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

LiDAR Surveys and Flood Mapping of Pajo River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Ateneo de Naga University

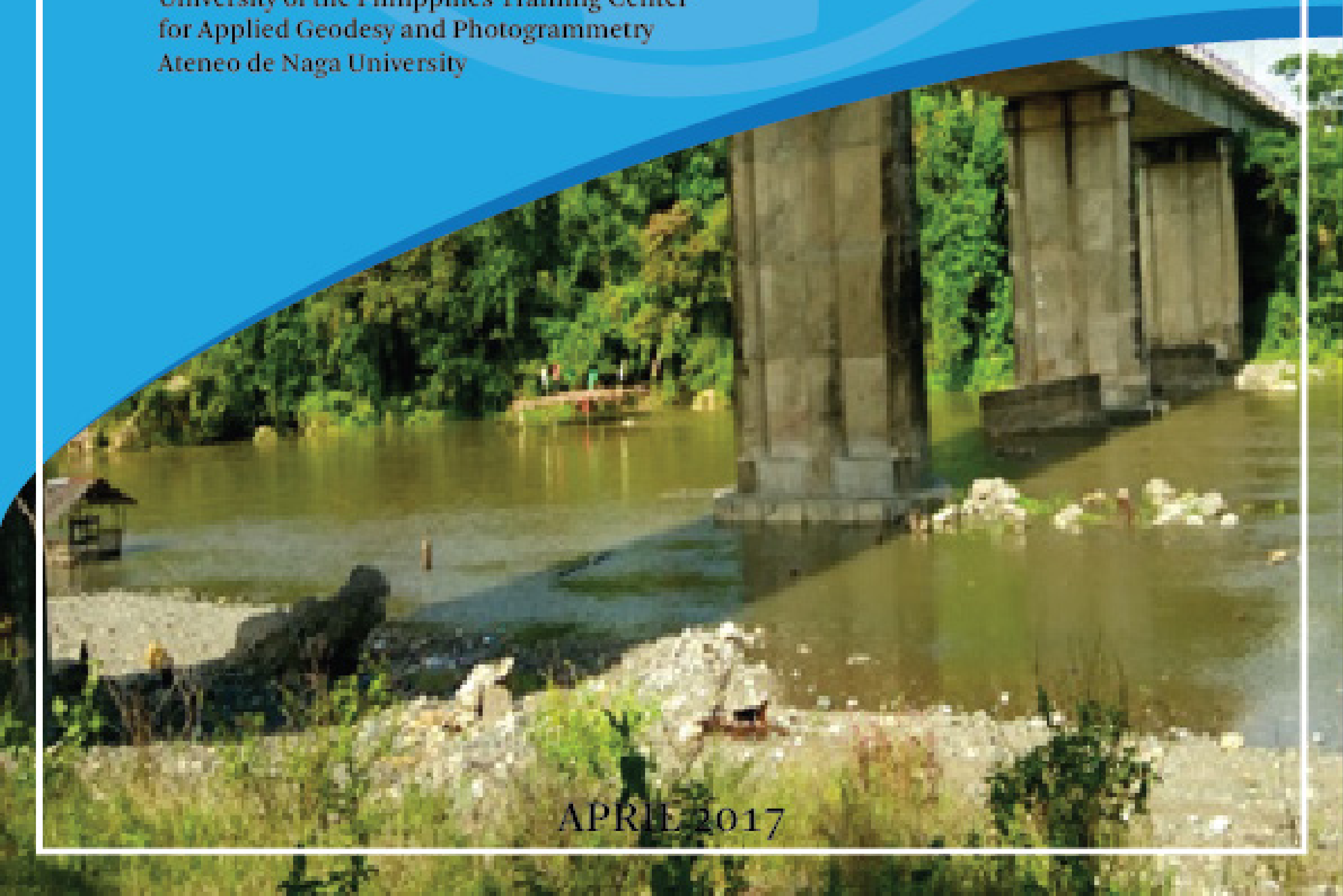

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ADNU	Ateneo de Naga University
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord

IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group

CHAPTER 1: OVERVIEW OF THE PROGRAM AND PAJO RIVER

Joanaviva Plopenio and Enrico C. Paringit, Dr. Eng.

1.1 Background of the Phil-LIDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1 in 2014, supported by the Department of Science and Technology (DOST) Grant-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

The program also aimed to produce an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication titled 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 Ateneo de Naga University (ADNU). ADNU 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 Pajo River. The university is located in Naga City in the province of Camarines Sur.

1.2 Overview of the Pajo River Basin

The Pajo River Basin covers the Municipalities of San Andres, Virac and San Miguel in Catanduanes. Virac is a first-class municipality, San Andres is a third-class municipality; and San Miguel, is a fifth-class municipality. According to DENR River Basin Control Office, it has a drainage area of 333km2 and an estimatedannual run-off of 450 million cubic meter (MCM) (RBCO, 2015).

Its main stem, Pajo River is part of the 24 river systems in the Bicol Region. It is about 98 km long. Pajo River empties out to Cabugao Bay by the town of Virac. It is bracketed to the west by the low mountains in San Andres: Mt. Cagmasuso and Mt. Putting-Padlos. In the east, it is bound by Mt. Howayon in Virac, Mt. Pacogon in San Miguel, and Mt. Lantad in the town of Bato. Mt. Lantad is more commonly known by the residents near it as Mt. Pinagkaayonan. The elevation of these mountains is all below 1000 mASL. The Catanduanes Watershed Forest Reserve is also in this area which includes the towns of Virac, Bato, San Miguel, Pandan, Calolbon, and Baras.
According to the 2010 national census of NSO, a total of 21,187 locals distributed among the sixteen (16) barangays in Municipality of Virac are residing in the immediate vicinity of the river.

Agriculture and fishing are the major industries in the area. Rice, corn, bananas, and root crops are the primary products while copra and abaca are the secondary products in the area (http://nap.psa.gov.ph/ru5/overview/profiles/virac/economy.htm, 2014). However, production is hampered by natural calamities since the area is usually passed by typhoons entering the Philippine Area of Responsibility. Other sources of income include tourism, cottage industry, and manufacturing. For tourism, the provincial tourism office initiated a "tramping" program last 2015. This is a combination of trekking and camping in Mt. Lantad. This program aims to promote ecotourism adventure showcasing the natural ecosystems in the island.

Catanduanes is classified under Type II in the modified classification of climate of the Philippines. As such, it experiences heavy rains from November to April and is rainy the rest of the year. There is no distinct dry season.

The most recent and significant flooding in the area was in November 2006 caused by Typhoon Durian "Reming," resulting in damage to transmission lines and evacuation of 166 families among areas in Catanduanes including Virac (http://www.gmanetwork.com/news/story/22477/news/nation/reming-downgraded-to-typhoon, 2006).

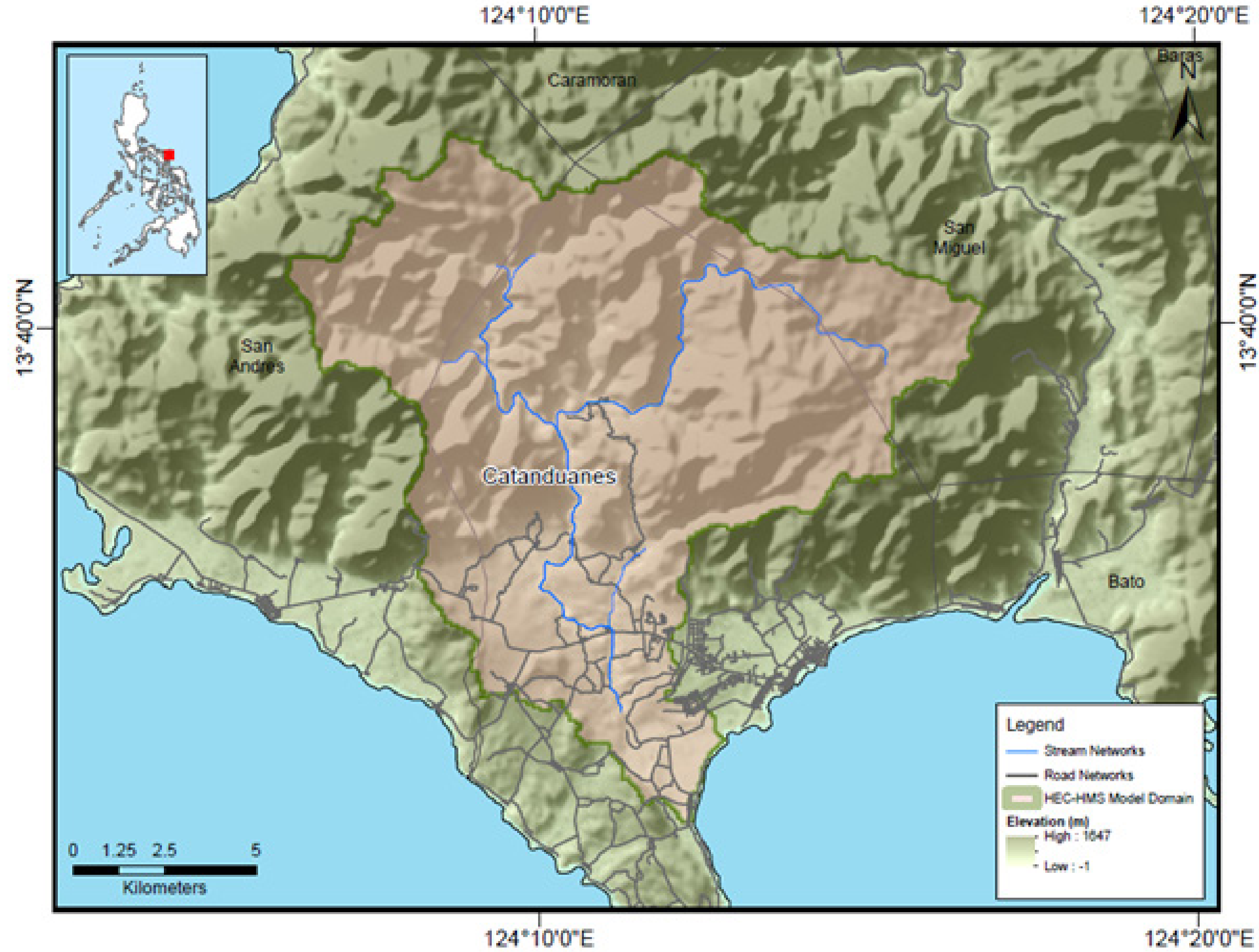

Figure 1. Map of Pajo River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE PAJO 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 Pajo Floodplain in Catanduanes. These missions were planned for 14 lines that run for at most four (4) hours including take-off, landing, and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plans for Pajo Floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK25A	1000	20	50	200	30	130	5
BLK25B	1000	20	50	200	30	130	5
BLK25C	1000	20	50	200	30	130	5
BLK25H	1000	20	50	200	30	130	5

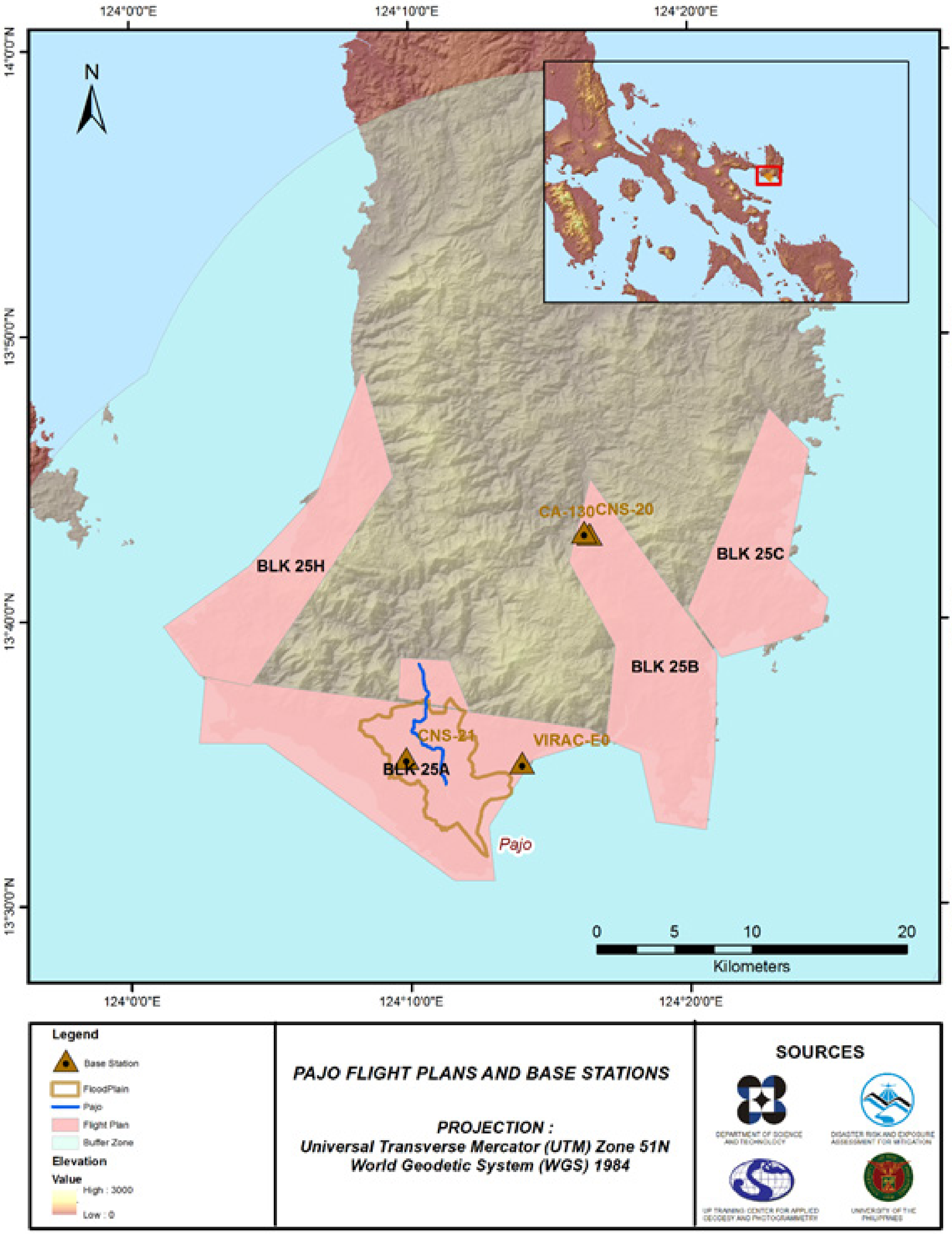


Figure 2. Flight plan and base stations used to cover Pajo Floodplain

2.2 Ground Base Stations

The project team was able to recover two (2) NAMRIA reference points: CNS-20 and CNS-21 which are of second (2nd) order accuracy, and one (1) NAMRIA benchmark CA-130, which is of first (1st) order accuracy. The benchmark was used as vertical reference point and was also established as ground control point. The team also established one (1) base station, VIRAC-E0.The certifications for the NAMRIA reference points are found in Annex 2 while the baseline processing report for the benchmark and established point are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (January 20 – February 4, 2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 985 and TOPCON GR5. Flight plans and location of base stations used during the aerial LiDAR acquisition in Pajo Floodplain are shown in Figure 2.

Figure 3 to Figure 6 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 5 present the details about the following NAMRIA control stations. Table 6 lists all ground control points occupied during the acquisition with corresponding dates of utilization.

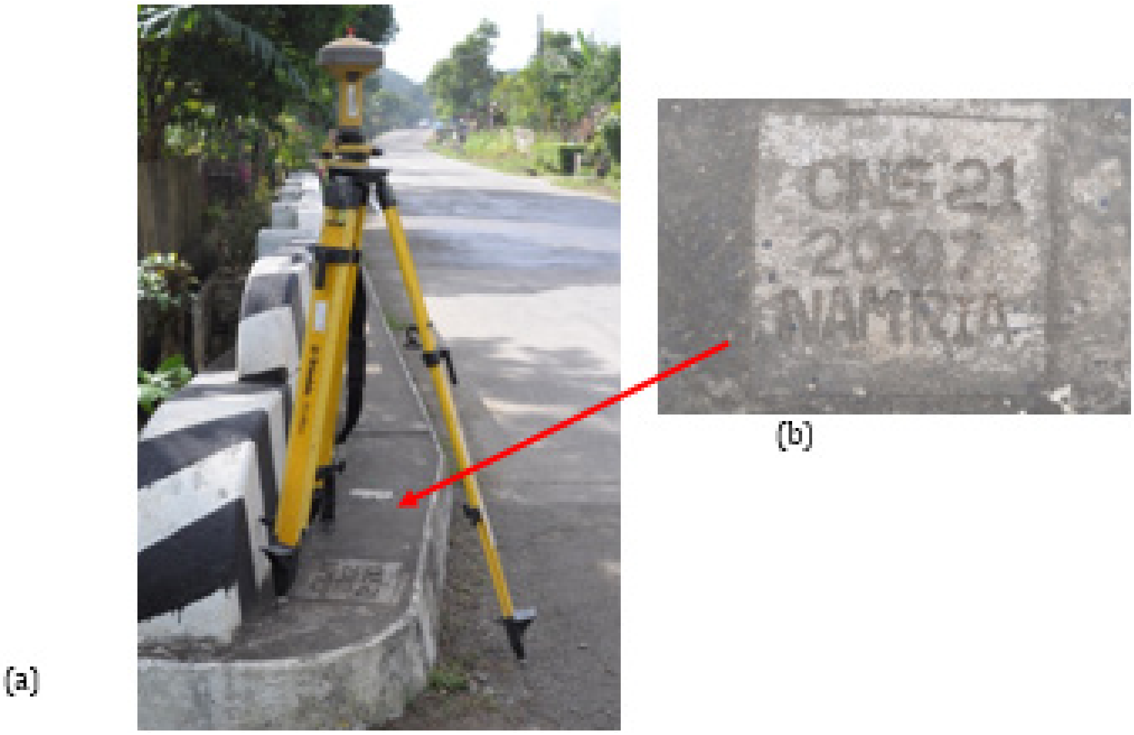


Figure 3. GPS set-up over CNS-21at Palta bridge, Barangay Palta Small, Virac along the circumferential road (a) and NAMRIA reference point CNS-21 (b) as recovered by the field team

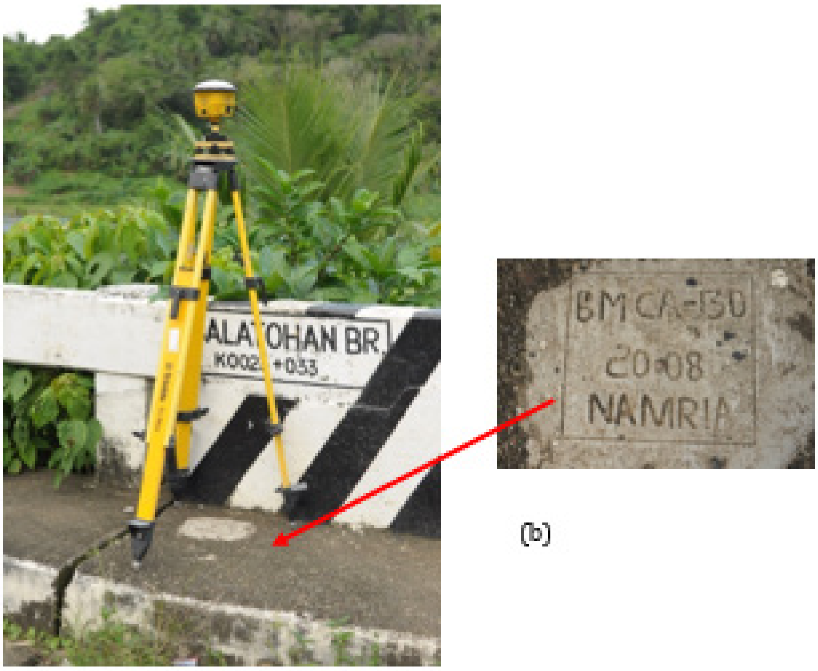
Table 3. Details of the recovered NAMRIA horizontal control point NGW-50 used as base station for the LiDAR

Station Name	**CNS-21**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 35' 14.37180" North 124° 9' 45.40531" East 83.10600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	625,825.638 meters 1,502,820.29meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 35' 9.45275"North 124° 9' 50.36457" East 137.19500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	625,781.60 meters 1,502,294.28 meters

Figure 4. GPS set-up over CNS-20 at Malmag bridge, Barangay Pagsangahan, San Miguel along circumferential road (a) and NAMRIA reference point CNS-20 (b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point CNS-20 used as base station for the LiDAR Acquisition

Station Name	**CNS-20**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 43’ 8.77572” North 124° 16’ 9.57152” East 43.752 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	637,300.168 meters 1,517,459.029 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 43’ 3.83355” North 124° 16’ 14.51857” East 97.736 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	637,252.11 meters 1,516,927.89 meters



(b)

(a)

Figure 5. GPS set-up over CA-130 at Balatohan bridge, Barangay Balatohan, San Miguel (a) and NAMRIA reference point CA-130 (b) as recovered by the field team

Table 4. Details of the recovered NAMRIA vertical control point CA-130 used as base station for the LiDAR acquisition with established coordinates

Station Name	**CA-130**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13° 43’ 8.77572” North 124° 16’ 9.57152” East 43.752 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13° 43’ 3.83355” North 124° 16’ 14.51857” East 97.736 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	637,252.11 meters 1,516,927.89 meters

Figure 6. GPS set-up over VIRAC-E0 established at Barangay Palta Small, Virac Catanduanes.

Table 5. Details of the established horizontal control point VIRAC-E0 used as base station for the LiDAR acquisition.

Station Name	**VIRAC-E0**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°35'03.52757" North 124°13'53.85198" East 4.565 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°34'58.61487" North 124°13'58.81098" East 58.830 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	633,250.707 meters 1,501,997.753 meters

Table 6. Ground Control points using LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
January 22, 2016	3010P	1BLK25A022A	CNS-21, VIRAC-E0
January 23, 2016	3012P	1BLK25B023A	CNS-20, CNS-21
January 24, 2016	3016P	1BLK25E024A	CNS-20, CNS-21
January 27, 2016	3028P	1BLK25F027A	CNS-20, CA-130

2.3 Flight Missions

Four (4) missions were conducted to complete the LiDAR data acquisition in Pajo Floodplain, for a total of thirteen hours and twenty minutes (13+20) of flying time for RP-C9122. All missions were acquired using the Pegasus LiDAR system. Table 7 shows the total area of actual coverage and the corresponding flying hours per mission while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight Missions for LiDAR data acquisition in Pajo Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
January 22, 2016	3010P	256.29	167.89	37.91	129.98	NA	4	5
January 23, 2016	3012P	354.97	164.79	16.92	147.87	426	4	5
January 24, 2016	3016P	352.55	123.14	11.43	111.71	NA	2	41
January 27, 2016	3028P	340.85	15.99	0.2	15.79	NA	2	29
TOTAL		**1304.66**	**471.81**	**66.46**	**405.35**	**426**	**13**	**20**

Table 8. Actual Parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
3010P	1000	20	50	200	30	110-130	5
3012P	1000	20	50	200	30	110-130	5
3016P	1000	20	50	200	30	110-130	5
3028P	1000	20	50	200	30	110-130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Pajo Floodplain (See Annex 7). Pajo Floodplain is located in the province of Catanduanes with majority of the floodplain situated within the municipality of Virac. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 9. The actual coverage of the LiDAR acquisition for Pajo Floodplain is presented in Figure 7.

Table 9. List of municipalities and cities surveyed during Pajo Floodplain LiDAR survey

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Catanduanes	San Andres	111.97	172.88	65%
	Virac	110.76	175.30	63%
	Bato	26.66	45.83	58%
	San Miguel	56.14	174.25	32%
	Baras	16.32	75.39	22%
	Viga	8.07	158.74	5%
	Caramoran	11.84	266.80	4%
TOTAL		341.76	1069.19	312.85%

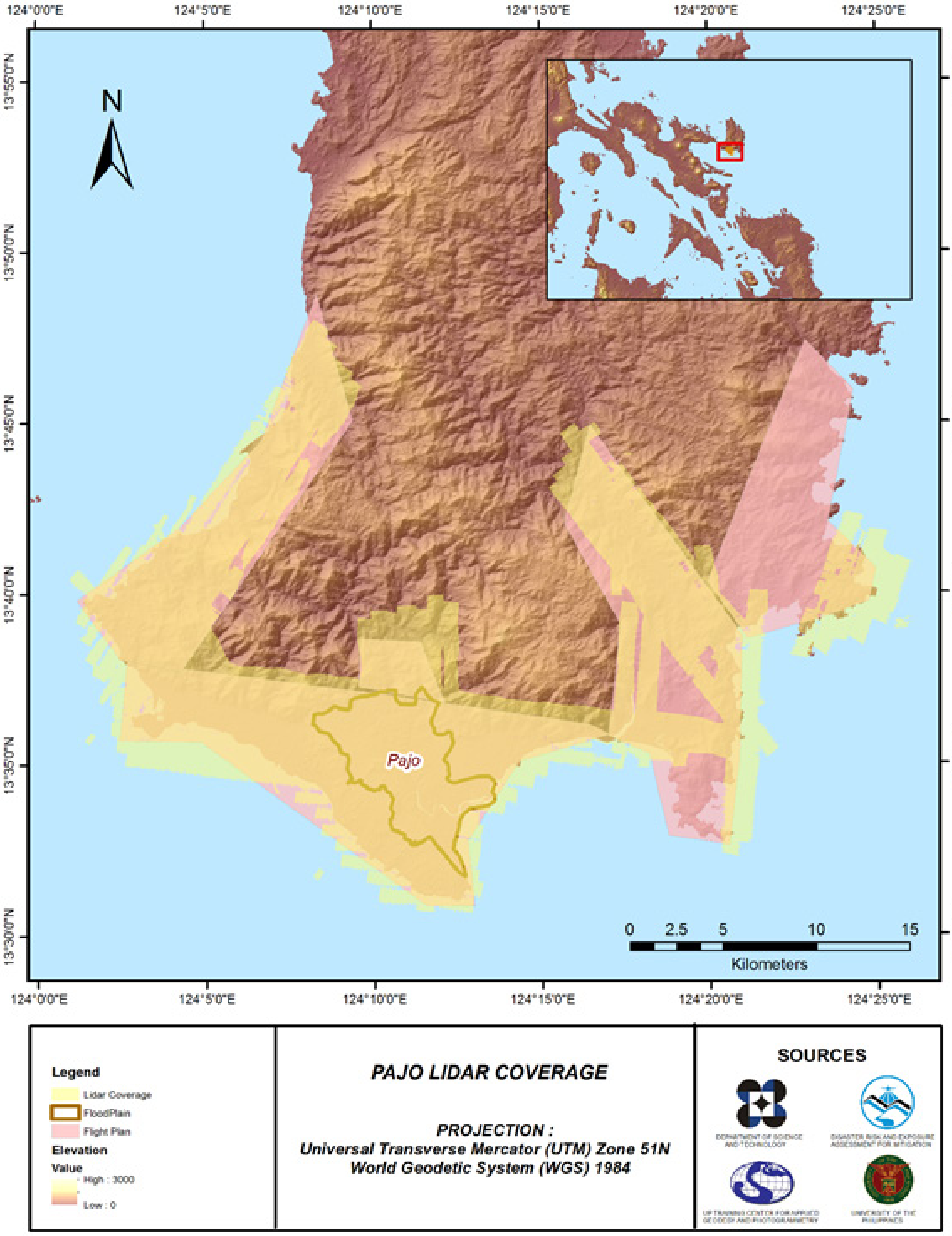


Figure 7. Actual LiDAR data acquisition for Pajo Floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE PAJO 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 were checked for completeness based on the list of raw files required to proceed with the pre-processing of the LiDAR data. Upon acceptance of the LiDAR field data, georeferencing of the flight trajectory was done to obtain the exact location of the LiDAR sensor when the laser was shot.

Point cloud georectification was performed to incorporate correct position and orientation for each point acquired. The georectified LiDAR point clouds were 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 were then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

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

These processes are summarized in the flowchart shown in Figure 8.

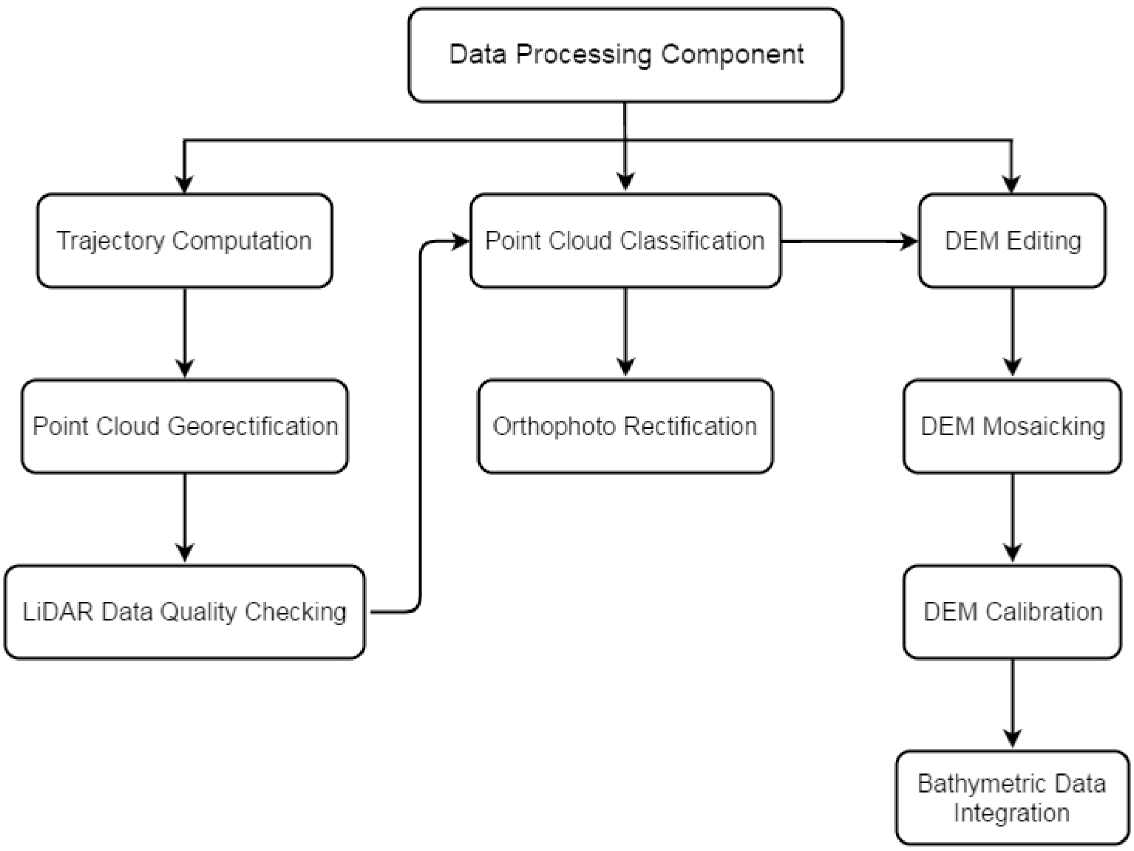


Figure 8. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Pajo floodplain can be found in Annex 5. Missions flown during the first survey conducted in January 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.)Pegasus over Virac, Catanduanes. The Data Acquisition Component (DAC) transferred a total of 64.38 Gigabytes of Range data, 794 Megabytes of POS data, 311.9 Megabytes of GPS base station data, and 27.9 Gigabytes of raw image data to the data server on January 27, 2016. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Pajo was fully transferred on February 12, 2016, as indicated in the Data Transfer Sheets for Pajo Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metricparameters of the computed trajectory for flight 3028P, one of the Pajoflights, which is the North, East, and Down position RMSE values are shown in Figure 9. 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 onJanuary 27, 201600:00AM. The y-axis is the RMSE value for that particular position.

Figure 9. Smoothed Performance Metric Parameters of a Pajo Flight 3028P.

The time of flight was from 259,000 seconds to 264,500 seconds, which corresponds to morning of February 27, 2016. 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 9 shows that the North position RMSE peaks at 1.25centimeters, the East position RMSE peaks at 1.20 centimeters, and the Down position RMSE peaks at 2.05centimeters, which are within the prescribed accuracies described in the methodology.

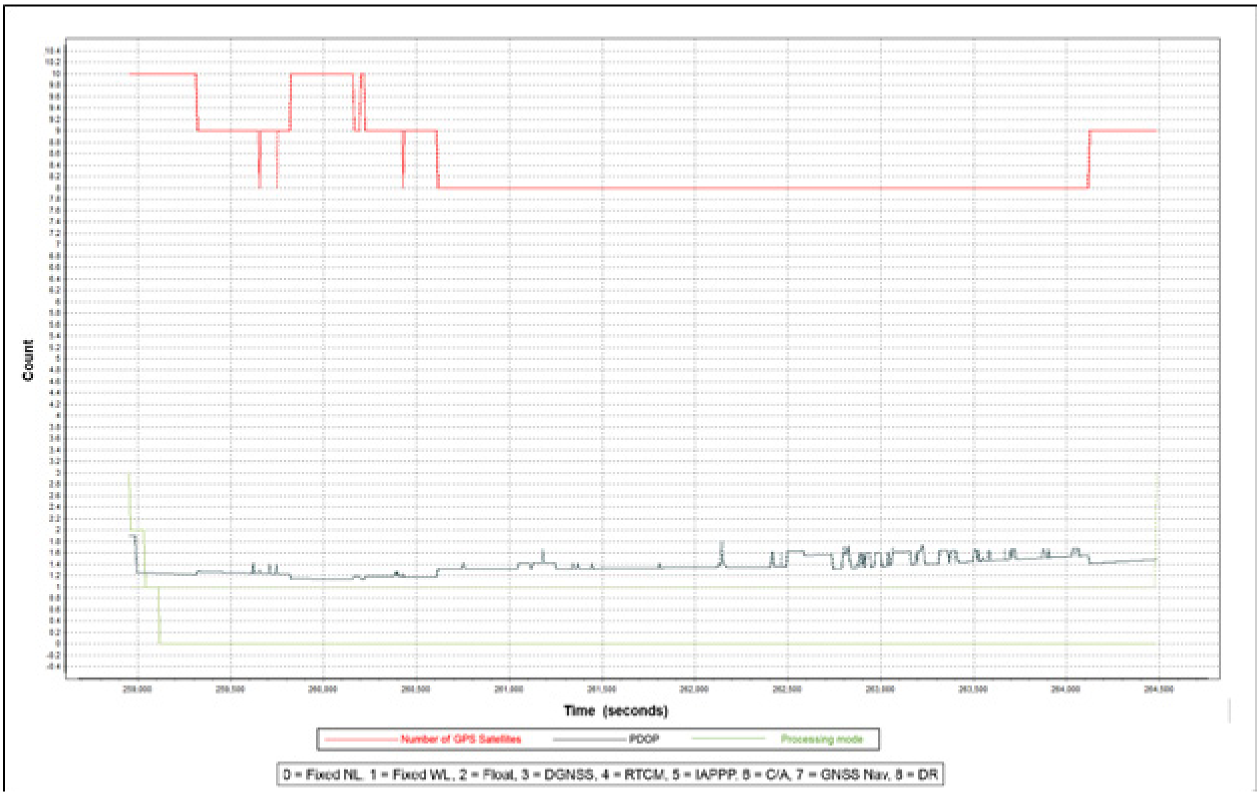


Figure 10. Solution Status Parameters of Pajo Flight 3028P.

The Solution Statusparameters of flight 3028P,one of the Pajoflights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down below 8. Majority of the time, the number of satellites tracked was between 8 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Pajo flights is shown in Figure 11.

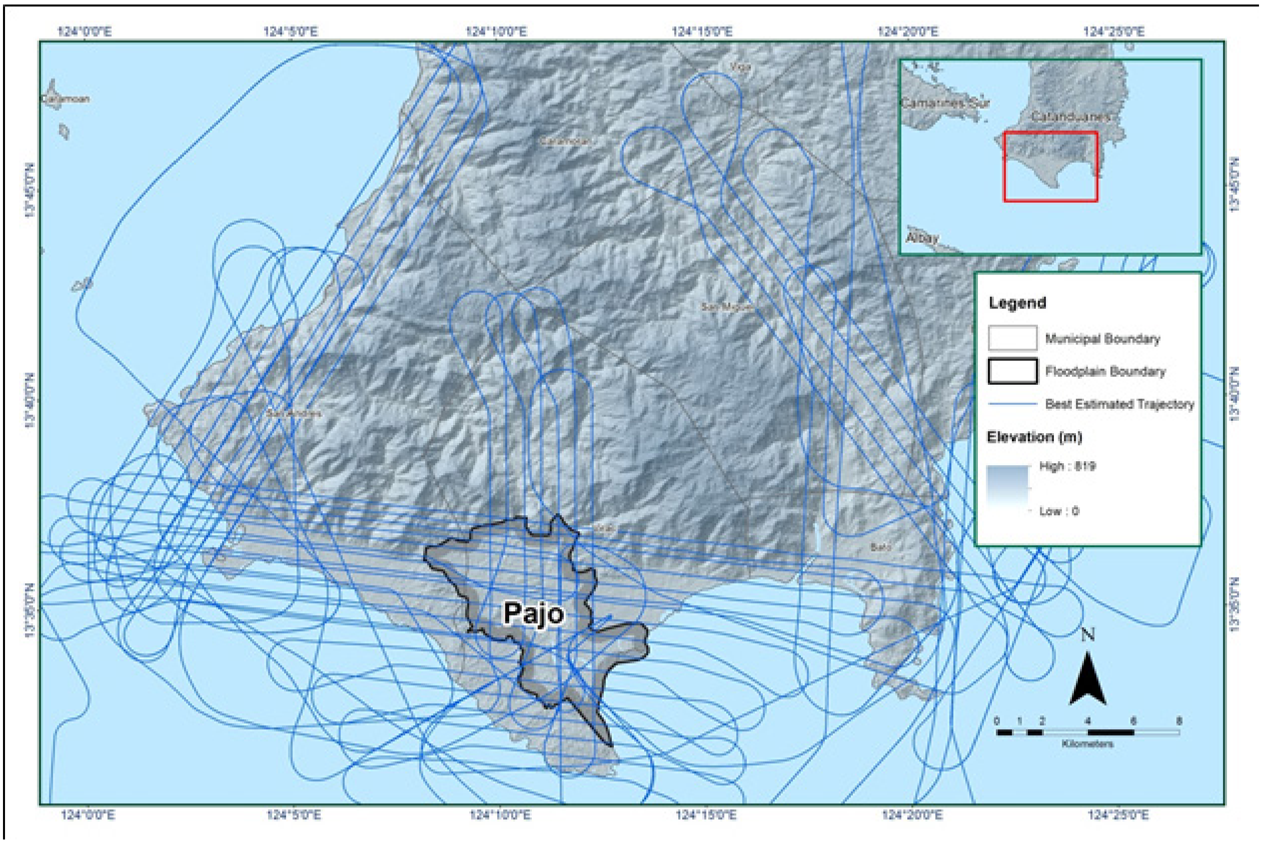


Figure 11. Best Estimated Trajectory for Pajo Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 54flight lines, with each flight line containing one channel, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Pajo Floodplain are given in Table 10.

Table 10. Self-Calibration Results values for Pajo flights

Parameter	Acceptable Value	Value
Boresight Correction stdev (<0.001degrees)	0.000462	0.000218
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000318	0.000903
GPS Position Z-correction stdev (<0.01meters)	0.0017	0.0027

The optimum accuracy was obtained for all Pajo flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the Annex 8.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Pajo Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

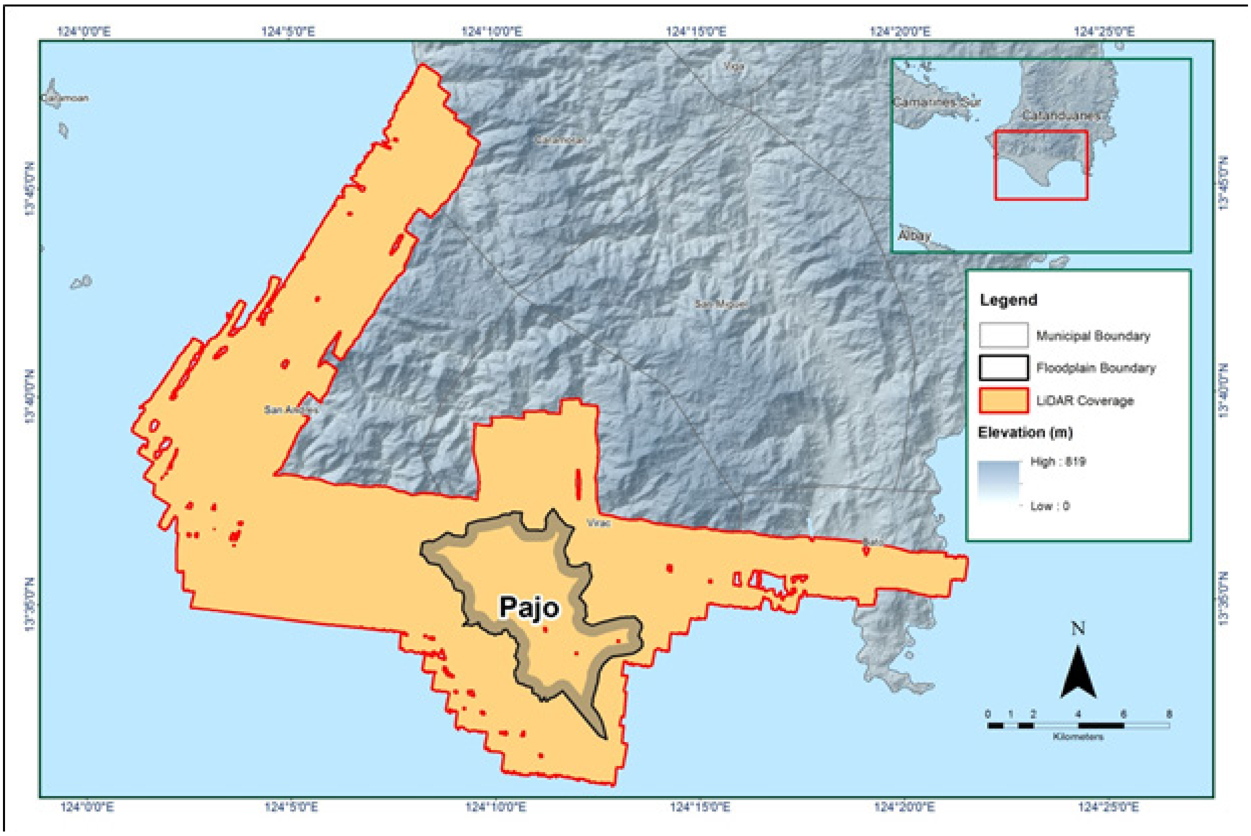


Figure 12. Boundary of the processed LiDAR data over Pajo Floodplain

The total area covered by the Pajo missions is 435.90 sq.km that is comprised of four (4) flight acquisitions grouped and merged into four (4) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for Pajo Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Catanduanes_Blk25A	3010P	152.32
	3028P	
Catanduanes_Blk25A_ supplement	3012P	98.48
Catanduanes_Blk25H_additional	3016P	102.41
Catanduanes_Blk25H_additional	3010P	82.69
TOTAL		**435.90 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 13. Since the Pegasus channel employs two channels, an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines are expected.

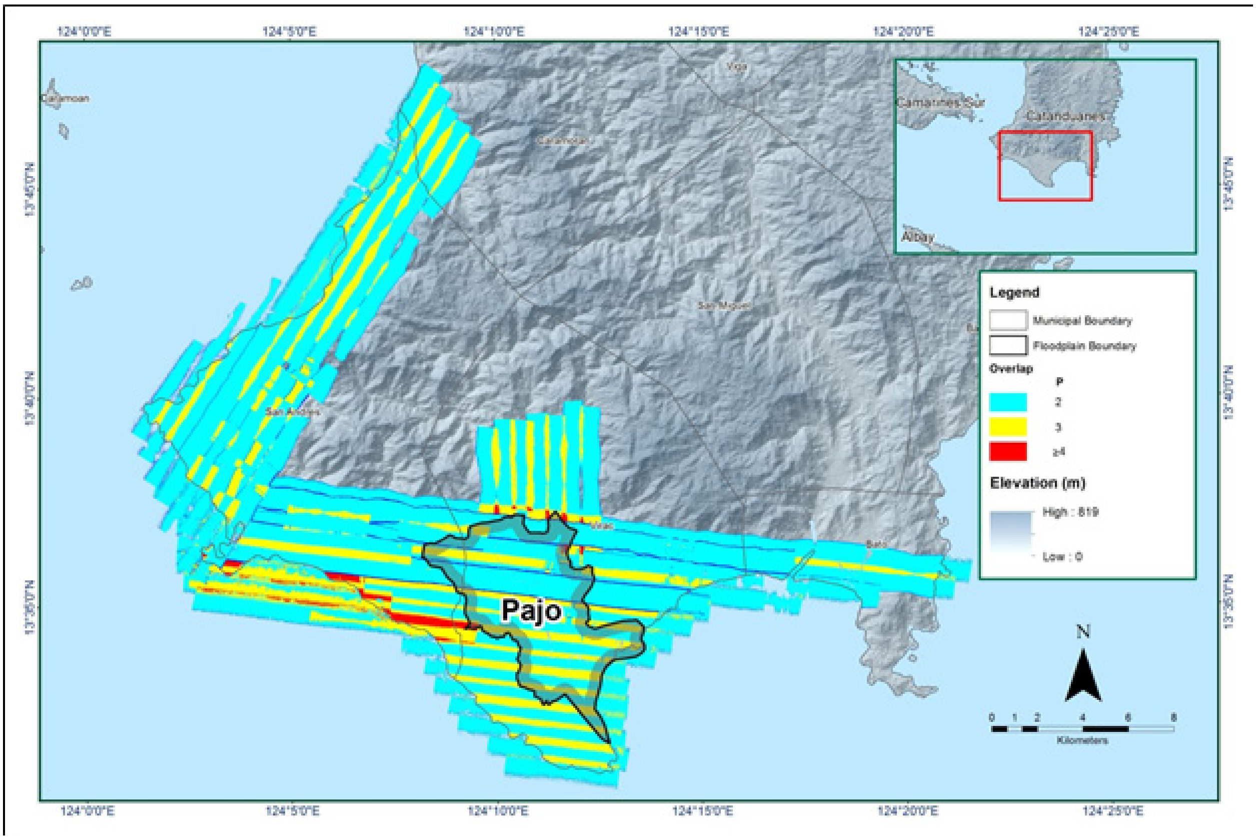


Figure 13. Image of data overlap for Pajo Floodplain

The overlap statistics per block for the Pajo 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 36.06%, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 14. It was determined that all LiDAR data for Pajo Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.09 points per square meter.

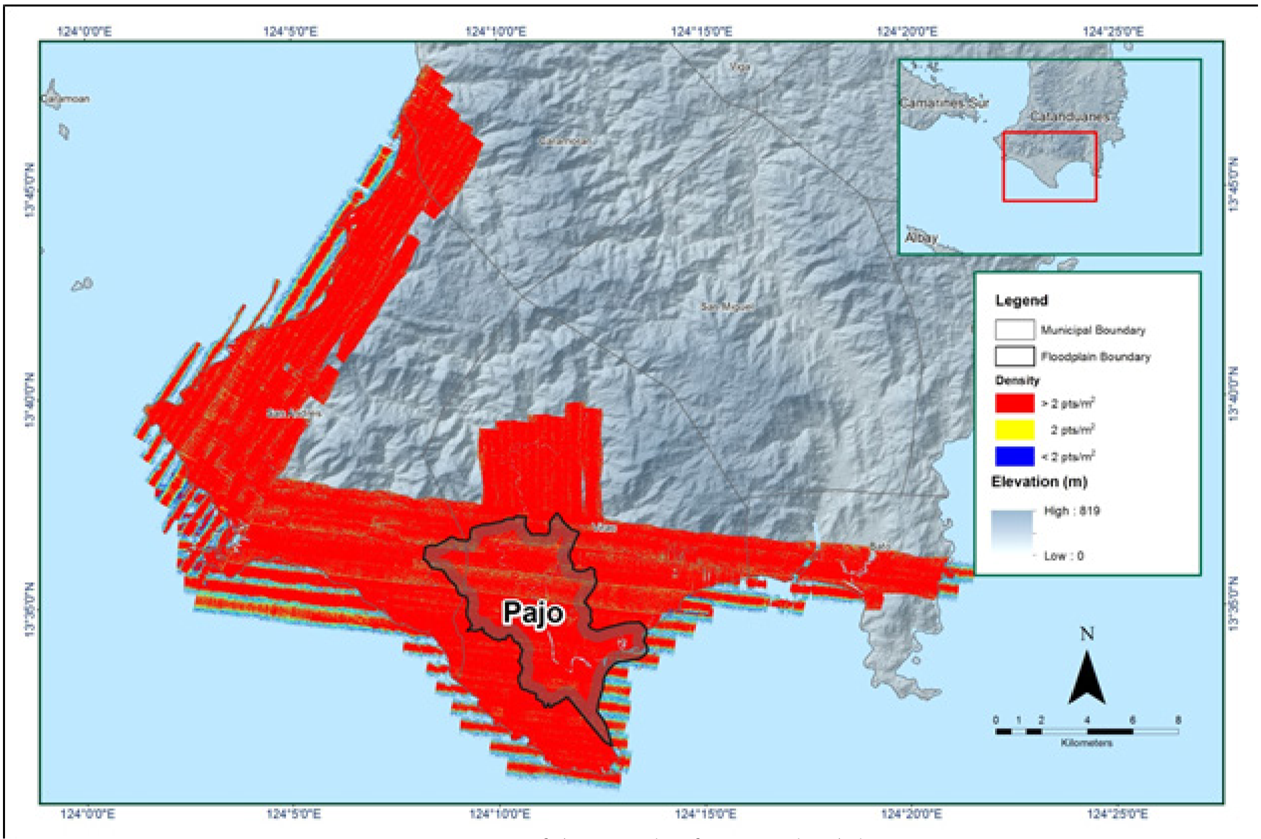


Figure 13. Image of data overlap for Pajo Floodplainv

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. 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.

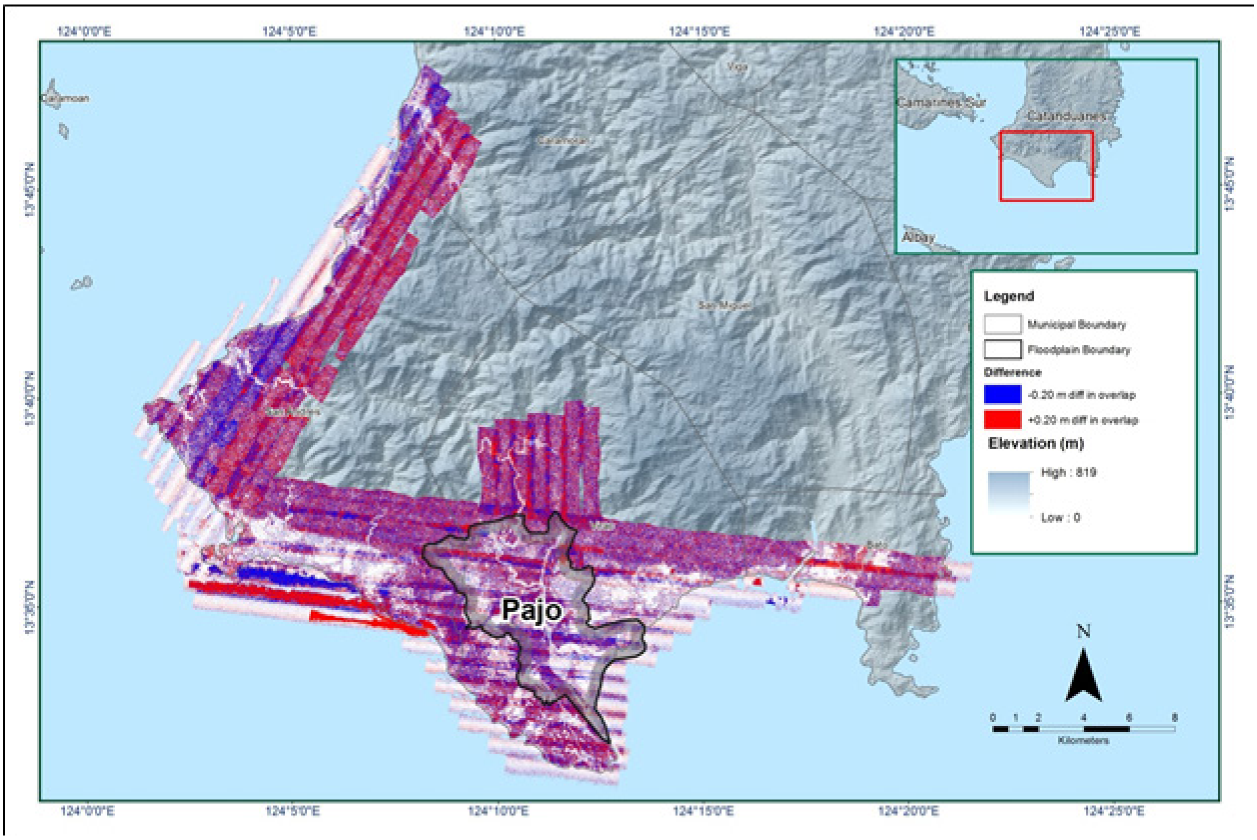


Figure 15. Elevation difference map between flight lines for Pajo Floodplain.

