LiDAR Surveys and Flood Mapping of Caguray River

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LIST OF ACRONYMS AND ABBREVIATIONS

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

Enrico C. Paringit, Dr. Eng. and Asst. Prof. Edwin R. Abucay, and Engr. Ariel U. Glorioso

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 Caguray River Basin

The Caguray River Basin is a 3,830-hectare watershed located on the southern part of the province of Occidental Mindoro. It covers the barangays of Paclolo, Gapasan, Lourdes, Purnaga, Nicolas, Poblacion, Caguray, Calawag, Sibalat and Leste in Magsaysay municipality; Bayotoot, Monte Carlo and Batasan in San Jose; Cabugao, San Isidro, San Francisco, Maujan and Benli in Bulalacao; Budburan, Don Pedro, Panaytayan, Santa Maria and Waygan in Mansalay.The DENR River Basin Control Office (RCBO) states that the Caguray River Basin has a drainage area of 234 km2 and an estimated 374 million cubic meter (MCM) annual run-off.

The basin area has seven geological classifications with Paleocene-Eocene as the most dominant while the rest include Jurassic, Oligocene-Miocene, Pliocene-Pleistocene, Pliocene-Quaternary and Recent. It also generally characterized by 3-8% slope and elevation of 301-2,200 meters above mean sea level. About six soil types can be found in Caguray River Basin including Magsaysay clay, Umingan loam, Faraon clay/river wash, Quingua silty clay, Bolinao clay, and San Manuel sandy loam. Hydrosol and rough mountain land (unclassified) can also be found in the area. The most dominant type of land cover is cultivated area mixed with brushland/grassland while the rest include arable land (crops mainly cereals and sugar), built-up area, closed canopy (mature trees covering > 50%), crop land mixed with coconut plantation, fishponds derived from mangrove, grassland (grass covering >70%) and open canopy (mature trees covering <50%).

Caguray River passes through Paclolo, Gapasan, Purnaga, Poblacion, Caguray, Calawag in Magsaysay municipality; Benli in Bulalacao; and, Budburan in Mansalay. The areas along the Caguray River are mainly used for agricultural purposes as early as the Spanish Regime on the Philippines. In 1982, the National Irrigation Administration (NIA) constructed a 45 kilometer road for irrigation along Caguray River from which twenty-one percent (21%) of the agricultural lands of the municipality of Magsaysay benefited (Candelario, n.d.). An estimated 14,806 people are residing within the immediate vicinity of the river which is distributed among the 4 barangays as of 2010 according to the Philippine Statistics Authority Census. Barangay Poblacion in Magsaysay is considered to be the most populated area per record in the 2010 NSO Census of Population and Housing.

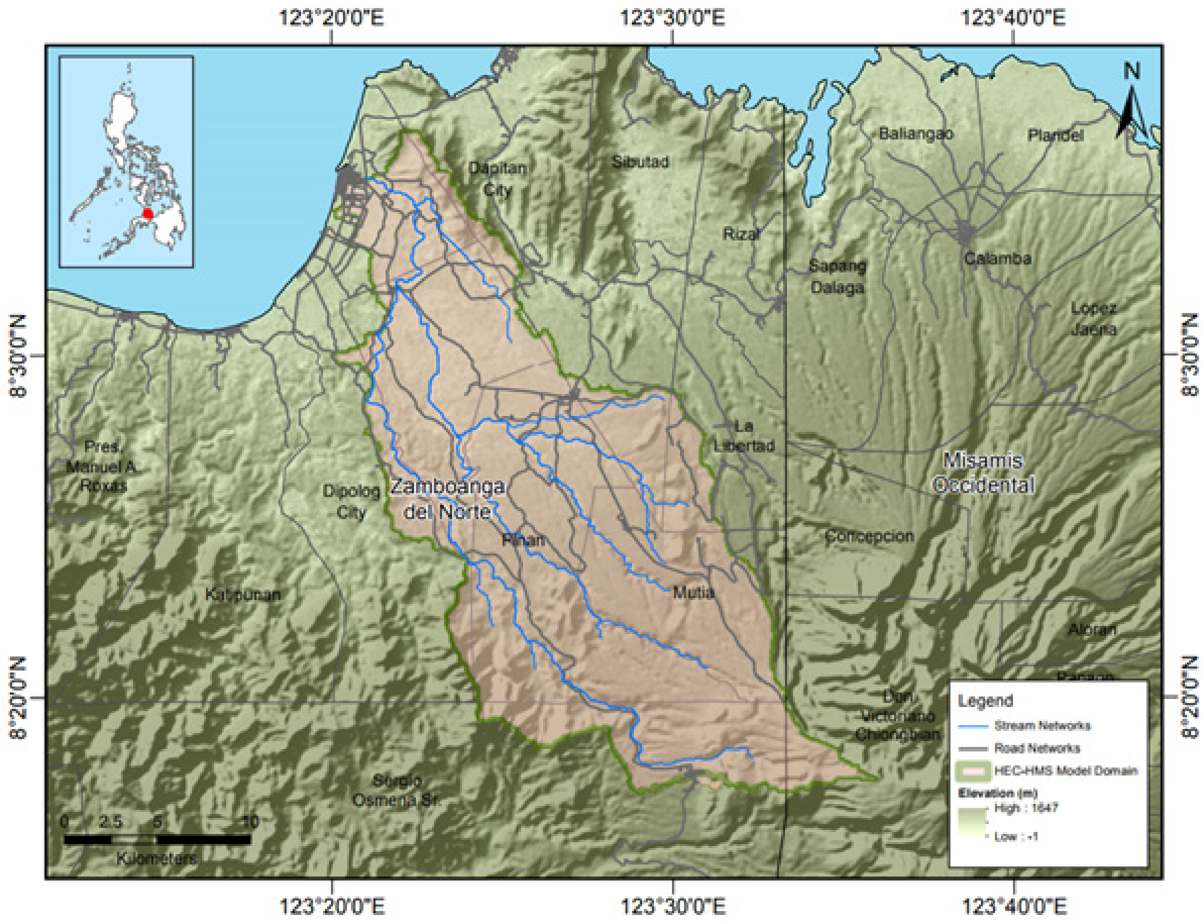

Figure 1. Map of Caguray River Basin (in brown)

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

Based on the studies conducted by the Mines and Geosciences Bureau, the barangays in both municipality of Magsaysay and Bulalacao in general have low to high risk to landslide and ood suscep bility. Additionally, the field surveys conducted by the PHIL-LiDAR 1 validation team showed that there were about eight notable weather disturbance that caused flooding in 1984 (Undang), 2008 (Frank), 2009 (Ondoy), 2014 (Glenda, Mario and Ruby), and 2015 (Nona).

CHAPTER 2: LIDAR ACQUISITION IN CAGURAY 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 Caguray Floodplain in Occidental Mindoro. These missions were planned for 18 lines that run 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 plan for Caguray Floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK29A	550	30	36	125	40	130	5
BLK29B	600	30	36	125	40	130	5
BLK29C	650	30	36	125	40	130	5
BLK29D	550, 600	30	36	125	40	130	5
BLK29K	550	30	36	125	40	130	5

Table 2. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK29N	850	30	50	200	50	130	5
BLK29Q	850	30	50	200	50	130	5
BLK29R	850, 1100	30	50	200	50	130	5
BLK29S	850	30	50	200	30	130	5

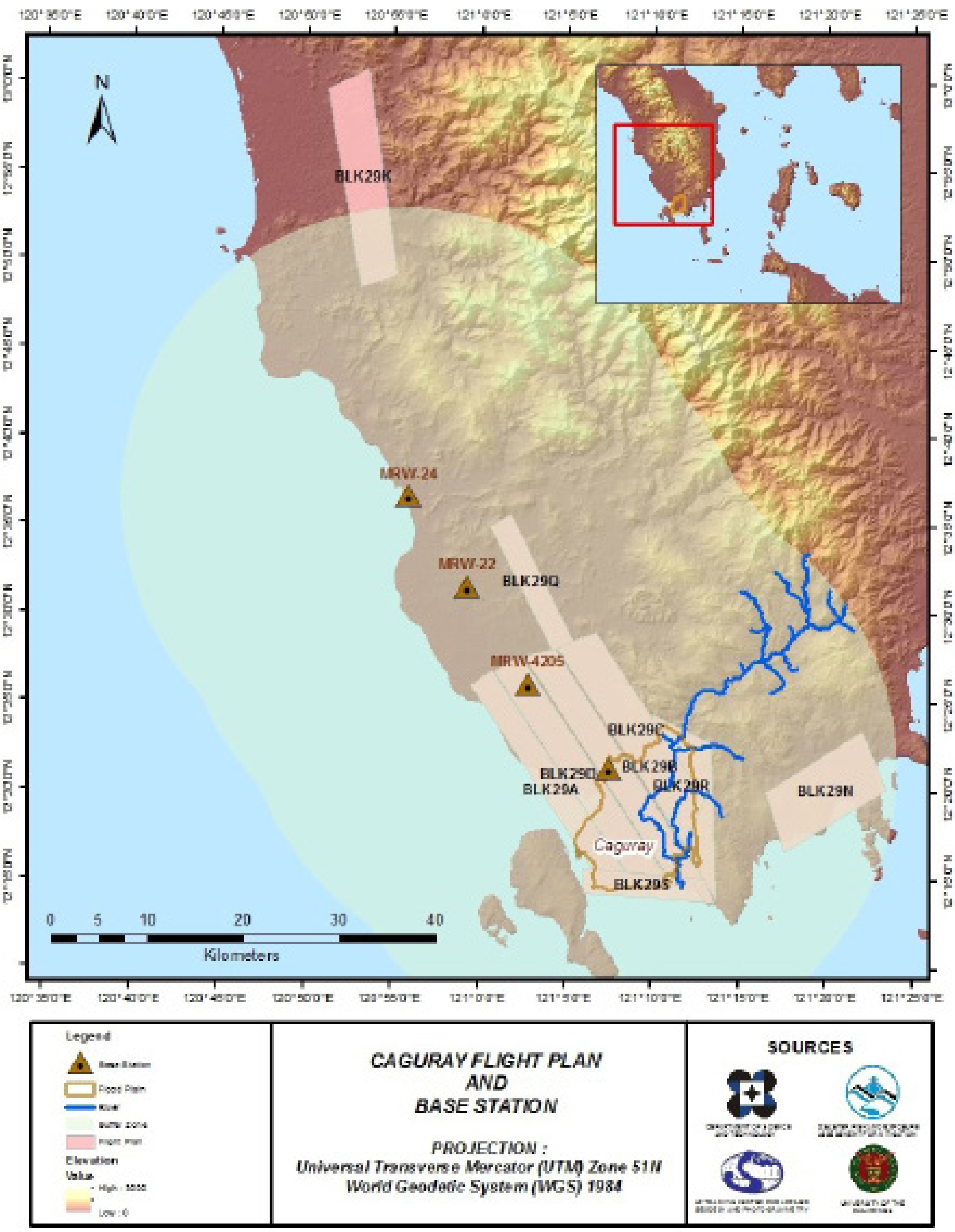


Figure 2. Flight plans and base stations used for Caguray Floodplain

2.2 Ground Base Station

The project team was able to recover five (5) NAMRIA ground control points: MRW-18, MRW-22 and MRW-24 which are of second (2nd) order accuracy and MRW- 4203 and MRW-4205 which are of third (3rd) order accuracy. The project team also established one (1) ground control point MRW-18A. The certifications for the NAMRIA reference points are found in Annex 2, while the baseline processing reports for the established ground control point is found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 28-March 3, 2014; December 11-12, 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 Caguray floodplain are shown in Figure 2. The list of team members are shown in Annex 4.

Figure 3 to Figure 5 show the recovered NAMRIA reference points within the area, in addition Table 3 to Table 7 show the details about the following NAMRIA control stations and established points, Table 8 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

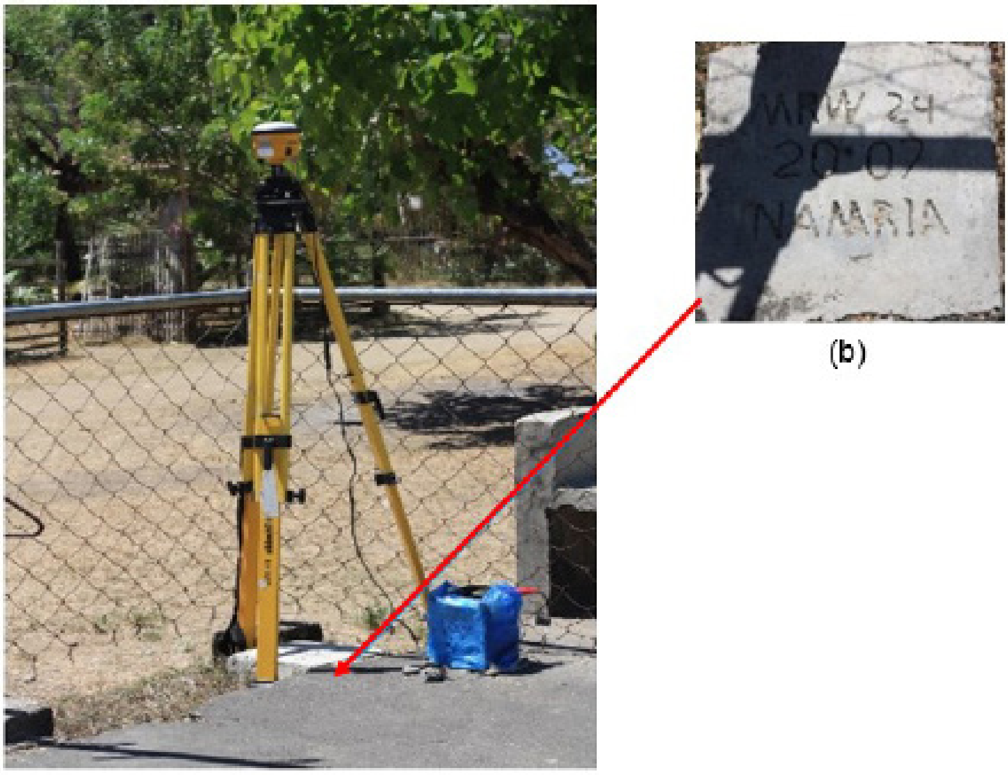
(b)

(a)

Figure 3. GPS set-up over MRW-22 as recovered in Lumintao Bridge in Brgy. Tanyag, municipality of Calintaan, Occidental Mindoro (a) and NAMRIA reference point MRW-22 (b) as recovered by the field team.

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

Station Name	MRW-22	
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°31'36.76881" North 120°59'13.46492" East 35.12700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	498595.125 meters 1385214.96 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°31'31.84278" North 120°59'18.53734" East 84.27100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting Northing	281265.62 meters 1385563.72 meters



(a)

(b)

Figure 4. GPS set-up over MRW-24 as recovered in the basketball court in Brgy. Iriron, municipality of Calintaan, Occidental Mindoro (a) and NAMRIA reference point MRW-24 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA horizontal control point MRE-24 used as base station for the LiDAR Acquisition.

Station Name	**MRW-24**	
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°36’42.98691” North 120°55’49.01762” East 5.69500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 5 PRS 92)	Easting Northing	492425.435 meters 1394624.897 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°36’38.03549” North 120°55’54.08296” East 54.47900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	275166.05 meters 1395022.71 meters

Figure 5. GPS set-up over MRW-4203 as recovered front of the barangay hall of Brgy. Mapaya, municipality of San Jose, Occidental Mindoro (a) and NAMRIA reference point MRW-4203 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point MRE-4203 used as base station for the LiDAR Acquisition.

Station Name	**MRW-4203**	
Order of Accuracy	**3rd Order**	
Relative Error (horizontal positioning)	**1:20000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°21’24.45294” North 121°07’26.92407” East 7.40100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	513501.246 meters 1366404.003 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°21’19.57973” North 121°07’32.01059” East 57.32000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRD 1992)	Easting Northing	296032.79 meters 1366637.32 meters

Table 6. Details of the recovered NAMRIA horizontal control point MRW-18 used as base station for the LiDAR Acquisition.

Station Name	MRW-18	
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°18'45.39463'' North 121°8'36.92441'' East 21.29500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	515618.524 meters 1361517.851 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°18'40.53383'' North 121°8'42.01469'' East 71.37500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	298113.89 meters 1361734.74 meters

Table 7. Details of the recovered NAMRIA horizontal control point MRW-18A used as base station for the LiDAR Acquisition.

Station Name	MRW-18A	
Order of Accuracy (benchmark)	2nd	
Elevation (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°18'45.53986'' North 121°8'36.76504'' East 21.84500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	298109.109 meters 1361739.241 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°18'40.67904'' North 121°8'41.85529'' East 71.92600 meters

Table 8. Details of the recovered NAMRIA horizontal control point MRW-4205 used as base station for the LiDAR Acquisition.

Station Name	MRW-4205	
Order of Accuracy	3rd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°26'8.33964'' North 121°2'46.62783'' East 12.56900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	505032.188 meters 1375124 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°26'4.44072'' North 121°2'51.70789'' East 62.09500 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	87627.78 meters 1375422.19 meters

Table 9. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
28-Feb-14	1158A	3BLK29A59B	MRW-22, MRW-24, MRW-4205
1-Mar-14	1160A	3BLK29C60A	MRW-22, MRW-4205
1-Mar-14	1162A	3BLK29AS60B	MRW-22, MRW-4205
2-Mar-14	1164A	3BLK29N61A	MRW-22, MRW-4203
2-Mar-14	1166A	3BLK29BS62A	MRW-22, MRW-4203
3-Mar-14	1168A	3BLK29BS62A	MRW-4203, MRW-22
11-Dec-15	3078P	1BLK29NQRS345A	MRW-18, MC-252
12-Dec-15	3082P	1BLK29R346A	MRW-18, MRW-18A

2.3 Flight Missions

Eight (8) missions were conducted to complete the LiDAR Data Acquisition in Caguray Floodplain, for a total of thirty hours and thirty-two minutes (30+32) of flying time for RP-C9122. All missions were acquired using the Aquarius and Pegasus LiDAR system. Table 10 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 11 presents the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions for LiDAR data acquisition in Caguray 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
28-Feb-14	1158A	72.02	100.05	NA	100.05	652	3	41
1-Mar-14	1160A	97.59	107.85	38.84	69.01	200	4	35
1-Mar-14	1162A	160.96	87.17	27.33	59.84	594	3	41
2-Mar-14	1164A	162.96	112.10	8.68	103.42	NA	4	53
2-Mar-14	1166A	85.08	115.93	46.42	69.51	NA	3	59
3-Mar-14	1168A	90.69	60.65	18.29	42.36	212	4	29
11-Dec-15	3078P	221.86	81.14	41.04	40.10	192	2	37
12-Dec-15	3082P	76.62	60.65	18.29	42.36	212	2	37
TOTAL		967.77	725.54	198.89	526.65	1850	30	32

Table 11. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
28-Feb-14	1158A	600	50	50	40	130	5
1-Mar-14	1160A	600	50	50	40	130	5
1-Mar-14	1162A	600	50	50	40	130	5
2-Mar-14	1164A	600	50	50	40	130	5
2-Mar-14	1166A	600	50	50	40	130	5
3-Mar-14	1168A	600	40, 36	70, 50	40	120	5
11-Dec-15	3078P	850	50	200	32	120	5
12-Dec-15	3082P	1100	50	200	30	120	5

2.4 Survey Coverage

Caguray floodplain is located in the province of Zamboanga del Norte with the floodplain situated within the municipalities of Dapitan City, Caguray City, Pinan, and Polanco. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 14. The actual coverage of the LiDAR acquisition for Caguray floodplain is presented in Figure 10. Annex 7 shows the flight status reports.

Table 12. List of municipalities and cities surveyed in Caguray Floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Oriental Mindoro	Bulalacao	365.58	77.68	21%
Occidental Mindoro	Magsaysay	256.56	190.74	74%
	Rizal	184.98	24.11	13%
	San Jose	449.82	183.89	41%
TOTAL		1256.94	476.42	37.90%

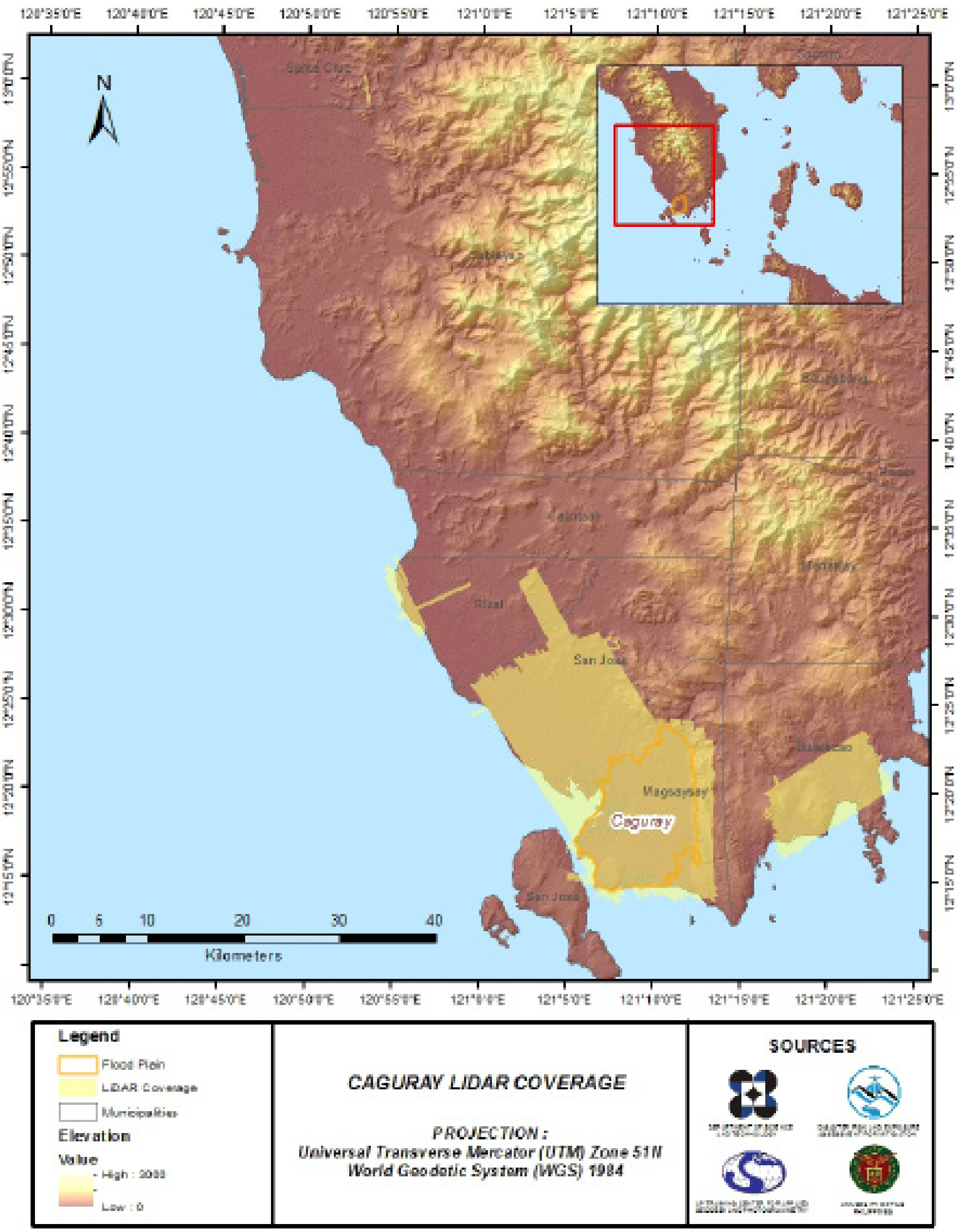


Figure 6. Actual LiDAR data acquisition for Caguray floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR CAGURAY FLOODPLAIN

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

3.1 Overview of LiDAR Data Pre-Processing

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 7.

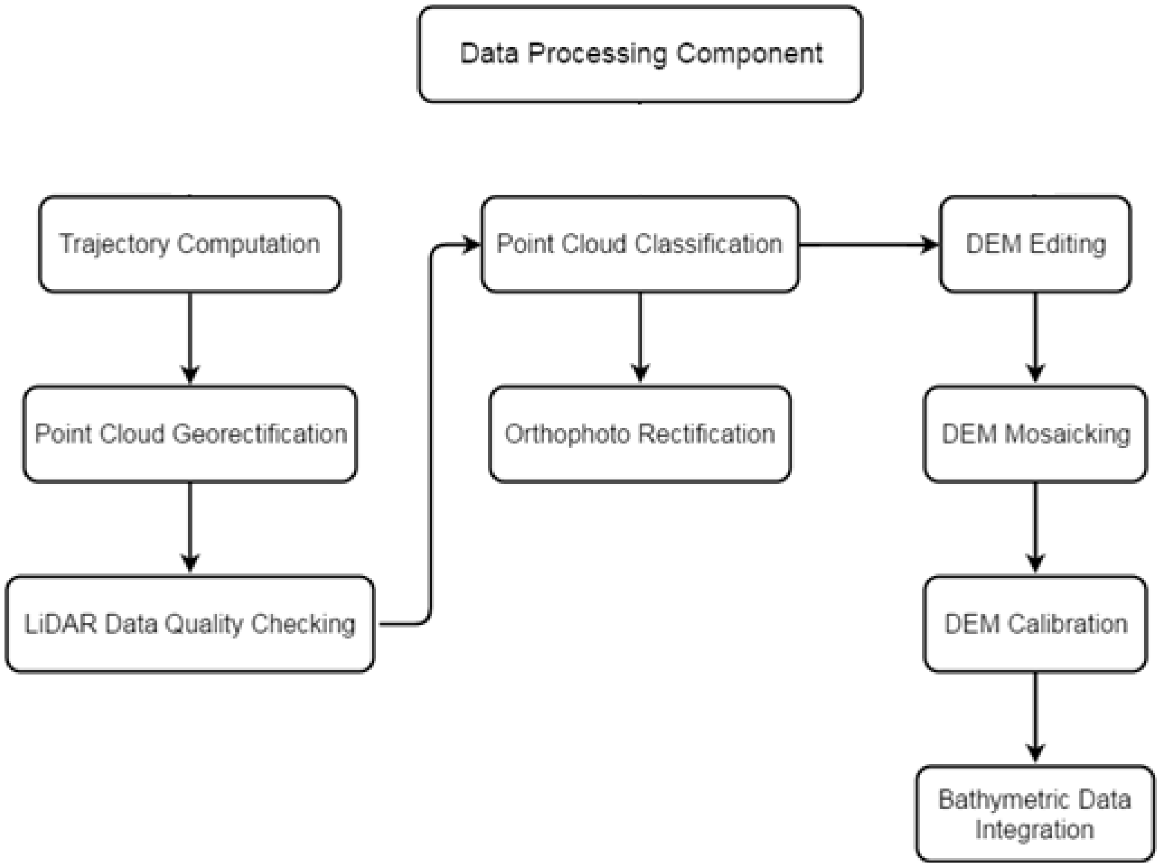


Figure 7. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Caguray floodplain can be found in Annex 5. Missions flown during the first survey conducted on March 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 Magsaysay, Occidental Mindoro.

The Data Acquisition Component (DAC) transferred a total of 43.96 Gigabytes of Range data, 0.88 Gigabytes of POS data, 60.91 Megabytes of GPS base station data, and 64.6 Gigabytes of raw image data to the data server on April 23, 2014 for the first survey and January 15, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Caguray was fully transferred on January 15, 2016, as indicated on the Data Transfer Sheets for Caguray floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1166A, one of the Caguray flights, which is the North, East, and Down position RMSE values are shown in Figure 8. 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 March 2, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

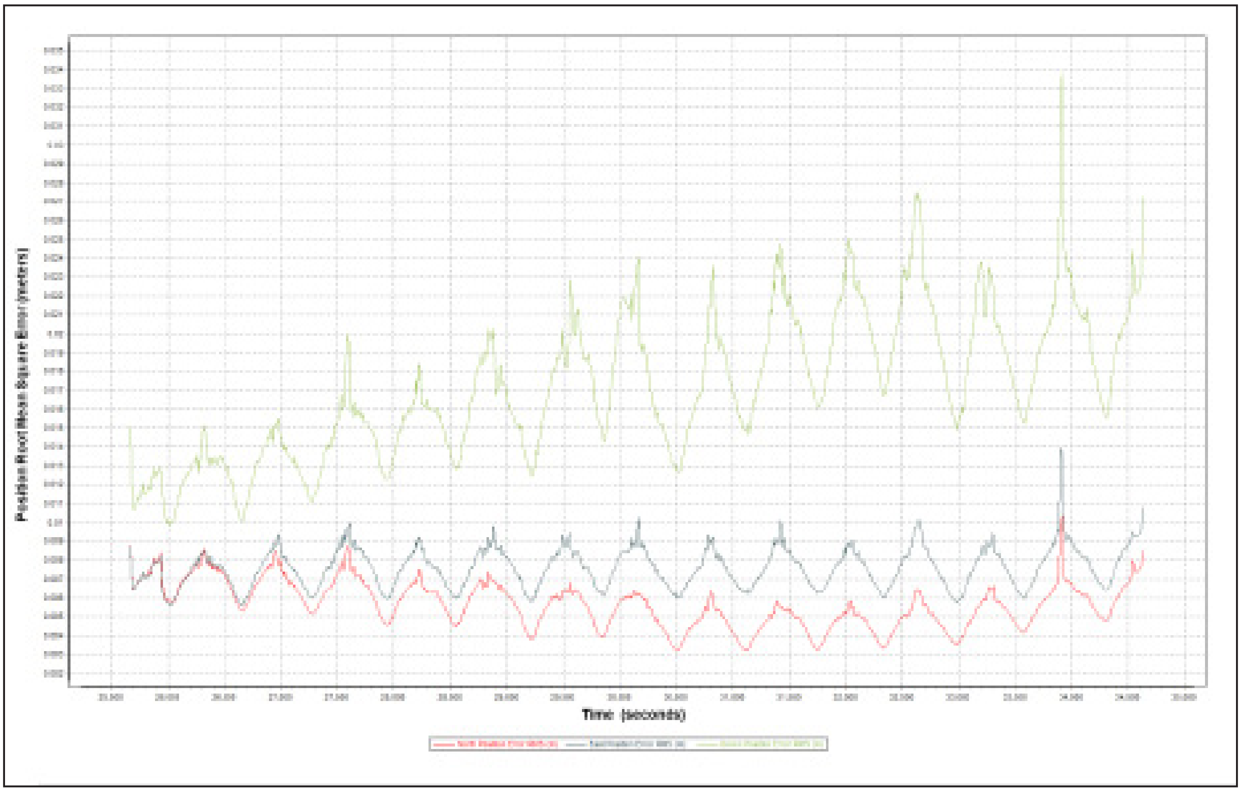


Figure 8. Smoothed Performance Metrics of Caguray Flight 1166A.

The time of flight was from 25500 seconds to 34500 seconds, which corresponds to afternoon of March 2, 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 8 shows that the North position RMSE peaks at 1.00 centimeters, the East position RMSE peaks at 1. 40 centimeters, and the Down position RMSE peaks at 3.40 centimeters, which are within the prescribed accuracies described in the methodology.

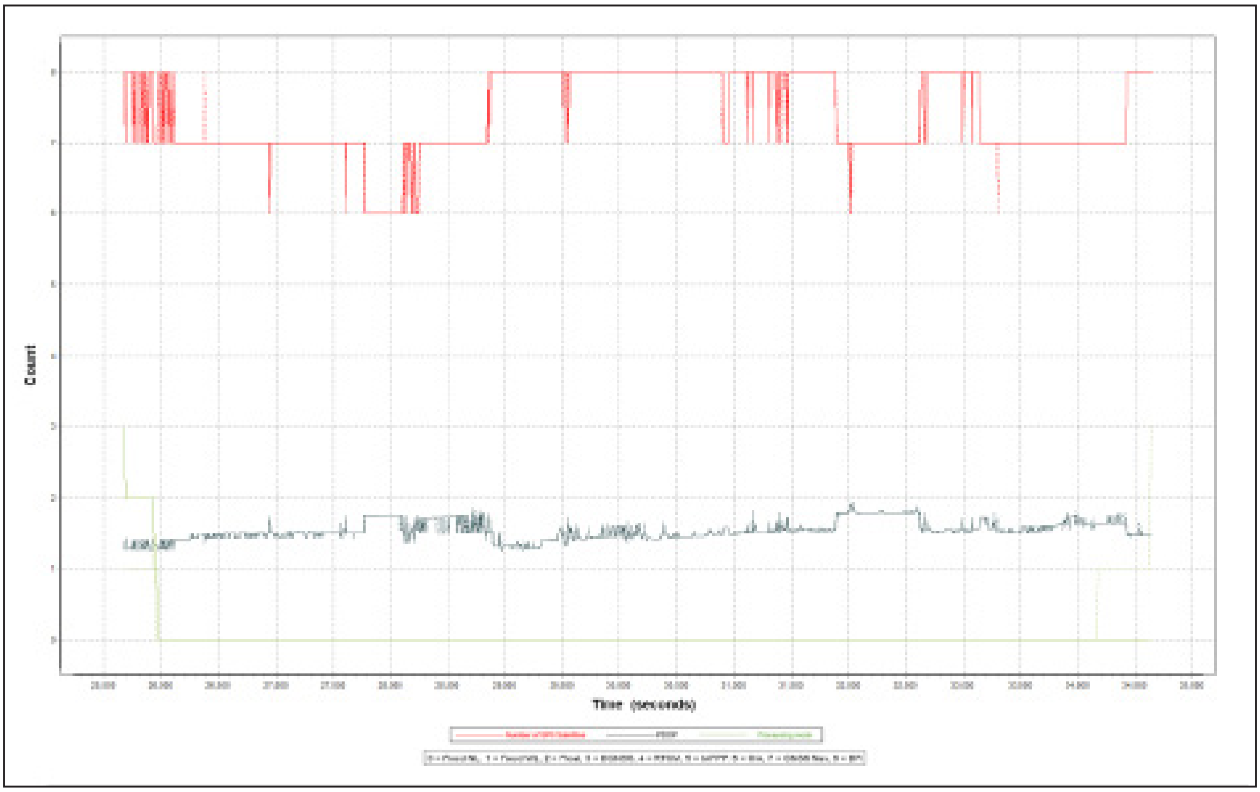


Figure 9. Solution Status Parameters of Caguray Flight 1166A.

The Solution Status parameters of flight 1166A, one of the Caguray flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 9. 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 8. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Caguray flights is shown in Figure 10.

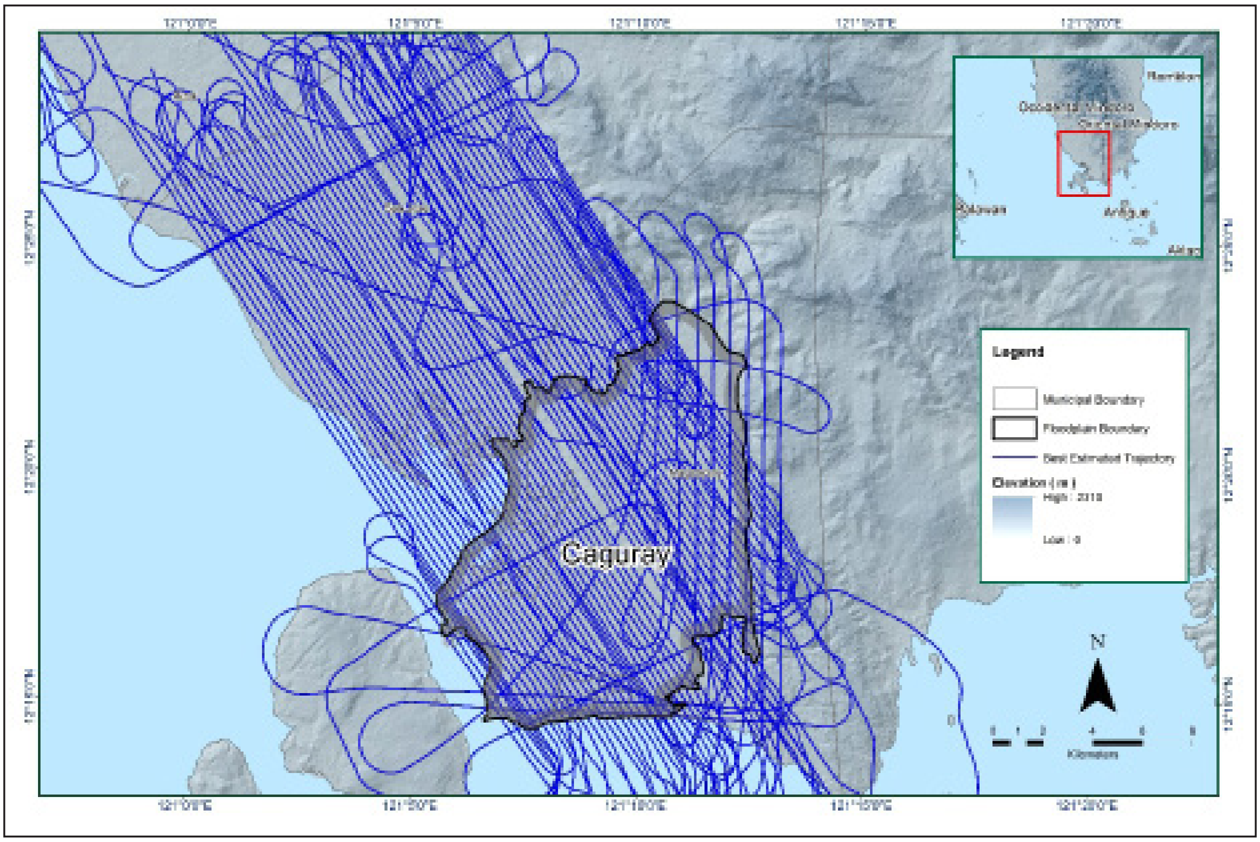


Figure 10. Best Estimated Trajectory for Caguray Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 77 flight lines, with each flight line containing one channel for the 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 Caguray floodplain are given in Table 13.

Table 13. Self-Calibration Results values for Caguray flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev	(<0.001degrees)	0.000426
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000960
GPS Position Z-correction stdev	(<0.01meters)	0.0034

The optimum accuracy is obtained for all Caguray 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 Caguray Floodplain is shown in Figure 11. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

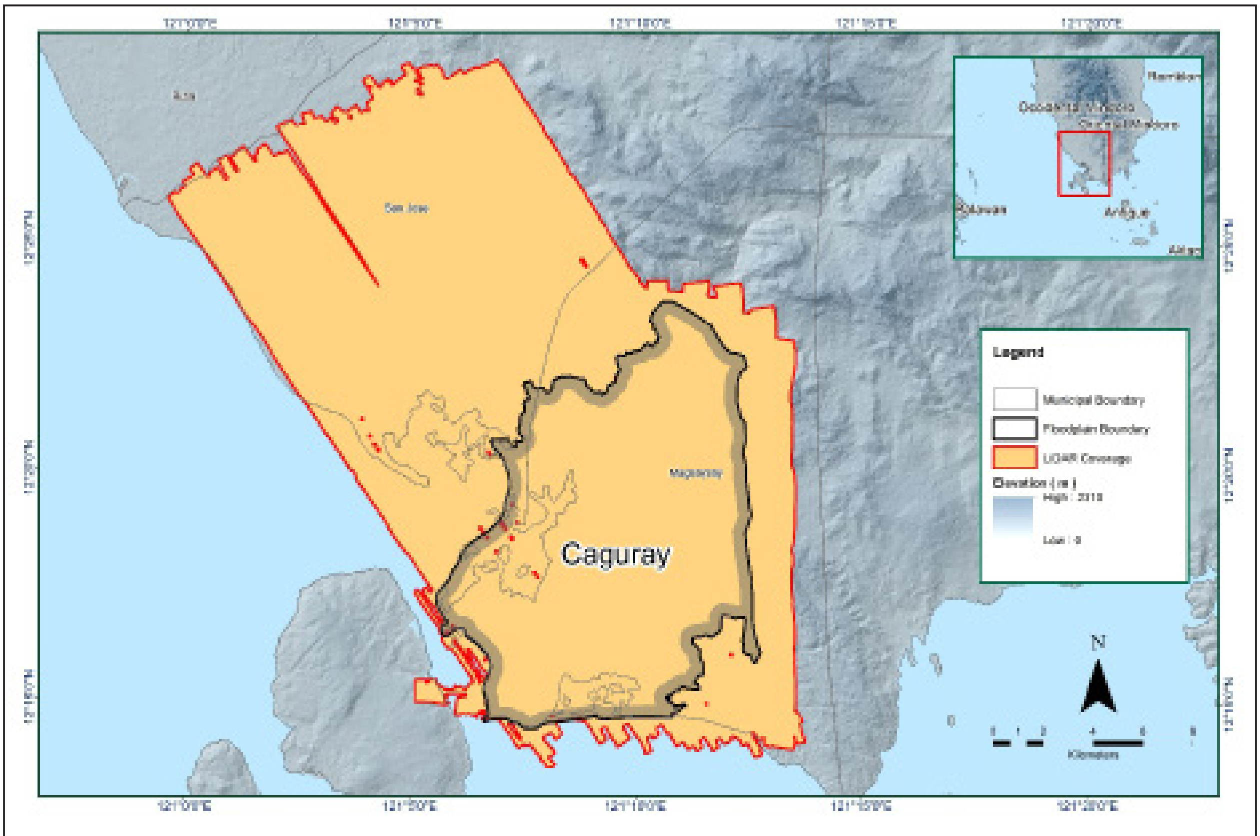


Figure 11. Boundary of the processed LiDAR data over Caguray Floodplain

The total area covered by the Caguray missions is 500.69 sq.km that is comprised of four (4) flight acquisitions grouped and merged into six (6) blocks as shown in Table 14.

Table 14. List of LiDAR blocks for Caguray Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
OccidentalMindoro_Blk29A	1158A	140.61
OccidentalMindoro_Blk29B	1166A	146.16
OccidentalMindoro_Blk29C	1160A	102.42
OccidentalMindoro_reflights_Blk29A_additional	3078P	14.30
OccidentalMindoro_reflights_Blk29B_additional	3078P	8.96
OccidentalMindoro_reflights_Blk29C_additional	3078P	88.24
TOTAL		500.69 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 12. Since the Aquarius system employs one channel and the Pegasus system employs two, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

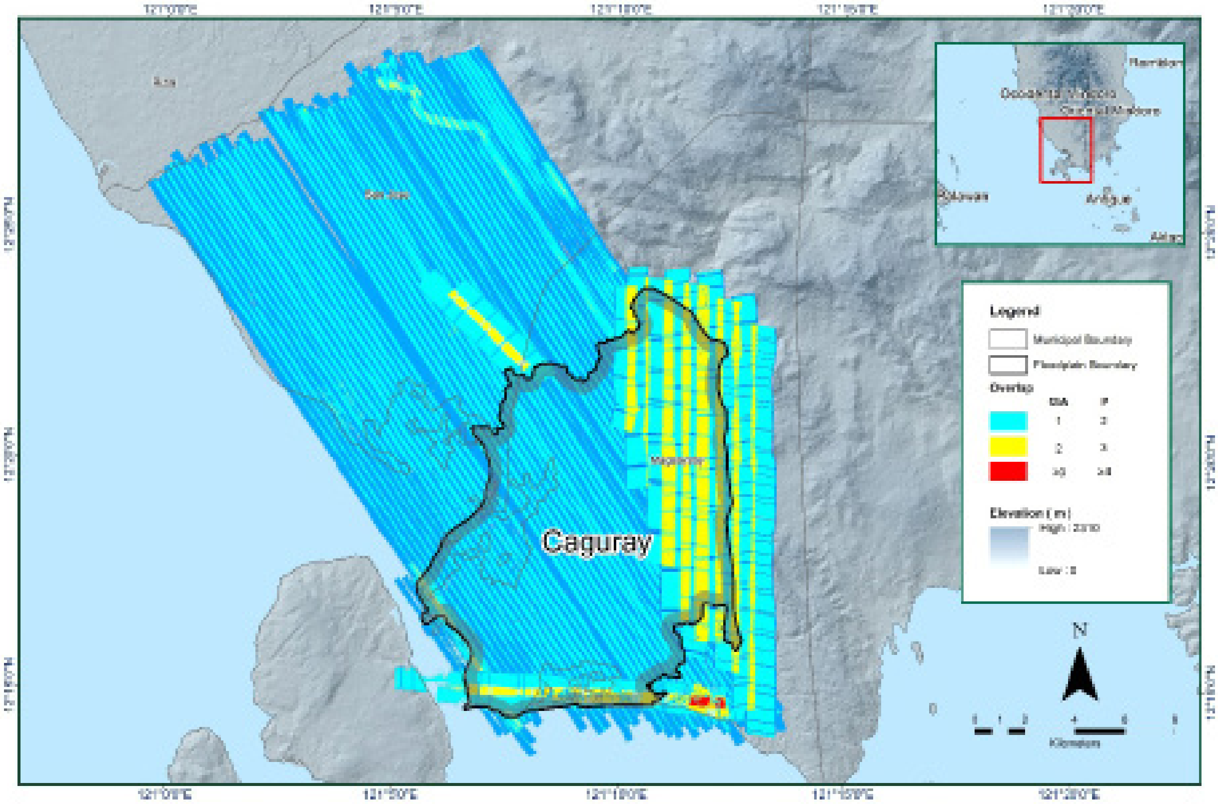


Figure 12. Image of data overlap for Caguray Floodplain.

