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

LiDAR Surveys and Flood Mapping of Mompong River

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

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND MOMPONG RIVER

Enrico C. Paringit, Dr. Eng., Asst. Prof. Edwin R. Abucay, and Mr. Dante Gideon K. Vergara

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Los Baños (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 Southern Luzon region. The university is located in Los Baños in the province of Laguna.

1.2 Overview of the Mompong River Basin

The Mompong River Basin is a 3,380-hectare watershed located in Occidental Mindoro. It covers the barangays of Santa Lucia, Poblacion, San Nicolas, General Emilio Aguinaldo, Batong Buhay, Ligaya, San Francisco, Malisbong and Buenavista in Sablayan municipality. The basin area has eight geological classifications with Oligocene as the most dominant while the remaining include Basement Complex, recent, Oligocene-Miocene, Cretaceous-Paleogene, Oligocene-Miocene and Upper Miocene-Pliocene. The topography in the river basin can be generally characterized by 8-18% slope and elevation >300 meters above mean sea level. About eight soil types can be found in Mompong River Basin: Banto clay loam, San Manuel silt, San Miguel silt loam, Quingua clay loam, Umingan loam, Quingua Lloam, San Manuel sandy loam, and Maranlig gravelly sandy clay loam. Rough mountain land (unclassified), beach sand and hydrosol can also be found in the area. The river basin is dominated by other wooded land mainly shrubs. Other land cover includes inland water, open forest (broadleaved), cultivated annual crop, cultivated perennial crop, natural barren land, natural grassland, built-up area and wooded grassland.

The DENR River Basin Control Office (RCBO) states that the Mompong River Basin has a drainage area of 353 km2 and an estimated 565 million cubic meter (MCM) annual run-off.

Meanwhile, its main stem, the Mompong River, passes through Santa Lucia, San Nicolas, Poblacion, Bagong Buhay, General Emilio Aguinaldo, Ligaya, San Francisco, Malisbong in Sablayan municipality. According to the National Irrigation Authority, and also based on the field survey execution, Mompong River Irrigation System provides water to the barangays it traverses. There is a total of 29,179 persons residing within the immediate vicinity of the river, with Brgy. Poblacion being the most populated having 6,471 residents as of 2010 according to the Philippine Statistics Authority Census.

Within the Mompong River Basin, Climate Type I and III prevails, same with the rest of the Mindoro, Marinduque, Romblon, and Palawan (MIMAROPA) region as well as Laguna program. This is 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,

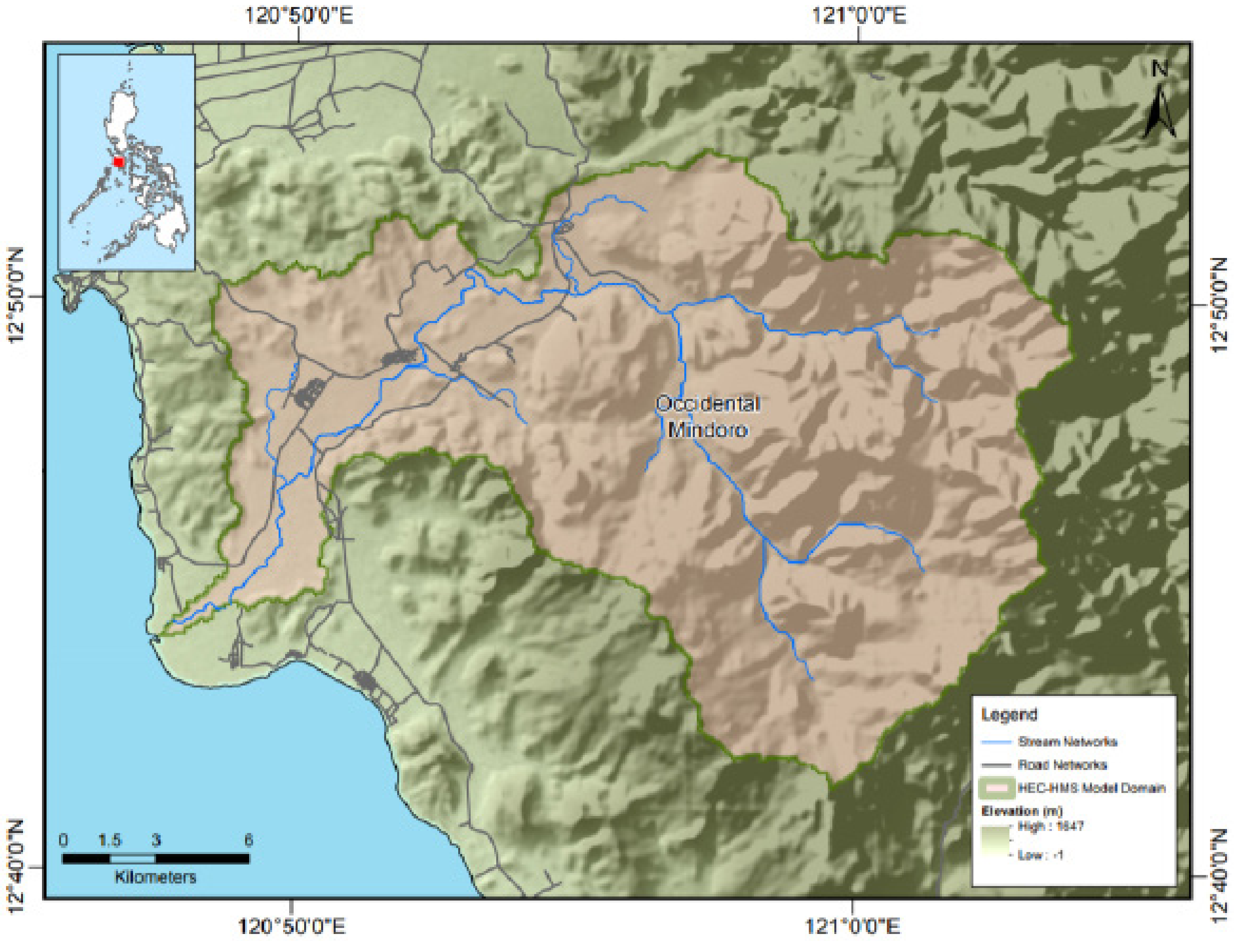

Figure 1. Map of the Mompong River Basin (in brown)

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.

The studies conducted by the Mines and Geosciences Bureau showed that the barangays of Santa Lucia, Poblacion and Batong Buhay have low to high risk to flooding while rest of the barangays have no flooding risk. The field surveys conducted by the PHIL-LiDAR 1 validation team found that notable weather disturbance caused flooding in 2009 (Ondoy), 2011 (Dodong), 2014 (Glenda), and 2016 (Lawin).

As for landslide susceptibility, Poblacion were classified to have low to moderate risk; Santa Lucia, San Nicolas, Batong Buhay, General Emilio Aguinaldo with low to high risk; and Ligaya, San Francisco and Malisbong with moderate to high risk.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE MOMPONG FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Mompong Floodplain in Occidental Mindoro. These missions were planned for 15 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 and Table 2. Figure 2 shows the flight plans and location of base stations for Mompong floodplain.

Table 1. Flight planning parameters for the Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK29H	600	30	36	125	40	130	5
BLK29I	600	30	36	125	40	130	5
BLK29J	600	30	36	125	40	130	5
BLK29K	600	30	36	125	40	130	5

Table 2. Flight planning parameters for the Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK29G	1100	30	50	200	30	130	5
BLK29H	1100	30	50	200	30	130	5
BLK29I	1100	30	50	200	30	130	5
BLK29J	1100	30	50	200	30	130	5

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

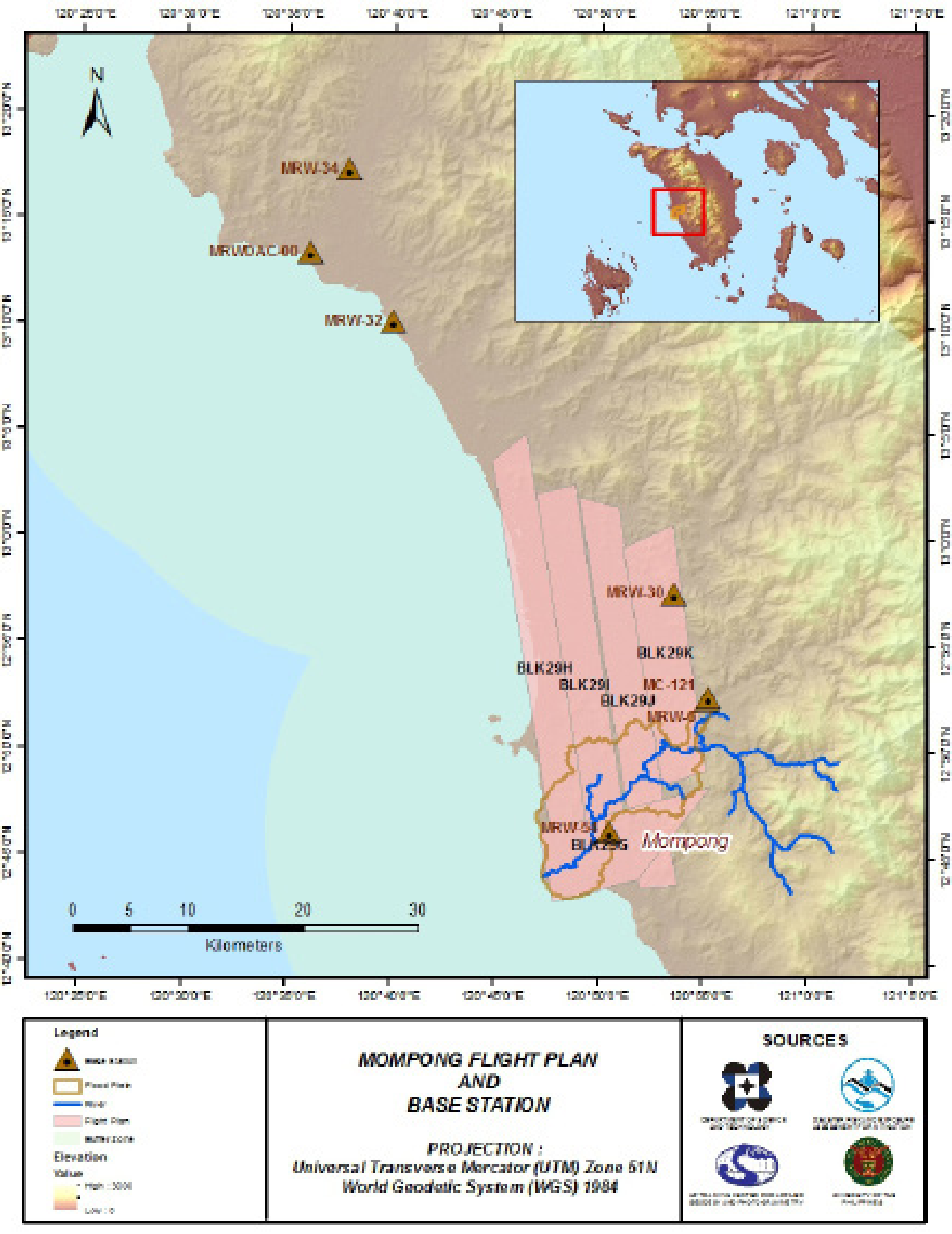


Figure 2. Flight Plan and base stations used for the Mompong Floodplain survey.

2.2 Ground Base Stations

The project team was able to recover five (5) NAMRIA ground control points: MRW-30, MRW-32, MRW-34 and MRW-54 which are of second (2nd) order accuracy and MRW-6 which is of third (3rd) order accuracy. One (1) NAMRIA benchmark was recovered, MC-121 This benchmark was used as vertical reference point and was also established as ground control point. The project team also established one (1) ground control point, MRWDAC-00. The certifications for the NAMRIA reference points are found in Annex 2, while the processing reports for the NAMIA benchmark and established ground control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 16-23, 2014; December 8-9, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Mompong floodplain are shown in Figure 2. The list of team members are shown in Annex 4.

Figure 3 to Figure 7 show the recovered NAMRIA reference points within the area, in addition Table 3 to Table 9 show the details about the following NAMRIA control stations and established points, Table 10 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

(b)

(a)

Figure 3. GPS set-up over MRW-6 at Patrick Bridge in Brgy. Yabang, municipality of Sablayan, Occidental Mindoro (a) and NAMRIA reference point MRW-6 (b) as recovered by the field team.

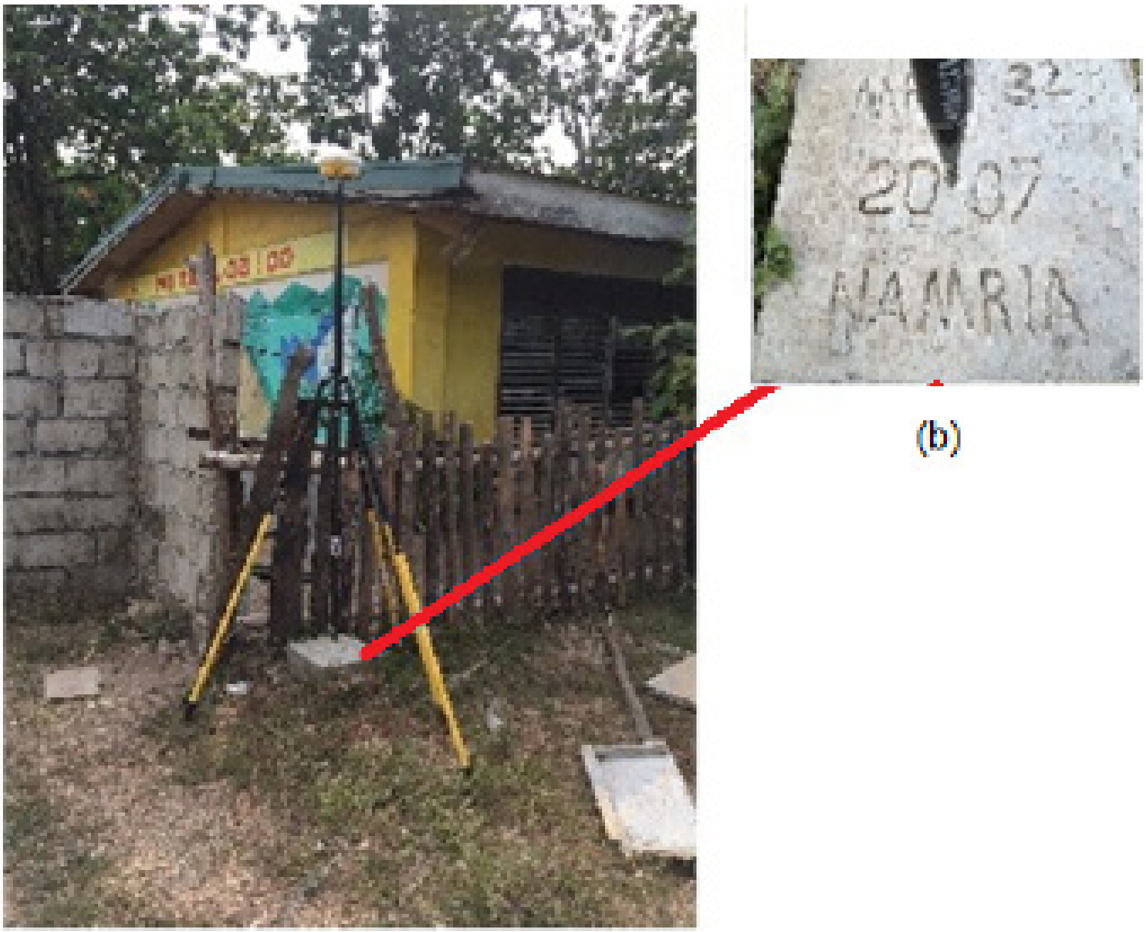
Table 3. Details of the recovered NAMRIA horizontal control point MRW-6 used as base station for the LiDAR Acquisition.

Station Name	MRW-6	
Order of Accuracy	3rd	
Relative Error (Horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°52'40.22762" North 120°55'6.44586" East 80.63530 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	491149.868 meters 1424038.201 meters
Geographic Coordinates World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°52'35.21155" North 120°55'11.48810" East 128.69600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS PRS 92)	Easting Northing	274116.83 meters 1424453.14 meters

Figure 4. GPS set-up over MRW-30 at Amnay Bridge in Brgy. Pinagturilan, municipality of Sta. Cruz, Occidental Mindoro (a) and NAMRIA reference point MRW-30 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point MRW-30 used as base station for the LiDAR Acquisition.

Station Name	**CGY-87**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°57'32.22950" North 120°53'28.50896" East 42.01300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	488201.05 meters 1433011.7 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°57'27.19115" North 120°53'33.54442" East 89.79300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	271237.33 meters 1433451.97 meters



(b)

(a)

Figure 5. GPS set-up over MRW-32 at the corner of a day care center in Brgy. Fatima, municipality of Mamburao, Occidental Mindoro (a) and NAMRIA reference point MRW-32 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point MRW-32 used as base station for the LiDAR Acquisition.

Station Name	MRW-32	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°10’14.92094” North 120°39’52.29557” East 1.47400 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	463632.46 meters 1456469.064 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°10’9.81293” North 120°39’57.31386” East 48.13600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	246845.90 meters 1457111.12 meters

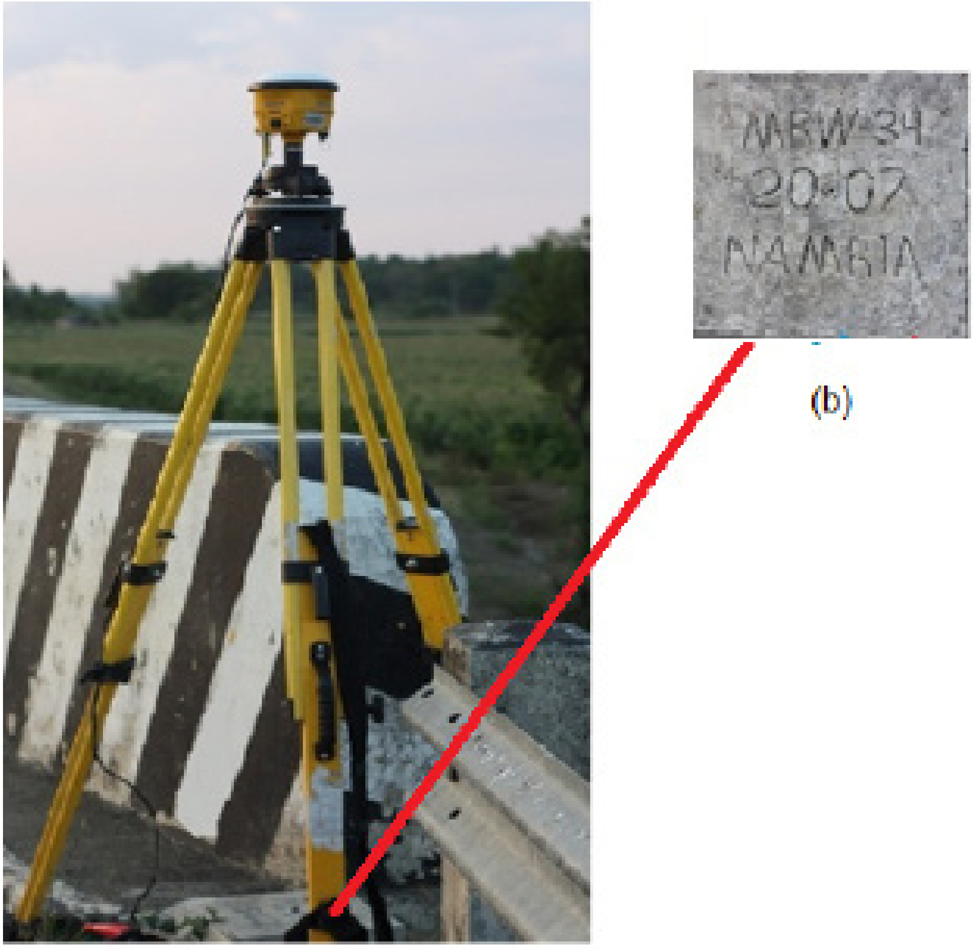


Figure 6. GPS set-up over MRW-34 in Balibago Bridge in Brgy. Armado, municipality of Abra de Ilog, Occidental Mindoro (a) and NAMRIA reference point MRW-34 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point MRW-34 used as base station for the LiDAR Acquisition.

Station Name	MRW-34	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°17'25.00981" North 120°37'41.53630" East 8.01600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	459714.493 meters 1469690.588 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°17'19.87026" North 120°37' 46.54446" East 54.26900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	243032.08 meters 1470369.33 meters

(a) (b)

Figure 7. GPS set-up over MRW-54 near basketball open court in Brgy. Malisbong, municipality of Sablayan, Occidental Mindoro (a) and NAMRIA reference point MRW-54 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point MRW-54 used as base station for the LiDAR Acquisition.

Station Name	MRW-54	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°46’18.56204” North 120°50’27.44152” East 28.20700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	482731.146 meters 1412314.677 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°46’13.56455” North 120°50’32.49343” East 76.35500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	265604.90 meters 1412791.69 meters

Table 8. Details of the recovered NAMRIA vertical control point MC-121 used as base station for the LiDAR Acquisition.

Station Name	MC-121	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:20,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°52'32.96110" North 120°55'04.36932" East 79.97100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	274052.406 meters 1424230.309 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°52'27.94499" North 120°55'09.41181" East 128.03500 meters

Table 9. Details of the recovered NAMRIA horizontal control point MRWDAC-00 used as base station for the LiDAR Acquisition.

Station Name	MRWDAC-00	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	13°13'23.10541" 120°35'55.10583" 11.60100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	239755.834 meters 1462963.518 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	13°13'17.97945" North 120°36'00.11991" East 57.96100 meters

Table 10. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
16-Feb-14	1108A	3BLK29J47A	MRW-30, MRW-6
16-Feb-14	1110A	3BLK29KJS47B	MRW-30, MRW-6
18-Feb-14	1116A	3BLK29KS49A	MRW-30, MRW-6
18-Feb-14	1118A	3BLK29JS49B	MRW-30, MRW-6
21-Feb-14	1128A	3BLK29I52A	MRW-32, MRW-34
22-Feb-14	1132A	3BLK29IS53A	MRW-30, MRW-6, MRW-34, MRW-32
23-Feb-14	1136A	3BLK29HB54A	MRW-54, MRW-6
8-Dec-15	3068P	1BLK29GJ342B	MRW-30, MRWDAC-00
9-Dec-15	3070P	1BLK29GHI343A	MRW-6, MC-121

2.3 Flight Missions

Nine (9) missions were conducted to complete the LiDAR Data Acquisition in Mompong Floodplain, for a total of thirty-three hours and seventeen minutes (33+17) of flying time for RP-C9122. All missions were acquired using the Aquarius and Gemini LiDAR system. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight missions for the LiDAR data acquisition of the Mompong 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
16-Feb-14	1108A	111.55	35.59	5.25	30.34	10	2	41
16-Feb-14	1110A	202.24	78.12	17.67	60.45	608	4	23
18-Feb-14	1116A	90.69	86.23	21.58	64.65	1056	4	23
18-Feb-14	1118A	111.55	59.60	11.04	48.56	734	3	35
21-Feb-14	1128A	117.38	116.66	22.05	94.61	99	4	35
22-Feb-14	1132A	248.63	120.42	24.38	96.04	610	4	41
23-Feb-14	1136A	131.25	69.06	NA	69.06	1241	4	29
8-Dec-15	3068P	182.62	36.42	7.78	28.64	74	1	55
9-Dec-15	3070P	319.70	98.32	25.43	72.89	209	2	35
TOTAL		1515.62	700.42	135.18	565.24	4641	33	17

Table 12. Actual parameters used during the LiDAR data acquisition of the Mompong Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1108A	600	30	36	125	40	130	5
1110A	600	30	36	125	40	110	5
1116A	600	30	36	125	40	130	5
1118A	600	30	36	125	40	110	5
1128A	600	30	36	125	40	130	5
1132A	600	30	36	125	40	130	5
1136A	600	30	36	125	40	130	5
3068P	1100	30	50	200	30	130	5
3070P	1100	30	50	200	30	130	5

2.4 Survey Coverage

Mompong floodplain is located in the provinces of Occidental Mindoro with majority of the floodplain situated within the municipality of Sablayan. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 13. The actual coverage of the LiDAR acquisition for Mompong floodplain is presented in Figure 8.

Table 13. List of municipalities and cities surveyed of the Mompong Floodplain LiDAR acquisition.

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Occidental Mindoro	Sablayan	2,350.46	409.74	17%
	Santa Cruz	709.53	93.76	13%
	Calintaan	282.31	14.04	5%
Total		**3342.3**	**517.54**	**15.48%**

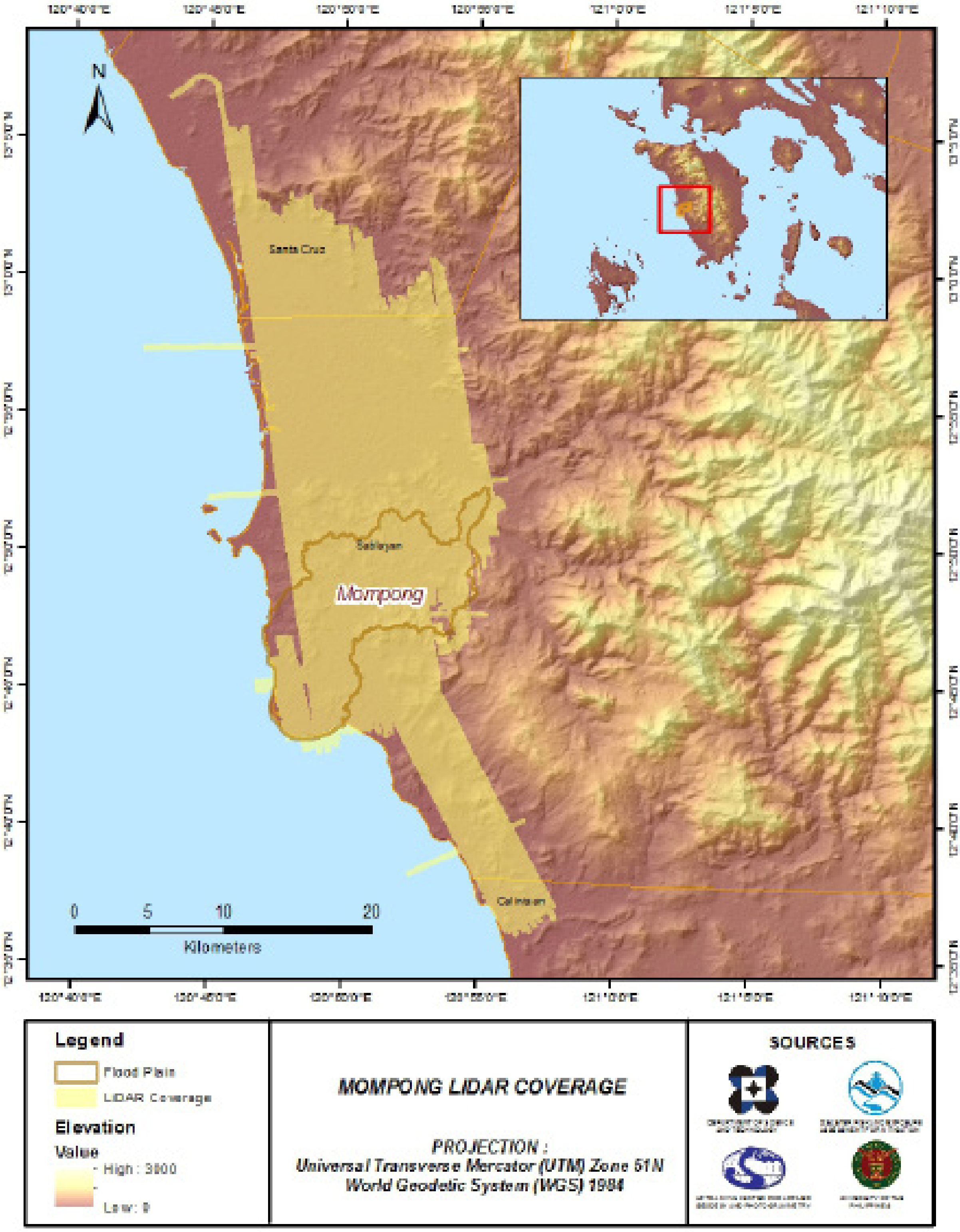


Figure 8. Actual LiDAR survey coverage of the Mompong Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE MOMPONG FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

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

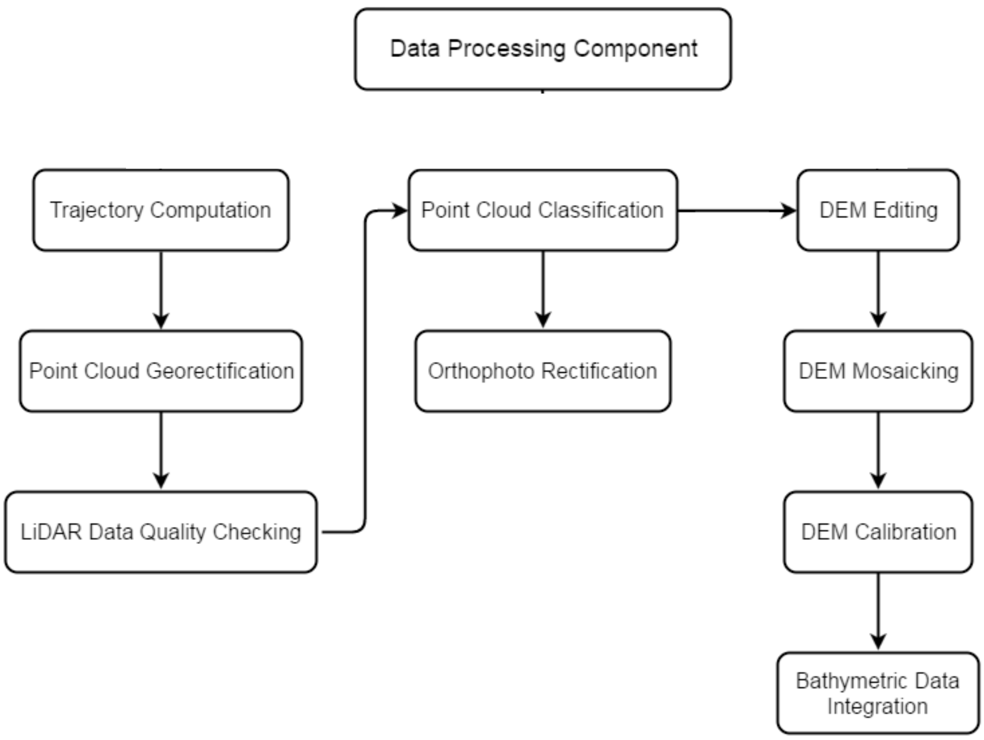

Figure 9. Schematic diagram for Data Pre-Processing Component.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Mompong floodplain can be found in Annex 5. Missions flown during the first survey conducted on January 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system while missions acquired during the second survey on December 2015 were flown using the Pegasus system over Sablayan, Occidental Mindoro.

The Data Acquisition Component (DAC) transferred a total of 90.2 Gigabytes of Range data, 1.77 Gigabytes of POS data, 122.06 Megabytes of GPS base station data, and 299.65 Gigabytes of raw image data to the data server on March 19, 2014 for the first survey and January 13, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Mompong was fully transferred on January 15, 2016, as indicated on the Data Transfer Sheets for Mompong floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1110A, one of the Mompong flights, which is the North, East, and Down position RMSE values are shown in Figure 10. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on February 16, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

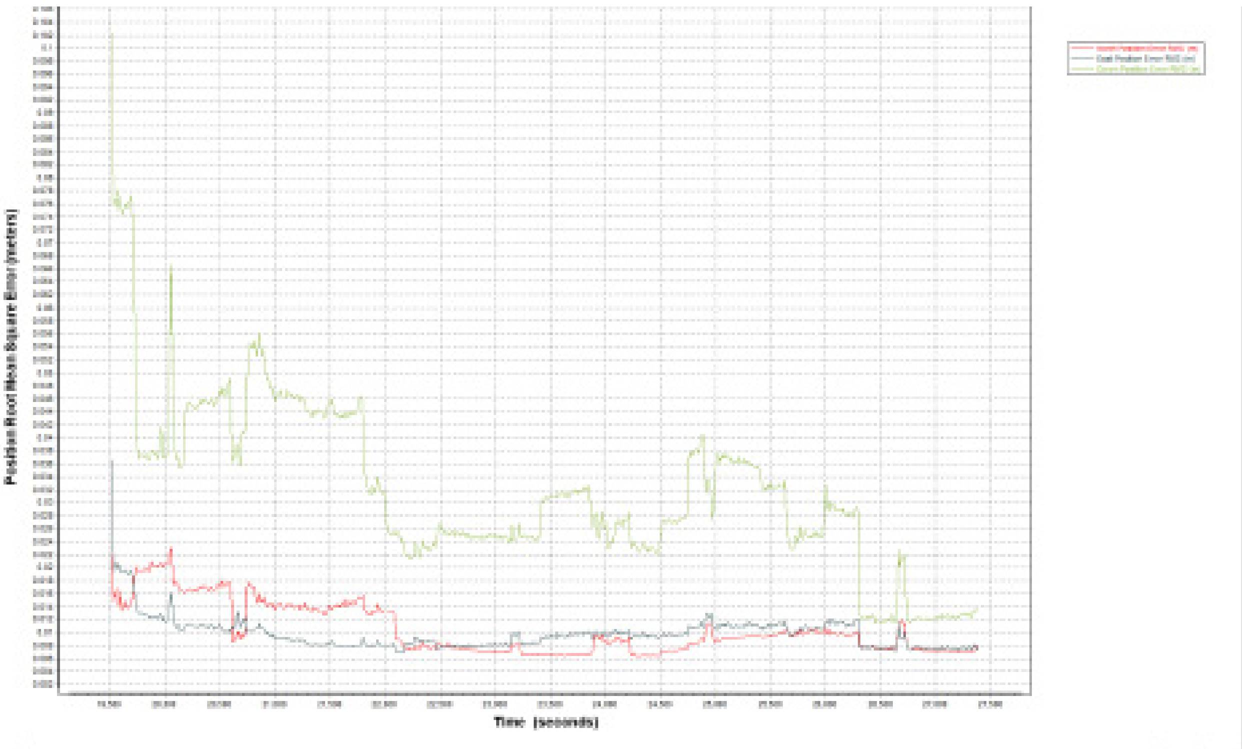

Figure 10. Smoothed Performance Metrics of Mompong Flight 1110A.

The time of flight was from 19500 seconds to 27500 seconds, which corresponds to morning of February 16, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 11 shows that the North position RMSE peaks at 2.40 centimeters, the East position RMSE peaks at 2.00 centimeters, and the Down position RMSE peaks at 5.60 centimeters, which are within the prescribed accuracies described in the methodology.

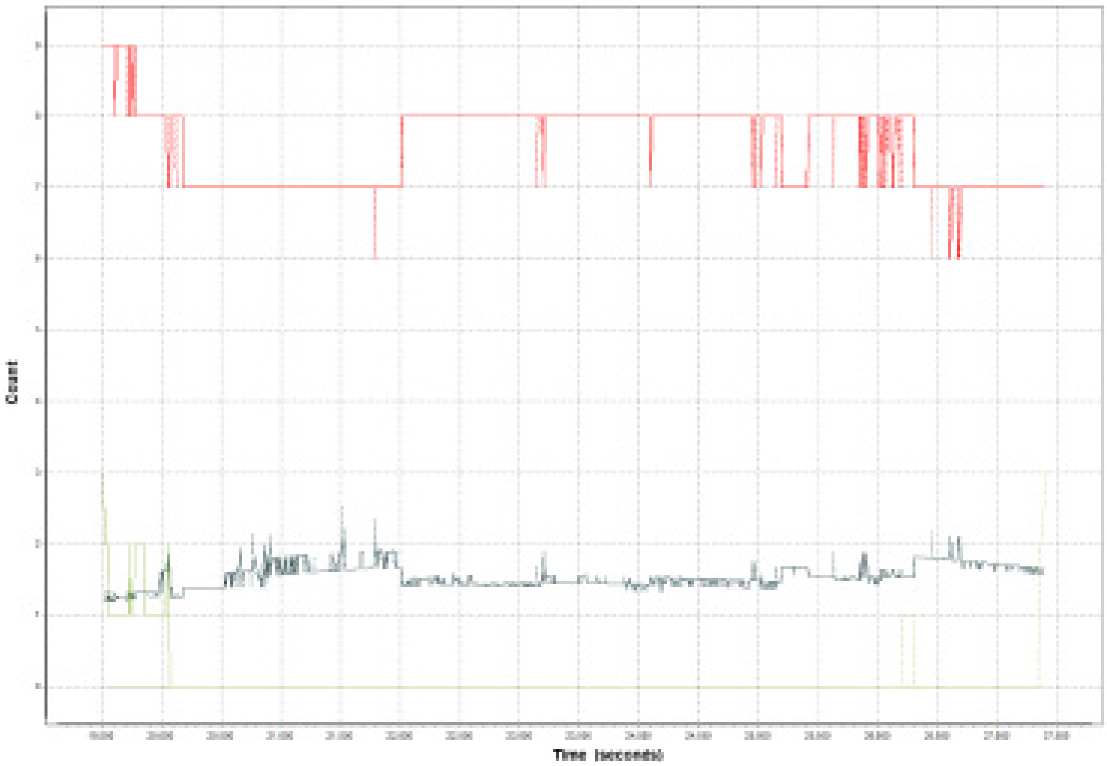

Figure 11. Solution Status Parameters of Mompong Flight 1110A.

The Solution Status parameters of flight 1110A, one of the Mompong flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 11. The graphs indicate that the number of satellites during the acquisition did not go down to 5. Majority of the time, the number of satellites tracked was between 6 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 Mompong flights is shown in Figure 12.

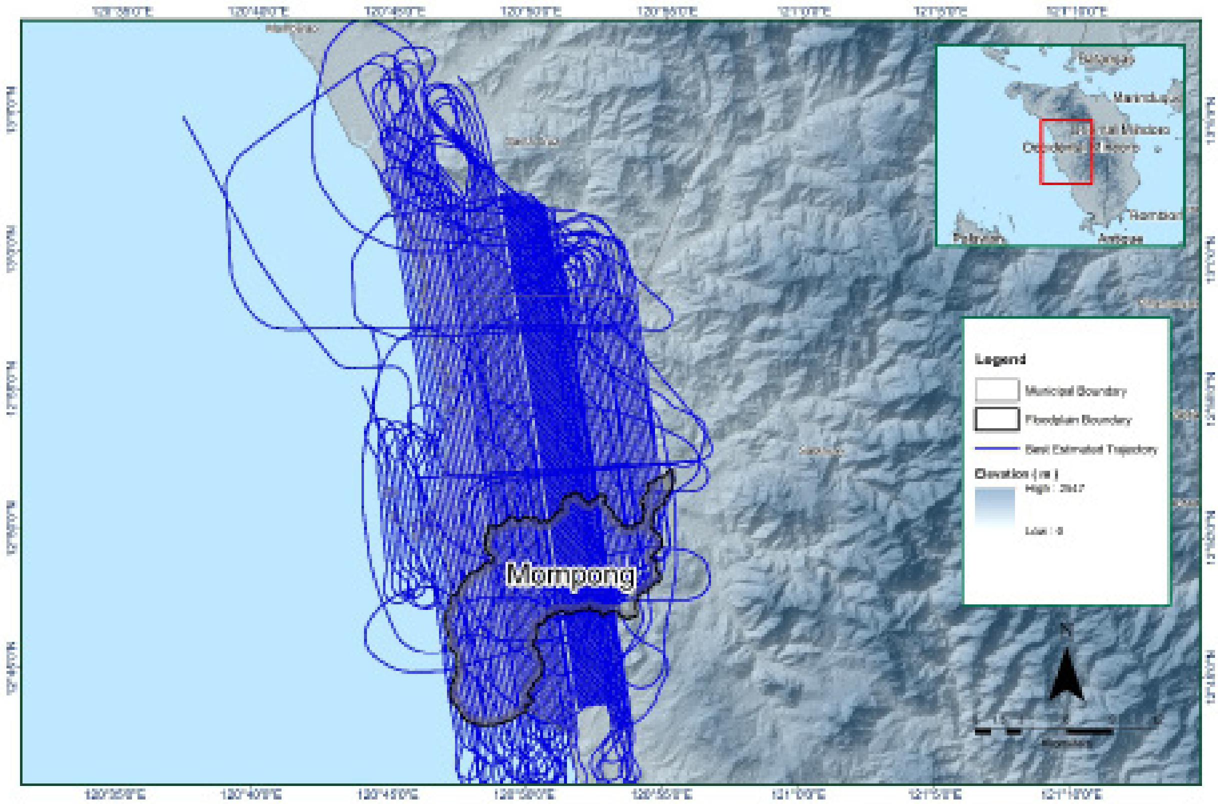

Figure 12. Best Estimated Trajectory of the LiDAR missions conducted over the Mompong Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 106 flight lines, with each flight line containing one channel for Aquarius system and two channels for the Pegasus system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Mompong floodplain are given in Table 14.

Table 14. Self-calibration Results values for Mompong flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev	<0.001degrees	0.000351
IMU Attitude Correction Roll and Pitch Correction stdev	<0.001degrees	0.000945
GPS Position Z-correction stdev	<0.01meters	0.0037

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Mompong Floodplain is shown in Figure 13. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

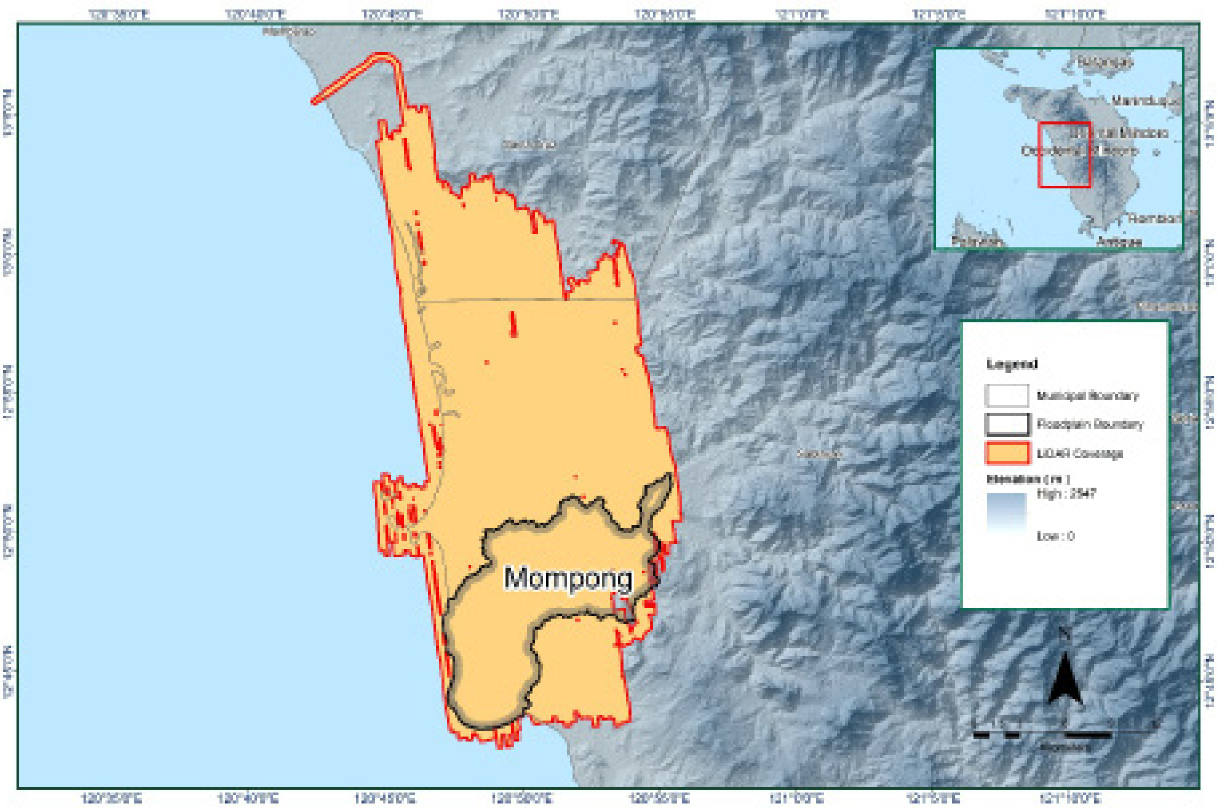

Figure 13. Boundary of the processed LiDAR data over Mompong Floodplain

The total area covered by the Mompong missions is 602.07 sq.km that is comprised of nine (9) flight acquisitions grouped and merged into seven (7) blocks as shown in Table 15.

Table 15. List of LiDAR blocks for Mompong Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
OccidentalMindoro_Blk29H	1136A	**109.65**
OccidentalMindoro_Blk29HI_supplement	1132A	49.01
OccidentalMindoro_Blk29I	1128A	102.32
OccidentalMindoro_Blk29JK	1110A	135.20
	1118A	
	1108A	
OccidentalMindoro_Blk29K_supplement	1116A	83.07
OccidentalMindoro_Reflight_Blk29HI	3068P	60.18
	3070P	
OccidentalMindoro_Reflight_Blk29JK	3070P	62.64
TOTAL		602.07 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 14. Since the Aquarius system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus system which employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

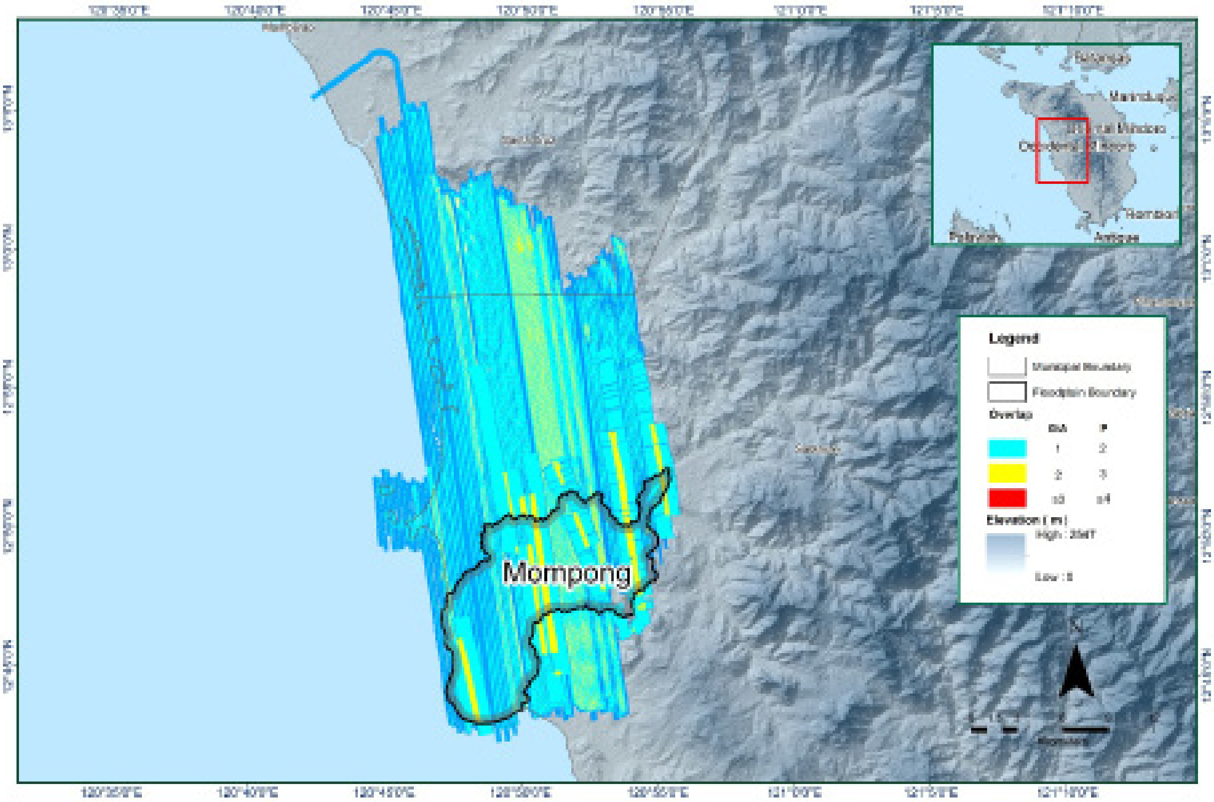

Figure 14. Image of data overlap for Mompong Floodplain.

The overlap statistics per block for the Mompong floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 37.19% and 82.92% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 15. It was determined that all LiDAR data for Mompong floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.53 points per square meter.

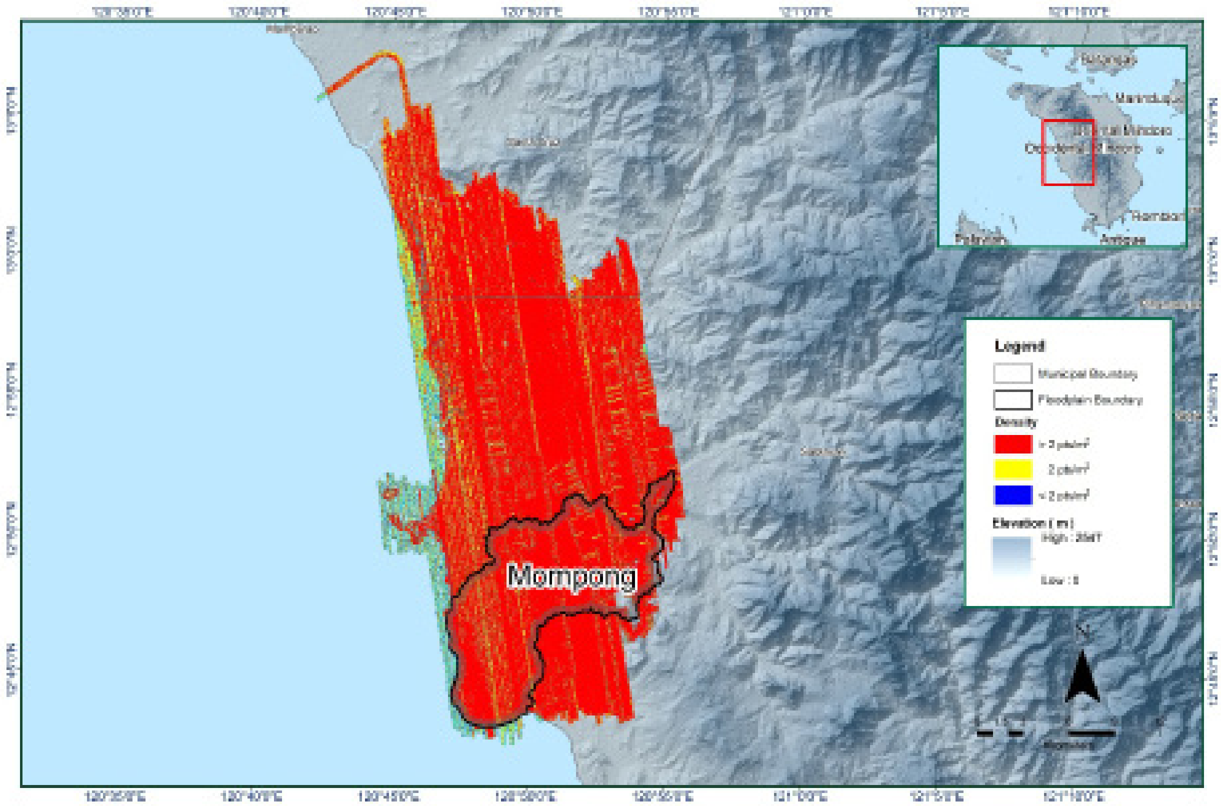

Figure 15. Pulse density map of merged LiDAR data for Mompong Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 16. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

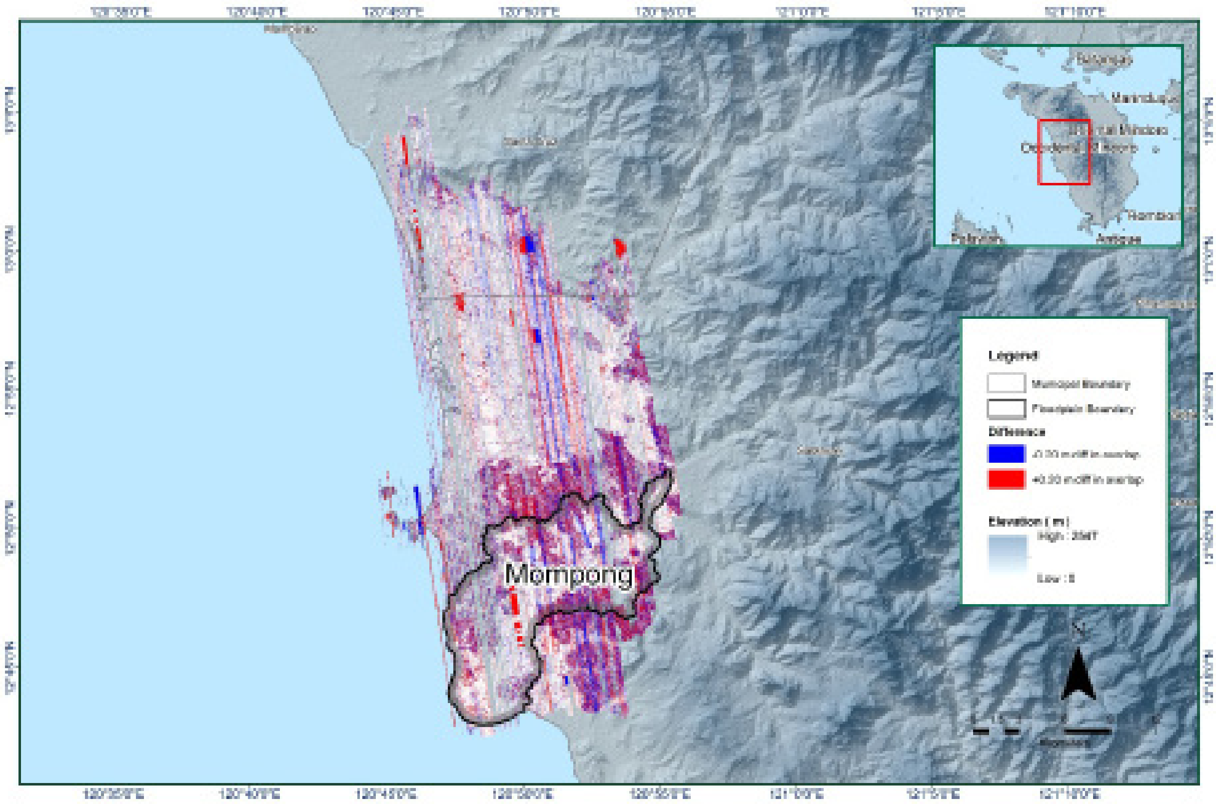

Figure 16. Elevation Difference Map between flight lines for Mompong Floodplain Survey.

A screen capture of the processed LAS data from a Mompong flight 1110A loaded in QT Modeler is shown in Figure 17. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

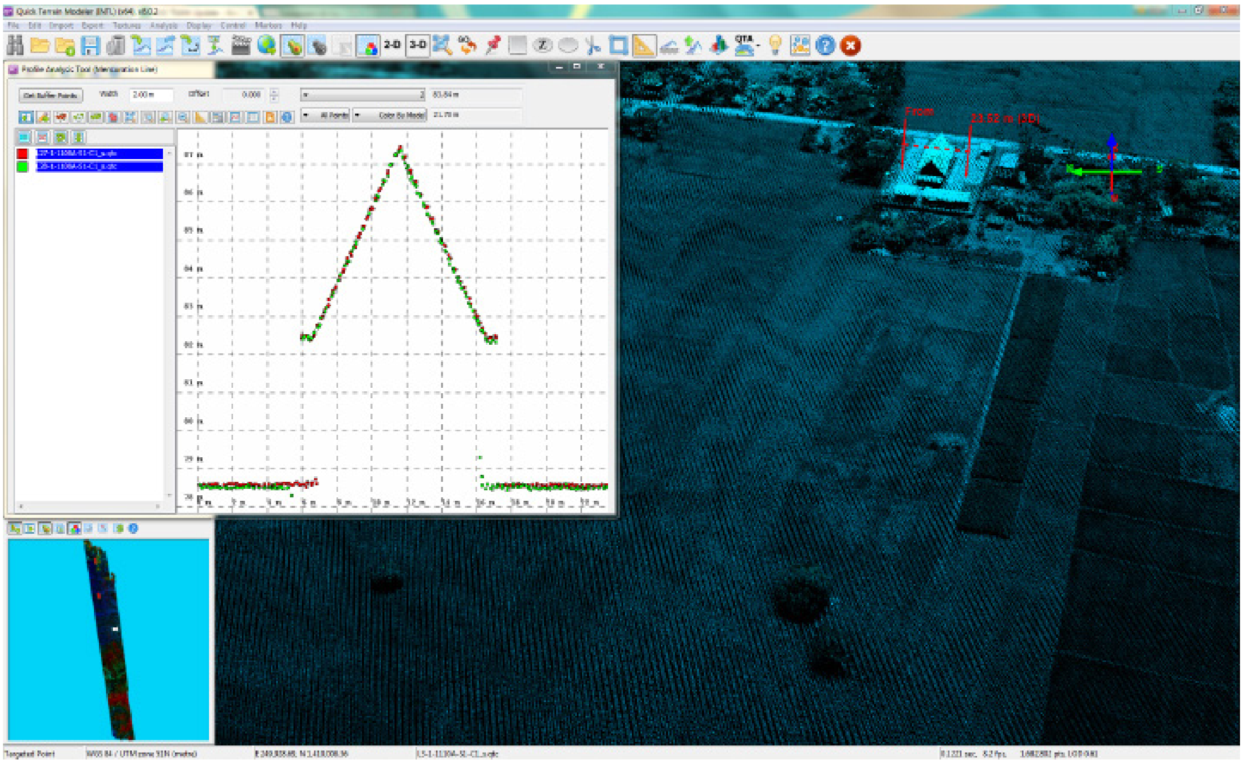

Figure 17. Quality checking for a Mompong flight 1110A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Mompong classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	499,161,921
Low Vegetation	595,014,653
Medium Vegetation	662,842,679
High Vegetation	509,321,477
Building	13,398,177

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Mompong floodplain is shown in Figure 18. A total of 1,026 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 16. The point cloud has a maximum and minimum height of 613.49 meters and 40.03 meters.

