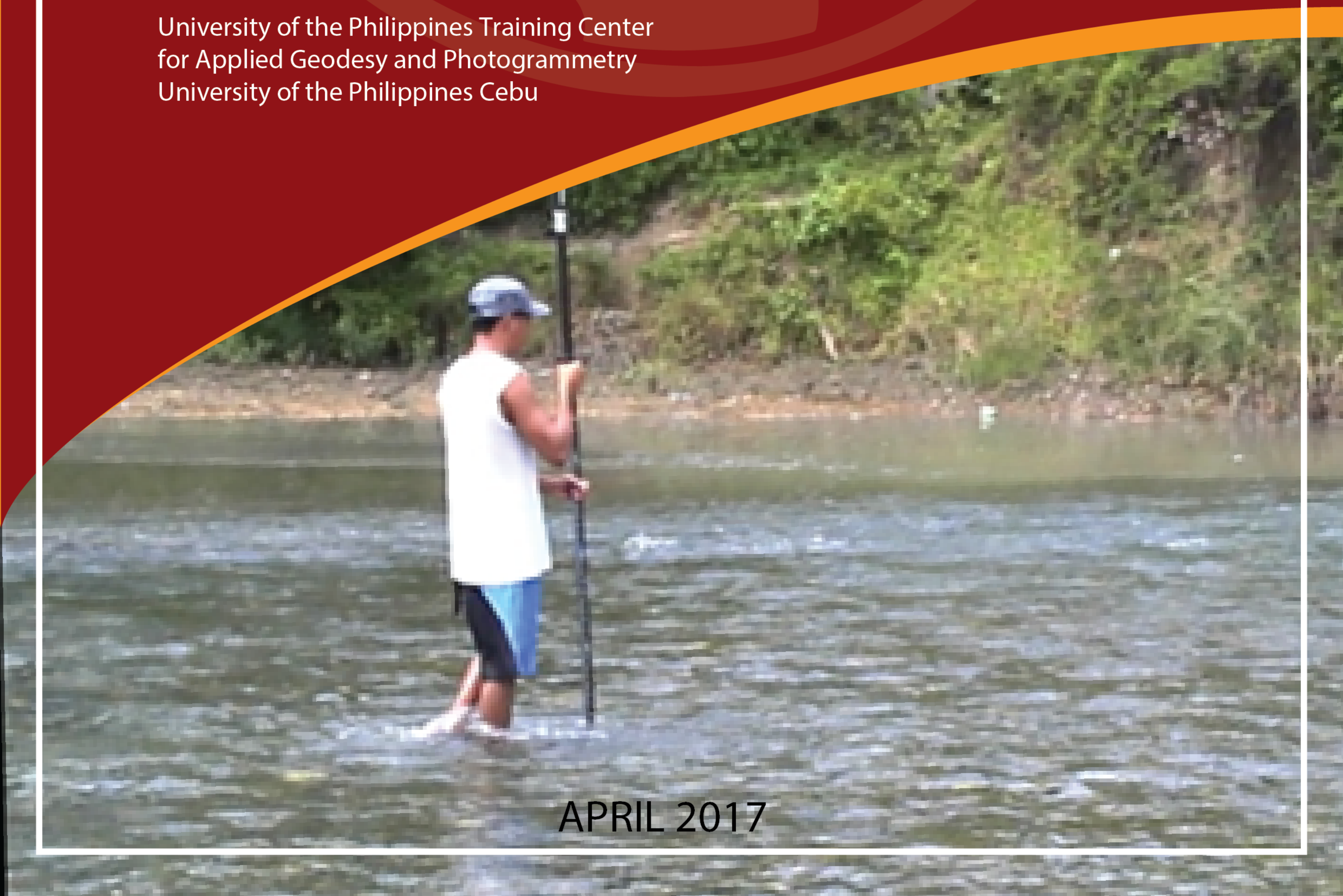
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Ipayo River

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



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LIST OF ACRONYMS AND ABBREVIATIONS

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

IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UPC	University of the Philippines Cebu
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND THE IPAYO RIVER

Enrico C. Paringit, Dr. Eng. and Jonnifer R. Sinogaya, PhD.

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Cebu (UPC). UPC is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for twenty-two (22) river basins in the Western Visayas region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Ipayo River Basin

Ipayo River Basin is located in the Province of Antique located at the west of Panay Island. The floodplain and drainage area of 29.05 km2 and 22.17 km2 respectively covers the portion of the Municipalities of Valderrama, San Remegio, and most of the Municipality of Patnongon, all of which are in Antique. The DENR River Basin Control Office (RBCO) identified the Ipayo river basin to be one of the 421 river basins in the Philippines, having an estimated 90 million cubic meter (MCM) annual run-off. It is also one of the seven (7) major river basins in Antique.

Its main stem, Ipayo River, passes along the Municipality of Patnongon. Ipayo River is part of the 23 river systems in the Western Visayas Region under the PHIL-LIDAR 1 partner HEI, the University of the Philippines Cebu. There is a total of 9, 387 people residing in the immediate vicinity of the river which is distributed among seven (7) barangays, namely: Amparo, Poblacion, Igbobon, Tamayoc, Villa Crespo, Villa Laua-An, and Villa Salomon (NSO, 2010). The river is rich in good quality gravel and sand wherein local private quarry companies extract from the riverbed and export abroad (Guntan, 2015).

The floodplain is 100% covered with LiDAR data, which compromises 2 blocks. The LiDAR data was calibrated then mosaicked with an RMSE of -0.004 and then bathy burned. The bathy survey conducted reached a total length of 14.13 km starting from Villa Elio, Patnongon up to the river mouth with 1190 points surveyed. There are 3920 buildings, 36.45 km roads, 19 water bodies, and 5 bridges digitized based from the LiDAR data. Feature Extraction Attribution was conducted, and among the building features, 3632 of them are residential, 83 are schools and 8 are medical institutions.

Meanwhile, the flood hazard map produced covers the 6.22 km2, 7.77 km2, 8.38 km2 for the 5-year, 25-year, and 100-year rainfall return period in Patnongon which affects 13 barangays. A flood depth validation was conducted using 205 randomly generated points, which is spread throughout the 6 ranges namely 0m-0.2m, 0.21m-0.5m, 0.51m-1m, 1.01m-2m, 2.10m-5m, 5m+ depth using the 25-yr rainfall flood depth map. It yielded a 0.698m RMSE.

A rating curve was developed at Tamayoc Bridge, Patnongon, Antique, which shows the relationship between the observed water levels at Tamayoc Bridge and outflow of the watershed at this location. This rating curve equation, expressed as Q = 2E-07e1.6985x, was used to compute the river outflow at Tamayoc Bridge for the calibration of the HEC-HMS model. The resulting outflow was used to simulate the flooded areas using HEC-RAS. The simulated model will be an integral part in determining the real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website.

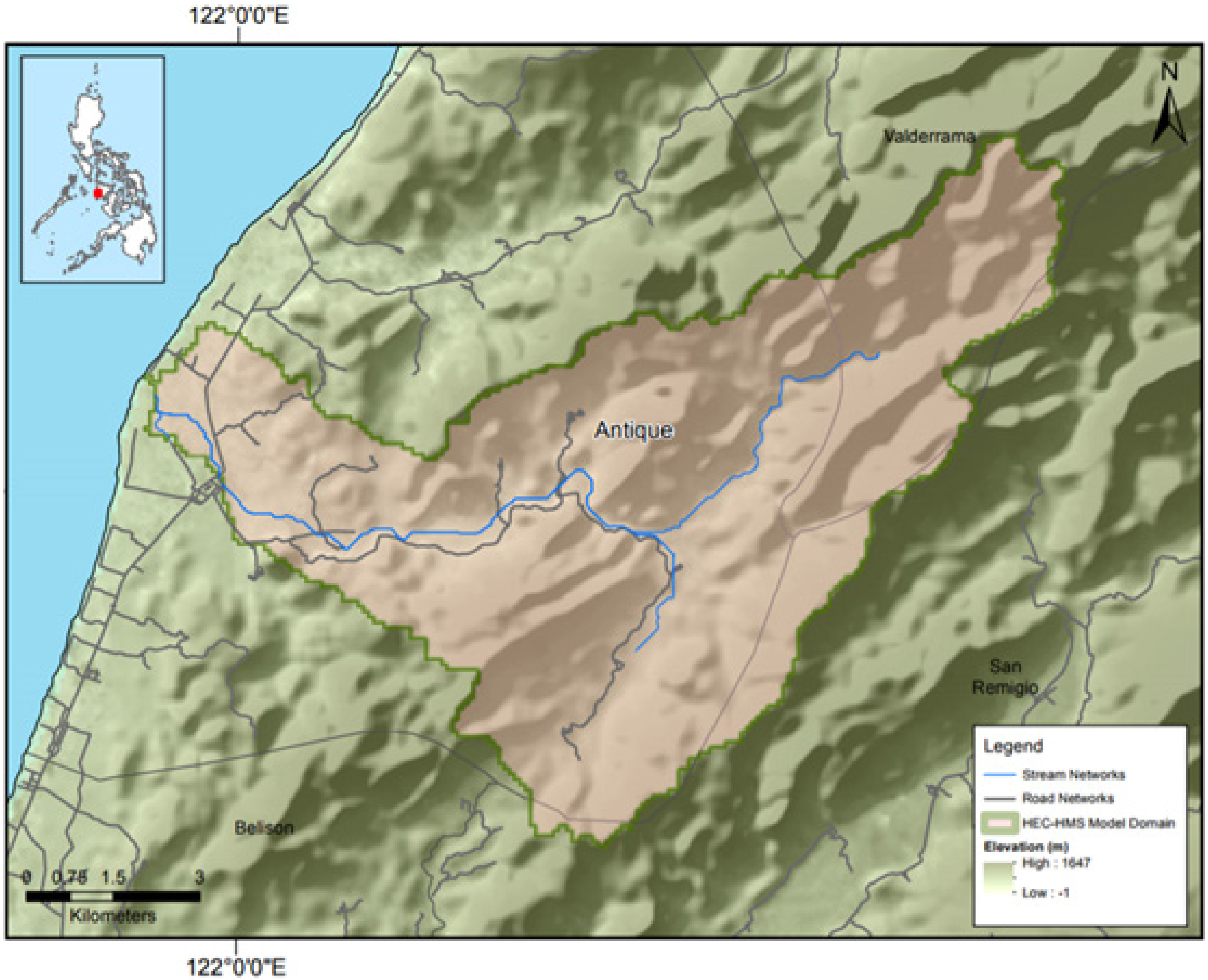

Figure 1. Map of Ipayo River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION OF THE IPAYO 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

To initiate the LiDAR acquisition survey of the Ipayo Floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Ipayo Floodplain in Iloilo. Each flight mission has an average of 15 lines and ran for at most four (4) hours including take-off, landing, and turning time (See Annex 1 for sensor specifications). The flight planning parameters[1] for the LiDAR system used are found in Table 1. Figure 2, on the other hand, shows the flight plans and base stations for Ipayo floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK43B	1000	30	50	200	30	130	5
BLK43D	1000	30	50	200	30	130	5
BLK43E	1000	30	50	200	30	130	5
BLK43F	1000	30	50	200	30	130	5

1 The explanation of the parameters used are in the volume "LiDAR Surveys and Flood Mapping in the Philippines: Methods."

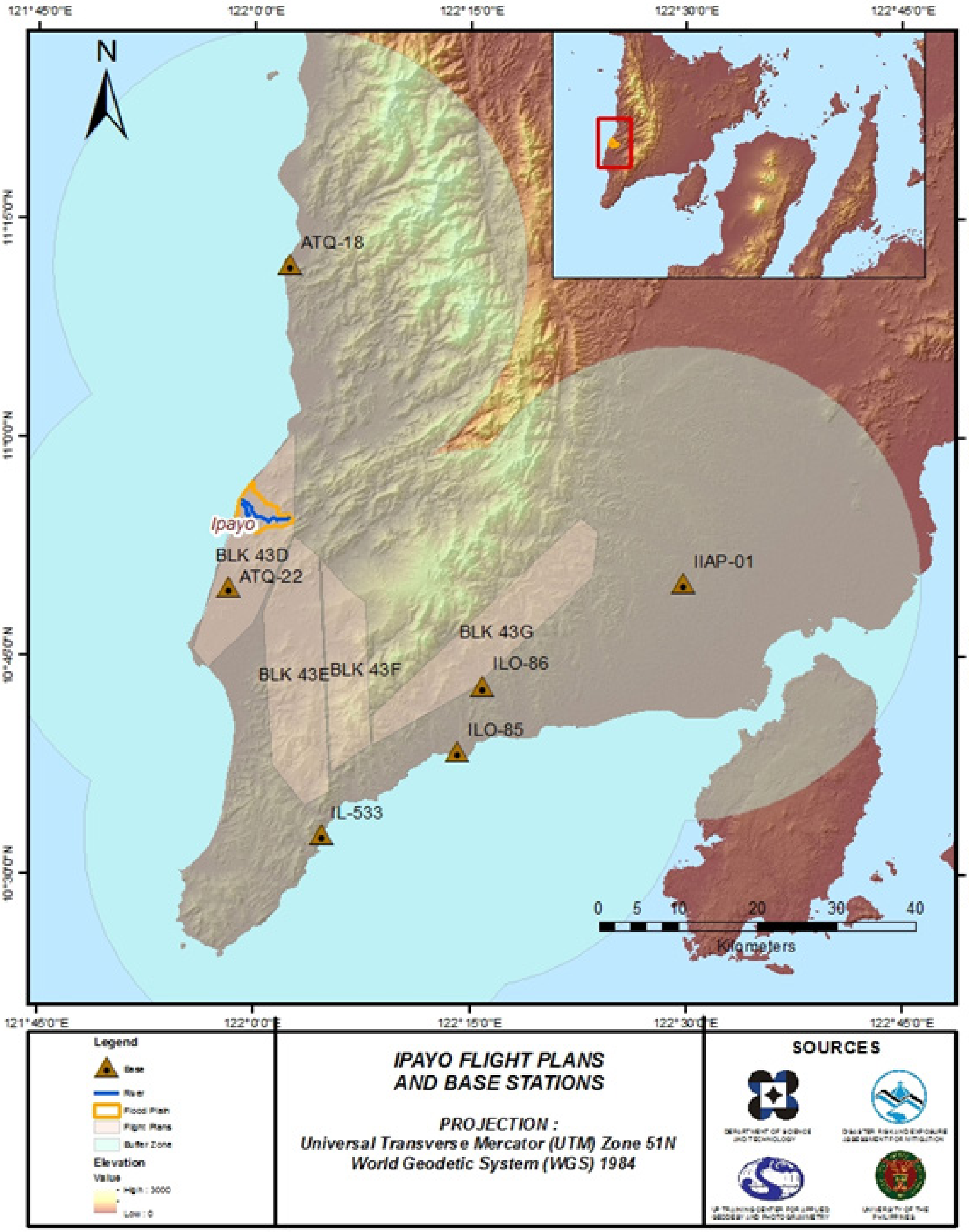


Figure 2. Flight plans and base stations used to cover Ipayo Floodplain

2.2 Ground Base Station

The field team for this undertaking was able to recover four (4) NAMRIA reference points: ILO-85, ILO-86, ATQ-22, and ATQ-18, which are of second (2nd) order accuracy. One (1) NAMRIA benchmark of first (1st) order accuracy, IL-533, was recovered. This benchmark was used as vertical reference point and was also established as ground control point. The project team also established one (1) ground control point, IIAP-01. The certifications for the base stations and benchmark points are found in Annex 2, while the baseline processing report for the established ground control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 14, 17 – 20, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 985 and TRIMBLE SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Ipayo Floodplain are shown in Figure 2. For the list of team members, see Annex 4.

Figures 3 to 7 show the recovered NAMRIA reference points within the area. In addition Tables 2 to 6 show the details about the following NAMRIA control stations and established points, while Table 7 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

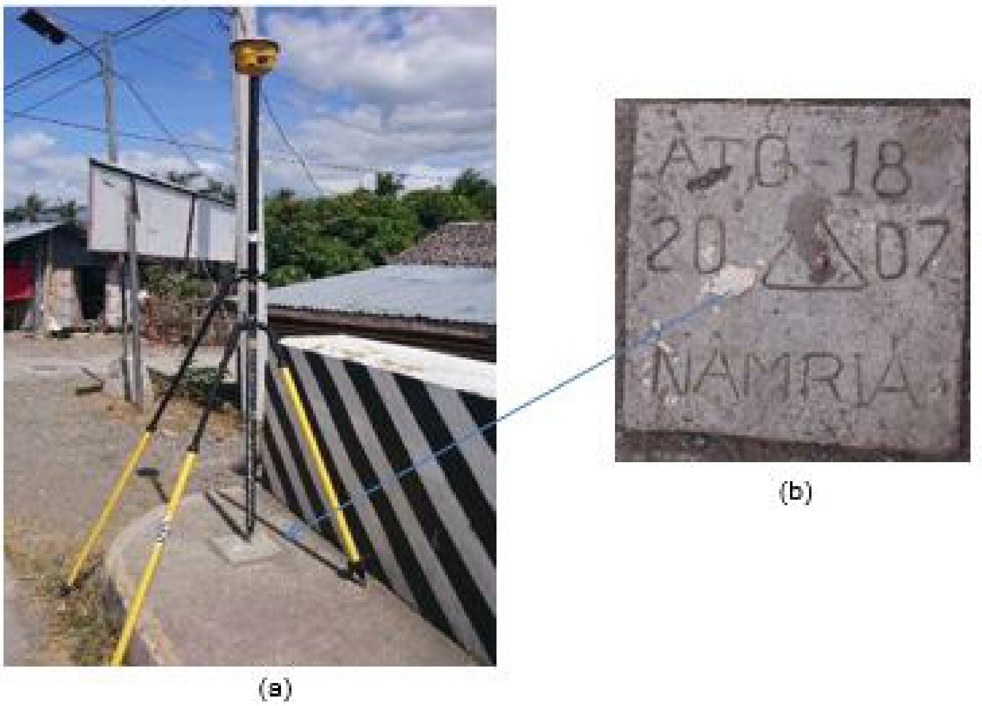
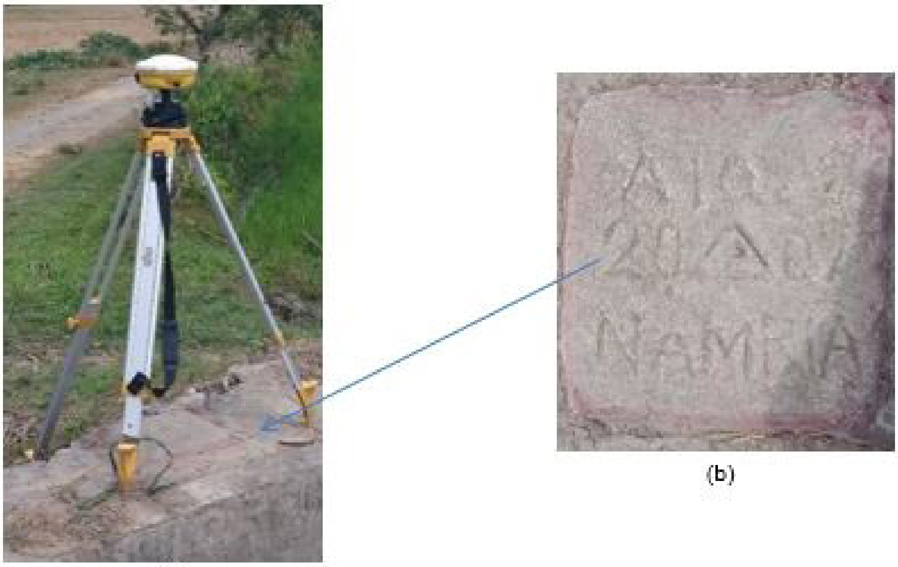


Figure 3. a) GPS set-up over ATQ-18 on the NE approach of Binangbang Bridge, about 600 meters NE of Barbaza Town Hall, 4 meters from the road centerline, 50 meters SE of Barbaza Multi-Purpose Coop, and b) NAMRIA reference point ATQ-18, as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point ATQ-18 used as base station for the LiDAR acquisition.

Station Name	ATQ-18	
Order of Accuracy	2rd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11’ 58.67081”119” North 122° 2’ 22.83300” East 10.902 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	395155.157 meters 1238579.674 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 11’ 54.16068” North 122° 2’ 28.01549” East 65.961 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	395155.87 meters 1238146.15 meters



(b)

(a)

Figure 4. a) GPS set-up over ATQ-22 on top of the N edge of the NW draft on an irrigation canal, 60 meters NE to the national highway centerline, 120 meters N of the road going to the barangay proper and about 300 meters E of KM Post 110, and b) NAMRIA reference point ATQ-22, as recovered by field team.

Table 3. Details of the recovered NAMRIA horizontal control point ATQ-22 used as base station for the LiDAR acquisition.

Station Name	ATQ-22	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 49’ 46.66618” 121° 58’ 11.90221” 12.250 m
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	387365.279 m 1197676.056 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 49’ 42.24271” 121° 58’ 17.11770” 68.022 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	387404.70 m 1197256.85 m

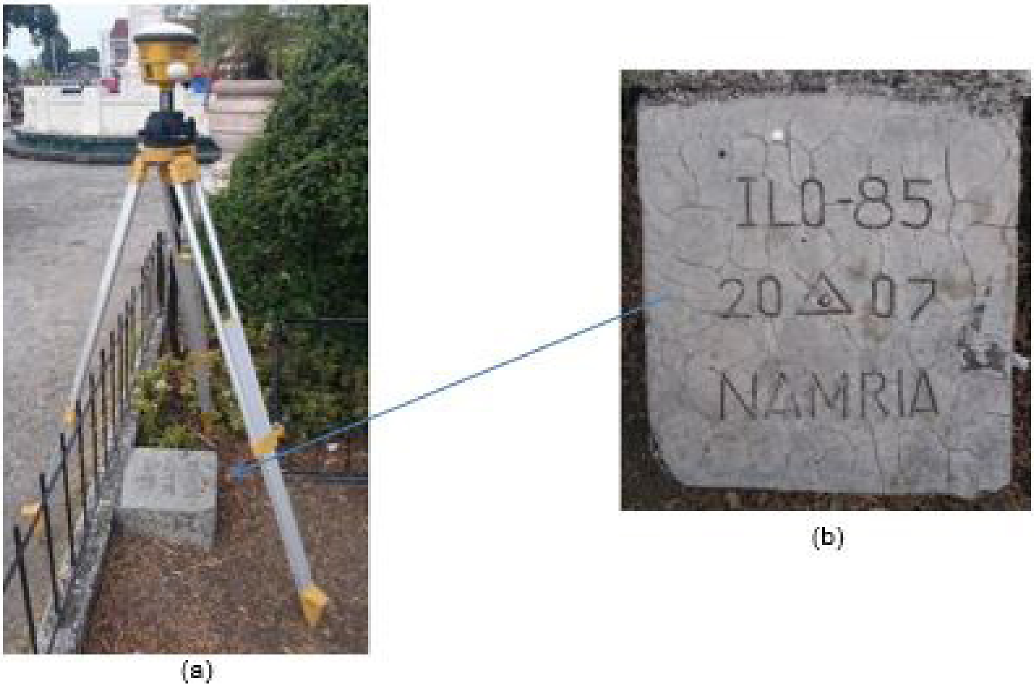


Figure 5. a) GPS set-up over ILO-85 at the corner of a planting strip and sidewalk at the town plaza of Brgy. Poblacion, Miagao, Iloilo, about 14 m fronting the Rizal monument, and b) NAMRIA reference point ILO-85, as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point ILO-85 used as base station for the LiDAR acquisition.

Station Name	ILO-85	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 : 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 38' 33.11352" North 122° 14' 03.70561" East 21.962 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	416097.644 meters 1176957.657 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 38' 28.75996" North 122° 14' 08.93597" East 78.828 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	416256.319 meters 1176484.099 meters

(a) (b)

Figure 6. a) GPS set-up over ILO-86, about 12 m from the circular fountain at the center of the town plaza of Brgy. Poblacion, Igbaras, Iloilo, about 14 m fronting the Rizal monument, and b) NAMRIA reference point ILO-86, as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point ILO-86 used as base station for the LiDAR acquisition.

Station Name	ILO-86	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 : 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 43’ 04.36044” North 122° 15’ 48.62123” East 47.315 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	419306.197 meters 1185284.087 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 42’ 59.99043” North 122° 15’ 53.84473” East 104.076 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	419463.955 meters 1184807.437 meters

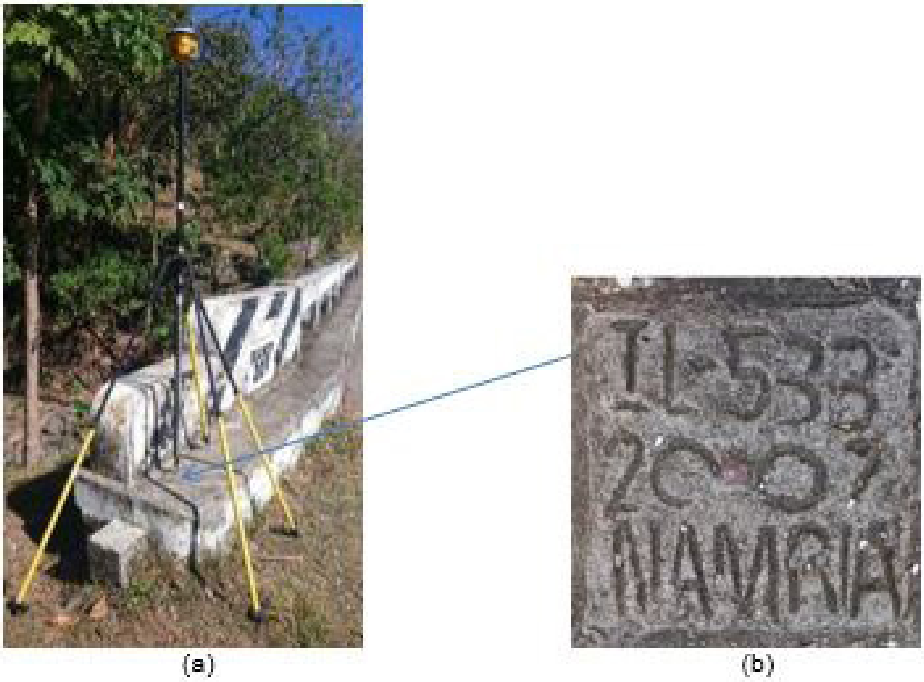


Figure 7. a) GPS set-up over IL-533, located 3 meters from the edge of the sidewalk of Amboyu-an Bridge at Brgy. Amboyu-an, San Joaquin, Iloilo, and b) NAMRIA reference point IL-533, as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point IL-533 used as base station for the LiDAR acquisition.

Station Name	IL-533	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10° 32’ 49.29908” North 122° 04’ 37.25566” East 51.412 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 5 PRS 92)	Easting Northing	398848.891 meters 1166439.919 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 32’ 44.95602” North 122° 04’ 42.49544” East 64.135 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	399013.479 meters 1165970.645 meters

Table 7. Ground control points used during LiDAR Data Acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 14, 2015	2569P	1BLK43D045A	ILO-85 and IIAP-01
February 17, 2015	2583P	1BLK43D048B	ILO-85 and IL-533
February 18, 2015	2587P	1BLK43ED049B	ILO-85, ILO-86 and IIAP-01
February 19, 2015	2589P	1BLK43EFD050A	ILO-85, ILO-86 and IIAP-01
February 20, 2015	2593P	1BLK43BDG051A	ATQ-22, ATQ-18 and IIAP-01

2.3 Flight Missions

Five (5) missions were conducted to complete LiDAR data acquisition in Ipayo Floodplain, for a total of 17 hours and 32 minutes (17+32) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR System. Table 8 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 9 presents the actual parameters used during the LiDAR data acquisition. Table 10 shows the total area of actual coverage per mission and the flying length for each mission, and Table 11 shows the actual parameters used during the LiDAR data acquisition.

Table 8. Flight missions for LiDAR data acquisition in Ipayo 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
February 14, 2015	2569P	248.27	80.23	6.09	74.14	163	3	29
February 17, 2015	2583P	248.27	114.22	11.59	102.63	253	2	53
February 18, 2015	2587P	352.53	154.14	12.45	141.69	0	3	47
February 19, 2015	2589P	459.17	133.13	1.53	131.6	261	3	41
February 20, 2015	2593P	398.78	182.53	7.55	174.98	427	3	29
TOTAL		807.27	488.61	22.15	466.46	1104	17	32

Table 9. 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
2569P	1100	30	50	200	30	130	5
2583P	1100	30	50	200	30	130	5
2587P	1100	30	50	200	30	130	5
2589P	1100	30	50	200	30	130	5
2593P	1100	30	50	200	30	130	5

2.4 Survey Coverage

Ipayo Floodplain is located in the Province of Antique, with the whole floodplain situated within the Municipality of Patnongon. Municipalities of Antique are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 14. The actual coverage of the LiDAR acquisition for Ipayo Floodplain is presented in Figure 11.

Table 10. List of municipalities and cities surveyed during Ipayo Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Antique	Patnongon	135.69	123.44	91
	San Jose	44.26	39.5	89.25
	Belison	36.8	32.46	88.2
	Sibalom	240.55	65.12	27.07
	Laua-an	165.65	30.52	18.42
	Hamtic	139.85	22.81	16.31
	Bugasong	178.8	27.83	15.56
	Barbaza	171.24	14	8.18
	San Remigio	370.9	22.9	6.17
Iloilo	San Joaquin	200.06	54.95	27.47
	Igbaras	132.37	8.04	6.07
	Miagao	170.53	2.82	1.65
Total		1,986.70	444.39	22.37%

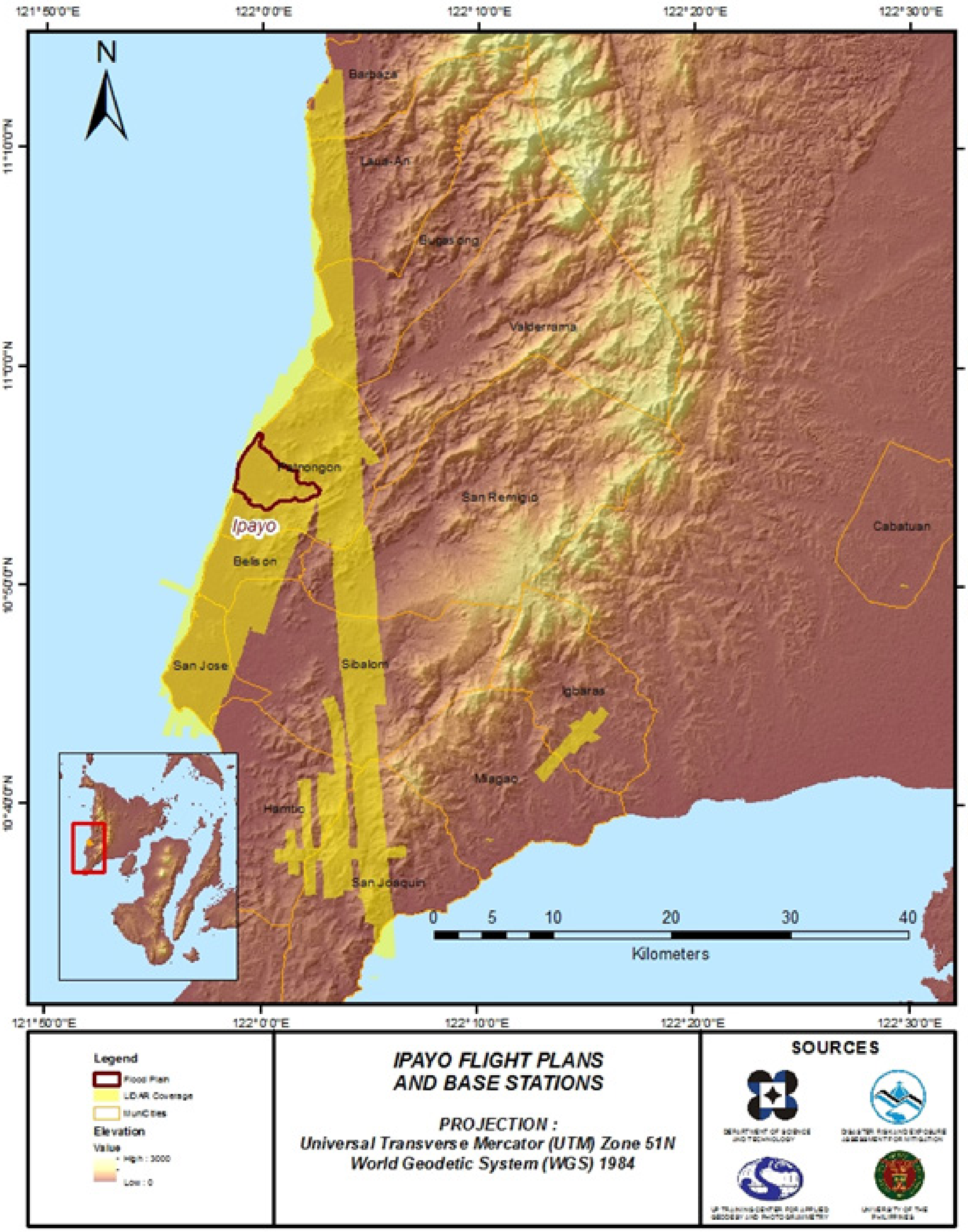


Figure 8. Actual LiDAR data acquisition for Ipayo Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE IPAYO 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 LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 9.

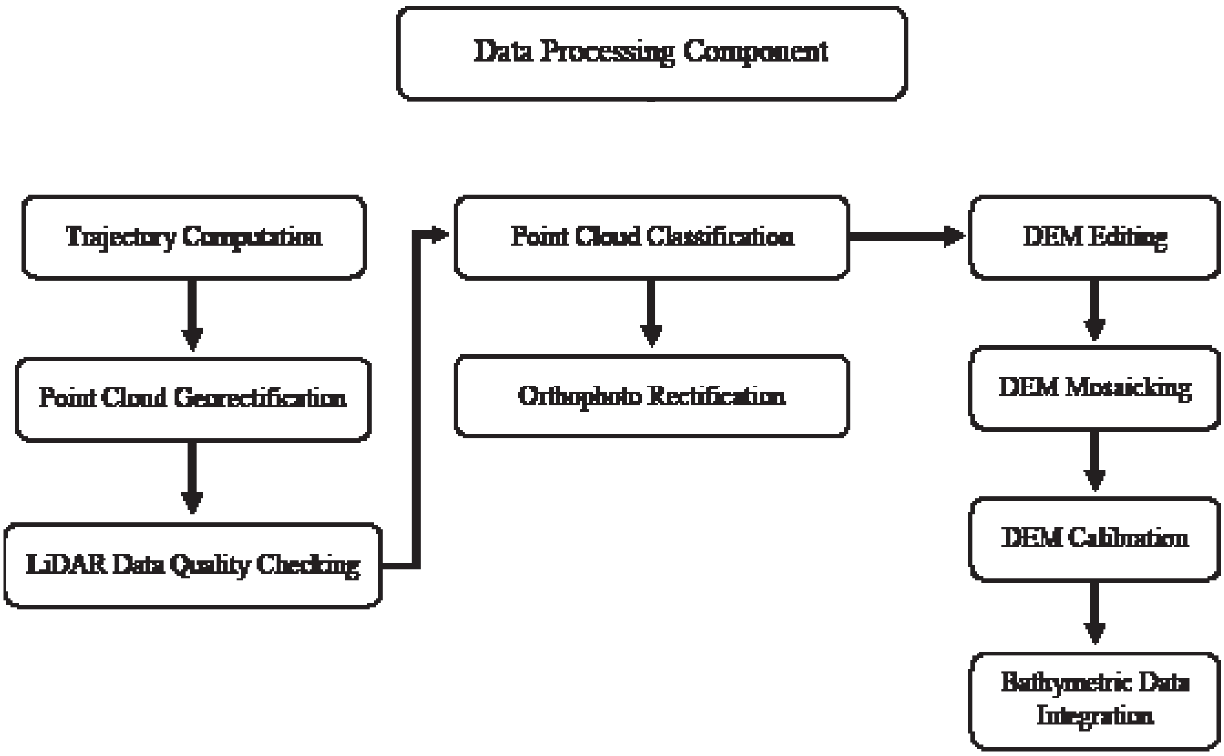


Figure 9. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Ipayo Floodplain can be found in Annex 5. Missions flown during the survey conducted on February 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus System over Patnongon, Antique. The Data Acquisition Component (DAC) transferred a total of 71.8 gigabytes of range data, 1.186 Gigabytes of POS data, 65.86 Megabytes of GPS base station data, and 88.8 Gigabytes of raw image data to the data server on March 23, 2015. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Ipayo was fully transferred on March 23, 2015, as indicated on the Data Transfer Sheets for Ipayo Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for Flight 2587P, one of the Ipayo flights, which is the North, East, and Down position RMSE values are shown in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 18, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

Figure 10. Smoothed Performance Metrics of Ipayo Flight 2587P.

The time of flight was from 283000 seconds to 292000 seconds, which corresponds to the afternoon of February 18, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.28 centimeters, the East position RMSE peaks at 2.45 centimeters, and the Down position RMSE peaks at 5.42 centimeters, which are within the prescribed accuracies described in the methodology.

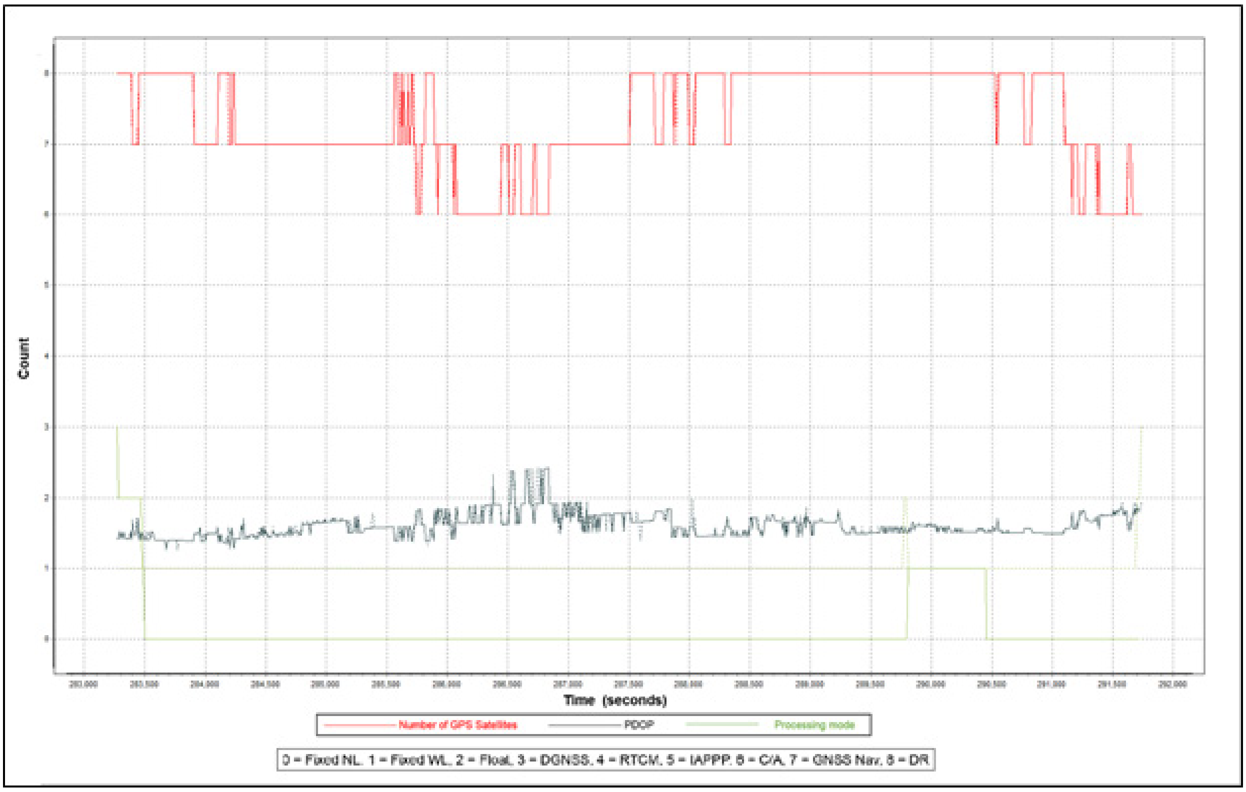


Figure 11. Solution Status Parameters of Ipayo Flight 2587P.

The Solution Status parameters of Flight 2587P, one of the Ipayo flights, which indicate the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Most of the time, the number of satellites tracked was between 6 and 8. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 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 Ipayo flights is shown in Figure 12.

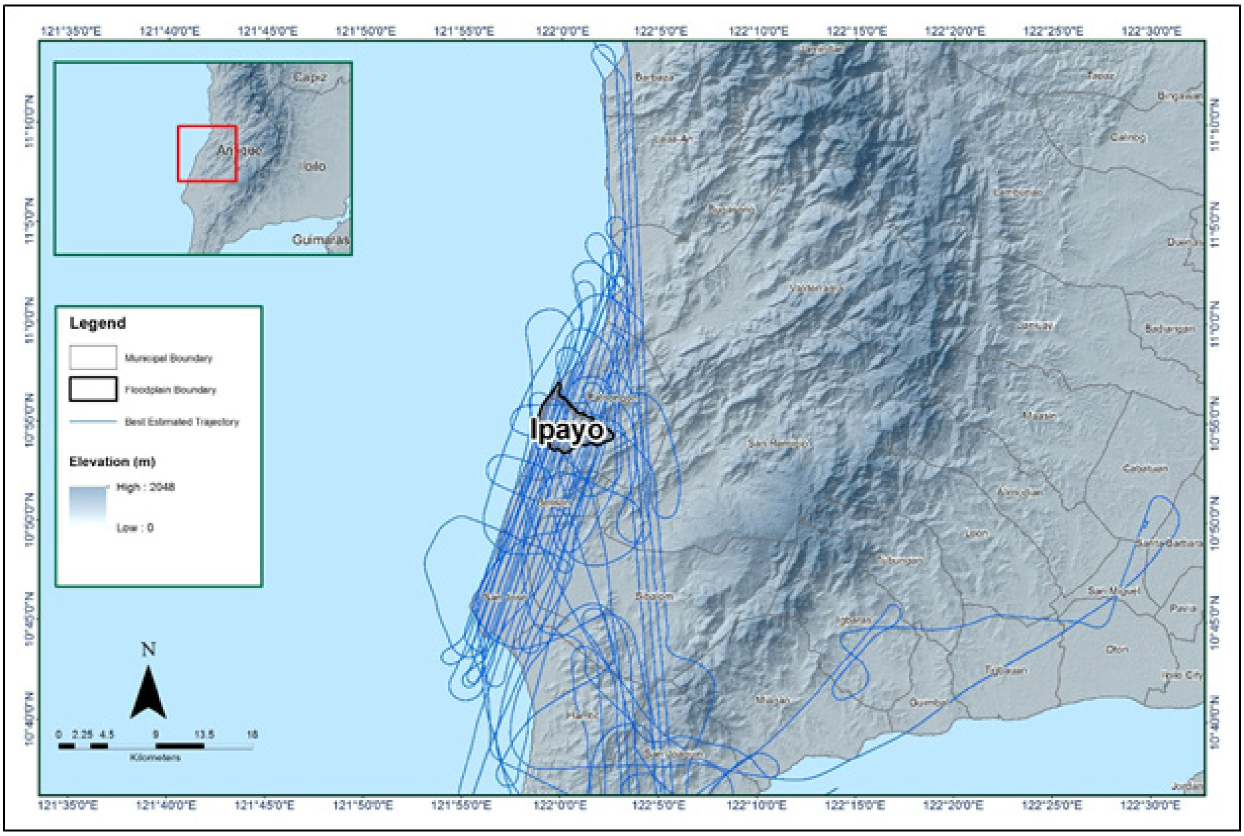


Figure 12. Best estimated trajectory of the LiDAR missions conducted over the Ipayo Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 27 flight lines, with each flight line containing two channels, 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 Ipayo Floodplain are given in Table 11.