The overlap statistics per block for the Caguray floodplain can be found in Annex B-1. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 29.39% and 44.16% 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 13. It was determined that all LiDAR data for Caguray floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.81 points per square meter.

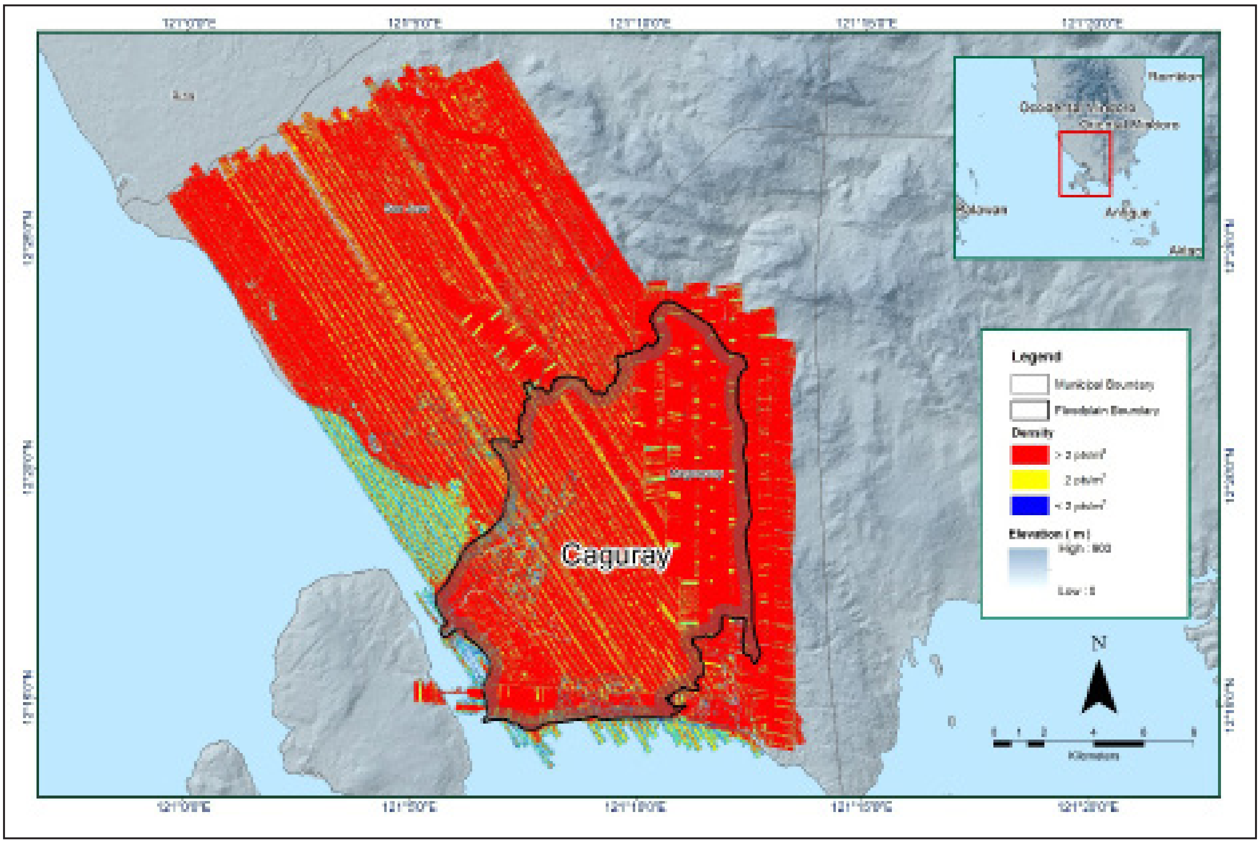


Figure 13. Pulse density map of merged LiDAR data for Caguray Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 14. 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

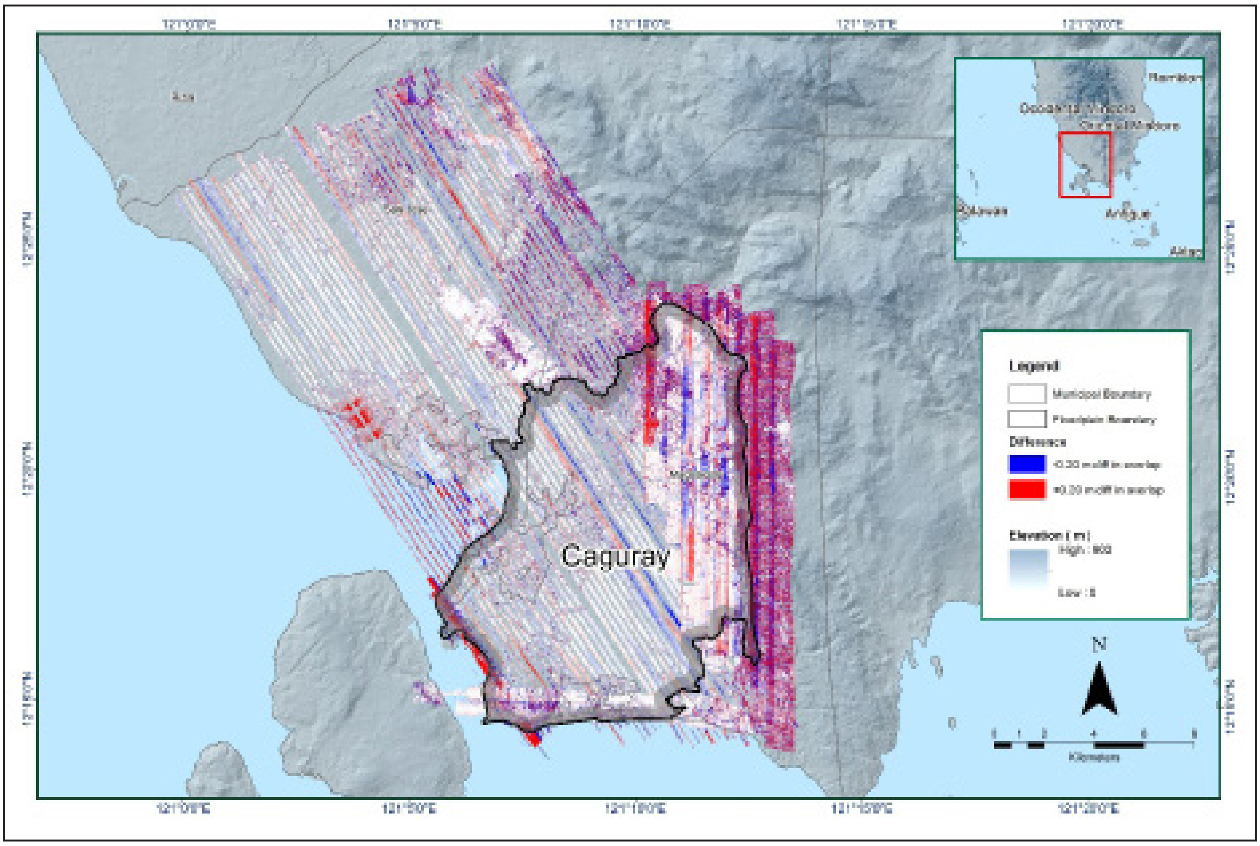


Figure 14. Elevation difference map between flight lines for Caguray Floodplain.

A screen capture of the processed LAS data from a Caguray flight 1166A loaded in QT Modeler is shown in Figure 15. 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.

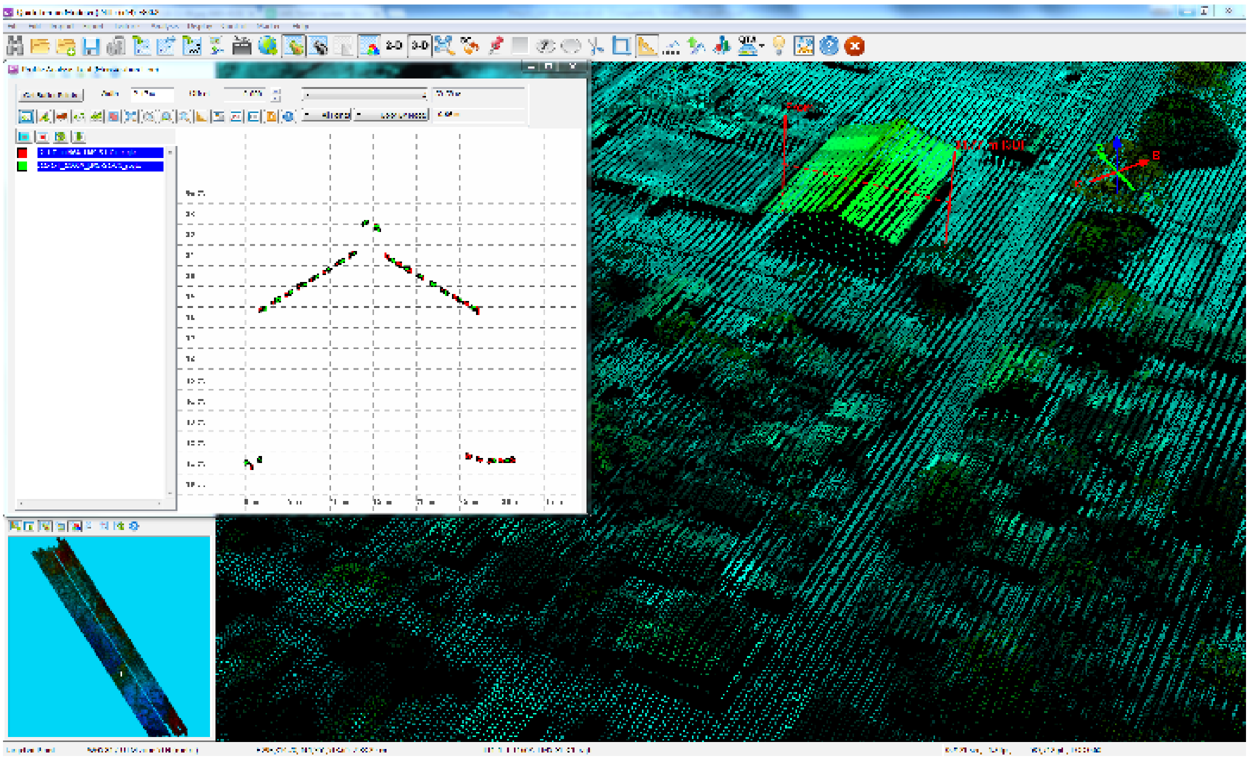


Figure 15. Quality checking for Caguray flight 1166A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Caguray classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	488,855,057
Low Vegetation	490,749,885
Medium Vegetation	444,550,801
High Vegetation	742,708,426
Building	23,923,698

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Caguray floodplain is shown in Figure 16. A total of 701 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 521.55 meters and 43.10 meters respectively.

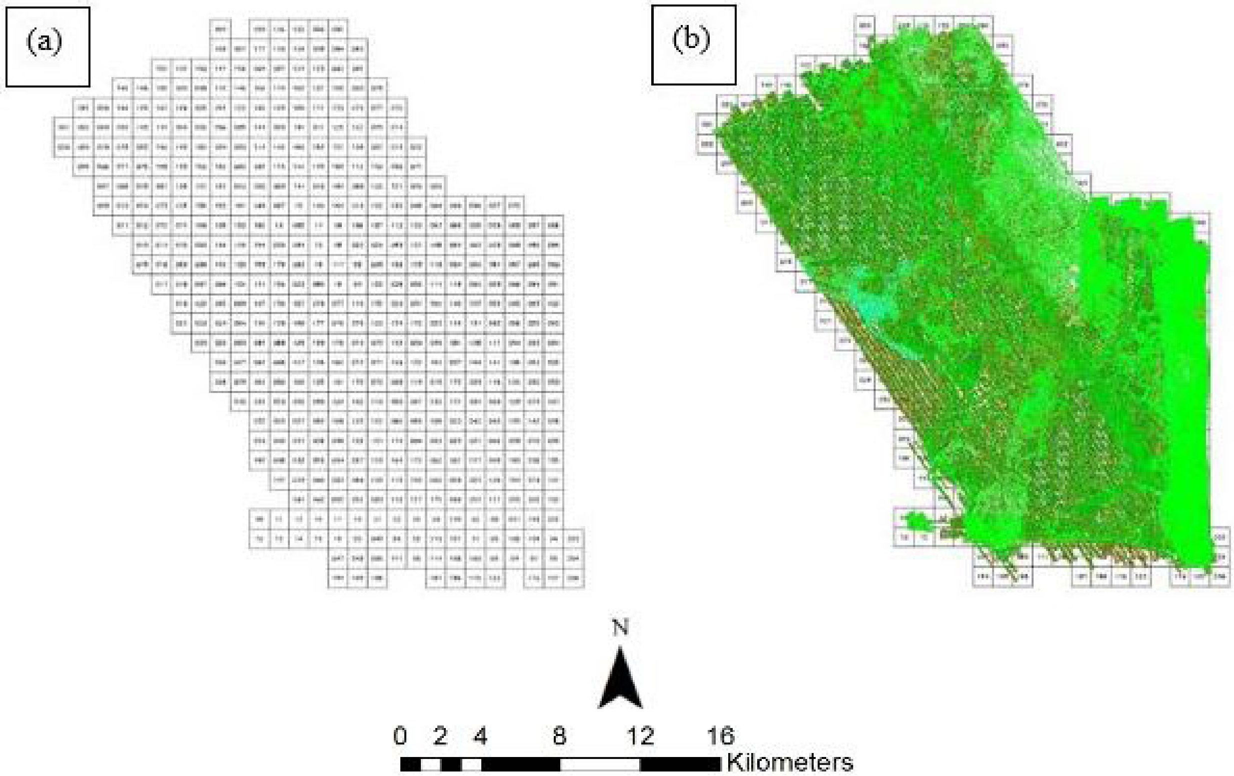


Figure 16. Tiles for Caguray Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 17. 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.

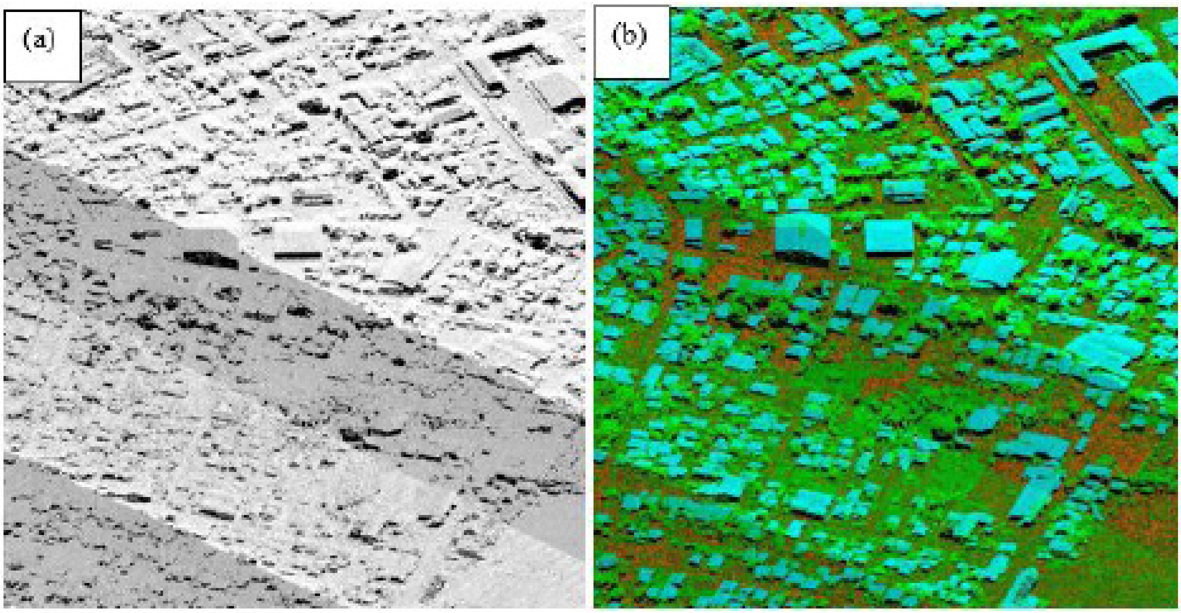


Figure 17. Point cloud before (a) and after (b) classification.

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

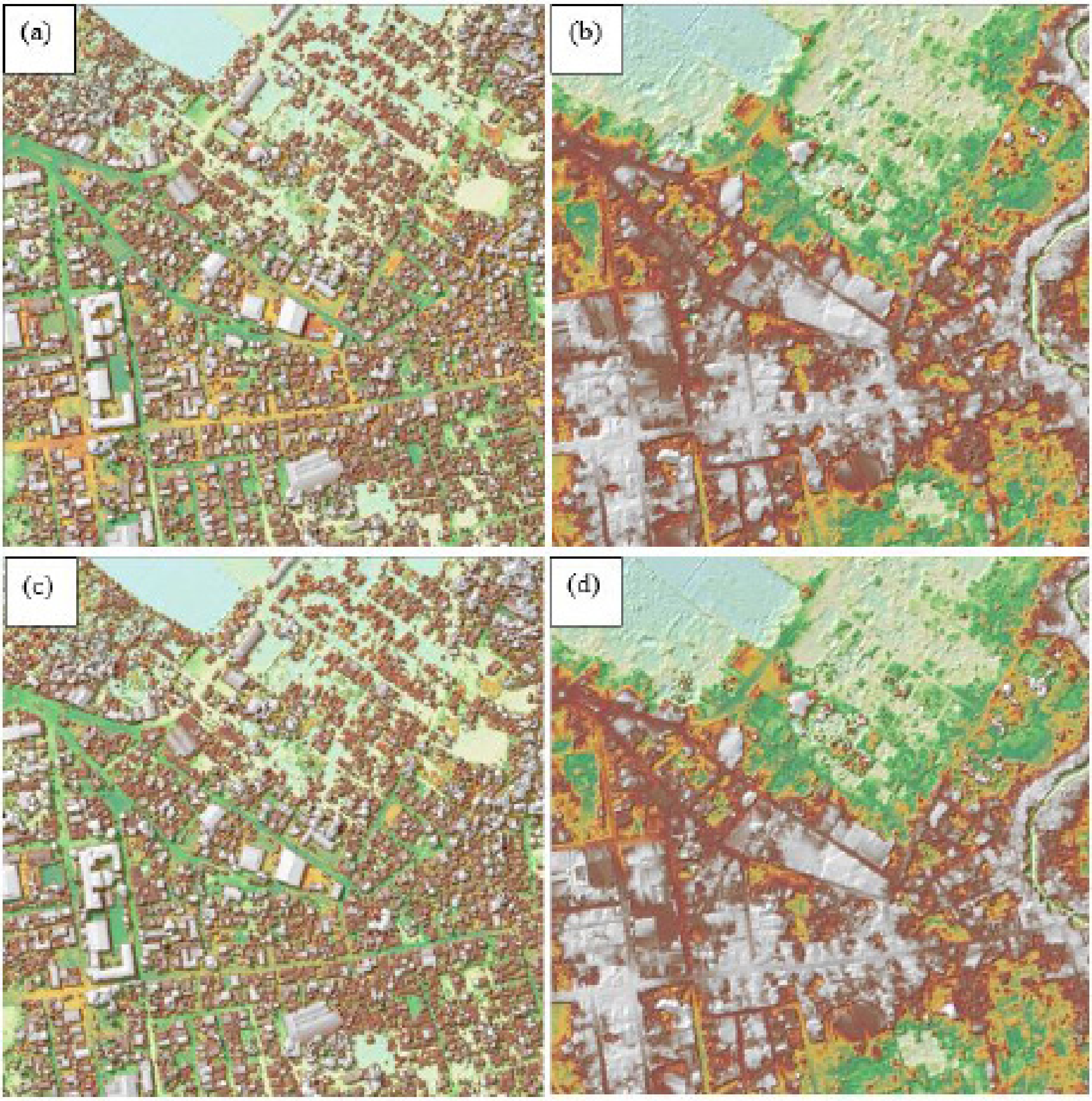


Figure 18. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Caguray Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 450 1km by 1km tiles area covered by Caguray 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 Caguray floodplain has a total of 251.35 sq.km orthophotogaph coverage comprised of 1,434 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 20.

Figure 19. Caguray Floodplain with available orthophotographs

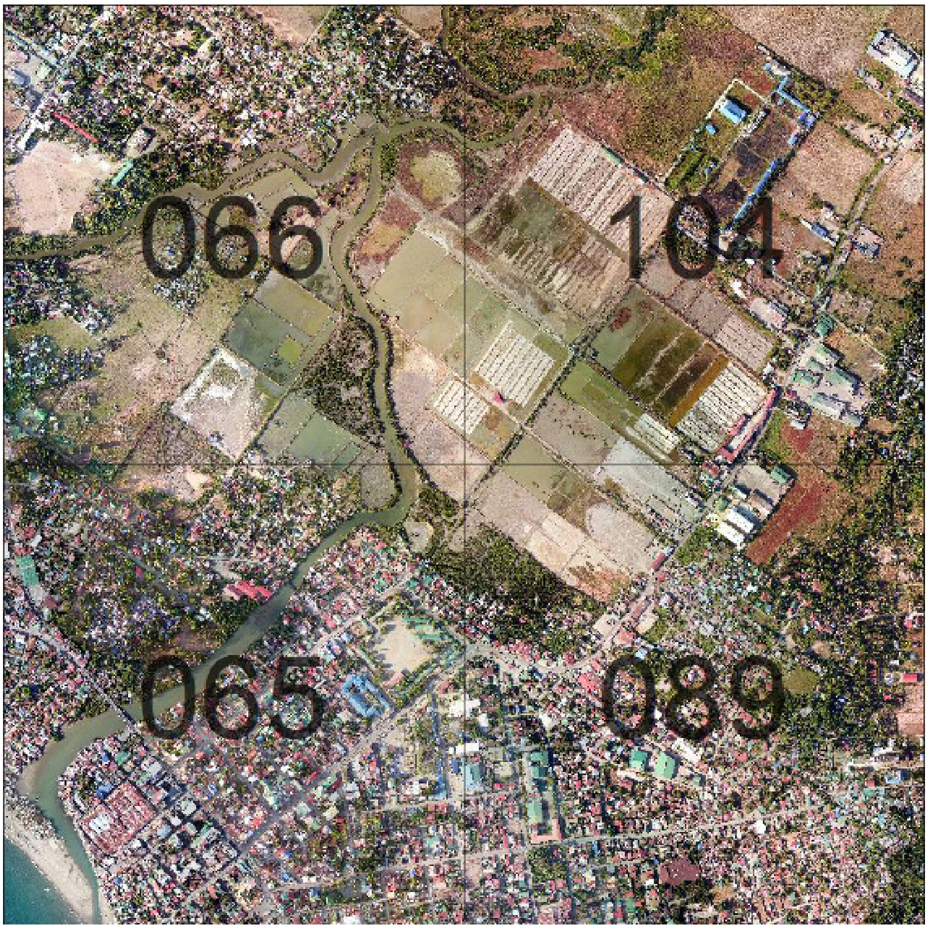


Figure 20. Sample orthophotograph tiles for Caguray Floodplain

3.8 DEM Editing and Hydro-Correction

Six (6) mission blocks were processed for Caguray flood plain. These blocks are composed of OccidentalMindoro and OccidentalMindoro_reflights blocks with a total area of 500.69 square kilometers. Table 16 shows the name and corresponding area of each block in square kilometers.

Table 16. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
OccidentalMindoro_Blk29A	140.61
OccidentalMindoro_Blk29B	146.16
OccidentalMindoro_Blk29C	102.42
OccidentalMindoro_reflights_Blk29A_additional	14.30
OccidentalMindoro_reflights_Blk29B_additional	8.96
OccidentalMindoro_reflights_Blk29C_additional	88.24
TOTAL	500.69 sq.km

Portions of DTM before and after manual editing are shown in Figure 21. The bridge (Figure 21a) is also considered to be an impedance to the flow of water along the river and has to be removed (Figure 21b) in order to hydrologically correct the river. The paddy field (Figure 21c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 21d) to allow the correct flow of water.

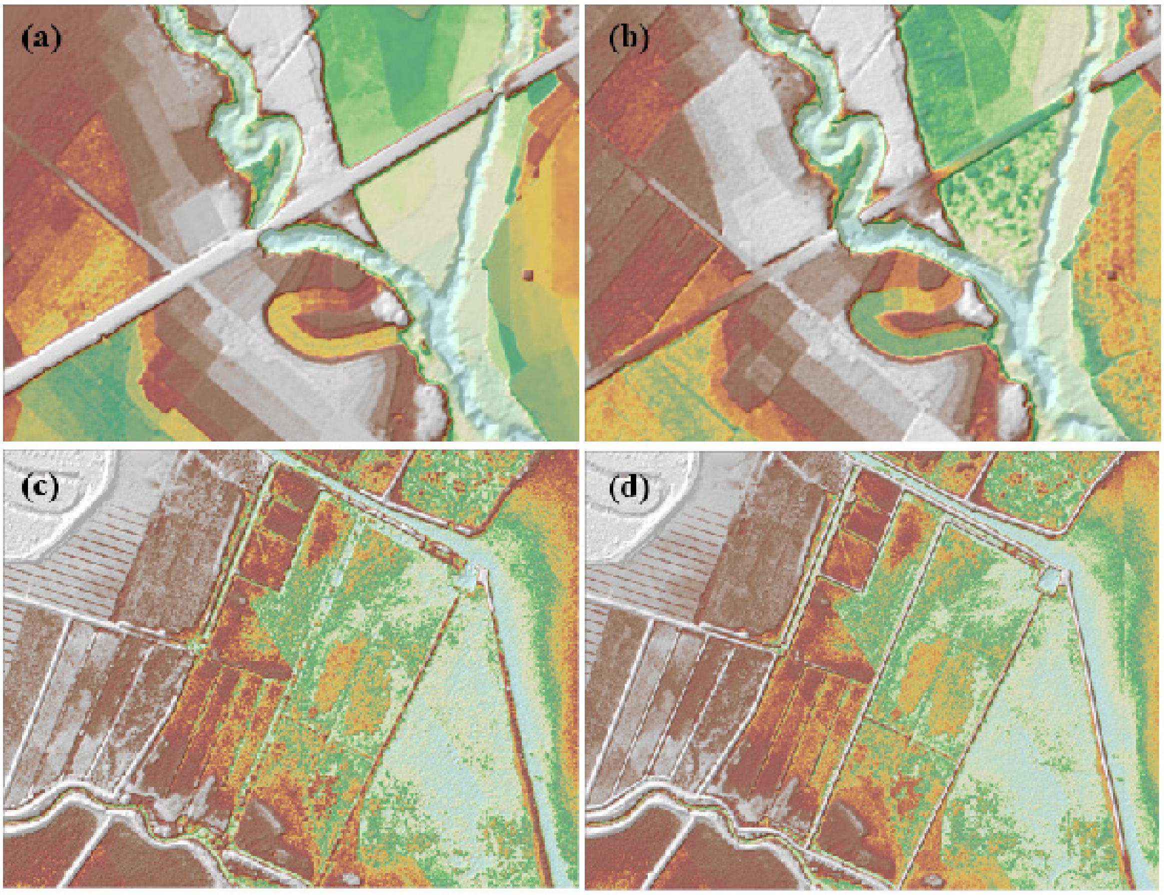


Figure 21. Portions in the DTM of Caguray floodplain – a bridge before (a) and after (b) manual editing; a paddy field before (c) and after (d) data retrieval.

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 17 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Caguray floodplain is shown in Figure 22. It can be seen that the entire Caguray floodplain is 100% covered by LiDAR data.

Table 17. Shift Values of each LiDAR Block of Caguray Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
OccidentalMindoro_Blk29A	0.00	0.00	-0.44
OccidentalMindoro_Blk29B	0.00	0.00	-0.55
OccidentalMindoro_Blk29C	0.00	0.34	-0.99
OccidentalMindoro_reflights_Blk29A_additional	0.00	0.00	-1.72
OccidentalMindoro_reflights_Blk29B_additional	0.00	0.00	-0.50
OccidentalMindoro_reflights_Blk29C_additional	0.00	0.00	-0.59

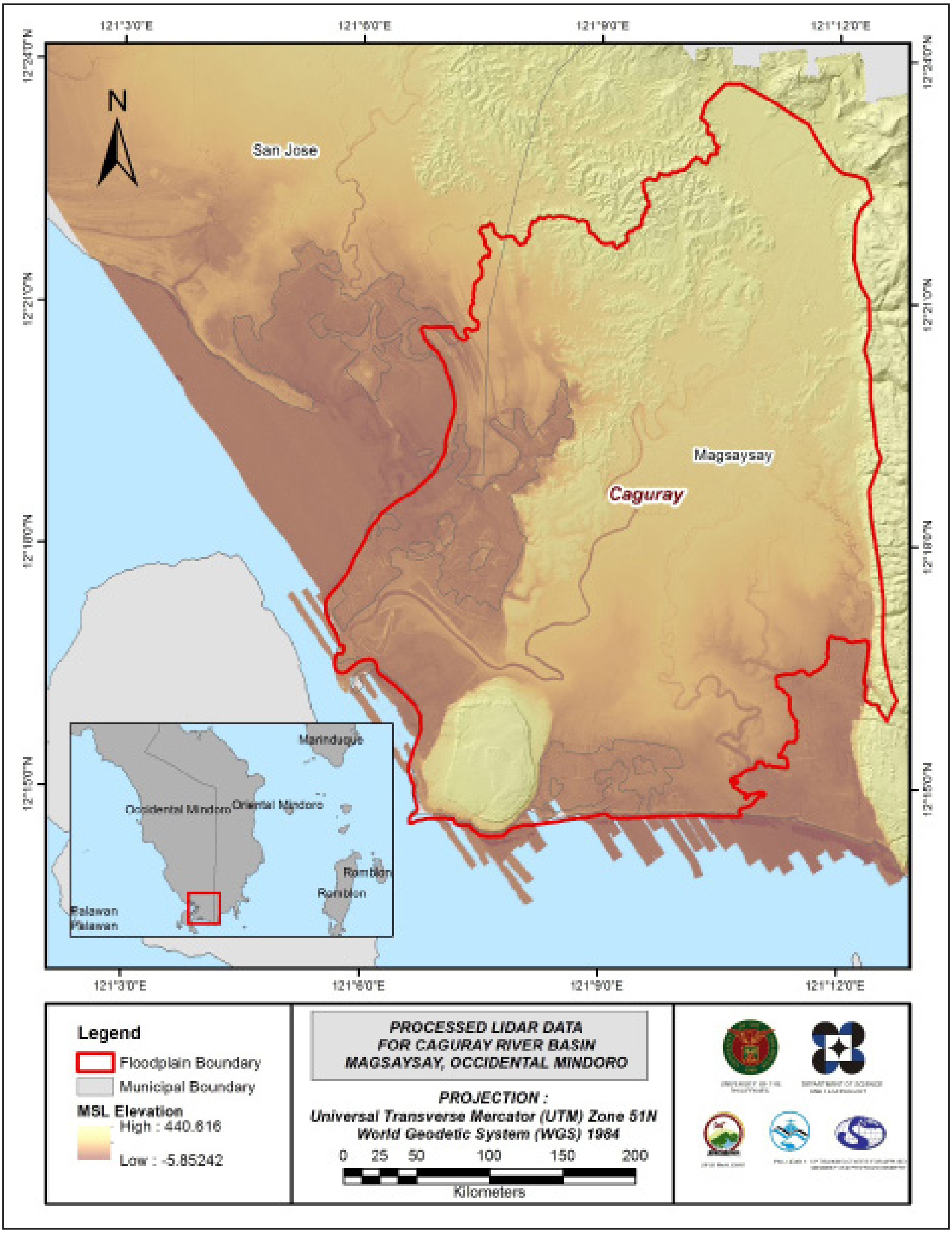


Figure 22. Map of Processed LiDAR Data for Caguray Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Caguray to collect points with which the LiDAR dataset is validated is shown in Figure 23. A total of 28,494 survey points were gathered for all the flood plains within Occidental Mindoro wherein the Caguray floodplain is located. 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 24. 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 Caguray LiDAR data was done by adding the height difference value, 0.23 meters, to Caguray mosaicked LiDAR data. Table 18 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

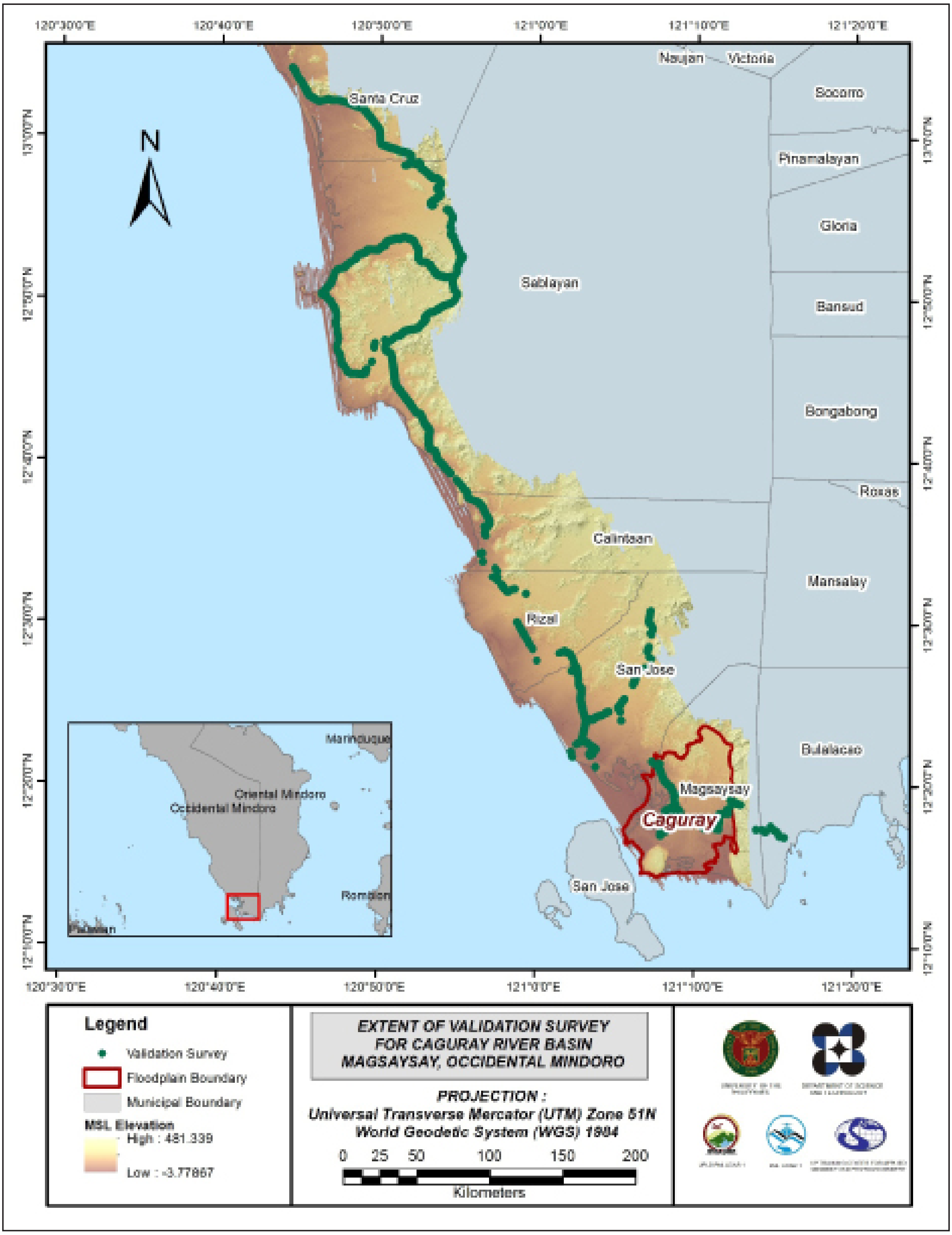


Figure 23. Map of Caguray Floodplain with validation survey points in green.

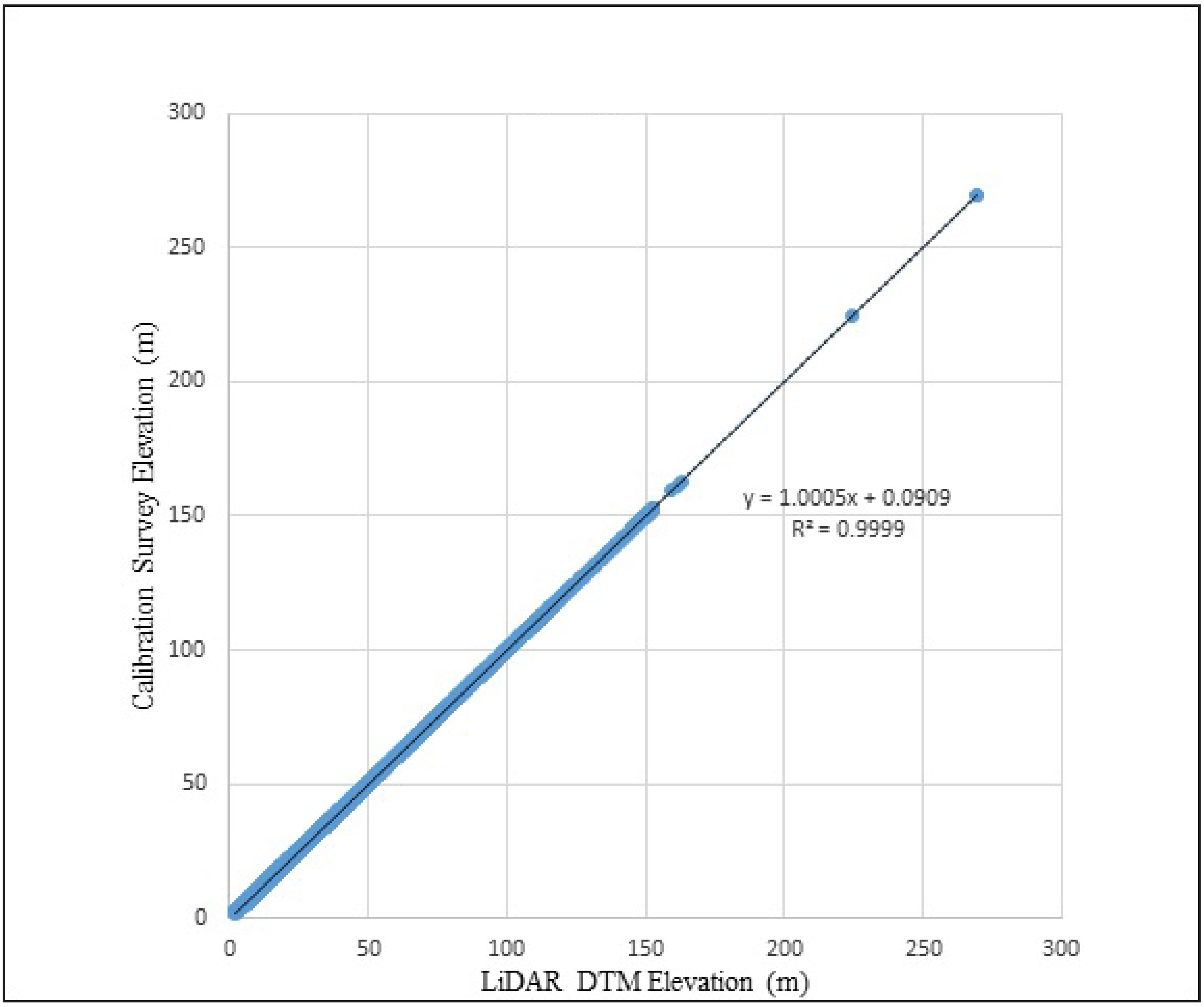


Figure 24. Correlation plot between calibration survey points and LiDAR data.

Table 18. 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 621 points. These were used for the validation of calibrated Caguray 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 25. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.17 meters with a standard deviation of 0.14 meters, as shown in Table 19.

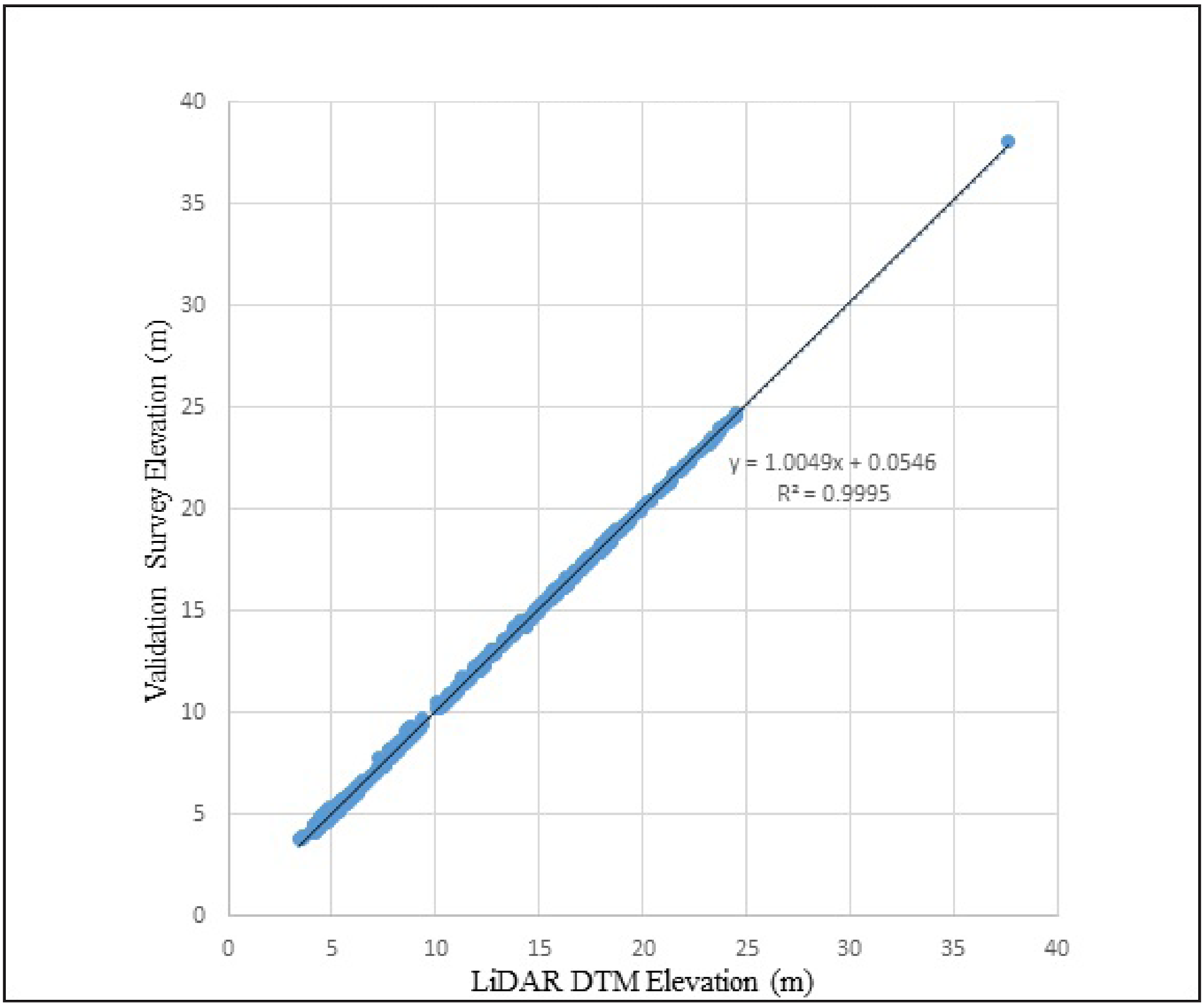


Figure 25. Correlation plot between validation survey points and LiDAR data.