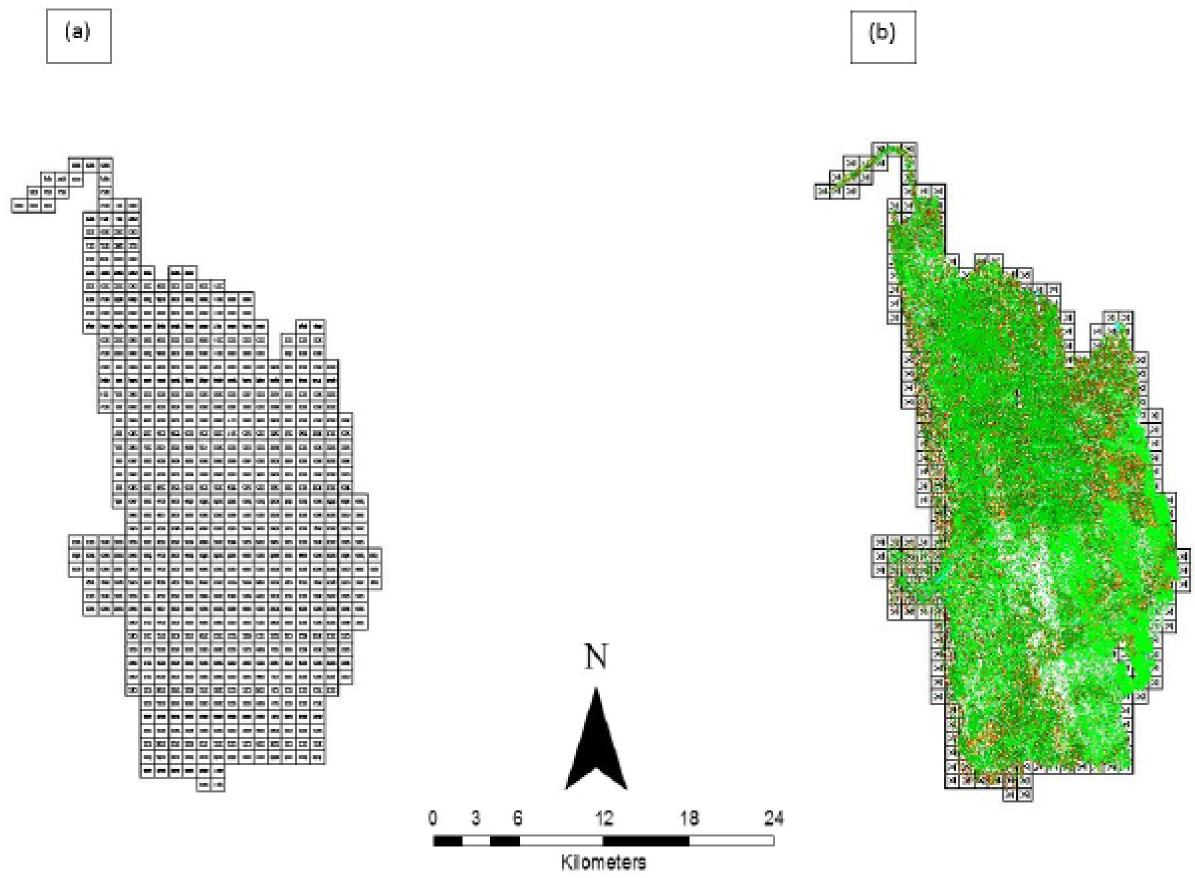

Figure 18. Tiles for Mompong Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 19. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below canopy are classified correctly, due to the density of the LiDAR data.

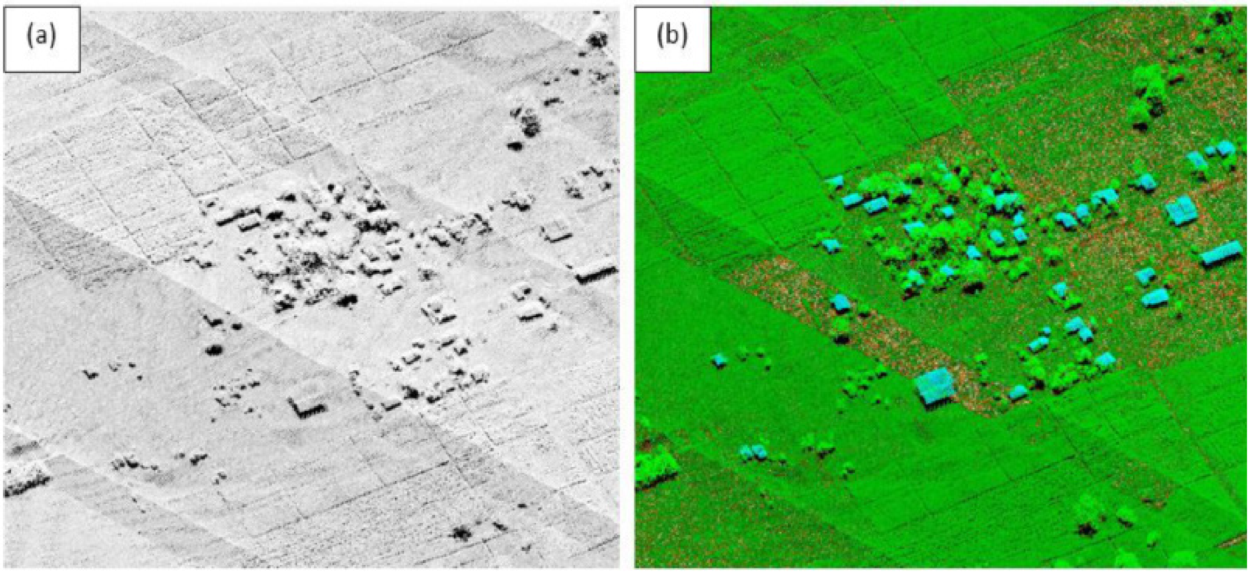

Figure 19. Point cloud before (a) and after (b) classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 20. It shows that DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

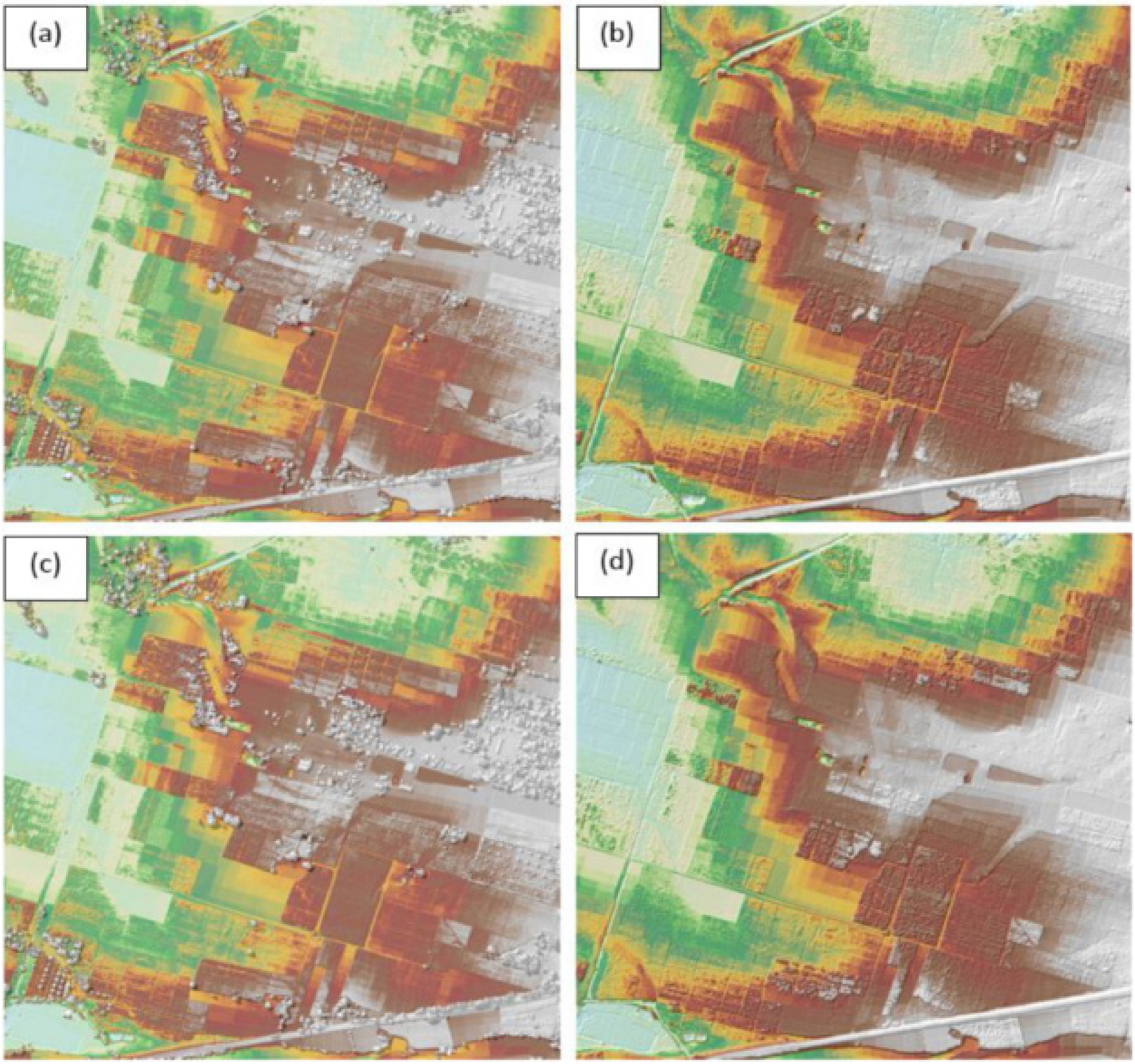

Figure 20. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Mompong Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,114 1km by 1km tiles area covered by Mompong floodplain is shown in Figure 19. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Mompong floodplain has a total of 692.81 sq.km orthophotogaph coverage comprised of 1,635 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

Figure 21. Mompong Floodplain with available orthophotographs.

Figure 22. Sample orthophotograph tiles for Mompong Floodplain.

3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for Mompong floodplain. These blocks are composed of Occidental_Mindoro and Occidental_Mindoro_Reflight blocks with a total area of 602.07 square kilometers. Table 17 shows the name and corresponding area of each block in square kilometers.

Table 17. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
OccidentalMindoro_Blk29H	109.65
OccidentalMindoro_Blk29HI_supplement	49.01
OccidentalMindoro_Blk29I	102.32
OccidentalMindoro_Blk29JK	135.20
OccidentalMindoro_Blk29K_supplement	83.07
OccidentalMindoro_Reflight_Blk29HI	60.18
OccidentalMindoro_Reflight_Blk29JK	62.64
TOTAL	602.07

Portions of DTM before and after manual editing are shown in Figure 23. The bridge (Figure 23a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 23b) in order to hydrologically correct the river. The paddy field (Figure 23c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 23d) to allow the correct flow of water.

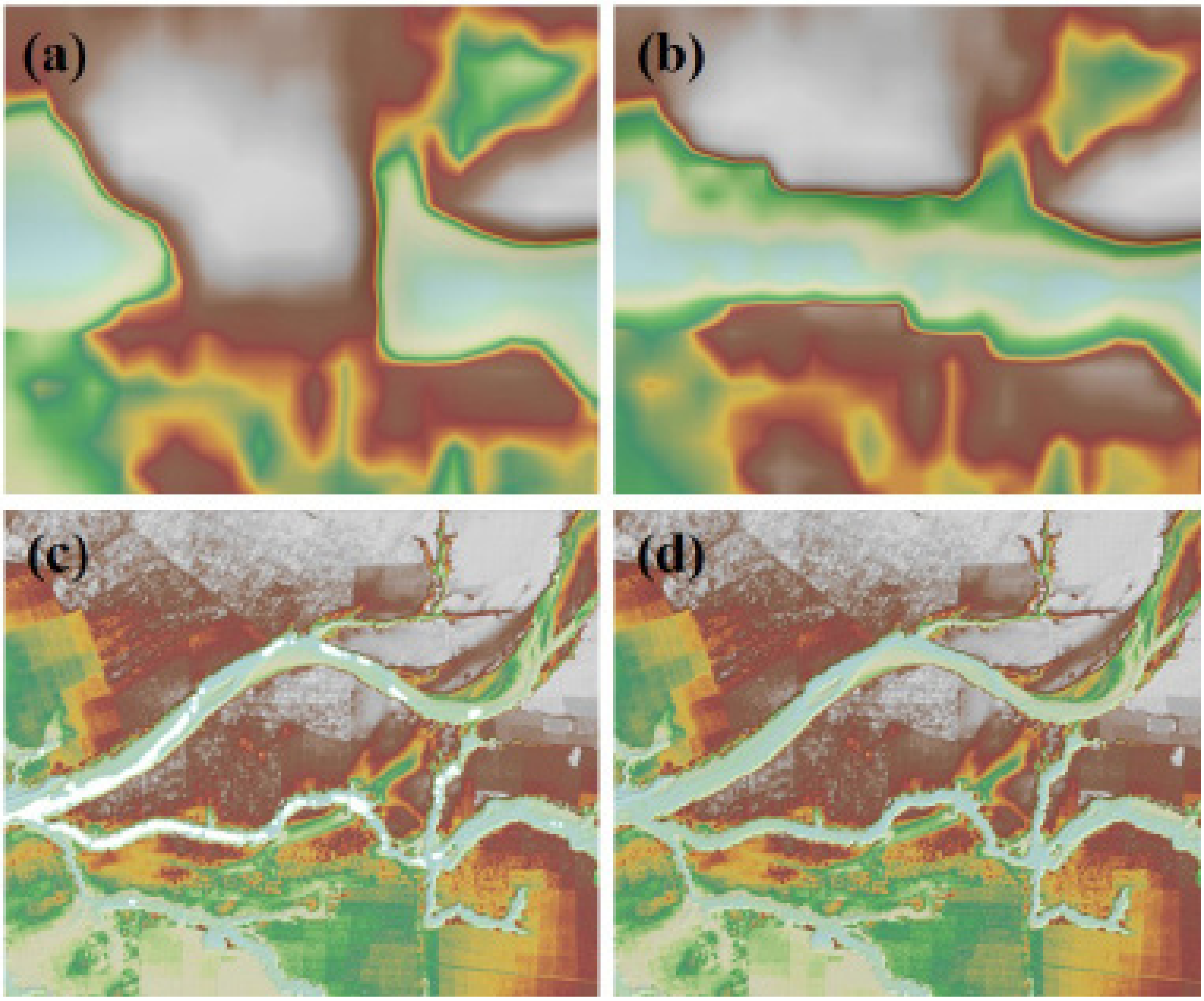

Figure 23. Portions in the DTM of Mompong Floodplain – a land bridge before (a) and after (b) interpolation process and part of the river with data gap before (c) and after (d) filling data gap.

3.9 Mosaicking of Blocks

OccidentalMindoro_Blk29M was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 18 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Mompong floodplain is shown in Figure 24. It can be seen that the entire

Table 18. Shift values of each LiDAR block of Mompong Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
OccidentalMindoro_Blk29H	0.00	0.00	0.00
OccidentalMindoro_Blk29HI_supplement	0.00	0.00	-0.88
OccidentalMindoro_Blk29I	0.00	0.00	-0.44
OccidentalMindoro_Blk29JK	0.00	0.00	-1.14
OccidentalMindoro_Blk29K_supplement	0.00	0.00	-0.96
OccidentalMindoro_Reflight_Blk29HI (Left)	0.00	0.00	-1.64
OccidentalMindoro_Reflight_Blk29HI (Right)	0.00	1.01	-1.64
OccidentalMindoro_Reflight_Blk29JK (Left)	0.00	0.00	-2.13
OccidentalMindoro_Reflight_Blk29JK (Upper_Middle)	0.00	0.00	-2.51
OccidentalMindoro_Reflight_Blk29JK (Lower_Middle)	0.00	0.00	-3.25
OccidentalMindoro_Reflight_Blk29JK (Right)	0.00	0.00	-2.36

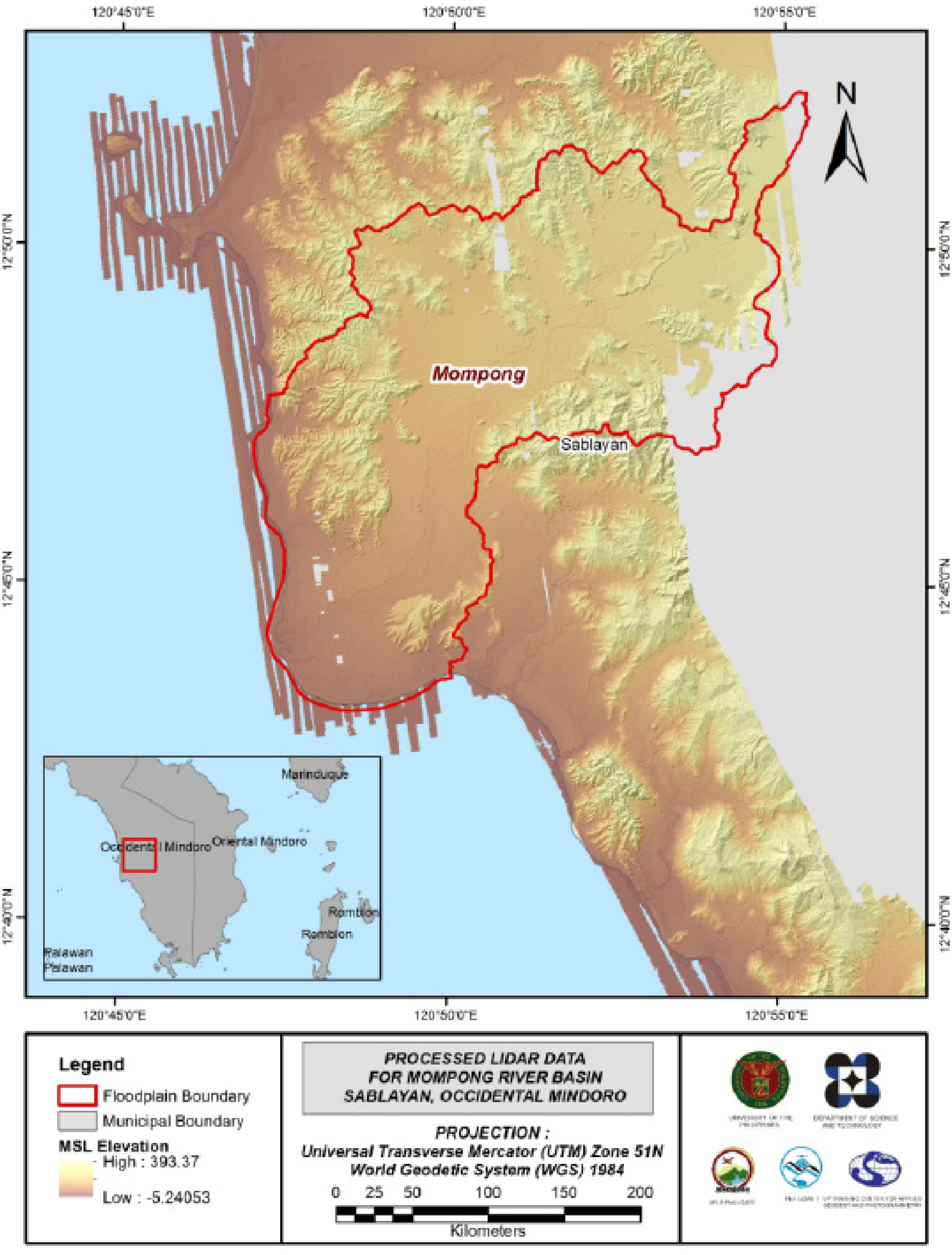

Figure 24 . Map of Processed LiDAR Data for Mompong Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model (DEM)

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Mompong to collect points with which the LiDAR dataset is validated is shown in Figure 25. A total of 28,494 survey points were used for calibration and validation of Mompong LiDAR data. Random selection of 80% of the survey points, resulting to 22,795 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 26. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.23 meters with a standard deviation of 0.20 meters. Calibration of Mompong LiDAR data was done by adding the height difference value, 0.23 meters, to Mompong mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

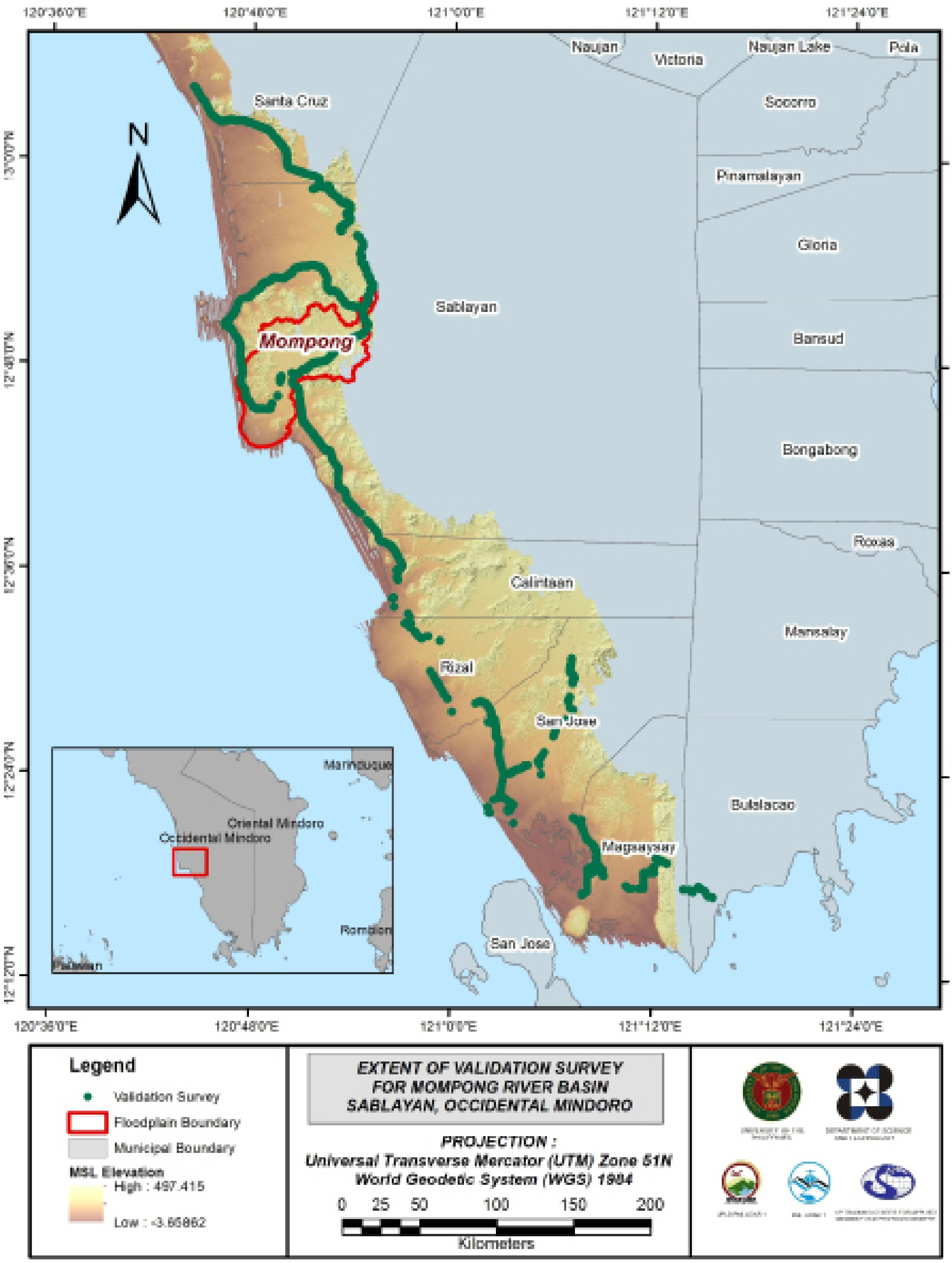

Figure 25. Map of Mompong Floodplain with validation survey points in green.

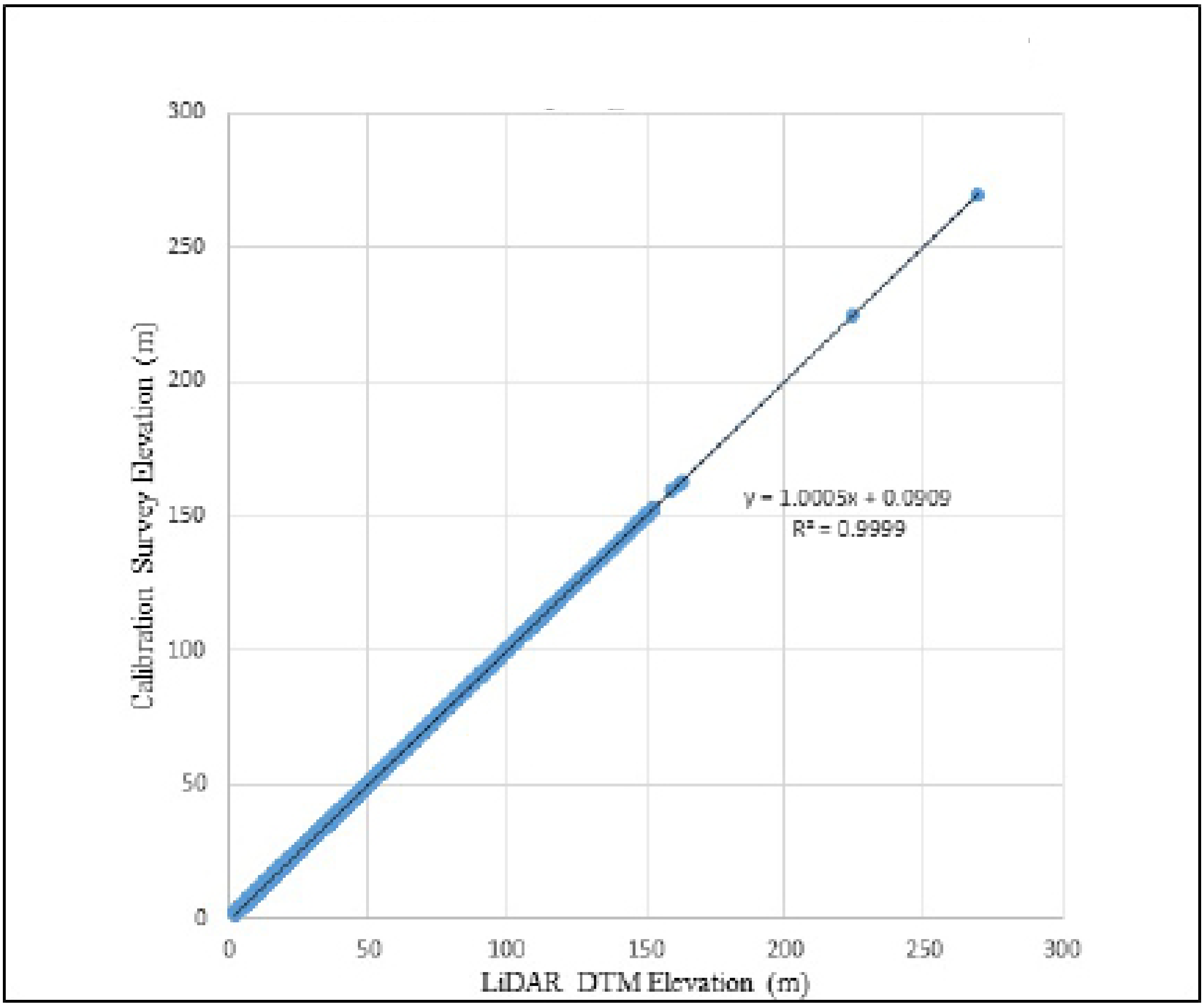

Figure 26. Correlation plot between calibration survey points and LiDAR data.

Table 19. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.23
Standard Deviation	0.20
Average	0.10
Minimum	-0.33
Maximum	0.53

The remaining 20% of the total survey points were intersected to the flood plain, resulting to 369 points. These were used for the validation of calibrated Mompong DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 27. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.19 meters, as shown in Table 20.

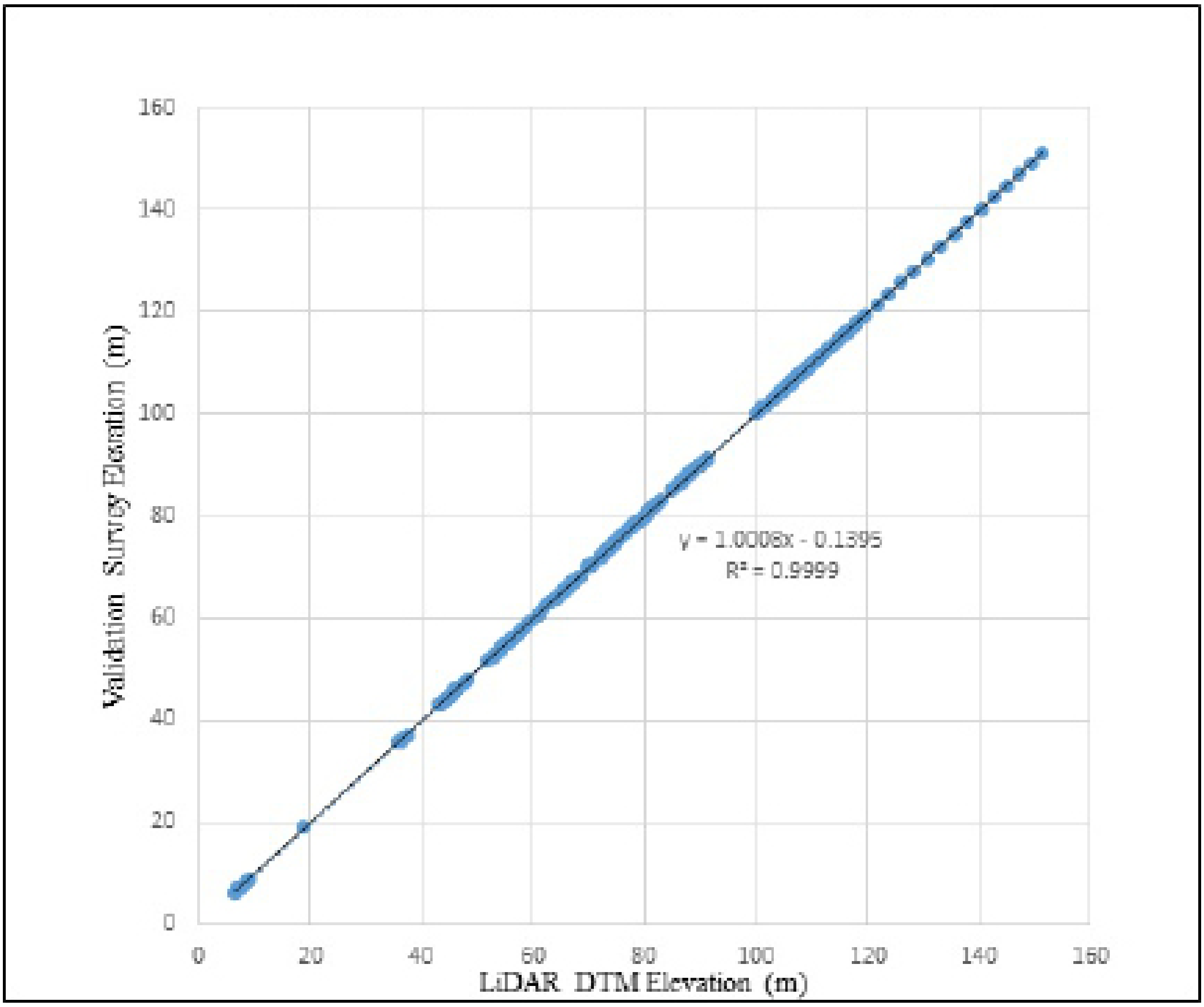

Figure 27. Correlation plot between validation survey points and LiDAR data.

Table 20. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.19
Average	-0.08
Minimum	-0.32
Maximum	0.39

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Mompong with 38,268 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barrier method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 1.13 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Mompong integrated with the processed LiDAR DEM is shown in Figure 28.

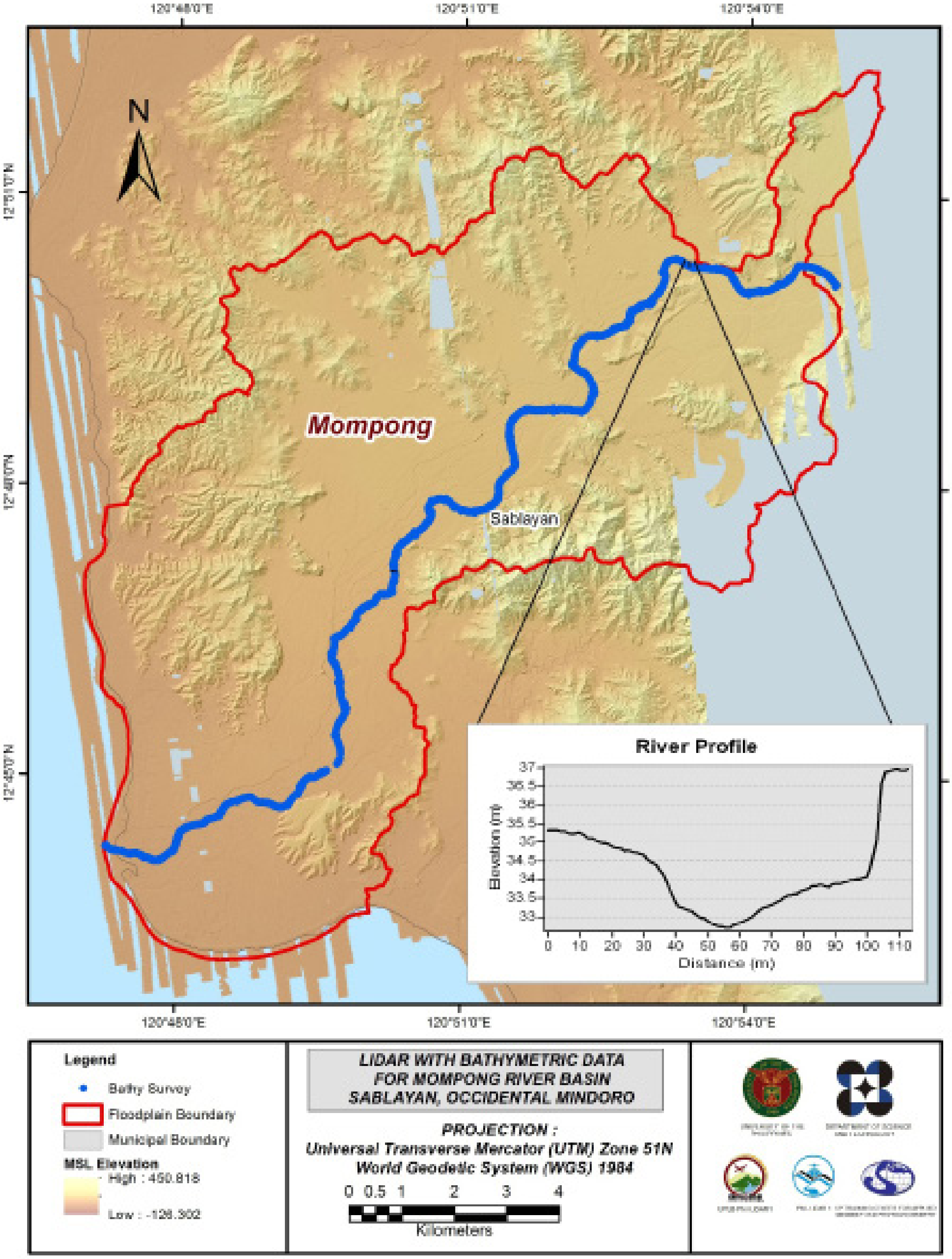

Figure 28. Map of Mompong Floodplain with bathymetric survey points shown in blue.

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted survey in Mompong River on November 3-24, 2015 with the following scope of work: cross-section, bridge as-built and water level marking in MSL of Mompong Bridge in Brgy. Sta. Lucia, Municipality of Sablayan, Occidental Mindoro; validation points-acquisition in the province of Occidental Mindoro which covers Mompong River Basin; and bathymetry survey from the mouth of the river in Brgy. Sta. Lucia, passing through Brgy. Poblacion to the area of Brgy. Batong-Buhay in the Municipality of Sablayan by feet using Trimble® GNSS PPK survey technique. See Figure 29.

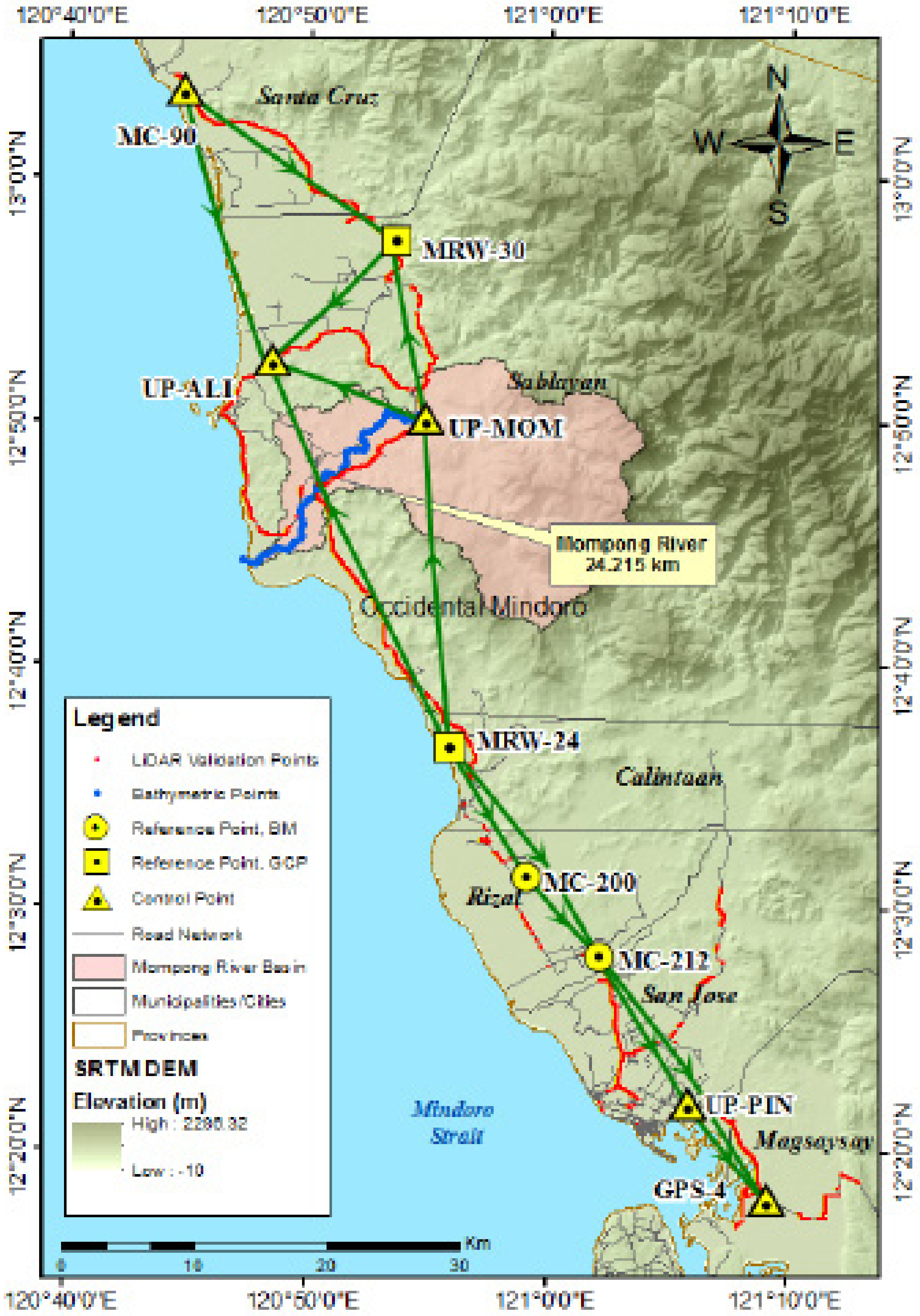


Figure 29. Extent of the bathymetric survey (in blue line) in Mompong River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Mompong River Basin is composed of five (5) loops established on November 5, 15 and 17, 2015 occupying the following reference points: MRW-24, a second order GCP in Brgy. Iriron, Municipality of Calintaan; MRW-30, a second order GCP in Bry. Pinagturilan, Municipality of Sta. Cruz; MC-200, a first order BM in Brgy. Magsikap, Municipality of Rizal; and MC-212, also a first order BM in Brgy. Sto. Niño in Rizal.

Three (3) control points were established along the approach of bridges, namely: UP-PIN at Pinamanaan Bridge in Brgy. Mapaya, Municipality of San Jose; UP-ALI at Alipid Bridge in Brgy. Sto. Niño, Municipality of Sablayan; and UP-MOM at Mompong Bridge in Brgy. Lumang Bato, also in Sablayan. The control point established by DPWH, namely GPS-4, in Brgy. Poblacion, Municipality of Magsaysay; and MC-90, established by NAMRIA, in Brgy. Barahan, Municipality of Sta. Cruz were also occupied to use as a marker for the network.

The summary of reference and control points and its location is summarized in Table 21 while the GNSS network established is illustrated in Figure 30.

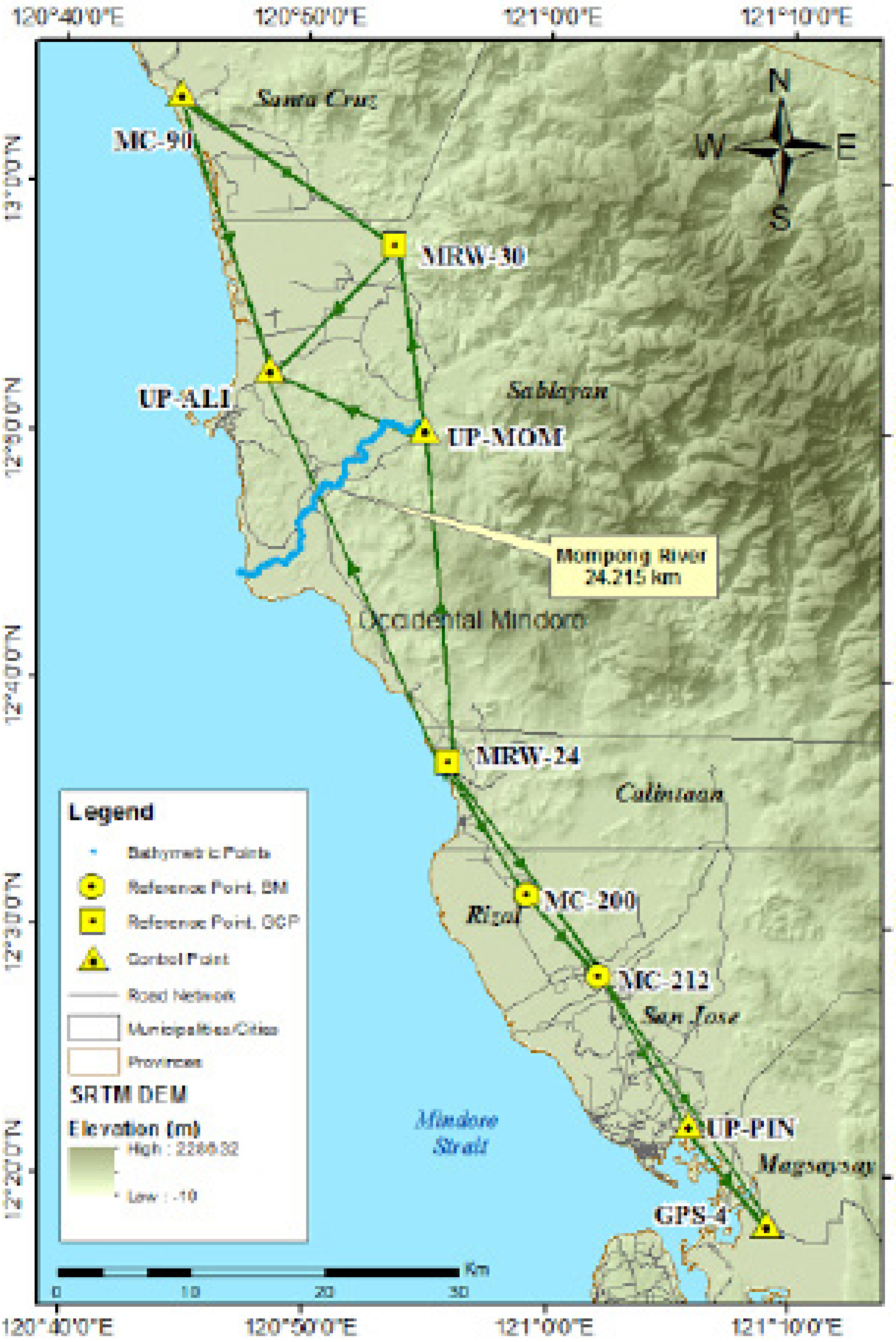


Figure 30. The GNSS Network established in the Panplona River Survey.

Table 21. List of Reference and Control Points occupied for Mompong River Survey
(Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
MC-200	1st order, BM	-	-	83.225	-	2007
MC-212	1st order, BM	-	-	74.473	-	2007
MRW-24	2nd order, GCP	12°36'38.03550"	120°55'54.08297"	53.435	4.746	2007
MRW-30	2nd order, GCP	12°57'27.19115"	120°53'33.54441"	88.823	41.752	2007
MC-90	UP Established	-	-	-	-	2007
UP-ALI	UP Established	-	-	-	-	2015
UP-MOM	UP Established	-	-	-	-	2015
UP-PIN	UP Established	-	-	-	-	2015
GPS-4	DPWH Established	-	-	-	-	2013

The GNSS set up in reference points and established control points in Occidental Mindoro survey are shown in Figure 31 to Figure 39.

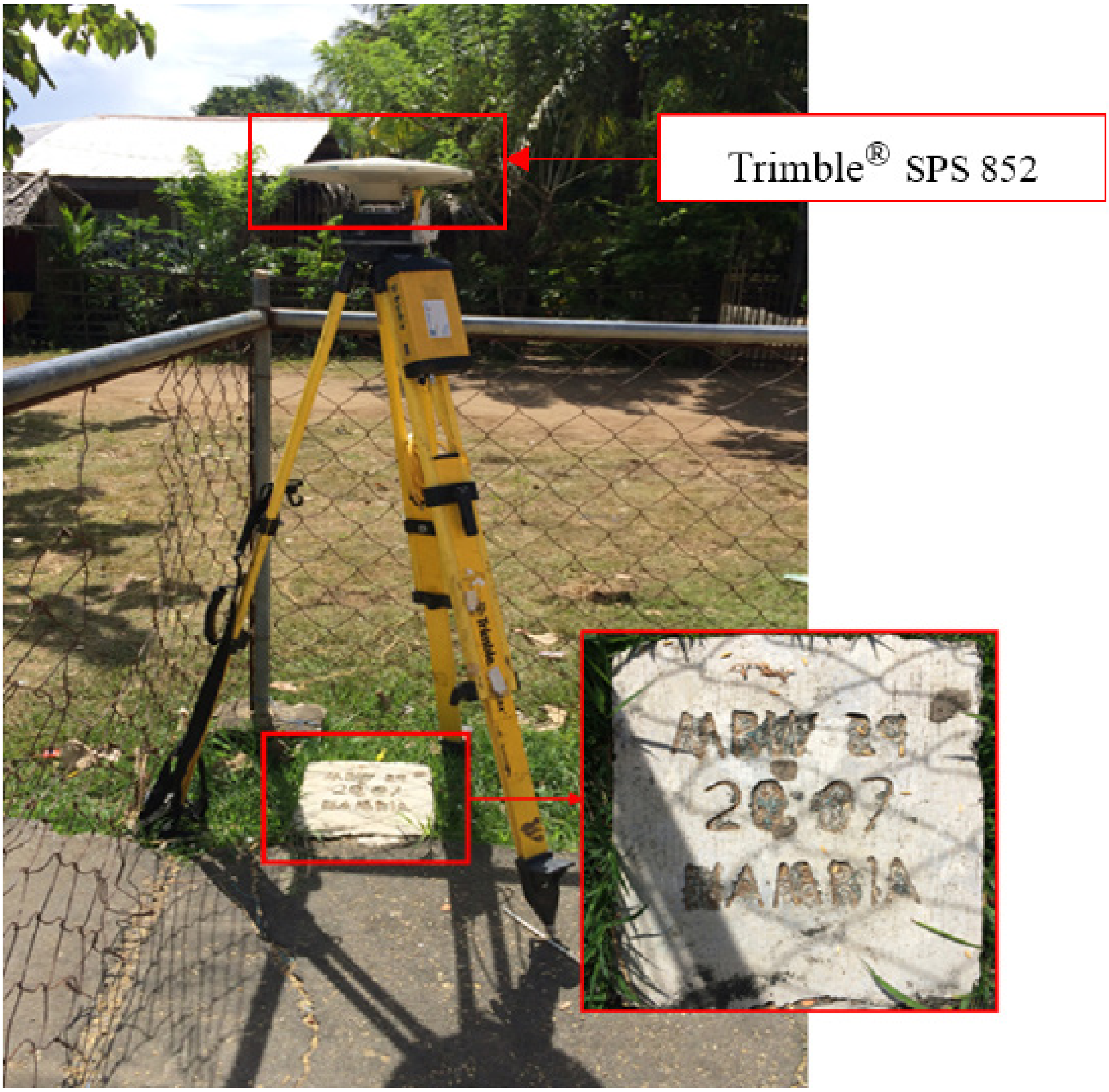


Figure 31. GNSS receiver set-up, Trimble® SPS 852, at MRW-24 in front of Iriron Elementary School in Brgy. Iriron, Municipality of Calintaan, Occidental Mindoro

Figure 32. GNSS receiver setup, Trimble® SPS 882, at MRW-30 Amnay Bridge approach in Sitio Kabangkalan, Brgy. Pinagturilan, Municipality of Santa Cruz, Occidental Mindoro

Figure 33. GNSS receiver set-up, Trimble® SPS 882, at MC-200, Lumintao Bridge approach in Brgy. Magsikap, Municipality of Rizal, Occidental Mindoro

Figure 34. GNSS receiver set-up, Trimble® SPS 882, at MC-212, Busuanga Bridge approach in Bgry. Sto Niño, Municipality of Rizal, Occidental Mindoro

Figure 35. GNSS receiver, Trimble® SPS 852, at MC-90, used as marker, located at the Pola Bridge approach in Brgy. Barahan, Municipality of Santa Cruz, Occidental Mindoro

Figure 36. GNSS receiver, Trimble® SPS 882, at GPS-4 on right side of the road abutment after Caguray Bridge going to Bulalacao in Brgy. Poblacion, Municipality of Magsaysay, Occidental Mindoro

Figure 37. GNSS base receiver set-up, Trimble® SPS 882, at UP-PIN Pinamanaan Bridge approach in Brgy. Mapaya, Municipality of San Jose, Occidental Mindoro

Figure 38. GNSS receiver set-up, Trimble® SPS 882, at UP-MOM, Mompong Bridge approached in Brgy. Lumang Bato, Municipality of Sablayan, Occidental Mindoro

Figure 39. GNSS receiver set up, Trimble® SPS 882, at UP-ALI, Alipid Bridge approach in Brgy. Sto. Niño, Municipality of Sablayan, Occidental Mindoro

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Mompong River Basin is summarized in Table 22 generated by TBC software.

Table 22. Baseline Processing Summary Report for Mompong River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MC-212 --- GPS-4	11-05-2015	Fixed	0.003	0.015	145°21'06"	22241.566	-11.807
MRW-30 --- UP-MOM	11-17-2015	Fixed	0.011	0.017	170°24'13"	13704.513	55.240
MRW-30 --- UP-MOM	11-17-2015	Fixed	0.003	0.023	170°24'12"	13704.541	55.249
MRW-30 --- MC-90	11-17-2015	Fixed	0.010	0.018	305°24'12"	19473.086	-35.515
UP-PIN --- MC-212	11-05-2015	Fixed	0.003	0.007	328°11'40"	12856.399	14.631
UP-PIN --- GPS-4	11-05-2015	Fixed	0.003	0.006	141°30'11"	9422.221	2.872
MC-200 --- UP-PIN	11-05-2015	Fixed	0.003	0.022	144°37'57"	20841.368	-23.356
MC-200 --- UP-MOM	11-05-2015	Fixed	0.009	0.014	346°57'26"	35544.301	60.755
MC-200 --- UP-MOM	11-05-2015	Fixed	0.004	0.014	346°57'27"	35544.309	60.692
MC-200 --- MC-212	11-05-2015	Fixed	0.003	0.006	138°58'31"	8048.668	-8.741

UP-ALI --- UP-MOM	11-15-2015	Fixed	0.008	0.013	110°57'37"	12258.370	88.024
UP-MOM --- UP-ALI	11-15-2015	Fixed	0.004	0.036	110°57'37"	12258.373	88.139
UP-ALI --- MRW-30	11-17-2015	Fixed	0.009	0.012	45°05'52"	12929.488	32.865
MRW-30 --- UP-ALI	11-17-2015	Fixed	0.004	0.017	45°05'52"	12929.476	32.850
MRW-30 --- UP-ALI	11-17-2015	Fixed	0.004	0.007	45°05'51"	12929.529	32.747
MC-90 --- UP-ALI	11-17-2015	Fixed	0.004	0.008	341°46'30"	21480.592	-2.784
MRW-24 --- UP-PIN	11-05-2015	Fixed	0.003	0.006	145°50'52"	32317.096	6.413
MRW-24 --- MC-200	11-05-2015	Fixed	0.005	0.007	148°04'31"	11489.166	29.777

As shown Table 22 a total of eighteen (18) baselines were processed with reference points MRW-24 and MRW-30 held fixed for coordinate and elevation values, including MC-200 and MC-212 also fixed for elevation values. All of them passed the required accuracy.

4.4 Network Adjustment

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

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

where:

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

for each control point. See the Network Adjustment Report shown in Table 23 to Table 25 for complete details.

The nine (9) control points, MRW-24, MRW-30, MC-200, MC-212, MC-90, GPS-4, UP-PIN, UP-MOM, and UP-ALI were occupied and observed simultaneously to form a GNSS loop. All 14 baselines acquired fixed solutions and passed the required ±20cm and ±10cm for horizontal and vertical precisions, respectively as shown in Table 23.

Table 23. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
MC-200	Grid				Fixed
MC-212	Grid				Fixed
MRW-24	Global	Fixed	Fixed		
MRW-30	Global	Fixed	Fixed		
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 25. The fixed control points MRW-24 and MRW-30; and MC-200 and MC-212 have no values for grid and elevation errors, respectively.

Table 24. Adjusted grid coordinates for the control points used in the Mompong River Floodplain survey.

Point ID	Easting	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
GPS-4	299069.894	0.039	1360649.962	0.032	12.062	0.068	
MC-200	281320.527	0.022	1385155.121	0.016	34.024	?	e
MC-212	286558.124	0.028	1379041.958	0.022	24.884	?	e
MC-90	255607.924	0.039	1444800.407	0.023	8.195	0.095	
MRW-24	275320.607	?	1394955.913	?	4.746	0.045	LL
MRW-30	271390.777	?	1433384.691	?	41.752	0.091	LL
UP-ALI	262152.459	0.020	1424334.041	0.015	9.503	0.071	
UP-MOM	273564.872	0.015	1419850.456	0.012	96.192	0.055	
UP-PIN	293256.669	0.031	1368066.413	0.024	9.659	0.045	

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in Table C-5.Using the equation for horizontal and   for the vertical; below is the computation for accuracy that passed the required precision:

a.GPS-4

Horizontal accuracy = $\sqrt{((3.9)^2 + (3.2)^2}$
= $\sqrt{(15.21 + 10.24)}$
= 5.0 cm < 20 cm
Vertical accuracy = 6.8 cm < 10 cm

b.MC-200

Horizontal accuracy = $\sqrt{((2.2)^2 + (1.6)^2}$
= $\sqrt{(4.84 + 2.56)}$
= 7.4 cm < 20 cm
Vertical accuracy = Fixed

c.MC-212

Horizontal accuracy = $\sqrt{((2.8)^2 + (2.2)^2}$
= $\sqrt{(7.84+ 4.84)}$
= 3.6 cm < 20 cm
Vertical accuracy = Fixed

d.MC-90

Horizontal accuracy = $\sqrt{((3.9)^2 + (2.3)^2}$
= $\sqrt{(15.21 + 5.29)}$
= 4.5 cm < 20 cm
Vertical accuracy = 9.5 cm < 10 cm

e.MRW-24

Horizontal accuracy = Fixed
Vertical accuracy = 4.5 cm < 10 cm

f.MRW-30

Horizontal accuracy = Fixed
Vertical accuracy = 9.1 cm < 10 cm

g.UP-ALI

Horizontal accuracy = $\sqrt{((2.0)^2 + (1.5)^2}$
= $\sqrt{(4.0 + 2.25)}$
= 2.5 cm < 20 cm
Vertical accuracy = 7.1 cm < 10 cm

h.UP-MOM

Horizontal accuracy = $\sqrt{((1.5)^2 + (1.2)^2}$
= $\sqrt{(2.25 + 1.44)}$
= 1.9 cm < 20 cm
Vertical accuracy = 5.5 cm < 10 cm

i.UP-PIN

Horizontal accuracy = $\sqrt{((3.1)^2 + (2.4)^2}$
= $\sqrt{(9.61 + 5.76)}$
= 3.9 cm < 20 cm
Vertical accuracy = 4.5 cm < 10 cm

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

Table 25. Adjusted geodetic coordinates for control points used in the Mompong River Floodplain validation.

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
GPS-4	N12°18'07.55698"	E121°09'08.74194"	62.705	0.068	
MC-200	N12°31'20.68884"	E120°59'15.31613"	83.225	?	e
MC-212	N12°28'03.07503"	E121°02'10.26310"	74.473	?	e
MC-90	N13°03'34.14427"	E120°44'46.70844"	53.232	0.095	
MRW-24	N12°36'38.03549"	E120°55'54.08296"	53.435	0.045	LL
MRW-30	N12°57'27.19115"	E120°53'33.54442"	88.823	0.091	LL
UP-ALI	N12°52'30.24359"	E120°48'29.69149"	55.998	0.071	
UP-MOM	N12°50'07.47193"	E120°54'49.30855"	144.013	0.055	
UP-PIN	N12°22'07.54999"	E121°05'54.64323"	59.843	0.045	

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

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

Table 26. Reference and control points 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)
MC-200	1st order, BM	12°31'20.68883"	120°59'15.31614"	83.225	1385155.121	281320.527	34.024
MC-212	1st order, BM	12°28'03.07504"	121°02'10.26310"	74.473	1379041.958	286558.124	24.884
MRW-24	2nd order, GCP	12°36'38.03550"	120°55'54.08297"	53.435	1394955.913	275320.607	4.746
MRW-30	2nd order, GCP	12°57'27.19115"	120°53'33.54441"	88.823	1433384.691	271390.777	41.752
MC-90	UP Established	13°03'34.14426"	120°44'46.70845"	53.232	1444800.407	255607.924	8.195
UP-ALI	UP Established	12°52'30.24358"	120°48'29.69148"	55.998	1424334.041	262152.459	9.503
UP-MOM	UP Established	12°50'07.47192"	120°54'49.30854"	144.013	1419850.456	273564.872	96.192
UP-PIN	UP Established	12°22'07.55000"	121°05'54.64323"	59.843	1368066.413	293256.669	9.659
GPS-4	DPWH Established	12°18'07.55700"	121°09'08.74194"	62.706	1360649.962	299069.894	12.062

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

Cross-section and As-built survey were conducted on November 20, 2015 at the downstream side of Mompong Bridge located in Brgy. Sta. Lucia, Municipality of Sablayan using Trimble® SPS 882 GNSS PPK survey technique as shown in Figure 40.

Figure 40. Bridge cross-section with water level elevation acquisition at Mompong Bridge, Brgy. Sta. Lucia, Municipality of Sablayan

A total of one hundred and six (106) points with corresponding length of 196.27 meters were gathered from the survey of the bridge using the control point UP-MOM as base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 41 to Figure 43, respectively.

