were acquired using the Pegasus and Leica ALS-80 HP LiDAR systems. The flight logs for the missions are found in Annex 6, Table 13 indicates the total area of actual coverage and the corresponding flying hours per mission, while Table 14 presents the actual parameters used during the LiDAR data acquisition.

Table 13. Flight missions for the LiDAR data acquisition in the Cañas 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
26 January 2014	1031P	124.00	123.10	NA	123.10	NA	3	17
29 January 2014	1043P	601.14	64.43	5.73	58.7	NA	2	23
3 February 2014	1063P	601.14	33.67	NA	33.67	348	2	59
22 February 2014	1139P	601.14	269.45	NA	269.45	474	3	56
28 February 2014	1039P	601.14	190.01	17.09	172.92	NA	3	17
18 August 2015	3309P	347.2	113.87	17.72	96.15	NA	3	16
7 May 2016	10144L	166.75	53.34	9.38	43.96	195	3	28
16 June 2016	23462P	243.68	123.09	NA	123.09	NA	3	17
TOTAL	2222.53	1302.49	329.81	972.68	8417	47	06	

Table 14. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1031P	1000	30	50	200	30	130	5
1043P	1000	30	50	200	30	130	5
1063P	1000	30	50	200	30	130	5
1139P	1200	30	50	200	30	130	5
1039P	1000	30	50	200	30	130	5
3309P	1100	30	50	200	30	130	5
10144L	1500	30	45	128	42	130	5
23462P	1000	60	50	200	32	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Cañas floodplain, which is situated within the municipalities in the province of Cavite. The City of Trece Martires in Cavite is mostly covered during the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is provided in Table 15. The actual coverage of the LiDAR acquisition for the Cañas floodplain is presented in Figure 8. The flight status reports are available in Annex 7.

Table 15. List of municipalities/cities surveyed during the Cañas floodplain LiDAR survey

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Batangas	Taal	29.37	25.22	85.85%
	Calaca	117.85	53.98	45.80%
	Lemery	82..32	29.28	35.57%
	Balayan	94.45	27.77	29.41%
	Lian	91.27	16.49	18.07%
	San Luis	42.04	1.61	3.83%
	Nasugbu	266.83	5.52	2.07%
Cavite	Trece Martires City	44.35	44.21	99.66%
	Dasmariñas	84.01	75.60	89.99%
	General Trias	85.98	76.65	89.15%
	Tanza	71.41	58.58	82.03%
	Indang	88.65	71.65	80.82%
	Naic	76.11	59.23	77.83%
	General Emilio Aguinaldo	39.39	23.32	59.21%
	Amadeo	45.90	24.21	52.75%
	Rosario	4.89	2.54	51.92%
	Maragondon	147.39	75.03	50.91%
	Magallanes	69.07	32.36	46.85%
	Bacoor	47.43	17.69	37.29%
	Imus	56.81	20.77	36.56%
	Silang	153.10	40.74	26.45%
	Noveleta	5.72	1.20	21.03%
	Ternate	44.52	1.87	4.21%
Laguna	San Pedro	21.41	2.73	12.76%
NCR	Muntinlupa	38.52	7.28	18.90%
	Las Piñas	33.19	3.90	11.74%
TOTAL		1799.66	799.43	45.03%

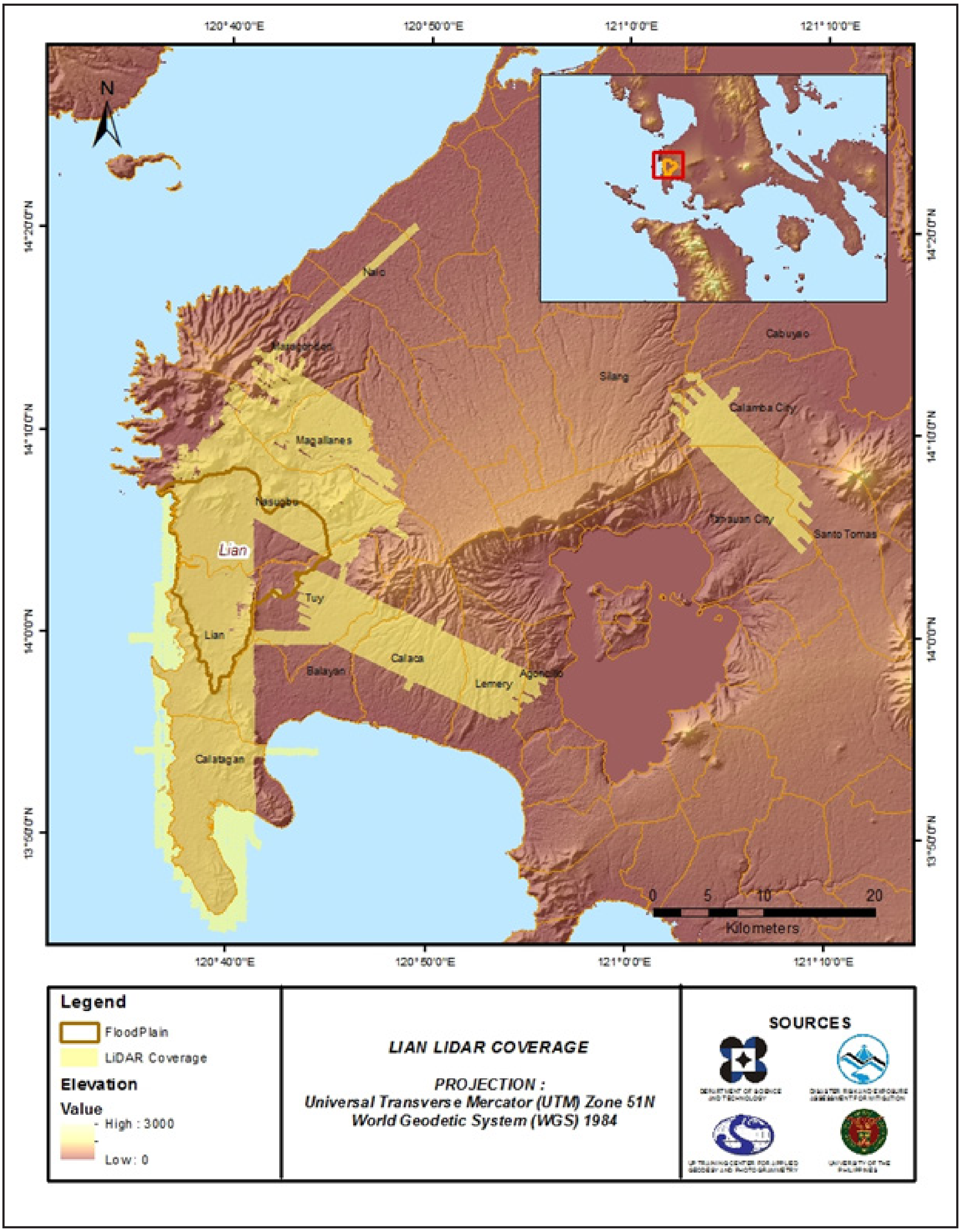


Figure 8. Actual LiDAR survey coverage of the Cañas floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE CAÑAS FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the diagram in Figure 9.

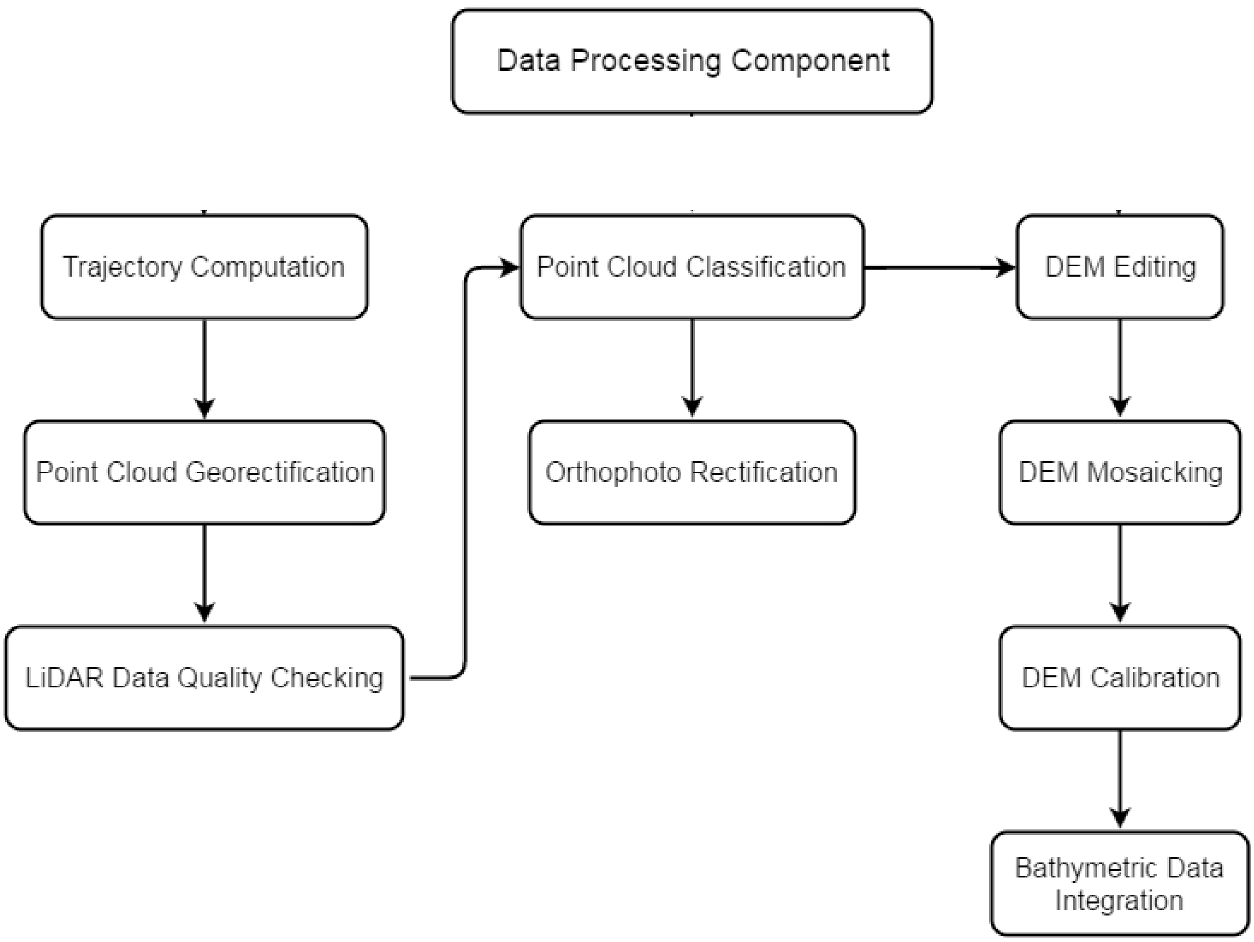

Figure 9. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Cañas floodplain can be found in Annex 5. Missions flown during the first, second, and fourth surveys conducted in January 2014, August 2015 and June 2016, respectively, used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system. On the other hand, missions acquired during the third survey in May 2016 were flown using the Leica system over General Trias, Cavite.

The Data Acquisition Component (DAC) transferred a total of 125.40 Gigabytes of Range data, 1.375 Gigabytes of POS data, 370.26 Megabytes of GPS base station data, and 55.65 Gigabytes of Image data to the data server on July 14, 2016 for the Optech LiDAR system. For the Leica Geosystems LiDAR system, a total of 25.39 Gigabytes of Raw Laser data, 1628.66 Megabytes of GNSSIMU data, 361.79 Megabytes of base station data, and 89.7 Gigabytes of RCD30 raw image data were transferred on June 7, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Cañas river basin survey was fully transferred on July 13, 2016, as indicated on the data transfer sheets for Cañas floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3309P, one of the Cañas flights, which are the North, East, and Down position RMSE values, are exhibited in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which fell on August 17, 2015 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

Figure 10. Smoothed Performance Metrics of a Cañas Flight 3309P.

The time of flight was from 171750 seconds to 176750 seconds, which corresponds to the morning of August 17, 2015. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values corresponds to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 demonstrates that the North position RMSE peaked at 2.30 centimeters, the East position RMSE peaked at 2.85 centimeters, and the Down position RMSE peaked at 3.00 centimeters, which are all within the prescribed accuracies described in the methodology.

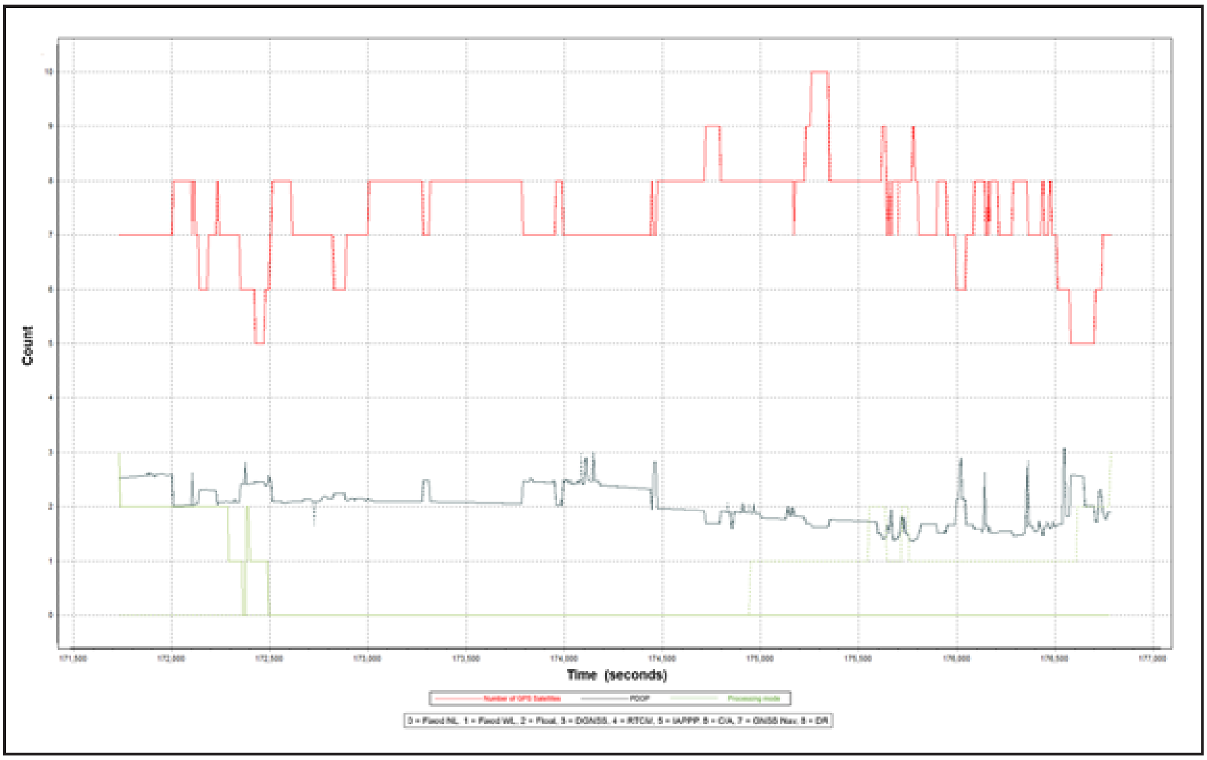

Figure 11. Solution Status Parameters of Cañas Flight 3309P.

The Solution Status parameters of flight 3309P, one of the Cañas flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are illustrated in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to five (5). Majority of the time, the number of satellites tracked was between five (5) and ten (10). The PDOP value did not go above the value of three (3), which indicates optimal GPS geometry. The processing mode remained at the value of zero (0) for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of zero (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 satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Cañas flights is exhibited in Figure 12.

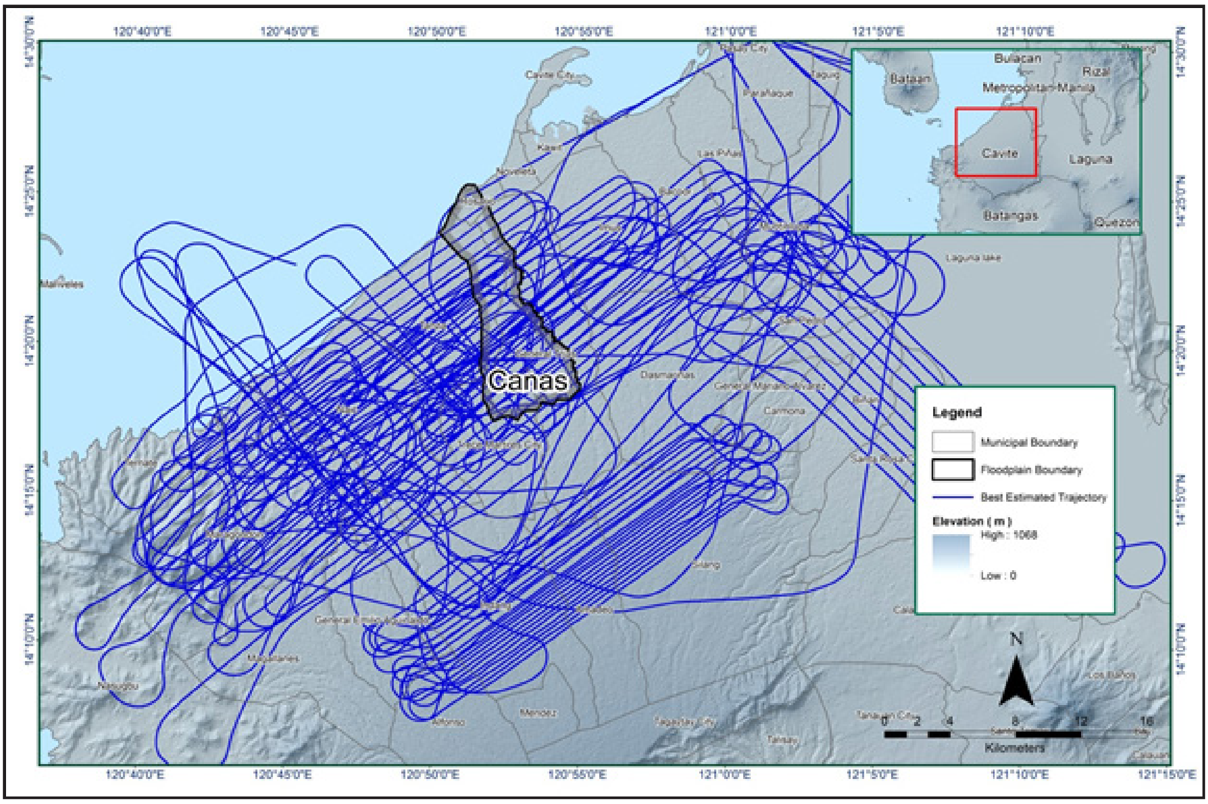

Figure 12. The best estimated trajectory conducted over the Cañas floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains ninety (90) flight lines, with each flight line containing two (2) channels, since the Pegasus and Leica systems both contain two (2) channels. The summary of the self-calibration results for all flights over Cañas floodplain, obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software, is given in Table 16.

Table 16. Self-calibration results values for the Cañas flights

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000798
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000359
GPS Position Z-correction stdev)	<0.01meters	0.0010

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

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Cañas floodplain are represented in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

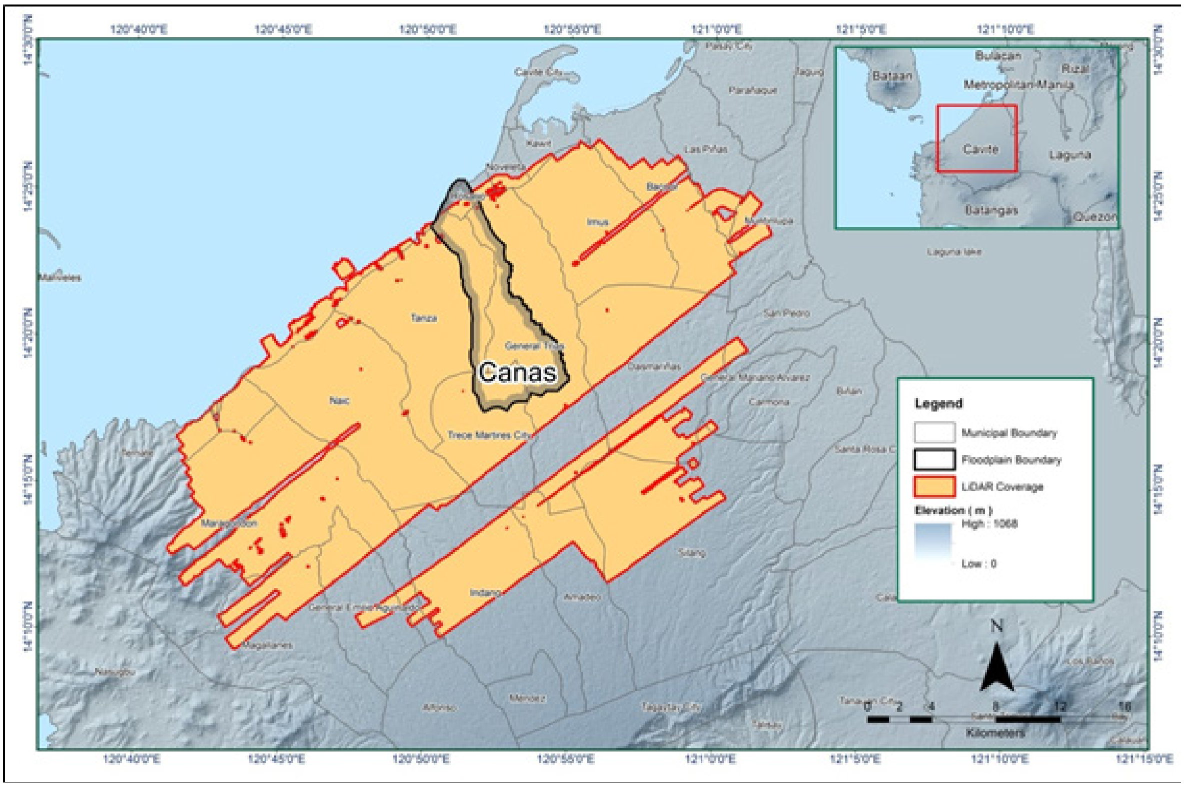

Figure 13. Boundaries of the processed LiDAR data over the Cañas Floodplain

The total area covered by the Cañas missions is 973.63 sq. km., comprised of eleven (11) flight acquisitions grouped and merged into nine (9) blocks, as outlined in Table 17.

Table 17. List of LiDAR blocks for the Cañas floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
CALABARZON_Blk18B_supplement	3309P	106.91
CALABARZON_Reflights_Blk18A	10136L	229.66
	10142L	
CALABARZON_Reflights_Blk18A_supplement	10144L	53.33
CALABARZON_Reflights_Blk18D	23462P	61.59
CALABARZON_Reflights_Blk18D_additional	23462P	27.68
Cavite Blk18A_supplement	1043P	56.96
Cavite Blk18A_supplement2	1139P	99.62
Cavite Blk18AB	1031P	127.12
	1035P	
Cavite Blk18C_additional	1039P	210.76
	1063P	
TOTAL		973.63 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is presented in Figure 14. Since the Pegasus and Leica systems both employ two (2) channels, it is expected to have an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three (3) or more overlapping flight lines.

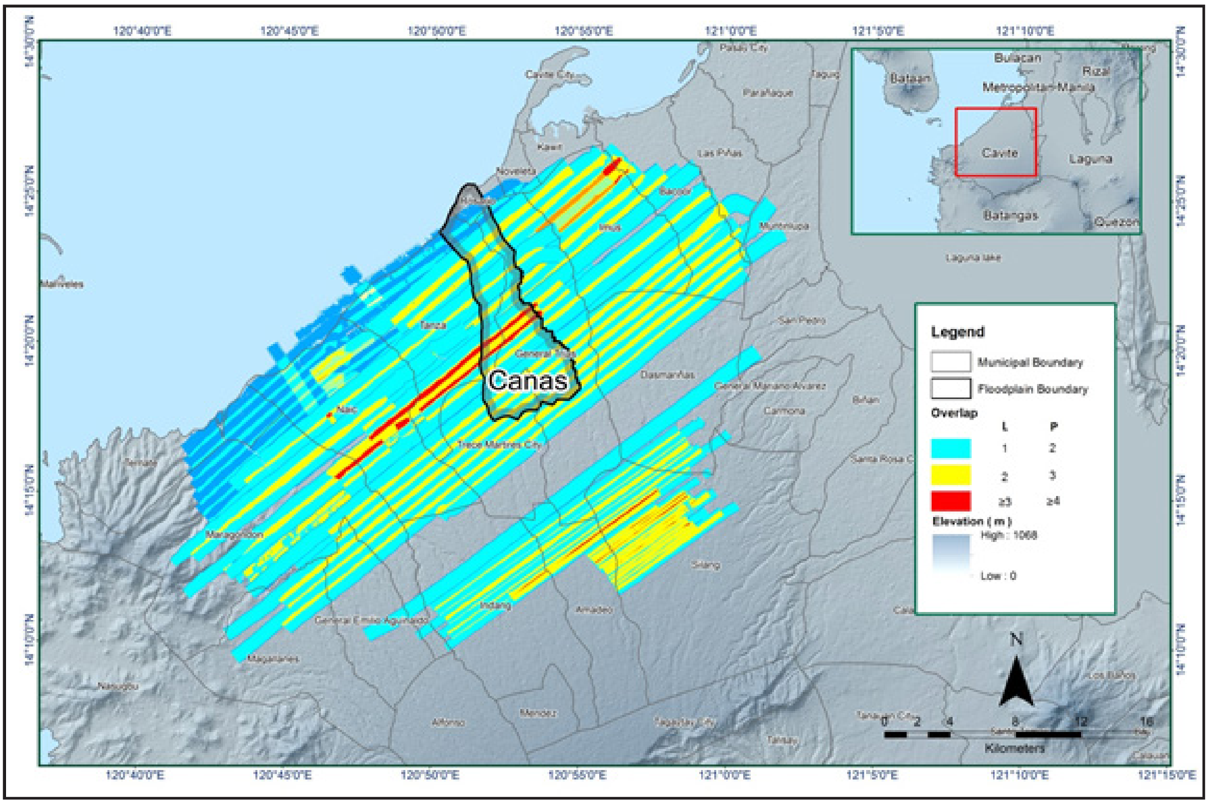

Figure 14. Image of data overlap for the Cañas Floodplain

The overlap statistics per block for the Cañas floodplain can be found in Annex 8. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 28.57% and 67.15%, respectively, which satisfied the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion, is illustrated in Figure 15. It was determined that all LiDAR data for the Cañas floodplain satisfy the point density requirement, and that the average density for the entire survey area is 3.43 points per square meter.

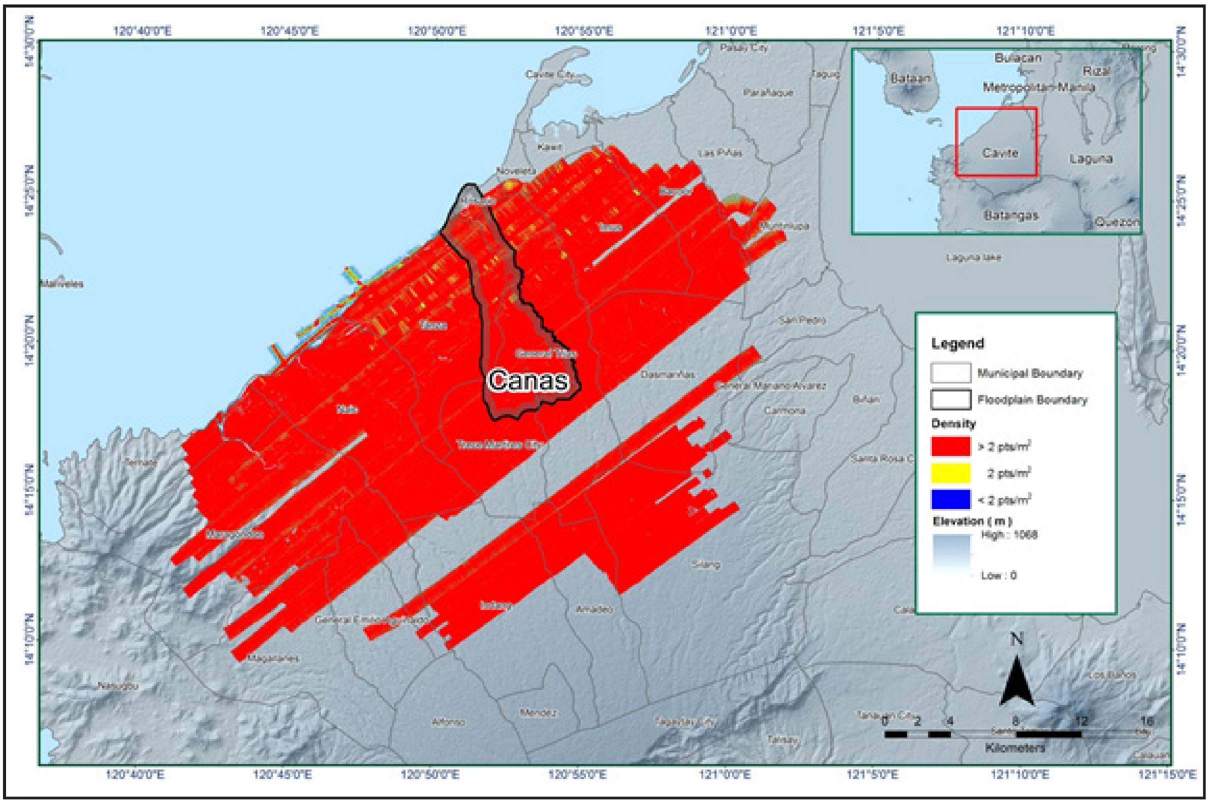

Figure 15. Pulse density map of merged LiDAR data for the Cañas Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. The default color range is from blue to red. Bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 meters 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 0.20 meters relative to elevations of its adjacent flight line. Areas with bright red or bright blue were investigated further using the Quick Terrain (QT) Modeler software.

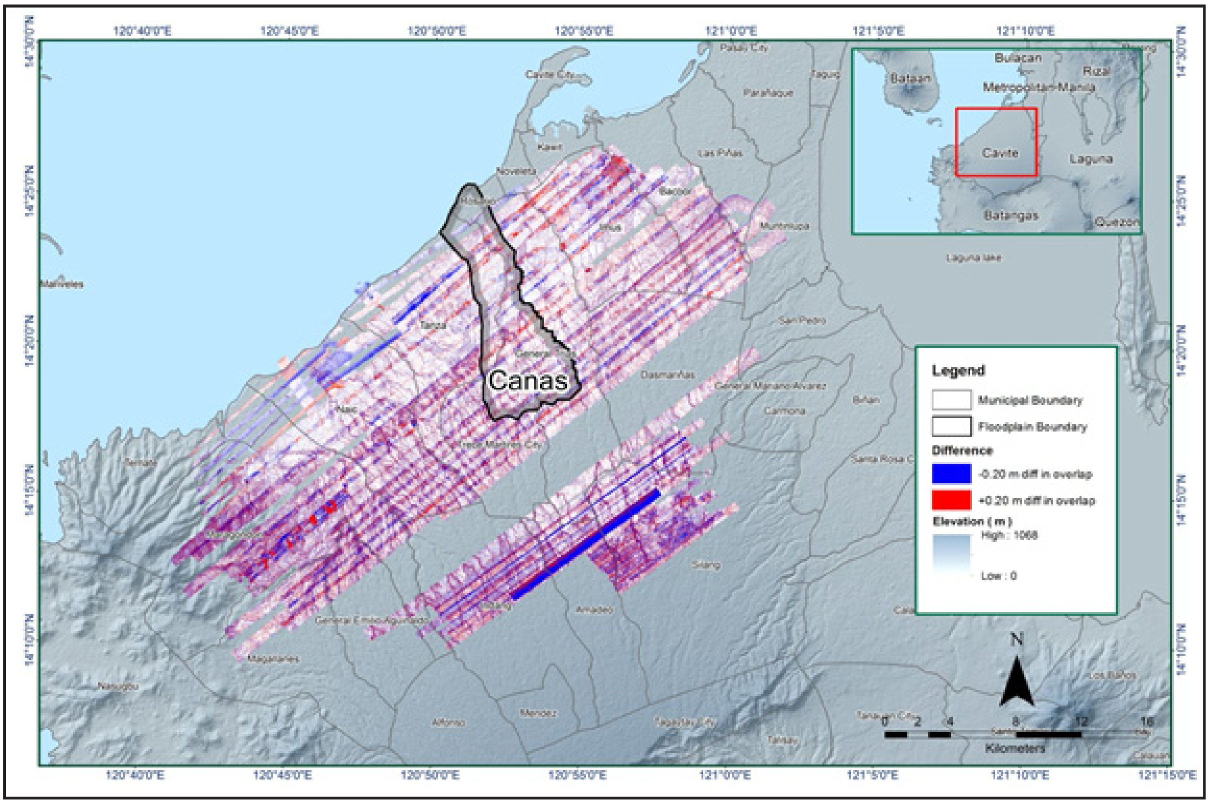

Figure 16. Elevation difference map between flight lines for the Cañas Floodplain

A screen capture of the processed LAS data from a Cañas flight 3309P loaded in the QT Modeler is provided in Figure 17. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

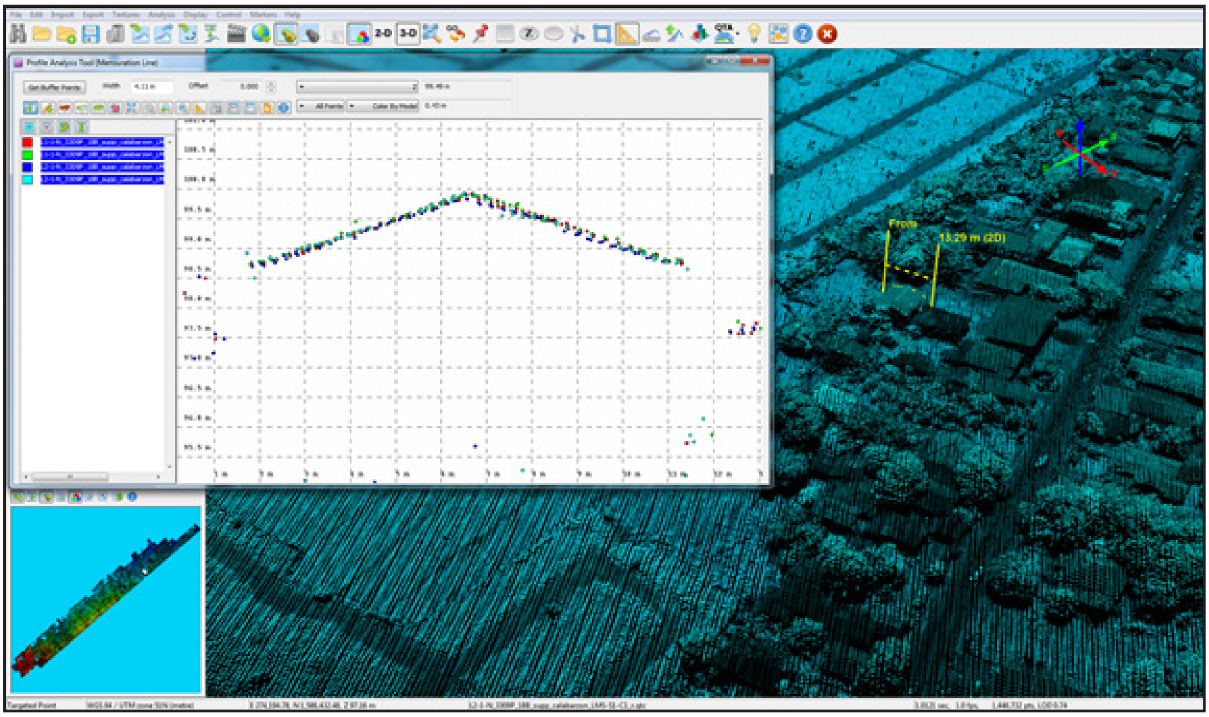

Figure 17. Quality checking for a Cañas flight 3309P using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 18. Cañas classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	1,276,862,251
Low Vegetation	962,422,278
Medium Vegetation	1,227,046,966
High Vegetation	1,230,323,979
Building	313,674,645

The tile system that TerraScan employed for the LiDAR data, as well as the final classification image for a block in the Cañas floodplain, are presented in Figure 18. A total of 1,559 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 18. The point cloud had a maximum and minimum height of 603.46 meters and 41.14 meters, respectively.

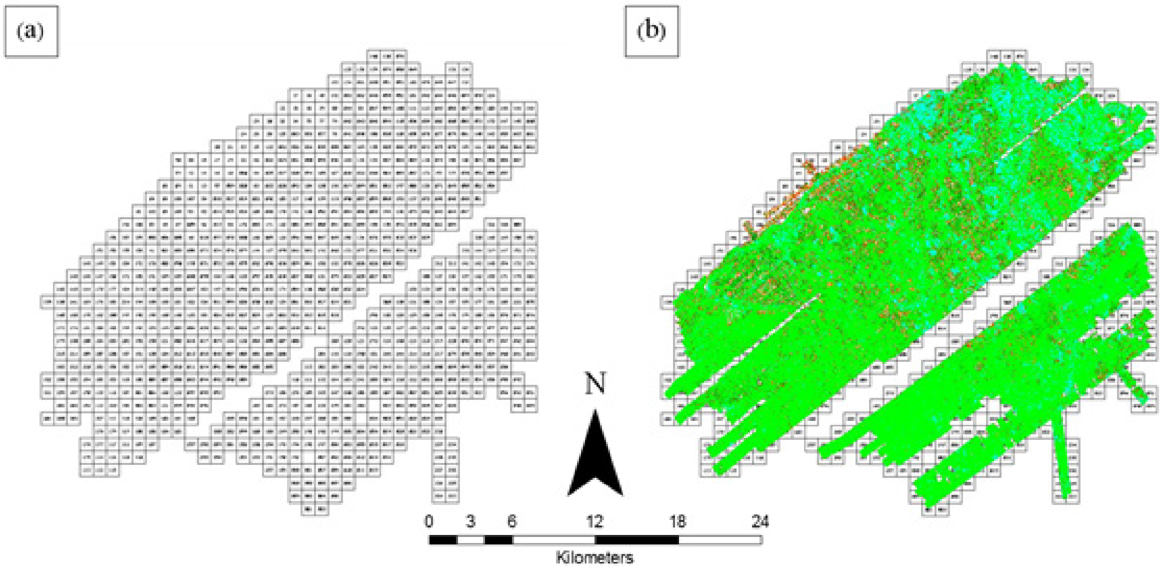

Figure 18. (a) Tiles for the Cañas floodplain; and (b) classification results in TerraScan

An isometric view of an area before and after running the classification routines is presented in Figure 19. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It is evident that residential structures adjacent or even below canopy were classified correctly, due to the density of the LiDAR data.

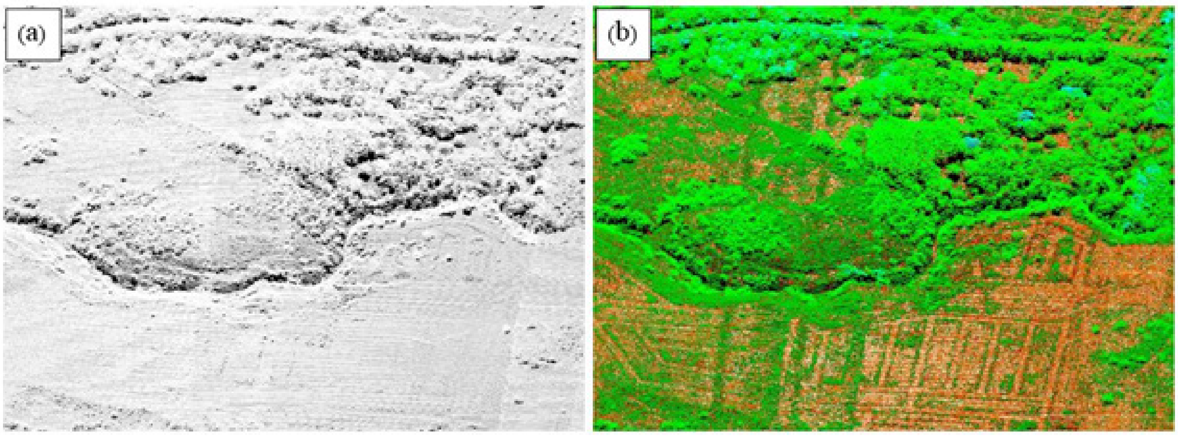

Figure 19. Point cloud (a) before and (b) after classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the area are illustrated in Figure 20, in top view display. The figures show that DTMs are the representation of the bare earth; while the DSMs reflect all features that are present, such as buildings and vegetation.

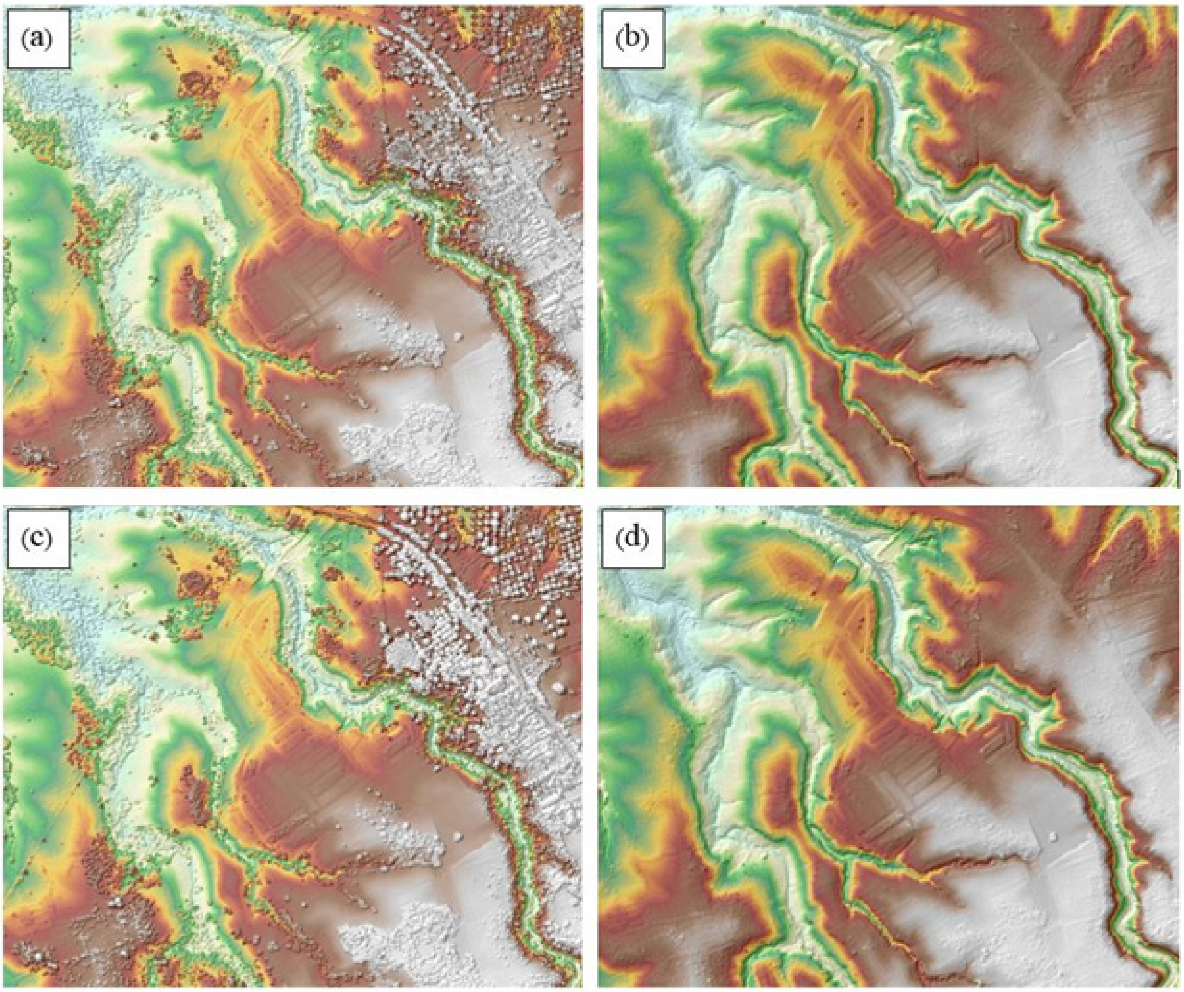

Figure 20. The production of (a) last return DSM and (b) DTM, (c) first return DSM and (d) secondary DTM in some portion of the Cañas Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 364 1km by 1km tiles area covered by the Cañas floodplain is represented in Figure 21. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Cañas floodplain survey attained a total of 237.89 sq. km. in orthophotographic coverage, comprised of 1,559 images. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 22.

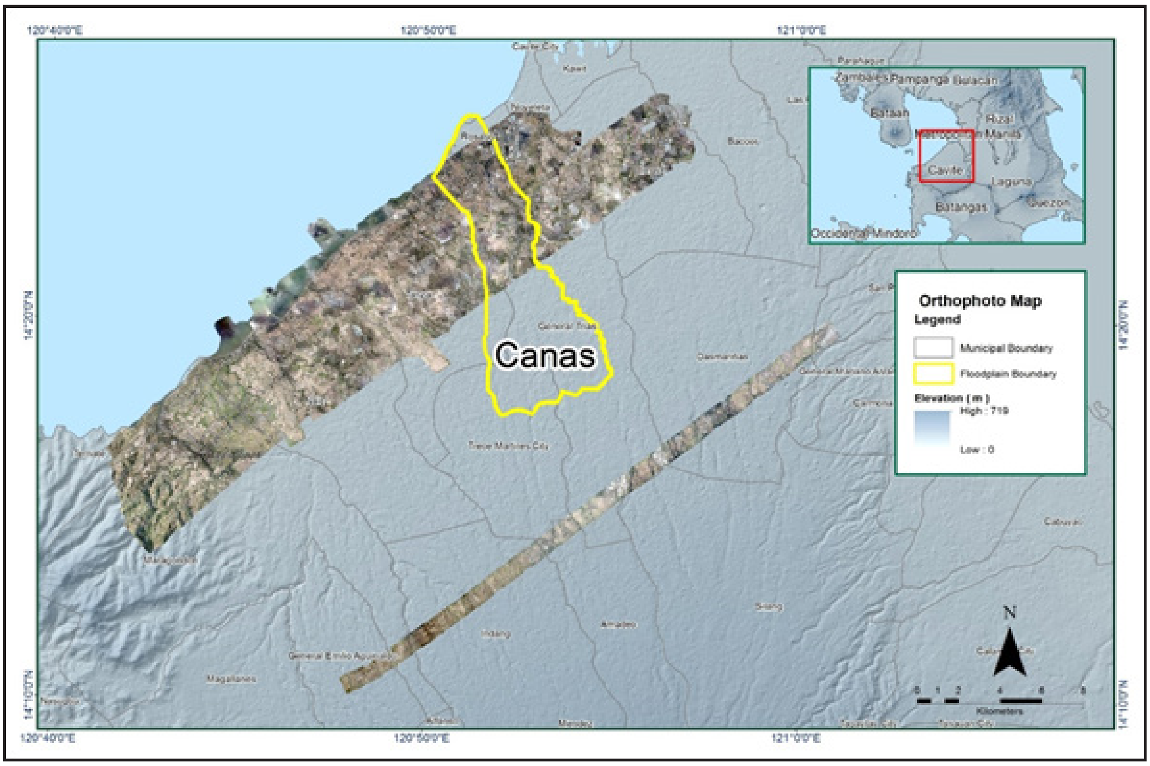

Figure 21. The Cañas Floodplain with available orthophotographs

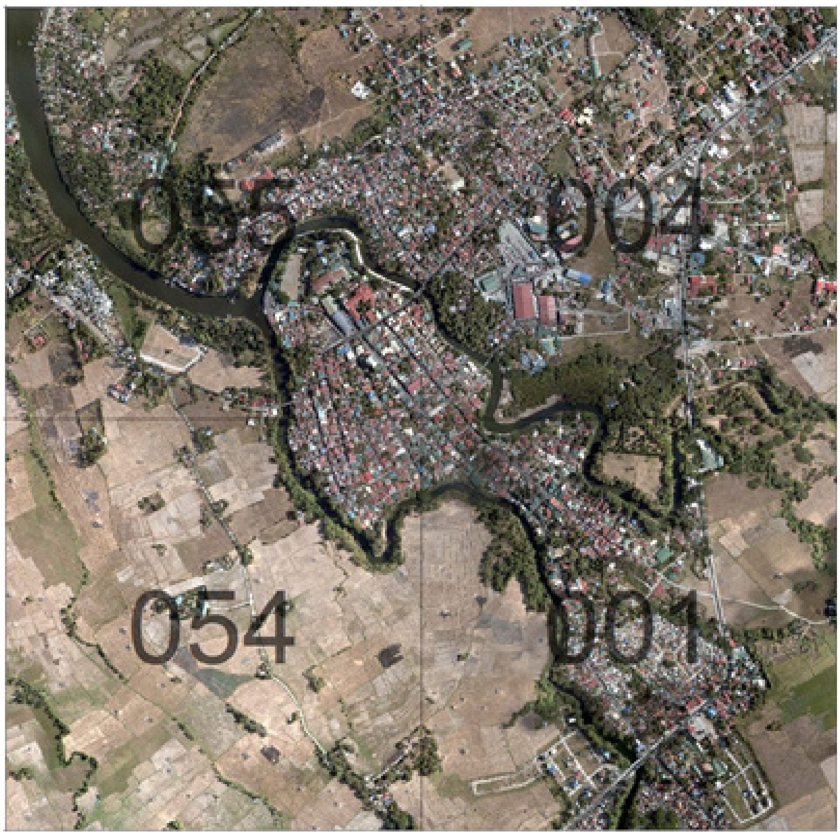

Figure 22. Sample orthophotograph tiles for the Cañas Floodplain

3.8 DEM Editing and Hydro-Correction

Nine (9) mission blocks were processed for the Cañas floodplain. These blocks are composed of CALABARZON blocks, with a total area of 973.63 square kilometers. Table 19 enumerates the names and corresponding areas of the blocks, in square kilometers.

Table 19. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
CALABARZON_Blk18B_supplement	106.91
CALABARZON_Reflights_Blk18A	229.66
CALABARZON_Reflights_Blk18A_supplement	53.33
CALABARZON_Reflights_Blk18D	61.59
CALABARZON_Reflights_Blk18D_additional	27.68
Cavite_Blk18A_supplement	56.96
Cavite_Blk18A_supplement2	99.62
Cavite_Blk18AB	127.12
Cavite_Blk18C_additional	210.76
TOTAL	973.63 sq.km

Portions of DTM before and after manual editing are exhibited in Figure 23. The bridge (Figure 23a) was considered to be an obstruction to the flow of water along the river, and had to be removed (Figure 23b) in order to hydrologically correct the river. The river embankment (Figure 23c) was misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 23d) to allow for the correct flow of water. Another case was a building that was still present in the DTM after classification (Figure 23e), and had to be removed through manual editing (Figure 23f).

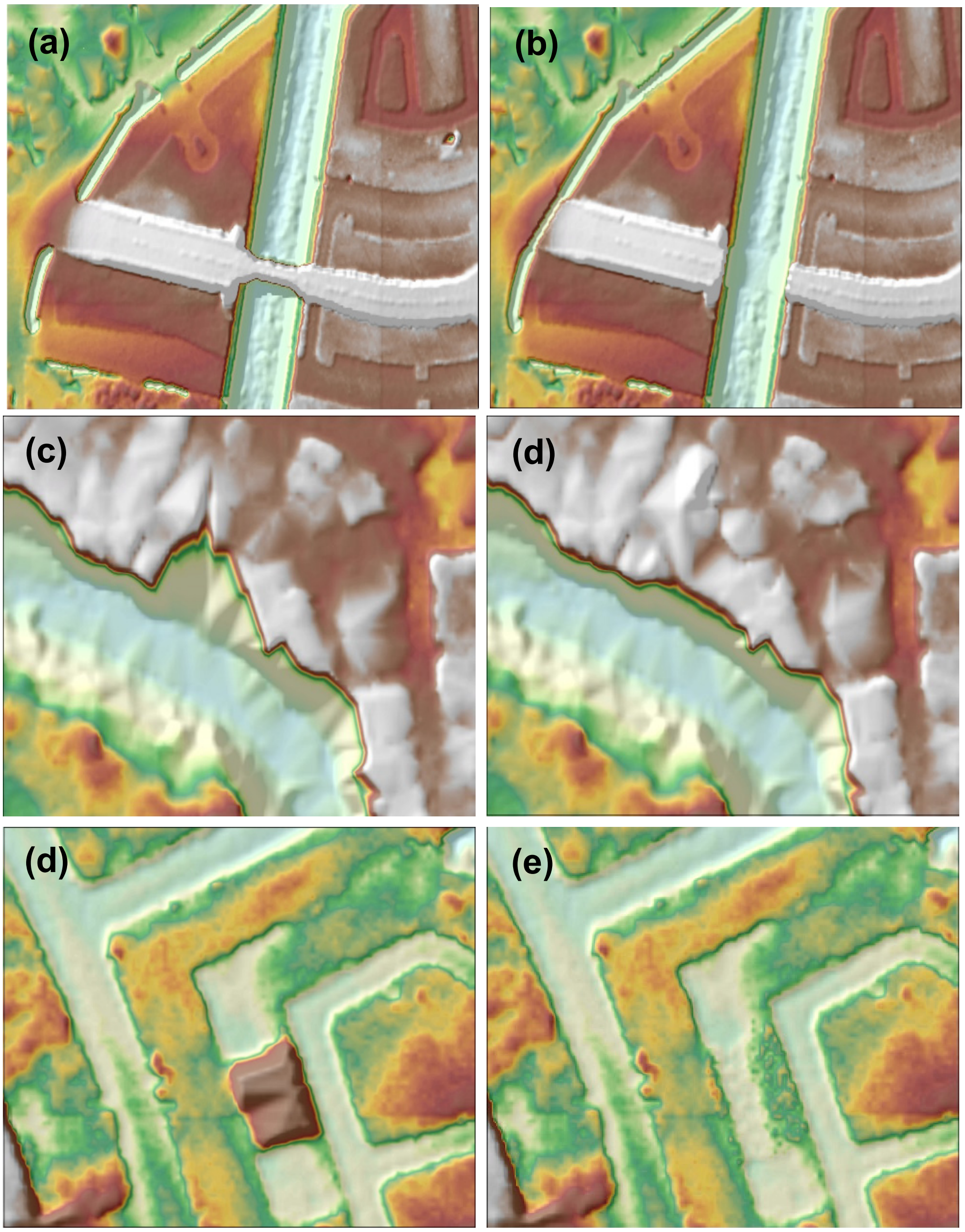

Figure 23. Portions in the DTM of the Cañas Floodplain – a bridge (a) before and (b) after manual editing; a river embankment (c) before and (d) after data retrieval; and a building (e) before and (f) after manual editing

3.9 Mosaicking of Blocks

No assumed reference block was used in the mosaicking process because the identified reference for shifting was an existing calibrated CALABARZON DEM, which overlapped with the blocks to be mosaicked. Table 20 lists the shift values applied to each LiDAR block during mosaicking.

The mosaicked LiDAR DTM for the Cañas floodplain is illustrated in Figure 24. The image demonstrates that the entire Cañas floodplain was 99.40% covered by LiDAR data.

Table 20. Shift values of each LiDAR block of the Cañas Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
CALABARZON_Blk18B_supplement	-1.85	1.08	0.10
CALABARZON_Reflights_Blk18A	-2.81	1.41	0.55
CALABARZON_Reflights_Blk18A_supplement	34.04	-20.59	1.40
CALABARZON_Reflights_Blk18D	-1.87	1.67	-0.05
CALABARZON_Reflights_Blk18D_additional	-3.51	0.56	0.09
Cavite_Blk18A_supplement	-1.55	1.14	-0.20
Cavite_Blk18A_supplement2	-2.31	1.34	0.00
Cavite_Blk18AB	-1.80	1.13	-0.50
Cavite_Blk18C_additional	-1.81	1.32	-0.50

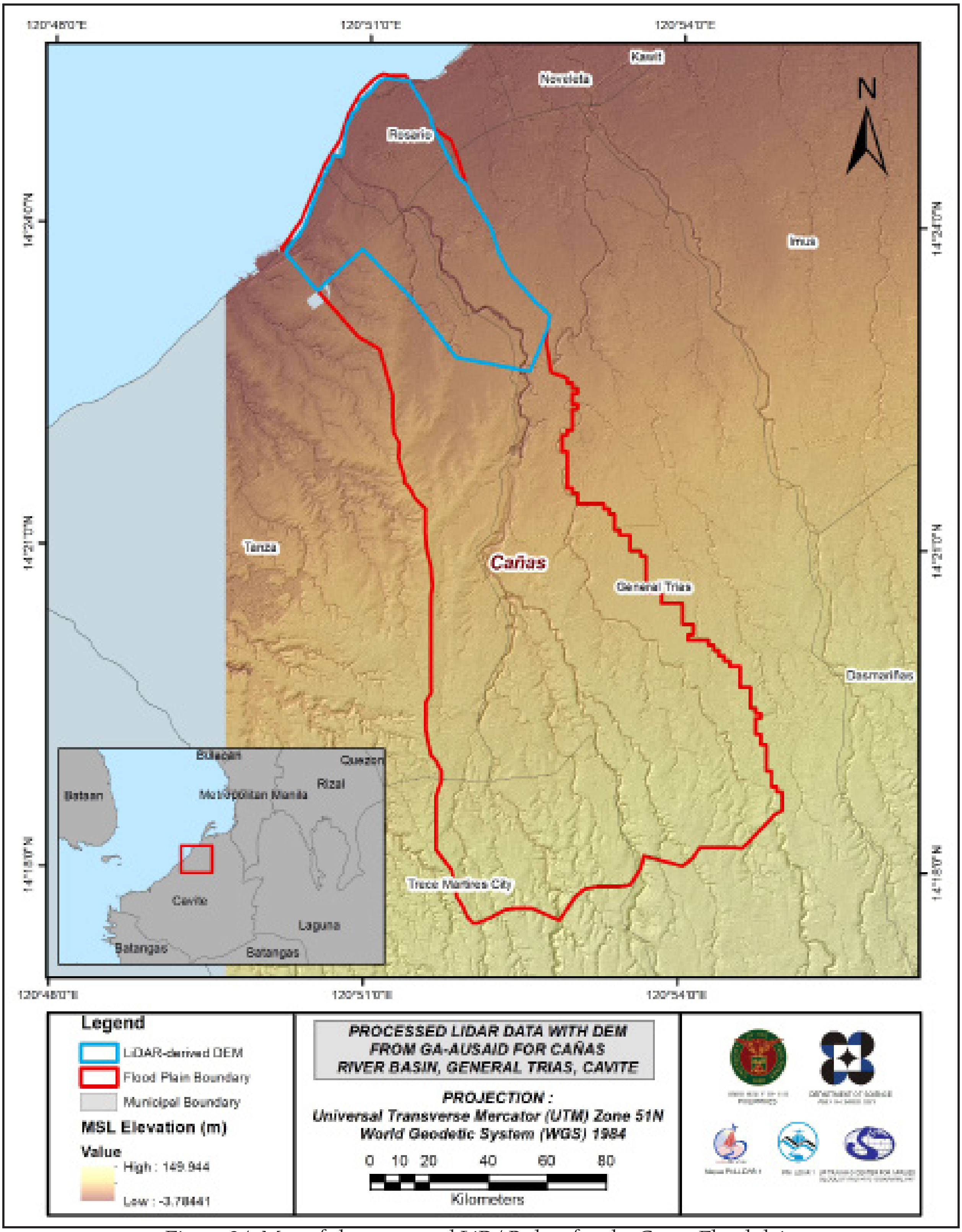

Figure 24. Map of the processed LiDAR data for the Cañas Floodplain

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 Cañas to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 24,251 survey points were gathered for all the flood plains within the provinces of CALABARZON wherein the Cañas floodplain is located. Random selection of 80% of the survey points, resulting to 19,401 points, was used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and ground survey elevation values is shown in Figure 26. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 2.97 meters with a standard deviation of 0.20 meters. Calibration of the LiDAR data was done by subtracting the height difference value, 2.97 meters, to the mosaicked LiDAR data. Table 21 shows the statistical values of the compared elevation values between the LiDAR data and calibration data.

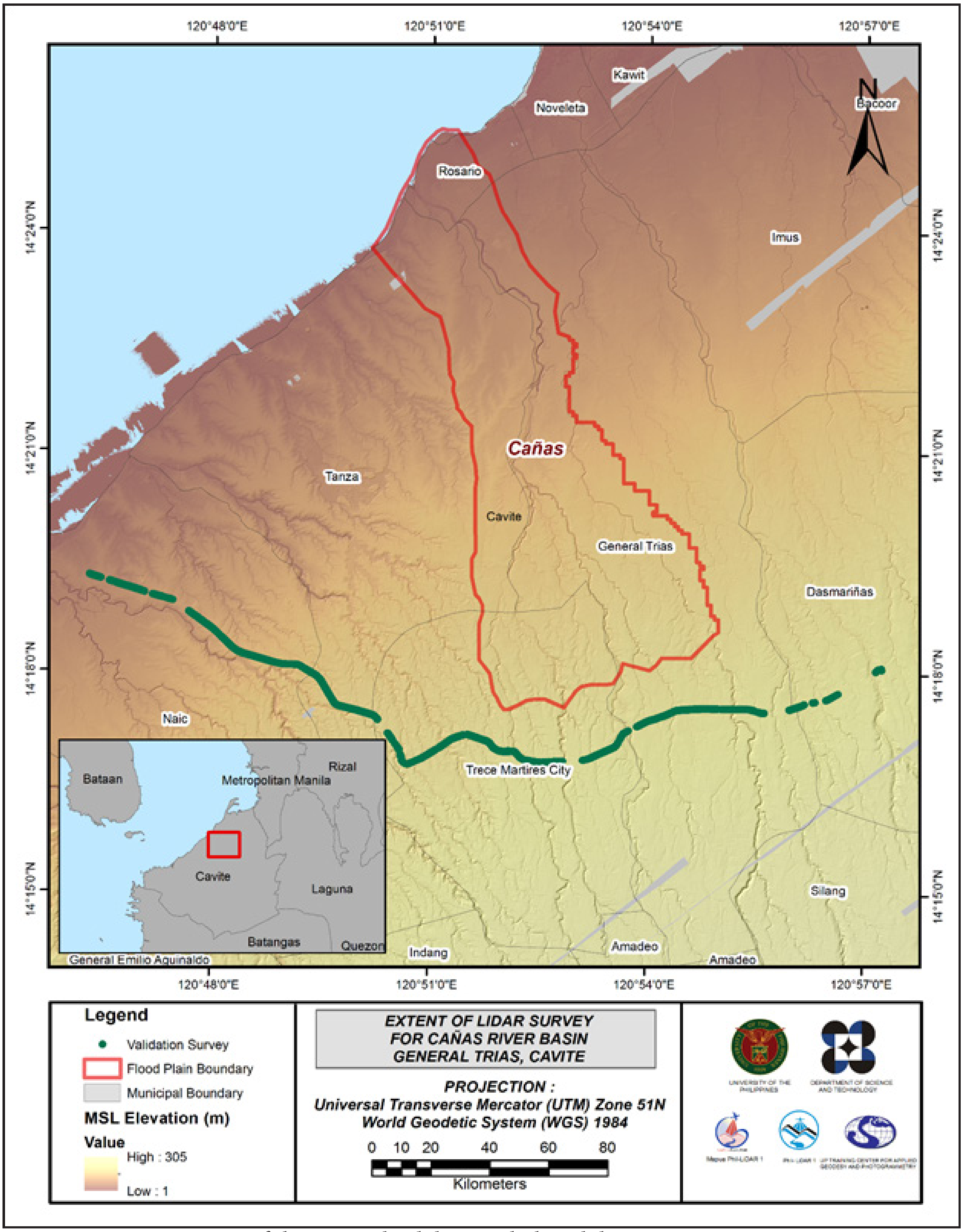

Figure 25. Map of the Cañas Floodplain, with the validation survey points in green

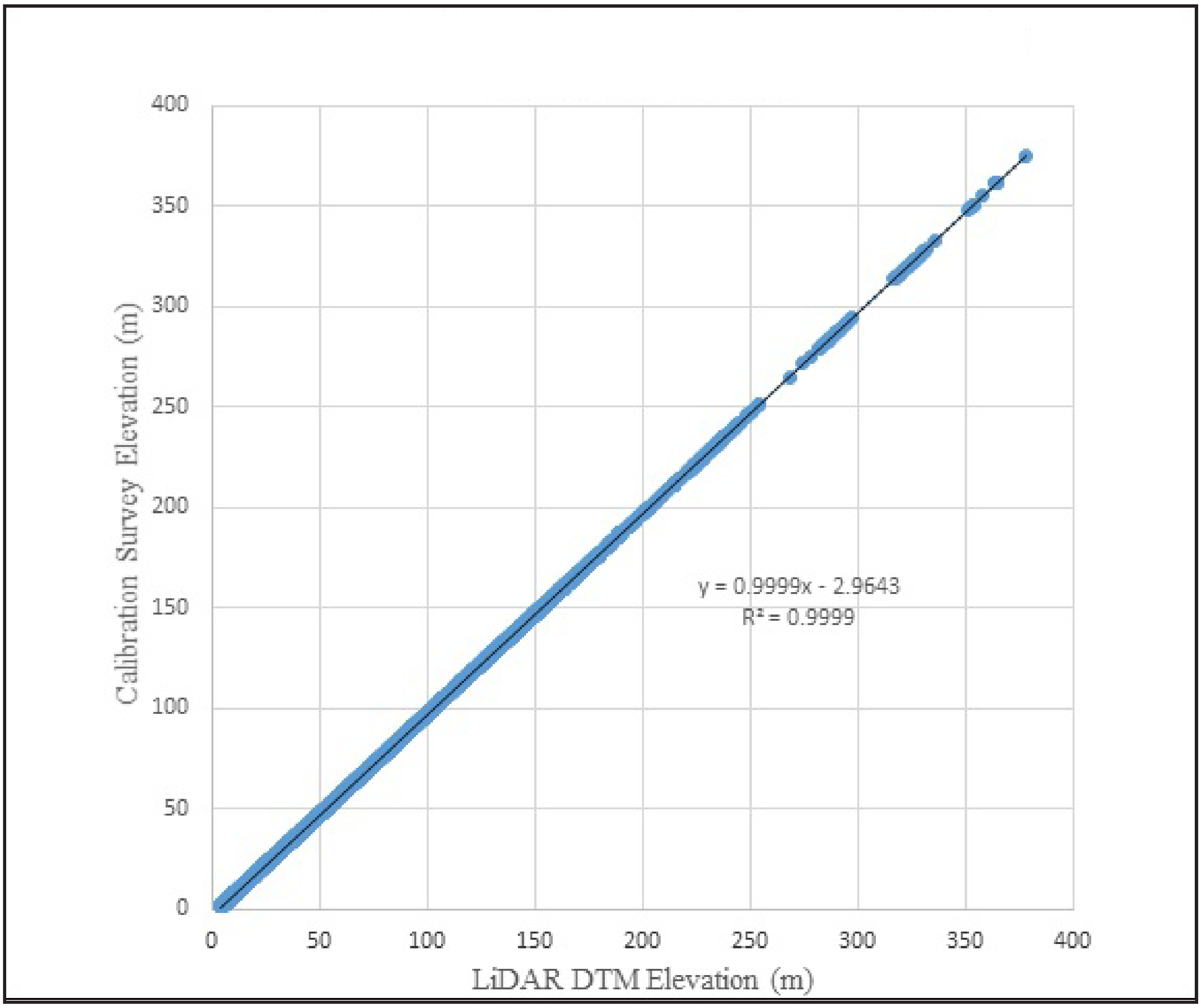

Figure 26. Correlation plot between the calibration survey points and the LiDAR data

Table 21. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	2.97
Standard Deviation	0.20
Average	-2.97
Minimum	-3.48
Maximum	-2.40

The remaining 20% of the total survey points that are near Canas flood plain, resulting to 362 points, were used for the validation of calibrated Canas DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM, is shown in Figure 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.15 meters, as shown in Table 22.

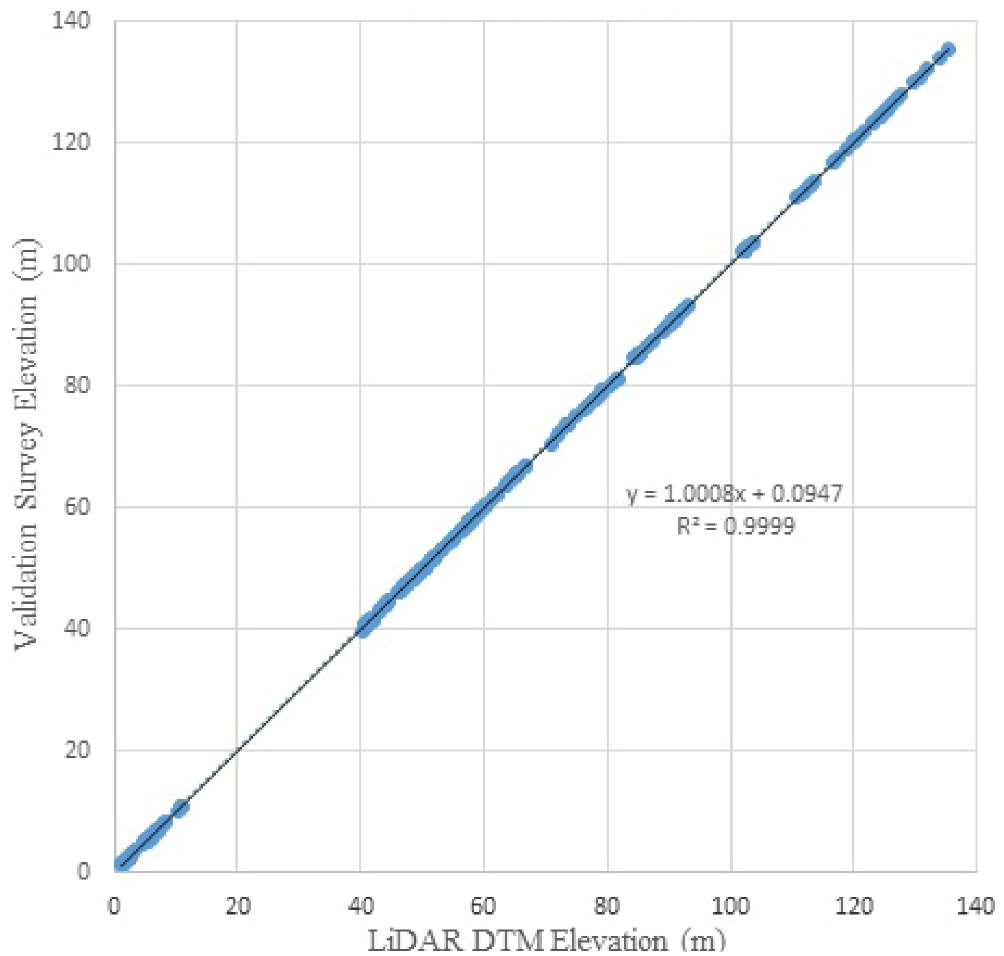

Figure 27. Correlation plot between the validation survey points and the LiDAR data

Table 22. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.15
Average	0.14
Minimum	-0.44
Maximum	0.31

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data were available for Cañas, with 6,667 bathymetric survey points. The resulting raster surface produced was obtained through the Kernel Interpolation (with Barriers) method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.35 meters. The extent of the bathymetric survey executed by the DVBC in the Cañas floodplain, integrated with the processed LiDAR DEM, is illustrated in Figure 28.

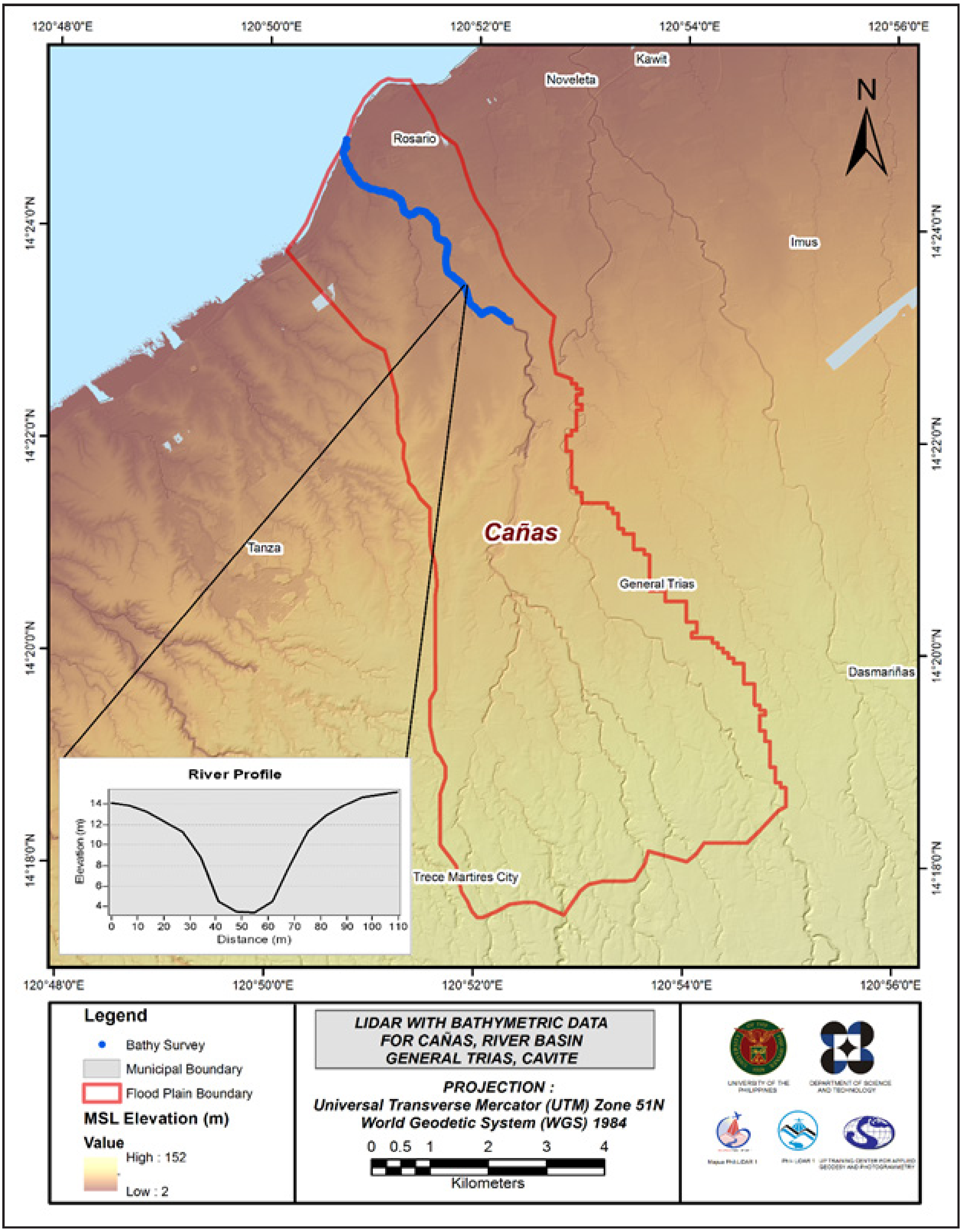

Figure 28. Map of the Cañas Floodplain with the bathymetric survey points in blue

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 DEM with a 1-meter resolution was used to delineate footprints of building features, which consist of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks – comprised of main thoroughfares, such as highways, and municipal and barangay roads – are essential for routing disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

The Cañas floodplain, including its 200-meter buffer zone, has a total area of 60.36 sq. km. Of this area, a total of 5.0 sq. km., corresponding to a total of 3,953 building features, was considered for quality checking (QC). Figure 29 presents the QC blocks for the Cañas floodplain.

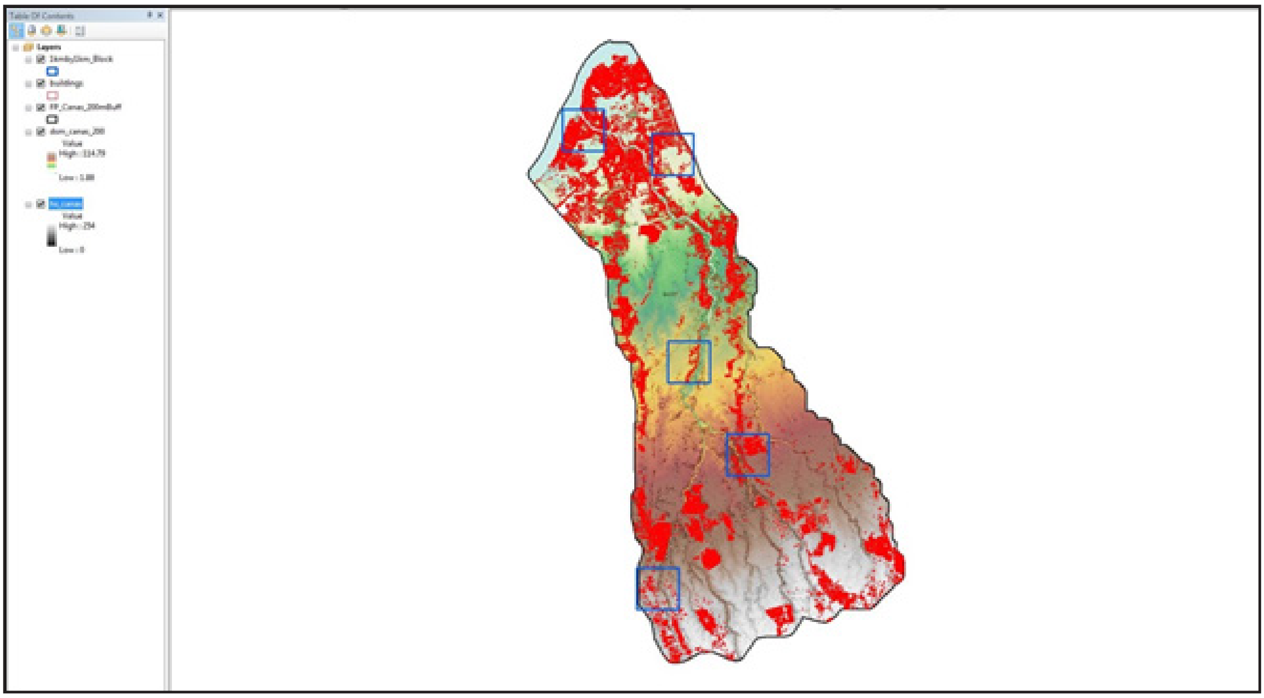

Figure 29. Blocks (in blue) of Cañas building features that were subjected to QC

Quality checking of the Cañas building features resulted in the ratings given in Table 23.

Table 23. Quality checking ratings for the Cañas building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Cañas	99.94	99.94	98.47	PASSED

3.12.2 Height Extraction

Height extraction was done for 54,340 building features in the Cañas floodplain. Of these building features, 2,780 were filtered out after height extraction, resulting in 51,560 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 9.60 meters.

3.12.3 Feature Attribution

The attributes were obtained through field data gathering. GPS devices were used to determine the coordinates of important features. These points were uploaded and overlaid in ArcMap and were then integrated with the shapefiles.

Table 24 summarizes the number of building features per type. Table 25 lists the total length of each road type, and Table 26 provides the number of water features extracted per type.

Table 24. Building features extracted for the Cañas Floodplain

Facility Type	No. of Features
Residential	50,779
School	317
Market	75
Agricultural/Agro-Industrial Facilities	13
Medical Institutions	44
Barangay Hall	42
Military Institution	0
Sports Center/Gymnasium/Covered Court	15
Telecommunication Facilities	0
Transport Terminal	1
Warehouse	1
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	3
Water Supply/Sewerage	15
Religious Institutions	67
Bank	16
Factory	0
Gas Station	24
Fire Station	1
Other Government Offices	20
Other Commercial Establishments	127
Total	51,560

Table 25. Total length of extracted roads for the Cañas Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Cañas	398.84	46.29	30.75	0.00	0.00	475.88

Table 26. Number of extracted water bodies for the Cañas Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Cañas	8	12	1	0	0	21

A total of thirty-five (35) bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 30 represents the Digital Surface Model (DSM) of the Cañas floodplain, overlaid with its ground features.

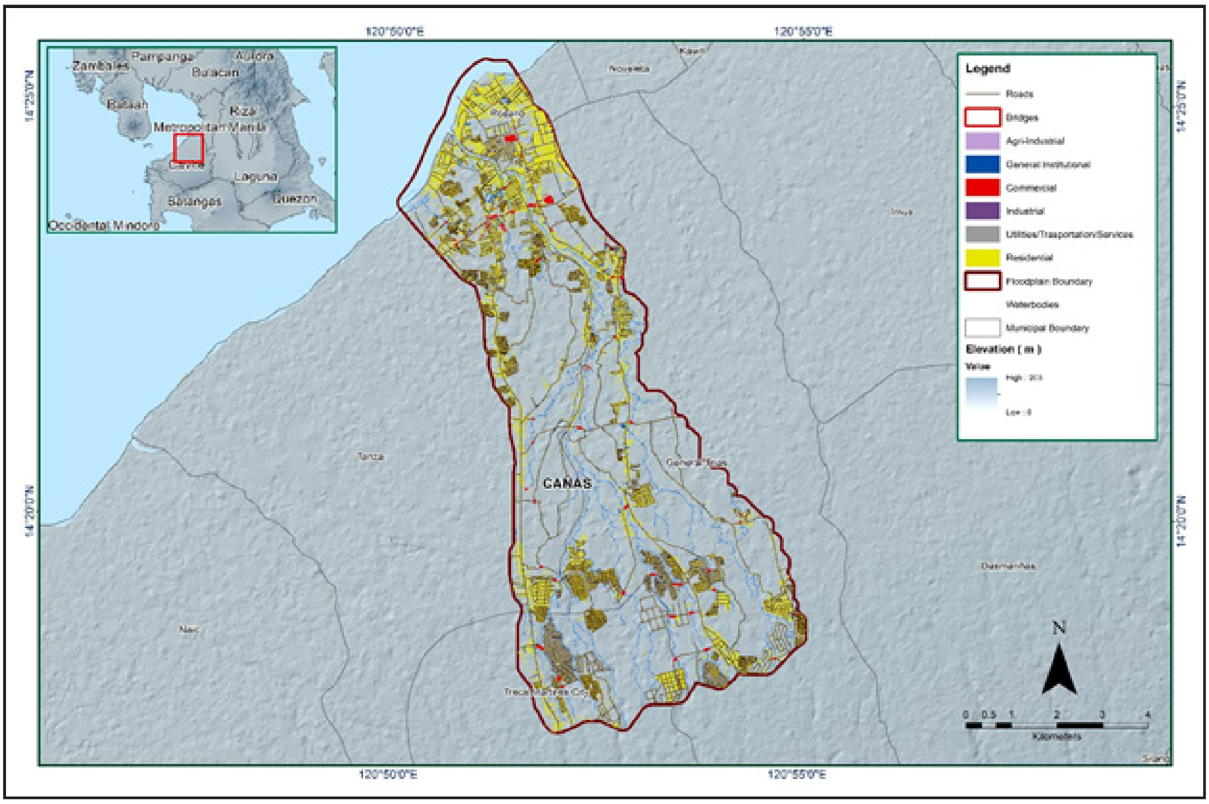

Figure 30. Extracted features for the Cañas Floodplain

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted field surveys in the Cañas River on September 13-25, 2015, in partnership with the MIT Phil-LiDAR 1 Team. The survey covered the bathymetric, bridge as-built and cross-section, and LiDAR validation surveys in the Cañas River. The bathymetric survey was conducted using an OHMEX™ single beam echo sounder to determine the depth of the river; while a Trimble® SPS 882 rover GPS was used to gather the coordinates and elevation values of the survey points. The extent of the surveys is illustrated in Figure 31.

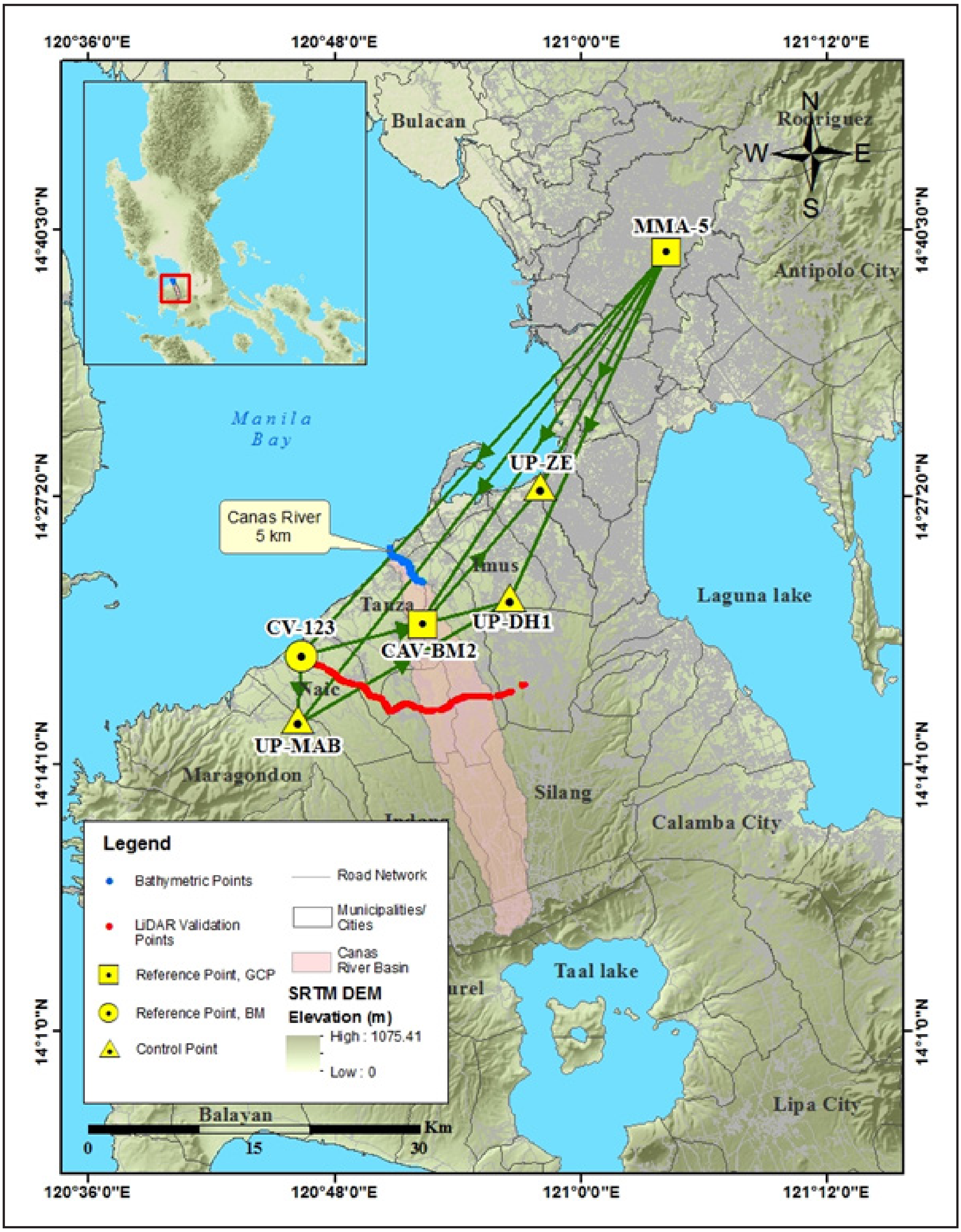


Figure 31. Extent of the bathymetric survey (in blue line) in the Cañas River Basin and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for the Cañas River Basin is composed of four (4) loops established on September 15 and 17, 2015, occupying the following reference points: (i.) MMA-5, a first-order GCP in the University of the Philippines Diliman in Barangay U.P. Campus, Quezon City; and (ii.) CV-123, a first-order BM, located in front of an Iglesia ni Cristo church in Barangay Amaya, Municipality of Naic, Cavite.

Four (4) control points were established along the approach of the bridges namely: (i.) UP-DH1, located at the Daang Hari Bridge in Barangay Anabu II-A, Municipality of Imus, Cavite; (ii.) UP-MAB, located at the Mabacao Bridge, Barangay Bucal IV B, Municipality of Maragondon, Cavite; (iii.) UP-ZE, located at the right side of the Zapote Bridge in Barangay Zapote, Basa I, Las Piñas City; and (iv.) CAV-BM2, located at the Cañas Bridge in Barangay Tapia, Municipality of General Trias, Cavite, which was also occupied as a marker during the survey.

The summary of the reference and control points and their corresponding locations is provided in Table 27, while the GNSS network established is illustrated in Figure 32.

Table 27. List of reference and control points occupied in the Cañas River survey
(Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
MMA-5	2nd Order, GCP	14°39'22.97451"	121°04'11.14940"	133.379	-	1956
CV-123	1st Order,					
BM	-	-	52.071	9.314	2008	
CAV-BM2	UP Established	-	-	-	-	Sept. 15, 2015
UP-DH1	UP Established	-	-	-	-	Sept. 15, 2015
UP-MAB	UP Established	-	-	-	-	Sept. 17, 2015
UP-ZE	UP Established	-	-	-	-	Sept. 17, 2015

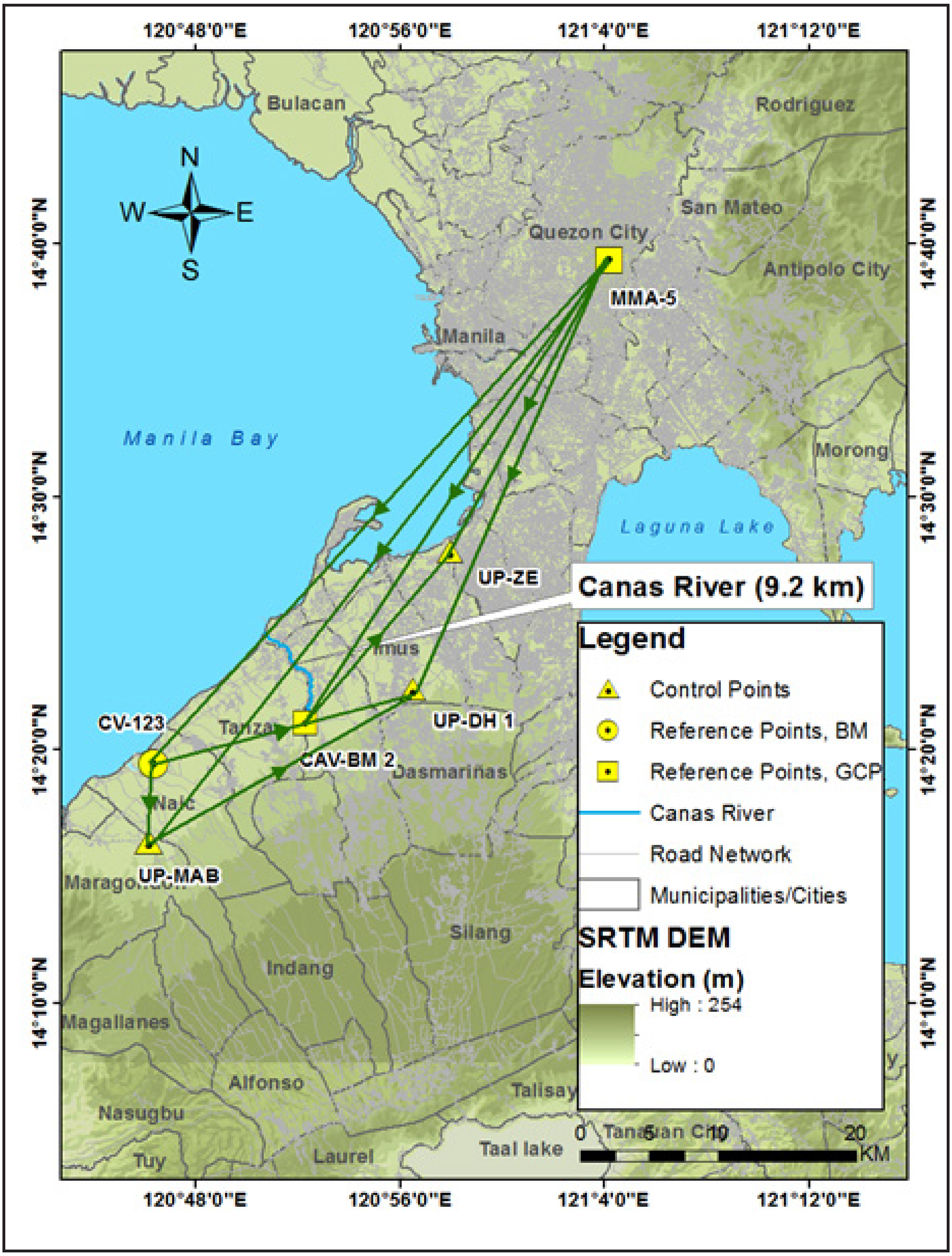


Figure 32. GNSS network covering the Cañas River

The GNSS set-ups established at the locations of the reference and control points are exhibited in Figure 33 to Figure 38.