Table 11. Self-Calibration Results values for Ipayo flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000352
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000953
GPS Position Z-correction stdev	(<0.01meters)	0.0021

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

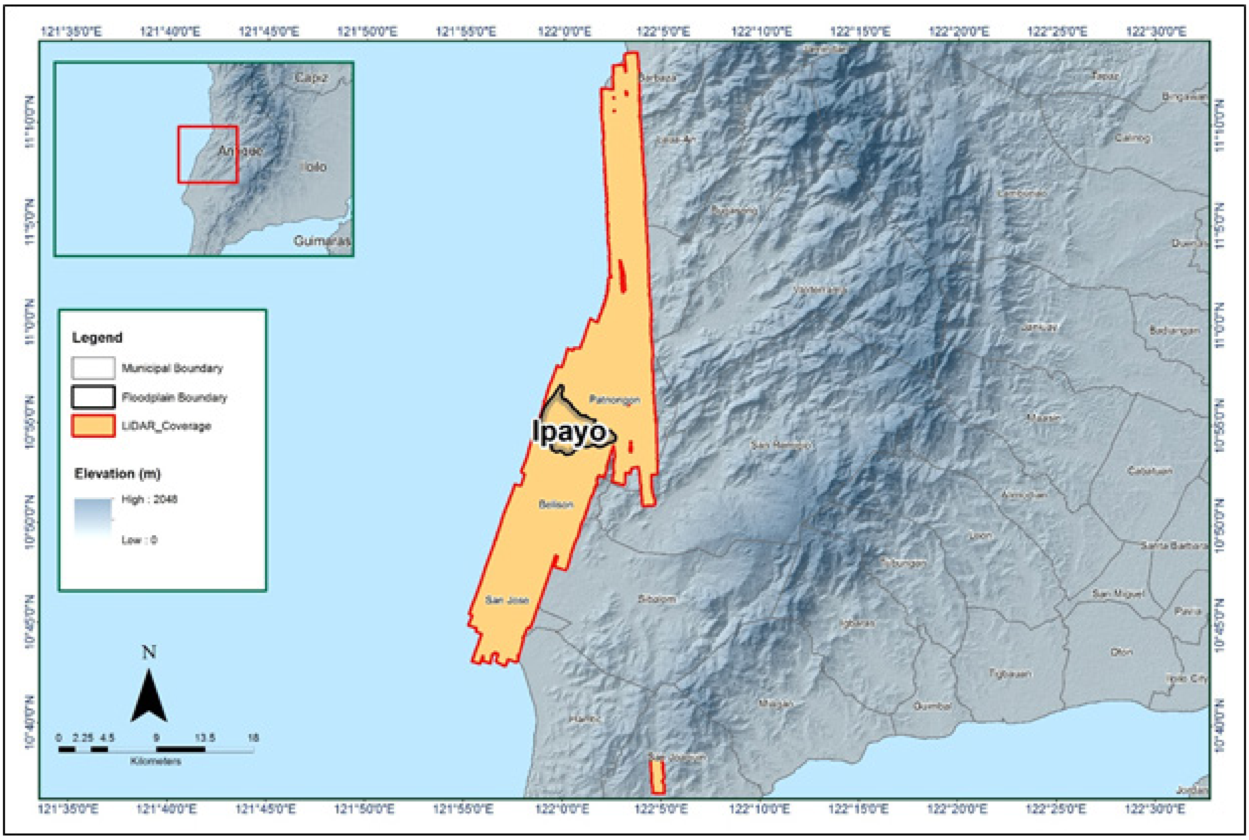


Figure 13. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Ipayo Floodplain.

The total area covered by the Ipayo missions is 348.06 km2 that is comprised of five (5) flight acquisitions grouped and merged into two (2) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Ipayo Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Iloilo_Blk43B	2593P	136.14
Iloilo_Blk43D	2569P	211.92
	2583P	
	2587P	
	2589P	
	2593P	
TOTAL		**348.06 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 14. Since the Pegasus system employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

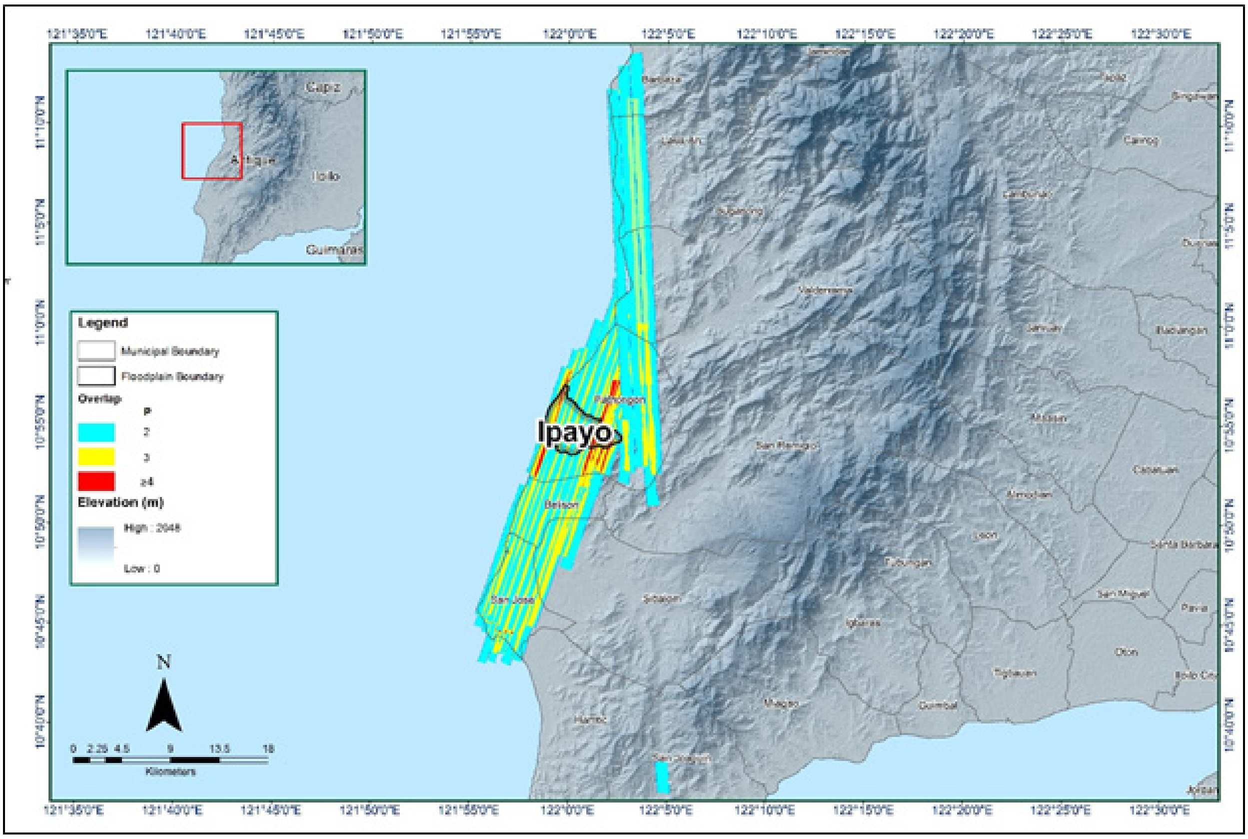


Figure 14. Image of data overlap for Ipayo Floodplain.

The overlap statistics per block for the Ipayo Floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.93% and 42.59% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 15. It was determined that all LiDAR data for Ipayo Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.12 points per square meter.

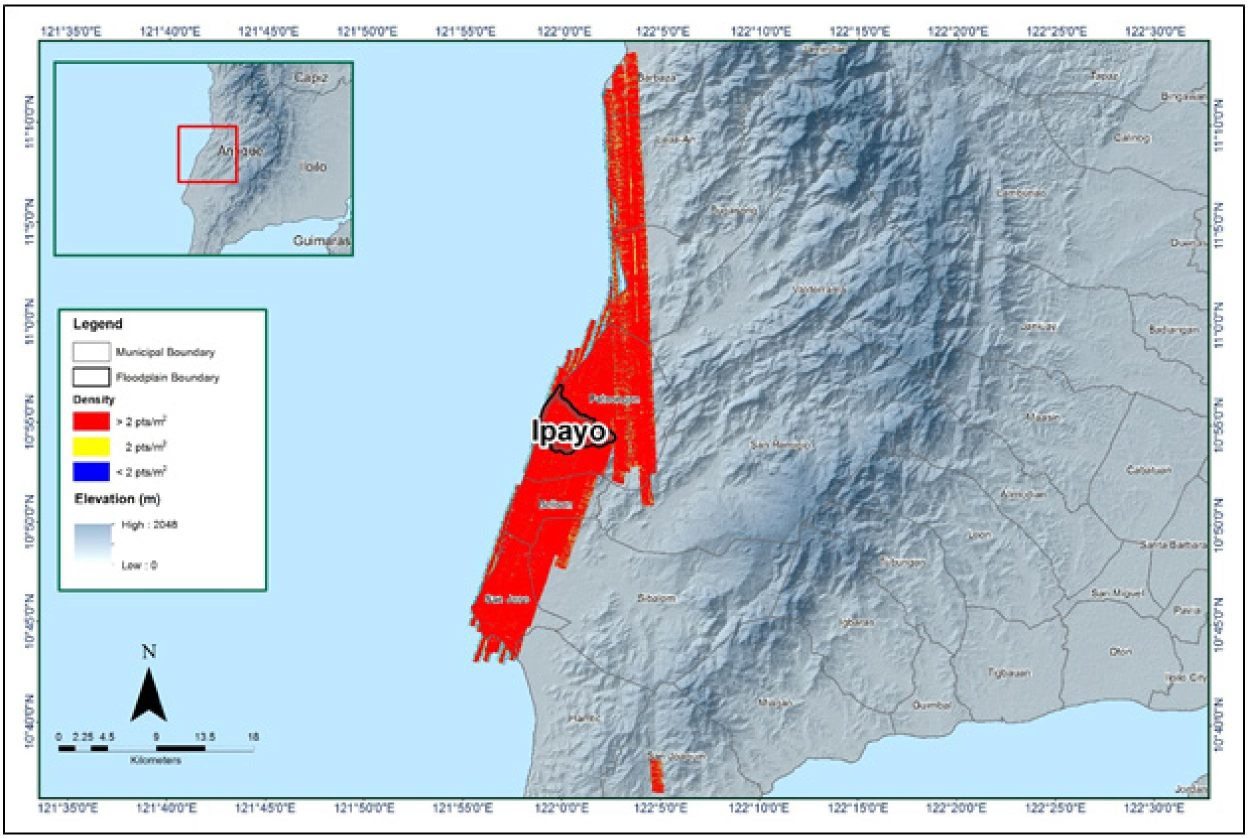


Figure 15. Pulse density map of merged LiDAR data for Ipayo Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. 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 0.20 m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 m 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.

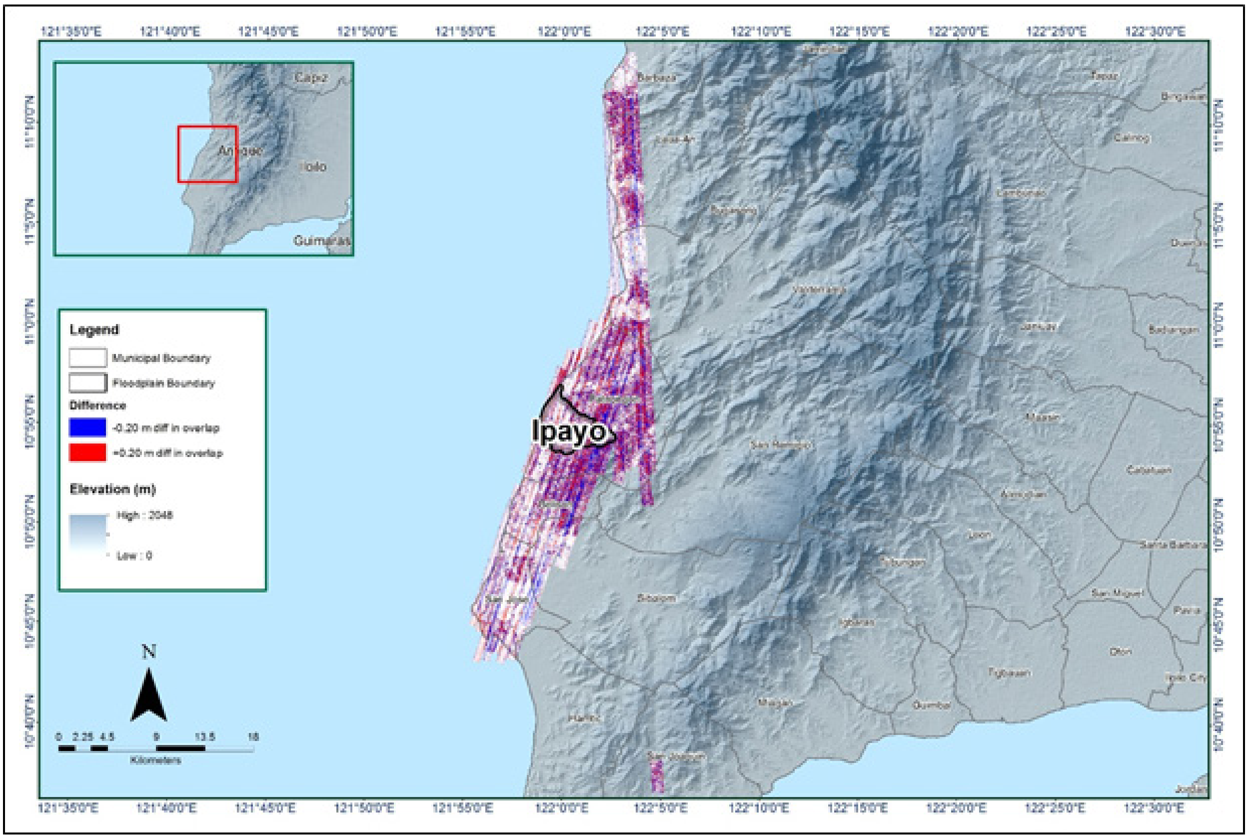


Figure 16. Elevation difference map between flight lines for Ipayo Floodplain.

A screen capture of the processed LAS data from Ipayo Flight 2587P loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

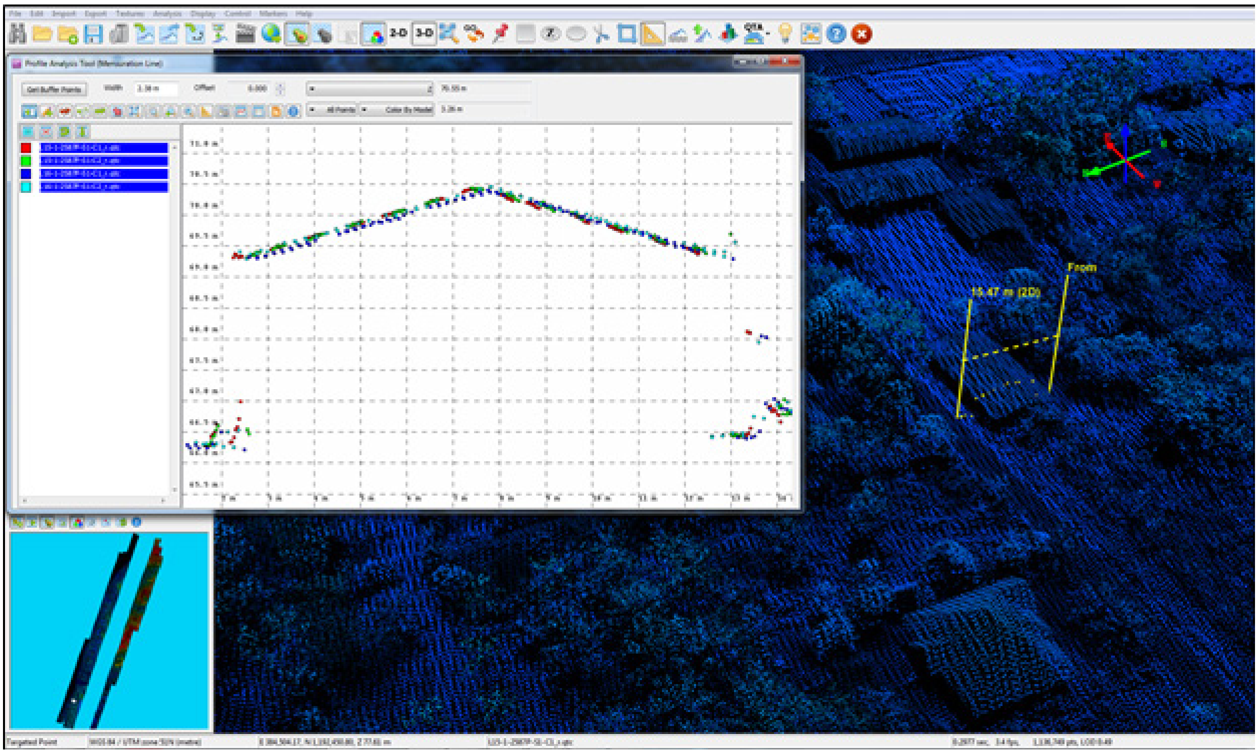


Figure 17. Quality checking for a Ipayo Flight 2587P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Ipayo classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	453,208,096
Low Vegetation	302,592,292
Medium Vegetation	422,860,786
High Vegetation	459,099,629
Building	17,865,784

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Ipayo Floodplain is shown in Figure 18. A total of 480 1 km by 1 km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 13. The point cloud has a maximum and minimum height of 623.41 meters and 21.6 meters, respectively.

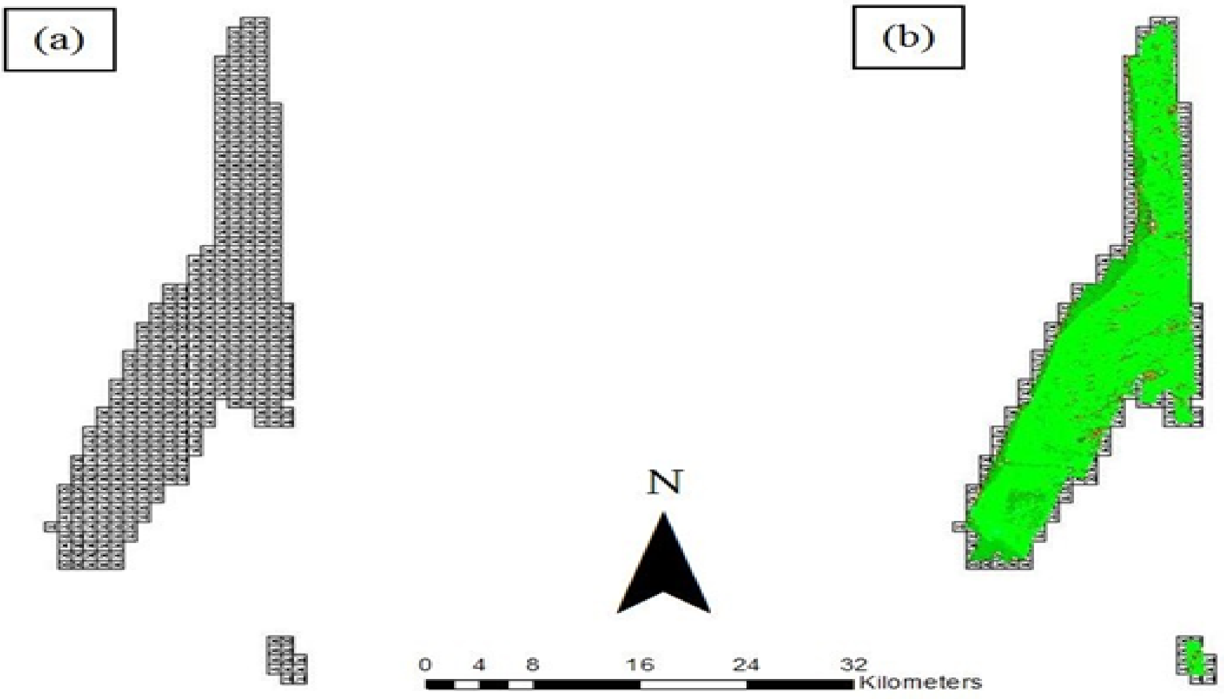


Figure 18. Tiles for Ipayo floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 19. 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.

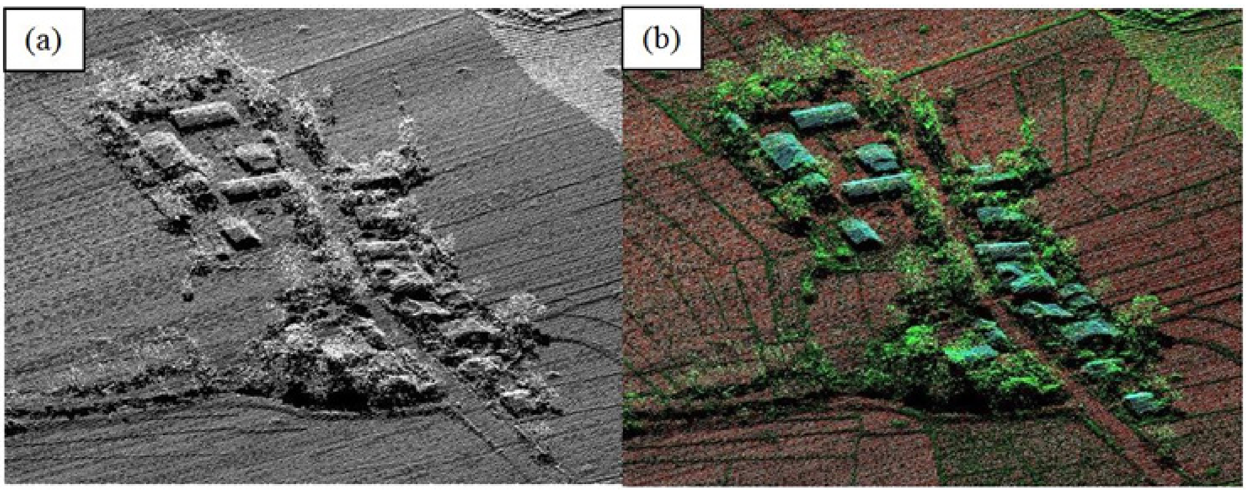


Figure 19. Point cloud before (a) and after (b) classification.

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

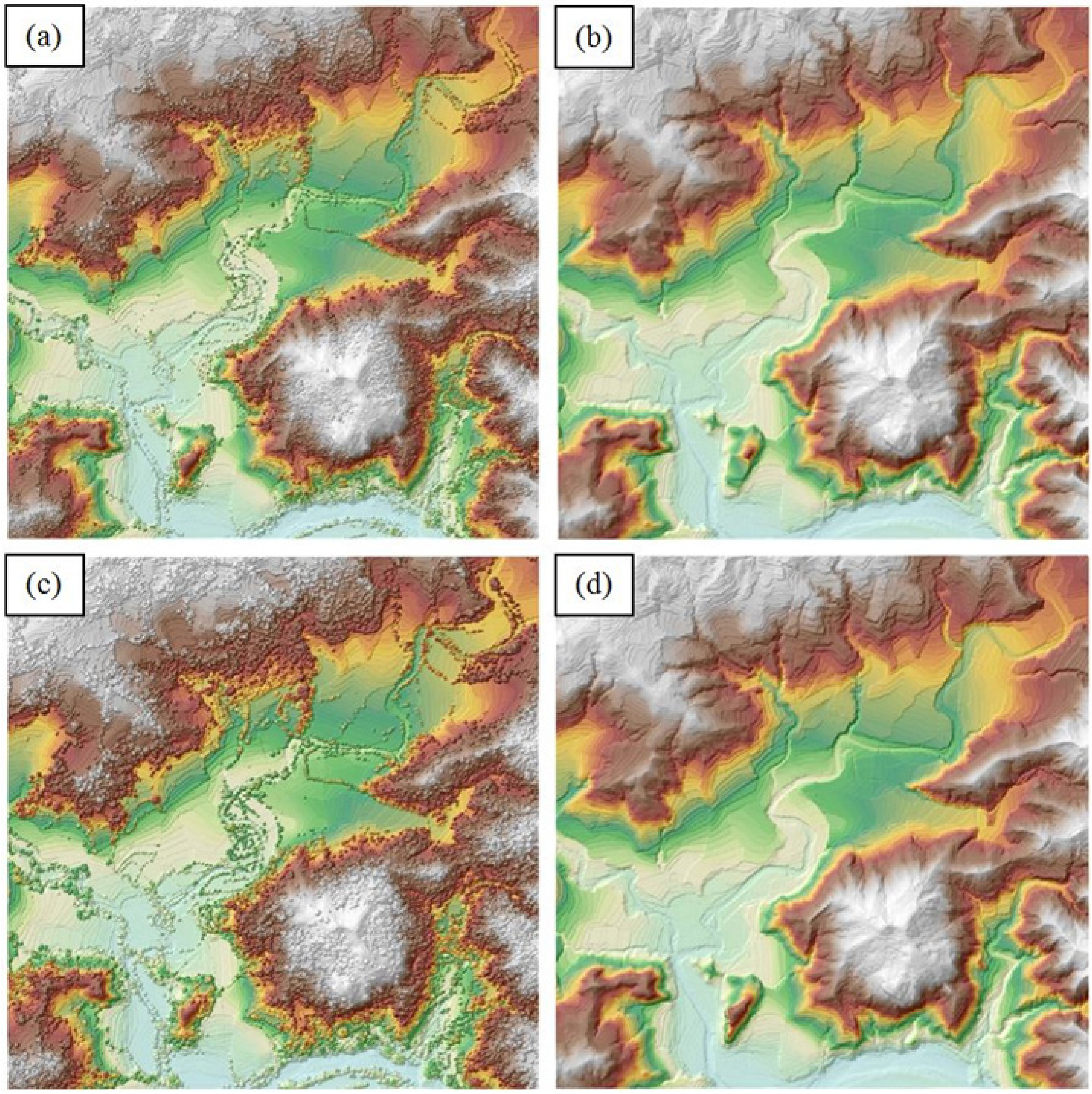


Figure 20. The Production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of IpayoFloodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 466 1km by 1km tiles area covered by IpayoFloodplain is shown in Figure 21. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Ipayo Floodplain has a total of 326.88km2 orthophotogaph coverage comprised of 1,055 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 22.

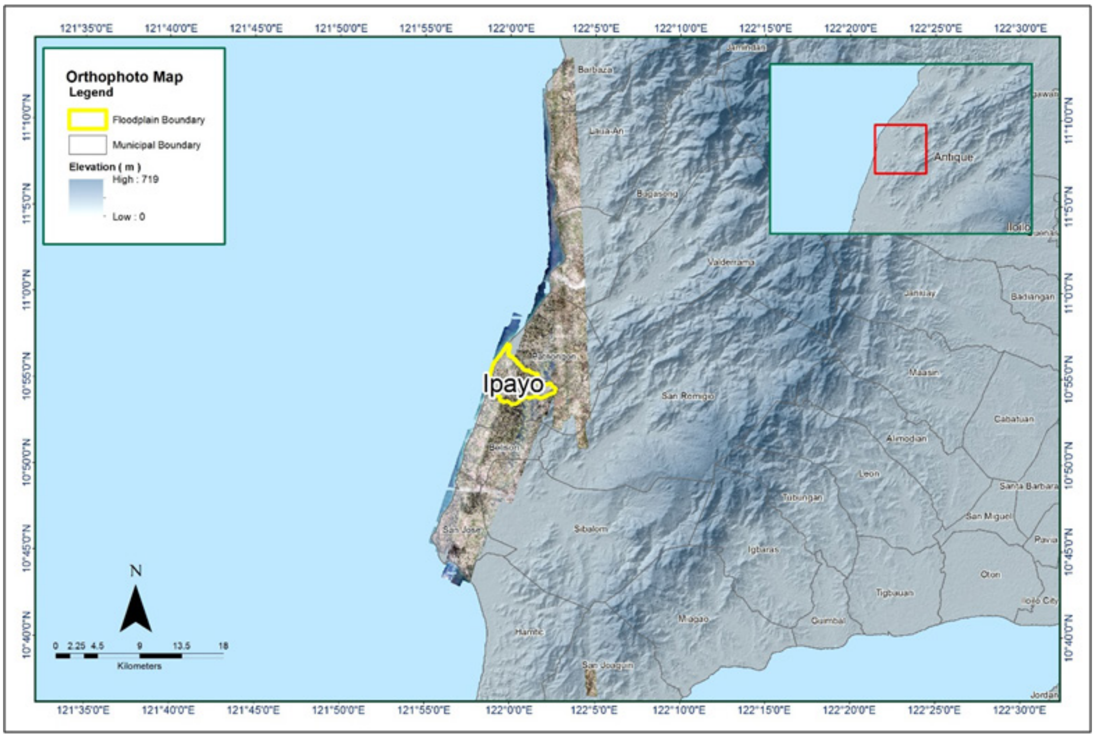


Figure 21. Ipayo Floodplain with available orthophotographs.

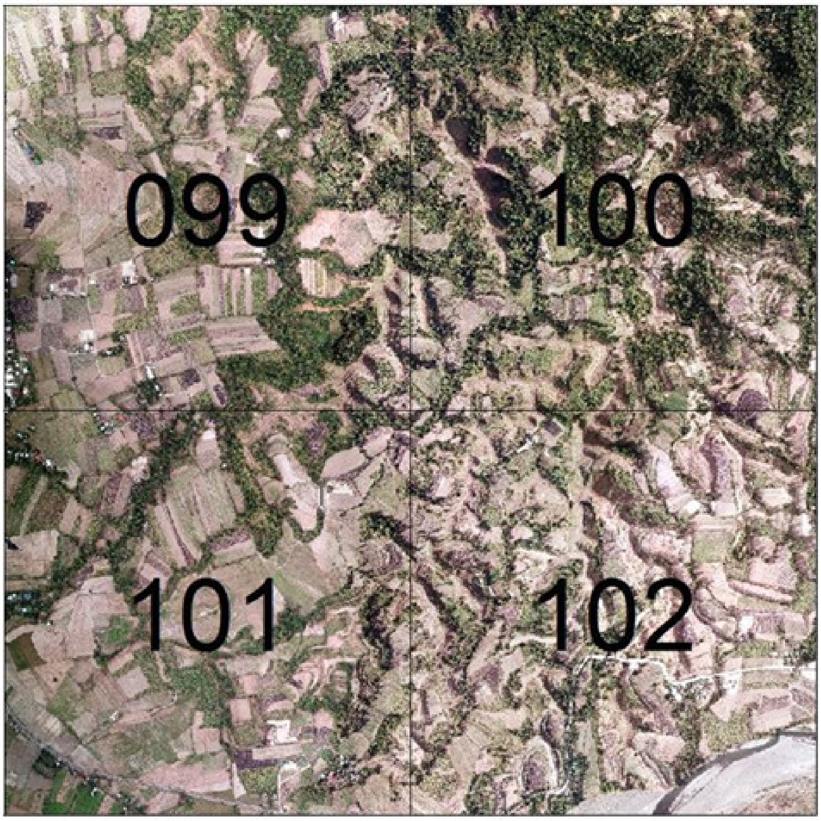


Figure 22. Sample orthophotograph tiles for IpayoFloodplain.

3.8 DEM Editing and Hydro-Correction

Two (2) mission blocks were processed for Ipayo Floodplain. These blocks are composed of Iloilo blocks with a total area of 348.06 km2. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Iloilo_Blk43B	136.14
Iloilo_Blk43D	211.92
TOTAL	**348.06 sq.km**

Figure 23 shows portions of DTM before and after manual editing. It shows that a mountain (Figure 23a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (23b). The bridges (23c) would be an impedance to the flow of water along the river and have to be removed (Figure 23d) in order to hydrologically correct the river.Another example is an area that has been misclassified (Figure 23e) and has to be retrieved through manual editing (Figure 23f).

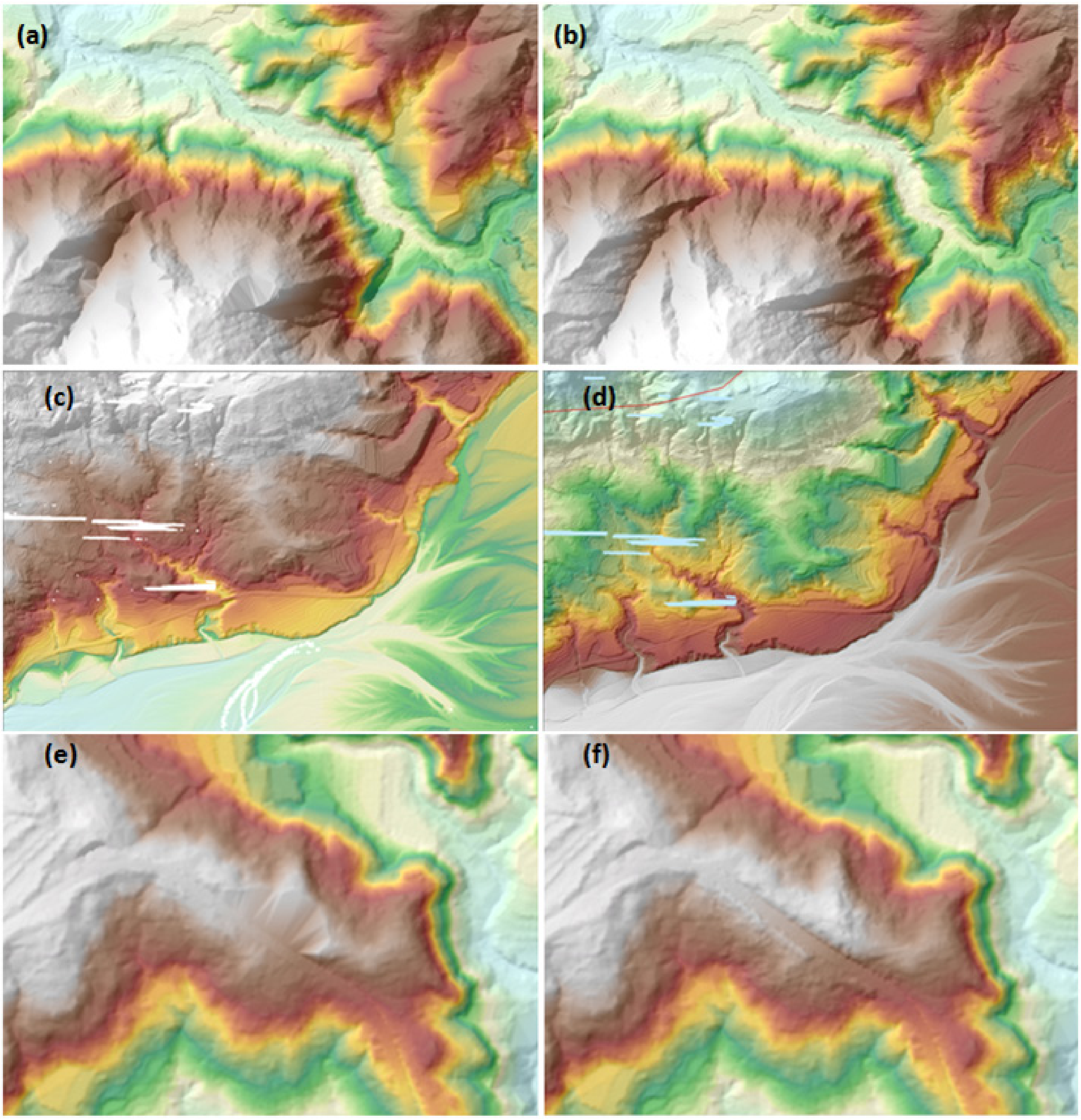


Figure 23. Portions in the DTM of Ipayo Floodplain – a mountain before (a) and after (b) data retrieval; bridges before (c) and after (d) manual editing; and an area before (e) and after (f) data retrieval.

3.9 Mosaicking of Blocks

Iloilo_Blk43B was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 15 shows the area of each LiDAR block and the shift values applied during mosaicking.

Mosaicked LiDAR DTM for Ipayo Floodplain is shown in Figure 24. It can be seen that the entire Ipayo Floodplain is 100% covered by LiDAR data.

Table 15. Shift Values of each LiDAR Block of IpayoFloodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Iloilo_Blk43B	0.00	0.00	-1.29
Iloilo_Blk43D	0.00	0.00	-1.23

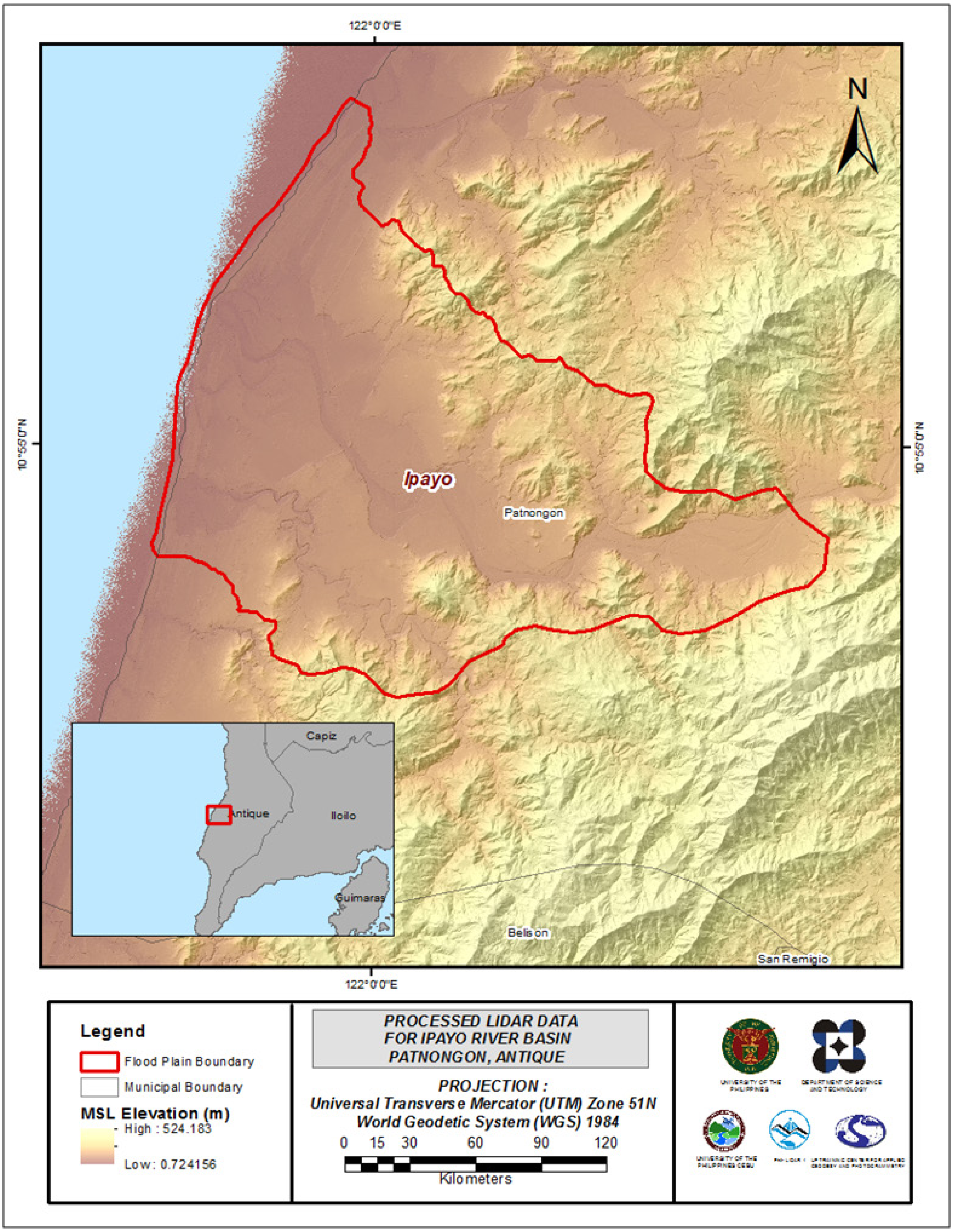


Figure 24. Map of Processed LiDAR Data for Ipayo Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Ipayo to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 7511 points were gathered for all the floodplains within the Province of Antique wherein the Ipayo is located. However, the point dataset was not used for the calibration of the LiDAR data for Ipayo because during the mosaicking process, each LiDAR block was referred to the calibrated Jalaur DEM. Therefore, the mosaicked DEM of Ipayo can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Jalaur LiDAR DTM and ground survey elevation values is shown in Figure 26. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 1.71 meters with a standard deviation of 0.17 meters. Calibration of Jalaur LiDAR data was done by subtracting the height difference value, 1.71 meters, to Jalaur mosaicked LiDAR data. Table 16 shows the statistical values of the compared elevation values between Jalaur LiDAR data and calibration data. These values were also applicable to the Ipayo DEM.

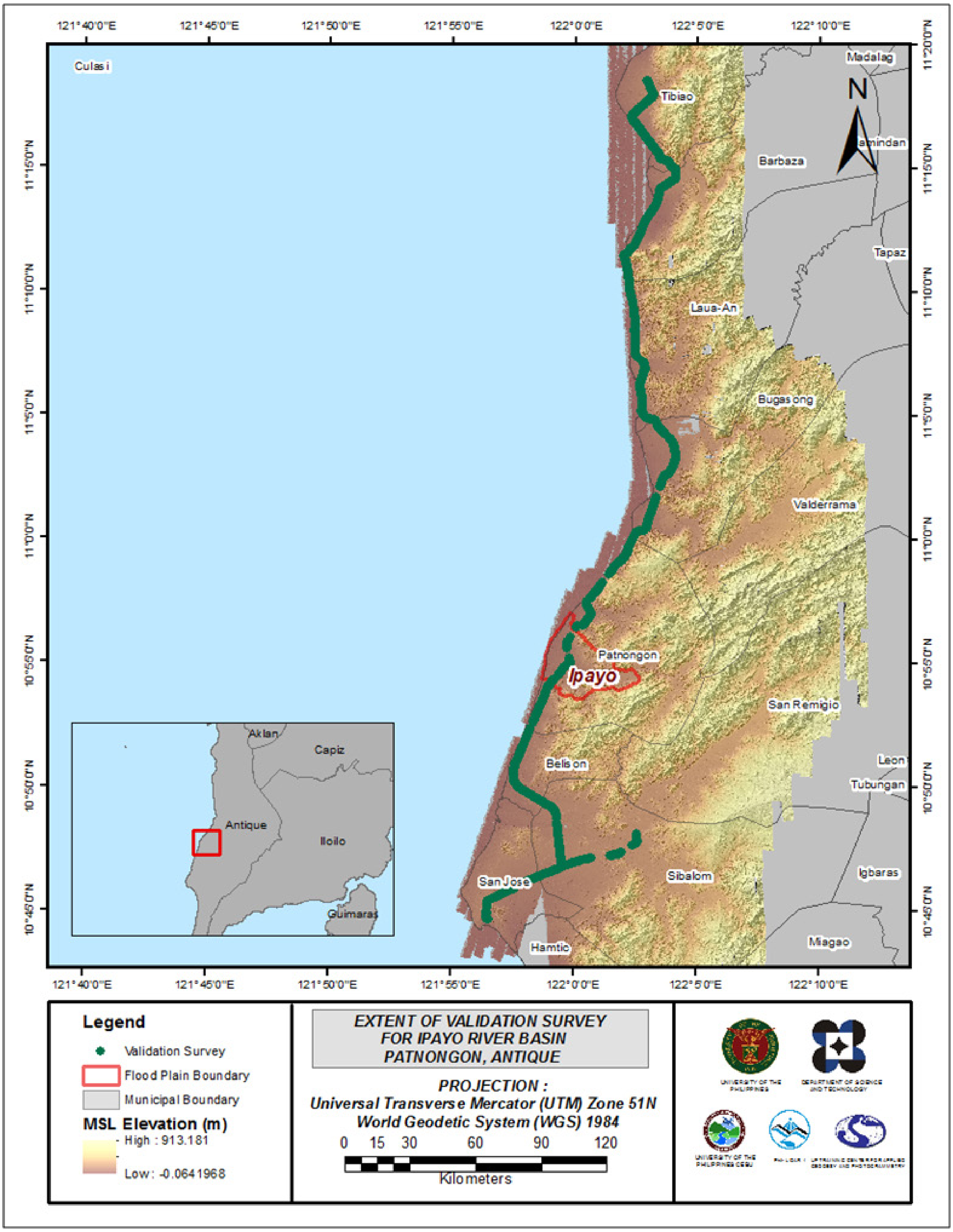


Figure 25. Map of Ipayo Floodplain with validation survey points in green.