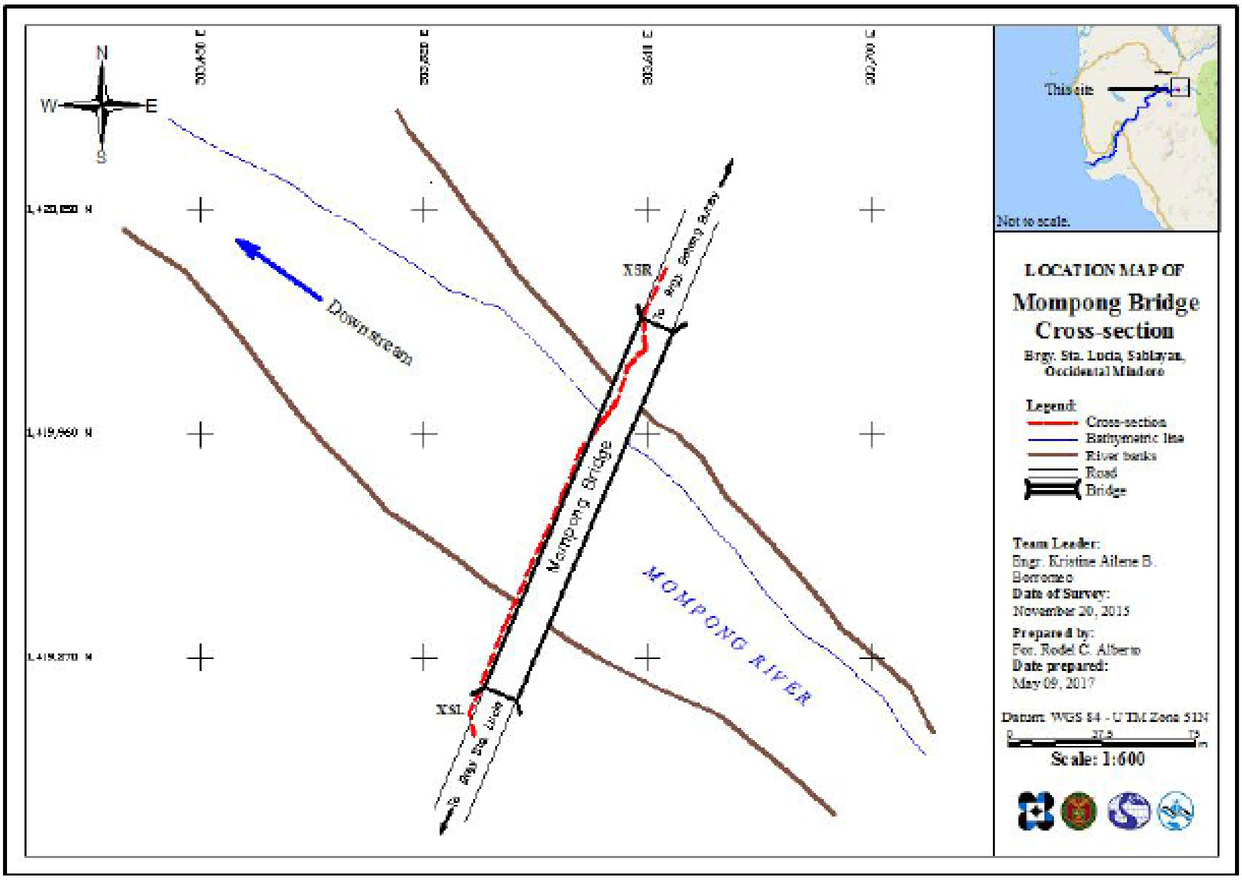


Figure 41. Location Map of Mompong Bridge River Cross-Section survey

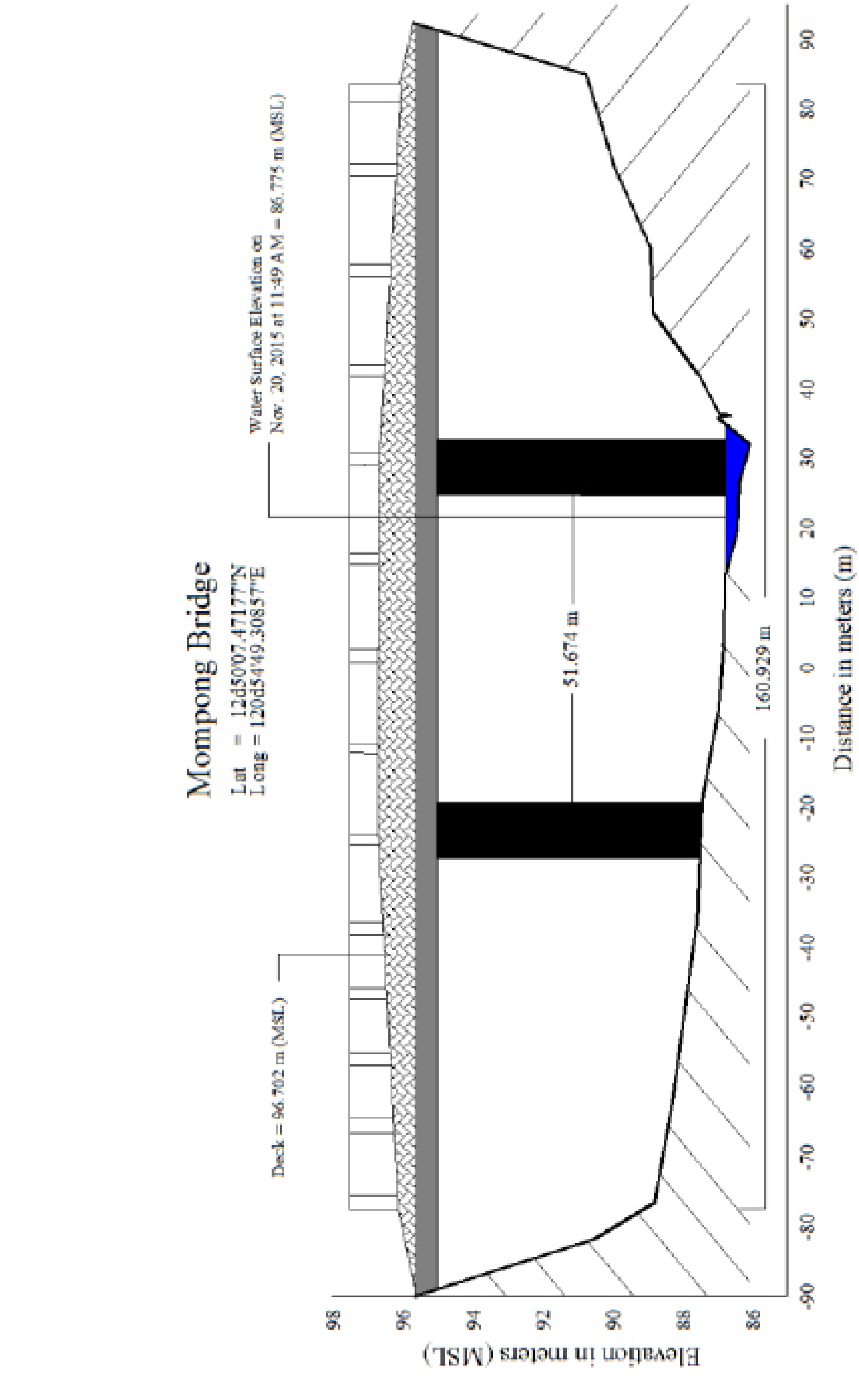
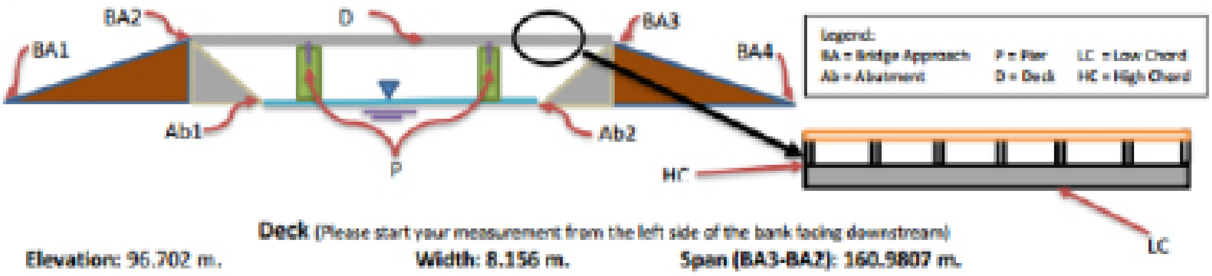


Figure 42. Mompong Bridge cross-section diagram

Bridge Data Form

Bridge Name: Mompong Bridge	**Date: November 20, 2015**
River Name: Mompong River	**Time: 12:05 PM**
Location: Brgy. Sta. Lucia, Municipality of Sablayan, Occidental Mindoro	
Survey Team: Kristine Ailene Borromeo, Maridel Miras, Precious Annie Lopez, Dona Rina Patricia Tajora, Kim Patrick Tort, Rodel Alberto, Caren Joy Ordoña	
Flow condition: low ✓ normal high	**Weather Condition:** ✓ fair rainy
Latitude: 12°50'07.47177" N	**Longitude: 120°54'49.30857" E**



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

Elevation: 96.702 m. **Width: 8.156 m.** **Span (BA3-BA2): 160.9807 m.**

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

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	95.617	BA3	173.372	96.028
BA2	12.443	96.105	BA4	182.336	95.705

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

	Station (Distance from BA1)	Elevation
Ab1	20.839	90.46
Ab2	162.790	88.82

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

Shape: Cylindrical Number of Piers: 2 Height of column footing: N/A

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	67.012	96.702	approx. 0.9 m.
Pier 2	118.686	96.66	approx. 0.9 m.

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

Figure 43. Bridge as-built form of Mompong Bridge

The water surface elevation of Mompong River was also acquired using Trimble® 882 GNSS PPK survey technique on November 20, 2015 at 11:49 a.m. The resulting water surface elevation at Mompong Bridge is 86.775 m above MSL which was then translated into a marking on the bridge's pier using digital level. The marking will serve as a reference for flow data gathering and depth gauge deployment of UP Los Baños PHIL-LiDAR 1. The water level marking for Mompong Bridge, shown in Figure 44, has an EGMOrtho value of 88.830 m which will be updated by UPLB to its respective MSL value of 87.786 m.

Figure 44. Water-level marking at Mompong Bridge, Brgy. Sta. Lucia, Municipality of Sablayan

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on November 6, 7, 8 14, 17, 18, and 21, 2015 using a survey-grade GNSS Rover, Trimble® SPS 882, receiver mounted on a pole which was attached either to the front or side of vehicle as shown in Figure 45. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.460 and 1.91 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with MC-212, GPS-4, MC-90 and MRW-30 occupied as the GNSS base stations all throughout the conduct of the survey.

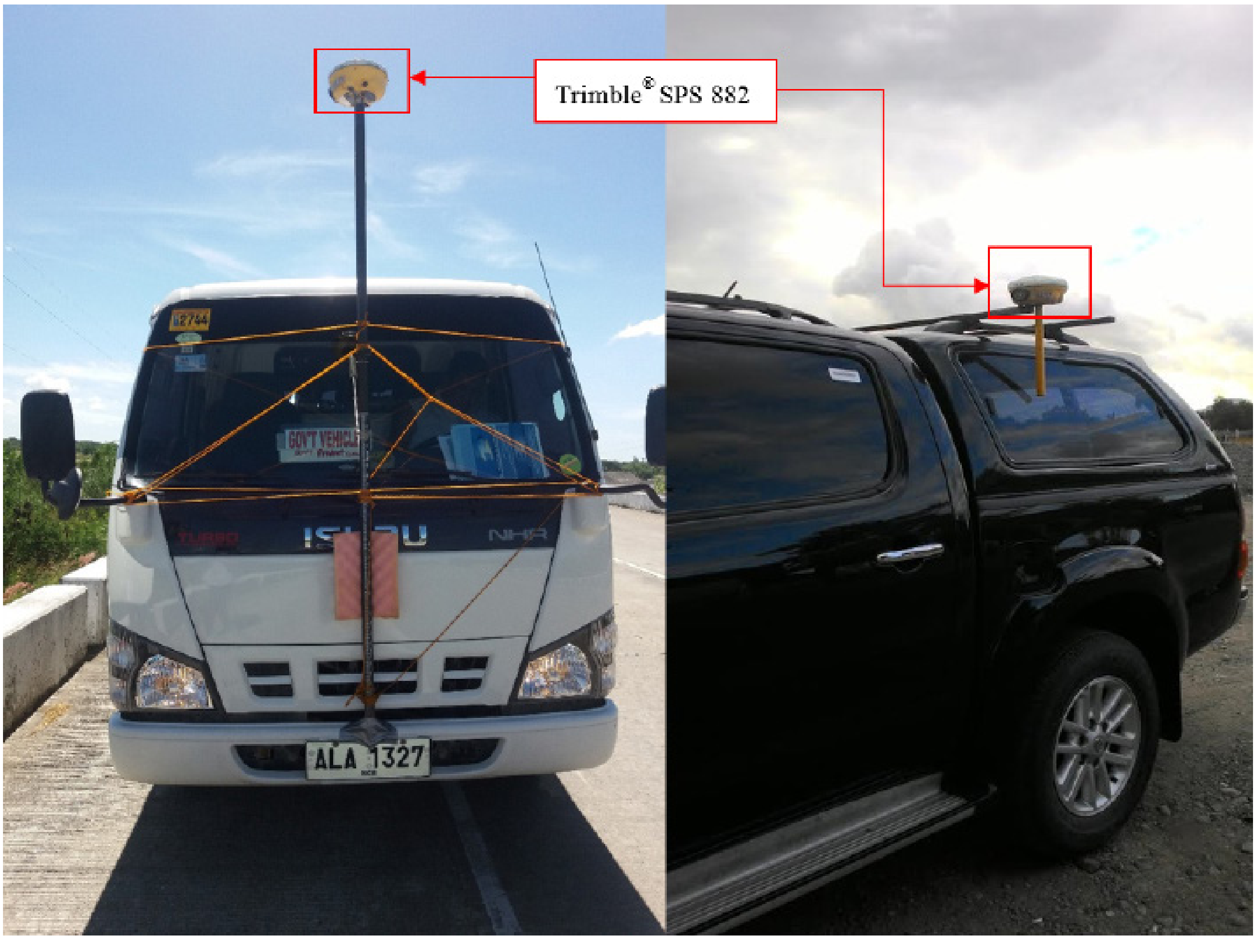


Figure 45. Validation points acquisition survey set up along Mompong River Basin

The validation points acquisition survey for the Mompong River Basin traversed the municipalities of Sta. Cruz, Sablayan, Calintaan, Rizal, San Jose and Magsaysay. The survey perpendicularly traversed the LiDAR flight strips in the survey area. A total of 26,449 points with an approximate length of 21.74 km was acquired for the validation points acquisition survey as shown in the map in Figure 46.

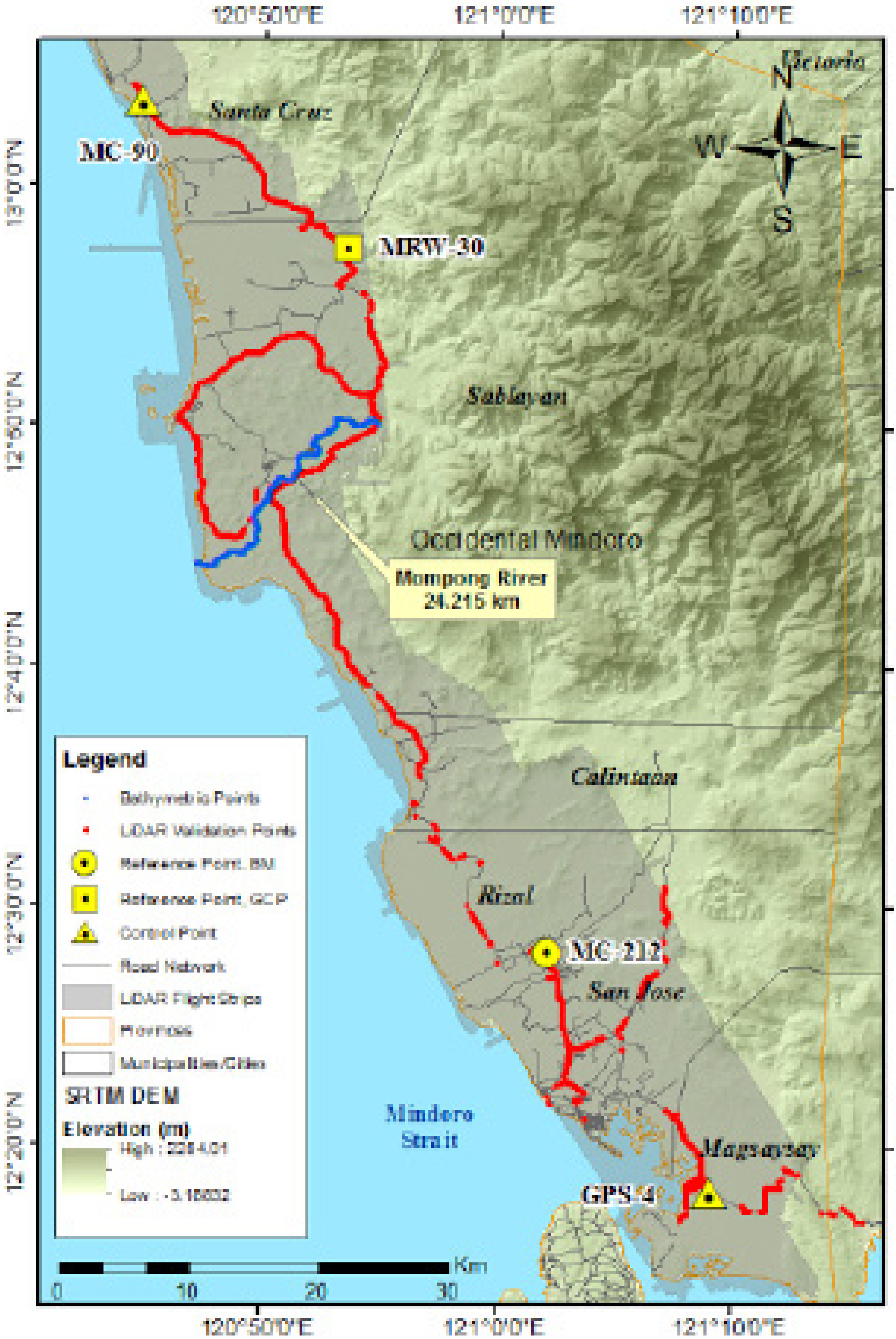


Figure 46. Validation point acquisition survey of Mompong River basin

4.7 River Bathymetric Survey

Manual bathymetric survey was conducted on November 20, 2015 using a Trimble® SPS 882 GNSS PPK technique with UP-MOM as the GNSS base station. The survey began at the upstream portion of the river in Brgy. Sta. Lucia, Municipality of Sablayan with coordinates 13°05'52.52627" 120°46'35.42482" and traversed the centerline of the river by foot down to Brgy. Poblacion and ended in the mouth of the river in Brgy. Sta Lucia with coordinates 13°03'44.63856" 120°43'58.36175". The set-up of manual bathymetry is shown in Figure 47.

Figure 47. Bathymetric survey using Ohmex™ single beam echo sounder in Mompong River

The bathymetric survey coverage for Mompong river is 24 km illustrated in Figure 48. Approximately 3 km of the delineated target bathymetric line was not covered due to absence of community in the upstream portion of the river. The processed data were generated into a map using GIS as shown in Figure 48.

Figure 48. Extent of the Mompong River Bathymetry Survey

A CAD drawing was also produced to illustrate the Mompong riverbed centerline profile as shown in Figure 49 to Figure 50. There is about an 80-m change in elevation observed within the 24.51-km bathymetric data from its upstream in Brgy. Poblacion down to the mouth of the river in Brgy. Sta. Lucia in Sablayan, Occidental Mindoro.

Figure 49. Mompong centerline riverbed profile (Upstream)

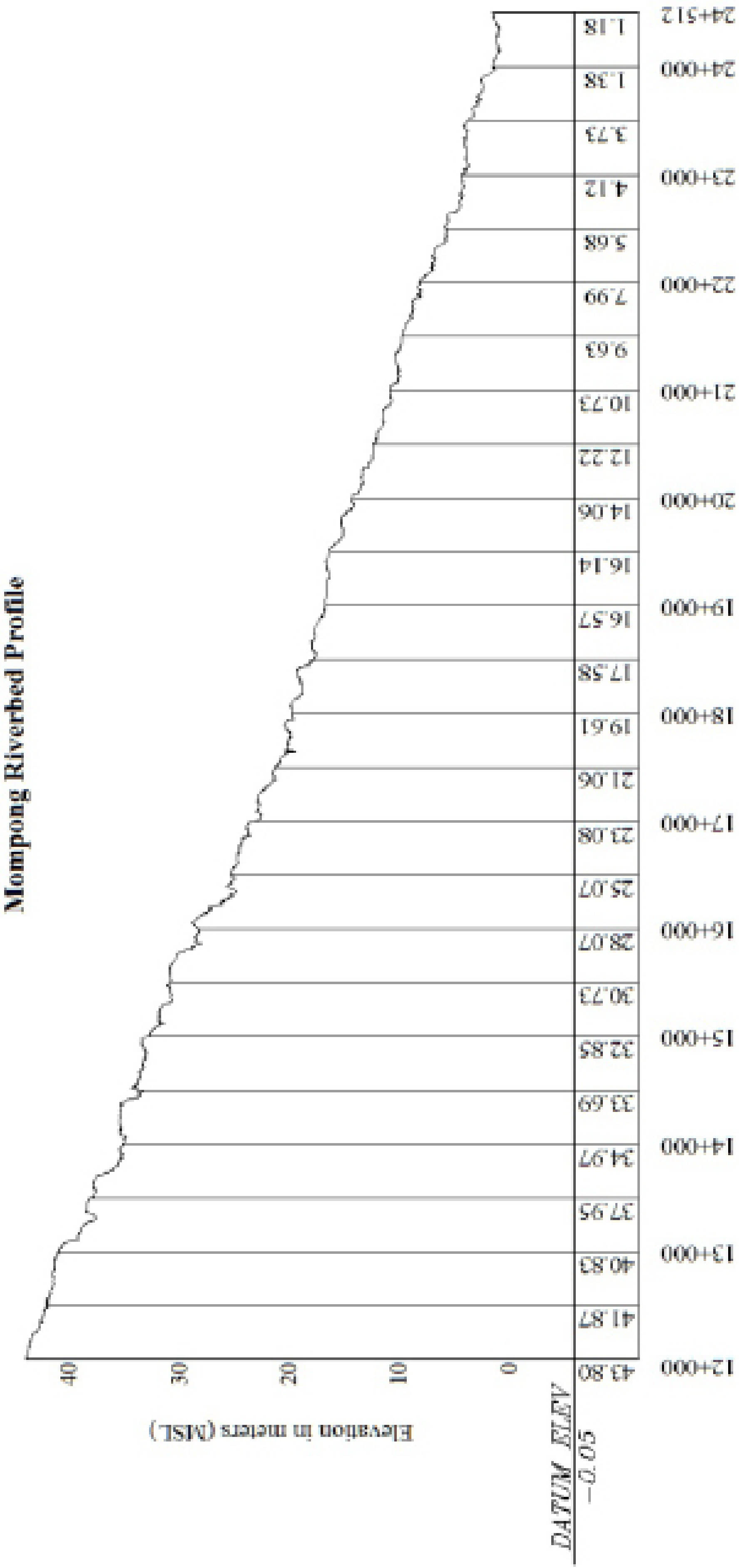


Figure 50. Mompong centerline riverbed profile (downstream)

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, Raphael P. Gonzales, and Kevin M. Manalo

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from a portable rain gauge (12.832494° N, 120.912058° E) deployed within the riverbasin. The location of the rain gauge is seen in Figure 51.

The total precipitation for this event is 9.40 mm. The peak rainfall is 3.80 mm on March 13, 2017 at 5:30 pm. The lag time between the peak rainfall and discharge is 5 hours and 20 minutes, as seen in Figure 54.

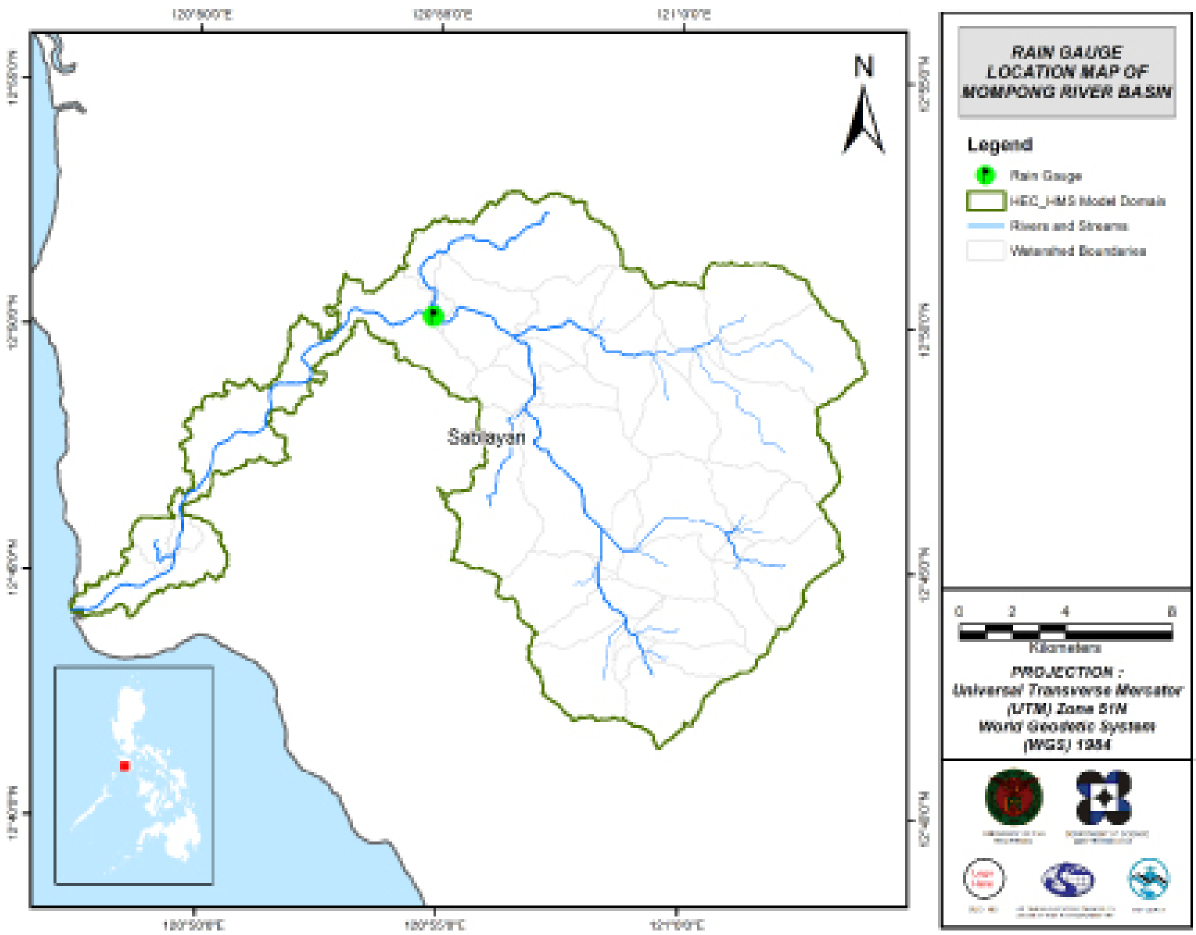


Figure 51. Location map of the Mompong HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Mompong Bridge, Sablayan, Occidental Mindoro (12.835409° N, 120.913697° E). It gives the relationship between the observed water levels from the Mompong Bridge and outflow of the watershed at this location using Bankfull Method in Manning's Equation.

For Mompong Bridge, the rating curve is expressed as Q = 37.601x2 -6506.8x +281499 as shown in Figure 53.

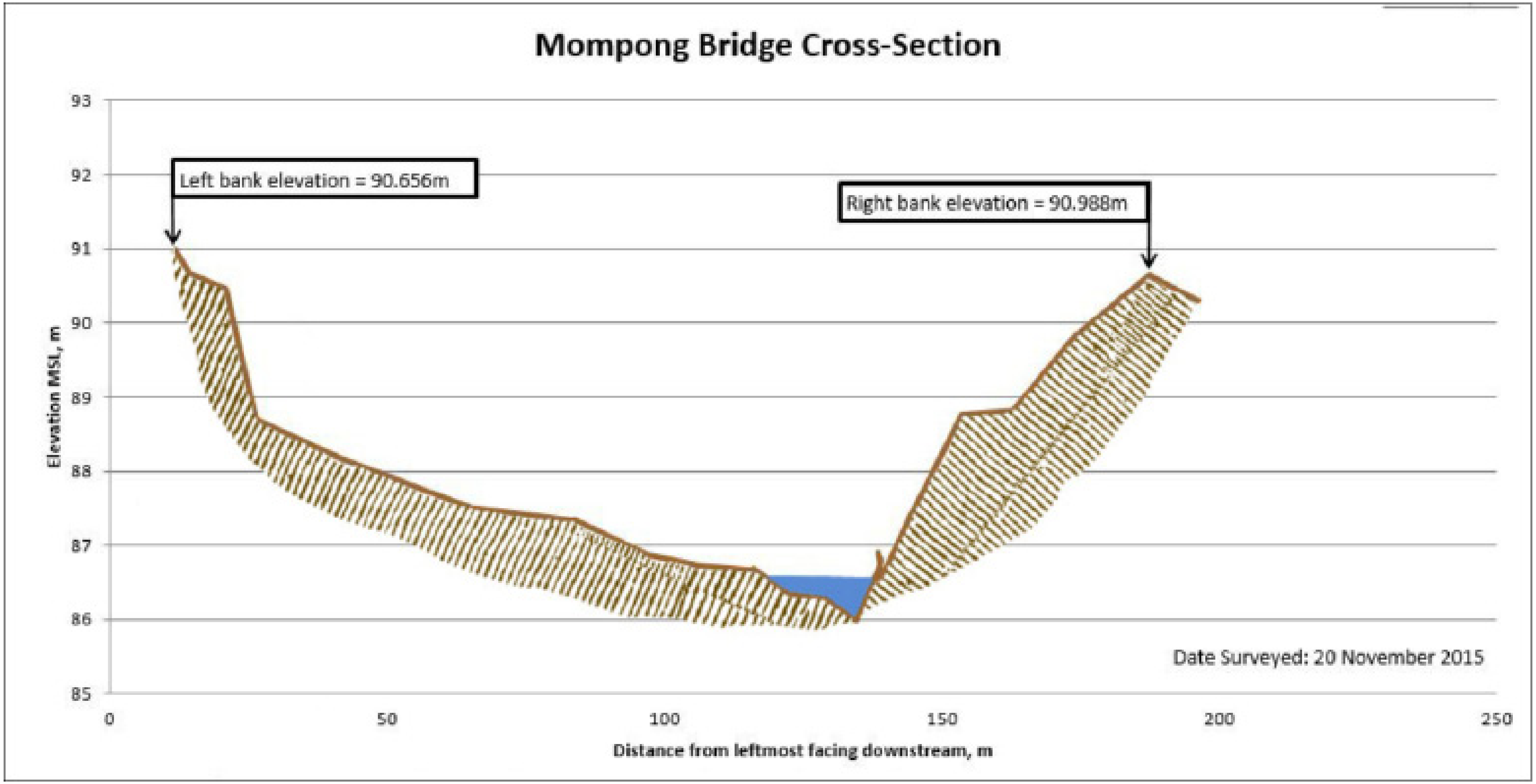


Figure 52. Cross-section plot of Mompong Bridge

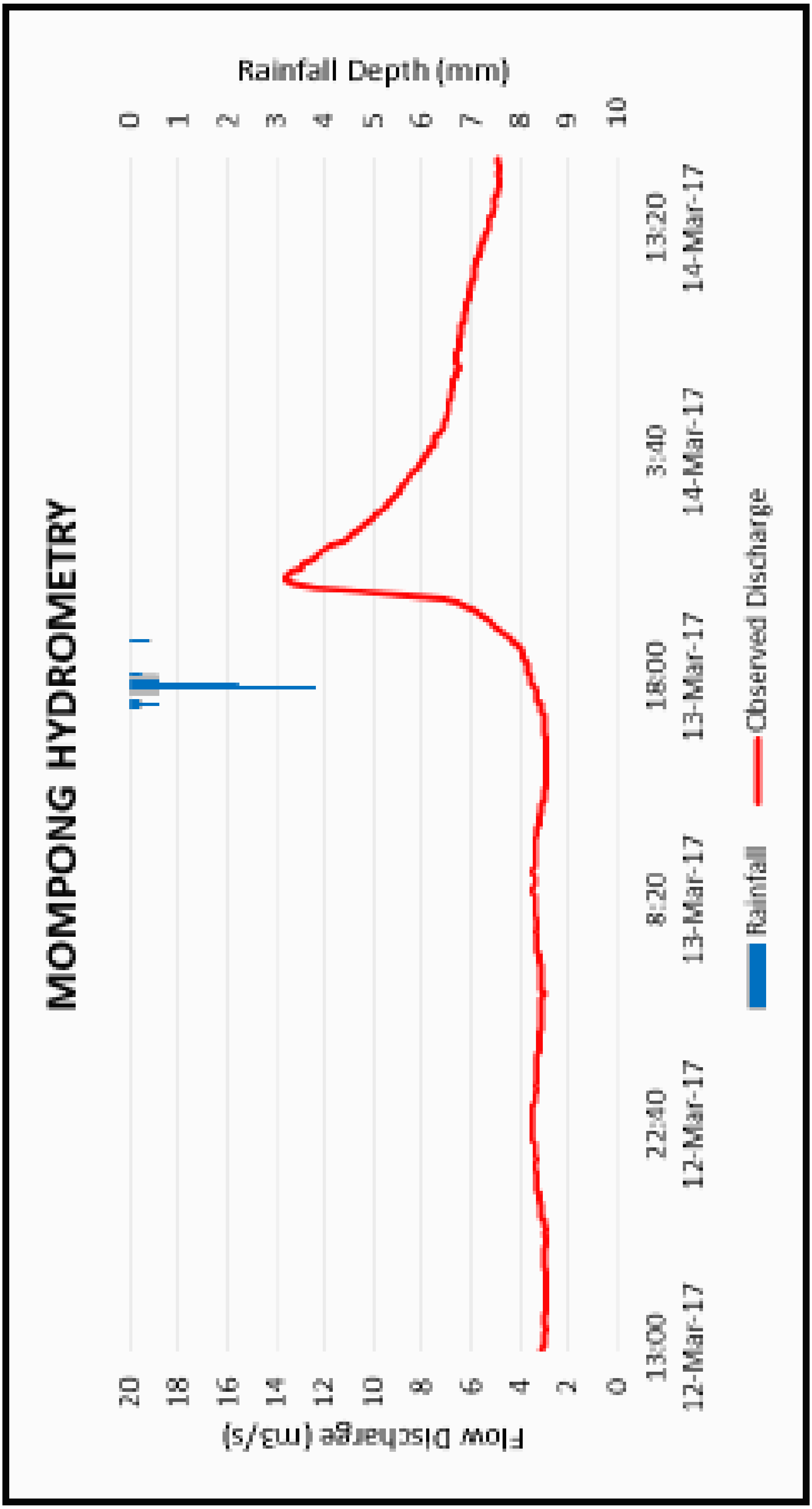


Figure 53. Rainfall and outflow data used for modeling

For the calibration of the HEC-HMS model, shown in Figure 54, actual flow discharge during a rainfall event was collected in the Mompong Bridge. Peak discharge is 13.60 cu.m/s on March 13, 2017 at 10:10 pm.

The Mompong River Rating Curve measured at Mompong Bridge is expressed as Q = 305.63e0.5029x (Figure 50).

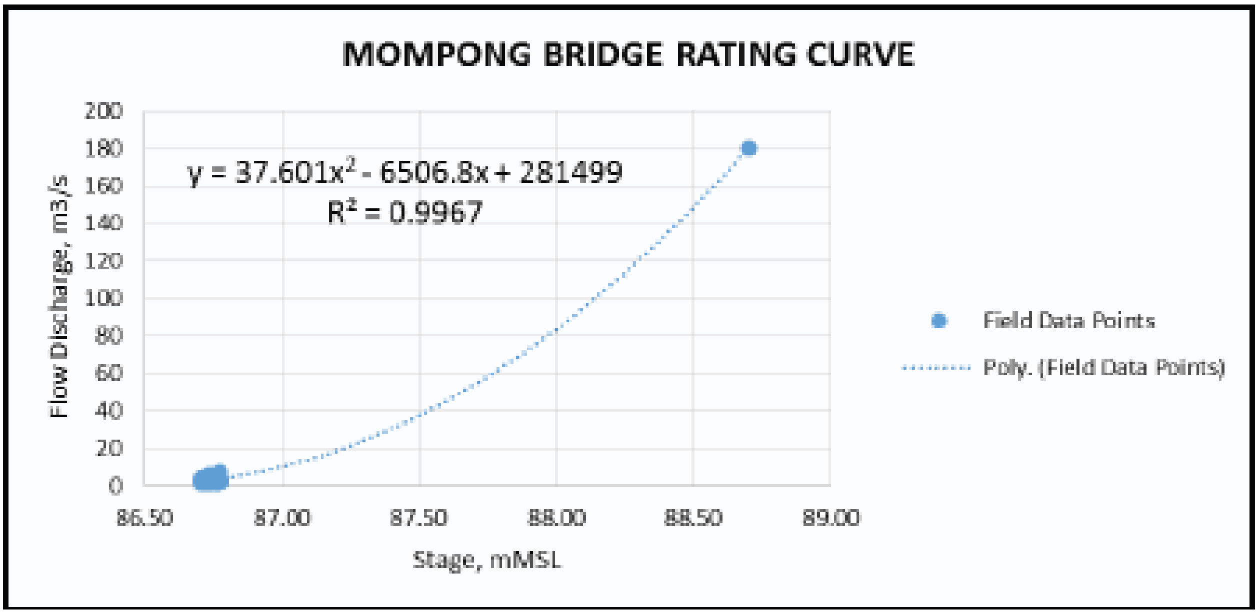


Figure 54. Rainfall and outflow data of Mompong River Basin, which was used for modeling.

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Ambulong Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the values in such a way a certain peak value will be attained at a certain time. This station chosen based on its proximity to the Ibod watershed. The extreme values for this watershed were computed based on a 54-year record, with the computed extreme values shown in Table 27.

Table 27. RIDF values for Aparri Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	22.7	35.5	36.3	50.2	68.2	80.1	104.1	125.7	150.8
5	27.9	45.5	53.8	74.2	103.4	122.5	159.7	192.9	226.7
10	34.2	52.1	65.4	90.1	126.7	150.6	196.5	237.3	276.9
15	37.8	57.4	71.9	99	139.8	166.4	217.3	262.4	305.3
20	40.3	61	76.5	105.3	149	177.5	231.9	280	325.1
25	42.2	63.9	80	110.1	156.1	186	243.1	293.5	340.4
50	48.1	72.6	90.9	125	178	212.3	277.6	335.2	387.5
100	54	81.2	101.6	139.8	199.7	238.4	311.8	376.6	434.3

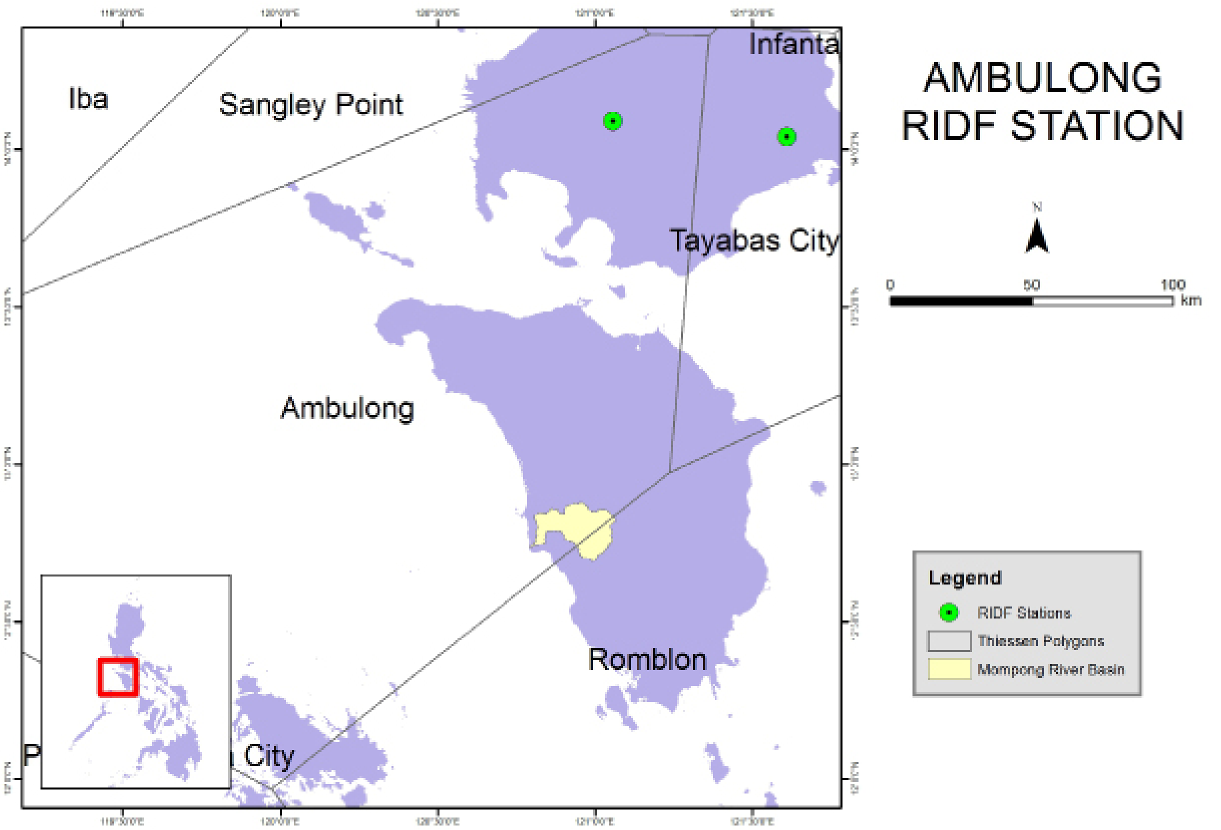


Figure 55. Location of Ambulong RIDF relative to Mompong River Basin

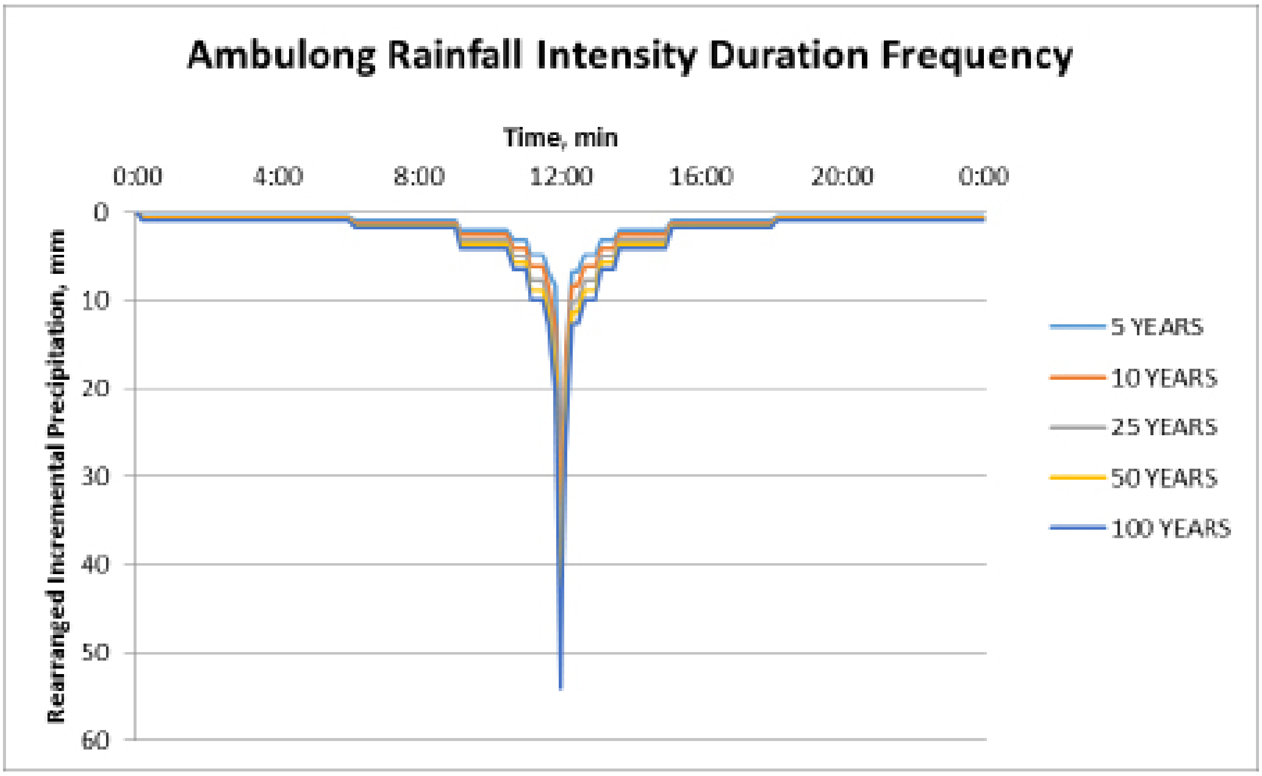


Figure 56. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils and Water Management under the Department of Agriculture (DA-BSWM). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Mompong River Basin are shown in Figure 57 and Figure 58, respectively.

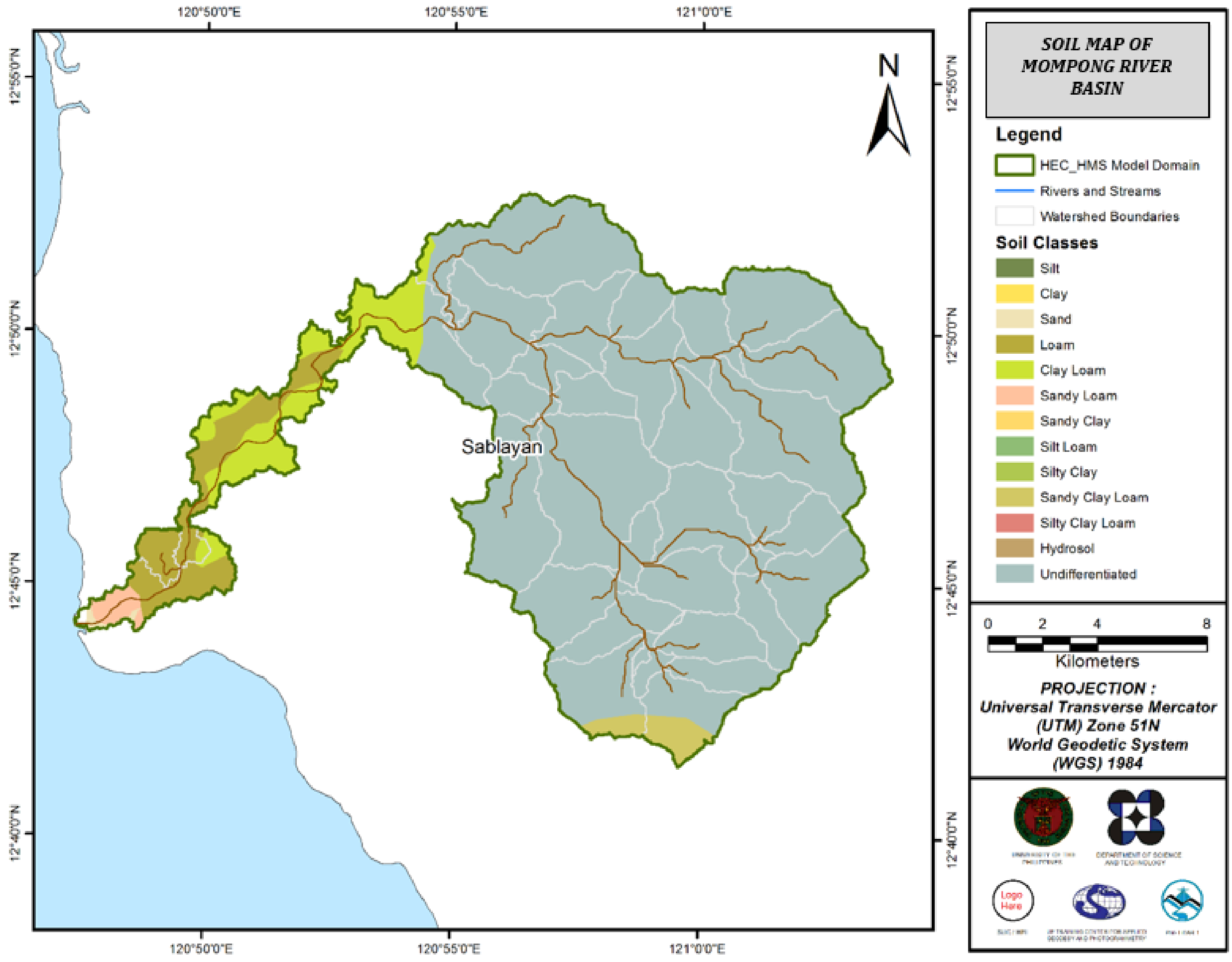


Figure 57. Soil map of Mompong River Basin used for the estimation of the CN parameter. (Source: DA)

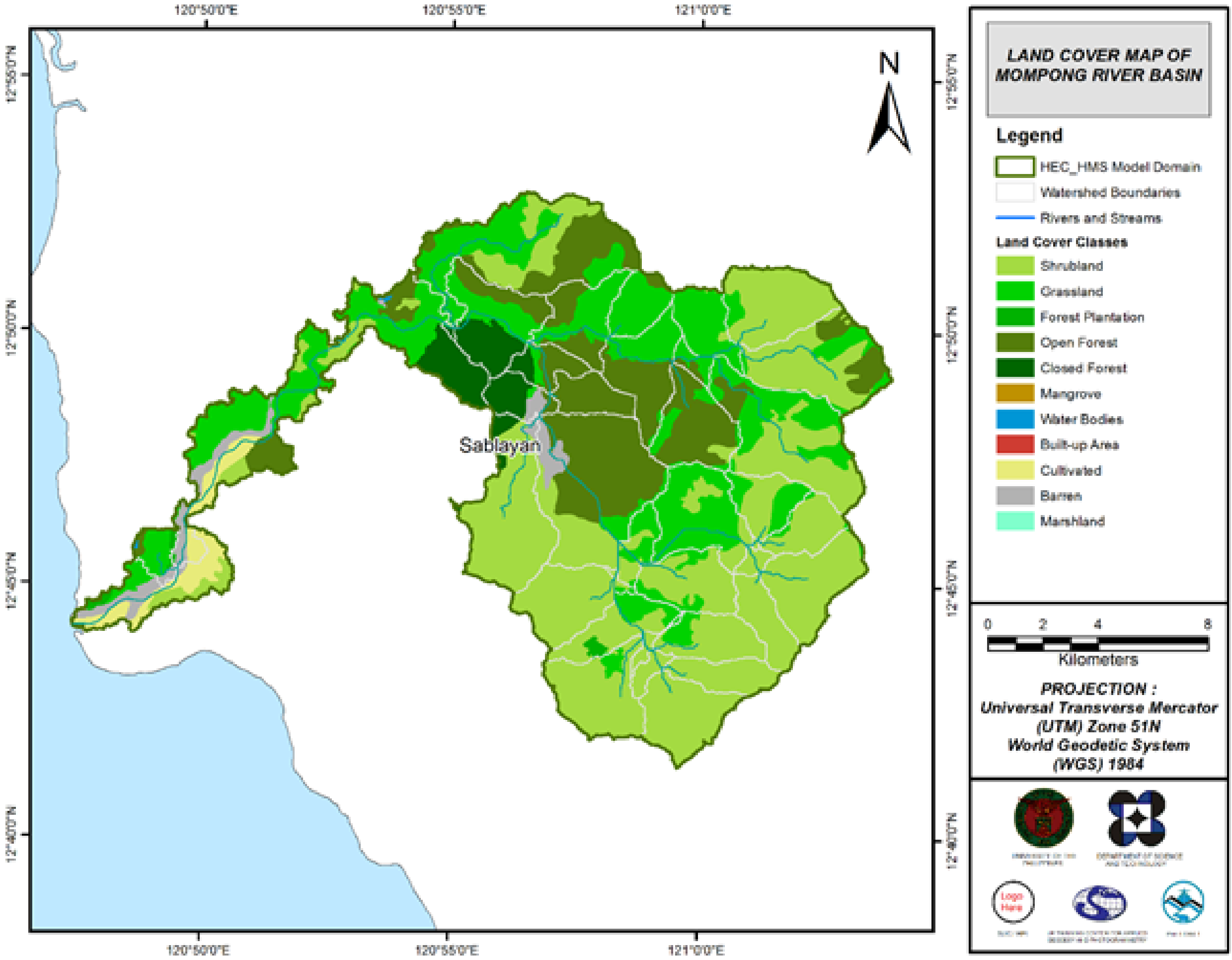


Figure 58. Land cover map of Mompong River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Mompong river basin, the five (5) soil classes identified were loam, clay loam, sandy loam, sandy clay loam and undifferentiated soil. The seven (7) land cover types identified were shrubland, grassland, forest plantation, open forest, closed forest, cultivated land, and barren land.

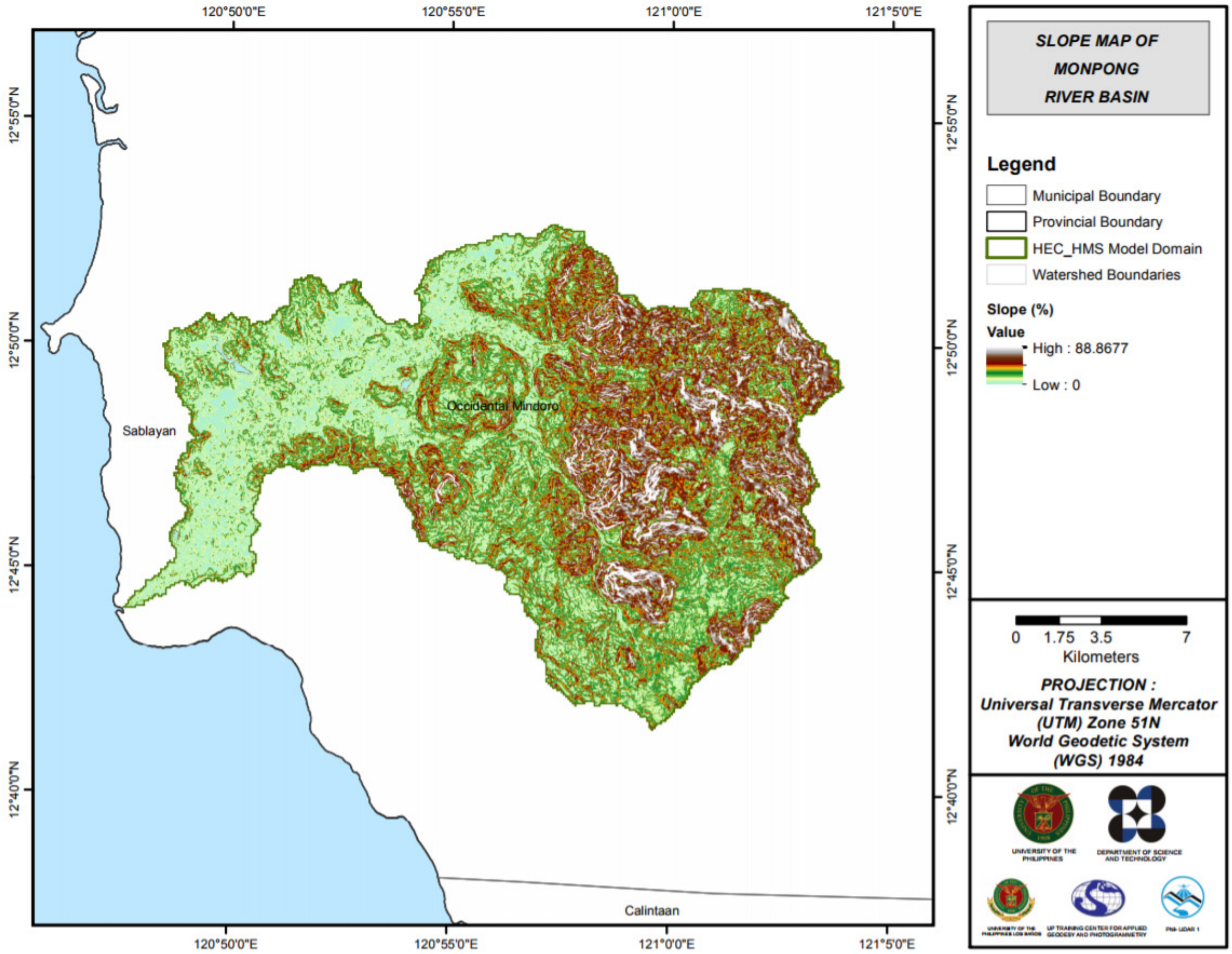


Figure 59. Slope map of Mompong River Basin

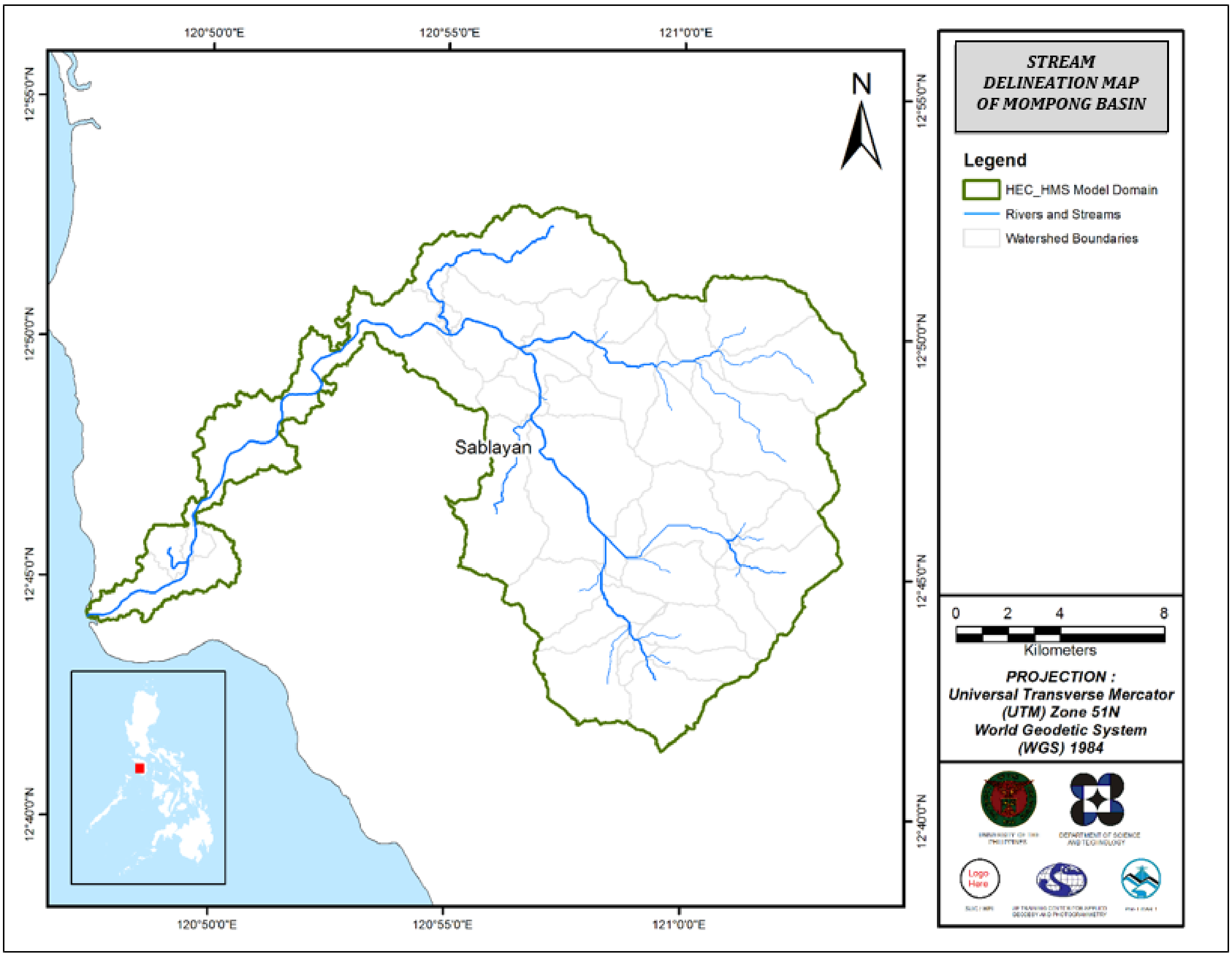


Figure 60. Stream delineation map of Mompong River Basin

Using SAR-based DEM, the Mompong basin was delineated and further subdivided into subbasins. The model consists of 38 sub basins, 38 reaches, and 19 junctions. The main outlet is Mompong Bridge, labelled as 120. This basin model is illustrated in Figure 61.