Table 19. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.17
Standard Deviation	0.14
Average	-0.10
Minimum	-0.18
Maximum	0.50

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, zigzag and centerline data were available for Caguray with 5,211 and 18,692 bathymetric survey points, respectively. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.63 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Caguray integrated with the processed LiDAR DEM is shown in Figure 26.

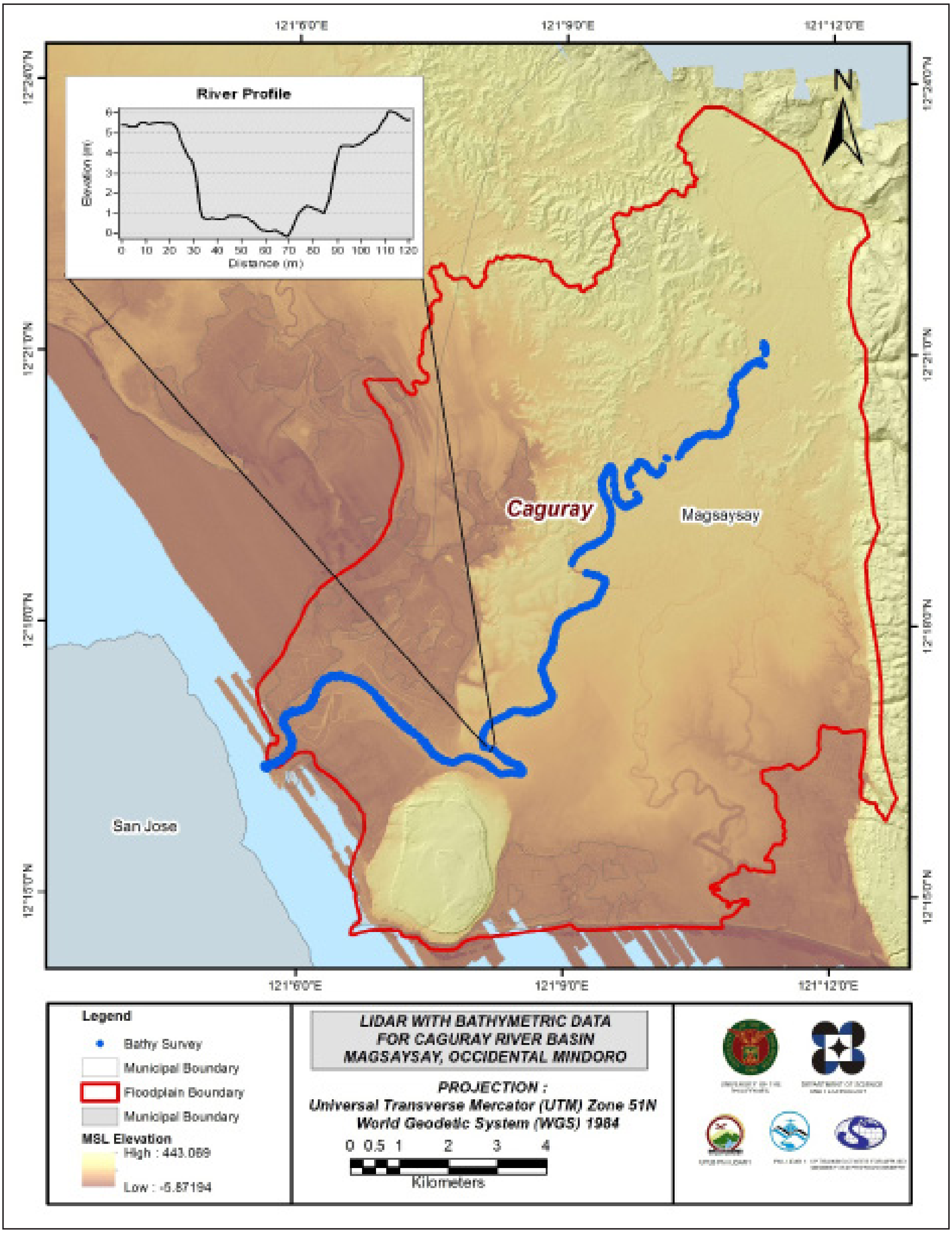


Figure 26. Map of Caguray Floodplain with bathymetric survey points shown in blue.

CHAPTER 4: DATA VALIDATION SURVEY AND MEASUREMENTS IN THE CAGURAY RIVER BASIN

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

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 field survey in Caguray River on November 3-24, 2015 with the following scope of work: reconnaissance to determine the viability of traversing the planned routes for bathymetric survey; courtesy call with UPLB, Rizal and San Jose LGUs and MDRRMC; control survey; cross-section survey, bridge as-built features determination and water level marking at Busuanga Bridge with coordinates Lat 12d18’07.55730”N and Long 121d09’08.74177”E; ground validation survey along the National Highway covering municipalities of Sta. Cruz, Sablayan, Calintaan, Rizal, San Jose and Magsaysay with an approximate distance of 191 km. Lastly, bathymetric survey from Brgy. Purnaga down to the mouth of the river in Brgy. Caguray, Magsaysay Municipality with an approximate length of 43.413 km using GNSS PPK survey technique. The entire survey extent is illustrated in Figure 27.

Figure 27. Caguray River Survey Extent

4.2 Control Survey

The GNSS network used for Caguray River Basin is composed of eight (8) 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, 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 20 while the GNSS network established is in Figure 28.

Figure 28. GNSS Network of Caguray Field Survey

Table 20. List of reference and control points used during the survey in Caguray River (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 29 to Figure 37.

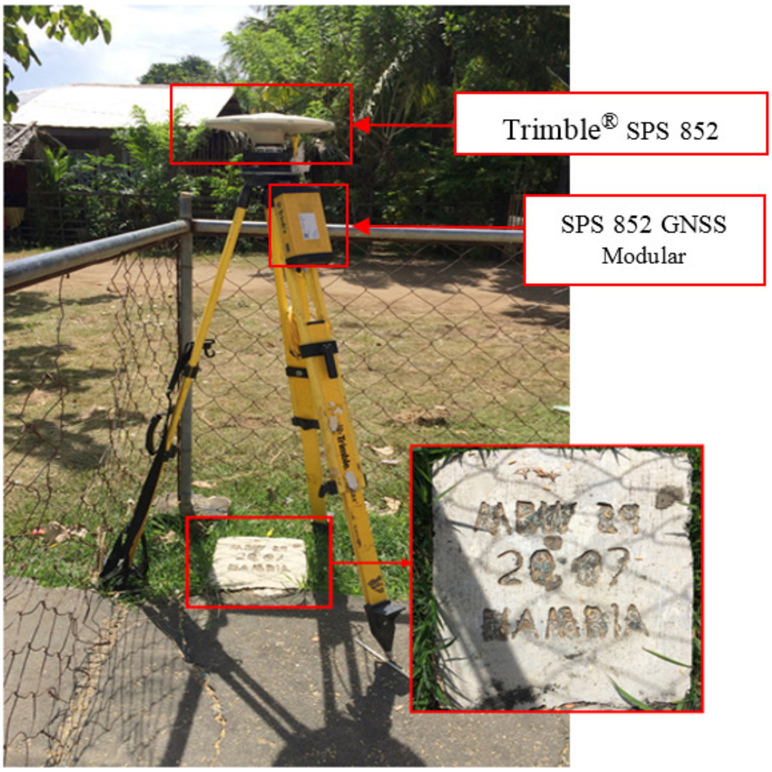


Figure 29. GNSS base set-up, Trimble® SPS 882, at MRW-24 in front of Iriron Elementary School in Brgy. Iriron, Municipality of Calintaan, Occidental Mindoro

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

Figure 31. GNSS base receiver, Trimble® SPS 882, setup at UP-ILA in Ilaya Bridge, Brgy. Ilaya, Dapitan City

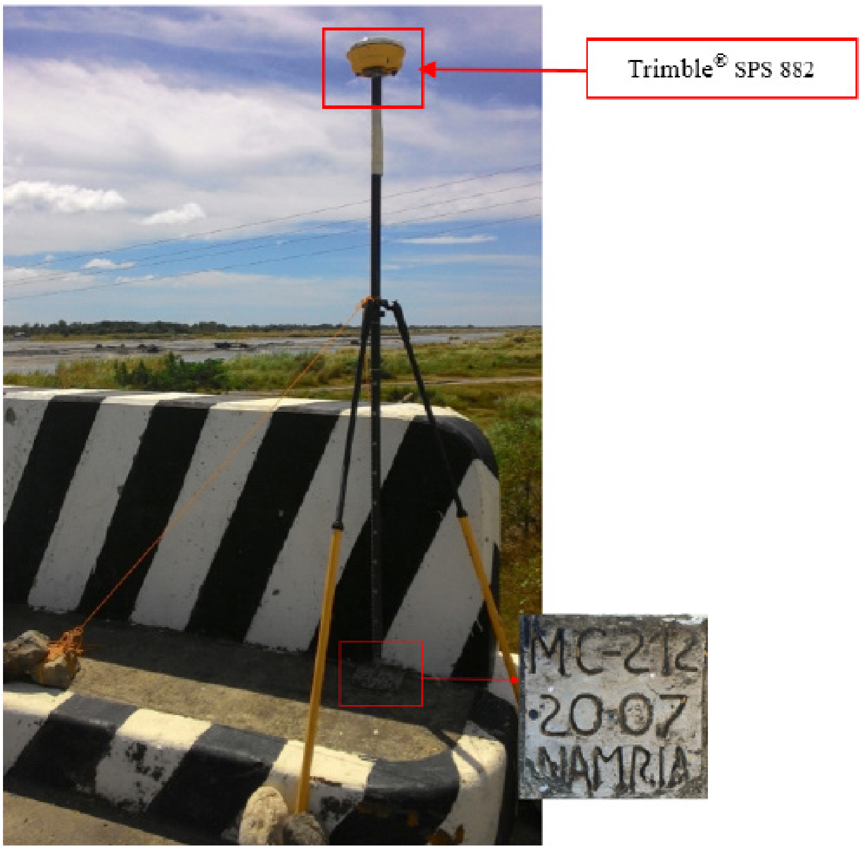


Figure 32. GNSS receiver set-up, Trimble® SPS 882, at MC-212, Busuanga Bridge approach in Bgry. Sto Niño, Municipality of Rizal, Occidental Mindoro

Figure 33. GNSS base, 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 34. 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 35. GNSS base receiver set-up, Trimble® SPS 882, at UP-PIN Pinamanaan Bridge approach in Brgy. Mapaya, Municipality of San Jose, Occidental Mindoro

Figure 36. GNSS receiver set-up, Trimble® SPS 882, at UP-MOM, Mompong Bridge approached in Brgy. Lumang Bato, Municipality of Sablayan, Occidental Mindoro

Figure 37. 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 +/-20cm and +/-10cm 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 Caguray River Basin is summarized in Table 21 using generated TBC software.

Table 21. Baseline Processing Report for Caguray River Static Survey
(Source: NAMRIA, UP-TCAGP)

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
MRW-24 --- UP-MOM	11-15-2015	Fixed	0.009	0.015	355°30'36"	24950.818	90.611
MRW-24 --- UP-MOM	11-15-2015	Fixed	0.003	0.006	355°30'36"	24950.824	90.574
MRW-24 --- UP-ALI	11-15-2015	Fixed	0.006	0.007	335°24'00"	32186.124	2.579

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:

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 22 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 22.

Table 22. Control Point Constraints

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 23. The fixed controls ZGN-138 and Z-44 have no values for and elevation error.

Table 23. Adjusted Grid Coordinates

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 23. Using the equation $\sqrt{((x_e)^2 + (y_e)^2)}$ <20cm and $z_e < 10\ cm$ for horizontal and for the vertical, respectively; 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 24. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	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 24. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 25.

Table 25. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	MSL Elevation (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
MC-90	2nd order, GCP	12°36'38.03550"	120°55'54.08297"	53.435	1394955.913	275320.607	4.746
MRW-24	2nd order, GCP	12°57'27.19115"	120°53'33.54441"	88.823	1433384.691	271390.777	41.752
MRW-30	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 survey and bridge as-built, as well as water level marking were conducted on November 19, 2015 at the downstream side of Caguray Bridge in Brgy. Poblacion, Magsaysay, Occidental Mindoro. A total of one hundred twenty-four (124) points were gathered from the survey of Caguray Bridge to determine the bridge as-built, and to elongate the cross section line.

Bridge cross section and As-built point gathering was executed using a Trimble® SPS 882 with base station GPS-4 (Figure 38). The location map, cross-section diagram, and the bridge data form are shown in Figure 39 to Figure 41, respectively.

Figure 38. As-built survey at Caguray Bridge, Brgy. Poblacion, Municipality of Magsaysay

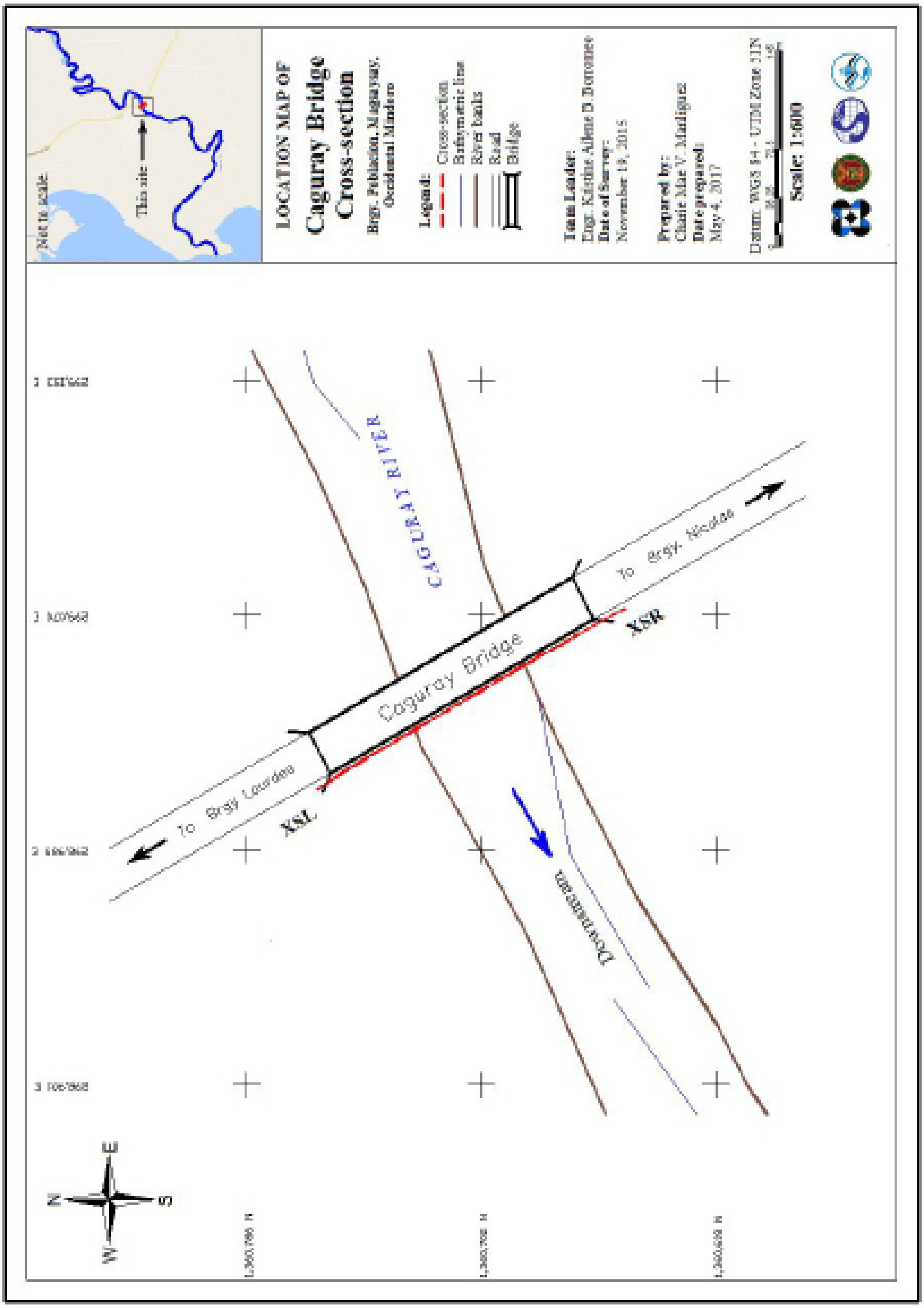


Figure 39. Location Map of Caguray Bridge River Cross-Section survey

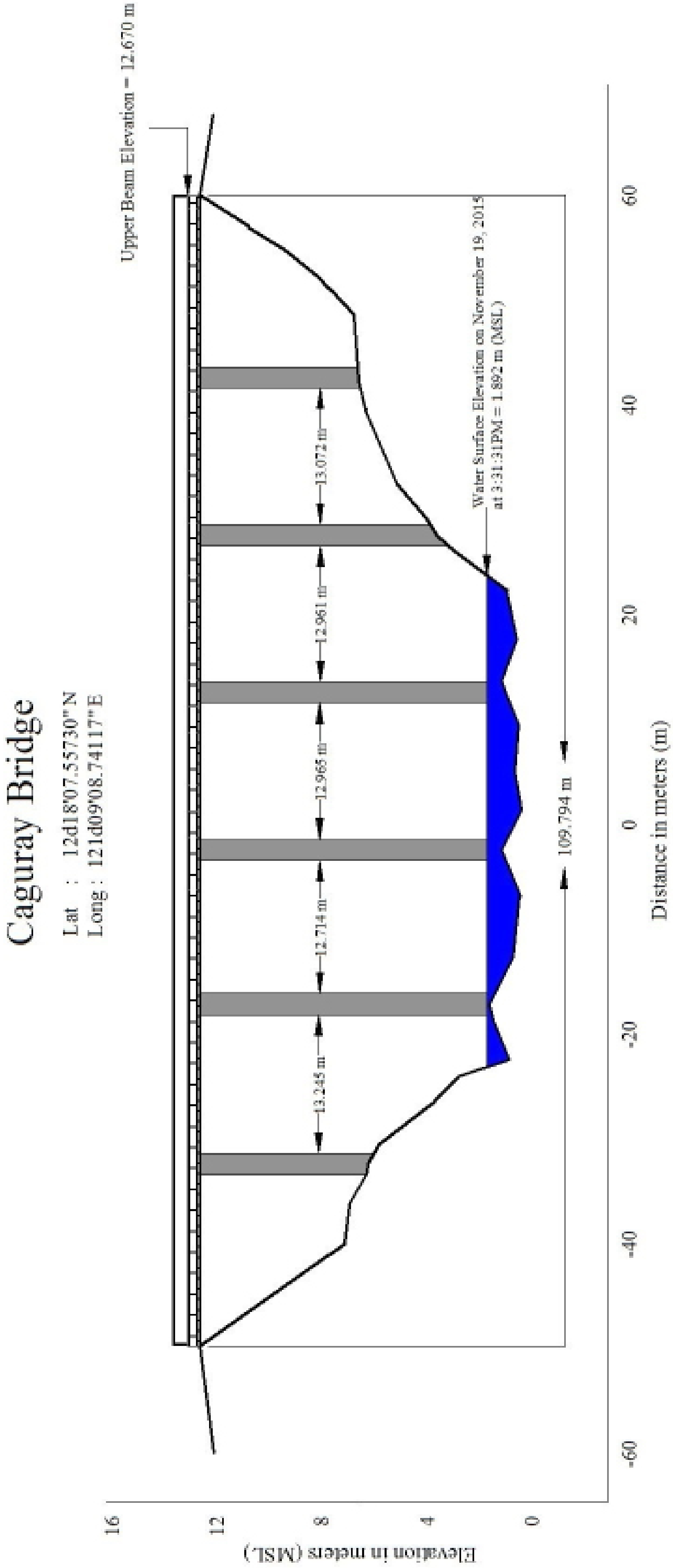


Figure 40. Caguray Bridge cross-section diagram

Bridge Data Form

Bridge Name: Caguray Bridge **Date:** November 19, 2015

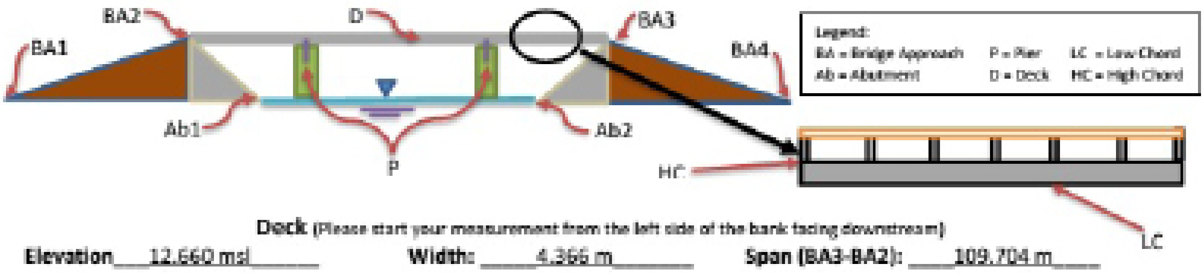
River Name: Caguray River **Time:** 12:49:10 PM

Location (Brgy, City, Region): Brgy. Poblacion, Magsaysay, Occidental Mindoro

Survey Team: Team Mady and Team Klyn

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

Latitude: 12d18'07.55730" **Longitude:** 121d09'08.74117"



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

Elevation 12.660 msl **Width:** 4.366 m **Span (BA3-BA2):** 109.704 m

	Station	High Chord Elevation	Low Chord Elevation
1			
2			

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	12.103	BA3	119.931	12.612
BA2	10.137	12.641	BA4	127.534	12.120

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: cylindrical **Number of Piers:** 6 **Height of column footing:**

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	27.541	12.641	0.5m
Pier 2	42.724	12.670	0.5m
Pier 3	57.500	12.669	0.5m
Pier 4	72.465	12.660	0.5m
Pier 5	87.426	12.653	0.5m
Pier 6	102.498	12.664	0.5m

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

Figure 41. Bridge as-built form of Caguray Bridge

The water surface elevation in MSL of Caguray River was determined using Trimble® SPS 882 in PPK mode technique on November 23, 2015 at 04:25 PM with a value of 1.892 m in MSL. This was translated vertically onto marking on the bridge's deck using a meter tape. The value of 13.7 m is still an assumed elevation and yet to be changed to the computed 12.656 m in MSL by UP Los Baños. They shall update the marked deck to reflect its corresponding MSL value. The marked deck will serve as their reference for flow data gathering and depth gauge deployment for Caguray River. The finished water level marking in Caguray Bridge is shown in Figure 42.

Figure 42. Water level marking at Caguray Bridge deck, Brgy. Poblacion, Municipality of Magsaysay

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 receiver, Trimble® SPS 882, mounted on a pole which was attached either to the front or side of vehicle as shown in Figure 43. 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 in the conduct of the survey.

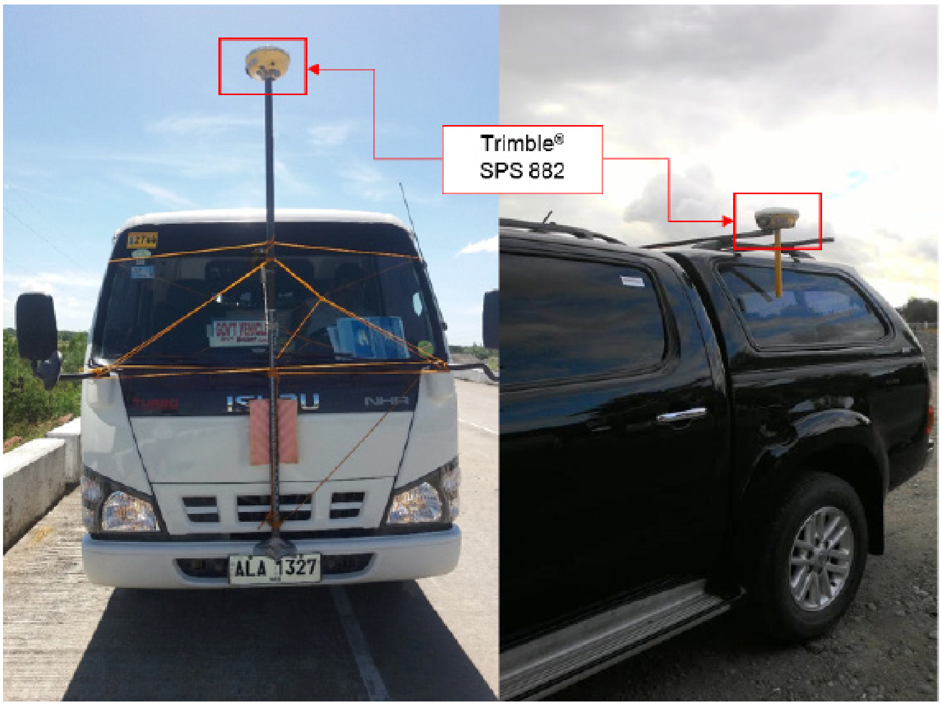


Figure 43. Validation Points Acquisition Set-up for Caguray River

The survey was along the National Highway covering municipalities of Sta. Cruz, Sablayan, Calintaan, Rizal, San Jose and Magsaysay with an approximate length of 191 km with 26,449 validation points gathered. The gaps in the validation line as shown in Figure 44 were due to road contractions and difficulties in receiving satellite signals because of the presence of obstructions such as dense canopy cover of trees along the roads.

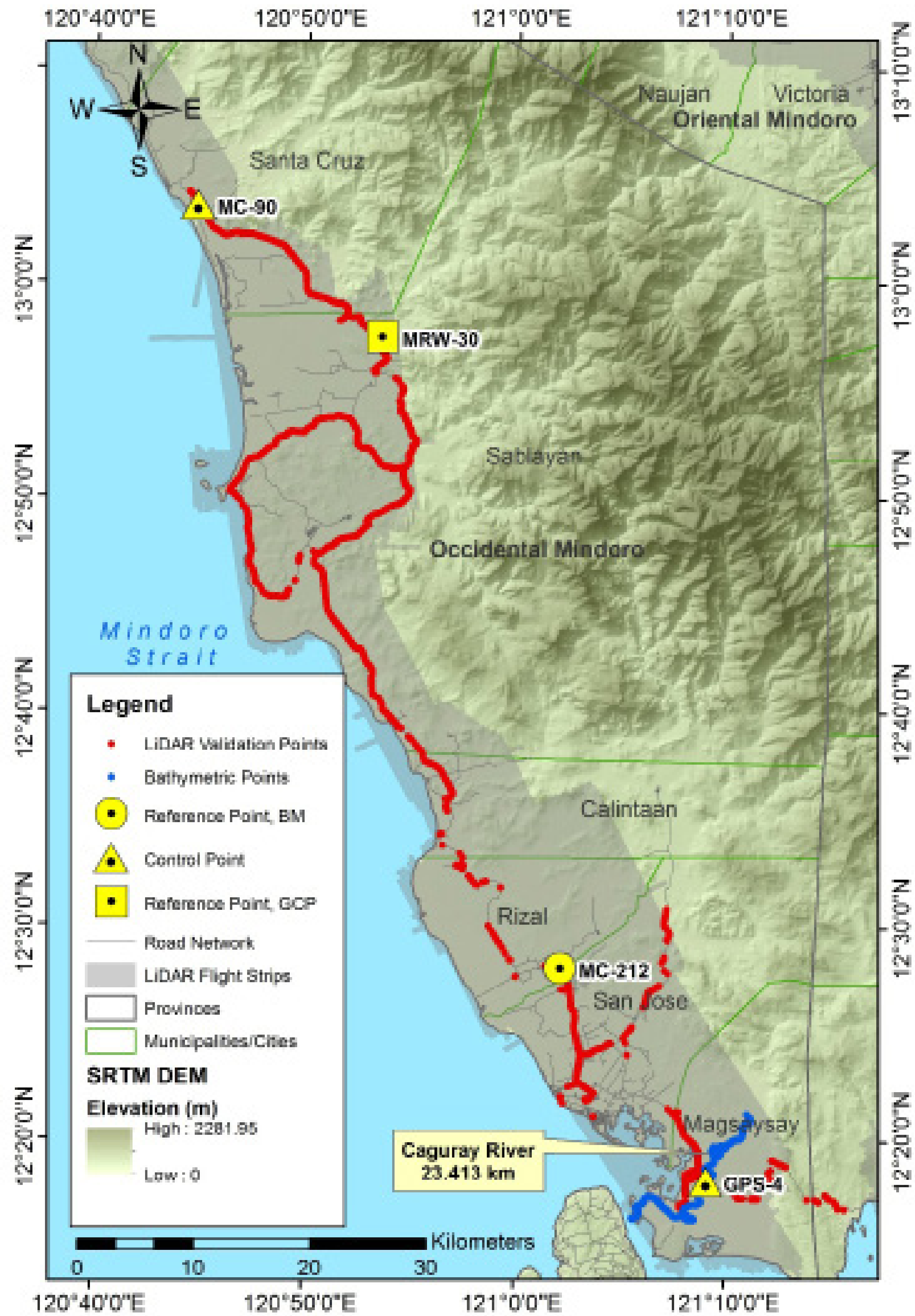


Figure 44. Validation point acquisition survey of Caguray River Basin

4.3.2 Bathymetric Survey

Bathymetric survey was performed on November 10, 11 and 14, 2015 using Hi-Target™ echo sounder and a Trimble® SPS 882 attached on a boat as shown in Figure 45. The survey started from Brgy. Calawag with coordinates 12°16'20.64459" 121°08'21.14222", down to the mount of the river in Brgy. Caguray, both in Municipality of Magsaysay with coordinates 12°16'22.86990" 121°05'40.63172".

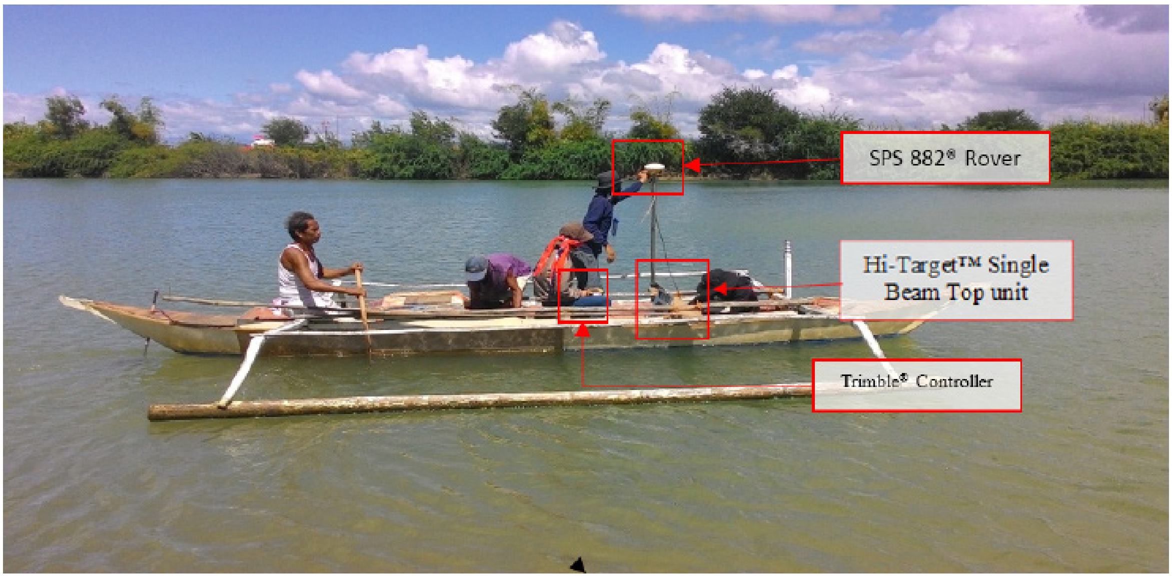


Figure 45. Bathymetric survey using Hi-Target™ Echo Sounder along Caguray River

On the other hand, manual bathymetric survey was executed on November 9, 10, 11, and 14 2015 carrying a Trimble bag with installed Trimble® SPS 882 using GNSS PPK survey technique as shown in Figure 46. The survey started at the upstream part of the river in Brgy. Purnaga with coordinates 12°21'06.41749" 121°11'13.79163", traversed down by foot and ended at the starting point of bathymetric survey using boat. The control points GPS 4 was used as base station on November 9, 10, and 14 while MC-200 was used on N0vember 13, 2015.

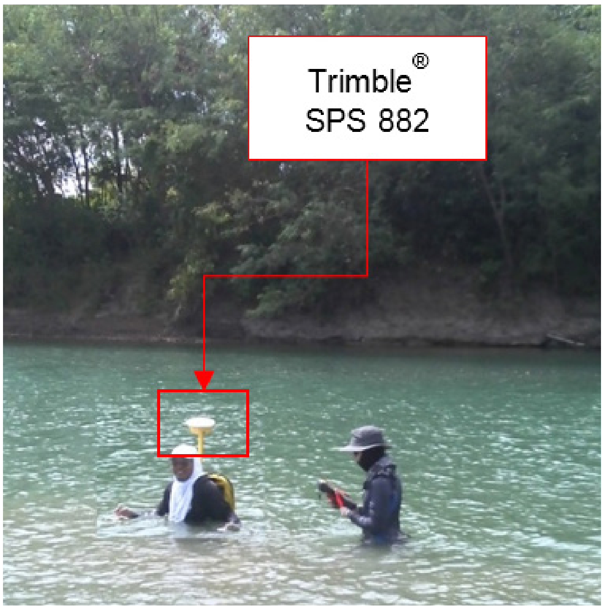


Figure 46. Manual bathymetric survey in Caguray River

The entire bathymetric data coverage for Caguray River is illustrated in the map in Figure 47. The gaps in the bathymetric survey was due to difficulties in acquiring satellite caused by obstructions such as dense canopy of trees and presence of rapids along the river.

A CAD drawing was also produced to illustrate the Caguray riverbed profile as illustrated in Figure 48 and Figure 49. An elevation drop of 15.39 meters in MSL was observed within the distance of approximately 23.413 km from the upstream in Brgy. Purnaga down to Brgy. Caguray with a total of 23,958 bathymetric points gathered. Gradual change in elevation can also be seen in the illustration with an average change elevation of about 0.327 for every 500-meter interval.

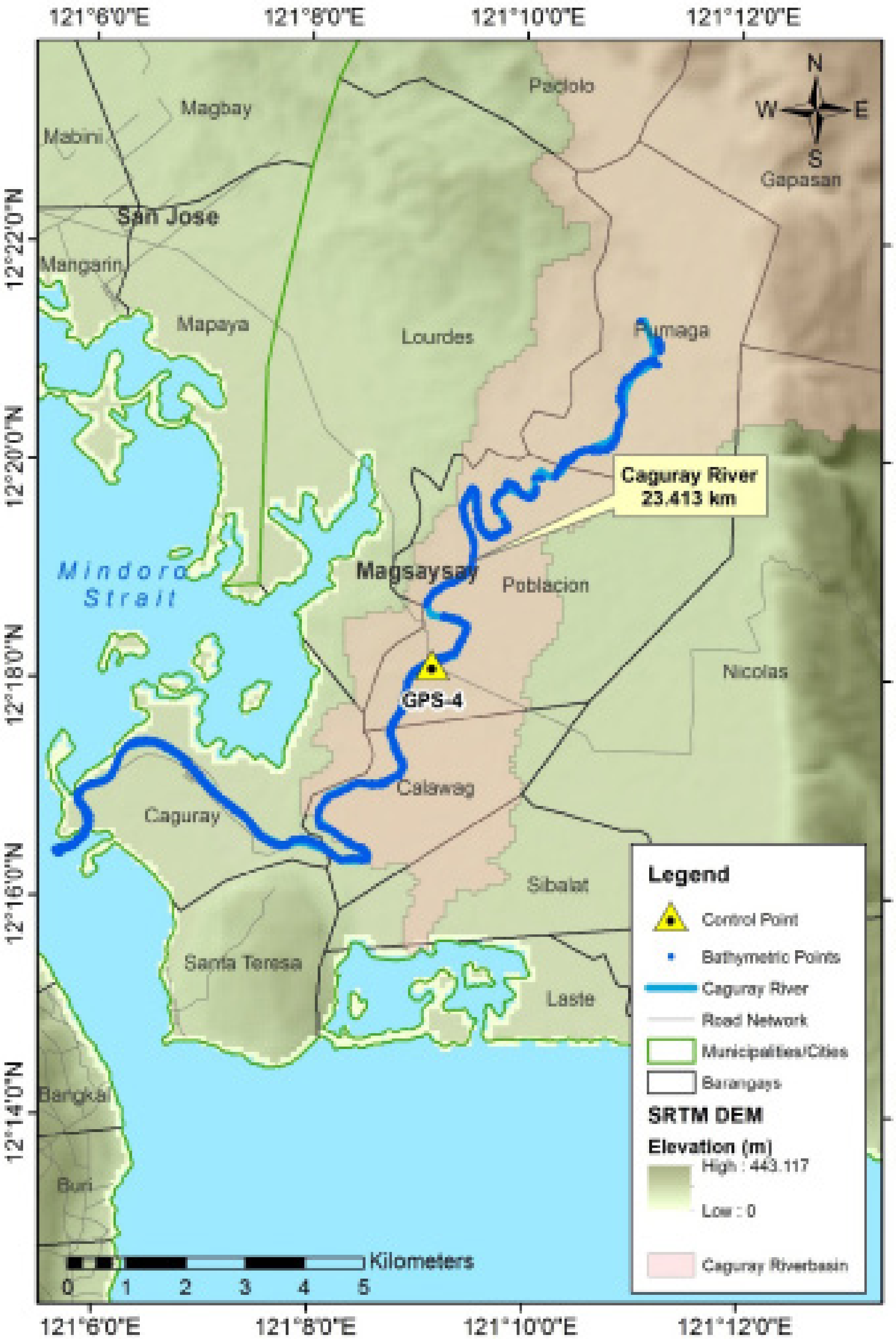


Figure 47. Bathymetric survey of Caguray River

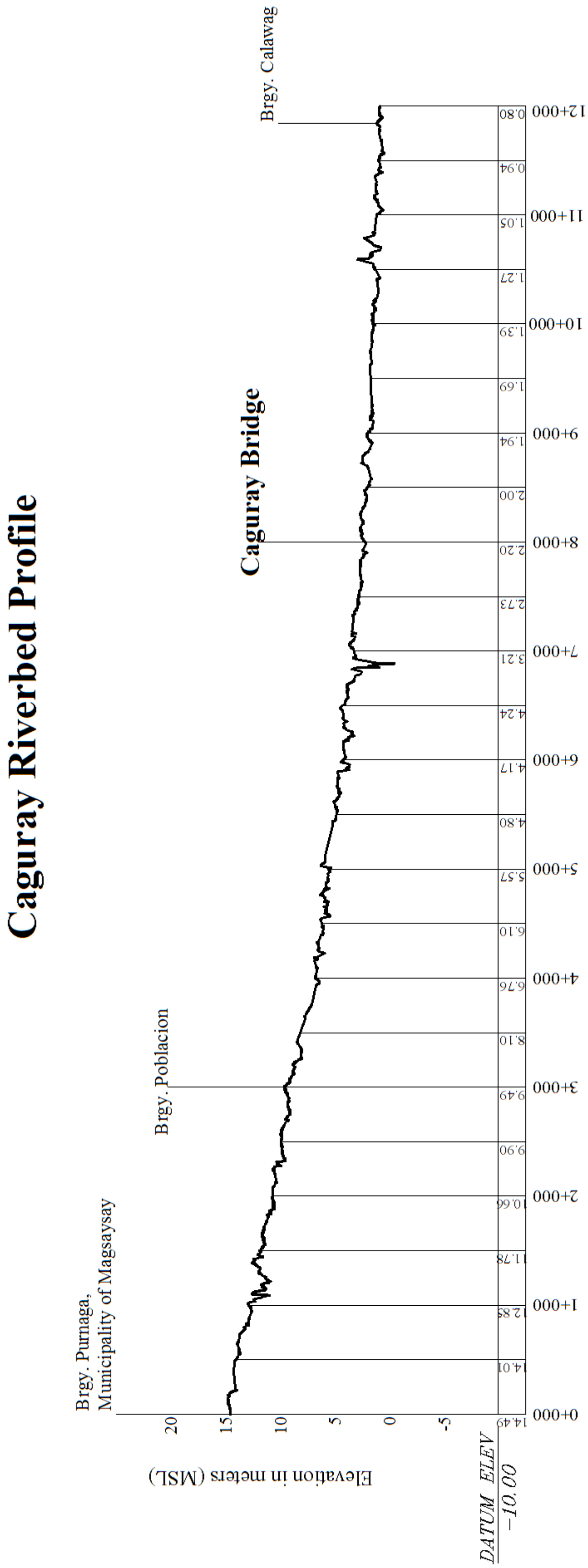


Figure 48. Caguray centerline riverbed profile (Upstream)

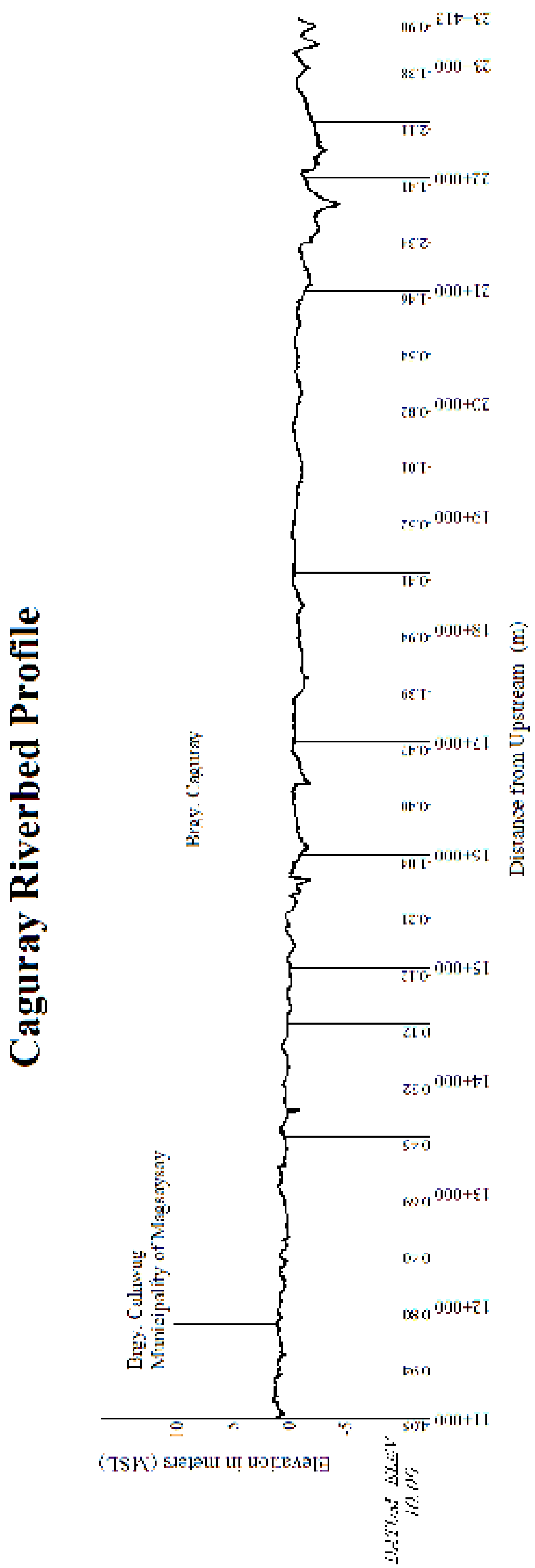


Figure 49. Caguray centerline riverbed profile (Downstream)

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, 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 Caguray 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 Caguray River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from a portable rain gauge (12.312039° N, 121.146231° E) deployed within the riverbasin. The location of the rain gauge is seen in Figure 50.

The total precipitation for this event is 24.0 mm. The peak rainfall is 7.40 mm on March 14, 2017 at 6:00 pm The lag time between the peak rainfall and discharge is 16 hours and 20 minutes, as seen in Figure 53.

