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

LiDAR Surveys and Flood Mapping of Paliwan River

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

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

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

E. C. Paringit, A. E. Milano, Jr., O. P. Jayag, L. P. Balicanta, C. Cruz, L. Acuña, G. Hipolito, J. S. Mars, R. C. Felismino, M. O. Ang, J. D. Fabila, S. D. Samalburo , G. Apat , J. F. Prieto , M. L. Olanda, J. S. Canlas, C. P. Añonuevo , F. D. Maraya, C. B. de Guzman, J. S. Caballero, P. P. dela Cruz, D. T. Lozano D. C. Tajora, E. Salvador, R. C. Alberto, A. Lagmay, C. Uichanco, S. Sueno, M. Moises, H. Ines, M. del Rosario, K. Punay, N. Tingin, N. Tan, M. Arias (2017), LiDAR Surveys and Flood Mapping Report of Clarin River, in Enrico C. Paringit, (Ed.), Flood Hazard Mapping of the Philippines using LIDAR, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry- 142 pp.

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND THE PALIWAN RIVER BASIN

Enrico C. Paringit, Dr. Jonnifer Sinogaya, and Engr. Omar P. Jayag

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 in 2014, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippine Cebu. UPC 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 22 river basins in the Central Visayas Region. The university is located in Cebu City, Cebu.

1.2 Overview of the Paliwan River Basin

Paliwan River Basin is located in the province of Antique at the west of Panay Island. The floodplain and drainage area of 38.48 km^2 and 28.4 km^2, respectively, covers the municipalities of Bugasong, Tapaz, Jamindan, Barbaza and Valderrama. The gathered LiDAR data covered 98.05% of the floodplain comprised by four (4) blocks. The LiDAR data was calibrated then mosaicked with an RMSE of -0.06 and then bathy burned. The bathy survey done reached a total length of 9.85 km starting from Maray, Bugasong up to the river mouth with 576 points surveyed. The LiDAR data also showed that there are 4013 buildings, 38.56 km roads, 11 waterbodies and 12 bridges. When Feature Extraction Attribution was conducted, among the building featured, 3852 of them are residential, 64 are schools and five (5) are medical Institutions.

The flood hazard map produced covers the 60.99 km^2, 74.98 km^2, 83.16 km^2 for the 5-year, 25-year, and 100-year rainfall return period in Barbaza which affects one (1) barangay as well as in Laua-an which affects 18 barangays, Bugasong with 28 barangays, Lambunao with one (1) barangay, Patnongon with 20 barangays, San Remigio with two (2) barangays, Tapaz with (1) barangay, and Valderrama with 23 barangays. In addition, a flood depth validation was conducted using 276 randomly generated points which was spread throughout the 6 ranges namely 0m-0.2m, 0.21m-0.5m, 0.51m-1m, 1.01m-2m, 2.10m-5m, 5m+ depth using the 25-year rainfall flood depth map. It yielded a 0.716m RMSE.

The rating curve developed at Brgy. Anilawan Flow Site, Bugasong, Antique shows the relationship between the observed water levels at Brgy. Anilawan Flow Site and outflow of the watershed in this location. This rating curve equation, expressed as Q = 66.291e0.5476x, was used to compute the river outflow at Brgy. Anilawan Flow Site for the calibration of the HEC-HMS model. The resulting outflow was used to simulate the flooded areas using HEC-RAS. The simulated model will be an integral part in determining the real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website.

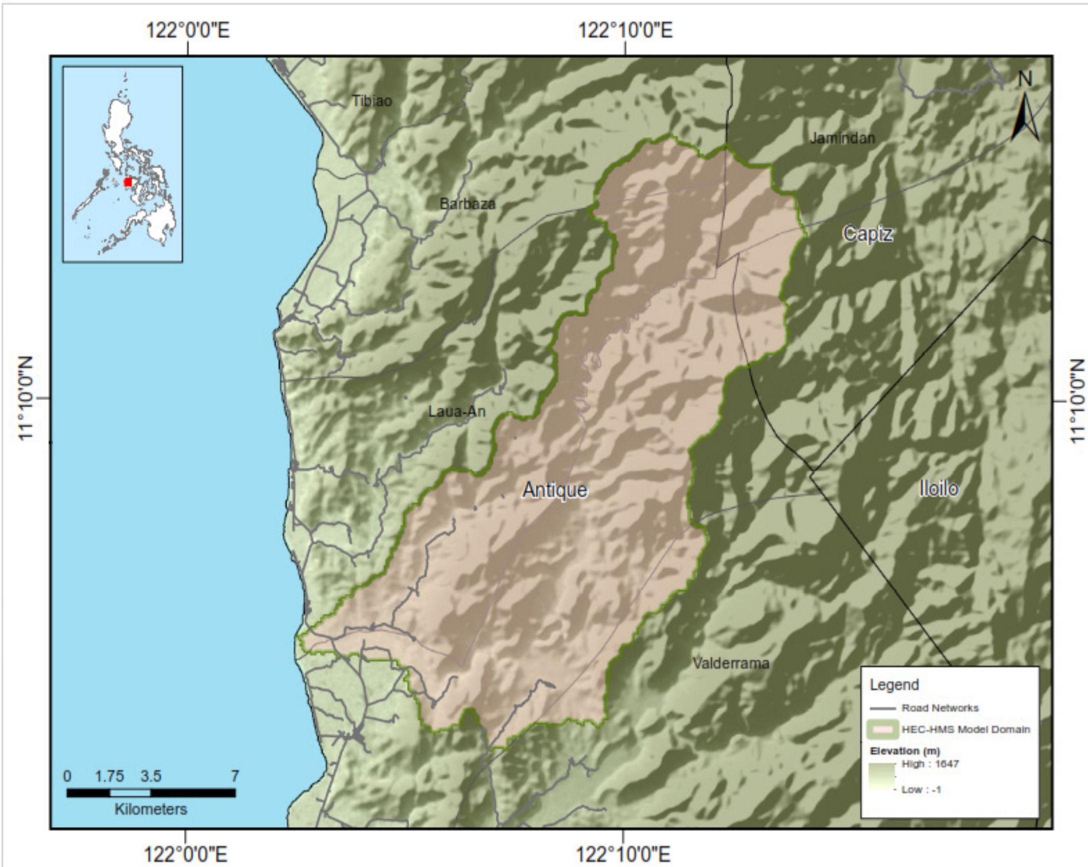

Figure 1. Map of the Paliwan River Basin (in brown)

Chapter 2: LIDAR DATA ACQUISITION OF THE PALIWAN FLOODPLAIN

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

2.1. Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Paliwan Floodplain in Antique. Each flight mission has an average of 12 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Tables 1 to 4. Figures 2 to 4 show the flight plans for Paliwan 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)
BLK43B	1200	30	50	100	50	120	5
BLK43C	1200	30	50	100	50	120	5

Table 2. Flight planning parameters for Pegasus LiDAR System.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK43B	1500	30	50	200	30	130	5

Table 3. Flight planning parameters for Aquarius 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)
BLK43K	600	30	36	50	45	130	5

Table 4. Flight planning parameters for CASI.

Block Name	Flying Height (m AGL)	Integration Time	Along Track Resolution	Across Track Reso-lution	Number of Bands	Aperture	Average speed of Plane (kts)
BLK37K	600	10 m/sec	0.6m	0.3m	72	Largest	120

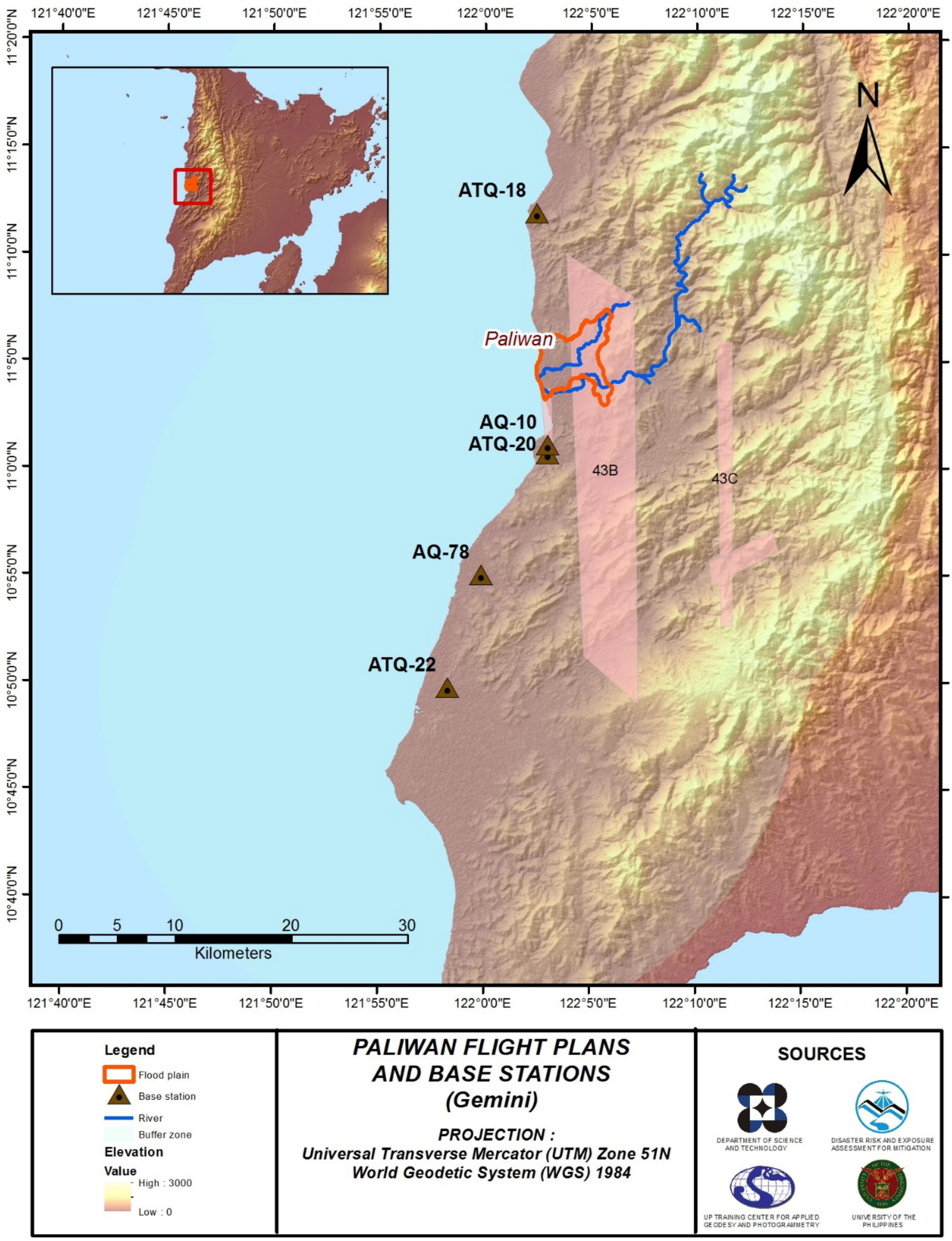


Figure 2. Flight plan and base stations using the Gemini system to cover Paliwan Floodplain.

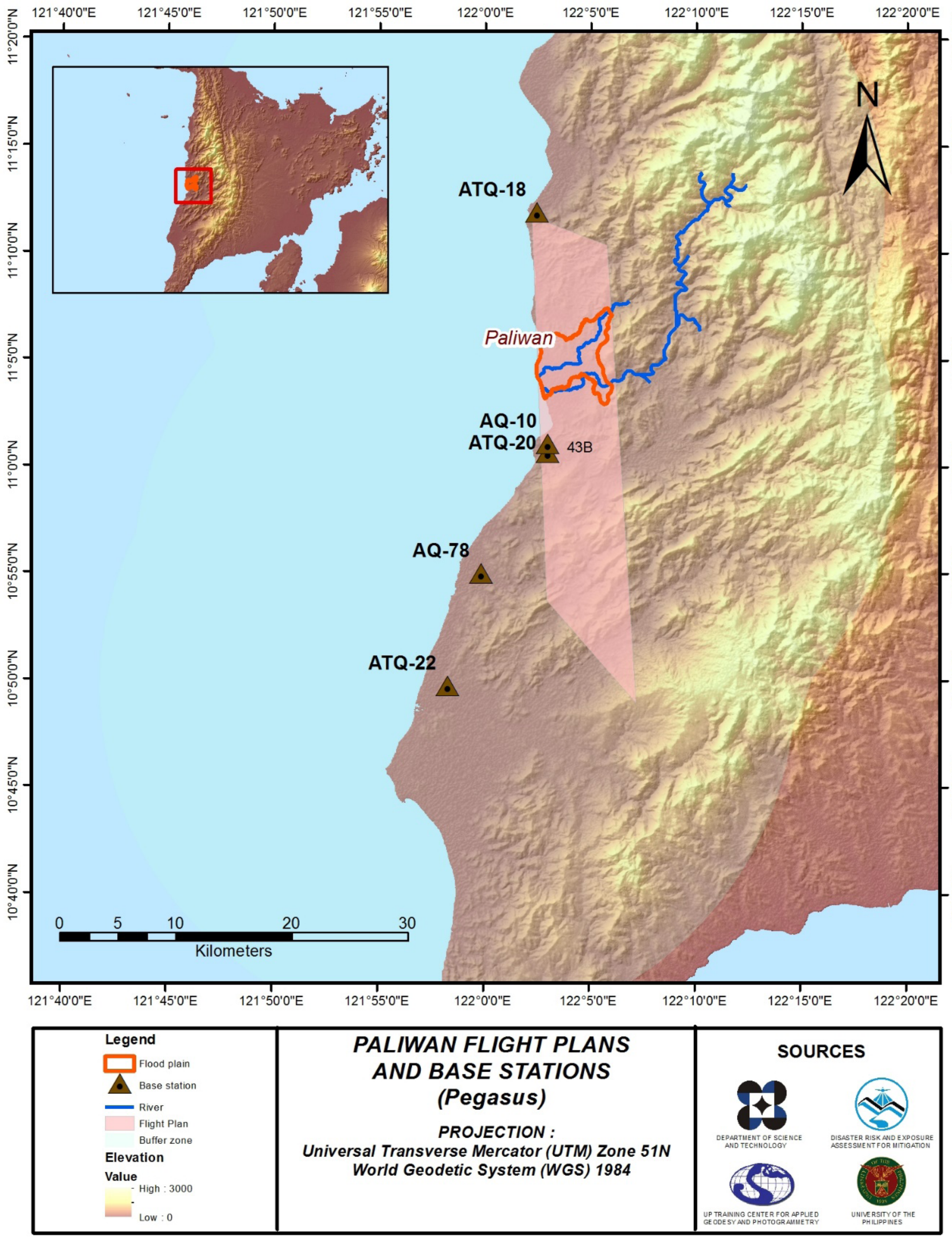


Figure 3. Flight plan and base stations using the Pegasus system to cover Paliwan Floodplain.

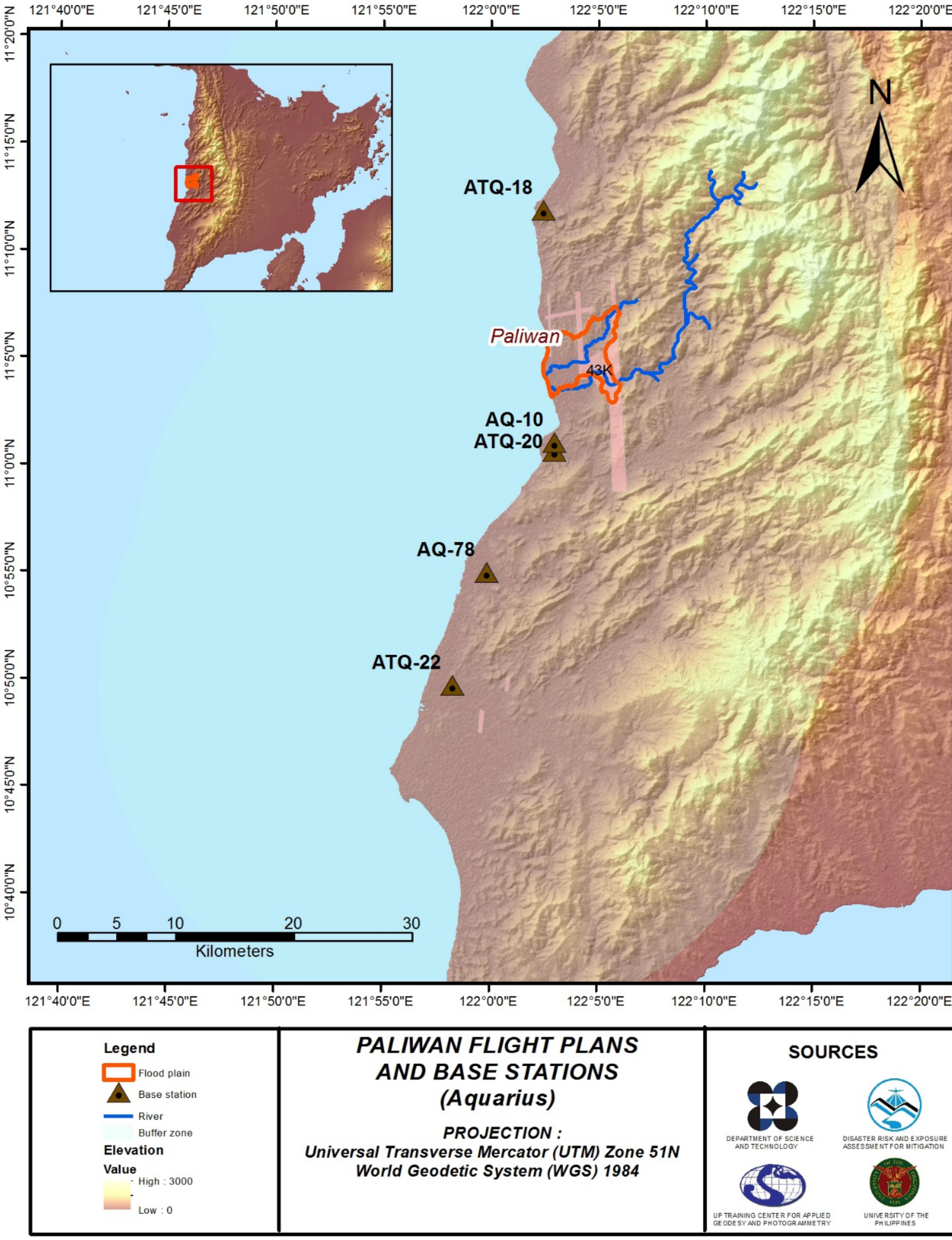


Figure 4. Flight plan and base stations using the Aquarius system to cover Paliwan Floodplain.

2.2 Ground Base Station

The project team was able to recover three (3) NAMRIA reference points: ATQ-18, ATQ-20 and ATQ-22 which is of second (2nd) order accuracy. There are two (2) established reference points: AQ-10 and AQ-78. The certification for the base station is found in Annex 4. These were used as base stations during flight operations for the entire duration of the survey (February 2015 and October 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and TRIMBLE SPS 985. Flight plans and location of base stations used during the aerial LiDAR Acquisition in Paliwan floodplain are shown in Figures 2 to 4.

Figure 5 to Figure 9 shows the recovered NAMRIA control station within the area, in addition Table 5 to Table 9 show the details about the following NAMRIA control stations and established points, Table 10 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

(a)

(b)

Figure 5. GPS set-up over ATQ-18 as recovered in Barangay Cubay, Barbaza, Province of Antique (a) NAMRIA reference point ATQ-18 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point ATQ-18 used as base station for the LiDAR Acquisition.

Station Name	ATQ-18	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	11° 11’ 58.67081”
	Longitude	122° 2’ 22.83300”
	Ellipsoidal Height	10.902 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	395155.157 meters
	Northing	1238579.674 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	11° 11’ 54.16068” North
	Longitude	122° 2’ 28.01549” East
	Ellipsoidal Height	65.961 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	395155.87 meters
	Northing	1238146.15 meters

(a)

(b)

Figure 6. GPS set-up over ATQ-20 as recovered in Brgy. Zaragoza of Bugasong (a) NAMRIA reference point ATQ-20 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point ATQ-20 used as base station for the LiDAR Acquisition.

Station Name	ATQ-20	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	11° 0’ 42.90484”
	Longitude	122° 2’ 54.07144”
	Ellipsoidal Height	10.56200 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	396000.488 meters
	Northing	1217812.272 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	11° 0’ 38.44240” North
	Longitude	122° 2’ 59.27039” East
	Ellipsoidal Height	66.09400 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	396036.89 meters
	Northing	1217386.02 meters

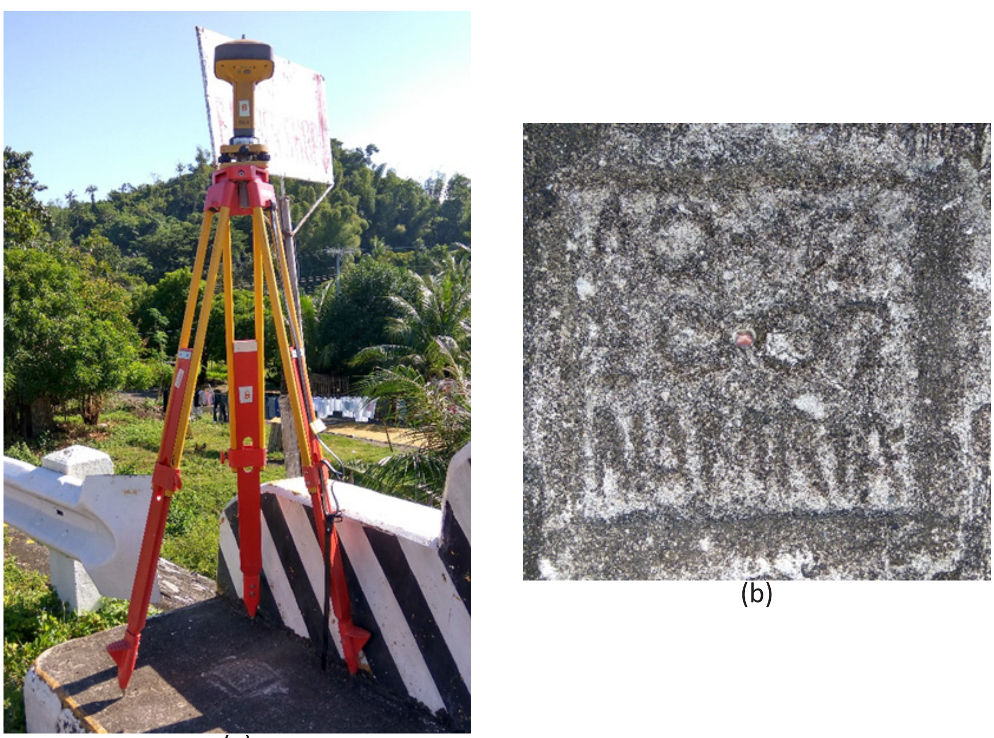
(b)

(a)

Figure 7. (a) ATQ-22 as recovered in Barangay Concepcion, Belison, Province of Antique. (b) NAMRIA reference point ILO-3134 as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point ATQ-22 used as base stationfor the LiDAR Acquisition.

Station Name	ATQ-22	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	10° 49' 46.66618"
	Longitude	121° 58' 11.90221"
	Ellipsoidal Height	12.250 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	387365.279 meters
	Northing	1197676.056 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	10° 49' 42.24271" North
	Longitude	121° 58' 17.11770" East
	Ellipsoidal Height	68.022 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	387404.70 meters
	Northing	1197256.85 meters



(a) (b)

Figure 8. GPS set-up over AQ-10 as recoverd in Brgy. Zaragoza (a) NAMRIA reference point AQ-10 (b) as recovered by the field team.

Table 8. Details of the recovered NAMRIA horizontal control point AQ-10 used as base station for the LiDAR Acquisition.

Station Name	ATQ-10	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	11° 01’ 03.59755”
	Longitude	122° 03’ 00.53639”
	Ellipsoidal Height	11.054 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	396235.105 meters
	Northing	1218020.995 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	11° 00’ 59.12282” North
	Longitude	122° 03’ 05.73482” East
	Ellipsoidal Height	66.576 meters

(a)

(b)

Figure 9. GPS set-up over AQ-78 as recovered in Barangay Ipayo, Patnongon, Province of Antique (a) NAMRIA reference point AQ-78 (b) as recovered by the field team.

Table 9. Details of the recovered NAMRIA vertical control point AQ-78 used as base station for the LiDAR Acquisition.

Station Name	AQ-78	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	10° 55’ 03.77330”
	Longitude	121° 59’ 46.81987”
	Ellipsoidal Height	48.448 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	390150.425 meters
	Northing	1207471.411 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	10° 54’ 59.33002” North
	Longitude	121° 59’ 52.02741” East
	Ellipsoidal Height	66.5525 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting	390319.320 meters
	Northing	1206987.603 meters

Table 10. Ground Control Points used during LiDAR data acquisiton.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
Feb. 20, 2015	2593P	1BLK43BDG051A	ATQ-18 and ATQ-22
Feb. 25, 2015	2602G	2BLK43B056A	ATQ-22 and AQ-78
Feb. 26, 2015	2606G	2BLK43BV057A	ATQ-22 and AQ-78
Feb. 27, 2015	2610G	2BLK43BV058A	ATQ-22 and AQ-78
Oct. 25, 2016	8511AC	3BLK43KJ299A	ATQ-20 and AQ-10
Oct. 27, 2016	8515AC	3BLK43K301A	ATQ-20 and AQ-10

2.3. Flight Missions

Six (6) missions were conducted to complete the LiDAR Data Acquisition in Paliwan Floodplain, for a total of twenty-one hours (21) of flying time for RP-C9122, RP-C9022 and RP-C9322 All missions were acquired using the Gemini, Pegasus and Aquarius LiDAR system. Table 11 shows the total area of actual coverage per mission and the flying length for each mission and Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight Missions for LiDAR Data Acquisition in Paliwan Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the River Systems (km^2)	Area Surveyed Outside the River Systems (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
Feb. 20, 2015	2593P	248.27	180.57	12.88	167.69	427	3	29
Feb. 21, 2015	2602G	224.96	89.82	7.99	81.83	0	3	17
Feb. 22, 2015	2606G		221.78	17.75	204.03	0	4	5
Feb. 20, 2015	2610G		34.35	1.15	33.2	0	3	5
Feb. 25, 2015	8511AC	29.89	25.58	4.8	20.78	0	3	35
Feb. 26, 2015	8515AC		17.2	9.02	8.18	0	3	29
TOTAL		503.12	569.3	53.59	515.71	427	21	00

Table 12. Actual Parameters used during LiDAR Data Acquisiton

Flight Number	Flying Height (AGL) (m)	Overlap (%)	Field of View	PRF (Hz)	Scan Frequency (Hz)	Speed of Plane (Kts)	Average Turn times (Minutes)
2593P	1800	30	40	200	50	120	5
2602G	1200	30	40	100	50	125	5
2606G	1800	30	40	70	56	110	5
2610G	2000	30	34	70	56	110	5
8511AC	600	30	18	45	50	120	5
8515AC	600	30	18	45	50	120	5

2.4. Survey Coverage

Paliwan floodplain is located in the provinces of Antique and Iloilowith majority of the floodplain situated within the municipality of Laua-An. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 13. The actual coverage of the LiDAR acquisition for Paliwan floodplain is presented in Figure 10.

Table 13. List of municipalities and cities surveyed during Paliwan floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Antique	Patnongon	135.68	79.96	59 %
	Laua-An	165.65	78.94	48 %
	Bugasong	178.8	69.82	39 %
	San Remigio	370.9	59.9	16 %
	Valderrama	309.67	39.53	13 %
	Barbaza	171.23	14.32	8 %
	Belison	36.8	2.62	7 %
	Sibalom	240.55	10.96	5 %
Iloilo	Igbaras	132.37	7.92	6 %
	San Joaquin	200.06	9.1	5 %
	Miagao	170.53	3.11	2 %

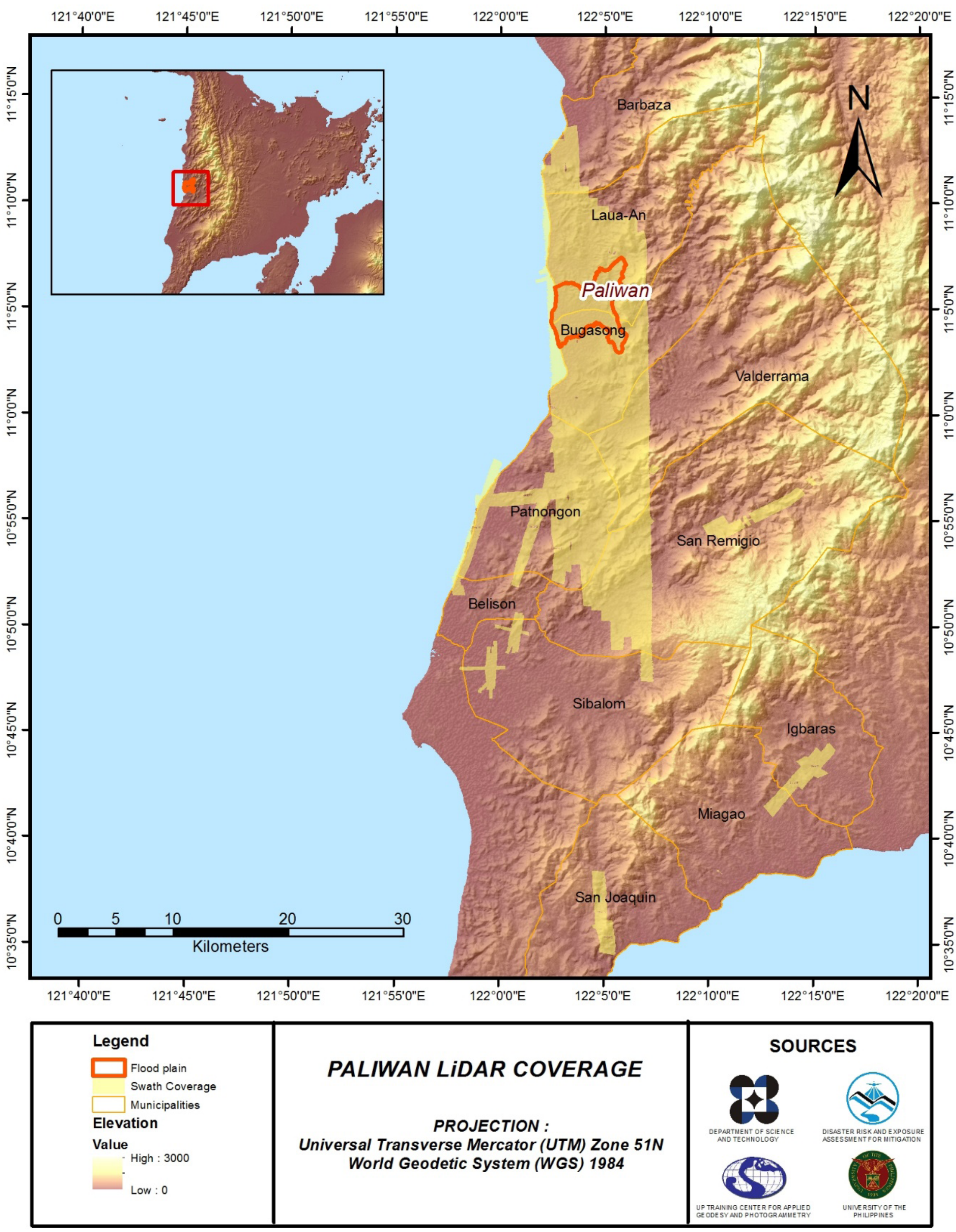


Figure 10. Actual LiDAR data acquisition of the Paliwan floodplain

Chapter 3: LIDAR DATA PROCESSING OF THE PALIWAN FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

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

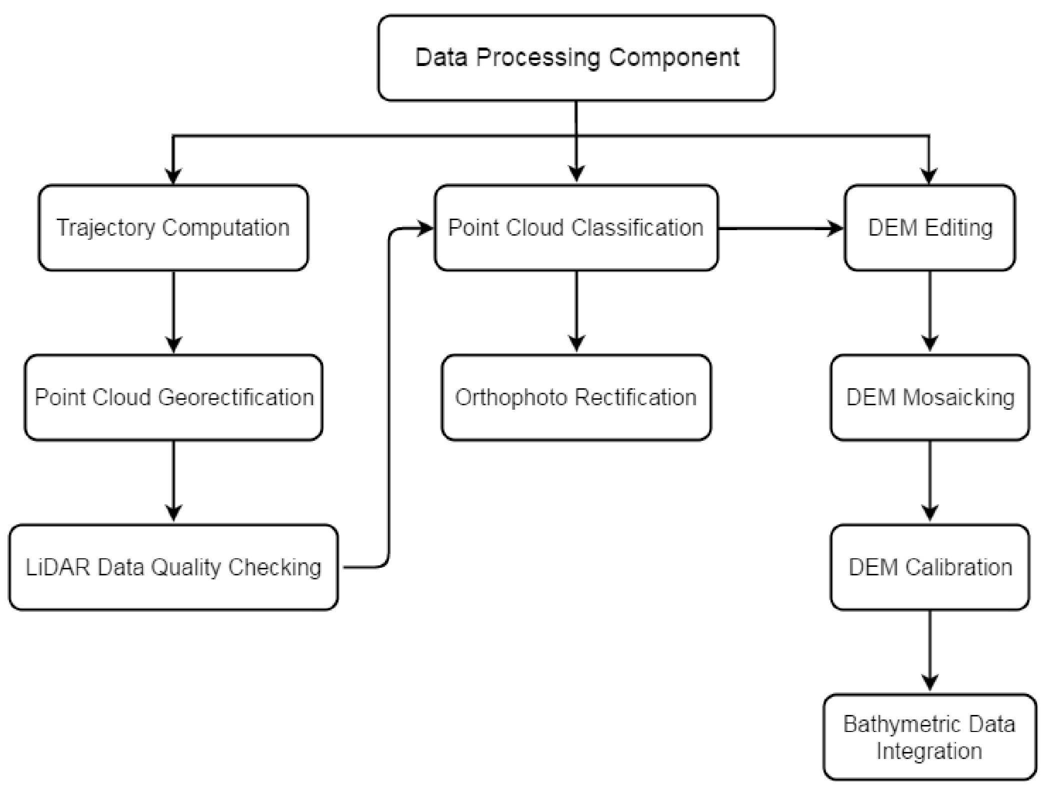


Figure 11. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Paliwan floodplain can be found in Annex 8 (Data Transfer Sheets). Missions flown during the first survey conducted last March 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system while missions acquired during the second survey last July 2015 were flown using the Gemini system over Laua-an, Antique. The Data Acquisition Component (DAC) transferred a total of 37.8 Gigabytes of Range data, 761 Megabytes of POS data, 38.69 Megabytes of GPS base station data, and 61.32 Gigabytes of raw image data to the data server last March 23, 2015 for the first survey and July 3, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Paliwan was fully transferred on July 3, 2015, as indicated on the Data Transfer Sheets for Paliwan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 2593P, one of the Paliwan flights, which is the North, East, and Down position RMSE values are shown in Figure 12. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 20, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

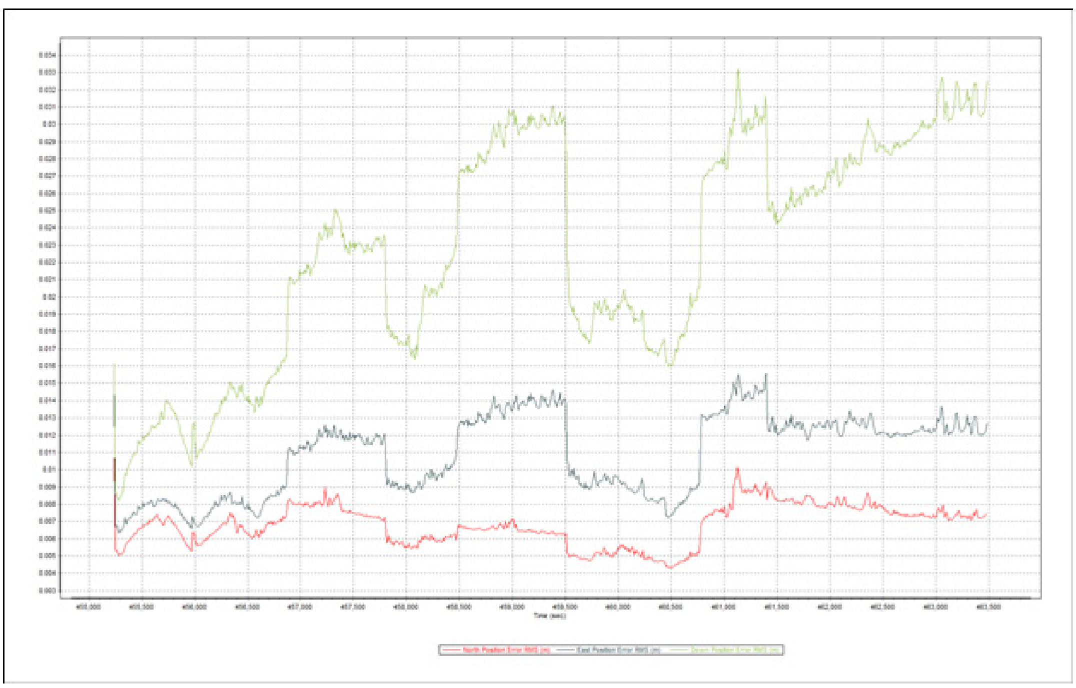


Figure 12. Smoothed Performance Metric Parameters of a Paliwan Flight 2593P.

The time of flight wafrom 455,250 seconds to 463,500 seconds, which corresponds to morning of February 20, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 12 shows that the North position RMSE peaks at 1.00 centimeters, the East position RMSE peaks at 1.60 centimeters, and the Down position RMSE peaks at 3.30 centimeters, which are within the prescribed accuracies described in the methodology.

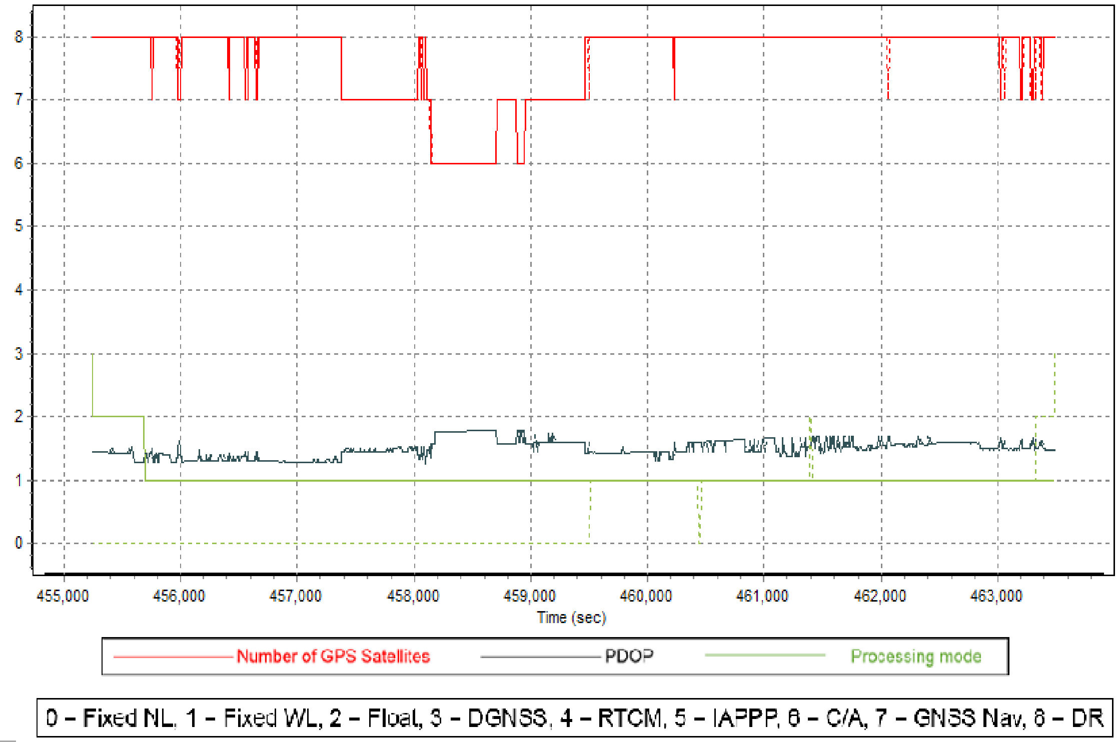


Figure 13. Solution Status Parameters of Paliwan Flight 2593P.

The Solution Status parameters of flight 2593P, one of the Paliwan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 13. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 8. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Paliwan flights is shown in Figure 14.

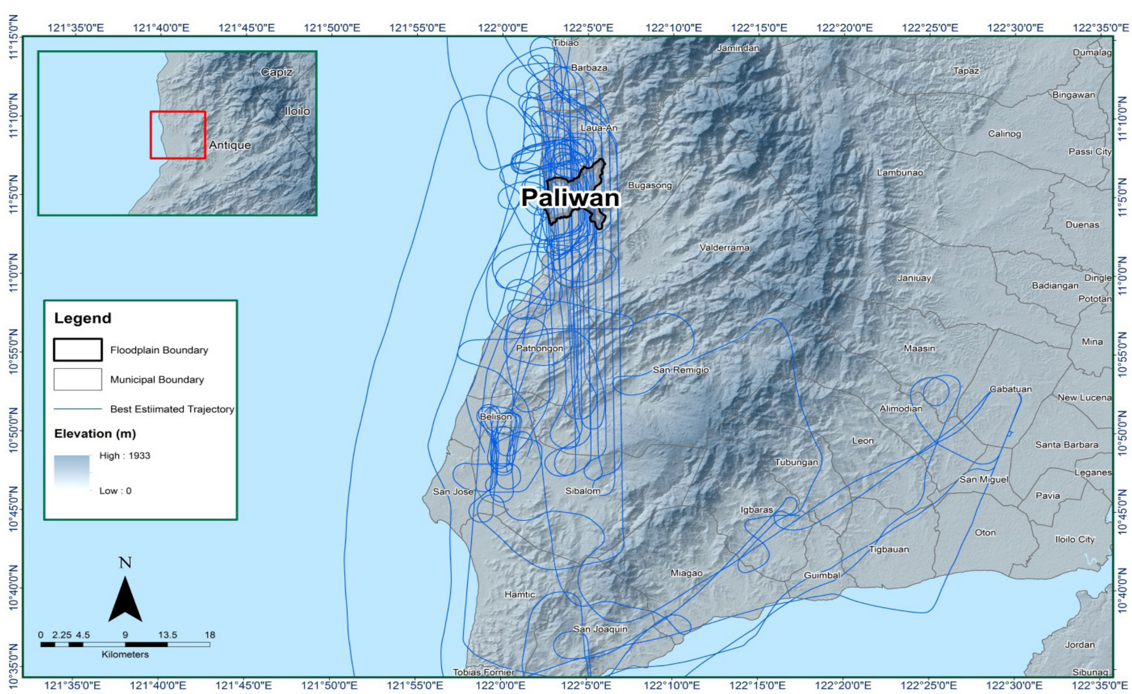


Figure 14. Best Estimated Trajectory for Paliwan floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 19 flight lines, with 6 flight lines containing two channels and the rest containing on channel only, since the Pegasus and Aquarius systems contain two and one channel respectively. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Paliwan floodplain are given in Table 14.

Table 14. Self-Calibration Results values for Paliwan flights.

Parameter	Accepted Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000371
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000661
GPS Position Z-correction stdev	(<0.01meters)	0.0091

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Paliwan Floodplain is shown in Figure 15. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

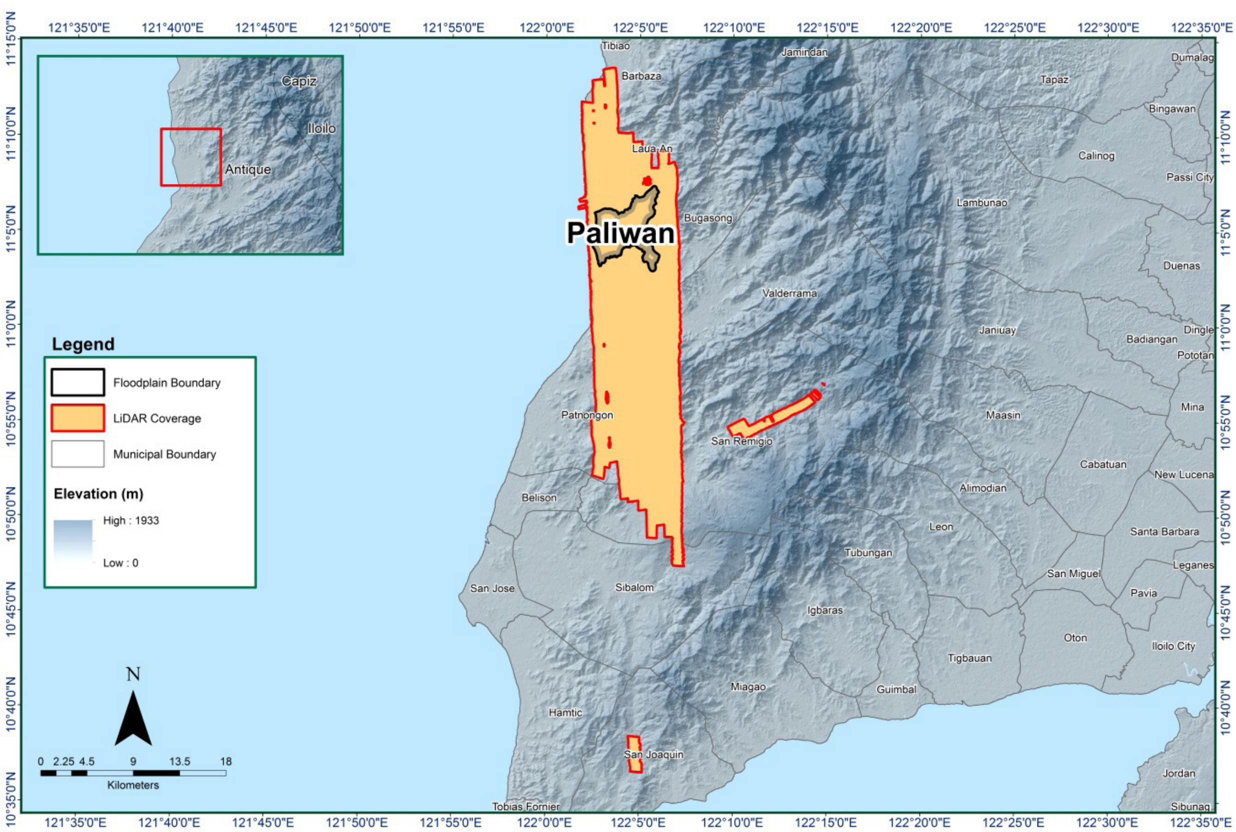


Figure 15. Boundary of the processed LiDAR data over Paliwan Floodplain

The total area covered by the Paliwan missions is 395.11 sq.km that is comprised of four (4) flight acquisitions grouped and merged into two (2) blocks as shown in Table 15.

Table 15. List of LiDAR blocks for Paliwan floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Iloilo_Blk43B	2593P	141.22
	2602G	
Iloilo_Blk43B_additional	2606G	229.08
	2610G	
Iloilo_reflights_Blk43B	8511AC	15.69
Iloilo_reflights_Blk43B_supplement	8515AC	17.23
TOTAL		395.11 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 16. Since the Pegasus and Aquarius systems employ two and one channel respectively, 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.

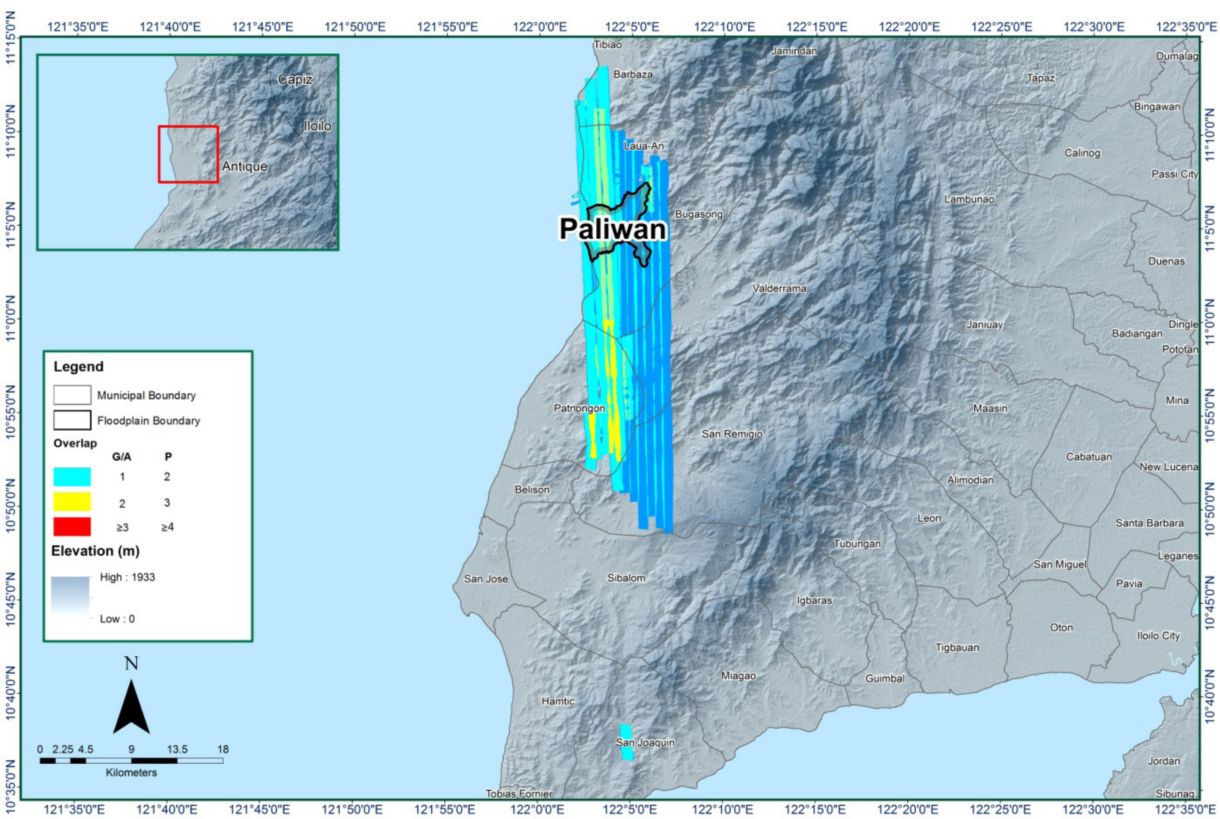


Figure 16. Image of data overlap for Paliwan floodplain.

The overlap statistics per block for the Paliwan floodplain can be found in Annex 5. One pixel corresponds to 25.0 square meters on the ground. For this area, the percent overlap is 25.93%, 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 two (2) points per square meter criterion is shown in Figure 17. It was determined that all LiDAR data for Paliwan floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.40 points per square meter.

