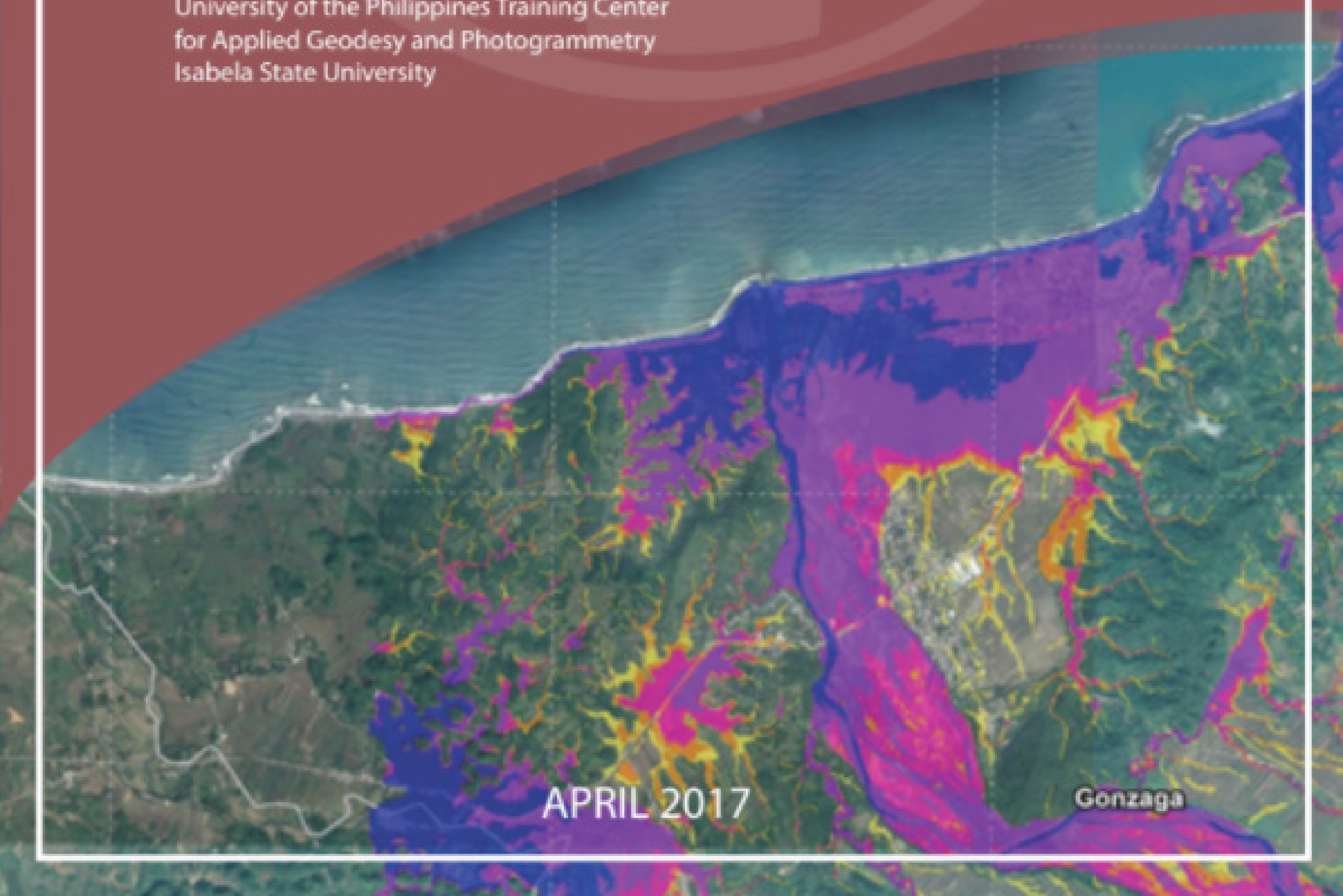
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Aunugay River

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



APRIL 2017

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND AUNUGAY RIVER

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

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Isabela State University (ISU). ISU is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 10 river basins in the Cagayan Region. The university is located in Echague, Isabela .

1.2. Overview of the Aunugay River Basin

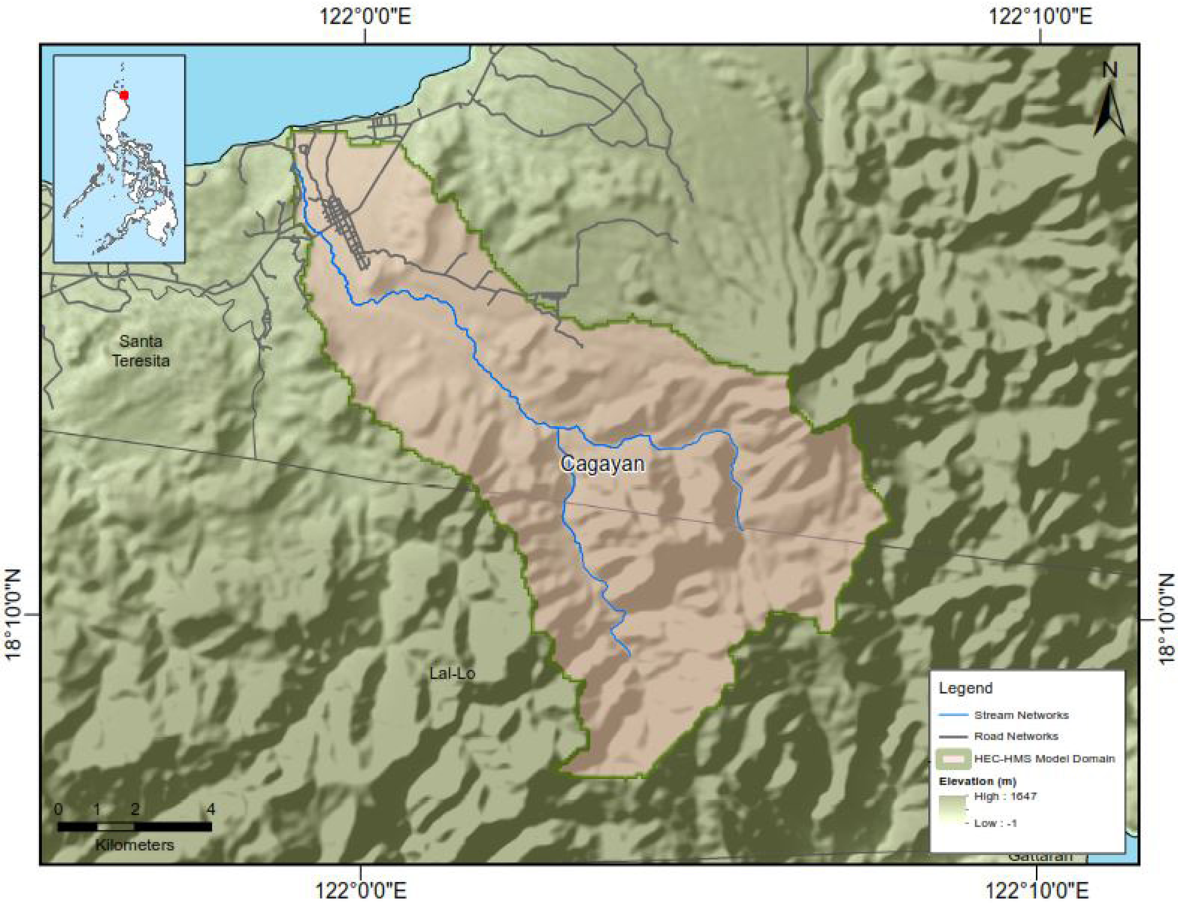


Figure 1. Map of the Aunugay River

The Province of Cagayan is generally warm, humid and sunny throughout the year. There are two types of climate prevailing in the province; the Type III and Type IV. Type III climate seasons are not very pronounced; relatively dry from November to April, wet during rest of the year. Type IV climate season on the other hand, has an even distribution of rainfall through the year. The Municipality of Gonzaga experiences this type of climate.

The Municipality of Gonzaga is endowed with various resources that can be tapped for different development activities. Its land can be developed for agriculture. It has a good eco-tourism potentials and it has rich bio-diversity with increased fishing and aquaculture potential. In approximately 12 km south of the Municipality of Gonzaga and 14 km south of Port Irene in Santa Ana, Cagayan, the Cagua Volcano, an active stratovolcano, can be found. It has a circular summit crater of 1.5 km in diameter, 1.16 km elevation and 12 km base diameter.

The Aunugay River (Figure 1) locally known as the Wangag River is located in the Municipality of Gonzaga and extends to the Municipality of Lal-lo, Province of Cagayan in the southern tip of the watershed. The water of Wangag River is used for irrigation; however the river also serves other purposes such as fishing location, channel of transportation, recreation and tourism.

Based on the 2010 Census of Population and Housing, a total of 24, 540 people are residing within the Aunugay River Basin distributed among fifteen (15) barangays in the Municipality of Gonzaga namely: Batangan,Callao, Calayan, Flourishing, Ipil, Isca, Magrafil, Minanga,Rebecca, Paradise, Pateng, Progressive, Santa Clara, Smart, and Tapel, including Barangays Dungeg and Dagupan in the Municipalities of Santa Teresita and Lallo, respectively.

The Municipality of Gonzaga was among the areas devastated by Typhoon Angela (Local Code Name: Rubing) on October 8, 1989 as well as Typhoon Haima (Local Code Name: Lawin) on October 20, 2016.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE AUNUGAY FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Ms. Jasmine T. Alviar, Engr. Brylle Adam G. De Castro

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

2.1 Flight Plans

In order to acquire LiDAR data, the Data Acquisition Component (DAC) created flight plans within the delineated priority area of the Aunugay Floodplain in the Province of Cagayan. These missions were planned for twelve (12) lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR System is found in Table 1. Figure 2 shows the flight plan for Aunugay Floodplain.

Table 1. Flight planning parameters for Gemini LiDAR System.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
Block 3A	1000	30	50	200	30	130	5
Block 21D	800	30	40	100	50	130	5
Block 61G	1000	30	40	100	50	130	5
Block 61E	1000	30	40	100	50	130	5
Block 21AB	1000	30	40	100	50	130	5
Block 3A	1000	30	40	100	50	130	5
Bock 21D additional	900	30	50	125	40	130	5
Block 21D	900	30	50	125	40	130	5

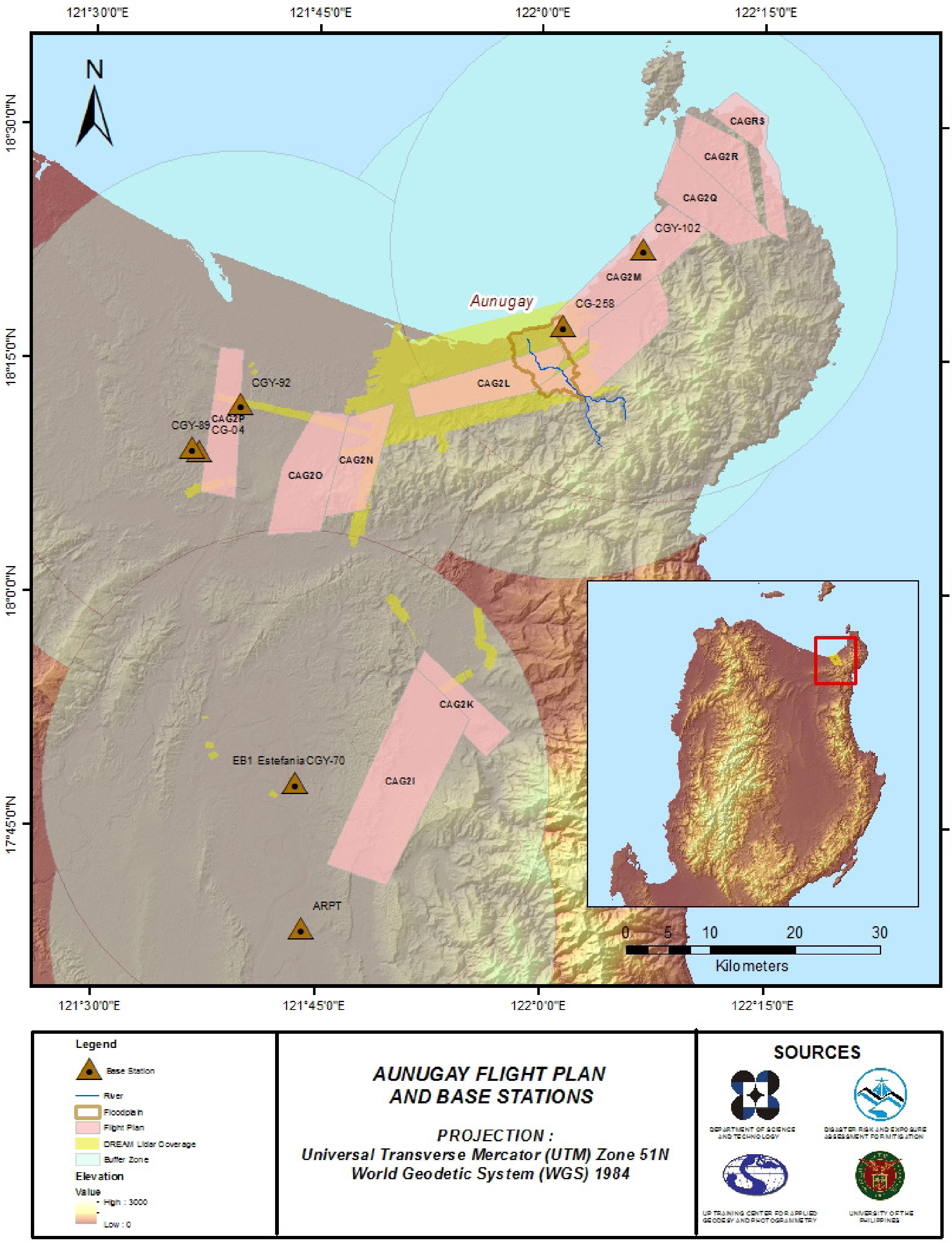
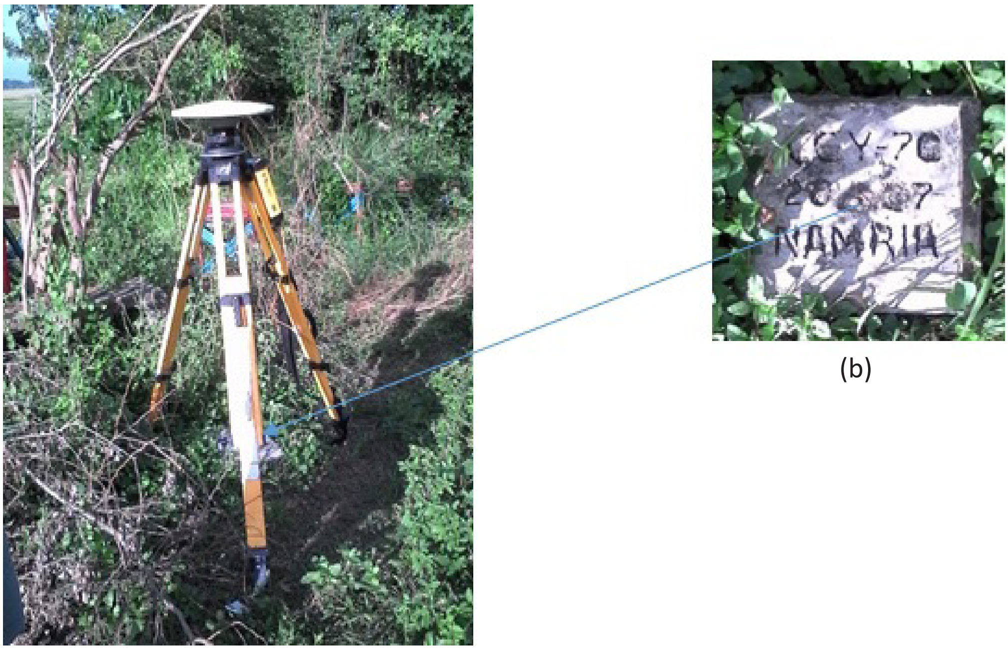


Figure 2. Flight plan and base stations used for Aunugay Floodplain

2.2 Ground Base Station

The Project Team was able to recover four (4) NAMRIA ground control points: CGY-70, CGY-89, CGY-92 and CGY-102 which are of second (2^{nd}) order accuracy. The team utilized two (2) NAMRIA benchmarks: CG-04 and CG-258 and also established two (2) ground control points: ARPT and EB1 Estefania. The certifications for the NAMRIA reference points are found in Annex 2 while the baseline processing reports for the established control point are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (November 30, 2015 and April 28 to May 8, 2016). Base stations were observed using Dual Frequency GPS receivers: TOPCON GR5, TRIMBLE SPS 852, TRIMBLE SPS 882 and TRIMBLE SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Aunugay Floodplain are shown in Figure 2.

Figures 3 to 10 show the recovered NAMRIA reference points within the area. In addition, Tables 2 to 9 show the details about the following NAMRIA control stations and established points, while Table 6 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.



(b)

(a)

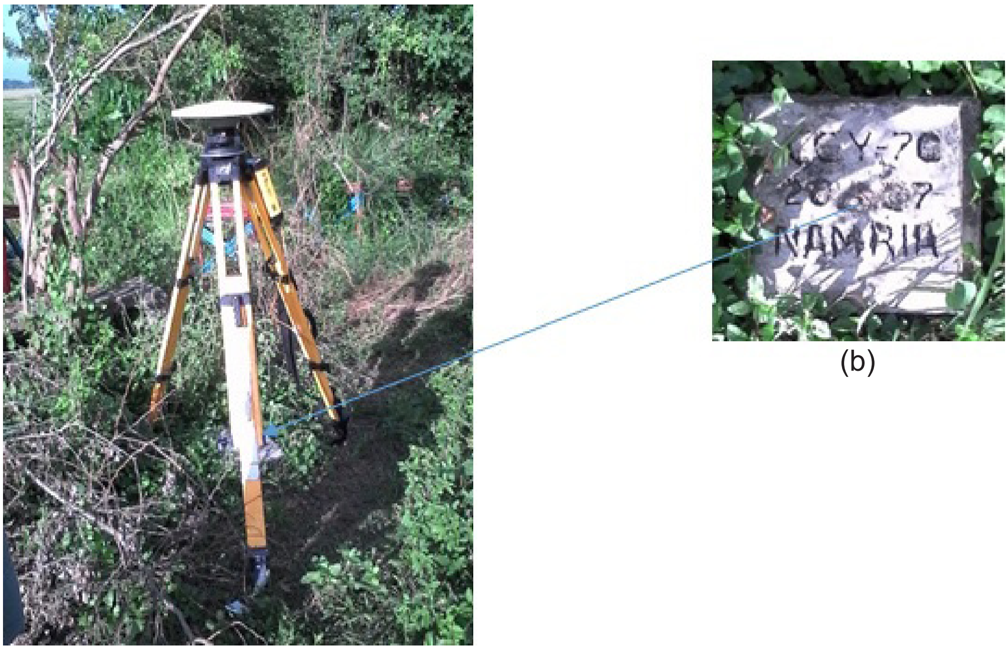
Figure 3. GPS set-up over CGY-70 at the corner of basketball court inside Estefania Elementary School campus (b) as recovered by the field team

Figures 3 to 10 show the recovered NAMRIA reference points within the area. In addition, Tables 2 to 9 show the details about the following NAMRIA control stations and established points,

Table 2. Details of the recovered NAMRIA horizontal reference point CGY-70 used as base station for the LiDAR acquisition.

Station Name		CGY-70
Order of Accuracy		2^{nd}
Relative Error (horizontal positioning)		1 in 50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	17° 47' 54.79038" North
	Longitude	121° 43' 31.26837" East
	Ellipsoidal Height	26.85900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	576,904.118 meters
	Northing	1968617.425 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	17° 47' 48.71170" North
	Longitude	121° 43' 35.88859" East
	Ellipsoidal Height	62.40000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	364899.00 meters
	Northing	1968239.03 meters

Figures 3 to 10 show the recovered NAMRIA reference points within the area. In addition, Tables 2 to 9 show the details about the following NAMRIA control stations and established points, while Table 6 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.



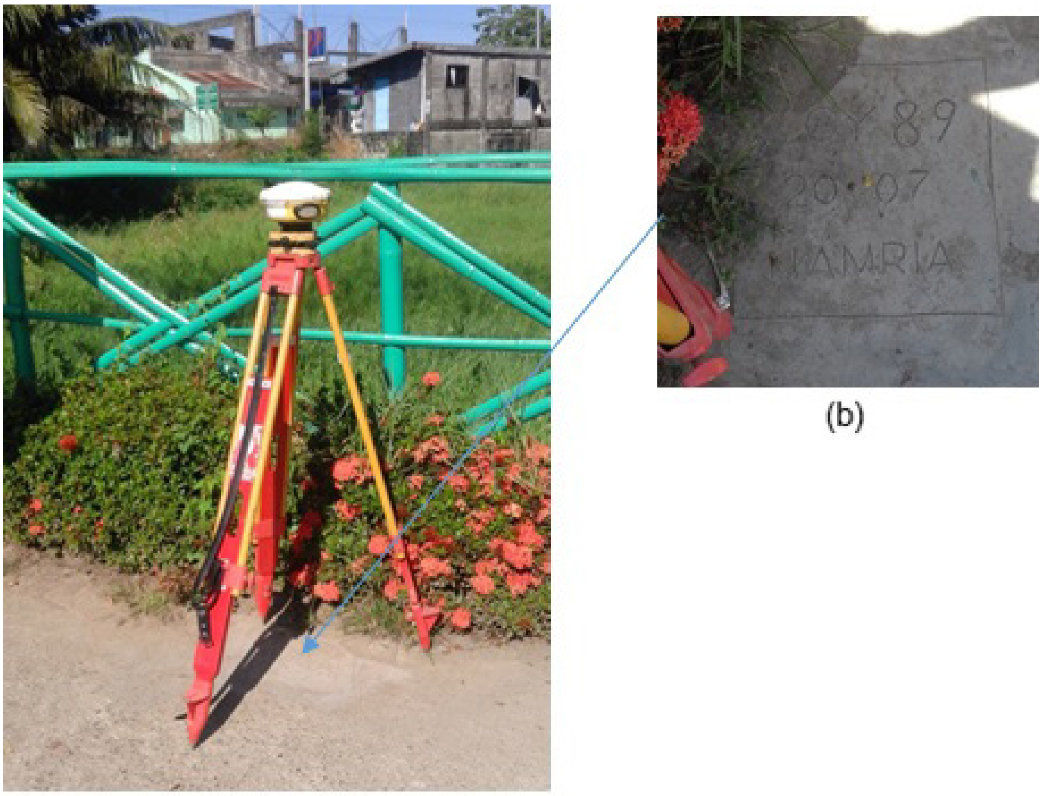
(b)

(a)

Figure 4. GPS set-up over CGY-70 at the corner of basketball court inside Estefania Elementary School campus (b) as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal reference point CGY-70 used as base station for the LiDAR acquisition

Station Name		CGY-70
Order of Accuracy		2^{nd}
Relative Error (horizontal positioning)		1 in 50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	17° 47' 54.79038" North 121° 43' 31.26837" East 26.85900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	576,904.118 meters 1968617.425 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	17° 47' 48.71170" North 121° 43' 35.88859" East 62.40000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	364899.00 meters 1968239.03 meters

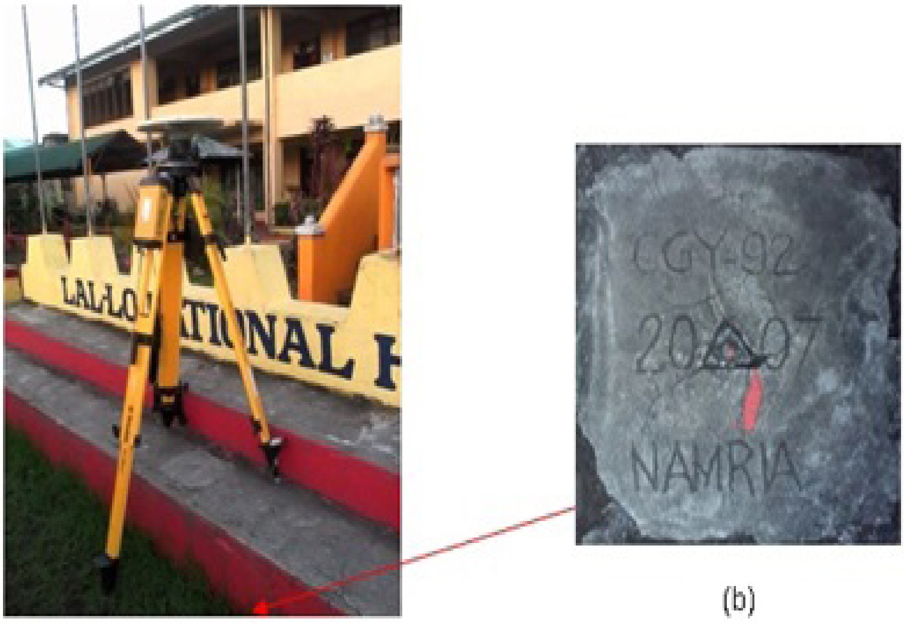


(a) (b)

Figure 5. GPS set-up over CGY-89 located on the left side of the access to Logac National High School in Barangay Logac, Municipality of Lal-lo (a) and NAMRIA horizontal reference point CGY-89 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal reference point CGY-89 used as base station for the LiDAR acquisition

Station Name		CGY-89
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1 in 50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	18° 9' 24.10576" North 121° 36' 27.80546" East 15.88200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	564302.582 meters 2008210.132 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18° 9' 17.94119" North 121° 36' 32.39657" East 49.97100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	352726.82 meters 2007958.66 meters

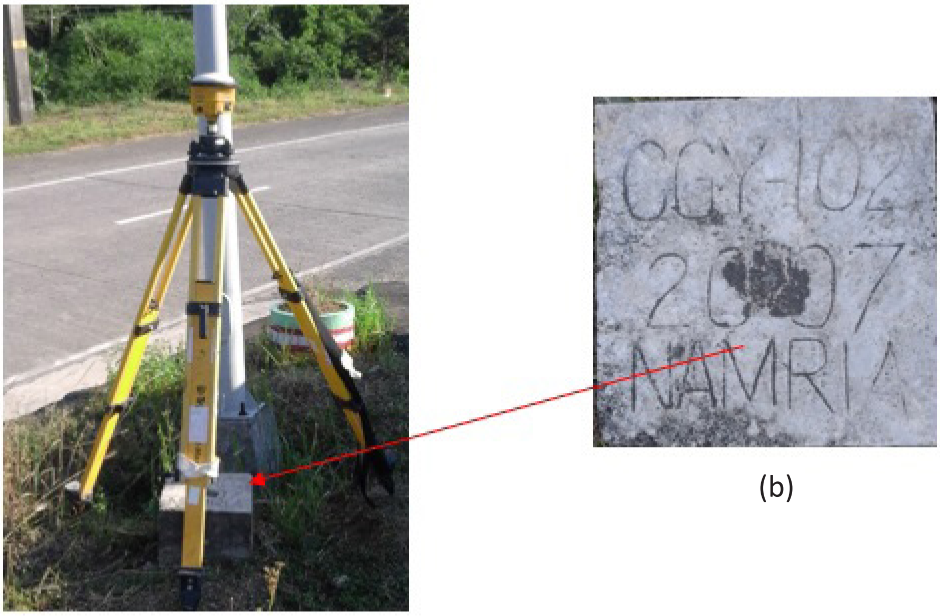


(a) (b)

Figure 6. GPS set-up over CGY-92 at Lal-lo National High School (a) and NAMRIA reference point CGY-92 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal reference point CGY-92 used as base station for the LiDAR acquisition

Station Name		CGY-92
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1 in 50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	18° 12' 11.42361" North 121° 39' 42.14392" East 14.47400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	569996.115 meters 2013373.807 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18° 12' 5.25321" North 121° 39' 46.73084" East 8.54000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	358475.41 meters 2013059.26 meters

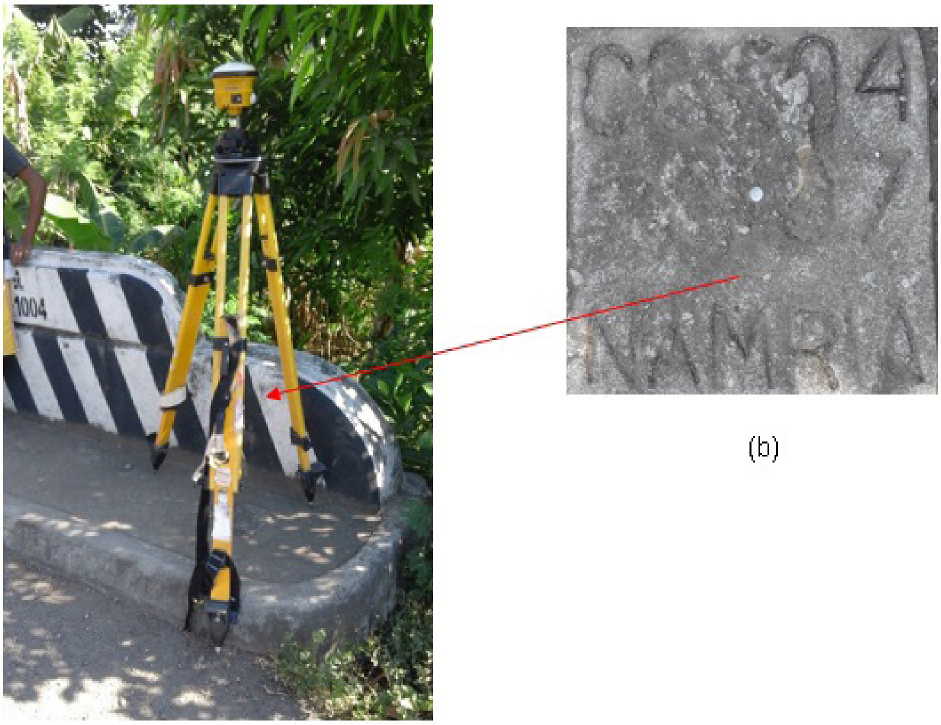


(a) (b)

Figure 7. GPS set-up over CGY-102 at the intersection of the national highway and the road to Port Irene (a) and NAMRIA reference point CGY-102 (b) as recovered by the field team

Table 5. Details of the established reference point CGY-102 used as base station for the LiDAR acquisition

Station Name		CGY-102
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1 in 50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	18° 22' 15.98573" North 122° 6' 41.74346" East 22.60800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	617476.569 meters 2032192.366 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18° 22' 9.81367" North 122° 6' 46.31361" East 57.195 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	406145.45 meters 2031351.34 meters

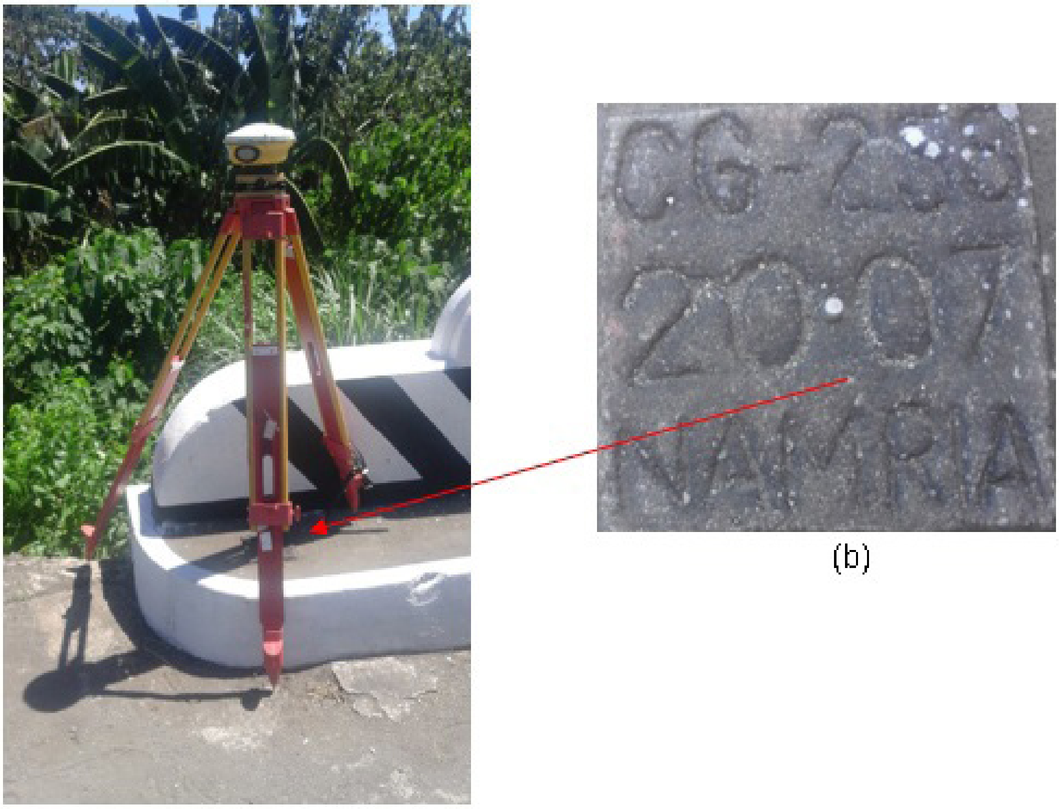


(a) (b)

Figure 8. GPS set-up over CG-04 in the municipality of Lal-lor (a) and NAMRIA reference point CG-04 (b) as recovered by the field team

Table 6. Details of the NAMRIA benchmark CG-04 with processed coordinates used as base station for the LiDAR acquisition

Station Name	CG-04	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	18° 9' 6.42823" North 121° 36' 59.69517" East 20.039 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18° 9' 0.26539" North 121° 37' 4.28663" East 54.165 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	353659.894 meters 2007408.207 meters



(a) (b)

Figure 9. GPS set-up over CG-258 in the Municipality of Gonzaga (a) and NAMRIA reference point CG-258 (b) as recovered by the field team

Table 7. Details of the NAMRIA benchmark CG-258 with processed coordinates used as base station for the LiDAR acquisition

Station Name		CG-258
Order of Accuracy		2nd
Relative Error (horizontal positioning)		1 in 50,000
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	18° 17' 21.32897" North 122° 1' 21.83970" East 12.774 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	18° 17' 15.16762" North 122° 1' 26.41723" East 47.419 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	396708.418 meters 2022343.154 meters

Table 8. Details of the NAMRIA benchmark ARPT used as base station for the LiDAR acquisition

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

Table 9. Details of the established control point EB1 Estefania used as base station for the LiDAR acquisition

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

Table 10. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
November 30, 2015	2916P	1BLK3A334B	CGY-92, CGY 102, EB1 Estefania & CGY-70
April 28, 2016	3971G	2BLK3CAG2MQR119A	CG-258 & CGY-102
May 01, 2016	3981G	2CAG2I122A	ARPT & CGY-70
May 03, 2016	3991G	2BLK3CAG2MNSQS124B	CG-258 & CGY-102
May 04, 2016	3993G	2BLK3CAG2LMNQR125A	CG-258 & CGY-102
May 05, 2016	3997G	2BLK3CAG2NO126A	CG-04 & CGY-89
May 06, 2016	4001G	2BLK3CAG2MRS127A	CG-258 & CGY-102
May 08, 2016	4009G	2CAG2K129A	ARPT & CGY-70

2.3 Flight Missions

Three (3) of the missions under DREAM program covered around seventy (70) square kilometers (Table 11) within Aunugay Floodplain, while eight (8) missions under Phil-LiDAR program were conducted to complete the LiDAR data acquisition in Aunugay Floodplain, for a total of twenty-seven hours and fifty-seven minutes (27+57) of flying time for RP-C9022 and RP-9122. The missions were acquired using the Pegasus and Gemini LiDAR Systems. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight missions under DREAM program which covers Aunugay Floodplain

Flight Number	Mission Name	Area Surveyed within the Floodplain (km^2)
766G	2CAG21C AND 21BS324A	23.584
768G	2CAG21D324B	31.619
770G	2CAG21DS325A	15.044
TOTAL		70.247

Table 12. Flight missions for LiDAR data acquisition in Aunugay Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	Flying Hours	
						Hr	Min
November 30, 2015	2916P	86.022	110.816	14.731	96.085	2	29
April 28, 2016	3971G	232.144	162.970	3.603	159.367	4	15
May 1, 2016	3981G	188.098	219.230	0.000	219.230	4	17
May 3, 2016	3991G	181.535	121.820	3.236	118.584	2	26
May 4, 2016	3993G	74.761	149.669	22.928	126.742	4	11
May 5, 2016	3997G	147.726	217.367	0.000	217.367	4	24
May 6, 2016	4001G	46.494	120.602	0.748	119.855	4	0
May 8, 2016	4009G	53.365	68.448	0.000	68.448	1	55
TOTAL		1010.145	1170.922	45.245	1125.677	27	57

Table 13. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2916P	1000	30	50	200	30	130	5
3971G	1000	30	40	100	50	130	5
3981G	1000	30	40	100	50	130	5
3991G	1000	30	40	100	50	130	5
3993G	800	30	40	100	50	130	5
3997G	1000	30	40	100	50	130	5
4001G	1000	30	40	100	50	130	5
4009G	1000	30	40	100	50	130	5
766G	900	30	50	125	40	130	5
768G	900	30	50	125	40	130	5
770G	900	30	50	125	40	130	5

2.4 Survey Coverage

The Aunugay Floodplain is located in the Province of Cagayan with majority of the floodplain situated within the Municipality of Gonzaga. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 14. The actual coverage of the LiDAR acquisition for Aunugay floodplain is presented in Figure 9.

Table 14. List of municipalities and cities surveyed during Aunugay Floodplain LiDAR survey

Province	Municipality/City	Area of Municipality (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed (%)
Cagayan	Santa Teresita	66.23	38.59	58.26%
	Gonzaga	497.62	198.81	39.95%
	Santa Ana	437.13	164.69	37.67%
	Lal-Lo	760.44	190.08	25.00%
	Iguig	97.59	20.34	20.84%
	Baggao	1009.05	119.61	11.85%
	Gattaran	557.09	59.05	10.60%
	Peñablanca	1213.01	120.47	9.93%
	Amulung	231.16	5.13	2.22%
	Tuguegarao City	129.61	1.63	1.25%
TOTAL		4998.94	918.38	18.37%

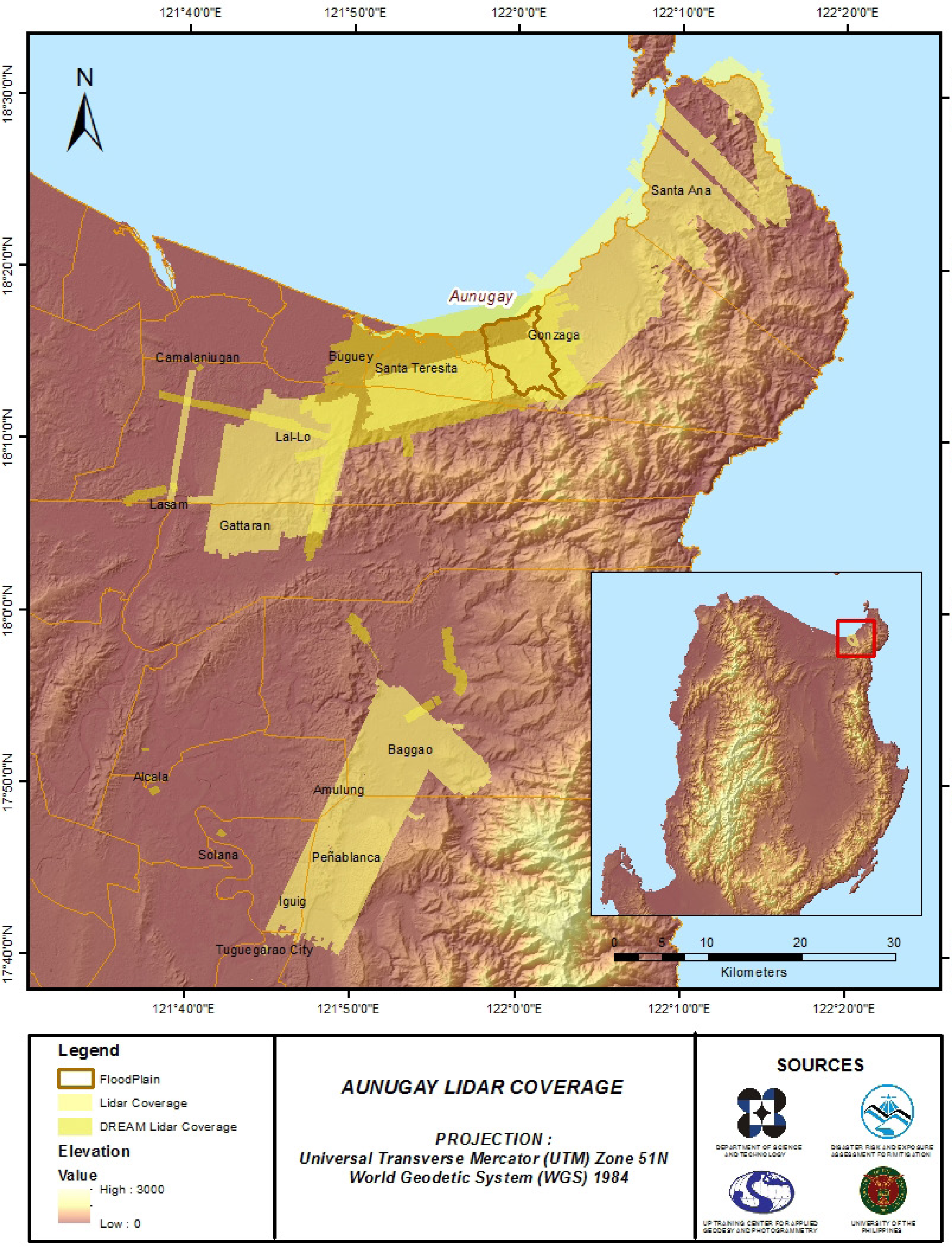


Figure 10. Actual LiDAR survey coverage for Aunugay Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE AUNUGAY FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 11.

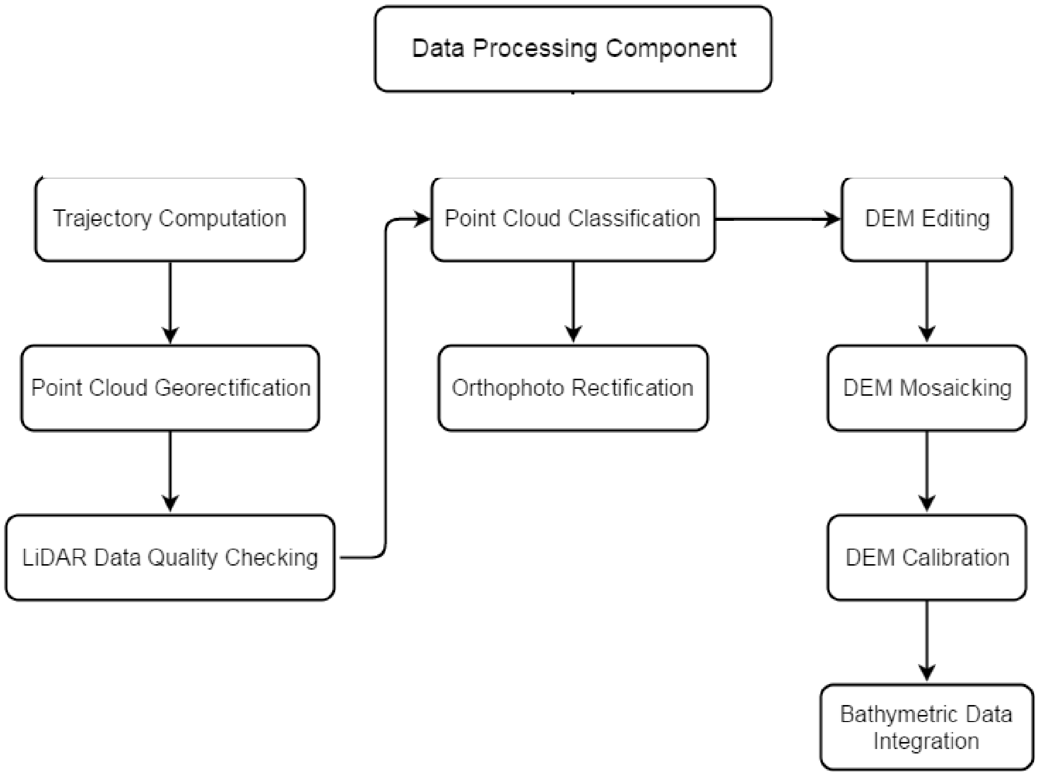

Figure 11. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of the Acquired LiDAR Data

The Data Transfer Sheets for all the LiDAR missions for Aunugay Floodplain can be found in Annex 5. Missions flown during most of the surveys conducted used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini System while a mission acquired during a survey on November 2015 were flown using the Pegasus System over Tuguegarao. The Data Acquisition Component (DAC) transferred a total of 194.90 Gigabytes of Range data, 2.25 Gigabytes of POS data, 244.26 Megabytes of GPS base station data, and 112.7 Gigabytes of raw image data to the data server on November 20, 2013 for the first survey and May 8, 2016 for the last survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Aunugay was fully transferred on June 21, 2016, as indicated on the Data Transfer Sheets for Aunugay Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 3981G, one of the Aunugay flights, which is the North, East, and Down position RMSE values are shown in Figure 11. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on May 1, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

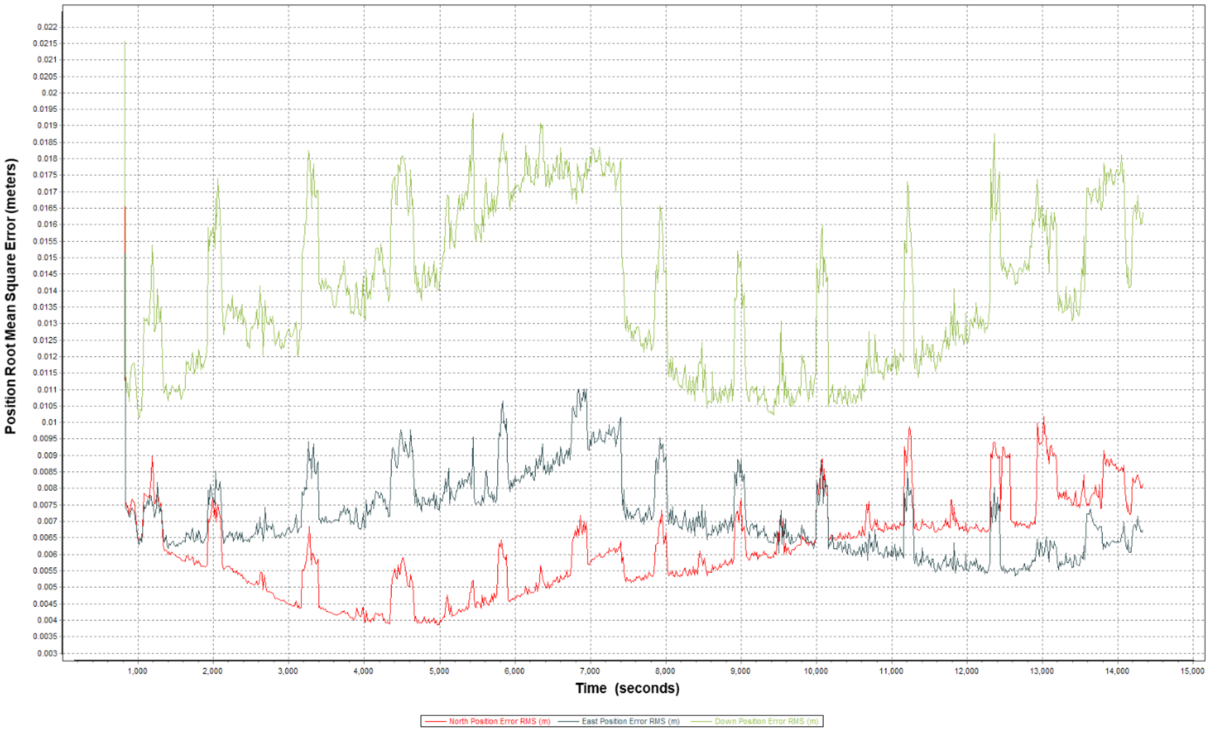

Figure 12. Smoothed Performance Metric Parameters of Aunugay Flight 3981G.

The time of flight was from 1000 seconds to 15000 seconds, which corresponds to morning of May 1, 2016. The initial spike seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and when the POS system started computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft made a turn to start a new flight line. Figure 11 shows that the North position RMSE peaks at 1.05 centimeters, the East position RMSE peaks at 1.10 centimeters, and the Down position RMSE peaks at 1.95 centimeters, which are within the prescribed accuracies described in the methodology.

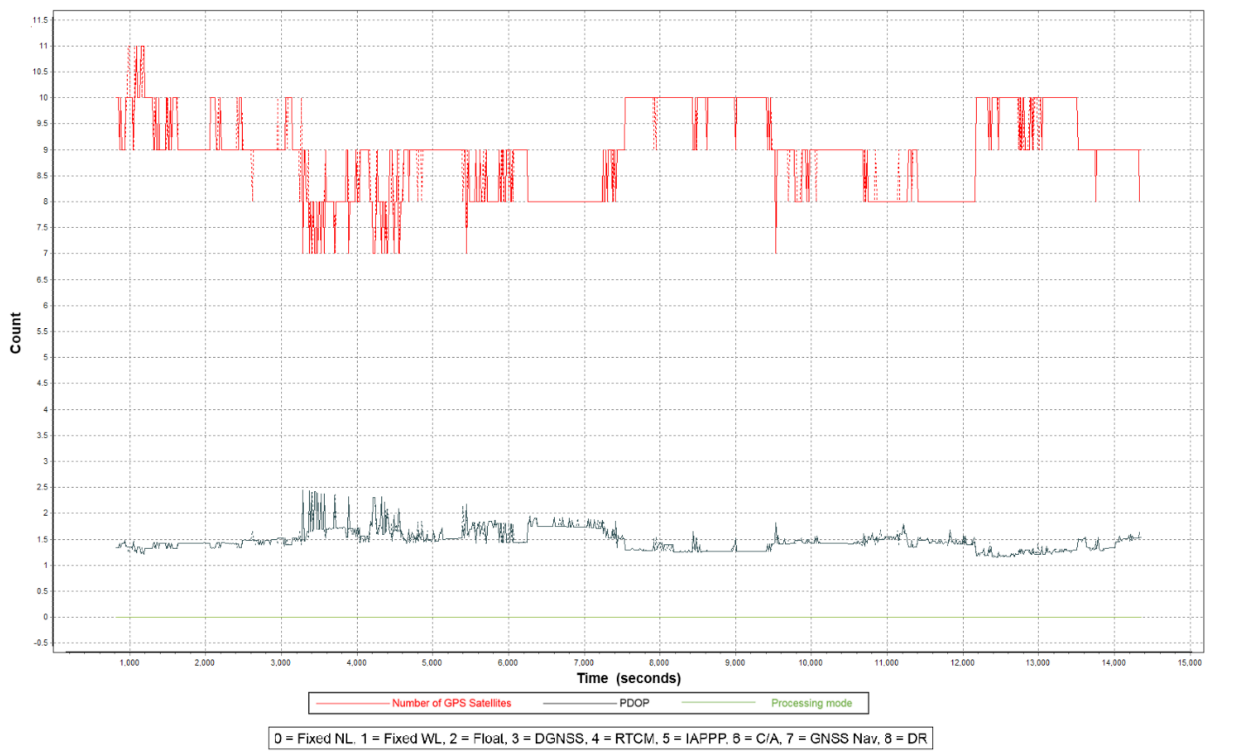

Figure 13. Solution Status Parameters of Aunugay Flight 3981G.

The Solution Status Parameters of flight 3981G, one of the Aunugay flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 11. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for the survey. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Aunugay flights is shown in Figure 13.

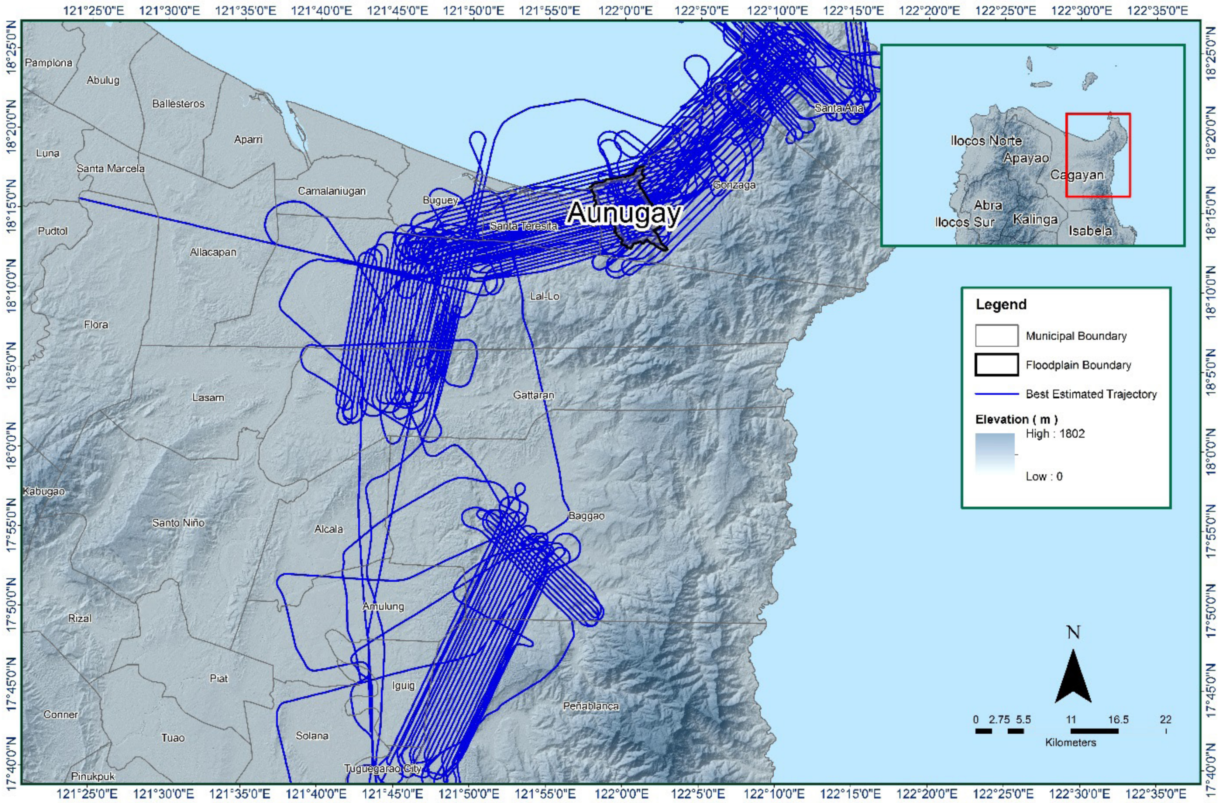

Figure 14. Best Estimated Trajectory for Aunugay Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contain 117 flight lines, with each flight line containing one channel, since the Gemini System contains one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Aunugay Floodplain are given in Table 15.

Table 15. Self-Calibration Results values for Aunugay flights.

Parameter	Acceptable Value
Boresight Correction stdev (<0.001degrees)	0.000179
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000662
GPS Position Z-correction stdev (<0.01meters)	0.0076

The optimum accuracy is obtained for all Aunugay flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the Annex 18. Mission Summary Reports.