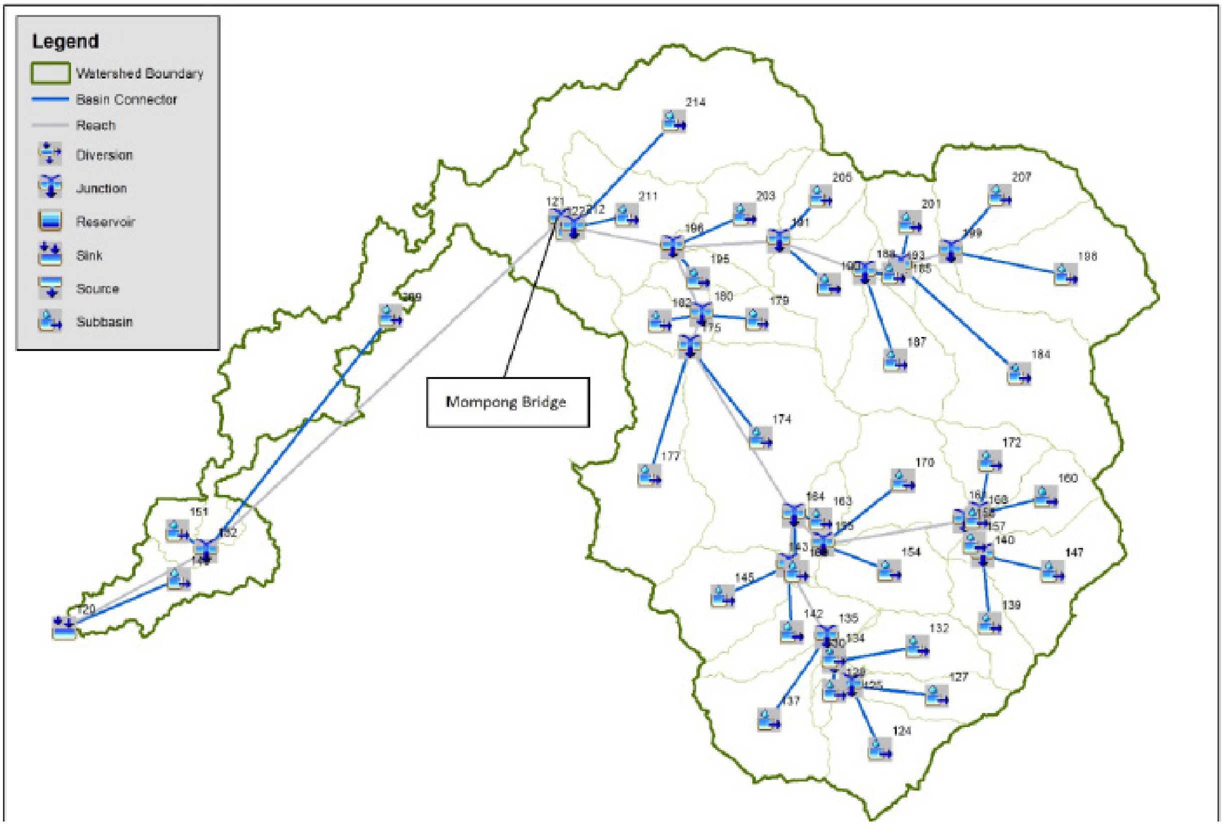


Figure 61. HEC-HMS generated Mompong River Basin Model.

5.4 Cross-section Data

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

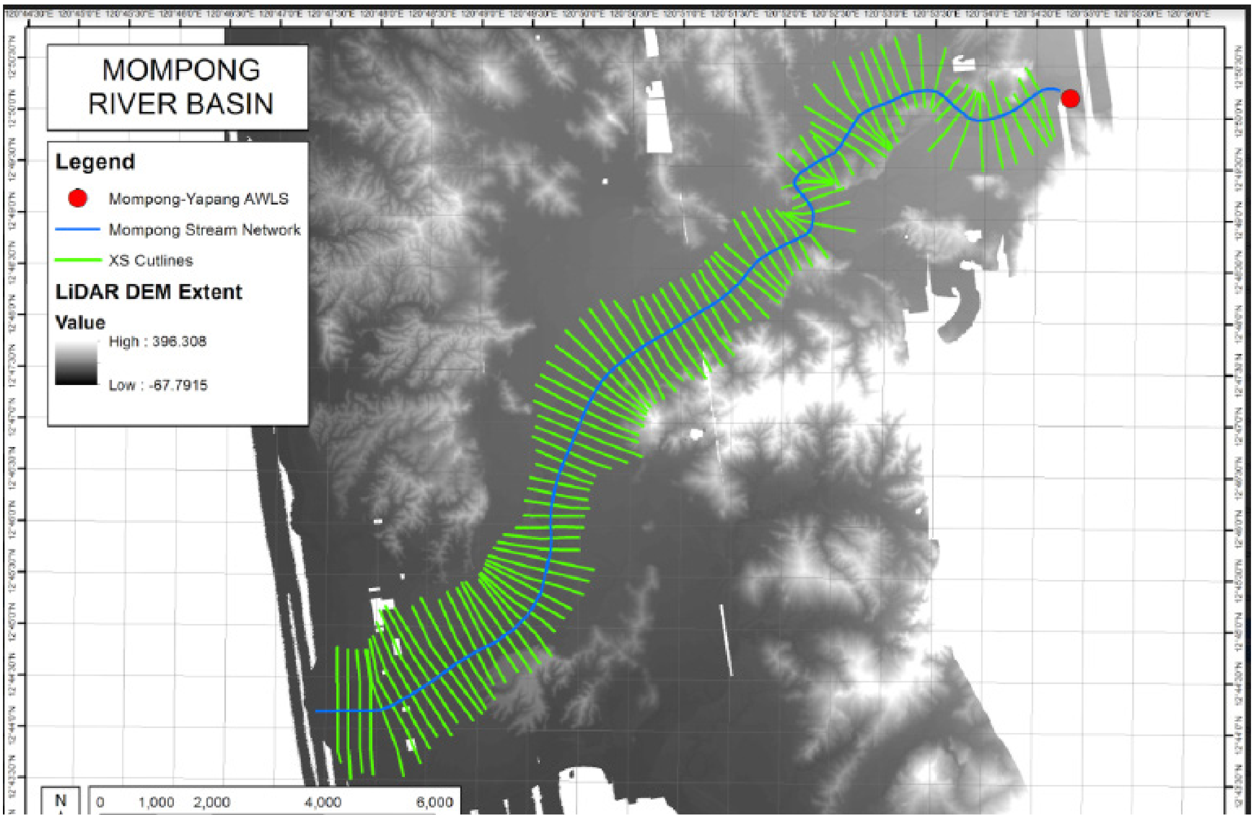


Figure 62. River cross-section of Mompong River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

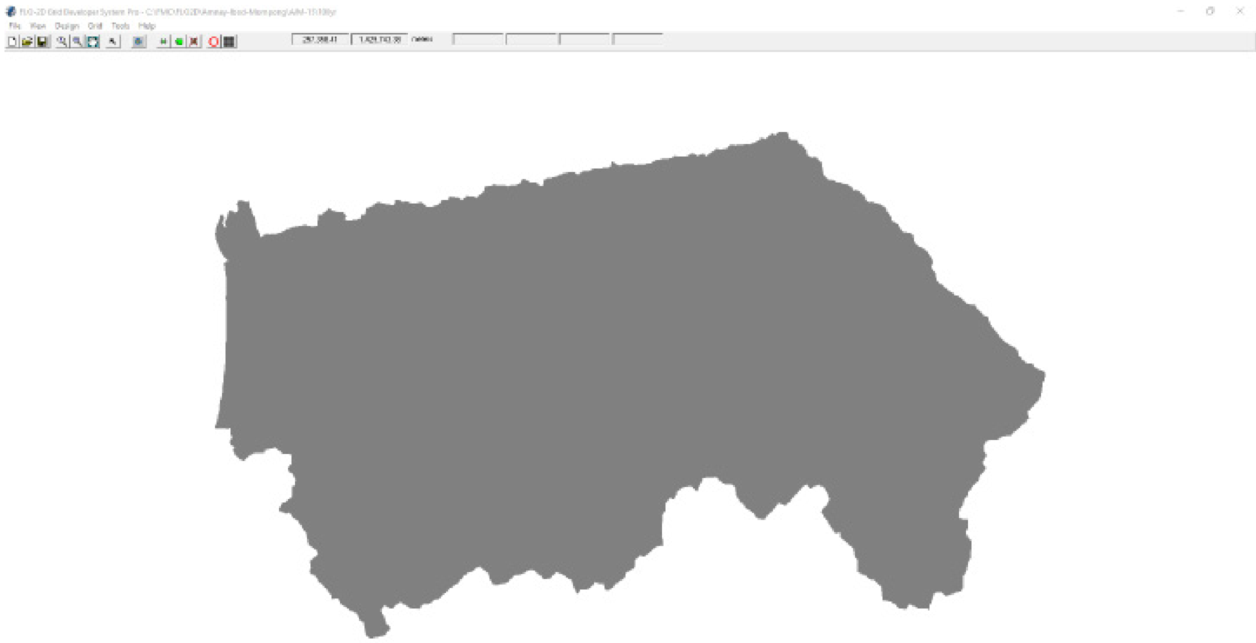


Figure 63. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 56.67261 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 85 377 120.00 m2.

There is a total of 31 901 219.95 m3 of water entering the model. Of this amount, 31 901 219.95 m3 is due to rainfall while 0.00 m3 is inflow from other areas outside the model. 10 046 270.00 m3 of this water is lost to infiltration and interception, while 12 697 027.47 m3 is stored by the flood plain. The rest, amounting up to 9 157 948.76 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Mompong HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 64 shows the comparison between the two discharge data.

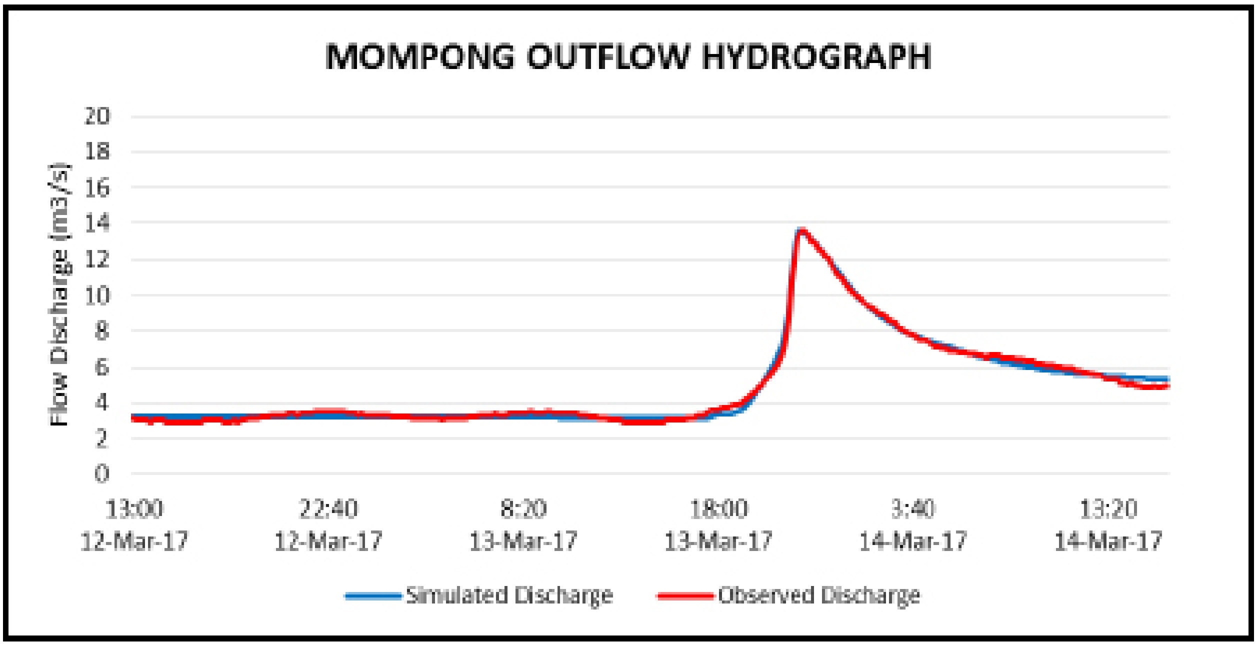


Figure 64. Outflow hydrograph of Mompong produced by the HEC-HMS model compared with observed outflow

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

Table 28. Range of calibrated values for Mompong River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	3 - 13
			Curve Number	36 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.3 - 10
			Storage Coefficient (hr)	0.3 - 14
	Baseflow	Recession	Recession Constant	0.6 - 1
			Ratio to Peak	0.2 - 1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.003 – 0.03

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 3 to 13mm means that there is a 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 36 to 99 means that there the characteristics of the subbasins within the watershed are very diverse with respect to the curve number.

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 0.3 to 14 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 0.6 to 1 indicates that the basin is unlikely to quickly go back to its original.

Manning's roughness coefficient of 0.003 to 0.03 is relatively low compared to the common roughness of watersheds. (Brunner, 2010).

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

Accuracy measure	Value
RMSE	0.223
r2	0.996
NSE	0.992
PBIAS	-2.401E-15
RSR	0.088

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 0.223.

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 0.996.

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 0.992.

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 -2.401E-15.

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 0.088.

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 65) shows the Mompong outflow using the Ambulong 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

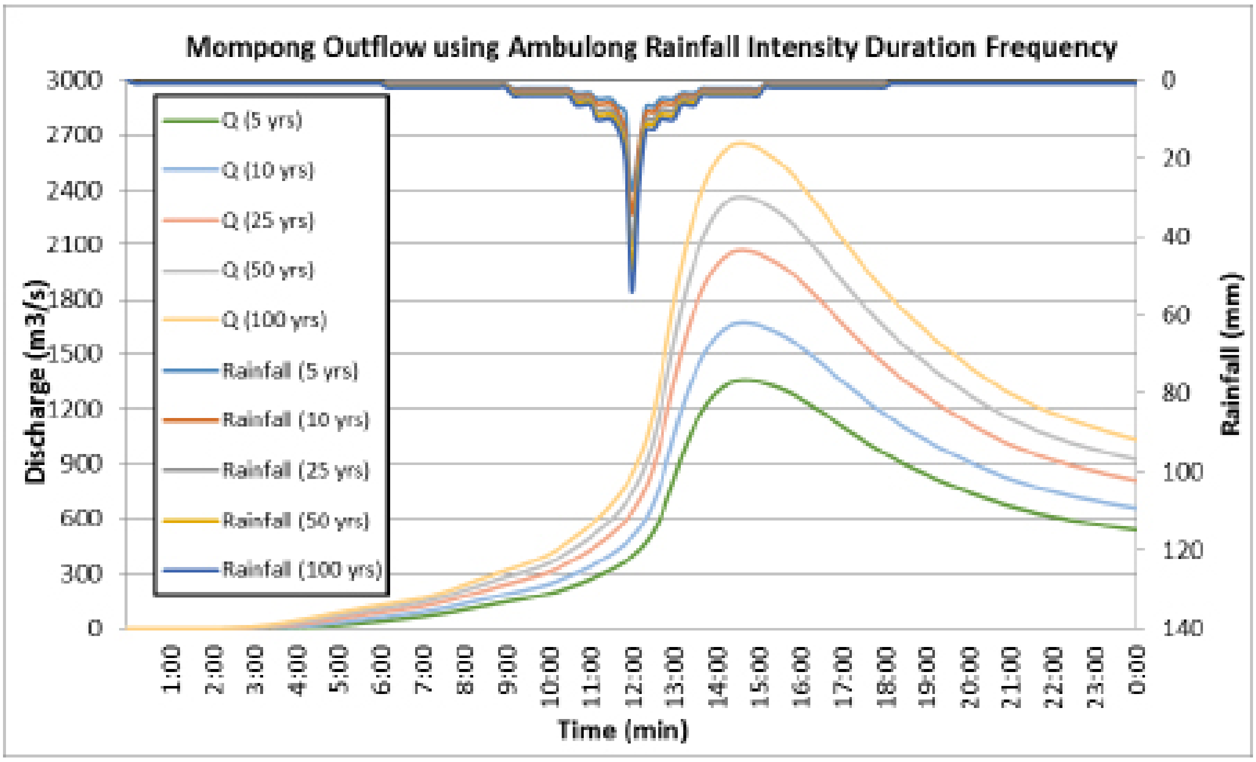


Figure 65. Outflow hydrograph at Mompong Station generated using Ambulong RIDF simulated in HEC-HMS

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

Table 30. Peak values of the Mompong HECHMS Model outflow using the Ambulong RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	226.70	27.90	1360.60	2 hours 40 minutes
10-Year	276.90	34.20	1672.60	2 hours 40 minutes
25-Year	340.40	42.20	2067.80	2 hours 40 minutes
50-Year	387.50	48.10	2362.50	2 hours 40 minutes
100-Year	434.30	54.0	2652.30	2 hours 40 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample map of Mompong River using the HMS base flow is shown on Figure 66 below.

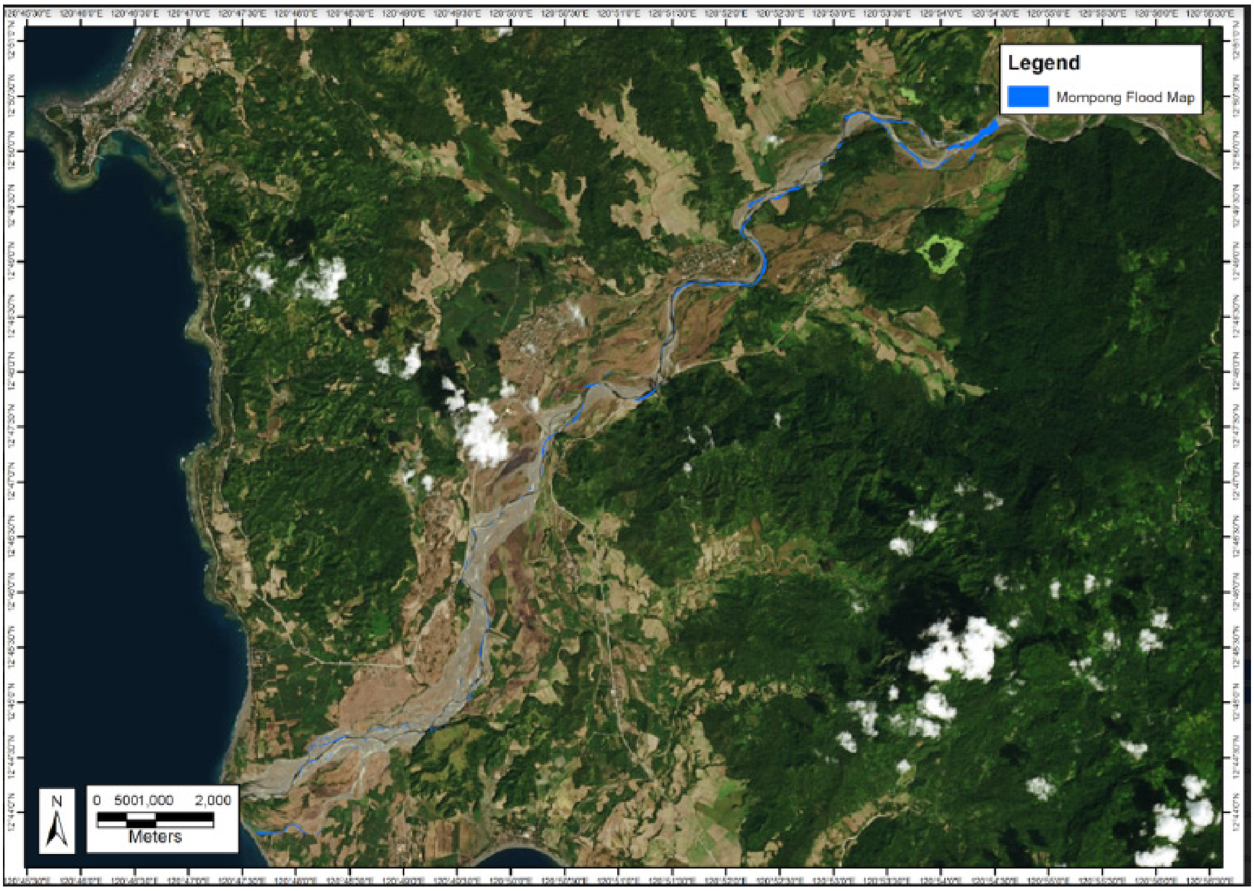


Figure 66. Sample output of Mompong RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Mompong floodplain are shown in Figure 67 to Figure 72. The floodplain, with an area of 509.59 sq. km., covers two municipalities namely Sablayan, and Santa Cruz. Table 31 shows the percentage of area affected by flooding per municipality.

Table 31. Municipalities affected in Mompong Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Sablayan	2350.46	358.08	0.15
Santa Cruz	709.53	147.95	0.21

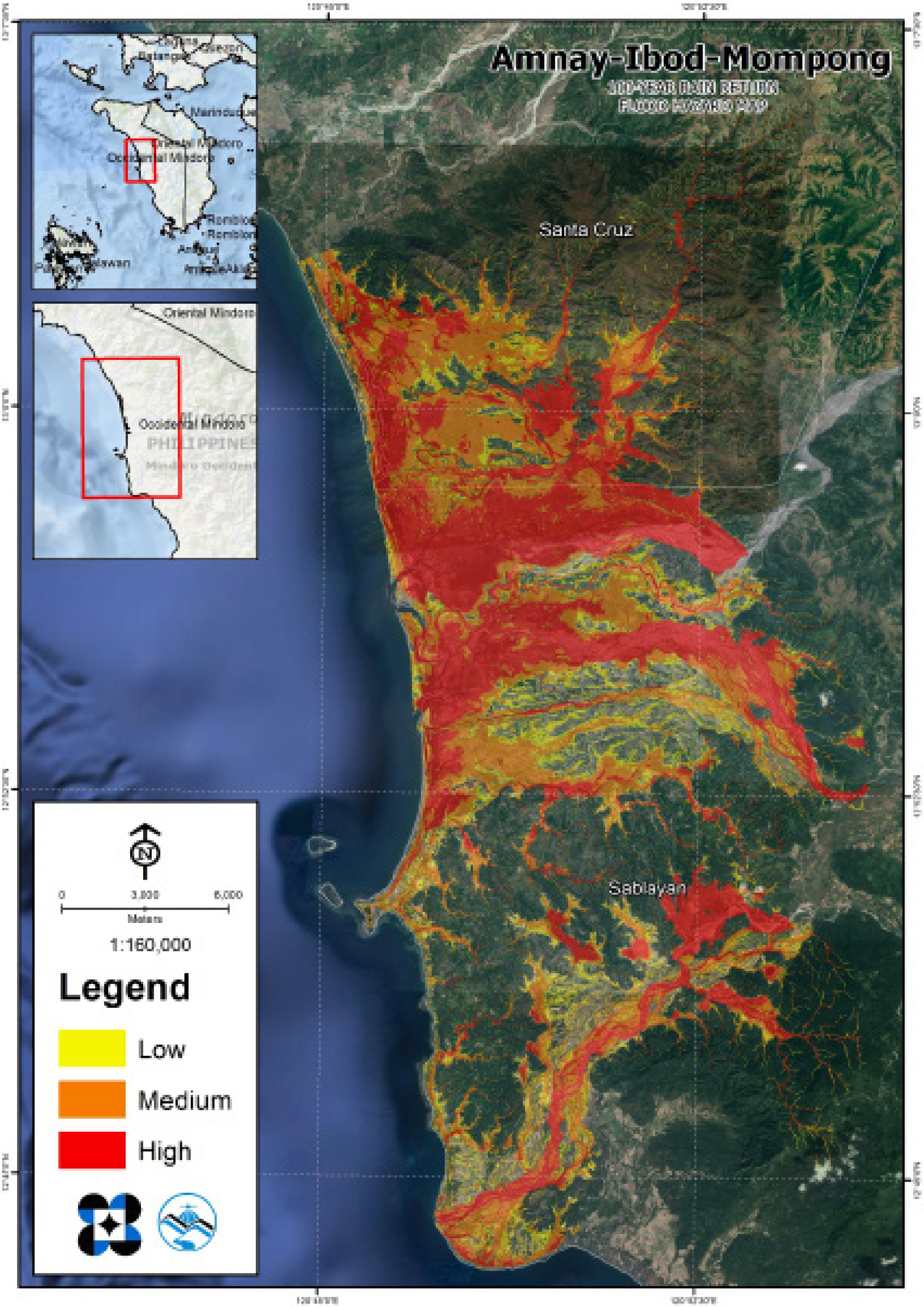


Figure 67. 100-year Flood Hazard Map for Amnay-Ibod-Mompong Floodplain overlaid on Google Earth imagery

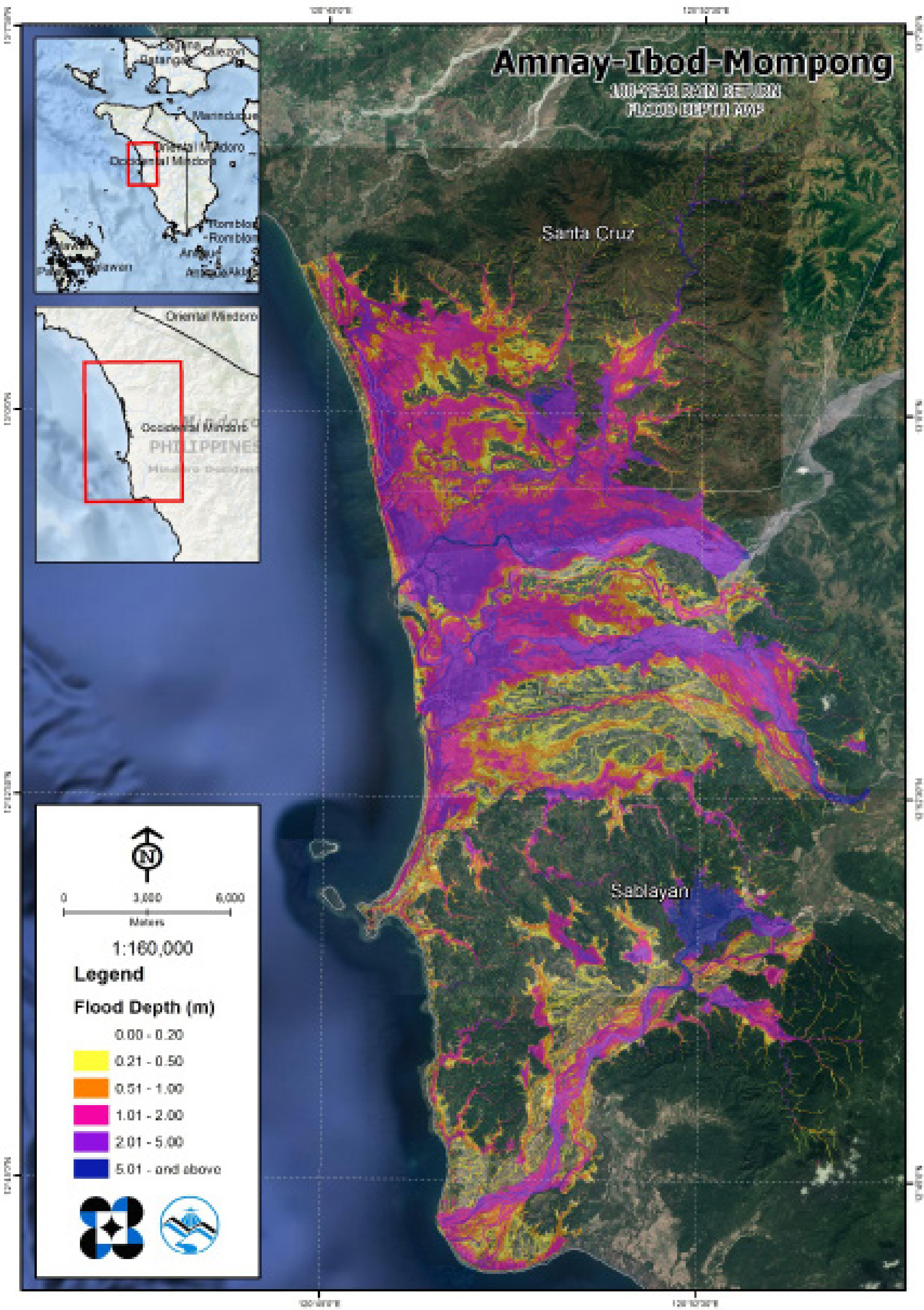


Figure 68. 100-year Flow Depth Map for Amnay-Ibod-Mompong Floodplain overlaid on Google Earth imagery

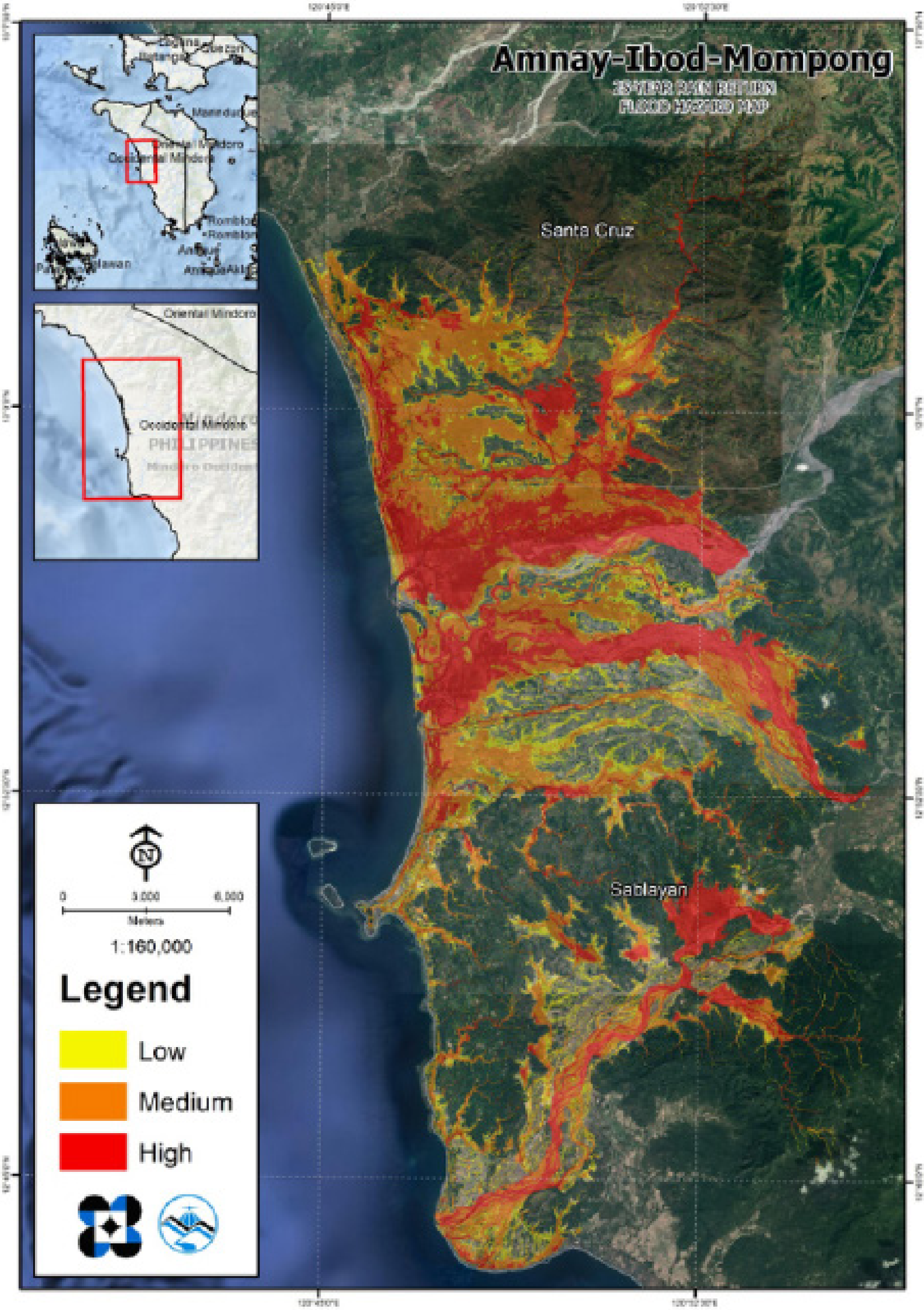


Figure 69. 25-year Flood Hazard Map for Amnay-Ibod-Mompong Floodplain overlaid on Google Earth imagery

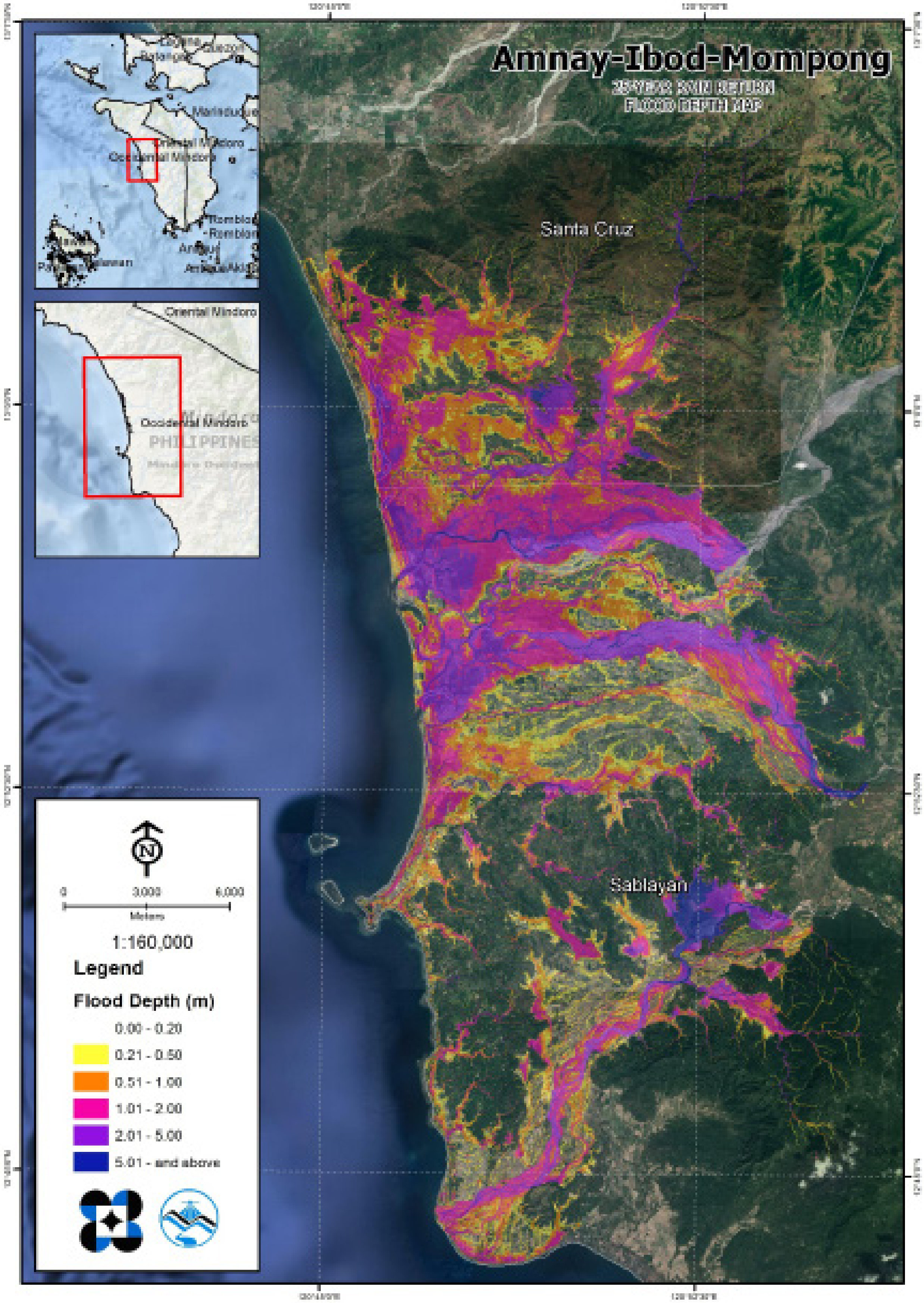


Figure 70. 25-year Flow Depth Map for Amnay-Ibod-Mompong Floodplain overlaid on Google Earth imagery

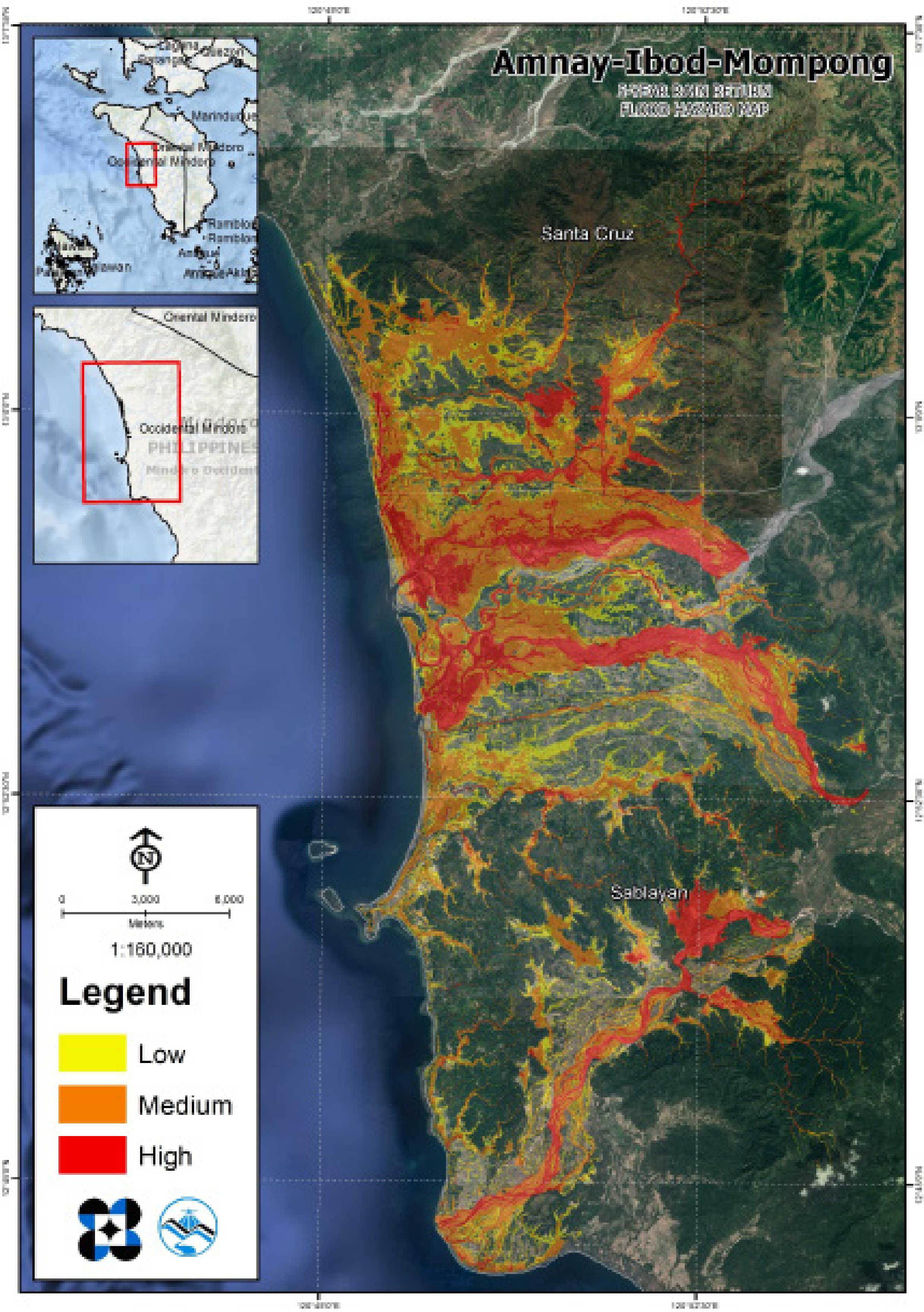


Figure 71. 5-year Flood Hazard Map for Amnay-Ibod-Mompong Floodplain overlaid on Google Earth imagery

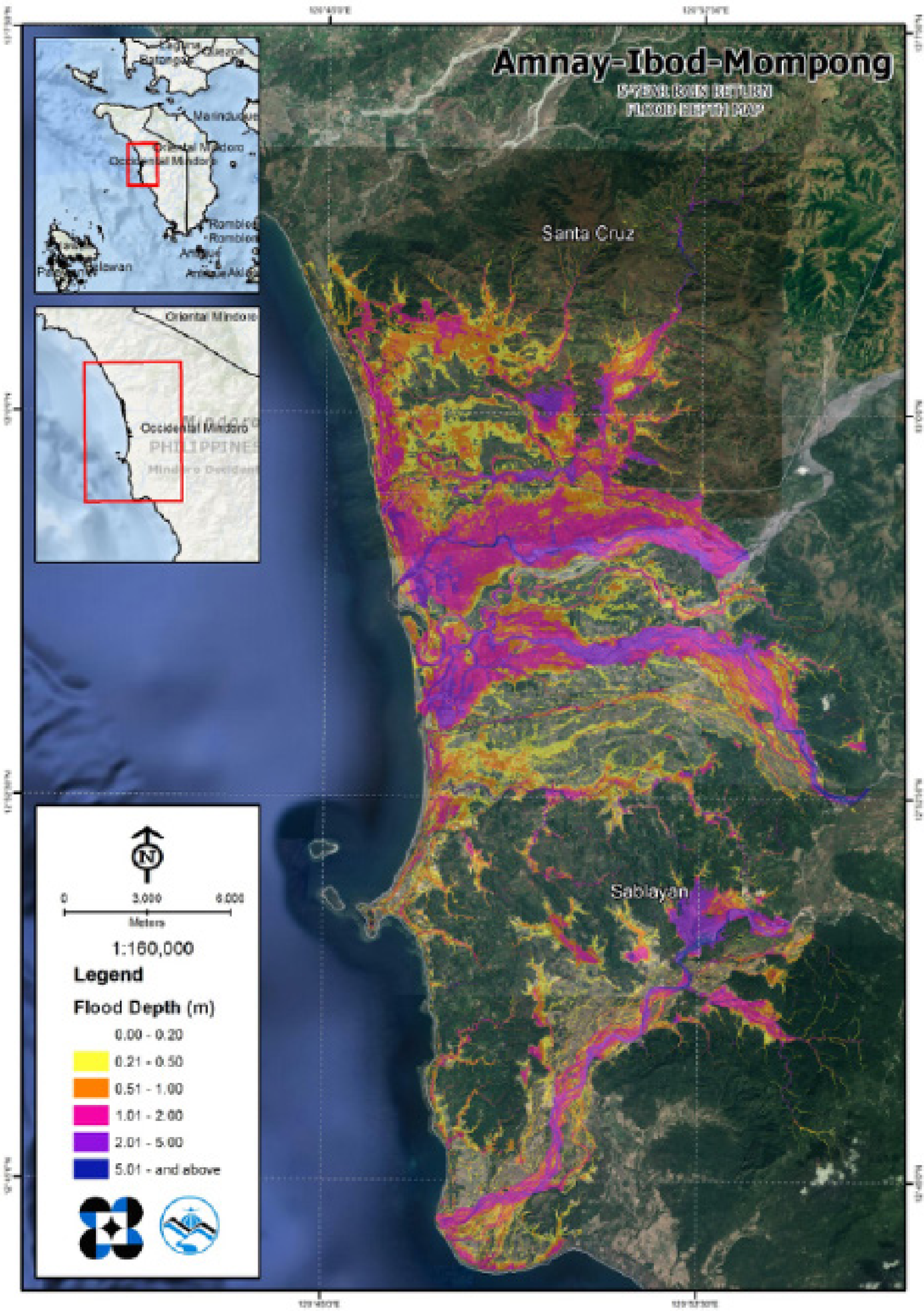


Figure 72. 5-year Flood Depth Map for Amnay-Ibod-Mompong Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Mompong river basin, grouped by municipality, are listed below. For the said basin, two (2) municipalities consisting of 20 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 10.1% of the municipality of Sablayan with an area of 2103.82 sq. km. will experience flood levels of less 0.20 meters. 1.78% of the area will experience flood levels of 0.21 to 0.50 meters while 1.79%, 2.25%, 1.06%, and 0.07% 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 32 and Table 33, and shown in Figure 73 are the affected areas in Sablayan in square kilometres by flood depth per barangay.

Table 32. Affected Areas in Sablayan, Occidental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sablayan (in sq. km.)							
	Batong Buhay	Buenavista	Claudio Salgado	Ibud	Ilvita	Lagnas	Paetan	Pag-Asa
0.03-0.20	13.02	21.06	11.84	4.8	9.85	6.49	5.41	3.9
0.21-0.50	0.59	2.34	5.57	0.75	3.21	0.77	1.17	0.33
0.51-1.00	0.46	2.55	9.73	0.56	3.36	1.2	1.74	0.2
1.01-2.00	0.39	1.37	21.02	0.28	7.14	1.69	1.53	0.11
2.01-5.00	0.3	0.28	7.91	0.072	2.13	1.08	0.62	0.071
> 5.00	0.15	0.0043	0.14	0.0001	0.0095	0.003	0.043	0.01

Table 33. Affected Areas in Sablayan, Occidental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sablayan (in sq. km.)							
	Poblacion	San Francisco	San Nicolas	San Vicente	Santa Lucia	Santo Niño	Tagumpay	Victoria
0.03-0.20	43.23	0.029	9.32	6.21	50.05	15.25	6.92	4.81
0.21-0.50	5.62	0	0.34	0.88	7.43	5.69	1.71	1
0.51-1.00	4.89	0	0.091	0.77	6.86	3.93	0.76	0.51
1.01-2.00	3.6	0	0.036	0.64	6.51	1.2	0.19	1.68
2.01-5.00	3.99	0	0.035	0.5	2.26	0.49	0.018	2.6
> 5.00	0.71	0	0.0036	0.35	0.043	0.048	0	0.0005

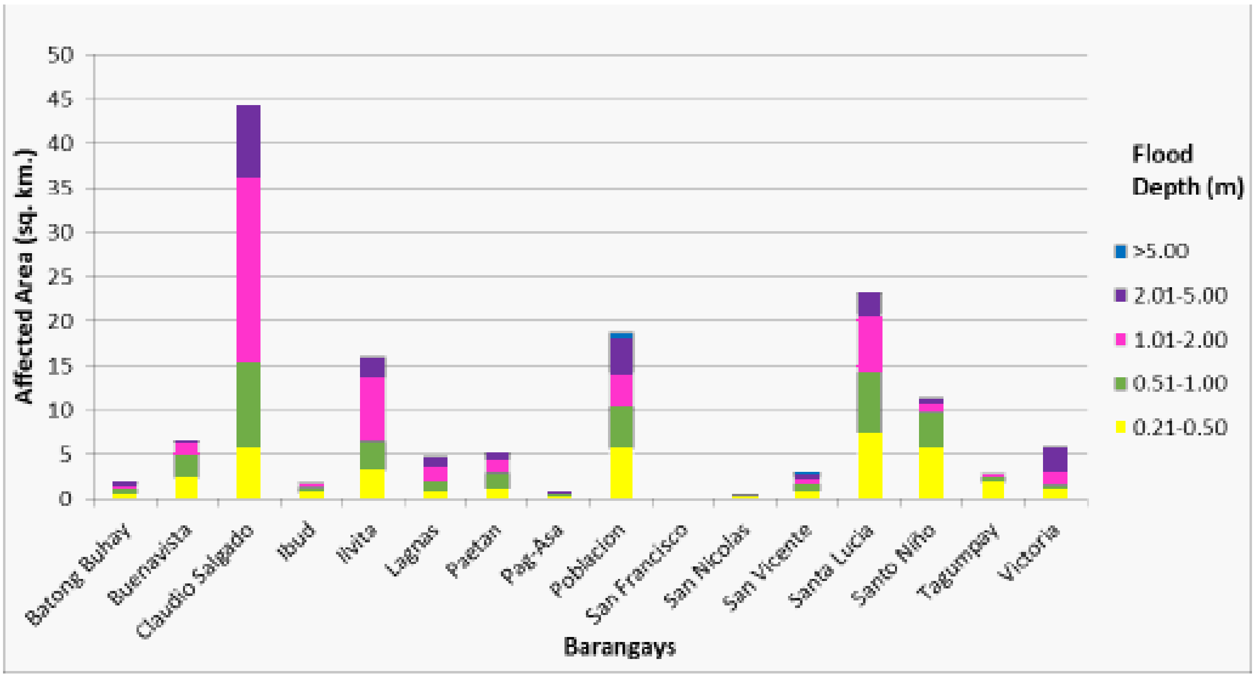


Figure 73. Affected Areas in Sablayan, Occidental Mindoro during 5-Year Rainfall Return Period

For the municipality of Santa Cruz, with an area of 689.03 sq. km., 14.5% will experience flood levels of less 0.20 meters. 2.22% of the area will experience flood levels of 0.21 to 0.50 meters while 2.57%, 1.64%, 0.55%, and 0.02% 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 34 and shown in Figure 74 are the affected areas in square kilometres by flood depth per barangay.

Table 34. Affected Areas in Santa Cruz, Occidental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Cruz (in sq. km.)			
	Barahan	Dayap	Lumangbayan	Pinagturilan
0.03-0.20	11.96	19.27	8.97	59.63
0.21-0.50	2.67	2.51	0.19	9.95
0.51-1.00	2.93	4.16	0.058	10.55
1.01-2.00	2.38	1.4	0.044	7.46
2.01-5.00	0.088	0.037	0.038	3.59
> 5.00	0	0	0.0058	0.16

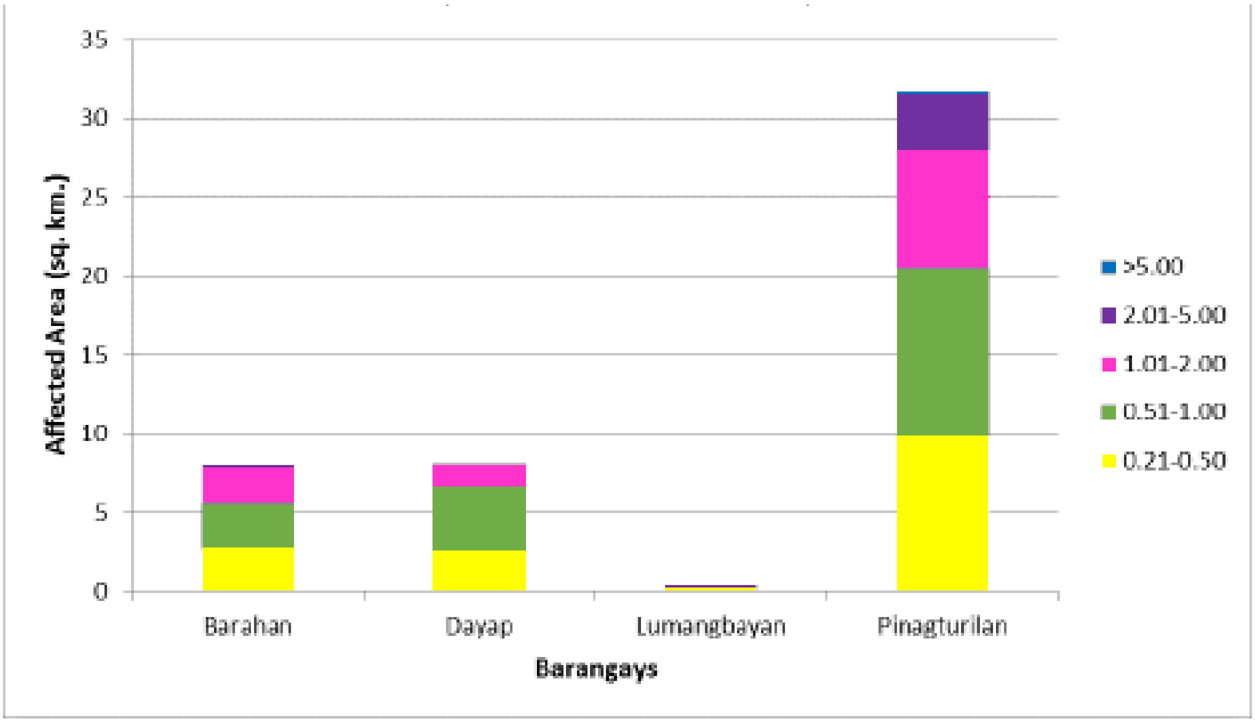


Figure 74. Affected Areas in Santa Cruz, Occidental Mindoro during 5-Year Rainfall Return Period

For the 25-year return period, 9.1% of the municipality of Sablayan with an area of 2103.82 sq. km. will experience flood levels of less 0.20 meters. 1.66% of the area will experience flood levels of 0.21 to 0.50 meters while 1.77%, 2.53%, 1.75%, and 0.22% 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 35 and Table 36, and shown in Figure 75 are the areas affected in Mansalay in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Sablayan, Occidental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sablayan (in sq. km.)							
	Batong Buhay	Buenavista	Claudio Salgado	Ibud	Ilvita	Lagnas	Paetan	Pag-Asa
0.03-0.20	12.75	20.13	7.11	4.4	7.76	6.17	4.95	3.75
0.21-0.50	0.62	2	4.24	0.78	2.82	0.54	0.78	0.39
0.51-1.00	0.47	2.55	7.07	0.72	3.72	0.82	1.38	0.24
1.01-2.00	0.5	2.43	21.56	0.46	6.56	1.82	2.34	0.13
2.01-5.00	0.37	0.48	15.9	0.1	4.81	1.81	1.01	0.085
> 5.00	0.21	0.0066	0.39	0.0006	0.027	0.064	0.062	0.024

Table 36. Affected Areas in Sablayan, Occidental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sablayan (in sq. km.)							
	Poblacion	San Francisco	San Nicolas	San Vicente	Santa Lucia	Santo Niño	Tagumpay	Victoria
0.03-0.20	40.64	0.029	9.17	5.57	46.69	12.71	6.02	3.63
0.21-0.50	5.73	0	0.42	0.81	7.92	4.74	2.06	1.16
0.51-1.00	4.69	0	0.14	0.87	7.1	5.45	1.1	0.91
1.01-2.00	4.35	0	0.048	0.92	8.02	2.86	0.39	0.91
2.01-5.00	3.57	0	0.042	0.7	3.34	0.78	0.031	3.86
> 5.00	3.06	0	0.01	0.51	0.095	0.063	0	0.11

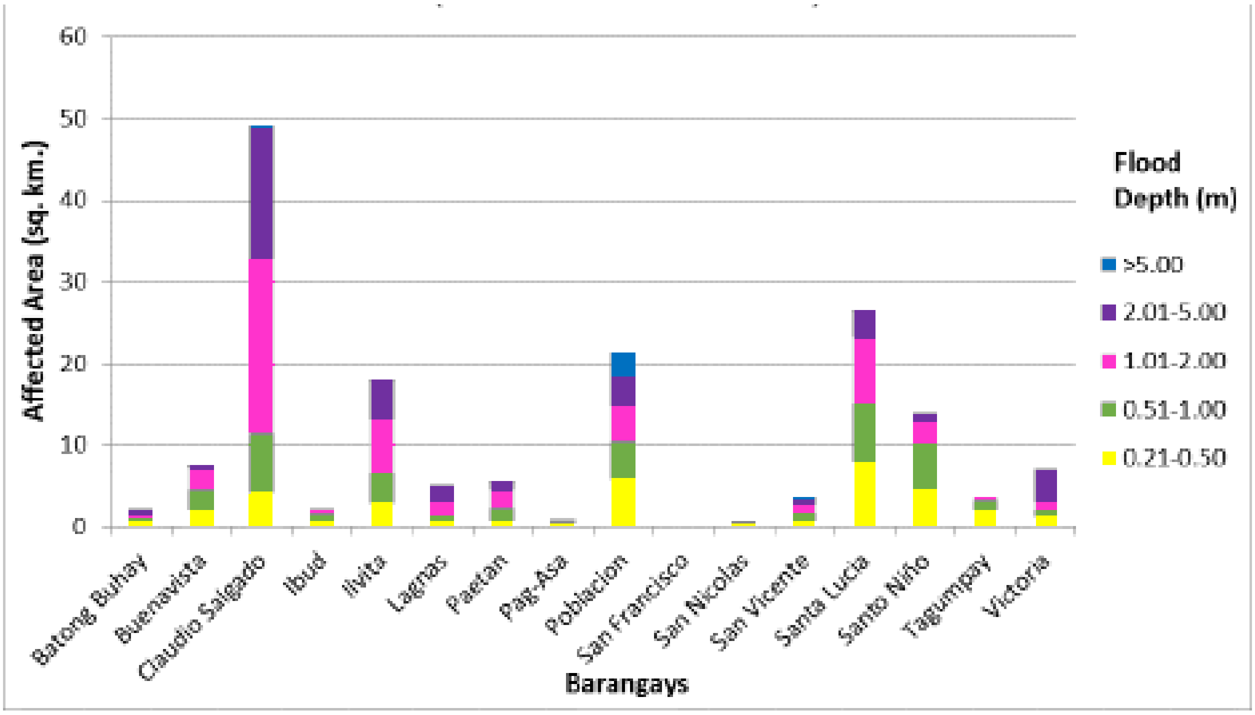


Figure 75. Affected Areas in Sablayan, Occidental Mindoro during 25-Year Rainfall Return Period

For the municipality of Santa Cruz, with an area of 689.03 sq. km., 13.2% will experience flood levels of less 0.20 meters. 1.62% of the area will experience flood levels of 0.21 to 0.50 meters while 2.7%, 2.97%, 0.92%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 and shown in Figure 77 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Santa Cruz, Occidental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Cruz (in sq. km.)			
	Barahan	Dayap	Lumangbayan	Pinagturilan
0.03-0.20	10.08	17.9	8.87	54.08
0.21-0.50	1.91	1.95	0.24	7.09
0.51-1.00	3.23	3.36	0.08	11.93
1.01-2.00	4.31	4.05	0.052	12.08
2.01-5.00	0.5	0.12	0.055	5.66
> 5.00	0	0.0012	0.0097	0.54

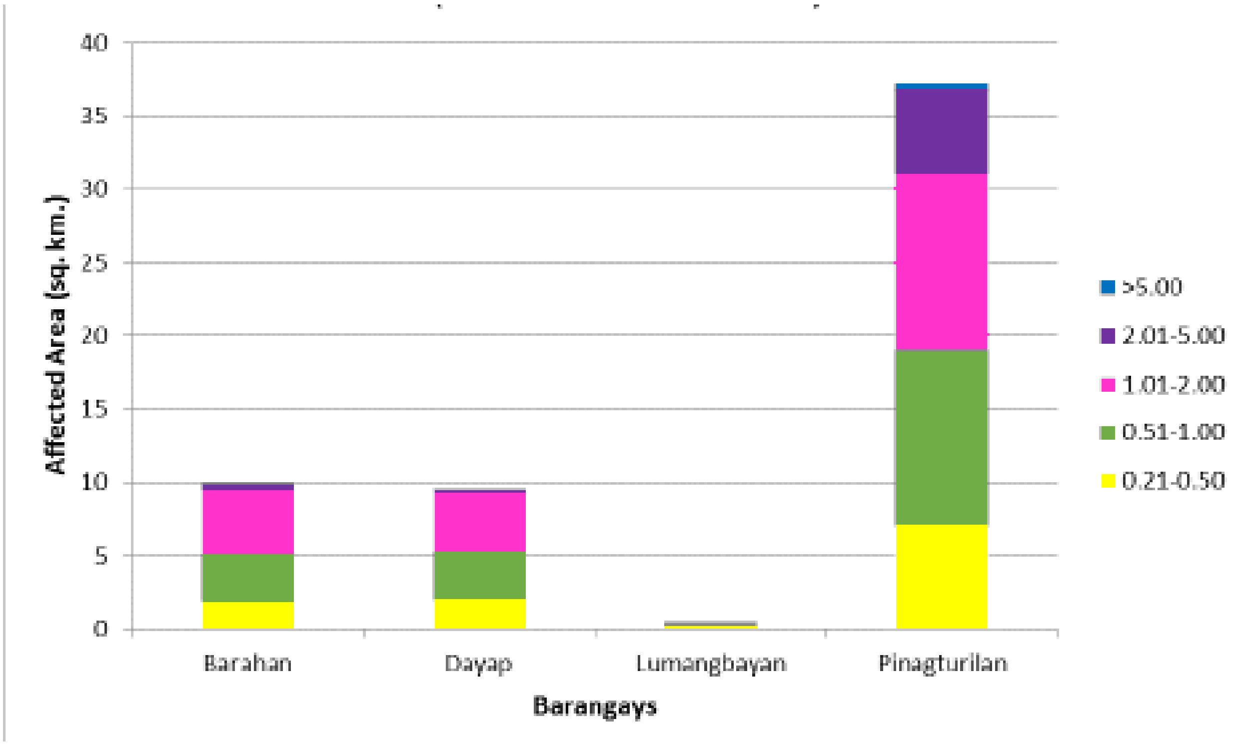


Figure 76. Affected Areas in Santa Cruz, Occidental Mindoro during 25-Year Rainfall Return Period

For the 100-year return period, 8.4% of the municipality of Sablayan with an area of 2103.82 sq. km. will experience flood levels of less 0.20 meters. 1.58% of the area will experience flood levels of 0.21 to 0.50 meters while 1.69%, 2.56%, 2.47%, and 0.35% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 and Table 39, and shown in Figure 77 are the affected areas in square kilometres by flood depth per barangay.