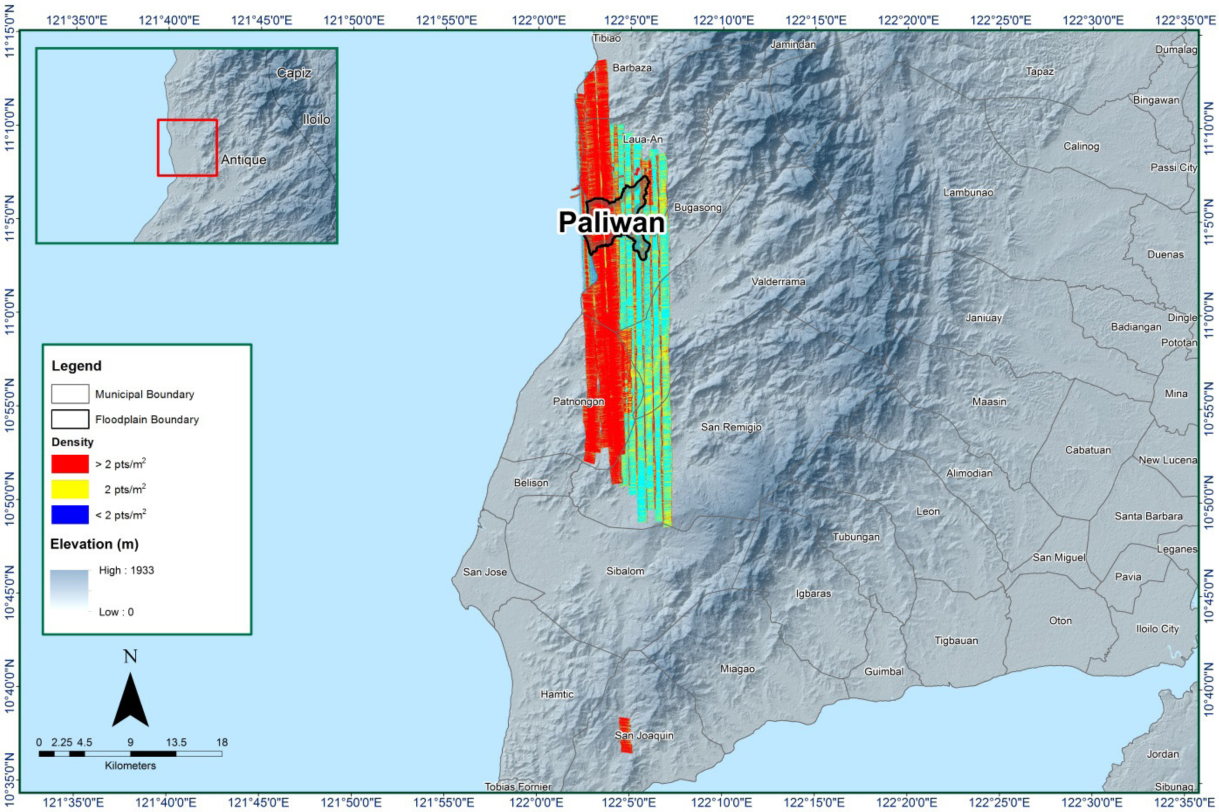


Figure 17. Density map of merged LiDAR data for Paliwan floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 18. 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.

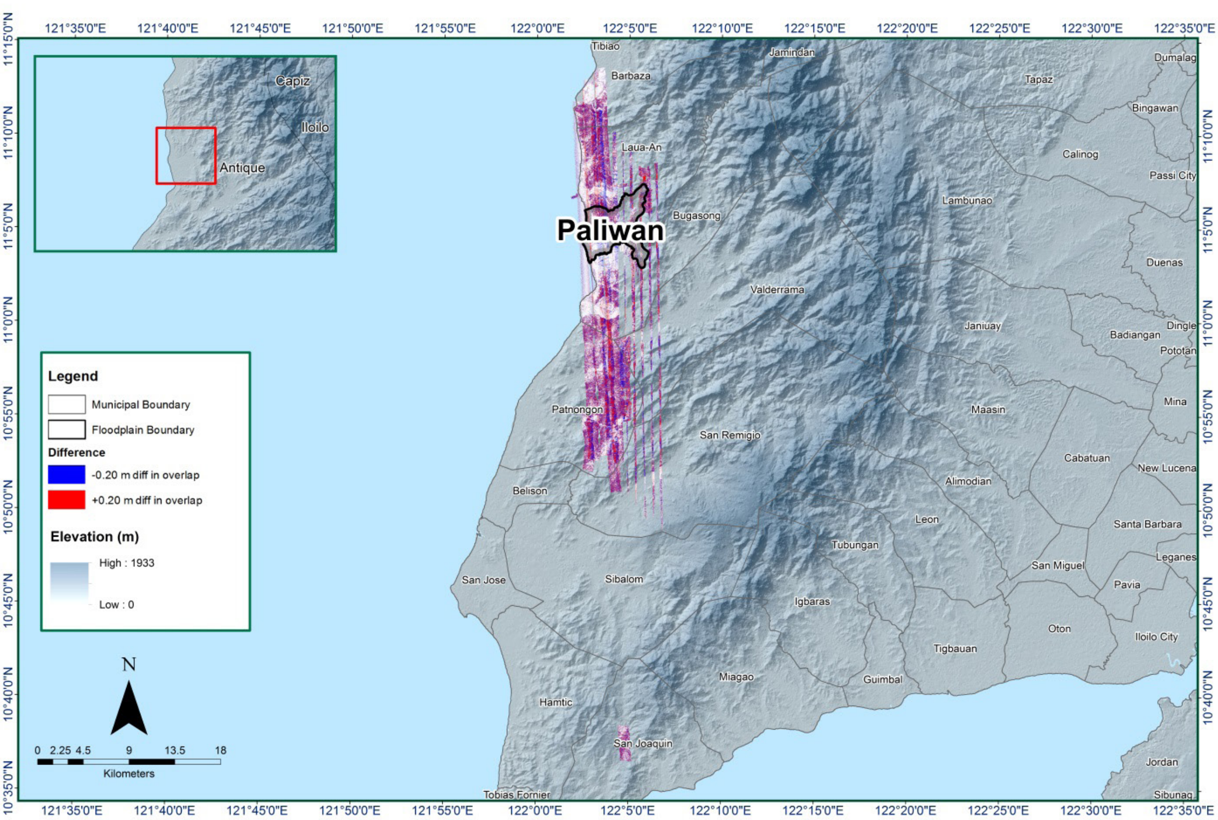


Figure 18. Elevation difference map between flight lines for Paliwan floodplain.

A screen capture of the processed LAS data from a Paliwan flight 2593P loaded in QT Modeler is shown in Figure 19. 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 researcher was satisfied with the quality of the LiDAR data. No reprocessing was done for this LiDAR dataset.

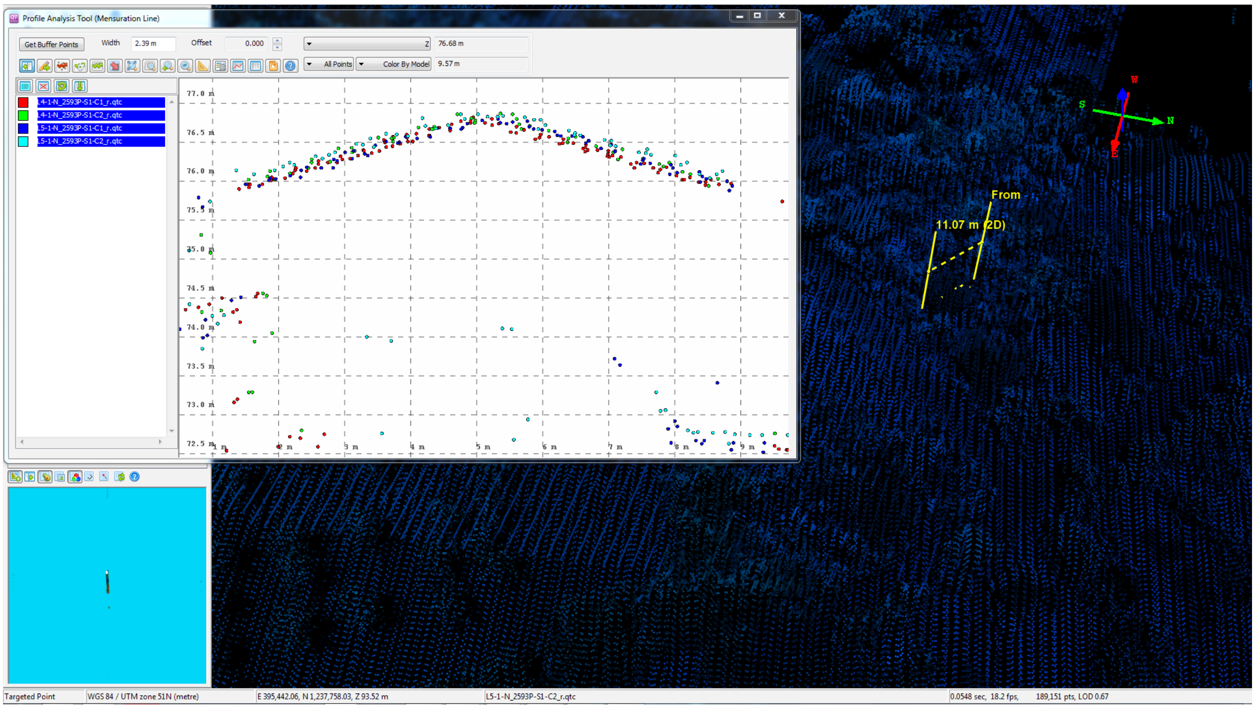


Figure 19. Quality checking for Paliwan flight 2593P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Paliwan classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	293,176,098
Low Vegetation	102,063,776
Medium Vegetation	227,297,359
High Vegetation	439,049,485
Building	5,263,821

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Paliwan floodplain is shown in Figure 20. A total of 485 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 16. The point cloud has a maximum and minimum height of 925.04 meters and 54.48 meters respectively.

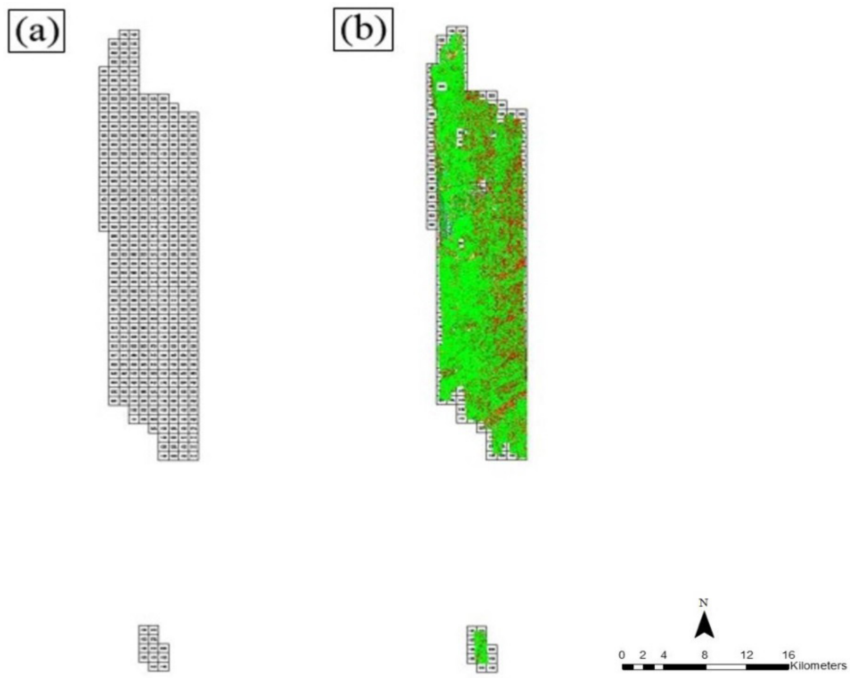


Figure 20. Tiles for Paliwan floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 21. 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.

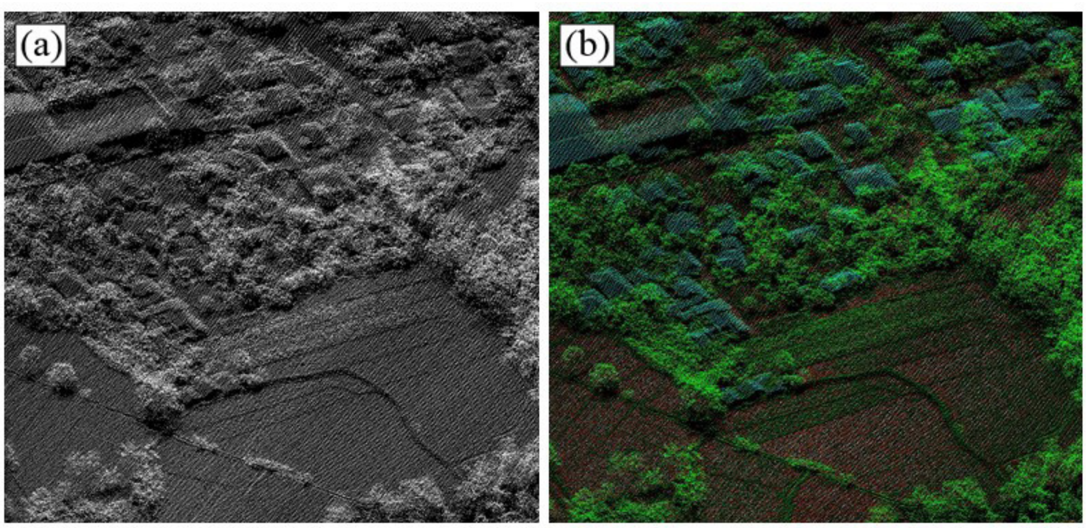


Figure 21. Point cloud before (a) and after (b) classification.

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

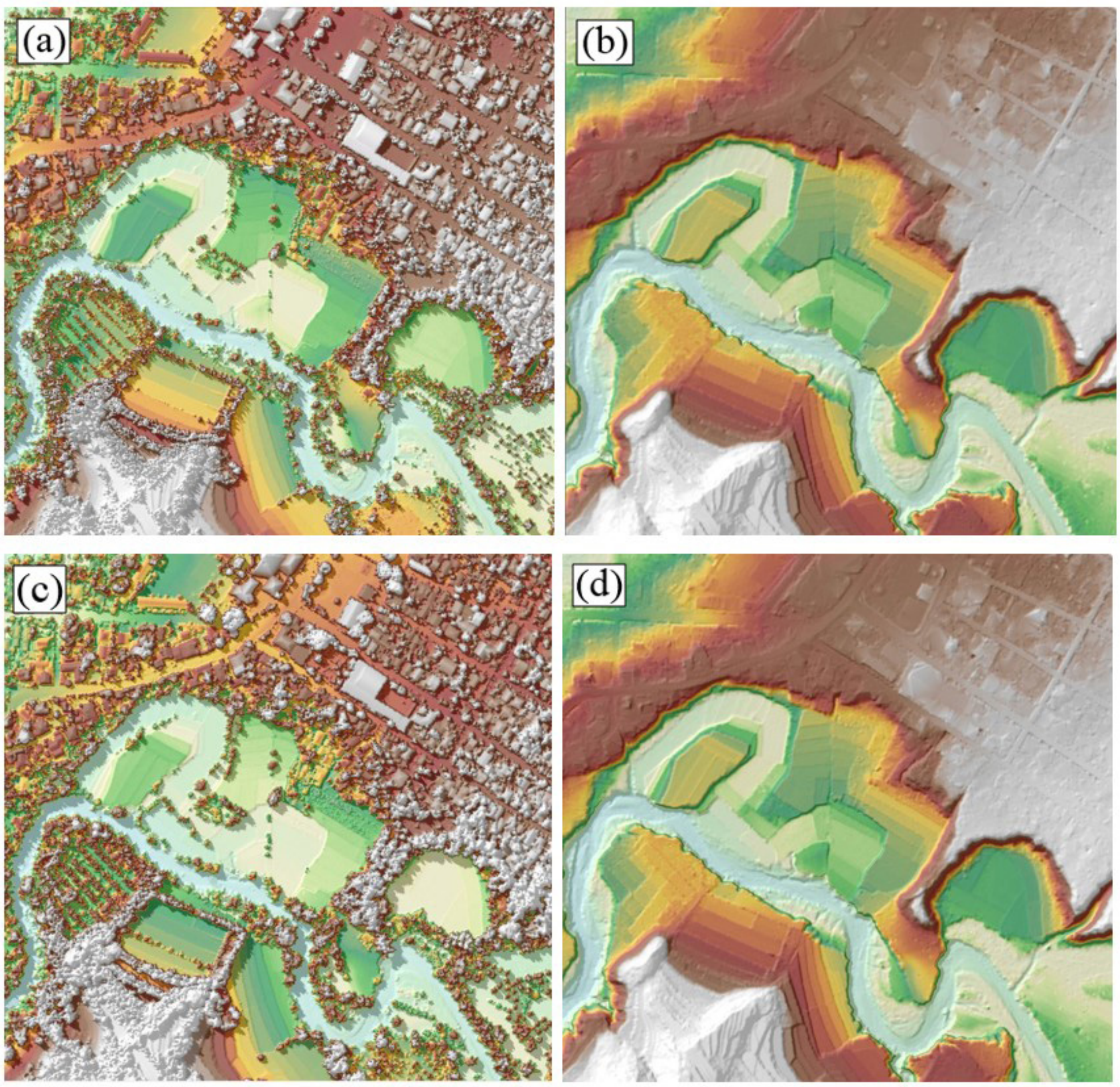


Figure 22. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Paliwan floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 482 1km by 1km tiles area covered by Paliwan floodplain is shown in Figure 23. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Paliwan floodplain has a total of 326.67 sq.km orthophotogaph coverage comprised of 772 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 24.

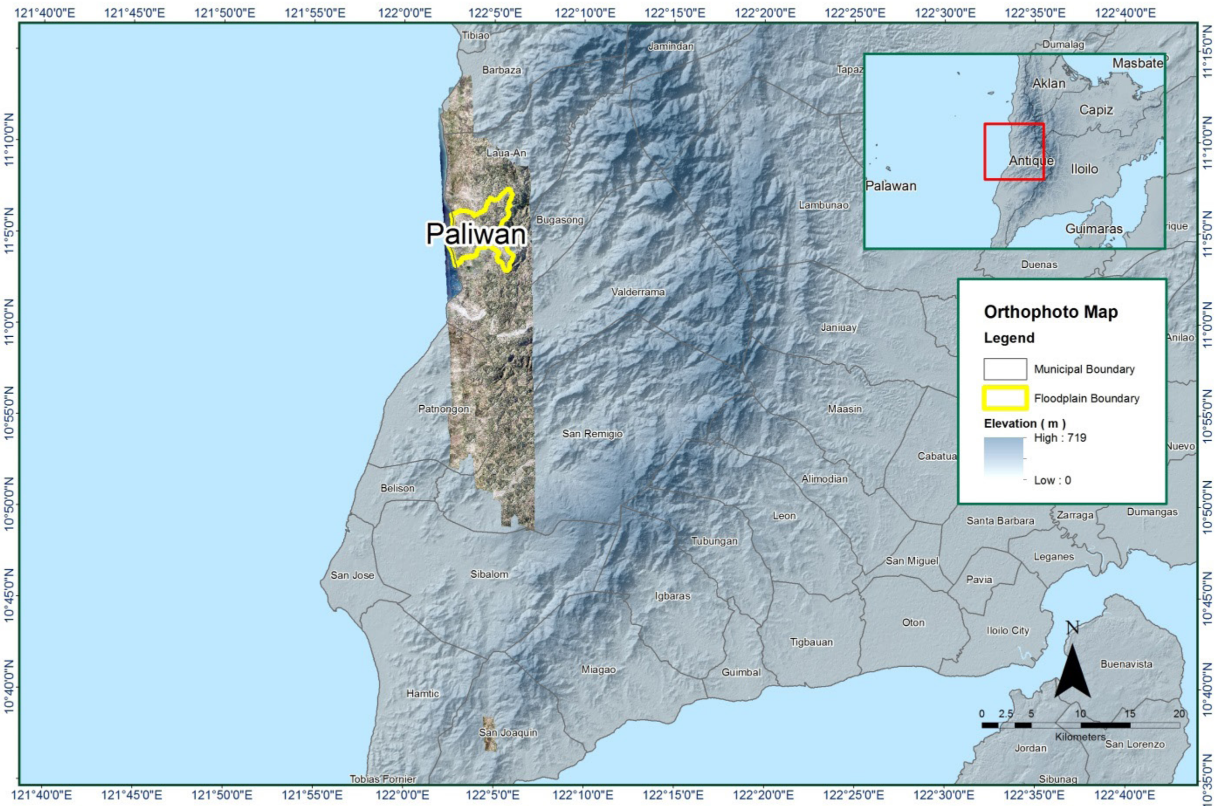


Figure 23. Paliwan floodplain with available orthophotographs.

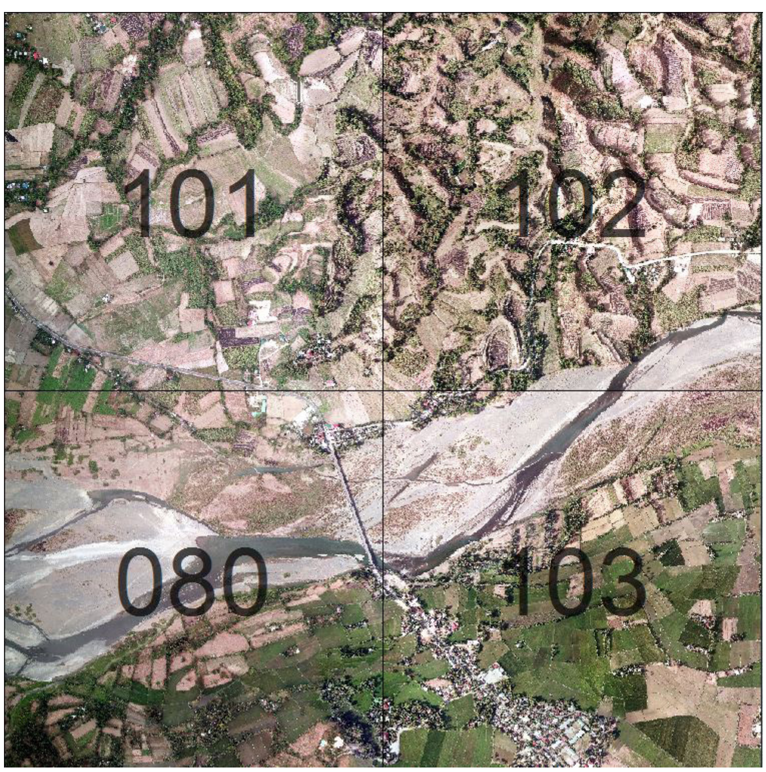


Figure 24. Sample orthophotograph tiles for Paliwan floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) blocks were processed for Paliwan floodplain. These blocks are composed Iloilo blocks and Iloilo reflights with a total area of 395.11 square kilometers. Table 17 shows the name and corresponding area of each block in square kilometers.

Table 17. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Iloilo_Blk43B	136.14
Iloilo_Blk43B_additional	226.06
Iloilo_reflights_Blk43B	15.69
Iloilo_reflights_Blk43B_supplement	17.23
TOTAL	395.11 sq.km

Portions of DTM before and after manual editing are shown in Figure 25. It shows that the paddy field (Figure 25a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 25b). The bridges (Figure 25c) would be an impedance to the flow of water along the river and have to be removed (Figure 25d) in order to hydrologically correct the river.

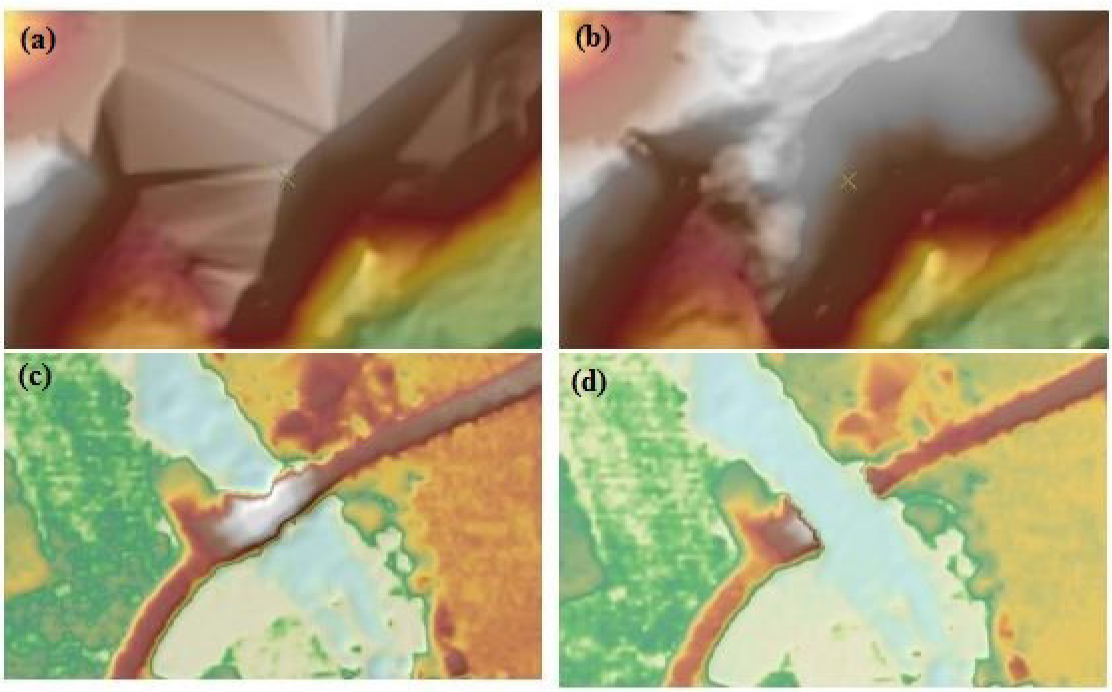


Figure 25. Portions in the DTM of Paliwan floodplain – a paddy field before (a) and after (b) data retrieval; bridge before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

Iloilo_Blk43B was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 18 shows the area of each LiDAR block and the shift values applied during mosaicking.

Mosaicked LiDAR DTM for Paliwan floodplain is shown in Figure 26. It can be seen that the Paliwan flood-plain is 98.05% covered by LiDAR data.

Table 18. Shift Values of each LiDAR Block of Paliwan floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Iloilo_Blk43B	0	0	0.00
Iloilo_Blk43B_additional(left portion)	0	1	0.22
Iloilo_Blk43B_additional(right portion)	0	1	0.14
Iloilo_reflights_Blk43B	0	0	0.93
Iloilo_reflights_Blk43B_sup-plement	0	0	0.82

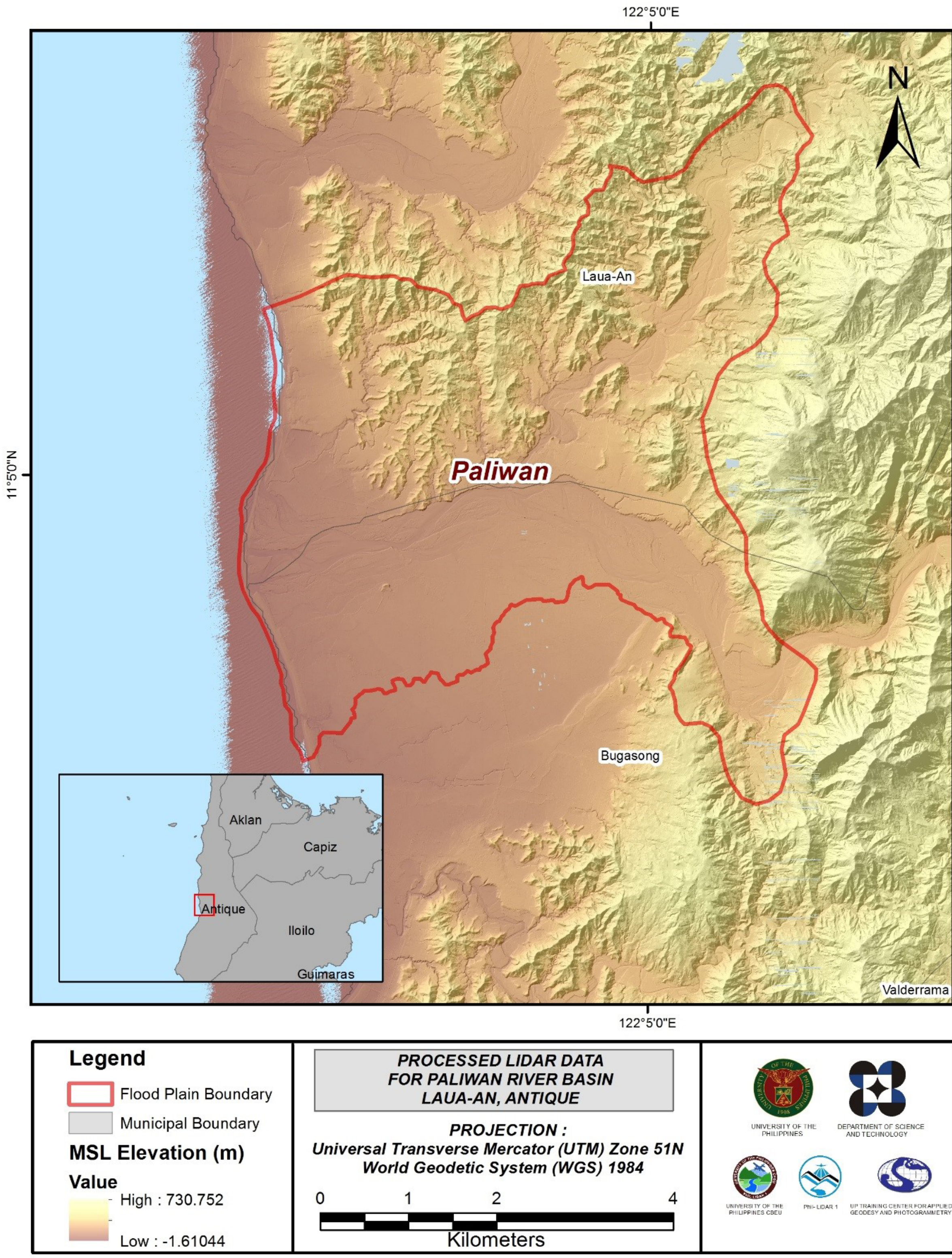


Figure 26. Map of Processed LiDAR Data for Paliwan Flood Plain.

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 Paliwan to collect points with which the LiDAR dataset is validated is shown in Figure 27. A total of 9221 survey points were used for calibration and validation of Paliwan LiDAR data. Random selection of 80% of the survey points, resulting to 6866 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 28. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 1.58 meters with a standard deviation of 0.14 meters. Calibration of Paliwan LiDAR data was done by adding the height difference value, 1.58 meters, to Paliwan mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

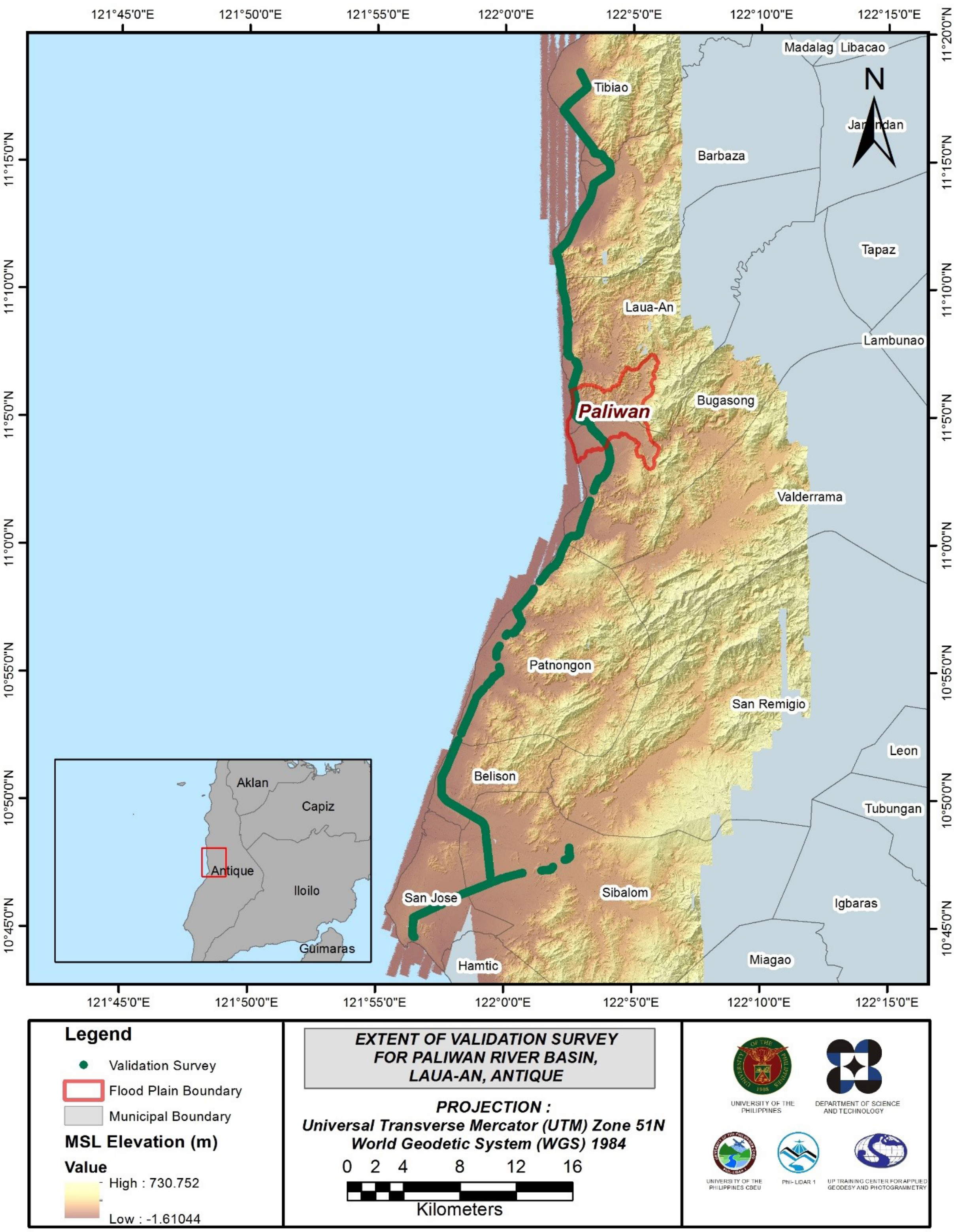


Figure 27. Map of Paliwan Flood Plain with validation survey points in green.

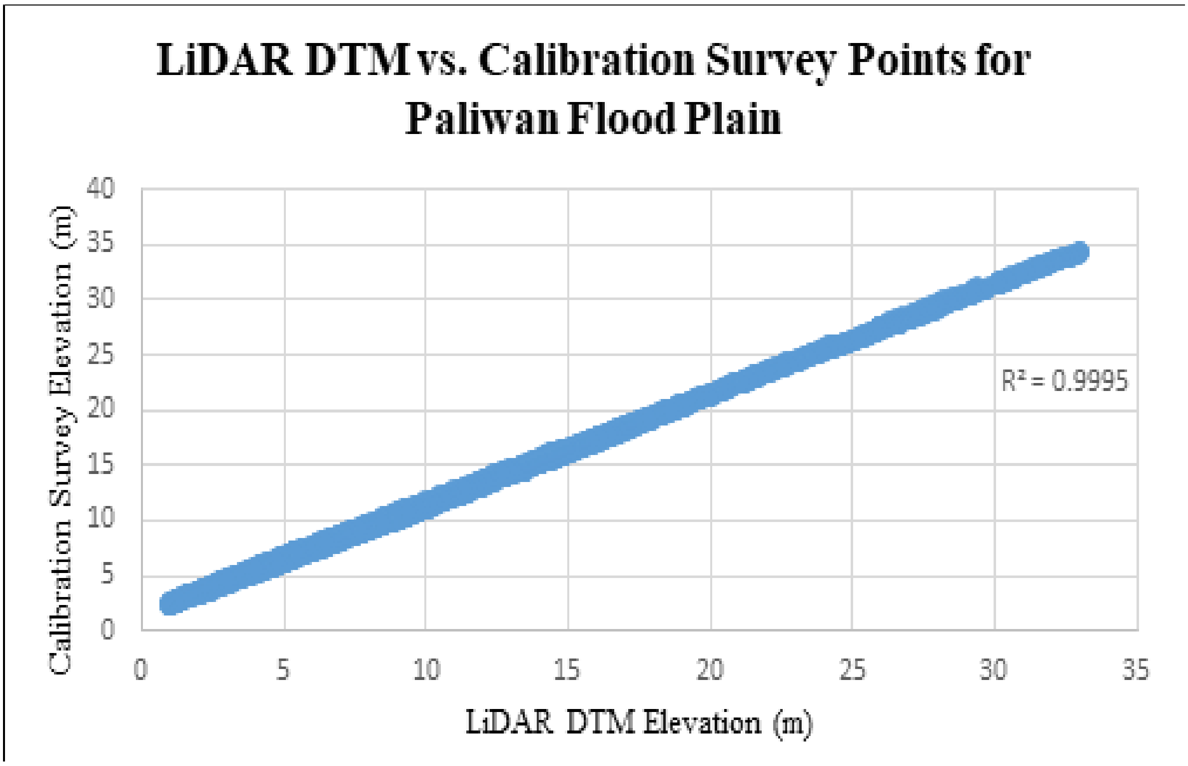


Figure 28. Correlation plot between calibration survey points and LiDAR data.

Table 19. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	1.58
Standard Deviation	0.14
Average	-1.57
Minimum	-1.73
Maximum	-1.25

The remaining 20% of the total survey points, resulting to 1844 points, were used for the validation of calibrated Paliwan 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 29. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.09 meters with a standard deviation of 0.05 meters, as shown in Table 20.

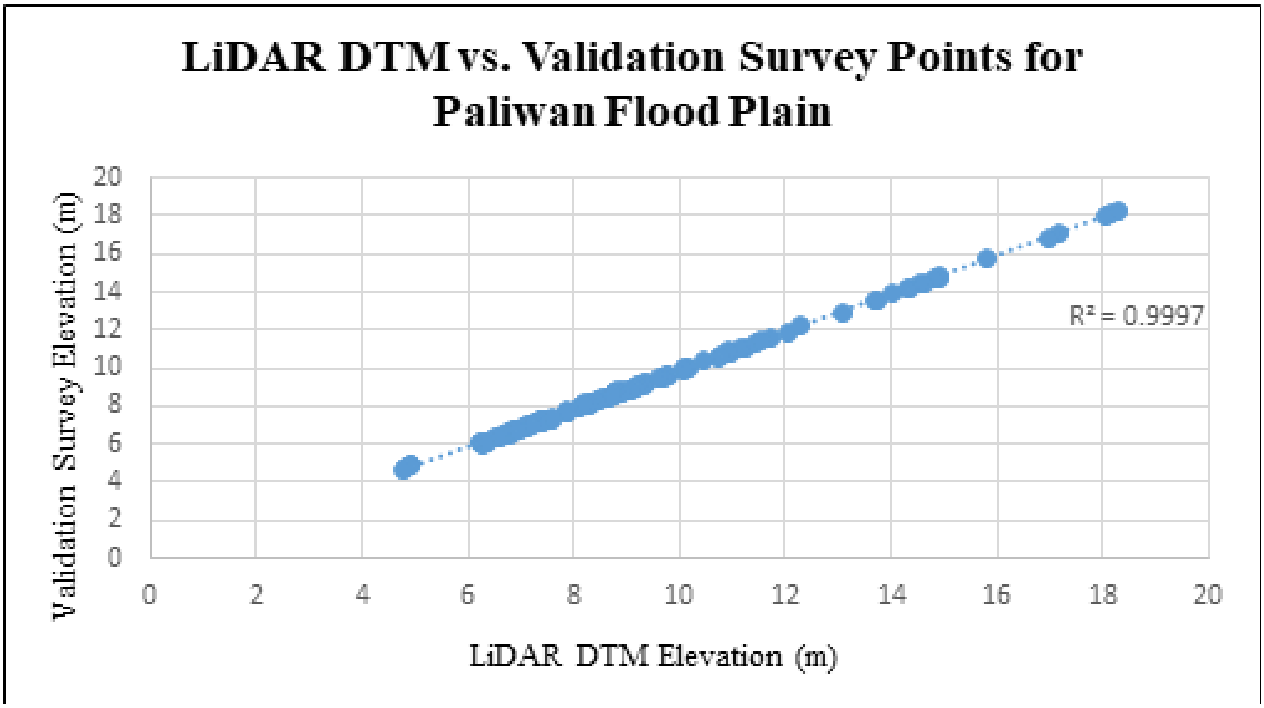


Figure 29. Correlation plot between validation survey points and LiDAR data.

Table 20. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.09
Standard Deviation	0.05
Average	0.07
Minimum	-0.04
Maximum	0.19

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Paliwan with 518 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 0.0025 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Paliwan integrated with the processed LiDAR DEM is shown in Figure 30.

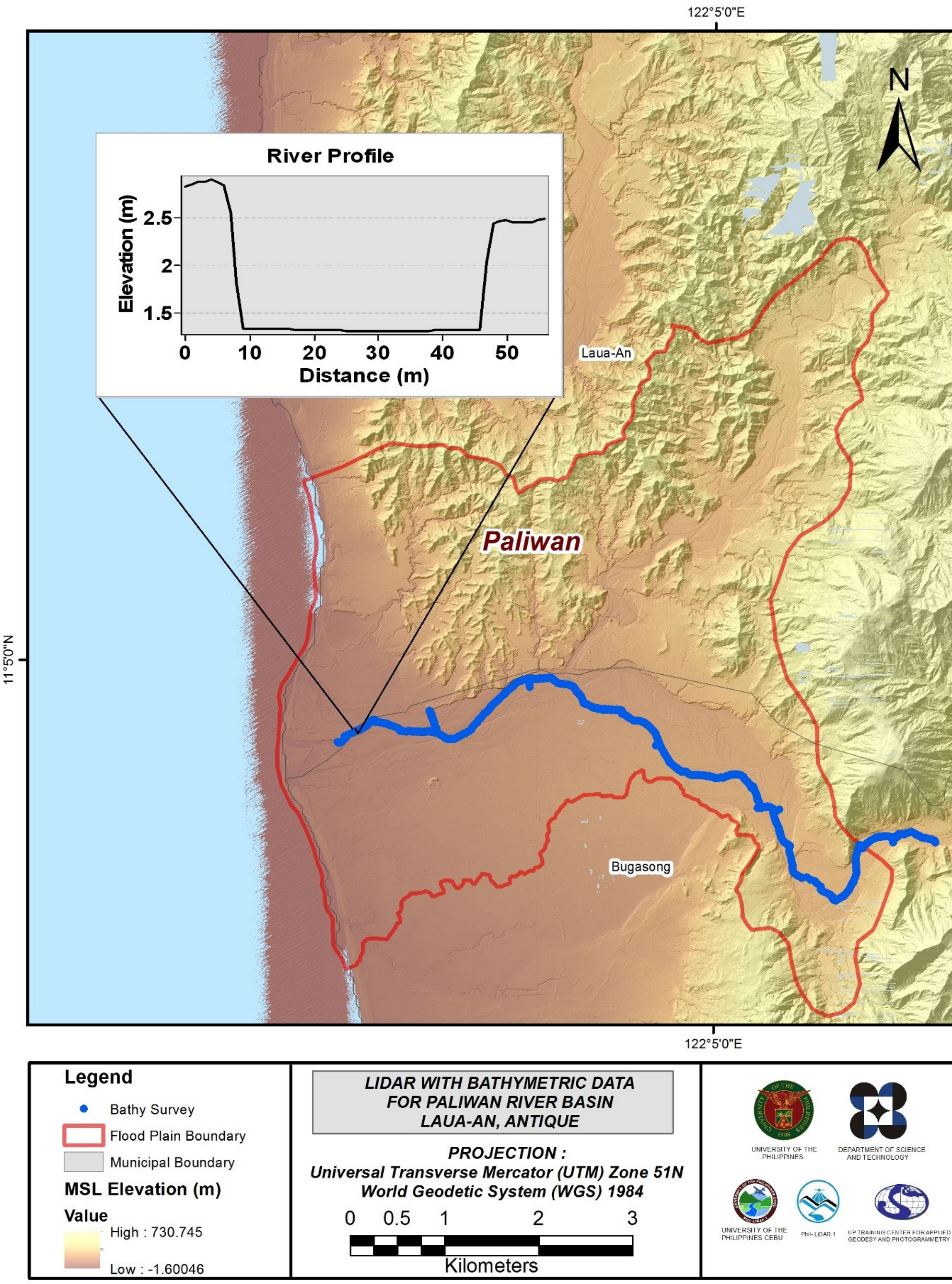


Figure 30. Map of Paliwan Flood Plain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Paliwan floodplain, including its 200 m buffer, has a total area of 208.01 sq km. For this area, a total of 6.0 sq km, corresponding to a total of 1031 building features, are considered for QC. Figure 31 shows the QC blocks for Paliwan floodplain.

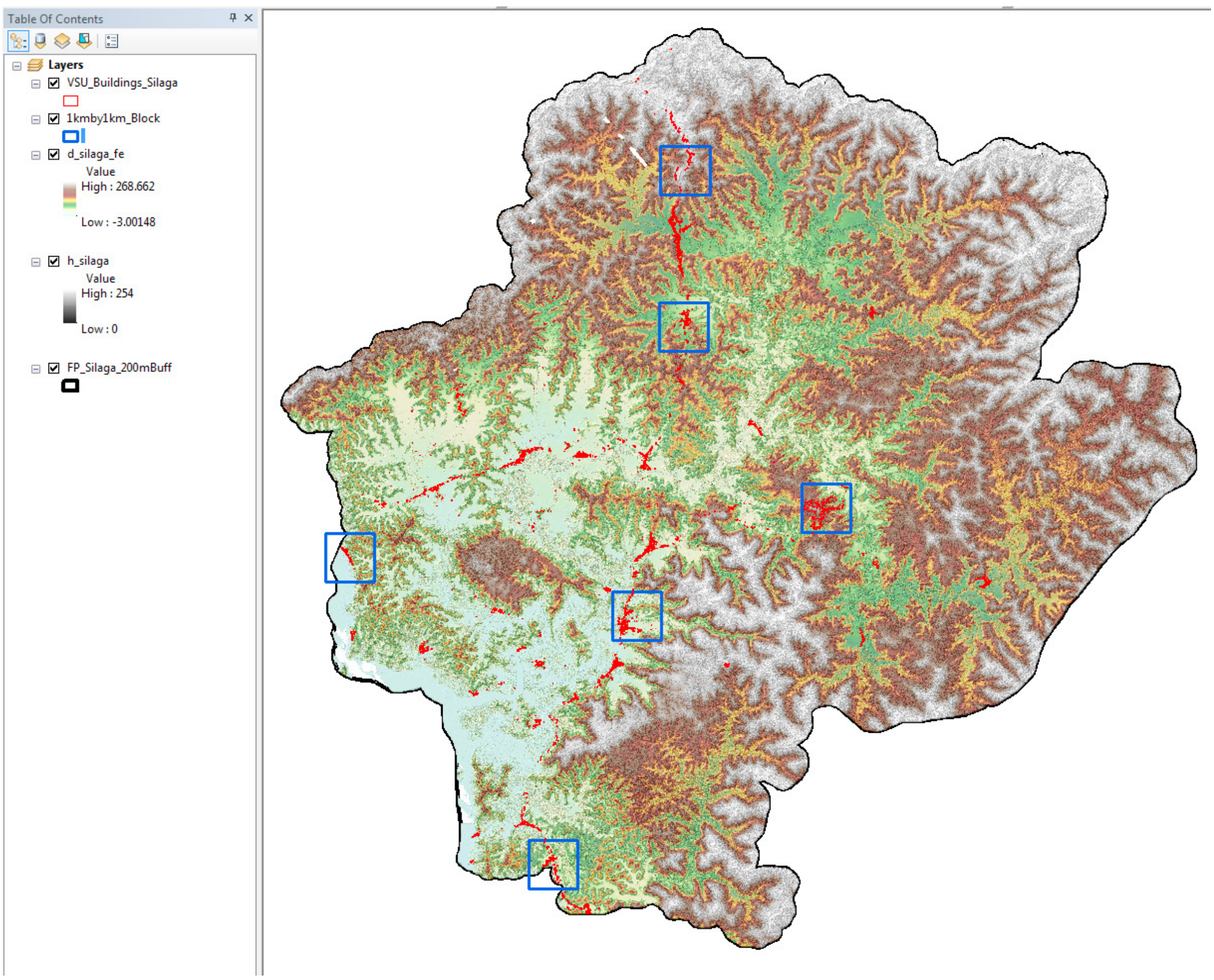


Figure 31. QC blocks for Paliwan building features.

Quality checking of Paliwan building features resulted in the ratings shown in Table 21.

Table 21. Quality Checking Ratings for Paliwan Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Paliwan				PASSED

3.12.2 Height Extraction

Height extraction was done for 5,690 building features in Paliwan floodplain. Of these building features, none was filtered out after height extraction, resulting to 5,690 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 8.74 m.

3.12.3 Feature Attribution

Feature Attribution was done for (no. of buildings) building features in Paliwan Floodplain with the use of participatory mapping and innovations. The approach used in participatory mapping undergoes the creation of feature extracted maps in the area and presenting spatial knowledge to the community with the premise that the local community in the area are considered experts in determining the correct attributes of the building features in the area.

The innovation used in this process is the creation of an android application called reGIS. The Resource Extraction for Geographic Information System (reGIS) (Resource Extraction for Geographic Information System (reGIS), 17 March 2015) app was developed to supplement and increase the field gathering procedures being done by the UPC Phil-LiDAR 1. The Android application allows the user to automate some procedures in data gathering and feature attribution to further improve and accelerate the geotagging process. The app lets the user record the current GPS location together with its corresponding exposure features, code, timestamp, accuracy and additional remarks. This is all done by a few swipes with the help of the device's pre-defined list of exposure features. This effectively allows unified and standardized sets of data.

Table 22 summarizes the number of building features per type while Table 23 shows the total length of each road type, and Table 24 shows the number of water features extracted per type.

Table 22. Building Features Extracted for Paliwan Floodplain.

Facility Type	No. of Features
Residential	
School	
Market	
Agricultural/Agro-Industrial Facilities	
Medical Institutions	
Barangay Hall	
Military Institution	
Sports Center/Gymnasium/Covered Court	
Telecommunication Facilities	
Transport Terminal	
Warehouse	
Power Plant/Substation	
NGO/CSO Offices	
Police Station	
Water Supply/Sewerage	
Religious Institutions	
Bank	
Factory	
Gas Station	
Fire Station	
Other Government Offices	
Other Commercial Establishments	
Total	

Table 23. Total Length of Extracted Roads for Paliwan Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Paliwan						

Table 24. Number of Extracted Water Bodies for Paliwan Floodplain.

Flood-plain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds			Fish Pen	
Pali-wan						

A total of 44 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 32 shows the Digital Surface Model (DSM) of Paliwan floodplain overlaid with its ground features.