A screen capture of the processed LAS data from a Pajo flight 3028P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

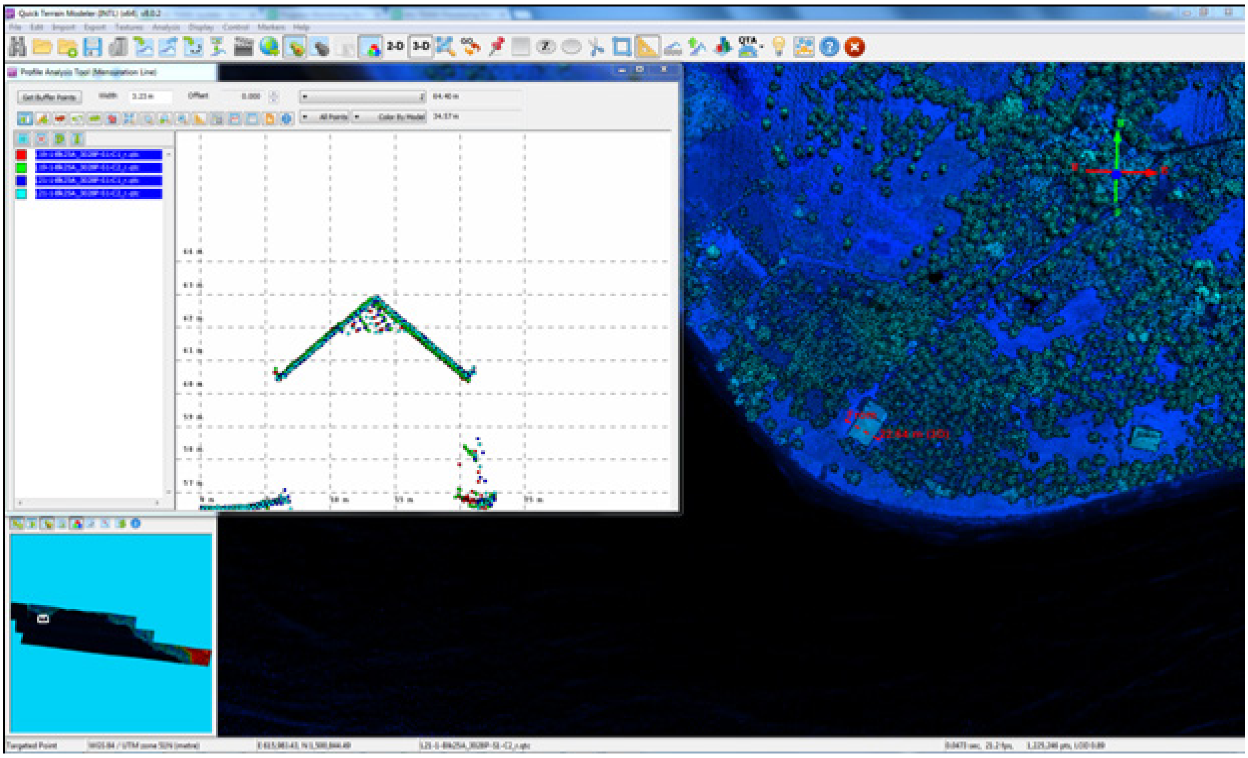


Figure 16. Quality checking for a Pajo flight 3028P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Pajo classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	289,239,547
Low Vegetation	145,162,515
Medium Vegetation	341,096,354
High Vegetation	1,510,621,817
Building	31,745,955

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Pajo Floodplain is shown in Figure 17. A total of 670 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 773.03 meters and 47.95 meters, respectively.

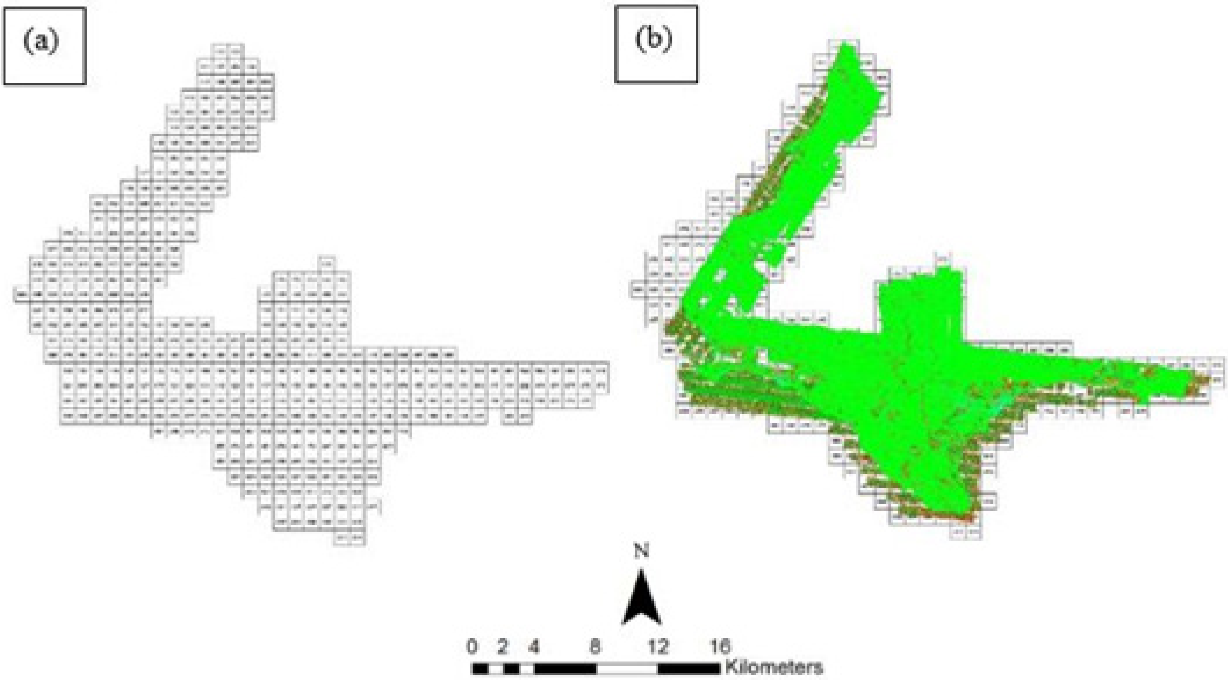


Figure 19. The coverage of the Pajo Floodplain Survey (a) the tile system (b) depicts the classification results in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 18. 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.

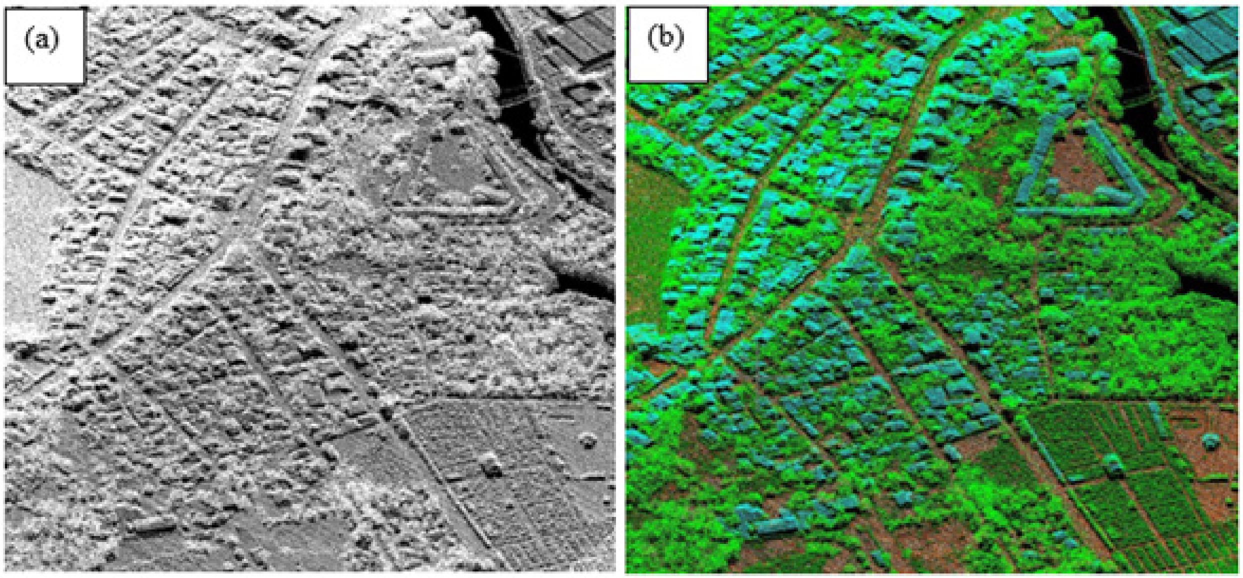


Figure 18. Point cloud before (a) and after (b) classification.

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

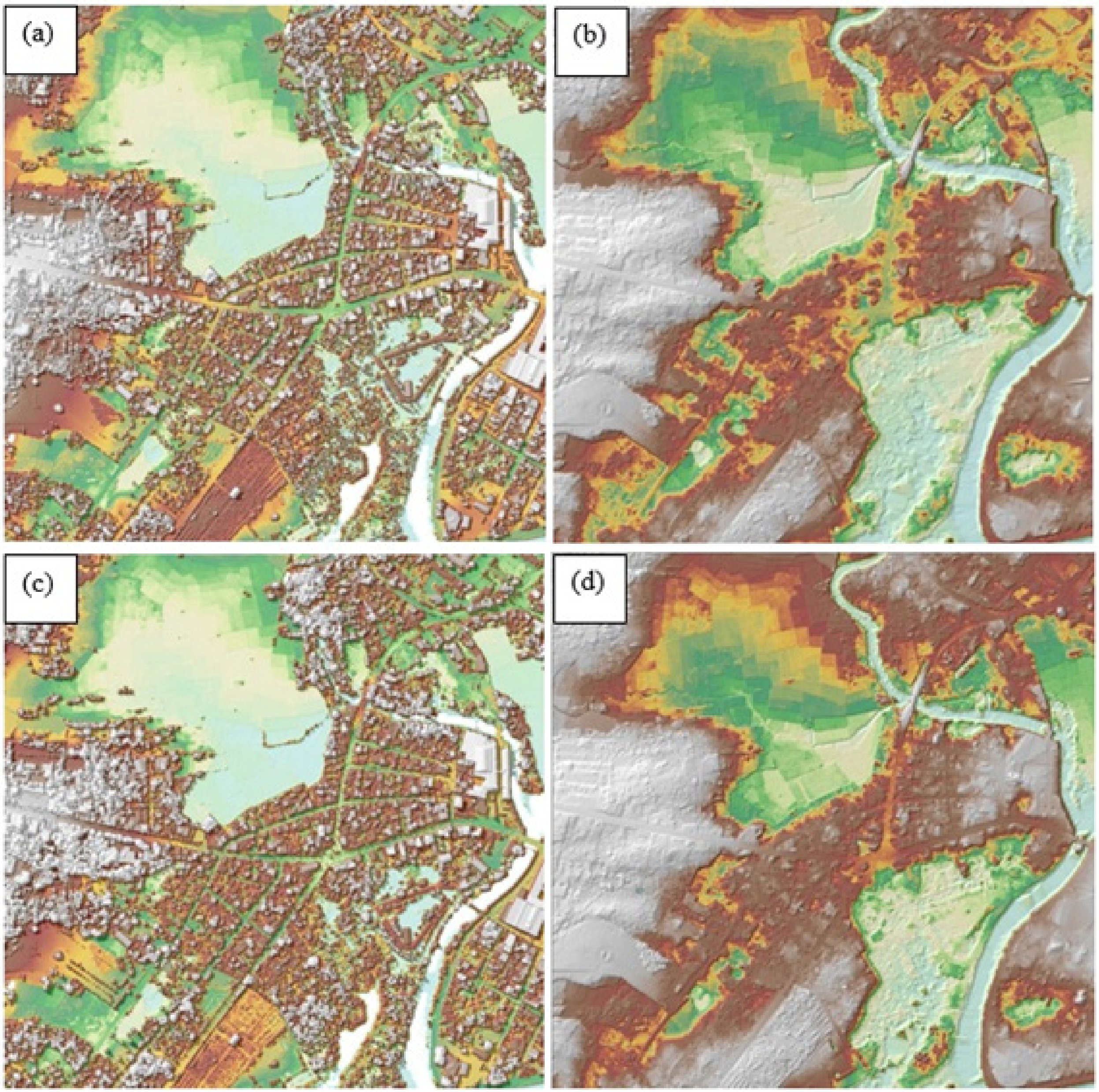


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Pajo Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 143 1km by 1km tiles area covered by Pajo Floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Pajo Floodplain has a total of 92.231 sq.km orthophotogaph coverage comprised of 227 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

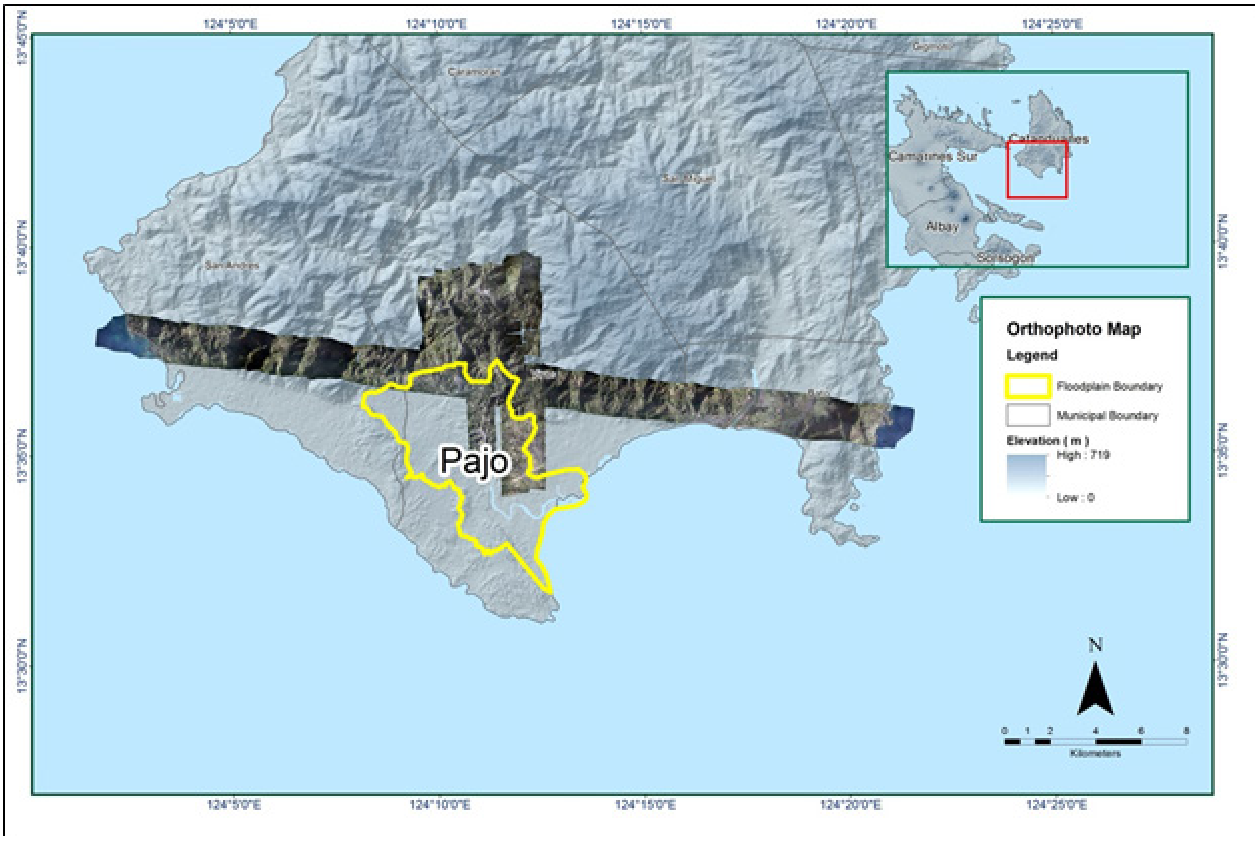


Figure 20. Pajo Floodplain with available orthophotographs

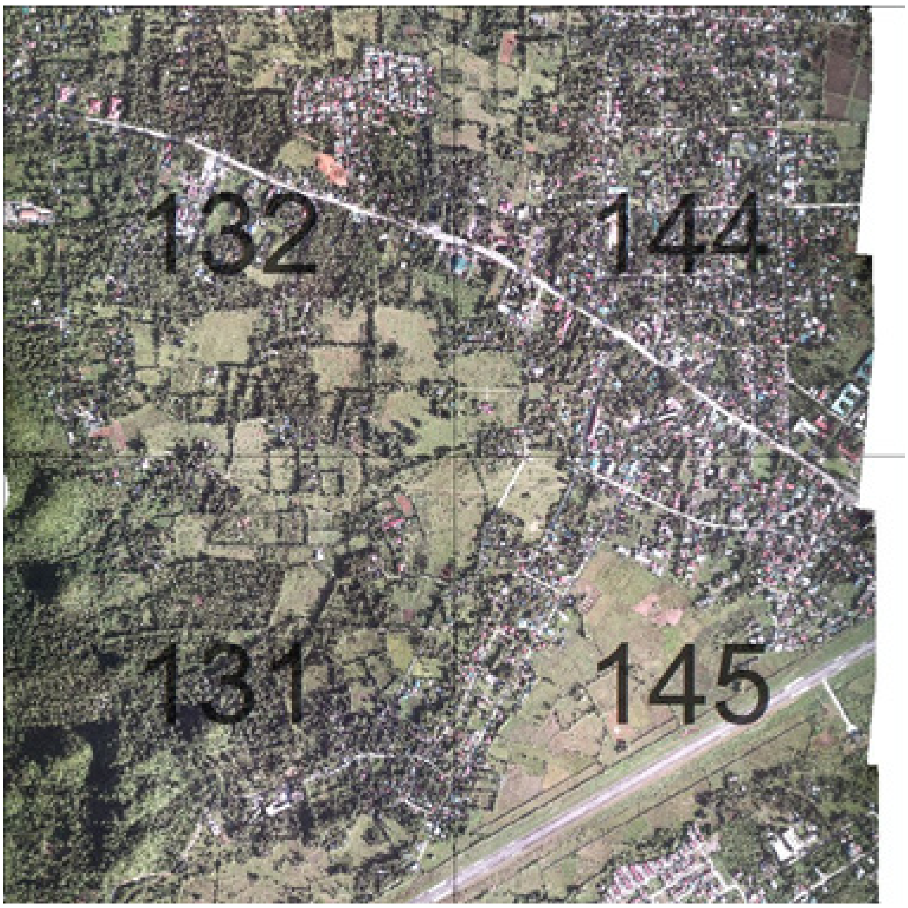


Figure 21. Sample orthophotograph tiles for Pajo Floodplain

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Pajo Floodplain. These blocks are composed of Catanduanes blocks with a total area of 435.90 sq. km. Table 13 shows the name and corresponding area of each block in square kilometers.

LiDAR Blocks	Area (sq.km)
Catanduanes_Blk25A	152.32
Catanduanes_BlK25A_supplement	98.48
Catanduanes_Blk25H_additional	102.41
Catanduanes_Blk25H	82.69
TOTAL	435.90 sq. km

Portions of DTM before and after manual editing are shown in Figure 22. The bridge (Figure 22a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 22b) in order to hydrologically correct the river. The paddy field (Figure 22c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 22d) to allow the correct flow of water. Another example is a building that is still present in the DTM after classification (Figure 22e) and has to be removed through manual editing (Figure 22f).

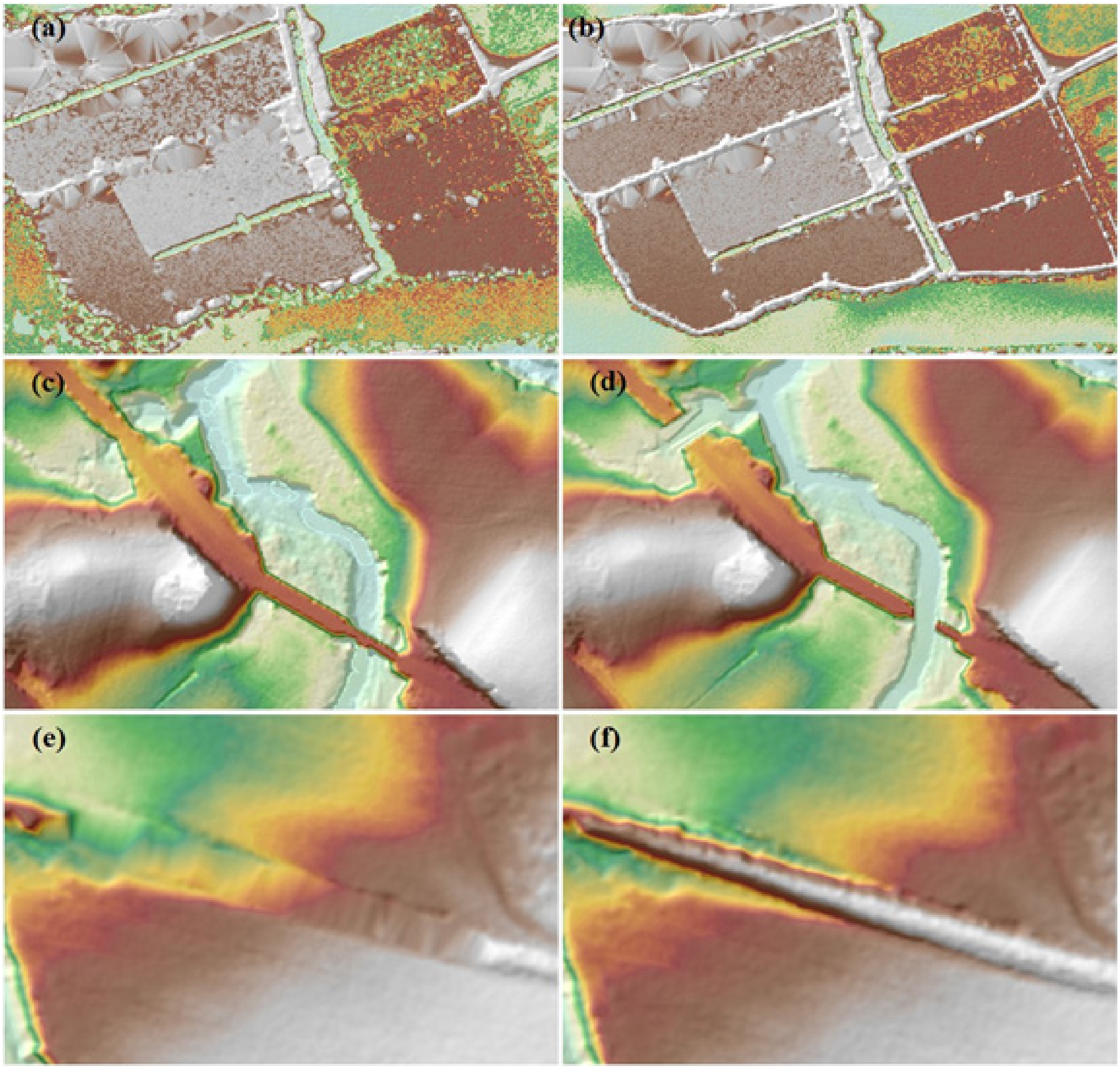


Figure 22. Portions in the DTM of Pajo Floodplain a hilltop before (a) and after (b) data retrieval; a bridge before (c) and after (d) manual editing; and a building before (e) and after (f) manual editing

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Catanduanes DEM overlapping with the blocks to be mosaicked. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Pajo Floodplain is shown in Figure 23. It can be seen that the entire Pajo Floodplain is 100% covered by LiDAR data.

Table 14. Shift Values of each LiDAR Block of Pajo Floodplain

Mission Blocks	**Shift Values (meters)**		
	x	**y**	**z**
Catanduanes_Blk25A	0.00	-1.00	-0.01
Catanduanes_BlK25A_supplement	0.00	0.00	-0.11
Catanduanes_Blk25H_additional	0.00	-1.00	-1.60
Catanduanes_Blk25H	0.00	0.00	-1.44

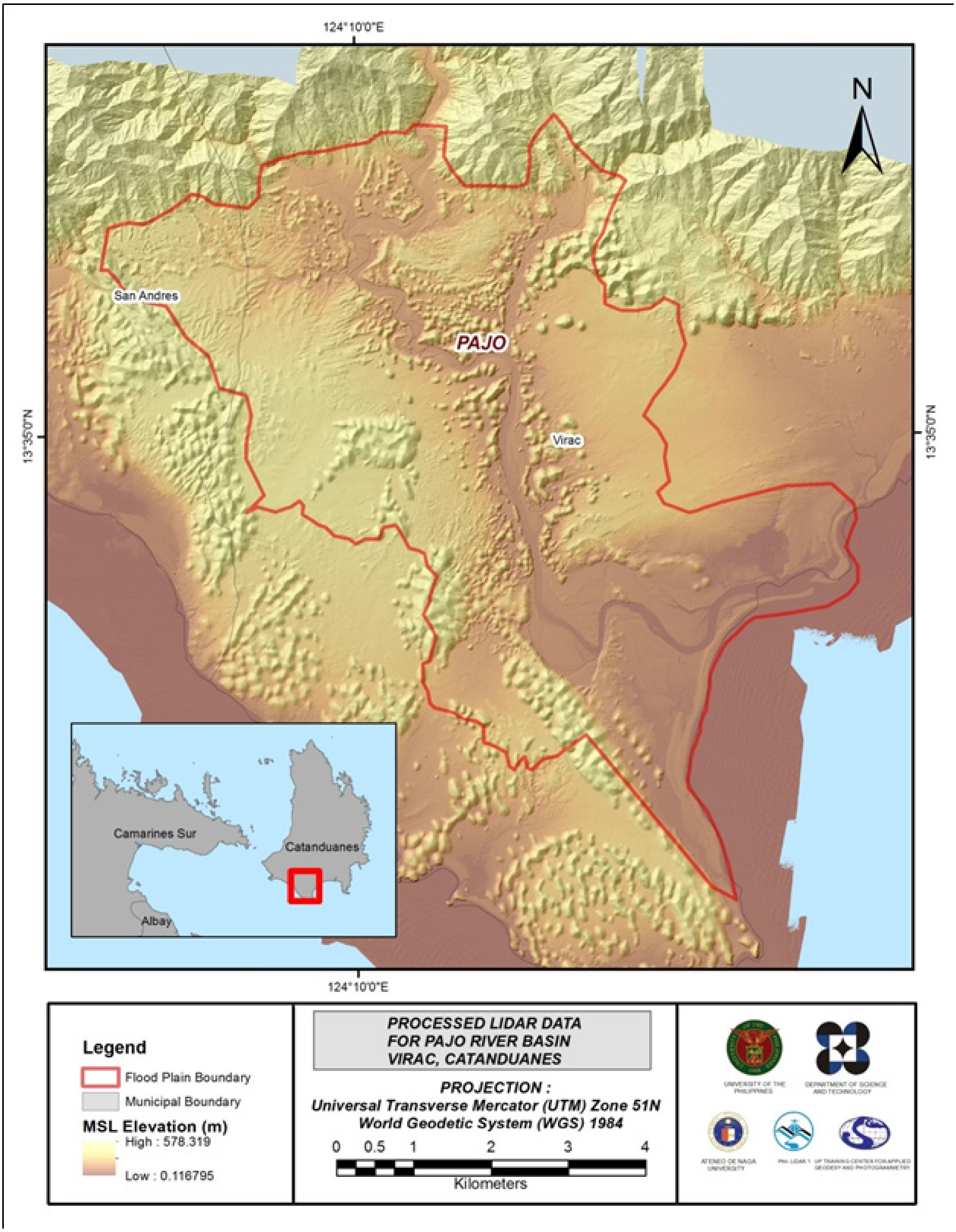


Figure 23. Map of Processed LiDAR Data for Pajo Floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Pajo to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 5,196 survey points were used for calibration and validation of Pajo LiDAR data. Random selection of 80% of the survey points, resulting in 4,782 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 25. 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 1.42 meters with a standard deviation of 0.10 meters. Calibration of Pajo LiDAR data was done by subtracting the height difference value, 1.42 meters, to Pajo mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

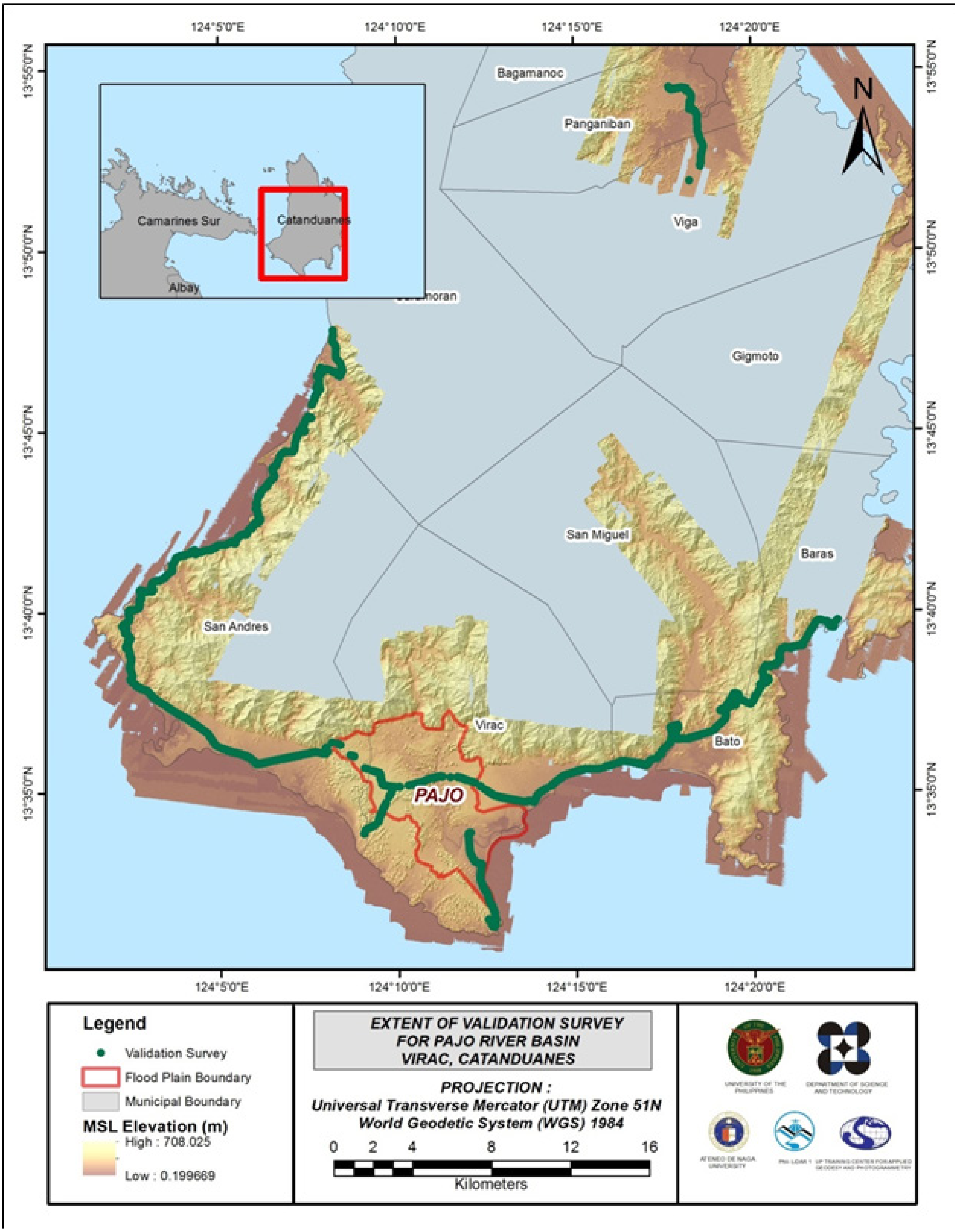


Figure 26. Map of Pajo Floodplain with validation survey points in green.

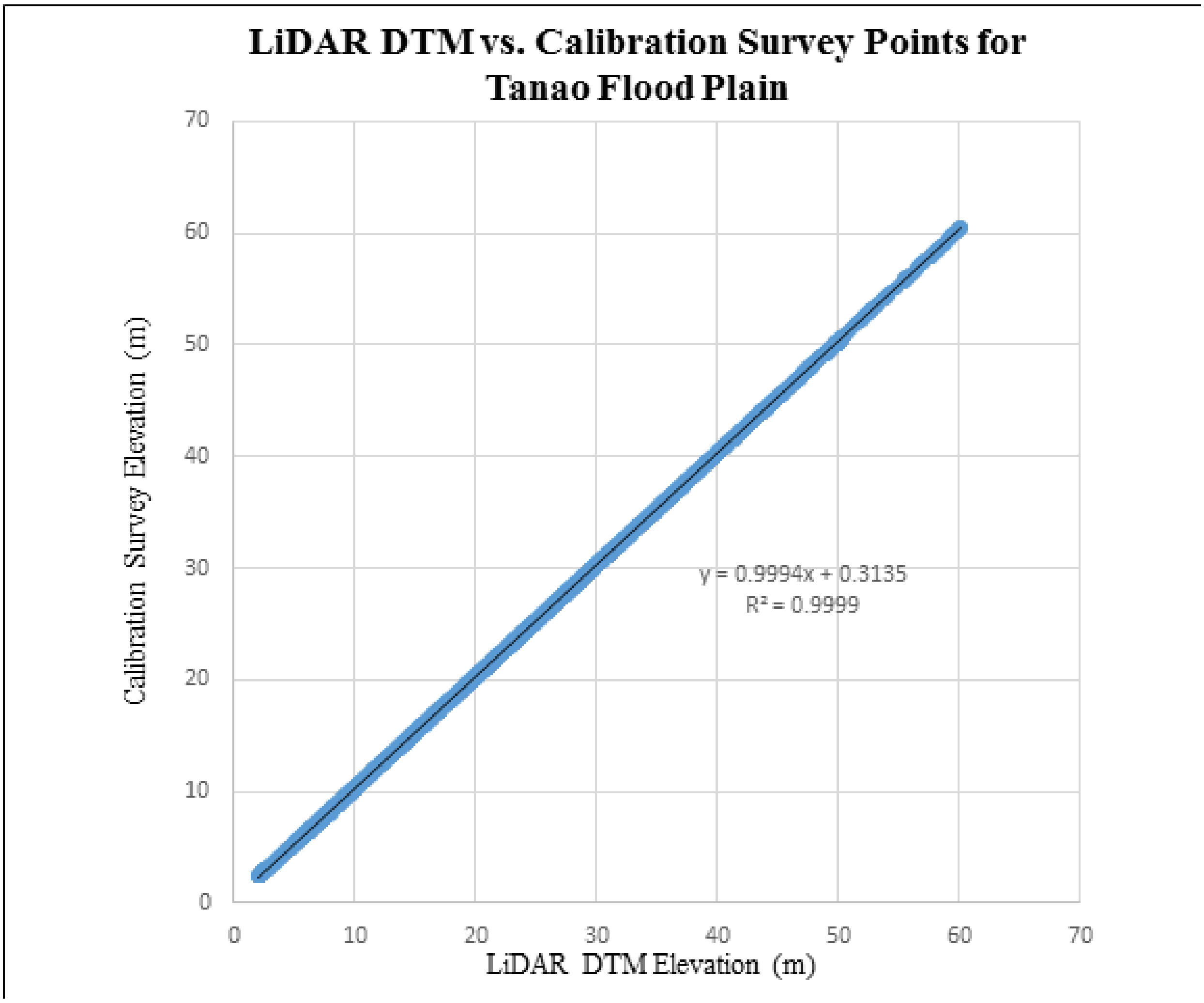


Figure 24. Map of Pajo Floodplain with validation survey points in green

Table 15. Calibration Statistical Measure.

Calibration Statistical Measures	Value (meters)
Height Difference	1.42
Standard Deviation	0.10
Average	-1.42
Minimum	-1.63
Maximum	-1.21

The remaining 20% of the total survey points, resulting in 265 points, were used for the validation of calibrated Pajo 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 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.19meters with a standard deviation of 0.04meters, as shown in Table 16.

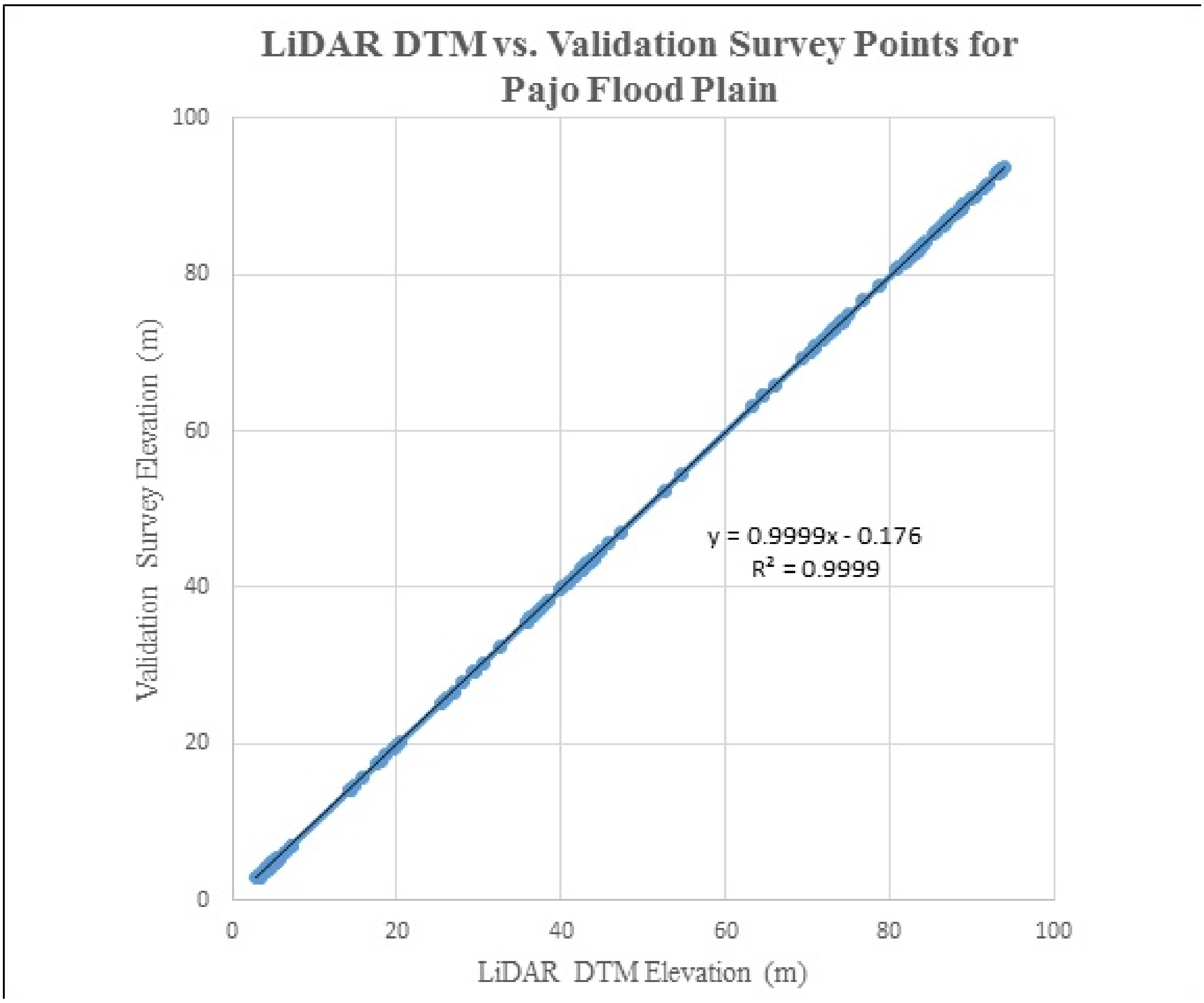


Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 16. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.19
Standard Deviation	0.04
Average	0.18
Minimum	0.10
Maximum	0.26

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Pajo with 7,164 bathymetric survey points. The resulting raster surface produced was done by Kernel interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.16 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Pajo integrated with the processed LiDAR DEM is shown in Figure 27.

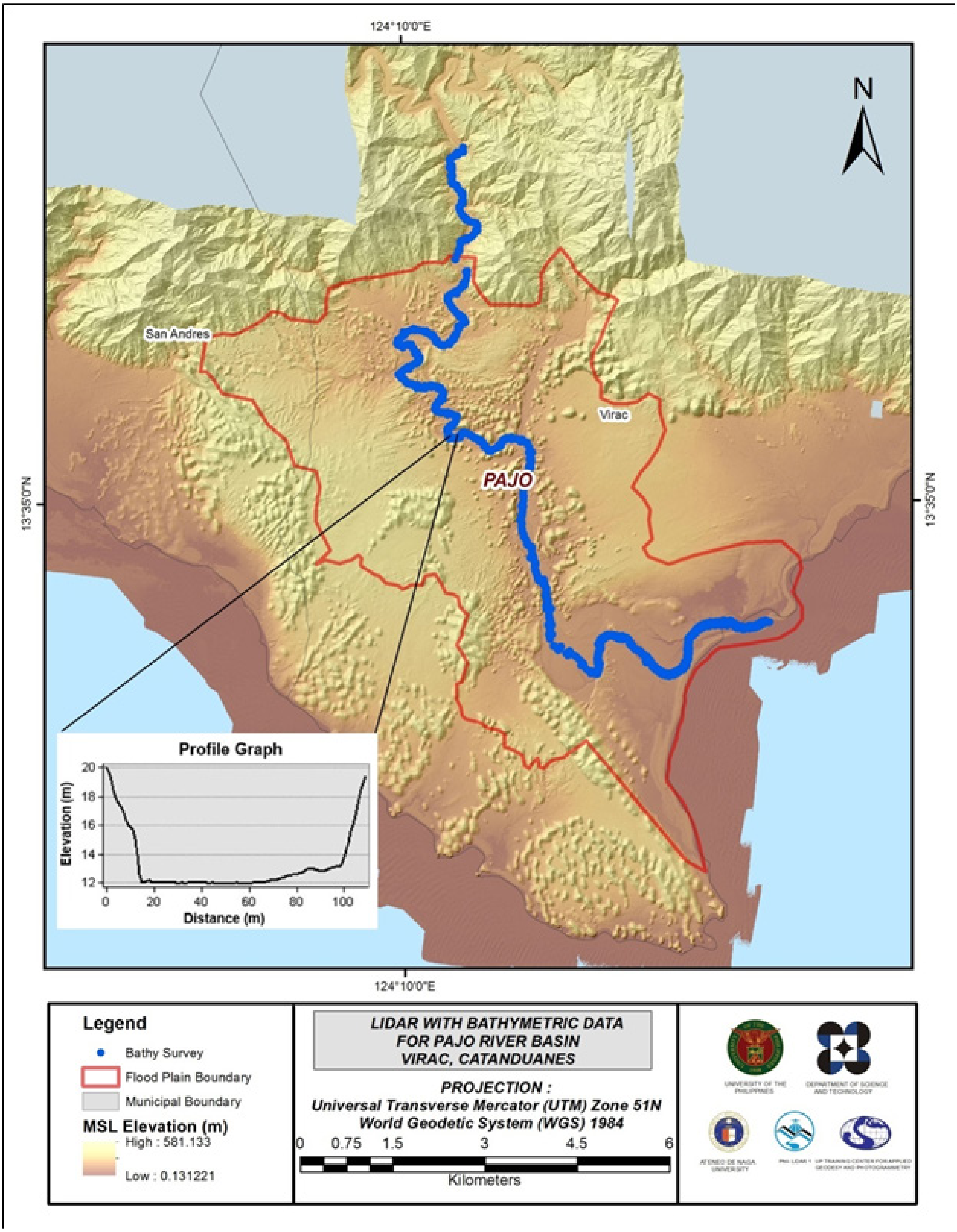


Figure 27. Map of Pajo Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges and water bodies within the floodplain area with 200 m buffer zone. Mosaicked LiDAR DEM with 1 m resolution was used to delineate footprints of building features, 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

Pajo Floodplain, including its 200 m buffer, has a total area of 42.11 sq km. For this area, a total of 0.6337 sq km, corresponding to a total of 7,904 building features, are considered for QC. Figure 28 shows the QC blocks for Pajo Floodplain.

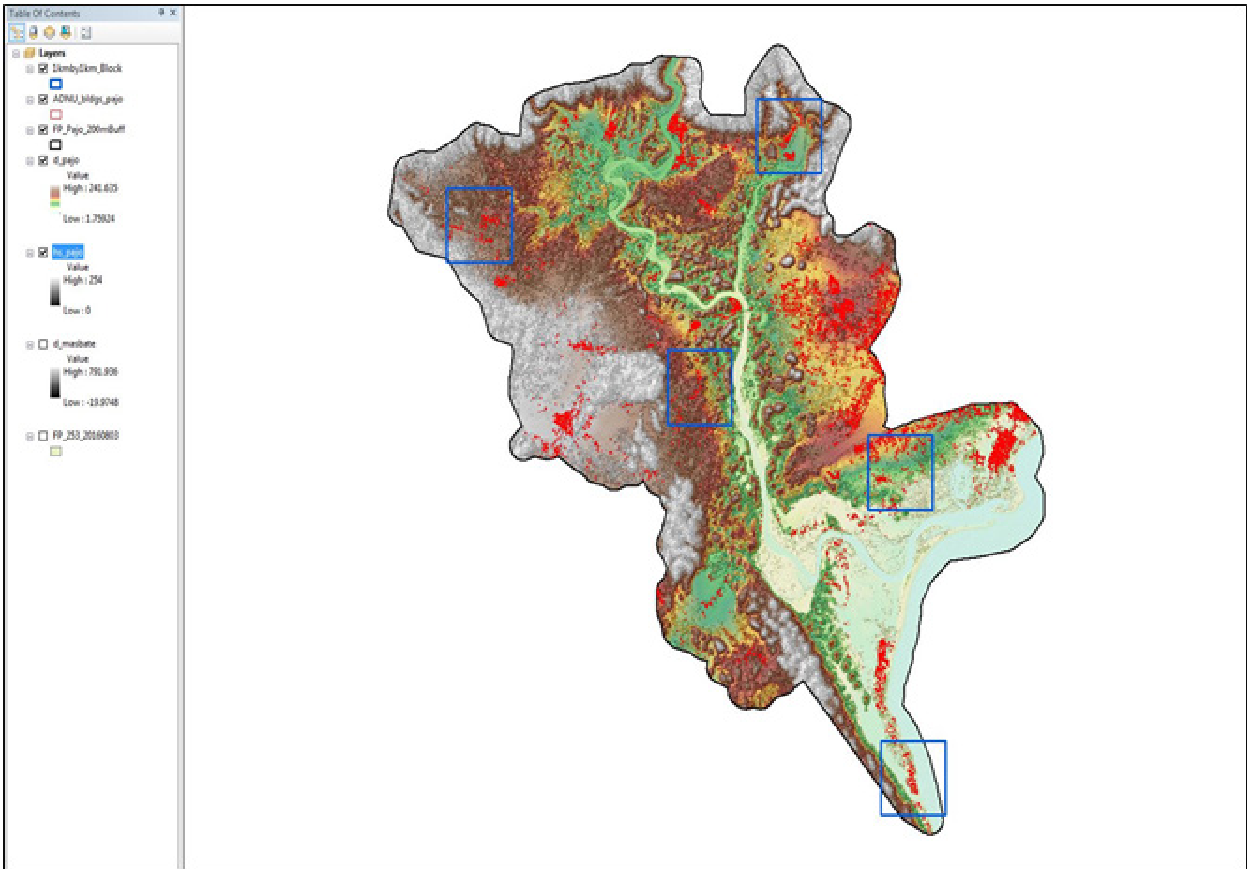


Figure 28. Blocks (in blue) of Pajo building features that were subjected in QC

Quality checking of Pajo building features resulted in the ratings shown in Table 17.

Table 19. Details of the quality checking ratings for the building features extracted for the Pajo River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Pajo	93.61	93.98	80.44	PASSED

3.12.2 Height Extraction

Height extraction was done for 7,949 building features in Pajo Floodplain. Of these building features, 45 were filtered out after height extraction, resulting in 7,904 buildings with height attributes. The lowest building height is at 2.00 m while the highest building is at 10.32 m.

3.12.3 Feature Attribution

Feature Attribution was done for 7,904 building features in Pajo 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 members of 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)[1] app was developed to supplement and increase the field gathering procedures being done by the AdNU 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 18 summarizes the number of building features per type. On the other hand, Table 19 shows the total length of each road type while Table 20 shows the number of water features extracted per type.

Table 18. Building Features Extracted for Pajo Floodplain

Facility Type	No. of Features
Residential	7615
School	129
Market	0
Agricultural/Agro-Industrial Facilities	13
Medical Institutions	16
Barangay Hall	24
Military Institution	1
Sports Center/Gymnasium/Covered Court	1
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	8
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	2
Water Supply/Sewerage	0
Religious Institutions	0
Bank	41
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	0
Other Commercial Establishments	31
Residential	23
Total	7904

Table 19. Total Length of Extracted Roads for Pajo Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Pajo	82.89363	4.05179	0	14.3749	0.00	

Table 20. Number of Extracted Water Bodies for Pajo Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Pajo	1	13	0	0	0	14

A total of 6 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 29 shows the Digital Surface Model (DSM) of Pajo Floodplain overlaid with its ground features.

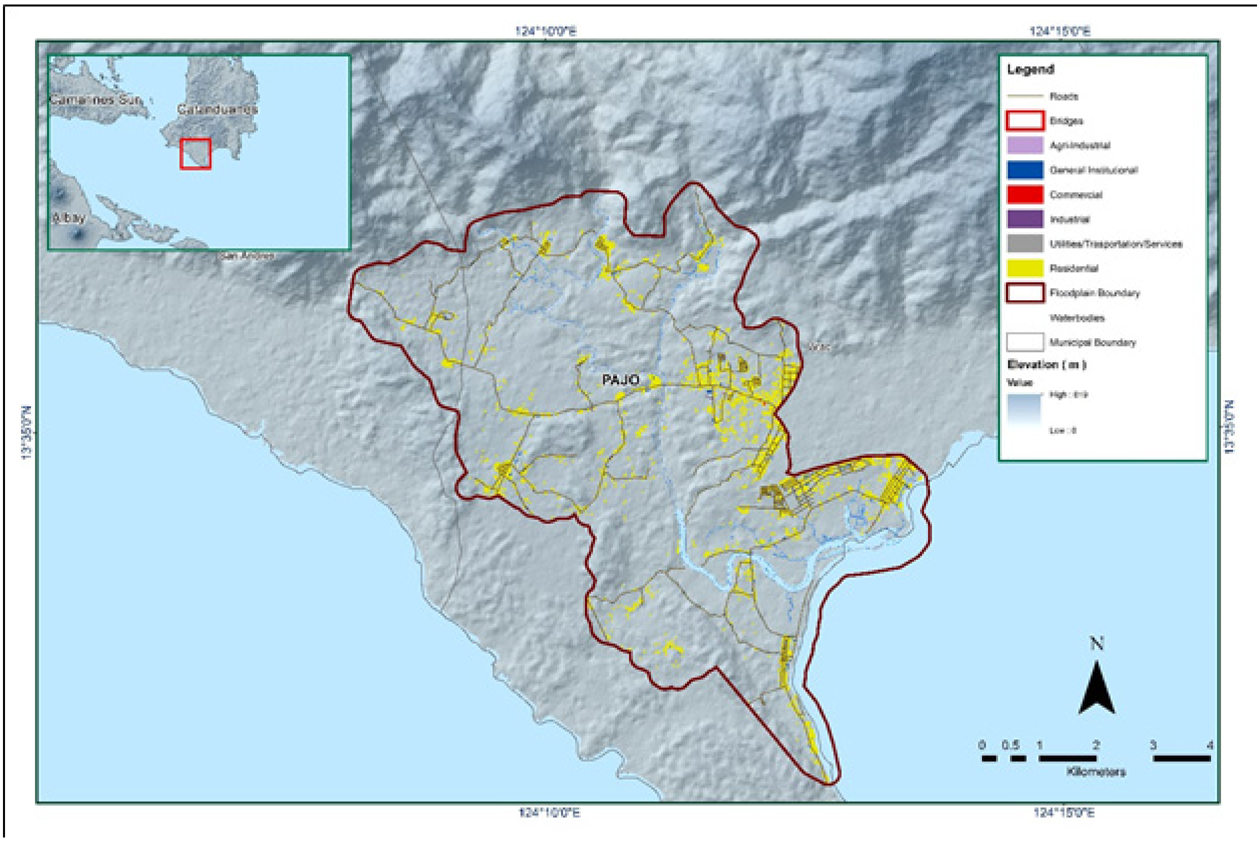


Figure 29. Extracted features for Pajo Floodplain

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, For. Rodel C. Alberto, Cybil Claire Atacador, Engr. Lorenz R. Taguse, Engr. Bien,

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

4.1 Summary of Activities

The DVBC conducted a field survey in Pajo River on April 8 to 22, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built survey at Marcos Bridge in Brgy. Bigaa; validation points acquisition of about 87 km covering the Pajo River Basin area; and bathymetric survey from its upstream in Brgy. Hicming, in Municipality of Virac down to the mouth of the river in Brgy. Palnab Del Sur, also in Municipality of Virac, with an approximate length of 18.314 km usingOhmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique as shown in Figure 30.

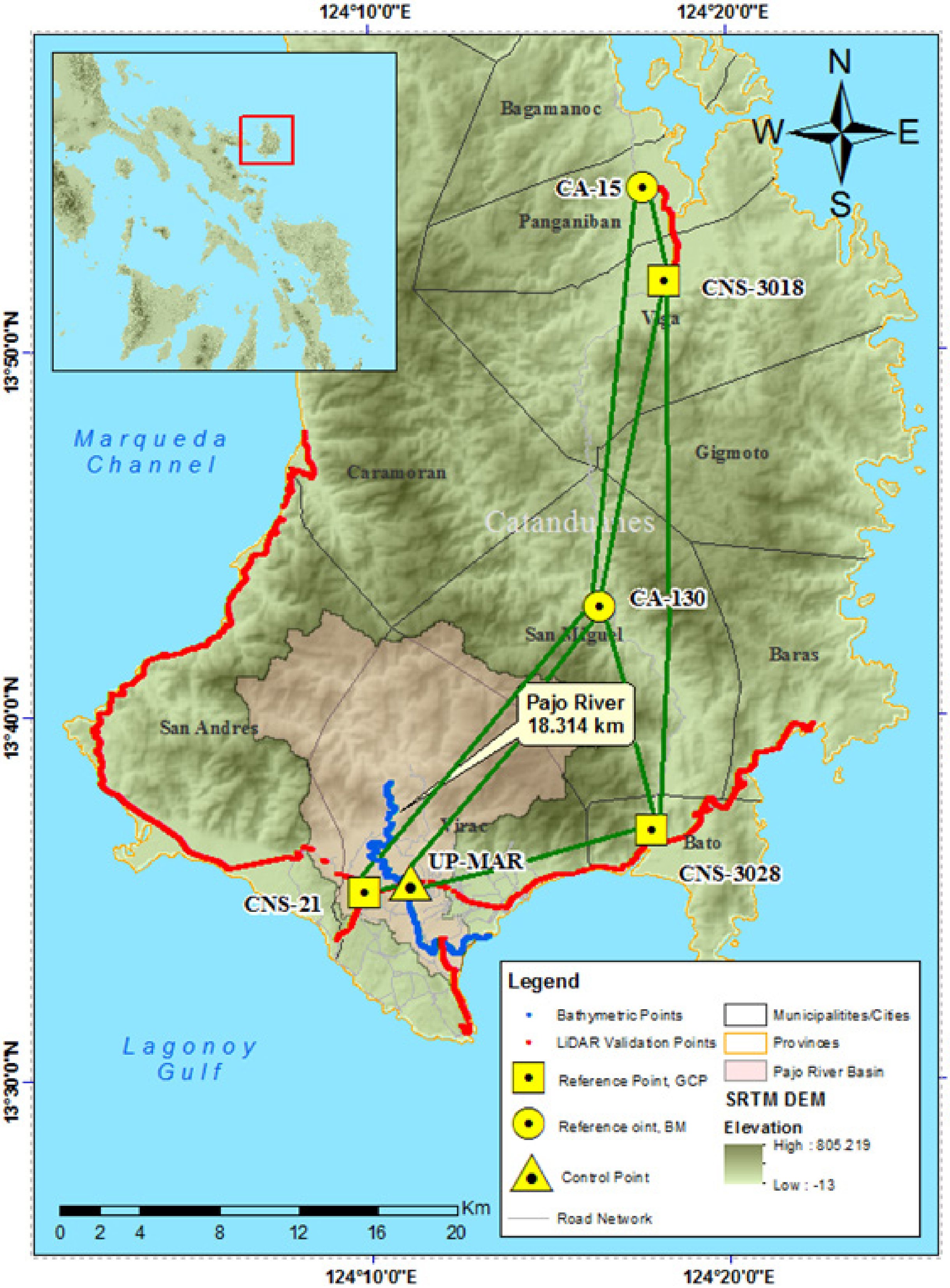


Figure 30. Extent of the bathymetric survey (in blue line) in Pajo River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for Pajo River Basin is composed of four (4) loops established on April 9 and 10, 2016 occupying the following reference points: CNS-21, a second-order GCP, in Brgy. Palta Small, Municipality of Virac; and CA-130, a first order BM in Brgy. Balatohan, Municipality of San Miguel.