Table 38. Affected Areas in Sablayan, Occidental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sablayan (in sq. km.)							
	Batong Buhay	Buenavista	Claudio Salgado	Ibud	Ilvita	Lagnas	Paetan	Pag-Asa
0.03-0.20	12.5	19.41	4.42	4.04	6.78	5.98	4.69	3.6
0.21-0.50	0.69	1.82	3.3	0.84	2.36	0.5	0.78	0.45
0.51-1.00	0.48	2.4	5.26	0.73	3.31	0.56	1.14	0.27
1.01-2.00	0.52	2.74	18.12	0.72	5.75	1.72	2.52	0.17
2.01-5.00	0.5	1.22	24.44	0.13	7.43	2.35	1.31	0.076
> 5.00	0.24	0.013	0.74	0.0009	0.063	0.12	0.074	0.053

Table 39. Affected Areas in Sablayan, Occidental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sablayan (in sq. km.)							
	Poblacion	San Francisco	San Nicolas	San Vicente	Santa Lucia	Santo Niño	Tagumpay	Victoria
0.03-0.20	38.19	0.029	9.02	5.29	43.4	11.22	5.28	2.8
0.21-0.50	5.83	0	0.49	0.82	8.05	3.93	2.25	1.18
0.51-1.00	4.96	0	0.18	0.92	7.64	5.24	1.38	1.06
1.01-2.00	5.03	0	0.06	1.01	9	4.66	0.63	1.19
2.01-5.00	3.19	0	0.05	0.79	4.86	1.48	0.048	4.1
> 5.00	4.85	0	0.017	0.54	0.21	0.084	0	0.27

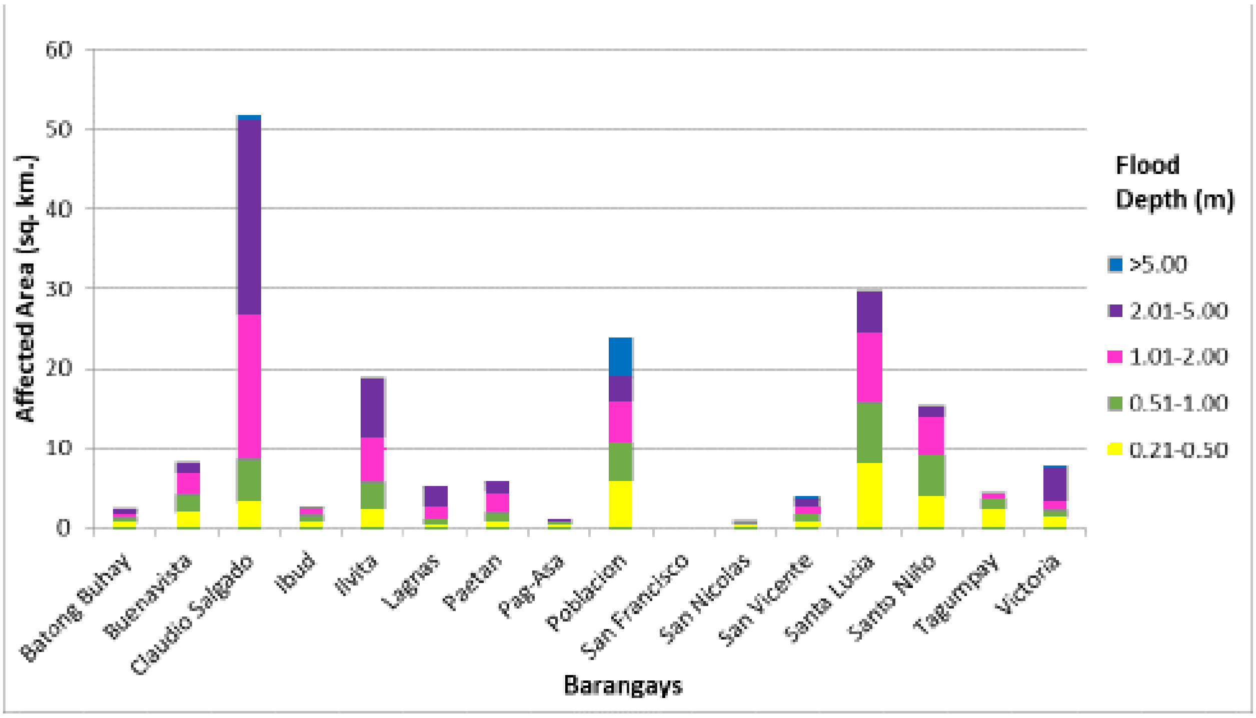


Figure 77. Affected Areas in Sablayan, Occidental Mindoro during 100-Year Rainfall Return Period

For the municipality of Santa Cruz, with an area of 689.03 sq. km., 12.5% will experience flood levels of less 0.20 meters. 1.37% of the area will experience flood levels of 0.21 to 0.50 meters while 2.04%, 3.94%, 1.58%, and 0.11% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 and shown in Figure 78 are the areas affected in Santa Cruz in square kilometers by flood depth per barangay.

Table 40. Affected areas in Santa Cruz, Occidental Mindoro during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Santa Cruz (in sq. km.)			
	Barahan	Dayap	Lumangbayan	Pinagturilan
0.03-0.20	8.86	17.23	8.8	50.95
0.21-0.50	1.57	1.38	0.26	6.22
0.51-1.00	2.49	2.64	0.1	8.86
1.01-2.00	5.42	5.34	0.061	16.3
2.01-5.00	1.69	0.78	0.066	8.34
> 5.00	0	0.0066	0.015	0.71

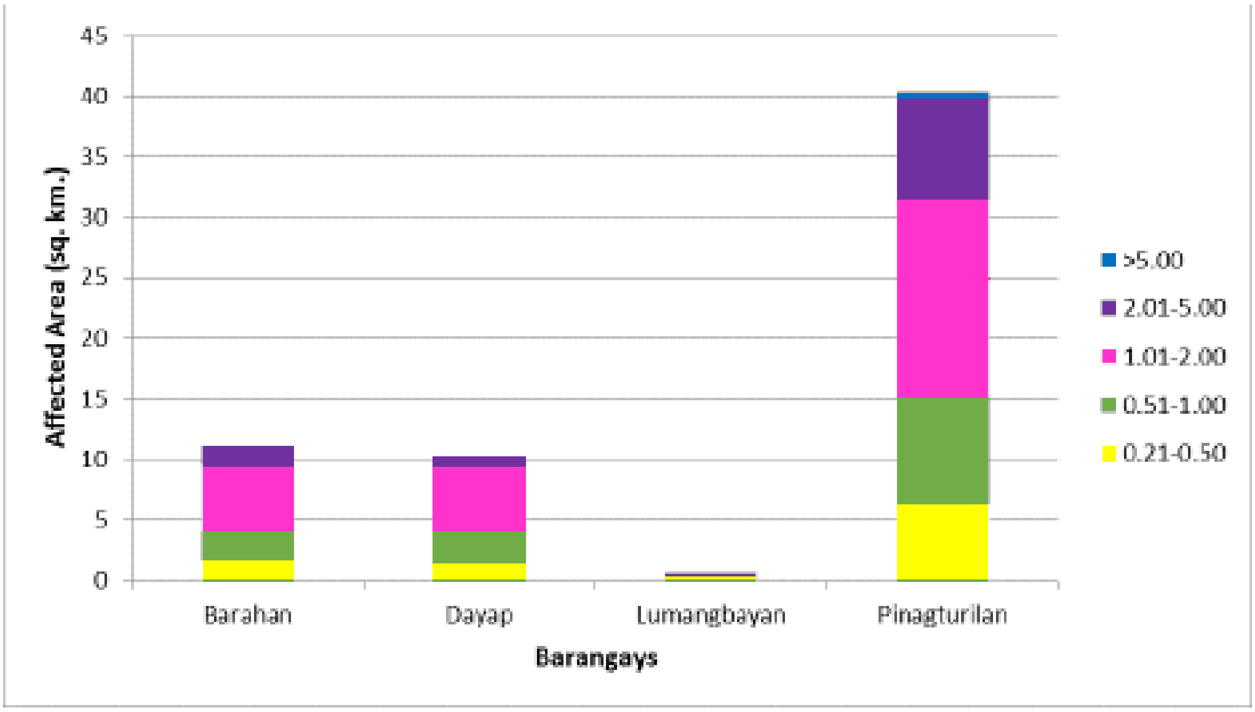


Figure 78. Affected areas in Santa Cruz, Occidental Mindoro during the 100-Year Rainfall Return Period

Among the barangays in the municipality of Sablayan, Santa Lucia is projected to have the highest percentage of area that will experience flood levels at 3.48%. Meanwhile, Poblacion posted the second highest percentage of area that may be affected by flood depths at 2.95%.

Among the barangays in the municipality of Santa Cruz, Pinagturilan is projected to have the highest percentage of area that will experience flood levels at 13.26%. Meanwhile, Dayap posted the second highest percentage of area that may be affected by flood depths at 3.97%.

5.11 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 were identified for validation.

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

After which, the actual data from the field was compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 80.

The flood validation consists of 94 points randomly selected all over the Mompong floodplain (Figure 79). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.32m. Table 41 shows a contingency matrix of the comparison.

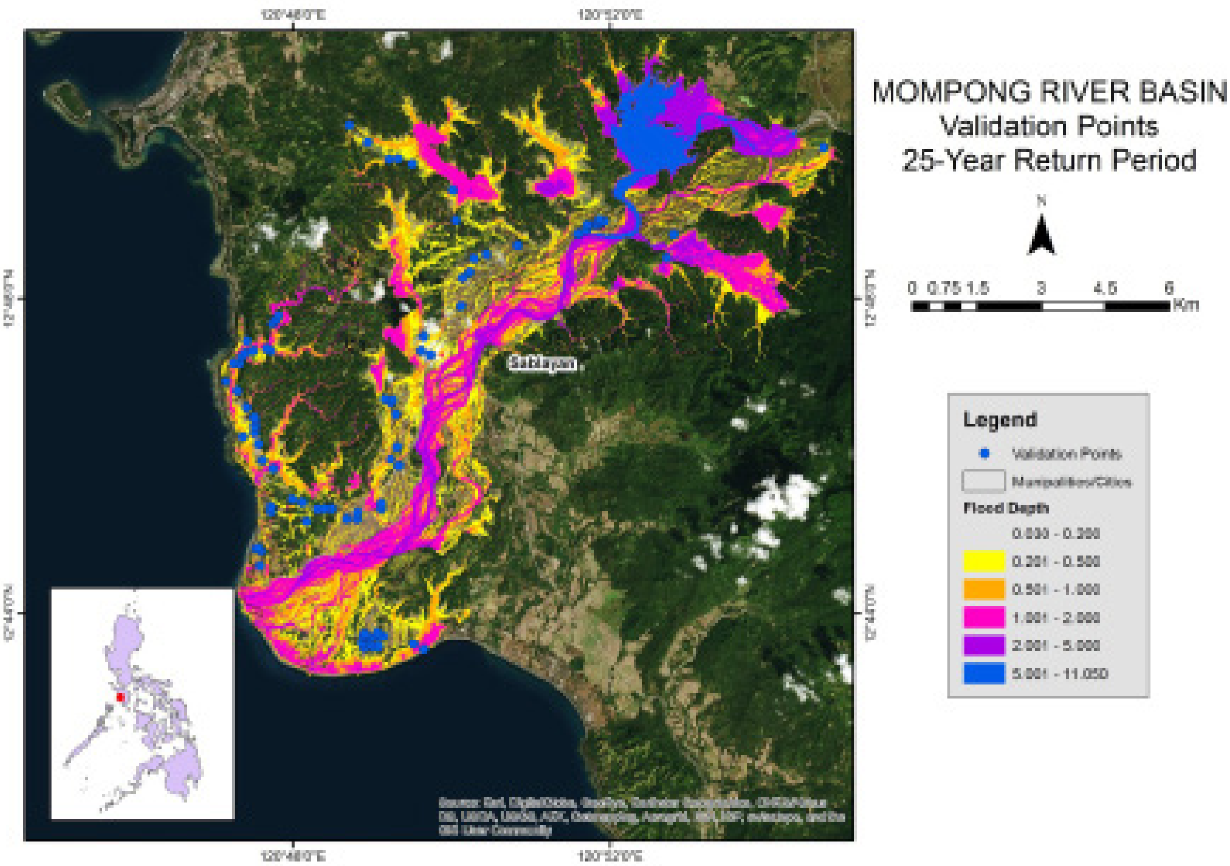


Figure 79. Validation points for 25-year Flood Depth Map of Mompong Floodplain

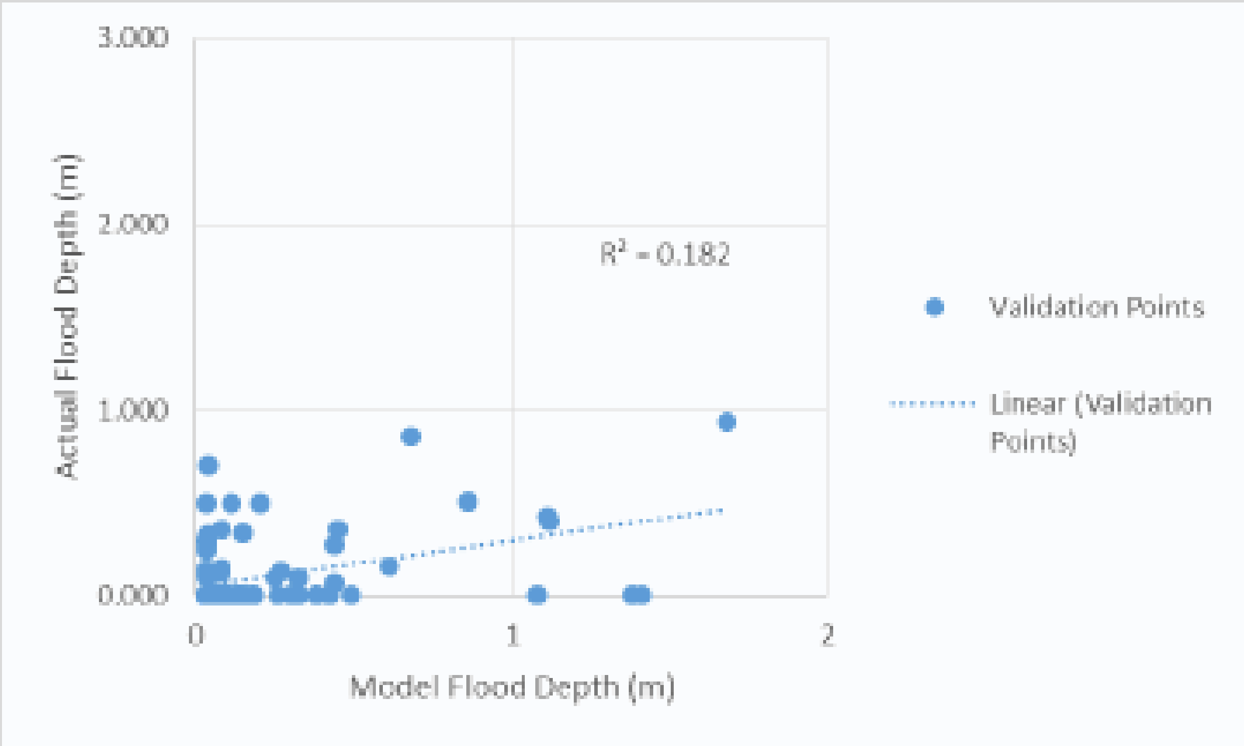


Figure 80. Flood map depth vs actual flood depth

Table 41. Actual flood vs simulated flood depth at different levels in the Mompong River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	62	11	1	3	0	0	77
0.21-0.50	9	2	0	2	0	0	13
0.51-1.00	1	0	2	1	0	0	4
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	72	13	3	6	0	0	94

The overall accuracy generated by the flood model is estimated at 70.21% with 66 points correctly matching the actual flood depths. In addition, there were 21 points estimated one level above and below the correct flood depths while there were 4 points and 3 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 10 points were underestimated in the modelled flood depths of Mompong. Table 42 depicts the summary of the Accuracy Assessment in the Mompong River Basin Survey.

Table 42. The summary of the Accuracy Assessment in the Mompong River Basin Survey

	No. of Points	%
Correct	66	70.21
Overestimated	18	19.15
Underestimated	10	10.64
Total	94	100.00

REFERENCES

Ang M.C., 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.C., Lagmay, A.F., 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.J.S., Paringit E.C., et al. 2014. DREAM Data Aquisition Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

ANNEXES

Annex 1. Optech Technical Specification of the Aquarius and Pegasus Sensors

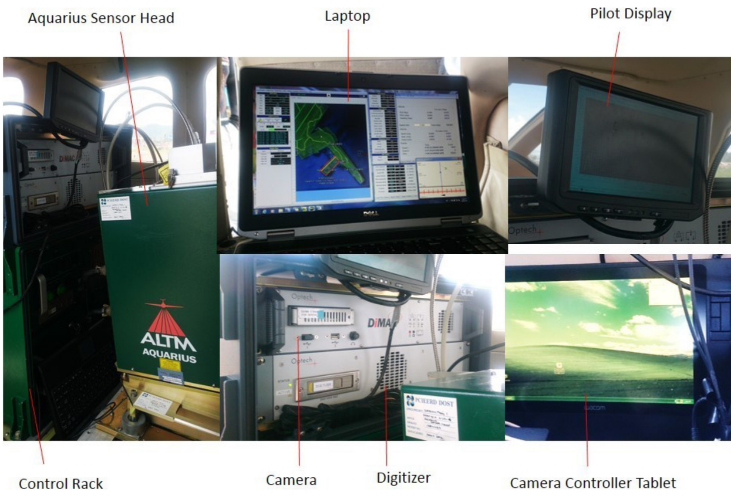


Figure A-1.1 Aquarius Sensor

Table A-1.1 Parameters and Specifications of the Aquarius Sensor

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

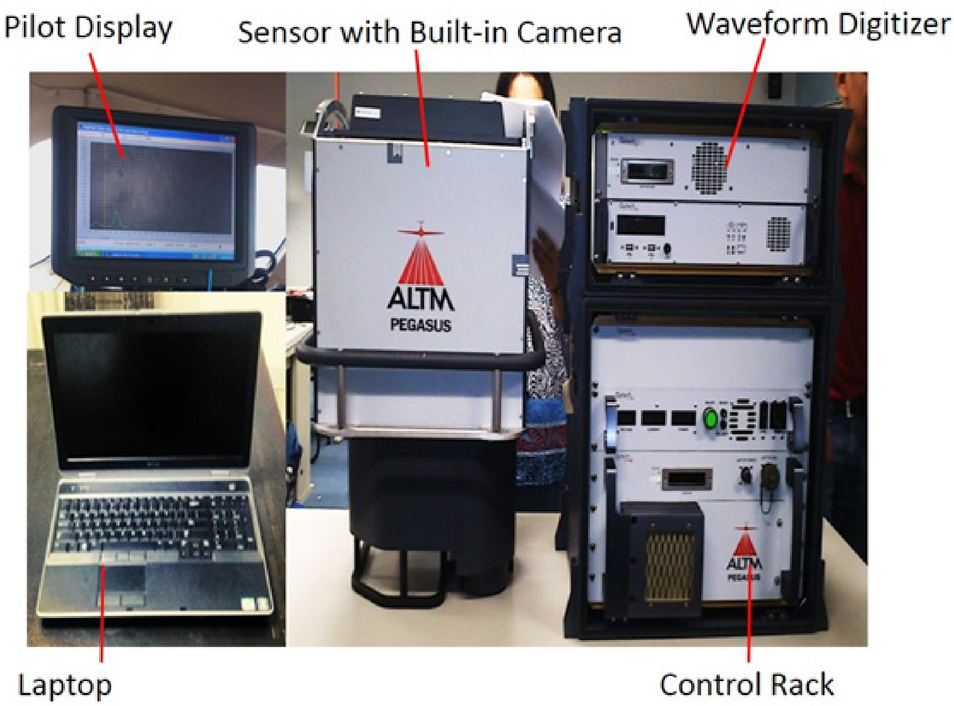


Figure A-1.2 Pegasus Sensor

Table A-1.2 Parameters and Specifications of the Pegasus Sensor

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

Annex 2. NAMRIA Certificates of Reference Points Used

1. MRW-6

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

February 19, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-6 (PCP-2992A)**
Order: **3rd**

Island: **LUZON**
Municipality: **SABLAYAN**
Barangay: **YAPANG**

PRS92 Coordinates

Latitude: **12° 52' 40.22762"**	Longitude: **120° 55' 6.44586"**	Ellipsoidal Hgt: **80.63530 m.**

WGS84 Coordinates

Latitude: **12° 52' 35.21155"**	Longitude: **120° 55' 11.48810"**	Ellipsoidal Hgt: **128.69600 m.**

PTM Coordinates

Northing: **1424038.201 m.**	Easting: **491149.868 m.**	Zone: **3**

UTM Coordinates

Northing: **1,424,453.14**	Easting: **274,116.83**	Zone: **51**

Location Description

MRW-6 (PCP-2992)
From the Depeartment of Agrarian Reform Office in Yapang, travel north along the national road for about 5 Kms. up to Patrick bridge. The point is permanently marked and located at the NW end of the catwalk of Patrick bridge and about 15 meters southwest of Km. Post 344. Mark is a 4" copper nail drilled in a hole and cement flush to the catwalk with inscription "MRW-6, 1993, NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795394 A**
T.N.: **2014-357**

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

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9902192014141007

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

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

Figure A-2.1. MRW-6

2. MRW-30

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

February 19, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-6 (PCP-2992A)**
Order: **3rd**

Island: **LUZON**		Barangay: **YAPANG**
Municipality: **SABLAYAN**		
	PRS92 Coordinates	
Latitude: **12° 52' 40.22762"**	Longitude: **120° 55' 6.44586"**	Ellipsoidal Hgt: **80.63530 m.**
	WGS84 Coordinates	
Latitude: **12° 52' 35.21155"**	Longitude: **120° 55' 11.48810"**	Ellipsoidal Hgt: **128.69600 m.**
	PTM Coordinates	
Northing: **1424038.201 m.**	Easting: **491149.868 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,424,453.14**	Easting: **274,116.83**	Zone: **51**

Location Description

MRW-6 (PCP-2992)
From the Depeartment of Agrarian Reform Office in Yapang, travel north along the national road for about 5 Kms. up to Patrick bridge. The point is permanently marked and located at the NW end of the catwalk of Patrick bridge and about 15 meters southwest of Km. Post 344. Mark is a 4" copper nail drilled in a hole and cement flush to the catwalk with inscription "MRW-6, 1993, NAMRIA".

Requesting Party:	**UP DREAM**
Pupose:	**Reference**
OR Number:	**8795394 A**
T.N.:	**2014-357**

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

9902192014141007

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

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Figure A-2.2. MRW-30

3. MRW-32

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

February 26, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-32**
Order: **2nd**

Island: **LUZON**
Municipality: **MAMBURAO (CAPITAL)**
Barangay: **FATIMA (TII)**

PRS92 Coordinates

Latitude: **13° 10' 14.92094"**	Longitude: **120° 39' 52.29557"**	Ellipsoidal Hgt: **1.47400 m.**

WGS84 Coordinates

Latitude: **13° 10' 9.81293"**	Longitude: **120° 39' 57.31386"**	Ellipsoidal Hgt: **48.13600 m.**

PTM Coordinates

Northing: **1456469.064 m.**	Easting: **463632.46 m.**	Zone: **3**

UTM Coordinates

Northing: **1,457,111.12**	Easting: **246,845.90**	Zone: **51**

Location Description

MRW-32
From Abra de Ilog to San Jose, along Nat'l Road, approx. 11.4 Km. from Mamburao Town Proper, 400 m from Km. post 396, 12.6 Km. before Sta. Cruz Town Proper, right side of road located brgy. hall of Fatima, Mamburao, Occ. Mindoro, beside Fatima Elem. School. Station is located in corner fence of Day Care Center. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-32, 2007, NAMRIA".

Requesting Party:	**UP DREAM**
Pupose:	**Reference**
OR Number:	**8795440 A**
T.N.:	**2014-397**

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

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Figure A-2.3. MRW-32

4. MRW-34

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

February 26, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-34**
Order: **2nd**

Island: **LUZON**		Barangay: **ARMADO**
Municipality: **ABRA DE ILOG**		
	PRS92 Coordinates	
Latitude: **13° 17' 25.00981"**	Longitude: **120° 37' 41.53630"**	Ellipsoidal Hgt: **8.01600 m.**
	WGS84 Coordinates	
Latitude: **13° 17' 19.87026"**	Longitude: **120° 37' 46.54446"**	Ellipsoidal Hgt: **54.26900 m.**
	PTM Coordinates	
Northing: **1469690.588 m.**	Easting: **459714.493 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,470,369.33**	Easting: **243,032.08**	Zone: **51**

Location Description

MRW-34

From Abra de Ilog to San Jose, along Nat'l Road approx. 20.3 Km. from Abra de Ilog Town Proper, 300 m from Km. post 418, 9.7 Km. before Mamburao Proper, located Balibago Bridge at Brgy. Armado, Sitio Balibago, Abra de Ilog, Occ. Mindoro. Station is located near footpath of Balibago Bridge. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-34, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795440 A**
T.N.: **2014-396**

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

9902262014143532

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CIP/4701/12/09/814

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Figure A-2.4. MRW-34

5. MRW-54

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-54**
Order: **2nd**

Island: **LUZON**
Municipality: **SABLAYAN**
Barangay: **MALISBONG**

PRS92 Coordinates

Latitude:	**12° 46' 18.56204"**	Longitude:	**120° 50' 27.44152"**	Ellipsoidal Hgt:	**28.20700 m.**

WGS84 Coordinates

Latitude:	**12° 46' 13.56455"**	Longitude:	**120° 50' 32.49343"**	Ellipsoidal Hgt:	**76.35500 m.**

PTM Coordinates

Northing:	**1412314.677 m.**	Easting:	**482731.146 m.**	Zone:	**3**

UTM Coordinates

Northing:	**1,412,791.69**	Easting:	**265,604.90**	Zone:	**51**

Location Description

MRW-54

From Abra de Ilog to San Jose, along Nat'l Road, turn right to Brgy. Road, approx. 1.1 Km. travel, right side of Brgy. Road located brgy. hall boundary of Malisbong, Sablayan, Occ., Mindoro. Station is located at the back of goal post of basketball court. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-54, 2007, NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795470 A**
T.N.:	**2014-445**

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

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Figure A-2.5. MRW-54

6. MC-121

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

February 10, 2016

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MC-121**

Island: **Luzon**	Municipality: **SABLAYAN**	Barangay: **BATONG BUHAY**
Elevation: **77.8103 +/- 0.14 m.**	Accuracy Class at 95% C.L:	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

MC-121
Marked is the head of a 4" copper nail flushed in a cement block embedded in the ground with inscription MC-121 2007 NAMRIA". The station is in Sitio Yapang Brgy. Batong Buhay, Sablayan Occidental Mindoro. From Sablayan located along National road in the South end of the Catwalk of Patrick bridge.

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8089774 I**
T.N.:	**2016-0330**

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

9902102016122044

CIP/4701/12/09/814

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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.6. MC-121

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

Project information		Coordinate System	
Name:	I:\Doc\DAC\2015\Fieldwork\2015-12-3_17 Mamburao, Occidental Mindoro\Baseline Processing Reports\2015-dec mamburao, occ mindoro.vce	Name:	UTM
		Datum:	PRS 92
		Zone:	51 North (123E)
Size:	779 KB	Geoid:	EGMPH
Modified:	7/14/2016 3:00:46 PM (UTC:8)	Vertical datum:	
Time zone:	Taipei Standard Time		
Reference number:			
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRW-6 --- MC-121 (B6)	MRW-6	MC-121	Fixed	0.002	0.004	195°39'56"	232.244	-0.011

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

MRW-6 - MC-121 (7:30:43 AM-10:37:36 AM) (S6)

Baseline observation:	MRW-6 --- MC-121 (B6)
Processed:	7/14/2016 2:46:55 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.002 m
Vertical precision:	0.004 m
RMS:	0.000 m
Maximum PDOP:	2.183
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	12/9/2015 7:30:43 AM (Local: UTC+8hr)
Processing stop time:	12/9/2015 10:37:36 AM (Local: UTC+8hr)
Processing duration:	03:06:53
Processing interval:	1 second

1

Figure A-3.1. Baseline Processing Report - A

Vector Components (Mark to Mark)

From:	MRW-6				
Grid		Local		Global	
Easting	274116.940 m	Latitude	N12°52'40.23826"	Latitude	N12°52'35.22171"
Northing	1424453.462 m	Longitude	E120°55'06.44928"	Longitude	E120°55'11.49159"
Elevation	80.387 m	Height	79.981 m	Height	128.042 m

To:	MC-121				
Grid		Local		Global	
Easting	274052.406 m	Latitude	N12°52'32.96110"	Latitude	N12°52'27.94499"
Northing	1424230.309 m	Longitude	E120°55'04.36932"	Longitude	E120°55'09.41181"
Elevation	80.376 m	Height	79.971 m	Height	128.035 m

Vector					
ΔEasting	-64.535 m	NS Fwd Azimuth	195°39'56"	ΔX	28.194 m
ΔNorthing	-223.153 m	Ellipsoid Dist.	232.244 m	ΔY	74.963 m
ΔElevation	-0.011 m	ΔHeight	-0.011 m	ΔZ	-218.000 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'01"	σ ΔX	0.001 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.002 m
σ ΔElevation	0.002 m	σ ΔHeight	0.002 m	σ ΔZ	0.001 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000017736		
Y	-0.0000014707	0.0000026993	
Z	-0.0000001320	0.0000005128	0.0000003728

2

Figure A-3.2. Baseline Processing Report - B

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRWDAC-00 --- MRW-30 (B1)	MRW-30	MRWDAC-00	Fixed	0.003	0.011	312°40'19"	43136.391	-30.412
MRWDAC-00 --- MRW-30 (B2)	MRW-30	MRWDAC-00	Fixed	0.006	0.016	312°40'19"	43136.383	-30.384

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

MRWDAC-00 - MRW-30 (7:22:03 AM-9:48:26 AM) (S1)

Baseline observation:	MRWDAC-00 --- MRW-30 (B1)
Processed:	12/15/2015 5:32:10 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.003 m
Vertical precision:	0.011 m
RMS:	0.004 m
Maximum PDOP:	2.308
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	12/8/2015 7:22:11 AM (Local: UTC+8hr)
Processing stop time:	12/8/2015 9:48:26 AM (Local: UTC+8hr)
Processing duration:	02:26:15
Processing interval:	1 second

1

Figure A-3.3. Baseline Processing Report – C

Vector Components (Mark to Mark)

From:	MRW-30				
Grid		Local		Global	
Easting	271237.336 m	Latitude	N12°57'32.22951"	Latitude	N12°57'27.19115"
Northing	1433451.975 m	Longitude	E120°53'28.50896"	Longitude	E120°53'33.54442"
Elevation	42.722 m	Height	42.013 m	Height	89.793 m

To:	MRWDAC-00				
Grid		Local		Global	
Easting	239755.834 m	Latitude	N13°13'23.10541"	Latitude	N13°13'17.97945"
Northing	1462963.518 m	Longitude	E120°35'55.10583"	Longitude	E120°36'00.11991"
Elevation	15.198 m	Height	11.601 m	Height	57.961 m

Vector					
ΔEasting	-31481.502 m	NS Fwd Azimuth	312°40'19"	ΔX	30671.804 m
ΔNorthing	29511.543 m	Ellipsoid Dist.	43136.391 m	ΔY	10509.502 m
ΔElevation	-27.524 m	ΔHeight	-30.412 m	ΔZ	28452.496 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000093026		
Y	-0.0000128686	0.0000223985	
Z	-0.0000041460	0.0000065394	0.0000035059

2

Figure A-3.4. Baseline Processing Report – D

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist	PAULINE JOANNE ARCEO	UP-TACGP
	Research Associate (RA)	PATRICIA YSABEL ALCANTARA	UP-TCAGP
	RA	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
	RA	ENGR. MILLIE SHANE REYES	UP-TCAGP
	RA	GRACE SINADJAN	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. FRANK NICOLAS ILEJAY	UP-TCAGP
	RA	GRACE SINADJAN	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. ERIC CACANINDIN	PHILIPPINE AIR FORCE (PAF)
		SSG. BENJAMIN CARBOLLEDO	PAF
	Pilot	CAPT. JEFFREY JEREMY ALAAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JACKSON JAVIER	AAC
		CAPT. SHERWIN ALFONSO III	AAC
		CAPT. JUSTINE JOYA	AAC

Annex 5. Data Transfer Sheets

DATA TRANSFER SHEET
Mar 4, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
16-2-14	1108A	3BLK29J47A	AQUARIUS	NA	368KB	622KB	134MB	699MB	2/1/6/1KB	5.37GB	NA	14MB	1KB	1KB	194KB	N/A	X:\Airborne_Raw\1108A
16-2-14	1110A	3BLK29K47B	AQUARIUS	NA	562/138KB	1.01MB	240MB	39.7 ~~14.7~~GB	1KB	13.3GB	43.6GB	14MB	1KB	1KB	46KB	N/A	X:\Airborne_Raw\1110A
18-2-14	1116A	3BLK29KS49A	AQUARIUS	NA	659KB	4.08MB	245MB	71.7GB	32/165/2535KB	12GB	61.6GB	15.3MB	1KB	1KB	46KB	N/A	X:\Airborne_Raw\1116A
18-2-14	1118A	3BLK29JS49B	AQUARIUS	NA	540KB	1.04MB	204MB	48GB	1/372KB	11.3GB	59.2GB	15.3MB	1KB	1KB	211KB	N/A	X:\Airborne_Raw\1118A
19-2-14	1120A	3BLK29L50A	AQUARIUS	NA	691KB	1.13MB	251MB	75.8GB	526KB	14.2GB	19.8GB	13.2MB	1KB	1KB	252KB	N/A	X:\Airborne_Raw\1120A
19-2-14	1122A	3BLK29O50B	AQUARIUS	NA	168KB	1.48MB	98.3MB	17.1GB	3/150KB	3.74GB	17.3GB	13.2MB	1KB	1KB	57KB	N/A	X:\Airborne_Raw\1122A
20-2-14	1124A	3BLK29OS51A	AQUARIUS	NA	308KB	1.34MB	246MB	75.4GB ~~42.5GB~~	1/103/418/24KB	12.6GB	16.7GB	17.7MB	1KB	1KB	18KB	N/A	X:\Airborne_Raw\1124A
20-2-14	1126A	3BLK29M51B	AQUARIUS	NA	803KB	1.71MB	235MB	78GB	NA	13.9GB	74.8GB	17.7MB	1KB	1KB	NA	N/A	X:\Airborne_Raw\1126A

Received from
Name CHRIS JOAQUIN
Position RA
Signature

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature

Figure A-5.1. Data Transfer Sheet for Mompong Floodplain - A

DATA TRANSFER SHEET
Mar 19, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Jan 15, 2014	989P	1PAMS015A	PEGASUS	1.02MB	NA	5.85MB	168MB	NA	NA	9.2GB	N/A	11MB	1KB	1KB	NA	N/A	X:\Airborne_Raw\989P
Jan 21, 2014	1004A	3PNG1AB021A	AQUARIUS	NA	NA	620KB	209MB	23.4GB	194KB	10.6GB	47.7GB	8.24MB	1KB	2KB	7/114/114KB	389/16KN	X:\Airborne_Raw\1004A
Jan 21, 2014	1006A	3PNG1ABS021B	AQUARIS	NA	NA	214KB	128MB	6.78GB	65KB	4.08GB	15.5GB	8.24MB	1KB	1KB	16/46/7KB	124KB	X:\Airborne_Raw\1006A
Jan 22, 2014	1008A	3PNG1AS022A	AQUARIUS	NA	NA	482KB	204MB	26.3GB	209KB	8.14GB	33.1GB	10.6MB	1KB	1KB	1/7/101KB	281KB	X:\Airborne_Raw\1008A
Feb 21, 2014	1128A	3BLK29I52A	AQUARIUS	NA	NA	1.34MB	269MB	6.32GB	1/672KB	16.1GB	NA	12.3MB	1KB	1KB	6/303KB	854KB	X:\Airborne_Raw\1128A
Feb 22, 2014	1132A	3BLK29IS53A/3BLK29H53A	AQUARIUS	NA	NA	1.62MB	276MB	34.3GB	251/1/326KB	16.1GB	63.7GB	13.4MB	1KB	1KB	432KB	383/506/320/384KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1132A
Feb 22, 2014	1134A	3BLK29MS53B/3BLK29MR53B	AQUARIUS	NA	NA	1.08MB	144MB	27.8GB	105/28/1/30/55/44KB	4.99GB	12.6GB	13.4MB	1KB	1KB	102KB	131KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1134A
Feb 23, 2014	1136A	3BLK29HS54A/3BLK29HB54A	AQUARIUS	NA	NA	1.37MB	256MB	86.5GB	227/337/61KB	15GB	NA	15.6MB	1KB	1KB	268KB	265/265/520/36KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1136A
Feb 23, 2014	1138A	3BLK29E54B	AQUARIUS	NA	NA	833KB	196MB	50.4GB	408KB	8.89GB	42.6GB	15.6MB	1KB	1KB	172KB	500KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1138A
Feb 24, 2014	1140A	3BLK29ES55A/3BLK29G55A	AQUARIUS	NA	NA	961KB	241MB	53.3GB	401KB	9.99GB	40.8GB	12.1MB	1KB	1KB	387KB	244/264KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1140A
Feb 24, 2014	1142A	3BLK29P55B	AQUARIUS	NA	NA	2.04MB	228MB	61.7GB	56/490KB	12.4GB	64.2GB	12.1MB	1KB	1KB	709KB	247KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1142A

TRANSFERRED IN FREENAS.

Received from

Name CHRIS JOAQUIN

Position RA

Signature

Received by

Name JOIDA PRIETO

Position SSRS

Signature

Figure A-5.2. Data Transfer Sheet for Mompong Floodplain - B

DATA TRANSFER SHEET
Occ. Mindoro 1/13/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
6-Dec-15	3058P	1BLK29C340A	pegasus	752	189	5.69	120	9.79	74	7.56	na	15.4	1KB	1KB	40	na	Z:\DAC\RAW DATA
6-Dec-15	3060P	1BLK29DE340B	pegasus	460	108	3.43	115	6.09	48	4.79	na	15.4	1KB	1KB	394/344/58	na	Z:\DAC\RAW DATA
7-Dec-15	3062P	1BLK29BCS341A	pegasus	1.45	430	9.18	206	26.6	192	14.4	na	7.51	1KB	1KB	100/89/95	na	Z:\DAC\RAW DATA
8-Dec-15	3066P	1BLK29ACDI342A	pegasus	982	276	7.18	177	17	121	9.79	na	16	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
8-Dec-15	3068P	1BLK29GJ342B	pegasus	0	67	2.7	114	4.63	37	2.77	na	16	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
9-Dec-15	3070P	1BLK29GHI343A	pegasus	953	217	5.7	143	14.3	na	9.37	na	5.96	1KB	1KB	146/156	na	Z:\DAC\RAW DATA
10-Dec-15	3074P	1BLK29KLMO344A	pegasus	2.09	212	9.12	225	30.9	224	20.7	na	14.1	1KB	1KB	313	na	Z:\DAC\RAW DATA
10-Dec-15	3076P	1BLK29P344B	pegasus	259	73	3.5	102	4.32	34	3.2	na	14.1	1KB	1KB	366/318/295/313/146/156	na	Z:\DAC\RAW DATA
11-Dec-15	3078P	1BLK29NQRS345A	pegasus	551	171	5.23	167	12.9	105	6.2	na	7.02	1KB	1KB	47/394/344/313/140	na	Z:\DAC\RAW DATA
12-Dec-15	3082P	1BLK29R346A	pegasus	932	206	6.85	174	13.1	95	9.22	na	7.61	1KB	1KB	47/140	na	Z:\DAC\RAW DATA

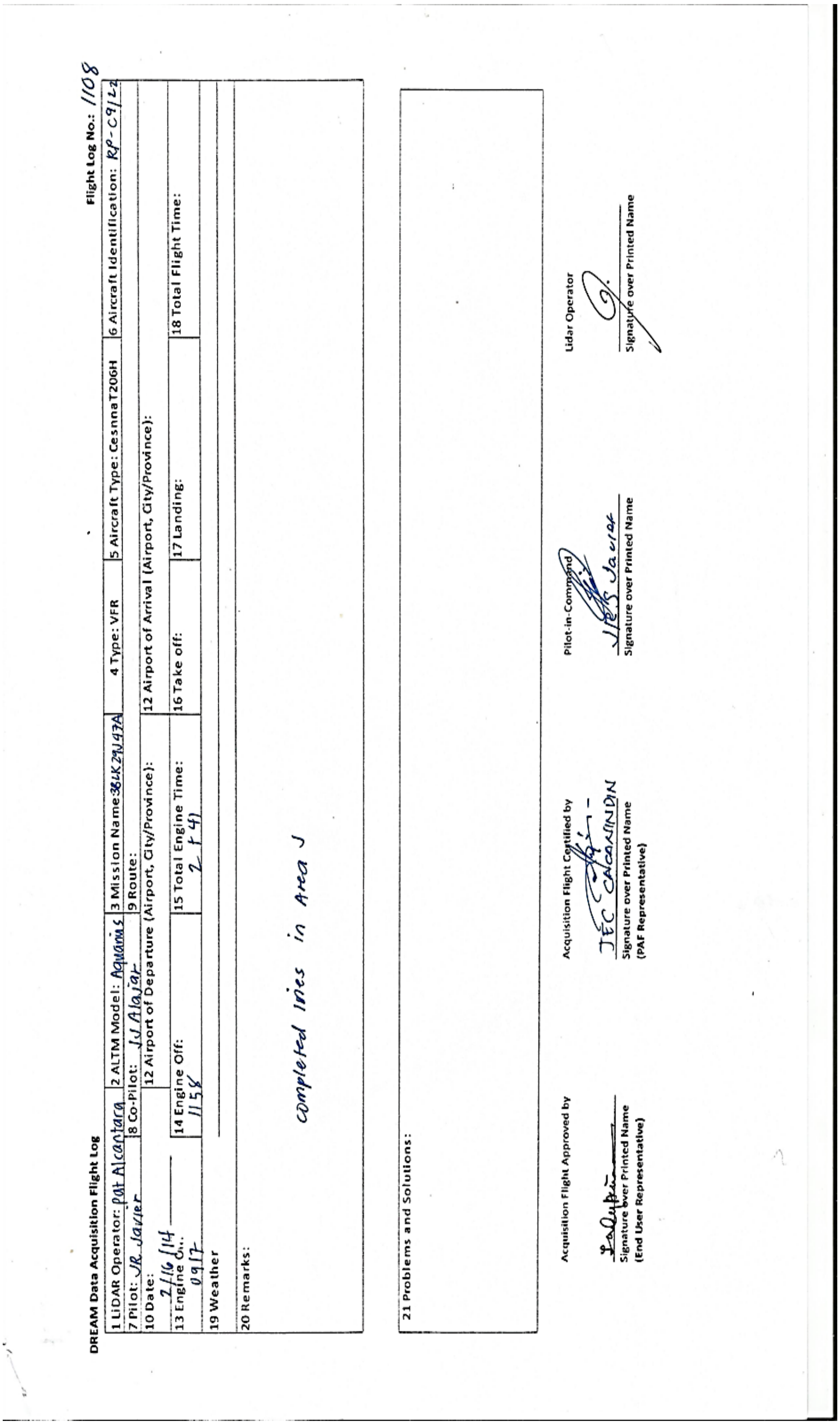
Received from
Name C. Joaquin
Position
Signature

Received by
Name AC Bongat
Position SSRA
Signature 1/15/16

Figure A-5.3. Data Transfer Sheet for Mompong Floodplain - C

Annex 6. Flight Logs

1. Flight Log for 3BLK29J47A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1108

1 LIDAR Operator: Pat Alcantara	2 ALTM Model: Aquarius	3 Mission Name: 3BLK29J47A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: JR Javier	8 Co-Pilot: JJ Alajar	9 Route:			
10 Date: 2/16/14	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0917	14 Engine Off: 1158	15 Total Engine Time: 2+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: completed lines in Area J					

21 Problems and Solutions:

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

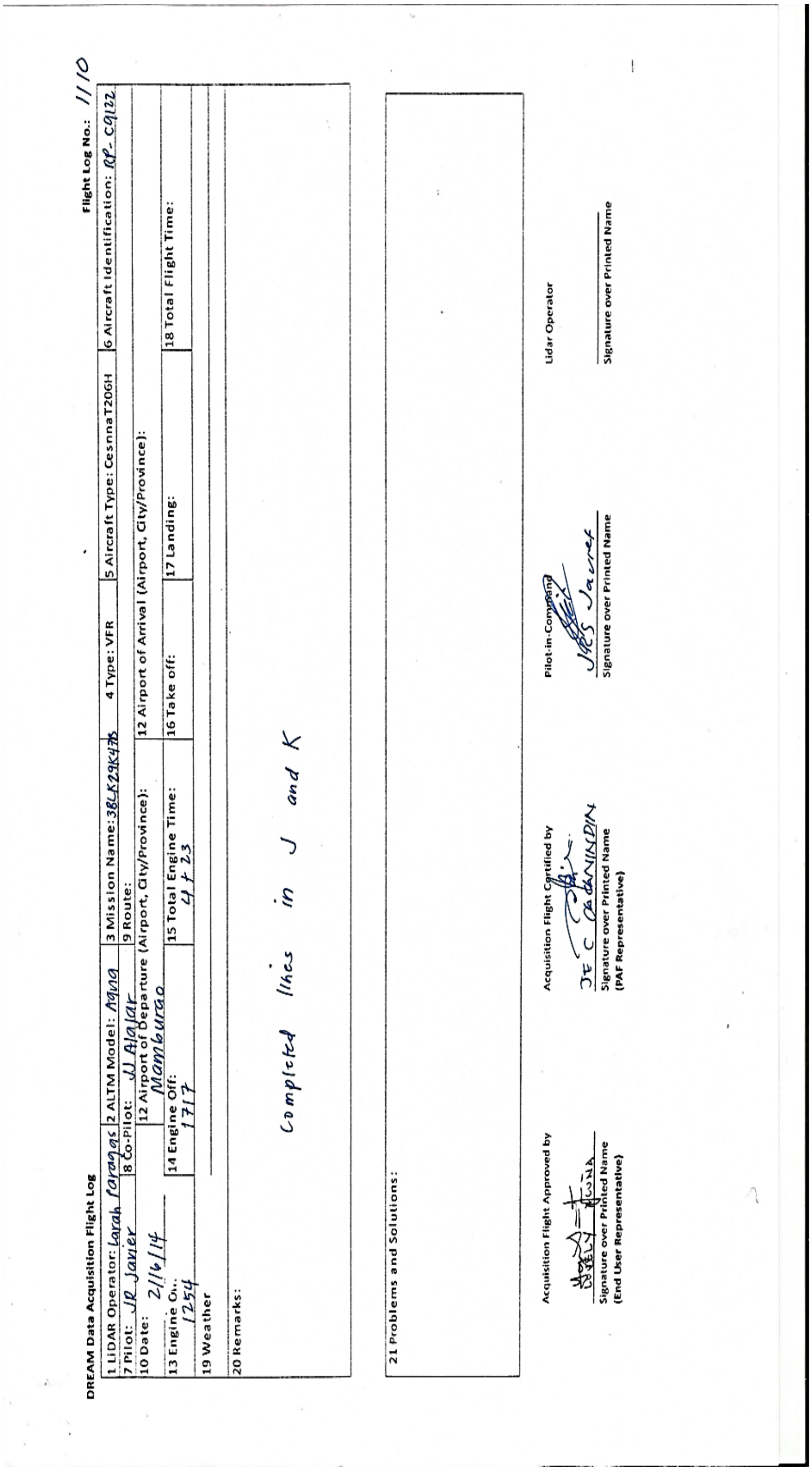
Acquisition Flight Certified by
JEC CACANINDIN
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JR S Javier
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.1. Flight Log for 3BLK29J47A Mission

2. Flight Log for 3BLK29K+JS47B Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1110

1 LiDAR Operator: Larah Paragas	2 ALTM Model: Aqua	3 Mission Name: 3BLK29K47B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9122
7 Pilot: JR Javier	8 Co-Pilot: JJ Alajar	9 Route:			
10 Date: 2/16/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1254	14 Engine Off: 1717	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed lines in J and K

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

JRS Javier

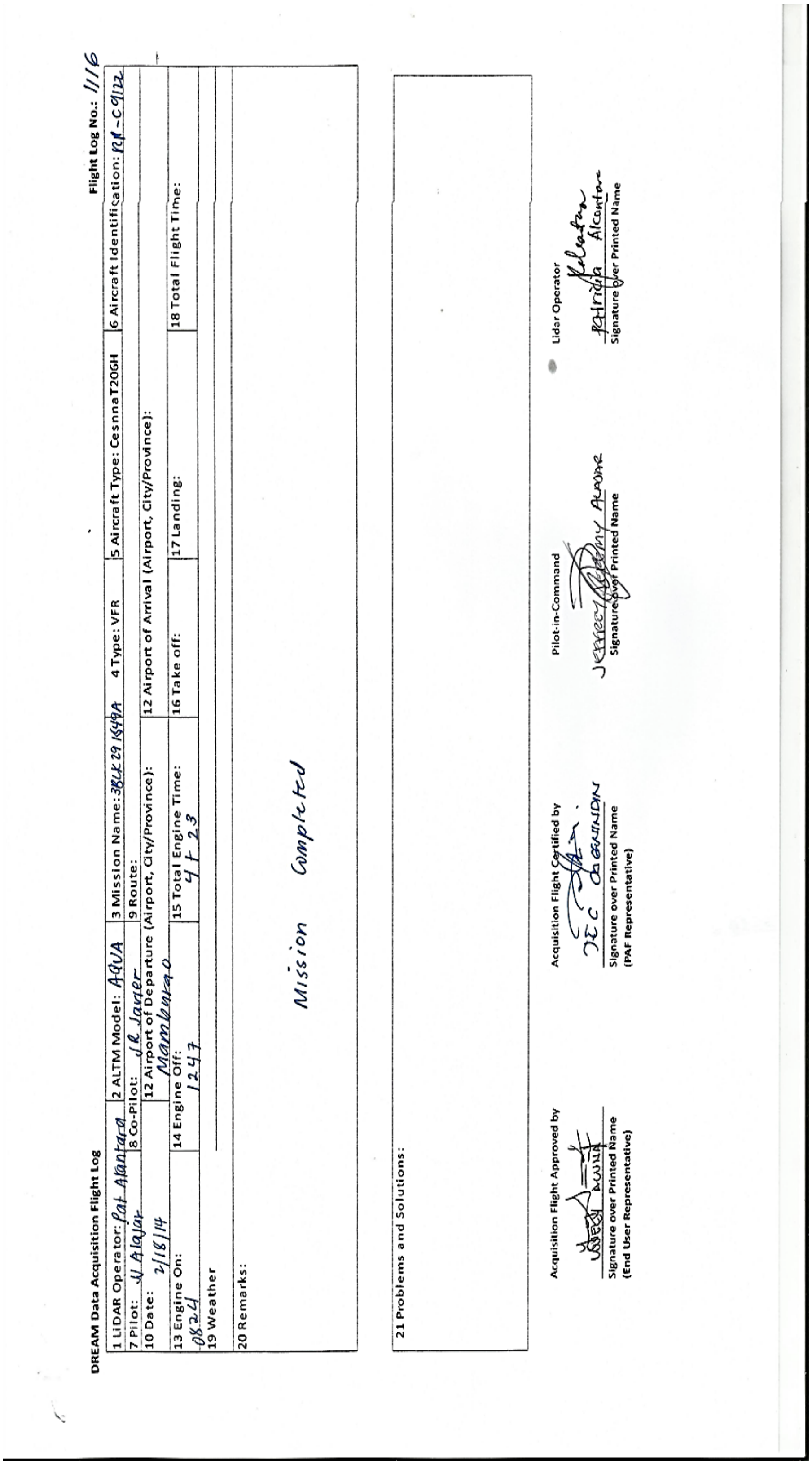
Signature over Printed Name

Lidar Operator

Signature over Printed Name

Figure A-6.2. Flight Log for 3BLK29K+JS47B Mission

3. Flight Log for 3BLK29KS49A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1116

1 LIDAR Operator: Pat Alcantara	2 ALTM Model: AQUA	3 Mission Name: 3BLK29KS49A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: J Alajar	8 Co-Pilot: JR Javier	9 Route:			
10 Date: 2/18/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0824	14 Engine Off: 1247	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission Completed					
21 Problems and Solutions:					

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

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

Pilot-in-Command
Signature over Printed Name

Lidar Operator
Patricia Alcantara
Signature over Printed Name

Figure A-6.3. Flight Log for 3BLK29KS49A Mission

4. Flight Log for 3BLK29JS49B Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1118

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29JS49B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9122
7 Pilot: JR Javier	8 Co-Pilot: JJ Alajar	9 Route:			
10 Date: 2/18/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1400	14 Engine Off: 1735	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission Completed

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Wiley Acuña	JEC Lacanindin	JRS Javier	LK Paragas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.4. Flight Log for 3BLK29JS49B Mission

5. Flight Log for 3BLK29I52A Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1128

1 LIDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29I52A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 2/21/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province): Mamburao		
13 Engine On: 820	14 Engine Off: 1255	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed 15 lines in area I

21 Problems and Solutions:

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

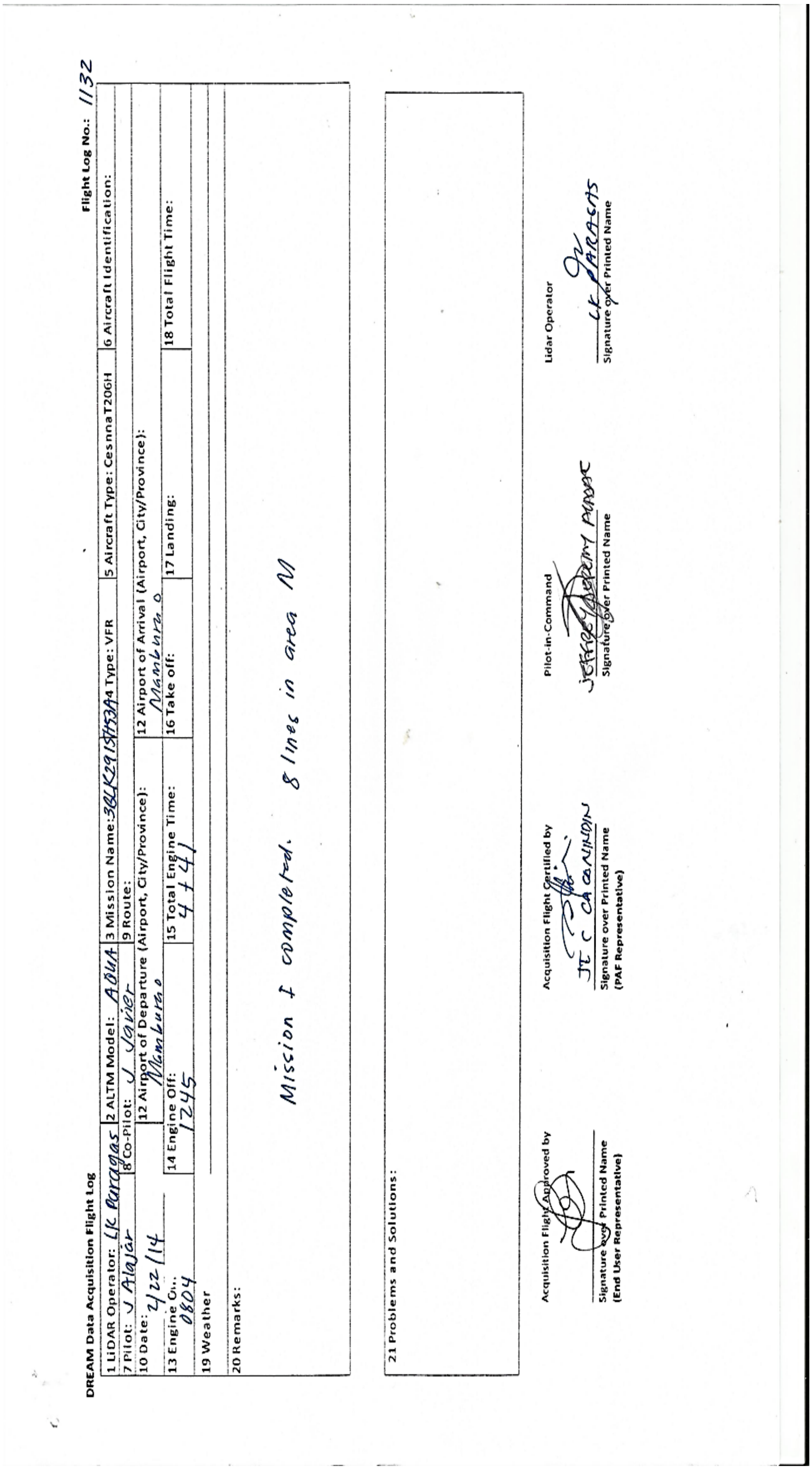
Acquisition Flight Certified by
Teo Cacanindin
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
J R S Javier
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.5. Flight Log for 3BLK29I52A Mission

6. Flight Log for 3BLK29IS+H53A Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 1132

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29IS+H53A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: J Alajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 2/22/14	12 Airport of Departure (Airport, City/Province): Mambusao		12 Airport of Arrival (Airport, City/Province): Mambusao		
13 Engine On: 0804	14 Engine Off: 1245	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission 1 completed. 8 lines in area M