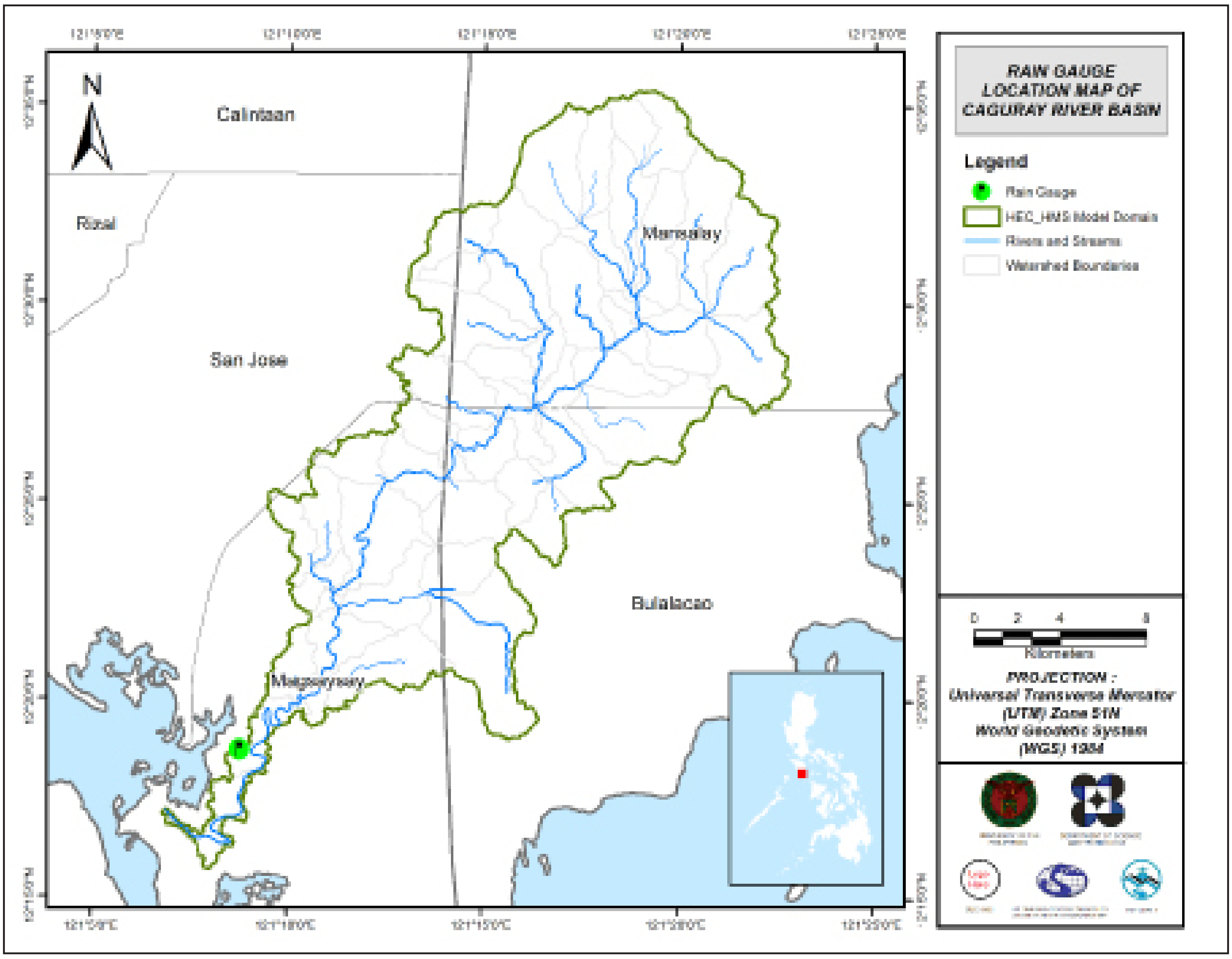


Figure 50. The location map of Caguray HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Caguray Bridge, Magsaysay, Occidental Mindoro (12.302542°N, 121.152133°E). It gives the relationship between the observed water levels from the Caguray Bridge and outflow of the watershed at this location using Bankfull Method in Manning's Equation.

For Caguray Bridge, the rating curve is expressed as Q = 4.1979x2.414 as shown in Figure 52.

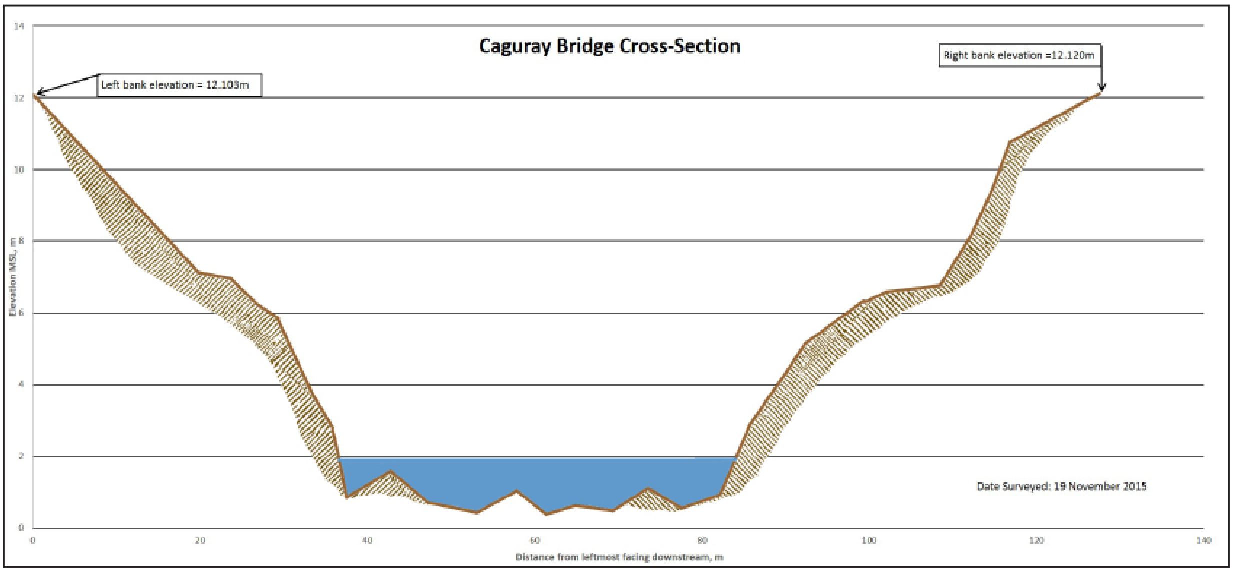


Figure 51. Cross-Section Plot of Caguray Bridge

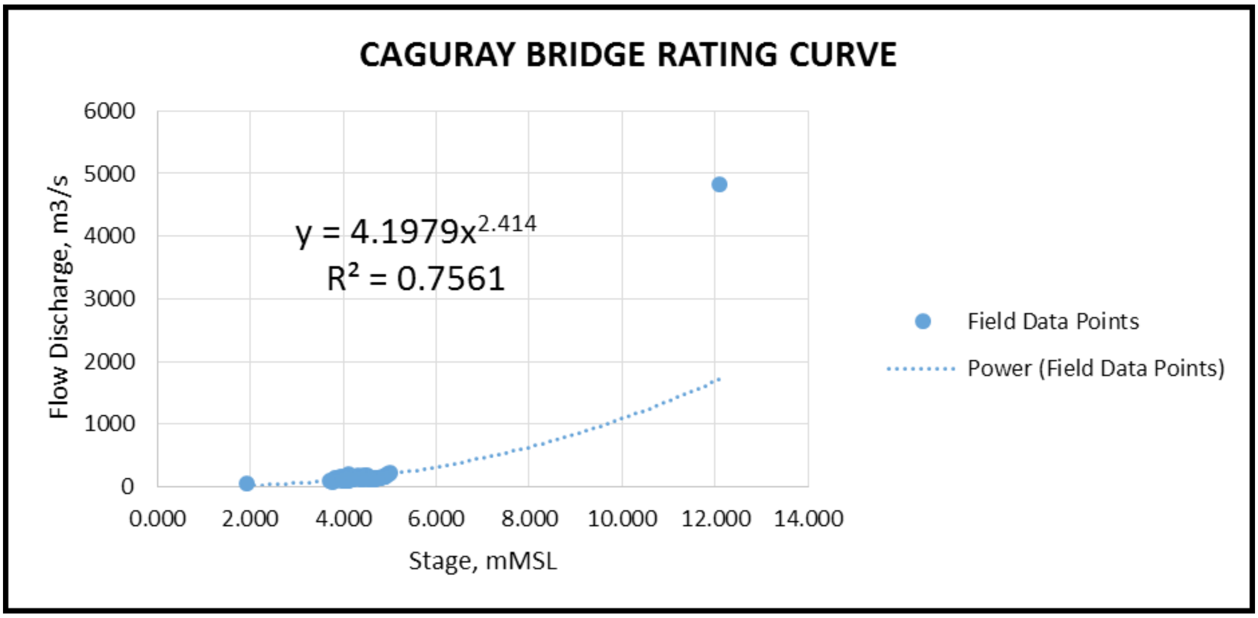


Figure 52. Rating Curve at Caguray Bridge, Magsaysay, Occidental Mindoro

For the calibration of the HEC-HMS model, shown in Figure 53, actual flow discharge during a rainfall event was collected in the Caguray Bridge. Peak discharge is 30.90 cu.m/s on March 15, 2017 at 10:20 pm.

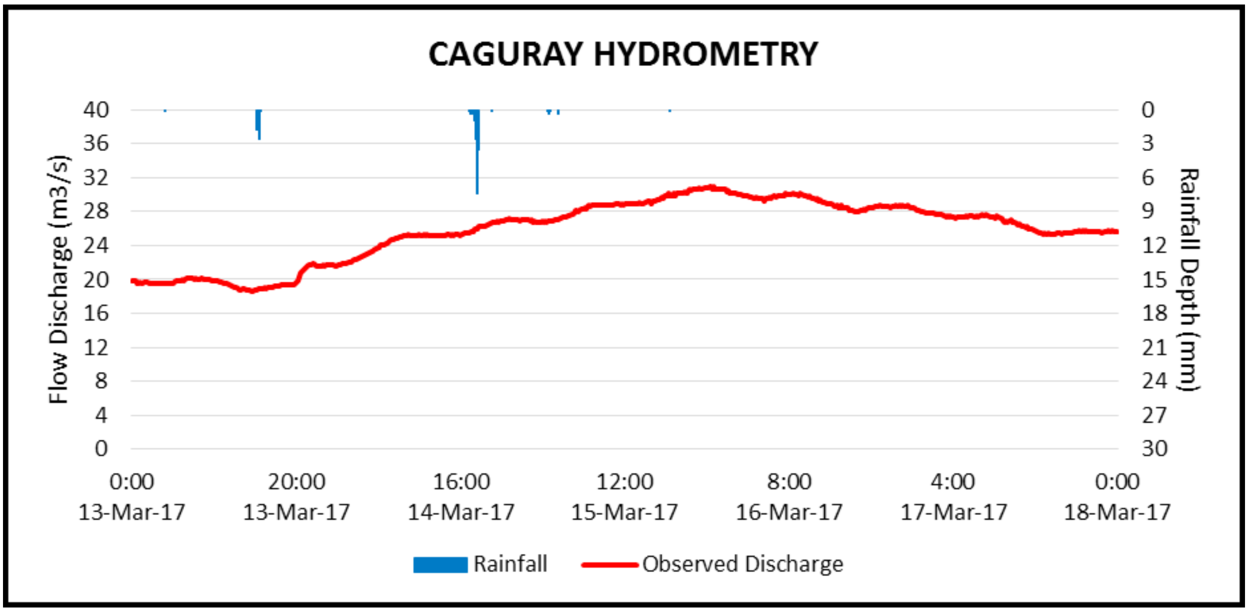


Figure 53. Rainfall and outflow data at Caguray River Basin used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Romblon 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 Caguray watershed. The extreme values for this watershed were computed based on a 48-year record, with the computed extreme values shown in Table 26.

Table 26. RIDF values for Romblon 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	18.2	27	33.5	44.3	59.5	70.4	89.5	107	119.8
5	26	37.7	46.5	60.7	82.2	97.6	125.5	152.9	171.6
10	31.1	44.8	55	71.5	97.3	115.7	149.3	183.4	205.9
15	34	48.8	59.9	77.7	105.8	125.8	162.8	200.5	225.2
20	36	51.6	63.3	82	111.8	133	172.2	212.6	238.8
25	37.6	53.8	65.9	85.3	116.4	138.4	179.4	221.8	249.2
50	42.4	60.4	74	95.4	130.5	155.3	201.8	250.3	281.4
100	47.2	67	81.9	105.5	144.5	172.1	223.9	278.6	313.3

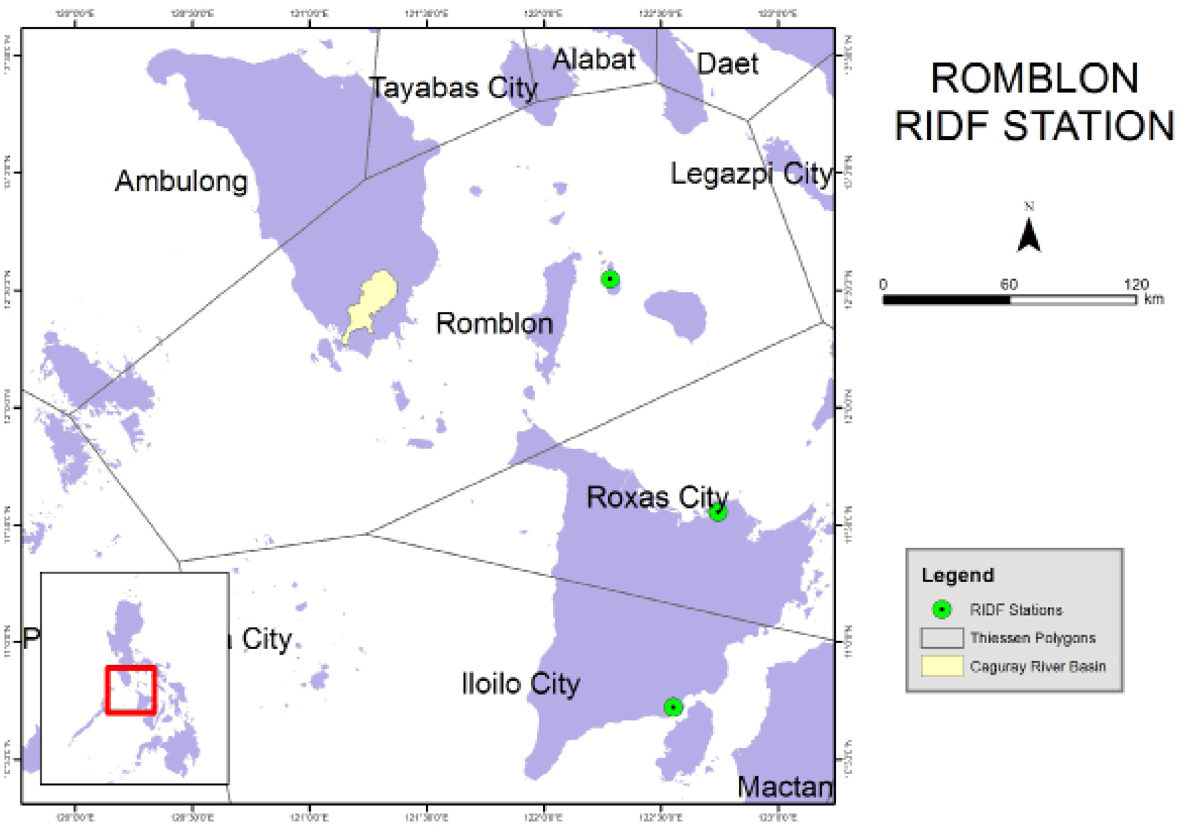


Figure 54. Location of Caguray RIDF station relative to Caguray River Basin

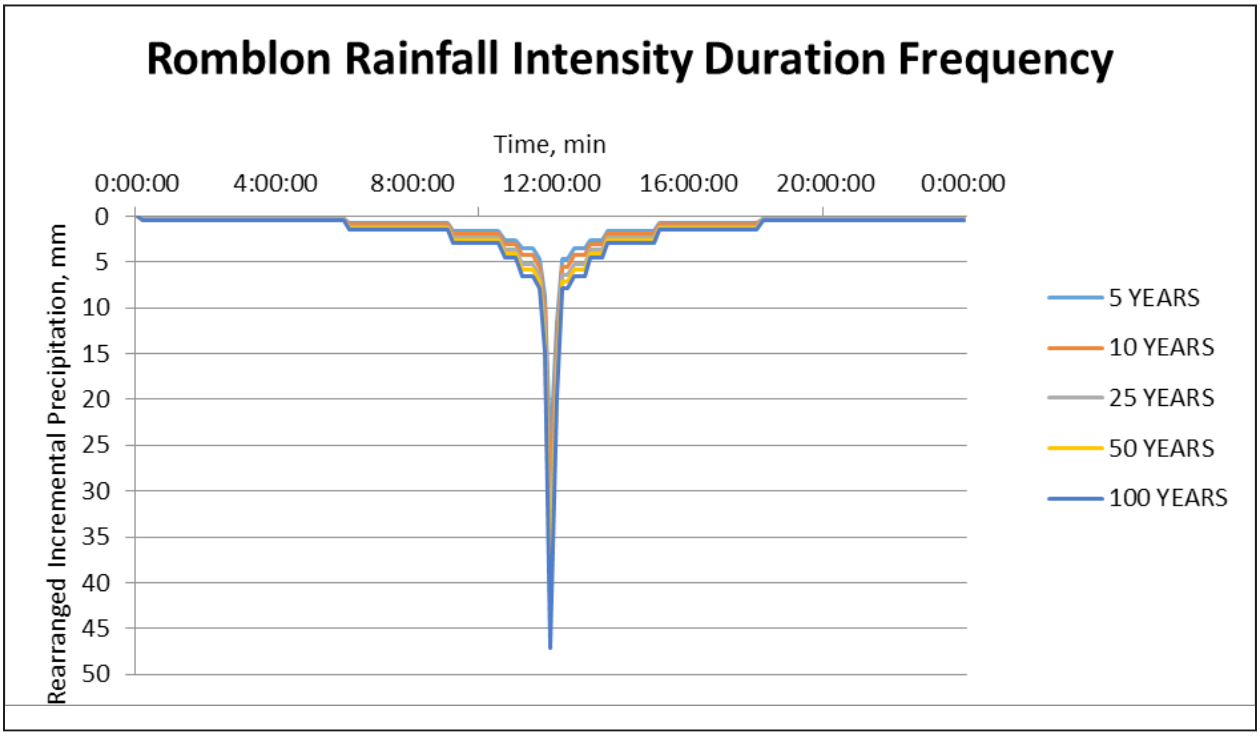


Figure 55. Synthetic storm generated for a 24-hr period rainfall for various return periods

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 Caguray River Basin are shown in Figure 56 and Figure 57, respectively.

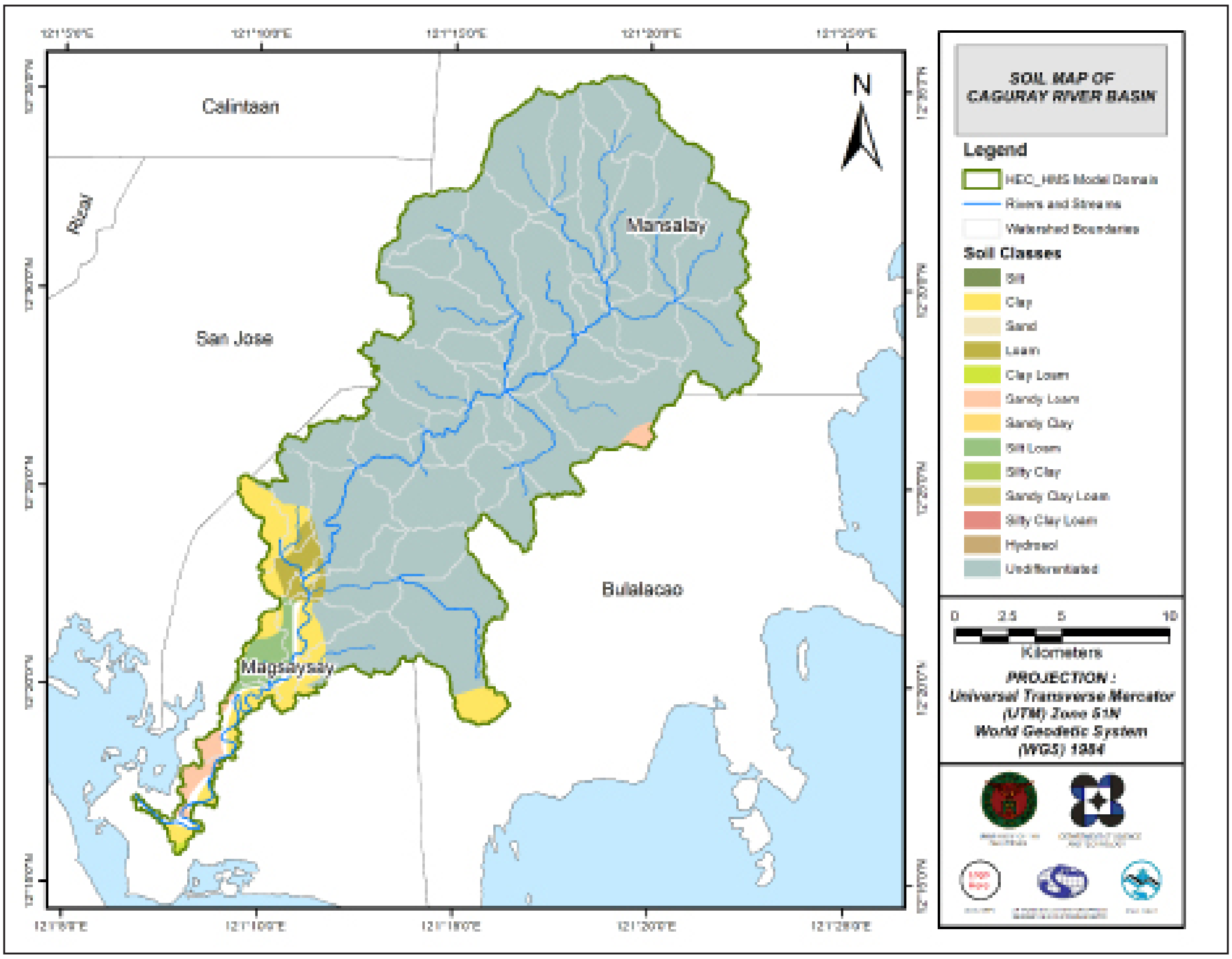


Figure 56. Soil map of Caguray River Basin used for the estimation of the CN parameter. (Source: DA)

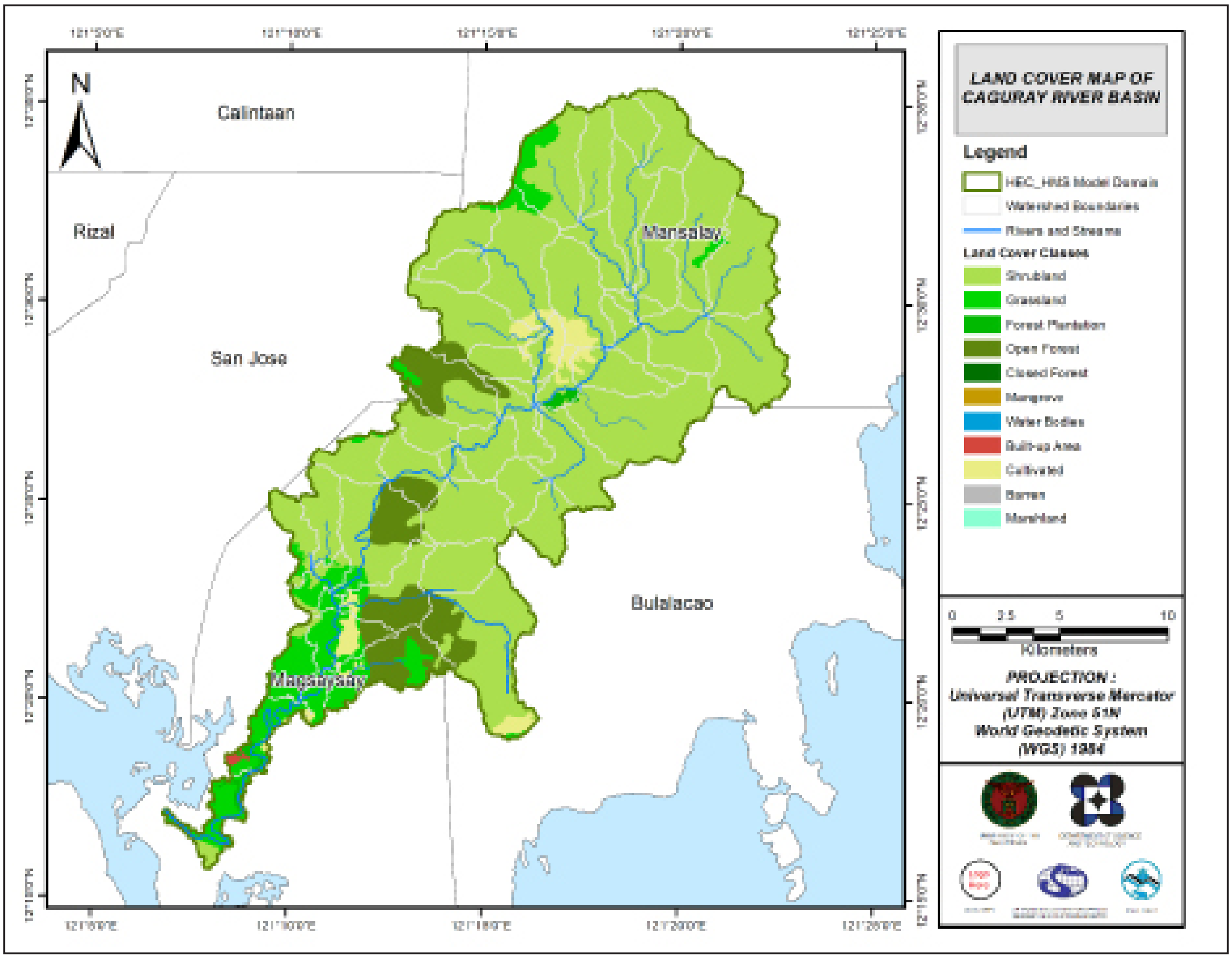


Figure 57. Land cover map of Caguray River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

For Caguray river basin, the six (6) soil classes identified were sandy clay, sandy loam, silt loam, clay loam, and hydrosol while the rest is undifferentiated. The six (6) land cover types identified were largely shrubland, with portions of grassland, forest plantation, open forest, cultivated land, and built-up area.

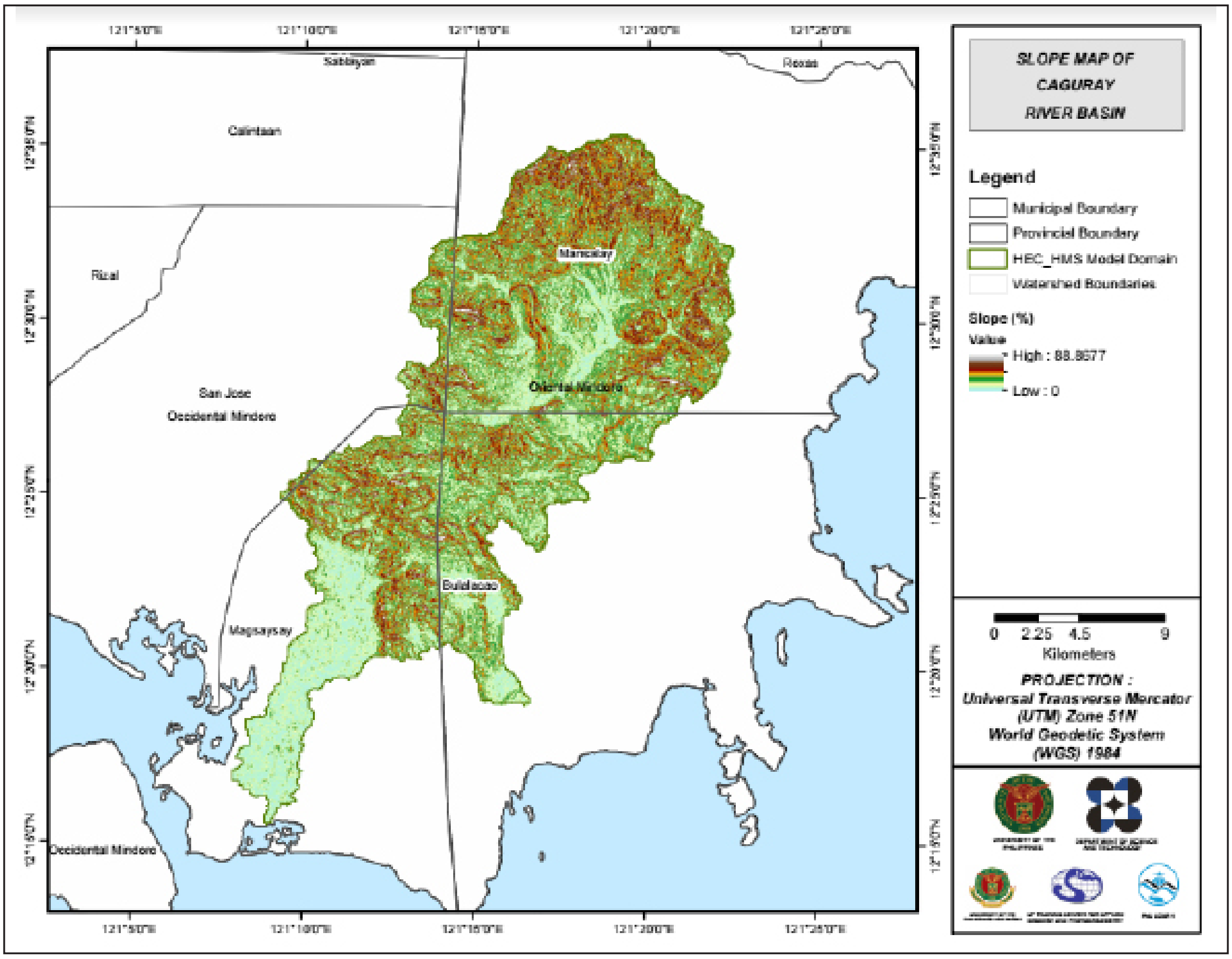


Figure 58. Slope map of Caguray River Basin

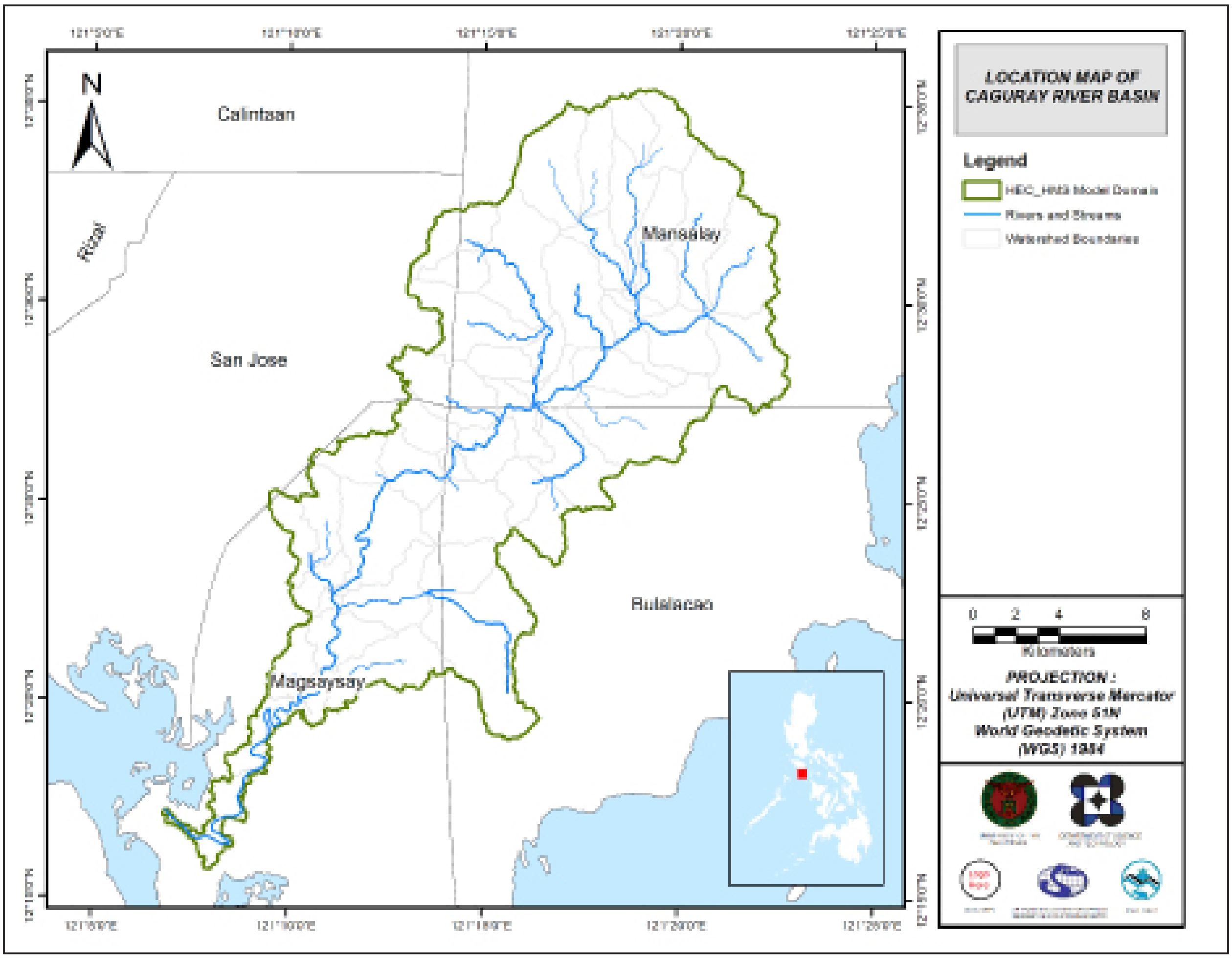


Figure 59. Stream Delineation Map of the Caguray River Basin

Using SAR-based DEM, the Caguray basin was delineated and further subdivided into subbasins. The model consists of 52 sub basins, 52 reaches, and 26 junctions as shown in Figure 60. The main outlet is Caguray Bridge, labelled as 166.

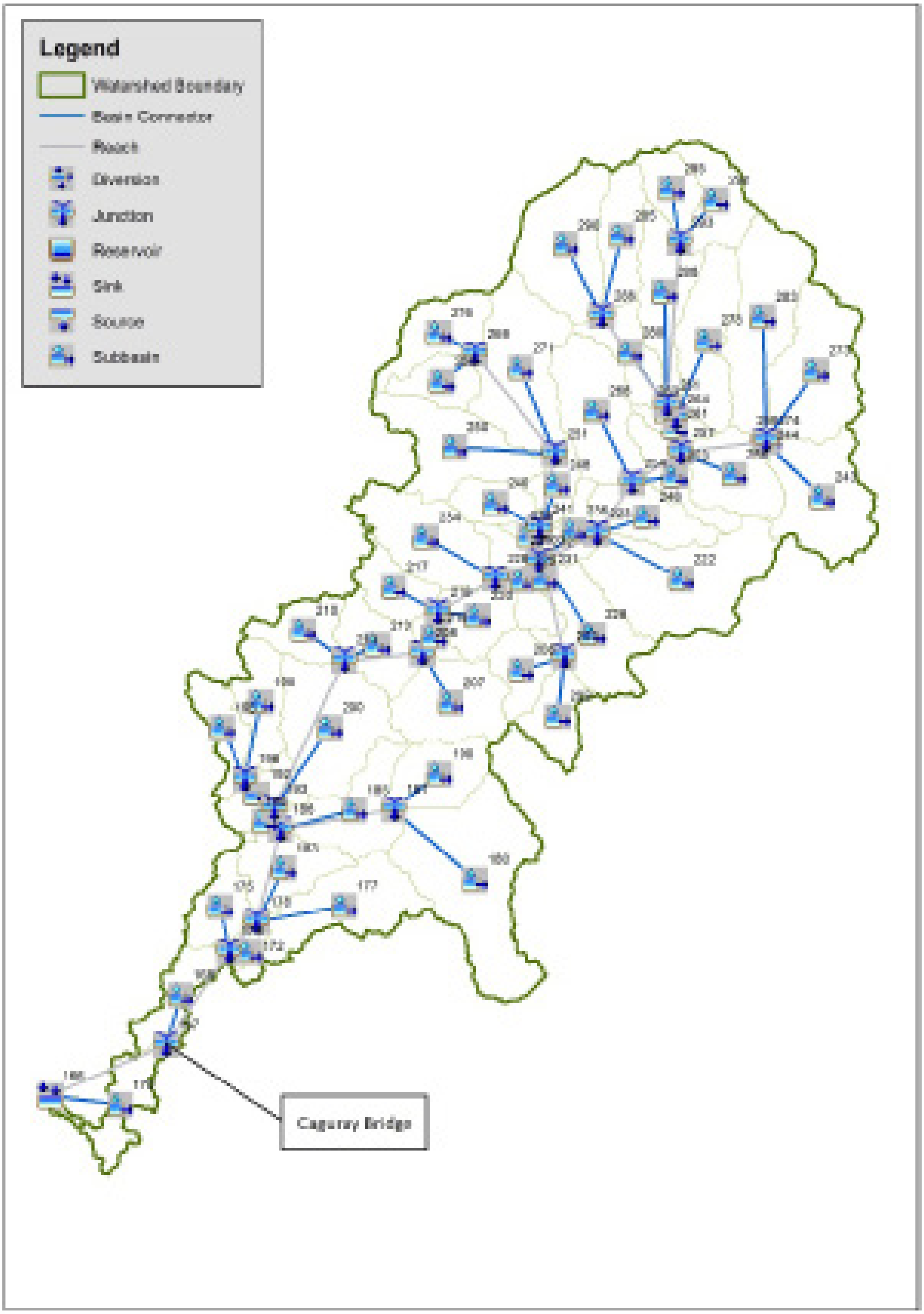


Figure 60. HEC-HMS generated Caguray River Basin Model.

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.

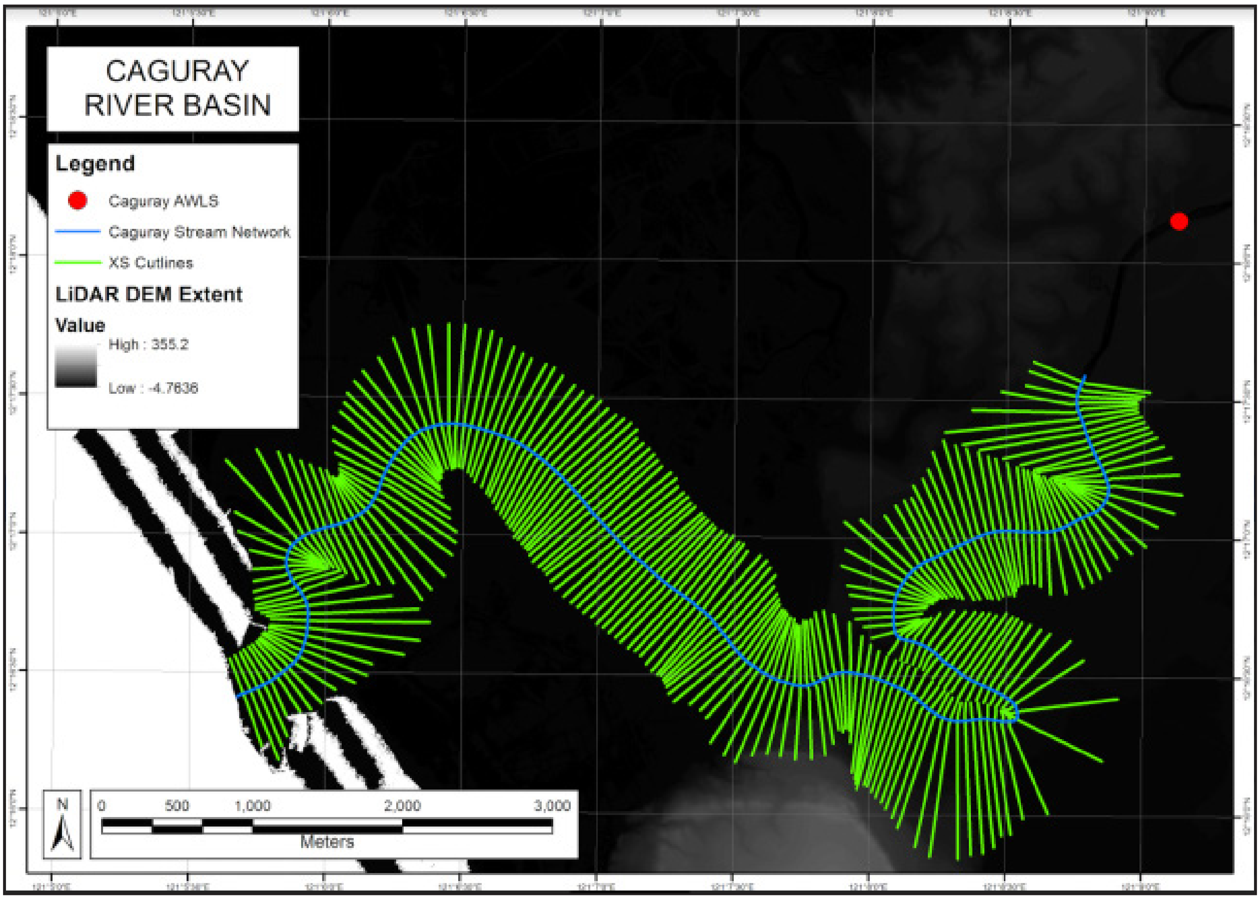


Figure 61. River cross-section of Baroc River generated through Arcmap HEC GeoRAS tool

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 north of the model to the southwest, following the main channel. As such, boundary elements in those particular regions of the model are assigned as inflow and outflow elements respectively.

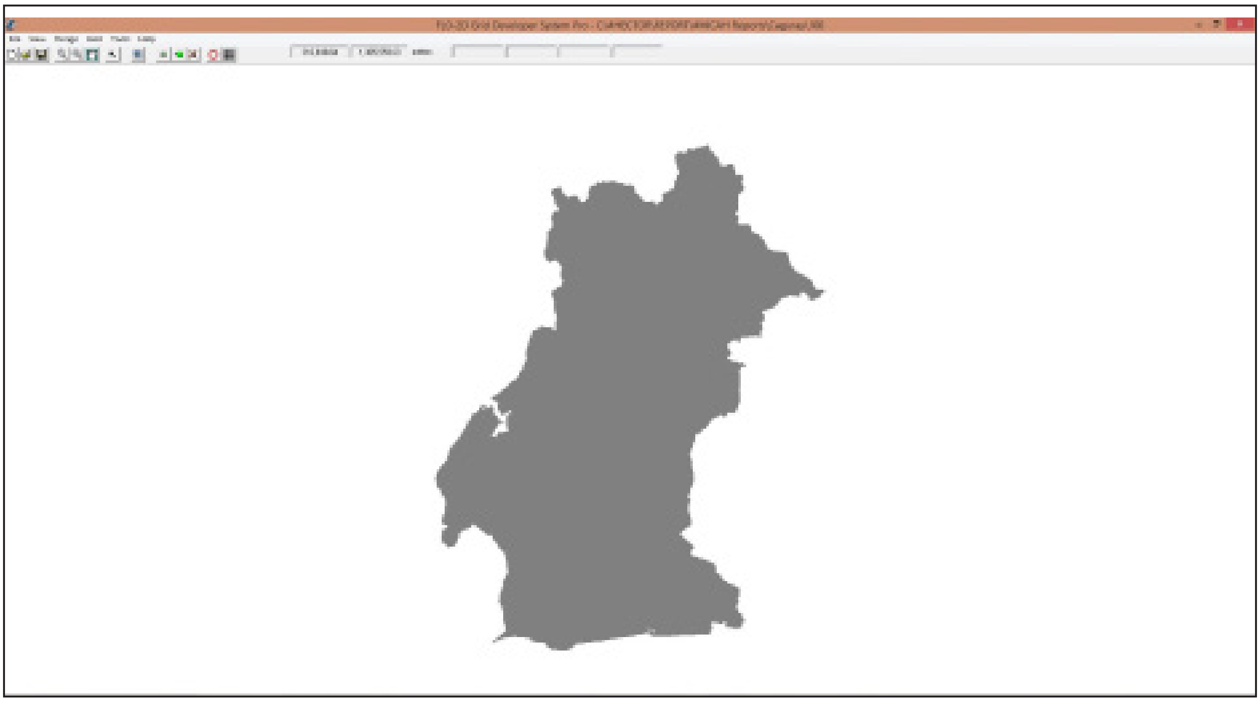


Figure 62. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 76.12183 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 93 534 700.00 m2.