The UP established control point UP-MAR located at the approach of Marcos Bridge in Brgy.Bigaa, Municipality of Virac; and NAMRIA established control points, namely CA-15 in Brgy. Sta. Maria, Municipality of Panganiban, CNS-3018 in Brgy. San Isidro, Muncipality of Viga, and CNS-3028 in Brgy. Tilis, in Municipality of Bato; were also occupied and used as marker for the network.

The summary of reference and control points and its location is summarized in Table 21 while GNSS network established is illustrated in Figure 31.

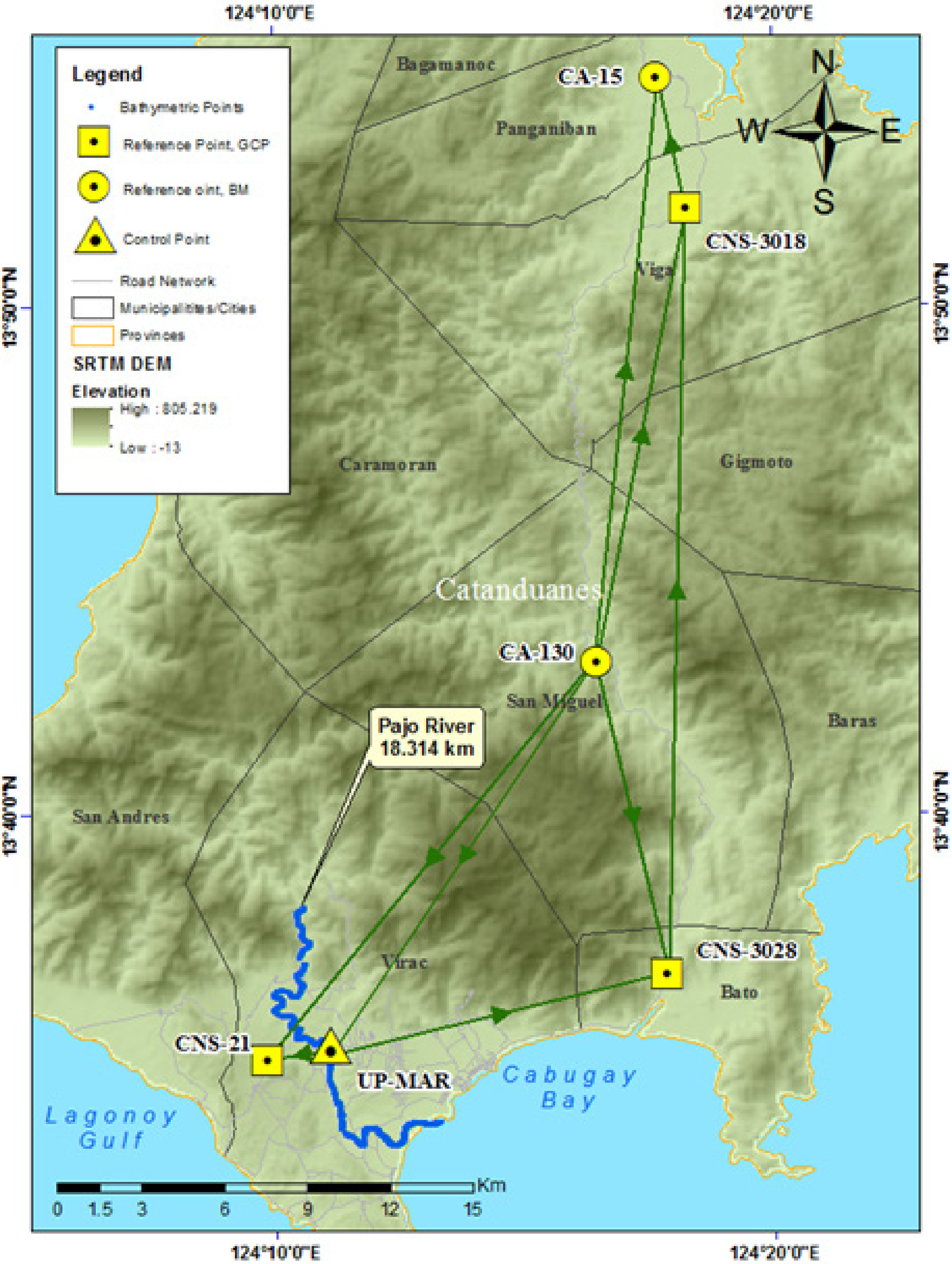


Table 21. List of reference and control points occupied for Pajo River Survey (Source: NAMRIA, UP-TCAGP)

Table 23. References used and control points established in the Pajo River Survey (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
CNS-21	2nd Order, GCP	13°35'09.45275" N	124°09'50.36457"	136.082	-	2007
CA-130	1st order Order, BM	-	-	90.506	37.6703	2008
CA-15	Used as Marker	-	-	-	-	2008
CNS-3018	Used as Marker	-	-	-	-	2007
CNS-3028	Used as Marker	-	-	-	-	2007
UP-MAR	UP Established	-	-	-	-	04-09-06

The GNSS set-ups made in the location of the reference and control points are shown in Figure 32 to Figure 37.

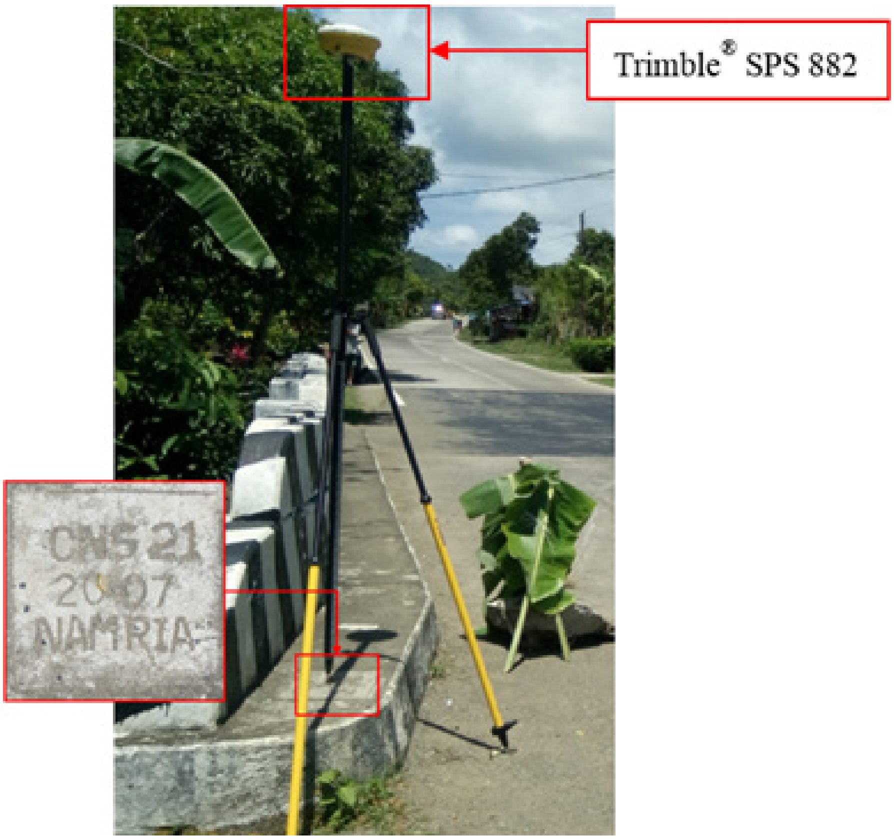


Figure 32. GNSS base set-up, Trimble® SPS 882, at CNS-21, located at Palta Bridge inBrgy. Palta Small, Municipality of Virac, Catanduanes

Figure 33. GNSS base set-up, Trimble® SPS 882, at CA-130, located at the end of pathwalk in Brgy. Balatohan, Municipality of San Miguel, Catanduanes

Figure 34. GNSS base set-up, Trimble® SPS 882, at CA-15, is located at the approach of the left side of Kanparel Bridge in Brgy. Santa Maria, Municipality of Panganiban, Catanduanes

Figure 35. GNSS base set-up, Trimble® SPS 882, atCNS-3018,located at the approach of Pilot Bridge along Catanduanes Circumferential Road in Brgy. San Isidro, Municipality of Viga, Catanduanes

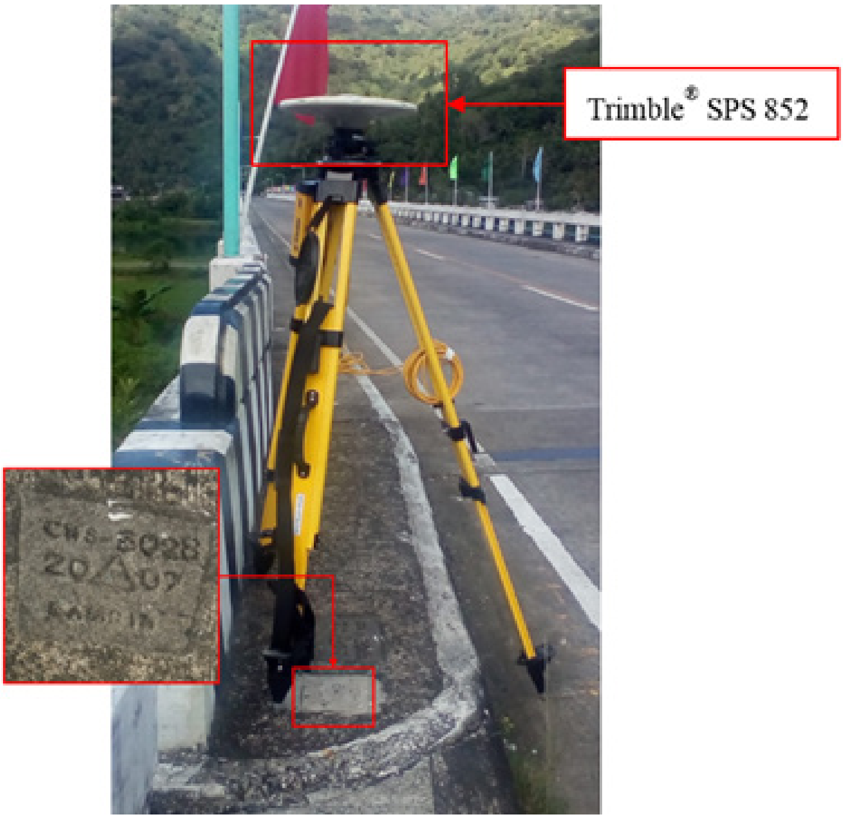


Figure 36. GNSS base set-up, Trimble® SPS 852, at CNS-3028,located at the approach of Bato Bridge along Catanduanes Circumferential Road in Brgy. Tilis, Municipality of Bato, Catanduanes

Figure 37. GNSS base set up, Trimble® SPS 852, at UP-MAR, located at the approach of the right side of Marcos Bridge in Brgy. Bigaa, Municipality of Virac, Catanduanes

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 was 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 Pajo River Basin is summarized in Table 22 generated by TBC software.

Table 22. Baseline Processing Report for Pajo River Basin Static Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
CNS-3018--- CA-15	04-10-16	Fixed	0.003	0.016	347°50'15"	4831.606	
CNS-3028--- CNS-3018	04-10-16	Fixed	0.002	0.014	1°35'28"	27798.226	
CA-130 --- CNS-3028	04-09-16	Fixed	0.004	0.024	167°24'47"	11614.119	
CNS-3028--- CA-130	04-09-16	Fixed	0.003	0.012	167°24'48"	11614.112	
CA-130 --- CNS-21	04-09-16	Fixed	0.003	0.016	219°31'42"	18701.297	
CA-130 --- CA-15	04-10-16	Fixed	0.003	0.006	6°08'58"	21298.173	
CA-130 --- CNS-3018	04-10-16	Fixed	0.003	0.015	11°20'31"	16780.283	
CA-130 --- CNS-3018	04-10-16	Fixed	0.003	0.014	11°20'31"	16780.296	
UP-MAR --- CNS-3028	04-09-16	Fixed	0.004	0.023	78°00'02"	12411.353	
UP-MAR --- CA-130	04-09-16	Fixed	0.003	0.011	34°37'02"	16907.625	
UP-MAR --- CNS-21	04-09-16	Fixed	0.002	0.009	77°20'46"	2349.293	

As shown in Table 22, a total of eleven (11) baselines were processed with reference points CNS-21 fixed for grid values; and CA-130 held fixed for elevation. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

For complete details, see the Network Adjustment Report shown in Table 26 to Table 29.

The six (6) control points, CNS-21, CA-130, CA-15, CNS-3018, CNS-3028, and UP-MAR were occupied and observed simultaneously to form a GNSS loop. Elevation value of CA-130 and coordinates of point CNS-21 were held fixed during the processing of the control points as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 25. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
CNS-21	Local	Fixed	Fixed		
CA-130	Grid				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 24. The fixed control points CNS-21 and CA-130 have no values for grid and elevation errors, respectively.

Table 24. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
CNS-21	625929.75	?	1502236.721	?	83.792	0.087	LL
CA-130	637754.30	0.014	1516720.821	0.012	37.67	?	e
CA-15	639923.02	0.020	1537904.832	0.017	9.219	0.048	
CNS-3018	640966.62	0.017	1533188.045	0.014	9.300	0.067	
CNS-3028	640344.33	0.018	1505401.099	0.014	12.262	0.073	
UP-MAR	628219.04	0.012	1502762.192	0.010	20.754	0.074	

The network is fixed at reference point CNS-21with known coordinates, and CA-130 with known elevation. As shown in Table 24, the standard errors (xe and ye) of CA-130 are 1.40 cm and 1.2 cm; CA-15 are 2.0 cm and 1.7 cm; CNS-3018 are 1.7cm and 1.40 cm; CNS-3028 are 1.80 cm and 1.40 cm; and UP-MAR are 1.20 cm and 1 cm. With the mentioned equation, <20cm for horizontal and z_e<10 cm for the vertical; the computation for the accuracy are as follows:

CNS-21
horizontal accuracy = Fixed
vertical accuracy = 8.7 cm < 10 cm

CA-130
horizontal accuracy = $\sqrt{((1.40)^2 + (1.20)^2}$
= $\sqrt{(1.96 + 1.44)}$
= 1.84cm < 20 cm
vertical accuracy = Fixed

CA-15
horizontal accuracy = $\sqrt{((2.0)^2 + (1.70)^2}$
= $\sqrt{(4+ 2.89)}$
= 2.62cm < 20 cm
vertical accuracy = 4.8 cm < 10 cm

CNS-3018
horizontal accuracy = $\sqrt{((1.70)^2 + (1.40)^2}$
= $\sqrt{(2.89 + 1.96)}$
= 2.20cm < 20 cm
vertical accuracy = 6.7cm < 10 cm

CNS-3028
horizontal accuracy = $\sqrt{((1.80)^2 + (1.40)^2}$
= $\sqrt{(3.24+ 1.96)}$
= 2.28cm < 20 cm
vertical accuracy = 7.3cm < 10 cm

UP-MAR
horizontal accuracy = $\sqrt{((1.20)^2 + (1.00)^2}$
= $\sqrt{(1.44 + 1.00)}$
= 1.56 cm < 20 cm
vertical accuracy = 7.4 cm < 10 cm

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

Table 24. Adjusted geodetic coordinates for control points used in the Pajo River Flood Plain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
CNS-21	13°35'09.45275" N	124°09'50.36457" E	136.082	0.087	LL
CA-130	13°42'58.90071" N	124°16'26.29487" E	90.506	?	e
CA-15	13°54'27.92390" N	124°17'42.29172" E	61.912	0.048	
CNS-3018	13°51'54.24025" N	124°18'16.19947" E	62.000	0.067	
CNS-3028	13°36'50.06664" N	124°17'50.49382" E	64.549	0.073	
UP-MAR	13°35'26.19548" N	124°11'06.61522" E	73.091	0.074	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. Based on the result of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 26.

Table 26. The reference and control points utilized in the Pajo River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
CNS-21	2nd Order, GCP	13°35'09.45275"	124°17'42.29172"	61.912	1537904.832	639923.023	9.219
CA-130	1st order Order, BM	13°42'58.90071"	124°16'26.29487"	90.506	1516720.821	637754.301	37.67
CA-15	Used as Marker	13°35'09.45275"	124°09'50.36457"	136.082	1502236.721	625929.746	83.792
CNS-3018	Used as Marker	13°51'54.24025"	124°18'16.19947"	62.000	1533188.045	640966.615	9.300
CNS-3028	Used as Marker	13°36'50.06664"	124°17'50.49382"	64.549	1505401.099	640344.326	12.262
UP-MAR	UP Established	13°35'26.19548"	124°11'06.61522"	73.091	1502762.192	628219.036	20.754

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

Cross-section survey was conducted on April 12 and 20, 2016 at the upstream part of Marcos Bridge in Brgy. Bigaa, Municipality of Virac, using a GNSS receiver, Trimble® SPS 882, in PPK survey technique as shown in Figure 38.

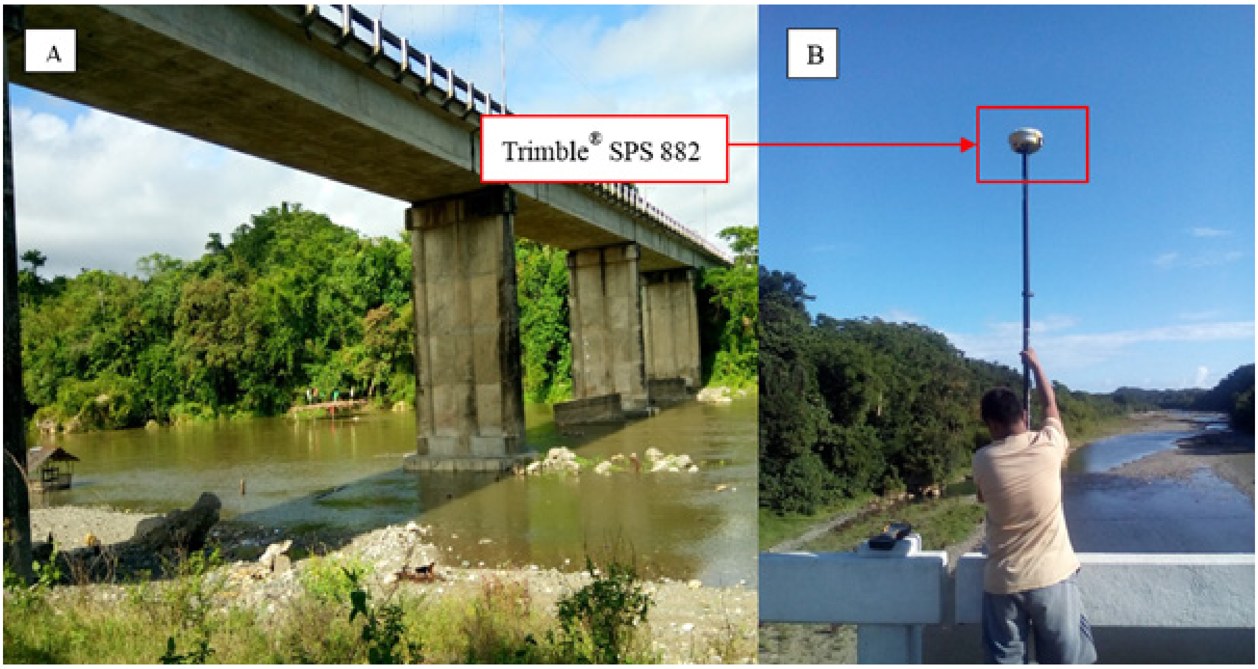


Figure 38. a) Marcos Bridge Panorama downstream side, and B) As-built Survey for Pajo River

The cross-sectional line length of the deployment site is about 335.877m with 26 cross-sectional points acquired using UP-MAR as the GNSS base station. The cross section diagram, location map, and bridge as-built form areillustrated in Figure 39 to Figure 41, respectively.

Water surface elevation in MSL of PajoRiver was determined using Trimble® SPS 882 in PPK mode technique on April 20, 2016 at 11:57AM with a value of 5.755 m in MSL. This was translated onto marking on the bridge pier by the VSU to serve as their reference for flow data gathering and depth gauge deployment for Pajo River.

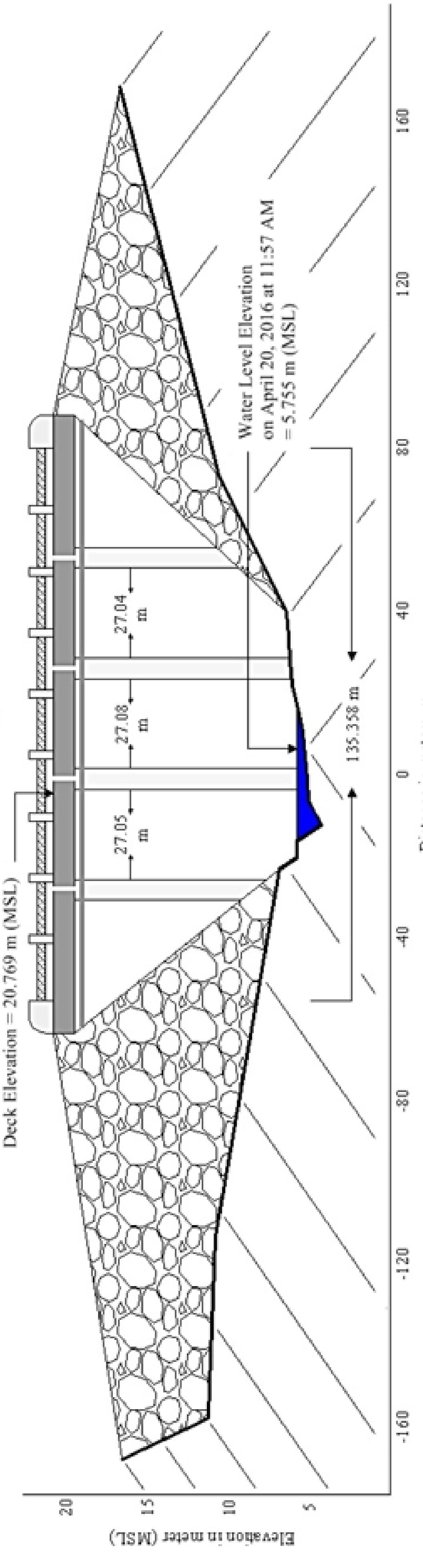


Figure 39. Marcos Bridge Cross-section Diagram

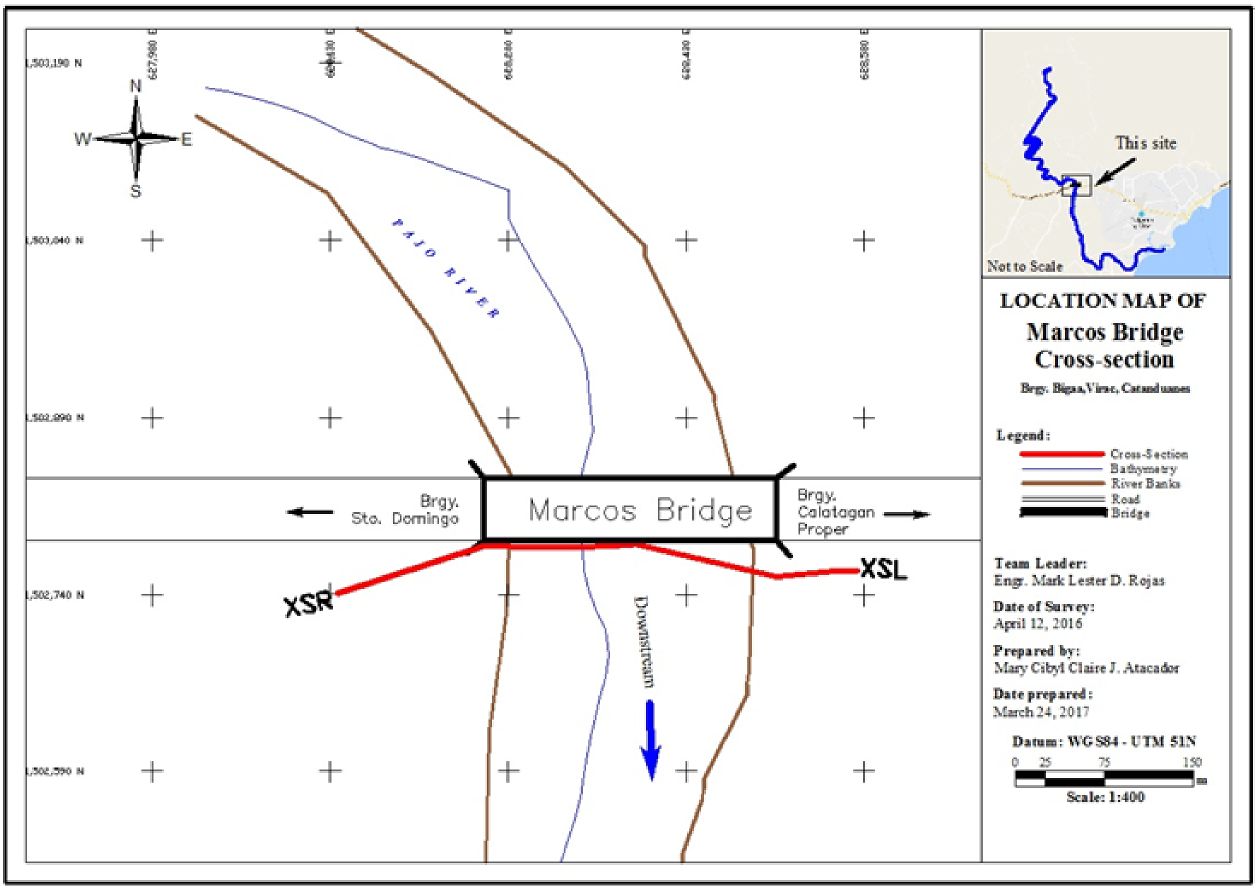
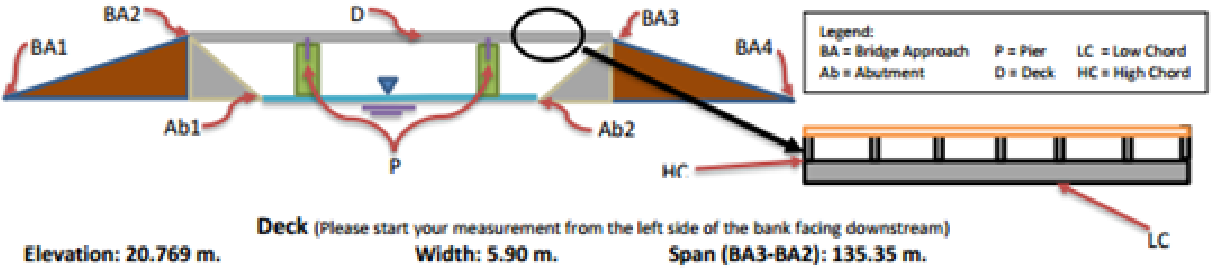


Figure 40. Marcos bridge cross-section location map

Bridge Data Form

Bridge Name: Marcos Bridge	**Date: April 12, 2016**
River Name: Pajo River	**Time: 2:30 PM**
Location: Brgy. Sto. Domingo, Virac, Catanduanes	
Survey Team: Mark Lester Rojas, Marla Tricia Joy Morris, Marck Lorenz Taguse	
Flow condition: low ✓ normal high	**Weather Condition:** ✓ fair rainy
Latitude: 13°35'26.26243"N	**Longitude: 124°11'14.95275"E**



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

Elevation: 20.769 m. **Width: 5.90 m.** **Span (BA3-BA2): 135.35 m.**

	Station	High Chord Elevation	Low Chord Elevation
1	139.349	20.775	18.666
2	166.399	20.765	18.665
3	174.392	20.769	18.669
4	193.479	20.754	18.654
5	220.579	20.759	18.659

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	16.519	BA3	247.5733	20.762
BA2	112.2152	20.738	BA4	335.877	16.640

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

	Station (Distance from BA1)	Elevation
Ab1	N/A	N/A
Ab2	240.9028	10.590

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

Shape: Cylindrical Number of Piers: 4 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	139.3490	20.725	1.0
Pier 2	166.3994	20.765	1.0
Pier 3	193.4799	20.754	1.0
Pier 4	220.5198	20.759	1.0

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

Figure 41. Marcos Bridge Data Form for Pajo River

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on April 9, 10, 11, and 12, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a roof of the vehicle as shown in Figure 42. It was secured with a cable tie to ensure that it was horizontally and vertically balanced. The antenna height was 1.935m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-MAR, CNS-3028, and CNS-3018occupied as the GNSS base stations in the conduct of the survey.

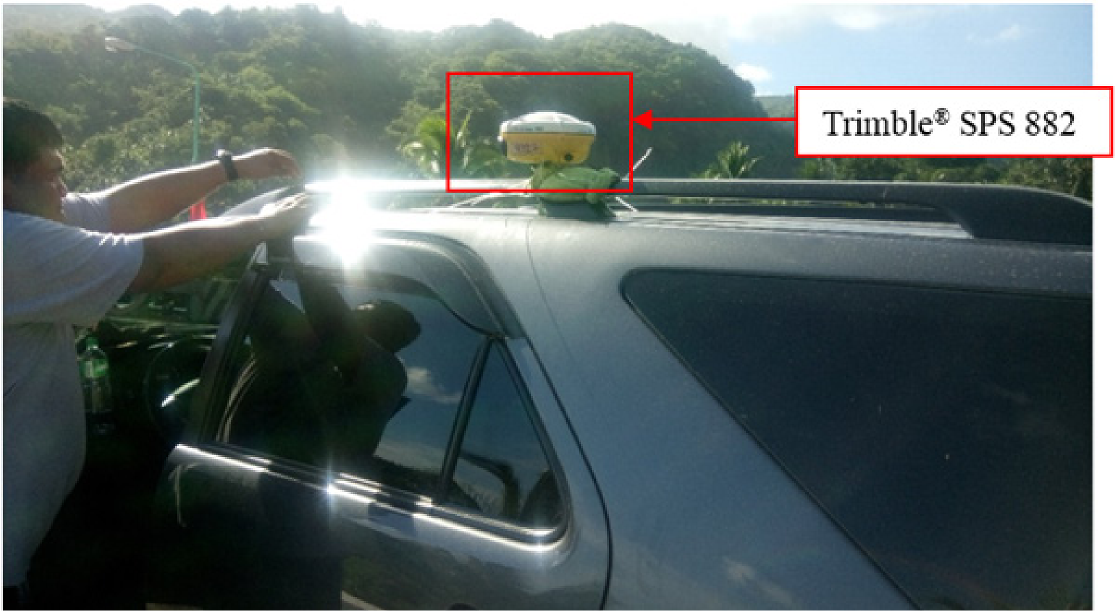


Figure 42. Validation points acquisition survey set up

The survey started from Brgy. Inalmasinan in the Municipality of Caramoan, going south towards the municipalities of San Andres, Virac, Bato, and ended in Brgy. Bagong Sirang. Municipality of Baras.This route aims to cut flight strips perpendicularly. The survey gathered 10,379 points with approximate length of 87.267 km using UP-MAR, CNS-3028, and CNS-3018 as GNSS base stations for the entire extent validation points acquisition survey, as illustrated in the map in Figure 43.

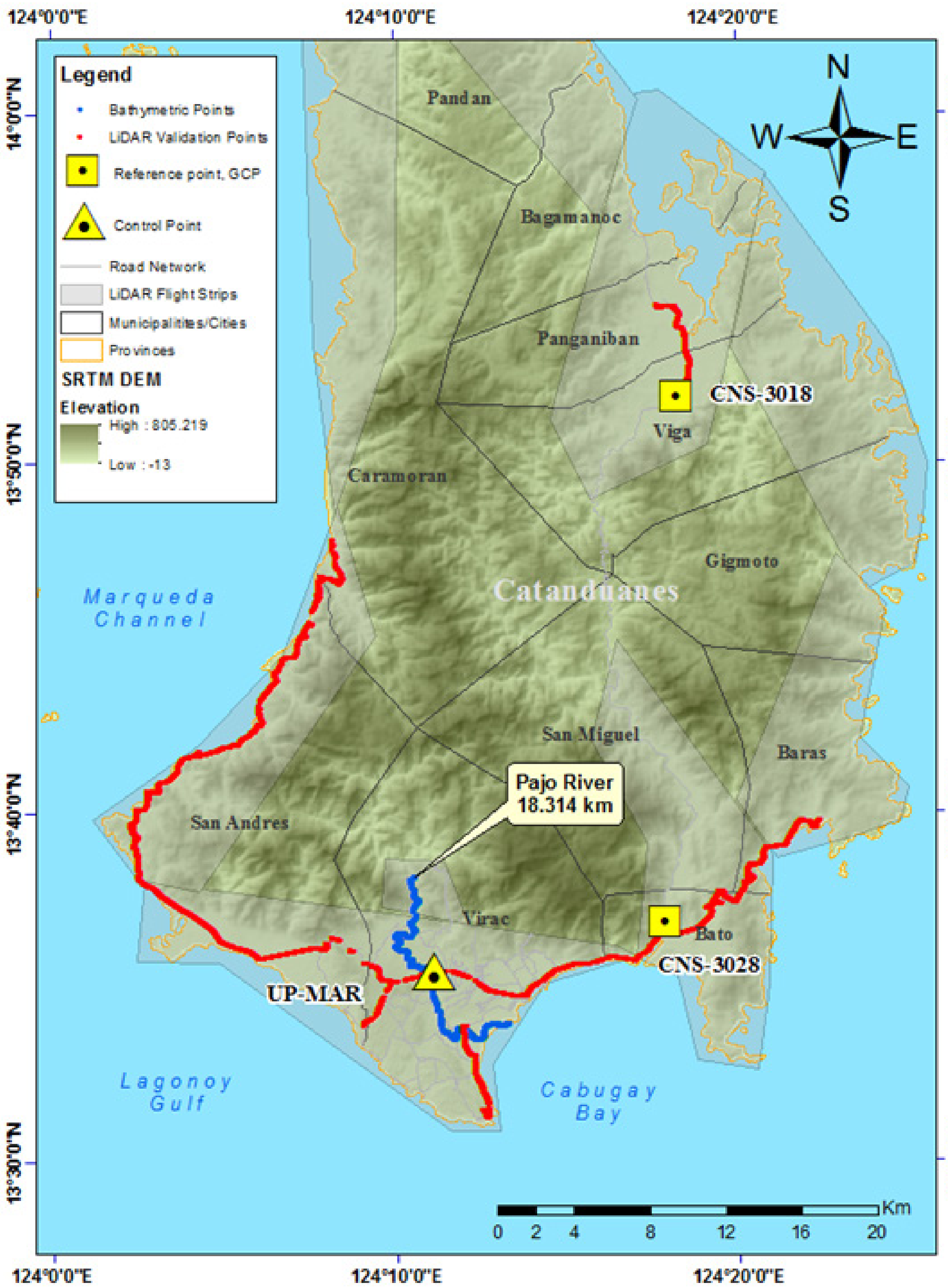


Figure 43. Validation points acquisition survey set up

4.7 River Bathymetric Survey

Bathymetric survey was executed on April19, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique and Ohmex™ single beam echo sounder. The extent of the survey is from the mid lower part of the river in Brgy. Pajo Baguio, Municipality of Virac with coordinates 13°33'29.22229"N, 124°11'42.52511"E, down to the mouth of the river in Brgy. Palnab Del Sur, also in Municipality of Virac with coordinates 13°33'55.55240"N, 124°13'17.70653"E.

Figure 44. Manual Bathymetry set up for PajoRiver survey

Manual Bathymetric survey was executed on April 20, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique as illustrated in Figure 44. The extent of the survey is from the upstream in Brgy. Hicming, Municipality of Virac with coordinates 13°38'08.90343"N, 124°10'33.42749"E, traversed down by foot and ended at the starting point of bathymetric survey using boat started.

A CAD drawing was also produced to illustrate the riverbed profile of Pajo River. As shown in Figure 46 and Figure 47, the highest and lowest elevation has a 27-meter difference. The highest elevation observed was 27.243 m above MSL located at the upstream portion of the river in Brgy. Hicming, Municipality of Virac while the lowest was 0.180 m MSL located at the mid downstream portion of the river in Brgy. Pajo San Isidro, also in Municipality of Virac. The bathymetric survey gathered a total of 7,308 points covering 18,314km of the river traversing sixteen barangays in Municipality of Virac.

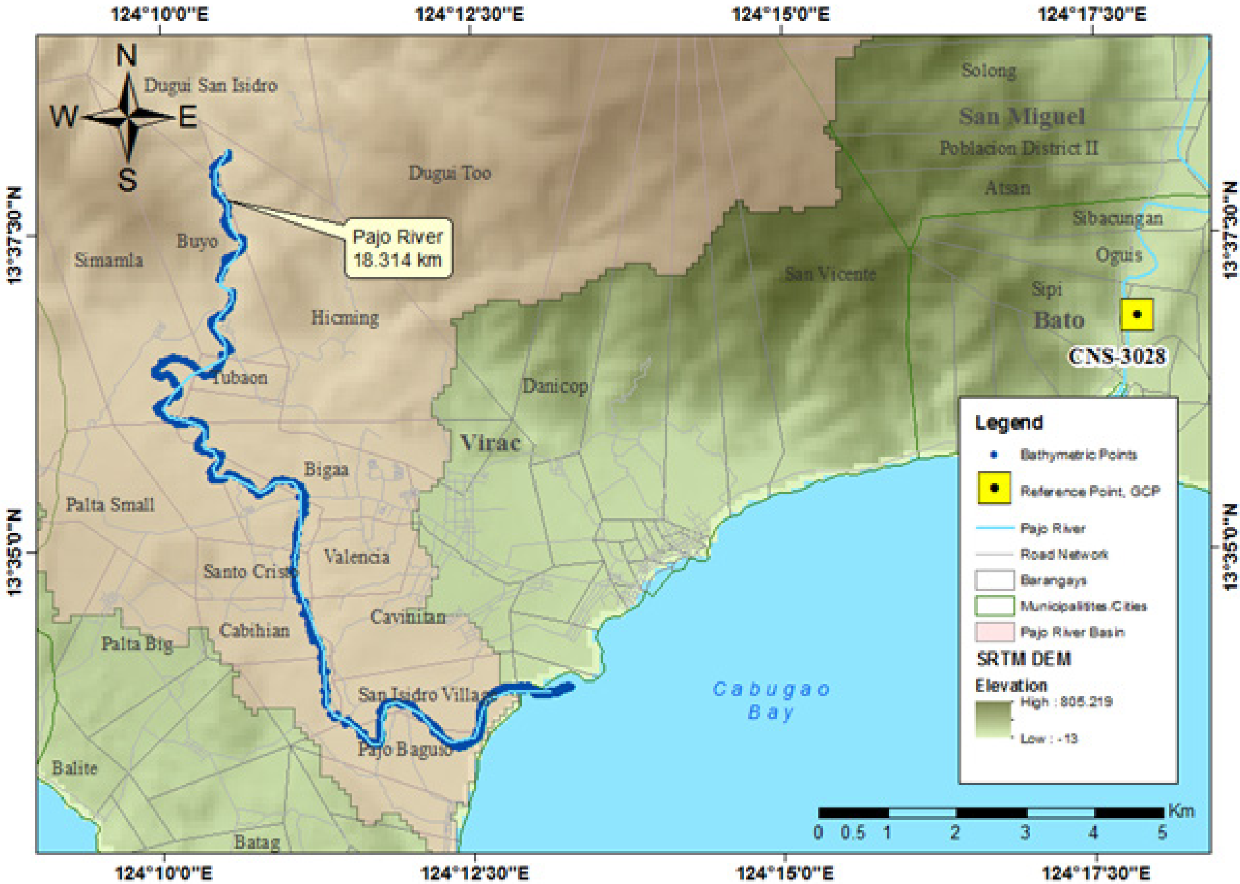


Figure 45. Bathymetric survey of Pajo River

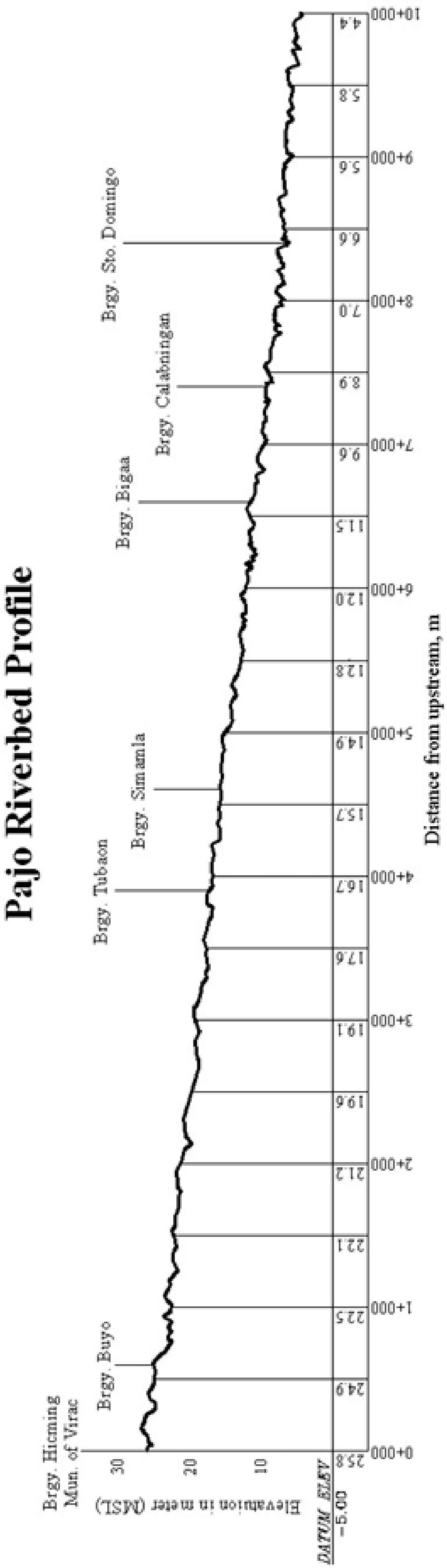


Figure 46. Riverbed profile of Pajo River, upstream part

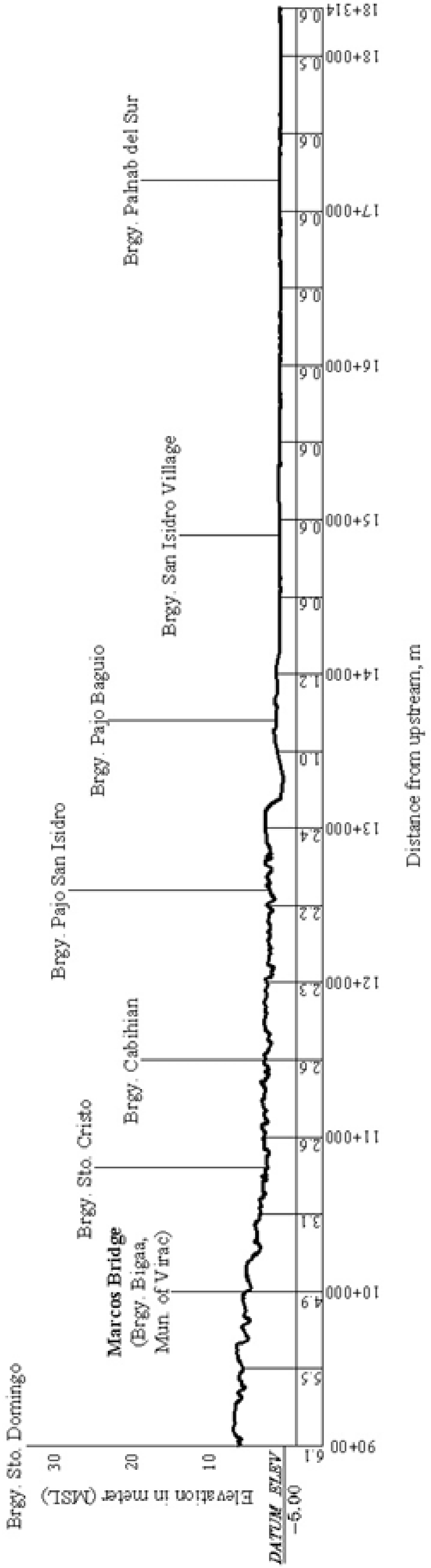


Figure 47. Riverbed Profile of Pajo River, downstream part

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, Gianni Sumajit, Engr. Ferdinand E. Bien, Christian Javier B. Arroyo Engr. Francis Patray P. Bolaños, Mark D. Delloro, Berlin Phil V. Garciano, Engr. Jan Karl T. Ilarde, Engr. Herminio A. Magpantay, Engr. Julius Hector S. Manchete, John Paul B. Obina , Engr. Lech Fidel C. Pante, Jan Carlo C. Plopenio , Ernesto F. Razal Jr.. Rox Harvey Rosales, Aaron P. Rosales, Engr.Herminio A. Magpantay, Engr. Mary Ruth A. Bongon, Aaron P. San Andres

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

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

5.1.2 Precipitation

Precipitation data was taken from one automatic rain gauge (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The rain gauge was installed at Brgy. Hicming (Figure 48). The precipitation data collection started from October 15, 2016 at 2:30 AM to October 16, 2016 at 6:00AM with a 15-minute recording interval.

The total precipitation for this event in Brgy. Hicming ARG is 312.5mm. It has a peak rainfall of 14mm on October 15, 2016, at5:30PM. The lag time between the peak rainfall and discharge is 1 hour and 45 minutes.

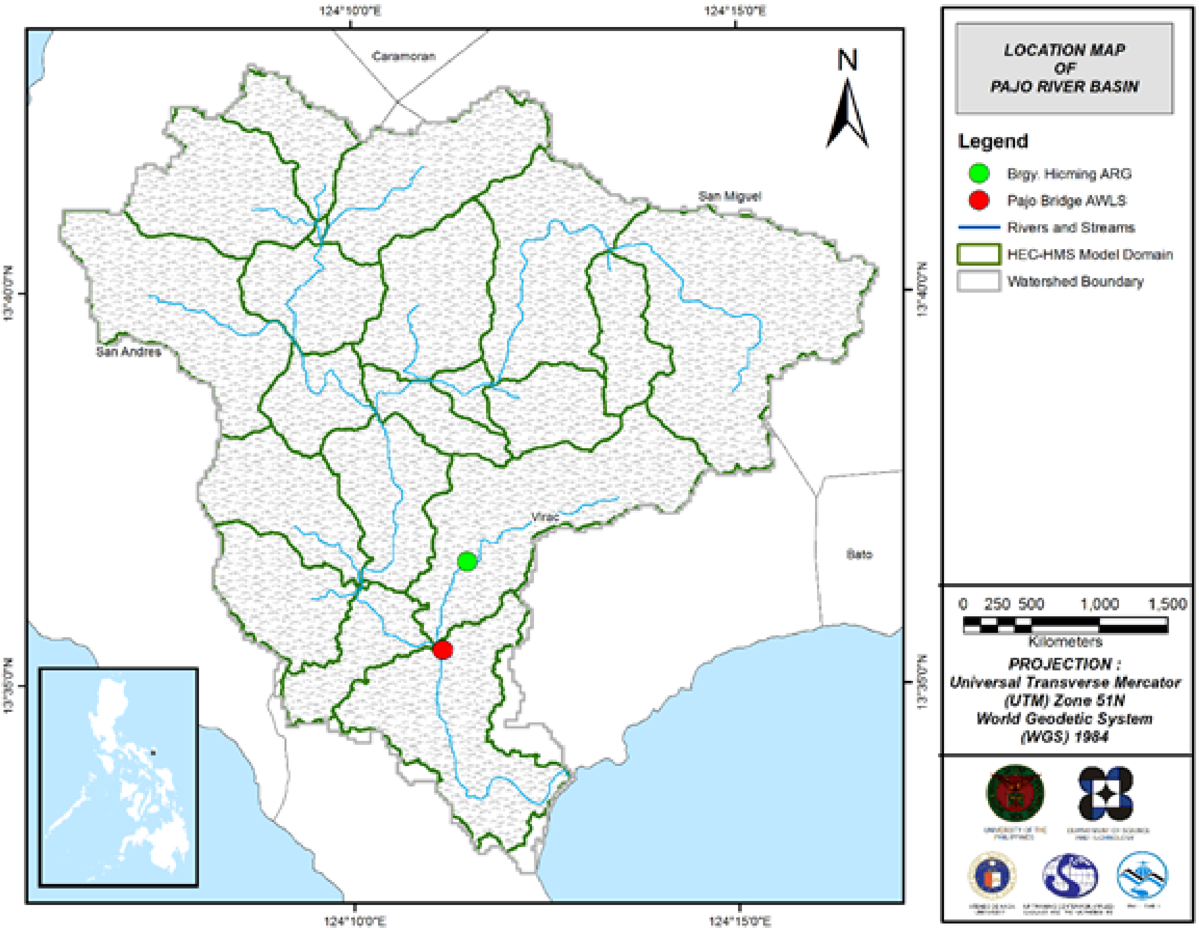


Figure 48. The location map of Pajo HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Pajo Bridge, Pajo, Catanduanes (13°35'26.31"N, 124°11'9.26"E). It gives the relationship between the observed water levels at Pajo Bridge and outflow of the watershed at this location.

For Pajo Bridge, the rating curve is expressed as Q=0.1586e0.824h as shown in Figure 50.

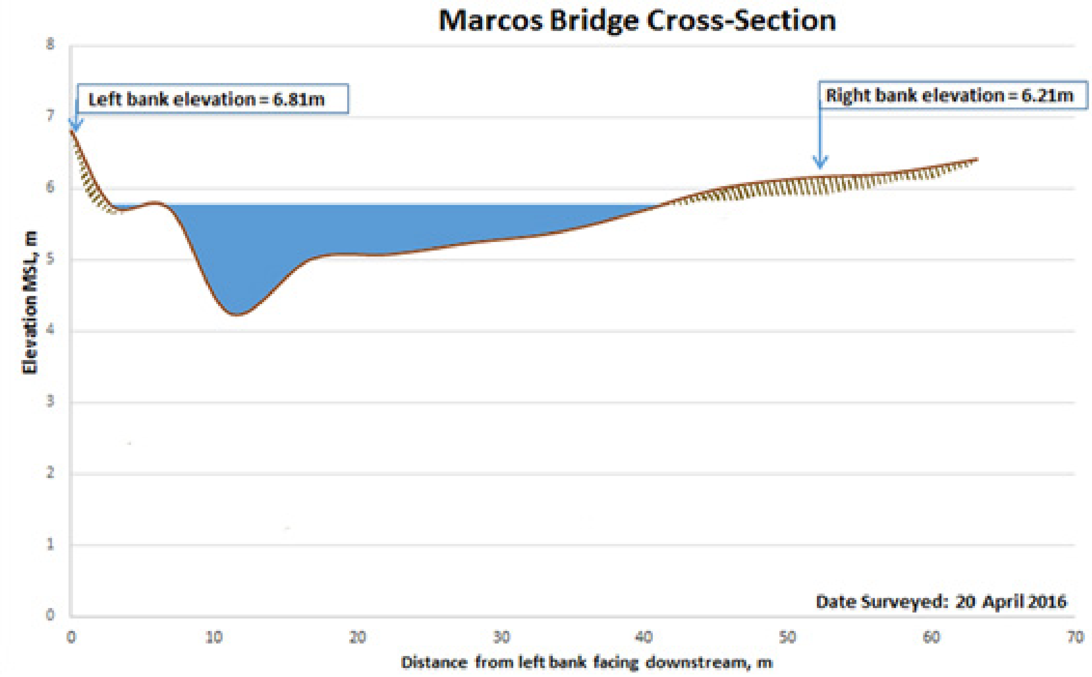


Figure 49. Cross-Section Plot of Pajo (Marcos) Bridge

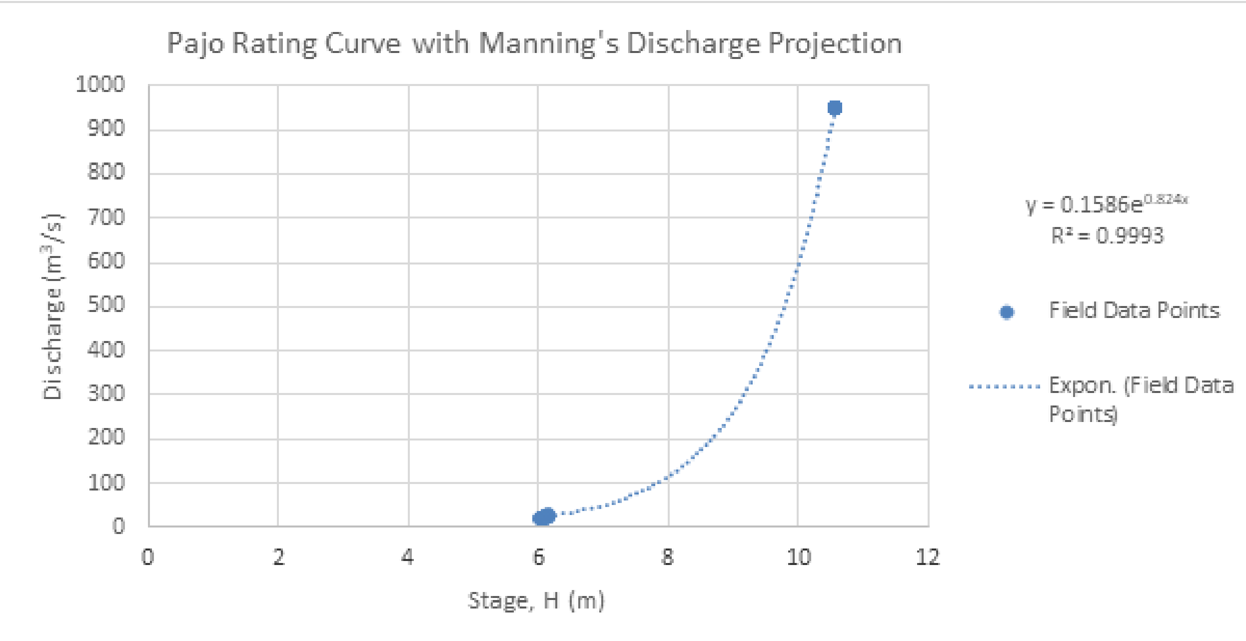


Figure 50. Rating Curve at Pajo Bridge, Catanduanes

This rating curve equation was used to compute the river outflow at Pajo Bridge for the calibration of the HEC-HMS model shown in Figure 51. The total rainfall for this event is 312.5mm and the peak discharge is 217.95m3/s at 9:00 AM, October 15, 2016.