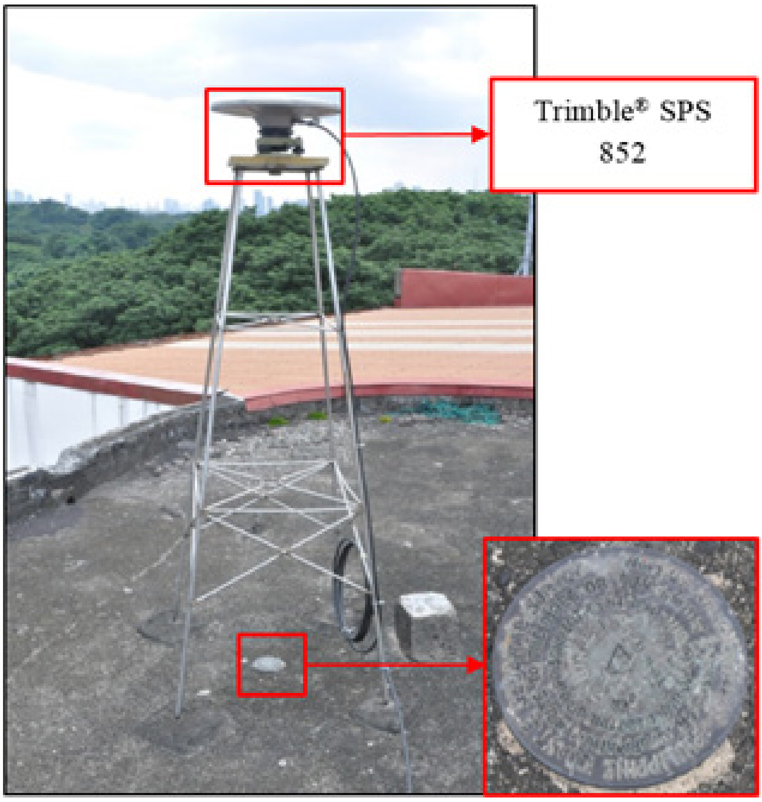


Figure 33. Trimble® SPS 852 set-up at MMA-5, located at the Melchor Hall, University of the Philippines Diliman in Barangay U.P. Campus, Quezon City

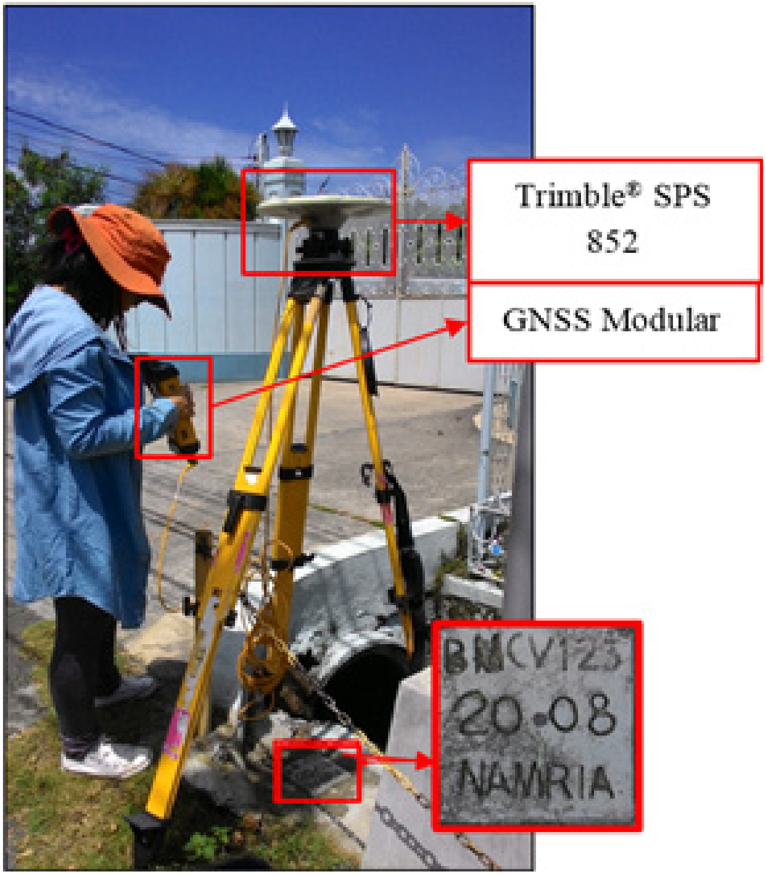


Figure 34. GPS set-up of Trimble® SPS 852 at CV-123, located in front of the Iglesia ni Cristo Chapel in Barangay Amaya, Municipality of Naic, Cavite

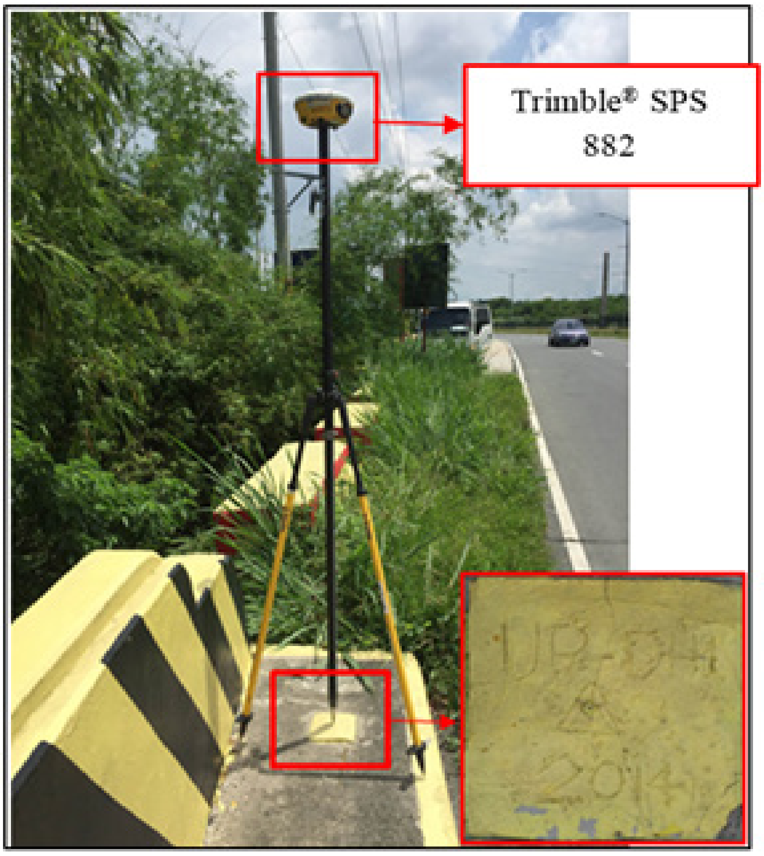


Figure 35. Trimble® SPS 882 set-up at UP-DH1 located at the Daang Hari Bridge in Barangay Anabu II-A, Municipality of Imus, Cavite

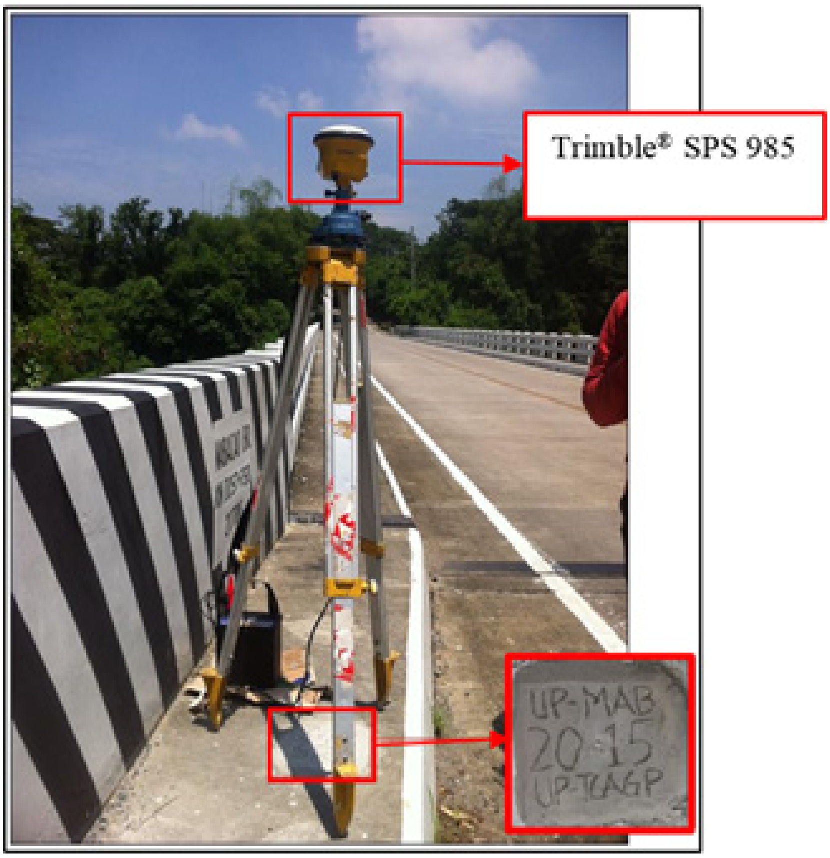


Figure 36. Trimble® SPS 985 set-up at UP-MAB, located at the approach of the Mabacao Bridge in Barangay Bucal IV B, Municipality of Maragondon, Cavite

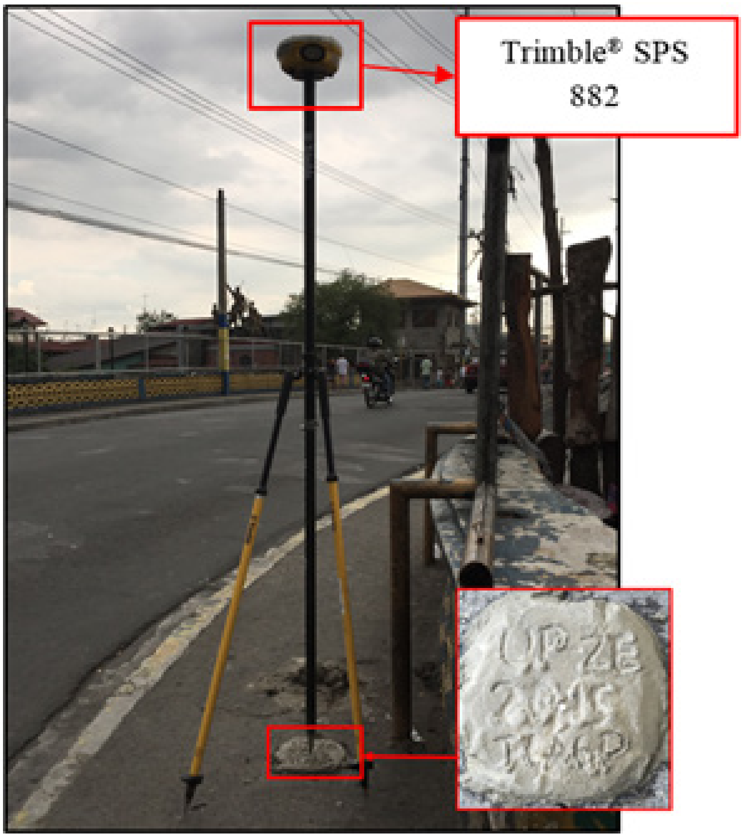


Figure 37. Trimble® SPS 882 set-up at UP-ZE, located at the Zapote Bridge in Barangay Zapote, Bacoor City, Cavite

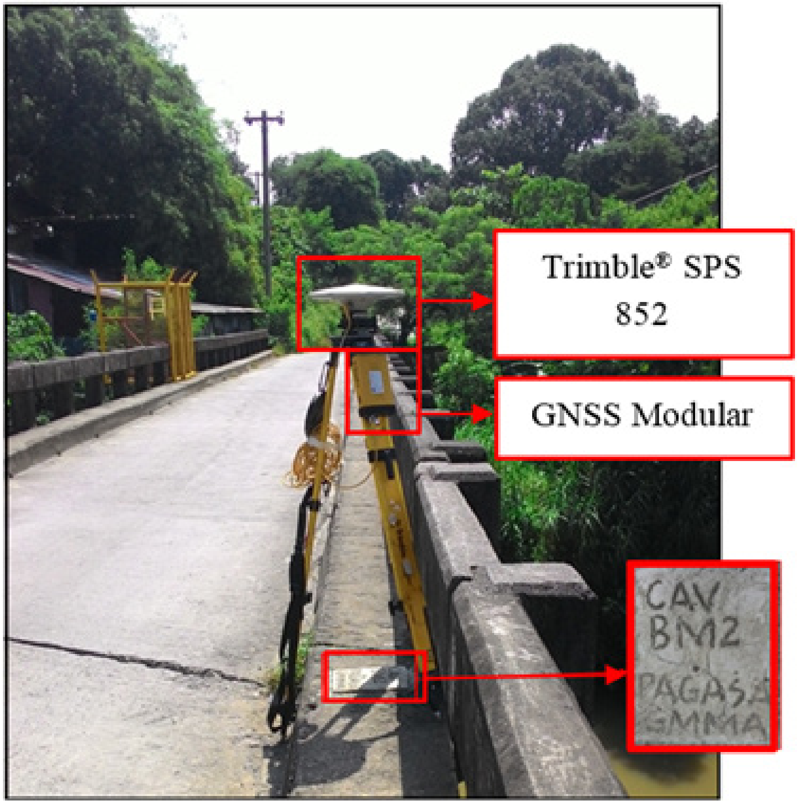


Figure 38. GPS set-up of Trimble® SPS 852 at CAV-BM 2, located at the Cañas Bridge in Barangay Tapia, Municipality of General Trias, Cavite

4.3 Baseline Processing

GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a re-survey is initiated. The baseline processing results of the control points used in the Cañas River survey, generated by TBC software, are summarized in Table 28.

Table 28. Baseline processing report used in the Cañas River Basin survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CV-123---UP-MAB	09-15-2015	Fixed	0.005	0.022	182°55'06"	5730.614	19.916
CV-123---UP-MAB	09-15-2015	Fixed	0.005	0.012	182°55'05"	5730.599	19.913
UP-DH1---UP-MAB	09-15-2015	Fixed	0.088	0.108	239°06'21"	21662.35	-9.875
UP-DH1---CV-123	09-15-2015	Fixed	0.006	0.034	253°33'16"	19073.15	-29.7
CAV-BM2---UP-ZE	09-17-2015	Fixed	0.005	0.022	39°14'40"	16153.02	-24.213
MMA-5---UP-DH1	09-15-2015	Fixed	0.006	0.014	203°41'56"	34213.76	-51.591
MMA-5---CV-123	09-15-2015	Fixed	0.023	0.021	221°06'52"	48736.51	-81.313
MMA-5---CV-123	09-15-2015	Fixed	0.023	0.025	221°06'52"	48736.48	-81.311
MMA-5---UP-ZE	09-17-2015	Fixed	0.005	0.018	207°38'44"	24003.52	-85.42
MMA-5—CAV-BM2	09-17-2015	Fixed	0.004	0.014	212°19'39"	39957.2	-61.233

As shown in Table 28, a total of ten (10) baselines were processed, with reference point MMA-5 held fixed for coordinate values; and CV-123 held fixed for elevation values. All of the baselines satisfied the required accuracy.

4.4 Network Adjustment

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

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

where:

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

The six (6) control points – MMA-5, CV-123, CAV-BM2, UP-DH1, UP-MAB, and UP-ZE – were occupied and observed simultaneously to form a GNSS loop. The coordinates of MMA-5 and the elevation values of CV-123 were held fixed during the processing of the control points, as presented in Table 29. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 29. Constraints applied to the adjustments of the control points

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
CV-123	Grid				Fixed
MMA-5	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001 (Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 30. All fixed control points have no values for grid and elevation errors.

Table 30. Adjusted grid coordinates for the control points used in the Cañas Floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MMA-5	292122.994	?	1621207.085	?	89.331	0.047	LL
CV-123	259759.978	0.023	1584752.533	0.010	9.314	?	e
CAV-BM2	270467.286	0.011	1587618.081	0.007	29.230	0.068	
UP-DH1	278104.989	0.018	1589990.469	0.007	38.572	0.055	
UP-MAB	259413.172	0.025	1579030.620	0.013	29.050	0.040	
UP-ZE	280803.732	0.012	1600035.582	0.009	4.798	0.076	

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

a.	MMA-5		
	Horizontal Accuracy	=	Fixed
	Vertical Accuracy	=	4.7 < 10 cm
b.	CV-123		
	Horizontal Accuracy	=	$\sqrt{((2.3)^2 + (1.0)^2}$
		=	$\sqrt{(5.29 + 1)}$
		=	2.51 < 20 cm
	Vertical Accuracy	=	Fixed
c.	CAV-BM2		
	Horizontal Accuracy	=	$\sqrt{((1.1)^2 + (0.7)^2}$
		=	$\sqrt{(1.21 + 0.49)}$
		=	1.30 < 20 cm
	Vertical Accuracy	=	6.8 cm < 10 cm
d.	UP-DH 1		
	Horizontal Accuracy	=	$\sqrt{((1.8)^2 + (0.7)^2}$
		=	$\sqrt{(3.24 + 0.49)}$
		=	1.93 cm < 20 cm
	Vertical Accuracy	=	5.5 < 10 cm
e.	UP-MAB		
	Horizontal Accuracy	=	$\sqrt{((2.5)^2 + (1.3)^2}$
		=	$\sqrt{(6.25 + 1.69)}$
		=	2.82 < 20 cm
	Vertical Accuracy	=	4.0 < 10 cm
f.	UP-ZE		
	Horizontal Accuracy	=	$\sqrt{((1.2)^2 + (0.9)^2}$
		=	$\sqrt{(1.44 + 0.81)}$
		=	1.5 < 20 cm
	Vertical Accuracy	=	7.6 < 10 cm

Following the given formula, the horizontal and vertical accuracy results of the two (2) occupied control points are within the required accuracy of the project.

Table 31. Adjusted geodetic coordinates for control points used in the Cañas River Floodplain validation

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
MMA-5	N14°39'22.97451"	E121°04'11.14940"	133.379	0.047	LL
CV-123	N14°19'27.61225"	E120°46'21.72442"	52.071	?	e
CAV-BM2	N14°21'04.09862"	E120°52'18.03337"	72.153	0.068	
UP-DH1	N14°22'23.52073"	E120°56'32.16087"	81.814	0.055	
UP-MAB	N14°16'21.39512"	E120°46'11.99131"	71.979	0.040	
UP-ZE	N14°27'51.06089"	E120°57'59.25259"	47.954	0.076	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as shown in Table 31. Based on the results of the computations, 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 Cañas River GNSS Static Survey are indicated in Table 32.

Table 32. Reference and control points used in the Cañas River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
MMA-5	2nd Order, GCP	14°39'22.97451"	121°04'11.14940"	133.379	1621207.085	292122.994	89.331
CV-123	1st Order, BM	14°19'27.61225"	120°46'21.72442"	52.071	1584752.533	259759.978	9.314
CAV-BM2	UP Established	14°21'04.09862"	120°52'18.03337"	72.153	1587618.081	270467.286	29.230
UP-DH1	UP Established	14°22'23.52073"	120°56'32.16087"	81.814	1589990.469	278104.989	38.572
UP-MAB	UP Established	14°16'21.39512"	120°46'11.99131"	71.979	1579030.620	259413.172	29.050
UP-ZE	UP Established	14°27'51.06089"	120°57'59.25259"	47.954	1600035.582	280803.732	4.798

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

The cross-section and bridge as-built surveys were conducted on September 21, 2015 at the downstream side of the Cañas Bridge in Barangay Tapia, Municipality of General Trias, as exhibited in Figure 39. A Trimble® SPS 882 in PPK survey technique at the upstream side of the bridge, as depicted in Figure 40.

Figure 39. The Cañas Bridge facing upstream

Figure 40. Cross-section survey using PPK Technique

The length of the cross-sectional line surveyed in the Cañas Bridge is about 102.41 meters with nineteen (19) cross-sectional points, using the control point CAV-BM2 as the GNSS base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 41 to Figure 43.

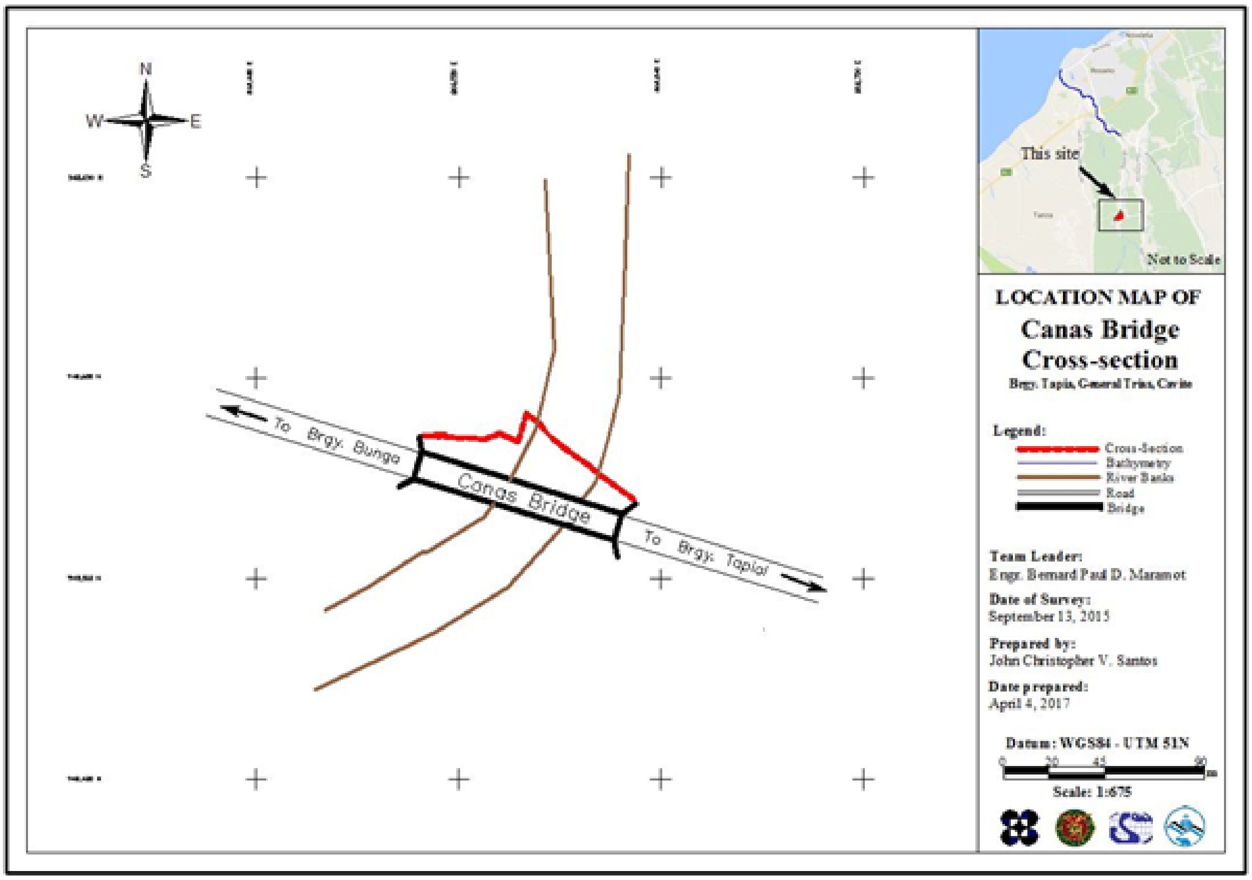


Figure 41. Cañas Bridge cross-section location map

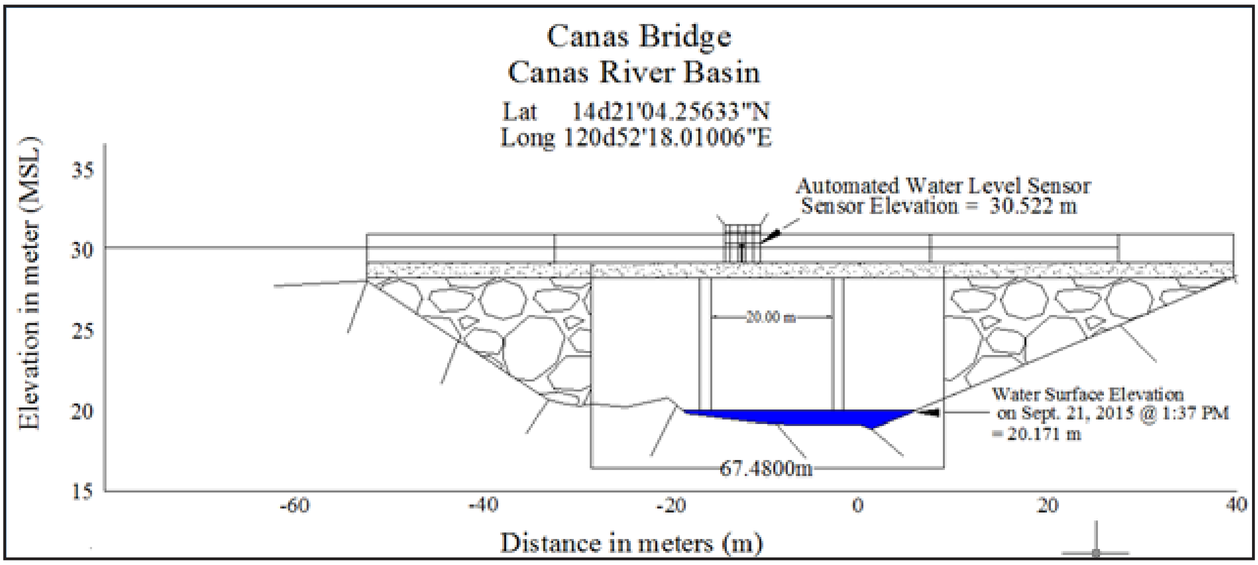
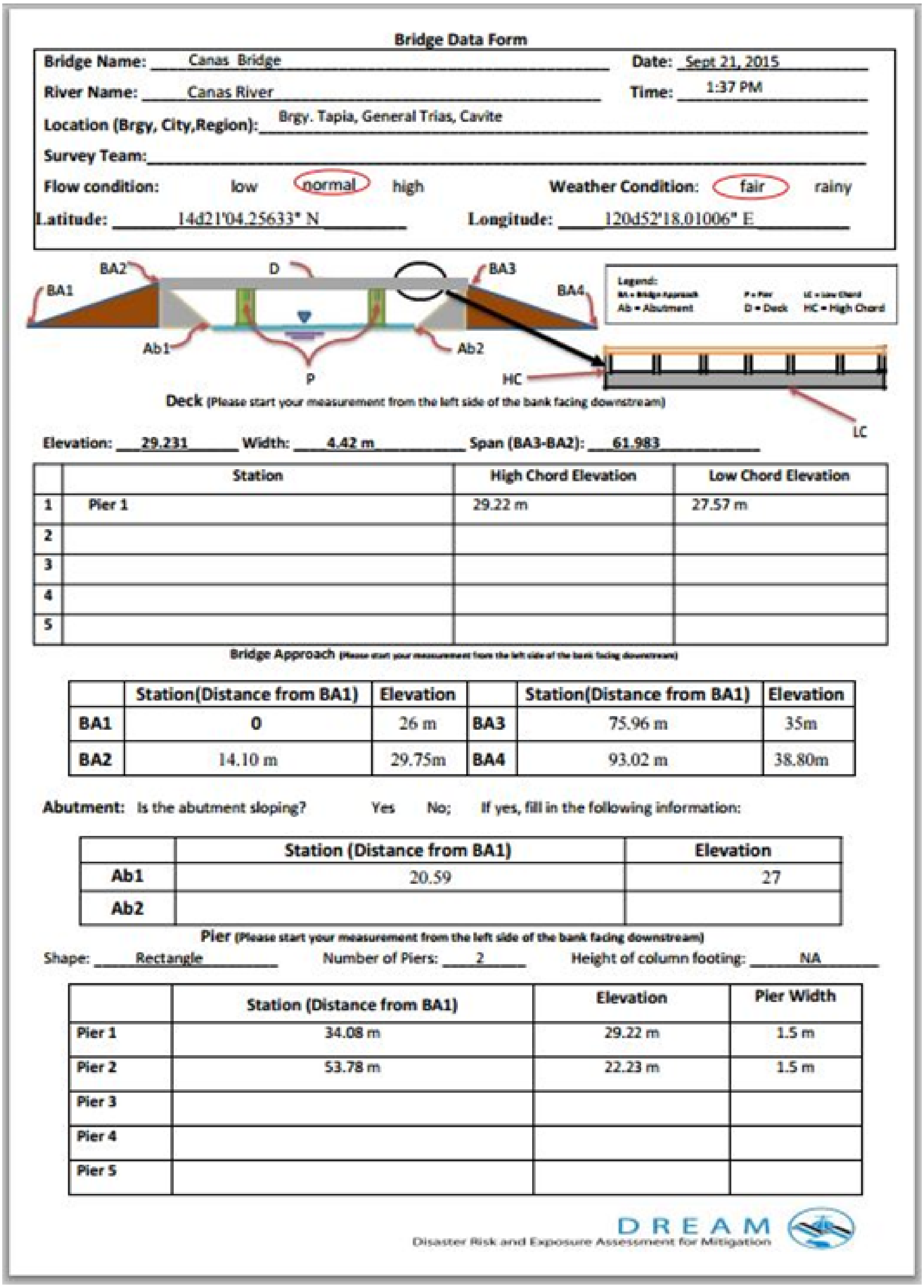


Figure 42. Cañas Bridge cross-sectional diagram



Bridge Data Form

Bridge Name: Canas Bridge Date: Sept 21, 2015

River Name: Canas River Time: 1:37 PM

Location (Brgy, City,Region): Brgy. Tapia, General Trias, Cavite

Survey Team:

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

Latitude: 14d21'04.25633" N Longitude: 120d52'18.01006" E

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

Elevation: 29.231 Width: 4.42 m Span (BA3-BA2): 61.983

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 1	29.22 m	27.57 m
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	26 m	BA3	75.96 m	35m
BA2	14.10 m	29.75m	BA4	93.02 m	38.80m

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

	Station (Distance from BA1)	Elevation
Ab1	20.59	27
Ab2		

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

Shape: Rectangle Number of Piers: 2 Height of column footing: NA

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	34.08 m	29.22 m	1.5 m
Pier 2	53.78 m	22.23 m	1.5 m
Pier 3			
Pier 4			
Pier 5			

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 43. Bridge as-built form of the Cañas Bridge

Figure 44. Water level markings on the side of the pier in the Cañas Bridge

The water surface elevation of the Cañas River was determined using Trimble® SPS 882 in PPK mode technique on September 21, 2015 at 13:37 hrs. The elevation had a value of 20.171 meters in MSL, as reflected in Figure 42. The water surface elevation was translated into markings on the bridge's pier using digital levels (Figure 44). The marked pier served as a reference for flow data gathering and depth gauge deployment by the MIT Phil-LiDAR 1 Team.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on September 17, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole attached in front of a vehicle, as depicted in Figure 45. It was secured with a cable tie to ensure that it is horizontally and vertically balanced. The antenna height was 2.36 meters, measured from the ground up to the bottom of notch of the GNSS Rover receiver. The activity started in Barangay Ibayo Silangan in Naic, Cavite, and ended in Barangay Sampaloc I in Trece Martires City, Cavite.

Figure 45. Validation points acquisition set-up for the Cañas River Basin

The conducted survey on September 17, 2015 started in Barangay Ibayo Silangan, Municipality of Naic, Cavite; and headed east towards Barangay Sampaloc I, Municipality of Dasmariñas, Cavite. A total of 3,854 ground validation points were acquired with an approximate length of 22.8 km., using UP-DH 1 as the GNSS base station. This is illustrated in the map in Figure 46.

Figure 46. Extent of the LiDAR ground validation survey of the Cañas River Basin

4.7 River Bathymetric Survey

A manual bathymetric survey was executed on September 24, 2015 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode, as demonstrated in Figure 47. The survey started in the upstream part of the river in Barangay San Juan II, General Trias City, Cavite, with coordinates 14°23'07.19151"N, 120°52'18.31967"E; and ended at the mouth of the river, with coordinates 14°24'39.12953"N, 120°50'42.28026"E, in Barangay Wawa II, Municipality of Rosario, Cavite. The control point CAV-BM2 was used as the GNSS base station all throughout the survey.

A total of 6,930 bathymetric points were acquired with an approximate length of 5.3 km., as illustrated in the bathymetry line from the mouth of the river in Figure 48. The planned bathymetry was not finished due to the difficulty of navigating the boat in the narrow parts of the upstream side of the river. The upper parts of the river were also too deep to be traversed by foot. Due to the difficulties with traversing the river and the time constraints, a follow-up survey will be scheduled to finish the planned coverage of the Cañas River.

Figure 47. Bathymetric survey using Ohmex™ single beam echo sounder in the Cañas River

The bathymetric survey for the Cañas River gathered a total of 6,930 points covering 5.3 km. of the river, traversing Barangay Juan II, General Trias City, Cavite downstream, until Barangay Wawa II, Municipality of Rosariom Cavite. A CAD drawing was also produced to illustrate the riverbed profile of the Cañas River, presented in Figure 49. The profile shows that the highest and lowest elevation had a -5.938-meter difference for the Cañas River. The highest elevation observed was –0.355 meters below MSL, located at the mouth of the Cañas River; while the lowest elevation was –6.293 meters below MSL, located in the upstream portion of the river.

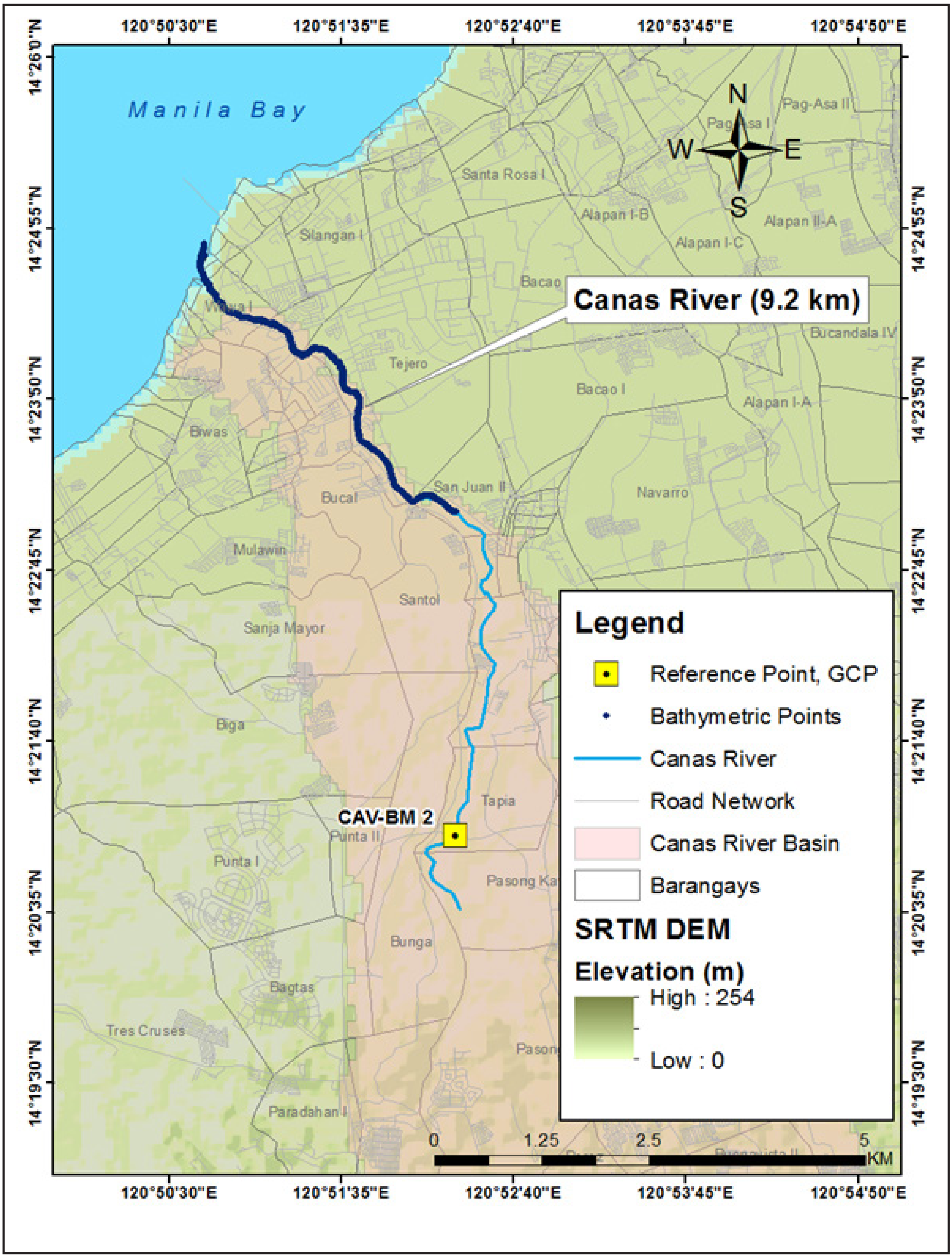


Figure 48. Extent of the bathymetric survey of the Cañas River

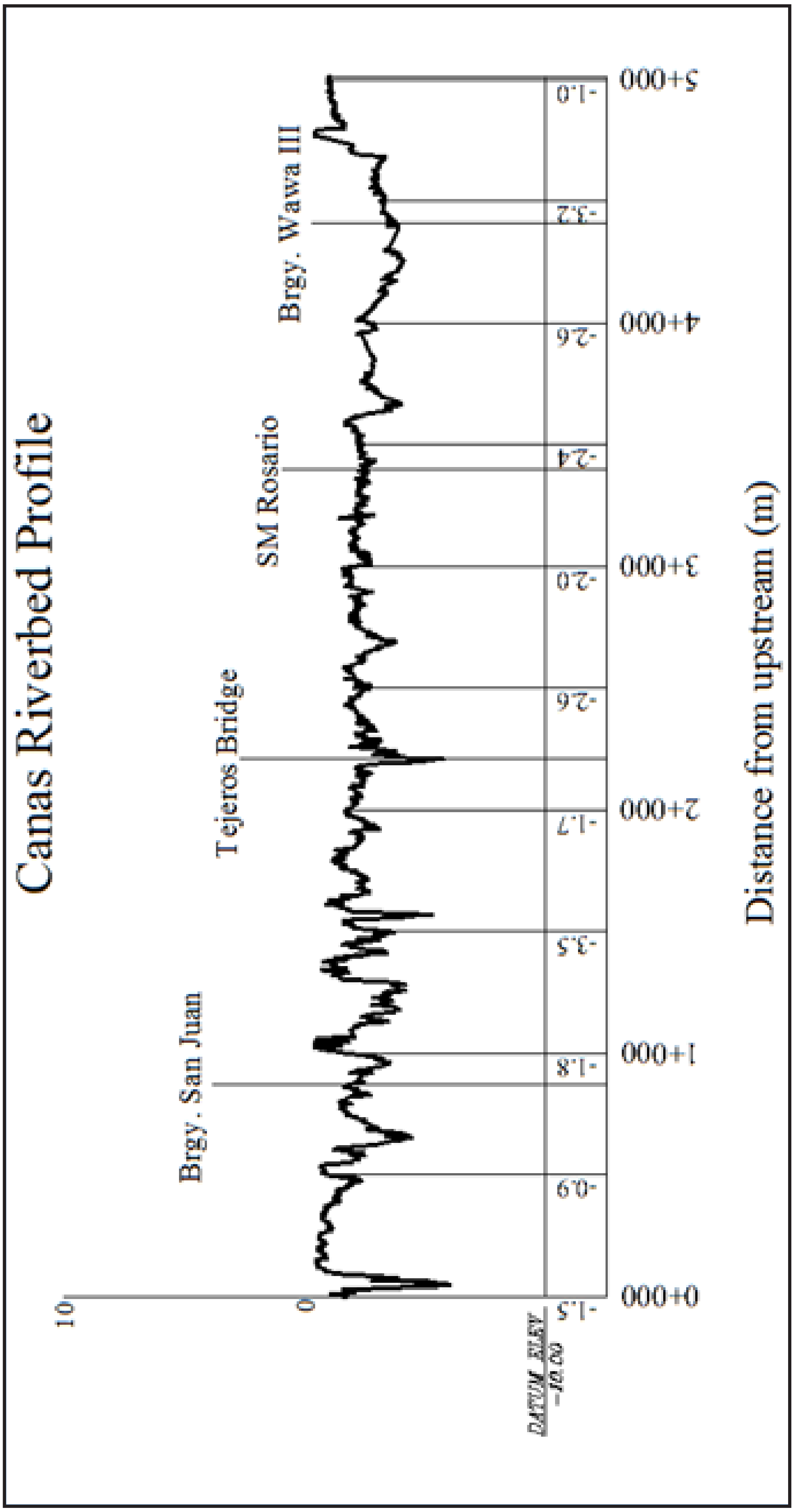


Figure 49. Riverbed profile of the Cañas River

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, and Pauline Racoma

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from three (3) automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The ARGs are located in Indang, Amadeo, and Dasmariñas. The location of the rain gauge is shown in Figure 50.

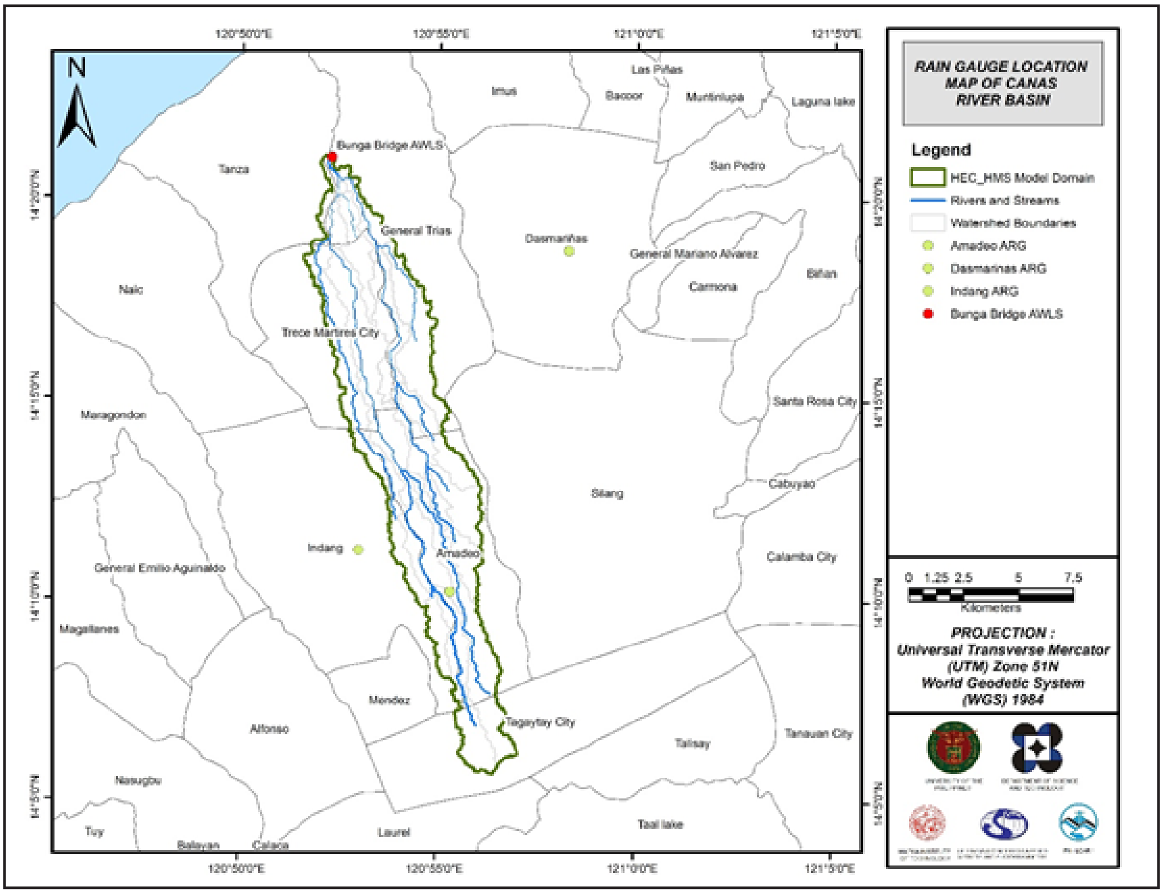


Figure 50. The location map of the rain gauges used for the calibration of the Cañas HEC-HMS Model

The total rain from the Amadeo rain gauge is 4.6 mm. It peaked at 1 mm. on May 25, 2016 at 19:30 hrs. The lag time between the peak rainfall and discharge was three (3) hours, as seen in Figure 53.

The total rain from the Indang (Cavite State University) rain gauge for this event was 11 mm. Peak rain of 3.6 mm. was recorded on May 25, 2016 at 18:00 hrs. The lag time between the peak rainfall and discharge was three (3) hours and forty-five (45) minutes, as seen in Figure 53.

The total rain from the Dasmariñas rain gauge was 3.6 mm. It peaked at .6 mm. on May 25, 2016 at 18:00 hrs. The lag time between the peak rainfall and discharge was three (3) hours and thirty (30) minutes, as seen in Figure 53.

5.1.3 Rating Curves and River Outflow

A rating curve was computed at the prevailing cross-section (Figure 51) at the Bunga Bridge in Tanza, Cavite (14°21'4.25"N, 120°52'18.51"E) to establish the relationship between the observed water levels (H) and the outflow (Q) of the watershed at this location. It is expressed in the form of the following equation:

$$Q=anh$$

where,

Q	:	Discharge (m3/s),
h	:	Gauge height, and
a and n	:	Constants.

For the Bunga Bridge, the rating curve is expressed as y = 2E-124e13.975x, as demonstrated in Figure 52.

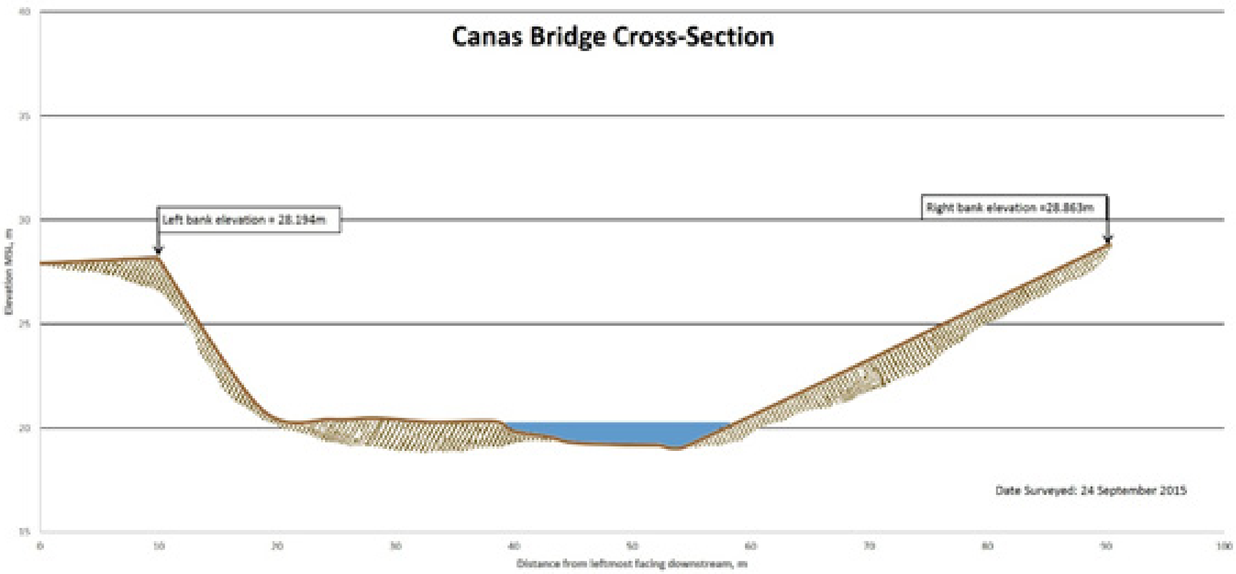


Figure 51. Cross-section plot of the Bunga Bridge

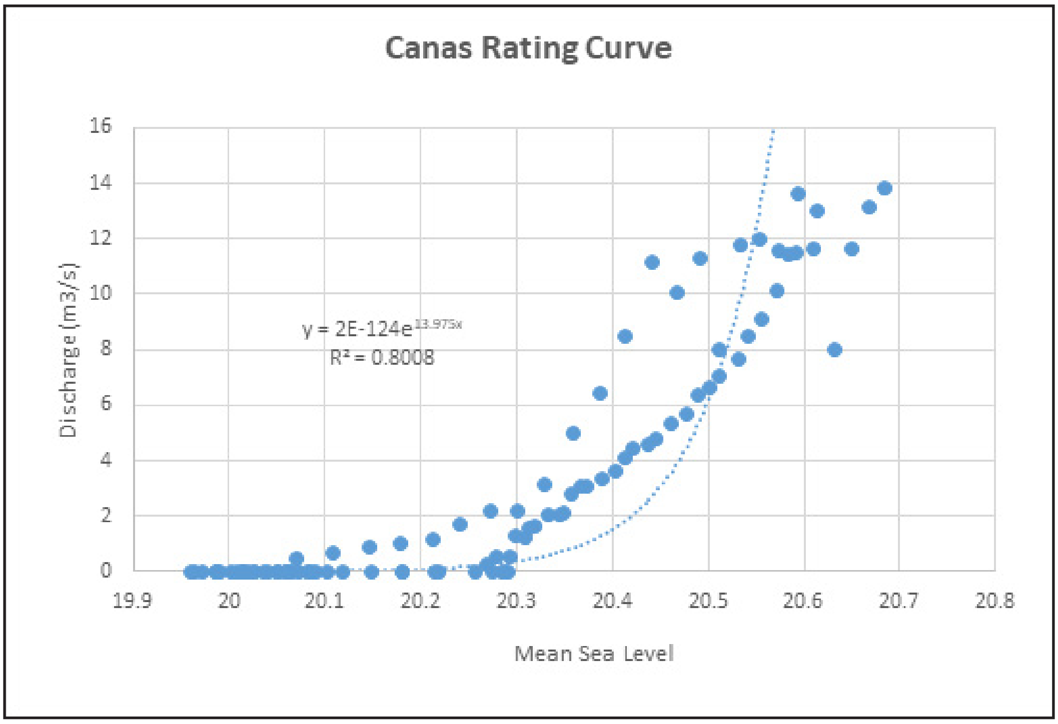


Figure 52. Rating curve at the Bunga Bridge, Tanza, Cavite

This rating curve equation was used to compute for the river outflow at the Bunga Bridge for the calibration of the HEC-HMS model shown in Figure 53. Peak discharge was 13.9 m3/s on May 25, 2016 at 21:30 hrs.

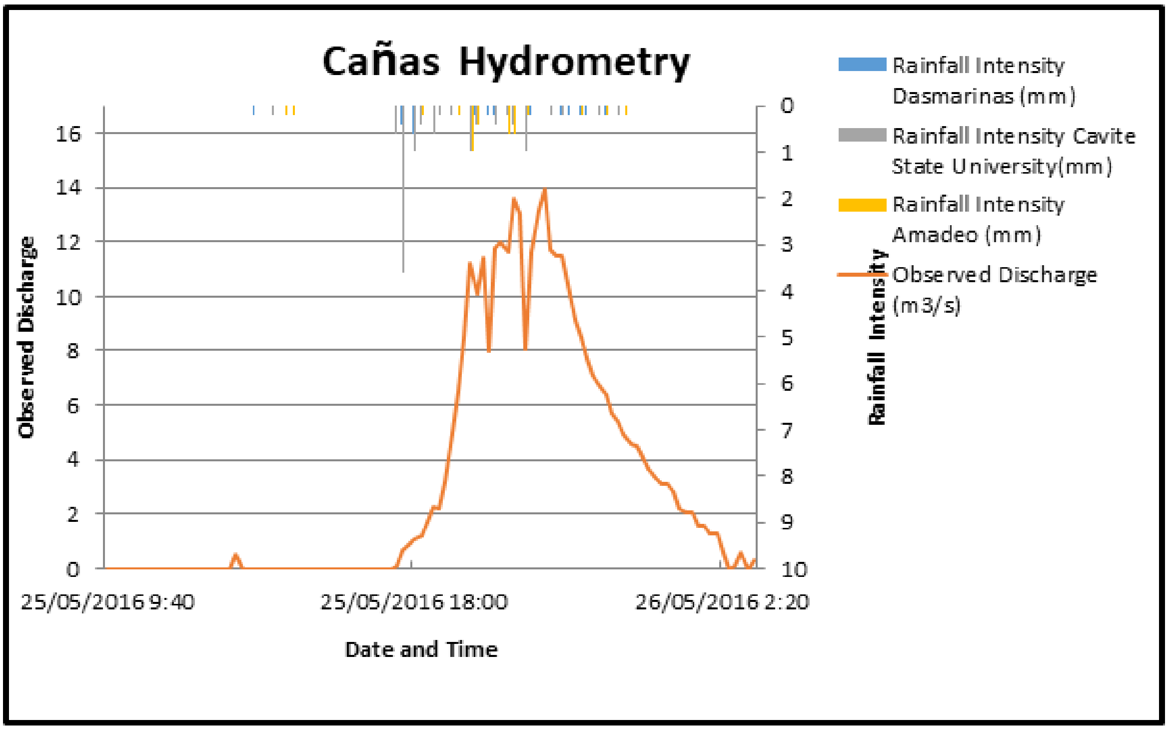


Figure 53. Rainfall and outflow data at Cañas used for modeling

5.2 RIDF Station

The PAGASA computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Sangley Point Gauge (Table 33). This station was selected based on its proximity to the Cañas watershed (Figure 54). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values such that certain peak values were attained at a certain time (Figure 55). The extreme values for this watershed were computed based on a 54-year record.

Table 33. RIDF values for the Sangley Point Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	20.3	30	36.6	46.4	63.2	74.6	96.6	119.6	147.9
5	28.3	41.8	50.8	64.6	89.8	106.8	140.3	174	209.4
10	33.6	49.7	60.2	76.7	107.3	128.2	169.2	210	250.1
15	36.6	54.1	65.5	83.5	117.2	140.3	185.6	230.3	273.1
20	38.7	57.2	69.2	88.3	124.2	148.7	197	244.6	289.1
25	40.3	59.6	72.1	91.9	129.5	155.2	205.8	255.5	301.5
50	45.3	66.9	80.9	103.3	146	175.2	233	289.3	339.7
100	50.3	74.2	89.7	114.5	162.3	195.1	259.9	322.8	377.6

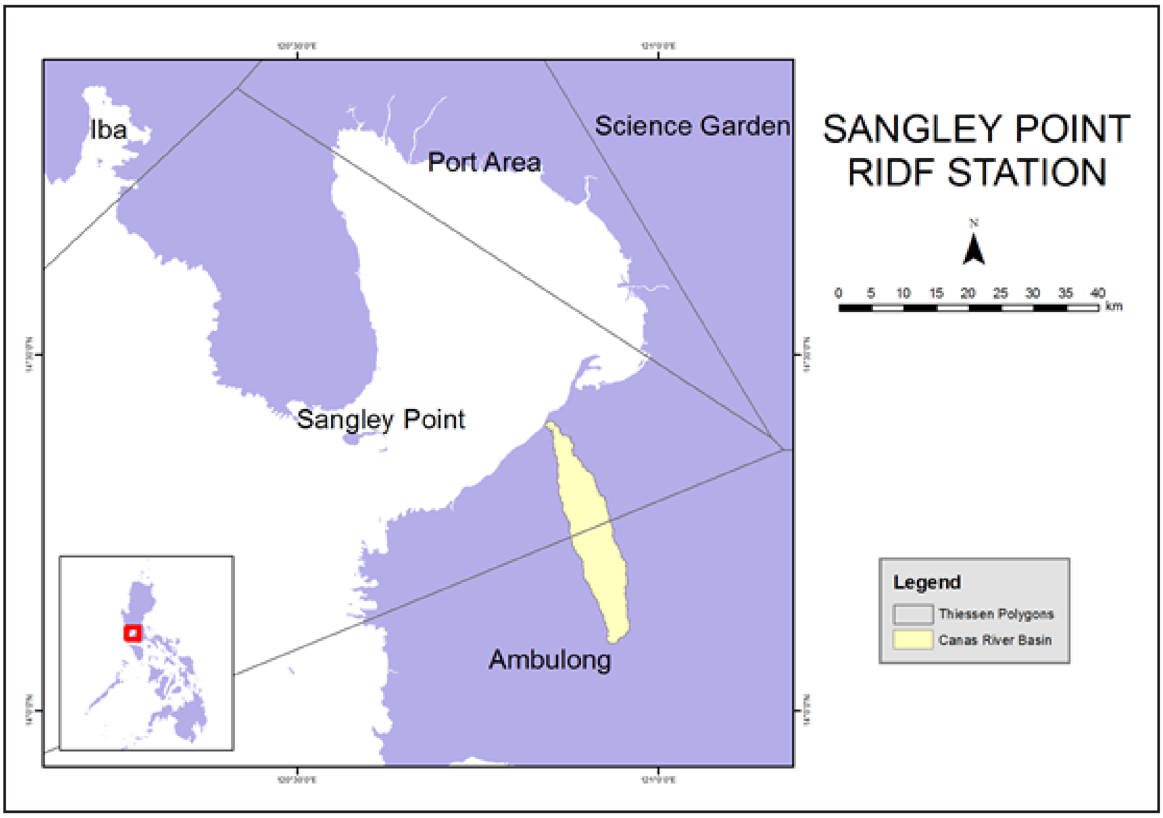


Figure 54. Sangley Point RIDF location relative to the Cañas River Basin

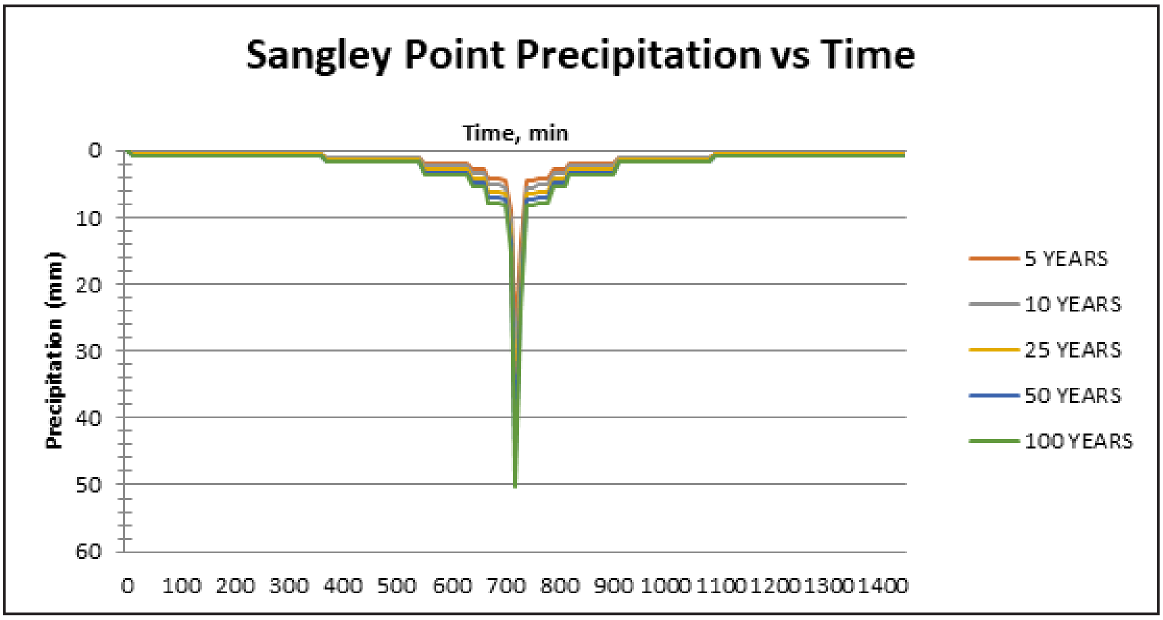


Figure 55. Synthetic storm generated from a 24-hr period rainfall, for various return periods

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004. The soil and land cover maps of the Cañas River Basin are presented in Figures 56 and 57, respectively.

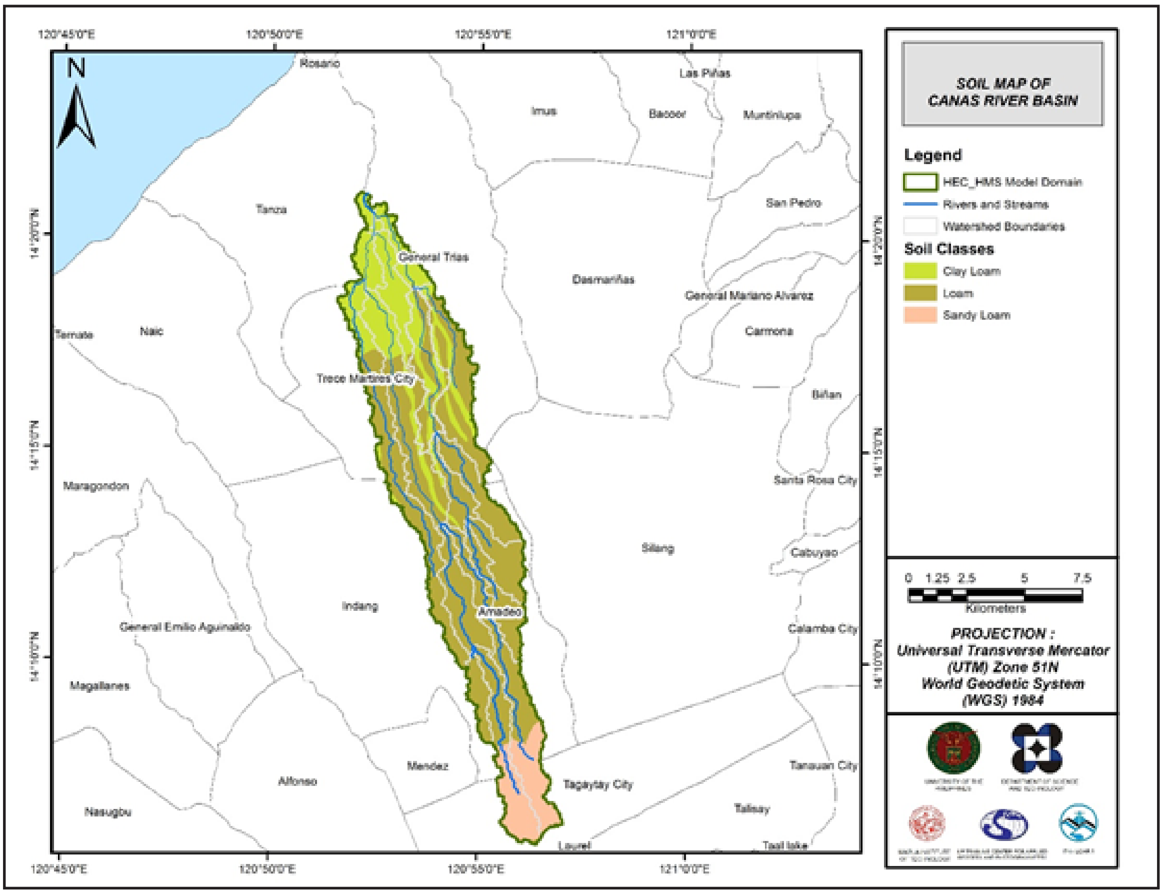


Figure 56. Soil map of the Cañas River Basin (Source: DA)

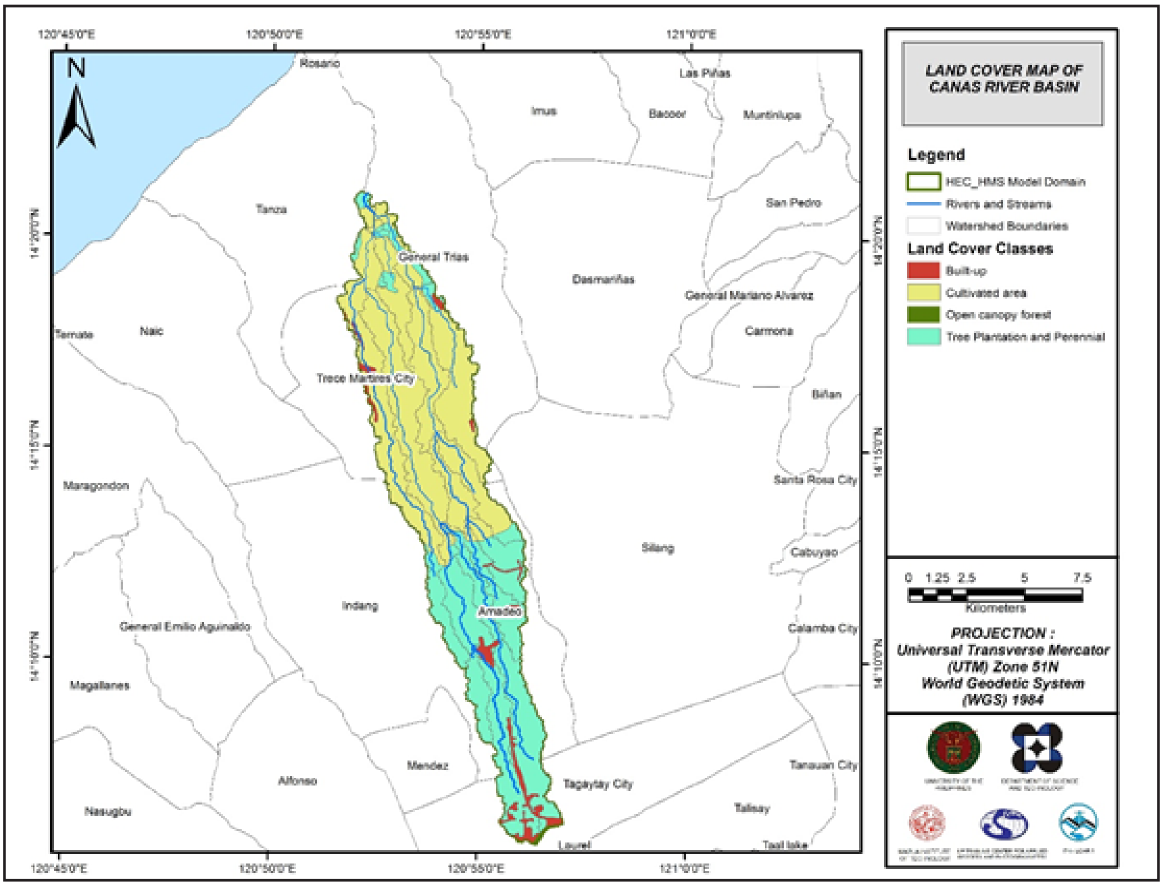


Figure 57. Land cover map of the Cañas River Basin (Source: NAMRIA)

The soil classes identified in the Cañas River Basin were clay loam, loam, and sandy loam. The land cover types identified were built-up areas, cultivated areas, open canopy forests, and tree plantations.

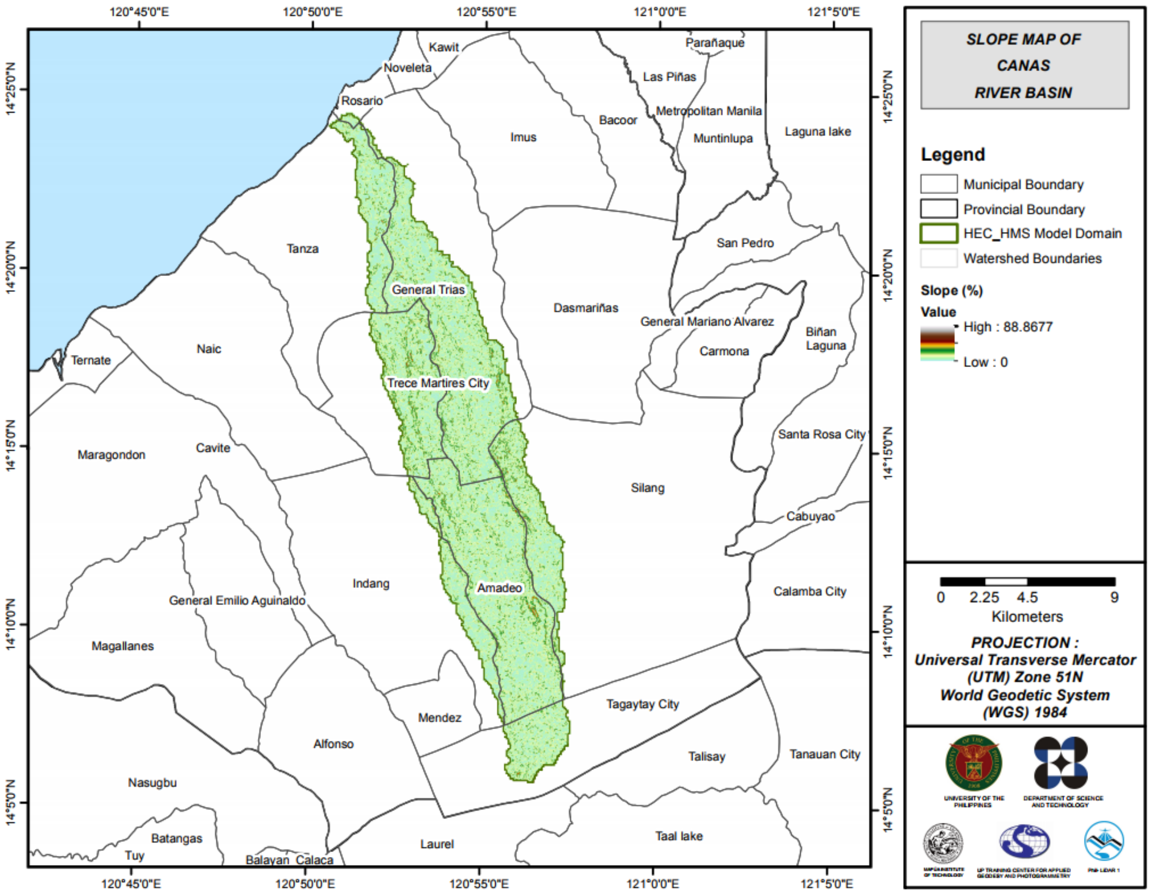


Figure 58. Slope map of the Cañas River Basin

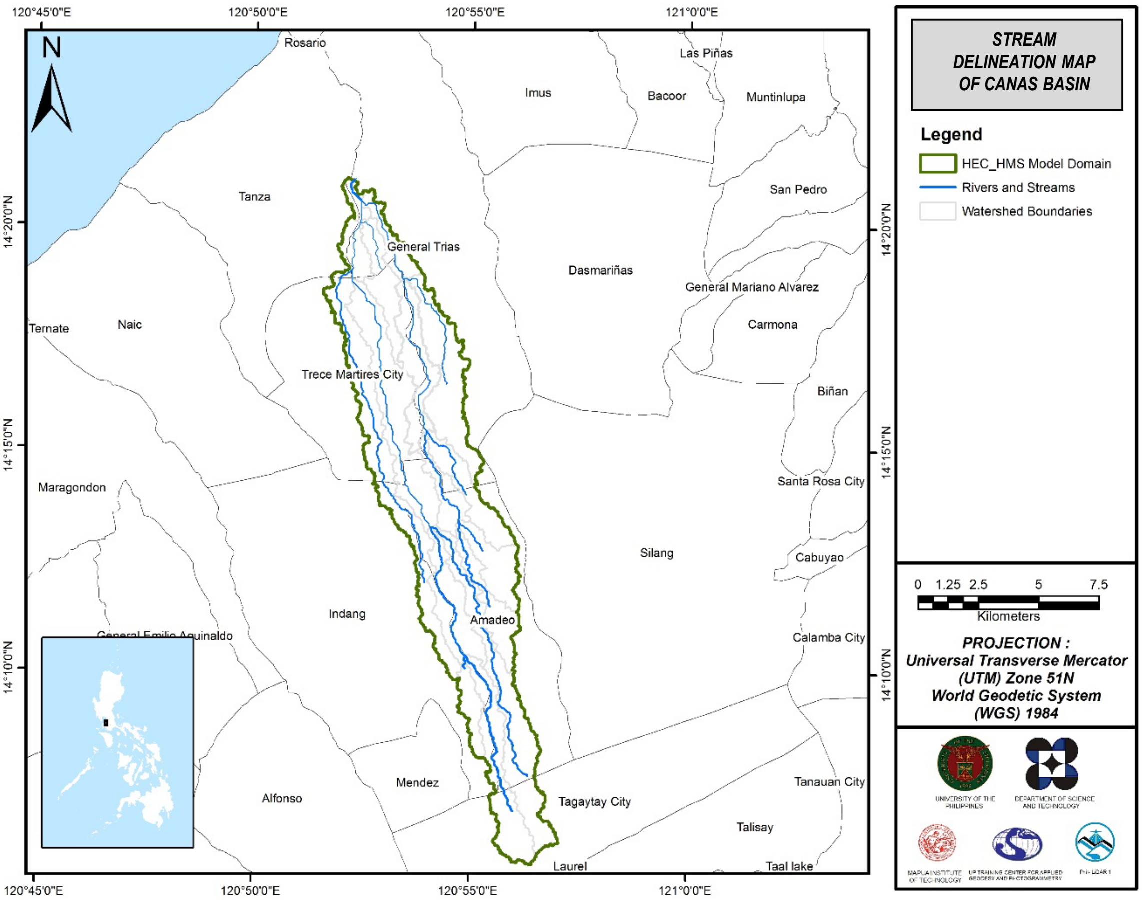


Figure 59. Stream delineation map of the Cañas River Basin

Using the SAR-based DEM, the Cañas basin was delineated and further divided into sub-basins. The Cañas Basin model consists of seventeen (17) sub-basins, eight (8) reaches, and eight (8) junctions. The main outlet is at Outlet 2. The basin model is illustrated in Figure 60. The basins were identified based on the soil and land cover characteristics of the area. Precipitation was taken from the installed Rain Gauge near and inside the area of the river basin. Finally, the model was calibrated using the data from the actual discharge flow taken at the Bunga Bridge. See Annex 10 for the Cañas Model Reach Parameters.

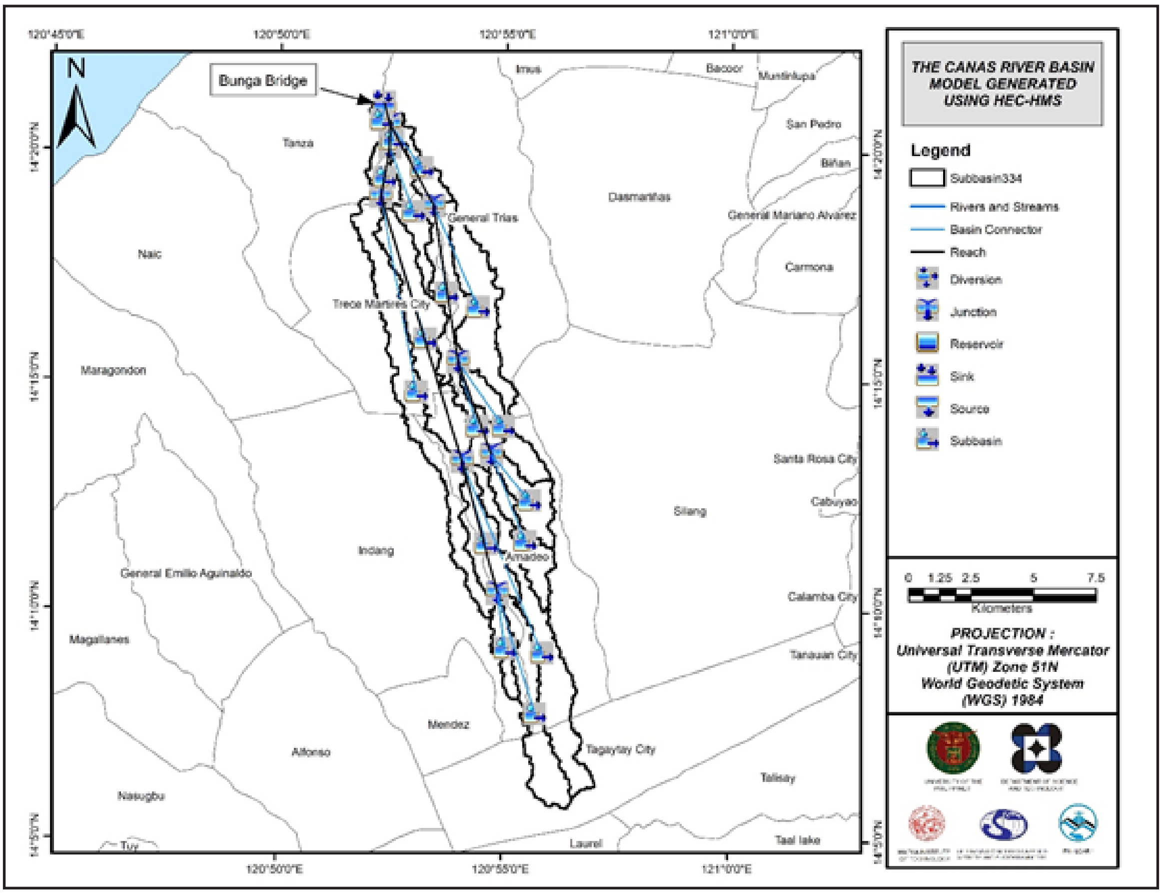


Figure 60. The Cañas River Basin Model Domain generated by HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model were derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 61).

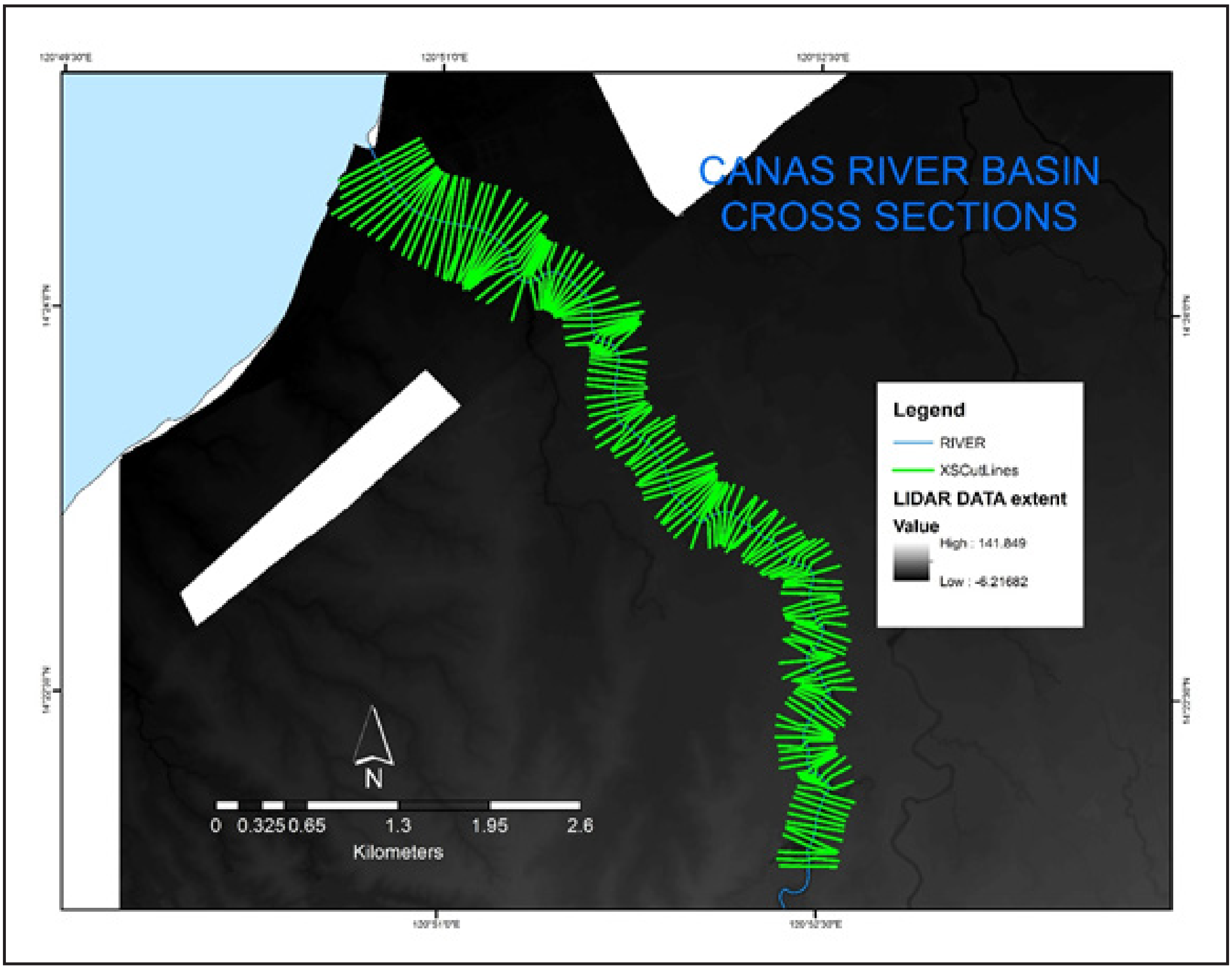


Figure 61. River cross-section of the Cañas River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

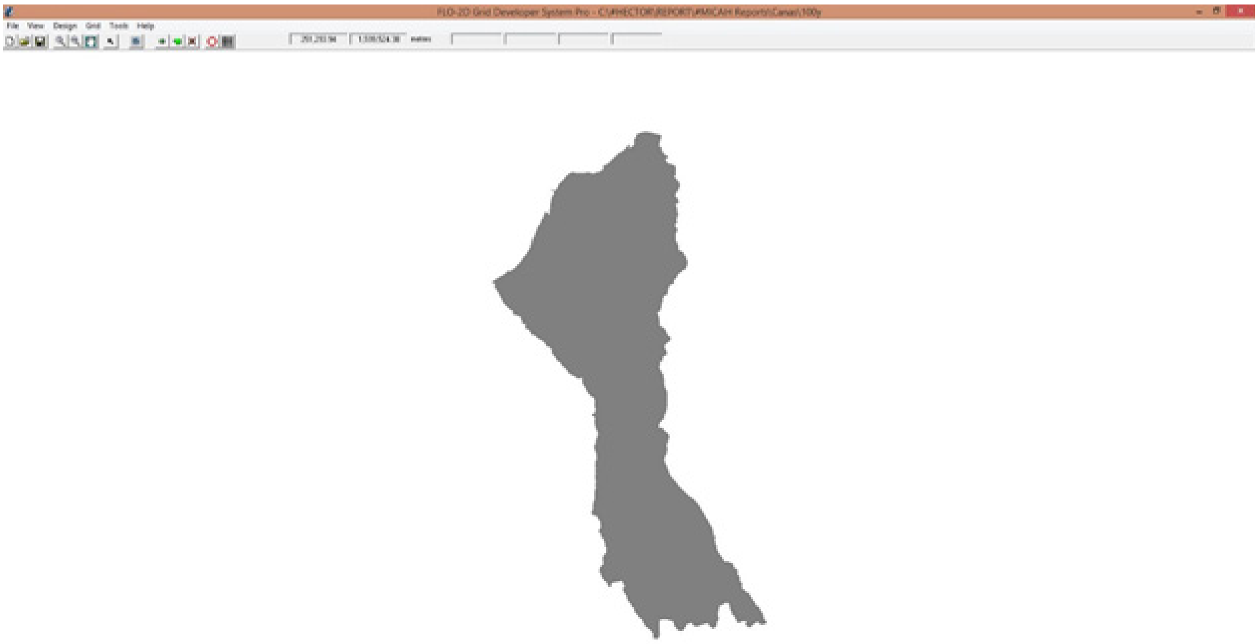


Figure 62. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 78.74243 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

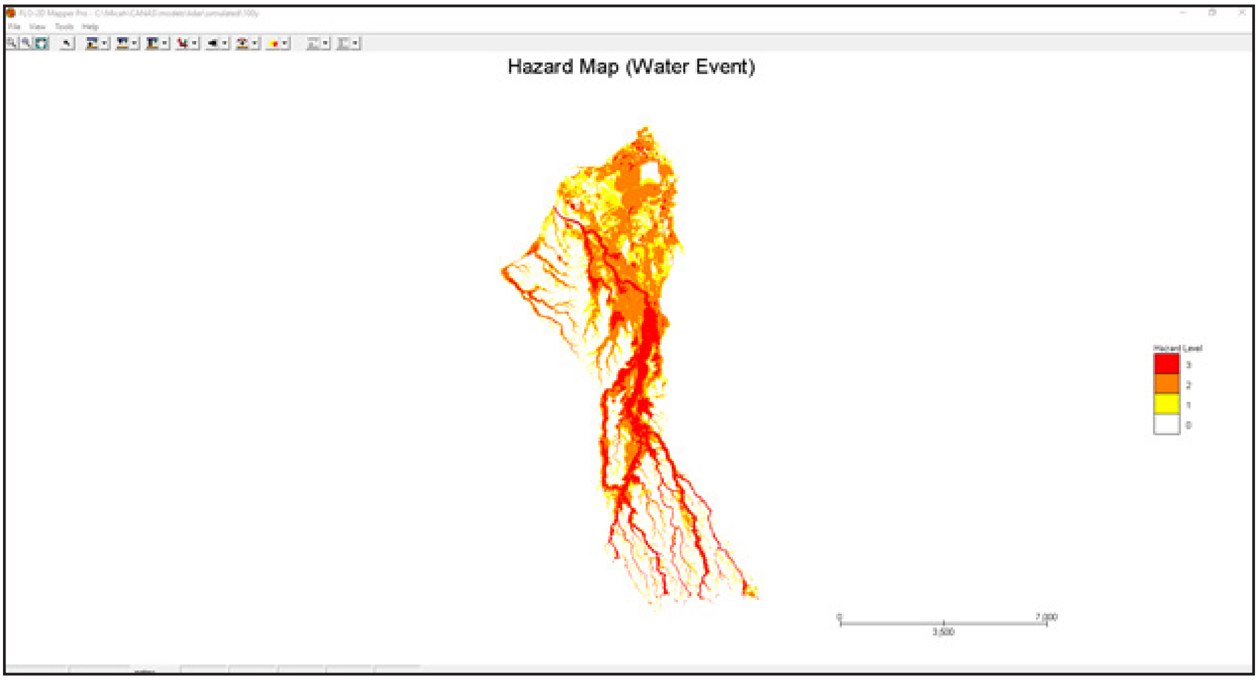


Figure 63. Generated 100-year rain return hazard map from FLO-2D Mapper

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 57 838 300.00 m2.

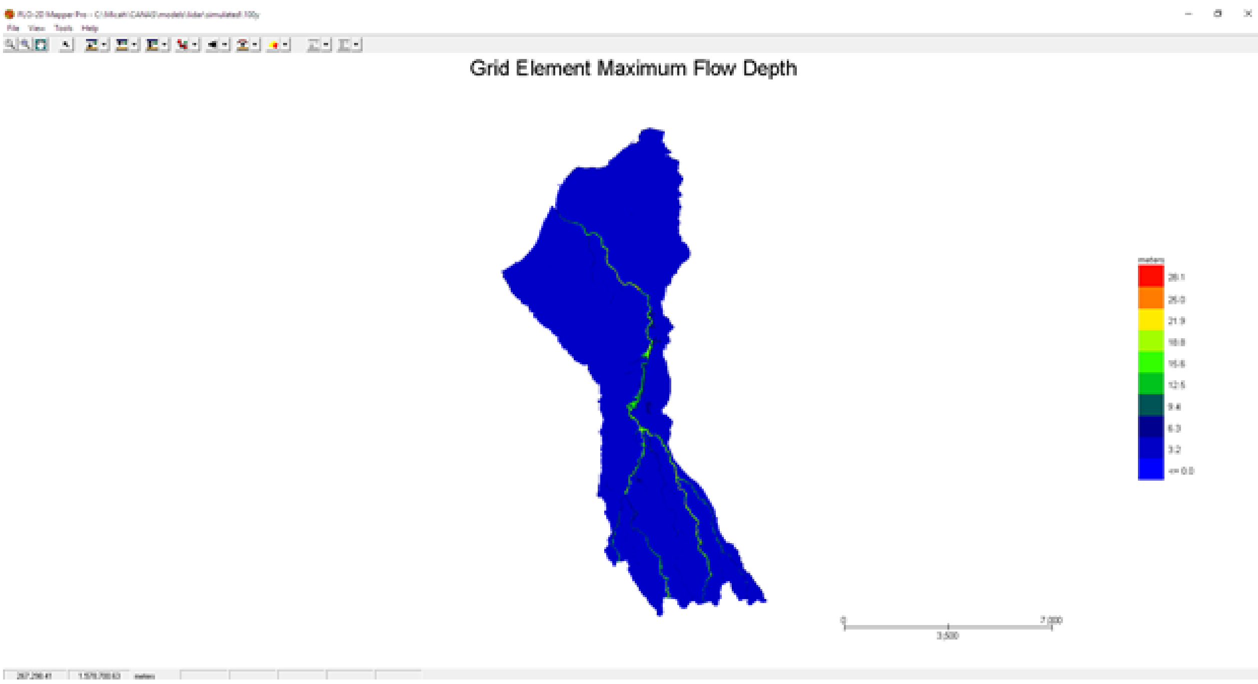


Figure 64. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 53 074 888.93 m3 of water entering the model. Of this amount, 26 846 095.45 m3 is due to rainfall while 26 228 793.48 m3 is inflow from other areas outside the model. 8 394 054.00 m3 of this water is lost to infiltration and interception, while 7 762 229.09 m3 is stored by the flood plain. The rest, amounting up to 36 918 617.58 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Cañas HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 65 depicts the comparison between the two (2) discharge data. The Cañas Model Basin Parameters are provided in Annex 9.

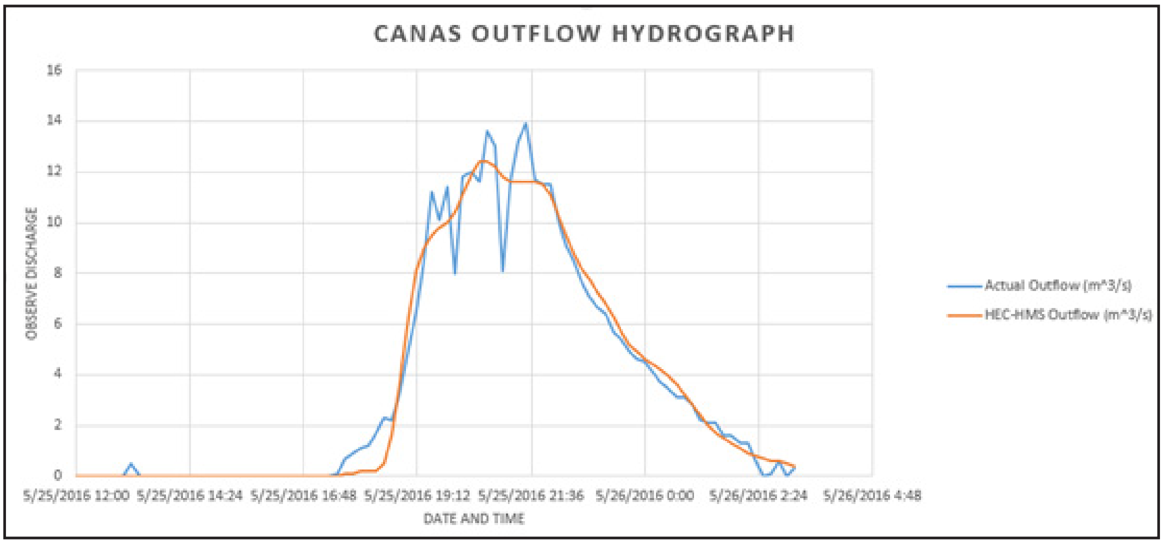


Figure 65. Outflow Hydrograph of Cañas produced by the HEC-HMS model, compared with observed outflow

Enumerated in Table 34 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 34. Range of calibrated values for the Cañas Model

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.43 – 15.91
			Curve Number	35.30 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.017 – 108.65
			Storage Coefficient (hr)	0.017 – 306.22
	Baseflow	Recession	Recession Constant	0.00001 - 1
			Ratio to Peak	0.0016 – 0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0024 – 0.047

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. The range of values from 0.43mm to 15.91mm for initial abstraction means that there is a minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range of the curve number in the Cañas River's sub-basins is from 35.30 to 99. For Cañas, the soil classes identified were clay loam, loam, and sandy loam. The land cover types identified were built-up areas, cultivated areas, open canopy forests, and tree plantations.