There is a total of 110 547 670.67 m3 of water entering the model. Of this amount, 28 843 972.86 m3 is due to rainfall while 81 703 697.81 m3 is inflow from other areas outside the model. 16 263 753.00 m3 of this water is lost to infiltration and interception, while 42 912 305.10 m3 is stored by the flood plain. The rest, amounting up to 51 371 606.23 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Caguray HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 63 shows the comparison between the two discharge data.

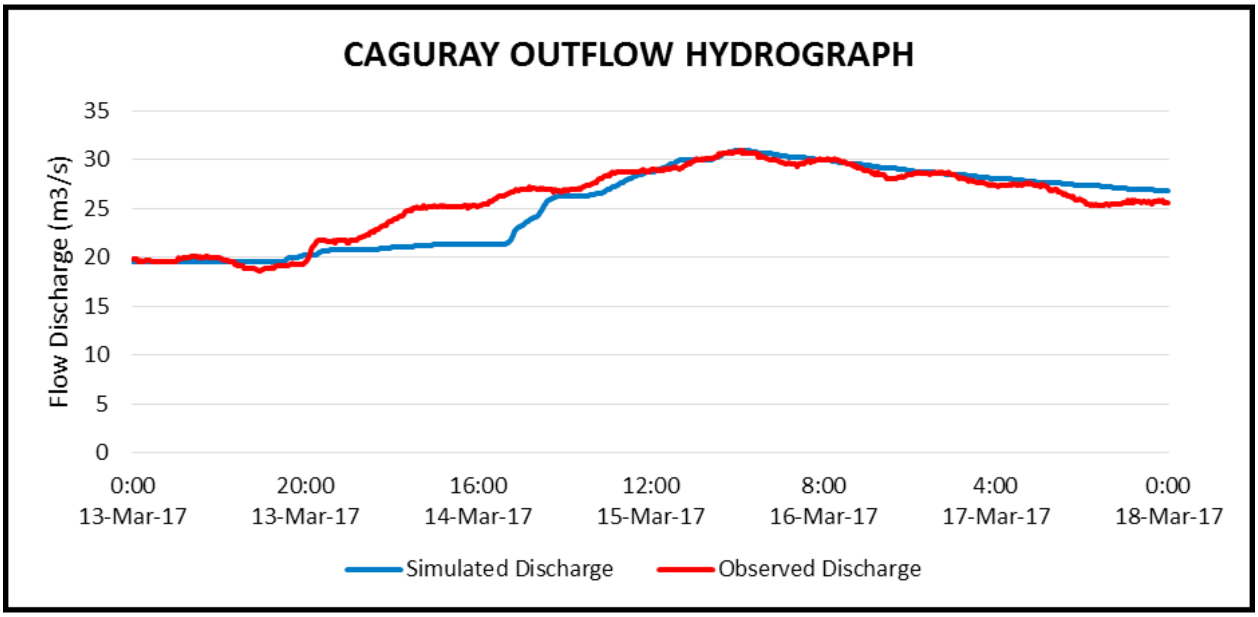


Figure 63. Outflow Hydrograph of Caguray produced by the HEC-HMS model compared with observed outflow.

Enumerated in Table 31 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 27. Range of Calibrated Values for Caguray River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.1 - 20
			Curve Number	43 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	.07 - 3
			Storage Coefficient (hr)	15 - 457
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.2 – 0.5
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04 – 0.5

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.1mm to 20mm means that the subbasins have a diverse soil and land cover characteristics wherein there is minimum to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 43 to 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area. For Caguray, the land cover mostly consists of shrubland, and grassland.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.07 to 457 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.2 to 0.5 indicates a steeper to relatively average receding limb of the outflow hydrograph.

Manning's roughness coefficient from 0.04 to 0.5 is high compared to the the common roughness of Philippine watersheds. This means that the riverbed is relatively rough and water will most likely flow slower. (Brunner, 2010).

Table 28. Summary of the Efficiency Test of Caguray HMS Model

Accuracy Measure	Value
RMSE	1.682
r2	0.918
NSE	0.782
PBIAS	1.761
RSR	0.467

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 1.682.

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 0.918.

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 0.782.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 1.761.

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 0.467.

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

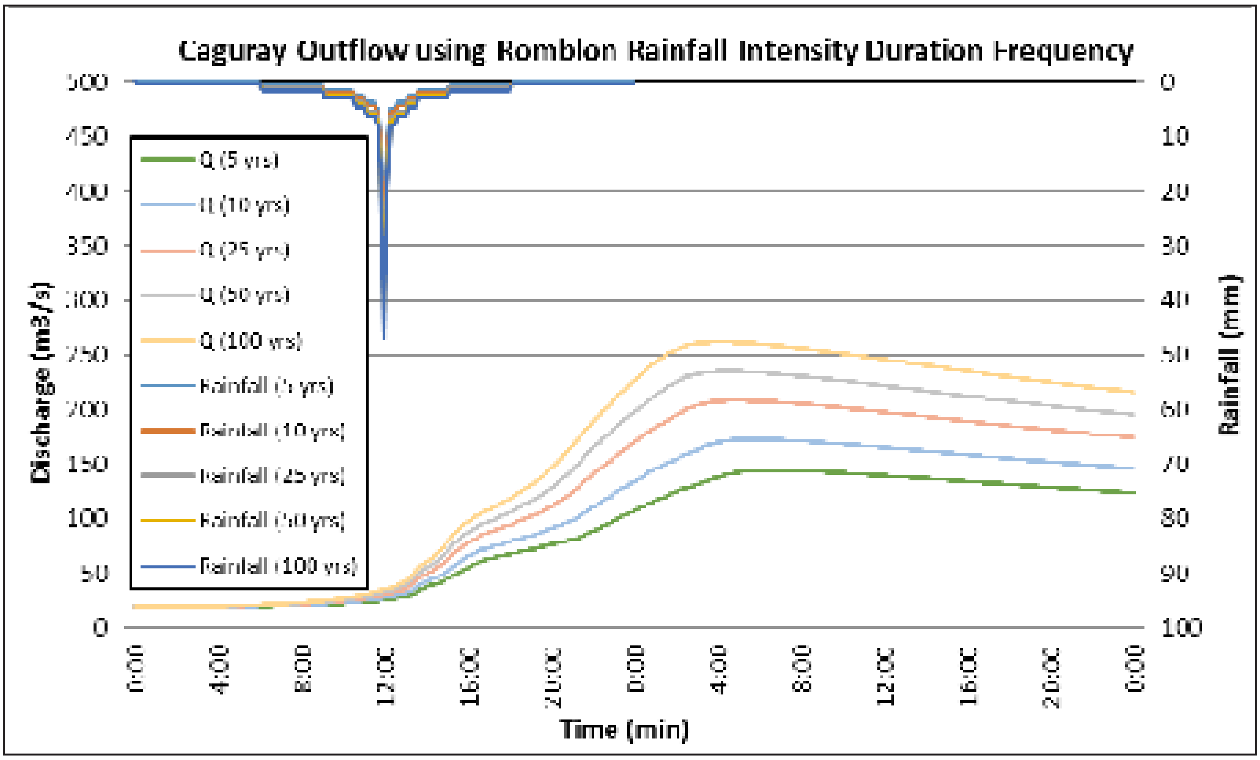


Figure 64. Outflow hydrograph at Caguray Station generated using Romblon RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, time to peak and lag time of the Caguray discharge using the Romblon Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 33.

Table 29. Peak values of the Caguray HECHMS Model outflow using the Romblon RIDF 24-hour values

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	171.60	26.0	144.40	18 hours 10 minutes
10-Year	208.90	31.10	172.50	17 hours 30 minutes
25-Year	249.20	37.60	208.20	16 hours 40 minutes
50-Year	281.40	42.40	234.90	16 hours 10 minutes
100-Year	313.30	47.20	261.50	15 hours 50 minutes

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

The river discharges for the two rivers entering the floodplain are shown in Figure 65 to Figure 66 and the peak values are summarized in Table 30 to Table 31.

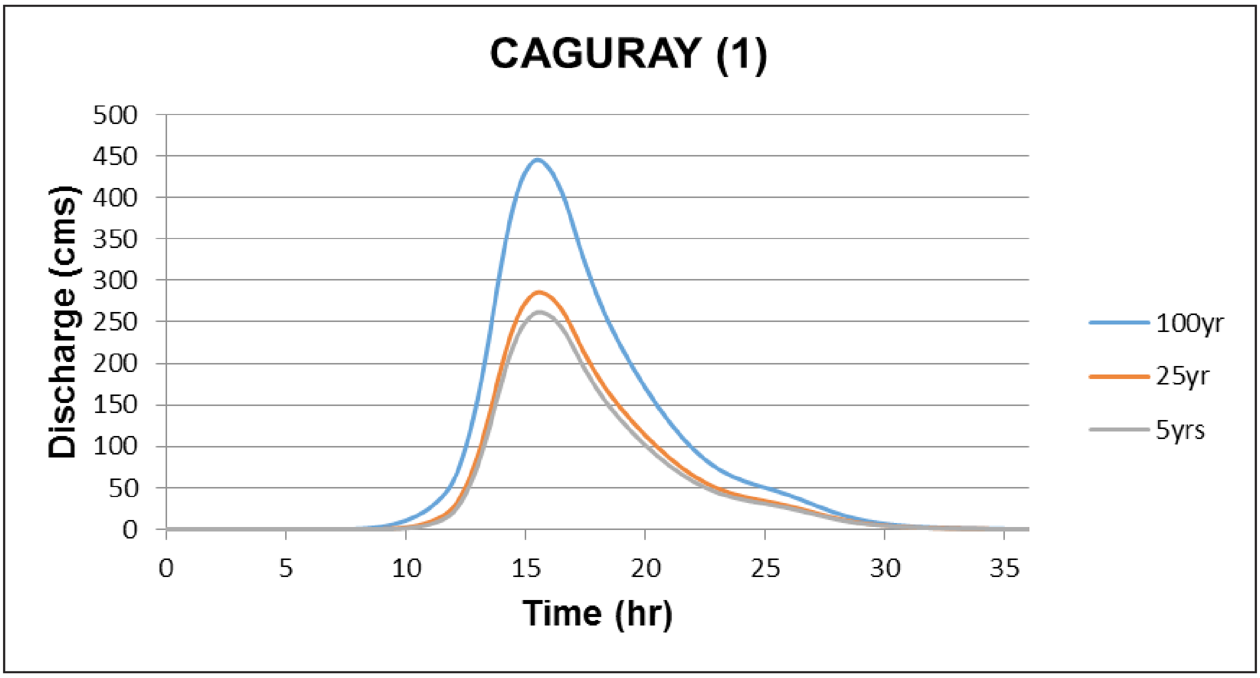


Figure 65. Caguray river (1) generated discharge using 5-, 25-, and 100-year Romblon rainfall intensity-duration-frequency (RIDF) in HEC-HMS

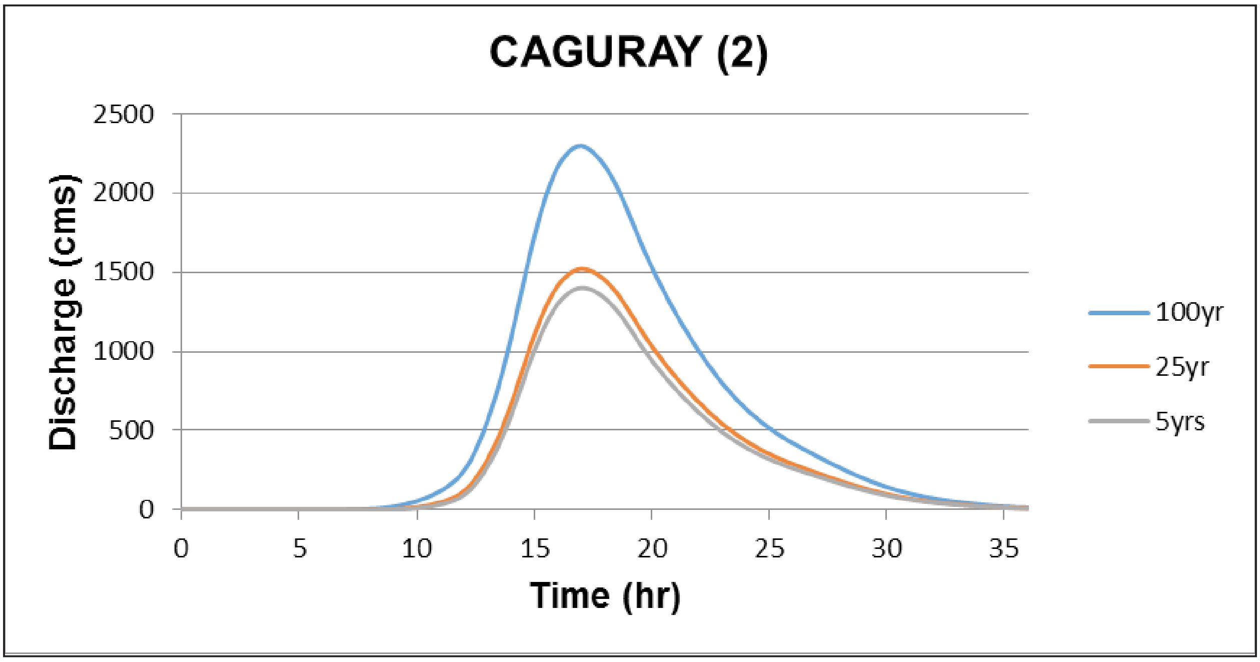


Figure 66. Caguray river (2) generated discharge using 5-, 25-, and 100-year Romblon rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 31. Summary of Caguray river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	445.6	15 hours, 30 minutes
25-Year	285.7	15 hours, 30 minutes
5-Year	261.9	15 hours, 40 minutes

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

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	2297.6	17 hours
25-Year	1521.5	17 hours
5-Year	1401.6	17 hours

Table 30. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Caguray (1)	305.95	305.95	305.95	Pass	Pass
Caguray (2)	305.95	305.95	305.95	Pass	Pass

All two values from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods. The calculated values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. However, these values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample map of Caguray River using the HMS base flow is shown on Figure 67 below.

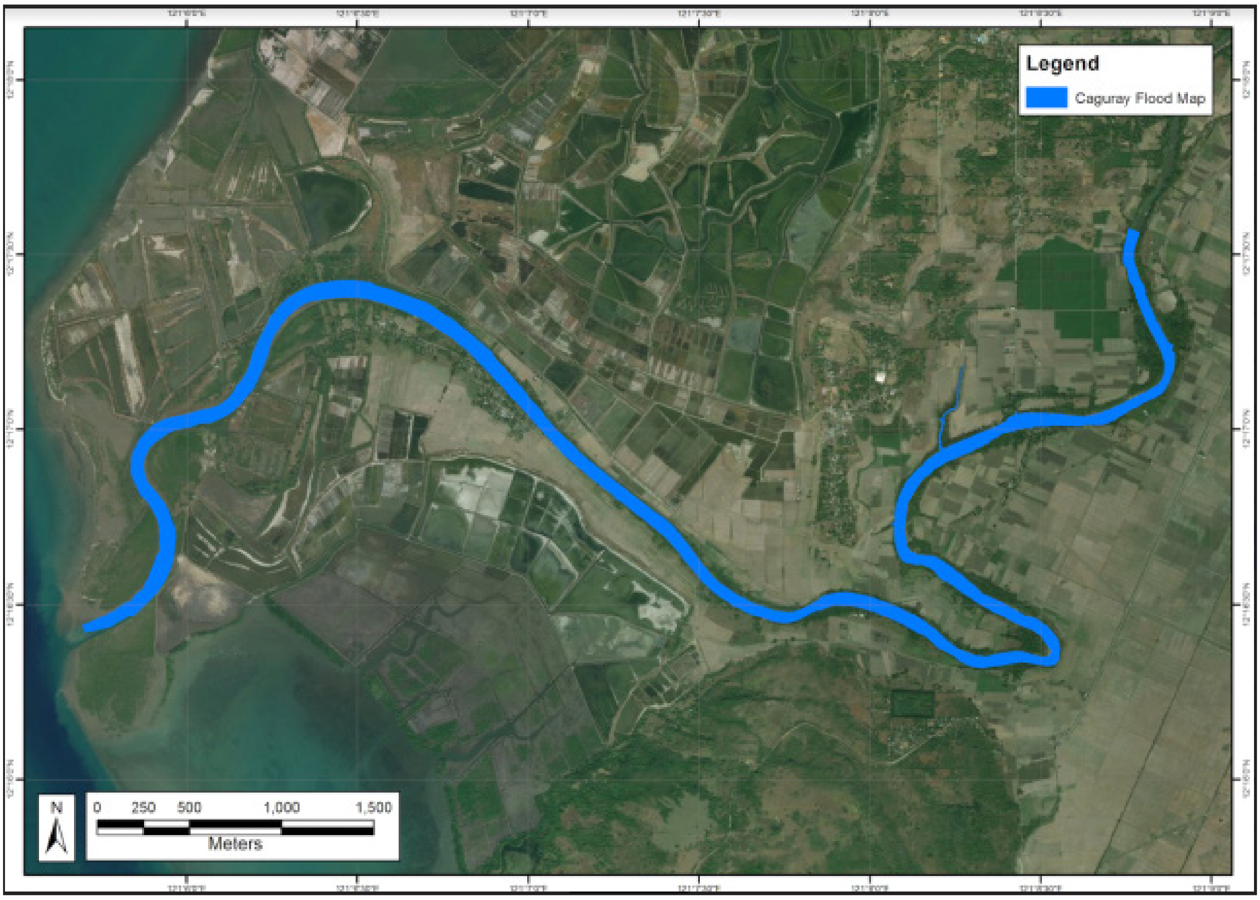


Figure 67. Sample output of Caguray RAS Model

5.9 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. The flood hazard and flow depth maps for the 5-, 25-, and 100-year rain return scenarios of the Caguray floodplain are shown in Figure 68 to Figure 73. The floodplain covers two municipalities in Occidental Mindoro, namely Magsaysay and San Jose. Table 33 shows the percentage of area affected by flooding per municipality.

Table 33. Municipalities affected in Caguray Floodplain

City / Municipality	Total Area (sq.km.)	Area Flooded (sq.km.)	% Flooded
Magsaysay	256.66		
San Jose	449.82		

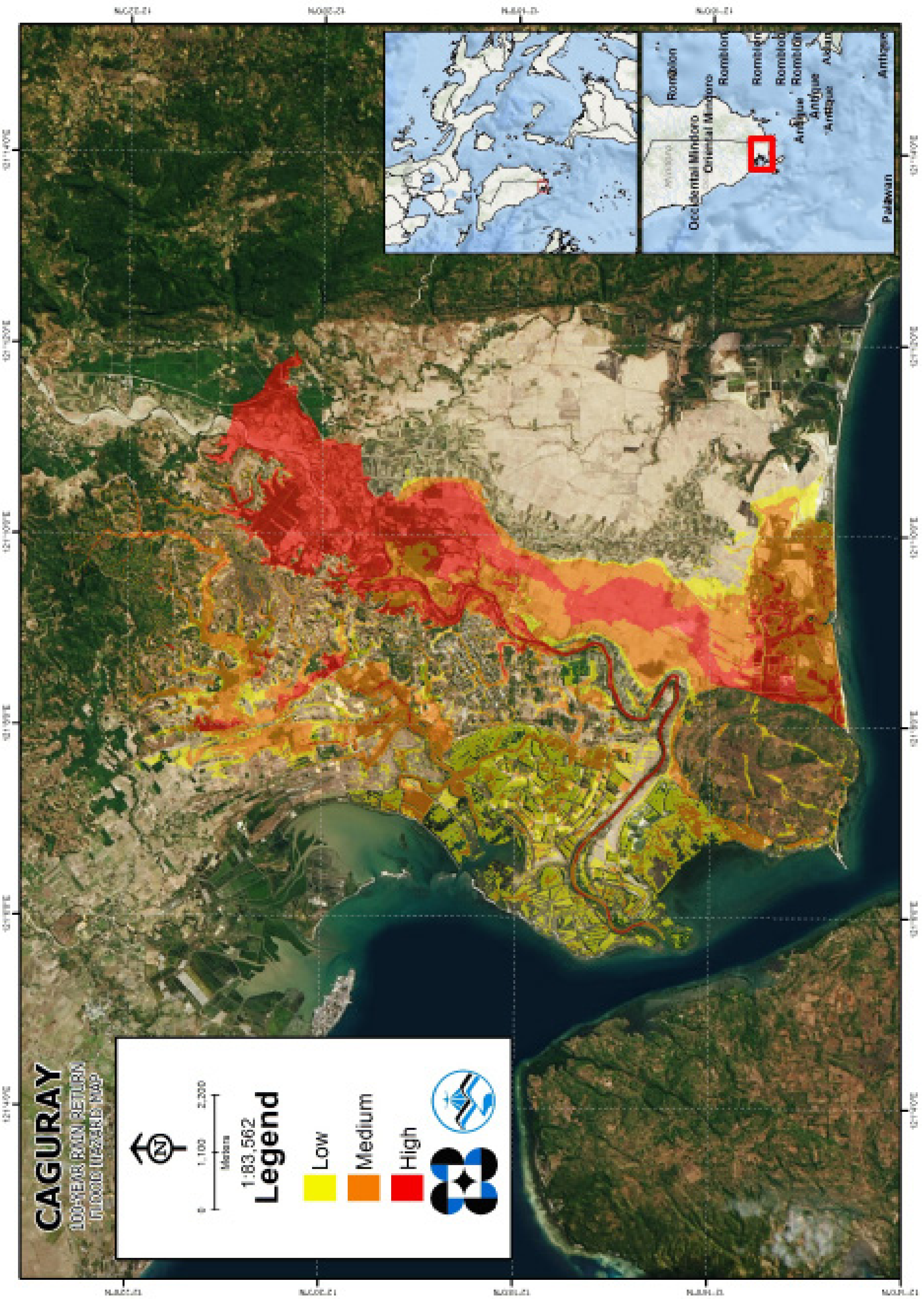


Figure 68. 100-year Flood Hazard Map for Caguray Floodplain overlaid in Google Earth imagery

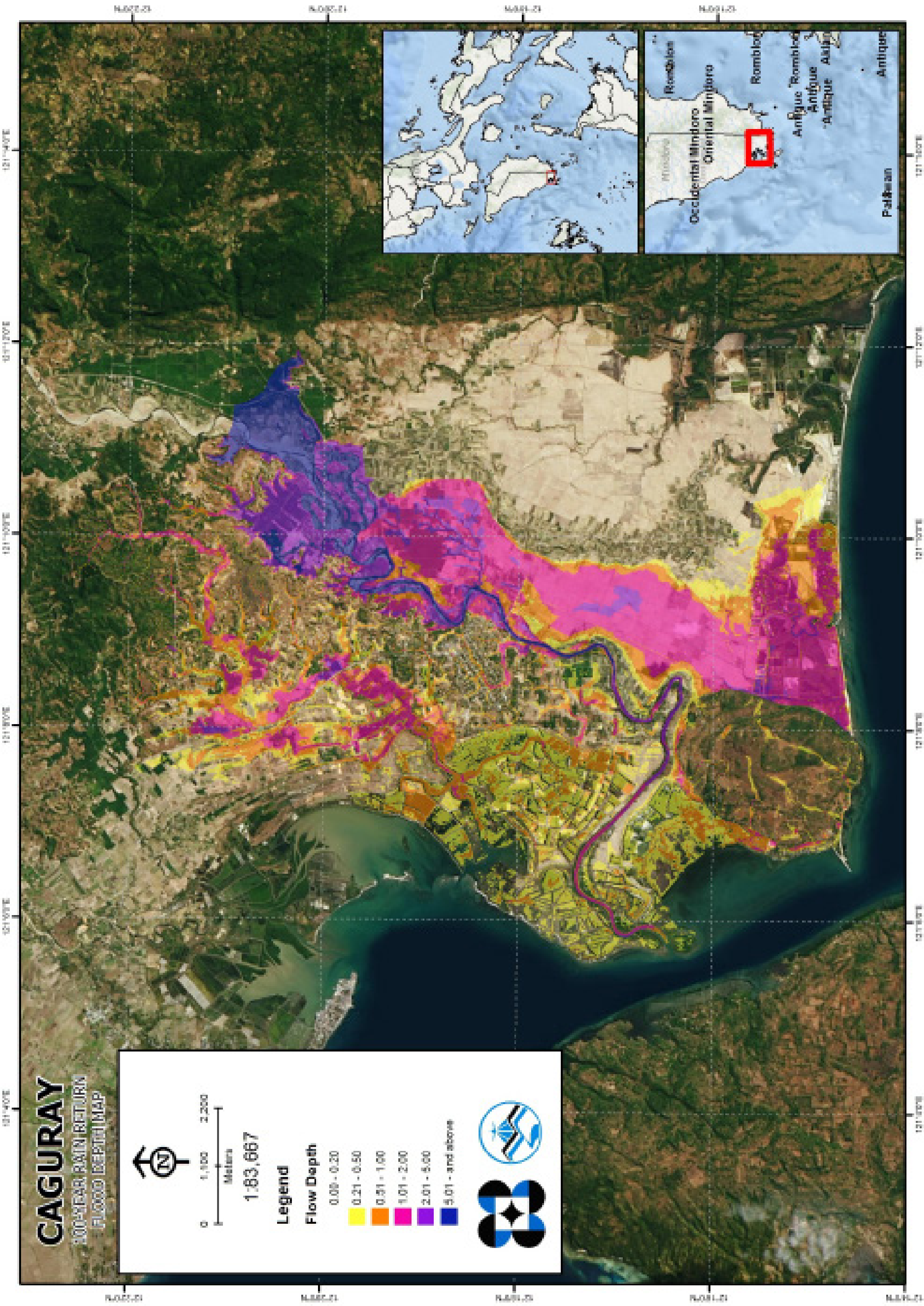


Figure 69. 100-year Flow Depth Map for Caguray Floodplain overlaid in Google Earth imagery

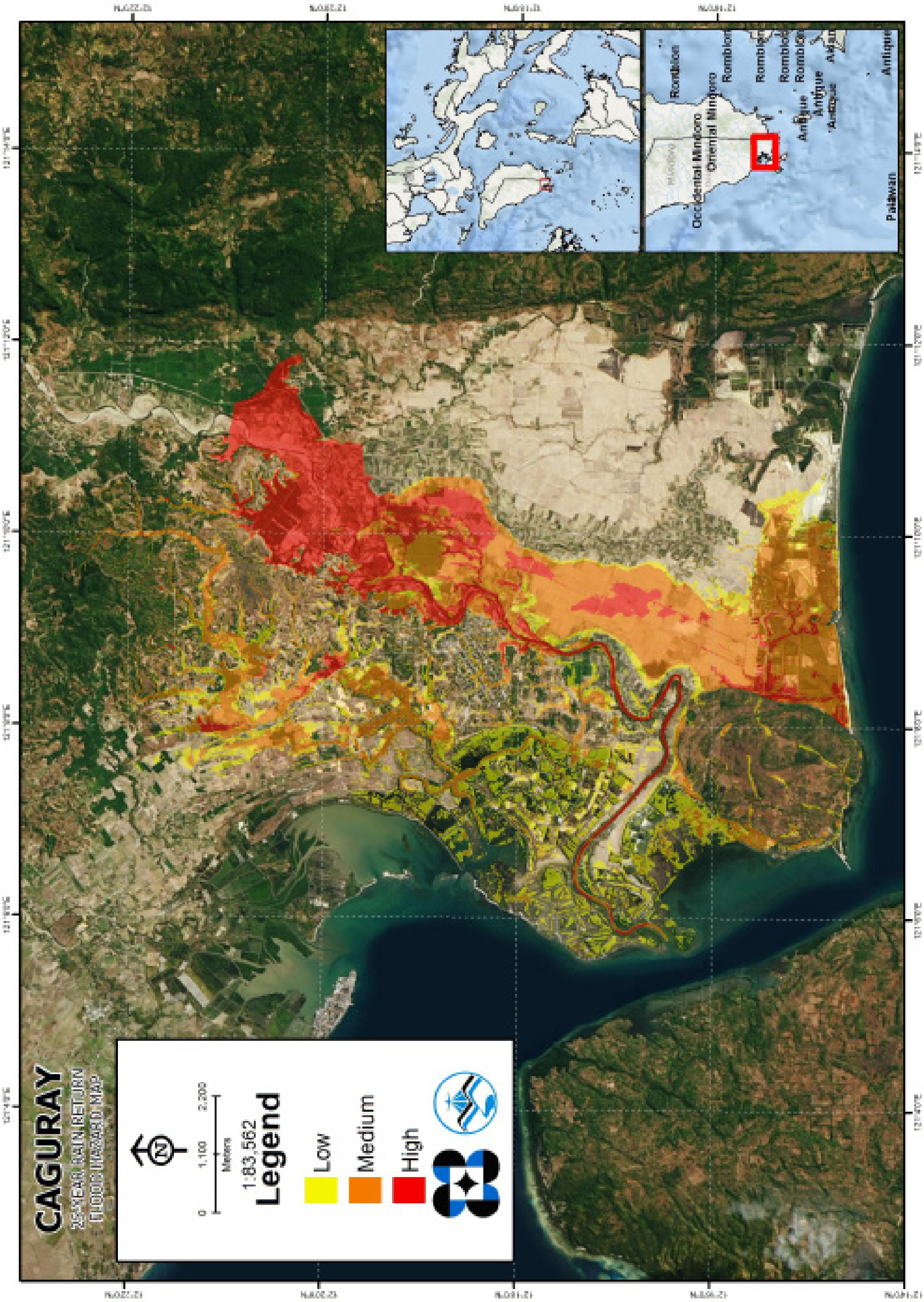


Figure 70. 25-year Flood Hazard Map for Caguray Floodplain overlaid in Google Earth imagery

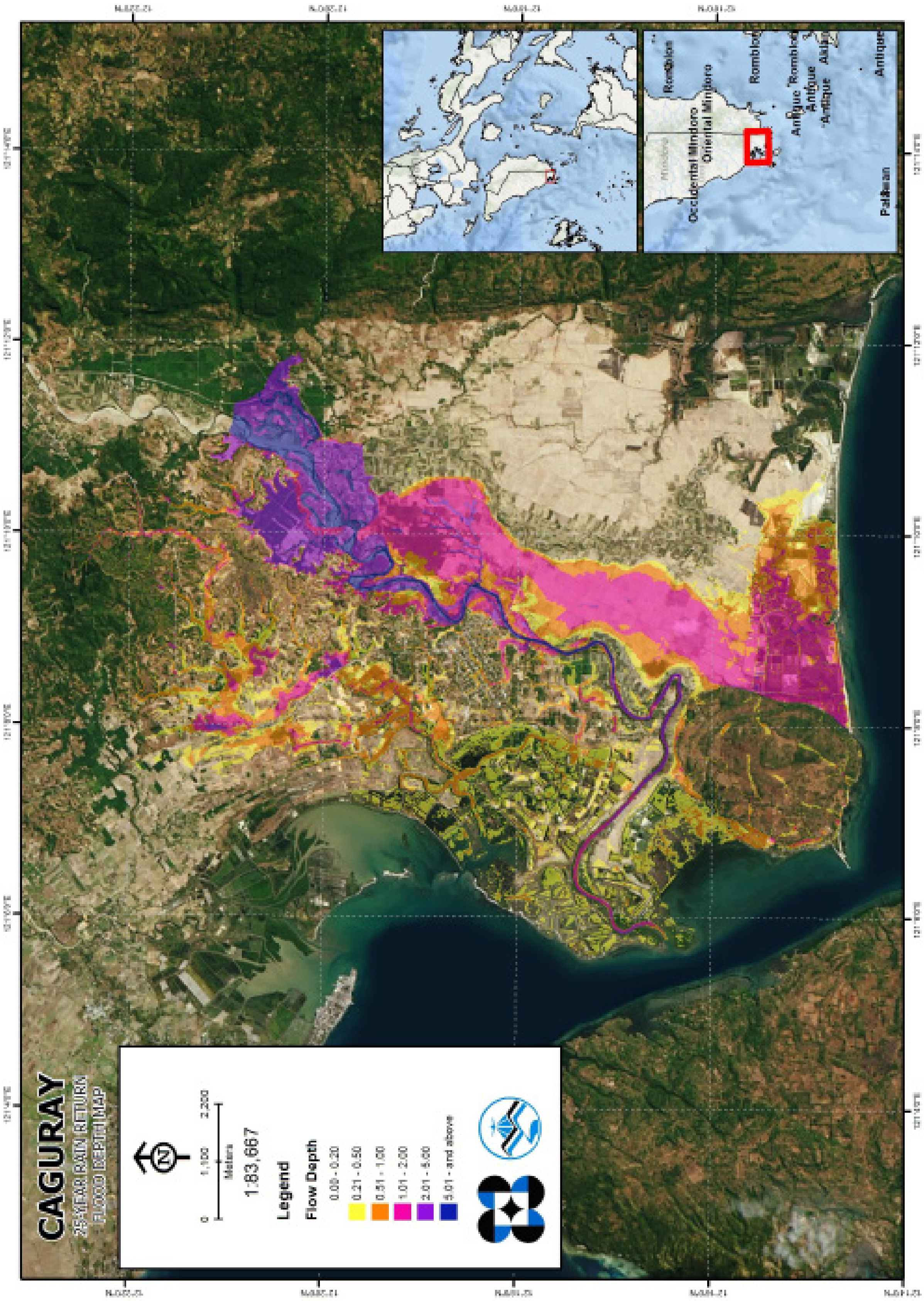


Figure 71. 25-year Flow Depth Map for Caguray Floodplain overlaid in Google Earth imagery

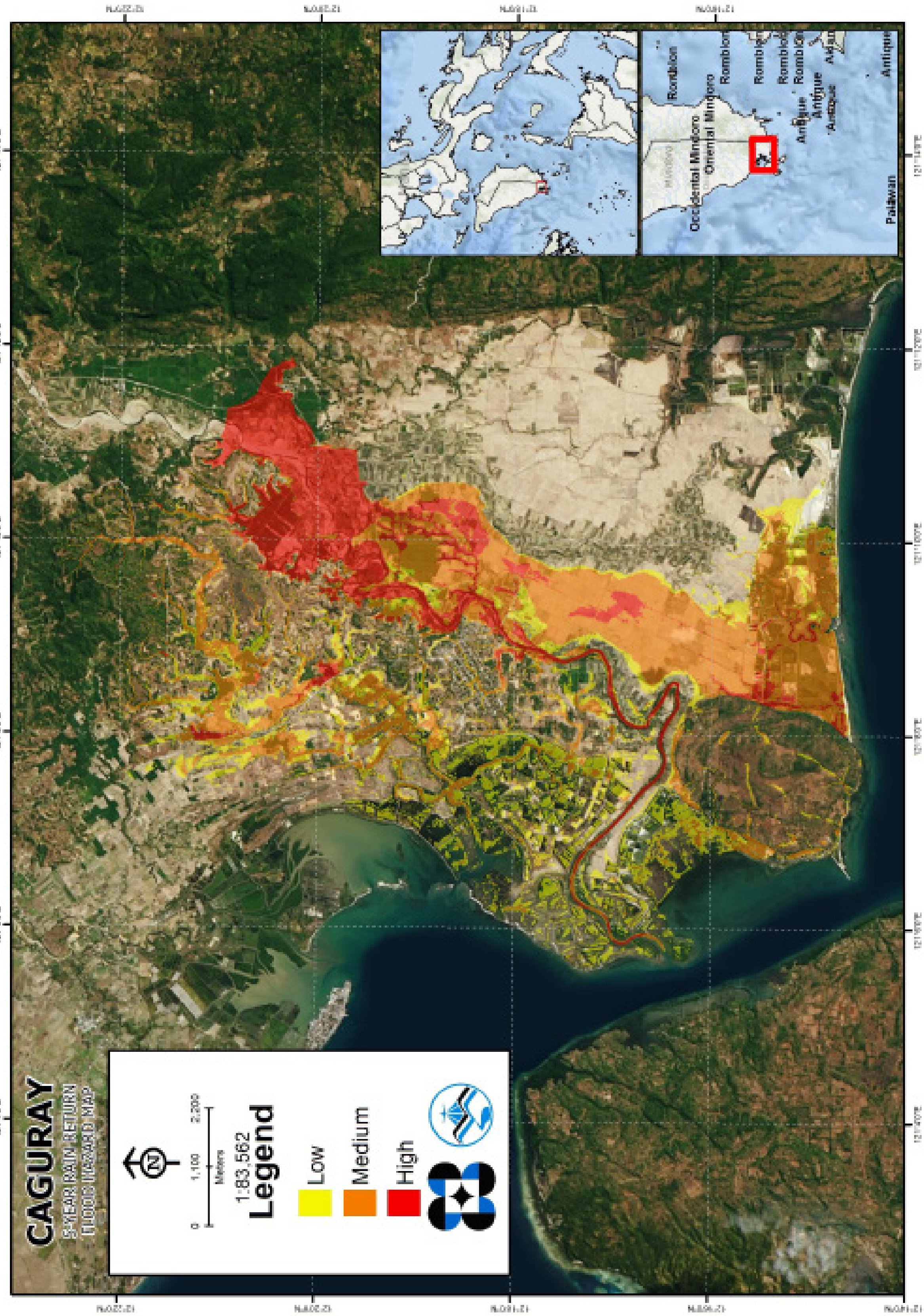


Figure 72. 5-year Flood Hazard Map for Caguray Floodplain overlaid in Google Earth imagery

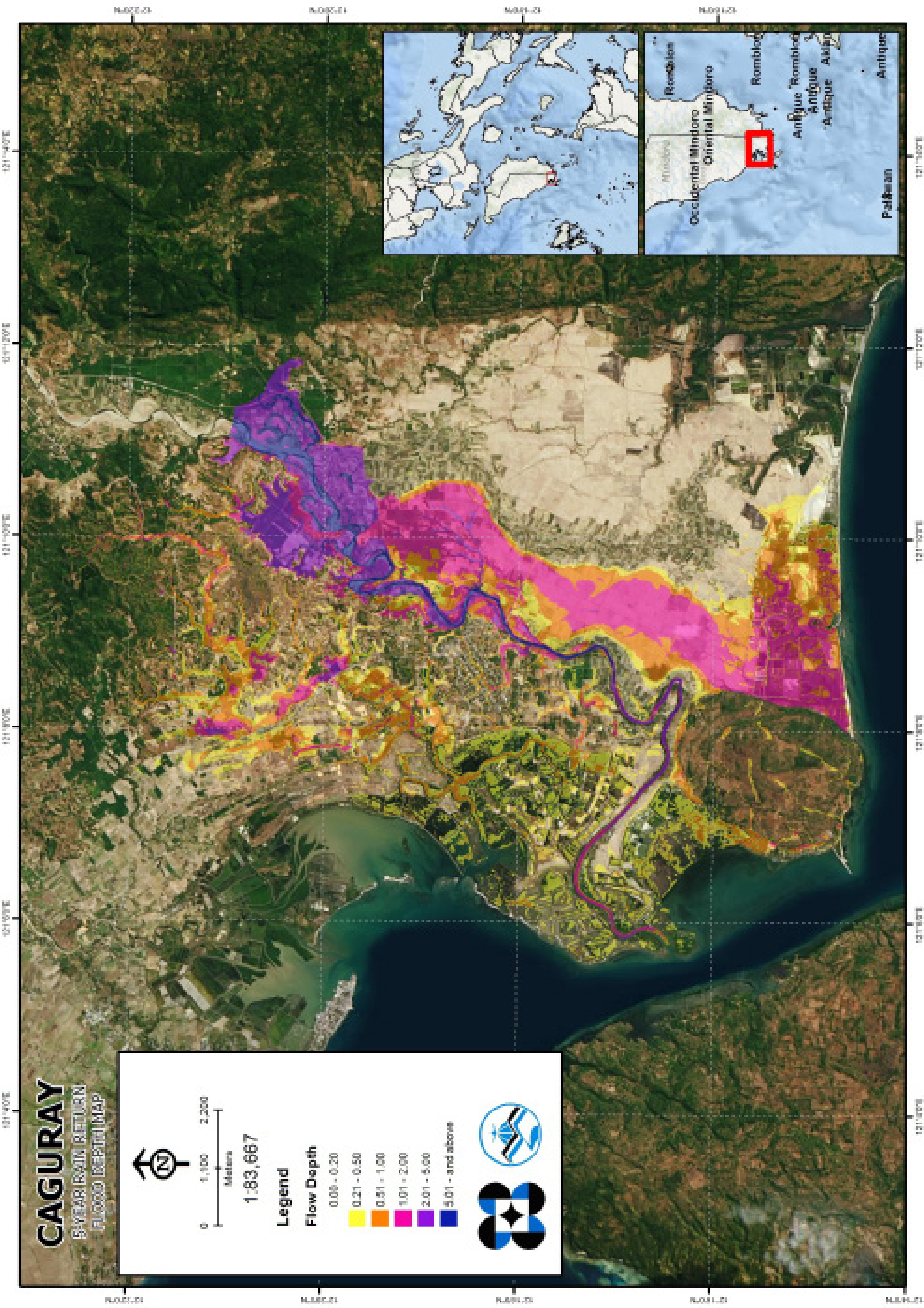


Figure 73. 5-year Flow Depth Map for Caguray Floodplain overlaid in Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Caguray river basin, grouped by municipality, are listed below. For the said basin, two municipalities consisting of 11 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 16.21% of the municipality of Magsaysay with an area of 256.56 sq. km. will experience flood levels of less 0.20 meters. 3.53% of the area will experience flood levels of 0.21 to 0.50 meters while 3.45%, 4.19%, 2.27%, and 0.76% 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 Table 35, and shown in Figure 74 are the affected areas in Magsaysay in square kilometres by flood depth per barangay.

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

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Magsaysay (in sq. km.)				
	Alibog	Caguray	Calawag	Laste	Lourdes
0.03-0.20	0.017	7.99	2.04	1.46	18.46
0.21-0.50	0	2.89	0.66	0.73	2.91
0.51-1.00	0	0.63	1.43	1	2.82
1.01-2.00	0	0.32	2.07	0.77	1.17
2.01-5.00	0	0.13	0.2	0.017	1.14
> 5.00	0	0	0.073	0	0.016

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Magsaysay (in sq. km.)				
	Nicolas	Poblacion	Purnaga	Santa Teresa	Sibalat
0.03-0.20	0.00026	2.24	0.93	6.76	1.69
0.21-0.50	0	0.92	0.044	0.47	0.44
0.51-1.00	0	1.83	0.064	0.33	0.76
1.01-2.00	0	4.51	0.35	0.055	1.5
2.01-5.00	0	2.21	2.13	0.0038	0.011
> 5.00	0	0	0	0	0

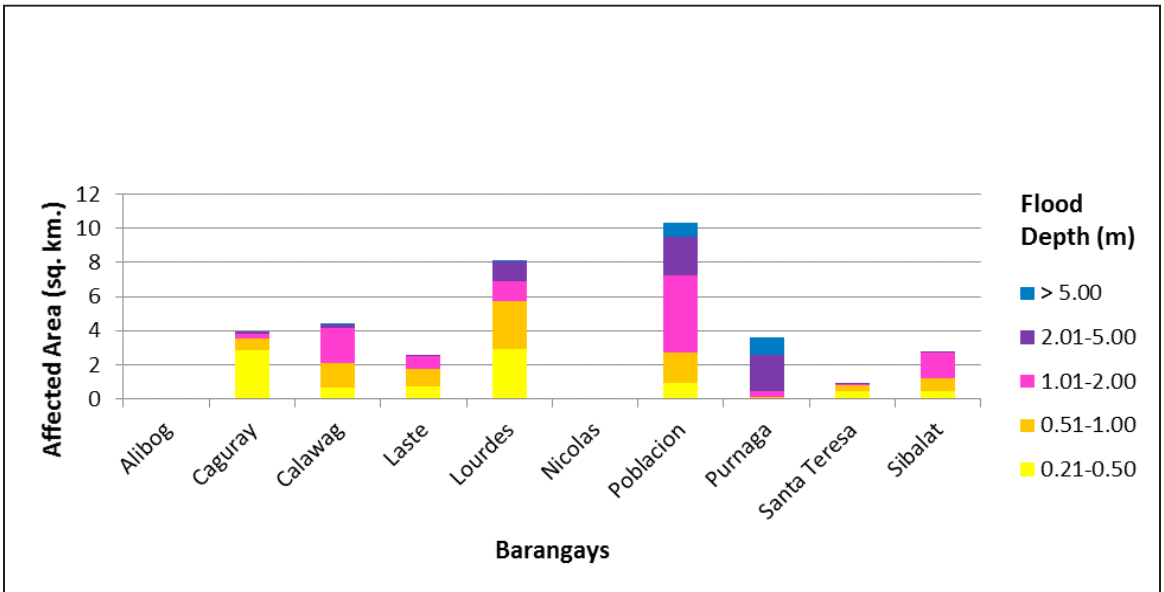


Figure 74. Affected Areas in Magsaysay, Occidental Mindoro during 5-Year Rainfall Return Period

For the municipality of San Jose, with an area of 449.82 sq. km., 0.35% will experience flood levels of less 0.20 meters. 0.8% of the area will experience flood levels of 0.21 to 0.50 meters while 0.01%, and 0.000008% of the area will experience flood depths of 0.51 to 1 meter, and 1.01 to 2 meters, respectively. Listed in Table 36 and shown in Figure 75 are the affected areas in square kilometres by flood depth per barangay.