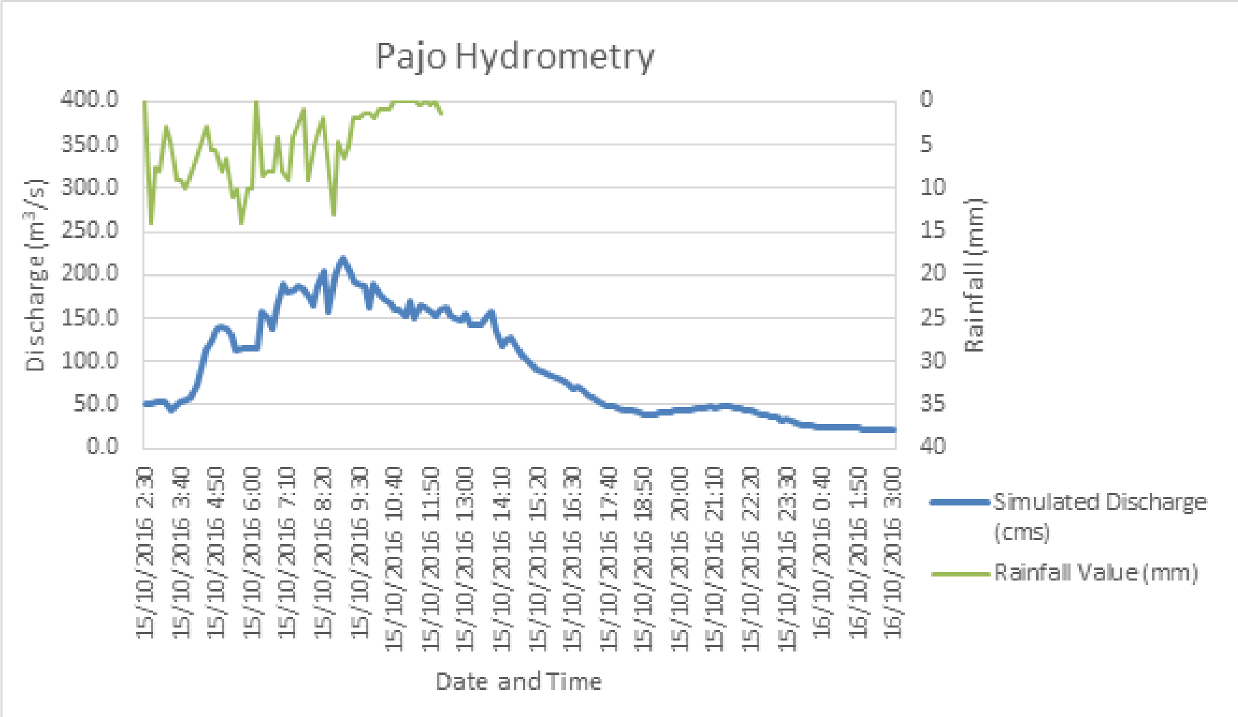


Figure 51. Rainfall and outflow data of the Pajo River Basin, which was used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Virac RIDF. 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. This station was chosen based on its proximity to the Pajo watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 27. RIDF values for Virac Rain Gauge computed by PAG-ASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	24	36.2	44.9	60	85.1	100.5	133.3	167.2	195.6
5	35.2	52.7	65.5	87.6	126.6	150.8	200.7	251.3	297
10	42.7	63.6	79.2	105.9	154.1	184.1	245.3	307.1	364.1
15	46.8	69.7	86.9	116.2	169.6	202.8	270.5	338.5	402
20	49.8	74	92.3	123.4	180.4	216	288.1	360.5	428.6
25	52	77.3	96.4	129	188.8	226.1	301.7	377.4	449
50	59	87.5	109.2	146.1	214.6	257.4	343	429.7	511.9
100	65.9	97.7	122	163.1	240.1	288.3	385	481.5	574.4

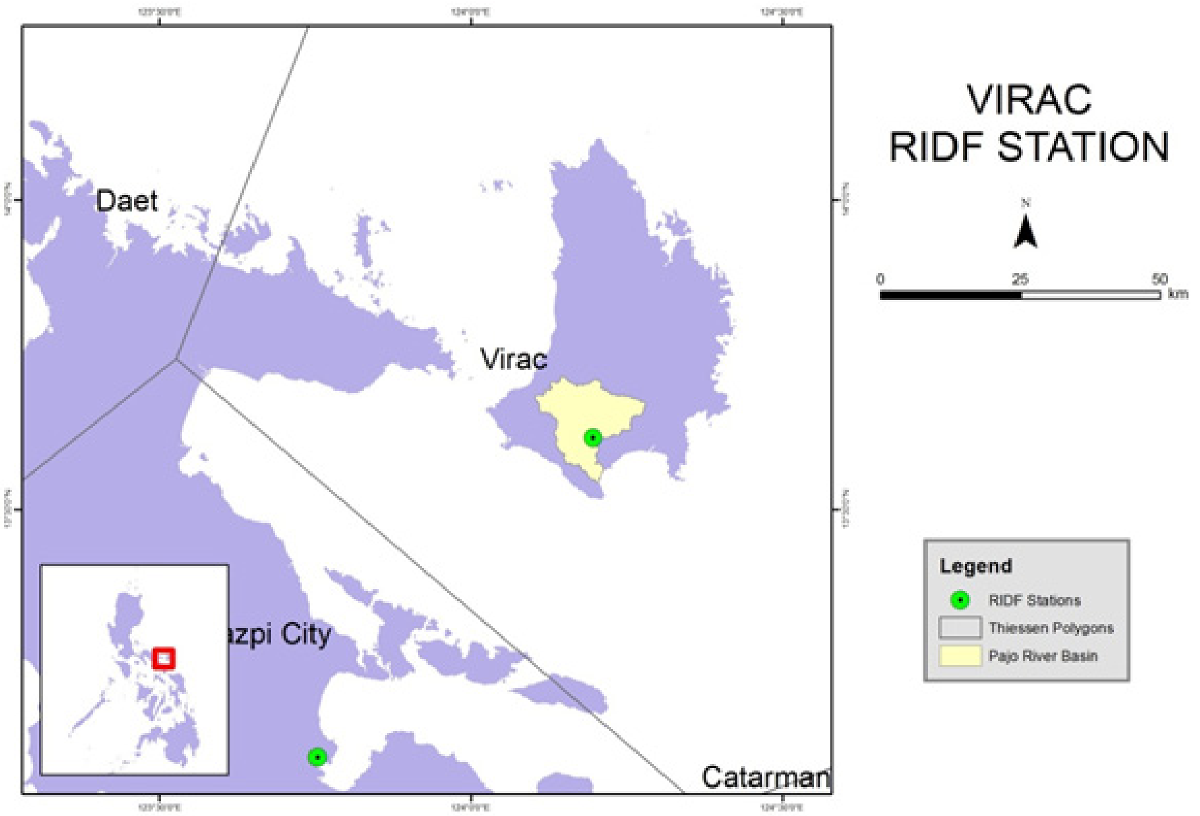


Figure 52. The location of the Virac RIDFstation relative to the Pajo River Basin

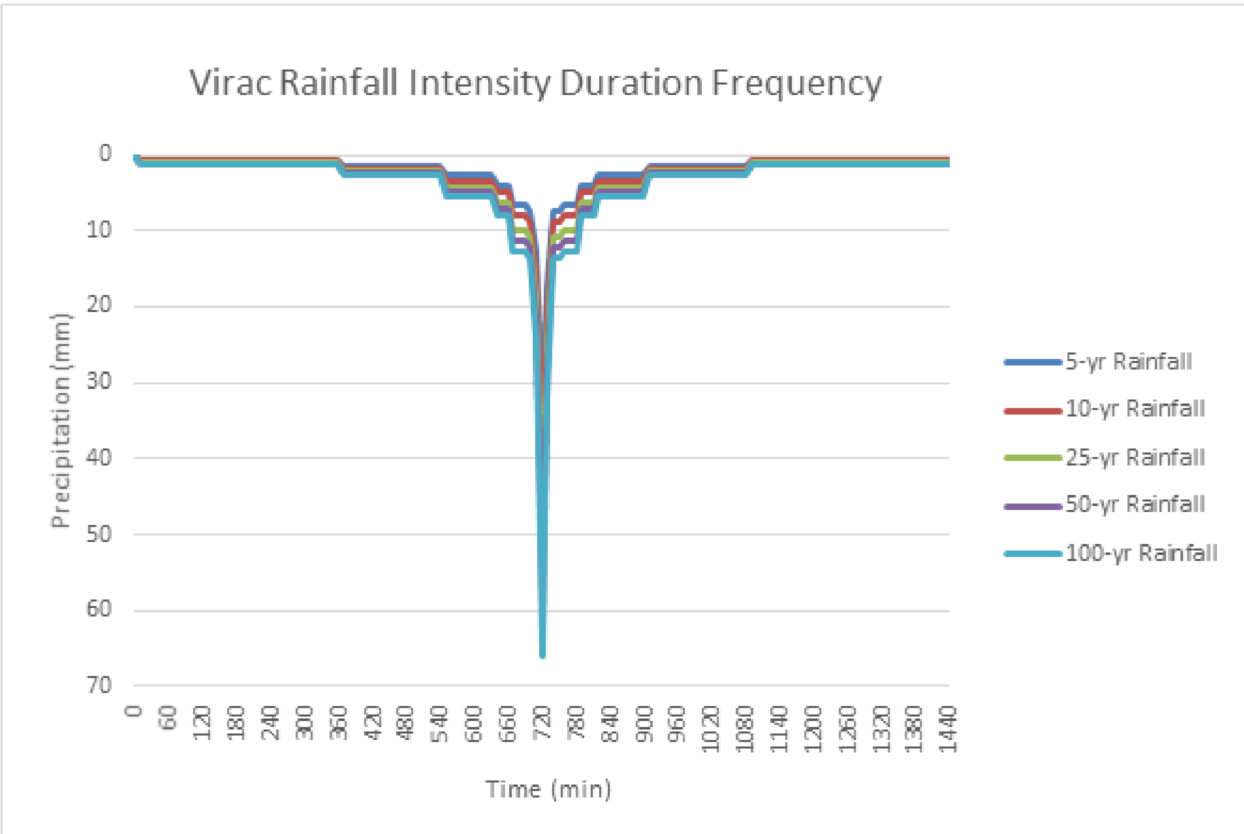


Figure 53. The synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Pajo River Basin are shown in Figure 54 and Figure 55, respectively.

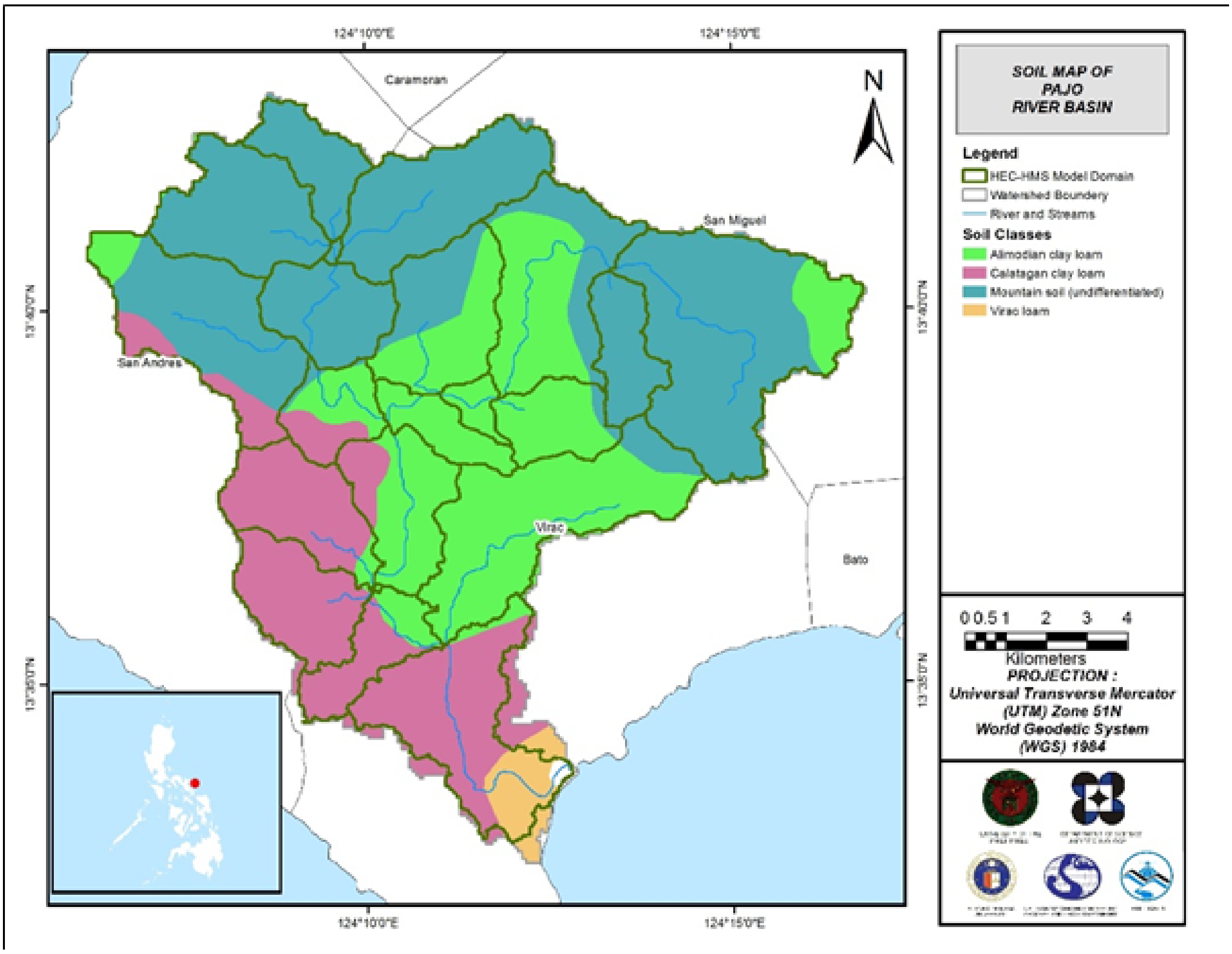


Figure 54. Soil map of Pajo River Basin

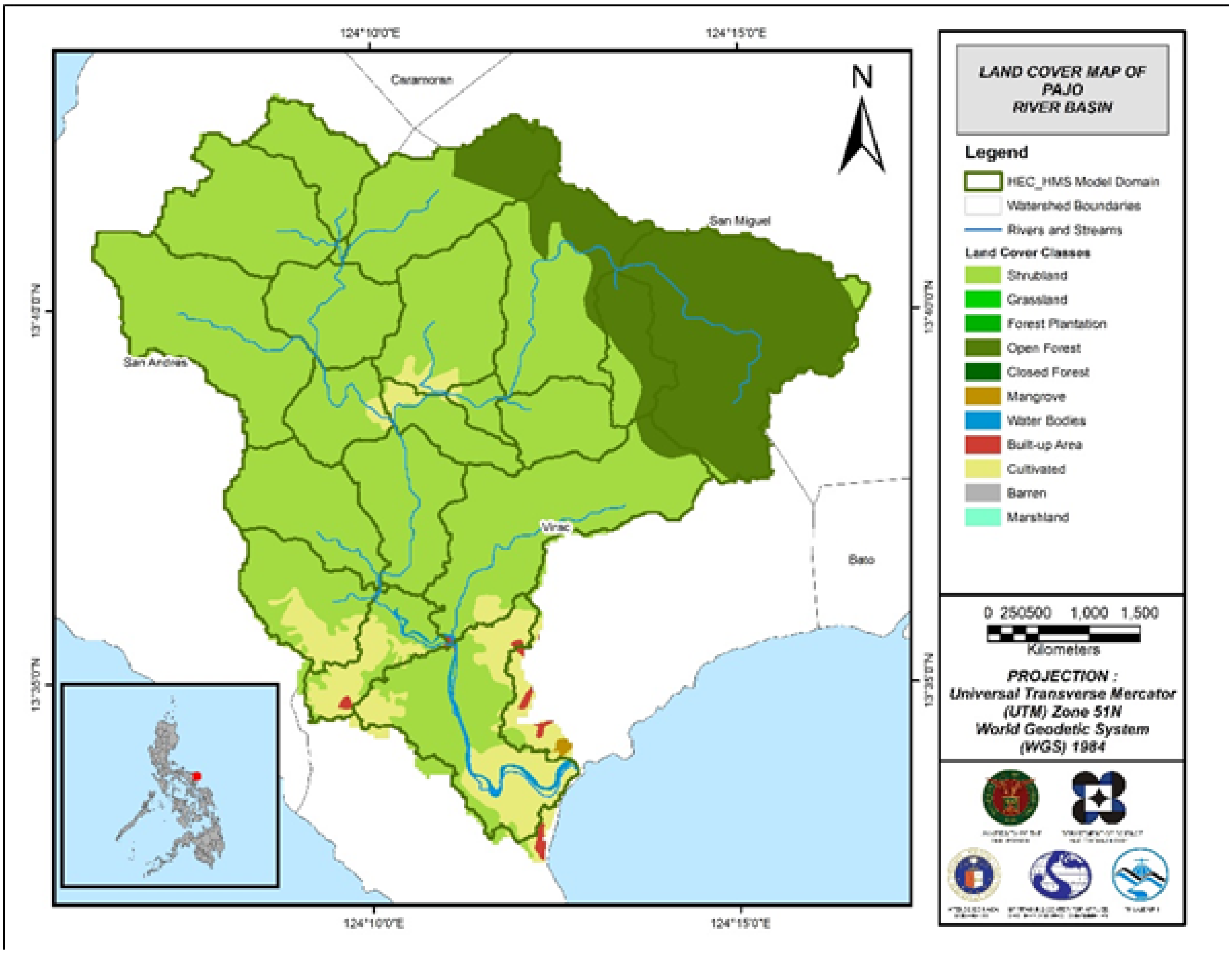


Figure 55. Land cover map of Pajo River Basin

For Pajo, four soil classes were identified. These are Alimodian clay loam, Calatagan clay loam, Virac loam, and undifferentiated mountain soil. Moreover, five land cover classes were identified. These are shrubland, open forest, cultivated, and built-up areas.

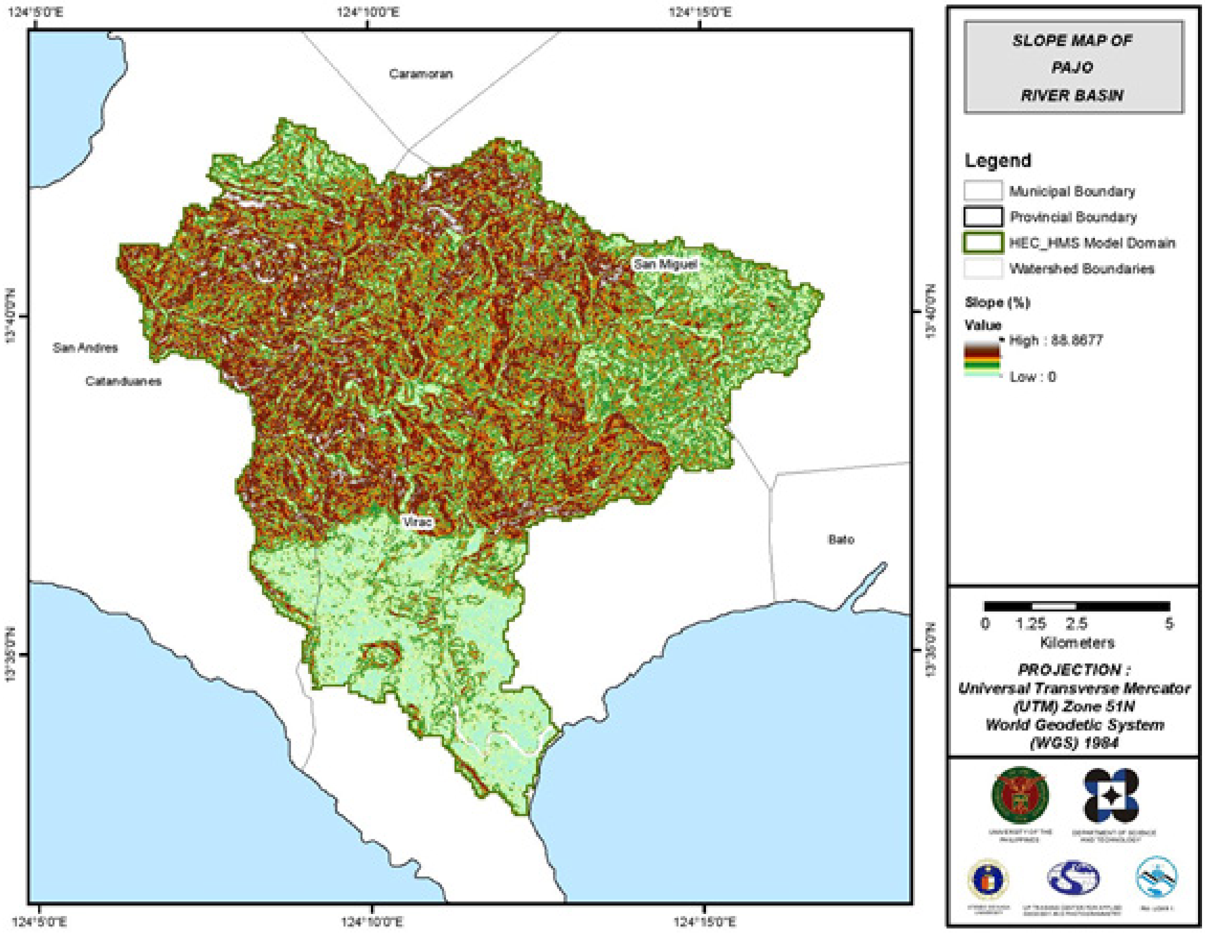


Figure 56. Slope map of Pajo River Basin

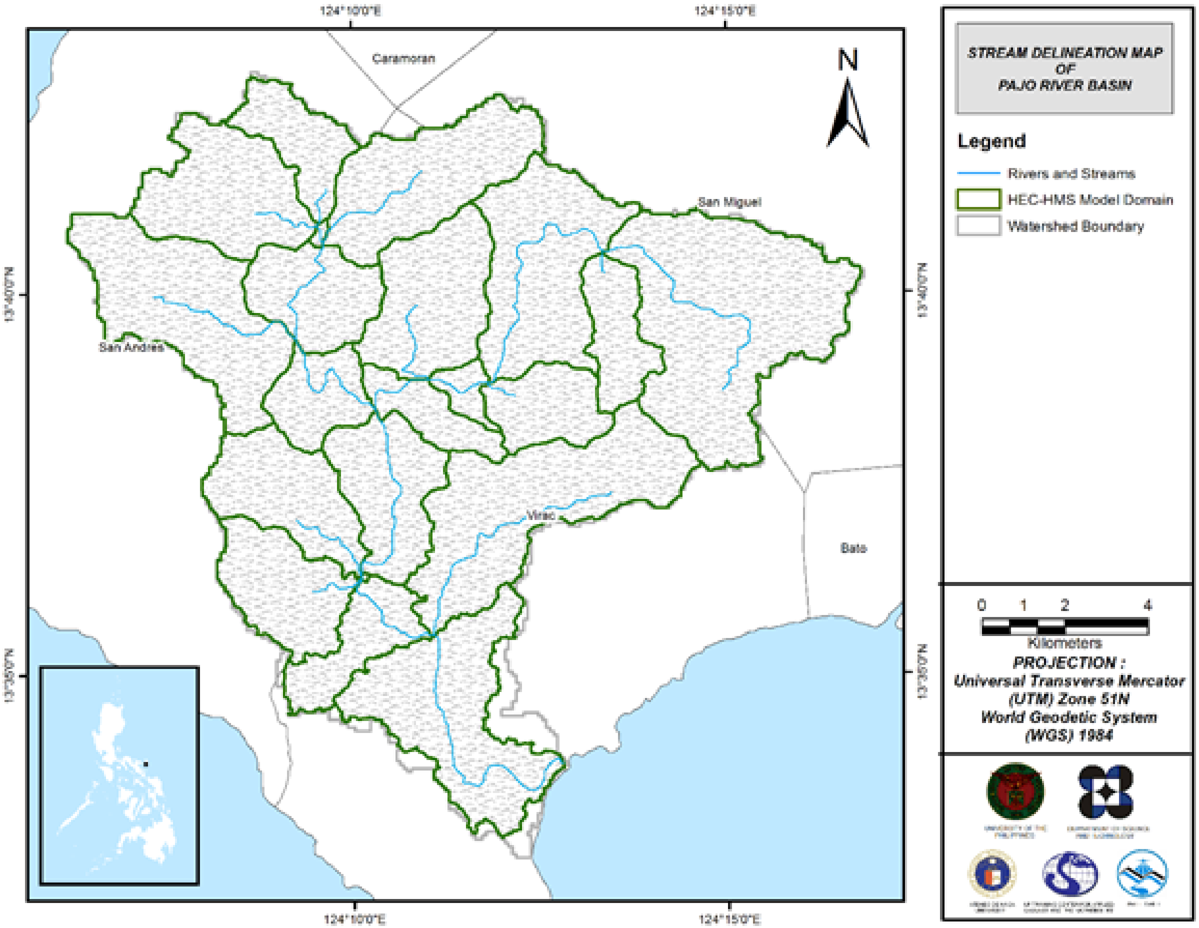


Figure 57. Stream delineation map of Pajo River Basin

Using the SAR-based DEM, the Pajo basin was delineated and further divided into subbasins. The model consists of 21 sub basins, 10 reaches, and 10 junctions, as shown in Figure 58 (See Annex 10). The main outlet is Pajo Bridge.

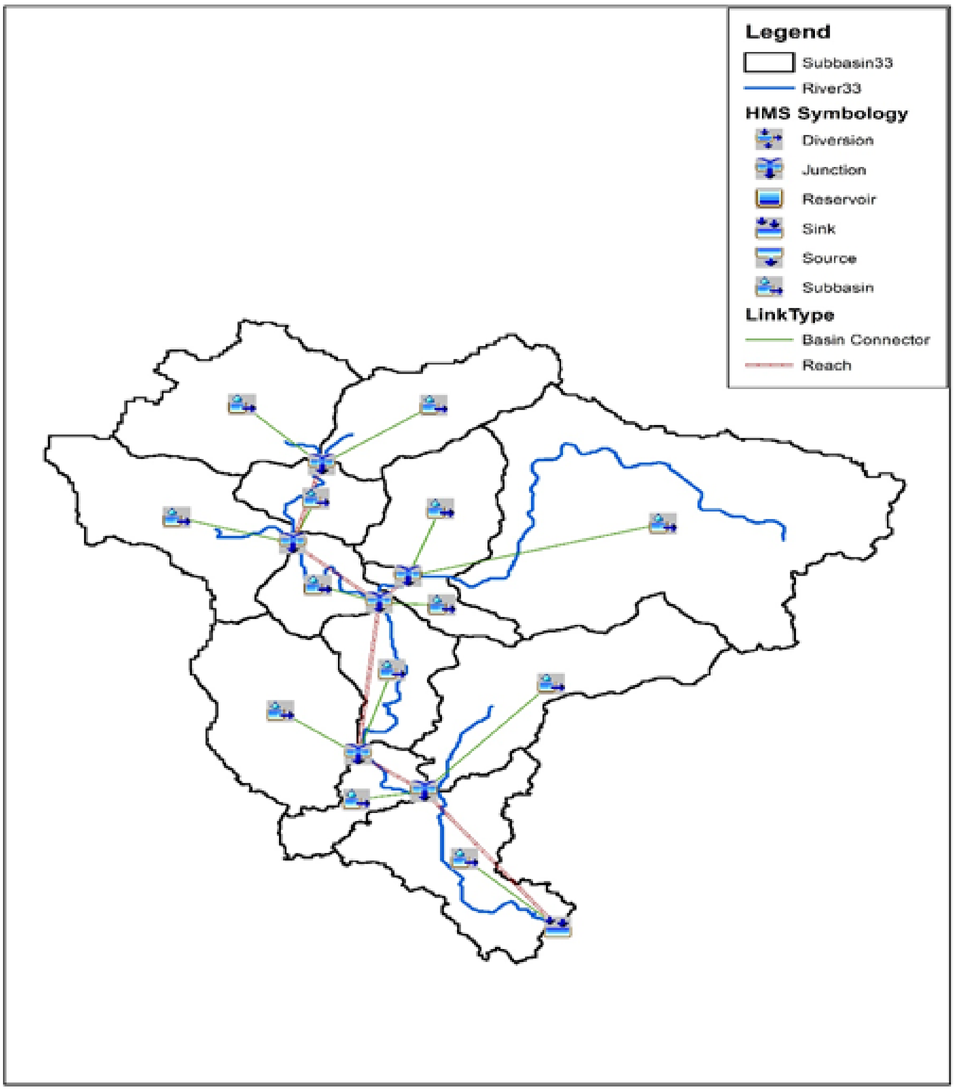


Figure 58. The Pajo River Basin model generated in HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data which was defined using the Arc Geo-RAS tool and was post-processed in ArcGIS (Figure 59).

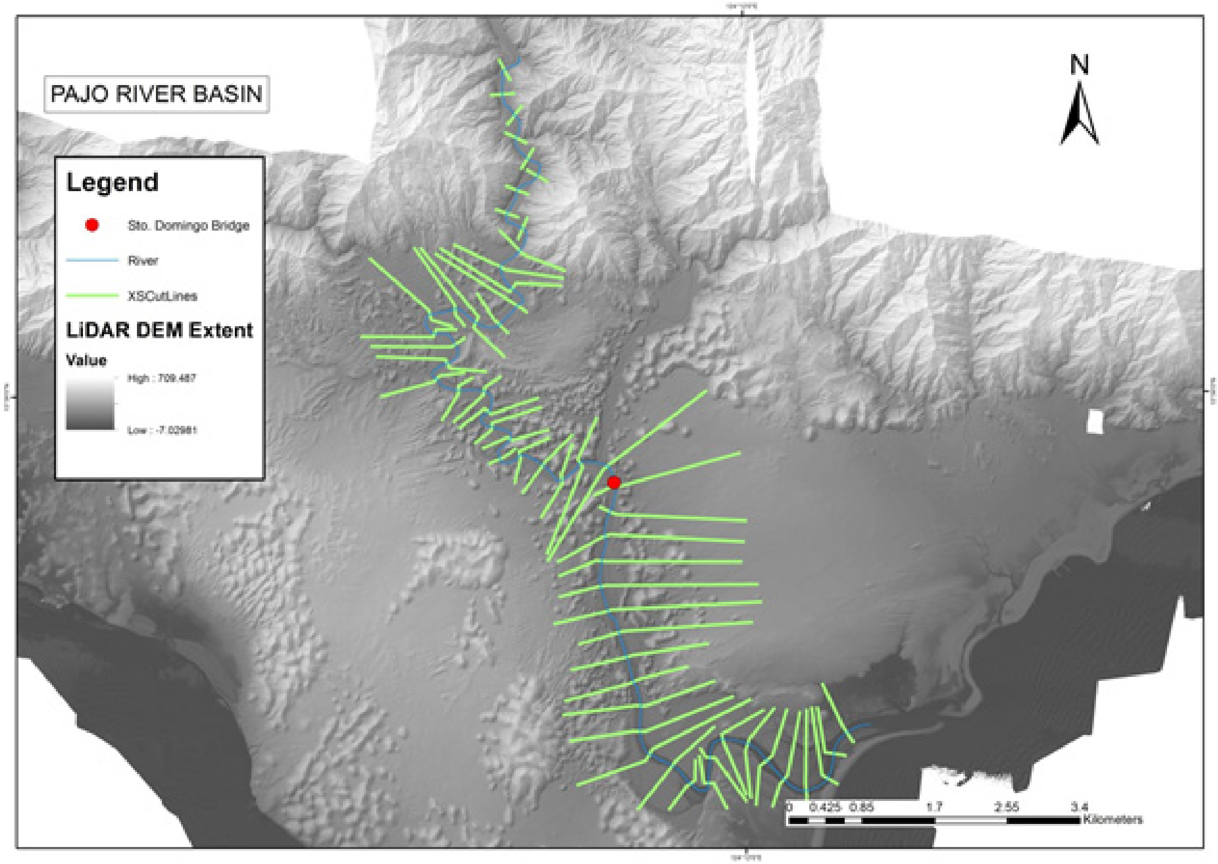


Figure 59. River cross-section of Pajo River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

[INSERT 2D REPORT]

Figure 60. SCREENSHOT

5.6 Results of HMS Calibration

After calibrating the Pajo HEC-HMS river basin model (See Annex 9), its accuracy was measured against the observed values. Figure 61 shows the comparison between the two discharge data.

The adjusted ranges of values of the parameters used in calibrating the model are enumerated in Table 28.

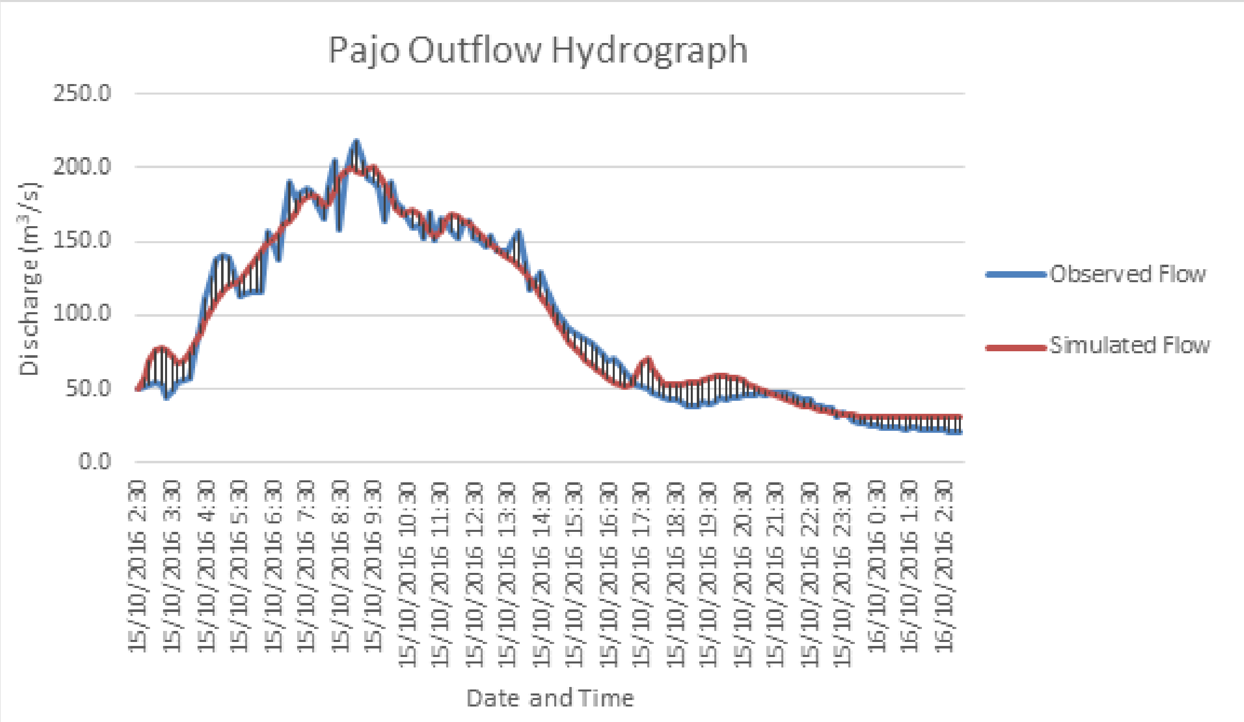


Figure 61. Outflow hydrograph of PajoRiver Basin produced by the HEC-HMS model compared with observed outflow

Table 28. Range of Calibrated Values for Pajo

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	2-373
			Curve Number	35-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.2-64
			Storage Coefficient (hr)	0.1-40
	Baseflow	Recession	Recession Constant	0.00001-0.004
			Ratio to Peak	0.0002-1
Reach	Routing	Muskingum-Cunge	Slope	0.00005-0.05
			Manning's n	0.0001-1

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 2mm to 373mm 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 35 to 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 Pajo, the basin mostly consists of grassland and the soil consists of Alimodian clay loam, Calatagan clay loam, and undifferentiated mountain soil.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.2 hours to 64 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. For Pajo it will take at least 11 hours from the peak discharge to go back to the initial discharge.

Manning's roughness coefficient of 0.0001 corresponds to the common roughness of Pajo watershed,which is determined to be built-up area that is concrete and float-finished (Brunner, 2010).

Table 29. Summary of the Efficiency Test of Pajo HMS Model

Accuracy measure	Value
r2	0.96
NSE	0.96
PBIAS	-3.88
RSR	0.20
RSR	0.22

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as12.23(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 0.96.

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 0.96.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -3.88.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.20.

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 62) shows the Pajo outflow using the synthetic storm events using the Virac 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 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 286.2m3/s in a 5-year return period to 713.3m3/s in a 100-year return period.

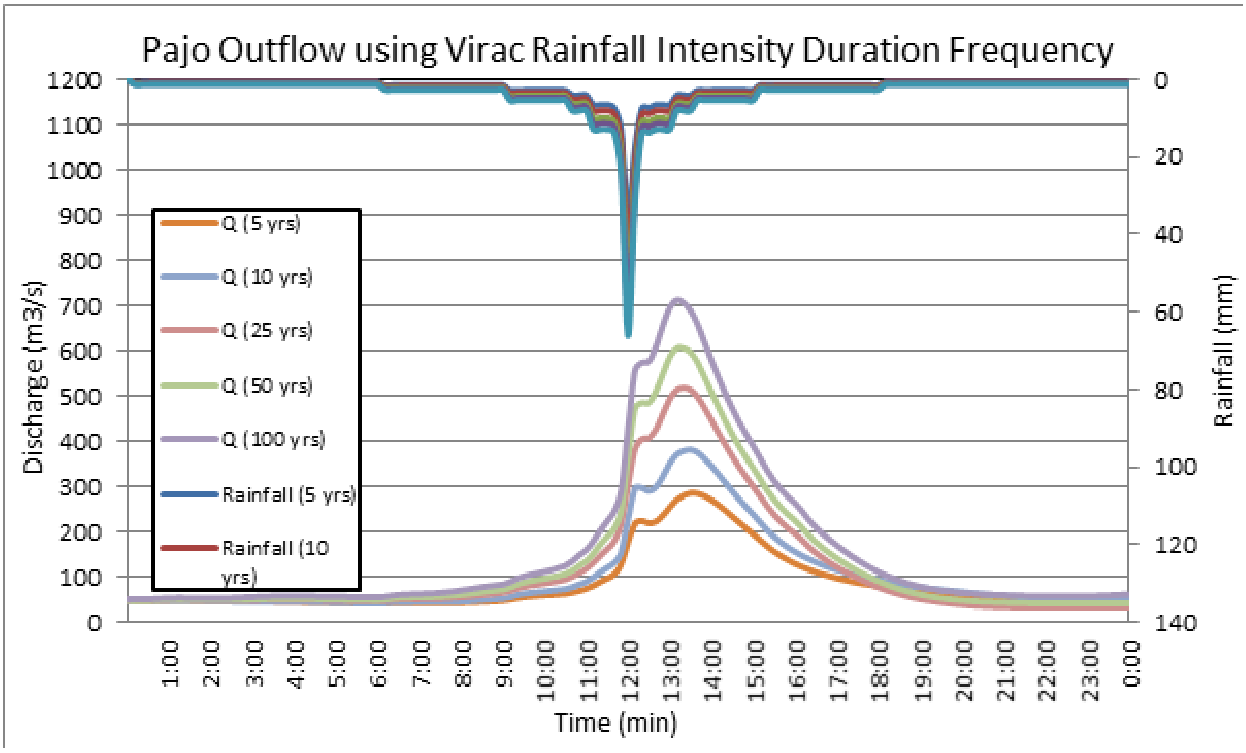


Figure 62. Outflow hydrograph at Pajo generated using Virac RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Pajo discharge using the Virac Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 30.

Table 30. Peak values of the Pajo HEC-HMS Model outflow using the Virac RIDF 24-hour values

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	297	35.2	286.2	1 hour, 30 minutes
10-Year	364.1	42.7	380.8	1 hour, 30 minutes
25-Year	449	52	520.5	1 hour, 20 minutes
50-Year	511.9	59	607	1 hour, 10 minutes
100-Year	574.4	65.9	713.3	hour, 10 minutes

5.7.2 Discharge Values using Dr. Horritt's Recommended Hydrological Method

The river discharges for the two rivers entering the floodplain are shown in Figure 63 and Figure 64 and the peak values are summarized in Table 31 and Table 32.

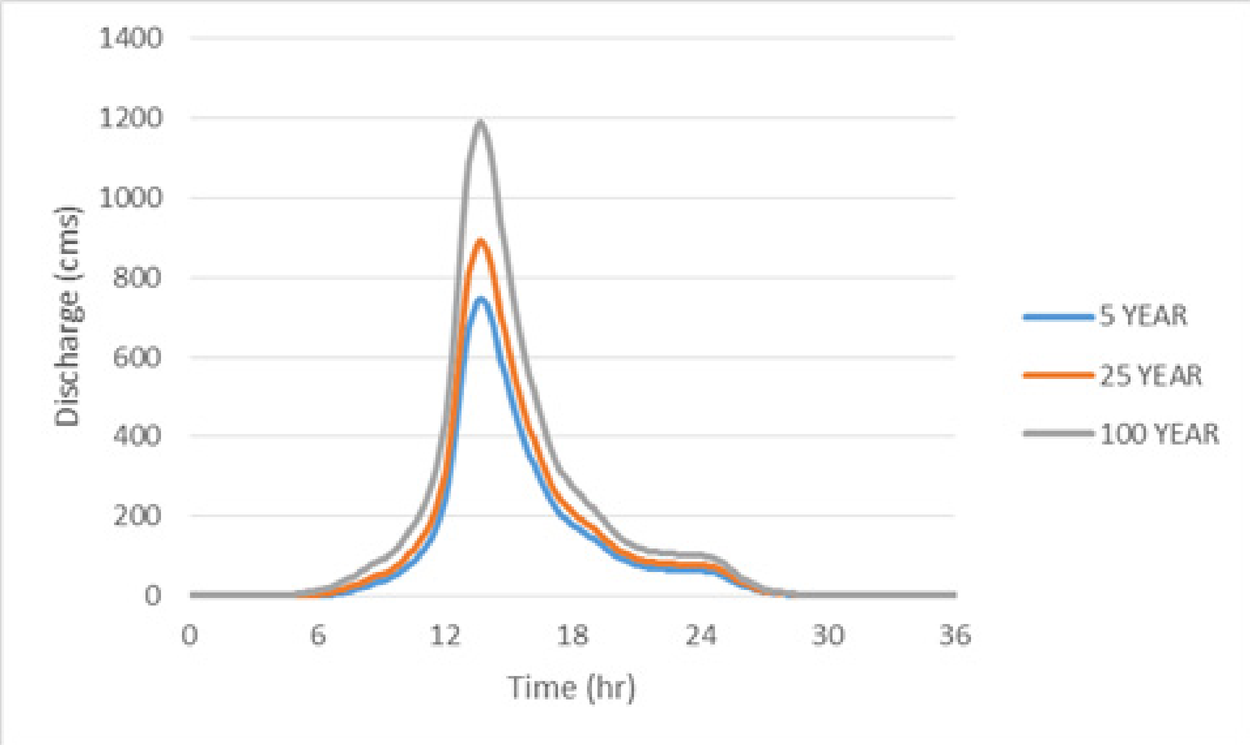


Figure 63. Pajo River (1) generated discharge using interpolated 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

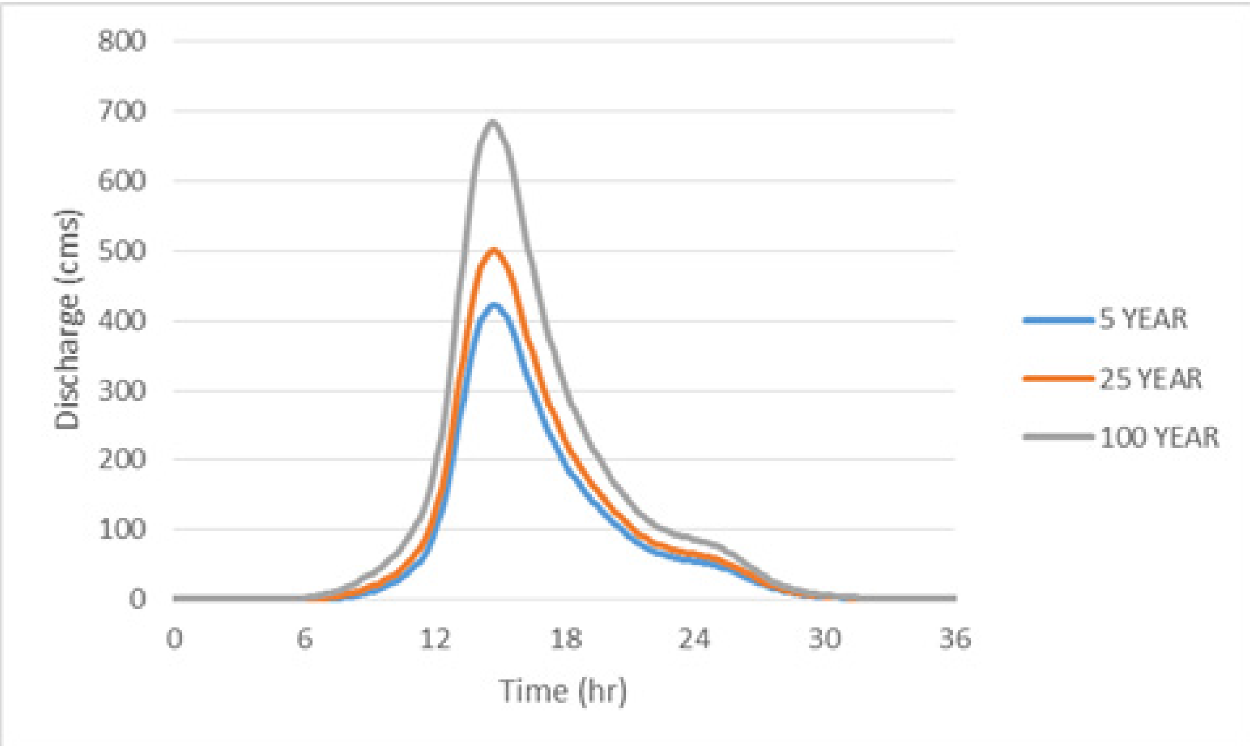


Figure 64. Pajo river (2) generated discharge using interpolated 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 31. Summary of Pajo River (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak (minutes)
100-Year	1190.2	104.20
25-Year	892.4	104.20
5-Year	748.6	104.20

Table 32. Summary of Pajo river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak (minutes)
100-Year	684.8	158.61
25-Year	501.1	158.61
5-Year	422.7	158.61

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 33.

Table 33. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Pajo (1)	658.768	1031.600	403.644	TRUE	FALSE
Pajo (2)	371.976	689.611	325.764	TRUE	TRUE

Both values from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful discharge method. The calculated values are based on theory but are supported using other discharge computation methods so they were good to use for flood modeling. However, 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 was used in determining the flooded areas within the model. The simulated model was an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river is shown since only the ADNU-DVC base flow was calibrated. Figure 65 shows a generated sample map of the Pajo River using the calibrated HMS base flow.

Figure 65. Sample output of Pajo RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 66 to Figure 71 show the 5-, 25-, and 100-year rain return scenarios of the Pajo Floodplain. The floodplain, with an area of 103.27km2, covers two (2) municipalities, namely San Andres and Virac. Table 34 shows the percentage of area affected by flooding per municipality.