The time of concentration and the storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. The range of calibrated values from 0.017 hours to 306.22 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; and the ratio to peak is the ratio of the baseflow discharge to the peak discharge. The recession constant in the Cañas sub-basins ranges from 0.00001 to 1, and the ratio to peak is from 0.0016 to 0.5.

A Manning's roughness coefficient of 0.0024 - 0.047 corresponds to the common roughness in the Cañas watershed.

Table 35. Summary of the Efficiency Test of the Cañas HMS Model

Accuracy measure	Value
RMSE	7.33
r2	0.9727
NSE	0.972
PBIAS	0.12
RSR	0.166

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 7.33 m^3/s.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. A coefficient value close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it was measured at 0.9727.

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 0.972.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is 0.12.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error units of the values are quantified. The model has an RSR value of 0.166.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 66) illustrates the Cañas outflow using the Sangley Point RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in the outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

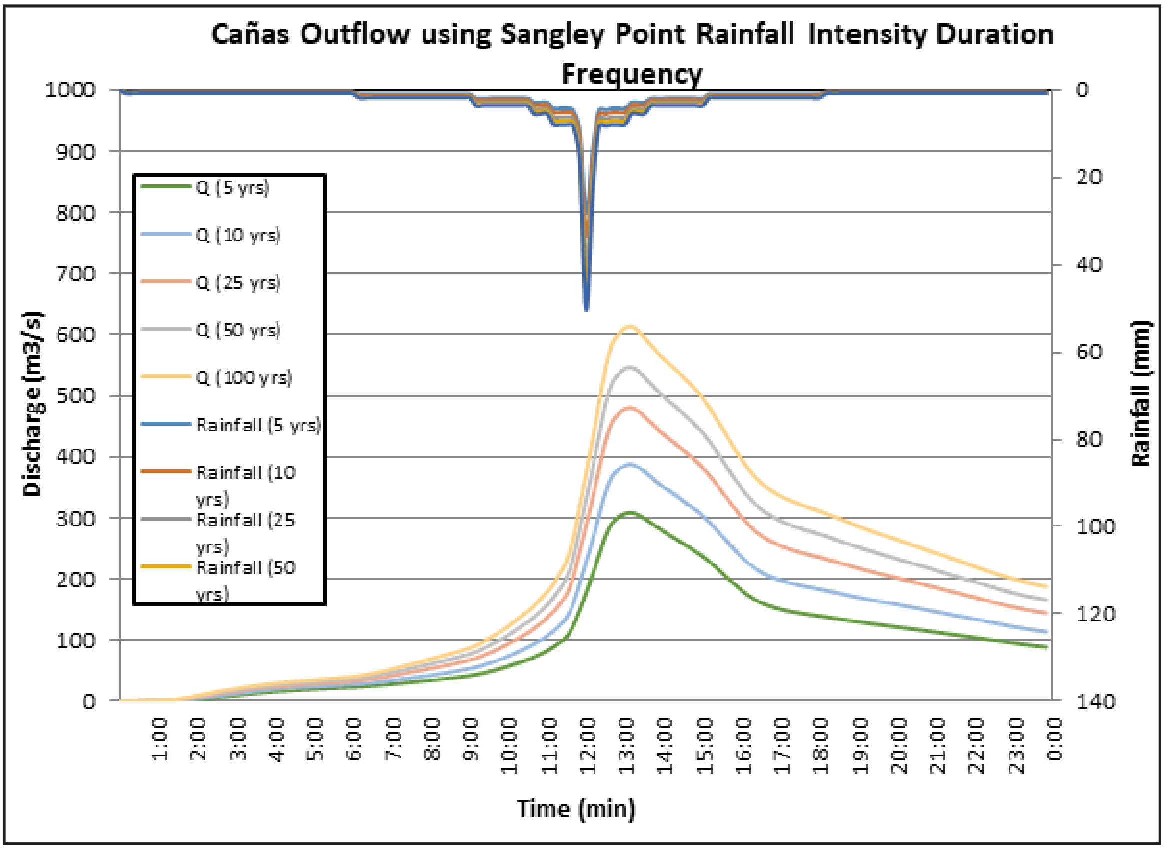


Figure 66. Outflow hydrograph at the Bunga Bridge generated using the Sangley Point RIDF, simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Cañas River discharge using the Sangley Point RIDF curves in five (5) different return periods is presented in Table 36.

Table 36. Peak values of the Cañas HEC-HMS Model outflow using the Sangley Point RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	209.4	28.3	318.7	13 hours, 10 minutes
10-Year	250.1	33.6	387.3	13 hours, 10 minutes
25-Year	273.1	40.3	480.2	13 hours, 10 minutes
50-Year	399.7	45.3	549.9	13 hours, 10 minutes
100-Year	377.6	50.3	613.3	13 hours, 10 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 the extent of real-time flood inundation of the river, after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river is provided, since only the MIT Flood Acquisition and Validation Component (MIT-FAVC) base flow was calibrated. The sample generated map of the Cañas River using the calibrated HMS base flow is presented in Figure 67.

Figure 67. Sample output map of the Cañas RAS Model

5.9 Flow Depth and Flood Hazard

The resulting flood hazard and flow depth maps have a 10-meter resolution. Figure 67 to Figure 72 exhibit the 5-year, 25-year, and 100-year rain return scenarios for the Cañas floodplain.

Table 37. Municipalities affected in the Cañas Floodplain

Municipality	Total Area	Area Flooded	% Flooded
General Trias	87.5	13.97	15.96%
Rosario	8.006	2.91	36.38%
Tanza	74.58	19.95	26.75%
Trece Martires	46.18	7.58	16.41%

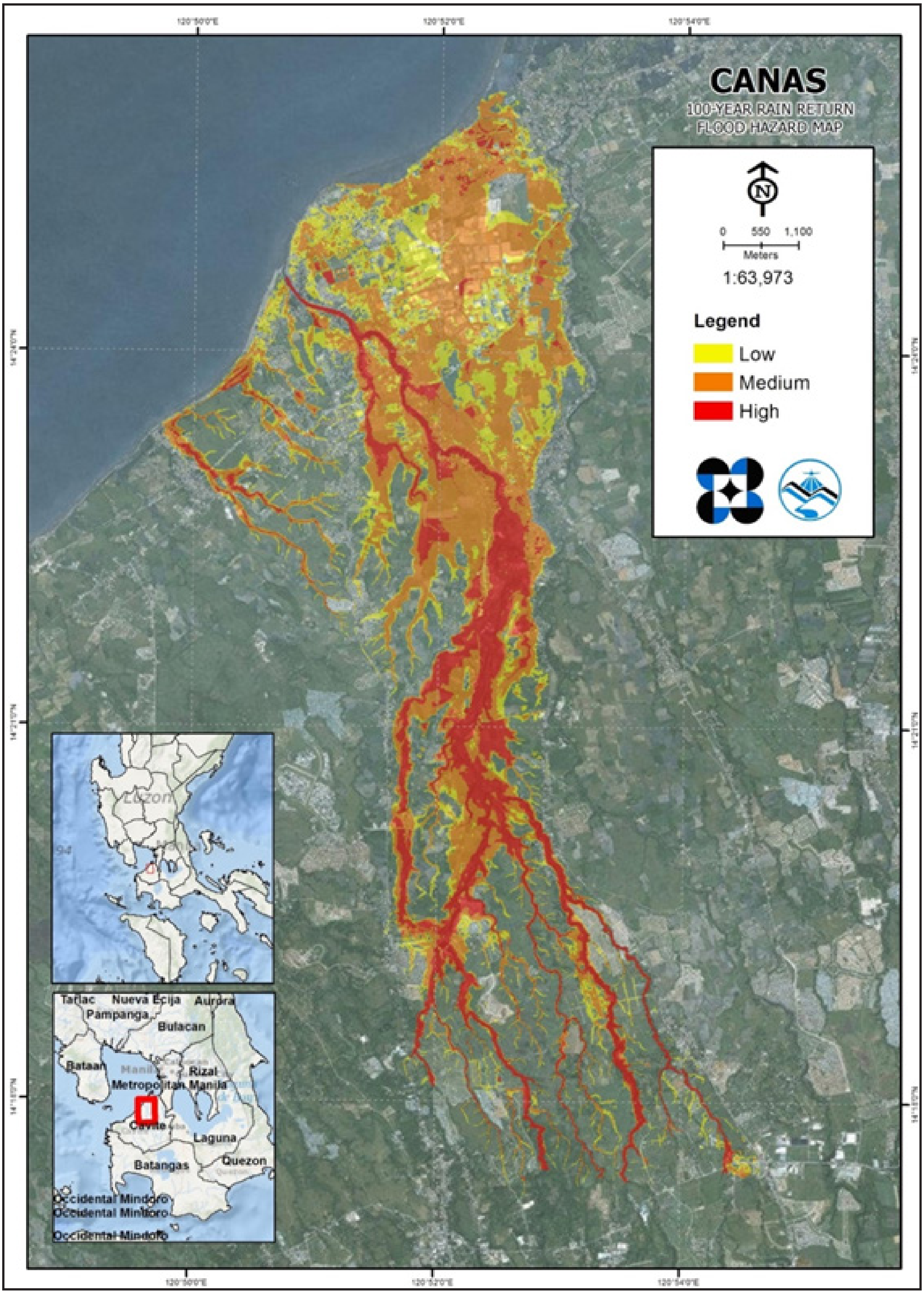


Figure 68. 100-year flood hazard map for the Cañas Floodplain

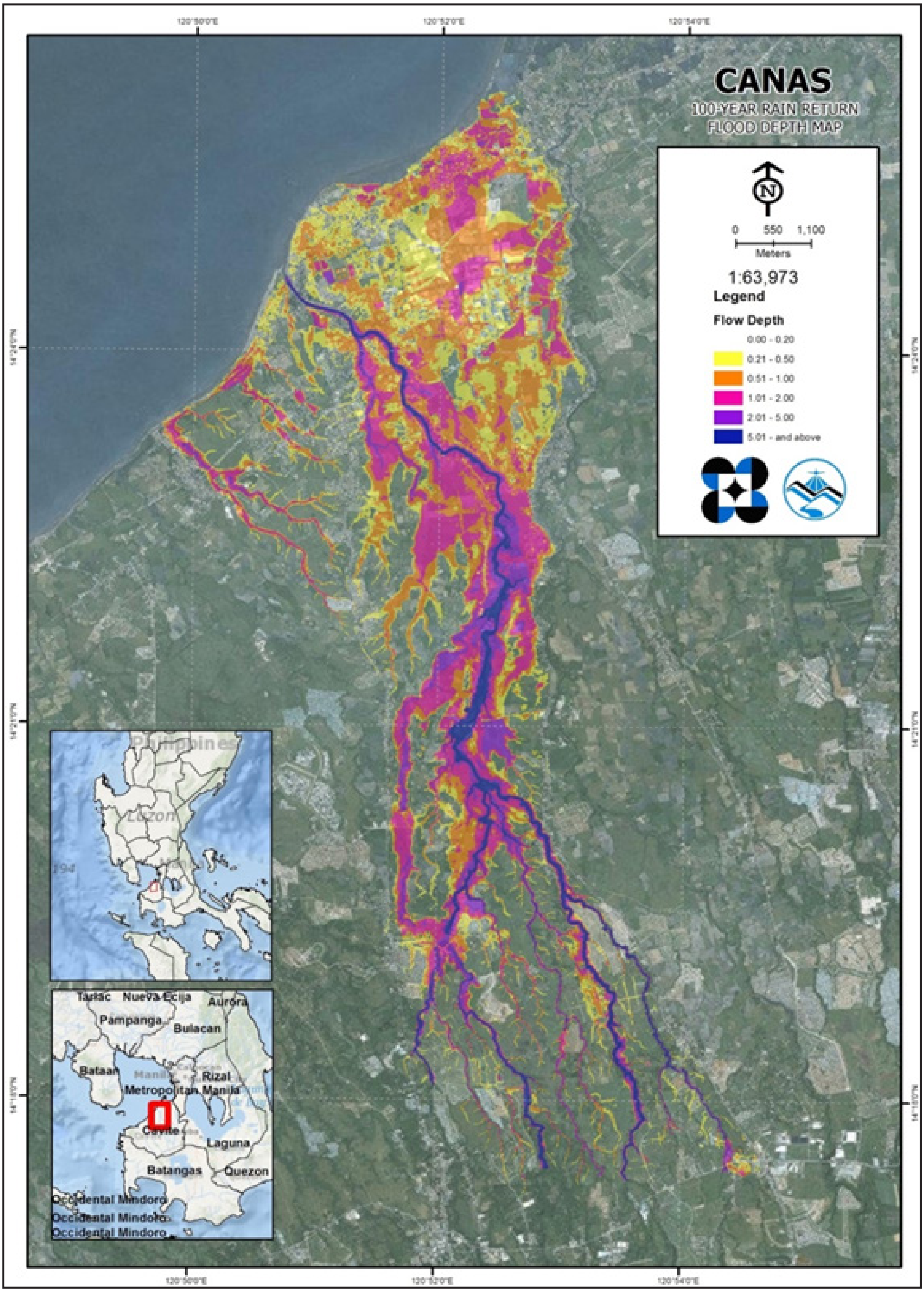


Figure 69. 100-year flow depth map for the Cañas Floodplain

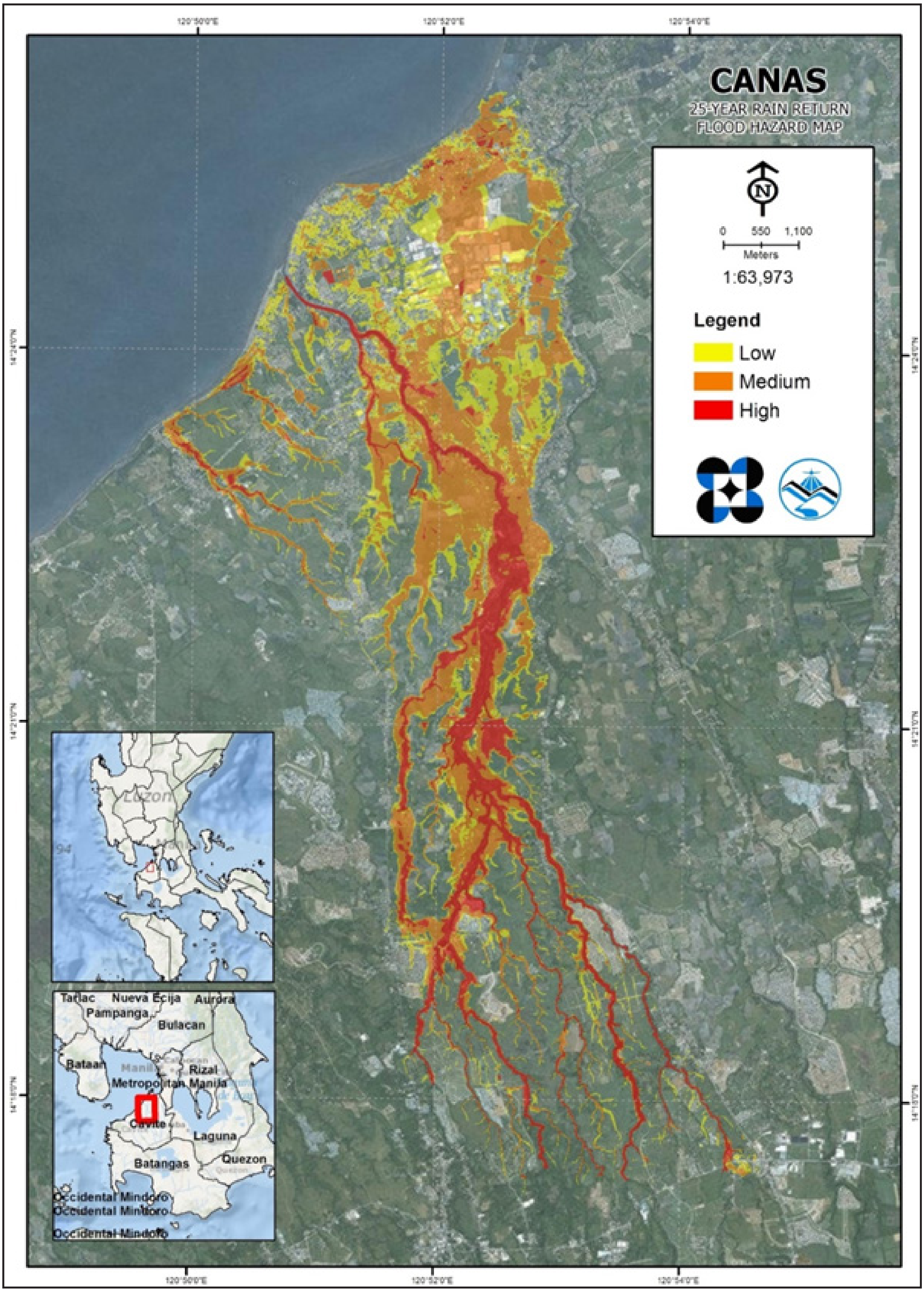


Figure 70. 25-year flood hazard map for the Cañas Floodplain

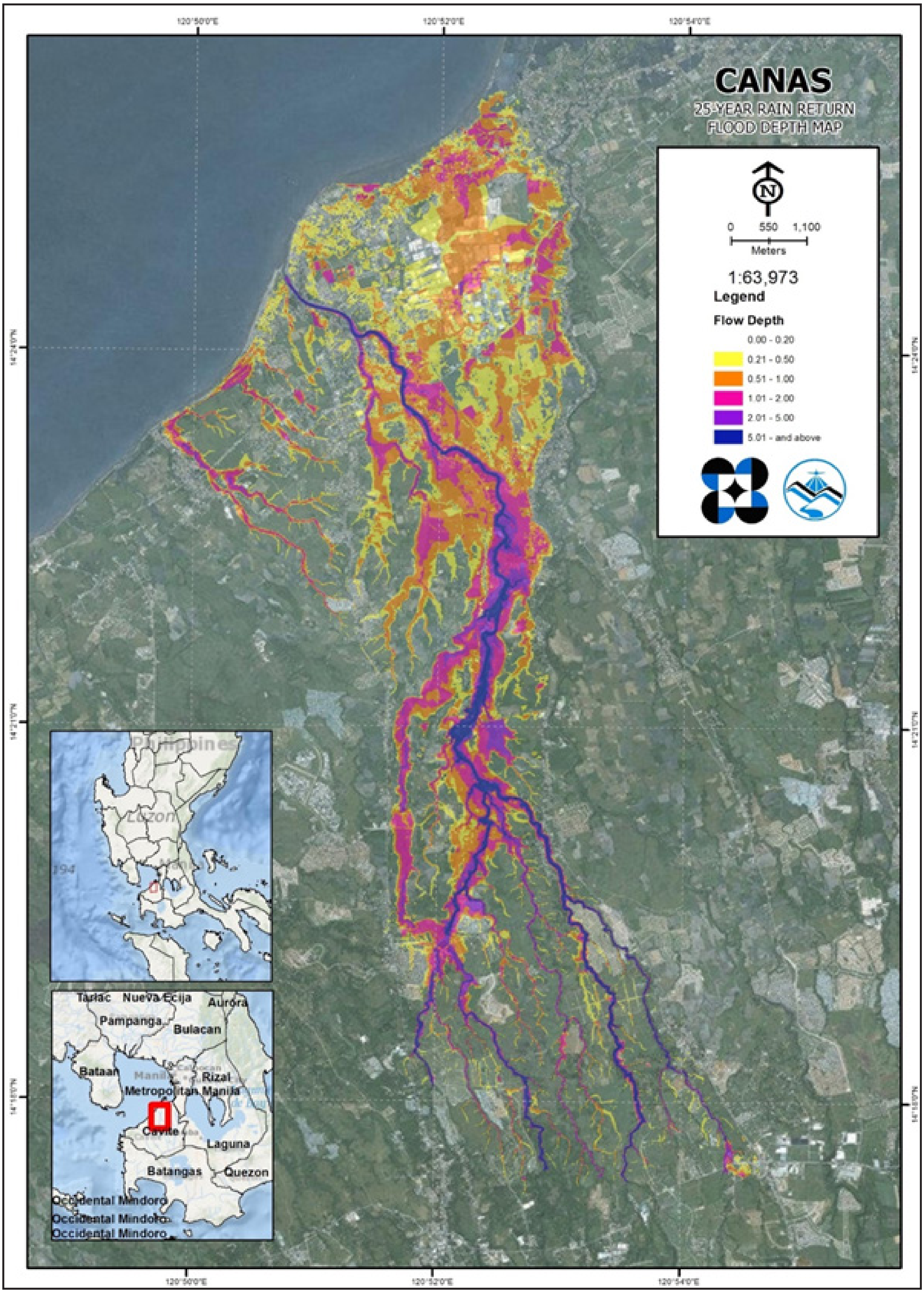


Figure 71. 25-year flow depth map for the Cañas Floodplain

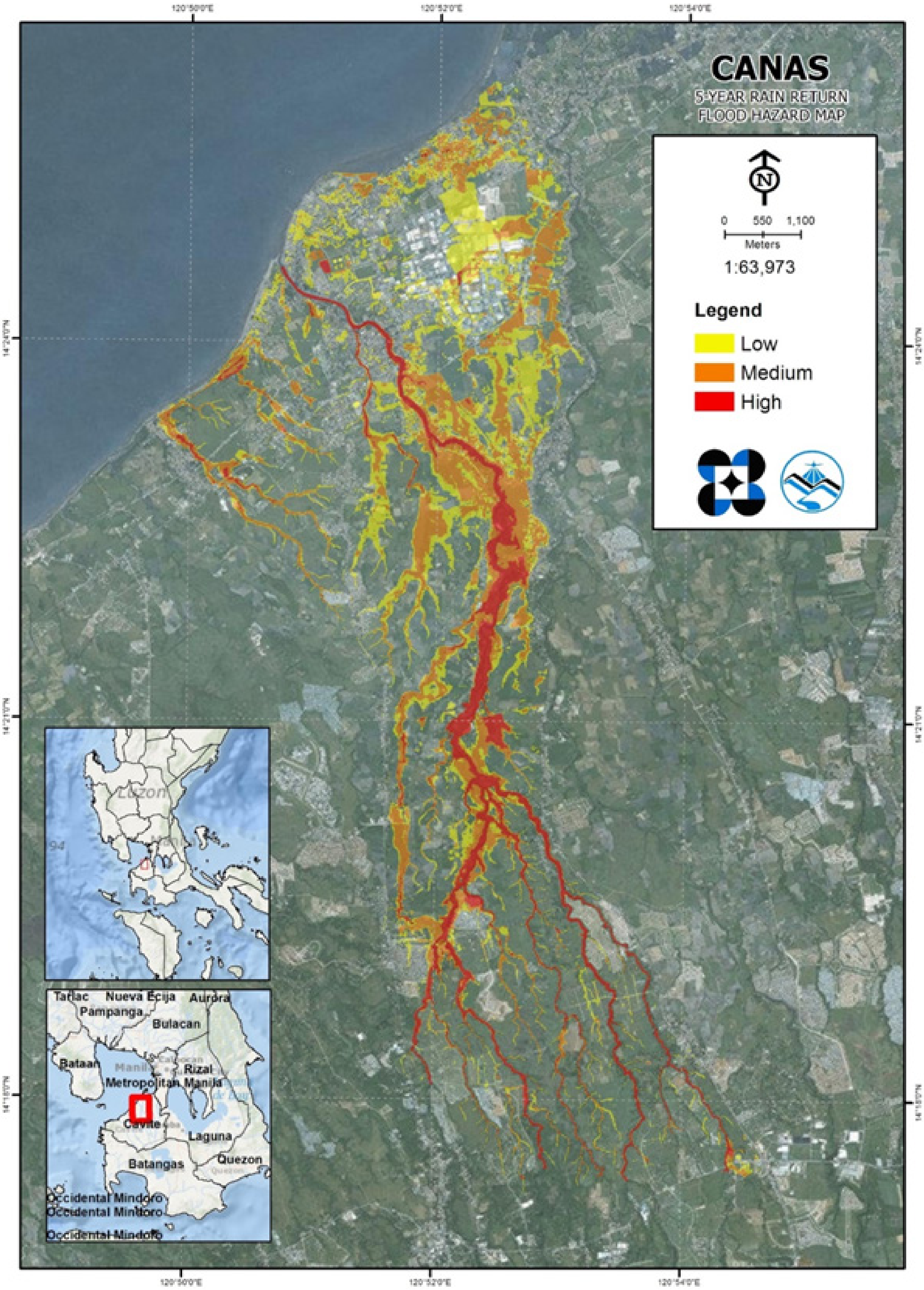


Figure 72. 5-year flood hazard map for the Cañas Floodplain

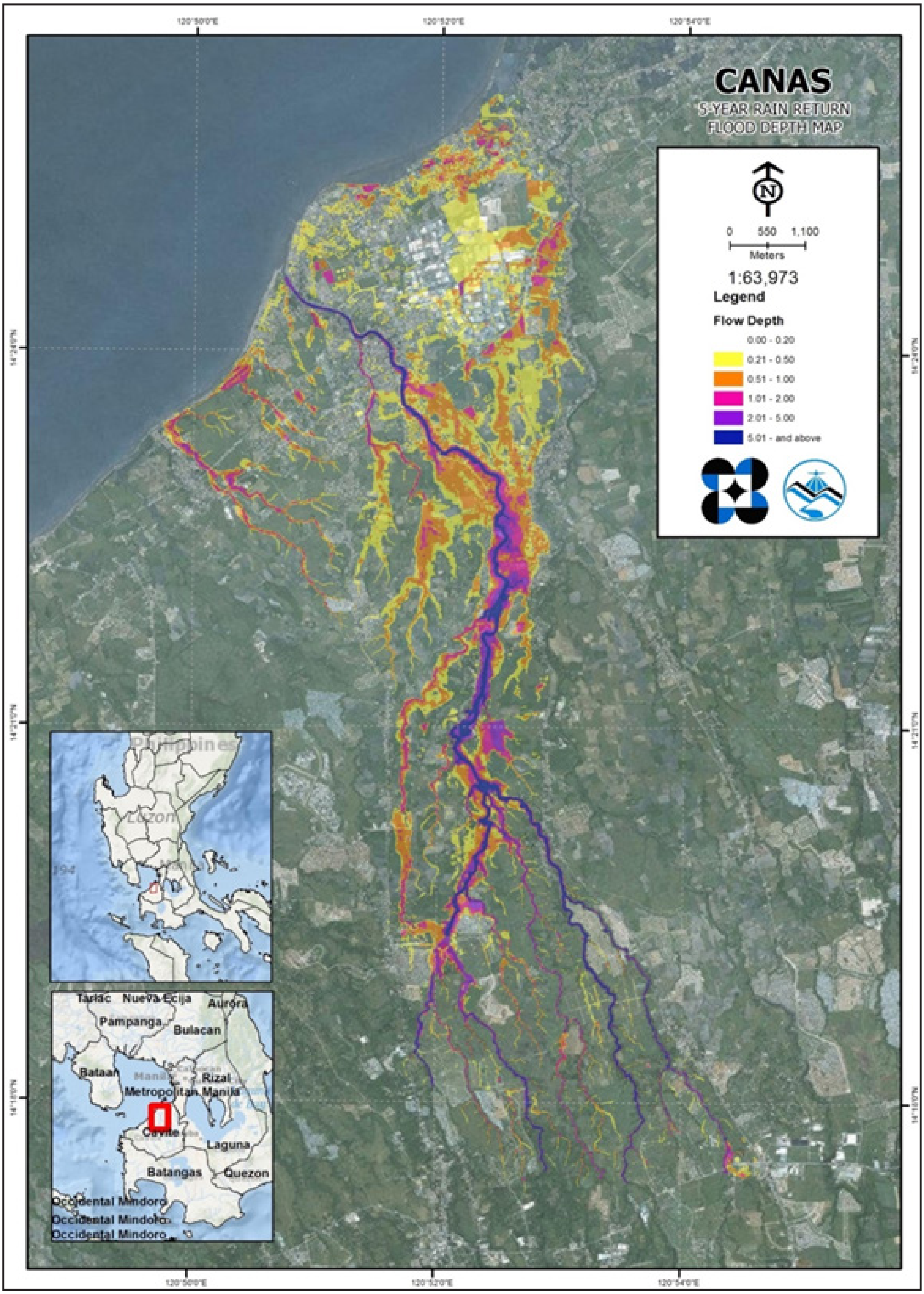


Figure 73. 5-year flow depth map for the Cañas Floodplain

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected in the Cañas River Basin, grouped accordingly by municipality. For the said basin, four (4) municipalities consisting of seventy-four (74) barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 10.04% of the Municipality of General Trias, with an area of 87.5 sq. km., will experience flood levels of less than 0.20 meters. 1.36% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.42%, 1.08%, 1.09%, and 0.98% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 38-40 are the affected areas, in square kilometers, by flood depth per barangay.

Table 38. Affected areas in General Trias, Cavite during a 5-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in General Trias (in sq. km.)										
	Arnaldo Poblacion	Bagumbayan Poblacion	Biclatan	Buenavista I	Buenavista II	Buenavista III	Corregidor Poblacion	Dulong Bayan Poblacion	Manggahan	Ninety Sixth Poblacion	Pasong Camachile I
0.03-0.20	0.00047	0.0051	0.22	0.62	0.62	1	0.0038	0.00016	1.16	0.0033	0.011
0.21-0.50	0.0068	0.005	0.015	0.016	0.022	0.042	0.012	0.0019	0.068	0.0078	0
0.51-1.00	0.023	0.00015	0.013	0.011	0.0072	0.0087	0.014	0	0.027	0.017	0
1.01-2.00	0.005	0	0.0049	0.0088	0.0066	0.015	0.0017	0	0.031	0.00093	0
2.01-5.00	0	0	0.0058	0.024	0.023	0.04	0	0	0.035	0	0
> 5.00	0	0	0.0037	0.042	0.043	0.031	0	0	0.017	0	0

Table 39. Affected areas in General Trias, Cavite during a 5-year rainfall return period

Affected Area (in sq. km.) by flood depth (in m.)	Area of affected barangays in General Trias (in sq. km.)										
	Pasong Camachile II	Pasong Kawayan I	Pasong Kawayan II	Pinagtipunan	Prinza Poblacion	Sampalucan Poblacion	San Juan I	San Juan II	Santa Clara	Tapia	Tejero
0.03-0.20	0.028	0.71	3.02	0.33	0.0002	0.0018	0.0086	0.12	0.0094	0.91	1.21
0.21-0.50	0.00011	0.12	0.29	0.14	0.0022	0.0047	0.026	0.22	0.023	0.16	0.46
0.51-1.00	0	0.16	0.25	0.26	0.052	0.0018	0.067	0.21	0.035	0.079	0.38
1.01-2.00	0	0.16	0.22	0.29	0.044	0.00031	0.055	0.049	0.0013	0.049	0.11
2.01-5.00	0	0.12	0.28	0.2	0.0081	0	0.051	0.025	0	0.14	0.054
> 5.00	0	0.15	0.21	0.15	0.00011	0	0.042	0.046	0	0.12	0.1

Table 40. Affected areas in General Trias, Cavite during a 5-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in General Trias (in sq. km.)
	Vibora Poblacion
0.03-0.20	0.0037
0.21-0.50	0.0058
0.51-1.00	0.0024
1.01-2.00	0
2.01-5.00	0
> 5.00	0

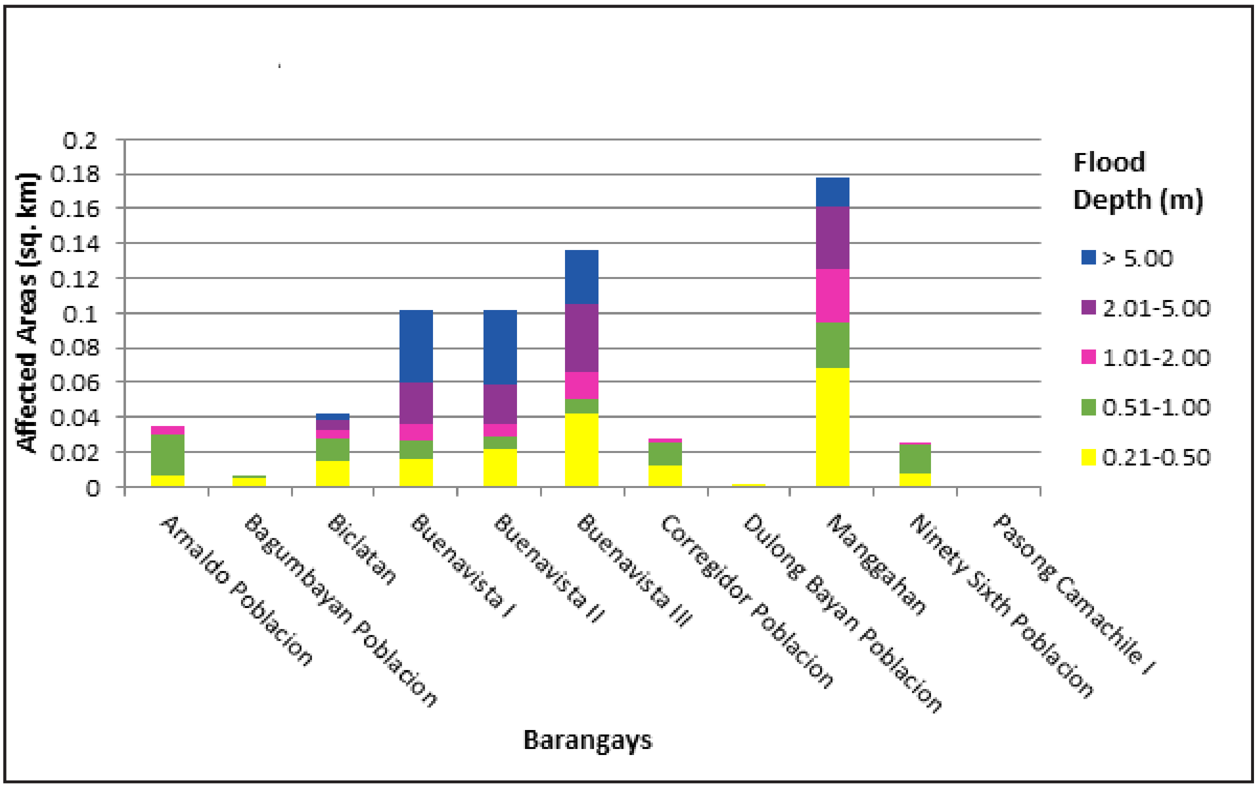


Figure 74. Affected areas in General Trias, Cavite during a 5-year rainfall return period

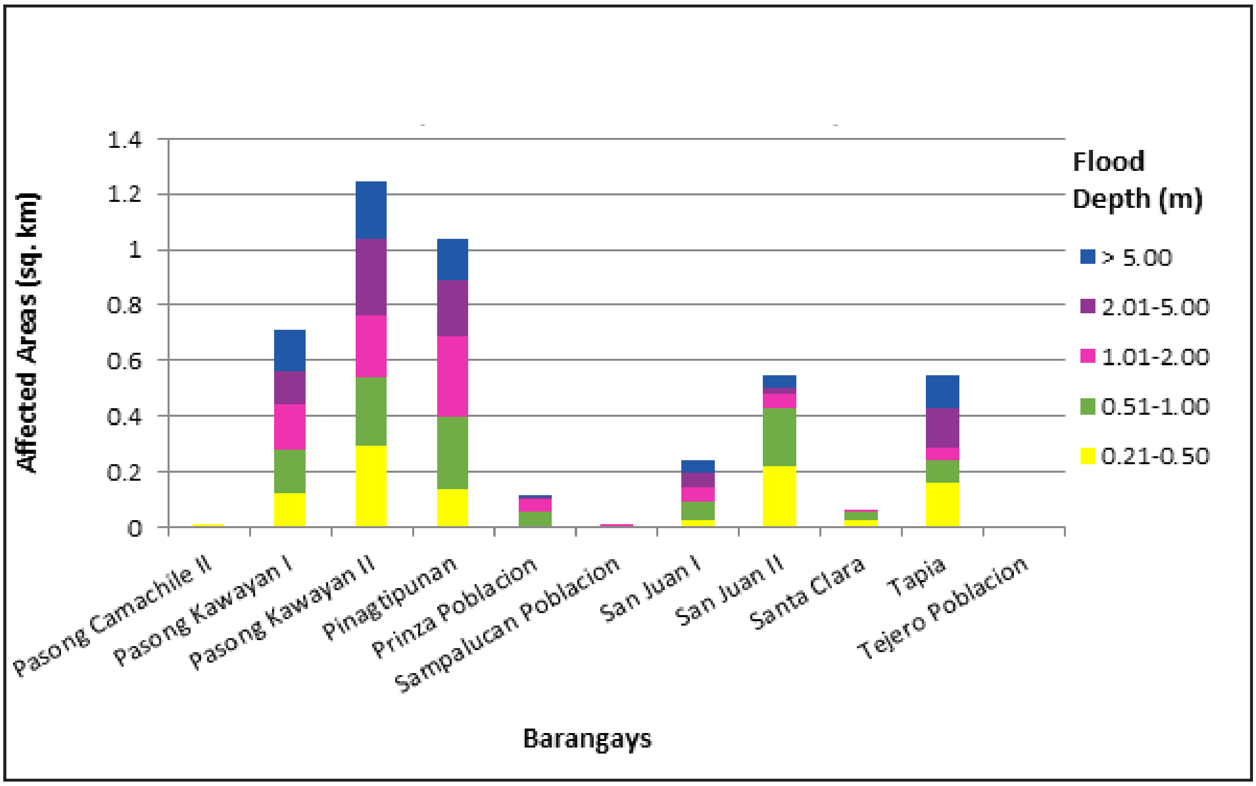


Figure 75. Affected areas in General Trias, Cavite during a 5-year rainfall return period

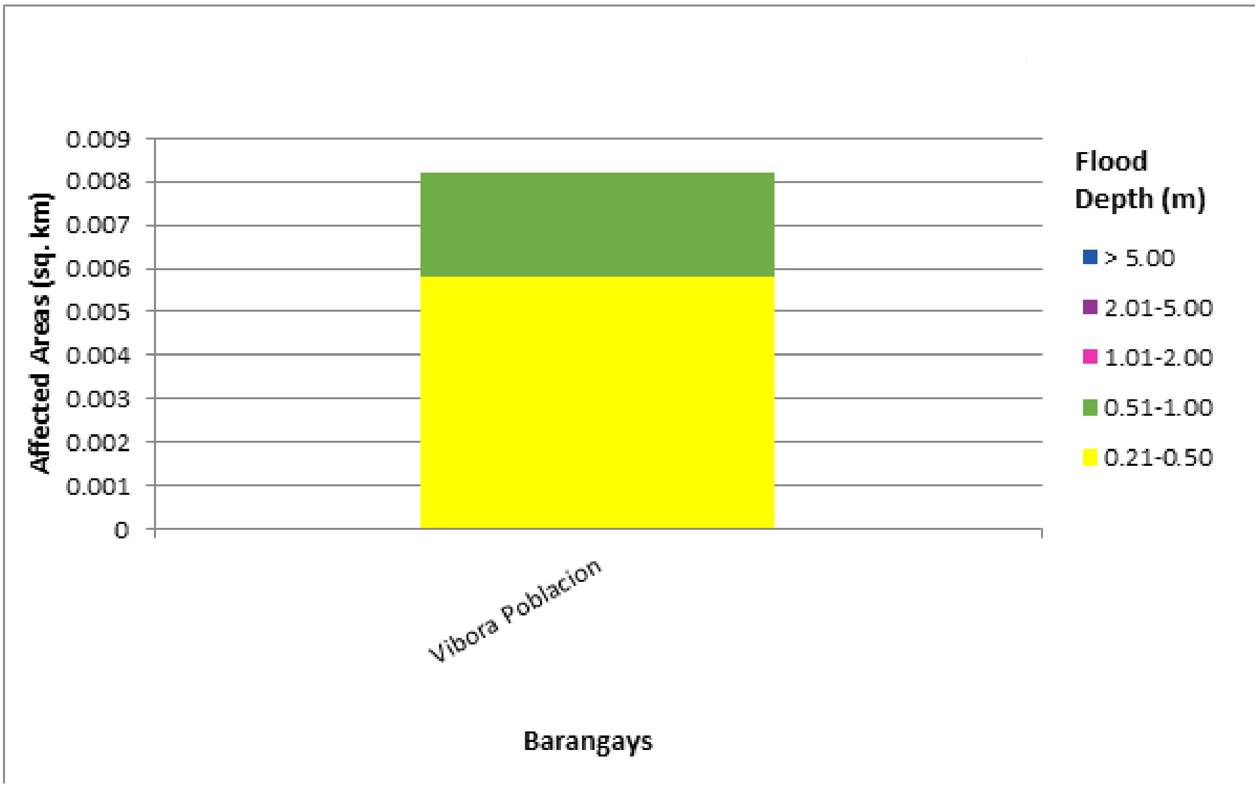


Figure 76. Affected areas in General Trias, Cavite during a 5-year rainfall return period

For the 5-year return period, 26.38% of the Municipality of Rosario, with an area of 8.006 sq. km., will experience flood levels of less than 0.20 meters. 7.46% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.22%, 0.63%, 0.34%, and 0.41% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 41-42 are the affected areas, in square kilometers, by flood depth per barangay.

Table 41. Affected areas in Rosario, Cavite during a 5-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Rosario (in sq. km.)							
	Kanluran	Ligton I	Muzon I	Muzon II	Poblacion	Sapa I	Sapa II	Sapa III
0.03-0.20	0.12	0	0.047	0.13	0.3	0.011	0.023	0.027
0.21-0.50	0.08	0	0.028	0.046	0.12	0.0012	0.015	0.013
0.51-1.00	0.0081	0	0.0047	0.0017	0.03	0	0	0.00074
1.01-2.00	0	0	0.0014	0	0.025	0	0	0
2.01-5.00	0	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0	0

Table 42. Affected areas in Rosario, Cavite during a 5-year rainfall return period

Affected Area (in sq. km.) by flood depth (in m.)	Area of affected barangays in Rosario (in sq. km.)						
	Sapa IV	Silangan I	Silangan II	Tejeros Convention	Wawa I	Wawa II	Wawa III
0.03-0.20	0.032	0.47	0.087	0.43	0.38	0.031	0.024
0.21-0.50	0.012	0.11	0.029	0.071	0.064	0.0022	0.0058
0.51-1.00	0.0049	0.0099	0.0056	0.01	0.022	0	0
1.01-2.00	0.0055	0.0002	0	0.0089	0.0098	0	0
2.01-5.00	0	0	0	0.0069	0.02	0	0.00016
> 5.00	0	0	0	0.017	0.016	0	0

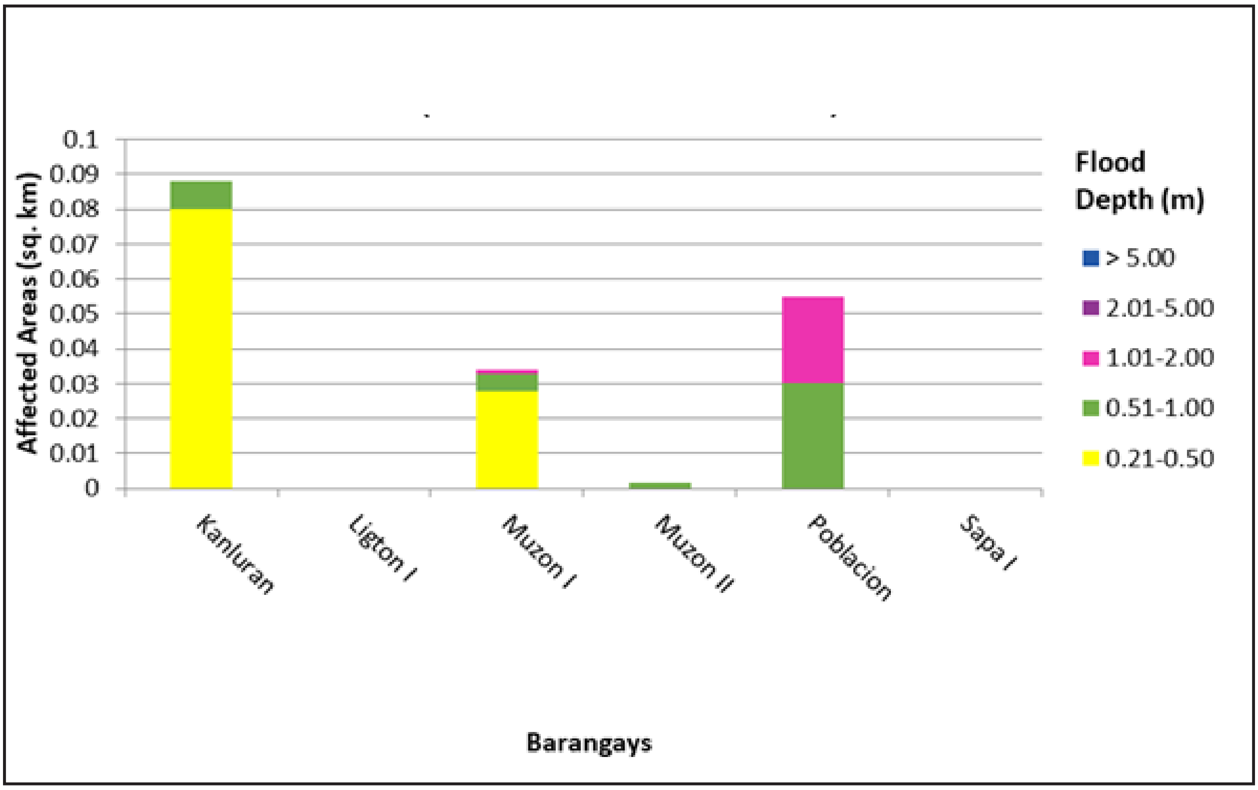


Figure 77. Affected areas in Rosario, Cavite for a 5-year return period

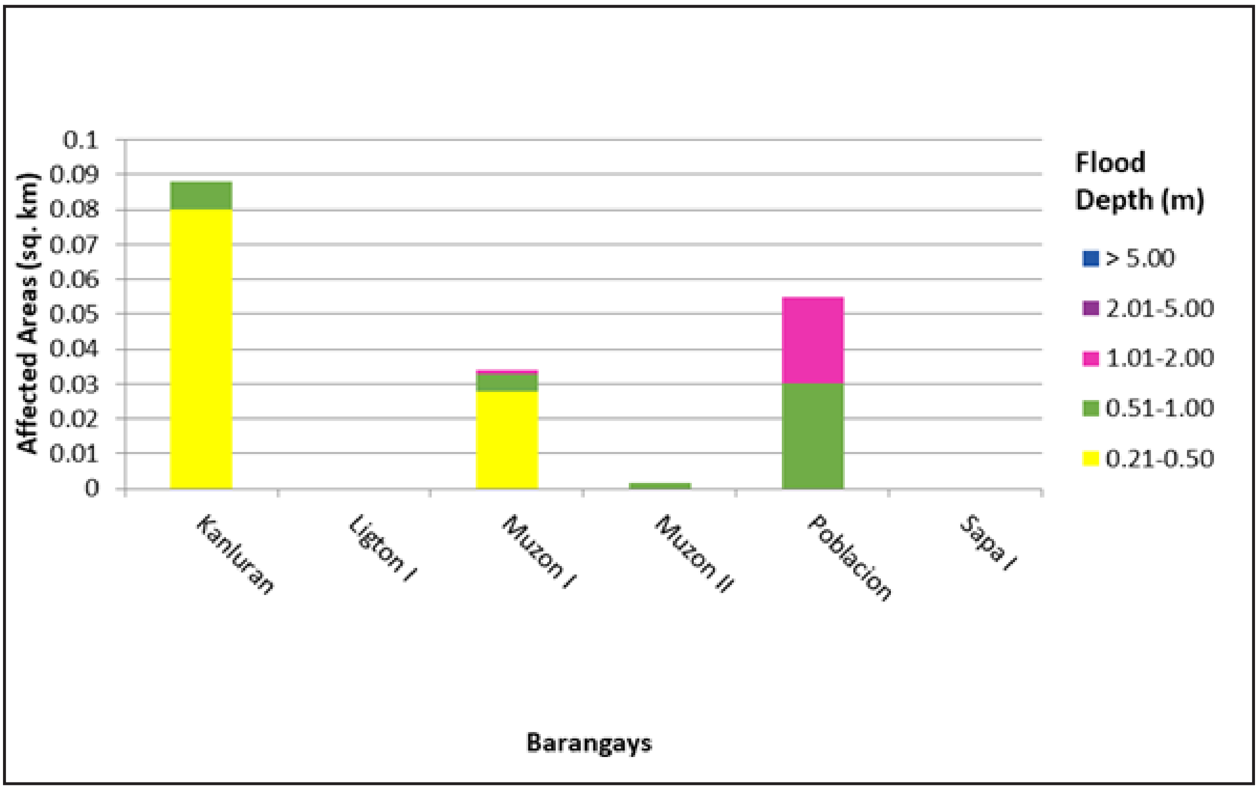


Figure 78. Affected areas in Rosario, Cavite for a 5-year return period

For the 5-year return period, 19.47% of the Municipality of Tanza, with an area of 74.58 sq. km., will experience flood levels of less than 0.20 meters. 3.45% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.65%, 0.97%, 0.19%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 43-45 are the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected areas in Tanza, Cavite during a 5-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Tanza (in sq. km.)									
	Amaya II	Amaya III	Amaya IV	Amaya V	Bagtas	Barangay I	Barangay II	Barangay III	Barangay IV	Biga
0.03-0.20	0.34	0.28	0.37	0.28	0.16	0.21	0.098	0.048	0.22	1.54
0.21-0.50	0.056	0.022	0.013	0.042	0.039	0.022	0.0037	0.0066	0.088	0.2
0.51-1.00	0.066	0.012	0.018	0.045	0.11	0.006	0.0011	0.000094	0.016	0.094
1.01-2.00	0.038	0.011	0.016	0.042	0.022	0.01	0.0014	0	0.011	0.0048
2.01-5.00	0.0037	0.005	0.0035	0.0058	0.00014	0.012	0.0006	0	0.012	0
> 5.00	0	0	0	0	0	0.0039	0	0	0	0

Table 44. Affected areas in Tanza, Cavite during a 5-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Tanza (in sq. km.)									
	Biwas	Bucal	Bunga	Daang Amaya I	Daang Amaya II	Daang Amaya III	Julugan I	Julugan II	Julugan III	Julugan IV
0.03-0.20	1.16	0.74	2.13	0.17	0.14	0.17	0.13	0.074	0.055	0.11
0.21-0.50	0.15	0.18	0.46	0.0074	0.0098	0.011	0.0022	0.013	0.0089	0.029
0.51-1.00	0.1	0.12	0.29	0	0	0.0046	0.00065	0.025	0.019	0.025
1.01-2.00	0.031	0.052	0.13	0	0	0.0032	0.00076	0.032	0.016	0.005
2.01-5.00	0.0024	0.018	0.017	0	0	0	0	0	0	0
> 5.00	0	0.001	0.0099	0	0	0	0	0	0	0

Table 45. Affected areas in Tanza, Cavite during a 5-year rainfall return period

Affected Areas in sq. km.) by flood depth (in m.)	Area of affected barangays in Tanza (in sq. km.)									
	Julugan V	Julugan VI	Julugan VII	Julugan VIII	Mulawin	Paradahan I	Paradahan II	Punta II	Sanja Mayor	Santol
0.03-0.20	0.072	0.081	0.072	0.13	1.66	0.12	1.08	0.35	1.88	0.65
0.21-0.50	0.02	0.023	0.016	0.015	0.2	0.0049	0.16	0.059	0.31	0.4
0.51-1.00	0.0082	0.0007	0.0039	0.0053	0.11	0	0.16	0.079	0.14	0.52
1.01-2.00	0.0002	0	0.001	0	0.041	0	0.12	0.06	0.031	0.044
2.01-5.00	0	0	0	0	0.0015	0	0.061	0.0012	0	0.00005
> 5.00	0	0	0	0	0	0	0.011	0	0	0

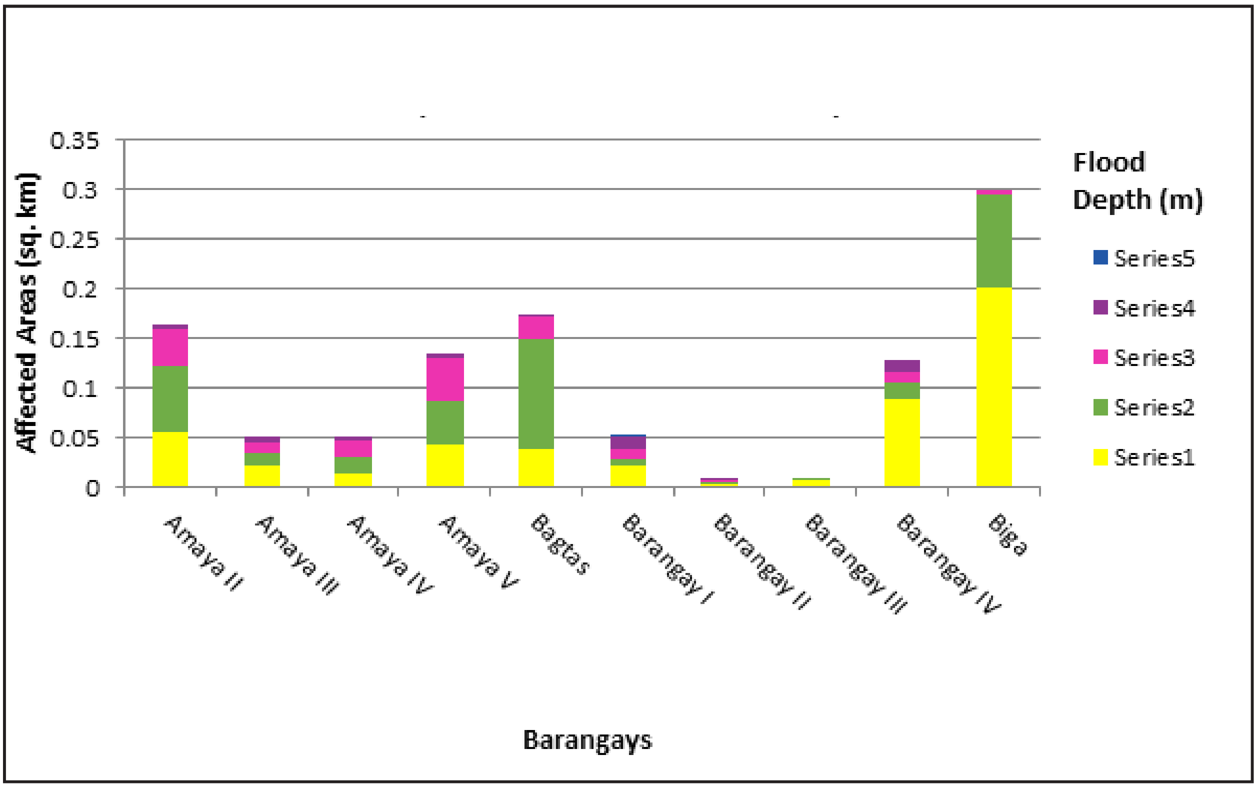


Figure 79. Affected areas in Tanza, Cavite during a 5-year rainfall return period

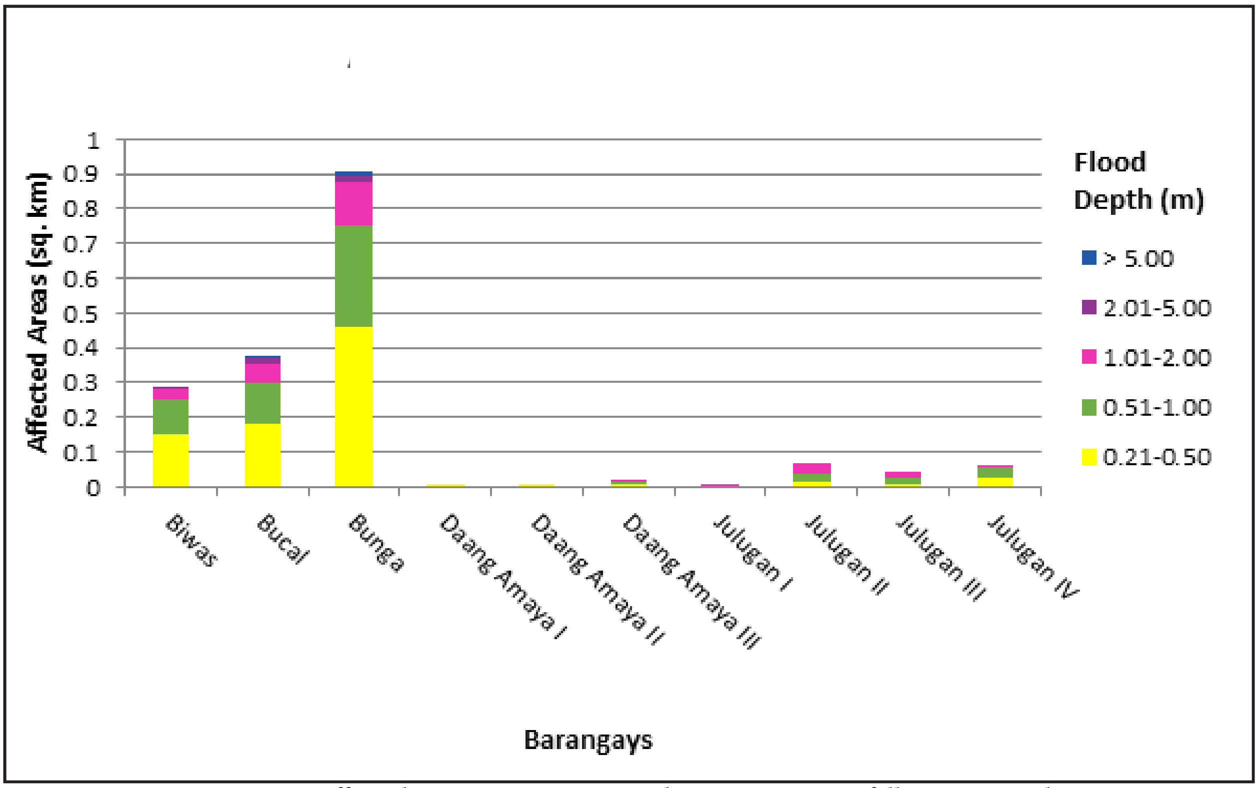


Figure 80. Affected areas in Tanza, Cavite during a 5-year rainfall return period

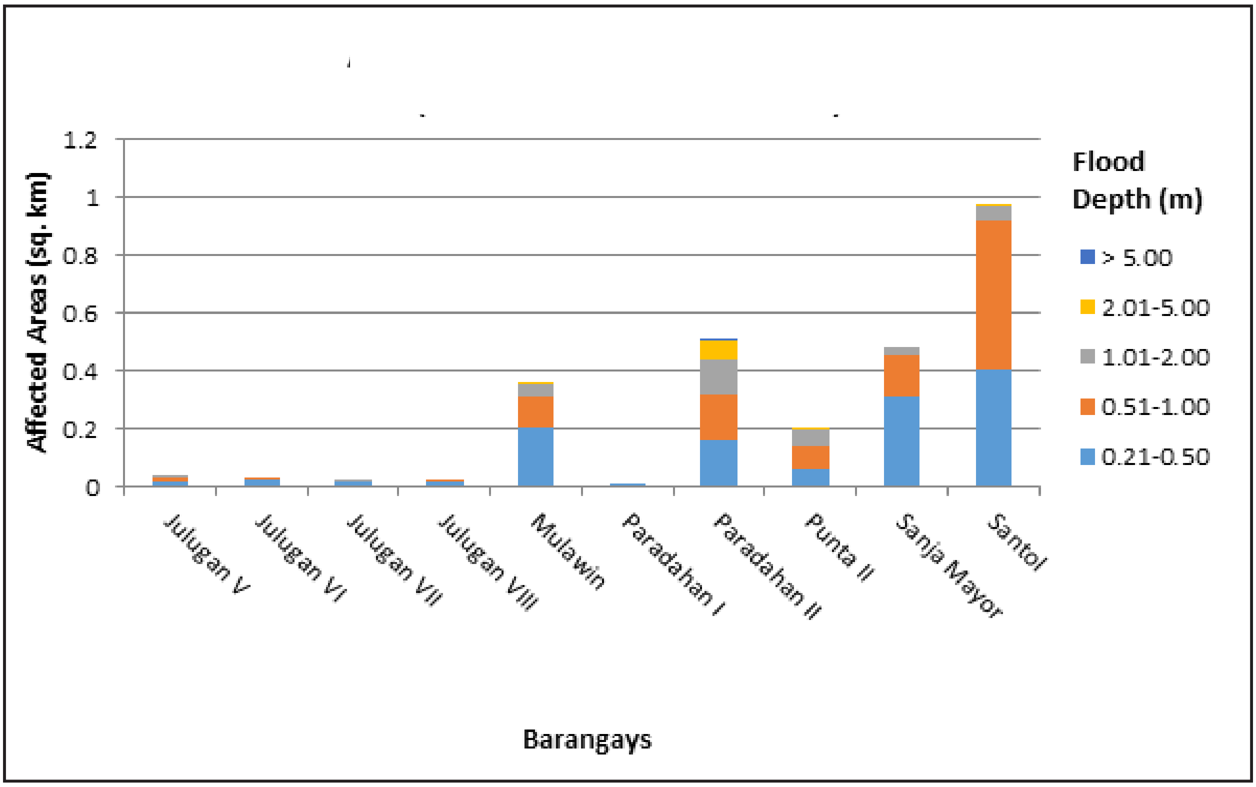


Figure 81. Affected areas in Tanza, Cavite during a 5-year rainfall return period

For the 5-year return period, 14.34% of the Municipality of Trece Martires City, with an area of 46.18 sq. km., will experience flood levels of less than 0.20 meters. 0.72% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.41%, 0.36%, 0.33%, and 0.26% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 46 are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected areas in Trece Martires, Cavite during a 5-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Trece Martires City (in sq. km.)			
	De Ocampo	Gregorio	Osorio	Perez
0.03-0.20	0.21	0.0084	2.35	4.056077
0.21-0.50	0.0073	0.000006	0.11	0.215726
0.51-1.00	0.0014	0.000079	0.072	0.113754
1.01-2.00	0.0004	0.00017	0.069	0.094546
2.01-5.00	0.00015	0.00028	0.067	0.085758
> 5.00	0	0.00067	0.06	0.059326

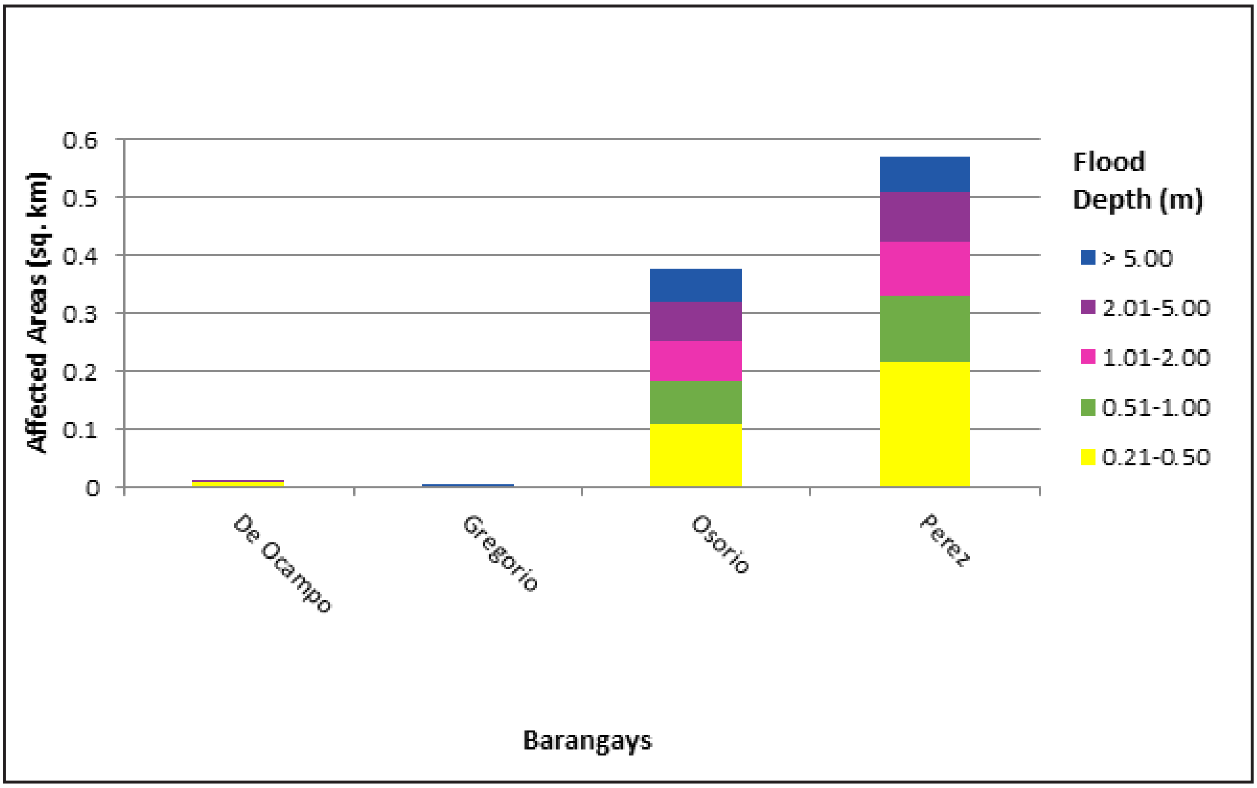


Figure 82. Affected areas in Trece Martires, Cavite during a 5-year rainfall return period

For the 25-year return period, 8.54% of the Municipality of General Trias, with an area of 87.5 sq. km., will experience flood levels of less than 0.20 meters. 1.33% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.61%, 1.82%, 1.45%, and 1.24% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 47-49 are the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected areas in General Trias, Cavite during 25-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in General Trias (in sq. km.)										
	Arnaldo Poblacion	Bagumbayan Poblacion	Biclatan	Buenavista I	Buenavista II	Buenavista III	Corregidor Poblacion	Dulong Bayan Poblacion	Manggahan	Ninety Sixth Poblacion	Pasong Camachile I
0.03-0.20	0	0.0017	0.21	0.56	0.57	0.92	0.0013	0.000099	1.09	0.0019	0.0065
0.21-0.50	0.003	0.0059	0.014	0.03	0.034	0.064	0.0085	0.00054	0.094	0.0037	0.0041
0.51-1.00	0.023	0.0026	0.015	0.022	0.015	0.018	0.015	0.0014	0.034	0.017	0.00034
1.01-2.00	0.0089	0	0.0076	0.02	0.015	0.028	0.0073	0	0.035	0.0064	0
2.01-5.00	0	0	0.0075	0.025	0.027	0.056	0	0	0.052	0	0
> 5.00	0	0	0.0049	0.061	0.066	0.059	0	0	0.033	0	0

Table 48. Affected areas in General Trias, Cavite during 25-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in General Trias (in sq. km.)										
	Pasong Camachile II	Pasong Kawayan I	Pasong Kawayan II	Pinagtipunan	Prinza Poblacion	Sampalucan Poblacion	San Juan I	San Juan II	Santa Clara	Tapia	Tejero Poblacion
0.03-0.20	0.027	0.57	2.64	0.22	0	0.00054	0.00021	0.025	0.0018	0.63	0
0.21-0.50	0.00096	0.093	0.31	0.088	0.0002	0.0032	0.0061	0.18	0.0056	0.21	0
0.51-1.00	0	0.13	0.34	0.18	0.008	0.0042	0.064	0.31	0.035	0.17	0
1.01-2.00	0	0.29	0.35	0.4	0.084	0.00071	0.081	0.094	0.026	0.14	0
2.01-5.00	0	0.18	0.37	0.32	0.015	0	0.054	0.028	0	0.13	0
> 5.00	0	0.17	0.26	0.17	0.00021	0	0.044	0.048	0	0.17	0

Table 49. Affected areas in General Trias, Cavite during 25-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in General Trias (in sq. km.)
	Vibora Poblacion
0.03-0.20	0.00068
0.21-0.50	0.0057
0.51-1.00	0.0051
1.01-2.00	0.00049
2.01-5.00	0
> 5.00	0

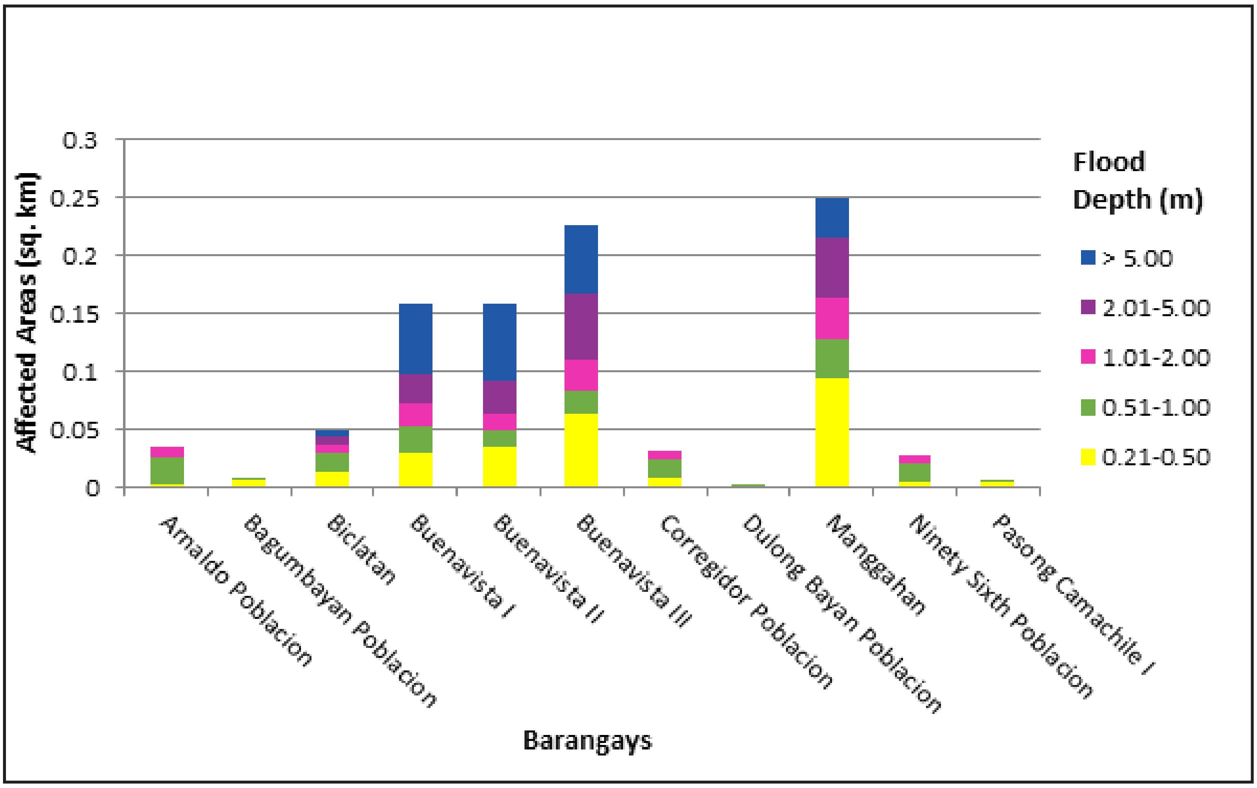


Figure 83. Affected areas in General Trias, Cavite during a 25-year rainfall return period

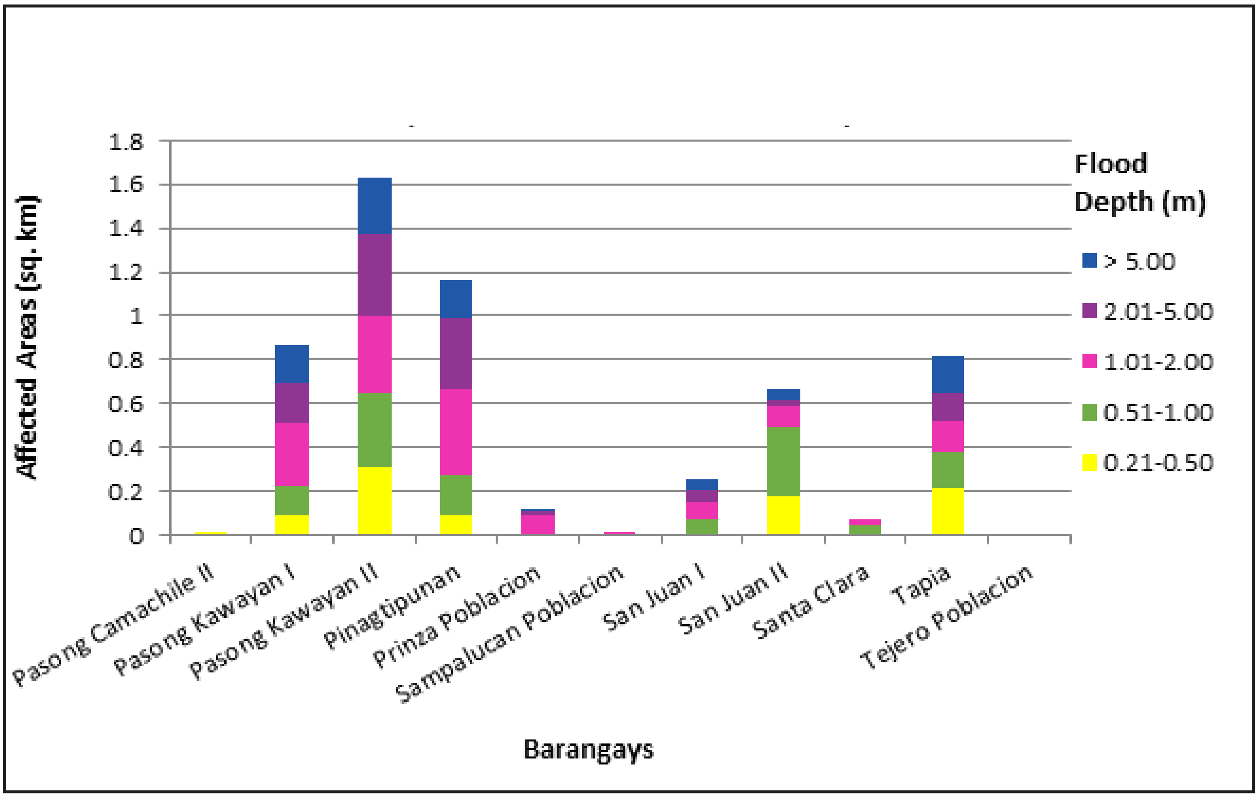


Figure 84. Affected areas in General Trias, Cavite during a 25-year rainfall return period

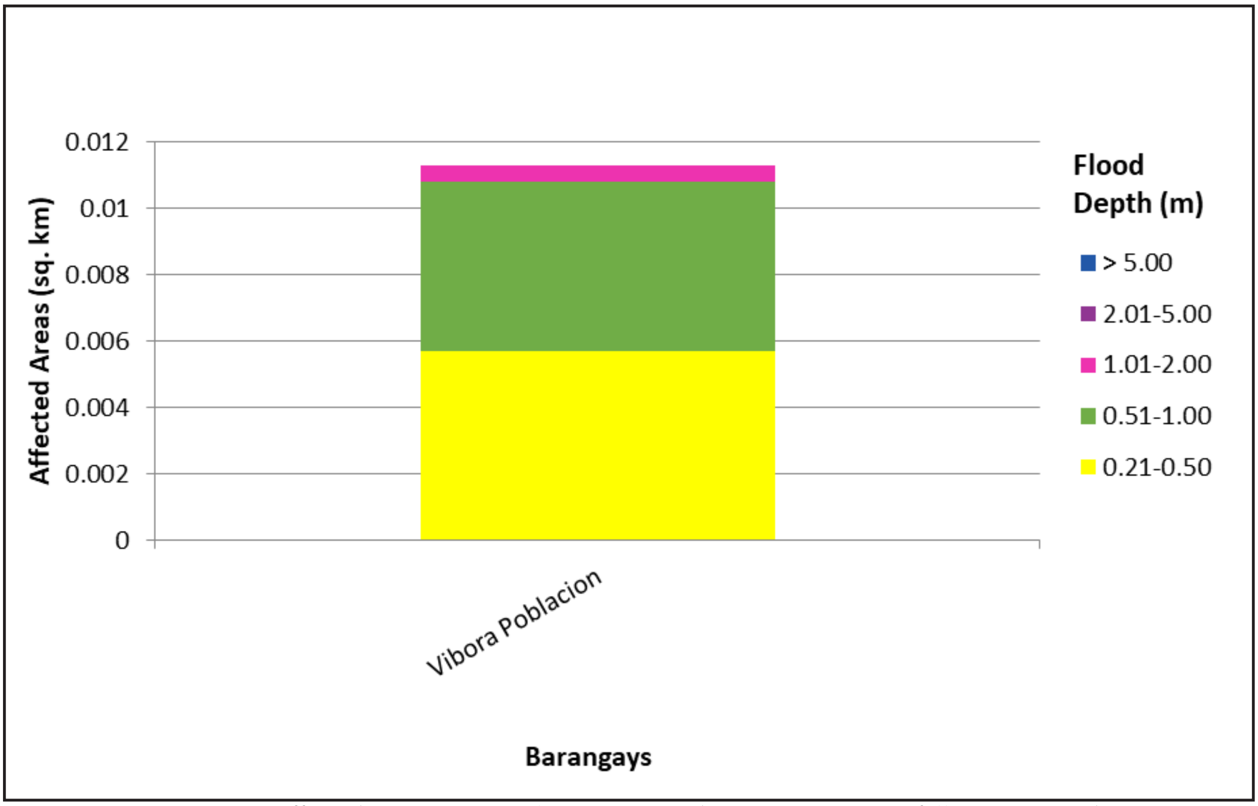


Figure 85. Affected areas in General Trias, Cavite during a 25-year rainfall return period

For the 25-year return period, 21.37% of the Municipality of Rosario, with an area of 8.006 sq. km., will experience flood levels of less than 0.20 meters. 10.69% of the area will experience flood levels of 0.21 to 0.50 meters, Meanwhile, 2.66%, 0.84%, 0.41%, and 0.57% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 50-51 are the affected areas, in square kilometers, by flood depth per barangay.

Table 50. Affected areas in Rosario, Cavite during a 25-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Rosario (in sq. km.)							
	Kanluran	Ligton I	Muzon I	Muzon II	Poblacion	Sapa I	Sapa II	Sapa III
0.03-0.20	0.08	0	0.028	0.11	0.24	0.01	0.017	0.022
0.21-0.50	0.1	0	0.043	0.065	0.15	0.0018	0.021	0.013
0.51-1.00	0.026	0	0.0083	0.0065	0.061	0	0.00094	0.0058
1.01-2.00	0.0001	0	0.0017	0	0.033	0	0	0
2.01-5.00	0	0	0	0	0.0027	0	0	0
> 5.00	0	0	0	0	0	0	0	0

Table 51. Affected areas in Rosario, Cavite during a 25-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Rosario (in sq. km.)						
	Sapa IV	Silangan I	Silangan II	Tejeros Convention	Wawa I	Wawa II	Wawa III
0.03-0.20	0.025	0.4	0.07	0.32	0.34	0.028	0.021
0.21-0.50	0.013	0.16	0.045	0.14	0.089	0.0057	0.0093
0.51-1.00	0.011	0.023	0.007	0.034	0.029	0	0.0001
1.01-2.00	0.006	0.0003	0.000002	0.014	0.012	0	0
2.01-5.00	0	0	0	0.014	0.016	0	0.00016
> 5.00	0	0	0	0.022	0.024	0	0

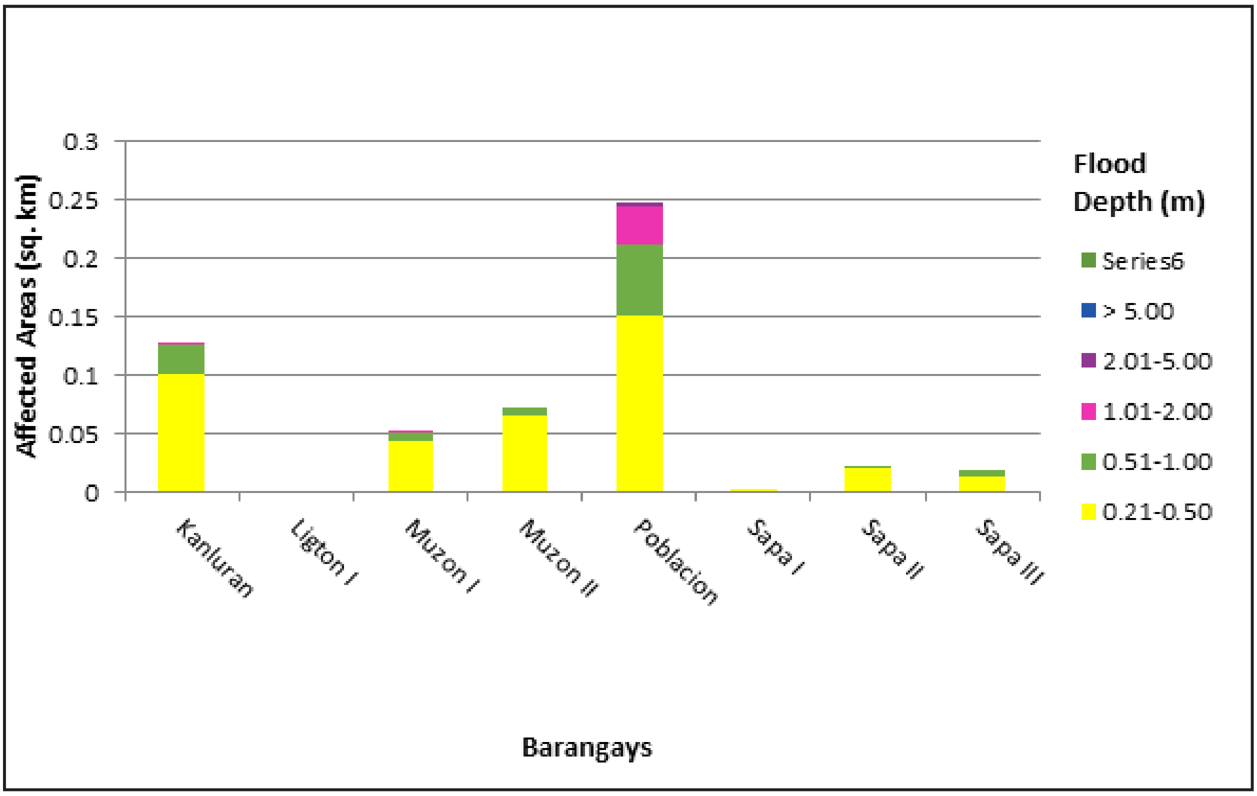


Figure 86. Affected areas in Rosario, Cavite during a 25-year rainfall return period

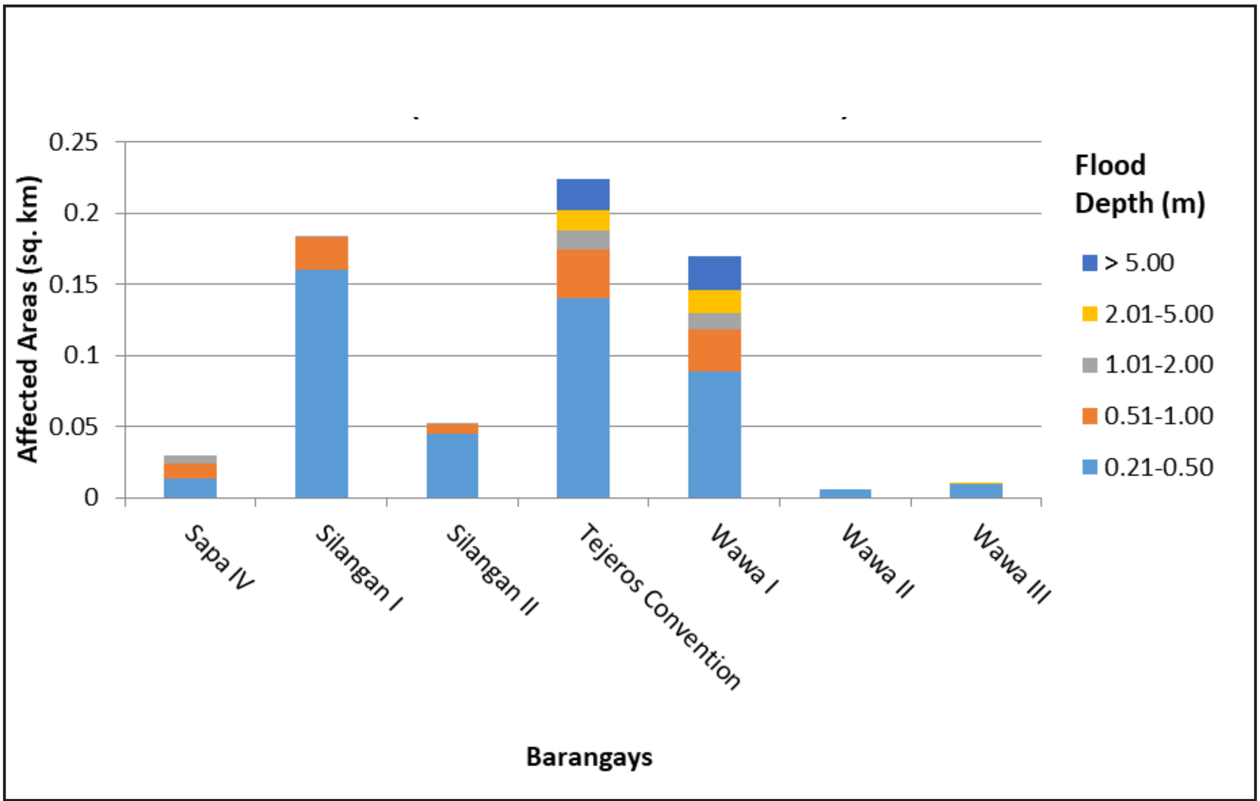


Figure 87. Affected areas in Rosario, Cavite during a 25-year rainfall return period

For the 25-year return period, 16.14% of the Municipality of Tanza, with an area of 74.58 sq. km., will experience flood levels of less than 0.20 meters. 3.37% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 3.92%, 2.67%, 0.57%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 52-54 are the affected areas, in square kilometers, by flood depth per barangay.

