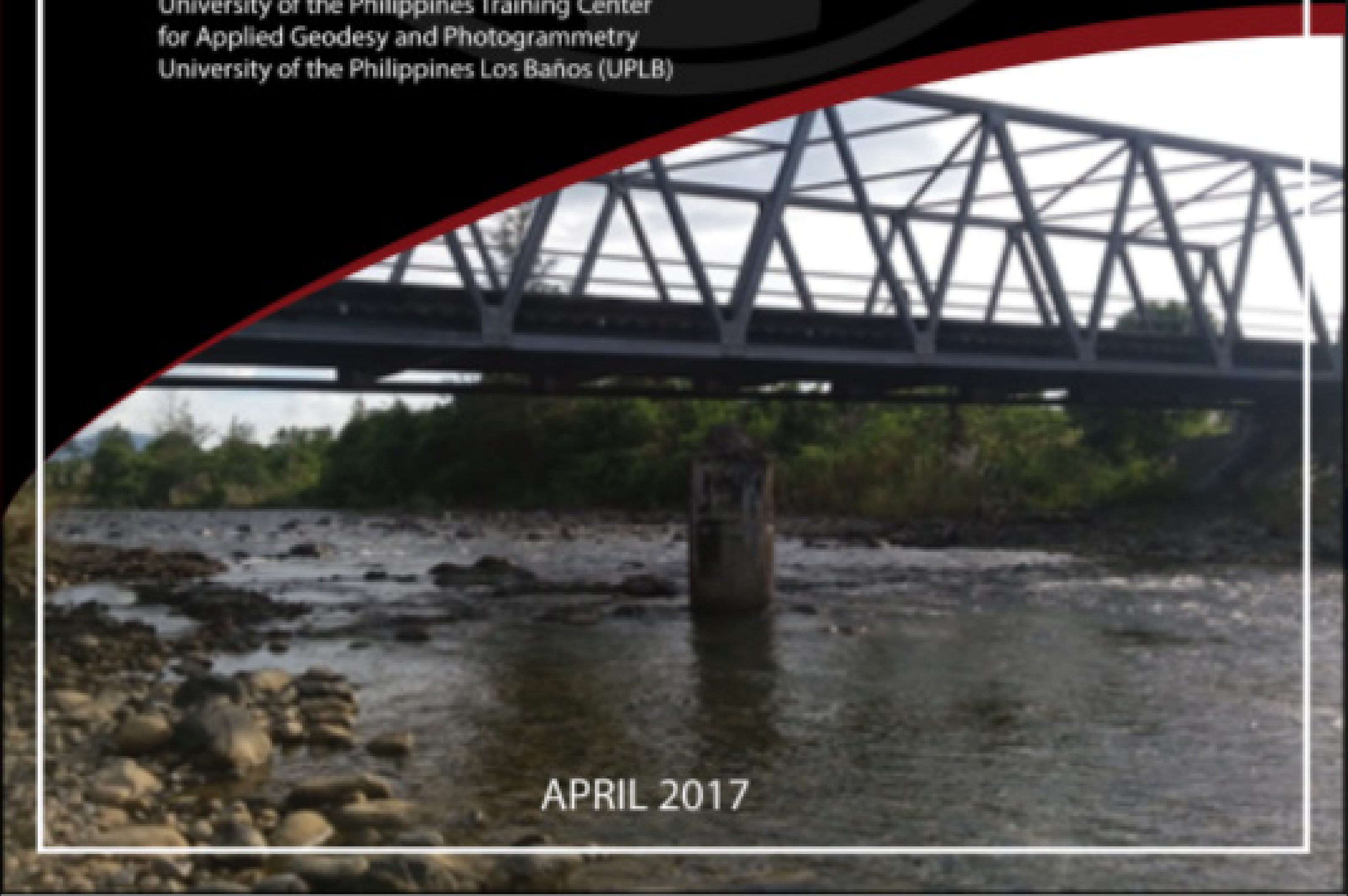
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Ilog - Ilog River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Los Baños (UPLB)



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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND ILOG-ILOG RIVER

Prof. Edwin R. Abucay and Enrico C. Paringit, Dr. Eng., Sandra S. Samantela

1.1 Background of the Phil-LIDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Phiippines Los Banos (UPLB). UPLB is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 45 river basins in the MIMAROPA. The university is located in Los Baños in the province of Laguna.

1.2 Overview of Ilog-Ilog River Basin

Climate Type I and III prevails in MIMAROPA and Laguna based on the Modified Corona Classification of climate. Type I has two pronounced seasons, dry from November to April, and wet the rest of the year with maximum rain period from June to September. On the other hand, Type III has no very pronounced maximum rain period and with short dry season lasting only from one to three months, during the period from December to February or from March to May.

Ilog-Ilog River Basin is a 83,340-hectare watershed located in Palawan. It covers the barangays of Amas, Salogon, Samareñana and Saraza in Brooke's Point municipality; and Campong Ulay and Ransang in Rizal. The river basin is generally characterized by > 50% slope. Sibul clay is the only soil type that can be found within the river basin. Unclassified soil in the rough mountain land can also be found in the area. Closed canopy (mature trees covering >50%) dominates the river basin. Other land cover types include crop land mixed with coconut plantations, cultivated area mixed with brushland/grassland, mossy forest and open canopy (mature trees covering <50%).

Ilog-Ilog River passes through Salogon, Samareñana and Saraza in Brooke's Point municipality; and, Campong Ulay and Ransang in Rizal. Barangay Salogon, Brooke's Point and Ransang, Rizal are considered to be the most populated area per record in the 2010 NSO Census of Population and Housing.

Based on the studies conducted by the Mines and Geosciences Bureau, only Ransang and Campong Ulay have flood susceptibility ranging from moderate to high risk. The field surveys conducted by the PHIL-LiDAR 1 validation team showed that only one notable weather disturbance caused flooding in 2012 (Pablo) which affected barangay Campong Ulay. In terms of landslide susceptibility, Ransang and Campong Ulay have none to low risk while the rest have a range of moderate to high risk.

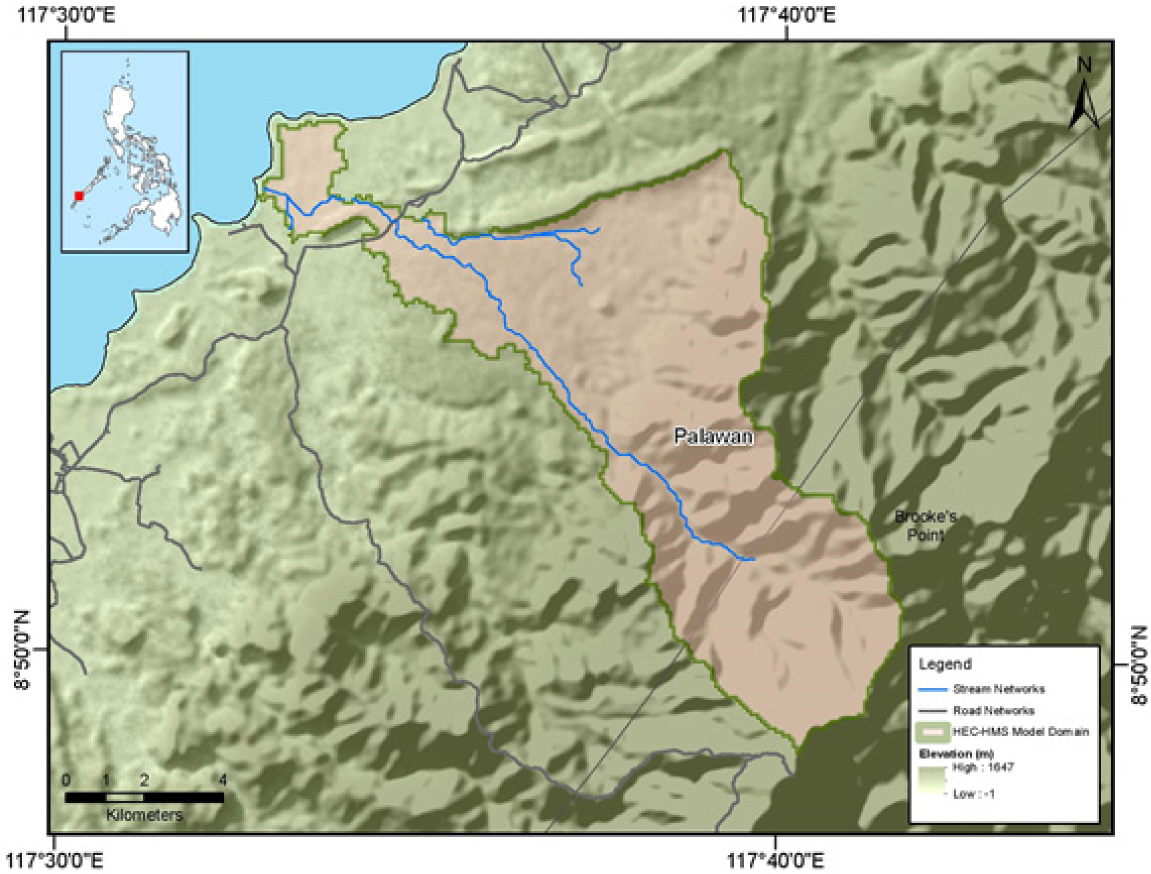

Figure 1. Map of Ilog-Ilog River.

CHAPTER 2: LIDAR ACQUISITION IN ILOG-ILOG FLOODPLAIN

Eng. Louie P. Balicanta, Eng. Christopher Cruz, Lovely Grace Acuña, Eng. Gerome Hipolito, Eng. Iro Niel D. Roxas, Ms. Rowena M. Gabua

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).

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Ilog-Ilog Floodplain in Palawan. These missions were planned for 19 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plan for Ilog-Ilog Floodplain.

Table 1. Parameters used in Pegasus LiDAR System during Flight Acquisition.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK42M	1200	30	50	200	30	130	5
BLK42N	1200	30	50	200	30	130	5
BLK42O	1200	30	50	200	30	130	5
BLK42P	1200	30	50	200	30	130	5

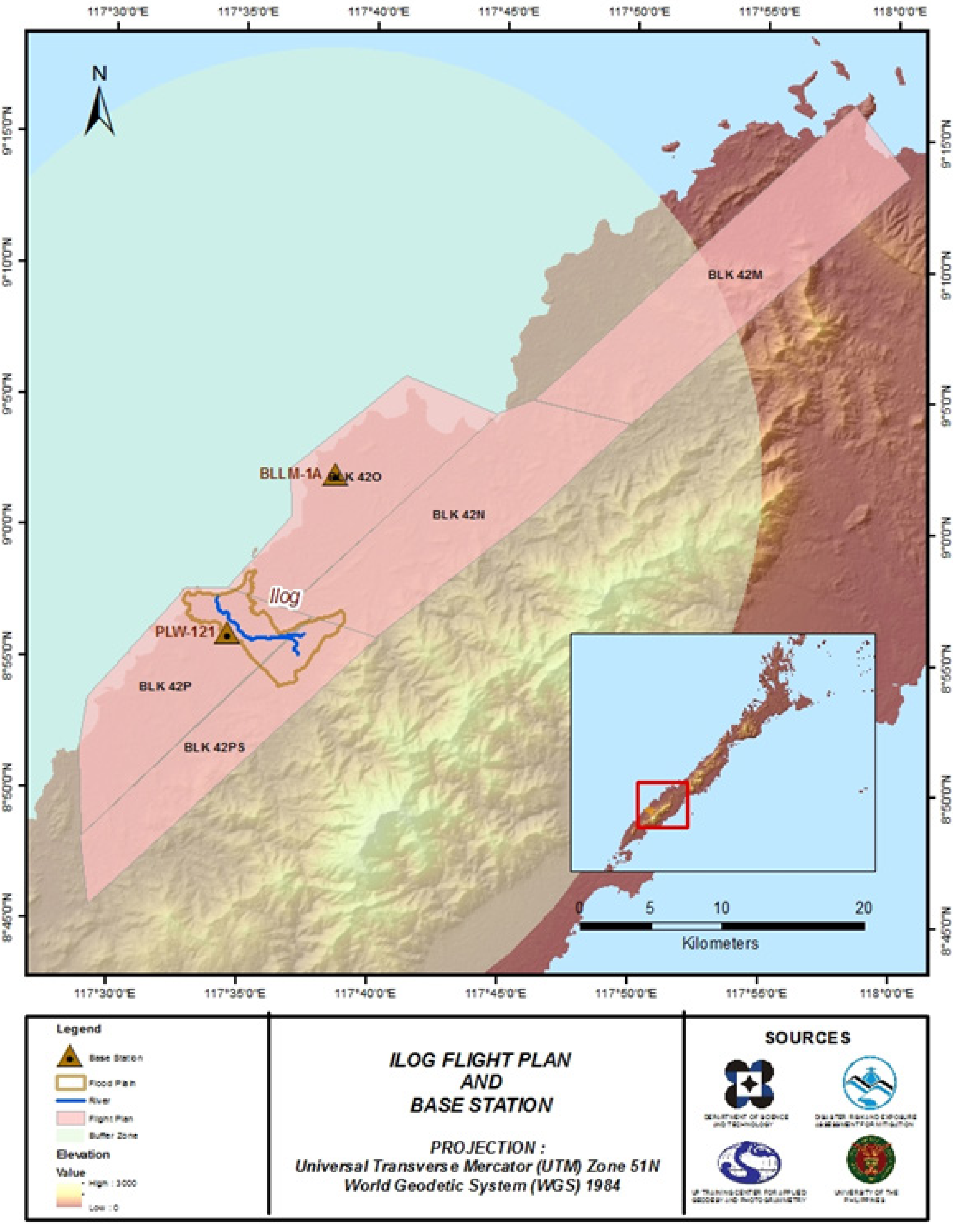

Figure 2. Flight plan used for Ilog-Ilog Floodplain.

2.2 Ground Base Stations

The project team was able to recover one (1) NAMRIA ground control points: PLW-121 which is of second (2nd) order accuracy. The project team also established one (1) ground control point, BLLM-1A. The certification for the NAMRIA reference point is found in Annex 2, while the processing report for the established ground control point can be found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (July 11, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS R8. Flight plans and location of base stations used during the aerial LiDAR acquisition in Ilog-Ilog Floodplain are shown in Figure 2.

Figure 3 shows the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 3 show the details about the following NAMRIA control stations and established points. Table 4 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

(b)

(a)

Figure 3. GPS set-up over PLW-121as recovered within the vicinity of Cabkungan Elementary School in Brgy. Campong Ulay, Rizal, Palawan (a) and NAMRIA reference point PLW-121(b) as recovered by the field team.

Table 2. Details of the recovered NAMRIA horizontal control point PLW-121 used as base station for the LiDAR Acquisition.

Station Name	PLW-121	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	8° 56' 1.71426" North 117° 34' 23.99157" East 8.98036 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	398086.54 meters 987945.887 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	8° 55' 57.38325" North 117° 34' 29.39124" East 58.05800 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	563030.26 meters 987521.12 meters

Table 3. Details of the recovered NAMRIA horizontal control point BLLM-1A used as base station for the LiDAR Acquisition.

Station Name	BLLM-1A	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 02' 07.68639" North 117° 38' 28.10618" East -2.0700 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 02' 03.33580" North 117° 38' 33.49665" East 46.965 meters
Grid Coordinates, Universal Transverse Mercator Zone 52 North (UTM 52N PRS 92)	Easting Northing	570465.682 meters 998772.489 meters

Table 4. Ground Control Points used during LiDAR Data Acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
11-Jul-15	3157P	1BLK42PO192A	PLW-121, BLLM-1A
11-Jul-15	3159P	1BLK42PO192B	PLW-121, BLLM-1A

2.3 Flight Missions

Two (2) missions were conducted to complete the LiDAR Data Acquisition in Ilog-Ilog Floodplain, for a total of seven hours and thirty-five minutes (7+35) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. Table 5 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 6 presents the actual parameters used during the LiDAR data acquisition.

Table 5. Flight Missions for LiDAR Data Acquisition in Ilog-Ilog 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
11-Jul-15	3157P	546.67	445.39	28.60	416.79	536	4	23
11-Jul-15	3159P	385.73	231.17	4.15	227.02	1	3	12
TOTAL		932.4	676.56	32.75	643.81	537	7	35

Table 6. 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)
3157P	1200	30	50	200	25	130	5
3159P	1200	30	50	200	25	130	5

2.4 Survey Coverage

Ilog-Ilog Floodplain is located in the provinces of Palawan with majority of the floodplain situated within the municipality of Rizal. The Municipalities of Rizal and Quezon were mostly covered by the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 7. The actual coverage of the LiDAR acquisition for Ilog-Ilog Floodplain is presented in Figure 4.

Table 7. List of municipalities and cities surveyed during Ilog-Ilog Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Palawan	Quezon	917.97	52.72	6%
	Rizal	980.59	460.78	47%
Total		**1898.56**	**513.50**	**27%**

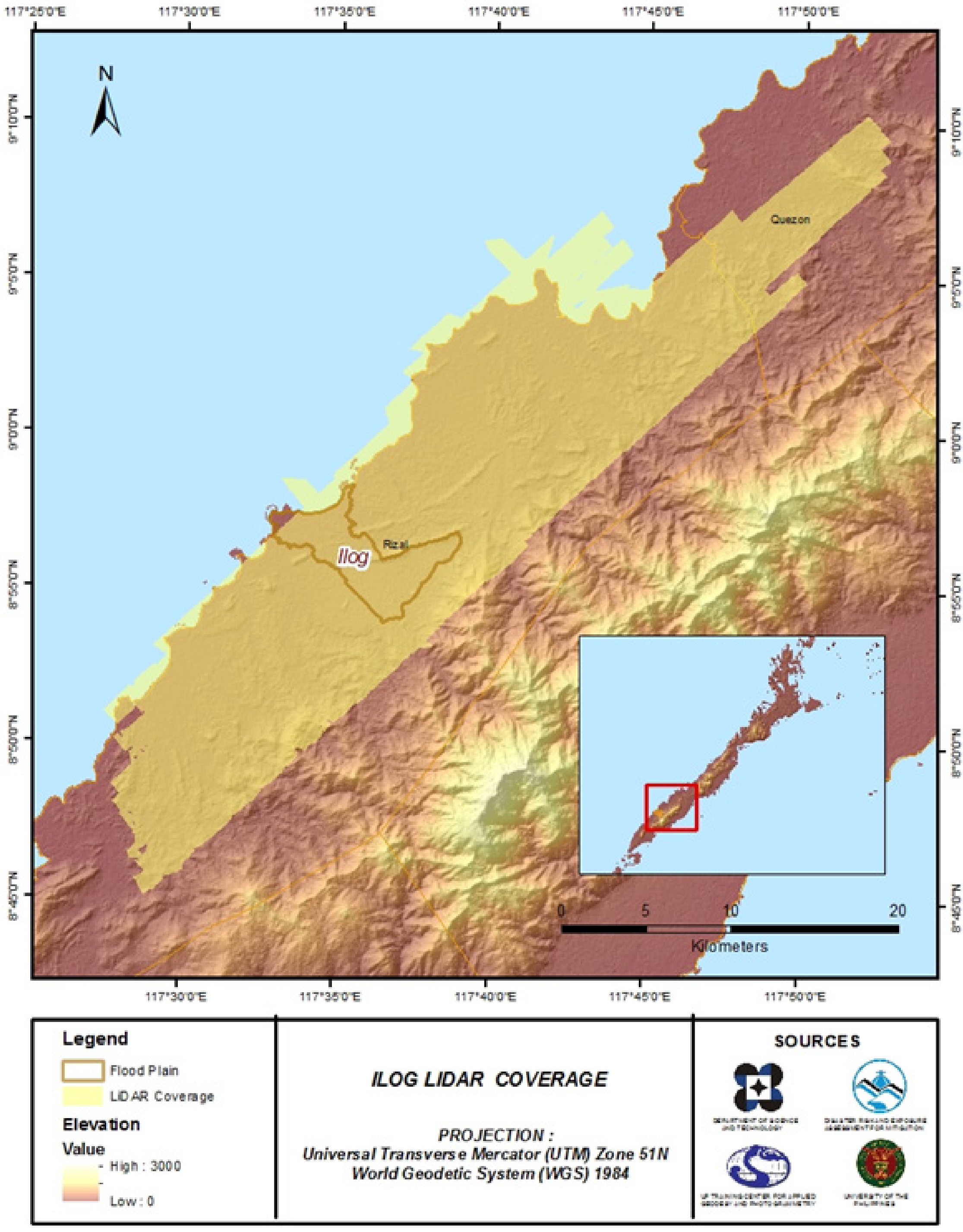

Figure 4 Actual LiDAR survey coverage for Ilog-Ilog Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR ILOG-ILOG FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

These processes are summarized in the flow chart shown in Figure 5.

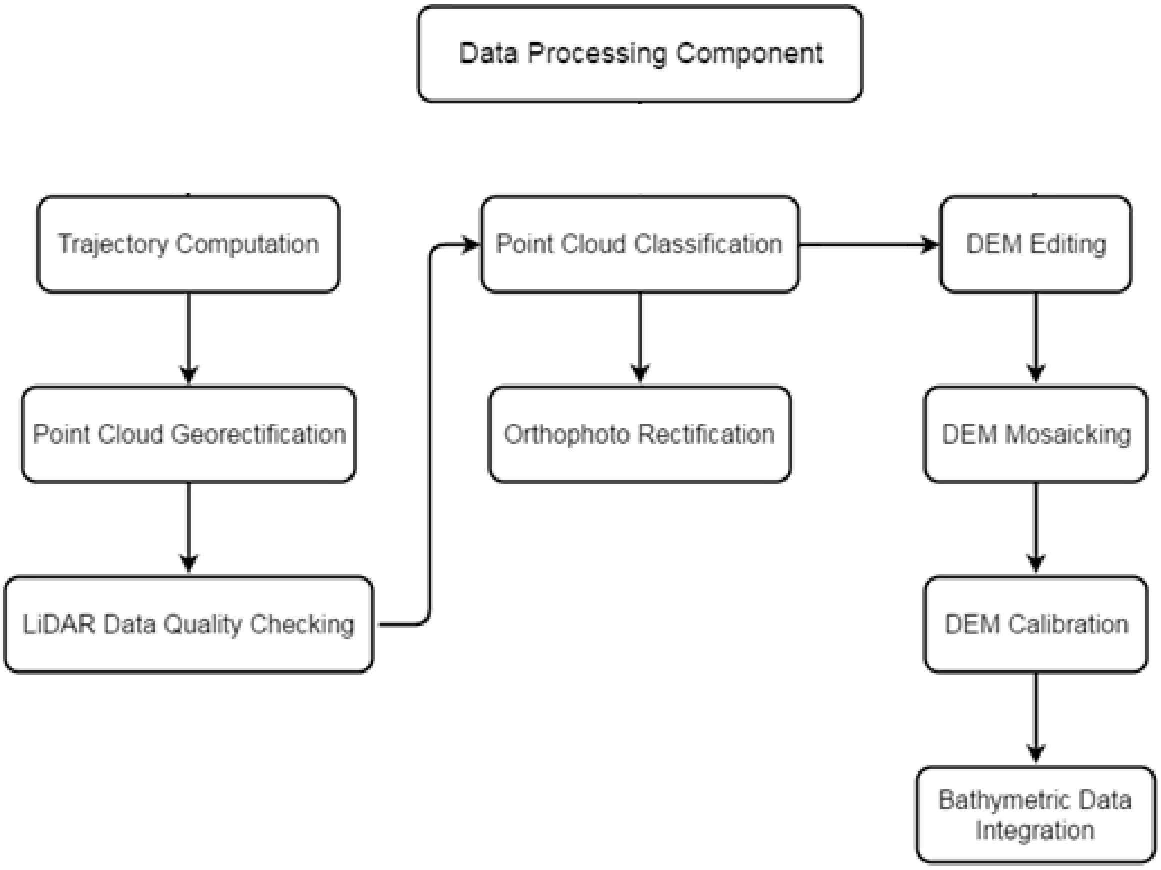


Figure 5 Schematic Diagram for Data.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Ilog-Ilog Floodplain can be found in Annex 5. Missions flown during the first survey conducted on July 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Rizal, Palawan. The Data Acquisition Component (DAC) transferred a total of 64.9 Gigabytes of Range data, 478 Gigabytes of POS data, 41.2 Megabytes of GPS base station data, and 90.7 Gigabytes of raw image data to the data server on August 3, 2015. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Ilog-Ilog was fully transferred on August 5, 2015, as indicated on the Data Transfer Sheets for Ilog-Ilog Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 3159P, one of the Ilog-Ilog flights, which is the North, East, and Down position RMSE values are shown in Figure 6. 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 July 11, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

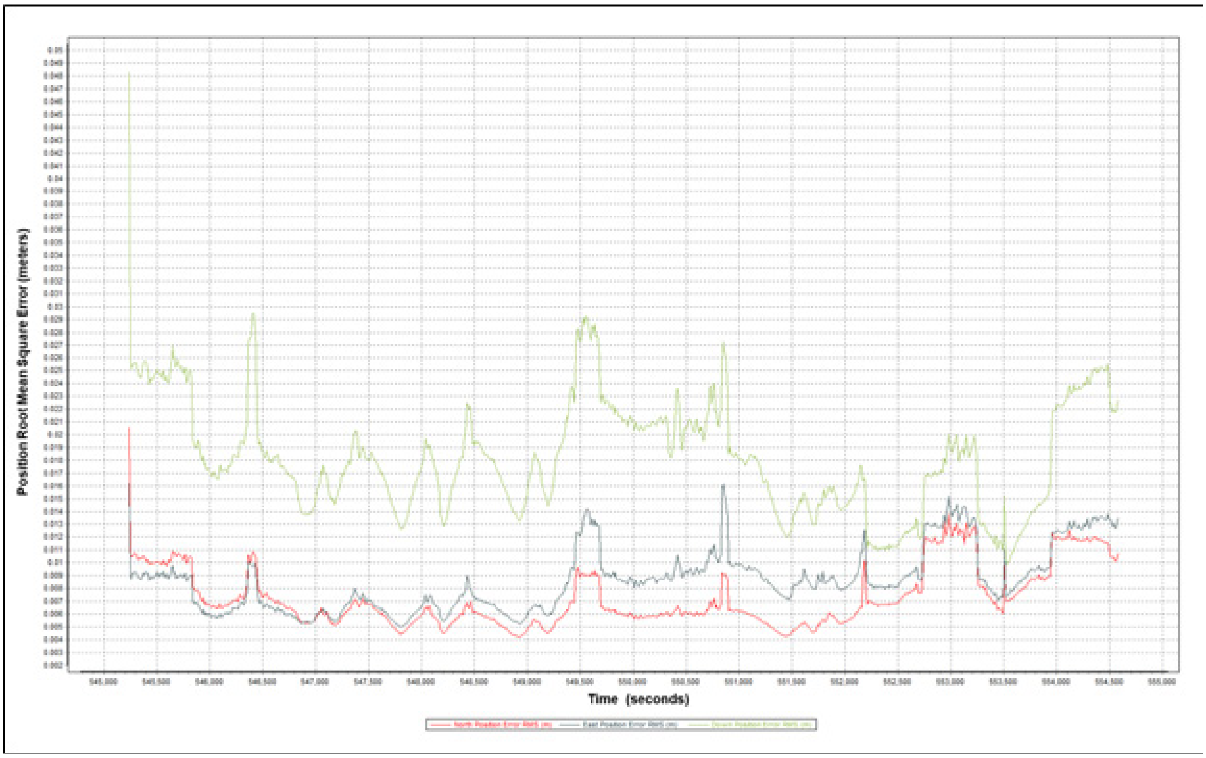


Figure 6. Smoothed Performance Metric Parameters of an Ilog-Ilog Flight 3159P.

The time of flight was from 545250 seconds to 554500 seconds, which corresponds to afternoon of July 11, 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

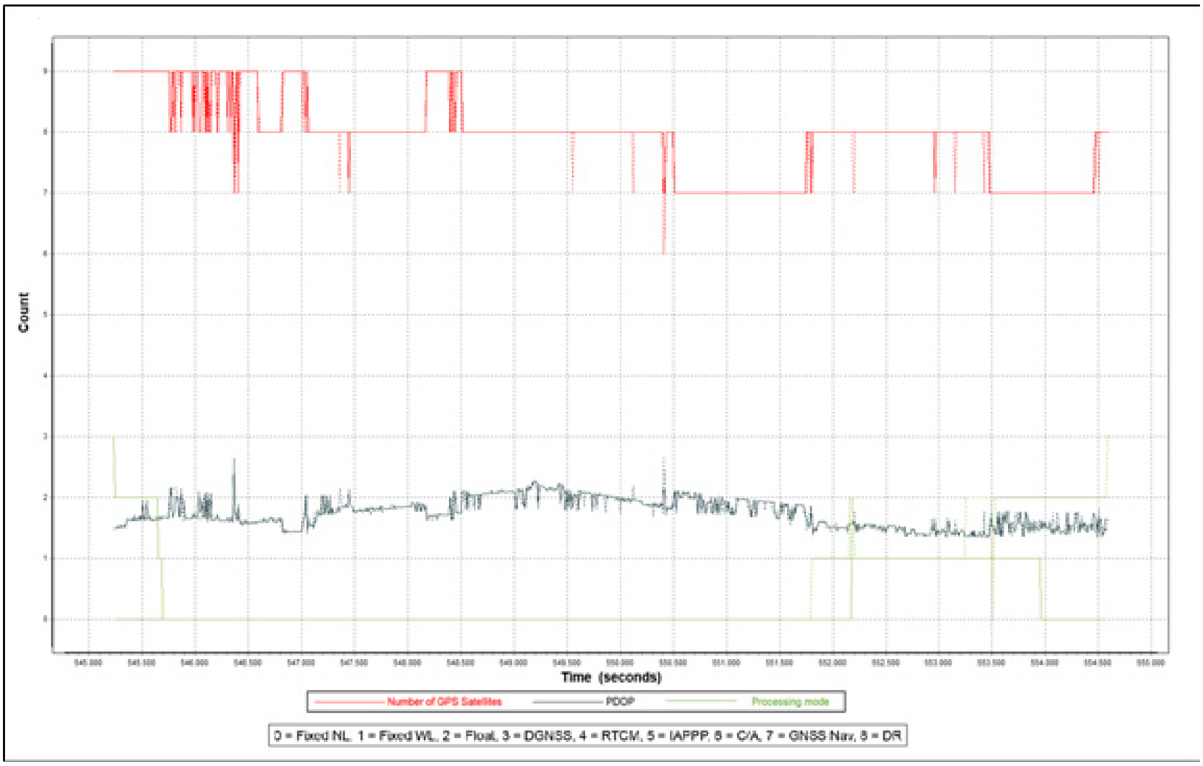


Figure 7. Solution Status Parameters of Ilog-Ilog Flight 3159P.

The Solution Status parameters of flight 3159P, one of the Ilog-Ilog flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 7. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 7 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Ilog-Ilog flights is shown in Figure 8.

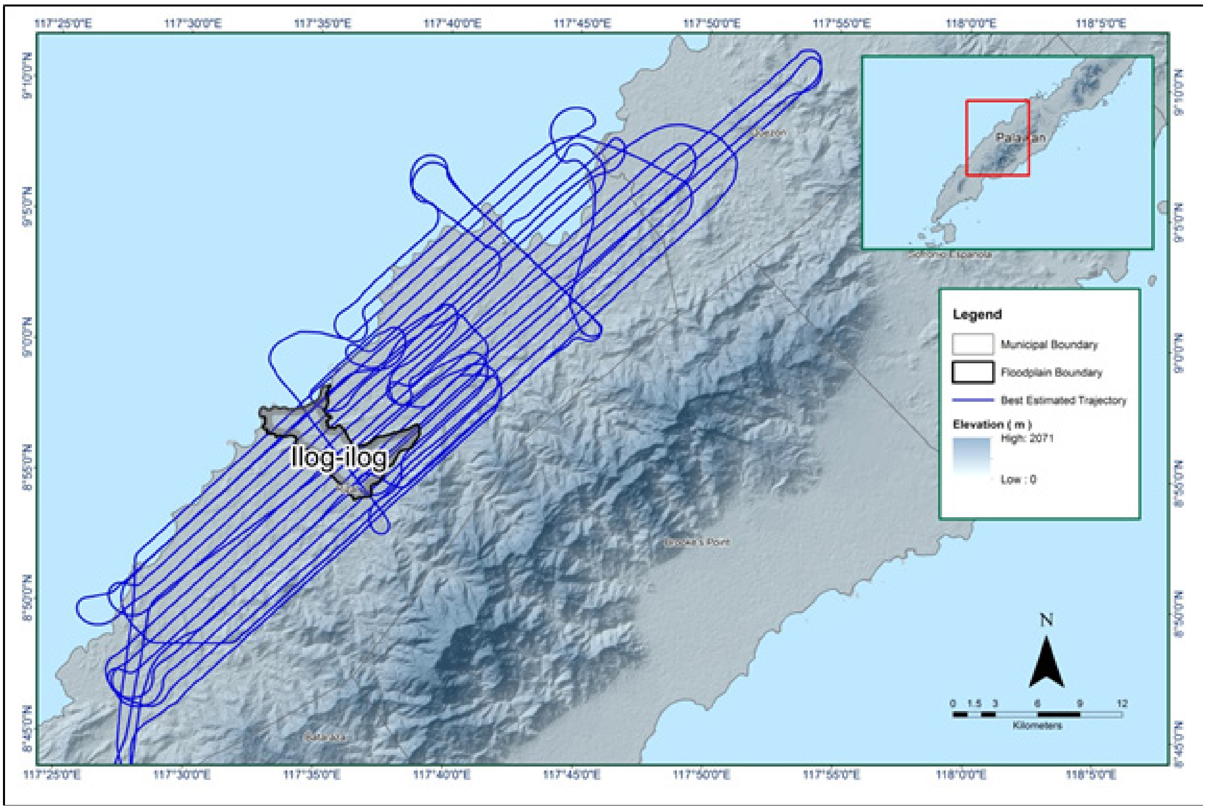


Figure 8 Best Estimated Trajectory for Ilog-Ilog Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 24 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 Ilog-Ilog Floodplain are given in Table 8.

Table 8 Self-Calibration Results values for Ilog-Ilog flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000423	0.000199
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000988	0.0000117985
GPS Position Z-correction stdev (<0.01meters)	0.0023	0.0071

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

3.5 LiDAR Quality Checking

he boundary of the processed LiDAR data on top of a SAR Elevation Data over Ilog-ilog Floodplain is shown in Figure 9. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

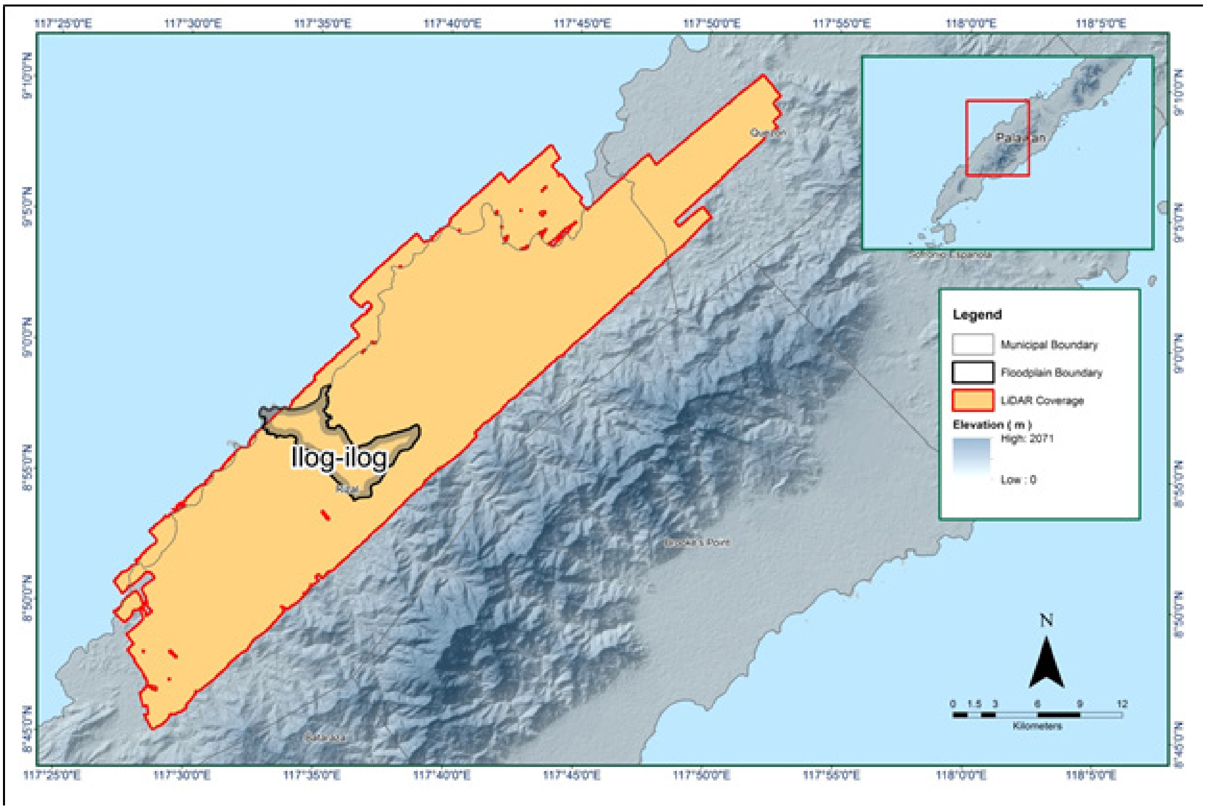


Figure 9. Boundary of the processed LiDAR data over Ilog-Ilog Floodplain.

The total area covered by the Ilog-Ilog missions is 606.96 sq.km which is comprised of two (2) flight acquisitions grouped and merged into three (3) blocks as shown in Table 9.

Table 9. List of LiDAR blocks for Ilog-Ilog Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq.km)
Palawan_Blk42N	3157P	188.81
	3159P	
Palawan_Blk42O	3157P	115.29
	3159P	
Palawan_Blk42P	3157P	302.86
	3159P	
	TOTAL	606.96 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 B-6. 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.

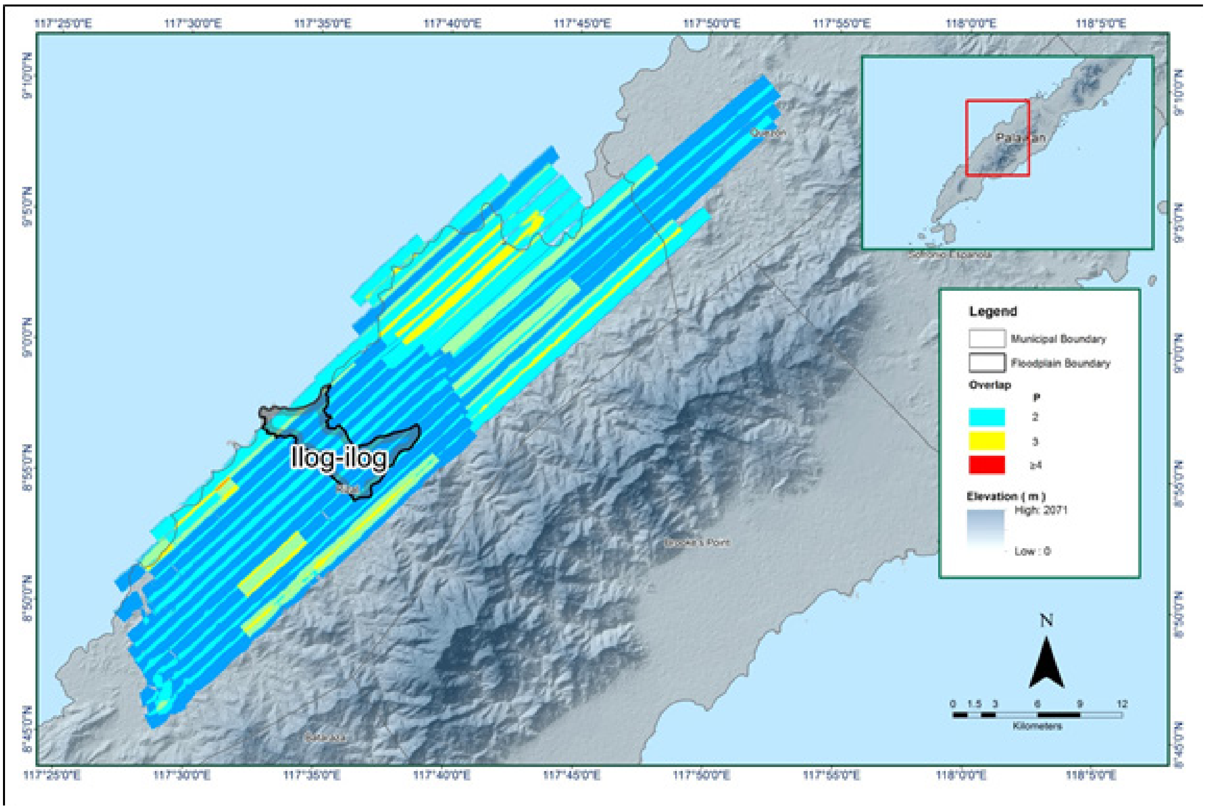


Figure 10. Image of data overlap for Ilog-Ilog Floodplain.