Table 36. Municipalities affected in Silaga floodplain

Municipality	Total Area	Area Flooded	% Flooded
San Andres	172.88	10.56	6.11
Virac	175.3	92.48	52.75

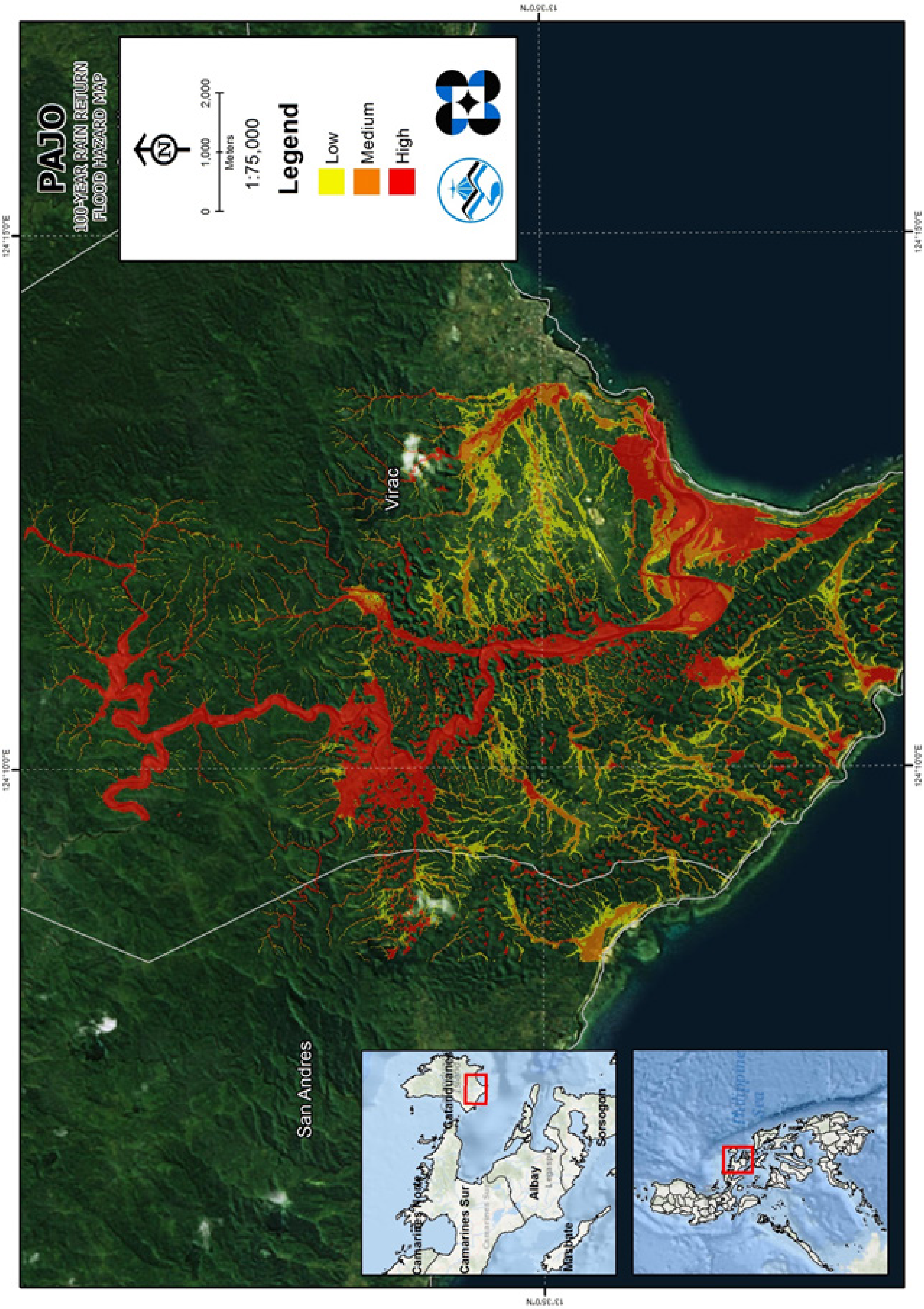


Figure 66. 100-year flood hazard map for the Pajo Floodplain overlaid on Google Earth imagery

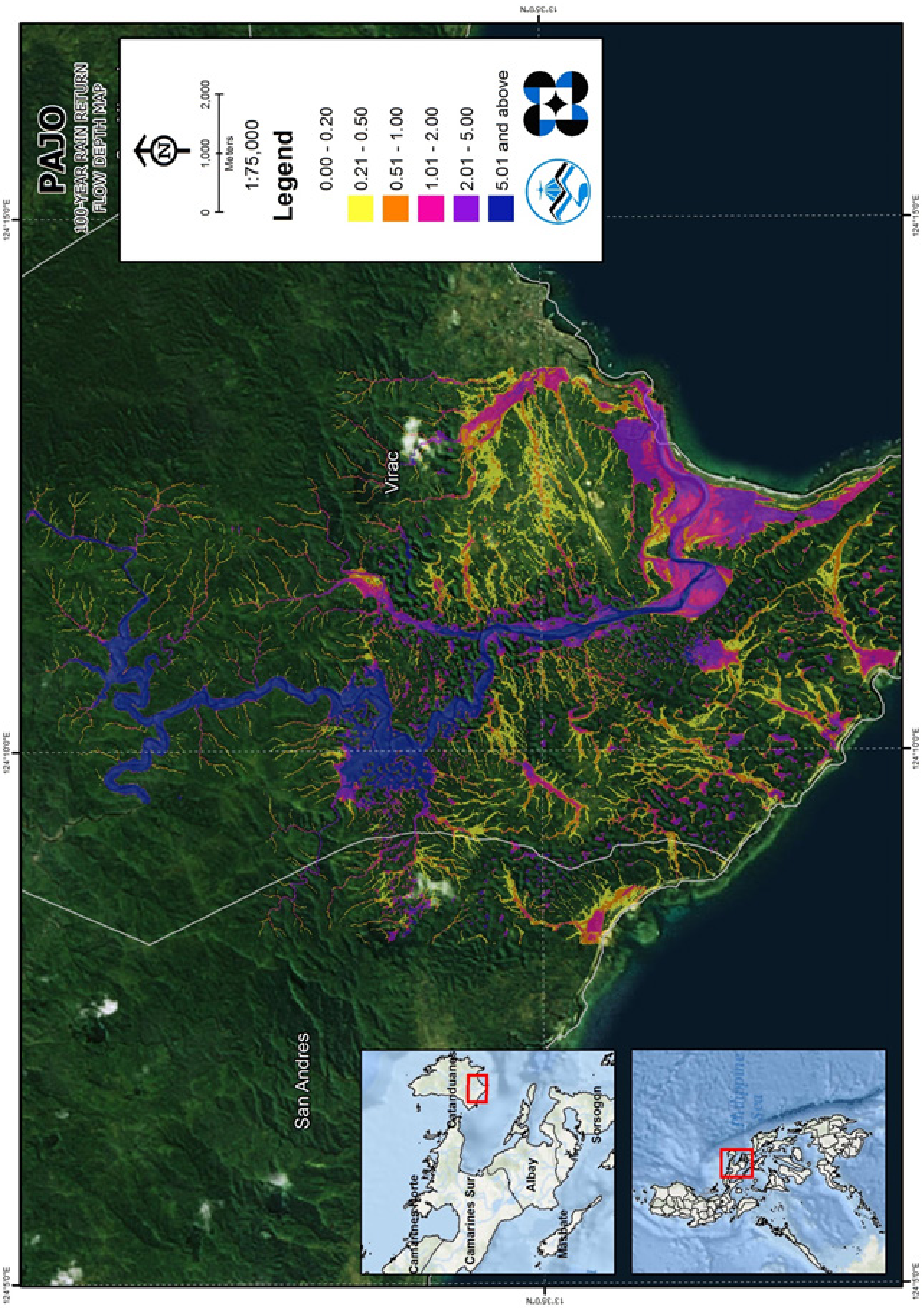


Figure 67. 100-year flow depth map for the Pajo Floodplain overlaid on Google Earth imagery

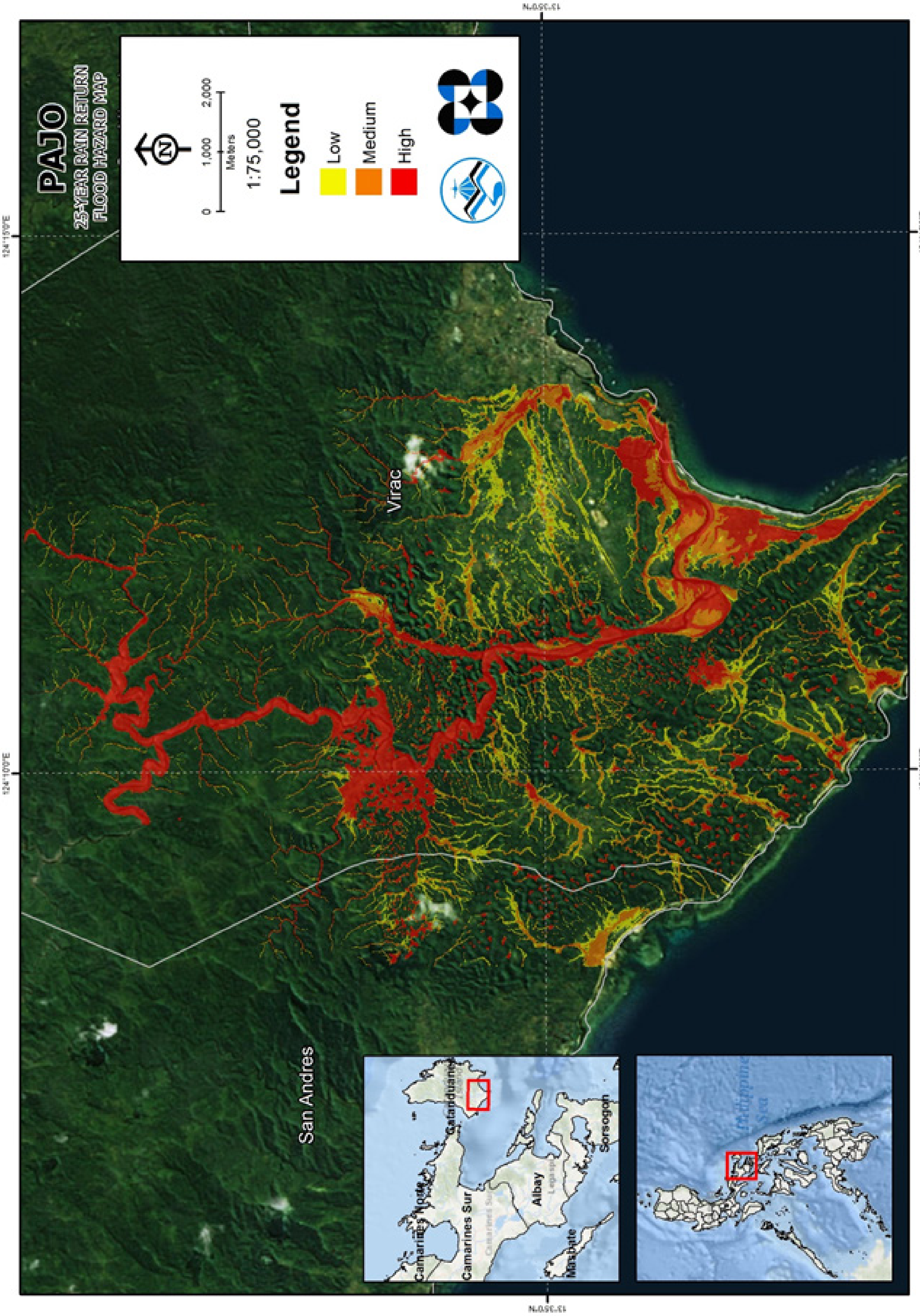


Figure 68. 25-year flood hazard map for the Pajo Floodplain overlaid on Google Earth imagery

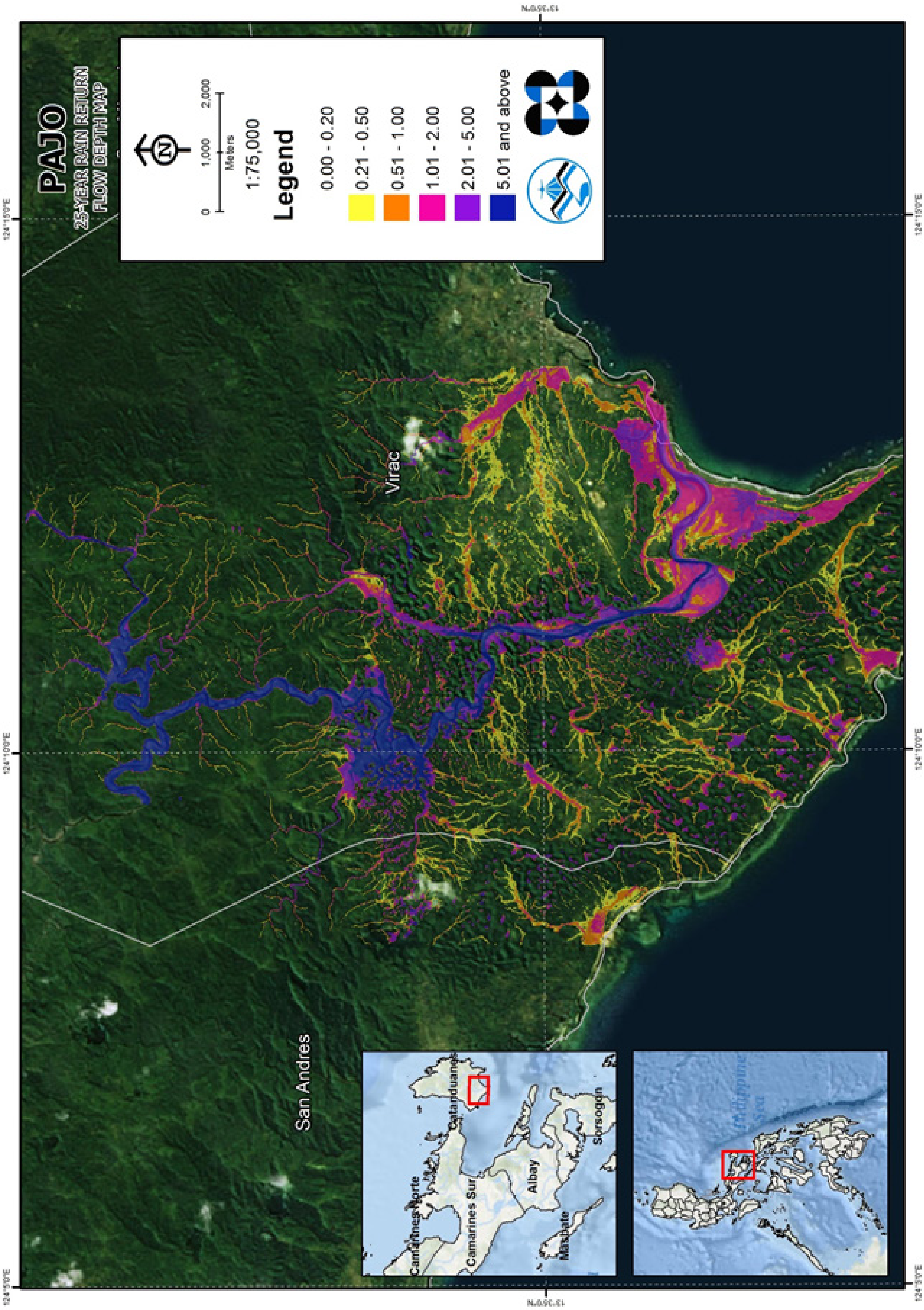


Figure 69. 25-year flow depth map for the Pajo Floodplain overlaid on Google Earth imagery

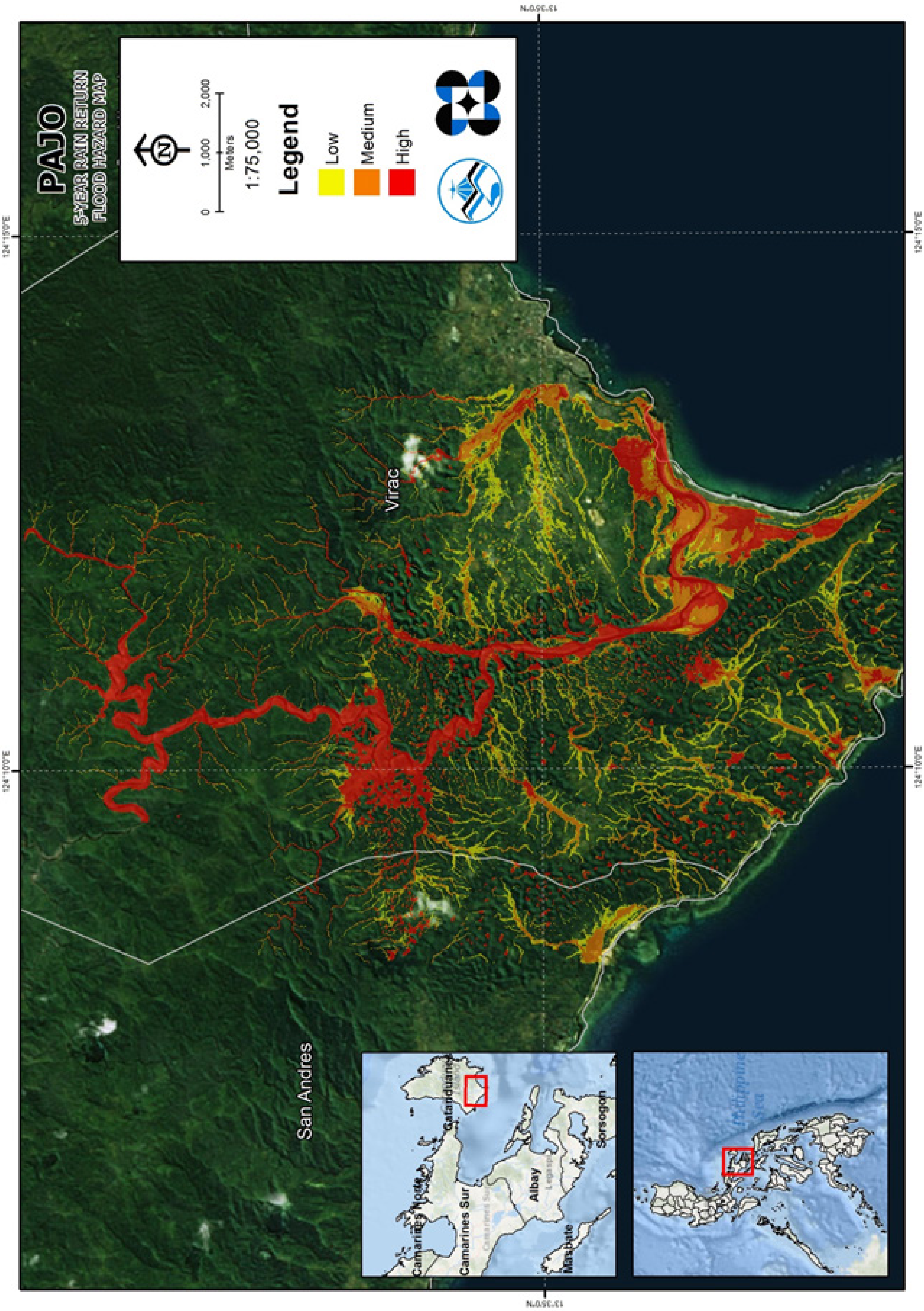


Figure 70. 5-year flood hazard map for the Pajo Floodplain overlaid on Google Earth imagery

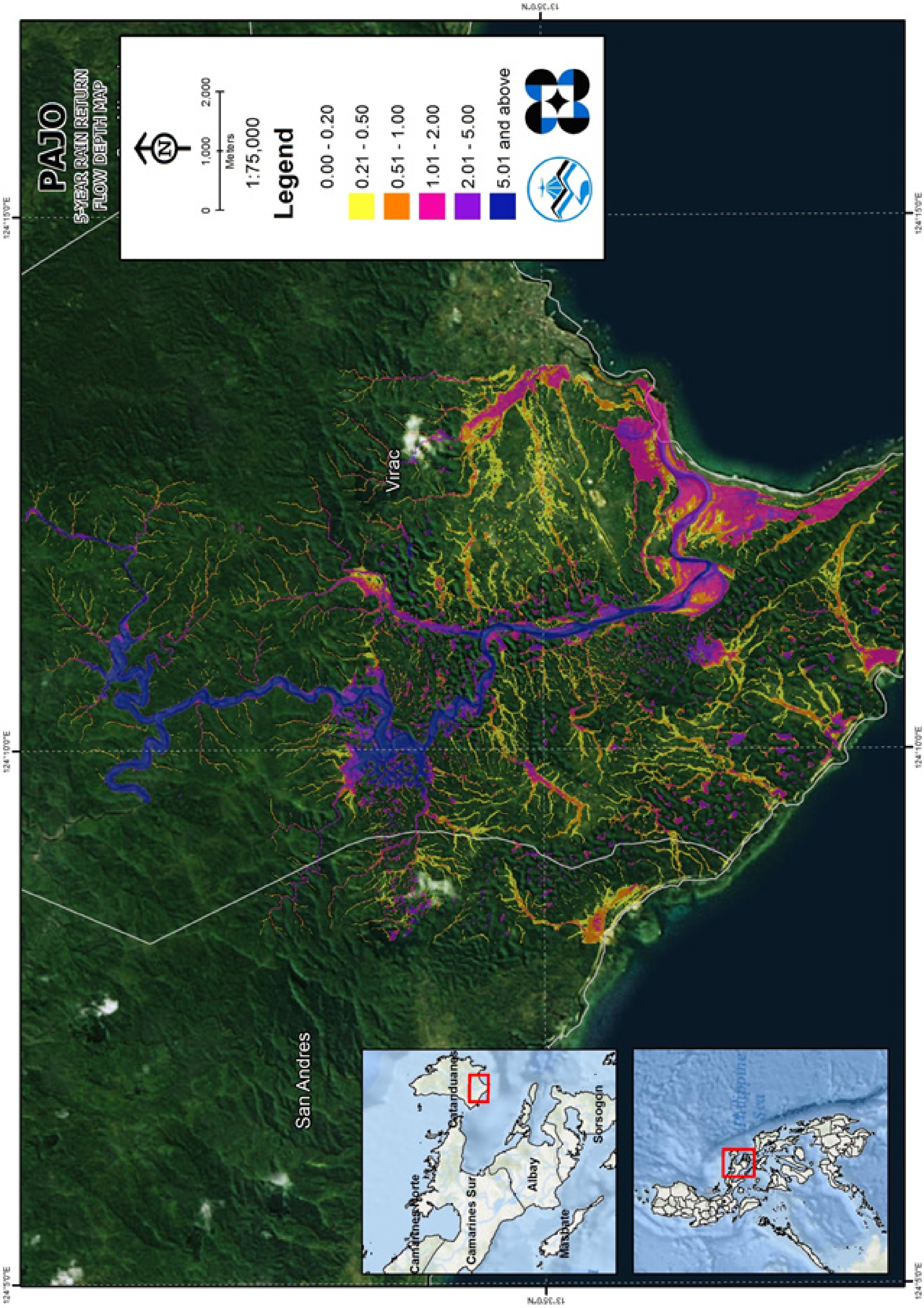


Figure 71. 5-year flow depth map for the Pajo Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Pajo River Basin, grouped accordingly by municipality. For the said basin, two(2) municipalities consisting of 51 barangays are expected to experience flooding when subjected to the three rainfall return period scenarios.

For the 5-year rainfall return period, 3.79% of the municipality of San Andres with an area of 172.88 sq. km. will experience flood levels of less than 0.20 meters. 0.45% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.26%, 0.12%, 0.11%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01to 5 meters, and greater than 5 meters, respectively. Figure 72 depicts the areas affected in San Andres in square kilometers by flood depth per barangay. Annex 12 and Annex 13 show the educational and health institutions exposed to flooding, respectively.

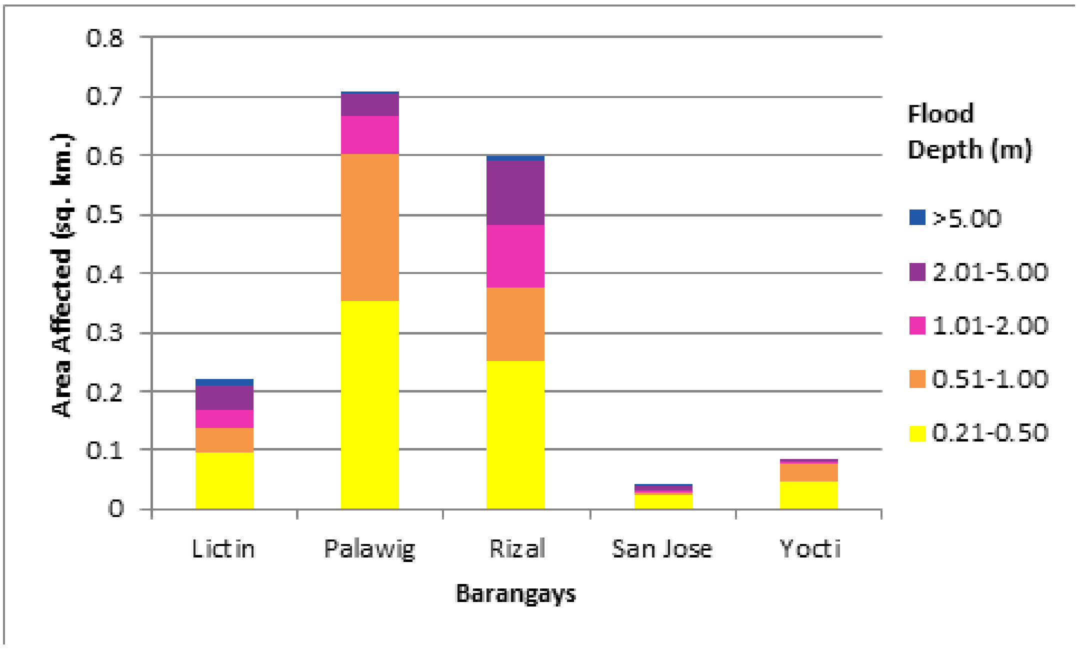


Figure 72. Affected Areas in San Andres, Catanduanes during the 5-Year Rainfall Return Period

For the municipality of Virac with an area of 175.3 sq. km., 7.82% will experience flood levels of less than 0.20 meters. 0.67% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.43%, 0.43%, 0.41%, and 0.44% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 73 to Figure 77 depict the areas affected in Virac in square kilometers by flood depth per barangay.

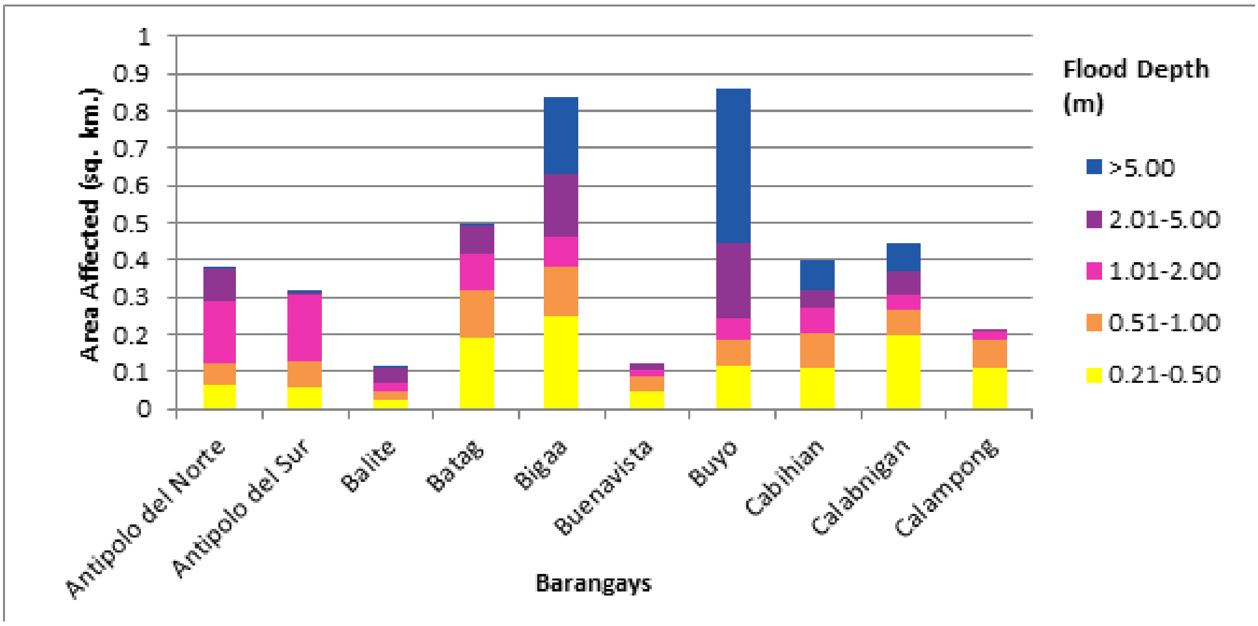


Figure 73. Affected Areas in Virac, Catanduanes during the 5-Year Rainfall Return Period

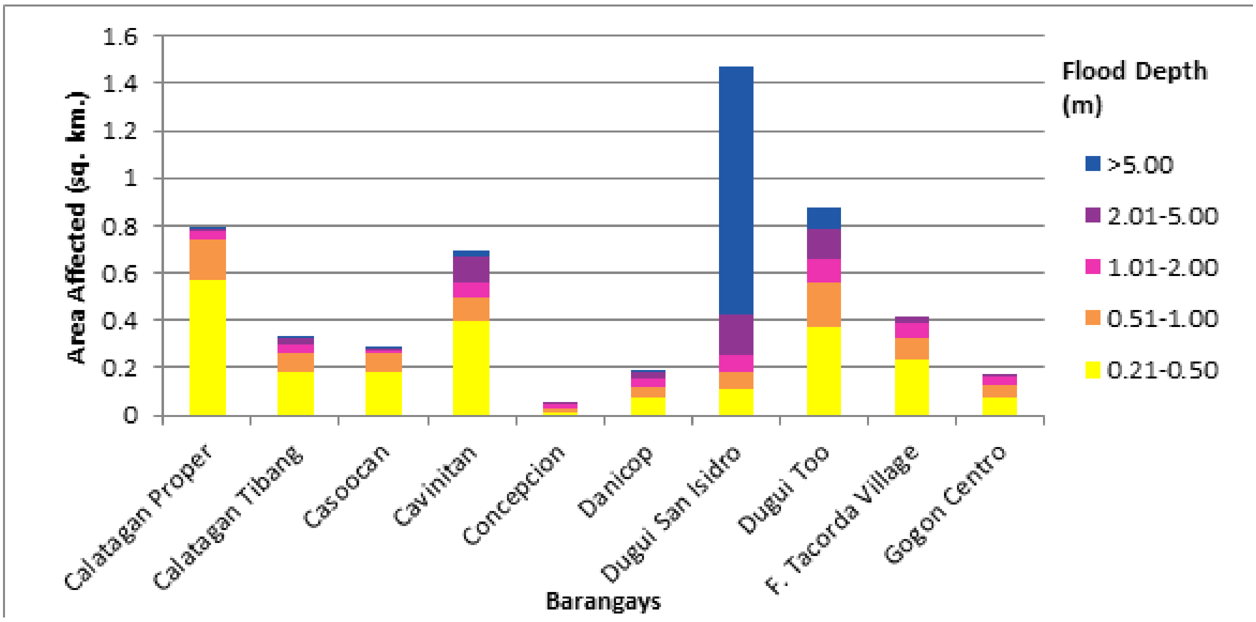


Figure 74. Affected Areas in Virac, Catanduanes during the 5-Year Rainfall Return Period

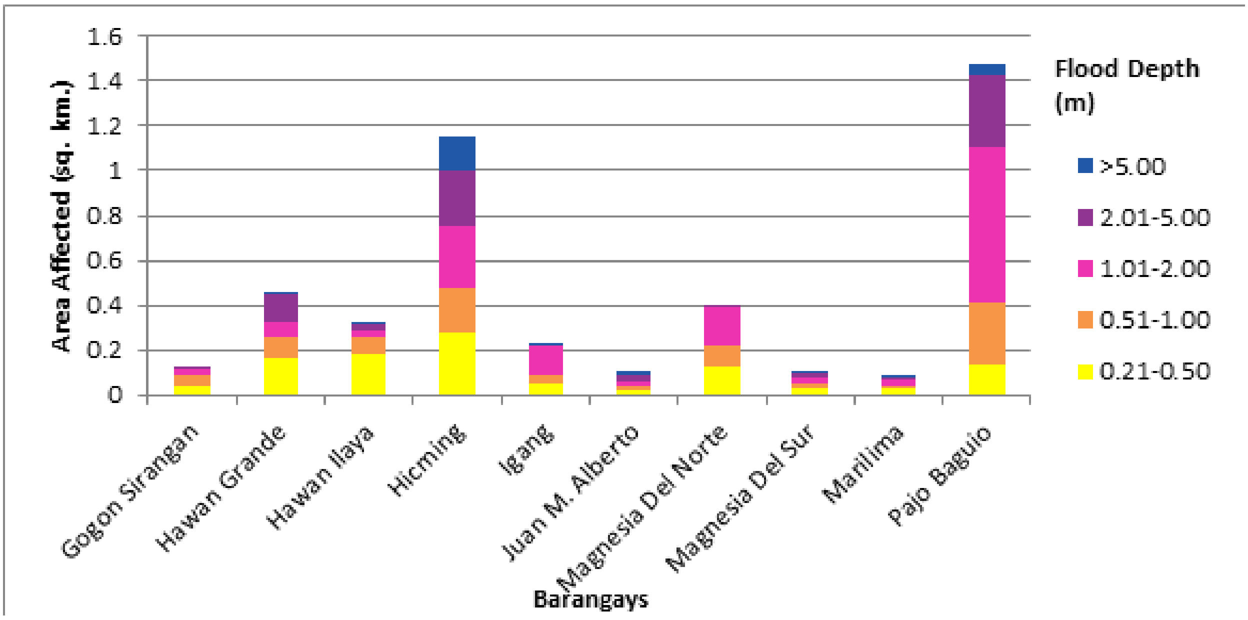


Figure 75. Affected Areas in Virac, Catanduanes during the 5-Year Rainfall Return Period

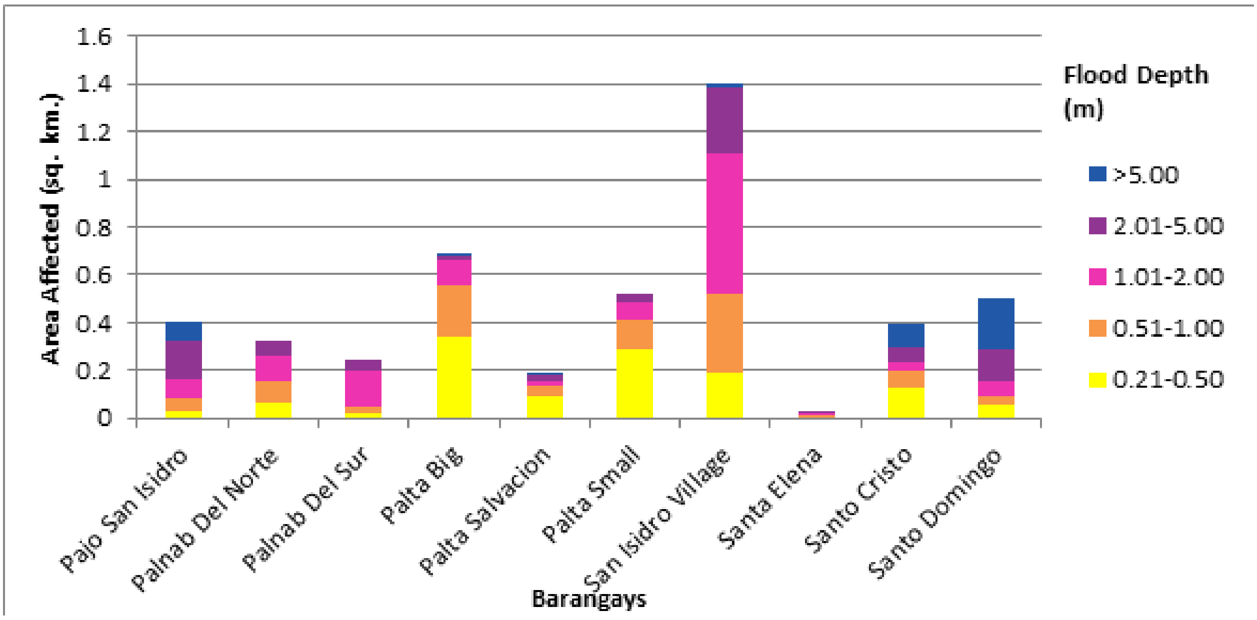


Figure 76. Affected Areas in Virac, Catanduanes during the 5-Year Rainfall Return Period

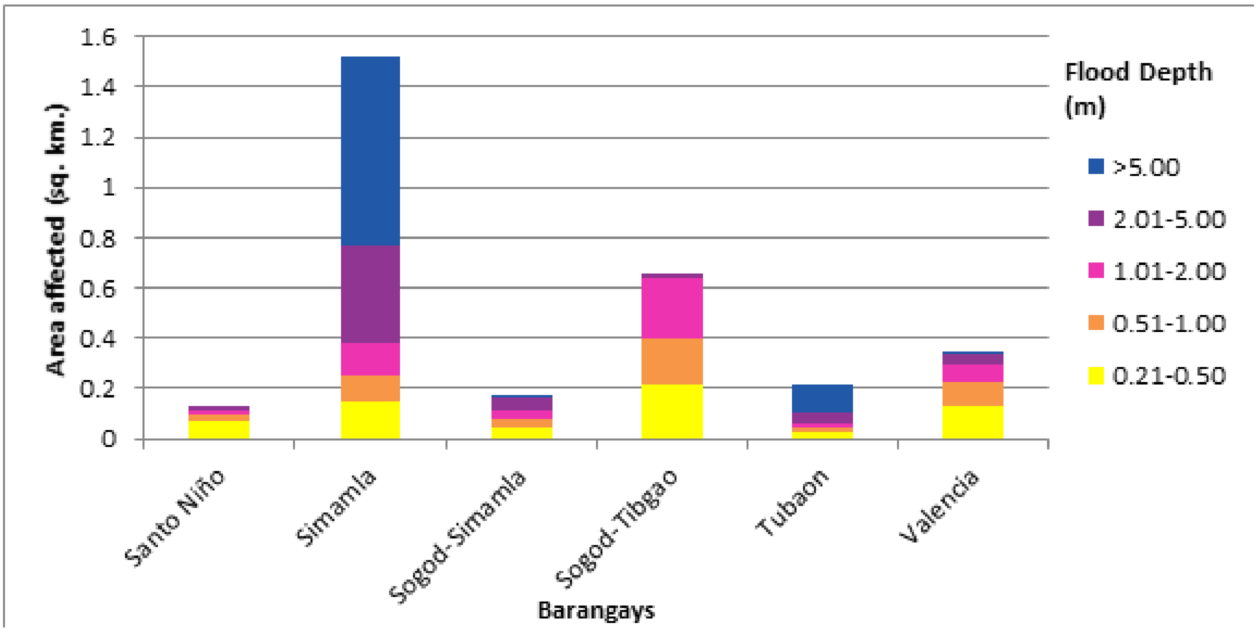


Figure 77. Affected Areas in Virac, Catanduanes during the 5-Year Rainfall Return Period

For the 25-year rainfall return period, 5.08% of the municipality of San Andres with an area of 172.88 sq. km. will experience flood levels of less than 0.20 meters. 0.47% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.26%, 0.15%, 0.12%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 78 depicts the areas affected in San Andres in square kilometers by flood depth per barangay.

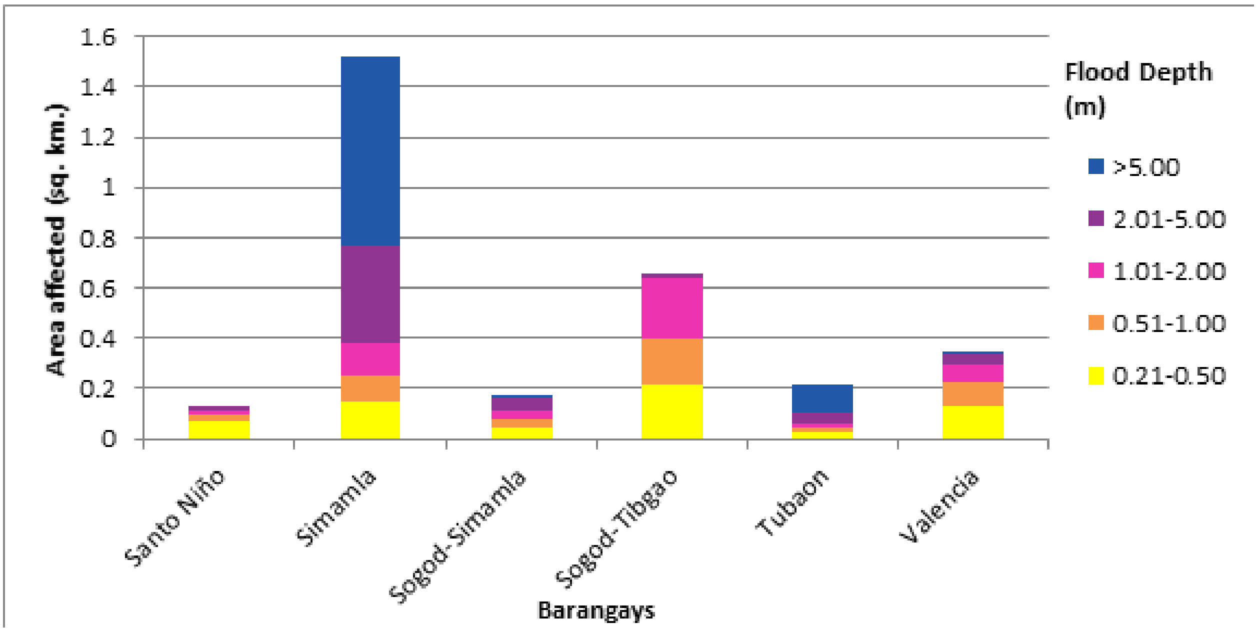


Figure 78. Affected Areas in San Andres, Catanduanes during the 25-Year Rainfall Return Period

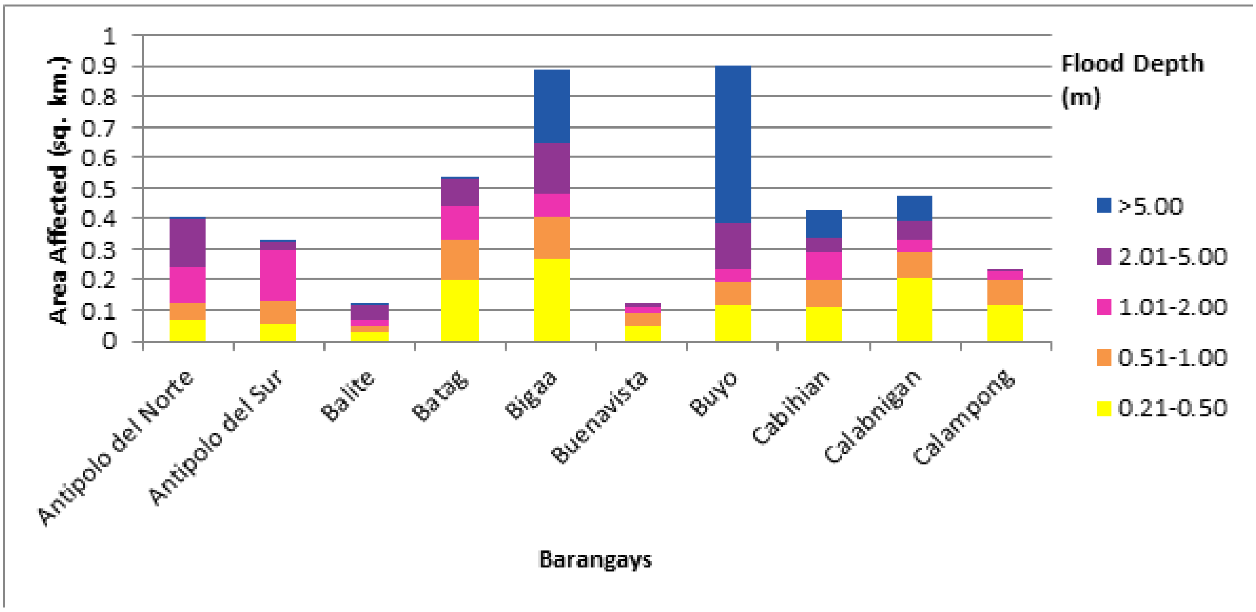


Figure 79. Affected Areas in Virac, Catanduanes during the 25-Year Rainfall Return Period

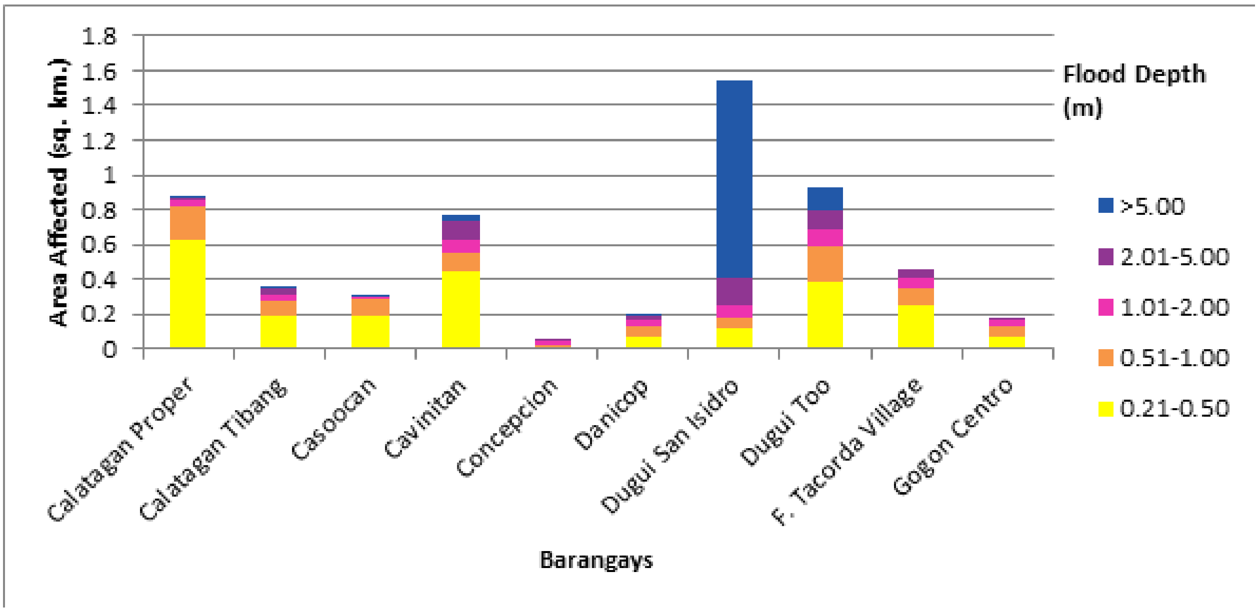


Figure 80. Affected Areas in Virac, Catanduanes during the 25-Year Rainfall Return Period

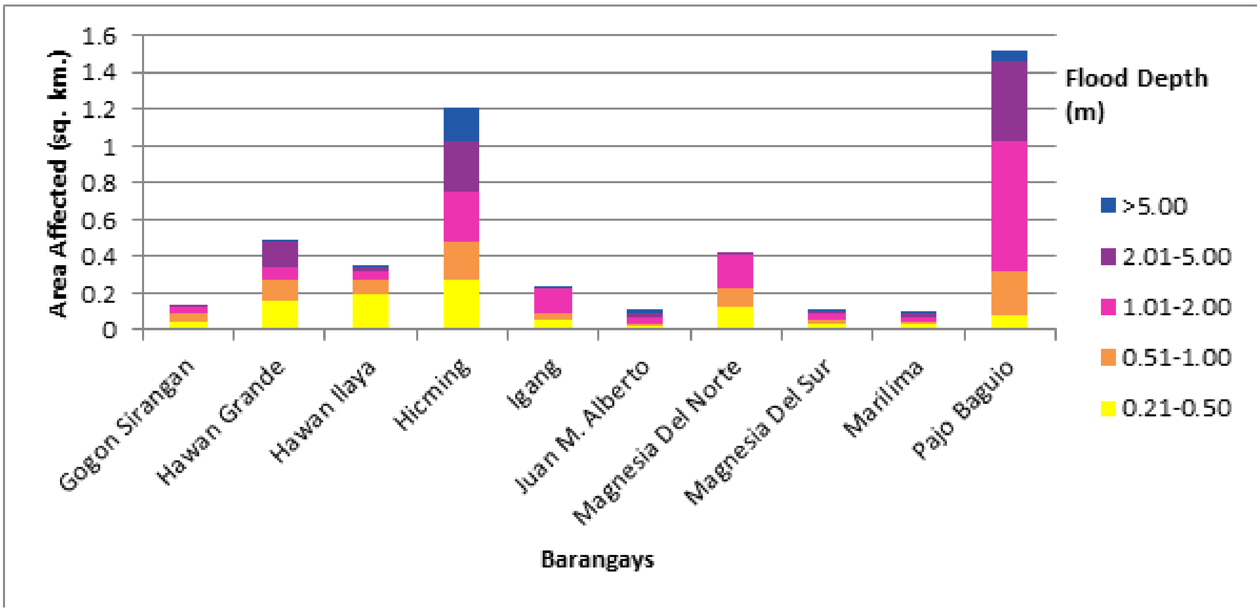


Figure 81. Affected Areas in Virac, Catanduanes during the 25-Year Rainfall Return Period

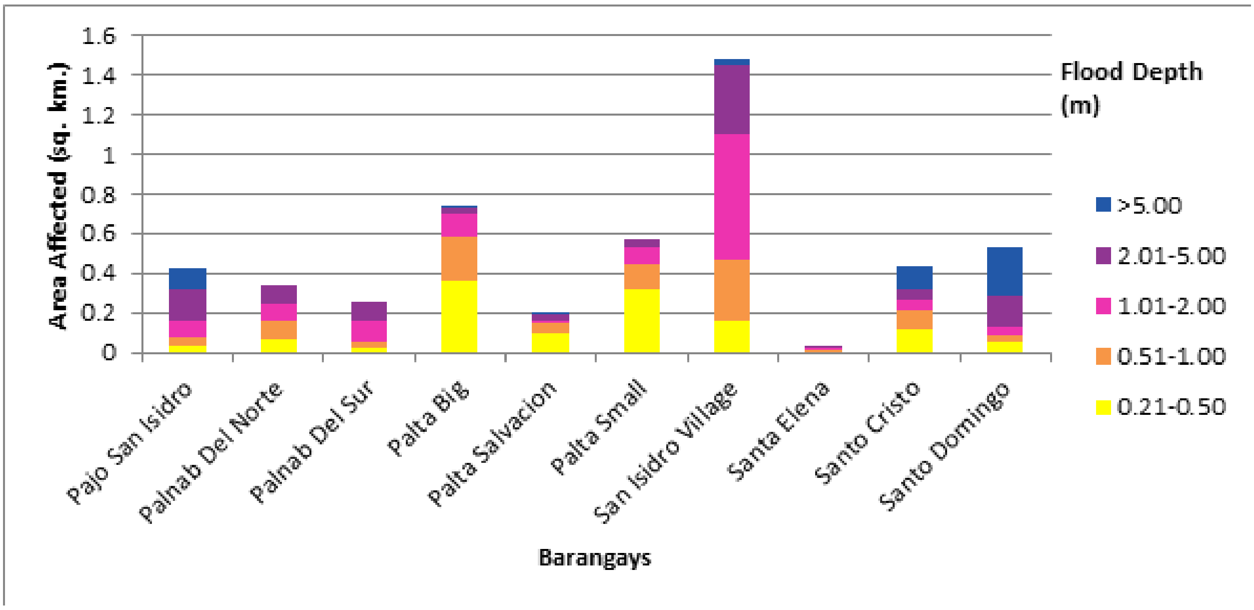


Figure 82. Affected Areas in Virac, Catanduanes during the 25-Year Rainfall Return Period

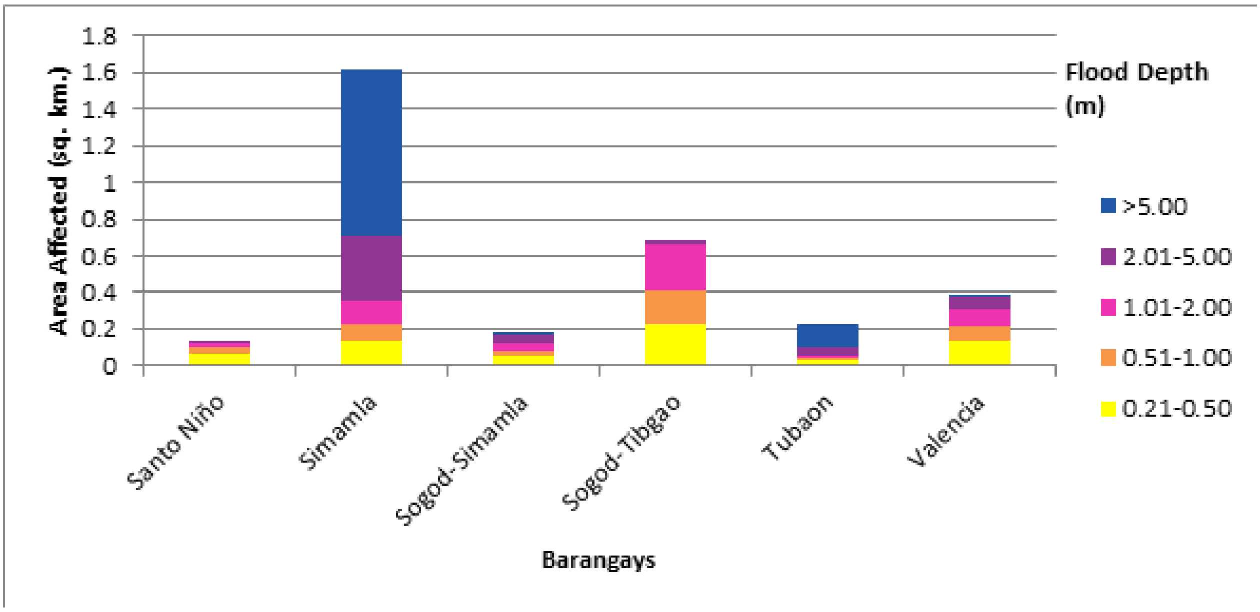


Figure 83. Affected Areas in Virac, Catanduanes during the 25-Year Rainfall Return Period

For the 100-year rainfall return period, 4.94% of the municipality of San Andres with an area of 172.88 sq. km. will experience flood levels of less than 0.20 meters. 0.52% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.28%, 0.19%, 0.15%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 84 depicts the areas affected in San Andres in square kilometers by flood depth per barangay.

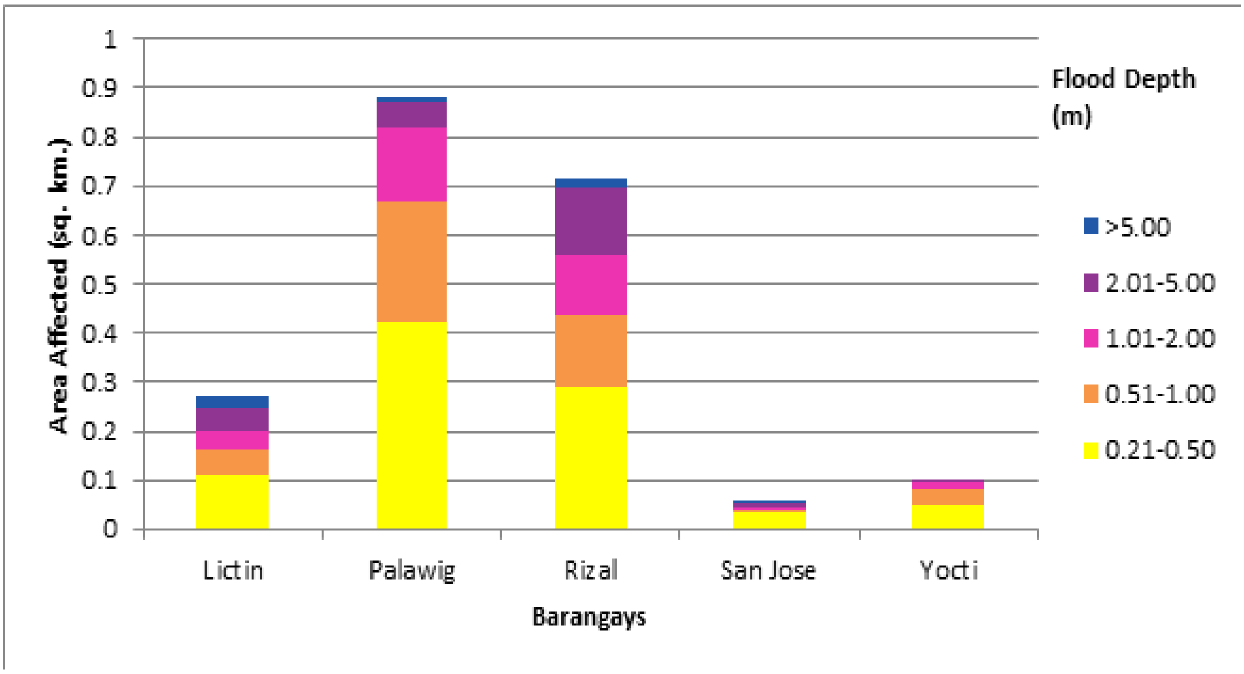


Figure 84. Affected Areas in San Andres, Catanduanes during the 100-Year Rainfall Return Period

For the municipality of Virac with an area of 175.3 sq. km., 7.35% will experience flood levels of less than 0.20 meters. 0.76% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.49%, 0.38%, 0.54%, and 0.69% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 85 to Figure 89 depict the areas affected in Virac in square kilometers by flood depth per barangay.