21 Problems and Solutions:

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

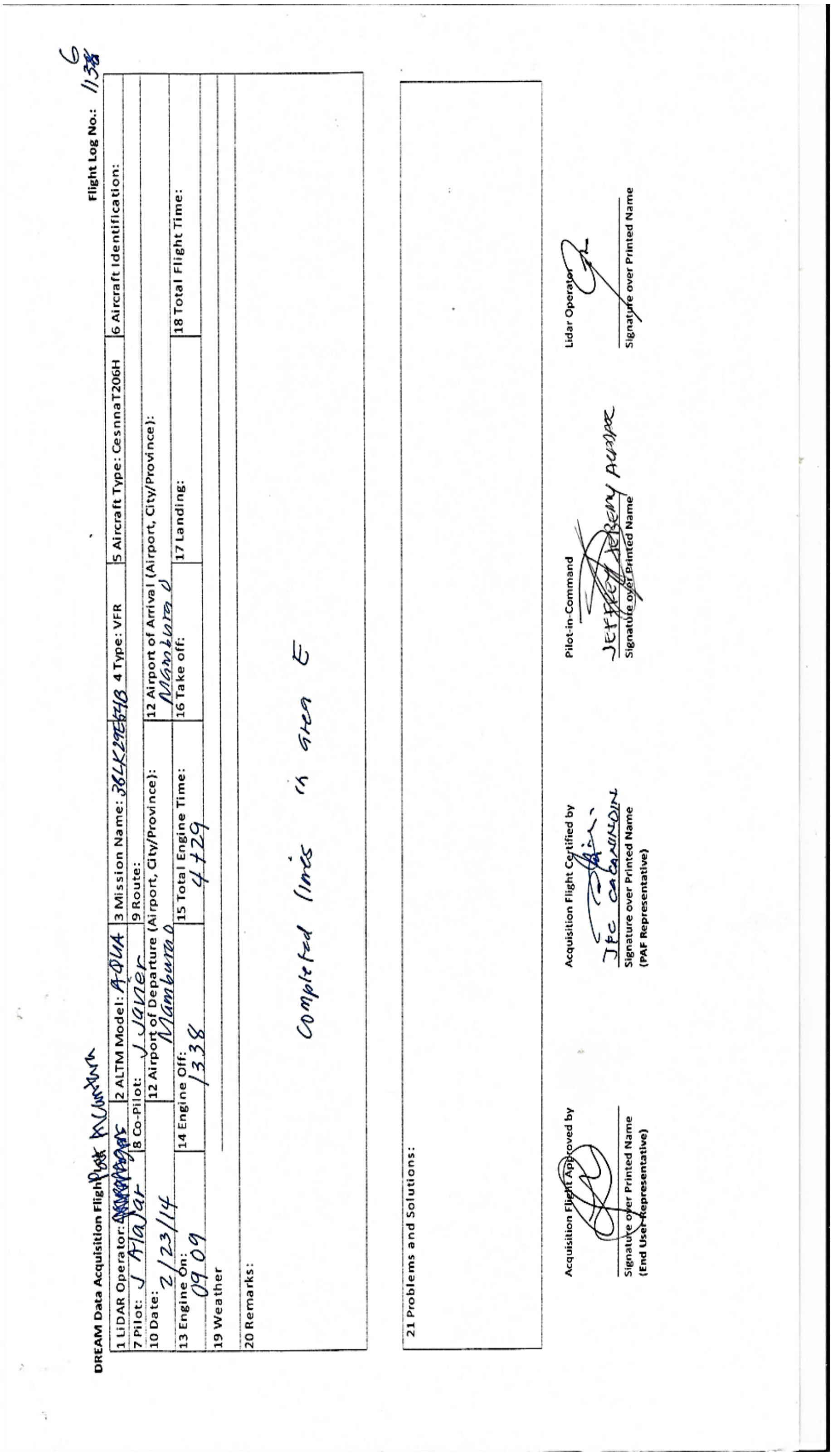
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — LK Paragas — Signature over Printed Name

Figure A-6.6. Flight Log for 3BLK29IS+H53A Mission

7. Flight Log for 3BLK29HS54A/3BLK29HB54A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1136

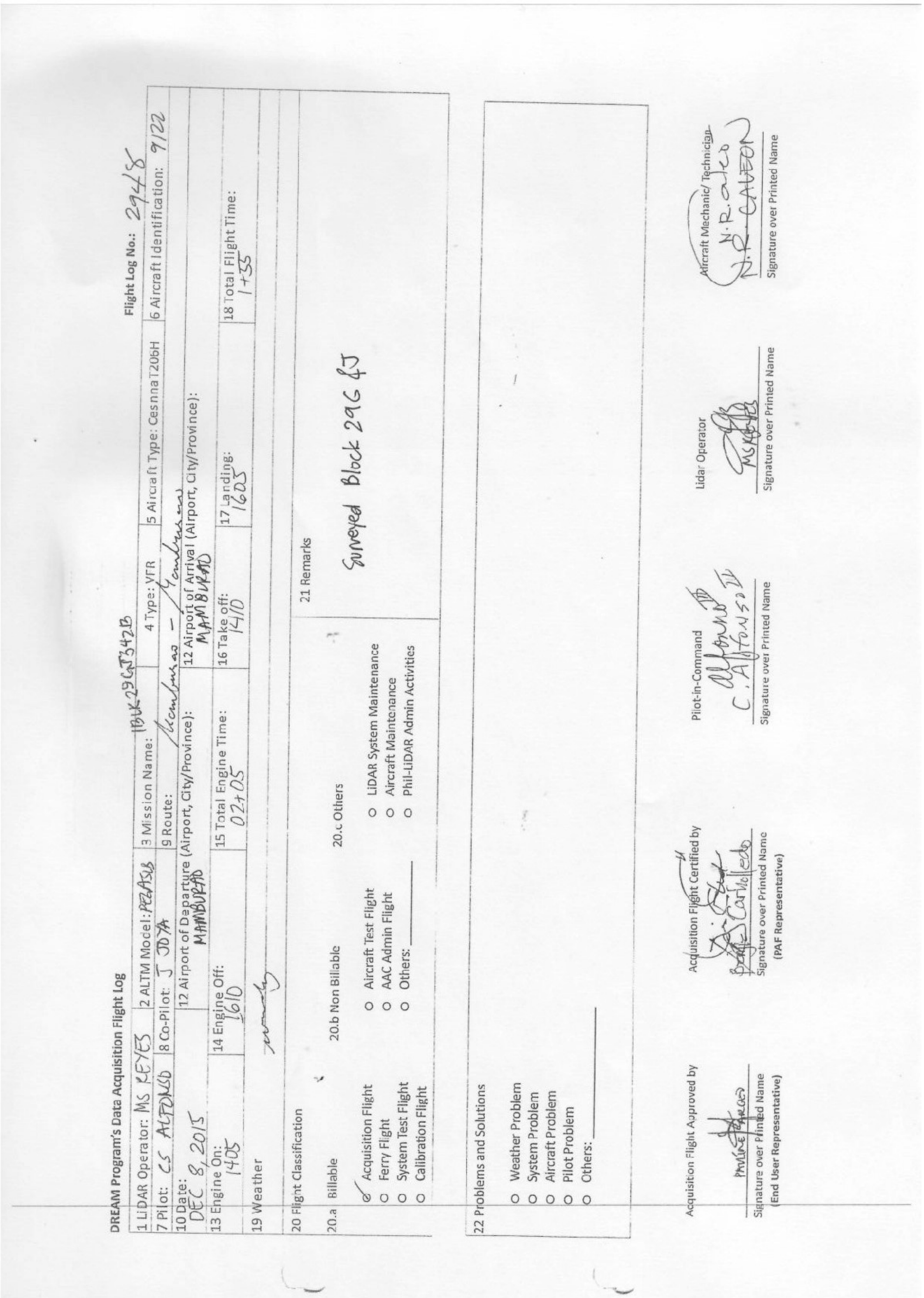
1 LiDAR Operator:	2 ALTM Model: AQUA	3 Mission Name: 3BLK29E54B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Alajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 2/23/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province): Mamburao		
13 Engine On: 0909	14 Engine Off: 1338	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed lines in area E					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	J/C Cagayundin Signature over Printed Name (PAF Representative)	Jeffrey Jeremy Alajar Signature over Printed Name	Signature over Printed Name

Figure A-6.7. Flight Log for 3BLK29HS54A/3BLK29HB54A Mission

8. Flight Log for 1BLK29GJ342B Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 2948

1 LiDAR Operator: MS REYES	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29GJ342B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: CS ALFONSO	8 Co-Pilot: J JOYA	9 Route: Mambusao - Mambusao			
10 Date: DEC 8, 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO		12 Airport of Arrival (Airport, City/Province): MAMBURAO		
13 Engine On: 1405	14 Engine Off: 1610	15 Total Engine Time: 02+05	16 Take off: 1410	17 Landing: 1605	18 Total Flight Time: 1+55
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed Block 29G GJ

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

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

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

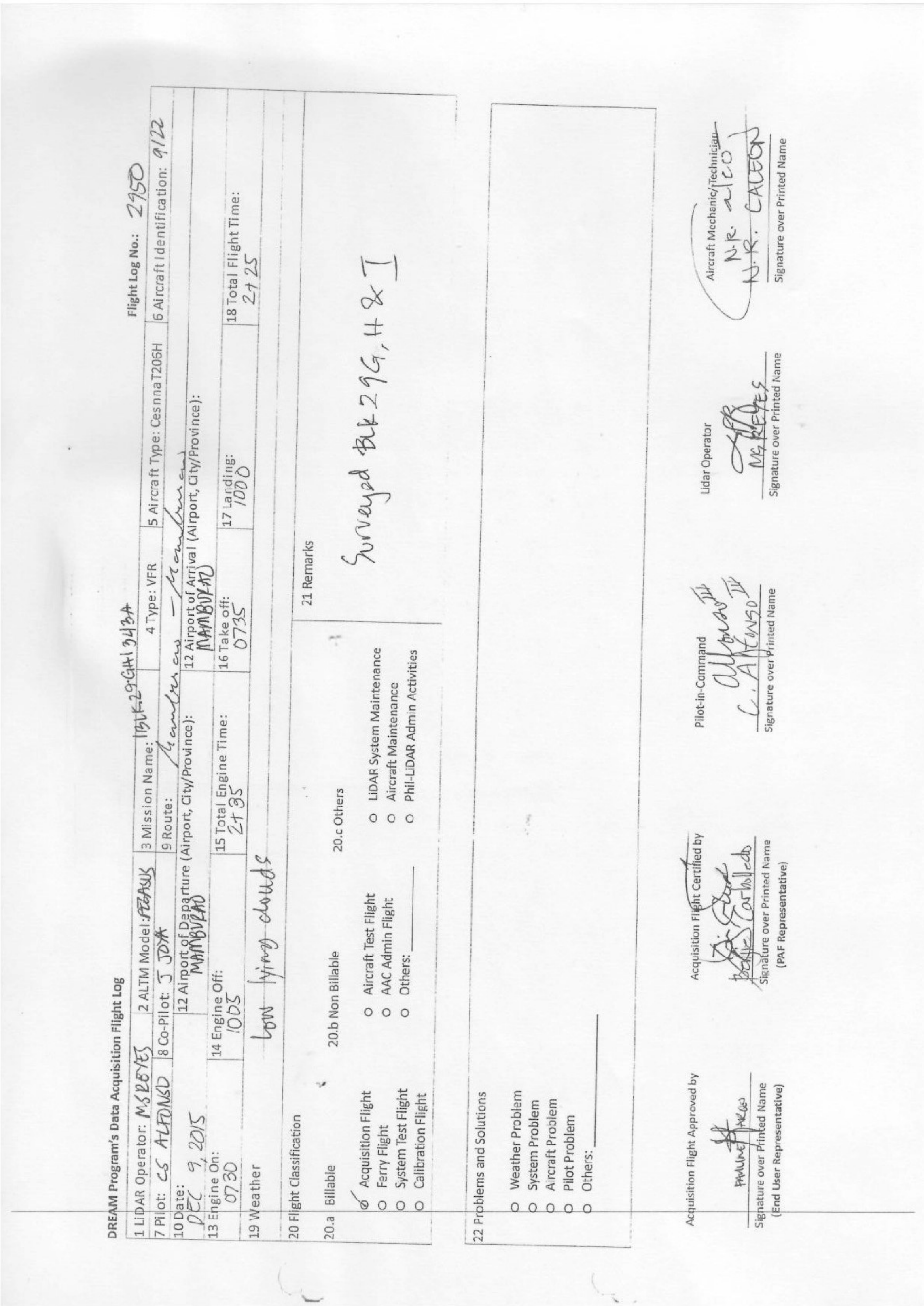
Pilot-in-Command: C. ALFONSO IV — Signature over Printed Name

Lidar Operator: MS REYES — Signature over Printed Name

Aircraft Mechanic/ Technician: N. R. CALEON — Signature over Printed Name

Figure A-6.8. Flight Log for 1BLK29GJ342B Mission

9. Flight Log for 1BLK29GHI343A Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 2950

1 LiDAR Operator: MS REYES	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29GHI343A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: CS ALFONSO	8 Co-Pilot: J JOYA	9 Route: Mamburao - Mamburao			
10 Date: DEC 9, 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO		12 Airport of Arrival (Airport, City/Province): MAMBURAO		
13 Engine On: 0730	14 Engine Off: 1005	15 Total Engine Time: 2+35	16 Take off: 0735	17 Landing: 1000	18 Total Flight Time: 2+25
19 Weather	Low lying clouds				

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 29G, H & I

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

Acquisition Flight Approved by: PAULINE ARCEO — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: Bonjie Carballedo — Signature over Printed Name (PAF Representative)

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

Lidar Operator: MG REYES — Signature over Printed Name

Aircraft Mechanic/Technician: N.R. CALEON — Signature over Printed Name

Figure A-6.9. Flight Log for 1BLK29GHI343A Mission

Annex 7. Flight Status Report

MOMPONG FLOODPLAIN
February 16-23, 2014; December 8-9, 2015

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1108A	BLK29J	3BLK29J47A	PY ALCANTARA	16-Feb-14	Completed 6 lines of Area J.
1110A	BLK29 K & BLK29J	3BLK29K+JS47B	L ASUNCION/ LK PARAGAS	16-Feb-14	Completed 4 lines of Area K and 10 lines of J.
1116A	BLK29K	3BLK29KS49A	PY ALCANTARA	18-Feb-14	Completed Area K
1118A	BLK29J	3BLK29JS49B	LK PARAGAS	18-Feb-14	Completed Area J.
1128A	BLK29I	3BLK29I52A	LK PARAGAS	21-Feb-14	Completed 15 lines in area I.
1132A	BLK29I & BLK29H	3BLK29IS+H53A	LK PARAGAS	22-Feb-14	Completed area I and 8 lines in area H.
1136A	BLK29H	3BLK29HS54A	PY ALCANTARA	23-Feb-14	Mission completed.
3068P	BLK29G & 29J	1BLK29GJ342B	MS REYES	8-DEC-15	Surveyed BLK29G & J
3070P	BLK29G, 29H & 29I	1BLK29GHI343A	MS REYES	9-DEC-15	Surveyed BLK29G, H & I

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

FLIGHT NO.	1108A	
AREA:	BLK29J	
MISSION NAME:	3BLK29J47A	
PARAMETERS:	Alt: 600 Scan Freq: 40 kHz	Scan Angle: 18 deg

SURVEY COVERAGE:

Figure A-7.1. Swath for Flight No. 1108A

FLIGHT NO.	1110A
AREA:	BLK29K and BLK29J
MISSION NAME:	3BLK29K+JS47B
PARAMETERS:	Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

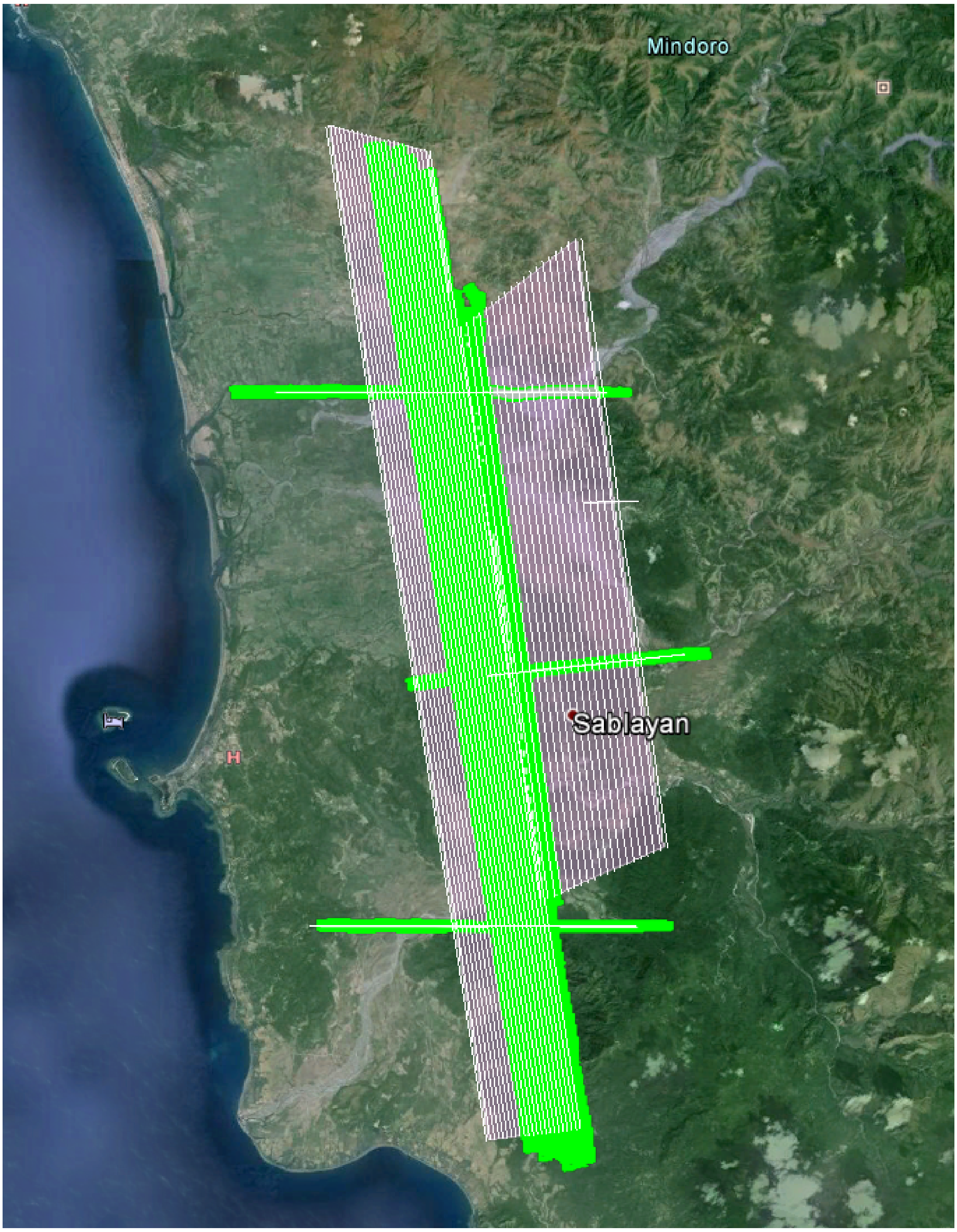


Figure A-7.2. Swath for Flight No. 1110A

FLIGHT NO.	1116A
AREA:	BLK29K
MISSION NAME:	3BLK29KS49A
PARAMETERS:	Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

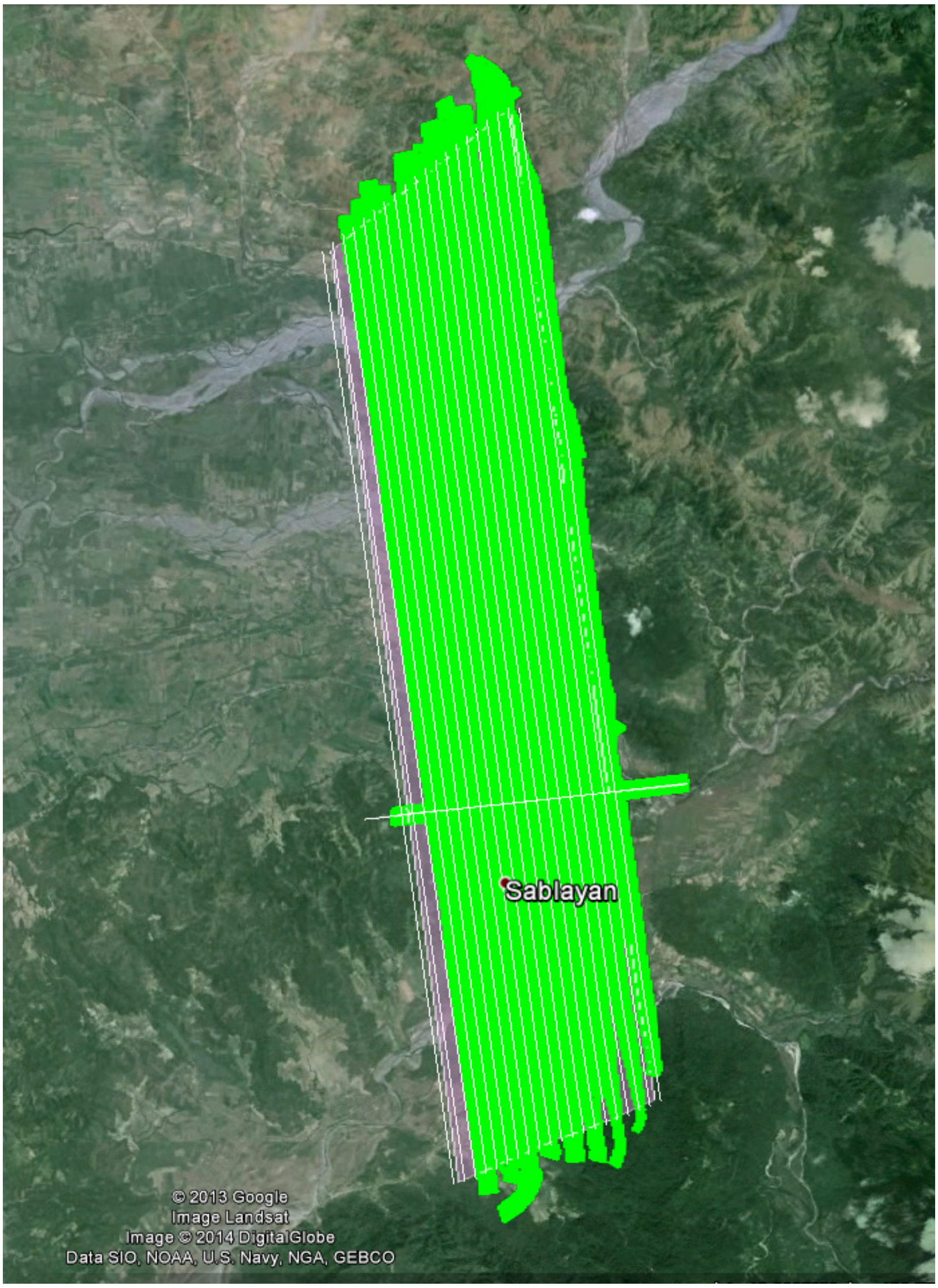


Figure A-7.4. Swath for Flight No. 1116A

FLIGHT NO. 1118A
AREA: BLK29J
MISSION NAME: 3BLK29JS49B
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

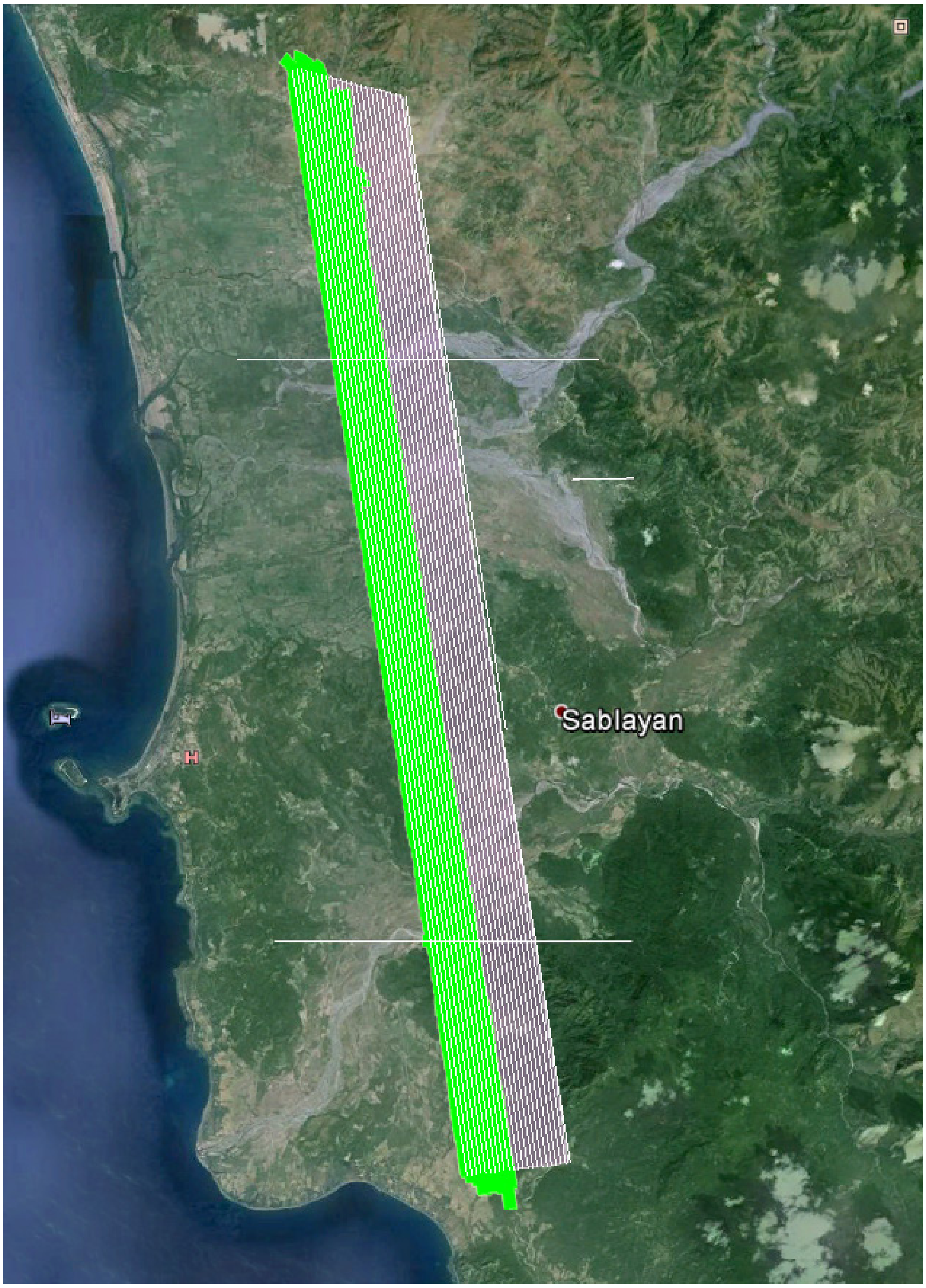


Figure A-7.5. Swath for Flight No. 1118A

FLIGHT NO.	1128A
AREA:	BLK29I
MISSION NAME:	3BLK29I52A
PARAMETERS:	Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

Figure A-7.6. Swath for Flight No. 1128A

FLIGHT NO. 1132A
AREA: BLK29I AND BLK29H
MISSION NAME: 3BLK29IS+H53A
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

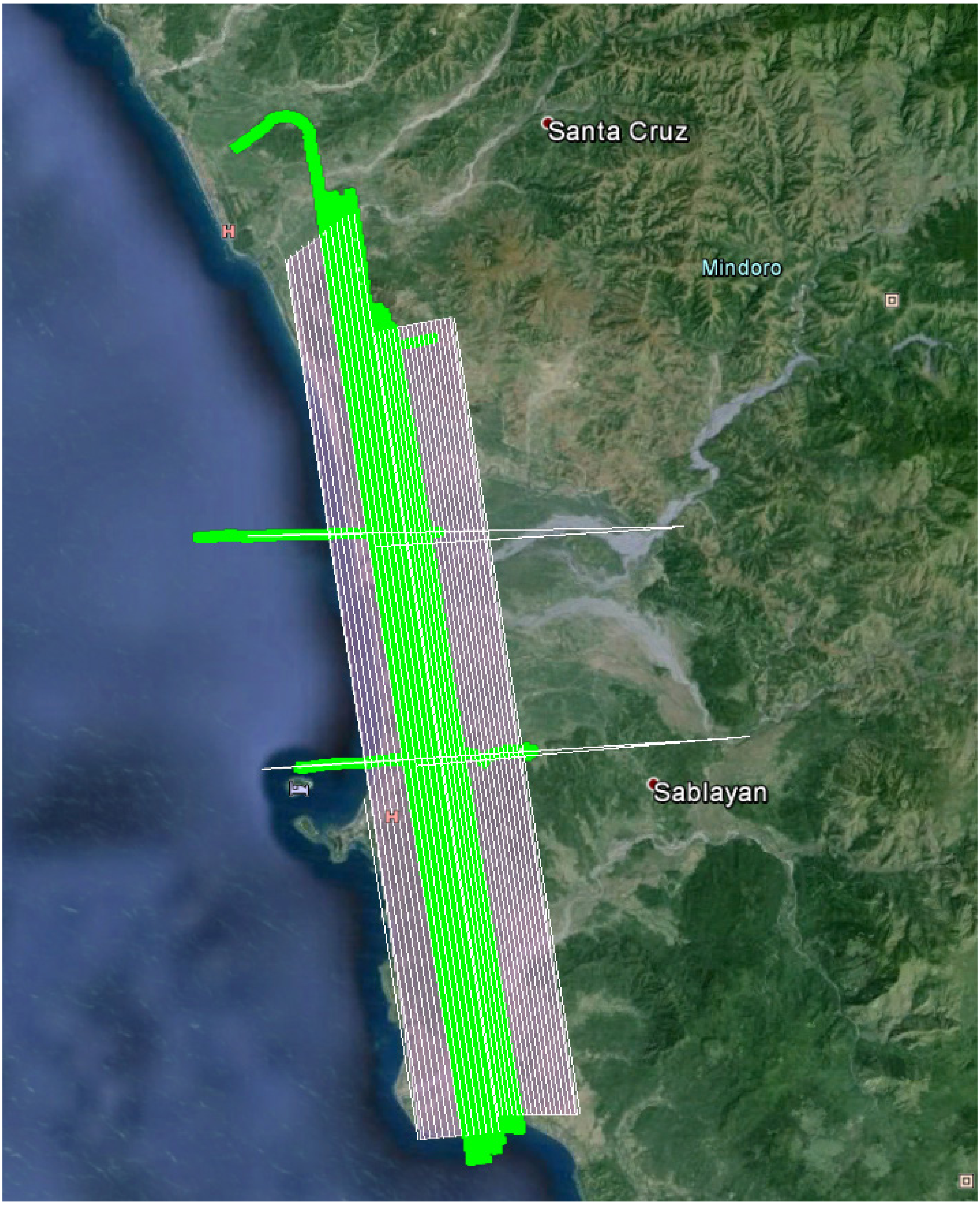


Figure A-7.7. Swath for Flight No. 1132A

FLIGHT NO.	1136A	
AREA:	BLK29H	
MISSION NAME:	3BLK29HS54A	
PARAMETERS	Alt: 600 Scan Freq: 40 kHz	Scan Angle: 18 deg

SURVEY COVERAGE:

Figure A-7.8. Swath for Flight No. 1136A

FLIGHT NO:	3068P
AREA:	BLK29G & 29J
MISSION NAME:	1BLK29GJ342B
PARAMETERS:	Alt: 1100 m Scan Freq: 30 Hz Scan Angle: 25 deg

SURVEY COVERAGE:

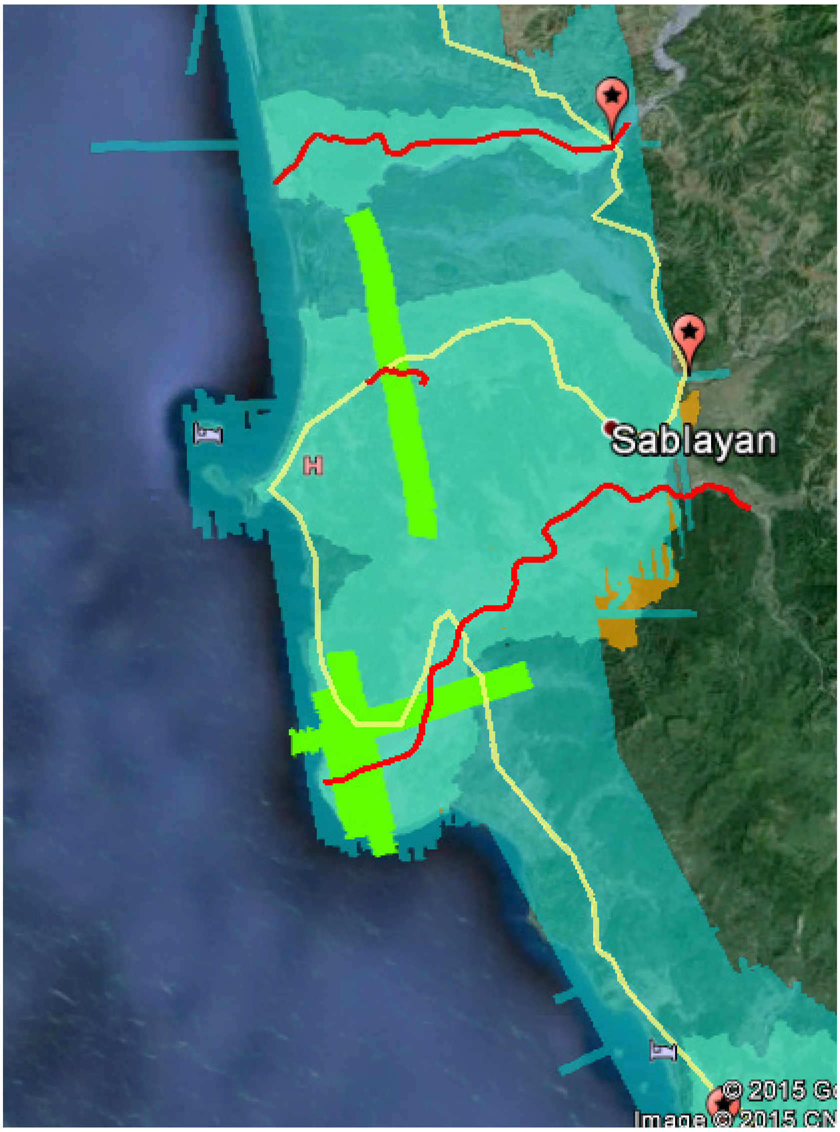


Figure A-7.9. Swath for Flight No. 3068P

FLIGHT NO.:	3070P
AREA:	BLK29G, 29H & 29I
MISSION NAME:	1BLK29GHI343A
PARAMETERS:	Alt: 1100 m Scan Freq: 30 Hz Scan Angle: 25 deg

SURVEY COVERAGE:

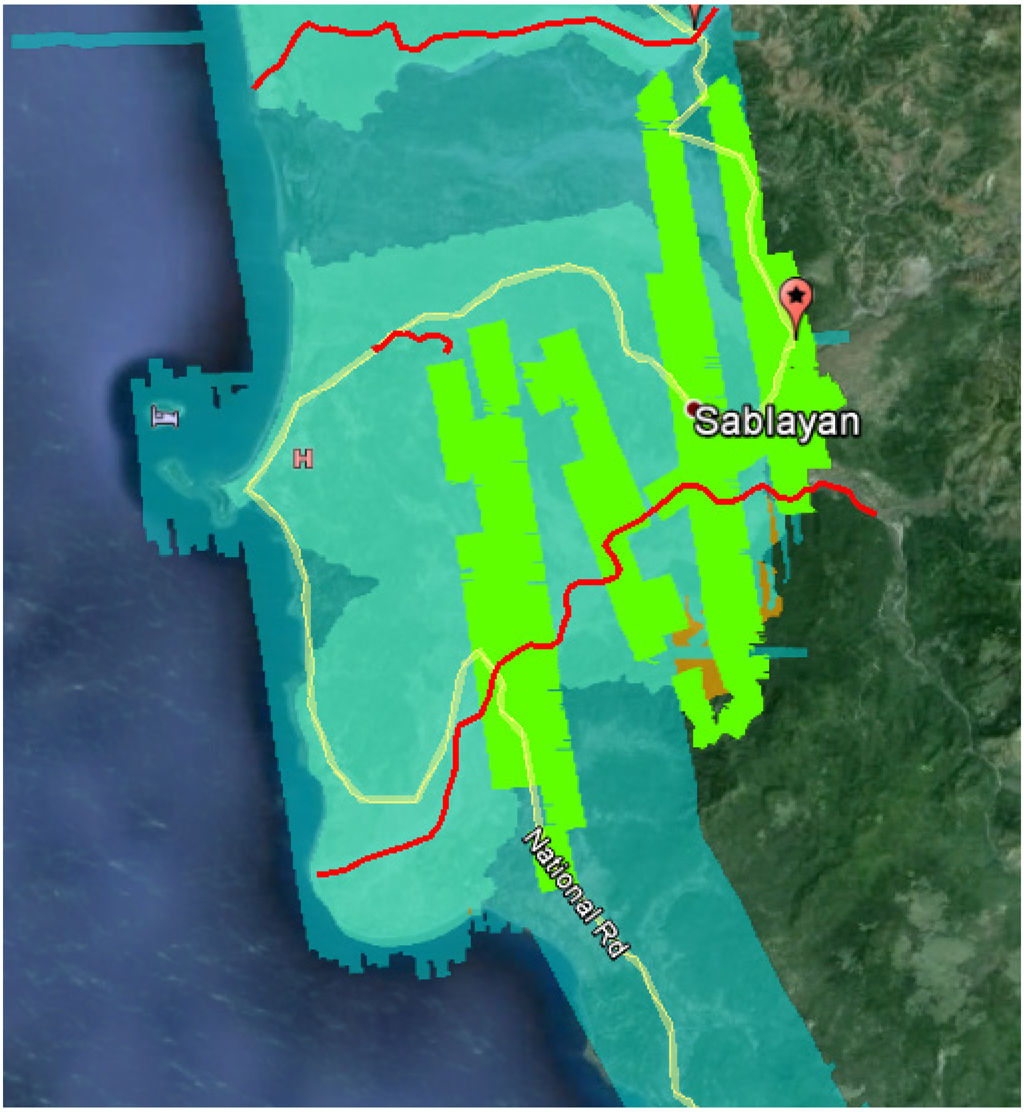


Figure A-7.10. Swath for Flight No. 3070P

Annex 8. Mission Summary Report

Table A-8.1 Mission Summary Report for Mission Blk29H

Flight Area	Occidental Mindoro
Mission Name	**Blk29H**
Inclusive Flights	1136A
Range data size	15 GB
Base data size	15.8 MB
POS	256 MB
Image	86.5 GB
Transfer date	03/19/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.5
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	4.4
Boresight correction stdev (<0.001deg)	0.000355
IMU attitude correction stdev (<0.001deg)	0.074523
GPS position stdev (<0.01m)	0.0409
Minimum % overlap (>25)	37.19%
Ave point cloud density per sq.m. (>2.0)	2.58
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	174
Maximum Height	613.49 m
Minimum Height	39.16 m
Classification (# of points)	
Ground	53,263,528
Low vegetation	57,288,707
Medium vegetation	68,165,762
High vegetation	30,718,677
Building	1,782,193
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Celina Rosete, Jovy Narisma

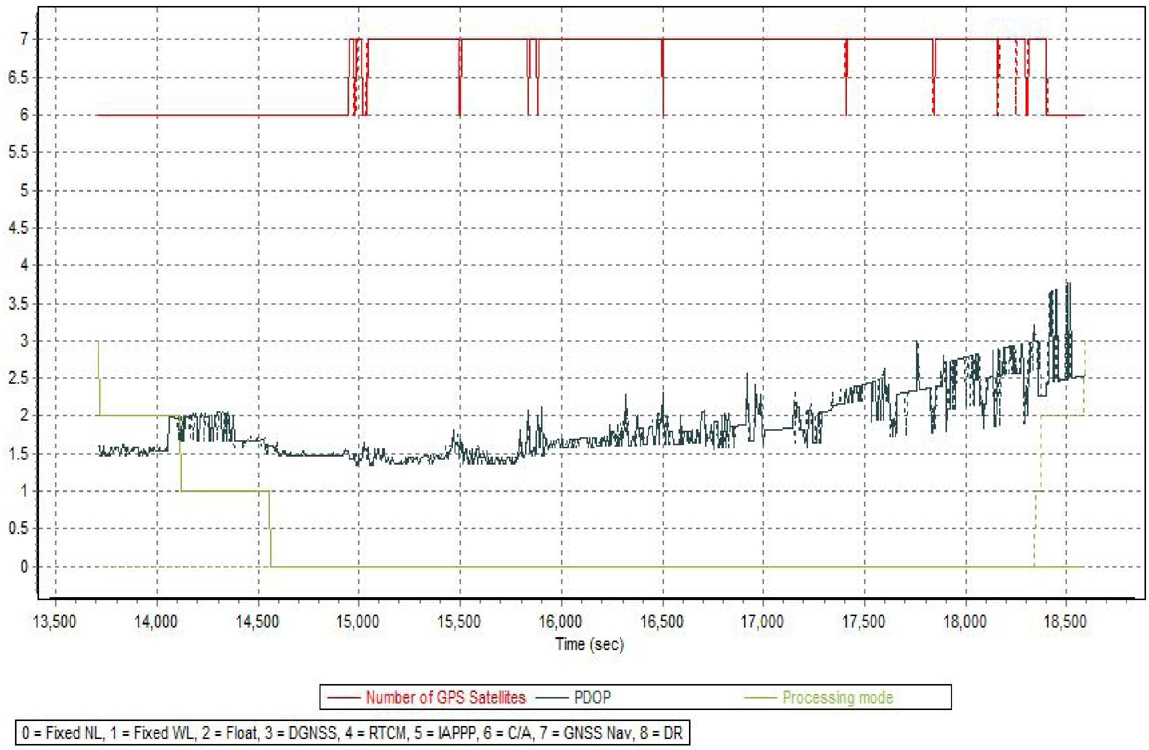


Figure A-8.1 Solution Status

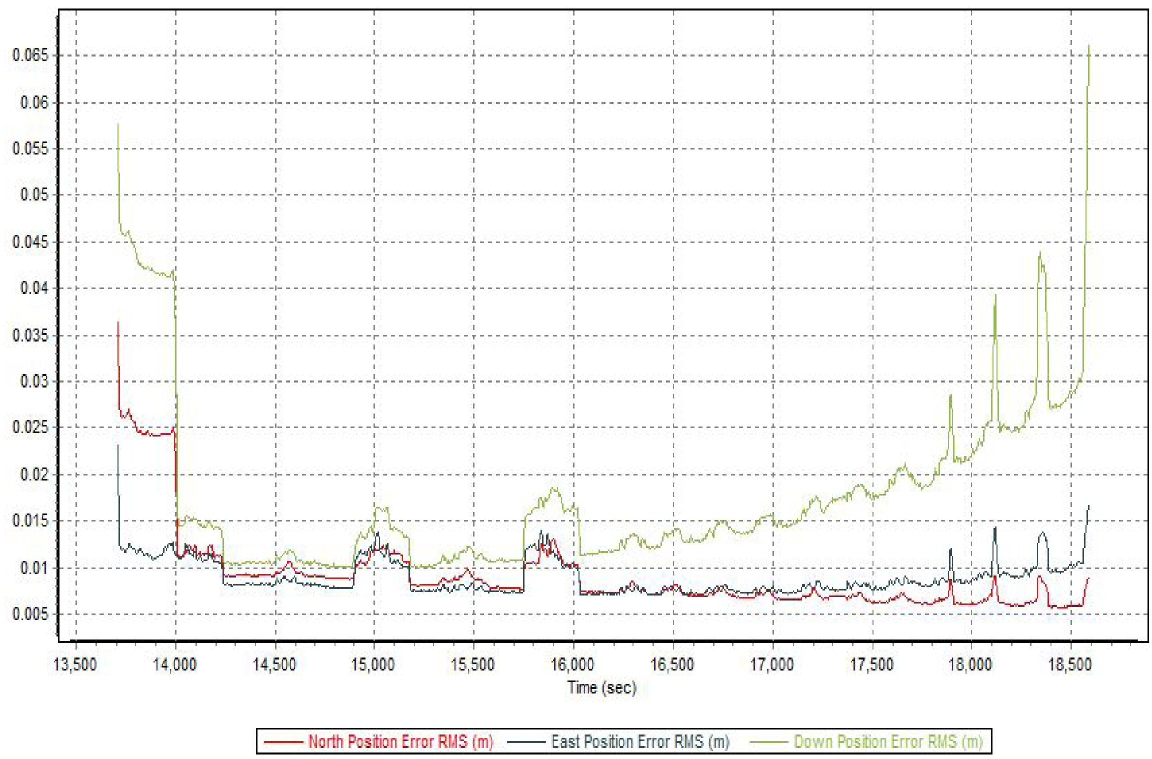


Figure A-8.2 Smoothed Performance Metrics Parameters

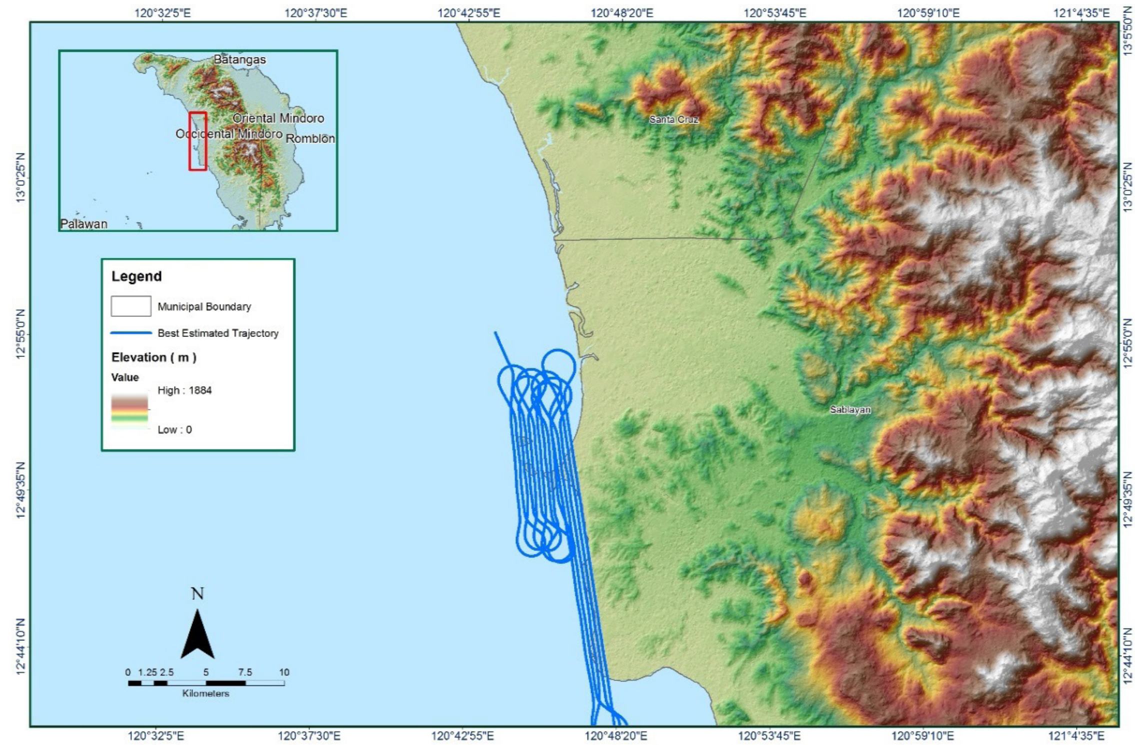


Figure A-8.3 Best Estimated Trajectory

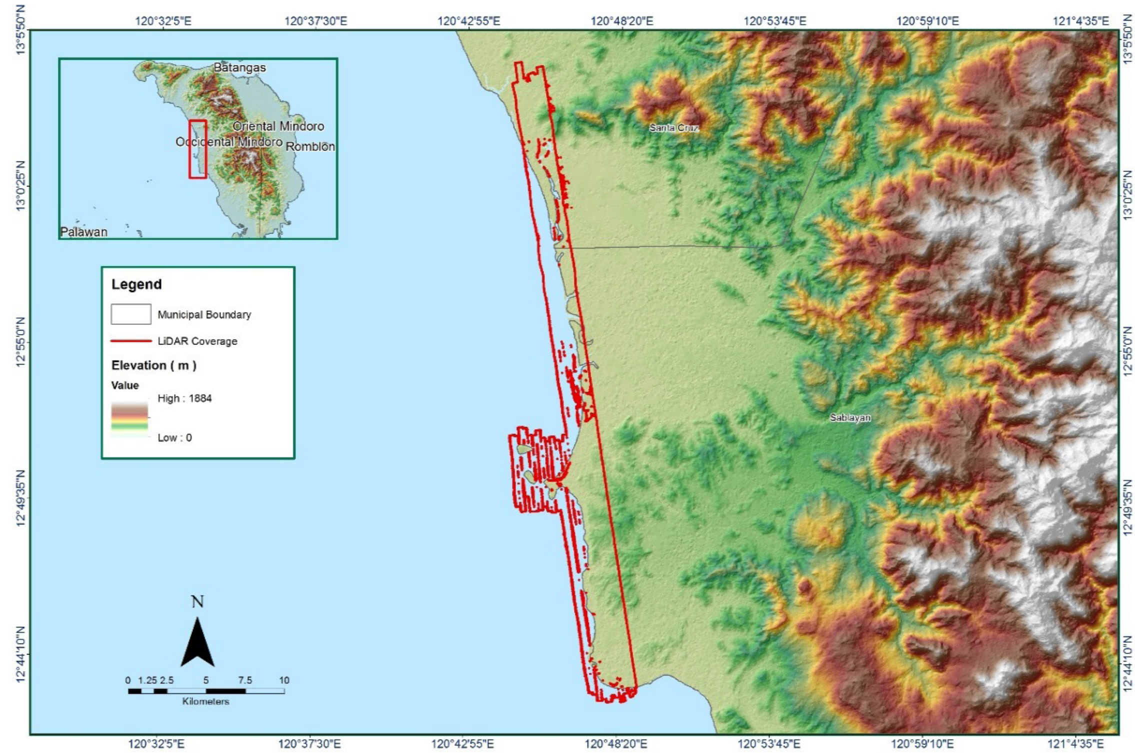


Figure A-8.4. Coverage of LiDAR data

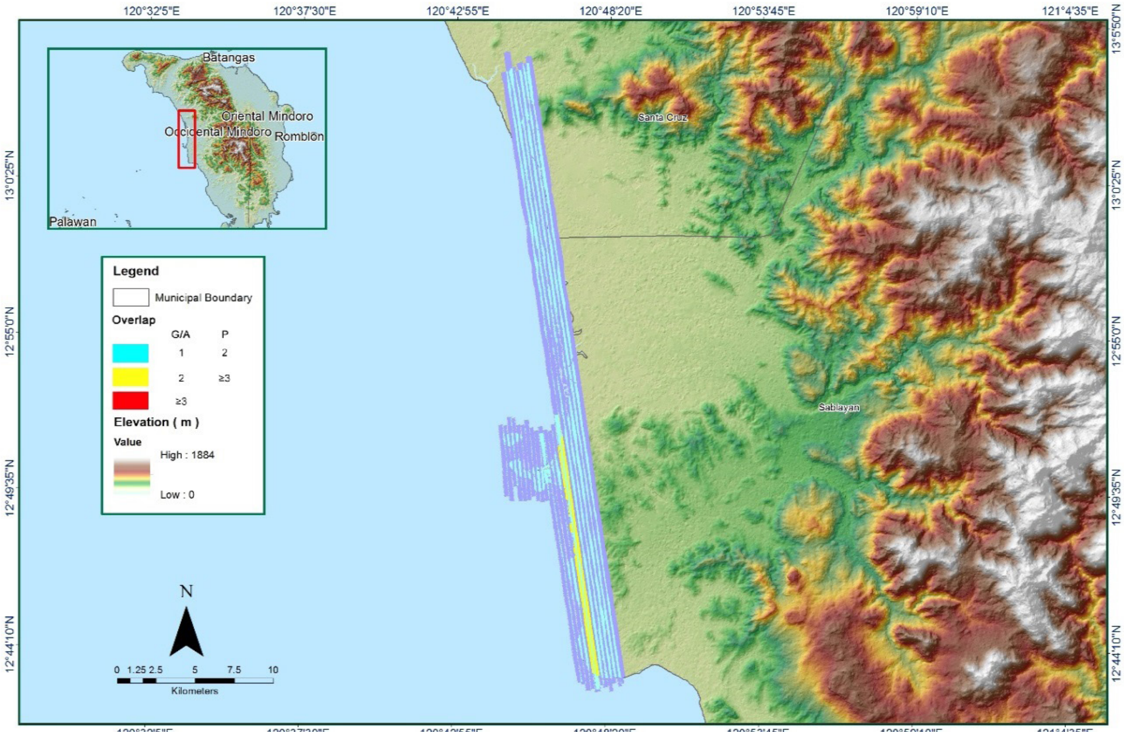


Figure A-8.5. Image of data overlap

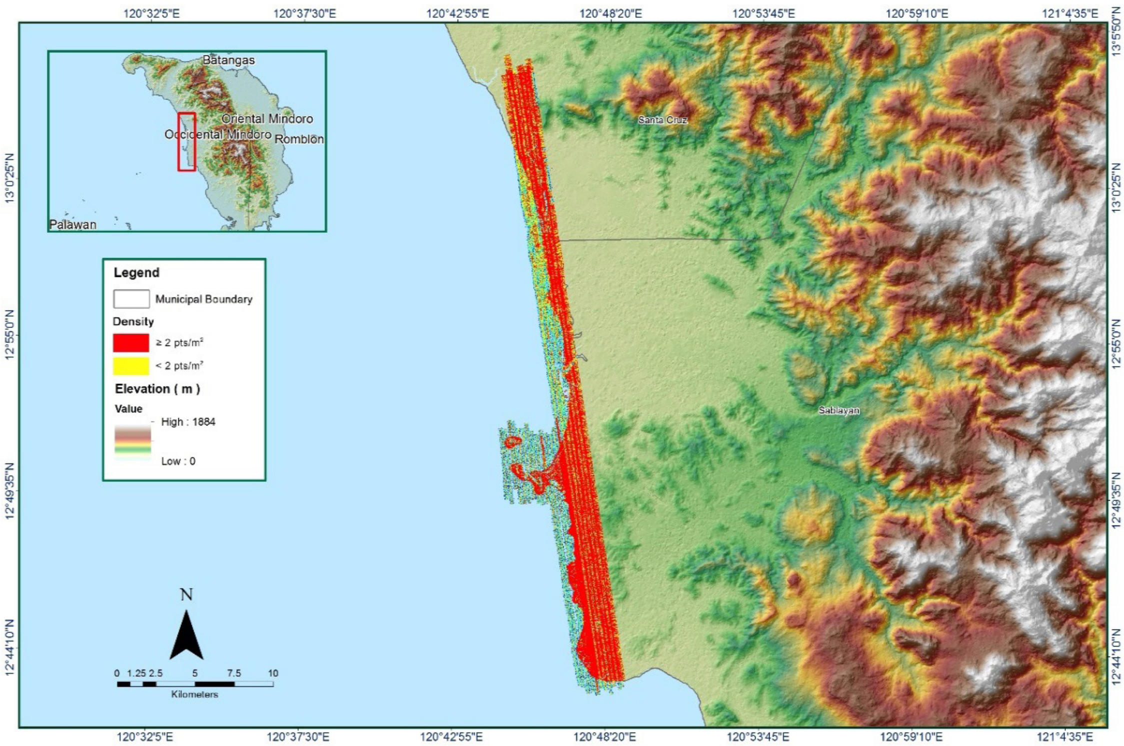


Figure A-8.6 Density of merged LiDAR data

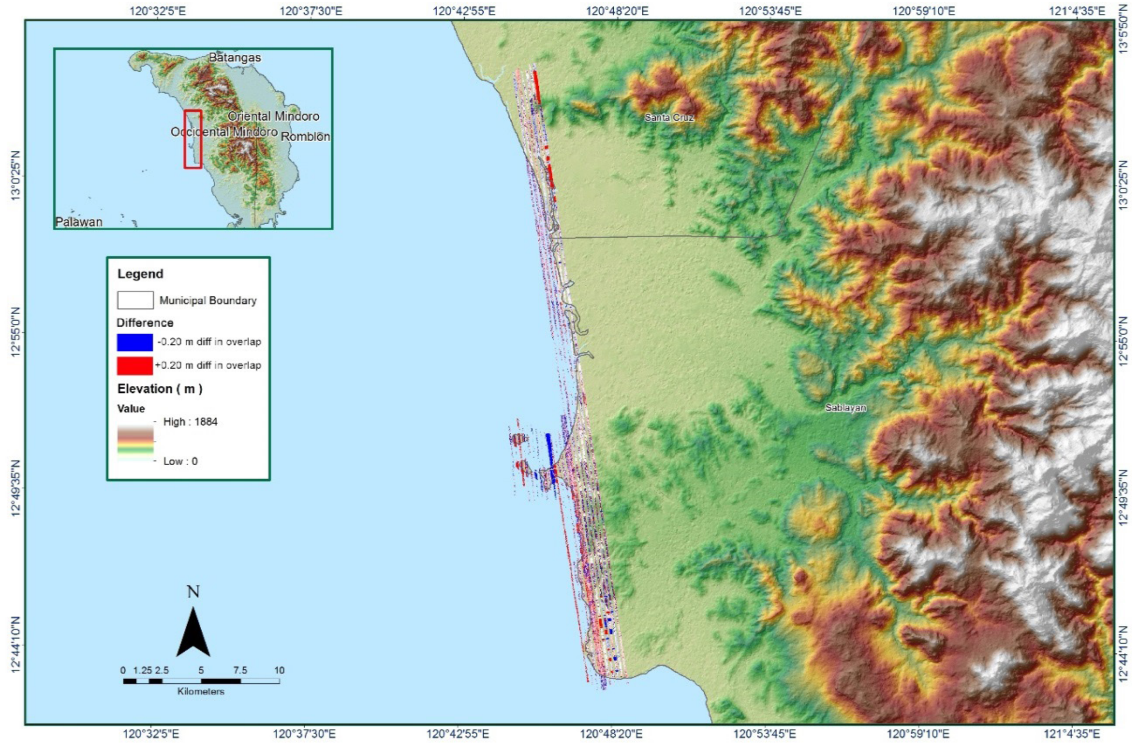


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk29HI_supplement

Flight Area	Occidental Mindoro
Mission Name	**Blk29HI_supplement**
Inclusive Flights	1132A
Range data size	16.1 GB
Base data size	13.4 MB
POS	276 MB
Image	34.3 GB
Transfer date	03/19/2014
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)	1.2
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000400
IMU attitude correction stdev (<0.001deg)	0.005740
GPS position stdev (<0.01m)	0.0138
Minimum % overlap (>25)	55.11%
Ave point cloud density per sq.m. (>2.0)	3.77
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	175
Maximum Height	308.28 m
Minimum Height	43.14 m
Classification (# of points)	
Ground	75,373,003
Low vegetation	106,983,904
Medium vegetation	125,916,220
High vegetation	46,925,200
Building	1,788,962
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Christy Lubiano, Engr. Jeffrey Delica