The overlap statistics per block for the Ilog-Ilog Floodplain can be found in Annex. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 13.66% and 21.33% respectively.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 11. It was determined that all LiDAR data for Ilog-Ilog Floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.11 points per square meter.

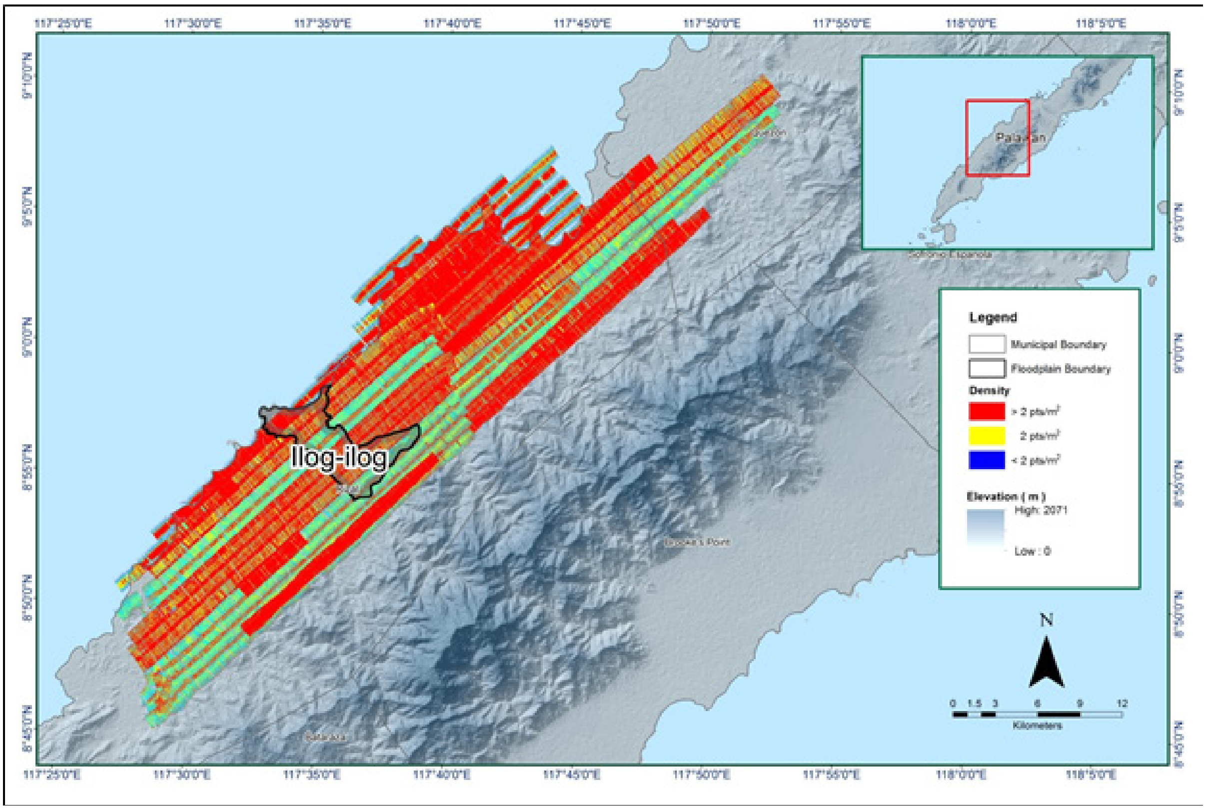


Figure 11 Density map of merged LiDAR data for Ilog-Ilog Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 12. 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.

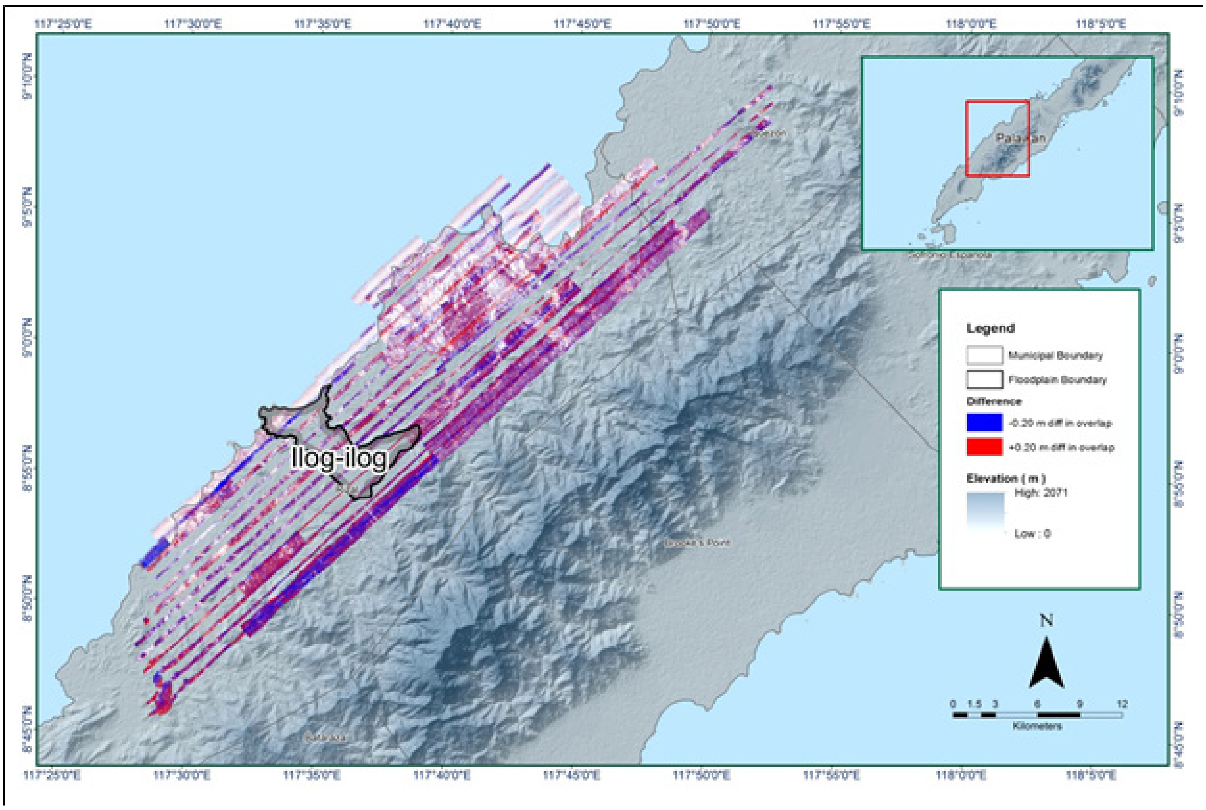


Figure 12 Elevation difference map between flight lines for Ilog-Ilog Floodplain.

A screen capture of the processed LAS data from an Ilog-Ilog flight 3159P loaded in QT Modeler is shown in Figure 13. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

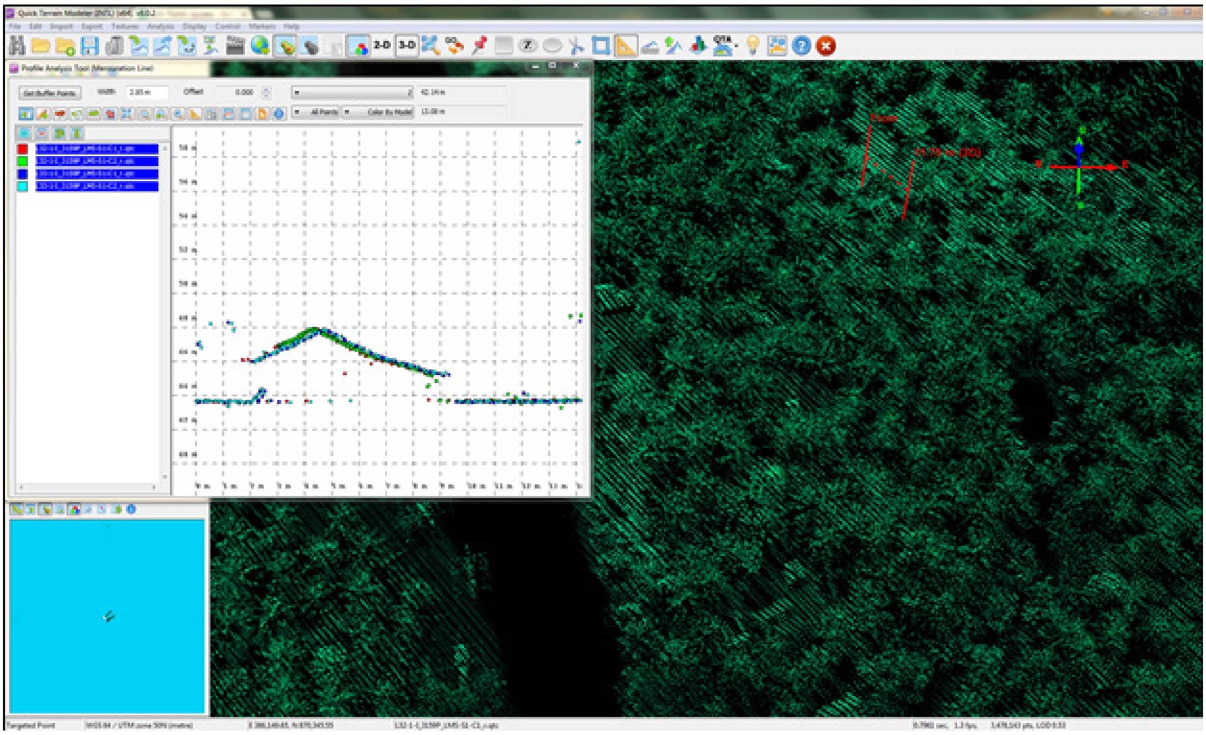


Figure 13 Quality checking for an Ilog-Ilog flight 3159P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 10 Ilog-Ilog classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	321,923,768
Low Vegetation	207,171,454
Medium Vegetation	413,535,820
High Vegetation	1,457,324855
Building	18,207,670

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Ilog-Ilog Floodplain is shown in Figure 14. A total of 785 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 10. The point cloud has a maximum and minimum height of 760.06 meters and 40.13 meters respectively.

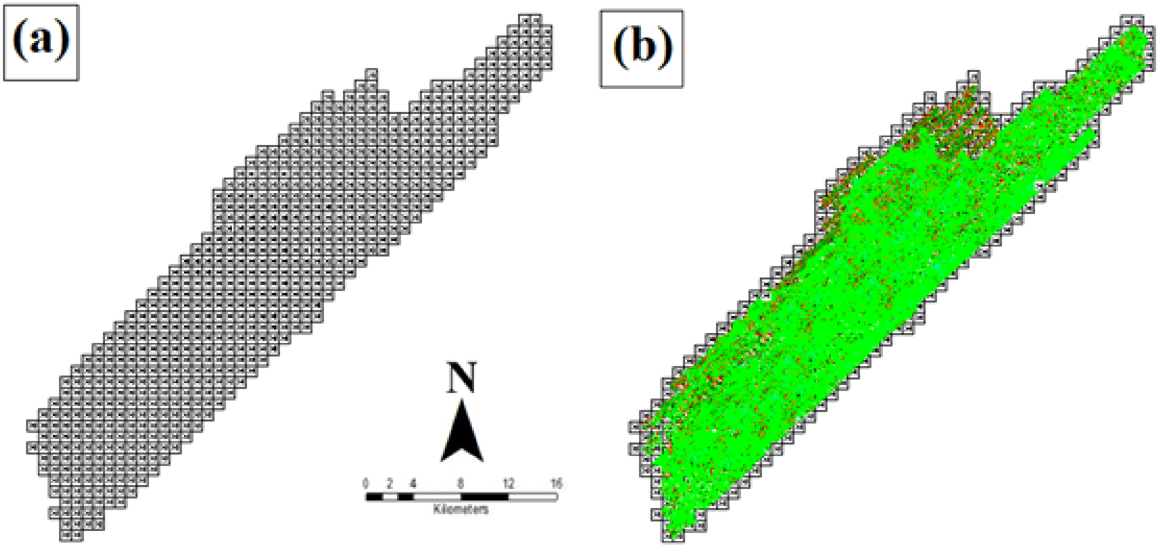


Figure 14 Tiles for Ilog-Ilog Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 15. 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.

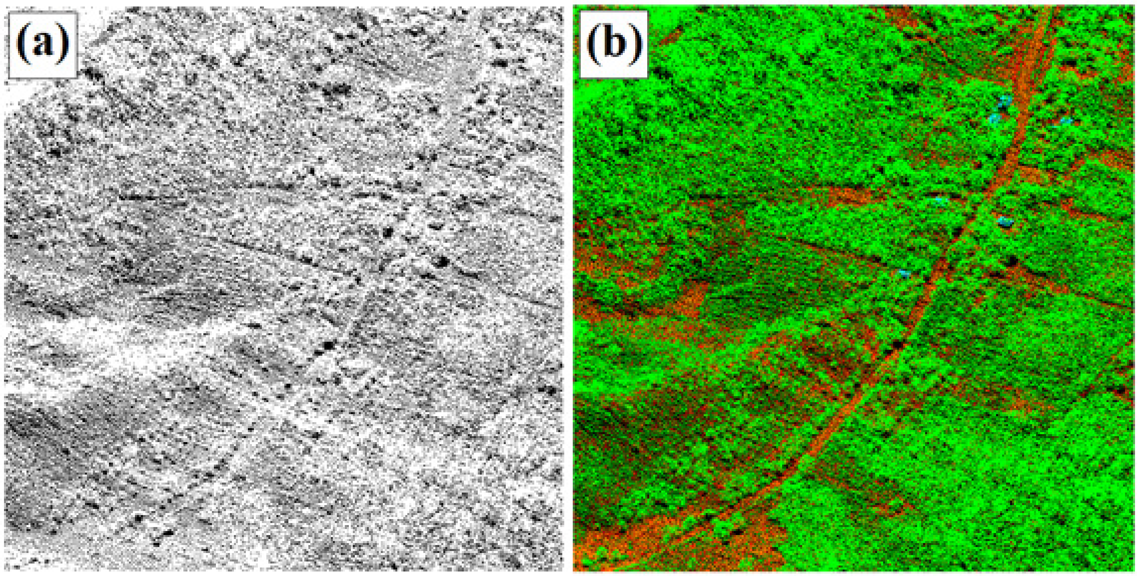


Figure 15 Point cloud before (a) and after (b) classification.

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

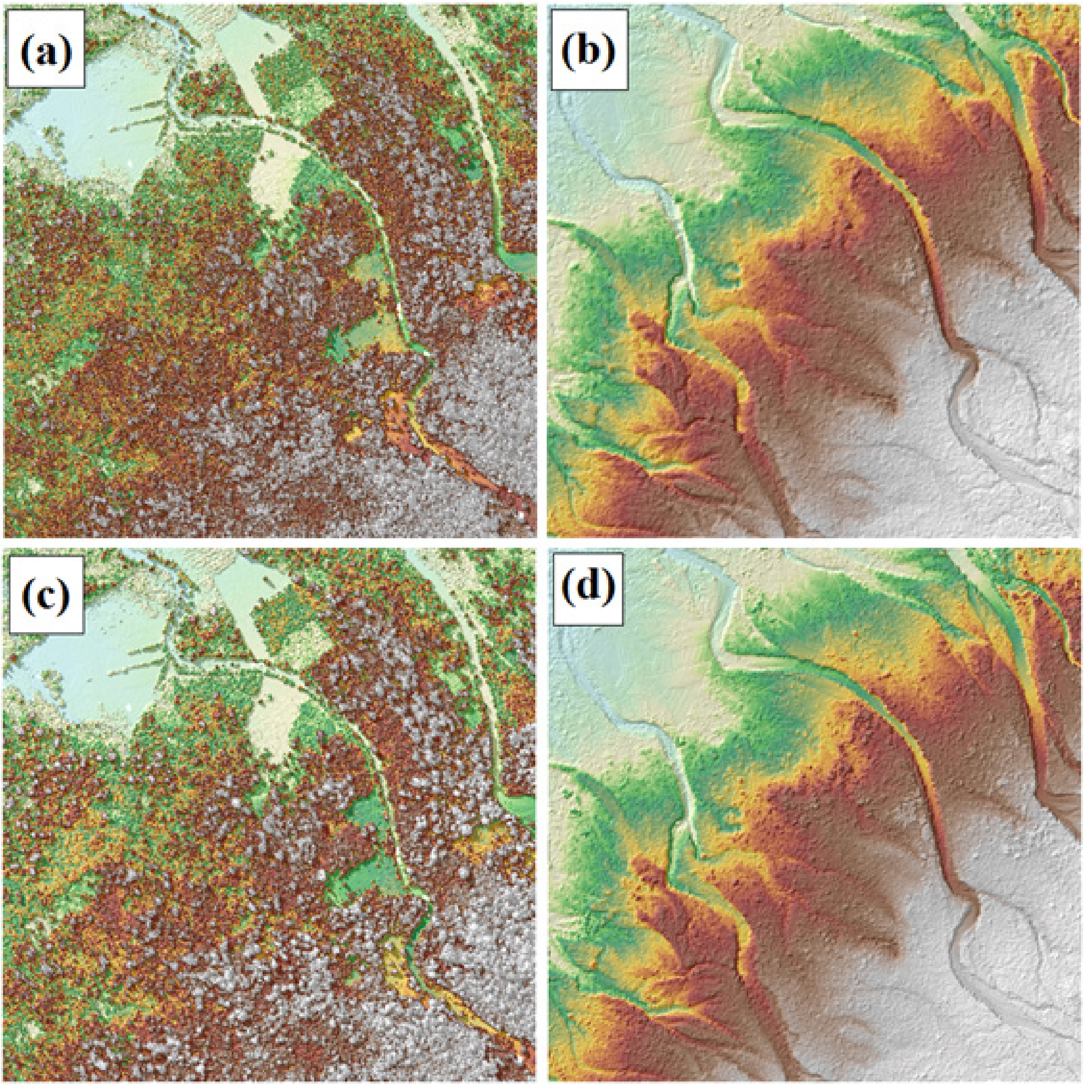


Figure 16 The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Ilog-Ilog Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 273 1km by 1km tiles area covered by Ilog-Ilog Floodplain is shown in Figure 17. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Ilog-Ilog Floodplain has a total of 153.14 sq.km orthophotogaph coverage comprised of 303 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 18.

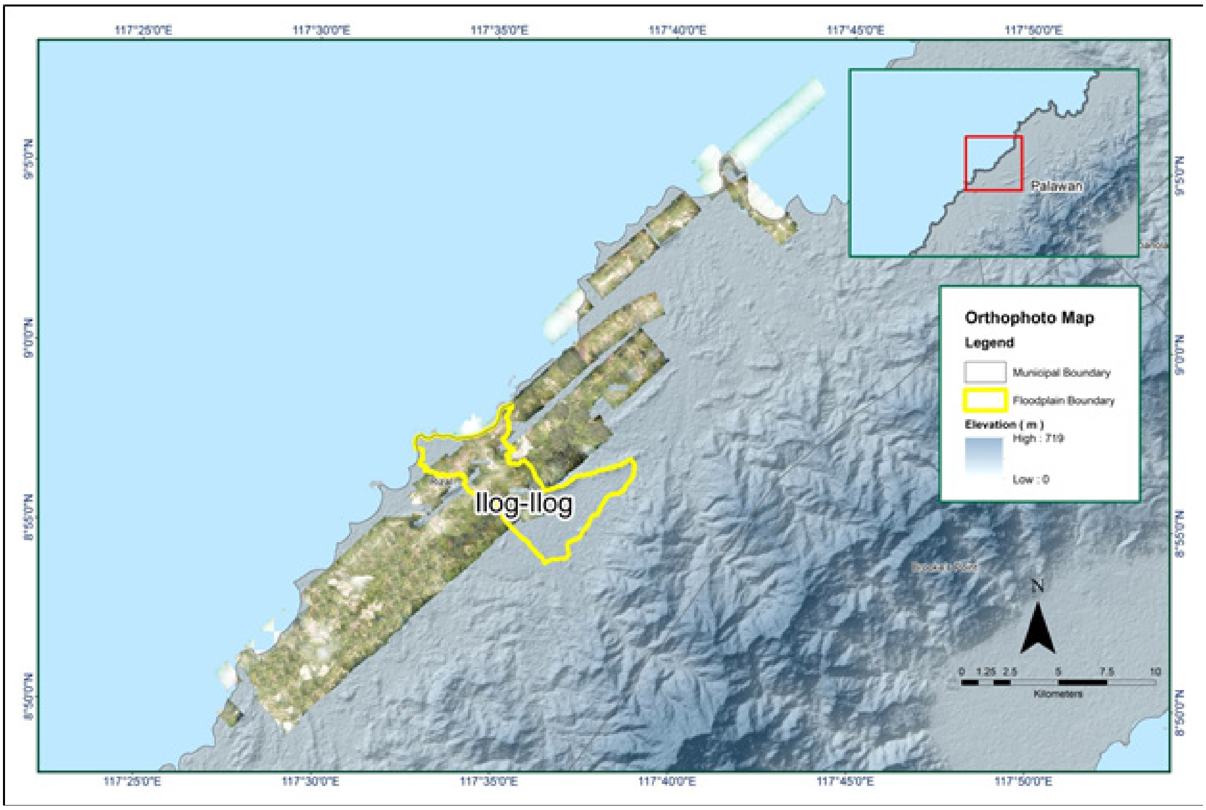


Figure 17. Ilog-Ilog Floodplain with available orthophotographs.

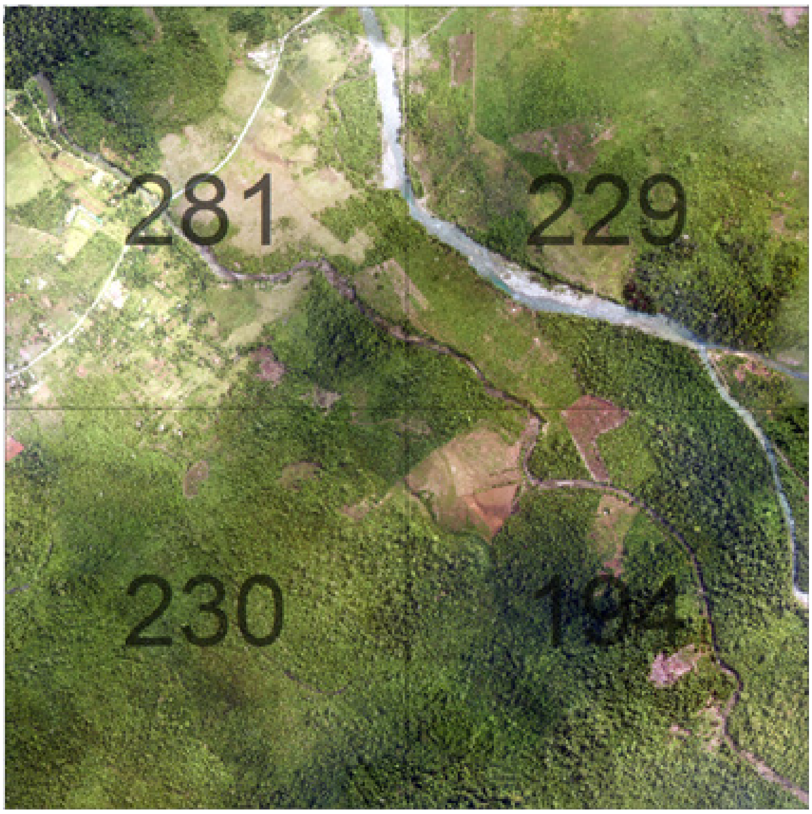


Figure 18 Sample orthophotograph tiles for Ilog-Ilog Floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Ilog-Ilog Floodplain. These blocks are composed of Palawan blocks with a total area of 606.96 square kilometers. Table 11 shows the name and corresponding area of each block in square kilometers.

Table 11. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq. km.)
Palawan_Blk42N	188.81
Palawan_Blk42O	115.29
Palawan_Blk42P	302.86
TOTAL	606.96 sq.km

Portions of DTM before and after manual editing are shown in Figure 19. The bridge (Figure 19a) was considered to be an impedance to the flow of water along the river and had to be removed (Figure 19b) in order to hydrologically correct the river. The data gap (Figure 19c) was filled to complete the surface (Figure 19d) to allow the correct flow of water.

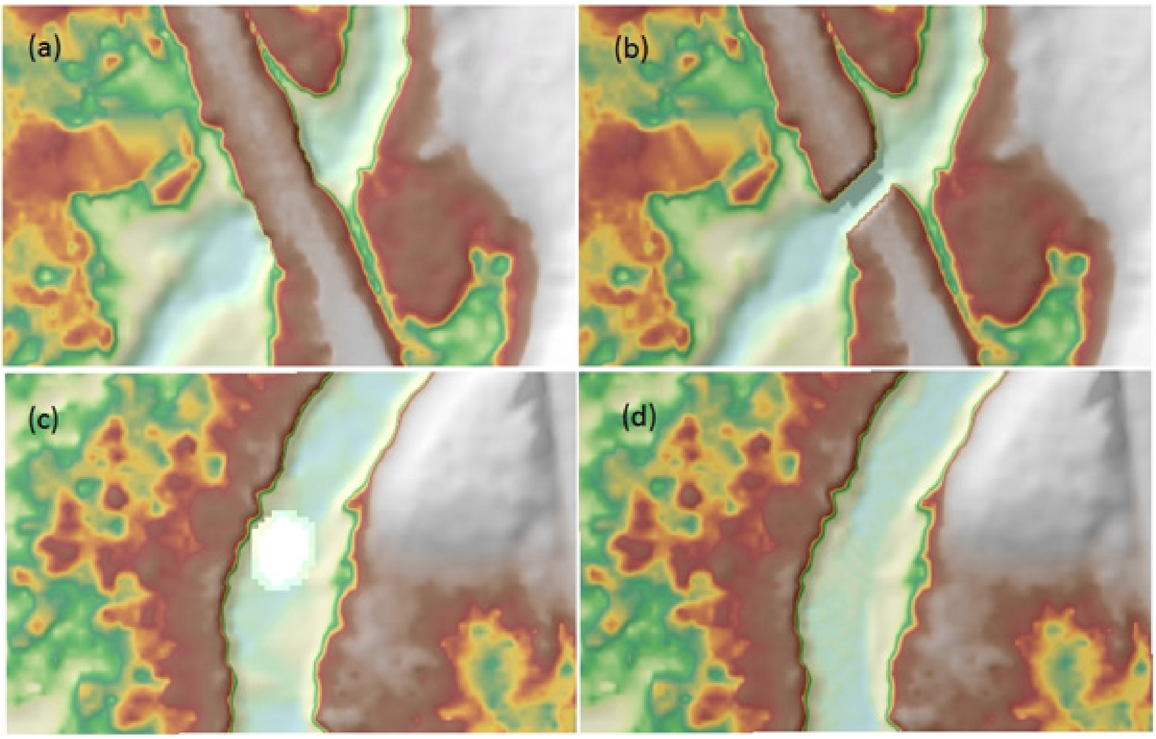


Figure 19 Portions in the DTM of Ilog-Ilog Floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

Palawan_Blk42A was used as the reference block at the start of mosaicking because it was the first block mosaicked to the larger DTM of West Coast Palawan. Upon inspection of the blocks mosaicked for the Ilog-Ilog Floodplain, it was concluded that the elevation of all the blocks needed to be adjusted before mosaicking the DTM. Table 12 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Ilog-Ilog Floodplain is shown in Figure 20. It can be seen that the entire Ilog-Ilog Floodplain is 96.64% covered by LiDAR data.

Table 12 Shift Values of each LiDAR Block of Ilog-Ilog Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Palawan_Blk42N	0.00	0.00	6.50
Palawan_Blk42O	0.00	0.00	6.49
Palawan_Blk42P	0.00	0.00	6.55

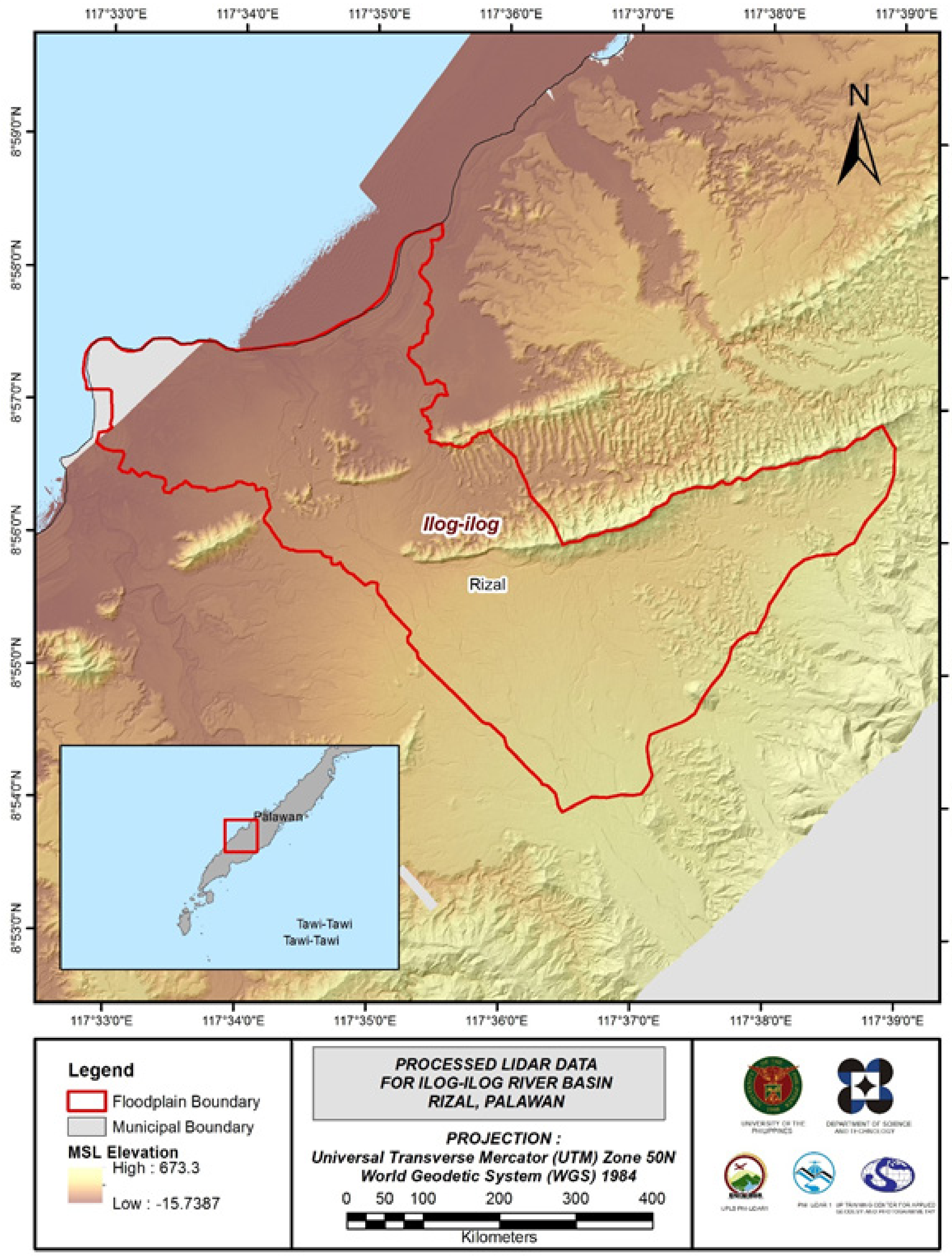


Figure 20 Map of Processed LiDAR Data for Ilog-Ilog Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Ilog-Ilog to collect points with which the LiDAR dataset was validated is shown in Figure 21. A total of 27 survey points were used for calibration and validation of Ilog-Ilog LiDAR data. Random selection of 80% of the survey points, resulting to 21 points, was used for calibration. The good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 22. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 14.65 meters with a standard deviation of 0.03 meters. Calibration of Ilog-Ilog LiDAR data was done by adding the height difference value, 14.65 meters, to Ilog-Ilog mosaicked LiDAR data. Table 13 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

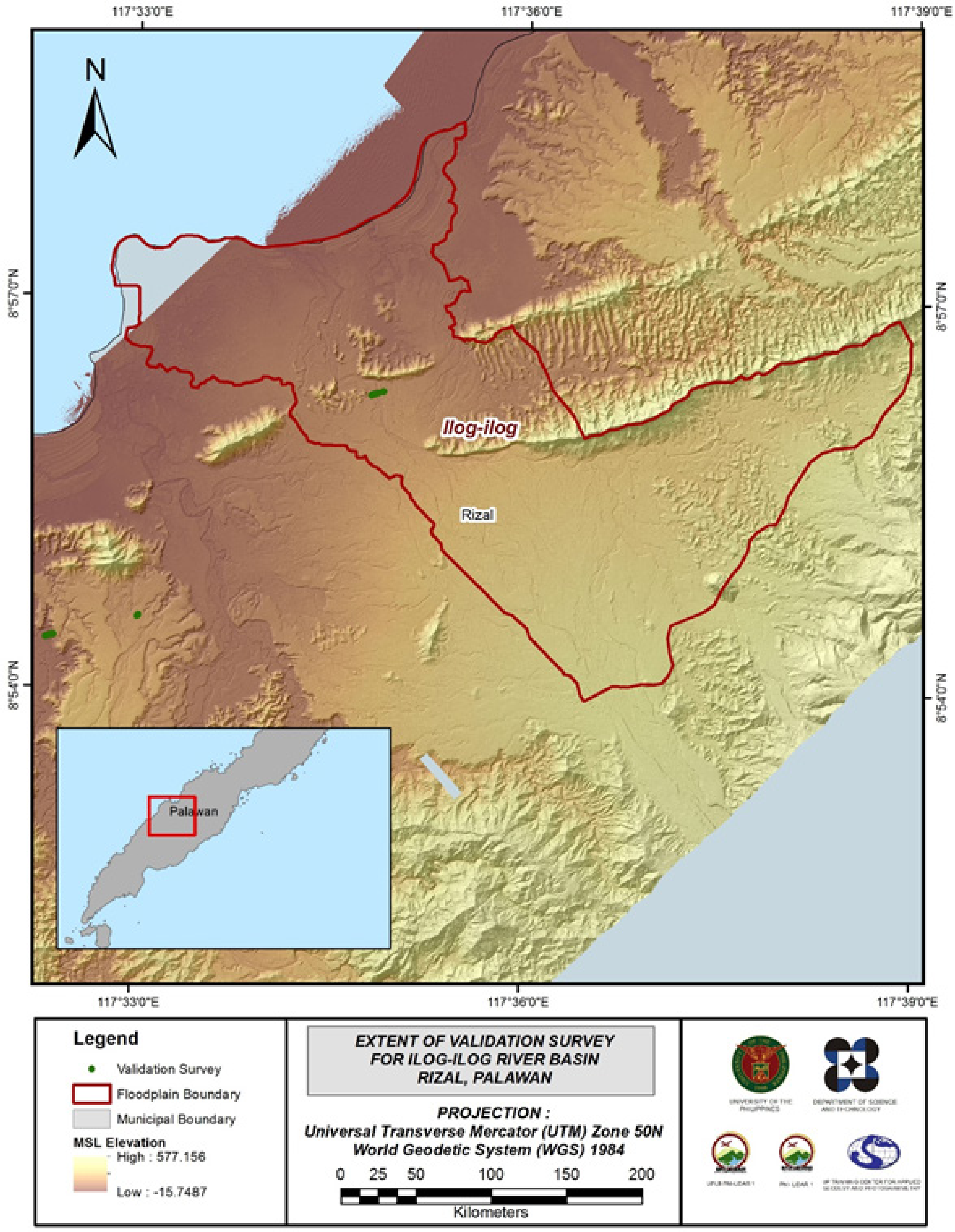


Figure 21. Map of Ilog-Ilog Floodplain with validation survey points in green.

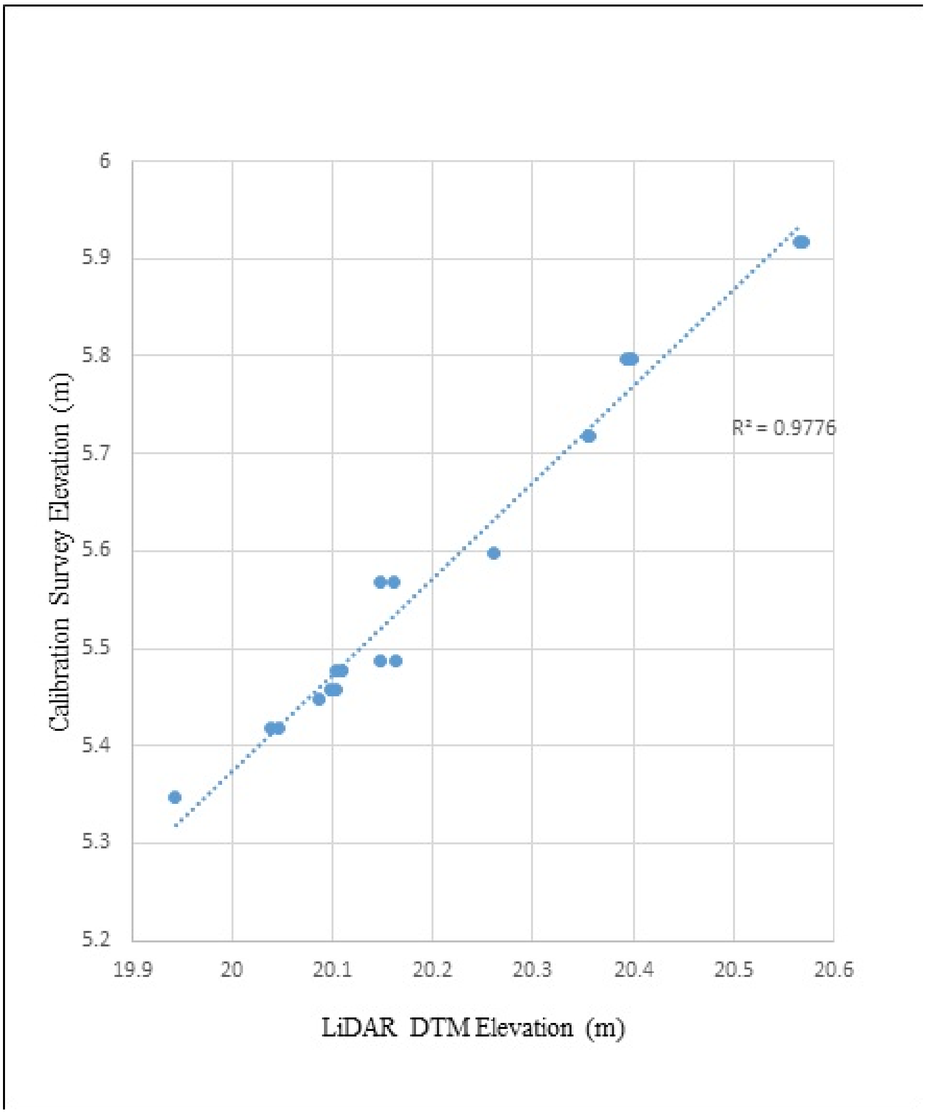


Figure 22 Correlation plot between calibration survey points and LiDAR data.

Table 13 Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	14.63
Standard Deviation	0.03
Average	14.63
Minimum	14.56
Maximum	14.68

The remaining 20% of the total survey points, resulting to 5, were used for the validation of calibrated Ilog-Ilog DTM. The 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 23. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.03 meters with a standard deviation of 0.02 meters, as shown in Table 14.