3.5 LiDAR Data Quality Checking

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

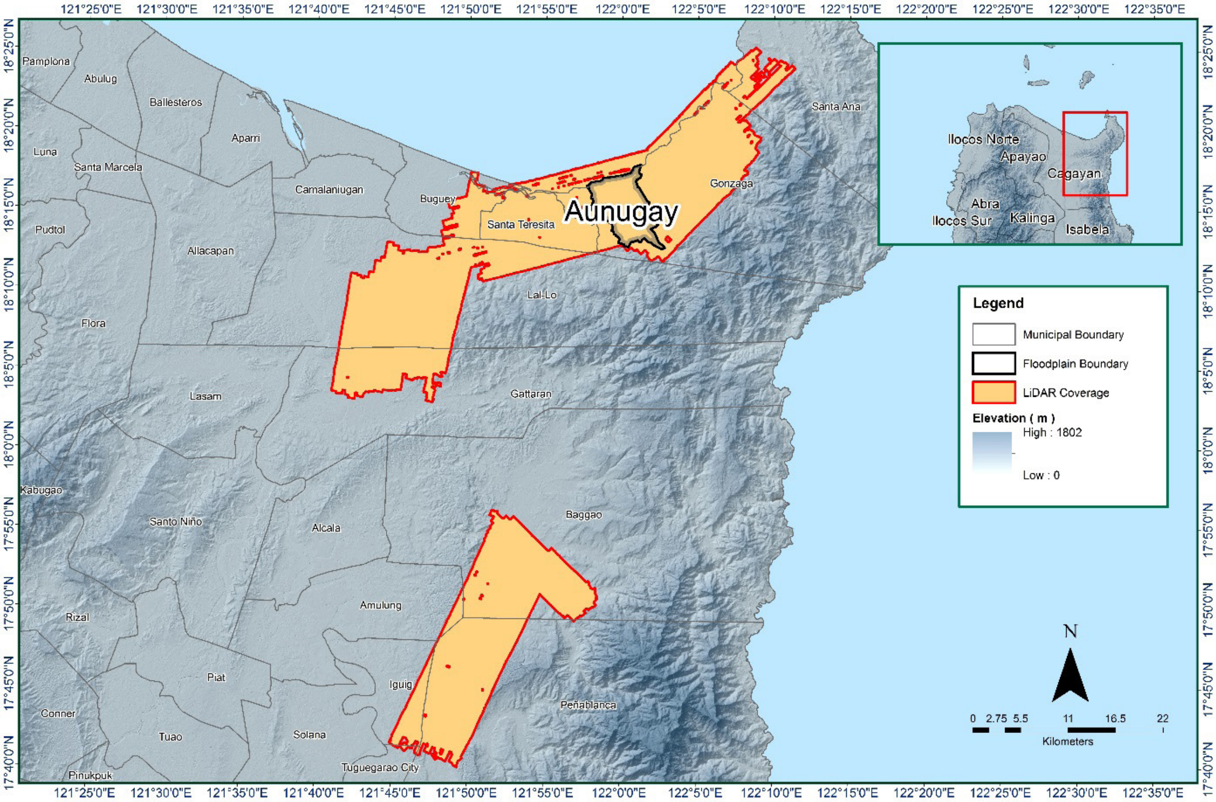

Figure 15. Boundary of the processed LiDAR data over Aunugay Floodplain

The total area covered by the Aunugay missions is 1056.01 sq.km that is comprised of eleven (11) flight acquisitions grouped and merged into nine (9) blocks as shown in Table 16.

Table 16. List of LiDAR blocks for Aunugay Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Cagayan_reflights_Tuguegarao_Blk3A	2916P	108.34
Cagayan_reflights_Blk21D	3993G	105.14
Cagayan_reflights_Blk61G	4009G	66.00
Cagayan_reflights_Blk61E	3981G	216.06
Cagayan_reflights_Blk21AB	3997G	201.22
Cagayan_reflights_Blk3A	3971G 3991G 4001G	108.73
Cagayan_Blk21D_additional	770G	24.99
Cagayan_Blk21D	768G	50.76
Cagayan_Blk21C	766G	174.79
	TOTAL	**1056.01 sq.km**

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

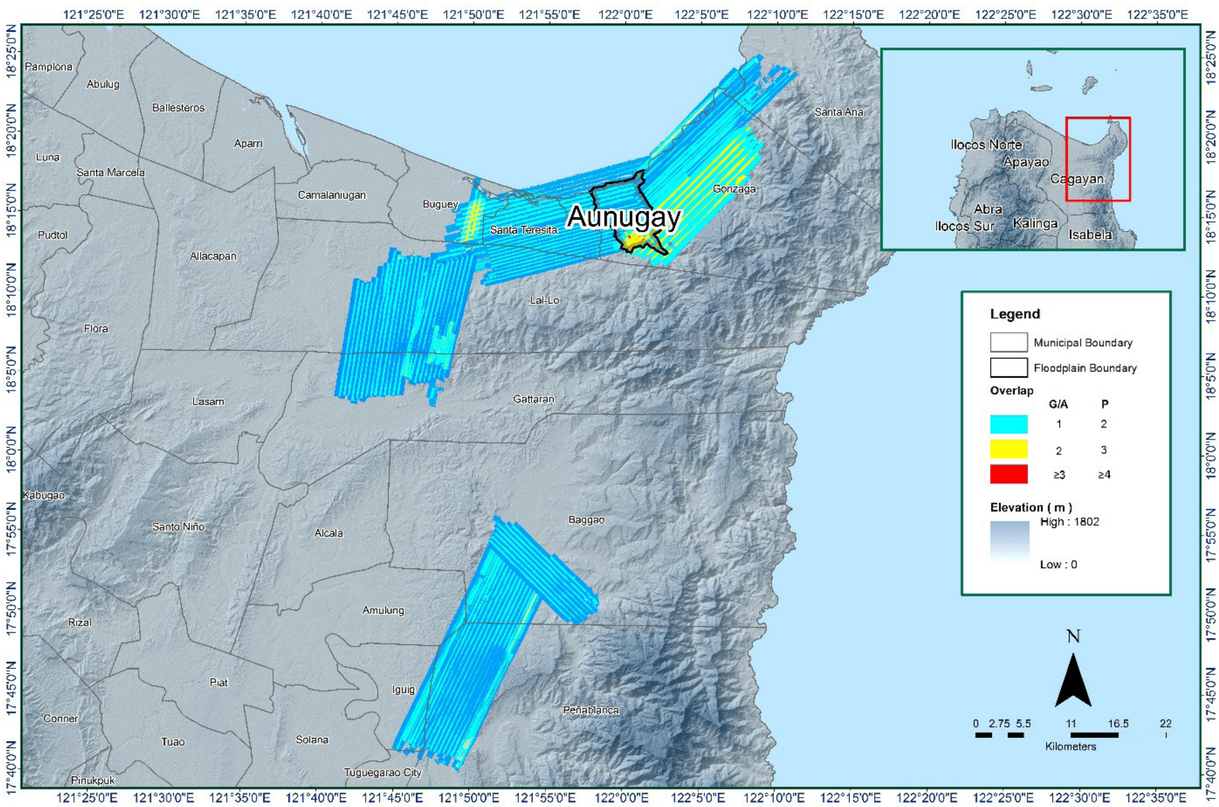

Figure 16. Image of data overlap for Aunugay Floodplain

The overlap statistics per block for the Aunugay Floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 26.57% and 42.36% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 16. It was determined that all LiDAR data for Aunugay Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.82 points per square meter.

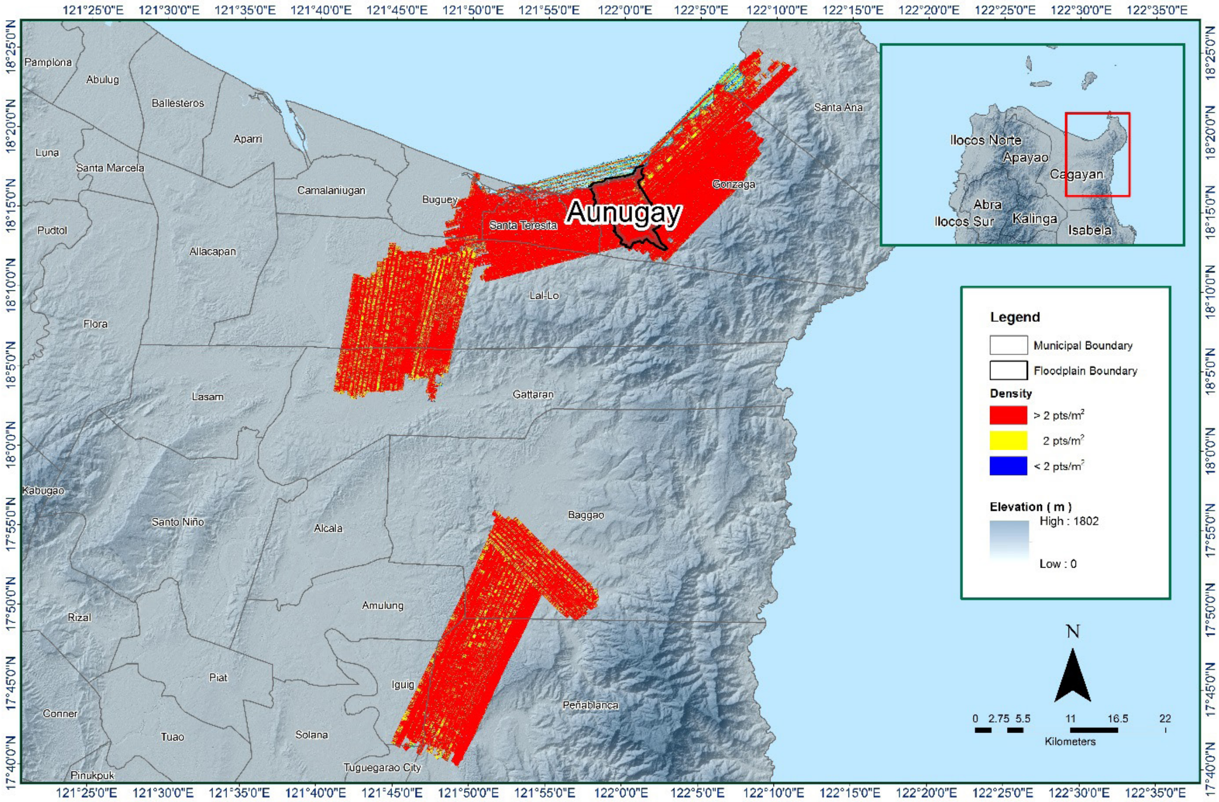

Figure 17. Density map of merged LiDAR data for Aunugay Floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

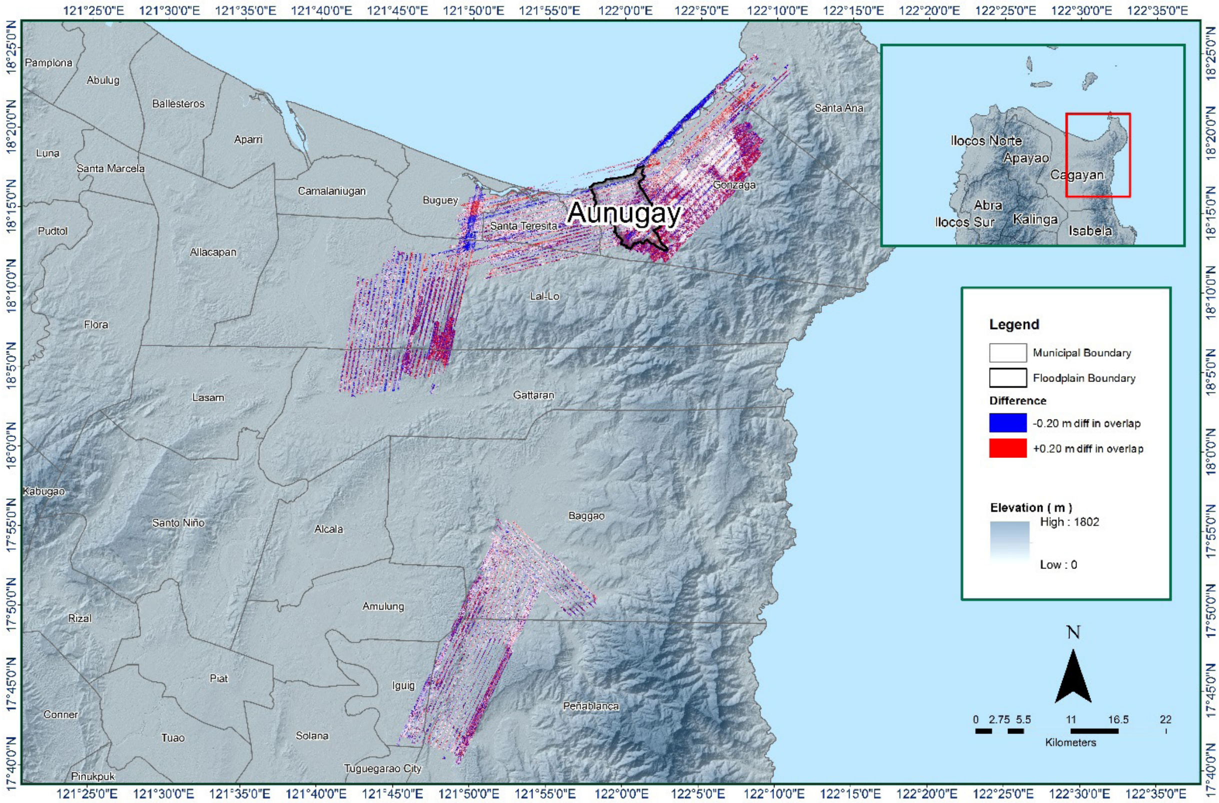

Figure 18. Elevation difference map between flight lines for Aunugay Floodplain

A screen capture of the processed LAS data from Aunugay flight 3981G loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

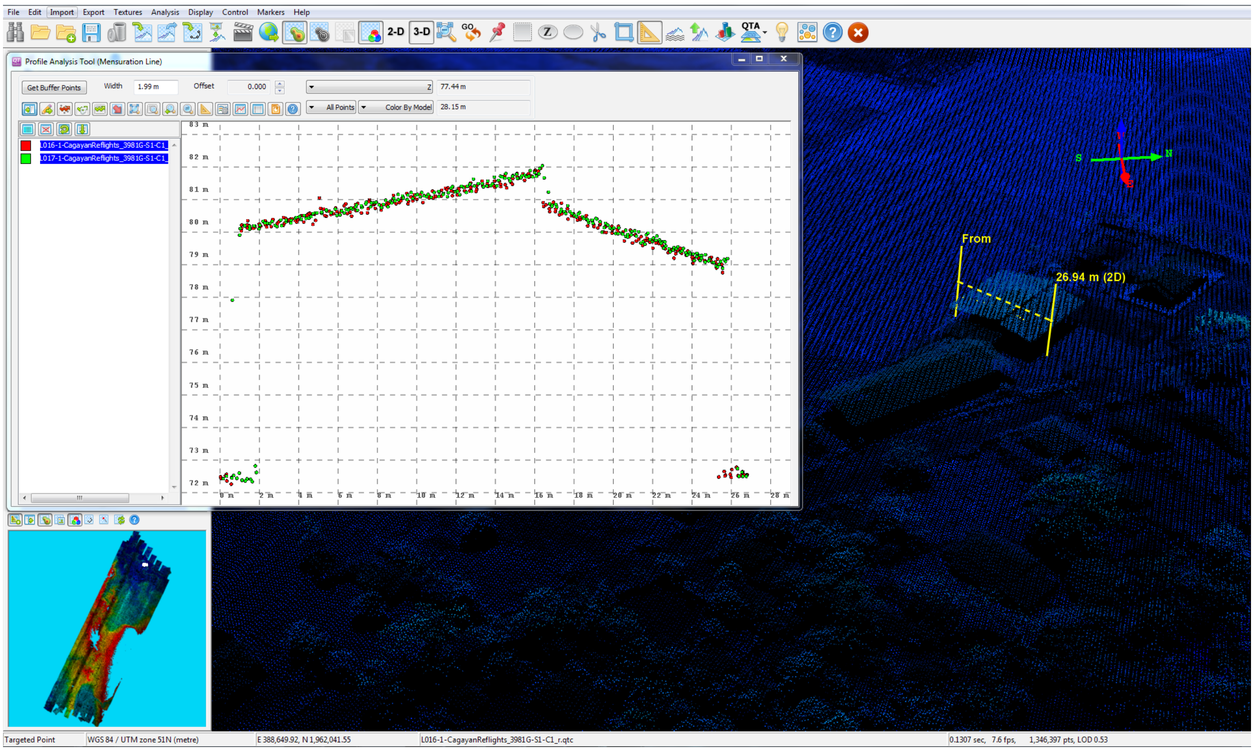

Figure 19. Quality checking for Aunugay flight 3981G using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 17. Aunugay classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	687,743,724
Low Vegetation	589,969,600
Medium Vegetation	1,525,468,396
High Vegetation	1,531,310,064
Building	22,581,280

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Aunugay Floodplain is shown in Figure 19. A total of 1,439 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 17. The point cloud has a maximum and minimum height of 677.25 meters and 39.41 meters respectively.

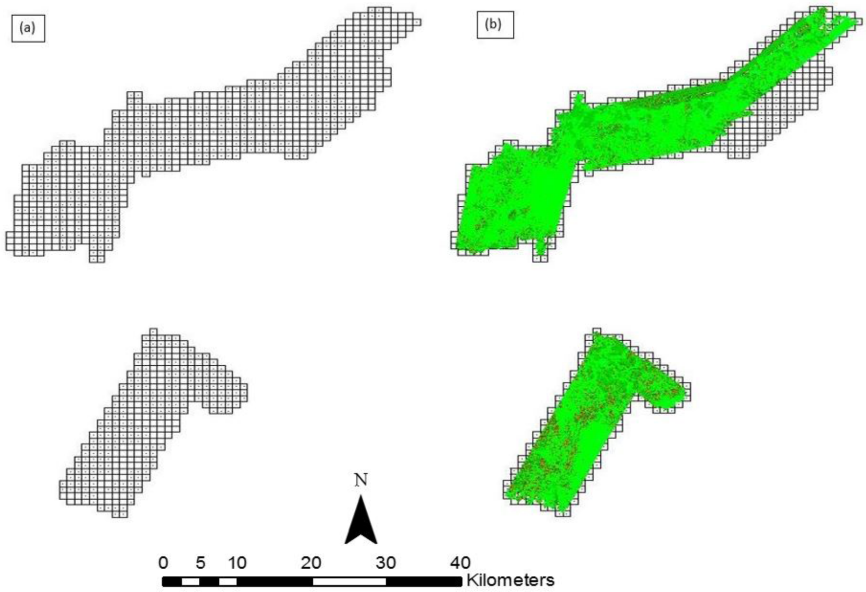

Figure 20. Tiles for Aunugay Floodplain (a) and classification results (b) in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 20. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

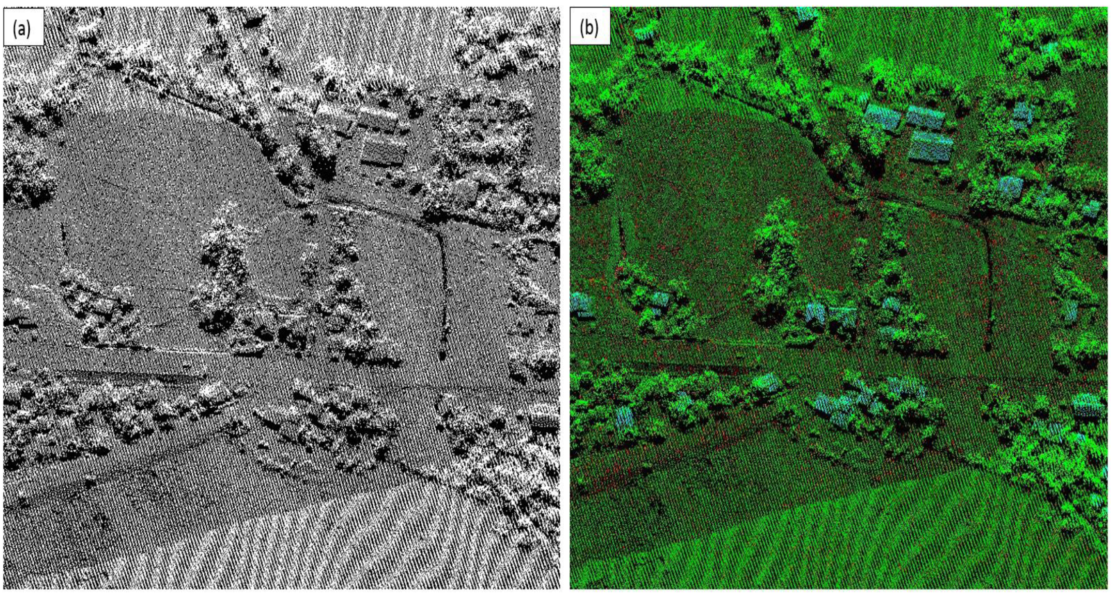

Figure 21. Point cloud before (a) and after (b) classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 21. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

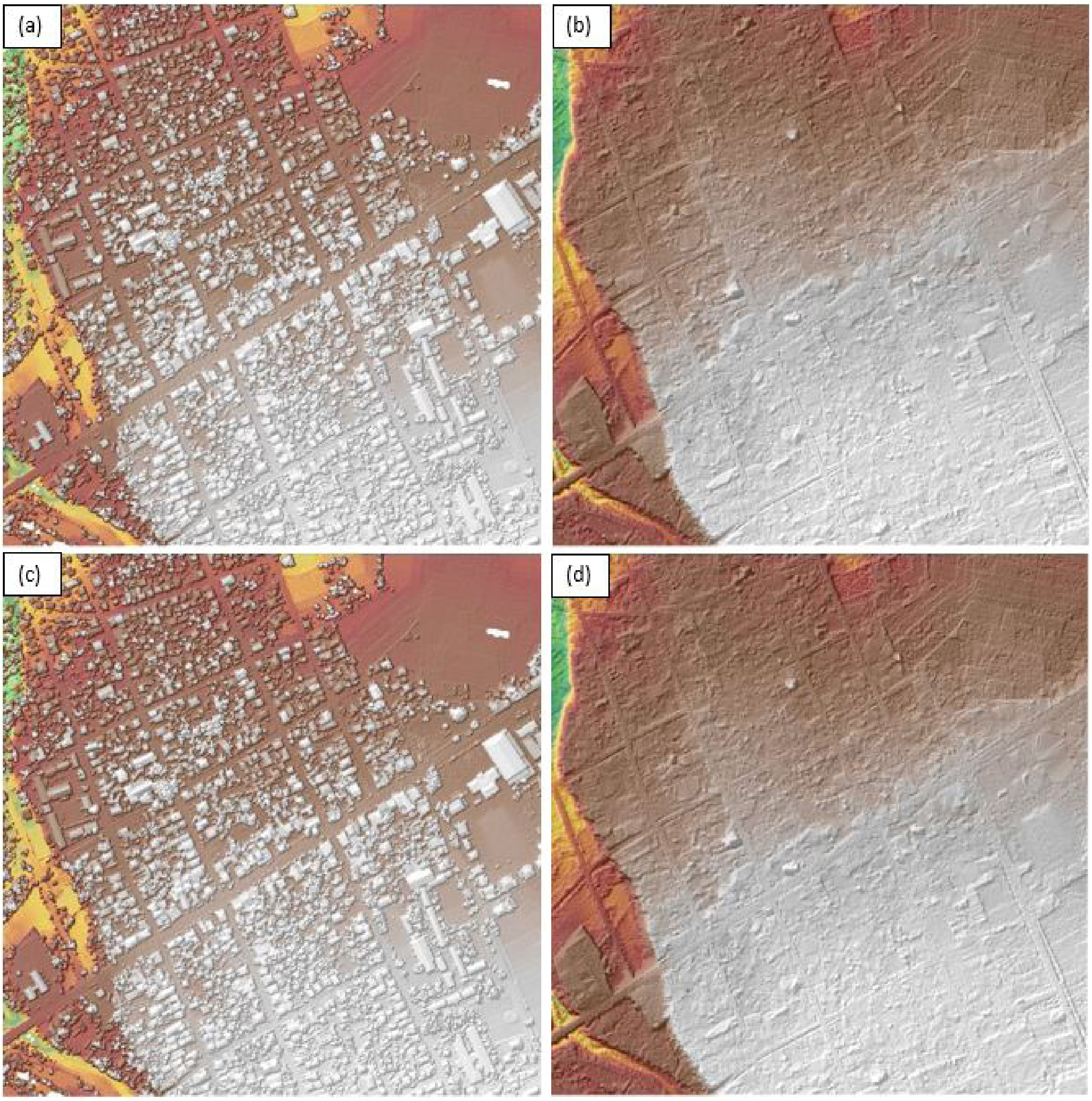

Figure 22. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Aunugay Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 408 1km by 1km tiles area covered by Aunugay Floodplain is shown in Figure 22. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Aunugay floodplain has a total of 285.88 sq.km orthophotogaph coverage comprised of 1,106 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

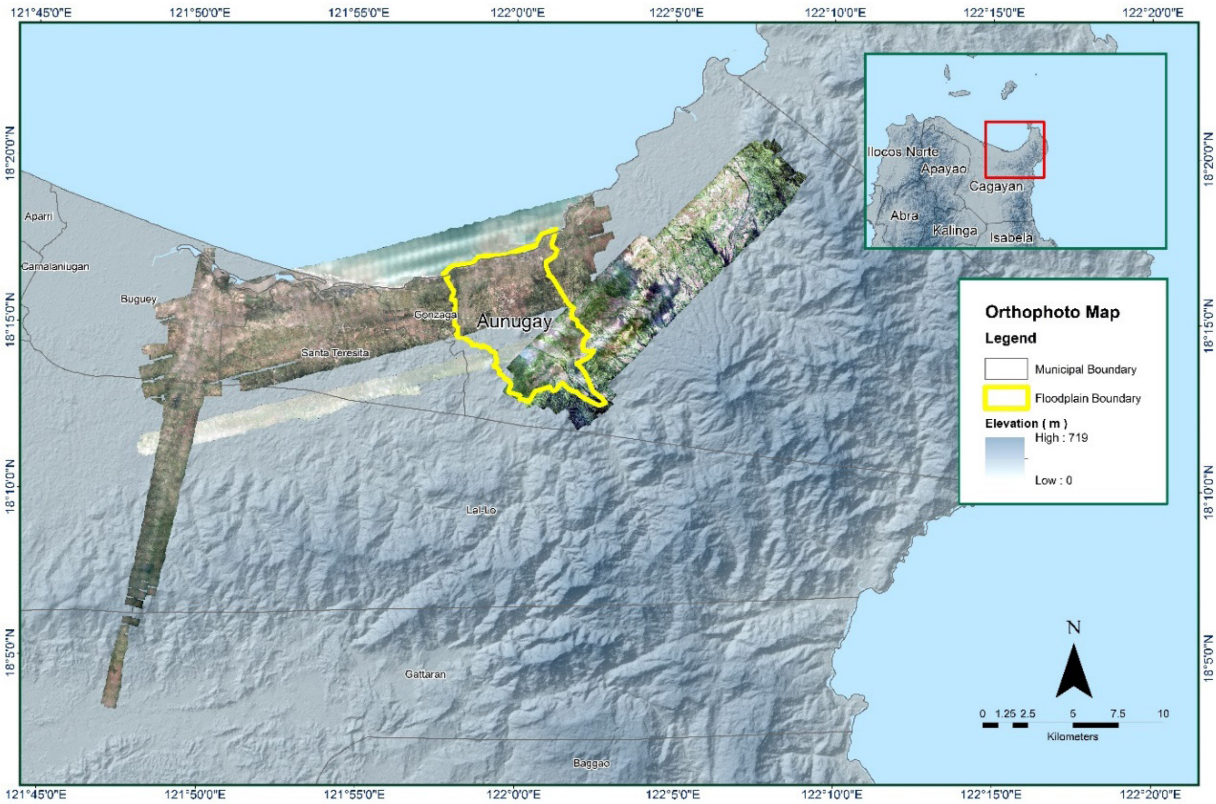

Figure 23. Aunugay Floodplain with available orthophotographs

Figure 24. Sample orthophotograph tiles for Aunugay Floodplain

3.8 DEM Editing and Hydro-Correction

Nine (9) mission blocks were processed for Aunugay Floodplain. These blocks are composed of Cagayan_reflights_Tugegarao, Cagayan_reflights, and Cagayan blocks with a total area of 1,056.01 square kilometers. Table 18 shows the name and corresponding area of each block in square kilometers.

Table 18. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq.km)
Cagayan_reflights_Tugegarao_Blk3A	108.34
Cagayan_reflights_Blk21D	105.14
Cagayan_reflights_Blk61G	66.00
Cagayan_reflights_Blk61E	216.06
Cagayan_reflights_Blk21AB	201.22
Cagayan_reflights_Blk3A	108.73
Cagayan_Blk21D_additional	24.99
Cagayan_Blk21D	50.76
Cagayan_Blk21C	174.79
TOTAL	**1056.01 sq.km**

Portions of DTM before and after manual editing are shown in Figure 24. The road (Figure 24a) has been misclassified and removed during classification process and has to be interpolated to complete the surface (Figure 24b) to allow the correct flow of water. Rice paddies (Figure 24c) are retrieved to achieve the actual surface of the DTM (Figure 24d). Another example is an interpolated river bank (Figure 24e) it has to be retrieved using object retrieval to achieve the actual surface (Figure 24f). A building (Figure 24g) that is still present in the DTM after classification has been removed through manual editing (Figure 24h).

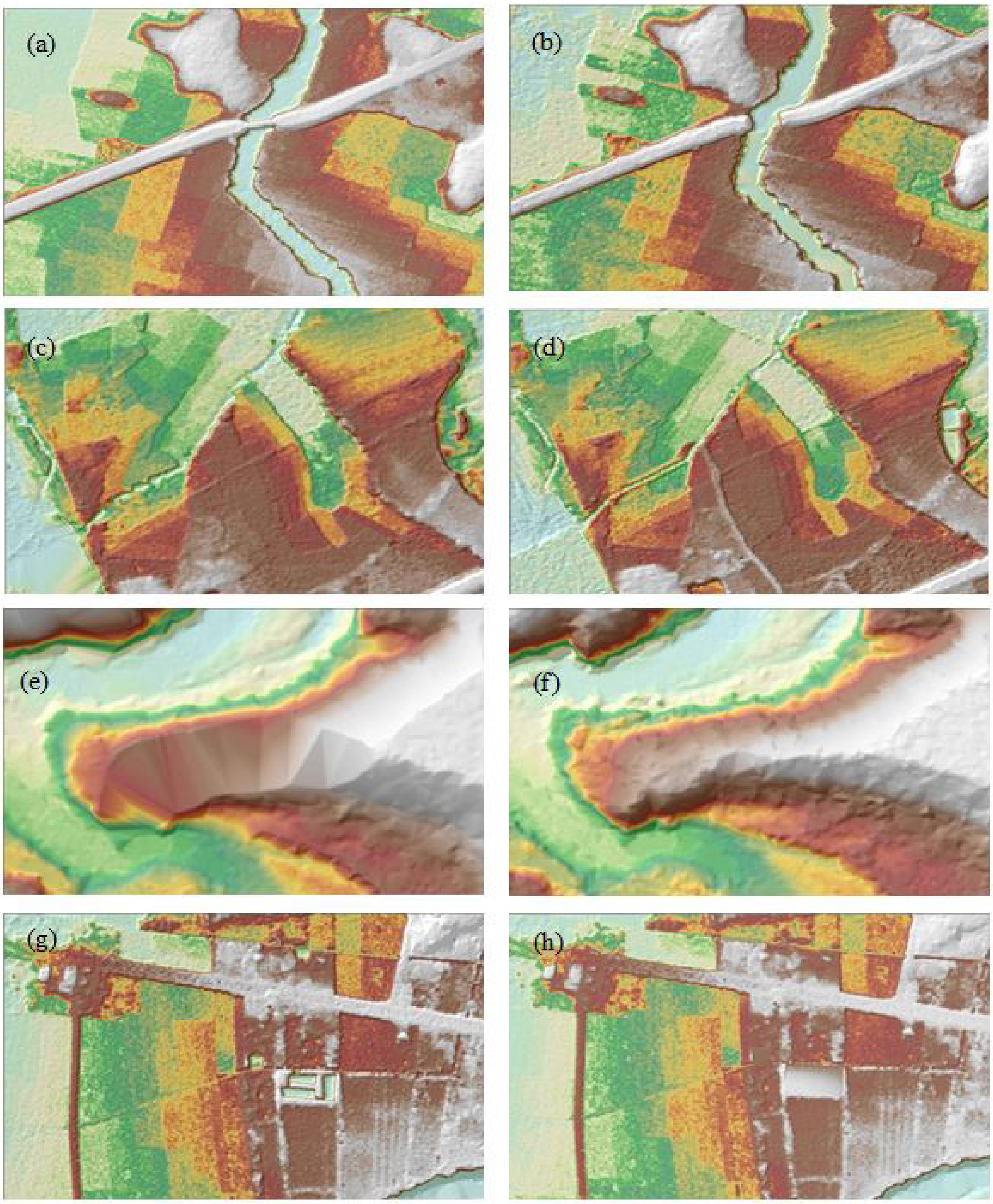

Figure 25. Portions in the DTM of Aunugay Floodplain – a road before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; interpolated bank before (e) and after (f) object retrieval; and a building before (g) and after (h) manual editing

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Cagayan DEM overlapping with the blocks to be mosaicked. Table 19 shows the shift values applied to each LiDAR block during mosaicking.
Mosaicked LiDAR DTM for Aunugay Floodplain is shown in Figure 25. It can be seen that the entire Aunugay Floodplain is 100% covered by LiDAR data.

Table 19. Shift Values of each LiDAR Block of Aunugay Floodplain.

Mission Blocks	Shift Values (meters)		
	x	Y	z
Cagayan_Blk21C	5.33	1.19	-5.32
Cagayan_Reflights_Blk21D	6.33	1.19	-4.87
Cagayan_Reflights_Tuguegarao_Blk3A	5.68	-0.32	-4.95
Cagayan_Reflights_Blk3A	6.32	1.18	-4.72
Cagayan_Blk21D	-4.88	0	0
Cagayan_Reflights_Blk61G	-5.18	2.61	1.77
Cagayan_Reflights_Blk21AB	-4.96	6.91	2.99
Cagayan_Reflights_Blk61E	-5.46	2.01	0.5
Cagayan_Blk21D_additonal			

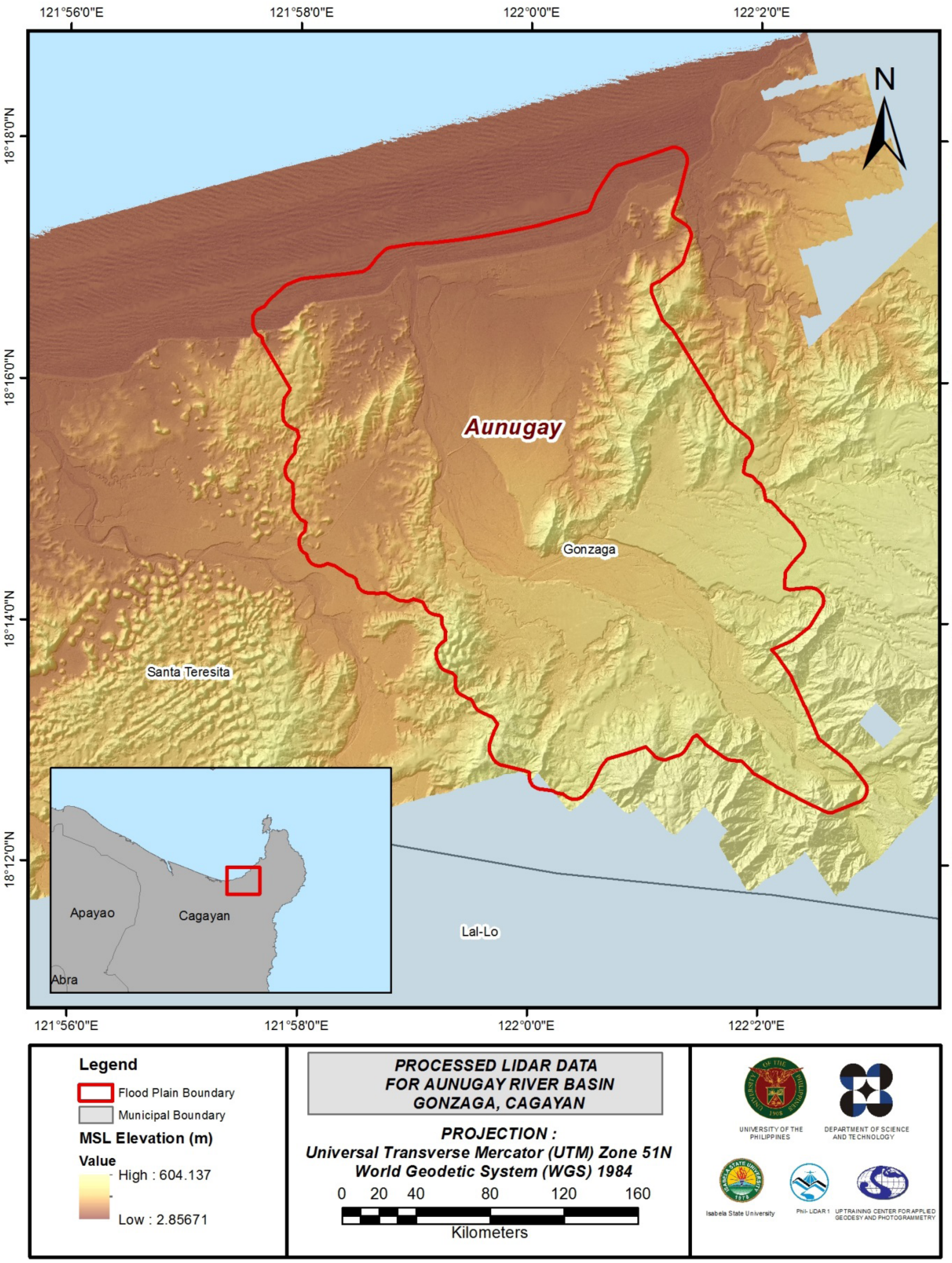

Figure 26. Map of Processed LiDAR Data for Aunugay Floodplain

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 Cagayan to collect points with which the LiDAR dataset is validated is shown in Figure 26. A total of 9,716 survey points were gathered for all the floodplains within Northern Cagayan wherein the Aunugay is located. However, the point dataset was not used for the calibration of the LiDAR data for Aunugay because during the mosaicking process, each LiDAR block was referred to the calibrated Cagayan DEM. Therefore, the mosaicked DEM of Aunugay can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Cagayan LiDAR DTM and ground survey elevation values is shown in Figure 27. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 4.07 meters with a standard deviation of 0.14 meters. Calibration of Cagayan LiDAR data was done by subtracting the height difference value, 4.07 meters, to Cagayan mosaicked LiDAR data. Table 20 shows the statistical values of the compared elevation values between Cagayan LiDAR data and calibration data. These values were also applicable to the Aunugay DEM.

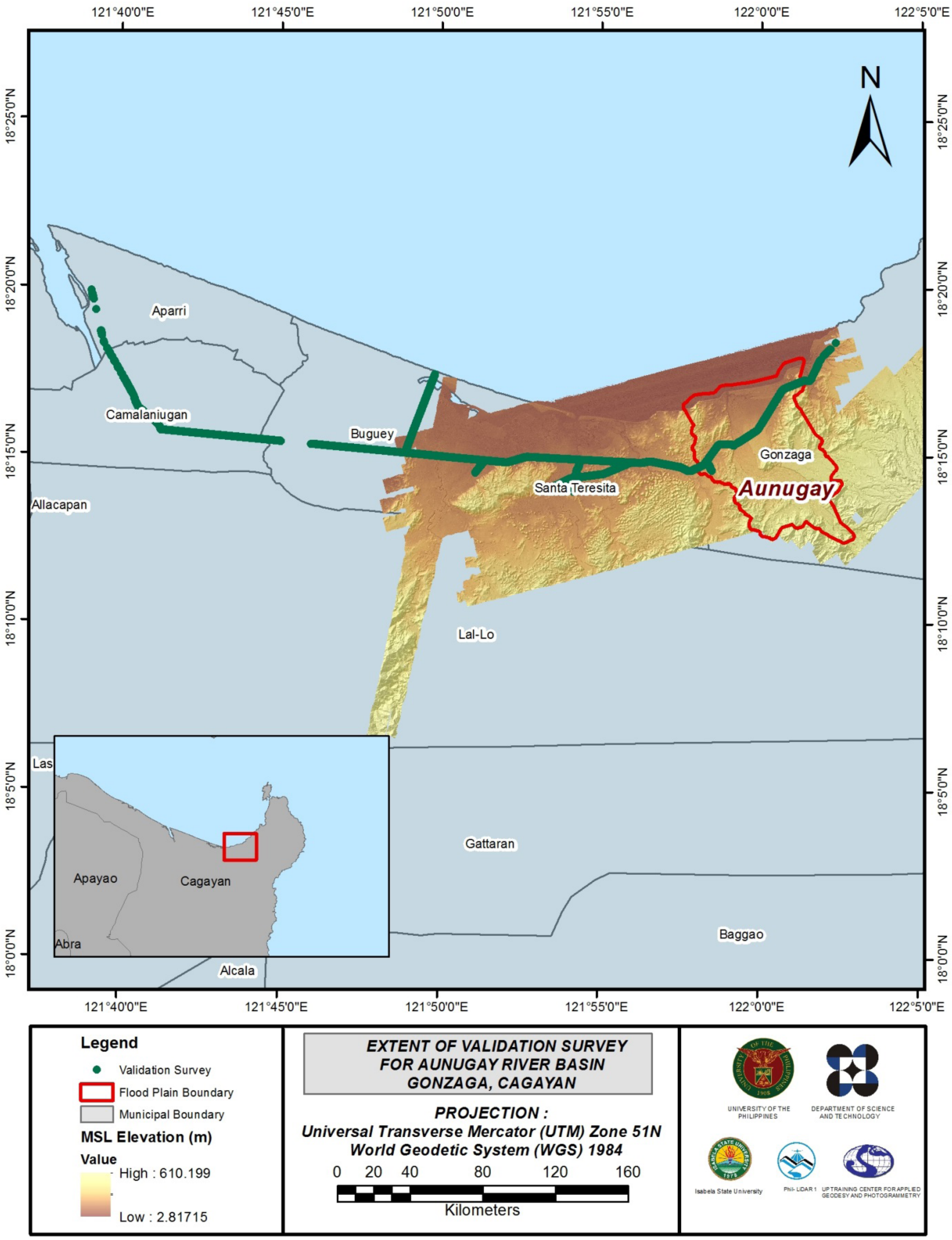

Figure 27. Map of Aunugay Floodplain with validation survey points in green.

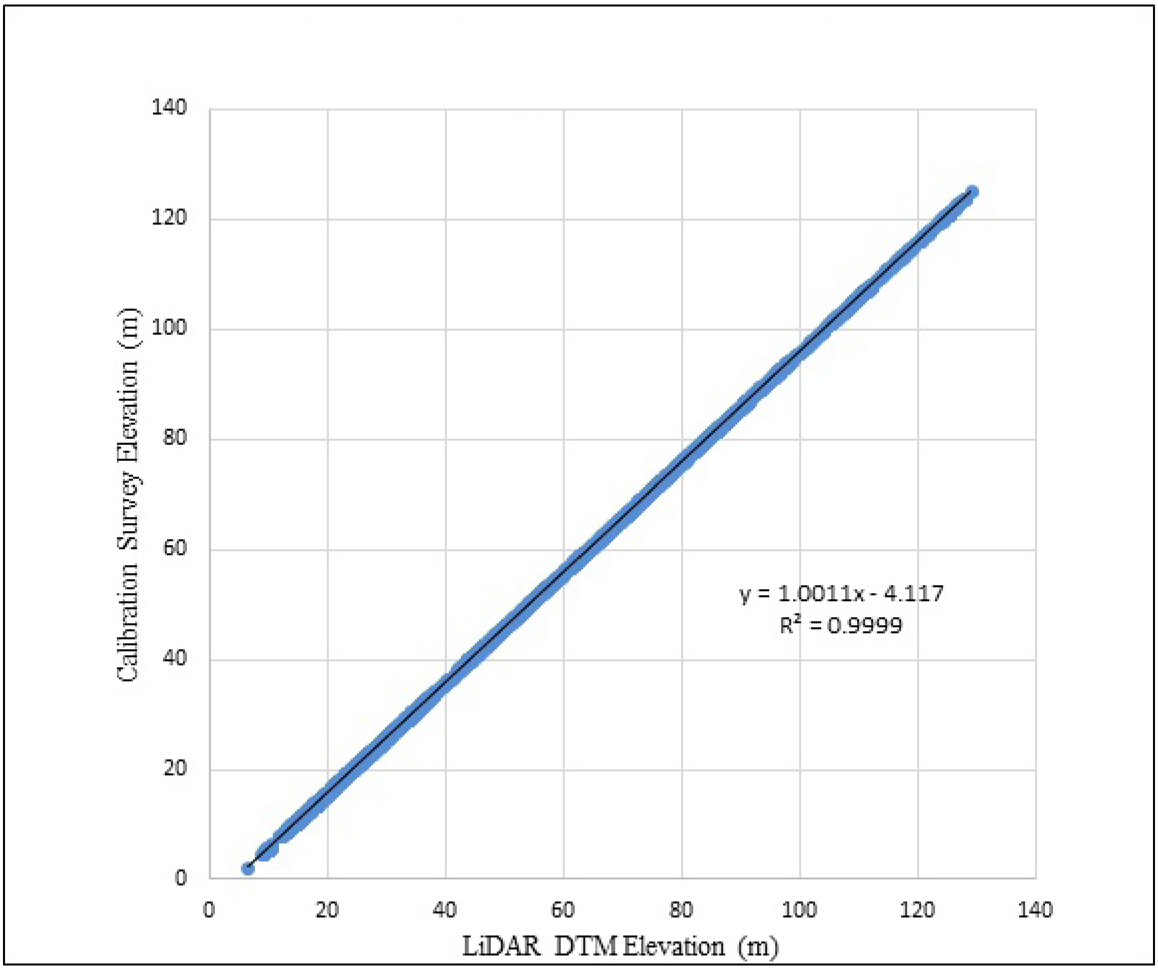

Figure 28. Correlation plot between calibration survey points and LiDAR data.

Table 20. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	4.07
Standard Deviation	0.14
Average	-4.07
Minimum	-4.50
Maximum	-3.77

The total survey points, resulting to 291 points, were used for the validation of calibrated Aunugay DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.06 meters, as shown in Table 21.

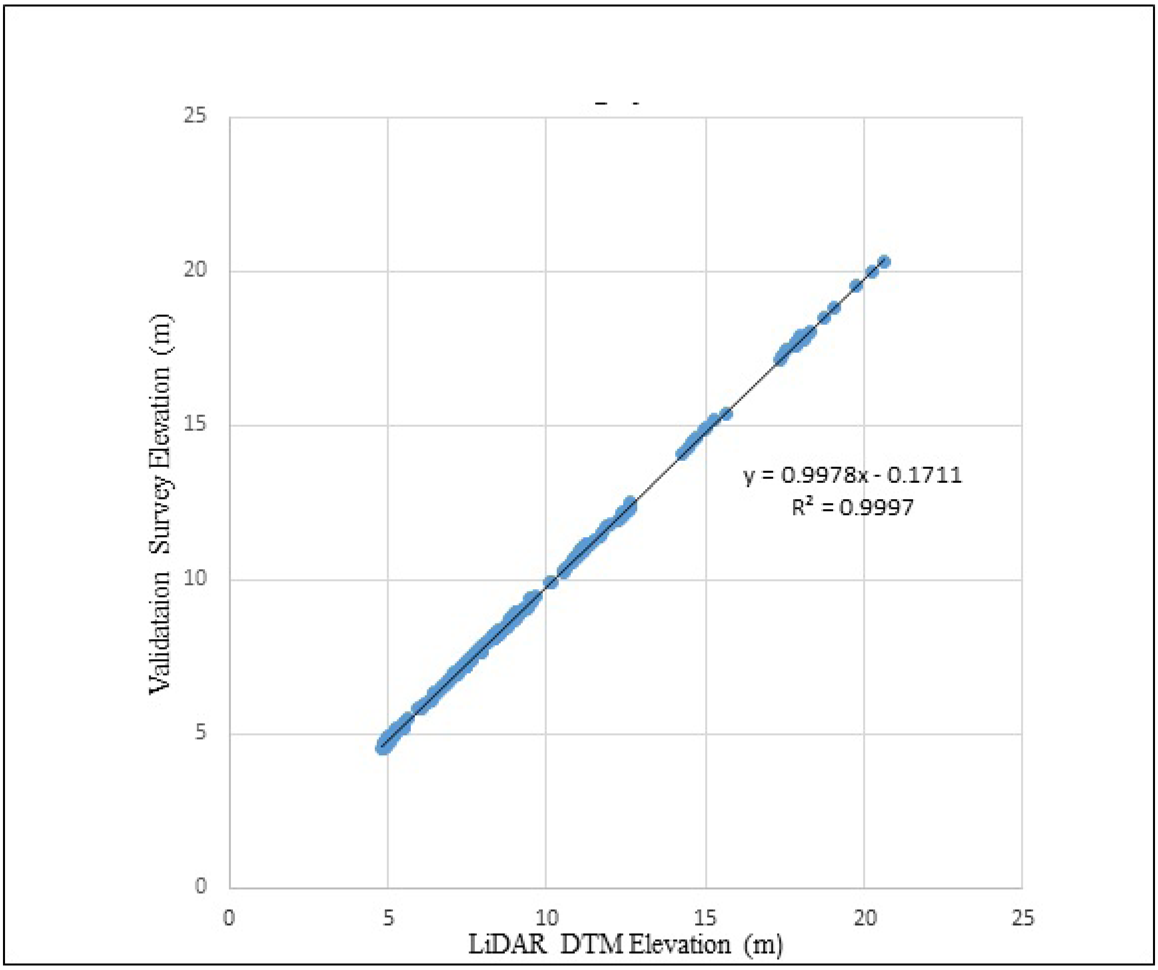

Figure 29. Correlation plot between validation survey points and LiDAR data

Table 21. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.06
Average	0.19
Minimum	0.06
Maximum	0.30

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Aunugay with 4,412 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.12 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Aunugay integrated with the processed LiDAR DEM is shown in Figure 29.

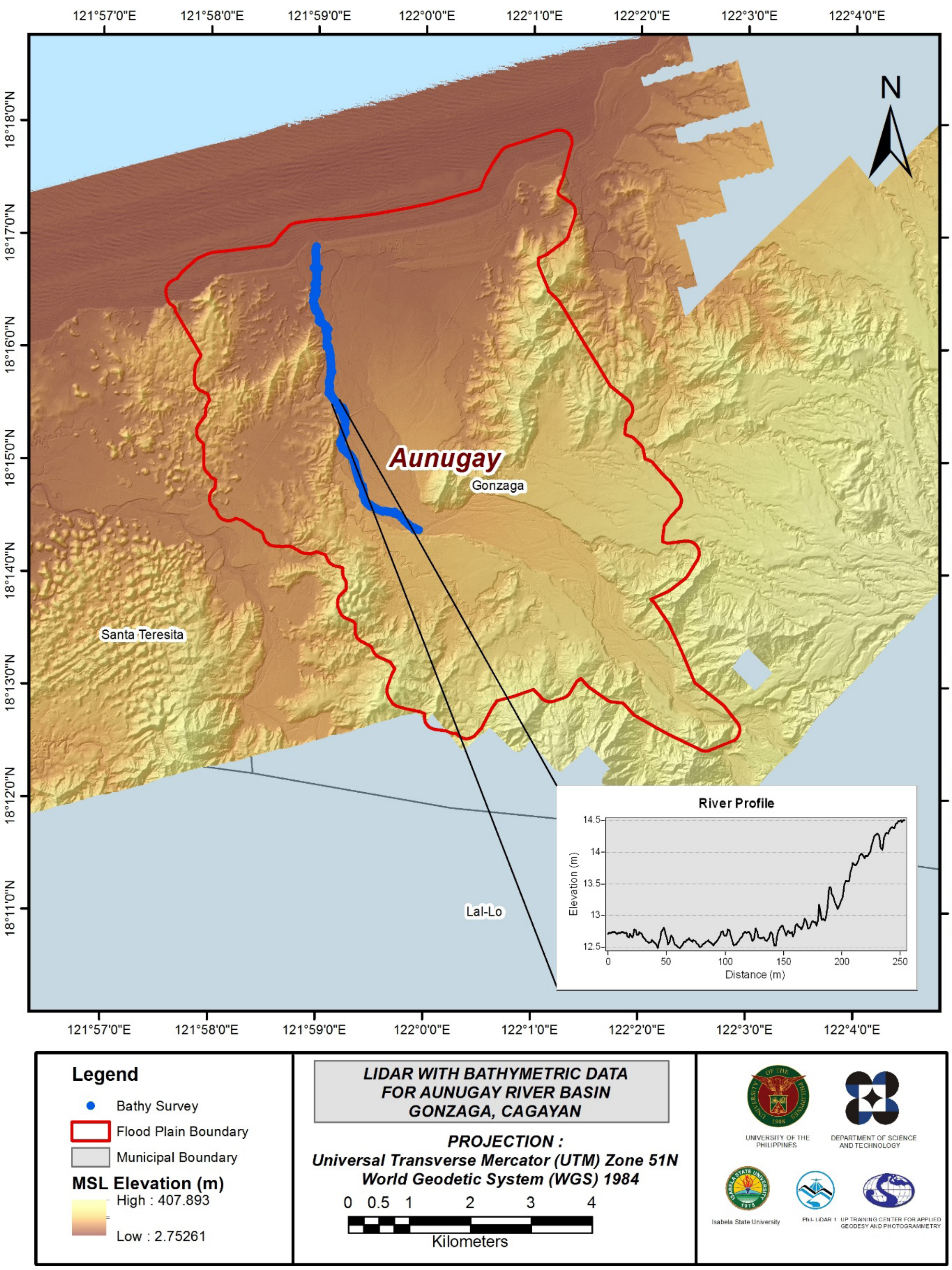

Figure 30. Map of Aunugay Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges and water bodies within the floodplain area with 200 m buffer zone. Mosaicked LiDAR DEM with 1 m resolution was used to delineate footprints of building features, 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 essential for routing of disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

The Aunugay Floodplain, including its 200 m buffer, has a total area of 52.24 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1790 building features, are considered for QC. Figure 30 shows the QC blocks for Aunugay Floodplain.

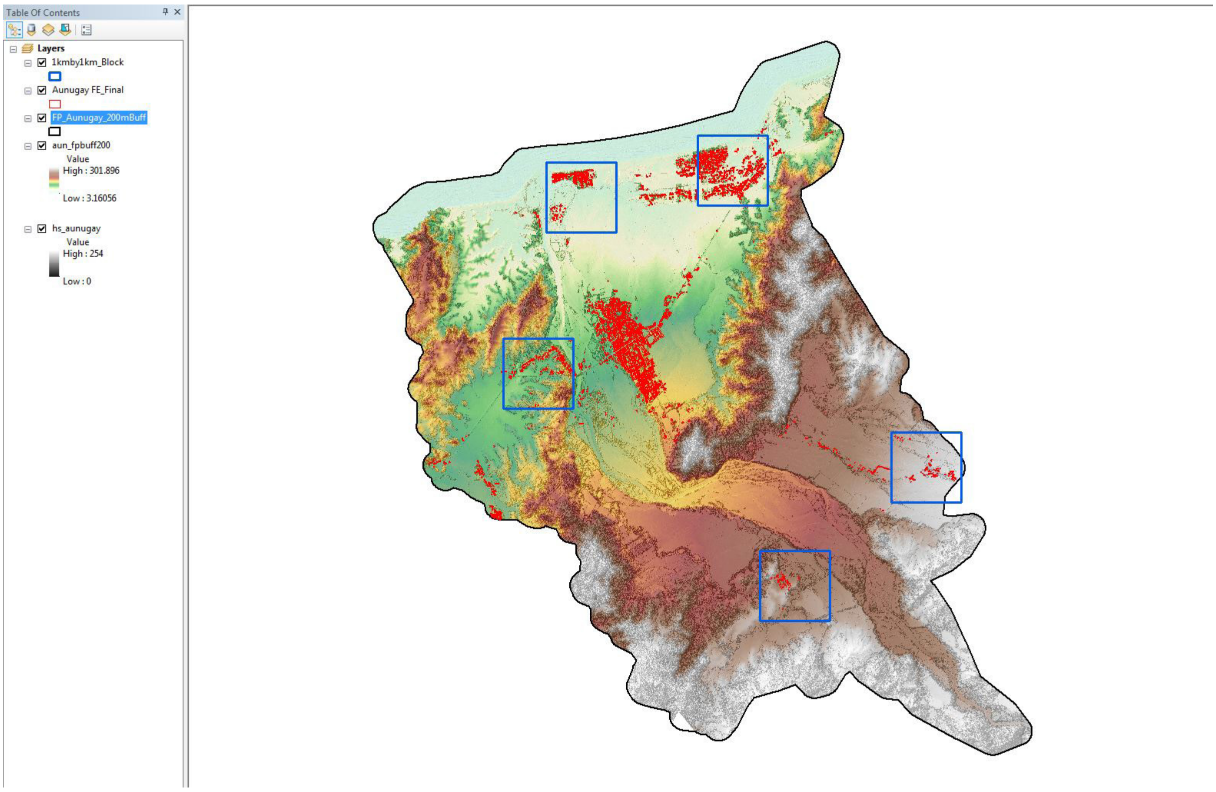

Figure 31. QC blocks for Aunugay building features

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

Table 22. Quality Checking Ratings for Aunugay Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Aunugay	95.97	99.78	90.84	PASSED

3.12.2 Height Extraction

Height extraction was done for 4,620 building features in Aunugay Floodplain. Of these building features, none was filtered out after height extraction, resulting to 4,620 buildings with height attributes. The lowest building height is at 3.27 m, while the highest building is at 9.40 m.