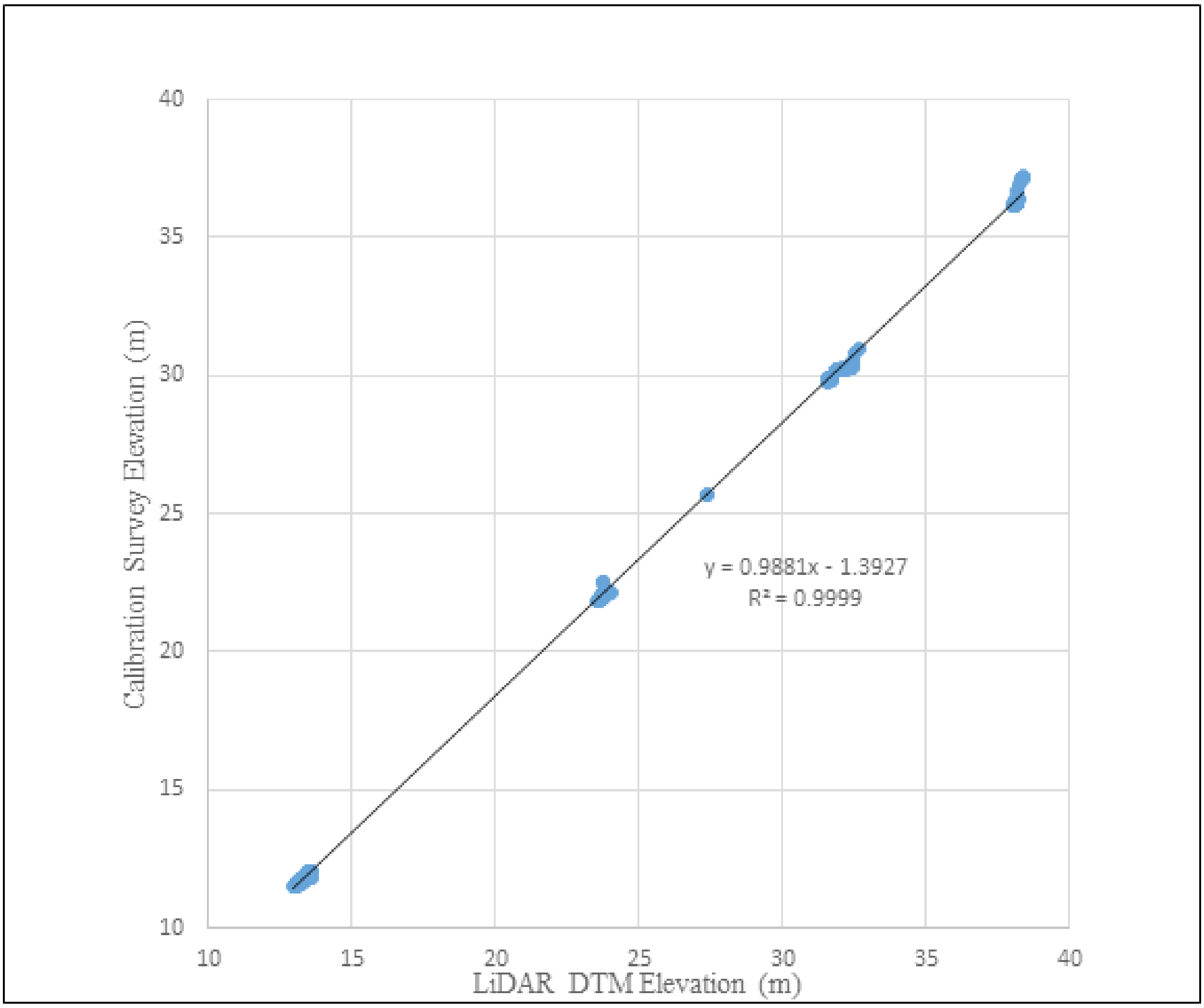


Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	1.71
Standard Deviation	0.17
Average	-1.70
Minimum	-2.13
Maximum	-1.16

A total of 251 survey points that are near the Ipayo flood plain were used for the validation of the calibrated Ipayo DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.11 meters with a standard deviation of 0.10 meters, as shown in Table 17.

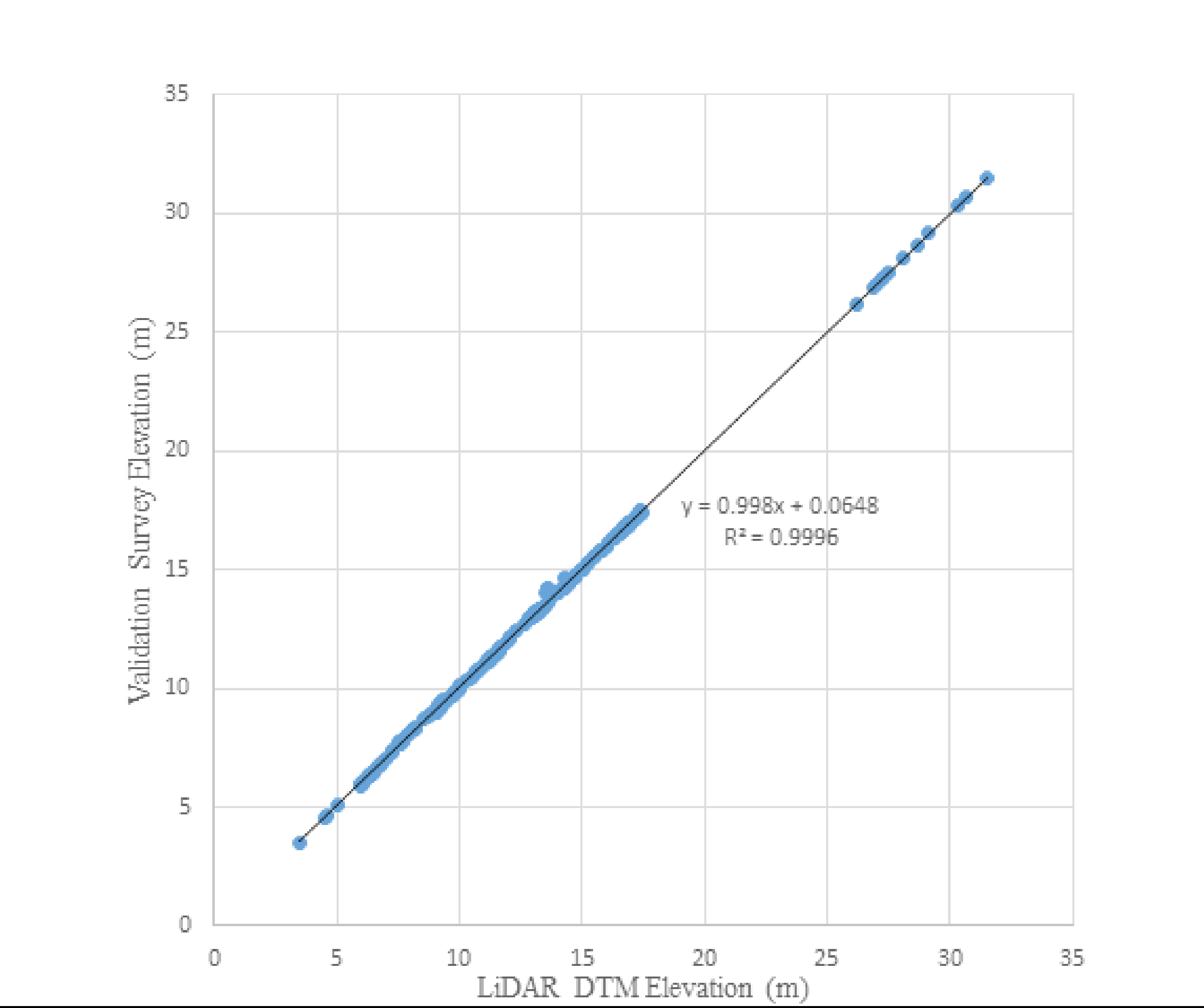


Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 17. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.11
Standard Deviation	0.10
Average	0.04
Minimum	-0.04
Maximum	0.04

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Ipayo with 1,190 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.0044 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Ipayo integrated with the processed LiDAR DEM is shown in Figure 28.

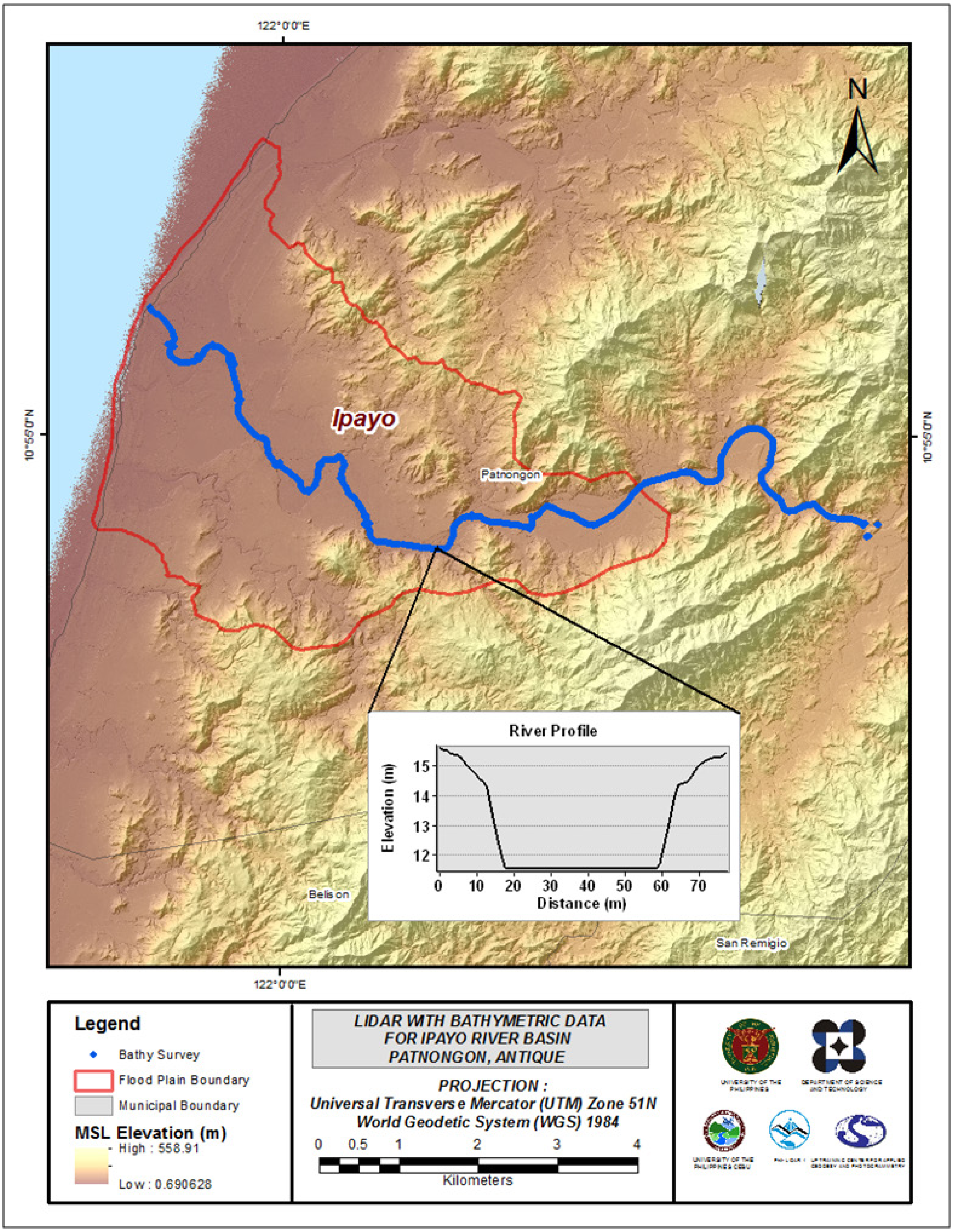


Figure 28. Map of Ipayo Floodplain with bathymetric survey points shown in blue.

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 (QC) of Digitized Features' Boundary

Ipayo Floodplain, including its 200 m buffer, has a total area of 26.92 sq. km. For this area, a total of 5.0 sq. km., corresponding to a total of 921 building features, are considered for QC. Figure 29 shows the QC blocks for Ipayo Floodplain.

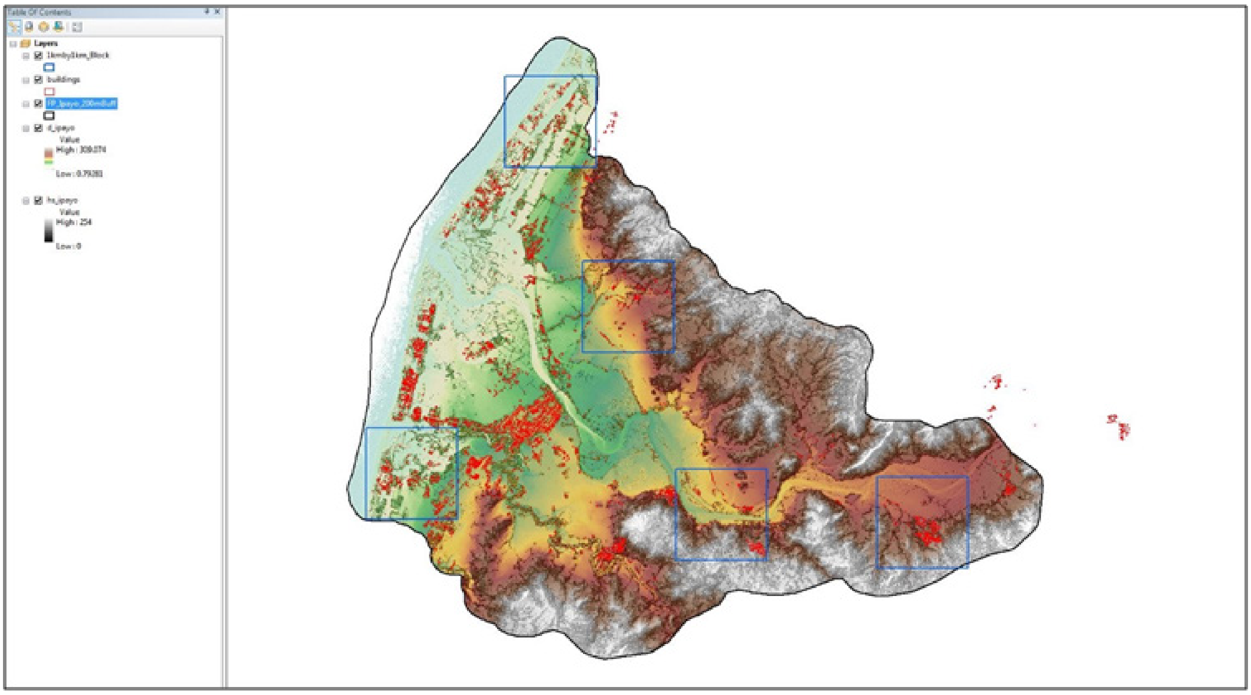


Figure 29. QC blocks for Ipayo building features.

Quality checking of Ipayo building features resulted in the ratings shown in Table 18.

Table 18. Quality Checking Ratings for Ipayo Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Ipayo	99.68	100.00	98.91	PASSED

3.12.2 Height Extraction

Height extraction was done for 4395 building features in Ipayo Floodplain. Of these building features, 475 were filtered out after height extraction, resulting to 3920 buildings with height attributes. The lowest building height is at 2.0 m, while the highest building is at 6.33 m.

3.12.3 Feature Attribution

Feature Attribution was conducted through a participatory community-based mapping in coordination with the local government units of municipalities/cities. The research associates of Phil-LiDAR 1 team visited local barangay units and interviewed key local personnel and officials who possessed expert knowledge of their local environments to identify and map out features.

Maps were displayed on a laptop and were presented to the interviewees for identification. The displayed map includes the orthophotographs, Digital Surface Models, existing landmarks, and extracted feature shapefiles. Physical surveys of the barangay were also done by the Phil-LiDAR 1 team every after interview for validation. The number of days by which the survey was conducted, was dependent on the number of features and number of barangays included in the floodplain of the river basin.

Table 19 summarizes the number of building features per type. On the other hand, Table 20 shows the total length of each road type, while Table 21 shows the number of water features extracted per type.

Table 19. Building Features Extracted for Ipayo Floodplain.

Facility Type	No. of Features
Residential	3632
School	83
Market	37
Agricultural/Agro-Industrial Facilities	10
Medical Institutions	8
Barangay Hall	9
Military Institution	0
Sports Center/Gymnasium/Covered Court	2
Telecommunication Facilities	1
Transport Terminal	0
Warehouse	1
Power Plant/Substation	0
NGO/CSO Offices	2
Police Station	1
Water Supply/Sewerage	3
Religious Institutions	29
Bank	0
Factory	0
Gas Station	4
Fire Station	0
Other Government Offices	18
Other Commercial Establishments	29
N/A	51
Total	**3920**

Table 20. Total Length of Extracted Roads for Ipayo Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Ipayo	21.46	0.00	10.04	4.95	0.00	36.45

Table 21. Number of Extracted Water Bodies for Ipayo Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Ipayo	2	0	0	0	17	19

A total of 5 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 30 shows the Digital Surface Model (DSM) of IpayoFloodplain overlaid with its ground features.

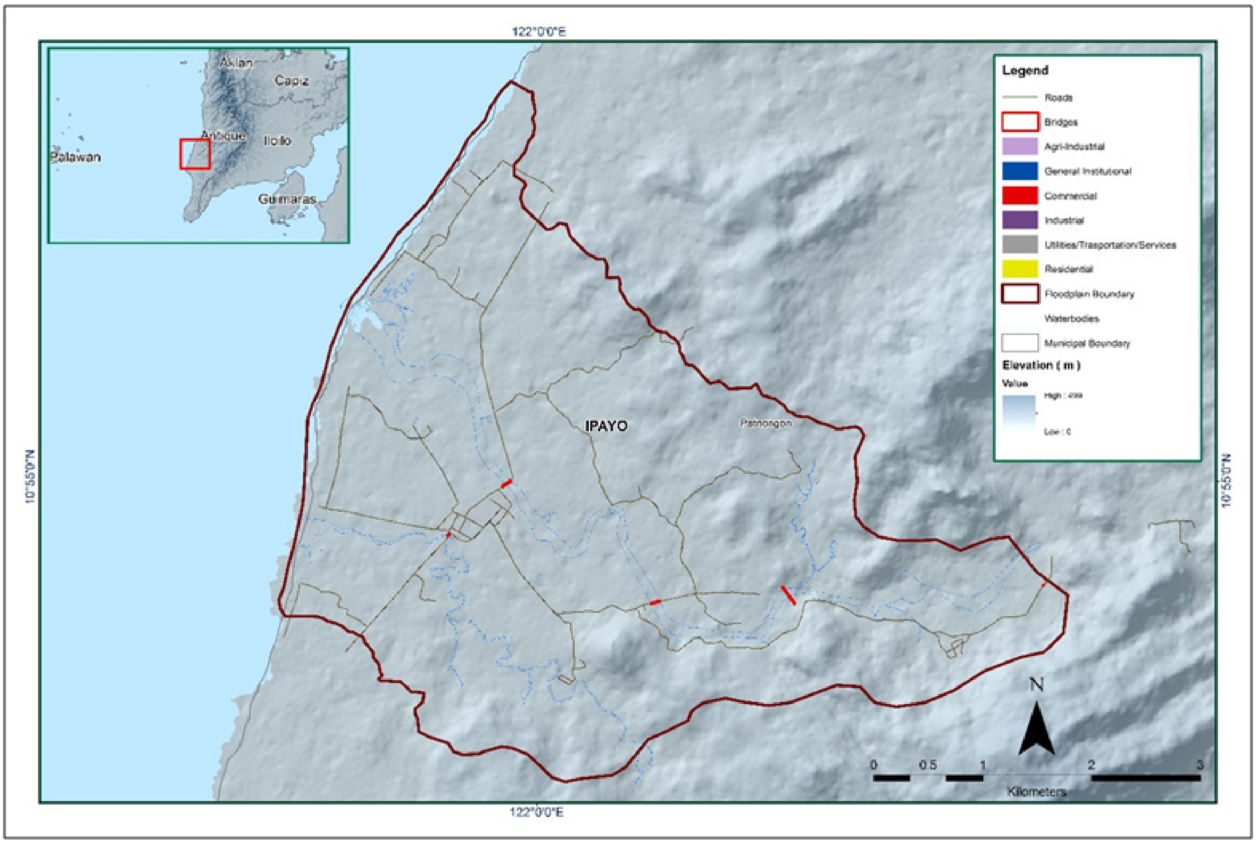


Figure 30. Extracted features for Ipayo Floodplain.

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted a field survey in Ipayo River from September 25 to October 9, 2014 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section, bridge as-built of Ipayo Bridge in Brgy. Poblacion, Municipality of Patnongon, Antique; ground validation data acquisition survey of about 82.264 km (for the whole Province of Antique); and bathymetric survey from Brgy. Villa Salomon, Municipality of Patnongon, Antique down to the mouth of the river in Brgy. Amparo, Municipality of Patnongon, Antique with an estimated length of 9.85 km using Trimble® SPS 883 GNSS PPK survey technique (Figure 33).

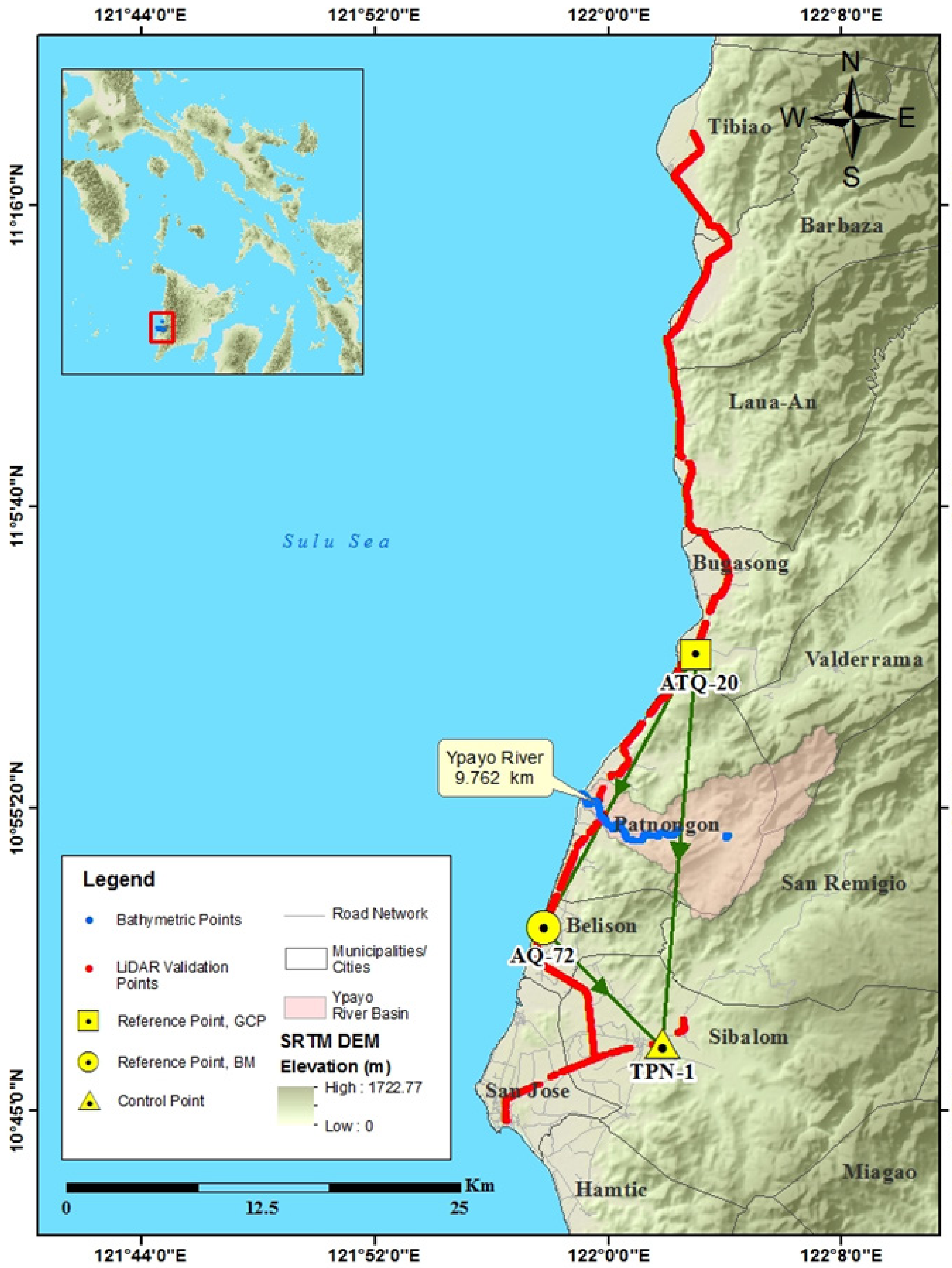


Figure 31. Extent of the bathymetric survey (in blue line) inIpayo River Survey and the LiDAR data validation survey (red)

4.2 Control Survey

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

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

The summary of references and control points used in IpayoSurvey is shown in Table 22, while the GNSS network established is illustrated in Figure 34.

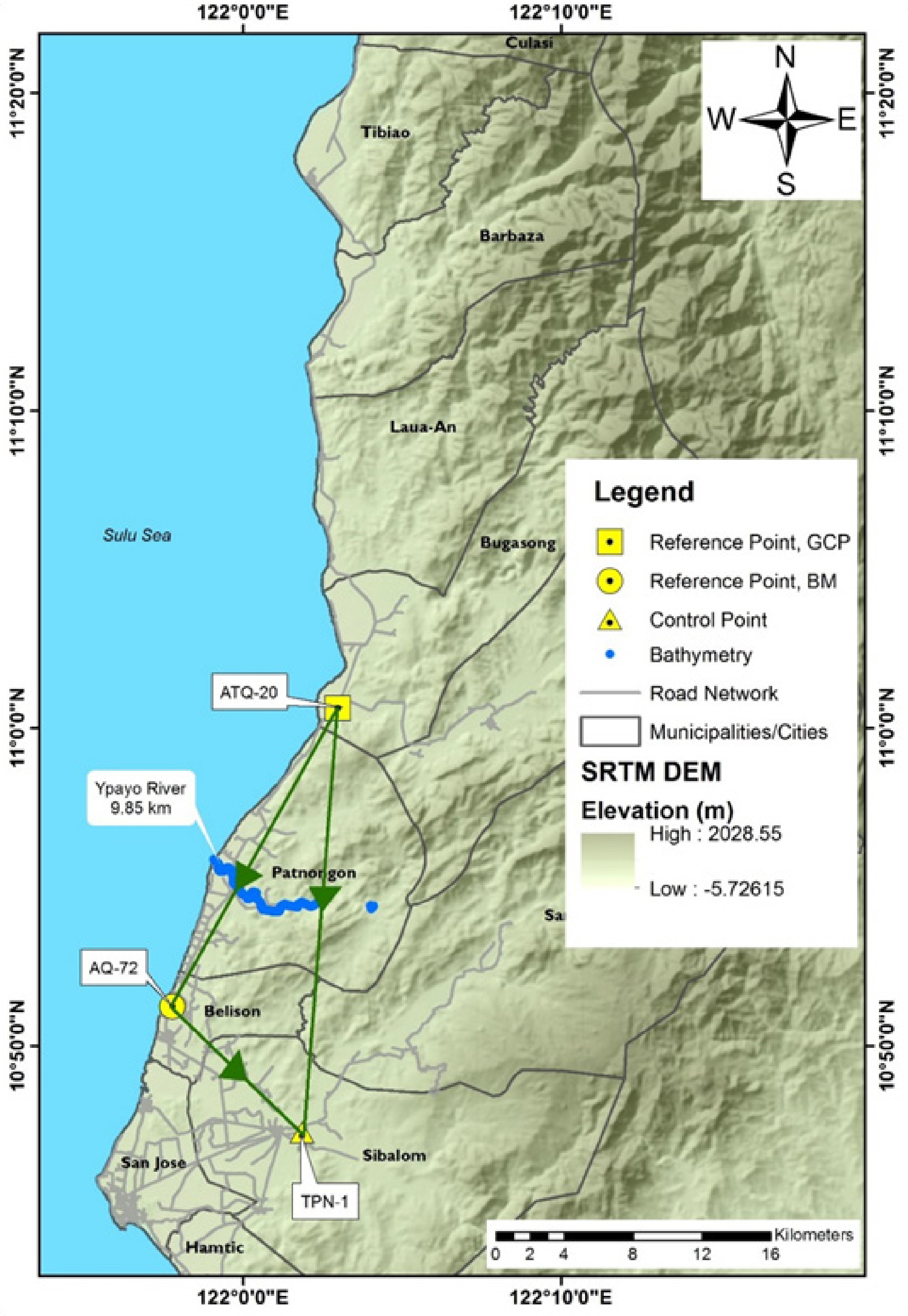


Figure 32. GNSS Network of Ipayo River field survey

Table 22. List of reference and control points occupied for Ipayo 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
ATQ-20	2nd	11°00'38.44240" N	122°02'59.27039" E	66.094	-	2009
AQ-72	1st	-	-	61.541	5.5842	2007
TPN-1	-	-	-	--	-	September 26, 2014

The GNSS set up of each reference and control points are exhibited in Figures35 to37.

Figure 33. GNSS base receiver set-up, Trimble® SPS 852 at ATQ-20 in Brgy. Zaragoza, Municipality of Bugasong, Antique

Figure 34. Benchmark, AQ-72, with Trimble® SPS 852 in Brgy. Delima, Municipality of Belison, Antique

Figure 35. UP-TCAGP established control point, TPN-1, with Trimble® SPS 882 on Tipuluan Bridge in Brgy. Pasong, Municipality of Sibalom, Antique

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within ± 20 cm and ± 10 cm requirement, respectively. In caseswhenone or more baselines did not meet all of these criteria, masking is performed. Masking is the removal or covering portions of these baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 23 presents the baseline processing result of control points in IpayoRiver Basin, as generated bythe TBC software.

Table 23. Baseline Processing Report for Ipayo River Basin Static Survey

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

As shown in Table23, a total of three (3) baselines were processed with reference points ATQ-20 and AQ-72 held fixed for coordinate and elevation values, respectively. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, the network adjustment is performed using the TBC software. Looking at the Adjusted Grid Coordinates, Table 25 of the TBC-generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation form:

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

Where:

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

for each control point.For complete details, see the Network Adjustment Report shown in Tables 3 24to 26 show the results of GNSS network adjustment.

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 21. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 24. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
ATQ-20	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

Likwise, 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 25. The fixed control point, ATQ-20, has no values for standard errors.

Table 25. Adjusted Grid Coordinates

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

The network is fixed at the reference point, ATQ-20, with known coordinates. With the mentioned equation, $\sqrt{((x_e)^2 + (y_e)^2)}$ <20cm and $z_e < 10\ cm$, <20cm for horizontal and z_e<10 cm for the vertical; The computation for the horizontal and vertical accuracy are as follows:

a. AQ-72
Horizontal accuracy = √((6.3)² + (3.3)²
= √(39.69 + 10.89)
= 7.11 cm < 20 cm

b. TPN-1
Horizontal accuracy = √((5.8)² + (3.1)²
= √(33.64 + 9.61)
= 6.58 cm < 20 cm

The list of adjusted geodetic coordinates: Latitude, Longitude, Height and computed standard errors of the control points in the network are shown in Table 26.

Table 26. Adjusted Geodetic Coordinates

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

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 26. 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 27.

Table 27. The reference and control points utilized in the Ipayo River Survey with its corresponding location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	MSL Elevation (m)
ATQ-20	2nd Order GCP	11°00'38.44240"	122°02'59.27039"	66.094	1217324.563	396195.506	9.8692
AQ-72	1st Order BM	10°51'14.92748"	121°57'46.85471"	61.541	1200045.589	386654.679	5.5842
TPN-1	UP Established	10°47'16.56550"	122°01'51.73167"	88.644	1192699.127	394067.041	32.1362

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

The cross-section and as-built surveys were conducted on September 29, 2014 along the downstream side of Ipayo Bridge in Brgy. Poblacion, Municipality of Patnongon using a GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 36.

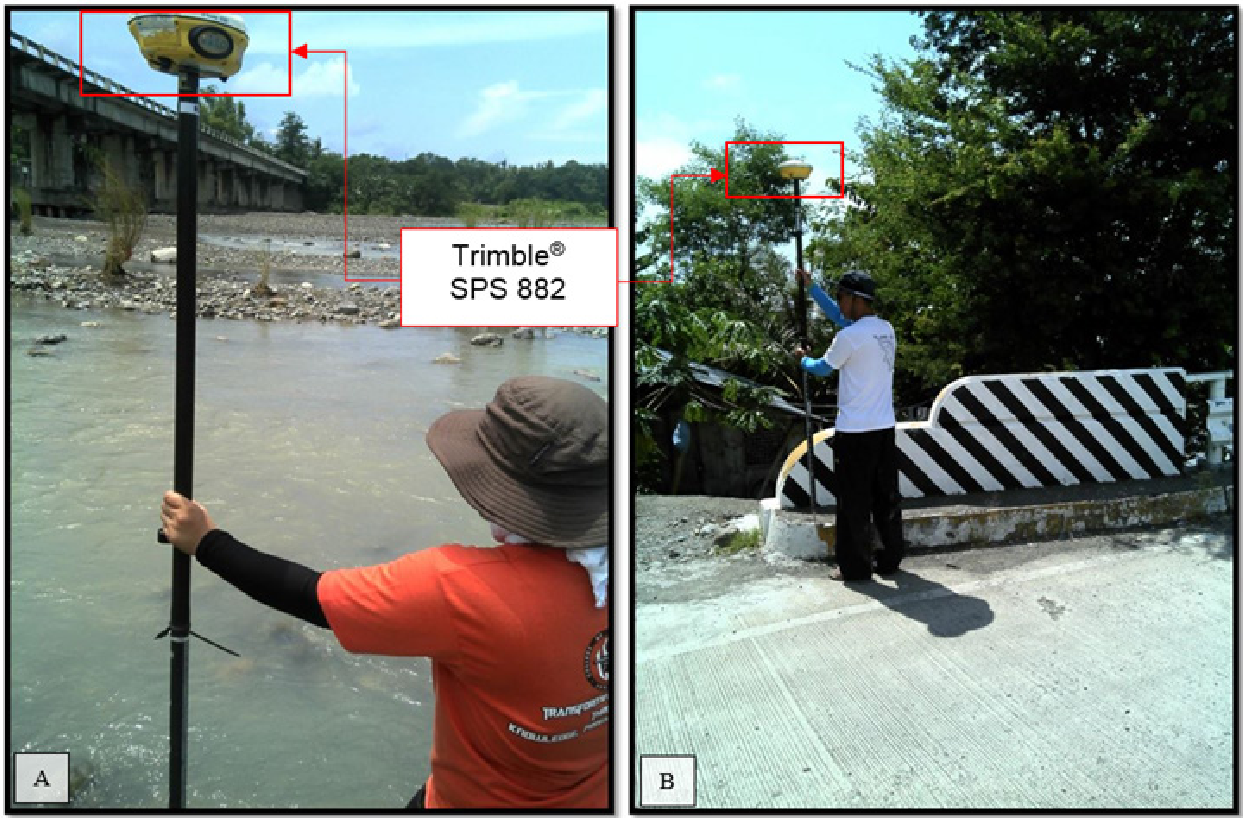


Figure 36. a) Cross-section survey, and b) Bridge-as-built survey ofIpayo Bridge in the Municipality of Patnongon

The cross-sectional line length of the deployment site is about 142.247 m with 19 cross-sectional points acquired using CNS-3018 as the GNSS base station. The location map, cross-section diagram, and bridge as-built form are illustrated in Figure 37 to Figure 38, respectively.

The cross-sectional line for Ipayo Bridge is about 60 m with 19 points gathered using ATQ-20 as GNSS base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 37 to Figure 39.

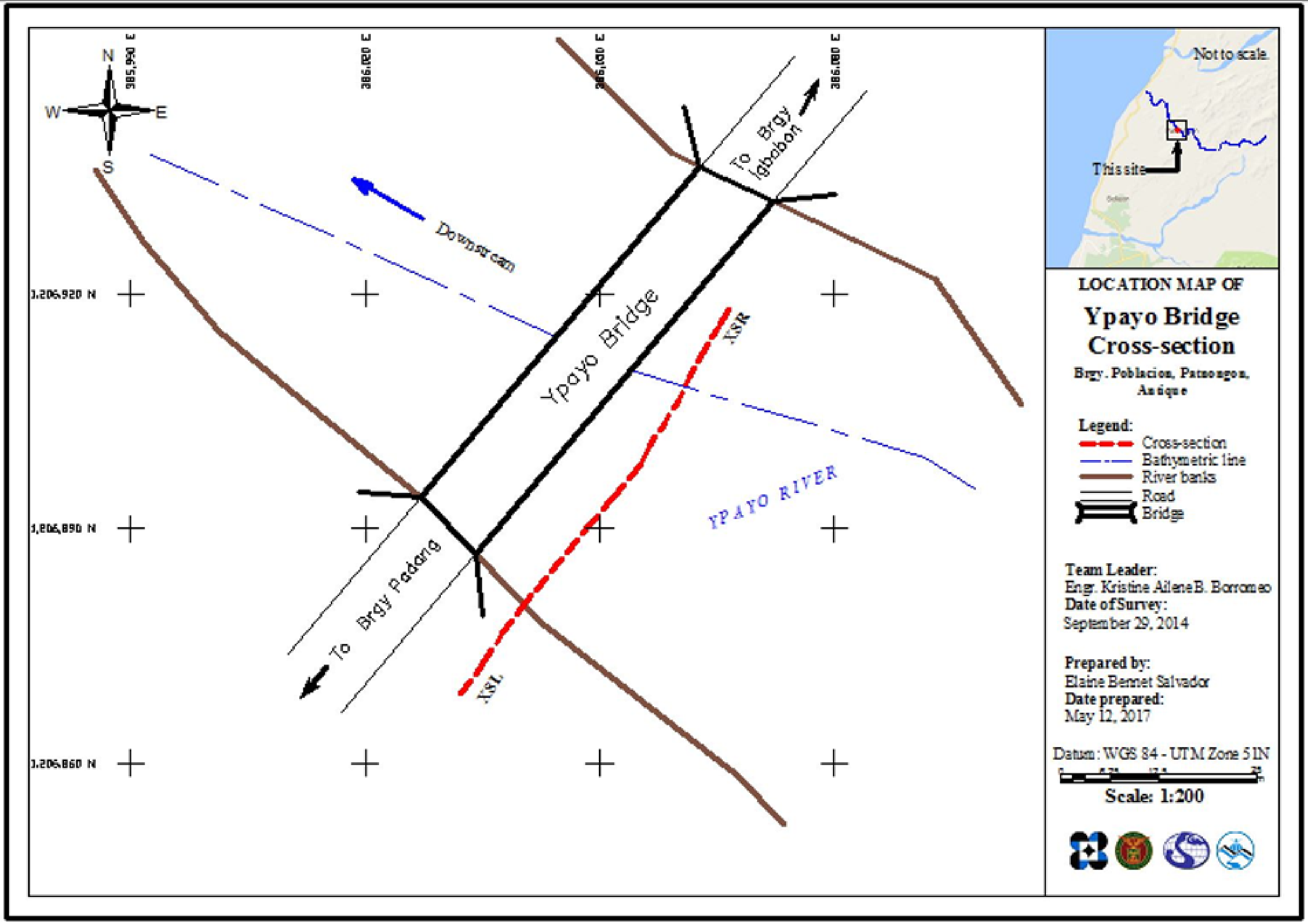


Figure 37. Ipayo Bridge cross-section location map

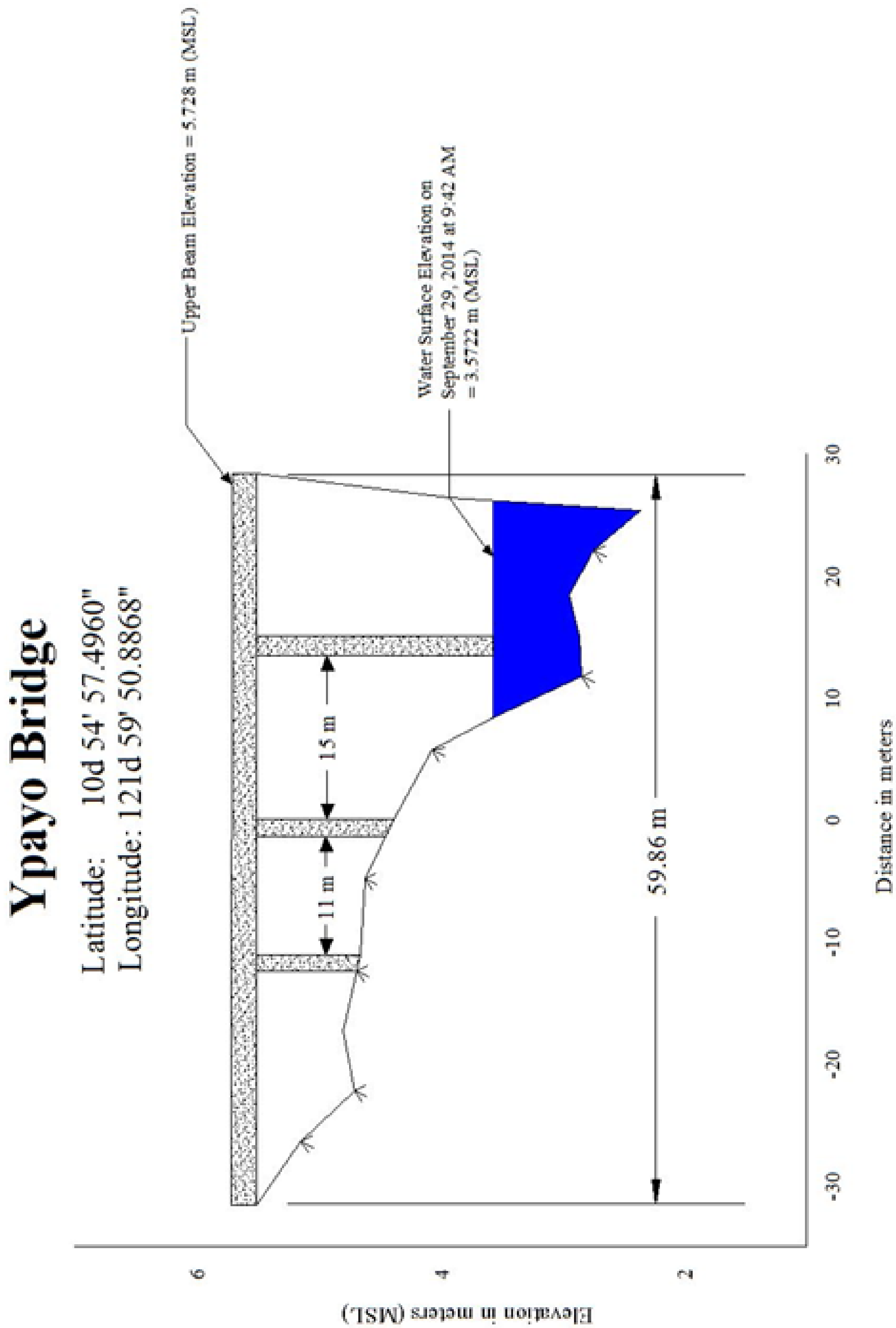


Figure 38. Cross section diagram at Ipayo Bridge

Bridge Data Form

Bridge Name: Ypayo Bridge Date: September 29, 2014

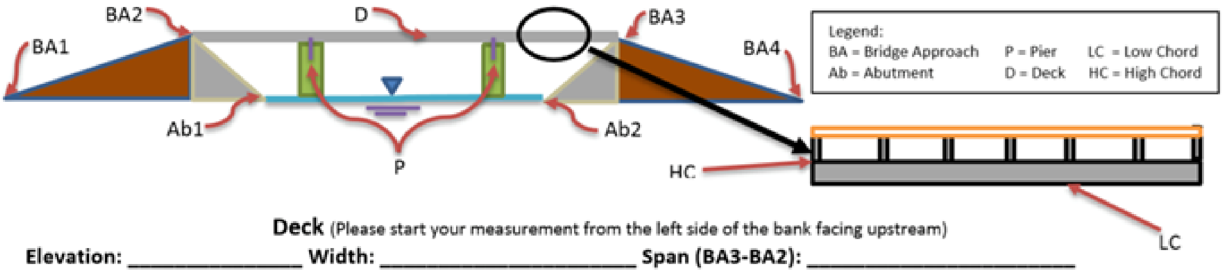
River Name: Ypayo River Time: 11:30 AM

Location (Brgy, City,Region): Brgy. Poblacion, Municipality of Patnongon, Antique

Survey Team: Antique Survey Team

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

Latitude: 10°54'57.49591"N Longitude: 121°59'50.88680"E



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

Elevation: ______________ Width: ____________________ Span (BA3-BA2): ____________________

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	5.5042	BA3	n/a	n/a
BA2	n/a	n/a	BA4	n/a	n/a

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	n/a	n/a

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

Shape: ____________________ Number of Piers: __________ Height of column footing: ______________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	20.52000244	4.6572	
Pier 2	31.59593108	4.3782	
Pier 3	46.64501685	2.8582	
Pier 4			
Pier 5			
Pier 6			

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

Figure 39. Brdige Data Form of Ipayo Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on October 3, 5, and 6, 2014 using a survey grade GNSS Rover receiver mounted on a pole which was attached in front of the vehicle as shown on Figure 42. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was measured from the ground up to the bottom of the notch of the GNSS Rover receiver. The survey was conducted using PPK technique on a continuous topography mode.