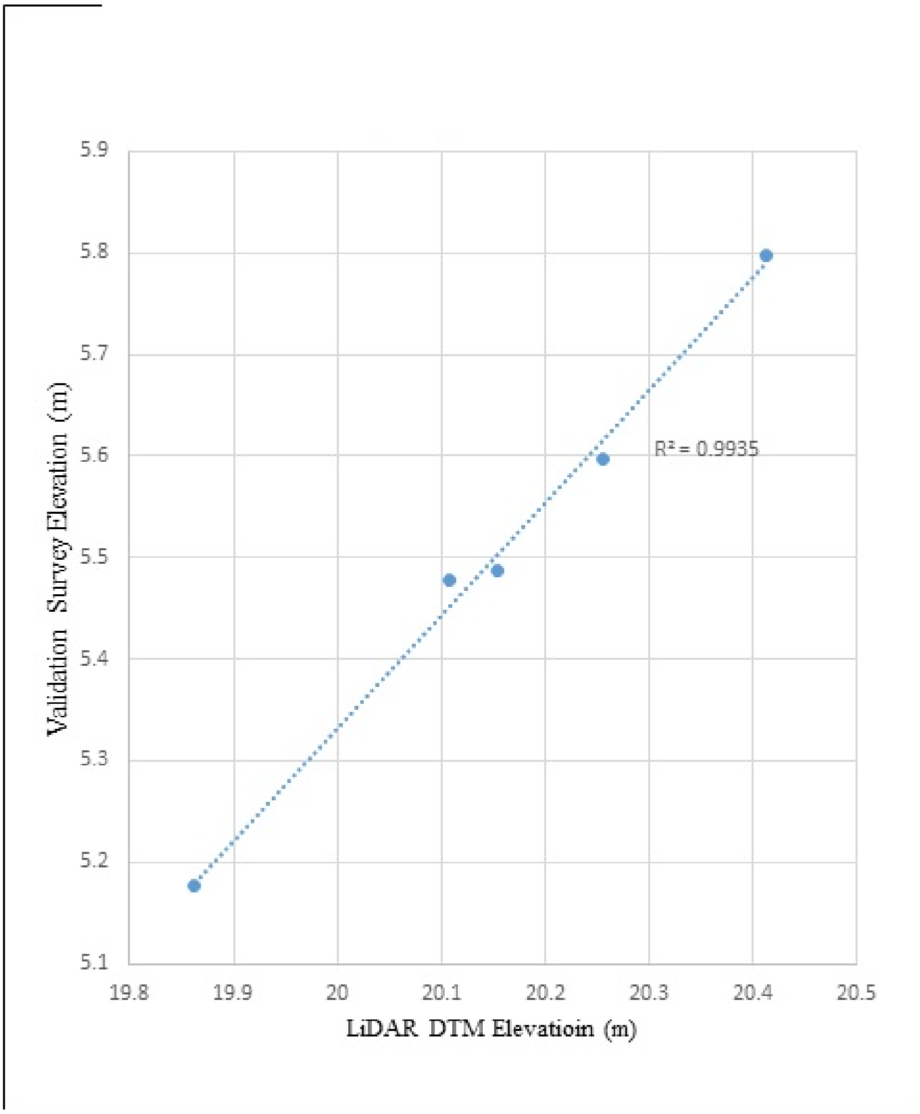


Figure 23. Correlation plot between validation survey points and LiDAR data.

Table 14. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.03
Standard Deviation	0.02
Average	0.02
Minimum	-0.01
Maximum	0.06

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathymetric data integration, only cross section was available for Ilog-Ilog with a total of 1,060 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 0.23 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Ilog-Ilog integrated with the processed LiDAR DEM is shown in Figure 24.

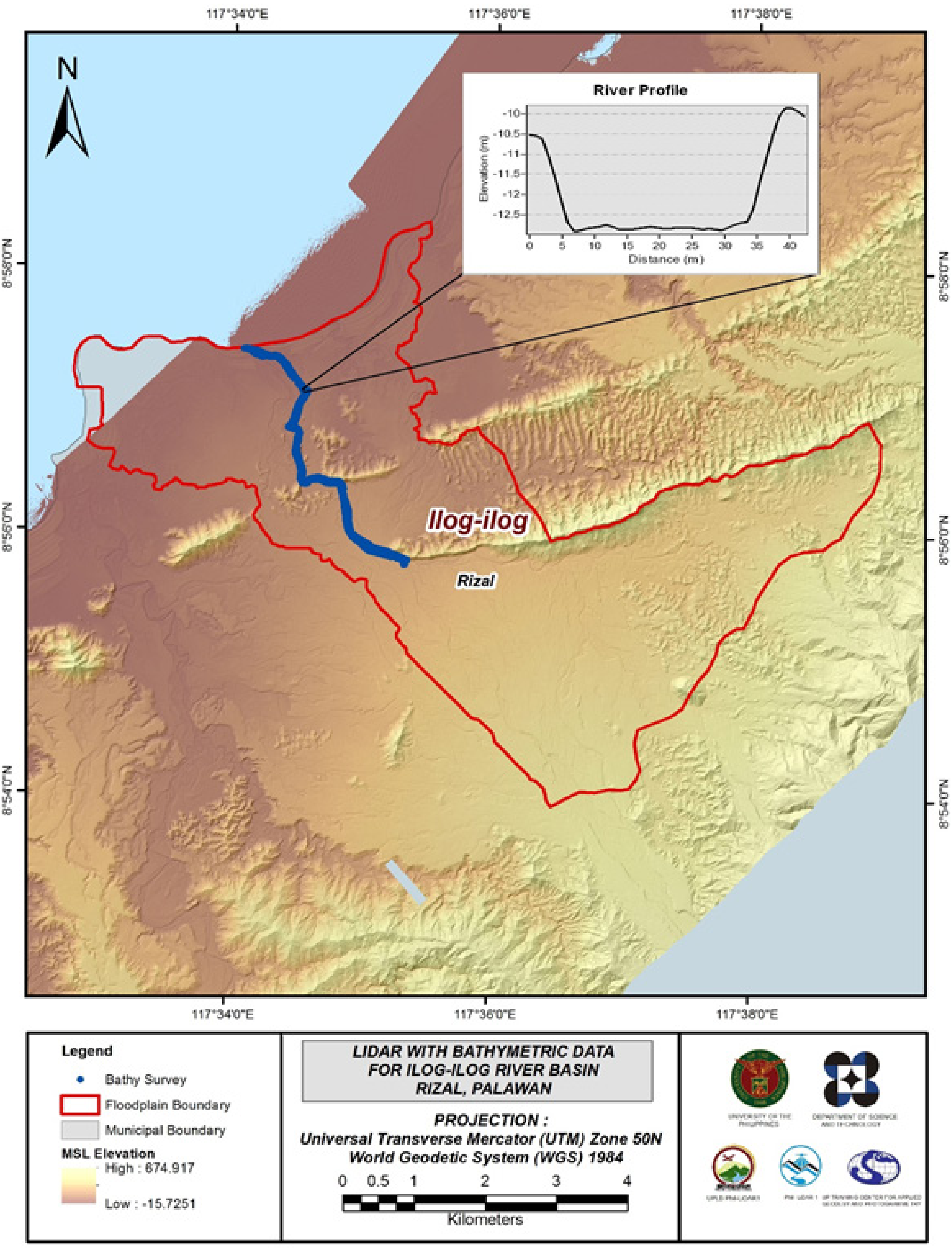


Figure 24. Map of Ilog-Ilog Floodplain with bathymetric survey points shown in blue.

CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF ILOG-ILOG RIVER BASIN

Eng. Louie P. Balicanta, Eng. Joemarie S. Caballero, Ms. Partizcia Mae P. dela Cruz, Eng. Kristine Ailene B. Borromeo, Ms. Jeline M. Amante, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Eng. Janina Jupiter, Vie Marie Paola M. Rivera

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).

4.1 Summary of Activities

The Ilog-Ilog River Basin covers two (2) municipalities in Palawan; namely, the municipalities of Rizal and Brooke's Point. The DENR River Basin Control Office (RBCO) states that the Ilog-Ilog River Basin has a drainage area of 70 km² and an estimated 112 cubic meter (MCM) annual run-off (RBCO, 2015).

Its main stem, Ilog-Ilog River, is part of the forty-five (45) river systems under the PHIL-LIDAR 1 Program partner HEI, University of the Philippines Los Baños. According to the 2015 national census of PSA, a total of 7,040 persons reside within the immediate vicinity of the river, which is distributed between barangays Campong Ulay and Ransang in the Municipality of Rizal. The economy of Palawan largely rests on agriculture particularly fishing, tourism, trade, commerce, and mineral extraction (Palawan Knowledge Platform for Biodiversity and Sustainable Development, 2007). On July 2, 2015, knee-deep flooding incident occurred in barangays Culasian, Iraan, Candawaga, and Ransang in the Municipality of Rizal due to heavy rains caused by Severe Tropical Storm "Egay" as per NDRRMC report (National Disaster Risk Reduction and Management Council, 2015).

In line with this, AB Surveying and Development (ABSD) conducted a field survey in Ilog-Ilog River on December 4-5, 2015 and January 21-23, 2016 with the following scope: reconnaissance; control survey; and cross-section and as-built survey at Ilog-Ilog Bridge in Brgy. Campong Ulay, Municipality of Rizal, Palawan. Random checking points for the contractor's cross-section and bathymetry data were gathered by DVBC on August 16-28, 2016 using an Ohmex™ Single Beam Echo Sounder and Trimble® SPS 882 GNSS PPK survey technique. In addition to this, validation points acquisition survey was conducted covering the Ilog-Ilog River Basin area. The entire survey extent is illustrated in Figure 25.

Figure 25. River Survey Extent.

4.2 Control Survey

The GNSS network used for Ilog-Ilog River is composed of two (2) loops established on August 17, 2016 occupying the following reference points: PLW-121 a second-order GCP, in Brgy. Ransang, Rizal, Palawan and UP_MAL-1, an established control point that was referred from the static survey of Malabangan River on August 16-28, 2016 in Brgy. Punta Baja, Rizal, Palawan.

Three (3) control points established in the area by ABSD were also occupied: UP_ILO-1 at the side of the railings near Ilog-Ilog Bridge in Brgy. Campong Ulay, Rizal, Province of Palawan, UP_RAN-2 located on a riprap near Ransang Bridge in Brgy. Ransang, Rizal, Palawan, and UP_IRA-2 at the side of Iraan Bridge in Brgy. Iraan, Rizal, Palawan.

The summary of reference and control points and its location is summarized in Table 15 while GNSS network established is illustrated in Figure 26.

Table 15 List of reference and control points used during the survey in Ilog-Ilog River (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoid Height (m)	Elevation (MSL) (m)	Date of Establishment
PLW-121	2nd order, GCP	8°55'57.38325"N	117°34'29.39124"E	58.058	16.172	2007
UP_MAL-1	Established	9°02'21.21274"N	117°39'10.37109"E	52.776	10.881	11-27-15
UP_ILO-1	Established	8°56'16.64151"N	117°34'53.41157"E	62.242	20.326	12-05-15
UP_RAN-2	Established	8°55'36.22496"N	117°33'21.55666"E	47.181	5.431	12-05-15
UP_IRA-2	Established	9°03'19.99012"N	117°41'29.98496"E	48.684	6.581	12-04-15

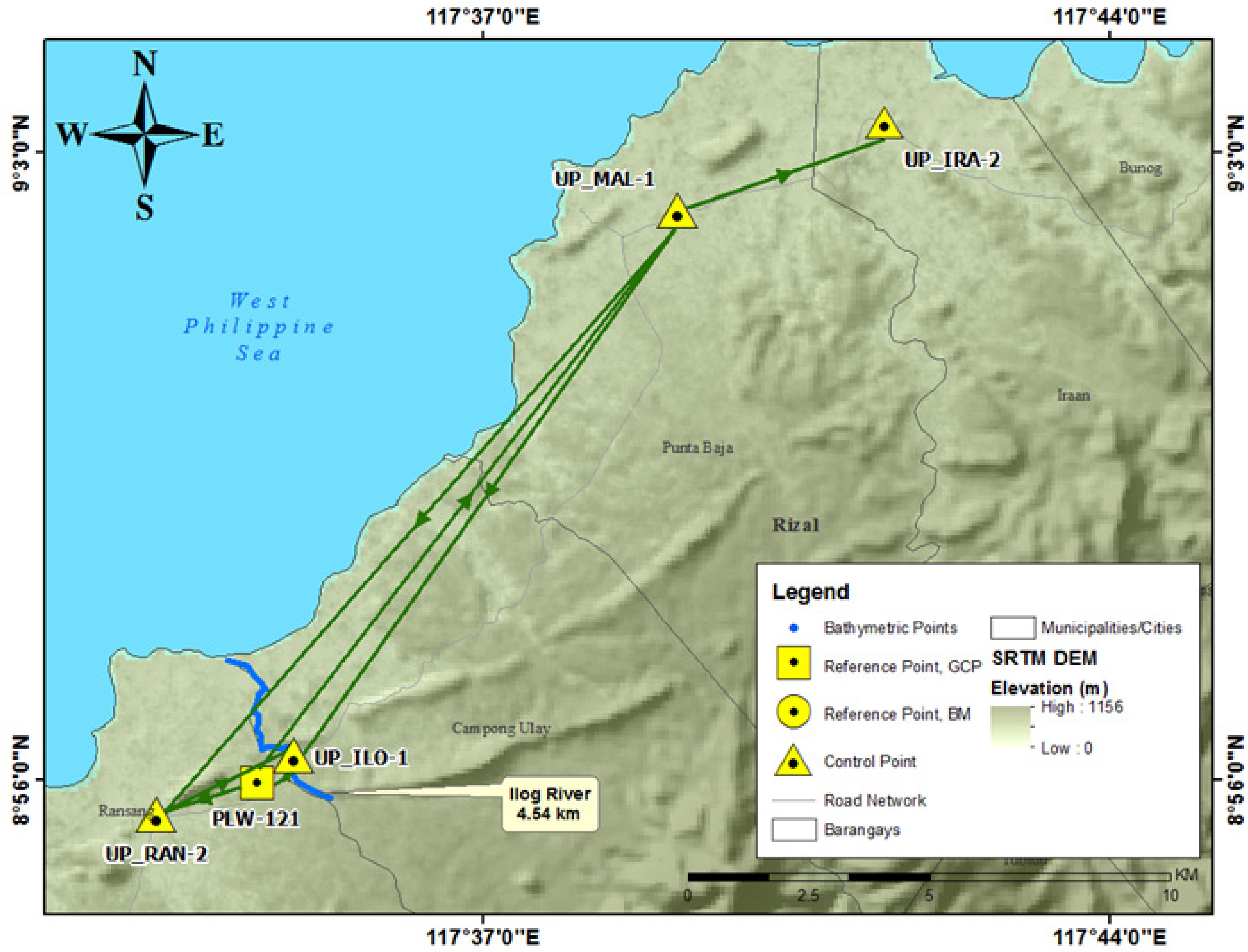


Figure 26. Ilog River Basin Control Survey Extent.

The GNSS set-ups on recovered reference points and established control points in Ilog-Ilog River are shown from Figure 27 to Figure 31.

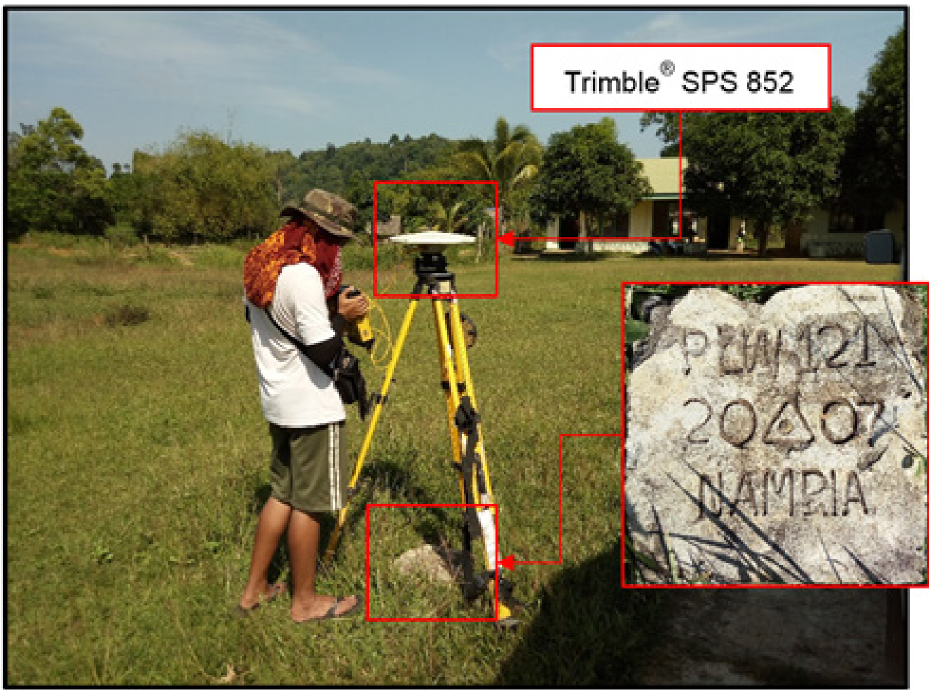


Figure 27. GNSS base set-up, Trimble® SPS 852, at PLW-121, located along the basketball court inside Cabcungan Elementary School in Brgy. Ransang, Rizal, Province of Palawan.

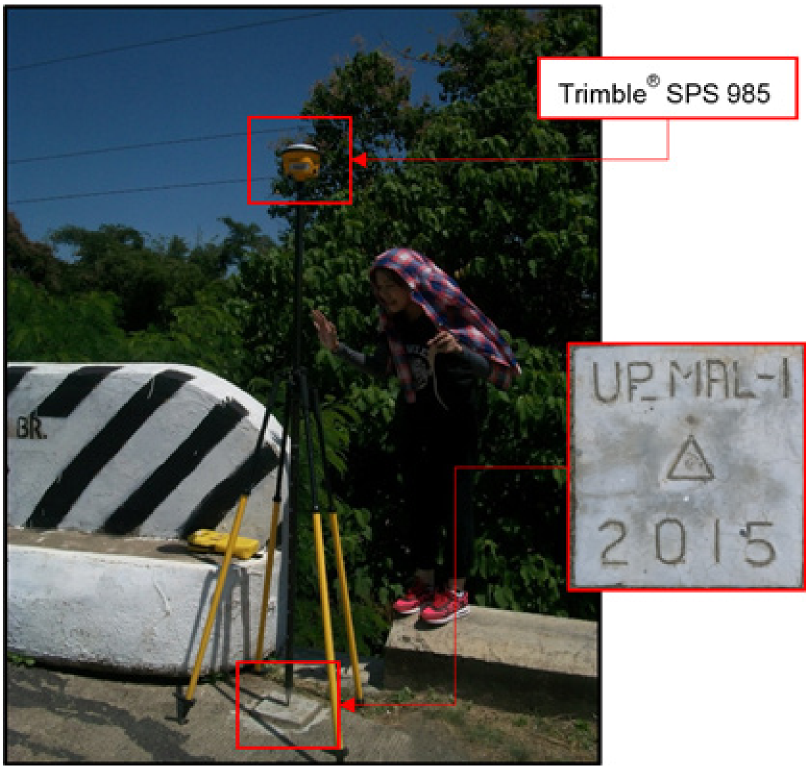


Figure 28 GNSS receiver set-up, Trimble® SPS 985, at UP_MAL-1, located beside the approach of Malambunga Bridge in Brgy. Punta Baja, Rizal, Province of Palawan.

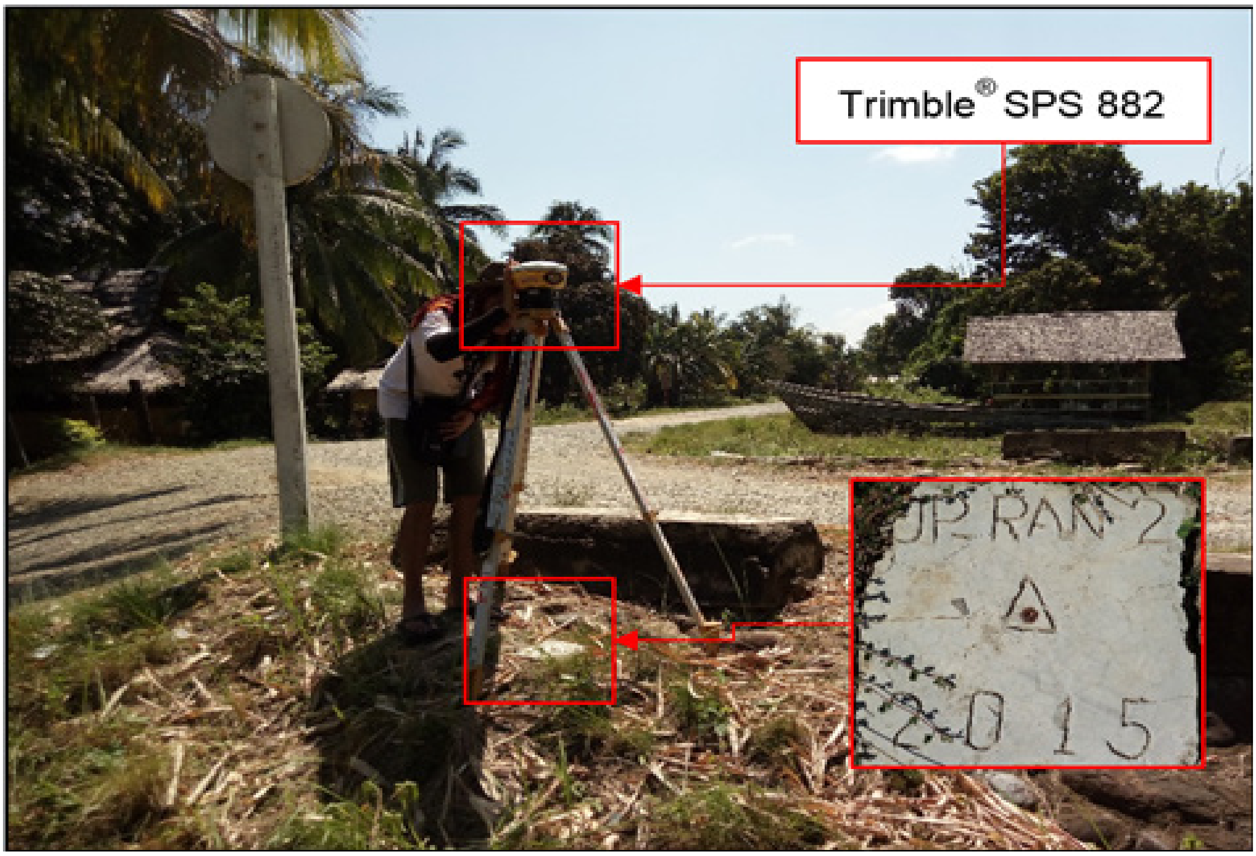


Figure 29. GNSS receiver set-up, Trimble® SPS 882, at UP_ILO-1, located at the side of the railings near Ilog-Ilog Bridge in Brgy. Campong Ulay, Rizal, Province of Palawan.

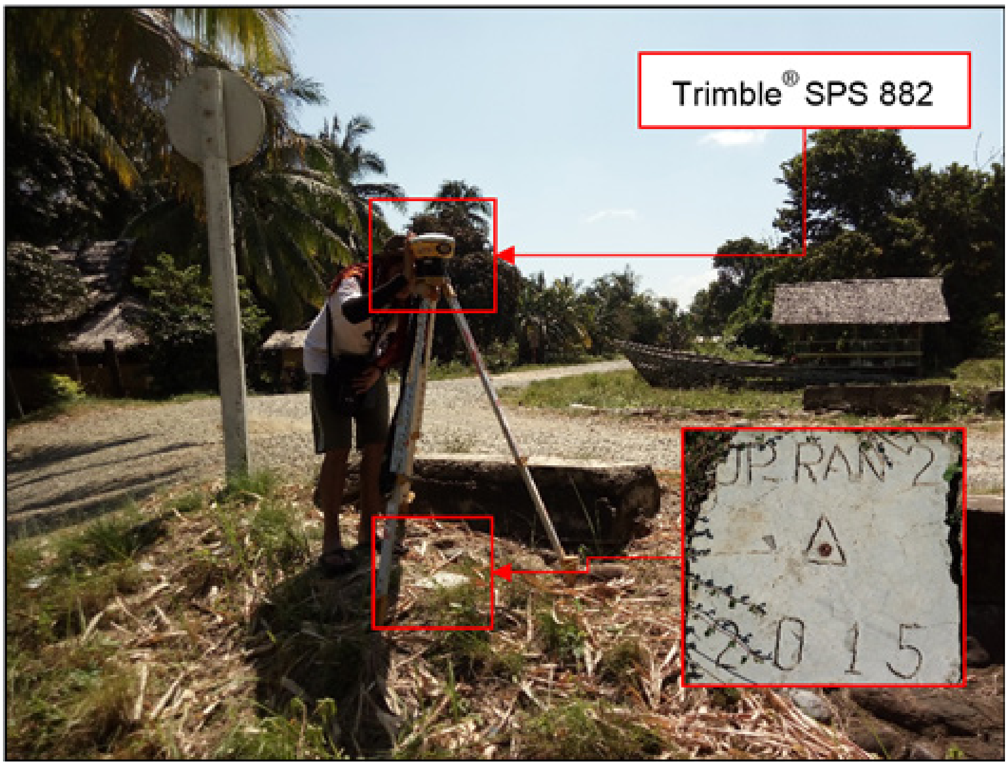


Figure 30. GNSS receiver set-up, Trimble® SPS 882, at UP_RAN-2, located on a riprap near Ransang Bridge in Brgy. Ransang, Rizal, Province of Palawan.

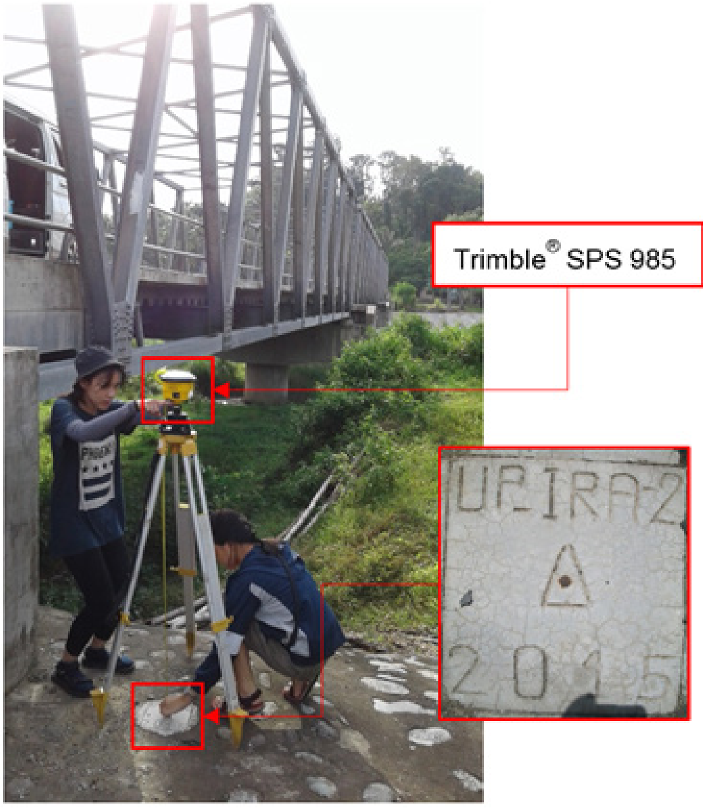


Figure 31. GNSS receiver set-up, Trimble® SPS 985, at UP_IRA-2, located on the side of Iraan Bridge in Brgy. Iraan, Rizal, Province of Palawan.

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/-20cm and +/-10cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking was performed. Masking was done by removing/masking portions of these baseline data using the same processing software. It was repeatedly processed until all baseline requirements were met. If the reiteration yielded out of the required accuracy, resurvey was initiated. Baseline processing result of control points in Ilog-Ilog River Basin is summarized in Table 16 generated by TBC software.

Table 16. Baseline Processing Report for Ilog-Ilog River Static Survey.

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (m)
UP_ILO-1 --- UP_MAL-1	8-20-2016	Fixed	0.004	0.013	215°01'35"	13676.838	9.465
UP_MAL-1 --- UP_IRA-2	8-20-2016	Fixed	0.009	0.023	67°02'36"	4630.420	-4.093
PLW-121 --- UP_ILO-1	8-20-2016	Fixed	0.002	0.002	231°07'17"	942.619	-4.184
PLW-121 --- UP_RAN-2	8-20-2016	Fixed	0.005	0.013	252°35'10"	2171.885	-10.878
PLW-121 --- UP_MAL-1	8-20-2016	Fixed	0.004	0.013	36°02'29"	14584.805	-5.289
UP_RAN-2 --- UP_ILO-1	8-20-2016	Fixed	0.005	0.015	66°07'44"	3068.568	15.065
UP_RAN-2 ---UP_MAL-1	8-20-2016	Fixed	0.005	0.018	40°34'00"	16380.815	5.587

As shown Table 16, a total of seven (7) baselines were processed with coordinate and ellipsoidal height values of PLW-137 held fixed. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

for each control point. See the Network Adjustment Report shown from Table 17 to Table 19 for the complete details. Refer to Appendix C for the computation for the accuracy of ABSD.

The five (5) control points, PLW-121, UP_MAL-1, UP-ILO-1, UP_RAN-2, and UP-IRA-2 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height values of PLW-121 and UP_MAL-1 were held fixed during the processing of the control points as presented in Table 17. Through this reference point, the coordinates and ellipsoidal height of the unknown control points was computed.

The control point UP_IRA-2 was only connected via baseline; hence, it is not reflected in the Network Adjustment.

Table 17. Control Point Constraints.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
PLW-121	Global	Fixed	Fixed	Fixed	
UP_MAL-1	Global	Fixed	Fixed	Fixed	
Fixed = 0.000001(Meter)					

Likewise, 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 23. All fixed control points have no value for grid and elevation error.

Table 18. Adjusted Grid Coordinates.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
PLW-121	563194.622	?	987450.572	?	10.335	?	LLh
UP_ILO-1	563927.242	0.001	988043.176	0.001	14.489	0.002	
UP_MAL-1	571754.477	?	999253.104	?	5.044	?	LLh
UP_RAN-2	561124.020	0.003	986797.593	0.002	-0.406	0.010	

The results of the computation for accuracy are as follows:

a. **PLW-121**

horizontal accuracy	=	Fixed
vertical accuracy	=	Fixed

b. **UP_ILO-1**

horizontal accuracy	=	$\sqrt{((0.1)^2 + (0.1)^2}$
	=	$\sqrt{(0.1 + 0.1)}$
	=	0.02< 20 cm
vertical accuracy	=	0.2< 10 cm

c. **UP_MAL-1**

horizontal accuracy	=	Fixed
vertical accuracy	=	Fixed

d. **UP_RAN-2**

horizontal accuracy	=	$\sqrt{((0.3)^2 + (0.2)^2}$
	=	$\sqrt{(0.9 + 0.4)}$
	=	1.3< 20 cm
vertical accuracy	=	1.0< 10 cm

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

Table 19 Adjusted Geodetic Coordinates.

Point ID	Latitude	Longitude	Ellipsoid Height (Meter)	Height Error (Meter)	Constraint
PLW-121	N8°55'57.38325"	E117°34'29.39124"	58.058	?	LLh
UP_ILO-1	N8°56'16.64151"	E117°34'53.41157"	62.242	0.002	
UP_MAL-1	N9°02'21.21274"	E117°39'10.37109"	52.776	?	LLh
UP_RAN-2	N8°55'36.22496"	E117°33'21.55666"	47.181	0.010	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown inTable 19. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference control points used is indicated in Table 20.

Table 20. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
PLW-121	**2nd order, GCP**	**8°55'57.38325"N**	**117°34'29.39124"E**	**58.058**	**987450.572**	**563194.622**	**16.172**
UP_MAL-1	Established	9°02'21.21274"N	117°39'10.37109"E	52.776	999253.104	571754.477	10.881
UP_ILO-1	Established	8°56'16.64151"N	117°34'53.41157"E	62.242	988043.176	563927.242	20.326
UP_RAN-2	Established	8°55'36.22496"N	117°33'21.55666"E	47.181	986797.593	561124.02	5.431
UP_IRA-2	Established	9°03'19.99012"N	117°41'29.98496"E	48.684	1001066.17	576013.515	6.581

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

Cross-section and as-built surveys were conducted on December 4, 2015 at the upstream side of Ilog-Ilog Bridge in Brgy. Campong Ulay, Municipality of Rizal as shown in Figure 32. A Nikon®Total Station was utilized for this survey as shown in Figure 33.

Figure 32. Ilog-Ilog Bridge facing upstream.

The cross-sectional line of Ilog-Ilog Bridge is about 166 m with thirty-seven (37) cross-sectional points using the control points UP_ILO-1 and UP_ILO-2 as the GNSS base stations. The cross-section diagram, location map, and the bridge data form are shown in Figure 35 toFigure 37. Gathering of random points for the checking of ABSD's bridge cross-section and bridge points data was performed by DVBC on August 20, 2016 using a survey grade GNSS Rover receiver attached to a 2-m pole as seen in Figure 34.

Figure 33. As-built survey of Ilog-Ilog Bridge.

The cross-sectional line of Ilog-Ilog Bridge is about 166 m with thirty-seven (37) cross-sectional points using the control points UP_ILO-1 and UP_ILO-2 as the GNSS base stations. The cross-section diagram, location map, and the bridge data form are shown in Figure 35 toFigure 37. Gathering of random points for the checking of ABSD's bridge cross-section and bridge points data was performed by DVBC on August 20, 2016 using a survey grade GNSS Rover receiver attached to a 2-m pole as seen in Figure 34.

Figure 34. Gathering of random bridge points along of Ilog-Ilog Bridge.

Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor was within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. The computed R2 values of 0.937 and 0.882 for the cross-section data and bridge points data, respectively, were obtained by comparing the data of the contractor and DVBC; signifying a strong correlation between the two (2) datasets.

In addition to the Linear Square Correlation, Root Mean Square (RMSE) analysis was also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the cross-section data and bridge points data, the computed values were 0.185 and 0.110, respectively. The computed R2 and RMSE values are within the accuracy requirement of the program.

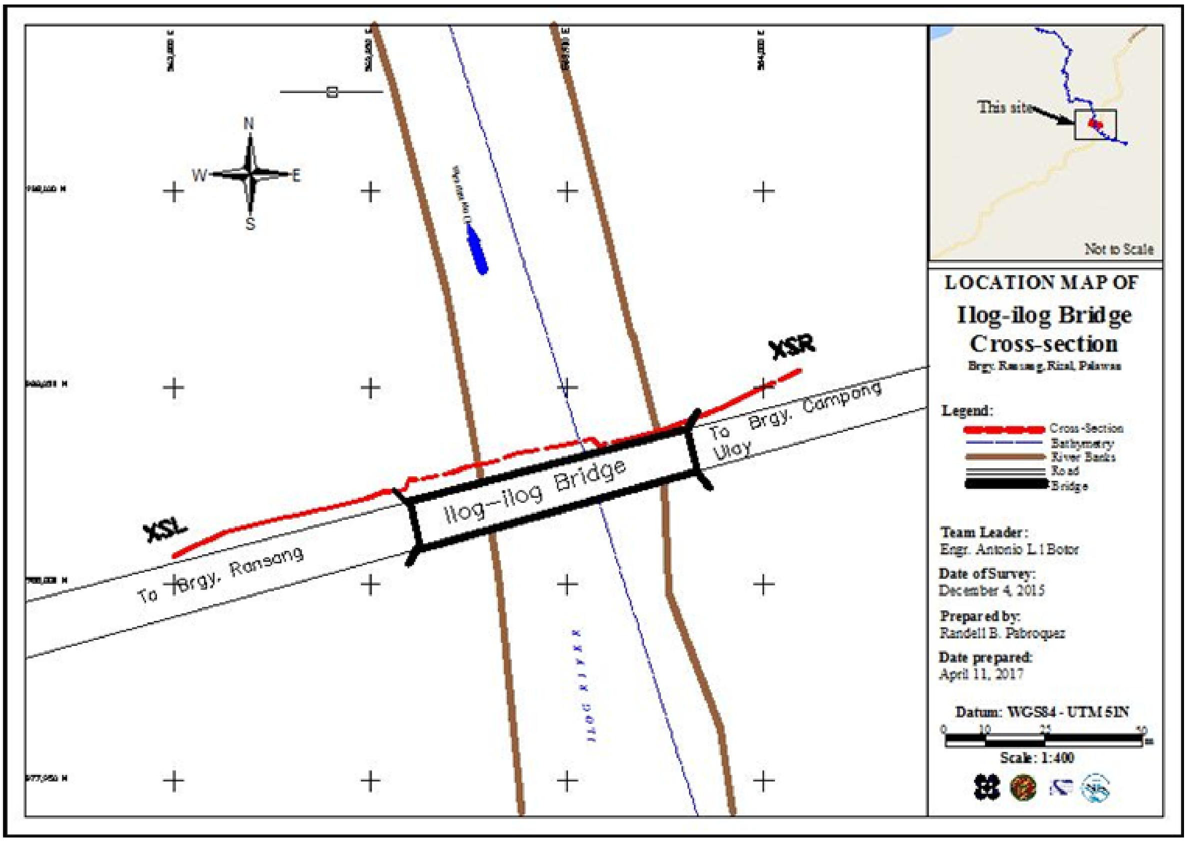


Figure 36. Location Map of Ilog-Ilog Bridge Cross-section.

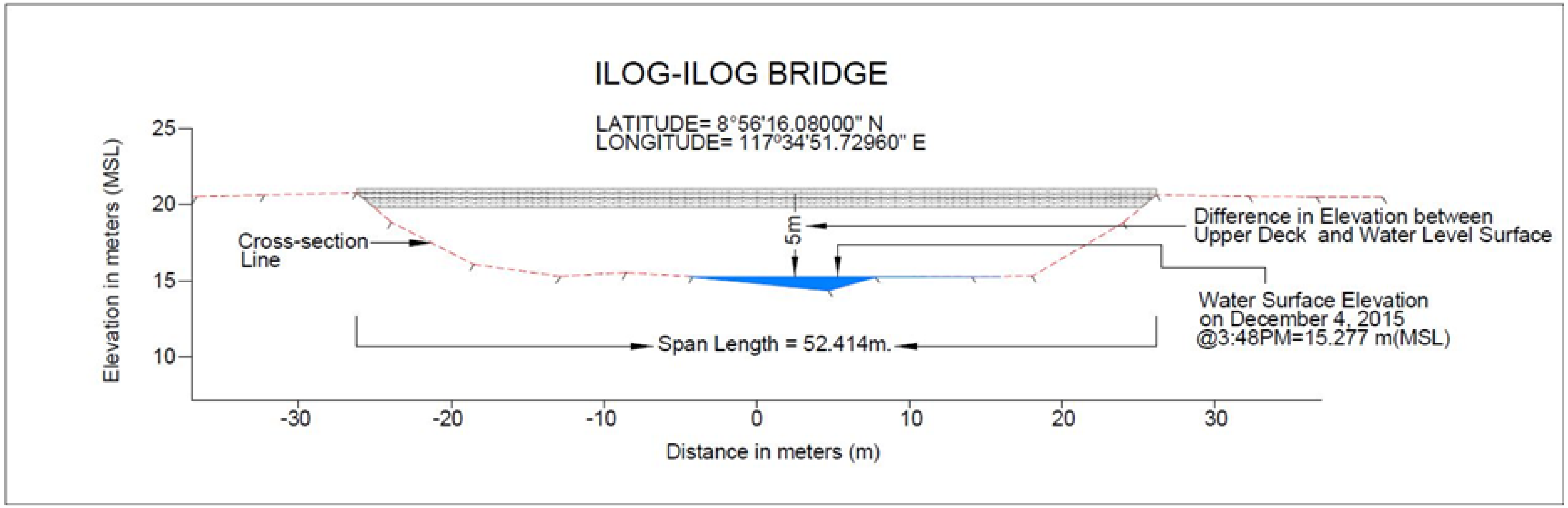


Figure 35 log-Ilog Bridge Cross-section Diagram.