3.12.3 Feature Attribution

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

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

Table 23. Building Features Extracted for Aunugay Floodplain

Facility Type	No. of Features
Residential	4,400
School	76
Market	9
Agricultural/Agro-Industrial Facilities	6
Medical Institutions	8
Barangay Hall	9
Military Institution	0
Sports Center/Gymnasium/Covered Court	6
Telecommunication Facilities	6
Transport Terminal	0
Warehouse	9
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	1
Water Supply/Sewerage	5
Religious Institutions	19
Bank	1
Factory	0
Gas Station	1
Fire Station	1
Other Government Offices	18
Other Commercial Establishments	44
Total	**4,620**

Table 24. Total Length of Extracted Roads for Aunugay Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Aunugay	14.74	17.41	7.91	8.03	0.88	**48.98**

Table 25. Number of Extracted Water Bodies for Aunugay Floodplain

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Aunugay	1.60357	0	0	0	0	**1.60357**

A total of 10 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 comprised the flood hazard exposure database for the floodplain. This completed the feature extraction phase of the project.

Figure 31 shows the Digital Surface Model (DSM) of Aunugay Floodplain overlaid with its ground features.

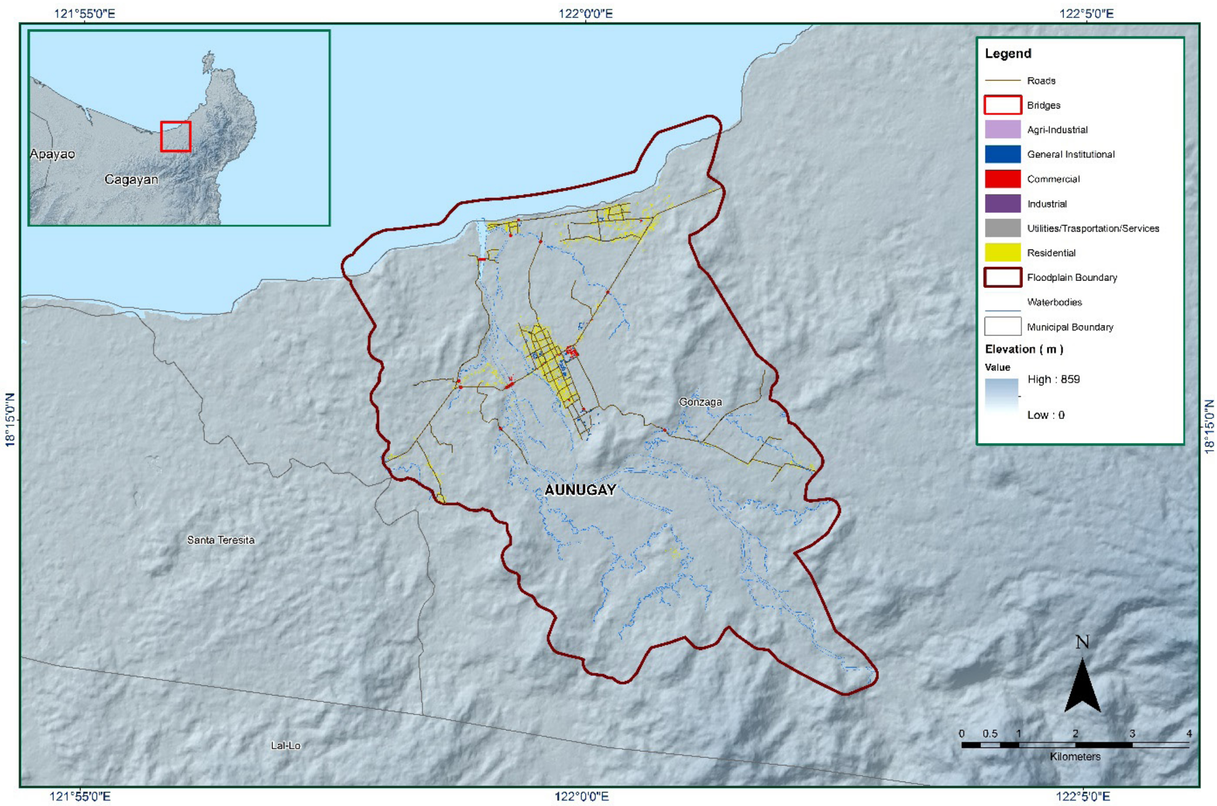

Figure 32. Extracted features for Aunugay Floodplain

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENT OF THE AUNUGAY RIVER BASIN

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

4.1 Summary of Activities

4.2 Control Survey

A GNSS network was previously established on November 15, 2014 for a Ground Control Reconciliation and Validation survey in the Province of Cagayan occupying the reference point GAMU in Brgy. Buenavista, Municipality of Gamu, Province of Isabela which has fixed coordinates and elevation value from a DREAM survey in the Province of Cagayan.

The GNSS network used for Aunugay River was composed of a single loop established on November 18, 2014 occupying the control point CGY-87, a second-order GCP, located in Brgy. Centro Sur, Municipality of Gattaran, Province of Cagayan, with fixed elevation and coordinate values from the previous PHIL-LiDAR 1 survey also conducted in the said province.

A control point was established along approach of Pateng Bridge in Brgy. Pateng, Municipality of Gonzaga, Province of Cagayan namely PAT-2; and a NAMRIA established control point namely CG-289, a first order benchmark in Brgy. Dalaya, Municipality of Buguey, also in the Province of Cagayan; were also occupied to use as marker during the survey.

The list of references and control points used is summarized in Table 26 while the GNSS network is illustrated in Figure 32.

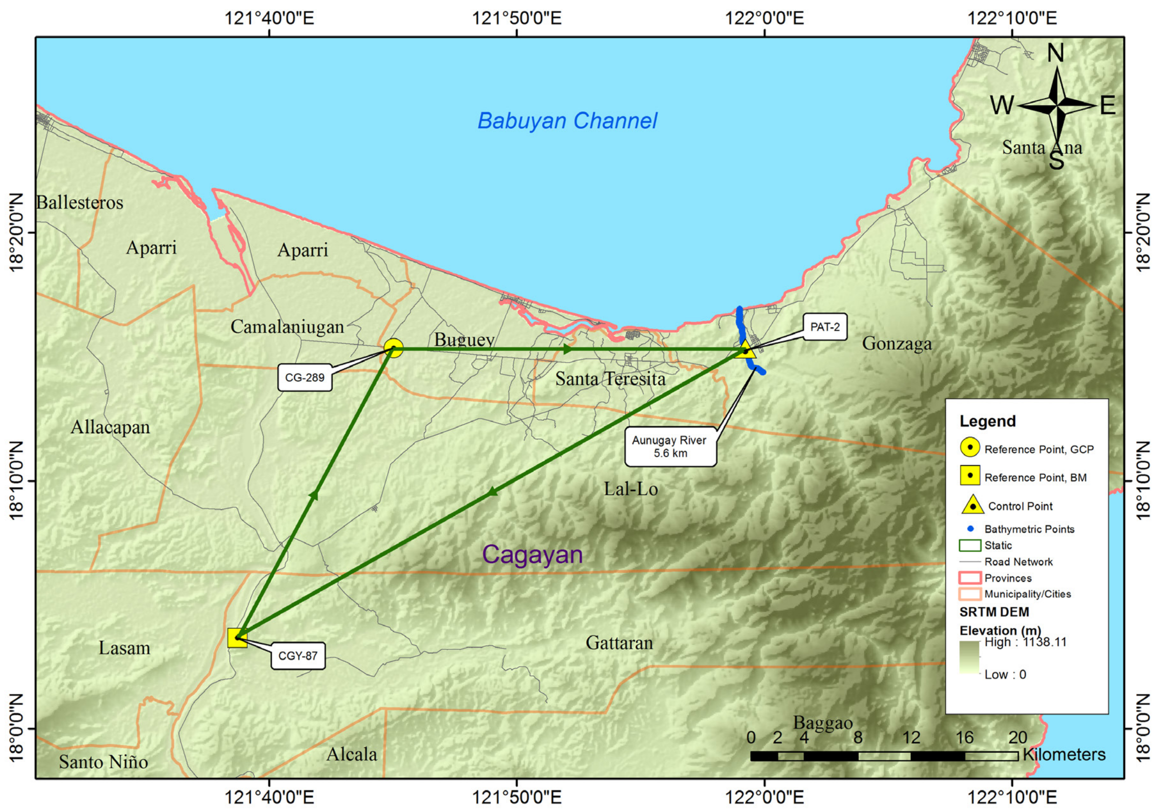


Figure 33. GNSS network of Aunugay River field survey

Table 26. List of References and Control Points used in Cagayan Fieldwork on November 18, 2015 (Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
CGY-87	2nd Order GCP	18°03'40.17188"	121°38'43.37010"	70.868	29.193	2007
CG-289	Used as Marker	-	-	-	-	2007
PAT-2	Used as Marker	-	-	-	-	Nov 18, 2014

The GNSS set-ups on recovered reference points and established control points are shown in Figures 33 to 35

Figure 34. GNSS base receiver, Trimble® SPS 852 setup at CGY-87 in Brgy. Centro Sur, Municipality of Gattaran, Cagayan

Figure 34. GNSS receiver, Trimble® SPS 882, setup at CG-289 in Cullit Bridge, Brgy. Dalaya, Municipality of Buguey, Cagayan

Figure 35. GNSS base receiver, Trimble® SPS 852, setup at PAT-2 in Pateng Bridge, Brgy. Pateng, Municipality of Gonzaga, Cagayan

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC. It was observed that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines fails to meet all of these criteria, masking was performed. Masking is the process of removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. The Baseline processing result of control points in Aunugay River Basin is summarized in Table 27 generated by TBC
software.

Table 27. Baseline Processing Report for Aunugay River Basin static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CG 289 --- PAT 2	Nov 18, 2014	Fixed	0.036	0.083	90°04’09”	25017.197	18.800
CGY 87 --- CG 289	Nov 18, 2014	Fixed	0.013	0.010	27°15’58”	24275.798	-26.710
CGY 87 --- PAT 2	Nov 18, 2014	Fixed	0.004	0.007	59°10’37”	42082.534	-7.976

As shown Table 27, a total of three (3) baselines were processed with reference point CGY-87 held fixed for coordinate and elevation values. All of them passed the required accuracy.

4.4 Network Adjustment

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

<20cm and

Where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

for each control point.

The coordinate which held fixed during the network adjustment is shown in Table 28 . Through that known control point, the coordinates of the unknown control points were computed.

Table 28. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
CGY-87	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 29. The fixed control CGY-87 has no values for grid errors and elevation error. An offset was applied based on the MSL elevation values of CG-289 after the processing.

Table 29. Adjusted grid coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
CG-289	367913.154	0.085	2018969.821	0.045	6.255	0.112	
CGY-87 356635.092 ? 1997477.440 ? 32.567						?	LLh
PAT-2	392924.044	0.033	2018768.902	0.024	24.879	0.080	

With the mentioned equation, for horizontal and for the vertical; the computation for the accuracy are as follows:

a. **CGY-87** = fixed

= fixed

b. **CG 289**

horizontal accuracy = √((8.5)² + (4.5)²

= √(72.25 + 20.25)

= 9.62 cm < 20 cm

Vertical accuracy = 1.12 cm < 10 cm

c. **PAT 2**

horizontal accuracy = √((3.3)² + (2.4)²

= √(10.89 + 5.76)

= 4.08 cm < 20 cm

vertical accuracy = 8.0 cm < 10 cm

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

Table 30. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
CG-289	N18°15'21.92010"	E121°45'01.96078"	44.094	0.112	
CGY-87	N18°03'40.17188"	E121°38'43.37010"	70.868	?	LLh
PAT-2	N18°15'20.41664"	E121°59'13.60140"	62.912	0.080	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 30. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

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

Table 31. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	MSL Elevation (m)
CGY-87	2nd order, GCP	18°03’40.17188”	121°38’43.37010”	70.868	1997477.44	356635.092	29.1929
CG-298	Used as Marker	18°15’21.92010”	121°45’01.96078”	44.094	2018969.821	367913.154	2.8809
PAT-2	Used as Marker	18°15’20.41664”	121°59’13.60140”	62.912	2018768.902	392924.044	21.5049

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

Cross section and bridge as-built surveys were conducted on November 16, 18 and 19, 2014 along the downstream side of Pateng Bridge in Brgy. Pateng, Municipality of Gonzaga using the GNSS receiver Trimble® SPS 882 utilizing GNSS PPK survey technique as shown in Figure 36. The established point, UP-PAT, in the bridge's approach served as the GNSS base station.

Figure 36. Left bank elevation acquisition (facing downstream) at Pateng Bridge, Brgy. Pateng, Municipality of Gonzaga

The cross-sectional line is about 176.47 meters with two hundred sixty-seven (267) points.
Figures 37 to 39 show the summary of gathered cross-section points in a diagram, planimetric map, and as-built data form of Pateng Bridge.

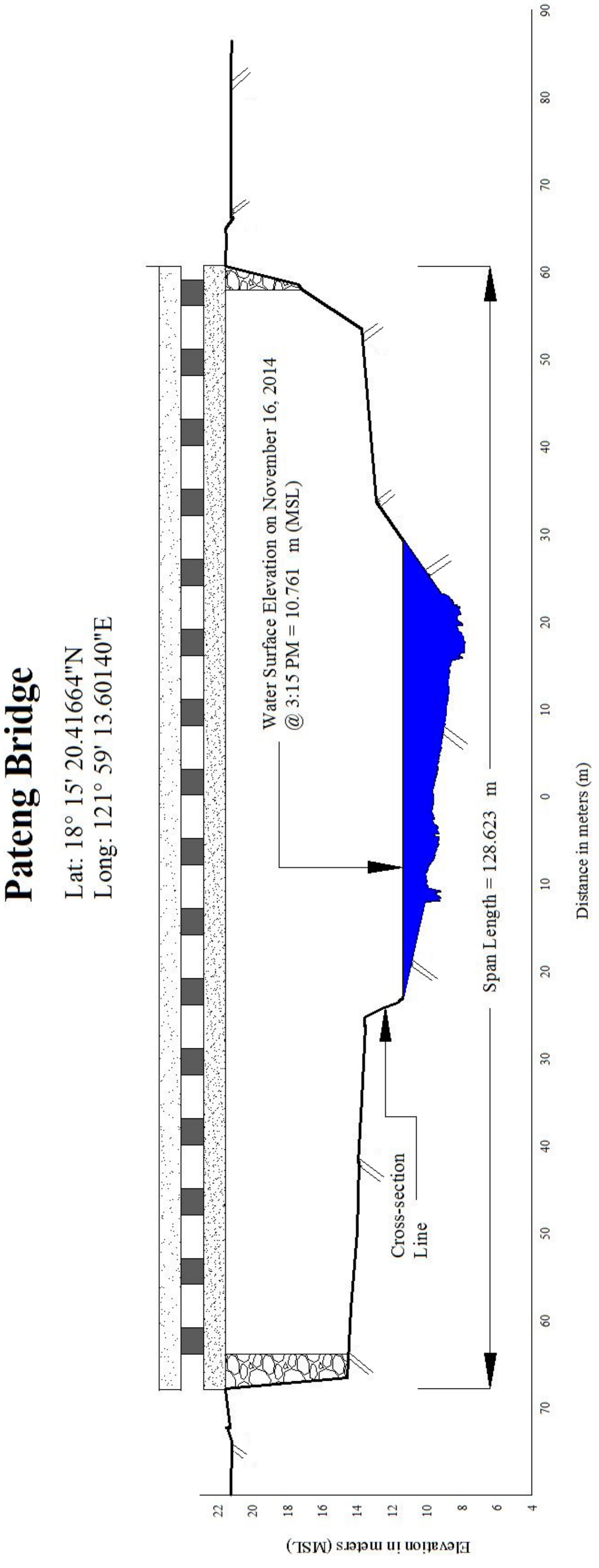


Figure 37. Pateng Bridge cross-section diagram

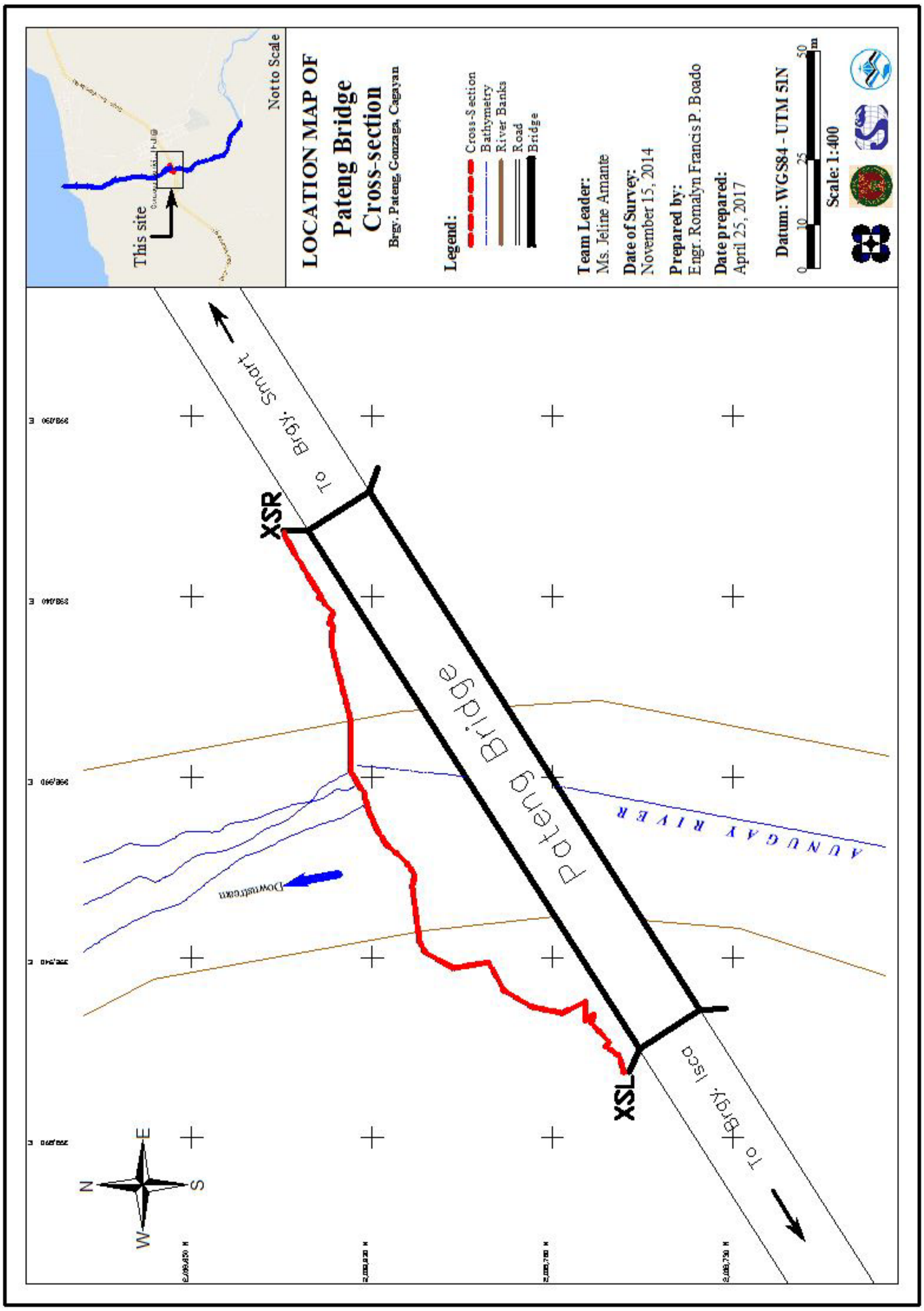
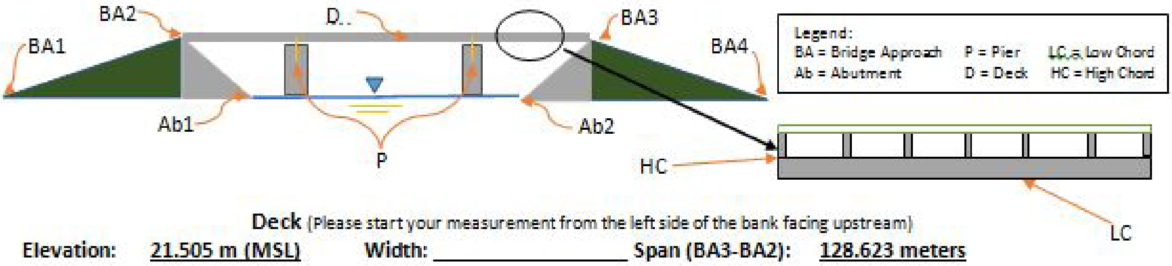


Figure 38. Pateng bridge cross-section planimetric map

Bridge Data Form

Bridge Name: Pateng Bridge	**Date:** November 15, 2014
River Name: Aunugay River	**Time:** ______________________
Location (Brgy, City,Region): Barangay Pateng, Gonzaga, Cagayan	
Survey Team: Jeline Amante, Nancy Dimayacyac, Erika Mae Coloma, Alex John Escobido	
Flow condition: low normal high	**Weather Condition:** fair rainy
Latitude: 18d15'20.41664"	**Longitude:** 121d59'13.60140"



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

Elevation: 21.505 m (MSL) **Width:** ______________ **Span (BA3-BA2):** 128.623 meters

	Station	High Chord Elevation	Low Chord Elevation
1	-	-	-

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	21.175	**BA3**	150.714	21.531
BA2	22.092	21.493	**BA4**	176.459	21.182

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

	Station (Distance from BA1)	Elevation
Ab1	156.226	21.047
Ab2	66.503	11.608

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

Shape: N/A Number of Piers: N/A Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	**N/A**	**N/A**	**N/A**

Figure 39. Pateng Bridge Data Form

The water surface elevation of Pateng Bridge on the left and right banks was acquired using GNSS receiver Trimble® SPS 882 in GNSS PPK survey technique on November 16, 2014 at 3:15:41 PM. It is about 10.761m above MSL. There is an existing water level mark on one of the piers of the old Pateng Bridge. It was calibrated and referred to MSL. The water level marking shown in Figure 40 shall serve as a reference for flow data gathering and depth gauge
deployment of Isabela State University.

Figure 40. Water level mark at one of the piers of the old Pateng Bridge

4.6 Validation Points Acquisition Survey

A validation points acquisition survey was conducted on November 17 to 20, 2014 using a survey grade GNSS rover receiver Trimble®SPS882 mounted on a pole which was attached in front of the vehicle as shown in Figure 41. It was secured with a steel rod and tied with cable ties to ensure that it was horizontally and vertically balanced. The antenna height was 1.906 m, measured from the ground up to the bottom of notch of the GNSS rover receiver. The GNSS rover receiver was set in a Continuous Topo Method utilizing PPK Survey Points were gathered along concrete roads of Cagayan-Valley Road (Camalaniugan) to Dugo-San Vicente Road (Gonzaga), observing
vehicle speed of 10-20 kph across the flight strips of the Data Acquisition Component (DAC).
The ground validation path is approximately 50 kilometers in length with 9,714points acquired using the UP established control point PAT-2 as the GNSS base staton. The map on Figure 42 shows the ground validation survey.

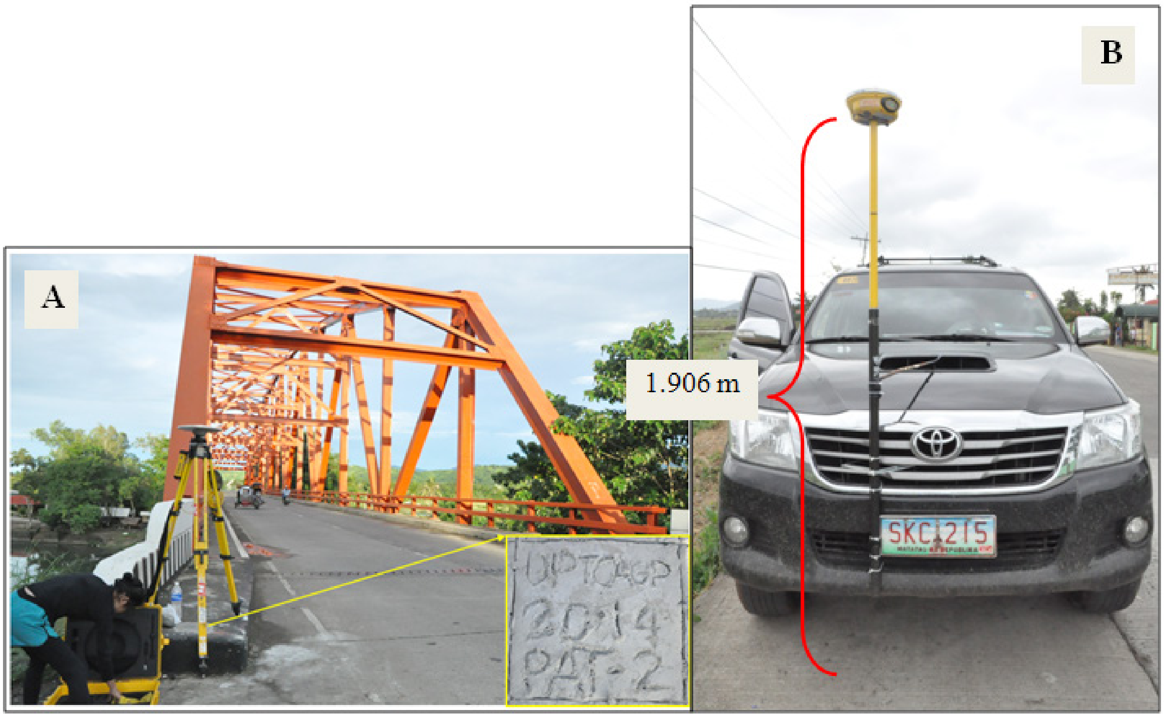


Figure 41. (A) Base setup at PAT-2 in Pateng Bridge, Municipality of Gonzaga and (B) Validation points acquisition survey setup attached in the vehicle

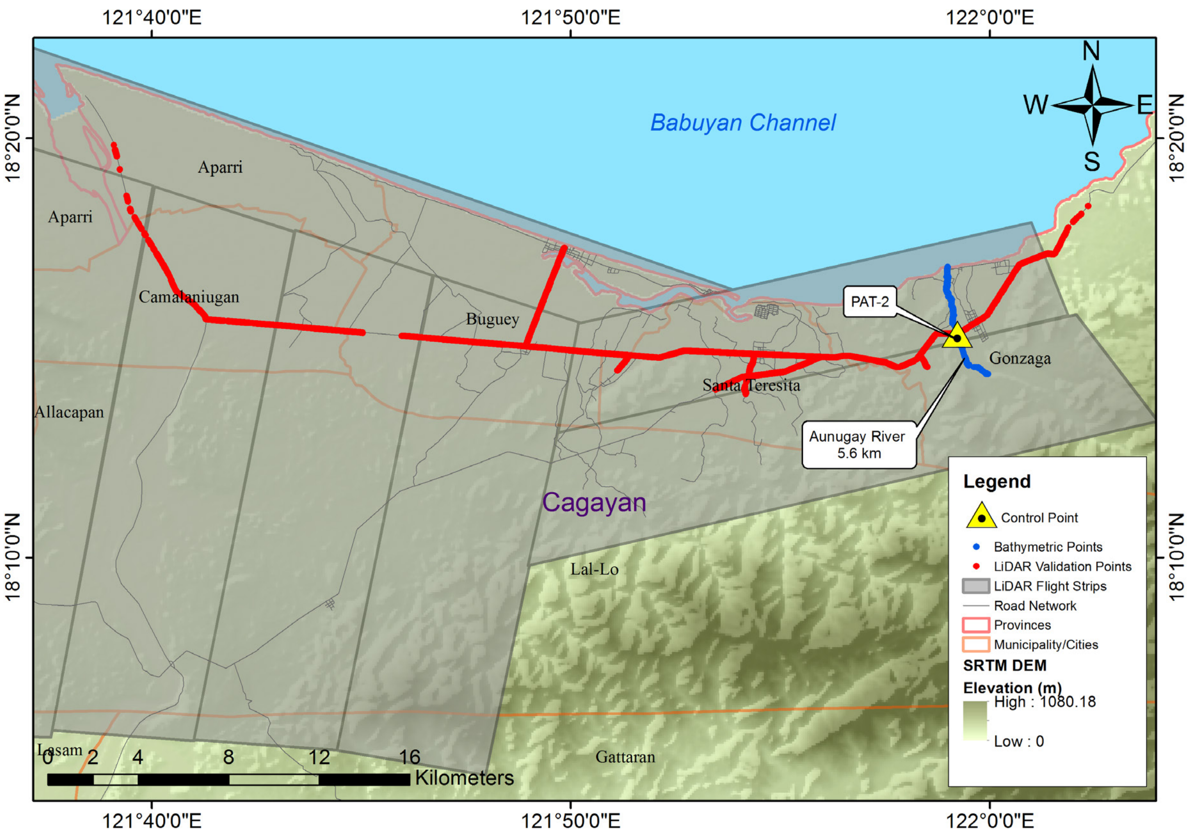


Figure 42. Validation Points Acquisition survey along Aunugay River Basin

4.7 River Bathymetric Survey

Ohmex™ single beam echo sounder integrated with a roving GNSS receiver, Trimble® SPS 882, installed on the boat to gather the riverbed elevation was utilized for bathymetry survey on November 18, 2014 for the Overflow Dam in Aunugay River.

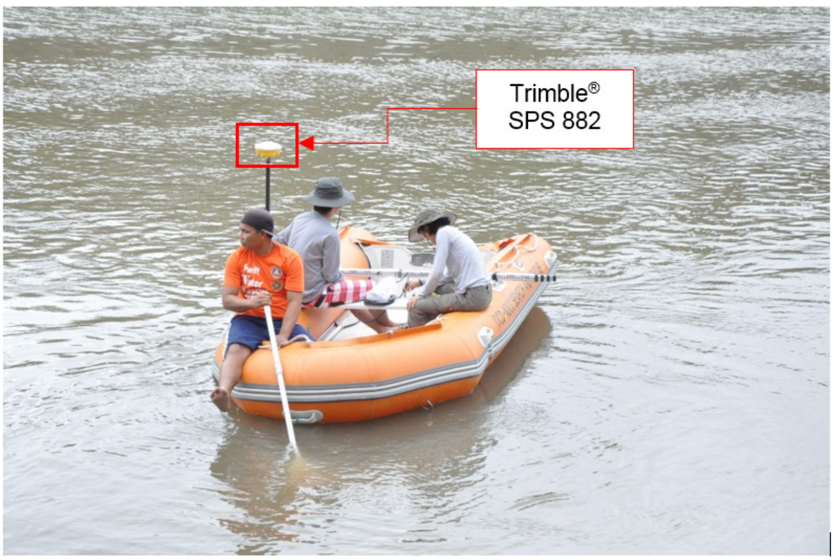


Figure 43. Bathymetric survey using Ohmex™ single beam echo sounder integrated

Manual bathymetry survey was conducted on November 16 and 19, 2014 for the shallow parts of the river not traversable by boat using Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 44. The survey began from the upstream part of the river in Brgy. Pateng, Municipality of Gonzaga with coordinates 18°14'22.92473" 121°59'57.13652", down to the mouth of the river in Brgy. Callao, also in Gonzaga with coordinates 18°16'52.74591" 121°58'59.05987".

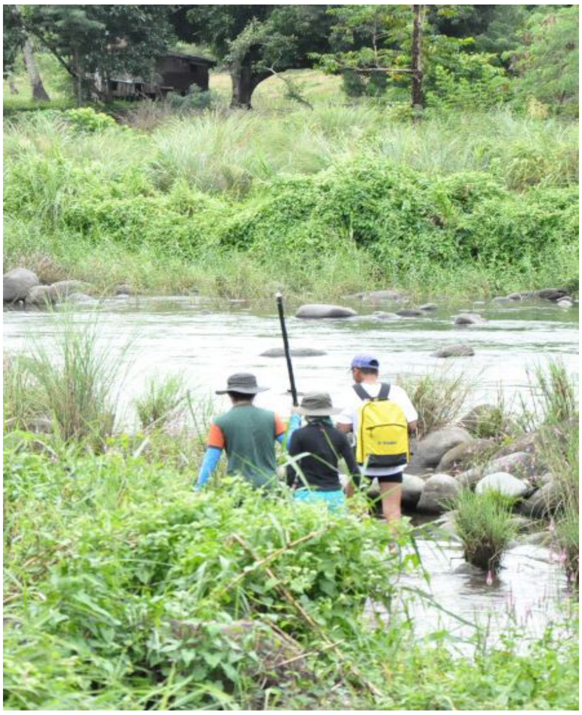


Figure 44. Team A performing manual bathymetric survey going upstream of Aunugay River

Bathymetric line is approximately 5.7kilometers in length with 4,242 points gathered using PAT-2 as the GNSS base station covering Brgy. Pateng down to Brgy. Minanga, Municipality of Gonzaga as shown in Figure 45. A CAD drawing of the centerline riverbed profile was also produced to illustrate the riverbed profile of Aunugay River. As shown in Figure C-16, the lowest elevation is -1.956 min MSL, recorded at about 2,200 meters downstream of Pateng Bridge, while the highest elevation observed was 28.08 m in MSL located in Brgy. Pateng.

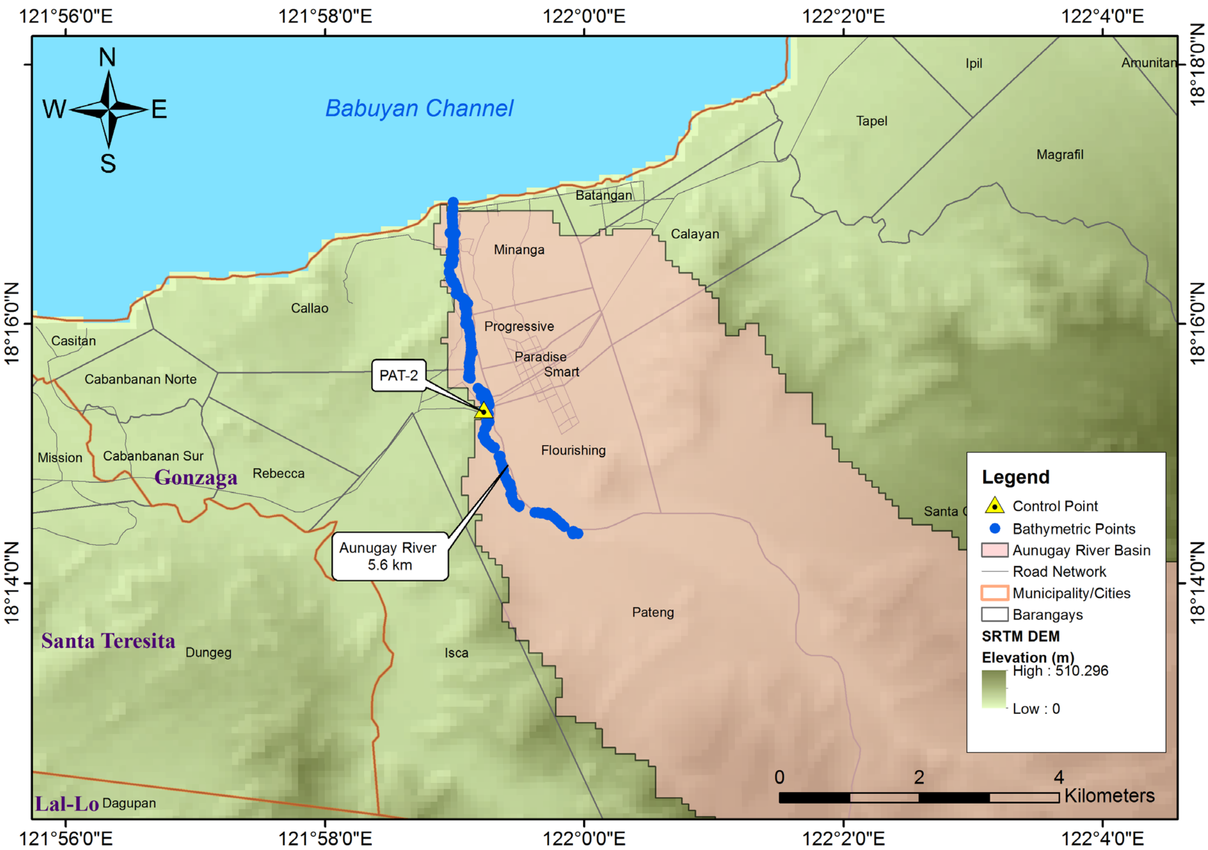


Figure 45. Bathymetric points gathered along Aunugay River

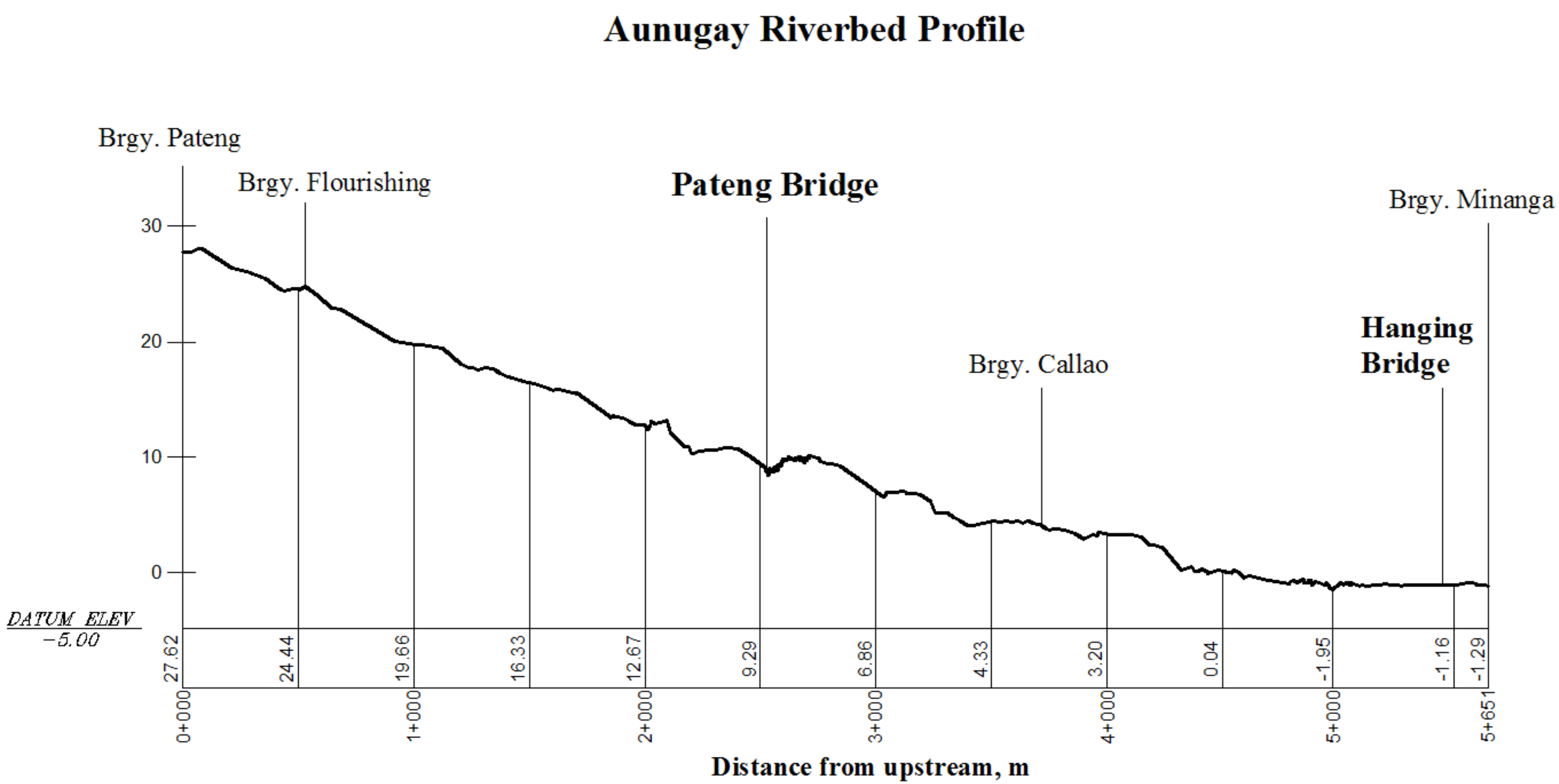


Figure 46. Riverbed profile of Aunugay River

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, Mariel Monteclaro

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

The Province of Cagayan, including the Aunugay River basin, experienced heavy and long term rain such as Monsoon Rain last 26 – 30 December 2016. The hydrologic data collection covered the period 00:00 on 26 December 2016 until 7:30 on 28 December 2016. Hydrologic data include the river velocity, water depth and rain collected from data logging sensors (mechanical velocity meter, depth gauge and rain gauges) in specific time period. Precipitation data was taken from three automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). This was the Brgy. Santa Clara ARG. The location of the rain gauges is seen in Figure 1. Rainfall data were downloaded from the web portal of Philippine E-Science Grid-ASTI (http://repo.pscigrid.gov.ph).

Total rain from Brgy. Santa Clara ARG is 91 mm. It peaked to 7.0 mm. on 27 December 2016 7:15 P.M. The lag time between the peak rainfall and discharge is 8 hours and 50 minutes. The ARGs for Aunugay River Basin is shown Figure 47.

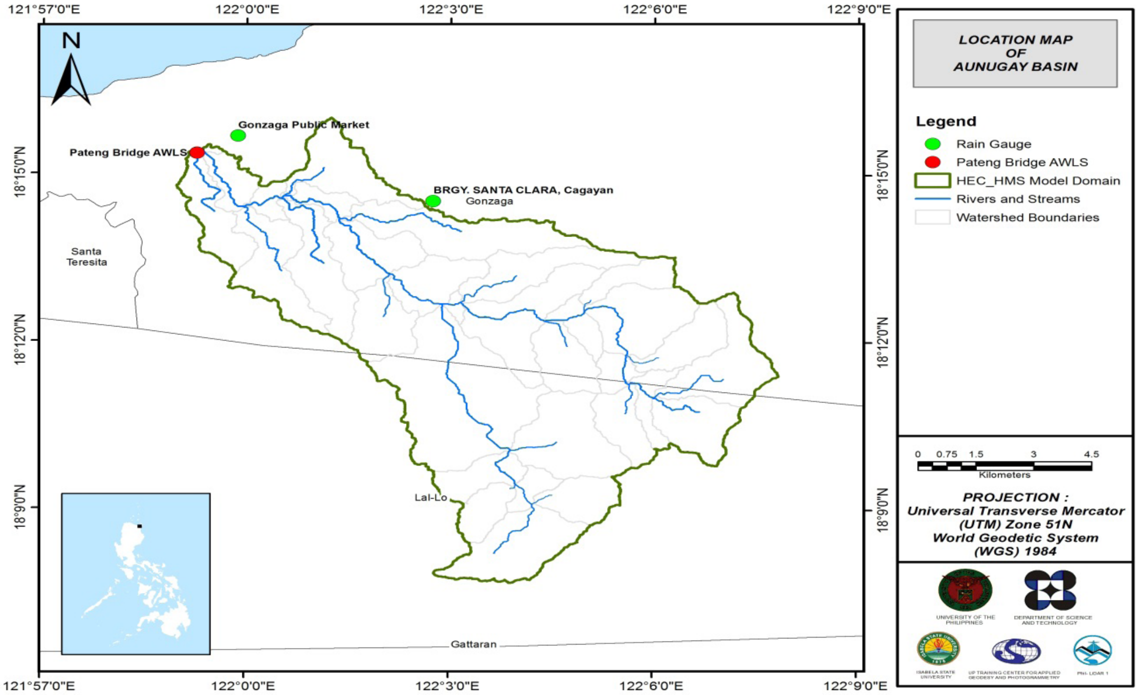


Figure 47. The location map of Aunugay HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

The monsoon rain that occurred on 26 – 30 December 2016 contributed to a 1.275 meter water level rise with peak discharge of 99.7 m^3/s recorded at 4:00 AM on 28 December 2016 with total accumulated rainfall of 91.0 mm. These hydrologic data are the actual event of Aunugay River and inputted to hydrologic modeling. Hydrologic measurements were taken from Pateng Bridge, Pateng, Gonzaga, Cagayan.

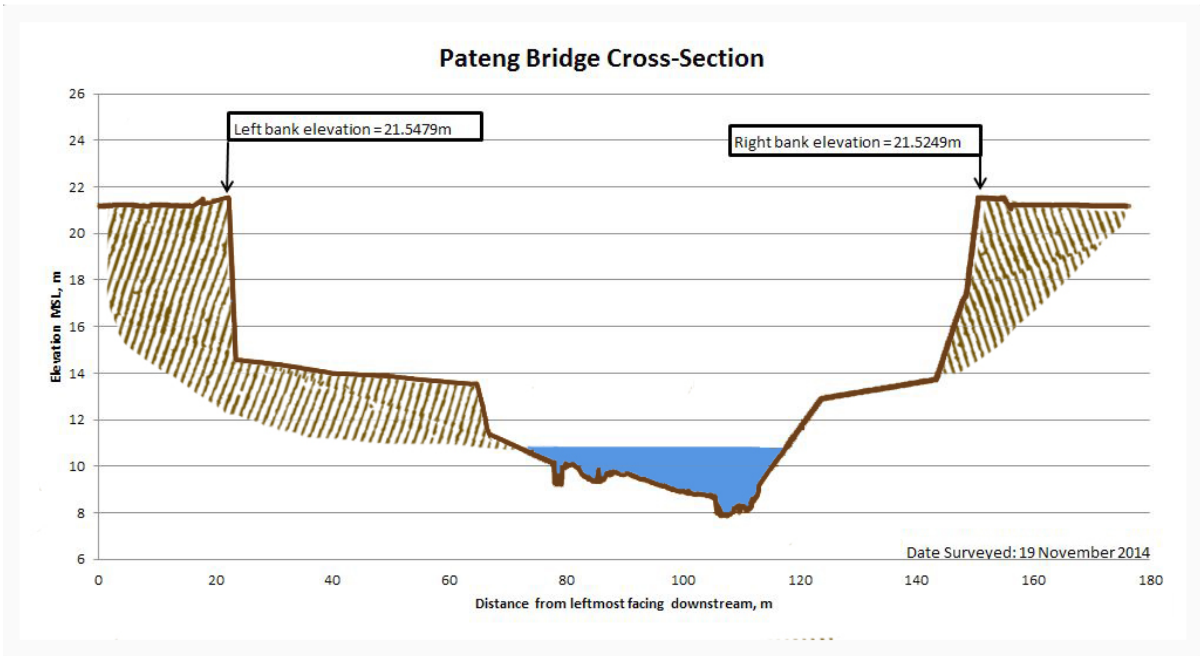


Figure 48. Cross-Section Plot of Pateng Bridge

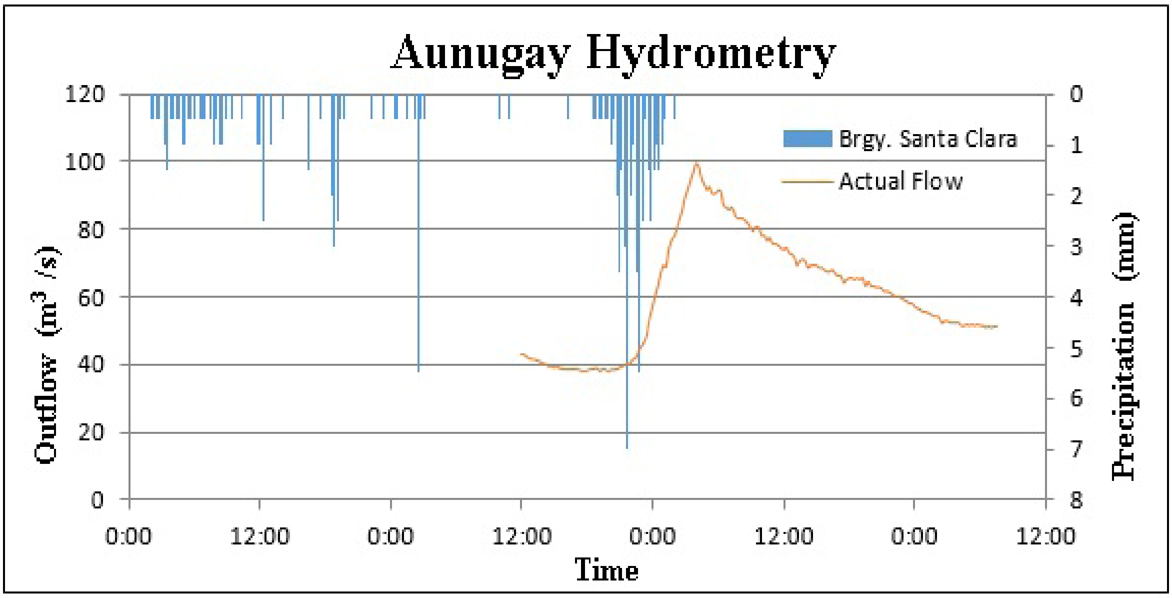


Figure 49. Rainfall and outflow data used for modeling

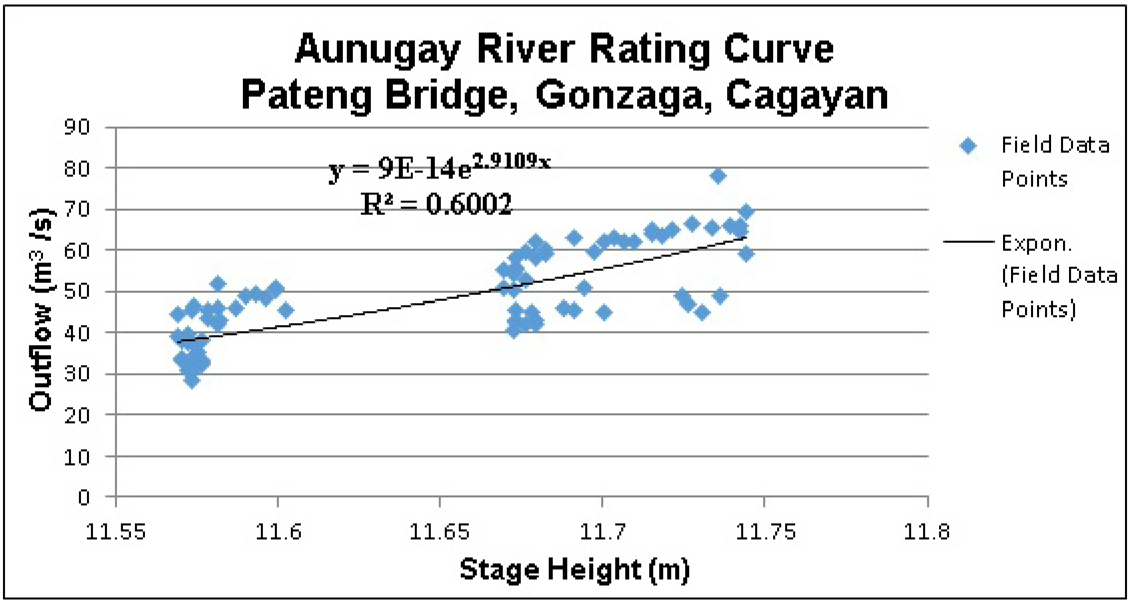


Figure 50. HQ Curve of HEC-HMS model

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for Rainfall Intensity Duration Frequency (RIDF) values for the Aparri Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station is chosen based on its proximity to the Aunugay watershed. The extreme values for this watershed were computed based on a 47-year record.

Table 32. RIDF values for Aparri 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	20.1	31.4	39.4	53.3	75.6	92.2	119.4	147.7	167.9
5	28.5	44.9	55.8	78.7	110.4	137	173.6	221.2	252.5
10	34.1	53.8	66.6	95.6	133.4	166.6	209.5	269.9	308.5
15	37.2	58.8	72.7	105.1	146.5	183.4	229.7	297.4	340.2
20	39.4	62.3	77	111.8	155.6	195.1	243.9	316.6	362.3
25	41.1	65	80.3	116.9	162.6	204.1	254.8	331.4	379.3
50	46.3	73.4	90.5	132.7	184.2	231.9	288.4	377.1	431.9
100	51.4	81.7	100.6	148.4	205.6	259.5	321.7	422.4	484

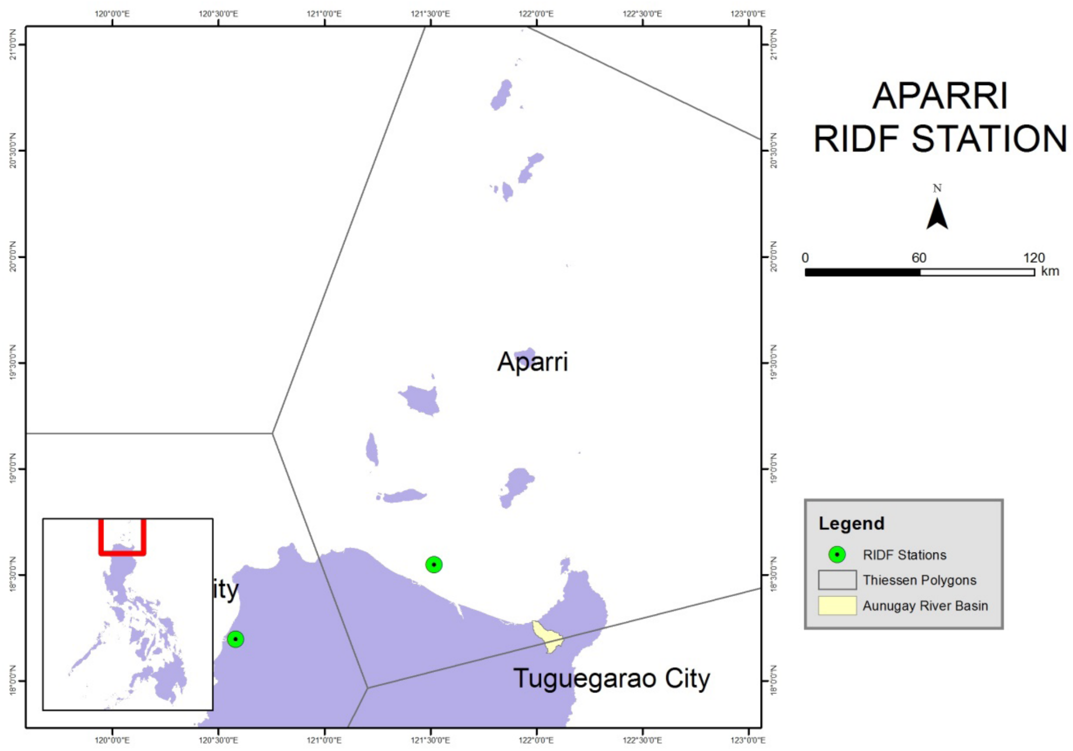


Figure 51. Location of Aparri RIDF Station relative to Aunugay River Basin

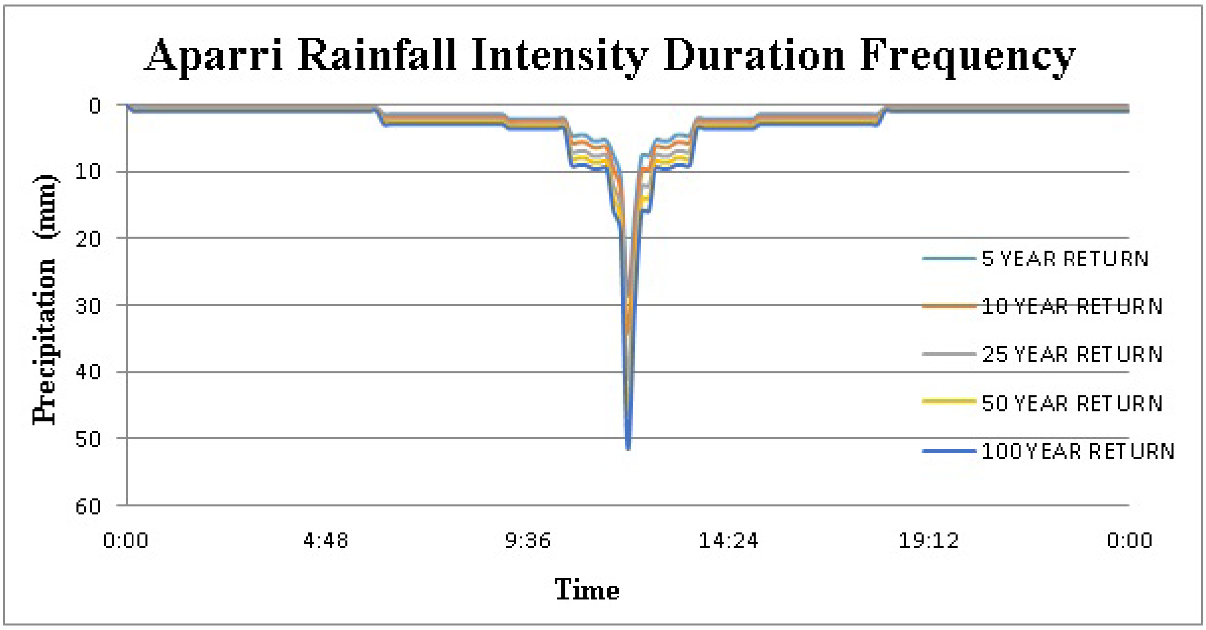


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset, taken in 2004, was sourced out from the Bureau of Soils under the Department of Agriculture. The land cover data, on the other hand, was taken from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Aunugay River Basin are shown in Figures 53 and 54, respectively.