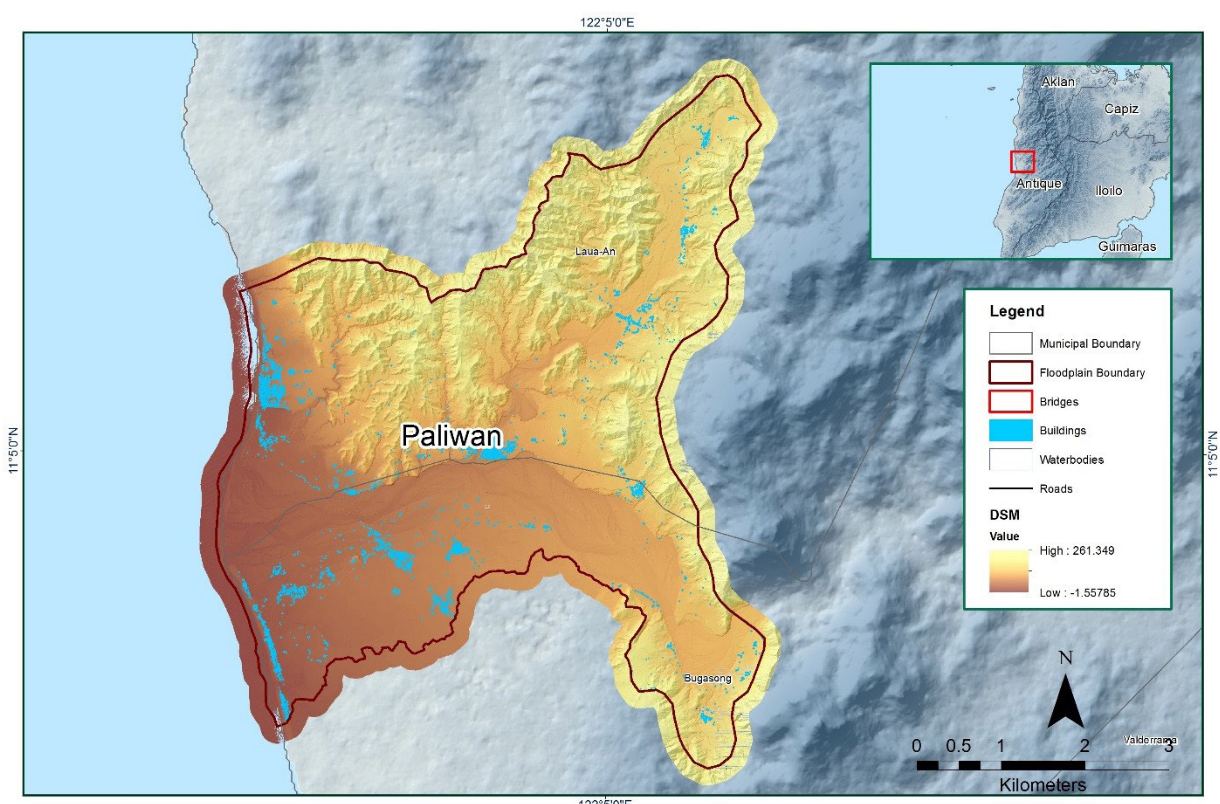


Figure 32. Extracted features for Paliwan floodplain.

Chapter 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE LANANG RIVER BASIN

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

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

4.1 Summary of Activities

Paliwan River Basin covers most of the Municipality of Bugasong, and a small portion of the Municipality of Laua-an, all of which are in Antique. The DENR river Basin Control Office (RCBO) identified it to be one of the 421 river basins in the Philippines, having a drainage area of 206 km^2 and an estimated 262 million cubic meter annual run-off. It is also one of the seven (7) major river basins in Antique (River Basin Control Office, 2017).

Its main stem, Paliwan River, passes along the Municipality Bugasong and is part of the 23 river systems in Western Visayas. There is a total of 6,791 people residing within the immediate vicinity of the river which is distributed among seven (7) barangays located in Municipality of Bugasong, namely: Maray, Anilawan, Tagudtud North, Talisay, Cubay North, Paliwan, and Lugta (Philippine Statistics Authority, 2016). The river is rich in good quality gravel and sand wherein local private quarry companies extract from the riverbed and export abroad (Guntan, 2015).

In line with this, DVBC conducted field survey in Paliwan River last September 25 – October 9, 2014 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section, bridge as-built of Paliwan Bridge piers; ground validation data acquisition of about 82.264 km for the whole province of Antique; and bathymetric survey from Brgy. Maray, Municipality of Bugasong, Antique down to Brgy. Lugta, Municipality of Bugasong, Antique with an estimated length of 9.356 km using GNSS PPK survey technique (Figure 33).

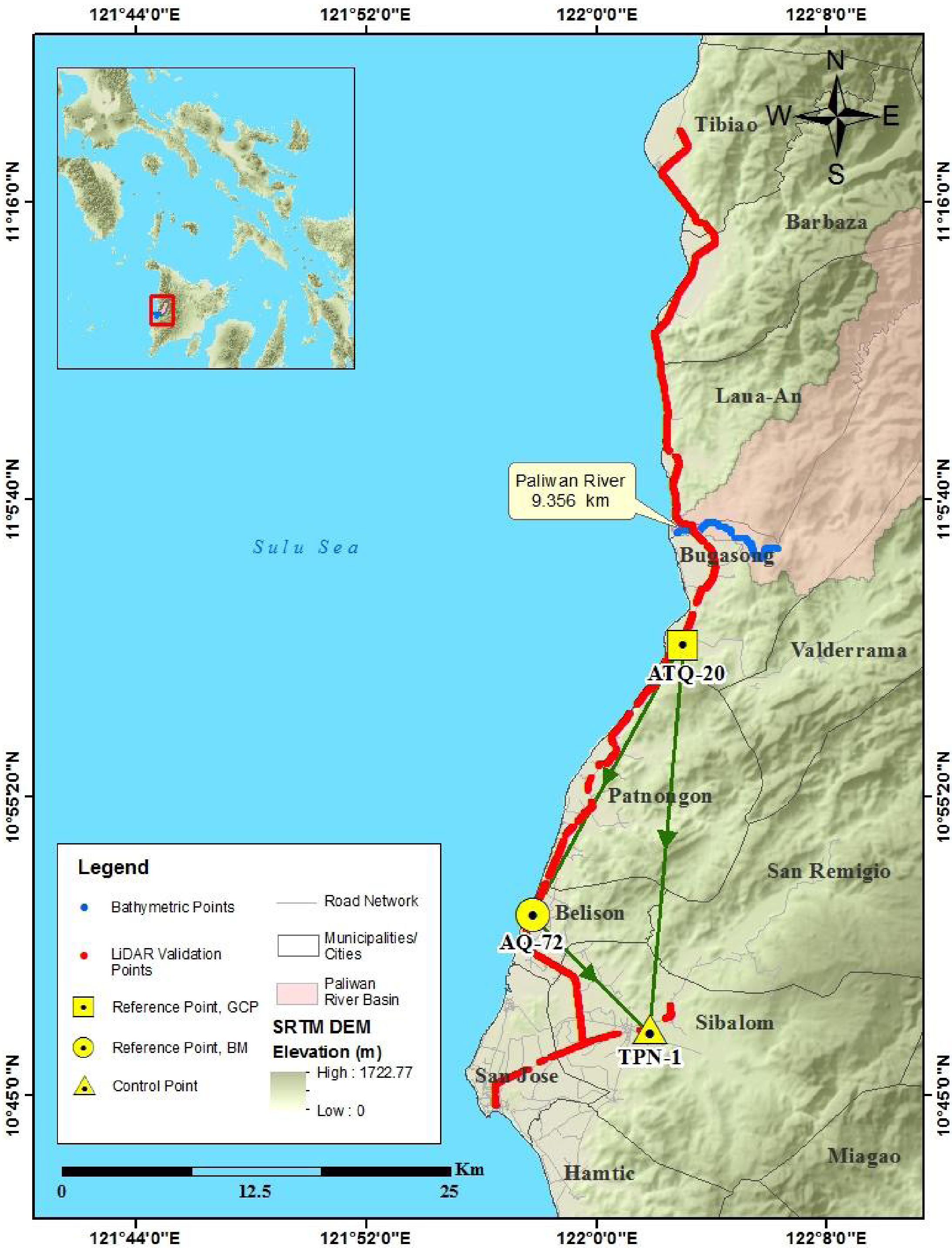


Figure 33. Extent of the bathymetric survey (in blue line) in Paliwan River.

4.2 Control Survey

The GNSS network used in Paliwan River Survey is composed of a single loop established on September 26, 2014 occupying the following reference points: ATQ-20, a second-order GCP, located in Brgy. Zaragoza, Municipality of Bugasong, Antique; and AQ-72, a first-order BM, located in Brgy. Delima, Municipality of Belison, Antique.

A control point was established on the approach of Tipuluan Bridge, namely: TPN-1, in Brgy. Pasong, Brgy. Sibalom, Antique, to use as marker during the survey.

The summary of references and control points used in Paliwan Survey is shown in Table 25, while the GNSS network established is illustrated in Figure 34.

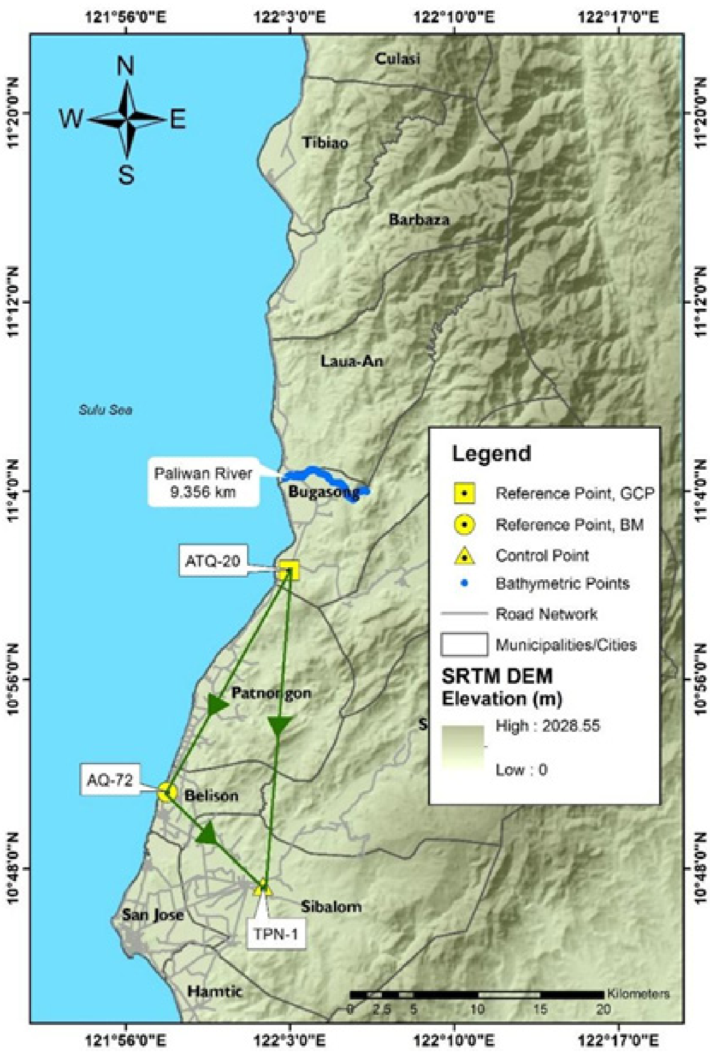


Figure 34. The GNSS Network established in the Paliwan River

Table 25. List of references and control points occupied during the control survey in Paliwan River survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	BM Ortho (Meter)	Date Established
ATQ-20	2nd	11°00’38.44240” N	122°02’59.27039” E	66.094	-	2009
AQ-72	1st	-	-	61.541	5.5842	2007
TPN-1	-	-	-	--	-	September 26, 2014

The GNSS set-ups on recovered reference points and established control points in Paliwan River are shown in Figure 35 to Figure 37.

Figure 35. GNSS base receiver setup, Trimble® SPS 852 at ATQ-20 in Brgy. Zaragoza, Municipality of Bugasong, Antique

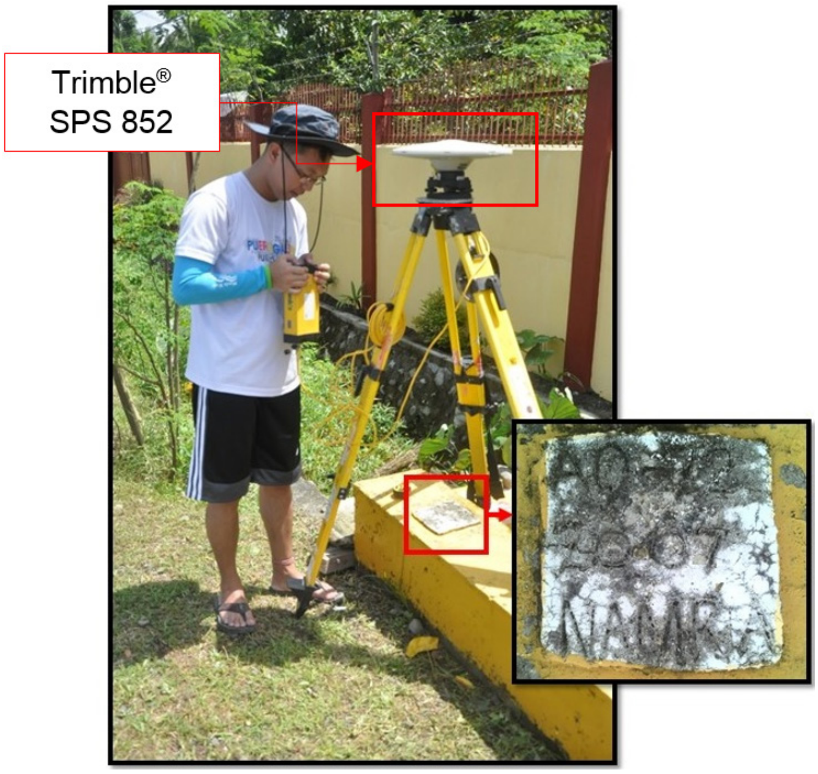


Figure 36. Benchmark, AQ-72, with Trimble® SPS 852 in Brgy. Delima, Municipality of Belison, Antique

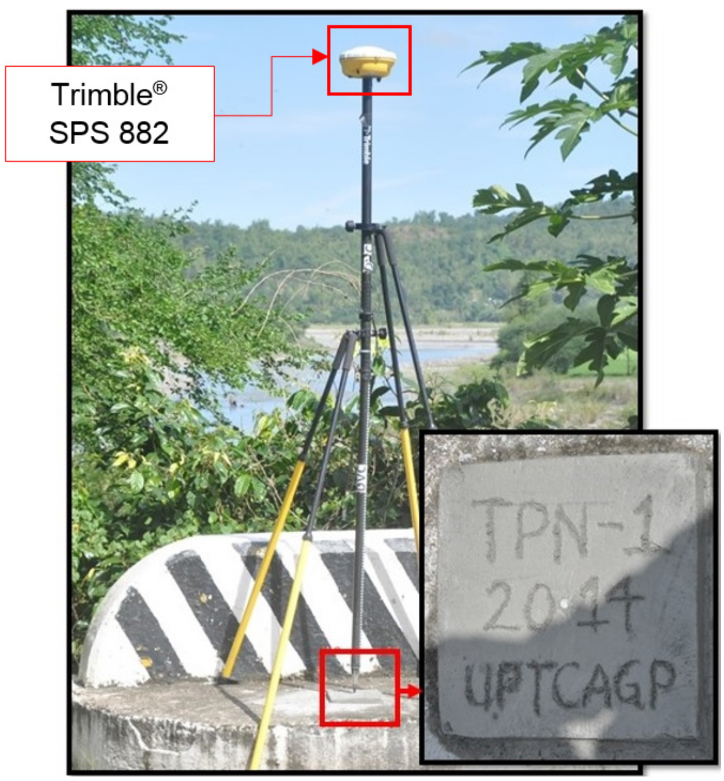


Figure 37. UP-TCAGP established control point, TPN-1, with Trimble® SPS 882 on Tipuluan Bridge in Brgy. Pasong, Municipality of Sibalom, Antique

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Paliwan River Basin is summarized in Table 26 generated by TBC software.

Table 26. Baseline processing summary report for Paliwan River control survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
ATQ-20 --- AQ-72 (B4775)	09-26-2014	Fixed	0.007	0.022	208°43'33"	19743.041	-4.554
ATQ-20 --- TPN-1 (B4775)	09-26-2014	Fixed	0.006	0.021	184°45'37"	24723.786	22.496
AQ-72 --- TPN-1 (B4776)	09-26-2014	Fixed	0.005	0.014	134°32'57"	10438.795	27.074

As shown in Table 26, a total of three (3) baselines were processed with reference points ATQ-20 and AQ-72 held fixed for coordinate and elevation values, respectively. All of them passed the required accuracy.

4.4 Network Adjustment

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

<20cm and

Where:

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

For complete details, see Network Adjustment Report shown in Tables 27 to 30 for reference.

The control point in which the coordinates were fixed during the network adjustment is shown in Table 27. Through this reference point, the coordinates of the unknown control points were computed. A difference in elevation of 0.9288 m between geoid (EGM2008) and MSL values of the reference point AQ-72 was applied for referring the elevation of the control points to MSL.

Table 27. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ATQ-20	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 28. The fixed control point, ATQ-20, has no values for standard errors.

Table 28. Adjusted grid coordinates for the control points used in the Paliwan River flood plain

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
AQ-72	386654.679	0.063	1200045.589	0.033	6.513	0.256	
ATQ-20	396195.506	?	1217324.5 63	?	10.798	?	LLh
TPN-1	394067.041	0.058	1192699.1 27	0.031	33.065	0.259	

The network is fixed at the reference point, ATQ-20, with known coordinates. With the mentioned equation, for horizontal and for the vertical; the computation for the horizontal and vertical accuracy are as follows:

a. AQ-72
horizontal accuracy = $\sqrt{((6.3)^2 + (3.3)^2}$
= $\sqrt{(39.69 + 10.89)}$
= 7.11 cm < 20 cm

b. TPN-1
horizontal accuracy = $\sqrt{((5.8)^2 + (3.1)^2}$
= $\sqrt{(33.64 + 9.61)}$
= 6.58 cm < 20 cm

The list of adjusted geodetic coordinates: Latitude, Longitude, Height and computed standard errors of the control points in the network are shown in Table 29.

Table 29. Adjusted geodetic coordinates for control points used in the Paliwan River Floodplain validation

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
AQ-72	N10°51'14.92748"	E121°57'46.85471"	61.541	0.256	
ATQ-20	N11°00'38.44240"	E122°02'59.27039"	66.094	?	LLh
TPN-1	N10°47'16.56550"	E122°01'51.73167"	88.644	0.259	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 29. 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 30.

Table 30. The reference and control points utilized in the Paliwan River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N	
		Latitude	Longitude	Ellipsoidal Height (m)	Easting	MSL Elevation (m)
ATQ-20	2nd Order GCP	11°00'38.44240"	122°02'59.27039"	66.094	396195.506	9.8692
AQ-72	1st Order BM	10°51'14.92748"	121°57'46.85471"	61.541	386654.679	5.5842
TPN-1	UP Established	10°47'16.56550"	122°01'51.73167"	88.644	394067.041	32.1362

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

Cross-section and as-built survey were conducted on October 1 and 7, 2014 at the upstream side of Paliwan Bridge in Brgy. Cubay North, Municipality of Bugasong using GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 38.

Figure 38. Cross section survey in Paliwan Bridge, Municipality of Bugasong

The cross-sectional line for Paliwan Bridge is about 250 m with twenty (20) points gathered using TAQ-20 as GNSS base station. Cross-section diagram and planimetric map are illustrated in Figure 39 and Figure 40, while the as-built form is shown in Figure 41.

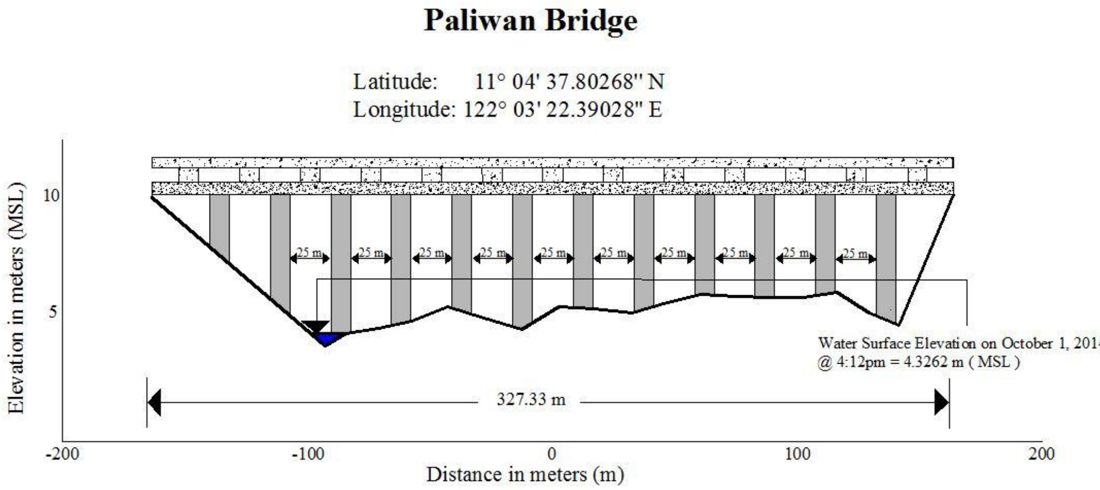


Figure 39. Paliwan Bridge cross-section survey drawn to scale

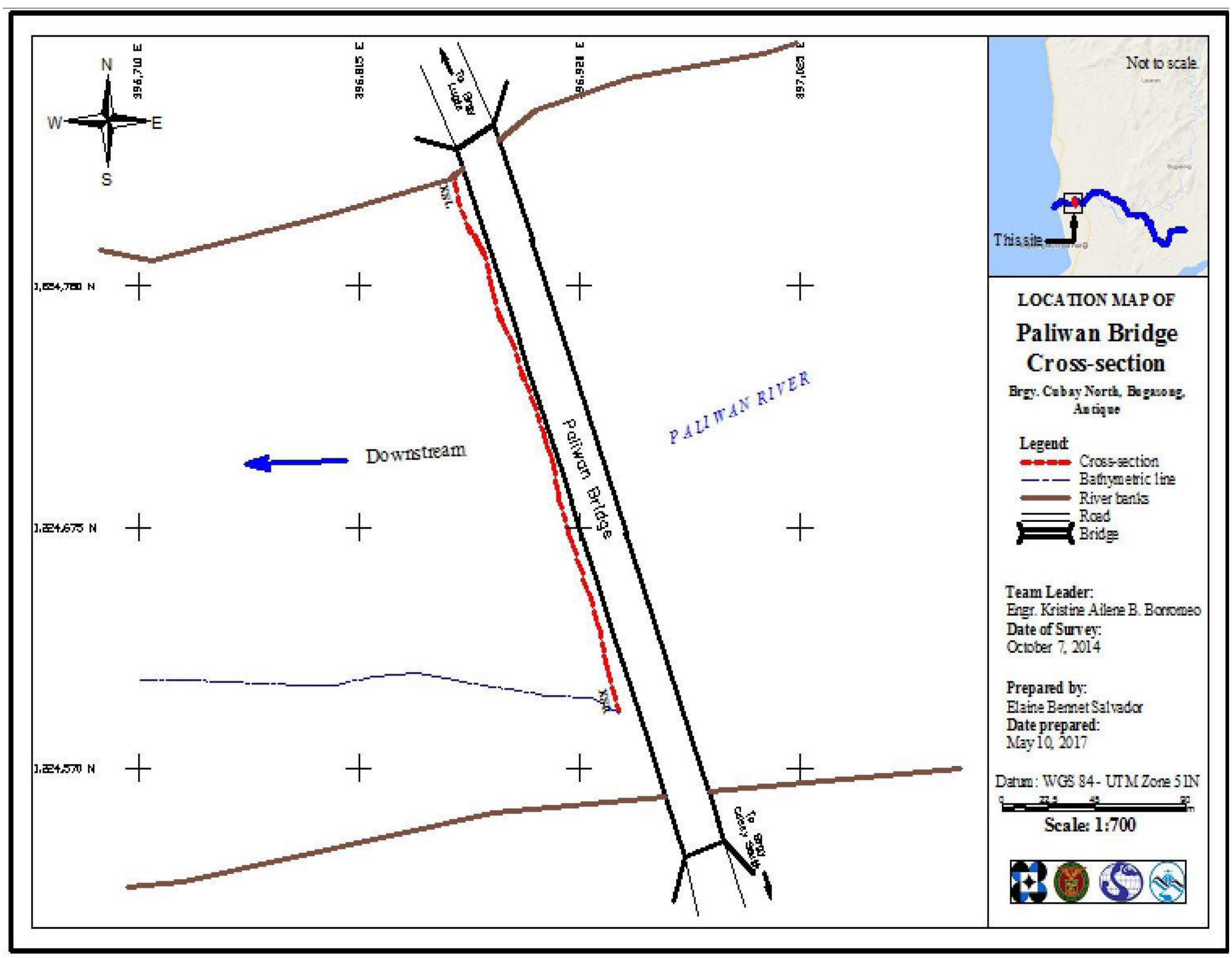


Figure 40. Location map of the Paliwan bridge cross-section survey

Bridge Data Form

Bridge Name: Paliwan Bridge **Date:** October 7, 2014

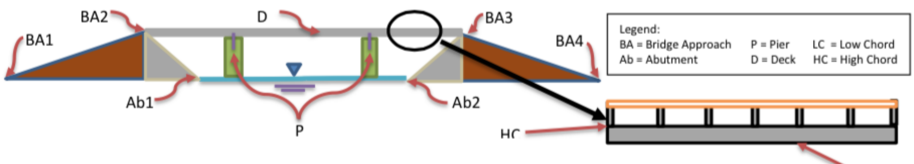
River Name: Paliwan River **Time:** 1:18 pm

Location (Brgy, City, Region): Bugasong, Antique

Survey Team: Borromeo, Labrador, Salvador, Garcia

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

Latitude: 11d04'37.80268" N **Longitude:** 122d03'22.39028" E



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

Elevation 10.4002 m **Width:** - **Span (BA3-BA2):** 327.3069 m

	Station	High Chord Elevation	Low Chord Elevation
1	-	-	-
2	-	-	-
3	-	-	-
4	-	-	-
5	-	-	-

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	10.4272 m	BA3	-	-
BA2	-	-	BA4	327.3299 m	10.4892 m

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

	Station (Distance from BA1)	Elevation
Ab1	-	-
Ab2	-	-

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

Shape: Round **Number of Piers:** 12 **Height of column footing:** -

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	27.5714 m	10.4642	-
Pier 2	52.3496 m	10.4492	-
Pier 8	126.7064 m	10.4172	-
Pier 9	126.6994 m	10.4142	-
Pier 10	151.4616 m	10.4032	-
Pier 11	151.4697 m	10.4002	-
Pier 12	176.1941 m	10.4232	-

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

Figure 41. Bridge As-built of Paliwan Bridge

4.6 Validation Points Acquisition Survey

Validation Points Acquisition Survey was conducted last October 3, 5, and 6, 2014 using a survey-grade GNSS rover receiver, Trimble® SPS 882, mounted on a pole which was attached in front of the vehicle as shown in Figure 42. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height of 1.53 m was measured from the ground up to the bottom of notch of the GNSS Rover receiver. The survey was conducted using PPK technique on a continuous topo mode.

The first day of ground validation started from Municipality of Tibiao and traversed major roads going to Municipality of Patnongon. Meanwhile, the second day of survey started from Municipality of San Jose up to Municipality of Patnongon, and the third ground validation survey comprised of the remaining areas. ATQ-20 was used as the GNSS base station all throughout the conduct of the survey.

Figure 42. Setup of Trimble® SPS 882 attached to a vehicle (A) and Setting up of GNSS base station at ATQ-20 (B)

The survey acquired 9,787 ground validation points with an approximate length of 82.264 km using the base station ATQ-20, as shown in the map in Figure 43.

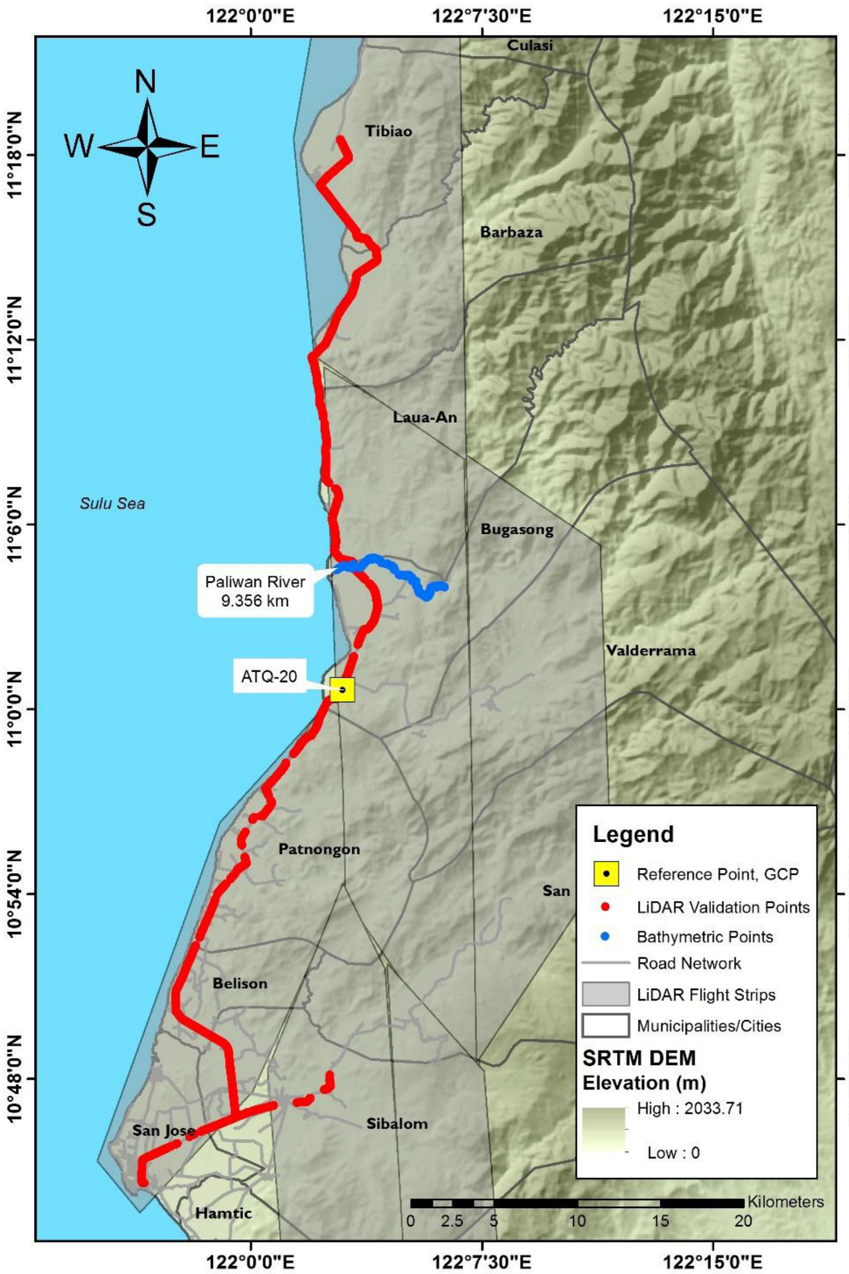


Figure 43. Extent of the LiDAR ground validation survey of Plaiwan River Basin

4.7 Bathymetric Survey

Bathymetric survey was executed in one day, last October 1, 2014 using Trimble® SPS 882 in GNSS PPK survey technique as shown in Figure 44. With the help from the MDRRMO of Bugasong, the survey started upstream from in Brgy. Maray, Municipality of Bugasong with coordinates 11°03'57.90330" 122°06'17.75217", traversed down the river by foot and ended the survey in Brgy. Paliwan, Municipality of Bugasong with coordinates 11°04'31.59860" 122°02'48.56782".

Figure 44. Bathymetric survey using a Trimble® SPS 882 in GNSS PPK in Paliwan River

The bathymetric line survey has an estimated length of 9.356 km with a total of 485 points acquired using ATQ-20 as GNSS base station. The processed data was generated into map using GIS and processed further using CAD for plotting the centerline of the river. The generated map, shown in Figure 45, exhibits the bathymetry survey coverage, while Figure 46 illustrates the Paliwan riverbed profile. The highest elevation was 33.40 m in mSL in Brgy. Maray, while the lowest elevation was 0.026 m in MSL in Brgy. Paliwan.

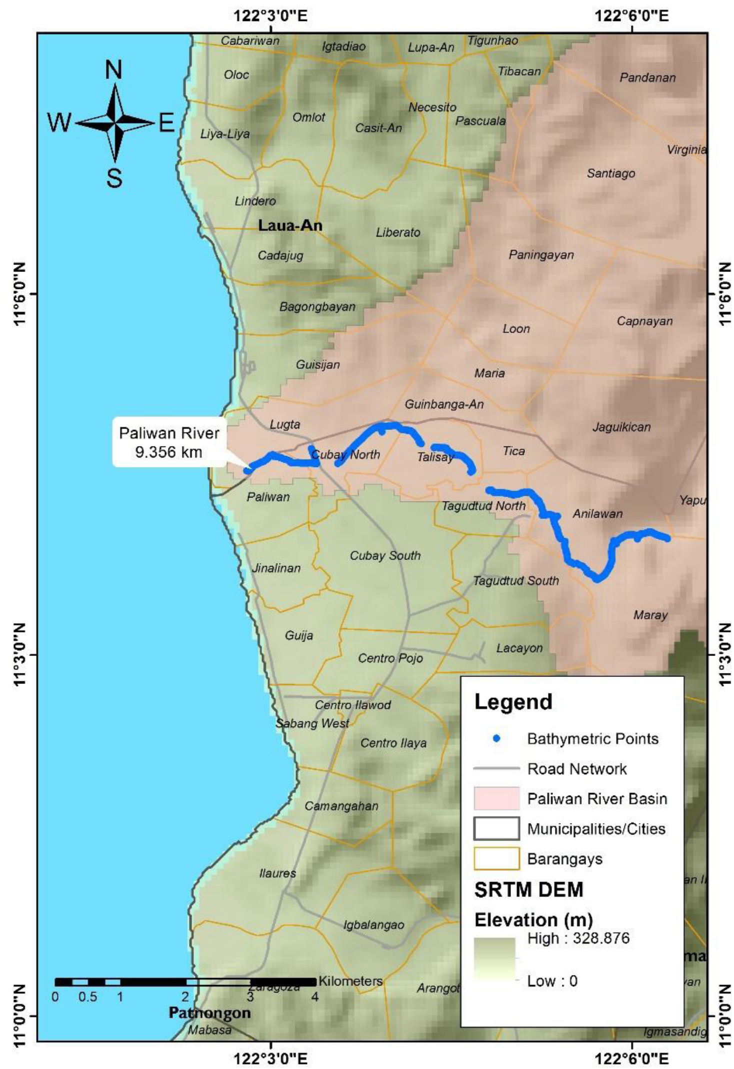


Figure 45. Extent of the Paliwan River Bathymetry Survey

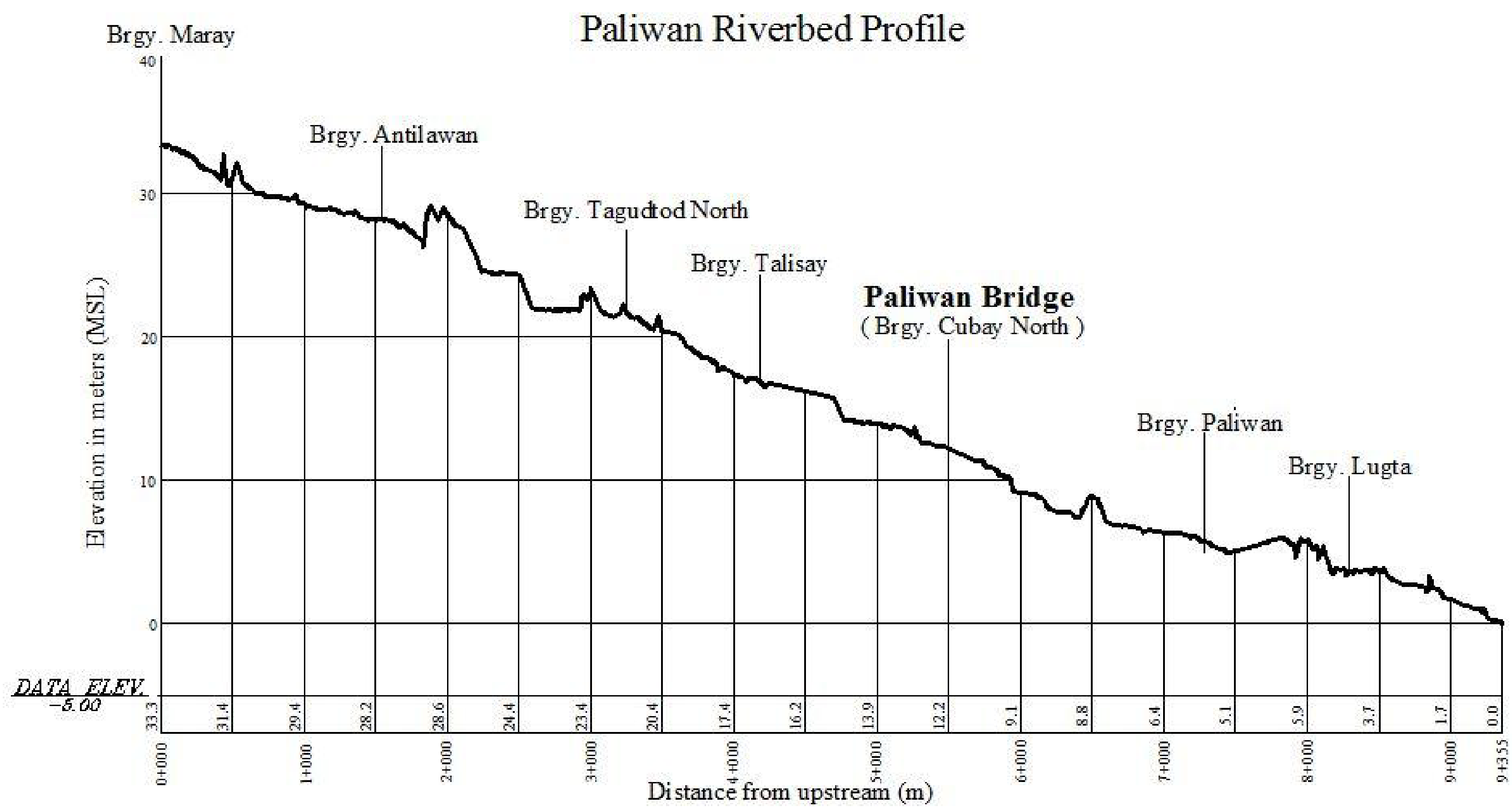


Figure 46. The Paliwan Riverbed Profile from Brgy. Maray, Municipality of Bugasong down to Brgy. Lugta, Municipality of Bugasong

Chapter 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the UP Cebu Flood Modeling Component (FMC) team. The ARG was installed at Brgy. Maray, Bugasong, Antique (Figure 47). The precipitation data collection started from December 8, 2016 at 4:20 PM to December 9, 2016 at 1:05 AM with a recording interval of 10 minutes.

The total precipitation for this event in Brgy Maray ARG was 48.4 mm, with a peak rainfall of 6.6 mm. on December 8, 2016 at 6:00 in the evening. The lag time between the peak rainfall and discharge is 1 hour and 50 minutes.

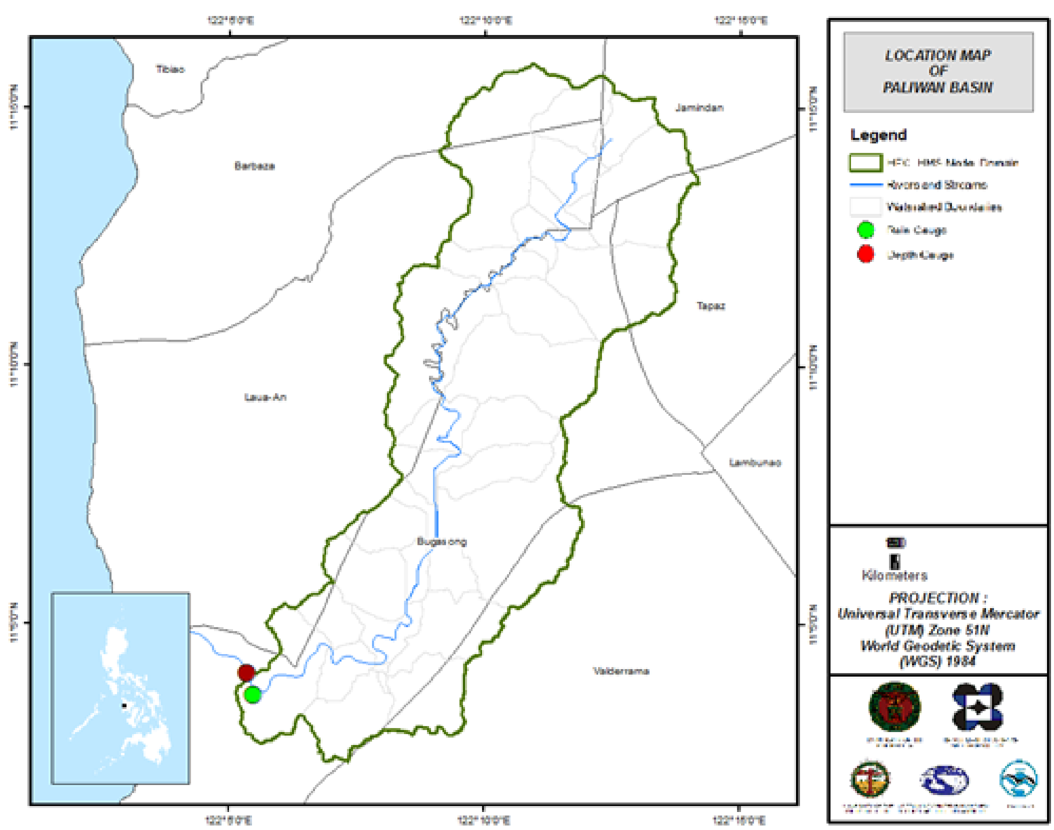


Figure 47. The location map of Paliwan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section shown in Figure 48 at Brgy Anilawan Flow Site, Bugasong, Antique (11° 4'0.49"N, 122° 5'22.27"E) to establish the relationship between the observed water levels at Brgy Anilawan Flow Site and outflow of the watershed at this location.

For Brgy. Anilawan Flow Site, the rating curve is expressed as Q = 66.291e0.5476x [see y formula] as shown in Figure 49.

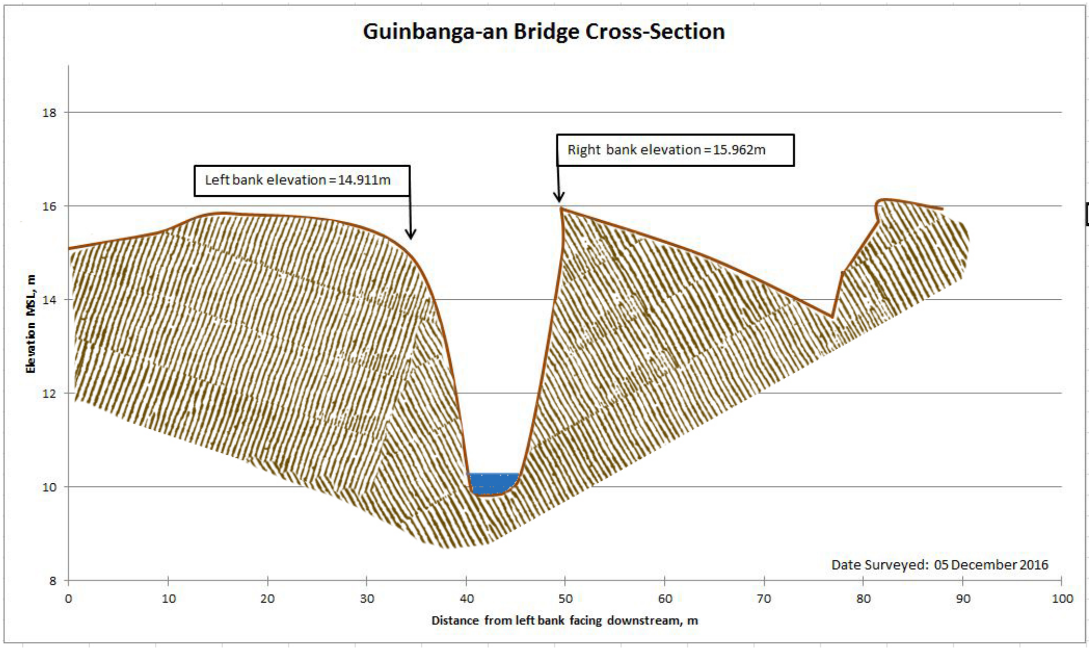


Figure 48. Cross-Section Plot of Guinabanga-an Bridge in Brgy. Anilawan

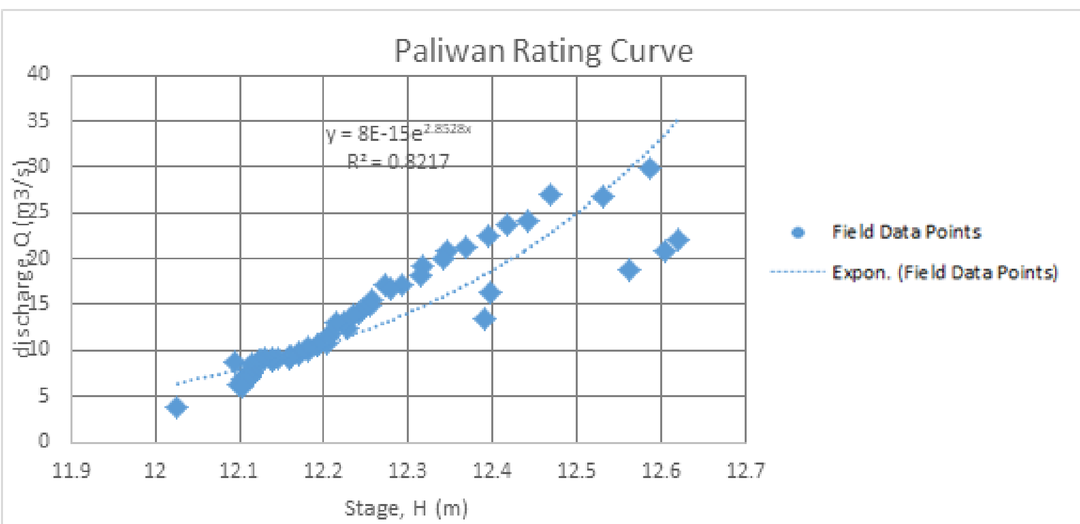


Figure 49. Rating Curve at Guinabanga-an Bridge, Brgy. Anilawan

This rating curve equation was used to compute the river outflow at Brgy. Anilawan Flow Site for the calibration of the HEC-HMS model shown in Figure 50. The total rainfall for this event is 6.6 mm and the peak discharge is 29.9 m^3 second at 7:50 PM, December 8, 2016.

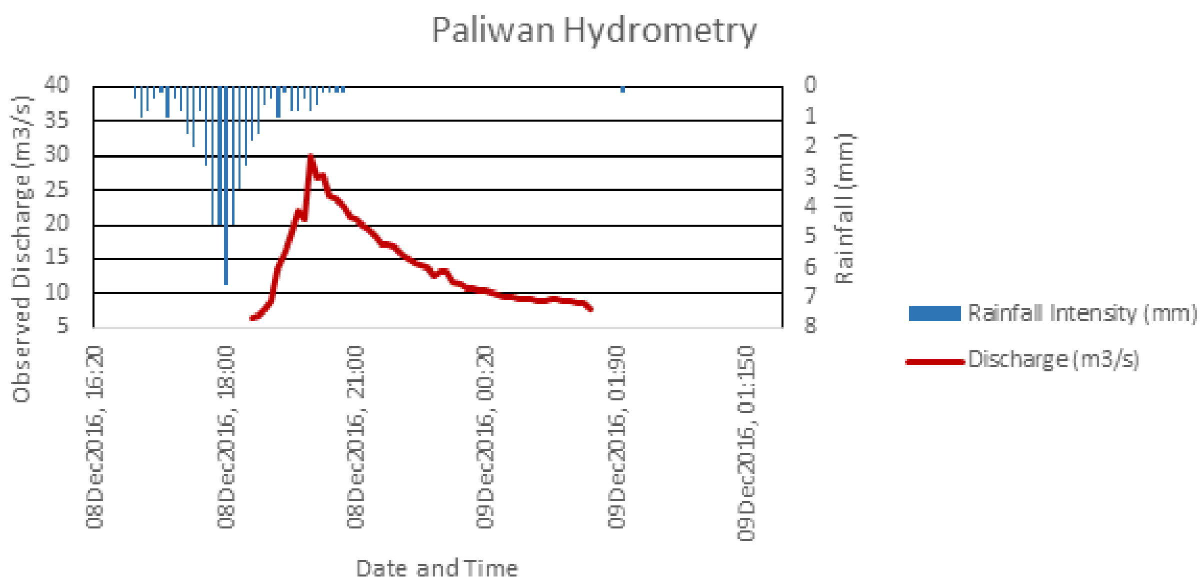


Figure 50. Rainfall and outflow data of the Paliwan River Basin, which was used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed the Rainfall Intensity Duration Frequency (RIDF) values for the Iloilo Rain Gauge (Figure 51). The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time (Figure 52). This station chosen based on its proximity to the Paliwan watershed. The extreme values for this watershed were computed based on a 59-year record shown in Table 31.