Bridge Data Form

Bridge Name: Ilog-Ilog Bridge

River Name: Ilog River

Location (Brgy, City, Region): Brgy. Campong Ulay, Rizal, Palawan

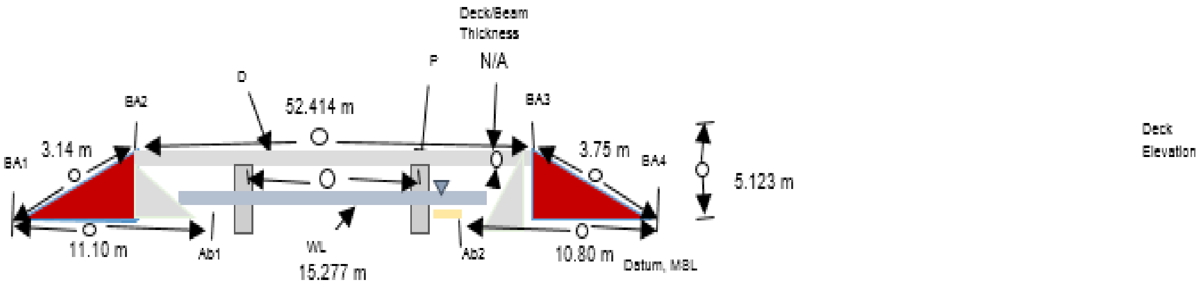
Survey Team: Jayson Illustre, Local Aid

Date and Time: December 4, 2015; 3:48 PM

Flow Condition: low ▯ normal high

Weather Condition: ▯ fair rainy ▯

Cross-sectional View (not to scale)



Legend:
BA = Bridge Approach
P = Pier

Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
◯ = Measurement Value

Line Segment	Measurement (m)	Remarks
1. BA1-BA2	3.14 m	
2. BA2-BA3	52.414 m	
3. BA3-BA4	3.75m	
4. BA1-Ab1	11.10 m	
5. Ab2-BA4	10.80 m	
6. Deck/beam thickness	N/A	
7. Deck elevation	5.123 m	

Note: Observer should be facing downstream

Figure 37. Ilog-Ilog Bridge Data Sheet

Water surface elevation of Ilog-Ilog River was determined by a Horizon® Total Station on December 4, 2015 at 3:48 PM at Ilog-Ilog Bridge area with a value of 15.277 m in MSL as shown in Figure 35. This was translated into marking on the bridge's abutment as shown in Figure 38. The marking served as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Ilog-Ilog River, the University of the Philippines Los Baños.

Figure 38. Water-level markings on Ilog-Ilog Bridge.

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted by DVBC from August 16-28, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 39. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 2.560 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP_ILO-1 occupied as the GNSS base station in the conduct of the survey.

Figure 39. Validation points acquisition survey set-up for Ilog-Ilog River.

The survey started from Brgy. Campong Ulay, Municipality of Rizal, Palawan going southwest along the national highway and ended in Brgy. Ransang, Municipality of Rizal, Palawan. The survey gathered a total of 123 points with approximate length of 7.02 km using UP_ILO-1 as GNSS base station for the entire extent of validation points acquisition survey as illustrated in the map in Figure 40. Because majority of the roads in the survey area were unpaved, more than 70% of the area does not have data.

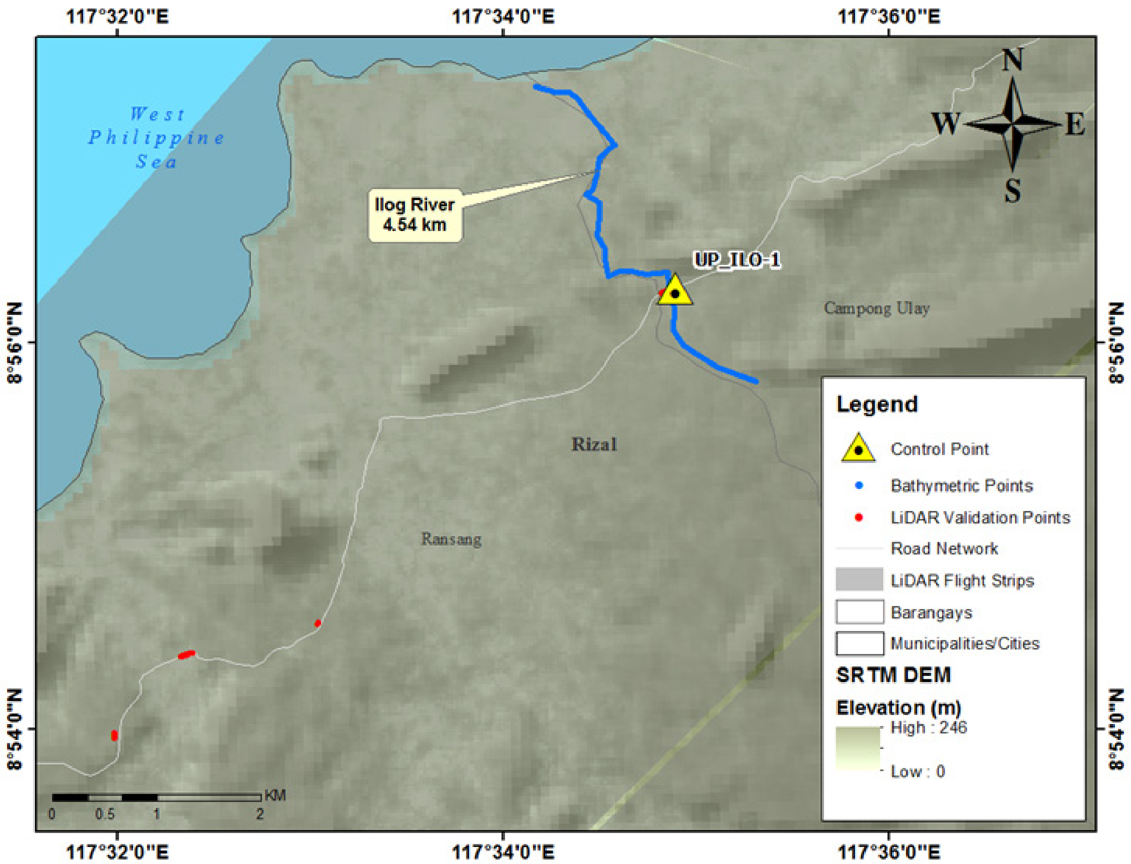


Figure 40 Validation points acquisition covering the Ilog-Ilog River Basin Area.

4.7 River Bathymetric Survey

Manual bathymetric survey was executed from January 21-23, 2016 using a Nikon® Total Station as illustrated in Figure 41. The survey started in Brgy. Campong Ulay, Municipality of Rizal with coordinates 8° 55' 45.44067"N, 117° 35' 20.89790"E, traversing down the river and ended at the mouth of the river in Brgy. Ransang, Municipality of Rizal with coordinates 8° 57' 22.79615"N, 117° 34' 5.54422"E. The control points UP_ILO-1 and UP_ILO-2 were used as GNSS base stations during the entire survey.

Figure 41. Manual bathymetric survey of ABSD along Ilog-Ilog River using a Nikon® Total Station.

Gathering of random points for the checking of ABSD's bathymetric data was performed by DVBC on August 20, 2016 using a GNSS Rover receiver, Trimble® SPS 882 attached to a 2-m pole, seeFigure 42. A map showing the DVBC bathymetric checking points is shown in Figure 44.

Figure 42. Gathering of bathymetric checking points along Ilog-Ilog River.

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets and a computed R2value of 0.998 is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.204 was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program. The bathymetric survey for Ilog-Ilog River gathered a total of 1,447 points covering 4.54 km of the river traversing barangays Campong Ulay and Ransang in the Municipality of Rizal. A CAD drawing was also produced to illustrate the riverbed profile of Ilog-Ilog River. As shown in Figure 45, the highest and lowest elevation has a 33-m difference. The highest elevation observed was 26.813 m below MSL in Brgy. Campong Ulay, Municipality of Rizal while the lowest was -5.868 m below MSL located in Brgy. Ransang, Municipality of Rizal.

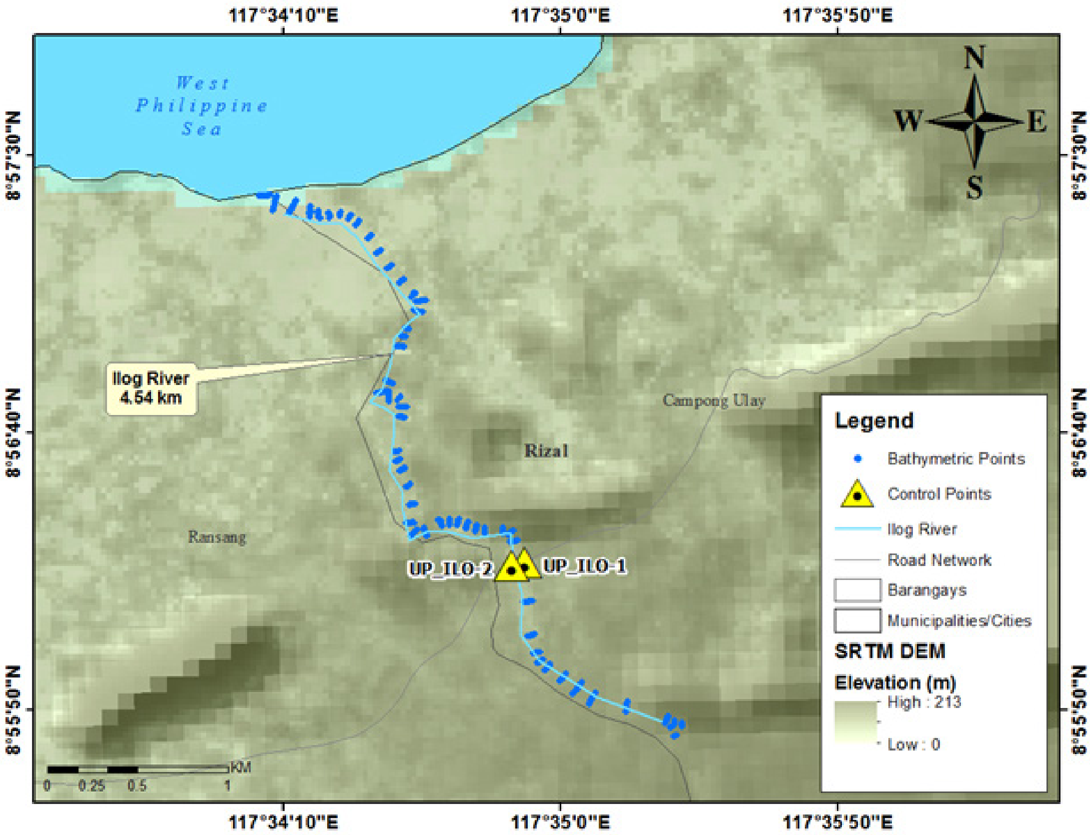


Figure 43. Bathymetric survey of Ilog-Ilog River.

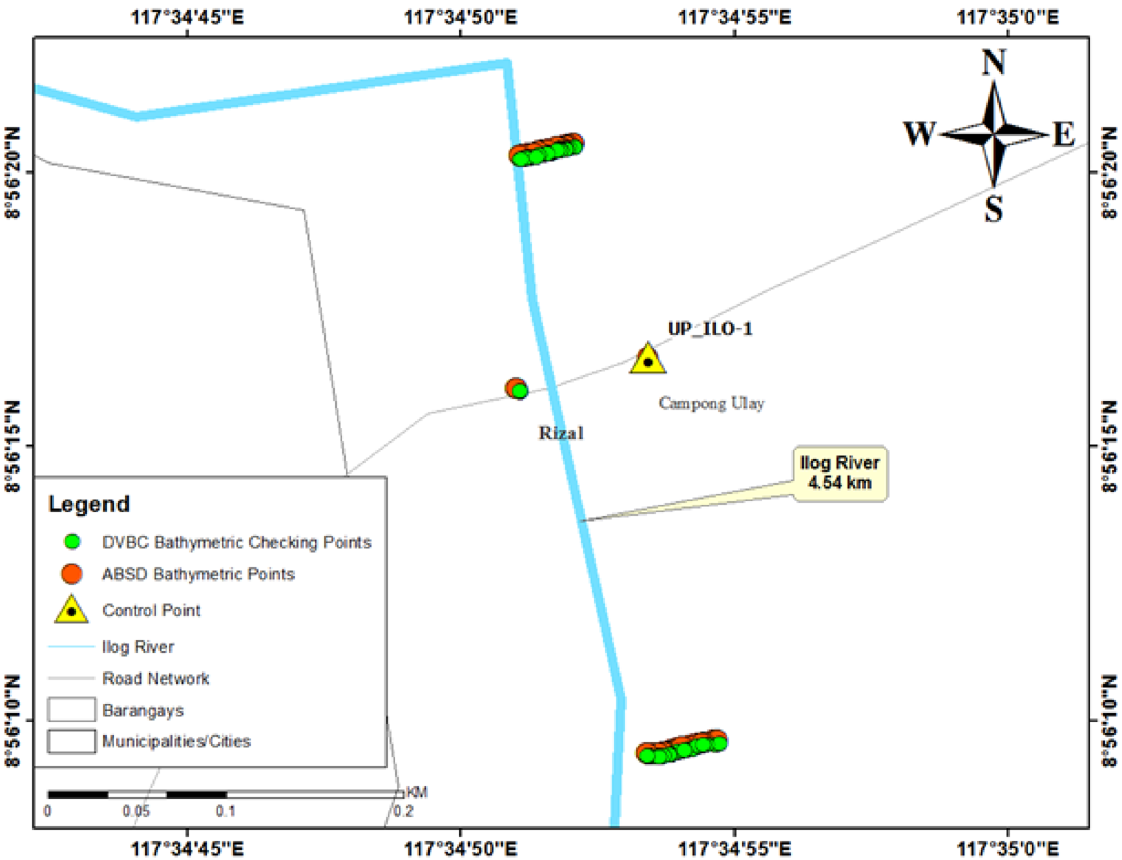


Figure 44. Quality checking points gathered along Ilog-Ilog River by DVBC.

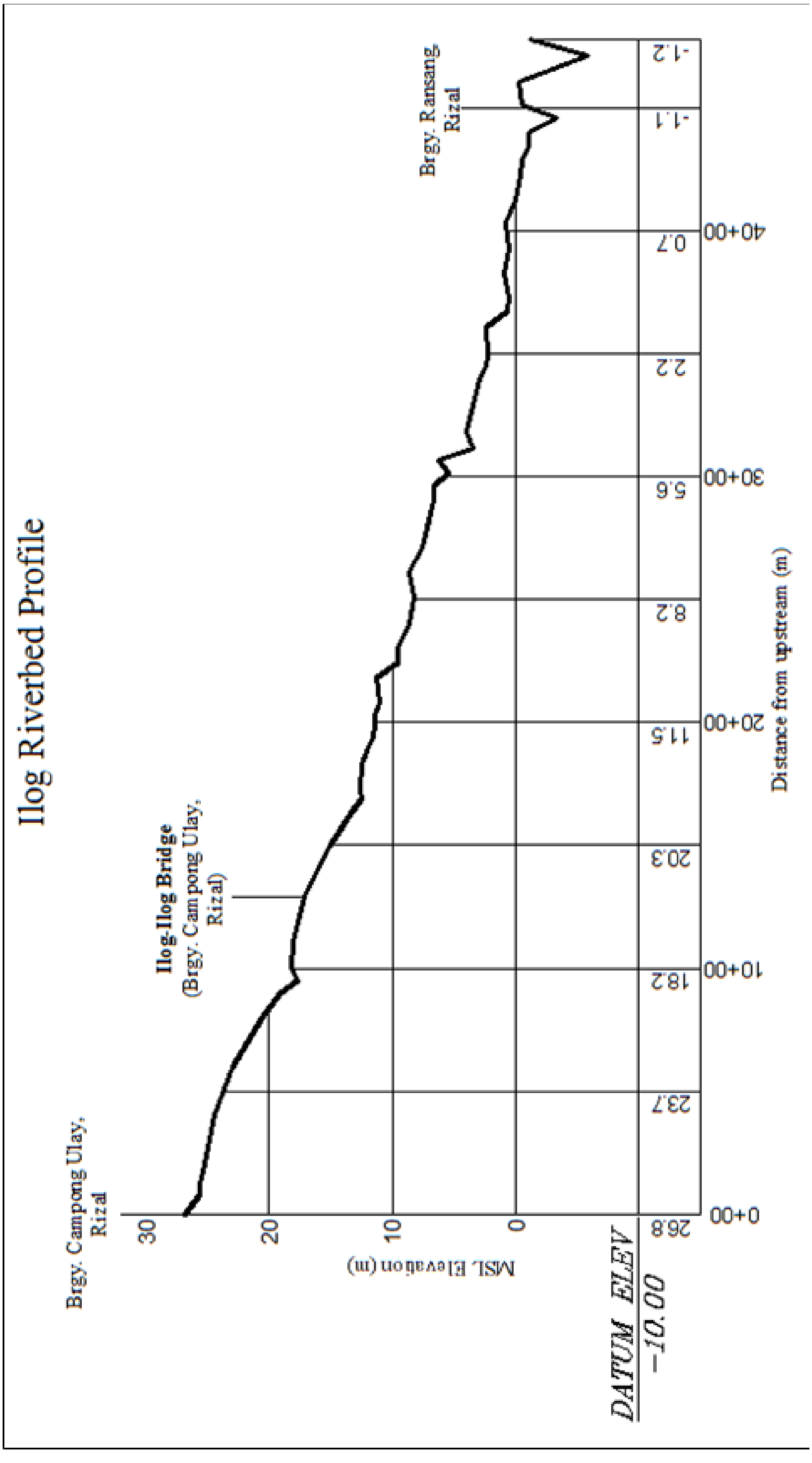


Figure 45. Ilog-Ilog Riverbed Profile.

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, Khristoffer Quinton, John Alvin B. Reyes, Alfi Lorenz B. Cura, Angelica T. Magpantay, Maria Michaela A. Gonzales Paulo Joshua U. Quilao, Jayson L. Arizapa, Kevin M. Manalo

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).

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from a portable rain gauge deployed on a strategic location within the riverbasin (8.937747˚ N, 117.581500˚ E). The location of the rain gauge is seen in Figure 46.

The total precipitation for this event was 16.0 mm. It had a peak rainfall of 2.60 mm on February 24, 2017 at 7:10 am. The lag time between the peak rainfall and discharge was 7 hour and 30 minutes, as seen in Figure 49.

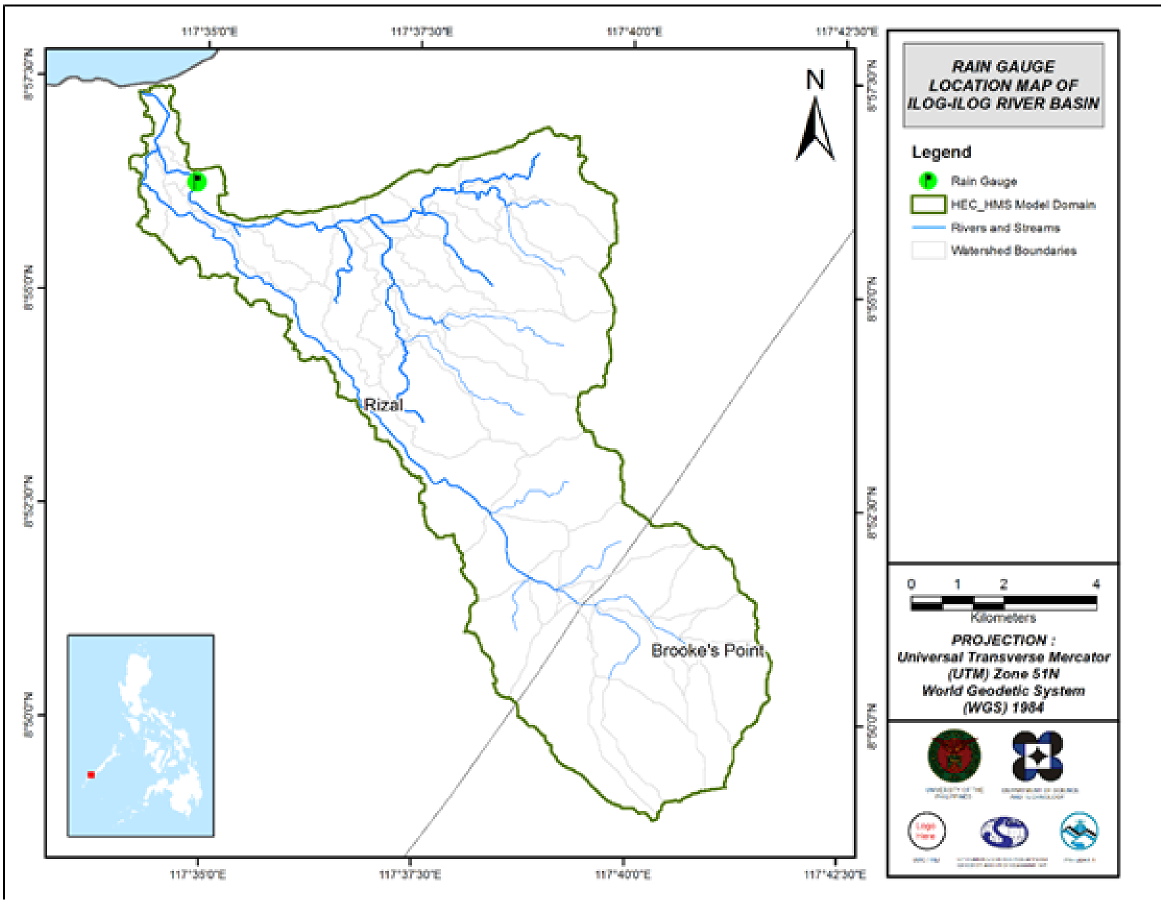


Figure 46 The location map of Ilog-Ilog HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Ilog-Ilog Bridge, Rizal, Palawan (8.937800° N, 117.581036° E). It gives the relationship between the observed water levels from the Ilog-Ilog Bridge and outflow of the watershed at this location using Bankfull Method in Manning's Equation.

For Ilog-Ilog Bridge, the rating curve is expressed as Q = 34.021x2 -997.12x +7306.60as shown in Figure 48.

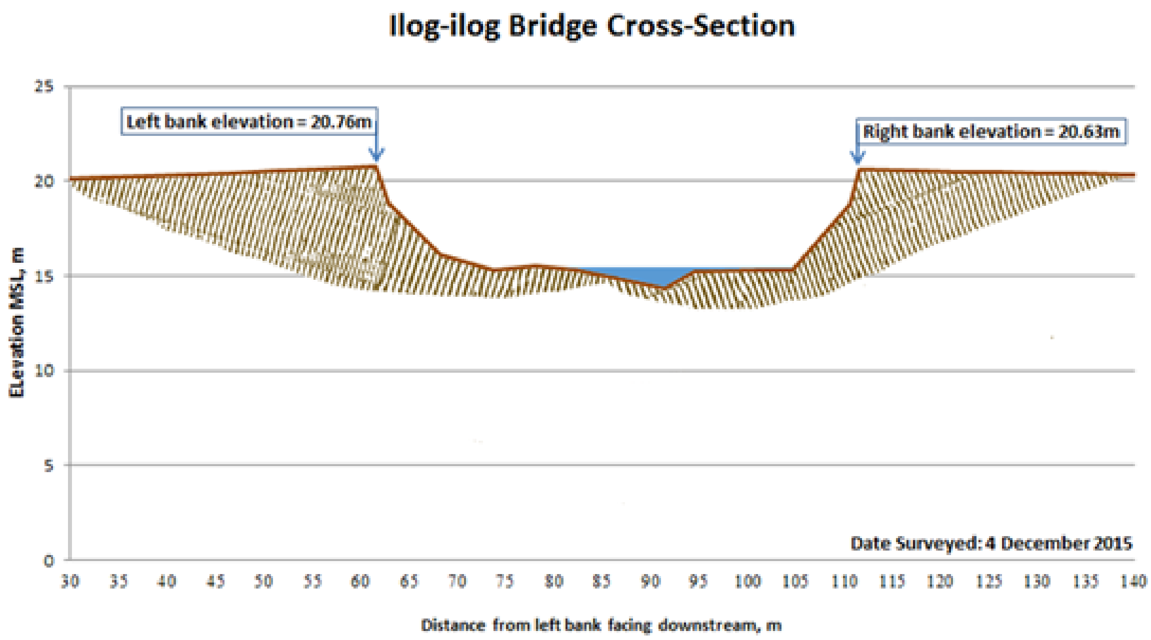


Figure 47. Cross Section Plot of Ilog-Ilog Bridge.

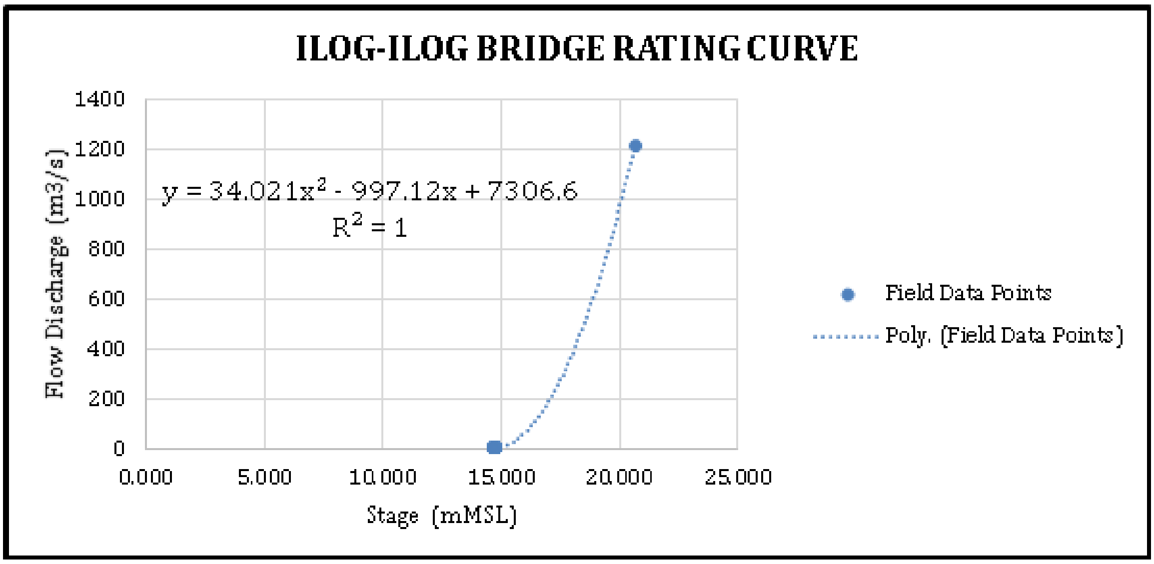


Figure 48 Rating Curve at Ilog-Ilog Bridge, Rizal, Palawan.

For the calibration of the HEC-HMS model, shown in Figure 48, actual flow discharge during a rainfall event was collected in the Ilog-Ilog bridge. Peak discharge was 14.77 cu.m/s on February 24, 2017 at 2:40 pm.

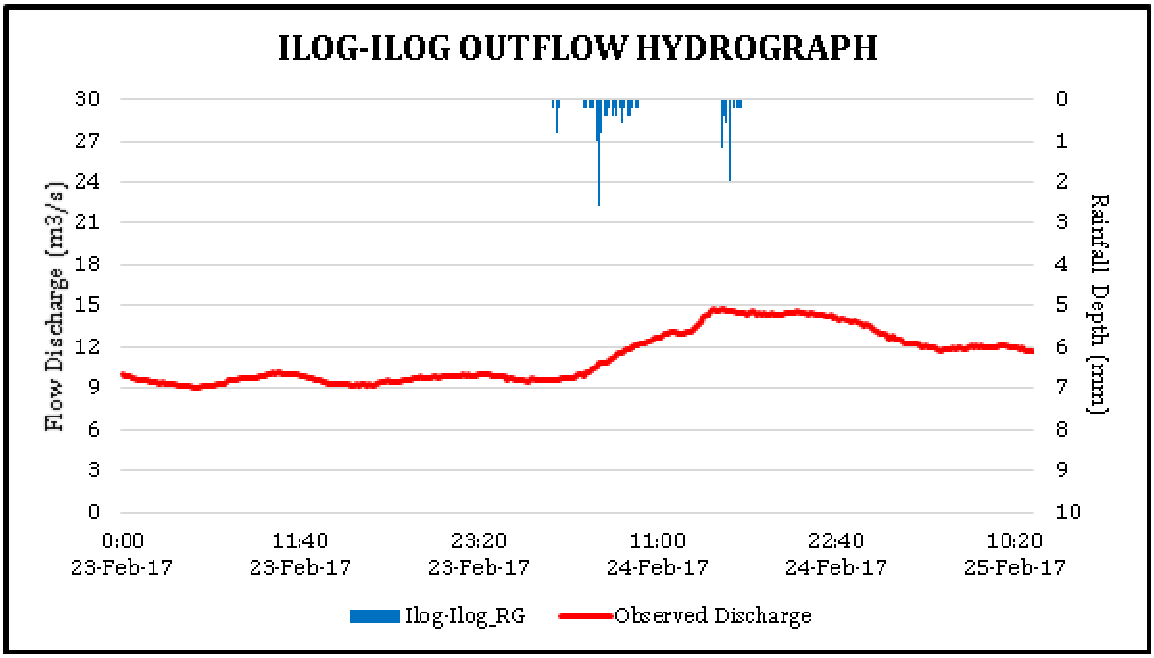


Figure 49. Rainfall and outflow data at Ilog-Ilog used for modeling.

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Puerto Princesa Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value was attained at a certain time. This station was chosen based on its proximity to the Ilog-Ilog watershed. The extreme values for this watershed were computed based on a 58-year record.

Table 21 RIDF values for Puerto Princesa Rain Gauge computed by PAGASA.

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	14.8	22	27.3	36.2	49.8	58.8	75.1	88	104.1
5	21.3	31.9	39.7	52.3	73	86.9	112.8	135.4	156.4
10	25.6	38.5	48	63	88.4	105.5	137.8	166.8	191.1
15	28.1	42.2	52.6	69	97	116	151.9	184.5	210.6
20	29.8	44.7	55.9	73.3	103.1	123.4	161.7	196.8	224.3
25	31.1	46.7	58.4	76.5	107.8	129.1	169.3	206.4	234.9
50	35.2	52.9	66.1	86.5	122.2	146.5	192.7	235.8	267.3
100	39.2	59	73.7	96.4	136.5	163.8	216	265	299.6

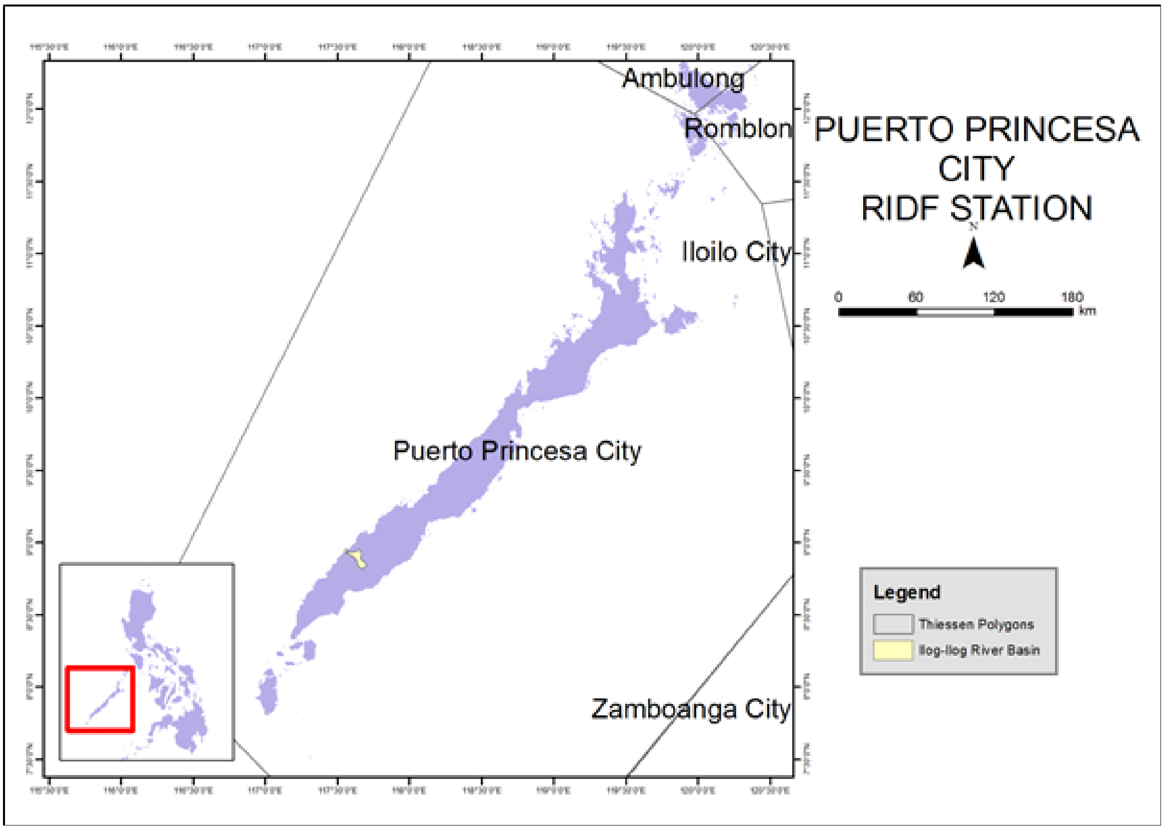


Figure 50. Location of Puerto Princesa RIDF relative to Ilog-Ilog River Basin.

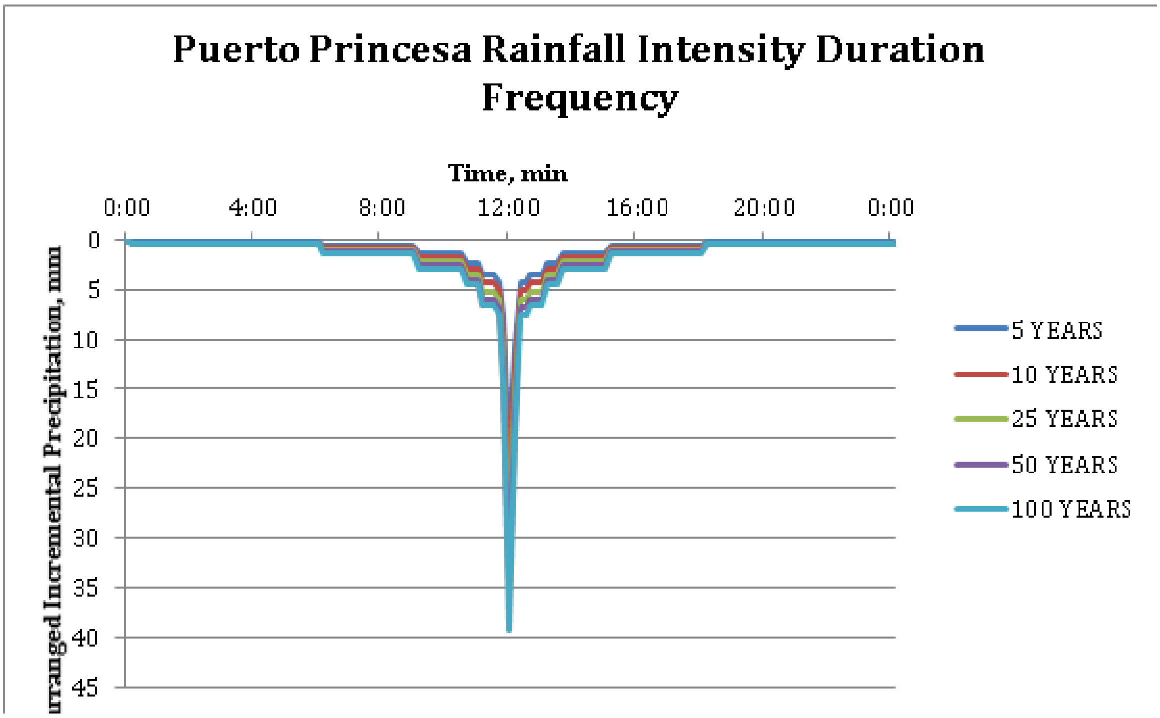


Figure 51. Synthetic Storm Generated For A 24-hr Period Rainfall For Various Return Periods.

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA).

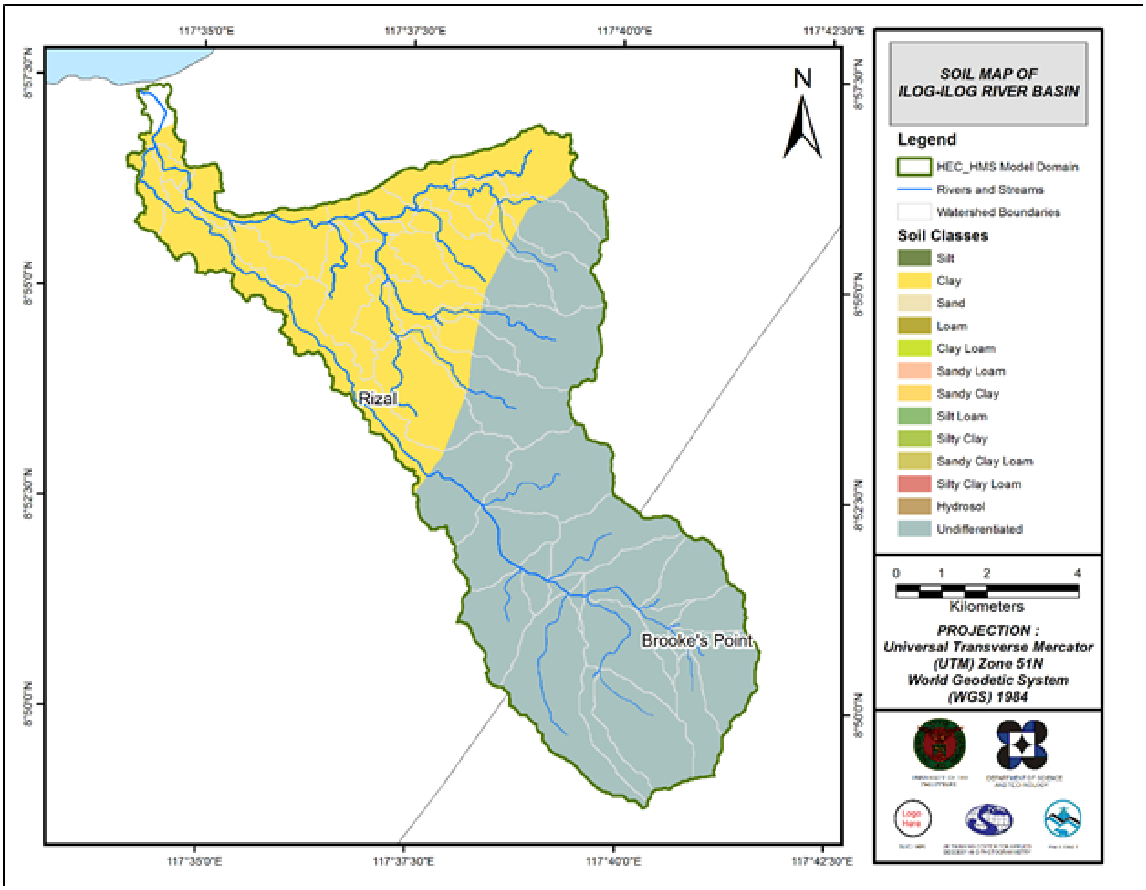


Figure 52 The soil map of the Ilog-Ilog River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture).

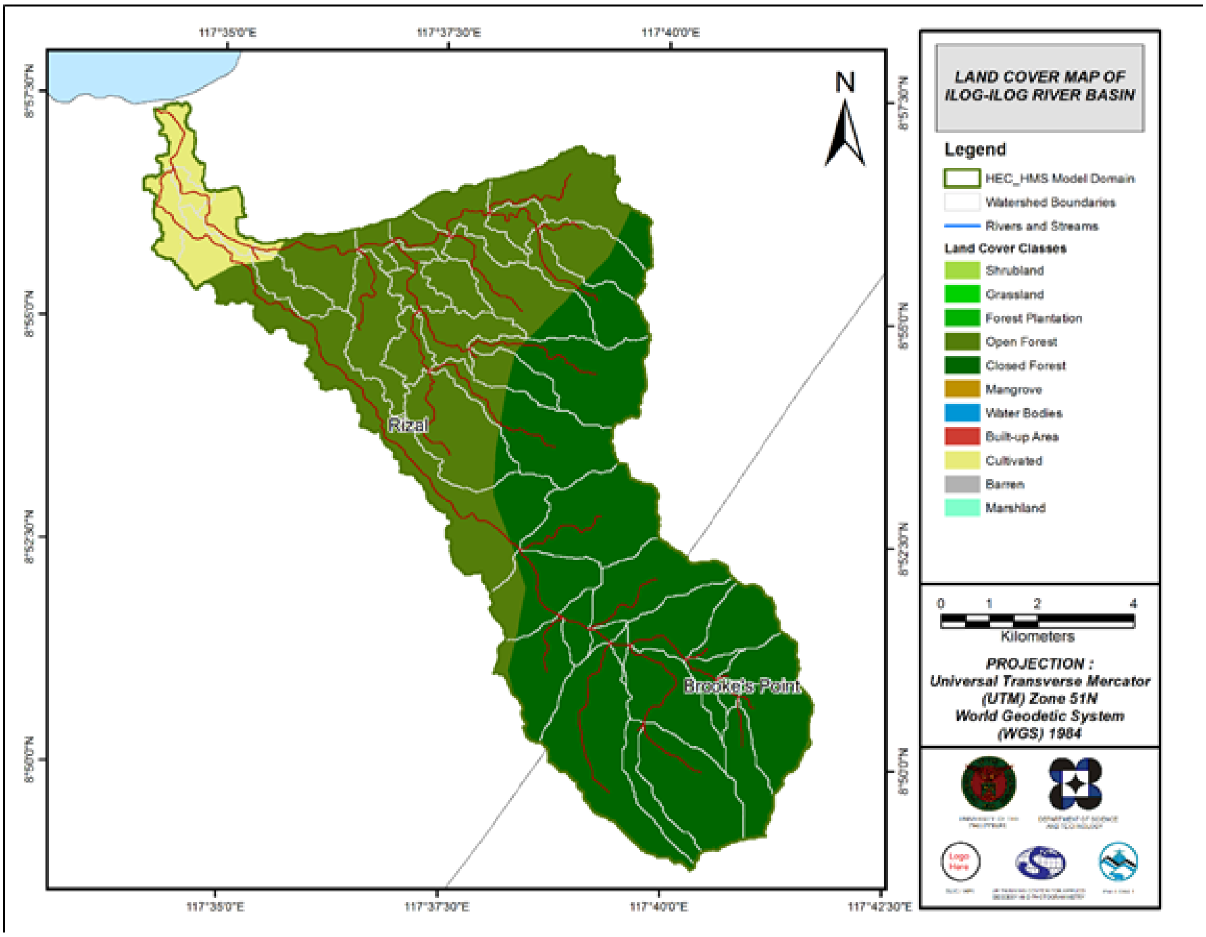


Figure 53 The land cover map of the Ilog-Ilog River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture).