Table 52. Affected areas in Tanza, Cavite during a 25-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Tanza (in sq. km.)									
	Amaya II	Amaya III	Amaya IV	Amaya V	Bagtas	Barangay I	Barangay II	Barangay III	Barangay IV	Biga
0.03-0.20	0.31	0.27	0.35	0.25	0.11	0.11	0.072	0.044	0.08	1.47
0.21-0.50	0.053	0.027	0.017	0.048	0.029	0.055	0.018	0.0095	0.088	0.19
0.51-1.00	0.073	0.011	0.018	0.046	0.053	0.049	0.0081	0.0008	0.13	0.17
1.01-2.00	0.059	0.016	0.023	0.057	0.13	0.022	0.0039	0.00038	0.026	0.012
2.01-5.00	0.006	0.0077	0.0066	0.012	0.014	0.027	0.0026	0	0.019	0
> 5.00	0	0	0	0	0	0.0066	0	0	0.0001	0

Table 53. Affected areas in Tanza, Cavite during a 25-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Tanza (in sq. km.)									
	Biwas	Bucal	Bunga	Daang Amaya I	Daang Amaya II	Daang Amaya III	Julugan I	Julugan II	Julugan III	Julugan IV
0.03-0.20	1.05	0.46	1.47	0.16	0.13	0.17	0.13	0.061	0.052	0.091
0.21-0.50	0.2	0.22	0.38	0.012	0.016	0.015	0.0022	0.017	0.0082	0.033
0.51-1.00	0.12	0.24	0.59	0.0003	0	0.0048	0.0013	0.024	0.017	0.031
1.01-2.00	0.057	0.15	0.48	0	0	0.0049	0.00094	0.04	0.021	0.0091
2.01-5.00	0.0038	0.046	0.11	0	0	0.0001	0.000021	0.0015	0	0
> 5.00	0	0.001	0.012	0	0	0	0	0	0	0

Table 54. Affected areas in Tanza, Cavite during a 25-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Tanza (in sq. km.)									
	Julugan V	Julugan VI	Julugan VII	Julugan VIII	Mulawin	Paradahan I	Paradahan II	Punta II	Sanja Mayor	Santol
0.03-0.20	0.063	0.067	0.055	0.12	1.56	0.12	0.86	0.26	1.79	0.3
0.21-0.50	0.026	0.035	0.029	0.02	0.22	0.008	0.19	0.035	0.27	0.24
0.51-1.00	0.01	0.0023	0.0062	0.0082	0.16	0	0.16	0.071	0.22	0.7
1.01-2.00	0.0012	0	0.0018	0	0.065	0	0.24	0.14	0.068	0.36
2.01-5.00	0	0	0	0	0.005	0	0.12	0.042	0	0.00065
> 5.00	0	0	0	0	0	0	0.018	0	0	0

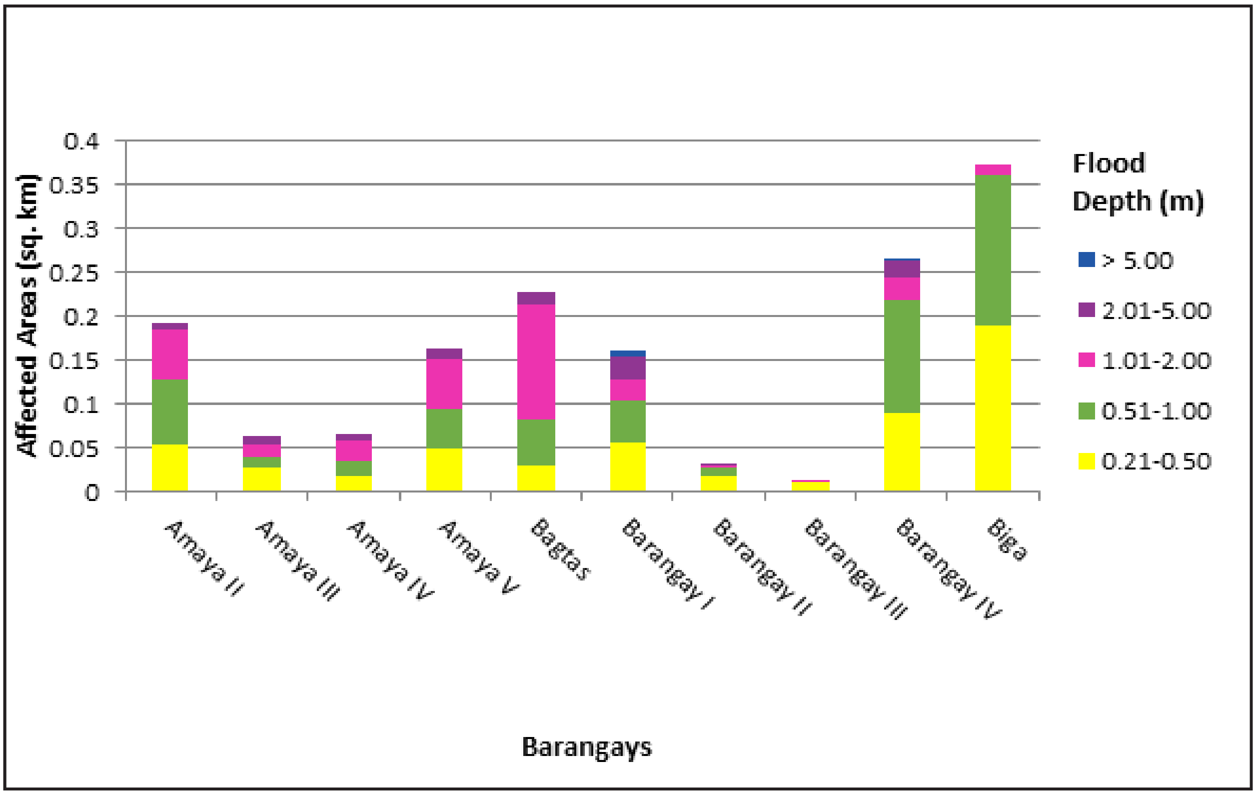


Figure 88. Affected areas in Tanza, Cavite during a 25-year rainfall return period

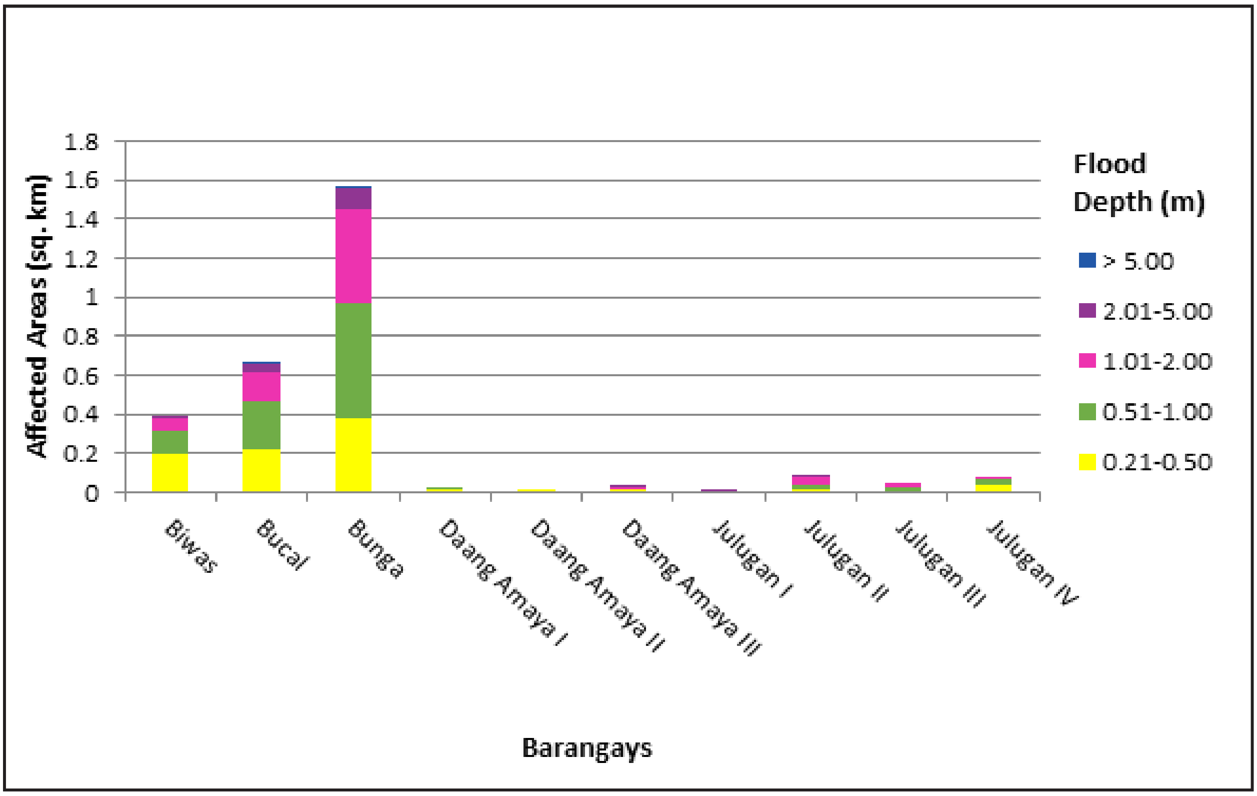


Figure 89. Affected areas in Tanza, Cavite during a 25-year rainfall return period

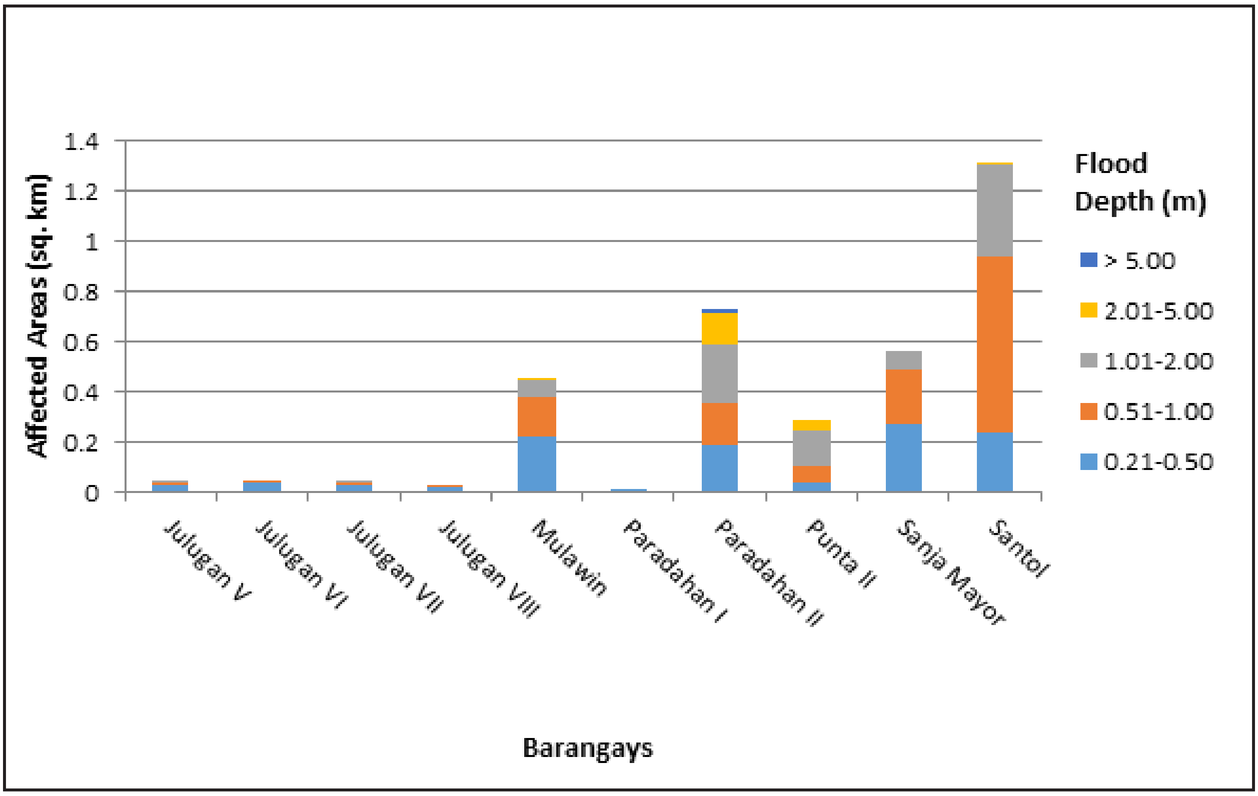


Figure 90. Affected areas in Tanza, Cavite during a 25-year rainfall return period

For the 25-year return period, 13.63% of the Municipality of Trece Martires City, with an area of 46.18 sq. km., will experience flood levels of less than 0.20 meters. 0.94% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.51%, 0.47%, 0.46%, and 0.40% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 55 are the affected areas, in square kilometers, by flood depth per barangay.

Table 55. Affected areas in Trece Martires, Cavite during a 25-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Trece Martires City (in sq. km.)			
	De Ocampo	Gregorio	Osorio	Perez
0.03-0.20	0.2	0.0076	2.23	3.86
0.21-0.50	0.011	0.00061	0.14	0.28
0.51-1.00	0.0014	0.0001	0.089	0.15
1.01-2.00	0.0016	0.0002	0.092	0.12
2.01-5.00	0.00041	0.0002	0.091	0.12
> 5.00	0.000052	0.00095	0.085	0.098

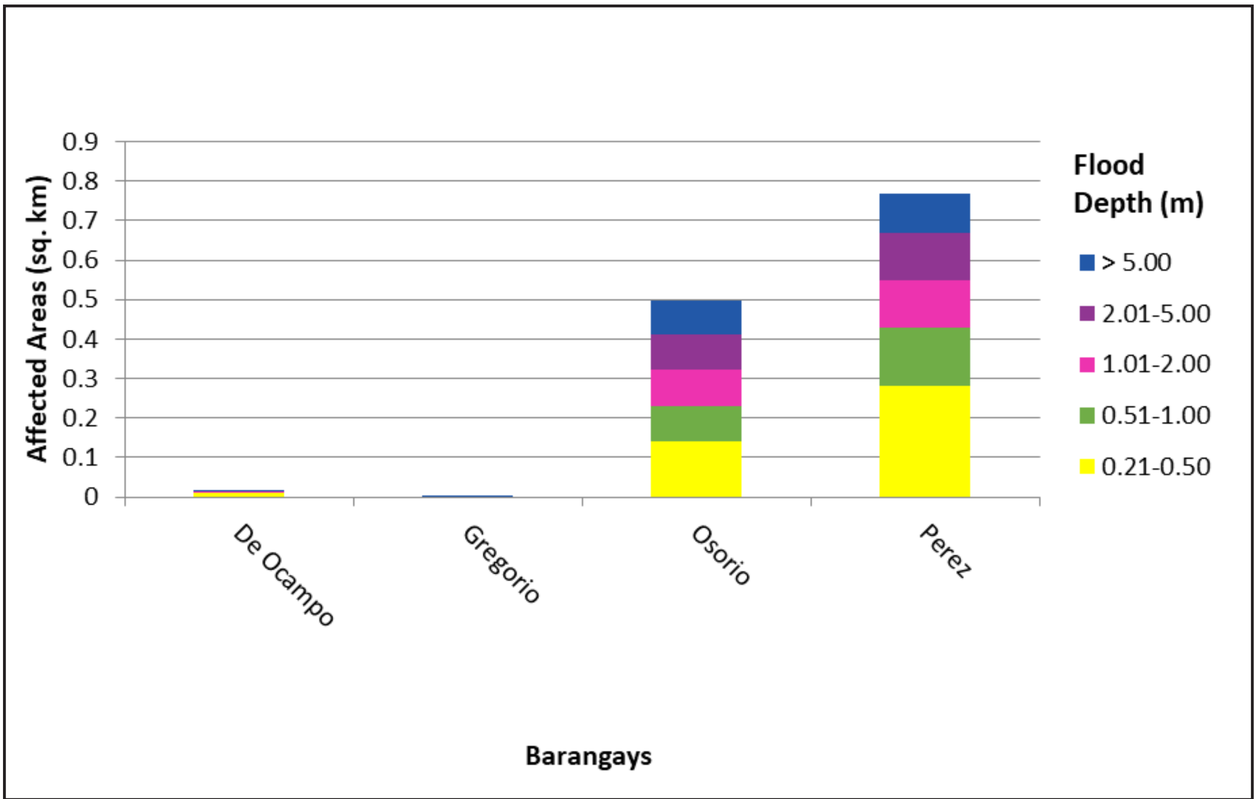


Figure 91. Affected areas in Trece Martires, Cavite during a 25-year rainfall return period

For the 100-year return period, 7.39% of the Municipality of General Trias, with an area of 87.5 sq. km., will experience flood levels of less than 0.20 meters. 1.33% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.60%, 2.35%, 1.88%, and 1.42% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 56-58 are the affected areas, in square kilometers, by flood depth per barangay.

Table 56. Affected areas in General Trias, Cavite during a 100-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in General Trias (in sq. km.)										
	Arnaldo Poblacion	Bagumbayan Poblacion	Biclatan	Buenavista I	Buenavista II	Buenavista III	Corregidor Poblacion	Dulong Bayan Poblacion	Manggahan	Ninety Sixth Poblacion	Pasong Camachile I
0.03-0.20	0	0.00095	0.21	0.52	0.52	0.86	0.00076	0	1.03	0.0011	0.0027
0.21-0.50	0.0014	0.0049	0.014	0.033	0.047	0.076	0.0054	0.00023	0.12	0.0024	0.005
0.51-1.00	0.022	0.0044	0.016	0.028	0.018	0.02	0.015	0.0018	0.043	0.015	0.0034
1.01-2.00	0.011	0	0.0096	0.034	0.023	0.032	0.01	0	0.041	0.011	0
2.01-5.00	0	0	0.0078	0.031	0.037	0.074	0	0	0.065	0	0
> 5.00	0	0	0.0061	0.071	0.077	0.079	0	0	0.044	0	0

Table 57. Affected areas in General Trias, Cavite during a 100-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in General Trias (in sq. km.)										
	Pasong Camachile II	Pasong Kawayan I	Pasong Kawayan II	Pinagtipunan	Prinza Poblacion	Sampalucan Poblacion	San Juan I	San Juan II	Santa Clara	Tapia	Tejero Poblacion
0.03-0.20	0.024	0.49	2.32	0.09	0	0.000043	0	0.0051	0.00025	0.39	0
0.21-0.50	0.001	0.095	0.35	0.068	0	0.0021	0.0024	0.12	0.0025	0.21	0
0.51-1.00	0.0019	0.11	0.36	0.13	0.0033	0.0055	0.05	0.32	0.017	0.21	0
1.01-2.00	0.00083	0.28	0.48	0.44	0.084	0.00097	0.097	0.15	0.048	0.3	0
2.01-5.00	0	0.26	0.45	0.46	0.019	0	0.055	0.032	0	0.15	0
> 5.00	0	0.19	0.3	0.19	0.00032	0	0.045	0.049	0	0.19	0

Table 58. Affected areas in General Trias, Cavite during a 100-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in General Trias (in sq. km.)
	Vibora Poblacion
0.03-0.20	0.0005
0.21-0.50	0.0032
0.51-1.00	0.0072
1.01-2.00	0.00092
2.01-5.00	0
> 5.00	0

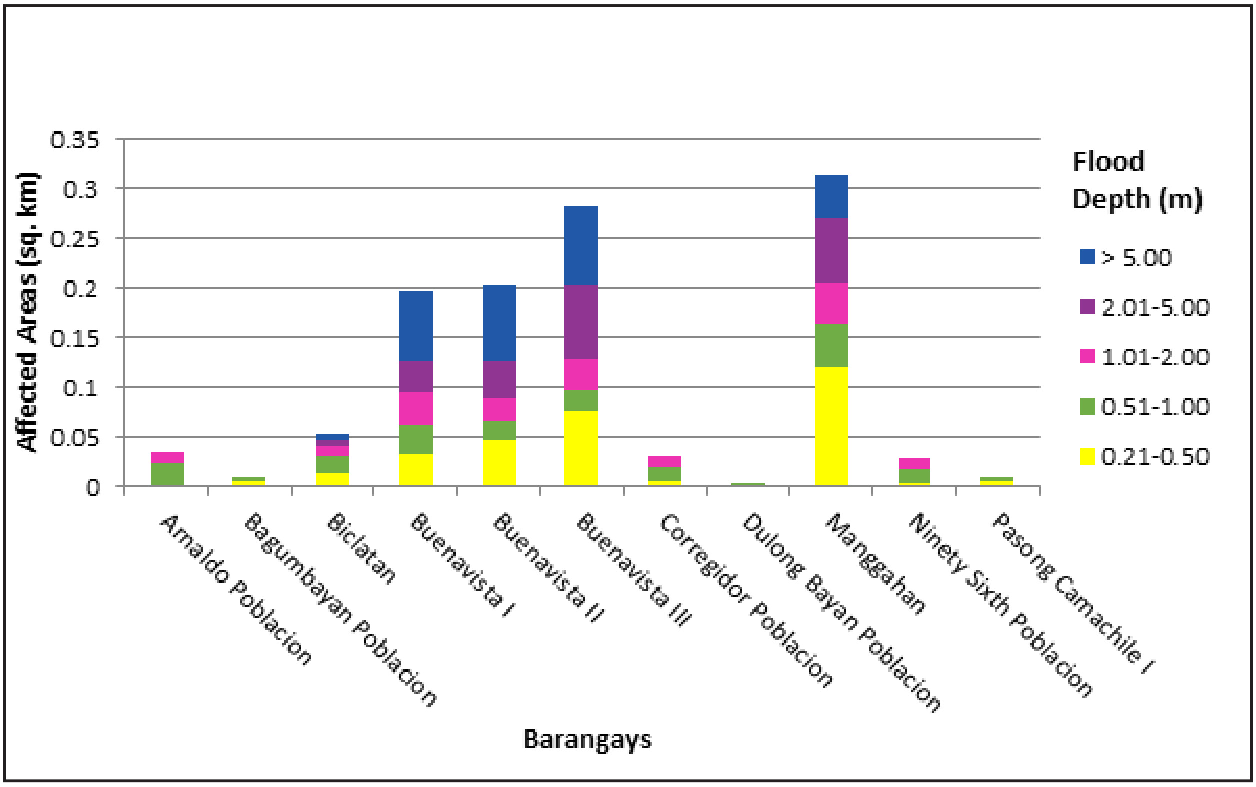


Figure 92. Affected areas in General Trias, Cavite during a 100-year rainfall return period

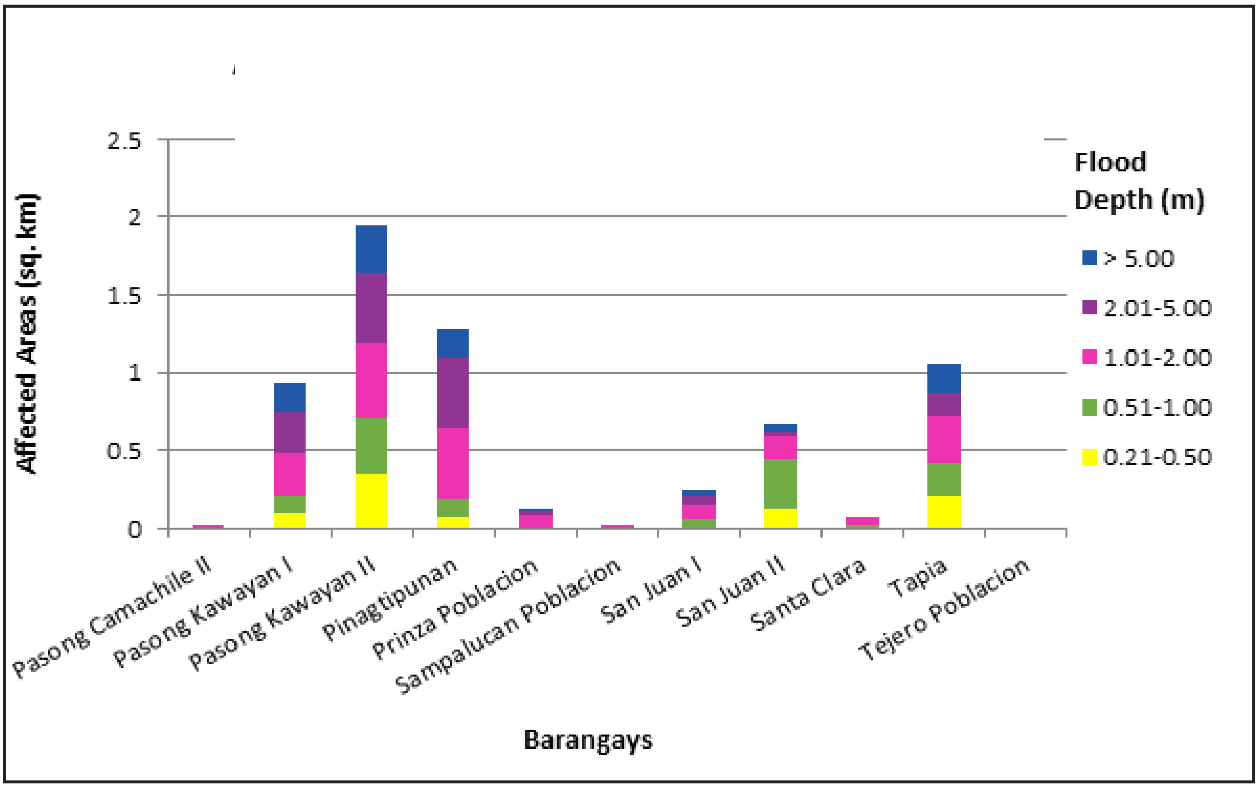


Figure 93. Affected areas in General Trias, Cavite during a 100-year rainfall return period

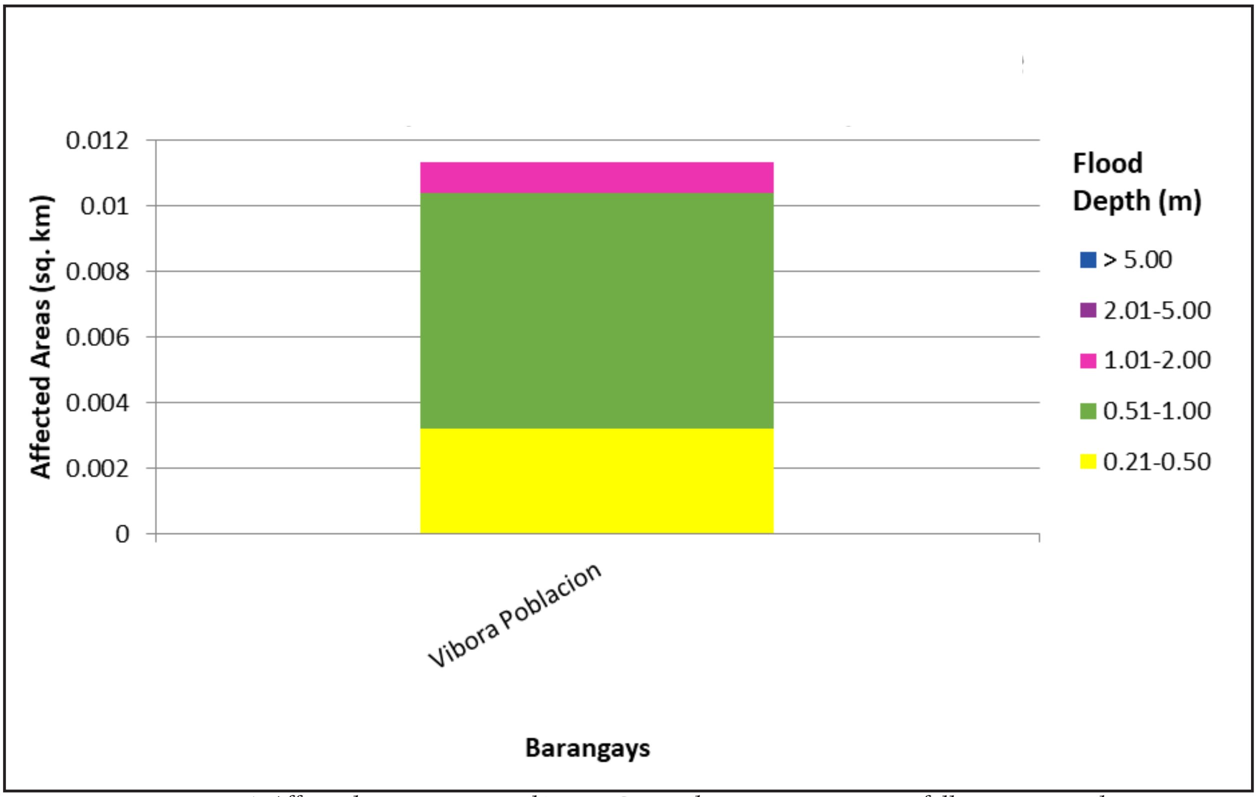


Figure 94. Affected areas in General Trias, Cavite during a 100-year rainfall return period

For the 100-year return period, 13.93% of the Municipality of Rosario, with an area of 8.006 sq. km., will experience flood levels of less than 0.20 meters. 12.88% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 6.99%, 1.21%, 0.69%, and 0.67% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 59-60 are the affected areas, in square kilometers, by flood depth per barangay.

Table 59. Affected areas in Rosario, Cavite during a 100-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Rosario (in sq. km.)							
	Kanluran	Ligton I	Muzon I	Muzon II	Poblacion	Sapa I	Sapa II	Sapa III
0.03-0.20	0.027	0	0.016	0.073	0.14	0.009	0.0086	0.011
0.21-0.50	0.11	0	0.05	0.09	0.14	0.0031	0.02	0.015
0.51-1.00	0.074	0	0.013	0.015	0.14	0	0.0094	0.014
1.01-2.00	0.0007	0	0.0019	0	0.035	0	0	0.00024
2.01-5.00	0	0	0	0	0.019	0	0	0
> 5.00	0	0	0	0	0	0	0	0

Table 60. Affected areas in Rosario, Cavite during a 100-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Rosario (in sq. km.)						
	Sapa IV	Silangan I	Silangan II	Tejeros Convention	Wawa I	Wawa II	Wawa III
0.03-0.20	0.012	0.25	0.057	0.16	0.31	0.024	0.018
0.21-0.50	0.016	0.26	0.056	0.15	0.1	0.0092	0.012
0.51-1.00	0.019	0.07	0.0091	0.16	0.036	0.00008	0.0003
1.01-2.00	0.0076	0.0012	0.00093	0.031	0.018	0	0
2.01-5.00	0	0	0	0.02	0.016	0	0.00016
> 5.00	0	0	0	0.026	0.028	0	0

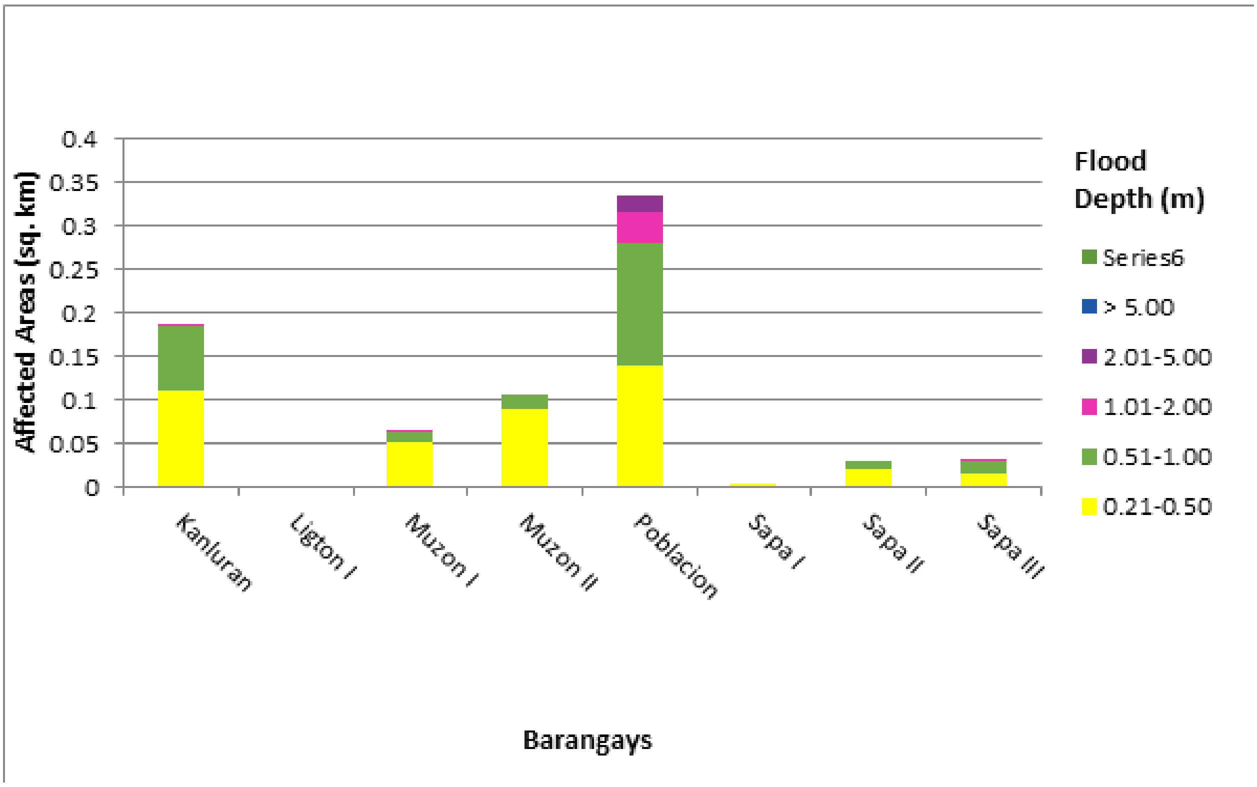


Figure 95. Affected areas in Rosario, Cavite during a 100-year rainfall return period

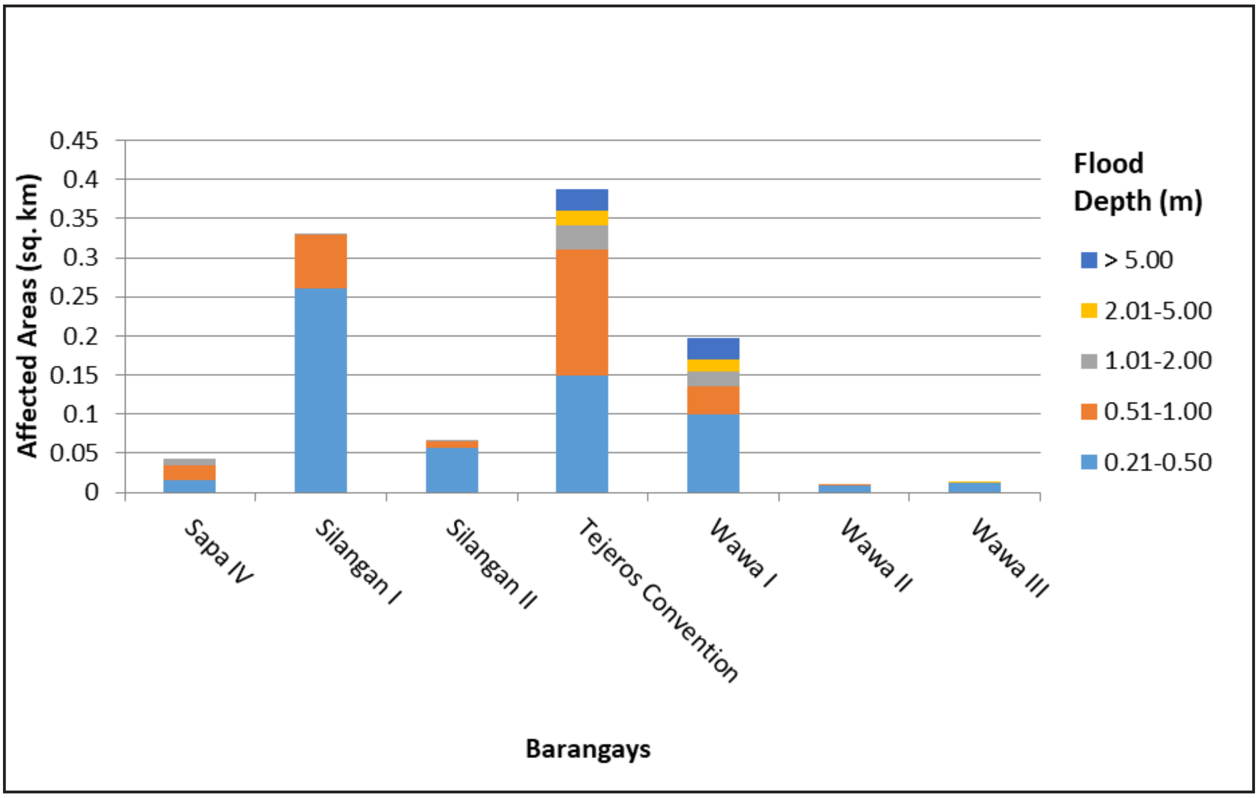


Figure 96. Affected areas in Rosario, Cavite during a 100-year rainfall return period

For the 100-year return period, 14.50% of the Municipality of Tanza, with an area of 74.58 sq. km., will experience flood levels of less than 0.20 meters. 3.05% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 3.79%, 4.33%, 1.00%, and 0.07% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 61-63 are the affected areas, in square kilometers, by flood depth per barangay.

Table 61. Affected areas in Tanza, Cavite during a 100-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Tanza (in sq. km.)									
	Amaya II	Amaya III	Amaya IV	Amaya V	Bagtas	Barangay I	Barangay II	Barangay III	Barangay IV	Biga
0.03-0.20	0.3	0.26	0.34	0.24	0.087	0.024	0.053	0.033	0.04	1.42
0.21-0.50	0.051	0.031	0.021	0.05	0.027	0.041	0.011	0.013	0.052	0.2
0.51-1.00	0.076	0.014	0.018	0.049	0.045	0.079	0.013	0.0067	0.12	0.21
1.01-2.00	0.071	0.017	0.029	0.064	0.14	0.066	0.022	0.0018	0.11	0.021
2.01-5.00	0.0081	0.01	0.0085	0.015	0.032	0.043	0.0054	0.000094	0.027	0.0002
> 5.00	0	0	0	0	0	0.012	0.0002	0	0.0003	0

Table 62. Affected areas in Tanza, Cavite during a 100-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Tanza (in sq. km.)									
	Biwas	Bucal	Bunga	Daang Amaya I	Daang Amaya II	Daang Amaya III	Julugan I	Julugan II	Julugan III	Julugan IV
0.03-0.20	0.96	0.28	1.21	0.16	0.12	0.16	0.13	0.053	0.049	0.082
0.21-0.50	0.25	0.17	0.29	0.016	0.024	0.02	0.0039	0.02	0.0076	0.034
0.51-1.00	0.15	0.26	0.55	0.0006	0.0004	0.0044	0.0017	0.023	0.016	0.035
1.01-2.00	0.073	0.31	0.73	0	0	0.0061	0.001	0.044	0.025	0.013
2.01-5.00	0.0054	0.09	0.25	0	0	0.0003	0.000091	0.0047	0.00038	0.0002
> 5.00	0	0.0013	0.014	0	0	0	0	0	0	0

Table 63. Affected areas in Tanza, Cavite during a 100-year rainfall return period

Affected Areas (in sq. km.) by flood depth (in m.)	Area of affected barangays in Tanza (in sq. km.)									
	Julugan V	Julugan VI	Julugan VII	Julugan VIII	Mulawin	Paradahan I	Paradahan II	Punta II	Sanja Mayor	Santol
0.03-0.20	0.053	0.06	0.043	0.11	1.5	0.11	0.77	0.23	1.73	0.21
0.21-0.50	0.032	0.041	0.038	0.025	0.22	0.0097	0.2	0.03	0.24	0.11
0.51-1.00	0.014	0.004	0.0096	0.011	0.18	0.000061	0.17	0.056	0.27	0.44
1.01-2.00	0.0024	0	0.002	0.0003	0.11	0	0.27	0.15	0.11	0.84
2.01-5.00	0	0	0	0	0.0088	0	0.15	0.077	0	0.013
> 5.00	0	0	0	0	0	0	0.018	0	0	0

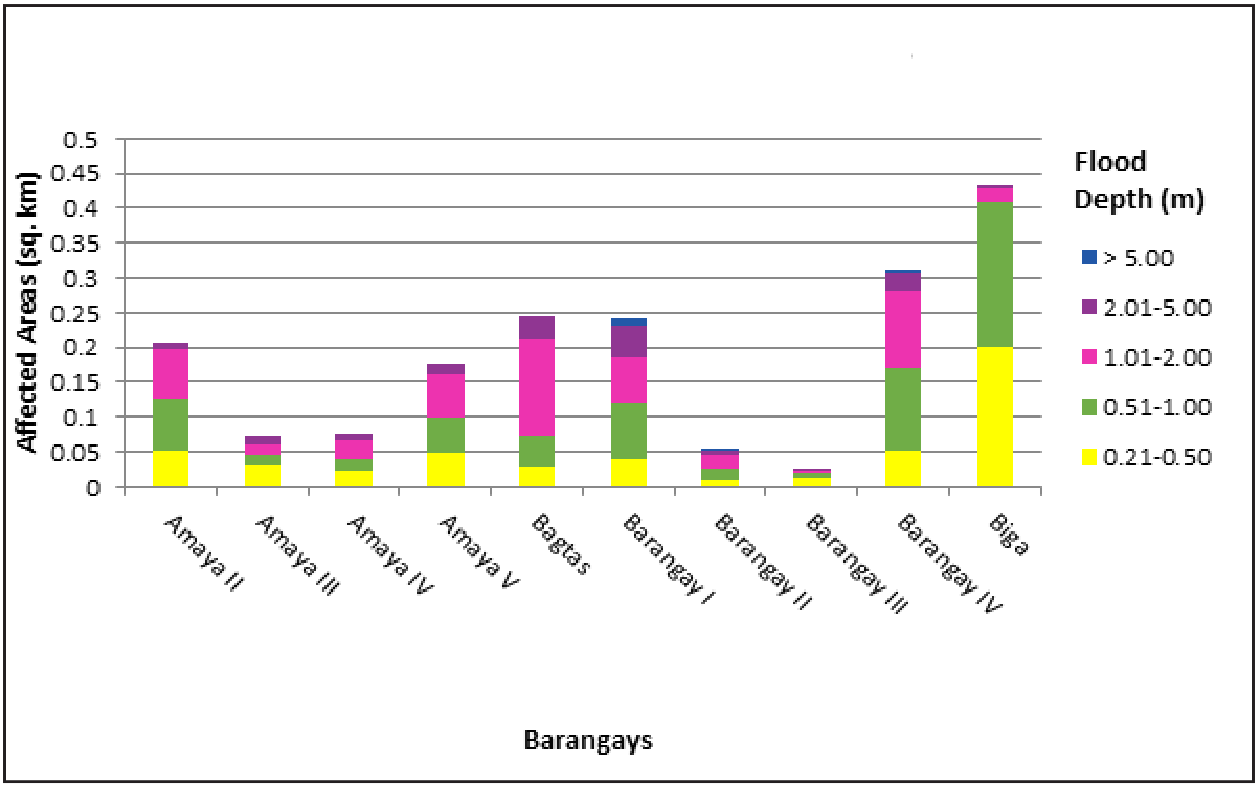


Figure 97. Affected areas in Rosario, Cavite during a 100-year rainfall return period

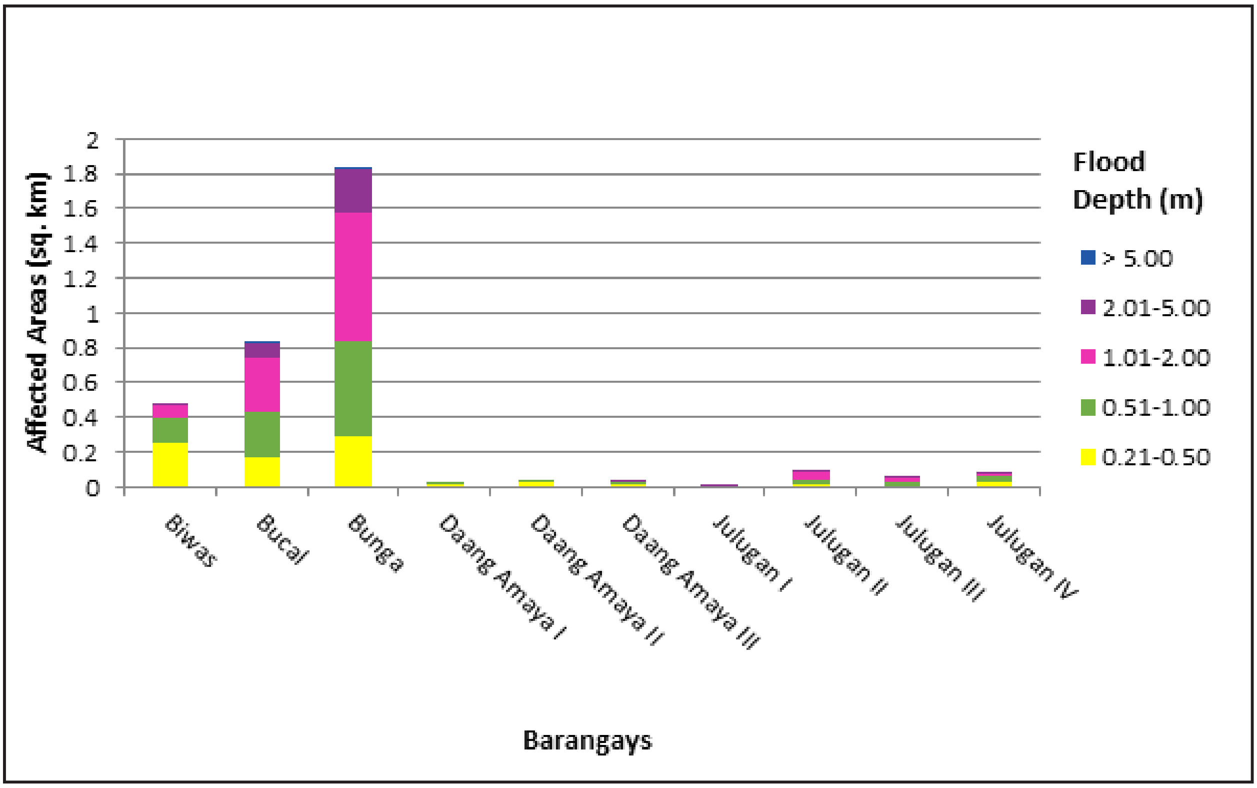


Figure 98. Affected areas in Rosario, Cavite during a 100-year rainfall return period

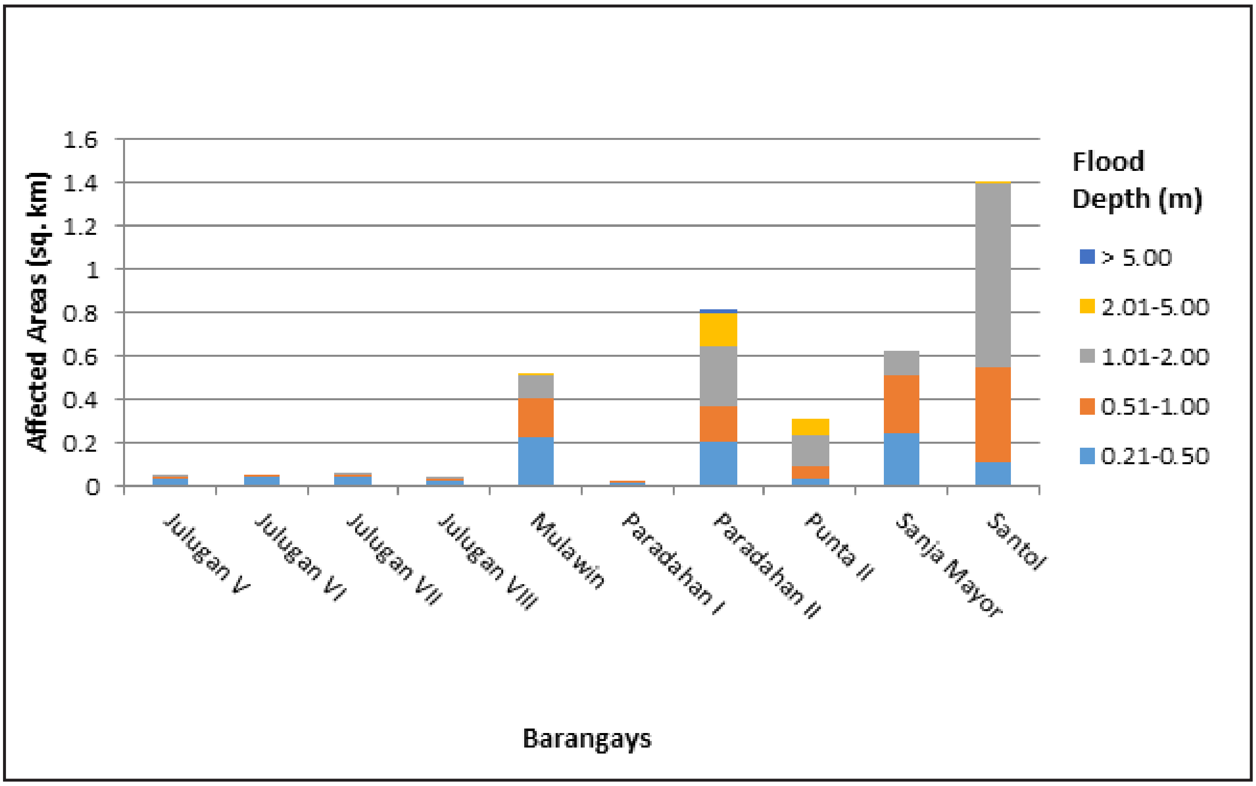


Figure 99. Affected areas in Rosario, Cavite during a 100-year rainfall return period

For the 100-year return period, 12.93% of the Municipality of Trece Martires City, with an area of 46.18 sq. km., will experience flood levels of less than 0.20 meters. 1.11% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.71%, 0.60%, 0.57%, and 0.48% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 64 are the affected areas, in square kilometers, by flood depth per barangay.

Table 64. Affected areas in Trece Martires, Cavite during a 100-Year rainfall return period

Affected Area (in sq. km.) by flood depth (in m.)	Area of affected barangays in Trece Martires City (in sq. km.)			
	De Ocampo	Gregorio	Osorio	Perez
0.03-0.20	0.2	0.0074	2.15	3.61
0.21-0.50	0.013	0.0004	0.17	0.33
0.51-1.00	0.0024	0.0001	0.095	0.23
1.01-2.00	0.0008	0.00041	0.1	0.18
2.01-5.00	0.0015	0.00035	0.11	0.15
> 5.00	0.000052	0.001	0.1	0.12

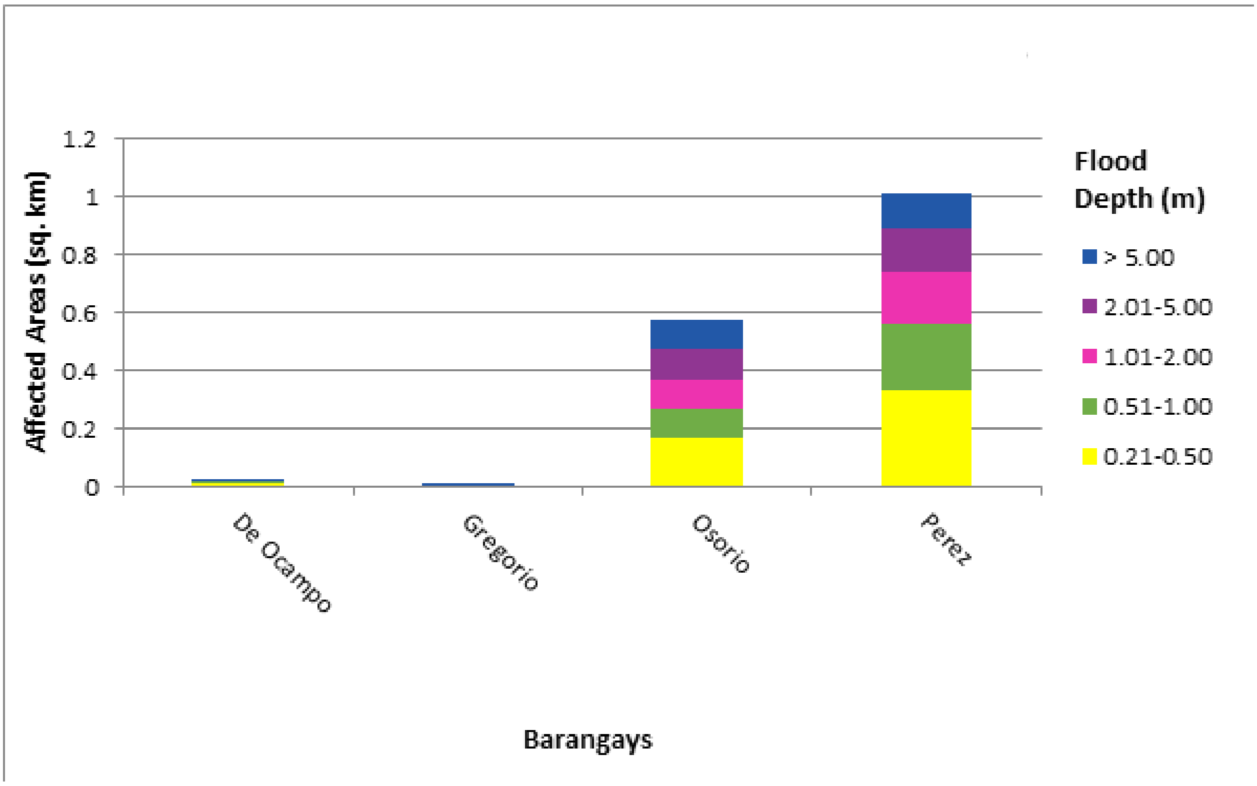


Figure 100. Affected areas in Trece Martires, Cavite during a 100-year rainfall return period

The generated flood hazard maps for the Cañas Floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for the flood hazard maps – “Low”, “Medium”, and “High” – the affected institutions were given an individual assessment for each flood hazard scenario (i.e., 5-year, 25-year, and 10-year). The lists of the educational institutions and medical institutions exposed to flooding in the Cañas floodplain are presented in Annex 12 and 13, respectively.

Table 65. Areas covered by each warning level with respect to the rainfall scenarios

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	8.14	8.44	8.08
Medium	6.96	12.47	15.09
High	3.12	4.91	6.97
TOTAL	18.22	25.83	30.14

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared with the simulated data to assess the accuracy of the flood depth maps produced, and to improve on the results of the flood map. The points in the flood map versus the corresponding validation depths are illustrated in Figure 103.

The flood validation consists of 256 points, randomly selected all over the Cañas floodplain (Figure 102). Comparing it with the flood depth map of the nearest storm event, the map had an RMSE value of 0.87 meters. Table 66 presents a contingency matrix of the comparison. The Cañas field validation points are found in Annex 11.

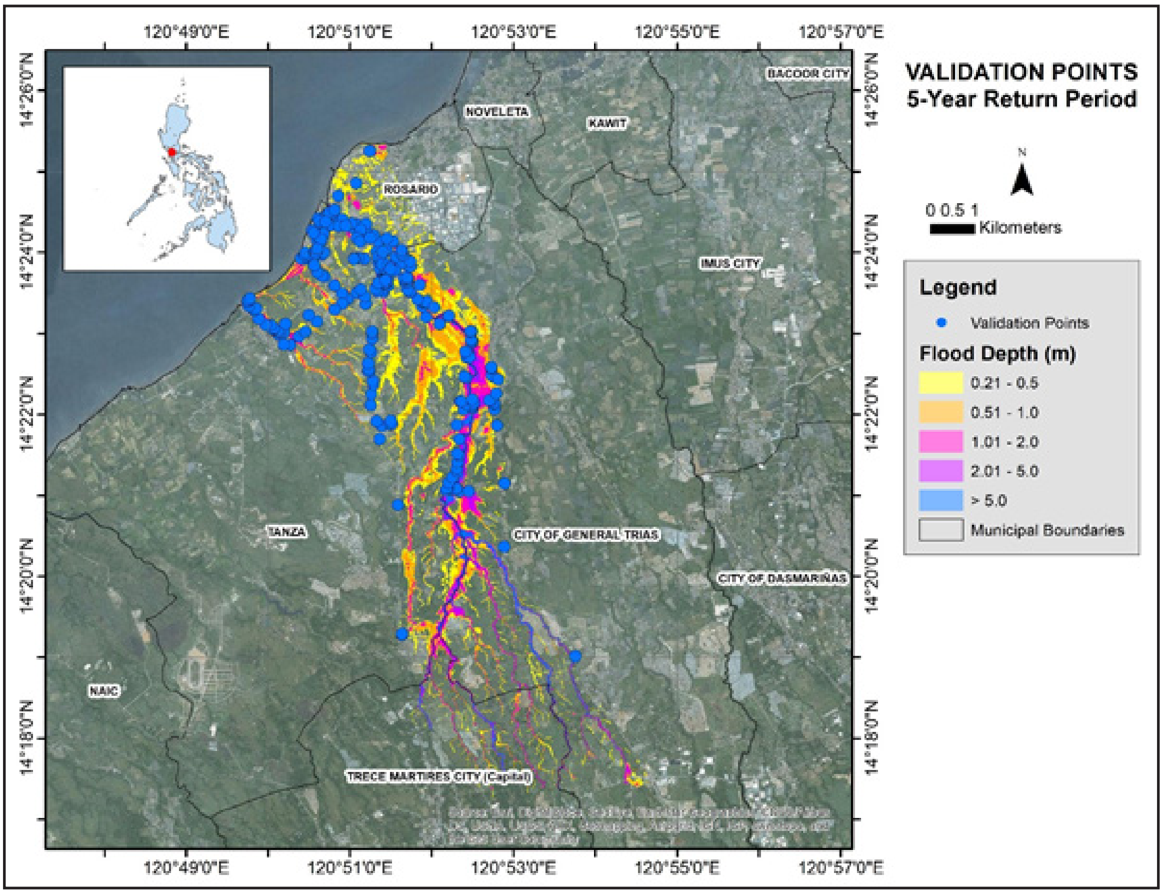


Figure 101. Validation points for a 5-year flood depth map of the Cañas Floodplain

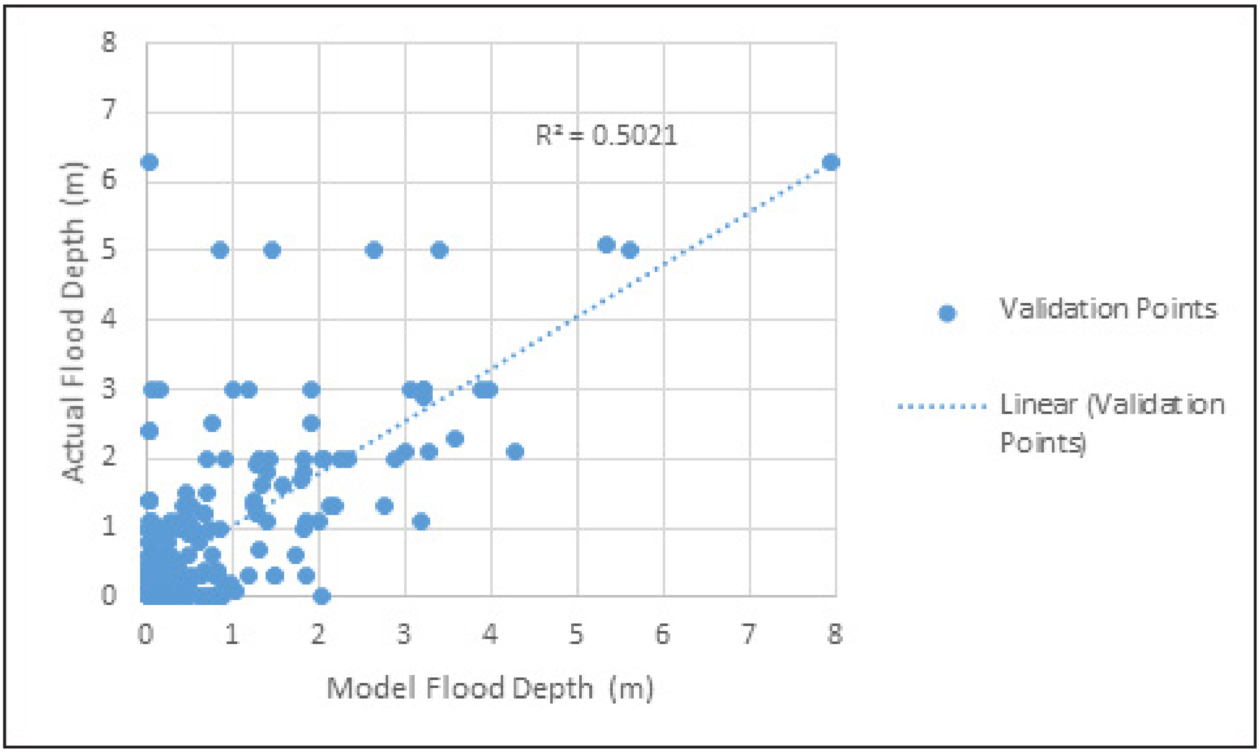


Figure 102. Flood map depth vs. actual flood depth

Table 66. Actual flood depth vs. Simulated flood depth in the Cañas Floodplain

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	97	9	10	1	1	0	118
0.21-0.50	24	8	7	4	0	0	43
0.51-1.00	12	7	6	3	0	0	28
1.01-2.00	5	5	6	14	10	0	40
2.01-5.00	4	0	2	5	12	1	24
> 5.00	1	0	0	0	0	2	3
Total	143	29	31	27	23	3	256

The overall accuracy generated by the flood model is estimated at 54.30%, with one hundred and thirty-nine (139) points correctly matching the actual flood depths. There were sixty-five (65) points estimated one (1) level above and below the correct flood depths. On the other hand, there were thirty-three (33) points and twelve (12) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood depths, respectively. A total of four (4) points were overestimated, while a total of seventy-one (71) points were underestimated in the modeled flood depths of the Cañas floodplain. Table 67 depicts the accuracy assessment of the Cañas model.

Table 67. Summary of the Accuracy Assessment in the Cañas River Basin Survey

	No. of Points	%
Correct	139	54.30
Overestimated	46	17.97
Underestimated	71	27.73
Total	256	100.00

REFERENCES

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LiDAR Sensors used in the Cañas Floodplain Survey

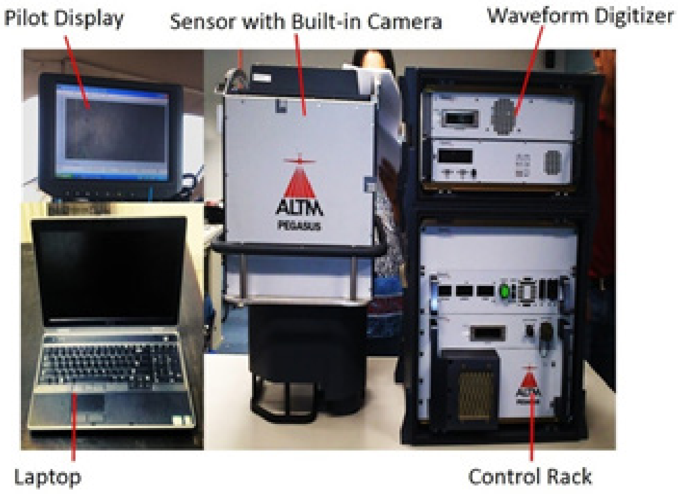


Figure A-1.1. Pegasus Sensor

Table A-1.1. Technical Specifications of the Pegasus Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 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

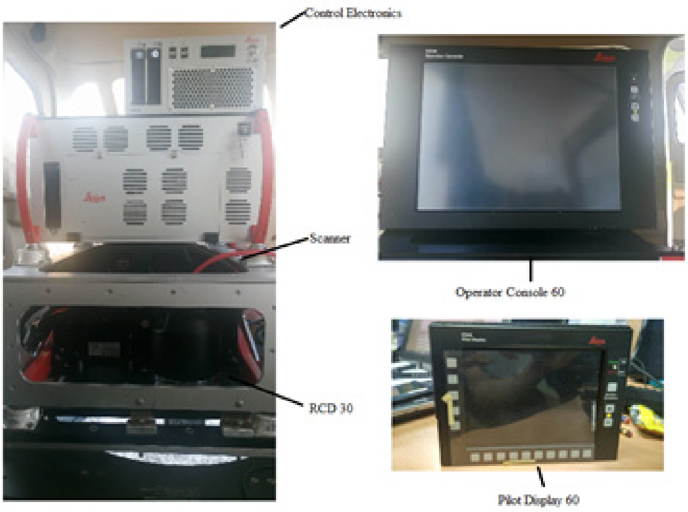


Figure A-1.2. ALS80-HP Sensor

Table A-1.2. Technical Specifications of the ALS80-HP Sensor

Parameter	Specification
Operational altitude	100 to 3500 m max AGL
Maximum measurement rate	1000 kHz
Maximum scan rate	200 Hz for sine; 158 for triangle;120 for raster
Field of view (degrees, full angle, user-adjustable)	0 to 72
Roll Stabilization(automatic adaptive, degrees)	72 – active FOV
Number of returns	unlimited
Number of intensity measurements	3(first, second and third)
Data Storage	ALS80: removable SSD hard disk (800GB each volume)
Power Consumption	922 W @ 22.0-30.3 VDC
Dimensions and weight	Scanner:37 W x 68 L x 26 H cm; 47 kg; Control Electronics: 45 W x 47 D x 25 H cm; 33 kg
Operating temperature	0-40˚C

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

1. CVT-199

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

February 26, 2014

CERTIFICATION

To whom it may concern:

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

Province: **CAVITE**
Station Name: **CVT-199**
Order: **2nd**

Island: **LUZON**
Municipality: **INDANG**
Barangay: **CALUMPANG LEJOS**

PRS92 Coordinates

Latitude:	14° 14' 16.32329"	Longitude:	120° 50' 40.63536"	Ellipsoidal Hgt:	166.20100 m.

WGS84 Coordinates

Latitude:	14° 14' 10.97763"	Longitude:	120° 50' 45.56096"	Ellipsoidal Hgt:	210.38600 m.

PTM Coordinates

Northing:	1574493.218 m.	Easting:	483231.789 m.	Zone:	3

UTM Coordinates

Northing:	1,575,012.80	Easting:	267,428.74	Zone:	51

Location Description

CVT-199
To reach Brgy. Calumpang Lejos, take the nat'l. road from Indang Town Proper towards Naic for about 5 km. Station is located approx. 15 m. NW of the chapel, about 8 m. N of the basketball covered court. Mark is the head of a 4 in. copper nail centered and embedded on a 30 cm. x 30 cm. x 10 cm. concrete block, with inscriptions "CVT-199 2007 NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795440 A**
T.N.: **2014-391**

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

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

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-2.1. CVT-199

2. CVT-194

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

February 04, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **CAVITE**	
	Station Name: **CVT-194 (BLLM-1)**	
Island: **LUZON**	Order: **2nd**	Barangay: **POBLACION**
Municipality: **GENERAL TRIAS**		
	PRS92 Coordinates	
Latitude: **14° 23' 15.01186"**	Longitude: **120° 52' 43.52184"**	Ellipsoidal Hgt: **18.33700 m.**
	WGS84 Coordinates	
Latitude: **14° 23' 9.63386"**	Longitude: **120° 52' 48.43458"**	Ellipsoidal Hgt: **62.18400 m.**
	PTM Coordinates	
Northing: **1591045.311 m.**	Easting: **486924.253 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,591,537.44**	Easting: **271,265.13**	Zone: **51**

Location Description

CVT-194 (BLLM-1)
Is located inside the mun. park, about 100 m. SE from the Gen. Trias Mun. Hall. Mark is a brass rod centered and embedded on a concrete block, with inscriptions "BLLM No. 1 PSC-54".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795255 A**
T.N.: **2014-200**

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

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

CIP/4701/12/09/614

Figure A-2.2. CVT-194

3. BTG-45

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **BATANGAS**
Station Name: **BTG-45**
Order: **2nd**

Island: **LUZON**
Municipality: **TUY**
Barangay: **MALIBU**

	PRS92 Coordinates	
Latitude: **13° 59' 52.18294"**	Longitude: **120° 42' 18.96476"**	Ellipsoidal Hgt: **48.43000 m.**
	WGS84 Coordinates	
Latitude: **13° 59' 46.88216"**	Longitude: **120° 42' 23.91169"**	Ellipsoidal Hgt: **92.94300 m.**
	PTM Coordinates	
Northing: **1547952.281 m.**	Easting: **468159.677 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,548,591.80**	Easting: **252,125.62**	Zone: **51**

Location Description

BTG-45
From Tuy Town Proper, travel S on the road going to Balayan, then turn right to the road going to Brgy. Malibu. Station is located on the NW side of a fenced garden and about 10 m. W of the school bldg. of Santiago De Guzman Elem. School. Mark is the head of a 4 in. copper nail centered and embedded on a 30 cm. x 30 cm. concrete block, with inscriptions "BTG-45 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-444**

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

9 9 0 3 0 4 2 0 1 4 1 6 0 1 1 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-2.3. BTG-45

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

1. CVT-3051

Table A-3.1. CVT-3051

Project Information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CVT-199 --- CVT-3051 (B1)	CVT-199	CVT-3051	Fixed	0.073	0.128	12°58'47"	16463.417	-145.079

Acceptance Summary

Processed	Passed	Flag	Fail
1	0	1	0

CVT-199 - CVT-3051 (3:06:13 PM-4:03:02 PM) (S1)

Baseline observation:	CVT-199 --- CVT-3051 (B1)
Processed:	9/2/2015 11:27:19 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.073 m
Vertical precision:	0.128 m
RMS:	0.006 m
Maximum PDOP:	9.772
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	9/1/2015 3:06:41 PM (Local: UTC+8hr)
Processing stop time:	9/1/2015 4:03:02 PM (Local: UTC+8hr)
Processing duration:	00:56:21
Processing interval:	1 second

1

Vector Components (Mark to Mark)

From:	CVT-199				
Grid		Local		Global	
Easting	267428.741 m	Latitude	N14°14'16.32329"	Latitude	N14°14'10.97763"
Northing	1575012.795 m	Longitude	E120°50'40.63536"	Longitude	E120°50'45.56096"
Elevation	167.120 m	Height	166.201 m	Height	210.386 m

To:	CVT-3051				
Grid		Local		Global	
Easting	271276.565 m	Latitude	N14°22'58.33330"	Latitude	N14°22'52.95639"
Northing	1591024.612 m	Longitude	E120°52'44.06059"	Longitude	E120°52'48.97372"
Elevation	22.137 m	Height	21.122 m	Height	64.983 m

Vector					
ΔEasting	3847.824 m	NS Fwd Azimuth	12°58'47"	ΔX	-1068.623 m
ΔNorthing	16011.817 m	Ellipsoid Dist.	16463.417 m	ΔY	-5421.802 m
ΔElevation	-144.982 m	ΔHeight	-145.079 m	ΔZ	15509.176 m

Standard Errors

Vector errors:					
σ ΔEasting	0.029 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.036 m
σ ΔNorthing	0.020 m	σ Ellipsoid Dist.	0.019 m	σ ΔY	0.058 m
σ ΔElevation	0.065 m	σ ΔHeight	0.065 m	σ ΔZ	0.029 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0012710639		
Y	-0.0011111494	0.0033830758	
Z	-0.0004897536	0.0012701754	0.0008644866

2. GC-2

Table A-3.2. GC-2

CVT-194 - GC-2 (12:30:05 PM-5:29:00 PM) (S3)

Baseline observation:	CVT-194 --- GC-2 (B3)
Processed:	6/23/2016 4:43:59 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.005 m
Vertical precision:	0.008 m
RMS:	0.008 m
Maximum PDOP:	4.511
Ephemeris used:	Broadcast
Antenna model:	NGS Relative
Processing start time:	6/1/2016 12:30:28 PM (Local: UTC+8hr)
Processing stop time:	6/1/2016 5:29:00 PM (Local: UTC+8hr)
Processing duration:	04:58:32
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	CVT-194				
Grid		**Local**		**Global**	
Easting	271265.139 m	**Latitude**	N14°23'15.01186"	**Latitude**	N14°23'09.63386"
Northing	1591537.437 m	**Longitude**	E120°52'43.52183"	**Longitude**	E120°52'48.43458"
Elevation	19.356 m	**Height**	18.337 m	**Height**	62.184 m

To:	GC-2				
Grid		**Local**		**Global**	
Easting	276510.220 m	**Latitude**	N14°22'03.22135"	**Latitude**	N14°21'57.85198"
Northing	1589282.856 m	**Longitude**	E120°55'39.22621"	**Longitude**	E120°55'44.14039"
Elevation	38.946 m	**Height**	38.103 m	**Height**	82.125 m

Vector					
ΔEasting	5245.082 m	**NS Fwd Azimuth**	112°44'00"	**ΔX**	-4808.073 m
ΔNorthing	-2254.581 m	**Ellipsoid Dist.**	5707.790 m	**ΔY**	-2217.178 m
ΔElevation	19.590 m	**ΔHeight**	19.766 m	**ΔZ**	-2132.143 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**	0.003 m
σ ΔElevation	0.004 m	**σ ΔHeight**	0.004 m	**σ ΔZ**	0.002 m

2

3. GC-1

Table A-3.3. GC-1

Vector Components (Mark to Mark)

From:	CVT-194				
Grid		Local		Global	
Easting	271265.139 m	Latitude	N14°23'15.01186"	Latitude	N14°23'09.63386"
Northing	1591537.437 m	Longitude	E120°52'43.52183"	Longitude	E120°52'48.43458"
Elevation	19.356 m	Height	18.337 m	Height	62.184 m

To:	GC-1				
Grid		Local		Global	
Easting	276510.990 m	Latitude	N14°22'02.99339"	Latitude	N14°21'57.62404"
Northing	1589275.842 m	Longitude	E120°55'39.25400"	Longitude	E120°55'44.16819"
Elevation	38.698 m	Height	37.855 m	Height	81.878 m

Vector					
ΔEasting	5245.852 m	NS Fwd Azimuth	112°47'42"	ΔX	-4809.557 m
ΔNorthing	-2261.595 m	Ellipsoid Dist.	5711.270 m	ΔY	-2216.320 m
ΔElevation	19.342 m	ΔHeight	19.518 m	ΔZ	-2138.991 m

Standard Errors

Vector errors:					
σ ΔEasting	0.008 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.009 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.007 m	σ ΔY	0.005 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000811702		
Y	-0.0000062897	0.0000293977	
Z	-0.0000136491	0.0000092066	0.0000091504

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4. CVT-3123

Table A-3.4. CVT-3123

Project information		Coordinate System	
Name:	I:\Doc\DAC\2016\Fieldwork\Baseline Processing Requests\QZ-352 vs QZN-62 + CVT-3123 vs CVT-199.vce	Name:	UTM
		Datum:	PRS 92
Size:	665 KB	Zone:	51 North (123E)
Modified:	6/7/2016 9:10:46 PM (UTC:8)	Geoid:	EGMPH
Time zone:	Taipei 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)
CVT-199 --- CVT-3123 (B3)	CVT-199	CVT-3123	Fixed	0.001	0.001	121°10'48"	43.218	1.326
CVT-3123 --- CVT-199 (B4)	CVT-199	CVT-3123	Fixed	0.002	0.003	121°11'34"	43.216	1.383

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

CVT-199 - CVT-3123 (6:10:41 AM-2:38:11 PM) (S3)

Baseline observation:	CVT-199 --- CVT-3123 (B3)
Processed:	6/7/2016 9:18:19 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.001 m
RMS:	0.001 m
Maximum PDOP:	5.311
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	5/3/2016 6:11:22 AM (Local: UTC+8hr)
Processing stop time:	5/3/2016 2:38:11 PM (Local: UTC+8hr)
Processing duration:	08:26:49
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	CVT-199				
Grid		Local		Global	
Easting	267428.741 m	Latitude	N14°14'16.32329"	Latitude	N14°14'10.97763"
Northing	1575012.795 m	Longitude	E120°50'40.63536"	Longitude	E120°50'45.56096"
Elevation	167.120 m	Height	166.201 m	Height	210.386 m

To:	CVT-3123				
Grid		Local		Global	
Easting	267465.517 m	Latitude	N14°14'15.59521"	Latitude	N14°14'10.24962"
Northing	1574990.072 m	Longitude	E120°50'41.86874"	Longitude	E120°50'46.79435"
Elevation	168.445 m	Height	167.527 m	Height	211.713 m

Vector					
ΔEasting	36.776 m	NS Fwd Azimuth	121°10'48"	ΔX	-35.227 m
ΔNorthing	-22.723 m	Ellipsoid Dist.	43.218 m	ΔY	-13.131 m
ΔElevation	1.325 m	ΔHeight	1.326 m	ΔZ	-21.362 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'01"	σ ΔX	0.000 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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000001903		
Y	-0.0000001733	0.0000004088	
Z	-0.0000000653	0.0000001166	0.0000001007

5. PB-1

Table A-3.5. PB-1

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	WGS 1984
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
PB-1 --- CVT-194 (B1)	CVT-194	PB-1	Fixed	0.004	0.017	88°08'29"	9467.724	25.384

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

PB-1 - CVT-194 (4:15:24 AM-8:06:34 AM) (S1)

Baseline observation:	PB-1 --- CVT-194 (B1)
Processed:	2/4/2014 9:50:26 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.017 m
RMS:	0.005 m
Maximum PDOP:	2.254
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	2/3/2014 4:15:24 AM (Local: UTC+8hr)
Processing stop time:	2/3/2014 8:06:34 AM (Local: UTC+8hr)
Processing duration:	03:51:10
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	CVT-194				
Grid		Local		Global	
Easting	271413.844 m	Latitude	N14°23'09.63386"	Latitude	N14°23'09.63386"
Northing	1591468.703 m	Longitude	E120°52'48.43458"	Longitude	E120°52'48.43458"
Elevation	19.356 m	Height	62.184 m	Height	62.184 m

To:	PB-1				
Grid		Local		Global	
Easting	280881.093 m	Latitude	N14°23'19.56635"	Latitude	N14°23'19.56635"
Northing	1591688.776 m	Longitude	E120°58'04.29835"	Longitude	E120°58'04.29835"
Elevation	44.199 m	Height	87.568 m	Height	87.568 m

Vector					
ΔEasting	9467.249 m	NS Fwd Azimuth	88°08'29"	ΔX	-8091.412 m
ΔNorthing	220.073 m	Ellipsoid Dist.	9467.724 m	ΔY	-4906.972 m
ΔElevation	24.843 m	ΔHeight	25.384 m	ΔZ	302.003 m

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	0.007 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000191800		
Y	-0.0000293093	0.0000523957	
Z	-0.0000093650	0.0000161874	0.0000064708

2

6. BTG-45A

Table A-3.6. BTG-45A

Project Information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
BTG-45 --- BTG-45A (B1)	BTG-45	BTG-45A	Fixed	0.001	0.001	175°32'41"	6.995	0.659

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

BTG-45 - BTG-45A (7:15:33 AM-11:52:39 AM) (S1)

Baseline observation:	BTG-45 --- BTG-45A (B1)
Processed:	9/2/2015 11:37:56 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.001 m
RMS:	0.000 m
Maximum PDOP:	2.331
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	9/1/2015 7:15:33 AM (Local: UTC+8hr)
Processing stop time:	9/1/2015 11:52:39 AM (Local: UTC+8hr)
Processing duration:	04:37:06
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	BTG-45				
Grid		Local		Global	
Easting	252125.624 m	Latitude	N13°59'52.18294"	Latitude	N13°59'46.88216"
Northing	1548591.799 m	Longitude	E120°42'18.96476"	Longitude	E120°42'23.91169"
Elevation	49.818 m	Height	48.430 m	Height	92.943 m

To:	BTG-45A				
Grid		Local		Global	
Easting	252126.100 m	Latitude	N13°59'51.95603"	Latitude	N13°59'46.65526"
Northing	1548584.818 m	Longitude	E120°42'18.98286"	Longitude	E120°42'23.92980"
Elevation	50.478 m	Height	49.089 m	Height	93.602 m

Vector					
ΔEasting	0.476 m	NS Fwd Azimuth	175°32'41"	ΔX	-1.655 m
ΔNorthing	-6.981 m	Ellipsoid Dist.	6.995 m	ΔY	1.723 m
ΔElevation	0.659 m	ΔHeight	0.659 m	ΔZ	-6.607 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'12"	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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000002866		
Y	-0.0000001658	0.0000003931	
Z	-0.0000000756	0.0000000861	0.0000001315

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. 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	
		ENGR. LOUIE P. BALICANTA	
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUNA	
		LOVELYN ASUNCION	
		ENGR. GEROME B. HIPOLITO	
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP TCAGP
		AUBREY MATIRA	
	Research Associate	ENGR. LARAH PARAGAS	
		PAULINE JOANNE ARCEO	
		MARY CATHERINE ELIZABETH BALIGUAS	
		JONALYN GONZALES	
		FAITH JOY SABLE	
		KRISTINE JOY ANDAYA	
Ground Survey, Data Download and Transfer	Research Associate	ENGR. RENAN PUNTO	
		MA. VERLINA TONGA	
		ENGR. KENNETH QUISADO	
LiDAR Operation/ Ground Survey	Research Associate	ENGR. RENAN PUNTO	
		ENGR. DAN ALDOVINO	
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
		TSG. CEBU	
	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. RAUL SAMAR	
		CAPT. FRANCO PEPITO	
		CAPT. CAESAR ALFONSO II	
		CAPT. DANTHONY LOGRONIO	
		CAPT. CEDRIC DE ASIS	

Annex 5. Data Transfer Sheet for Cañas Floodplain

DATA TRANSFER SHEET
Apr 4, 2014

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	
Jan 24, 2014	1023P	1BLK18B024A	PEGASUS	958MB	1.01MB	4.74MB	52.6MB	11.5GB	111KB	9.28GB	59.8GB	8.34MB	109B	245B	33.3KB	N/A	Z:\Airborne_Raw\1023P
Jan 25, 2014	1027P	1BLK18A025A	PEGASUS	1.51GB	1.62MB	5.69MB	194MB	7.11GB	83.9KB	14.3GB	N/A	8.71MB	112B	718B	105KB	N/A	Z:\Airborne_Raw\1027P
Jan 28, 2014	1031P	1BLK18C028A	PEGASUS	1.67GB	1.63MB	5.60MB	185MB	N/A	N/A	14.7GB	N/A	8.02MB	110B	82B	40.6KB	N/A	Z:\Airborne_Raw\1031P
Jan 29, 2014	1043P	1BLK18A5029A	PEGASUS	594MB	687KB	3.52MB	125MB	N/A	N/A	6.13GB	N/A	6.76MB	141B	362B	39.2KB	N/A	Z:\Airborne_Raw\1043P
Jan 31, 2014	1051P	1BLK18S031A	PEGASUS	1.29GB	1.60MB	5.47MB	182MB	14.4GB	154KB	13.3GB	N/A	2.28MB	217B	504B	76.5KB	N/A	Z:\Airborne_Raw\1051P
Feb 2, 2014	1059P	1BLK18F033A	PEGASUS	1.04GB	1.13MB	5.61MB	167MB	11.7GB	115KB	10.1GB	N/A	3MB	221B	421B	123KB	N/A	Z:\Airborne_Raw\1059P
Feb 3, 2014	1063P	1BLK18D034A	PEGASUS	1.18GB	852KB	5.17MB	144MB	19.2GB	174KB	18.6GB	N/A	5.95MB	191B	321B	29.3KB	N/A	Z:\Airborne_Raw\1063P
Feb 4, 2014	1067P	1BLK18I035A	PEGASUS	921MB	1.39MB	4.99MB	167MB	11.6GB	111KB	11.5GB	N/A	5.02MB	130B	330B	63.5KB	N/A	Z:\Airborne_Raw\1067P
Feb 5, 2014	1071P	[illegible]	PEGASUS	1.62GB	1.81MB	4.91MB	157MB	16GB	157KB	15.4GB	N/A	2.50MB	164B	411B	95.2KB	N/A	Z:\Airborne_Raw\1071P
Feb 7, 2014	1079P	1BLKEFS038A	PEGASUS	451MB	603MB	3.17MB	132MB	4.97GB	55.8KB	5.51GB	N/A	3.01MB	194B	479B	69.9KB	N/A	Z:\Airborne_Raw\1079P
Feb 8, 2014	1083P	1BLK18J39A	PEGASUS	1.47GB	1.92MB	5.56MB	193MB	22.6GB	157KB	16.5GB	N/A	12.4MB	180B	604B	62.6KB	N/A	Z:\Airborne_Raw\1083P
Feb 9, 2014	1087P	1BLK18K40A	PEGASUS	1.29GB	1.77MB	5.19MB	183MB	16GB	139KB	14.8GB	N/A	10.7MB	188B	420B	32.6KB	N/A	Z:\Airborne_Raw\1087P
Feb 10, 2014	1091P	1BLK18W41A	PEGASUS	2.17GB	2.40MB	8.22MB	171MB	32.7GB	550KB	20.2GB	N/A	10.1MB	185B	425B	66.1KB	N/A	Z:\Airborne_Raw\1091P
Feb 11, 2014	1095P	1BLK18U42A	PEGASUS	1.15GB	1.53MB	7.92MB	235MB	96.9MB	1.61KB	14.9GB	N/A	11.4MB	205B	287B	78.7KB	N/A	Z:\Airborne_Raw\1095P
Feb 12, 2014	1099P	1BLK18US43A	PEGASUS	1.70GB	2.39MB	7.46MB	234MB	N/A	739B	20.7GB	N/A	11.4MB	205B	643B	95.2KB	N/A	Z:\Airborne_Raw\1099P
Feb 13, 2014	1103P	1BLK18VWS44A	PEGASUS	2.13GB	2.39MB	8.99MB	221MB	N/A	N/A	19.8GB	N/A	16.6MB	303B	429B	191KB	N/A	Z:\Airborne_Raw\1103P
Feb 13,2014	1105P	1BLK18T44B	PEGASUS	2.32GB	2.67MB	6.85MB	210MB	N/A	N/A	22.2GB	N/A	16.6MB	303B	394B	161KB	N/A	Z:\Airborne_Raw\1105P
Feb 14,2014	1107P	1BLK18CRS45A	PEGASUS	709MB	1.54MB	7.09MB	215MB	16.7GB	149KB	10.2GB	N/A	12MB	217B	N/A	N/A	N/A	Z:\Airborne_Raw\1107P
Feb 14,2014	1109P	1BLK18US45B	PEGASUS	N/A	1.67MB	5.61MB	183MB	N/A	N/A	15.9GB	N/A	12MB	217B	310B	106KB	N/A	Z:\Airborne_Raw\1109P

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

Feb 15,2014	1111P	1BLK18RS46A	PEGASUS	1.39GB	1.74MB	6.22MB	194MB	19.7GB	172KB	14.7GB	N/A	10.9MB	216B	569B	71KB	N/A	Z:\Airborne_Raw\1111P
Feb 17,2014	1119P	1BLK18C48A	PEGASUS	1.02GB	1.95MB	8.25MB	250MB	21.5GB	195KB	16.8GB	N/A	11.7MB	212MB	520B	41KB	N/A	Z:\Airborne_Raw\1119P
Feb 18, 2014	1123P	1BLK18Q849A	PEGASUS	1.36GB	1.81MB	6.45MB	193MB	N/A	N/A	14.7GB	N/A	12.5MB	213B	504B	43KB	N/A	Z:\Airborne_Raw\1123P
Feb 18,2014	1125P	1BLK18S49B	PEGASUS	374MB	665KB	4.21MB	144MB	N/A	N/A	5.57GB	N/A	12.6MB	213B	282B	79.7KB	N/A	Z:\Airborne_Raw\1125P
Feb 19, 2014	1127P	1BLK18G50A	PEGASUS	985MB	1.54MB	5.26MB	190MB	N/A	N/A	12.1GB	N/A	6.85MB	218B	507B	67.1KB	N/A	Z:\Airborne_Raw\1127P
Feb 20, 2014	1131P	1BLK18Z51A	PEGASUS	1.64GB	2.39MB	7.83MB	219MB	30.3GB	254KB	20GB	90.4GB	13.2MB	133B	910B	91.9KB	N/A	Z:\Airborne_Raw\1131P
Feb 20,2014	1133P	1BLK18Z51B	PEGASUS	1.06GB	1.41MB	4.71MB	166MB	18.9GB	140KB	12.1GB	N/A	13.2MB	133B	266B	91.5KB	N/A	Z:\Airborne_Raw\1133P
Feb 21, 2014	1135P	1BLK18Y52A	PEGASUS	1.54GB	2.04MB	7.96MB	235MB	7.41GB	117KB	17.4GB	33.9GB	7.52MB	133B	335B	91.9KB	N/A	Z:\Airborne_Raw\1135P
Feb 22,2014	1139P	1BLK18X53A	PEGASUS	2.19GB	2.45MB	7.52MB	236MB	29.3GB	236KB	215B	N/A	6.71MB	133B	0B	147KB	N/A	Z:\Airborne_Raw\1139P
Feb 22 2014	1141P	1BLK18S53B	PEGASUS	1.05GB	1.60MB	7.26MB	219MB	24GB	176KB	15.4GB	N/A	6.25MB	157B	410B	171KB	N/A	Z:\Airborne_Raw\1141P
28-Jan	1039P	1BLK18B028A	PEGASUS	2.05	36KB	11.6	165	NA	NA	19.1	NA	7.43	141B	242B	40.5	NA	Z:\Airborne_Raw\1039P

Received from

Name

Position

Signature

Received by

Name JOIDA F. PRIETO

Position SSRS

Signature

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

DATA TRANSFER SHEET
Calabarzon 9/10/15

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	
17-Aug	3307P	1BLK18JS229B	Pegasus	972	756	6.66	171	na	na	9.59	na	18.4	1KB	1KB	1/42	na	Z:\DAC\RAW DATA
18-Aug	3309P	1BLK18AsS230A	Pegasus	1.17	757	7.65	202	na	na	11.9	na	19.4	1KB	1KB	88	na	Z:\DAC\RAW DATA
3-Sep	3373P	1BLK18OS246A	Pegasus	1.81	2.06	9.59	212	na	na	18.2	na	7.67	1KB	1KB	1	na	Z:\DAC\RAW DATA
4-Sep	3377P	1BLK18JS247A	Pegasus	1.29	777	8.1	196	na	na	13.4	na	6.43	1KB	1KB	61.6	na	Z:\DAC\RAW DATA
5-Sep	3381P	1BLK18OS248A	Pegasus	2.12	1.54	10.3	256	na	na	20.6	na	9.05	1KB	1KB	59/59	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature

Received by

Name AC Bongat 9/11/15
Position SSRS
Signature

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

DATA TRANSFER SHEET
CALABARZON 6/72016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	KML (swath)	GnssImu	LogFiles	TestData	RawLaser	RawTDC	RawWFD	WebCam	RCD30 RAW IMAGES	BASE STATION(S)		SERVER LOCATION
													BASE STATION(S)	Base Info (.txt)	
3-May-16	10136L	4BLK18B1 24A	ALS 80	51	463	136	41.7	6.59/3.92	4.64/2.98	NA	275/182	43.4	103	1KB	Z:\DAC\RAW DATA
6-May-16	10142L	4BLK18AB 127A	ALS 80	195	506	151	40.4	9.28	6.39	NA	359	33.4	97	1KB	Z:\DAC\RAW DATA
7-May-16	10144L	4BLKABS1 28A	ALS 80	88	408	115	95.6	3.59	2.3	NA	152	12.9	155	1KB	Z:\DAC\RAW DATA

Received from

Name
Position
Signature

Received by

Name AC Bongat
Position SSRS
Signature 6/20/16

Figure A-5.4. Data Transfer Sheet for Cañas Floodplain – D

DATA TRANSFER SHEET
CALABARZON 7/13/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	KML (swath)	GnssImu	LogFiles	TestData	RawLaser	RawTDC	RawWFD	WebCam	RCD30 RAW IMAGES	BASE STATION(S): BASE STATION(S)	BASE STATION(S): Base Info (.txt)	SERVER LOCATION
13-Jun-16	10161L	4BLK18CF 165A	ALS 80	NA	352	134	79.7	4.65	3.89	NA	145	22	649	1KB	Z:\DAC\RAW DATA
13-Jun-16	10162L	4BLK18CF S165B	ALS 80	NA	353	96.5	21.5	8.99	7.55	NA	262	39.5	649	1KB	Z:\DAC\RAW DATA
15-Jun-16	10165L	4BLK18RN 167A	ALS 80	NA	472	130	43.8	12.7	7.2	NA	285	26.7	653	1KB	Z:\DAC\RAW DATA
15-Jun-16	10166L	4BLK18CF 167B	ALS 80	NA	251	102	124	3.42	2.66	NA	79.3	NA	653	1KB	Z:\DAC\RAW DATA
16-Jun-16	10167L	4BLK18R MNS168A	ALS 80	NA	454	134	44	13.8	8.88	NA	320	36.9	316	1KB	Z:\DAC\RAW DATA

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS: Output LAS	RAW LAS: KML (swath)	LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S): BASE STATION(S)	BASE STATION(S): Base Info (.txt)	OPERATOR LOGS (OPLOG)	FLIGHT PLAN: Actual	FLIGHT PLAN: KML	SERVER LOCATION
June 16, 2016	23462P	1BLK18CF S168A	PEGASUS	2.76	NA	10.4	225	NA	NA	25.7	NA	316	1KB	1KB	359/364/268/ 464/201/203	NA	Z:\DAC\RAW DATA
June 22, 2016	23474P	1BLK18Q1 73A	PEGASUS	1.22	NA	8.87	200	NA	NA	12.7	NA	468	1KB	1KB	268/464/201/ 203	NA	Z:\DAC\RAW DATA

Received from

Name: R. PANTO
Position: RA
Signature: [signature]

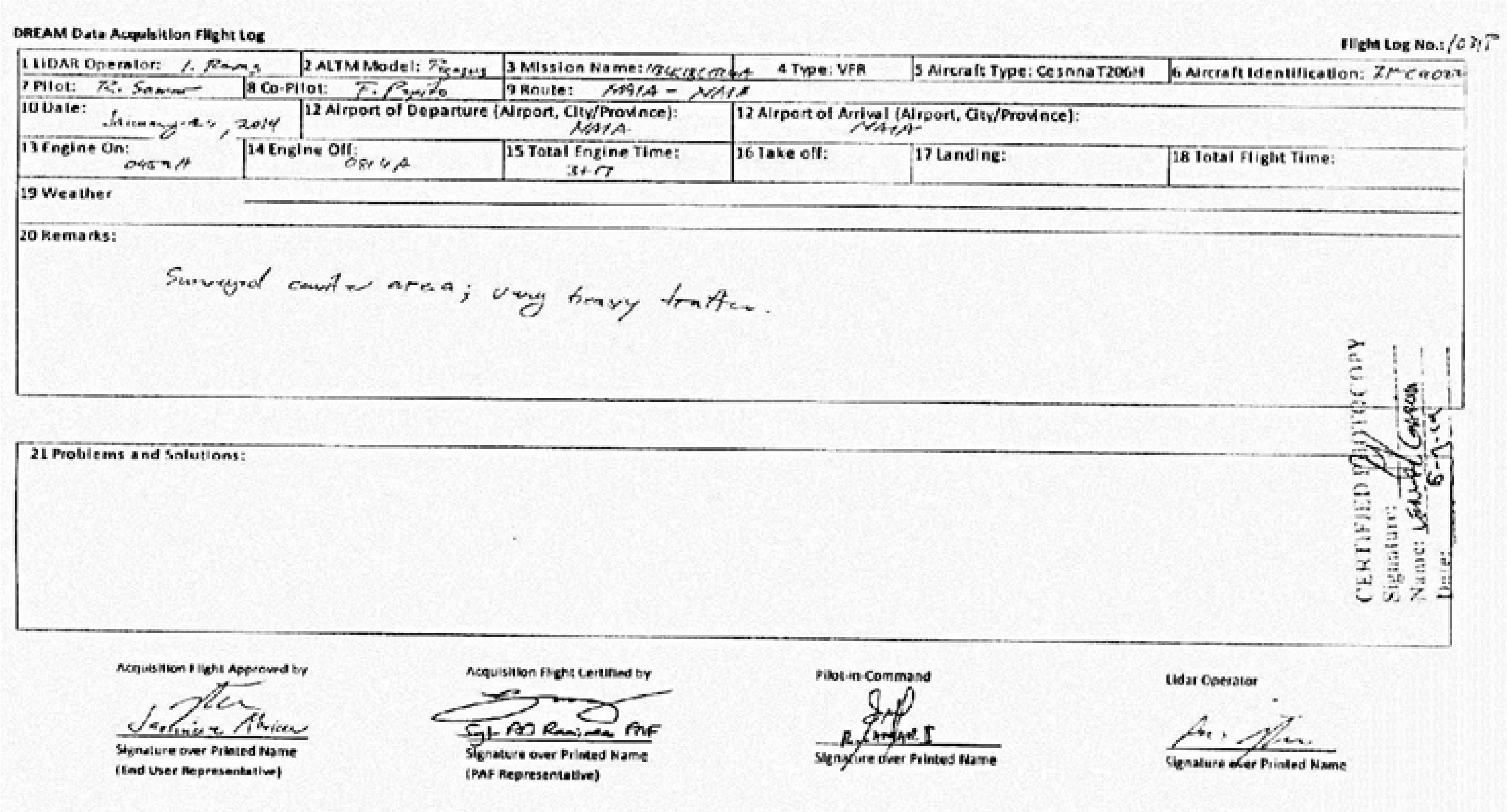
Received by

Name: AC Bongat
Position: SSRS
Signature: [signature] 7/14/16

Figure A-5.5. Data Transfer Sheet for Cañas Floodplain – E

Annex 6. Flight logs for the flight missions

1. Flight Log for 1031P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1031P

1 LIDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: R. Samson	8 Co-Pilot: F. Pupido	9 Route: NAIA – NAIA			
10 Date: January, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather

20 Remarks:

Surveyed ... area; very heavy traffic.