Table 35. Affected Areas in San Jose, Occidental Mindoro during 5-Year Rainfall Return Period

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)
	Mapaya
0.03-0.20	1.56
0.21-0.50	0.35
0.51-1.00	0.06
1.01-2.00	0.000035
2.01-5.00	0
> 5.00	0

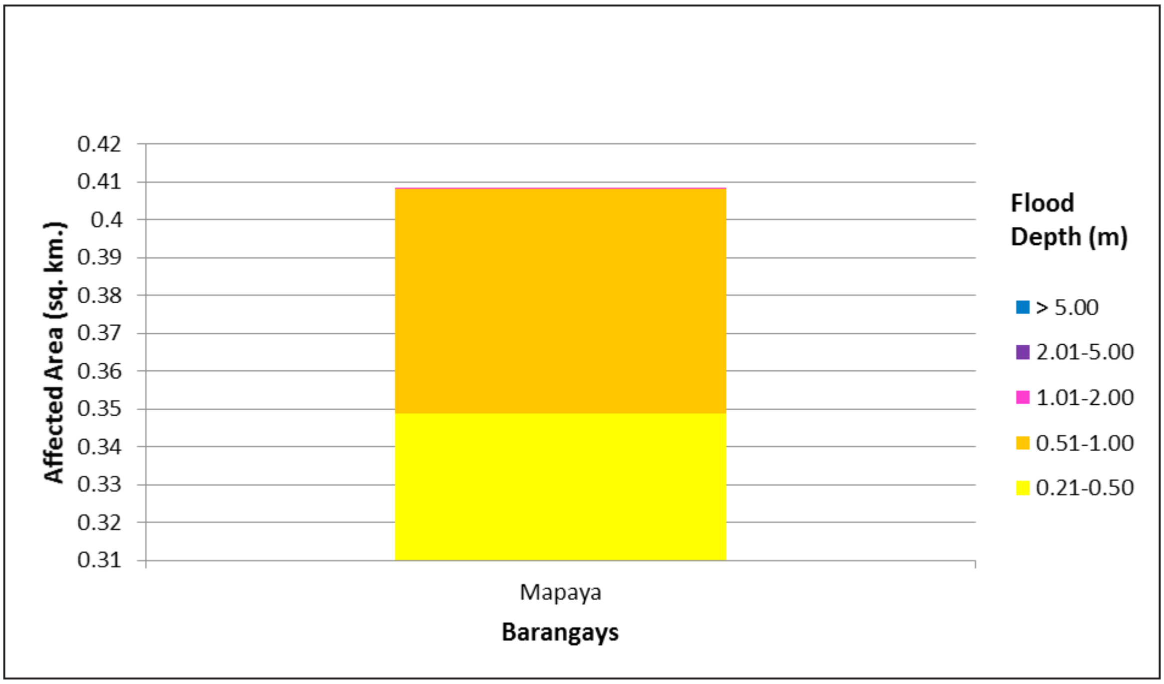


Figure 75. Affected Areas in San Jose, Occidental Mindoro during 5-Year Rainfall Return Period

For the 25-year return period, 15.82% of the municipality of Magsaysay with an area of 256.56 sq. km. will experience flood levels of less 0.20 meters. 3.46% of the area will experience flood levels of 0.21 to 0.50 meters while 3.39%, 4.55%, 2.31%, and 0.89% 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 meter, respectively. Listed in Table 37 and Table 38, and shown in Figure 76 are the areas affected in Magsaysay in square kilometers by flood depth per barangay.

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

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Magsaysay (in sq. km.)				
	Alibog	Caguray	Calawag	Laste	Lourdes
0.03-0.20	0.017	7.73	1.92	1.34	18.22
0.21-0.50	0	3.06	0.63	0.67	2.86
0.51-1.00	0	0.72	1.2	1.06	2.93
1.01-2.00	0	0.33	2.45	0.89	1.3
2.01-5.00	0	0.13	0.21	0.024	1.18
> 5.00	0	0	0.07	0	0.02

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Magsaysay (in sq. km.)				
	Nicolas	Poblacion	Purnaga	Santa Teresa	Sibalat
0.03-0.20	0.00026	2.16	0.91	6.72	1.58
0.21-0.50	0	0.69	0.041	0.49	0.45
0.51-1.00	0	1.68	0.059	0.34	0.7
1.01-2.00	0	4.78	0.23	0.061	1.65
2.01-5.00	0	2.32	2.05	0.0044	0.018
> 5.00	0	0.91	1.26	0	0

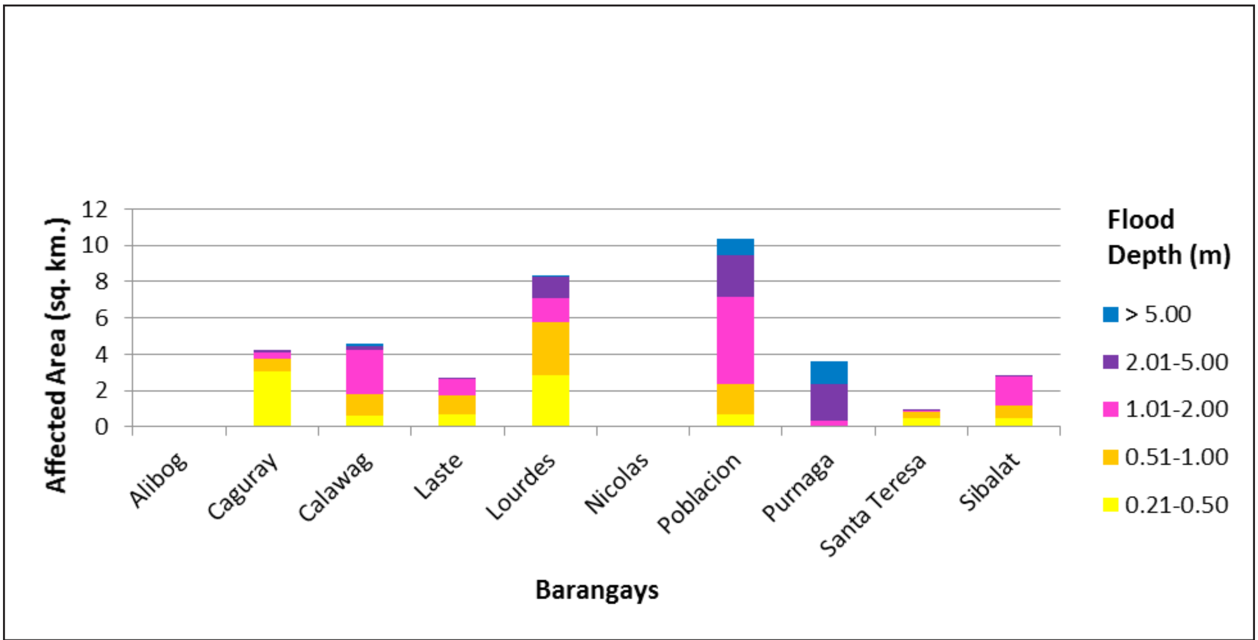


Figure 76. Affected Areas in Magsaysay, Occidental Mindoro during 25-Year Rainfall Return Period

For the municipality of San Jose, with an area of 449.82 sq. km., 0.34% will experience flood levels of less 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters while 0.02%, and 0.000008% of the area will experience flood depths of 0.51 to 1 meter, and more than 1 meter, respectively. Listed in Table 39 and shown in Figure 77 are the affected areas in square kilometres by flood depth per barangay.

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

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)
	Mapaya
0.03-0.20	1.53
0.21-0.50	0.37
0.51-1.00	0.071
1.01-2.00	0.000035
2.01-5.00	0
> 5.00	0

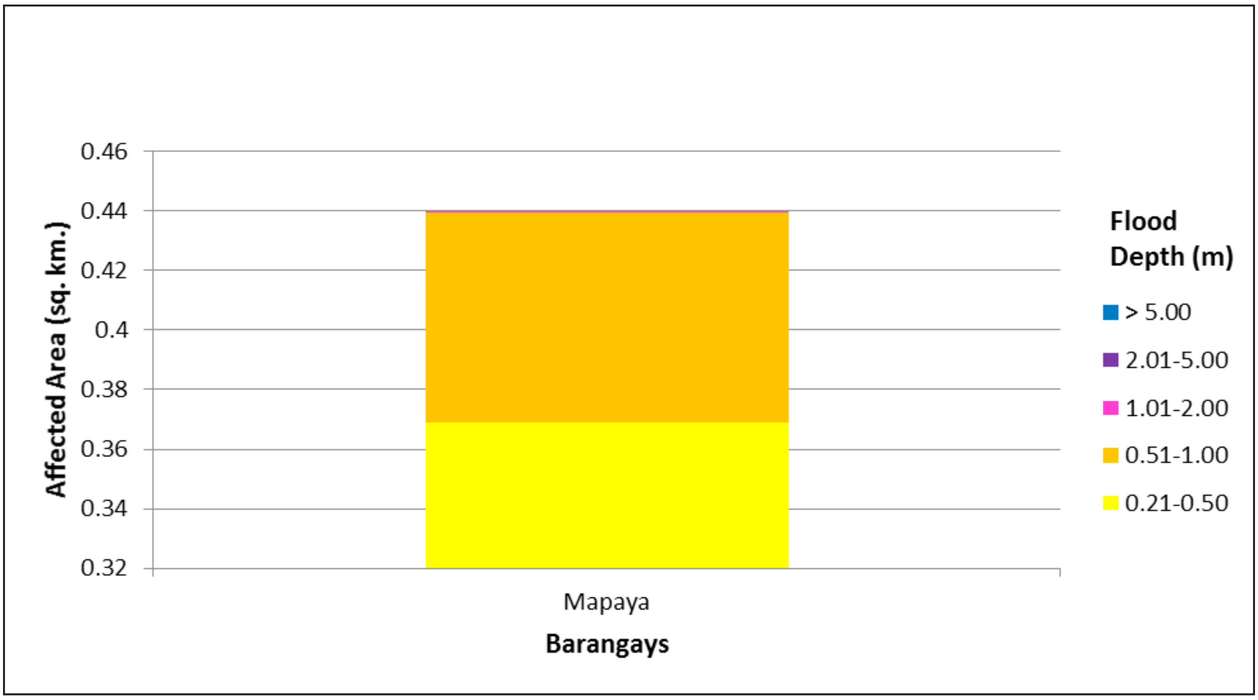


Figure 77. Affected Areas in San Jose, Occidental Mindoro during 25-Year Rainfall Return Period

For the 100-year return period, 14.27% of the municipality of Magsaysay with an area of 256.56 sq. km. will experience flood levels of less 0.20 meters. 3.57% of the area will experience flood levels of 0.21 to 0.50 meters while 3.38%, 5.31%, 2.28%, and 1.60% 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 Table 41, and shown in Figure 78 are the affected areas in square kilometres by flood depth per barangay.

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

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Magsaysay (in sq. km.)				
	Alibog	Caguray	Calawag	Laste	Lourdes
0.03-0.20	0.017	6.42	1.62	0.98	17.04
0.21-0.50	0.00018	3.73	0.56	0.67	2.6
0.51-1.00	0	1.29	0.84	1.03	3.19
1.01-2.00	0	0.42	2.88	1.23	2.28
2.01-5.00	0	0.092	0.5	0.069	1.19
> 5.00	0	0	0.066	0	0.2

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Magsaysay (in sq. km.)				
	Nicolas	Poblacion	Purnaga	Santa Teresa	Sibalat
0.03-0.20	0.00026	2.03	0.77	6.5	1.24
0.21-0.50	0	0.4	0.032	0.61	0.55
0.51-1.00	0	1.3	0.042	0.39	0.61
1.01-2.00	0	4.67	0.081	0.12	1.95
2.01-5.00	0	2.8	1.13	0.0069	0.065
> 5.00	0	1.35	2.49	0	0

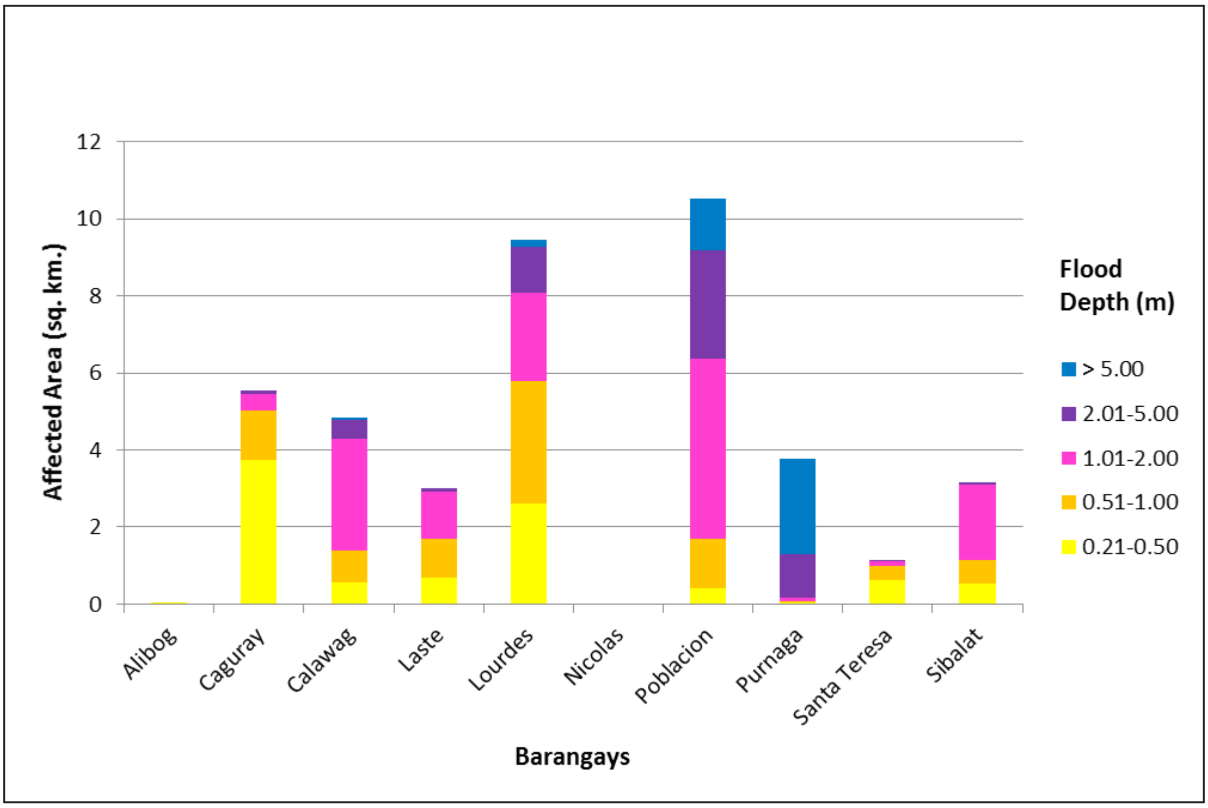


Figure 78. Affected Areas in Magsaysay, Occidental Mindoro during 100-Year Rainfall Return Period

For the municipality of San Jose, with an area of 449.82 sq. km., 0.29% will experience flood levels of less 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters while 0.04%, 0.00007%, and 0.0000004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and more than 2 meters, respectively. Listed in Table 42 and shown in Figure 79 are the areas affected in San Jose in square kilometers by flood depth per barangay.

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

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in San Jose (in sq. km.)
	Mapaya
0.03-0.20	1.29
0.21-0.50	0.48
0.51-1.00	0.2
1.01-2.00	0.0003
2.01-5.00	0.000002
> 5.00	0

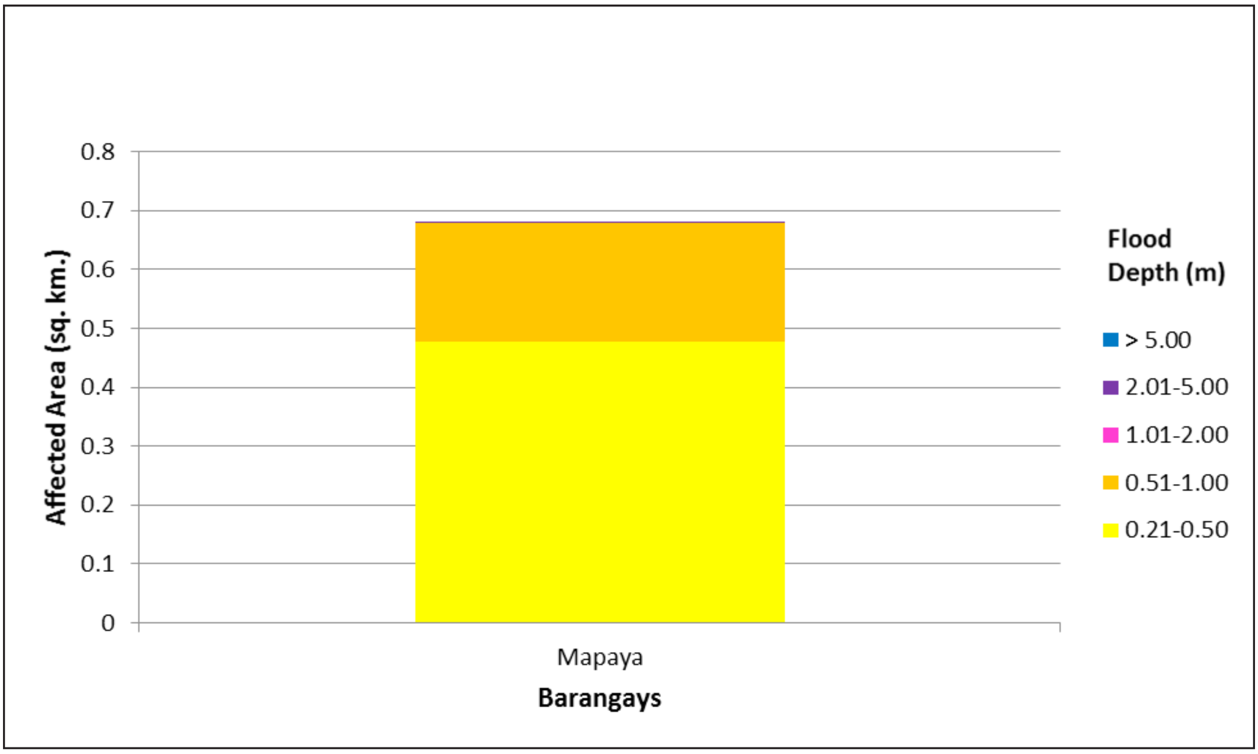


Figure 79. Affected Areas in San Jose, Occidental Mindoro during 100-Year Rainfall Return Period

Among the barangays in the municipality of Magsaysay, Poblacion is projected to have the highest percentage of area that will experience flood levels at 4.89%. Meanwhile, Caguray posted the second highest percentage of area that may be affected by flood depths at 4.66%.

Among the barangays in the municipality of San Jose, Mapaya is projected to have the highest percentage of area that will experience flood levels at 0.44%.

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

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 81.

The flood validation consists of 135 points randomly selected all over the Caguray floodplain. It has an RMSE value of 0.42. Table 40 shows a contingency matrix of the comparison.

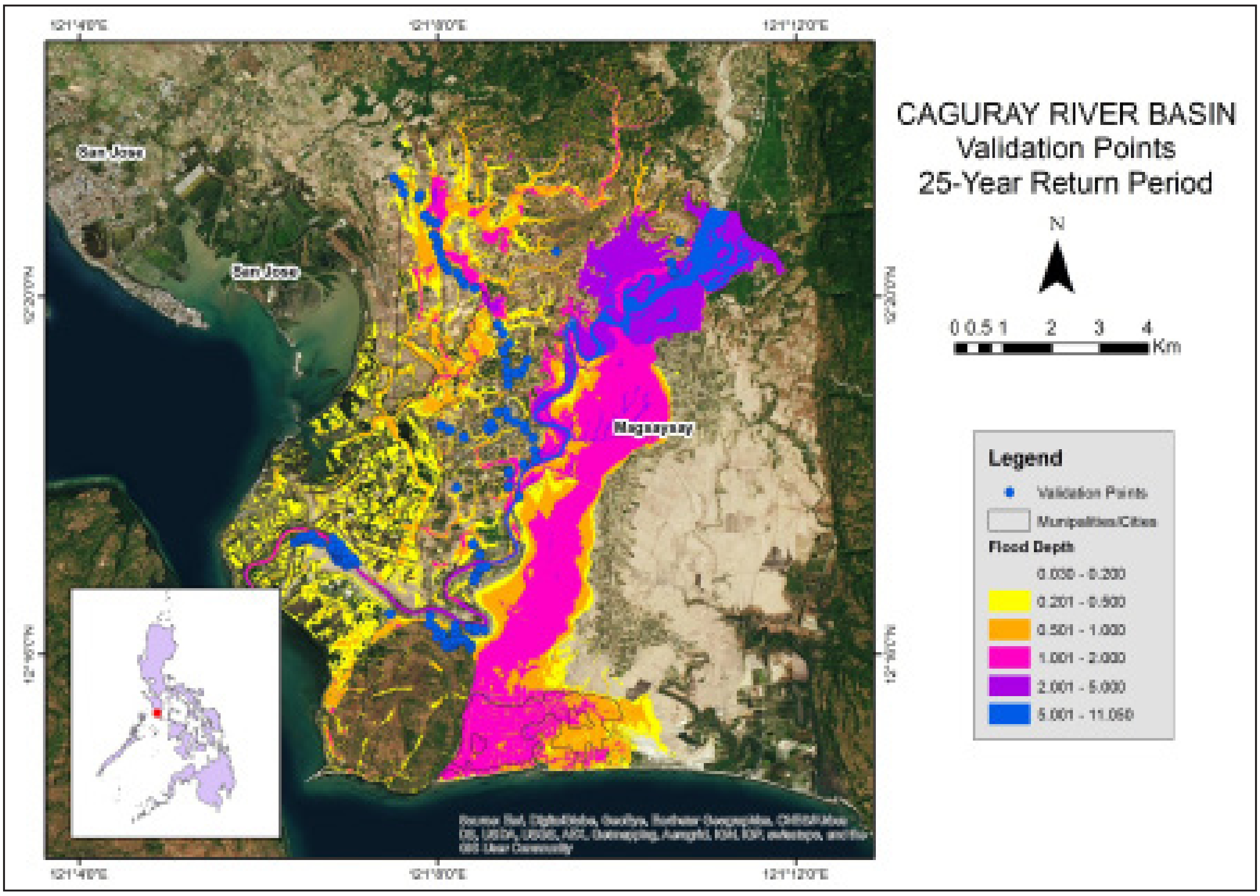


Figure 80. Validation points for 25-year Flood Depth Map of Caguray Floodplain

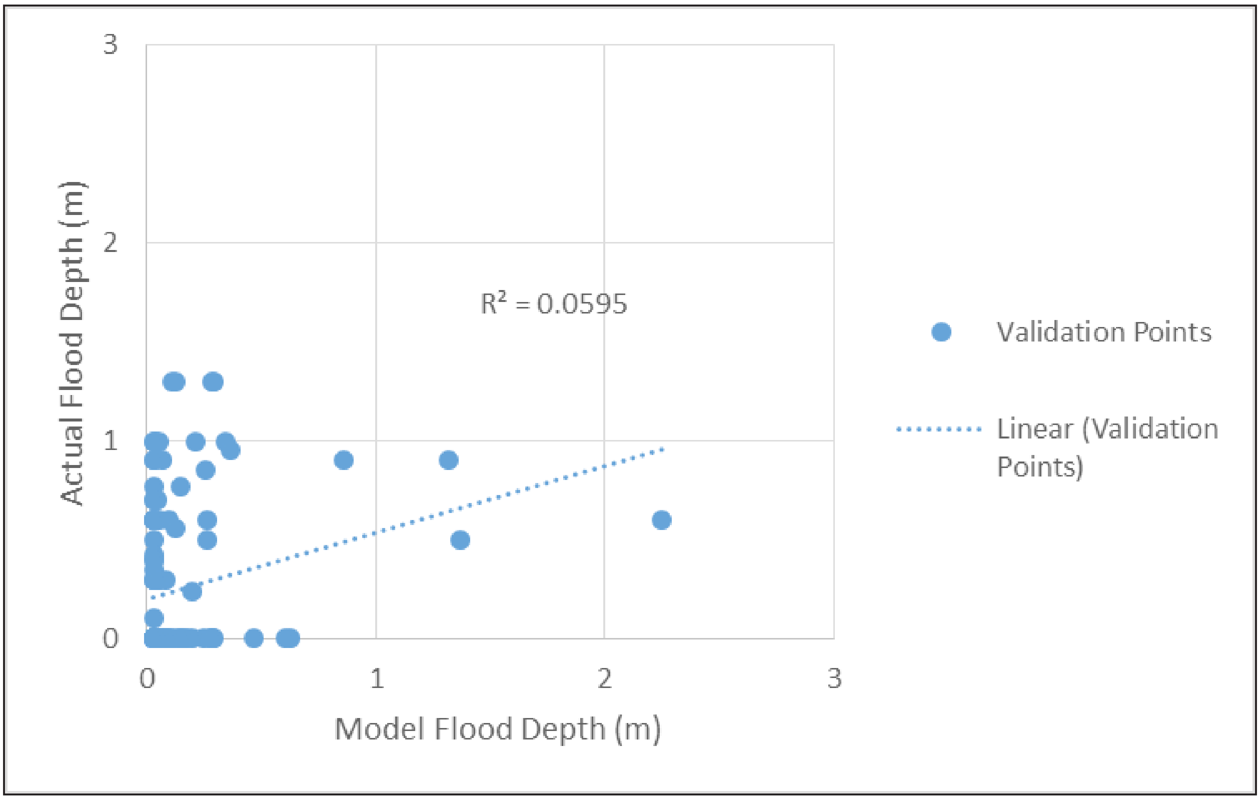


Figure 81. Flood map depth vs. actual flood depth

Table 40. Actual flood vs simulated flood depth at different levels in the Caguray 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	80	6	2	0	0	0	88
0.21-0.50	13	1	0	1	0	0	15
0.51-1.00	20	5	1	1	1	0	28
1.01-2.00	2	2	0	0	0	0	4
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	115	14	3	2	1	0	135

The overall accuracy generated by the flood model is estimated at 60.74%, with 82 points correctly matching the actual flood depths. In addition, there were 25 points estimated one level above and below the correct flood depths while there were 26 points and 2 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 11 points were overestimated while a total of 42 points were underestimated in the modelled flood depths of Caguray. Table 44 depicts the summary of the Accuracy Assessment in the Caguray River Basin Survey..

Table 41. Summary of Accuracy Assessment in Caguray River Basin Survey

	No. of Points	%
Correct	82	60.74
Overestimated	11	8.15
Underestimated	42	31.11
Total	135	100

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

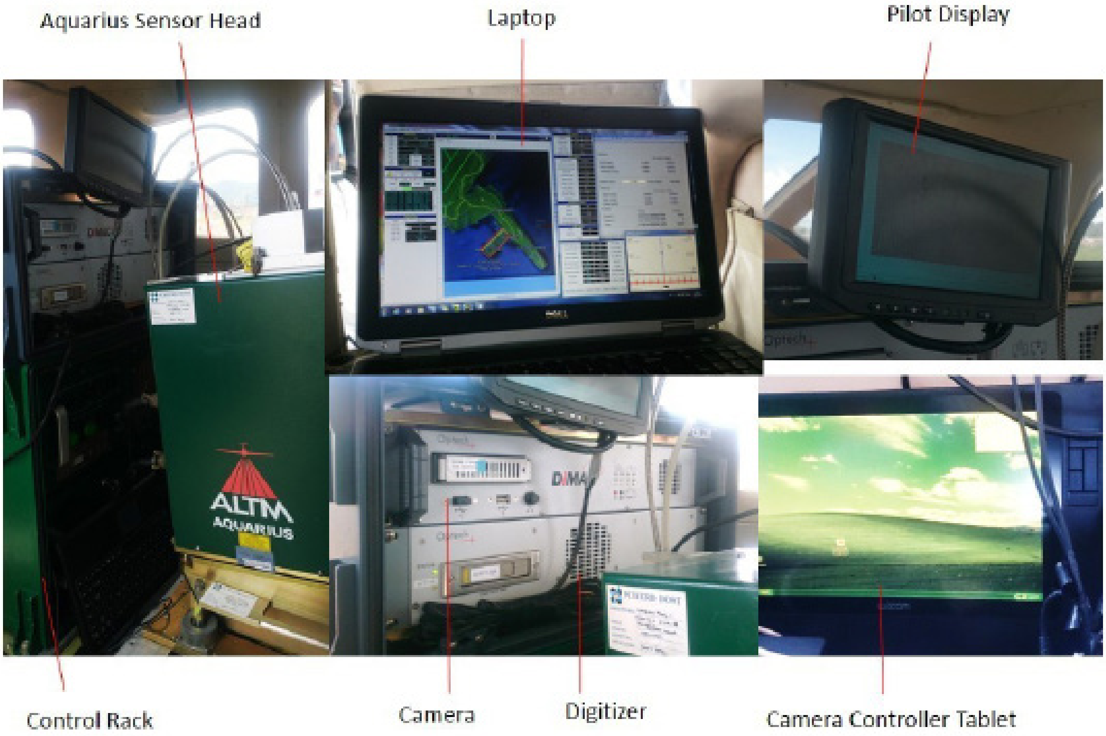
Paringit, E.C., Balicanta, L.P., Ang, M.C., Lagmay, A.F., Sarmiento, C. 2017, Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry

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.

Annex 1. Optech Technical Specification of the Sensor

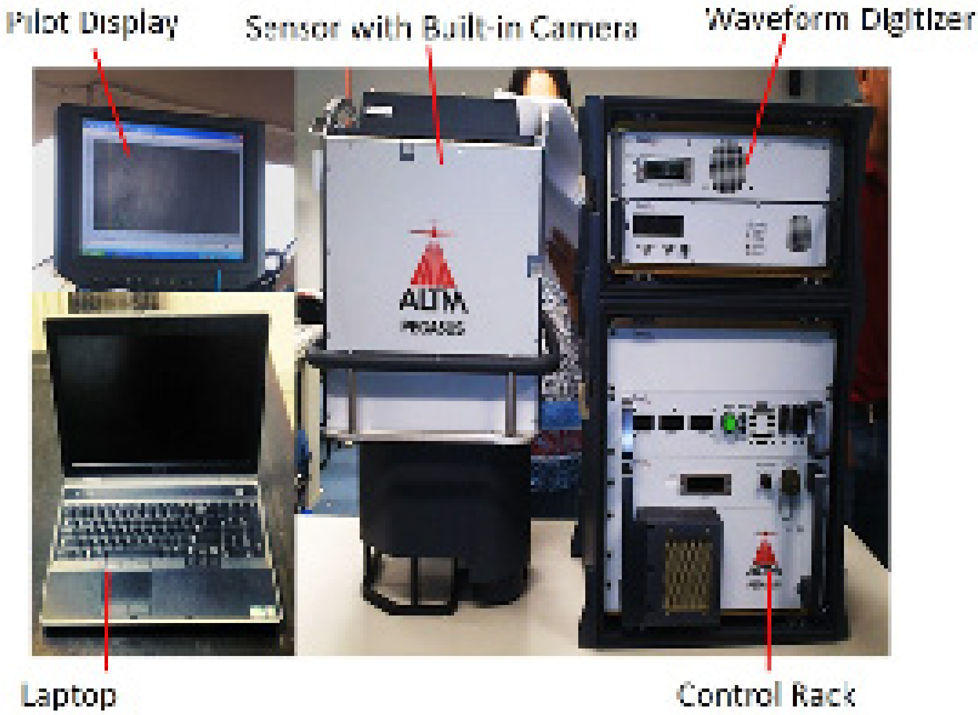
1. AQUARIUS SENSOR



2. 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
Relative humidity	0-95% non-condensing

3. PEGASUS SENSOR



4. 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

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

Annex 2. NAMRIA Certificates of Reference Points Used

1. MRW-18

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

December 11, 2015

CERTIFICATION

To whom it may concern:

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

Province: OCCIDENTAL MINDORO
Station Name: MRW-18
Order: 2nd

Island:	LUZON	Barangay:			
Municipality:	MAGSAYSAY	MSL Elevation:			
		PRS92 Coordinates			
Latitude:	12° 18' 45.39463"	Longitude:	121° 8' 36.92441"	Ellipsoidal Hgt:	21.29500 m.
		WGS84 Coordinates			
Latitude:	12° 18' 40.53383"	Longitude:	121° 8' 42.01469"	Ellipsoidal Hgt:	71.37500 m.
		PTM / PRS92 Coordinates			
Northing:	1361517.851 m.	Easting:	515618.524 m.	Zone:	3
		UTM / PRS92 Coordinates			
Northing:	1,361,734.74	Easting:	298,113.89	Zone:	51

Location Description

MRW-18

From Municipality of Magsaysay, located in front of statue of President Ramon Magsaysay, inside the Municipal Compound, about 40 m SE of Municipal Bldg. of Magsaysay. Station is located in Municipality of Magsaysay, Occ. Mindoro. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-18, 2007, NAMRIA".

Requesting Party: UP DREAM
Purpose: Reference
OR Number: 8088861 I
T.N.: 2015-4114

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. MRW-22

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-22**
Order: **2nd**

Island: **LUZON**		Barangay: **TANYAG**
Municipality: **CALINTAAN**		
	PRS92 Coordinates	
Latitude: **12° 31' 36.76881"**	Longitude: **120° 59' 13.46492"**	Ellipsoidal Hgt: **35.12700 m.**
	WGS84 Coordinates	
Latitude: **12° 31' 31.84278"**	Longitude: **120° 59' 18.53734"**	Ellipsoidal Hgt: **84.27100 m.**
	PTM Coordinates	
Northing: **1385214.96 m.**	Easting: **498595.125 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,385,663.72**	Easting: **281,265.62**	Zone: **51**

Location Description

MRW-22

From Abra de Ilog to San Jose, along Nat'l Road, approx. 9 Km. from Calintaan Town Proper, located Lumintao Bridge at Brgy. Tanyag, Sitio Marilao, Calintaan, Occ. Mindoro. Station is located at the N end of the catwalk of Lumintao Bridge. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-22, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-446**

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

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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www.namria.gov.ph

3. MRE-56

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

October 28, 2015

CERTIFICATION

To whom it may concern:

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

Province: **ORIENTAL MINDORO**
Station Name: **MRE-56**
Order: **2nd**

Island: **LUZON**	Barangay:	
Municipality: **MANSALAY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **12° 31' 25.76362"**	Longitude: **121° 26' 25.21109"**	Ellipsoidal Hgt: **7.87000 m.**
	WGS84 Coordinates	
Latitude: **12° 31' 20.87629"**	Longitude: **121° 26' 30.28143"**	Ellipsoidal Hgt: **58.13600 m.**
	PTM / PRS92 Coordinates	
Northing: **1384916.657 m.**	Easting: **547857.861 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **1,384,892.31**	Easting: **330,530.08**	Zone: **51**

Location Description

MRE-56

From Calapan City to Bulalacao, along Nat'l Road approx. 4 Km. from Roxas Proper is an intersection of Roxas, Mansalay, Bongabong Road, turn left, approx. 14 Km. travel, right side of Nat'l Road located Mun. Hall of Mansalay, Oriental Mindoro, in front of Mansalay Hospital. Station is located in corner wall of Mun. Park in front of Mun. Hall. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscritions, "MRE-56, 2007, NAMRIA".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8088472 I**
T.N.: **2015-3523**

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

9 9 1 0 2 8 2 0 1 5 1 3 4 8 1 7

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www.namria.gov.ph

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4. MRW-4203

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

March 25, 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-4203**
Order: **3rd**

Island: **LUZON**		Barangay: **MAPAYA**
Municipality: **SAN JOSE**		
	PRS92 Coordinates	
Latitude: **12° 21' 24.45294"**	Longitude: **121° 7' 26.92407"**	Ellipsoidal Hgt: **7.40100 m.**
	WGS84 Coordinates	
Latitude: **12° 21' 19.57973"**	Longitude: **121° 7' 32.01059"**	Ellipsoidal Hgt: **57.32000 m.**
	PTM Coordinates	
Northing: **1366404.003 m.**	Easting: **513501.246 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,366,637.32**	Easting: **296,032.79**	Zone: **51**

Location Description

MRW-4203

From San Jose Town Proper to Brgy. Mapaya, approx. 7.8 Km. travel to reach brgy. hall. The station is located inside the compound of brgy. plaza, beside the gate post, left side fronting brgy. hall about 40 m NE of brgy. hall, 200 m NW of post Km. post 228, along Nat'l Road, 7 Km. to San Jose. Station is located in Brgy. Mapaya, San Jose, Occ., Mindoro. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-4203, 2007, NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8795829 A**
T.N.: **2014-643**

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

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

5. MRW-4205

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-4205**
Order: **3rd**

Island: **LUZON**
Municipality: **SAN JOSE**
Barangay: **CENTRAL**

PRS92 Coordinates

Latitude: **12° 26' 8.33964"**	Longitude: **121° 2' 46.62783"**	Ellipsoidal Hgt: **12.56900 m.**

WGS84 Coordinates

Latitude: **12° 26' 3.44072"**	Longitude: **121° 2' 51.70789"**	Ellipsoidal Hgt: **62.09500 m.**

PTM Coordinates

Northing: **1375124 m.**	Easting: **506032.188 m.**	Zone: **3**

UTM Coordinates

Northing: **1,375,422.19**	Easting: **287,627.78**	Zone: **51**

Location Description

MRW-4205

From Abra de Ilog to San Jose, along Nat'l Road, approx. 10 Km. travel from San Jose Town Proper, 70 m E of Km. post 247 located Mabuhay Home Based ECCD Center for Health and Nutrition Bldg. located at Brgy. Central, Sitio Mabuhay, San Jose, Occ., Mindoro. Station is located beside fence, 2.0 m SW of Sitio Mabuhay Home Based ECCD Center of Health and Nutrition Post, 40 m NE of Nat'l Road, 70 m E of Km. post 247. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-4205, 2007, NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795470 A**
T.N.:	**2014-448**

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

CERTIFICATION INTERNATIONAL ISO 9001:2008
CIP/4701/12/09/604

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Annex 3. Baseline Processing Report of Reference Points Used

Baseline Processing Report - A

Project information		Coordinate System	
Name:	C:\Users\qwerty\Documents\Business Center - HCE\mrw18-mrw18a.vce	Name:	UTM
Size:	156 KB	Datum:	PRS 92
Modified:	12/21/2015 2:56:44 PM (UTC:8)	Zone:	51 North (123E)
Time zone:	Taipei 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)
MRW-18 --- MRW-18a (B1)	MRW-18	MRW-18a	Fixed	0.001	0.002	312°48'54"	6.566	0.551

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

MRW-18 - MRW-18a (6:38:43 AM-10:41:45 AM) (S1)

Baseline observation:	MRW-18 --- MRW-18a (B1)
Processed:	12/21/2015 3:00:47 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.001 m
Vertical precision:	0.002 m
RMS:	0.000 m
Maximum PDOP:	2.035
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	12/12/2015 6:38:51 AM (Local: UTC+8hr)
Processing stop time:	12/12/2015 10:41:45 AM (Local: UTC+8hr)
Processing duration:	04:02:54
Processing interval:	1 second

1

Baseline Processing Report - B

Vector Components (Mark to Mark)

From:	MRW-18				
Grid		Local		Global	
Easting	298113.895 m	Latitude	N12°18'45.39463"	Latitude	N12°18'40.53383"
Northing	1361734.745 m	Longitude	E121°08'38.92444"	Longitude	E121°08'42.01469"
Elevation	20.797 m	Height	21.295 m	Height	71.375 m

To:	MRW-18a				
Grid		Local		Global	
Easting	298109.109 m	Latitude	N12°18'45.53986"	Latitude	N12°18'40.67904"
Northing	1361739.241 m	Longitude	E121°08'38.76504"	Longitude	E121°08'41.85529"
Elevation	21.348 m	Height	21.845 m	Height	71.926 m

Vector					
ΔEasting	-4.786 m	NS Fwd Azimuth	312°48'54"	ΔX	4.336 m
ΔNorthing	4.496 m	Ellipsoid Dist.	6.566 m	ΔY	2.137 m
ΔElevation	0.551 m	ΔHeight	0.551 m	ΔZ	4.477 m

Standard Errors

Vector errors:					
σ ΔEasting	0.000 m	σ NS fwd Azimuth	0°00'11"	σ ΔX	0.000 m
σ ΔNorthing	0.000 m	σ Ellipsoid Dist.	0.000 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.000 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000002319		
Y	-0.0000003031	0.0000009420	
Z	-0.0000000578	0.0000001601	0.0000001302

2

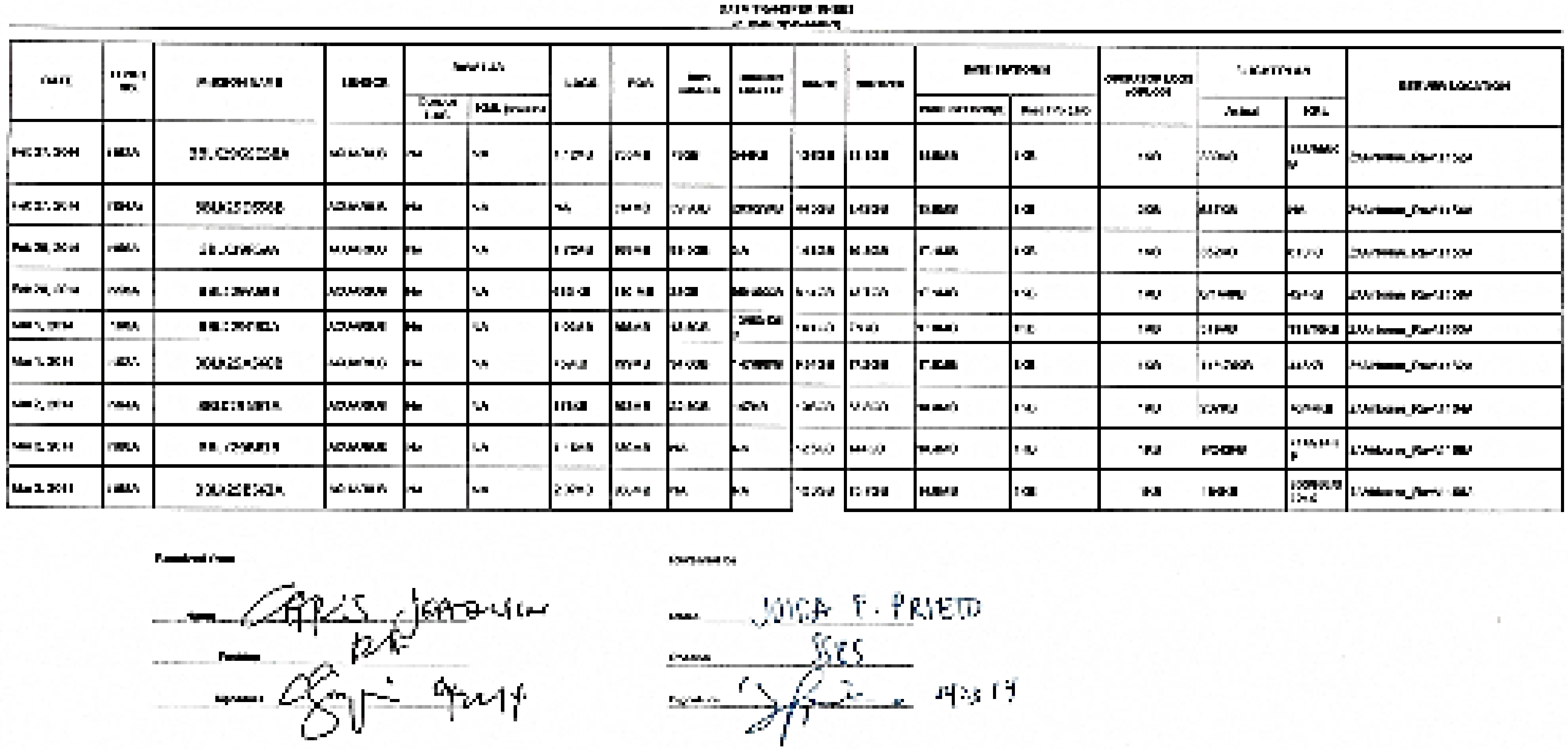
Annex 4. The LiDAR Survey Team Composition