Table 31. RIDF values for Iloilo Rain Gauge computed by PAGASA

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

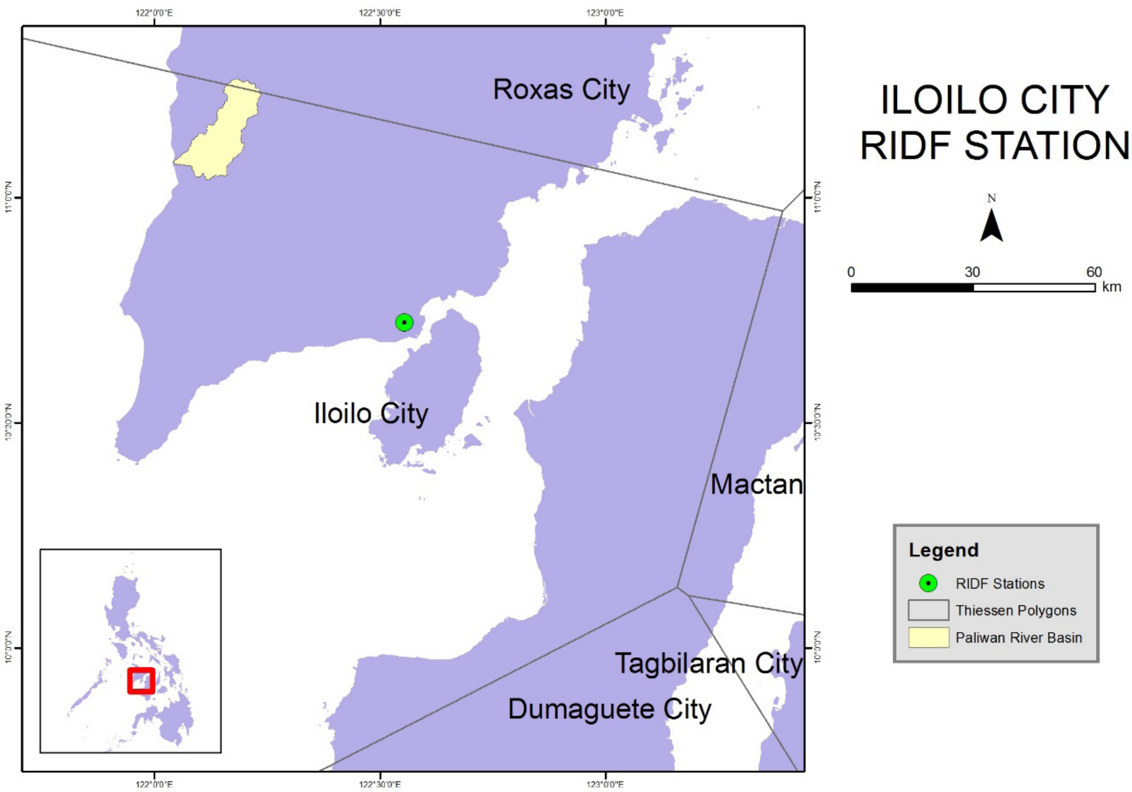


Figure 51. Location of Iloilo RIDF station relative to the Paliwan River Basin

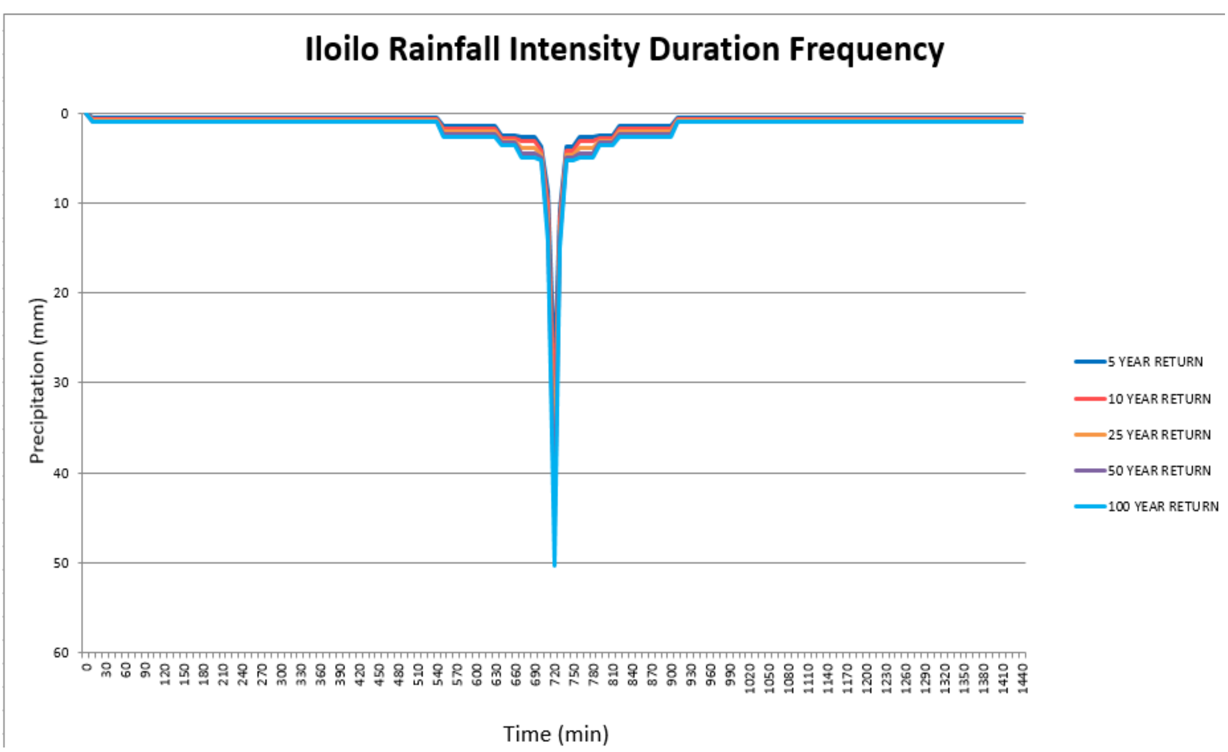


Figure 52. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management. The land cover shape file is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Paliwan River Basin are shown in Figures 53 and 54, respectively.

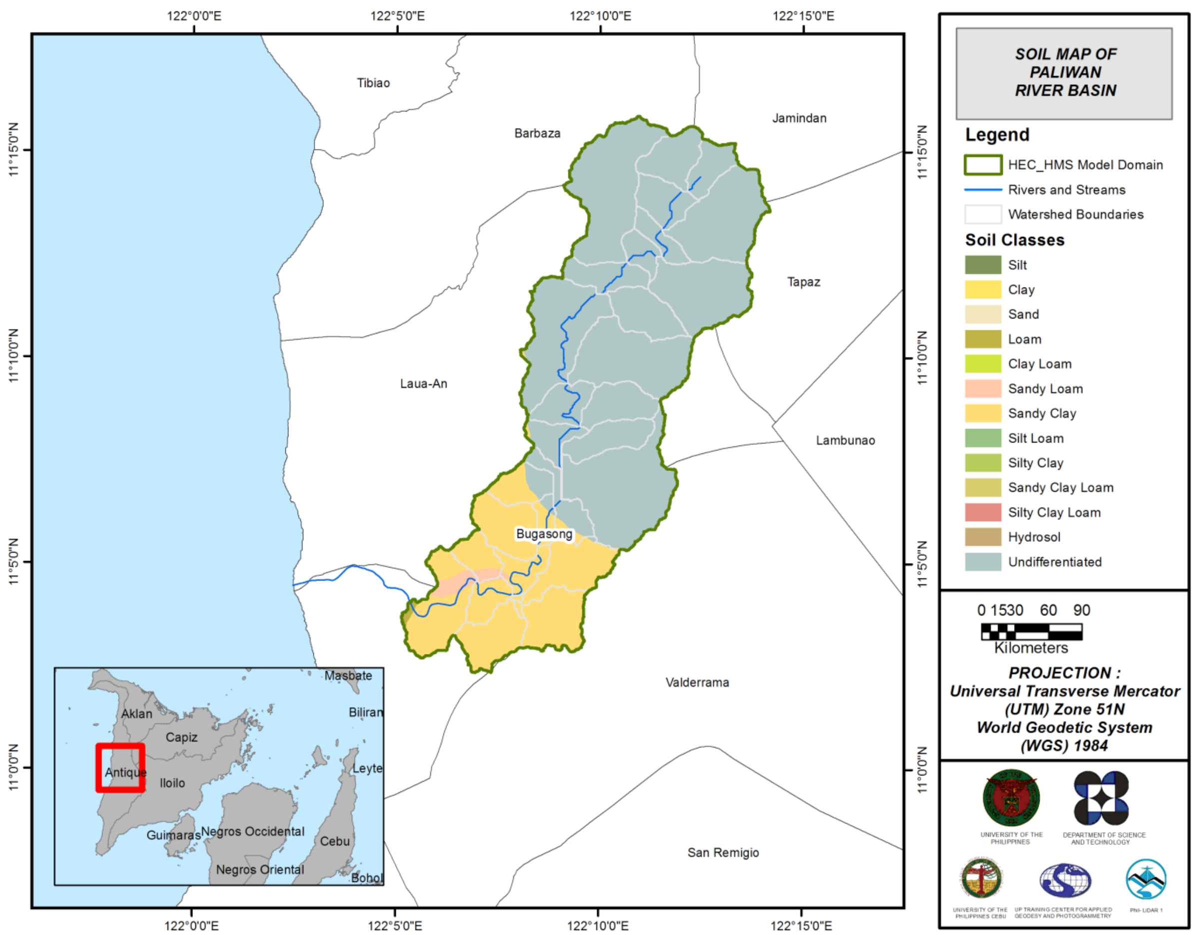


Figure 53. The soil map of the Paliwan River Basin

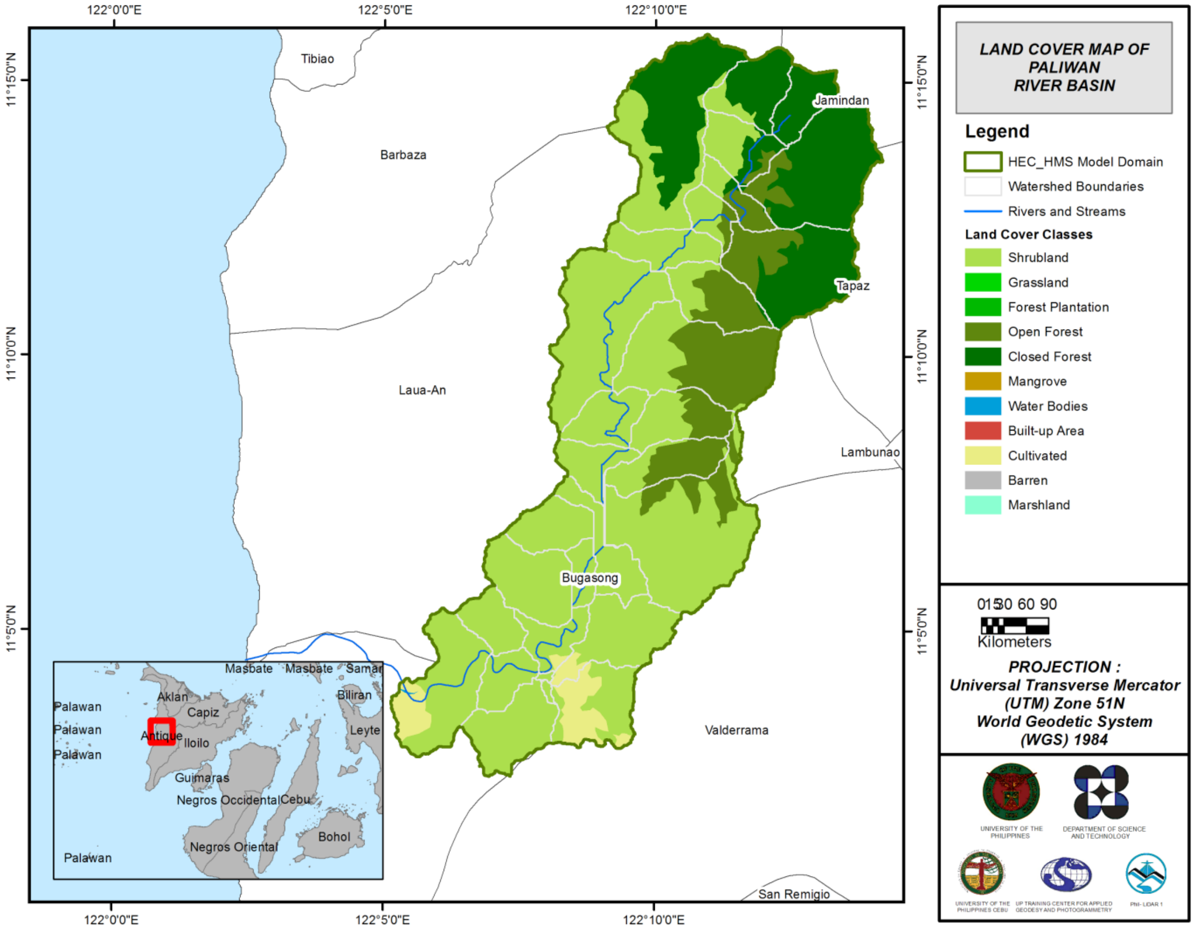


Figure 54. The land cover map of the Paliwan River Basin

For Bago, three soil classes were identified. These are sandy loam, clay, and undifferentiated soil. Moreover, four land cover classes were identified. These are open and closed forest, shubland, and cultivated area.

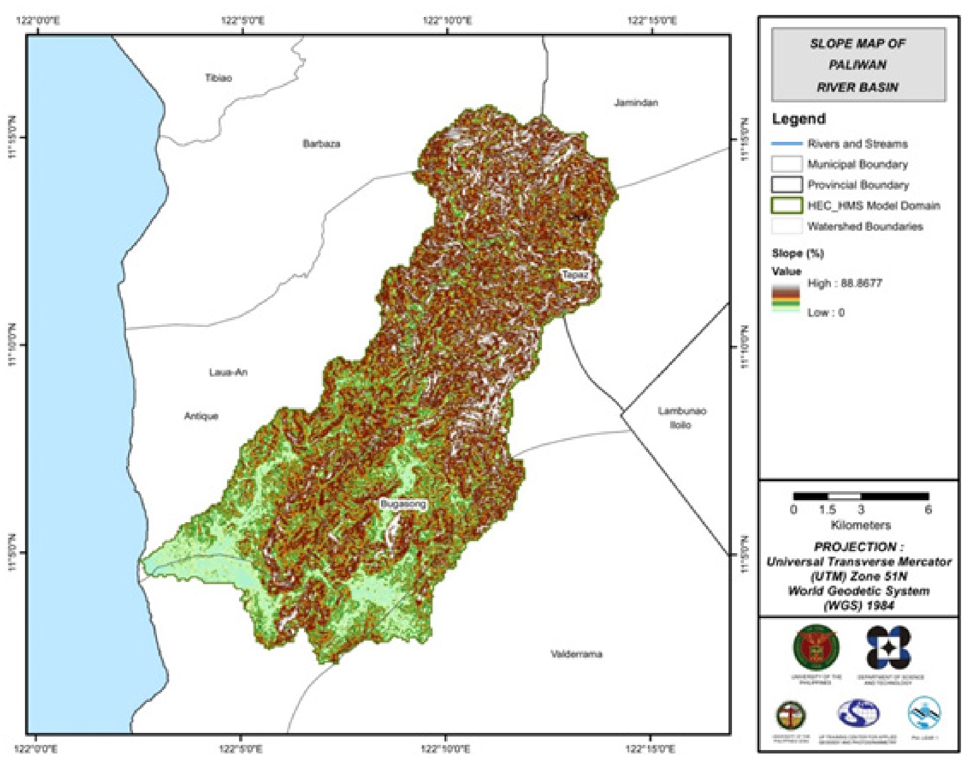


Figure 55. Slope map of the Paliwan River Basin

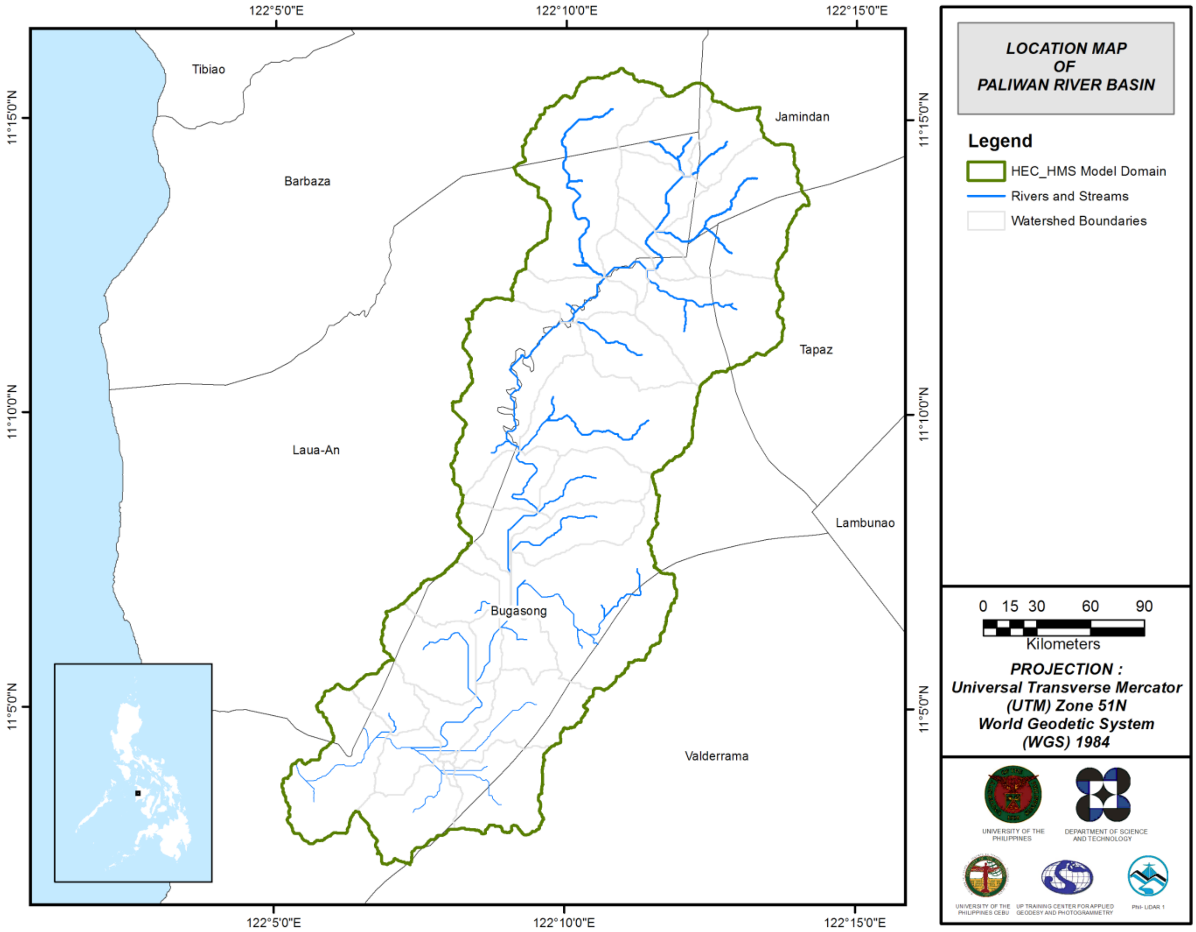


Figure 56. Stream delineation map of the Paliwan river basin

Using the SAR-based DEM, the Paliwan basin was delineated and further subdivided into subbasins. The model consists of 31 sub basins, 15 reaches, and 15 as shown in Figure 57. The main outlet is at Brgy. Anilawan Flow Site.

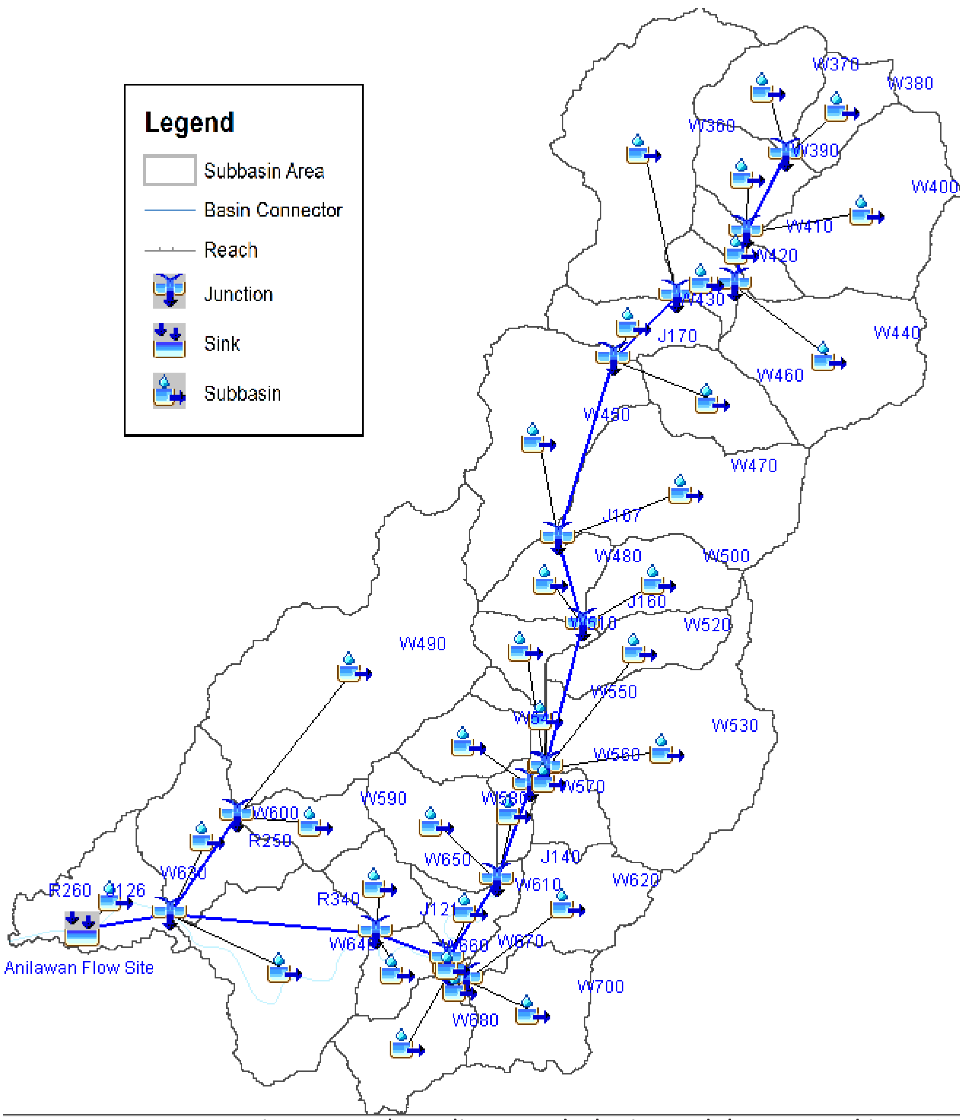


Figure 57. The Paliwan Hydrologic Model generated in HEC-HMS

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).

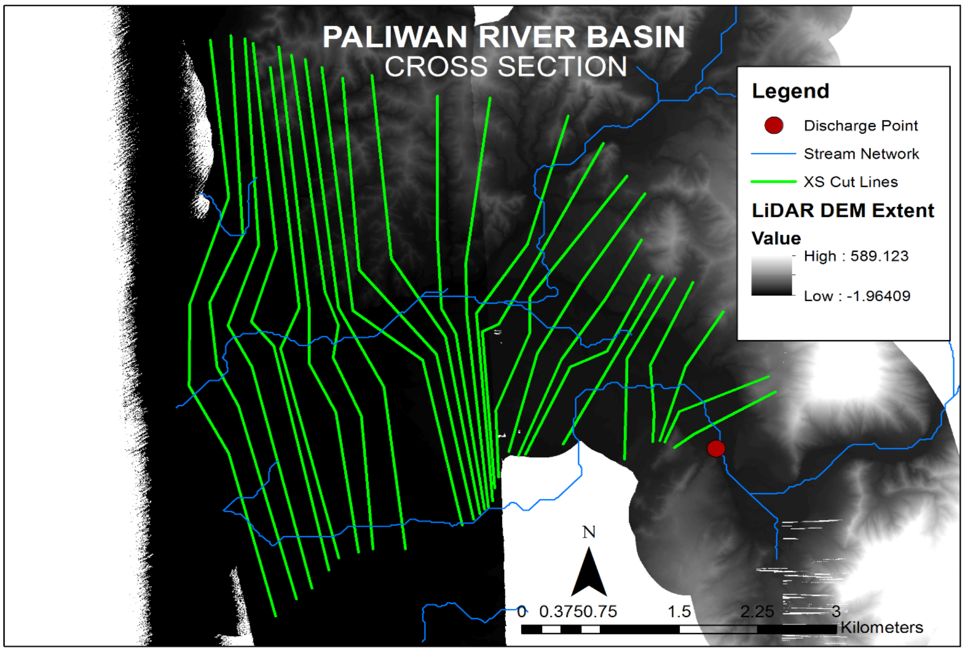


Figure 58. River cross-section of Paliwan River through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

Based on the elevation and flow direction, it is seen that the water will generally flow from the south of the model to the northeast, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively (See Figure 59).

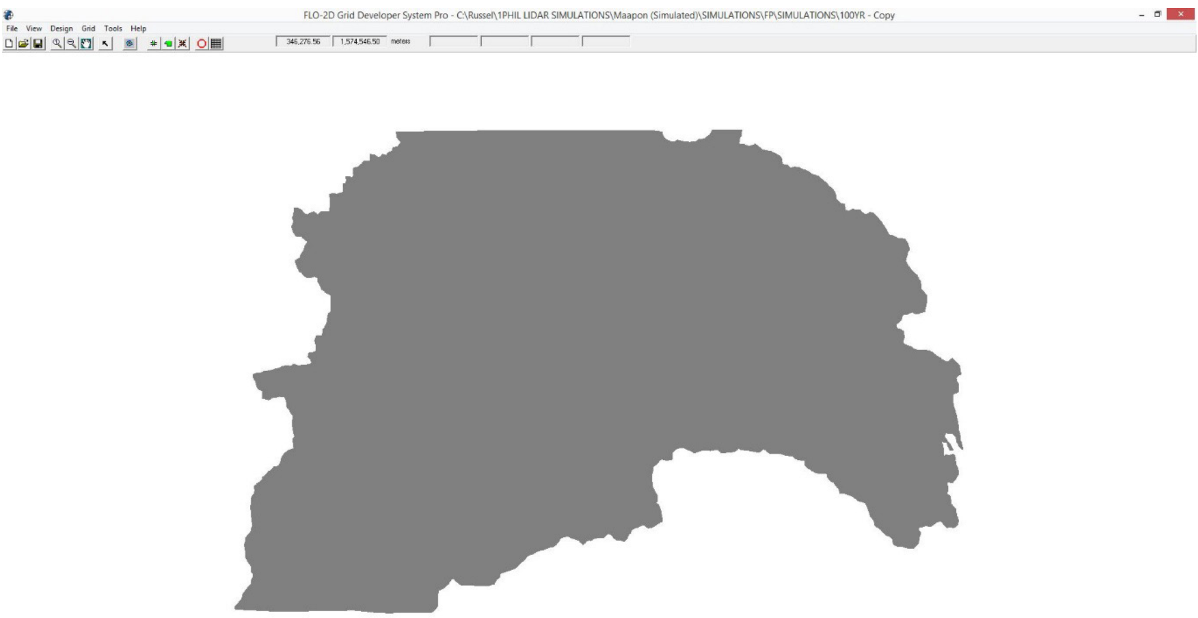


Figure 59. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Development System Pro (FLO-@D GDS Pro)

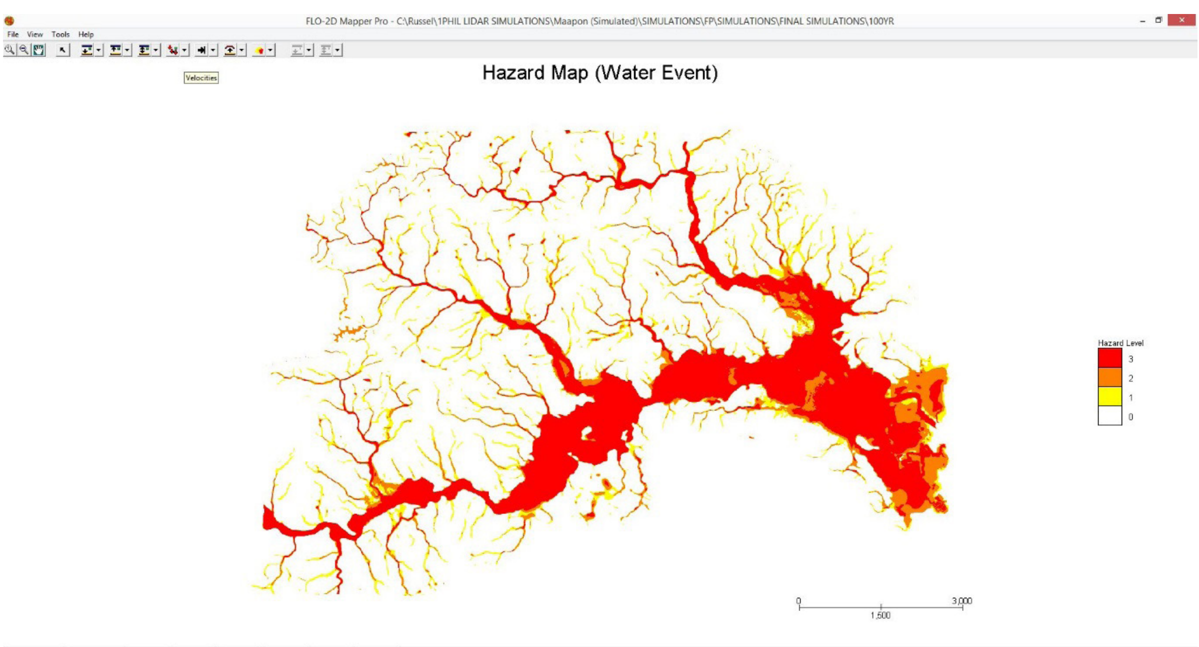


Figure 60. Generated 100-year rain return hazard map from FLO-2D Mapper

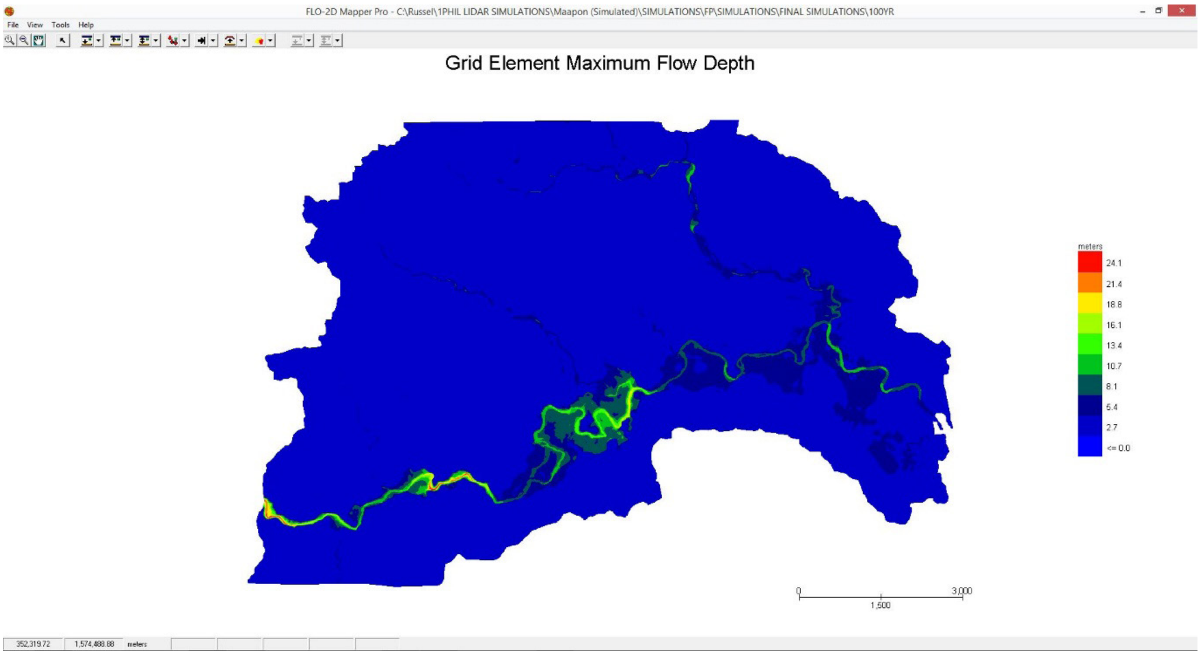


Figure 61. Generated 100-year rain return flow depth map from FLO-2D Mapper

5.6 Results of HMS Calibration

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

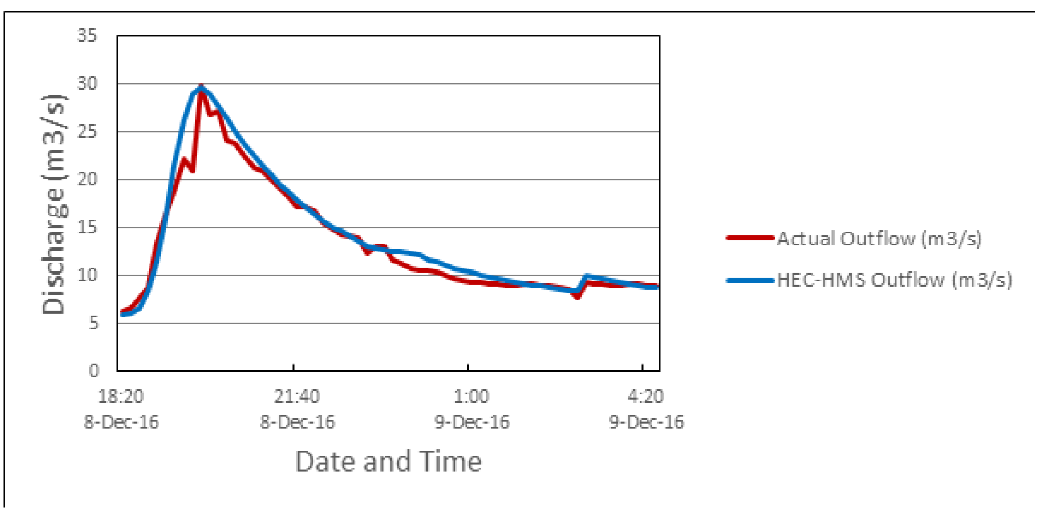


Figure 62. Outflow hydrograph of Paliwan produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 32 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 32. Range of Calibrated Values for the Paliwan River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.12-2.36
			Curve Number	51.5-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.25-0.295
			Storage Coefficient (hr)	1.25-12.1
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.0001
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0001

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.12 mm - 2.36 mm 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 51.5-99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Paliwan, the basin mostly consists of shrubland, closed and open forests, and cultivated areas, and the soil consists of clay, sandy loam, and undifferentiated areas.

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 0.25 hours to 12.1 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.0001 indicates a much steeper receding limb of the outflow hydrograph.

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

Table 33. Summary of the Efficiency Test of Paliwan HMS Model

Accuracy measure	Value
RMS Error	1.4
r2	0.9816
NSE	0.94
RSR	0.25
PBIAS	-4.41

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 1.4 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9816.

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 0.94.

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 0.25.

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 -4.41.

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

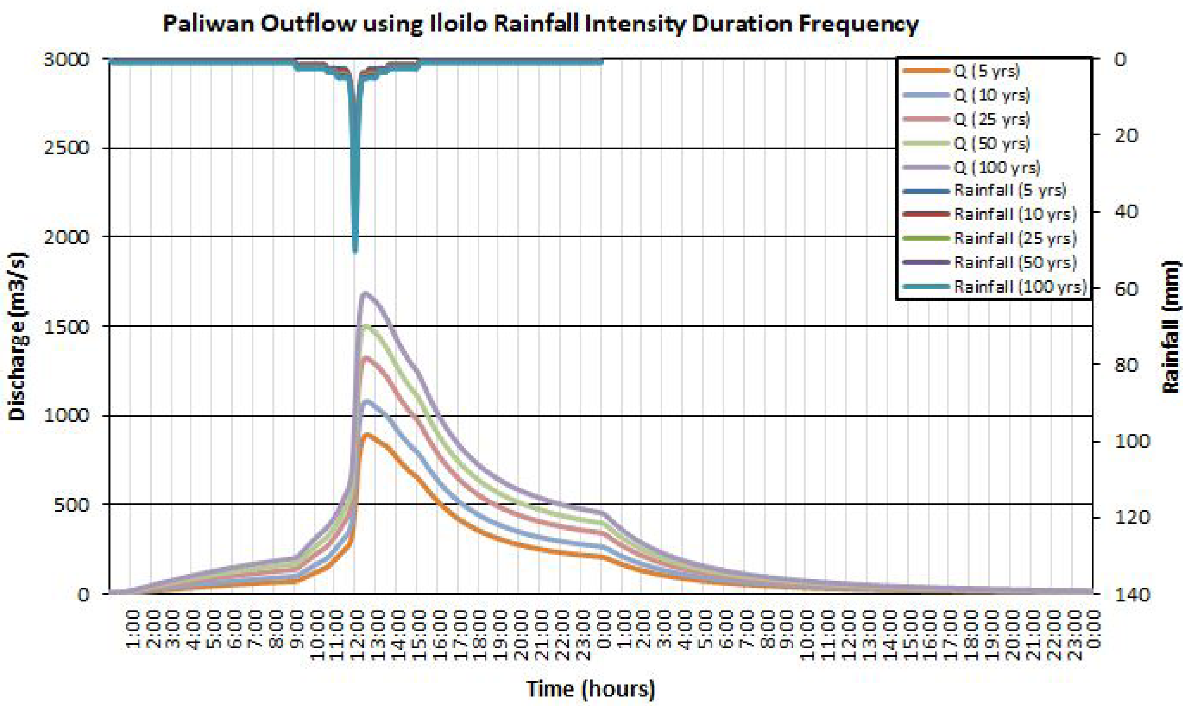


Figure 63. Outflow hydrograph at Paliwan Station generated using Iloilo RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Paliwan discharge using the Iloilo Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 34.

Table 34. Peak values of the Paliwan HEC-HMS Model outflow using the Iloilo RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	165.2	28.7	891.1	40 minutes
10-Year	198.9	33.9	1079.9	30 minutes
25-Year	241.5	40.5	1323.7	30 minutes
50-Year	273.1	45.4	1504.7	30 minutes
100-Year	304.5	50.3	1686.4	30 minutes

5.7.2 Discharge data using Dr. Horritts's recommended hydrologic method

The river discharges entering the floodplain are shown in Figure 64 to Figure 65 and the peak values are summarized in Table 35 to Table 36.

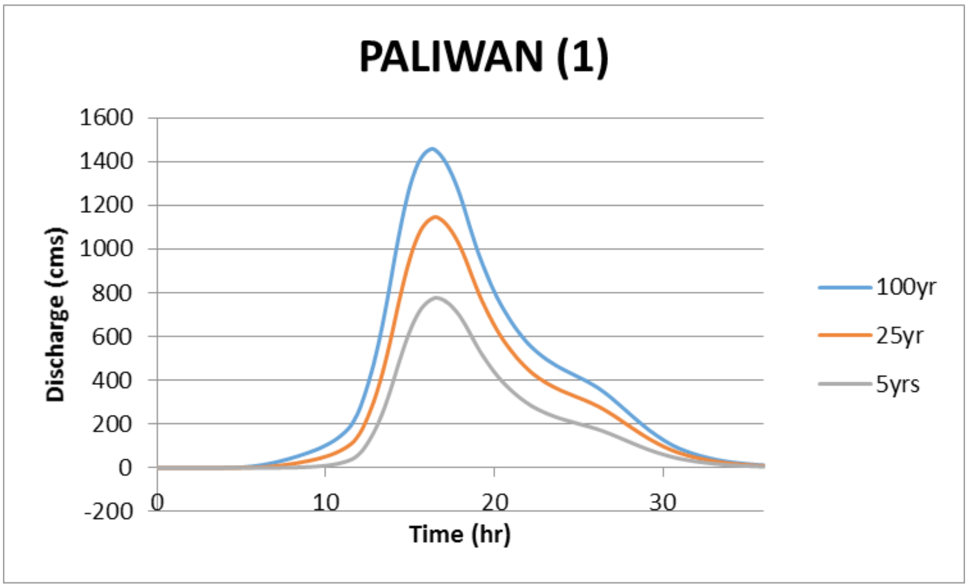


Figure 64. Paliwan river (1) generated discharge using 5-, 25-, and 100-year Iloilo rainfall intensity-duration-frequency (RIDF) in HEC-HMS

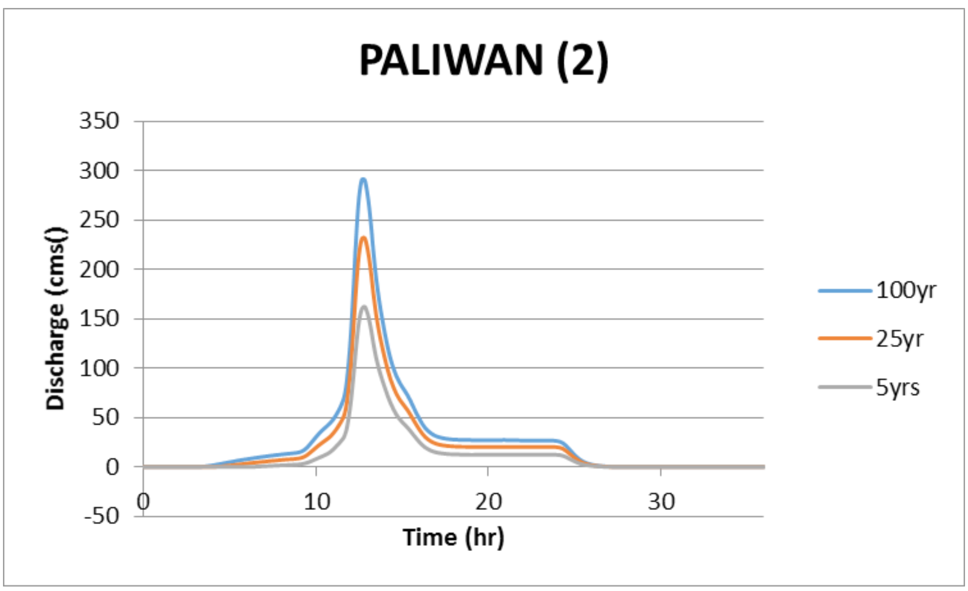


Figure 65. Paliwan river (2) generated discharge using 5-, 25-, and 100-year Iloilo rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 35. Summary of Paliwan river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	1457.8	7 hours, 3 minutes
25-Year	1146.6	7 hours, 3 minutes

Table 36. Summary of Paliwan river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	290.6	0 hours, 57 minutes
25-Year	231.6	0 hours, 57 minutes
5-Year	162.2	0 hours, 57 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 37.

Table 37. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Sumlog (1)	1282.864	2506.382	573.673	Pass	Fail
Sumlog (2)	255.728	426.104	573.673	Pass	Fail

Both river (1) and river (2) have satisfied the conditions for validation using the Bankful method while both rivers did not pass the conditions for validation using the specific discharge method. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

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. The sample generated map of Paliwan River using the calibrated HMS event flow is shown in Figure 66.

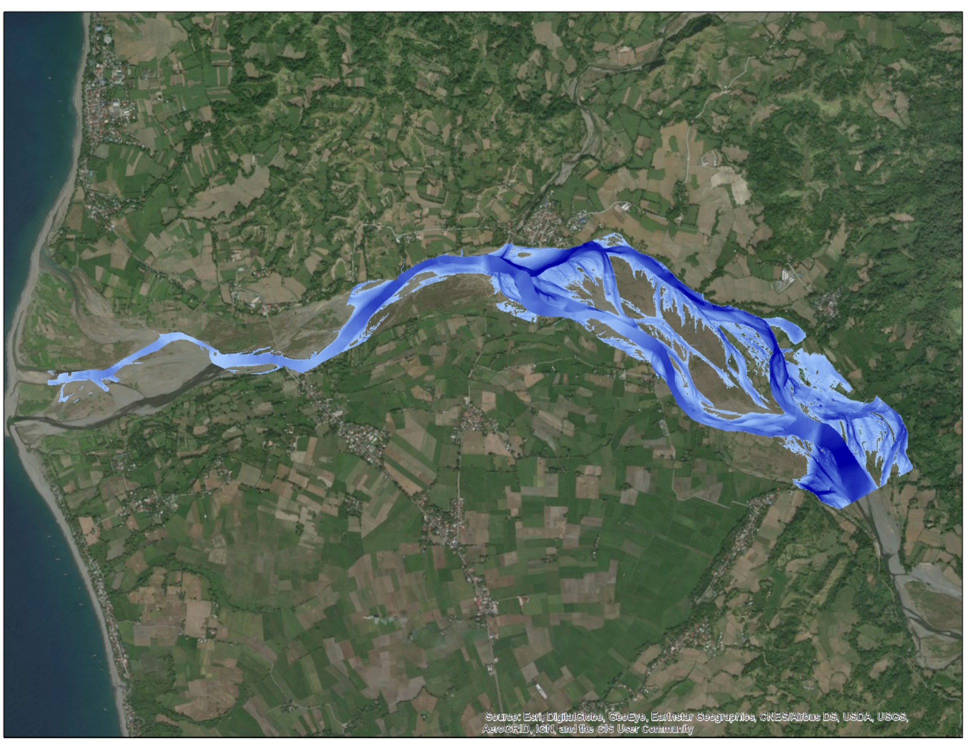


Figure 66. Sample output map of the Paliwan RAS Model

5.9 Flood Depth and Flow Hazard

The resulting hazard and flow depth maps have a 10 m resolution. Figures 67 to 72 show the 5-, 25-, and 100-year rain return scenarios of the Paliwan floodplain. The floodplain, with an area of 55.28 sq.km., covers two municipalities namely, Bugasong, and Laua-An. Table 38 shows the percentage of area affected by flooding in the municipality.

Table 38. Municipalities affected in the Paliwan Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Bugasong	174.08	23.177	13.314
Laua-An	159.77	27.83	17.419

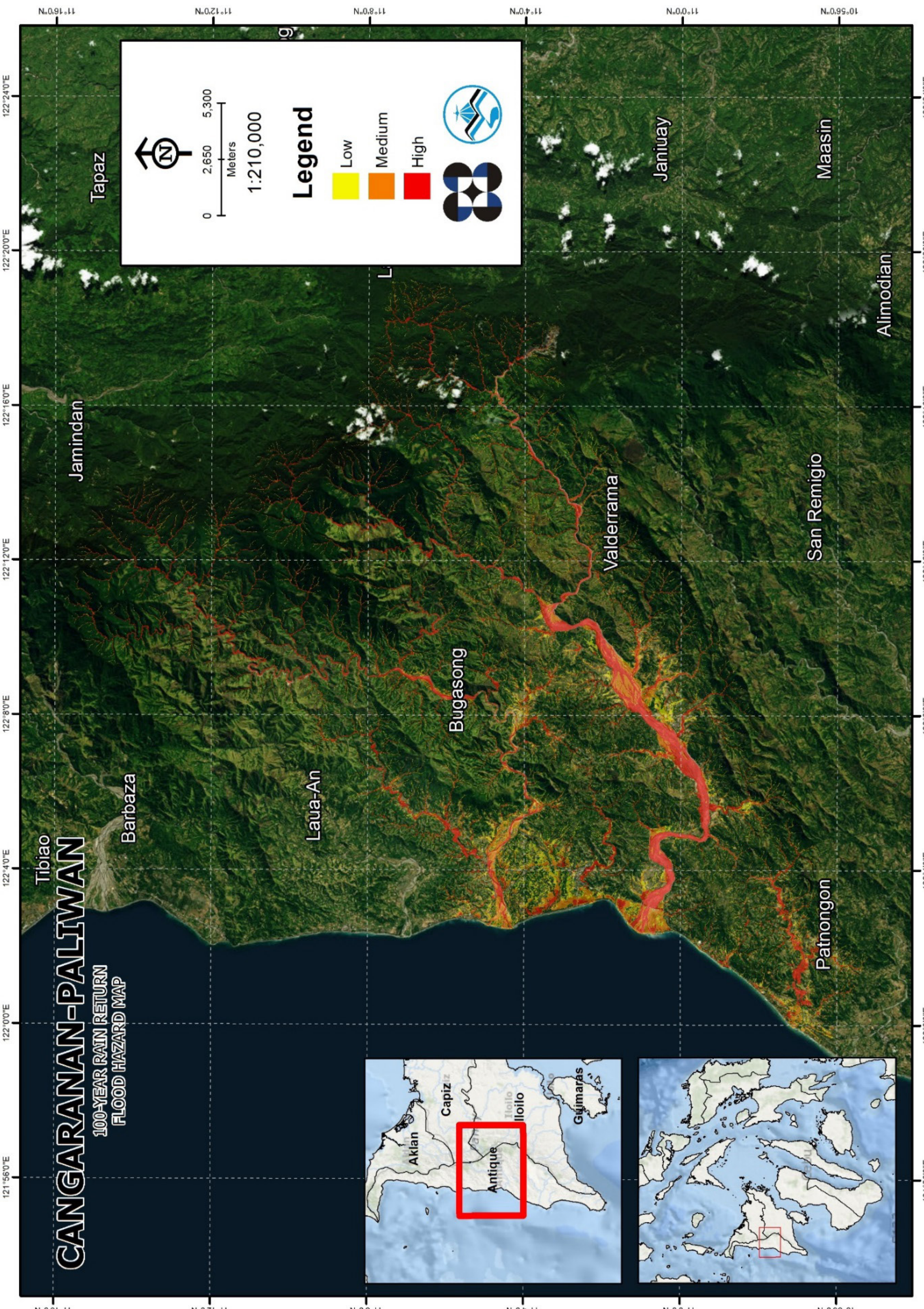


Figure 67. 100-year Flood Hazard Map for Cangaranan-Paliwan Floodplain overlaid on Google Earth imagery

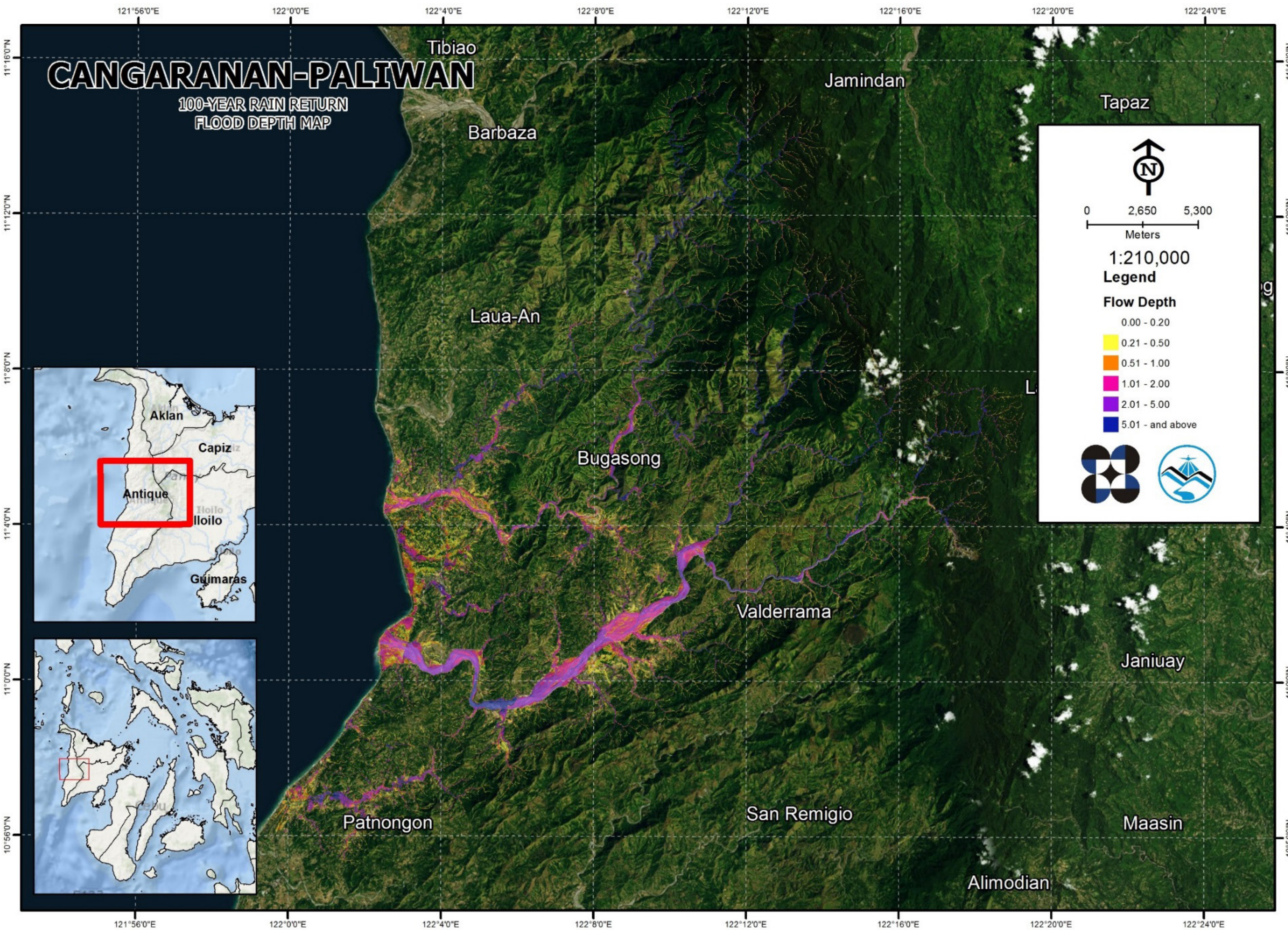


Figure 68. 100-year Flow Depth Map for Cangaranan-Paliwan Floodplain overlaid on Google Earth imagery