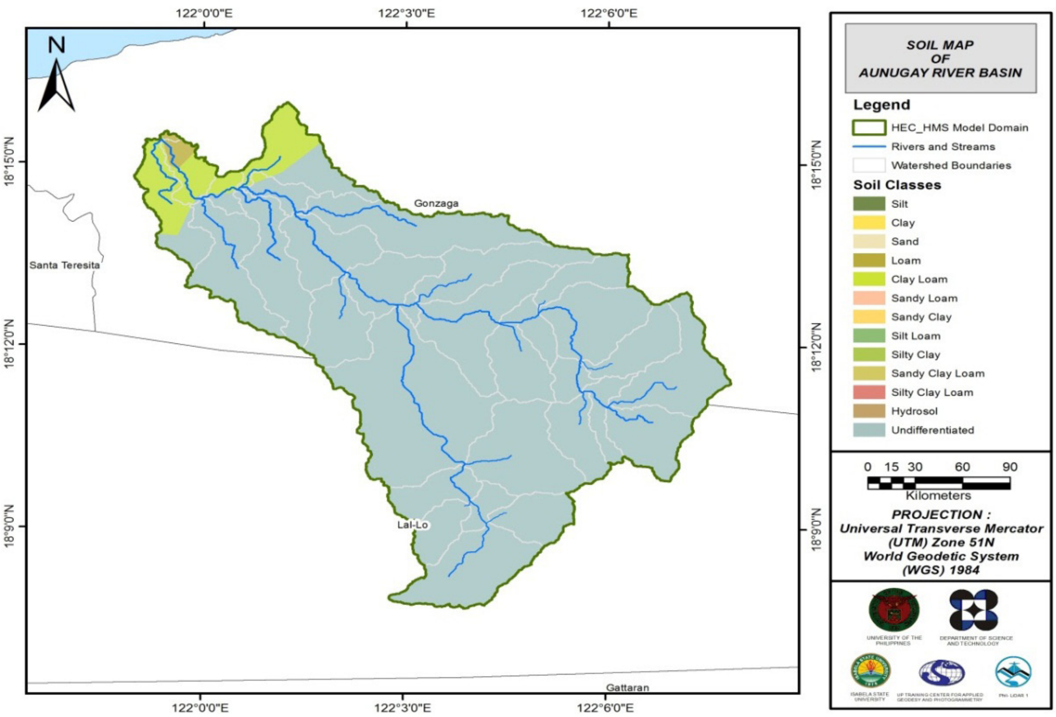


Figure 53. The soil map of the Aunugay River Basin

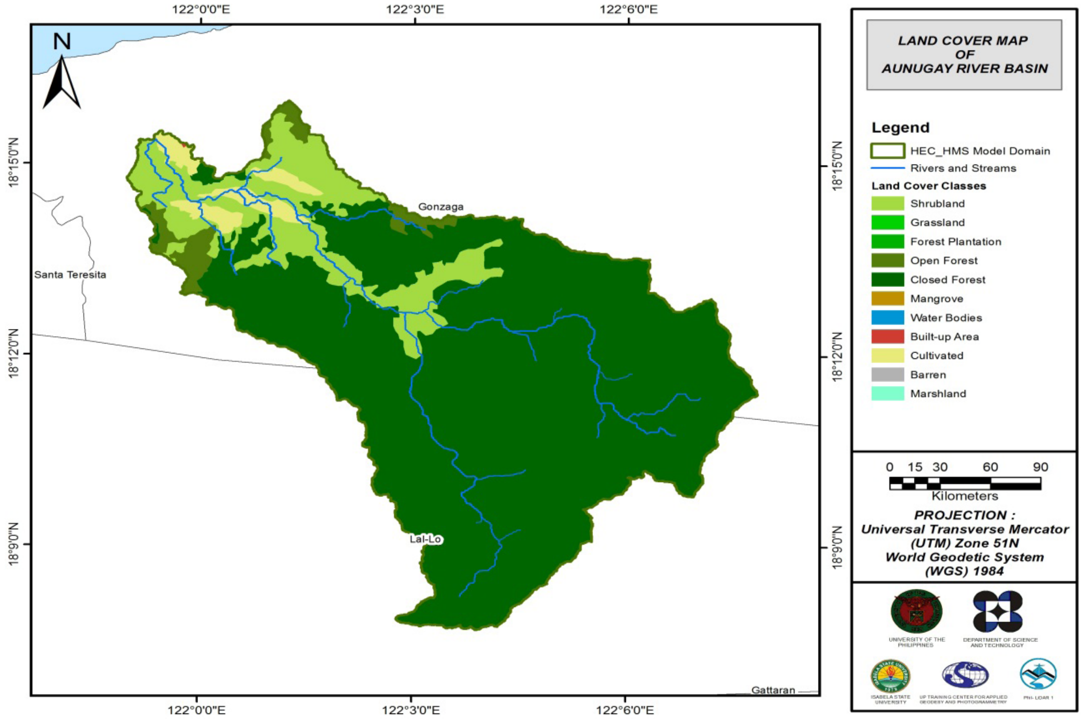


Figure 54. The land cover map of the Aunugay River Basin

For Aunugay, three (3) soil classes were identified. These are loam, clay loam, and undifferentiated soil. Moreover, four (4) land cover classes were identified. These are shrubland, open forest, closed forest and cultivated land.

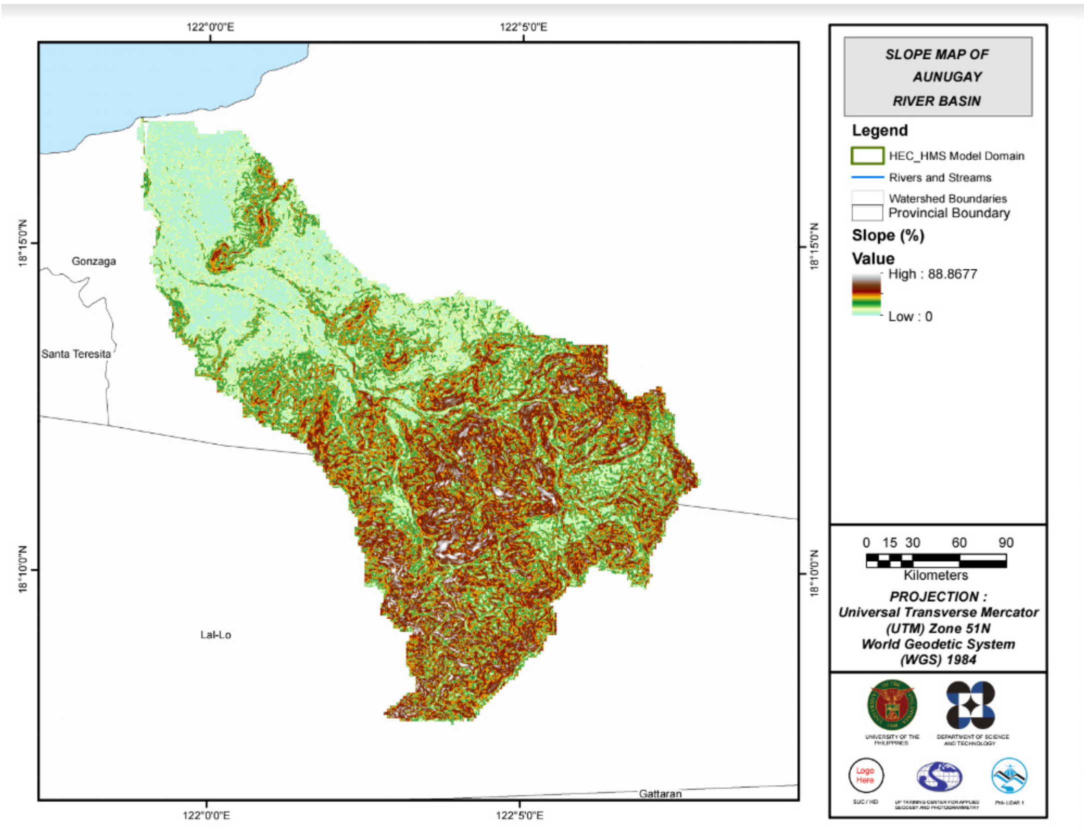


Figure 55. The slope map of the Aunugay River Basin

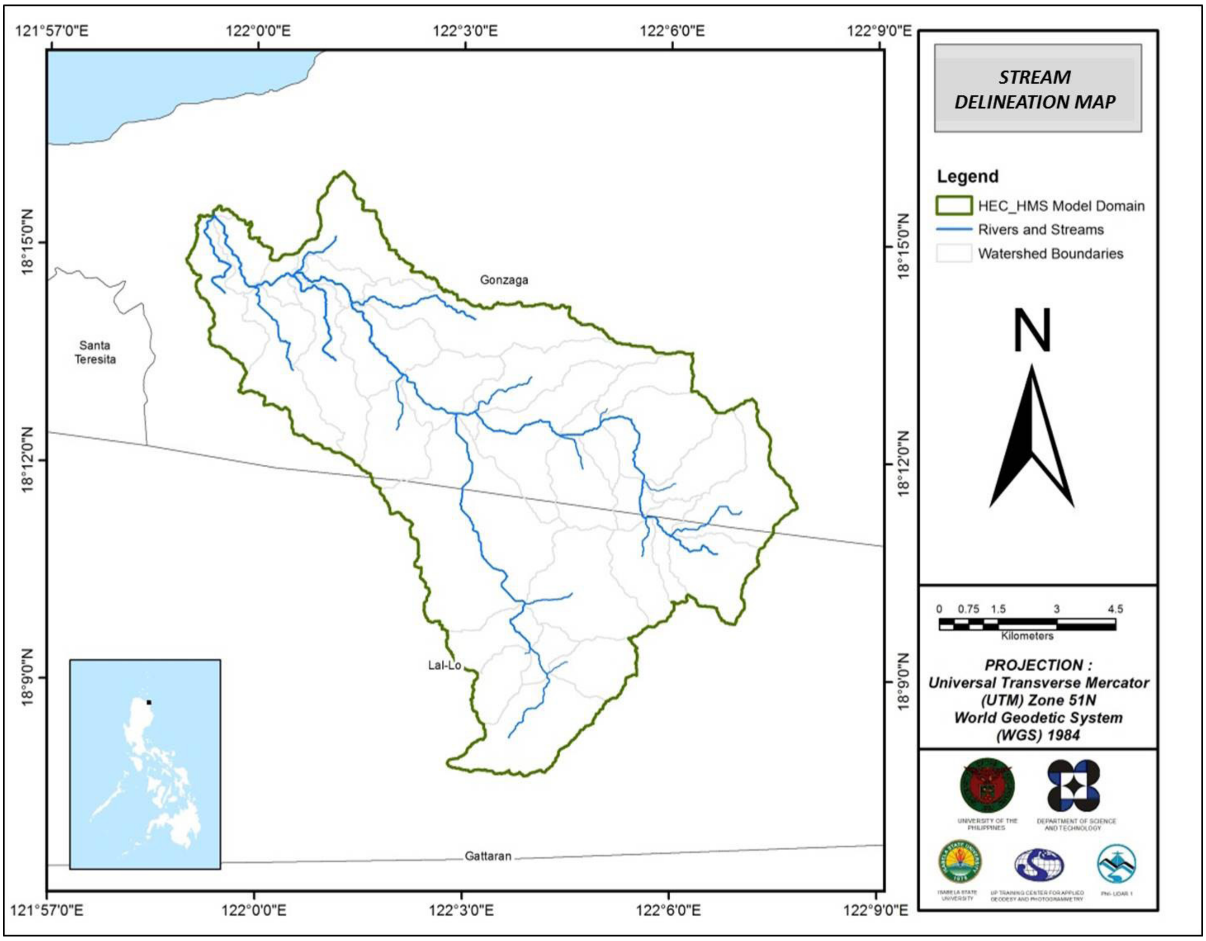


Figure 56. Stream delineation map of Aunugay river basin

A drainage system includes the basin boundary, subbasin and the stream networks of the basin. Using ArcMap 10.1 with HEC-GeoHMS version 10.1 extension, the Aunugay River centerline and SAR-DEM 10m resolution served as primary data, delineating the drainage system of the
Aunugay river basin. The river centerline was digitized starting from upstream towards
downstream in Google Earth (2014). Default threshold area used is 140 hectares.
Using the SAR-based DEM, the Aunugay basin was delineated and further subdivided into
subbasins. The Aunugay basin model consists of 33 sub basins, 16 reaches, and 16 junctions. The main outlet is Outlet 1. This basin model is illustrated in Figure 56. The basins were identified based on soil and land cover characteristics of the area. Precipitation from the 26-27 December 2016 (Monsoon Rain) was taken from DOST rain gauges. Finally, it was calibrated using data from the Aunugay depth gauge sensor.

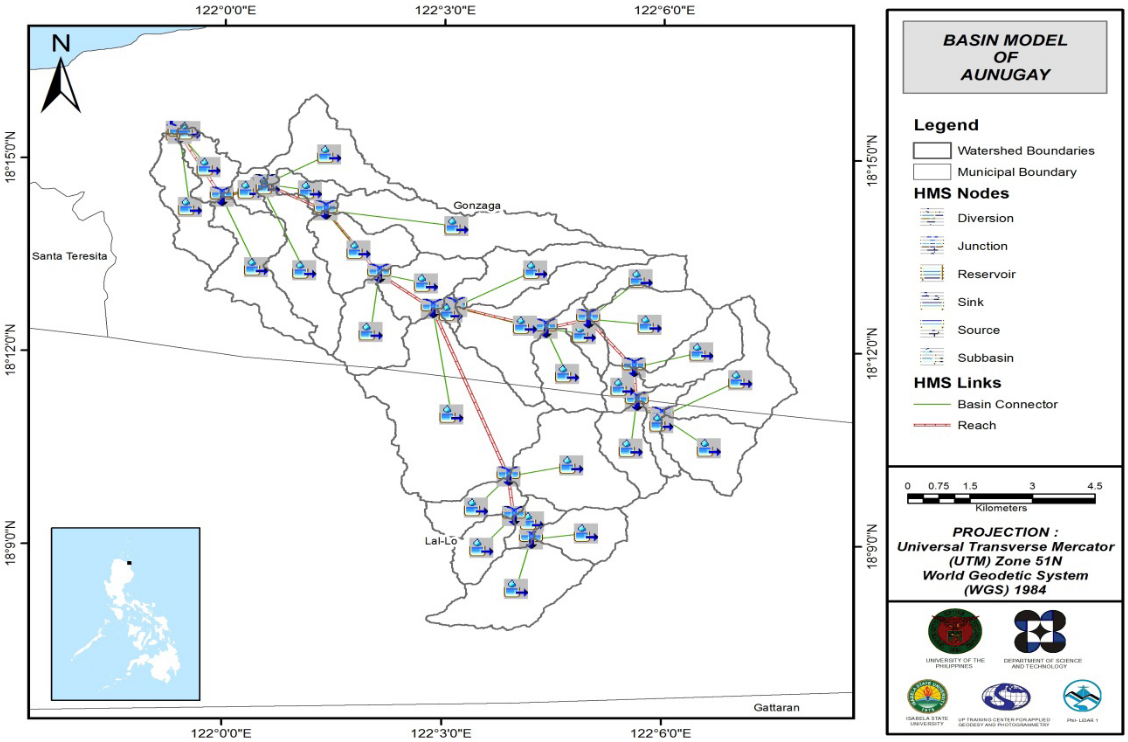


Figure 57. The Aunugay river basin model generated in HEC-HMS

5.4 Cross-section Data

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

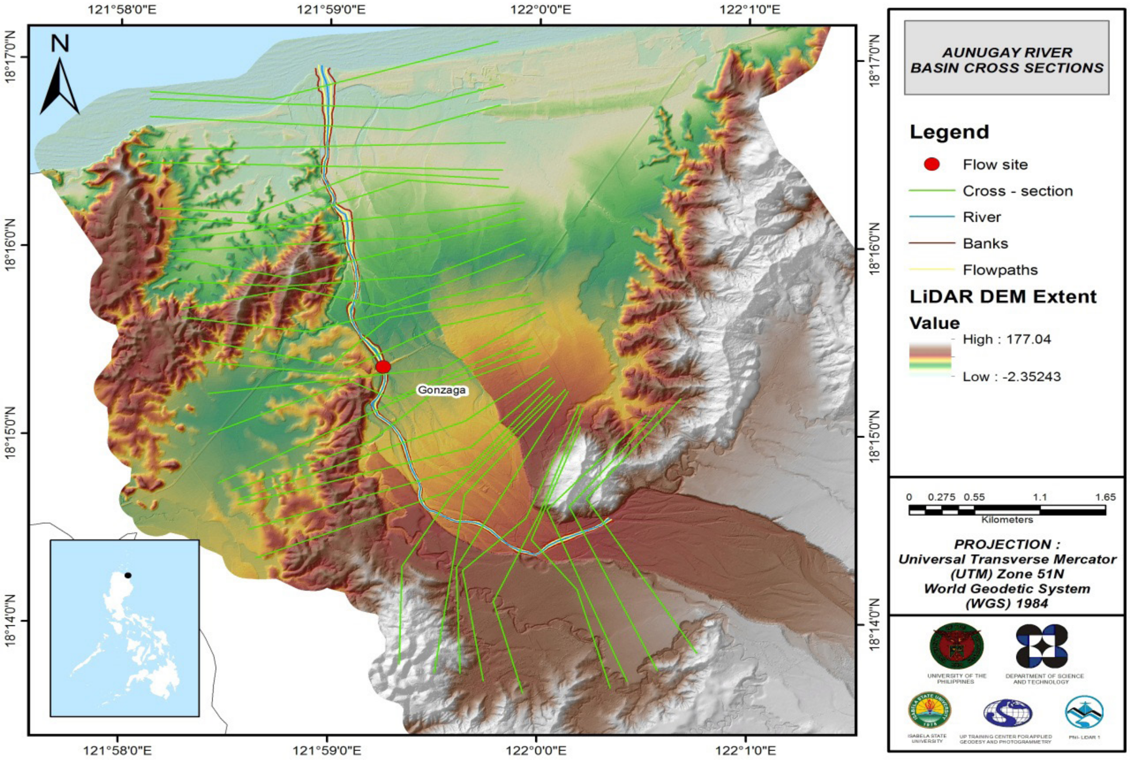


Figure 58. Aunugay River Cross-section generated using HEC GeoRAS tool

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.

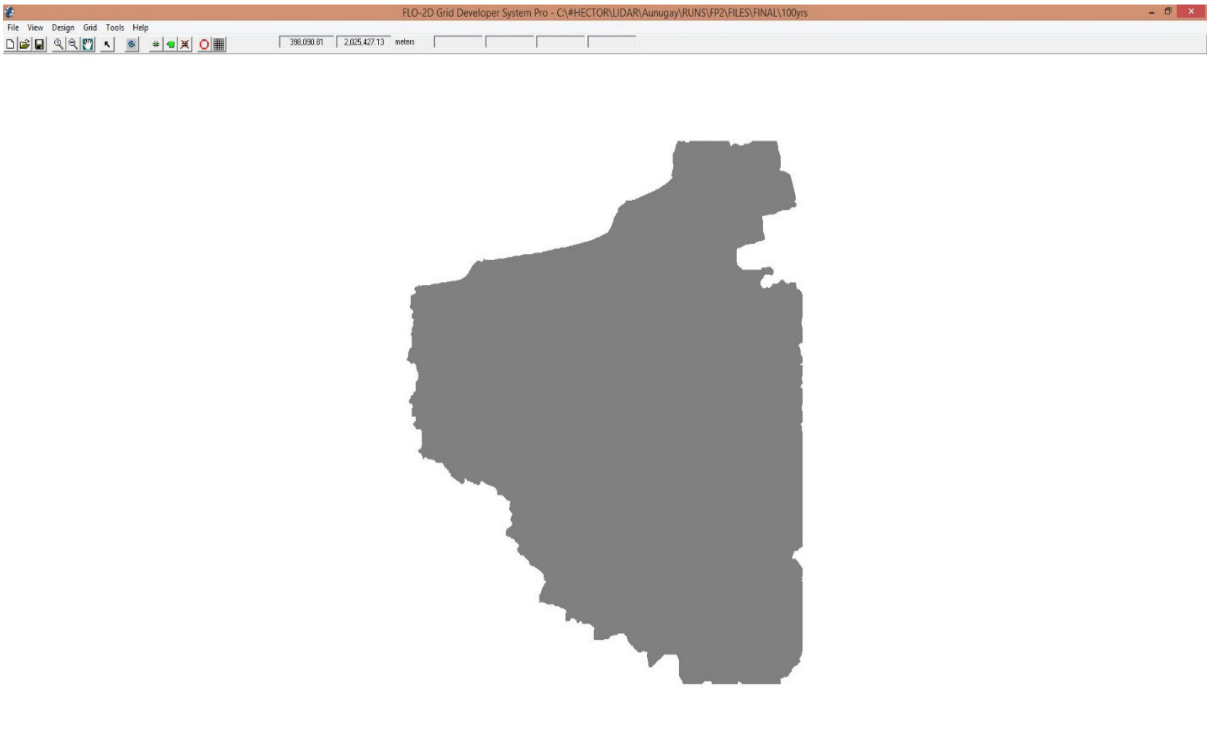


Figure 59. Screenshot of subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 66.01416 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m^2/s.

The 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 75 540 864.00 m^2.

There is a total of 69 380 809.26 m^3 of water entering the model. Of this amount, 34 076 965.57 m^3 is due to rainfall while 35 303 843.69 m^3 is inflow from other areas outside the model. 7 434 141.50 m^3 of this water is lost to infiltration and interception, while 4 597 277.06 m^3 is stored by the flood plain. The rest, amounting up to 57 349 012.21 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Aunugay HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 62 shows the comparison between the two is charge data.

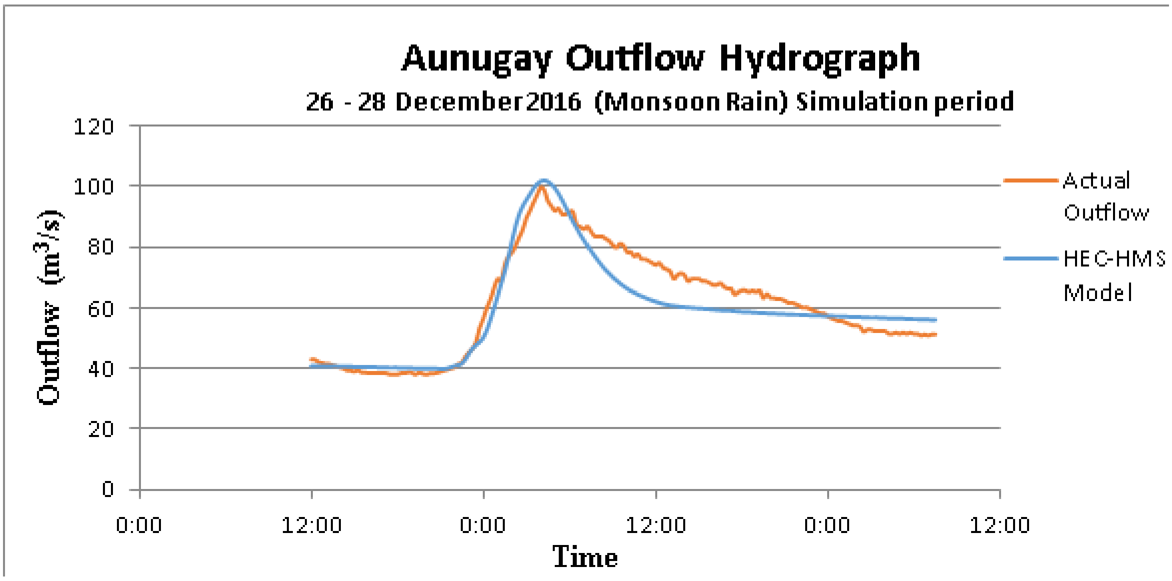


Figure 60. Outflow Hydrograph of Aunugay produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 33 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 33. Range of Calibrated Values for Aunugay

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	4 – 22
			Curve Number	69 – 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.03 – 0.4
			Storage Coefficient (hr)	0.4 – 5.5
	Baseflow	Recession	Recession Constant	0.9
			Ratio to Peak	0.2 – 1.0
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.025

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 4mm to 22mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 69 to 99 for curve number is higher than the advisable value for Philippine watersheds depending on the soil and land cover of the area. For Aunugay, the basin mostly consists of
shrubland and closed forest and the soil consists of clay loam and undifferentiated soil.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.03 hours to 5.5 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.9 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.2-1 indicates a gradual decrease in the receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.025 is less than the usual Manning's n value in the Philippines.

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

r^2	0.8896
NSE	0.88
PBIAS	3.32
RSR	0.35

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 6 (m3/s).

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.8896.

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 0.88.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction.
Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 3.32.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.35.

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 61) shows the Aunugay River outflow using the Cagayan de Oro Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

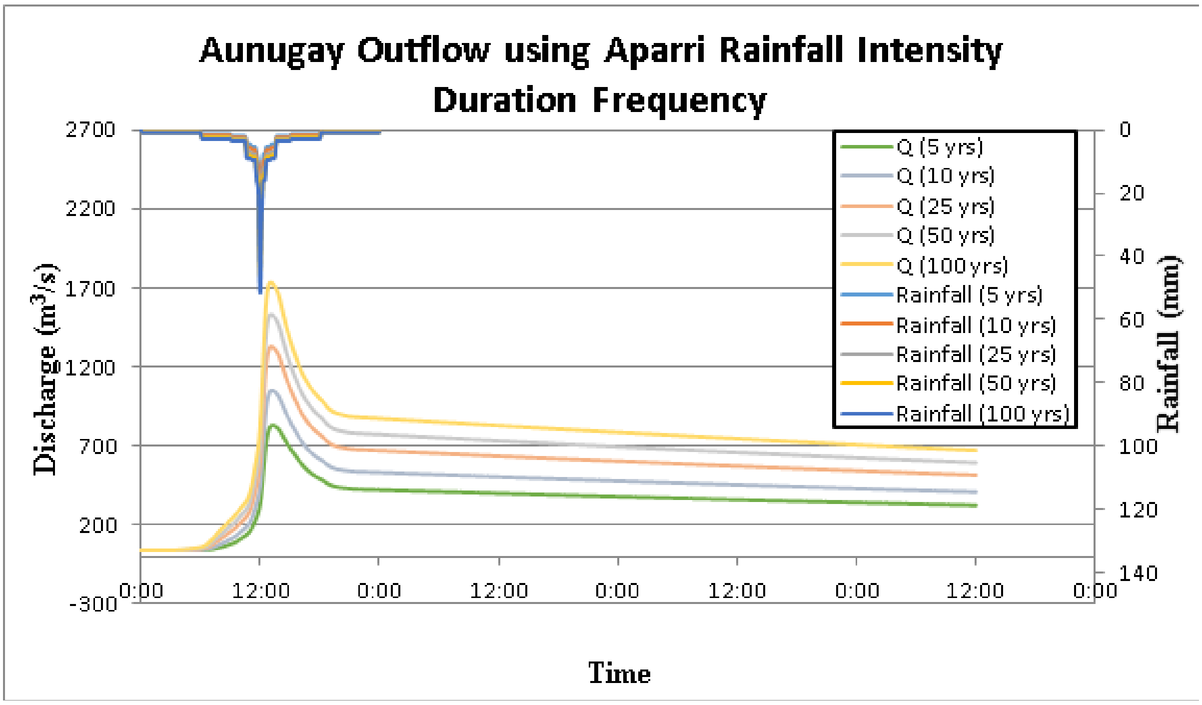


Figure 61. Outflow hydrograph at Aunugay Station generated using Cagayan de Oro RIDF simulated in HEC-HMS

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

Table 35. Peak values of the Aunugay HECHMS Model outflow using the Cagayan de Oro RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^{3}s)	Time to Peak
5-Year	252.5	28.5	831.3	1 hour, 20 minutes
10-Year	308.5	34.1	1052.1	1 hour, 10 minutes
25-Year	379.3	41.1	1329.2	1 hour, 10 minutes
50-Year	431.9	46.3	1532.2	1 hour, 10 minutes
100-Year	484	51.4	1734.4	1 hour

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. The sample generated map of Aunugay River using the calibrated HMS base flow is shown in Figure 62.

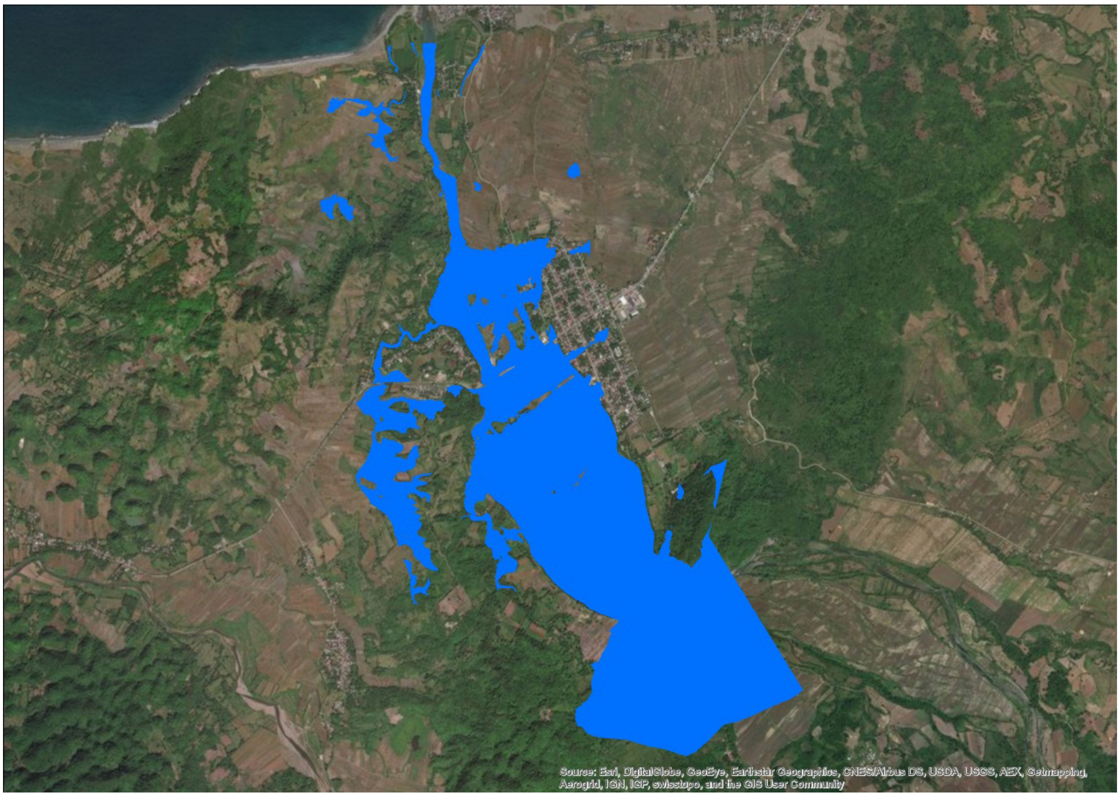


Figure 62. Sample output of Aunugay RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figures 63 to 68 show the 5-, 25-, and 100-year rain return scenarios of the Aunugay floodplain. The floodplain, with an area of 94.0728 sq. km., covers the municipalities of Gonzaga and Santa Tersita. Table 36 shows the percentage of area affected by flooding.

Table 36. Municipalities affected in Aunugay Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Gonzaga	527.15	87.78	16.65%
Santa Teresita	127.51	6.30	4.94%

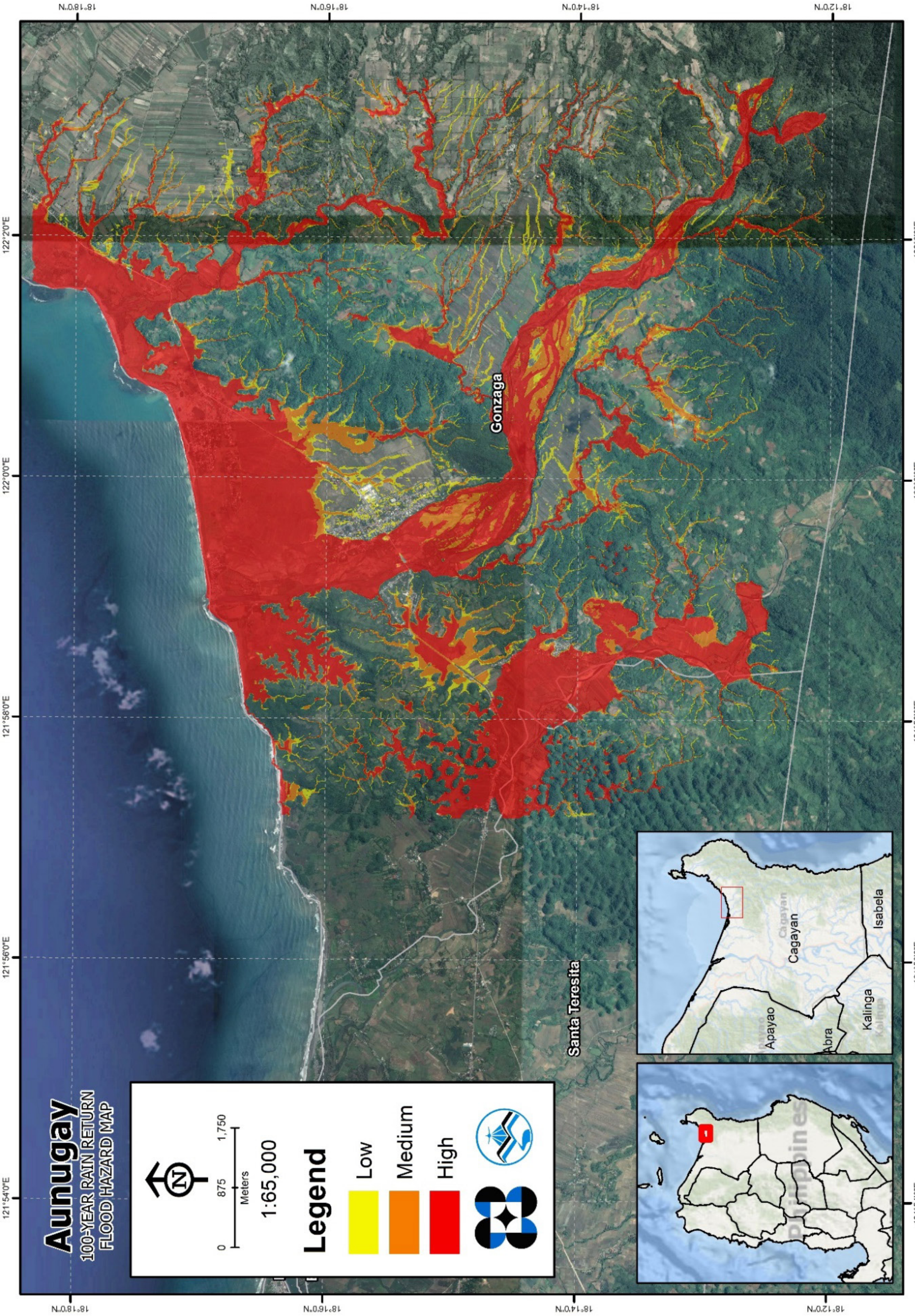


Figure 63. 100-year Flood Hazard Map for Aunugay Floodplain

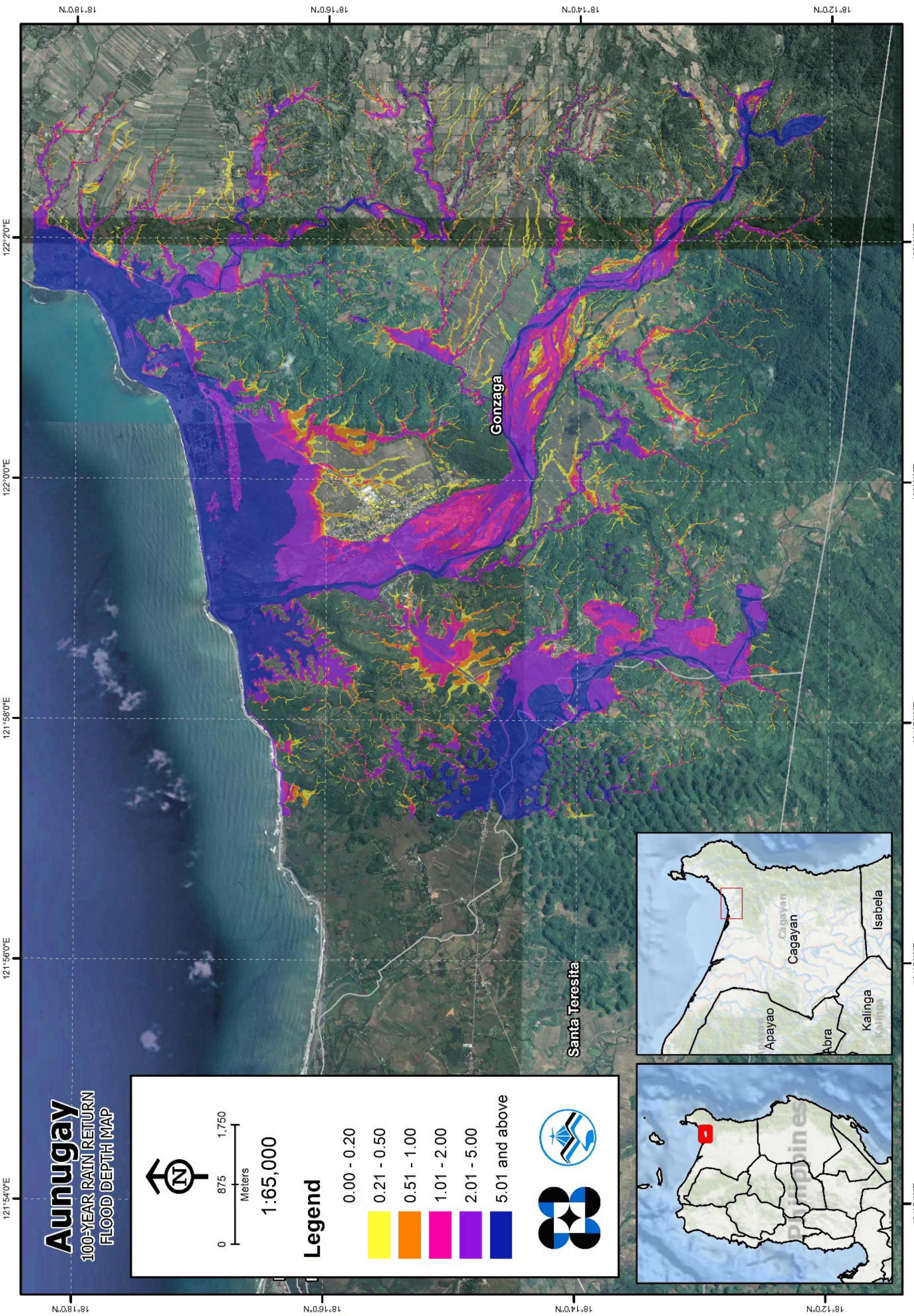


Figure 64. 100-year Flow Depth Map for Aunugay Floodplain

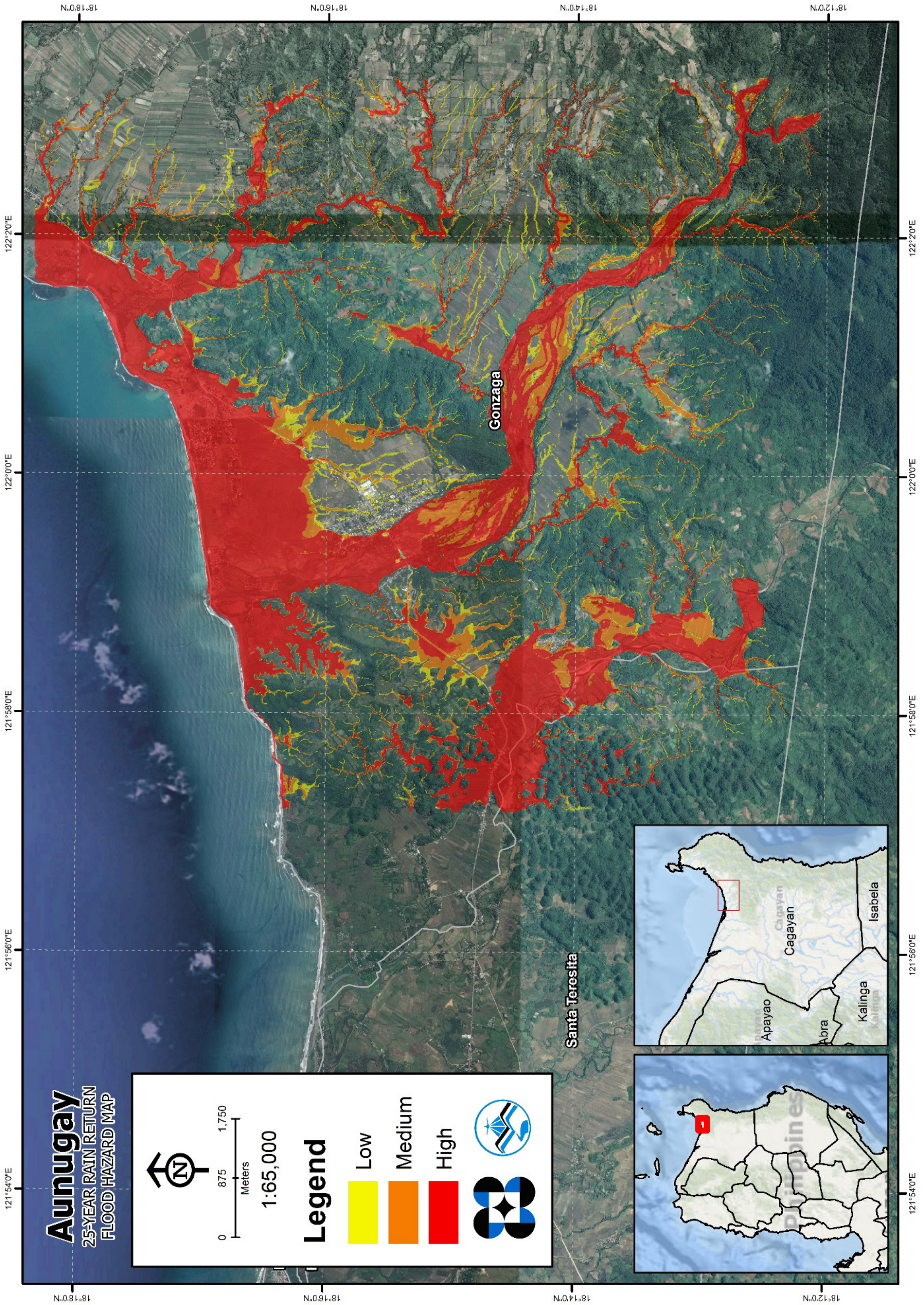


Figure 65. 25-year Flood Hazard Map for Aunugay Floodplain

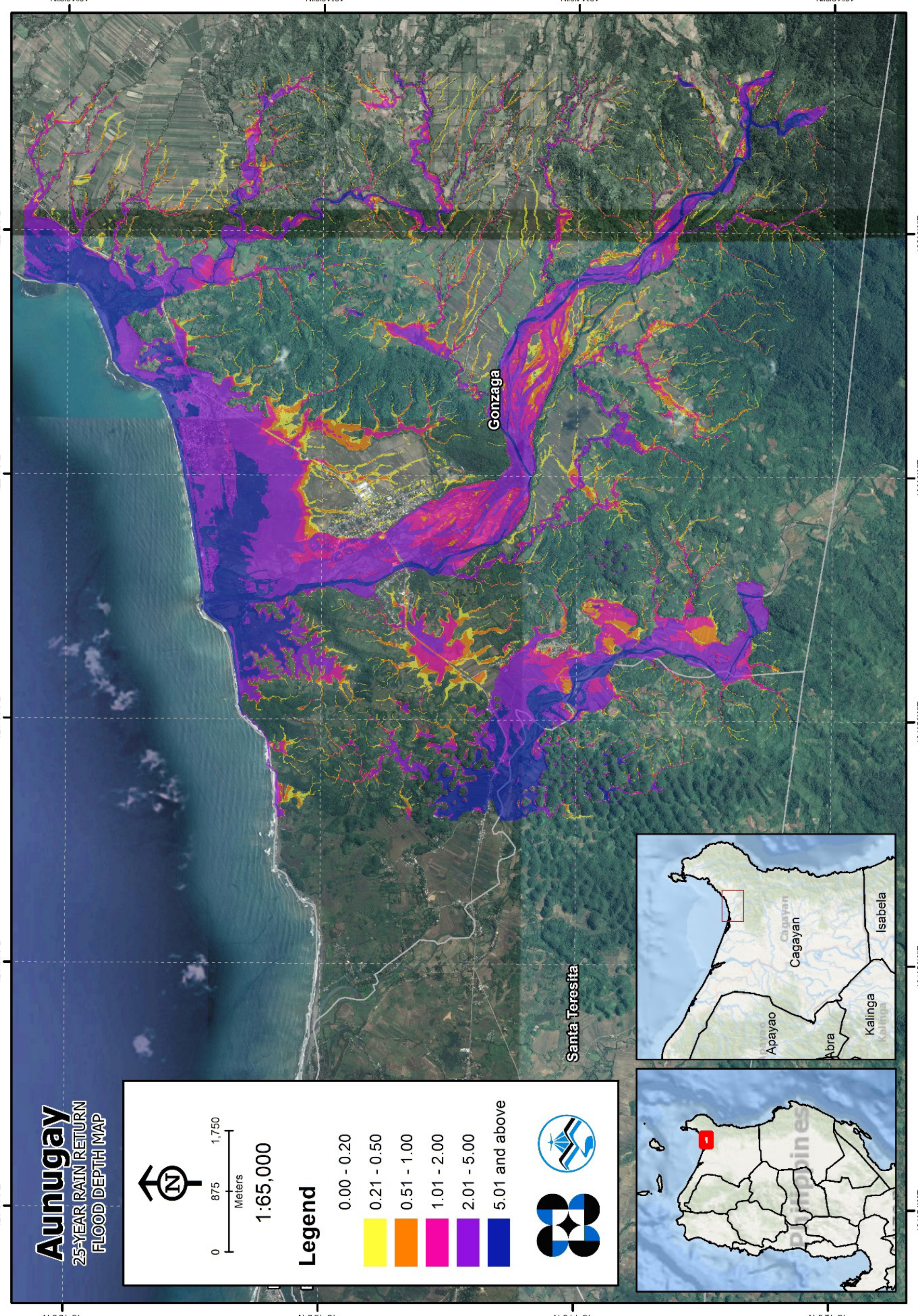


Figure 66. 25-year Flow Depth Map for Aunugay Floodplain

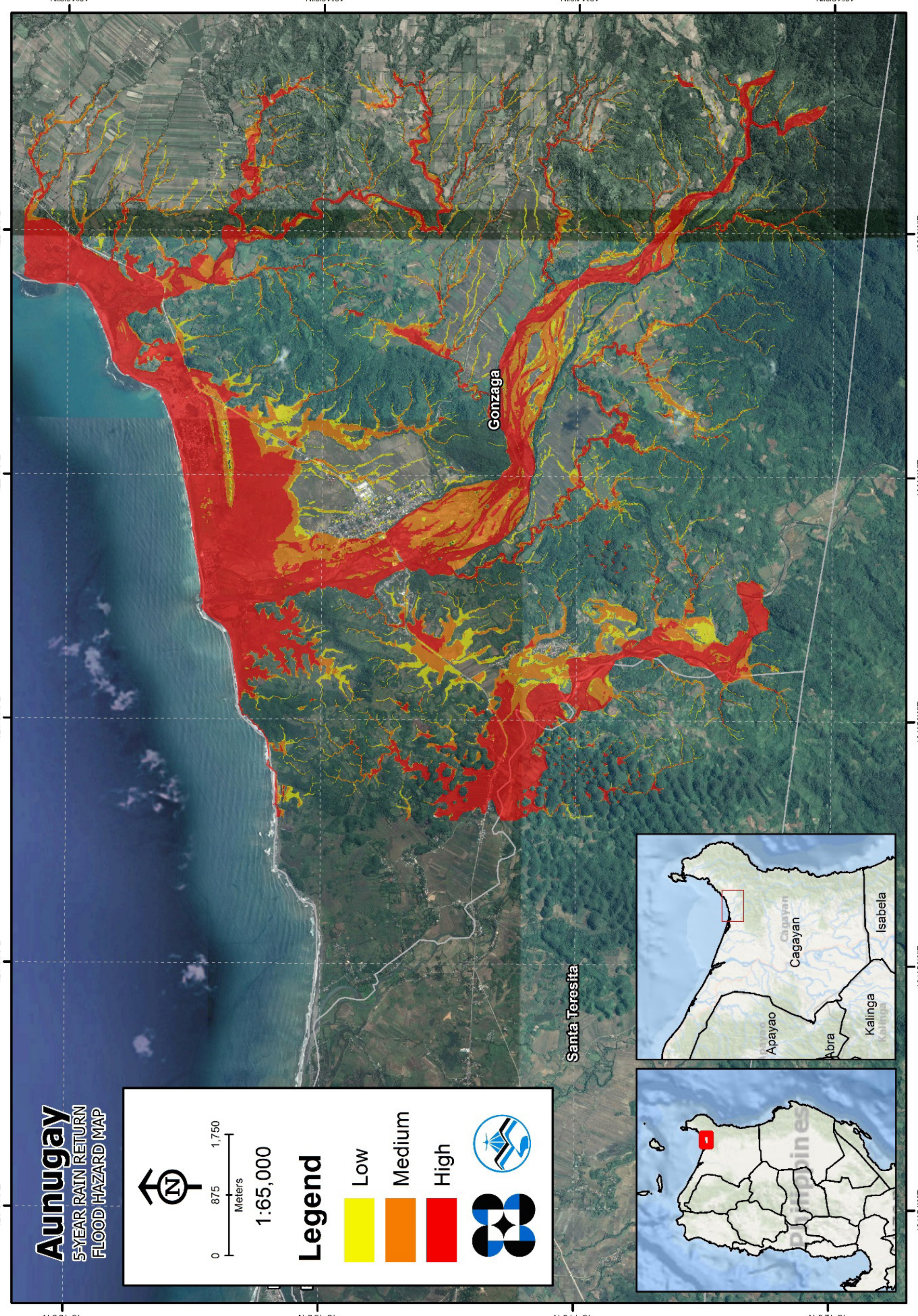


Figure 67. 5-year Flood Hazard Map for Aunugay Floodplain

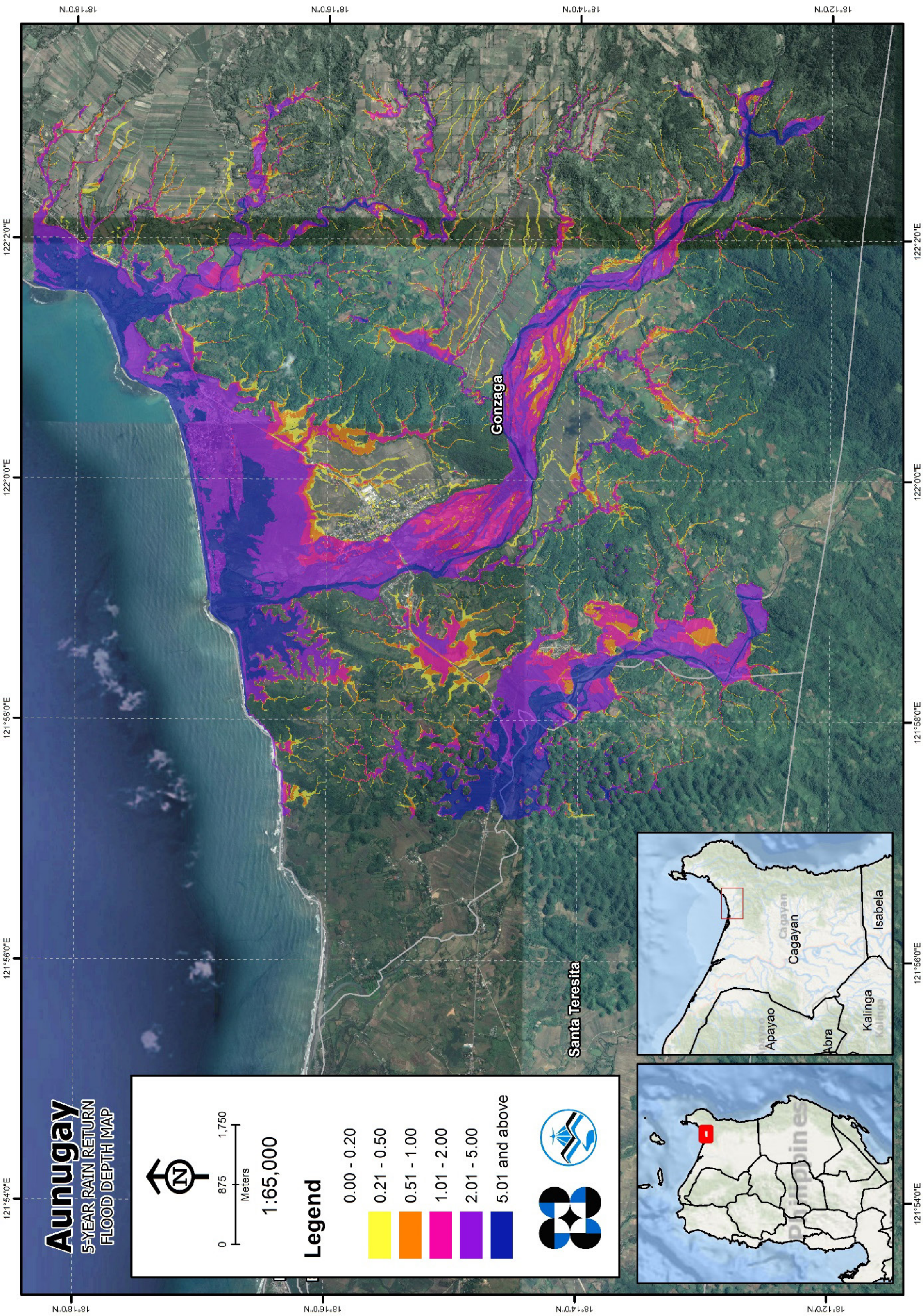


Figure 68. 5-year Flood Depth Map for Aunugay Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Aunugay River Basin, grouped by municipality, are listed below. For the said basin, three (3) municipalities consisting of seventeen (17) barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 7.25% of the municipality of Santa Teresita with an area of 66.23 sq. km. will experience flood levels of less 0.20 meters. 0.35% of the area will experience flood levels of 0.21 to 0.50 meters while 0.36%, 0.38%, 0.64%, and 0.235% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 37 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Santa Teresita, Cagayan during 5-Year Rainfall Return Period

AUNUGAY BASIN		Affected Barangays in Santa Teresita
		Dungeg
Affected Area (sq. km.)	0.03-0.20	4.8
	0.21-0.50	0.23
	0.51-1.00	0.24
	1.01-2.00	0.25
	2.01-5.00	0.42
	> 5.00	0.16

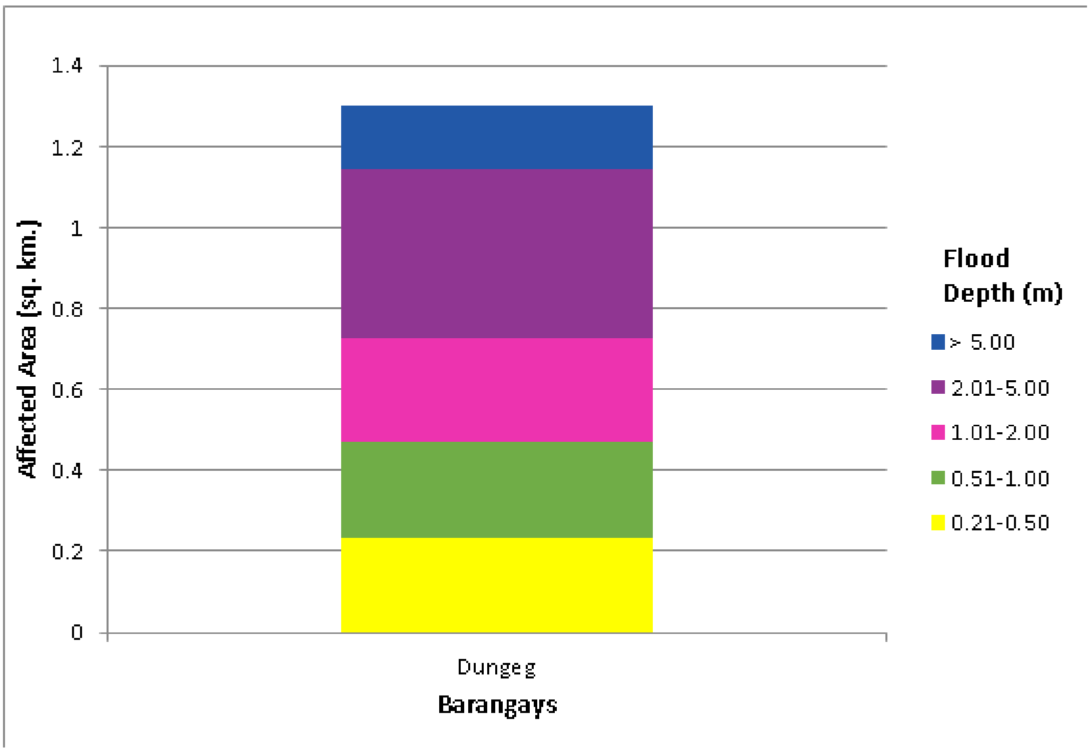


Figure 69. Affected Areas in Santa Teresita, Cagayan during 5-Year Rainfall Return Period

For the 5-year return period, 0.0008456% of the municipality of Lal-lo with an area of 760.444 sq. km. will experience flood levels of less 0.20 meters.