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

The base was setup at the NAMRIA established reference point, NGW-50, in Himoga-an Bridge on September 12, 2014 and the gathering of validation points started from Brgy. Poblacion, Toboso to Himoga-An Bridge, Sagay City. The ground validation line is approximately 37 km in length and with overall gathered points of 4,238. Figure 41 shows the length of the acquired points for the survey.

Figure 40. Validation points acquisition survey set up

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

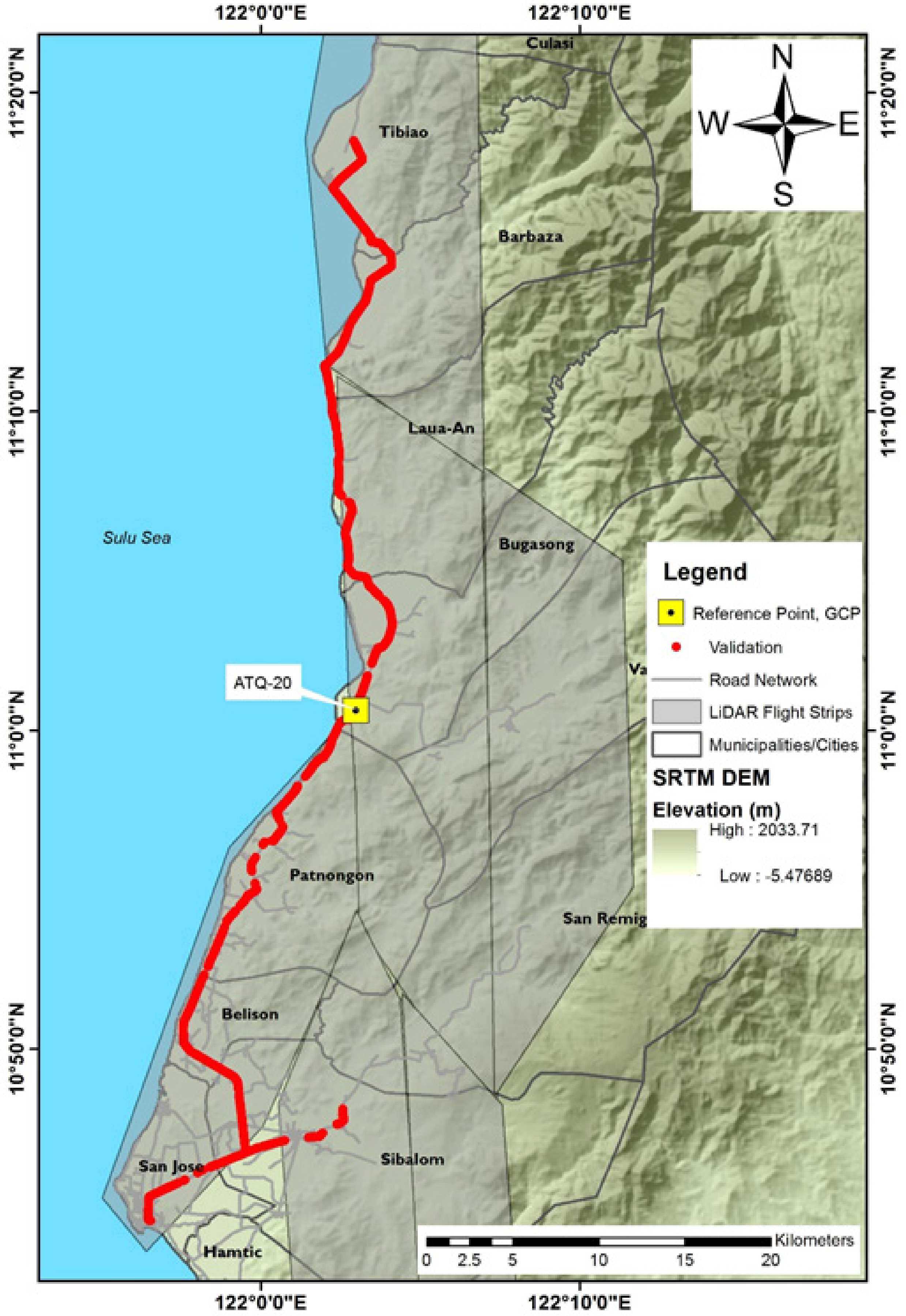


Figure 41. LiDAR Ground Validation Survey along Ipayo River Basin

4.7 River Bathymetric Survey

Manual bathymetric survey was executed on September 29, 2014 using a Trimble® SPS 882 GNSS receiver attached to a range pole through PPK survey technique as shown in Figure 44. The survey started in the upstream part of the river in Brgy. Villa Salomon, Municipality of Patnongon with coordinates 10°54’37.97273” 122°02’27.38863”, going downstream of Ipayo River by foot, and ended in Brgy. Amparo, Municipality of Patnongon with coordinates 10°55’52.10818” 121°59’05.43531”.

Figure 42. Bathymetric Survey along Ipayo River accompanied by a local aide

The bathymetric line has an estimated length of 9.85 km with a total of 847 points acquired using ATQ-20 as the GNSS base station. The processed data were generated into a map using GIS and processed further using CAD for plotting the centerline of the river. Figure 45 shows the generated map that exhibits the bathymetric survey coverage while Figure 46 illustrates the Ipayo riverbed profile. There is a change in elevation of about 25.19 m MSL from the upstream to downstream. The highest elevation was 24.11 m in MSL in Brgy. Villa Salomon, while the lowest elevation was -0.464 m below MSL in Brgy. Amparo.

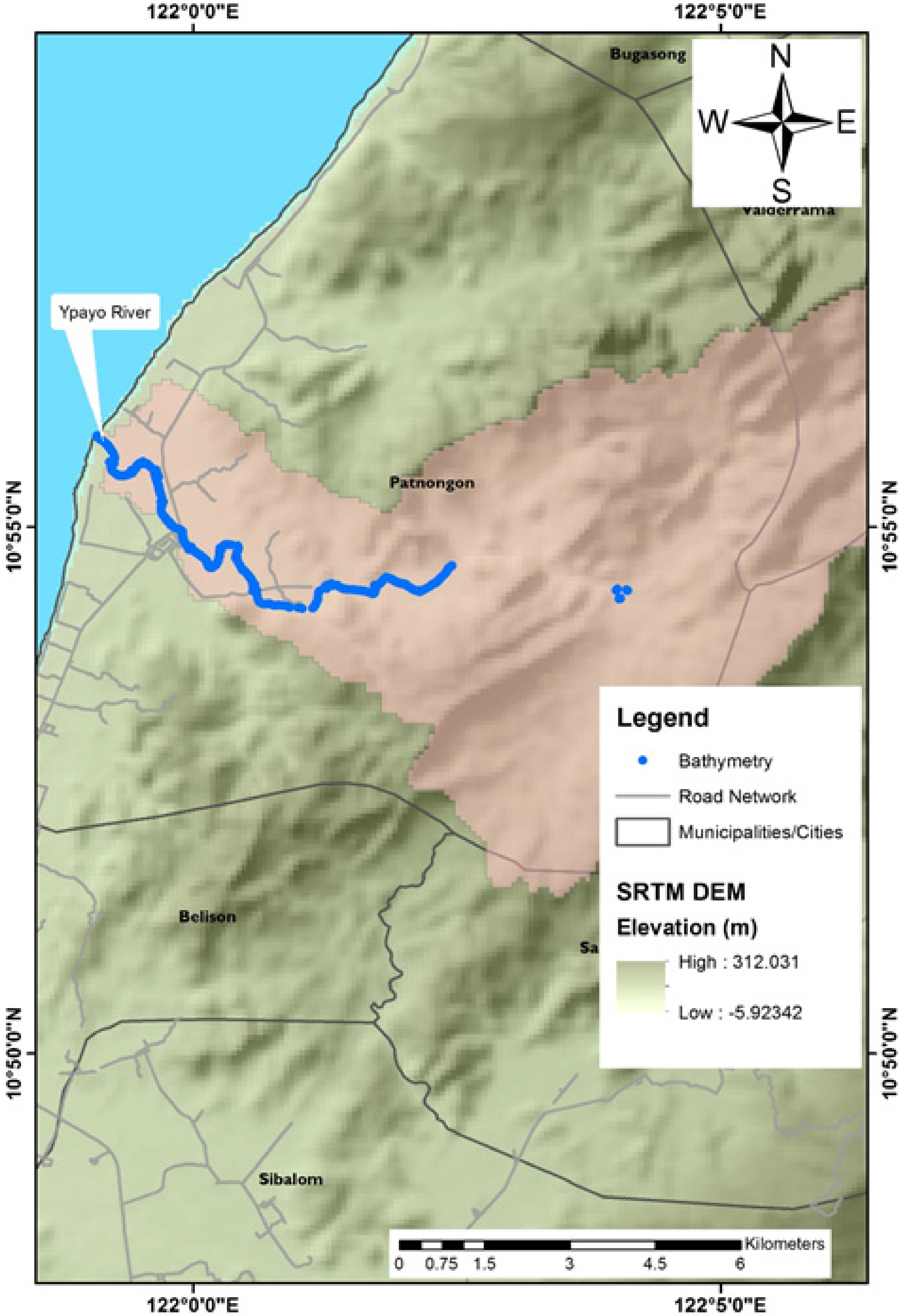


Figure 43. Bathymetric Survey of Ipayo River

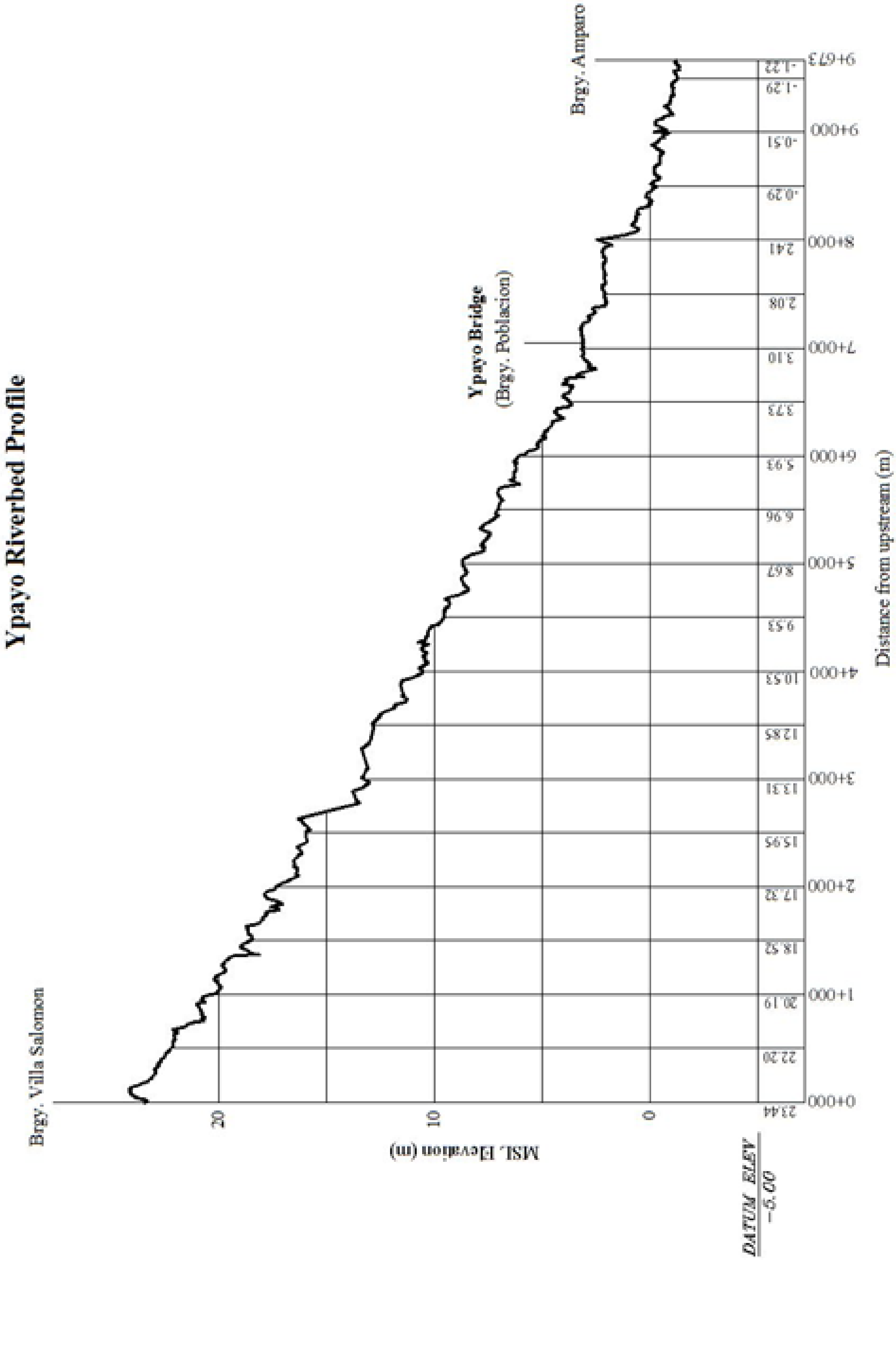


Figure 44. Riverbed profile of Danao River

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Gianni Sumajit

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

5.1 Data used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data that affect the hydrologic cycle of the Ipayo 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 Ipayo River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the UP Cebu Flood Modeling Component (FMC) team. The ARG was installed at Brgy. Tamayoc, Patnongon, Antique (Figure 47). The precipitation data collection started from August 8, 2016 at 8:20 PM to August 9, 2016 at 7:40 AM with with a 10-minute recording interval.

The total precipitation for this event in Brgy. Tamayoc ARG was 9.2 mm, with a peak rainfall of 5 mm on August 9, 2016 at 4:40 in the morning. The lag time between the peak rainfall and discharge is 7 hours and 25 minutes.

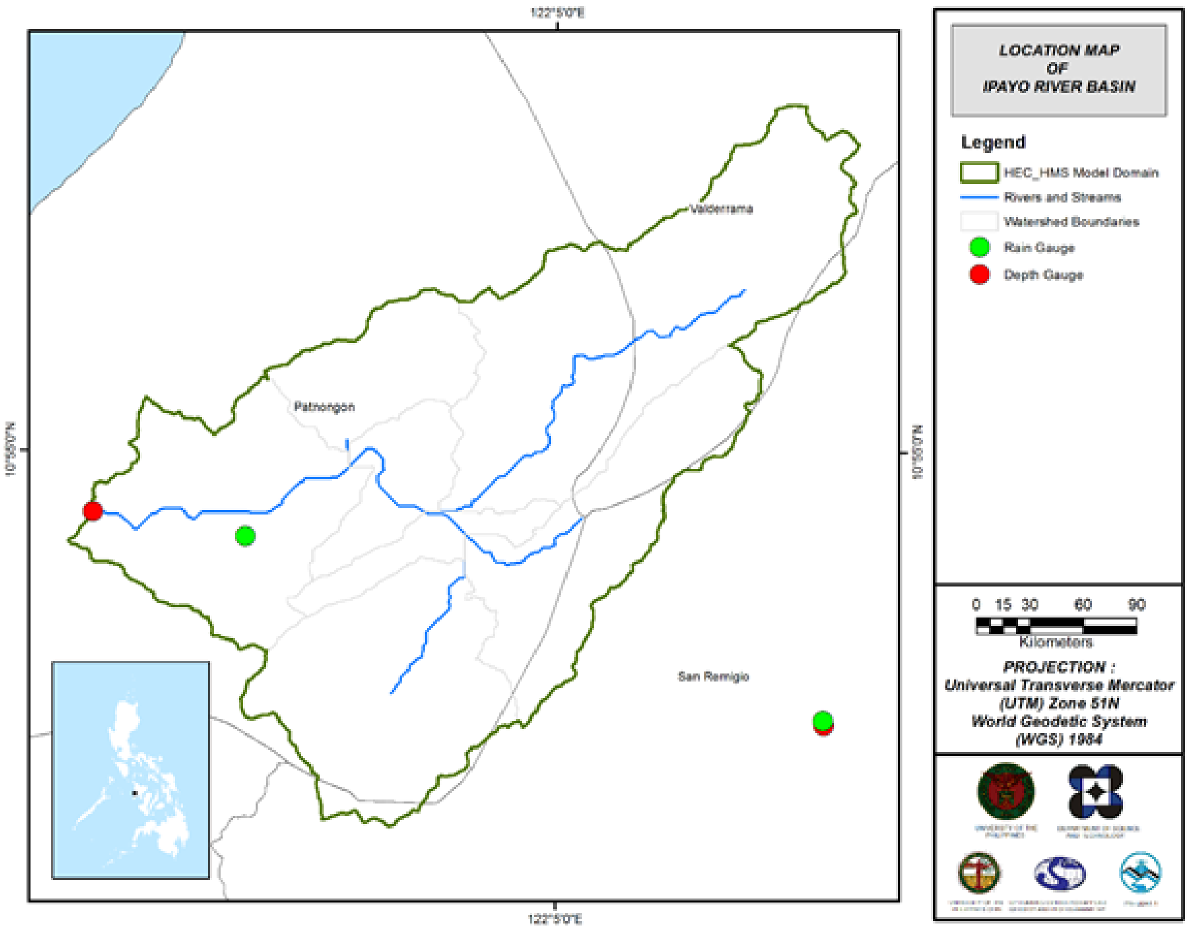


Figure 45. The location map of Ipayo HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 48) at Tamayoc Bridge, Patnongon, Antique (10°54'23.55"N, 122° 0'35.83"E). It gives the relationship between the observed water levels at Tamayoc Bridge and outflow of the watershed at this location.

For Tamayoc Bridge, the rating curve is expressed as Q = 2E-07e1.6985x [see y formula] as shown in Figure 49.

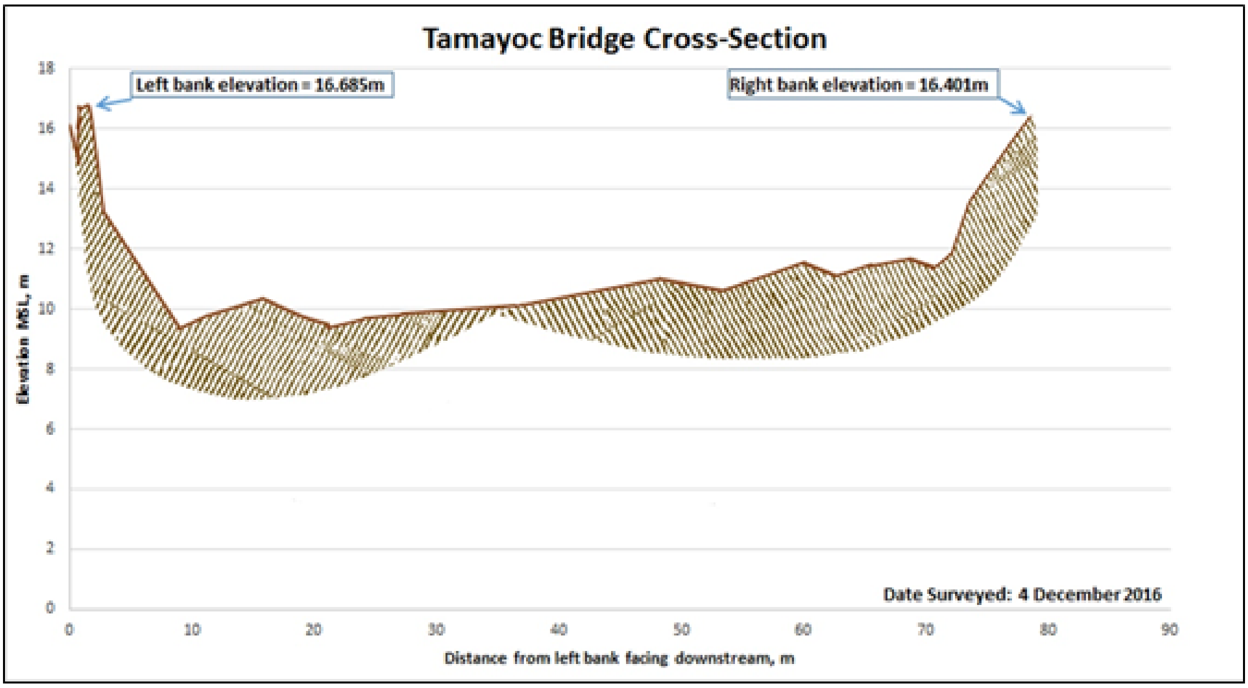


Figure 46. Cross-Section Plot of Tamayoc Bridge

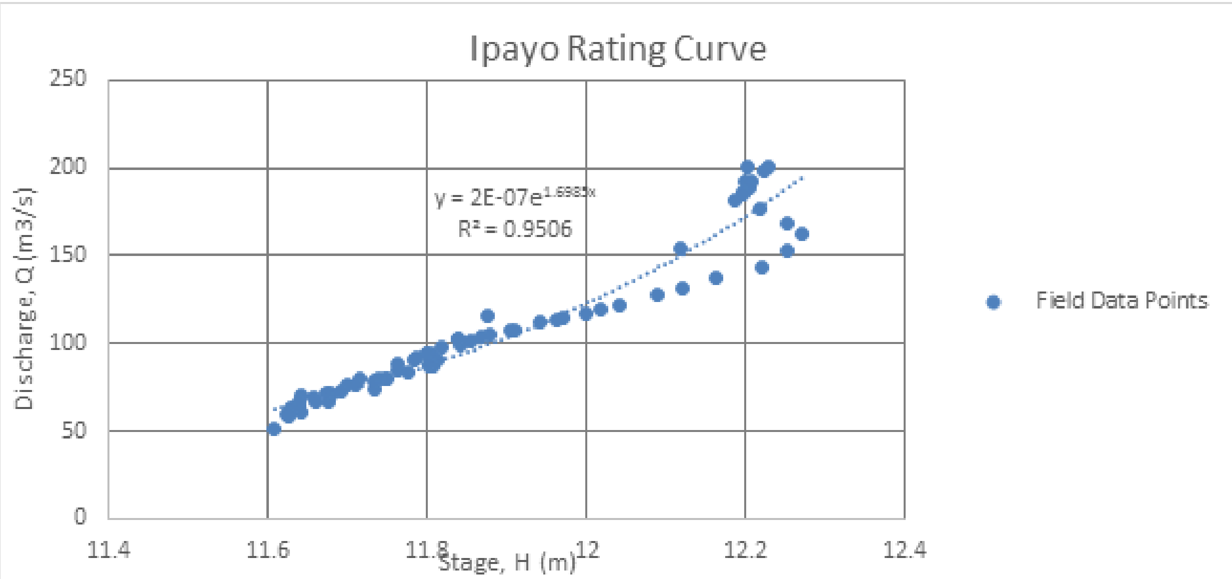


Figure 47. The rating curve of Tamayoc Bridge, Patnongon, Antique

This rating curve equation was used to compute the river outflow at Tamayoc Bridge for the calibration of the HEC-HMS model shown in Figure 50. The total rainfall for this event is 9.2mm and the peak discharge is 201.0511 cubic meters per second at 5:05 AM, August 9, 2016.

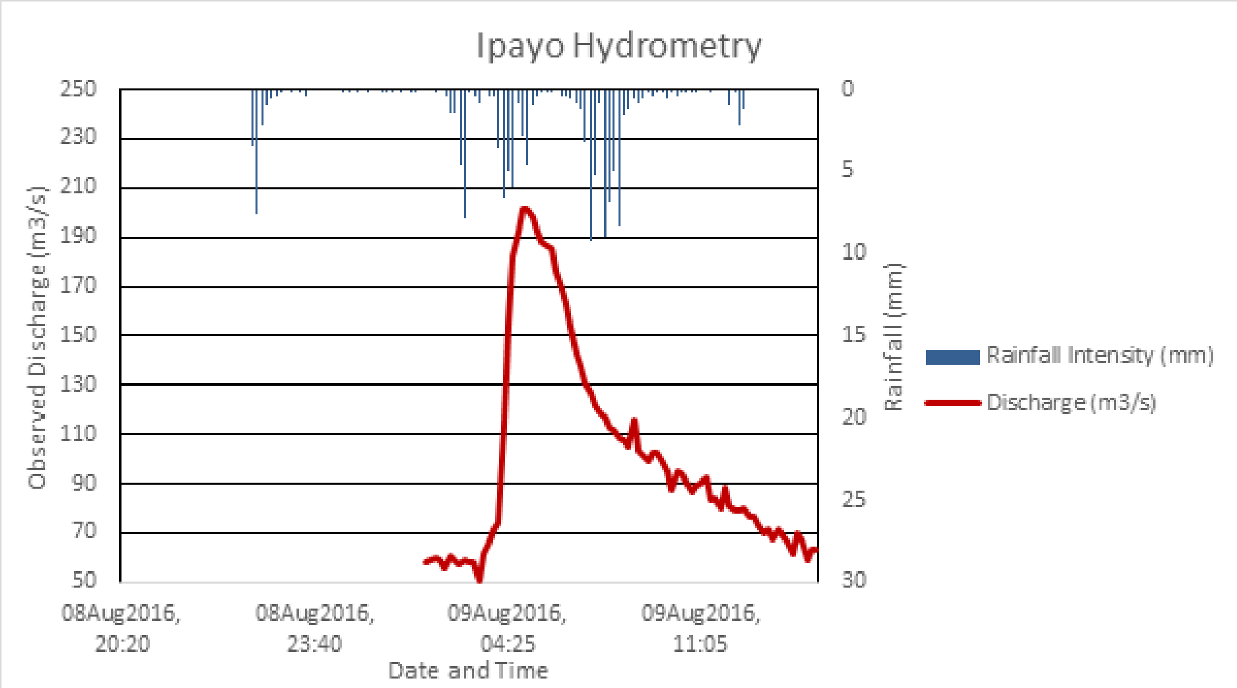


Figure 48. Rainfall and outflow data of the Ipayo River Basin, which was used for modeling

5.2 RIDF Station

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

Table 28. 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
5	28.7	39.4	48	59.4	74.9	90	114.7	131.7	165.2
10	33.9	45.6	55.6	68.1	85	103.6	133.6	155.4	198.9
25	40.5	53.5	65.3	79.2	97.6	120.8	157.6	185.3	241.5
50	45.4	59.4	72.4	87.3	107	133.5	175.3	207.4	273.1
100	50.3	65.2	79.5	95.4	116.4	146.2	193	229.4	304.5

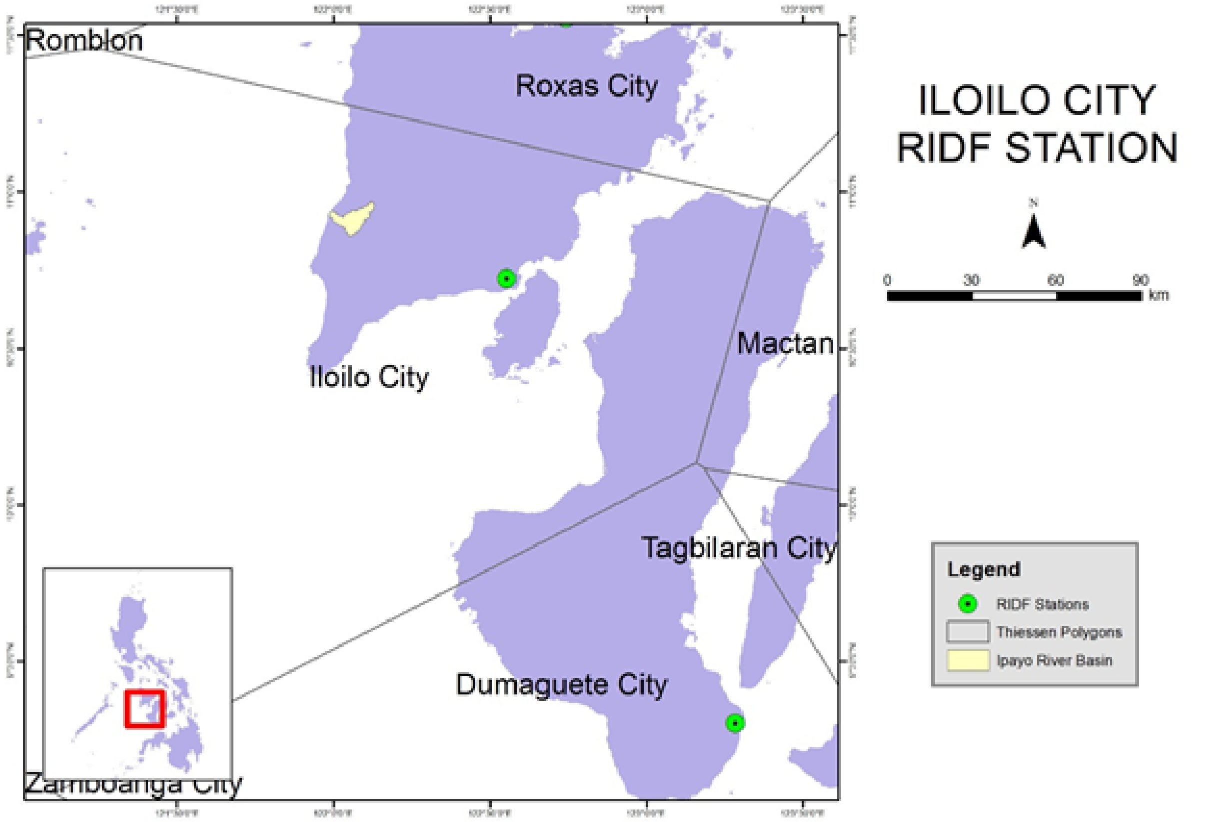


Figure 49. The location of the Virac RIDF station relative to the Ipayo River Basin

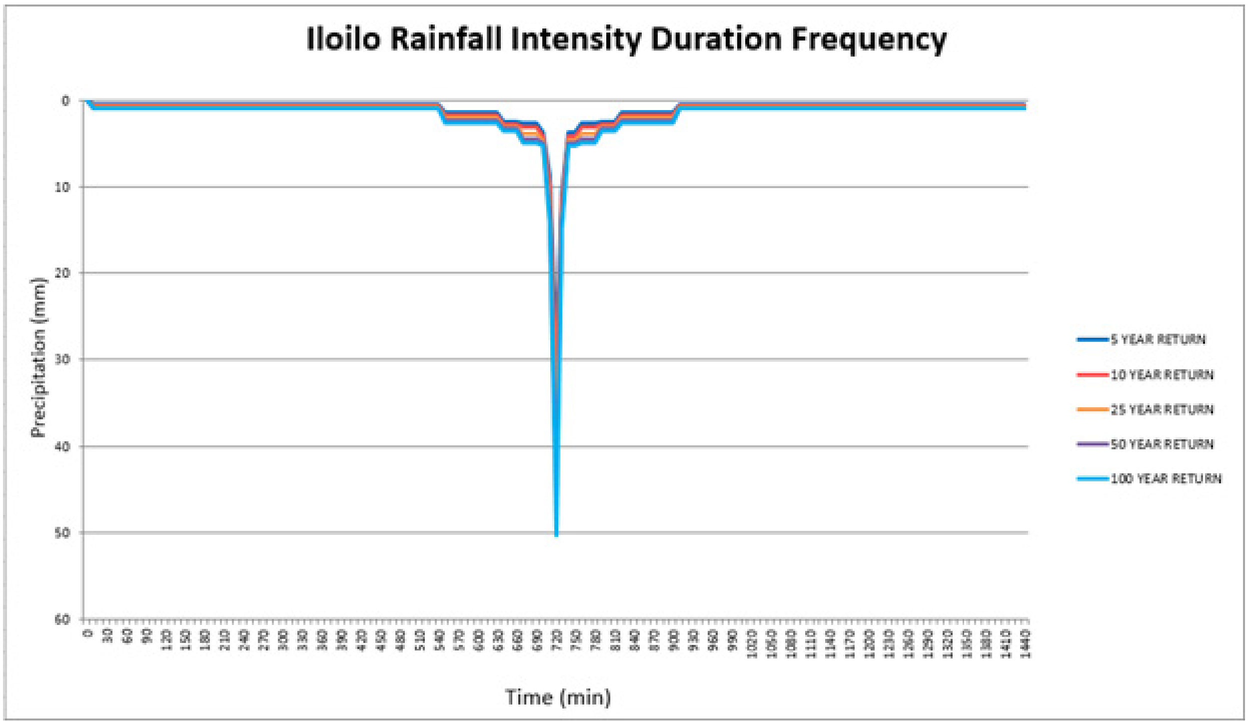


Figure 50. The synthetic storm generated for a 24-hour period for various return periods

5.3 HMS Model

The soil dataset was taken before 2004 from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Ipayo River Basin are shown in Figures 53 and 54, respectively.

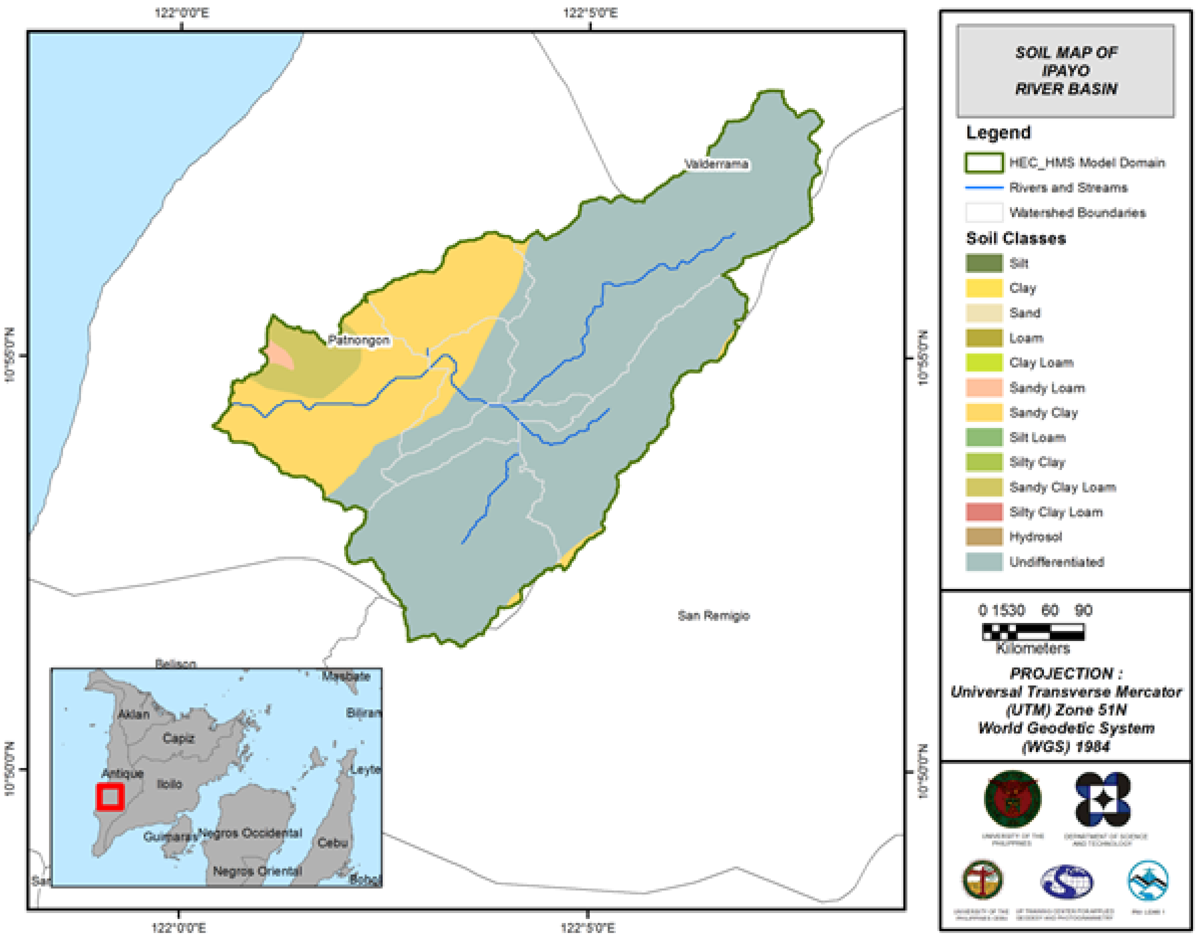


Figure 51. Soil Map of Ipayo River Basin

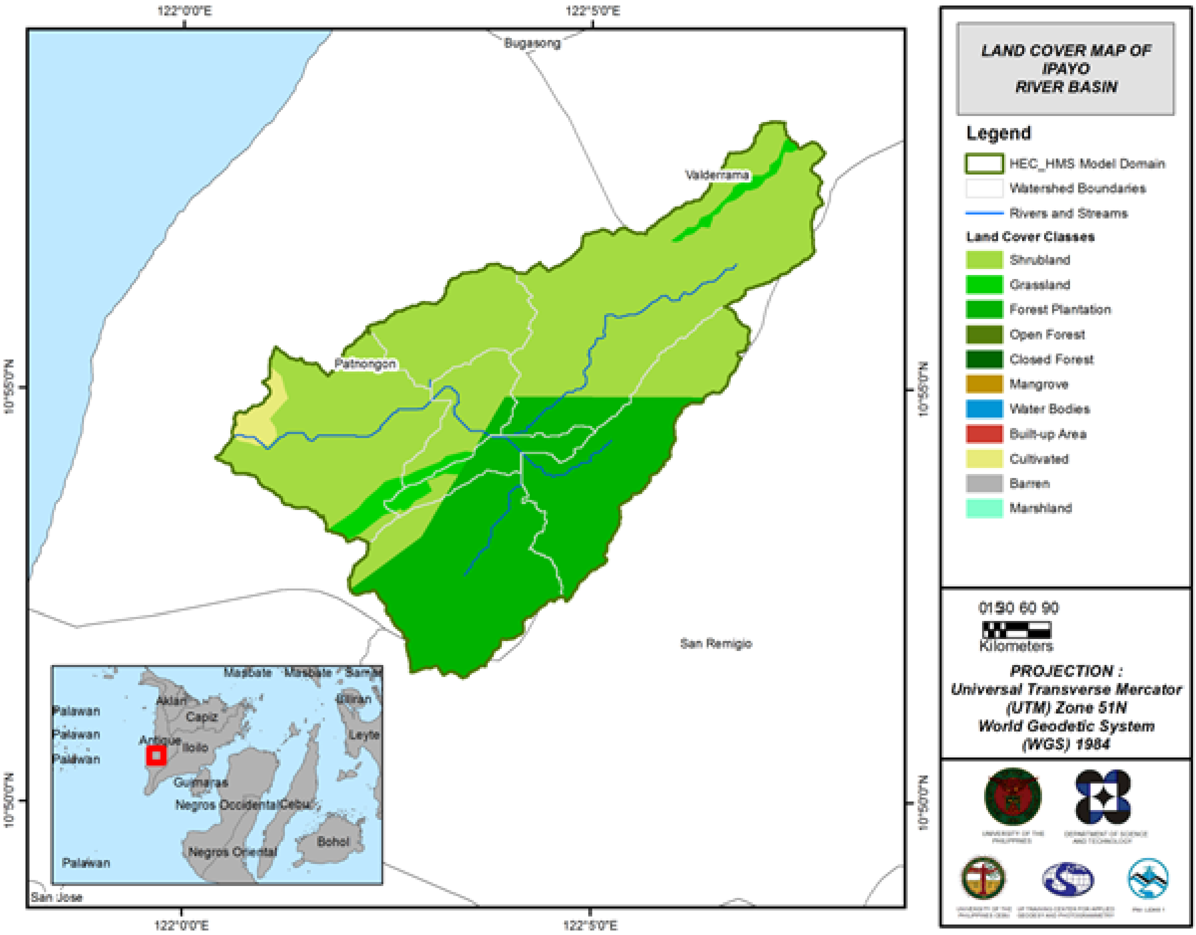


Figure 52. Land cover map of the Danao River Basin

For Ipayo, four soil classes were identified. These are loam, sandy loam, clay, and undifferentiated soil. Moreover, four land cover classes were identified. These are cultivated area, shrubland, grassland, and forest plantation.