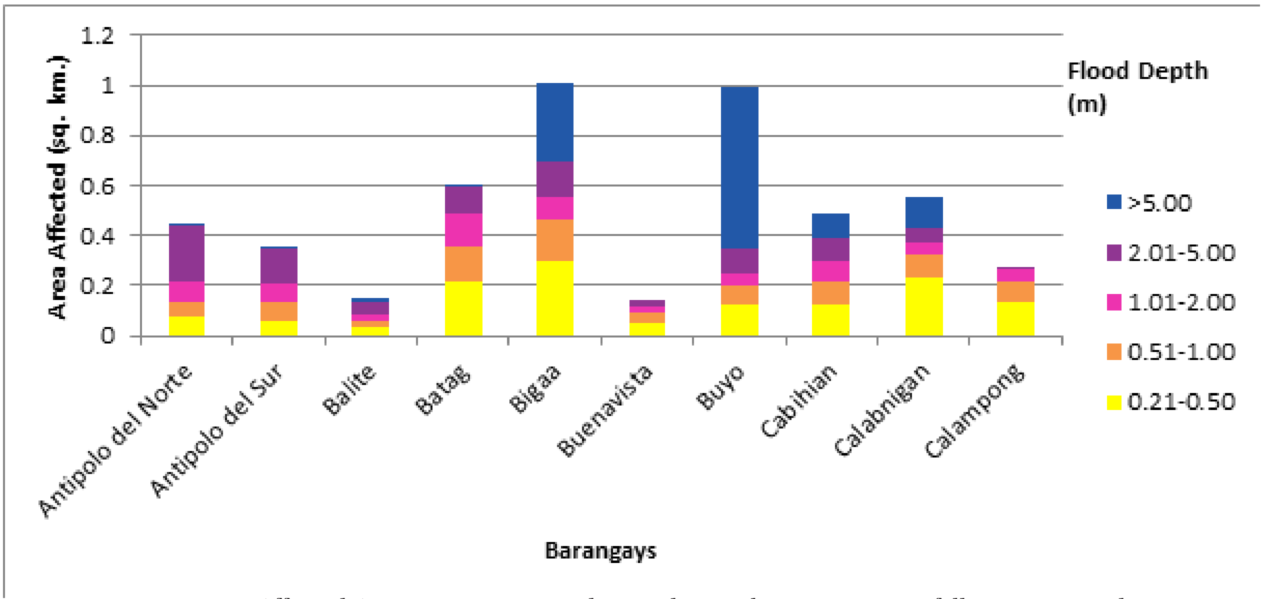


Figure 85. Affected Areas in Virac, Catanduanes during the 100-Year Rainfall Return Period

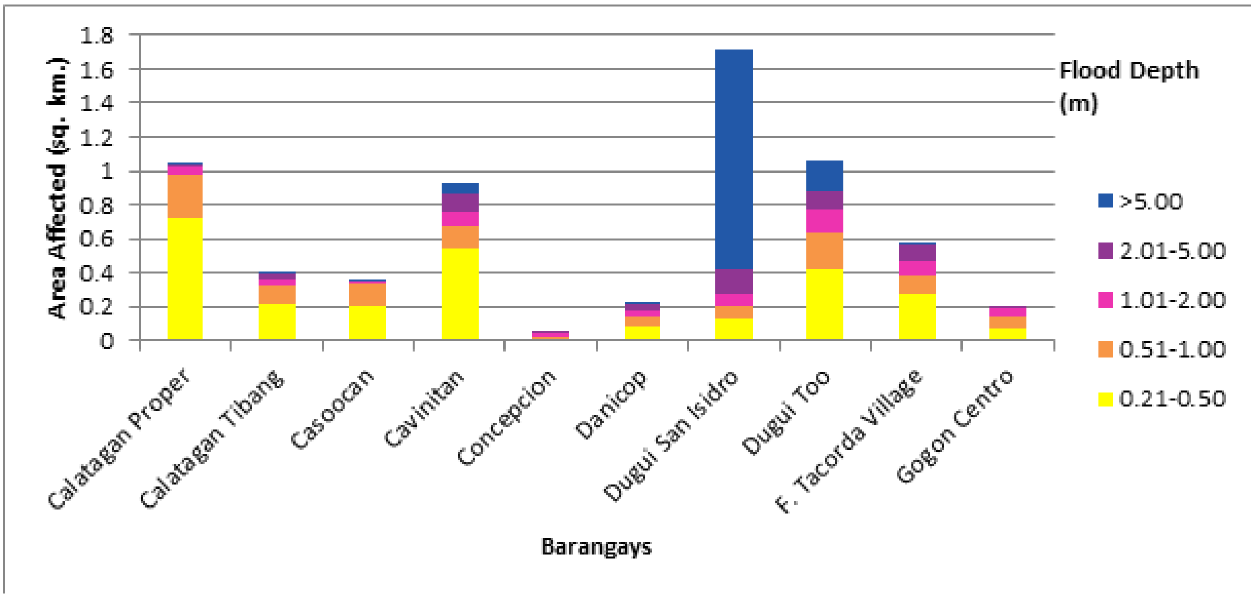


Figure 86. Affected Areas in Virac, Catanduanes during the 100-Year Rainfall Return Period

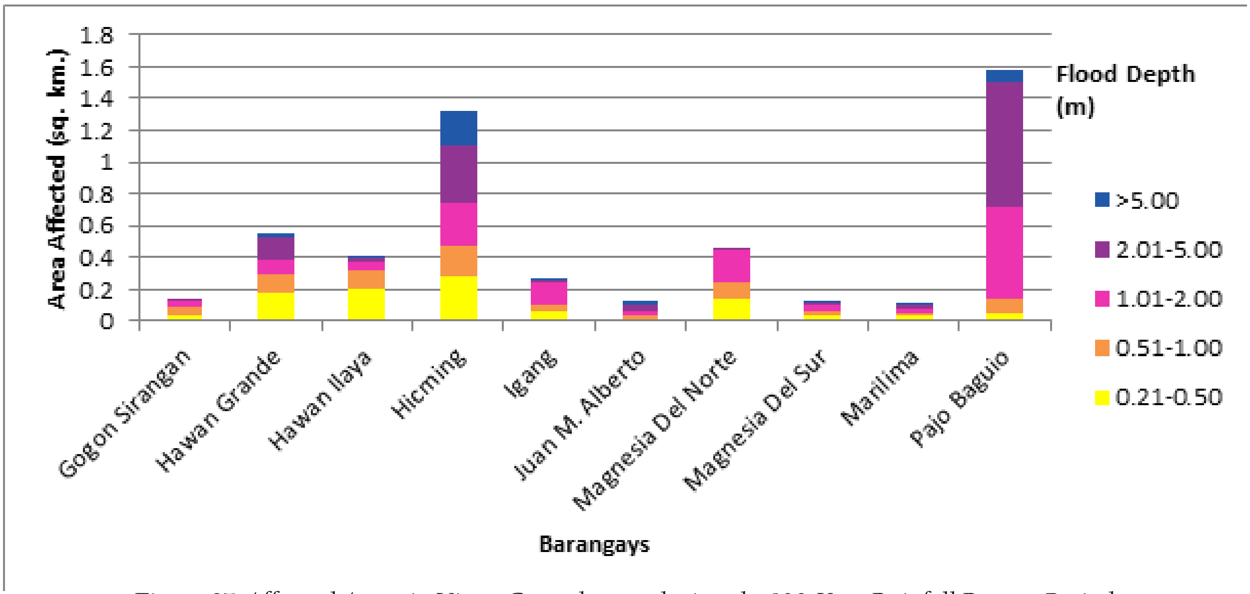


Figure 87. Affected Areas in Virac, Catanduanes during the 100-Year Rainfall Return Period

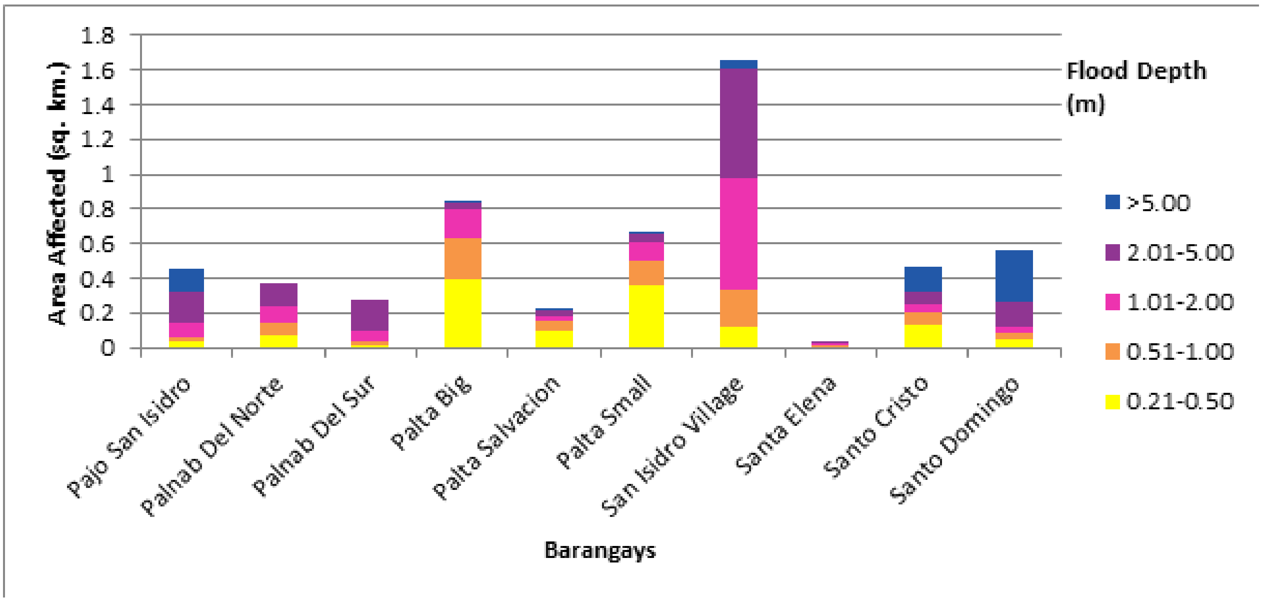


Figure 88. Affected Areas in Virac, Catanduanes during the 100-Year Rainfall Return Period

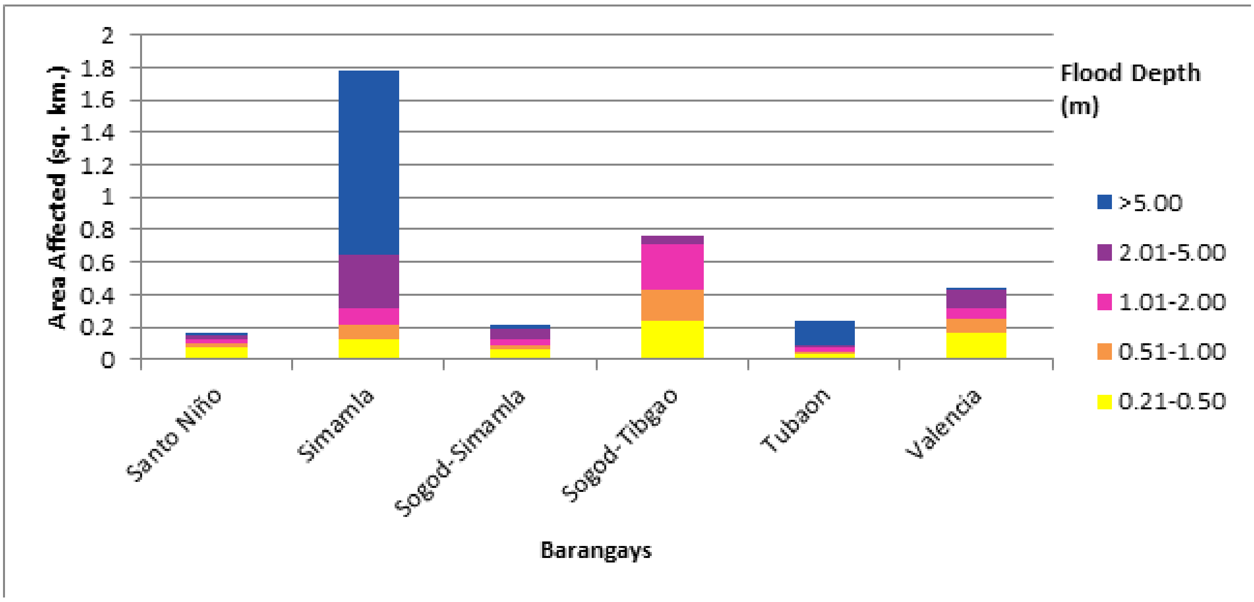


Figure 89. Affected Areas in Virac, Catanduanes during the 100-Year Rainfall Return Period

Among the barangays in the municipality of San Andres, Rizal is projected to have the highest percentage of area that will experience flood levels at 2.19%. Meanwhile, Palawig posted the second highest percentage of area that may be affected by flood depths at 1.96%.

Among the barangays in the municipality of Virac, Dugui Too is projected to have the highest percentage of area that will experience flood levels at 6.56%. Meanwhile, Hicming posted the second highest percentage of area that may be affected by flood depths at 4.63%.

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

Table 35. 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	7.1	7.32	7.94
Medium	7.07	7.16	7.24
High	9.59	10.75	13.1

Of the 37 identified Educational Institutions in Pajo Floodplain, 7 were assessed to be exposed to low, 5 to medium, and 6 to high level flooding during the 5-year scenario. In the 25-year scenario, 6 were assessed to be exposed to low, 5 to medium, and 7 to high level flooding. In the 100-year scenario, 7 were assessed to be exposed to low, 3 to medium, and 10 to high level flooding.

Of the 15 identified Medical Institutions in Pajo Floodplain, none was assessed to be exposed to low, 2 to medium, and 3 to high level flooding during the 5-year scenario. In the 25-year scenario, none was assessed to be exposed to low, 2 to medium, and 3 to high level flooding. In the 100-year scenario, none was assessed to be exposed to low, 3 to medium, and 3 to high level flooding.

5.11 Flood Validation

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

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

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

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation consists of 196 points randomly selected all over the Pajo Floodplain. It has an RMSE value of 3.21185694. The validation points are found in Annex 11.

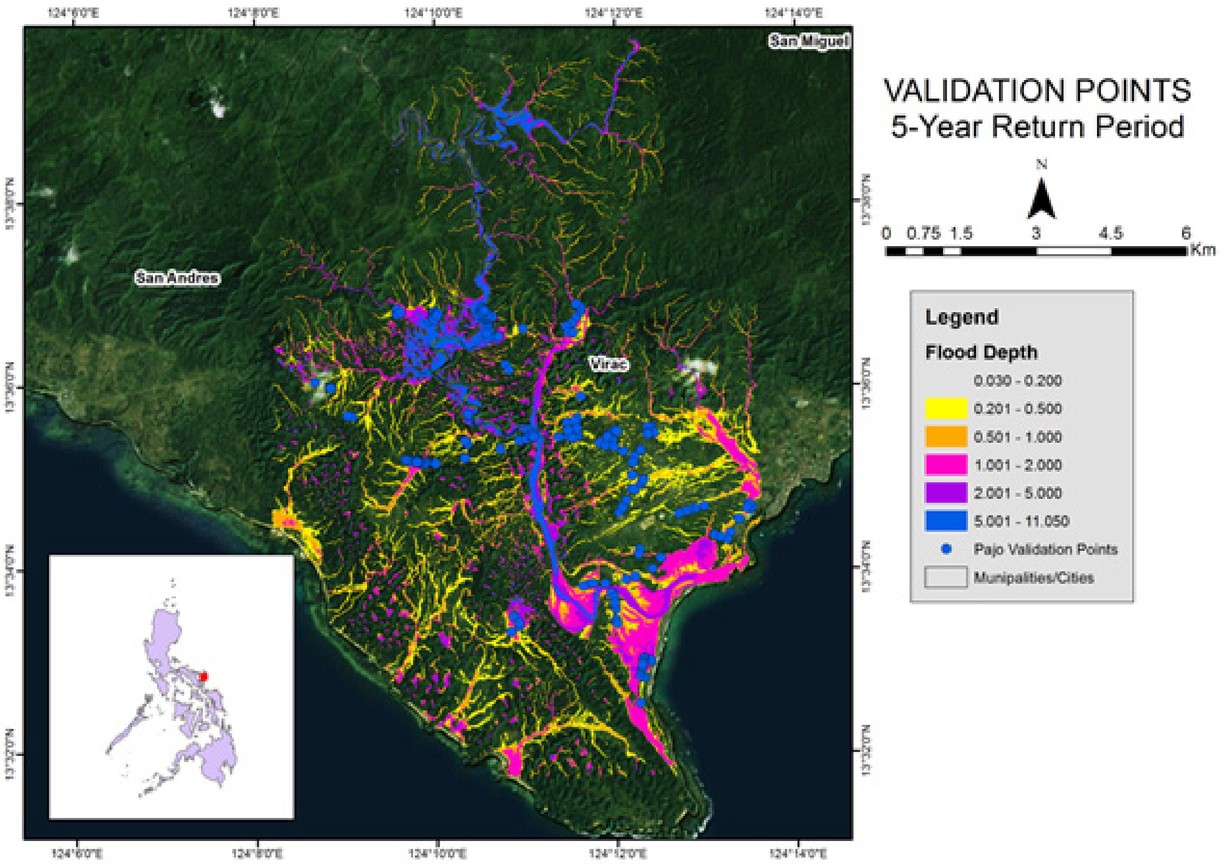


Figure 90. The validation points for the 5-Year flood depth map of the Pajo Floodplain

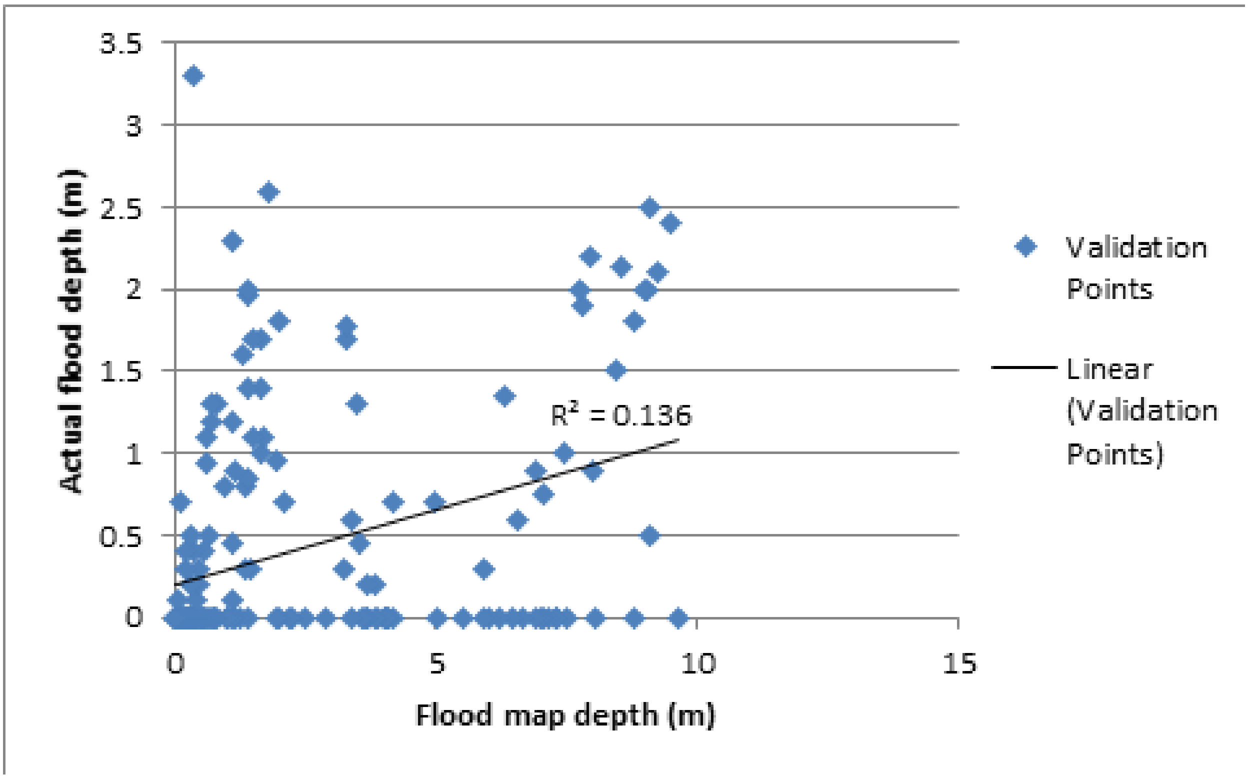


Figure 91. Flood map depth vs. actual flood depth

Table 36. Actual flood vs. Simulated flood depth at different levels in the Pajo River Basin

HIMOGAANPajo BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	42	31	15	8	19	17	132
	0.21-0.50	2	3	2	3	2	2	14
	0.51-1.00	1	0	2	5	4	5	17
	1.01-2.00	0	0	4	11	3	7	25
	2.01-5.00	0	1	0	2	0	5	8
	> 5.00		0	0	0	0	0	0
Total		45	35	23	29	28	36	196

On the whole, the overall accuracy generated by the flood model is estimated at 29.59%, with 58 points correctly matching the actual flood depths. In addition, there were 54 points estimated one level above and below the correct flood depths, 30 points estimated two levels above and below, and 54 points estimated three or more levels above and below the correct flood depths. A total of 128 points were overestimated while a total of 10 points were underestimated in the modelled flood depths of Pajo. Table 37 depicts the summary of the accuracy assessment in the Pajo River Basin survey.

Table 37. The Summary of Accuracy Assessment in the Pajo River Basin Survey

	No. of Points	%
Correct	58	29.59
Overestimated	128	65.31
Underestimated	10	5.10
Total	196	100

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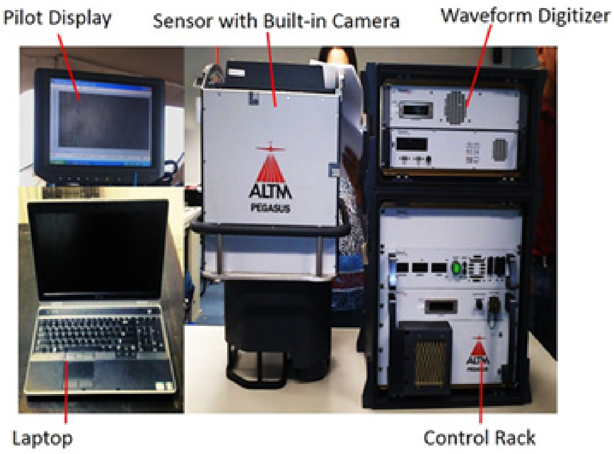
ANNEXES

ANNEX 1. Technical Specifications of the LIDAR Sensors used in the Pajo Pajo Survey



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

ANNEX 2. NAMRIA Certification of Reference Points Used in the LIDAR Survey

CA-130

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

January 27, 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: **CATANDUANES** Station Name: **CA-130**	
Island: **Luzon**	Municipality: **SAN MIGUEL**	Barangay: **BALATOHAN**
Elevation: **37.6703 +/- 0.09 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

BM CA-130
Marked is the head of a 4" copper nail flushed in a cement block embedded in the ground with inscriptions "BMCA-130; 2008; NAMRIA". The station is situated in drilled hole cement putty end of pathwalk of Balatohan San Miguel Catanduanes 20 m. east to km post 23, approximate 11 km to San Miguel Town Proper.

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089687 I**
T.N.: **2016-0247**

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

9 9 0 1 2 7 2 0 1 6 1 5 1 4 3 4

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

CNS-20

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

January 27, 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: **CATANDUANES**		
	Station Name: **CNS-20**		
	Order: **2nd**		
Island: **LUZON**	Barangay: **PAGSANGAHAN**		
Municipality: **SAN MIGUEL**	MSL Elevation:		
	PRS92 Coordinates		
Latitude: **13° 43' 8.77572"**	Longitude: **124° 16' 9.57152"**	Ellipsoidal Hgt:	**43.75200 m.**
	WGS84 Coordinates		
Latitude: **13° 43' 3.83355"**	Longitude: **124° 16' 14.51857"**	Ellipsoidal Hgt:	**97.73600 m.**
	PTM / PRS92 Coordinates		
Northing: **1517459.029 m.**	Easting: **637300.168 m.**	Zone:	**4**
	UTM / PRS92 Coordinates		
Northing: **1,516,927.89**	Easting: **637,252.11**	Zone:	**51**

Location Description

CNS-20

From Virac Town Proper, travel N passing through Mun. of San Miguel for about 25 Km. Station is located at NW wing of Malmag bridge along Circumferential Road going to Mun. of Viga. Mark is the head of a 4 in. copper nail centered on a drilled hole with cement putty, embedded at concrete bridge with inscriptions, "CNS-20, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089687 I**
T.N.: **2016-0244**

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

9 9 0 1 2 7 2 0 1 6 1 5 1 3 3 5

CERTIFICATION INTERNATIONAL ISO 9001:2008
CIP/4701/12/09/854

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

CNS-21

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

January 27, 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: **CATANDUANES**	
	Station Name: **CNS-21**	
	Order: **2nd**	
Island: **LUZON**	Barangay: **PALTA SMALL**	
Municipality: **VIRAC (CAPITAL)**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **13° 35' 14.37180"**	Longitude: **124° 9' 45.40531"**	Ellipsoidal Hgt: **83.10600 m.**
	WGS84 Coordinates	
Latitude: **13° 35' 9.45275"**	Longitude: **124° 9' 50.36457"**	Ellipsoidal Hgt: **137.19500 m.**
	PTM / PRS92 Coordinates	
Northing: **1502820.29 m.**	Easting: **625825.638 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,502,294.28**	Easting: **625,781.60**	Zone: **51**

Location Description

CNS-21

From Virac Town Proper, travel NW for about 9 Km. along Circumferential Road going to Mun. of San Andres. Station is located at Palta Bridge. It was established at SE approach of bridge along Circumferentail Road. Mark is the head of a 4 in. copper nail centered on a drilled hole with cement putty, embedded at concrete bridge with inscriptions, "CNS-21, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Purpose: **Reference**
OR Number: **8089687 I**
T.N.: **2016-0245**

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

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

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

CP/4701/12/09/814

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

1. CA-130

Vector Components (Mark to Mark)

From:	CNS-20 2016-1-27 TOPCON_GR5_ECQW				
Grid		Local		Global	
Easting	637252.110 m	Latitude	N13°43'08.77572"	Latitude	N13°43'03.83355"
Northing	1516927.891 m	Longitude	E124°16'09.57152"	Longitude	E124°16'14.51857"
Elevation	44.886 m	Height	43.752 m	Height	97.736 m

To:	CA-130				
Grid		Local		Global	
Easting	637606.660 m	Latitude	N13°43'03.83983"	Latitude	N13°42'58.89826"
Northing	1516778.097 m	Longitude	E124°16'21.34732"	Longitude	E124°16'26.29446"
Elevation	38.672 m	Height	37.511 m	Height	91.507 m

Vector					
ΔEasting	354.550 m	NS Fwd Azimuth	113°12'17"	ΔX	-309.234 m
ΔNorthing	-149.795 m	Ellipsoid Dist.	384.959 m	ΔY	-174.525 m
ΔElevation	-6.214 m	ΔHeight	-6.240 m	ΔZ	-148.827 m

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000019397		
Y	-0.0000007127	0.0000032012	
Z	-0.0000005242	0.0000008142	0.0000005724

2. VIRAC-E0

Vector Components (Mark to Mark)

From:	CNS-21				
Grid		Local		Global	
Easting	625781.597 m	Latitude	N13°35'14.37180"	Latitude	N13°35'09.45275"
Northing	1502294.277 m	Longitude	E124°09'45.40531"	Longitude	E124°09'50.36457"
Elevation	84.905 m	Height	83.106 m	Height	137.195 m

To:	VIRAC-E0				
Grid		Local		Global	
Easting	633250.707 m	Latitude	N13°35'03.52757"	Latitude	N13°34'58.61487"
Northing	1501997.753 m	Longitude	E124°13'53.85198"	Longitude	E124°13'58.81098"
Elevation	6.533 m	Height	4.565 m	Height	58.830 m

Vector					
ΔEasting	7469.110 m	NS Fwd Azimuth	92°32'48"	ΔX	-6178.777 m
ΔNorthing	-296.523 m	Ellipsoid Dist.	7476.432 m	ΔY	-4196.366 m
ΔElevation	-78.372 m	ΔHeight	-78.542 m	ΔZ	-342.164 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.010 m
σ ΔNorthing	0.003 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.014 m
σ ΔElevation	0.017 m	σ ΔHeight	0.017 m	σ ΔZ	0.006 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0001019463		
Y	-0.0001313494	0.0001848713	
Z	-0.0000508365	0.0000677488	0.0000313776

2

ANNEX 4. The LIDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader - I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Data Component Project Leader – I	ENGR. LOUIE P. BALICANTA	UP-TCAGP
	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
		LOVELY GRACIA ACUÑA	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELYN ASUNCION	UP-TCAGP

FIELD TEAM

LiDAR Operation / Ground Survey / Data Download and Transfer	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	KENNETH QUISADO	UP-TCAGP
		KRISTINE JOY ANDAYA	UP-TCAGP
	Research Associate (RA)	NICOLAS ILEJAY	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. LEE JAY PUNZALAN	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. SHERWIN ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JERICHO JECIEL	AAC

ANNEX 5. Data Transfer Sheet for Silaga Floodplain

DATA TRANSFER SHEET
Catanduanes 1/28/16

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	
22-Jan	3010P	1BLK25A022A	pegasus	1.95	867/453	12.6	229	na	na	22.9	na	69.3	1KB	1KB	103/136/121/107	na	Z:\DAC\RAW DATA
23-Jan	3012P	1BLK25AC023A	pegasus	1.92	1196/399	12.1	263	27.9	219	22.1	na	95.7	1KB	1KB	190/158	na	Z:\DAC\RAW DATA
23-Jan	3014P	1BLK25BC023B	pegasus	1.1	2026/198	8.39	145	3.5/7.18	25/54	12	na	95.7	1KB	1KB	285/240	na	Z:\DAC\RAW DATA
24-Jan	3016P	1BLK25E024A	pegasus	1.3	491/290	6.79	167	na	na	14.6	na	82.4	1KB	1KB	240	na	Z:\DAC\RAW DATA

Received from
Name CJoaquin III
Position FA
Signature

Received by
Name AC Bongat
Position SSRS
Signature 1/28/16

DATA TRANSFER SHEET (Catanduanes)
2/10/16

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	
3-Feb	10081AC	3AQUACALIB034A	Aquarius	NA	47	143	110	12.7	29.1/31.8/31.1/34	2.44	na	4.32	1KB	1KB	4KB	30KB	Z:\DAC\RAW DATA
27-Jan	3028P	1BLK25F027A	Pegasus	303	617KB/91KB	6.04	135	NA	NA	4.78	NA	64.5	1KB	1KB	NA	617KB/91KB	Z:\DAC\RAW DATA
28-Jan	3032P	1BLK25E028B	Pegasus	3.34	47KB	4.53	149	NA	NA	3.27	na	95.9	1KB	NA	312KB/283KB/303KB	47KB	Z:\DAC\RAW DATA
1-Feb	3048P	1BLK25F032A	Pegasus	983	557KB/231KB	7.84	195	NA	NA	12.9	na	91.5	1KB	NA	NA	557KB/231KB	Z:\DAC\RAW DATA
1-Feb	3050P	1BLK25E032B	Pegasus	1.29	2801KB/291KB	8.5	196	NA	NA	14.8	na	91.5	1KB	NA	312KB/283KB/303KB	2801KB/291KB	Z:\DAC\RAW DATA

Received from

Name: Jonalyn Gonzales
Position: RA
Signature:

Received by

Name: AC Bongat 2/12/16
Position: SSRS
Signature:

ANNEX 6. Flight logs for the flight missions

Flight Log for 3010P Mission

D R E A M | Data Acquisition Flight Log

Flight Log No.: 3010P

1 LiDAR Operator: Kenneth Quisado	2 ALTM Model: Pegasus	3 Mission Name: 1BLK25A022A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: S. Alfonso	8 Co-Pilot: J. Jeciel	9 Route: Virac Area			
10 Date: Jan 22, 2016	12 Airport of Departure (Airport, City/Province): Virac, Catanduanes		12 Airport of Arrival (Airport, City/Province): Virac, Catanduanes		
13 Engine On: 7:15	14 Engine Off: 11:20	15 Total Engine Time: 4+05	16 Take off: 7:20	17 Landing: 11:15	18 Total Flight Time: 3+55
19 Weather	Clear sky to cloudy				

20 Flight Classification

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

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

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

21 Remarks

Successful flight, surveyed a total of 17 lines over San Andres and Virac Area

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
J. Alviar	L. Punzalan	C. Alfonso III	Kenneth Quisado	
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

Flight Log for 3012P Mission

D R E A M | Data Acquisition Flight Log — **Flight Log No.:** 3012P

1 LiDAR Operator: Nic Ilejay	2 ALTM Model: Pegasus	3 Mission Name: 1BLK25B023A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC9122
7 Pilot: S. Alfonso	8 Co-Pilot: J. Jeciel	9 Route: RPUV - Virac Area			
10 Date: Jan 23, 2016	12 Airport of Departure (Airport, City/Province): Virac, Catanduanes		12 Airport of Arrival (Airport, City/Province): Virac, Catanduanes		
13 Engine On: 6:30	14 Engine Off: 10:35	15 Total Engine Time: 4:05	16 Take off: 6:35	17 Landing: 10:30	18 Total Flight Time: 3+55
19 Weather: Clear, Fair weather					

20 Flight Classification

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

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

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

21 Remarks

Successful flight, surveyed area over San Miguel

22 Problems and Solutions

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name (End User Representative)	L Pangan Signature over Printed Name (PAF Representative)	C. Alfonso III Signature over Printed Name	Frank Nicolas Ilejay Signature over Printed Name	Signature over Printed Name

Flight Log for 3016P Mission

D R E A M | Data Acquisition Flight Log — Flight Log No.: 3016P

1 LiDAR Operator: Jas Alviar	2 ALTM Model: Pegasus	3 Mission Name: 1BLK25E024A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP C9122
7 Pilot: S. Alfonso	8 Co-Pilot: J. Jeciel	9 Route: RPUV - San Andres Area			
10 Date: Jan 24, 2016	12 Airport of Departure (Airport, City/Province): Virac, Catanduanes		12 Airport of Arrival (Airport, City/Province): Virac, Catanduanes		
13 Engine On: 6:35	14 Engine Off: 9:16	15 Total Engine Time: 2+41	16 Take off: 6:40	17 Landing: 9:11	18 Total Flight Time: 2+31
19 Weather	Cloudy				

20 Flight Classification

20.a Billable
- ø 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 DREAM Admin Activities

21 Remarks

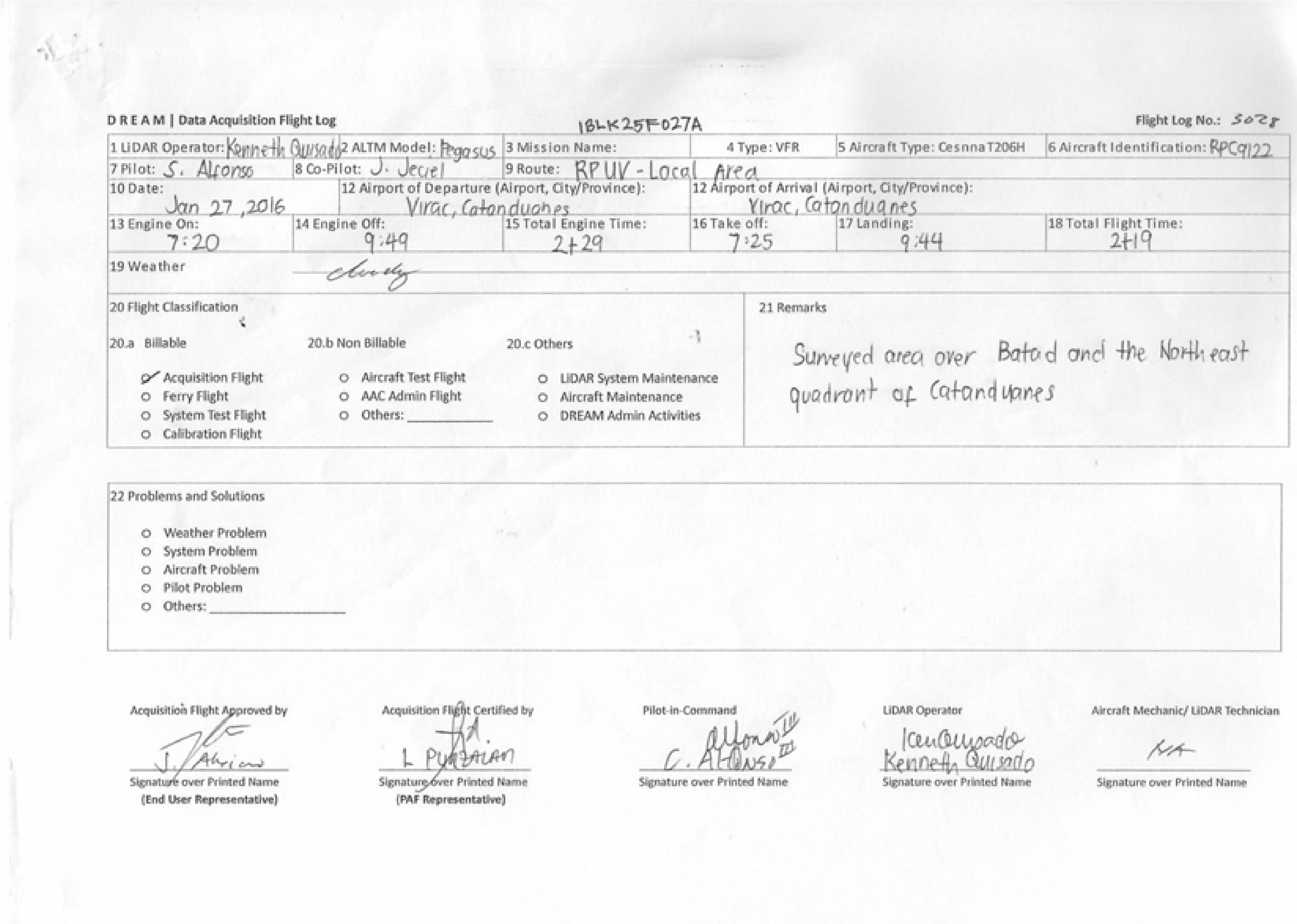
Surveyed remaining areas over Virac and San Andres

22 Problems and Solutions

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
J. Alviar	L Punzalan	C. Alfonso III	Jasmine Alviar	N/A
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Flight Log for 3028P Mission



D R E A M | Data Acquisition Flight Log

IBLK25F027A

Flight Log No.: 3028

1 LiDAR Operator: Kenneth Quisado	2 ALTM Model: Pegasus	3 Mission Name:	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC9122
7 Pilot: S. Alfonso	8 Co-Pilot: J. Jeciel	9 Route: RPUV - Local Area			
10 Date: Jan 27, 2016	12 Airport of Departure (Airport, City/Province): Virac, Catanduanes		12 Airport of Arrival (Airport, City/Province): Virac, Catanduanes		
13 Engine On: 7:20	14 Engine Off: 9:49	15 Total Engine Time: 2+29	16 Take off: 7:25	17 Landing: 9:44	18 Total Flight Time: 2+19
19 Weather	cloudy				

20 Flight Classification

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

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

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

21 Remarks

Surveyed area over Batad and the Northeast quadrant of Catanduanes

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
J. Alviar	L. Pulzaian	C. Alfonso III	Kenneth Quisado	NA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

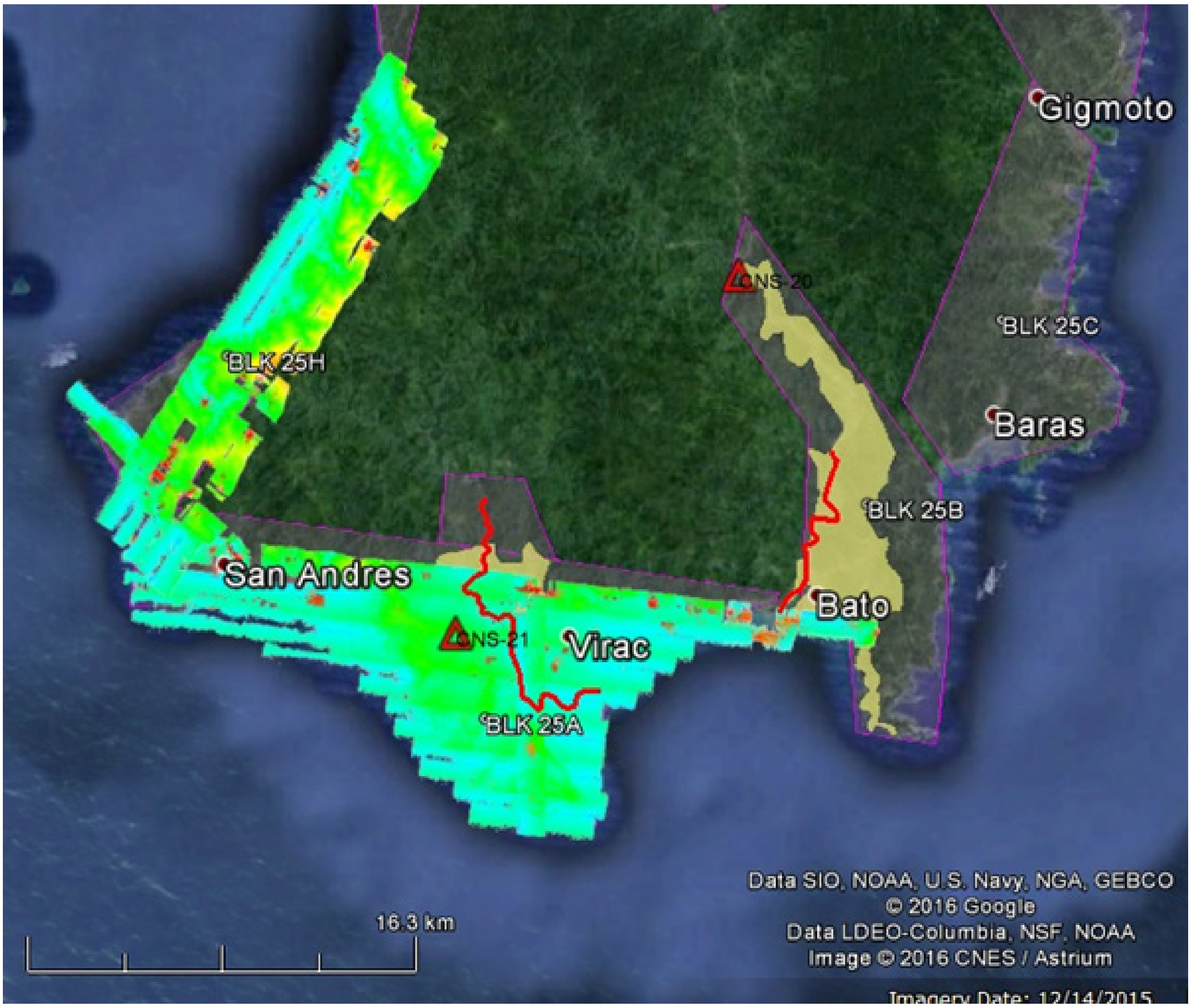
ANNEX 7. Flight status reports

CATANDUANES
(January 20 – February 4, 2016)

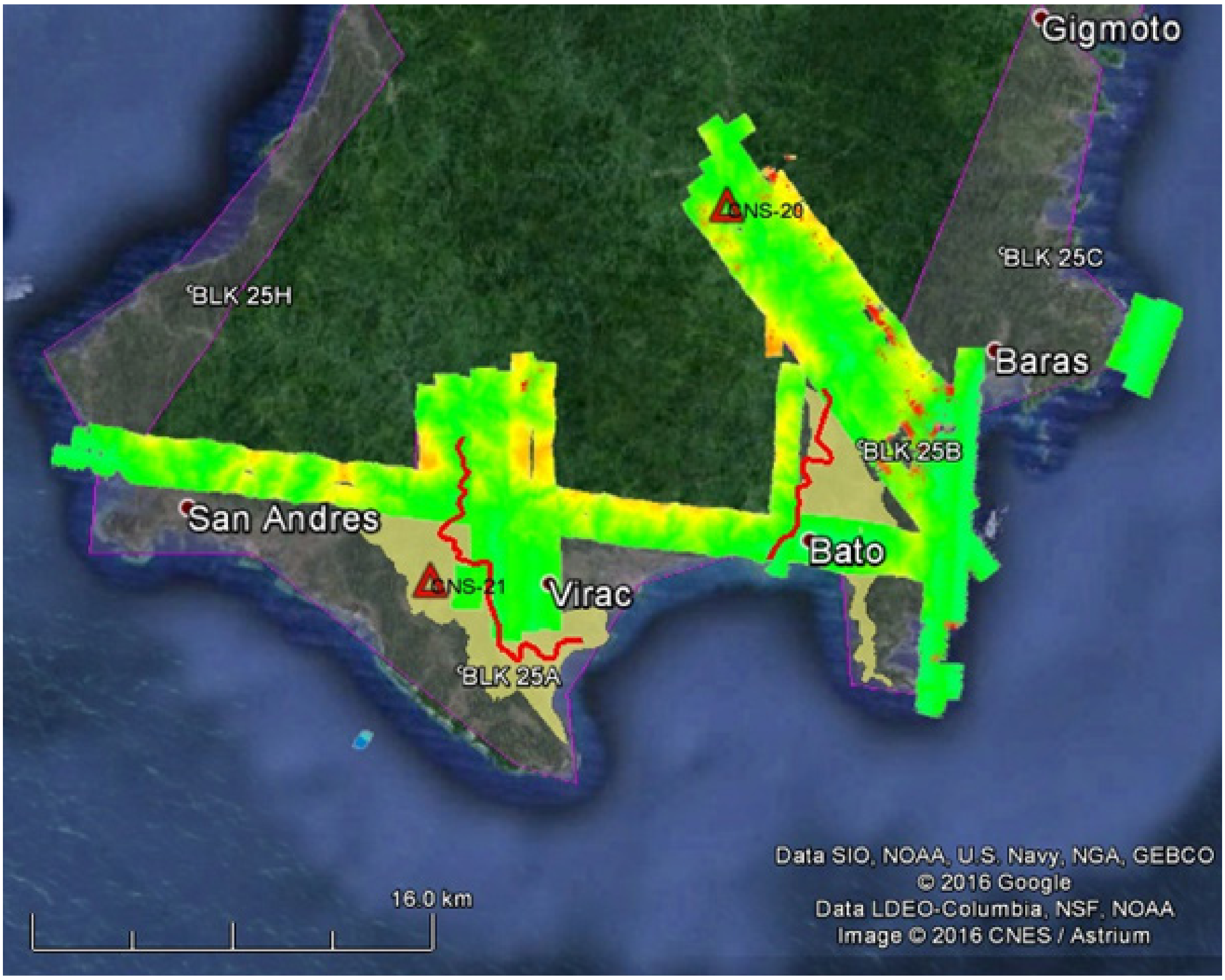
FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
3010P	BLK 25AH PAJO FP	1BLK25A022A	KA QUISADO	January 22, 2016	SURVEYED BLK 25A AND BLK 25H 247.54 SQ.KM
3012P	BLK 25BAS PAJO AND BATO FP	1BLK25AC023A	FN ILEJAY	January 23, 2016	SURVEYED BLK 25B AND BLK 25AS; SEVERAL RESTARTS DUE TO TRANSITION ERROR 208.58 SQ.KM
3016P	BLK 25HABS GAP FILLING	1BLK25E024A	JT ALVIAR	January 24, 2016	GAP FILLING IN BLK 25A, B, H; TURNED OFF CAMERA TO AVOID TRANSITION ERROR 148.48 SQ.KM
3028P	BLK 25C, AS	1BLK25F027A	KA QUISADO	January 25, 2016	SURVEYED BLK 25CAS 66 SQ.KM

LAS BOUNDARIES PER FLIGHT

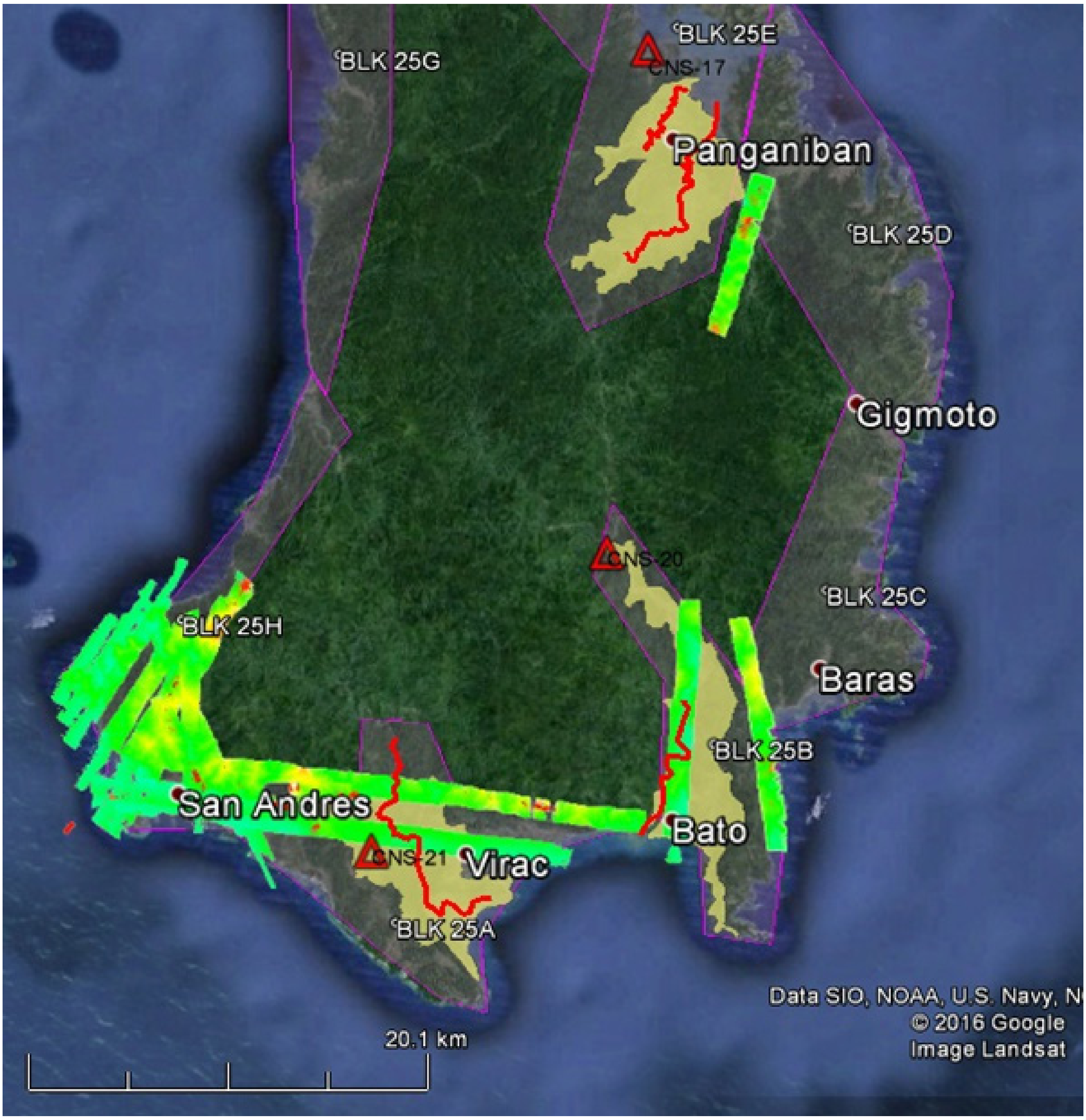
Flight No. : 3010P
Area: BLK 25AH
Mission Name: 1BLK25A022A
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 20%



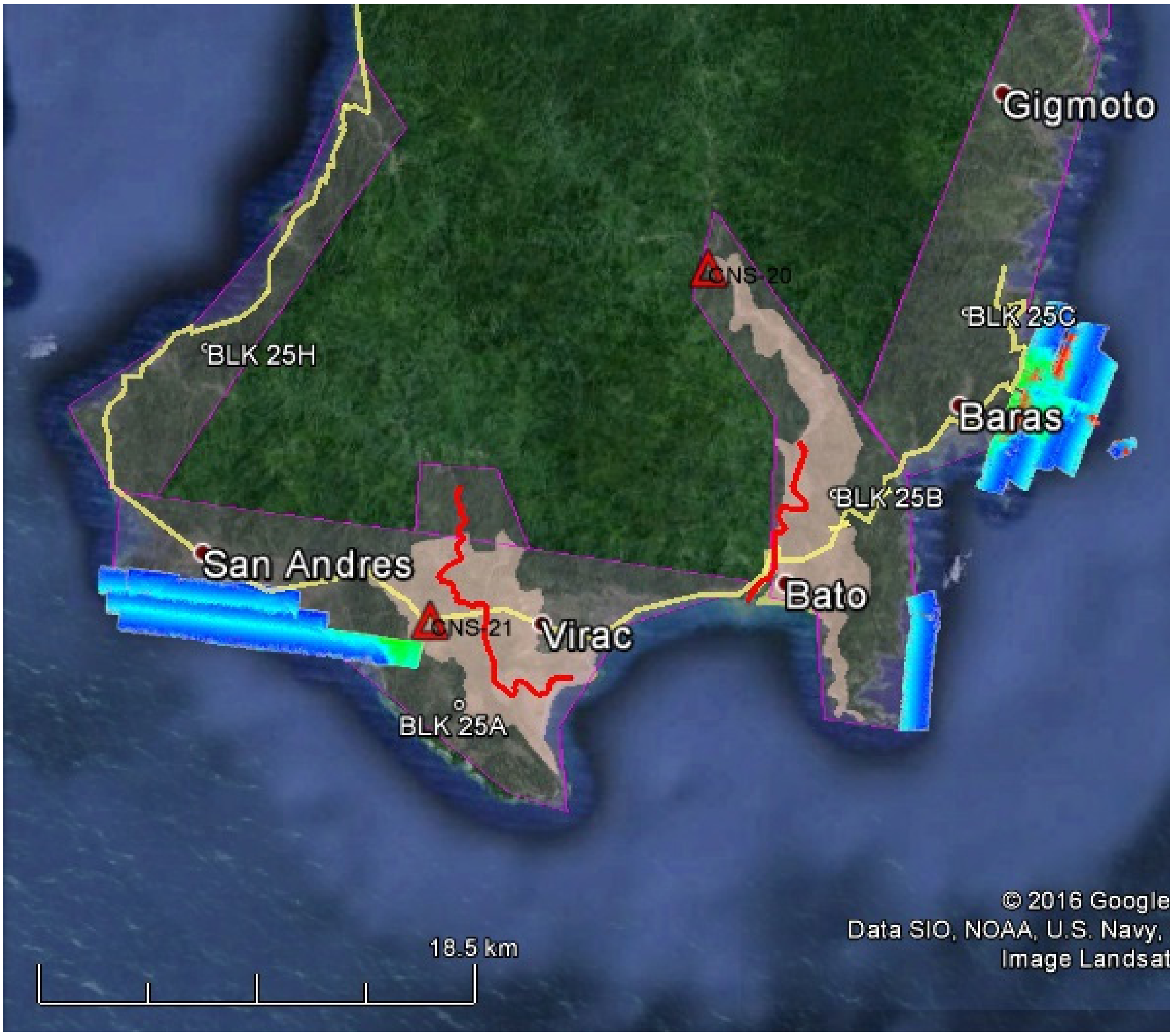
Flight No. : 3012P
Area: BLK 25BAS
Mission Name: 1BLK25AC023A
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 20%



Flight No. : 3016P
Area: BLK 25HABS
Mission Name: 1BLK25E024A
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 20%

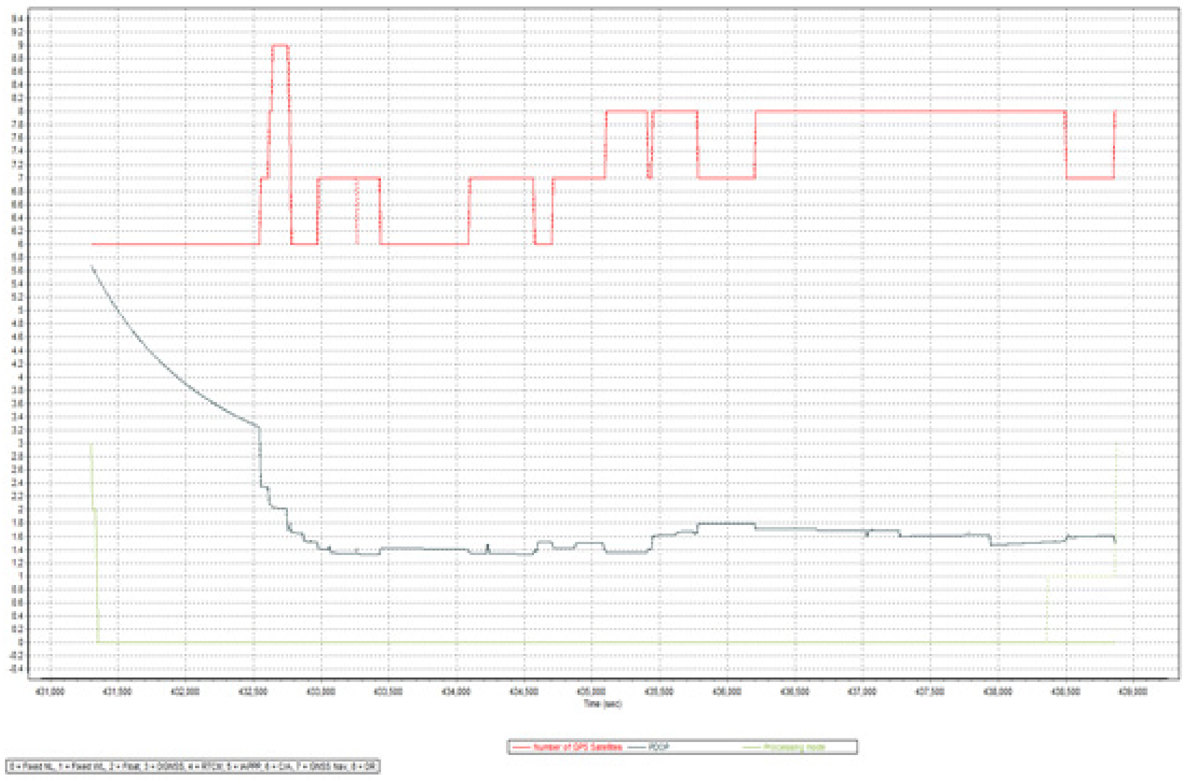


Flight No. : 3028P
Area: BLK 25CAS
Mission Name: 1BLK25F027A
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle: 25deg; Overlap: 20%