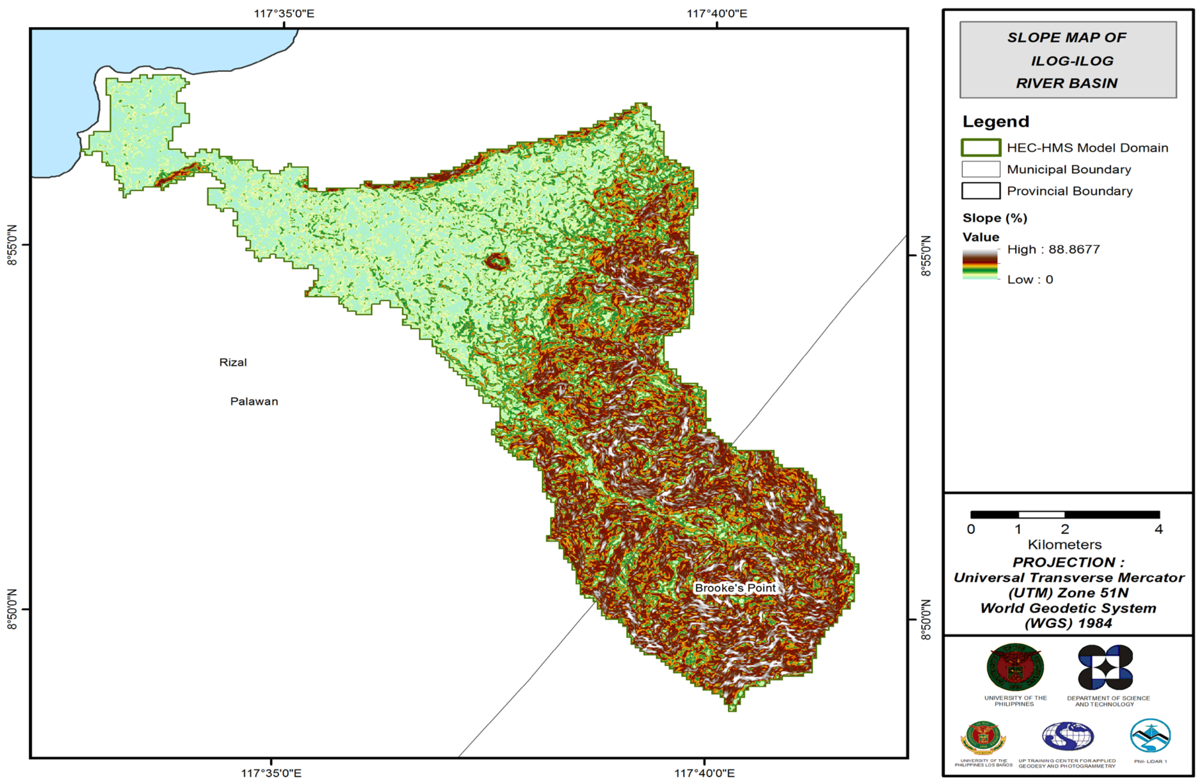


Figure 54 Slope Map of Ilog-Ilog River Basin.

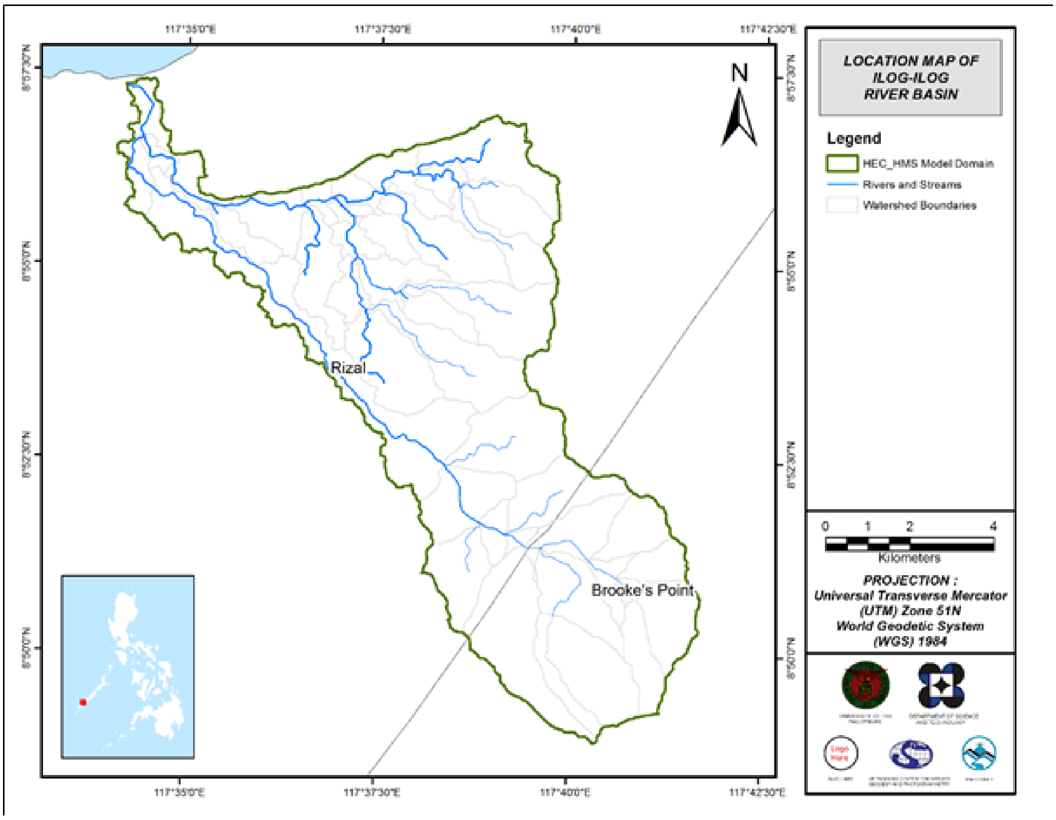


Figure 55 Stream Delineation Map of the Ilog-Ilog River Basin.

Using SAR-based DEM, the Ilog-Ilog basin was delineated and further subdivided into subbasins. The model consists of 43 sub basins, 22 reaches, and 22 junctions. The main outlet is at Ilog-Ilog Bridge.

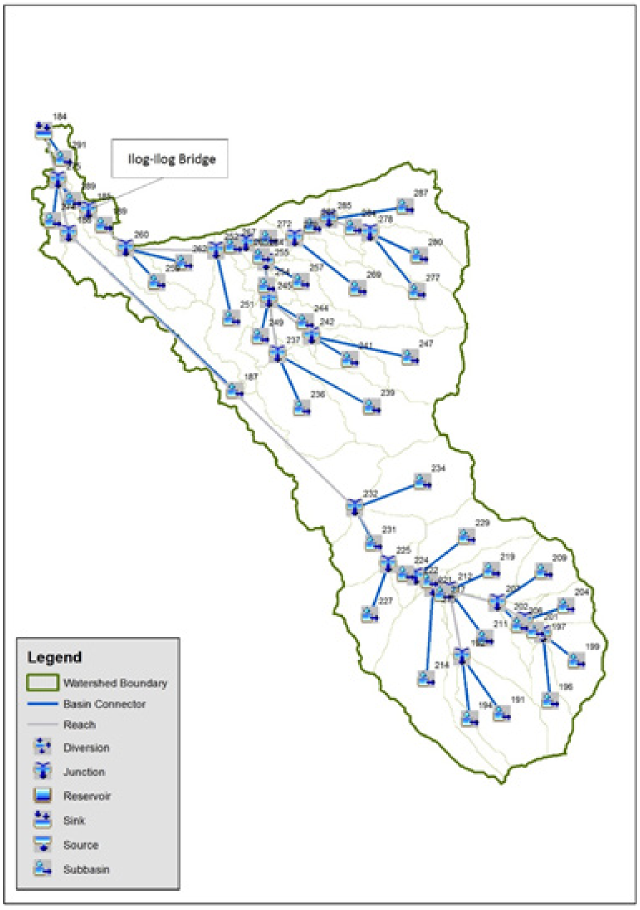


Figure 56 The Ilog-Ilog river basin model generated using HEC-HMS.

5.4 Cross-section Data

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

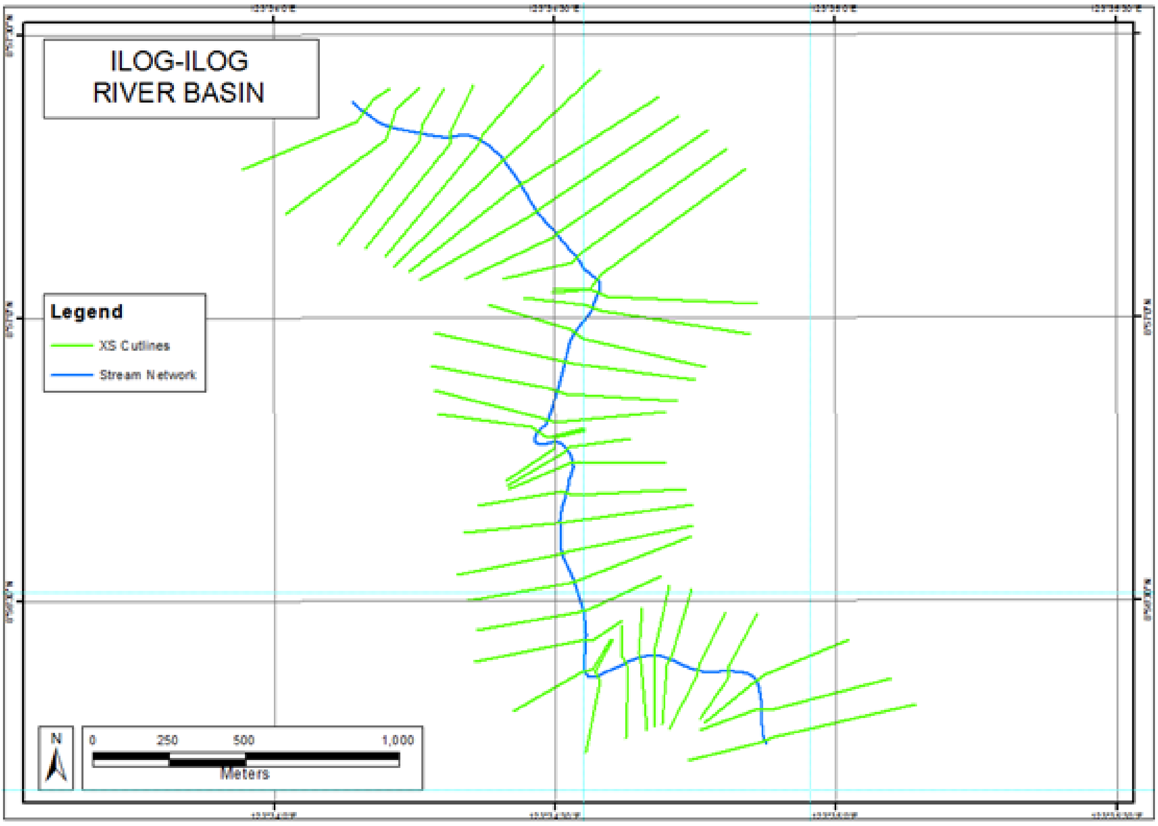


Figure 57 River cross-section of Ilog-Ilog River generated through Arcmap HEC GeoRAS tool.

5.5 Flo 2D Model

Figure 58 Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro.

5.6 Results of HMS Calibration

After calibrating the Ilog-Ilog HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 59 shows the comparison between the two discharge data.

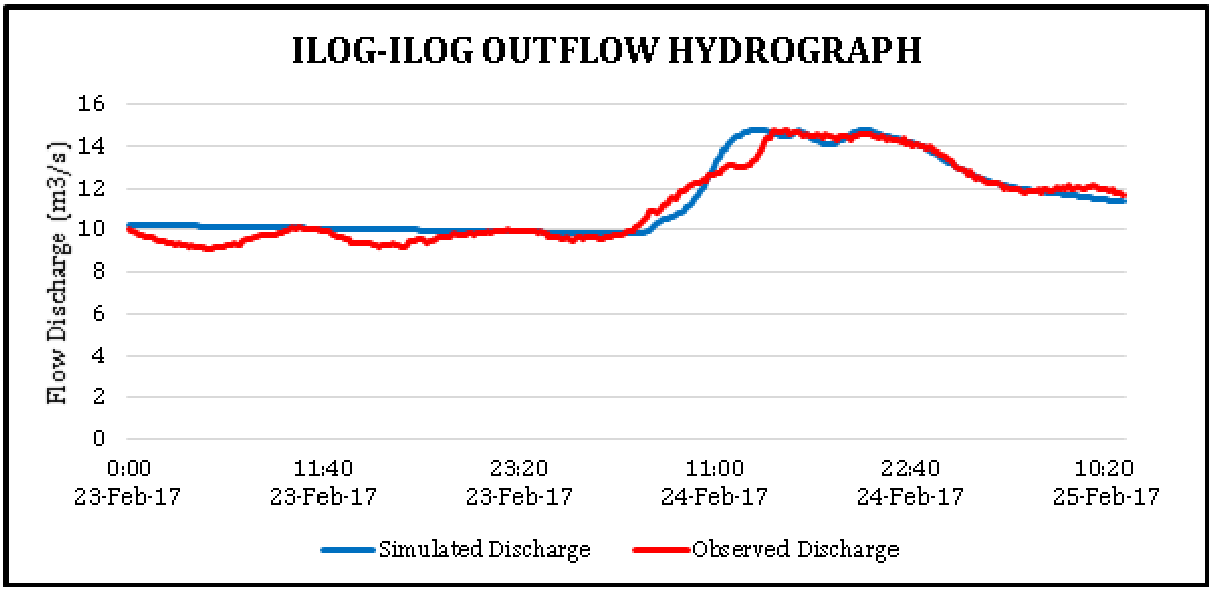


Figure 59 Outflow Hydrograph of Ilog-Ilog produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 22 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 22 Range of Calibrated Values for Ilog-Ilog.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.02 - 10
			Curve Number	55 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.03 - 46
			Storage Coefficient (hr)	0.2 - 17
	Baseflow	Recession	Recession Constant	0.7 - 1
			Ratio to Peak	0.06 – 0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.005 – 0.7

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.02 to 10mm means that there is minimal amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 55 to 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.03 hours to 46 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.7 to 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.06 to 5 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.005 to 0.7 means that there is a diverse roughness in Ilog-Ilog watershed per reach.

Table 23 Summary of the Efficiency Test of Ilog-Ilog HMS Model.

Root Mean Square Error (RMSE)	0.520
Pearson Correlation Coefficient (r2)	0.966
Nash-Sutcliffe (E)	0.924
Percent Bias (PBIAS)	-1.620
Observation Standard Deviation Ratio (RSR)	0.276

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.520.

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 0.966.

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 0.924.

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 -1.620. 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 0.276.

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 60) shows the Ilog-Ilog outflow using the Puerto Princesa Rainfail Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

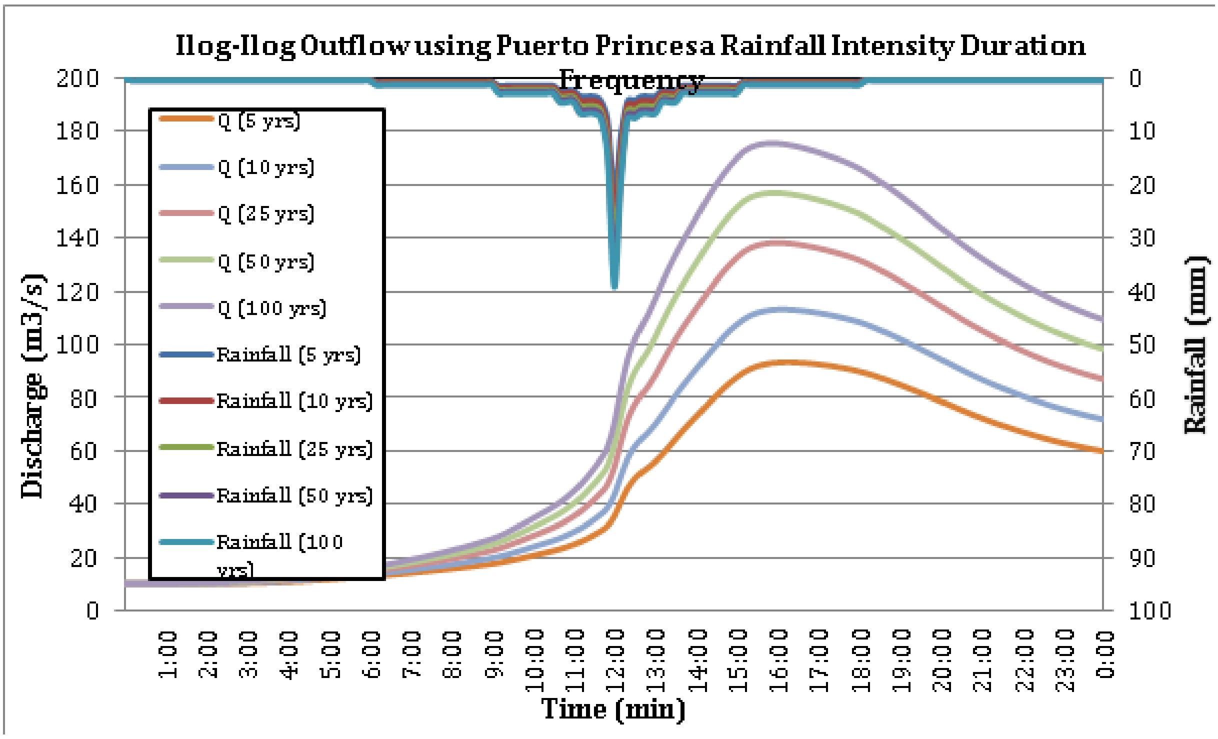


Figure 60 Outflow hydrograph at Ilog-Ilog Station generated using Puerto Princesa RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow, time to peak and lag time of the Ilog-Ilog discharge using the Puerto Princesa Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 24.

Table 24 Peak values of the Ilog-Ilog HECHMS Model outflow using the Puerto Princesa RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	156.40	21.30	93.404	4 hours 10 minutes
10-Year	191.10	25.60	113.137	4 hours 10 minutes
25-Year	234.90	31.10	138.215	4 hours
50-Year	267.30	35.20	156.917	4 hours
100-Year	299.60	39.20	175.462	3 hours 50 minutes

5.8 Discharge data using Dr. Horritts' recommended hydrologic method

5.8.1 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 map of Ilog-Ilog River using the HMS base flow is shown on Figure 61 below.

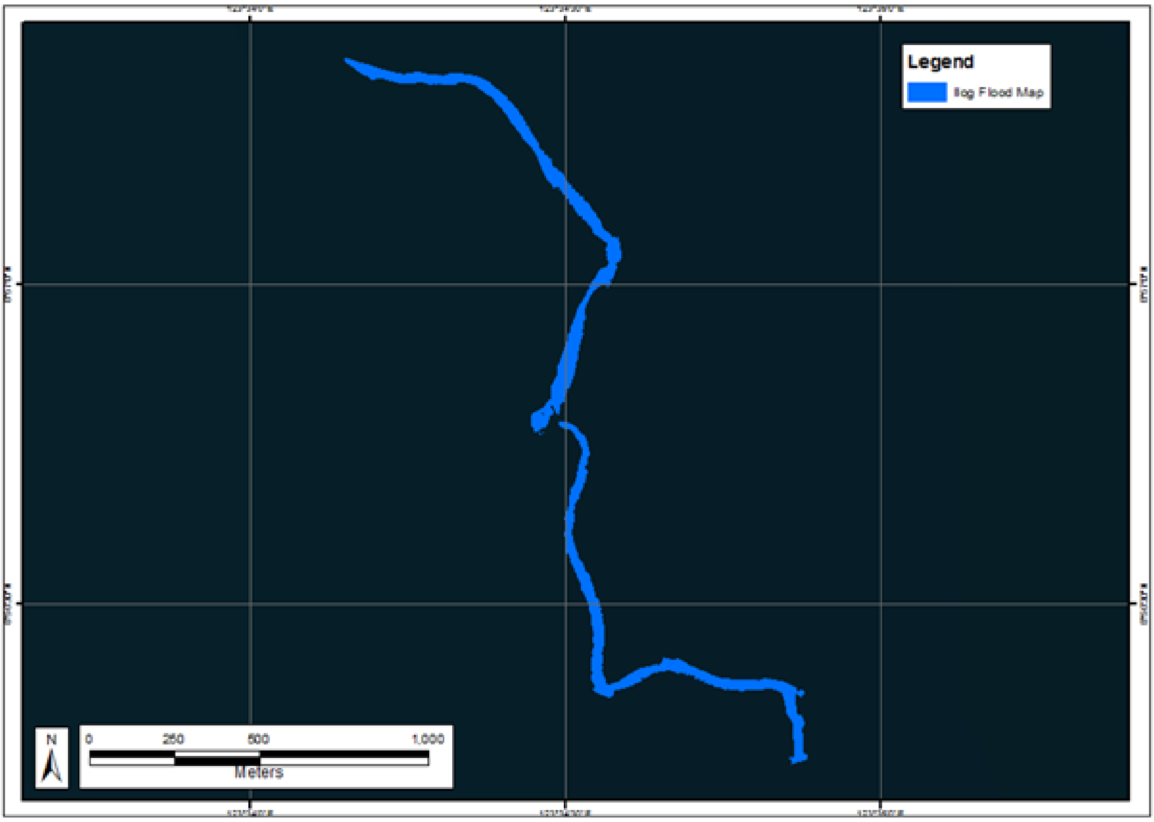


Figure 61 Ilog-Ilog HEC-RAS Output.

5.8.2 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Ilog-Ilog Floodplain are shown in Figure 62 to 67. The floodplain, with an area of 49.72 sq. km., covers one municipality namely Rizal. Table 25 shows the percentage of area affected by flooding per municipality.

Table 25 Municipalities affected in Ilog-Ilog Floodplain.

Municipality	Total Area	Area Flooded	% Flooded
Rizal	980.59	49.72	5.07

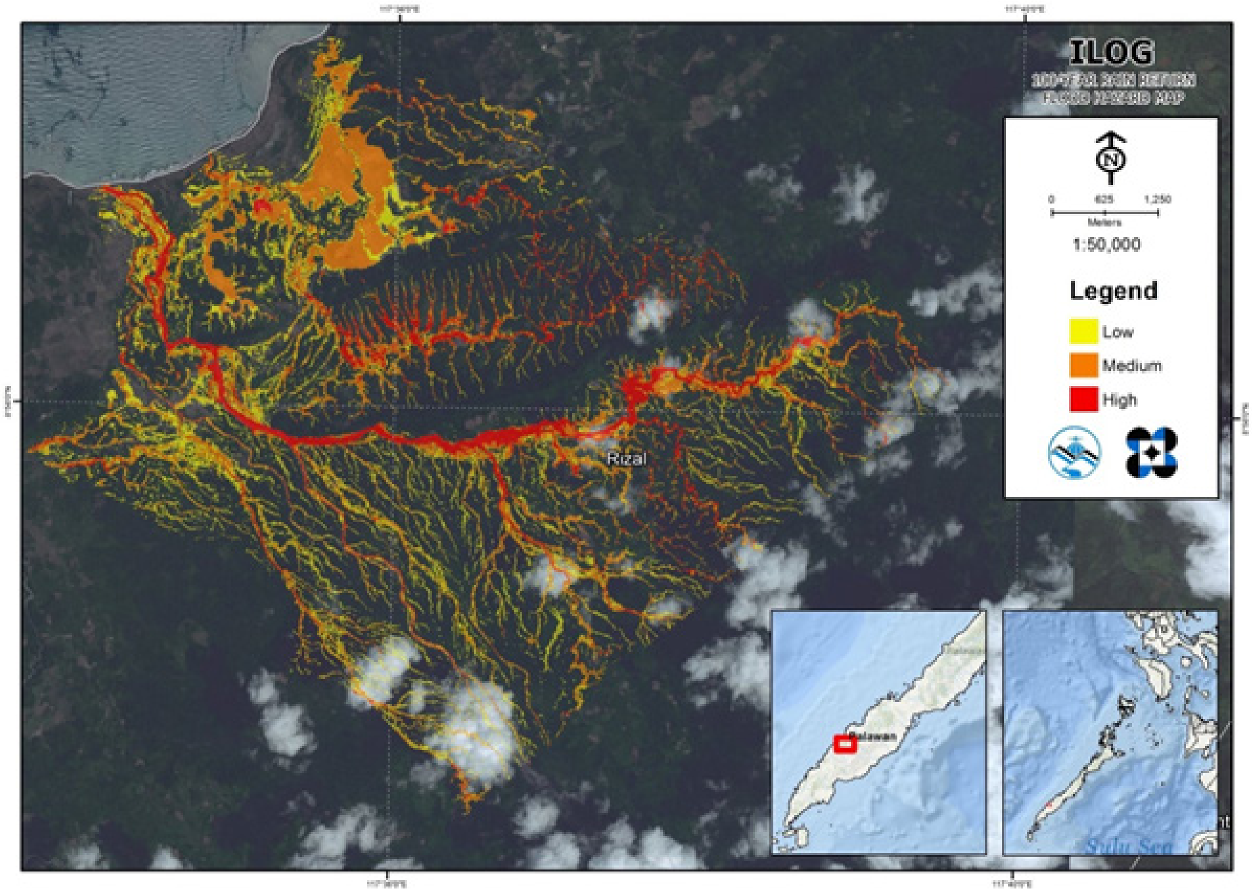


Figure 62 100-year Flood Hazard Map for Ilog-Ilog Floodplain.

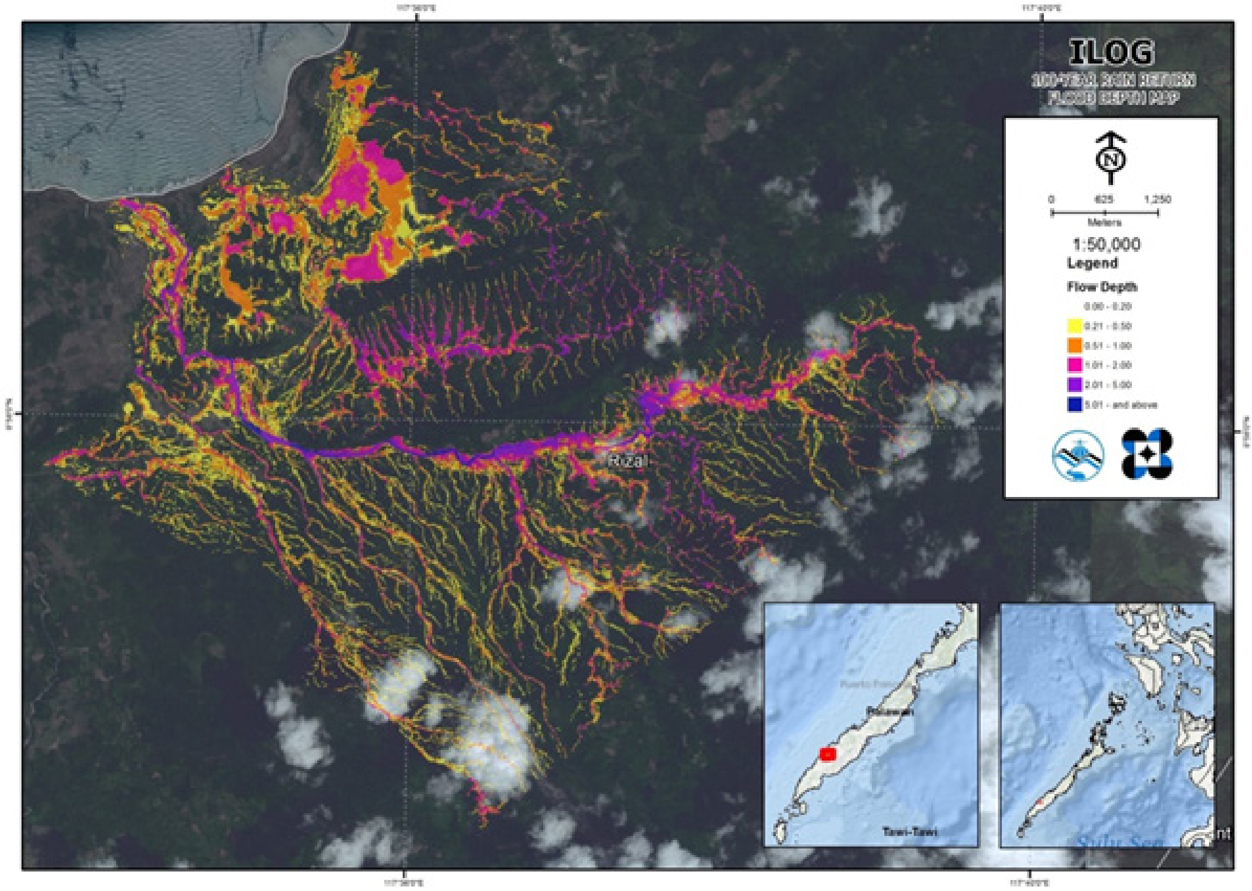


Figure 63 100-year Flow Depth Map for Ilog-Ilog Floodplain.

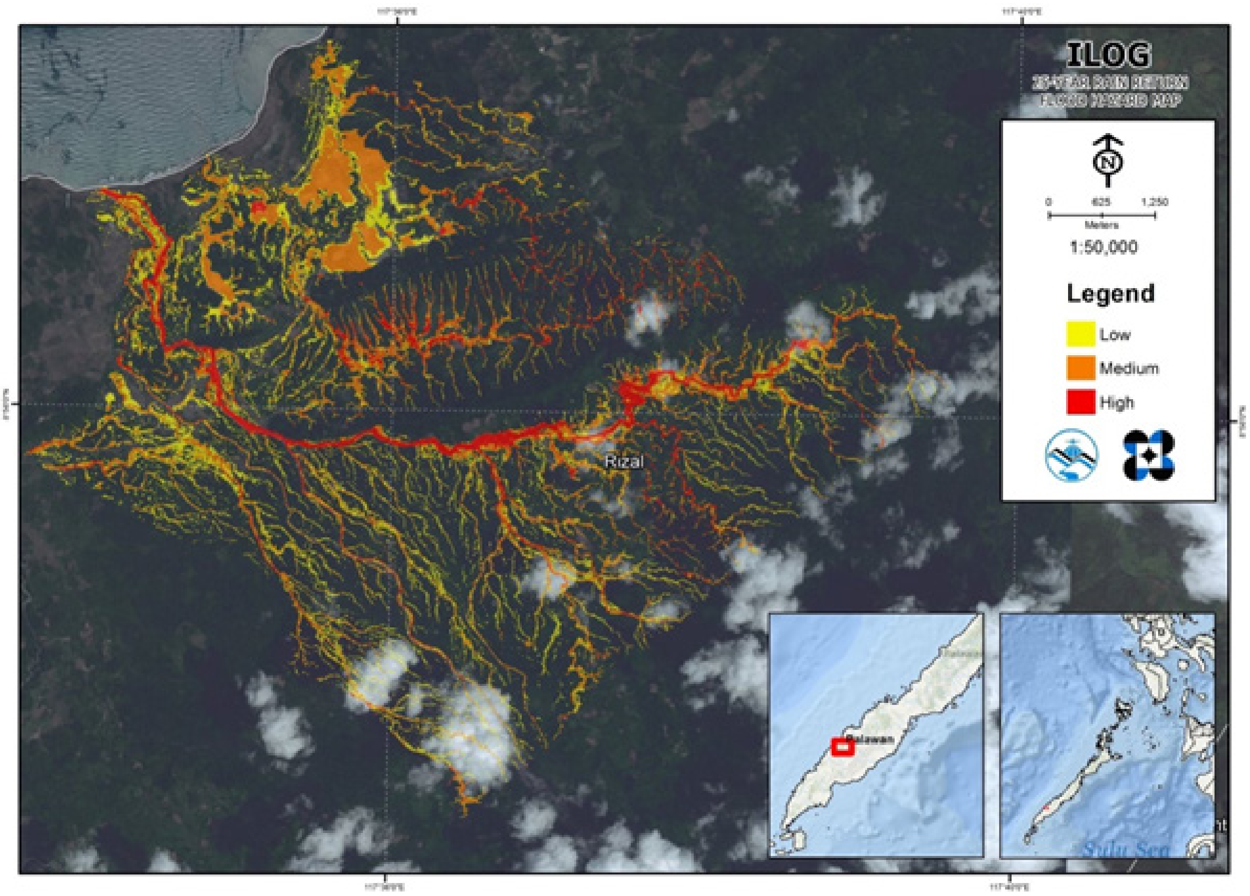


Figure 64 25-year Flood Hazard Map for Ilog-Ilog Floodplain.

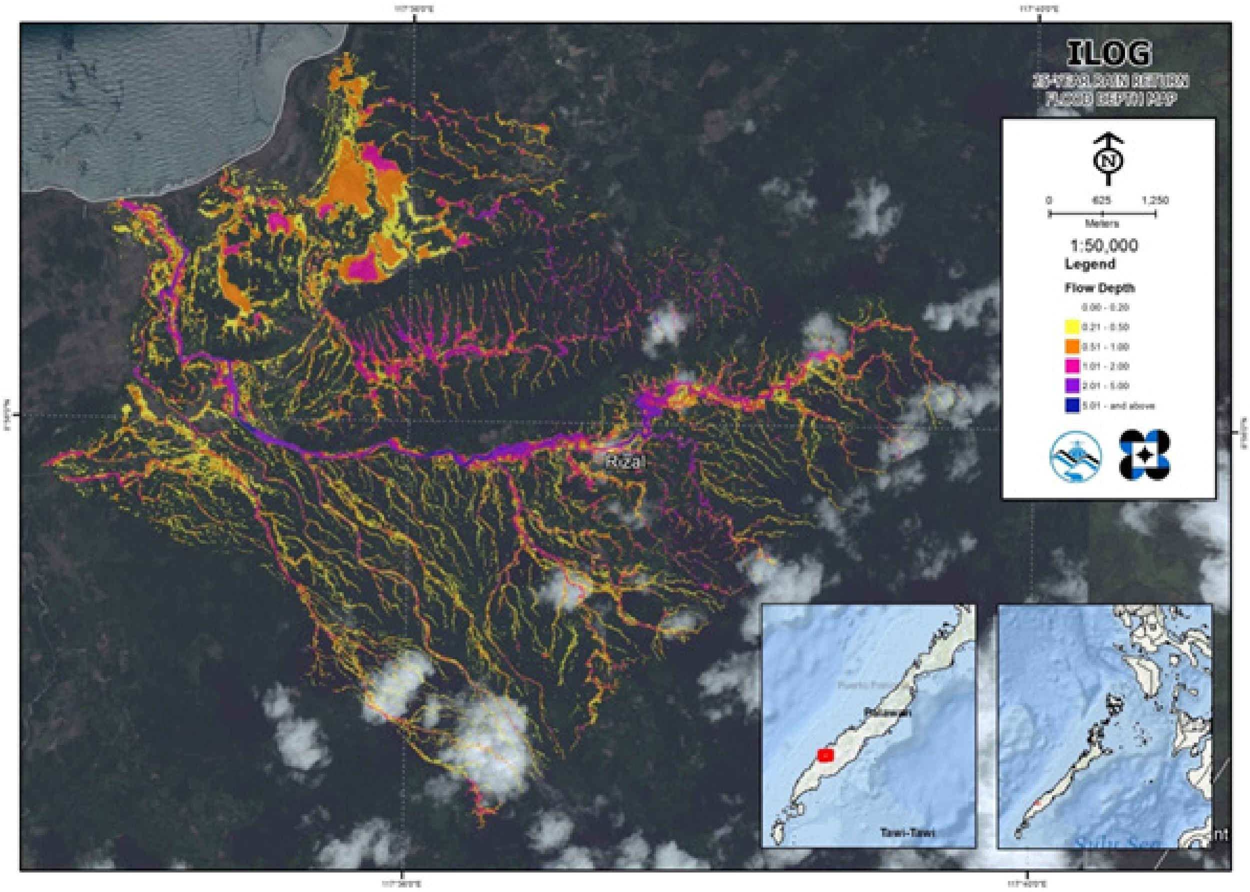


Figure 65 25-year Flow Depth Map for Ilog-Ilog Floodplain

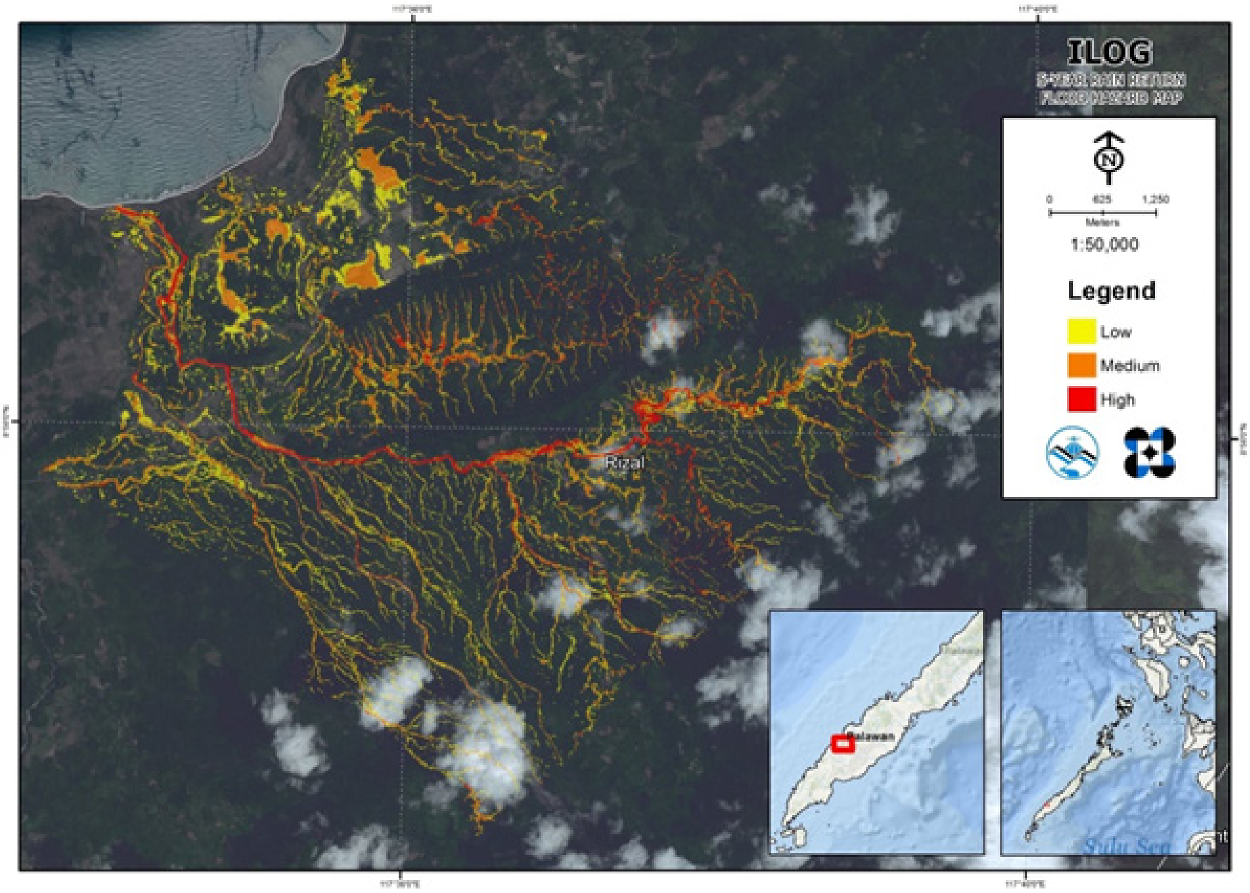


Figure 66 5-year Flood Hazard Map for Ilog-Ilog Floodplain.