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

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist (SSRS)	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 Sheet For Caguray Floodplain



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	732	109	5.09	120	8.78	74	7.86	na	10.4	1KB	1KB	40	na	Z:\DAC\RAW DATA
6-Dec-15	3060P	1BLK29DE340B	pegasus	480	108	5.83	115	6.06	48	4.79	na	10.4	1KB	1KB	394/344/50	na	Z:\DAC\RAW DATA
7-Dec-15	3062P	1BLK29BCS341A	pegasus	1.40	430	9.18	208	20.6	182	14.4	na	7.01	1KB	1KB	100/55/56	na	Z:\DAC\RAW DATA
8-Dec-15	3066P	1BLK29ACDG342A	pegasus	882	278	7.18	177	17	121	9.79	na	18	1KB	1KB	145/150	na	Z:\DAC\RAW DATA
8-Dec-15	3068P	1BLK29GJ342B	pegasus	6	67	2.7	114	4.83	37	2.77	na	16	1KB	1KB	145/155	na	Z:\DAC\RAW DATA
9-Dec-15	3070P	1BLK29GHI343A	pegasus	853	217	8.7	140	14.3	na	9.37	na	8.98	1KB	1KB	146/166	na	Z:\DAC\RAW DATA
10-Dec-15	3074P	1BLK29KLMO344A	pegasus	2.39	212	9.12	220	30.9	224	20.7	na	14.1	1KB	1KB	313	na	Z:\DAC\RAW DATA
10-Dec-15	3076P	1BLK29P344B	pegasus	256	73	3.5	102	4.32	34	3.2	na	14.1	1KB	1KB	366/316/350/315/146/156	na	Z:\DAC\RAW DATA
11-Dec-15	3078P	1BLK29NQRS345A	pegasus	641	171	6.29	167	12.9	105	8.2	na	7.02	1KB	1KB	41/394/344/313/140	na	Z:\DAC\RAW DATA
12-Dec-15	3082P	1BLK29R346A	pegasus	892	206	6.85	174	13.1	96	6.33	na	7.41	1KB	1KB	47/140	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin

Position

Signature

Received by

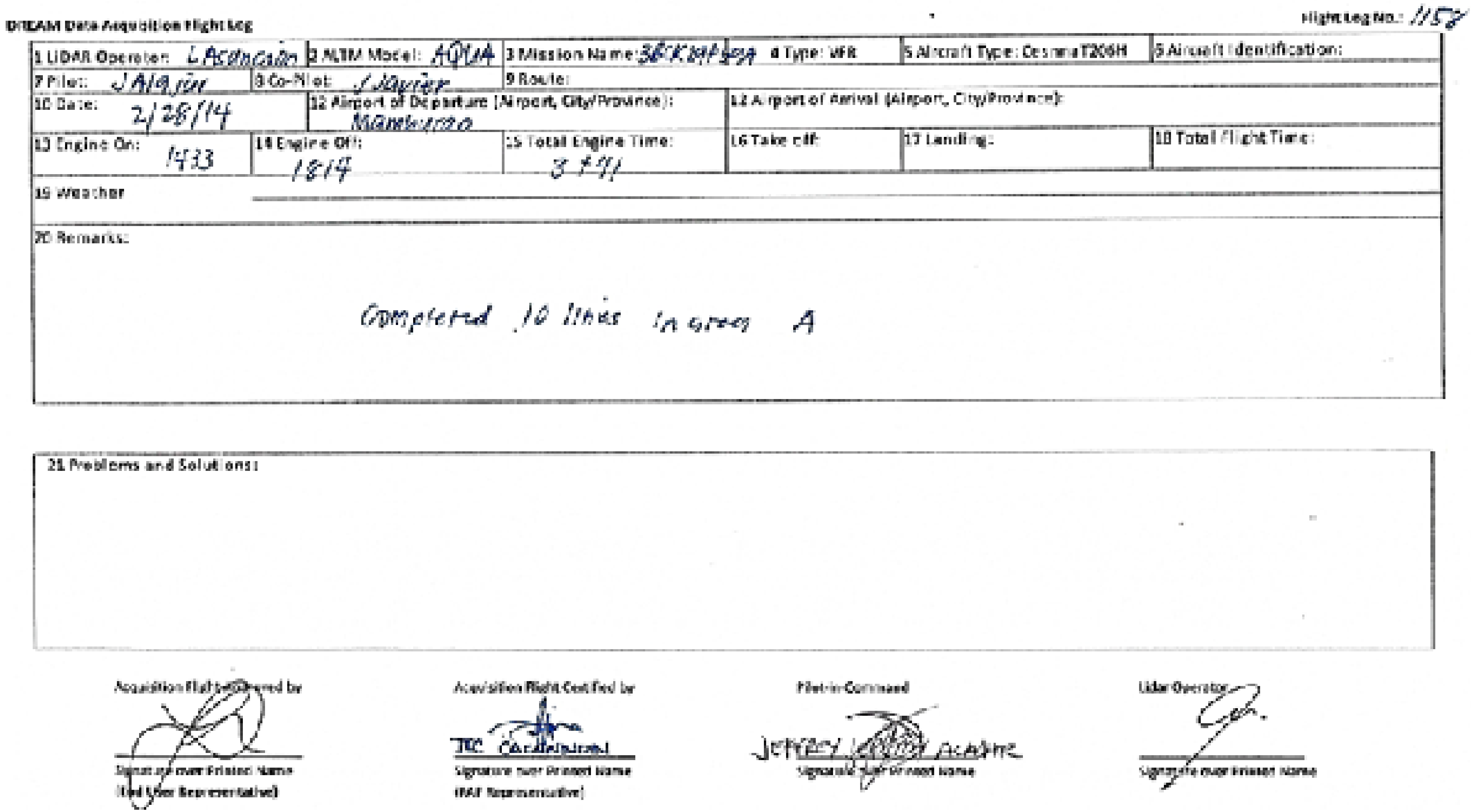
Name AC Bongat

Position SSRS

Signature 1/13/16

Annex 6. Flight Logs

1. Flight Log for 3BLK29A59B Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1152

1 LIDAR Operator: L.Ascuncion	2 ALTM Model: AQUA	3 Mission Name: 3BLK29A59A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: J.Alajar	8 Co-Pilot: J.Javier	9 Route:			
10 Date: 2/28/14	12 Airport of Departure (Airport, City/Province): Mambucao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1433	14 Engine Off: 1814	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed 10 lines in area A					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	TC Cardenas Signature over Printed Name (PAF Representative)	Jeffrey Alajar Signature over Printed Name	Signature over Printed Name

2. Flight Log for 3BLK29C60A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1160

1 LiDAR Operator: L.K Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29C60A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: J. Javier	8 Co-Pilot: J. Alajar	9 Route:			
10 Date: 3/1/14	12 Airport of Departure (Airport, City/Province): Mambukao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 8:22	14 Engine Off: 1257	15 Total Engine Time: 4+35	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

J. Javier

Signature over Printed Name

Lidar Operator

Signature over Printed Name

3. Flight Log for 3BLK29AS60B Mission

REAM Data Acquisition Flight Log

Flight Log No.: 1162

1 LIDAR Operator: L Asuncion	2 ALTM Model: AQUA	3 Mission Name: 3BLK29AS60B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 3/1/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1438	14 Engine Off: 1819	15 Total Engine Time: 3+41	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
	Jec Cagaanan	J Javier	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

4. Flight Log for 3BLK29N61A Mission

(EAM Data Acquisition Flight Log

Flight Log No.: 1164

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29N61A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Alajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 3/2/14	12 Airport of Departure (Airport, City/Province): Nambuan		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0812	14 Engine Off: 1305	15 Total Engine Time: 4+53	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
	TEC CACANINDIN	JEFFREY ALAJAR	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

5. Flight Log for 3BLK29B61B Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1166

1 LiDAR Operator: LAsuncion	2 ALTM Model: AQUA	3 Mission Name: 3BLK29B61B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: JAlajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 3/2/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1423	14 Engine Off: 1822	15 Total Engine Time: 3+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed lines in Area B

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
	TEC CAGUINDON	JEFFREY [illegible] BLAPAR	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

6. Flight Log for 3BLK29BS62A Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1168

1 LIDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29BS62A	4 Type: VFR	5 Aircraft Type: Cessna T206H
6 Aircraft Identification:				
7 Pilot: J. Javier	8 Co-Pilot: J. Alajar	9 Route:		
10 Date: 3/3/14	12 Airport of Departure (Airport, City/Province): Nambuan	12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0813	14 Engine Off: 1242	15 Total Engine Time: 4+29	16 Take off:	17 Landing:
18 Total Flight Time:				
19 Weather				

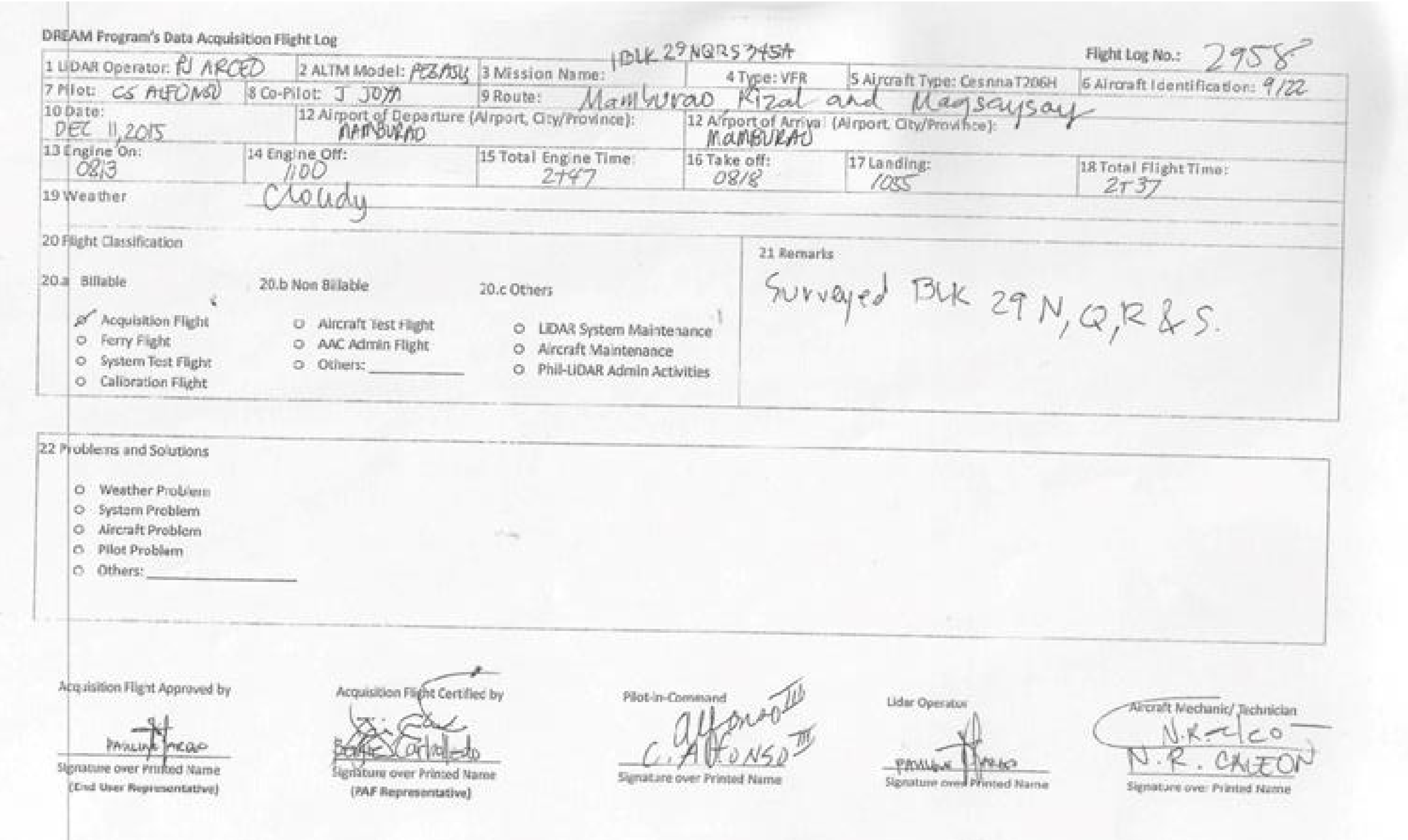
20 Remarks:

Mission completed

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	JEC CABANILLA Signature over Printed Name (PAF Representative)	J. Javier Signature over Printed Name	Signature over Printed Name

7. Flight Log for 1BLK29NQRS345A Mission


DREAM Program's Data Acquisition Flight Log

Flight Log No.: 2958

1 LIDAR Operator: RJ ARCEO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29NQRS345A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: CS ALFONSO	8 Co-Pilot: J JOYA	9 Route: Mamburao Rizal and Magsaysay			
10 Date: DEC 11, 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO		12 Airport of Arrival (Airport, City/Province): MAMBURAO		
13 Engine On: 0813	14 Engine Off: 1100	15 Total Engine Time: 2+47	16 Take off: 0818	17 Landing: 1055	18 Total Flight Time: 2+37
19 Weather: Cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 29 N, Q, R & S.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	C. ALFONSO III — Signature over Printed Name	Signature over Printed Name	N.R. CALEON — Signature over Printed Name

8. Flight Log for 1BLK29R346A Mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 20962

1 LiDAR Operator: G SINADJAN	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29R346A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification: 9122
7 Pilot: CA ALFONSO	8 Co-Pilot: J JOYA	9 Route: Mamburao, San Jose			
10 Date: DEC 12, 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO		12 Airport of Arrival (Airport, City/Province): MAMBURAO		
13 Engine On: 0714	14 Engine Off: 1001	15 Total Engine Time: 2+47	16 Take off: 0719	17 Landing: 0952	18 Total Flight Time: 2+37
19 Weather: Fair					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 29R

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
[signature] Mary [illegible]	[signature] [illegible] Cortez	[signature] C. Alfonso III	[signature] G. Sinadjan	[signature] N. Caleon
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Annex 7. Flight Status

FLIGHT STATUS REPORT
CAGURAY FLOODPLAIN
February 28-March 3, 2014; December 11-12, 2015

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1158A	BLK29A	3BLK29A59B	L. ASUNCION	28-Feb-14	Covered 10 lines.
1160A	BLK29C	3BLK29C60A	L. PARAGAS	01-Mar-14	Mission completed.
1162A	BLK29A & 29D	3BLK29AS+DV60B	L. ASUNCION	01-Mar-14	Mission completed. Continuation of BLK29A and covered voids in BLK29D.
1164A	BLK29N & 29B	3BLK29N+B61A	L. PARAGAS	02-Mar-14	Mission completed. Covered lines 10 and 11 of BLK29B.
1166A	BLK29B	3BLK29B61B	L. ASUNCION	02-Mar-14	Covered gap in line 10 from the morning flight.
1168A	BLK29B, 29A, 29D, 29C & 29K	3BLK29BS+ AB+DB+CV+ KV62B	L. PARAGAS	03-Mar-14	Mission completed.
3078P	BLK 29N, 29Q, 29R & 29S.	1BLK29NQRS345A	P. ARCEO	11-Dec-15	Surveyed BLK 29N, Q, R & S.
3082P	BLK 29R	1BLK29R346A	G. SINADJAN	12-Dec-15	Surveyed BLK29R.

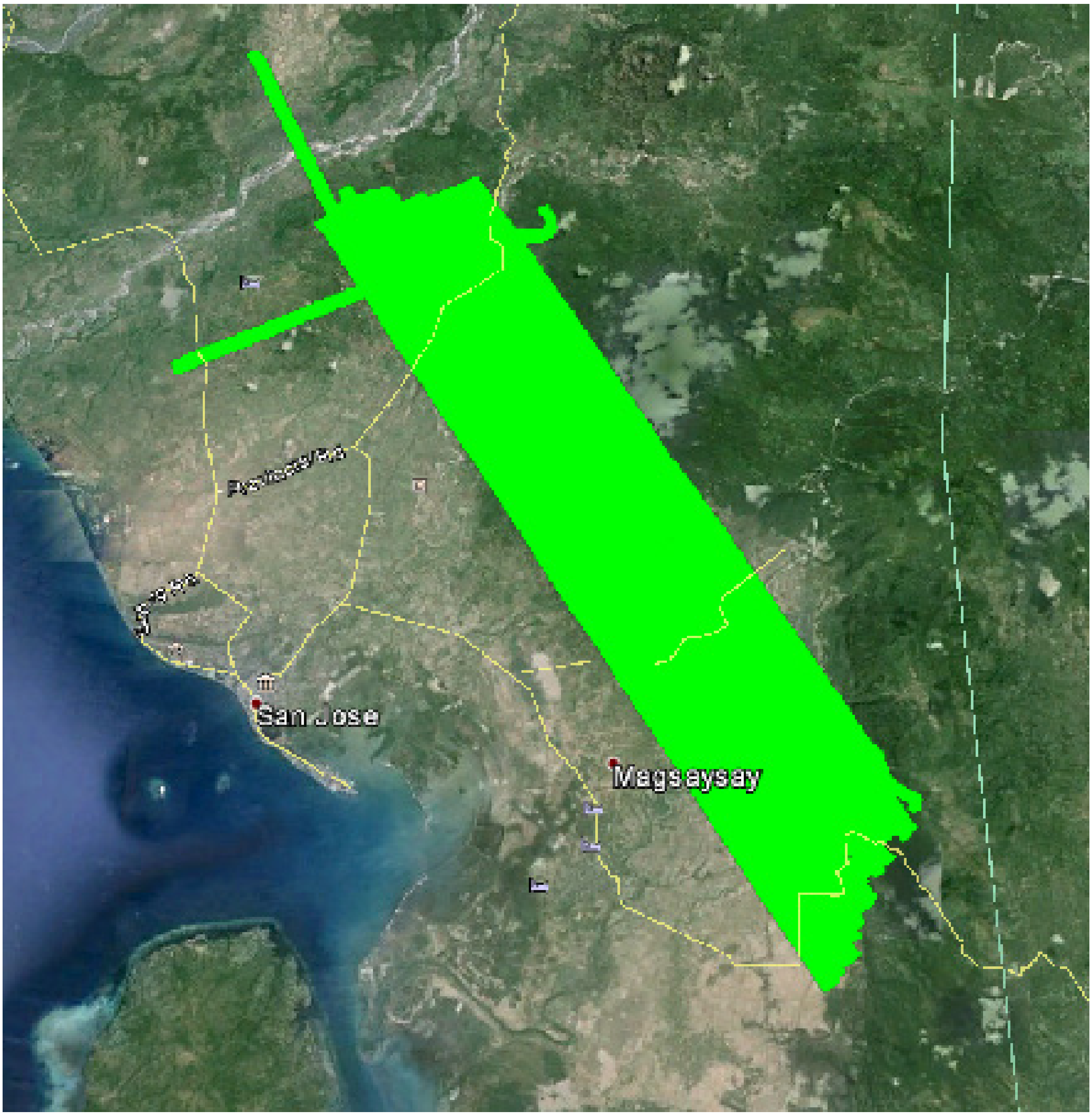
LAS/SWATH BOUNDARIES PER MISSION FLIGHT

FLIGHT LOG NO. 1158A
AREA: BLK29A
MISSION NAME: 3BLK29A59B
PARAMETERS: Alt: 550 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

FLIGHT LOG NO. 1160A
AREA: BLK29C
MISSION NAME: 3BLK29C60A
PARAMETERS: Alt: 650 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:



FLIGHT LOG NO. 1162A
AREA: BLK29A AND BLK29D
MISSION NAME: 3BLK29AS+DV60B
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

FLIGHT LOG NO. 1164A
AREA: BLK29N AND BLK29B
MISSION NAME: 3BLK29N+B61A
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

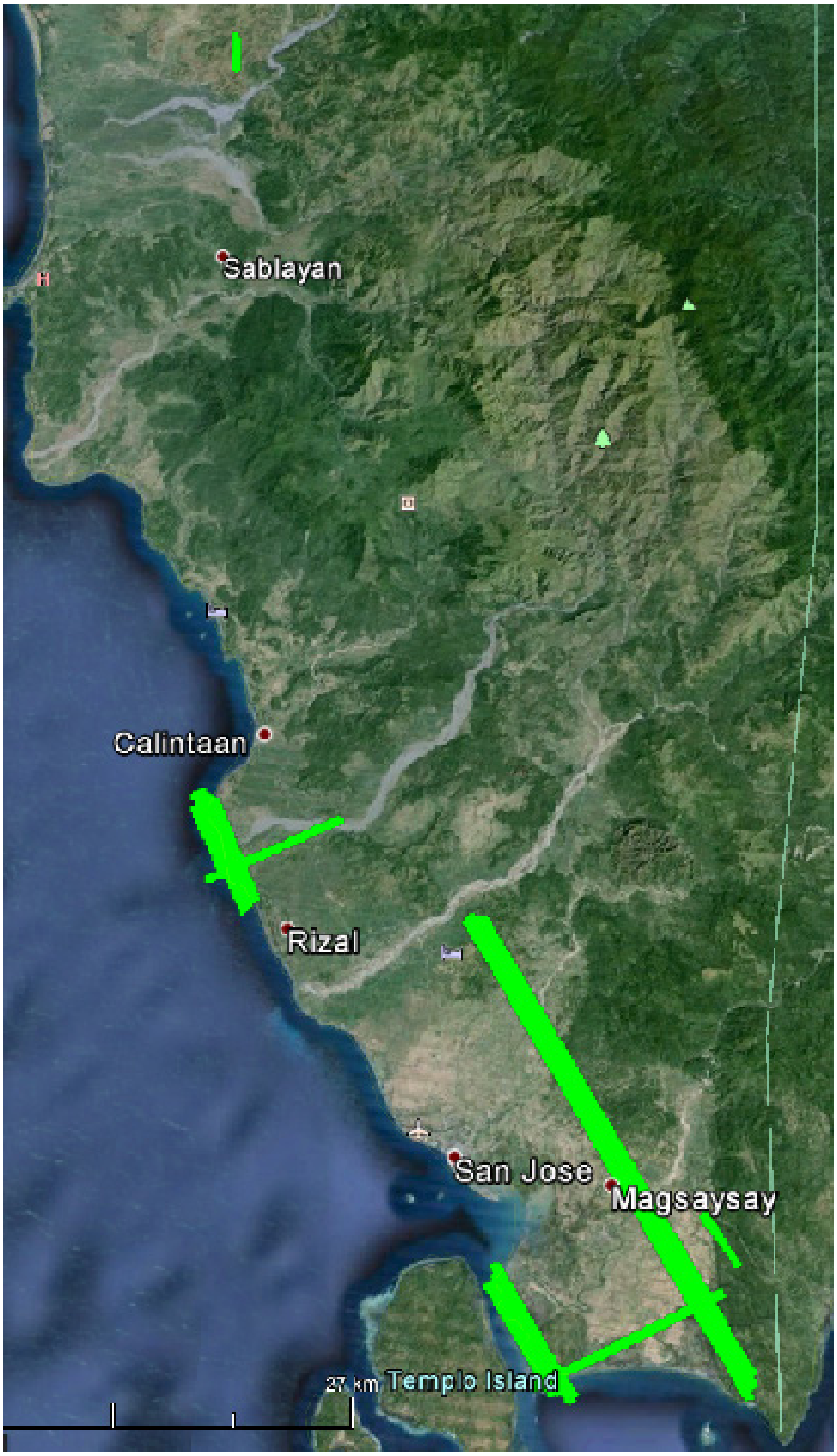
SURVEY COVERAGE:

FLIGHT LOG NO. 1166A
AREA: BLK29B
MISSION NAME: 3BLK29B61B
PARAMETERS: Alt: 600 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:

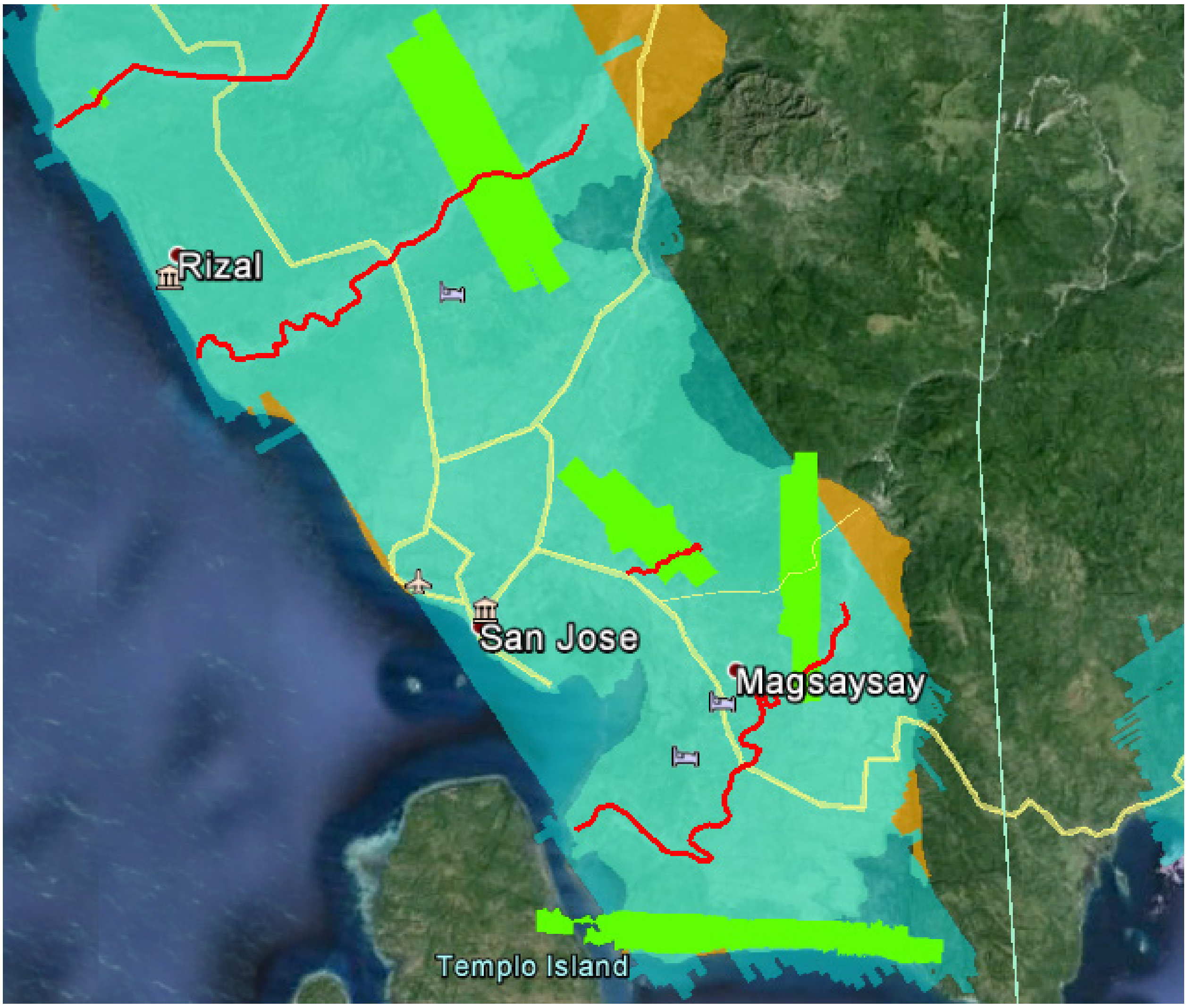
FLIGHT LOG NO.	1168A
AREA:	BLK29B, BLK29A, BLK29D, BLK29C AND BLK29K
MISSION NAME:	3BLK29BS+AB+DB+CV+KV62B
PARAMETERS:	Alt: 550 Scan Freq: 40 kHz Scan Angle: 18 deg

SURVEY COVERAGE:



FLIGHT NO.:	3078P
AREA:	BLK29N, BLK29Q, BLK29R & BLK29S
MISSION NAME:	1BLK29NQRS345A
PARAMETERS:	Alt: 850 m Scan Freq: 32 Scan Angle: 25

SURVEY COVERAGE:



FLIGHT NO.:	3082P		
AREA:	BLK29R		
MISSION NAME:	1BLK29R346A		
PARAMETERS:	Alt: 1100 m	Scan Freq: 30	Scan Angle: 25

SURVEY COVERAGE:

Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Mission Blk29A

Flight Area	Davao Oriental
Mission Name	Blk29A
Inclusive Flights	1158A. 1162A, 1168A
Range data size	29.98 GB
POS	677 MB
Image	72.6 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	2.1
RMSE for Down Position (<8.0 cm)	4.4
Boresight correction stdev (<0.001deg)	0.000443
IMU attitude correction stdev (<0.001deg)	0.002081
GPS position stdev (<0.01m)	0.0294
Minimum % overlap (>25)	43.28%
Ave point cloud density per sq.m. (>2.0)	2.76
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	194
Maximum Height	165.41 m
Minimum Height	43.10 m
Classification (# of points)	
Ground	104,722,532
Low vegetation	130,224,088
Medium vegetation	60,206,940
High vegetation	16,625,237
Building	4,886,963
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Harmond Santos, Engr. Gladys Mae Apat