Table 38. Affected Areas in Lal-lo, Cagayan during 5-Year Rainfall Return Period

AUNUGAY BASIN		Affected Barangays in Lal-lo
		Dagupan
Affected Area (sq. km.)	0.03-0.20	0.00056
	0.21-0.50	0
	0.51-1.00	0
	1.01-2.00	0
	2.01-5.00	0
	> 5.00	0

For the 5-year return period, 12.96% of the municipality of Gonzaga with an area of 467.619 sq. km., will experience flood levels of less 0.20 meters. 1.04% of the area will experience flood levels of 0.21 to 0.50 meters while 1.04%, 1.42%, 1.07% and 0.12% 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 2 meters,
respectively. Listed in Table 39 are the affected areas in square kilometres by flood depth per barangay.

Table 39. Affected Areas in Gonzaga, Cagayan during 5-Year Rainfall Return Period

AUNUGAY BASIN		Affected Barangays in Gonzaga							
		Batangan	Calayan	Callao	Flourishing	Ipil	Isca	Magrafil	Minanga
Affected Area (sq. km.)	0.03-0.20	1.08	2.97	4.03	1.95	0.9	5.37	0.42	0.27
	0.21-0.50	0.24	0.5	0.37	0.16	0.03	0.72	0.028	0.16
	0.51-1.00	0.15	0.53	0.3	0.43	0.048	0.78	0.006	0.39
	1.01-2.00	0.17	0.48	0.45	0.78	0.066	0.68	0.007	0.95
	2.01-5.00	0.063	0.19	0.36	0.4	0.022	0.88	0.017	0.65
	> 5.00	0	0.0069	0.061	0.0091	0.0002	0.17	0	0

Table 40. Affected Areas in Gonzaga, Cagayan during 5-Year Rainfall Return Period

AUNUGAY BASIN		Affected Barangays in Gonzaga						
		Paradise	Pateng	Progressive	Rebecca	Santa Clara	Smart	Tapel
Affected Area (sq. km.)	0.03-0.20	0.29	14.88	0.55	1.3	26.34	0.34	3.81
	0.21-0.50	0.031	1.05	0.076	0.14	1.23	0.051	0.39
	0.51-1.00	0.016	0.94	0.047	0.12	0.99	0.032	0.41
	1.01-2.00	0.12	1.28	0.31	0.13	1.22	0.031	0.36
	2.01-5.00	0.056	0.99	0.12	0.13	1.23	0.035	0.19
	> 5.00	0	0.14	0	0.0015	0.22	0	0.004

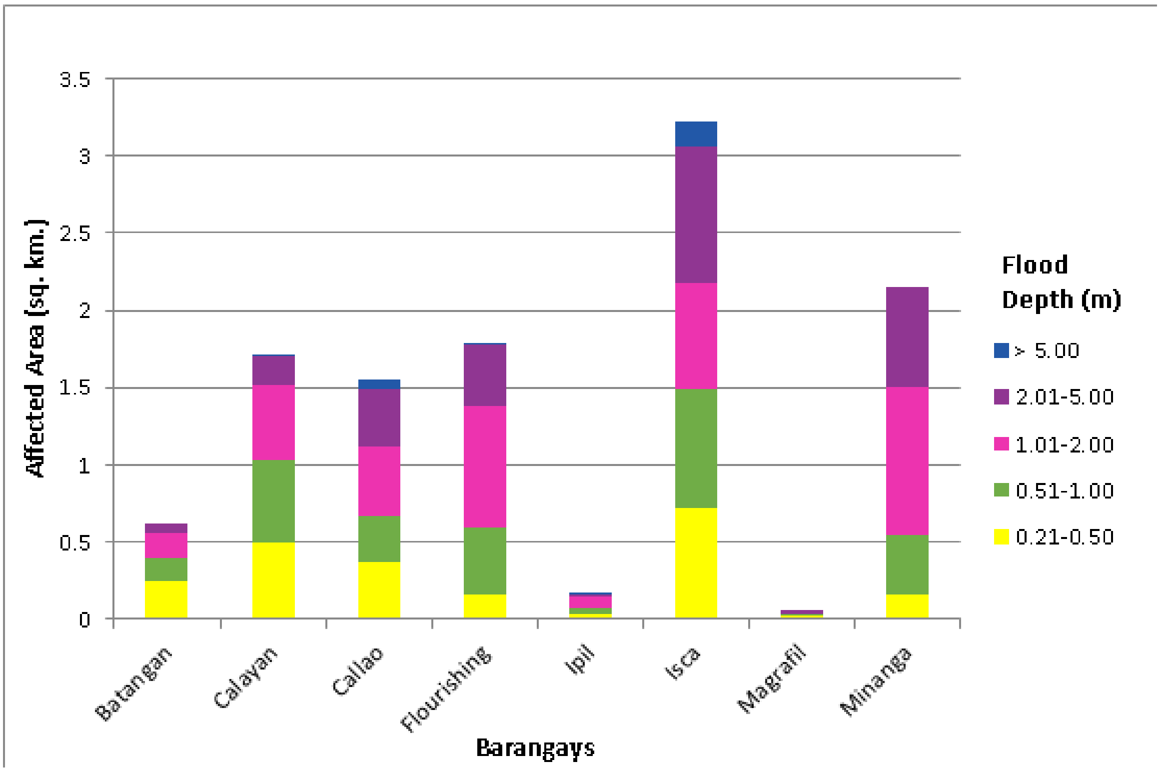


Figure 70. Affected Areas in Gonzaga, Cagayan during 5-Year Rainfall Return Period

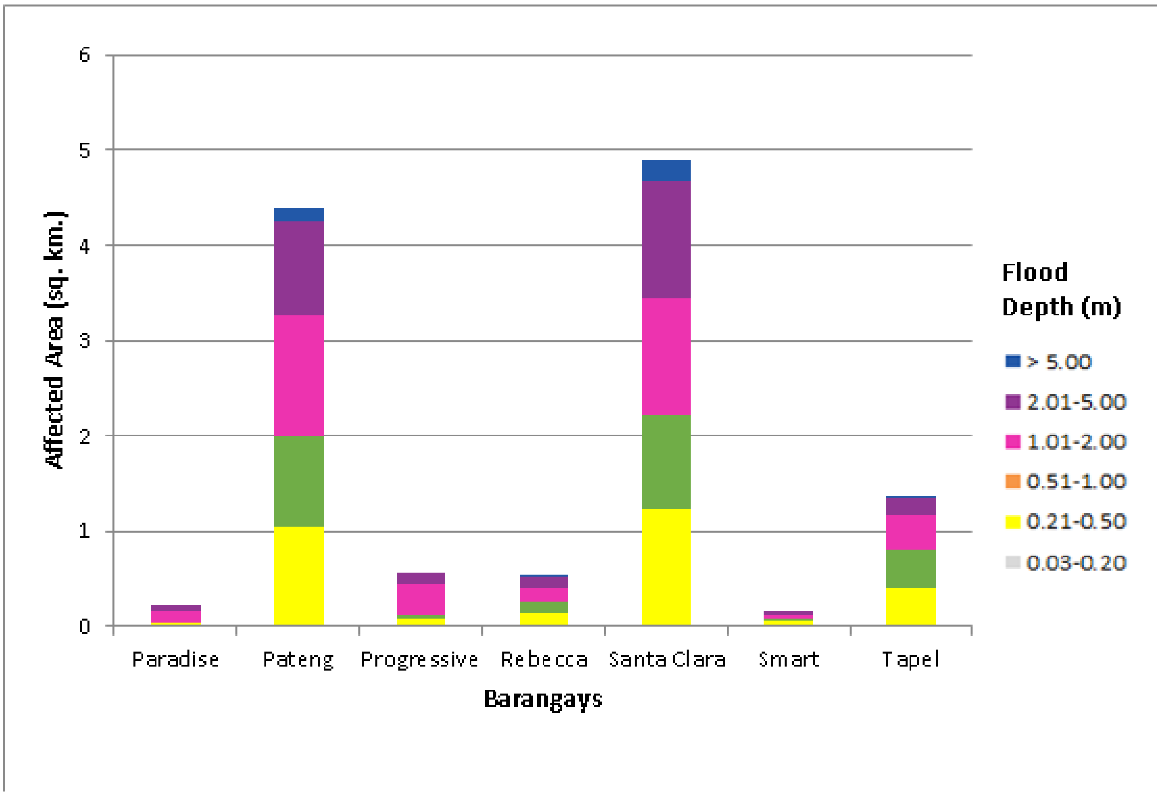


Figure 71. Affected Areas in Gonzaga, Cagayan during 5-Year Rainfall Return Period

For the 25-year return period, 6.92% of the municipality of Santa Teresita with an area of 66.225 sq. km. will experience flood levels of less 0.20 meters. 0.30% of the area will experience flood levels of 0.21 to 0.50 meters while 0.31%, 0.50%, 0.83%, and 0.35% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 41 are the affected areas in square kilometres by flood depth per barangay.

Table 41. Affected Areas in Santa Teresita, Cagayan during 25-Year Rainfall Return Period

AUNUGAY BASIN		Affected Barangays in Santa Teresita
		Dungeg
Affected Area (sq. km.)	0.03-0.20	4.58
	0.21-0.50	0.2
	0.51-1.00	0.21
	1.01-2.00	0.33
	2.01-5.00	0.55
	> 5.00	0.23

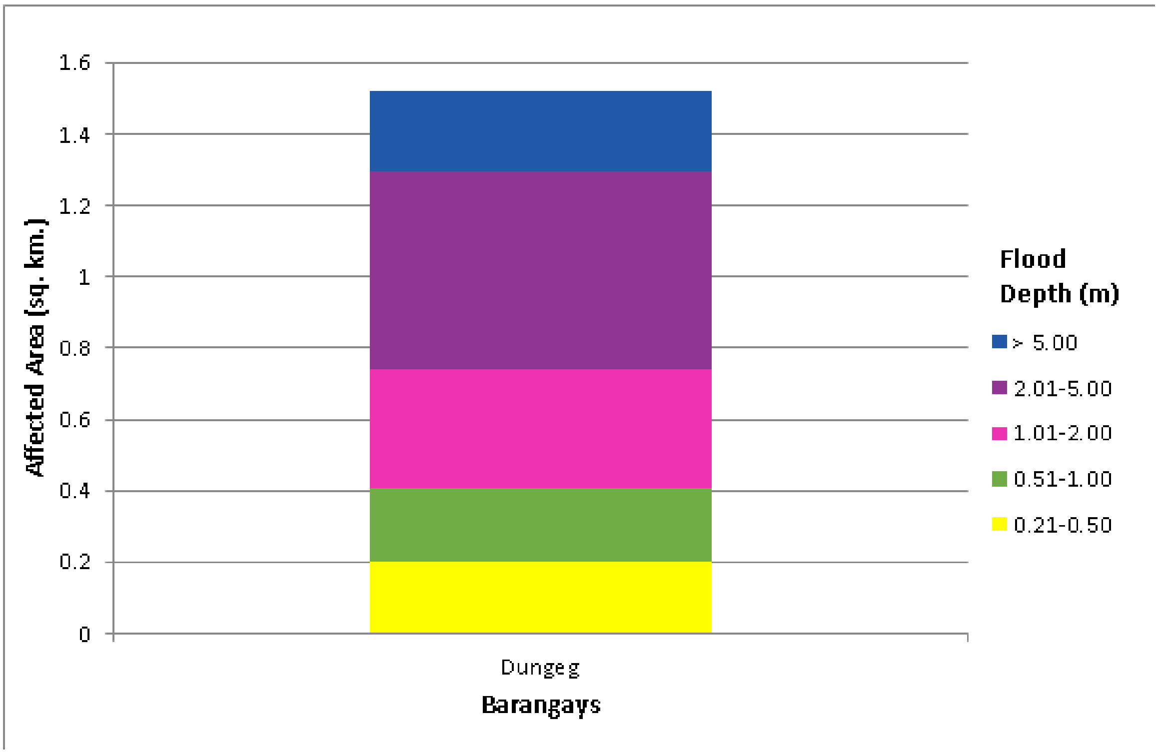


Figure 72. Affected Areas in Santa Teresita, Cagayan during 25-Year Rainfall Return Period

For the 25-year return period, 0.0008456% of the municipality of Lal-lo with an area of 760.444 sq. km. will experience flood levels of less 0.20 meters.

Table 42. Affected Areas in Lal-lo, Cagayan during 25-Year Rainfall Return Period

AUNUGAY BASIN		Affected Barangays in Lal-lo
		Dagupan
Affected Area (sq. km.)	0.03-0.20	0.00056
	0.21-0.50	0
	0.51-1.00	0
	1.01-2.00	0
	2.01-5.00	0
	> 5.00	0

For the 25-year return period, 12.26% of the municipality of Gonzaga with an area of 497.619 sq. km. will experience flood levels of less 0.20 meters. 0.98% of the area will experience flood levels of 0.21 to 0.50 meters while 0.91%, 1.49%, 1.76% and 0.25% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 43 are the affected areas in square kilometres by flood depth per barangay.

Table 43. Affected Areas in Gonzaga, Cagayan during 25-Year Rainfall Return Period

AUNUGAY BASIN		Affected Barangays in Gonzaga							
		Batangan	Calayan	Callao	Flourishing	Ipil	Isca	Magrafil	Minanga
Affected Area (sq. km.)	0.03-0.20	2.74	3.85	1.88	0.88	4.84	0.39	0.11	0.1099
	0.21-0.50	0.44	0.36	0.17	0.034	0.36	0.048	0.11	0.10708
	0.51-1.00	0.46	0.32	0.1	0.039	0.68	0.0074	0.16	0.15909
	1.01-2.00	0.61	0.37	0.78	0.069	1.18	0.0064	0.8	0.79693
	2.01-5.00	0.42	0.59	0.77	0.047	1.22	0.013	1.24	1.23767
	> 5.00	0.017	0.092	0.029	0.0004	0.31	0.0072	0.0025	0.0025

Table 44. Affected Areas in Gonzaga, Cagayan during 25-Year Rainfall Return Period

AUNUGAY BASIN		Affected Barangays in Gonzaga						
		Paradise	Pateng	Progressive	Rebecca	Santa Clara	Smart	Tapel
Affected Area (sq. km.)	0.03-0.20	0.27	14.19	0.45	1.12	25.56	0.31	3.59
	0.21-0.50	0.044	1.01	0.1	0.17	1.29	0.07	0.36
	0.51-1.00	0.014	0.9	0.069	0.14	0.99	0.033	0.42
	1.01-2.00	0.027	1.35	0.15	0.16	1.19	0.026	0.49
	2.01-5.00	0.16	1.57	0.33	0.24	1.69	0.053	0.29
	> 5.00	0	0.25	0	0.013	0.51	0	0.0073

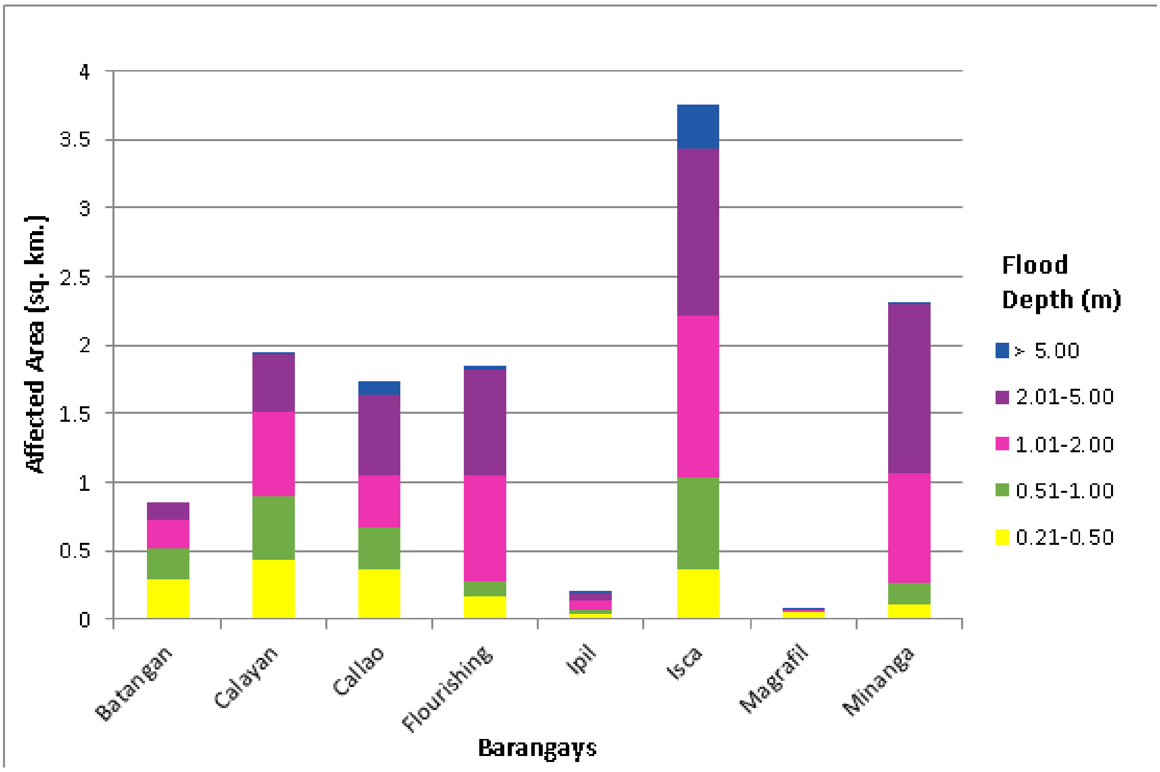


Figure 73. Affected Areas in Gonzaga, Cagayan during 25-Year Rainfall Return Period

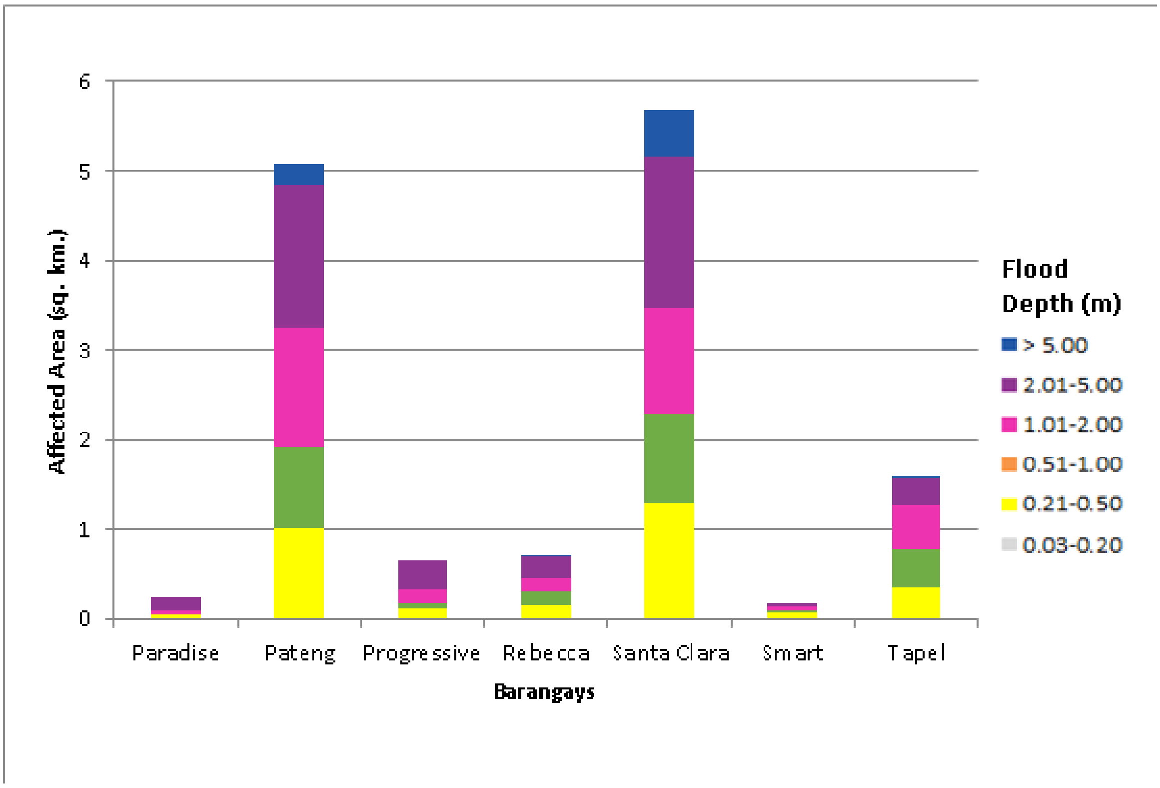


Figure 74. Affected Areas in Gonzaga, Cagayan during 25-Year Rainfall Return Period

For the 100-year return period, 6.76% of the municipality of Santa Teresita with an area of 66.225 sq. km. will experience flood levels of less 0.20 meters. 0.29% of the area will experience flood levels of 0.21 to 0.50 meters while 0.28%, 0.45%, and 0.99% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 45 are the affected areas in square kilometres by flood depth per barangay.

Table 45. Affected Areas in Santa Teresita, Cagayan during 100-Year Rainfall Return Period

AUNUGAY BASIN		Affected Barangays in Santa Teresita
		Dungeg
Affected Area (sq. km.)	0.03-0.20	4.48
	0.21-0.50	0.19
	0.51-1.00	0.19
	1.01-2.00	0.3
	2.01-5.00	0.66
	> 5.00	0

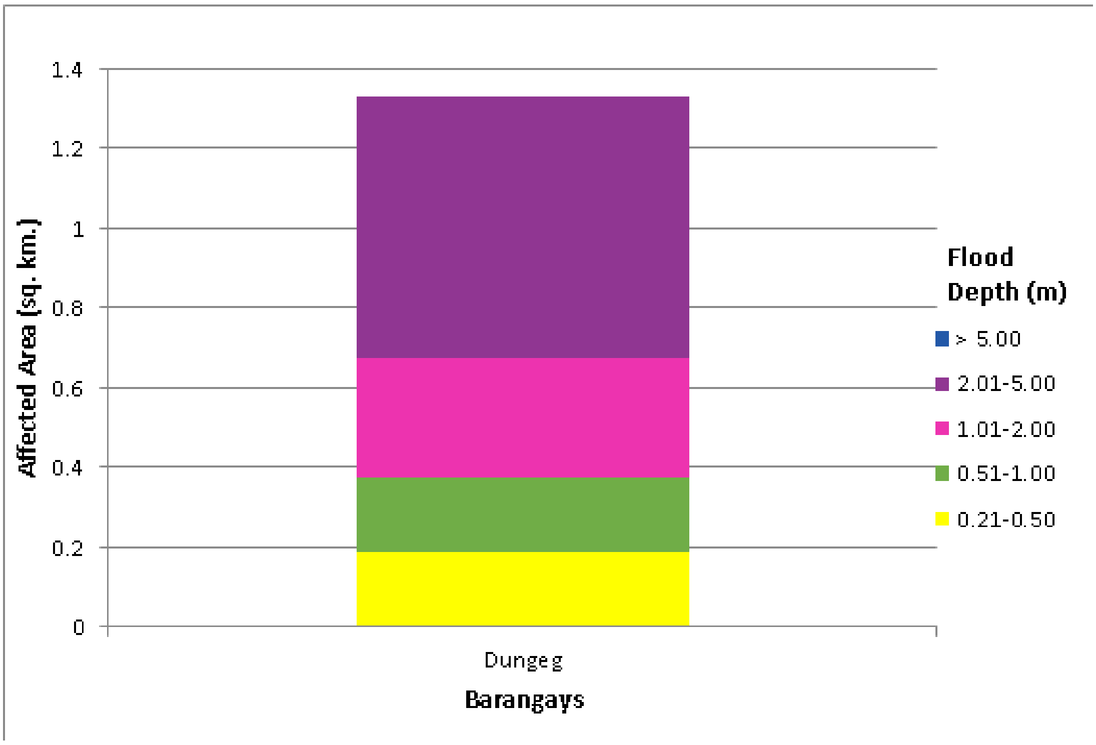


Figure 75. Affected Areas in Santa Teresita, Cagayan during 100-Year Rainfall Return Period

For the 100-year return period, 0.0008456% of the municipality of Lal-lo with an area of 760.444 sq. km. will experience flood levels of less 0.20 meters.

Table 46. Affected Areas in Lal-lo, Cagayan during 100-Year Rainfall Return Period

AUNUGAY BASIN		Affected Barangays in Lal-lo
		Dagupan
Affected Area (sq. km.)	0.03-0.20	0.00056
	0.21-0.50	0
	0.51-1.00	0
	1.01-2.00	0
	2.01-5.00	0
	> 5.00	0

For the 100-year return period, 11.89% of the municipality of Gonzaga with an area of 467.619 sq. km. will experience flood levels of less 0.20 meters. 1.00% of the area will experience flood levels of 0.21 to 0.50 meters while 0.85%, 1.41%, 2.15% and 0.34% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 47 are the affected areas in square kilometres by flood depth per barangay.

Table 47. Affected Areas in Gonzaga, Cagayan during 100-Year Rainfall Return Period

AUNUGAY BASIN		Affected Barangays in Gonzaga							
		Batangan	Calayan	Callao	Flourishing	Ipil	Isca	Magrafil	Minanga
Affected Area (sq. km.)	**0.03-0.20**	0.74	2.6	3.75	1.83	0.86	4.69	0.37	0.073
	0.21-0.50	0.32	0.42	0.35	0.2	0.037	0.31	0.064	0.089
	0.51-1.00	0.25	0.45	0.33	0.089	0.037	0.39	0.009	0.14
	1.01-2.00	0.23	0.6	0.37	0.65	0.067	1.2	0.0069	0.6
	2.01-5.00	0.16	0.59	0.68	0.92	0.068	1.58	0.011	1.51
	> 5.00	0	0.027	0.1	0.043	0.0006	0.43	0.011	0.0049

Table 48. Affected Areas in Gonzaga, Cagayan during 100-Year Rainfall Return Period

AUNUGAY BASIN		Affected Barangays in Gonzaga						
		Paradise	Pateng	Progressive	Rebecca	Santa Clara	Smart	Tapel
Affected Area (sq. km.)	**0.03-0.20**	0.25	13.81	0.39	0.99	25.07	0.29	3.46
	0.21-0.50	0.057	1.03	0.12	0.19	1.34	0.085	0.37
	0.51-1.00	0.016	0.87	0.087	0.15	0.99	0.033	0.42
	1.01-2.00	0.0087	1.32	0.083	0.17	1.16	0.024	0.52
	2.01-5.00	0.18	1.91	0.42	0.28	1.96	0.061	0.39
	> 5.00	0	0.34	0	0.032	0.71	0.0002	0.011

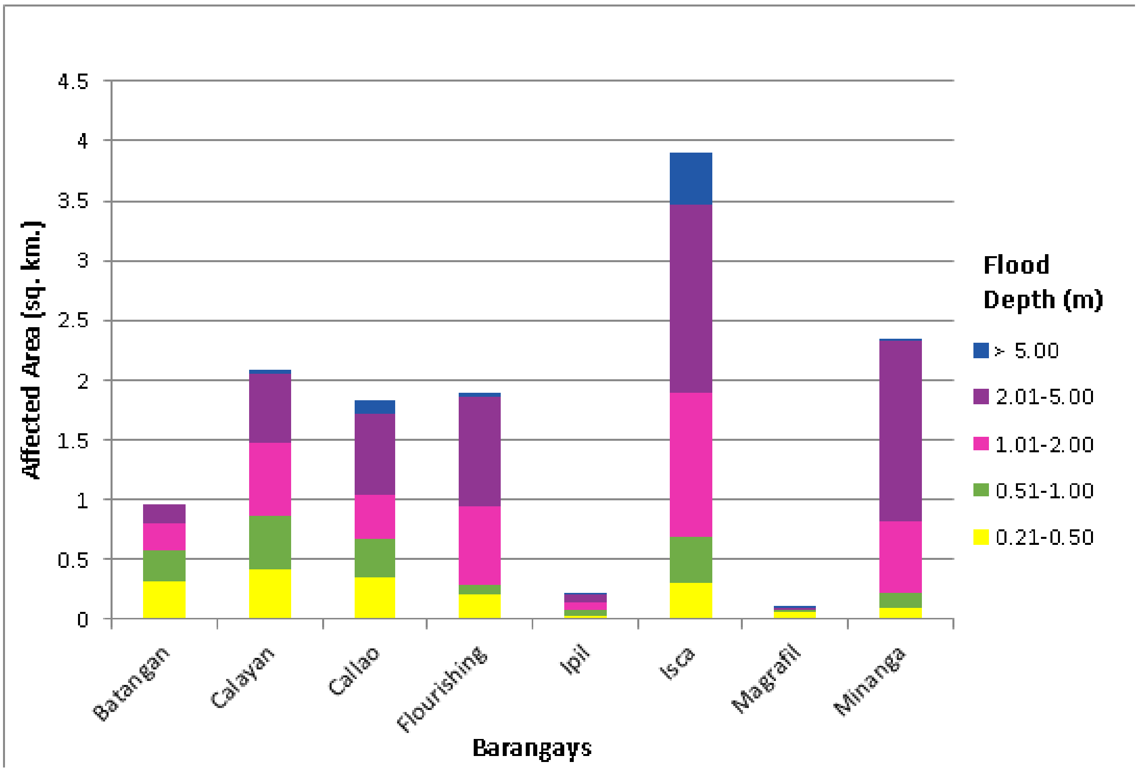


Figure 76. Affected Areas in Gonzaga, Cagayan during 100-Year Rainfall Return Period

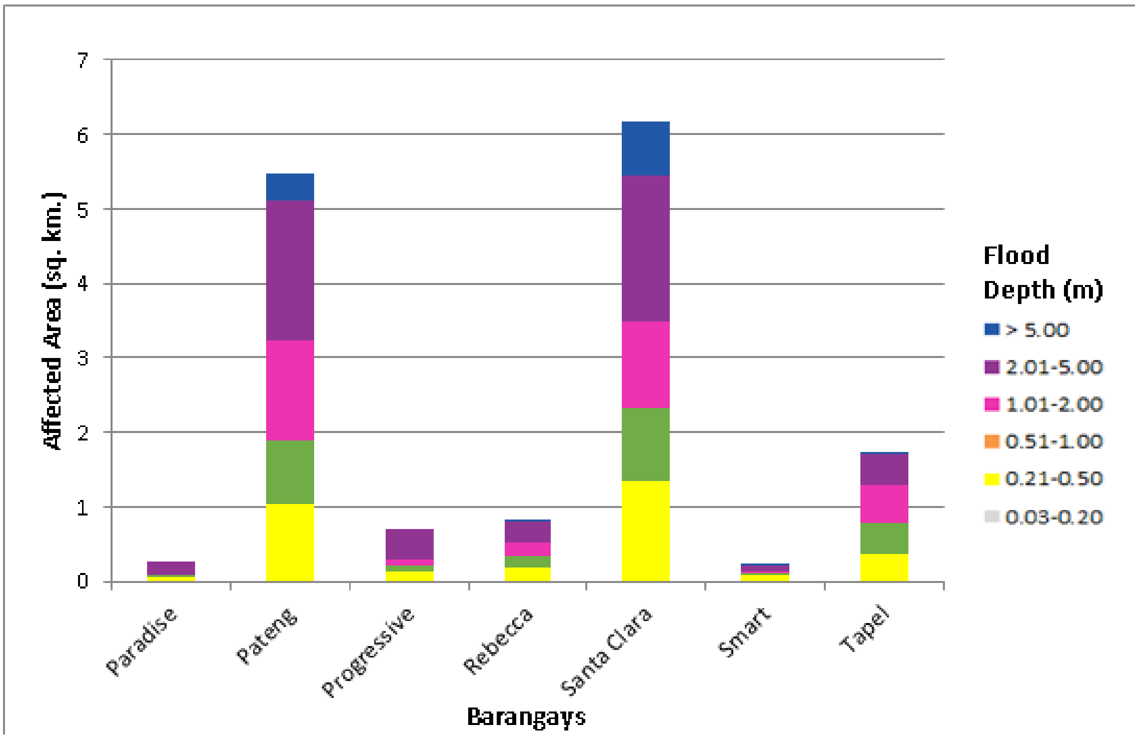


Figure 77. Affected Areas in Gonzaga, Cagayan during 100-Year Rainfall Return Period

Barangay Dungeg in the municipality of Santa Teresita, Cagayan is projected to experience flood levels at 9.22% while Barangay Dagupan in the municipality of Lal-lo, Cagayan is projected to experience flood levels at 7.36%
Among the barangays in the municipality of Gonzaga, Santa Clara is projected to have the highest percentage of area that will experience flood levels at 6.28%. Meanwhile, Pateng posted the second highest percentage of area that may be affected by flood depths at 3.87%.
Moreover, the generated flood hazard maps for the Aunugay Floodplain were used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAG-ASA for hazard maps - “Low”, “Medium”, and “High” - the affected institutions were given their individual assessment for each Flood Hazard Scenario (5 yr, 25 yr, and 100 yr).

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

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	4.37874	3.97809	4.01994
Medium	7.83492	6.19935	5.65985
High	15.9919	21.356701	23.762199

Of the 12 identified Education Institute in Aunugay Flood plain, 1 school was assessed to be exposed to the medium level flooding during a 5 year scenario while 4 schools were assessed to be exposed to high level flooding in the same scenario. In the 25 year scenario, 2 schools were assessed to be exposed to the Low level flooding while 5 schools were assessed to be exposed to high level flooding. For the 100 year scenario, 3 schools were assessed for Low level flooding and 1 school for medium level flooding. In the same scenario, 5 schools were assessed to be exposed to high level flooding.

Six (6) Medical Institutions were identified in Aunugay Floodplain, two were assessed to be exposed to low level flooding while one is exposed to high level flooding in all the scenarios.

5.11 Flood Validation

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

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

The validation personnel will then go to the specified points identified in a river basin and will gather data regarding the actual flood level in each location. Data gathering can be done through a local DRRM office to obtain maps or situation reports about the past flooding events or interview some residents with knowledge of or have had experienced flooding in a particular area.

After which, the actual data from the field will be compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The flood validation consists of 178 points randomly selected all over the Aunugay flood plain. It has an RMSE value of 2.01.

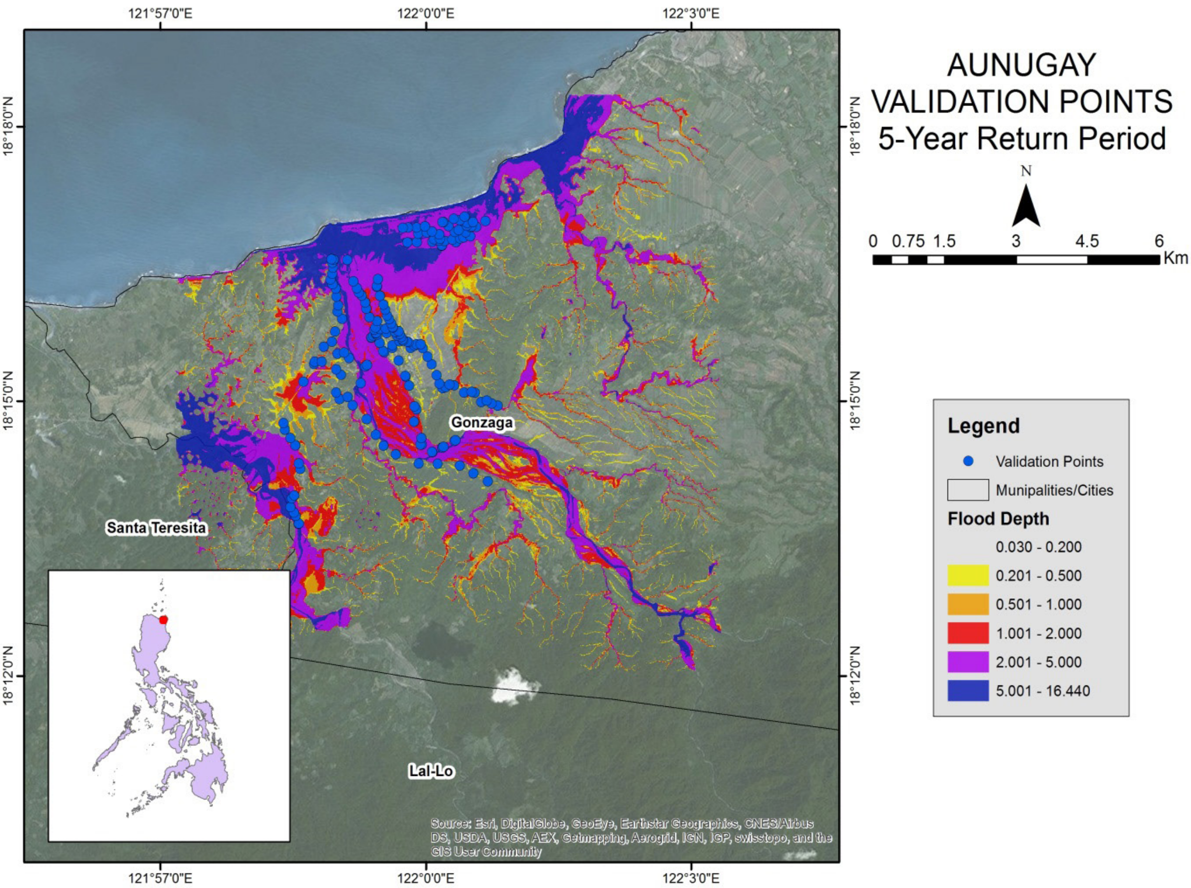


Figure 78. Aunugay Flood Validation Points

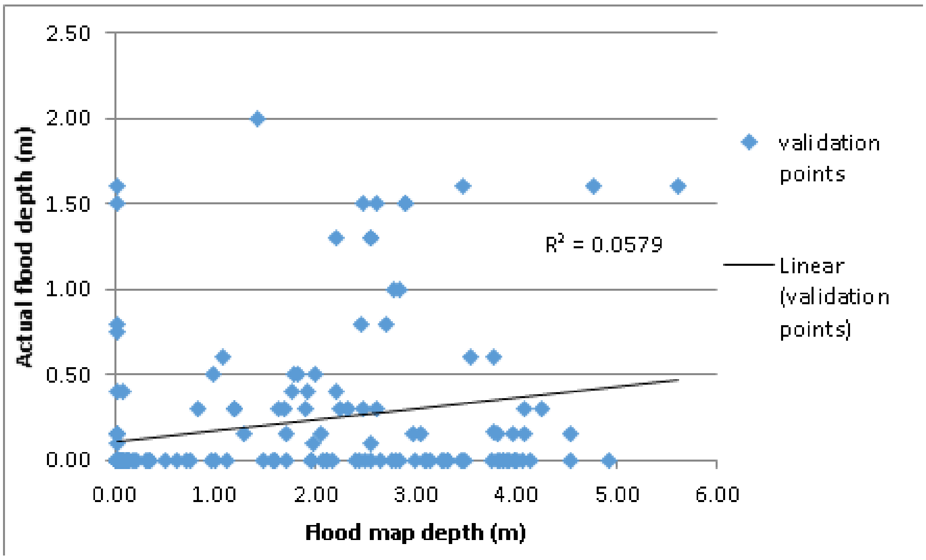


Figure 79. Flood map depth vs. actual flood depth

REFERENCES

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

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

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

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

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

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

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

ANNEXES

ANNEX 1. Technical Specifications of the Lidar Sensors Used In The Bansud Floodplain `Survey

GEMINI SENSOR

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

PEGASUS SENSOR

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

ANNEX 2. NAMRIA Certificates of Reference Points Used in the LiDAR Survey

1. CGY-70

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

November 05, 2013

CERTIFICATION

To whom it may concern:

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

Province: **CAGAYAN**
Station Name: **CGY-70**
Order: **2nd**

Island: **LUZON**
Municipality: **AMULUNG**
Barangay: **ESTEFANIA**

	PRS92 Coordinates	
Latitude: **17° 47' 54.79038"**	Longitude: **121° 43' 31.26837"**	Ellipsoidal Hgt: **26.85900 m.**
	WGS84 Coordinates	
Latitude: **17° 47' 48.71170"**	Longitude: **121° 43' 35.88859"**	Ellipsoidal Hgt: **62.40000 m.**
	PTM Coordinates	
Northing: **1968617.425 m.**	Easting: **576904.118 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,968,239.03**	Easting: **364,899.00**	Zone: **51**

Location Description

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

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

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

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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

2. CGY-89

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

May 17, 2016

CERTIFICATION

To whom it may concern:

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

Province: **CAGAYAN**
Station Name: **CGY-89**
Order: **2nd**

Island:	**LUZON**	Barangay:	**LOGAC**		
Municipality:	**LAL-LO**	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**18° 9' 24.10576"**	Longitude:	**121° 36' 27.80546"**	Ellipsoidal Hgt:	**15.88200 m.**
		WGS84 Coordinates			
Latitude:	**18° 9' 17.94119"**	Longitude:	**121° 36' 32.39657"**	Ellipsoidal Hgt:	**49.97100 m.**
		PTM / PRS92 Coordinates			
Northing:	**2008210.132 m.**	Easting:	**564302.582 m.**	Zone:	**3**
		UTM / PRS92 Coordinates			
Northing:	**2,007,958.66**	Easting:	**352,726.82**	Zone:	**51**

Location Description

CGY-89
From Magapit Bridge, travel along the nat'l. highway to Ilocos. Logac Nat'l. High School is across Km. Post 705. Station is located on the left side of the access road to the entrance of the said school, about 8 m. S of the gate entrance. Mark is the head of a copper nail centered and flushed on a 30 cm. x 30 cm. concrete monument, with inscriptions "CGY-89 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8090370 I**
T.N.: **2016-1117**

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

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CIP/4701/12/09/814

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www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. CGY-92

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

October 29, 2013

CERTIFICATION

To whom it may concern:

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

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

Location Description

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

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

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

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

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www.namria.gov.ph

3. CGY-102

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

December 02, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **CAGAYAN**	
	Station Name: **CGY-102**	
	Order: **2nd**	
Island: **LUZON**	Barangay: **CASAMBALANGAN**	
Municipality: **SANTA ANA**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **18° 22' 15.98573"**	Longitude: **122° 6' 41.74346"**	Ellipsoidal Hgt: **22.60800 m.**
	WGS84 Coordinates	
Latitude: **18° 22' 9.81367"**	Longitude: **122° 6' 46.31361"**	Ellipsoidal Hgt: **57.19500 m.**
	PTM / PRS92 Coordinates	
Northing: **2032192.366 m.**	Easting: **617476.569 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **2,031,351.34**	Easting: **406,145.45**	Zone: **51**

Location Description

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

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

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

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CIP/4701/12/09/814

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

1. CGY-70

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

November 05, 2013

CERTIFICATION

To whom it may concern:

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

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

Location Description

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

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

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

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

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

2. CGY-89

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

May 17, 2016

CERTIFICATION

To whom it may concern:

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

	Province: **CAGAYAN**		
	Station Name: **CGY-89**		
	Order: **2nd**		
Island: **LUZON**	Barangay: **LOGAC**		
Municipality: **LAL-LO**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **18° 9' 24.10576"**	Longitude: **121° 36' 27.80546"**	Ellipsoidal Hgt:	**15.88200 m.**
	WGS84 Coordinates		
Latitude: **18° 9' 17.94119"**	Longitude: **121° 36' 32.39657"**	Ellipsoidal Hgt:	**49.97100 m.**
	PTM / PRS92 Coordinates		
Northing: **2008210.132 m.**	Easting: **564302.582 m.**	Zone:	**3**
	UTM / PRS92 Coordinates		
Northing: **2,007,958.66**	Easting: **352,726.82**	Zone:	**51**

Location Description

CGY-89
From Magapit Bridge, travel along the nat'l. highway to Ilocos. Logac Nat'l. High School is across Km. Post 705. Station is located on the left side of the access road to the entrance of the said school, about 8 m. S of the gate entrance. Mark is the head of a copper nail centered and flushed on a 30 cm. x 30 cm. concrete monument, with inscriptions "CGY-89 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Purpose: **Reference**
OR Number: **8090370 I**
T.N.: **2016-1117**

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

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CIP/4701/12/09/814

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3. CGY-92

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

October 29, 2013

CERTIFICATION

To whom it may concern:

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

Province: **CAGAYAN**
Station Name: **CGY-92**
Order: **2nd**

Island: **LUZON**
Municipality: **LAL-LO**
Barangay: **POBLACION**

PRS92 Coordinates

Latitude: **18° 12' 11.42361"**	Longitude: **121° 39' 42.14392"**	Ellipsoidal Hgt: **14.47400 m.**

WGS84 Coordinates

Latitude: **18° 12' 5.25321"**	Longitude: **121° 39' 46.73084"**	Ellipsoidal Hgt: **48.54000 m.**

PTM Coordinates

Northing: **2013373.807 m.**	Easting: **569996.115 m.**	Zone: **3**

UTM Coordinates

Northing: **2,013,059.26**	Easting: **358,475.41**	Zone: **51**

Location Description

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

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

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

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4. CGY-102

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

December 02, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **CAGAYAN**	
	Station Name: **CGY-102**	
	Order: **2nd**	
Island: **LUZON**	Barangay: **CASAMBALANGAN**	
Municipality: **SANTA ANA**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **18° 22' 15.98573"**	Longitude: **122° 6' 41.74346"**	Ellipsoidal Hgt: **22.60800 m.**
	WGS84 Coordinates	
Latitude: **18° 22' 9.81367"**	Longitude: **122° 6' 46.31361"**	Ellipsoidal Hgt: **57.19500 m.**
	PTM / PRS92 Coordinates	
Northing: **2032192.366 m.**	Easting: **617476.569 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **2,031,351.34**	Easting: **406,145.45**	Zone: **51**

Location Description

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

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

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

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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

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ANNEX 4. The LIDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Lead-er	Data Component Project Leader – I	ENGR. LOUIE BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
LiDAR Operation	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		ENGR. GEROME HIPOLITO	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. IRO NIEL ROXAS	UP-TCAGP
		AUBREY PAGADOR	UP-TCAGP
	Research Associate (RA)	JONATHAN ALMALVEZ	UP-TCAGP
		SANDRA POBLETE	UP-TCAGP
		GRACE SINADJAN	UP-TCAGP
		FRANK NICOLAS ILEJAY	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	DARYL AUSTRIA	UP-TCAGP
		GEF SORIANO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG JOHN ERIC CACANINDIN	PHILIPPINE AIR FORCE (PAF)
		SSG DIOSCORO SOBERANO	PAF
	Pilot	CAPT. JEROME MOONEY	ASIAN AERO-SPACE CORPORA-TION (AAC)
		CAPT. DOMER CORPUZ	AAC
		CAPT. CESAR SHERWIN AL-FONSO III	AAC
		CAPT. JERICO JECIEL	AAC

ANNEX 5. Data Transfer Sheet for Aunugay Floodplain

DATA TRANSFER SHEET
21/06/2016 TUGUEGARAO

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
4/27/2016	3965G	2CAG2DGH118A	GEMINI	NA	367	585	251	NA	NA	28.2	NA	9.67	1KB	1KB	252	NA	Z:\DAC\RAWDATA
4/28/2016	3971G	2BLK3CAG2MQR119A	GEMINI	NA	193	559	252	NA	NA	21	NA	9.78	1KB	1KB	65.1	NA	Z:\DAC\RAWDATA
4/29/2016	3973G	2CAG2GSHS120A	GEMINI	NA	740	662	274	NA	NA	28.6	NA	9.24	1KB	1KB	506	NA	Z:\DAC\RAWDATA
4/30/2016	3977G	2CAG2FG121A	GEMINI	NA	392/99.5/404/107	767	255	NA	NA	29.4	NA	12.1	1KB	1KB	NA	NA	Z:\DAC\RAWDATA
4/30/2016	3979G	2CAG2E121B	GEMINI	NA	99.5	193	71.1	NA	NA	7.57	NA	12.1	1KB	1KB	67.2	NA	Z:\DAC\RAWDATA
5/1/2016	3981G	2CAG2I122A	GEMINI	NA	404	730	263	NA	NA	30.2	NA	8.23	1KB	1KB	23.2/20.6/276/129	NA	Z:\DAC\RAWDATA
5/1/2016	3983G	2CAG2CJ122B	GEMINI	NA	107	220	103	NA	NA	8.25	NA	8.23	1KB	1KB	72.4	NA	Z:\DAC\RAWDATA
5/3/2016	3989G	2BLK3CAG2QSR124A	GEMINI	NA	136/319	514	245	NA	NA	17.1	NA	14.6	1KB	1KB	NA	NA	Z:\DAC\RAWDATA
5/3/2016	3991G	2BLK3CAG2MNSQS124B	GEMINI	NA	204	228	143	NA	NA	8.65	NA	14.6	1KB	1KB	137	NA	Z:\DAC\RAWDATA
5/4/2016	3993G	2BLK3CAG2LMNQR125A	GEMINI	NA	435	161	244	NA	NA	21.2	NA	8.65	1KB	1KB	294	NA	Z:\DAC\RAWDATA
5/5/2016	3997G	2BLK3CAG2NO126A	GEMINI	NA	353	691	272	NA	NA	26.4	NA	13.9	1KB	1KB	239	NA	Z:\DAC\RAWDATA
5/5/2016	3999G	2CAG2P126B	GEMINI	NA	151	290	137	NA	NA	11.6	NA	13.9	1KB	1KB	102	151	Z:\DAC\RAWDATA
5/6/2016	4001G	2BLK3CAG2MRS127A	GEMINI	NA	208	459	245	NA	NA	16.1	NA	9.35	1KB	1KB	138	NA	Z:\DAC\RAWDATA
5/7/2016	4005G	2CAG2ABC128A	GEMINI	NA	316	NA	257	NA	NA	24	NA	8.88	1KB	1KB	215	NA	Z:\DAC\RAWDATA
5/8/2016	4009G	2CAG2K129A	GEMINI	NA	132	286	118	NA	NA	10	NA	5.85	1KB	1KB	114	NA	Z:\DAC\RAWDATA

Name DARRYL AUSTRIA
Position R.A.
Signature

Name AC Bongat
Position SSRS
Signature ACBongat 6/21/16

16-40

DATA TRANSFER SHEET
cagayan3 12/7/15

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	
25-Nov	2894P	1BLK2S329A	pegasus	2.54	na	10.7	215	36.8	304	22.3	NA	8.95	1KB	1KB	114	NA	Z:\DAC\RAW DATA
26-Nov	2898P	1BLK2S330A	pegasus	2.14	na	9.07	167	25.9	218	19.2	NA	62.2	1KB	1KB	166/173/146	NA	Z:\DAC\RAW DATA
30-Nov	2914P	1BLK3A334A	pegasus	1.8	na	8.69	190	3.48	1/101	17.1	NA	97.1	1KB	1KB	163/173/146	NA	Z:\DAC\RAW DATA
30-Nov	2916P	1BLK3A334B	pegasus	1.23	na	6.82	150	17.9	1/150	11.8	NA	97.1	1KB	1KB	57/163/173/146/180	NA	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position
Signature

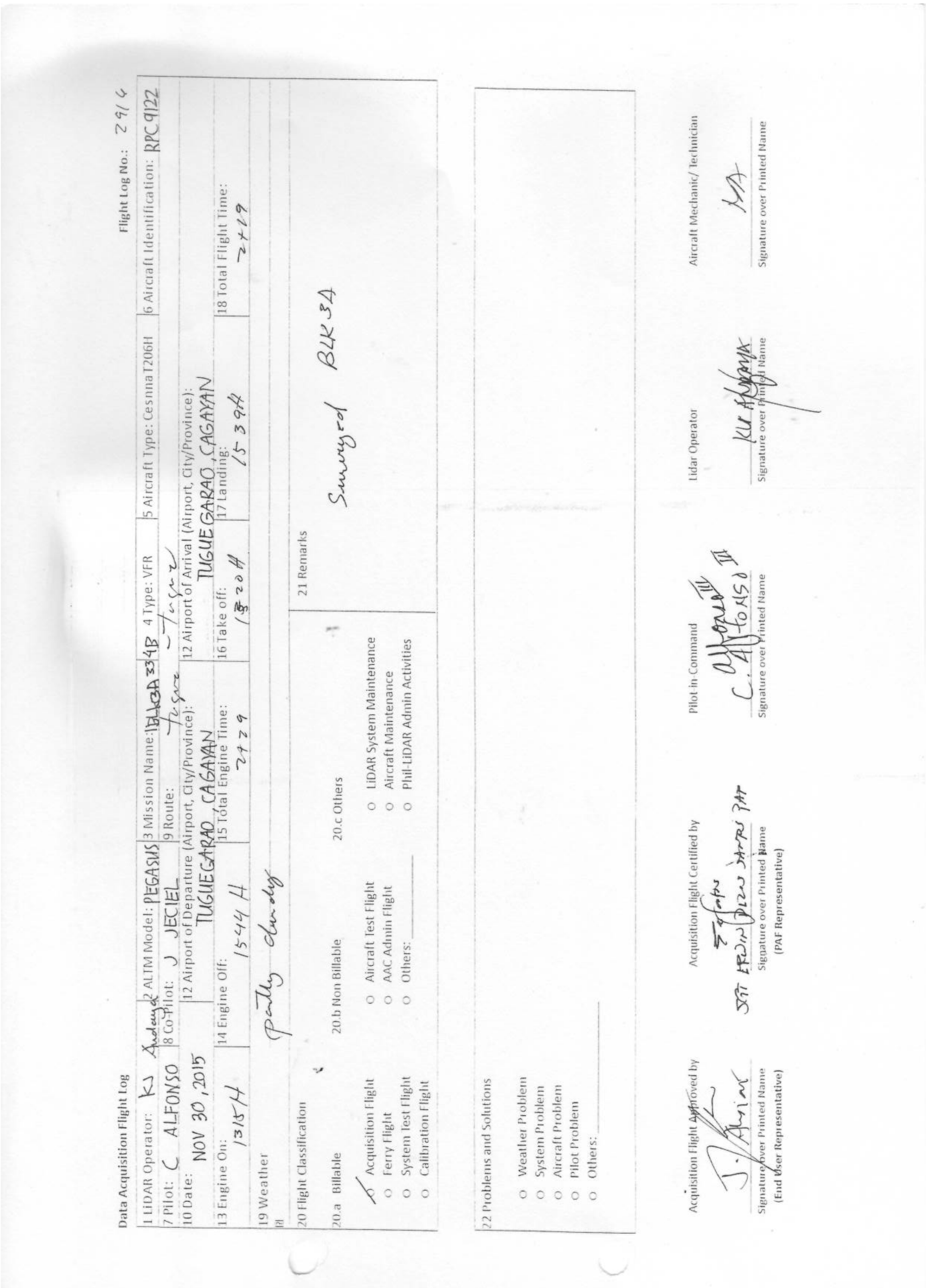
Received by

Name KC Bongat 12/8/2015
Position SSRS
Signature

15-43

ANNEX 6. Flight logs for the Flight Missions

1. Flight Log for 1BLK3A334B Mission



Data Acquisition Flight Log

Flight Log No.: 2916

1 LiDAR Operator: KJ Andaya | 2 ALTM Model: PEGASUS | 3 Mission Name: 1BLK3A334B | 4 Type: VFR | 5 Aircraft Type: Cesnna T206H | 6 Aircraft Identification: RPC9122

7 Pilot: C ALFONSO | 8 Co-Pilot: J JECIEL | 9 Route: Tugue - Tugue

10 Date: NOV 30, 2015 | 12 Airport of Departure (Airport, City/Province): TUGUEGARAO, CAGAYAN | 12 Airport of Arrival (Airport, City/Province): TUGUEGARAO, CAGAYAN