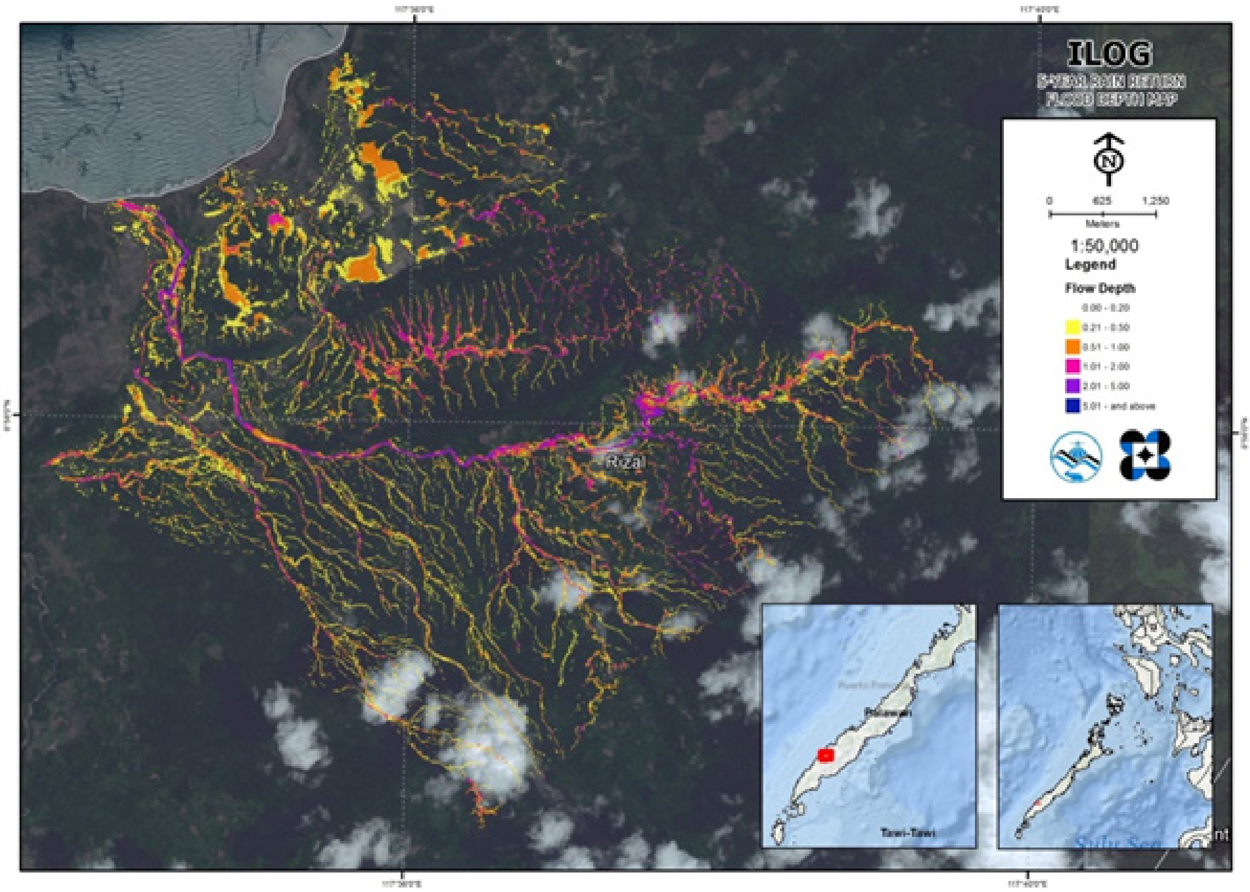


Figure 67 5-year Flow Depth Map for Ilog-Ilog Floodplain.

5.9 Inventory of Areas Exposed to Flooding

Affected barangays in Ilog-Ilog river basin, grouped by municipality, are listed below. For the said basin, one municipality consisting of 2 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 349.52% of the municipality of Rizal with an area of 980.59 sq. km. will experience flood levels of less 0.20 meters. 30.92% of the area will experience flood levels of 0.21 to 0.50 meters while 18.80%, 8.60%, 2.92%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 26 are the affected areas in square kilometres by flood depth per barangay.

Table 26 Affected Areas in Rizal, Palawan during 5-Year Rainfall Return Period

ILOG BASIN		Affected Barangays in Rizal	
		Campong Ulay	Ransang
Affected Area (sq. km.)	0.03-0.20	34.23	8.09
	0.21-0.50	2.84	0.9
	0.51-1.00	1.89	0.39
	1.01-2.00	0.92	0.12
	2.01-5.00	0.34	0.012
	> 5.00	0.0062	0

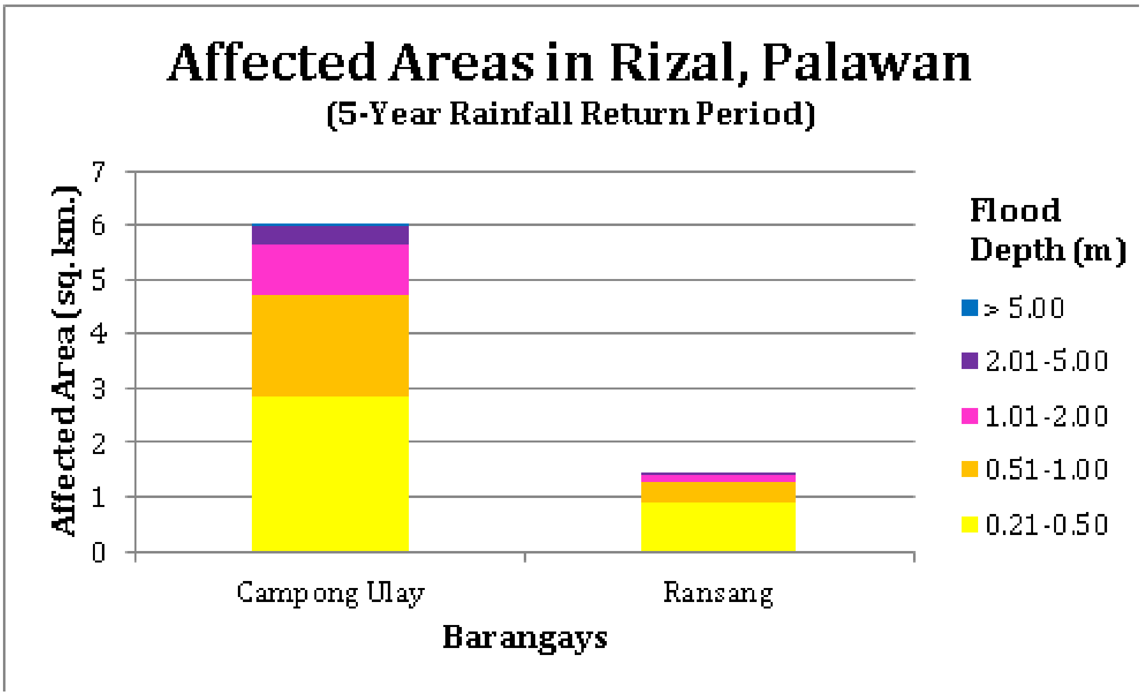


Figure 68 Affected Areas in Rizal, Palawan during 5-Year Rainfall Return Period.

For the 25-year return period, 4.45% of the municipality of Rizal with an area of 980.59 sq. km. will experience flood levels of less 0.20 meters. 0.36% of the area will experience flood levels of 0.21 to 0.50 meters while 0.19%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, and more than 1 meter, respectively. Listed in Table 27 are the affected areas in square kilometers by flood depth per barangay.

Table 27 Affected Areas in Rizal, Palawan during 25-Year Rainfall Return Period.

ILOG BASIN		Affected Barangays in Rizal	
		Campong Ulay	Ransang
Affected Area (sq. km.)	0.03-0.20	34.92	8.7
	0.21-0.50	2.93	0.56
	0.51-1.00	1.64	0.23
	1.01-2.00	0.73	0.023
	2.01-5.00	0	0
	> 5.00	0	0

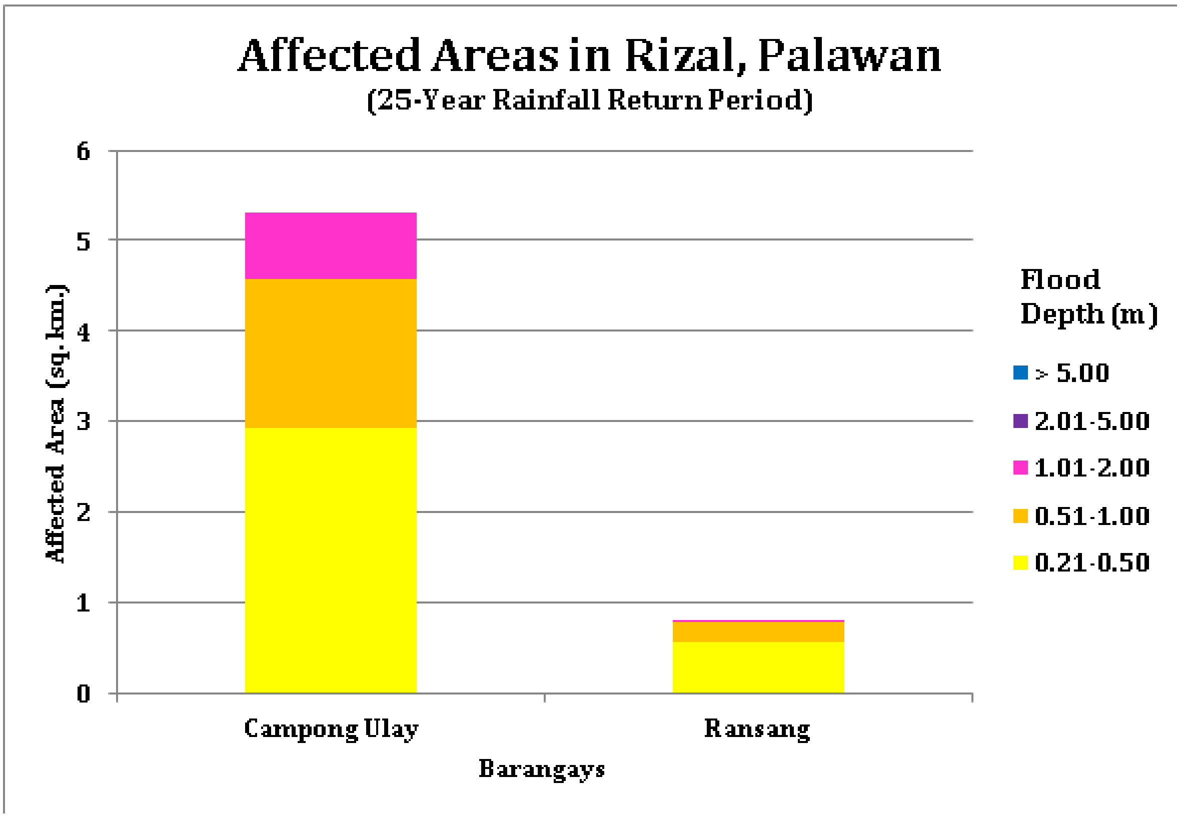


Figure 69 Affected Areas in Rizal, Palawan during 25-Year Rainfall Return Period.

For the 100-year return period, 3.81% of the municipality of Rizal with an area of 980.59 sq. km. will experience flood levels of less 0.20 meters. 0.49% of the area will experience flood levels of 0.21 to 0.50 meters while 0.40%, 0.28%, 0.10%, and 0.009% 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 28 are the affected areas in square kilometers by flood depth per barangay.

Table 28 Affected Areas in Rizal, Palawan during 100-Year Rainfall Return Period.

ILOG BASIN		Affected Barangays in Rizal	
		Campong Ulay	Ransang
Affected Area (sq. km.)	0.03-0.20	30.18	7.16
	0.21-0.50	3.43	1.33
	0.51-1.00	3.2	0.69
	1.01-2.00	2.42	0.29
	2.01-5.00	0.91	0.038
	> 5.00	0.091	0

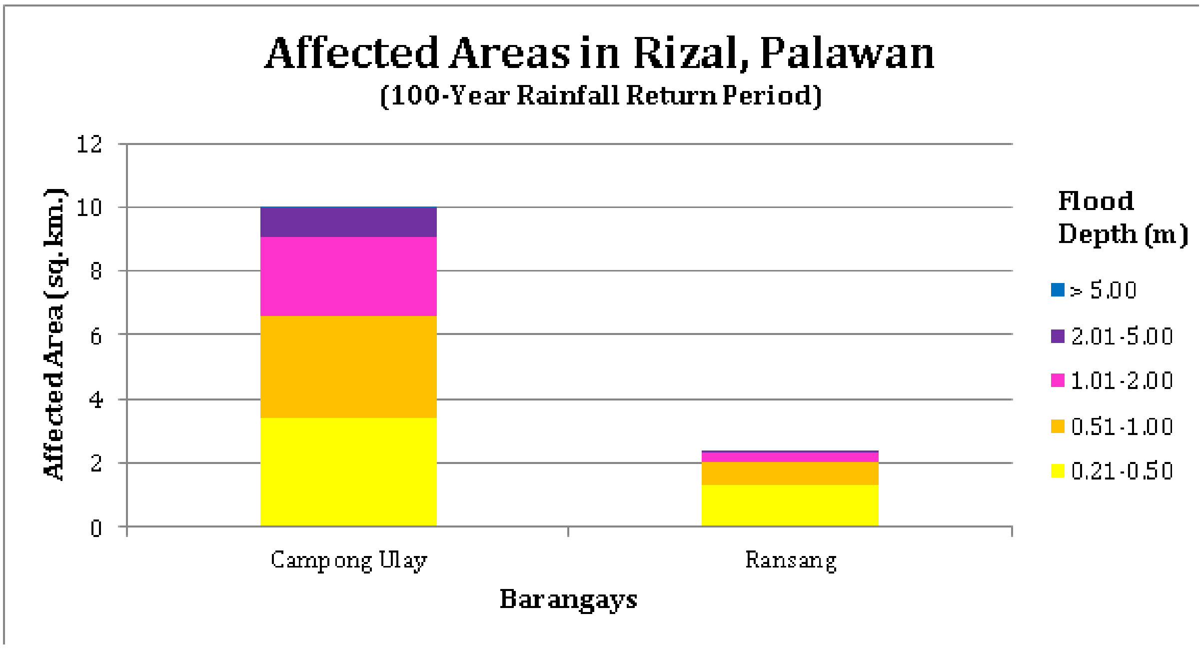


Figure 70 Affected Areas in Rizal, Palawan during 100-Year Rainfall Return Period.

Among the barangays in the municipality of Rizal, Campong Ulay is projected to have the highest percentage of area that will experience flood levels at 4.10%. Meanwhile, Ransang posted the second highest percentage of area that may be affected by flood depths at 0.70%.

5.10 Flood Validation

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

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

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

After which, 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 72.
The flood validation consists of 100 points randomly selected all over the Ilog-Ilog flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.14m. Table 29 shows a contingency matrix of the comparison.

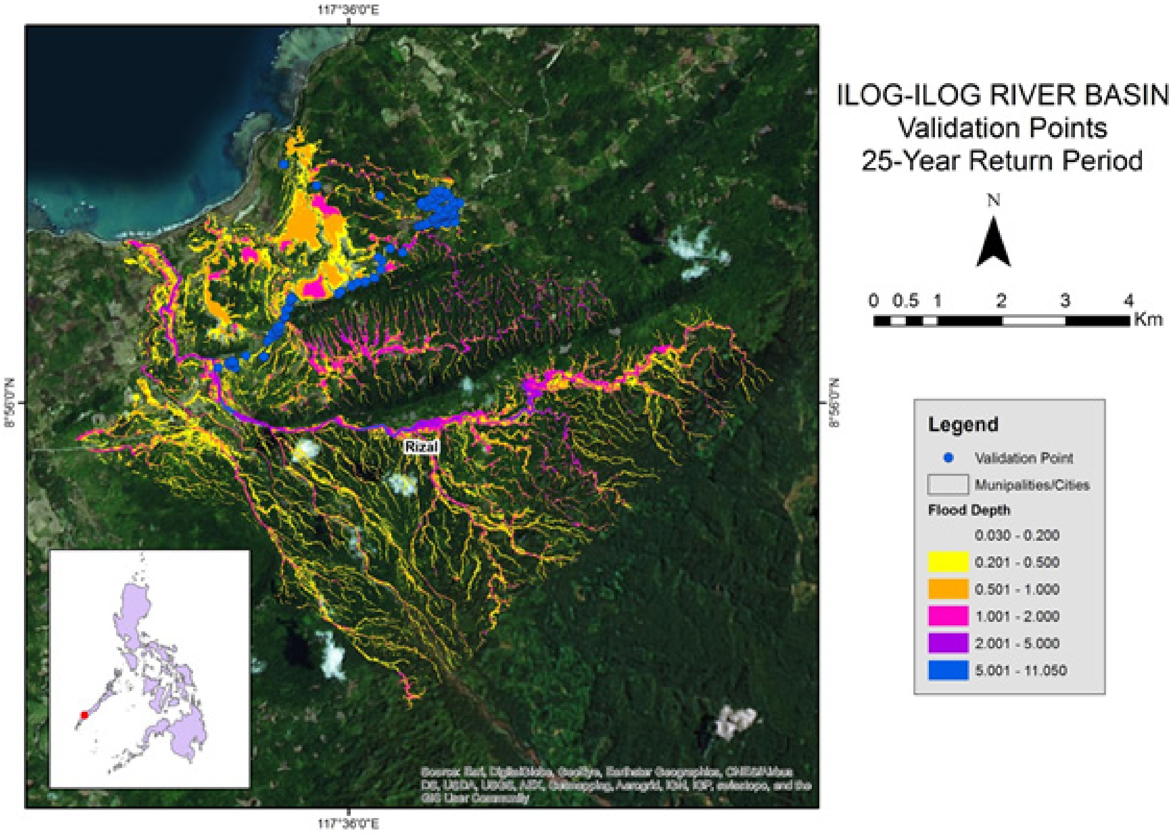


Figure 71 Validation points for 25-year Flood Depth Map of Ilog-Ilog Floodplain.

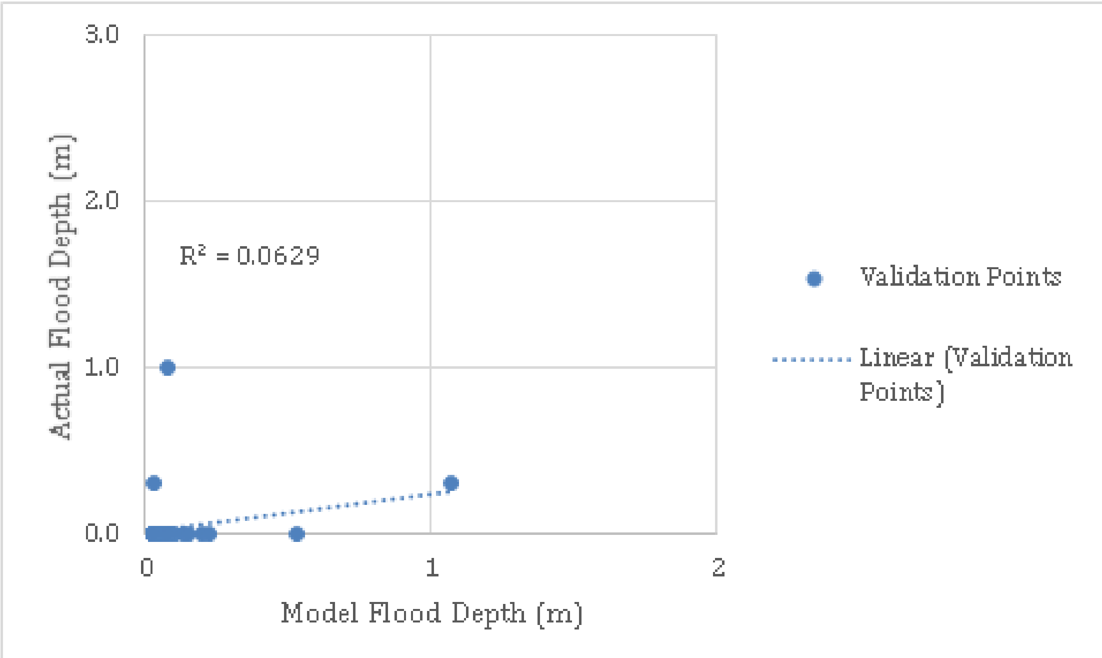


Figure 72 Flood map depth vs actual flood depth.

Table 29 Actual Flood Depth vs Simulated Flood Depth at different levels in the Ilog-Ilog River Basin.

ILOG-ILOG BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	95	1	1	0	0	0	97
	0.21-0.50	1	0	0	1	0	0	2
	0.51-1.00	1	0	0	0	0	0	1
	1.01-2.00	0	0	0	0	0	0	0
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	97	1	1	1	0	0	100

The overall accuracy generated by the flood model is estimated at 95.00% with 95 points correctly matching the actual flood depths. In addition, there were 2 points estimated one level above and below the correct flood depths while there were 3 points and 0 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 2 points were underestimated in the modelled flood depths of Ilog-Ilog. Table 30 depicts the summary of the Accuracy Assessment in the Ilog-Ilog River Basin Survey.

Table 30 Summary of Accuracy Assessment in the Ilog-Ilog River Basin Survey.

ILOG-ILOG	No. of Points	%
Correct	95	**95.00**
Overestimated	3	3.00
Underestimated	2	2.00
Total	100	100.00

REFERENCES

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

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

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

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

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

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

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

ANNEXES

ANNEX 1. Optech Technical Specification

Table A-1.1. Optech Technical Specification

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

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

1. PLW-121

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

July 21, 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: **PALAWAN**			
		Station Name: **PLW-121**			
		Order: **2nd**			
Island: **LUZON**		Barangay: **CAMPONG ULAY**			
Municipality: **PUERTO PRINCESA CITY (CAPITAL)**		MSL Elevation:			
		PRS92 Coordinates			
Latitude:	**8° 56' 1.71426"**	Longitude:	**117° 34' 23.99157"**	Ellipsoidal Hgt:	**8.98036 m.**
		WGS84 Coordinates			
Latitude:	**8° 55' 57.38325"**	Longitude:	**117° 34' 29.39124"**	Ellipsoidal Hgt:	**58.05800 m.**
		PTM / PRS92 Coordinates			
Northing:	**987945.887 m.**	Easting:	**398086.54 m.**	Zone:	**1A**
		UTM / PRS92 Coordinates			
Northing:	**987,521.12**	Easting:	**563,030.26**	Zone:	**50**

Location Description

PLW-121
From poblacion Rizal travel S towards Brgy. Campong Ulay approximately 16 kms. up to Cabkungan Elem. School. Station is located in an open lot inside the school SW edge of the basketball court. Mark is the head of 4" copper nail flushed in a cement putty 30cm x 30cm x 120cm embedded 1m on the ground with inscriptions "PLW-121 2007 NAMRIA."

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8086767 I**
T.N.: **2015-1696**

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

9907212015170528

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

Figure A-2.1. PLW-23

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

Vector Components (Mark to Mark)

From:	PLW 121				
Grid		Local		Global	
Easting	563030.260 m	Latitude	N8°56'01.71425"	Latitude	N8°55'57.38325"
Northing	987521.114 m	Longitude	E117°34'23.99161"	Longitude	E117°34'29.39124"
Elevation	10.335 m	Height	8.980 m	Height	58.058 m

To:	BLLM1A				
Grid		Local		Global	
Easting	570465.682 m	Latitude	N9°02'07.68639"	Latitude	N9°02'03.33580"
Northing	998772.489 m	Longitude	E117°38'28.10618"	Longitude	E117°38'33.49665"
Elevation	-0.716 m	Height	-2.070 m	Height	46.965 m

Vector					
ΔEasting	7435.421 m	NS Fwd Azimuth	33°32'53"	ΔX	-5788.617 m
ΔNorthing	11251.375 m	Ellipsoid Dist.	13490.902 m	ΔY	-5020.895 m
ΔElevation	-11.052 m	ΔHeight	-11.050 m	ΔZ	11103.460 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.002 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.005 m	σ ΔHeight	0.005 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000061683		
Y	-0.0000089563	0.0000212884	
Z	-0.0000018603	0.0000039102	0.0000013613

Figure A-3.1.Baseline Processing Report of Control Points Used in LIdar Survery

2

ANNEX 4. The LIDAR Survey Team Composition

Data Acquisition Component	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	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	Research Associate (RA)	JASMINE ALVIAR	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	GRACE SINADJAN	UP-TCAGP
	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. ARIES TORNO	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JUSTINE JOYA	AAC

Figure A-4.1. The LiDAR Survey Team Composition

ANNEX 5. Data Transfer Sheet for Ilog-Ilog Floodplain Flights

DATA TRANSFER SHEET
8/3/2015(pelayan)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS Output LAS	RAW LAS KML (swath)	LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S) BASE STATION(S)	BASE STATION(S) Base Info (.txt)	OPERATOR LOGS (OPLOG)	FLIGHT PLAN Actual	FLIGHT PLAN KML	SERVER LOCATION
14-Jun-15	3049P	1BLK42S165A	Pegasus	969	na	7	162	31	252	18.3	29.3	16.3	1KB	1KB	70/67	na	Z:\DAC\RAW DATA
20-Jun-15	3073P	1BLK42S171A	Pegasus	361	na	3.65	107	12.3	88	7.1	NA	4.16	1KB	1KB	92	na	Z:\DAC\RAW DATA
7-Jul	3141P	1BLK42QRT188A	Pegasus	1.84	na	11.6	266	2.11	15/20/61	35.5	108	8.43	1KB	1KB	95	na	Z:\DAC\RAW DATA
8-Jul	3145P	1BLK42QRT189A	Pegasus	752	na	5.41	124	184	101	14.8	NA	11.9	1KB	1KB	176/95	na	Z:\DAC\RAW DATA
11-Jul	3157P	1BLK42PO192A	Pegasus	2.29	na	13	279	35.2	369	43.3	113	20.6	1KB	1KB	206	na	Z:\DAC\RAW DATA
11-Jul	3159P	1BLK42PO192B	Pegasus	1.11	na	8.95	199	65.5	1	21.6	25.9	20.6	1KB	1KB	NA	na	Z:\DAC\RAW DATA
12-Jul	3161P	1BLK42LM193A	Pegasus	1.51	477/407	9.62	214	41.7	359	28.8	67.6	4.29	1KB	1KB	216	na	Z:\DAC\RAW DATA
13-Jul	3165P	1BLK42LM194A	Pegasus	1.5	na	10.5	255	26.4	295	28.9	na	11.5	1KB	1KB	na	na	Z:\DAC\RAW DATA
13-Jul	3167P	1BLK42JS194B	Pegasus	329	na	3.65	106	4.93	2	7.36	11	11.5	1KB	1KB	106/123	NA	Z:\DAC\RAW DATA
15-Jul	3173P	1BLK42KS196A	Pegasus	160	96/08	2.73	63.2	na	na	3.33	7.6	1.19	1KB	1KB	11	NA	Z:\DAC\RAW DATA

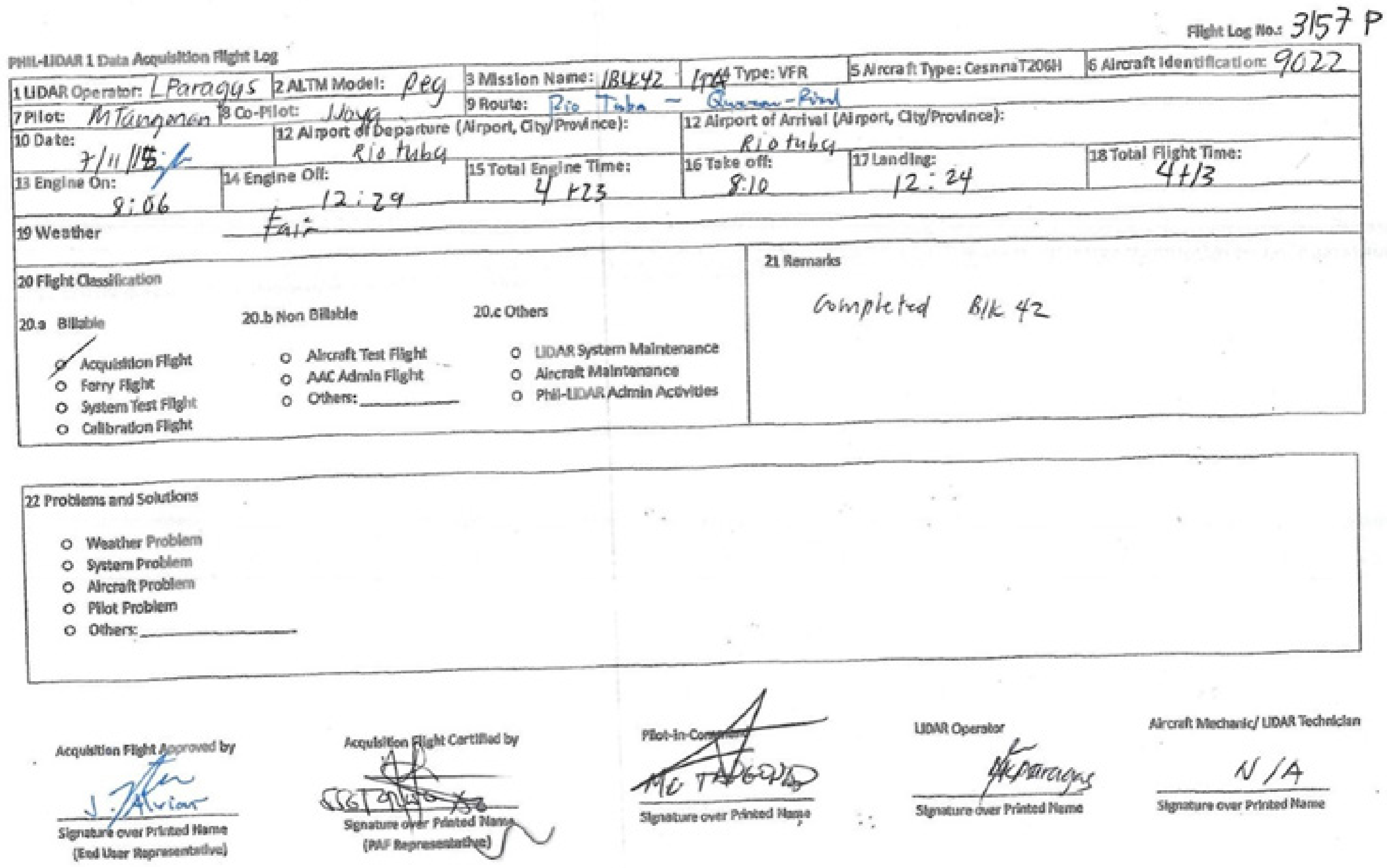
Received from
Name [illegible]
Position RA
Signature

Received by
Name AC Bongat
Position SSRS
Signature
8/5/2015

Figure A-5.1. Data Transfer Sheet for Ilog ilohg Floodplian Fighta

ANNEX 6. Flight logs for the flight missions

1. Flight Log for 1BLK42PO192A Mission



Flight Log No.: 3157 P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: L Paragas	2 ALTM Model: Peg	3 Mission Name: 1BLK42	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M Tangonan	8 Co-Pilot: J Noya	9 Route: Rio Tuba – Quezon-Pal			
10 Date: 7/11/15	12 Airport of Departure (Airport, City/Province): Rio tuba		12 Airport of Arrival (Airport, City/Province): Rio tuba		
13 Engine On: 8:06	14 Engine Off: 12:29	15 Total Engine Time: 4+23	16 Take off: 8:10	17 Landing: 12:24	18 Total Flight Time: 4+13
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Completed Blk 42

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

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

Acquisition Flight Certified by: SSgt [illegible] — Signature over Printed Name (PAF Representative)

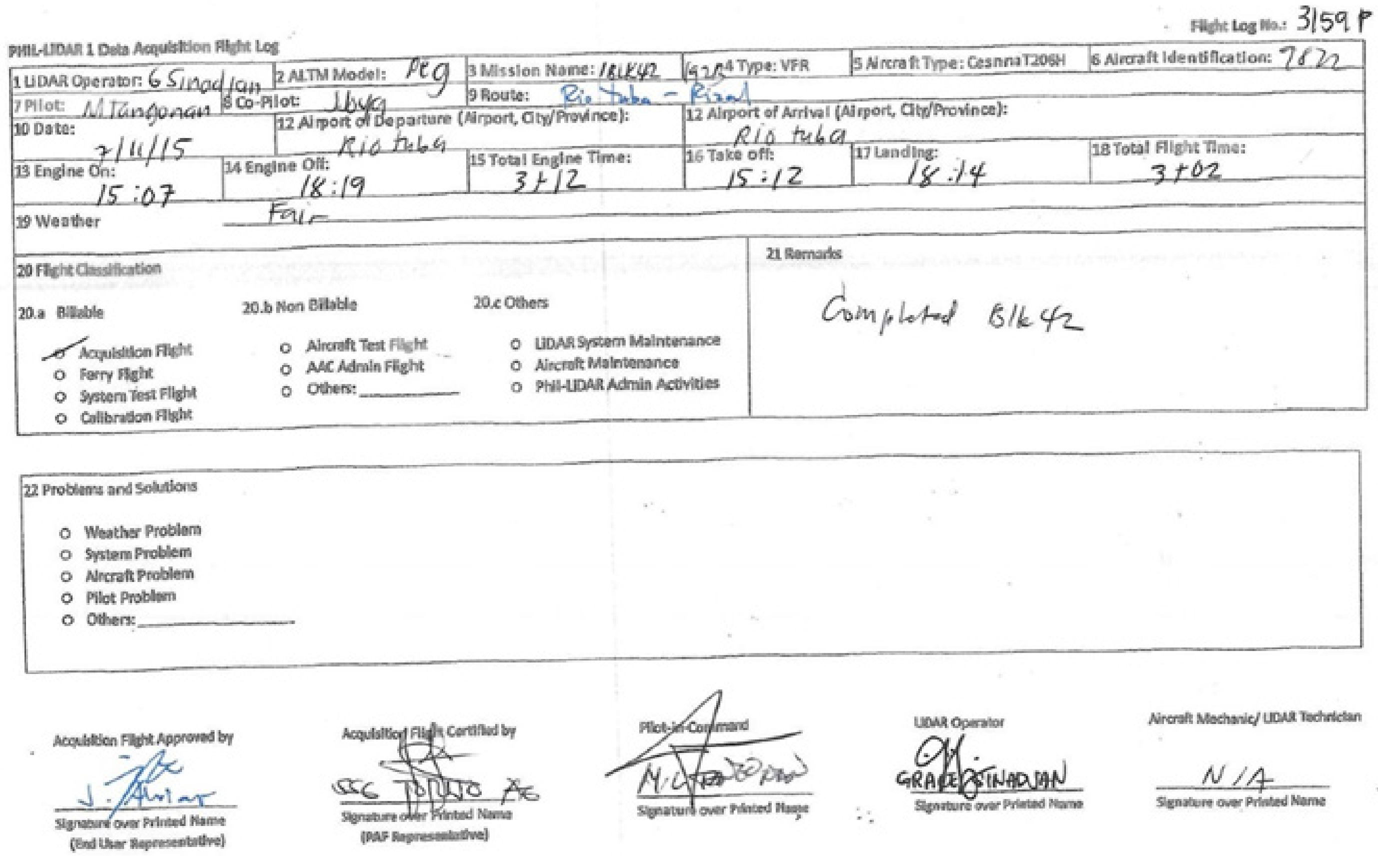
Pilot-in-Command: MC Tangonan — Signature over Printed Name

LiDAR Operator: LK Paragas — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: N/A — Signature over Printed Name

Figure A-5.2. Flight Log for 1BLK42PO192A Mission

2. Flight Log for 1BLK42PO192B Mission



Flight Log No.: 3159P

PHIL-LIDAR 1 Data Acquisition Flight Log

1 LIDAR Operator: G Sinadjan	2 ALTM Model: Peg	3 Mission Name: 1BLK42 192B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 7822
7 Pilot: M Tangonan	8 Co-Pilot: Ibyag	9 Route: Rio Tuba - Rizal			
10 Date: 7/11/15	12 Airport of Departure (Airport, City/Province): Rio tuba		12 Airport of Arrival (Airport, City/Province): Rio tuba		
13 Engine On: 15:07	14 Engine Off: 18:19	15 Total Engine Time: 3+12	16 Take off: 15:12	17 Landing: 18:14	18 Total Flight Time: 3+02
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Completed Blk 42

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

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

Acquisition Flight Certified by: SSG Tolato PAF — Signature over Printed Name (PAF Representative)

Pilot-in-Command: M. Tangonan — Signature over Printed Name

LIDAR Operator: GRACE SINADJAN — Signature over Printed Name

Aircraft Mechanic/ LIDAR Technician: N/A — Signature over Printed Name

Figure A-5.2. Flight Log for 1BLK42PO192B Mission

ANNEX 7. Flight status reports

Table A-7.1. Fight Status Report

ILOG FLOODPLAIN
(July 11, 2015)

`

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
3157P	BLK 42P, PS, N, M	1BLK42PO192A	L. Paragas	July 11, 2015	Surveyed BLK 42P, PS, N, and parts of M
3159P	BLK 42O, N, P	1BLK42PO192B	G. Sinadjan	July 11, 2015	Surveyed BLK 42O, N, and gaps in BLK 42P

FLIGHT LOG NO. 3157P Scan Freq: 30 Hz

AREA: BLOCK 42P, 42PS, 42N & 42M Scan Angle: 25deg

MISSION NAME: 1BLK42PO192A PRF: 200

SURVEY COVERAGE:

LAS

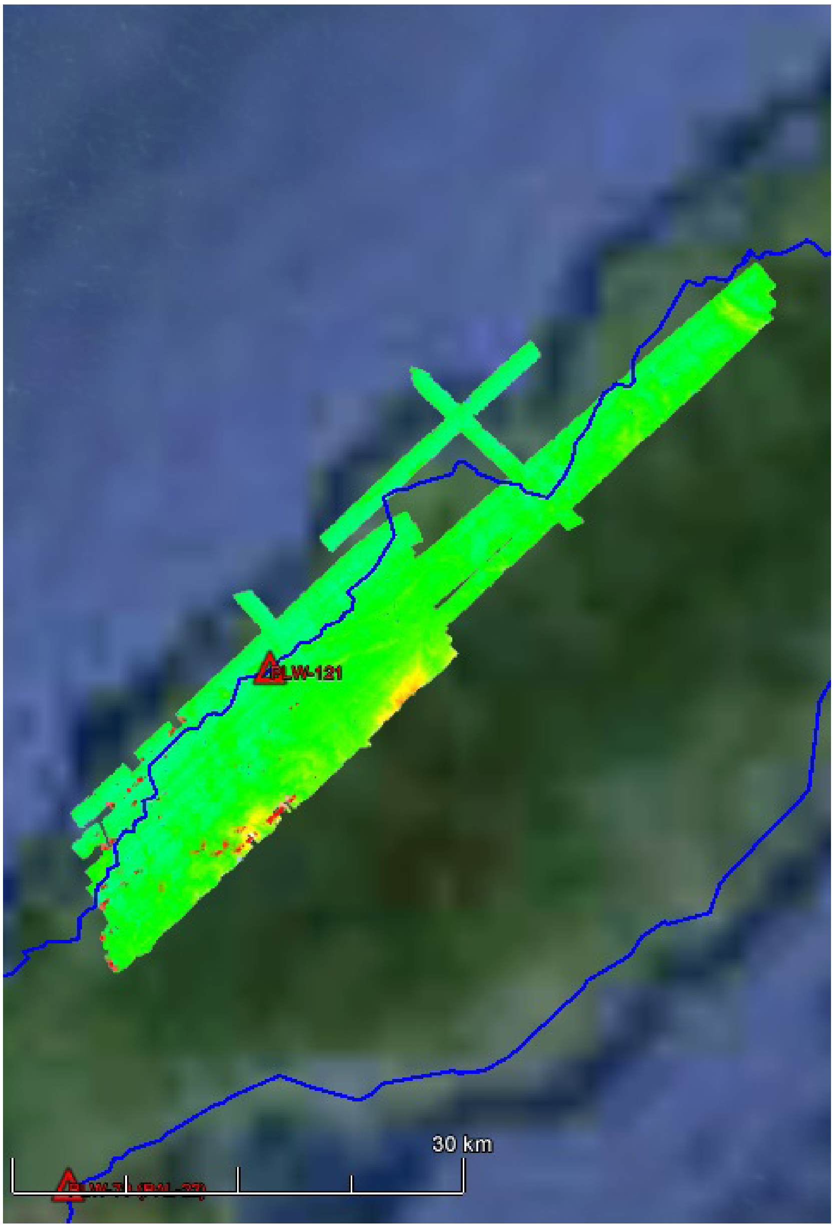


Figure A-7.1. FLIGHT LOG NO. 3157P

FLIGHT LOG NO. 3159P Scan Freq: 30 Hz

AREA: BLOCK 42ONP Scan Angle: 25 deg

MISSION NAME: 1BLK42PO192B PRF: 200

SURVEY COVERAGE:

LAS

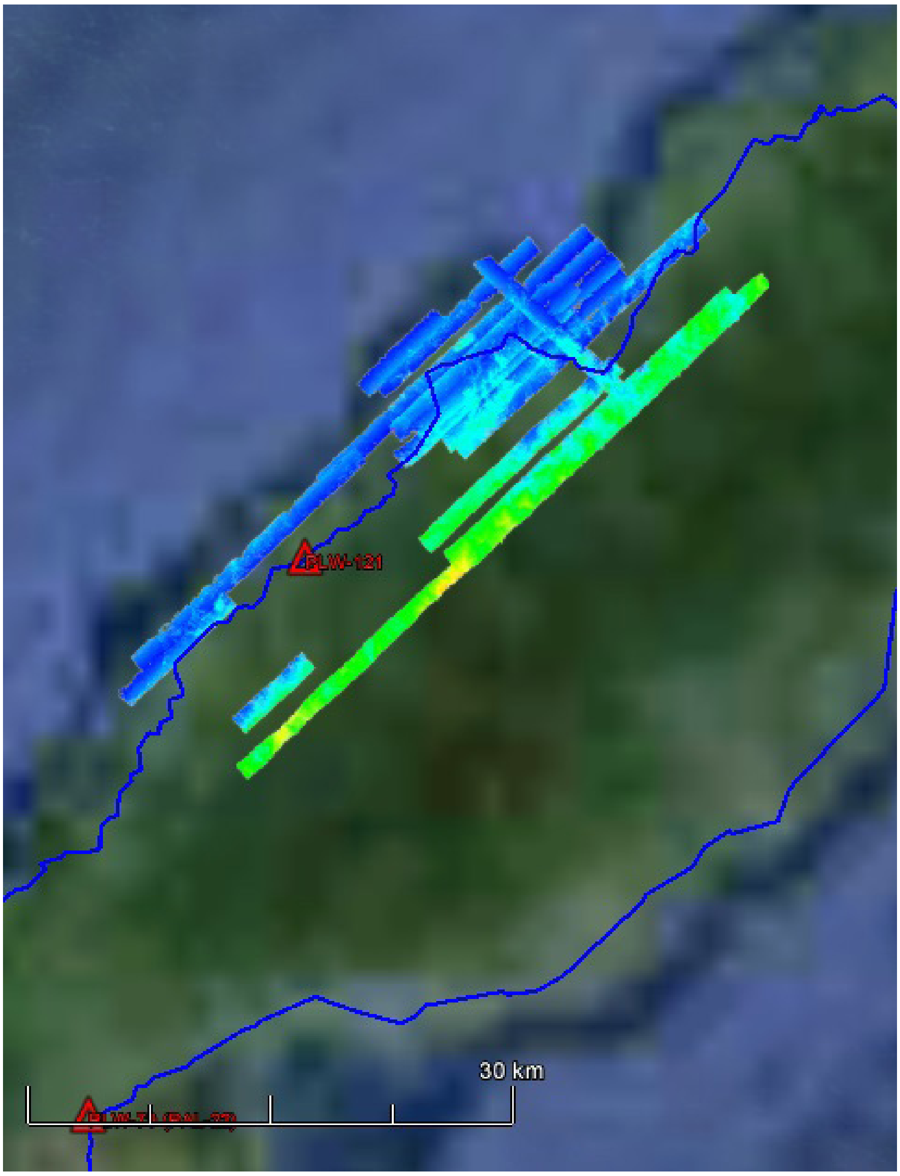


Figure A-7.2. FLIGHT LOG NO. 3159P

ANNEX 8. Mission Summary Reports

Table A-8.1 MISSION SUMMARY REPORT for Mission Block 42N

Flight Area	**West Palawan**
Mission Name	**Block 42N**
Inclusive Flights	3157P and 3159P
Range data size	64.90 GB
Base data size	41.2 MB
POS	478 MB
Image	90.70 GB
Transfer date	August 5, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.22
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	3.40
Boresight correction stdev (<0.001deg)	0.000370
IMU attitude correction stdev (<0.001deg)	0.000558
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	18.19
Ave point cloud density per sq.m. (>2.0)	2.43
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	251
Maximum Height	658.32
Minimum Height	42.09
Classification (# of points)	
Ground	83015160
Low vegetation	50176090
Medium vegetation	153087772
High vegetation	599974416
Building	9903936
Orthophoto	No
Processed by	Engr. Irish Cortez, AljonRieAraneta, Engr. Elainne Lopez

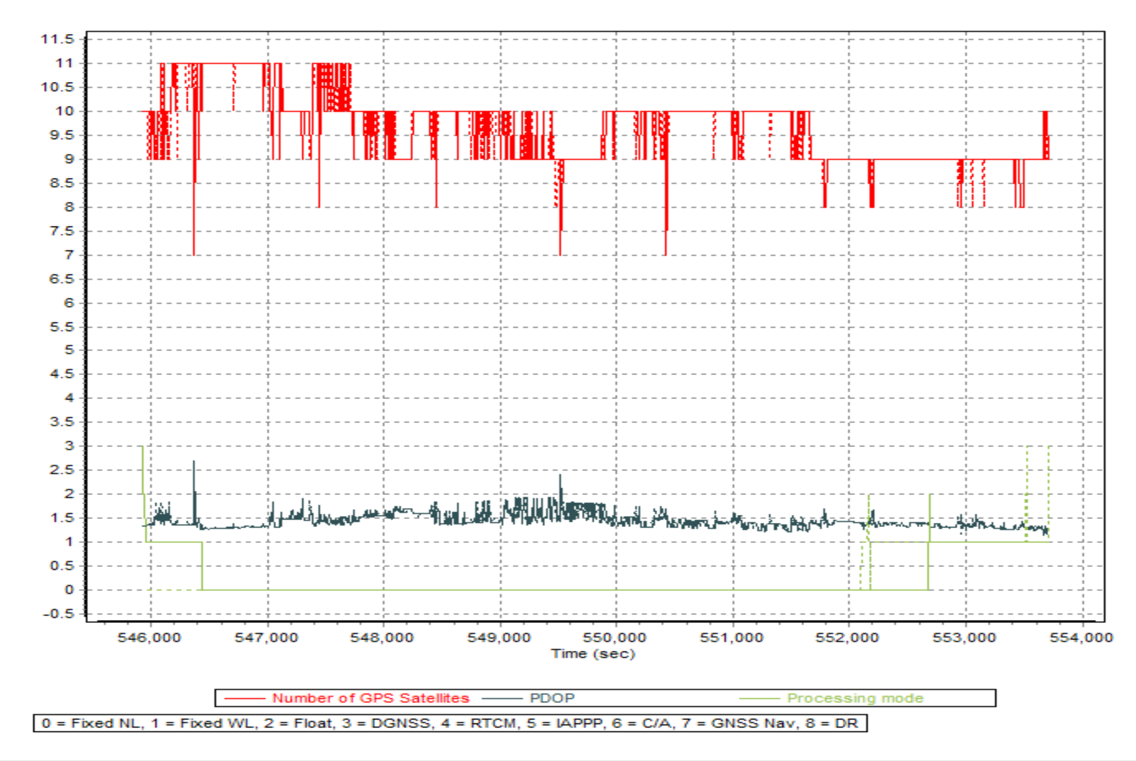


Figure A-8.1 Solution Status

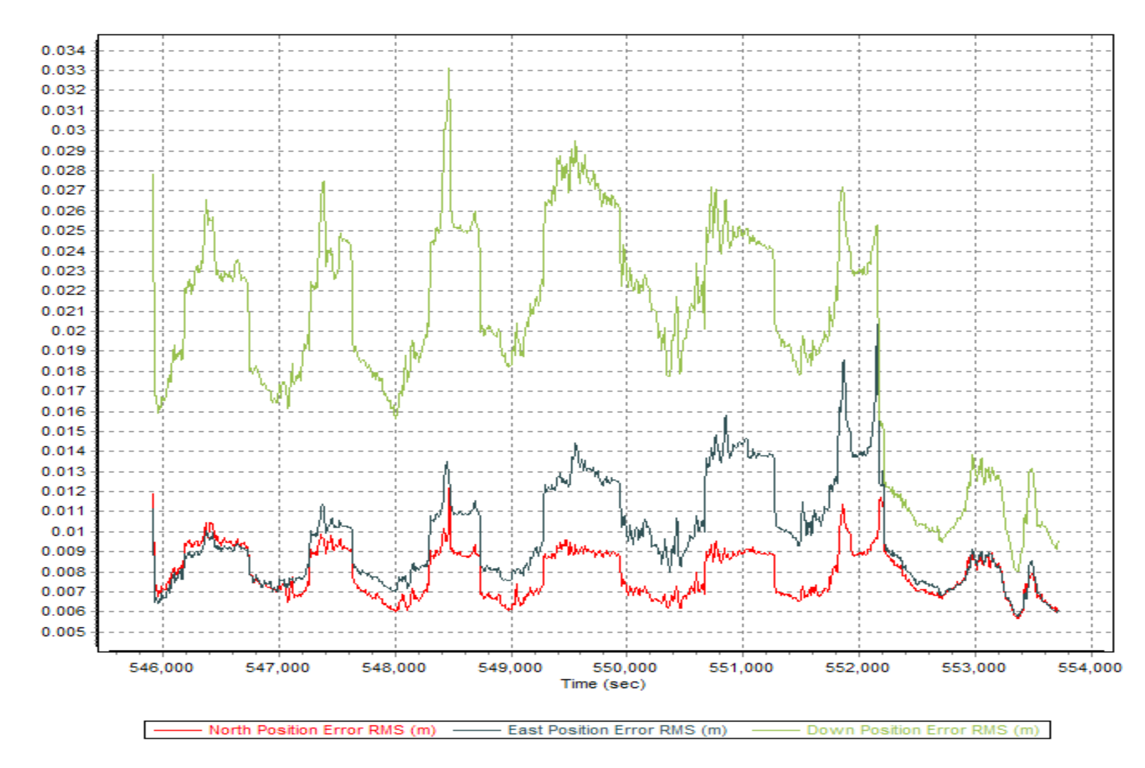


Figure A-8.2 Smoothed Performance Metric Parameters

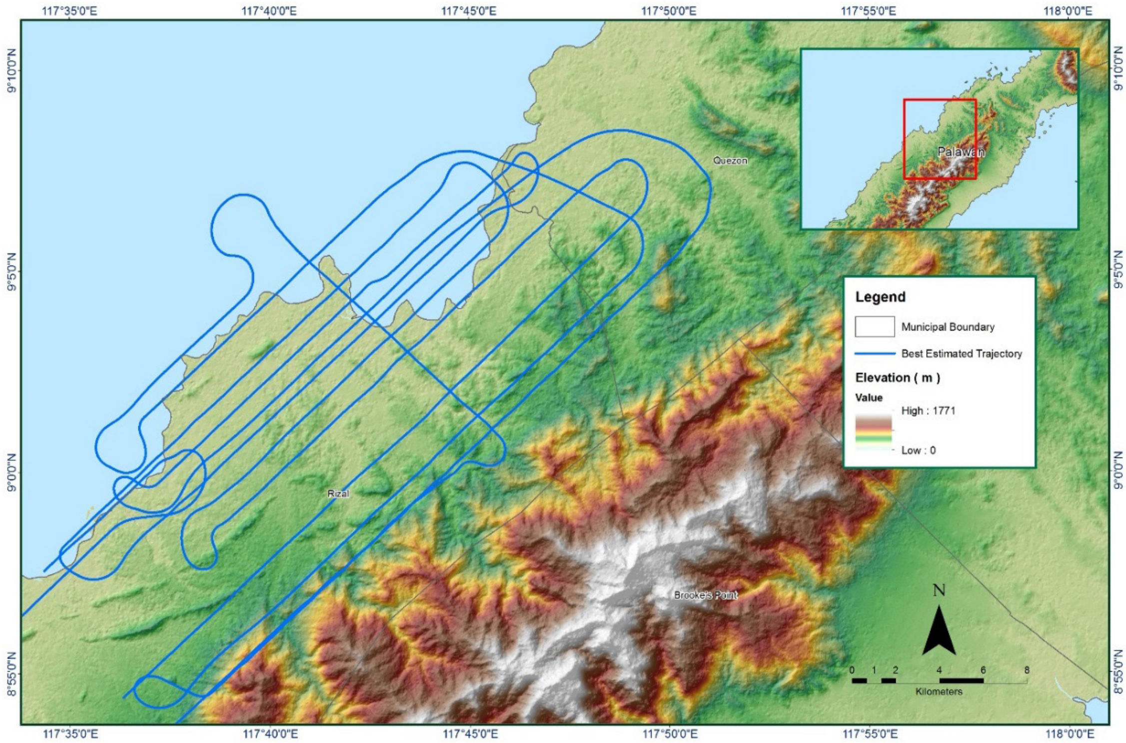


Figure A-8.3 Best Estimated Trajectory

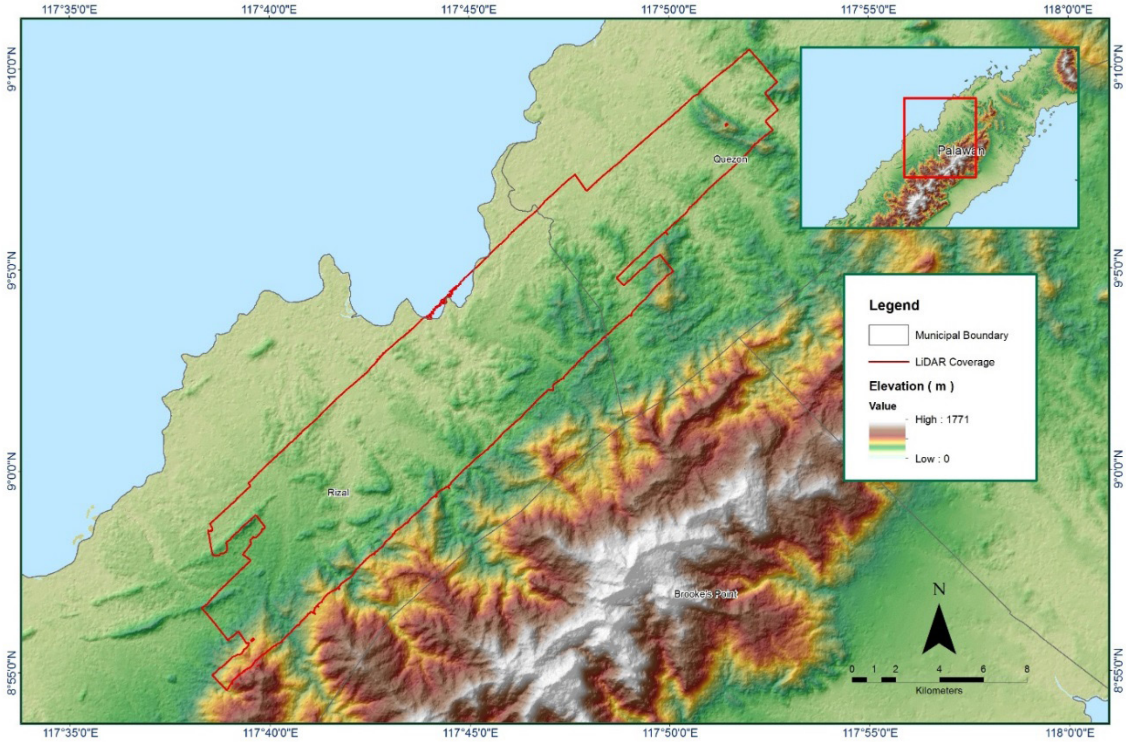


Figure A-8.4 Coverage of LiDAR data

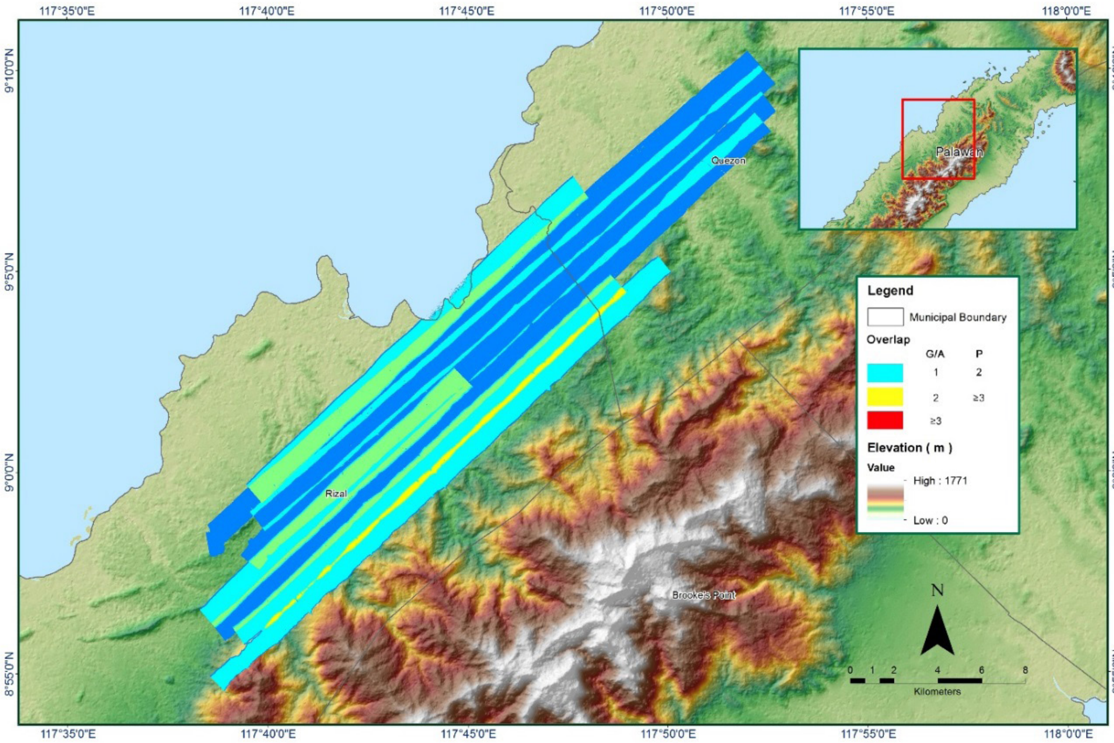


Figure A-8.5 Image of data overlap

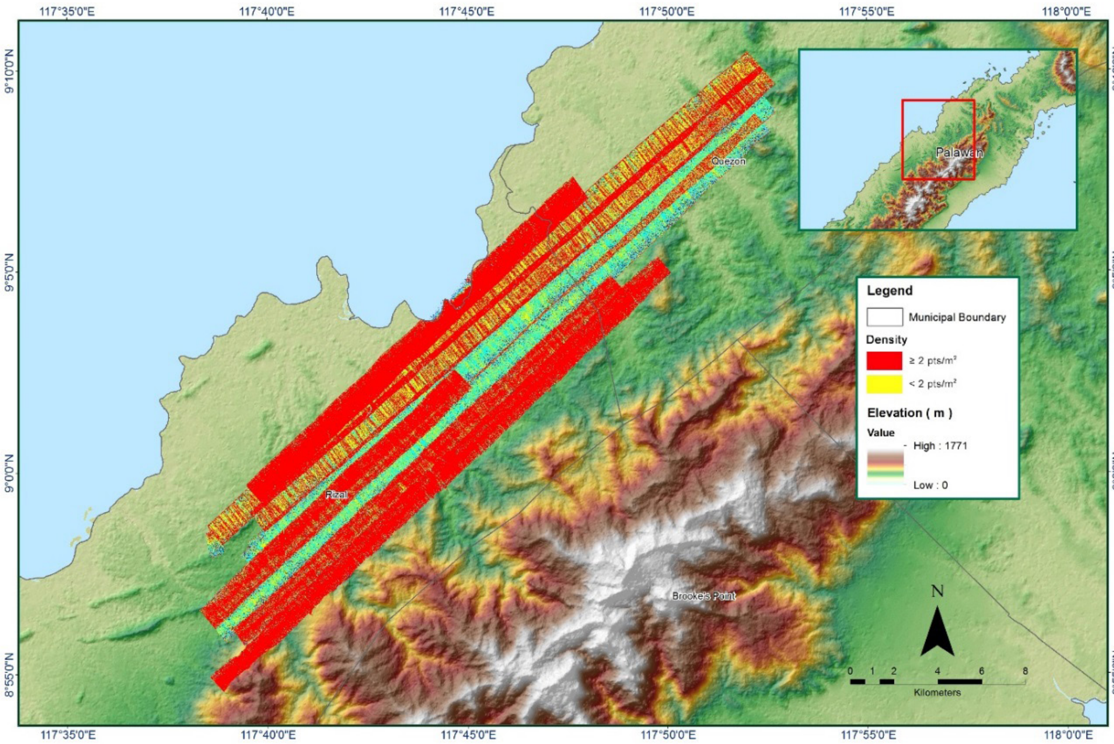


Figure A-8.6 Density map of merged LiDAR data

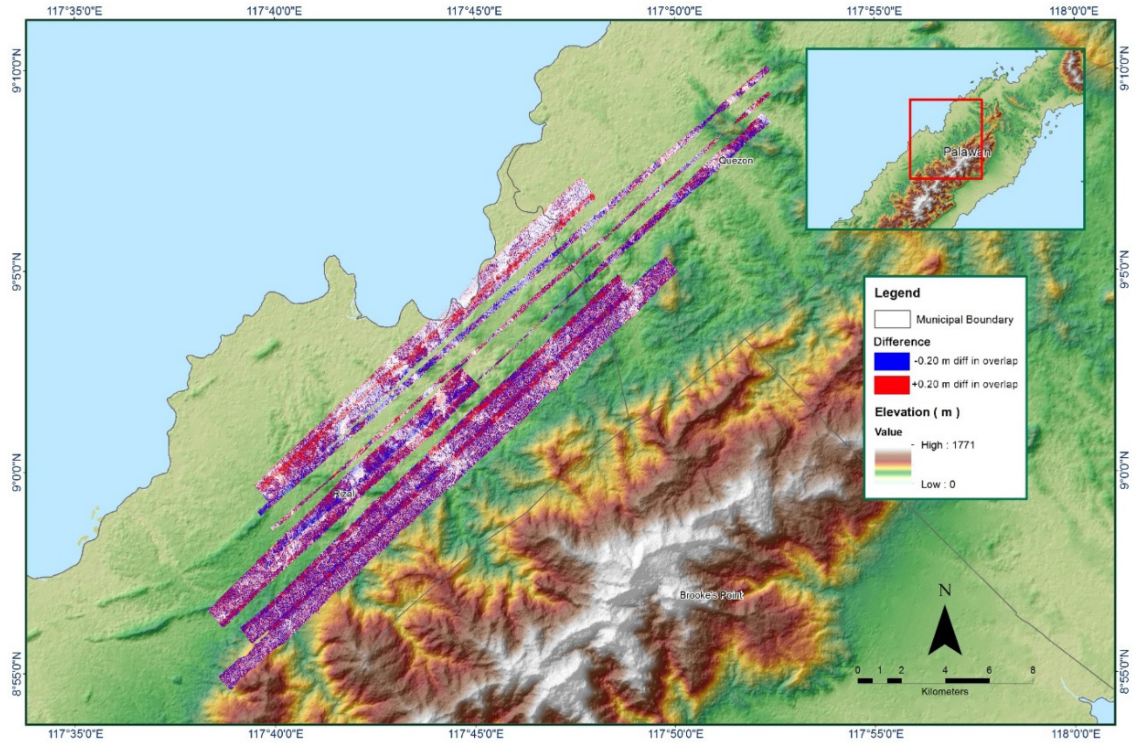


Figure A-8.7 Elevation difference between flight lines

Table A-8.2 MISSION SUMMARY REPORT for Mission Block 42O

Flight Area	**West Palawan**
Mission Name	**Block 42O**
Inclusive Flights	3157P and 3159P
Range data size	64.90 GB
Base data size	41.2 MB
POS	478 MB
Image	90.70 GB
Transfer date	August 5, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.22
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	3.40
Boresight correction stdev (<0.001deg)	0.000370
IMU attitude correction stdev (<0.001deg)	0.000558
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	21.33
Ave point cloud density per sq.m. (>2.0)	1.96
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	160
Maximum Height	178.72
Minimum Height	40.13
Classification (# of points)	
Ground	112805844
Low vegetation	95911890
Medium vegetation	80712706
High vegetation	142125592
Building	4713926
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Alex John Escobido

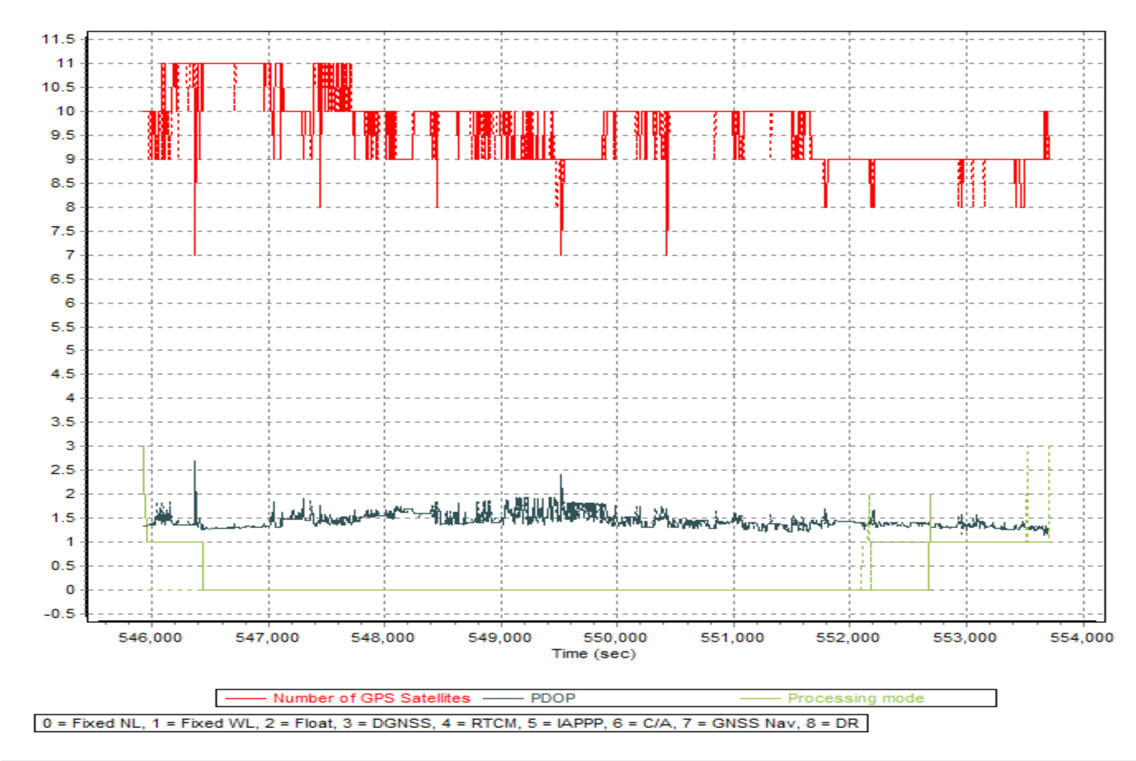


Figure A-8.8 Solution Status

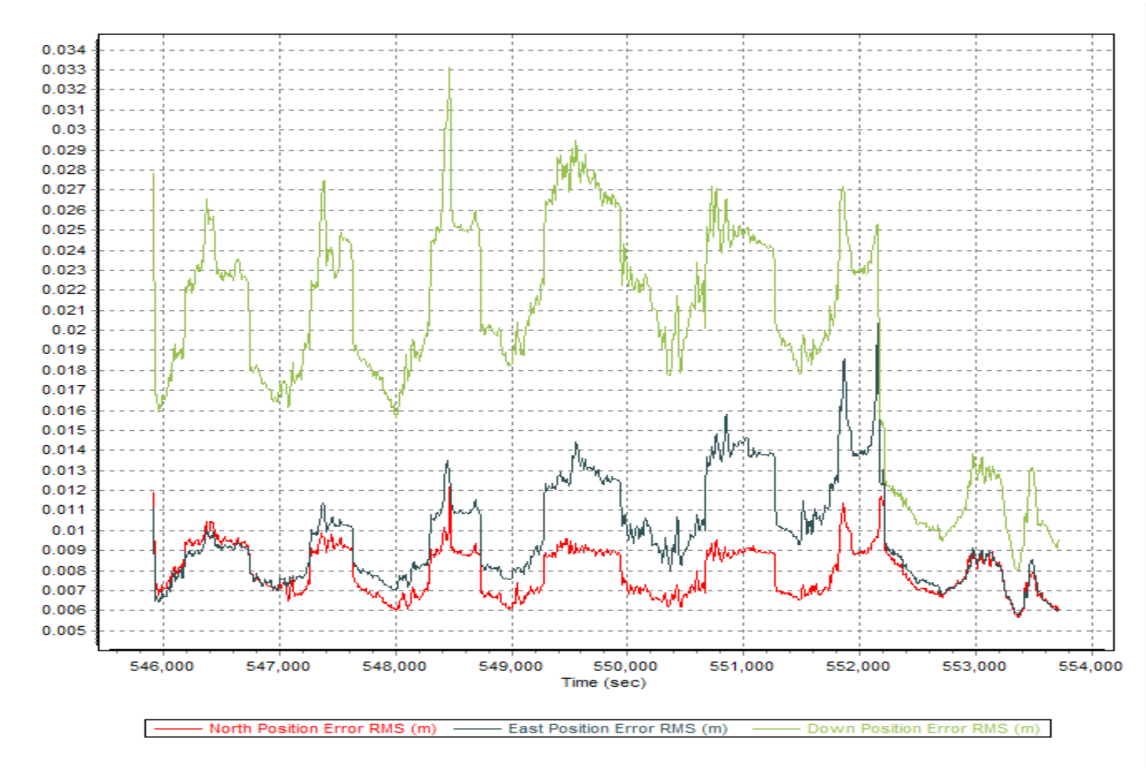


Figure A-8.9 Smoothed Performance Metric Parameters

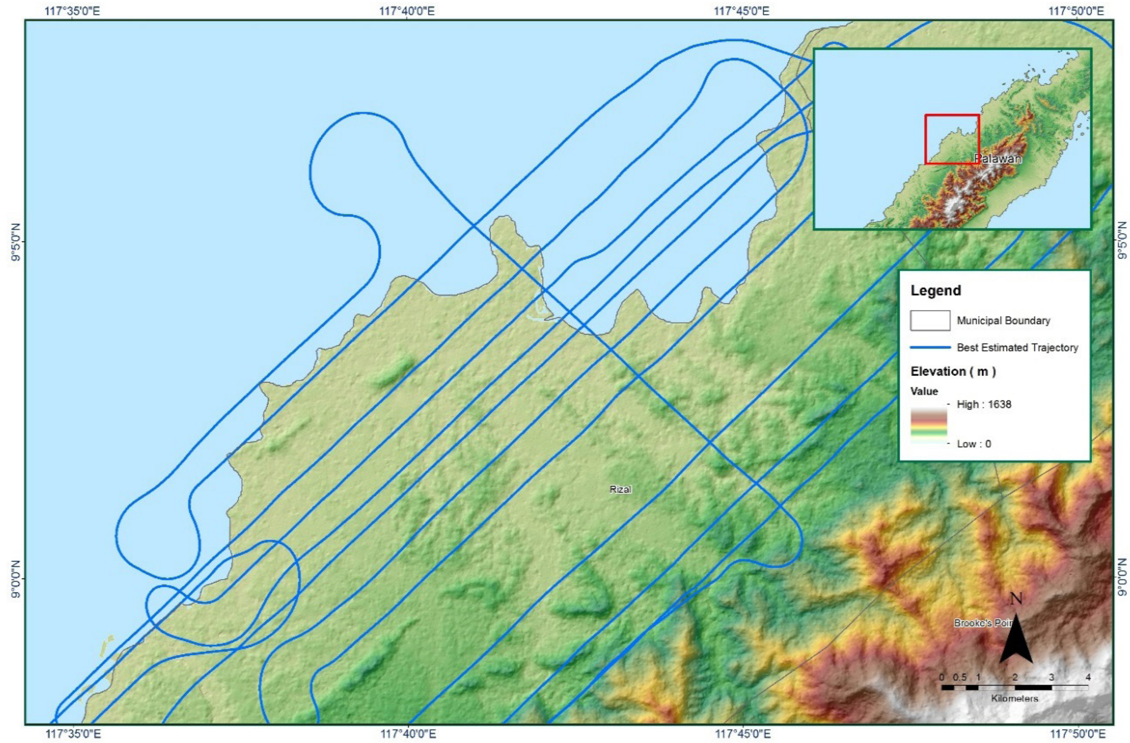


Figure A-8.10 Best Estimated Trajectory

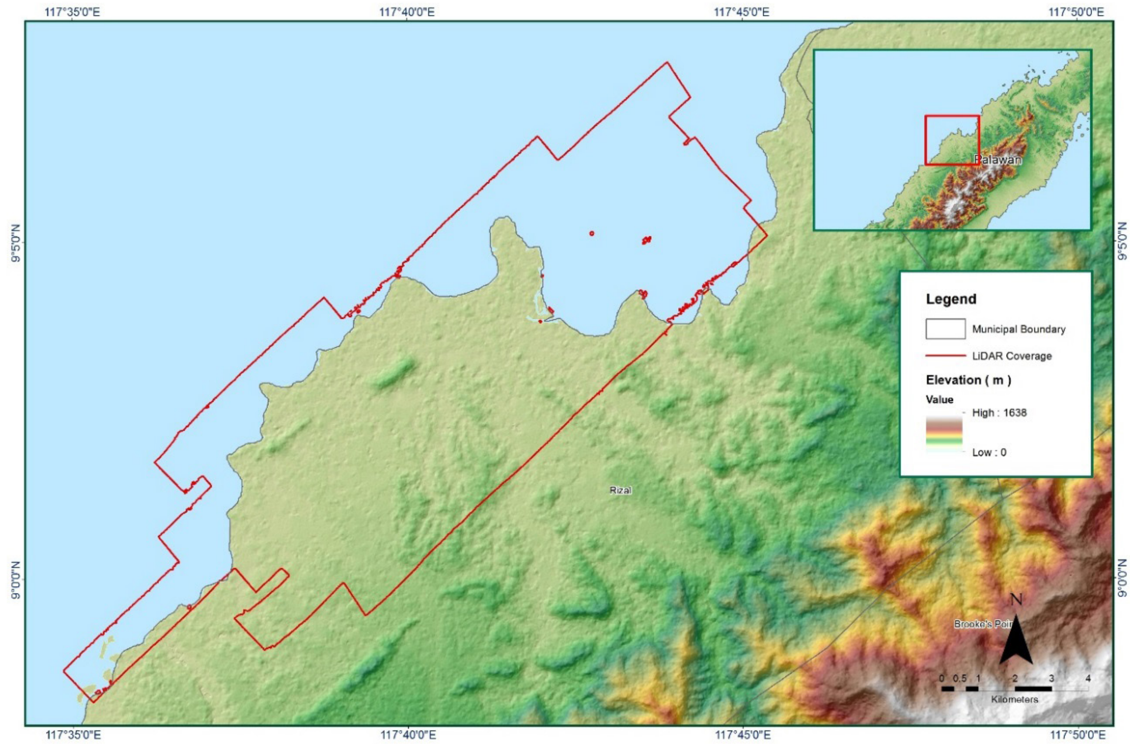


Figure A-8.11 Coverage of LiDAR data

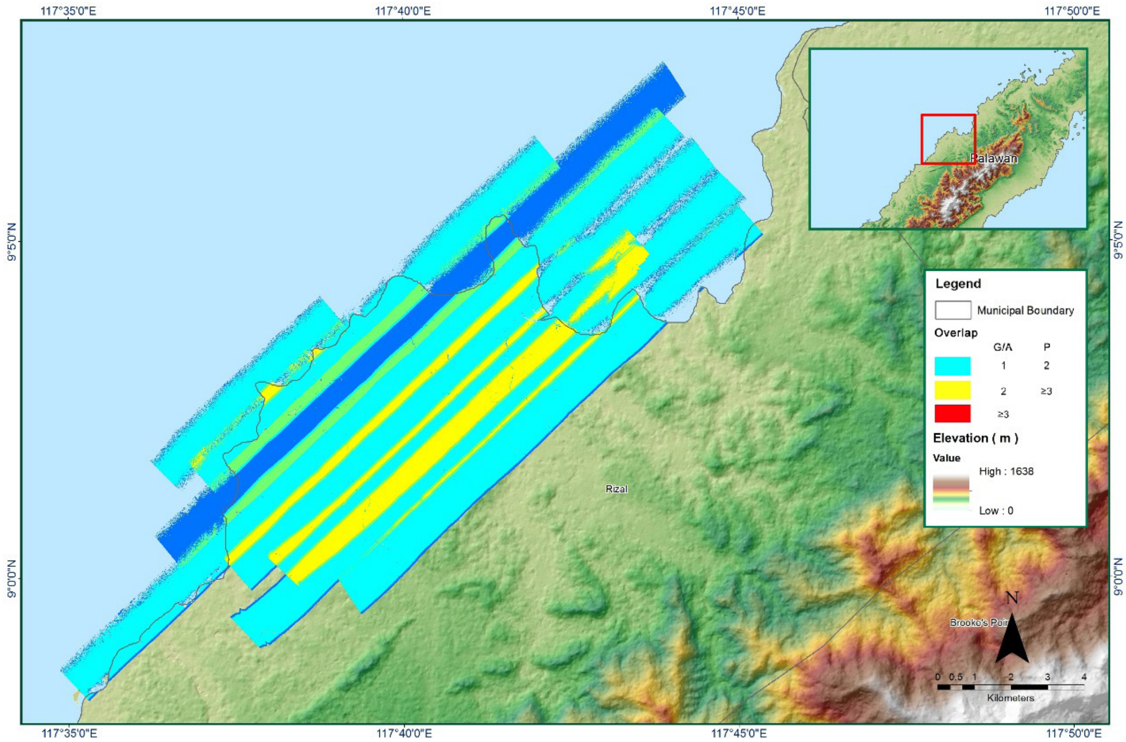


Figure A-8.12 Image of data overlap

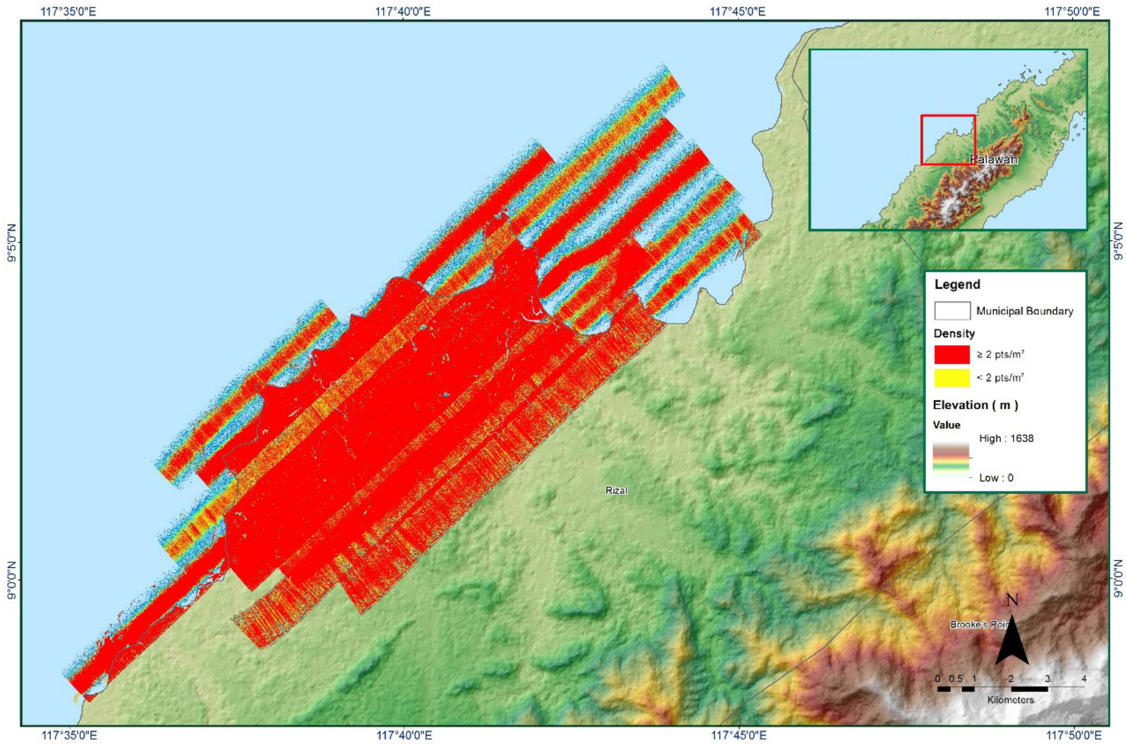


Figure A-8.13 Density map of merged LiDAR data

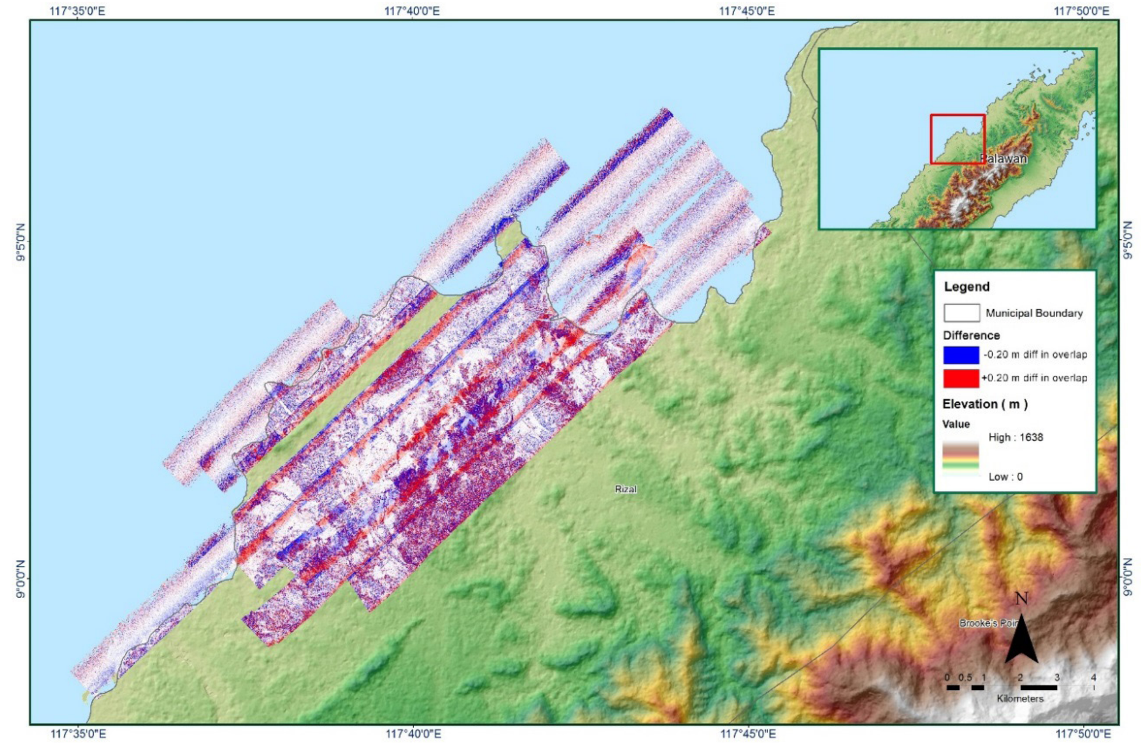


Figure A-8.14 Elevation difference between flight lines

Table A-8.3 MISSION SUMMARY REPORT for Mission Block 42P

Flight Area	**West Palawan**
Mission Name	**Block 42P**
Inclusive Flights	3157P and 3159P
Range data size	64.90 GB
Base data size	41.2 MB
POS	478 MB
Image	90.70 GB
Transfer date	August 5, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.22
RMSE for East Position (<4.0 cm)	2.10
RMSE for Down Position (<8.0 cm)	3.40
Boresight correction stdev (<0.001deg)	0.000370
IMU attitude correction stdev (<0.001deg)	0.000558
GPS position stdev (<0.01m)	0.0026
Minimum % overlap (>25)	13.66
Ave point cloud density per sq.m. (>2.0)	1.95
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	374
Maximum Height	760.06
Minimum Height	40.51
Classification (# of points)	
Ground	126102764
Low vegetation	61083474
Medium vegetation	179735342
High vegetation	715224847
Building	3589808
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Krisha Marie Bautista