21 Problems and Solutions:

CERTIFIED PHOTOCOPY
Signature:
Name:
Date:

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

Figure A-6.1. Flight Log for Mission 1031P

2. Flight Log for 1039P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1039P

1 LIDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK18B384	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: R. Samar	8 Co-Pilot: F. Pepito	9 Route: NAIA — NAIA			
10 Date: Jan. 24, 2014	12 Airport of Departure (Airport, City/Province): NAIA	12 Airport of Arrival (Airport, City/Province): NAIA			
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks:					
21 Problems and Solutions:					

CERTIFIED PHOTOCOPY
Signature:
Name: Lenny Garcia
Date:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
	SGT (D) Ramirez PAF	R. SAMAR II	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for Mission 1039P

3. Flight Log for 1043P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1043P

1 LIDAR Operator: P. Arceo	2 ALTM Model: Pegasus	3 Mission Name: 1BLK18AS029A [illegible]	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: E. Saman	8 Co-Pilot: N. Aguevia	9 Route: NAIA - NAIA			
10 Date: Jan 29, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0519H	14 Engine Off: 0742H	15 Total Engine Time: 2+23	16 Take off:	17 Landing:	18 Total Flight Time:

19 Weather

20 Remarks:

Data acquired at 1600m AGL

21 Problems and Solutions:

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

CERTIFIED PHOTOCOPY
Signature:
Name:
Date: 6-9-14

Figure A-6.3. Flight Log for Mission 1043P

4. Flight Log for 1063P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1063P

1 LiDAR Operator: L. Paragas	2 ALTM Model: Peg	3 Mission Name: 1BLK18D034A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: E. Samar	8 Co-Pilot: M. Acaweje	9 Route: NAIA - NAIA			
10 Date: Feb 3, 2013	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0519H	14 Engine Off: 0818H	15 Total Engine Time: 2+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy to heavy build up					

20 Remarks:

Dropouts experienced; heavy build up & traffic surveyed 1 line

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alviar	Emmanuel Tendoc	E. Samar	L. Paragas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.4. Flight Log for Mission 1063P

5. Flight Log for 1139P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1139P

1 LIDAR Operator: J. ALVIAR	2 ALTM Model: PEG	3 Mission Name: 1BLK18X53A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: C9022
7 Pilot: F. YEPRO	8 Co-Pilot: A. AGBAYANI	9 Route:			
10 Date: FEB. 22, 2014	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0650	14 Engine Off: 0546	15 Total Engine Time: 3+56	16 Take off:	17 Landing:	18 Total Flight Time: 3+42
19 Weather: cloudy					
20 Remarks: SUCCESSFUL FLIGHT					

21 Problems and Solutions:

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

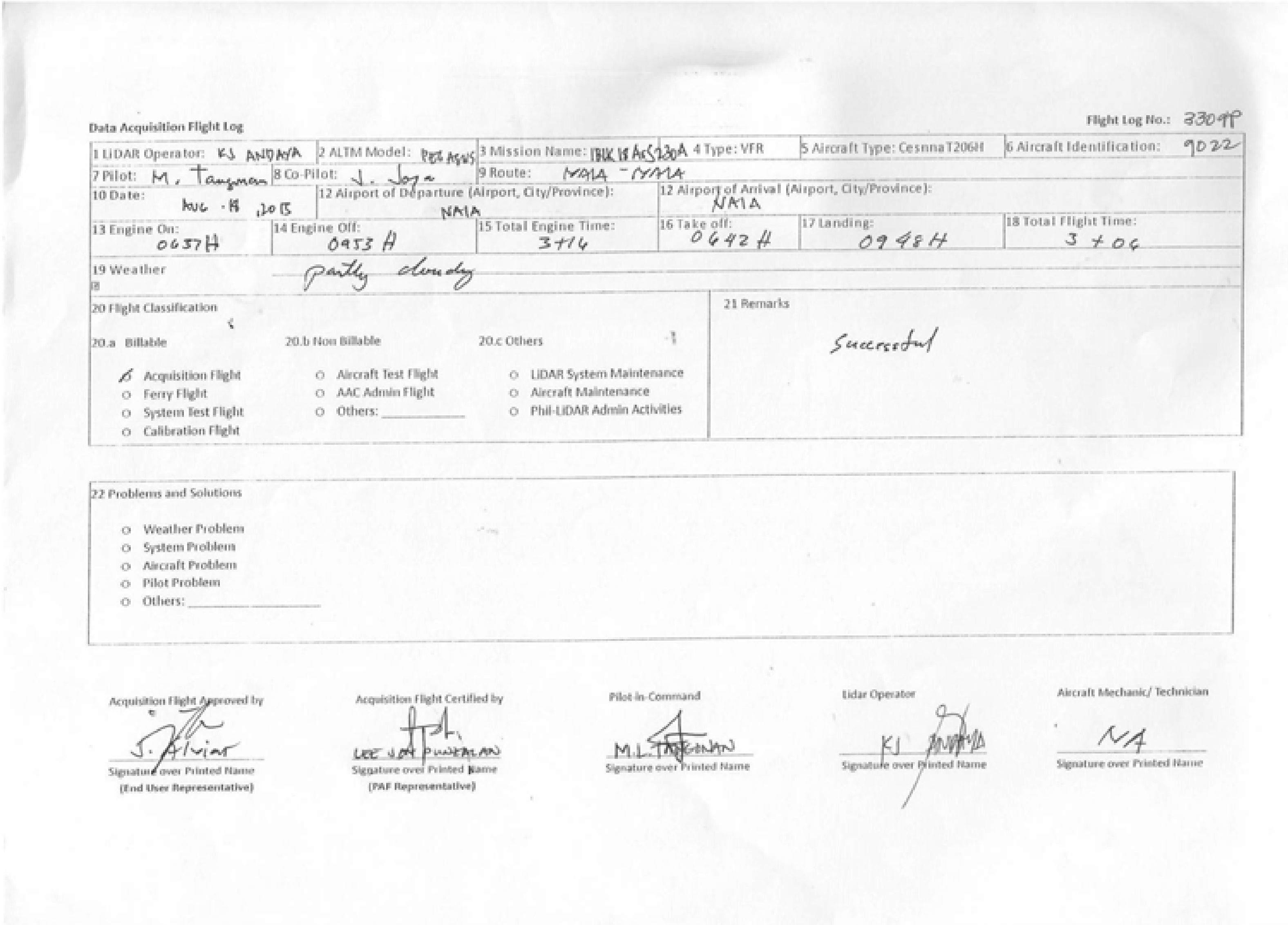
Acquisition Flight Certified by
Sgt. Dae Ramirez
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
AGBAYANI
Signature over Printed Name

Lidar Operator
Jasmine Alviar
Signature over Printed Name

Figure A-6.5. Flight Log for Mission 1139P

6. Flight Log for 3309P Mission



Data Acquisition Flight Log

Flight Log No.: 3309P

1 LiDAR Operator: KJ ANDAYA	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK18ACS230A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. Tangonan	8 Co-Pilot: J. Joya	9 Route: NAIA - NAIA			
10 Date: AUG. 18, 2015	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 0637H	14 Engine Off: 0953 H	15 Total Engine Time: 3+16	16 Take off: 0642 H	17 Landing: 0948H	18 Total Flight Time: 3+06
19 Weather: 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

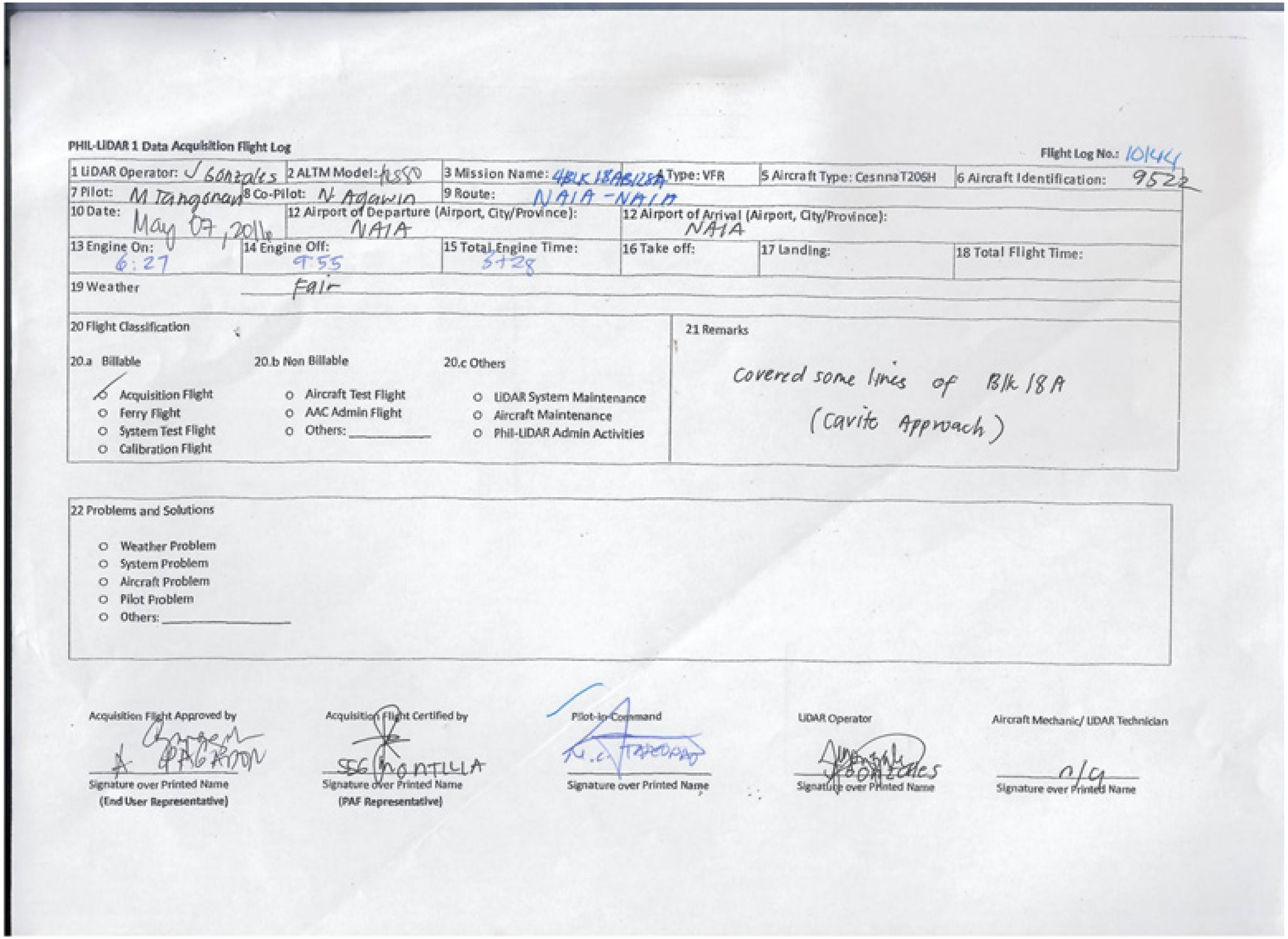
Successful

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/ Technician
J. Alviar	LEE JAY PUNZALAN	M.L. TANGONAN	KJ ANDAYA	NA
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-6.6. Flight Log for Mission 3309P

7. Flight Log for 10144L Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 10144

1 LiDAR Operator: J Gonzales	2 ALTM Model: A550	3 Mission Name: 4BLK18ABI28A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9522
7 Pilot: M Tangonan	8 Co-Pilot: N Agawin	9 Route: NAIA - NAIA			
10 Date: May 07, 2016	12 Airport of Departure (Airport, City/Province): NAIA		12 Airport of Arrival (Airport, City/Province): NAIA		
13 Engine On: 6:27	14 Engine Off: 9:55	15 Total Engine Time: 3+28	16 Take off:	17 Landing:	18 Total Flight Time:
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

Covered some lines of Blk 18A (Cavite Approach)

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
A. Pagaron	SSG Montilla	M.C. Tangonan	J. Gonzales	n/a
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-6.7. Flight Log for Mission 10144L

8. Flight Log for 23462P Mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 23462

1 LiDAR Operator: N. BALIGUAS	2 ALTM Model: PEG	3 Mission Name: 1BLK18RL163A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: C. ALFONSO III	8 Co-Pilot: C. DE ASIS	9 Route:			
10 Date: June 14, 2016	12 Airport of Departure (Airport, City/Province): RPLL		12 Airport of Arrival (Airport, City/Province): RPLL		
13 Engine On: 0624	14 Engine Off: 0959	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed 18 lines in Dasmariñas, Cavite

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
	TSg Cejon PAF	C. Alfonso III	N. Baliguas	NA
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-6.8. Flight Log for Mission 23462P

Annex 7. Flight status reports

CALABARZON
(January 26-February 22, 2014, August 18, 2015, May 7, 2016 and June 16, 2016)

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1031P	BLK 18CD	1BLK18C026A	I. Roxas	26 Jan 2014	Acquired data at 1000m, broken lines and irregular survey pattern due to very heavy traffic and tower restrictions
1039P	BLK 18BC	1BLK18B028A	I. Roxas	28 Jan 2014	Data acquired at 1000m AGL
1043P	BLK 18AS	1BLK18AS029A	P.J. Arceo	29 Jan 2014	Data acquired at 1000m AGL
1063P	BLK 18D	1BLK18D034A	L. Paragas	3 Feb 2014	Dropouts experienced, heavy build up and traffic, surveyed 1 line
1139P	BLK 18X & (ABCY)s	1BLK18X53A	J. Alviar	22 Feb 2014	Surveyed gaps in southern Cavite, voids in BLK 18Z and covered BLK 18X at 1200m flying height
3309P	BLK 18AsS	1BLK18AsS230A	KJ ANDAYA	18 Aug 2015	Voids due to low cloud cover, lines cut due to air traffic Without Digitizer and Camera
10144L	BLK18 AB	4BLK18ABS128A	J. Gonzales	7 May 2016	Covered some lines of Blk 18 AB
23462P	BLK18CF	1BLK18CFS168A	MCE BALIGUAS	16 June 2016	Covered 25 lines over Dasmariñas

LAS BOUNDARIES PER FLIGHT

Flight No. : 1031P
Area: BLK 18BC
Mission Name: 1BLK18B028A

LAS

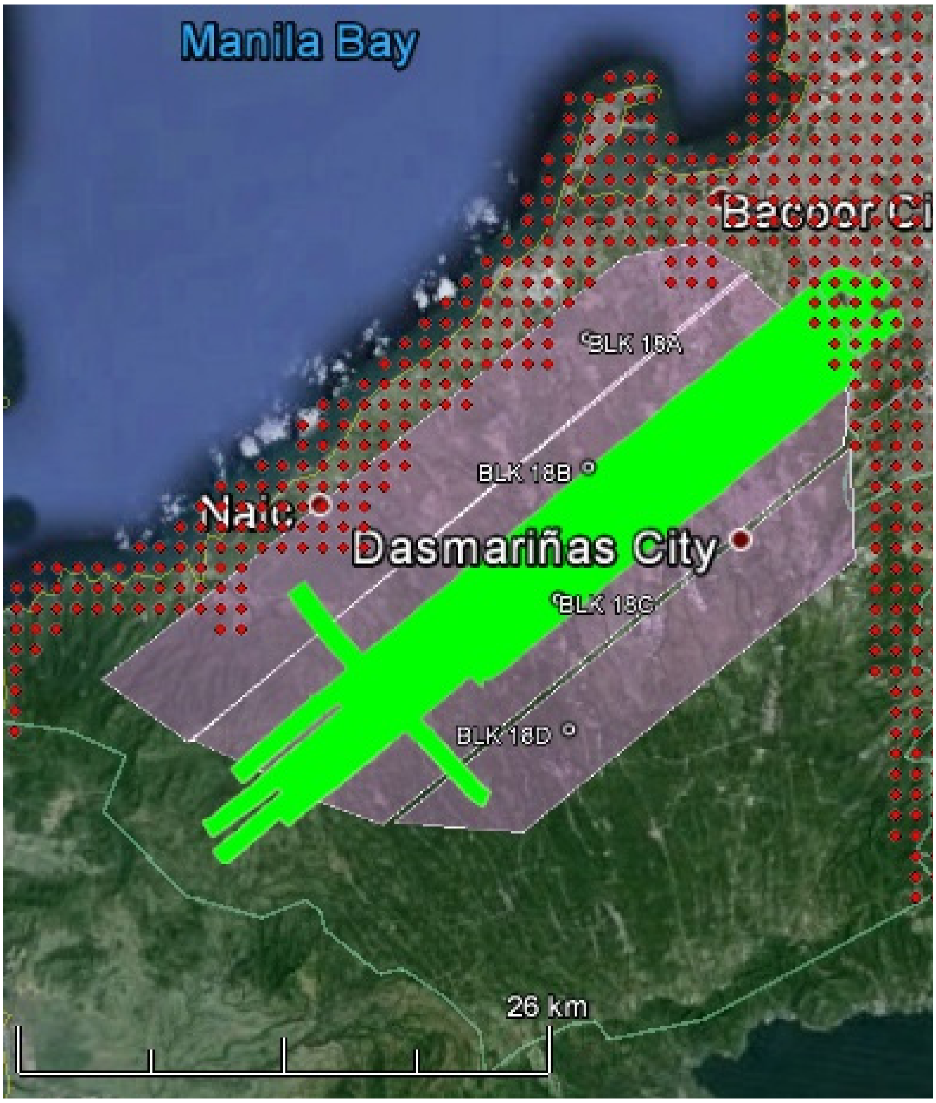


Figure A-7.1. Swath for Flight No. 1031P

Flight No. : 1039P
Area: BLK 18BC
Mission Name: 1BLK18B028A

LAS

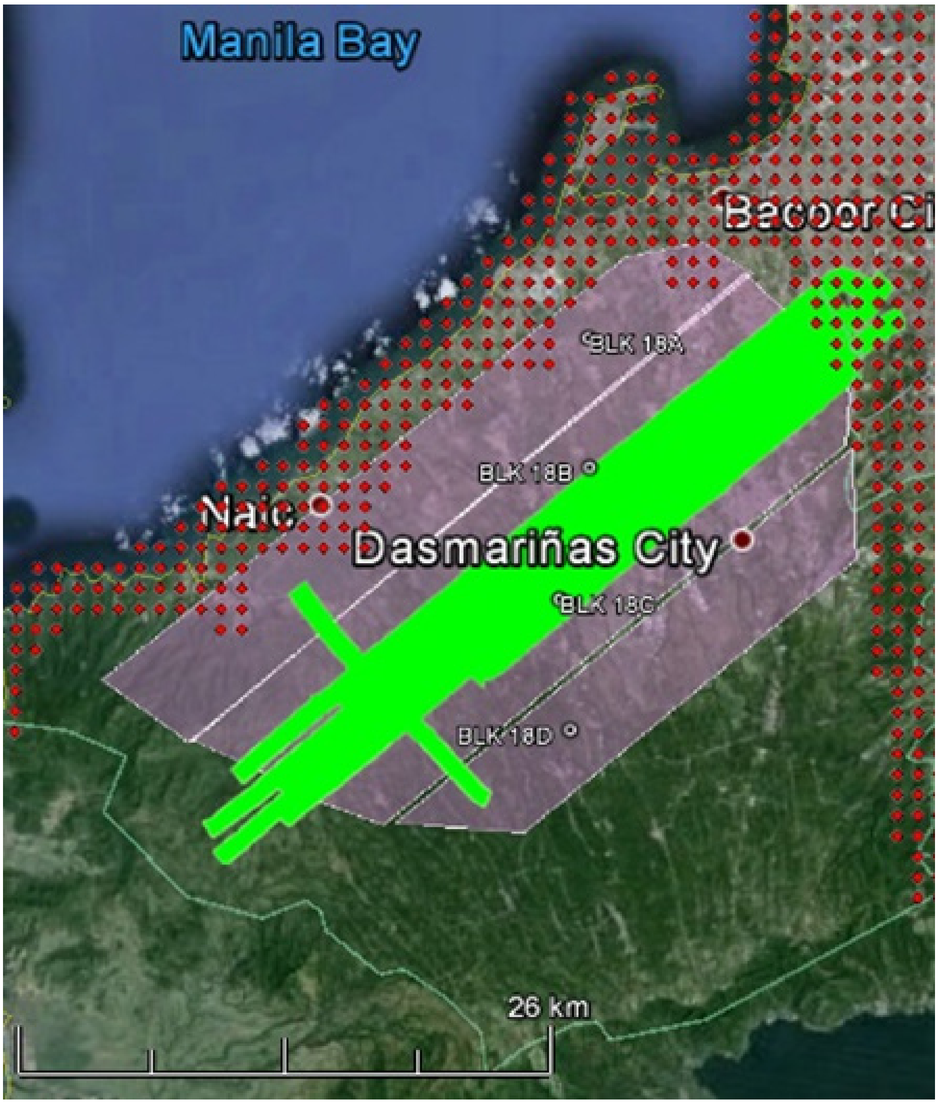


Figure A-7.2. Swath for Flight No. 1039P

Flight No. : 1043P
Area: BLK 18AS
Mission Name: 1BLK18AS029A

LAS

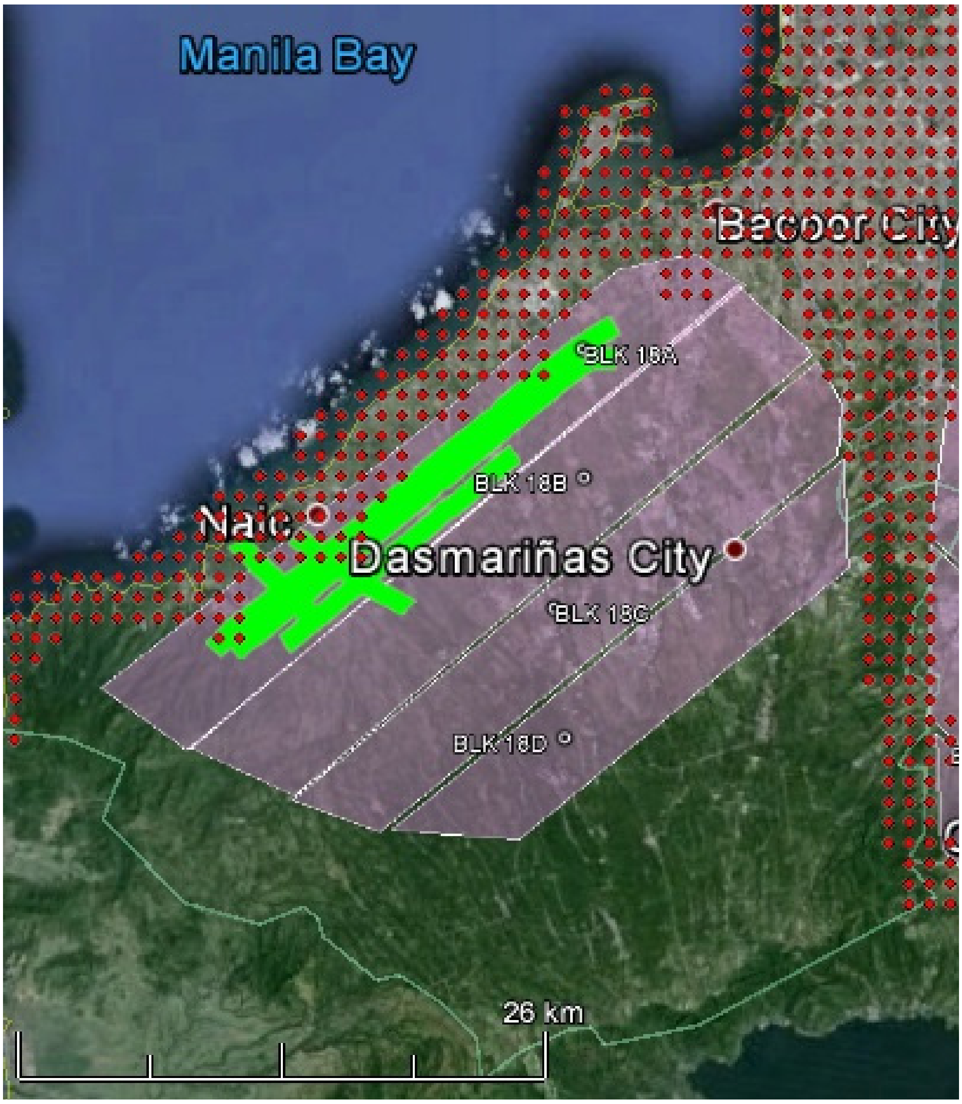


Figure A-7.3. Swath for Flight No. 1043P

Flight No. : 1063P
Area: BLK 18D
Mission Name: 1BLK18D034A

LAS

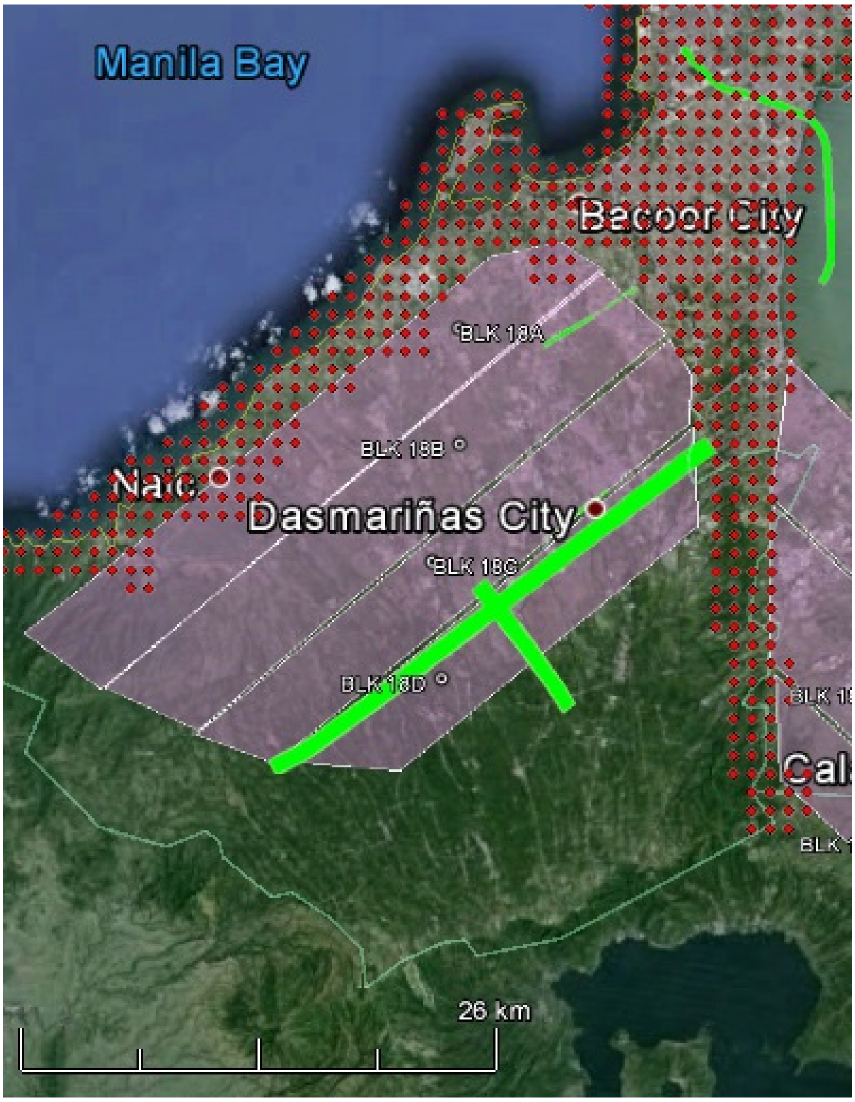


Figure A-7.4. Swath for Flight No. 1063P

Flight No. :	1139P (renamed from 1137P)
Area:	BLK 18X & (ABCY)s
Mission Name:	1BLK18S53A

LAS

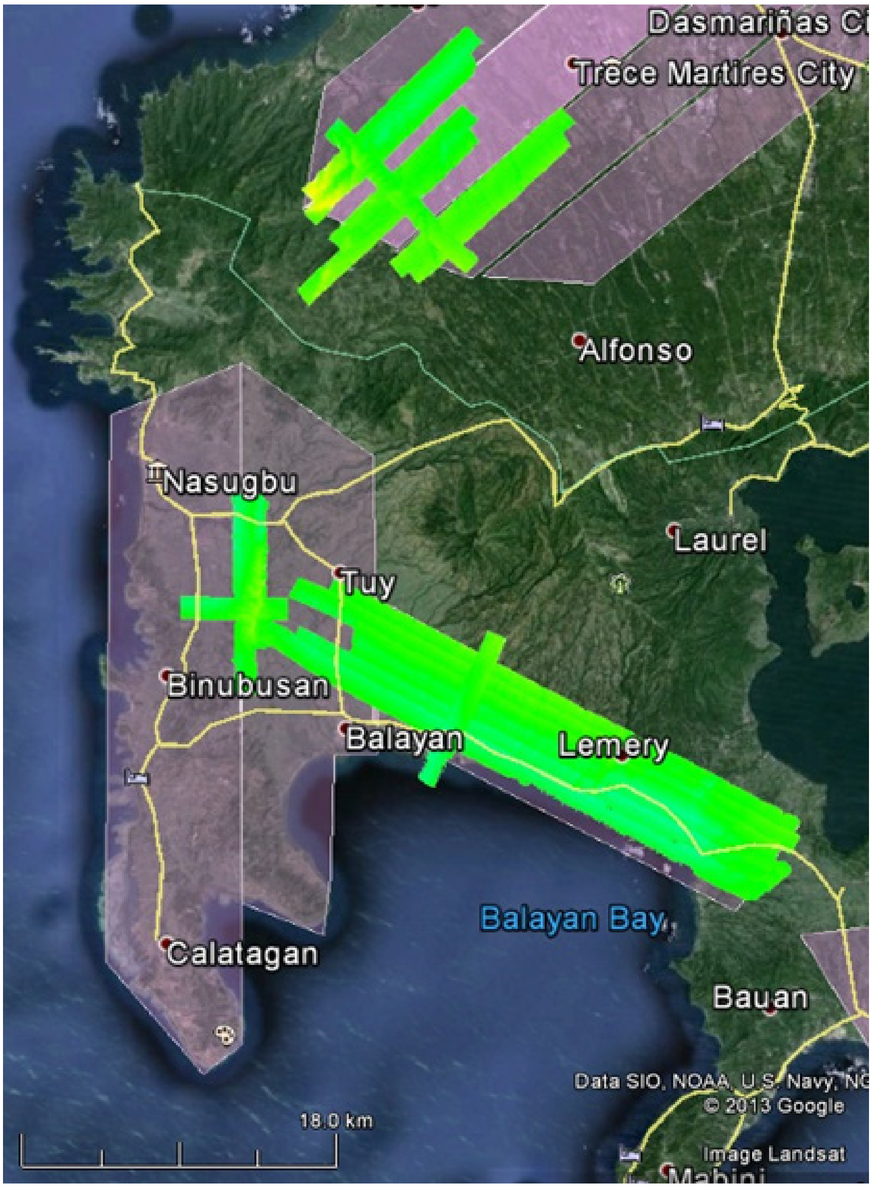


Figure A-7.4. Swath for Flight No. 1063P

Flight No. : 3309P
Area: BLK 18
Mission Name: 1BLK18AsS230A

LAS

Figure A-7.6. Swath for Flight No. 3309P

Flight No. : 10144L
Area: BLK18AB
Mission Name: 4BLK18ABS128A

LAS

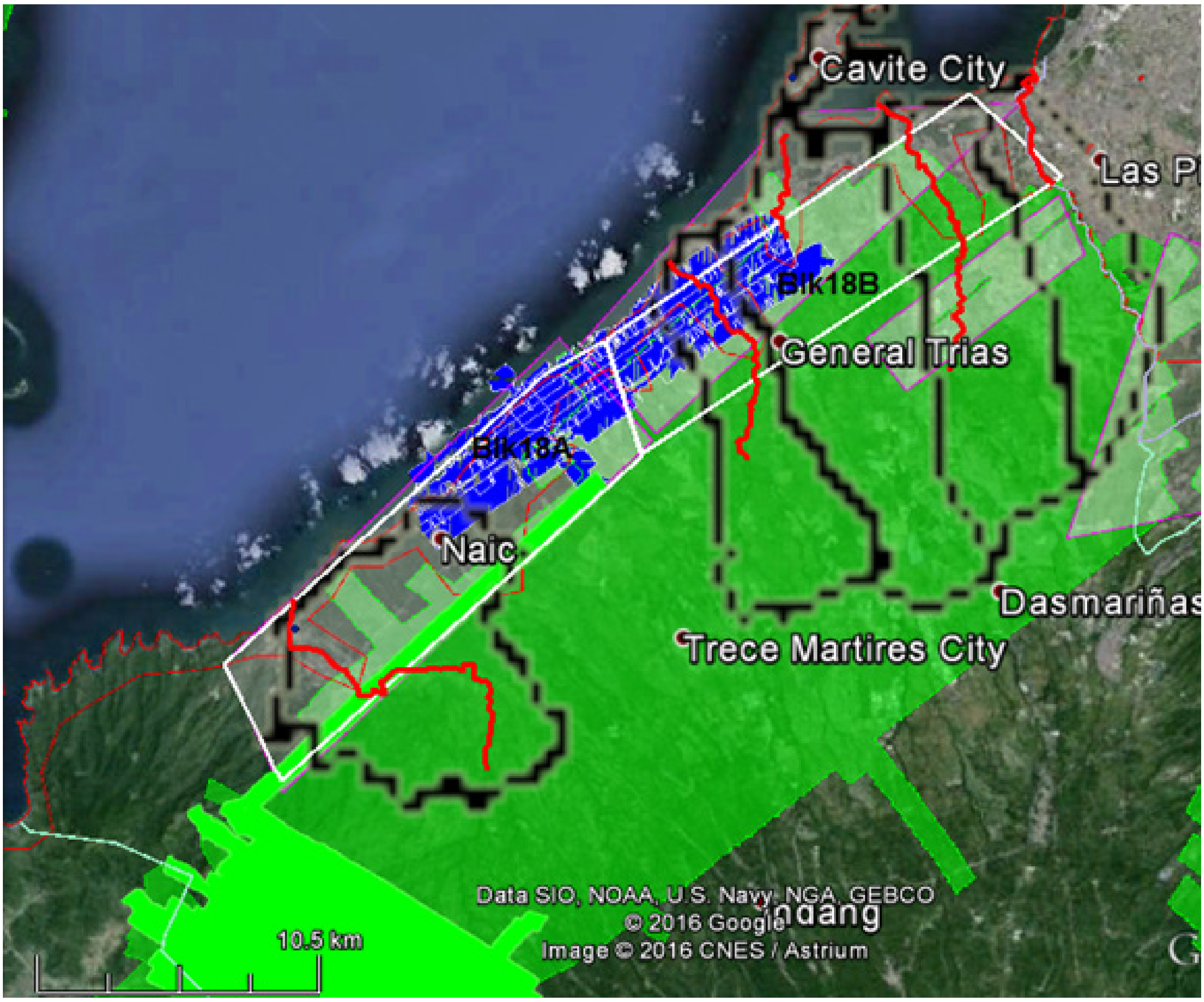


Figure A-7.7. Swath for Flight No. 10144L

Flight No. :	23462P
Area:	BLK18RM, BLK18RN
Mission Name:	4BLK18RMNS168A

LAS

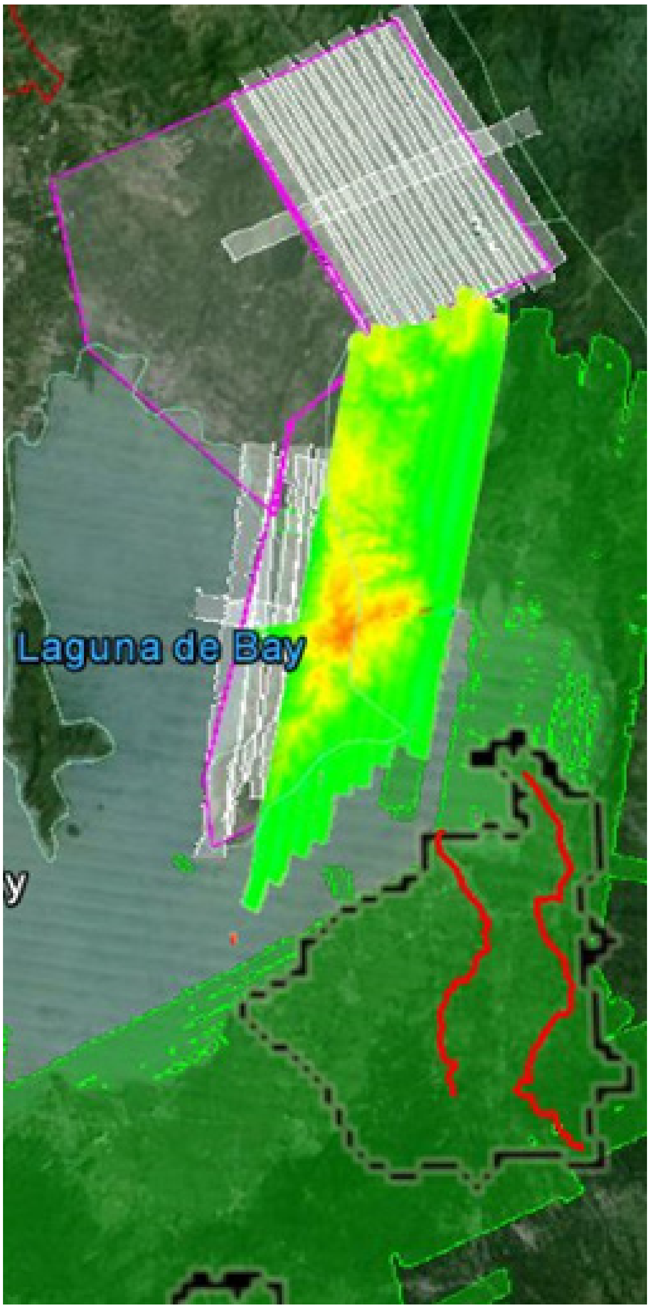


Figure A-7.8. Swath for Flight No. 23462P

Annex 8. Mission Summary Reports

Table A-8.1. Flight Status Report for Mission Blk18B_supplement

Flight Area	CALABARZON
Mission Name	Blk18B_supplement
Inclusive Flights	3309P
Range data size	11.9GB
POS data size	202 MB
Base data size	19.4 MB
Image	N/A
Transfer date	September 11, 2015
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
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)	2.9
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	0.000273
IMU attitude correction stdev (<0.001deg)	0.000737
GPS position stdev (<0.01m)	0.0103
Minimum % overlap (>25)	43.55%
Ave point cloud density per sq.m. (>2.0)	2.82
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	171
Maximum Height	426.11 m
Minimum Height	57.0 m
Classification (# of points)	
Ground	95,328,099
Low vegetation	65,505,303
Medium vegetation	120,204,321
High vegetation	132,825,937
Building	23,238,819
Orthophoto	No
Processed By	Engr. Analyn Naldo, Aljon Rie Araneta, Jovy Narisma

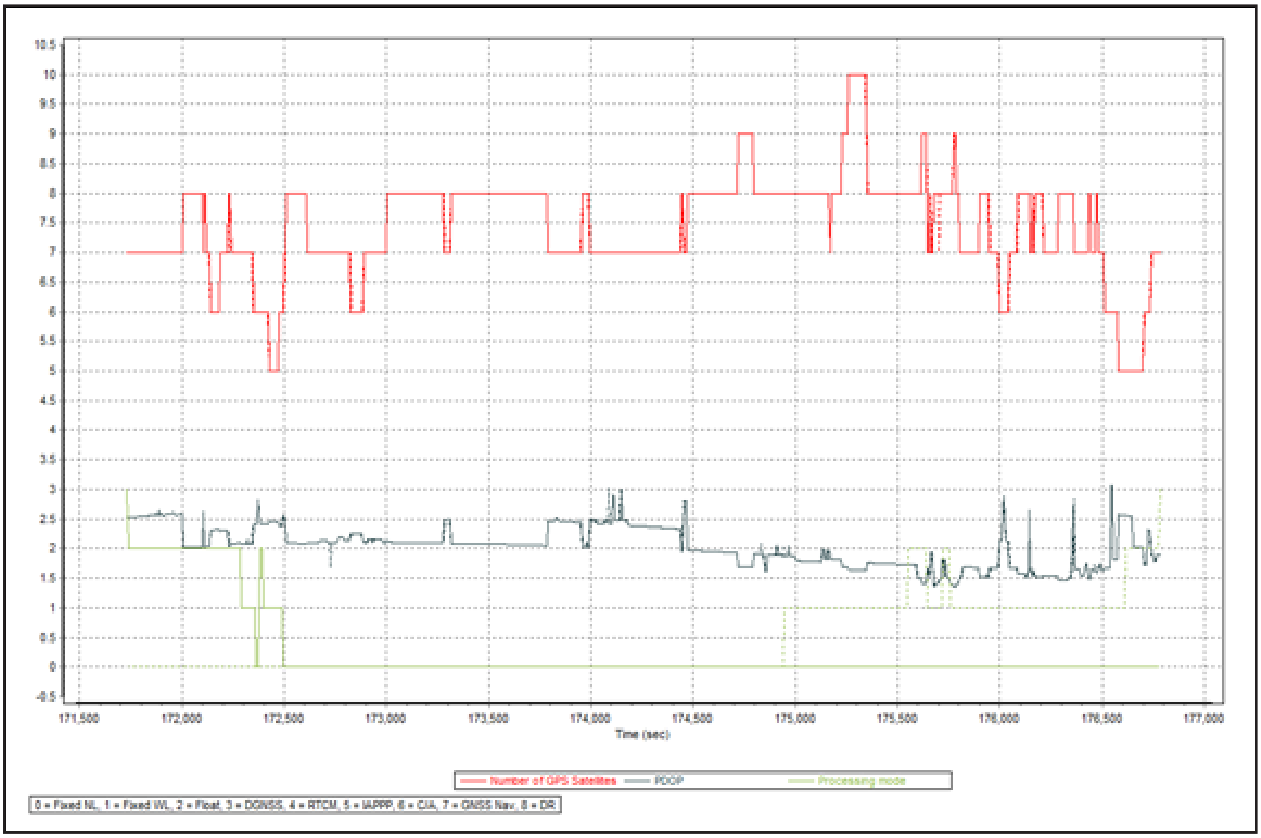


Figure A-8.1. Solution Status

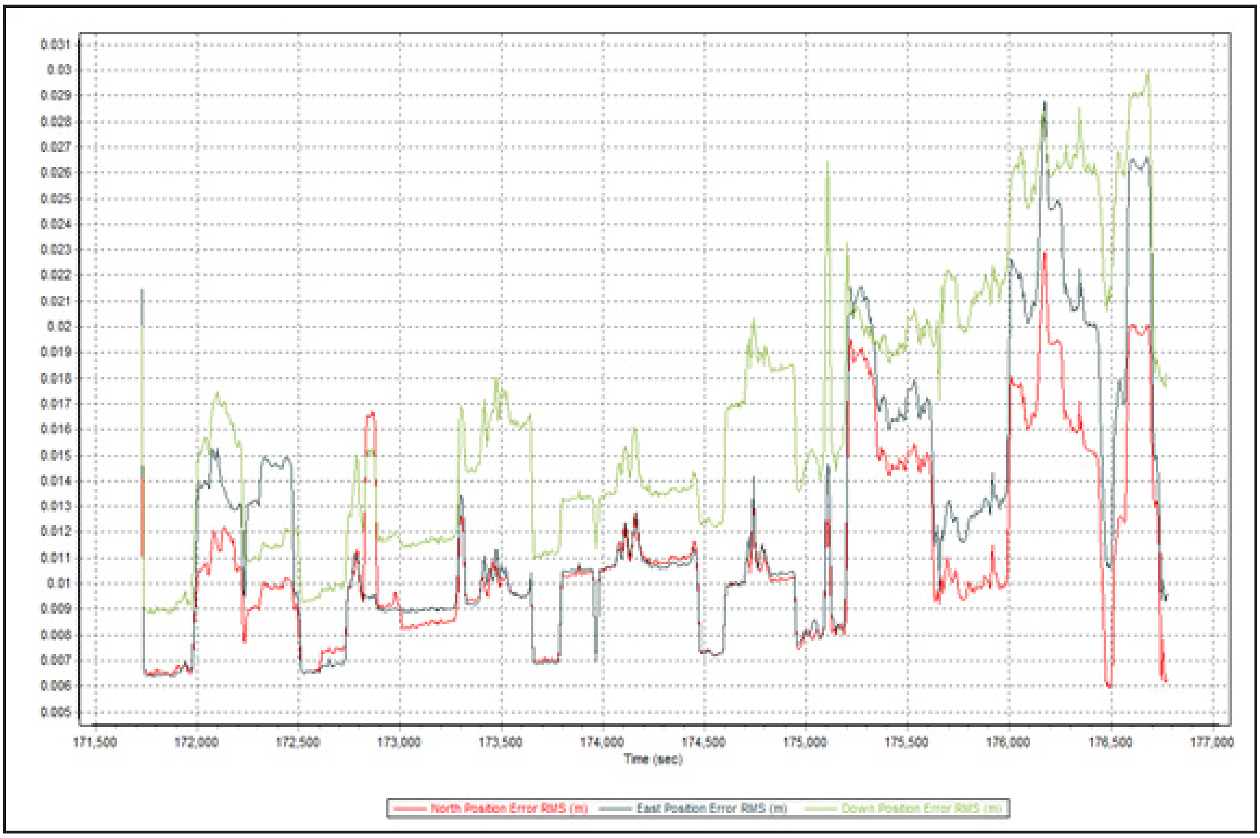


Figure A-8.2 Smoothed Performance Metrics Parameters

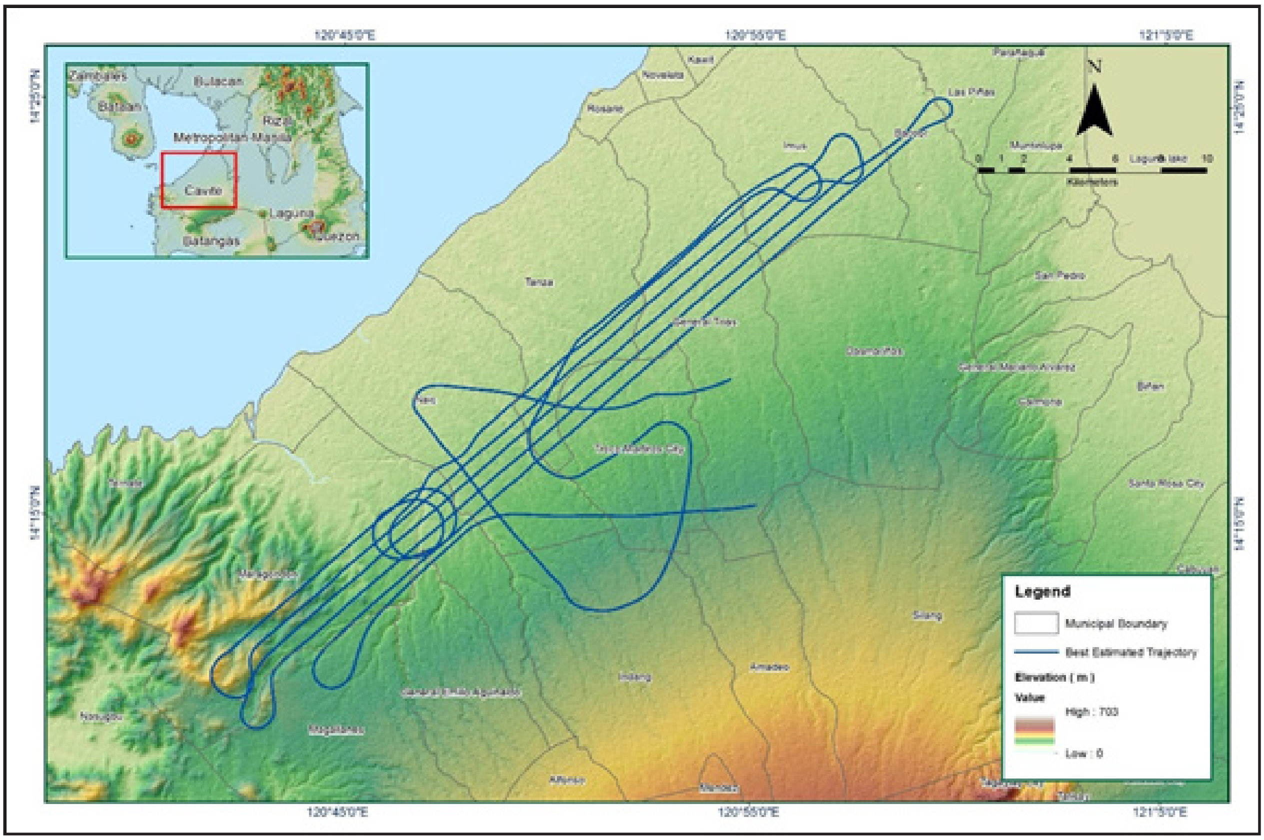


Figure A-8.3. Best Estimated Trajectory

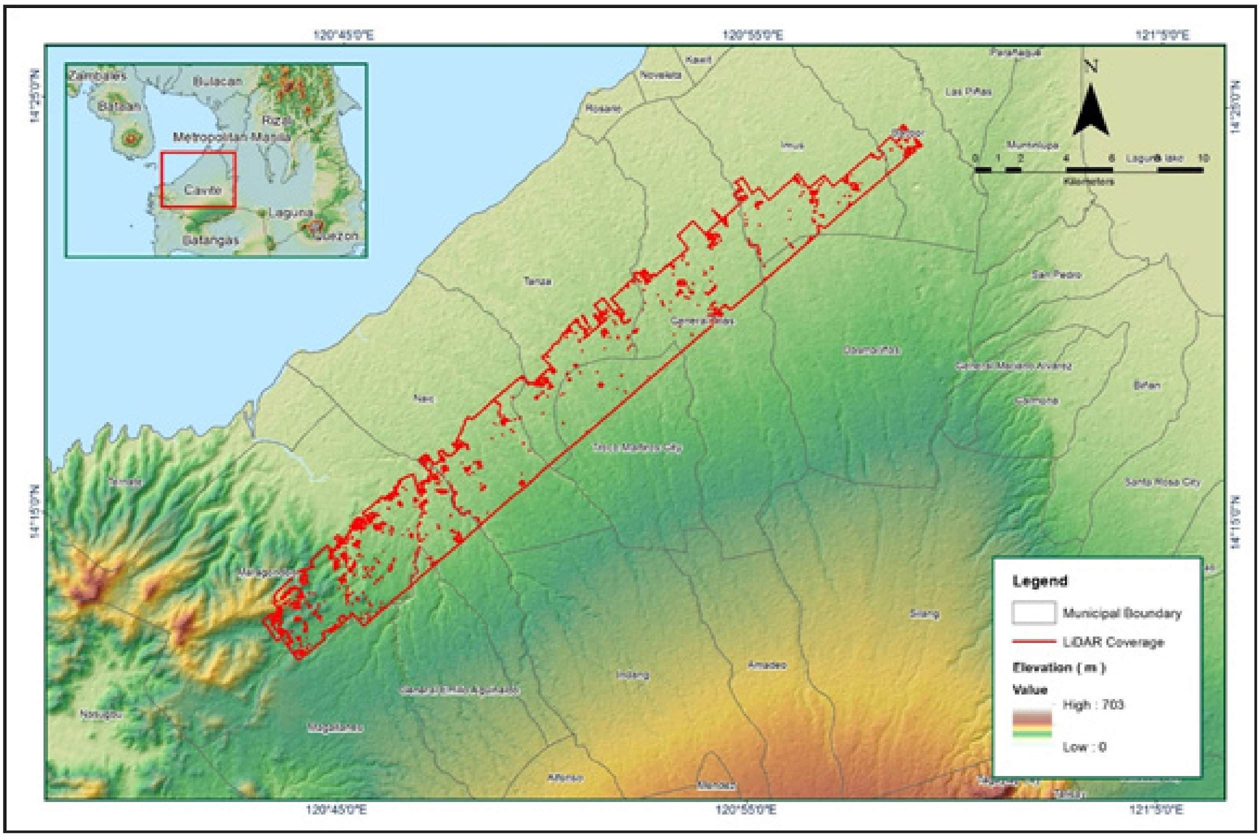


Figure A-8.4. Coverage of LiDAR data

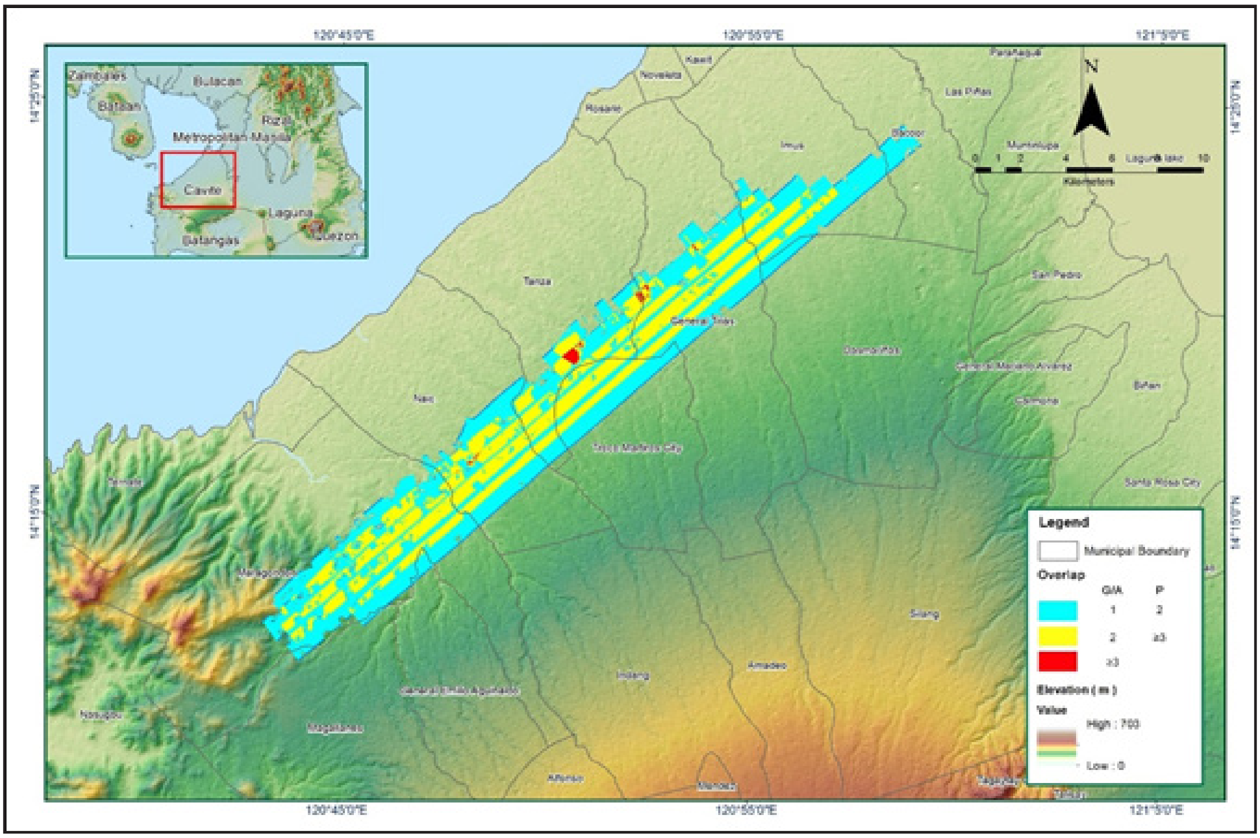


Figure A-8.5. Image of data overlap

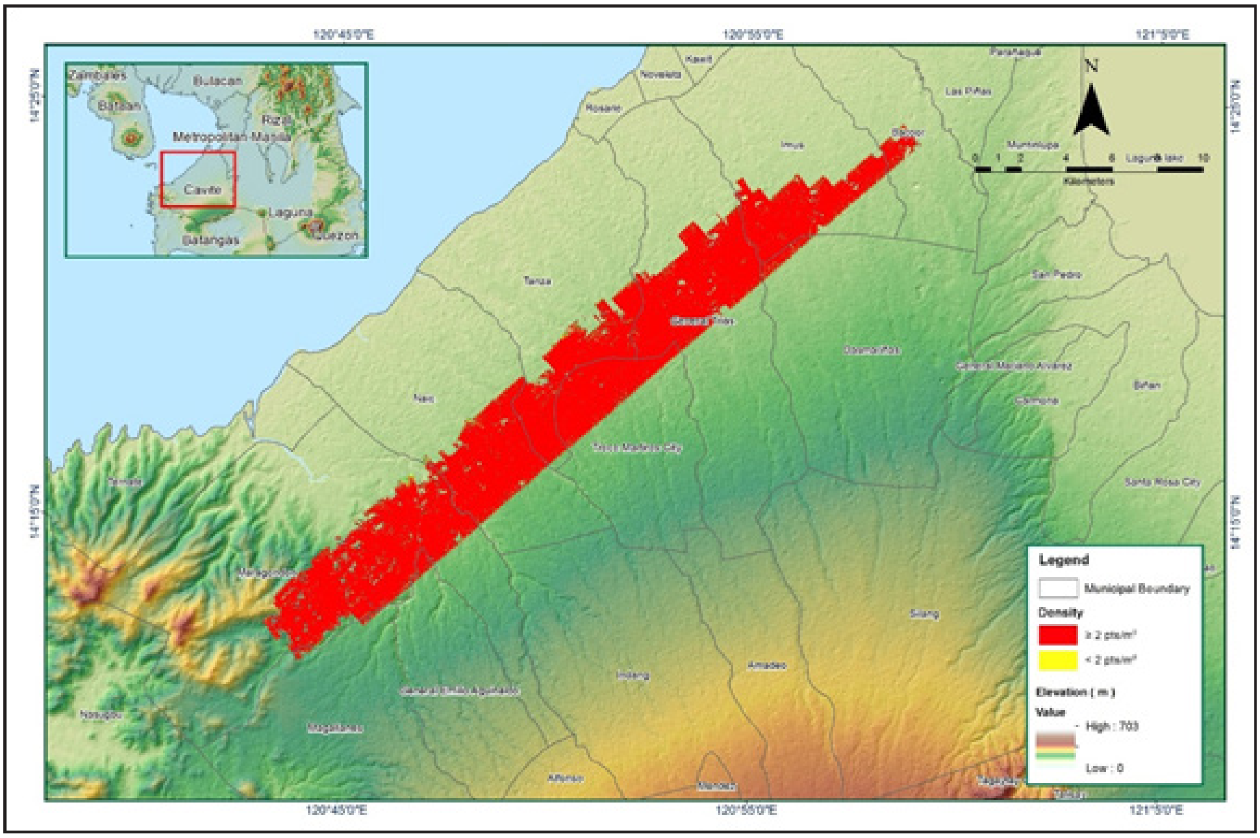


Figure A-8.6. Density map of merged LiDAR data

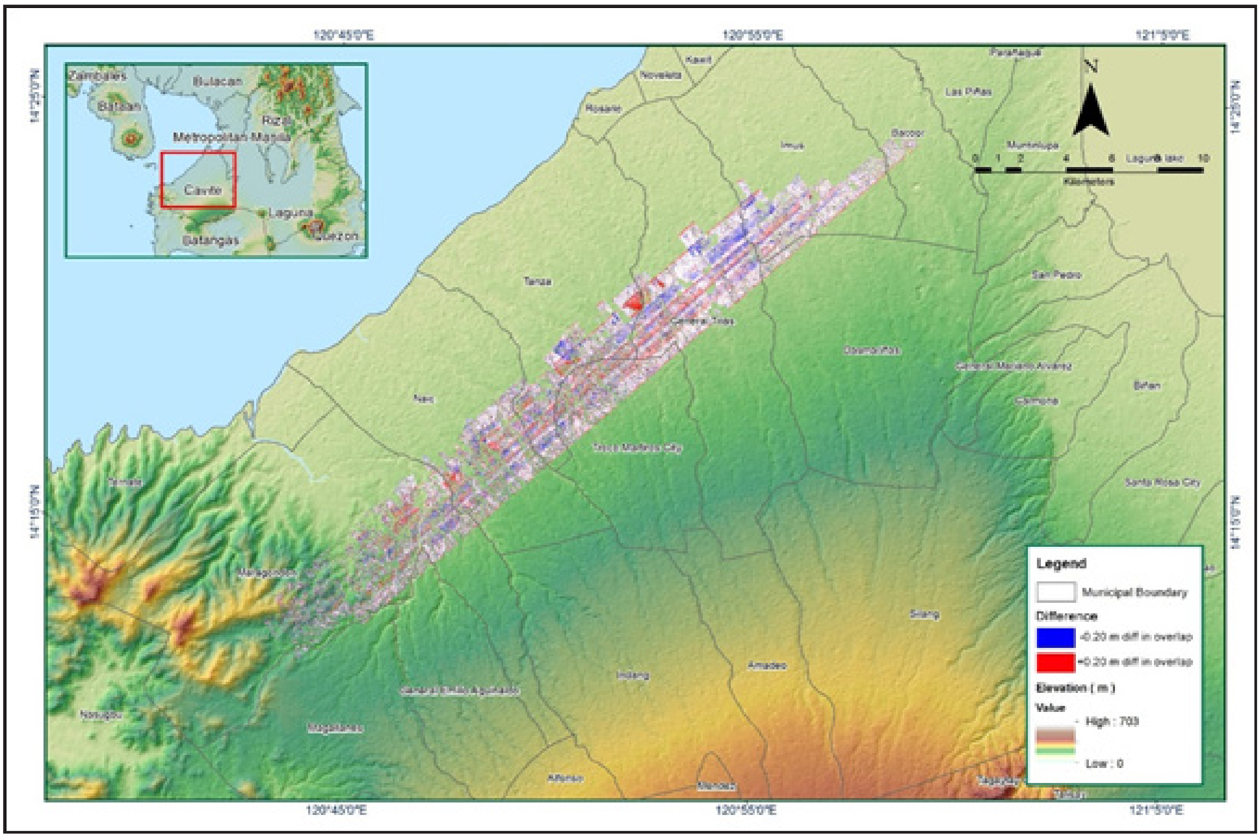


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Flight Status Report for Mission Blk18A

Flight Area	**CALABARZON Reflights**
Mission Name	Blk18A
Inclusive Flights	10136L, 10142L
Range data size	19.79 GB
POS data size	200 MB
Base data size	969 MB
Image	76.8 GB
Transfer date	6/20/2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Combined Separation (-0.1 up to 0.1)	Yes
Estimated Position Accuracy (in cm)	
Estimated Standard Devation for North Position (<4.0 cm)	0.65
Estimated Standard Devation for East Position (<4.0 cm)	0.80
Estimated Standard Devation for Height Position (<8.0 cm)	1.80
Minimum % overlap (>25)	47.33%
Ave point cloud density per sq.m. (>2.0)	3.22
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	215
Maximum Height	354.74 m
Minimum Height	44.59 m
Classification (# of points)	
Ground	258,626,866
Low vegetation	250,593,109
Medium vegetation	204,765,100
High vegetation	216,443,750
Building	62,593,079
Orthophoto	Yes
Processed By	Engr. Regis Guhiting, Engr. Melanie Hingpit, Kathryn Claudyn Zarate

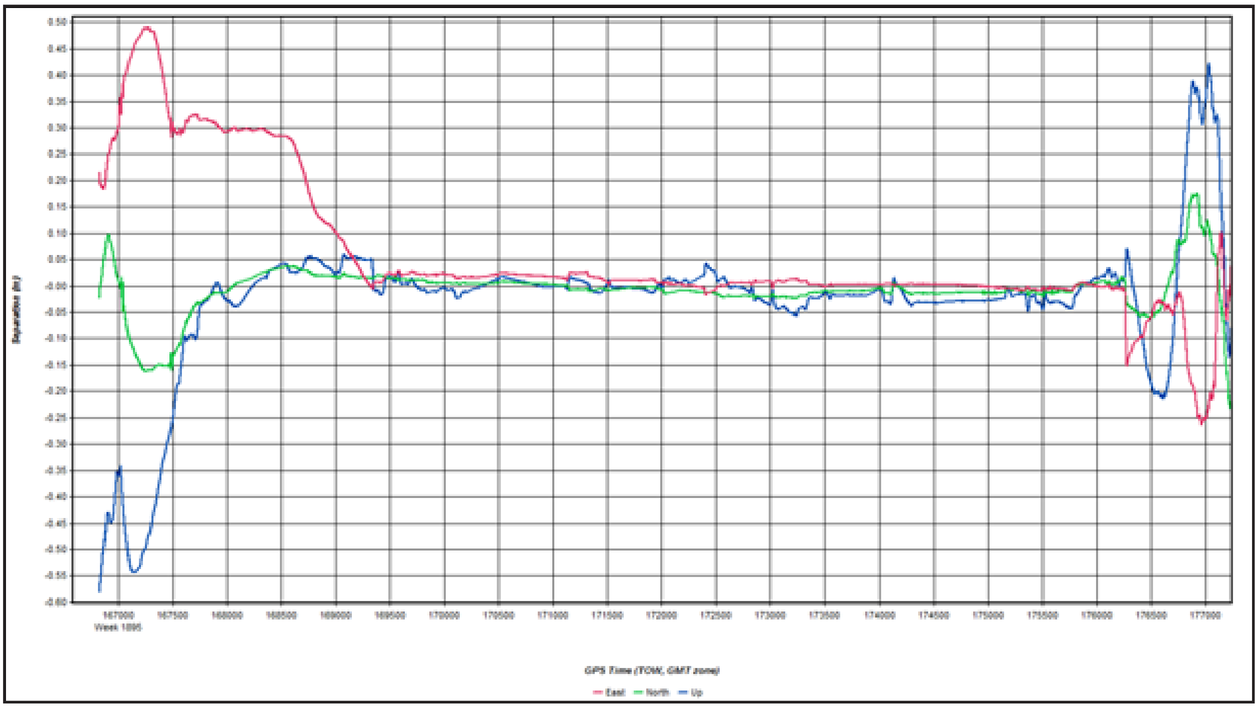


Figure A-8.8. Combined Separation

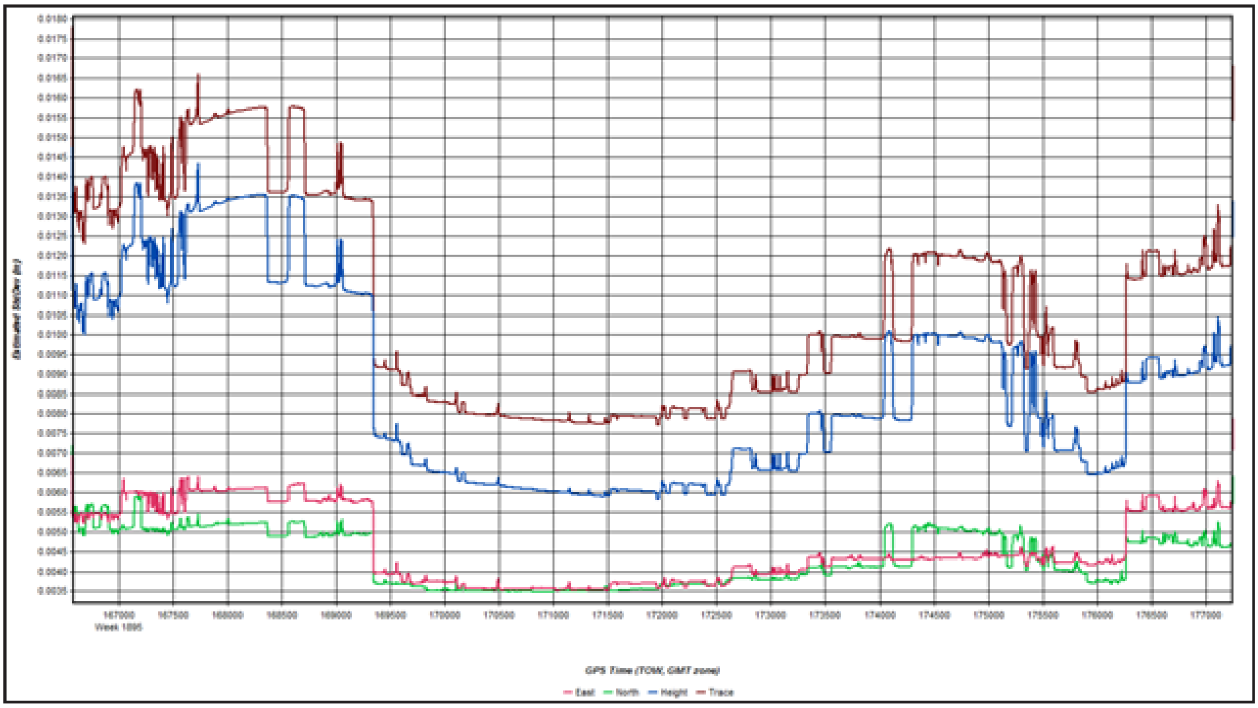


Figure A-8.9. Estimated Position of Accuracy

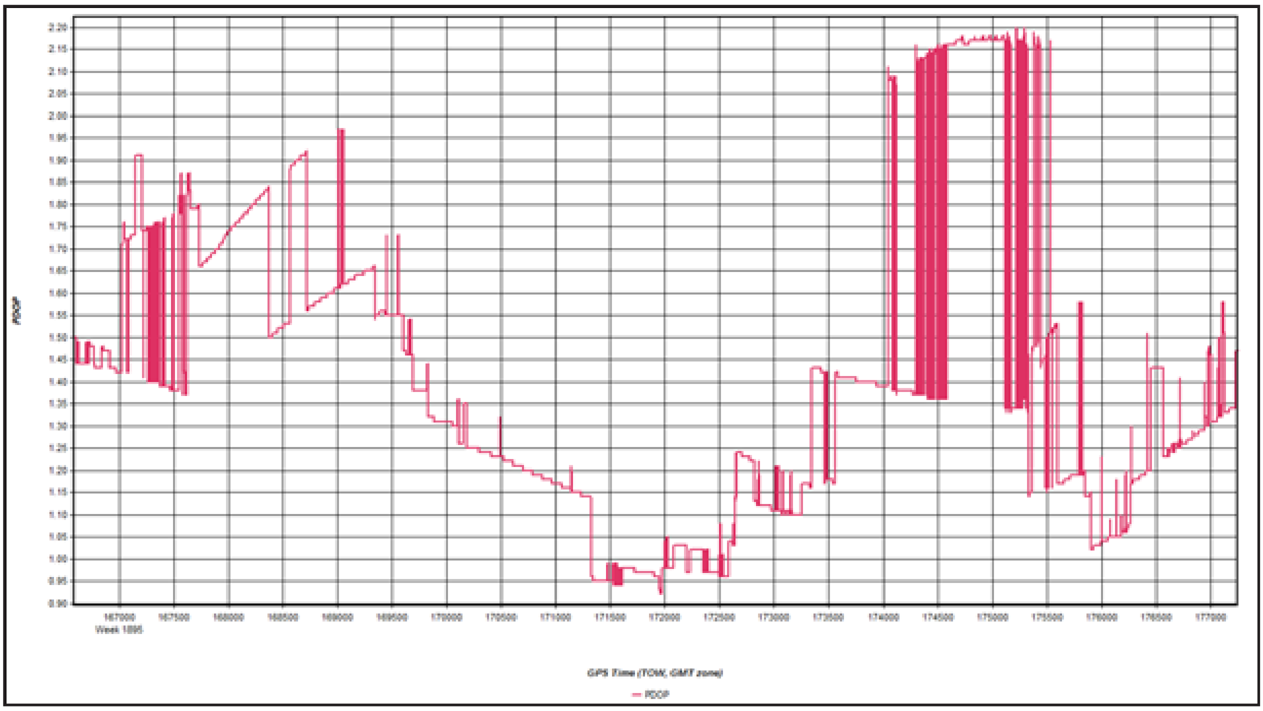


Figure A-8.10. PDOP

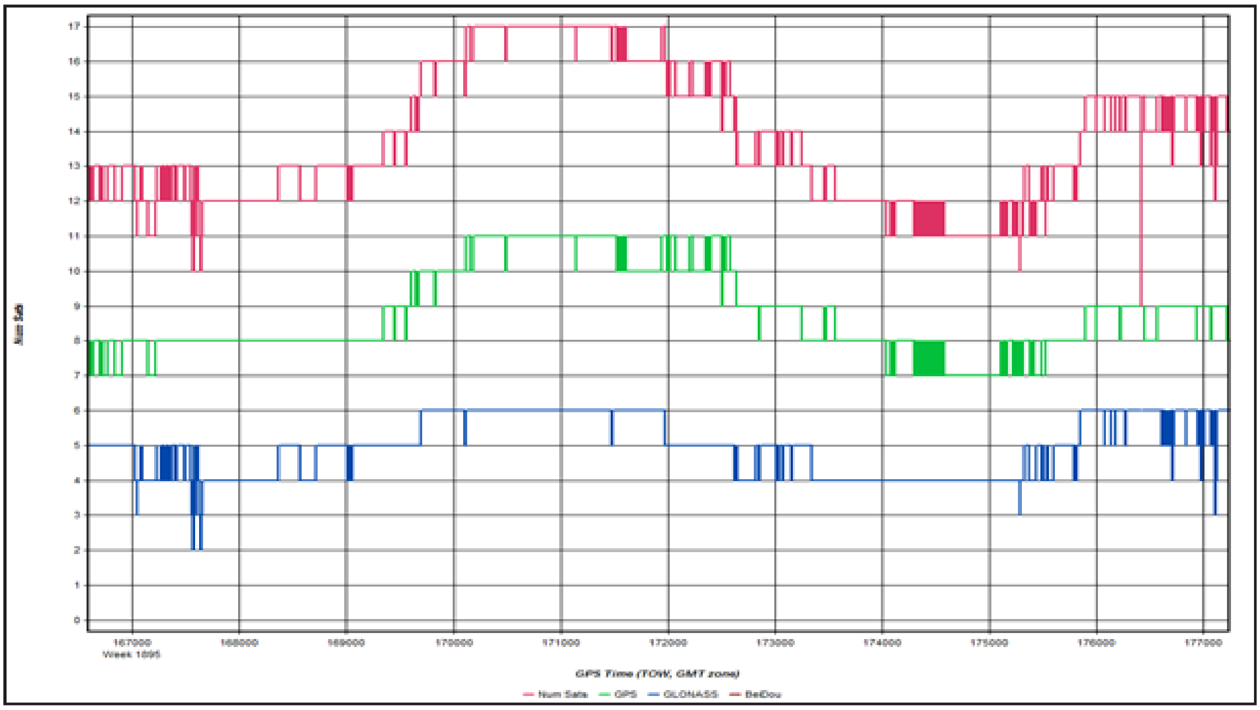


Figure A-8.11. Number of Satellites

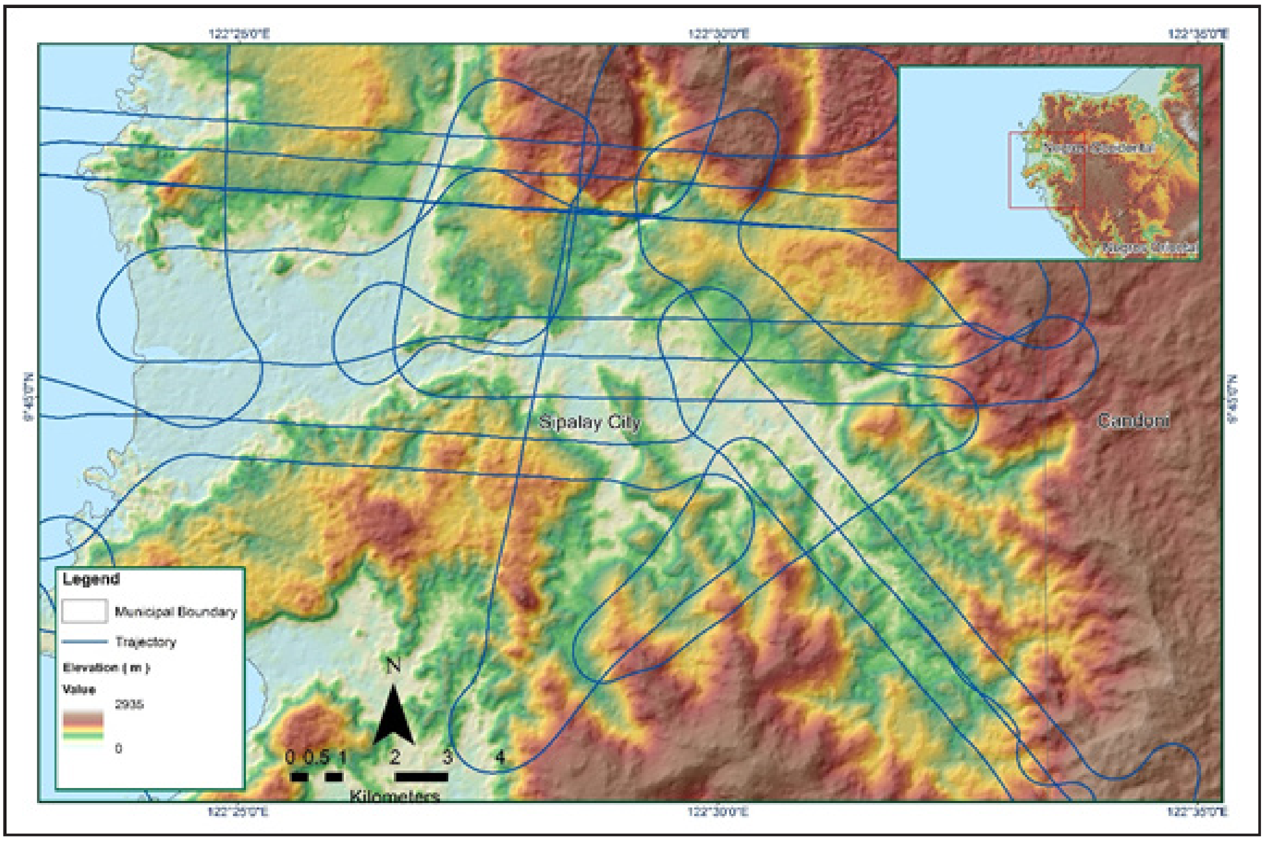


Figure A-8.12. Best Estimated Trajectory

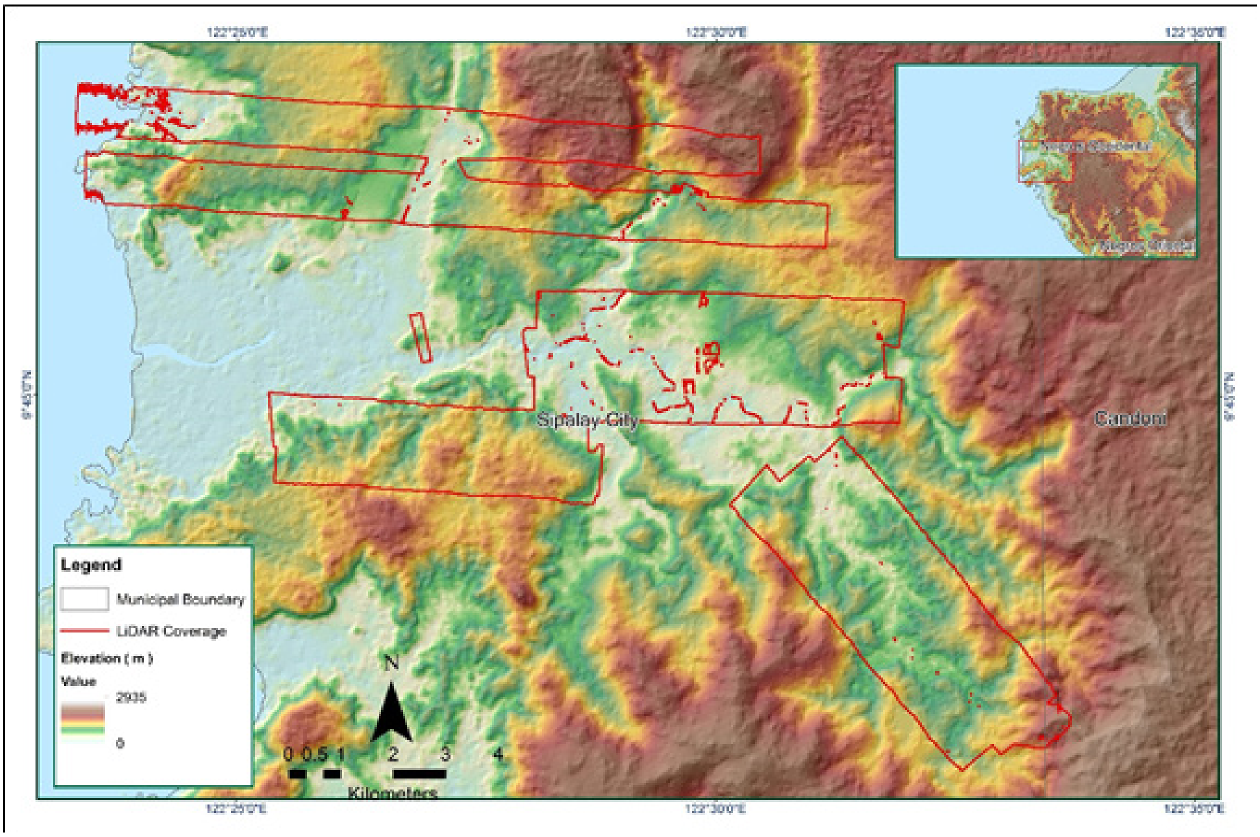


Figure A-8.13. Coverage of LiDAR data

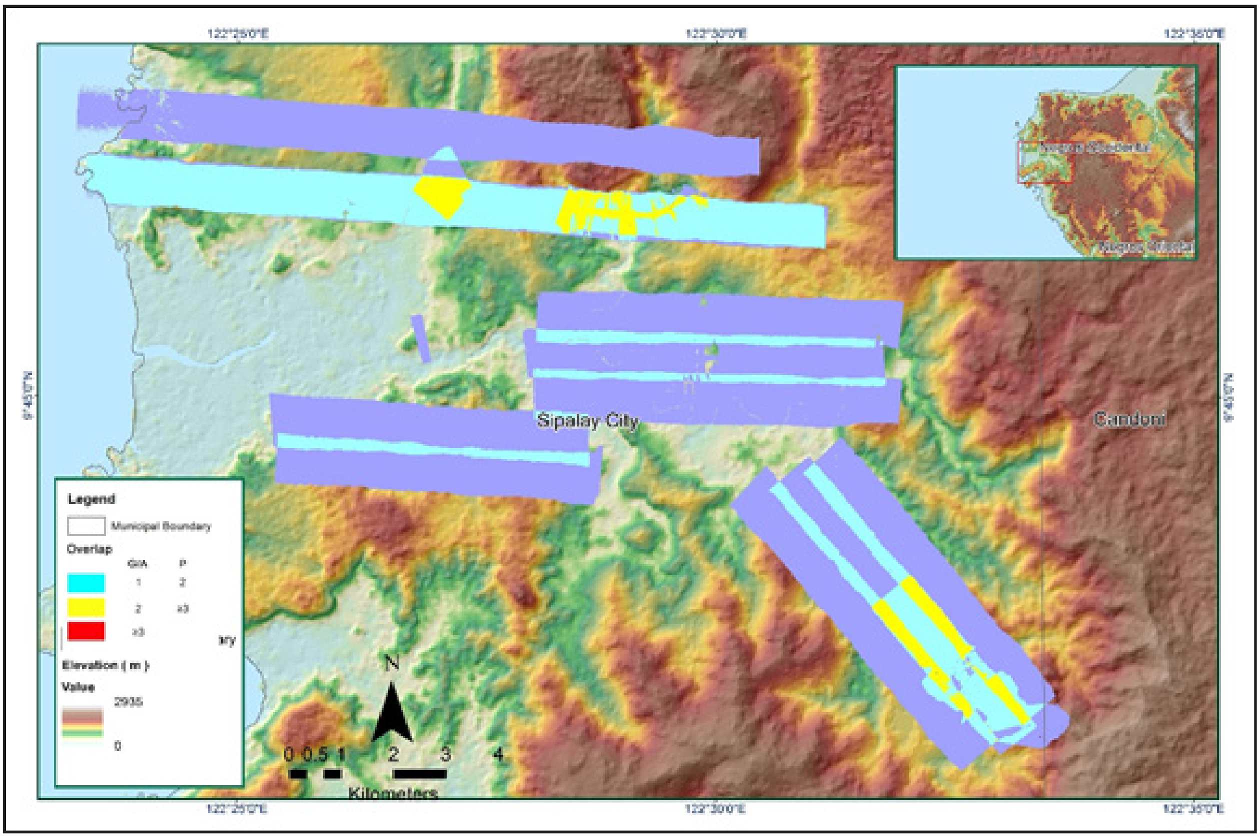


Figure A-8.14. Image of data overlap

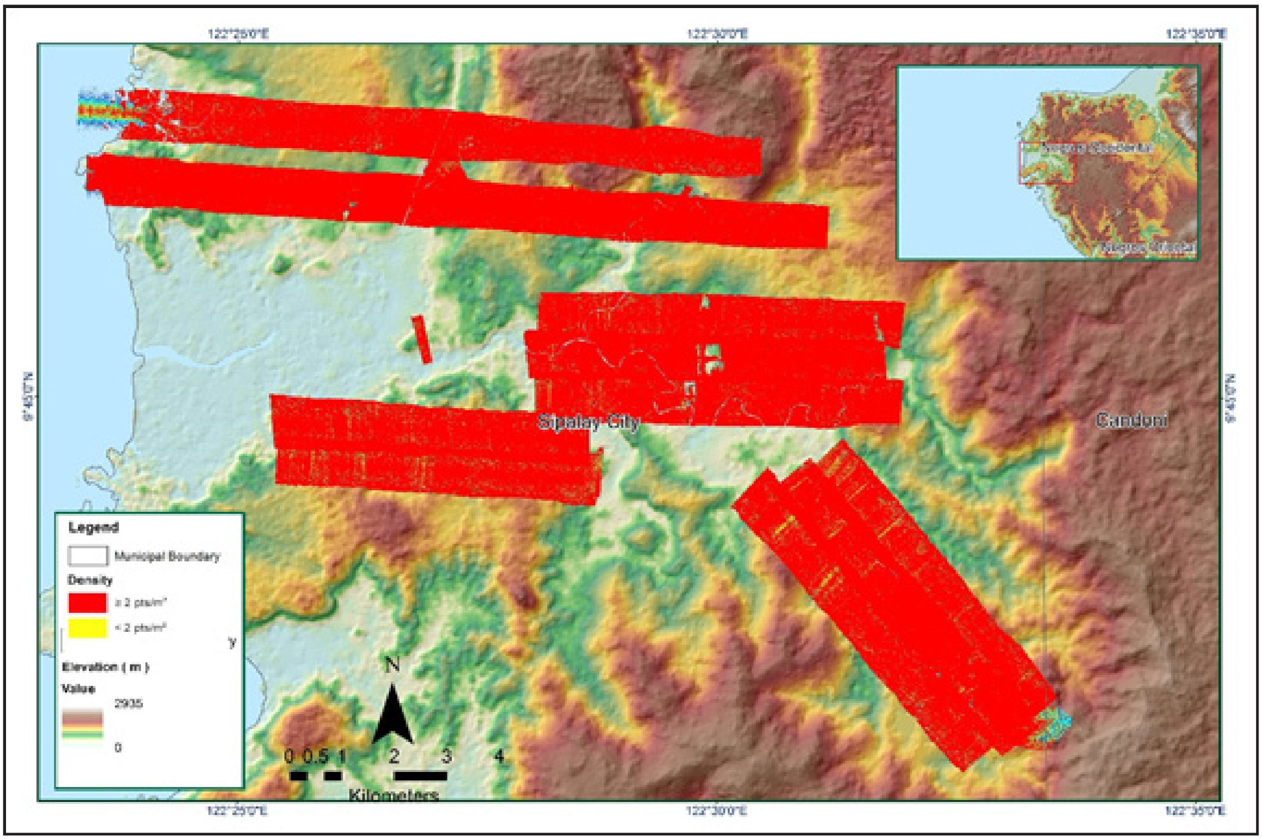


Figure A-8.6. Density map of merged LiDAR data

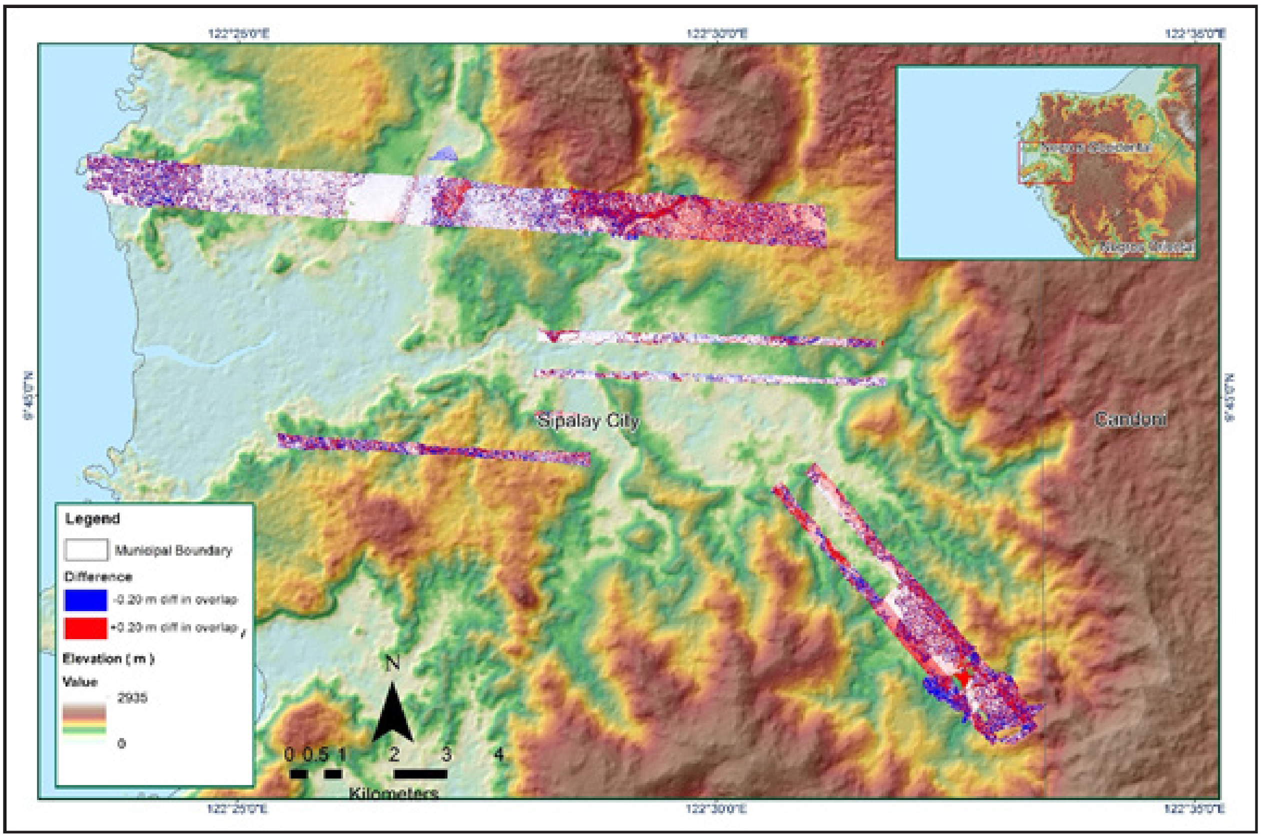


Figure A-8.16. Elevation difference between flight lines

Table A-8.3. Flight Status Report for Mission Blk18A_supplement

Flight Area	CALABARZON Reflights
Mission Name	Blk18A_supplement
Inclusive Flights	10144L
Range data size	3.59 GB
POS data size	155 MB
Base data size	408 MB
Image	12.9 GB
Transfer date	6/20/2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Combined Separation (-0.1 up to 0.1)	Yes
Estimated Position Accuracy (in cm)	
Estimated Standard Devation for North Position (<4.0 cm)	0.55
Estimated Standard Devation for East Position (<4.0 cm)	0.45
Estimated Standard Devation for Height Position (<8.0 cm)	1.00
Minimum % overlap (>25)	43.07%
Ave point cloud density per sq.m. (>2.0)	4.60
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	92
Maximum Height	106.83 m
Minimum Height	41.14 m
Classification (# of points)	
Ground	65,752,105
Low vegetation	34,201,252
Medium vegetation	22,488,691
High vegetation	24,727,914
Building	20,212,718
Orthophoto	Yes
Processed By	Engr. Regis Guhiting, Engr. Melanie Hingpit, Engr. Elainne Lopez