13 Engine On: 1315H | 14 Engine Off: 1544H | 15 Total Engine Time: 2+29 | 16 Take off: 1320H | 17 Landing: 1539H | 18 Total Flight Time: 2+19

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: Surveyed BLK3A

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

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

Acquisition Flight Certified by: SSGT ERWIN DIZON SANTOS PAF — Signature over Printed Name (PAF Representative)

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

Lidar Operator: KJ ANDAYA — Signature over Printed Name

Aircraft Mechanic/ Technician — Signature over Printed Name

2. Flight Log for 2BLK3CAG2MQR119A Mission

UP DREAM **Data Acquisition Flight Log** **Flight Log No.:** 3971

1 LiDAR Operator: J. ALMALVEZ	2 ALTM Model: GEMINI	3 Mission Name: 2BLK3CAG2MQR119A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORPUZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: APRIL 28, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 1009 H	14 Engine Off: 1424 H	15 Total Engine Time: 04 + 15	16 Take off: 1014 H	17 Landing: 1419 H	18 Total Flight Time: 04 + 05
19 Weather	FAIR				

20 Flight Classification

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

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

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

21 Remarks

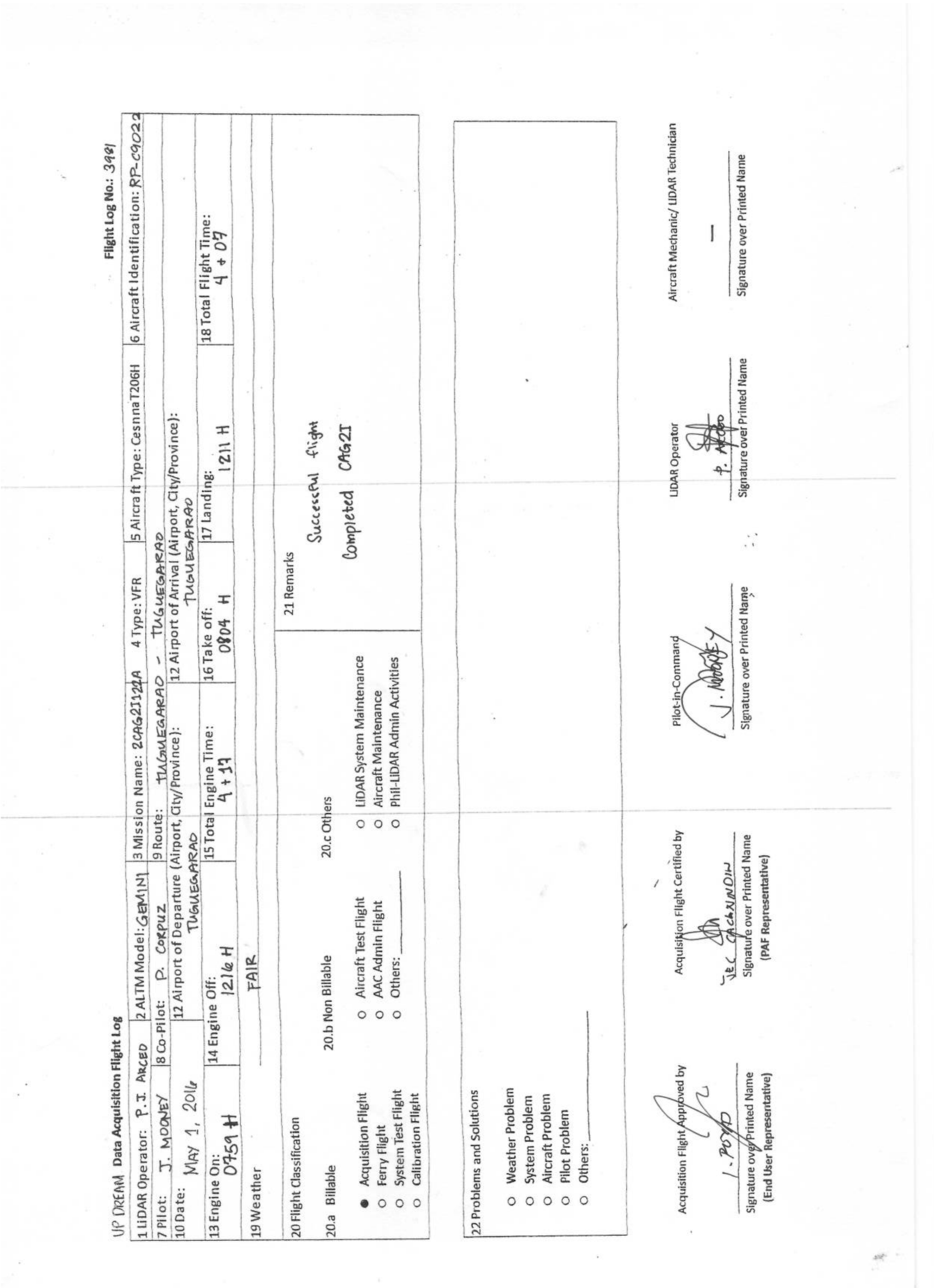
SUCCESSFUL FLIGHT

Covered Baua, Casambalangan & Palawig floodplains

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
I. ROXAS	JEC PACAWNON	J. MOONEY	J. ALMALVEL	–
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

3. Flight Log for 2CAG2I122A Mission



UP DREAM Data Acquisition Flight Log

Flight Log No.: 3981

1 LiDAR Operator: P.J. ARCEO	2 ALTM Model: GEMINI	3 Mission Name: 2CAG2I122A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: P. CORPUZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: MAY 1, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 0759 H	14 Engine Off: 1216 H	15 Total Engine Time: 4 + 17	16 Take off: 0804 H	17 Landing: 1211 H	18 Total Flight Time: 4 + 07
19 Weather: FAIR					

20 Flight Classification

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

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

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

21 Remarks

Successful flight

Completed CAG2I

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
I. POYAO	JEC CACHANINDIN	J. MOONEY	P. ARCEO	—
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

4. Flight Log for 2BLK3CAG2MNSQS124B Mission

UP DREAM Data Acquisition Flight Log

Flight Log No.: 3991

1 LiDAR Operator: J. ALMALVEZ	2 ALTM Model: GEMINI	3 Mission Name: 2BLK3CAG2MSQS124B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORPUZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: MAY 3, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 1334 H	14 Engine Off: 1600 H	15 Total Engine Time: 2+26	16 Take off: 1339 H	17 Landing: 1555 H	18 Total Flight Time: 2+16
19 Weather	PARTLY CLOUDY				

20 Flight Classification

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

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

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

21 Remarks

Successful flight

Covered CAG2M and O

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
[illegible]	[illegible]	J. MOONEY	J. Almalvez	—
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

5. Flight Log for 2BLK3CAG2LMNQR125A Mission

UP DREAM **Data Acquisition Flight Log**

Flight Log No.: 3993

1 LiDAR Operator: J. ALMALVEZ	2 ALTM Model: GEMINI	3 Mission Name: 2BLK3CAG2LMNQR125A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORPUZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: MAY 4, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 0853 H	14 Engine Off: 1304 H	15 Total Engine Time: 4+11	16 Take off: 0858 H	17 Landing: 1259 H	18 Total Flight Time: 4+01
19 Weather: PARTLY CLOUDY					

20 Flight Classification

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

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

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

21 Remarks

Successful Flight

Covered CAG2L, M and Q

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
I. ROXAS	JEC GAGANDIN	J. MOONEY	J. ALMALVEZ	—
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

6. Flight Log for 2BLK3CAG2NO126A Mission

UP DREAM **Data Acquisition Flight Log**

Flight Log No.: 3997

1 LiDAR Operator: I. ROXAS	2 ALTM Model: GEMINI	3 Mission Name: 2BLK3CAG2NO126A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORRUZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: MAY 5, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 0820 H	14 Engine Off: 1244 H	15 Total Engine Time: 4 + 24	16 Take off: 0825 H	17 Landing: 1239 H	18 Total Flight Time: 4 + 14
19 Weather	FAIR				

20 Flight Classification

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

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

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

21 Remarks

Successful Flight
Completed CAG2N and O

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

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

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

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

LiDAR Operator
I. ROXAS
Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician
-
Signature over Printed Name

7. Flight Log for 2BLK3CAG2MRS127A Mission

UP DREAM **Data Acquisition Flight Log**

Flight Log No.: 4001

1 LiDAR Operator: J. ALMALVEZ	2 ALTM Model: GEMINI	3 Mission Name: 2BLK3CAG2MRS127A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORPUZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: MAY 6, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 1033 H	14 Engine Off: 1433 H	15 Total Engine Time: 4+00	16 Take off: 1038 H	17 Landing: 1428 H	18 Total Flight Time: 3+50
19 Weather: PARTLY CLOUDY					

20 Flight Classification

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

21 Remarks

Successful flight

Completed CAG2M and Gambalangan Floodplain

22 Problems and Solutions

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
I. ROXAS	JEC CAPANINON	J. MOONEY	[illegible]	–
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

8. Flight Log for 2CAG2K129A Mission

UP DREAM Data Acquisition Flight Log

Flight Log No.: 4009

1 LiDAR Operator: J. ROXAS	2 ALTM Model: GEMINI	3 Mission Name: 2CAG2K129A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. MOONEY	8 Co-Pilot: D. CORPUZ	9 Route: TUGUEGARAO - TUGUEGARAO			
10 Date: MAY 8, 2016	12 Airport of Departure (Airport, City/Province): TUGUEGARAO		12 Airport of Arrival (Airport, City/Province): TUGUEGARAO		
13 Engine On: 1020 H	14 Engine Off: 1215 H	15 Total Engine Time: 1+55	16 Take off: 1025 H	17 Landing: 1210 H	18 Total Flight Time: 1+45
19 Weather: PARTLY CLOUDY					

20 Flight Classification

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

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

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

21 Remarks

Successful flight
Completed CAG2K

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
I. ROXAS	JEC CALCANHOA	J. MOONEY	I. ROXAS	—
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

ANNEX 7. Flight Status Reports

TUGUEGARAO (November 30, 2015 and April 28 to May 8, 2016)					
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2916P	BLK 3A AUNUGAY FP, BAUA FP	1BLK3A334B	KJ ANDAYA	NOV 30, 2015	SURVEYED AUNUGAY AND BAUA FPs 120.97 SQ.KM
3971G	CAG2M, CAG2Q, CAG2R	2BLK3CAG2MQR119A	J. ALMALVEZ	April 28, 2016	Covered Baua, Casambalangan and Palawig Floodplains
3981G	CAG2I	2CAG2I122A	P. ARCEO	May 1, 2016	Completed CAG2I
3991G	CAG2M, CAG2Q, CAG2R	2BLK3CAG2MSQS124B	J. ALMALVEZ	May 3, 2016	Covered CAG2M and Q
3993G	CAG2L, CAG2M, CAG2Q, CAG2R	2BLK3CAG2LMQR125A	J. ALMALVEZ	May 4, 2016	Covered CAG2L, M, and Q
3997G	CAG2N, CAG2O	2BLK3CAG2NO126A	I. ROXAS	May 5, 2016	Completed CAG2N and O
4001G	CAG2M, CAG2R	2BLK3CAG2MRS127A	J. ALMALVEZ	May 6, 2016	Completed CAG2M and
4009G	CAG2K	2CAG2K129A	I. ROXAS	May 8, 2016	Completed CAG2K

LAS BOUNDARIES PER FLIGHT

Flight No.: 2916P

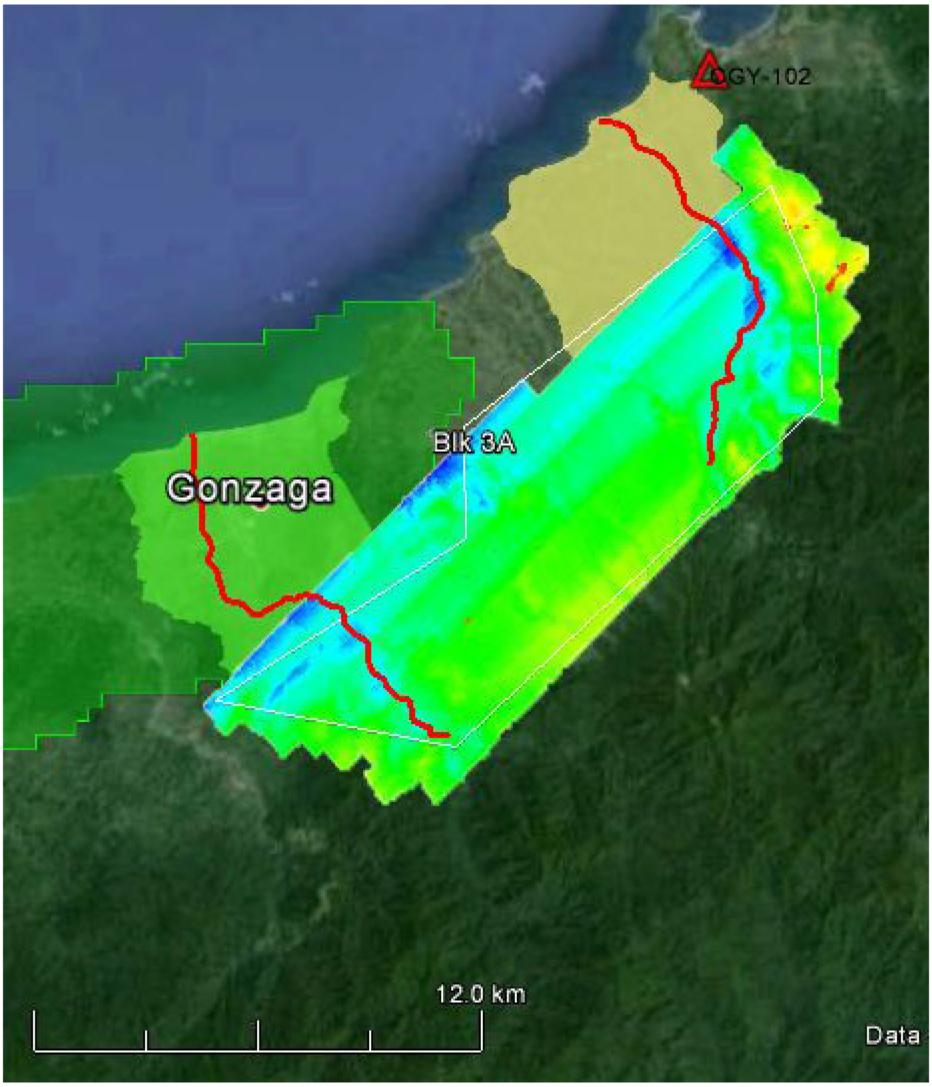
Area: BLK 3A

Mission Name: 1BLK3A334B

Parameters: Altitude: 1000 m; Scan Frequency: 30 Hz;

Scan Angle: 30 deg; Overlap: 30%

LAS



Flight No.: 3971G

Area: CAG2M, CAG2Q, CAG2R

Mission Name: 2BLK3CAG2MQR119A

Parameters: Altitude: 1000 m; Scan Frequency: 50 Hz;

Scan Angle: 30 deg; Overlap: 30%

LAS

Flight No.: 3981G

Area: CAG2I

Mission Name: 2CAG2I122A

Parameters: Altitude: 1000 m; Scan Frequency: 50 Hz;

Scan Angle: 30 deg; Overlap: 30%

LAS

Flight No.: 3991G

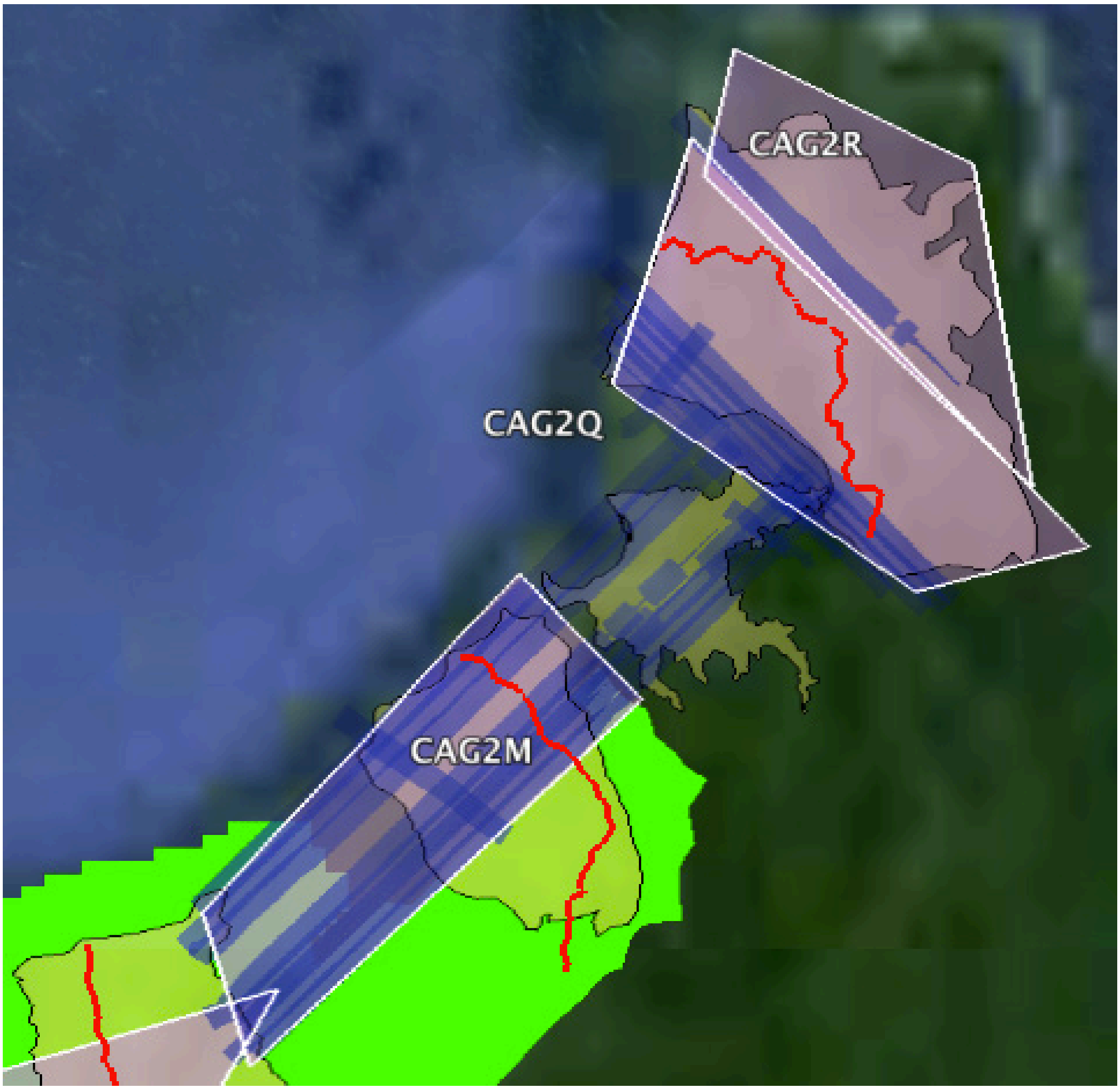
Area: CAG2M, CAG2Q, CAG2R

Mission Name: 2BLK3CAG2MNSQS124B

Parameters: Altitude: 1000 m; Scan Frequency: 50 Hz;

Scan Angle: 30 deg; Overlap: 35%

LAS



Flight No.: 3993G

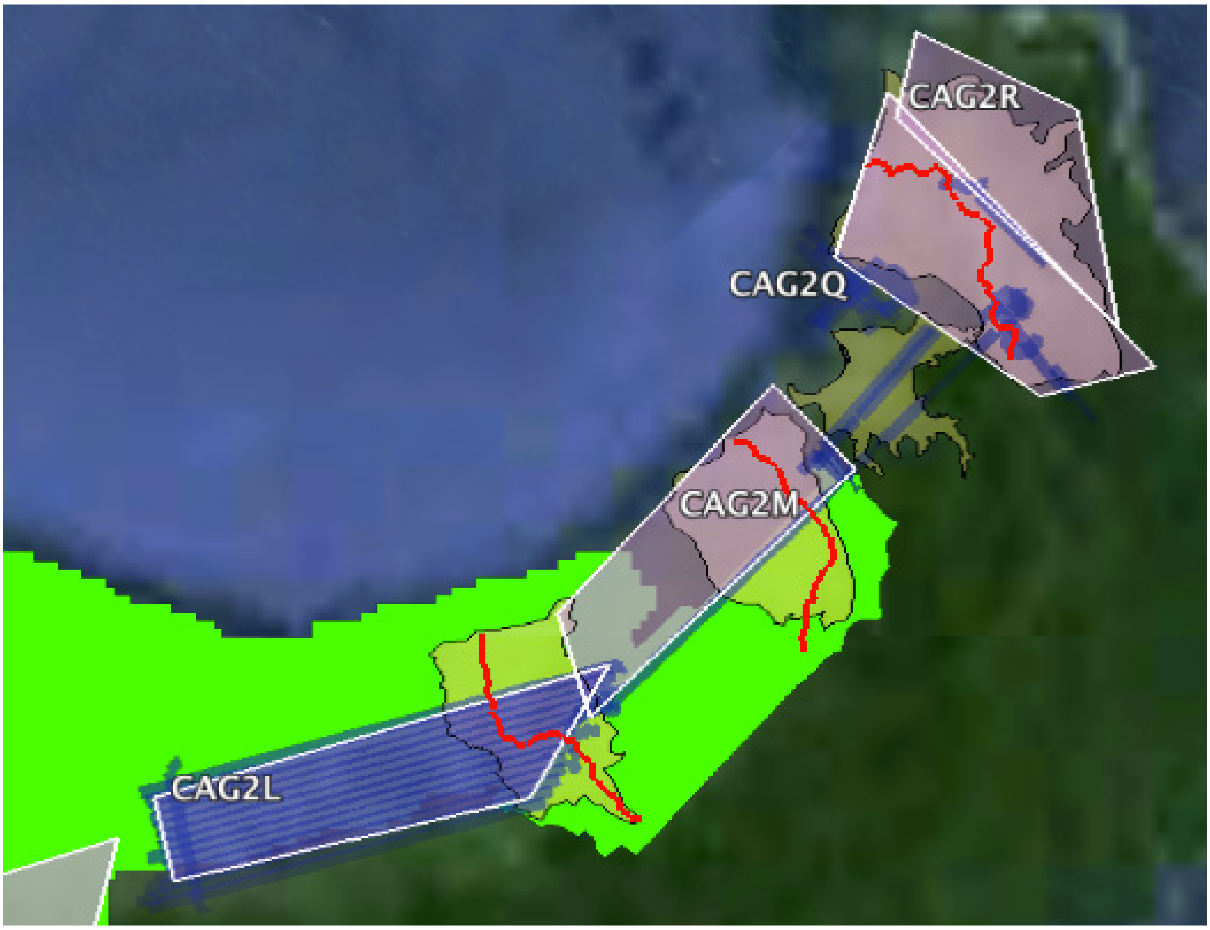
Area: CAG2M, CAG2Q, CAG2R

Mission Name: 2BLK3CAG2LMNQR125A

Parameters: Altitude: 800 m; Scan Frequency: 50 Hz;

Scan Angle: 30 deg; Overlap: 35%

LAS



Flight No.: 3997G

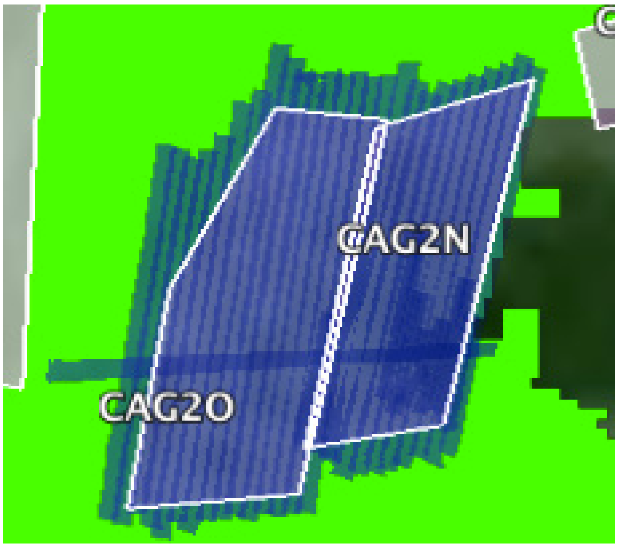
Area: CAG2N, CAG2O

Mission Name: 2BLK3CAG2NO126A

Parameters: Altitude: 1000 m; Scan Frequency: 50 Hz;

Scan Angle: 30 deg; Overlap: 35%

LAS



Flight No.: 4001G

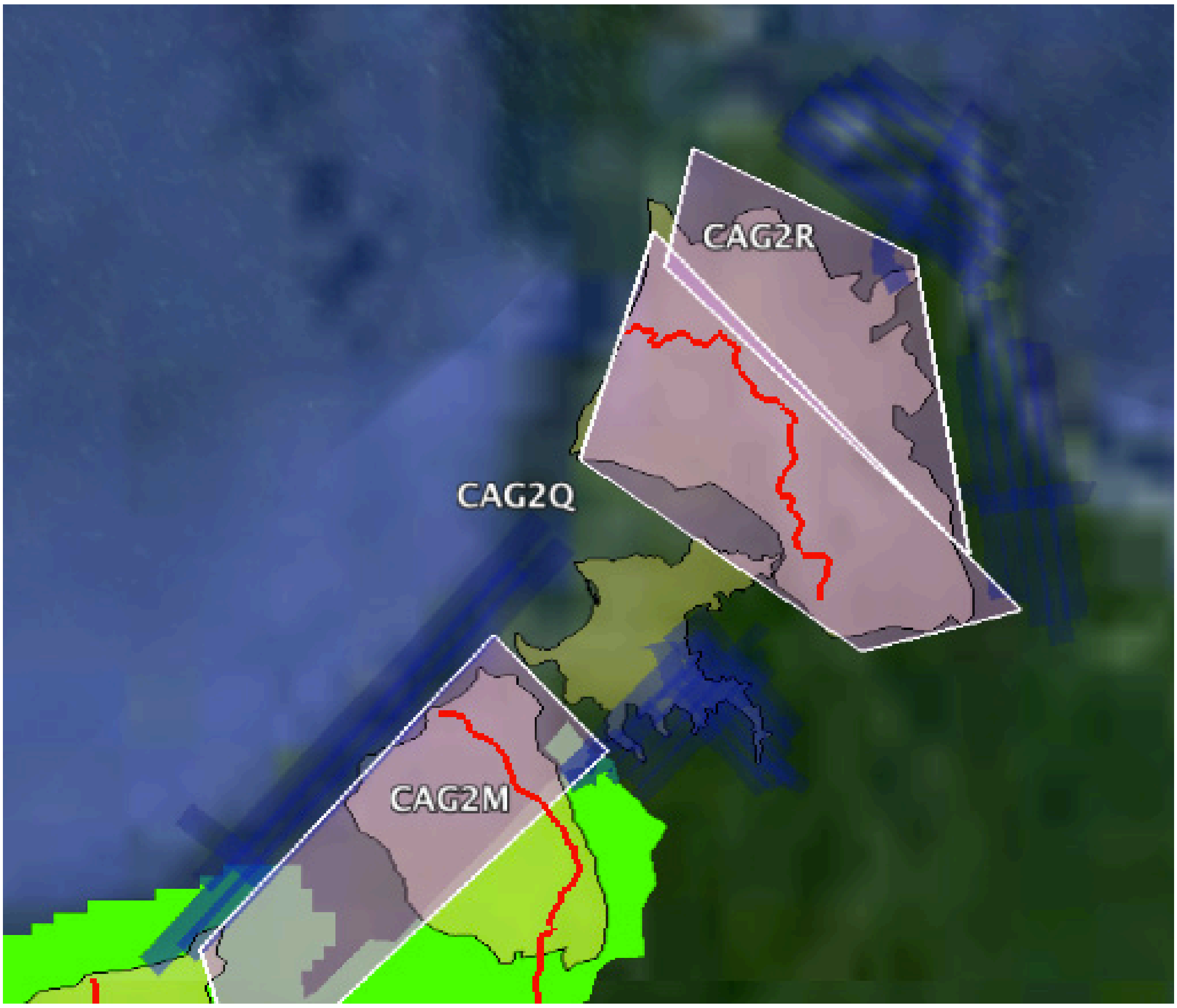
Area: CAG2M, CAG2R

Mission Name: 2BLK3CAG2MRS127A

Parameters: Altitude: 1000 m; Scan Frequency: 50 Hz;

Scan Angle: 30 deg; Overlap: 35%

LAS



Flight No.: 4009G

Area: CAG2K

Mission Name: 2CAG2K129A

Parameters: Altitude: 1000 m; Scan Frequency: 50 Hz;

Scan Angle: 30 deg; Overlap: 35%

LAS

ANNEX 8. Mission Summary Reports

Flight Area	Cagayan Reflights(Tuguegarao)
Mission Name	Blk3A
Inclusive Flights	2916P
Range data size	11.8GB
Base data size	97.1 MB
POS	150MB
Image	17.9MB
Transfer date	December 8, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.87
RMSE for East Position (<4.0 cm)	1.65
RMSE for Down Position (<8.0 cm)	2.61
Boresight correction stdev (<0.001deg)	0.000319
IMU attitude correction stdev (<0.001deg)	0.001384
GPS position stdev (<0.01m)	0.0023
Minimum % overlap (>25)	30.46
Ave point cloud density per sq.m. (>2.0)	3.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	138
Maximum Height	677.25 m
Minimum Height	57.52 m
Classification (# of points)	
Ground	109,071,592
Low vegetation	74,643,090
Medium vegetation	133,250,063
High vegetation	287,388,029
Building	8,589,940
Orthophoto	Yes
Processed by	Engr. Angelo Carlo Bongat, Ma. Joanne Balaga, Jovy Narisma

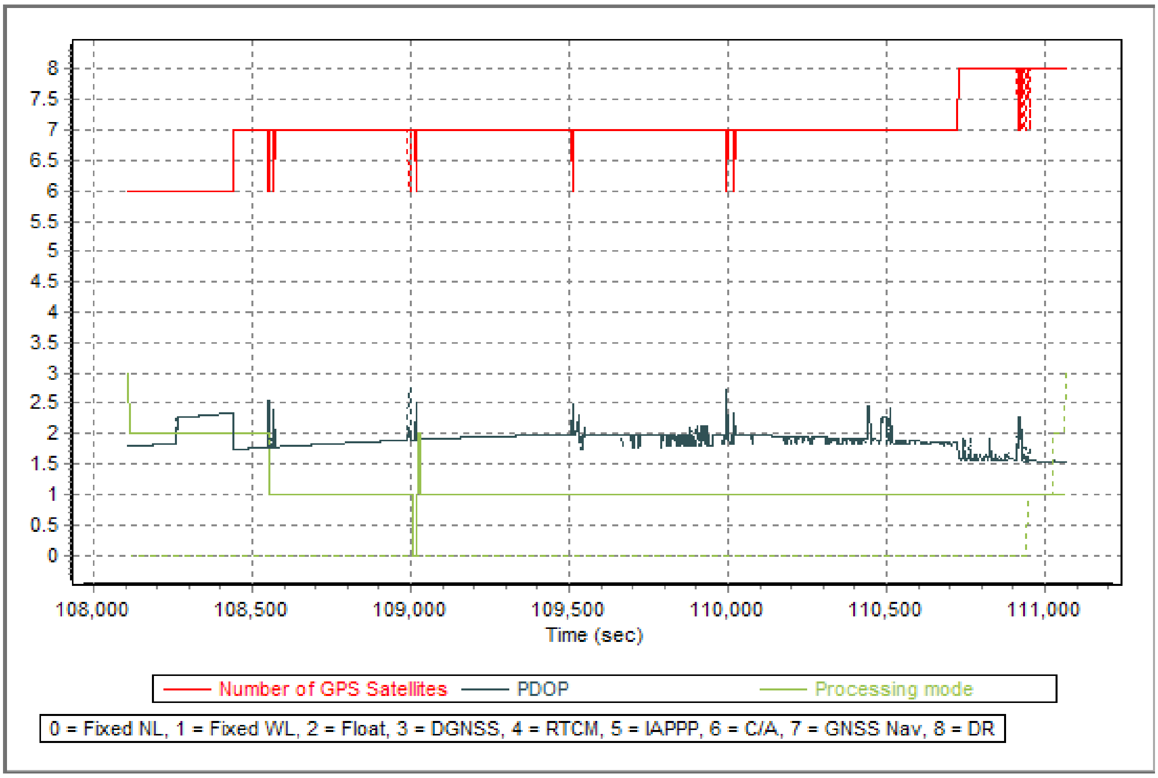


Figure 1.1.1. Solution Status

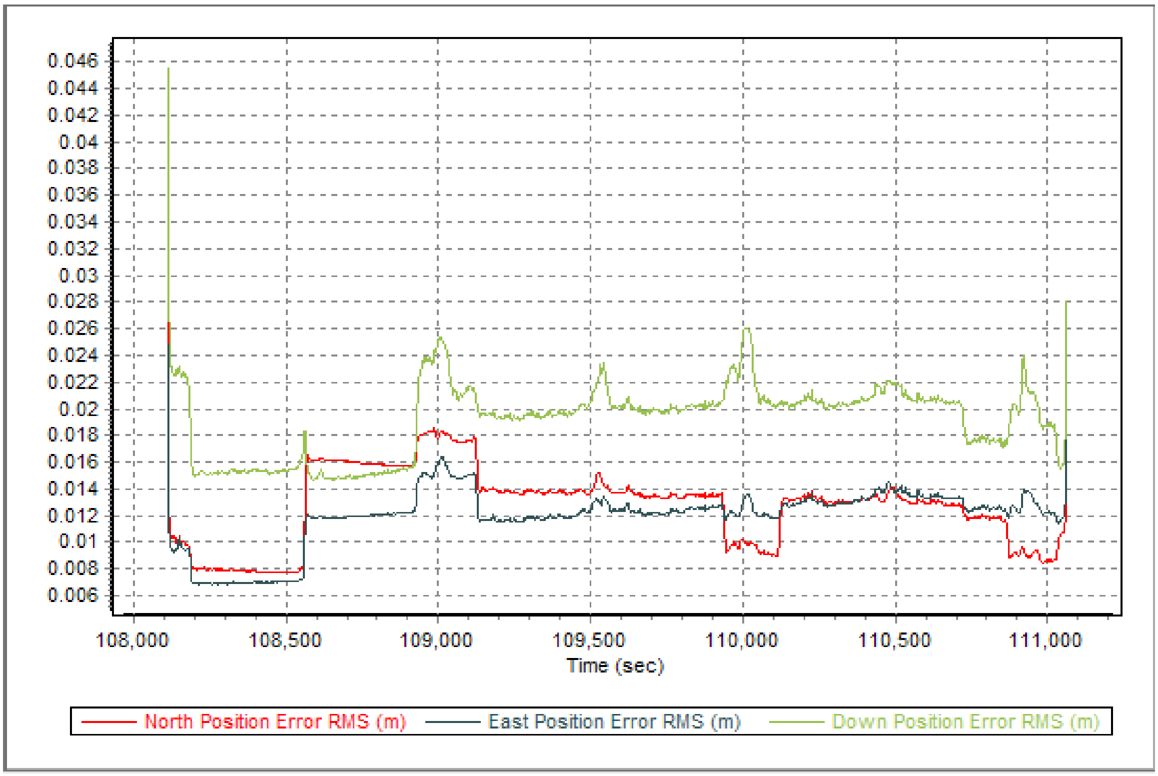


Figure 1.1.2. Smoothed Performance Metric Parameters

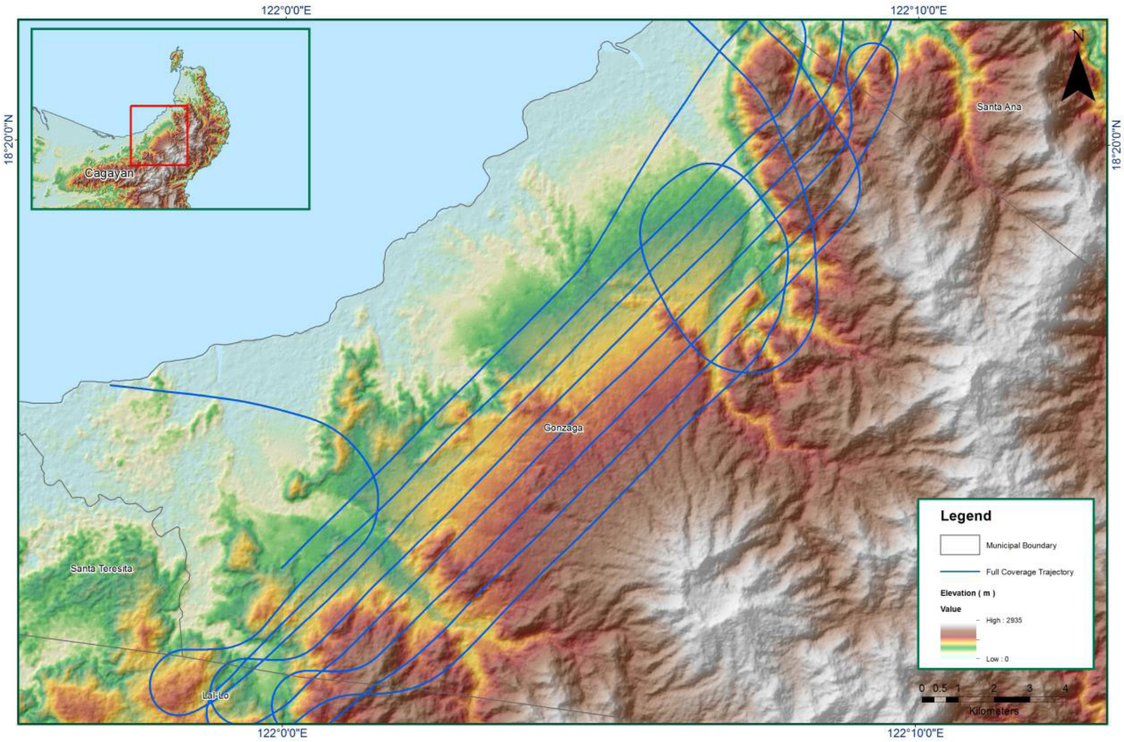


Figure 1.1.3. Best Estimated Trajectory

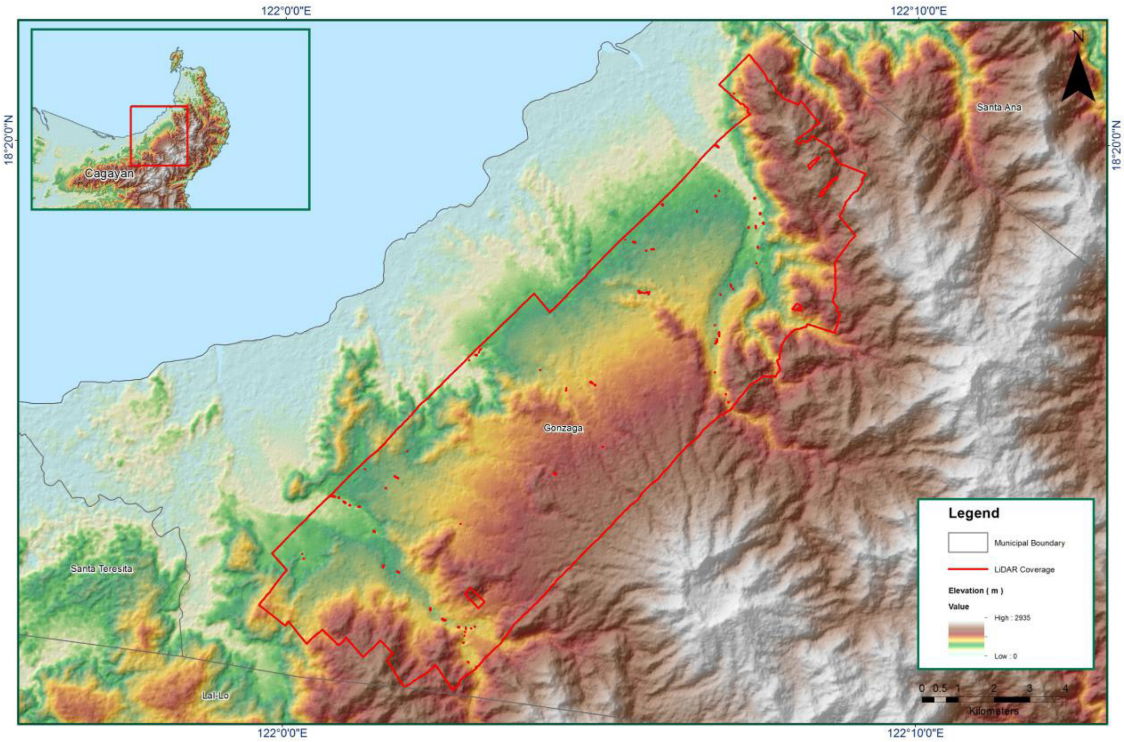


Figure 1.1.4. Coverage of LiDAR Data

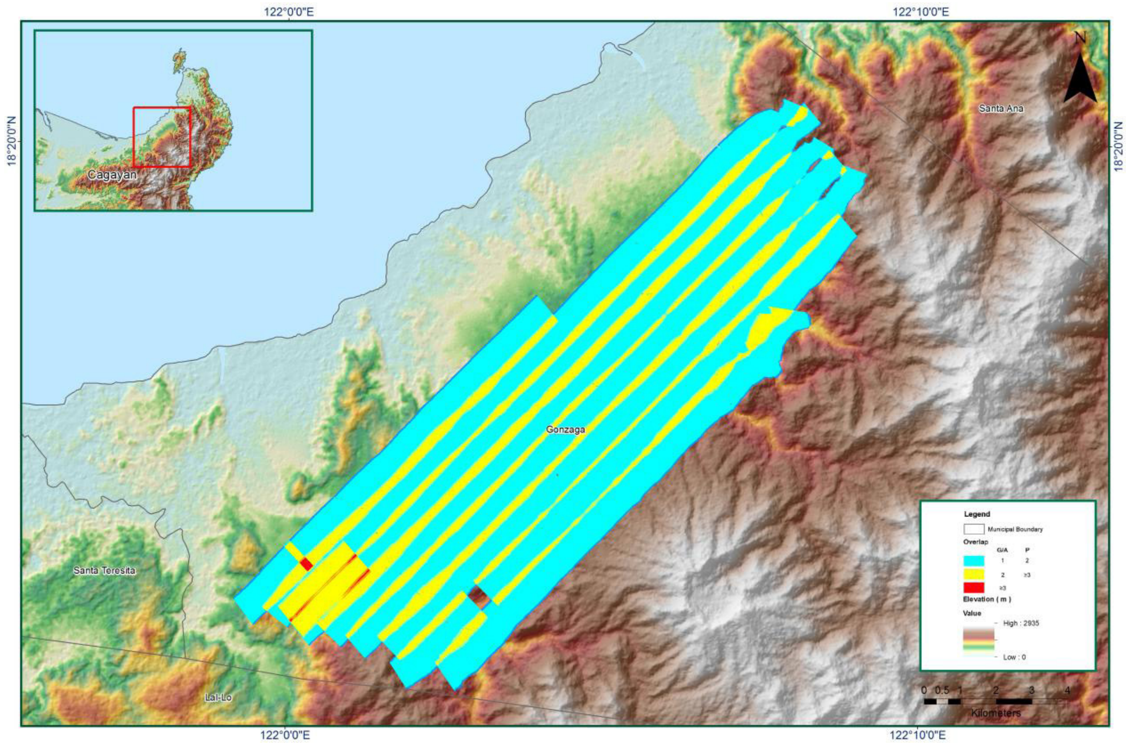


Figure 1.1.5. Image of data overlap

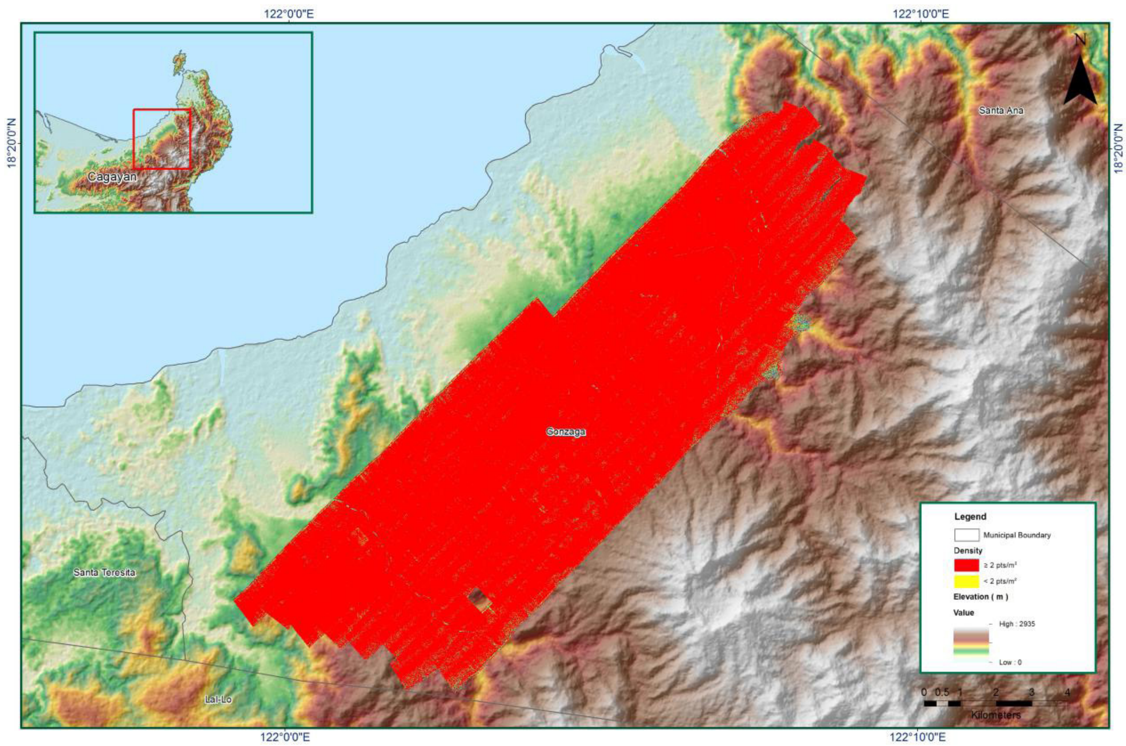


Figure 1.1.6. Density map of merged LiDAR data

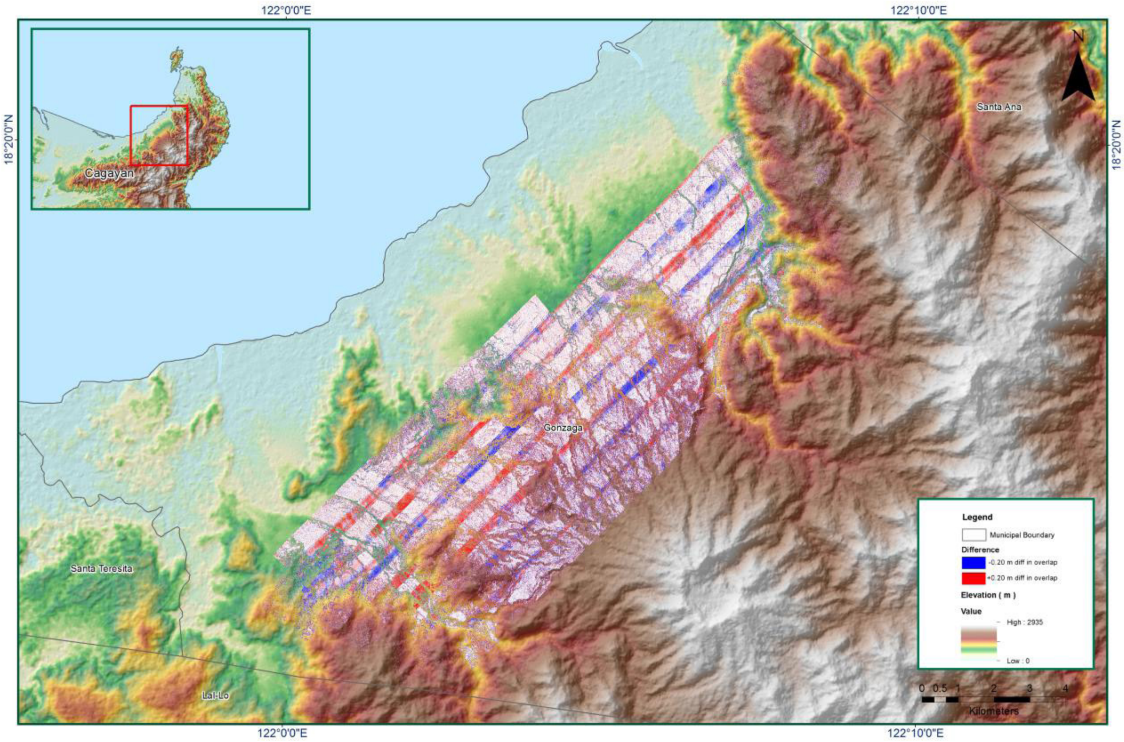


Figure 1.1.7. Elevation difference between flight lines

Flight Area	Cagayan
Mission Name	**Cagayan_reflights_Blk21D**
Inclusive Flights	3993G
Range data size	21.2 GB
Base data size	8.65 MB
POS data size	244 MB
Base data size	8.65 MB
Image	NA
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	6.0
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	35.79%
Ave point cloud density per sq.m. (>2.0)	4.25
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	140
Maximum Height	282.18 m
Minimum Height	41.94 m
Classification (# of points)	
Ground	82,018,459
Low vegetation	70,074,365
Medium vegetation	144,345,343
High vegetation	141,186,272
Building	1,222,089
Orthophoto	No
Processed by	Engr. Angelo Carlo Bongat, Engr. Edgardo Gubatanga, Jr., Jovy Narisma