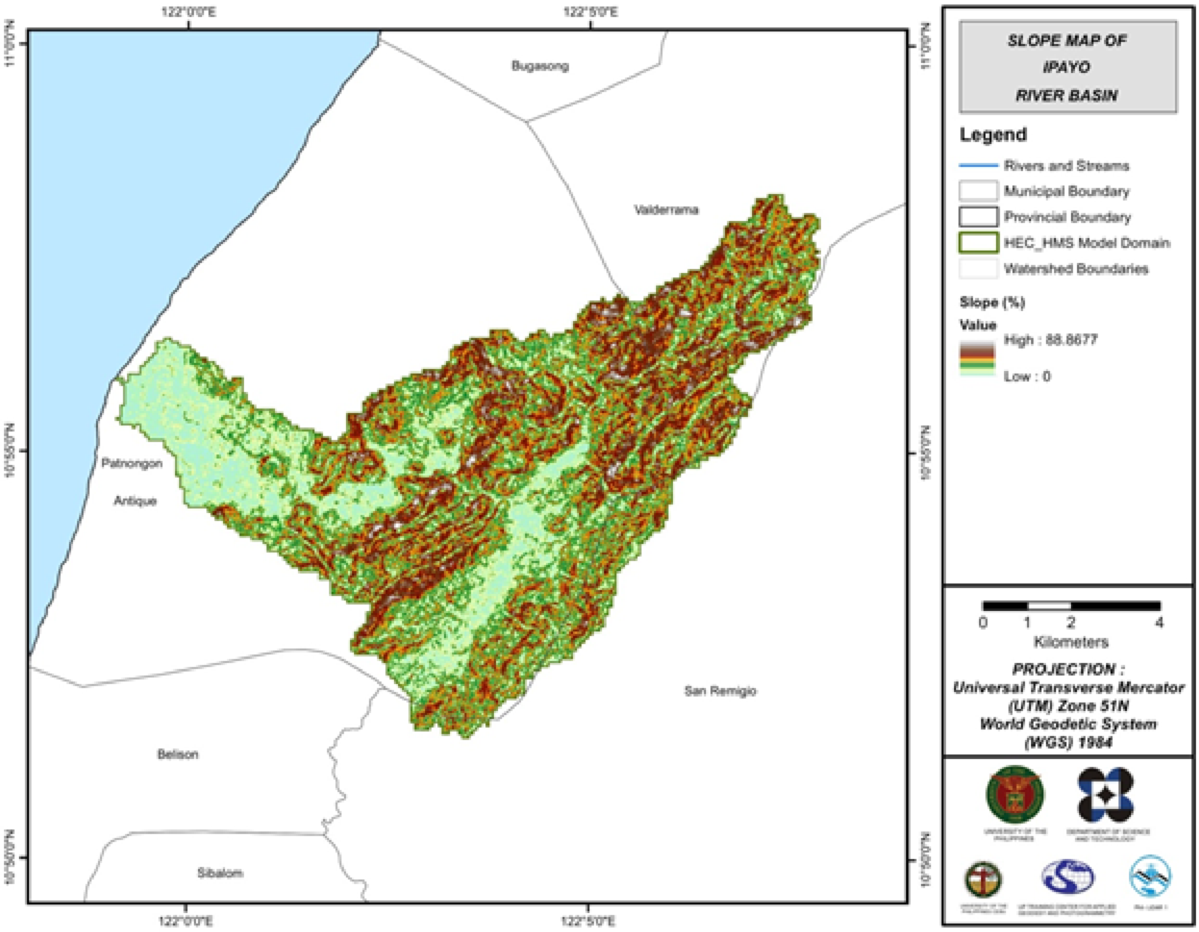


Figure 53. Slope map of Ipayo River Basin

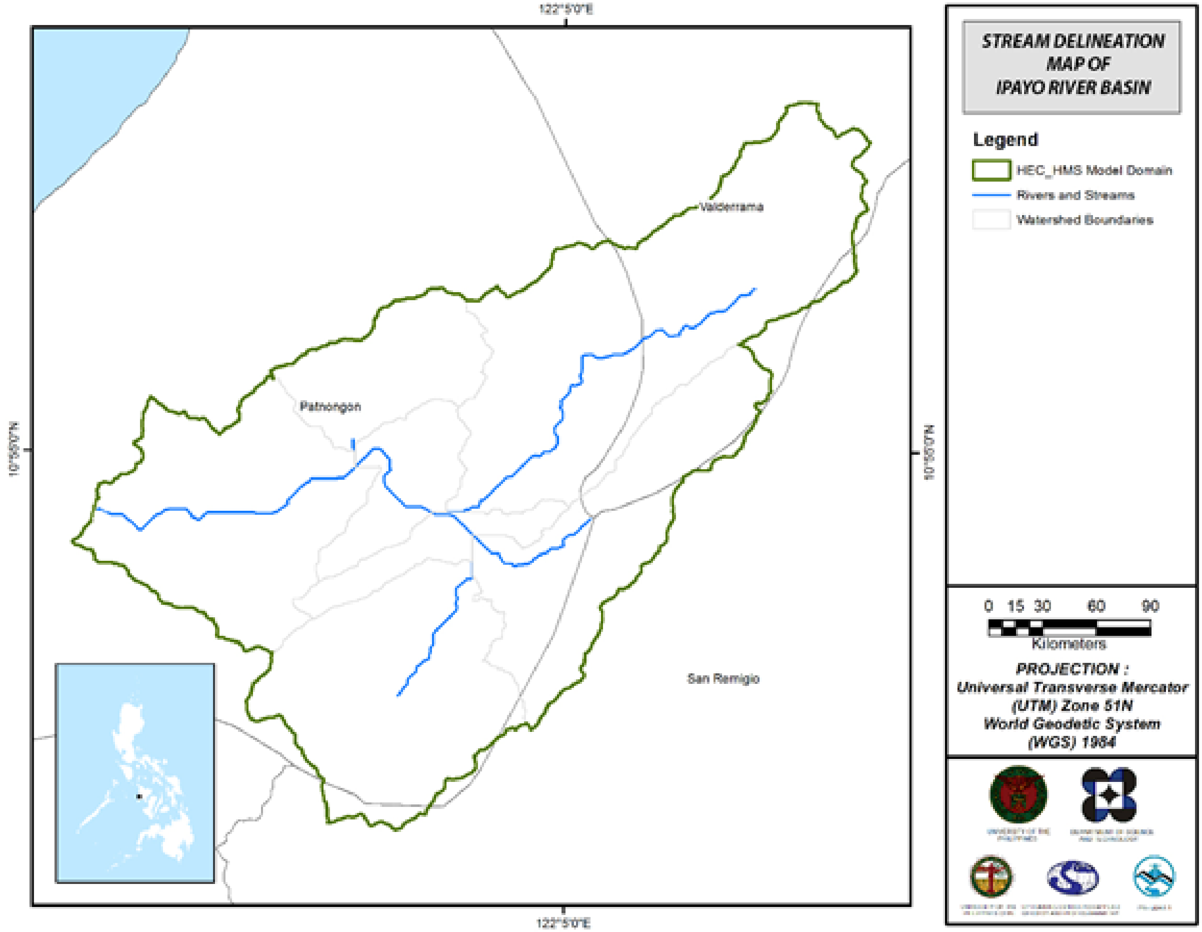


Figure 54. Stream delineation map of Ipayo River Basin

Using the SAR-based DEM, the Ipayo basin was delineated and further subdivided into subbasins. The model consists of 7 sub basins, 3 reaches, and 3 junctions as shown in Figure 57 (See Annex 10). The main outlet is at Tamayoc Bridge.

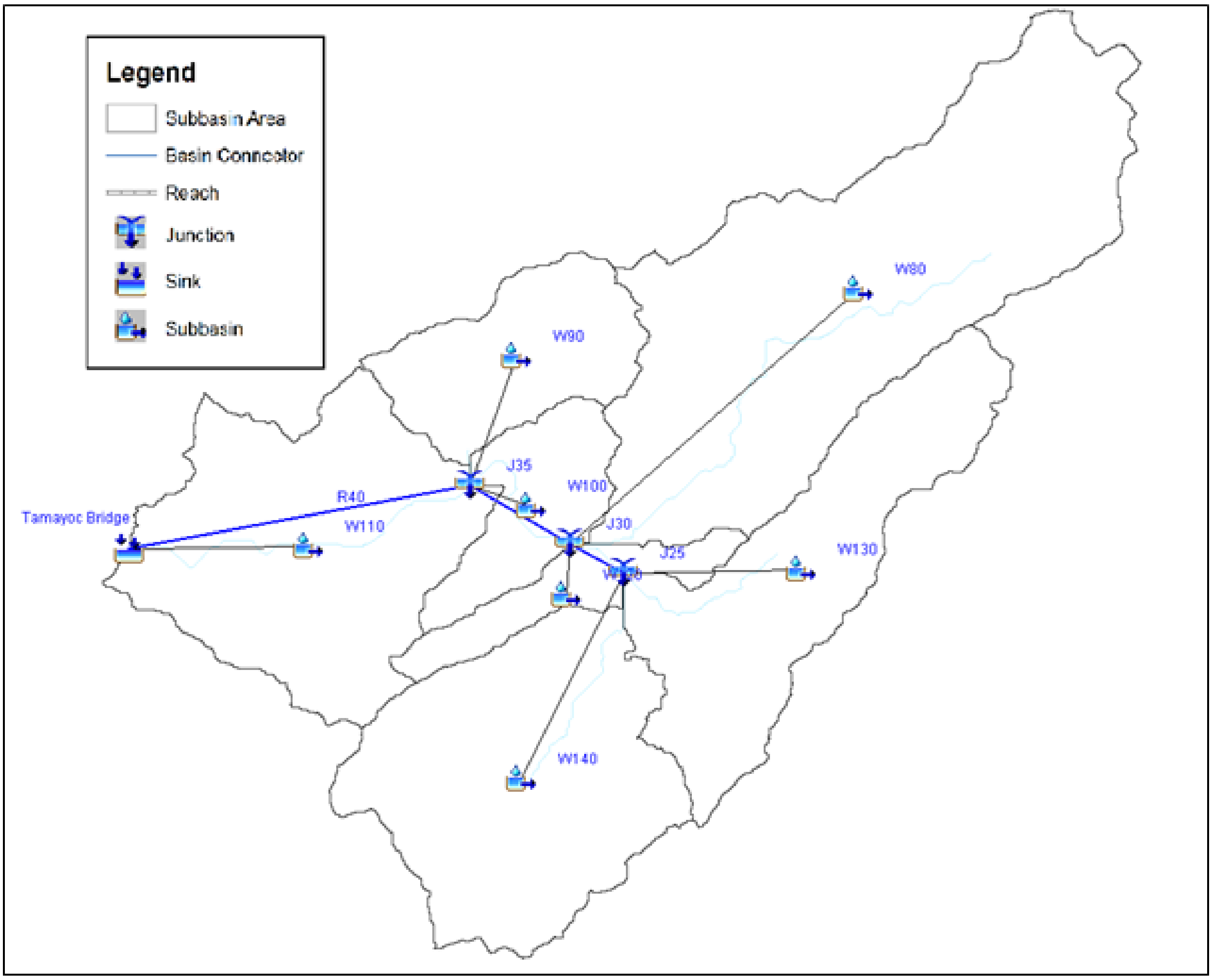


Figure 55. The Ipayo River Basin model generated using HEC-HMS

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 58).

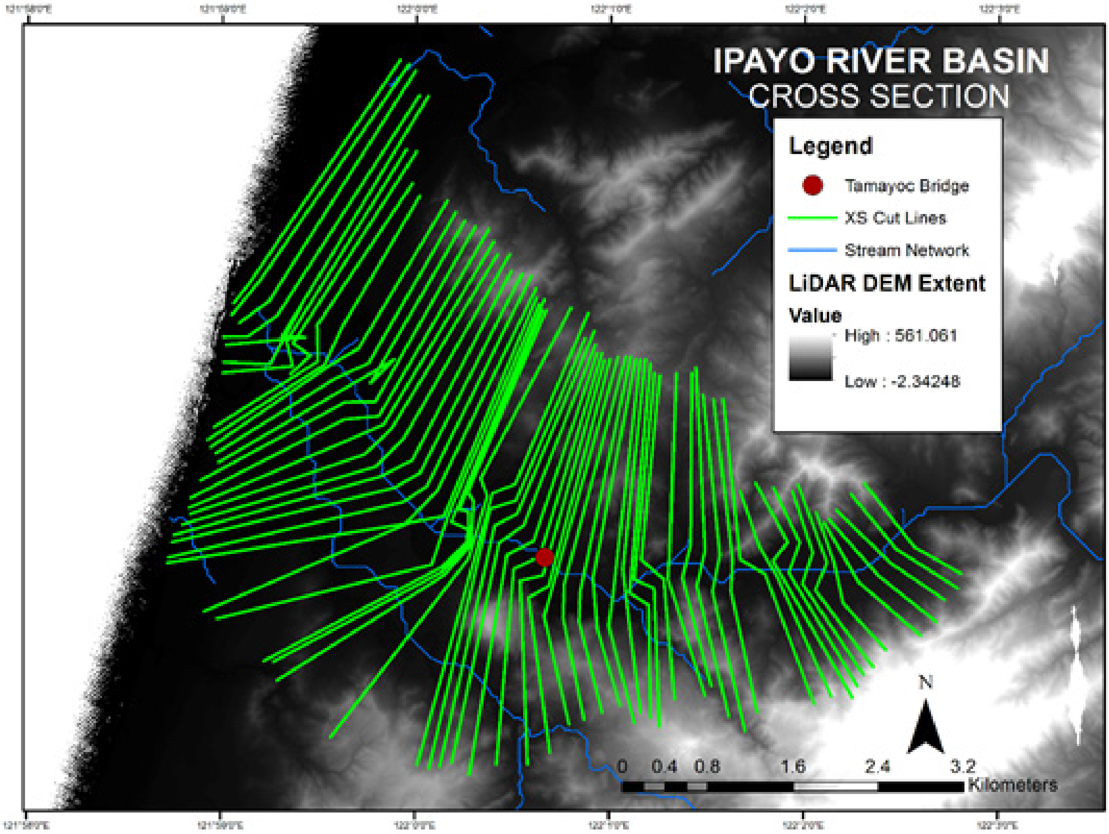


Figure 56. River cross-section of Ipayo River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

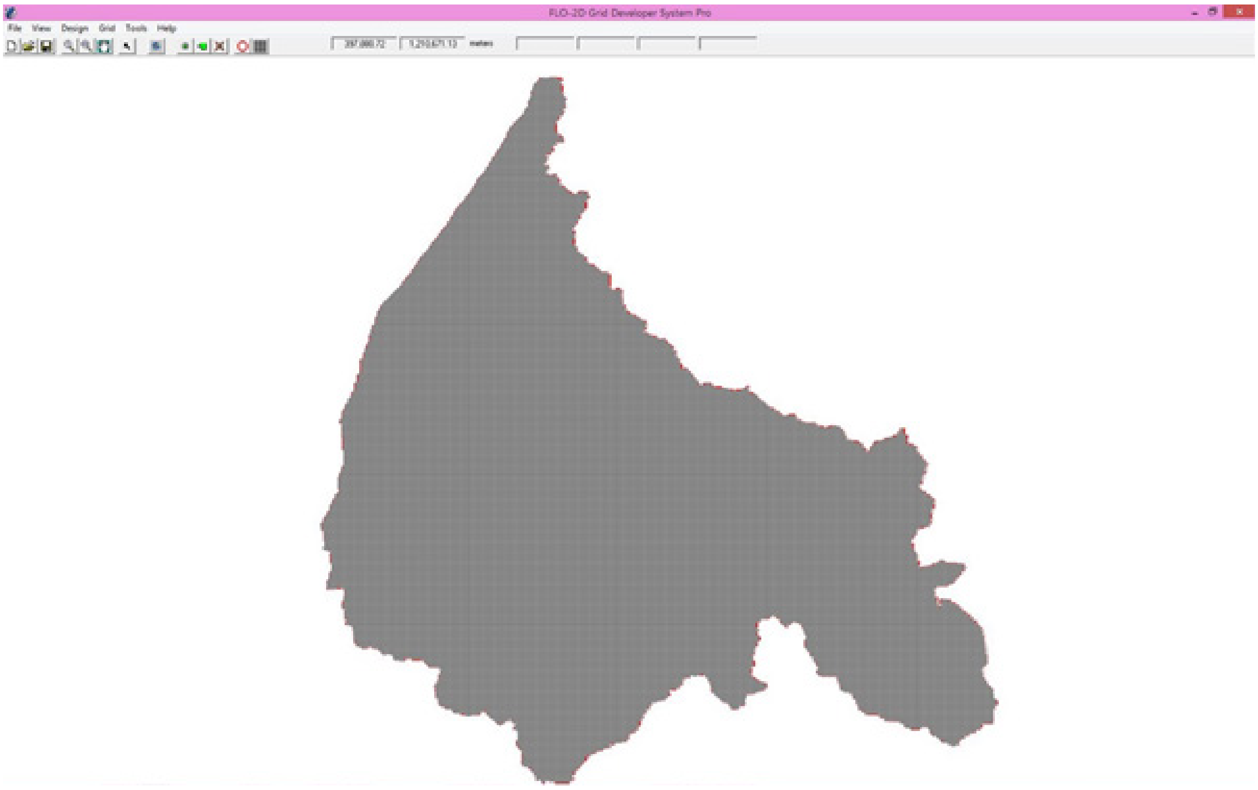


Figure 57. A screenshot of the river subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 9.64453 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

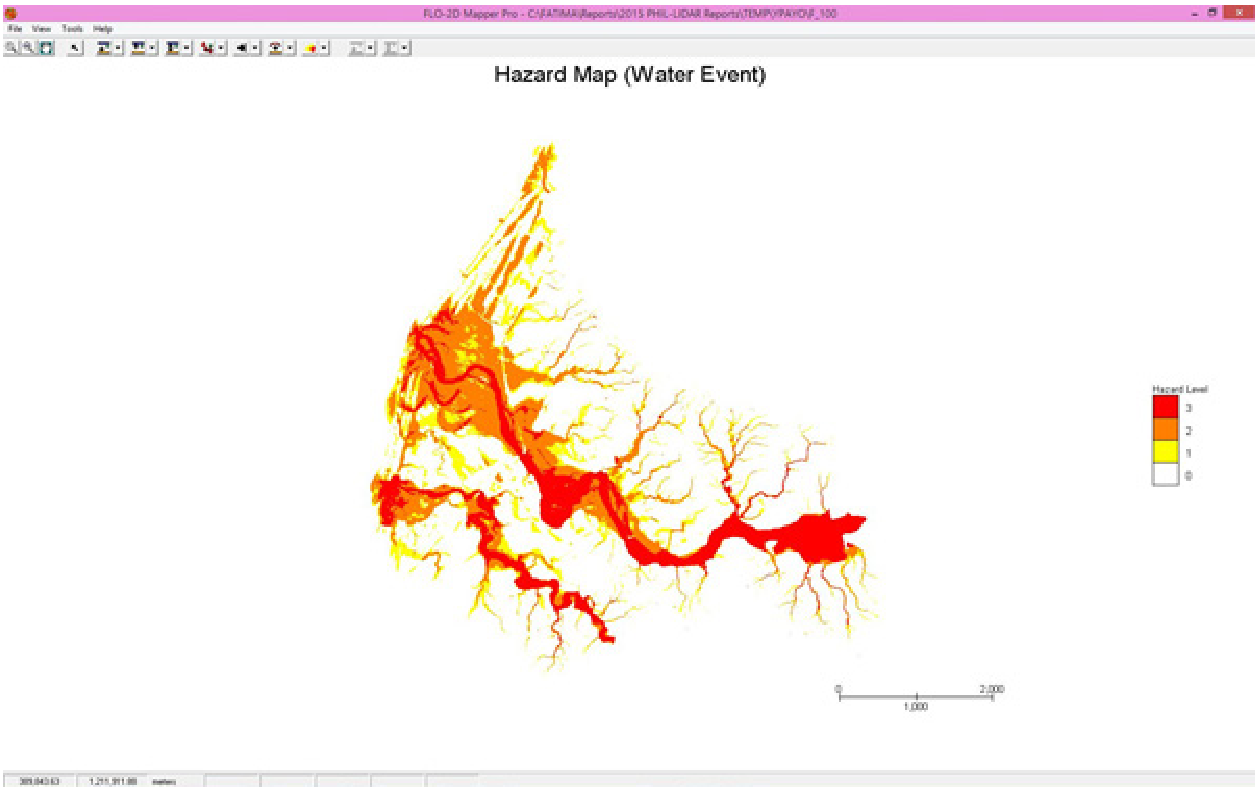


Figure 58. Generated 100-year rain return hazard map from FLO-2D Mapper

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 23910300.00 sq. m.

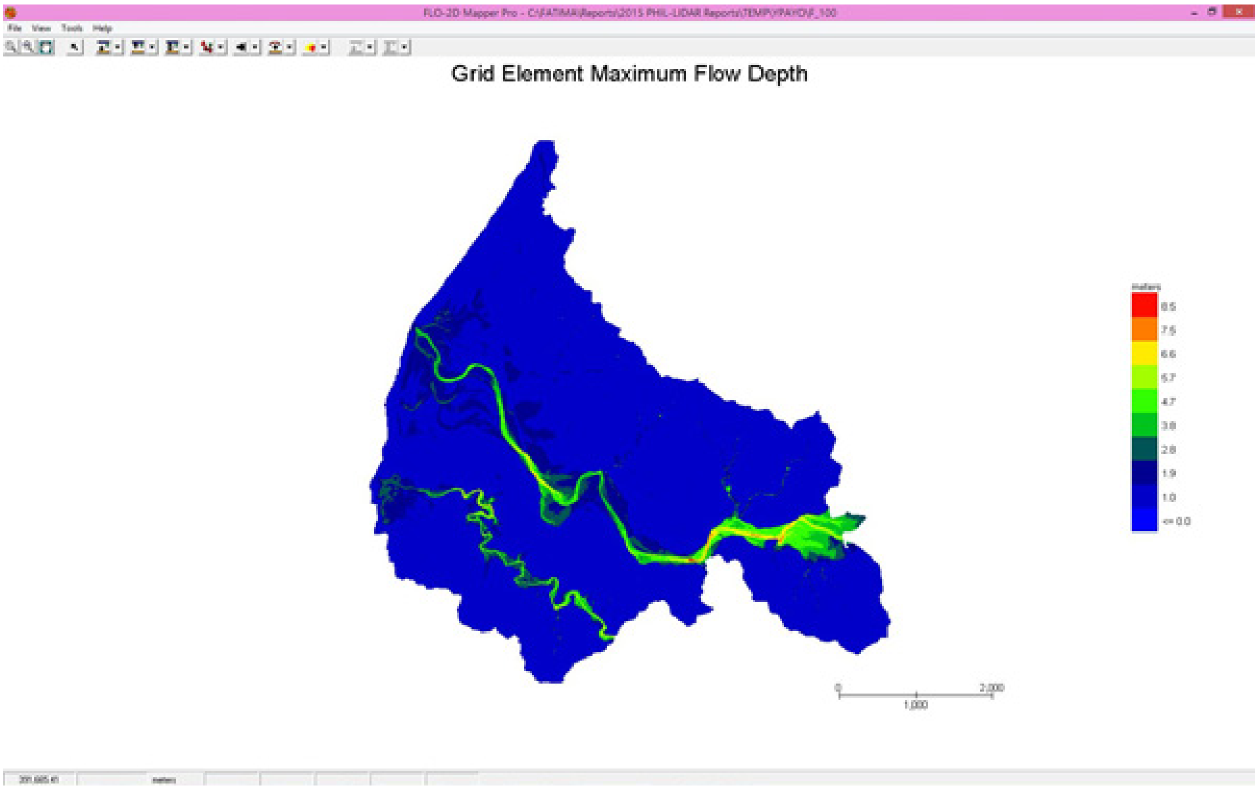


Figure 59. Generated 100-year rain return flow depth map from FLO-2D Mapper

There is a total of 31058602.28 m3 of water entering the model. Of this amount, 7258803.71 m3 is due to rainfall, while 23799798.57 m3 is inflow from other areas outside the model. 3342211.50 m3 of this water is lost to infiltration and interception, while 1399818.66 m3 is stored by the floodplain. The rest, amounting up to 26316571.73 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Ipayo HEC-HMS river basin model (See Annex 9), its accuracy was measured against the observed values. Figure 62 shows the comparison between the two discharge data.

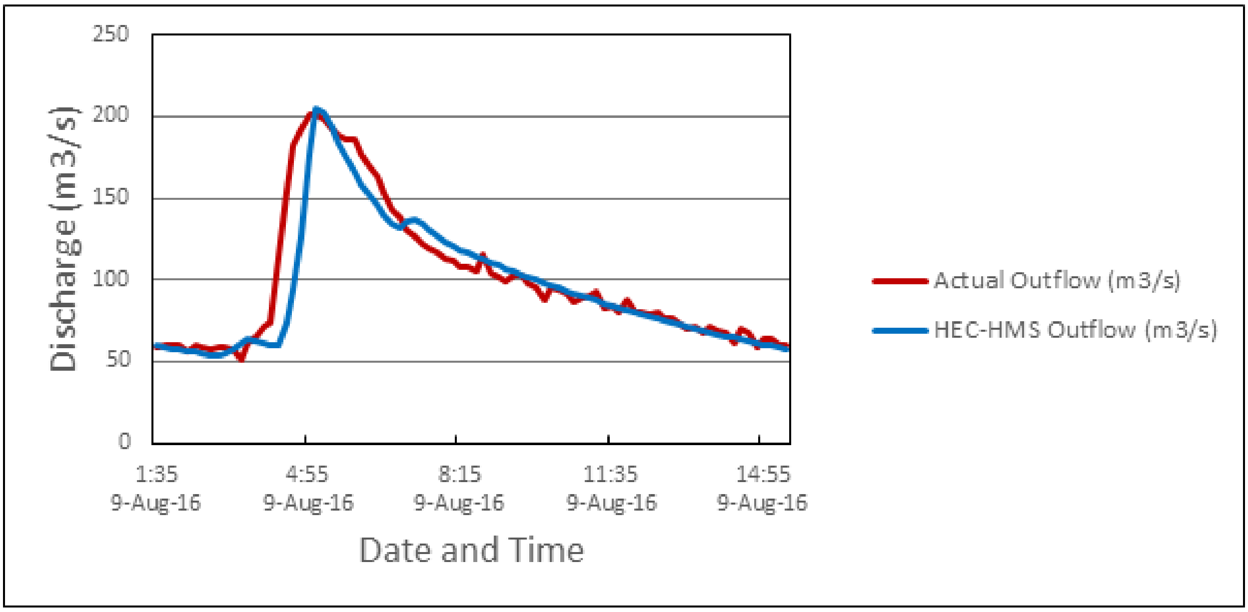


Figure 60. Outflow Hydrograph of Ipayo River Basin produced by the HEC-HMS model compared with observed outflow

Table 29 shows the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of calibrated values for the Ipayo River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	31.7-81
			Curve Number	59-85.5
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.07-0.32
			Storage Coefficient (hr)	1.14-5.3
	Baseflow	Recession	Recession Constant	0.09
			Ratio to Peak	0.6
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0001

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 31.7 mm to 81 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 59 – 85.5 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Ipayo, the basin mostly consists of shrublands, grassland, and cultivated areas, and the soil consists of sandy loam, loam, clay, and undifferentiated soil.

The time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.07 hours to 5.3 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events, while ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.09 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.6 indicates a gradual limb of the outflow hydrograph.

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

Table 30. Summary of the Efficiency Test of Ipayo HMS Model

ACCURACY MEASURE	VALUE
RMS Error	17.5
r2	0.9169
NSE	0.83
RSR	0.41
PBIAS	4.43

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 17.5 (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 0.9169.

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 0.83.

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 4.43.

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 0.41.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

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

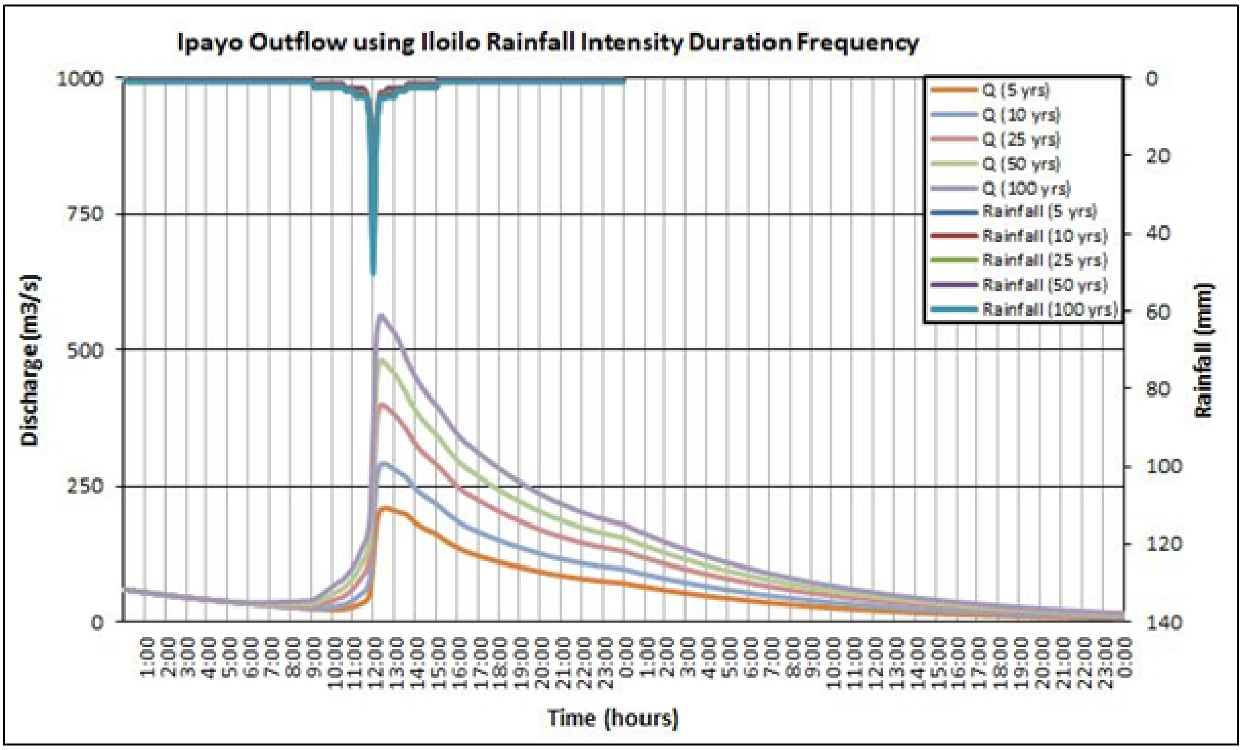


Figure 61. The Outflow hydrograph at Ipayo Station, generated using Iloilo RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Ipayo discharge using the Iloilo RIDF in five different return periods is shown in Table 31.

Table 31. Outlines the peak values of the Ipayo HEC-HMS Model outflow using the Iloilo

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	165.2	28.7	208.88	40 minutes
10-Year	198.9	33.9	290.54	30 minutes
25-Year	241.5	40.5	398.37	20 minutes
50-Year	273.1	45.4	480.87	20 minutes
100-Year	304.5	50.3	563.12	20 minutes

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

The river discharges for the three rivers entering the floodplain are shown in Figures 64 to 68, and the peak values are summarized in Tables 32 to 36.

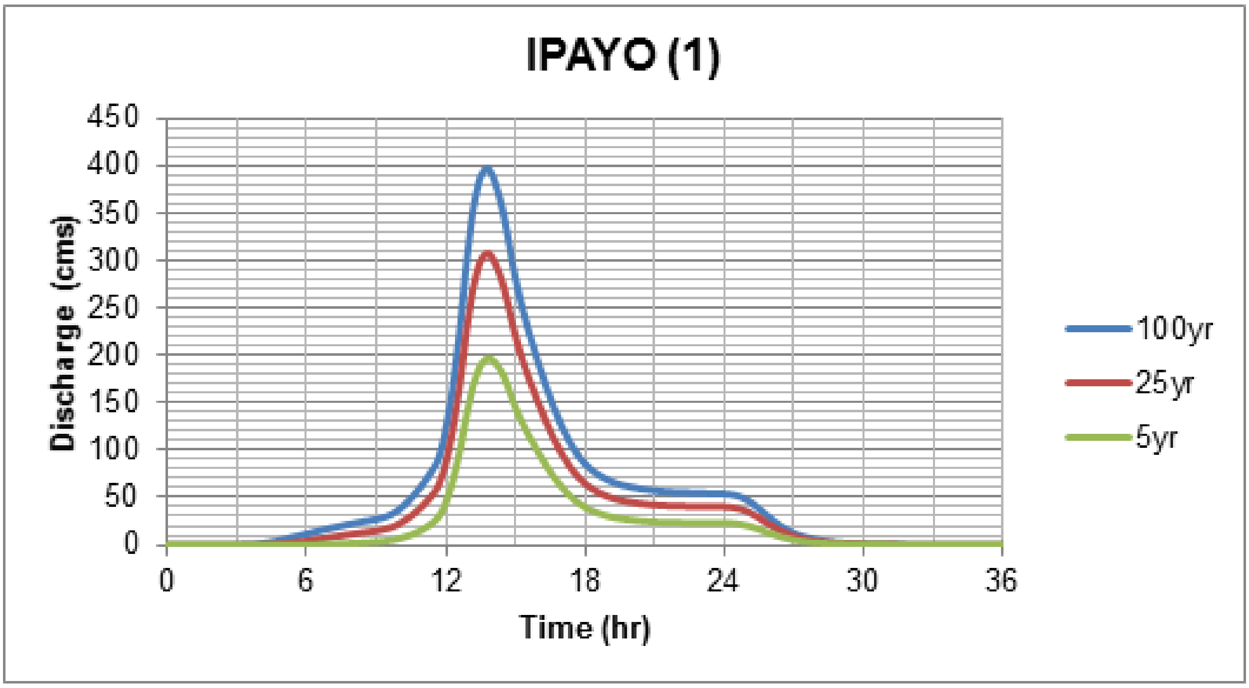


Figure 62. Ipayo river (1) generated discharge using 5-, 25-, and 100-year Iloilo RIDF in HEC-HMS

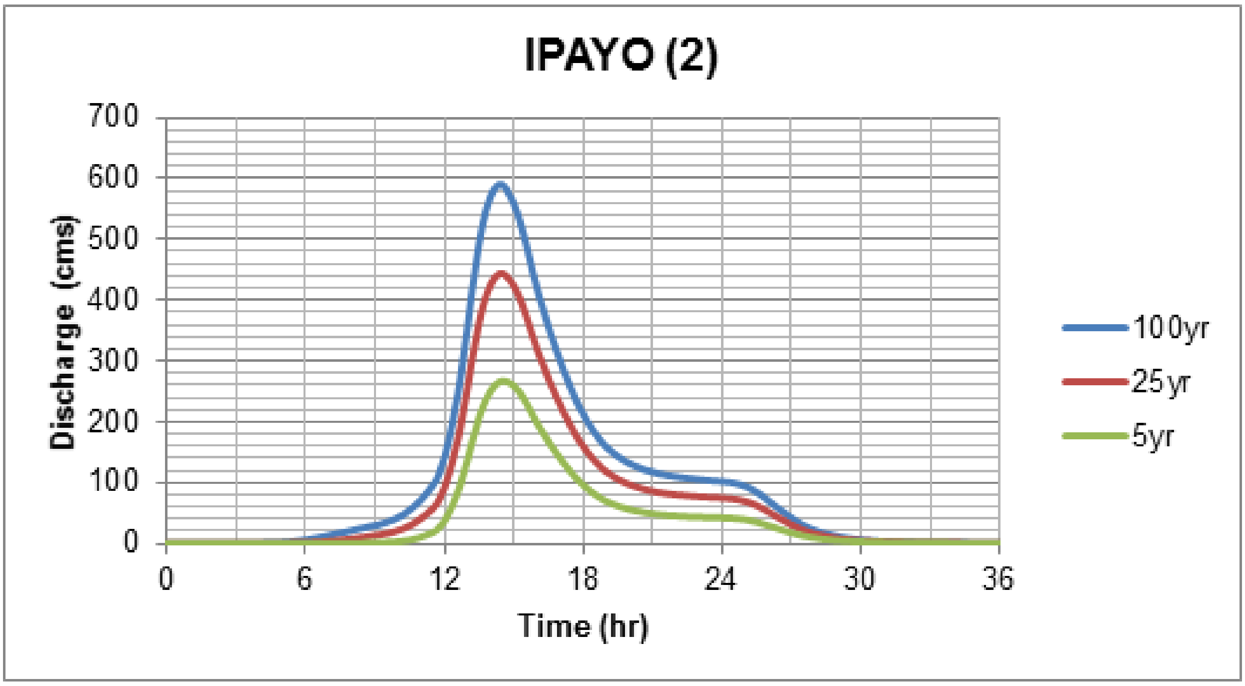


Figure 63. Ipayo river (2) generated discharge using 5-, 25-, and 100-year Iloilo RIDF in HEC-HMS

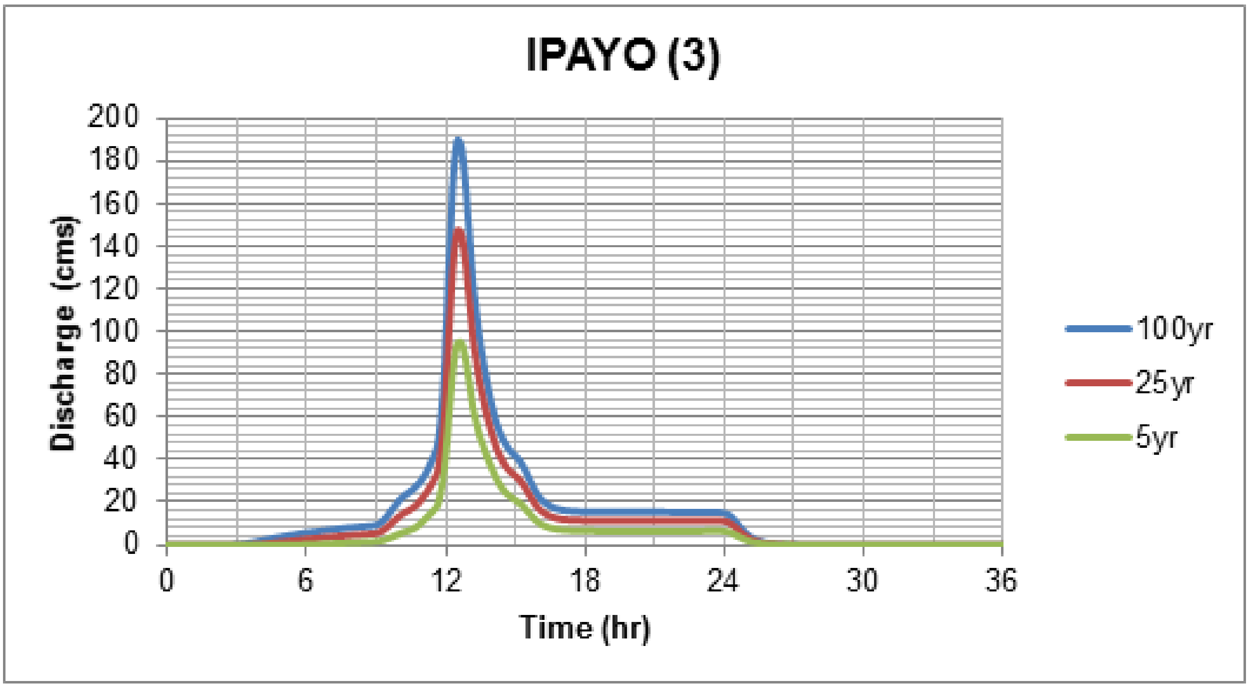


Figure 64. Ipayo River (3) generated discharge using 5-, 25-, and 100-year Iloilo RIDF

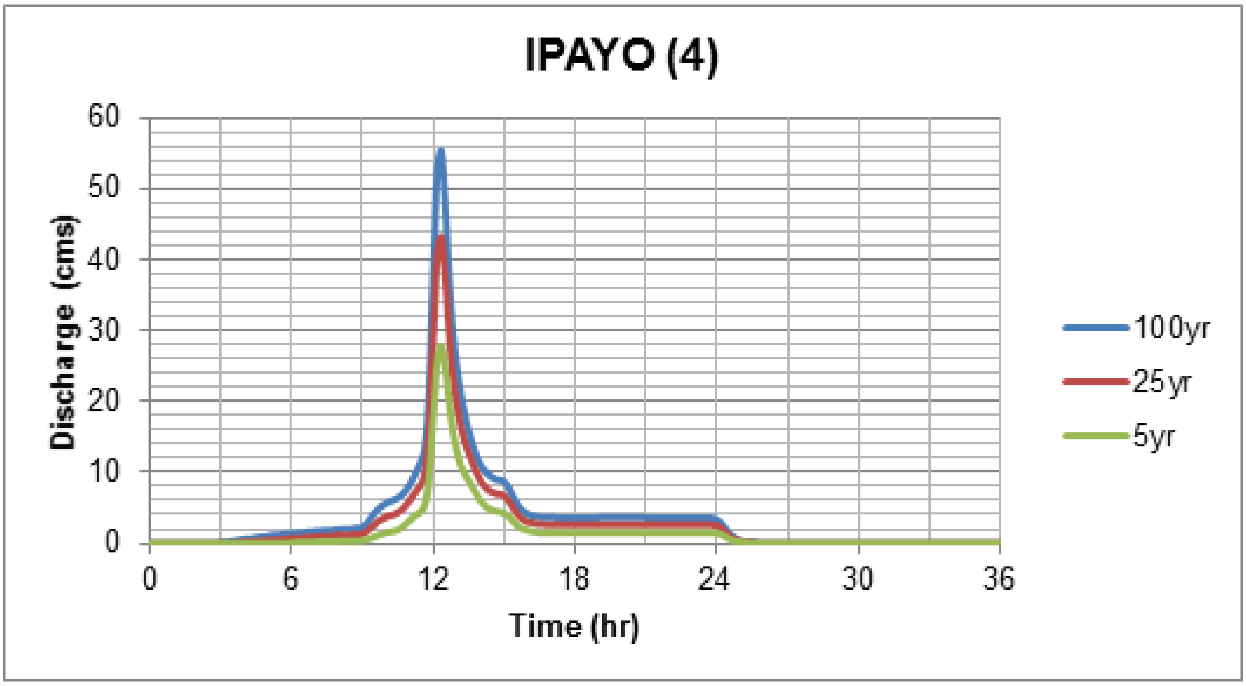


Figure 65. Ipayo river (3) generated discharge using 5-, 25-, and 100-year Iloilo RIDF in HEC-HMS

Table 32. Summary of Ypayo river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	396.8	13 hours, 50 minutes
25-Year	307.5	13 hours, 50 minutes
5-Year	196.8	13 hours, 50 minutes

Table 33. Summary of Ypayo river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	589.8	14 hours, 30 minutes
25-Year	444.1	14 hours, 30 minutes
5-Year	267.2	14 hours, 30 minutes

Table 34. Summary of Ypayo river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	189.7	12 hours, 30 minutes
25-Year	147.3	12 hours, 30 minutes
5-Year	94.8	12 hours, 30 minutes

Table 35. Summary of Ypayo river (4) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	55.4	12 hours, 20 minutes
25-Year	43.2	12 hours, 20 minutes
5-Year	27.8	12 hours, 20 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 5.

Table 36. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Ypayo (1)	173.184	141.379	117.873	Pass	Pass
Ypayo (2)	235.136	174.190	182.976	Pass	Pass
Ypayo (3)	83.424	95.243	45.300	Pass	Fail
Ypayo (4)	24.464	23.684	12.765	Pass	Fail

All four values from the HEC-HMS river discharge estimates were able to satisfy at least one of the conditions for validation using the bankful and specific discharge methods. The calculated values are based on theory but are supported using other discharge computation methods so they were good to use 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 Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Ipayo River using the calibrated HMS event flow is shown in Figure 14.

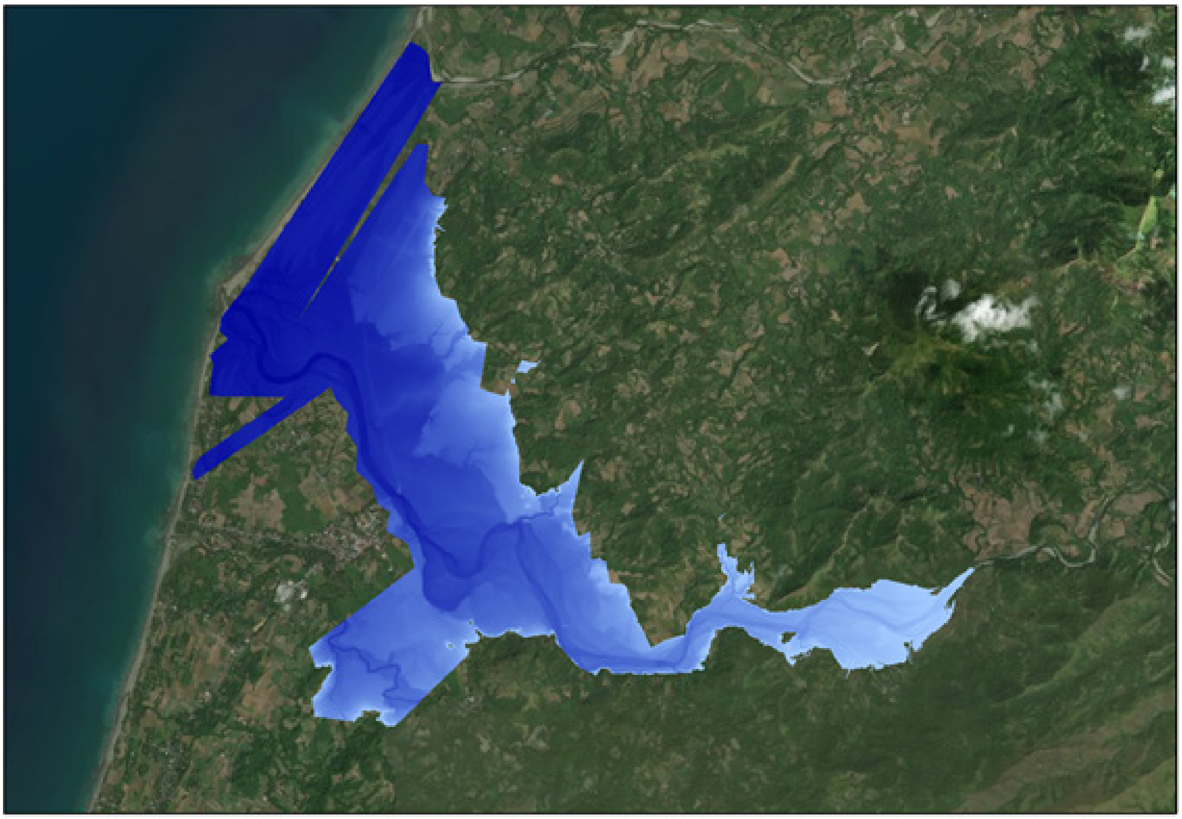


Figure 66. Sample output of the Ipayo RAS Model

5.9 Flood Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figures 70 to 76 show the 5-, 25-, and 100-year rain return scenarios of the Ipayo Floodplain. The floodplain, with an area of 21.82 km2., covers one municipality namely, Patnongon.