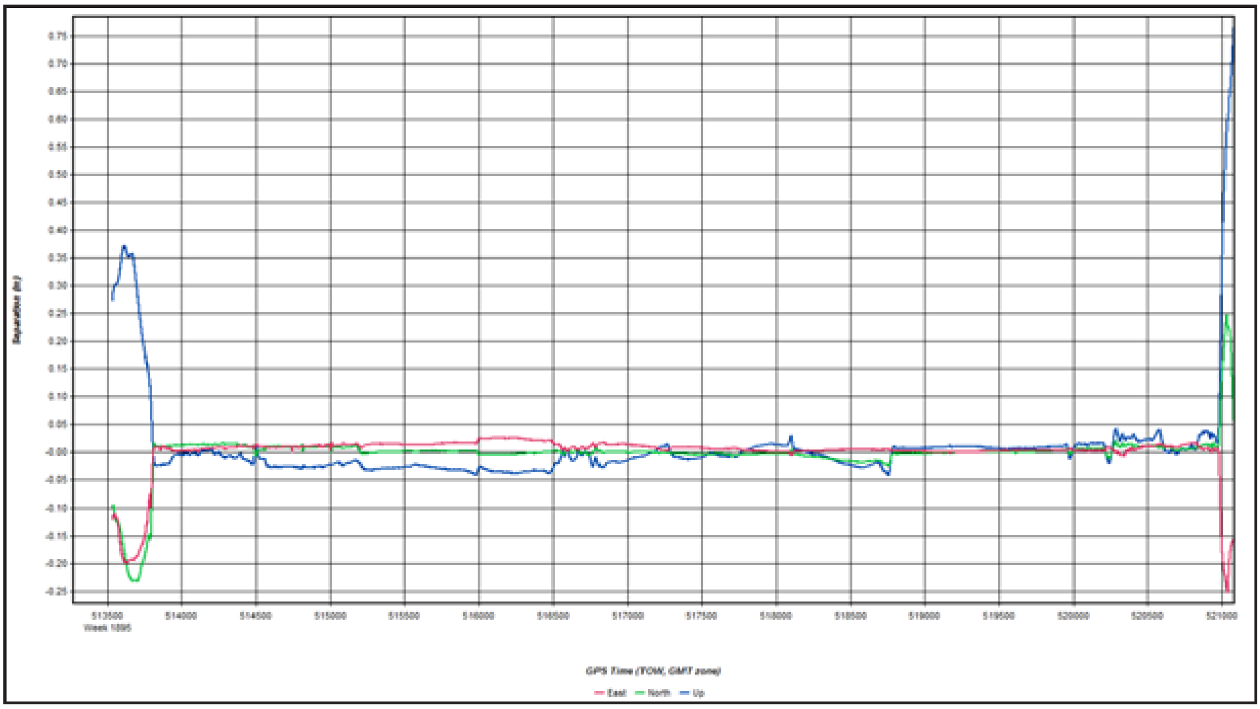


Figure A-8.17. Combined Separation

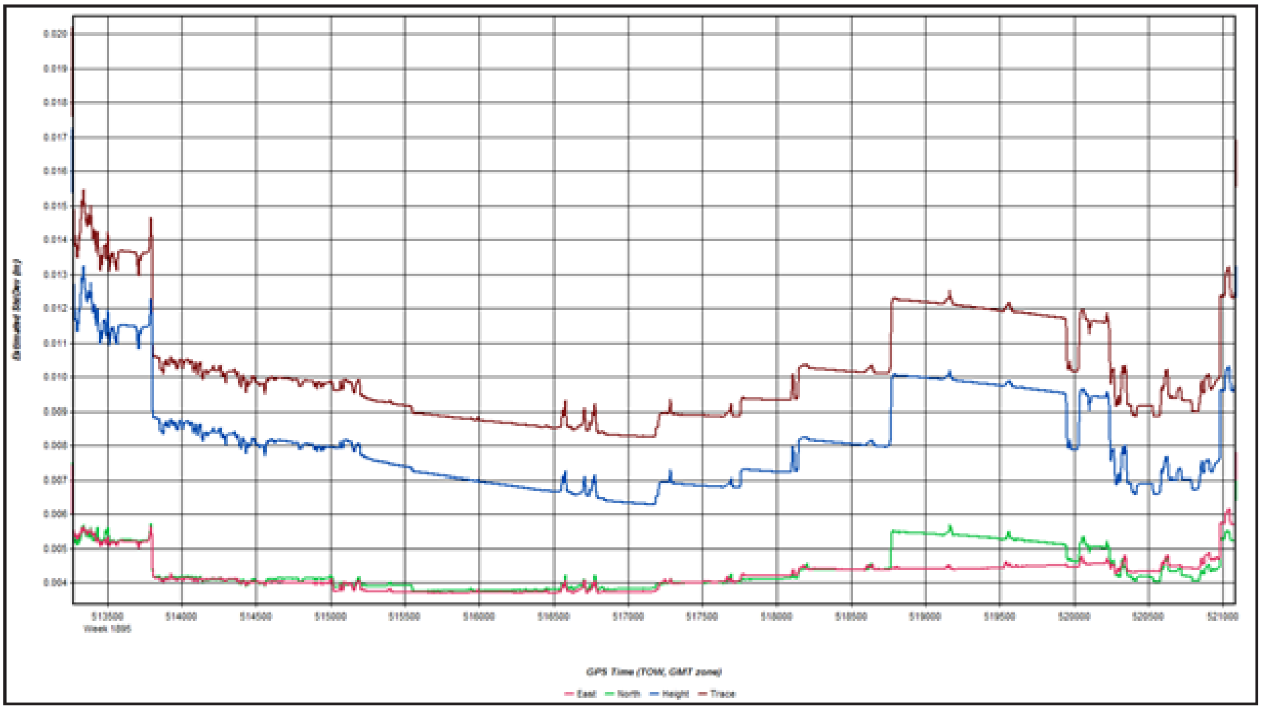


Figure A-8.18. Estimated Position of Accuracy

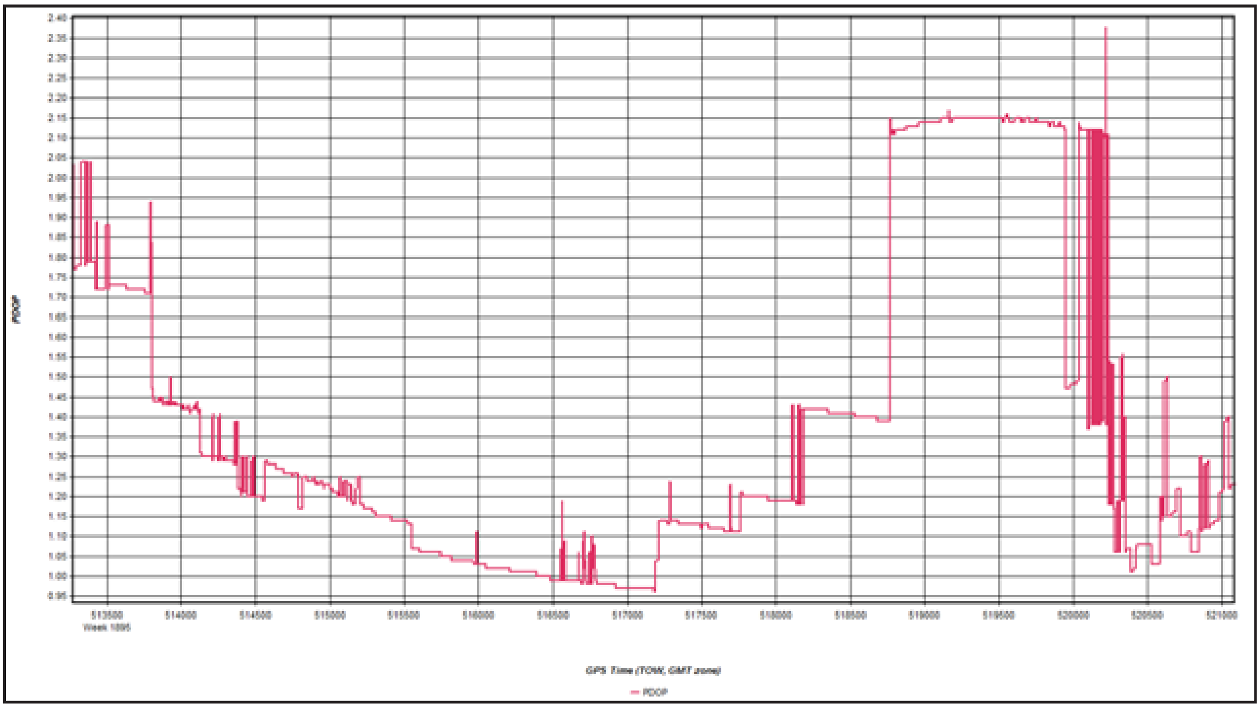


Figure A-8.19. PDOP

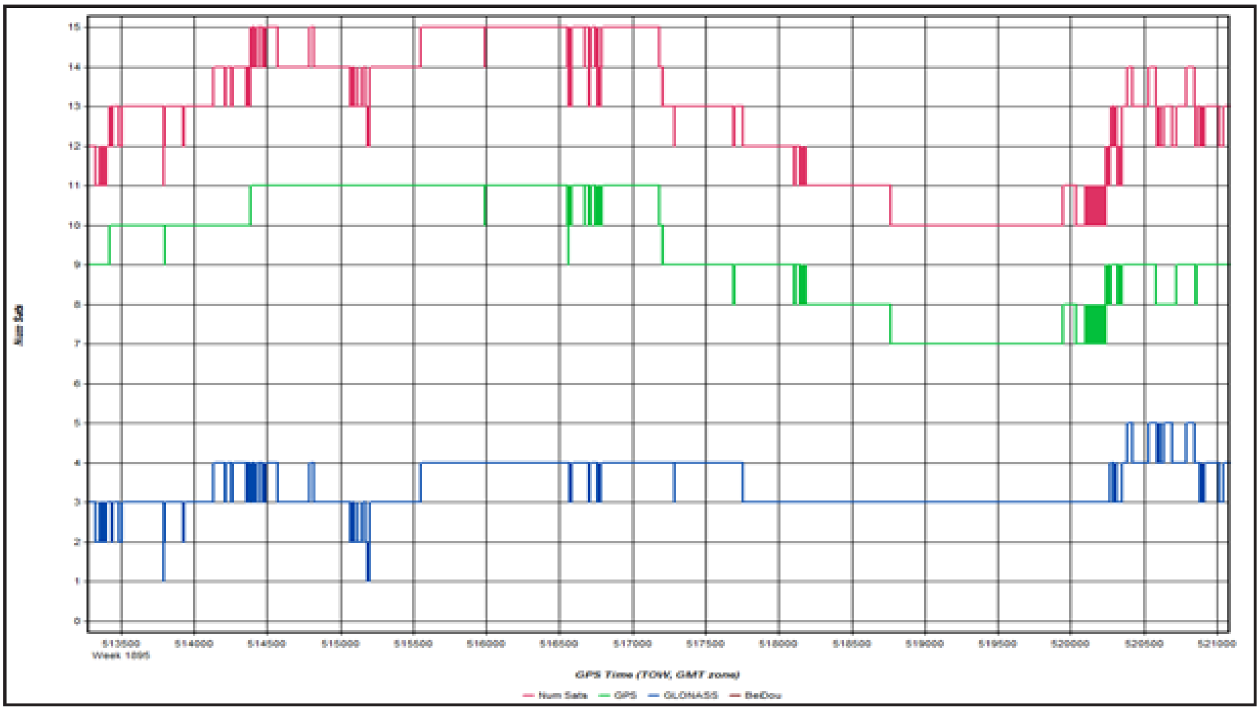


Figure A-8.20. Number of Satellites

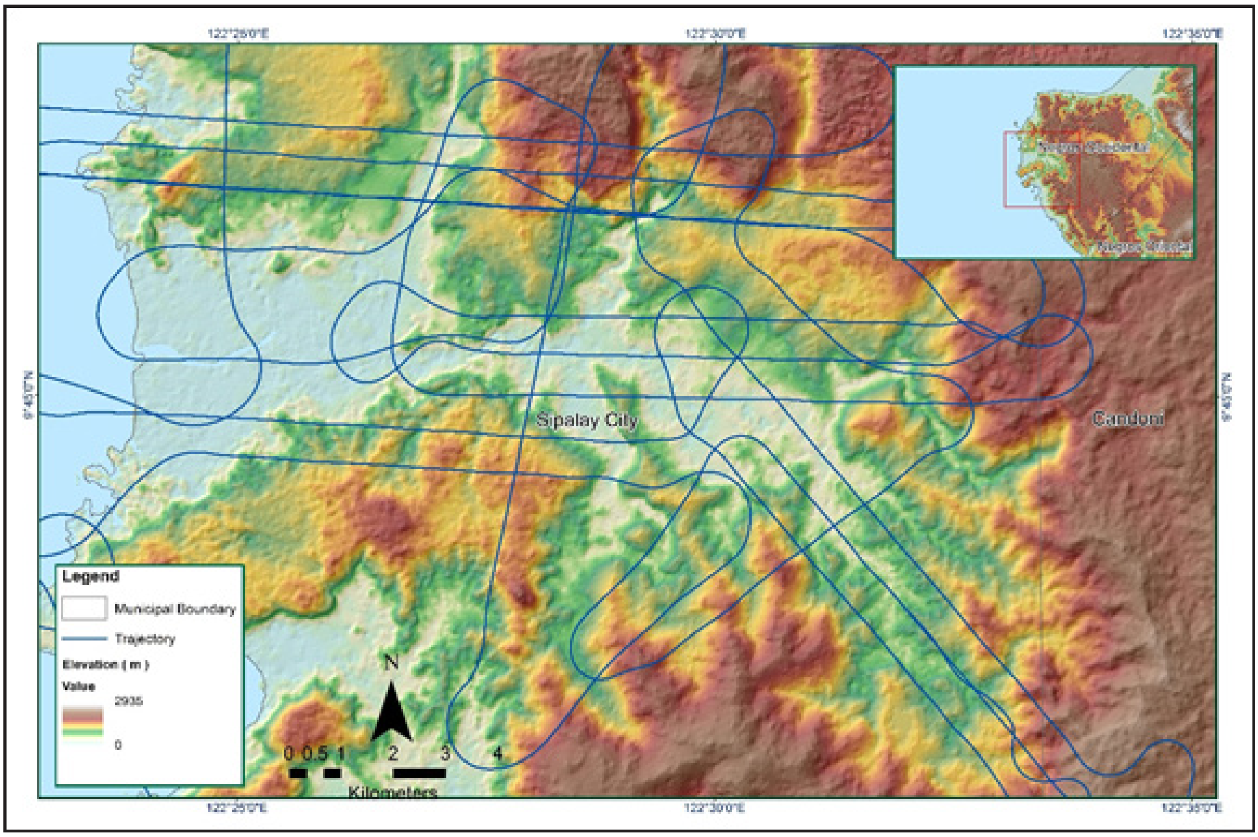


Figure A-8.21. Best Estimated Trajectory

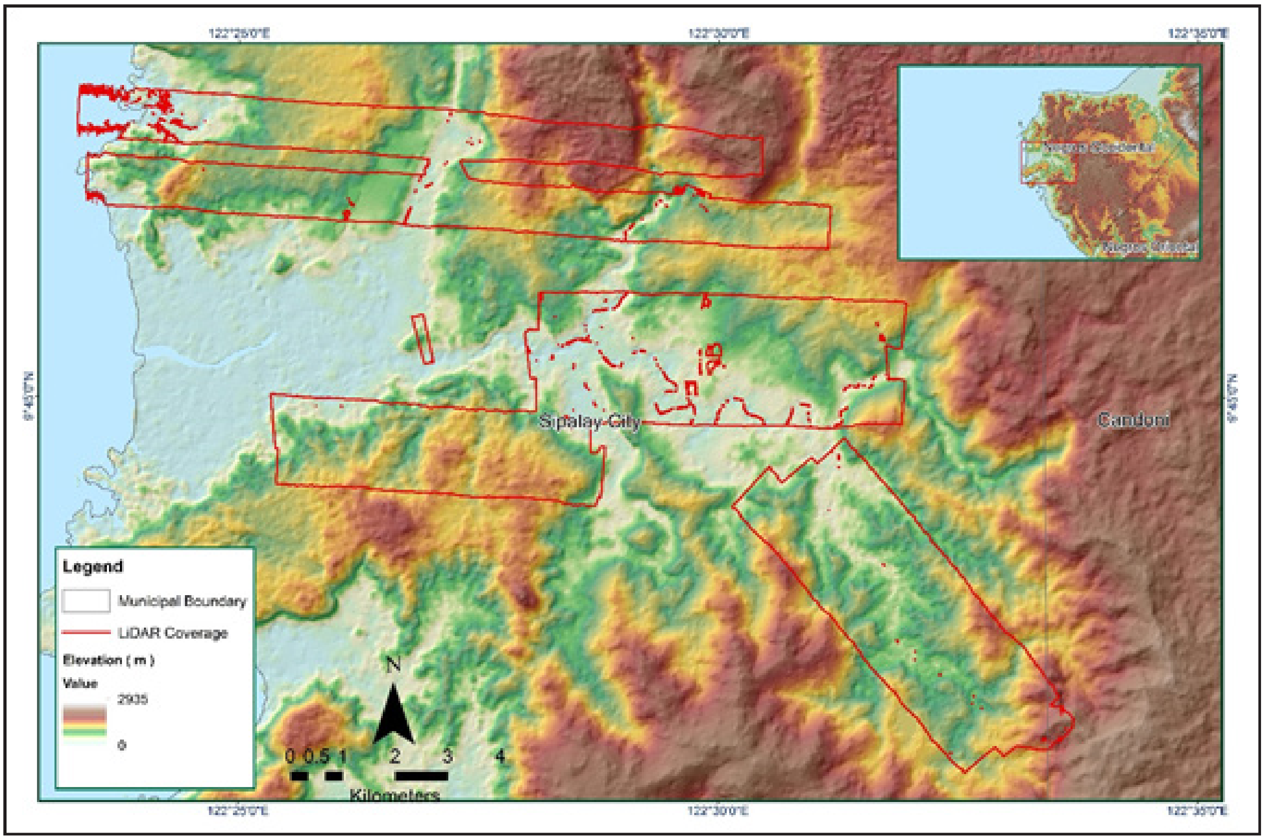


Figure A-8.22. Coverage of LiDAR data

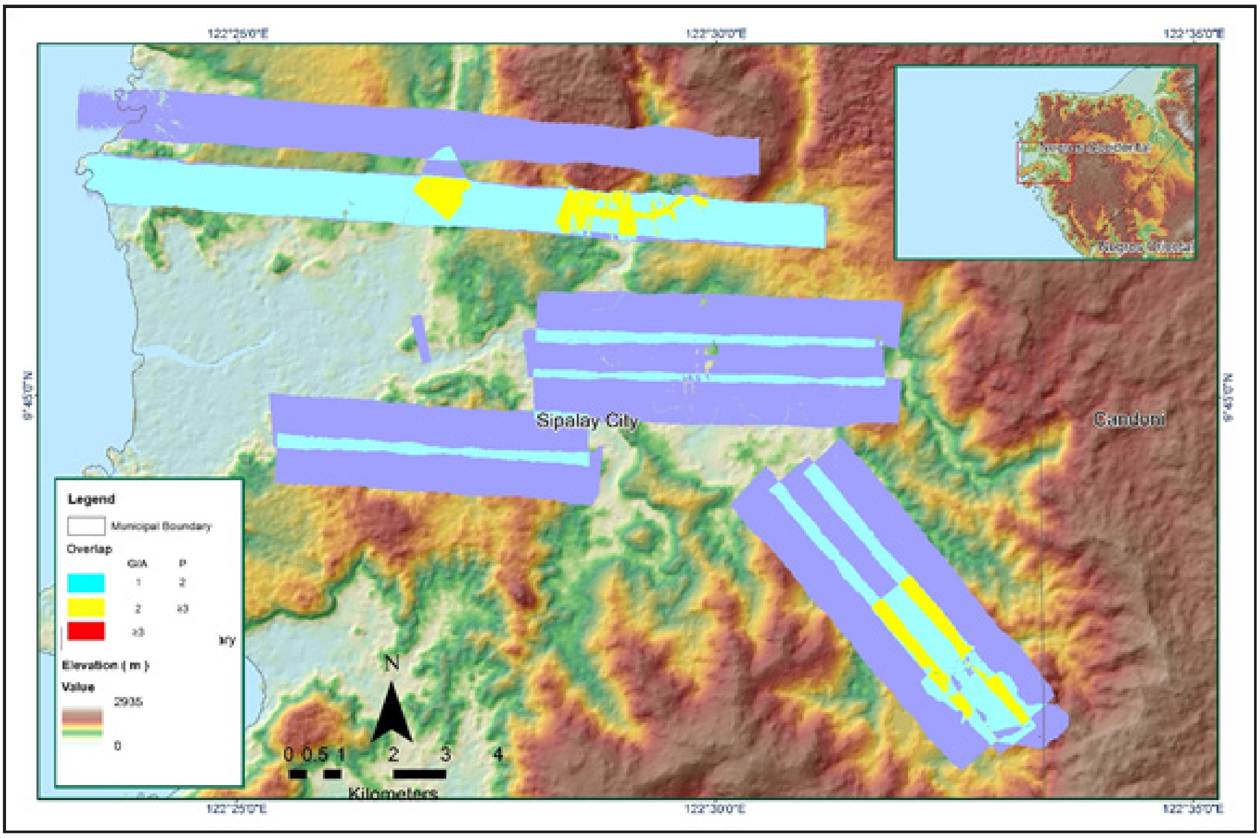


Figure A-8.23. Image of data overlap

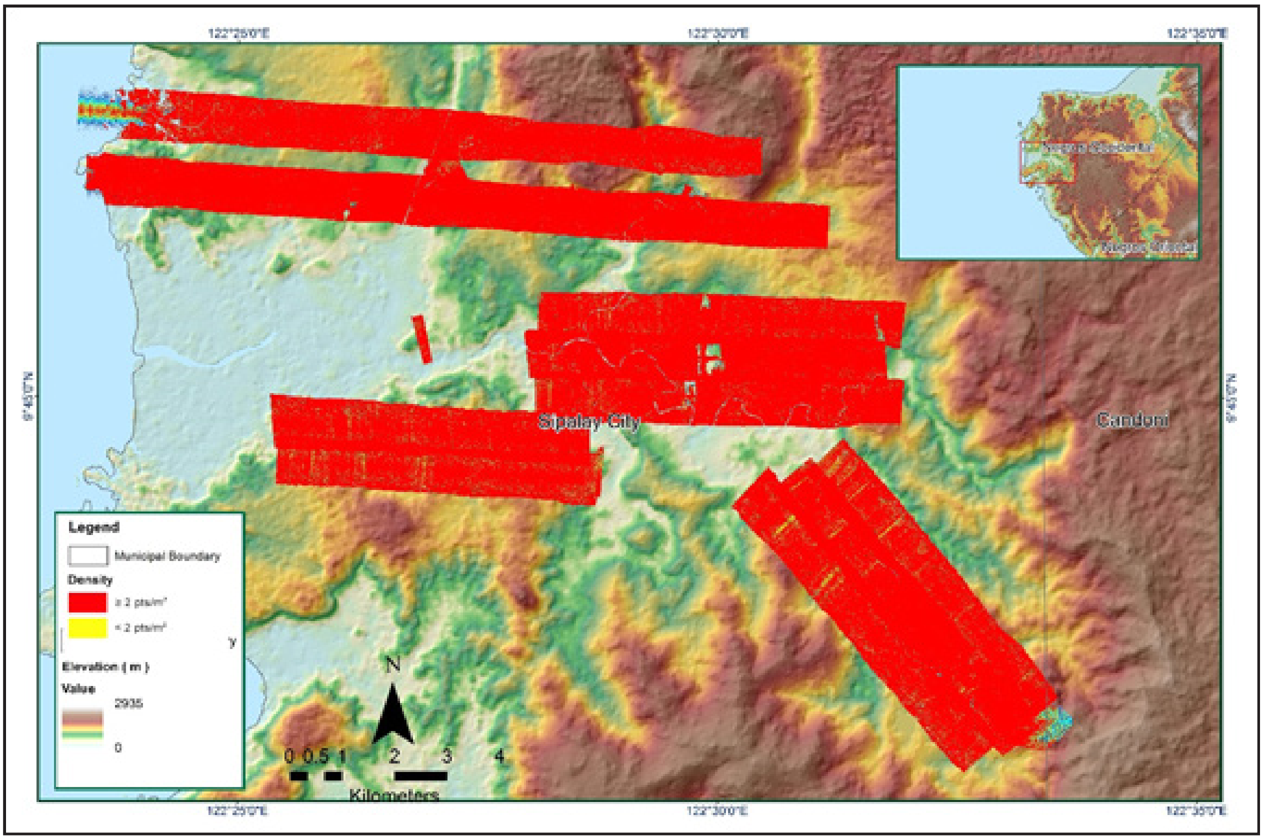


Figure A-8.24. Density map of merged LiDAR data

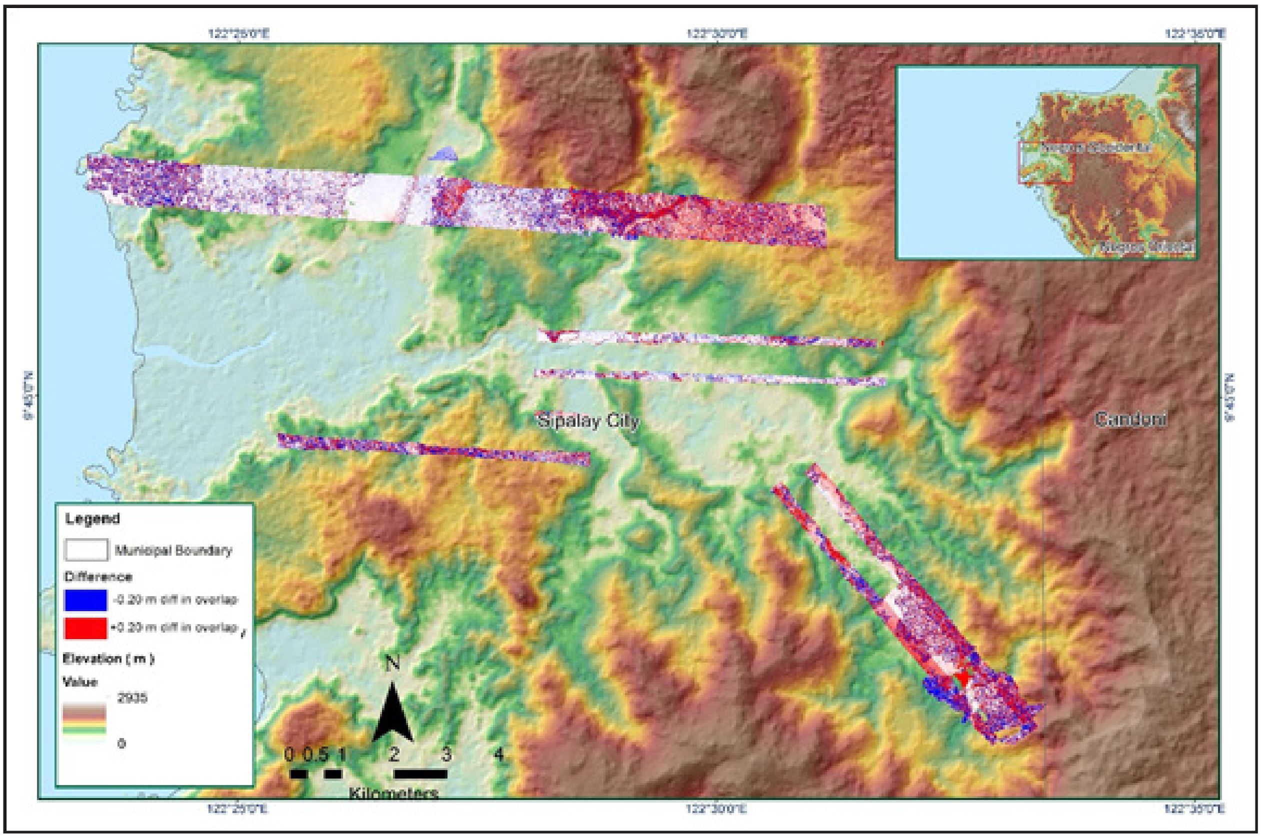


Figure A-8.25. Elevation difference between flight lines

Table A-8.4. Flight Status Report for Mission Blk18D

Flight Area	CALABARZON
Mission Name	Blk18D
Inclusive Flights	23462P
Range data size	25.7 GB
POS data size	225 MB
Base data size	316 MB
Image	N/A
Transfer date	July 14, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.99
RMSE for East Position (<4.0 cm)	2.50
RMSE for Down Position (<8.0 cm)	5.40
Boresight correction stdev (<0.001deg)	0.000798
IMU attitude correction stdev (<0.001deg)	0.000359
GPS position stdev (<0.01m)	0.0010
Minimum % overlap (>25)	38.08
Ave point cloud density per sq.m. (>2.0)	4.98
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	257
Maximum Height	954.88 m
Minimum Height	94.71 m
Classification (# of points)	
Ground	194177239
Low vegetation	141108412
Medium vegetation	378714820
High vegetation	385911435
Building	49706497
Orthophoto	No
Processed By	Engr. Sheila-Maye Santillan, Engr. Melanie Hingpit, Jovy Narisma

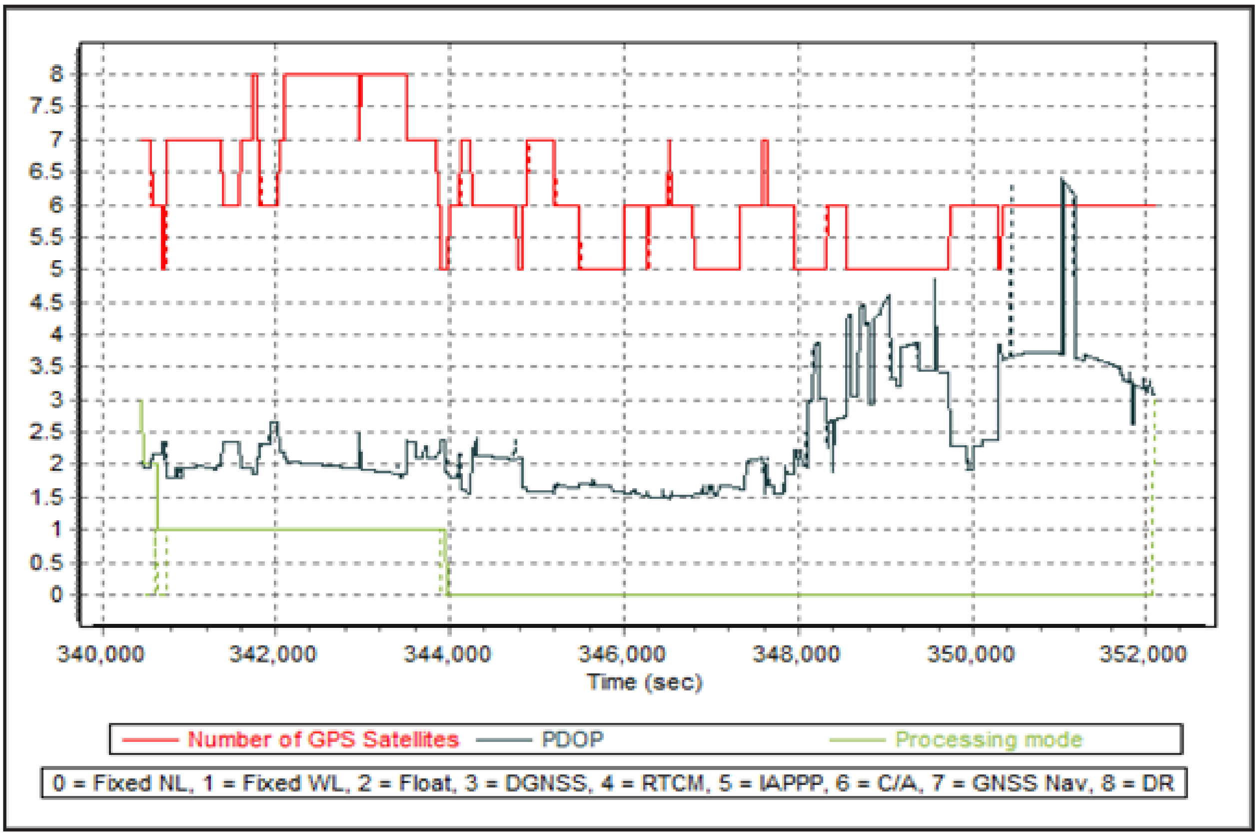


Figure A-8.26. Solution Status

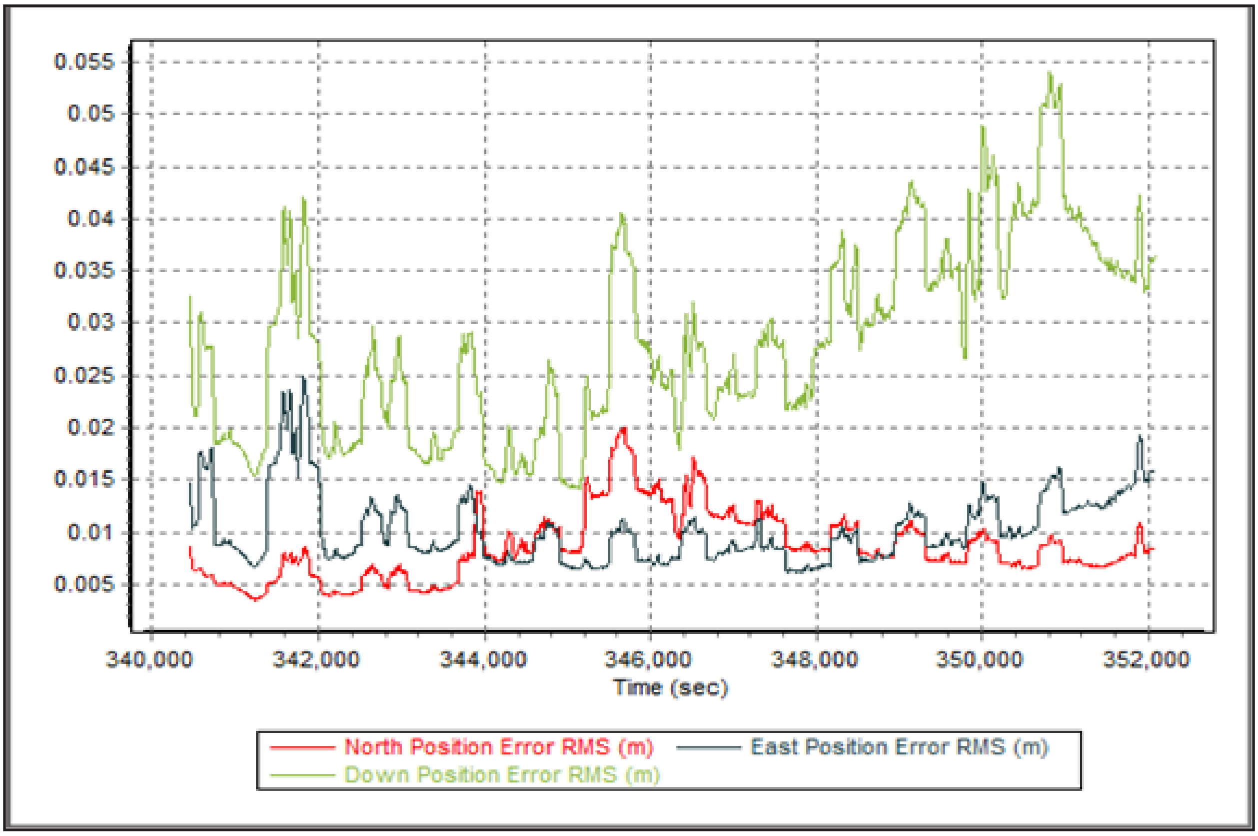


Figure A-8.27. Smoothed Performance Metric Parameters

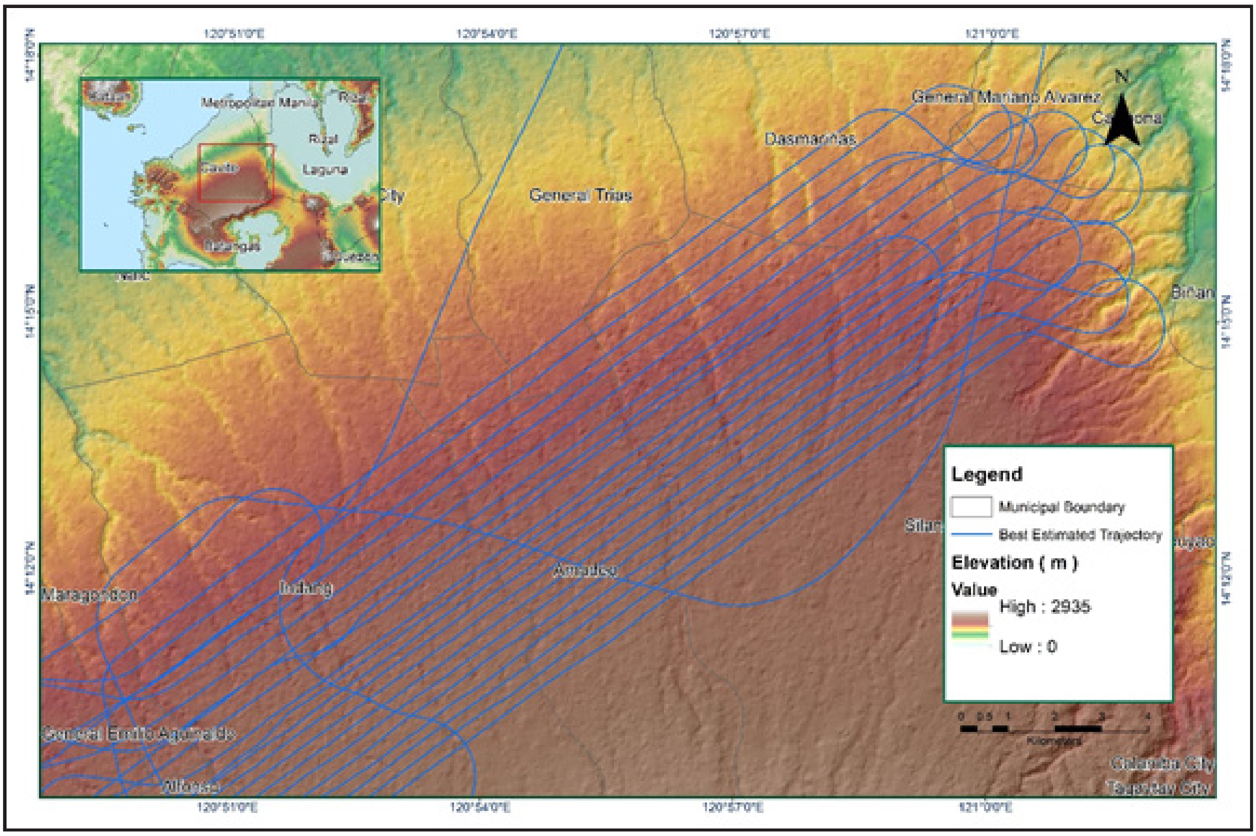


Figure A-8.28. Best Estimated Trajectory

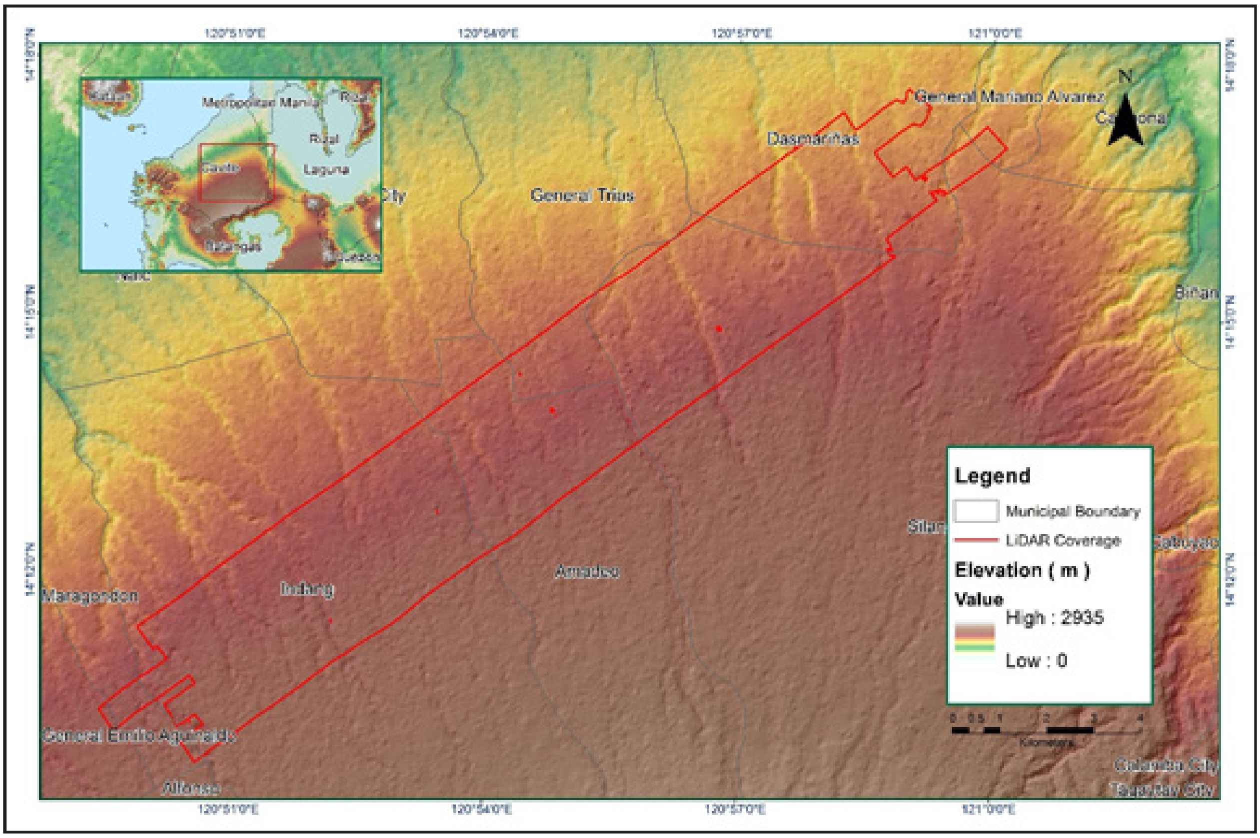


Figure A-8.29. Coverage of LiDAR Data

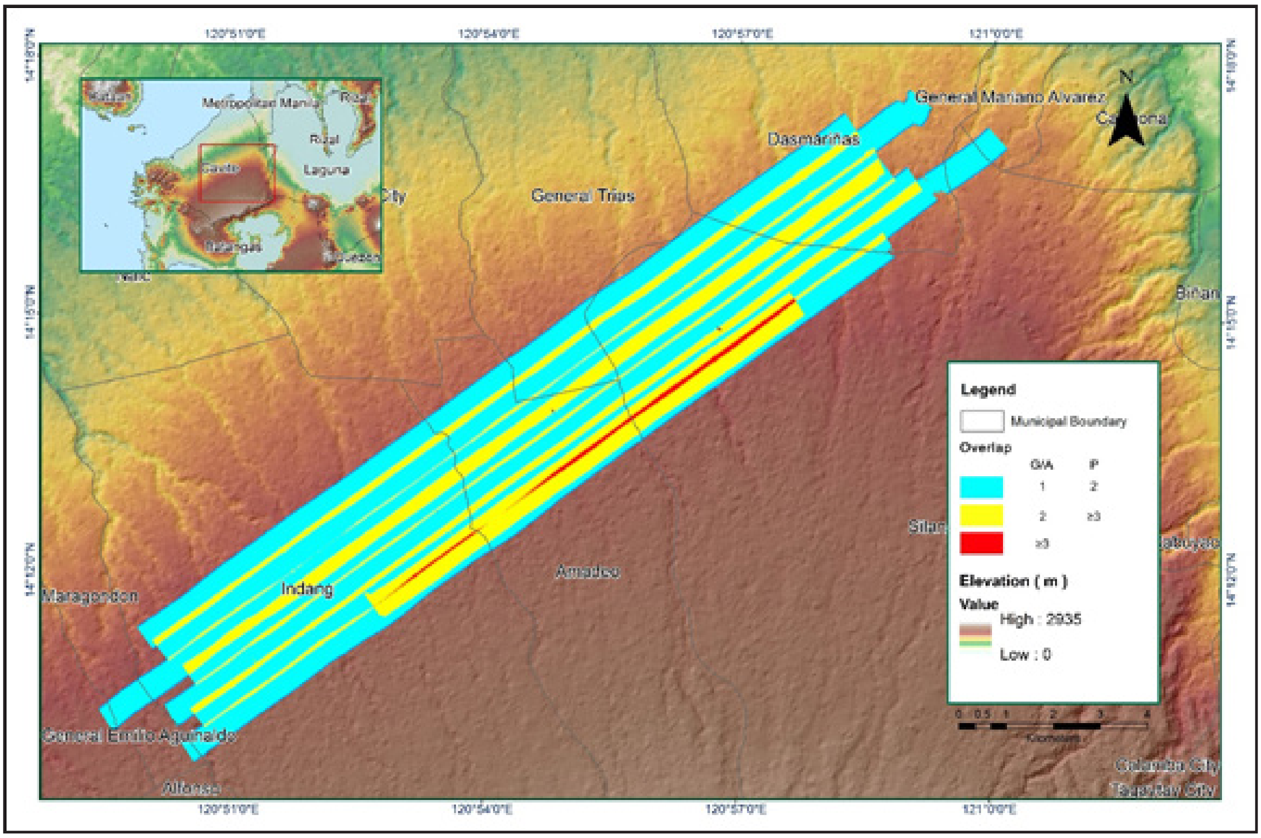


Figure A-8.30. Image of data overlap

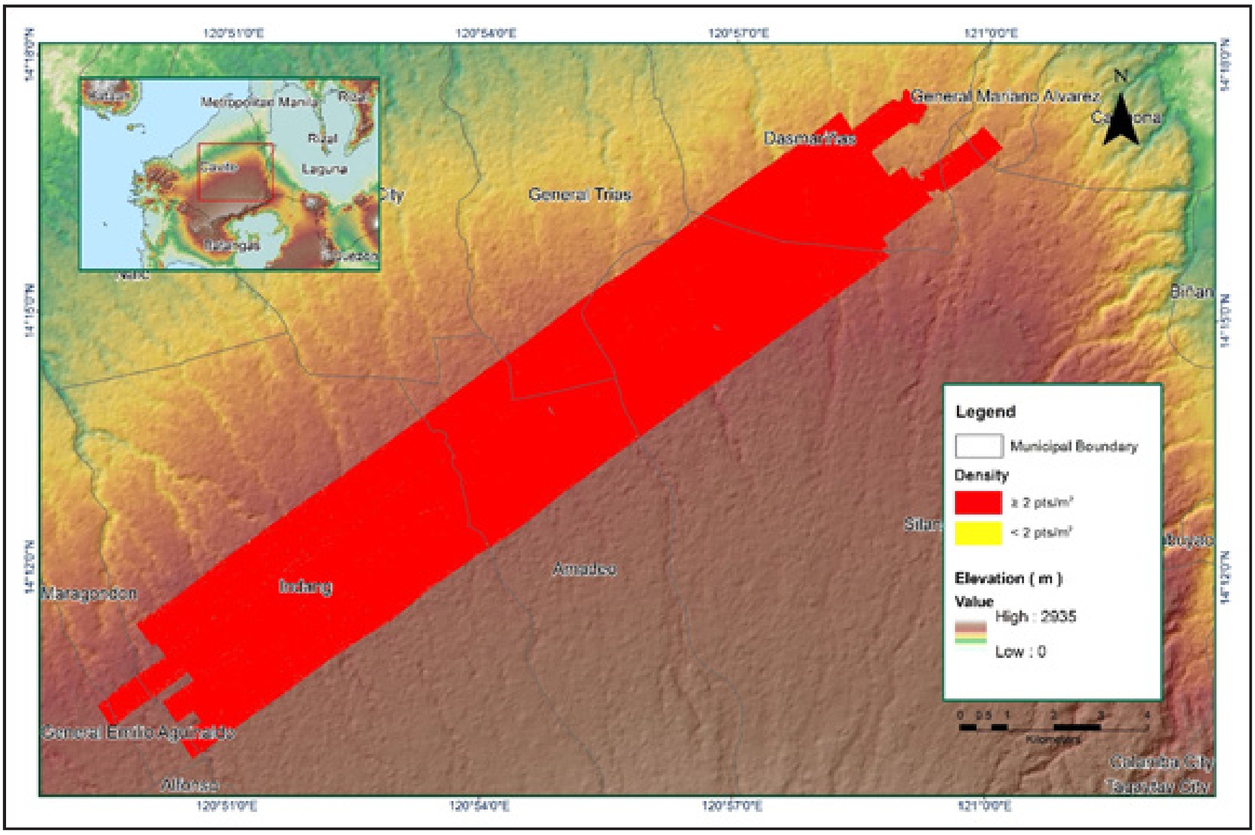


Figure A-8.31. Density map of merged LiDAR data

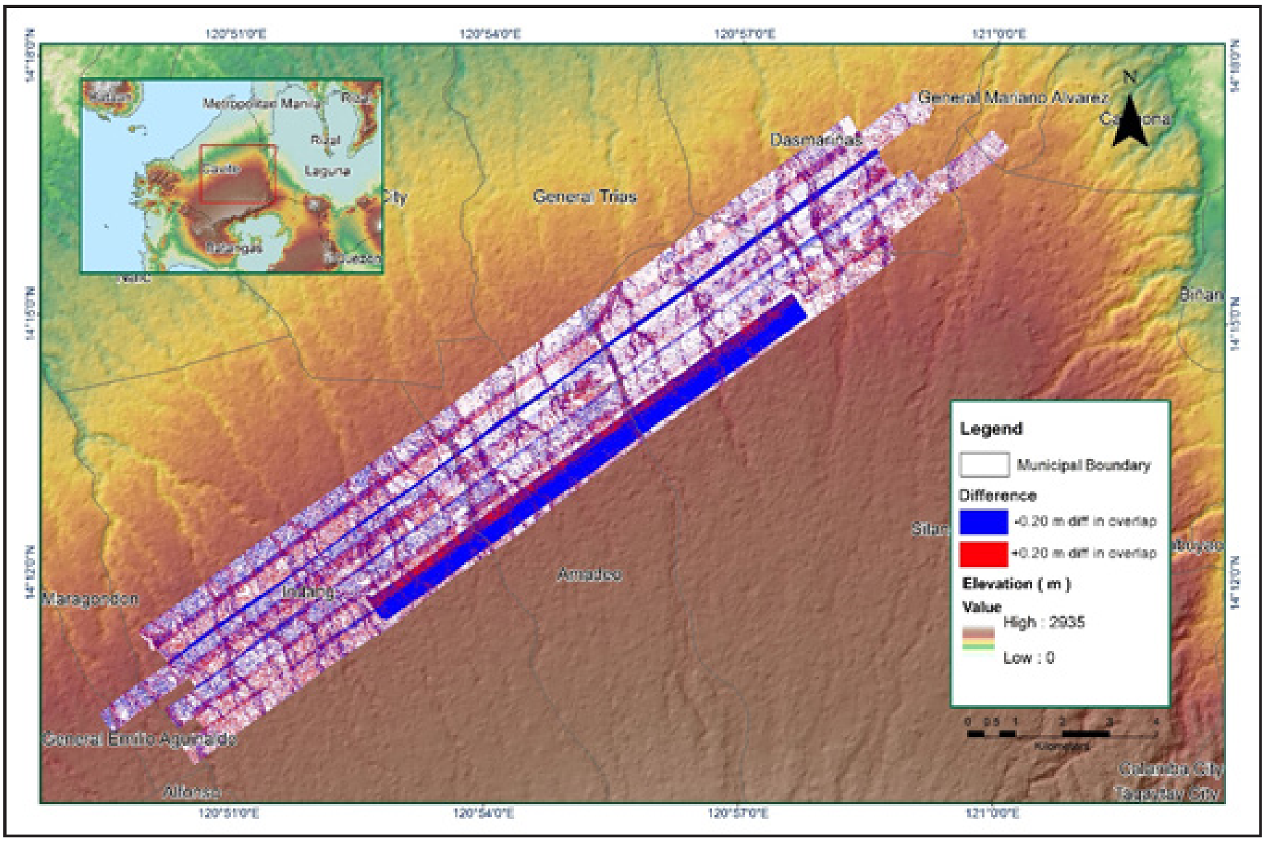


Figure A-8.32. Elevation difference between flight lines

Table A-8.5. Flight Status Report for Mission Blk18D_additional

Flight Area	CALABARZON
Mission Name	Blk18D_additional
Inclusive Flights	23462P
Range data size	25.7 GB
POS data size	225 MB
Base data size	316 MB
Image	N/A
Transfer date	July 14, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.99
RMSE for East Position (<4.0 cm)	2.50
RMSE for Down Position (<8.0 cm)	5.40
Boresight correction stdev (<0.001deg)	0.000798
IMU attitude correction stdev (<0.001deg)	0.000359
GPS position stdev (<0.01m)	0.0010
Minimum % overlap (>25)	67.15
Ave point cloud density per sq.m. (>2.0)	6.64
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	50
Maximum Height	438.30 m
Minimum Height	252.83 m
Classification (# of points)	
Ground	54,941,037
Low vegetation	42,647,662
Medium vegetation	93,264,338
High vegetation	129,714,722
Building	27,210,717
Orthophoto	No
Processed By	Engr. Sheila-Maye Santillan, Aljon Rie Araneta, Engr. Monalyne Rabino

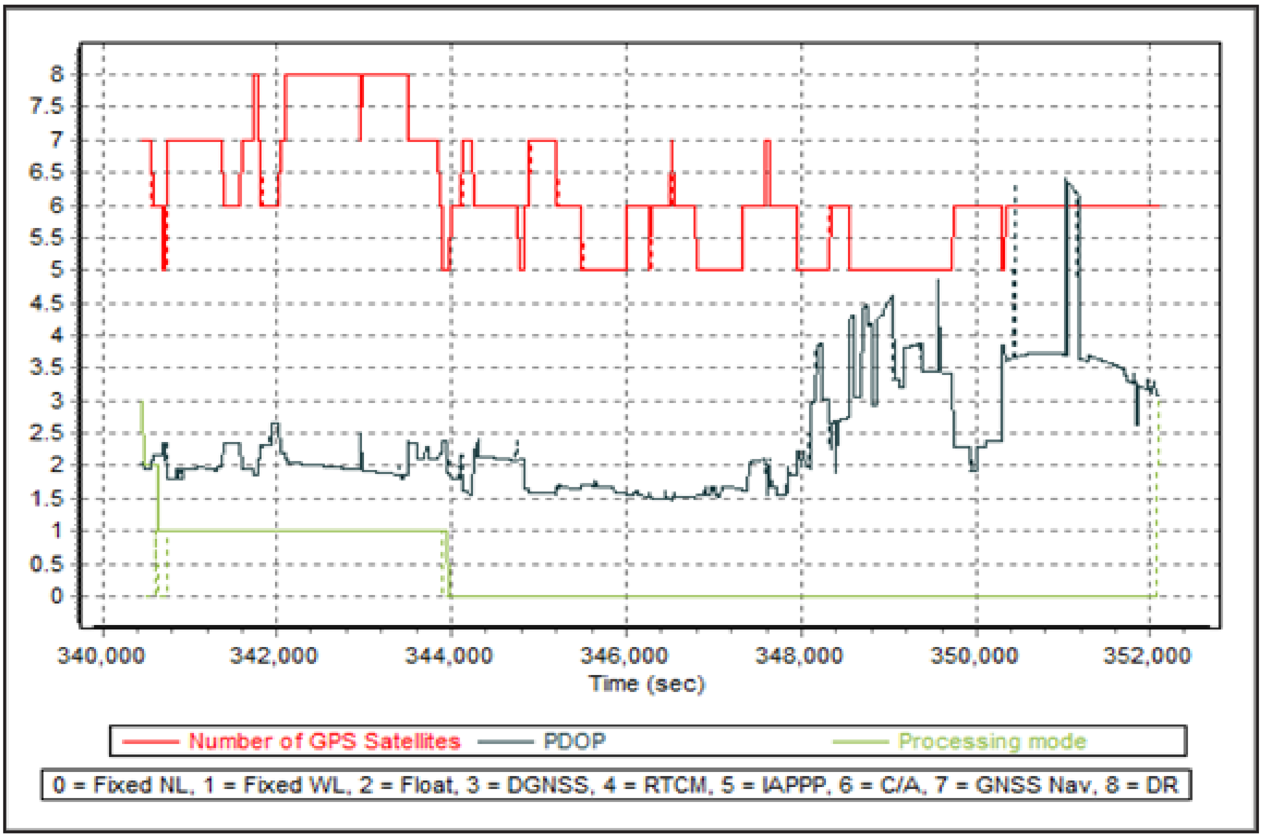


Figure A-8.33. Solution Status

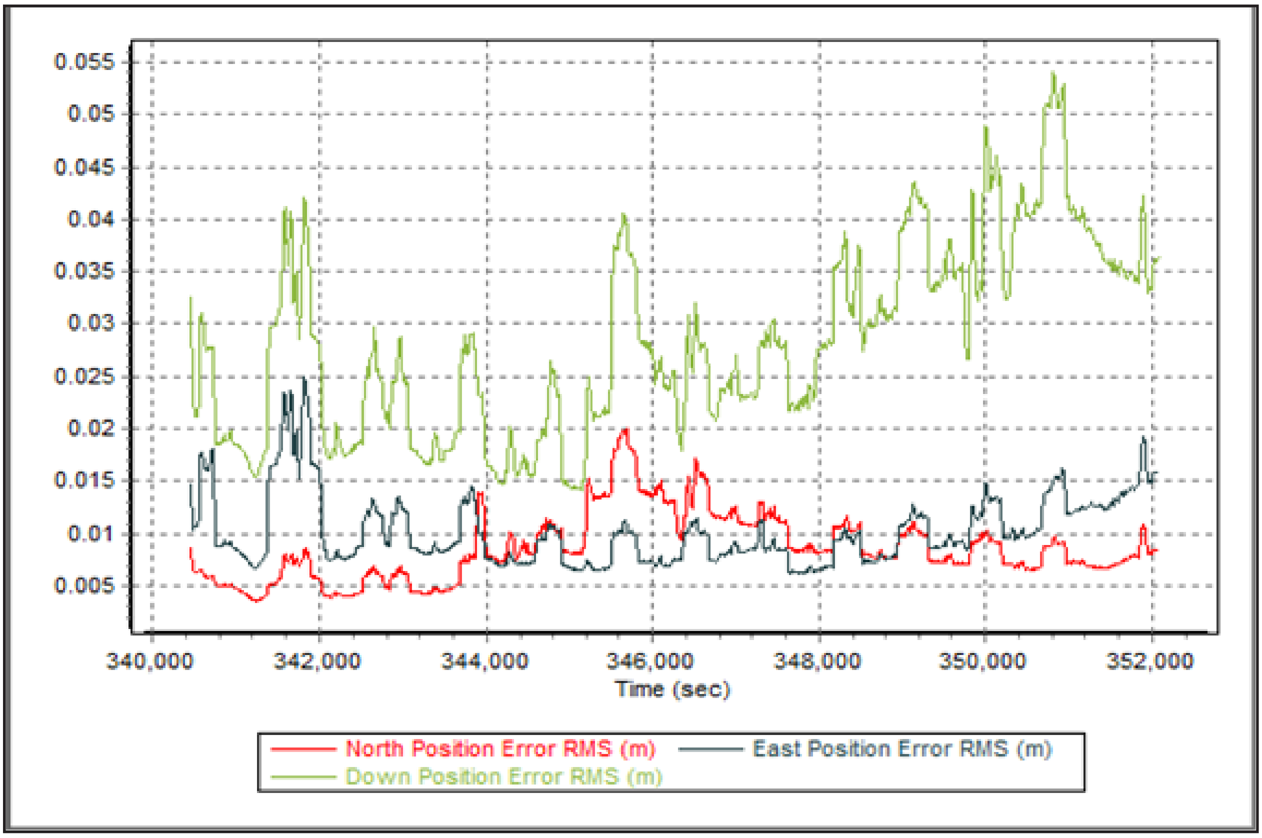


Figure A-8.34. Smoothed Performance Metric Parameters

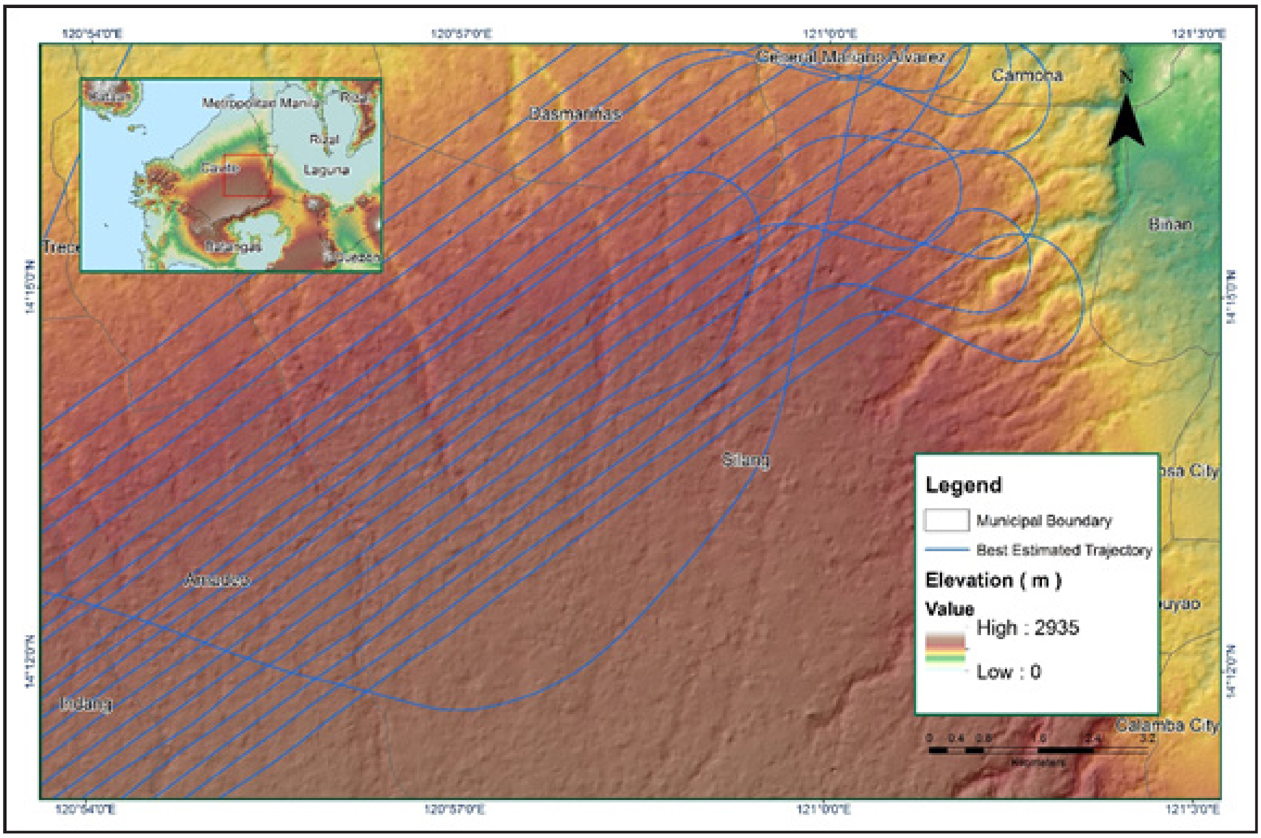


Figure A-8.35. Best Estimated Trajectory

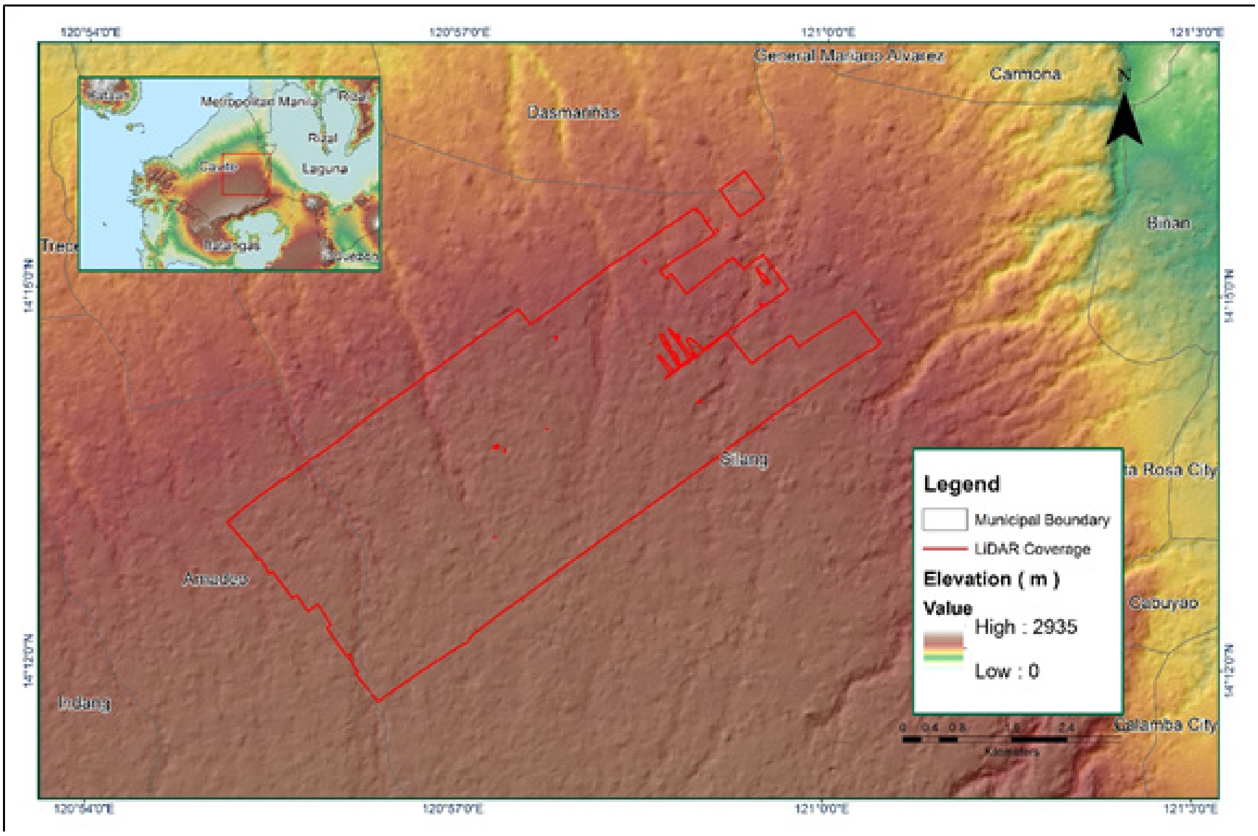


Figure A-8.36. Coverage of LiDAR Data

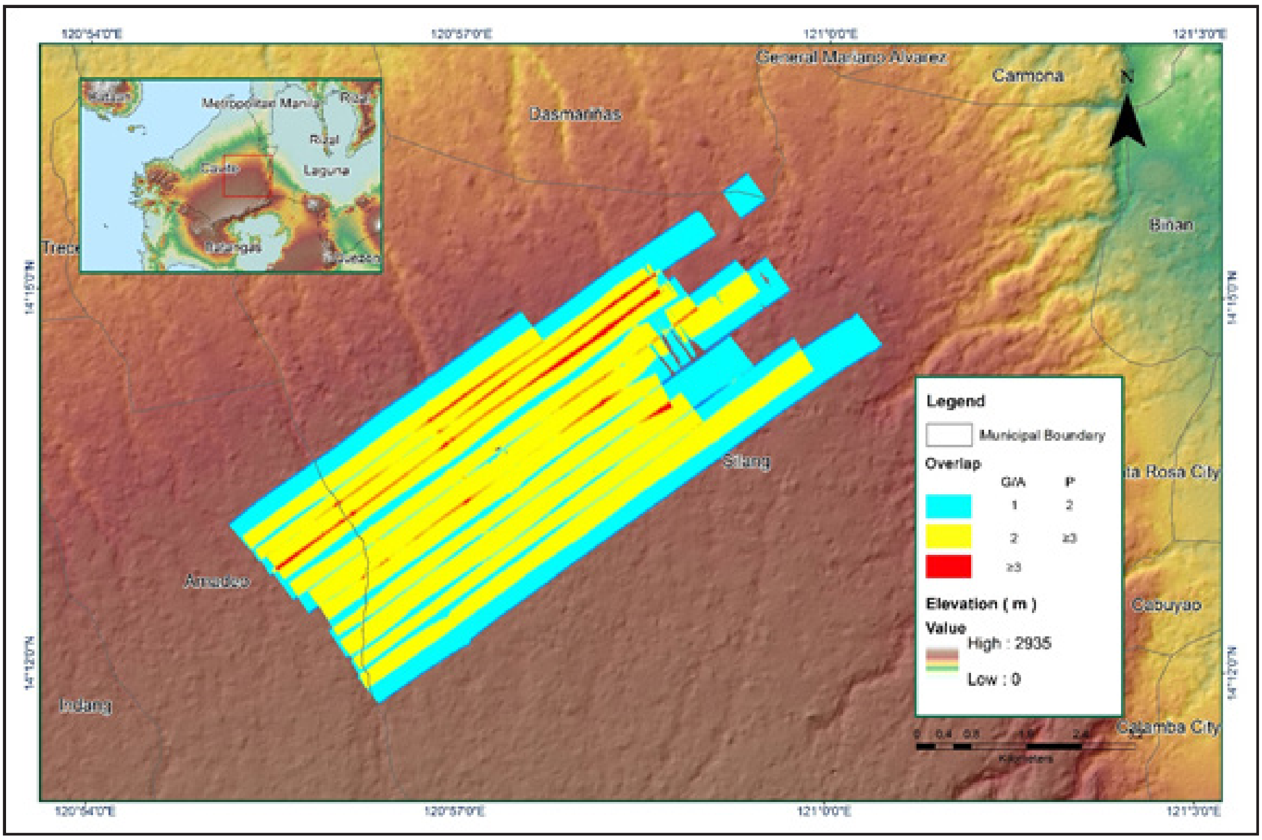


Figure A-8.37. Image of data overlap

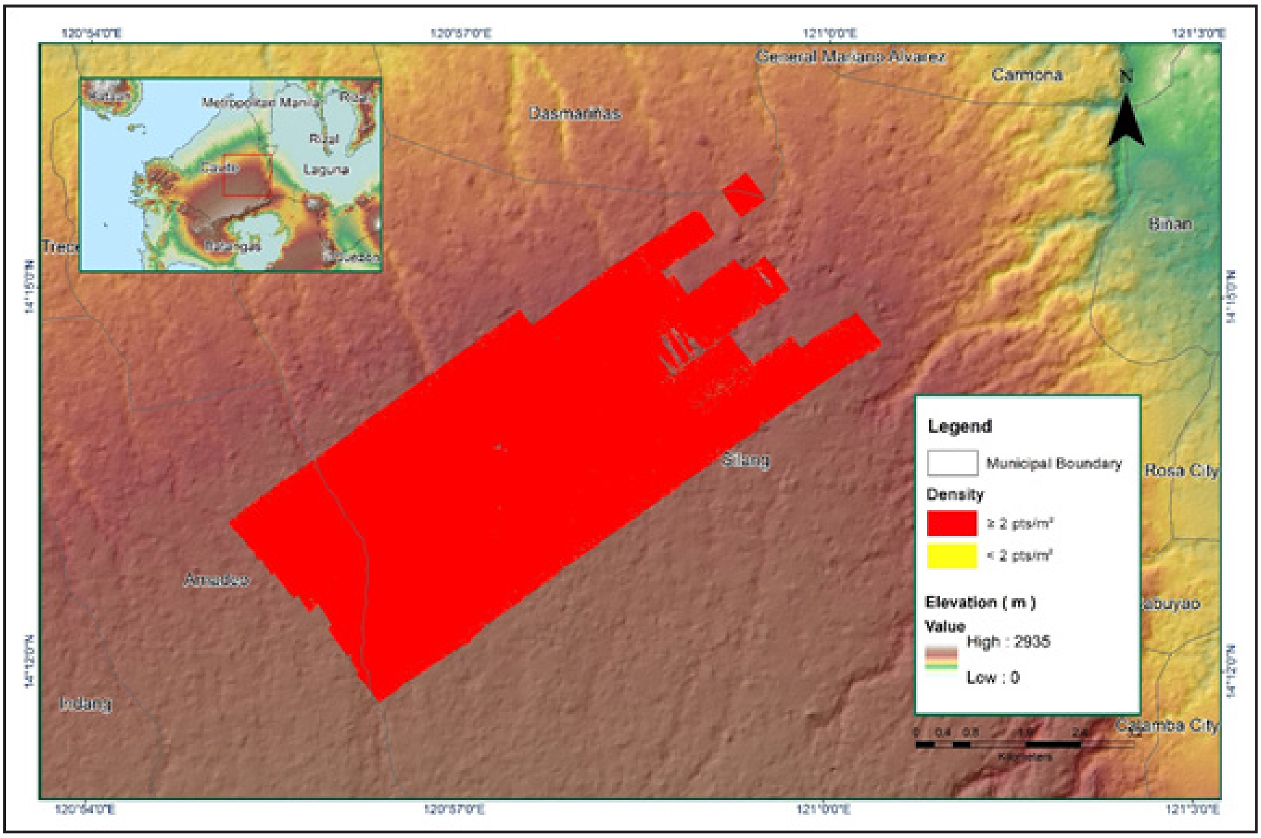


Figure A-8.38. Density map of merged LiDAR data

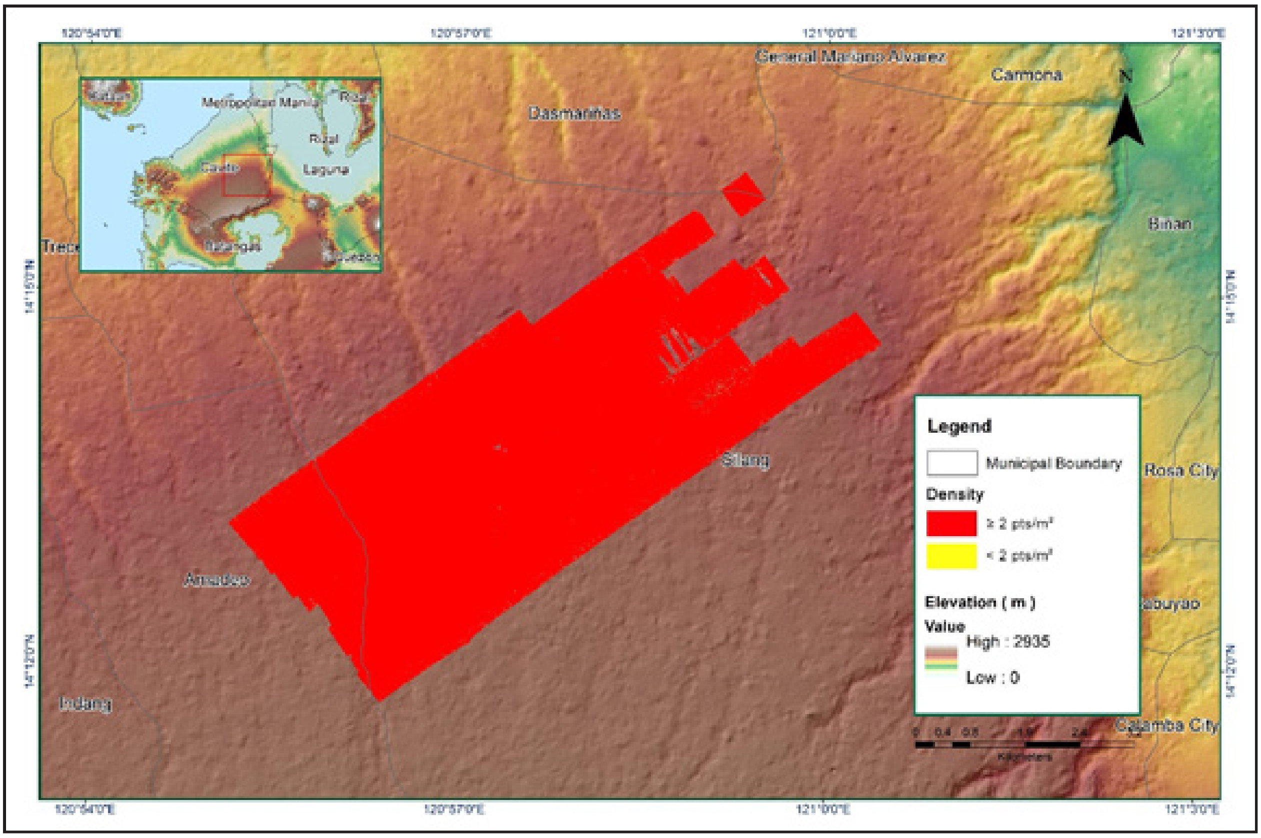


Figure A-8.39. Elevation difference between flight lines

Table A-8.6. Flight Status Report for Mission Blk18B_Supplement2

Flight Area	**CALABARZON Reflights**
Mission Name	Blk18B_Supplement2
Inclusive Flights	10321L
RawLaser	6.16 GB
GnssImu	329 MB
Image	7.32 GB
Transfer date	2/13/2017
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Combined Separation (-0.1 up to 0.1)	No
Estimated Position Accuracy (in cm)	
Estimated Standard Devation for North Position (<4.0 cm)	2.7
Estimated Standard Devation for East Position (<4.0 cm)	3.2
Estimated Standard Devation for Height Position (<8.0 cm)	3.5
Minimum % overlap (>25)	NA
Ave point cloud density per sq.m. (>2.0)	0.36
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	4
Maximum Height	80.78 m
Minimum Height	44.26 m
Classification (# of points)	
Ground	567,120
Low vegetation	71,493
Medium vegetation	207,551
High vegetation	367,049
Building	812,227
Orthophoto	Yes
Processed By	Engr. Regis Guhiting, Engr. Harmond Santos, Engr. Gladys Mae Apat

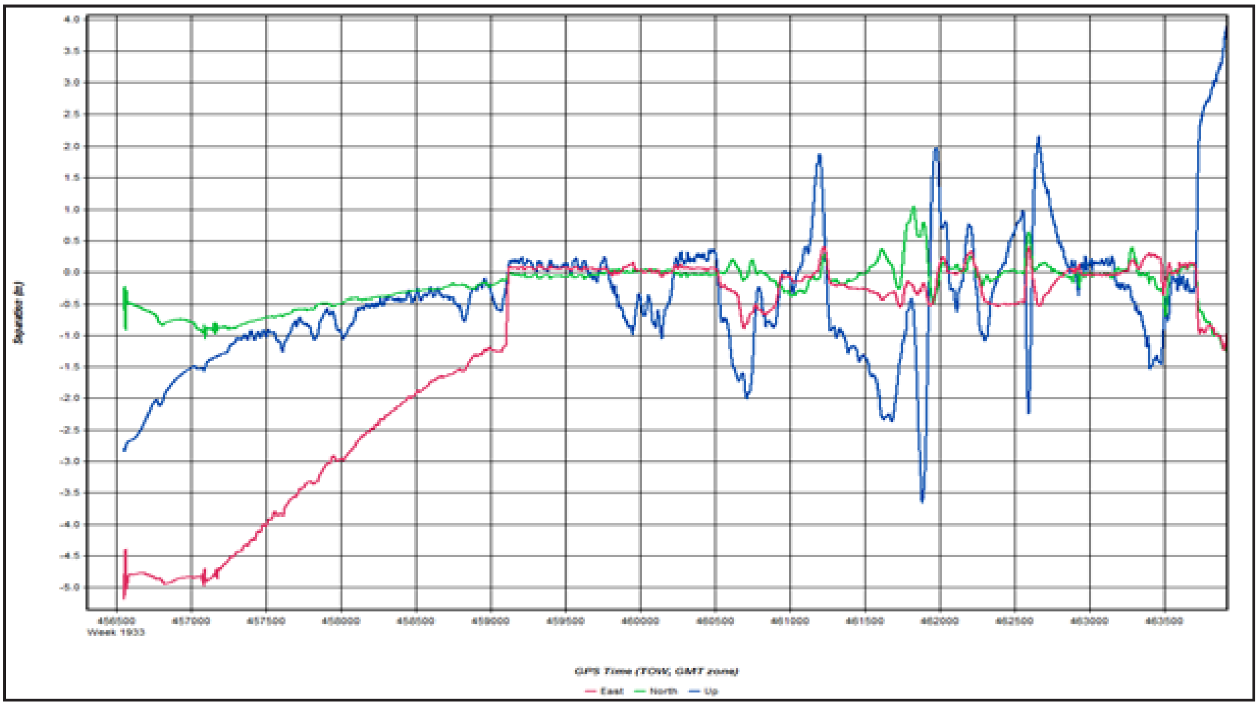


Figure A-8.40. Combined Separation

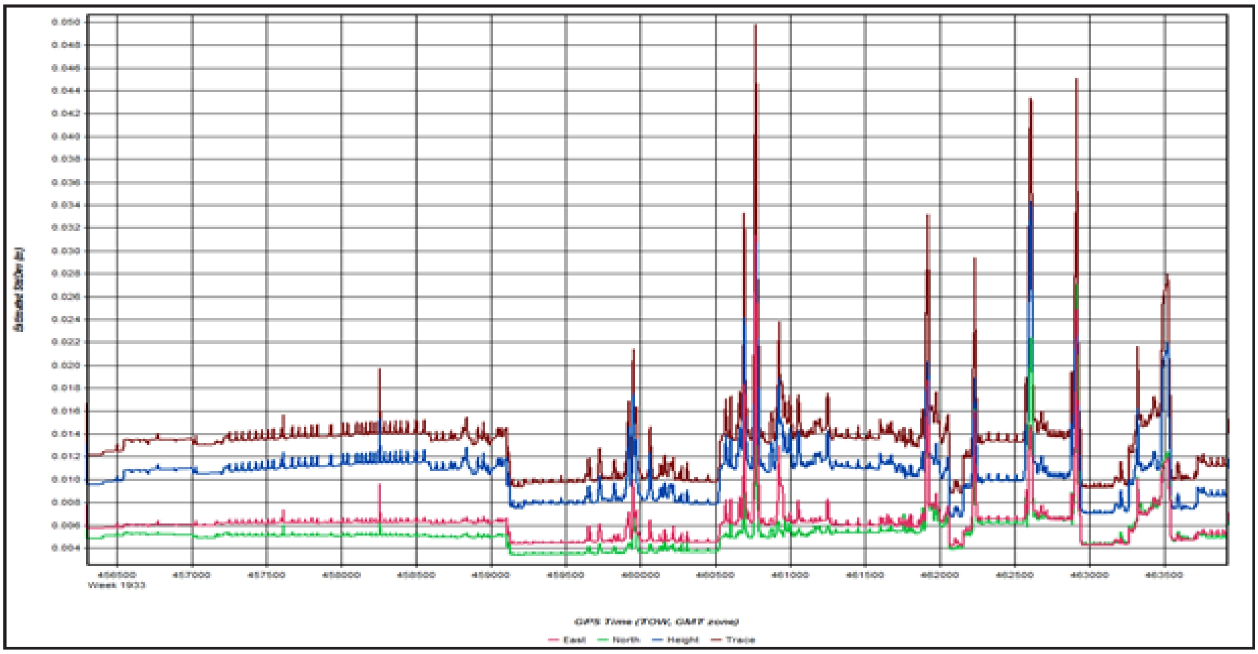


Figure A-8.41. Estimated Position of Accuracy

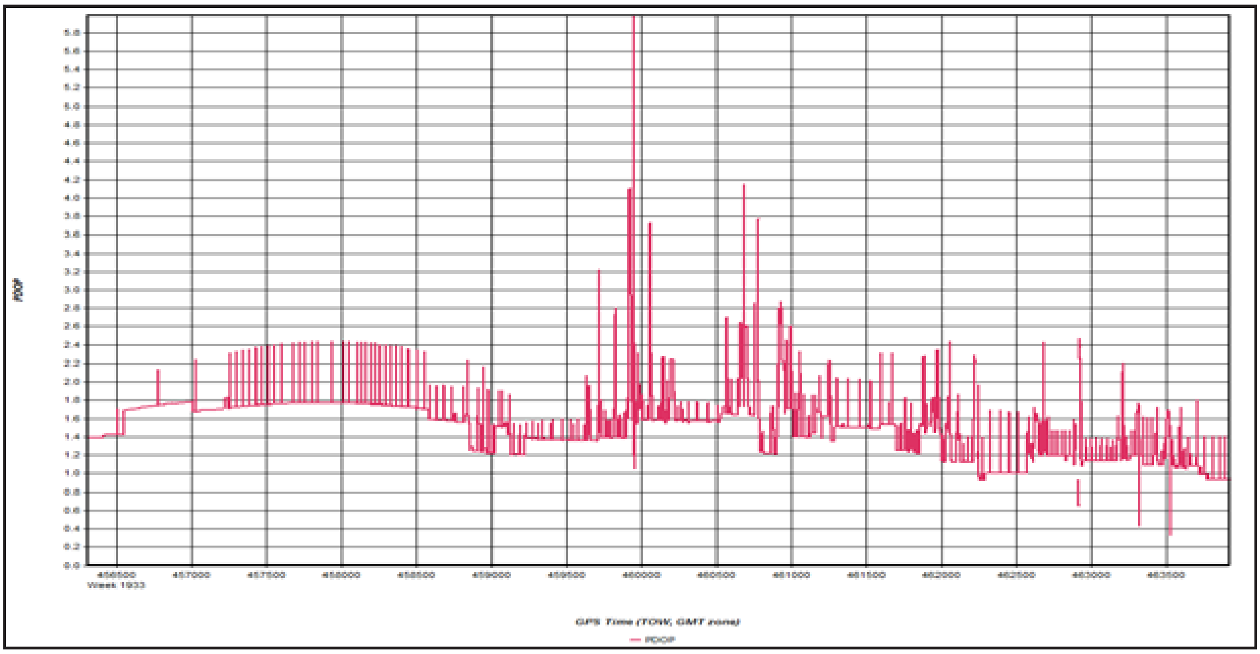


Figure A-8.42. PDOP

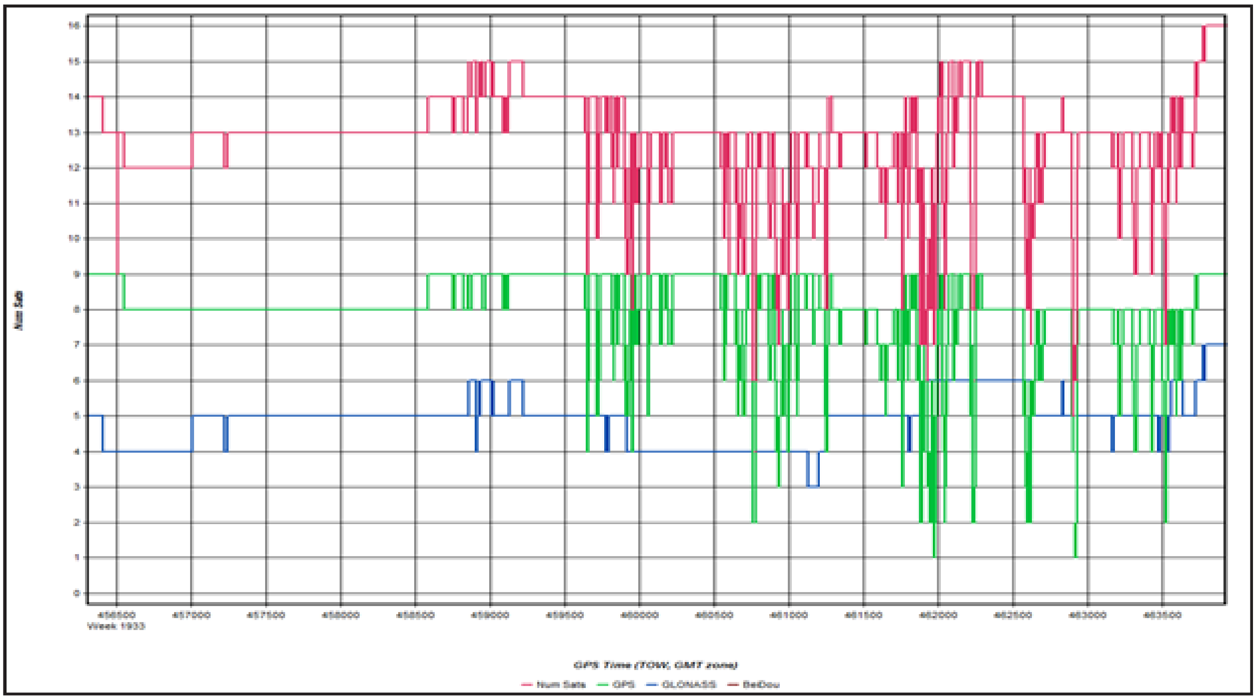


Figure A-8.43. Number of Satellites

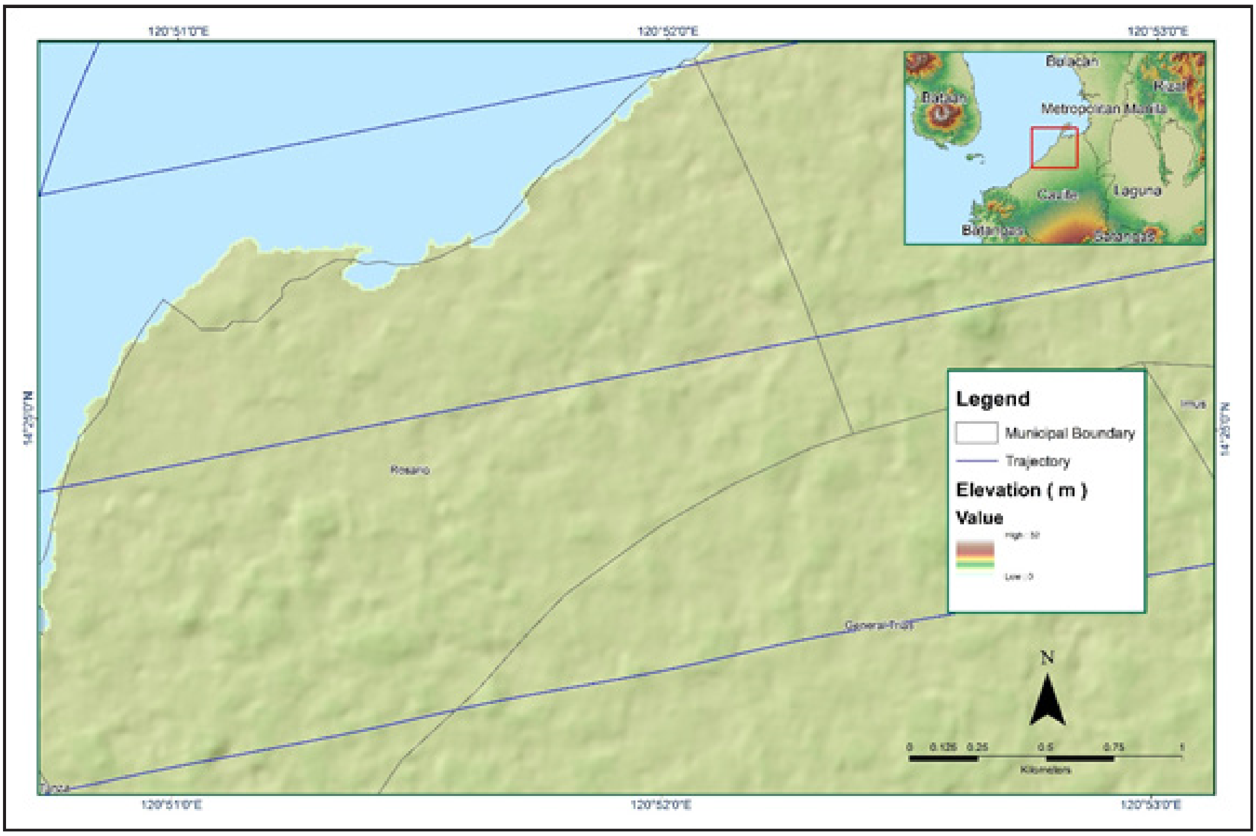


Figure A-8.44. Best Estimated Trajectory

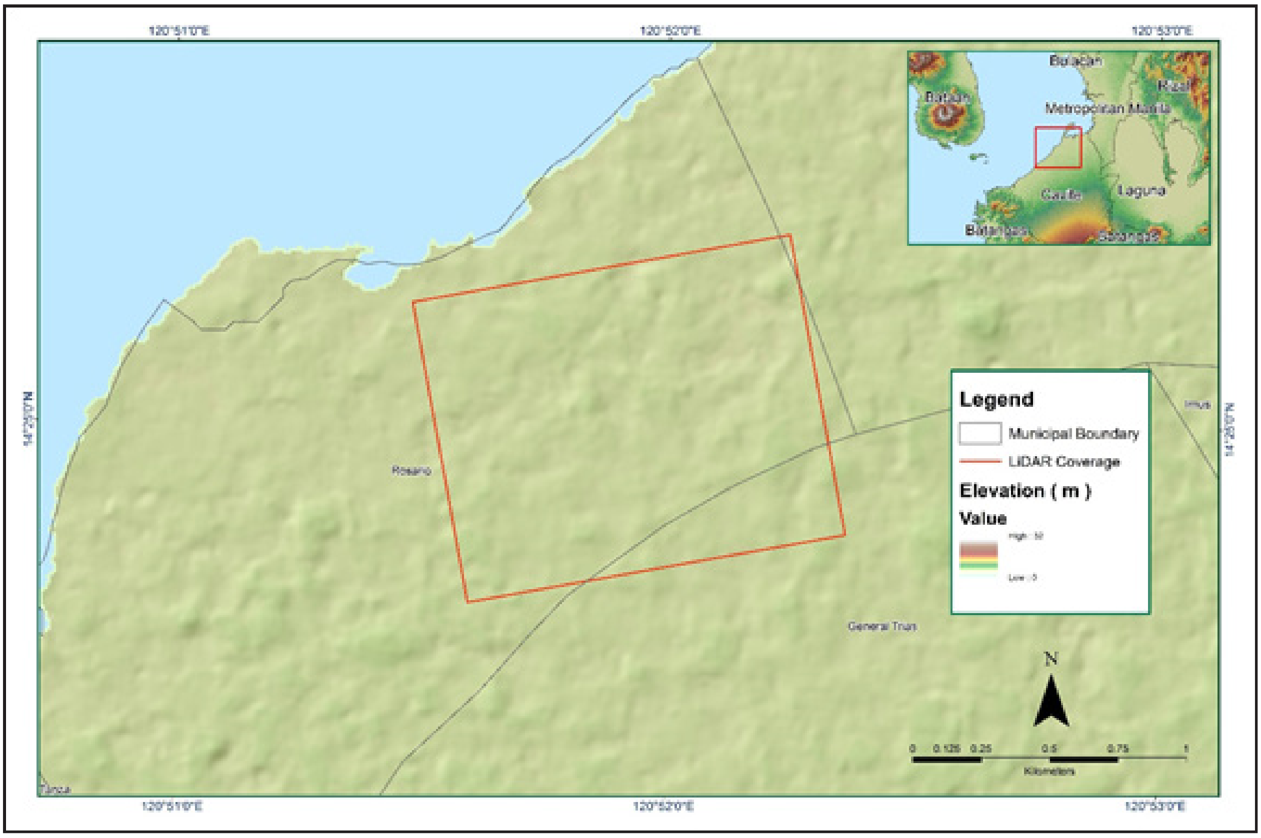


Figure A-8.45. Coverage of LiDAR data

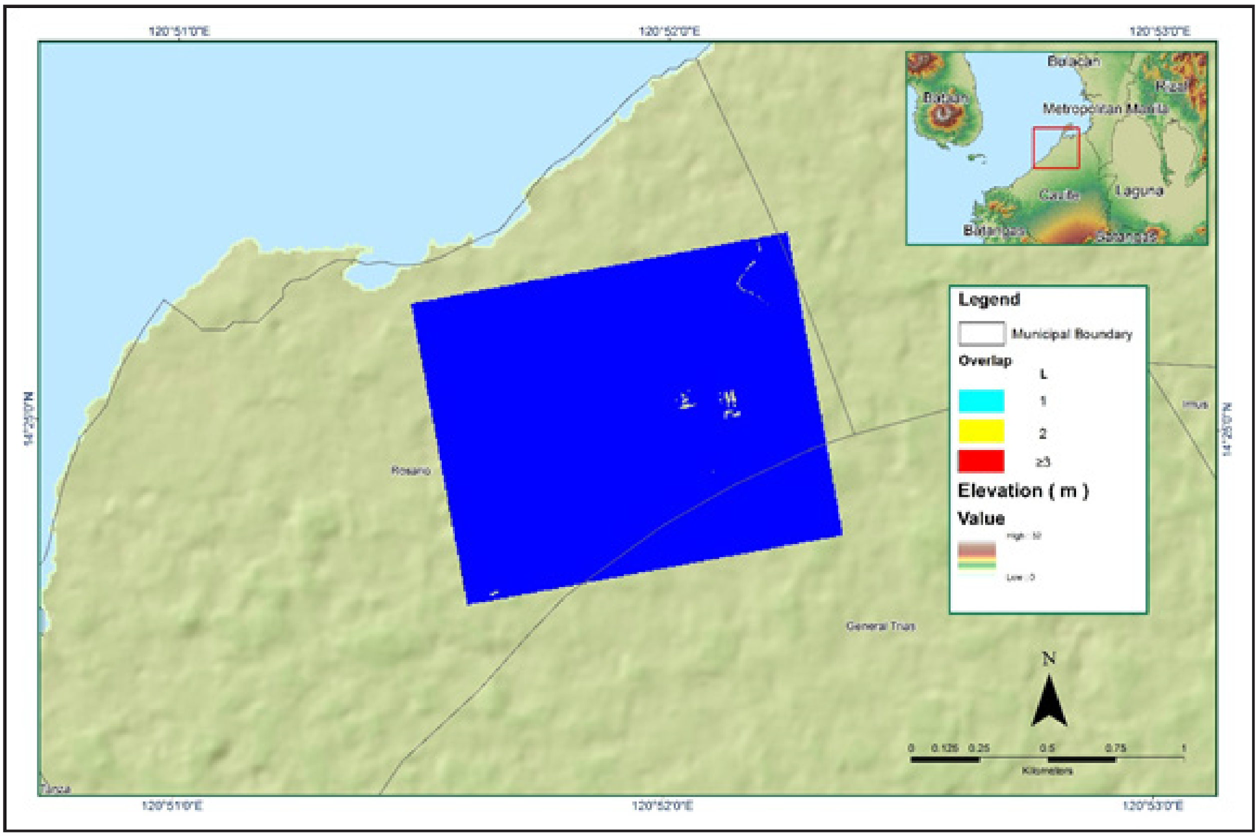


Figure A-8.46. Image of data overlap

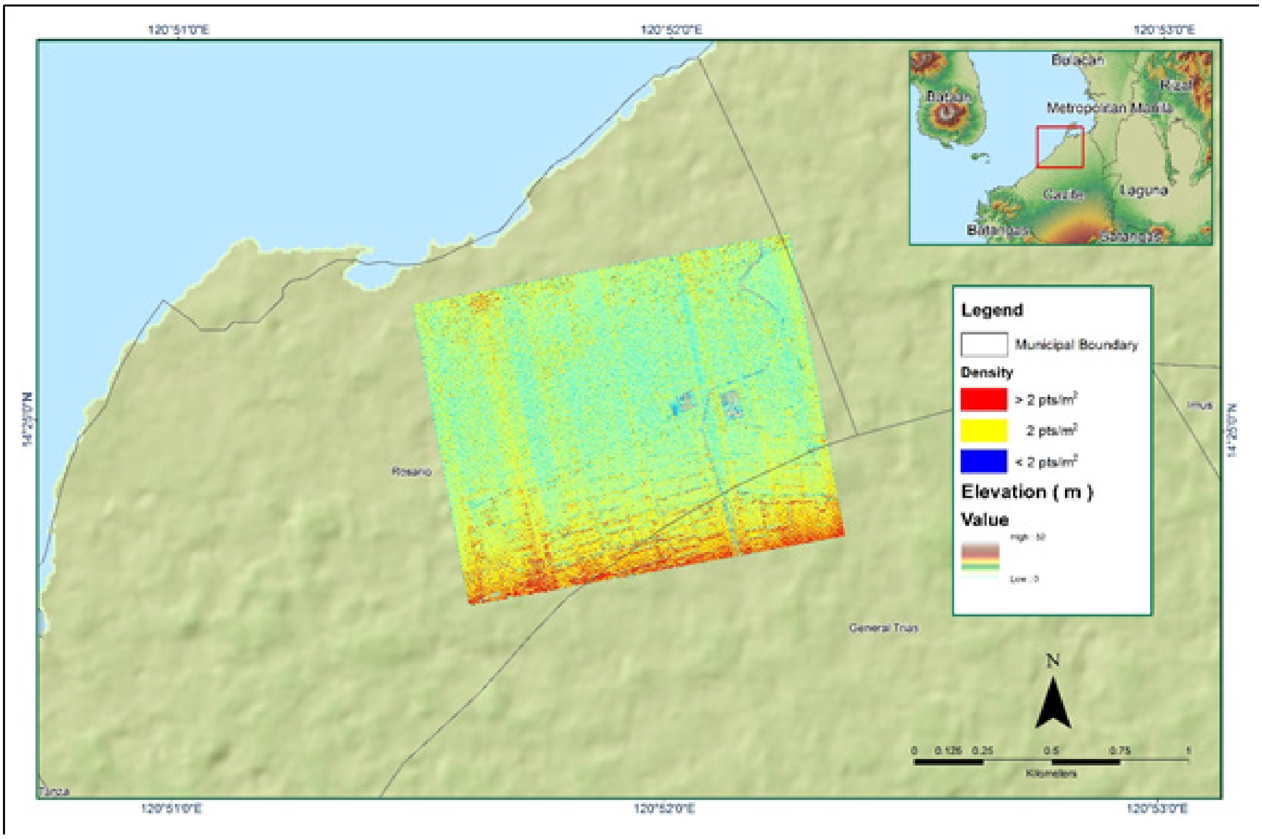


Figure A-8.47. Density map of merged LiDAR data

Table A-8.7. Flight Status Report for Mission Blk18D_Supplement1

Flight Area	CALABARZON
Mission Name	Blk18D_Supplement1
Inclusive Flights	1063P, 23462P
Range data size	44.22 GB
POS data size	369.55 MB
Base data size	321.96 MB
Image	n/a
Transfer date	July 14, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.1
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	8.1
Boresight correction stdev (<0.001deg)	0.000690
IMU attitude correction stdev (<0.001deg)	0.0009
GPS position stdev (<0.01m)	0.000286
Minimum % overlap (>25)	69.04%
Ave point cloud density per sq.m. (>2.0)	8.23
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	62
Maximum Height	494.08 m
Minimum Height	280.91 m
Classification (# of points)	
Ground	48,712,778
Low vegetation	33,328,464
Medium vegetation	169,208,992
High vegetation	171,273,810
Building	17,106,047
Orthophoto	No
Processed By	Engr. Sheila-Maye Santillan, Engr. Harmond Santos, Engr. Gladys Mae Apat