Figure A-8.8. Solution Status

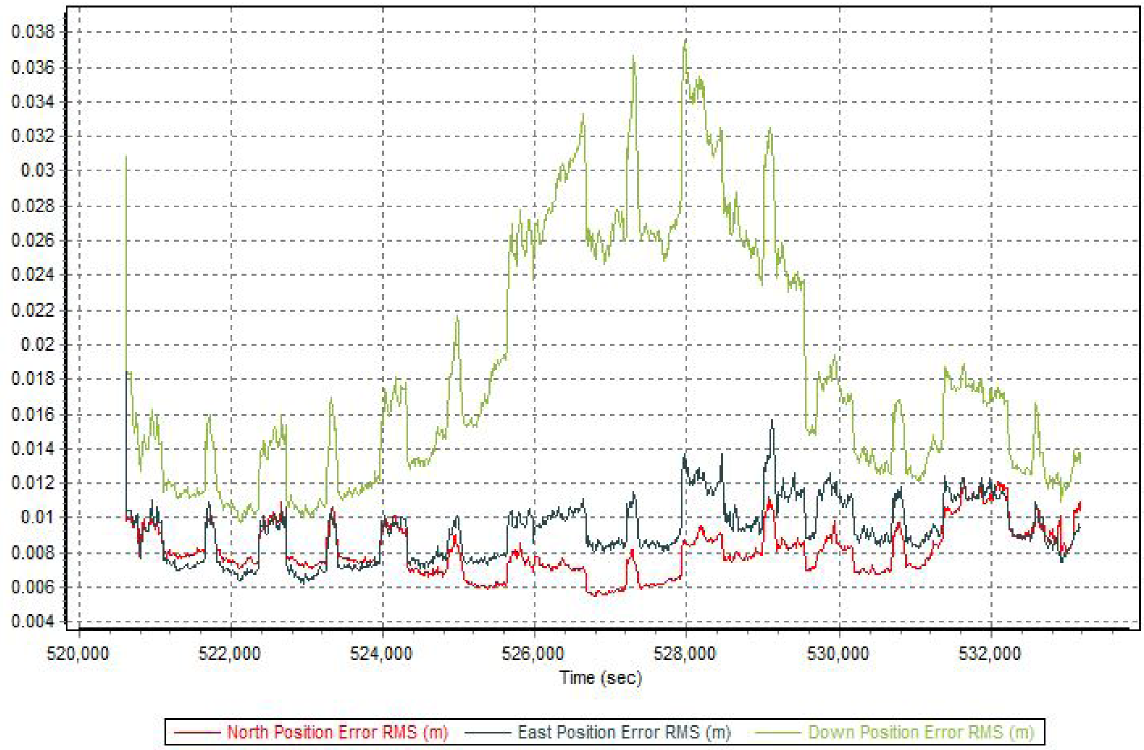


Figure A-8.9. Smoothed Performance Metrics Parameters

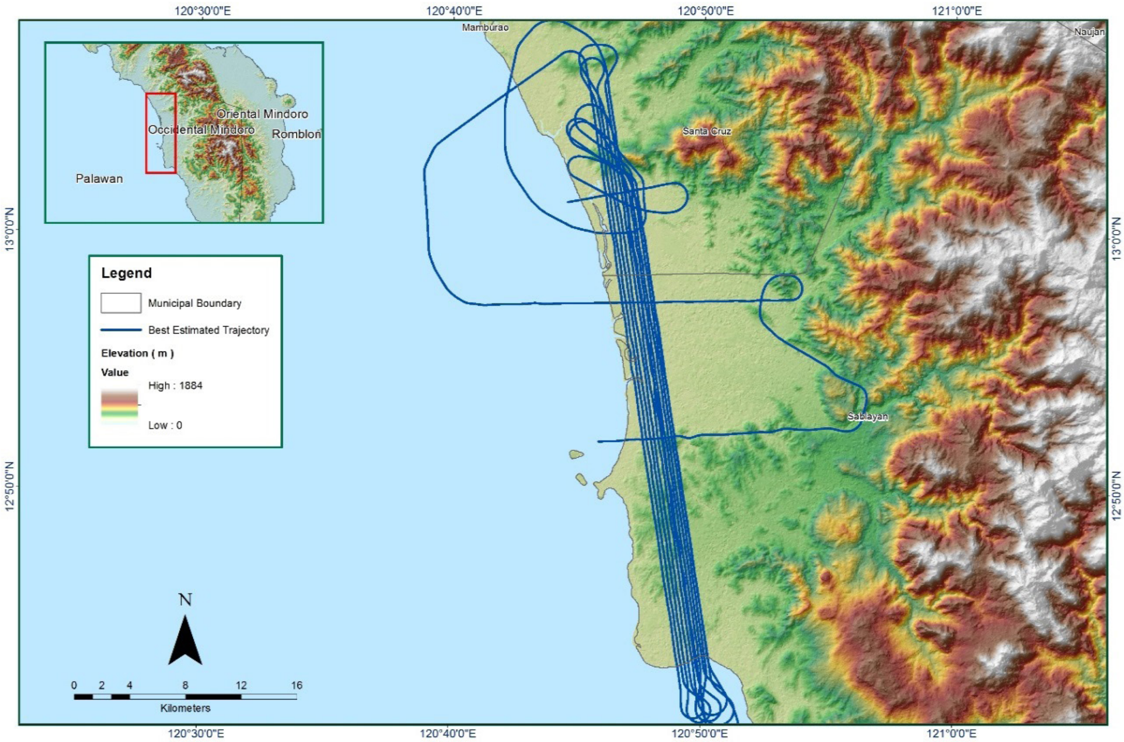


Figure A-8.10. Best Estimated Trajectory

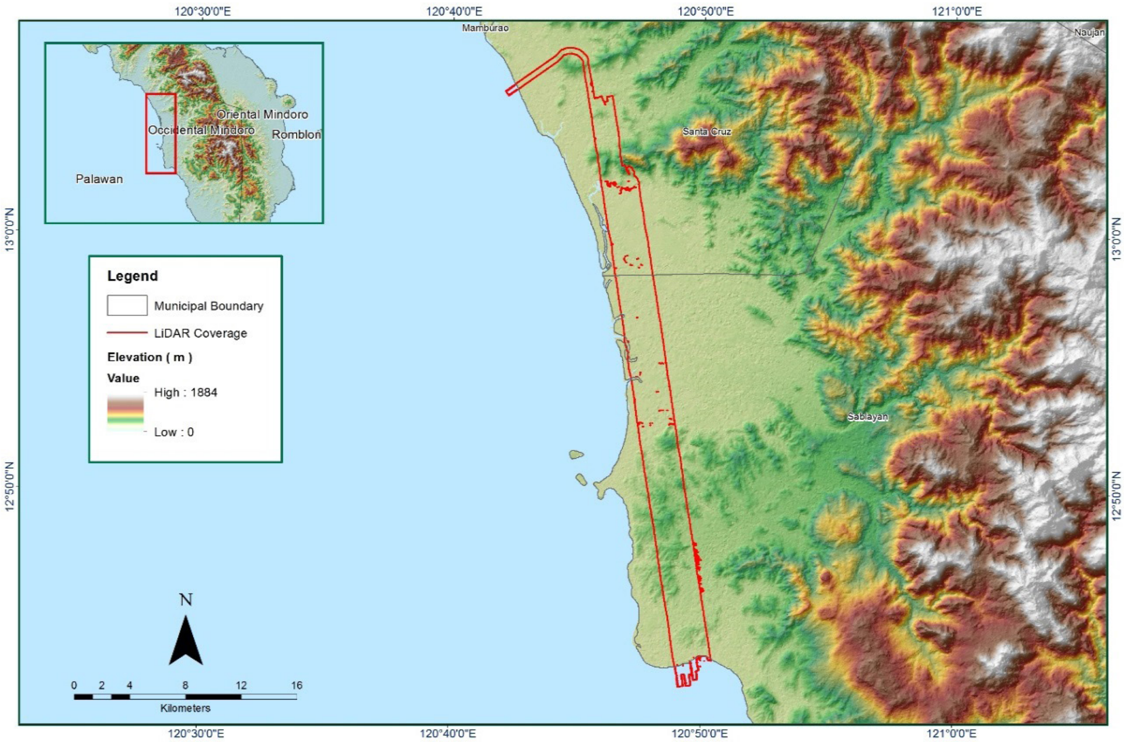


Figure A-8.11. Coverage of LiDAR data

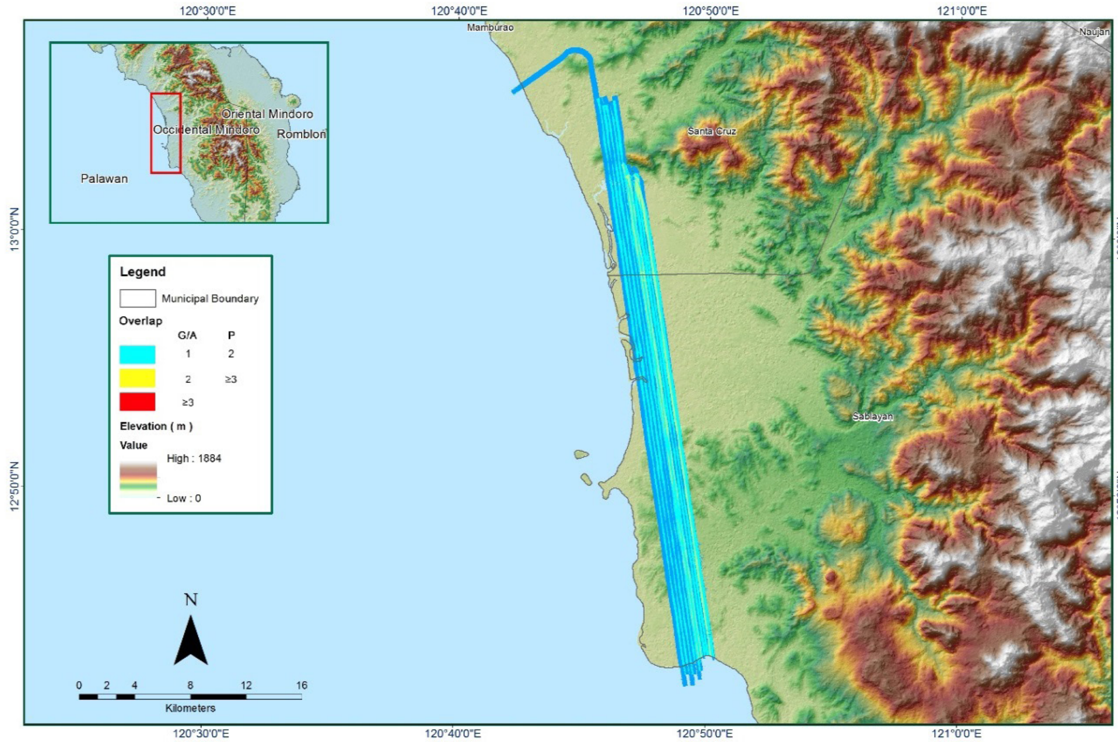


Figure A-8.12. Image of data overlap

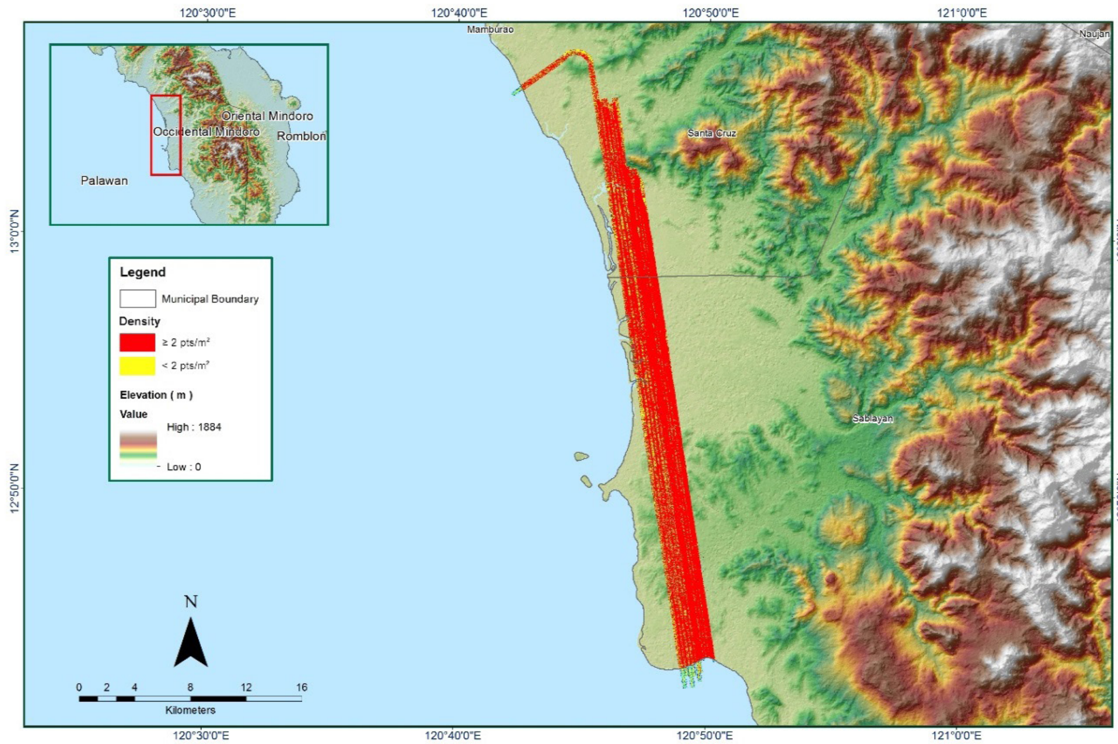


Figure A-8.13. Density of merged LiDAR data

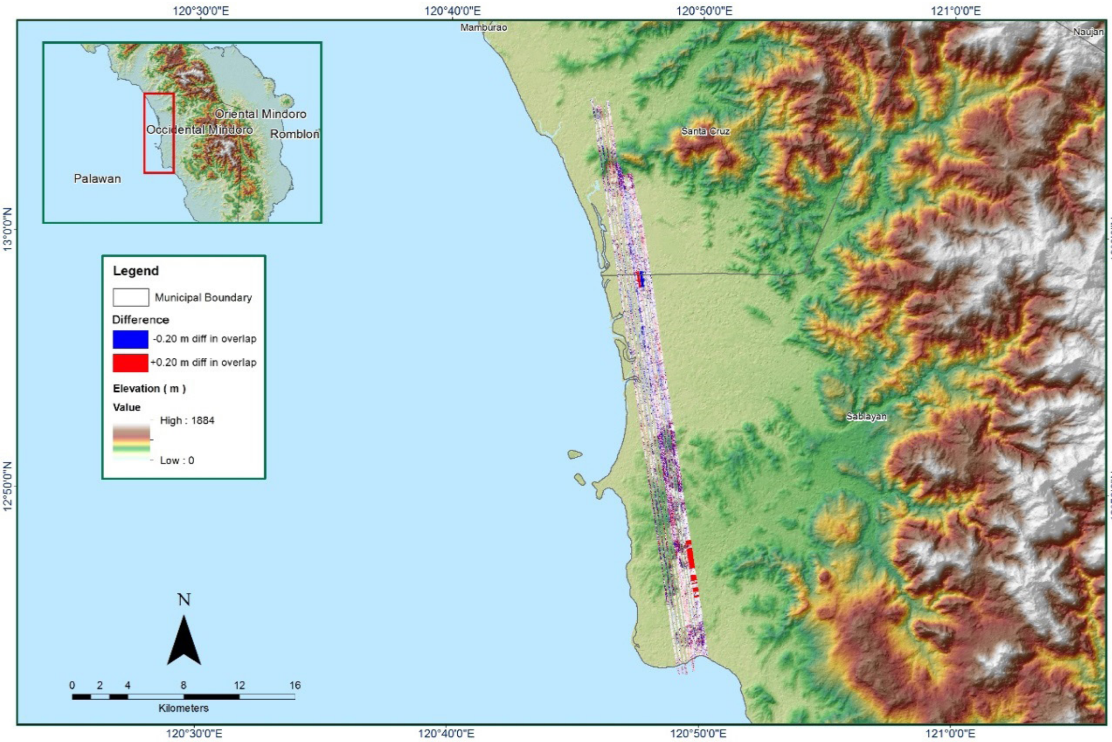


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk29I

Flight Area	Occidental Mindoro
Mission Name	**Blk29I**
Inclusive Flights	1128A
Range data size	16.1 GB
Base data size	12.3 MB
POS	269 MB
Image	6.32 GB
Transfer date	03/19/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.8
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000390
IMU attitude correction stdev (<0.001deg)	0.002145
GPS position stdev (<0.01m)	0.0110
Minimum % overlap (>25)	64.97%
Ave point cloud density per sq.m. (>2.0)	3.83
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	150
Maximum Height	303.6 m
Minimum Height	42.27 m
Classification (# of points)	
Ground	74,217,818
Low vegetation	115,333,090
Medium vegetation	94,560,605
High vegetation	27,638,490
Building	1,366,906
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Melanie Hingpit, Jovy Narisma

Figure A-8.15. Solution Status

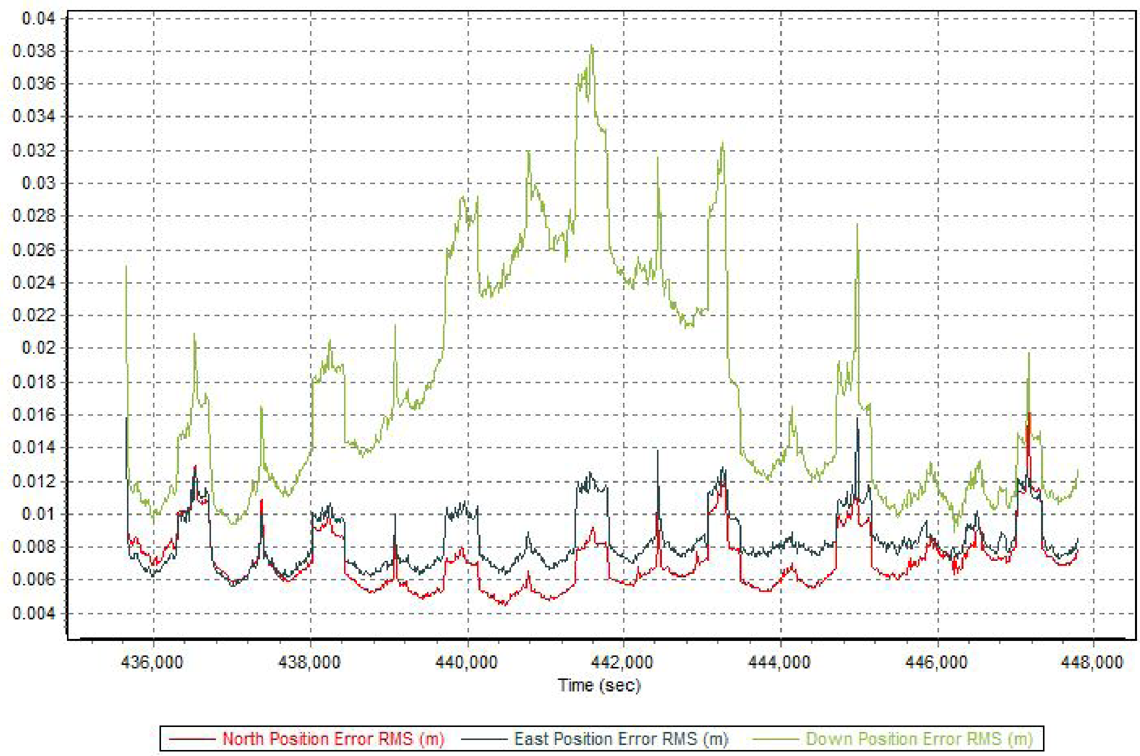


Figure A-8.16. Smoothed Performance Metrics Parameters

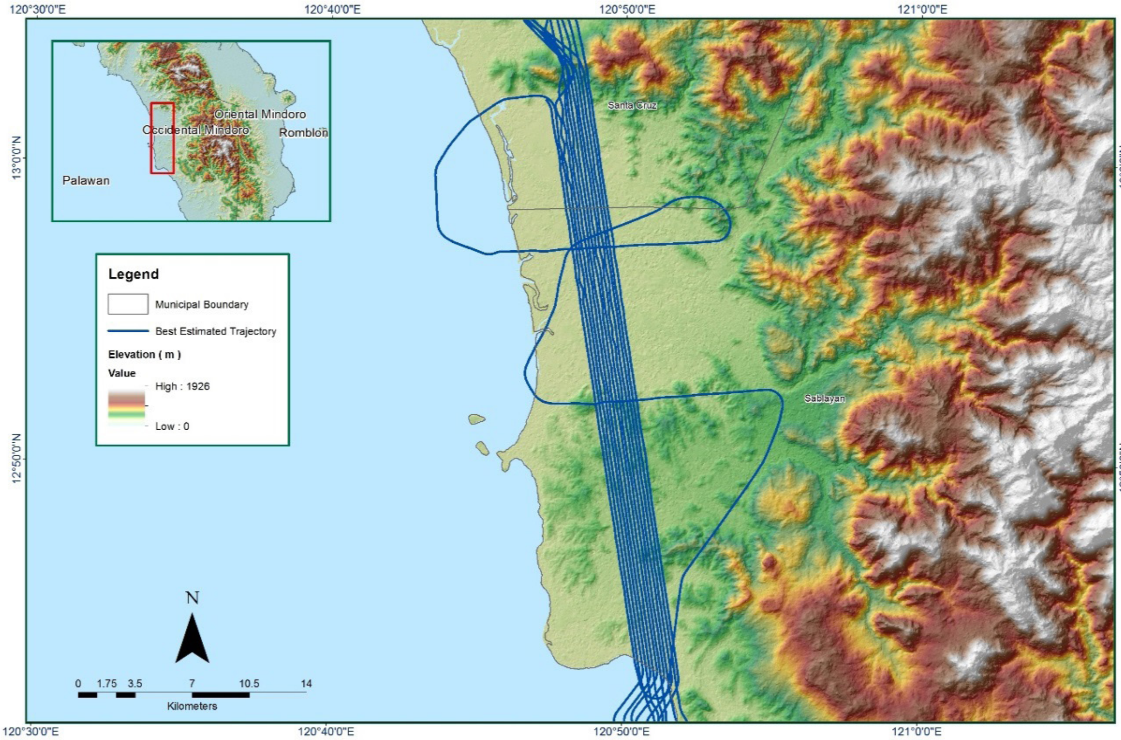


Figure A-8.17. Best Estimated Trajectory

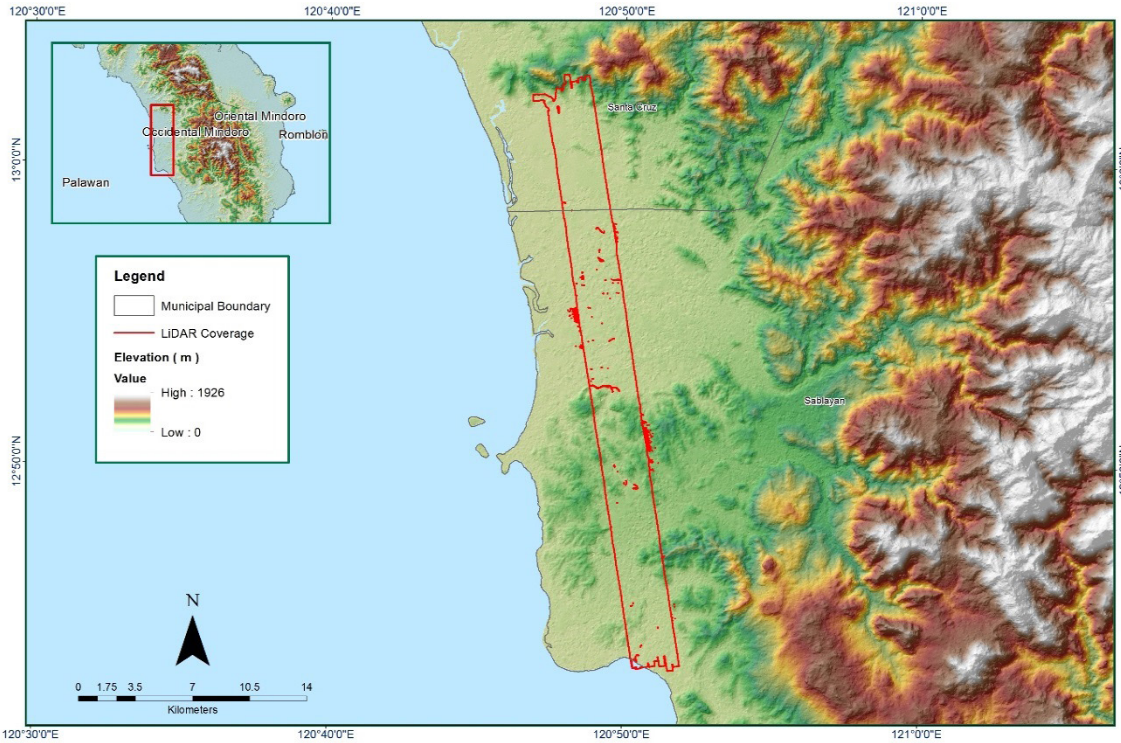


Figure A-8.18. Coverage of LiDAR data

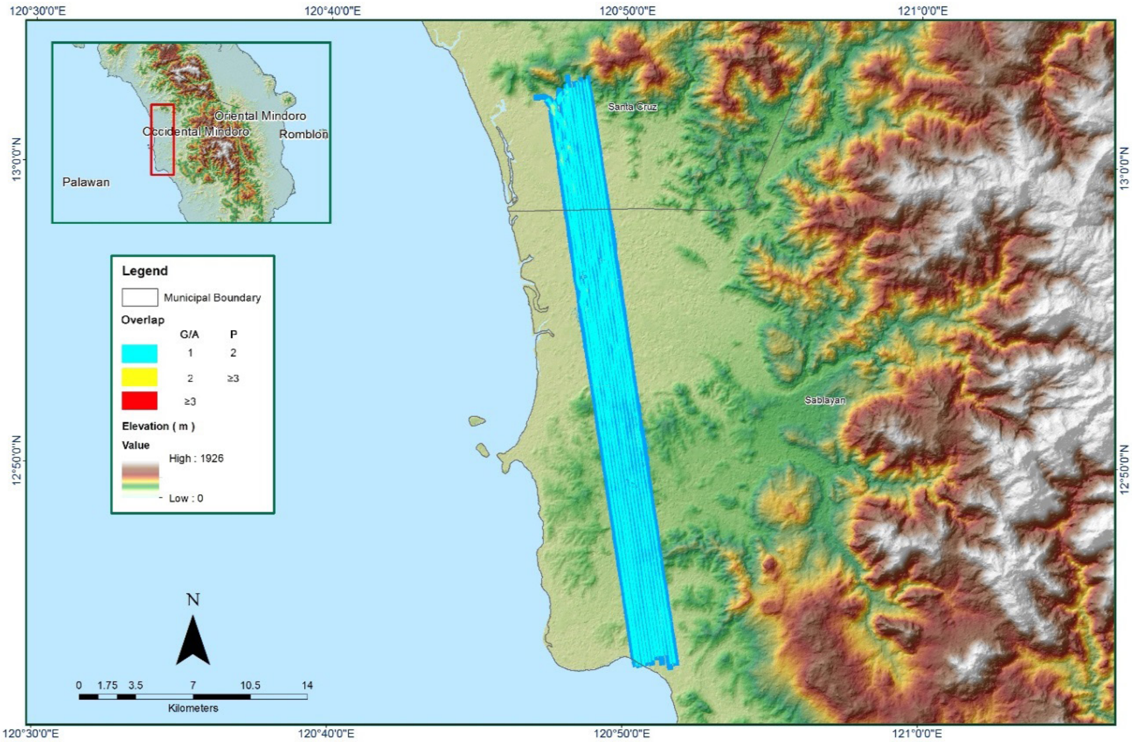


Figure A-8.19. Image of data overlap

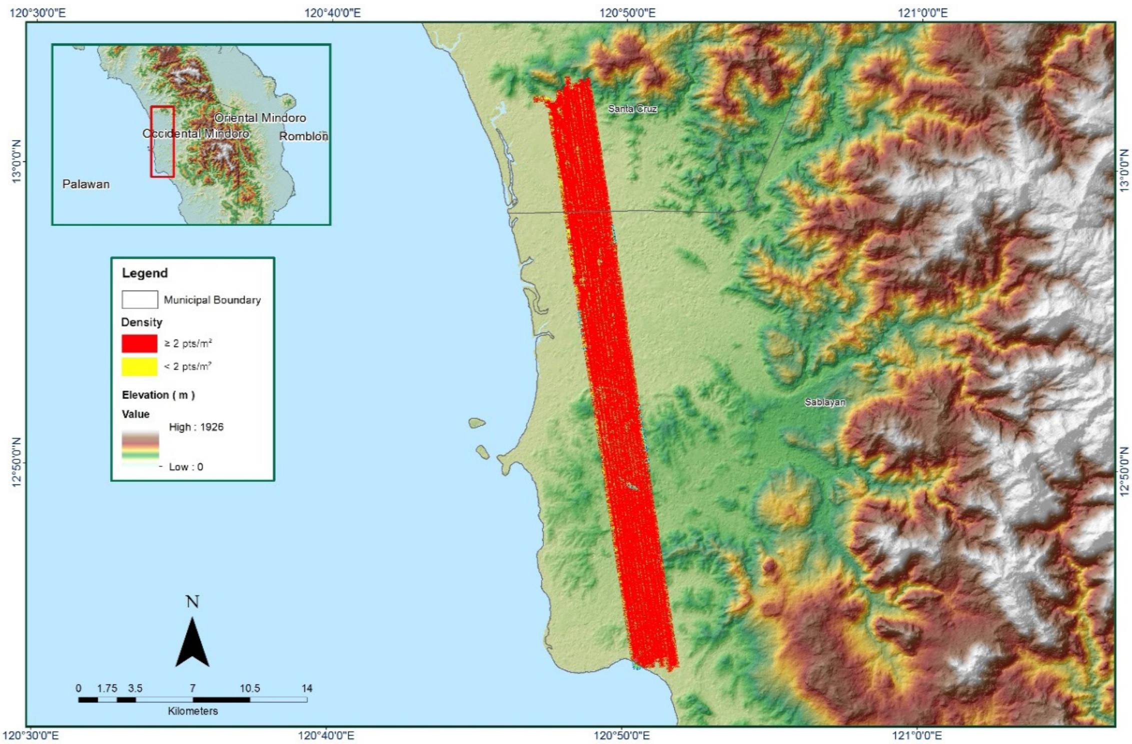


Figure A-8.20. Density of merged LiDAR data

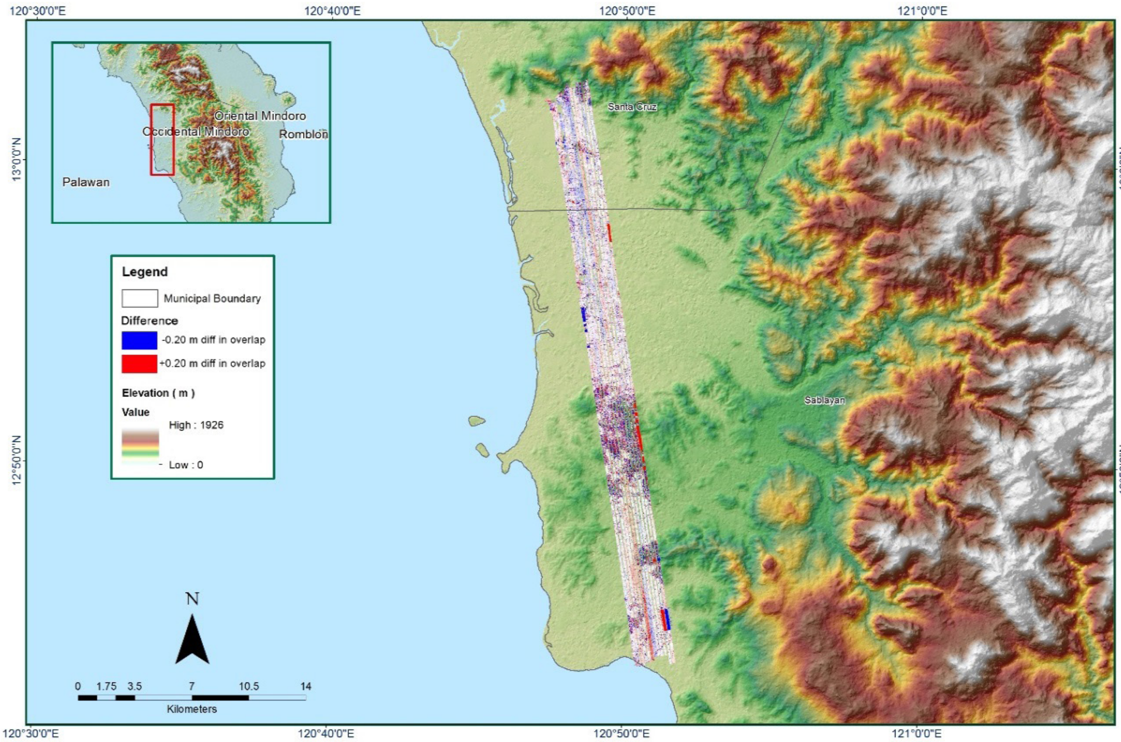


Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk29JK

Flight Area	Occidental Mindoro
Mission Name	**Blk29JK**
Inclusive Flights	1110A, 1118A, 1108A
Range data size	29.97 GB
Base data size	43.3 MB
POS	578 MB
Image	88.399 GB
Transfer date	03/07/2014
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)	1.2
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	2.2
Boresight correction stdev (<0.001deg)	0.000351
IMU attitude correction stdev (<0.001deg)	0.001607
GPS position stdev (<0.01m)	0.0035
Minimum % overlap (>25)	82.92%
Ave point cloud density per sq.m. (>2.0)	5.35
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	181
Maximum Height	427.61 m
Minimum Height	51.93 m
Classification (# of points)	
Ground	104,888,569
Low vegetation	178,889,703
Medium vegetation	207,266,587
High vegetation	112,361,804
Building	3,147,266
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibanez, Engr. Angelo Carlo Bongat, Engr. Christy Lubiano, Engr. Jeffrey Delica

Figure A-8.22. Solution Status

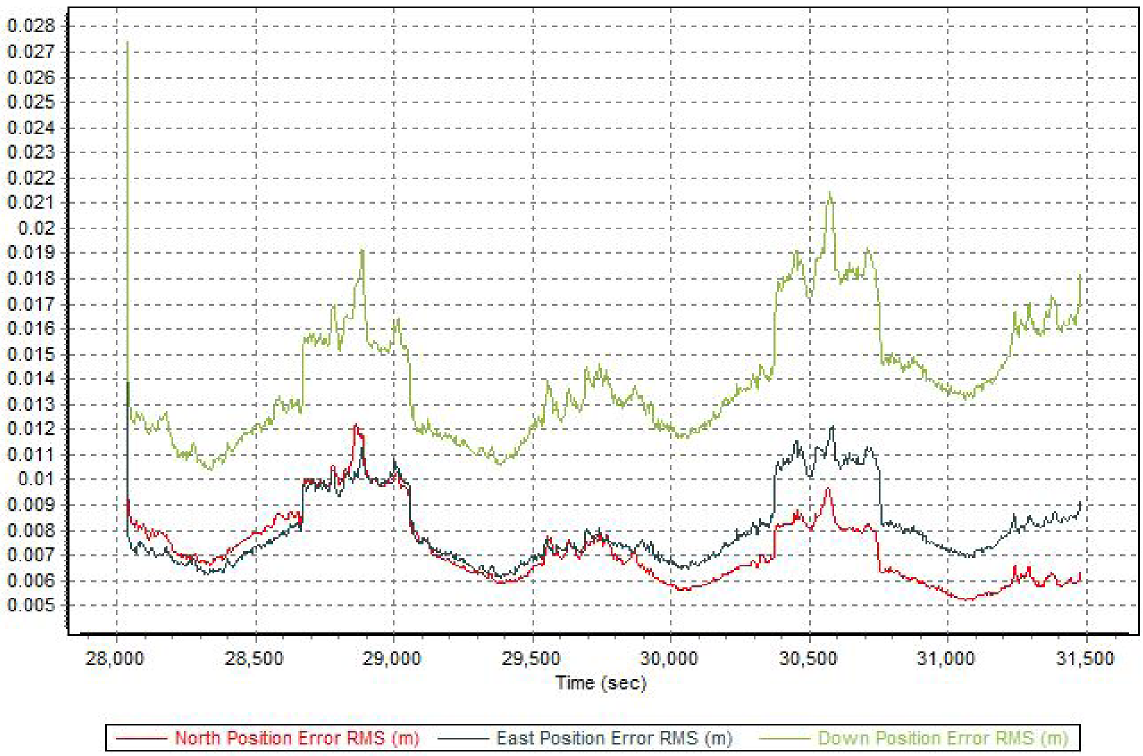


Figure A-8.23. Smoothed Performance Metrics Parameters

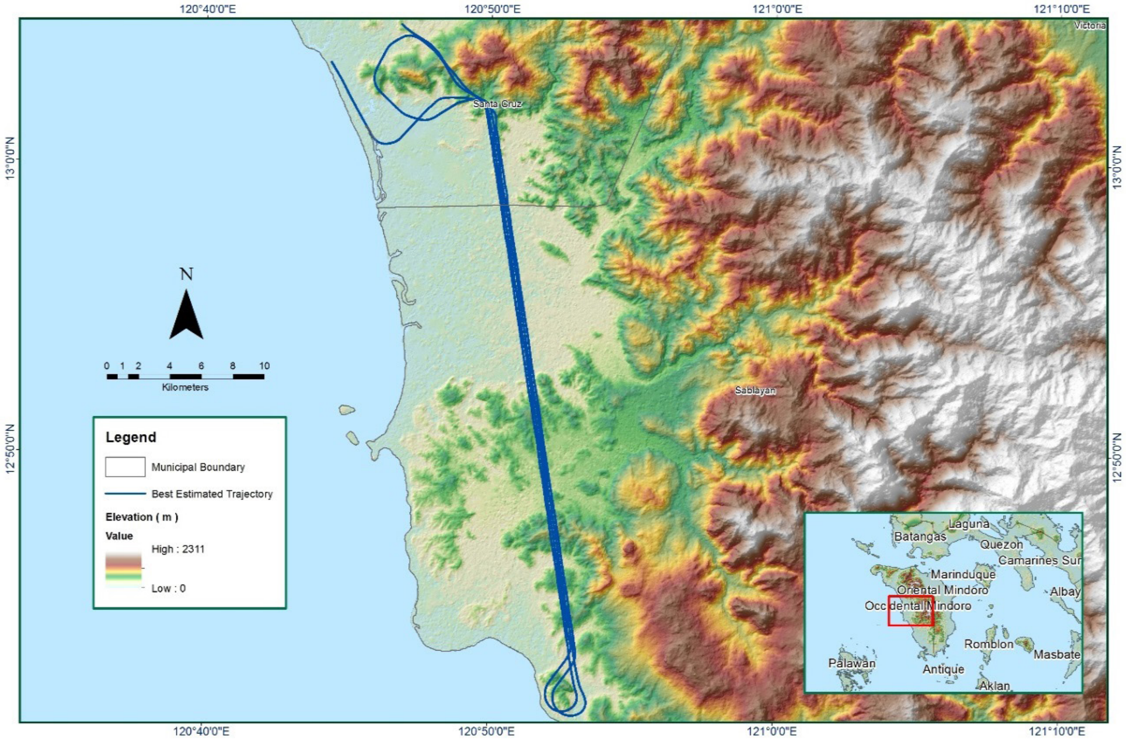


Figure A-8.24. Best Estimated Trajectory

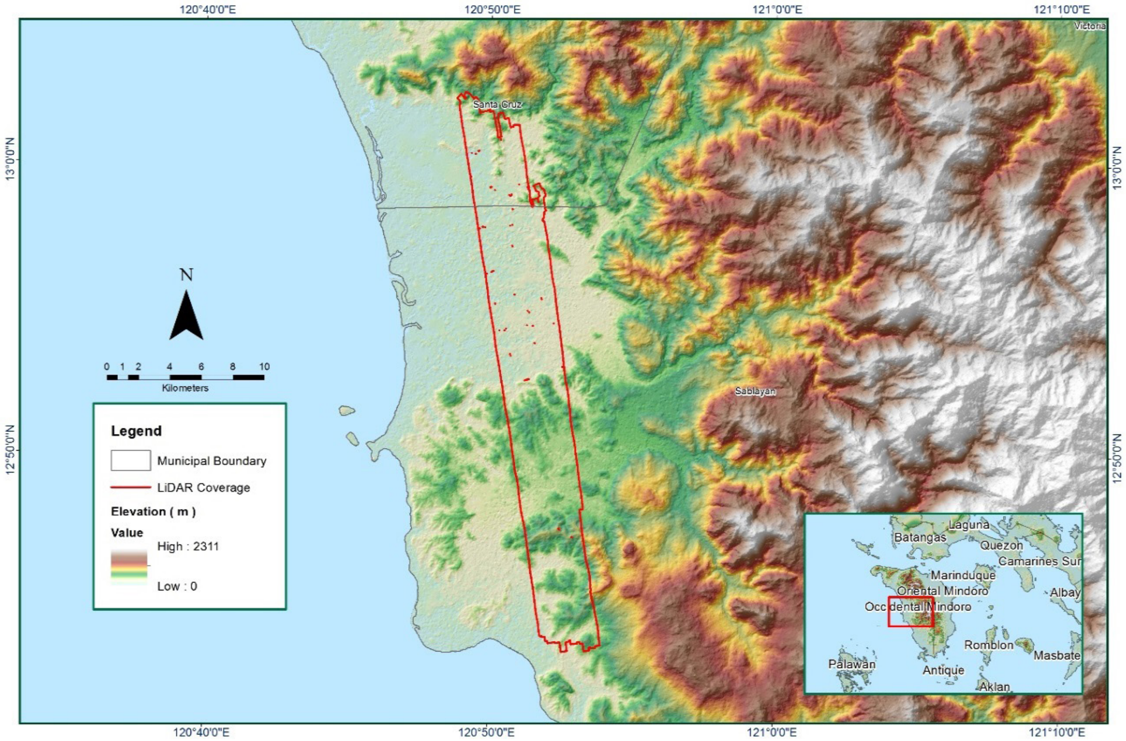


Figure A-8.25. Coverage of LiDAR data

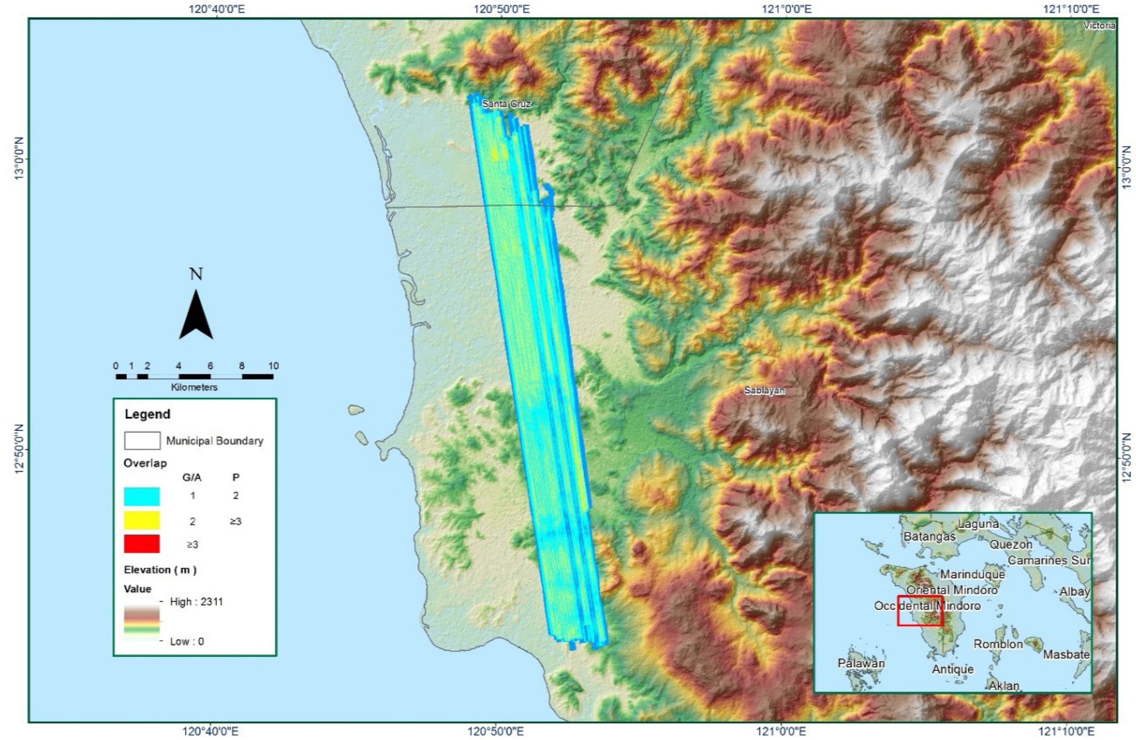


Figure A-8.26. Image of data overlap

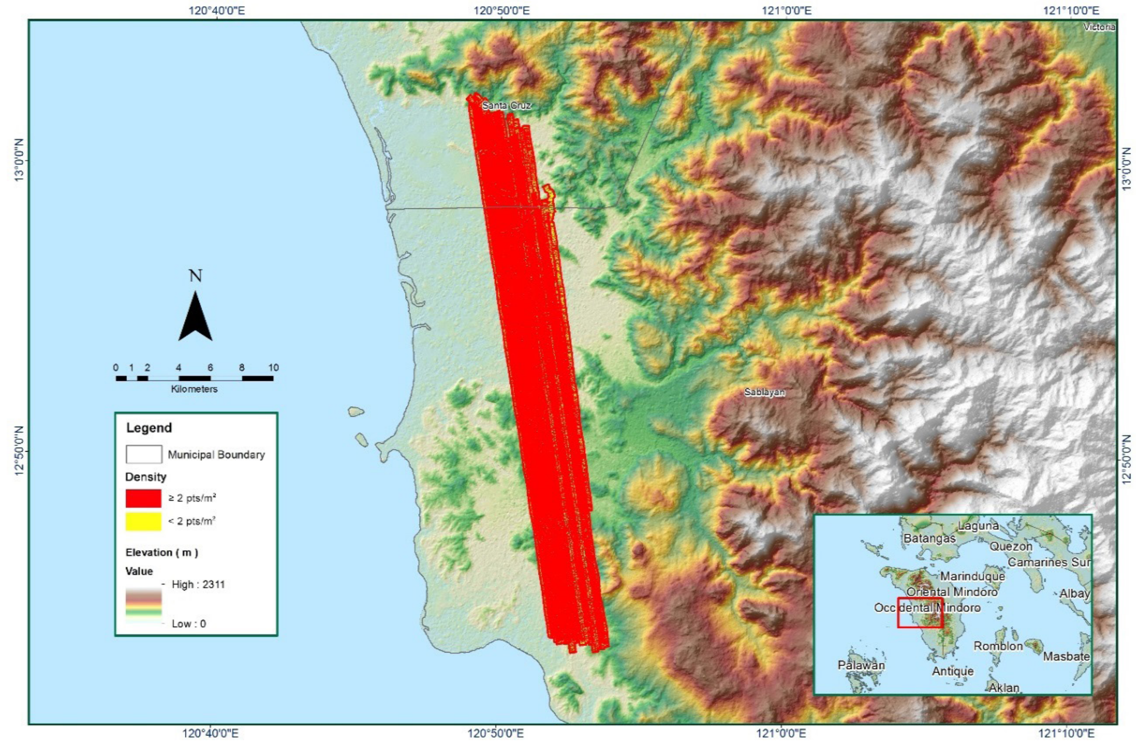


Figure A-8.27. Density of merged LiDAR data

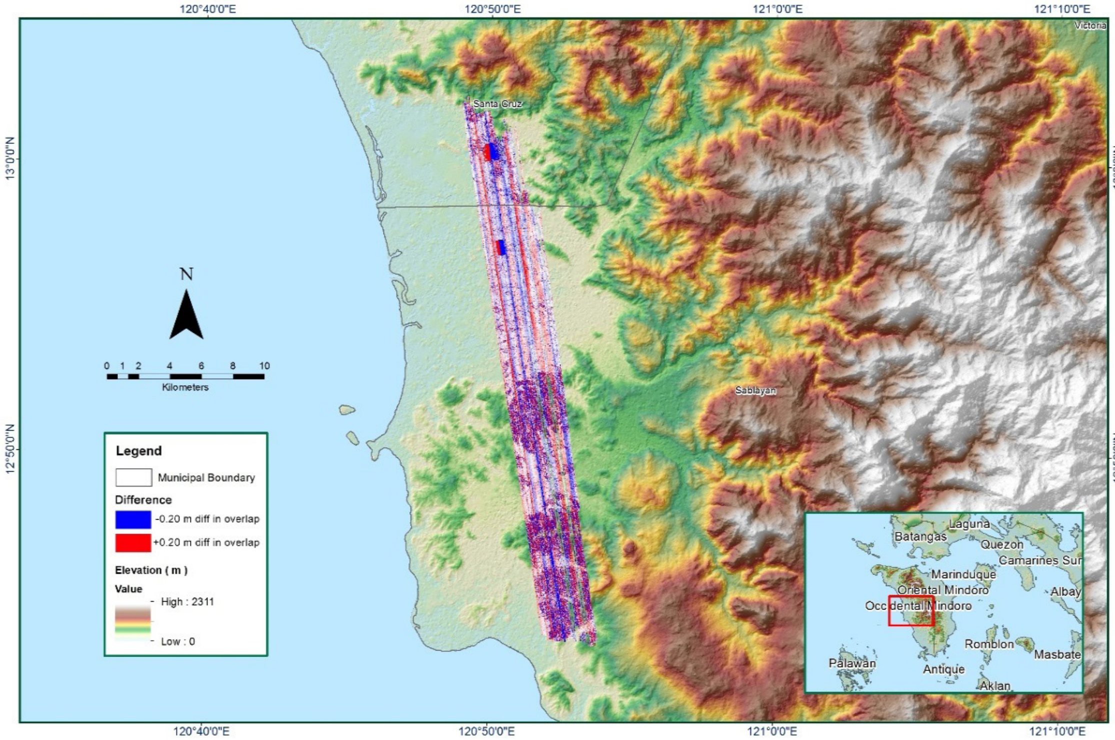


Figure A-8.28. Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Mission Blk29K_supplement

Flight Area	Occidental Mindoro
Mission Name	**Blk29K_supplement**
Inclusive Flights	1116A
Range data size	12 GB
Base data size	15.3 MB
POS	245 MB
Image	71.7 GB
Transfer date	03/07/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	3.1
Boresight correction stdev (<0.001deg)	0.000270
IMU attitude correction stdev (<0.001deg)	0.000746
GPS position stdev (<0.01m)	0.0093
Minimum % overlap (>25)	50.49%
Ave point cloud density per sq.m. (>2.0)	3.92
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	120
Maximum Height	480.52 m
Minimum Height	40.03 m
Classification (# of points)	
Ground	70,346,563
Low vegetation	80,229,446
Medium vegetation	59,317,225
High vegetation	53,714,475
Building	2,710,470
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Mary Celine Vasquez,

Figure A-8.29. Solution Status

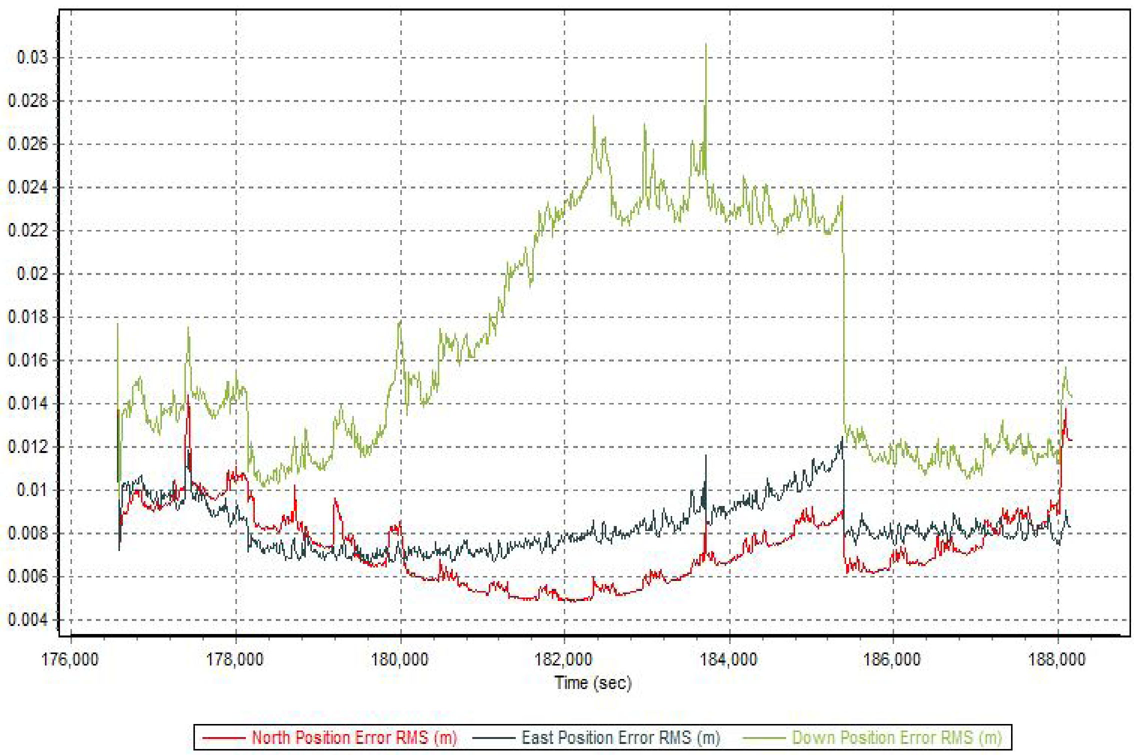


Figure A-8.30. Smoothed Performance Metrics Parameters

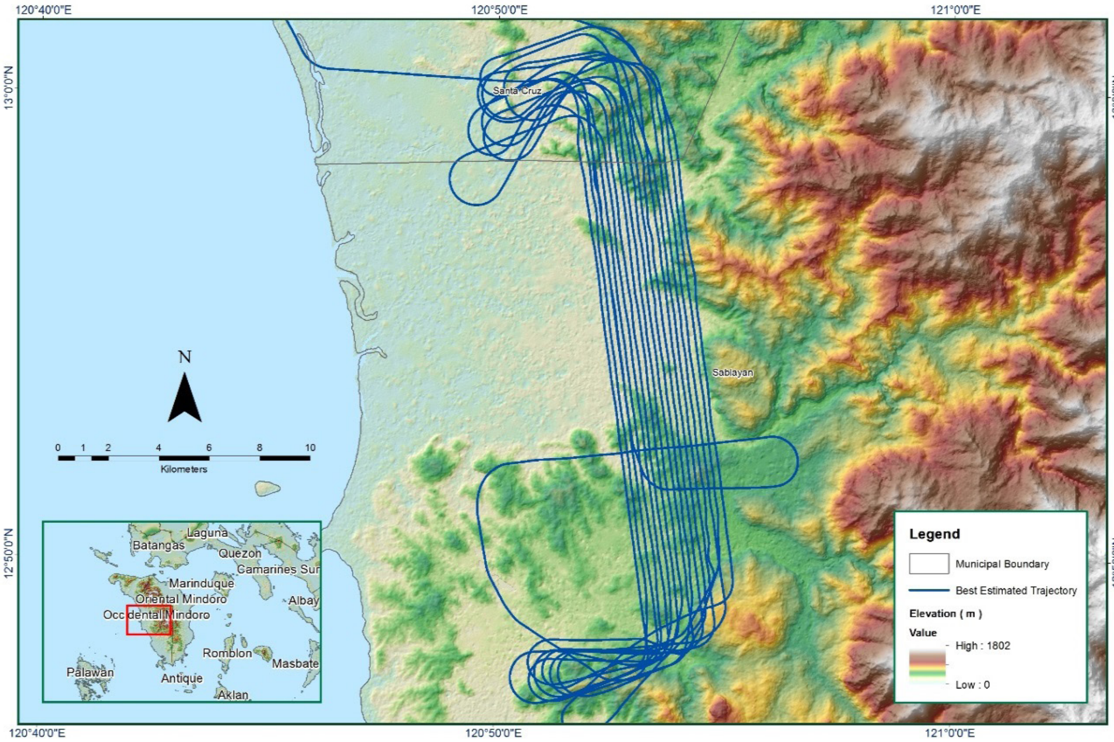


Figure A-8.31. Best Estimated Trajectory

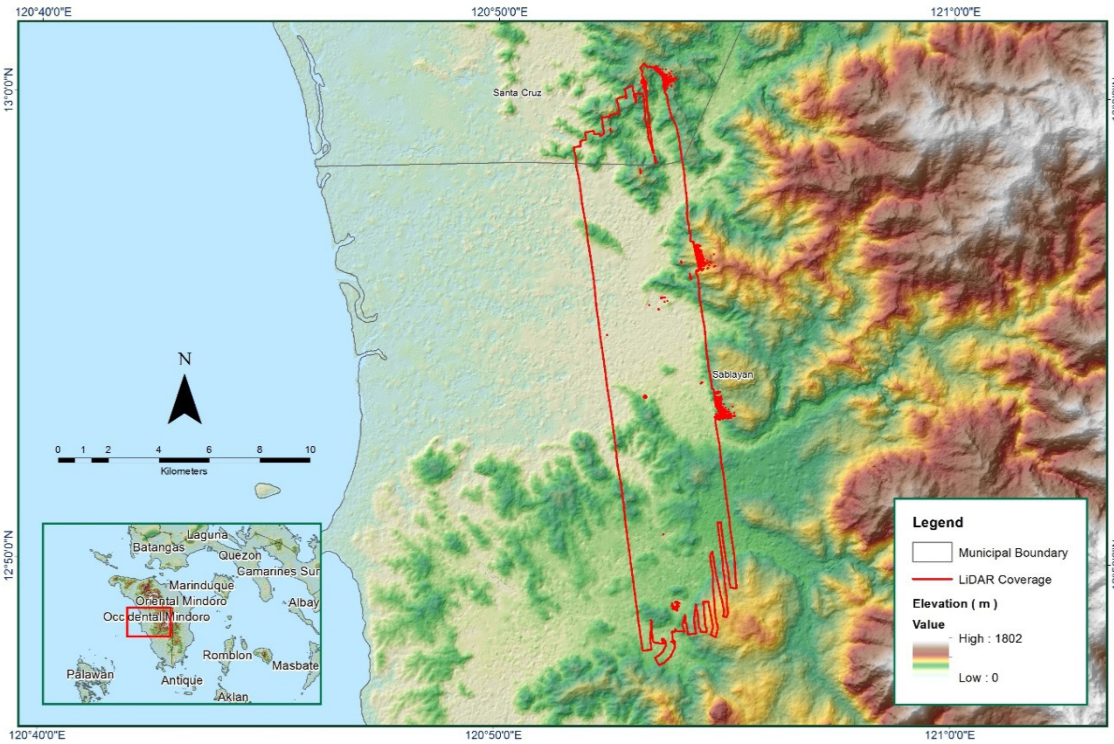


Figure A-8.32. Coverage of LiDAR data

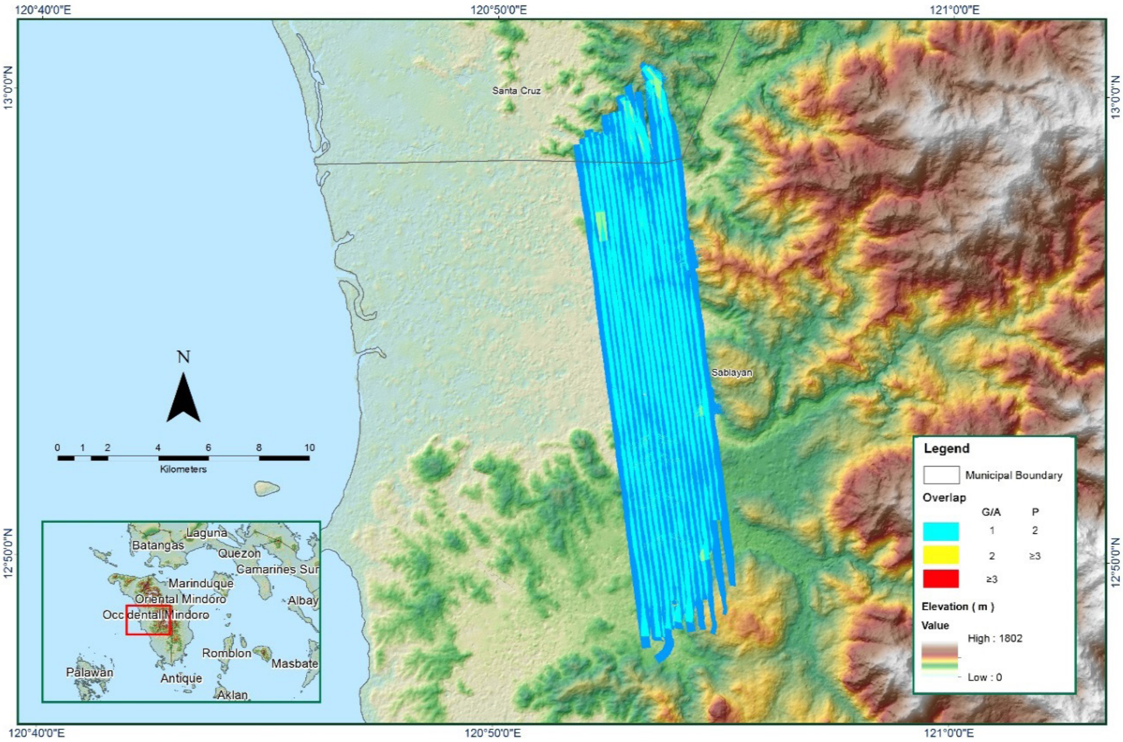


Figure A-8.33. Image of data overlap

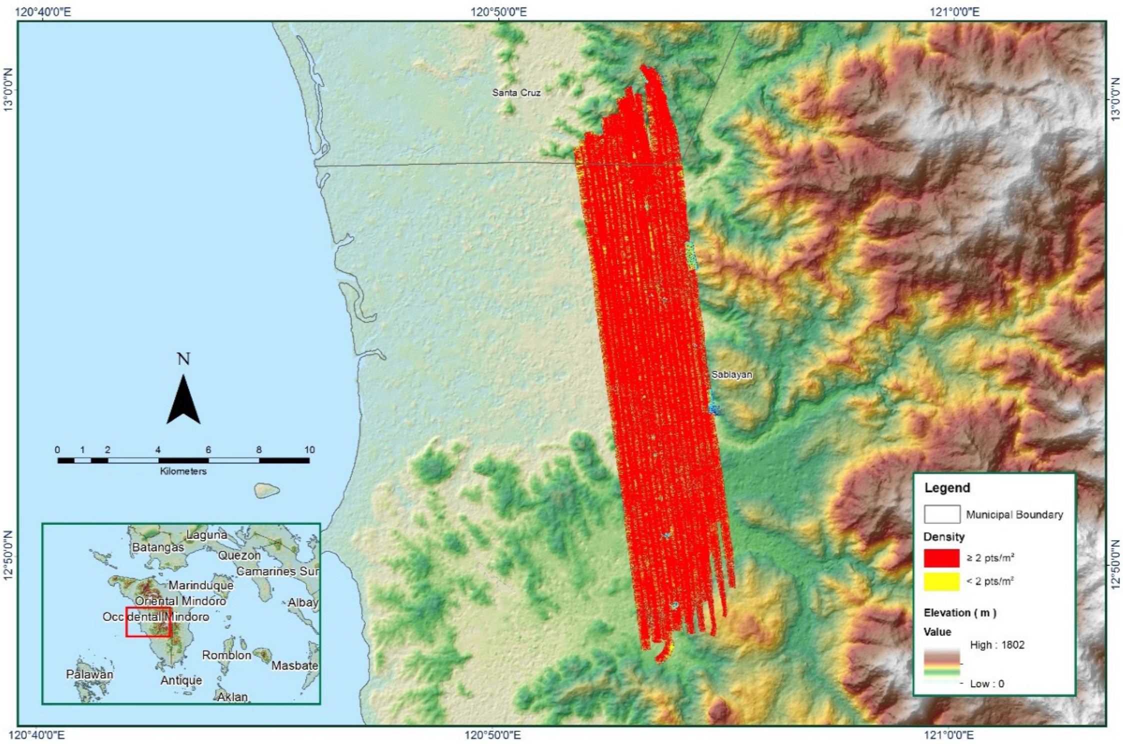


Figure A-8.34. Density of merged LiDAR data

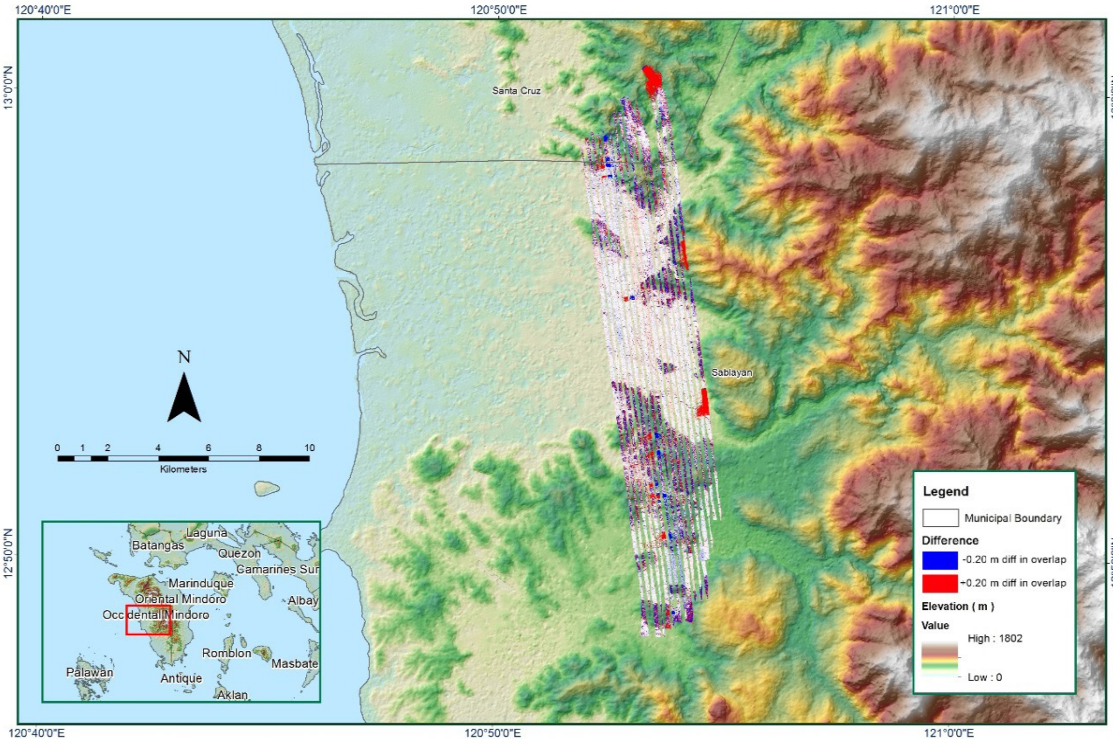


Figure A-8.35. Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Mission Blk29HI