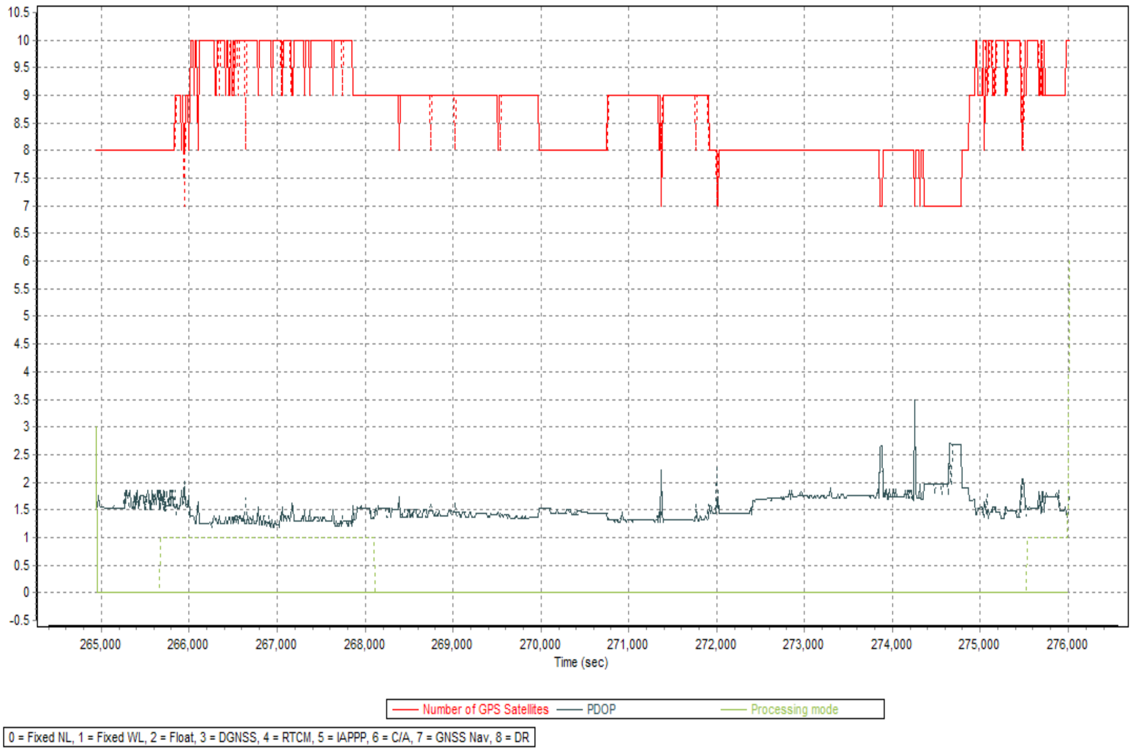


Figure 1.2.1. Solution Status

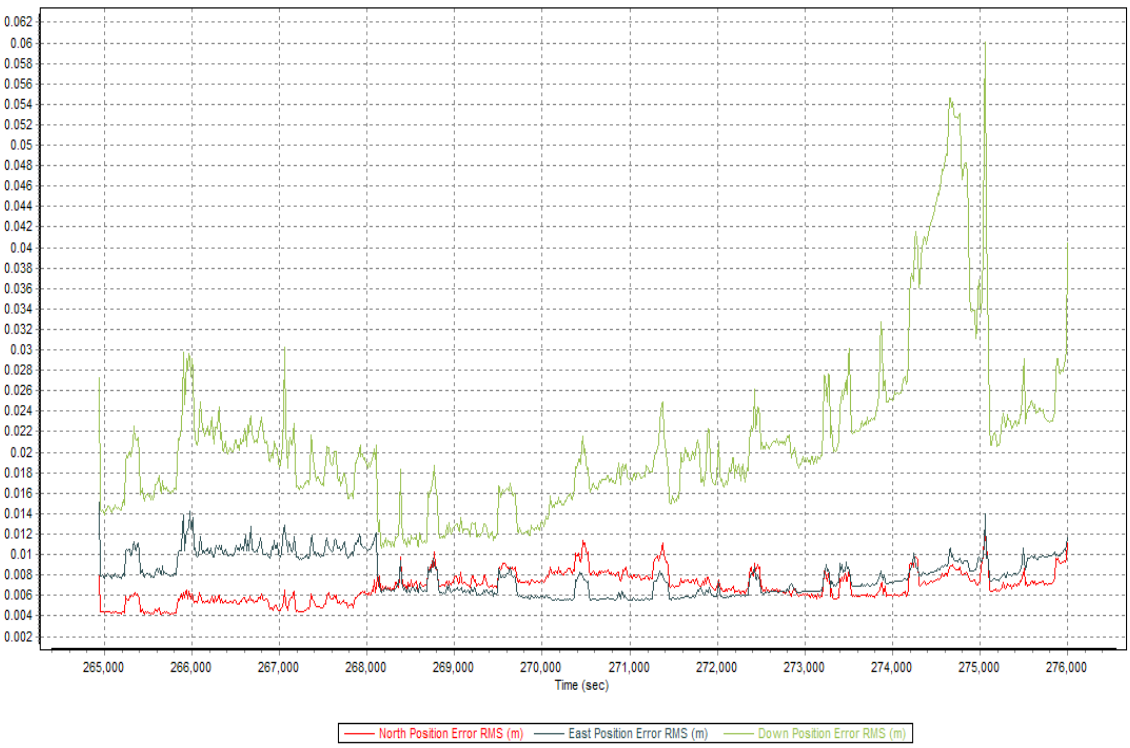


Figure 1.2.2. Smoothed Performance Metric Parameters

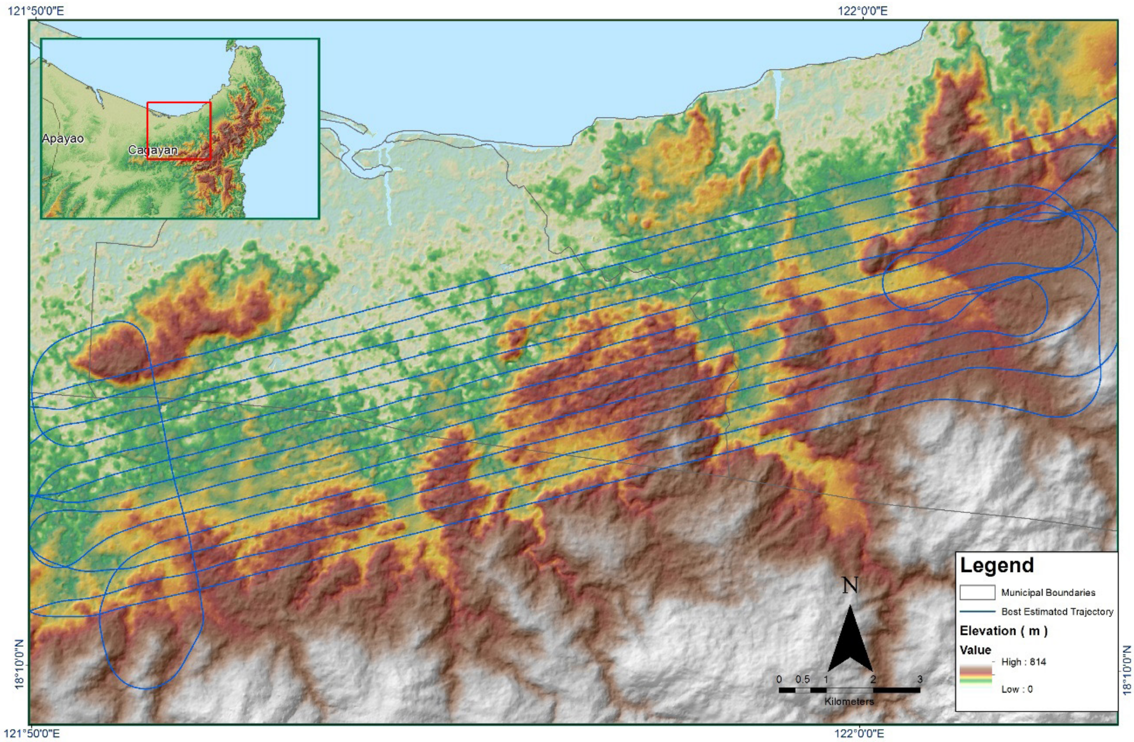


Figure 1.2.3. Best Estimated Trajectory

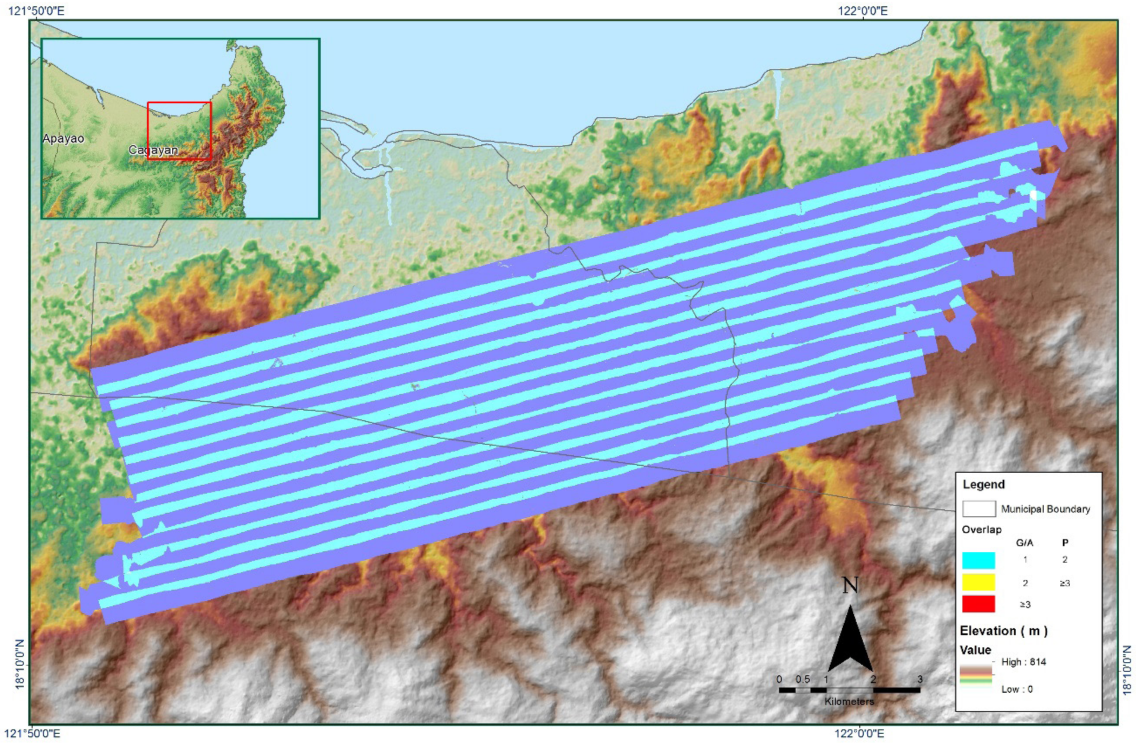


Figure 1.2.4. Coverage of LiDAR Data

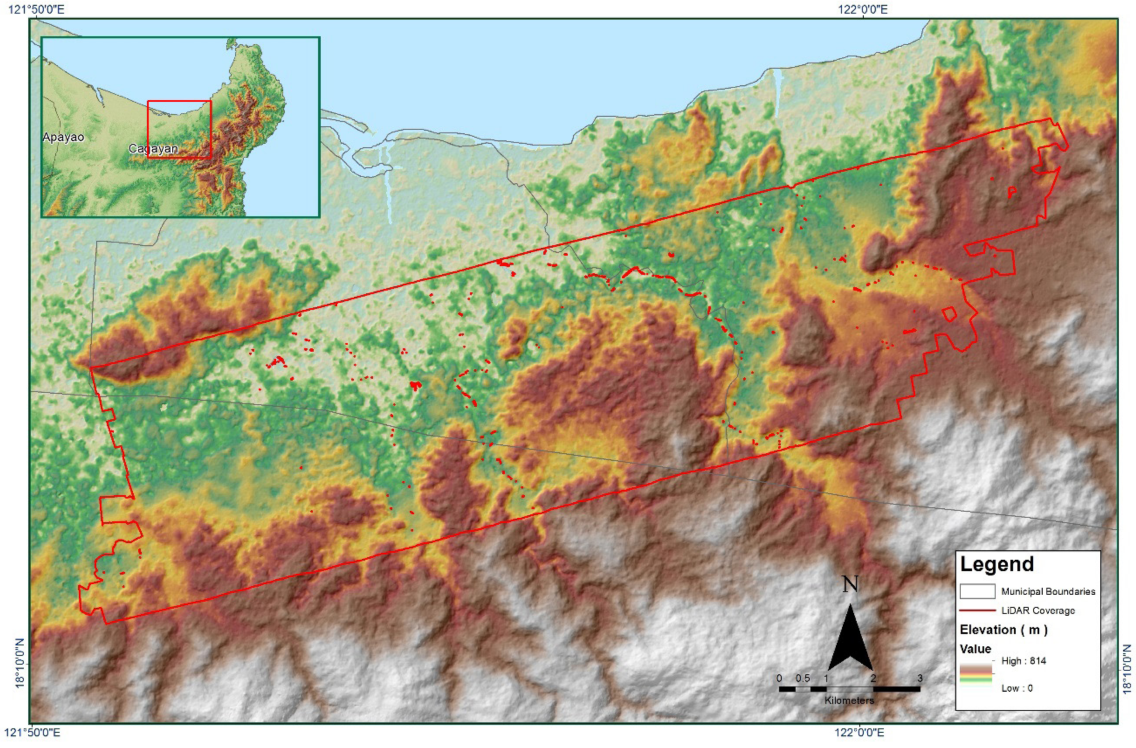


Figure 1.2.5. Image of data overlap

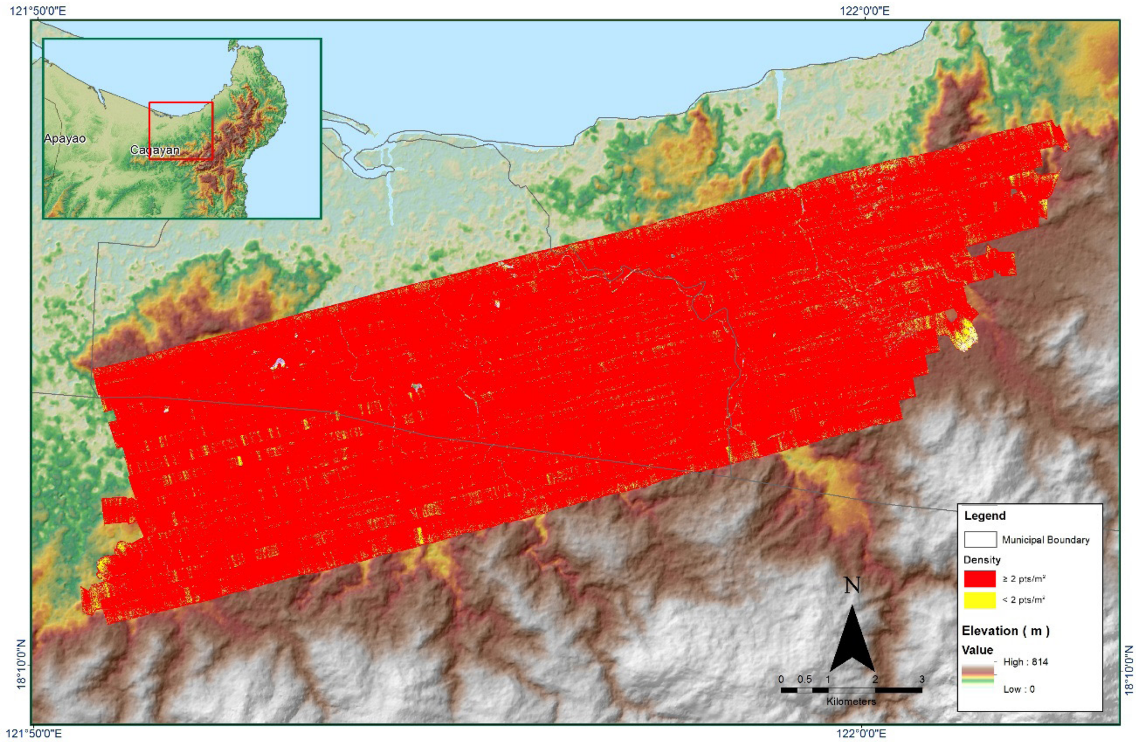


Figure 1.2.6. Density map of merged LiDAR data

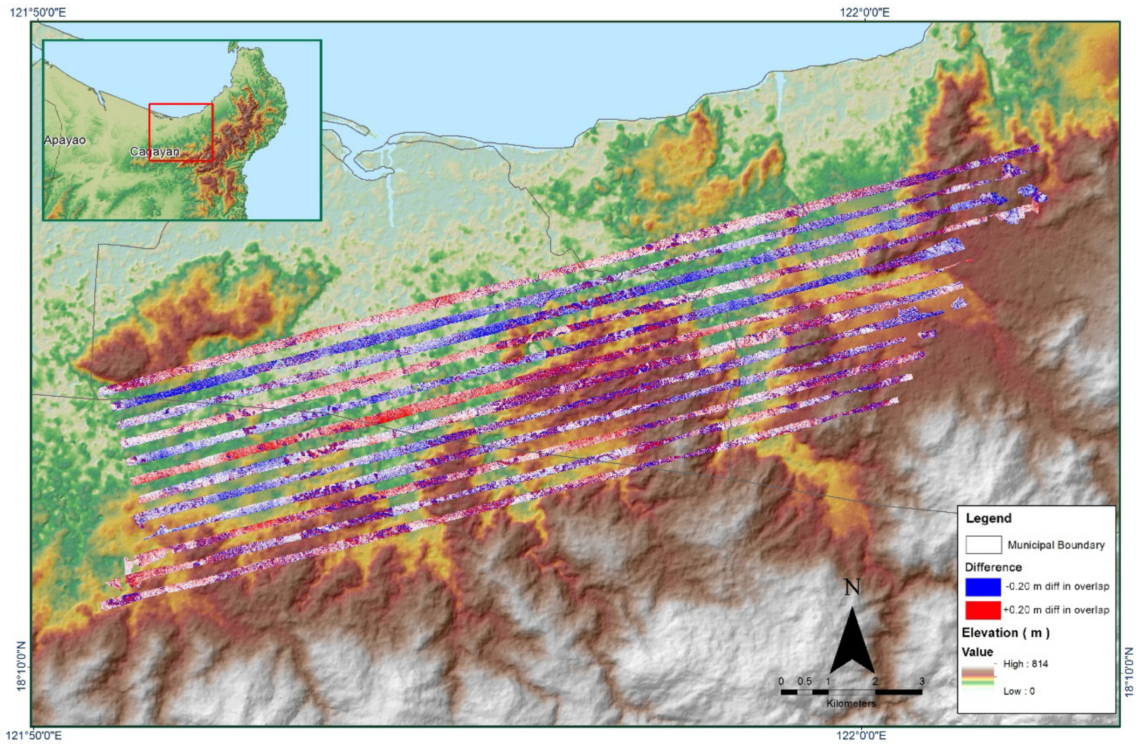


Figure 1.2.7. Elevation difference between flight lines

Flight Area	**Cagayan_Reflights**
Mission Name	**Cagayan_Reflights_BLK61G**
Inclusive Flights	4009G
Range data size	10 GB
Base data size	5.85 MB
POS data size	118 MB
Base data size	5.85 MB
Image	n/a
Transfer date	June 21,2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	4.2
Boresight correction stdev (<0.001deg)	0.000279
IMU attitude correction stdev (<0.001deg)	0.001017
GPS position stdev (<0.01m)	0.0090
Minimum % overlap (>25)	33.66%
Ave point cloud density per sq.m. (>2.0)	3.26
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	96
Maximum Height	445.51 m
Minimum Height	54.91 m
Classification (# of points)	
Ground	55,094,671
Low vegetation	42,587,673
Medium vegetation	71,619,168
High vegetation	39,106,290
Building	330,413
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Edgardo Gubatanga, Jr., engr. Gladys Mae Apat

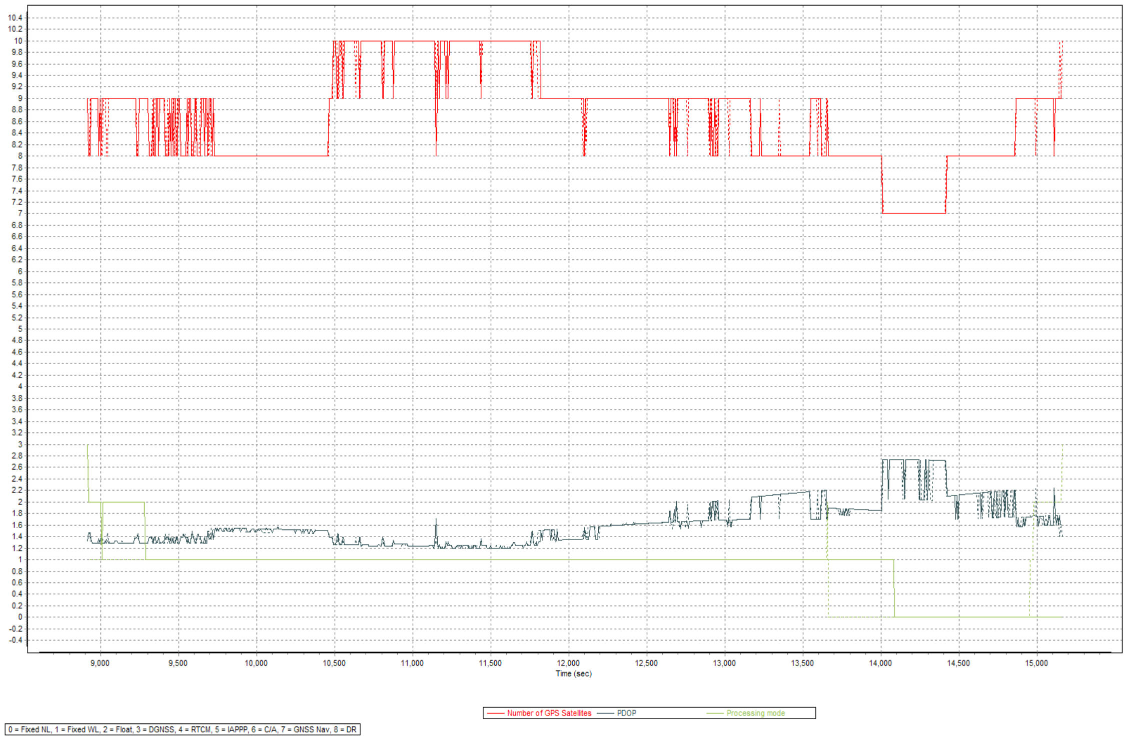


Figure 1.3.1. Solution Status

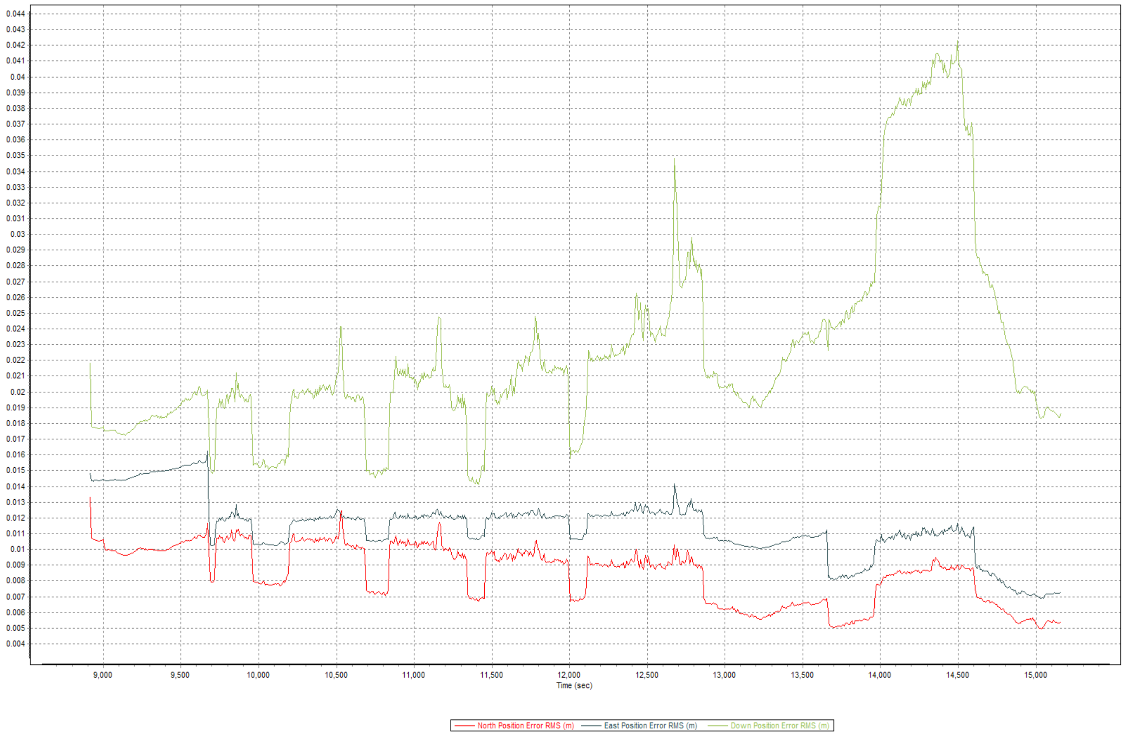


Figure 1.3.2. Smoothed Performance Metric Parameters

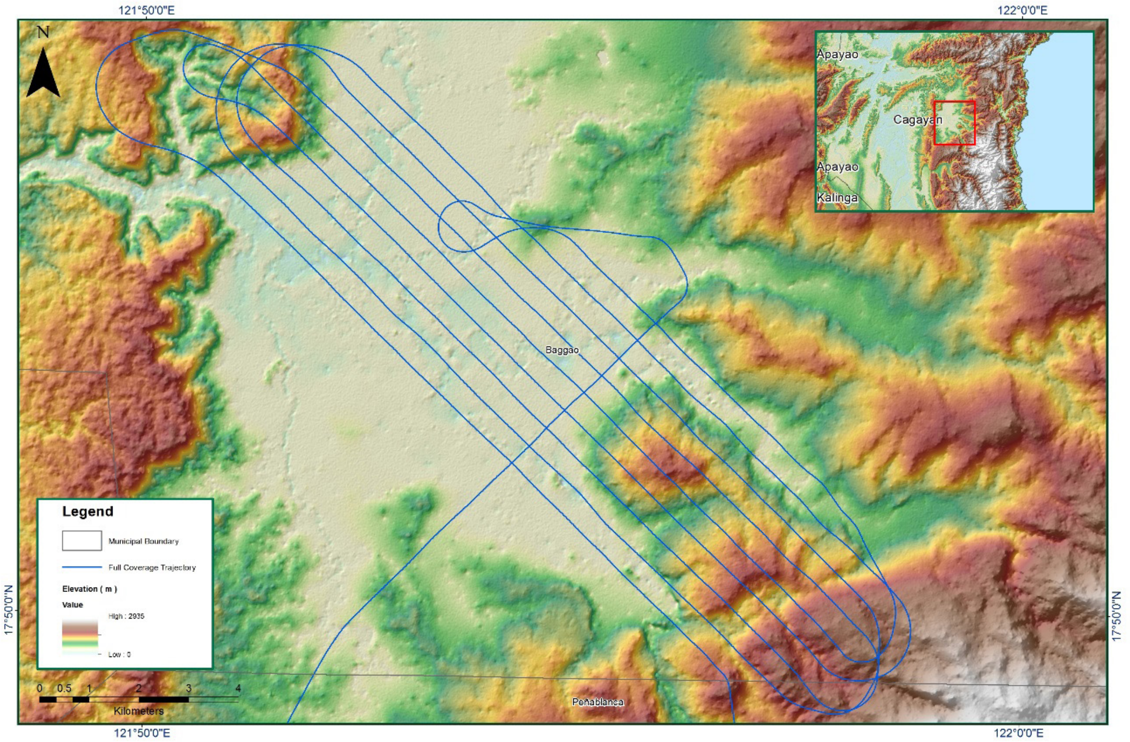


Figure 1.3.3. Best Estimated Trajectory

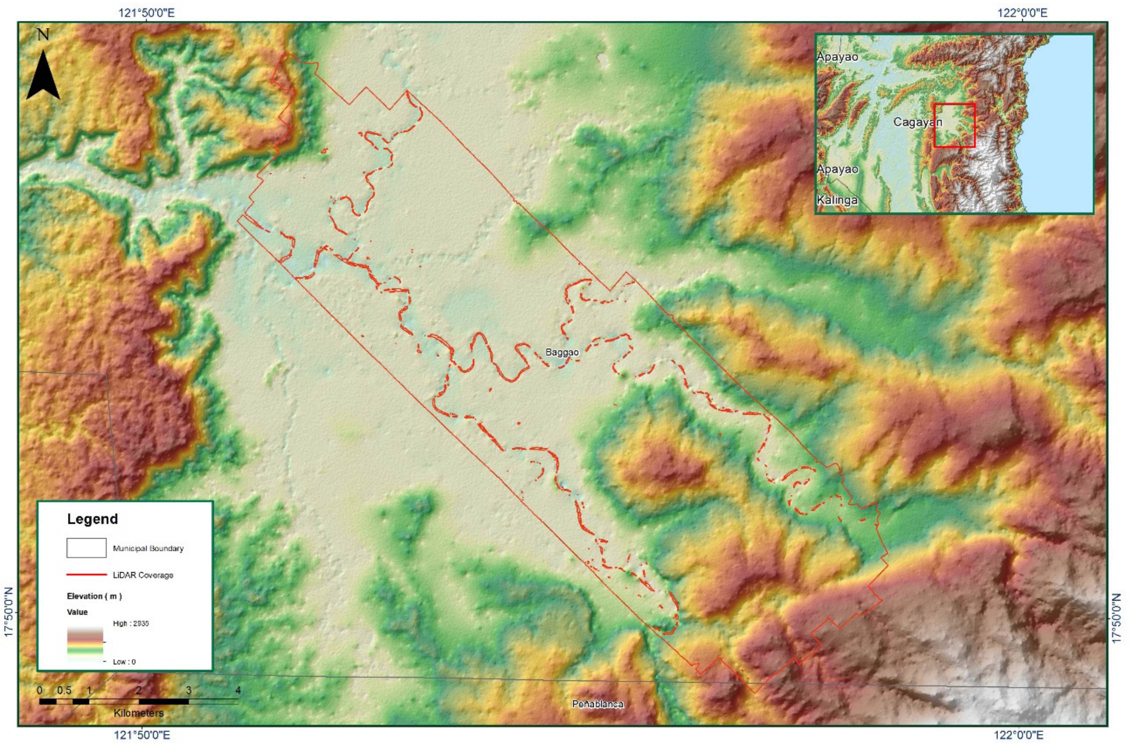


Figure 1.3.4. Coverage of LiDAR Data

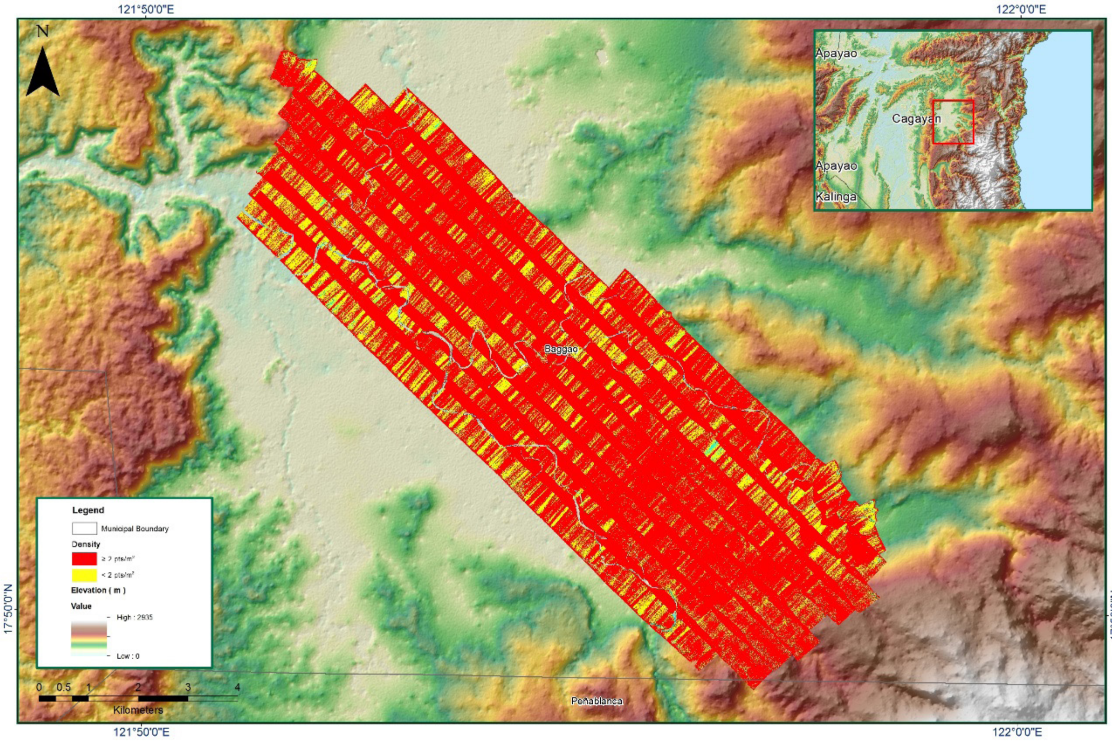


Figure 1.3.5. Image of data overlap

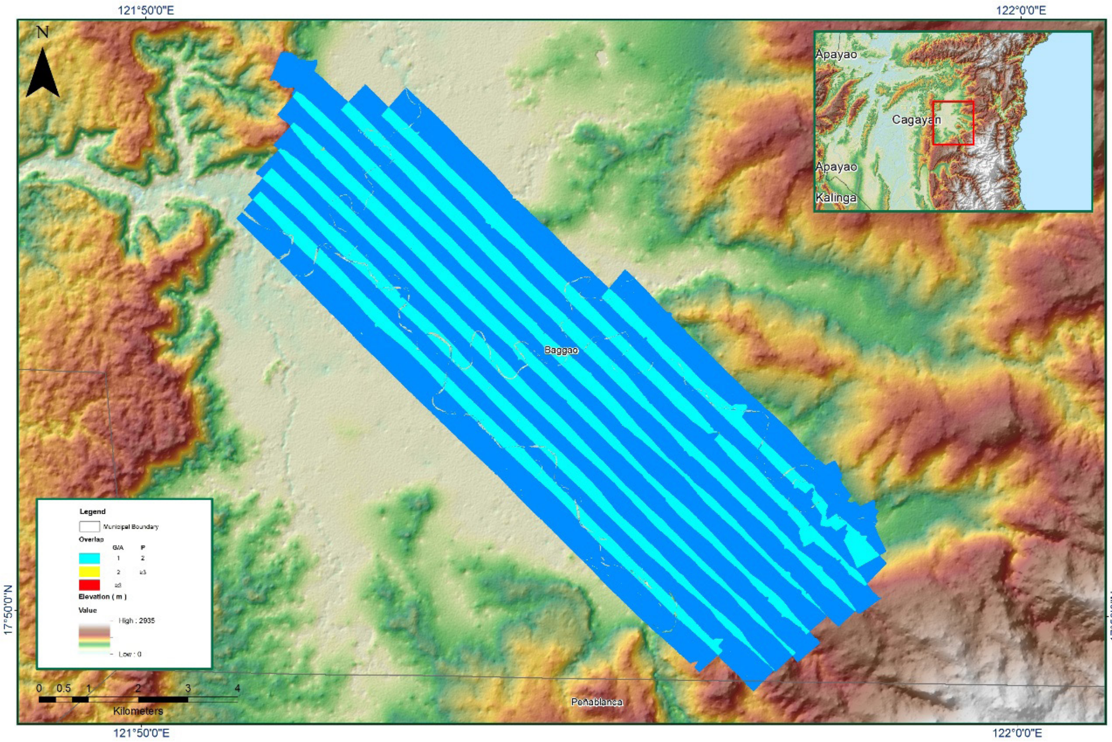


Figure 1.3.6. Density map of merged LiDAR data

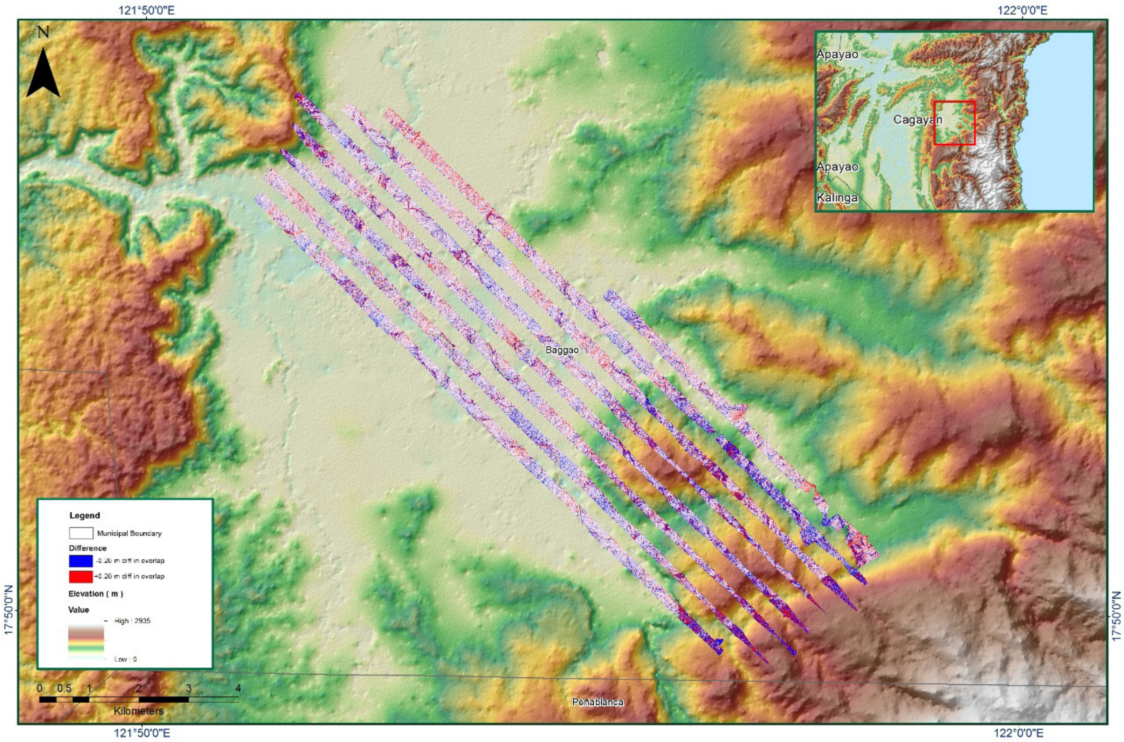


Figure 1.3.7. Elevation difference between flight line

Flight Area	Cagayan
Mission Name	**Cagayan_reflights_Blk61E**
Inclusive Flights	3981G
Range data size	30.2 GB
Base data size	8.23 MB
POS data size	263 MB
Base data size	8.23 MB
Image	NA
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	1.9
Boresight correction stdev (<0.001deg)	0.000179
IMU attitude correction stdev (<0.001deg)	0.000662
GPS position stdev (<0.01m)	0.0077
Minimum % overlap (>25)	38.81%
Ave point cloud density per sq.m. (>2.0)	4.32
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	267
Maximum Height	534.48 m
Minimum Height	53.39 m
Classification (# of points)	
Ground	175,807,154
Low vegetation	132,289,620
Medium vegetation	244,186,114
High vegetation	341,704,738
Building	3,772,102
Orthophoto	No
Processed by	Engr. Jommer Medina, Engr. Edgardo Gubatanga, Jr., Ailyn Biñas

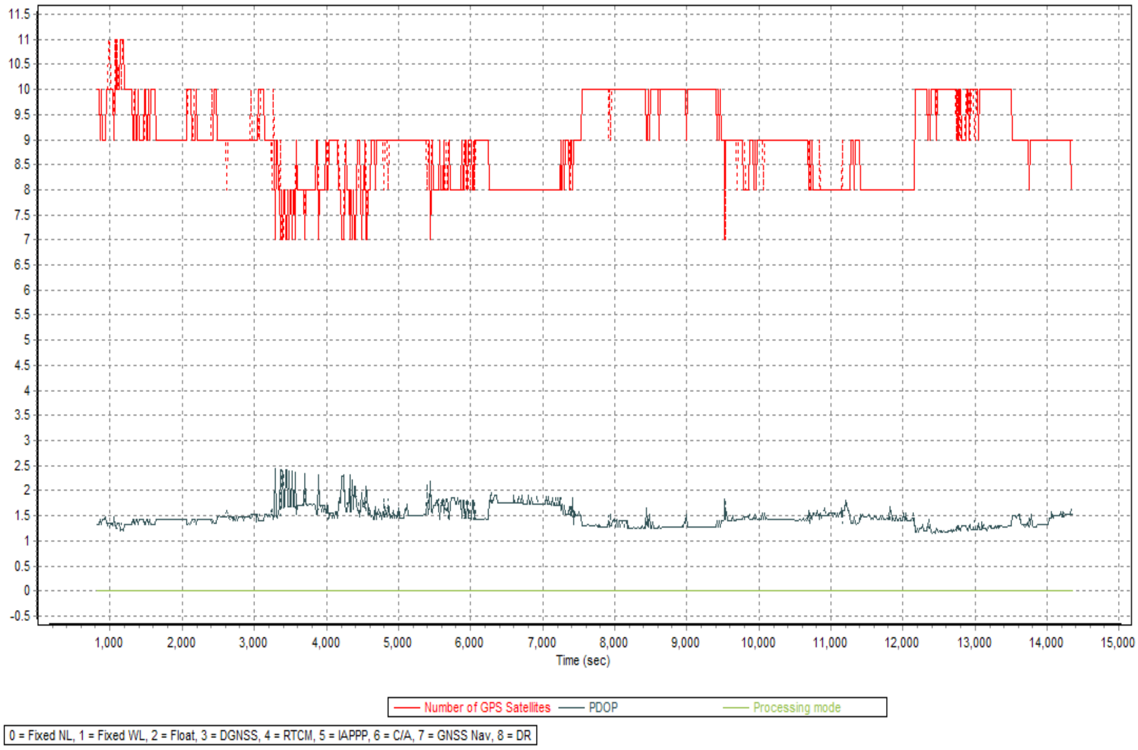


Figure 1.4.1. Solution Status

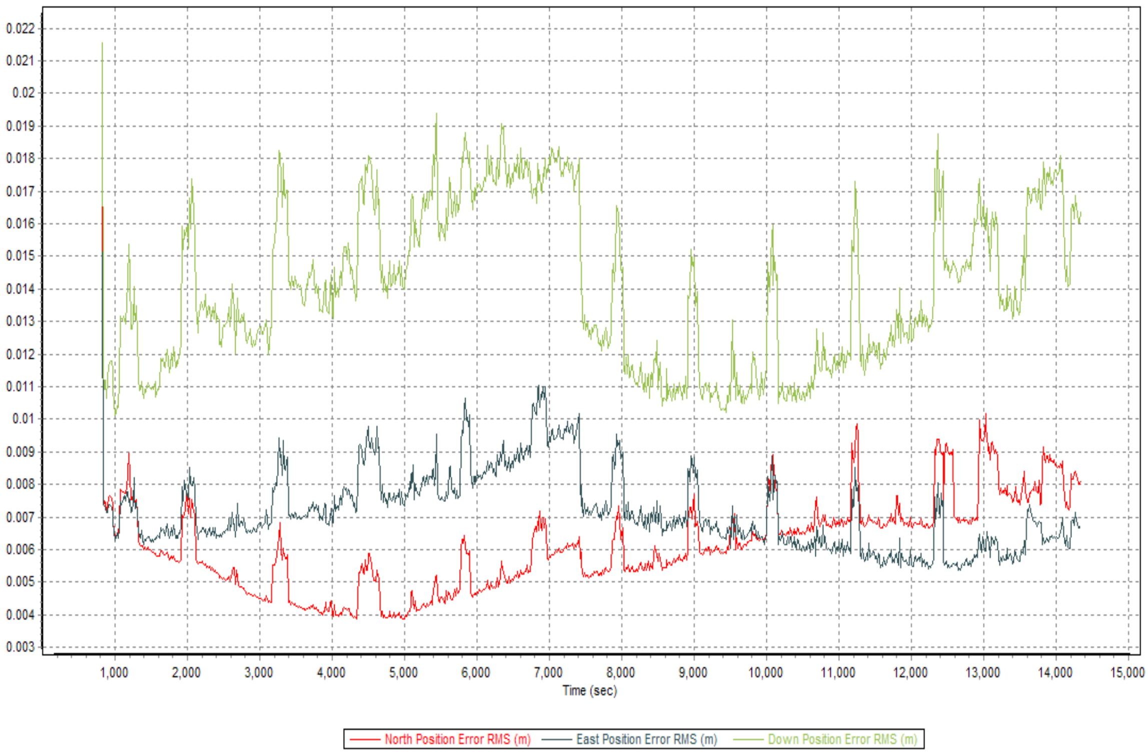


Figure 1.4.2. Smoothed Performance Metric Parameters

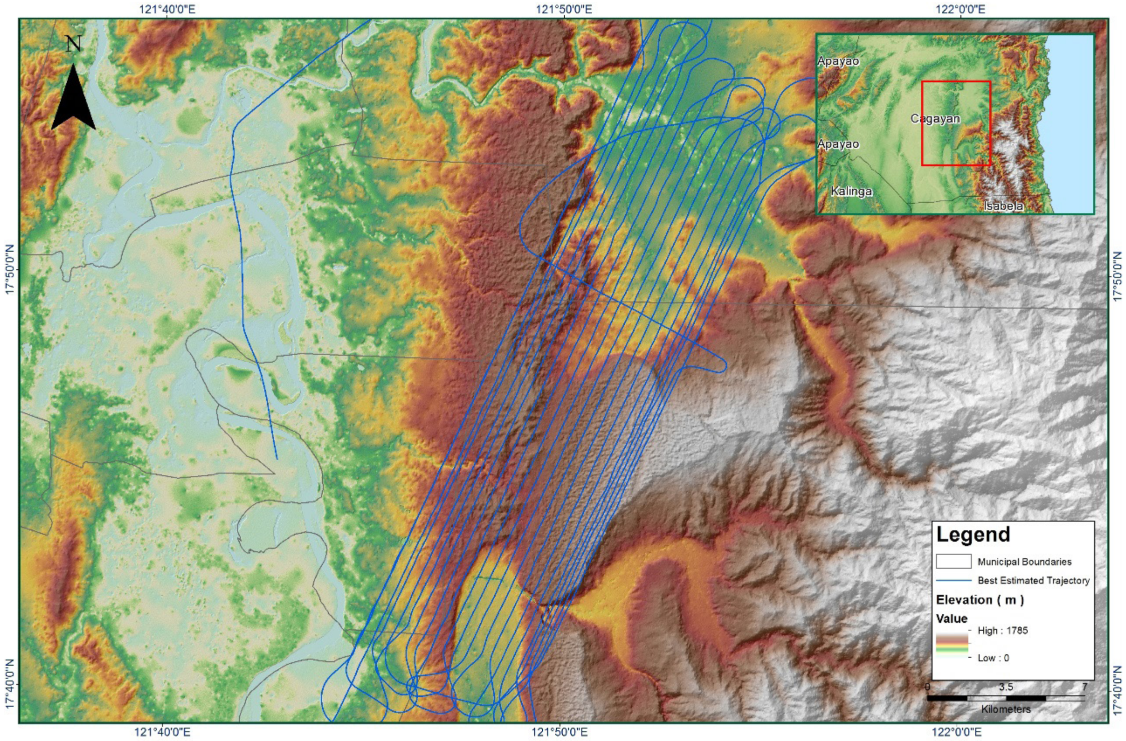


Figure 1.4.3. Best Estimated Trajectory

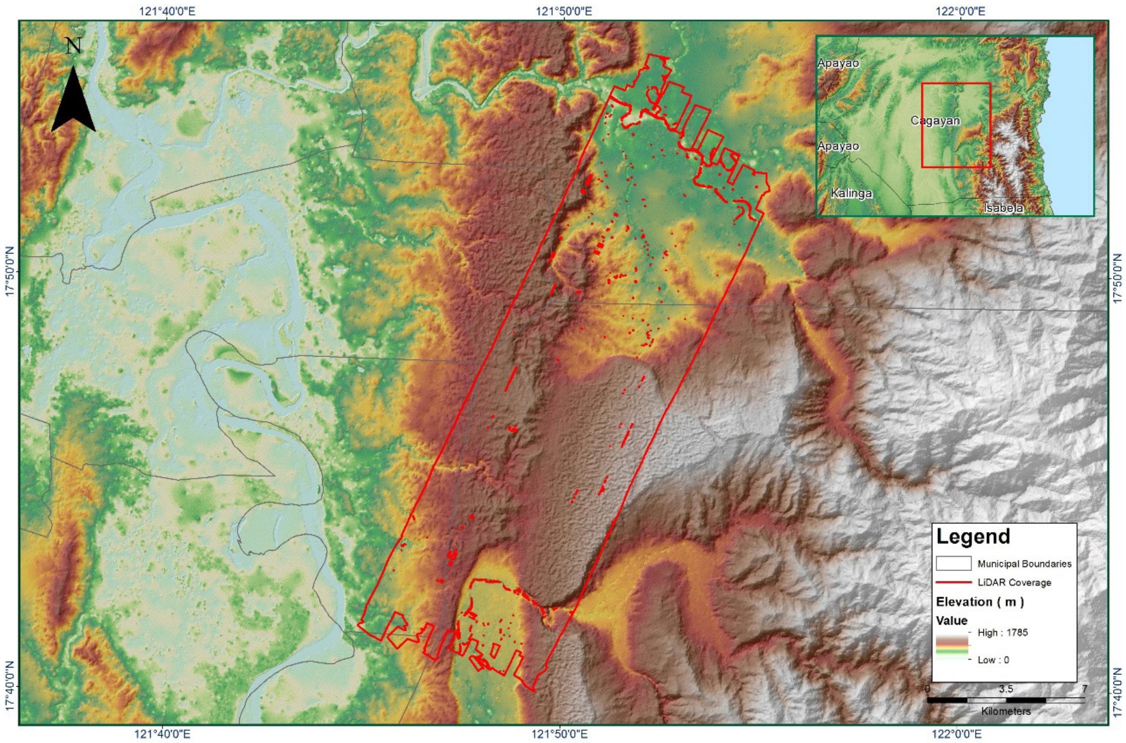


Figure 1.4.4. Coverage of LiDAR Data

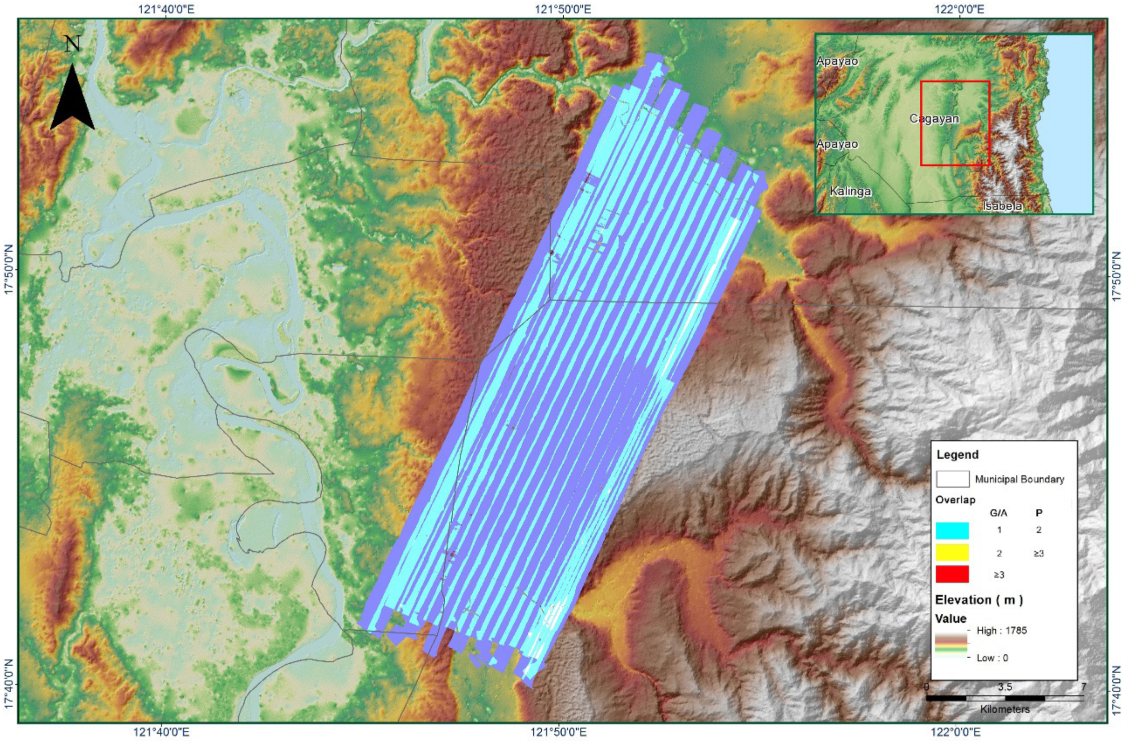


Figure 1.4.5. Image of data overlap

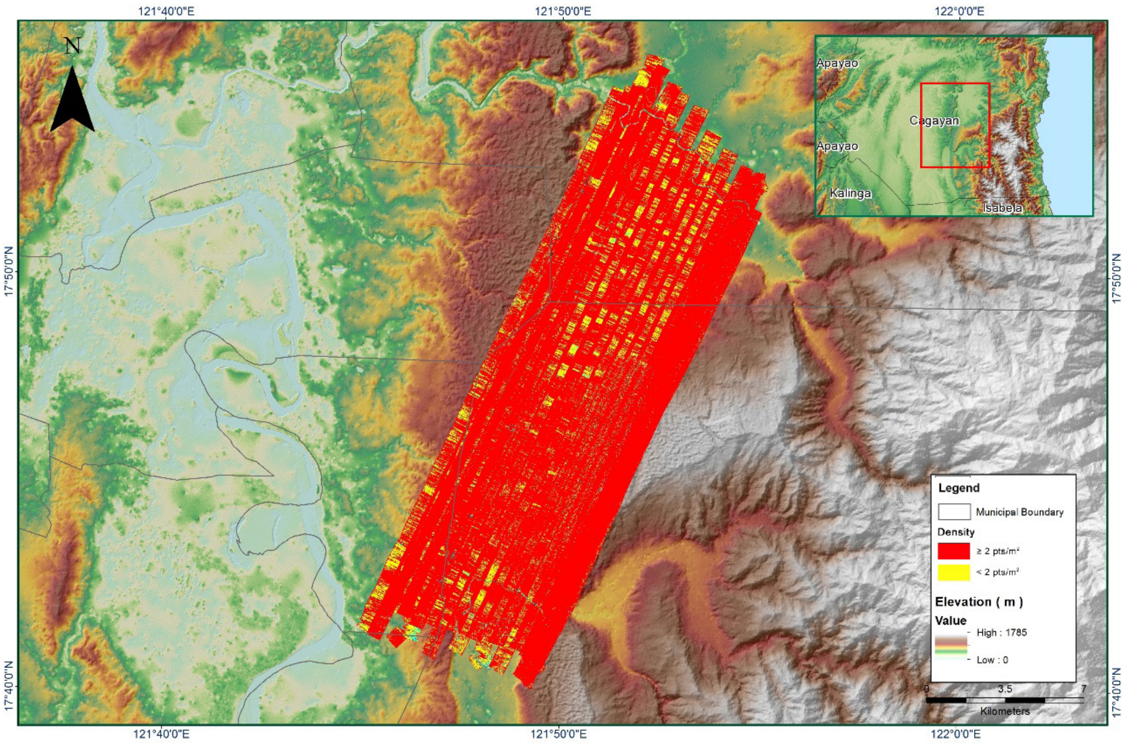


Figure 1.4.6. Density map of merged LiDAR data

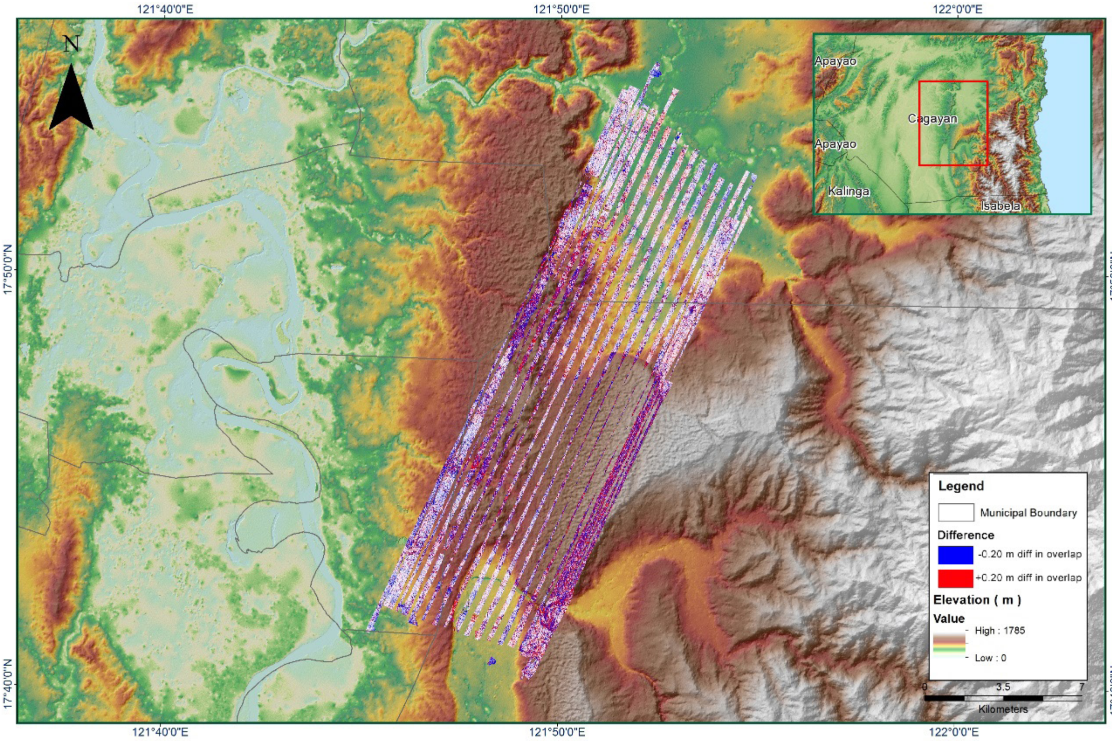


Figure 1.4.7. Elevation difference between flight lines

Flight Area	**Cagayan**
Mission Name	**Cagayan_reflights_Blk21AB**
Inclusive Flights	3997G
Range data size	26.4 GB
Base data size	13.9 MB
POS data size	272 MB
Base data size	13.9 MB
Image	NA
Transfer date	June 21, 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)	1.0
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	40.47%
Ave point cloud density per sq.m. (>2.0)	3.95
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	240
Maximum Height	513.84 m
Minimum Height	46.25 m
Classification (# of points)	
Ground	76,453,194
Low vegetation	68,963,286
Medium vegetation	240,167,095
High vegetation	395,221,345
Building	799,122
Orthophoto	No
Processed by	Ben Joseph Harder, Engr. Merven Matthew Natino, Engr. Monalyne Rabino