Table 37. Municipalities affected in Ipayo flood plain

City / Municipality	Total Area	Area Flooded	% Flooded
Patnongon	133.218	21.7	16.29

Figure 67. 100-year flood hazard map for the Ipayo flood plain overlaid on Google Earth imagery

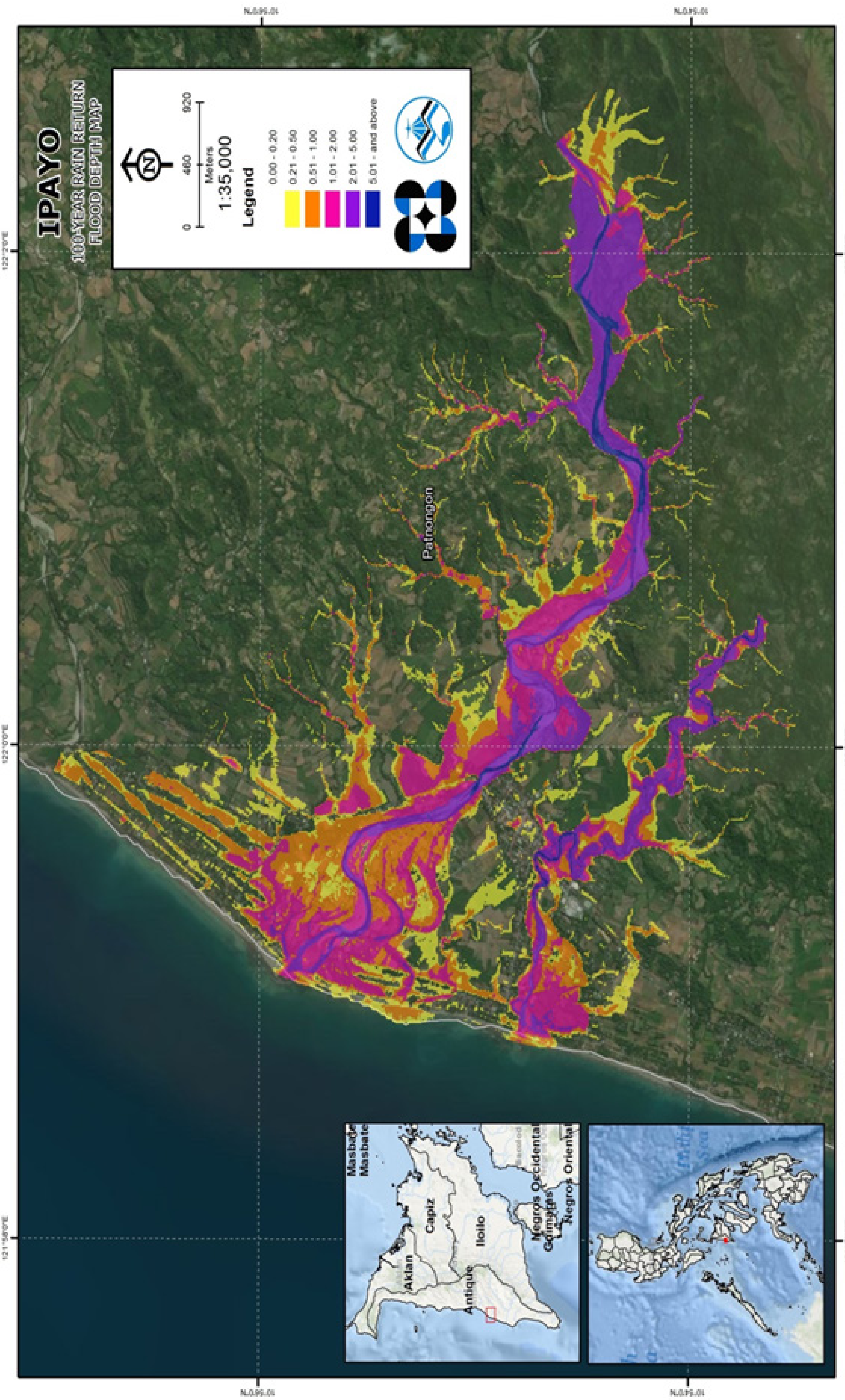


Figure 68. 100-year flow depth map for the Ipayo flood plain overlaid on Google Earth imagery

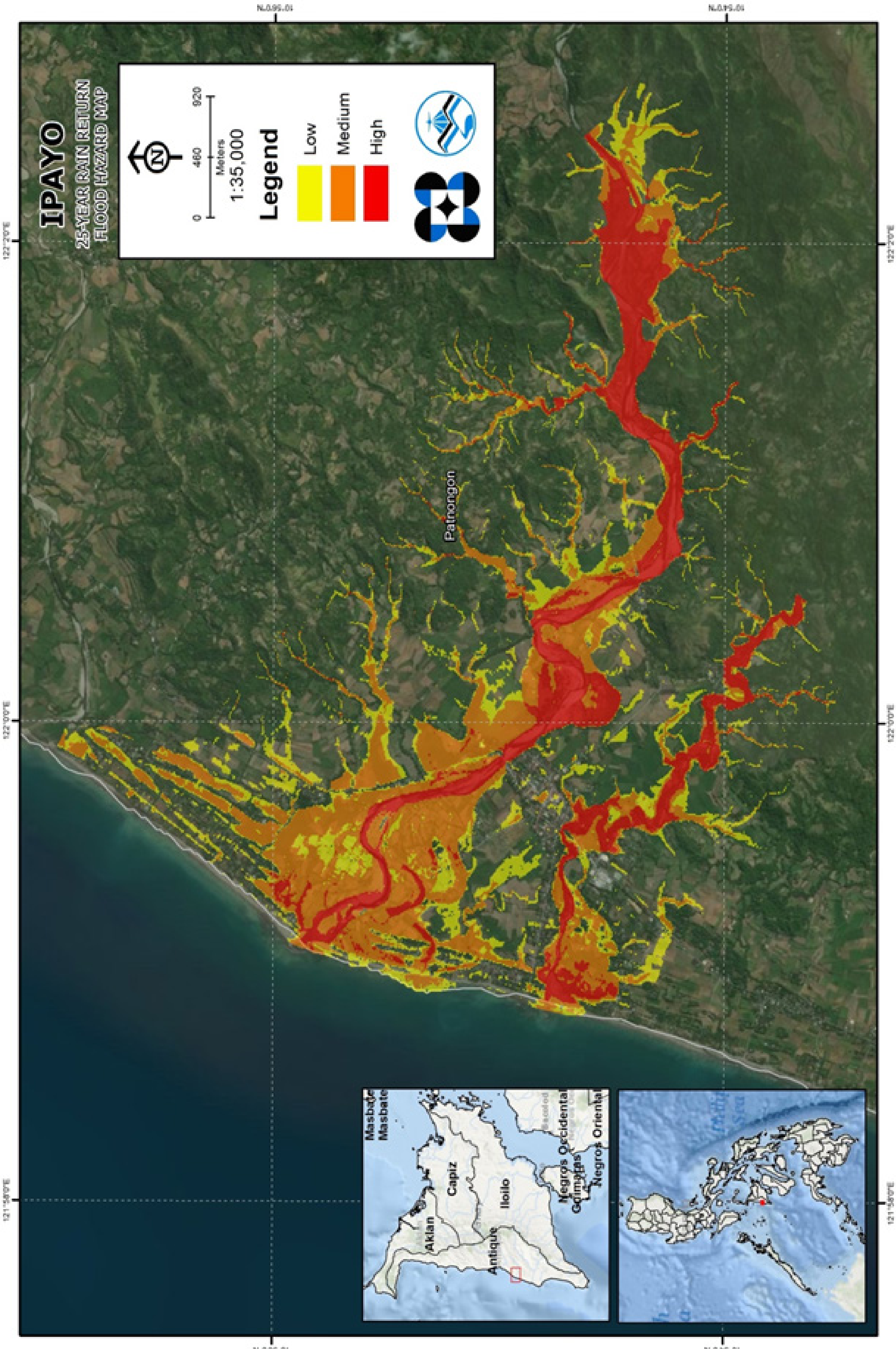


Figure 69. 25-year flood hazard map for the Ipayo flood plain overlaid on Google Earth imagery

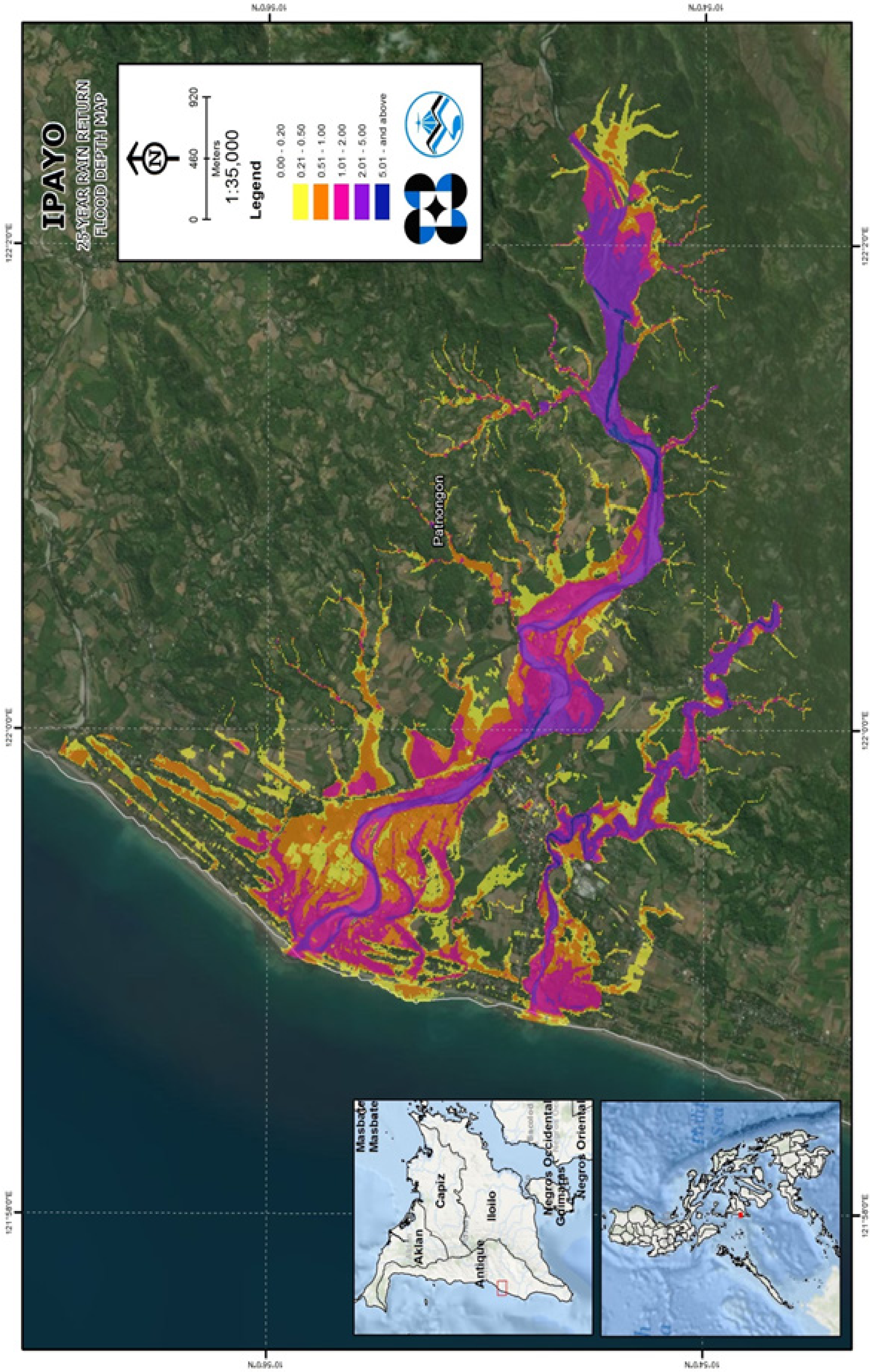


Figure 70. 25-year flow depth map for the Ipayo flood plain overlaid on Google Earth imagery

Figure 71. 5-year flood hazard map for the Ipayo flood plain overlaid on Google Earth imagery

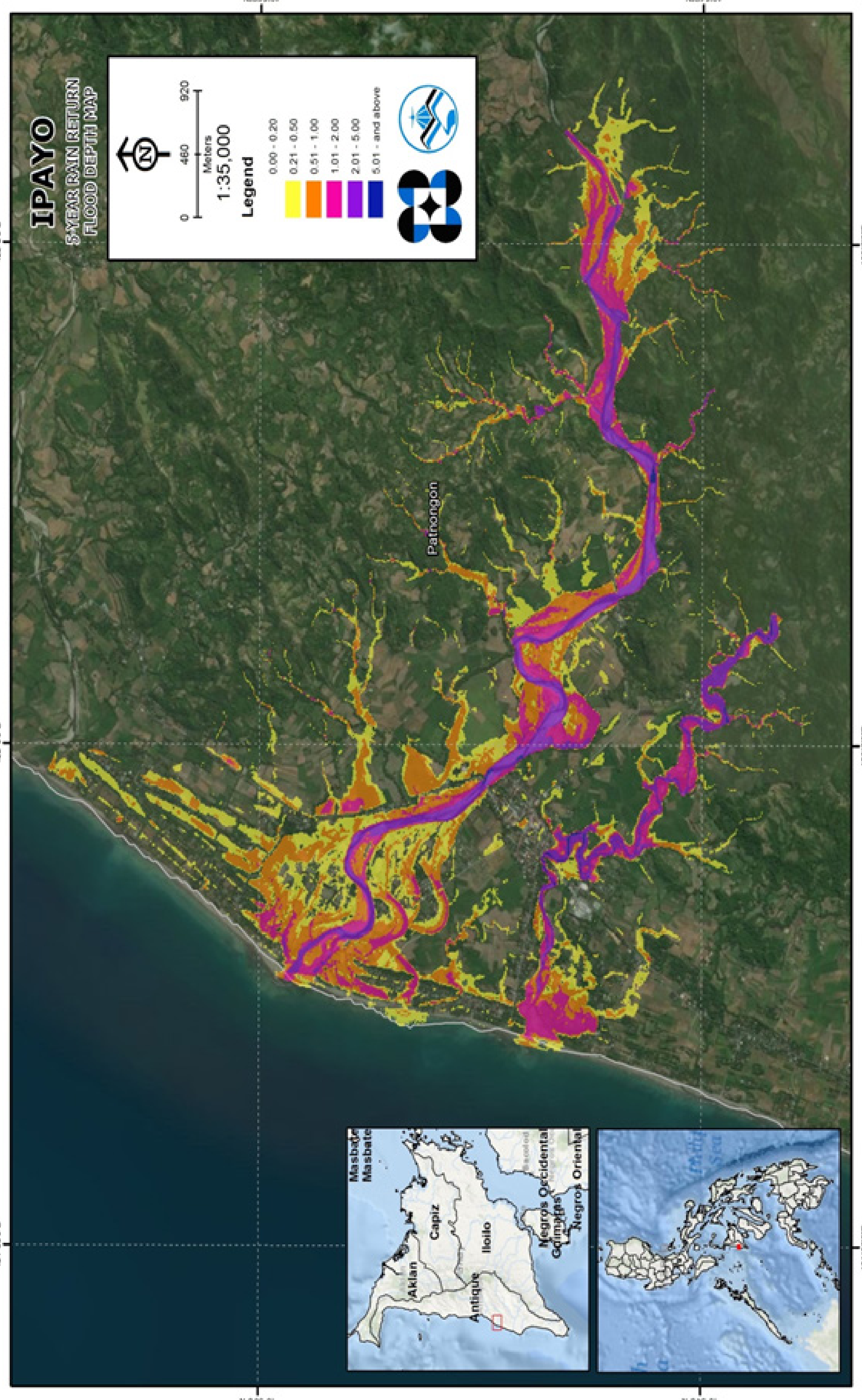


Figure 72. 5-year flow depth map for the Ipayo flood plain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Ipayo River Basin, grouped accordingly by municipality. For the said basin, one municipality consisting of 13 barangays is expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 11.71% of the Municipality of Patnongon with an area of 132.218 km2 will experience flood levels of less than 0.20 meters. 1.65% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.37%, 0.94%, 0.61%, and 0.014% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas in square kilometers by flood depth per barangay.

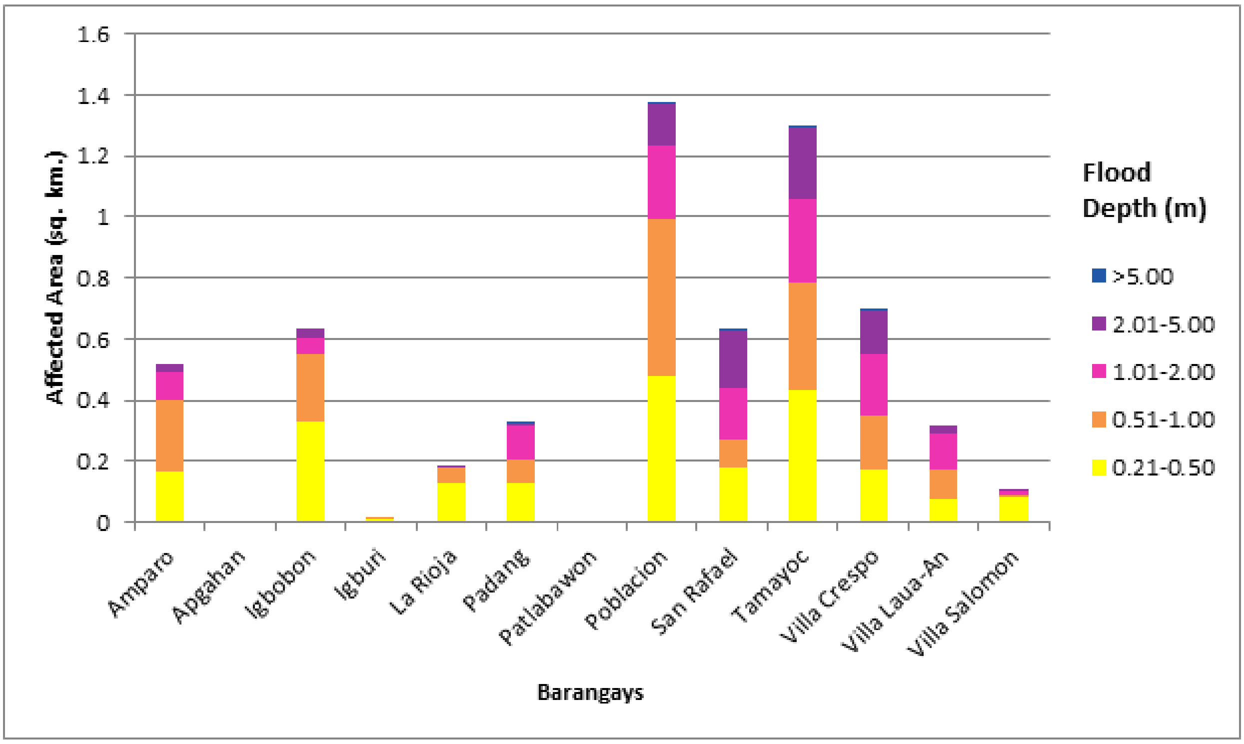


Figure 73. Affected Areas in Patnongon, Antique during 5-Year Rainfall Return Period

Table 38. Affected Areas in Patnongon, Antique during 5-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (m)	Area of affected barangays in Patnongon (in sq. m.)					
	Amparo	Apgahan	Igbobon	Igburi	La Rioja	Padang
0.03-0.20	0.44	0.075	1.5	0.2	0.82	0.49
0.21-0.50	0.16	0.000003	0.33	0.013	0.13	0.13
0.51-1.00	0.24	0	0.22	0.00037	0.047	0.078
1.01-2.00	0.087	0	0.051	0	0.001	0.11
2.01-5.00	0.026	0	0.033	0	0.0002	0.012
> 5.00	0	0	0	0	0	0.0003

Affected area (sq.km.) by flood depth (m)	Area of affected barangays in Patnongon (in sq. m.)						
	Patlabawon	Poblacion	San Rafael	Tamayoc	Villa Crespo	Villa Laua-An	Villa Salomon
0.03-0.20	0.028	1.72	2.81	4.39	2.02	0.93	0.17
0.21-0.50	0	0.48	0.18	0.43	0.18	0.076	0.08
0.51-1.00	0	0.51	0.091	0.35	0.17	0.1	0.012
1.01-2.00	0	0.24	0.16	0.27	0.2	0.11	0.011
2.01-5.00	0	0.14	0.19	0.24	0.14	0.03	0.0042
> 5.00	0	0.0054	0.0076	0.0011	0.0041	0	0

For the 25-year return period, 10.54% of the Municipality of Patnongon with an area of 132.218km2will experience flood levels of less than 0.20 meters. 1.53% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.55%, 1.46%, 1.12%, and 0.08%of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 39 are the affected areas in square kilometers by flood depth per barangay.

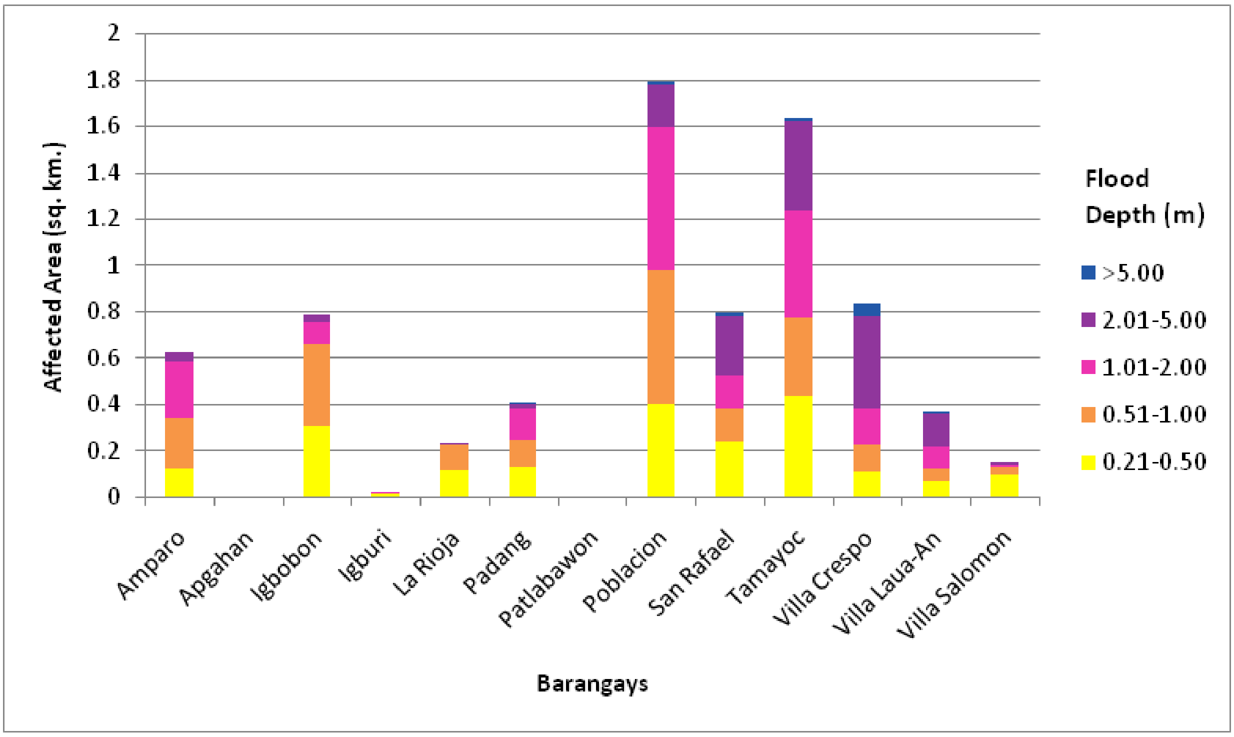


Figure 74. Affected Areas in Patnongon, Antique during 25-Year Rainfall Return Period

Table 39. Affected Areas in Patnongon, Antique during 100-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (m)	Area of affected barangays in Patnongon (in sq. m.)					
	Amparo	Apgahan	Igbobon	Igburi	La Rioja	Padang
0.03-0.20	0.32	0.074	1.35	0.19	0.77	0.41
0.21-0.50	0.12	0.00042	0.31	0.022	0.12	0.13
0.51-1.00	0.22	0	0.36	0.00091	0.11	0.11
1.01-2.00	0.24	0	0.09	0.000017	0.0021	0.14
2.01-5.00	0.044	0	0.035	0	0.0002	0.027
> 5.00	0	0	0	0	0	0.0015

Affected area (sq.km.) by flood depth (m)	Area of affected barangays in Patnongon (in sq. m.)						
	Patlabawon	Poblacion	San Rafael	Tamayoc	Villa Crespo	Villa Laua-An	Villa Salomon
0.03-0.20	0.028	1.3	2.65	4.05	1.88	0.89	0.13
0.21-0.50	0.000093	0.4	0.24	0.43	0.11	0.071	0.097
0.51-1.00	0	0.58	0.14	0.35	0.12	0.049	0.029
1.01-2.00	0	0.62	0.14	0.46	0.15	0.1	0.0079
2.01-5.00	0	0.18	0.26	0.39	0.4	0.14	0.014
> 5.00	0	0.013	0.013	0.013	0.059	0.0048	0

For the 100-year return period, 10.09% of the Municipality of Patnongon with an area of 132.218km2will experience flood levels of less than 0.20 meters. 1.59% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.59%, 1.56%, 1.32%, and 0.13%of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table40 are the affected areas in square kilometers by flood depth per barangay.

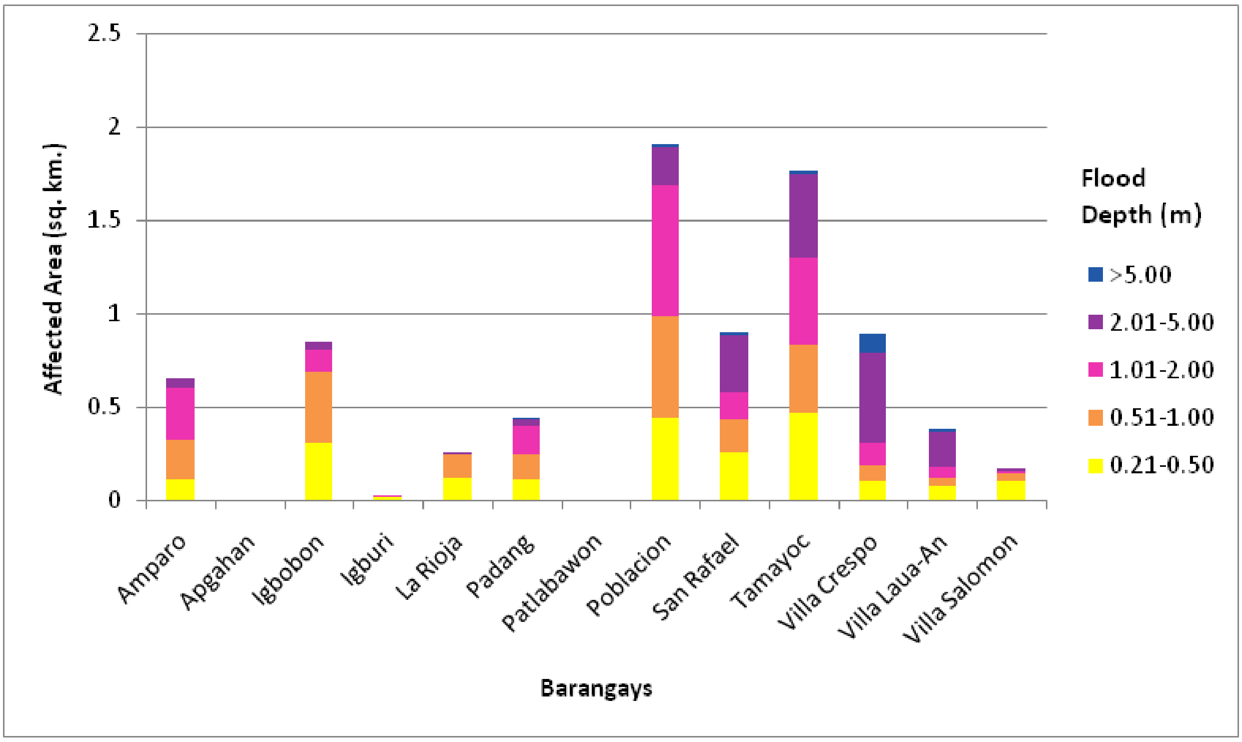


Figure 75. Affected Areas in Patnongon, Antique during 100-Year Rainfall Return Period

Table 40. Affected Areas in Patnongon, Antique during 100-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (m)	Area of affected barangays in Patnongon (in sq. m.)					
	Amparo	Apgahan	Igbobon	Igburi	La Rioja	Padang
0.03-0.20	0.3	0.074	1.29	0.18	0.75	0.37
0.21-0.50	0.11	0.0011	0.3	0.027	0.12	0.11
0.51-1.00	0.21	0	0.38	0.0011	0.14	0.14
1.01-2.00	0.28	0	0.13	0.000017	0.0029	0.15
2.01-5.00	0.05	0	0.036	0	0.0003	0.04
> 5.00	0	0	0	0	0	0.0021

Affected area (sq.km.) by flood depth (m)	Area of affected barangays in Patnongon (in sq. m.)						
	Patlabawon	Poblacion	San Rafael	Tamayoc	Villa Crespo	Villa Laua-An	Villa Salomon
0.03-0.20	0.028	1.18	2.55	3.92	1.83	0.87	0.11
0.21-0.50	0.000093	0.44	0.26	0.47	0.1	0.075	0.1
0.51-1.00	0	0.55	0.18	0.36	0.08	0.048	0.039
1.01-2.00	0	0.7	0.15	0.47	0.12	0.056	0.011
2.01-5.00	0	0.2	0.3	0.45	0.48	0.19	0.016
> 5.00	0	0.016	0.019	0.019	0.1	0.02	0

Among the barangays in the Municipality of Patnongon, Tamayoc is projected to have the highest percentage of area that will experience flood levels at 4.27%. Meanwhile, Villa Crespo posted the second highest percentage of area that may be affected by flood depths at 2.04%.

Moreover, the generated flood hazard maps for the Ipayo Floodplain were used to assess the vulnerability of 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 41. 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	2.23	2.10	2.18
Medium	2.72	3.37	3.53
High	1.29	2.33	2.71
TOTAL	**6.24**	**7.8**	**8.42**

Of the 17 identified education institutionsin the Ipayo Floodplain, 2 schools were assessed to be exposed to Low level flooding during a 5-year scenario, while 1 school was assessed to be exposed to Medium level flooding scenario. In the 25-year scenario, 1 school was assessed to be exposed to Low level flooding scenario, while 2 schools were assessed to be exposed to Medium level flooding. For the 100-year scenario, 2 schools were assessed to be exposed to Low level flooding,while 2 schools were assessed to be exposed to Medium level flooding. See Annex 12 for a detailed enumeration of schools in the Ipayo Floodplain.

Four (4) medical institutions were identified in the Ipayo Floodplain, of which 1 was assessed to be exposed to low level flooding during a 5-year scenario. In the 25-year scenario, 1 was assessed to be exposed to low level flooding, while 1 medical institution was assessed to be exposed to medium level flooding. In the 100-year scenario, 2 were assessed to be exposed to medium level flooding. See Annex 13 for a detailed enumeration of hospitals and clinics in the Ipayo Floodplain.

5.11 Flood Validation

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

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

The validation personnel then went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was done through a local DRRM office to obtain maps or situation reports about the past flooding events or interview of 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 points in the flood map versus its corresponding validation depths are shown in Figure 77.

The flood validation consists of 205 points randomly selected all over the Ipayo Floodplain. The flood validation points were obtained on December 13, 2016. Comparing it with the flood depth map of the nearest storm event, the maphas an RMSE value of 1.23m. Table 42 shows a contingency matrix of the comparison.

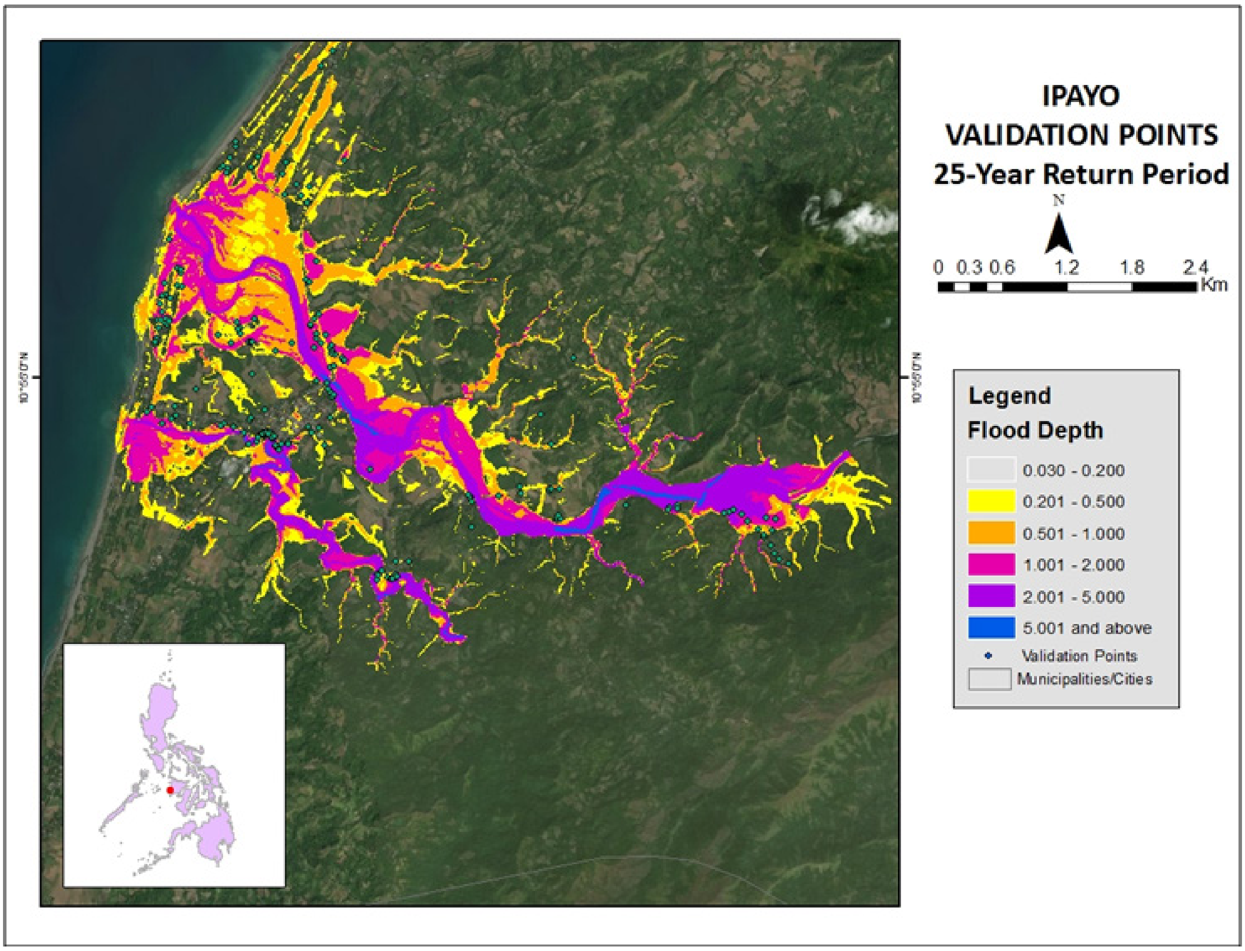


Figure 76. Flood validation points for 25-year Flood Depth Map of Ipayo Floodplain

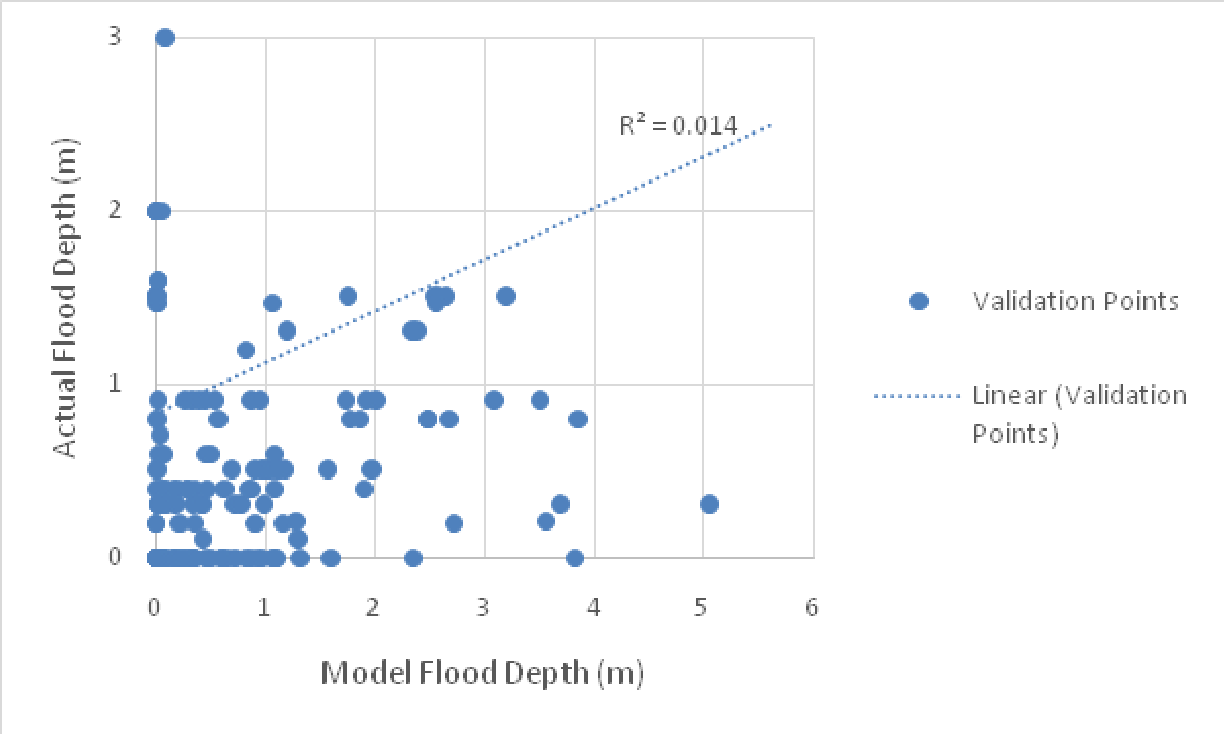


Figure 77. Flood map depth vs actual flood depth

Table 42. Actual flood vs simulated flood depth in the Ipayo River Basin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	54	11	10	7	3	0	85
0.21-0.50	17	8	10	10	2	1	48
0.51-1.00	7	5	5	5	7	0	29
1.01-2.00	15	0	1	3	7	0	26
2.01-5.00	8	0	0	0	2	1	11
> 5.00	0	1	3	2	0	0	6
Total	101	25	29	27	21	2	205

On the whole, the overall accuracy generated by the flood model is estimated at 35.12% with 72 points correctly matching the actual flood depths. In addition, there were 52 points estimated one level above and below the correct flood depths, while there were 36 points and 40 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated, while a total of 59 points were underestimated in the modelled flood depths of Ipayo.Table 43 depicts the summary of the accuracy assessment in the Ipayo River Basin survey.

Table 43. Summary of Accuracy Assessment in Ipayo River Basin Survey

	No. of Points	%
Correct	72	35.12
Overestimated	74	36.10
Underestimated	59	28.78
Total	205	100.00

REFERENCES

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

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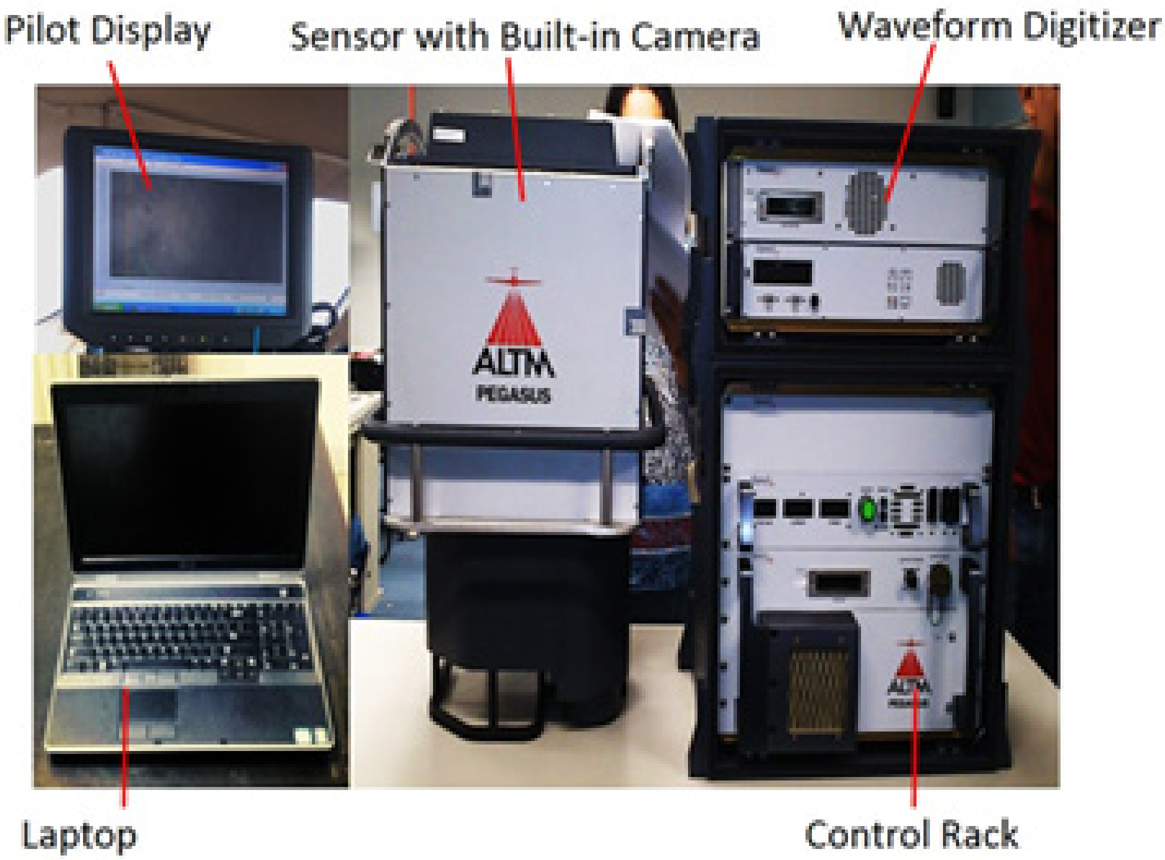
Paringit E.C, Balicanta L.P., Ang, M.O., Sarmiento, C. 2017. Flood Mapping of Rivers in the Philippines Using Airborne Lidar: Methods. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

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

ANNEXES

Annex 1. Optech Technical Specification of the Pegasus Sensor



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

1. Target reflectivity ≥20%
2. Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility
3. Angle of incidence ≤20˚
4. Target size ≥ laser footprint5 Dependent on system configuration

Annex 2. NAMRIA Certificates of Reference Points Used

1. ATQ-18

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

March 02, 2015

CERTIFICATION

To whom it may concern:

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

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

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

PRS92 Coordinates

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

WGS84 Coordinates

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

PTM / PRS92 Coordinates

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

UTM / PRS92 Coordinates

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

Location Description

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

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

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

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

CPI 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

2. ATQ-22

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

March 02, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **ANTIQUE**	
	Station Name: **ATQ-22**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **CONCEPCION**	
Municipality: **BELISON**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **10° 49' 46.66618"**	Longitude: **121° 58' 11.90221"**	Ellipsoidal Hgt: **12.25000 m.**
	WGS84 Coordinates	
Latitude: **10° 49' 42.24271"**	Longitude: **121° 58' 17.11770"**	Ellipsoidal Hgt: **68.02200 m.**
	PTM / PRS92 Coordinates	
Northing: **1197676.056 m.**	Easting: **387365.279 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,197,256.85**	Easting: **387,404.70**	Zone: **51**

Location Description

ATQ-22

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

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

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

9903022015130958

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. ILO-85

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **ILOILO**	
	Station Name: **ILO-85**	
Island: **VISAYAS**	Order: **2nd**	Barangay: **UBOS ILAWOD (POB.)**
Municipality: **MIAG-AO**		
	PRS92 Coordinates	
Latitude: **10° 38' 33.11352"**	Longitude: **122° 14' 3.70560"**	Ellipsoidal Hgt: **21.96200 m.**
	WGS84 Coordinates	
Latitude: **10° 38' 28.75996"**	Longitude: **122° 14' 8.93597"**	Ellipsoidal Hgt: **78.82800 m.**
	PTM Coordinates	
Northing: **1176896.034 m.**	Easting: **416226.997 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,176,484.10**	Easting: **416,256.32**	Zone: **51**

Location Description

ILO-85
From Iloilo City, travel W for about 40 km. to the Mun. of Miag-ao. Then proceed directly to the Town Plaza, where the station is located. Station is located at the corner of a planting strip and sidewalk, about 14 m. fronting the Rizal monument. Mark is the head of a 4 in. copper nail set flushed on top of a 30 cm. x 30 cm. concrete monument protruding 20 cm. above the ground, with inscriptions "ILO-85 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-836**

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

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

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

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. ILO-86

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **ILOILO**	
	Station Name: **ILO-86**	
	Order: **2nd**	
Island: **VISAYAS**		Barangay: **BARANGAY 3 POBLACION**
Municipality: **IGBARAS**		
	PRS92 Coordinates	
Latitude: **10° 43' 4.36044"**	Longitude: **122° 15' 48.62123"**	Ellipsoidal Hgt: **47.31500 m.**
	WGS84 Coordinates	
Latitude: **10° 42' 59.99043"**	Longitude: **122° 15' 53.84473"**	Ellipsoidal Hgt: **104.07600 m.**
	PTM Coordinates	
Northing: **1185222.285 m.**	Easting: **419435.758 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,184,807.44**	Easting: **419,463.96**	Zone: **51**

Location Description

ILO-86
From Iloilo City, travel W to the Mun. of Igbaras. Then proceed directly to the Town Plaza, where the station is located. Station is located about 12 m. from the circular fountain at the center of the said plaza.