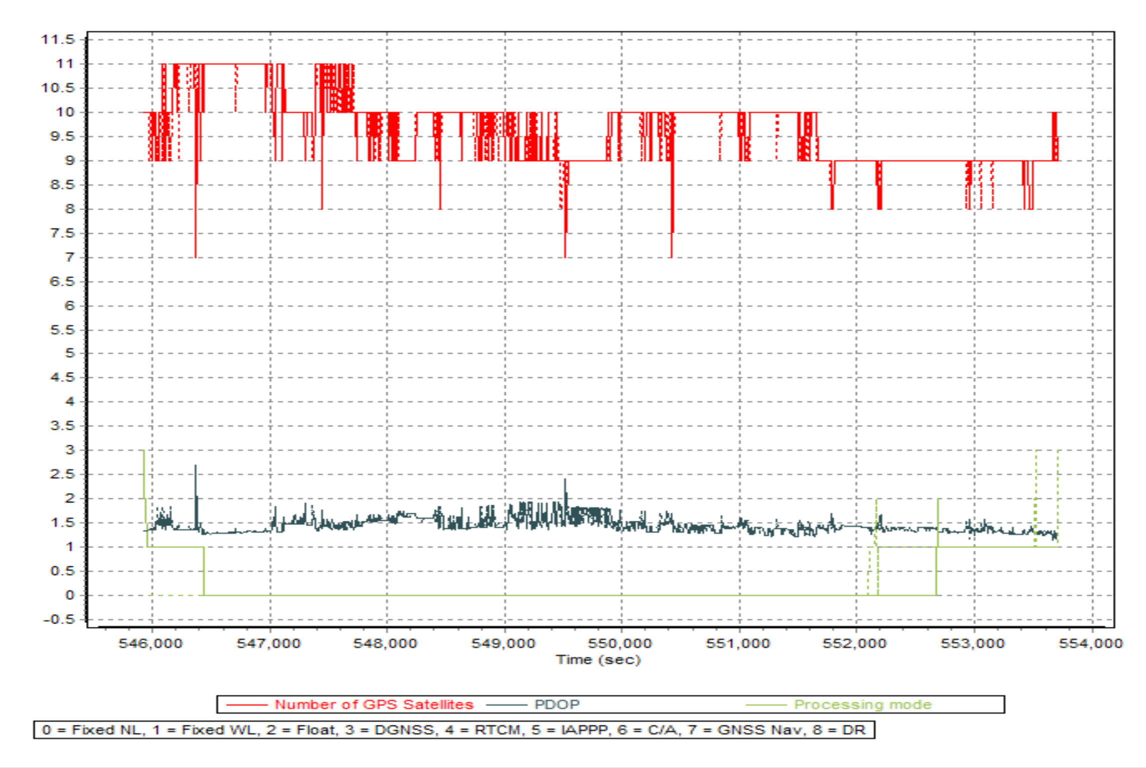


Figure A-8.15 Solution Status

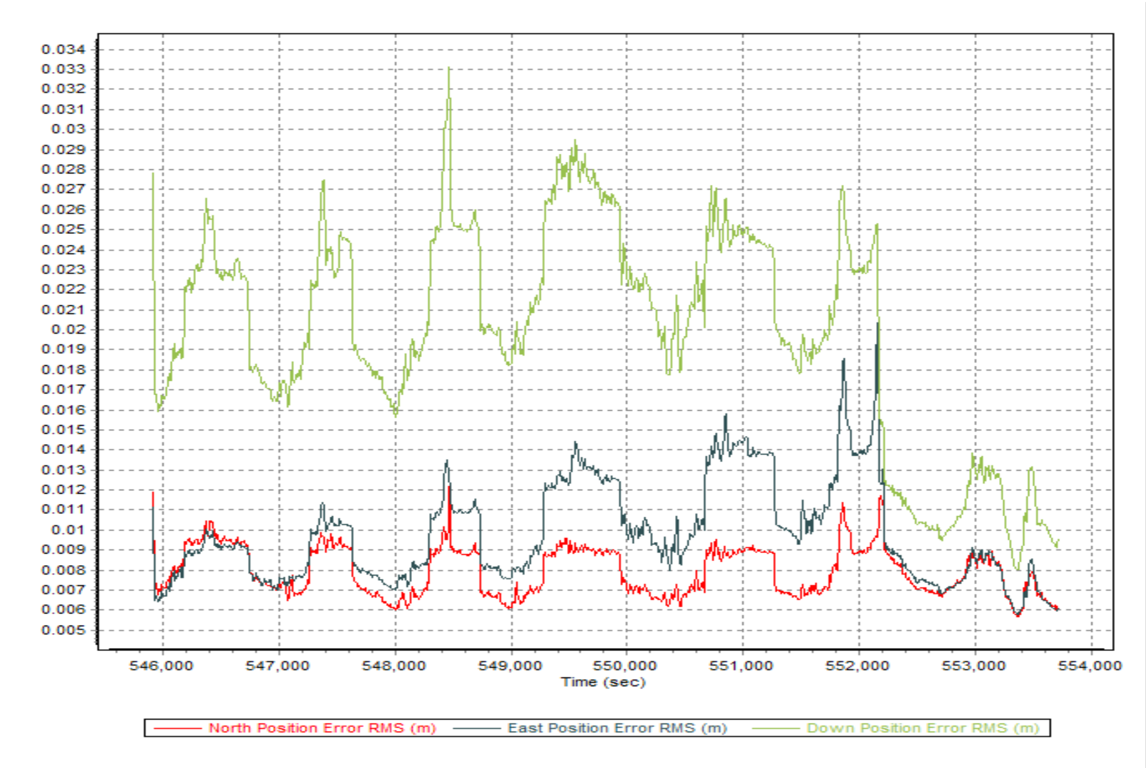


Figure A-8.16 Smoothed Performance Metric Parameters

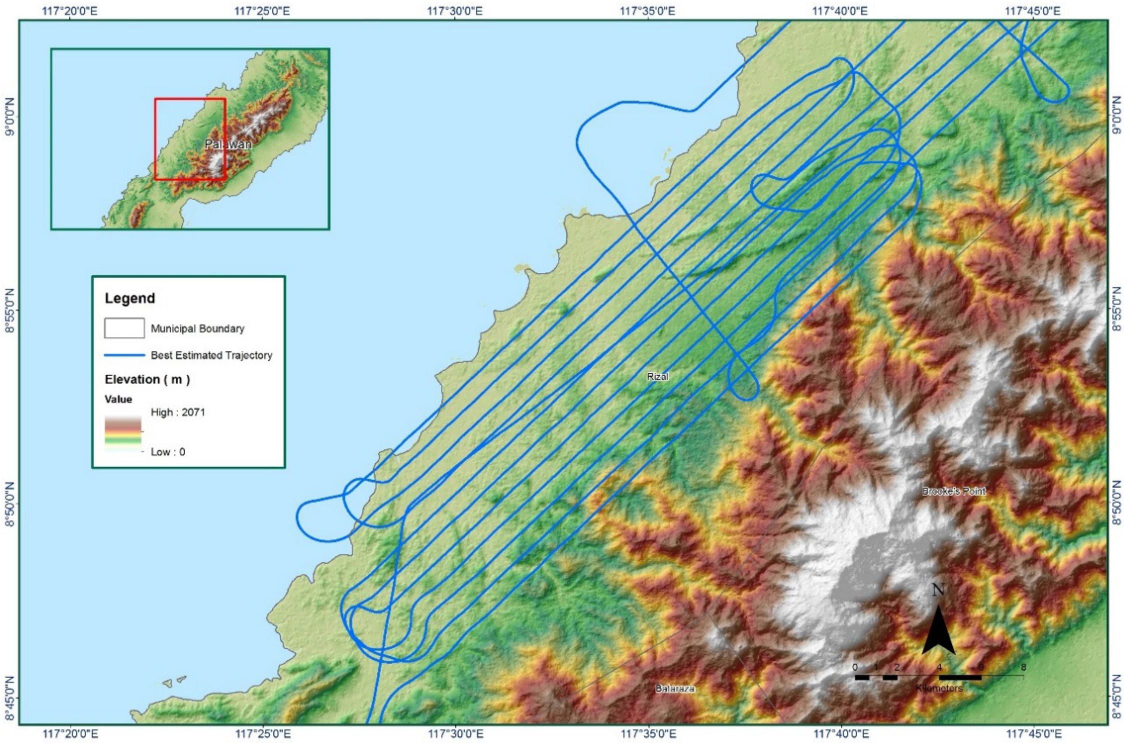


Figure A-8.17 Best Estimated Trajectory

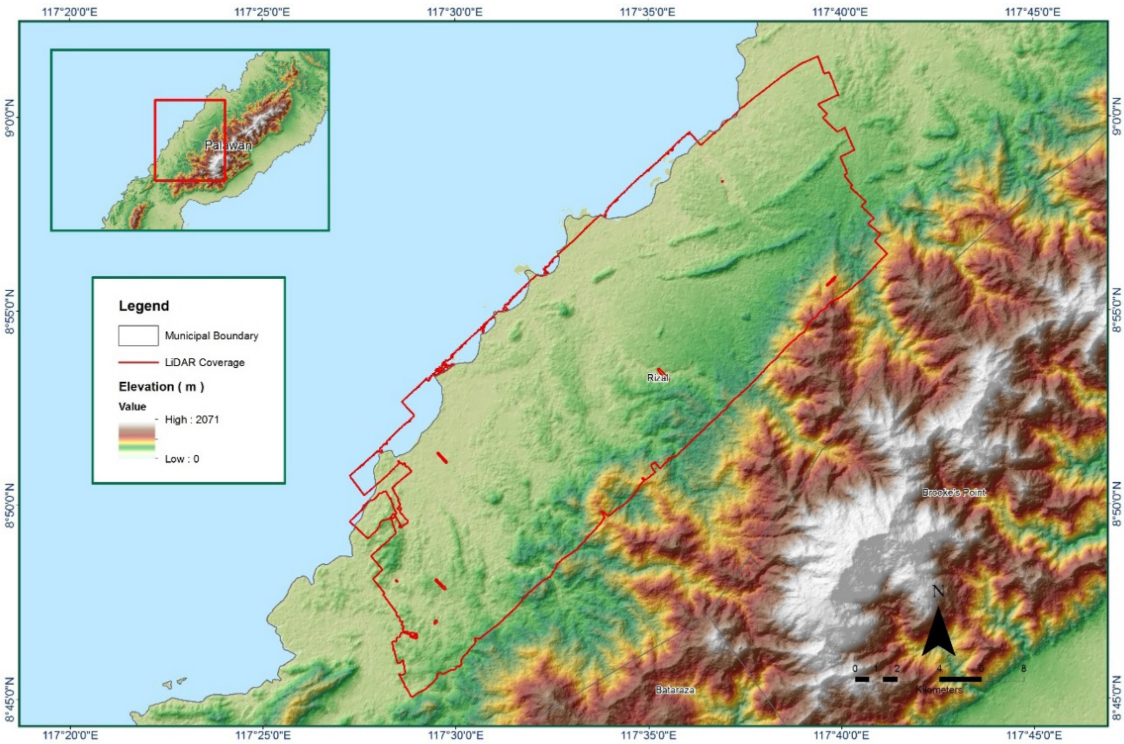


Figure A-8.18 Coverage of LiDAR data

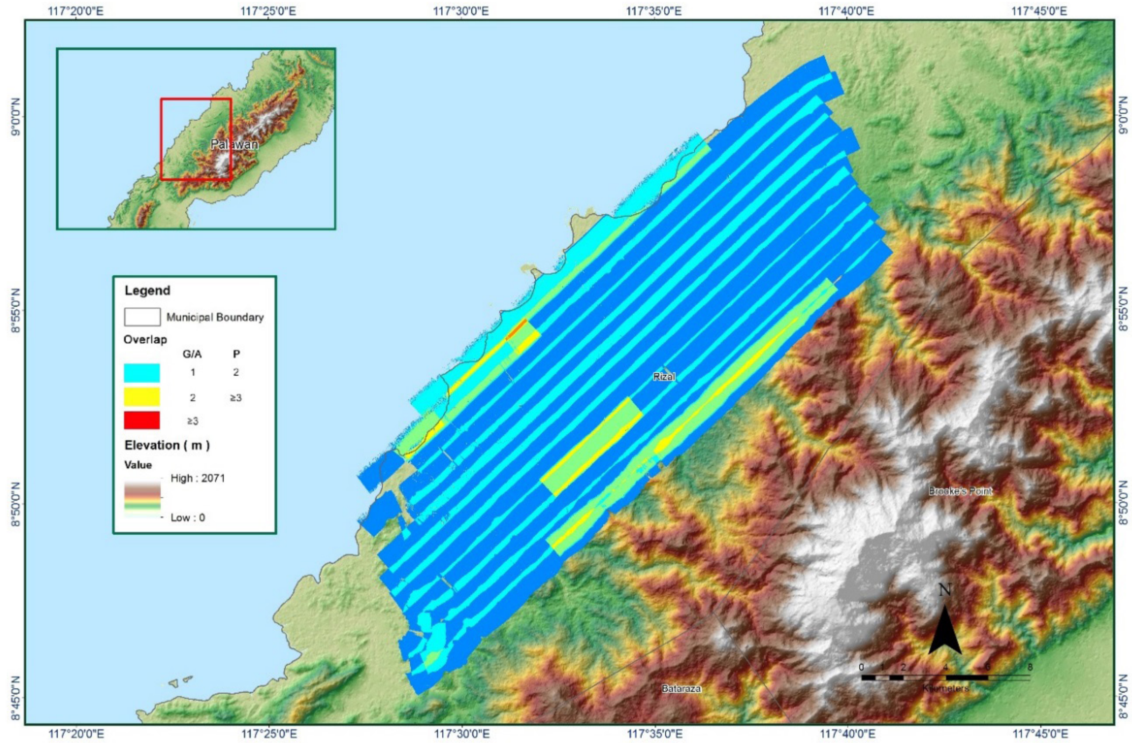


Figure A-8.19 Image of data overlap

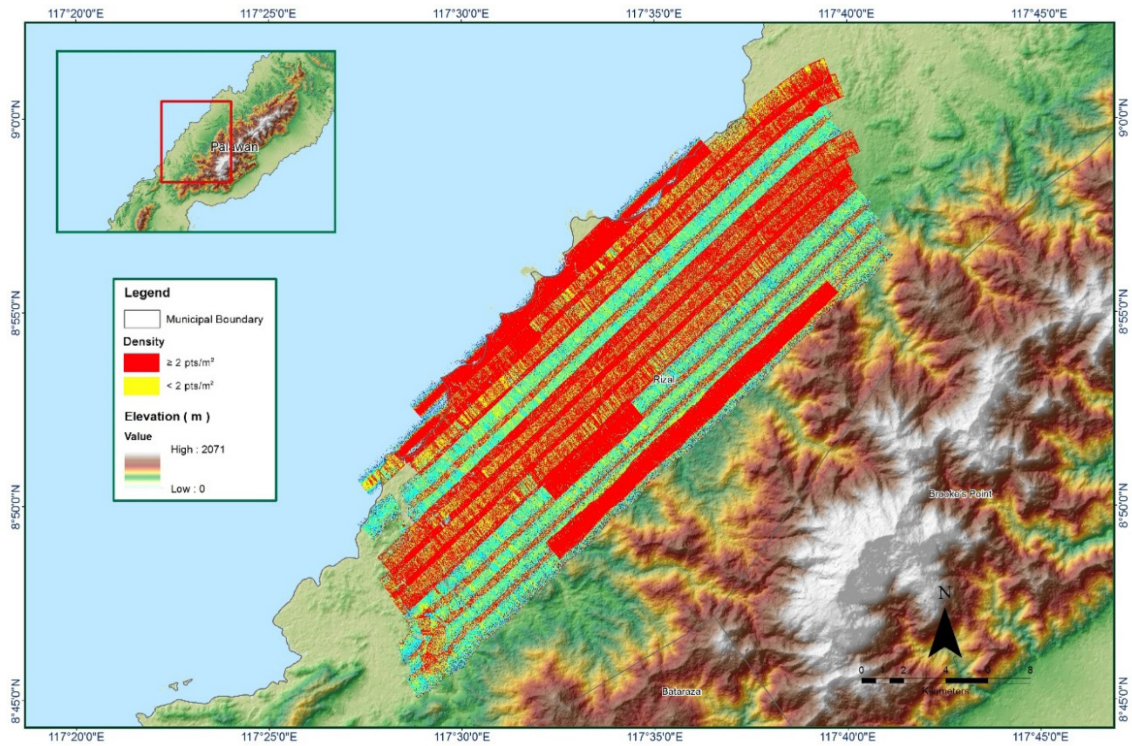


Figure A-8.20 Density map of merged LiDAR data

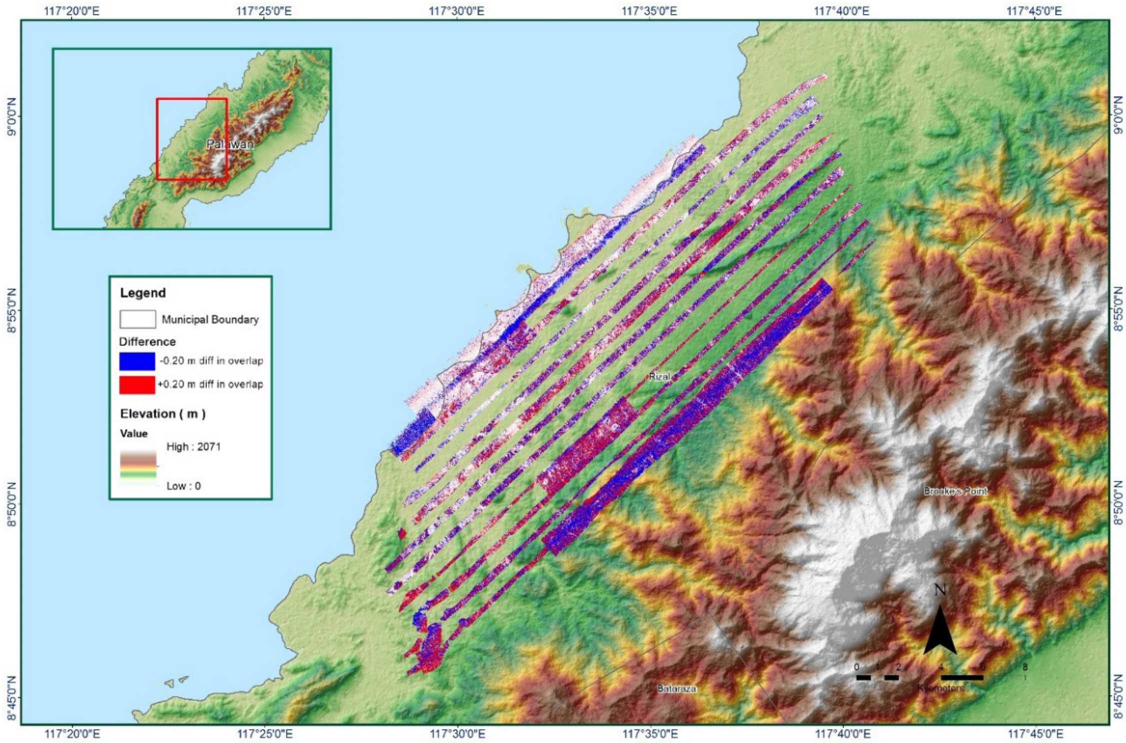


Figure A-8.21 Elevation difference between flight lines

ANNEX 9. Ilog-Ilog Model Basin Parameters

Table A-9.1. Ilog-Iloh Model Basin Parameters

Subbasin	SCS CURVE NUMBER LOSS			CLARK UNIT HYDROGRAPH TRANSFORM		RECESSION BASEFLOW		
	Initial Abstraction (MM)	Curve Number	Imperviousness (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W1280	1.5500	89.0000	0.0	0.7761	1.2666	0.1131	1.0000	0.5000
W1290	1.5500	89.0000	0.0	0.7949	1.2972	0.2375	1.0000	0.5000
W1330	1.5500	89.0000	0.0	2.8171	4.5976	0.2669	1.0000	0.5000
W1340	4.5197	73.7530	0.0	3.5547	5.8012	2.5306	1.0000	0.5000
W420	1.5500	89.0000	0.0	1.1503	1.8773	0.2652	1.0000	0.5000
W440	1.0550	99.0000	0.0	2.9068	1.4467	0.9770	1.0000	0.2033
W450	0.0419	99.0000	0.0	6.2037	6.6611	0.2062	0.6533	0.3355
W460	0.5427	99.0000	0.0	7.0584	1.7416	0.4404	0.8164	0.2329
W470	0.0999	99.0000	0.0	4.8705	2.1465	0.5515	0.9000	0.1537
W480	0.0173	99.0000	0.0	4.8761	8.4953	0.5262	0.9660	0.1585
W500	0.1937	99.0000	0.0	0.1458	13.6940	0.1965	0.6667	0.1584
W510	0.4343	99.0000	0.0	24.5640	9.1728	0.8625	1.0000	0.1113
W520	1.6532	66.8440	0.0	0.1621	0.3638	0.1394	1.0000	0.0785
W530	1.3927	63.3860	0.0	0.1658	0.2434	0.0981	0.8737	0.0581
W540	0.0783	99.0000	0.0	0.0333	14.0060	0.5239	1.0000	0.1628
W550	0.1032	99.0000	0.0	12.4900	5.7959	0.2801	1.0000	0.3881
W560	0.6352	99.0000	0.0	0.1481	15.4810	0.2677	0.8609	0.2264
W570	0.1978	66.0000	0.0	0.1473	1.6209	0.2055	1.0000	0.1552
W580	0.1989	99.0000	0.0	0.1459	16.6250	0.6705	1.0000	0.1189
W590	1.8556	99.0000	0.0	0.1675	10.1570	0.2642	1.0000	0.1104
W600	0.9285	99.0000	0.0	45.7000	7.3802	1.0457	1.0000	0.1690
W610	0.6356	66.0000	0.0	0.5068	1.4061	0.4093	1.0000	0.3056
W620	2.0182	99.0000	0.0	22.1220	1.9528	0.3187	1.0000	0.1127
W630	1.2291	99.0000	0.0	25.7480	12.5360	1.0351	1.0000	0.1690
W640	1.0619	99.0000	0.0	8.0978	1.8636	0.9564	1.0000	0.1127
W650	10.3880	55.0070	0.0	1.4388	2.3481	1.0756	1.0000	0.5000
W660	9.4679	57.2900	0.0	1.0133	1.6537	0.7192	1.0000	0.5000
W670	10.3500	55.0000	0.0	1.3052	2.1301	0.7521	1.0000	0.5000
W680	9.7249	56.6330	0.0	1.2289	2.0055	0.6394	1.0000	0.5000
W690	10.3500	55.0000	0.0	0.6600	1.0771	0.2058	1.0000	0.5000
W700	10.3500	55.0000	0.0	0.4810	0.7850	0.0703	1.0000	0.5000
W710	10.3500	55.0000	0.0	0.9646	1.5742	0.5291	1.0000	0.5000
W720	10.3500	55.0000	0.0	0.4552	0.7428	0.0541	1.0000	0.5000
W730	10.3500	55.0000	0.0	1.8171	2.9655	1.4319	1.0000	0.5000
W740	10.3500	55.0000	0.0	1.2094	1.9737	0.7462	1.0000	0.5000
W750	10.3500	55.0000	0.0	0.8753	1.4285	0.4769	1.0000	0.5000
W760	10.3500	55.0000	0.0	0.7707	1.2577	0.2125	1.0000	0.5000
W770	10.3500	55.0000	0.0	0.7156	1.1679	0.3159	1.0000	0.5000
W780	10.3500	55.0000	0.0	0.4100	0.6691	0.0730	1.0000	0.5000

W790	10.3500	55.0000	0.0	0.7629	1.2450	0.6314	1.0000	0.5000
W800	10.3500	55.0000	0.0	0.9211	1.5033	0.4381	1.0000	0.5000
W810	10.3500	55.0000	0.0	1.0770	1.7576	0.2885	1.0000	0.5000
W820	10.3500	55.0000	0.0	1.0117	1.6510	0.9577	1.0000	0.5000

ANNEX 10. Ilog-Ilog Model Reach Parameters

Table A-9.1. Ilog-Iloh Model Reach Parameters

REACH	MUSKINGUM CUNGE CHANNEL ROUTING						
	Time Step Method	Length (M)	Slope(M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R10	Automatic Fixed Interval	1703.6	0.0112379	0.0400	Trapezoid	35	1
R110	Automatic Fixed Interval	711.54	0.0098780	0.2383	Trapezoid	35	1
R1310	Automatic Fixed Interval	1634.4	0.0089557	0.0061	Trapezoid	35	1
R1360	Automatic Fixed Interval	11279	0.0186166	0.0400	Trapezoid	35	1
R140	Automatic Fixed Interval	1111.5	0.0093498	0.2286	Trapezoid	35	1
R170	Automatic Fixed Interval	1722.0	0.0336568	0.7027	Trapezoid	35	1
R190	Automatic Fixed Interval	1610.2	0.0172605	0.0287	Trapezoid	35	1
R230	Automatic Fixed Interval	1888.2	0.0033178	0.0400	Trapezoid	35	1
R250	Automatic Fixed Interval	1779.9	0.0333663	0.0400	Trapezoid	35	1
R270	Automatic Fixed Interval	792.55	0.0371046	0.0400	Trapezoid	35	1
R280	Automatic Fixed Interval	551.84	0.0519236	0.0400	Trapezoid	35	1
R290	Automatic Fixed Interval	410.71	0.0679402	0.0400	Trapezoid	35	1
R30	Automatic Fixed Interval	1702.0	0.0152774	0.2707	Trapezoid	35	1
R300	Automatic Fixed Interval	1476.8	0.0939310	0.0400	Trapezoid	35	1
R330	Automatic Fixed Interval	861.54	0.12075	0.0400	Trapezoid	35	1
R350	Automatic Fixed Interval	576.69	0.12149	0.0400	Trapezoid	35	1
R370	Automatic Fixed Interval	2633.2	0.11581	0.0400	Trapezoid	35	1
R50	Automatic Fixed Interval	1446.4	0.0056049	0.1019	Trapezoid	35	1
R60	Automatic Fixed Interval	1520.5	0.0088994	0.1544	Trapezoid	35	1
R70	Automatic Fixed Interval	1365.0	0.0036115	0.0400	Trapezoid	35	1
R80	Automatic Fixed Interval	819.41	0.0020975	0.1337	Trapezoid	35	1
R90	Automatic Fixed Interval	2550.7	0.0064915	0.0046	Trapezoid	35	1

ANNEX 11. Ilog-Ilog Validation Points

Table A-9.1. Ilog-Iloh Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/ Scenario
	Latitude	Longitude						
1	8.93826738700	117.58408010000	0.030	0.000	-0.030			25-Year
2	8.93827543400	117.58163490000	0.080	1.000	0.920	Pablo		25-Year
3	8.93860158100	117.58325410000	0.030	0.000	-0.030			25-Year
4	8.93889243500	117.58381260000	0.030	0.000	-0.030			25-Year
5	8.93894431200	117.58402760000	0.050	0.000	-0.050			25-Year
6	8.93893142300	117.58311970000	1.070	0.300	-0.770	Pablo		25-Year
7	8.93904964100	117.58333320000	0.030	0.300	0.270	Pablo		25-Year
8	8.93912620800	117.58370210000	0.030	0.000	-0.030			25-Year
9	8.93983144300	117.58808350000	0.070	0.000	-0.070			25-Year
10	8.93996712400	117.58553420000	0.030	0.000	-0.030			25-Year
11	8.94199398800	117.58864910000	0.030	0.000	-0.030			25-Year
12	8.94233800000	117.58887100000	0.030	0.000	-0.030			25-Year
13	8.94276582100	117.58969420000	0.030	0.000	-0.030			25-Year
14	8.94299155900	117.58982180000	0.030	0.000	-0.030			25-Year
15	8.94307906300	117.58937260000	0.050	0.000	-0.050			25-Year
16	8.94330418100	117.59022420000	0.040	0.000	-0.040			25-Year
17	8.94330191400	117.58999040000	0.040	0.000	-0.040			25-Year
18	8.94336710600	117.59014810000	0.080	0.000	-0.080			25-Year
19	8.94372357800	117.59032020000	0.030	0.000	-0.030			25-Year
20	8.94389610800	117.58996170000	0.200	0.000	-0.200			25-Year
21	8.94418271500	117.59036060000	0.030	0.000	-0.030			25-Year
22	8.94520032900	117.59094400000	0.030	0.000	-0.030			25-Year
23	8.94536488800	117.59100850000	0.030	0.000	-0.030			25-Year
24	8.94552145700	117.59110260000	0.030	0.000	-0.030			25-Year

25	8.94637884200	117.59109740000	0.100	0.000	-0.100			25-Year
26	8.94664425400	117.59156190000	0.130	0.000	-0.130			25-Year
27	8.94762367600	117.59185390000	0.030	0.000	-0.030			25-Year
28	8.94771281600	117.59174980000	0.030	0.000	-0.030			25-Year
29	8.94801284900	117.59218070000	0.030	0.000	-0.030			25-Year
30	8.94803780800	117.59191140000	0.030	0.000	-0.030			25-Year
31	8.94866688100	117.59860770000	0.030	0.000	-0.030			25-Year
32	8.94900043200	117.59893830000	0.030	0.000	-0.030			25-Year
33	8.94978277500	117.60047380000	0.030	0.000	-0.030			25-Year
34	8.95024660300	117.60234140000	0.030	0.000	-0.030			25-Year
35	8.95030241400	117.60127000000	0.050	0.000	-0.050			25-Year
36	8.95049835400	117.60241350000	0.030	0.000	-0.030			25-Year
37	8.95082898200	117.60377760000	0.060	0.000	-0.060			25-Year
38	8.95087933600	117.60360860000	0.080	0.000	-0.080			25-Year
39	8.95093430700	117.60358450000	0.150	0.000	-0.150			25-Year
40	8.95209136100	117.60456690000	0.030	0.000	-0.030			25-Year
41	8.95336337500	117.60469530000	0.030	0.000	-0.030			25-Year
42	8.95381213400	117.60418390000	0.030	0.000	-0.030			25-Year
43	8.95447487500	117.60763520000	0.030	0.000	-0.030			25-Year
44	8.95507659900	117.60591290000	0.030	0.000	-0.030			25-Year
45	8.95818608300	117.60986600000	0.030	0.000	-0.030			25-Year
46	8.95819256800	117.61008040000	0.030	0.000	-0.030			25-Year
47	8.95834431800	117.61037560000	0.030	0.000	-0.030			25-Year
48	8.95837007400	117.61065410000	0.030	0.000	-0.030			25-Year
49	8.95850341400	117.61250250000	0.030	0.000	-0.030			25-Year
50	8.95859965100	117.61386280000	0.030	0.000	-0.030			25-Year
51	8.95856875400	117.61115150000	0.030	0.000	-0.030			25-Year
52	8.95867354700	117.61268030000	0.030	0.000	-0.030			25-Year

53	8.95875689900	117.61354340000	0.030	0.000	-0.030			25-Year
54	8.95878143200	117.61498740000	0.030	0.000	-0.030			25-Year
55	8.95887376800	117.61202870000	0.050	0.000	-0.050			25-Year
56	8.95924708000	117.61199340000	0.030	0.000	-0.030			25-Year
57	8.95932114700	117.61288500000	0.030	0.000	-0.030			25-Year
58	8.95931421900	117.61214830000	0.040	0.000	-0.040			25-Year
59	8.95938253100	117.61318890000	0.030	0.000	-0.030			25-Year
60	8.95946117700	117.61423220000	0.040	0.000	-0.040			25-Year
61	8.95951186700	117.61264450000	0.030	0.000	-0.030			25-Year
62	8.95957744600	117.61330880000	0.050	0.000	-0.050			25-Year
63	8.95965335600	117.61345110000	0.070	0.000	-0.070			25-Year
64	8.95972018100	117.61412940000	0.090	0.000	-0.090			25-Year
65	8.95977011700	117.61357390000	0.070	0.000	-0.070			25-Year
66	8.95979941600	117.61492300000	0.030	0.000	-0.030			25-Year
67	8.95979233900	117.61301920000	0.030	0.000	-0.030			25-Year
68	8.95983401100	117.61467200000	0.030	0.000	-0.030			25-Year
69	8.95990802100	117.61442770000	0.040	0.000	-0.040			25-Year
70	8.95991009500	117.61376850000	0.220	0.000	-0.220			25-Year
71	8.96003770200	117.61397140000	0.030	0.000	-0.030			25-Year
72	8.96004976600	117.61341910000	0.060	0.000	-0.060			25-Year
73	8.96030448000	117.61472820000	0.030	0.000	-0.030			25-Year
74	8.96060945600	117.61262800000	0.030	0.000	-0.030			25-Year
75	8.96064239500	117.61392230000	0.030	0.000	-0.030			25-Year
76	8.96088610100	117.61120020000	0.090	0.000	-0.090			25-Year
77	8.96093198300	117.61425120000	0.030	0.000	-0.030			25-Year
78	8.96098489400	117.61084580000	0.040	0.000	-0.040			25-Year
79	8.96109232900	117.61510260000	0.030	0.000	-0.030			25-Year
80	8.96125388500	117.61190480000	0.060	0.000	-0.060			25-Year

81	8.96125520700	117.61025750000	0.050	0.000	-0.050			25-Year
82	8.96147956000	117.61527090000	0.030	0.000	-0.030			25-Year
83	8.961495555	117.6156505	0.030	0.000	-0.030			25-Year
84	8.961573179	117.61478	0.030	0.000	-0.030			25-Year
85	8.961513003	117.610363	0.040	0.000	-0.040			25-Year
86	8.961941371	117.6129884	0.030	0.000	-0.030			25-Year
87	8.96196005	117.611454	0.040	0.000	-0.040			25-Year
88	8.962000347	117.612638	0.030	0.000	-0.030			25-Year
89	8.962215068	117.6133744	0.030	0.000	-0.030			25-Year
90	8.962254354	117.6143045	0.080	0.000	-0.080			25-Year
91	8.962243517	117.6118823	0.530	0.000	-0.530			25-Year
92	8.962589155	117.6138591	0.030	0.000	-0.030			25-Year
93	8.962476739	117.6044647	0.030	0.000	-0.030			25-Year
94	8.962640344	117.6123693	0.040	0.000	-0.040			25-Year
95	8.962945056	117.613126	0.030	0.000	-0.030			25-Year
96	8.962965589	117.61375	0.030	0.000	-0.030			25-Year
97	8.963012618	117.6122087	0.030	0.000	-0.030			25-Year
98	8.963214859	117.612824	0.030	0.000	-0.030			25-Year
99	8.963929987	117.5955552	0.030	0.000	-0.030			25-Year
100	8.966895758	117.590878	0.030	0.000	-0.030			25-Year

ANNEX 12. Educational Institutions affected by flooding in Ilog-ilog Floodplain

This River Basin has no Annex 12

ANNEX 12. Medical Institutions affected by flooding in Ilog-ilog Floodplain

This River Basin has no Annex 13

Annex 14. Phil-LiDAR 1 UPLB Team Composition

Project Leader
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Project Staffs/Study Leaders
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Asst. Prof. Joan Pauline P. Talubo (CHE, UPLB)
Ms. Sandra Samantela (CHE, UPLB)
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Allen Roy C. Roberto

Information Systems Analyst
Jan Martin C. Magcale

Project Assistants
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Kaye Anne A. Matre
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