Flight Area	Occidental Mindoro Reflights
Mission Name	**Blk29HI**
Inclusive Flights	3068P, 3070P
Range data size	12.14GB
Base data size	21.96 MB
POS	257 MB
Image	18.93 MB
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.20
RMSE for East Position (<4.0 cm)	1.56
RMSE for Down Position (<8.0 cm)	3.52
Boresight correction stdev (<0.001deg)	0.000567
IMU attitude correction stdev (<0.001deg)	0.000448
GPS position stdev (<0.01m)	0.0011
Minimum % overlap (>25)	20.41
Ave point cloud density per sq.m. (>2.0)	1.75
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	107
Maximum Height	270.48 m
Minimum Height	47.62 m
Classification (# of points)	
Ground	54,972,808
Low vegetation	33,840,636
Medium vegetation	55,240,382
High vegetation	47,256,226
Building	347,251
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Velina Angela Bemida, Jovy Narisma

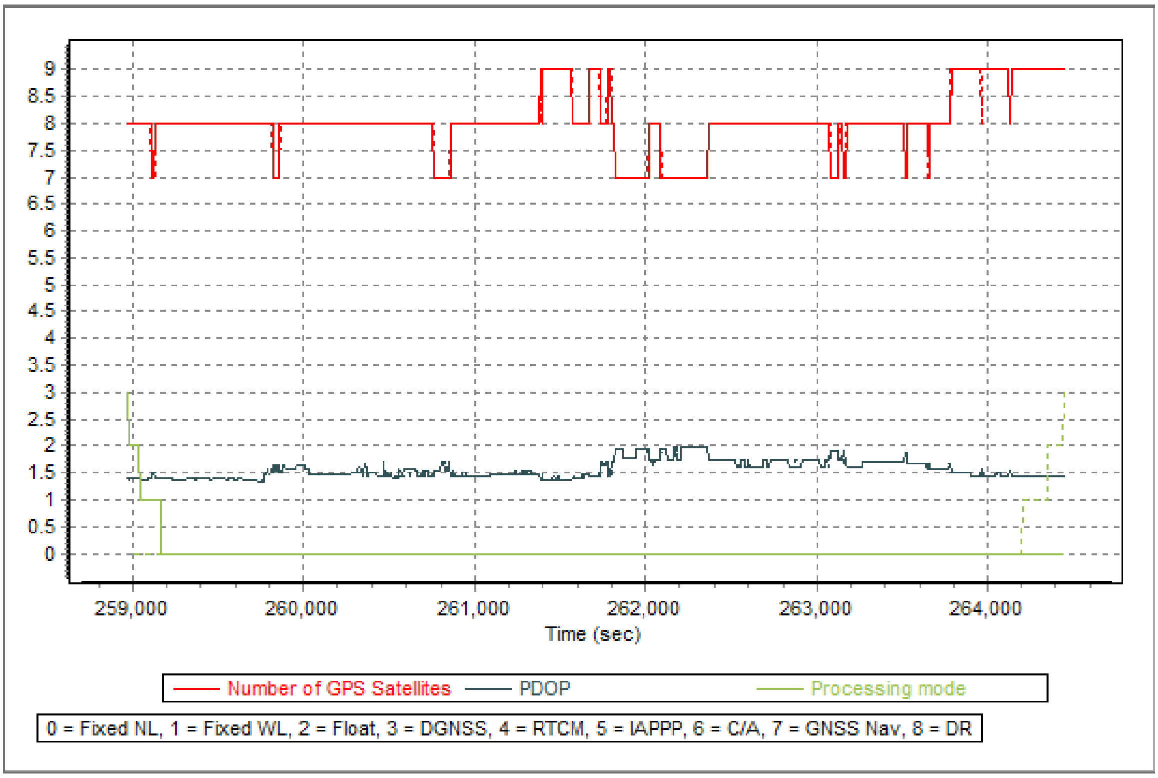


Figure A-8.36. Solution Status

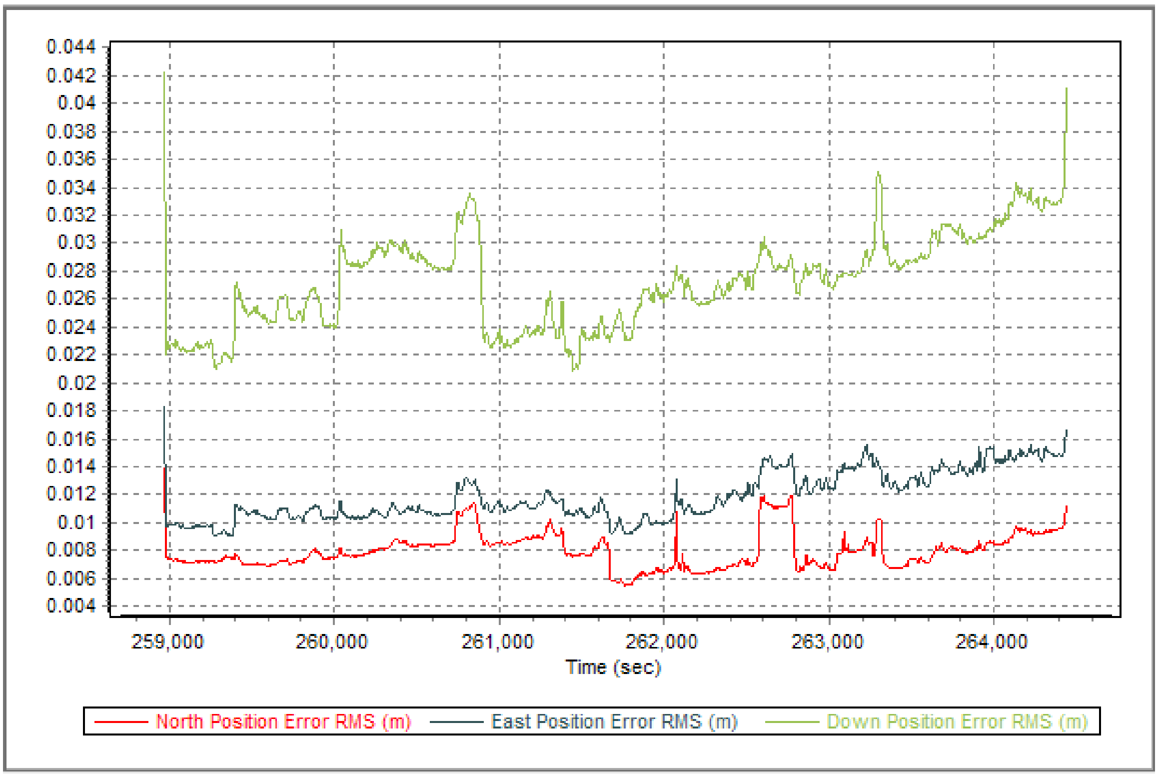


Figure A-8.37. Smoothed Performance Metric Parameters

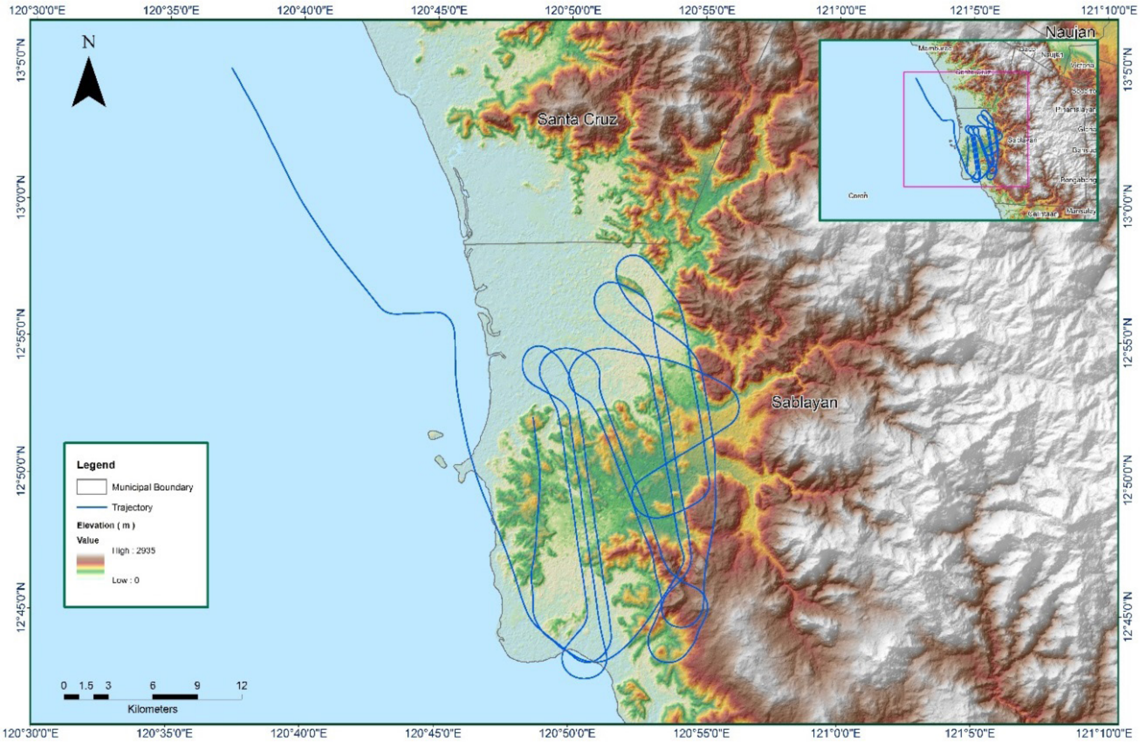


Figure A-8.38. Best Estimate Trajectory

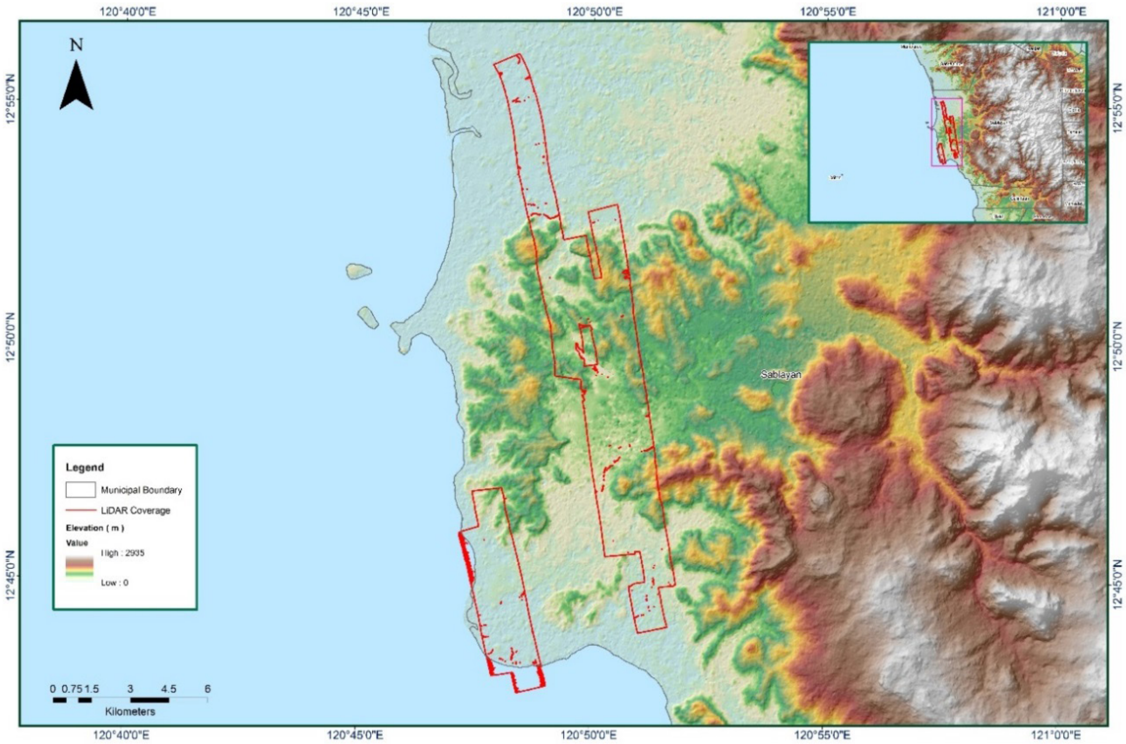


Figure A-8.39. Coverage of LiDAR data

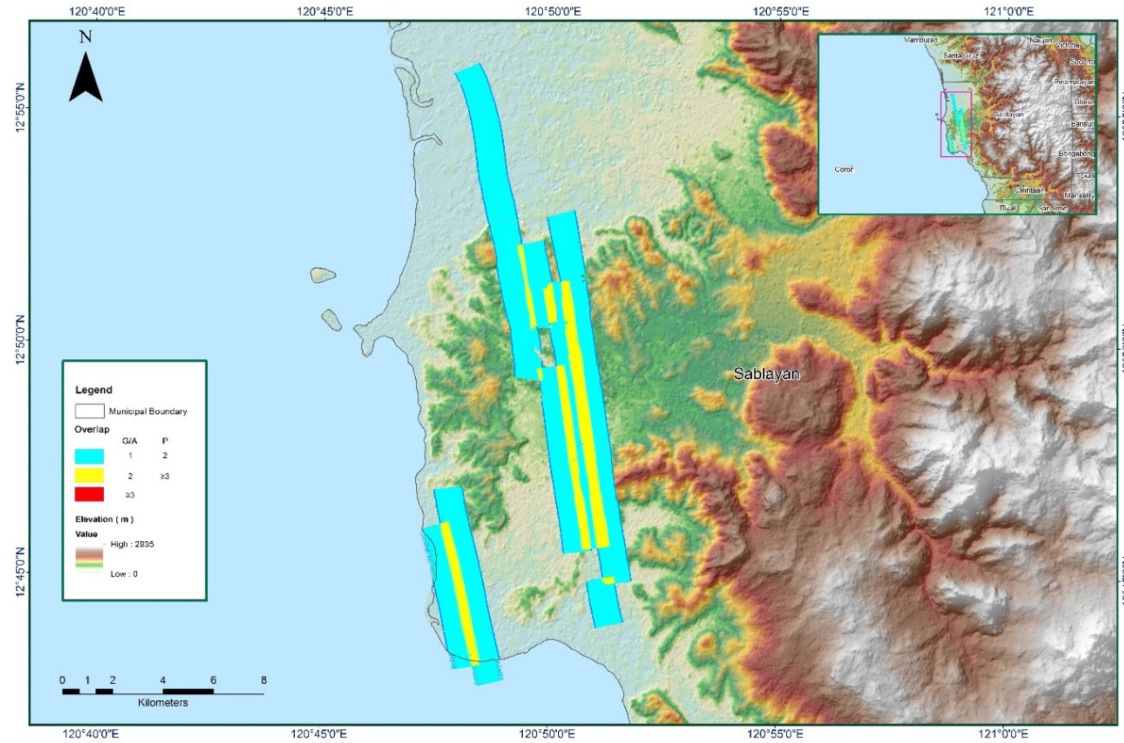


Figure A-8.40 Image of data overlap

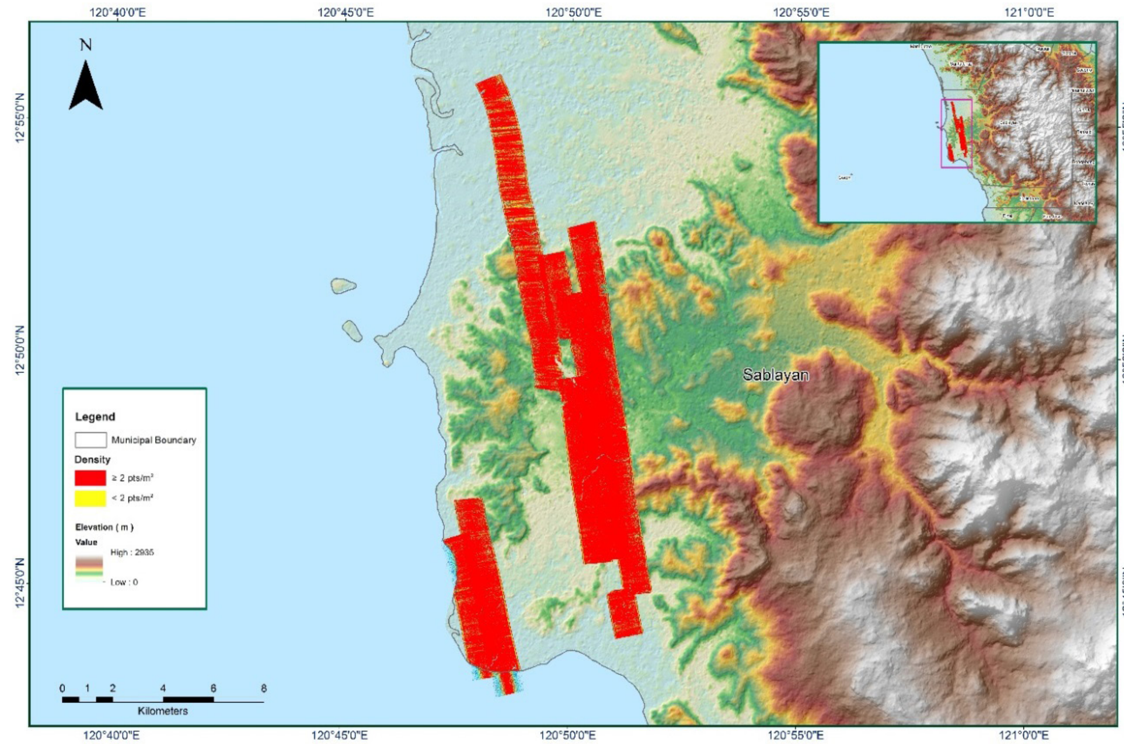


Figure A-8.41 Density Map of merged LiDAR data

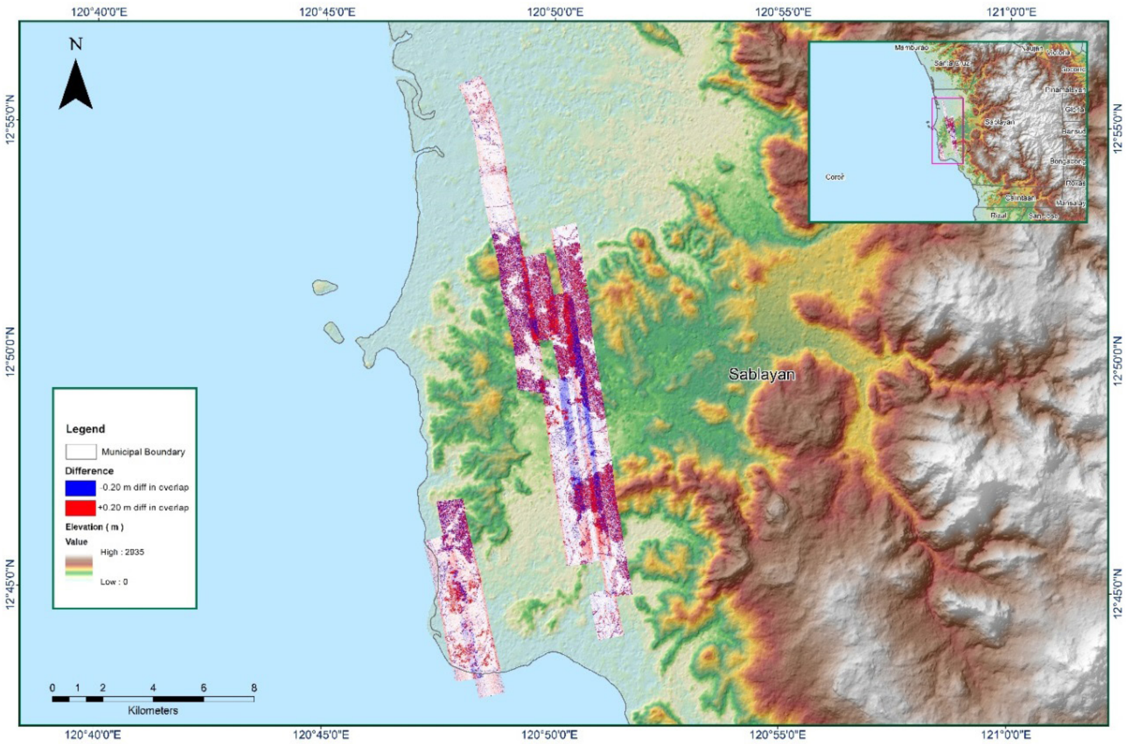


Figure A-8.42 Elevation Difference Between flight lines

Table A-8.7 Mission Summary Report for Mission Blk29JK

Flight Area	Occidental Mindoro Reflights
Mission Name	**Blk29JK**
Inclusive Flights	3070P
Range data size	9.37GB
Base data size	5.96 MB
POS	143MB
Image	14.3MB
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.20
RMSE for East Position (<4.0 cm)	1.56
RMSE for Down Position (<8.0 cm)	3.52
Boresight correction stdev (<0.001deg)	0.000474
IMU attitude correction stdev (<0.001deg)	0.000477
GPS position stdev (<0.01m)	0.0013
Minimum % overlap (>25)	15.48
Ave point cloud density per sq.m. (>2.0)	1.80
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	119
Maximum Height	569.33 m
Minimum Height	60.49 m
Classification (# of points)	
Ground	66,099,632
Low vegetation	22,449,167
Medium vegetation	52,375,898
High vegetation	190,706,605
Building	2,255,129
Orthophoto	No
Processed by	Engr. Sheila-Maye Santillan, Engr. Justine Francisco, Engr. Krisha Marie Bautista

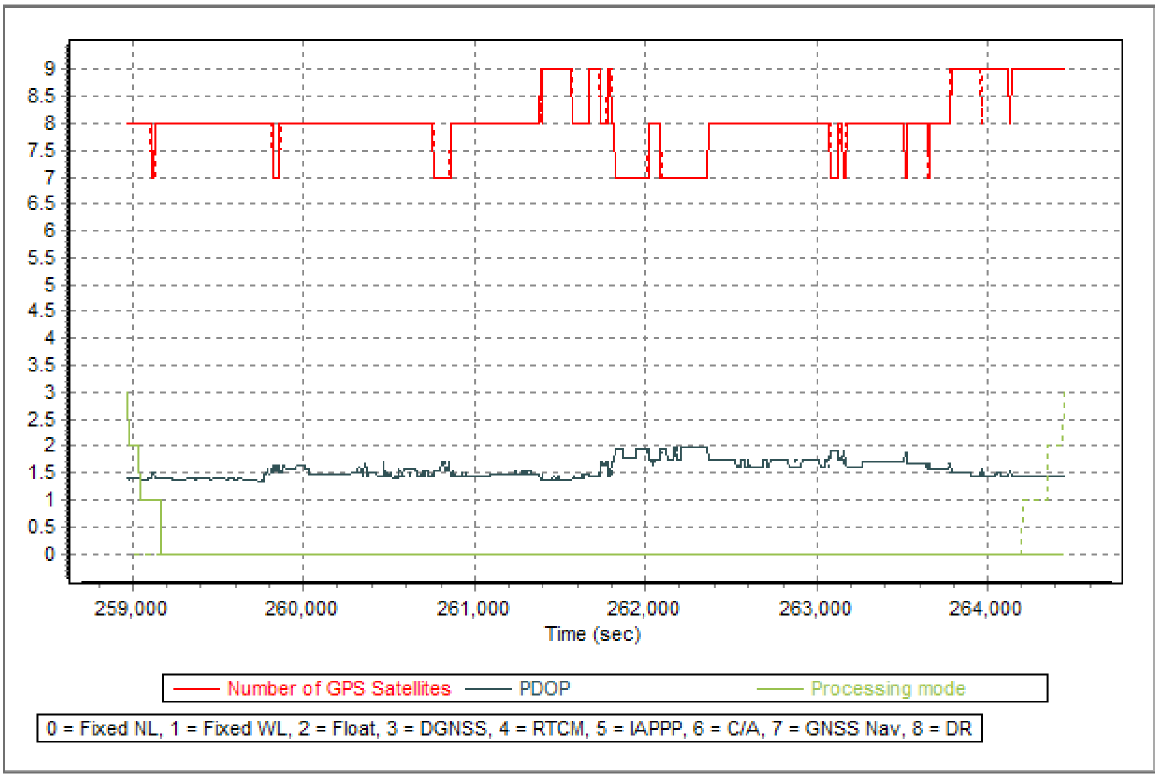


Figure A-8.43. Solution Status

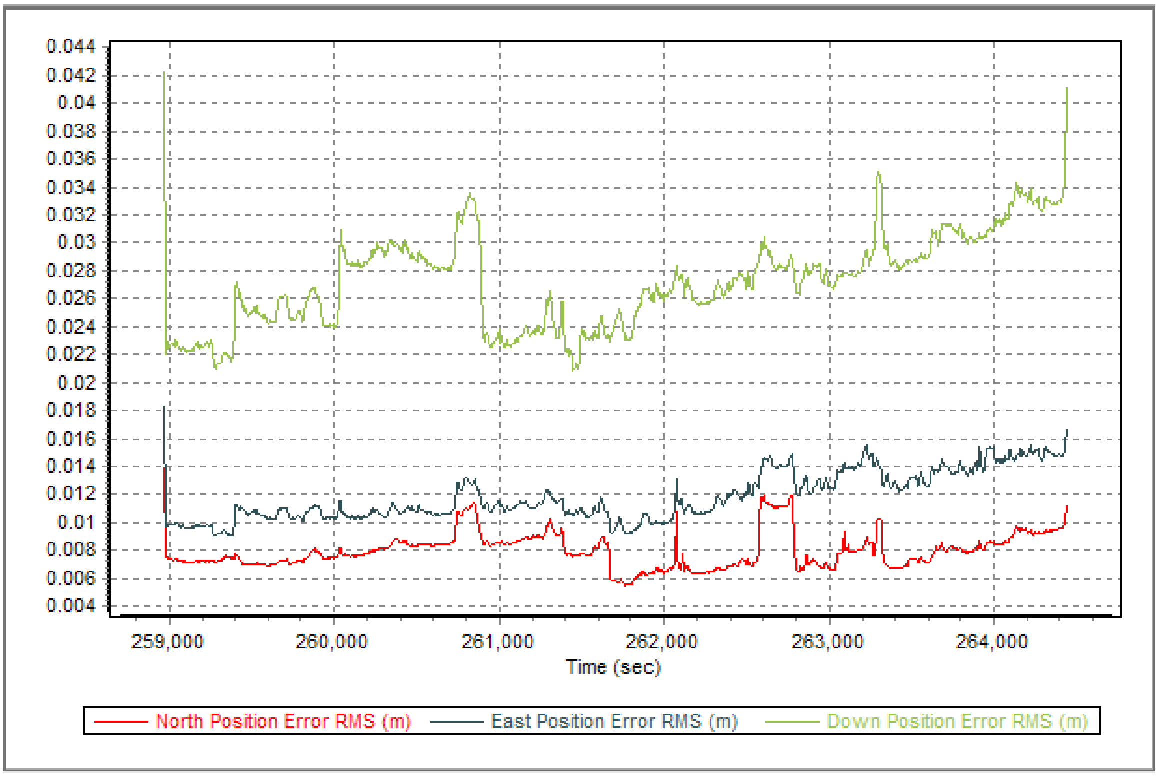


Figure A-8.44. Smoothed Performance Metric Parameters

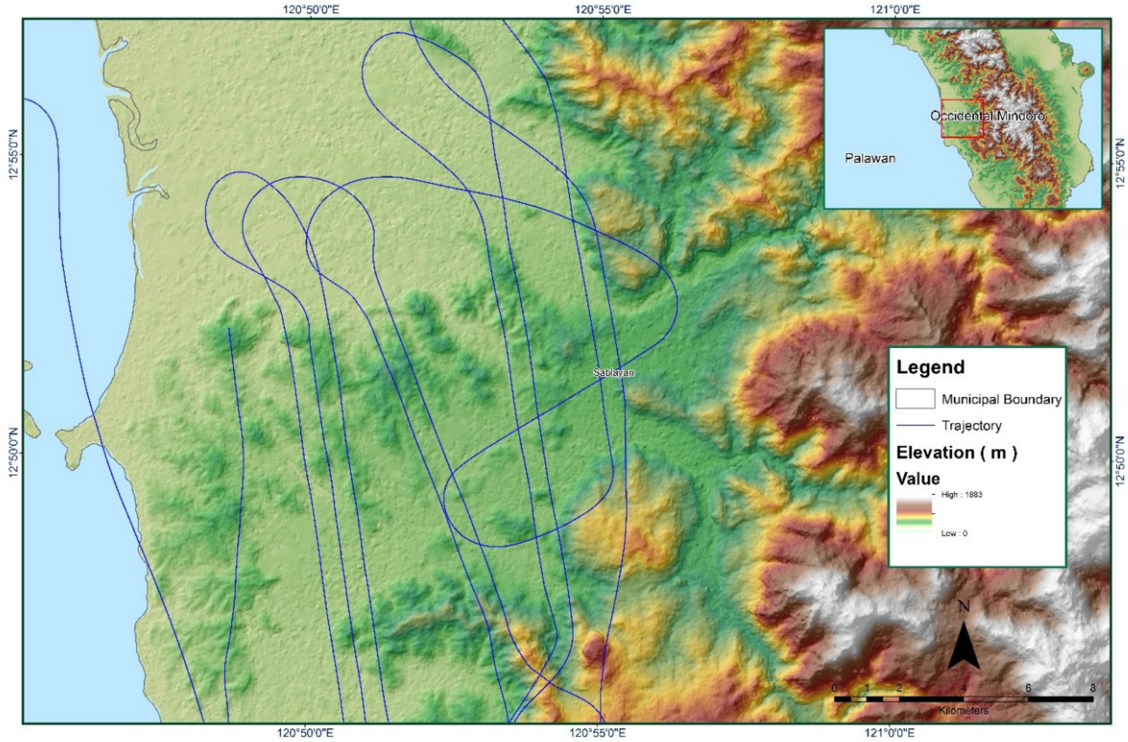


Figure A-8.45. Best Estimate Trajectory

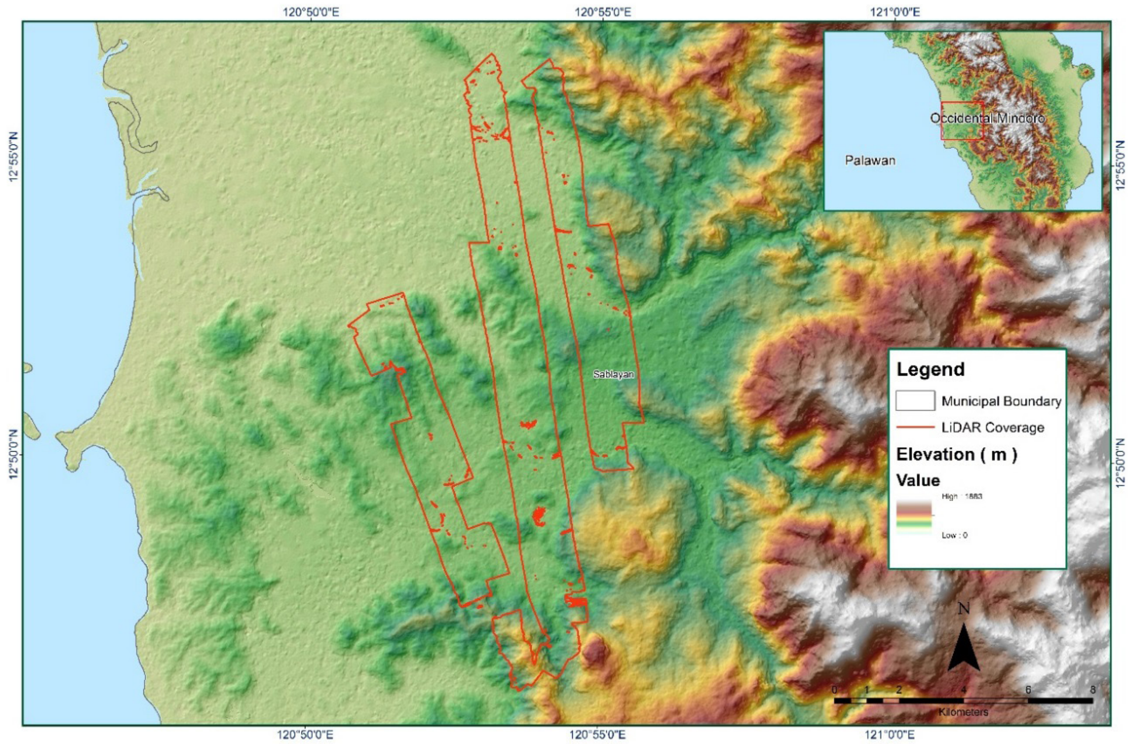


Figure A-8.46. Coverage of LiDAR data

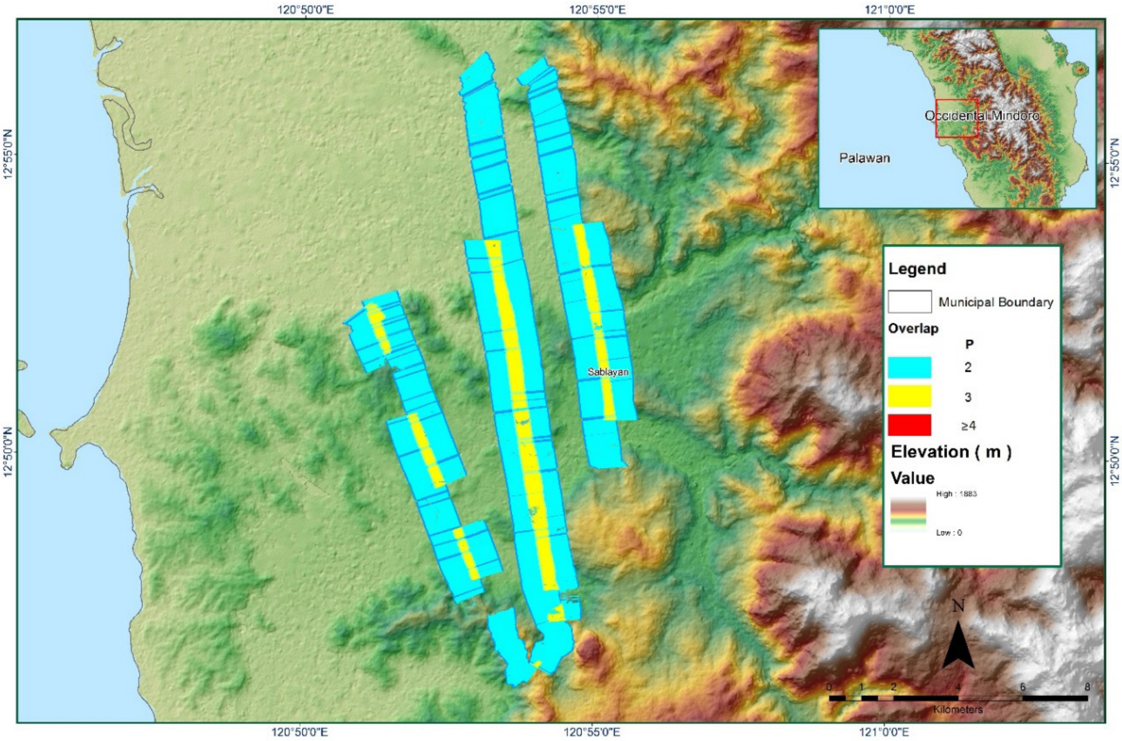


Figure A-8.47 Image of data overlap

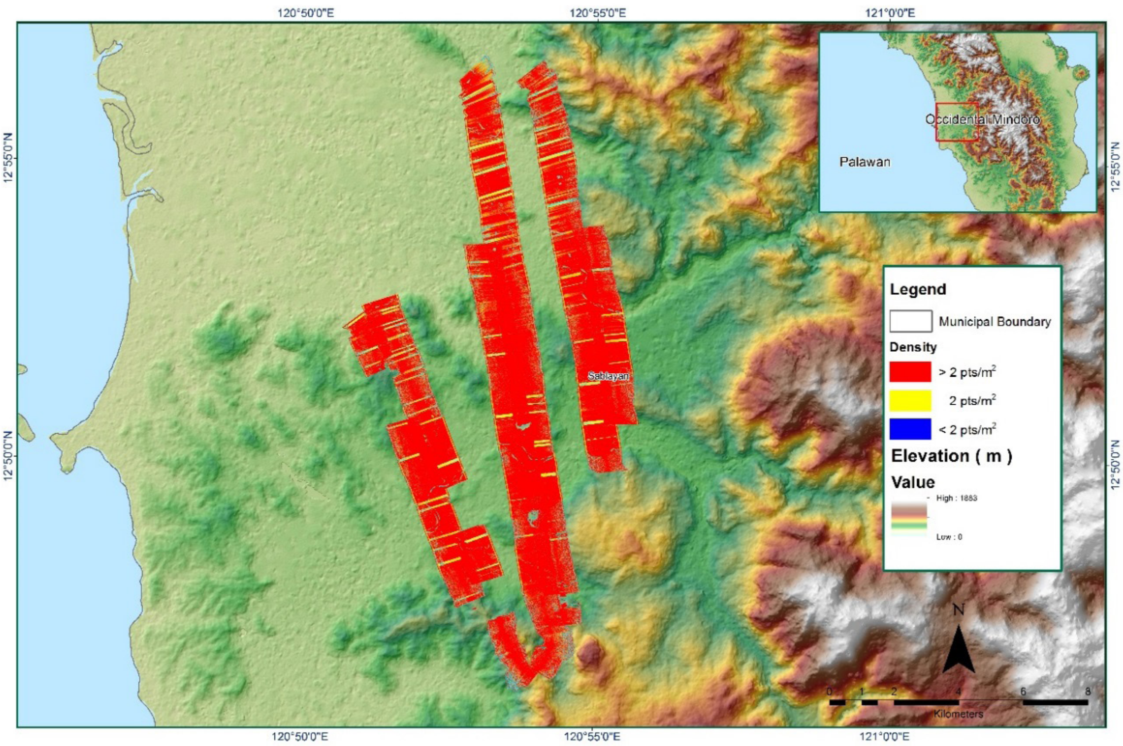


Figure A-8.48 Density Map of merged LiDAR data

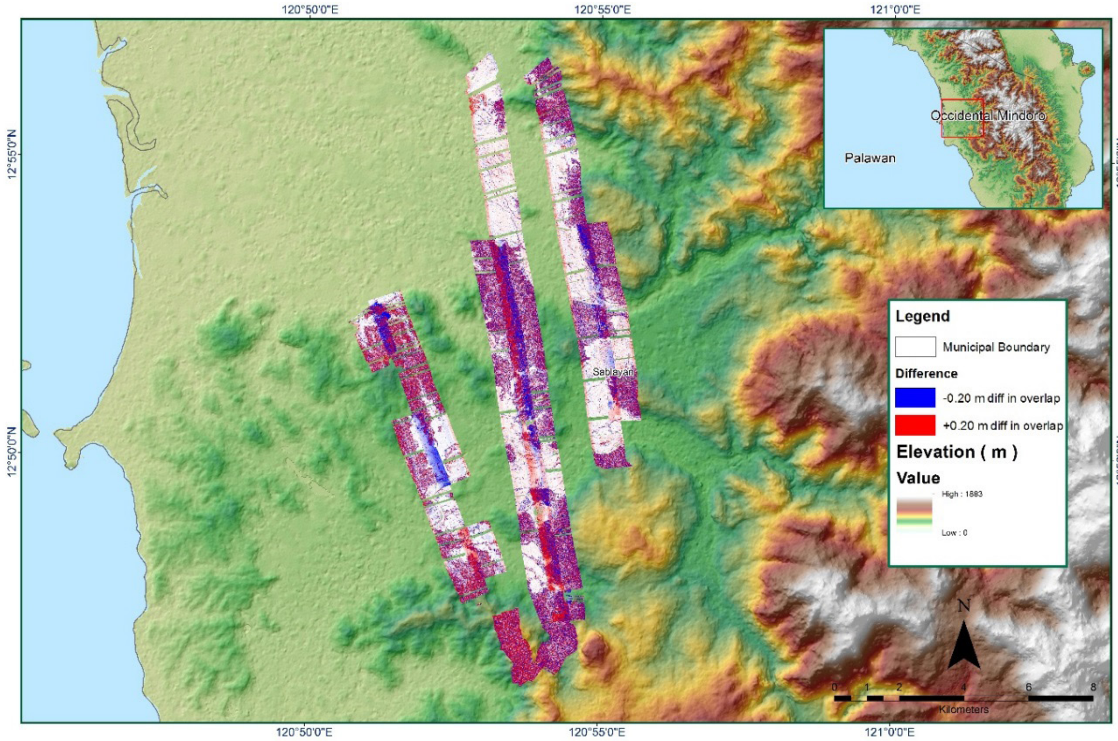


Figure A-8.49 Elevation Difference Between flight lines

Annex 9. Mompong Model Basin Parameters

Table A-9.1 Mompong 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
W380	6.0261	98.197	0.0	5.5316	6.2941	0.29534	0.98	0.25
W390	6.0951	98.971	0.0	4.4117	3.2947	0.12806	1	0.37107
W410	8.1993	98.985	0.0	0.8846	3.592	0.13197	1	0.25
W420	5.9732	94.728	0.0	1.7343	2.2139	0.0560618	1	0.24287
W430	5.7935	99	0.0	4.0255	1.7992	0.0951919	1	0.25354
W440	6.0665	99	0.0	1.2584	2.0086	0.0668658	1	0.25087
W450	6.8247	99	0.0	4.1784	6.019	0.17362	1	0.2401
W460	6.1042	99	0.0	0.8752	2.1605	0.0432015	1	0.2547
W470	5.772	99	0.0	1.1014	1.2426	0.0176548	0.65333	0.24825
W480	8.569	99	0.0	1.7469	4.6799	0.10957	0.9	0.2512
W490	5.5416	99	0.0	2.3212	1.7784	0.11227	0.63311	0.25443
W500	6.8953	99	0.0	2.1965	5.6343	0.22879	0.92865	0.245
W510	8.9323	99	0.0	1.6763	2.8826	0.0458540	1	0.25248
W520	5.4199	99	0.0	2.0433	2.3942	0.0511861	1	0.25412
W530	7.3261	99	0.0	9.5494	4.8588	0.19817	1	0.25
W540	5.3059	98.392	0.0	2.9991	5.4646	0.28665	0.9651	0.56019
W550	4.9139	99	0.0	0.6522	1.0059	0.0665891	0.87318	0.16884
W560	6.1919	99	0.0	1.3455	4.6639	0.13473	1	0.16333
W570	13.365	99	0.0	0.9232	1.0547	0.0015587	1	0.25
W580	13.406	99	0.0	0.4987	0.5697	0.0055831	1	0.25
W590	10.469	99	0.0	1.0217	1.1666	0.0398531	1	0.245

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
W600	8.0661	99	0.0	3.271	2.4982	0.0601932	1	0.25
W610	13.289	35.907	0.0	1.188	1.3615	0.0130201	1	0.25
W620	7.6321	99	0.0	1.1335	2.9094	0.0953046	1	0.25
W630	5.5468	99	0.0	2.4172	2.7614	0	1	1
W640	4.1215	99	0.0	8.3786	9.5717	0	1	1
W650	8.7936	99	0.0	1.8931	1.4054	0.12221	1	0.25
W660	8.9266	99	0.0	3.7609	3.9575	0.10857	1	0.25
W670	8.9524	82.13	0.0	2.3407	5.8362	0.0800627	1	0.25
W680	8.7316	99	0.0	1.8313	3.06	0.0601832	1	0.25
W690	7.4615	99	0.0	4.143	5.9031	0.12450	1	0.25
W700	8.6077	99	0.0	1.8335	4.6705	0.0099697	1	0.25
W710	7.8956	99	0.0	2.2033	4.26	0.0790288	1	0.25
W720	8.7841	99	0.0	1.3245	2.445	0.0175051	0.99481	0.25
W730	8.7703	99	0.0	1.8897	1.9039	0.0575122	1	0.25
W740	10.424	99	0.0	2.6899	3.0731	0.10657	1	0.245
W760	3.5459	99	0.0	8.6818	14.1686	0	1	1
W770	3.8849	99	0.0	0.2698	0.3441	0	1	0.24233

Annex 10. Mompong Model Reach Parameters

Table A-10.1 Mompong 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)
R100	Automatic Fixed Interval	2369.9	0.0107339	0.0115805	Trapezoid	160.929	1
R130	Automatic Fixed Interval	1029.8	0.0107339	0.0121987	Trapezoid	160.929	1
R170	Automatic Fixed Interval	6179.5	0.0142328	0.0103978	Trapezoid	160.929	1
R190	Automatic Fixed Interval	496.3	0.0261562	0.0034747	Trapezoid	160.929	1
R200	Automatic Fixed Interval	1117.2	0.0179974	0.007746	Trapezoid	160.929	1
R210	Automatic Fixed Interval	4704.2	0.0553442	0.0076832	Trapezoid	160.929	1
R220	Automatic Fixed Interval	18002.0	0.0040358	0.008	Trapezoid	160.929	1
R230	Automatic Fixed Interval	1141.2	0.0174672	0.027	Trapezoid	160.929	1
R250	Automatic Fixed Interval	1408.0	0.0365805	0.011365	Trapezoid	160.929	1
R30	Automatic Fixed Interval	3682.3	0.0021861	0.0181432	Trapezoid	160.929	1
R300	Automatic Fixed Interval	5108.9	0.0034773	0.008	Trapezoid	160.929	1
R310	Automatic Fixed Interval	2501.4	0.0066728	0.0120452	Trapezoid	160.929	1
R320	Automatic Fixed Interval	758.7	0.0188941	0.0180358	Trapezoid	160.929	1
R340	Automatic Fixed Interval	932.6	0.0219219	0.0108352	Trapezoid	160.929	1
R40	Automatic Fixed Interval	3445.3	0.0110988	0.0180727	Trapezoid	160.929	1
R60	Automatic Fixed Interval	1547.4	0.0345487	0.0075667	Trapezoid	160.929	1
R70	Automatic Fixed Interval	1182.3	0.0534398	0.020286	Trapezoid	160.929	1
R780	Automatic Fixed Interval	442.8	0.0214628	0.0061838	Trapezoid	160.929	1
R80	Automatic Fixed Interval	3053.5	0.0190556	0.0119899	Trapezoid	160.929	1

Annex 11. Mompong Flood Validation Data

Table A-11.1 Mompong Flood Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
1	12.725785	120.82756	0.03	0.00	-0.03		25-Year
2	12.726061	120.815165	0.18	0.00	-0.18		25-Year
3	12.726254	120.817021	0.42	0.00	-0.42		25-Year
4	12.72635	120.81807	0.05	0.00	-0.05		25-Year
5	12.726362	120.815386	0.09	0.00	-0.09		25-Year
6	12.726977	120.82548	0.44	0.27	-0.17	Lawin / 2016	25-Year
7	12.726945	120.816173	0.03	0.00	-0.03		25-Year
8	12.727193	120.814634	0.03	0.00	-0.03		25-Year
9	12.728101	120.81616	0.12	0.00	-0.12		25-Year
10	12.728265	120.81531	0.07	0.00	-0.07		25-Year
11	12.728279	120.81606	0.03	0.00	-0.03		25-Year
12	12.728334	120.81502	0.03	0.00	-0.03		25-Year
13	12.728402	120.81809	0.11	0.50	0.39		25-Year
14	12.728673	120.819	0.2	0.50	0.30	Ondoy	25-Year
15	12.728744	120.81502	0.03	0.00	-0.03		25-Year
16	12.729222	120.81519	0.03	0.00	-0.03		25-Year
17	12.729442	120.81777	0.1	0.00	-0.10		25-Year
18	12.743464	120.79323	0.03	0.00	-0.03		25-Year
19	12.746528	120.7935	0.03	0.00	-0.03		25-Year
20	12.747076	120.79245	0.09	0.00	-0.09		25-Year
21	12.747189	120.79288	0.13	0.00	-0.13		25-Year
22	12.752879	120.80301	0.03	0.14	0.11	2014	25-Year
23	12.753412	120.81364	0.1	0.00	-0.10		25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
24	12.753439	120.81146	0.16	0.00	-0.16		25-Year
25	12.754759	120.81372	0.06	0.00	-0.06		25-Year
26	12.754949	120.79551	0.03	0.00	-0.03		25-Year
27	12.755546	120.8186	0.3	0.00	-0.30		25-Year
28	12.755449	120.80538	0.32	0.09	-0.23	Sept. 2016	25-Year
29	12.755498	120.80813	0.03	0.00	-0.03		25-Year
30	12.755521	120.80664	0.03	0.00	-0.03		25-Year
31	12.755971	120.79546	0.04	0.33	0.29	Glenda / 2014	25-Year
32	12.75667	120.81858	0.26	0.00	-0.26		25-Year
33	12.75686	120.80215	0.03	0.00	-0.03		25-Year
34	12.757553	120.8001	0.27	0.13	-0.14	Sept. 2012	25-Year
35	12.764087	120.7959	1.08	0.00	-1.08		25-Year
36	12.764737	120.82243	0.06	0.00	-0.06		25-Year
37	12.765775	120.79374	0.03	0.28	0.25	2016	25-Year
38	12.766039	120.82062	0.03	0.00	-0.03		25-Year
39	12.76851	120.82203	0.03	0.30	0.27	Nov. 2016	25-Year
40	12.769239	120.79291	0.04	0.00	-0.04		25-Year
41	12.770701	120.78973	0.15	0.00	-0.15		25-Year
42	12.771628	120.79211	0.09	0.00	-0.09		25-Year
43	12.773085	120.79222	0.05	0.00	-0.05		25-Year
44	12.774433	120.79217	0.45	0.35	-0.10	Lawin	25-Year
45	12.775003	120.79205	0.15	0.34	0.19	Sept. 2015	25-Year
46	12.775589	120.82176	0.03	0.00	-0.03		25-Year
47	12.776987	120.7905	0.38	0.00	-0.38		25-Year
48	12.777904	120.82069	0.03	0.00	-0.03		25-Year
49	12.77853	120.82114	0.03	0.50	0.47		25-Year
50	12.77874	120.81945	0.32	0.00	-0.32		25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
51	12.780452	120.78853	0.03	0.10	0.07	Glenda / 2014	25-Year
52	12.782455	120.78607	0.03	0.00	-0.03		25-Year
53	12.786276	120.78893	0.03	0.00	-0.03		25-Year
54	12.786423	120.78769	0.03	0.00	-0.03		25-Year
55	12.788028	120.82896	0.49	0.00	-0.49		25-Year
56	12.787771	120.78952	1.41	0.00	-1.41		25-Year
57	12.788411	120.79014	0.86	0.51	-0.35	June, 2012	25-Year
58	12.788978	120.82695	0.38	0.00	-0.38		25-Year
59	12.788958	120.79544	1.11	0.43	-0.68	Nov. 2016	25-Year
60	12.78894	120.79183	0.08	0.35	0.27	Sept. 2016	25-Year
61	12.789447	120.79468	0.68	0.86	0.18	Aug. 2016	25-Year
62	12.791008	120.79054	0.44	0.07	-0.37	Aug. 2015	25-Year
63	12.791991	120.82759	0.03	0.00	-0.03		25-Year
64	12.794785	120.79588	0.06	0.00	-0.06		25-Year
65	12.795505	120.79629	0.18	0.00	-0.18		25-Year
66	12.795773	120.79667	1.68	0.94	-0.74	Aug. 21, 2016	25-Year
67	12.796465	120.7971	0.61	0.16	-0.45	Sept. 2012	25-Year
68	12.798468	120.83542	0.05	0.00	-0.05		25-Year
69	12.804456	120.8357	0.08	0.15	0.07	2016	25-Year
70	12.805646	120.83724	0.08	0.12	0.04	Aug. 2016	25-Year
71	12.808601	120.87855	1.38	0.00	-1.38		25-Year
72	12.808469	120.83816	0.03	0.00	-0.03		25-Year
73	12.809379	120.84066	0.03	0.00	-0.03		25-Year
74	12.811144	120.84727	0.25	0.09	-0.16	Aug. 2016	25-Year
75	12.813486	120.88008	0.03	0.00	-0.03		25-Year
76	12.813662	120.85996	0.03	0.00	-0.03		25-Year
77	12.814424	120.86159	0.09	0	-0.09		25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Latitude	Longitude					
78	12.815533	120.862857	0.1	0	-0.1		25-Year
79	12.815545	120.86369	0.14	0	-0.14		25-Year
80	12.815625	120.86392	0.07	0	-0.07		25-Year
81	12.81566	120.861742	0.06	0	-0.06		25-Year
82	12.815884	120.86451	0.07	0	-0.07		25-Year
83	12.815992	120.86496	0.03	0	-0.03		25-Year
84	12.816033	120.864819	0.03	0	-0.03		25-Year
85	12.816428	120.86534	0.03	0	-0.03		25-Year
86	12.816792	120.86431	0.03	0	-0.03		25-Year
87	12.816633	120.83439	0.03	0	-0.03		25-Year
88	12.822875	120.83382	0.03	0	-0.03		25-Year
89	12.82854	120.8252	1.12	0.4	-0.72	Aug. 2016	25-Year
90	12.829526	120.82027	0.03	0	-0.03		25-Year
91	12.829679	120.82228	0.04	0.7	0.66	Sept. 2016	25-Year
92	12.831871	120.91134	0.03	0	-0.03		25-Year
93	12.833078	120.81581	0.03	0.25	0.22	Isang / 2001	25-Year
94	12.836687	120.81205	0.03	0	-0.03		25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

Project Leader
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