Mark is the head of a 4 in. copper nail set flushed on top of a 30 cm. x 30 cm. concrete monument protruding 20 cm. above the ground, with inscriptions "ILO-86 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-837**

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

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

CIP/4701/12/09/814

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

5. IL-533

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

March 02, 2015

CERTIFICATION

To whom it may concern:

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

Province: **ILOILO**
Station Name: **IL-533**

Island: **PANAY**	Municipality: **SAN JOAQUIN**	Barangay: **AMBOYU-AN**
Elevation: **8.0971 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude: **10° 32' 45.00000"**	Longitude: **122° 4' 42.48000"**	

Location Description

BM IL-533
Station is located at the sidewalk of Ambuyuan bridge 0.30m. from thr edge. Mark is the head of a 4in. copper nail set flush on a cement putty with inscriptions " IL-533, 2007, NAMRIA."

Requesting Party:	**PHIL-LIDAR 1**
Purpose:	**Reference**
OR Number:	**8077754 I**
T.N.:	**2015-0505**

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

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

CIP/4701/12/09/814

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Annex 3. Baseline Processing Report of Reference Points Used

1. IIAP-01

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
IIAP-01 --- ILO-85 (B1)	ILO-85	IIAP-01	Fixed	0.005	0.021	53°20'16"	35787.597	21.428
IIAP-01 --- ILO-85 (B2)	ILO-85	IIAP-01	Fixed	0.004	0.019	53°20'16"	35787.597	21.398

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	ILO-85				
Grid		Local		Global	
Easting	416256.319 m	Latitude	N10°38'33.11352"	Latitude	N10°38'28.75996"
Northing	1176484.099 m	Longitude	E122°14'03.70561"	Longitude	E122°14'08.93597"
Elevation	22.539 m	Height	21.962 m	Height	78.828 m

To:	IIAP-01				
Grid		Local		Global	
Easting	445007.365 m	Latitude	N10°50'08.21923"	Latitude	N10°50'03.83971"
Northing	1197773.997 m	Longitude	E122°29'48.82359"	Longitude	E122°29'54.03518"
Elevation	42.806 m	Height	43.390 m	Height	100.449 m

Vector					
ΔEasting	28751.046 m	NS Fwd Azimuth	53°20'16"	ΔX	-22136.041 m
ΔNorthing	21289.898 m	Ellipsoid Dist.	35787.597 m	ΔY	-18716.081 m
ΔElevation	20.268 m	ΔHeight	21.428 m	ΔZ	20987.226 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.009 m
σ ΔElevation	0.011 m	σ ΔHeight	0.011 m	σ ΔZ	0.003 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000339995		
Y	-0.0000470076	0.0000752539	
Z	-0.0000131643	0.0000196178	0.0000077986

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 S. SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist (SSRS)	GEROME HIPOLITO	UP-TCAGP
	Research Associate (RA)	REGINA FELISMINO	UP-TCAGP
		KRISTINE ANDAYA	UP-TCAGP
		VERLINA TONGA	UP-TCAGP
		REMEDIOS VILLANUEVA	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	KENNETH QUISADO	UP-TCAGP
		IRO ROXAS	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. SHERWIN ALFONSO III	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. FERDINAND DE OCAMPO	AAC
		CAPT. BRYAN DONGUINES	AAC
		CAPT. JUSTINE JOYA	AAC

Annex 5. Data Transfer Sheet for Ipayo Floodplain

DATA TRANSFER SHEET
03/23/2015(Ipayo pegs)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
14-Feb-15	2569P	1BLK43D045A	pegasus	1.23	640	6.86	196	10.6	36/48	14.4	na	10.5	1KB	1KB	76	na	Z:\DAC\RAW DATA
16-Feb-15	2579P	1BLK43M047B	pegasus	1.77	1.21	10.4	221	26.4	251	19.1	na	12.2	1KB	1KB	77/18	na	Z:\DAC\RAW DATA
17-Feb-15	2582P	1BLK43MN048A	pegasus	2.06	1.35	9.59	263	34.3	285	21.4	na	20.2	1KB	1KB	76/77/21	na	Z:\DAC\RAW DATA
17-Feb-15	2583P	1BLK43D048B	pegasus	1.11	710	6.06	170	14	127	11.4	na	20.2	1KB	1KB	86/70	na	Z:\DAC\RAW DATA
18-Feb-15	2585P	1BLK43EF049A	pegasus	2.91	1.71	5.97	203	42	214	27.8	na	14.3	1KB	1KB	99/117	na	Z:\DAC\RAW DATA
18-Feb-15	2587P	1BLK43ED049B	pegasus	1.7	1.02	5.05	190	15.5	98/71	17.4	na	7.46	1KB	1KB	1/22/177	na	Z:\DAC\RAW DATA
19-Feb-15	2589P	1BLK43EFD050A	pegasus	1.2	739	7.76	417	17.3	133	12.3	na	16.7	1KB	1KB	86/77/626/02 1	na	Z:\DAC\RAW DATA
19-Feb-15	2591P	1BLK37I050B	pegasus	5.53	1.82	8.47	189	45.9	343	25.3	na	9.75	1KB	1KB	64	na	Z:\DAC\RAW DATA
20-Feb-15	2593P	1BLK43BDG051A	pegasus	3.14	1.01	7.62	213	27	216	16.3	na	11	1KB	1KB	114	na	Z:\DAC\RAW DATA
21-Feb-15	2597P	1BLK43N052A	pegasus	2.09	1.29	8.69	257	37.9	274	21	na	11.5	1KB	1KB	32	na	Z:\DAC\RAW DATA
22-Feb-15	2601P	1BLK37IFV053A	pegasus	2.13	1.27	9.06	225	32.2	256	20.7	na	17.7	1KB	1KB	101/76	na	Z:\DAC\RAW DATA

Received from

Name C. JOAQUIN
Position RA
Signature

Received by

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

Annex 6. Flight logs

1. Flight Log for 2569P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2569

1 LiDAR Operator: V. Tonga	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43D045A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: B. Donguines	9 Route:			
10 Date: 02 - 14 - 2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1027	14 Engine Off: 1356	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	cloudy				

20 Remarks:

Moved to and surveyed BLK43D.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[signature]	LEE JAY PUNZALAN [signature]	C. Alfonso III [signature]	[signature]
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

2. Flight Log for 2583P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2583

1 LiDAR Operator: MR Villanueva	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43D048B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9022
7 Pilot: A. Alfonso	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 02-17-2016	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1428	14 Engine Off: 1721	15 Total Engine Time: 2+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Moved to and surveyed BLK 43D

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[signature]	LJ Pumarian [signature]	C. Alfonso III [signature]	MR Villanueva [signature]
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

3. Flight Log for 2587P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2587

1 LiDAR Operator: KJ. Andaya	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43ED049B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 02 - 18 - 2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1407	14 Engine Off: 1754	15 Total Engine Time: 3+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: fair					

20 Remarks:

Surveyed voids over BLK 43E and gaps over BLK 43D.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[signature]	LJ Puzalan [signature]	C. Alfonso III [signature]	KJ Andaya [signature]
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

4. Flight Log for 2589P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2589

1 LiDAR Operator: MR Villanueva	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43EFD050A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joya	9 Route:			
10 Date: 02-19-2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0818	14 Engine Off: 1159	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	fair				

20 Remarks:

Surveyed BLK 43EF and voids over BLK 43D.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	LJ Pun... Signature over Printed Name (PAF Representative)	C. Alfonso III Signature over Printed Name	MR Villanueva Signature over Printed Name

5. Flight Log for 2593P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 2593

1 LiDAR Operator: I. Roxas	2 ALTM Model: Pegasus	3 Mission Name: 1BLK43BD051A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-9022
7 Pilot: C. Alfonso	8 Co-Pilot: J. Joyd	9 Route:			
10 Date: 02 - 20 - 2015	12 Airport of Departure (Airport, City/Province): Iloilo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1341	14 Engine Off: 1710	15 Total Engine Time: 3+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: fair					
20 Remarks: Surveyed BLK 43B and voids over BLK 43D and 43G.					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. Hipolito	LJ Puyaran	C. Alfonso III	I. Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Annex 7. Flight Status Reports

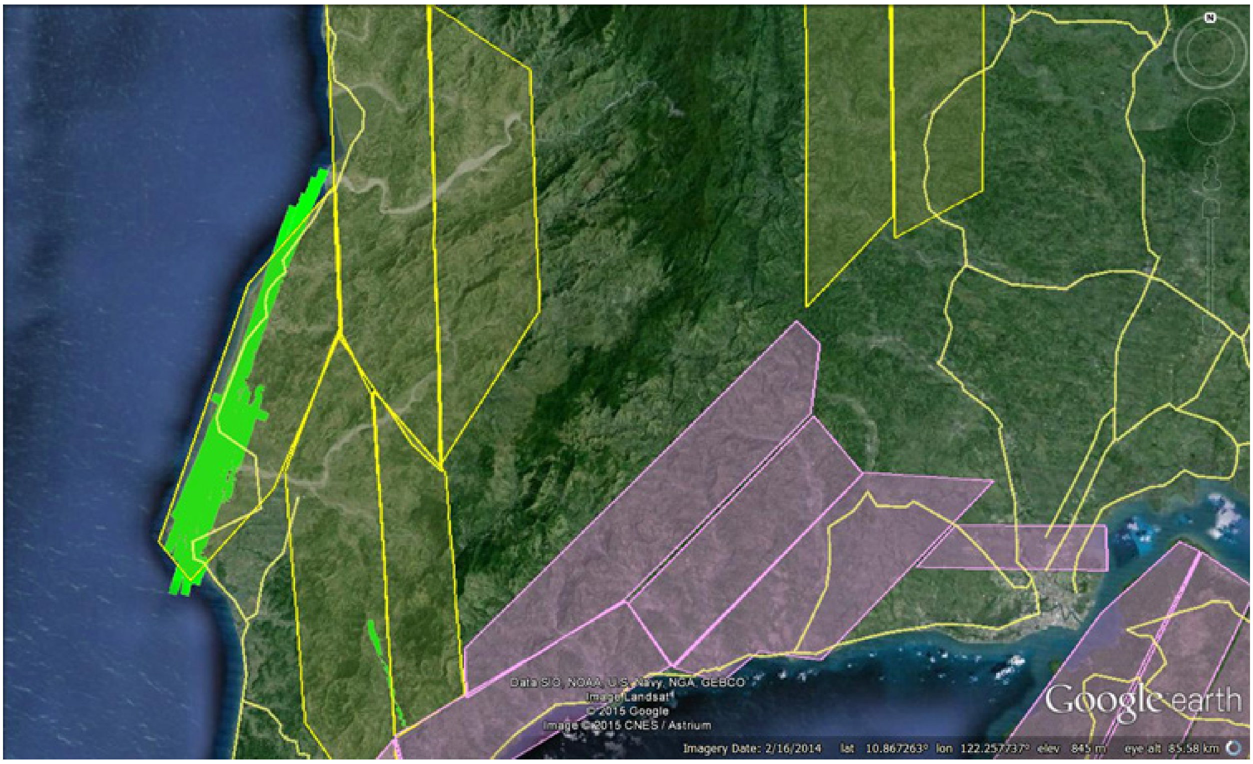
FLIGHT STATUS REPORT
ILOILO
February 14 - 20, 2015

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
2569P	BLK 43D	1BLK43D045A	MVE TONGA	14 FEB 15	Moved to and surveyed BLK 43D
2583P	BLK 43D	1BLK43D048B	MR VILLANUEVA	17 FEB 15	Moved to and surveyed BLK43D
2587P	BLK 43E, 43D	1BLK43ED049B	KJ ANDAYA	18 FEB 15	Surveyed voids on BLK43E and gaps on BLK43D
2589P	BLK 43E, 43F, 43D	1BLK43EFD050A	MR VILLANUEVA	19 FEB 15	Surveyed BLK 43E to 43F and voids on BLK43D
2593P	BLK 43B, 43D, 43G	1BLK43BDG051A	IRO ROXAS	20 FEB 15	Surveyed BLK43B and voids on BLK 43D and 43G

LAS BOUNDARIES PER FLIGHT

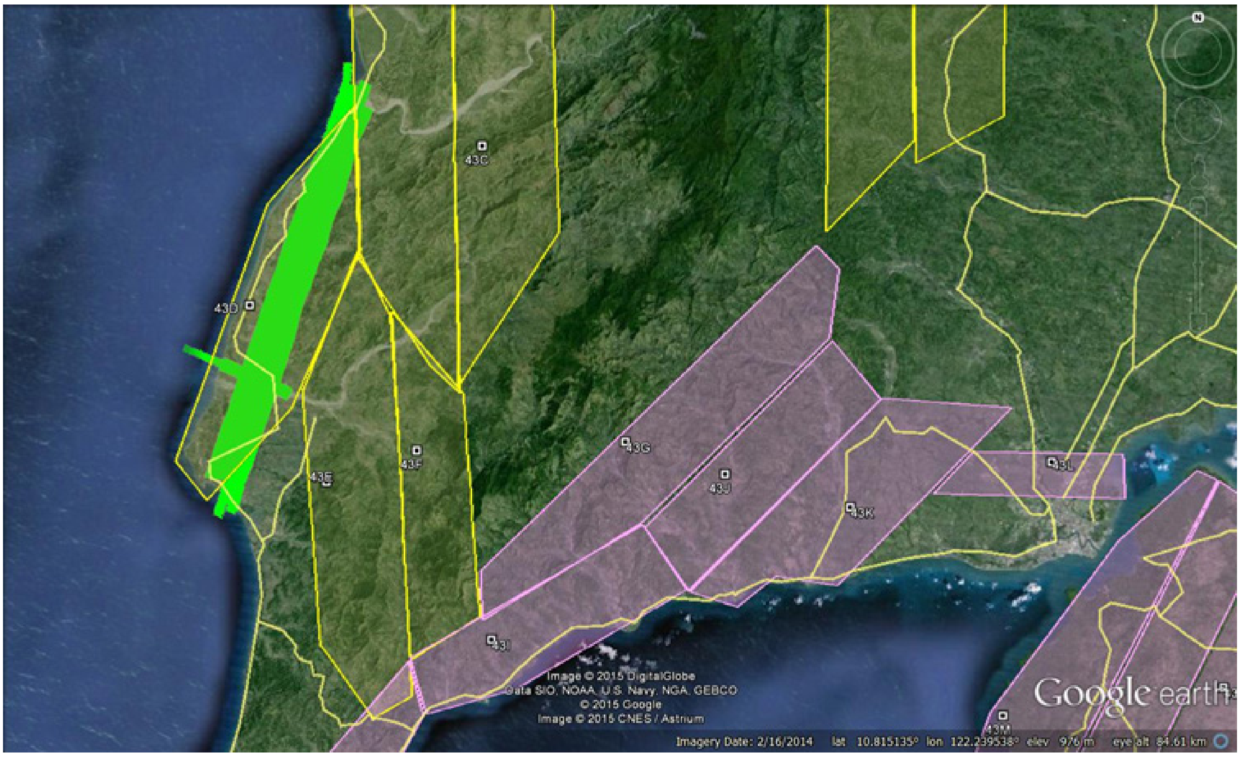
Flight No.:	2569P	
Area:	BLK43D	
Mission Name:	1BLK43D045A	
Parameters:	Altitude: 1100;	Scan Frequency: 50;
	Scan Angle: 25;	Overlap: 30%

LAS



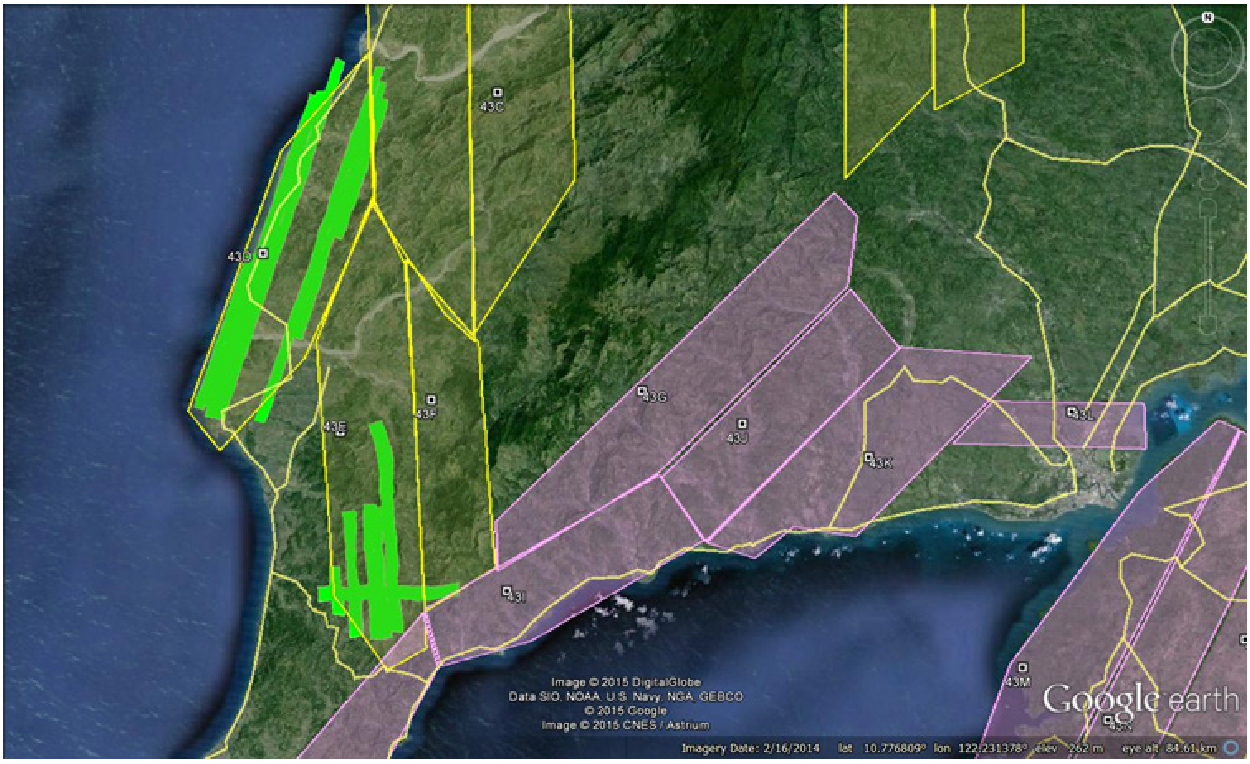
Flight No.:	2583P	
Area:	BLK 43D	
Mission Name:	1BLK43D048B	
Parameters:	Altitude: 1100;	Scan Frequency: 50;
	Scan Angle: 25;	Overlap: 30%

LAS



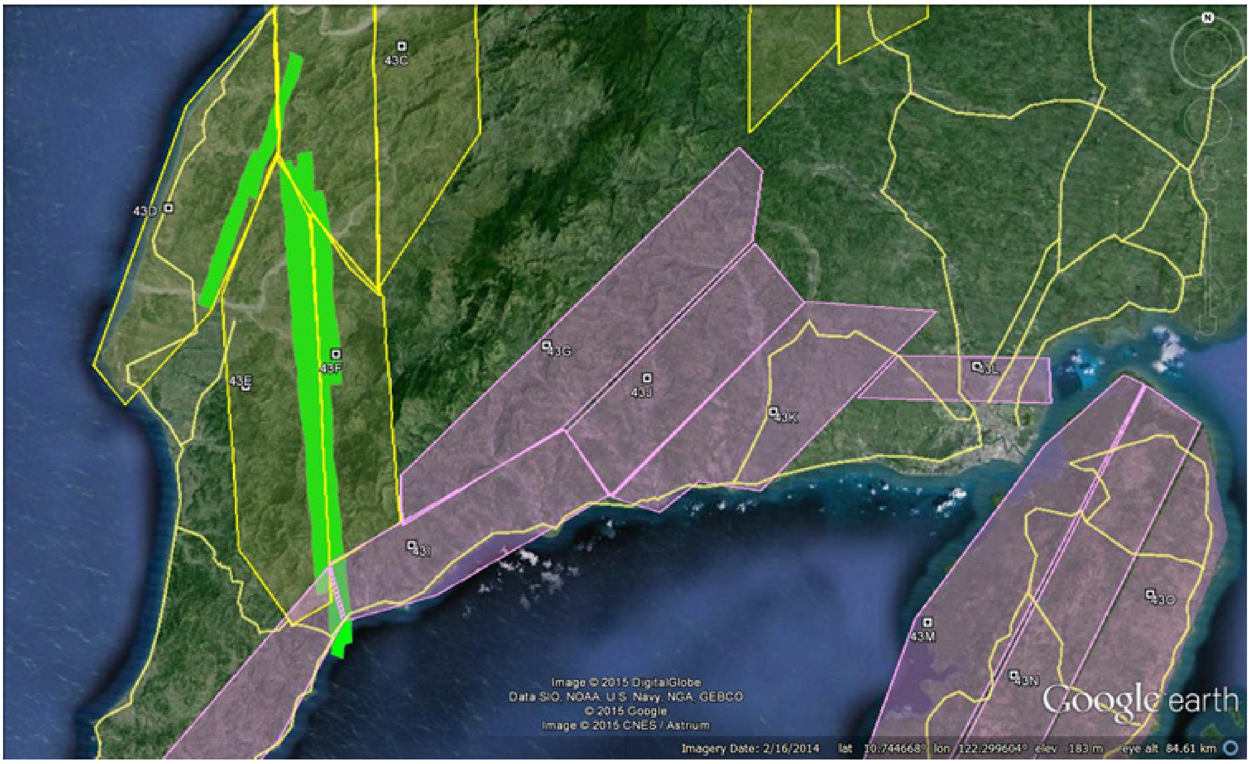
Flight No.:	2587P	
Area:	BLK 43E & 43D	
Mission Name:	1BLK43EF049B	
Parameters:	Altitude: 1100;	Scan Frequency: 50;
	Scan Angle: 20;	Overlap: 30%

LAS



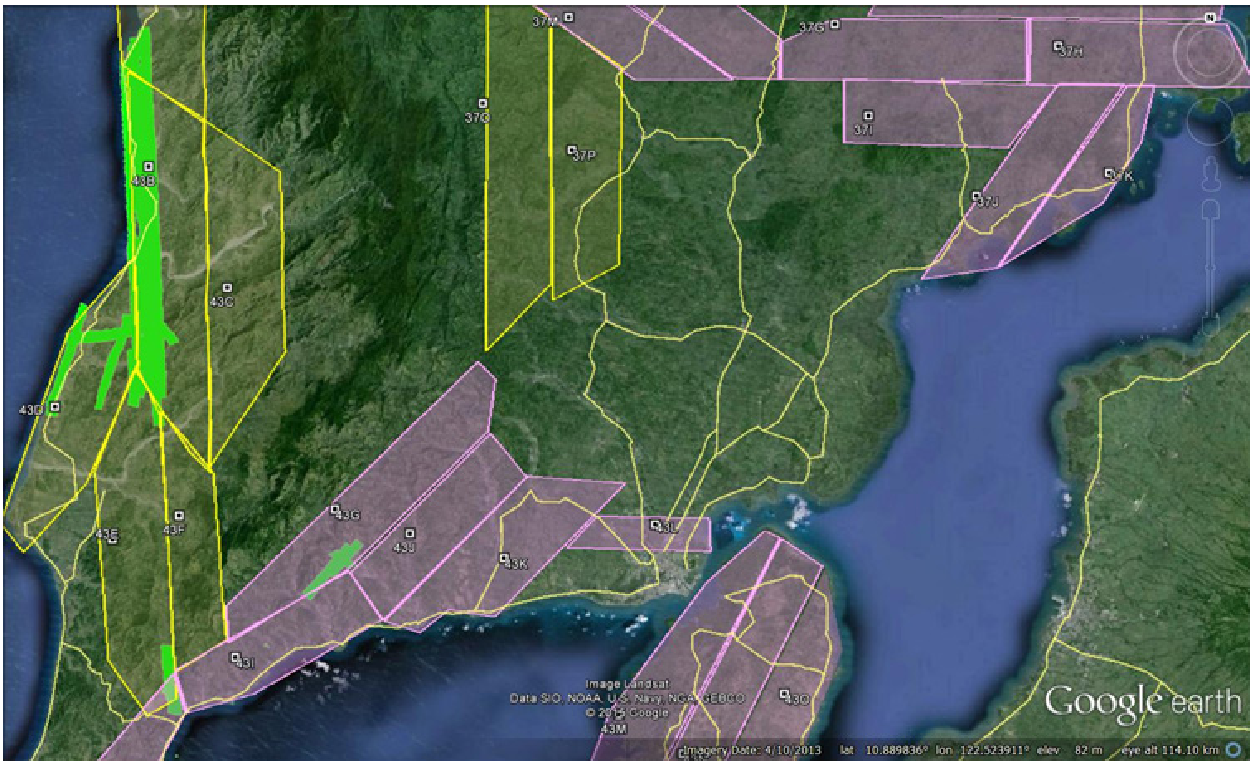
Flight No.:	2589P	
Area:	BLK 43E, 43F & 43D	
Mission Name:	1BLK43EF050A	
Parameters:	Altitude: 1100;	Scan Frequency: 50;
	Scan Angle: 20;	Overlap: 30%

LAS



Flight No.:	2593P	
Area:	BLK 43B, 43D & 43G	
Mission Name:	1BLK43BC051A	
Parameters:	Altitude: 1100;	Scan Frequency: 50;
	Scan Angle: 20;	Overlap: 30%

LAS



Annex 8. Mission Summary Reports

Flight Area	Iloilo
Mission Name	Blk43B
Inclusive Flights	2593P
Range data size	16.3 GB
POS	213 MB
Image	27 GB
Base data size	11.0 MB
Transfer date	March 23, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.01
RMSE for East Position (<4.0 cm)	1.56
RMSE for Down Position (<8.0 cm)	3.33
Boresight correction stdev (<0.001deg)	0.000371
IMU attitude correction stdev (<0.001deg)	0.000661
GPS position stdev (<0.01m)	0.0091
Minimum % overlap (>25)	25.93%
Ave point cloud density per sq.m. (>2.0)	2.57
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	200
Maximum Height	594.49 m
Minimum Height	54.70 m
Classification (# of points)	
Ground	152,186,273
Low vegetation	75,056,947
Medium vegetation	152,053,797
High vegetation	281,227,721
Building	4,634,683
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Harmond Santos, Engr. Melissa Fernandez