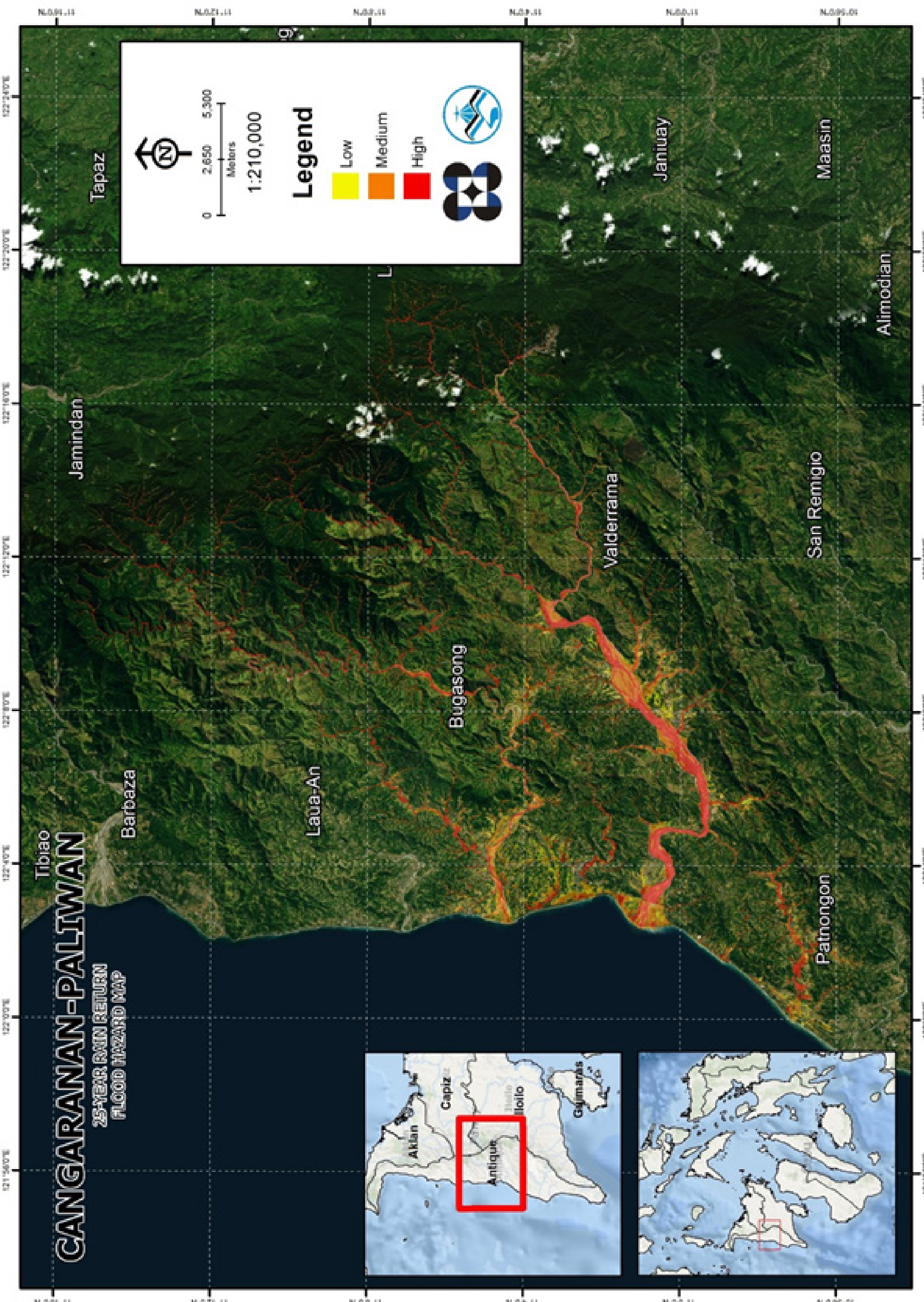


Figure 69. 25-year Flood Hazard Map for Cangaranan-Paliwan Floodplain overlaid on Google Earth imagery

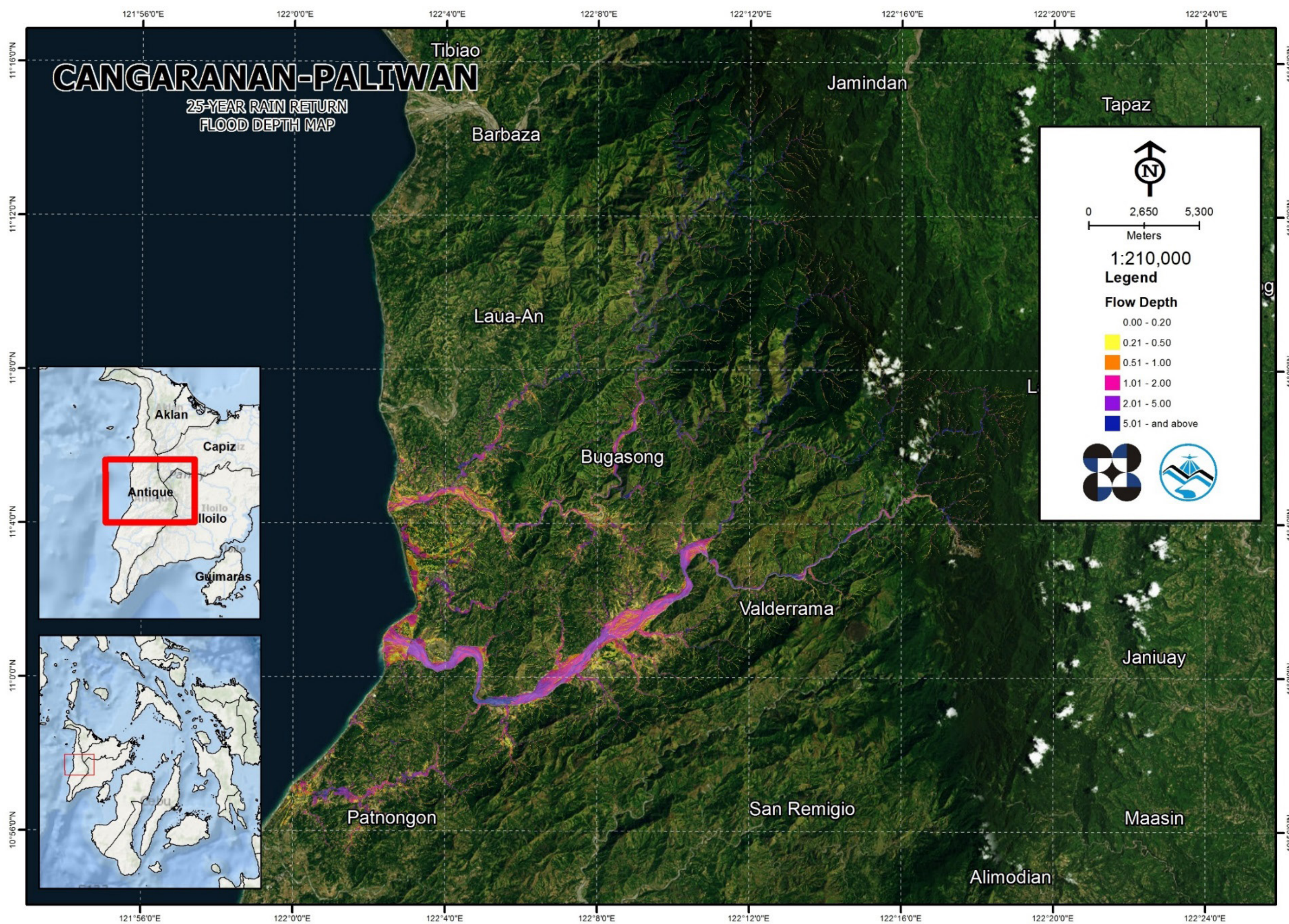


Figure 70. 25-year Flow Depth Map for Cangaranan-Paliwan Floodplain overlaid on Google Earth imagery

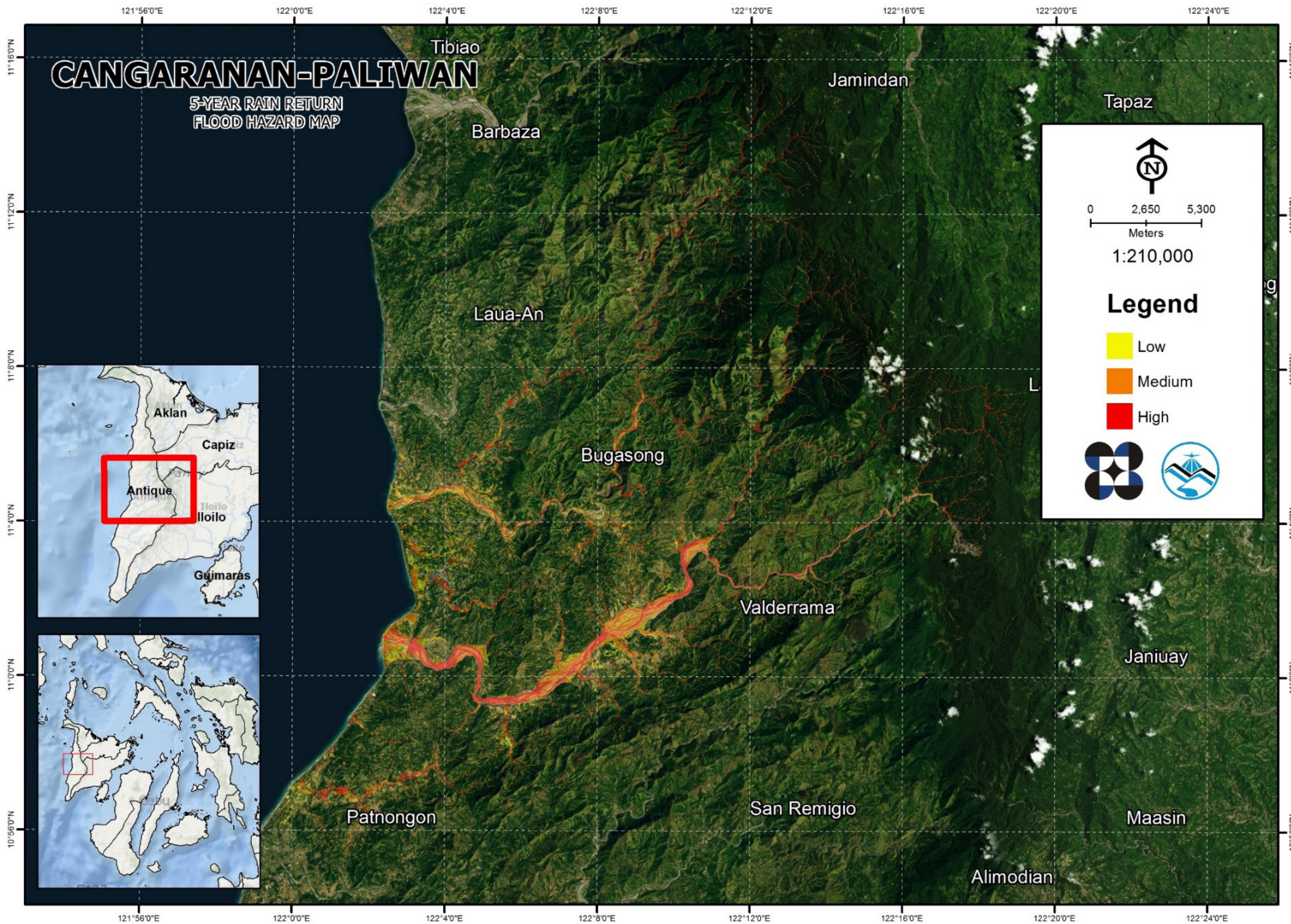


Figure71. 5-year Flood Hazard Map for Cangaranan-Paliwan Floodplain overlaid on Google Earth imagery

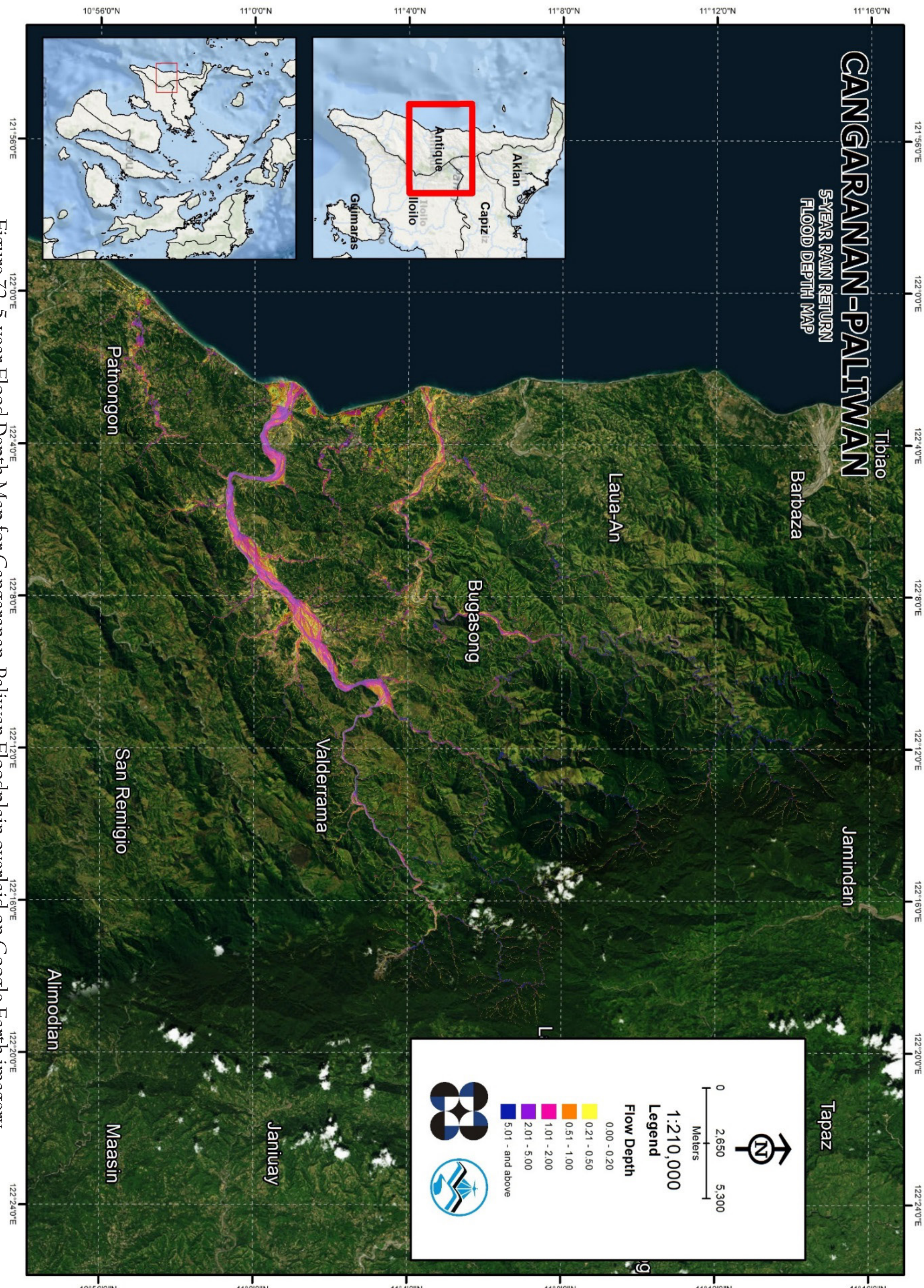


Figure 72. 5-year Flood Depth Map for Cangaranan-Paliwan Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Paliwan river basin, grouped by municipality, are listed below. For the said basin, two municipalities consisting of 34 barangays are expected to experience flooding when subjected to 5-year rainfall return period.

For the 5-year return period, 10.97% of the municipality of Ibajay with an area of 174.08 sq. km. will experience flood levels of less 0.20 meters. 1.55% of the area will experience flood levels of 0.21 to 0.50 meters while 1.04%, 0.7%, 0.36%, and 0.37% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Shown in Figure 73 and in Table 39 are the affected areas in square kilometres by flood depth per barangay.

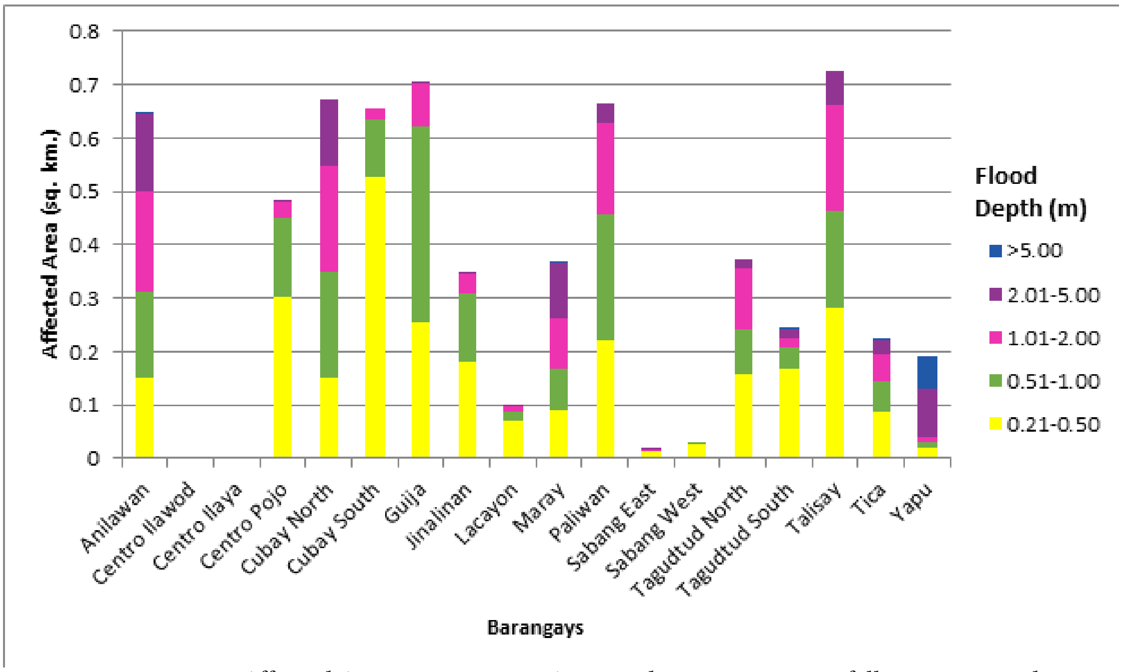


Figure 73. Affected Areas in Bugasong, Antique during 5-Year Rainfall Return Period

PALIWAN BASIN		Affected Barangays in Bugasong									
		Centro Ilawod	Centro Ilaya	Centro Pojo	Cubay North	Cubay South	Guija	Jinalinan	Lacayon	Maray	
Affected Area (sq. km.)	0.03-0.20	1.71	0.015	0.023	1.06	0.54	3.41	0.73	0.85	1.46	2.95
	0.21-0.50	0.15	0	0	0.3	0.15	0.53	0.26	0.18	0.072	0.091
	0.51-1.00	0.16	0	0	0.15	0.2	0.11	0.36	0.13	0.016	0.077
	1.01-2.00	0.19	0	0	0.032	0.2	0.019	0.083	0.035	0.0083	0.094
	2.01-5.00	0.14	0	0	0.0005	0.12	0	0.0015	0.0002	0.0037	0.1
	> 5.00	0.0002	0	0	0	0	0	0	0	0	0.0024
Paliwan		Sabang East	Sabang West	Tagudtud North	Tagudtud South	Talisay	Tica	Yapu			
Affected Area (sq. km.)	0.03-0.20	0.76	0.049	0.84	2.1	0.66	0.44	0.73	0.727561		
	0.21-0.50	0.013	0.026	0.16	0.17	0.28	0.089	0.019	0.018802		
	0.51-1.00	0.0025	0.000014	0.085	0.042	0.18	0.054	0.0097	0.009693		
	1.01-2.00	0.00093	0	0.11	0.017	0.2	0.053	0.011	0.010893		
	2.01-5.00	0.0003	0	0.018	0.014	0.065	0.026	0.092	0.09186		
	> 5.00	0	0	0	0.0002	0	0.0004	0.061	0.060702		

Table 39. Affected Areas in Bugasong, Antique during 5-Year Rainfall Return Period

For the municipality of Laua-An, with an area of 159.77 sq. km., 16.6% will experience flood levels of less 0.20 meters. 0.7% of the area will experience flood levels of 0.21 to 0.50 meters while 0.47%, 0.44%, 0.35%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 and shown in Figure 74 are the affected areas in square kilometres by flood depth per barangay.

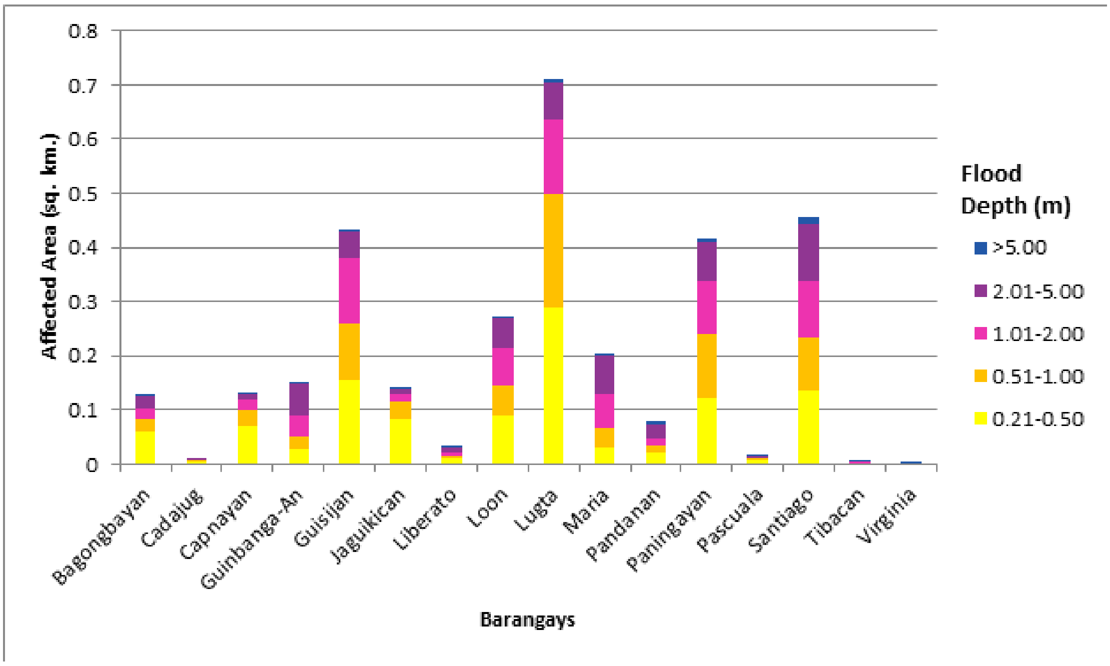


Figure 74. Affected Areas in Laua-An, Antique during 5-Year Rainfall Return Period

PALIWAN BASIN		Affected Barangays in Laua-An									
Bagongbayan		Cadajug	Capnayan	Guinbanga-An	Guisijan	Jaguikican	Liberato	Loon	Lugta	Maria	
Affected Area (sq. km.)	0.03-0.20	1.74	0.38	3.45	0.9	2.73	3.93	0.72	1.32	1.38083	0.960183
	0.21-0.50	0.062	0.0057	0.07	0.029	0.16	0.084	0.0099	0.088	0.290521	0.031615
	0.51-1.00	0.022	0.0011	0.03	0.022	0.1	0.032	0.0058	0.058	0.206895	0.03502
	1.01-2.00	0.019	0.0003	0.02	0.039	0.12	0.014	0.0064	0.067	0.138116	0.063656
	2.01-5.00	0.022	0.00039	0.0084	0.057	0.05	0.0088	0.0092	0.057	0.06908	0.069078
	> 5.00	0.0025	0	0.0002	0.0002	0.0023	0.004	0.0016	0.0007	0.0058	0.003606
Pandanan		Paningayan	Pascuala	Santiago	Tibacan	Virginia					
Affected Area (sq. km.)	0.03-0.20	0.85	2.48	0.4	5.11	0.12	0.052				
	0.21-0.50	0.02	0.12	0.0066	0.13	0.001	0.00075				
	0.51-1.00	0.014	0.12	0.003	0.099	0.0012	0.0001				
	1.01-2.00	0.013	0.097	0.0024	0.11	0.0014	0				
	2.01-5.00	0.027	0.073	0.0028	0.1	0.0022	0.000077				
	> 5.00	0.0044	0.0081	0.00046	0.014	0.0004	0.000038				

Table 40. Affected Areas in Laua-An, Antique during 5-Year Rainfall Return Period

For the 25-year return period, 10.16% of the municipality of Ibajay with an area of 174.08 sq. km. will experience flood levels of less 0.20 meters. 1.8% of the area will experience flood levels of 0.21 to 0.50 meters while 1.2%, 0.9%, 0.46%, and 0.11% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 and shown in Figure 75 are the affected areas in square kilometres by flood depth per barangay.

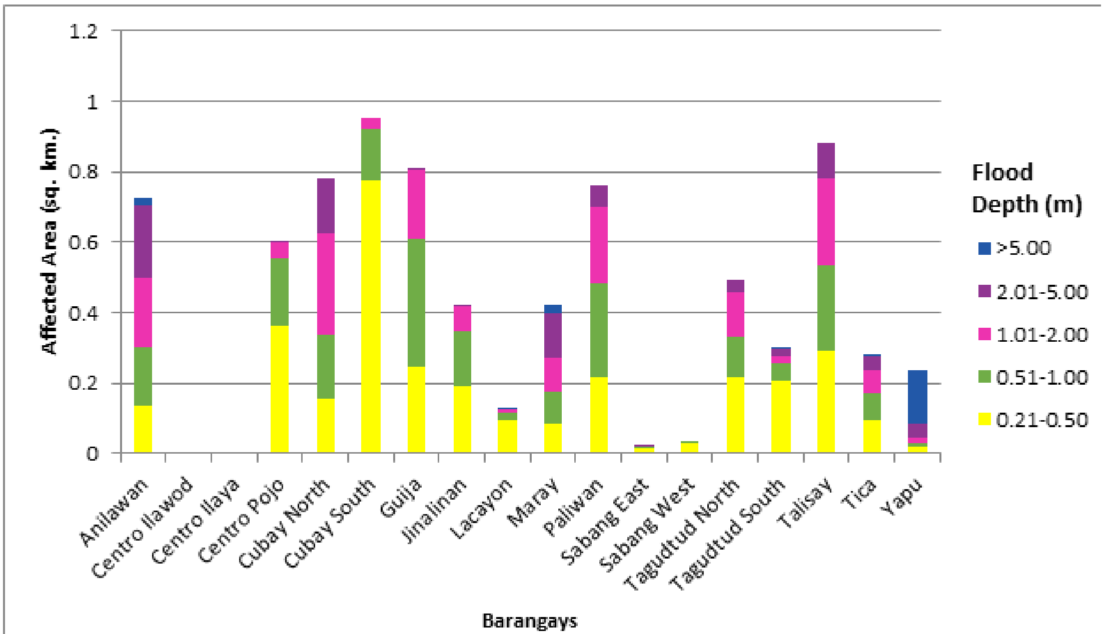


Figure 75. Affected Areas in Bugasong, Antique during 25-Year Rainfall Return Period

PALIWAN BASIN		Affected Barangays in Bugasong									
Anilawan		Centro Ilawod	Centro Ilaya	Centro Pojo	Cubay North	Cubay South	Guija	Jinalinan	Lacayon	Maray	
Affected Area (sq. km.)	0.03-0.20	1.63	0.015	0.023	0.94	0.43	3.11	0.63	0.78	1.44	2.89359
	0.21-0.50	0.13	0	0	0.36	0.16	0.77	0.24	0.19	0.094	0.085897
	0.51-1.00	0.17	0	0	0.19	0.18	0.15	0.37	0.16	0.02	0.090022
	1.01-2.00	0.2	0	0	0.047	0.28	0.032	0.19	0.072	0.01	0.094434
	2.01-5.00	0.21	0	0	0.0006	0.16	0	0.0026	0.0019	0.0044	0.126231
	> 5.00	0.019	0	0	0	0	0	0	0	0.000067	0.026623
Paliwan		Sabang East	Sabang West	Tagudtud North	Tagudtud South	Talisay	Tica	Yapu			
Affected Area (sq. km.)	0.03-0.20	0.68	0.75	0.042	0.72	2.04	0.5	0.38	0.68		
	0.21-0.50	0.22	0.015	0.032	0.22	0.2	0.29	0.095	0.021		
	0.51-1.00	0.26	0.0036	0.00085	0.11	0.055	0.24	0.076	0.0083		
	1.01-2.00	0.22	0.00083	0	0.13	0.017	0.25	0.068	0.015		
	2.01-5.00	0.06	0.0004	0	0.036	0.02	0.1	0.04	0.04		
	> 5.00	0	0	0	0	0.0002	0	0.0005	0.15		

Table 41. Affected Areas in Bugasong, Antique during 25-Year Rainfall Return Period

For the municipality of Laua-An, with an area of 159.77 sq. km., 16.26% will experience flood levels of less 0.20 meters. 0.8% of the area will experience flood levels of 0.21 to 0.50 meters while 0.54%, 0.5%, 0.46%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 and shown in Figure 76 are the affected areas in square kilometres by flood depth per barangay.

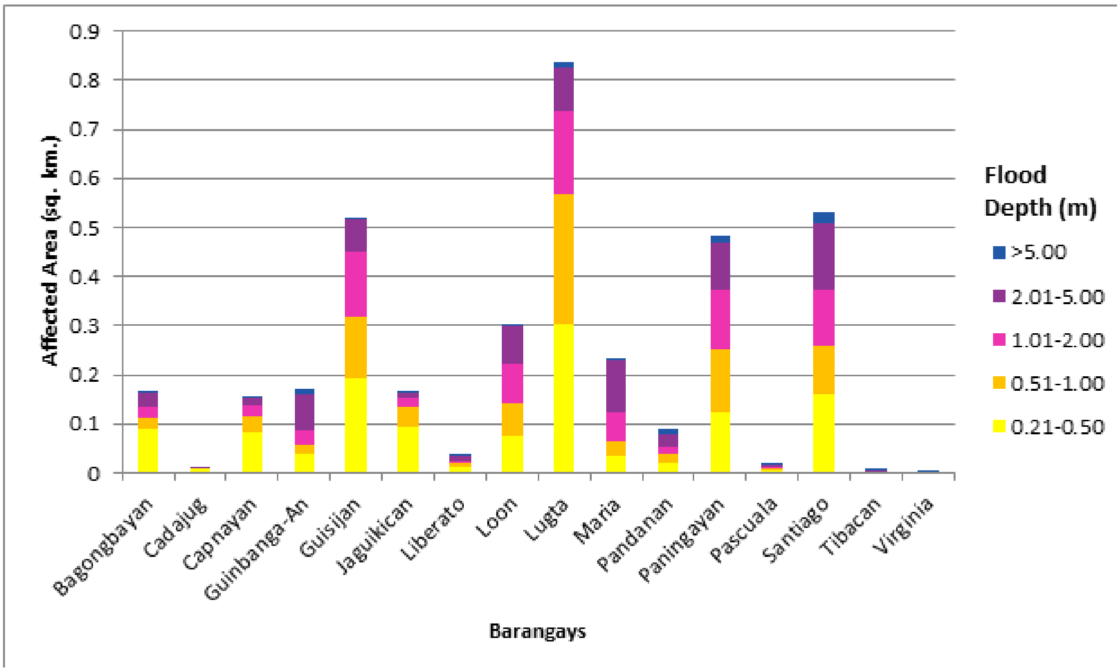


Figure 76. Affected Areas in Laua-An, Antique during 25-Year Rainfall Return Period

PALIWAN BASIN		Affected Barangays in Laua-An										
Bagongbayan		Cadajug	Capnayan	Guinbanga-An	Guisijan	Jaguikican	Liberato	Loon	Lugta	Maria		
Affected Area (sq. km.)	0.03-0.20	1.7	0.37	3.43	0.88	2.64	3.91	0.72	1.29	1.25	0.93	
	0.21-0.50	0.09	0.0084	0.082	0.04	0.19	0.095	0.012	0.077	0.3	0.035	
	0.51-1.00	0.023	0.0013	0.035	0.017	0.13	0.04	0.0061	0.066	0.27	0.03	
	1.01-2.00	0.021	0.0004	0.022	0.03	0.13	0.017	0.0066	0.079	0.17	0.059	
	2.01-5.00	0.028	0.00039	0.013	0.074	0.063	0.012	0.0095	0.079	0.086	0.1	
	> 5.00	0.0032	0	0.0004	0.01	0.005	0.0049	0.0025	0.0015	0.013	0.0058	
Pandanan		Paningayan	Pascuala	Santiago	Tibacan	Virginia						
Affected Area (sq. km.)	0.03-0.20	0.84	2.41	0.4	5.04	0.12	0.051					
	0.21-0.50	0.022	0.12	0.0067	0.16	0.0011	0.00085					
	0.51-1.00	0.016	0.13	0.0039	0.1	0.0011	0.00021					
	1.01-2.00	0.015	0.12	0.0022	0.11	0.001	0					
	2.01-5.00	0.027	0.096	0.0034	0.14	0.0027	0.000077					
	> 5.00	0.011	0.013	0.00046	0.023	0.0007	0.000038					

Table 42. Affected Areas in Laua-An, Antique during 25-Year Rainfall Return Period

For the 100-year return period, 9.5% of the municipality of Ibajay with an area of 174.08 sq. km. will experience flood levels of less 0.20 meters. 2% of the area will experience flood levels of 0.21 to 0.50 meters while 1.2%, 1.17%, 0.6%, and 0.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 42 and shown in Figure 77 are the affected areas in square kilometres by flood depth per barangay.

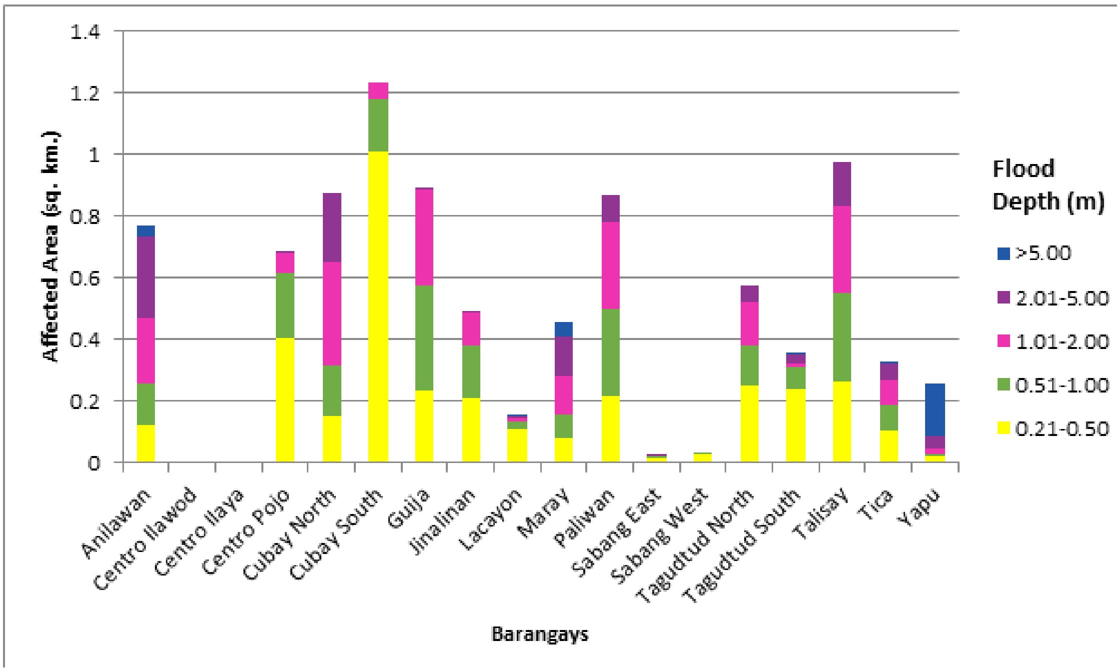


Figure 77. Affected Areas in Bugasong, Antique during 100-Year Rainfall Return Period

PALIWAN BASIN		Affected Barangays in Bugasong									
Anilawan		Centro Ilawod	Centro Ilaya	Centro Pojo	Cubay North	Cubay South	Guija	Jinalinan	Lacayon	Maray	
Affected Area (sq. km.)	0.03-0.20	1.58	0.015	0.023	0.86	0.34	2.83	0.54	0.71	1.41	2.86
	0.21-0.50	0.12	0.000001	0	0.41	0.15	1.01	0.23	0.21	0.11	0.084
	0.51-1.00	0.13	0	0	0.21	0.16	0.17	0.34	0.17	0.021	0.072
	1.01-2.00	0.21	0	0	0.063	0.34	0.05	0.31	0.1	0.012	0.12
	2.01-5.00	0.26	0	0	0.0006	0.22	0	0.0049	0.0044	0.0053	0.13
	> 5.00	0.04	0	0	0	0	0	0	0	0.000067	0.05
Paliwan		Sabang East	Sabang West	Tagudtud North	Tagudtud South	Talisay	Tica	Yapu			
Affected Area (sq. km.)	0.03-0.20	0.57	0.75	0.037	0.64	1.99	0.41	0.34	0.66		
	0.21-0.50	0.22	0.019	0.031	0.25	0.24	0.26	0.1	0.021		
	0.51-1.00	0.28	0.0034	0.0074	0.13	0.068	0.29	0.082	0.0098		
	1.01-2.00	0.28	0.0011	0	0.14	0.016	0.28	0.082	0.015		
	2.01-5.00	0.085	0.0005	0	0.053	0.027	0.14	0.056	0.042		
	> 5.00	0	0	0	0	0.0002	0	0.0005	0.17		

Table 43. Affected Areas in Bugasong, Antique during 100-Year Rainfall Return Period

For the municipality of Laua-An, with an area of 159.77 sq. km., 16.1% will experience flood levels of less 0.20 meters. 0.8% of the area will experience flood levels of 0.21 to 0.50 meters while 0.56%, 0.5%, 0.53%, and 0.1% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 43 and shown in Figure 78 are the affected areas in square kilometres by flood depth per barangay.

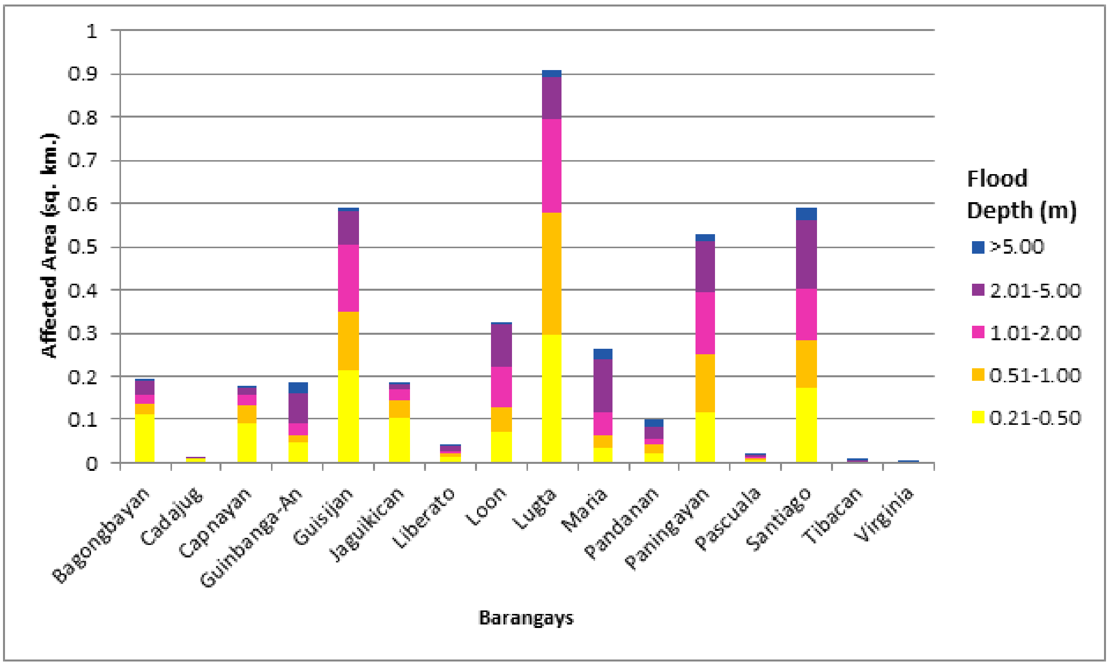


Figure 78. Affected Areas in Laua-An, Antique during 100-Year Rainfall Return Period

PALIWAN BASIN		Affected Barangays in Laua-An									
	Bagongbayan	Cadajug	Capnayan	Guinban-ga-An	Guisijan	Jaguikican	Liberato	Loon	Lugta	Maria	
Affected Area (sq. km.)	0.03-0.20	1.67	0.37	3.4	0.87	2.57	3.89	0.71	1.27	1.18	0.9
	0.21-0.50	0.11	0.0092	0.092	0.045	0.21	0.1	0.014	0.073	0.3	0.035
	0.51-1.00	0.026	0.0013	0.039	0.018	0.14	0.042	0.0062	0.057	0.28	0.029
	1.01-2.00	0.02	0.00058	0.024	0.031	0.15	0.022	0.0066	0.093	0.22	0.053
	2.01-5.00	0.032	0.00039	0.018	0.069	0.079	0.013	0.0098	0.097	0.097	0.12
	> 5.00	0.0043	0	0.0006	0.024	0.009	0.0067	0.0034	0.0034	0.017	0.024
	Pandanan	Paningayan	Pascuala	Santiago	Tibacan	Virginia					
Affected Area (sq. km.)	0.03-0.20	0.83	2.37	0.4	4.98	0.12	0.051				
	0.21-0.50	0.023	0.12	0.0066	0.17	0.0012	0.00079				
	0.51-1.00	0.017	0.13	0.0045	0.11	0.0012	0.00049				
	1.01-2.00	0.015	0.14	0.0025	0.12	0.0009	0				
	2.01-5.00	0.026	0.12	0.0034	0.16	0.0023	0.000078				
	> 5.00	0.018	0.018	0.00056	0.03	0.0015	0.000051				

Table 44. Affected Areas in Laua-An, Antique during 100-Year Rainfall Return Period

Among the barangays in the municipality of Bugasong, Cubay South is projected to have the highest percentage of area that will experience flood levels at 2.33%. Meanwhile, Aniliawan posted the second highest percentage of area that may be affected by flood depths at 1.35%.

Among the barangays in the municipality of Laua-An, Santiago is projected to have the highest percentage of area that will experience flood levels at 3.48%. Meanwhile, Jaguikican posted the second highest percentage of area that may be affected by flood depths at 2.55%.

Moreover, the generated flood hazard maps for the Paliwan 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-year, 25-year, and 100-year) as shown in Table 44.

Table 45. 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	3.4921	2.9709	4.2891
Medium	3.212	3.8835	4.2205
High	3.2045	4.2027	5.1207

Of the 16 identified Education Institutions in the Paliwan Flood plain, 4 schools were assessed to be exposed to the Low level flooding during a 5 year scenario.

Of the 4 identified Medical Institutions in the Paliwan Flood Plain, no schools were assessed to be exposed to any of the flooding 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 went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events and/or interviews of some residents with knowledge of or have had experienced flooding in a particular area.

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 79.

The flood validation consists of 156 points randomly selected all over the Cangaranan-Paliwan flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.768 m. Table 45 shows a contingency matrix of the comparison.

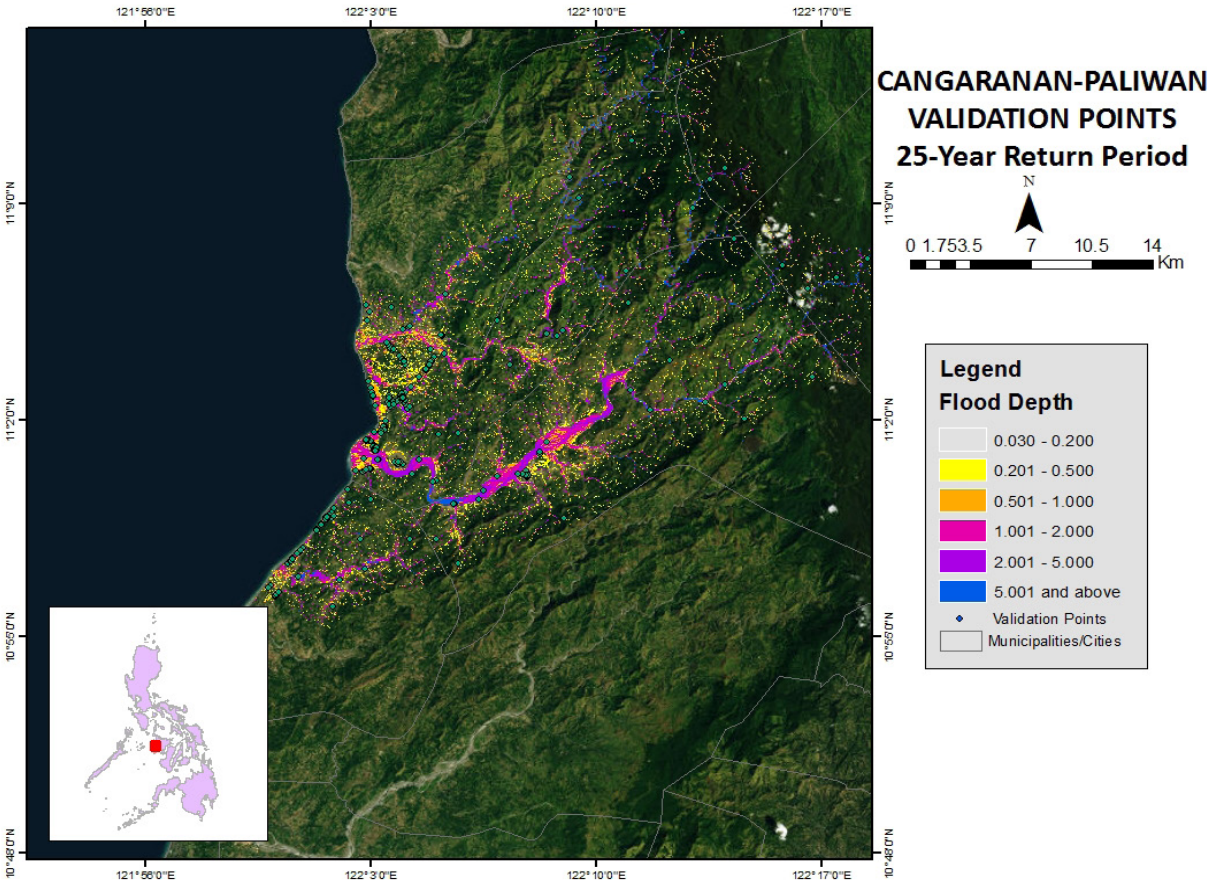


Figure 79. Validation points for 25-year Flood Depth Map of Cangaranan-Paliwan Floodplain

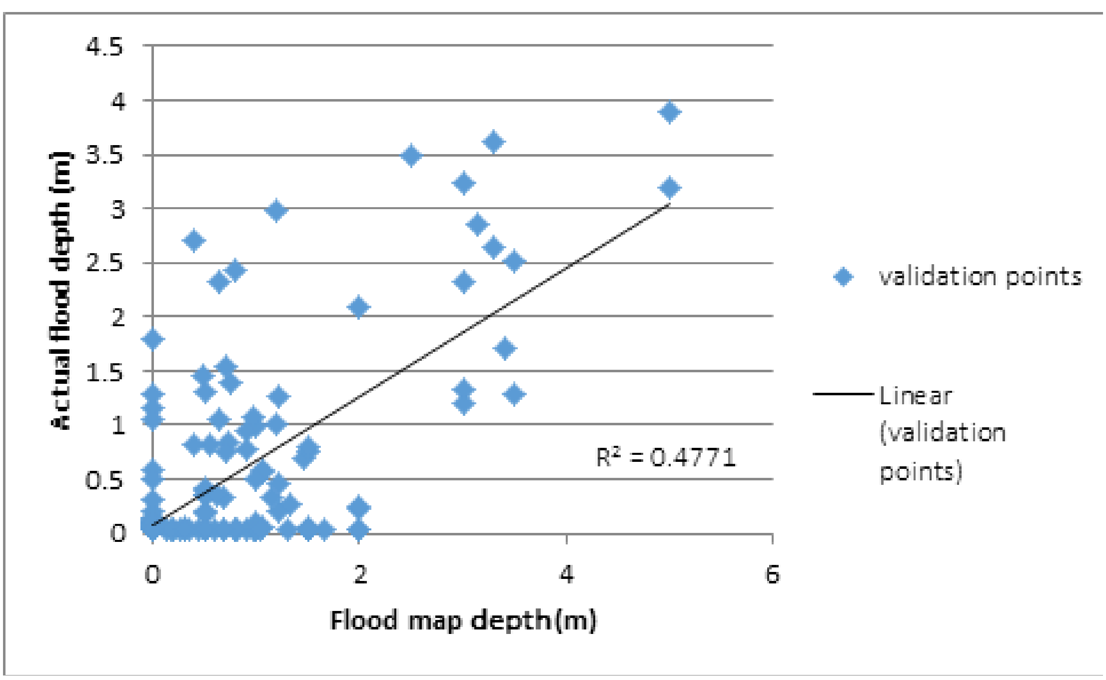


Figure 80. Flood depth map vs Actual flood depth

Table 46. Actual Flood Depth vs. Simulated Flood Depth in the Cangaranan-Paliwan River Basin

CANGA-RANAN-PALI-WAN		Modeled Flood Depth (m)						
0-0.20		0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total	
Actual Flood Depth (m)	0-0.20	65	1	1	4	0	0	71
	0.21-0.50	11	3	1	2	1	0	18
	0.51-1.00	12	3	6	4	2	0	27
	1.01-2.00	11	5	6	1	2	0	25
	2.01-5.00	0	0	0	4	9	0	13
	> 5.00	0	0	0	0	2	0	2
	Total	99	12	14	15	16	0	156

The overall accuracy generated by the flood model is estimated at 53.85%, with 84 points correctly matching the actual flood depths. In addition, there were 34 points estimated one level above and below the correct flood depths while there were 20 points and 16 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 18 points were overestimated while a total of 54 points were underestimated in the modelled flood depths of Cangaranan-Paliwan. Table 46 depicts the summary of the Accuracy Assessment in the Cangaranan-Paliwan River Basin Survey.