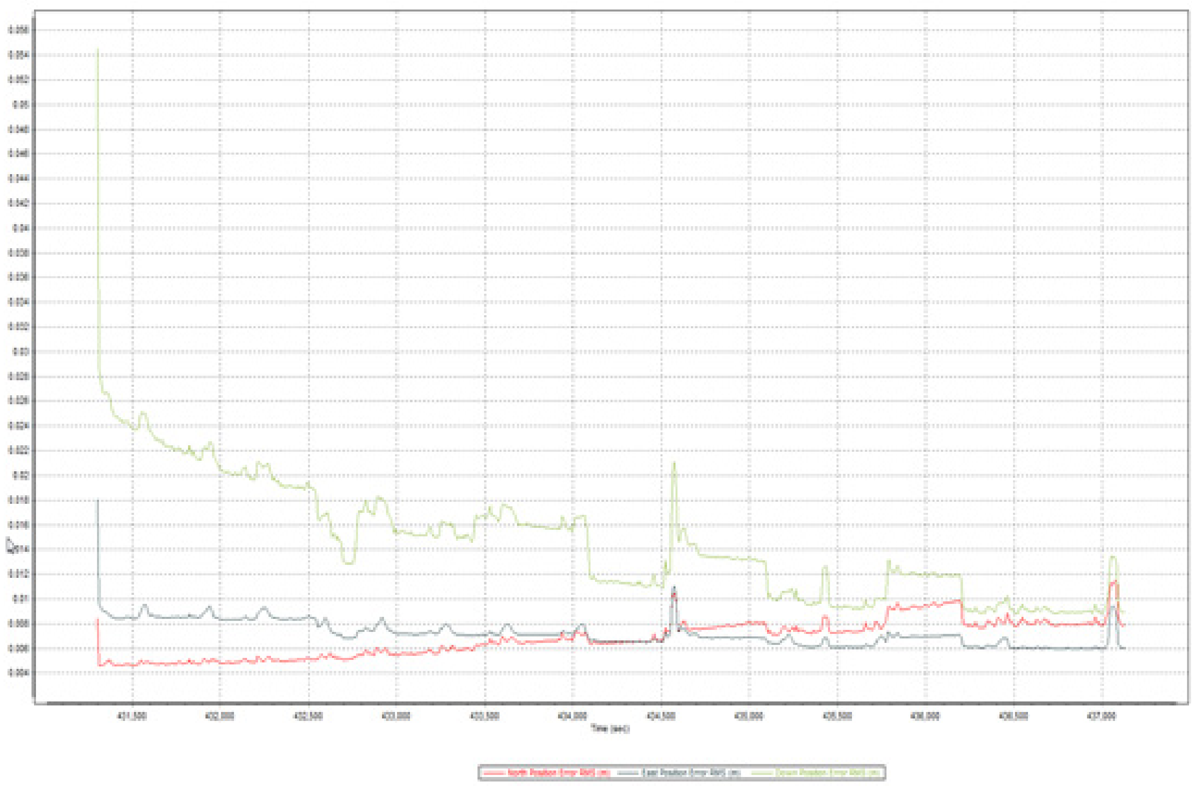


ANNEX 8. Mission Summary Reports

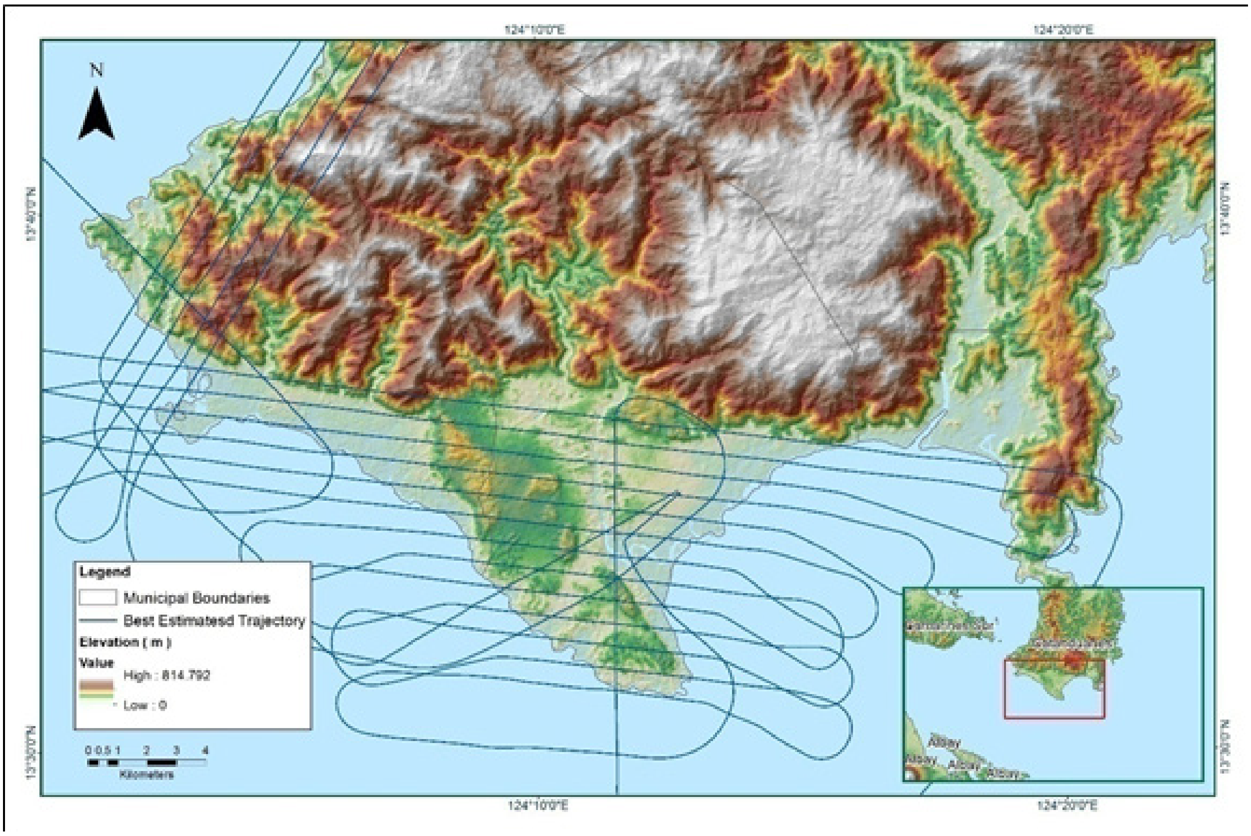
Flight Area	**Samar-Leyte**
Mission Name	Blk25A
Inclusive Flights	3010P/3028P
Range data size	27.68 GB
POS data size	364 MB
Base data size	133.8 MB
Image	NA
Transfer date	February 12, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.1
RMSE for Down Position (<8.0 cm)	2.1
Boresight correction stdev (<0.001deg)	0.000261
IMU attitude correction stdev (<0.001deg)	0.000827
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	22.64
Ave point cloud density per sq.m. (>2.0)	3.28
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	209
Maximum Height	559.96 m
Minimum Height	47.95 m
Classification (# of points)	
Ground	140,462,027
Low vegetation	73,242,229
Medium vegetation	110,584,950
High vegetation	347,813,357
Building	10,845,125
Orthophoto	Yes
Processed by	Engr. Abigail Joy Ching, Engr. Velina Angela Bemida, Maria Tamsyn Malabanan



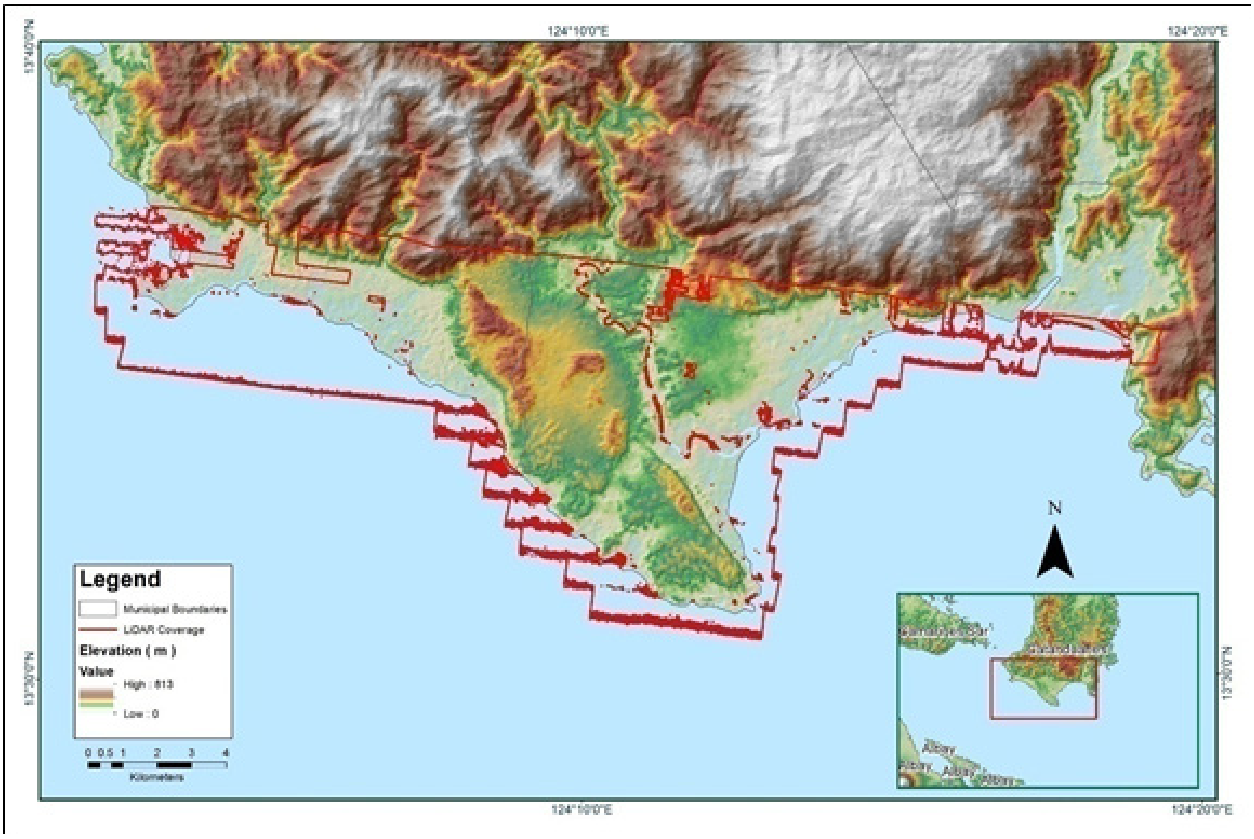
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

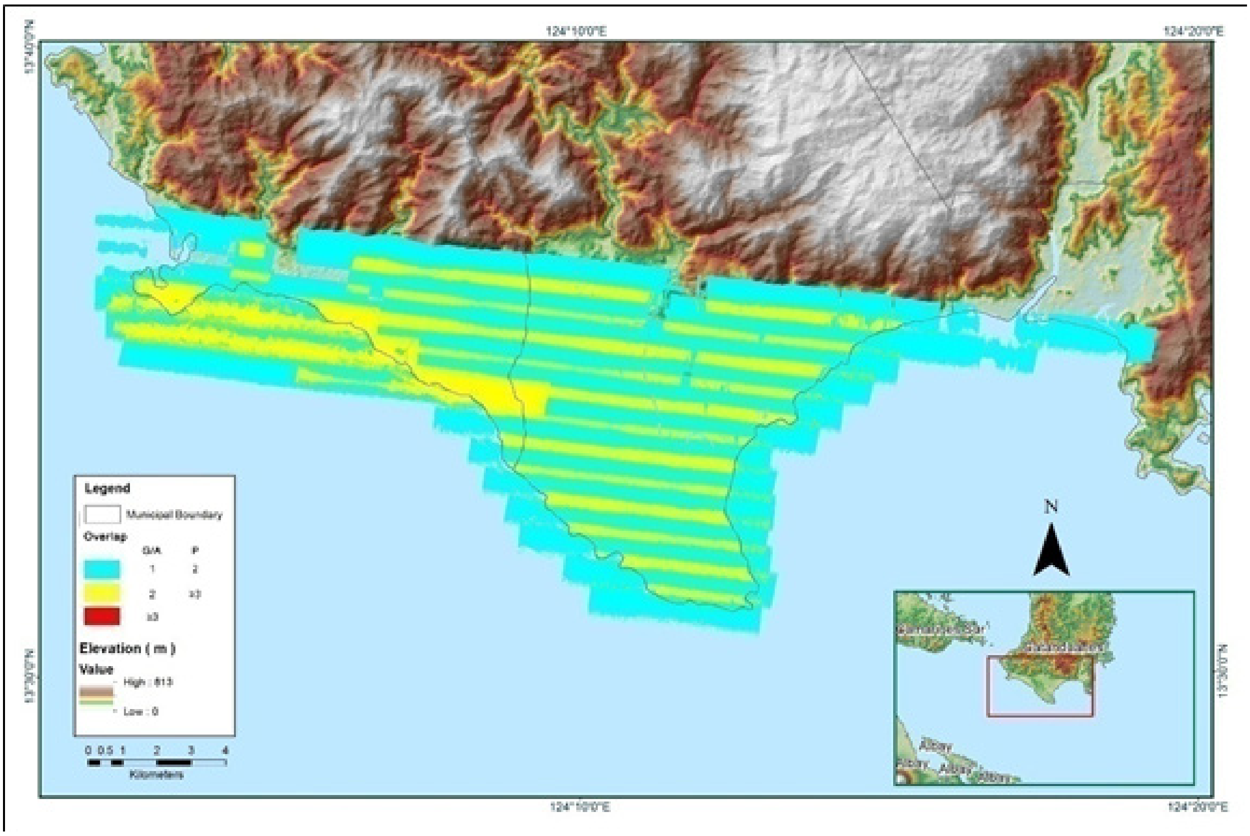
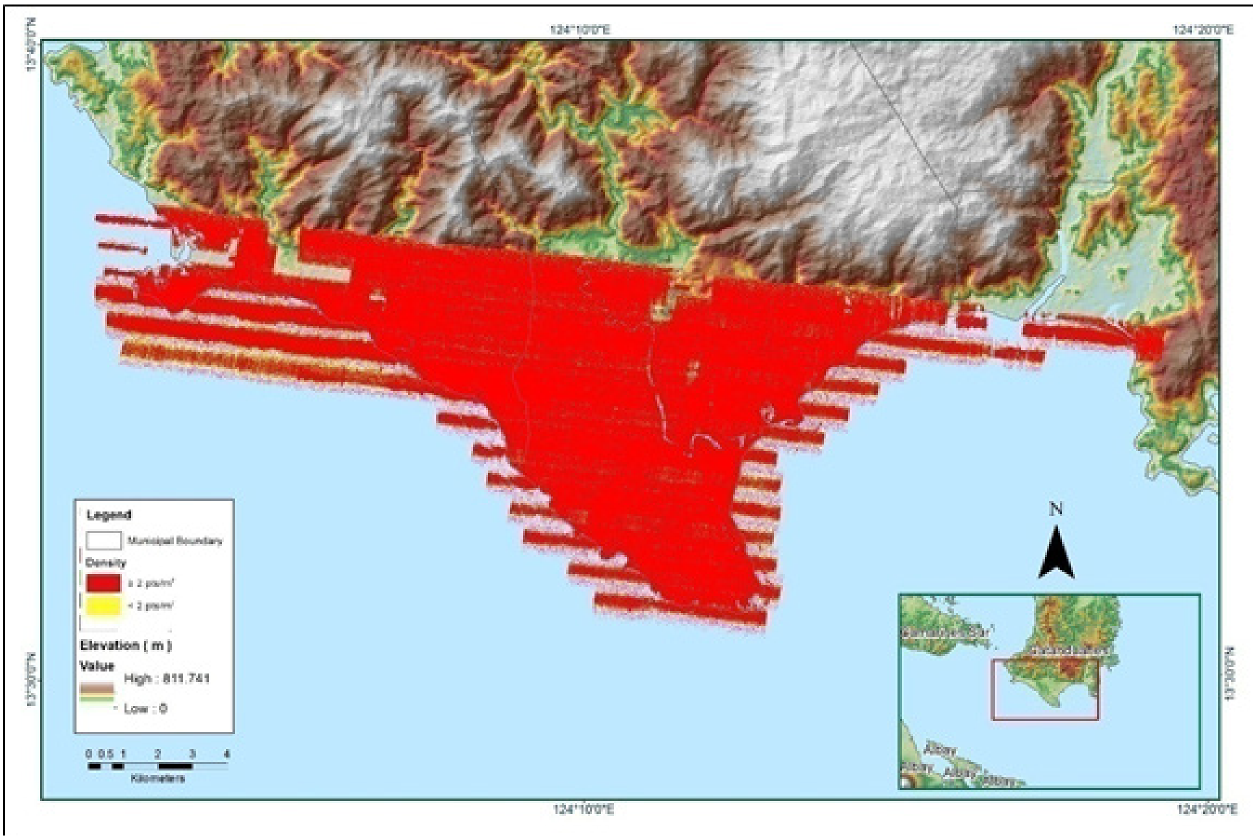
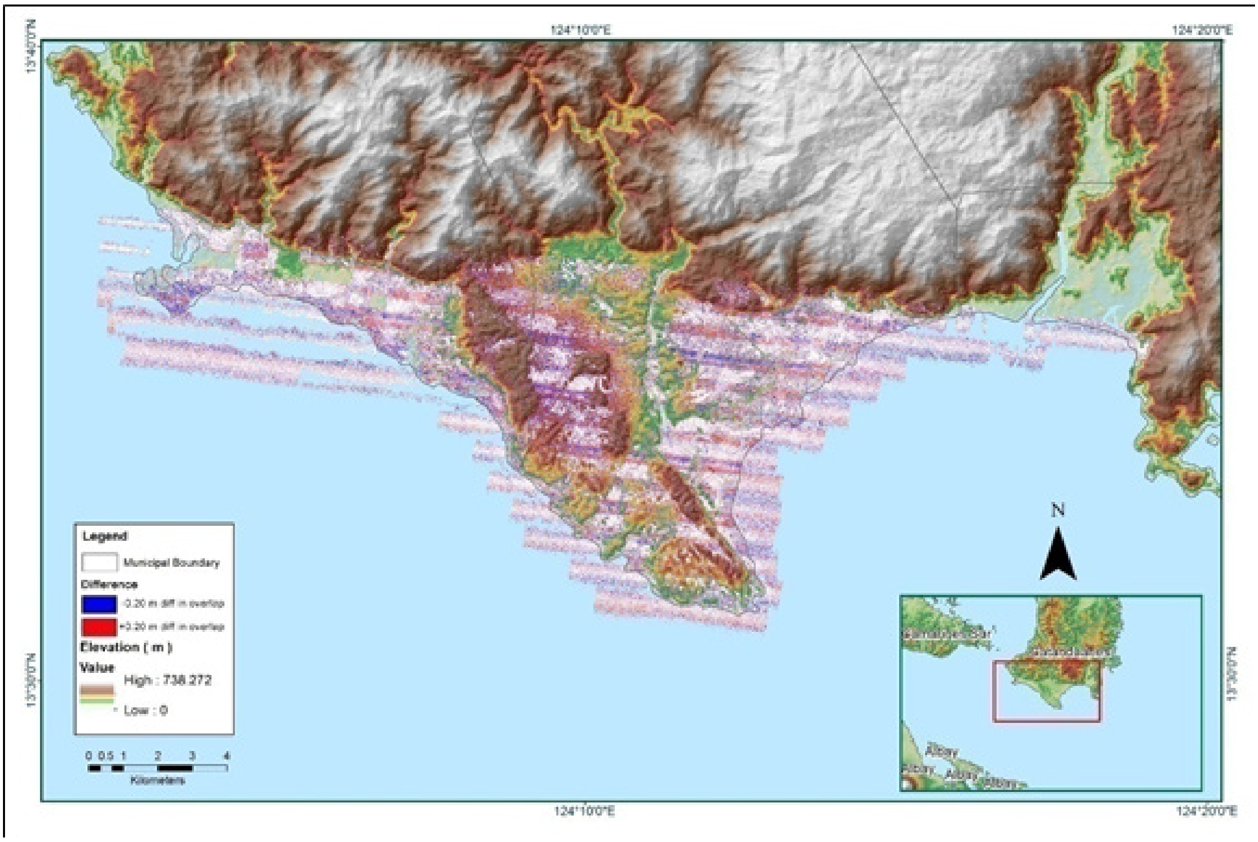


Image of Data Overlap

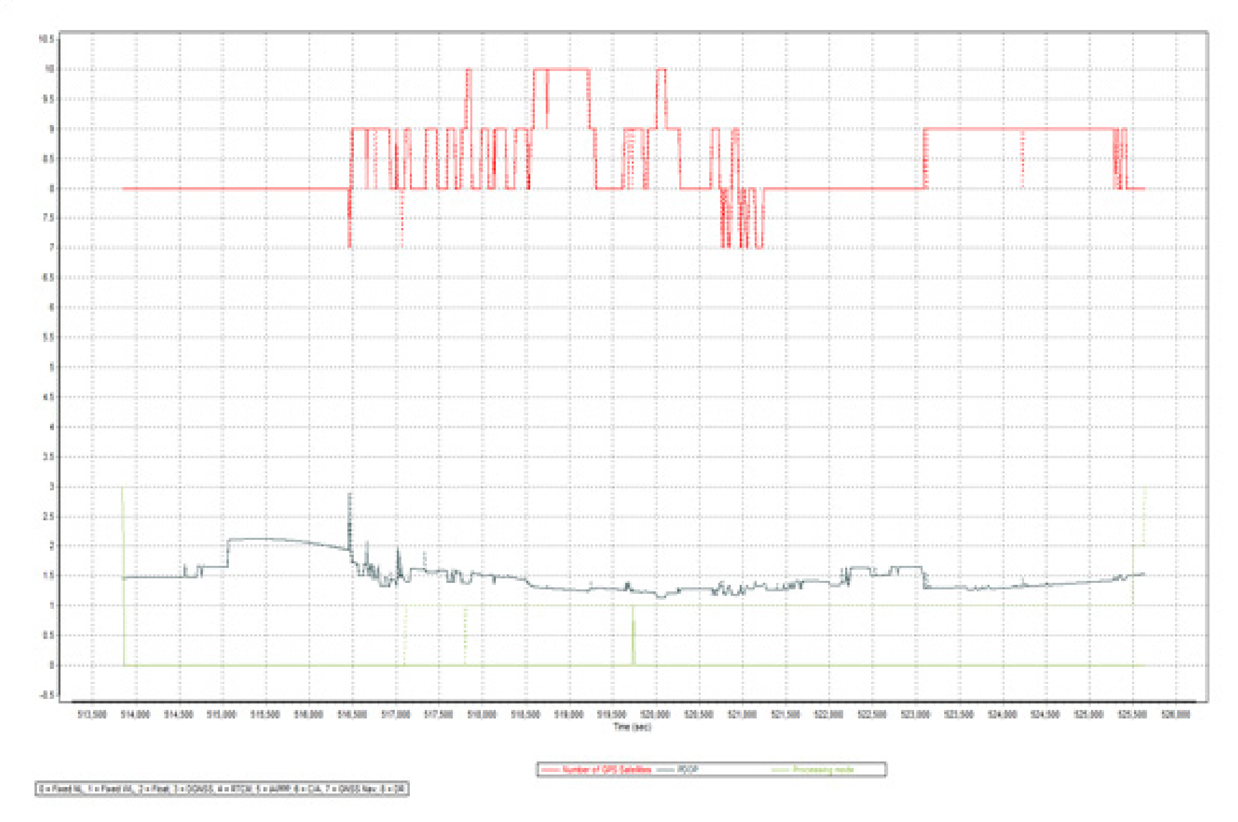


Density map of merged LiDAR data

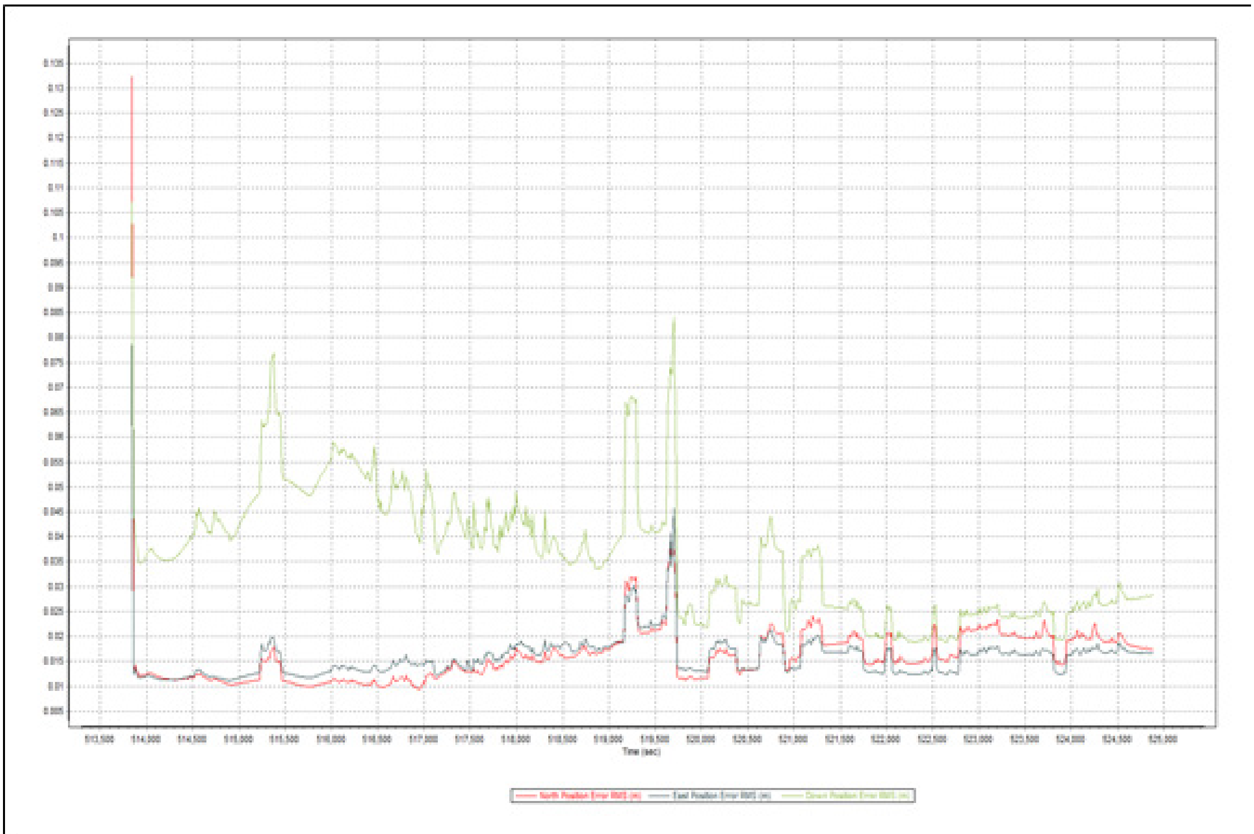


Elevation difference between flight lines

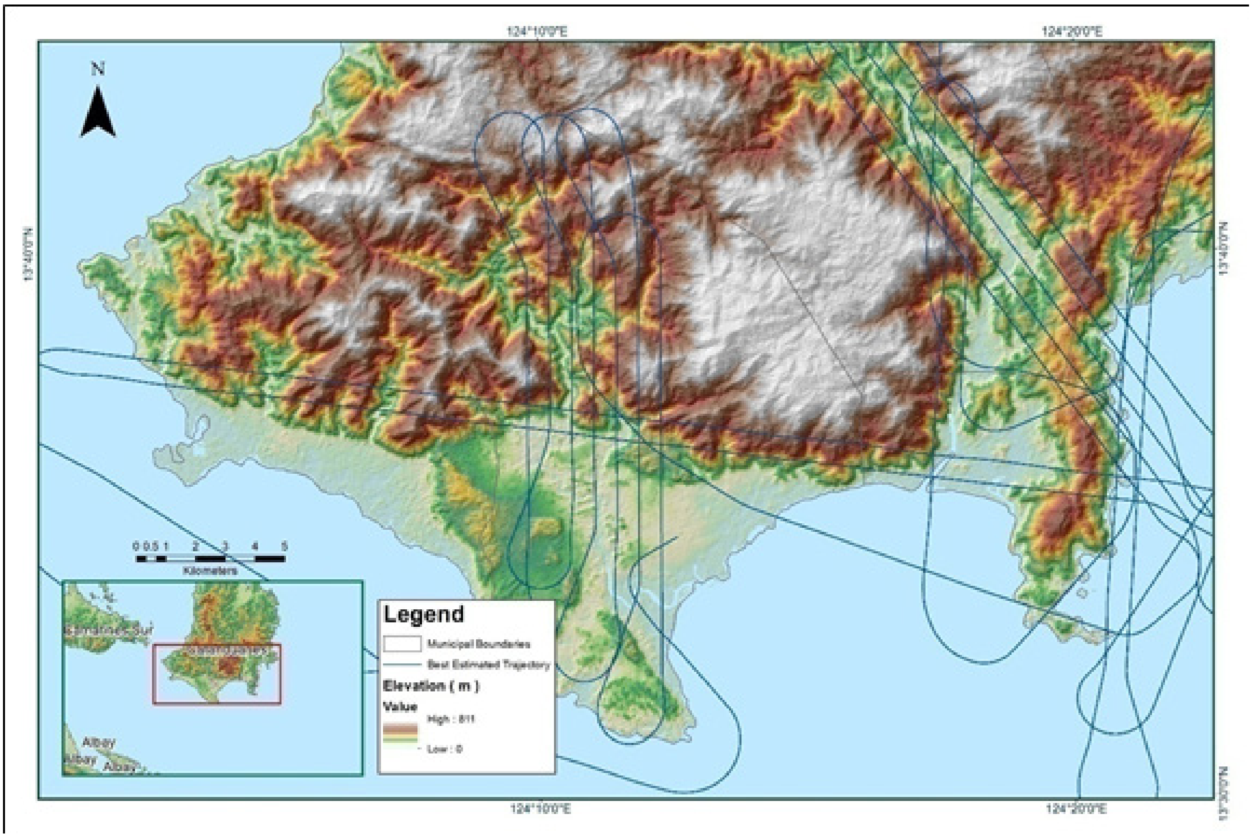
Flight Area	Samar-Leyte
Mission Name	Blk25A_Supplement
Inclusive Flights	3012P
Range data size	22.1 GB
POS data size	263 MB
Base data size	95.7 MB
Image	27.9 GB
Transfer date	January 28, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.8
RMSE for East Position (<4.0 cm)	4.6
RMSE for Down Position (<8.0 cm)	8.4
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	36.06
Ave point cloud density per sq.m. (>2.0)	2.71
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	148
Maximum Height	642.48 m
Minimum Height	52.79 m
Classification (# of points)	
Ground	59,518,090
Low vegetation	21,144,287
Medium vegetation	88,886,665
High vegetation	448,684,984
Building	8,146,424
Orthophoto	No
Processed by	Engr. Regis Guhiting, Ma. Joanne Balaga, Alex John Escobido



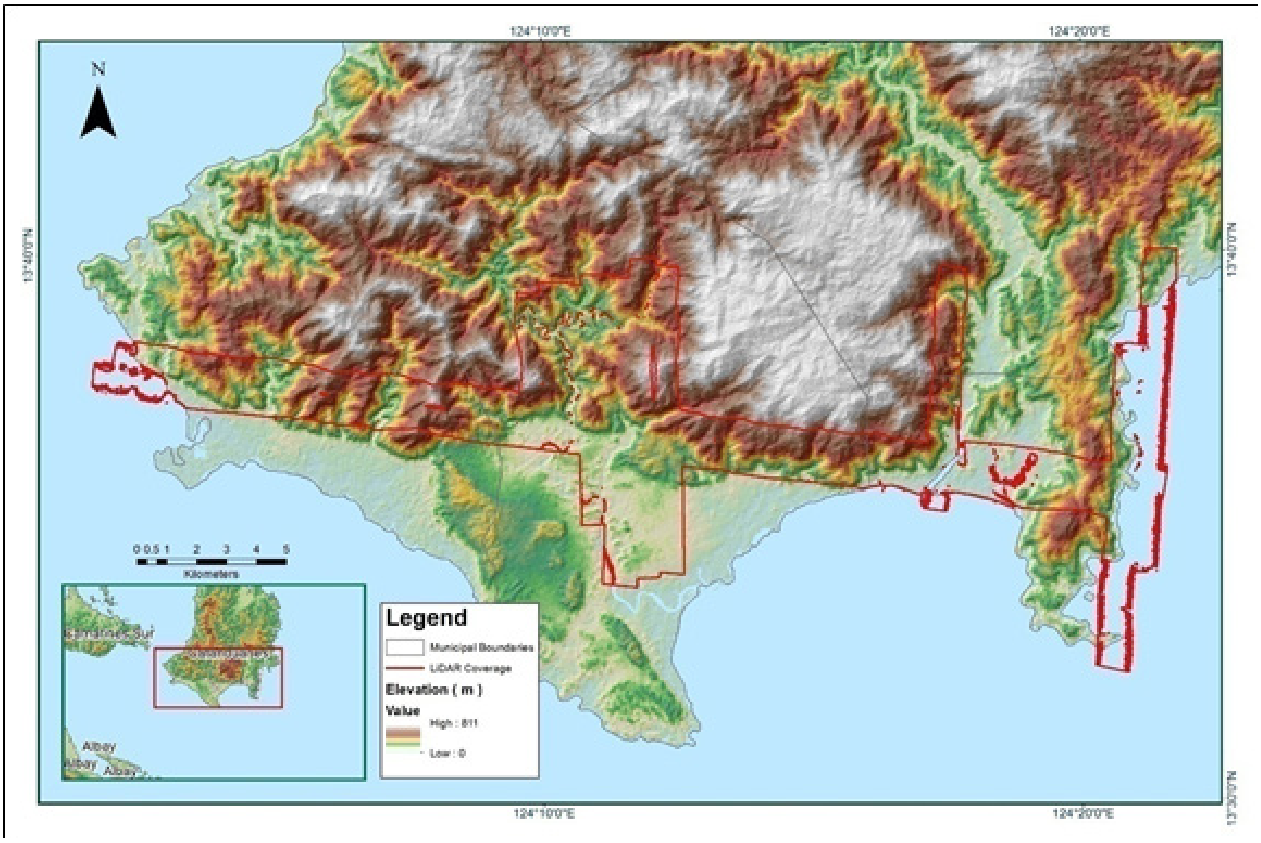
Solution Status Parameters



Smoothed Performance Metrics Parameters



Best Estimated Trajectory



Coverage of LiDAR data

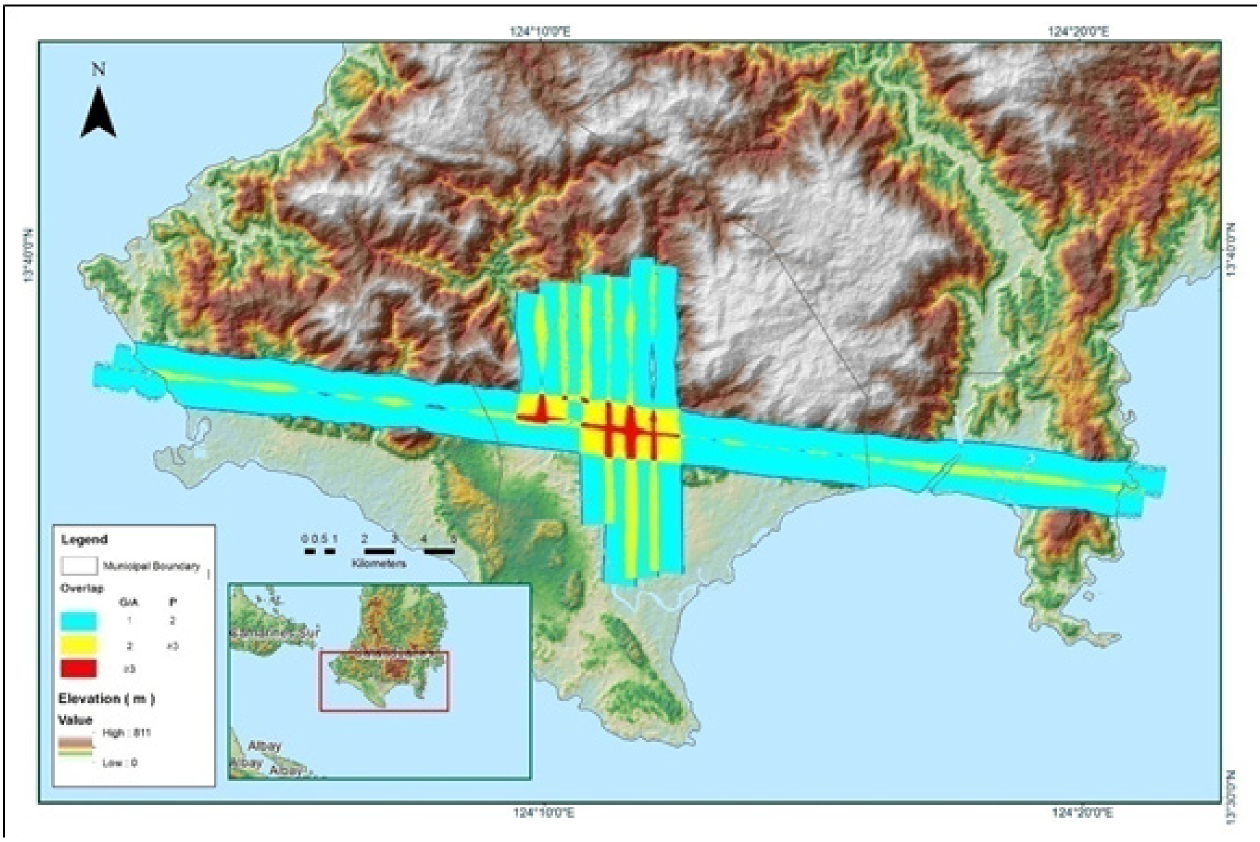
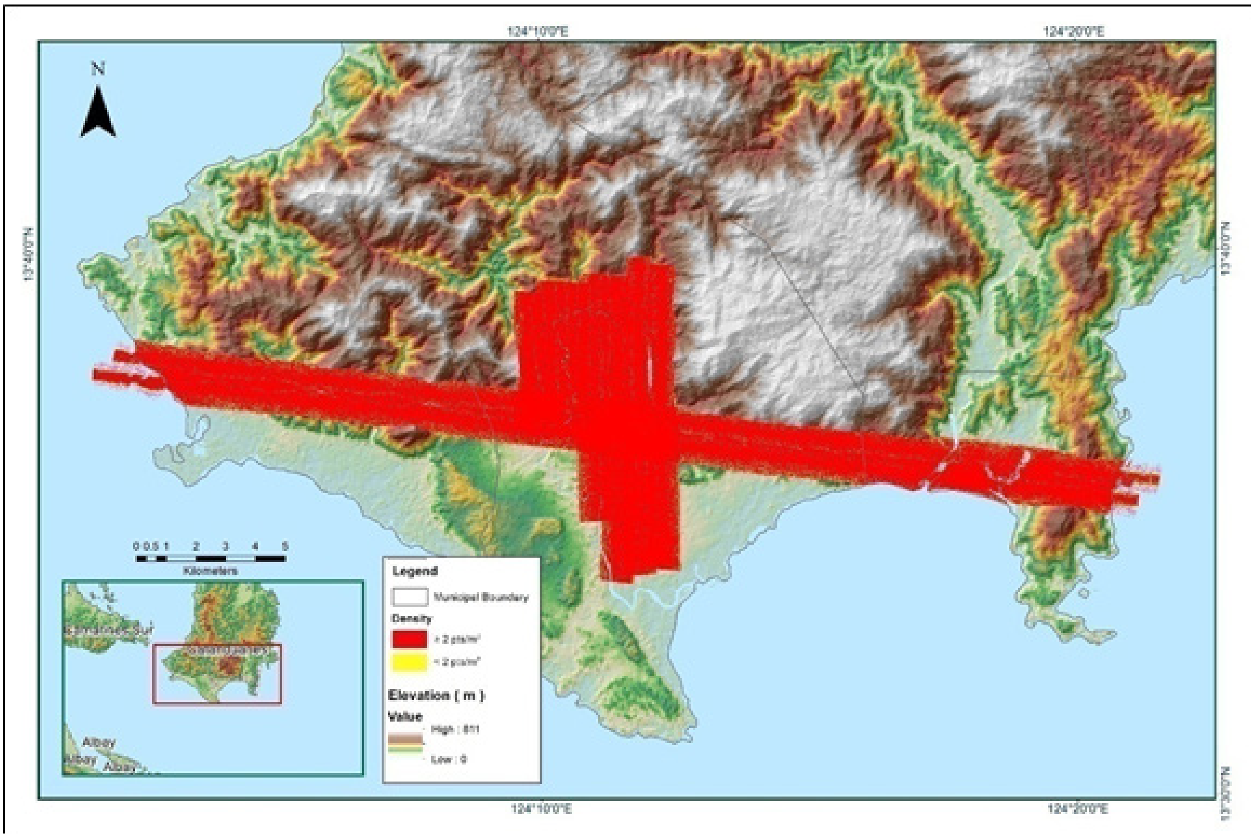
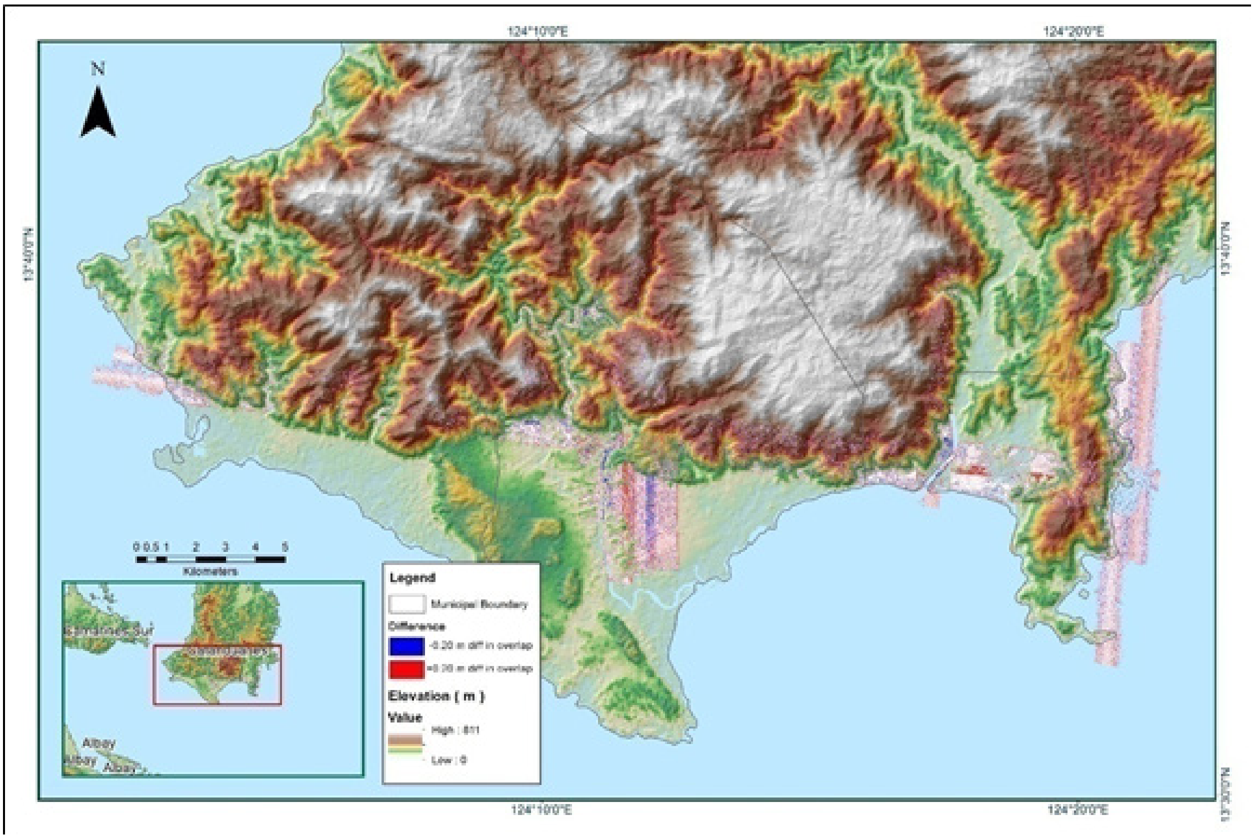


Image of Data Overlap

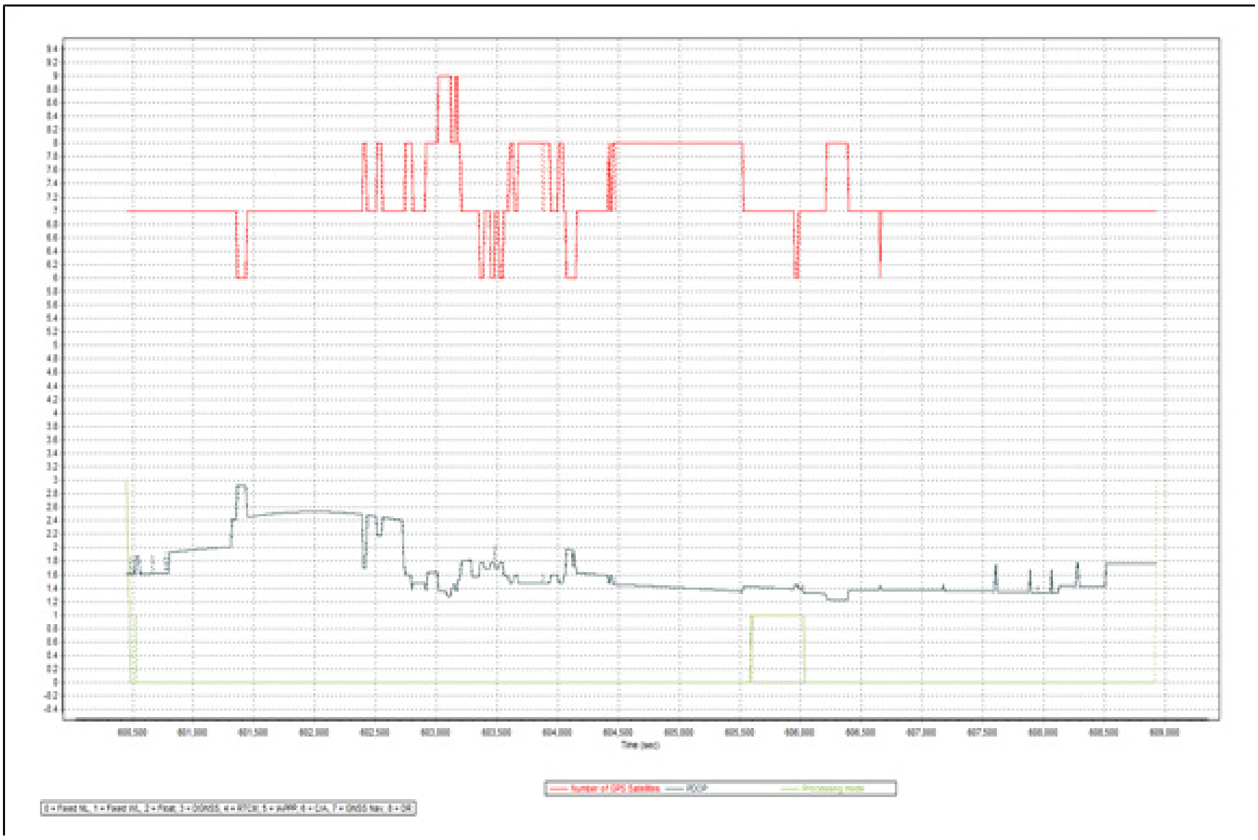


Density map of merged LiDAR data

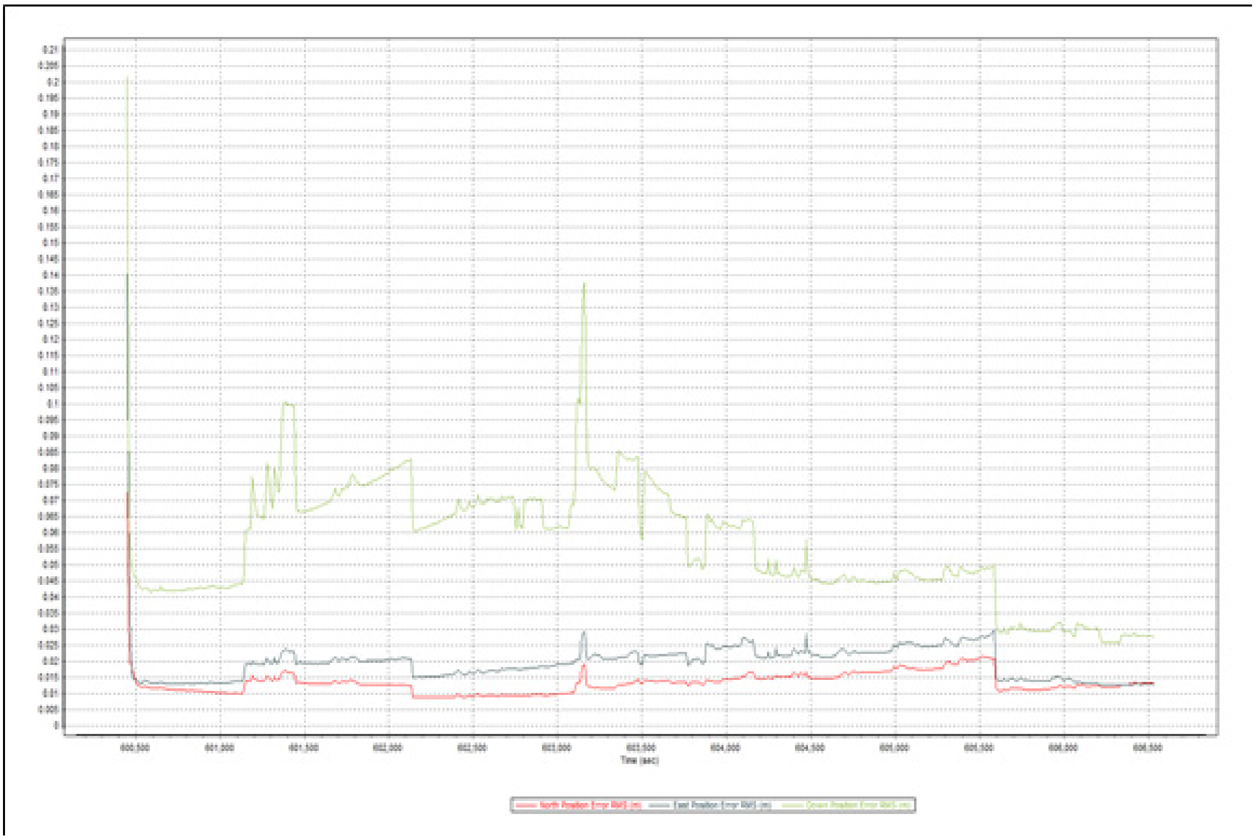


Elevation difference between flight lines

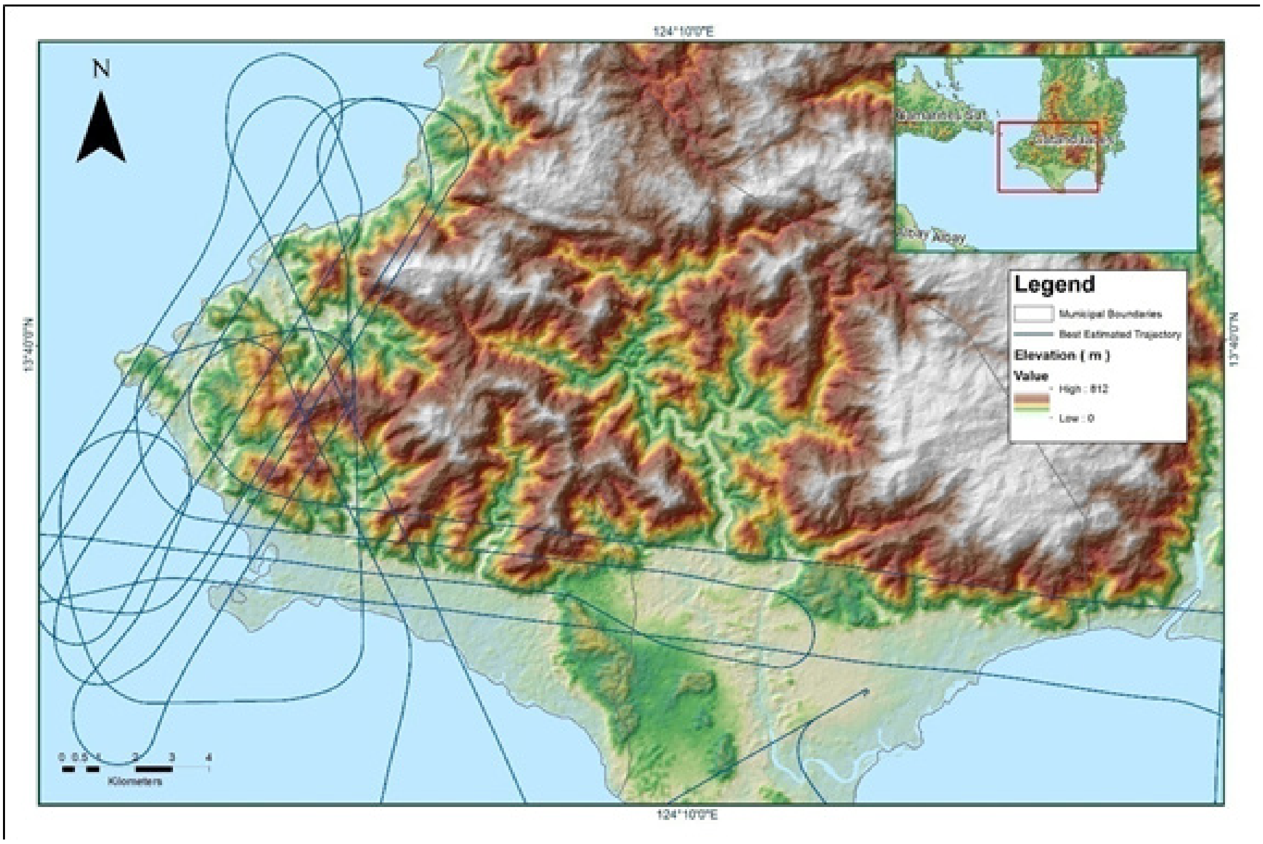
Flight Area	Leyte
Mission Name	Blk25H_Additional
Inclusive Flights	3016P
Range data size	14.6 GB
POS data size	167 MB
Base data size	82.4 MB
Image	NA
Transfer date	January 28, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.2
RMSE for East Position (<4.0 cm)	2.9
RMSE for Down Position (<8.0 cm)	13.8
Boresight correction stdev (<0.001deg)	0.000376
IMU attitude correction stdev (<0.001deg)	0.001333
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	15.26
Ave point cloud density per sq.m. (>2.0)	2.95
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	185
Maximum Height	767.53 m
Minimum Height	53.54 m
Classification (# of points)	
Ground	54,421,428
Low vegetation	29,724,310
Medium vegetation	75,930,262
High vegetation	362,898,505
Building	7,347,715
Orthophoto	No
Processed by	Engr. Sheila-Maye Santillan, Engr. Chelou Prado, Alex John Escobido
Processed by	Engr. Sheila Maye Santillan, Engr. Elainne Lopez, Engr. Merven Matthew Natino