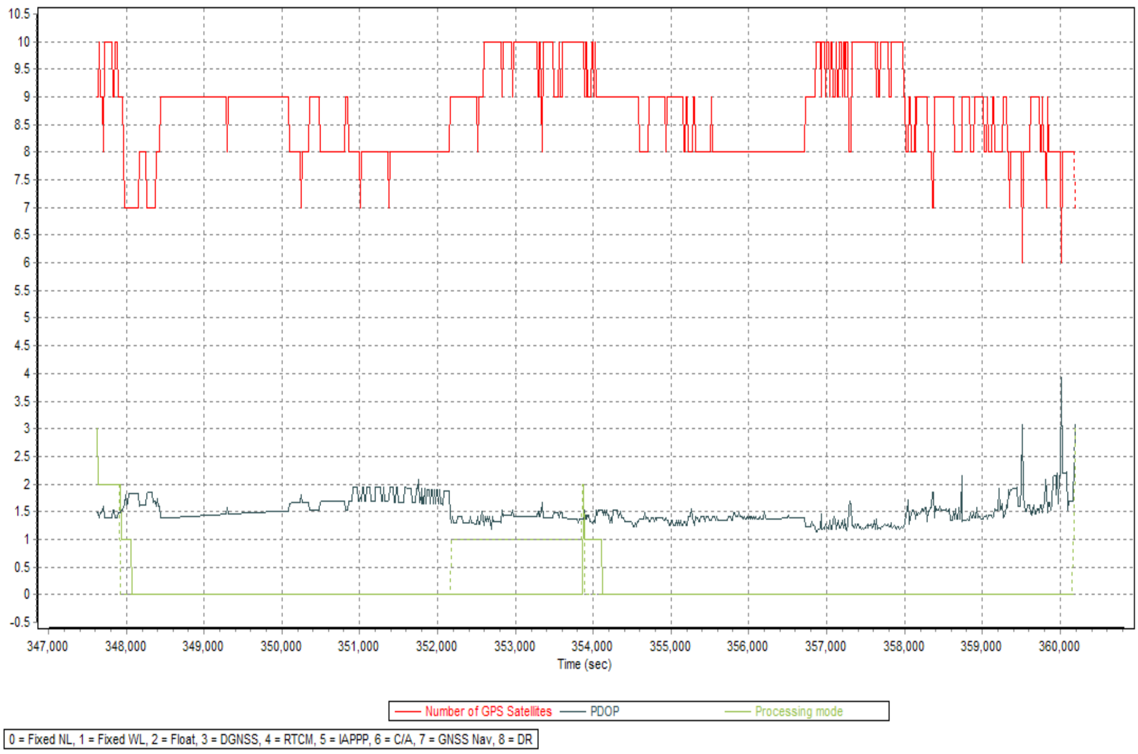


Figure 1.5.1. Solution Status

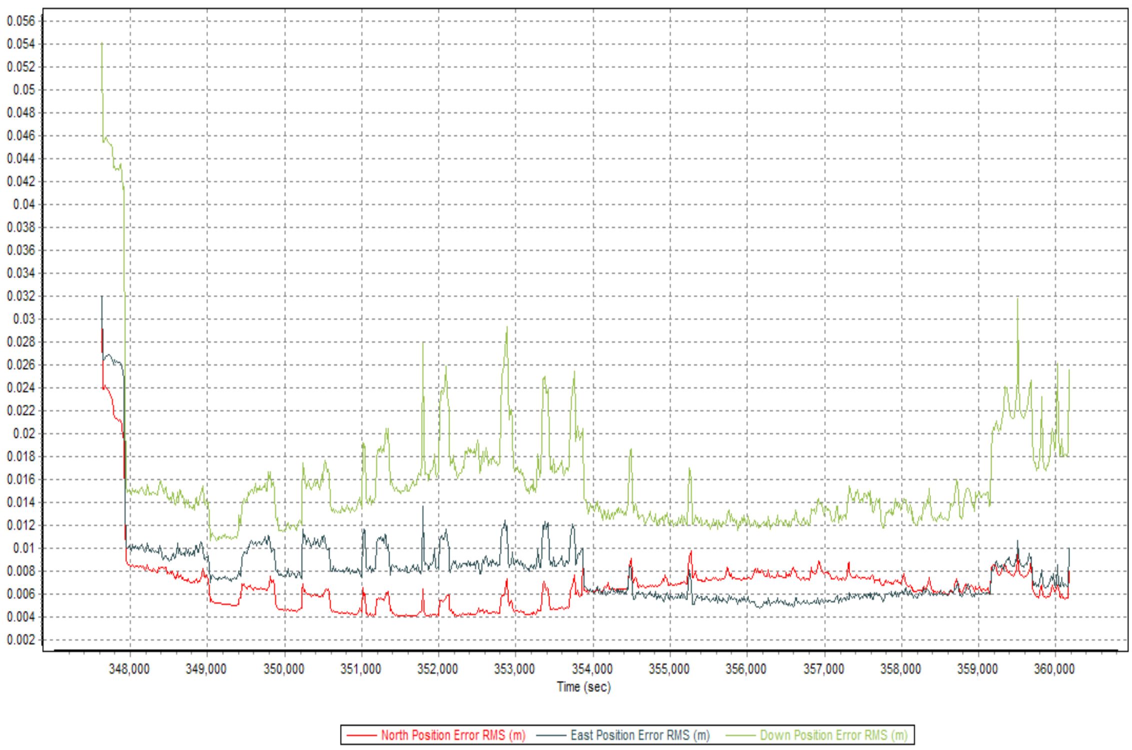


Figure 1.5.2. Smoothed Performance Metric Parameters

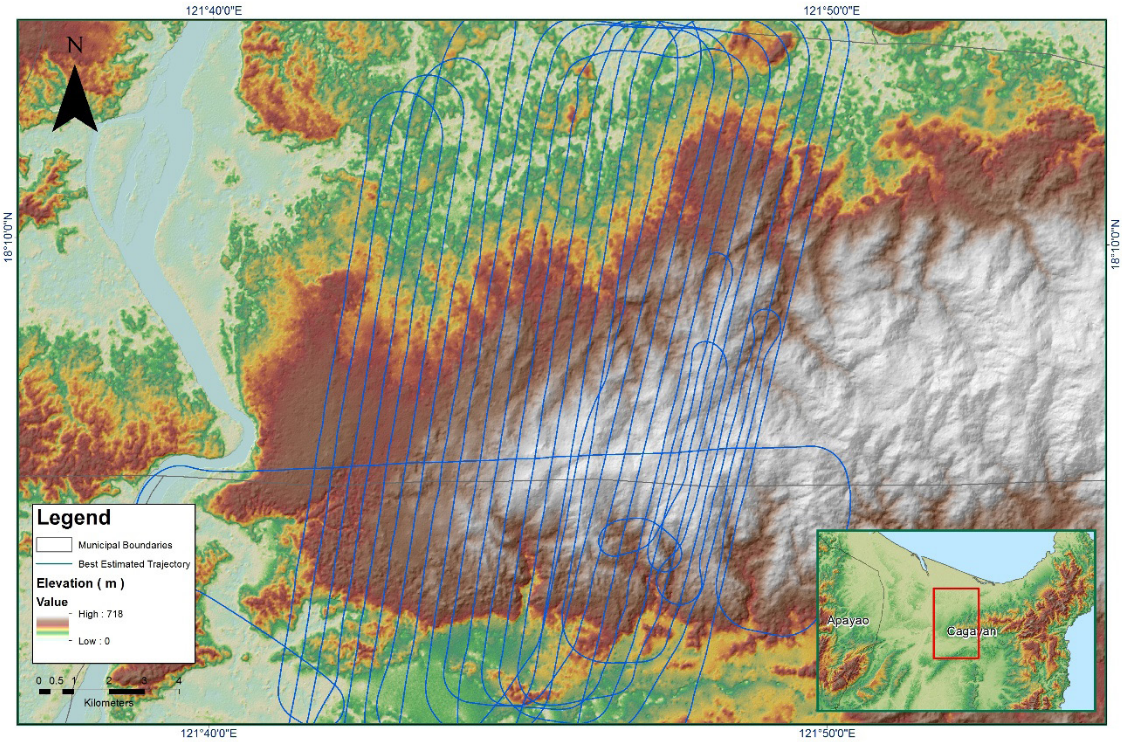


Figure 1.5.3. Best Estimated Trajectory

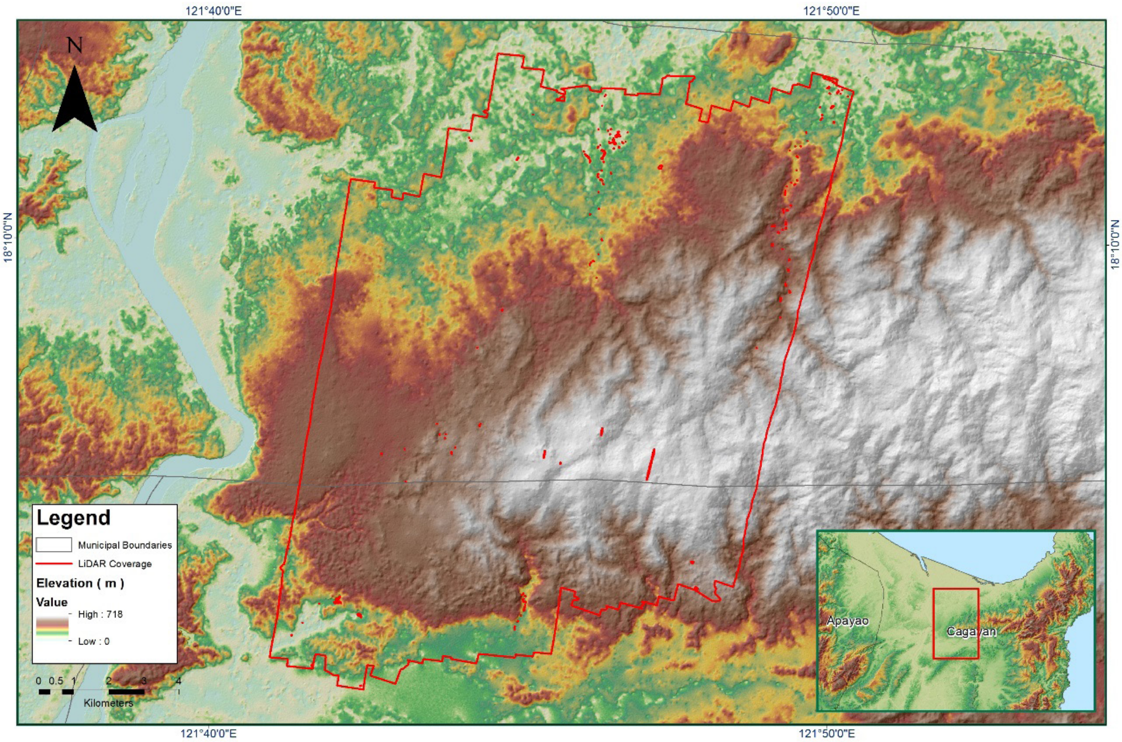


Figure 1.5.4. Coverage of LiDAR Data

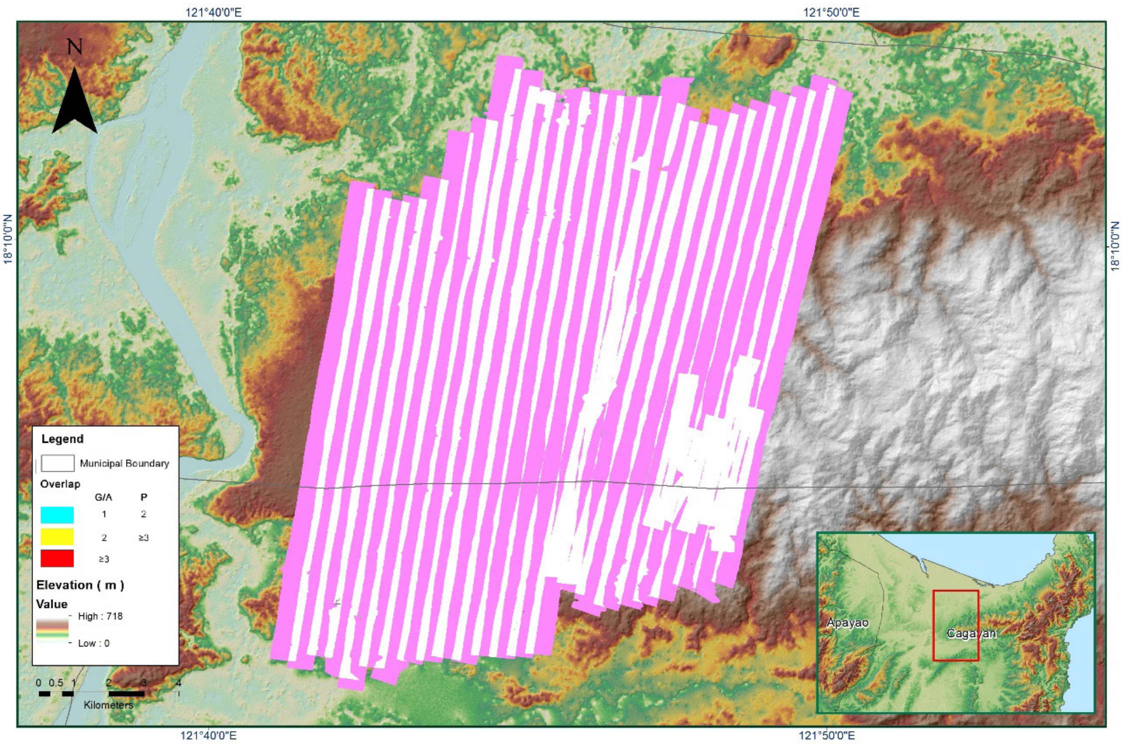


Figure 1.5.5. Image of data overlap

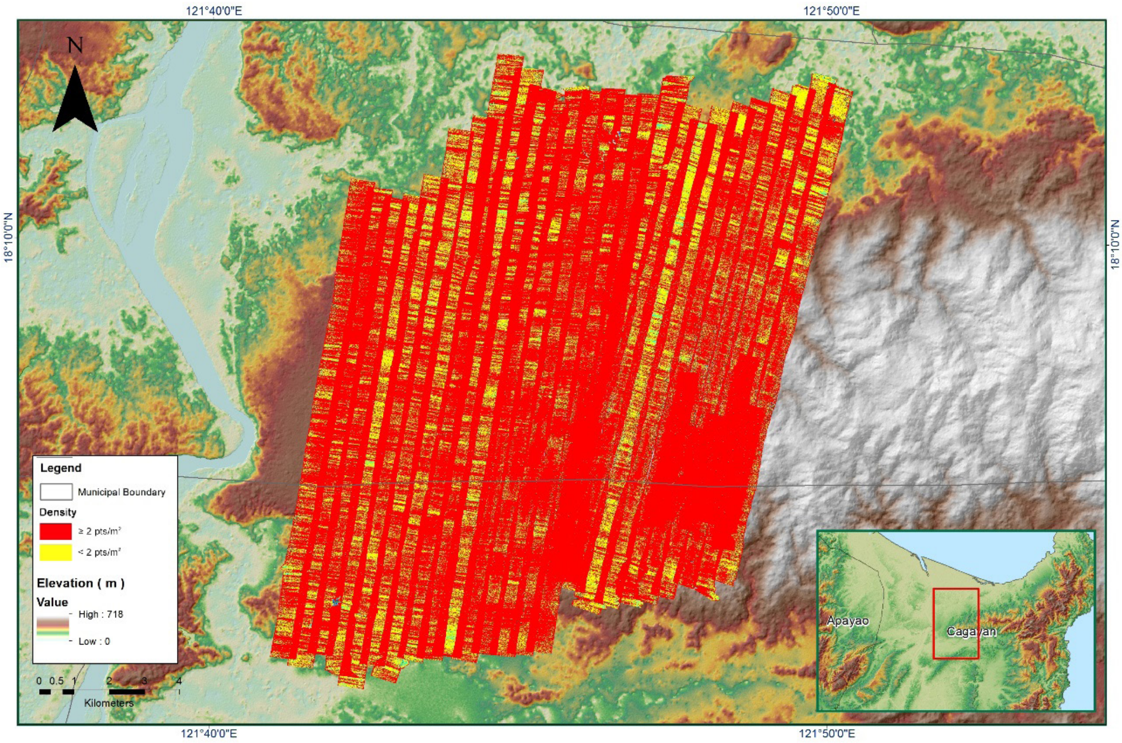


Figure 1.5.6. Density map of merged LiDAR data

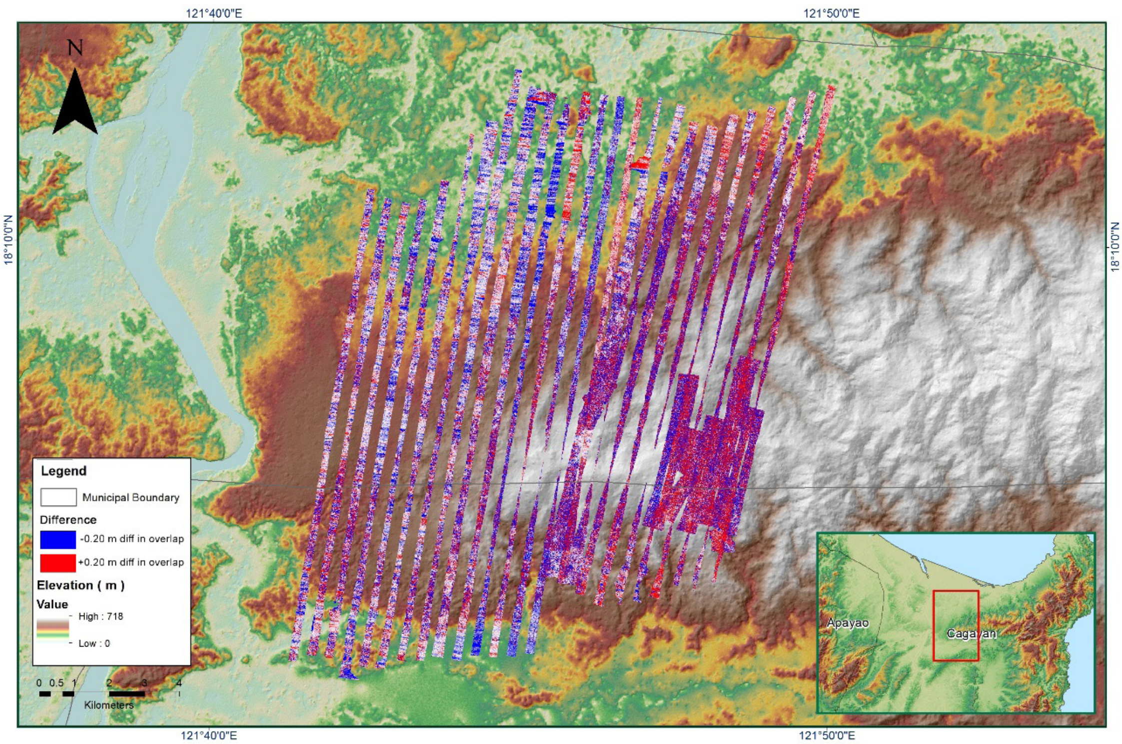


Figure 1.5.7. Elevation difference between flight lines

Flight Area	Cagayan
Mission Name	**Cagayan_reflights_Blk3A**
Inclusive Flights	3971G, 3991G, 4001G
Range data size	45.75 GB
Base data size	33.73 MB
POS data size	640 MB
Base data size	33.73 MB
Image	NA
Transfer date	June 21, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.5
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	2.4
Boresight correction stdev (<0.001deg)	0.000876
IMU attitude correction stdev (<0.001deg)	0.015089
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	42.36%
Ave point cloud density per sq.m. (>2.0)	3.56
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	156
Maximum Height	526.96 m
Minimum Height	39.41 m
Classification (# of points)	
Ground	70,619,413
Low vegetation	72,372,299
Medium vegetation	199,312,514
High vegetation	122,546,677
Building	5,607,920
Orthophoto	No
Processed by	Engr. Don Matthew Banatin, Engr. Christy Lubiano, Karl Adrian Vergara

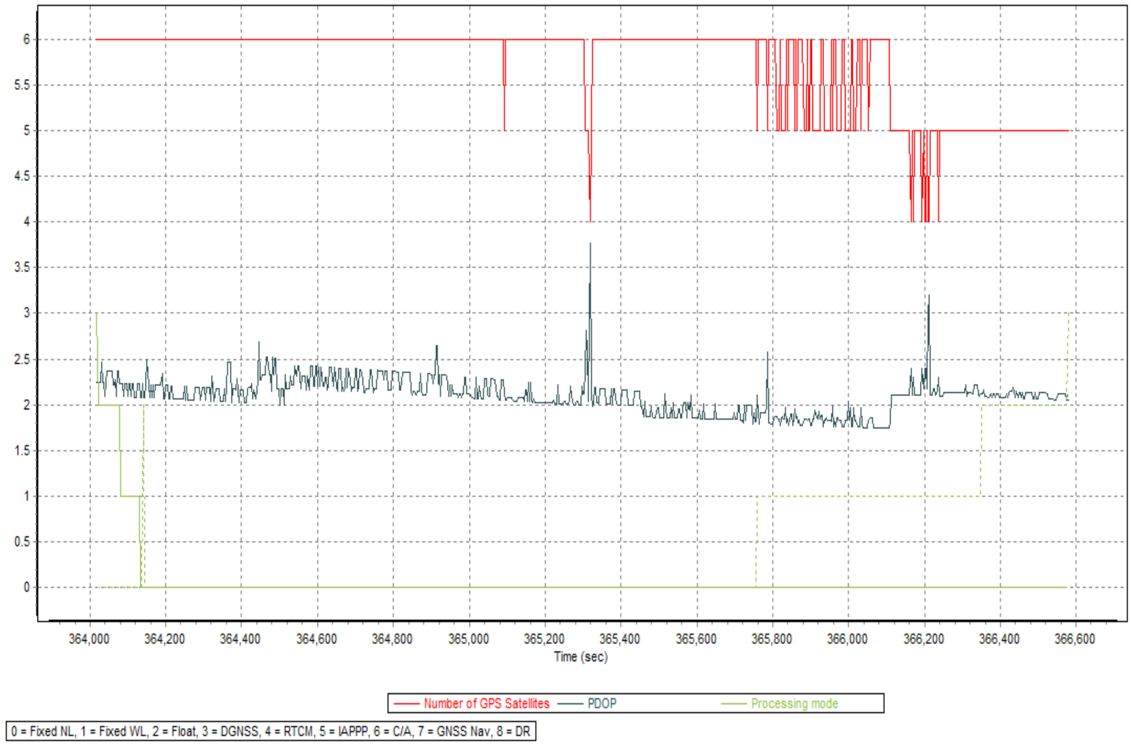


Figure 1.6.1. Solution Status

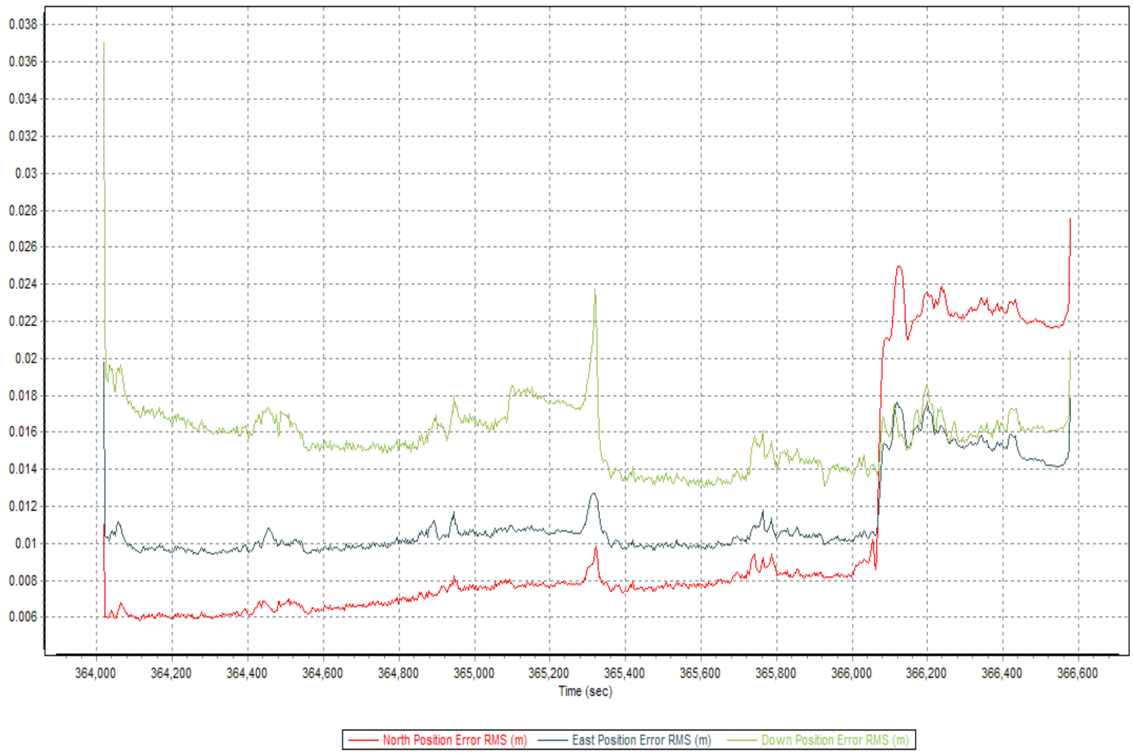


Figure 1.6.2. Smoothed Performance Metric Parameters

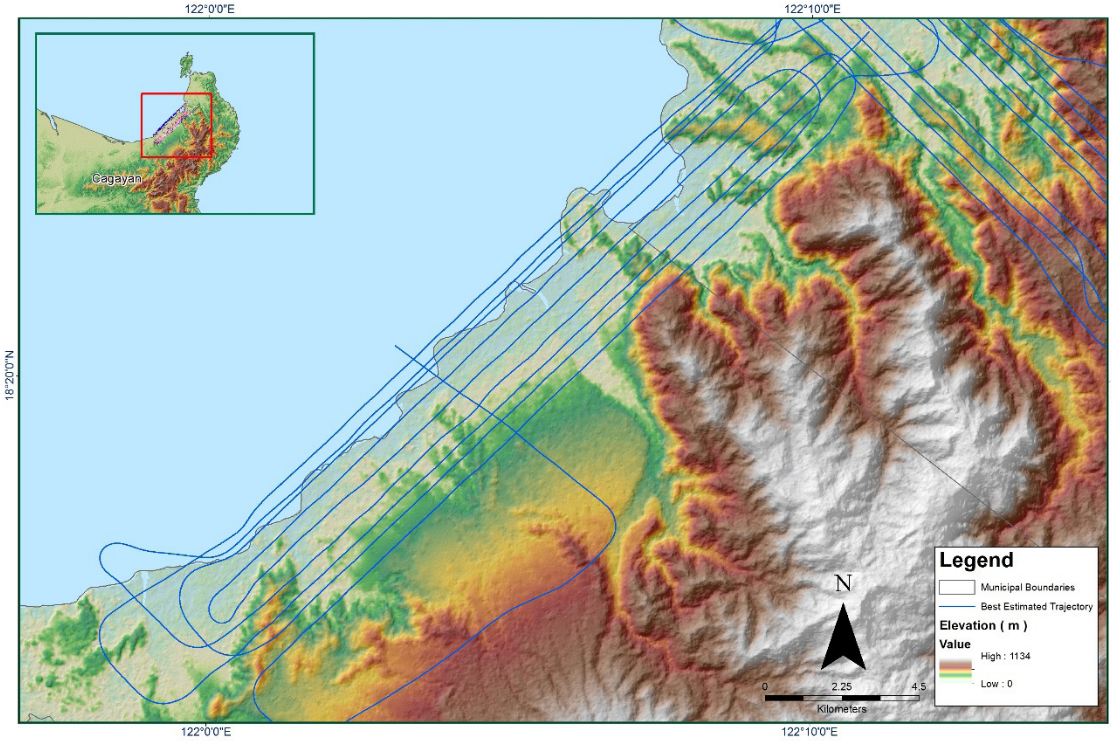


Figure 1.6.3. Best Estimated Trajectory

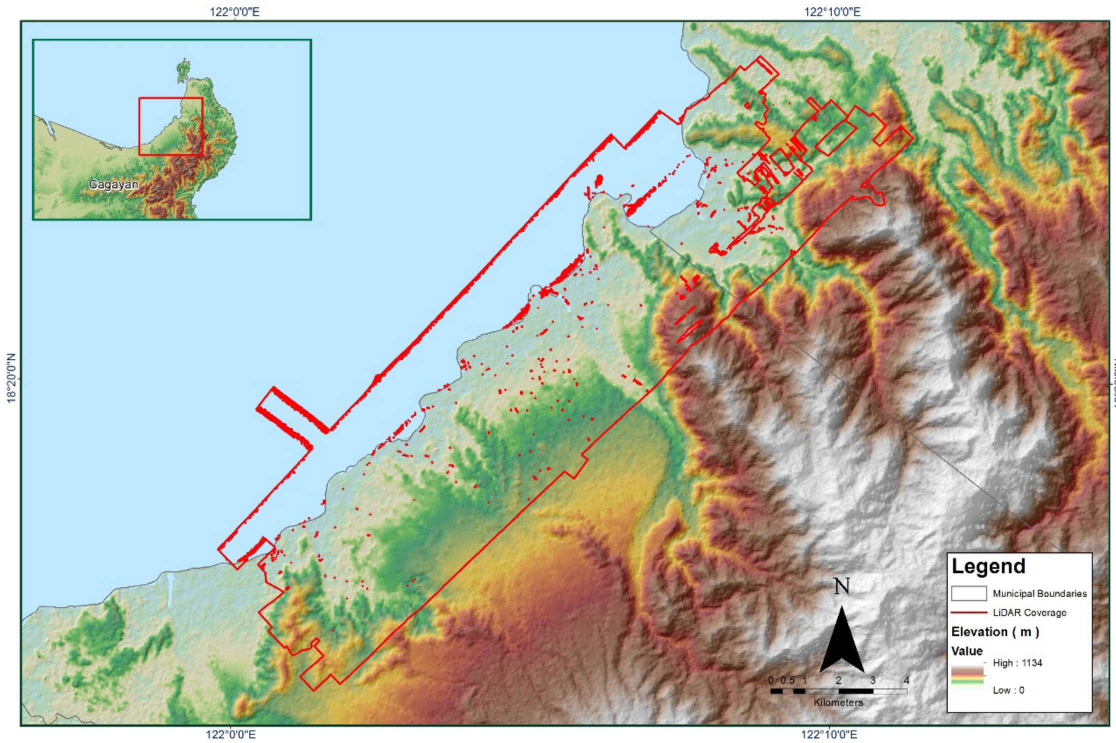


Figure 1.6.4. Coverage of LiDAR Data

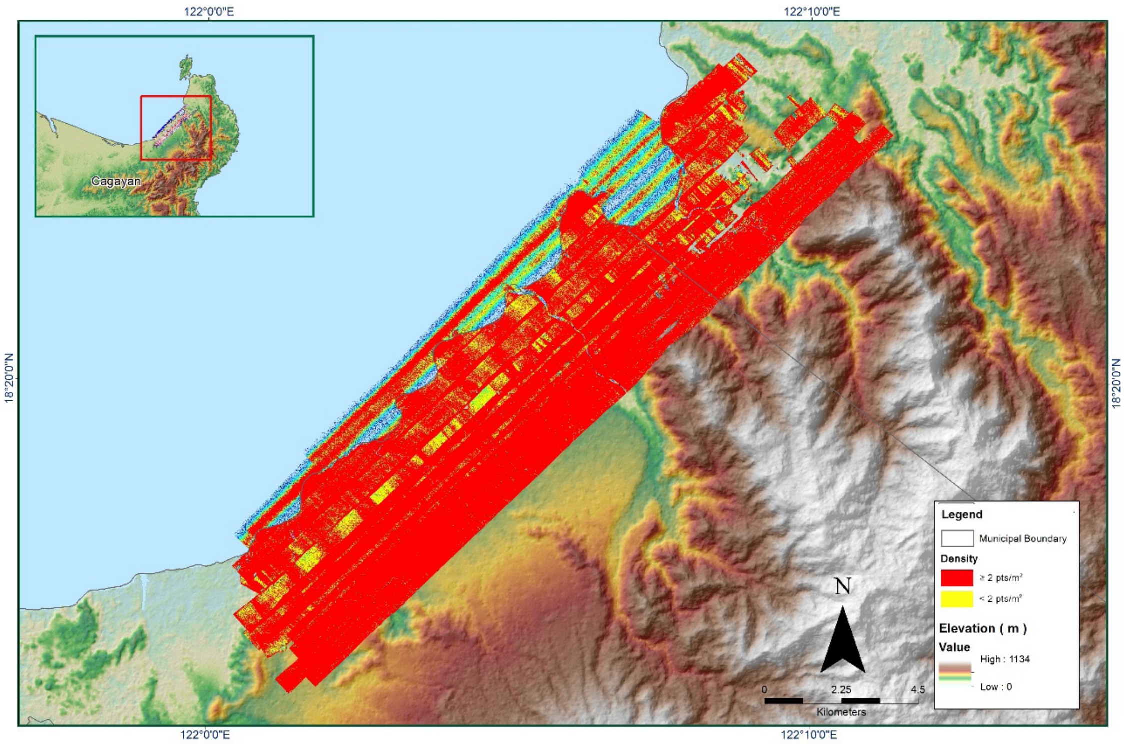


Figure 1.6.5. Image of data overlap

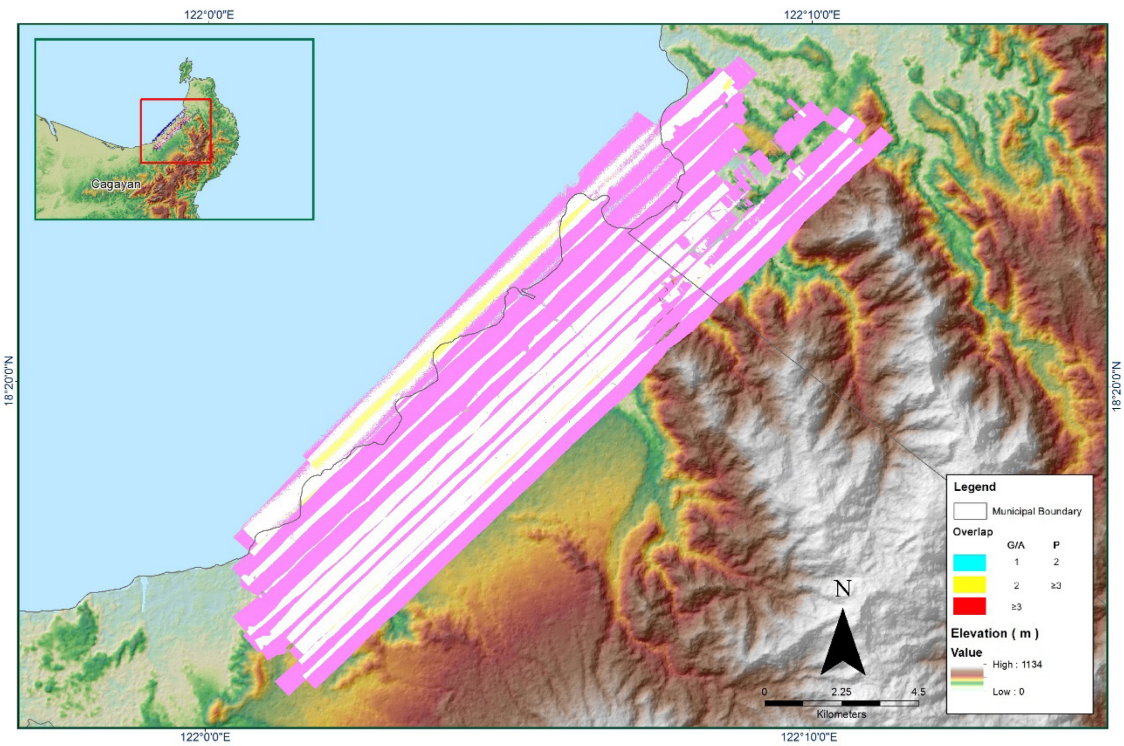


Figure 1.6.6. Density map of merged LiDAR data

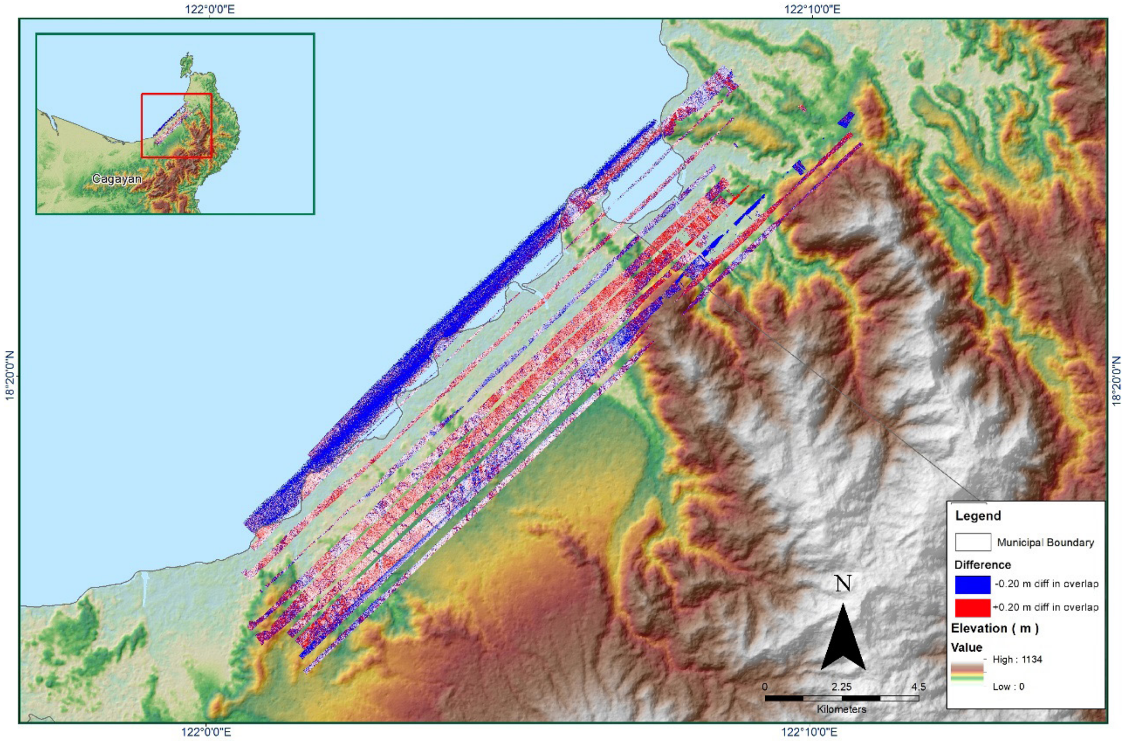


Figure 1.6.7. Elevation difference between flight lines

ANNEX 9. Aunugay 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
W340	4.3594	99	0	0.0333283	0.48348	Discharge	0.0220427	0.9	Ratio to Peak	0.75383
W350	10.057	96.993	0	0.29824	4.3265	Discharge	0.0401185	0.9	Ratio to Peak	0.49637
W360	5.6907	99	0	0.0970165	1.4074	Discharge	1.3679	0.9	Ratio to Peak	0.75981
W370	10.96642	94.175	0	0.28123	4.0796	Discharge	0.69622	0.9	Ratio to Peak	0.50000
W380	14.960	83.515	0	0.0718728	1.0426	Discharge	1.6732	0.9	Ratio to Peak	0.49482
W390	10.701	94.980	0	0.0954149	1.3842	Discharge	0.0154178	0.9	Ratio to Peak	0.73862
W400	13.126	88.0940165	0	0.19542	2.8349	Discharge	0.35154	0.9	Ratio to Peak	0.73862
W410	16.081	80.944	0	0.29126	4.2252	Discharge	0.46475	0.9	Ratio to Peak	0.50000
W420	16.636	79.727	0	0.37525	5.4436	Discharge	1.7913	0.9	Ratio to Peak	0.50000
W430	17.721	77.454	0	0.23814	3.4546	Discharge	2.5250	0.9	Ratio to Peak	1.00000
W440	14.513	84.5874608	0	0.28272	4.1013	Discharge	1.4989	0.9	Ratio to Peak	0.33333
W450	16.743	79.497	0	0.15059	2.1846	Discharge	1.9047	0.9	Ratio to Peak	0.50000
W460	18.428	76.039	0	0.26189	3.7992	Discharge	1.3735	0.9	Ratio to Peak	0.50000
W470	18.148	76.593	0	0.23620	3.4265	Discharge	1.5917	0.9	Ratio to Peak	0.33333
W480	16.625	79.75	0	0.12269	1.7798	Discharge	1.2316	0.9	Ratio to Peak	0.50000
W490	21.932	69.734	0	0.0962965	1.3969	Discharge	0.76495	0.9	Ratio to Peak	0.56630

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
W500	16.625	79.75	0	0.17607	2.5541	Discharge	0.13149	0.9	Ratio to Peak	0.33333
W510	17.113	78.712	0	0.22220	3.2234	Discharge	1.9390	0.9	Ratio to Peak	0.50000
W520	16.625	79.75	0	0.0929285	1.3481	Discharge	2.3176	0.9	Ratio to Peak	0.32829
W530	16.625	79.75	0	0.12634	1.8327	Discharge	0.56247	0.9	Ratio to Peak	0.50000
W540	16.625	79.75	0	0.0659018	0.95602	Discharge	1.1896	0.9	Ratio to Peak	0.74551
W550	16.625	79.75	0	0.15057	2.1843	Discharge	0.44594	0.9	Ratio to Peak	0.33333
W560	16.625	79.75	0	0.22180	3.2175	Discharge	1.1250	0.9	Ratio to Peak	0.50000
W570	16.625	79.75	0	0.11838	1.7174	Discharge	1.9521	0.9	Ratio to Peak	0.75675
W580	16.625	79.75	0	0.14616	2.1203	Discharge	0.56876	0.9	Ratio to Peak	0.33333
W590	16.625	79.75	0	0.17796	2.5816	Discharge	1.0195	0.9	Ratio to Peak	0.49441
W600	16.625	79.75	0	0.14052	2.0385	Discharge	1.4092	0.9	Ratio to Peak	0.33333
W610	16.7979751	79.379	0	0.29576	4.2905	Discharge	2.3427	0.9	Ratio to Peak	0.50000
W620	16.625	79.75	0	0.10836	1.5719	Discharge	5.4674	0.9	Ratio to Peak	0.75694
W630	16.625	79.75	0	0.11066	1.6053	Discharge	0.90254	0.9	Ratio to Peak	0.75518
W640	16.625	79.75	0	0.0679090	0.98513	Discharge	0.75014	0.9	Ratio to Peak	0.75667
W650	16.625	79.75	0	0.11065	1.6052	Discharge	0.43045	0.9	Ratio to Peak	0.22222
W660	16.625	79.75	0	0.15798	2.2918	Discharge	0.99582	0.9	Ratio to Peak	0.5

ANNEX 10. Aunugay Model Reach Parameters

Table A-10.1 Aunungay Model Reach Parameters

Reach Number	MuskingumCunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	101.57	0.17444	0.025	Trapezoid	30.928	0.3517
R110	Automatic Fixed Interval	2672.5	0.0113143	0.025	Trapezoid	30.928	0.3517
R130	Automatic Fixed Interval	1976.5	0.0178055	0.025	Trapezoid	30.928	0.3517
R140	Automatic Fixed Interval	599.71	0.0260266	0.025	Trapezoid	30.928	0.3517
R170	Automatic Fixed Interval	2936.6	0.0379635	0.025	Trapezoid	30.928	0.3517
R180	Automatic Fixed Interval	1157.7	0.0284295	0.025	Trapezoid	30.928	0.3517
R200	Automatic Fixed Interval	2821.8	0.0387443	0.025	Trapezoid	30.928	0.3517
R220	Automatic Fixed Interval	1133.6	0.0273476	0.025	Trapezoid	30.928	0.3517
R230	Automatic Fixed Interval	909.12	0.0304302	0.025	Trapezoid	30.928	0.3517
R270	Automatic Fixed Interval	6294.4	0.0228970	0.025	Trapezoid	30.928	0.3517
R290	Automatic Fixed Interval	1624.1	0.0369025	0.025	Trapezoid	30.928	0.3517
R30	Automatic Fixed Interval	113.14	0.001	0.025	Trapezoid	30.928	0.3517
R310	Automatic Fixed Interval	878.11	0.0657445	0.025	Trapezoid	30.928	0.3517
R40	Automatic Fixed Interval	2482.5	0.0078475	0.025	Trapezoid	30.928	0.3517
R50	Automatic Fixed Interval	1242.0	0.0058146	0.025	Trapezoid	30.928	0.3517
R70	Automatic Fixed Interval	2064.1	0.0096041	0.025	Trapezoid	30.928	0.3517

ANNEX 11. Aunugay Field Validation Points

Table A-11.1 Aunungay Field Validation Points

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	18.227691	121.976006	3.47	1.60	-1.87		5 Yr
2	18.227759	121.976082	1.01	0.00	-1.01		5 Yr
3	18.229139	121.975465	3.96	0.15	-3.81	TS Lawin/ October 2016	5 Yr
4	18.229734	121.975137	2.97	0.16	-2.81	TS Lawin/ October 2016	5 Yr
5	18.230713	121.974458	3.78	0.17	-3.61	TS Lawin/ October 2016	5 Yr
6	18.232314	121.974725	3.11	0.00	-3.11	TS Lawin/ October 2016	5 Yr
7	18.232819	121.975181	2.49	0.00	-2.49		5 Yr
8	18.235448	122.011686	0.03	0.00	-0.03		5 Yr
9	18.236906	122.008970	0.03	0.00	-0.03		5 Yr
10	18.237693	121.976343	0.03	0.15	0.12		5 Yr
11	18.238264	122.006346	0.09	0.00	-0.09		5 Yr
12	18.238581	122.002177	0.03	0.00	-0.03		5 Yr
13	18.238678	121.998606	0.03	0.00	-0.03		5 Yr
14	18.238665	121.976056	0.97	0.00	-0.97	TS Lawin/ October 2016	5 Yr
15	18.240303	121.994339	0.03	0.00	-0.03		5 Yr
16	18.240725	122.001239	2.47	1.50	-0.97		5 Yr
17	18.240797	122.001169	2.21	1.30	-0.91	TS Lawin/ October 2016	5 Yr
18	18.241577	122.003059	2.90	1.50	-1.40	TS Lawin/ October 2016	5 Yr
19	18.241592	122.003118	2.90	1.50	-1.40	TS Lawin/ October 2016	5 Yr
20	18.241703	122.003354	2.61	1.50	-1.11	TS Lawin/ October 2016	5 Yr
21	18.241922	121.992042	0.03	0.00	-0.03	TS Lawin/ October 2016	5 Yr
22	18.241941	121.975403	0.03	0.00	-0.03		5 Yr
23	18.241941	121.975403	1.60	0.00	-1.60		5 Yr
24	18.241941	121.975403	0.03	0.00	-0.03		5 Yr
25	18.241941	121.975403	1.60	0.00	-1.60	TS Lawin/ October 2016	5 Yr
26	18.242094	121.999214	2.71	0.80	-1.91	TS Lawin/ October 2016	5 Yr
27	18.242126	121.998955	2.78	1.00	-1.78		5 Yr
28	18.242750	122.005414	1.43	2.00	0.57	1989 Typhoon	5 Yr
29	18.242903	122.005589	0.03	1.60	1.57	TS Lawin/ October 2016	5 Yr
30	18.243277	121.999136	2.46	0.80	-1.66		5 Yr
31	18.243313	121.974488	0.03	0.00	-0.03		5 Yr
32	18.243869	121.990563	0.03	0.00	-0.03		5 Yr
33	18.244789	121.973422	0.03	1.50	1.47		5 Yr

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
34	18.245990	121.973139	0.03	0.15	0.12		5 Yr
35	18.246247	121.997758	0.99	0.50	-0.49	TS Lawin/ October 2016	5 Yr
36	18.246714	121.988857	0.03	0.00	-0.03	TS Lawin/ October 2016	5 Yr
37	18.248536	121.998216	2.20	0.40	-1.80		5 Yr
38	18.249024	121.997838	1.93	0.40	-1.53		5 Yr
39	18.249159	122.013500	0.35	0.00	-0.35		5 Yr
40	18.249278	121.986205	0.03	0.00	-0.03		5 Yr
41	18.249578	122.012403	0.03	0.00	-0.03		5 Yr
42	18.249865	122.010431	0.08	0.00	-0.08	TS Lawin/ October 2016	5 Yr
43	18.250119	122.011499	0.03	0.00	-0.03		5 Yr
44	18.250382	121.983714	0.83	0.30	-0.53		5 Yr
45	18.250793	121.985256	0.03	0.00	-0.03		5 Yr
46	18.251564	122.009237	0.03	0.00	-0.03		5 Yr
47	18.251585	122.007157	0.31	0.00	-0.31		5 Yr
48	18.251670	122.008609	0.03	0.00	-0.03		5 Yr
49	18.251589	121.983058	0.03	0.00	-0.03		5 Yr
50	18.252375	122.003164	0.04	0.00	-0.04		5 Yr
51	18.252532	122.003741	0.62	0.00	-0.62		5 Yr
52	18.252869	122.005351	0.03	0.00	-0.03		5 Yr
53	18.252843	121.996878	0.03	0.00	-0.03		5 Yr
54	18.253006	122.004471	0.51	0.00	-0.51		5 Yr
55	18.253226	122.002530	0.09	0.00	-0.09		5 Yr
56	18.253317	121.987685	3.93	0.00	-3.93		5 Yr
57	18.253554	121.976961	2.05	0.15	-1.90		5 Yr
58	18.254474	121.996219	0.03	0.00	-0.03		5 Yr
59	18.254634	121.996148	0.06	0.00	-0.06		5 Yr
60	18.254728	122.002006	0.33	0.00	-0.33		5 Yr
61	18.254801	121.983977	0.03	0.00	-0.03	TS Lawin/ October 2016	5 Yr
62	18.255816	121.983093	0.75	0.00	-0.75		5 Yr
63	18.256360	121.988547	0.03	0.80	0.77		5 Yr
64	18.256612	121.988895	0.03	0.15	0.12	TS Lawin/ October 2016	5 Yr
65	18.256711	122.001085	0.03	0.00	-0.03		5 Yr
66	18.256764	121.978930	1.08	0.60	-0.48		5 Yr
67	18.257161	121.979015	1.58	0.00	-1.58		5 Yr
68	18.257190	121.980391	0.03	0.00	-0.03		5 Yr
69	18.257393	121.994839	0.03	0.00	-0.03	TS Lawin/ October 2016	5 Yr
70	18.257834	121.985524	0.03	0.00	-0.03		5 Yr
71	18.258128	122.000271	0.03	0.00	-0.03		5 Yr
72	18.258643	121.983349	0.03	0.00	-0.03		5 Yr
73	18.258909	121.992162	1.72	0.15	-1.57	TS Lawin/ October 2016	5 Yr

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
74	18.258871	121.984593	0.03	0.00	-0.03		5 Yr
75	18.259090	121.991976	1.76	0.40	-1.36		5 Yr
76	18.259651	121.999451	0.03	0.00	-0.03		5 Yr
77	18.259690	121.993694	0.13	0.00	-0.13	TS Lawin/ October 2016	5 Yr
78	18.259711	121.997092	0.04	0.00	-0.04		5 Yr
79	18.259920	121.980765	2.85	1.00	-1.85		5 Yr
80	18.260089	121.997817	0.03	0.00	-0.03		5 Yr
81	18.260190	121.993645	0.03	0.00	-0.03		5 Yr
82	18.260342	121.998268	0.06	0.00	-0.06	TS Lawin/ October 2016	5 Yr
83	18.260378	121.999023	0.35	0.00	-0.35		5 Yr
84	18.260606	121.991311	1.90	0.30	-1.60		5 Yr
85	18.260754	121.996738	0.04	0.00	-0.04		5 Yr
86	18.260811	121.996452	0.08	0.00	-0.08		5 Yr
87	18.260827	121.982302	0.03	0.00	-0.03		5 Yr
88	18.260896	121.995033	0.14	0.00	-0.14		5 Yr
89	18.261019	121.995693	0.14	0.00	-0.14	TS Lawin/ October 2016	5 Yr
90	18.261204	121.995573	0.12	0.00	-0.12	TS Lawin/ October 2016	5 Yr
91	18.261570	121.989732	2.56	1.30	-1.26		5 Yr
92	18.261598	121.989748	2.56	1.30	-1.26	TS Lawin/ October 2016	5 Yr
93	18.261698	121.995353	0.22	0.00	-0.22		5 Yr
94	18.261920	121.990115	2.00	0.50	-1.50	TS Lawin/ October 2016	5 Yr
95	18.261955	121.994513	0.12	0.00	-0.12		5 Yr
96	18.262108	121.990754	1.70	0.30	-1.40	TS Lawin/ October 2016	5 Yr
97	18.262215	121.995086	0.11	0.00	-0.11	TS Lawin/ October 2016	5 Yr
98	18.262364	121.990537	1.79	0.50	-1.29		5 Yr
99	18.262407	121.990608	1.64	0.30	-1.34		5 Yr
100	18.262438	121.992600	0.05	0.00	-0.05		5 Yr
101	18.262630	121.994244	0.03	0.00	-0.03		5 Yr
102	18.262645	121.994194	0.05	0.00	-0.05		5 Yr
103	18.262735	121.994859	0.18	0.00	-0.18		5 Yr
104	18.262681	121.982902	0.03	0.00	-0.03		5 Yr
105	18.263041	121.990329	1.71	0.00	-1.71		5 Yr
106	18.263154	121.991361	1.11	0.00	-1.11		5 Yr
107	18.263190	121.992497	0.15	0.00	-0.15		5 Yr
108	18.263407	121.993831	0.13	0.00	-0.13		5 Yr
109	18.263433	121.990527	2.11	0.00	-2.11		5 Yr
110	18.263485	121.993739	0.09	0.00	-0.09		5 Yr
111	18.264125	121.993461	0.07	0.00	-0.07		5 Yr
112	18.264581	121.990850	1.49	0.00	-1.49		5 Yr

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
113	18.264936	121.993068	0.04	0.00	-0.04		5 Yr
114	18.265010	121.984238	0.03	0.00	-0.03		5 Yr
115	18.265283	121.989348	1.97	0.00	-1.97	TS Lawin/ October 2016	5 Yr
116	18.265585	121.992699	0.06	0.00	-0.06		5 Yr
117	18.266322	121.983352	0.08	0.40	0.32		5 Yr
118	18.266646	121.992374	0.21	0.00	-0.21		5 Yr
119	18.266858	121.988788	1.20	0.30	-0.90	TS Lawin/ October 2016	5 Yr
120	18.267437	121.983478	0.03	0.10	0.07		5 Yr
121	18.267596	121.992046	0.72	0.00	-0.72		5 Yr
122	18.268007	121.988598	1.98	0.10	-1.88	TS Lawin/ October 2016	5 Yr
123	18.269014	121.983157	0.07	0.00	-0.07		5 Yr
124	18.269143	121.991349	1.30	0.15	-1.15		5 Yr
125	18.269263	121.987903	1.96	0.00	-1.96		5 Yr
126	18.269740	121.987355	2.12	0.00	-2.12	TS Lawin/ October 2016	5 Yr
127	18.270463	121.983002	1.82	0.50	-1.32		5 Yr
128	18.270550	121.986996	2.55	0.10	-2.45	TS Lawin/ October 2016	5 Yr
129	18.270805	121.990786	3.09	0.00	-3.09	TS Lawin/ October 2016	5 Yr
130	18.270924	121.990790	3.14	0.00	-3.14	TS Lawin/ October 2016	5 Yr
131	18.271285	121.982424	0.03	0.40	0.37		5 Yr
132	18.271788	121.986347	3.00	0.00	-3.00	TS Lawin/ October 2016	5 Yr
133	18.272124	121.982005	2.62	0.30	-2.32	TS Lawin/ October 2016	5 Yr
134	18.272212	121.990928	3.75	0.00	-3.75		5 Yr
135	18.273186	121.982338	0.03	0.75	0.72	TS Lawin/ October 2016	5 Yr
136	18.274336	121.982467	2.47	0.30	-2.17	TS Lawin/ October 2016	5 Yr
137	18.275217	121.982370	1.19	0.30	-0.89	TS Lawin/ October 2016	5 Yr
138	18.275711	121.985178	4.55	0.15	-4.40	TS Lawin/ October 2016	5 Yr
139	18.275784	121.982607	5.61	1.60	-4.01	TS Lawin/ October 2016	5 Yr
140	18.275827	121.982221	4.78	1.60	-3.18	TS Lawin/ October 2016	5 Yr
141	18.278327	122.002990	3.55	0.60	-2.95		5 Yr
142	18.278343	122.003032	3.78	0.60	-3.18		5 Yr
143	18.278943	122.005630	2.56	0.00	-2.56		5 Yr
144	18.278900	121.996544	2.81	0.00	-2.81		5 Yr
145	18.278979	121.998299	2.65	0.00	-2.65		5 Yr
146	18.278999	122.001225	2.44	0.00	-2.44		5 Yr

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
147	18.279144	122.003520	2.07	0.00	-2.07		5 Yr
148	18.279236	122.002440	2.40	0.00	-2.40	TS Lawin/ October 2016	5 Yr
149	18.279403	122.004964	2.17	0.00	-2.17		5 Yr
150	18.279512	122.001541	2.84	0.00	-2.84		5 Yr
151	18.279540	122.002639	3.06	0.15	-2.91		5 Yr
152	18.279621	122.006419	2.33	0.30	-2.03		5 Yr
153	18.279840	122.007101	2.25	0.30	-1.95	TS Lawin/ October 2016	5 Yr
154	18.280045	122.008346	2.77	0.00	-2.77		5 Yr
155	18.280325	122.002562	3.81	0.15	-3.66		5 Yr
156	18.280474	121.998536	3.98	0.00	-3.98		5 Yr
157	18.280688	122.000158	4.54	0.00	-4.54		5 Yr
158	18.280728	122.007490	4.26	0.30	-3.96		5 Yr
159	18.280814	122.005451	3.29	0.00	-3.29		5 Yr
160	18.280855	122.001144	4.92	0.00	-4.92		5 Yr
161	18.281148	122.006167	3.32	0.00	-3.32		5 Yr
162	18.281581	121.998215	3.84	0.00	-3.84		5 Yr
163	18.281576	121.996627	3.27	0.00	-3.27		5 Yr
164	18.281574	121.995683	3.50	0.00	-3.50		5 Yr
165	18.281684	122.008434	3.47	0.00	-3.47		5 Yr
166	18.281742	122.009504	3.46	0.00	-3.46		5 Yr
167	18.281814	122.008631	4.06	0.00	-4.06		5 Yr
168	18.281784	121.999847	3.92	0.00	-3.92		5 Yr
169	18.281866	122.004271	3.99	0.00	-3.99		5 Yr
170	18.281956	122.007673	4.08	0.30	-3.78		5 Yr
171	18.282489	122.007753	4.08	0.15	-3.93		5 Yr
172	18.282573	122.008922	3.81	0.00	-3.81		5 Yr
173	18.282602	122.003342	3.88	0.00	-3.88		5 Yr
174	18.282612	122.003138	4.00	0.00	-4.00		5 Yr
175	18.282823	122.011184	3.31	0.00	-3.31		5 Yr
176	18.282926	122.006405	4.15	0.00	-4.15		5 Yr
177	18.283195	122.005272	3.88	0.00	-3.88		5 Yr
178	18.283575	122.007304	3.98	0.00	-3.98		5 Yr
				RMSE	**2.01**		

ANNEX 12. Educational Institutions Affected by Flooding in Aunugay Floodplain

Table A-12.1. Educational Institutions Affected by Flooding in Aunungay Floodplain

Cagayan				
Gonzaga				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Batangan Elementary School	Batangan	High	High	High
Day Care Center	Calayan	High	High	High
Callao Primary School	Callao			Medium
Cagayan State University	Flourishing			
Gonzaga National High School	Flourishing		Low	Low
Minanga Elementary School	Minanga	High	High	High
Minanga Day Care Center	Minanga	High	High	High
St. Anthony Academy of Gonzaga	Paradise			
Gonzaga North Central School	Paradise		Low	Low
Gonzaga Bible Baptist Church Academy Elem. Sc.	Progressive	Medium	High	High
Gonzaga National High School	Smart			Low
Gonzaga South Central School	Smart			

ANNEX 13. Health Institutions Affected by Flooding in Aunugay Floodplain

Table A-12.1. Medical Institutions Affected by Flooding in Aunungay Floodplain

Cagayan				
Gonzaga				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Barangay Health Center	Calayan	High	High	High
Alfonso Ponce Enrile Memorial District Hospital	Flourishing			
Gonzaga Community Clinic	Paradise			
Residential	Paradise	Low	Low	Low
Gonzaga Municipal Health Office	Smart			
Medical Institution	Smart	Low	Low	Low