Table 47. Summary of Accuracy Assessment in the Cangaranan-Paliwan River Basin Survey

PALIWAN	No. of Points	%
Correct	84	53.85
Overestimated	18	11.54
Underestimated	54	34.62
Total	156	100.00

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 Paliwan Floodplain Survey

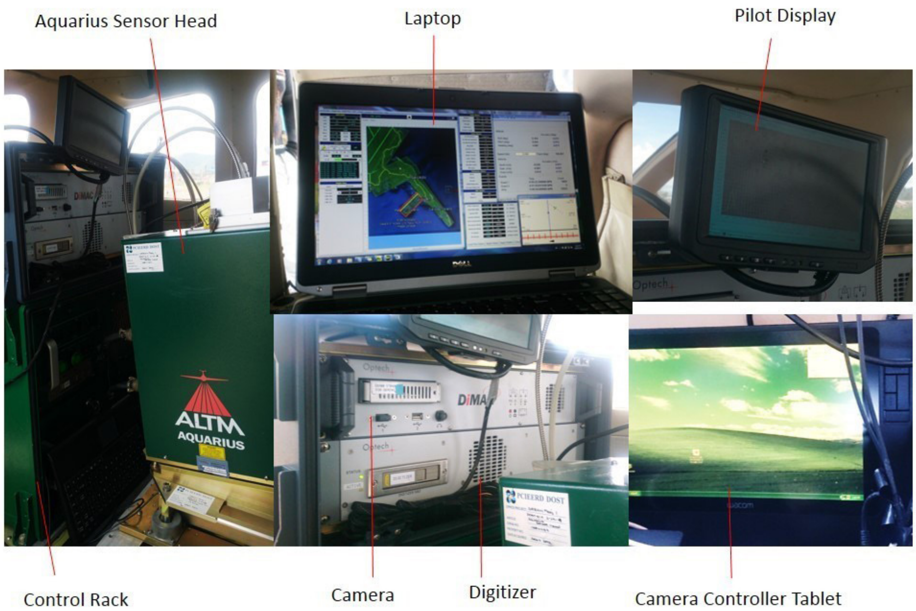
OPTECH TECHNICAL SPECIFICATION OF THE GEMINI SENSOR

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

OPTECH TECHNICAL SPECIFICATION OF THE 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, 1Ó
Elevation accuracy (2)	< 5-20 cm, 1Ó
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 (optional)
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

OPTECH TECHNICAL SPECIFICATION OF THE AQUARIUS SENSOR



Parameter	Specification
Operational altitude	300-600 m AGL
Laser pulse repetition rate	33, 50. 70 kHz
Scan rate	0-70 Hz
Scan half-angle	0 to ± 25 ˚
Laser footprint on water surface	30-60 cm
Depth range	0 to > 10 m (for k < 0.1/m)
Topographic mode	
Operational altitude	300-2500
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	12-bit dynamic measurement range
Position and orientation system	POS AVTM 510 (OEM) includes embedded 72-channel GNSS receiver (GPS and GLONASS)
Data Storage	Ruggedized removable SSD hard disk (SATA III)
Power	28 V, 900 W, 35 A
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Dimensions and weight	Sensor:250 x 430 x 320 mm; 30 kg; Control rack: 591 x 485 x 578 mm; 53 kg
Operating temperature	0-35˚C
Relative humidity	0-95% no-condensing

ANNEX 2. NAMRIA CERTIFICATION OF REFERENCE POINTS USED IN THE LIDAR SURVEY

1. ATQ-18

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

March 02, 2015

CERTIFICATION

To whom it may concern:

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

Province: **ANTIQUE**
Station Name: **ATQ-18**
Order: **2nd**

Island: **VISAYAS**
Municipality: **BARBAZA**
Barangay: **CUBAY**
MSL Elevation:

PRS92 Coordinates

Latitude: **11° 11' 58.67081"** Longitude: **122° 2' 22.83300"** Ellipsoidal Hgt: **10.90200 m.**

WGS84 Coordinates

Latitude: **11° 11' 54.16068"** Longitude: **122° 2' 28.01549"** Ellipsoidal Hgt: **65.96100 m.**

PTM / PRS92 Coordinates

Northing: **1238579.674 m.** Easting: **395119.157 m.** Zone: **4**

UTM / PRS92 Coordinates

Northing: **1,238,146.15** Easting: **395,155.87** Zone: **51**

Location Description

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

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

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

9903022015131346

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

CIP/4701/12/09/814

2. ATQ-20

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

November 14, 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: **ANTIQUE**
Station Name: **ATQ-20**
Order: **2nd**

Island: **VISAYAS**
Municipality: **BUGASONG**
Barangay: **ZARAGOZA**
MSL Elevation:

	PRS92 Coordinates	
Latitude: **11° 0' 42.90484"**	Longitude: **122° 2' 54.07144"**	Ellipsoidal Hgt: **10.56200 m.**
	WGS84 Coordinates	
Latitude: **11° 0' 38.44240"**	Longitude: **122° 2' 59.27039"**	Ellipsoidal Hgt: **66.09400 m.**
	PTM / PRS92 Coordinates	
Northing: **1217812.272 m.**	Easting: **396000.488 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,217,386.02**	Easting: **396,036.89**	Zone: **51**

Location Description

ATQ-20
From San Jose, travel N for about 45 km. to Brgy. Zaragoza, Mun. of Bugasong. Station is located on the left side of the first approach of Cangaranan Bridge. Mark is the head of a 4 in. copper nail centered on a 30 cm. x 30 cm. cement putty, with inscriptions "ATQ-20 2007 NAMRIA".

Requesting Party:	**Phil Lidar 1**
Purpose:	**Reference**
OR Number:	**FREE ISSUE**
T.N.:	**2016-2057**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. ATQ-22

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

March 02, 2015

CERTIFICATION

To whom it may concern:

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

Province: **ANTIQUE**
Station Name: **ATQ-22**
Order: **2nd**

Island: **VISAYAS**
Municipality: **BELISON**
Barangay: **CONCEPCION**
MSL Elevation:

PRS92 Coordinates

Latitude:	**10° 49' 46.66618"**	Longitude:	**121° 58' 11.90221"**	Ellipsoidal Hgt:	**12.25000 m.**

WGS84 Coordinates

Latitude:	**10° 49' 42.24271"**	Longitude:	**121° 58' 17.11770"**	Ellipsoidal Hgt:	**68.02200 m.**

PTM / PRS92 Coordinates

Northing:	**1197676.056 m.**	Easting:	**387365.279 m.**	Zone:	**4**

UTM / PRS92 Coordinates

Northing:	**1,197,256.85**	Easting:	**387,404.70**	Zone:	**51**

Location Description

ATQ-22

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

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

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

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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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

4. AQ-78

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

March 02, 2015

CERTIFICATION

To whom it may concern:

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

Province: **ANTIQUE**
Station Name: **AQ-78**

Island: **Visayas**	Municipality: **PATNONGON**	Barangay: **IPAYO**
Elevation: **10.6092 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude: **10° 54' 59.40000"**	Longitude: **121° 59' 52.10000"**	

Location Description

BM AQ-78
Station is located at the northwestern side of the side walk of Ipayo Bridge km. 122+244.79. Mark is the head of a 4in. copper nail set flush on a cement putty with inscriptions "AQ-78,2007,NAMRIA".

Requesting Party:	**PHIL-LIDAR 1**
Purpose:	**Reference**
OR Number:	**8077754 I**
T.N.:	**2015-0506**

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

ANNEX 3. BASE PROCESSING REPORTS OF CONTROL POINTS USED IN THE LIDAR SURVEY

Vector Components (Mark to Mark)

From:	ATQ-20				
Grid		Local		Global	
Easting	396036.890 m	Latitude	N11°00'42.90484"	Latitude	N11°00'38.44240"
Northing	1217386.017 m	Longitude	E122°02'54.07144"	Longitude	E122°02'59.27039"
Elevation	10.798 m	Height	10.563 m	Height	66.094 m

To:	AQ-				
Grid		Local		Global	
Easting	396235.105 m	Latitude	N11°01'03.59755"	Latitude	N11°00'59.13382"
Northing	1218020.995 m	Longitude	E122°03'00.53639"	Longitude	E122°03'05.73482"
Elevation	11.276 m	Height	11.054 m	Height	66.576 m

Vector					
ΔEasting	198.215 m	NS Fwd Azimuth	17°09'16"	ΔX	-102.123 m
ΔNorthing	634.978 m	Ellipsoid Dist.	665.374 m	ΔY	-206.684 m
ΔElevation	0.478 m	ΔHeight	0.491 m	ΔZ	624.160 m

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000003727		
Y	-0.0000004068	0.0000012949	
Z	-0.0000001072	0.0000002886	0.0000002405

ANNEX 4. THE LIDAR SURVEY TEAM COMPOSITION

Data Acquisition Component Sub-team	Designation	Name	Agency/Affiliation
Data Acquisition Component Leader	Data Component Program Leader	ENRICO C. PARINGIT	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader -I	ENGR. CZAR JAKIRI S. SARMIENTO ENGR. LOUIE P. BALICANTA	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP TCAGP
LiDAR Operation	Senior Science Research Specialist	ENGR. LOVELYN ASUNCION ENGR. GEROME HIPOLITO ENGR. IRO NIEL ROXAS	UP TCAGP
LiDAR Operation	Research Associate	PAULINE JOANNE ARCEO VERLINA TONGA REGINA FELISMINO MARY CATHERINE ELIZABETH BALIGUAS	UP TCAGP
	Research Associate	RENAN PUNTO MA. REMEDIOS VILLANUEVA KRISTINE ANDAYA	UP TCAGP
Ground Survey	Research Associate	JERIEL PAUL ALAMBAN KENNETH QUISADO IRO NIEL ROXAS SANDRA POBLETE	UP TCAGP
Data Download and Transfer	Senior Science Research Specialist	RENAN PUNTO VERLINA TONGA MA. REMEDIOS VILLANUEVA	UP TCAGP
LiDAR Operation	Airborne Security	SSG. LEE JAY PUNZALAN SSG. DAVE GUMBAN	PILIPPINE AIR FORCE (PAF)
LiDAR Operation	Pilot	CAPT. JACKSON JAVIER CAPT. JEFFREY ALAJAR CAPT. BRYAN	ASIAN AEROSPACE CORPORATION (AAC)
LiDAR Operation	Co-Pilot	CAPT. NEIL ACHILLES AGAWIN CAPT. ALBERT LIM CAPT. HOYA	AAC

ANNEX 5. DATA TRANSFER SHEET FOR CABULIG FLOODPLAIN

DATA TRANSFER SHEET
03/23/2015(Iloilo-gem)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
16-Feb-15	2566G	2BLK37V047A	gemini	na	1517	1.13	209	28	206	13	1.36	10.7	1KB	1KB	19	19	Z:\DAC\RAW DATA
16-Feb-15	2568G	2BLK37GSIV047B	gemini	na	952	1.34	222	46.8	383	21.9	2.12	6.61	1KB	1KB	7/4	15/12	Z:\DAC\RAW DATA
17-Feb-15	2570G	2BLK43H048A	gemini	na	1078	1.43	222	48.5	342	21.7	3.4	14.4	1KB	1KB	3	3	Z:\DAC\RAW DATA
19-Feb-15	2578G	2BLK43GV050A	gemini	na	586	891	184	8.07	67.8	19.4	na	11.1	1KB	1KB	7	na	Z:\DAC\RAW DATA
19-Feb-15	2580G	2BLK43F050B	gemini	na	740	990	163	25.6	203	16.2	3.29	4.11	1KB	1KB	4	8	Z:\DAC\RAW DATA
20-Feb-15	2582G	2BLK43A051A	gemini	na	169	254	106	6.84	57.4	4.65	ns	11	1KB	1KB	6	13	Z:\DAC\RAW DATA
21-Feb-15	2586G	2BLK43A052A	gemini	na	613	670	182	15.4	63.9	8.3	1.43	11.5	1KB	1KB	5	10	Z:\DAC\RAW DATA
22-Feb-15	2590G	2BLK43A053A	gemini	na	694	0.97	198	21.2	94.4/628	12.1	na	17	1KB	1KB	5	10	Z:\DAC\RAW DATA
23-Feb-15	2594G	2BLK43C054A	gemini	na	856	1.05	240	28.2	17.2/163	16.3	na	11.6	1KB	1KB	6	14	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature

Received by

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

DATA TRANSFER SHEET

03/23/2015(Iloilo-peg)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
14-Feb-15	2569P	1BLK43D045A	pegasus	1.28	940	6.06	196	10.5	38/48	14.4	na	10.5	1KB	1KB	76	na	Z:\DAC\RAW DATA
16-Feb-15	2579P	1BLK43M047B	pegasus	1.77	1.21	10.4	221	26.4	251	19.5	na	12.2	1KB	1KB	77/18	na	Z:\DAC\RAW DATA
17-Feb-15	2581P	1BLK43MN048A	pegasus	2.06	1.35	9.99	263	34.3	265	21.4	na	20.2	1KB	1KB	76/77/21	na	Z:\DAC\RAW DATA
17-Feb-15	2583P	1BLK43D048B	pegasus	1.11	716	6.06	170	14	127	11.4	na	20.2	1KB	1KB	96/70	na	Z:\DAC\RAW DATA
18-Feb-15	2585P	1BLK43EF049A	pegasus	2.91	1.71	9.97	283	42	314	27.8	na	14.3	1KB	1KB	99/117	na	Z:\DAC\RAW DATA
18-Feb-15	2587P	1BLK43ED049B	pegasus	1.7	1.02	9.05	190	19.9	16/71	17.4	na	7.46	1KB	1KB	1/607/77	na	Z:\DAC\RAW DATA
19-Feb-15	2589P	1BLK43EFD050A	pegasus	1.2	739	7.78	417	17.3	133	12.3	na	16.7	1KB	1KB	86/77/026/021	na	Z:\DAC\RAW DATA
19-Feb-15	2591P	1BLK37I050B	pegasus	5.53	1.62	9.47	199	49.9	343	25.3	na	9.75	1KB	1KB	64	na	Z:\DAC\RAW DATA
20-Feb-15	2593P	1BLK43BDG051A	pegasus	3.14	1.01	7.62	213	27	218	16.3	na	11	1KB	1KB	114	na	Z:\DAC\RAW DATA
21-Feb-15	2597P	1BLK43N052A	pegasus	2.09	1.29	8.69	257	37.9	274	21	na	11.5	1KB	1KB	52	na	Z:\DAC\RAW DATA
22-Feb-15	2601P	1BLK37IFV053A	pegasus	2.13	1.27	9.06	225	32.2	256	20.7	na	17.7	1KB	1KB	101/76	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position RA
Signature

Received by

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

DATA TRANSFER SHEET
7/3/2014(Iloilo)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
25-Feb-15	2602G	2BLK43B056A	GEMINI	NA	278	402	167	8.44	61	5.95	NA	9.49	1KB	1KB	12	17	Z:\DAC\RAW DATA
26-Feb-15	2606G	2BLK43BV057A	GEMINI	NA	739	932	208	22.5	92	12.6	NA	9.26	1KB	1KB	12	18	Z:\DAC\RAW DATA
27-Feb-15	2610G	2BLK43BV058A	GEMINI	NA	100	190	173	2.88	25	2.95	NA	8.94	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
5-Mar-15	2634G	2BLK37FV064A	GEMINI	NA	298	532	170	14.6	122	5.2	NA	22.7	1KB	1KB	8	13	Z:\DAC\RAW DATA
5-Mar-15	2636G	2BLK43OS064B	GEMINI	NA	468	770	205	23.2	106	5.05	NA	22.7	1KB	1KB	8	18	Z:\DAC\RAW DATA
6-Mar-15	2638G	2BLK43OS065A	GEMINI	NA	581	894	234	27.5	100	12.5	NA	20.1	1KB	1KB	13	21	Z:\DAC\RAW DATA
25-Feb-15	2613P	1BLK37IFV056A	PEGASUS	1.94	652	6.14	151	17.6	134	10	NA	16.6	1KB	1KB	101/76	NA	Z:\DAC\RAW DATA
26-Feb-15	2617P	1BLK37OP057A	PEGASUS	7.28	2.14	12.3	260	55.2	457	34.5	NA	18.7	1KB	1KB	196	NA	Z:\DAC\RAW DATA
27-Feb-15	2621P	1BLK37P058A	PEGASUS	3.11	1.93	12.8	245	48.1	414	27.3	NA	15.5	1KB	1KB	160	NA	Z:\DAC\RAW DATA
3-Mar-15	2637P	1BLK43NO062A	PEGASUS	1.82	1.15	9.81	245	32.8	237	18.3	NA	10.7	1KB	1KB	21/107	NA	Z:\DAC\RAW DATA
3-Mar-15	2639P	1BLK37M062B	PEGASUS	858	510	4.92	114	9.94	89	8.09	1.65	10.7	1KB	1KB	172	NA	Z:\DAC\RAW DATA
5-Mar-15	2645P	1BLK37Q064A	PEGASUS	2.74	.99	10.1	263	35.8	264	18.3	53.5	22.7	1KB	1KB	185/188	NA	Z:\DAC\RAW DATA
5-Mar-15	2647P	1BLK37MQ064B	PEGASUS	NA	1.16	9.62	235	71.5	4	17.8	NA	22.7	1KB	1KB	238/154	NA	Z:\DAC\RAW DATA
6-Mar-15	2649P	1BLK37Q065A	PEGASUS	582	505	5.92	202	15.1	105	7.9	50.4	20.1	1KB	1KB	231/210	NA	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position
Signature

Received by

Name Angelo Carlo Bongat
Position
Signature

DATA TRANSFER SHEET
ILOILO 11/14/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	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	
October 23, 2016	8507AC	3BLK37C297A	AQUA CASI	NA	198	686	206	NA	NA	8.18	NA	134	1KB	1KB	16	NA	Z:\DAC\RAW DATA
October 24, 2016	8509AC	3BLK37A298A	AQUA CASI	NA	105	311	204	NA	NA	5.27	NA	127	1KB	1KB	8	20	Z:\DAC\RAW DATA
October 24, 2016	8510AC	3BLK37B298B	AQUA CASI	NA	116	642	160	NA	NA	5.11	NA	127	1KB	1KB	23	NA	Z:\DAC\RAW DATA
October 25, 2016	8511AC	3BLK43KJ299A	AQUA CASI	NA	92	337	217	NA	NA	4.91	NA	71.7	1KB	1KB	9	NA	Z:\DAC\RAW DATA
October 26, 2016	8513AC	3BLK43D300A	AQUA CASI	NA	316	664	244	NA	NA	13.2	NA	208	1KB	1KB	66	NA	Z:\DAC\RAW DATA
October 26, 2016	8514AC	3BLK43G300B	AQUA CASI	NA	41	127	142	NA	NA	2.7	NA	208	1KB	1KB	6	NA	Z:\DAC\RAW DATA
October 27, 2016	8515AC	3BLK43K301A	AQUA CASI	NA	156	273	189	NA	NA	3.35	NA	104	1KB	1KB	5	NA	Z:\DAC\RAW DATA

Received from

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

Received by

Name: AC Bongat
Position: SSRS
Signature: [signature] 11/22/16

ANNEX 6. FLIGHT LOGS FOR THE FLIGHT MISSIONS

1. Flight Log for 2593P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2593

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43BDG051A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joyo	9 Route:			
10 Date: 02-20-2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1341	14 Engine Off: 1710	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	fair				

20 Remarks:

Surveyed BLK 43B and voids over BLK 43D and 43G.

21 Problems and Solutions:

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

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

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

Lidar Operator
I. Roxas
Signature over Printed Name

2. Flight log for 2602G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2602

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK43B056A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: ILOILO			
10 Date: 25 Feb 15	12 Airport of Departure (Airport, City/Province): ILOILO		12 Airport of Arrival (Airport, City/Province): ILOILO		
13 Engine On: 8:14	14 Engine Off: 11:31	15 Total Engine Time: 3+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Surveyed 2 lines of BLK 43B; aborted due to cloud buildup below the prescribed flying height

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
E. Hipolito	SSG Punzalan	FB Docampo	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

3. Flight log for 2606G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2606

1 LiDAR Operator: RA Felismino	2 ALTM Model: Gemini	3 Mission Name: 2BLK43BV057B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date: 26 FEB 2015	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 7:00	14 Engine Off: 11:05	15 Total Engine Time: 4+5	16 Take off: 7:05	17 Landing: 11:00	18 Total Flight Time: 3+55
19 Weather: cloudy					

20 Remarks:

Surveyed 10 lines of BLK 43B

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Geron Chilianto	LI Puntavan	P. Dongquines	raFelismino
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

4. Flight log for 2610G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2610

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK43BV53A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: B. Donguines	8 Co-Pilot: A. Lim	9 Route:			
10 Date: 27 FEB 2015	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 7:03	14 Engine Off: 10:08	15 Total Engine Time: 3+5	16 Take off: 7:08	17 Landing: 10:03	18 Total Flight Time: 2+55
19 Weather: Cloudy					

20 Remarks:

Surveyed voids of BLK43B; mission aborted due to cloud buildup and strong wind

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
C. Alviola	LV Purbalai	B. DONGUINES	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

5. Flight log for 8511AC Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 8511AC

1 LiDAR Operator: MS REYES	2 ALTM Model: AQUARIUS + CASI	3 Mission Name: 3BLK43KJ299A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: D. LOGRONIO	8 Co-Pilot: J. NASTOR	9 Route: BUGASONG, VALDERRAMA, BELISON, SIBALOM			
10 Date: OCT. 25, 2016	12 Airport of Departure (Airport, City/Province): ILOILO CITY		12 Airport of Arrival (Airport, City/Province): ILOILO CITY		
13 Engine On: 09 00	14 Engine Off: 12 35	15 Total Engine Time: 3+35	16 Take off: 09 05	17 Landing: 12 30	18 Total Flight Time: 3+25
19 Weather: FAIR					

20 Flight Classification

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

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

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

21 Remarks

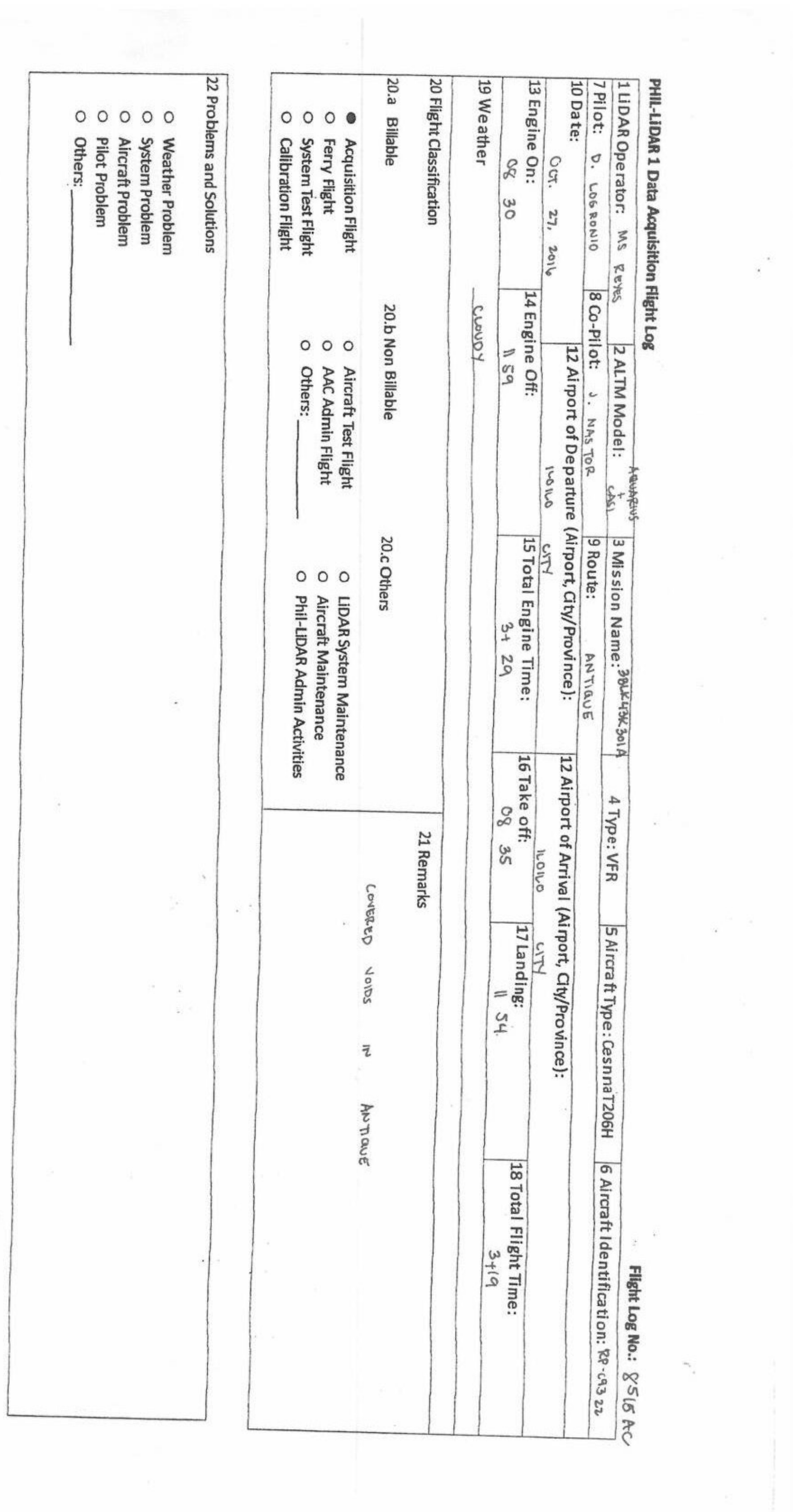
COVERED VOIDS IN ANTIQUE

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. POYAS	TSg Antonio T Valenciano Jr PAF	D'ANTHONY LOGRONIO	MS REYES	-
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 8515AC Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 8515 AC

1 LiDAR Operator: MS Reyes	2 ALTM Model: Aquarius + CASI	3 Mission Name: 3BLK43K301A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9322
7 Pilot: D. Logronio	8 Co-Pilot: J. Nastor	9 Route: Antique			
10 Date: Oct. 27, 2016	12 Airport of Departure (Airport, City/Province): Iloilo City		12 Airport of Arrival (Airport, City/Province): Iloilo City		
13 Engine On: 08 30	14 Engine Off: 11 59	15 Total Engine Time: 3+29	16 Take off: 08 35	17 Landing: 11 54	18 Total Flight Time: 3+19
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Covered voids in Antique

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

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

Acquisition Flight Certified by: TSg Antonio T Velenzgano Jr PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: D. Anthony Logronio — Signature over Printed Name

LiDAR Operator: MS Reyes — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: ____________ Signature over Printed Name

ANNEX 7. FLIGHT STATUS

FLIGHT STATUS REPORT

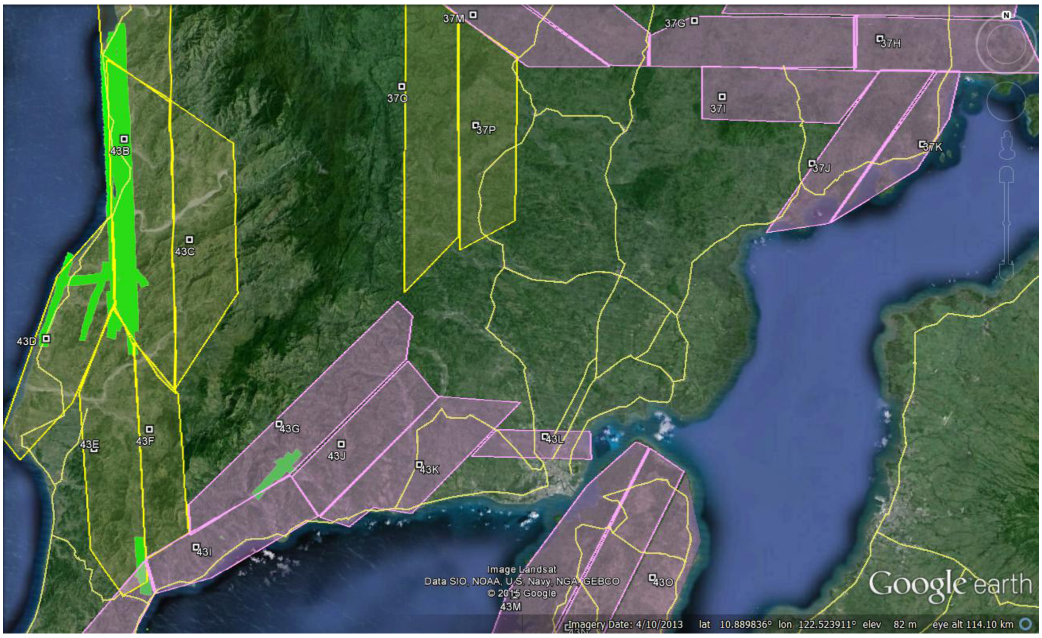
PALIWAN

(February 2015)

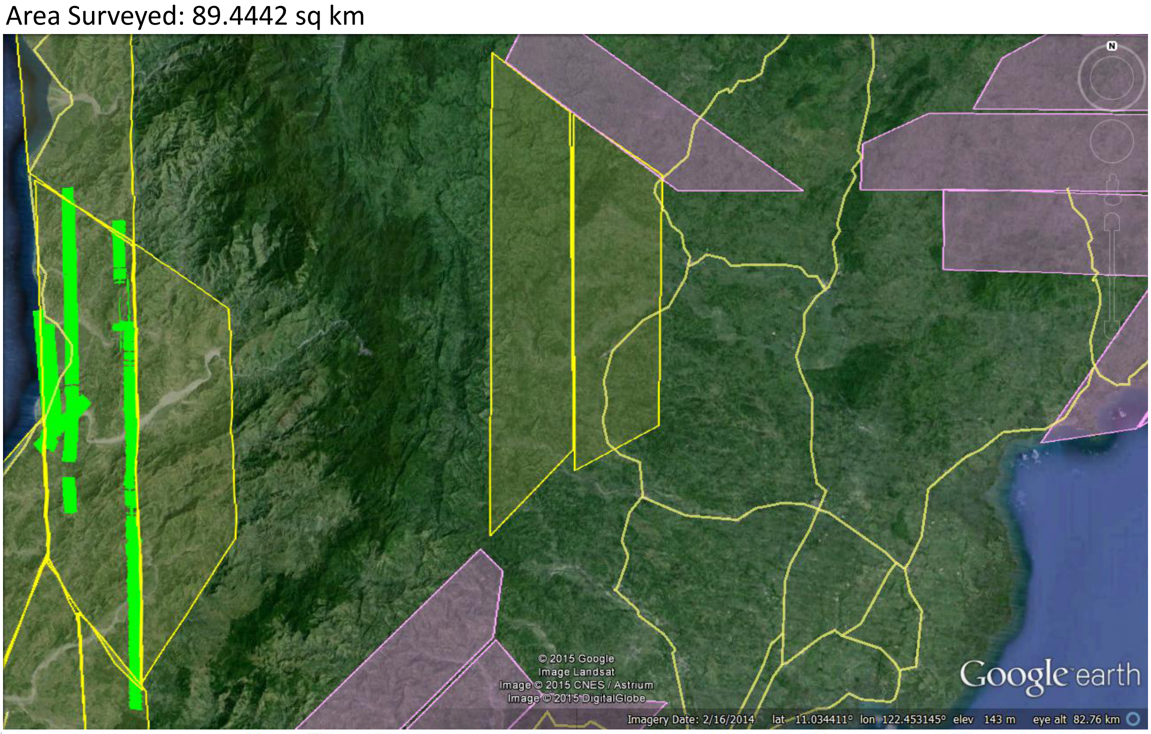
FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2593P	BLK 43B, 43D, 43G	1BLK43BDG051A	IRO ROXAS	20 FEB 15	Surveyed BLK43B and voids on BLK 43D and 43G
2602G	BLK 43B	2BLK43B056A	MVE TONGA	25 FEB 15	Surveyed 2 lines of BLK43B; aborted due to cloud buildup below the prescribed flying height
2606G	BLK 43B	2BLK43BV057A	RA FELISMINO	26 FEB 15	Surveyed 10 lines of BLK43B
2610G	BLK 43B, 43C	2BLK43BV058A	MVE TONGA	27 FEB 15	Surveyed voids of BLK43B; mission aborted due to cloud buildup and strong wind
8511AC	BLK43K, Sibalom2 FP	3BLK43KJ299A	MS REYES	25 OCT 16	Covered voids over Cairawan, Paliwan, and Sibalom2 Floodplains
8515AC	BLK43K	3BLK43K301A	MS REYES	27 OCT 16	Coverd voids over Cairawan, Paliwan, and Cangaranan Floodplains

LAS BOUNDARIES PER MISSION FLIGHT

Flight No. 2593P
Area: BLK 43B, 43D, 43G
Mission Name: 1BLK43BC051A
Total Area Surveyed: 181.2 sq km

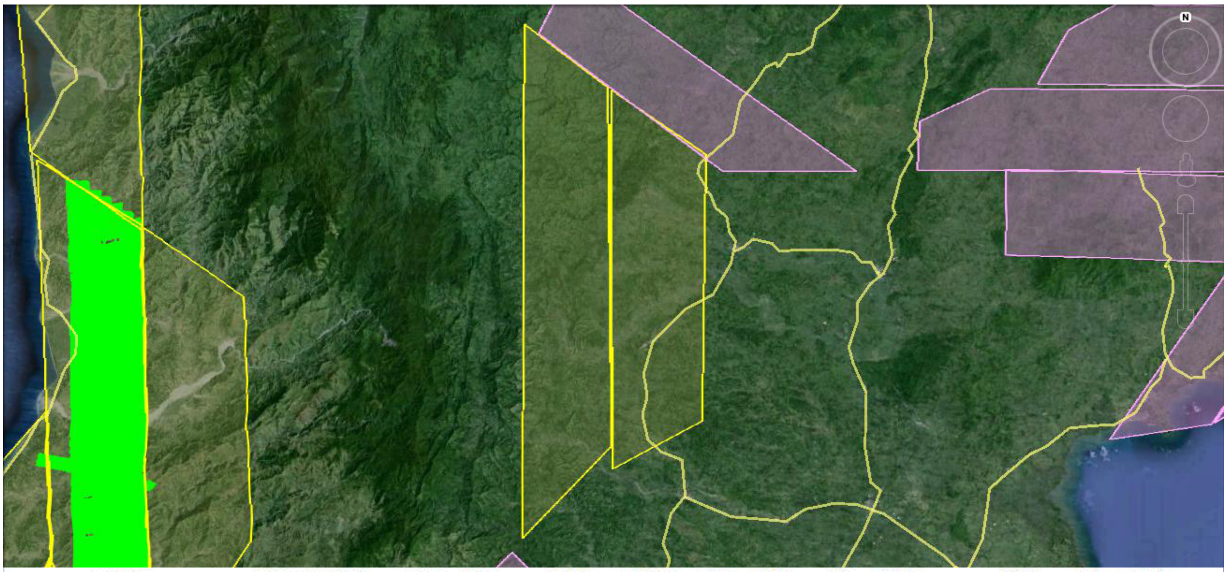


Flight No. : 2602G
Area: BLK 43B
Mission Name: 2BLK43B056A
Total Area Surveyed: 89.4442 sq km



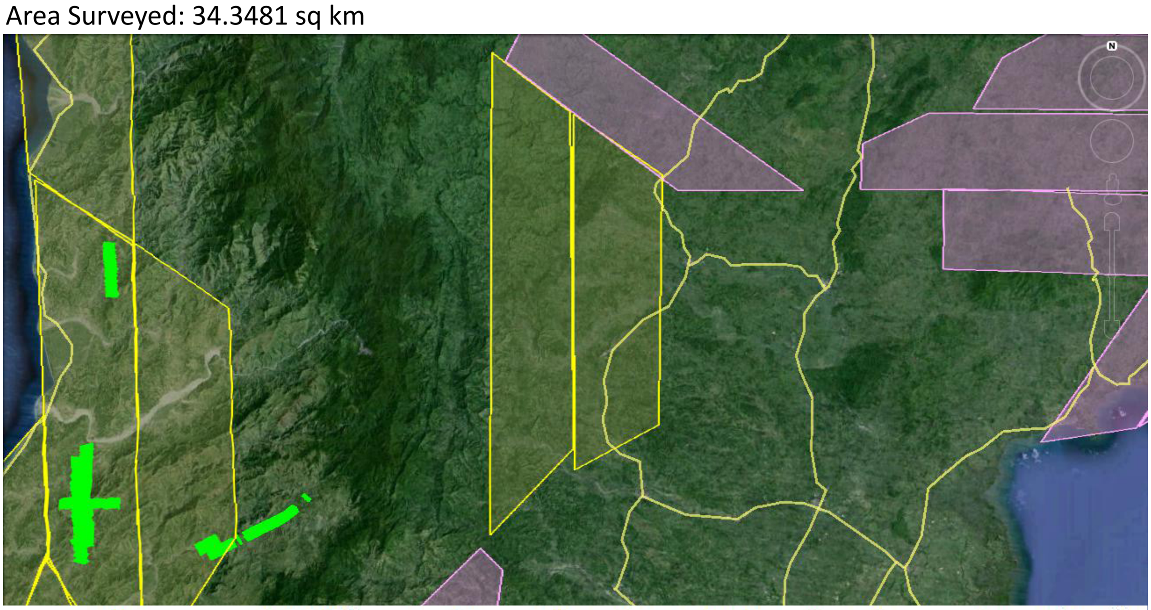
START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
01:16:44.084	01:16:53.609	6	2007	70	56.00	17.00	OFF	NAR	OFF	OFF	359.00	BLK43B+voids.pln
01:19:10.718	01:29:02.284	6	2010	70	56.00	17.00	OFF	NAR	OFF	OFF	359.00	BLK43B+voids.pln
01:34:53.261	01:37:49.33	7	1998	70	56.00	17.00	OFF	NAR	ON	OFF	179.00	BLK43B+voids.pln
01:49:20.984	01:55:26.476	13	2009	70	56.00	17.00	OFF	NAR	ON	OFF	179.00	BLK43B+voids.pln
01:55:43.231	01:56:35.811	13	2000	70	56.00	17.00	OFF	NAR	ON	OFF	179.00	BLK43B+voids.pln
01:55:43.231	01:56:35.811	13	2000	70	56.00	17.00	OFF	NAR	ON	OFF	179.00	BLK43B+voids.pln
02:01:38.303	02:03:14.407	13	1998	70	56.00	17.00	OFF	NAR	ON	OFF	179.00	BLK43B+voids.pln
02:01:38.303	02:03:14.407	13	1997	70	56.00	17.00	OFF	NAR	OFF	OFF	175.00	BLK43B+voids.pln
02:06:19.196	02:08:56.229	15	2007	70	56.00	17.00	OFF	NAR	OFF	OFF	355.00	BLK43B+voids.pln
02:06:19.196	02:08:56.229	15	2007	70	56.00	17.00	OFF	NAR	OFF	OFF	355.00	BLK43B+voids.pln
02:15:37.301	02:18:46.919	18	1317	100	50.00	20.00	OFF	NAR	ON	OFF	175.00	BLK43B+voids.pln
02:15:37.301	02:18:46.919	18	1315	100	50.00	20.00	OFF	NAR	ON	OFF	175.00	BLK43B+voids.pln
02:23:29.657	02:26:09.025	19	1322	100	50.00	20.00	OFF	NAR	ON	OFF	355.00	BLK43B+voids.pln

Flight No. : 2606G
Area: BLK 43B
Mission Name: 2BLK43BV057A
Total Area Surveyed: 221.78 sq km



START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
00:11:54.389	00:22:30.563	6	1989	70	56.00	17.00	OFF	NAR	ON	OFF	179.00	BLK43B+voids.pln
00:25:58.867	00:35:27.217	7	2052	70	56.00	17.00	OFF	NAR	ON	OFF	359.00	BLK43B+voids.pln
00:40:59.394	00:51:35.149	8	2011	70	56.00	17.00	OFF	NAR	ON	OFF	179.00	BLK43B+voids.pln
00:54:20.907	01:04:13.013	9	2020	70	56.00	17.00	OFF	NAR	ON	OFF	359.00	BLK43B+voids.pln
01:10:09.225	01:20:31.505	11	1988	70	56.00	17.00	OFF	NAR	ON	OFF	359.00	BLK43B+voids.pln
01:29:53.086	01:35:05.718	11	1659	70	50.00	20.00	OFF	NAR	ON	OFF	359.00	BLK43B+voids.pln
01:41:46.495	01:51:45.261	12	1618	70	50.00	20.00	OFF	NAR	ON	OFF	179.00	BLK43B+voids.pln
01:56:15.014	02:05:48.089	13	1700	70	50.00	20.00	OFF	NAR	ON	OFF	359.00	BLK43B+voids.pln
02:15:47.72	02:18:45.404	13	1692	70	50.00	20.00	OFF	NAR	ON	OFF	359.00	BLK43B+voids.pln

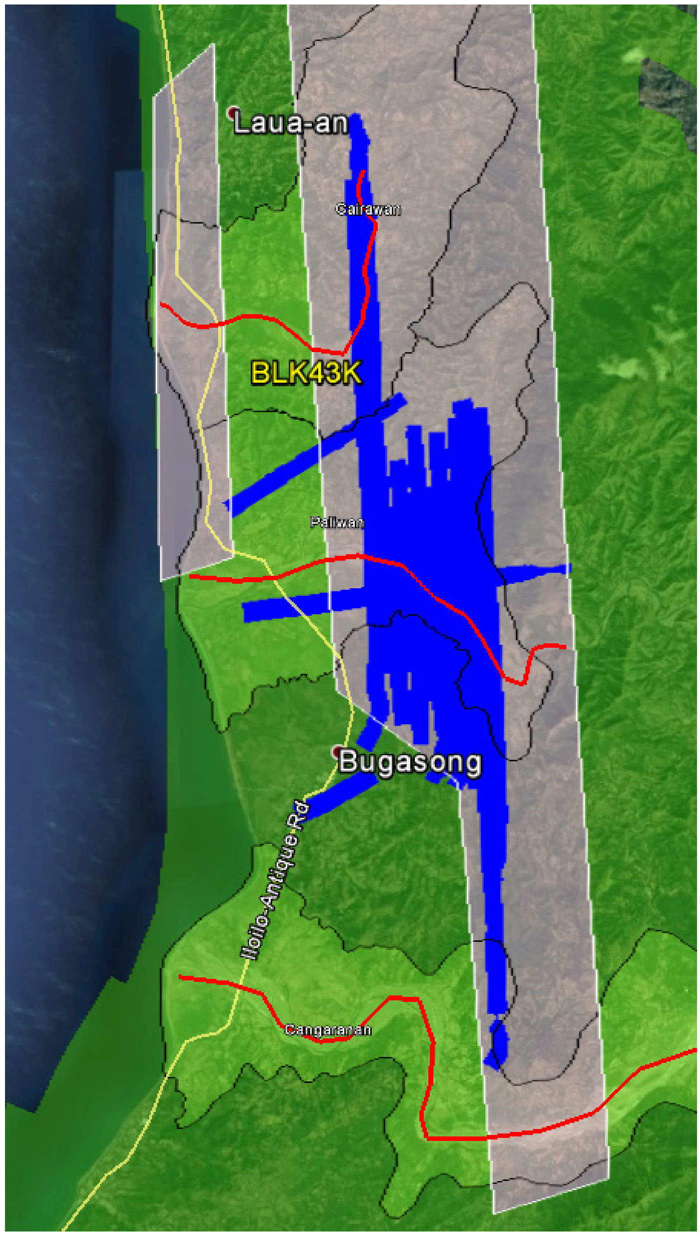
Flight No. : 2610G
Area: BLK 43B, 43C
Mission Name: 2BLK43BV058A
Total Area Surveyed: 34.3481 sq km



START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
23:40:19.177	23:42:33.071	18	1952	70	56.00	17.00	OFF	NAR	ON	OFF	243.00	BLK43V.pln
23:46:52.074	23:47:31.933	16	1978	70	56.00	17.00	OFF	NAR	ON	OFF	63.00	BLK43V.pln
23:50:39.002	23:51:52.106	31	2001	70	56.00	17.00	OFF	NAR	OFF	OFF	92.86	BLK43V.pln
00:00:16.672	00:02:34.11	27	1995	70	56.00	17.00	OFF	NAR	OFF	OFF	179.00	BLK43V.pln
00:06:35.458	00:09:14.797	28	2021	70	56.00	17.00	OFF	NAR	OFF	OFF	359.00	BLK43V.pln
00:13:25.97	00:14:48.759	24	1986	70	56.00	17.00	OFF	NAR	OFF	OFF	266.00	BLK43V.pln

Flight no.: 8511AC
Mission Name: 3BLK43J299A
Area: BLK43K, Sibalom2 FP
Total area surveyed: 18.2km²

Flight no.: 8515AC
Mission Name: 3BLK43K301A
Area: BLK43K
Total area surveyed: 15.52km^2



ANNEX 8. MISSION SUMMARY REPORT

Flight Area	Iloilo
Mission Name	**Blk43B**
Inclusive Flights	2593P
Range data size	16.3 GB
POS	213 MB
Base Data Size	11 MB
Image	27 GB
Transfer date	March 23, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.01
RMSE for East Position (<4.0 cm)	1.56
RMSE for Down Position (<8.0 cm)	3.33
Boresight correction stdev (<0.001deg)	0.000371
IMU attitude correction stdev (<0.001deg)	0.000661
GPS position stdev (<0.01m)	0.0091
Minimum % overlap (>25)	25.93%
Ave point cloud density per sq.m. (>2.0)	2.57
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	200
Maximum Height	594.49 m
Minimum Height	54.70 m
Classification (# of points)	
Ground	152,186,273
Low vegetation	75,056,947
Medium vegetation	152,053,797
High vegetation	281,227,721
Building	4,634,683
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Harmond Santos, Engr. Melissa Fernandez