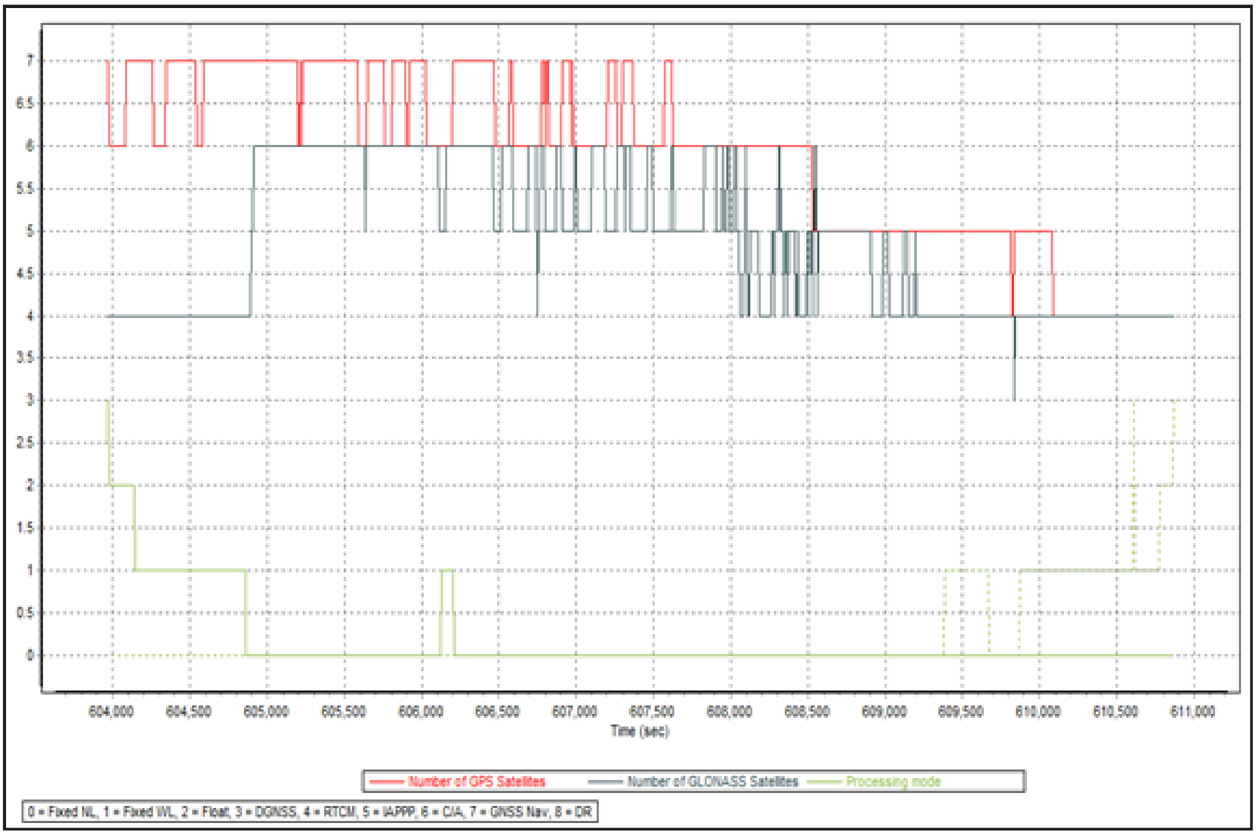


Figure A-8.48. Solution Status

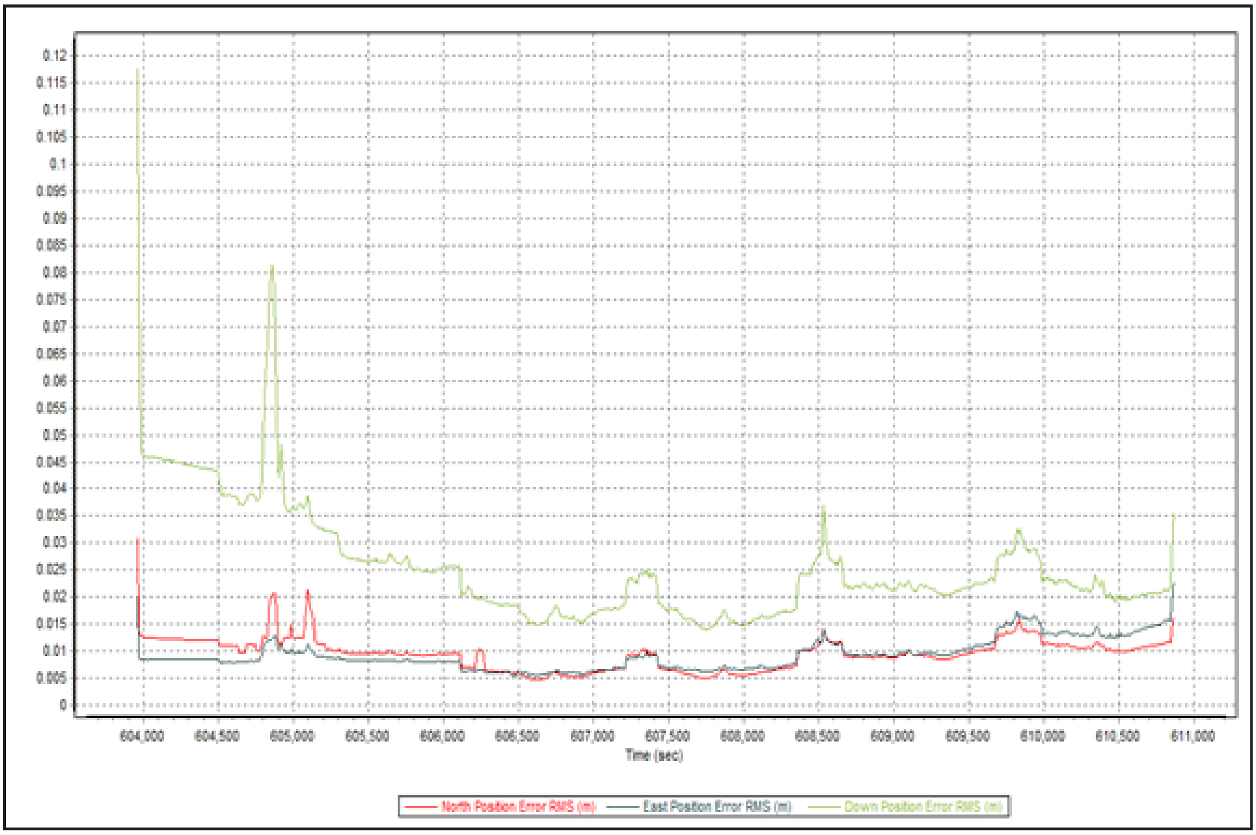


Figure A-8.49. Smoothed Performance Metric Parameters

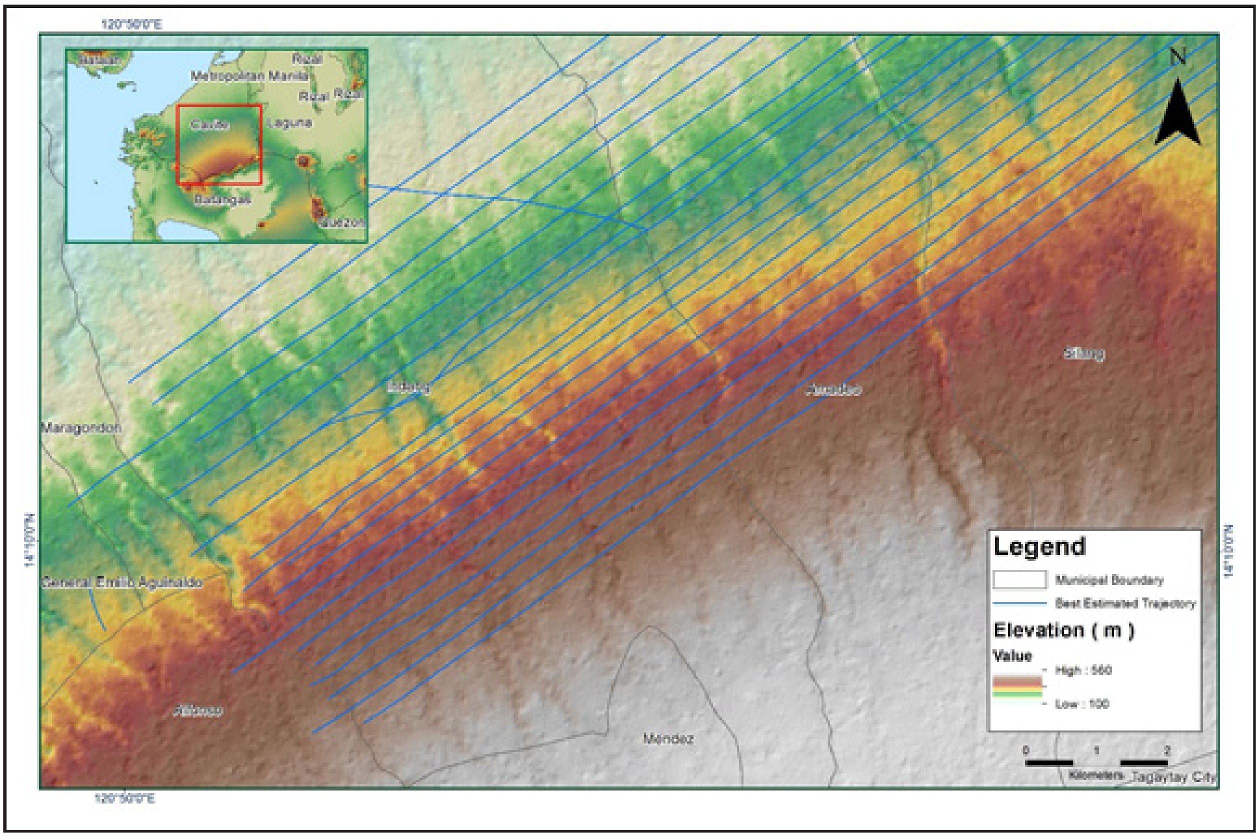


Figure A-8.50. Best Estimated Trajectory

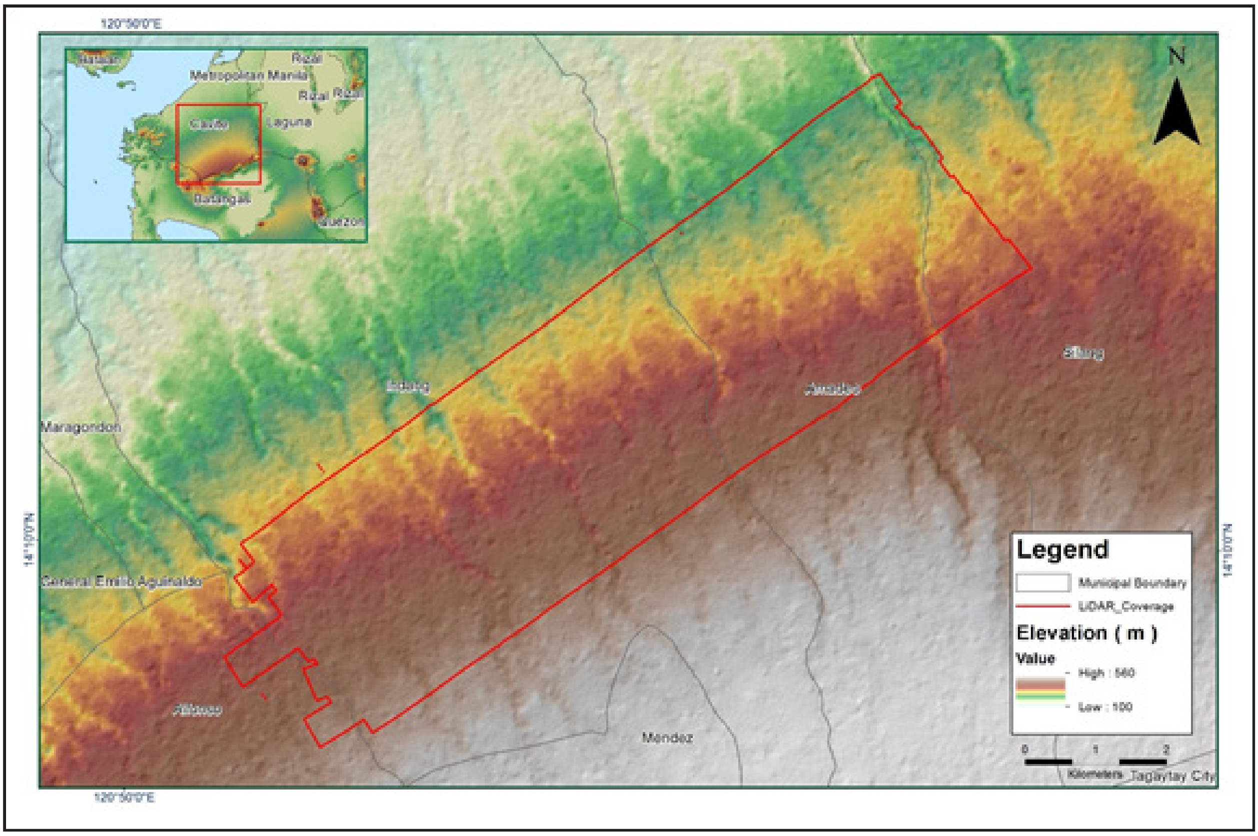


Figure A-8.51. Coverage of LiDAR Data

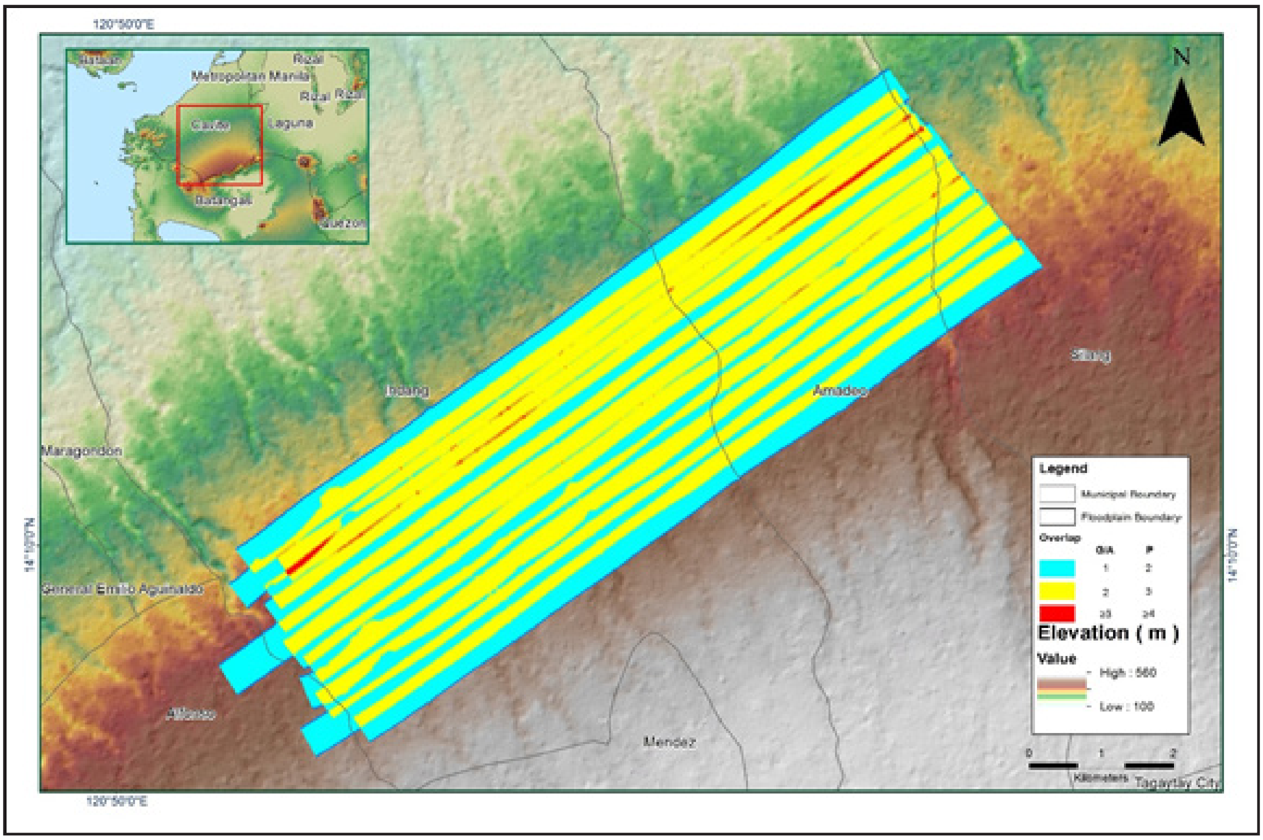


Figure A-8.52. Image of data overlap

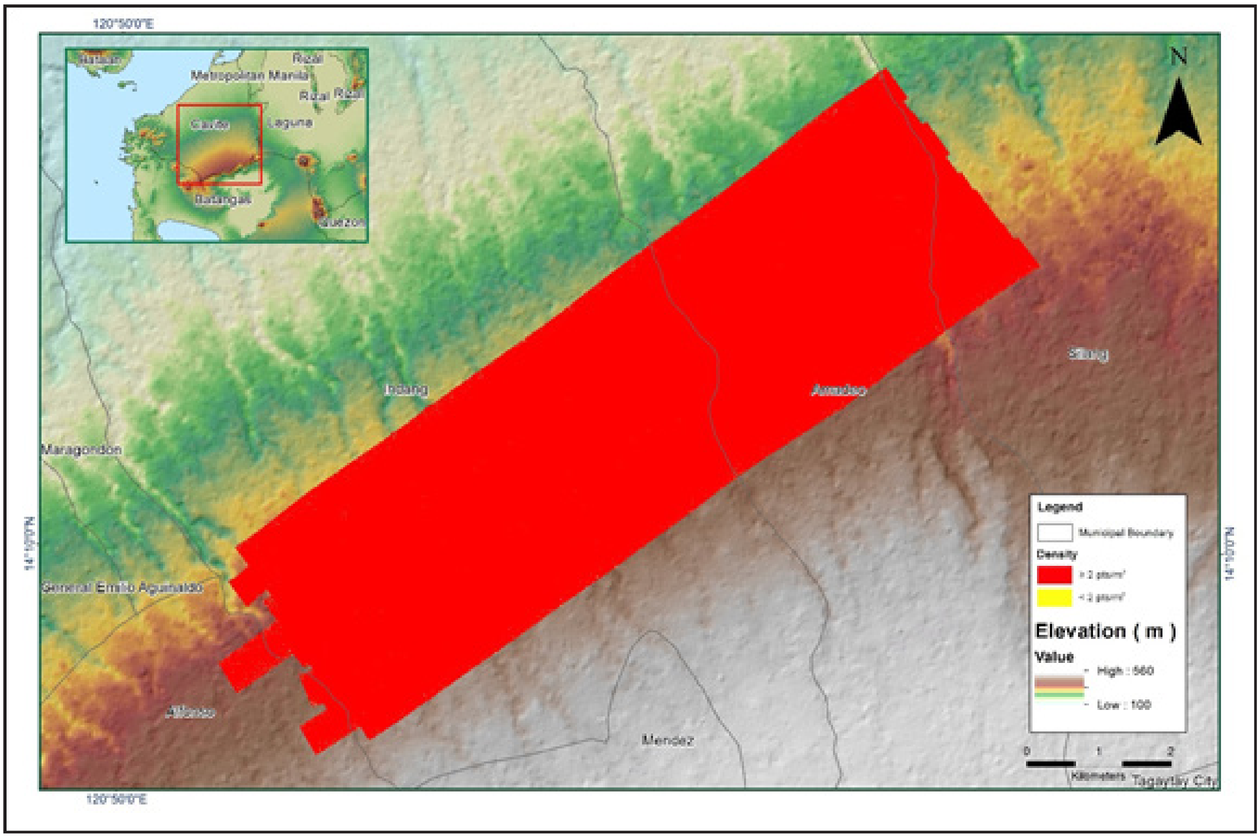


Figure A-8.53. Density map of merged LiDAR data

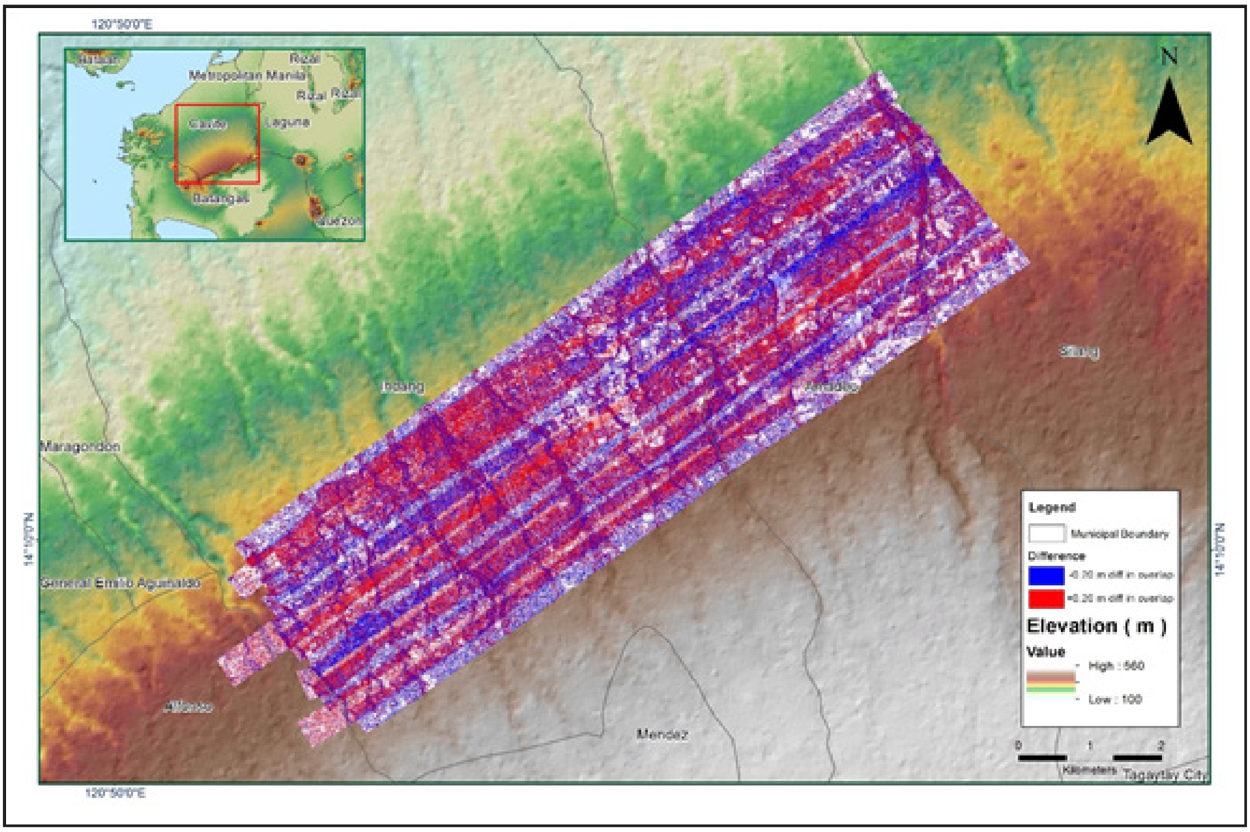


Figure A-8.54. Elevation difference between flight lines

Table A-8.8. Flight Status Report for Mission Blk18D_supplement2

Flight Area	CALABARZON Reflights
Mission Name	Blk18D_supplement2
Inclusive Flights	10161L, 10162L, 10166L
RawLaser	17.06 GB
Base data size	1.95 GB
GnssImu	956 MB
Image	61.5 GB
Transfer date	7/13/2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Combined Separation (-0.1 up to 0.1)	Yes
Estimated Position Accuracy (in cm)	
Estimated Standard Devation for North Position (<4.0 cm)	0.35
Estimated Standard Devation for East Position (<4.0 cm)	0.37
Estimated Standard Devation for Height Position (<8.0 cm)	0.50
Minimum % overlap (>25)	11.41%
Ave point cloud density per sq.m. (>2.0)	4.12
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	233
Maximum Height	584.35 m
Minimum Height	88.64 m
Classification (# of points)	
Ground	207,648,445
Low vegetation	70,430,231
Medium vegetation	222,085,553
High vegetation	376,381,682
Building	87,357,607
Orthophoto	Yes
Processed by	Engr. Ben Joseph Harder, Engr. Harmond Santos, Engr. Gladys Mae Apat

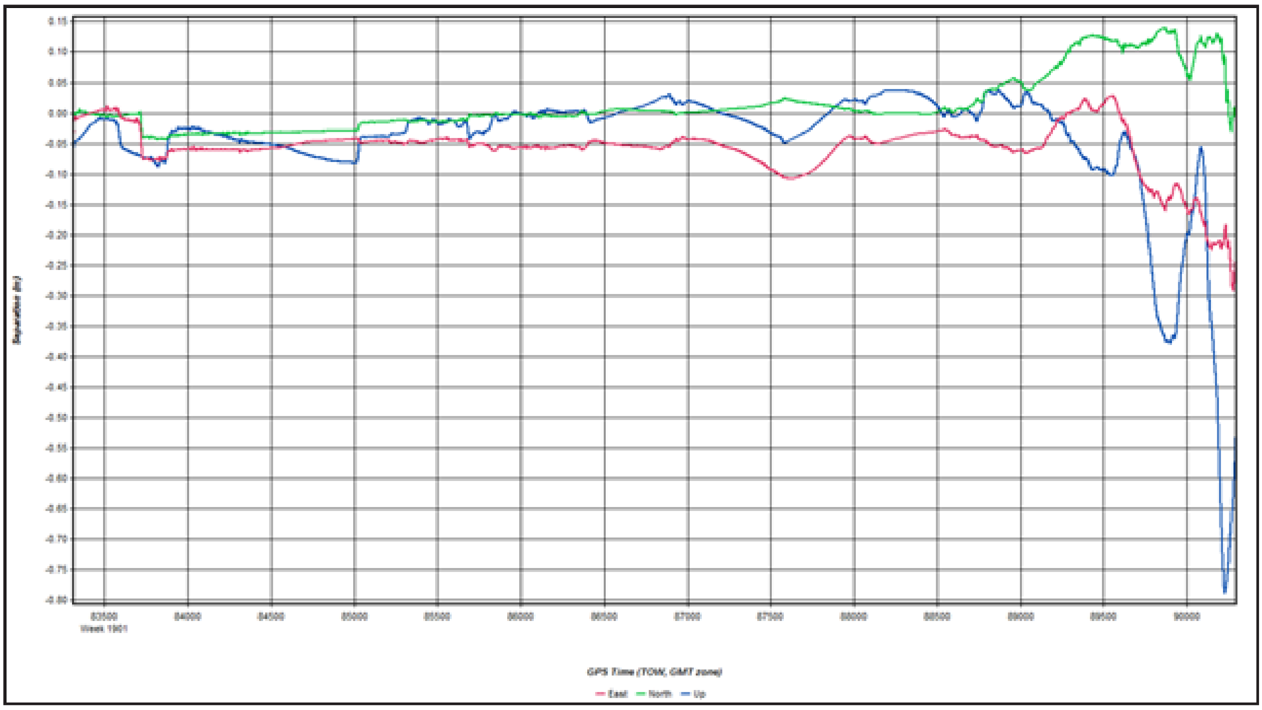


Figure A-8.55. Combined Separation

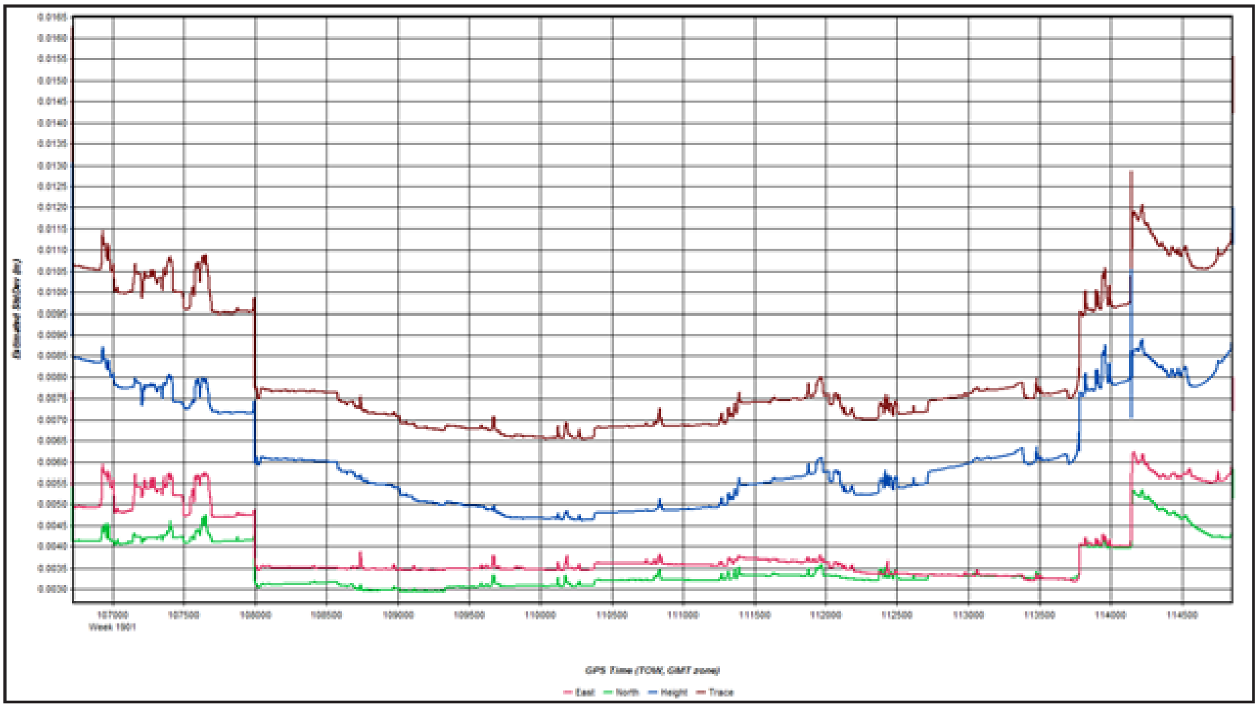


Figure A-8.56. Estimated Position of Accuracy

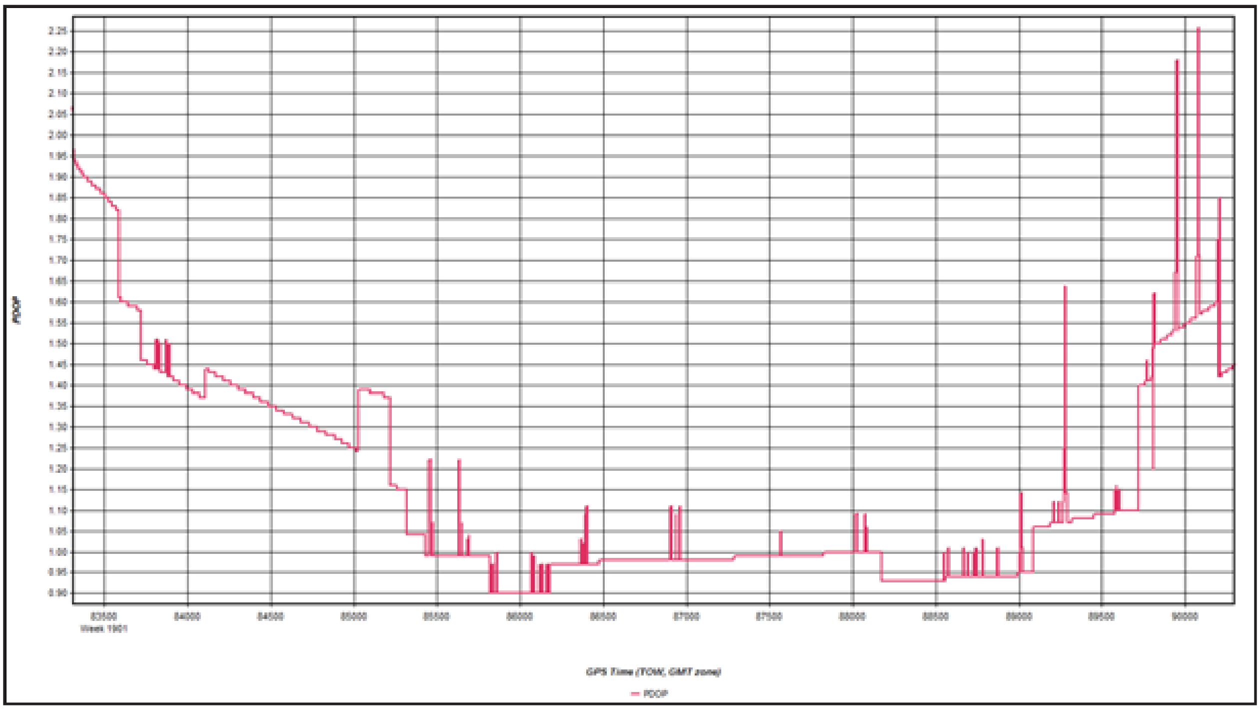


Figure A-8.57. PDOP

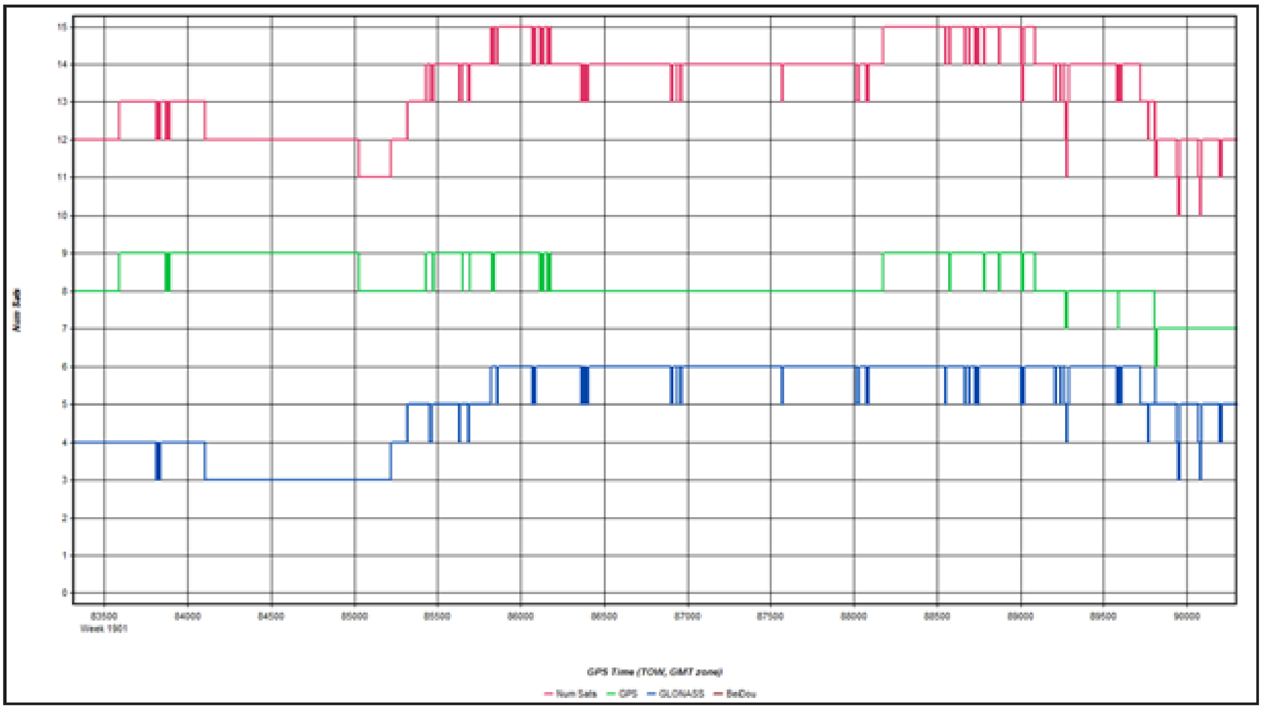


Figure A-8.58. Number of Satellites

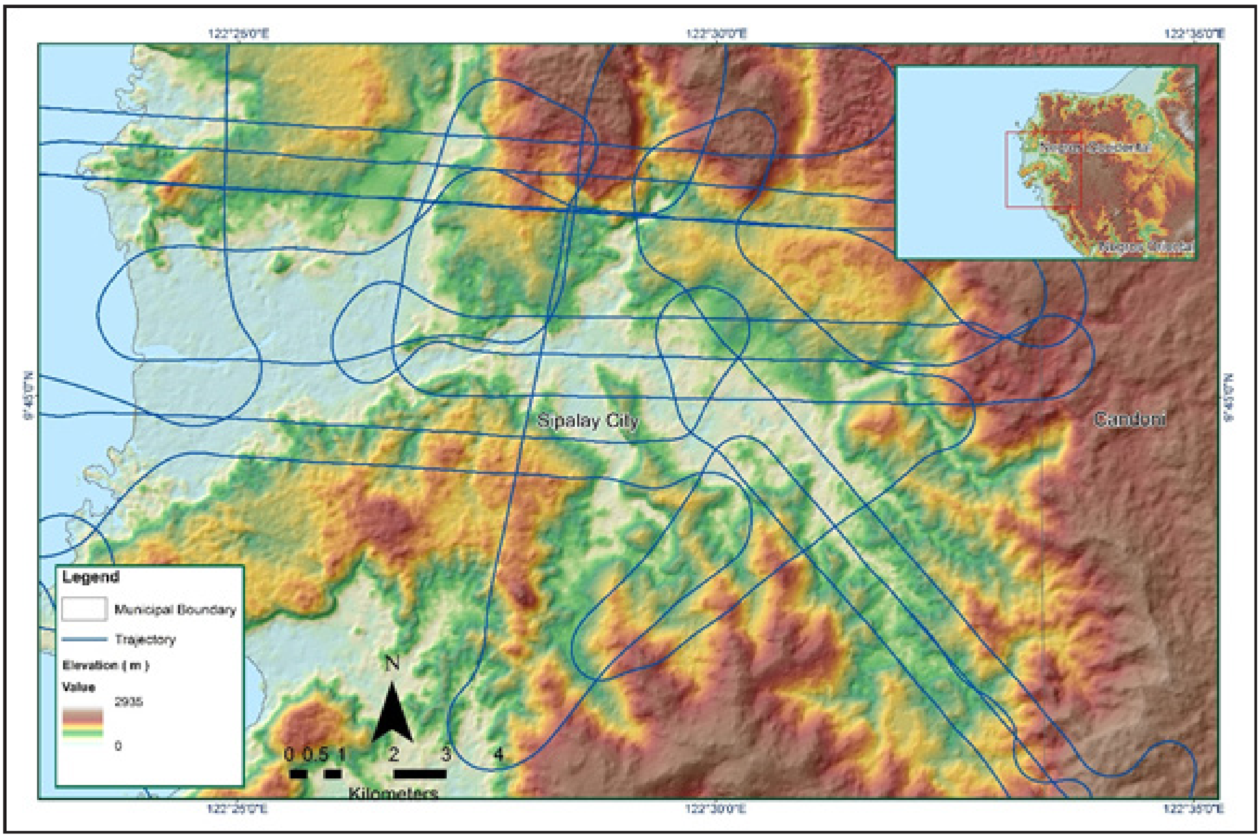


Figure A-8.59. Best Estimated Trajectory

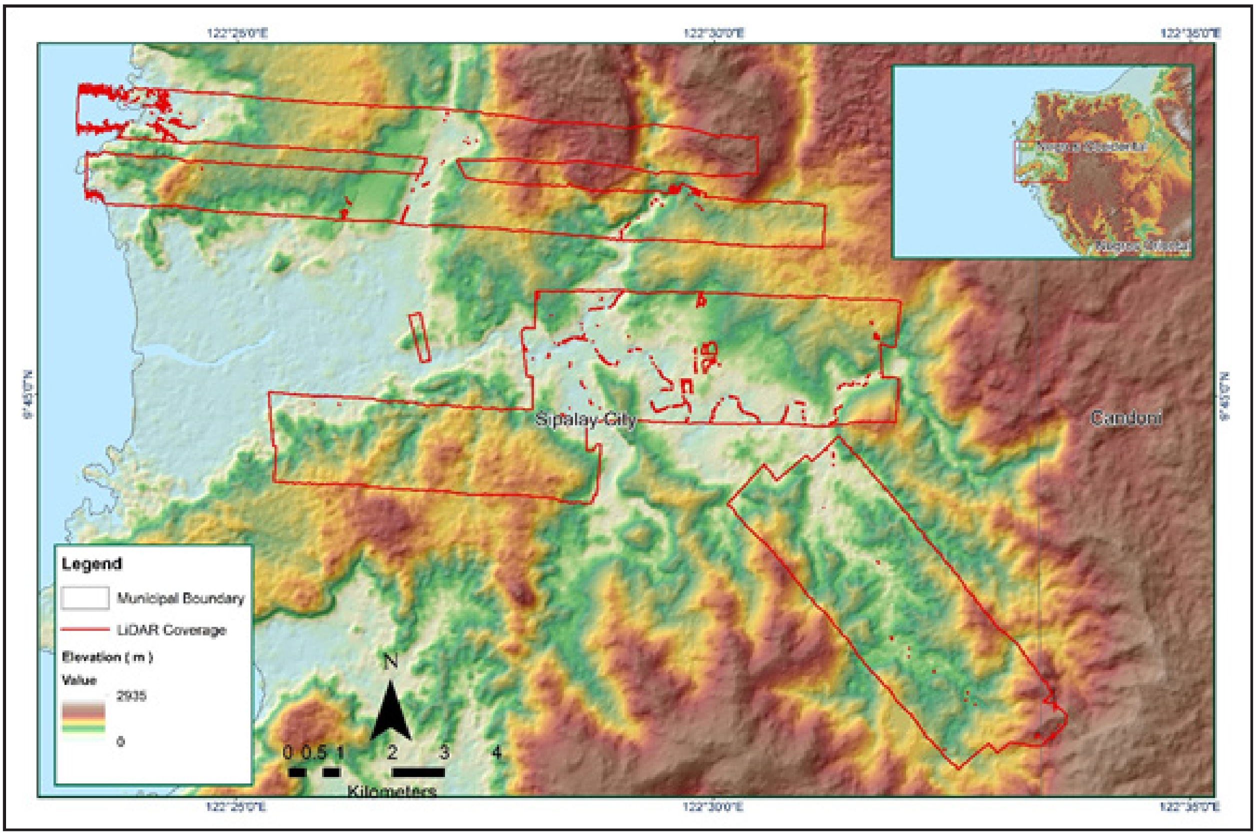


Figure A-8.60. Coverage of LiDAR data

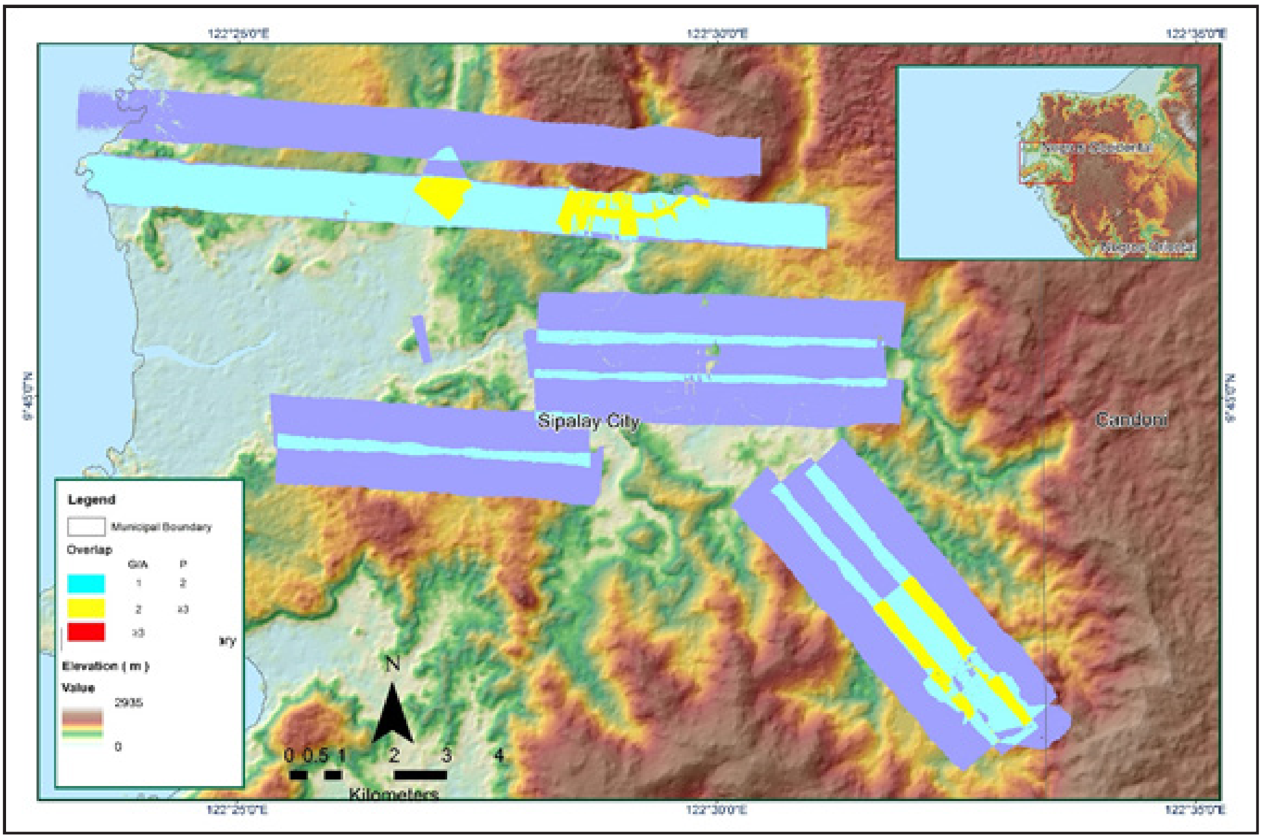


Figure A-8.61. Image of data overlap

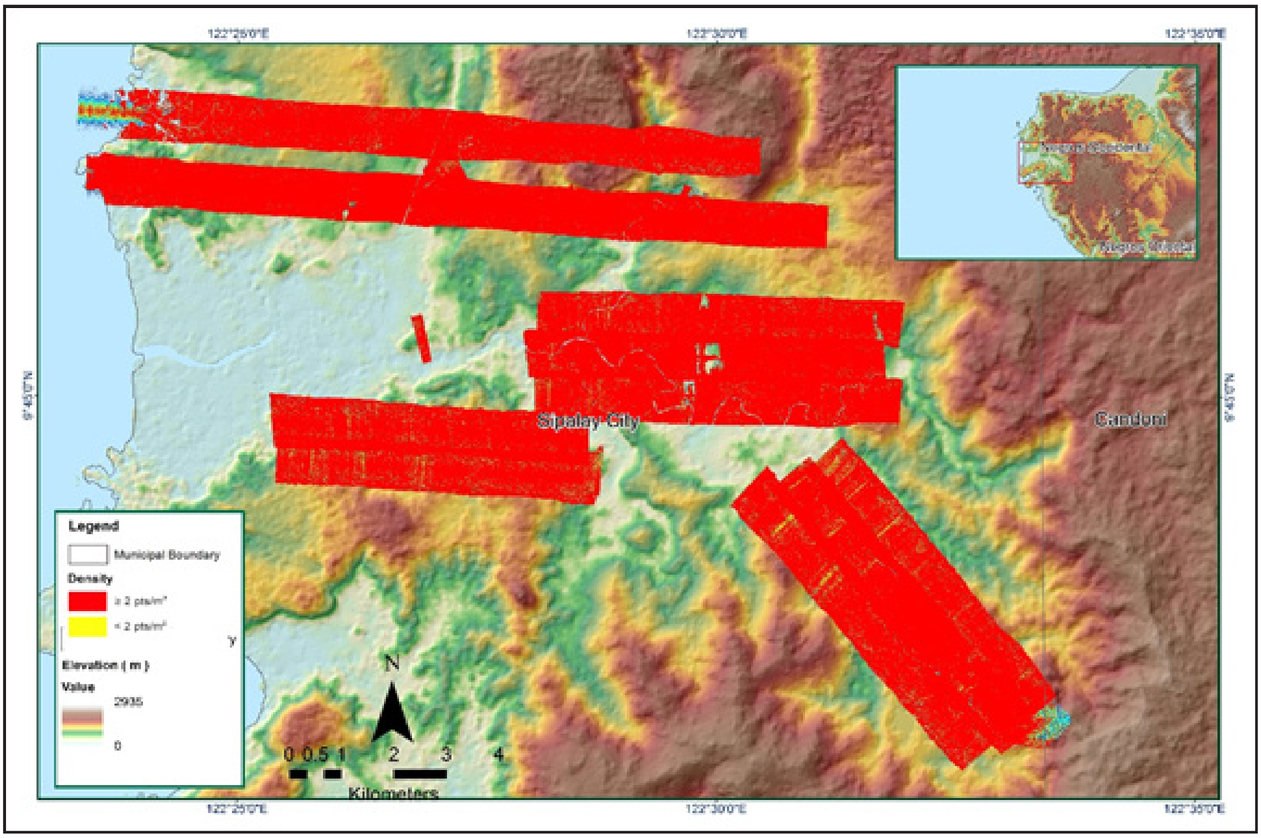


Figure A-8.53. Density map of merged LiDAR data

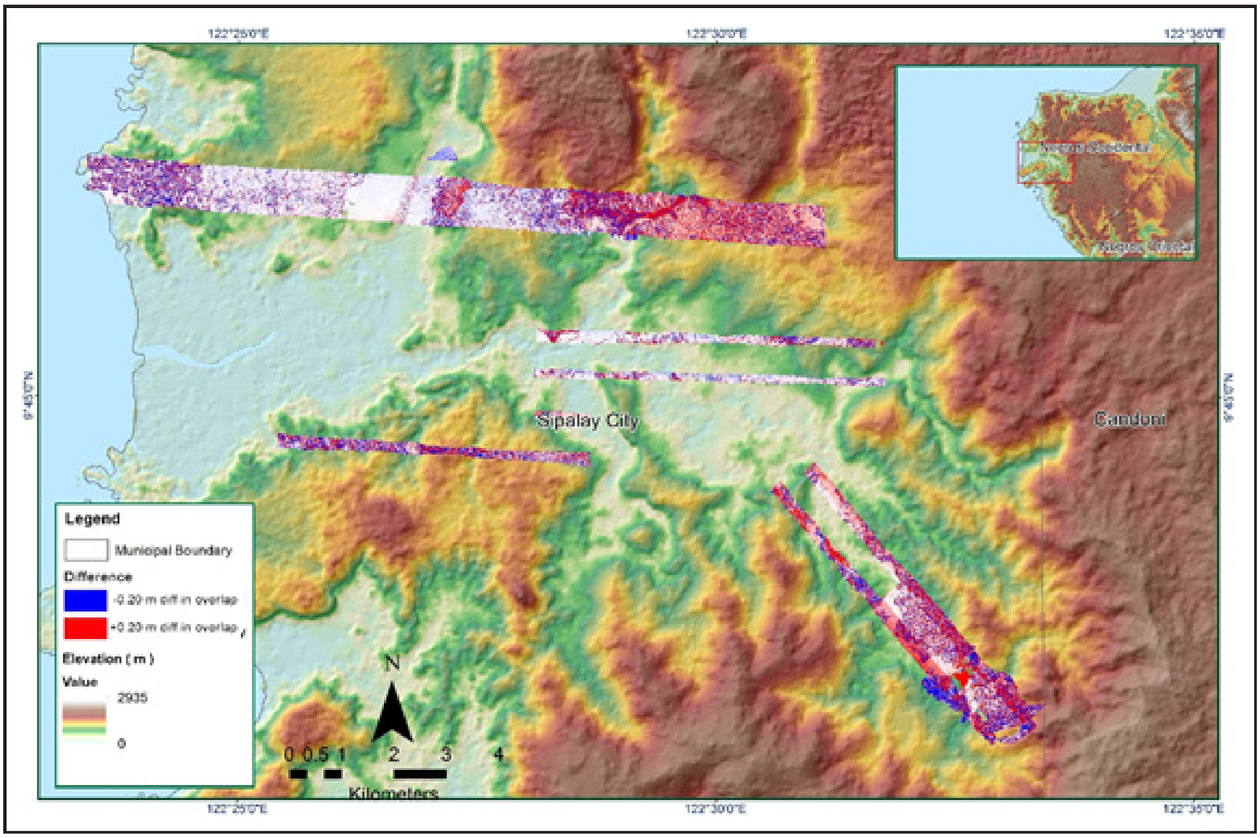


Figure A-8.63. Elevation difference between flight lines

Table A-8.9. Flight Status Report for Mission Blk18A_supplement

Flight Area	CALABARZON
Mission Name	Blk18A_supplement
Inclusive Flights	1043P
Range data size	6.13 GB
Base data size	6.79 MB
POS	125 MB
Image	N/A
Transfer date	04/23/2014
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)	1.1
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	2.6
Boresight correction stdev (<0.001deg)	0.000829
IMU attitude correction stdev (<0.001deg)	0.001021
GPS position stdev (<0.01m)	0.0013
Minimum % overlap (>25)	11.00%
Ave point cloud density per sq.m. (>2.0)	2.31
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	103
Maximum Height	157.83 m
Minimum Height	45.2 m
Classification (# of points)	
Ground	76,835,956
Low vegetation	48,258,042
Medium vegetation	42,822,105
High vegetation	19,332,576
Building	7,920,574
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Celina Rosete, Engr. Gladys Mae Apat

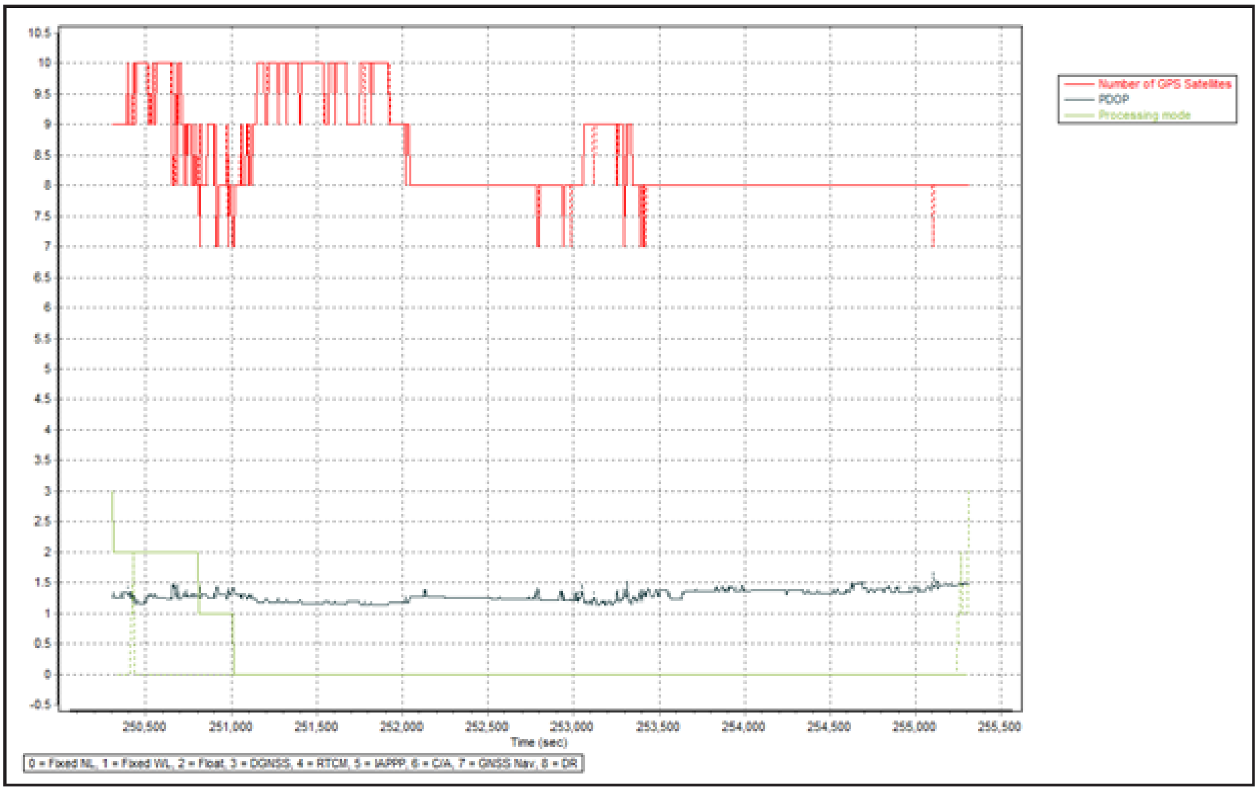


Figure A-8.64. Solution Status

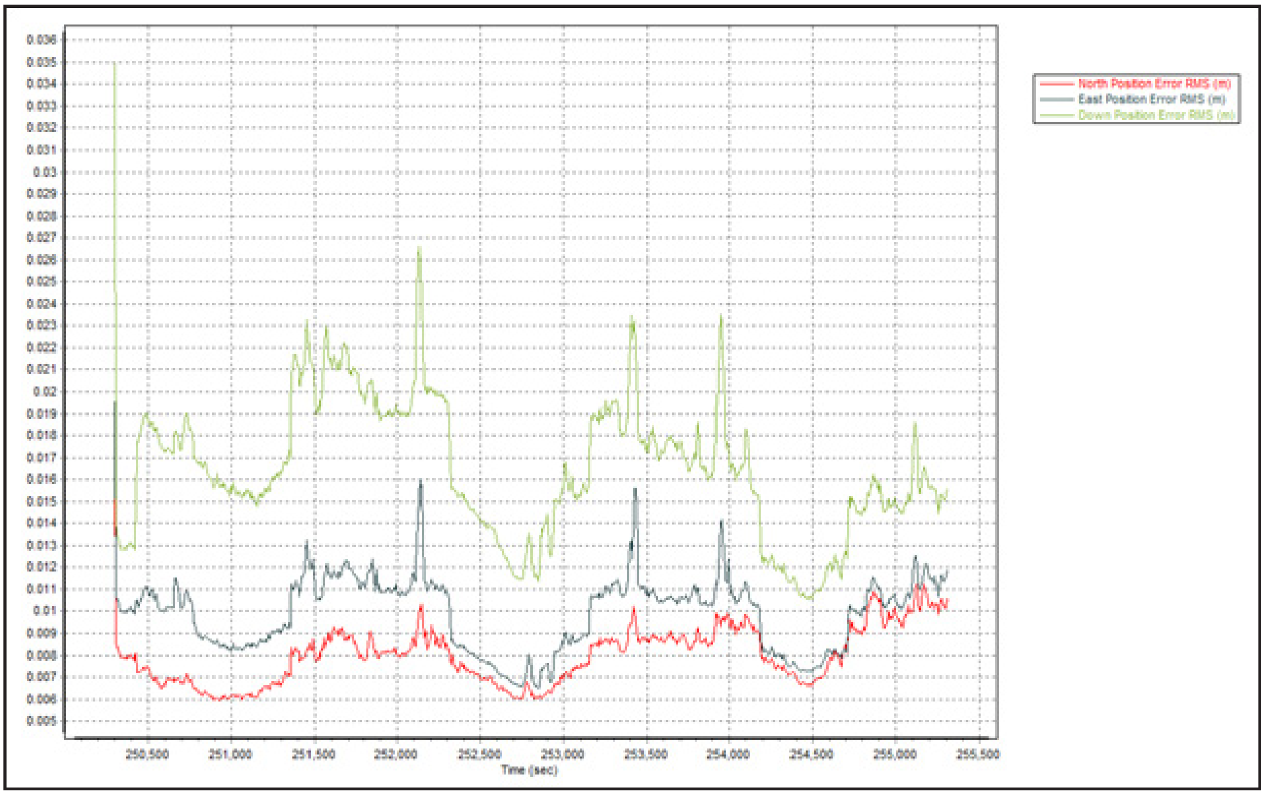


Figure A-8.60. Coverage of LiDAR data

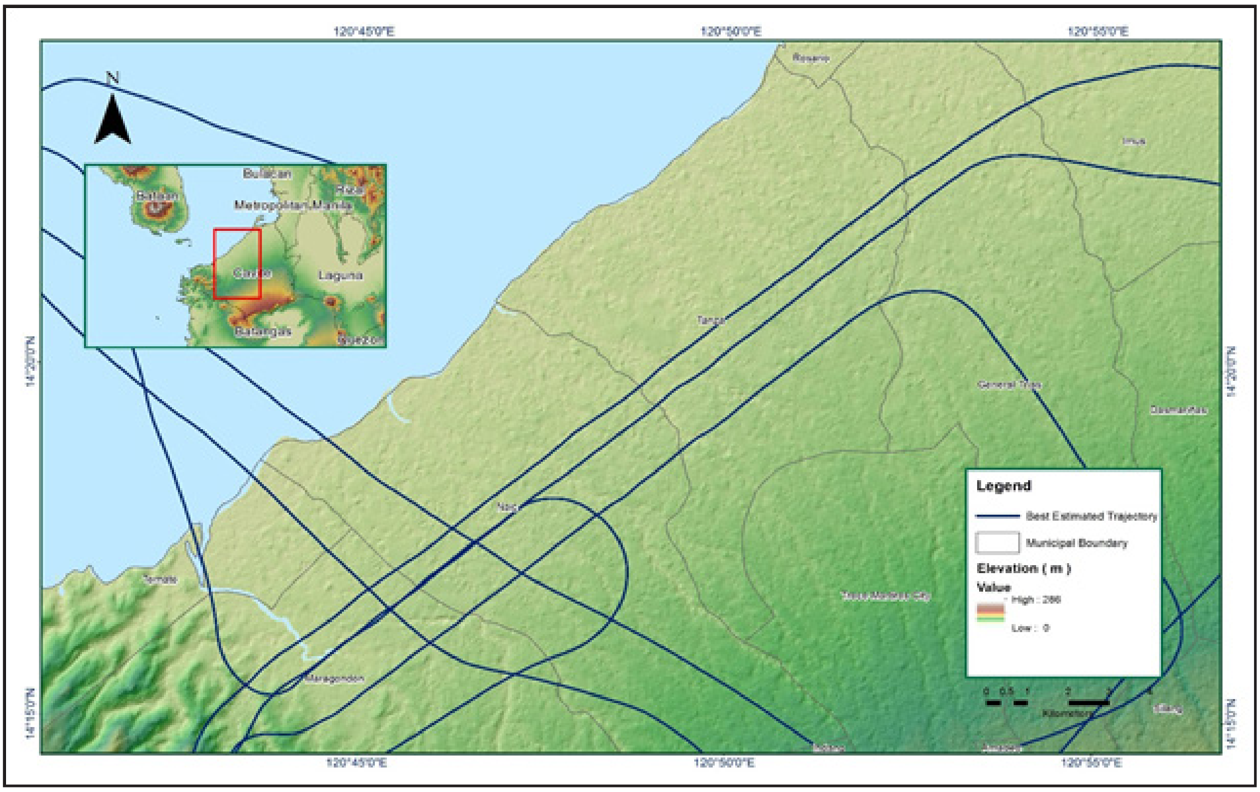


Figure A-8.66. Best Estimated Trajectory

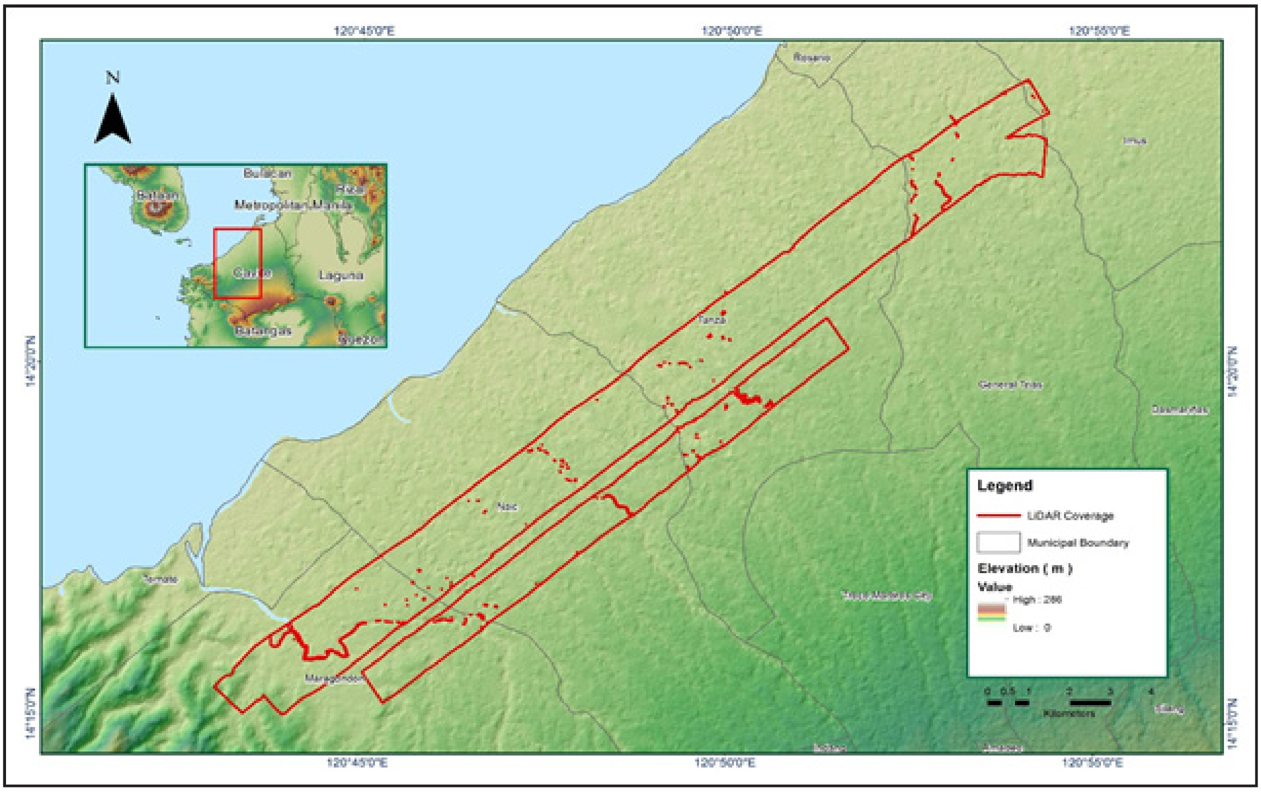


Figure A-8.67. Coverage of LiDAR data

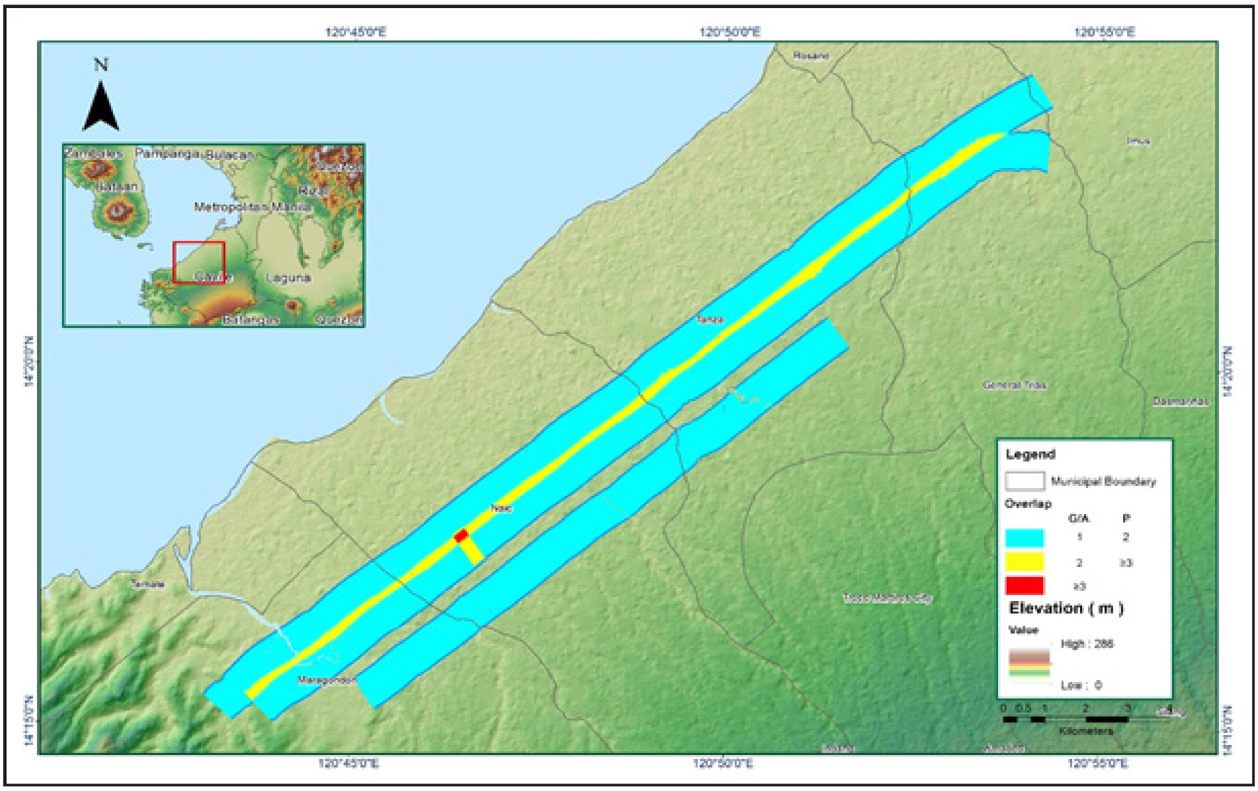


Figure A-8.68. Image of data overlap

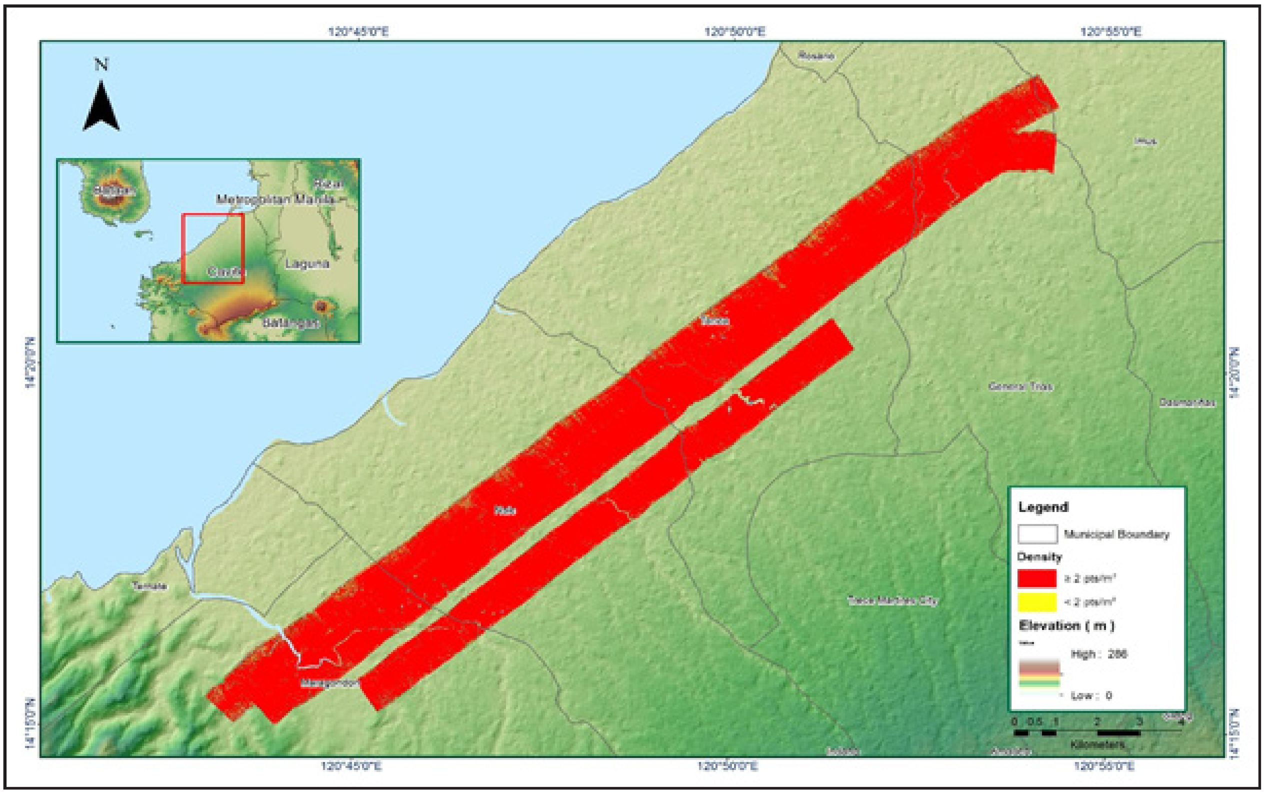


Figure A-8.69. Density map of merged LiDAR data

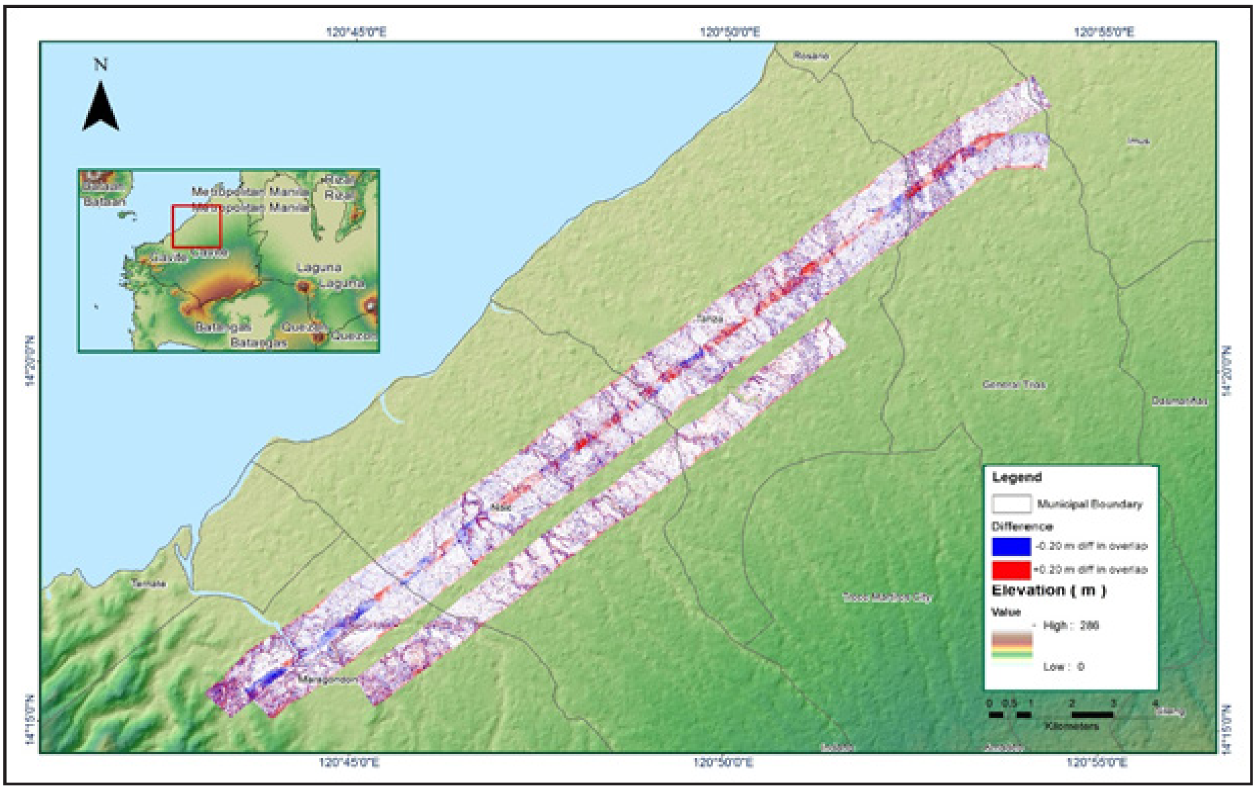


Figure A-8.70. Elevation difference between flight lines

Table A-8.10. Flight Status Report for Mission Blk18As2

Flight Area	CALABARZON
Mission Name	Blk18As2
Inclusive Flights	1141P (formerly 1139P)
Range data size	15.4 GB
Base data size	6.25 MB
POS	219 MB
Image	24 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	3.6
Boresight correction stdev (<0.001deg)	0.000426
IMU attitude correction stdev (<0.001deg)	0.001019
GPS position stdev (<0.01m)	0.0155
Minimum % overlap (>25)	35.84%
Ave point cloud density per sq.m. (>2.0)	1.90
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	140
Maximum Height	133.73 m
Minimum Height	45.56 m
	133.73 m
Classification (# of points)	
Ground	104,162,308
Low vegetation	84,606,924
Medium vegetation	52,451,573
High vegetation	28,217,832
Building	1,102,474
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Melanie Hingpit, Engr. Jeffrey Delica