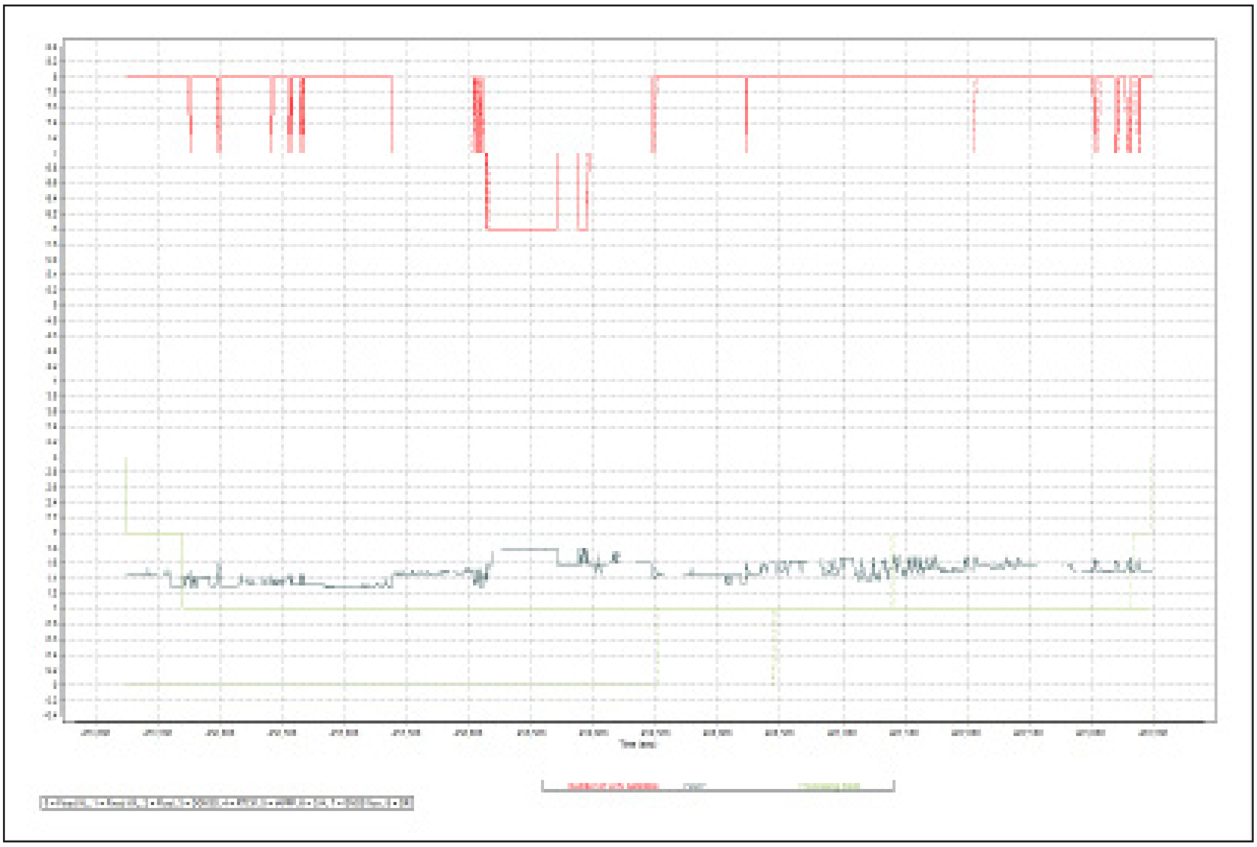


Figure A-8.1. Solution Status

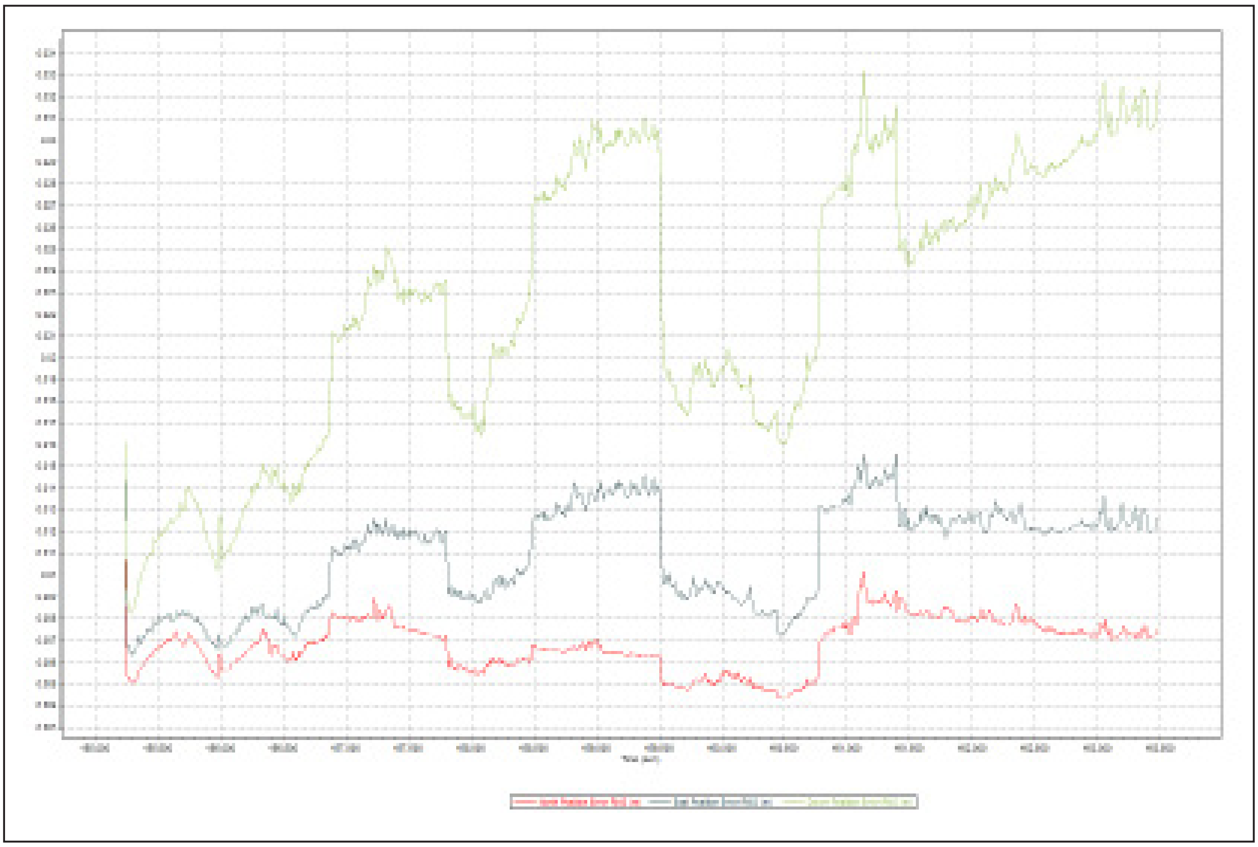


Figure A-8.2. Smoothed Performance Metric Parameters

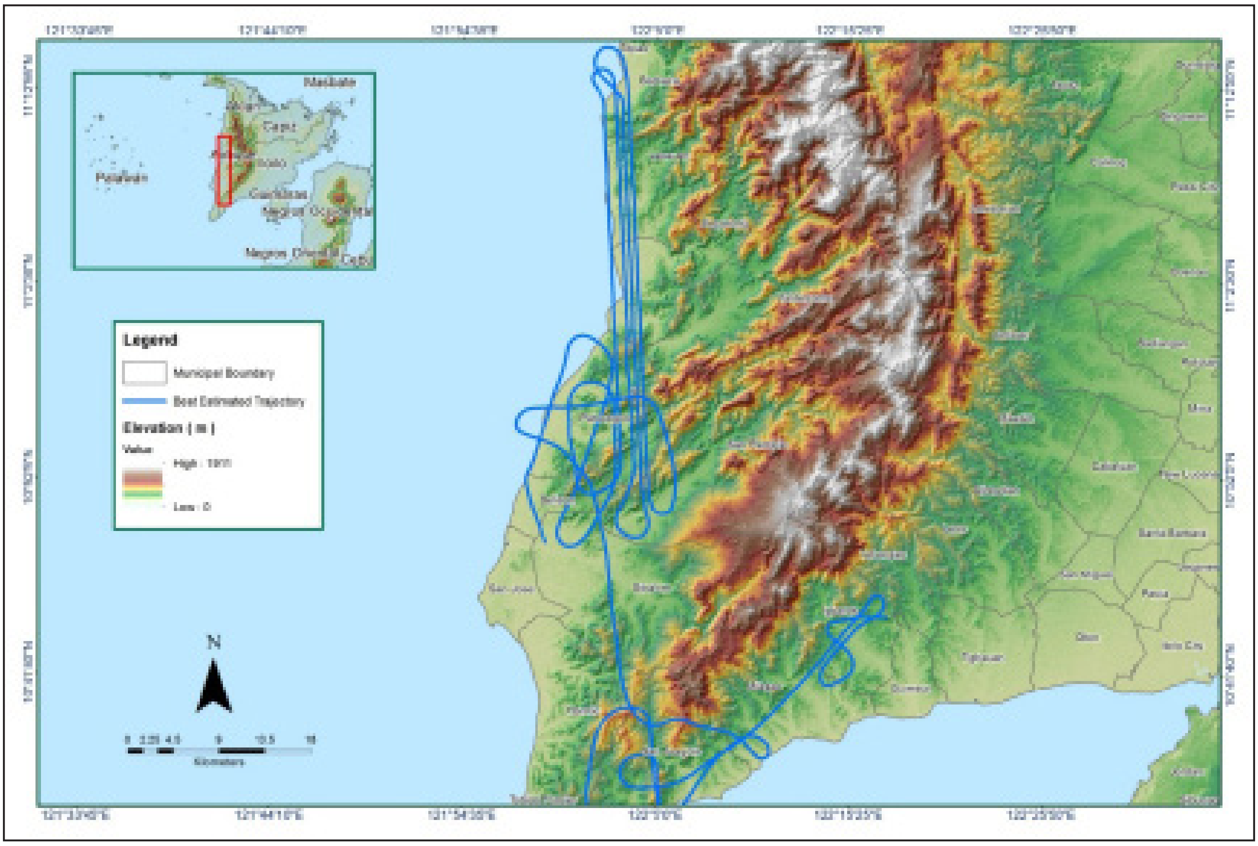


Figure A-8.3. Best Estimated Trajectory

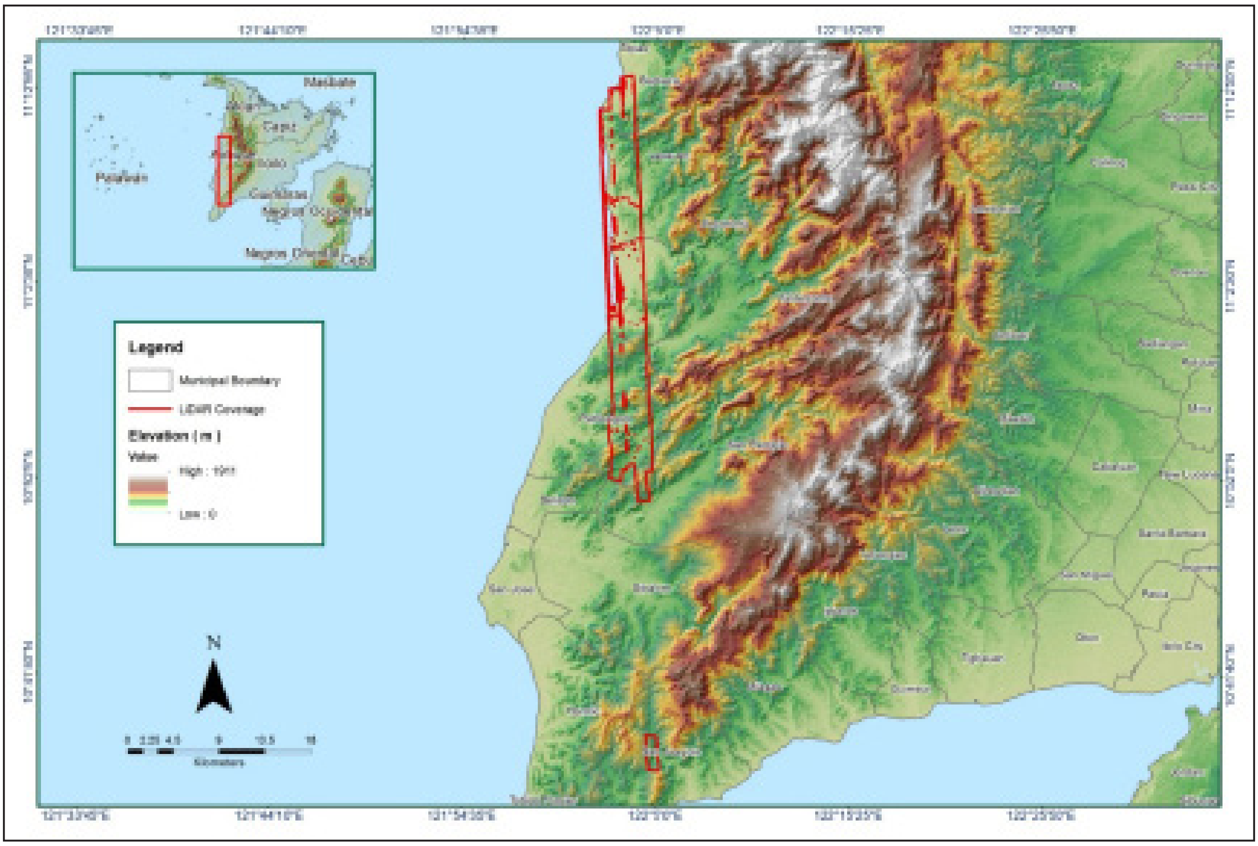


Figure A-8.4. Coverage of LiDAR data

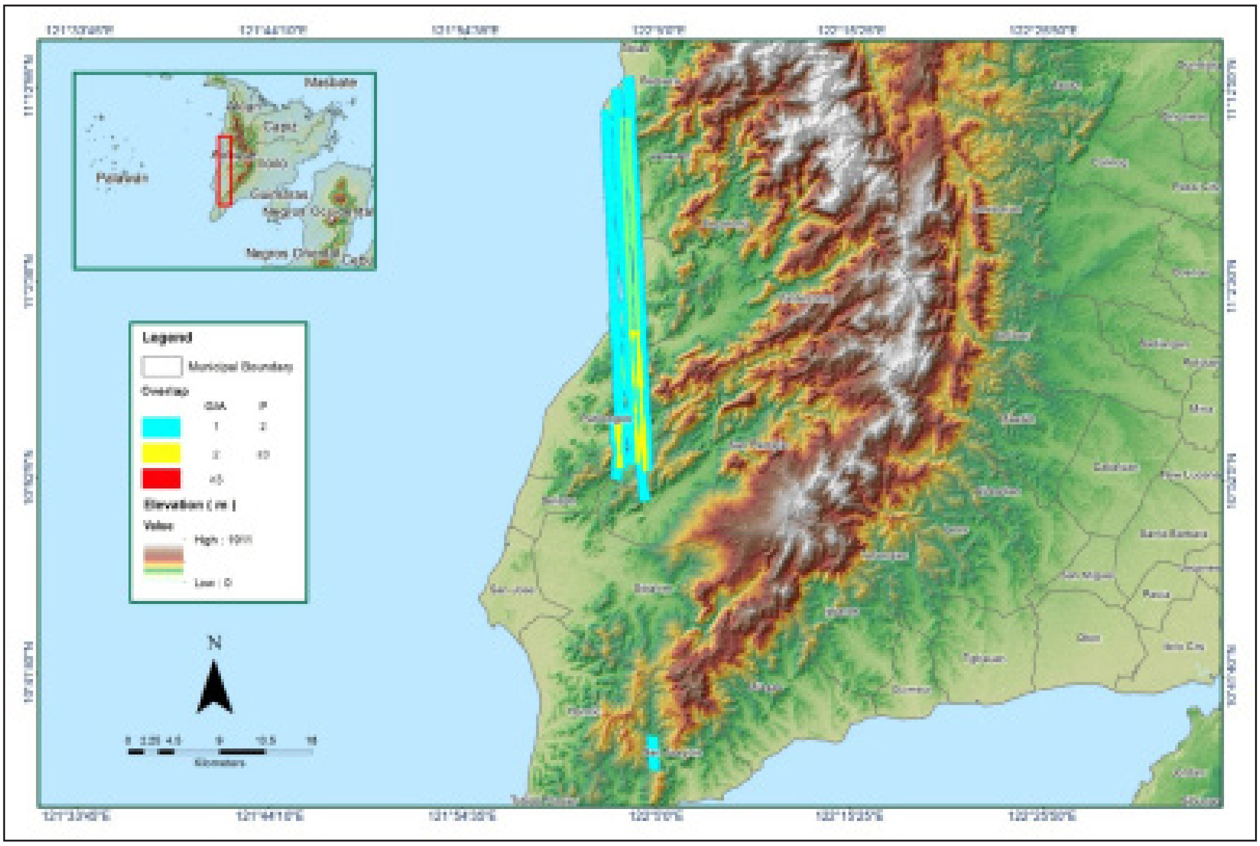


Figure A-8.5. Image of data overlap

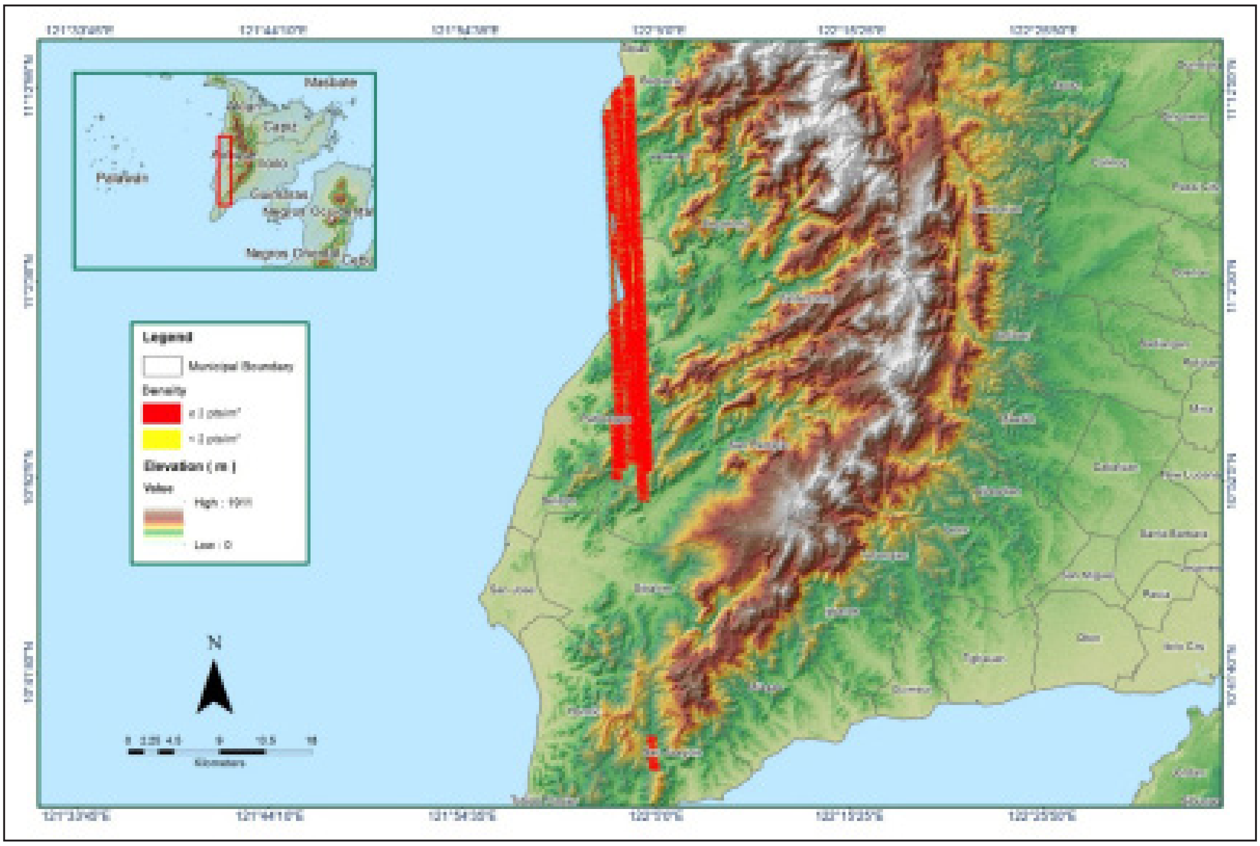


Figure A-8.6. Density map of merged LiDAR data

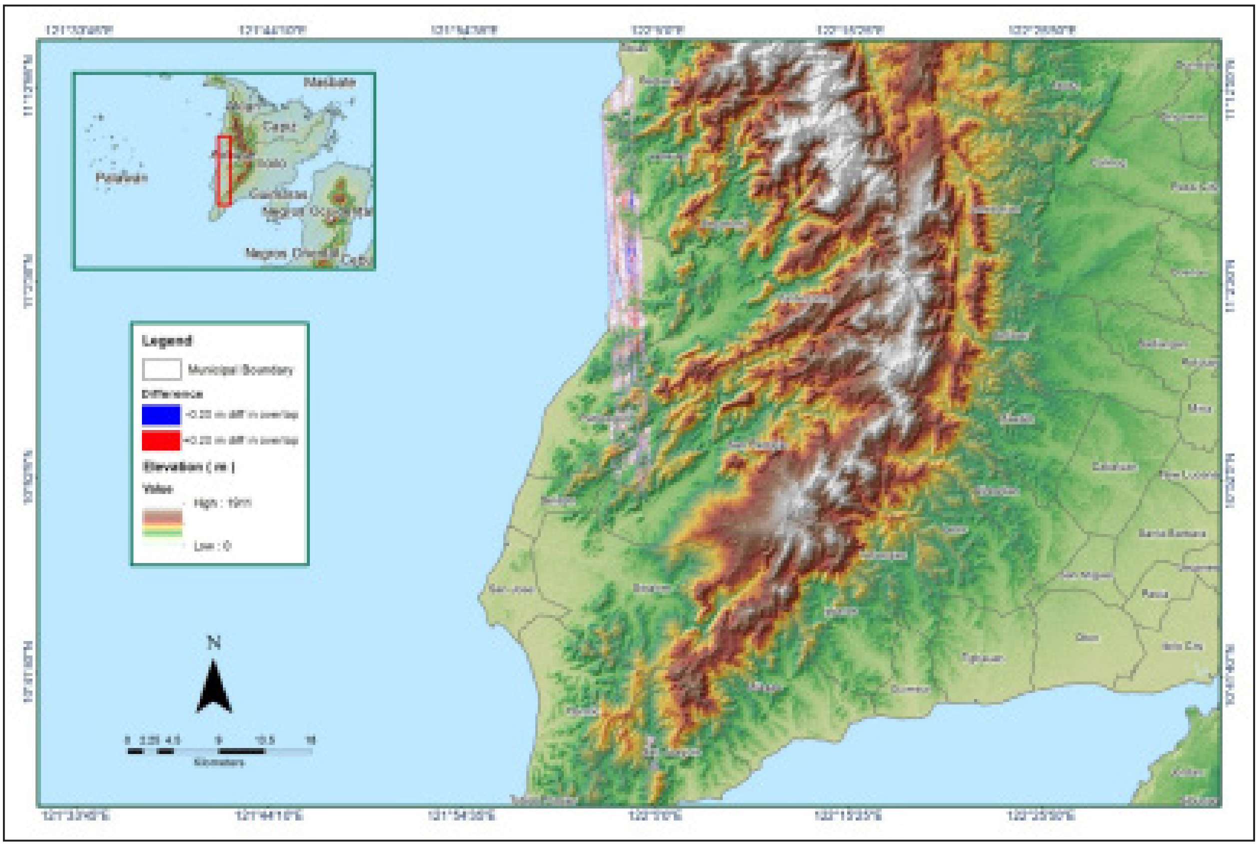


Figure A-8.7. Elevation difference between flight lines

Flight Area	Iloilo
Mission Name	Blk43D
Inclusive Flights	2569P, 2583P, 2587P, 2589P, 2593P
Range data size	71.8 GB
POS	999 MB
Image	88.8 GB
Base data size	65.86 MB
Transfer date	March 23, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.26
RMSE for East Position (<4.0 cm)	2.44
RMSE for Down Position (<8.0 cm)	5.4
Boresight correction stdev (<0.001deg)	0.000352
IMU attitude correction stdev (<0.001deg)	0.001171
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	42.59%
Ave point cloud density per sq.m. (>2.0)	3.67
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	280
Maximum Height	545.37 m
Minimum Height	52.12 m
Classification (# of points)	
Ground	301,021,823
Low vegetation	227,535,345
Medium vegetation	270,806,989
High vegetation	177,871,908
Building	13,231,101
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Analyn Naldo, Engr. Edgardo Gubatanga Jr., Engr. Krisha Bautista

Figure A-8.8. Solution Status

Figure A-8.9. Smoothed Performance Metric Parameters

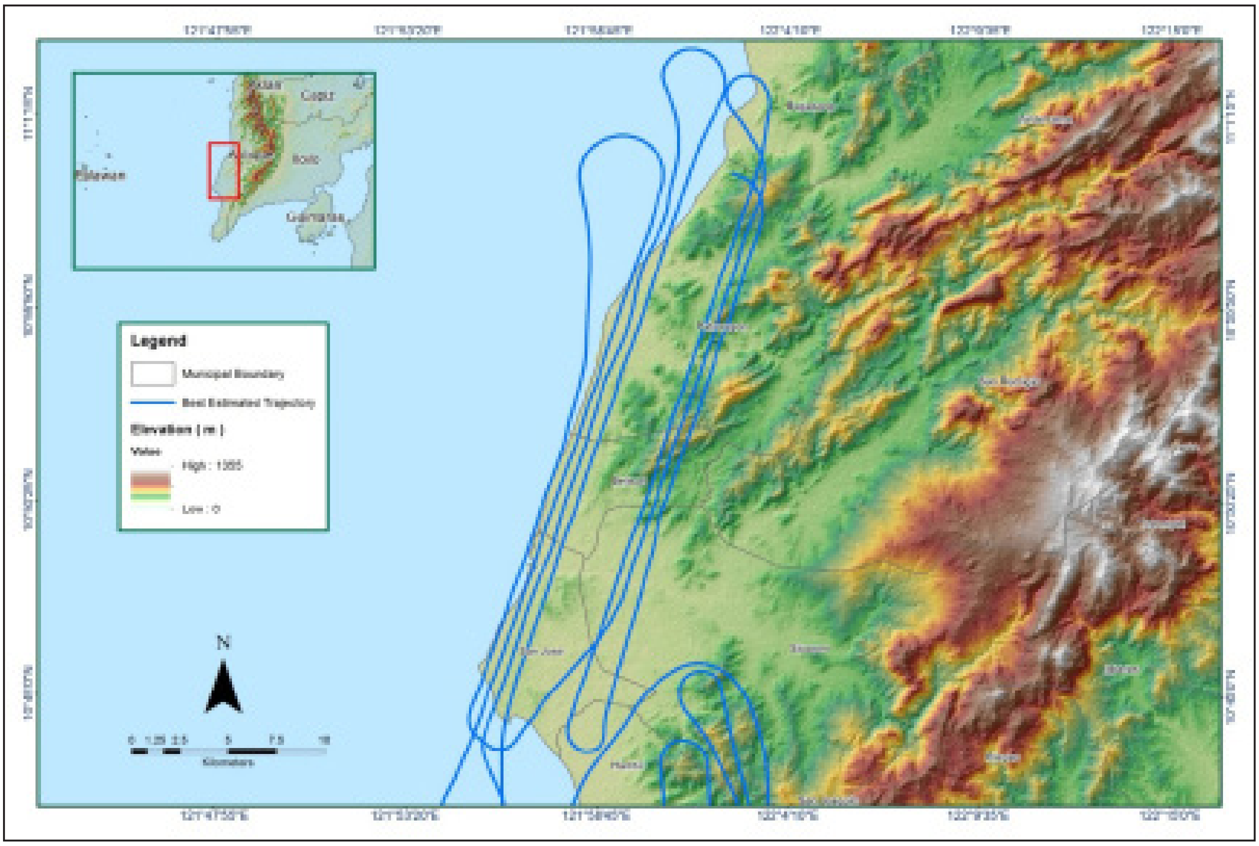


Figure A-8.10. Best Estimated Trajectory

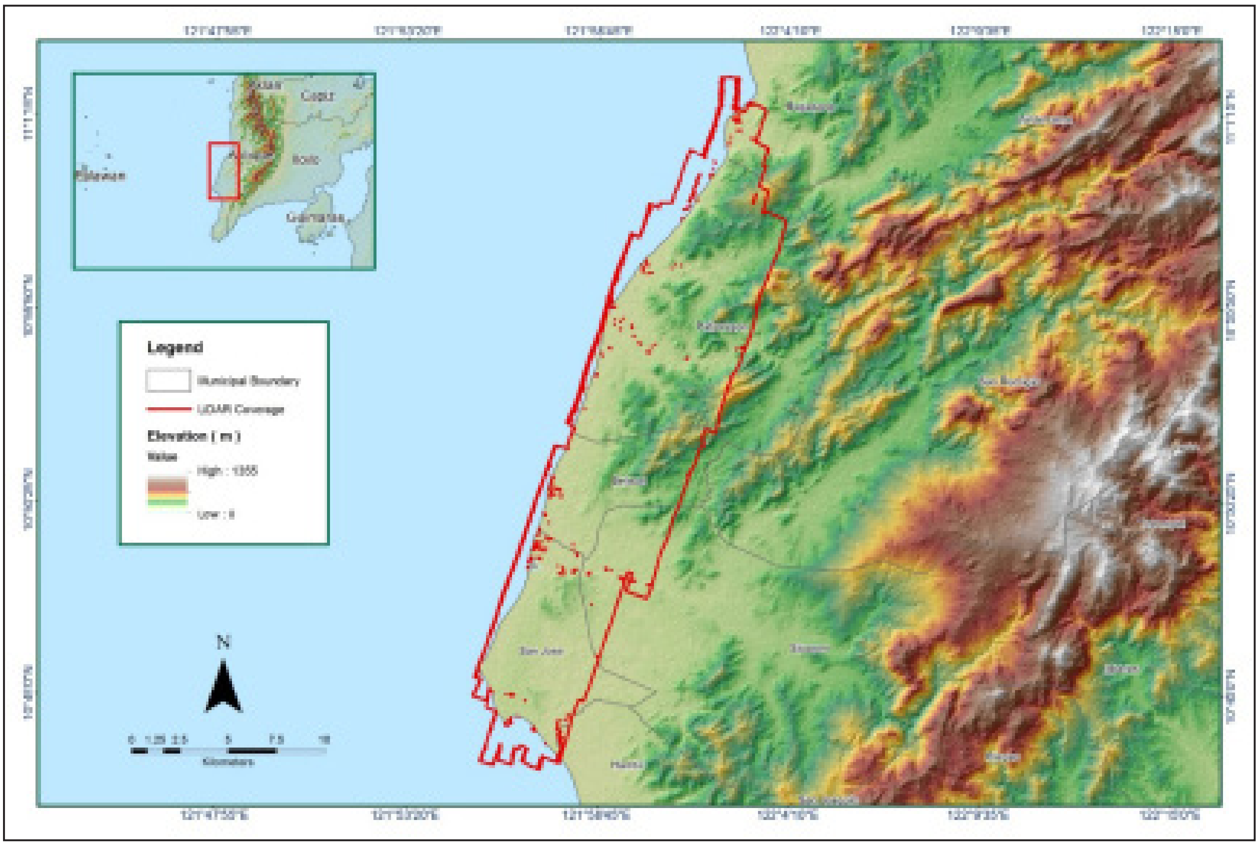


Figure A-8.11. Coverage of LiDAR data

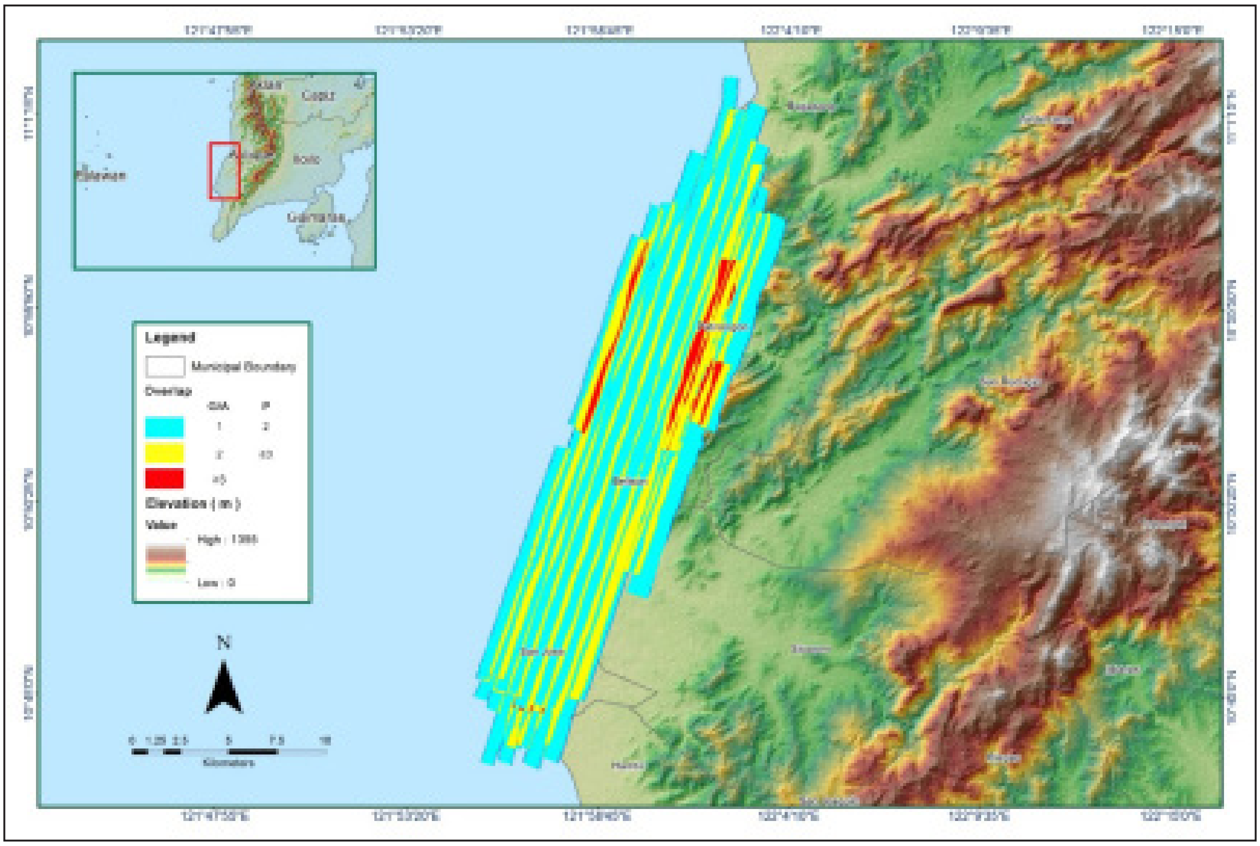


Figure A-8.12. Image of data overlap

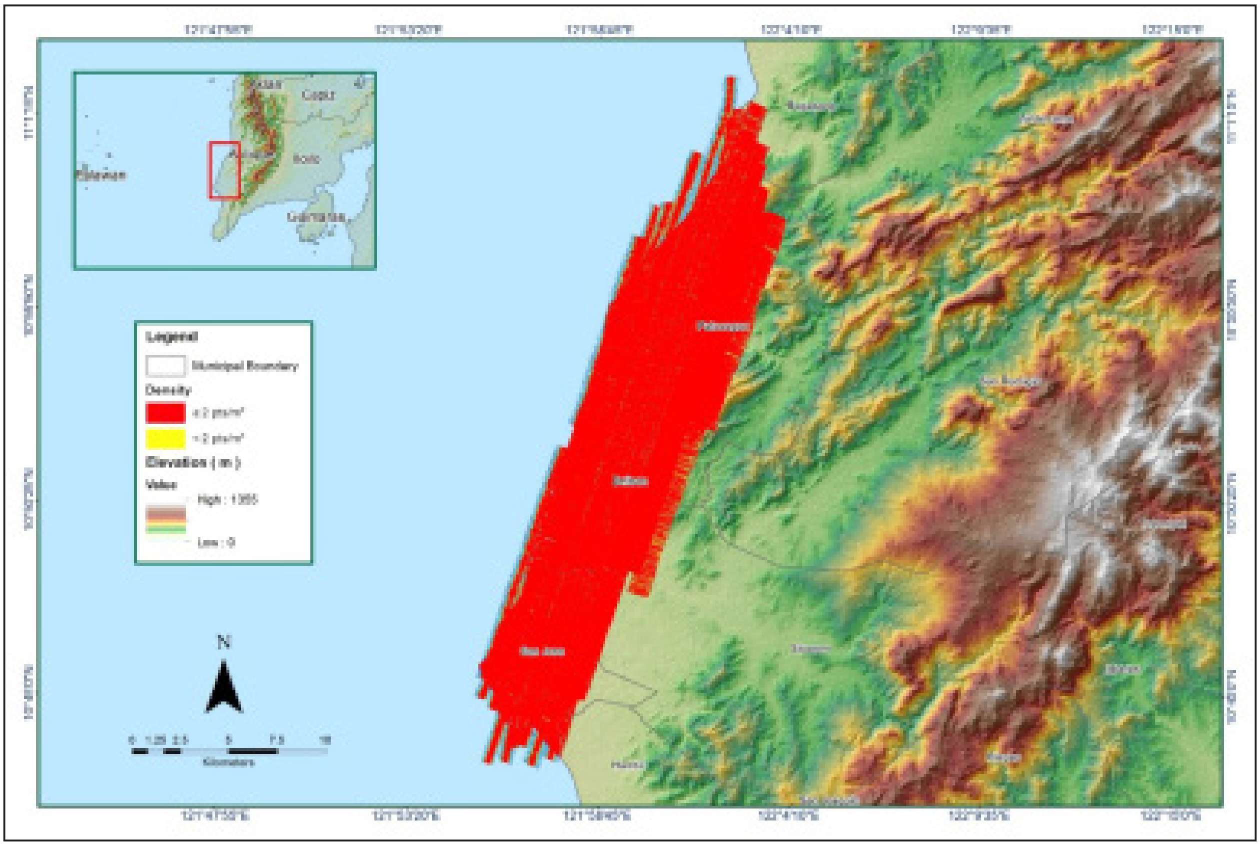


Figure A-8.13. Density map of merged LiDAR data

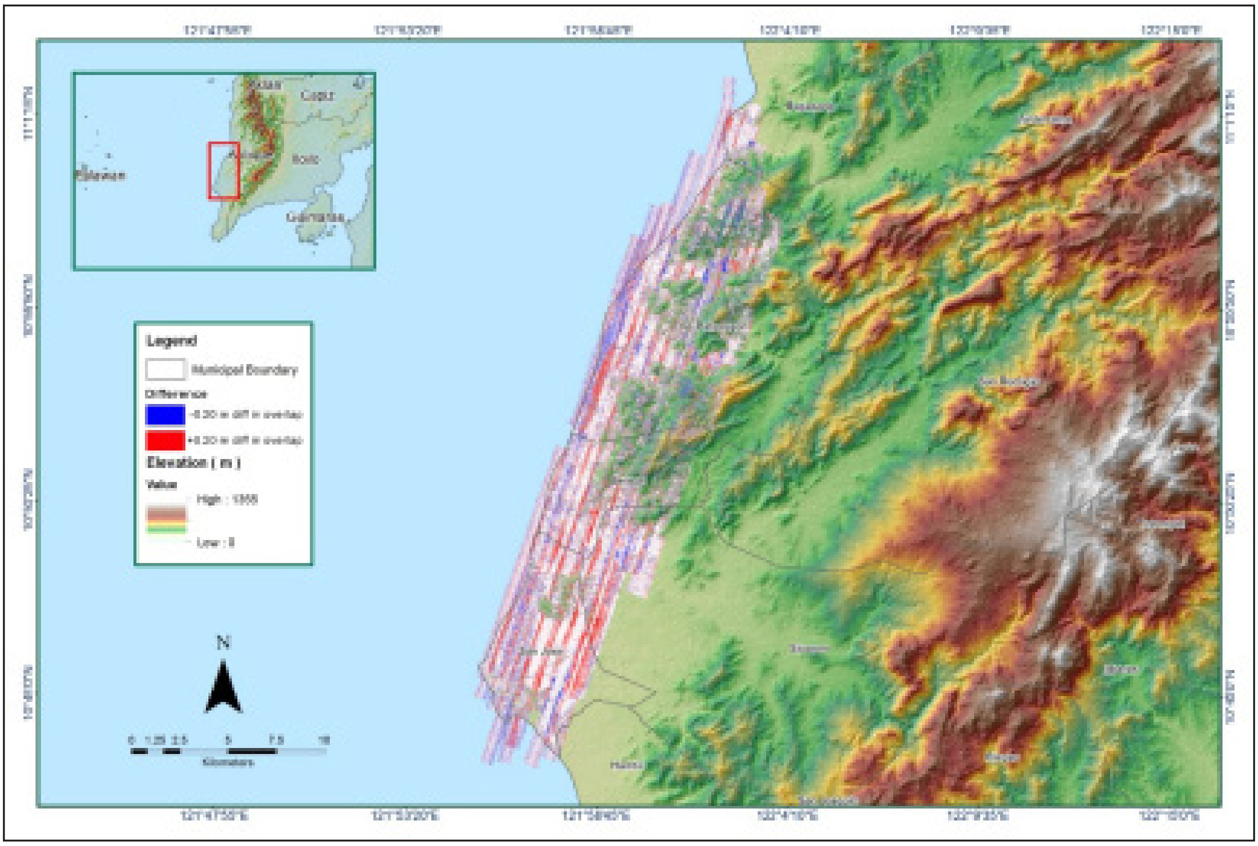


Figure A-8.14. Elevation difference between flight lines

Annex 9. Ipayo 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
W100	58.90744	68.6448	1	0.101455	1.65575	Discharge	3.154	0.09	Ratio to Peak	0.6
W110	32.45886	84.972	1	0.12403	2.0242	Discharge	11.053	0.09	Ratio to Peak	0.6
W120	52.7806	71.8428	1	0.070305	1.14735	Discharge	2.15	0.09	Ratio to Peak	0.6
W130	50.73956	72.9756	1	0.15477	2.52585	Discharge	8.9	0.09	Ratio to Peak	0.6
W140	46.48388	75.4548	1	0.175815	2.86935	Discharge	10.983	0.09	Ratio to Peak	0.6
W80	80.9534	59.1672	1	0.319675	5.217	Discharge	18.519	0.09	Ratio to Peak	0.6
W90	31.78182	85.4928	1	0.074655	1.21835	Discharge	4.68	0.09	Ratio to Peak	0.6

Annex 10. Ipayo Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R20	Automatic Fixed Interval	2288.4	0.0122277	0.0001	Trapezoid	60.385	1
R40	Automatic Fixed Interval	5348.8	0.0026872	0.0001	Trapezoid	60.385	1
R50	Automatic Fixed Interval	861.54	0.0076945	0.0001	Trapezoid	60.385	1

Annex 11. Ipayo Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
0	10.9130535	121.9909312	0.03	0	0.001		
1	10.91279996	121.9888281	0.03	0	0.001		
2	10.92557348	121.9852357	0.03	0.3	0.073		
3	10.91323617	121.991045	0.09	0	0.008		
4	10.91501587	121.9976446	0.03	0	0.001		
5	10.91346917	121.984834	0.03	0	0.001		
6	10.91393553	121.9921695	0.06	0	0.004		
7	10.91697546	121.9911148	0.11	3	8.352	Frank	100-Year
8	10.91233871	121.9967054	0.03	0	0.001		
9	10.91250337	121.9958056	0.04	0	0.002		
10	10.92488725	121.9956891	0.03	0	0.001		
11	10.9132918	121.9976392	0.03	0	0.001		
12	10.91091457	121.9972054	0.03	0	0.001		
13	10.91426417	121.9847451	0.04	0	0.002		
14	10.92495073	121.995609	0	0	0.000		
15	10.91574247	121.9865037	0.04	0	0.002		
16	10.92001346	121.9831259	1.16	0.2	0.922	Frank	100-Year
17	10.92370593	121.983882	0.03	0.3	0.073		
18	10.92360411	121.9835876	0.03	0.3	0.073		
19	10.91760244	121.9976449	0.67	0	0.449		
20	10.92112001	121.9839764	0.4	0.9	0.250	Frank	100-Year
21	10.9189082	121.9930867	0.47	10.00	90.821	Frank	100-Year
22	10.91244114	121.9895611	0.83	0	0.689		
23	10.91319593	121.984432	0.26	0	0.068		
24	10.91275711	121.9859393	0.34	0	0.116		
25	10.91105115	121.9935261	0.37	0	0.137		
26	10.91376228	121.9823817	1.32	0.1	1.488		
27	10.92296258	121.9834536	0.44	0.3	0.020		
28	10.91200283	121.9961407	0.45	0.9	0.203	Frank	100-Year
29	10.92083962	121.983306	0.2	0.3	0.010		
30	10.92034784	121.9902022	0.48	0.6	0.014	Frank	100-Year
31	10.9216418	121.9962792	0.03	0	0.001		
32	10.92339869	121.9842724	0.1	0.3	0.040		
33	10.92158447	121.9832754	0.03	0.6	0.325		
34	10.9244298	121.9848879	0.04	0.3	0.068		
35	10.92135067	121.983854	0.89	0.9	0.000	Frank	100-Year
36	10.92837626	121.9842496	0.03	0.3	0.073		
37	10.91862347	121.9980153	1.03	0.5	0.281	Frank	100-Year
38	10.91965323	121.9908662	0.03	0	0.001		

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
39	10.91635023	121.9964713	0.35	0.9	0.303	Frank	100-Year
40	10.91815893	121.9987198	1.18	0.5	0.462	Frank	100-Year
42	10.91867633	121.9977527	1	0.5	0.250	Frank	100-Year
43	10.91899385	121.997772	1.06	0.5	0.314	Frank	100-Year
44	10.91959422	121.9894087	0.95	0.9	0.002	Frank	100-Year
45	10.91835652	121.9985965	1.12	0.5	0.384	Frank	100-Year
46	10.92227519	121.9836524	0.34	0.3	0.002		
47	10.92435083	121.9852787	0.42	0.3	0.014		
48	10.91816655	121.9987992	0	0.5	0.250	Frank	100-Year
50	10.91917548	121.9976474	0.69	0.5	0.036	Frank	100-Year
51	10.91414583	121.982728	0.44	0.1	0.116		
52	10.92091783	121.9901842	0.06	0.6	0.292		
53	10.9207254	121.9899349	0.08	0.6	0.270		
54	10.91962897	121.9968722	0.98	0.5	0.230	Frank	100-Year
55	10.92477138	121.9959141	0.51	0	0.260		
57	10.92655301	121.9964622	1.1	0.5	0.360	Frank	100-Year
58	10.91767758	121.9979352	0.93	0.5	0.185	Frank	100-Year
59	10.92104235	121.9960557	0.74	0	0.548		
60	10.91943377	121.9977696	1.57	0.5	1.145	Frank	100-Year
61	10.91120616	121.9941186	1.76	1.5	0.068		
62	10.91953586	121.9830521	0.65	0.4	0.063		
63	10.92137047	121.9898613	1.09	0.6	0.240		
64	10.9216364	121.9841963	1.74	0.9	0.706	Frank	100-Year
65	10.92003931	121.9965164	0.87	0.4	0.221		
66	10.92112915	121.9960547	0	0	0.000		
67	10.91561103	121.9976039	1.07	1.47	0.160		
68	10.919671	121.9830154	0	0.2	0.040	Frank	100-Year
69	10.9259448	121.9848519	0.74	0.3	0.194		
70	10.91254825	121.9885475	0.94	0	0.884		
71	10.92158179	121.9835186	0.51	0.6	0.008		
73	10.91971511	121.9909988	0.18	0	0.032	Frank	100-Year
74	10.92462941	121.9838276	0.99	0.3	0.476		
75	10.92586712	121.9851891	0.8	0.3	0.250		
76	10.91968891	121.9911496	0.03	0	0.001		
77	10.92037826	121.9964777	1.09	0.4	0.476		
78	10.91923646	121.9963177	0.93	0.2	0.533	Yolanda	5-Year
80	10.91080004	121.9931048	1.34	0	1.796		
81	10.91273156	121.9835811	0.89	0	0.792		
82	10.91120993	121.9915245	1.3	0.21	1.188	Undang	5-Year
83	10.91099332	121.9941389	2.65	1.5	1.323		
84	10.91505297	121.9979017	0.03	1.5	2.161	Frank	100-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
85	10.91188794	121.9919407	5.05	0.3	22.563	Nitang	5-Year
86	10.92166553	121.983916	2.03	0.9	1.277	Frank	100-Year
87	10.91052987	121.9933659	1.78	0.8	0.960		
88	10.91093371	121.9930521	1.62	0	2.624		
89	10.91545231	121.9976468	0.03	1.47	2.074		
90	10.92148612	121.9841902	1.92	0.9	1.040	Frank	100-Year
91	10.9157263	121.9975198	0	1.47	2.161		
92	10.91521654	121.9979938	2.58	1.5	1.166	Frank	100-Year
93	10.91187001	121.9920679	0	0	0.000		
94	10.91188975	121.9926505	3.22	1.5	2.958	Frank	100-Year
95	10.91181601	121.9918144	3.69	0.3	11.492	Nitang	5-Year
96	10.91190491	121.9923778	0.63	0	0.397		
97	10.91190459	121.9925521	0	1.5	2.250	Frank	100-Year
98	10.91202255	121.9904556	1.11	0	1.232		
99	10.91193323	121.9922752	3.83	0	14.669		
100	10.9120574	121.9924242	0	0	0.000		
101	10.9119378	121.9924597	0	0	0.000		
102	10.91205261	121.9925055	0	0	0.000		
103	10.91180836	121.9920594	0.2	0	0.040		
104	10.91196627	121.992247	0	0	0.000		
105	10.91102154	121.9908578	3.56	0.21	11.223	Undang	5-Year
106	10.90122408	122.035133	0.03	0	0.001		
107	10.9431439	121.9968693	0.03	0.5	0.221	Yolanda	5-Year
108	10.90174412	122.0346721	0.03	0	0.001		
109	10.90109699	122.0041721	0.04	0	0.002	Frank	100-Year
110	10.90241193	122.0344165	0.03	0	0.001		
111	10.93627551	121.9897279	0.1	0.4	0.090	Frank	100-Year
112	10.93303747	121.9948448	0.08	0	0.006		
113	10.9354236	121.9916248	0.06	0	0.004		
114	10.90107762	122.0031028	0.03	0	0.001		
115	10.90084205	122.035844	0.03	0	0.001		
116	10.91838149	122.0179928	0.03	0	0.001	Frank	100-Year
117	10.90402909	122.0094396	0.04	0	0.002		
118	10.94601174	121.9978275	0.03	1.6	2.465	Yolanda	5-Year
119	10.93207383	121.9952307	0.2	0	0.040		
120	10.93216756	121.9938683	0.28	0.4	0.014	Frank	100-Year
121	10.94437414	121.9978249	0.27	0.9	0.397	Frank	100-Year
122	10.93438958	121.9890815	0.36	0.4	0.002	Frank	100-Year
123	10.93283781	121.9959078	0.22	0.4	0.032	Yolanda	5-Year
124	10.93394936	121.9936328	0.36	0.2	0.026	Frank	100-Year
125	10.91099132	122.016123	0.31	0	0.096	Frank	100-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
126	10.91359063	122.0152416	0.03	0	0.001	Frank	100-Year
127	10.90367336	122.0345305	1.07	0	1.145	Frank	100-Year
128	10.93443049	121.9885276	0.83	1.2	0.137	Frank	100-Year
129	10.90314352	122.033869	0.37	0	0.137		
130	10.94547528	121.998596	0.03	1.6	2.465	Yolanda	5-Year
131	10.93450834	121.9910407	0.31	0.4	0.008	Undang	5-Year
132	10.89970039	122.002477	0.33	0	0.109		
133	10.93515285	121.9988236	0.89	0.4	0.240	Yolanda	5-Year
134	10.90472731	122.0348593	3.11	0.9	4.884	Frank	100-Year
135	10.9088433	122.0009792	0.98	0	0.960		
136	10.89953046	122.0015226	1.99	0.5	2.220	Nitang	5-Year
137	10.90477405	122.0339948	3.51	0.9	6.812	Frank	100-Year
138	10.934626	121.988715	0.47	0.4	0.005	Frank	100-Year
139	10.934042	121.989002	0.03	0	0.001		
140	10.934943	121.993969	0.05	0.4	0.123	Frank	100-Year
141	10.931558	121.995803	0.06	0.4	0.116	Frank	100-Year
142	10.93153	121.995682	0	0.4	0.160	Frank	100-Year
143	10.906493	122.009374	0.04	0.7	0.436	Frank	100-Year
144	10.906671	122.01172	0.24	0.2	0.002	Yolanda	5-Year
145	10.904592	122.016545	0.03	0	0.001		
146	10.907131	122.015878	0.03	0	0.001		
147	10.907031	122.015853	0	0	0.000		
148	10.905668	122.025902	3.87	0.8	9.425	Frank	100-Year
149	10.905868	122.02661	0.06	2	3.764	Undang	5-Year
150	10.905608	122.026605	0.03	0.9	0.757	Undang	5-Year
151	10.905291	122.030953	0.59	0.8	0.044	Undang	5-Year
152	10.905057	122.031941	0.06	0.3	0.058	Yolanda	5-Year
153	10.904465	122.032495	0.48	0	0.230		
154	10.903348	122.03383	0	0	0.000		
155	10.899971	122.003099	2.7	0.8	3.610	Frank	100-Year
156	10.899582	122.002763	2.73	0.2	6.401	Frank	100-Year
157	10.900165	122.001872	1.2	1.3	0.010	Ruping	5-Year
158	10.906796	122.013558	0.25	0	0.063		
159	10.904748	122.016565	0.03	0	0.001		
160	10.907218	122.01588	0	0	0.000		
161	10.905433	122.031332	0.54	0.9	0.130		
162	10.936642	121.989742	0.08	0.4	0.102	Undang	5-Year
163	10.935284	121.989292	0.03	0.8	0.593	Frank	100-Year
164	10.945962	121.999306	0.09	0	0.008	Frank	100-Year
165	10.906579	122.009226	0.05	0.3	0.063	Yolanda	5-Year
166	10.906774	122.009167	0.17	0.4	0.053	Yolanda	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
167	10.906173	122.009481	0.03	0	0.001	Ruping	5-Year
168	10.907378	122.013442	0.03	0	0.001	Frank	100-Year
169	10.90473	122.016851	0.03	0	0.001	Frank	100-Year
170	10.905025	122.016669	0.1	0	0.010	Frank	100-Year
171	10.907202	122.016068	0.03	0	0.001	Frank	100-Year
172	10.907268	122.016735	0.6	0	0.360	Frank	100-Year
173	10.905847	122.022325	0.04	0	0.002	Frank	100-Year
174	10.905477	122.025855	2.35	0	5.523	Frank	100-Year
175	10.905527	122.026637	0	0	0.000	Yolanda	5-Year
176	10.905205	122.030567	1.91	0.4	2.280	Frank	100-Year
177	10.903804	122.033315	1.09	0	1.188	Frank	100-Year
178	10.899778	122.002972	0	0.8	0.640	Yolanda	5-Year
179	10.90034	122.001937	1.87	0.8	1.145	Yolanda	5-Year
180	10.91200415	121.9921463	0	1.5	2.250	Frank	100-Year
181	10.91197149	121.9924154	0	2	4.000	Frank	100-Year
182	10.91197837	121.9924454	0	2	4.000	Frank	100-Year
183	10.91178072	121.9928706	5.63	4	2.657	Frank	100-Year
184	10.91149888	121.9928508	4.45	4	0.203	Frank	100-Year
185	10.91185076	121.9921218	0	1.5	2.250	Frank	100-Year
186	10.91171337	121.9928332	0	4	16.000	Frank	100-Year
187	10.91162688	121.9928509	0	4	16.000	Frank	100-Year
188	10.91161698	121.9928529	0	4	16.000	Frank	100-Year
189	10.91187724	121.9921348	0	1.5	2.250	Frank	100-Year
190	10.91187202	121.9919669	0	1.5	2.250	Frank	100-Year
191	10.91195152	121.9922944	0	2	4.000	Frank	100-Year
192	10.9116208	121.9916106	2.54	1.5	1.082	Frank	100-Year
193	10.91189206	121.9927827	0	4	16.000	Frank	100-Year
194	10.91153696	121.9928322	0	4	16.000	Frank	100-Year
195	10.91159424	121.9928391	0	4	16.000	Frank	100-Year
196	10.91190638	121.9925327	0	2	4.000	Frank	100-Year
197	10.91614908	121.997362	2.56	1.47	1.188	Frank	100-Year
198	10.89975113	122.0031287	2.49	0.8	2.856	Yolanda	5-Year
199	10.90003713	122.00157	2.36	1.3	1.124	Ruping	5-Year
200	10.91184193	121.992929	2.71	4	1.664	Frank	100-Year
201	10.89989363	122.0016453	2.4	1.3	1.210	Ruping	5-Year
202	10.89961061	122.0028421	0	0.2	0.040	Frank	100-Year
203	10.91165906	121.9929712	0	4	16.000	Frank	100-Year
204	10.89979397	122.0032403	2.49	0.8	2.856	Yolanda	5-Year

Annex 12. Educational Institutions Affected by Flooding in Ipayo Floodplain

ANTIQUE				
PATNONGON				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Amparo Day Care Center	Patnongon			
Igbobon Day Care Center	Patnongon	Low	Medium	Medium
Igbobon Elementary School	Patnongon			Low
Larioja Day Care Center	Patnongon			
Padang Elementary School	Patnongon			
Padang Elementary School Stage	Patnongon			
Patnongon Central Elementary School	Patnongon			
Poblacion School	Patnongon			
School	Patnongon			
San Rafael Day Care Center	Patnongon			
San Rafael Elementary School	Patnongon			
School	Patnongon	Low	Low	Low
Tamayoc School	Patnongon			
Igburi Elementary School	Patnongon			
Igburi National High School	Patnongon	Medium	Medium	Medium
SCHOOL	Patnongon			
Villacrespo Day Care Center	Patnongon			

Annex 13. Health Institutions Affected by Flooding in Ipayo Floodplain

ANTIQUE				
PATNONGON				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Padang Barangay Health Center	Padang		Low	Medium
Patnongon Municipal Health Center	Poblacion	Low	Medium	Medium
Tamayoc Catholic Chapel	Tamayoc			
Villa Crespo Barangay Health Center	Villa Crespo			

Annex 14. UPC Phil-LiDAR 1 Team Composition

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