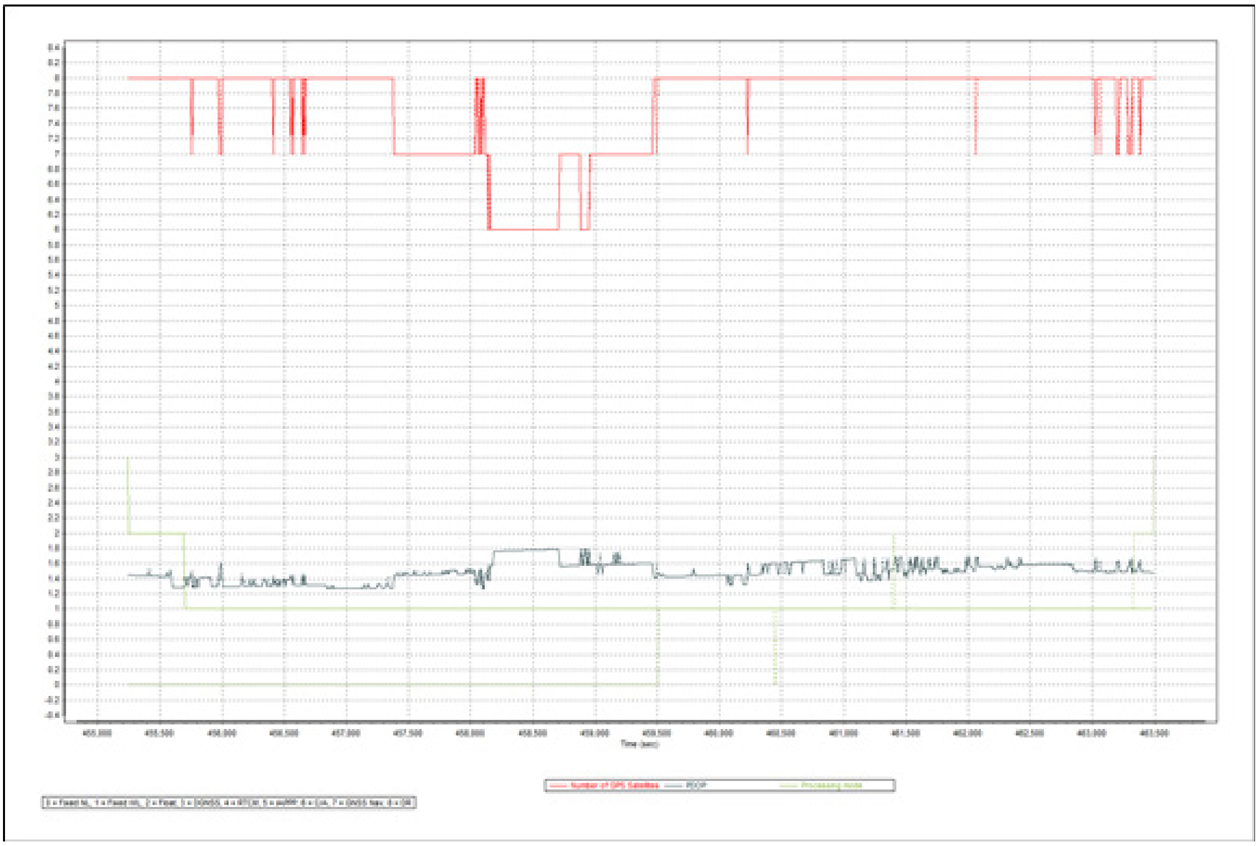


Figure 1.1.1 Solution Status

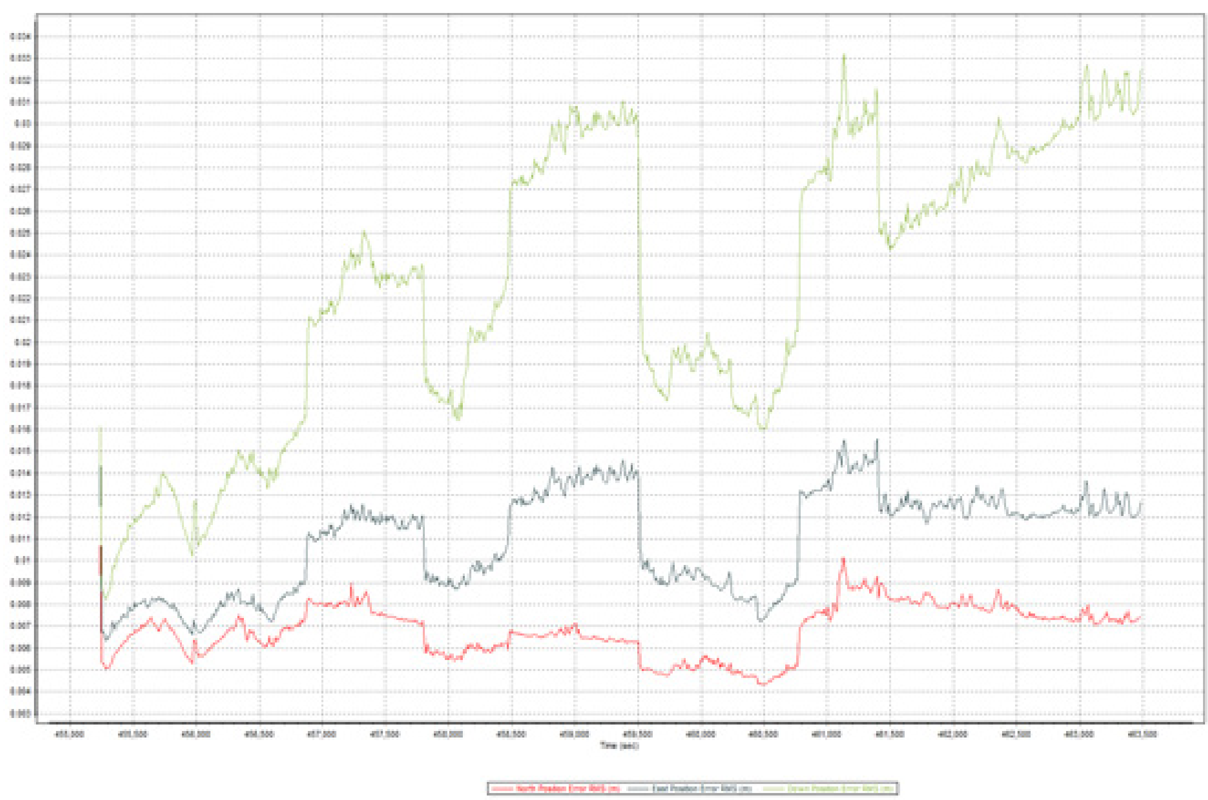


Figure 1.2.2 Smoothed Performance Metric Parameters

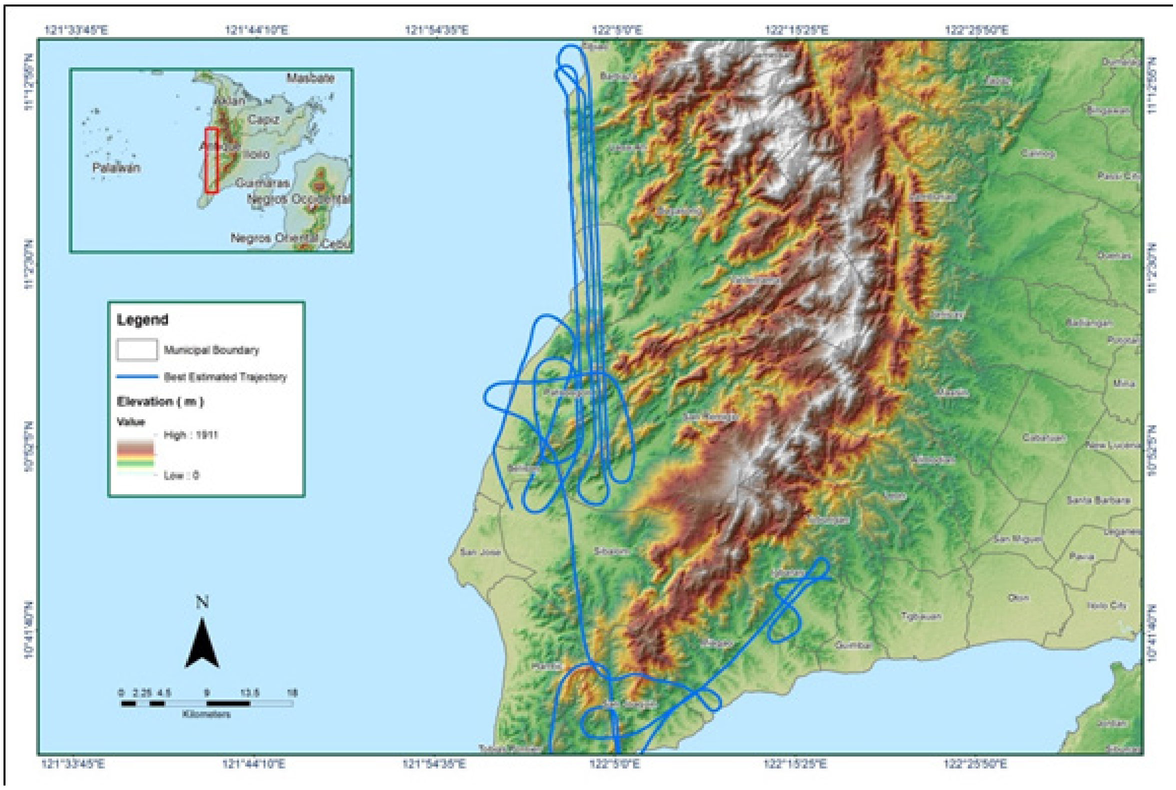


Figure 1.1.3 Best Estimated Trajectory

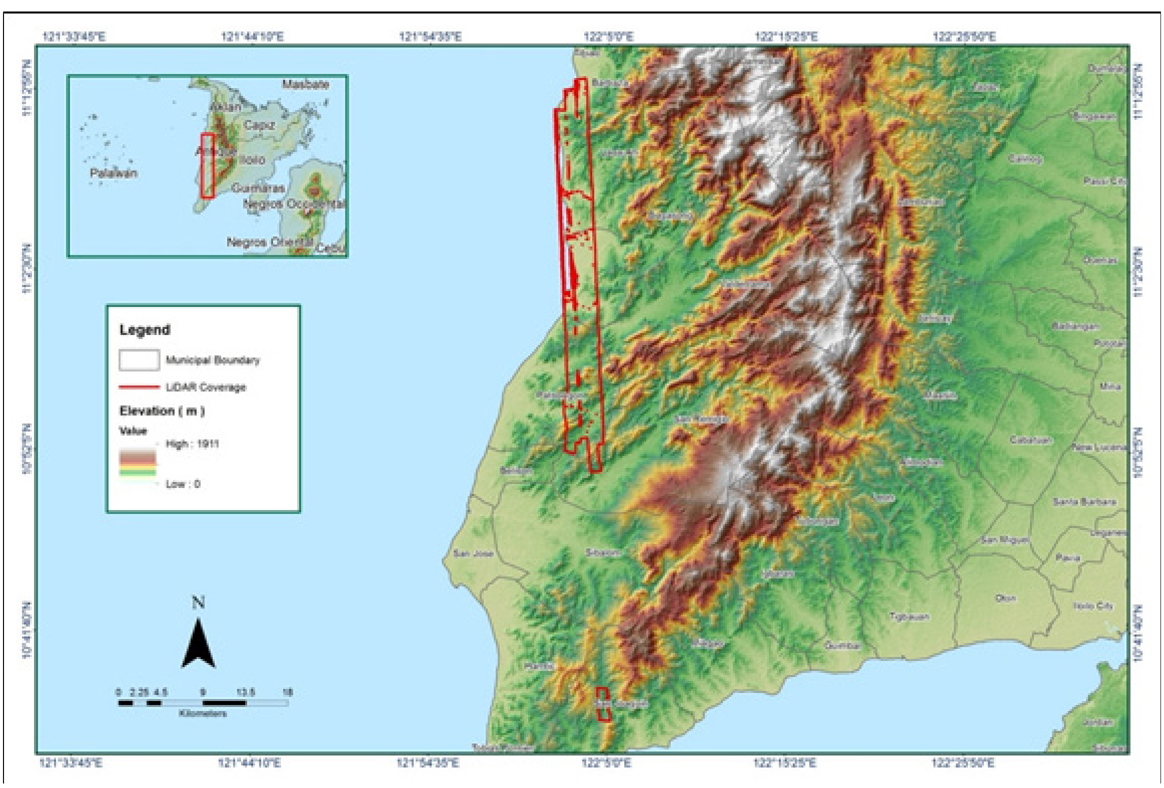


Figure 1.1.4 Coverage of LiDAR data

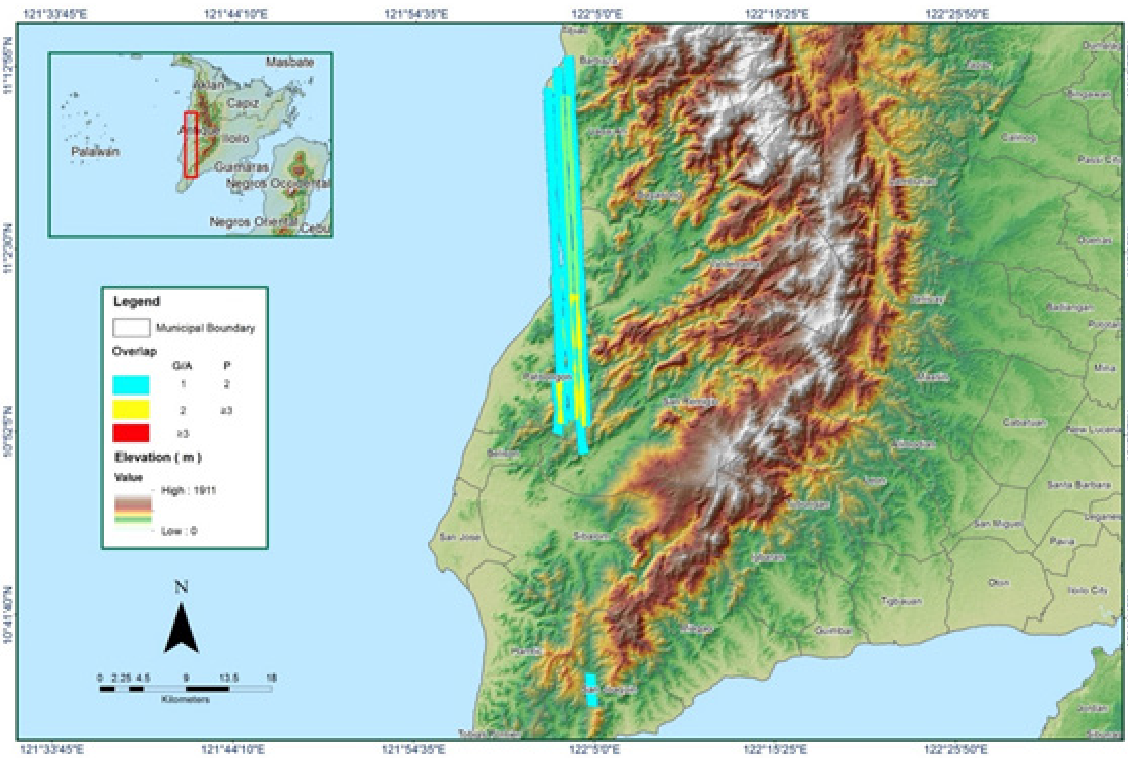


Figure 1.1.5 Image of data overlap

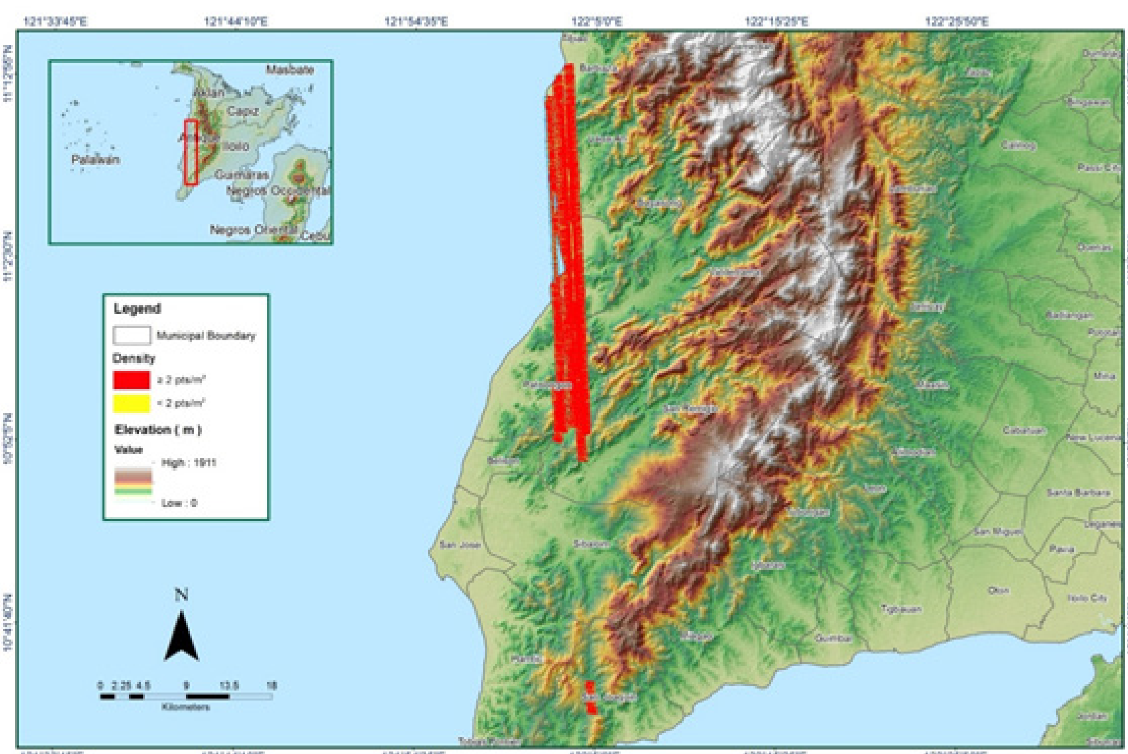


Figure 1.1.6 Density map of merged LiDAR data

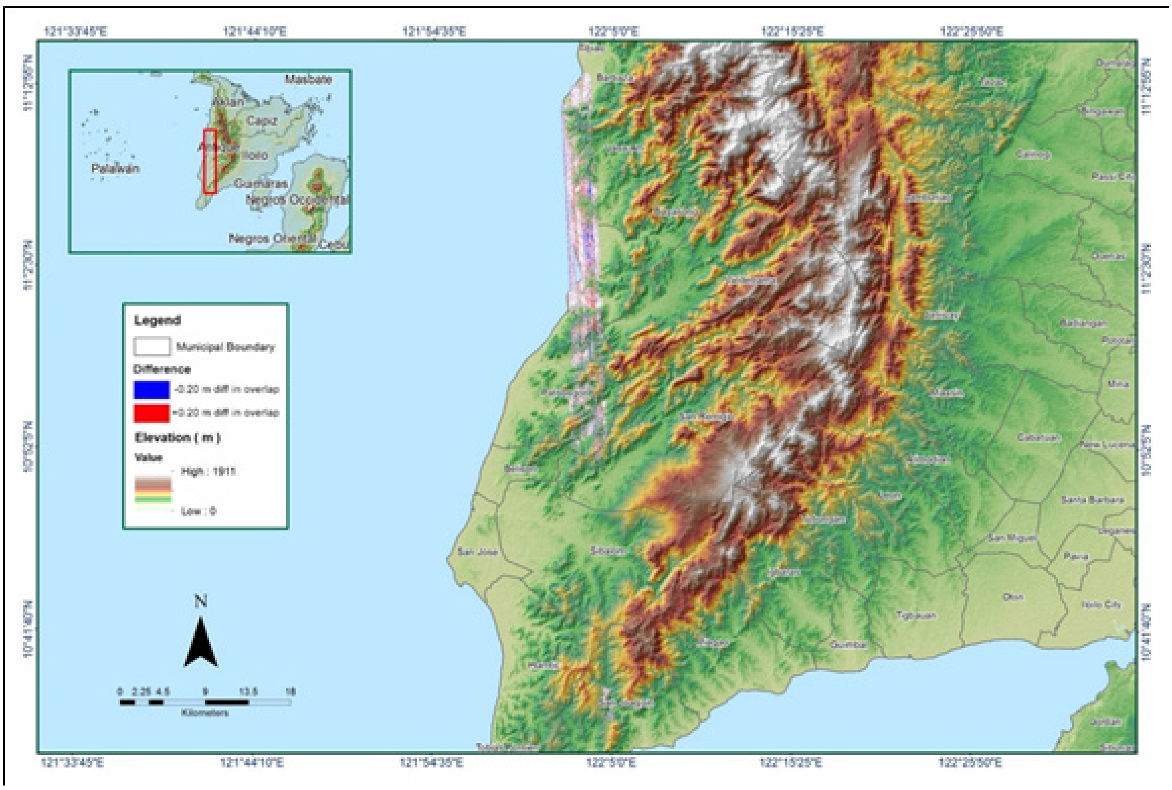


Figure 1.1.7 Elevation difference between flight lines

Flight Area	Iloilo
Mission Name	**Blk43B_additional**
Inclusive Flights	2602G, 2606G, 2610G
Range data size	21.5 GB
POS	548 MB
Base data size	27.69 MB
Image	33.82 GB
Transfer date	July 07, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.34
RMSE for East Position (<4.0 cm)	1.45
RMSE for Down Position (<8.0 cm)	3.95
Boresight correction stdev (<0.001deg)	0.000279
IMU attitude correction stdev (<0.001deg)	0.017983
GPS position stdev (<0.01m)	0.0032
Minimum % overlap (>25)	24.04%
Ave point cloud density per sq.m. (>2.0)	1.91
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	285
Maximum Height	925.04 m
Minimum Height	54.48 m
Classification (# of points)	
Ground	140,989,825
Low vegetation	27,006,829
Medium vegetation	75,243,562
High vegetation	157,821,764
Building	629,138
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Antonio Chua, Jr., Maria Tamsyn Malabanan

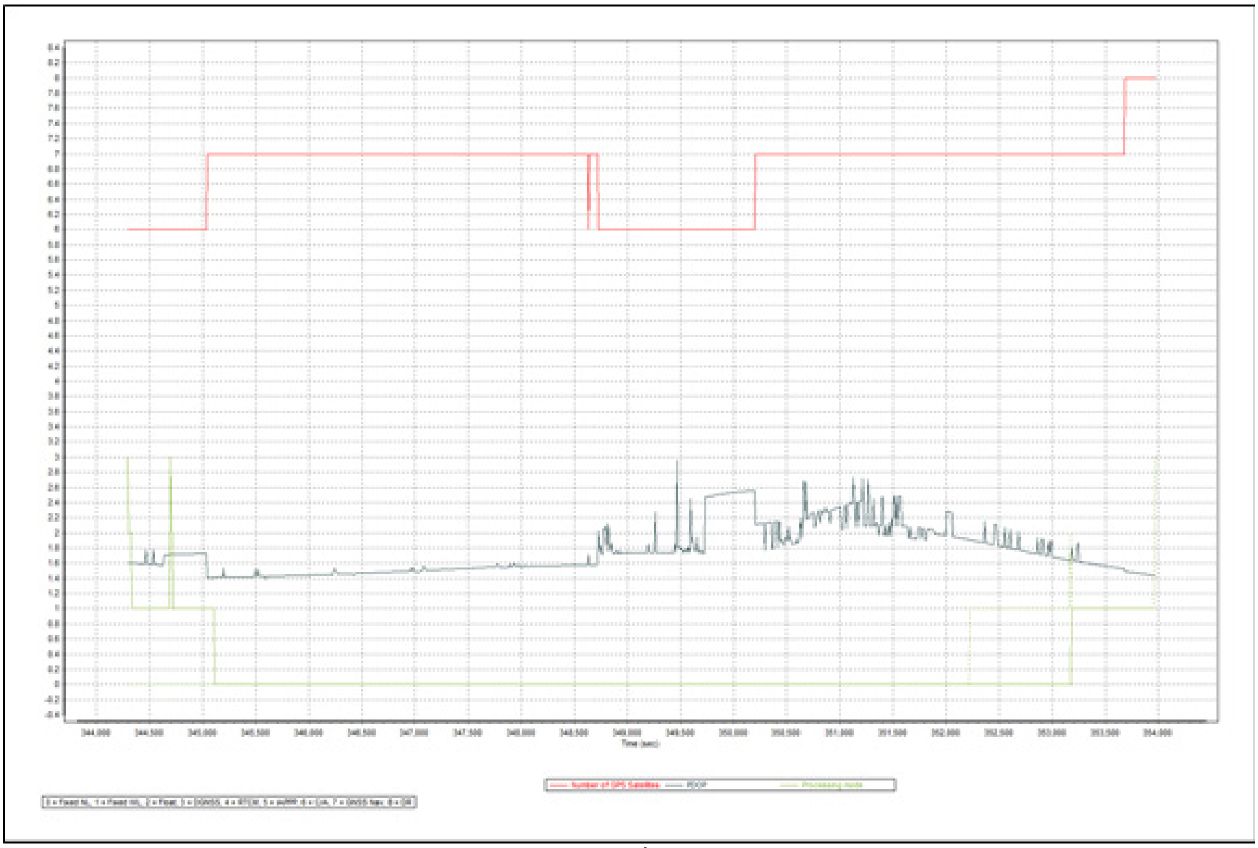


Figure 1.2.1 Solution Status

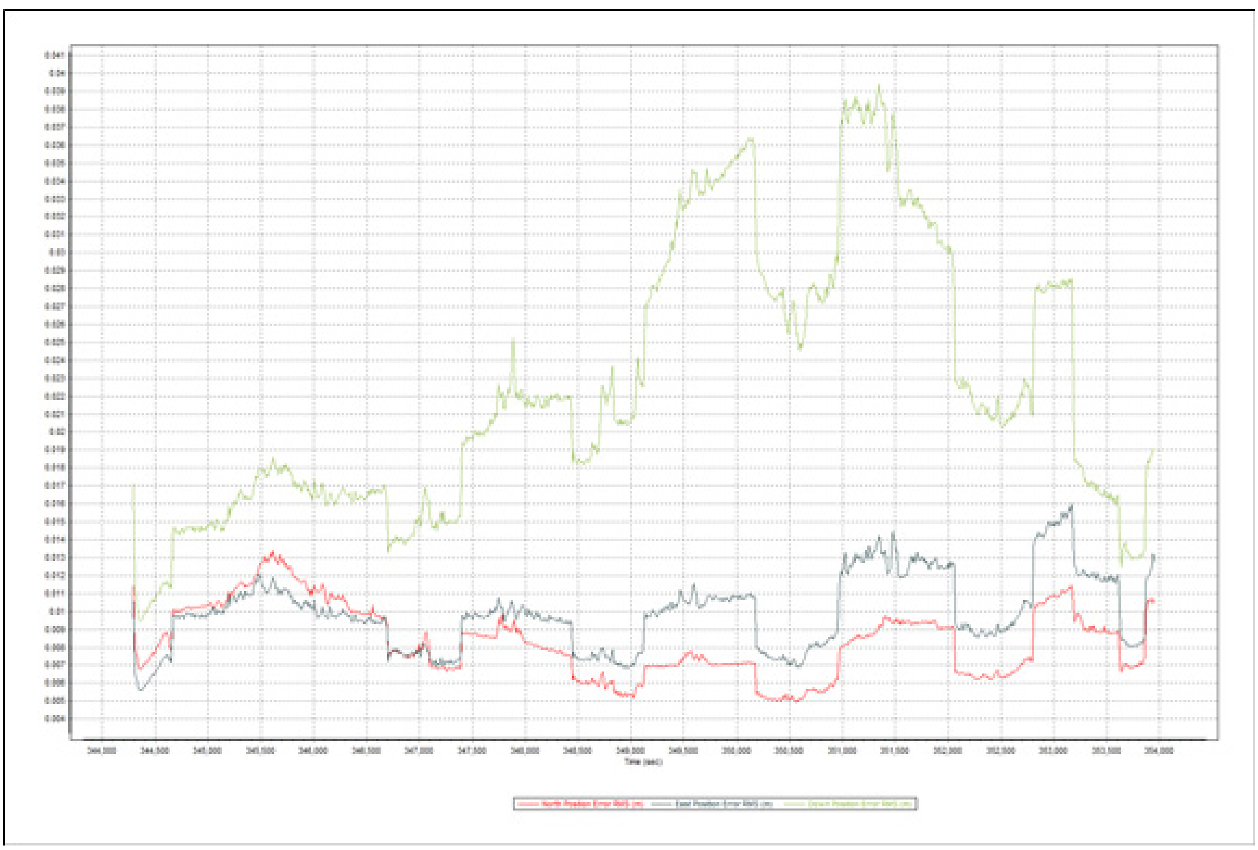


Figure 1.2.2 Smoothed Performance Metric Parameters

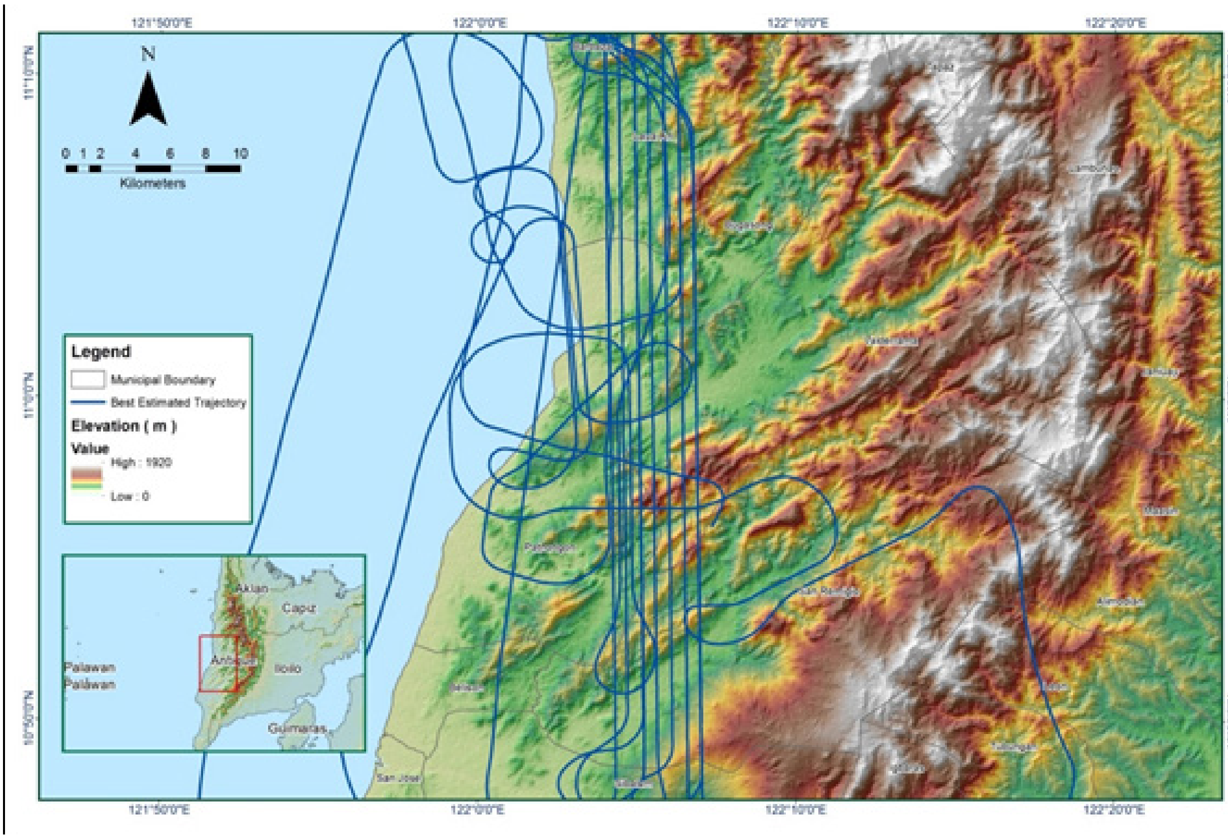


Figure 1.2.3 Best Estimated Trajectory

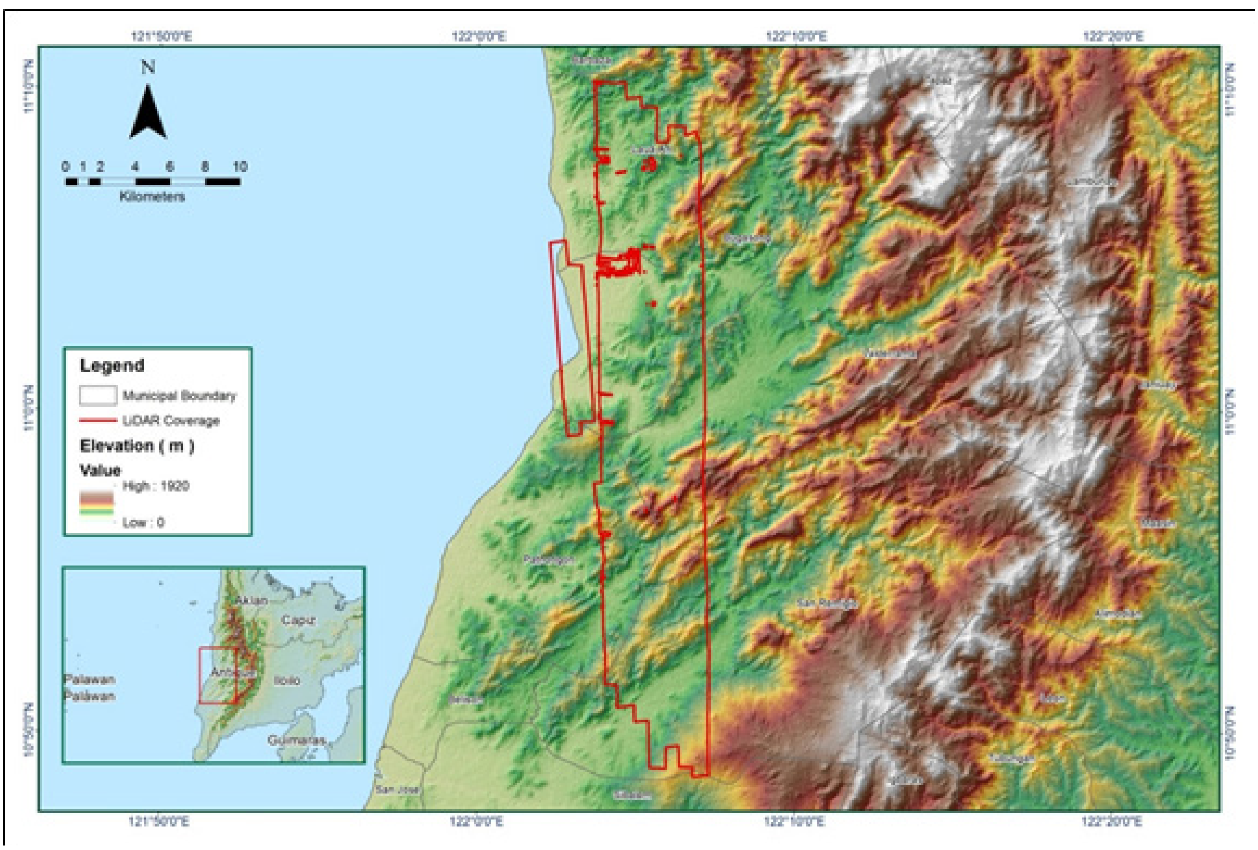


Figure 1.2.4 Coverage of LiDAR data

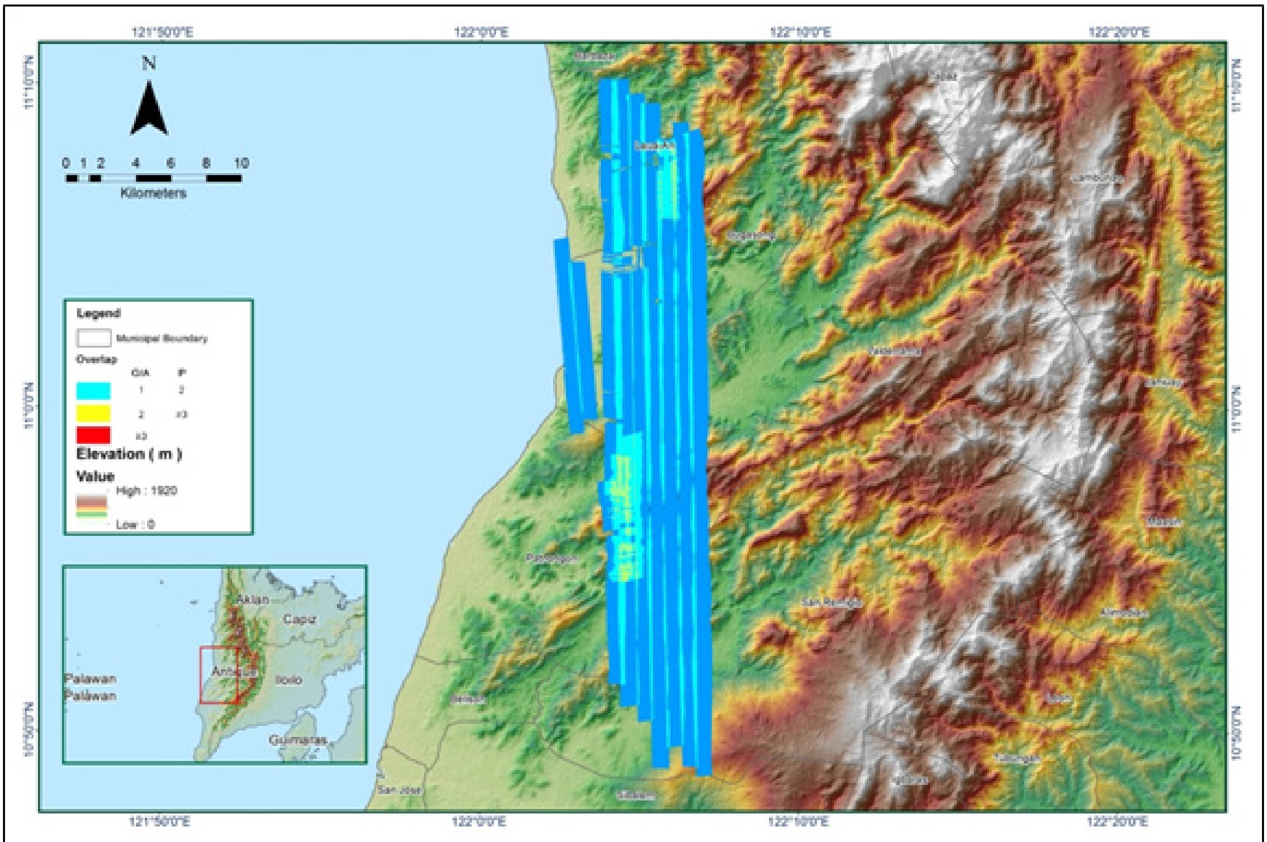


Figure 1.2.5 Image of data overlap

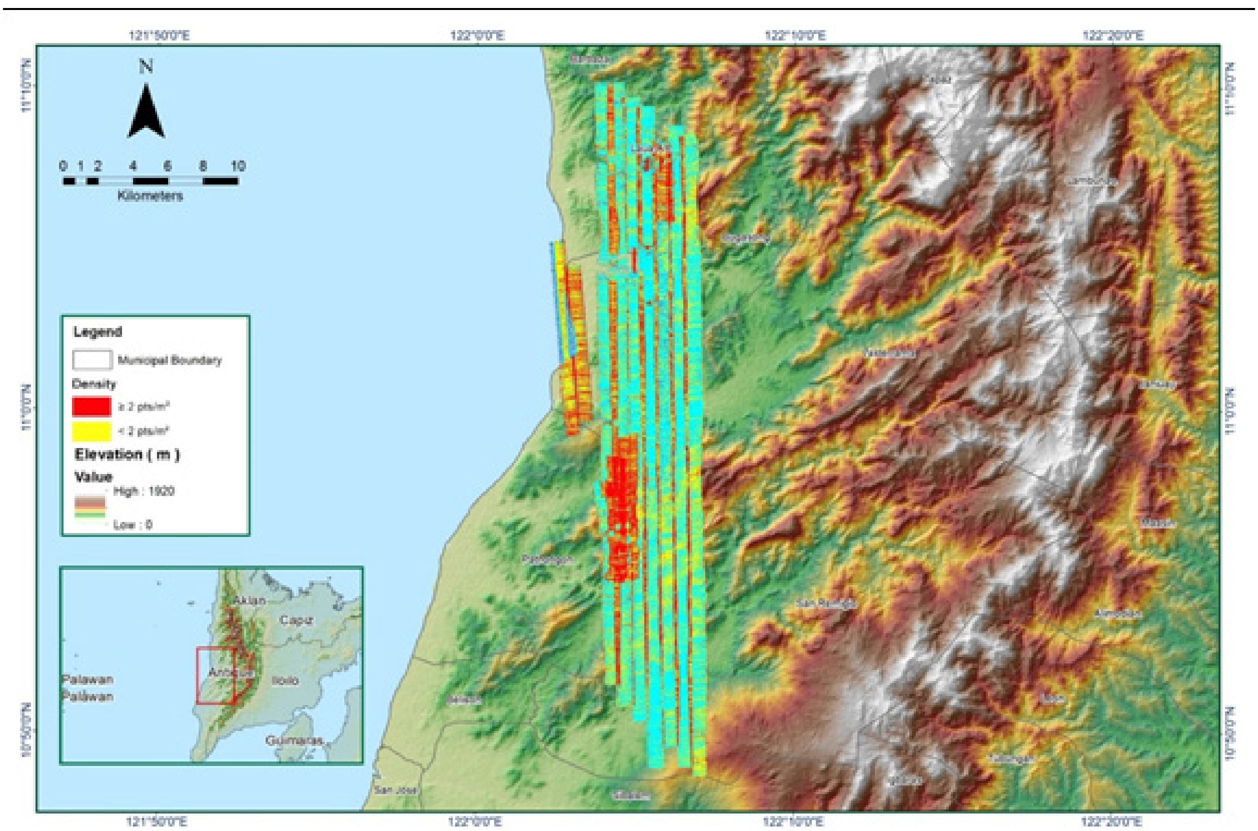


Figure 1.2.6 Density map of merged LiDAR data

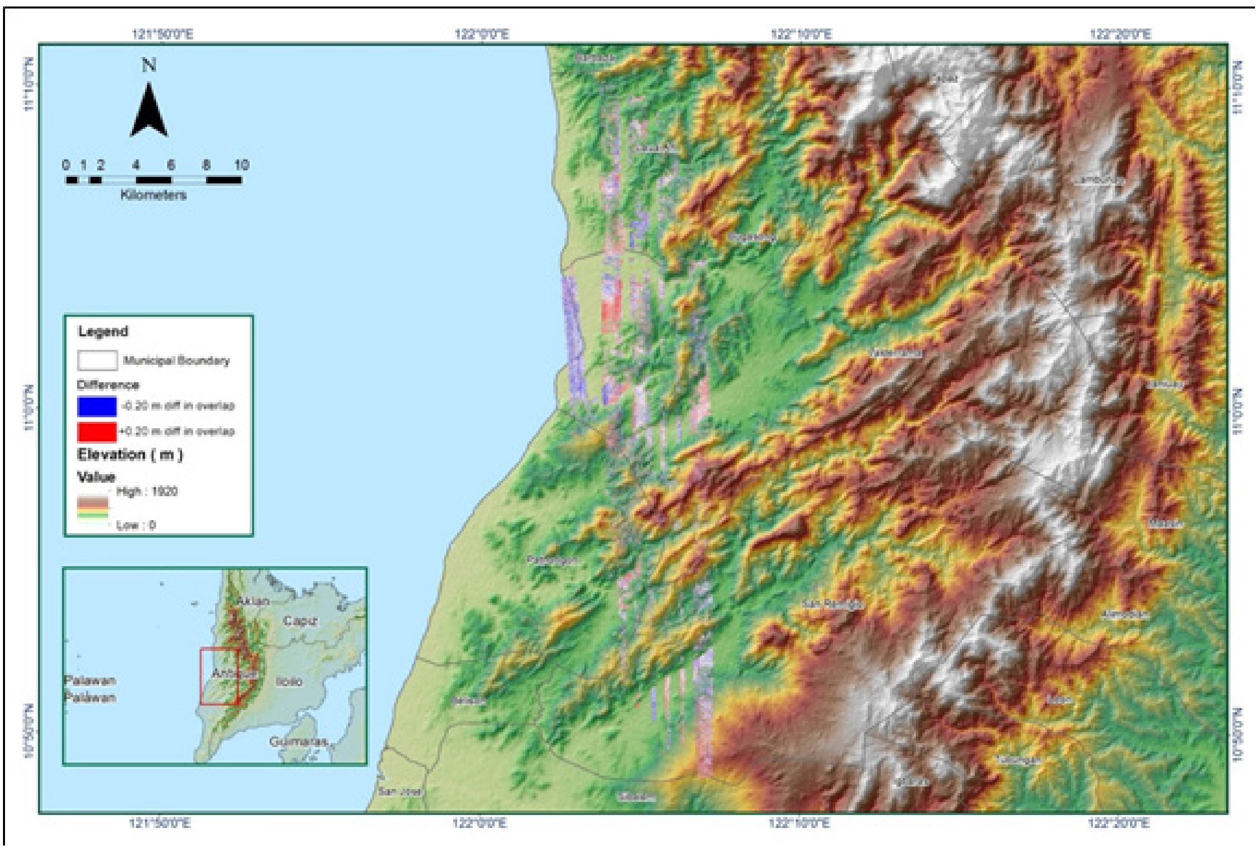


Figure 1.2.7 Elevation difference between flight lines

Flight Area	Iloilo
Mission Name	**Blk43B**
Inclusive Flights	8511AC
Range data size	4.91 GB
POS	217 MB
Base data size	71.7 MB
Image	NA
Transfer date	October 25, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.02
RMSE for East Position (<4.0 cm)	1.29
RMSE for Down Position (<8.0 cm)	2.57
Boresight correction stdev (<0.001deg)	0.000449
IMU attitude correction stdev (<0.001deg)	0.000900
GPS position stdev (<0.01m)	0.0013
Minimum % overlap (>25)	47.78
Ave point cloud density per sq.m. (>2.0)	4.16
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	50
Maximum Height	270.21
Minimum Height	51.5
Classification (# of points)	
Ground	14,416,707
Low vegetation	13,416,268
Medium vegetation	12,278,605
High vegetation	17,861,711
Building	2,114,843
Orthophoto	None
Processed by	