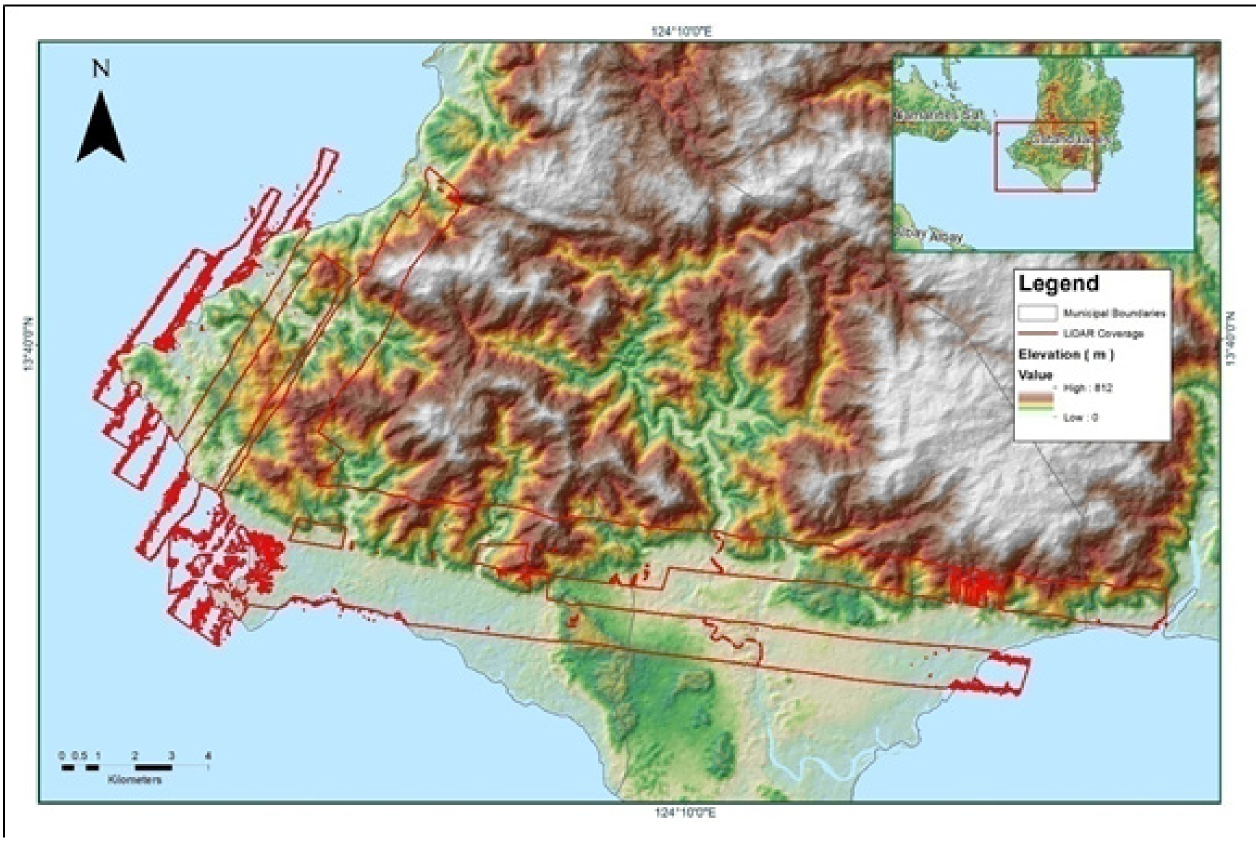
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

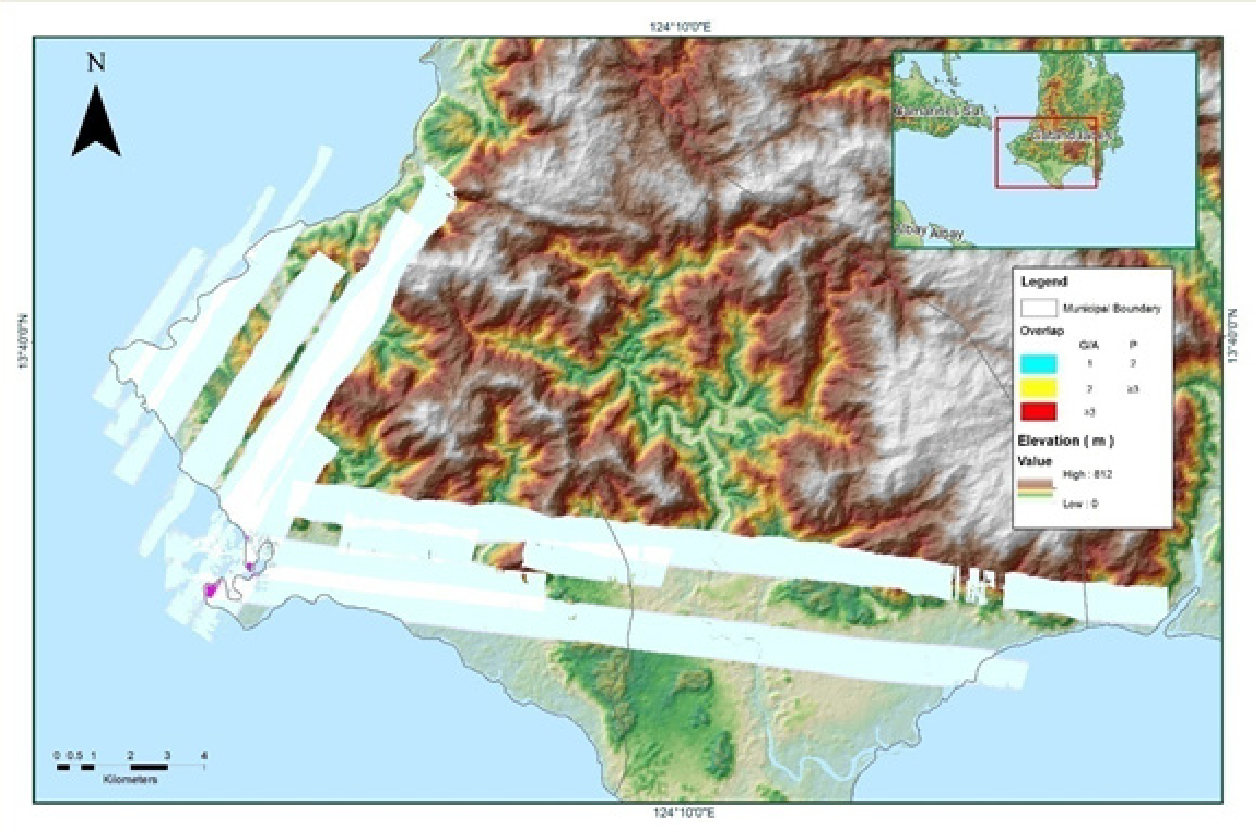
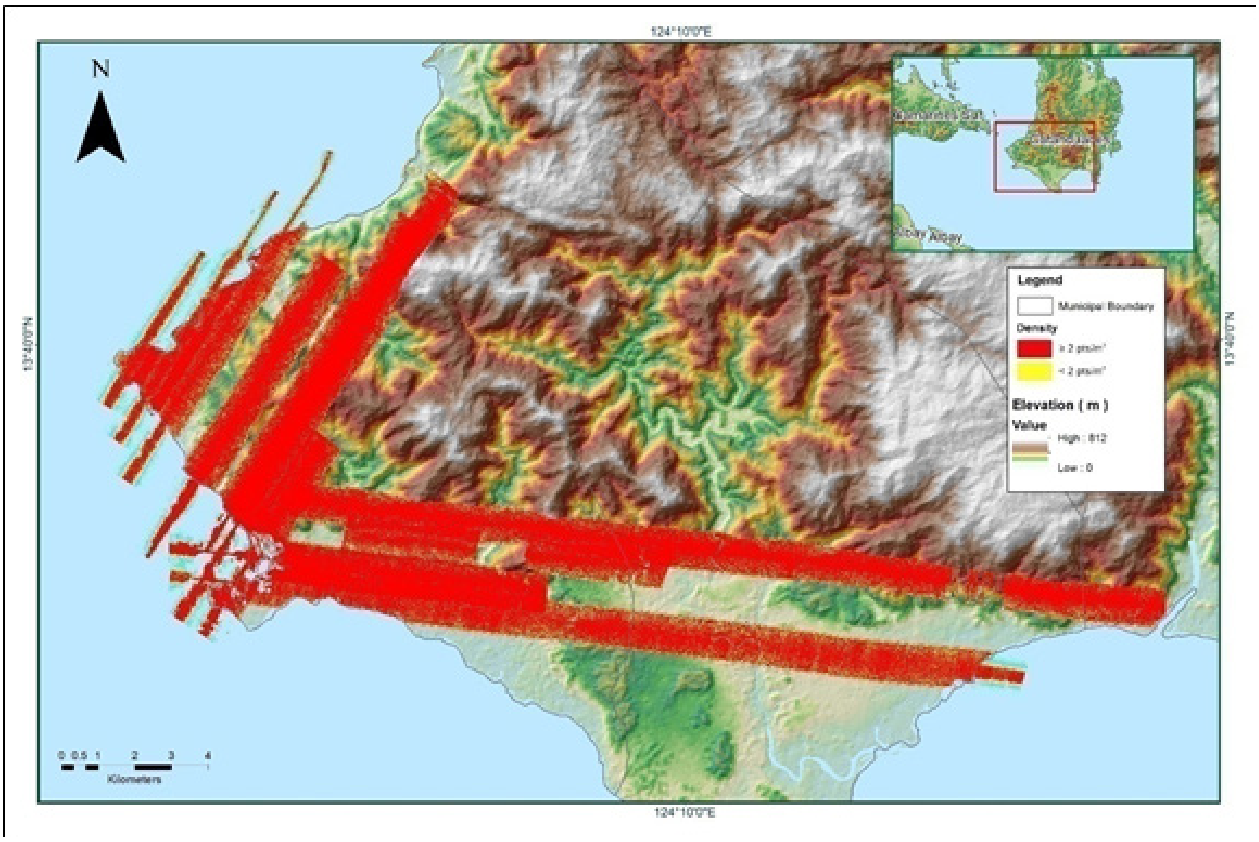
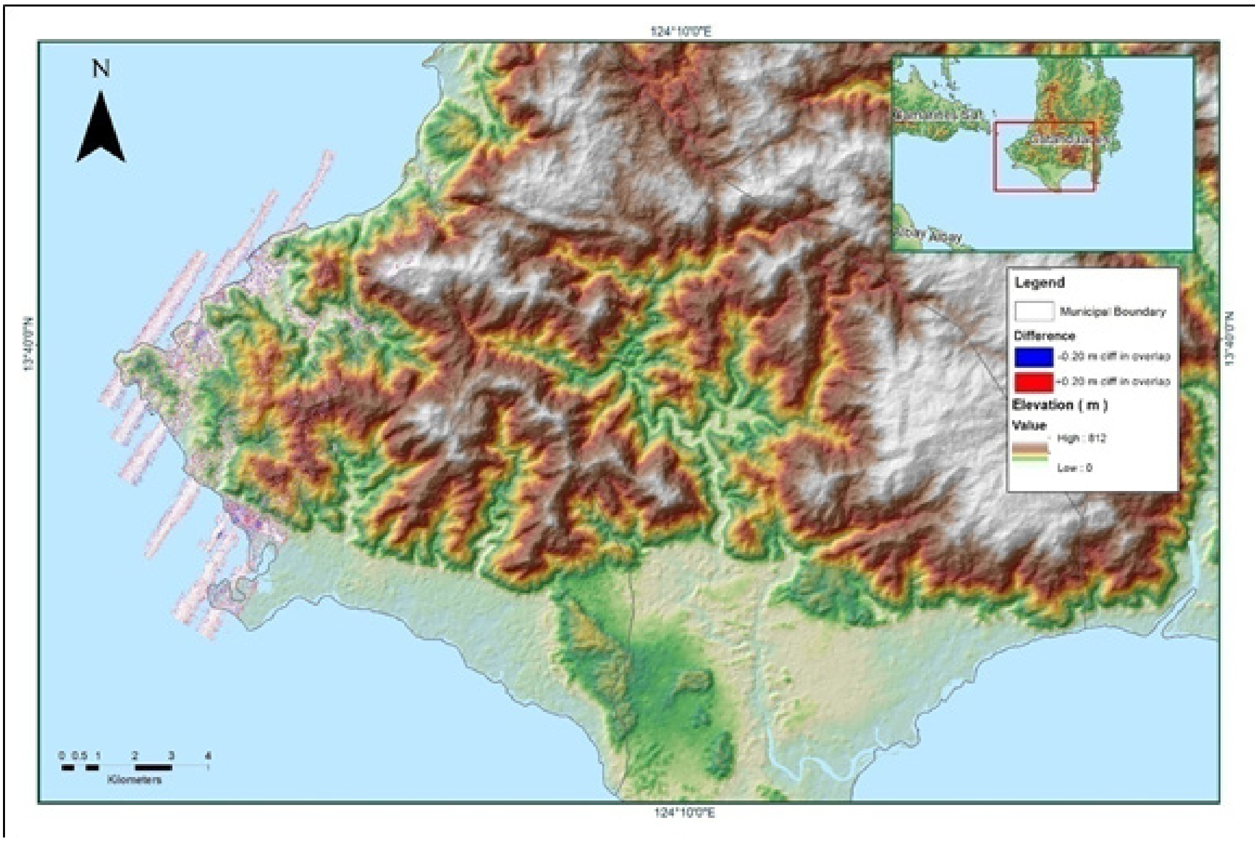


Image of Data Overlap

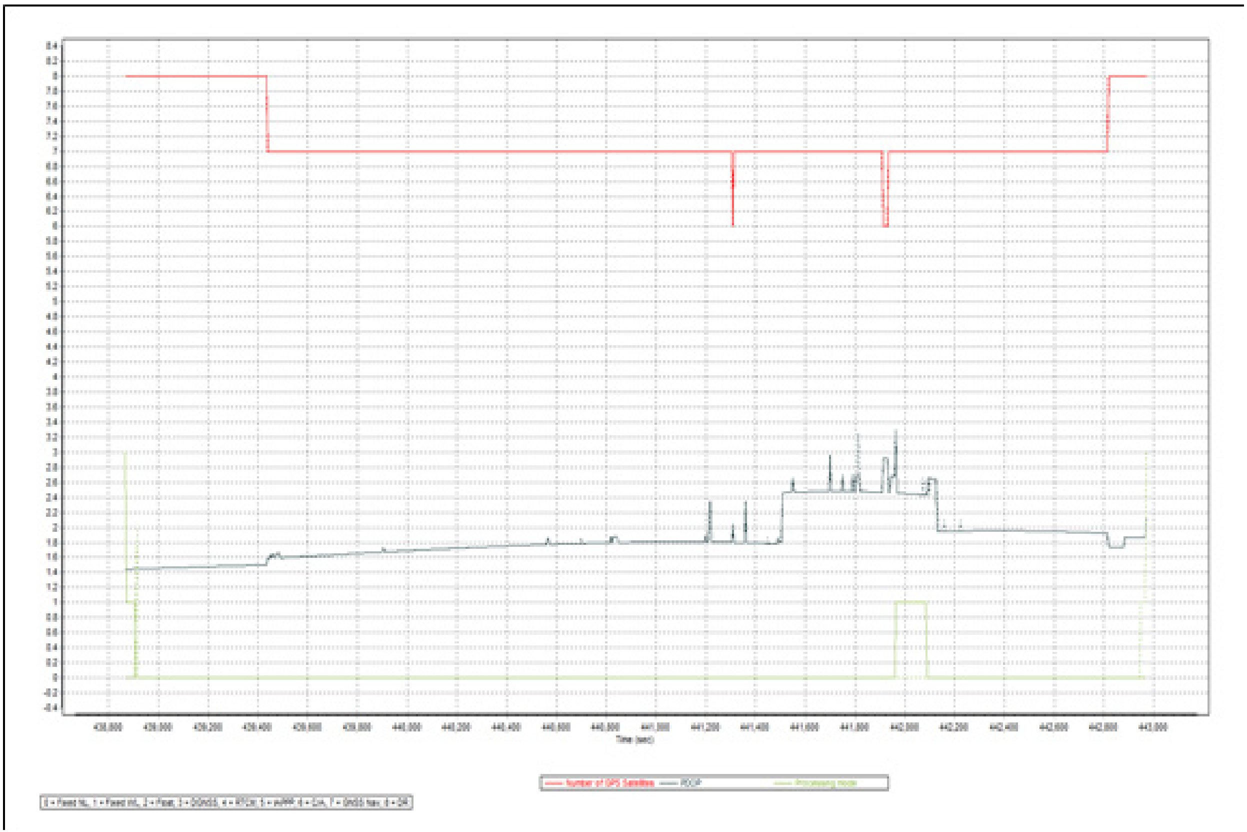


Density map of merged LiDAR data

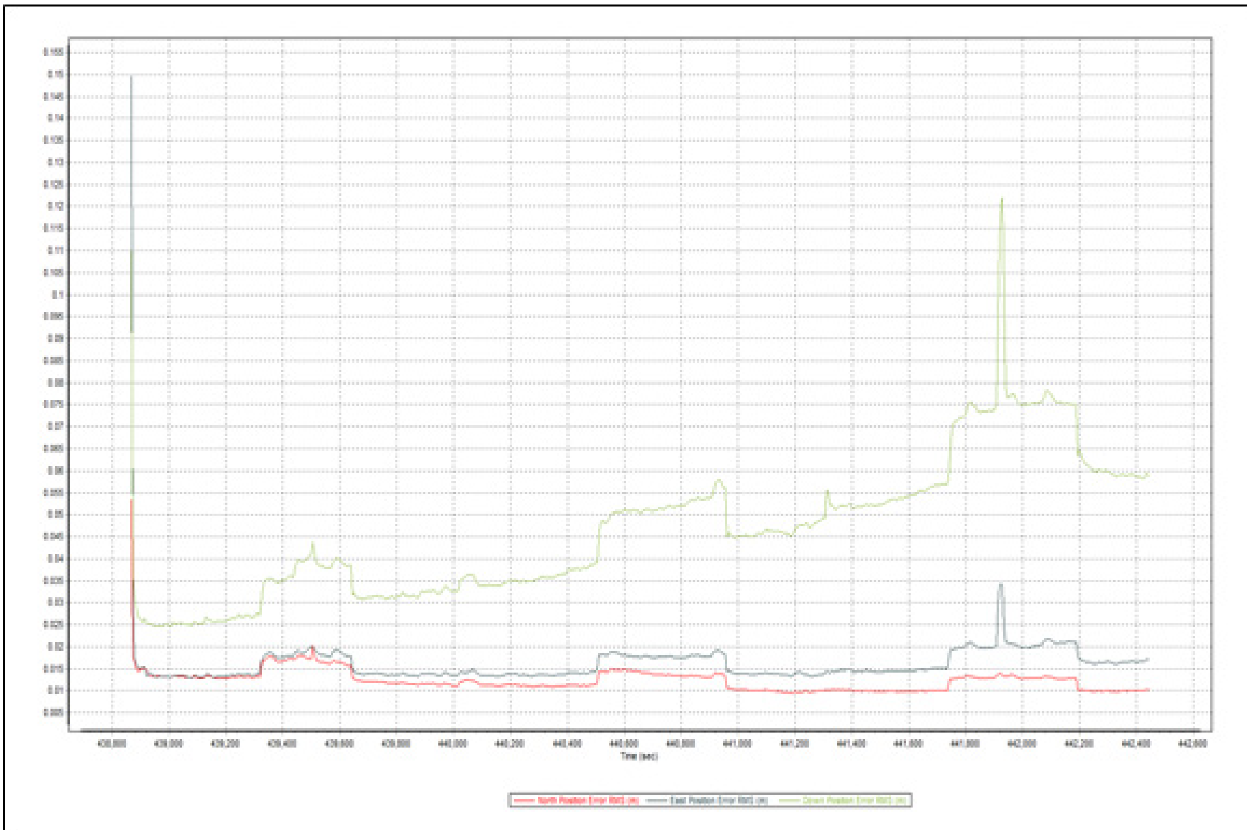


Elevation difference between flight lines

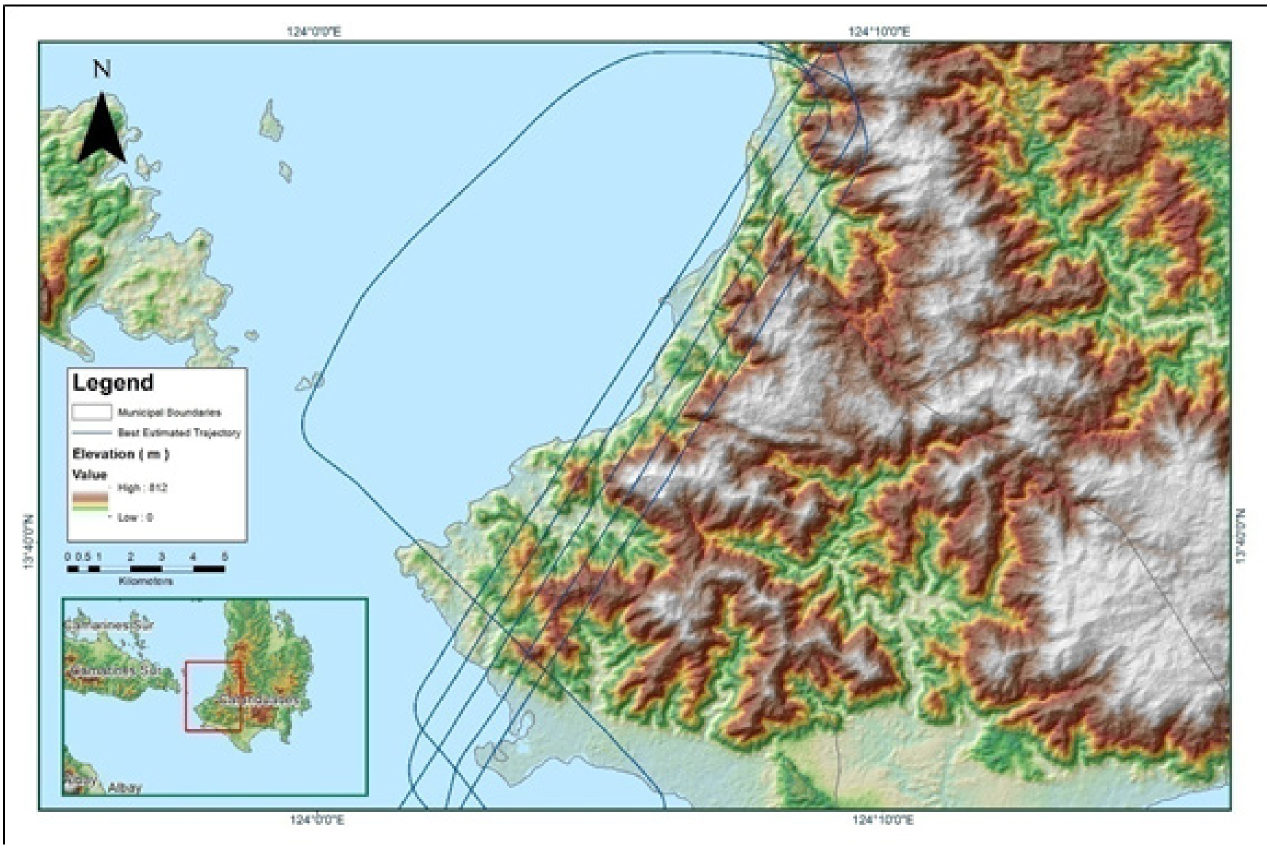
Flight Area	Samar-Leyte
Mission Name	Blk25H
Inclusive Flights	3010P
Range data size	22.9 GB
POS data size	229 MB
Base data size	69.3 MB
Image	NA
Transfer date	January 28, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.0
RMSE for East Position (<4.0 cm)	3.4
RMSE for Down Position (<8.0 cm)	12.2
Boresight correction stdev (<0.001deg)	0.000462
IMU attitude correction stdev (<0.001deg)	0.000318
GPS position stdev (<0.01m)	0.0017
Minimum % overlap (>25)	19.10
Ave point cloud density per sq.m. (>2.0)	3.41
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	128
Maximum Height	773.03 m
Minimum Height	53.51 m
Classification (# of points)	
Ground	34,838,002
Low vegetation	21,051,689
Medium vegetation	65,694,477
High vegetation	351,224,971
Building	5,406,691
Orthophoto	No
Processed by	Engr. Abigail Ching, Ma. Joanne Balaga, Engr. Elainne Lopez



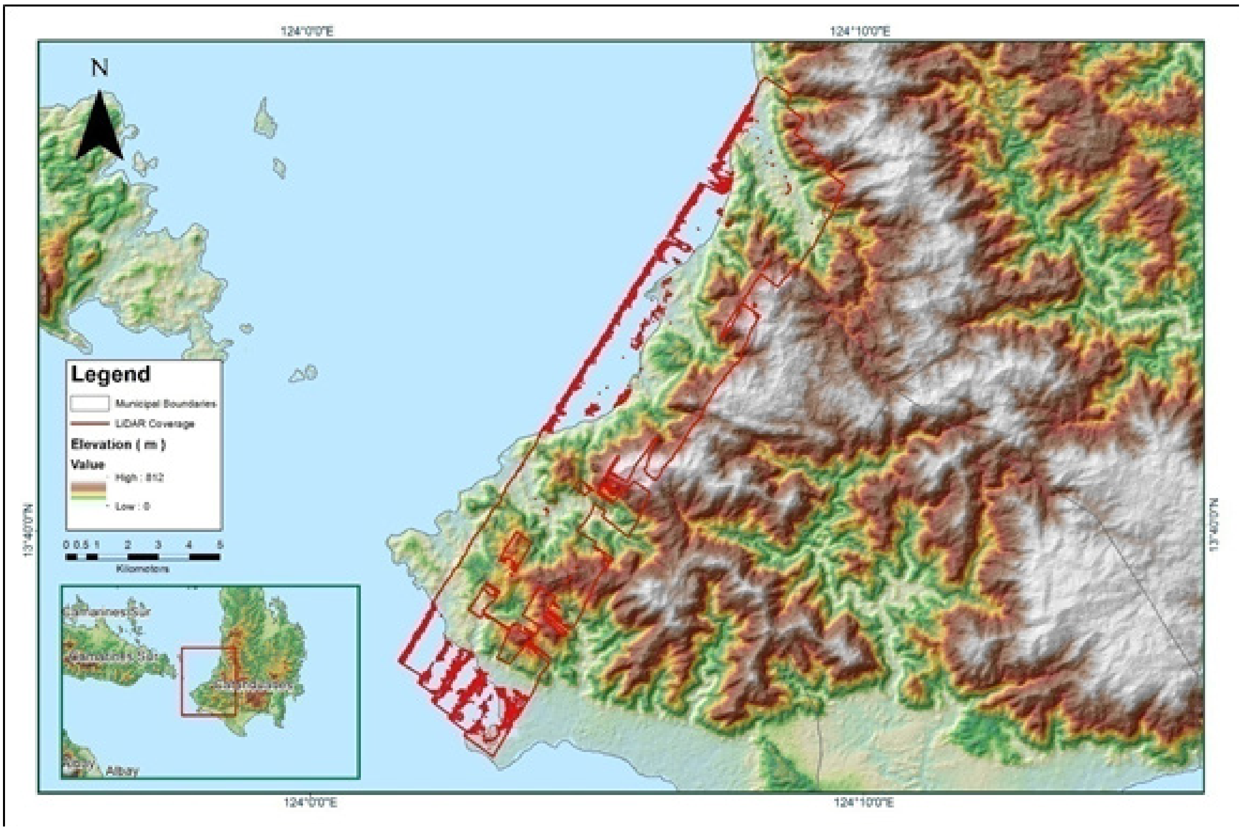
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

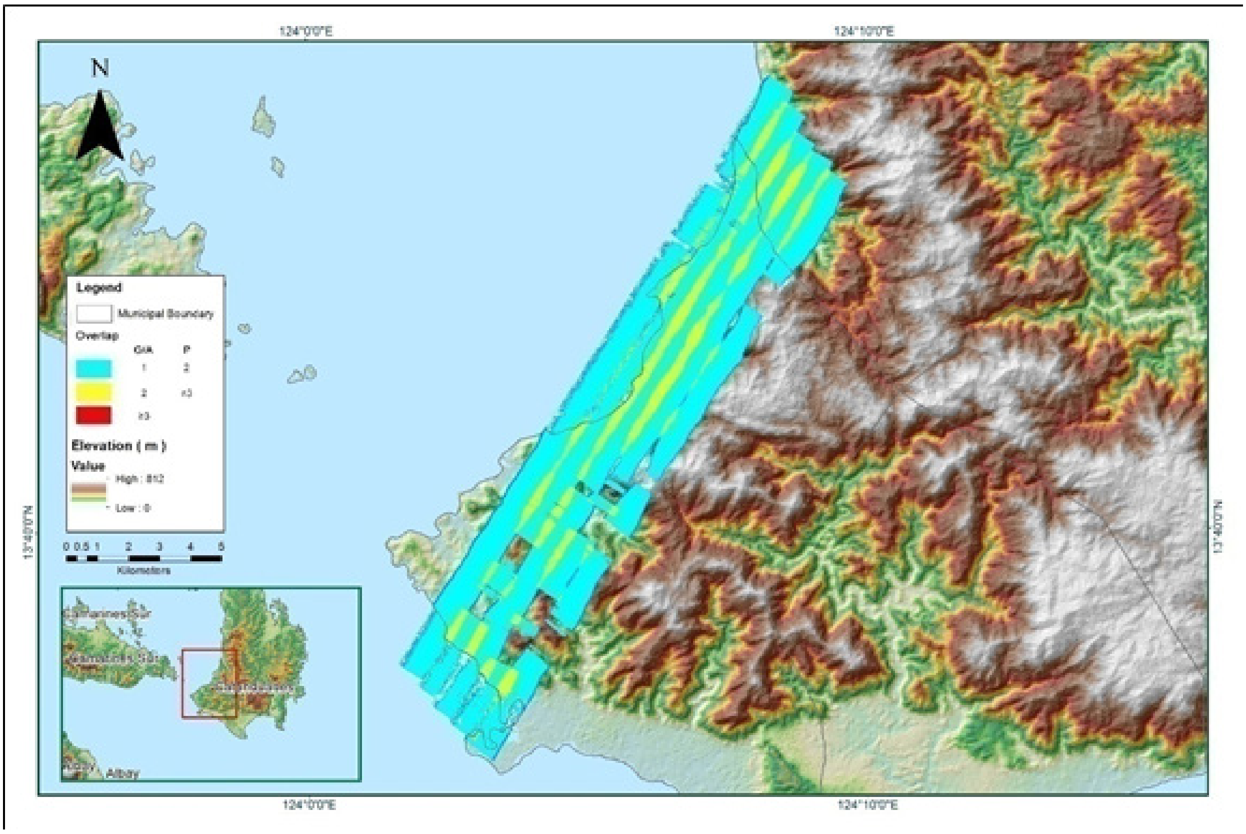
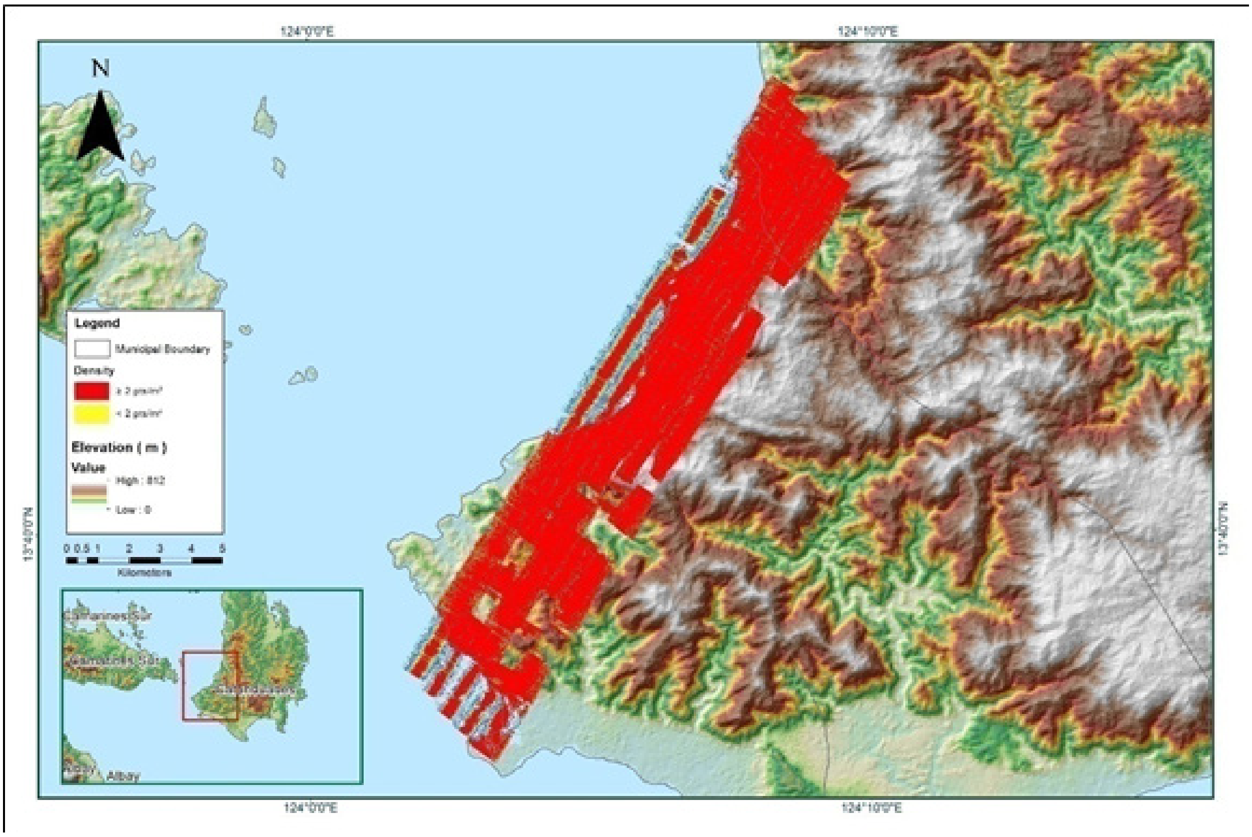
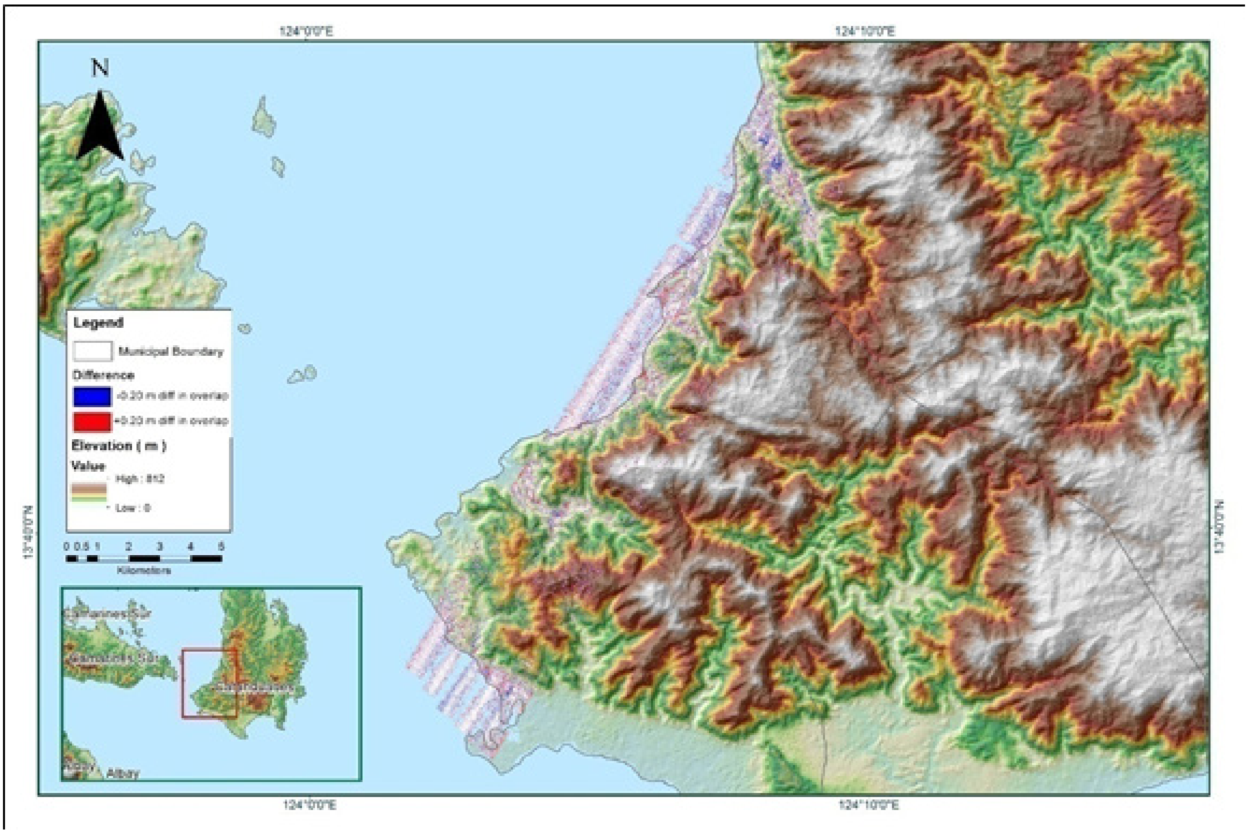


Image of Data Overlap



Density map of merged LiDAR data



Elevation difference between flight lines

ANNEX 9. Pajo 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
W220	312.100	35.310	0	29.737	32.65300	Discharge	3.3679	0.00001	Ratio to Peak	1.00000
W230	366.700	52.716	0	23.475	7.70920	Discharge	1.4282	0.00001	Ratio to Peak	1.00000
W240	167.120	35.185	0	39.532	28.98500	Discharge	2.9314	0.00003	Ratio to Peak	1.00000
W250	372.880	35.144	0	0.298	8.77370	Discharge	0.0538	0.00001	Ratio to Peak	0.03673
W260	367.600	53.008	0	0.017	39.77400	Discharge	3.8746	0.00270	Ratio to Peak	1.00000
W270	366.820	52.722	0	2.501	31.45100	Discharge	1.9390	0.00022	Ratio to Peak	1.00000
W280	159.600	77.180	0	24.277	11.81200	Discharge	6.6786	0.00001	Ratio to Peak	1.00000
W290	272.060	52.774	0	2.516	9.68400	Discharge	1.3622	0.00001	Ratio to Peak	0.99626
W300	297.840	35.038	0	0.460	21.23500	Discharge	2.8205	0.00397	Ratio to Peak	0.18849
W310	85.747	35.068	0	64.199	14.13500	Discharge	4.1963	0.00022	Ratio to Peak	1.00000
W320	4.541	99.000	0	0.294	0.50936	Discharge	1.3472	0.00245	Ratio to Peak	0.00039
W330	2.353	99.000	0	0.838	0.25970	Discharge	1.0317	0.00303	Ratio to Peak	0.00044
W340	1.649	99.000	0	0.165	0.14298	Discharge	0.4132	0.00025	Ratio to Peak	0.00086
W350	2.178	35.194	0	0.399	0.13543	Discharge	1.4413	0.00087	Ratio to Peak	0.00110
W360	4.231	50.656	0	0.161	1.33990	Discharge	2.3234	0.00152	Ratio to Peak	0.00019
W370	306.970	35.203	0	22.034	10.81900	Discharge	4.9119	0.00004	Ratio to Peak	0.28149
W380	6.114	35.277	0	0.211	0.38014	Discharge	2.3553	0.00398	Ratio to Peak	0.00095
W390	18.375	99.000	0	0.147	0.36109	Discharge	0.0118	0.00018	Ratio to Peak	0.00024
W400	347.020	52.939	0	5.211	2.55530	Discharge	2.1587	0.00120	Ratio to Peak	0.12770
W410	1.683	99.000	0	0.167	0.30574	Discharge	1.4983	0.00002	Ratio to Peak	0.00019

ANNEX 10. Pajo 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	538.1	0.03364	0.00010	Trapezoid	63.161	1
R70	Automatic Fixed Interval	3141.9	0.01006	0.00224	Trapezoid	63.161	1
R90	Automatic Fixed Interval	7383.4	0.02346	0.99958	Trapezoid	63.161	1
R110	Automatic Fixed Interval	1839.5	0.04557	0.42630	Trapezoid	63.161	1
R130	Automatic Fixed Interval	4097.3	0.00973	0.07753	Trapezoid	63.161	1
R140	Automatic Fixed Interval	1922.9	0.00374	0.07103	Trapezoid	63.161	1
R160	Automatic Fixed Interval	5187.9	0.0065987	0.10171	Trapezoid	63.161	1
R170	Automatic Fixed Interval	119	0.0074265	1	Trapezoid	63.161	1
R200	Automatic Fixed Interval	3035.4	0.00081923	0.0644249	Trapezoid	63.161	1
R210	Automatic Fixed Interval	8717.5	0.00005	0.0891314	Trapezoid	63.161	1

ANNEX 11. Pajo Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	13.59959	124.1472	0.1	3.400000095	2.2801		
2	13.59438	124.1513	0	2.5	15.3664		
3	13.61295	124.1595	0.45	2.599999905	16.4025		
4	13.61351	124.1596	0	2.400000095	3.3489		
5	13.61389	124.1596	0	2.700000048	9		
6	13.58586	124.1666	0	2.599999905	0.9409		
7	13.58594	124.1649	0.95	3.200000048	9.1809		
8	13.58579	124.1646	0	2.700000048	22.09		
9	13.58583	124.1643	0.7	3.700000048	1.4884		
10	13.58604	124.1638	1	2.299999952	24.5025		
11	13.58598	124.1636	0	2.799999952	22.6576		
12	13.58601	124.1633	0	2.200000048	9.9856		
13	13.6117	124.1655	2.13	3.599999905	1.0404		
14	13.6124	124.1661	0.9	2.5	1.9044		
15	13.61268	124.1662	0	2.799999952	8.8209		
16	13.61318	124.1663	0.2	2.700000048	6.8121		
17	13.61315	124.1665	0	2.400000095	19.4481		
18	13.61324	124.1666	0	2.299999952	22.4676		
19	13.61343	124.1665	0	2.700000048	18.1476		
20	13.61324	124.1668	0	2.700000048	0.0256		
21	13.61298	124.1669	0	2.5	5.76		
22	13.61313	124.1672	0.3	3.200000048	1.9321		
23	13.58935	124.1725	0	2.5	6.0516		
24	13.5945	124.1728	1.35	2.700000048	0		
25	13.58994	124.1825	0.7	2.700000048	4.7089		
26	13.59055	124.1841	0	3.5	0.0009		
27	13.59173	124.1837	0	3	0		
28	13.59105	124.1842		2.700000048	0		
29	13.61064	124.1913	0	3.200000048	0.04		
30	13.61097	124.1916		2.5	0.0529		
31	13.61133	124.192	0.45	2.900000095	104.6529		
32	13.61251	124.1929	0	2.5	31.5844		
33	13.61346	124.1935	0	2.5	32.1489		
34	13.61388	124.1936	0	3	0.0196		
35	13.61442	124.1933	0	2.900000095	28.8369		
36	13.61472	124.1928	0	2.299999952	0.0016		
37	13.60859	124.1774		2.099999905	3.6864		
38	13.60992	124.1767	0	1.700000048	0.0009		
39	13.61119	124.1764	0.5	3.299999952	0.0036		
40	13.61184	124.1763		1	24.3049		
41	13.61203	124.1763	2.4	1.100000024	0.0025		
42	13.61221	124.1759	2.1	1.299999952	0		

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
43	13.61239	124.1754		1.299999952			
44	13.61255	124.175	1.9	2.200000048			
45	13.61275	124.1746		2.5			
46	13.61353	124.175	0	1.399999976			
47	13.61337	124.1753	0	1.700000048			
48	13.6142	124.1752		2.099999905			
49	13.61405	124.1754	0	2.099999905			
50	13.59311	124.1909		1			
51	13.59338	124.1927	0	1.399999976			
52	13.5941	124.1929		0.899999976			
53	13.59132	124.1929	0	2.700000048			
54	13.59064	124.1929	0	2.299999952			
55	13.59056	124.1894	0	3.5			
56	13.59067	124.1913	0	2.299999952			
57	13.59172	124.1999		1.100000024			
58	13.59106	124.1989	0	1.899999976			
59	13.59077	124.1984	0	1.100000024			
60	13.58992	124.1994	0	4.599999905			
61	13.58799	124.2014		2.299999952			
62	13.57683	124.2006	0	5.699999809			
63	13.57781	124.2012	0	1.200000048			
64	13.57905	124.2019	0	1.100000024			
65	13.58236	124.2047		1			
66	13.58289	124.2051	0.1	1.200000048			
67	13.59247	124.2064		1.399999976			
68	13.59241	124.2062	0.5	1.5			
69	13.59237	124.2059		1			
70	13.58804	124.2046	0	1.399999976			
71	13.57799	124.2163	0	3.5			
72	13.57753	124.2147	0	1.600000024			
73	13.5772	124.2135		1			
74	13.57705	124.2128	0	1			
75	13.57661	124.2115		1			
76	13.57012	124.2043	0	1			
77	13.56862	124.2082	0	1.100000024			
78	13.56658	124.2066	0	1			
79	13.56469	124.2018	0.8	1			
80	13.56384	124.1949	1.2	1			
81	13.56215	124.199	1.96	1			
82	13.56196	124.1995	1.4	1.399999976			
83	13.56044	124.1997	0.94	1.600000024			
84	13.55937	124.1999	2.3	2.700000048			
85	13.55735	124.1999		1			
86	13.55725	124.1999	0.8	1.399999976			

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
87	13.54685	124.2051	0	1			
88	13.54719	124.2044	0	1			
89	13.54797	124.2045	1.2	1.799999952			
90	13.54846	124.2047	0.7	2.299999952			
91	13.54889	124.2047	0.5	1			
92	13.55679	124.1819	1.77	1.5			
93	13.55618	124.182		1.799999952			
94	13.55515	124.1805	0.1	1.5			
95	13.60064	124.1444	0	1.899999976			
96	13.59455	124.1504	0	1.700000048			
97	13.61287	124.1597	0.2	0.800000012			
98	13.6133	124.1602	0.3	0.899999976			
99	13.58648	124.1611	0	2.799999952			
100	13.58642	124.1614	0.4	1.899999976			
101	13.58626	124.1623	0	1.100000024			
102	13.58641	124.1629	0	1			
103	13.58617	124.163		1.899999976			
104	13.58609	124.163	0.4	1			
105	13.58612	124.1632	0	1			
106	13.61232	124.1662		0.800000012			
107	13.61222	124.1663	2	1.100000024			
108	13.61199	124.1665	2.5	1.200000048			
109	13.61266	124.167	1	1.899999976			
110	13.58678	124.1721	0	1			
111	13.58985	124.1722	3.3	0.899999976			
112	13.59477	124.1726	0.3	1.399999976			
113	13.58841	124.1786	0	0.899999976			
114	13.58982	124.1823	0	1.200000048			
115	13.58994	124.1821		1			
116	13.59022	124.1835	0.7	1.200000048			
117	13.59061	124.1844	0	1			
118	13.5909	124.1842	0	1			
119	13.59121	124.1845	0.6	1.799999952			
120	13.59095	124.1848	0	2.200000048			
121	13.59064	124.1848		1			
122	13.61071	124.1908	0.3	0.800000012			
123	13.6096	124.1913	1.1	1			
124	13.60949	124.1922	0.9	1			
125	13.61029	124.1829	0	1			
126	13.6089	124.1784		1.200000048			
127	13.60882	124.1767	0.75	2.200000048			
128	13.60871	124.1763		2.599999905			
129	13.60945	124.1762	0.6	1.700000048			
130	13.6125	124.1764	2	2.400000095			

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
131	13.6128	124.1767	0	2.400000095			
132	13.61253	124.1771	0	1.200000048			
133	13.61264	124.1763	2	2.5			
134	13.61283	124.1756	1.8	0.899999976			
135	13.61295	124.1753		1			
136	13.6133	124.1754	2.2	2.799999952			
137	13.61377	124.1757	0.9	1			
138	13.6136	124.1758	1.5	1			
139	13.60368	124.1797	0	1			
140	13.60277	124.1802	0	0.800000012			
141	13.5932	124.1909	0	1.5			
142	13.5935	124.1925	0	1			
143	13.59798	124.1936	0	1.399999976			
144	13.5921	124.1928	0	1			
145	13.5905	124.1923	0	1.200000048			
146	13.59041	124.1919	0	2.5			
147	13.59179	124.1912	0	1			
148	13.58951	124.197	0	1.899999976			
149	13.58905	124.198	0	4.5			
150	13.58875	124.1996	0	1.100000024			
151	13.59162	124.2002	0	1.600000024			
152	13.59056	124.1984	0	1			
153	13.58796	124.2014	0	1			
154	13.58701	124.2034	0	1			
155	13.58592	124.2031	0	1			
156	13.58357	124.203	0	1			
157	13.58103	124.2029	0	2			
158	13.58104	124.2033	0	1			
159	13.58189	124.2045	0	1			
160	13.58229	124.2048	0.2	1			
161	13.58276	124.2051	0.3	1			
162	13.59129	124.2071	0	1			
163	13.59126	124.2059	0.2	2.400000095			
164	13.59107	124.2059	0	1.100000024			
165	13.58819	124.2046	0	1.5			
166	13.56929	124.2041	0	1.600000024			
167	13.56857	124.2082	0	1			
168	13.56657	124.2067	0	4.099999905			
169	13.56522	124.2035	0	1.799999952			
170	13.56391	124.198	0	1.299999952			
171	13.56395	124.1956	1.6	0.899999976			
172	13.56348	124.1939	1.1	1.700000048			
173	13.56217	124.199	1.4	1.5			

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
176	13.55737	124.1999	0.4	1.100000024			
177	13.55666	124.2001	1.3	1.200000048			
178	13.54991	124.2063	2.6	2.099999905			
179	13.55041	124.205	1.7	1			
180	13.55032	124.2049	2	1.100000024			
181	13.55032	124.2049		1			
182	13.54995	124.2048	1.8	1.700000048			
183	13.54951	124.2048	1.7	1			
184	13.54928	124.2047	1.1	1.100000024			
185	13.54222	124.2043	0.3	1			
186	13.55797	124.1809	1.3	1.299999952			
187	13.55678	124.1819	1.7	1			
188	13.57783	124.2251	1.2	3			
189	13.5783	124.2245	0.2	3			
190	13.57769	124.2242	0.3	3			
191	13.57194	124.2205	0.2	3			
192	13.57235	124.2193	0	4			
193	13.57738	124.2247	0.6	8			
194	13.57562	124.2227	0.4	8			
195	13.57318	124.2211	0.1	12			
196	13.57268	124.2183	0	8			

ANNEX 12. Educational Institutions Affected by flooding in Pajo Flood Plain

CATANDUANES				
San Andres				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
Daycare	Rizal			
Jose Rizal elem. School	Rizal	Low	Low	Low
Rizal elem. School San Abdres east District	San Jose			
Virac	Fabrica Elementary School			
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Antipolo Elem. School	Antipolo del Norte			
Antipolo National highschool	Antipolo del Norte	Medium	Medium	High
Antipolo Elem. School	Antipolo del Sur			
Bigaa Elem. School	Bigaa			Low
Buyo/Tubaon Integrated School	Buyo	High	High	High
Calabnigan Daycare	Calabnigan	Medium	Medium	Medium
Calabnigan Elem School	Calabnigan	Low	Low	Low
Brgy. Calampong Daycare	Calampong			
Calampong Elem. School	Calampong			
Calatagan Highschool	Calatagan Proper	Medium	Medium	Medium
Cavinitan Daycare	Cavinitan			
Cavinitan Elem. School	Cavinitan	Low	Low	Low
Cavinitan Highschool	Cavinitan	Low	Low	Low

ANNEX 13. Health Institutions affected by flooding in Silaga Floodplain

Catanduanes				
San Andres				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Rizal Health Center	Rizal			

Catanduanes				
Virac				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Health Center	Antipolo del Norte			
Health Center	Bigaa	High	High	High
Hospital	Bigaa	Medium	Medium	Medium
Joson Orthopaedic Clinic	Bigaa			
Sta. Josefa Diocesan Clinic	Bigaa			
Health Center, Daycare	Buyo	High	High	High
Health Center	Cabihian			
Health Center	Calampong			
Health center	Cavinitan			
Health Center	Pajo Baguio			Medium
Health Center	Palnab Del Norte			
Health Center	Palta Big			
Palta Small Health center	Palta Small	Medium	Medium	Medium
Simamla Health center	Simamla	High	High	High