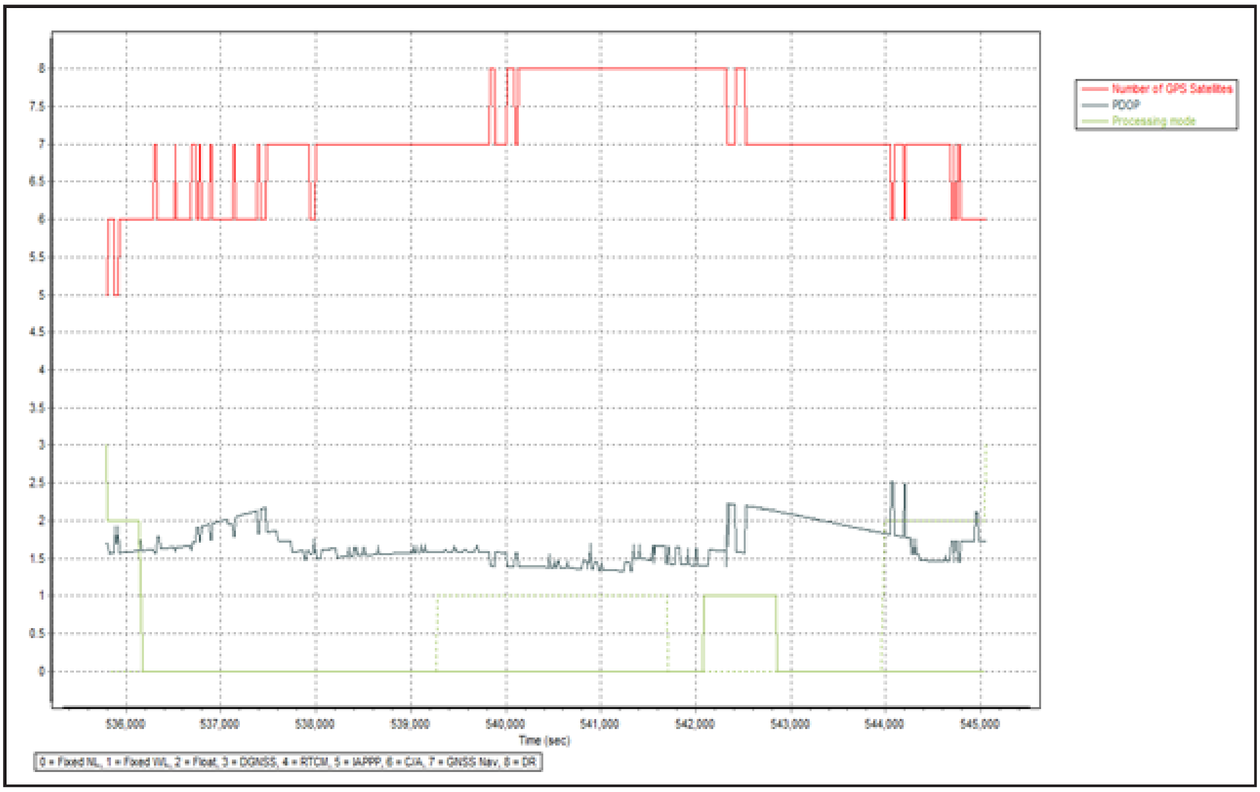


Figure A-8.71. Solution Status

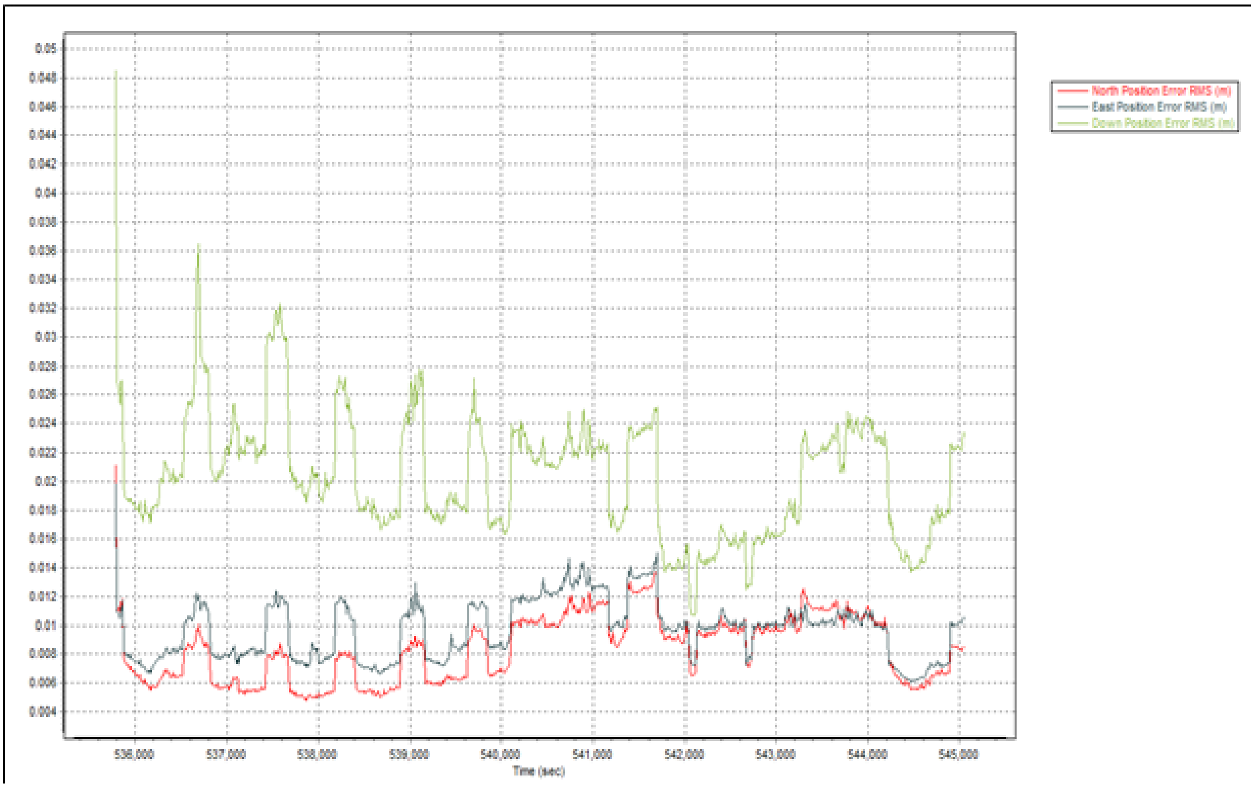


Figure A-8.72. Smoothed Performance Metrics Parameters

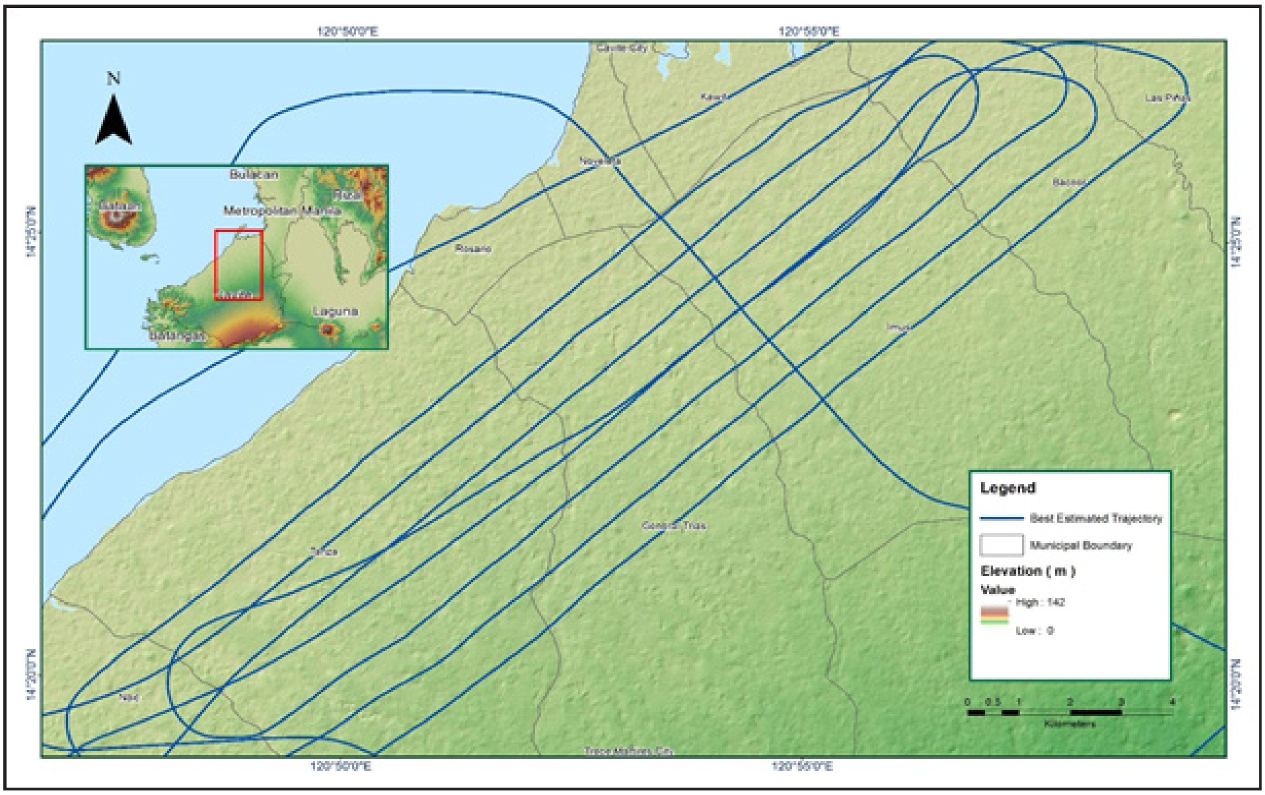


Figure A-8.73. Best Estimated Trajectory

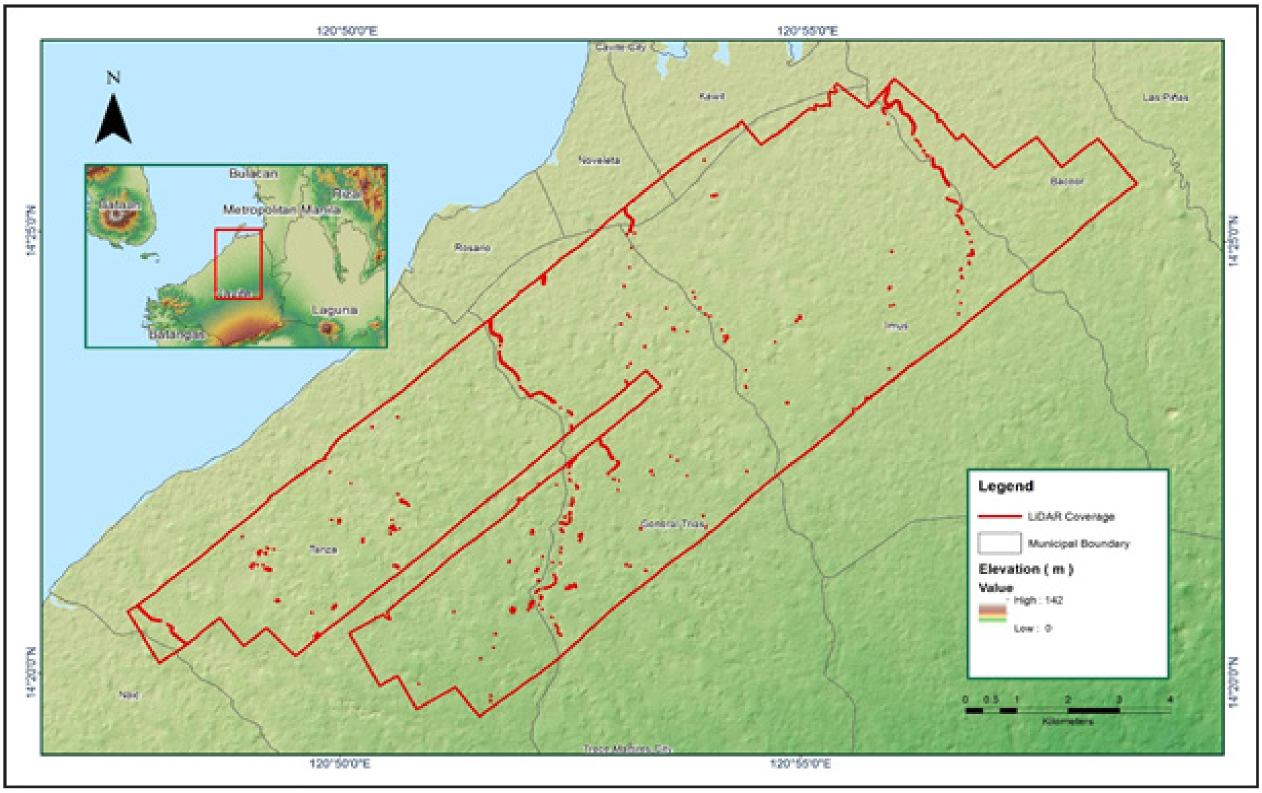


Figure A-8.74. Coverage of LiDAR data

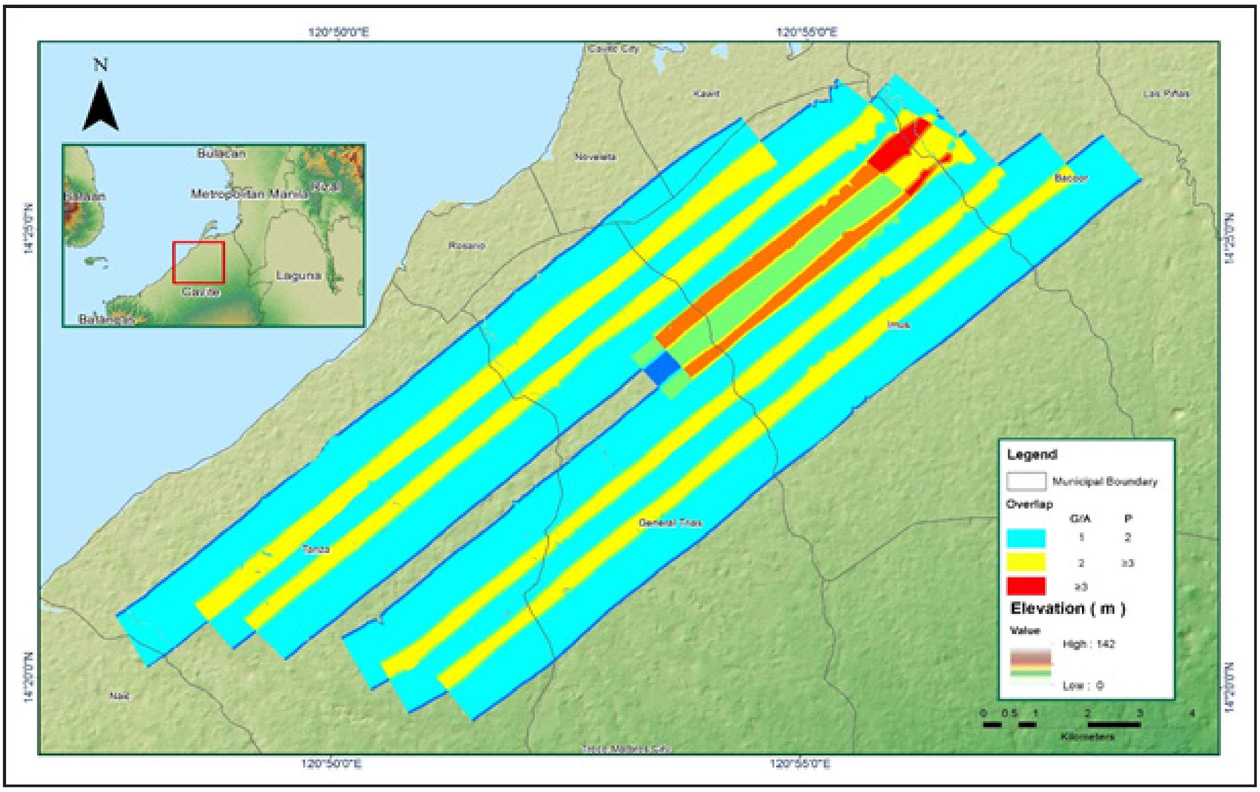


Figure A-8.75. Image of data overlap

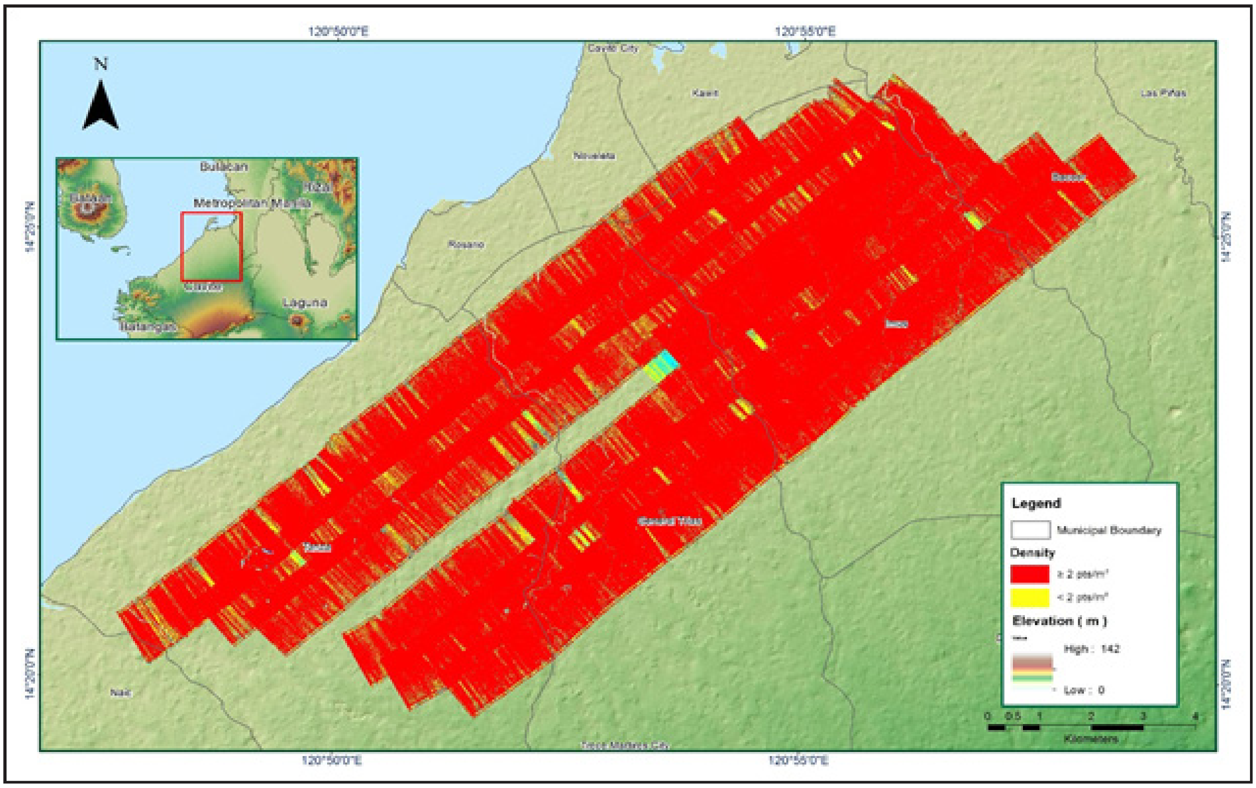


Figure A-8.76. Density map of merged LiDAR data

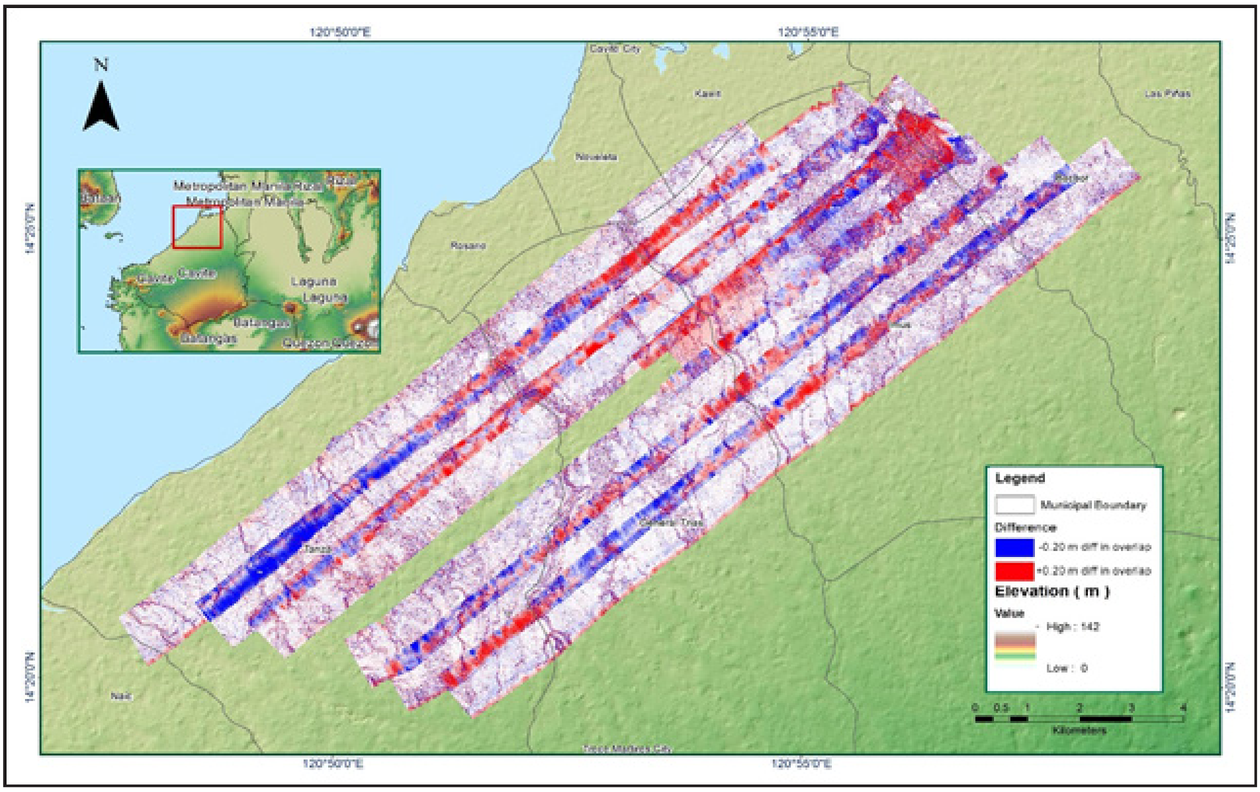


Figure A-8.77. Elevation difference between flight lines

Table A-8.11. Flight Status Report for Mission Blk18AB

Flight Area	CALABARZON
Mission Name	Blk18AB
Inclusive Flights	1031P, 1027P
Range data size	29.0 GB
Base data size	14.75 MB
POS	379 MB
Image	7.11 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	2.0
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000453
IMU attitude correction stdev (<0.001deg)	0.005473
GPS position stdev (<0.01m)	0.0019
Minimum % overlap (>25)	28.57%
Ave point cloud density per sq.m. (>2.0)	3.24
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	204
Maximum Height	45.76 m
Minimum Height	603.46 m
Classification (# of points)	
Ground	175,046,421
Low vegetation	131,824,752
Medium vegetation	148,659,196
High vegetation	95,993,464
Building	30,587,801
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Celina Rosete, Engr. Gladys Mae Apat

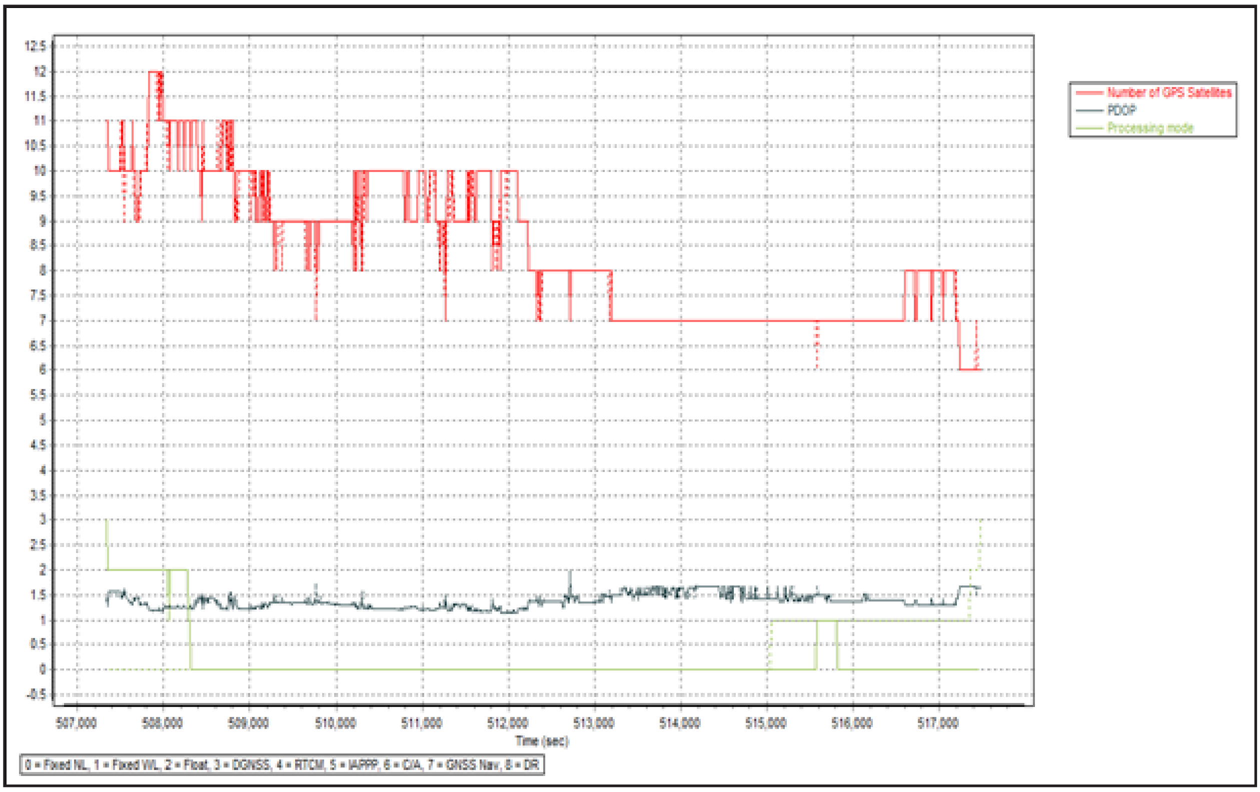


Figure A-8.78. Solution Status

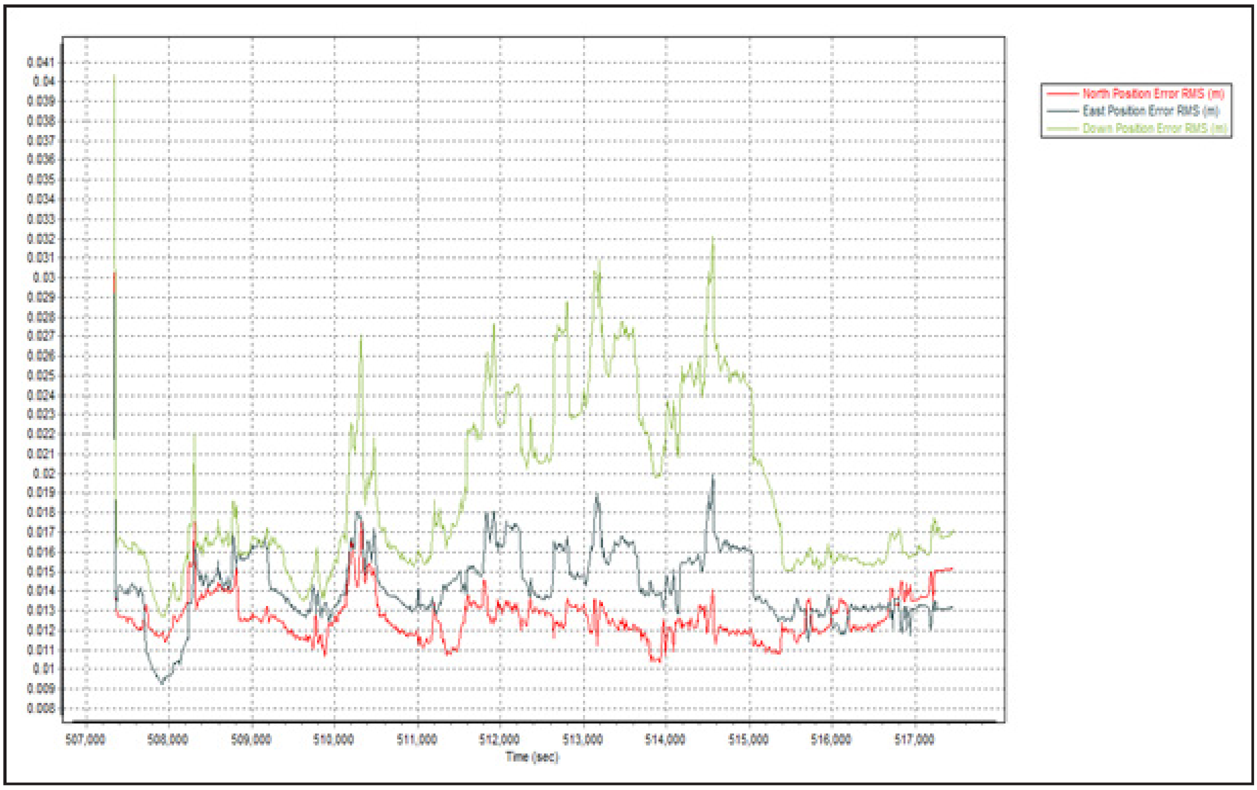


Figure A-8.79. Smoothed Performance Metrics Parameters

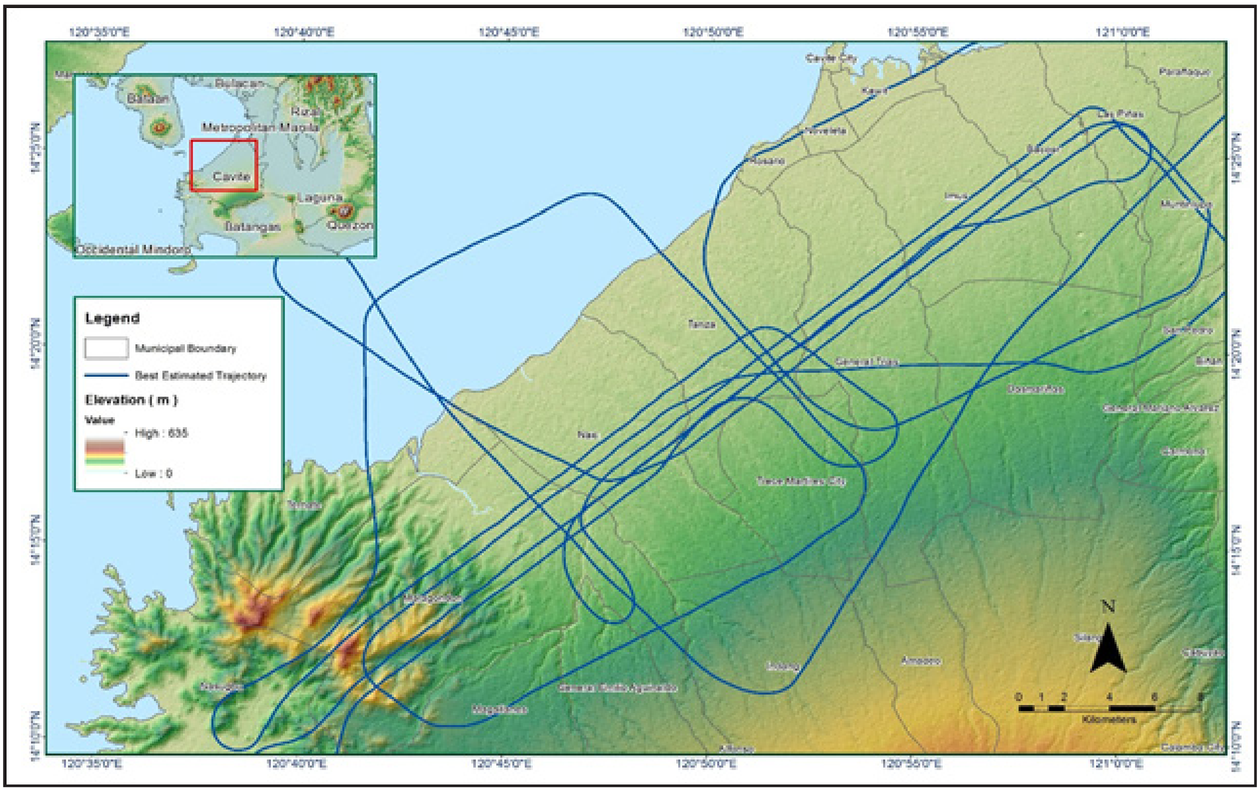


Figure A-8.80. Best Estimated Trajectory

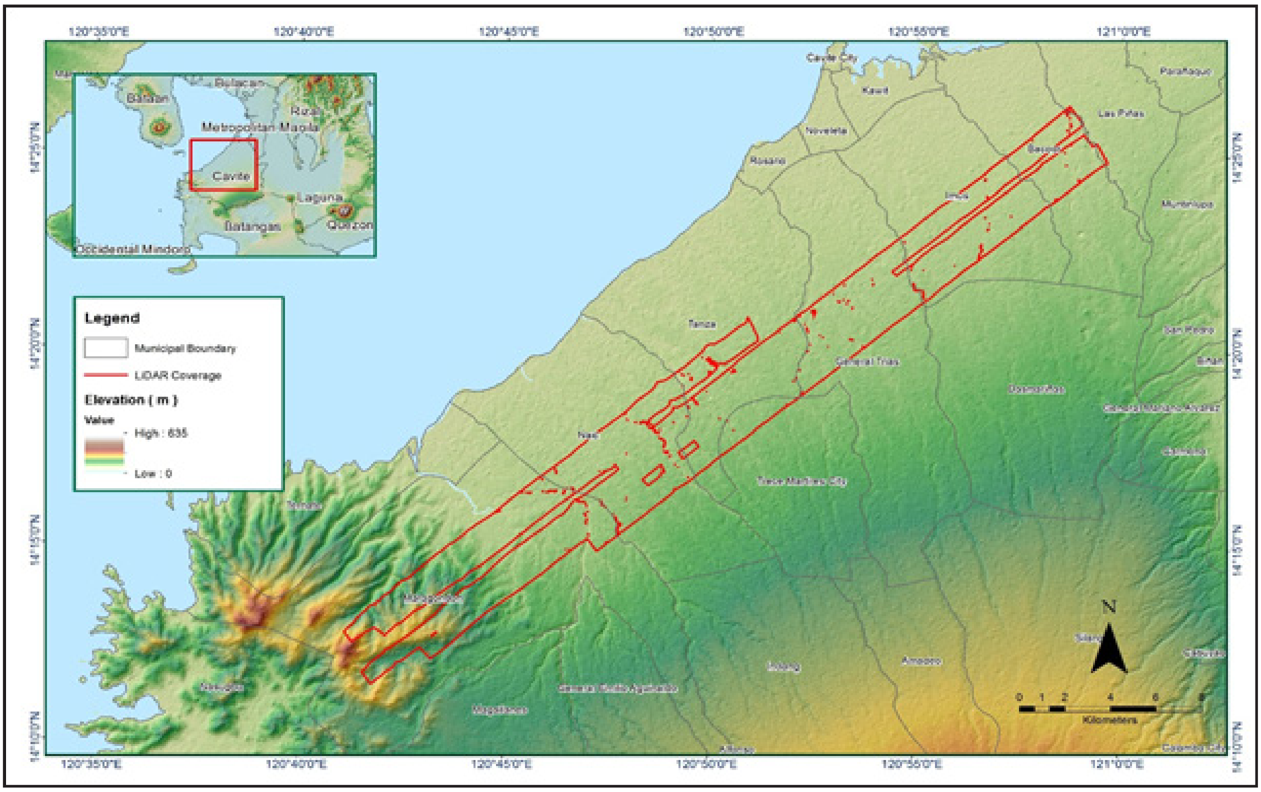


Figure A-8.81. Coverage of LiDAR data

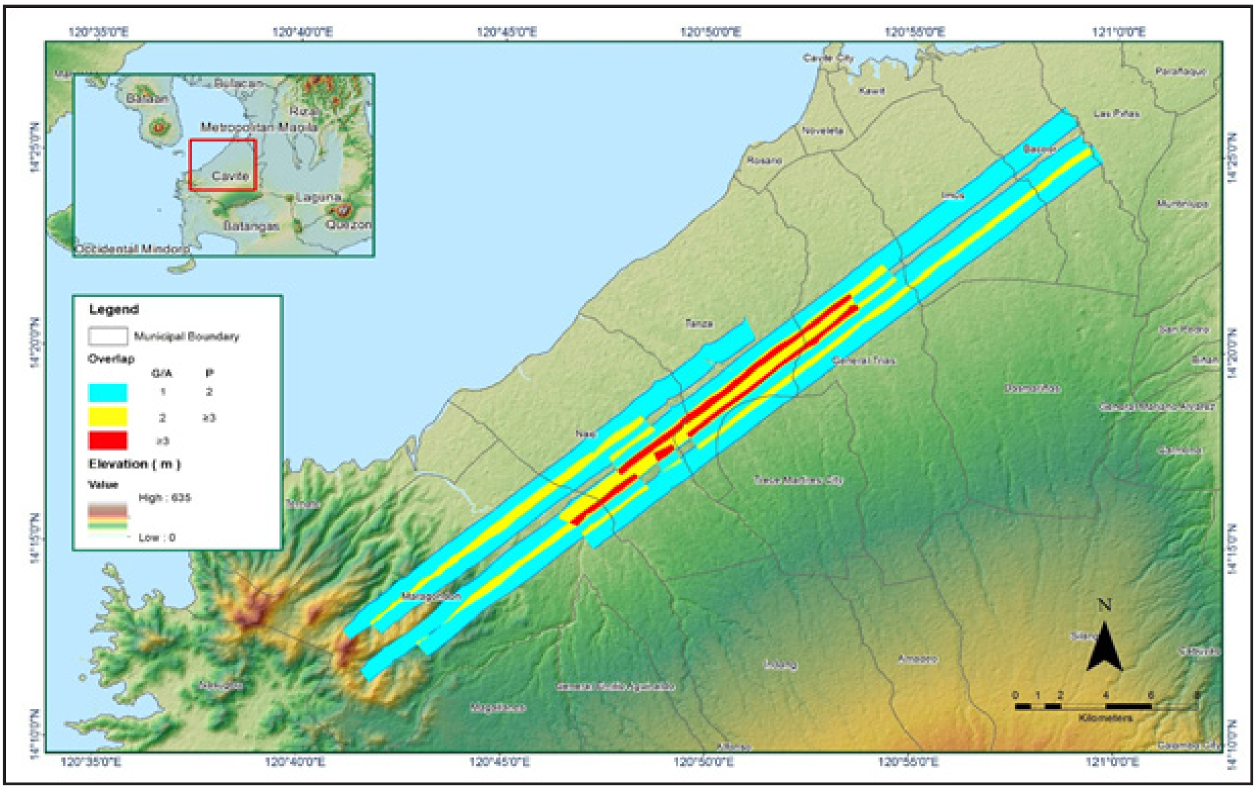


Figure A-8.82. Image of data overlap

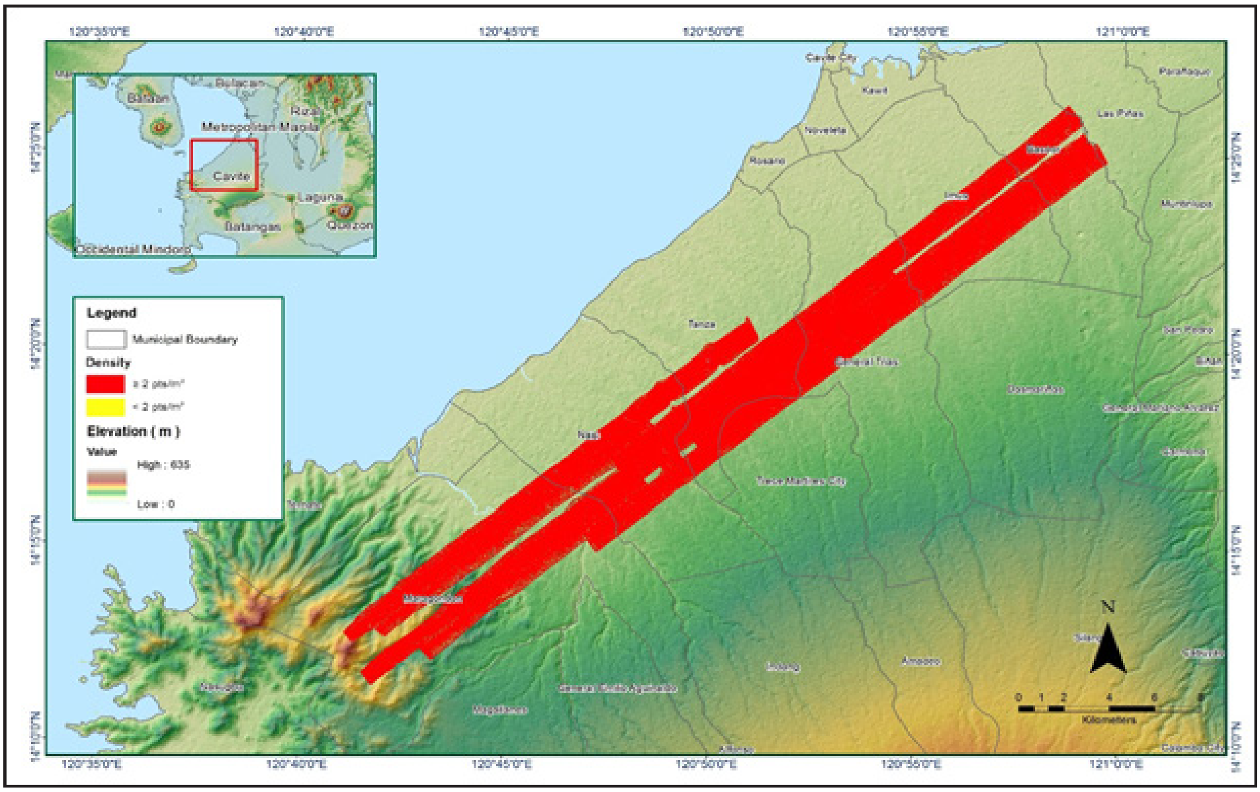


Figure A-8.83. Density map of merged LiDAR data

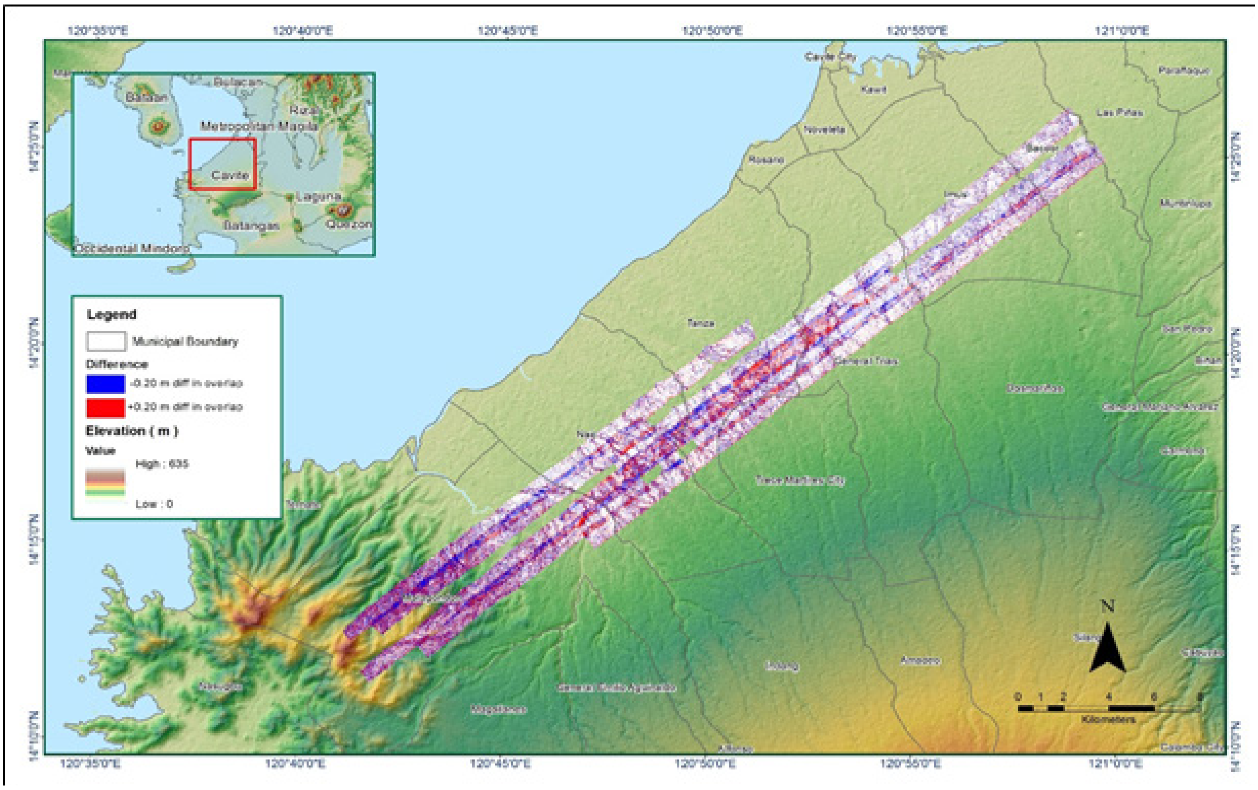


Figure A-8.84. Elevation difference between flight lines

Table A-8.12. Flight Status Report for Mission Blk18C_additional

Flight Area	CALABARZON
Mission Name	Blk18C_additional
Inclusive Flights	1031P; 1063P
Range data size	33.2 GB
Base data size	14.00 MB
POS	329 MB
Image	19.2 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.5
RMSE for East Position (<4.0 cm)	1.9
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	0.000508
IMU attitude correction stdev (<0.001deg)	0.001492
GPS position stdev (<0.01m)	0.0092
Minimum % overlap (>25)	29.92%
Ave point cloud density per sq.m. (>2.0)	2.78
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	327
Maximum Height	460.70 m
Minimum Height	60.39 m
Classification (# of points)	
Ground	187,497,140
Low vegetation	163,676,822
Medium vegetation	212,619,439
High vegetation	144,490,617
Building	59,922,956
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Merven Matthew Natino, Celina Rosete

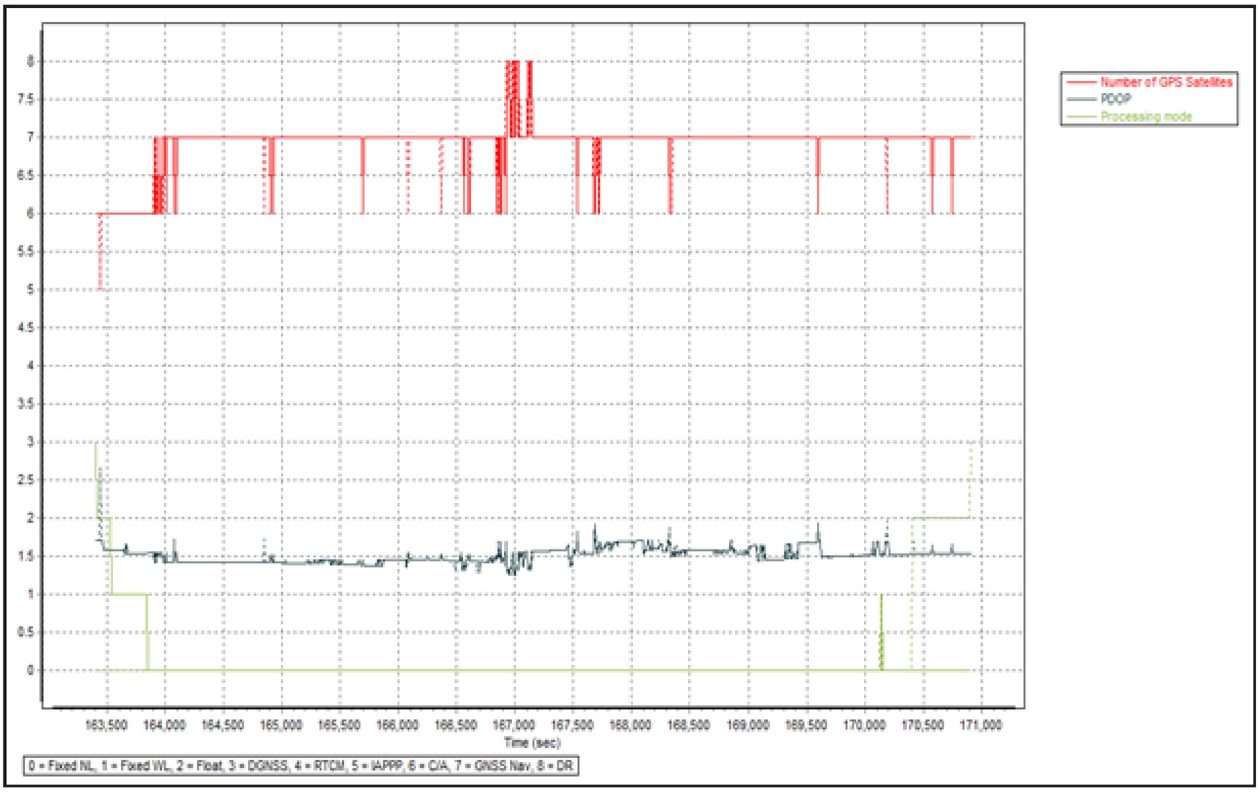


Figure A-8.78. Solution Status

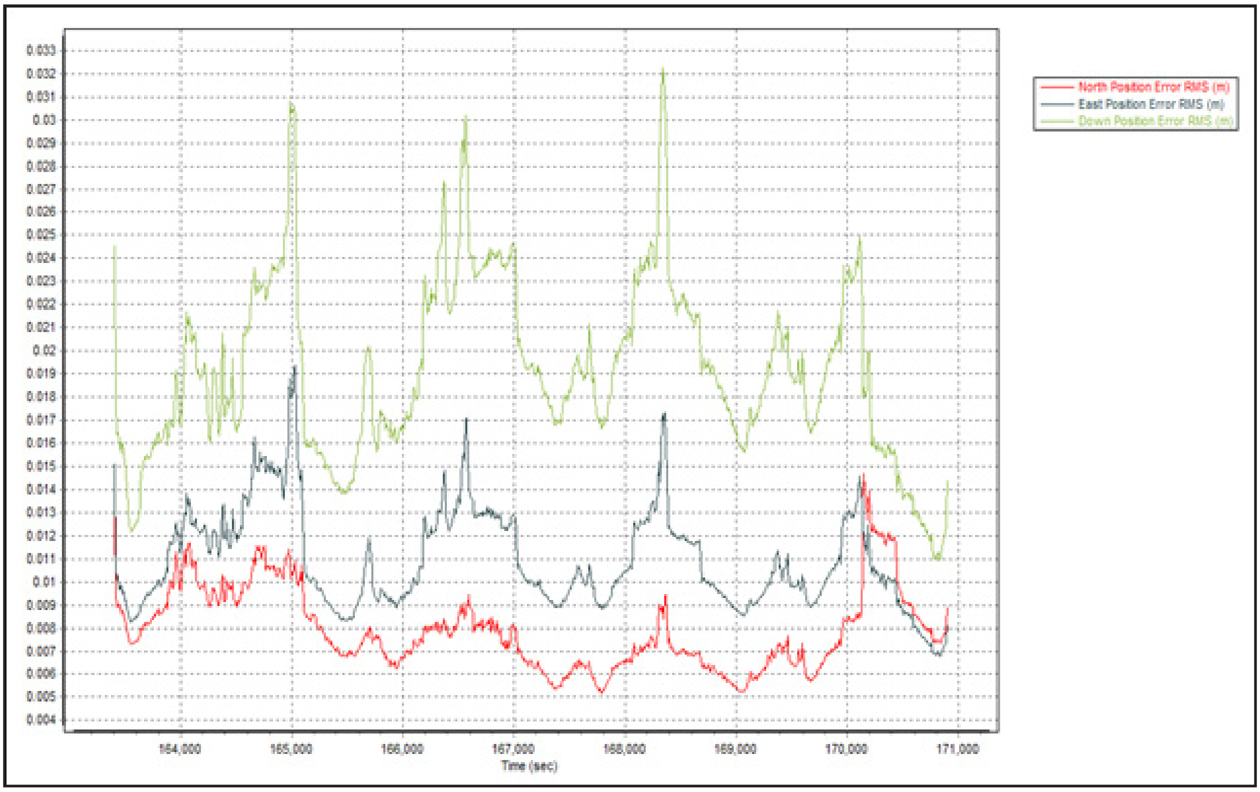


Figure A-8.86. Smoothed Performance Metrics Parameters

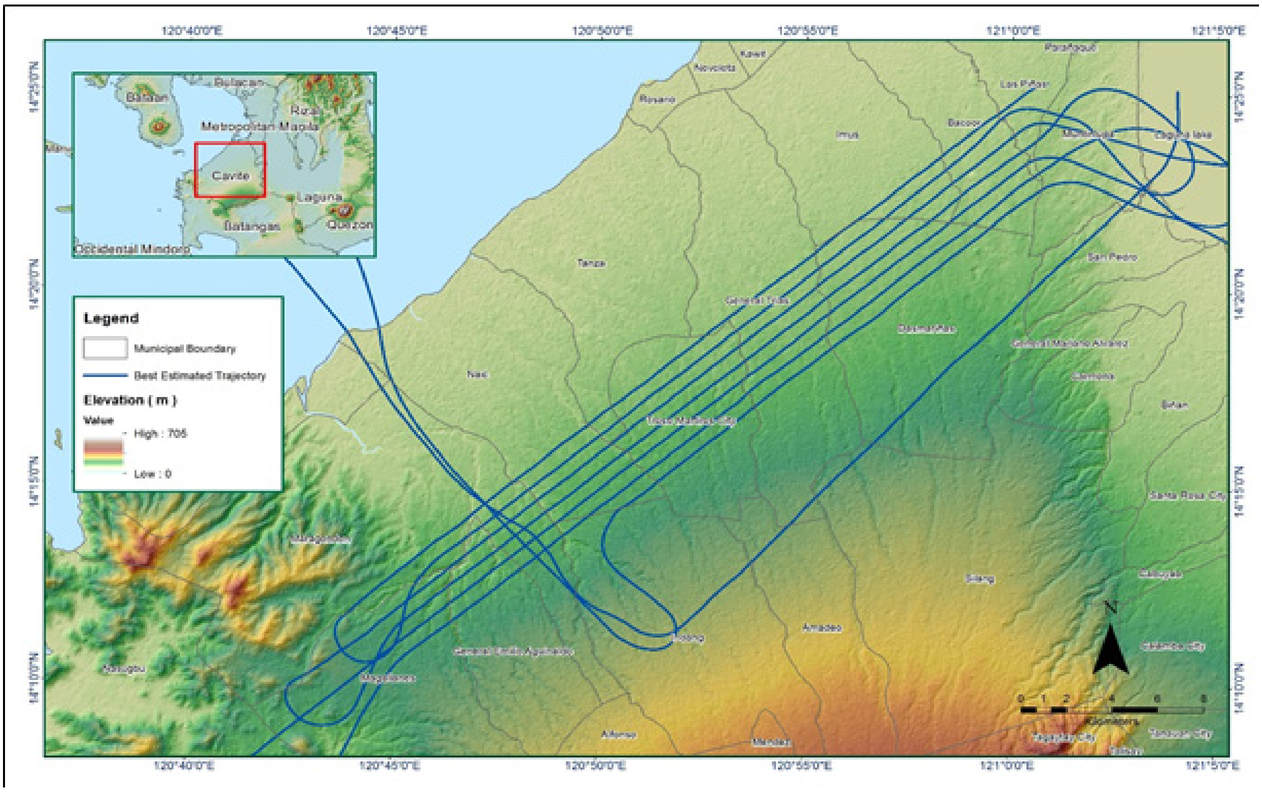


Figure A-8.87. Best Estimated Trajectory

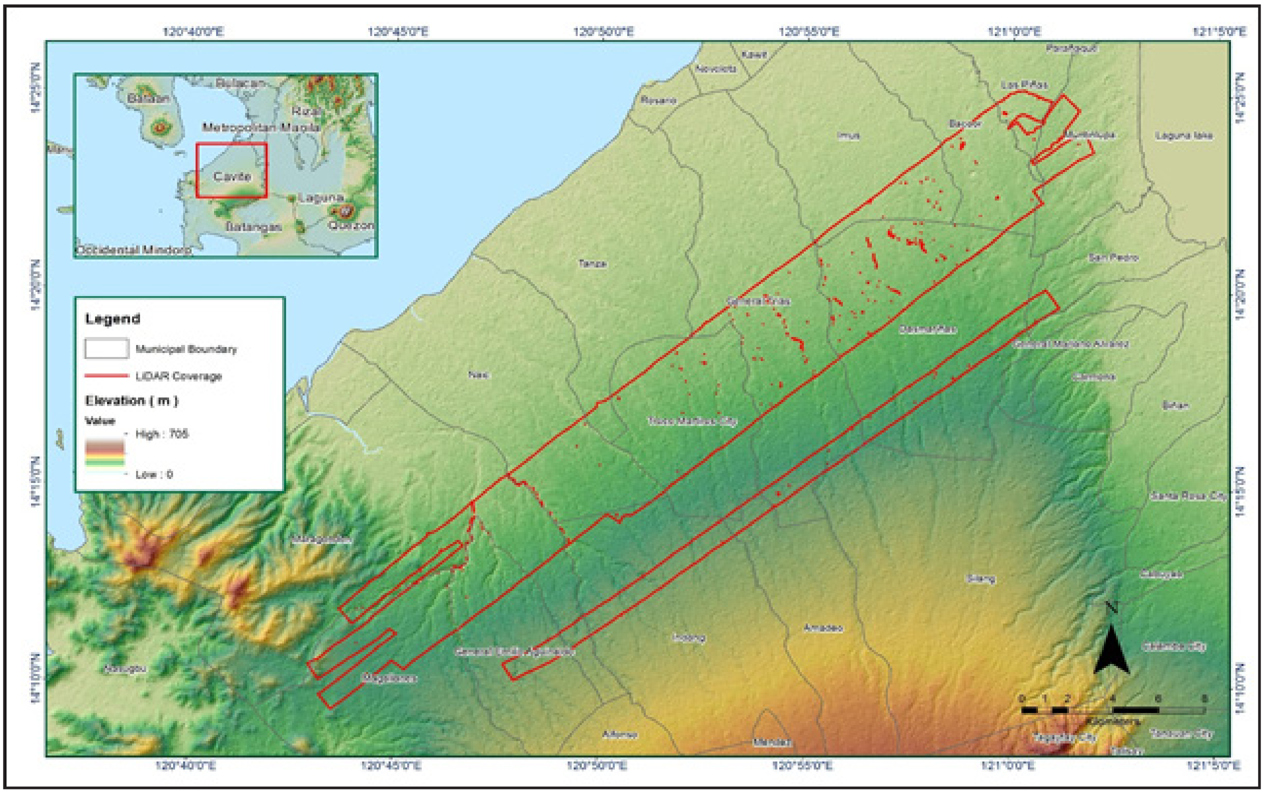


Figure A-8.88. Coverage of LiDAR data

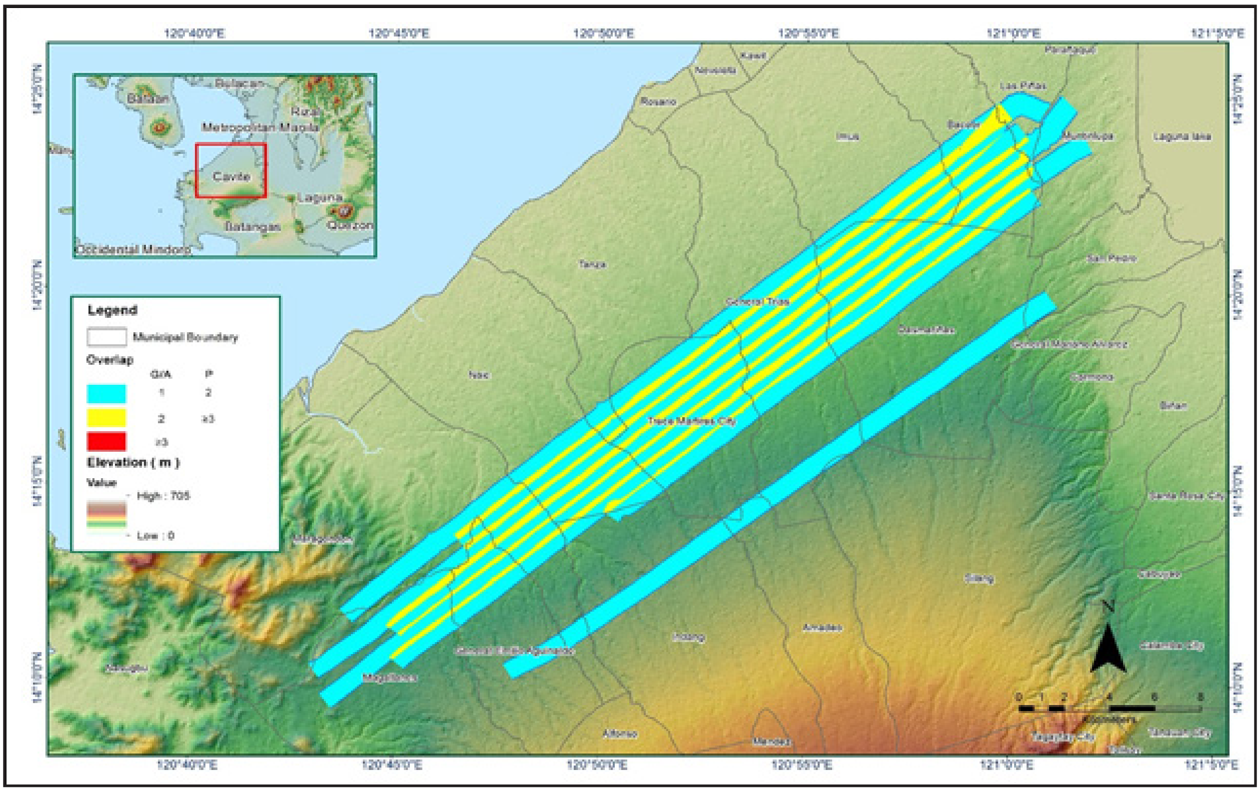


Figure A-8.89. Image of data overlap

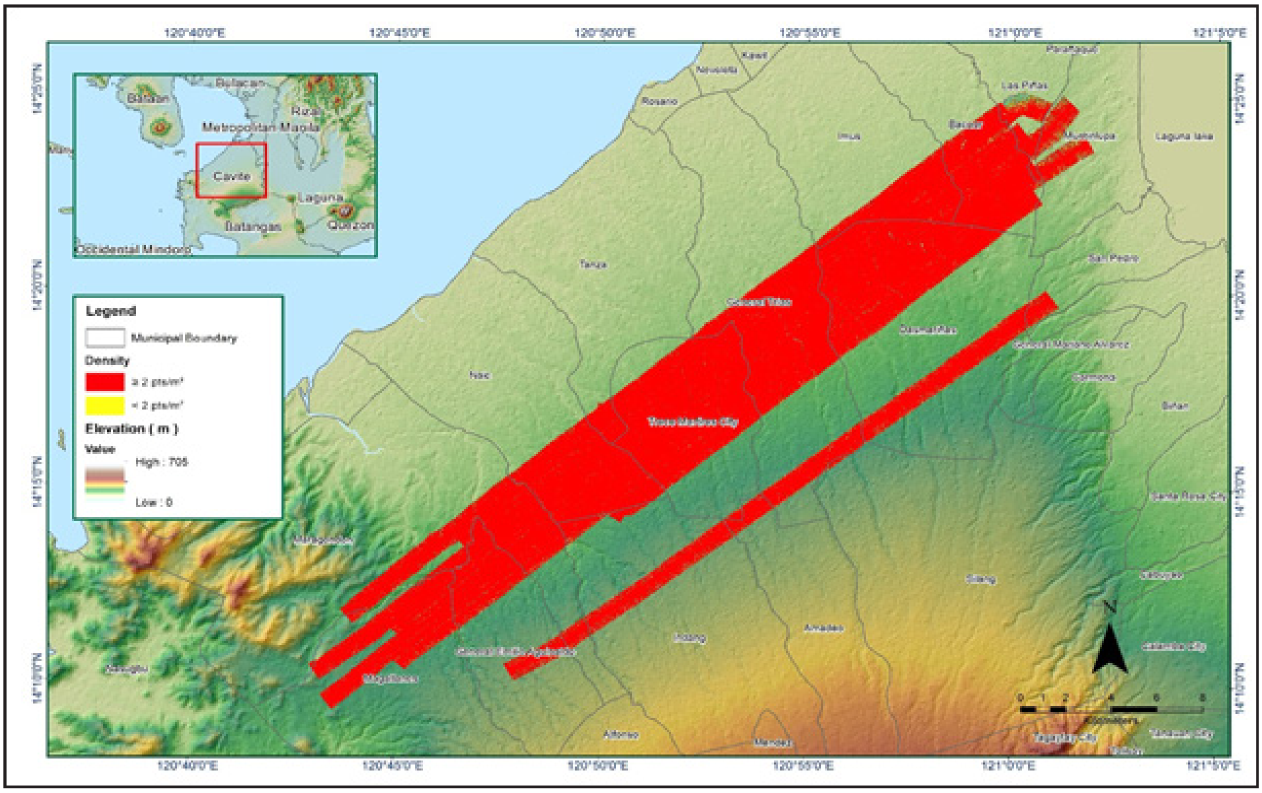


Figure A-8.90. Density map of merged LiDAR data

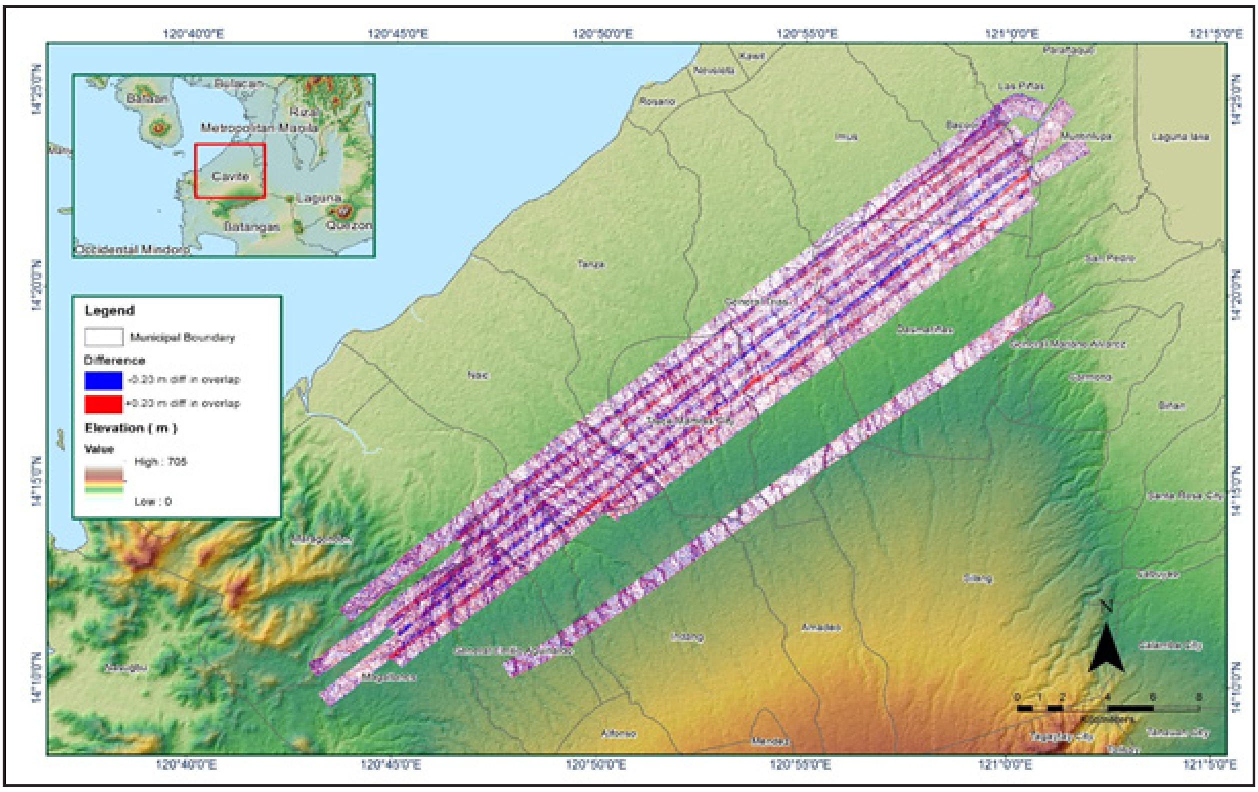


Figure A-8.91. Elevation difference between flight lines

Annex 9. Cañas Model Basin Parameters

Table A-9.1. Cañas 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
W180	0.0508355	99	0	0.0166667	0.08022	Discharge	0.0014777	8.46E-05	Ratio to Peak	0.015309
W190	3.6006	57.297	0	0.11739	0.0615407	Discharge	0.0004569	0.000123834	Ratio to Peak	0.25634
W200	3.582	99	0	7.6648	26.938	Discharge	0.0007948	2.42E-05	Ratio to Peak	0.005665
W210	3.4401	35.304	0	8.5743	22.295	Discharge	0.0011085	5.50E-05	Ratio to Peak	0.007209
W220	0.0828658	91.719	0	0.14772	0.07978	Discharge	0.0021432	0.0013901	Ratio to Peak	0.009042
W230	0.0429779	99	0	3.4542	0.39576	Discharge	0.0007943	2.89E-05	Ratio to Peak	0.016178
W240	3.8704	52.638	0	5.4086	306.22	Discharge	0.0022474	1.00E-05	Ratio to Peak	0.5
W250	4.2288	37.732	0	108.65	20.007	Discharge	0.0008889	1.00E-05	Ratio to Peak	0.5
W260	15.911	92.732	0	0.0166667	2.5541	Discharge	0.0005855	1.00E-05	Ratio to Peak	0.5
W270	5.4979	75.592	0	9.9021	0.0166667	Discharge	0.0011539	1.00E-05	Ratio to Peak	0.5
W280	2.8742	99	0	0.73501	0.58611	Discharge	0.001753	1.00E-05	Ratio to Peak	0.001564
W290	3.7063	69.553	0	2.9497	4.8139	Discharge	0.0026267	1	Ratio to Peak	0.5
W300	7.9092	61.623	0	8.9912	14.674	Discharge	0.0004288	1	Ratio to Peak	0.5
W310	5.7883	68.584	0	4.0494	6.6086	Discharge	0.0008162	1	Ratio to Peak	0.5
W320	9.2744	67.256	0	4.1698	6.8051	Discharge	0.0005166	1	Ratio to Peak	0.5
W330	6.5	66	0	3.0319	10.634	Discharge	4.92E-05	1	Ratio to Peak	0.5
W340	9.1837	58.034	0	6.5162	10.634	Discharge	0.0001484	1	Ratio to Peak	0.5

Annex 10. Cañas Model Reach Parameters

Table A-10.1. Cañas Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	1192.8	0.002853	0.0464227	Trapezoid	30	45
R100	Automatic Fixed Interval	12716	0.0147348	0.04	Trapezoid	30	45
R140	Automatic Fixed Interval	6693.4	0.0230826	0.04	Trapezoid	30	45
R20	Automatic Fixed Interval	943.14	0.006679	0.046809	Trapezoid	30	45
R40	Automatic Fixed Interval	2328.9	0.0074418	0.0023852	Trapezoid	30	45
R50	Automatic Fixed Interval	4450.6	0.0079053	0.0292076	Trapezoid	30	45
R70	Automatic Fixed Interval	7548.8	0.0141239	0.023007	Trapezoid	30	45
R90	Automatic Fixed Interval	4812	0.0172215	0.04	Trapezoid	30	45

Annex 11. Cañas Field Validation Points

Table A-11.1. Cañas Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	14.350785	120.872294	0.617	0	-0.617	Milenyo/Sept 26, 2006	5-year
2	14.350845	120.874252	0.501	0	-0.501	Milenyo/Sept 26, 2006	5-year
3	14.351137	120.869555	0.072	0	-0.072	Milenyo/Sept 26, 2006	5-year
4	14.351168	120.871459	5.3330002	5.1	-0.233	Milenyo/Sept 26, 2006	5-year
5	14.351282	120.870808	3.5880001	2.3	-1.288	Milenyo/Sept 26, 2006	5-year
6	14.351389	120.871678	7.928	6.3	-1.628	Milenyo/Sept 26, 2006	5-year
7	14.351402	120.870026	0.031	0	-0.031	Milenyo/Sept 26, 2006	5-year
8	14.351479	120.869782	0.035	6.3	6.265	Milenyo/Sept 26, 2006	5-year
9	14.352599	120.870158	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
10	14.353791	120.870925	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
11	14.354977	120.871915	2.02	1.1	-0.920	Milenyo/Sept 26, 2006	5-year
12	14.355517	120.871883	2.776	1.3	-1.476	Milenyo/Sept 26, 2006	5-year
13	14.356859	120.872029	0.066	0	-0.066	Milenyo/Sept 26, 2006	5-year
14	14.358355	120.872271	0.067	0	-0.067	Milenyo/Sept 26, 2006	5-year
15	14.358632	120.871938	0.03	0.1	0.070	Milenyo/Sept 26, 2006	5-year
16	14.36153	120.856055	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
17	14.361569	120.87236	2.3559999	2	-0.356	Milenyo/Sept 26, 2006	5-year
18	14.364346	120.856555	0.067	0.1	0.033	Milenyo/Sept 26, 2006	5-year
19	14.364366	120.879964	0.03	1.4	1.370	Milenyo/Sept 26, 2006	5-year
20	14.364478	120.871857	0.696	1.5	0.804	Milenyo/Sept 26, 2006	5-year
21	14.364587	120.858191	0.314	0.3	-0.014	Milenyo/Sept 26, 2006	5-year
22	14.364773	120.858567	0.213	1	0.787	Milenyo/Sept 26, 2006	5-year
23	14.365265	120.85544	0.03	0.1	0.070	Milenyo/Sept 26, 2006	5-year
24	14.365362	120.858336	0.112	1	0.888	Milenyo/Sept 26, 2006	5-year
25	14.367638	120.87324	0.031	0.4	0.369	Milenyo/Sept 26, 2006	5-year
26	14.36769	120.879486	0.031	1.4	1.369	Milenyo/Sept 26, 2006	5-year
27	14.368039	120.875008	5.6160002	5	-0.616	Milenyo/Sept 26, 2006	5-year
28	14.368319	120.874972	3.8759999	3	-0.876	Milenyo/Sept 26, 2006	5-year
29	14.368577	120.875084	3.984	3	-0.984	Milenyo/Sept 26, 2006	5-year
30	14.368615	120.854263	0.06	0.1	0.040	Milenyo/Sept 26, 2006	5-year
31	14.368731	120.873862	0.149	0	-0.149	Milenyo/Sept 26, 2006	5-year
32	14.368844	120.879599	0.03	0.8	0.770	Milenyo/Sept 26, 2006	5-year
33	14.369018	120.875284	3.184	1.1	-2.084	Milenyo/Sept 26, 2006	5-year
34	14.369025	120.879275	0.05	0.6	0.550	Milenyo/Sept 26, 2006	5-year
35	14.36931	120.872519	0.046	0.6	0.554	Milenyo/Sept 26, 2006	5-year
36	14.369337	120.872721	0.031	0.3	0.269	Milenyo/Sept 26, 2006	5-year
37	14.369528	120.878678	2.651	5	2.349	Milenyo/Sept 26, 2006	5-year
38	14.369535	120.878431	3.233	3	-0.233	Milenyo/Sept 26, 2006	5-year
39	14.36973	120.875021	1.845	0.3	-1.545	Milenyo/Sept 26, 2006	5-year
40	14.370824	120.854402	0.03	0.3	0.270	Milenyo/Sept 26, 2006	5-year
41	14.370992	120.879826	0.259	0.8	0.541	Milenyo/Sept 26, 2006	5-year
42	14.372793	120.854849	0.03	0.3	0.270	Milenyo/Sept 26, 2006	5-year
43	14.373572	120.854746	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year

44	14.37426	120.873765	0.496	0	-0.496	Milenyo/Sept 26, 2006	5-year
45	14.374382	120.879383	0.628	0.8	0.172	Milenyo/Sept 26, 2006	5-year
46	14.374448	120.87333	0.03	0.2	0.170	Milenyo/Sept 26, 2006	5-year
47	14.374783	120.878889	0.54	1.3	0.760	Milenyo/Sept 26, 2006	5-year
48	14.375502	120.854026	0.036	0	-0.036	Milenyo/Sept 26, 2006	5-year
49	14.375583	120.853805	0.03	0.1	0.070	Milenyo/Sept 26, 2006	5-year
50	14.376062	120.853863	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
51	14.376164	120.878883	0.683	1.2	0.517	Milenyo/Sept 26, 2006	5-year
52	14.376374	120.87887	0.667	1.2	0.533	Milenyo/Sept 26, 2006	5-year
53	14.377191	120.853763	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
54	14.378425	120.873877	0.788	0.3	-0.488	Milenyo/Sept 26, 2006	5-year
55	14.378467	120.874391	1.469	5	3.531	Milenyo/Sept 26, 2006	5-year
56	14.379463	120.854343	0.031	0	-0.031	Milenyo/Sept 26, 2006	5-year
57	14.379585	120.873547	0.489	0.1	-0.389	Milenyo/Sept 26, 2006	5-year
58	14.380022	120.854012	0.031	0	-0.031	Milenyo/Sept 26, 2006	5-year
59	14.380983	120.837903	2.24	2	-0.240	Milenyo/Sept 26, 2006	5-year
60	14.381055	120.836584	0.792	0	-0.792	Milenyo/Sept 26, 2006	5-year
61	14.381397	120.874881	1.4859999	0.3	-1.186	Milenyo/Sept 26, 2006	5-year
62	14.381695	120.875004	1.178	0.3	-0.878	Milenyo/Sept 26, 2006	5-year
63	14.381975	120.874861	1.507	0.3	-1.207	Milenyo/Sept 26, 2006	5-year
64	14.382062	120.874731	4.2940001	2.1	-2.194	Milenyo/Sept 26, 2006	5-year
65	14.382286	120.854572	0.049	0.1	0.051	Milenyo/Sept 26, 2006	5-year
66	14.382757	120.839674	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
67	14.383096	120.835519	0.402	0.2	-0.202	Milenyo/Sept 26, 2006	5-year
68	14.383383	120.854589	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
69	14.383502	120.835664	1.304	0.7	-0.604	Milenyo/Sept 26, 2006	5-year
70	14.383541	120.836649	0.448	1.3	0.852	Milenyo/Sept 26, 2006	5-year
71	14.383695	120.874502	3.2309999	2.9	-0.331	Milenyo/Sept 26, 2006	5-year
72	14.383713	120.835841	1.177	3	1.823	Milenyo/Sept 26, 2006	5-year
73	14.383743	120.840975	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
74	14.383747	120.854601	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
75	14.383781	120.874853	0.892	0	-0.892	Milenyo/Sept 26, 2006	5-year
76	14.383851	120.874648	1.238	1.4	0.162	Milenyo/Sept 26, 2006	5-year
77	14.383962	120.835471	1.016	3	1.984	Milenyo/Sept 26, 2006	5-year
78	14.384201	120.834349	0.373	0.5	0.127	Milenyo/Sept 26, 2006	5-year
79	14.384263	120.834298	0.75	1	0.250	Milenyo/Sept 26, 2006	5-year
80	14.384365	120.834503	1.9119999	3	1.088	Milenyo/Sept 26, 2006	5-year
81	14.385025	120.833841	1.836	2	0.164	Milenyo/Sept 26, 2006	5-year
82	14.385113	120.832893	0.038	0	-0.038	Milenyo/Sept 26, 2006	5-year
83	14.385237	120.868316	0.539	0.3	-0.239	Milenyo/Sept 26, 2006	5-year
84	14.385293	120.836929	0.169	0	-0.169	Milenyo/Sept 26, 2006	5-year
85	14.385826	120.843302	0.04	0	-0.040	Milenyo/Sept 26, 2006	5-year
86	14.386421	120.831444	0.06	0	-0.060	Milenyo/Sept 26, 2006	5-year
87	14.386646	120.865485	2.043	0	-2.043	Milenyo/Sept 26, 2006	5-year
88	14.386799	120.870089	3.0639999	3	-0.064	Milenyo/Sept 26, 2006	5-year

89	14.386935	120.870178	0.499	0.6	0.101	Milenyo/Sept 26, 2006	5-year
90	14.387129	120.841668	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
91	14.388081	120.830523	0.859	1	0.141	Milenyo/Sept 26, 2006	5-year
92	14.388364	120.83044	0.561	1	0.439	Milenyo/Sept 26, 2006	5-year
93	14.388446	120.830925	0.924	2	1.076	Milenyo/Sept 26, 2006	5-year
94	14.388817	120.864802	1.835	1	-0.835	Milenyo/Sept 26, 2006	5-year
95	14.388931	120.829432	0.609	0.9	0.291	Milenyo/Sept 26, 2006	5-year
96	14.38943	120.853189	0.069	0	-0.069	Milenyo/Sept 26, 2006	5-year
97	14.389596	120.865167	1.909	2.5	0.591	Milenyo/Sept 26, 2006	5-year
98	14.389849	120.865106	2.039	2	-0.039	Milenyo/Sept 26, 2006	5-year
99	14.389853	120.829229	0.395	1	0.605	Milenyo/Sept 26, 2006	5-year
100	14.389887	120.865271	0.79	0	-0.790	Milenyo/Sept 26, 2006	5-year
101	14.389913	120.865705	0.443	0	-0.443	Milenyo/Sept 26, 2006	5-year
102	14.39015	120.82928	0.451	1.5	1.049	Milenyo/Sept 26, 2006	5-year
103	14.390385	120.86376	0.65	0	-0.650	Milenyo/Sept 26, 2006	5-year
104	14.390426	120.849663	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
105	14.390523	120.829702	0.041	1	0.959	Milenyo/Sept 26, 2006	5-year
106	14.391799	120.862384	2.0580001	2	-0.058	Milenyo/Sept 26, 2006	5-year
107	14.391973	120.856839	2.177	1.3	-0.877	Milenyo/Sept 26, 2006	5-year
108	14.392012	120.86235	2.994	2.1	-0.894	Milenyo/Sept 26, 2006	5-year
109	14.39231	120.86181	1.415	1.1	-0.315	Milenyo/Sept 26, 2006	5-year
110	14.392554	120.857035	1.27	1.2	-0.070	Milenyo/Sept 26, 2006	5-year
111	14.393083	120.857827	0.037	0	-0.037	Milenyo/Sept 26, 2006	5-year
112	14.393291	120.855713	0.07	0	-0.070	Milenyo/Sept 26, 2006	5-year
113	14.393305	120.864321	0.129	0.2	0.071	Milenyo/Sept 26, 2006	5-year
114	14.393542	120.857308	1.727	0.6	-1.127	Milenyo/Sept 26, 2006	5-year
115	14.393636	120.857299	1.845	1.1	-0.745	Milenyo/Sept 26, 2006	5-year
116	14.393724	120.857296	1.3200001	2	0.680	Milenyo/Sept 26, 2006	5-year
117	14.393962	120.861193	0.123	0	-0.123	Milenyo/Sept 26, 2006	5-year
118	14.393969	120.861869	0.495	1.1	0.605	Milenyo/Sept 26, 2006	5-year
119	14.394307	120.861859	0.703	0	-0.703	Milenyo/Sept 26, 2006	5-year
120	14.394322	120.861761	0.859	5	4.141	Milenyo/Sept 26, 2006	5-year
121	14.39439	120.857787	0.781	2.5	1.719	Milenyo/Sept 26, 2006	5-year
122	14.394494	120.857414	0.848	0	-0.848	Milenyo/Sept 26, 2006	5-year
123	14.394559	120.861147	1.251	1.3	0.049	Milenyo/Sept 26, 2006	5-year
124	14.394643	120.861078	0.246	0.3	0.054	Milenyo/Sept 26, 2006	5-year
125	14.394774	120.86169	2.8940001	2	-0.894	Milenyo/Sept 26, 2006	5-year
126	14.394814	120.861753	0.974	0.21	-0.764	Milenyo/Sept 26, 2006	5-year
127	14.395043	120.844939	0.03	0.1	0.070	Milenyo/Sept 26, 2006	5-year
128	14.395051	120.857252	0.071	0	-0.071	Milenyo/Sept 26, 2006	5-year
129	14.395202	120.857444	2.1429999	1.3	-0.843	Milenyo/Sept 26, 2006	5-year
130	14.395637	120.856913	1.576	1.6	0.024	Milenyo/Sept 26, 2006	5-year
131	14.395642	120.856772	1.419	2	0.581	Milenyo/Sept 26, 2006	5-year
132	14.395781	120.856584	0.031	0	-0.031	Milenyo/Sept 26, 2006	5-year
133	14.395991	120.856742	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year

134	14.39617	120.856934	1.025	0.1	-0.925	Milenyo/Sept 26, 2006	5-year
135	14.396315	120.85738	0.161	0.4	0.239	Milenyo/Sept 26, 2006	5-year
136	14.396365	120.856879	0.377	1.1	0.723	Milenyo/Sept 26, 2006	5-year
137	14.396368	120.857056	3.2869999	2.1	-1.187	Milenyo/Sept 26, 2006	5-year
138	14.396401	120.857287	0.818	0.4	-0.418	Milenyo/Sept 26, 2006	5-year
139	14.396608	120.856642	0.634	0.3	-0.334	Milenyo/Sept 26, 2006	5-year
140	14.39666	120.856528	0.271	1.1	0.829	Milenyo/Sept 26, 2006	5-year
141	14.396827	120.856053	1.2920001	1.9	0.608	Milenyo/Sept 26, 2006	5-year
142	14.396887	120.8571	0.142	0	-0.142	Milenyo/Sept 26, 2006	5-year
143	14.397045	120.862107	3.21	3	-0.210	Milenyo/Sept 26, 2006	5-year
144	14.39709	120.862424	1.402	1.8	0.398	Milenyo/Sept 26, 2006	5-year
145	14.397424	120.859462	0.041	0	-0.041	Milenyo/Sept 26, 2006	5-year
146	14.397643	120.860181	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
147	14.397774	120.860509	3.408	5	1.592	Milenyo/Sept 26, 2006	5-year
148	14.398183	120.862331	0.03	0.2	0.170	Milenyo/Sept 26, 2006	5-year
149	14.398195	120.855892	0.172	0.6	0.428	Milenyo/Sept 26, 2006	5-year
150	14.39821	120.855749	1.795	1.7	-0.095	Milenyo/Sept 26, 2006	5-year
151	14.398423	120.84217	0.036	0.3	0.264	Milenyo/Sept 26, 2006	5-year
152	14.398585	120.840733	0.673	0.4	-0.273	Milenyo/Sept 26, 2006	5-year
153	14.398586	120.856103	0.03	0.3	0.270	Milenyo/Sept 26, 2006	5-year
154	14.398667	120.856007	1.351	1.6	0.249	Milenyo/Sept 26, 2006	5-year
155	14.398705	120.842438	0.49	0.2	-0.290	Milenyo/Sept 26, 2006	5-year
156	14.398715	120.840117	0.498	0.9	0.402	Milenyo/Sept 26, 2006	5-year
157	14.398982	120.842059	0.313	0.4	0.087	Milenyo/Sept 26, 2006	5-year
158	14.399003	120.841328	0.076	0.4	0.324	Milenyo/Sept 26, 2006	5-year
159	14.399079	120.859427	0.036	0	-0.036	Milenyo/Sept 26, 2006	5-year
160	14.399156	120.855816	1.813	1.8	-0.013	Milenyo/Sept 26, 2006	5-year
161	14.39921	120.842124	0.245	0.3	0.055	Milenyo/Sept 26, 2006	5-year
162	14.399349	120.842158	0.447	0.3	-0.147	Milenyo/Sept 26, 2006	5-year
163	14.399366	120.860865	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
164	14.399485	120.840791	0.194	0.1	-0.094	Milenyo/Sept 26, 2006	5-year
165	14.399573	120.841468	0.754	0.6	-0.154	Milenyo/Sept 26, 2006	5-year
166	14.399806	120.856686	0.093	0	-0.093	Milenyo/Sept 26, 2006	5-year
167	14.39982	120.860601	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
168	14.39997	120.840935	0.827	0.3	-0.527	Milenyo/Sept 26, 2006	5-year
169	14.400191	120.85547	0.032	1	0.968	Milenyo/Sept 26, 2006	5-year
170	14.40027	120.842855	0.118	0.4	0.282	Milenyo/Sept 26, 2006	5-year
171	14.400463	120.860576	0.051	0	-0.051	Milenyo/Sept 26, 2006	5-year
172	14.40053	120.857505	0.061	0	-0.061	Milenyo/Sept 26, 2006	5-year
173	14.40071	120.843299	0.149	0.1	-0.049	Milenyo/Sept 26, 2006	5-year
174	14.402329	120.858796	0.056	1.1	1.044	Milenyo/Sept 26, 2006	5-year
175	14.402332	120.844068	0.047	0.1	0.053	Milenyo/Sept 26, 2006	5-year
176	14.402399	120.855825	0.031	1.1	1.069	Milenyo/Sept 26, 2006	5-year
177	14.402707	120.843255	0.196	0.1	-0.096	Milenyo/Sept 26, 2006	5-year
178	14.402857	120.857561	0.03	0.3	0.270	Milenyo/Sept 26, 2006	5-year

179	14.40313	120.843674	0.039	0.1	0.061	Milenyo/Sept 26, 2006	5-year
180	14.403571	120.854824	0.061	3	2.939	Milenyo/Sept 26, 2006	5-year
181	14.404095	120.84278	0.154	0.5	0.346	Milenyo/Sept 26, 2006	5-year
182	14.404438	120.853229	0.033	0.3	0.267	Milenyo/Sept 26, 2006	5-year
183	14.404514	120.842346	0.055	0.2	0.145	Milenyo/Sept 26, 2006	5-year
184	14.405011	120.850665	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
185	14.405788	120.851351	0.095	0.3	0.205	Milenyo/Sept 26, 2006	5-year
186	14.405869	120.84524	0.125	0.4	0.275	Milenyo/Sept 26, 2006	5-year
187	14.405871	120.853265	0.281	0	-0.281	Milenyo/Sept 26, 2006	5-year
188	14.405996	120.850398	0.032	2.4	2.368	Milenyo/Sept 26, 2006	5-year
189	14.406107	120.843975	0.384	0.4	0.016	Milenyo/Sept 26, 2006	5-year
190	14.406187	120.8478	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
191	14.406783	120.848539	0.054	2.4	2.346	Milenyo/Sept 26, 2006	5-year
192	14.406913	120.843509	0.184	0.9	0.716	Milenyo/Sept 26, 2006	5-year
193	14.407078	120.845302	0.046	0.3	0.254	Milenyo/Sept 26, 2006	5-year
194	14.407736	120.845405	0.299	1	0.701	Milenyo/Sept 26, 2006	5-year
195	14.407849	120.846164	0.03	1	0.970	Milenyo/Sept 26, 2006	5-year
196	14.408018	120.845641	0.703	2	1.297	Milenyo/Sept 26, 2006	5-year
197	14.408262	120.845905	0.149	3	2.851	Milenyo/Sept 26, 2006	5-year
198	14.408735	120.846956	0.03	1.4	1.370	Milenyo/Sept 26, 2006	5-year
199	14.411679	120.847682	0.039	0.4	0.361	Milenyo/Sept 26, 2006	5-year
200	14.414234	120.85133	0.157	0.3	0.143	Milenyo/Sept 26, 2006	5-year
201	14.400005	120.844387	0.035	0	-0.035	Milenyo/Sept 26, 2006	5-year
202	14.405511	120.845846	0.243	0	-0.243	Milenyo/Sept 26, 2006	5-year
203	14.405402	120.84785	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
204	14.40545	120.849257	0.135	0	-0.135	Milenyo/Sept 26, 2006	5-year
205	14.404574	120.852215	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
206	14.402928	120.851487	0.031	0	-0.031	Milenyo/Sept 26, 2006	5-year
207	14.402205	120.852167	0.139	0	-0.139	Milenyo/Sept 26, 2006	5-year
208	14.402977	120.854125	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
209	14.399115	120.855814	0.75	0	-0.750	Milenyo/Sept 26, 2006	5-year
210	14.398427	120.856609	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
211	14.391724	120.851534	0.074	0	-0.074	Milenyo/Sept 26, 2006	5-year
212	14.397497	120.856669	0.06	0	-0.060	Milenyo/Sept 26, 2006	5-year
213	14.397403	120.857811	0.06	0	-0.060	Milenyo/Sept 26, 2006	5-year
214	14.396921	120.858392	0.081	0	-0.081	Milenyo/Sept 26, 2006	5-year
215	14.39632	120.85923	0.289	0	-0.289	Milenyo/Sept 26, 2006	5-year
216	14.39652	120.858278	0.059	0	-0.059	Milenyo/Sept 26, 2006	5-year
217	14.400171	120.856739	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
218	14.398635	120.853016	0.035	0	-0.035	Milenyo/Sept 26, 2006	5-year
219	14.398857	120.851747	0.046	0	-0.046	Milenyo/Sept 26, 2006	5-year
220	14.398709	120.850951	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
221	14.398577	120.85078	0.093	0	-0.093	Milenyo/Sept 26, 2006	5-year
222	14.391588	120.848418	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
223	14.389484	120.848474	0.031	0	-0.031	Milenyo/Sept 26, 2006	5-year

224	14.388231	120.846938	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
225	14.390957	120.853053	0.079	0	-0.079	Milenyo/Sept 26, 2006	5-year
226	14.391997	120.855587	0.196	0	-0.196	Milenyo/Sept 26, 2006	5-year
227	14.392546	120.855218	0.061	0	-0.061	Milenyo/Sept 26, 2006	5-year
228	14.393731	120.855817	0.04	0	-0.040	Milenyo/Sept 26, 2006	5-year
229	14.394307	120.857279	0.348	0	-0.348	Milenyo/Sept 26, 2006	5-year
230	14.393208	120.846943	0.031	0	-0.031	Milenyo/Sept 26, 2006	5-year
231	14.395198	120.844375	0.03	0	-0.030	Milenyo/Sept 26, 2006	5-year
232	14.395983	120.843387	0.045	0	-0.045	Milenyo/Sept 26, 2006	5-year
233	14.397325	120.842772	0.034	0	-0.034	Milenyo/Sept 26, 2006	5-year
234	14.399528	120.844331	0.031	0	-0.031	Milenyo/Sept 26, 2006	5-year
235	14.392387	120.852319	0.097	0	-0.097	Milenyo/Sept 26, 2006	5-year
236	14.31695	120.896009	0.03	0.03	0.000	Milenyo/Sept 26, 2006	5-year
237	14.339419	120.881514	0.03	0.03	0.000	Milenyo/Sept 26, 2006	5-year
238	14.348037	120.859893	0.03	0.1	0.070	Milenyo/Sept 26, 2006	5-year
239	14.399971	120.844663	0.03	0.12	0.090	Milenyo/Sept 26, 2006	5-year
240	14.373901	120.880216	0.882	0.13	-0.752	Milenyo/Sept 26, 2006	5-year
241	14.399645	120.842995	0.032	0.14	0.108	Milenyo/Sept 26, 2006	5-year
242	14.399924	120.844805	0.03	0.16	0.130	Milenyo/Sept 26, 2006	5-year
243	14.406552	120.843911	0.252	0.25	-0.002	Milenyo/Sept 26, 2006	5-year
244	14.403901	120.843332	0.03	0.3	0.270	Milenyo/Sept 26, 2006	5-year
245	14.406293	120.845064	0.034	0.3	0.266	Milenyo/Sept 26, 2006	5-year
246	14.403996	120.844729	0.084	0.35	0.266	Milenyo/Sept 26, 2006	5-year
247	14.403724	120.844626	0.03	0.4	0.370	Milenyo/Sept 26, 2006	5-year
248	14.352501	120.881569	0.03	0.4	0.370	Milenyo/Sept 26, 2006	5-year
249	14.402655	120.844121	0.046	0.5	0.454	Milenyo/Sept 26, 2006	5-year
250	14.400054	120.843123	0.04	0.5	0.460	Milenyo/Sept 26, 2006	5-year
251	14.404005	120.842628	0.282	0.6	0.318	Milenyo/Sept 26, 2006	5-year
252	14.400703	120.84338	0.189	0.65	0.461	Milenyo/Sept 26, 2006	5-year
253	14.321283	120.860682	0.03	0.8	0.770	Milenyo/Sept 26, 2006	5-year
254	14.321459	120.860658	0.03	0.95	0.920	Milenyo/Sept 26, 2006	5-year
255	14.388687	120.867187	0.161	0	-0.161	Milenyo/Sept 26, 2006	5-year
256	14.420866	120.854092	0.097	0.1	0.003	Milenyo/Sept 26, 2006	5-year
RMSE = 0.86577							

Annex 12. Educational Institutions Affected by Flooding in Cañas Floodplain

This information is not available for this river basin.

Annex 13. Health Institutions Affected by Flooding in Cañas Floodplain

This information is not available for this river basin.