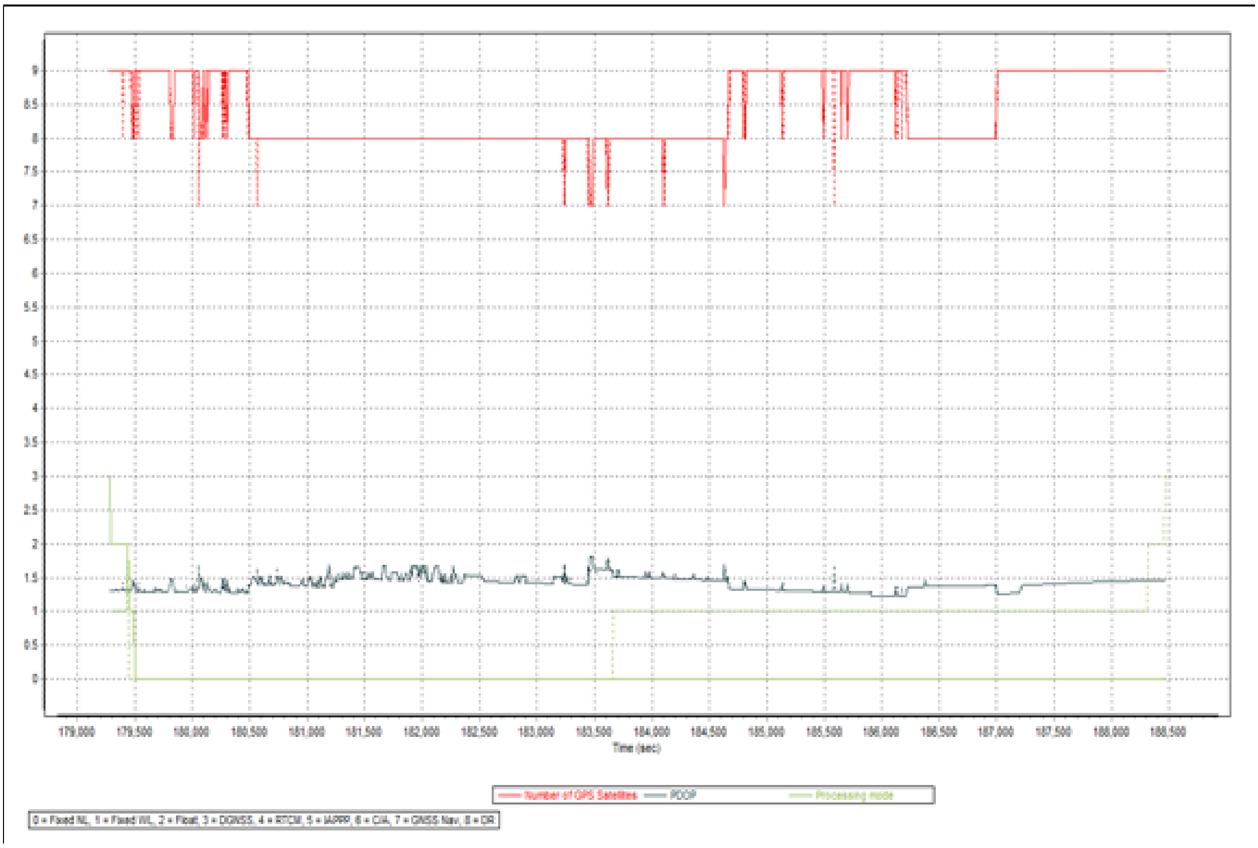


Figure 1.3.1 Solution Status

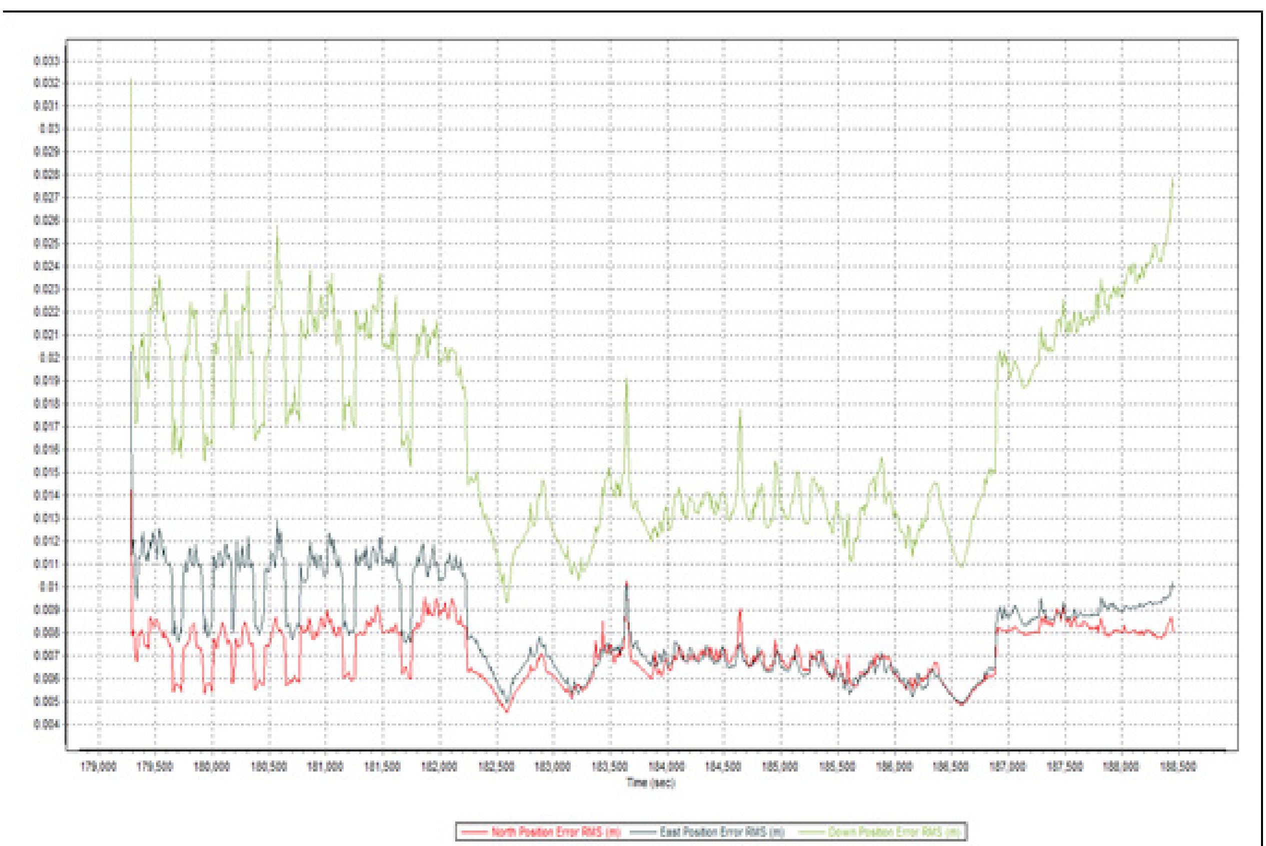


Figure 1.3.2 Smoothed Performance Metric Parameters

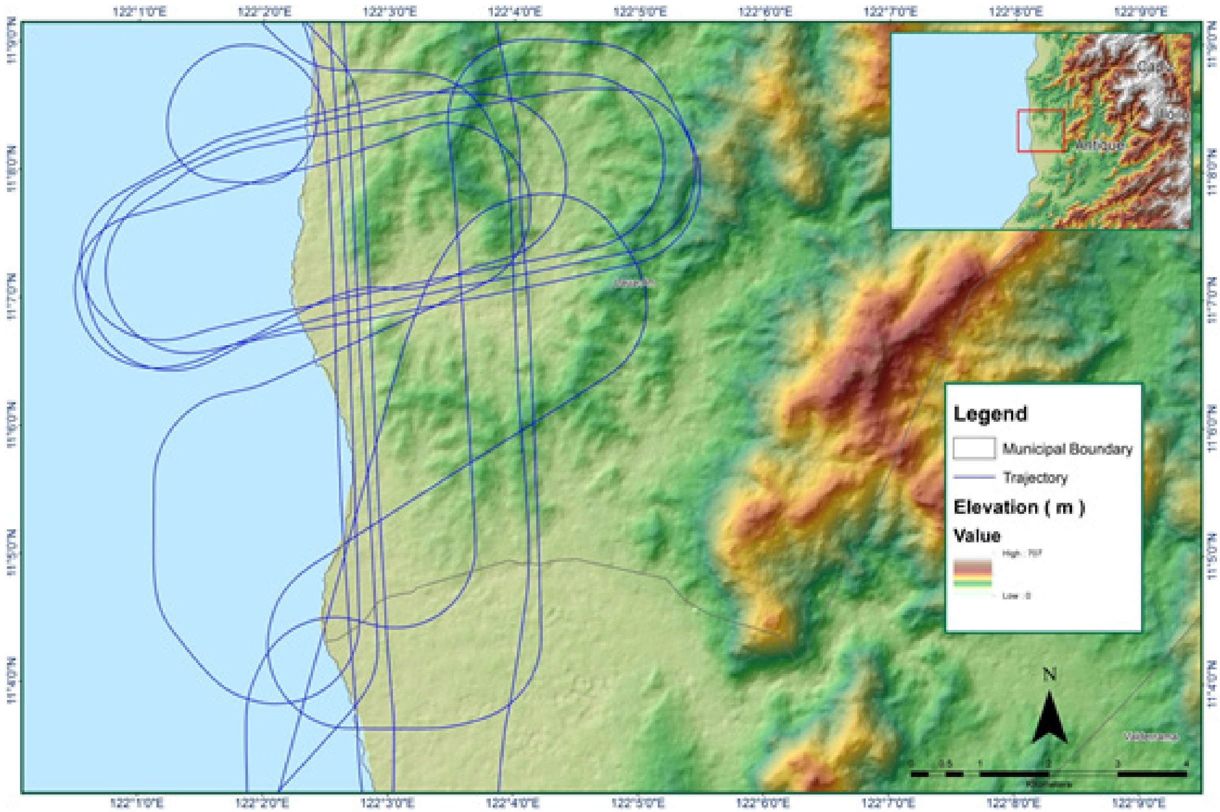


Figure 1.33 Best Estimated Trajectory

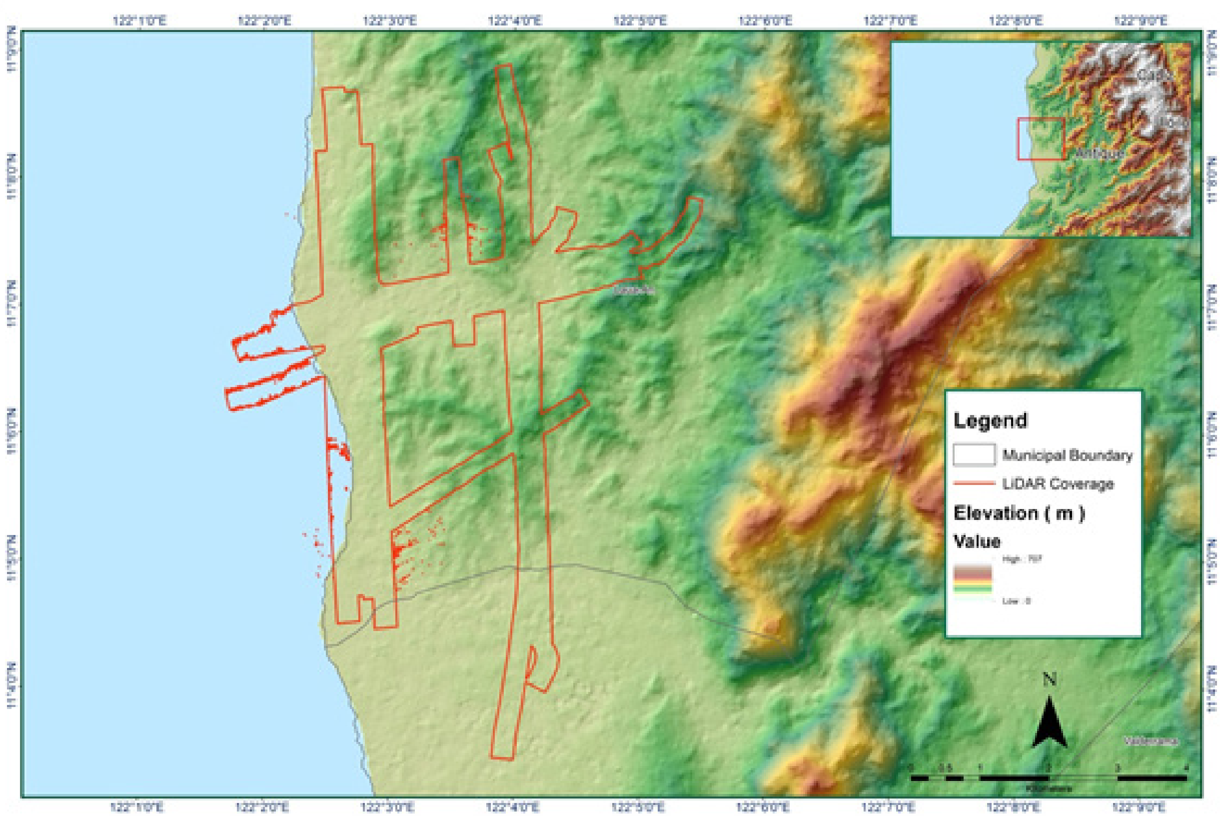


Figure 1.3.4 Coverage of LiDAR data

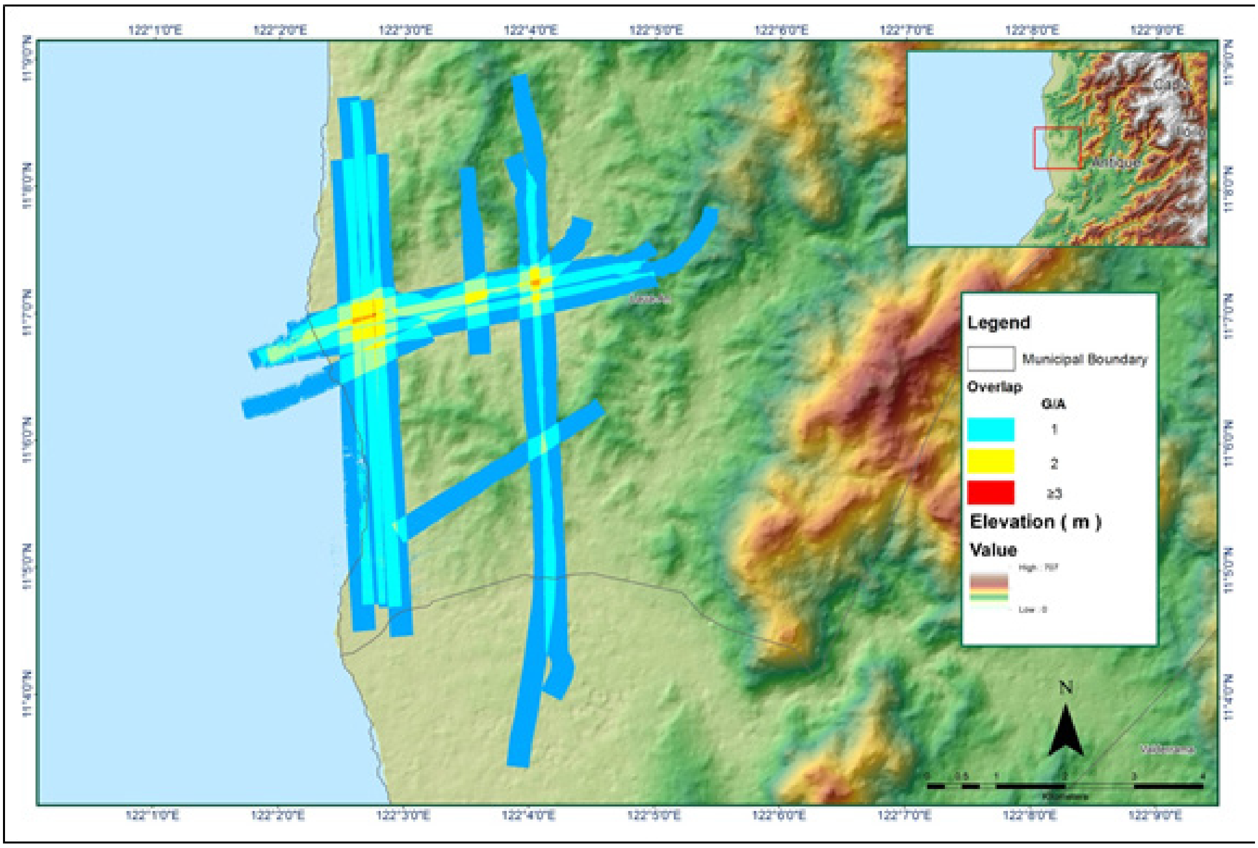


Figure 1.3.5 Image of data overlap

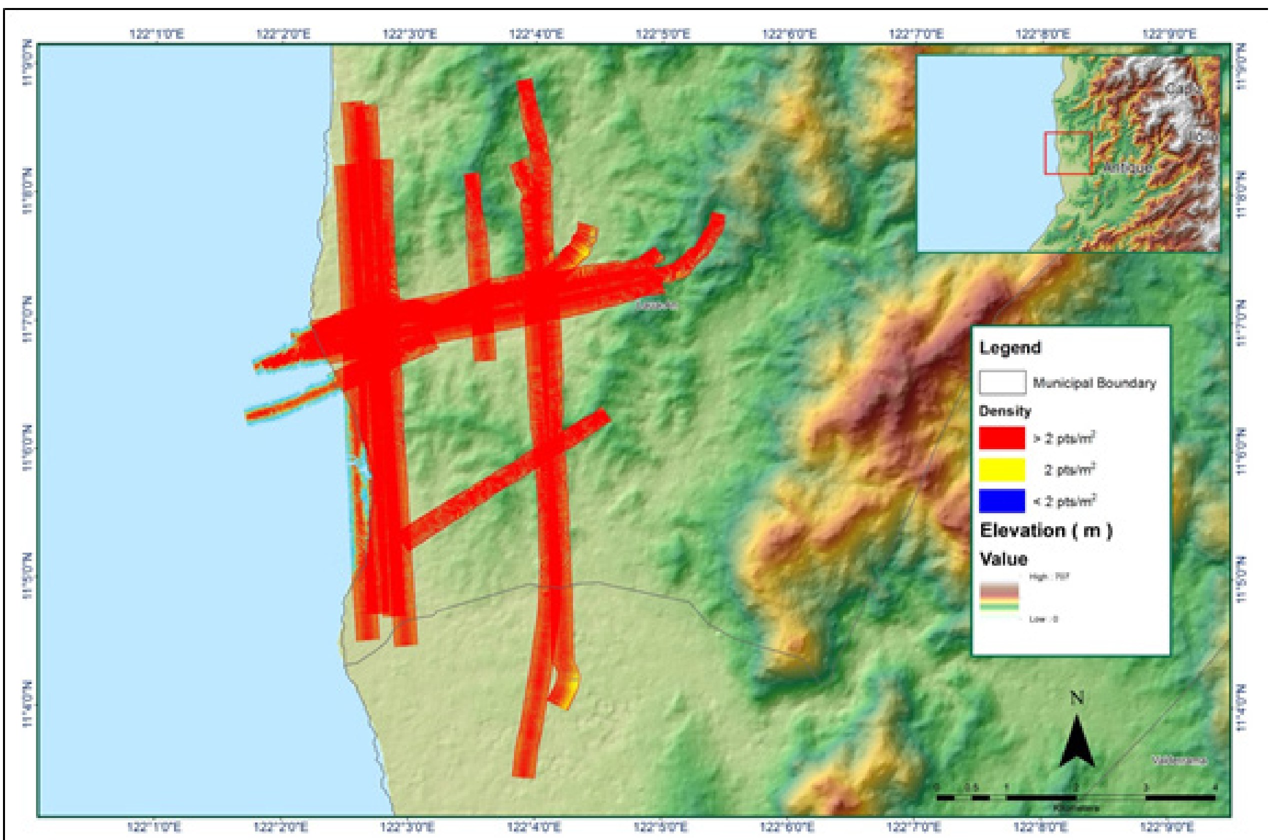


Figure 1.3.6 Density map of merged LiDAR data

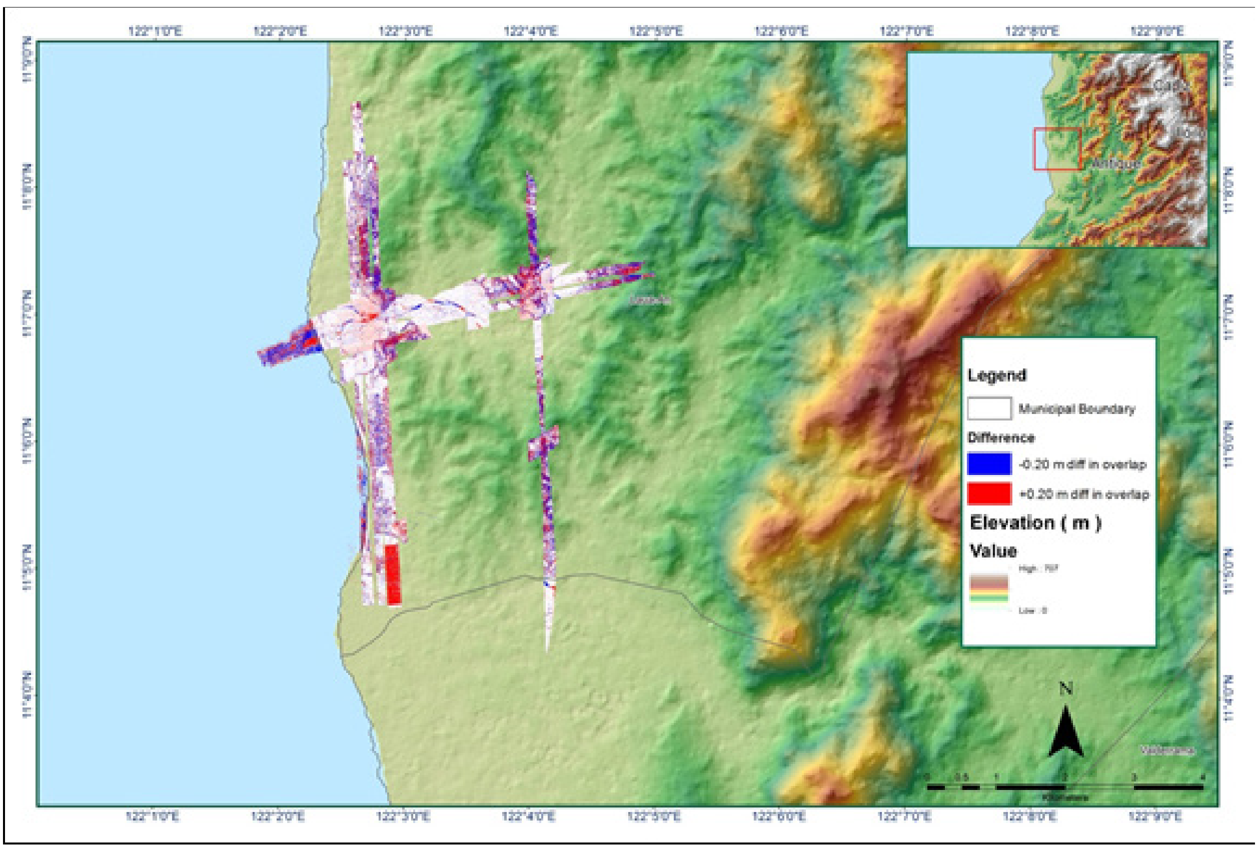


Figure 1.3.7 Elevation difference between flight lines

Flight Area	Iloilo Reflights
Mission Name	**Blk43B_supplement**
Inclusive Flights	8515AC
Range data size	3.35 GB
Base data size	104 MB
POS	189 MB
Image	NA
Transfer date	October 27, 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)	0.82
RMSE for East Position (<4.0 cm)	1.27
RMSE for Down Position (<8.0 cm)	2.21
Boresight correction stdev (<0.001deg)	0.000392
IMU attitude correction stdev (<0.001deg)	0.000914
GPS position stdev (<0.01m)	0.0093
Minimum % overlap (>25)	42.86
Ave point cloud density per sq.m. (>2.0)	3.91
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	38
Maximum Height	481.19
Minimum Height	58.9
Classification (# of points)	
Ground	23,696,880
Low vegetation	10,611,556
Medium vegetation	9,775,696
High vegetation	13,078,875
Building	590,106
Ortophoto	None
Processed by	Engr. Jennifer Saguran, Engr. Melanie Hingpit, Engr. Harmond Santos

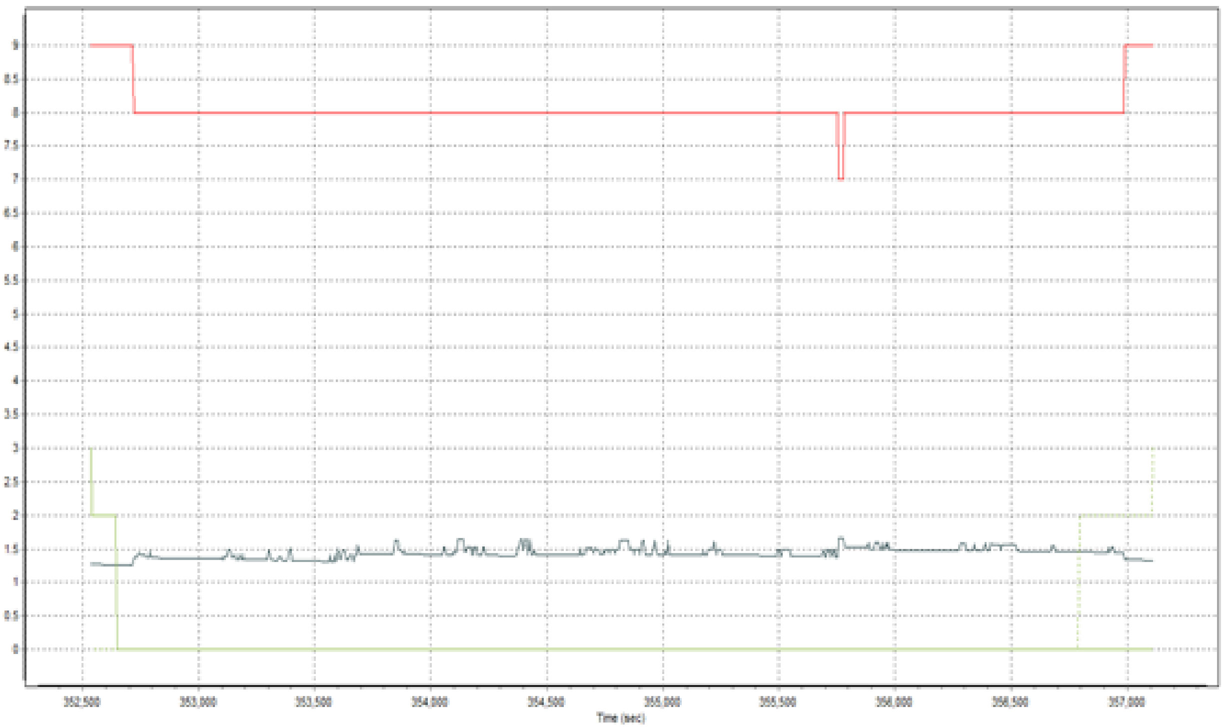


Figure 1.4.1. Solution Status

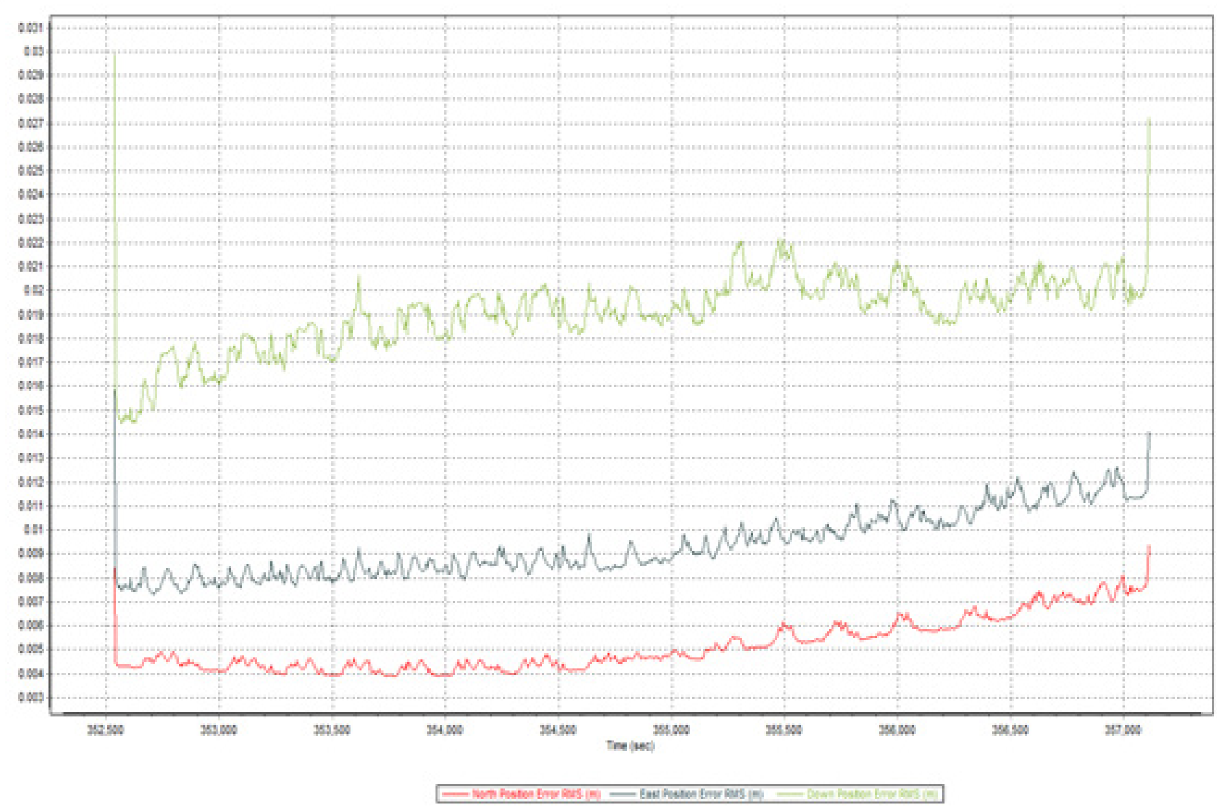


Figure 1.4.2. Smoothed Performance Metric Parameters

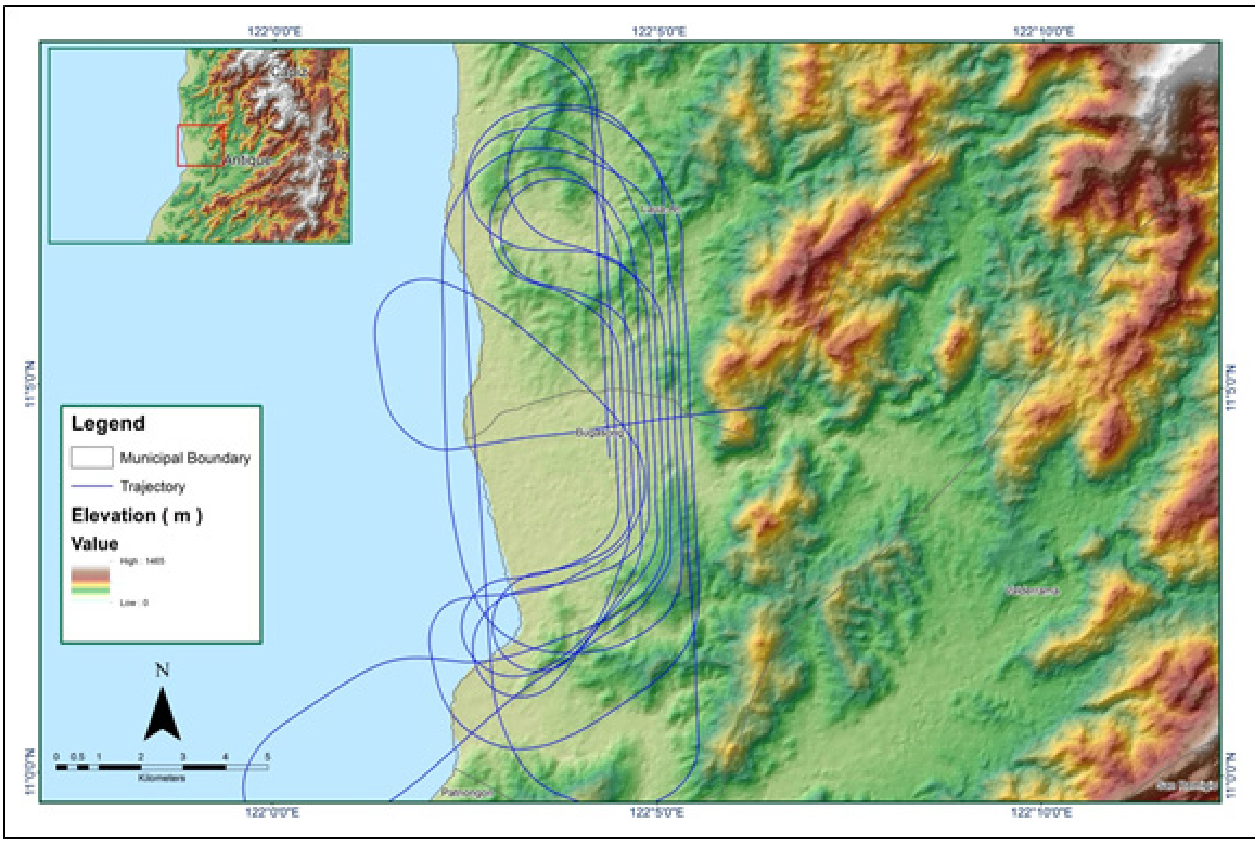


Figure 1.4.3 Best Estimated Trajectory

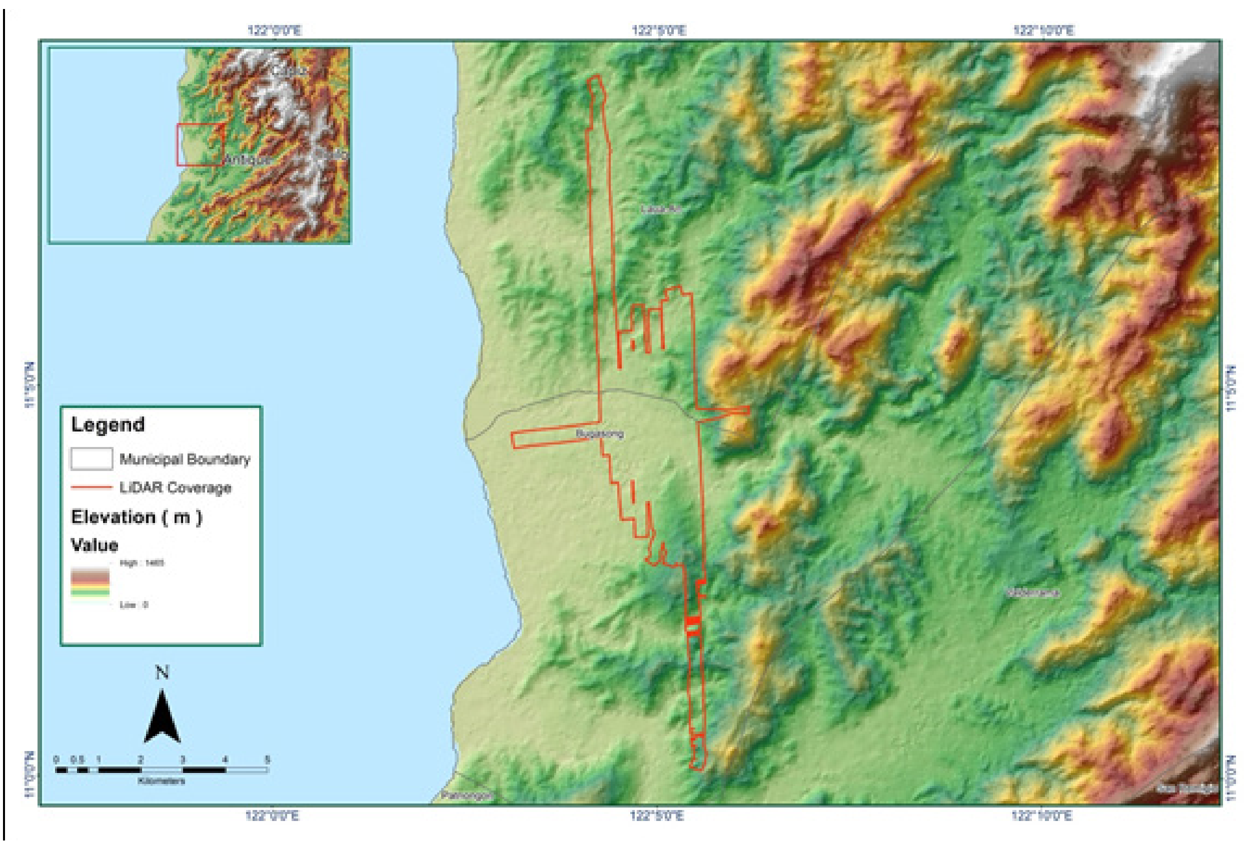


Figure 1.4.4 Coverage of LiDAR data

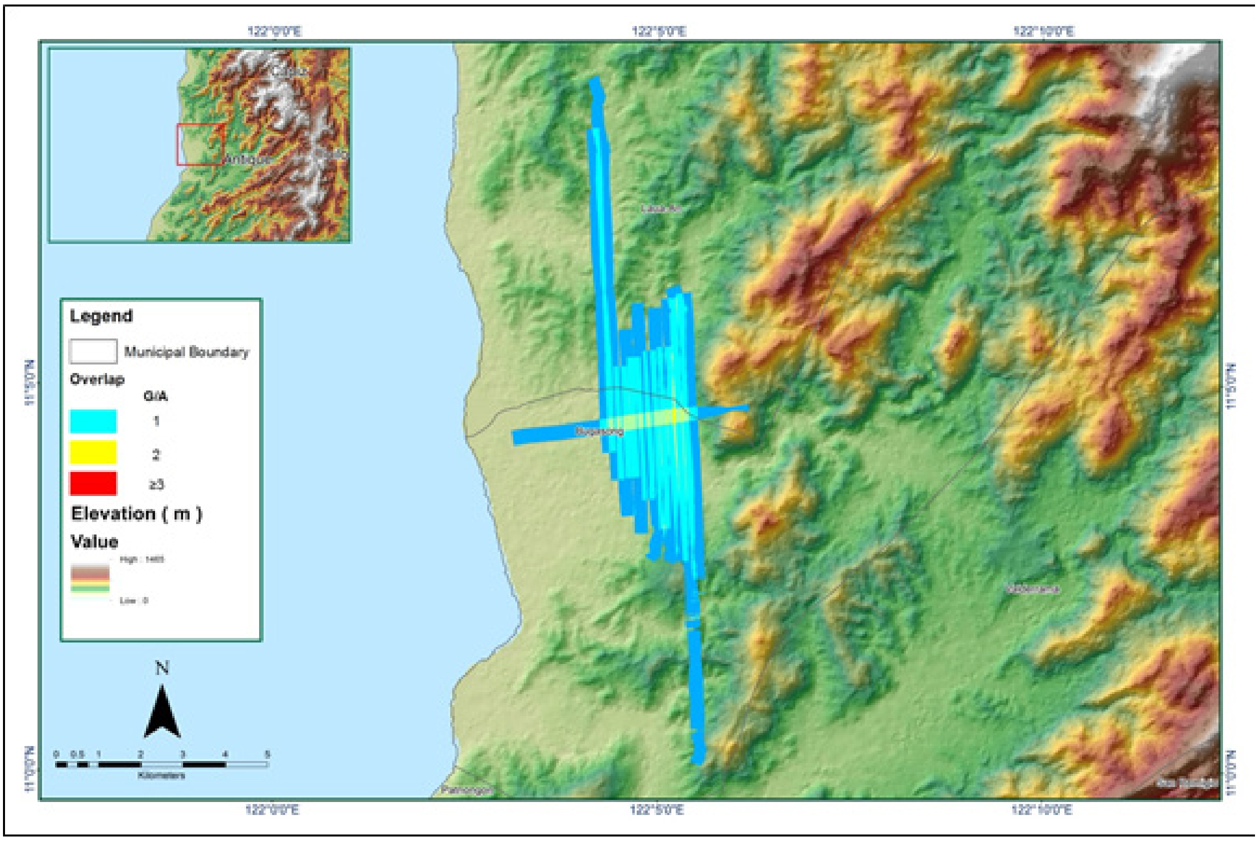


Figure 1.4.5 Image of data overlap

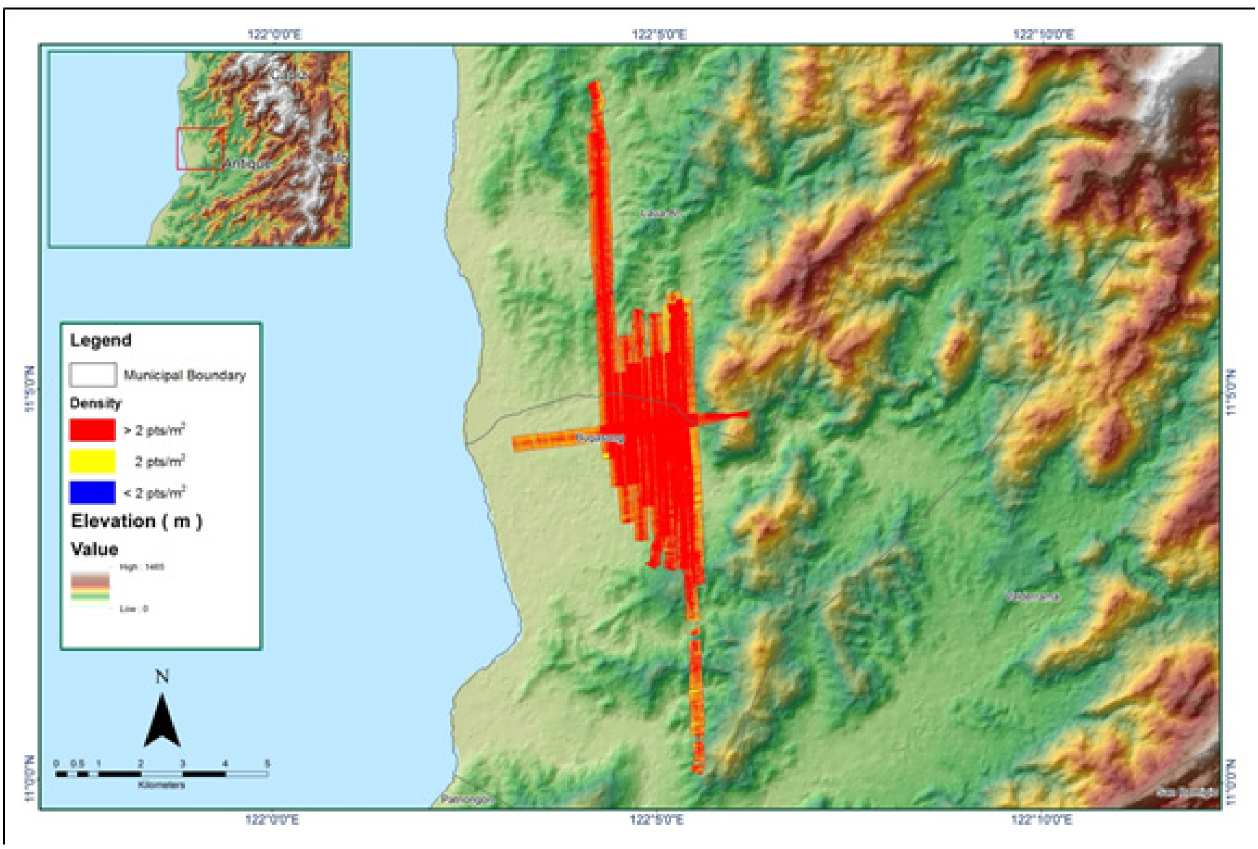


Figure 1.4.6 Density Map of merged LiDAR data

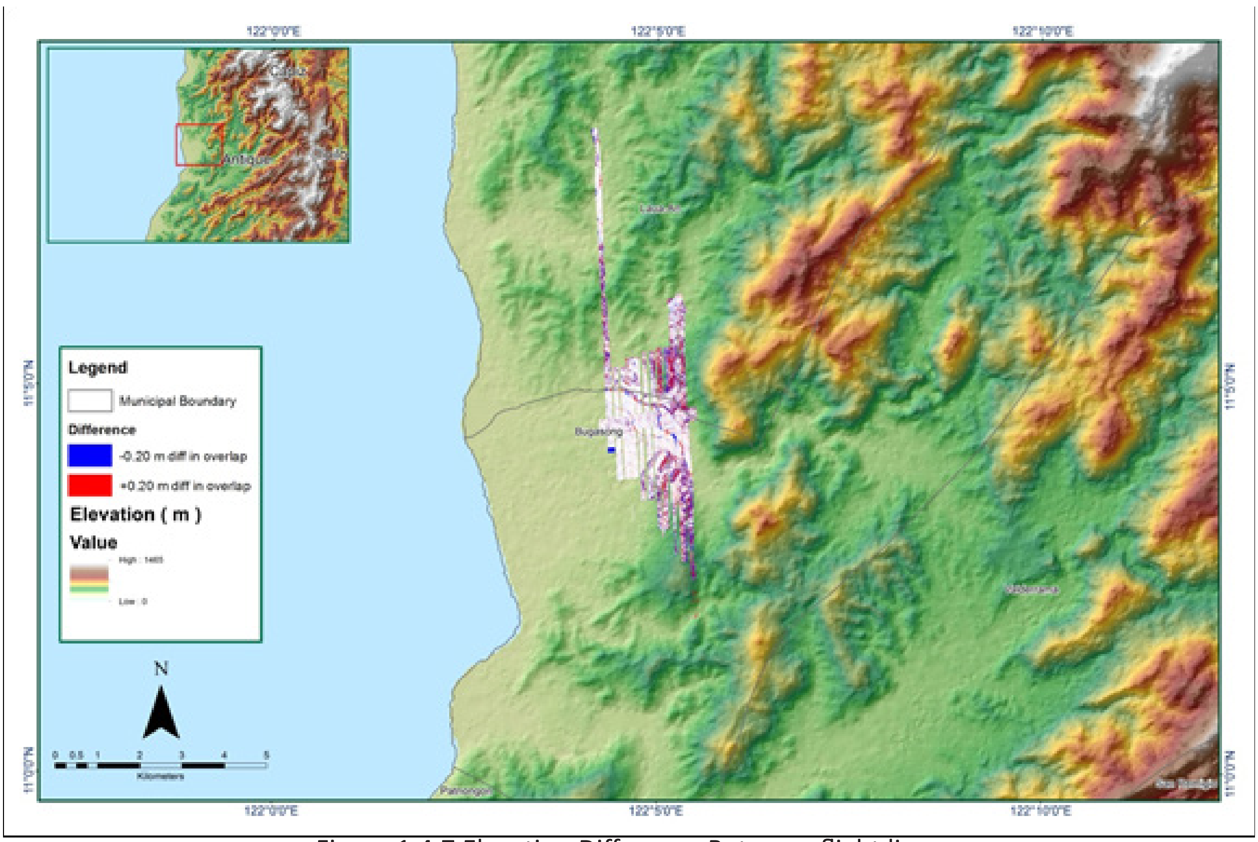


Figure 1.4.7 Elevation Difference Between flight lines

ANNEX 9. PALIWAN 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
W360	1.0629	96.314	0	0.27431	4.4247	Discharge	0.43437	1	Ratio to Peak	0.0001
W370	0.68659	99	0	0.0596092	2.1676	Discharge	0.13207	1	Ratio to Peak	0.0001
W380	0.95465	99	0	0.0626814	3.3373	Discharge	0.0923162	1	Ratio to Peak	0.0001
W390	1.1697	94.868	0	0.0666273	1.8537	Discharge	0.1106	1	Ratio to Peak	0.0001
W400	0.63195	99	0	0.11565	1.722	Discharge	0.32935	1	Ratio to Peak	0.0001
W410	0.98641	98.5	0	0.0591217	2.539	Discharge	0.0646545	1	Ratio to Peak	0.0001
W420	0.81573	91.463	0	0.071831	8.8378	Discharge	0.0656467	1	Ratio to Peak	0.0001
W430	0.58691	85.162	0	0.079049	1.9789	Discharge	0.11044	1	Ratio to Peak	0.0001
W440	0.1912	62.812	0	0.0944182	11.817	Discharge	0.29476	1	Ratio to Peak	0.0001
W450	0.27053	58.813	0	0.29361	2.1391	Discharge	0.36017	1	Ratio to Peak	0.0001
W460	1.007	87.569	0	0.081234	2.6602	Discharge	0.14386	1	Ratio to Peak	0.0001
W470	0.31125	67.65	0	0.12263	6.168	Discharge	0.343	1	Ratio to Peak	0.0001

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
W480	1.2941	94.678	0	0.13291	1.4152	Discharge	0.10369	1	Ratio to Peak	0.0001
W490	0.29526	81.199	0	0.26011	6.3296	Discharge	0.65588	1	Ratio to Peak	0.0001
W500	0.33697	57.836	0	0.0767774	6.3373	Discharge	0.13169	1	Ratio to Peak	0.0001
W510	0.84897	93.803	0	0.13743	1.487	Discharge	0.0807787	1	Ratio to Peak	0.0001
W520	0.32524	59.231	0	0.13478	11.294	Discharge	0.12574	1	Ratio to Peak	0.0001
W530	0.36588	51.538	0	0.21943	12.079	Discharge	0.46475	1	Ratio to Peak	0.0001
W540	0.21362	70.474	0	0.076959	2.8945	Discharge	0.10399	1	Ratio to Peak	0.0001
W550	0.39926	81.319	0	0.13553	3.4133	Discharge	0.0021609	1	Ratio to Peak	0.0001
W560	0.34326	57.883	0	0.0787234	2.8382	Discharge	0.10452	1	Ratio to Peak	0.0001
W570	0.1829	74.483	0	0.12166	3.0647	Discharge	0.0468615	1	Ratio to Peak	0.0001
W580	0.29772	79.059	0	0.0765576	6.3113	Discharge	0.16884	1	Ratio to Peak	0.0001
W590	0.36089	85.016	0	0.0451855	2.5234	Discharge	0.0928457	1	Ratio to Peak	0.0001
W600	0.4107	82.379	0	0.12252	6.946	Discharge	0.20987	1	Ratio to Peak	0.0001
W610	0.14547	73.142	0	0.0742638	2.7889	Discharge	0.0788076	1	Ratio to Peak	0.0001

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
W620	0.29329	81.468	0	0.09075	2.1857	Discharge	0.18583	1	Ratio to Peak	0.0001
W630	0.12044	74.781	0	0.10997	6.1709	Discharge	0.10607	1	Ratio to Peak	0.0001
W640	0.56505	76.182	0	0.1642	2.7678	Discharge	0.34946	1	Ratio to Peak	0.0001
W650	0.2009	72.159	0	0.0475412	1.7536	Discharge	0.0828219	1	Ratio to Peak	0.0001
W660	0.22043	80.149	0	0.0516449	1.9095	Discharge	0.077096	1	Ratio to Peak	0.0001
W670	2.3541	80.799	0	0.0252515	1.2529	Discharge	0.0021476	1	Ratio to Peak	0.0001

ANNEX 10. PALIWAN MODEL REACH PARAMETERS

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R30	Automatic Fixed Interval	2188.36	0.070163	0.0001	Trapezoid	300	1
R50	Automatic Fixed Interval	1949.66	0.060855	0.0001	Trapezoid	300	1
R70	Automatic Fixed Interval	1673.38	3.28E-02	0.0001	Trapezoid	300	1
R90	Automatic Fixed Interval	2278.65	0.026171	0.0001	Trapezoid	300	1
R110	Automatic Fixed Interval	5785.83	0.023764	0.0001	Trapezoid	300	1
R130	Automatic Fixed Interval	3522.62	0.017139	0.0001	Trapezoid	300	1
R160	Automatic Fixed Interval	3888.53	0.007438	0.0001	Trapezoid	300	1
R170	Automatic Fixed Interval	42.4264	0.105927	0.0001	Trapezoid	300	1
R190	Automatic Fixed Interval	494.975	0.021348	0.0001	Trapezoid	300	1
R240	Automatic Fixed Interval	2422.38	0.003718	0.0001	Trapezoid	300	1
R250	Automatic Fixed Interval	3688.48	0.008448	0.0001	Trapezoid	300	1
R260	Automatic Fixed Interval	2356.08	0.000829	0.0001	Trapezoid	300	1
R280	Automatic Fixed Interval	4119.78	0.0187	0.0001	Trapezoid	300	1
R290	Automatic Fixed Interval	2657.7	0.004916	0.0001	Trapezoid	300	1
R300	Automatic Fixed Interval	298.995	0.009267	0.0001	Trapezoid	300	1
R310	Automatic Fixed Interval	450.416	0.010361	0.0001	Trapezoid	300	1
R340	Automatic Fixed Interval	7481.15	0.004143	0.0001	Trapezoid	300	1

ANNEX 11. CANGARANAN-PALIWAN FIELD VALIDATION

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return/ Scenario
	Lat	Long					
1	11.04404016	122.0643791	0.059999999	0	0.004		
2	11.04719627	122.0663977	0.029999999	0	0.001		
3	11.06351053	122.0677705	0.029999999	0.43	0.160	Yolanda	5-Year
4	11.00539743	122.0456257	0.100000001	0	0.010		
5	11.02699656	122.0551218	0.029999999	0	0.001		
6	11.04017385	122.0687581	0.579999983	0	0.336		
7	10.95677243	122.0074533	0.039999999	0.3	0.068	Frank	100-Year
8	11.06796347	122.0646525	0.200000003	0.51	0.096	Yolanda	5-Year
9	10.94428104	121.9983045	0.029999999	0.2	0.029	Yolanda	5-Year
10	11.00387028	122.1306623	0.419999987	0.51	0.008		
11	11.00514439	122.129631	0.029999999	0	0.001		
12	11.00990291	122.0634626	0.050000001	0	0.003		
14	11.06532562	122.0816394	0.029999999	0	0.001		
15	10.97468923	122.0217892	0.090000004	0	0.008		
16	11.04346102	122.0638124	0.029999999	0	0.001		
17	11.04348437	122.0613686	0.029999999	0.5	0.221	Undang	5-Year
18	11.00606276	122.0470849	0.07	0	0.005		
19	11.06772967	122.0827564	0.029999999	0	0.001		
20	11.04149721	122.068553	0.029999999	0	0.001		
21	10.98812702	122.0928609	2.539999962	0	6.452		
22	11.01691689	122.0528669	0.029999999	0	0.001		
24	11.06558671	122.0813709	0	0	0.000		
25	11.04670697	122.0652931	0.029999999	0	0.001		
26	11.03026556	122.0566565	0.029999999	0	0.001		
27	11.0069148	122.0498218	0.129999995	0	0.017		
28	11.06059115	122.0784158	0.100000001	0	0.010		
29	11.04139844	122.0521073	1	1.2	0.040	Frank	100-Year
30	11.062625	122.0801022	0.029999999	0	0.001		
31	11.04856519	122.0678507	1.460000038	0.49	0.941	Frank	100-Year
34	10.9643594	122.0148831	0.029999999	0	0.001		
36	10.9472019	122.033573	0.059999999	0	0.004		
38	10.95911653	122.0094681	0.029999999	0.2	0.029	Yolanda	5-Year
50	11.047771	122.0657988	0.029999999	0	0.001		
51	11.0607562	122.078375	0	0	0.000		
52	11.00725319	122.048641	1.289999962	0	1.664		
53	11.02790262	122.0567448	0.029999999	0	0.001		
54	11.0186245	122.0524383	0.589999974	1.06	0.221	Frank	100-Year
55	11.02249607	122.0490881	0.460000008	1.21	0.562	Frank	100-Year
56	10.98090202	122.0297158	0.150000006	0	0.023		
58	11.00986712	122.0640066	0	0	0.000		
59	11.04588023	122.0511686	0.029999999	0.97	0.884	Frank	100-Year
60	11.01102341	122.0621546	0.209999993	0	0.044		
61	11.01053478	122.0655382	0.059999999	0.31	0.063	Yolanda	5-Year
62	11.02196988	122.0473721	0.029999999	0.82	0.624	Ruping	5-Year
63	11.00339685	122.1306646	0	0.51	0.260		
64	10.98151275	122.0302327	0.029999999	0	0.001		
65	11.04558119	122.0598263	0.029999999	0.5	0.221	Frank	100-Year
66	10.97746062	122.0243589	0.029999999	0	0.001		
67	11.00458605	122.1295053	0	0	0.000		
68	11.05069275	122.0495481	0.029999999	0	0.001		
69	11.02284123	122.0491835	0	1.21	1.464	Frank	100-Year
70	11.00551415	122.1304933	0.119999997	0	0.014		
71	11.00059276	122.0839586	0.100000001	0	0.010		
72	11.0223437	122.0495761	0.330000013	0.68	0.122	Frank	100-Year
73	11.0045539	122.1300589	0	0	0.000		
74	11.02741051	122.055324	0.119999997	0	0.014		
75	11.00298074	122.1308145	0	0.93	0.865	Frank	100-Year
76	11.06623469	122.0665362	0.810000002	0.56	0.063	Frank	100-Year
77	11.06617004	122.0661093	0	0.9	0.810	Frank	100-Year
78	11.04290752	122.067271	0.029999999	0	0.001		
79	11.0443049	122.06588	0.029999999	0.26	0.053	Frank	100-Year
80	11.00978012	122.0666671	0.029999999	0	0.001		
81	11.01965115	122.051459	0	1.04	1.082	Frank/ Nitang	100-Year
82	11.04550668	122.0652323	0.029999999	0	0.001		

Point No.	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/ Date	Rain Return/ Scenario
	Lat	Long					
83	11.00056741	122.0838646	0	0	0.000		
84	11.01065581	122.0651629	0	0.31	0.096	Yolanda	5-Year
85	11.04641037	122.0592663	0.360000014	0.5	0.020	Frank	100-Year
86	11.01834642	122.0521678	0.560000002	1.06	0.250	Frank	100-Year
87	11.01912883	122.0519958	0	0.5	0.250	Yolanda	5-Year
88	10.95756417	122.0085821	0.029999999	0	0.001		
91	11.08717759	122.0483329	0.029999999	0.9	0.757	Yolanda	5-Year
94	10.96952395	122.0702749	0.029999999	0	0.001		
95	10.93302146	122.0299397	0.050000001	0	0.003		
99	11.02724908	122.0515141	0.400000006	0.5	0.010	Frank	100-Year
100	11.01931613	122.0511899	0	1.25	1.563	Frank	100-Year
101	11.01081041	122.0641007	0.07	0	0.005		
102	11.0787808	122.0864507	0.07	0	0.005		
103	11.06489892	122.080985	0.029999999	0	0.001		
104	11.01820445	122.0517452	0	1.06	1.124	Frank	100-Year
105	11.01793002	122.052489	0.029999999	0	0.001		
106	11.01766187	122.0520374	0	0.95	0.903	Frank	100-Year
107	10.98374448	122.0293631	0.029999999	0.68	0.423	Frank	100-Year
108	11.00303965	122.1308857	0	0	0.000		
109	11.04328321	122.0589588	0.039999999	0.35	0.096	Frank	100-Year
110	11.07132661	122.0611982	0.029999999	1	0.941	Frank	100-Year
111	11.07236273	122.0612561	1.25999999	1.21	0.002	Frank	100-Year
112	11.00475658	122.1306831	0.349999994	0.5	0.023	Frank	100-Year
113	11.01092881	122.0640487	0	0	0.000		
114	11.00361797	122.1313115	0	1.21	1.464	Frank	100-Year
115	10.9562659	122.0072416	0	0.3	0.090	Frank	100-Year
117	11.02647552	122.0551956	0	0	0.000		
118	10.95728511	122.0084105	0	0	0.000		
119	11.01771548	122.0515164	0	1.63	2.657	Frank	100-Year
120	11.04570445	122.0595503	0	0.5	0.250	Frank	100-Year
121	11.04048376	122.0698528	0	1	1.000	Frank	100-Year
122	11.0058659	122.1299482	0.219999999	2	3.168	Lawin	5-Year
123	11.045929	122.0659367	0.029999999	0	0.001		
124	11.03307078	122.0574816	0.029999999	0	0.001		
125	11.00378924	122.1312014	0	1.21	1.464	Frank	100-Year
126	11.00405804	122.1304097	0.310000002	0	0.096		
127	11.02263259	122.0475884	0.829999983	0.73	0.010	Frank	100-Year
128	11.0228817	122.0481969	0	1.25	1.563	Frank	100-Year
129	11.02297139	122.0475469	0	0.96	0.922	Lawin	5-Year
130	10.93902928	122.00096	0.029999999	0	0.001		
131	11.04839076	122.0504137	0.99000001	1	0.000	Frank	100-Year
132	11.0184566	122.0527233	0	0	0.000	Frank	100-Year
133	10.96238128	122.0129551	0.029999999	0	0.001		
134	11.01683328	122.0514692	0.689999998	1.45	0.578	Frank	100-Year
137	10.93818813	122.0004052	0.029999999	0	0.001		
138	10.95733435	122.0089883	0	0.7	0.490	Frank	100-Year
139	11.00617698	122.0423088	0.75999999	1.5	0.548	Frank	100-Year
140	10.99594444	122.0376456	0.029999999	0	0.001		
141	11.09183229	122.0491072	0.029999999	0	0.001		
142	11.00337	122.1152199	0.769999981	0.9	0.017	Frank	100-Year
143	10.95301962	122.0467185	0.360000014	0.61	0.062		
148	11.01227141	122.0749224	2.420000076	6.39		Frank	100-Year
150	11.07317951	122.0596864	1.299999952	0.5	0.640	Frank	100-Year
151	11.06323004	122.0803316	0	0	0.000		
152	11.00741574	122.04953	0	0.52	0.270	Frank	100-Year
153	11.04462489	122.0666026	0	0	0.000		
154	11.04654608	122.0510006	1.070000052	0.97	0.010	Frank	100-Year
155	11.00747152	122.0490977	0	0	0.000		
156	11.07236169	122.0599095	0.029999999	0.6	0.325	Yolanda	5-Year

ANNEX 12. EDUCATIONAL INSTITUTIONS AFFECTED BY FLOODING IN PALIWAN FLOODPLAIN

Antique				
Bugasong				
Building Name	Barangay	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
School	Bugasong	Low		
School	Bugasong			
School	Bugasong			
School	Bugasong			
Jaguiguican Elementary School	Bugasong			
Laua-An				
Building Name	Barangay	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Guinbanga-an Elementary School	Guinbanga-An			
CRANS National School	Guisijan	Low		
Guisijan Elementary School	Guisijan			
Barangay Maria Day Care Center	Loon			
Eastern Laua-an National High School	Loon	Low		
Maria Elementary School	Loon			
Lugta Day Care Center	Lugta	Low		
Lugta Elementary School	Lugta			
Maria Elementary School	Paningayan	Mediun		
Paningayan Day Care Center	Santiago			
Paningayan Primary School	Santiago			

ANNEX 13. MEDICAL INSTITUTIONS AFFECTED BY FLOODING IN PALIWAN FLOODPLAIN

Laua-An				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Guinbanga-an Day Care Center	Guinbanga-An			
Guinbanga-an Health Center	Guinbanga-An			
Guisijan Health Center	Guisijan			
Paningayan Health Center	Santiago			