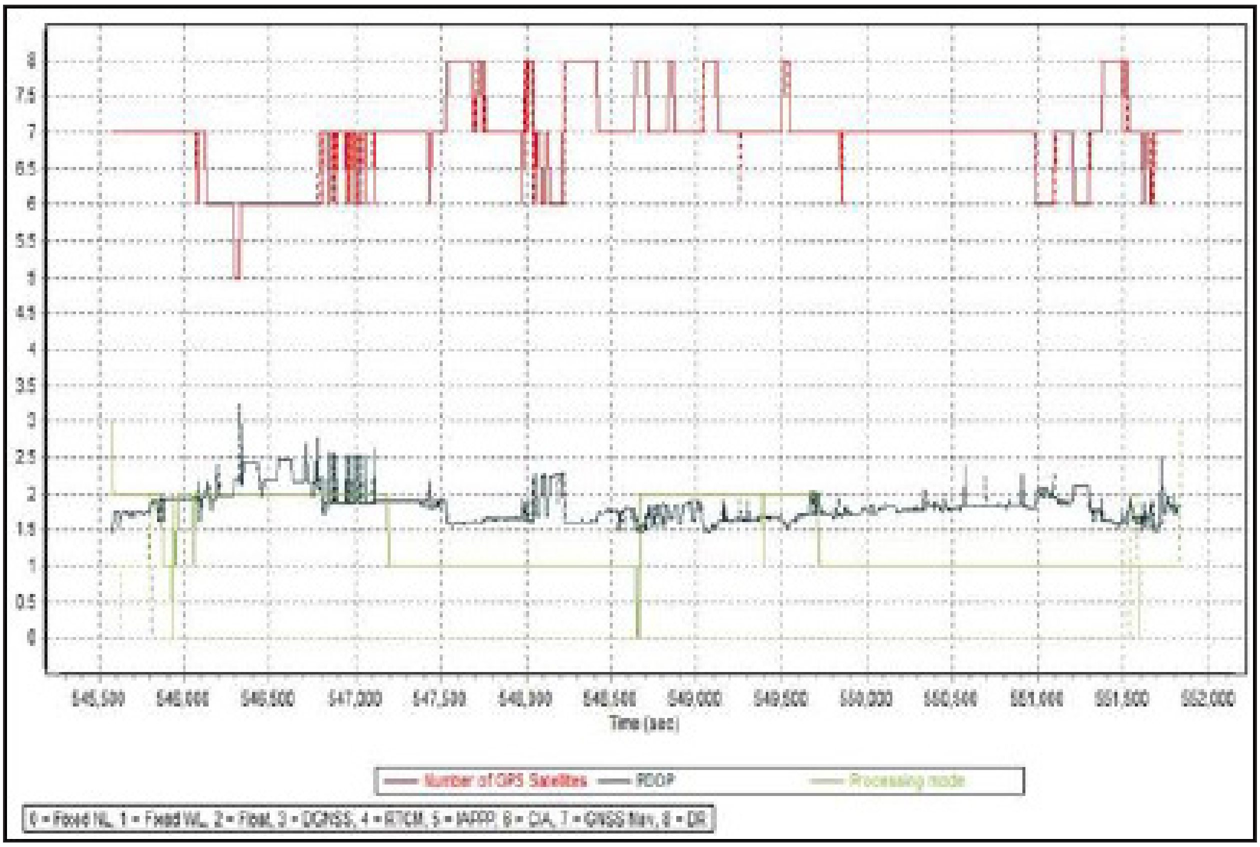


Figure A-8.1. Solution Status

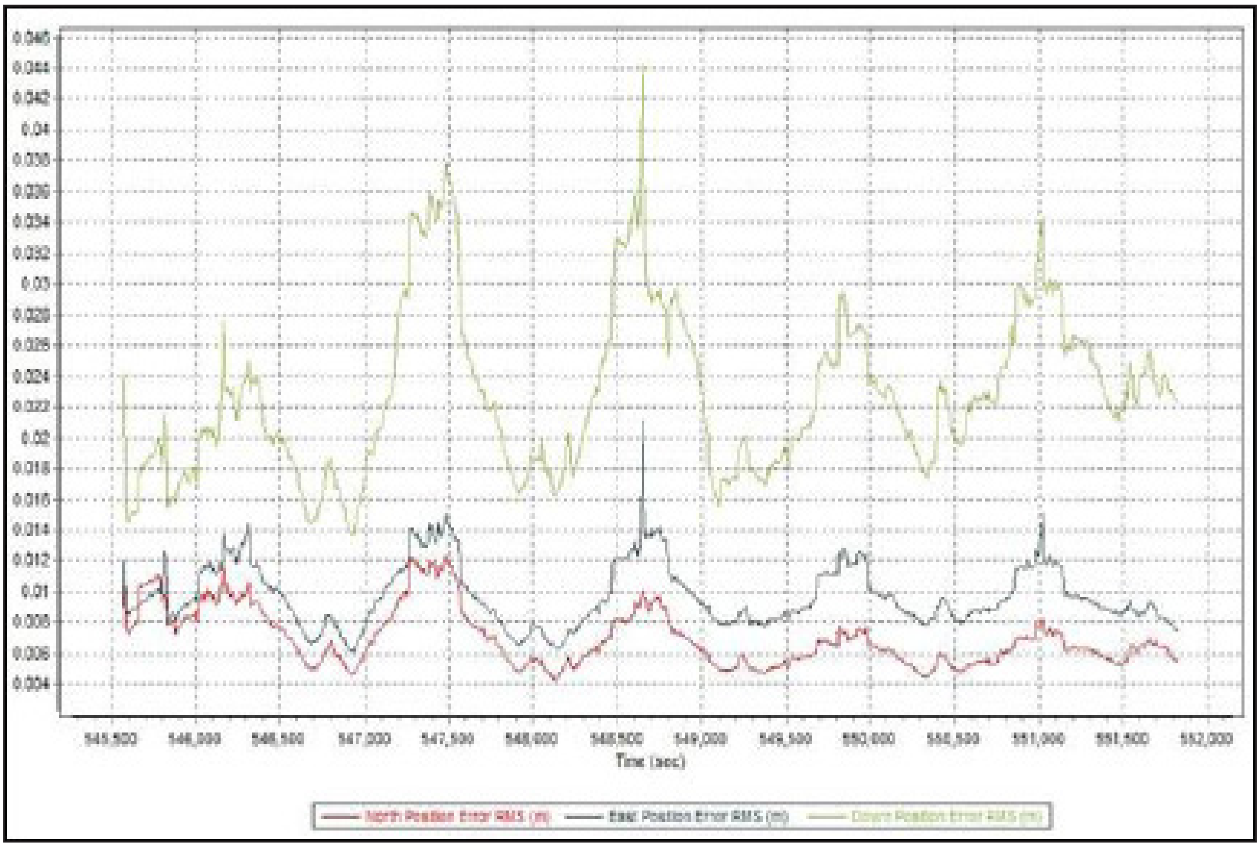


Figure A-8.2. Smoothed Performance Metric Parameters

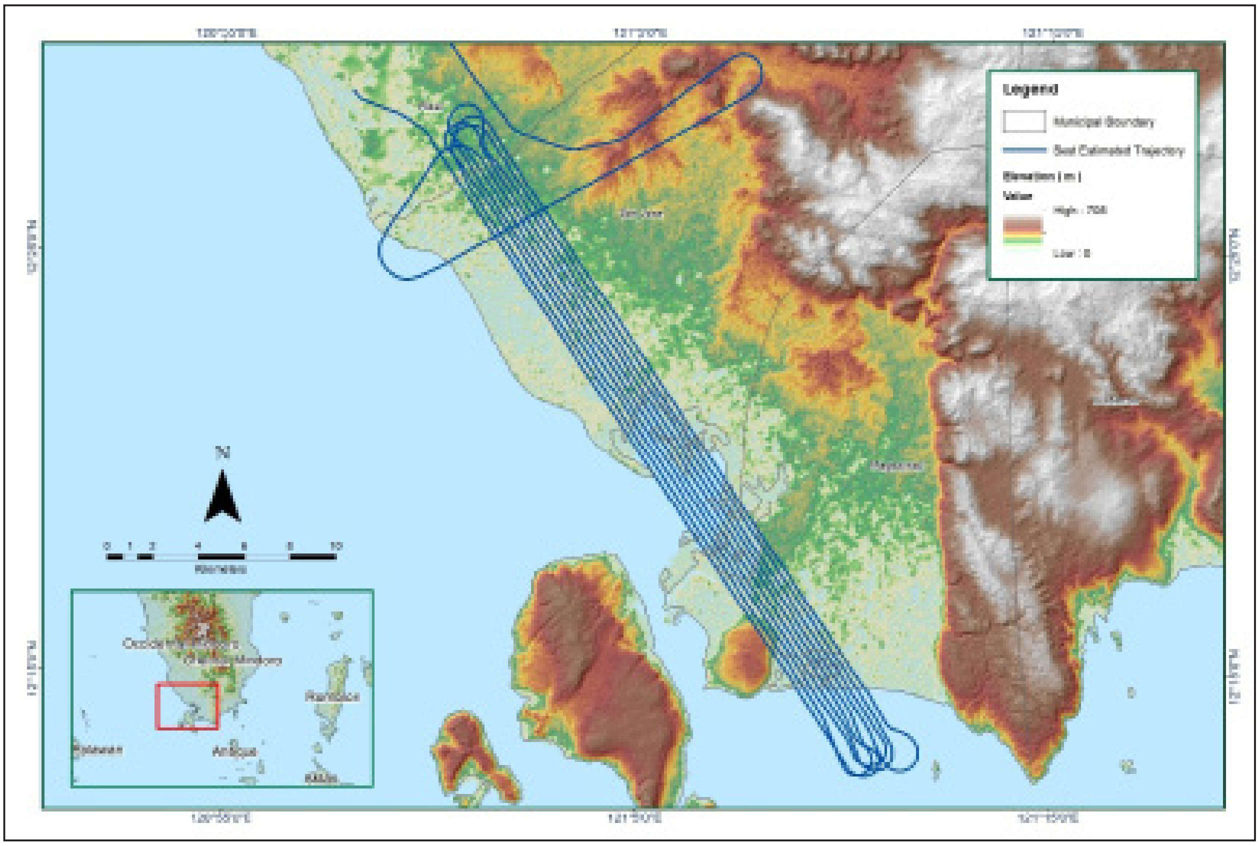


Figure A-8.3. Best Estimated Trajectory

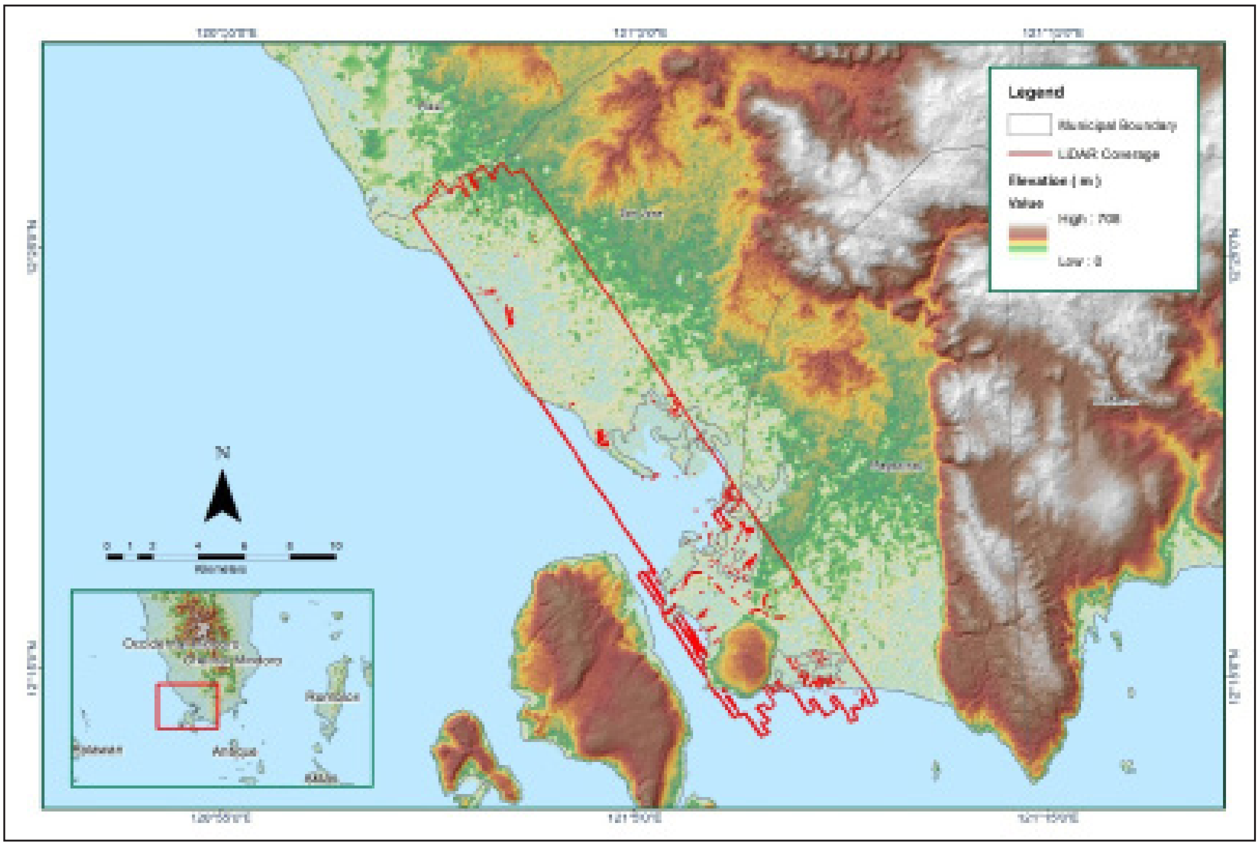


Figure A-8.4. Coverage of LiDAR data

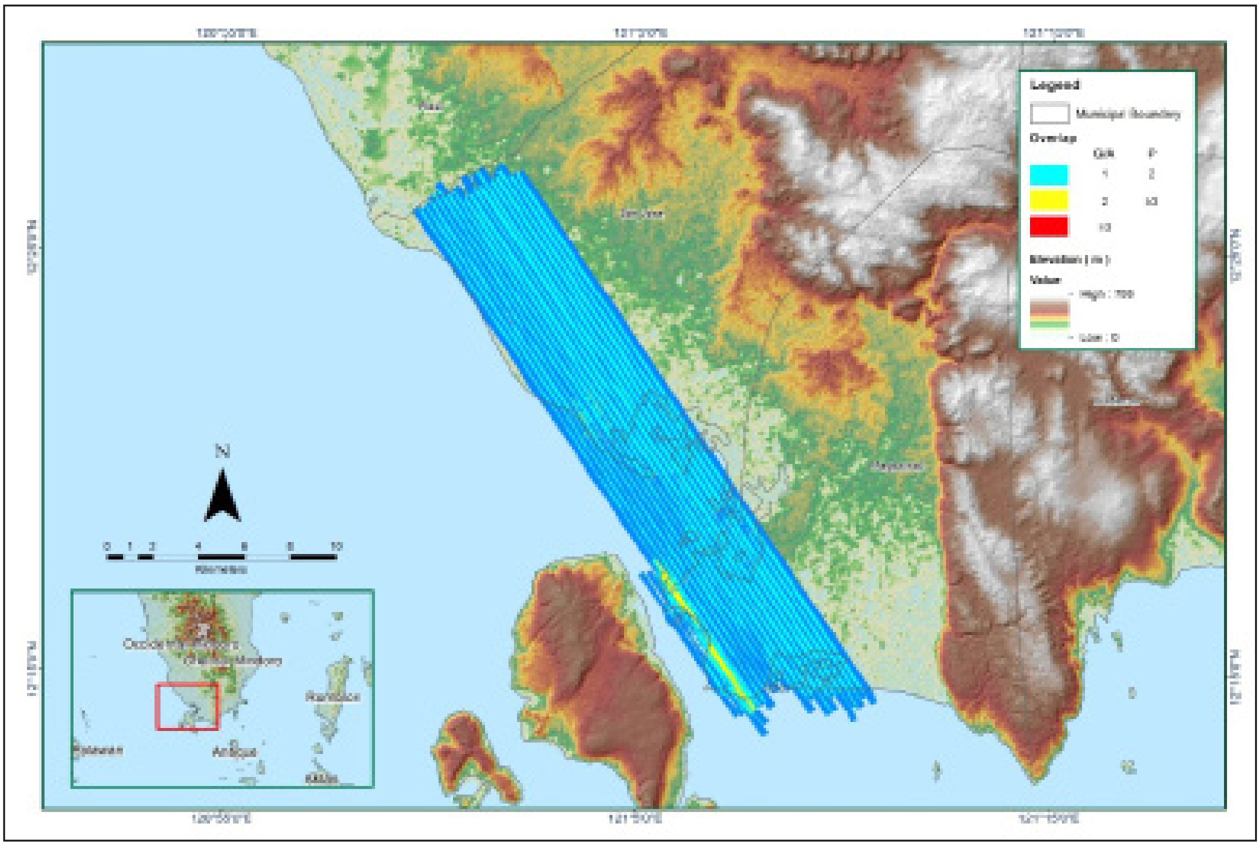


Figure A-8.5. Image of data overlap

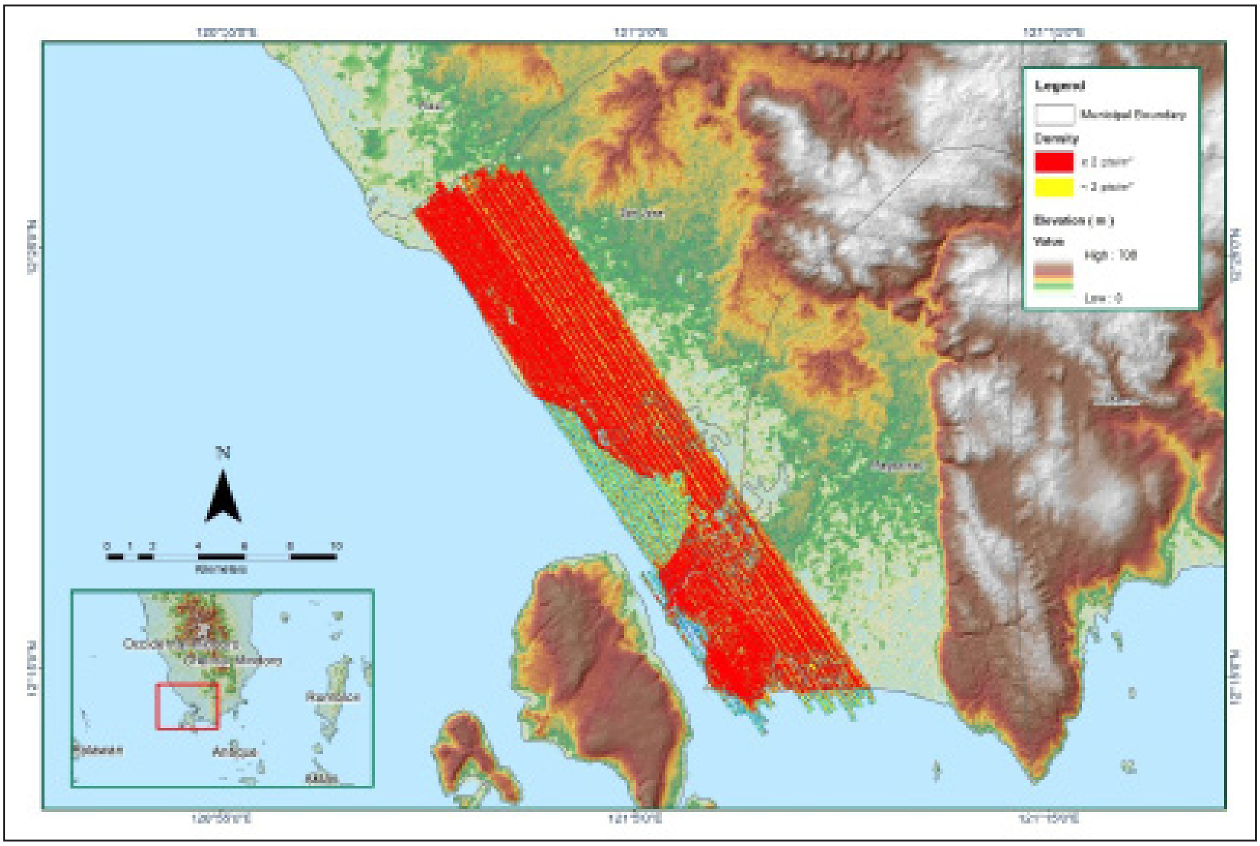


Figure A-8.6. Density map of merged LiDAR data

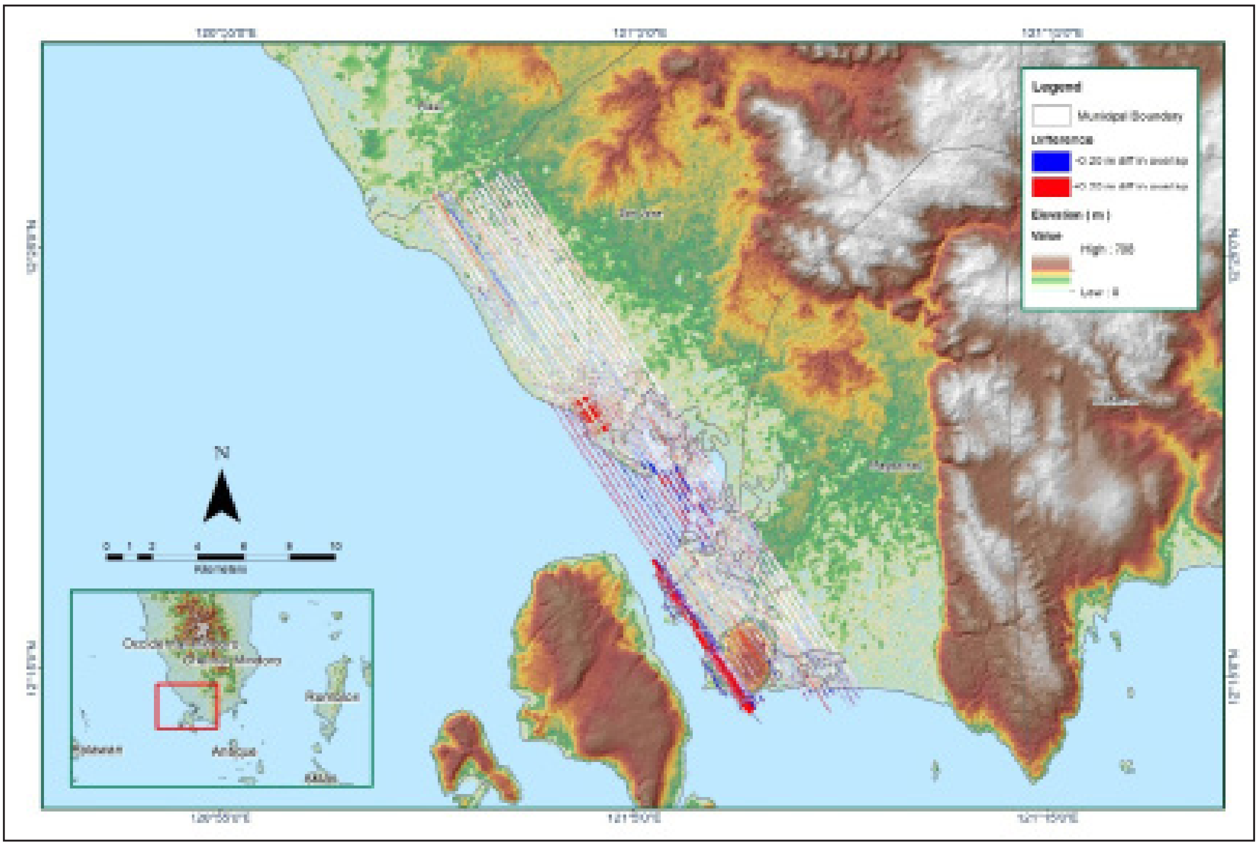


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk29B

Flight Area	Davao Oriental
Mission Name	Blk29B
Inclusive Flights	1164A. 1166A, 1168A
Range data size	38.4 GB
POS	791 MB
Image	22.5 GB
Transfer date	04/23/2014
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)	1.3
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000629
IMU attitude correction stdev (<0.001deg)	0.002510
GPS position stdev (<0.01m)	0.0158
Minimum % overlap (>25)	43.01%
Ave point cloud density per sq.m. (>2.0)	3.09
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	197
Maximum Height	258.38 m
Minimum Height	46.77 m
Classification (# of points)	
Ground	115,311,089
Low vegetation	138,979,099
Medium vegetation	95,318,939
High vegetation	30,819,969
Building	2,104,153
Orthophoto	Yes
Processed by	Ma. Victoria Rejuso, Engr. Harmond Santos, Engr. John Dill Macapagal

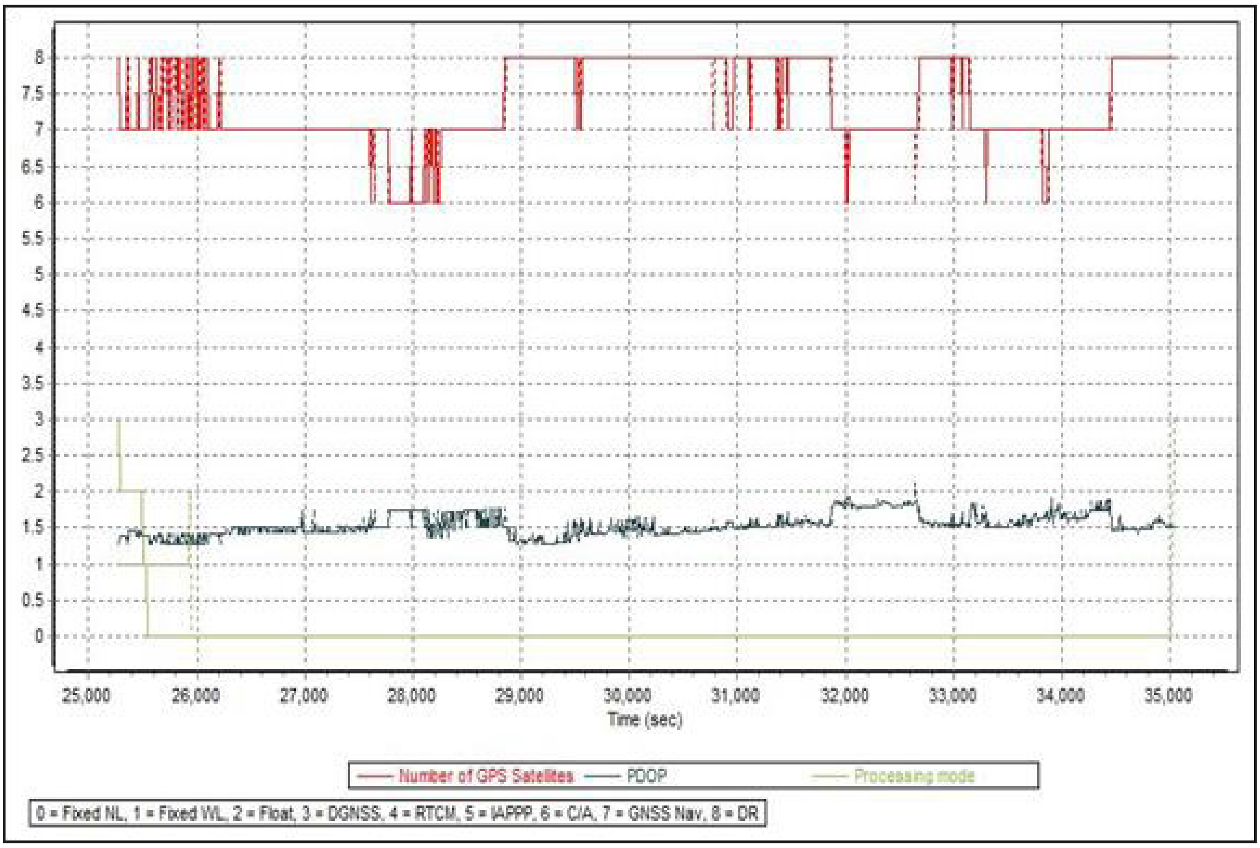


Figure A-8.8. Solution Status

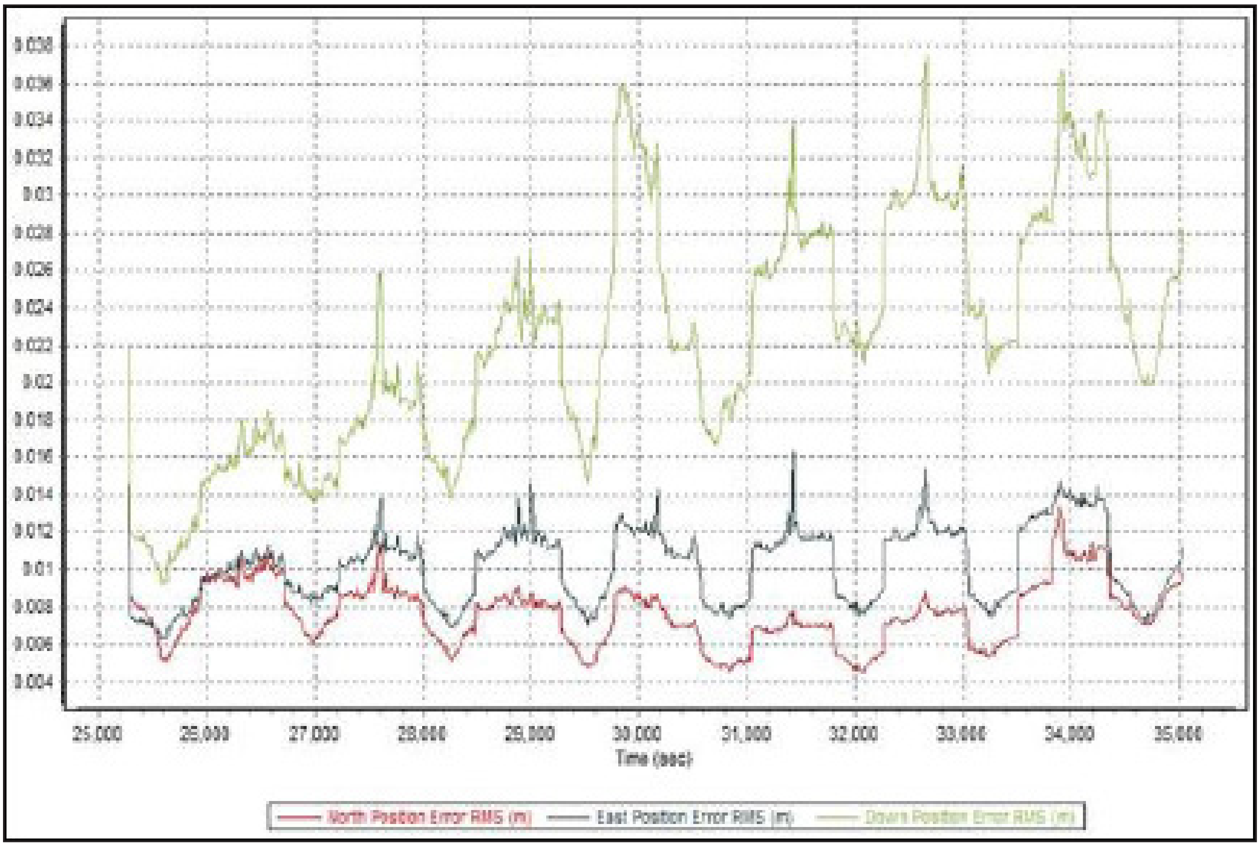


Figure A-8.9. Smoothed Performance Metric Parameters

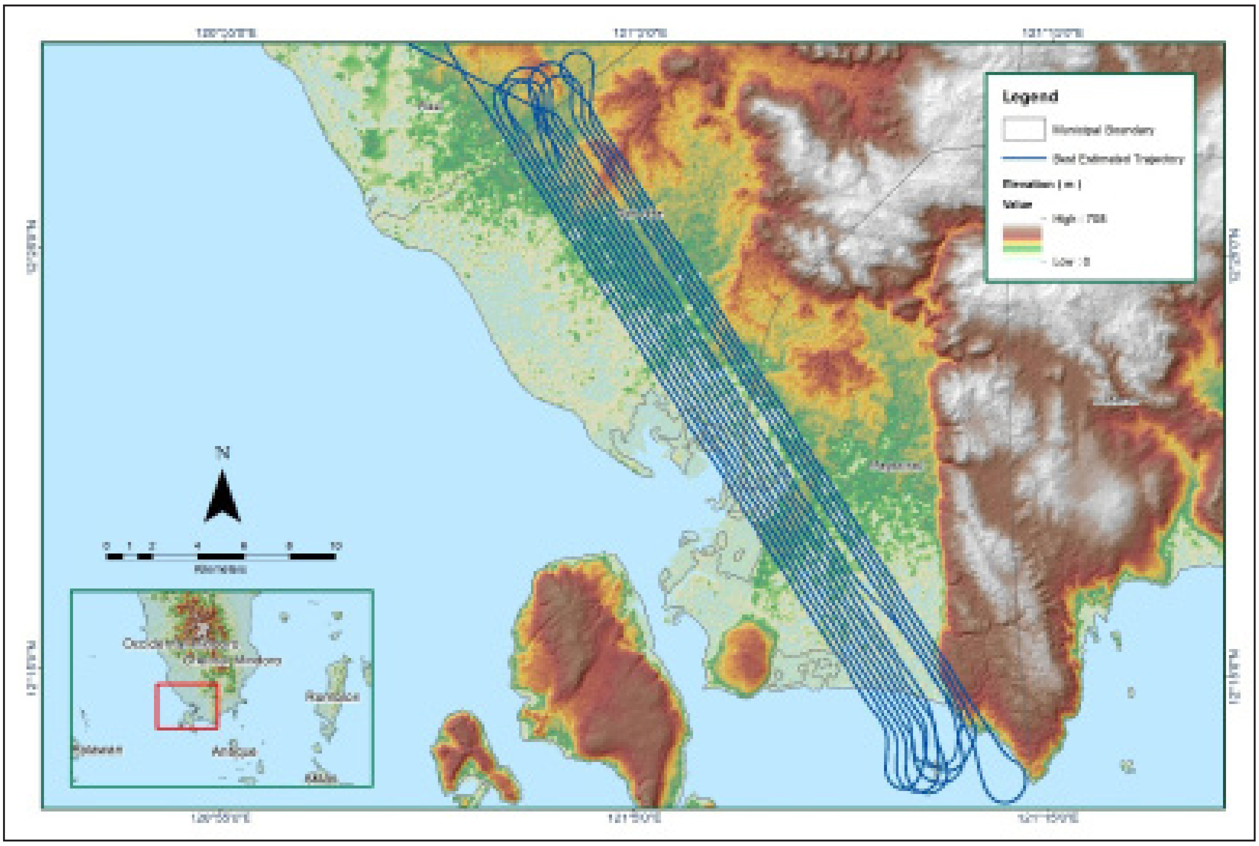


Figure A-8.10. Best Estimated Trajectory

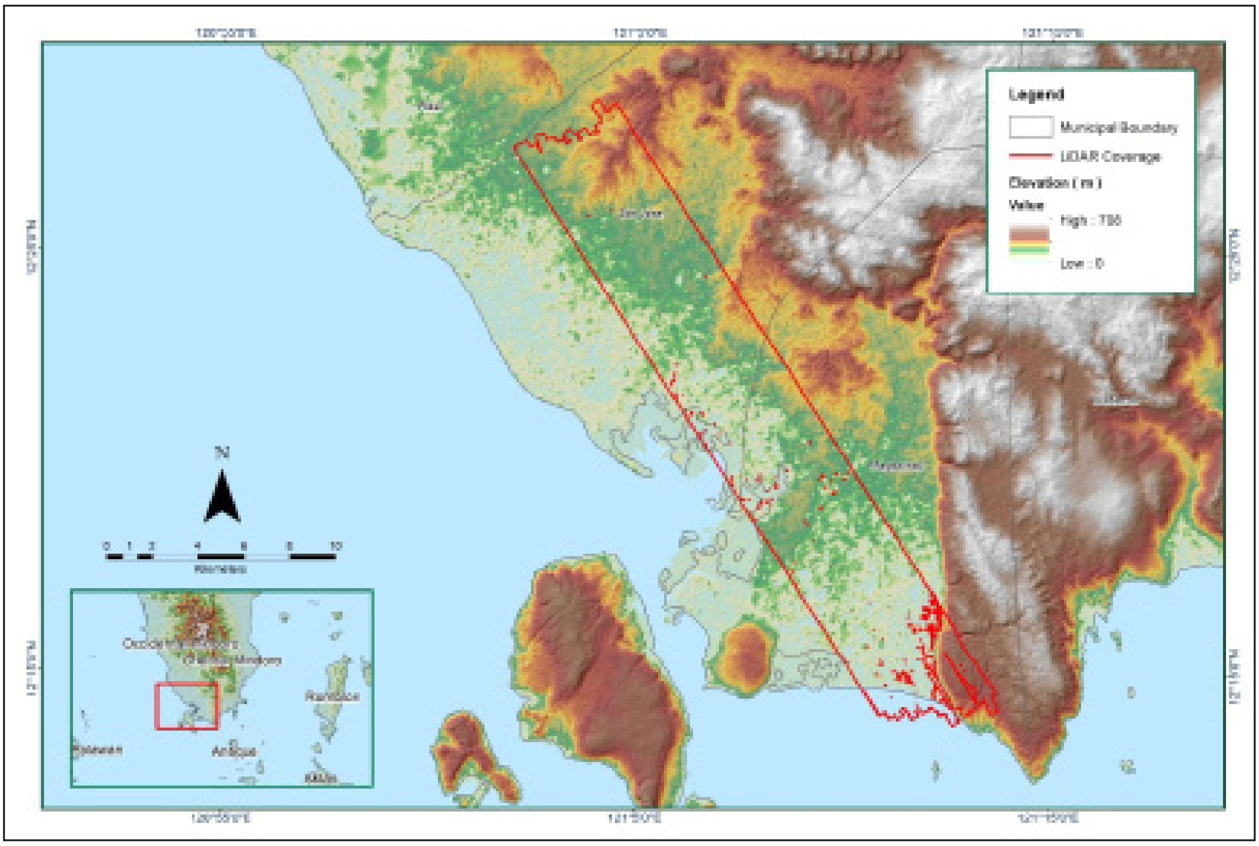


Figure A-8.11. Coverage of LiDAR data

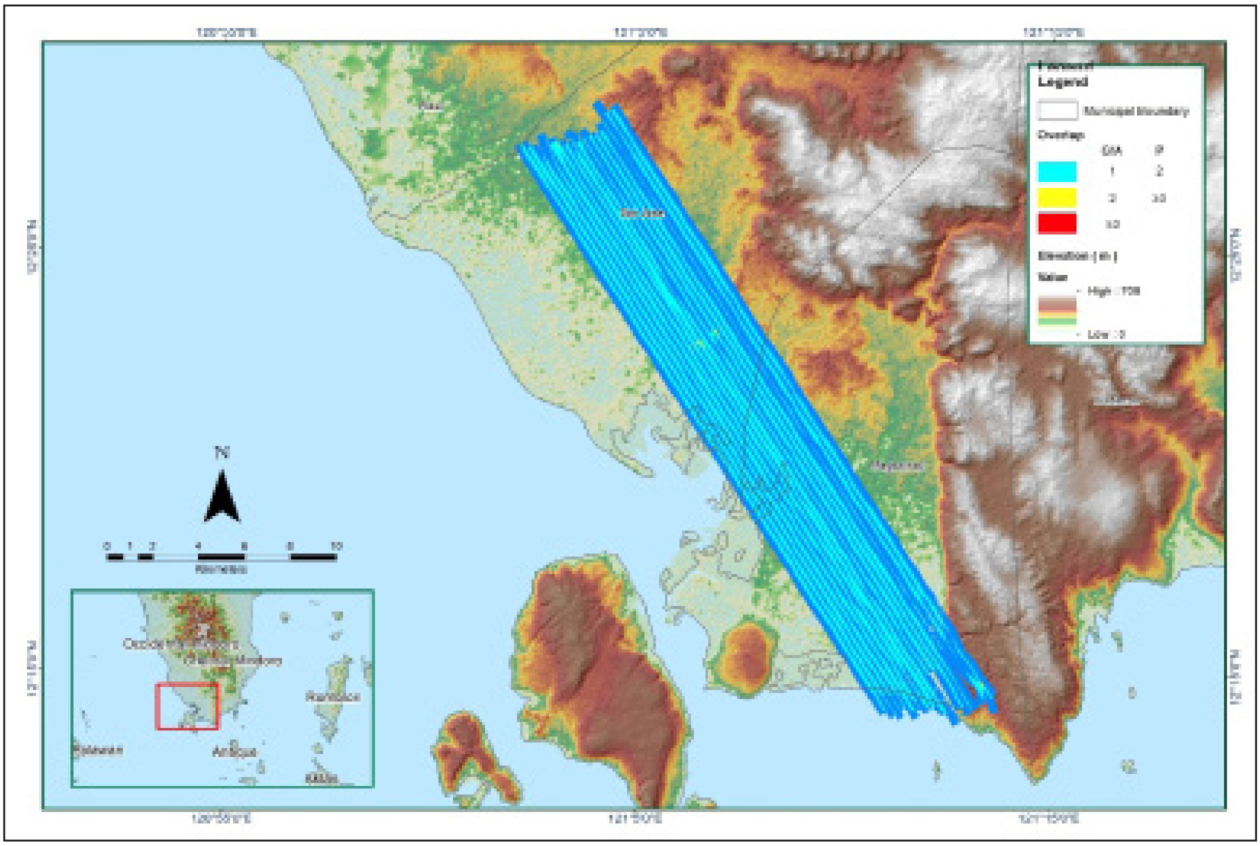


Figure A-8.12. Image of data overlap

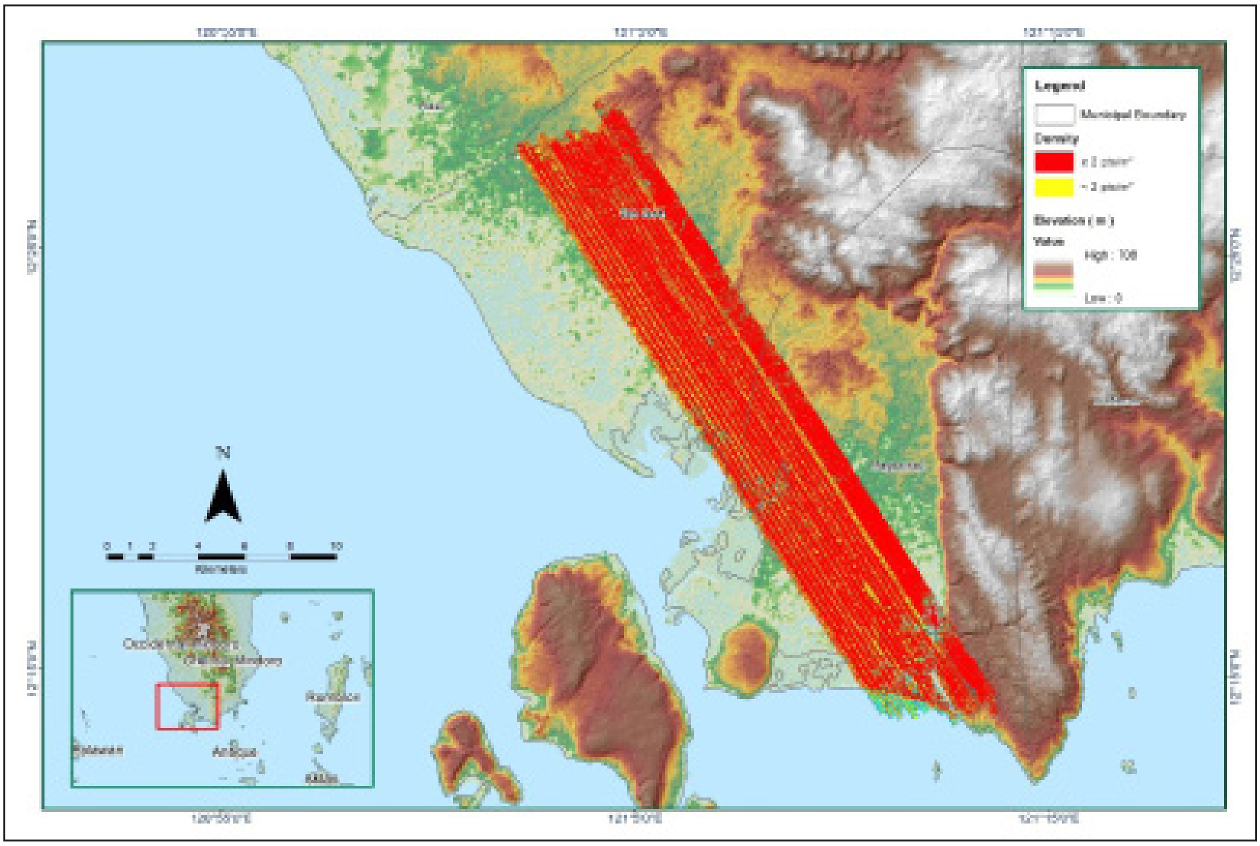


Figure A-8.13. Density map of merged LiDAR data

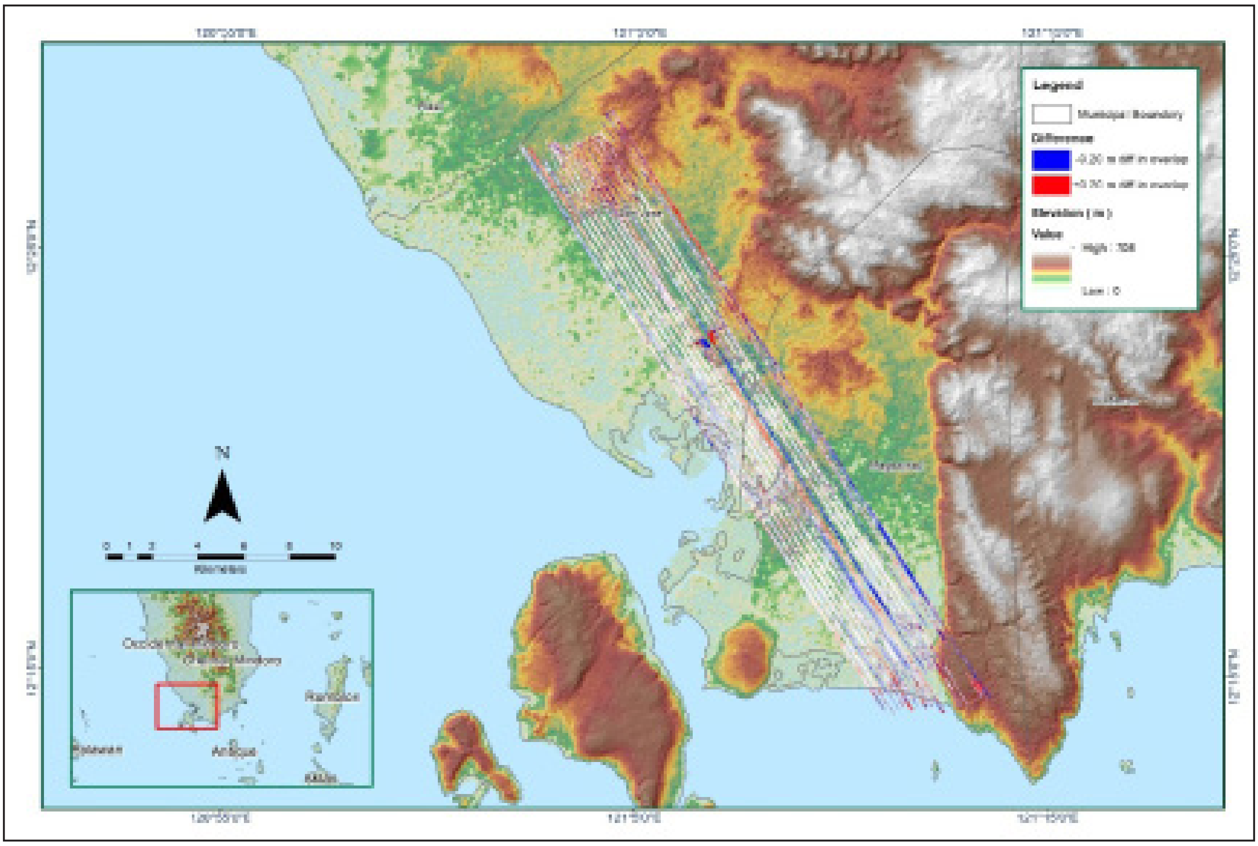


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk29C

Flight Area	Davao Oriental
Mission Name	Blk29C
Inclusive Flights	1160A
Range data size	14.1 GB
POS	268 MB
Image	13.5 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	4.8
RMSE for East Position (<4.0 cm)	2.2
RMSE for Down Position (<8.0 cm)	5.1
Boresight correction stdev (<0.001deg)	0.000373
IMU attitude correction stdev (<0.001deg)	0.001768
GPS position stdev (<0.01m)	0.0032
Minimum % overlap (>25)	44.16%
Ave point cloud density per sq.m. (>2.0)	3.59
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	143
Maximum Height	481.99 m
Minimum Height	51.54 m
Classification (# of points)	
Ground	109,156,938
Low vegetation	80,757,959
Medium vegetation	73,247,510
High vegetation	71,877,948
Building	1,281,773
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Harmond Santos, Ailyn Biñas

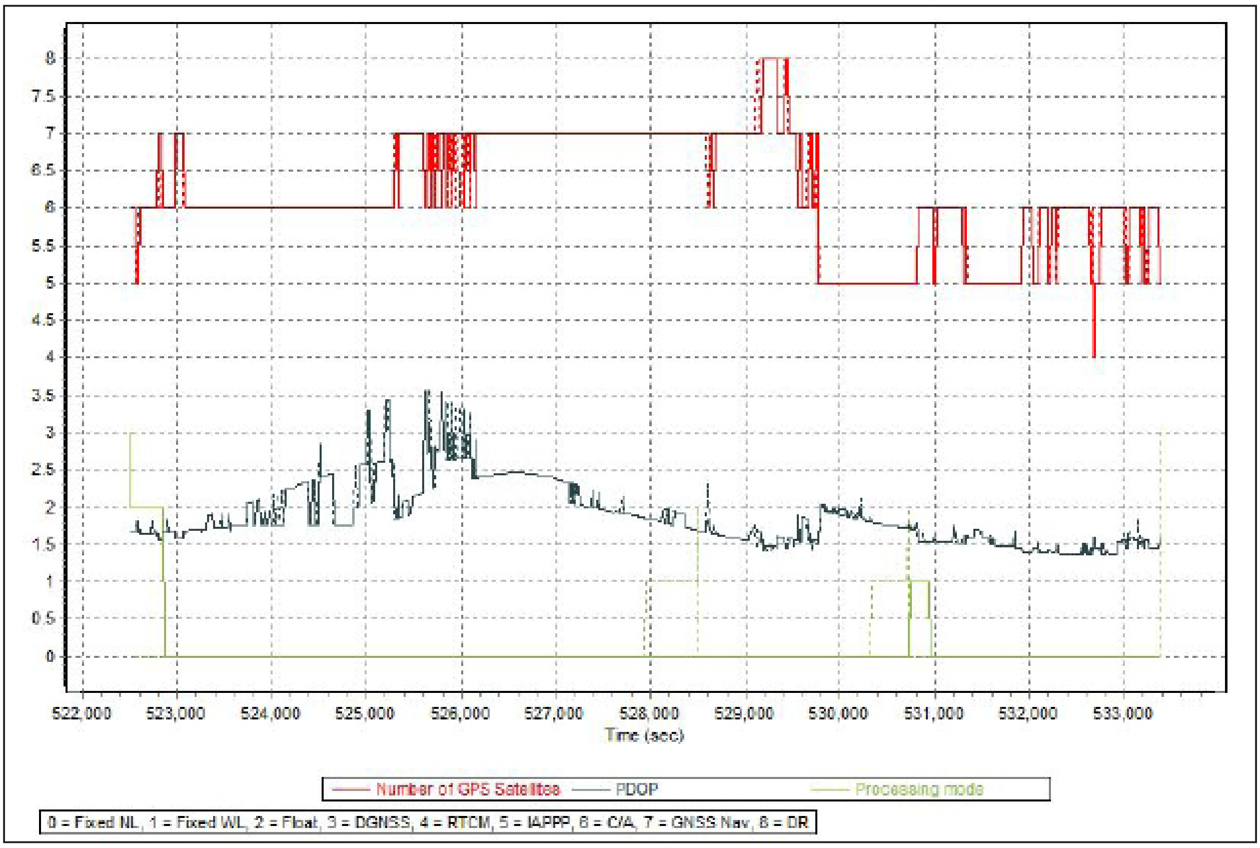


Figure A-8.15. Solution Status

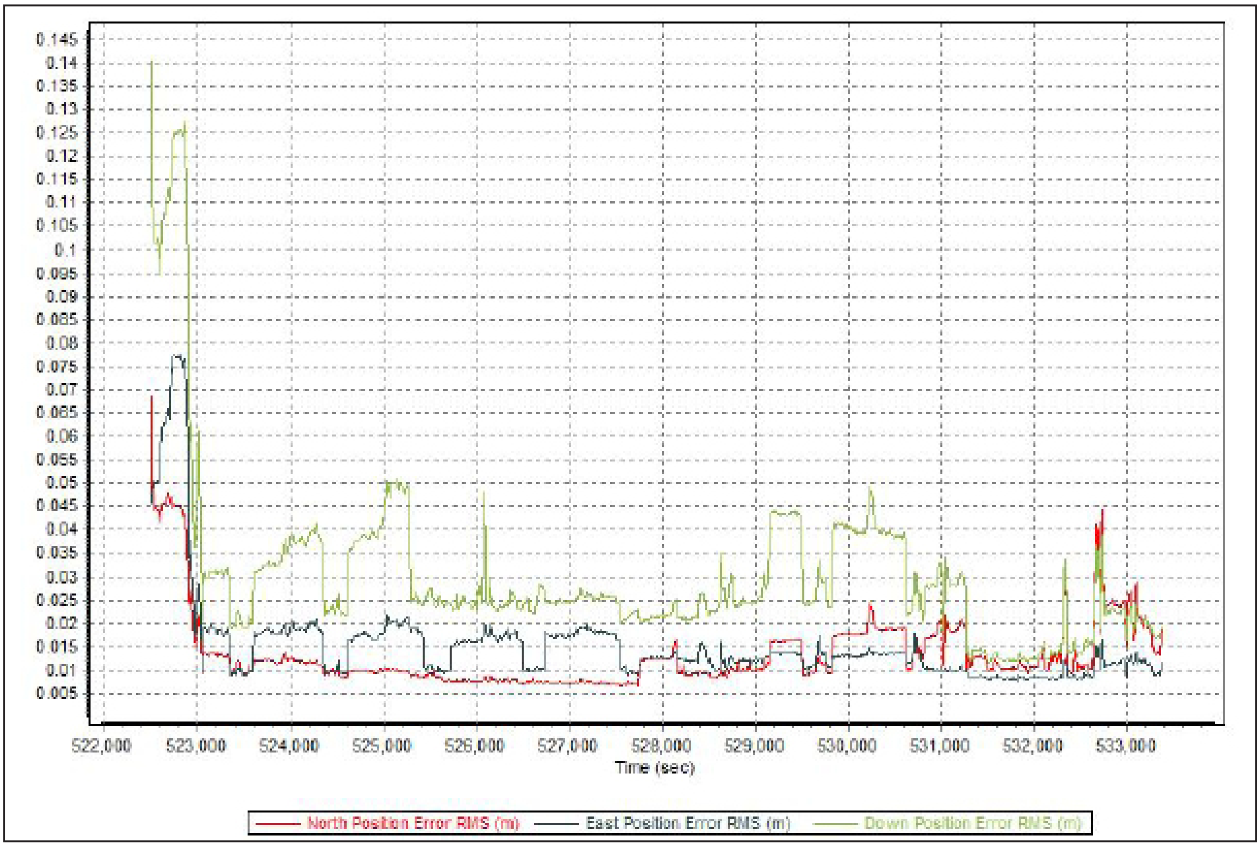


Figure A-8.16. Smoothed Performance Metric Parameters

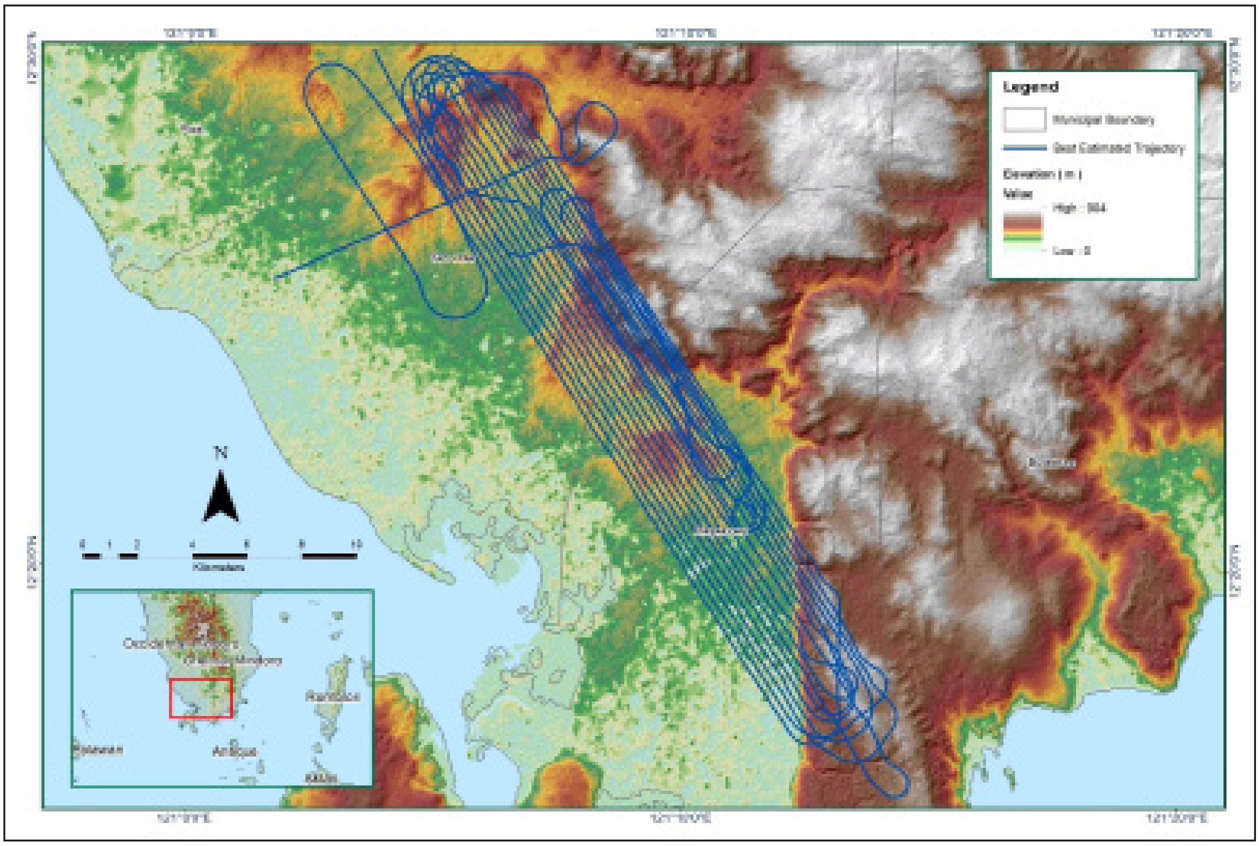


Figure A-8.17. Best Estimated Trajectory

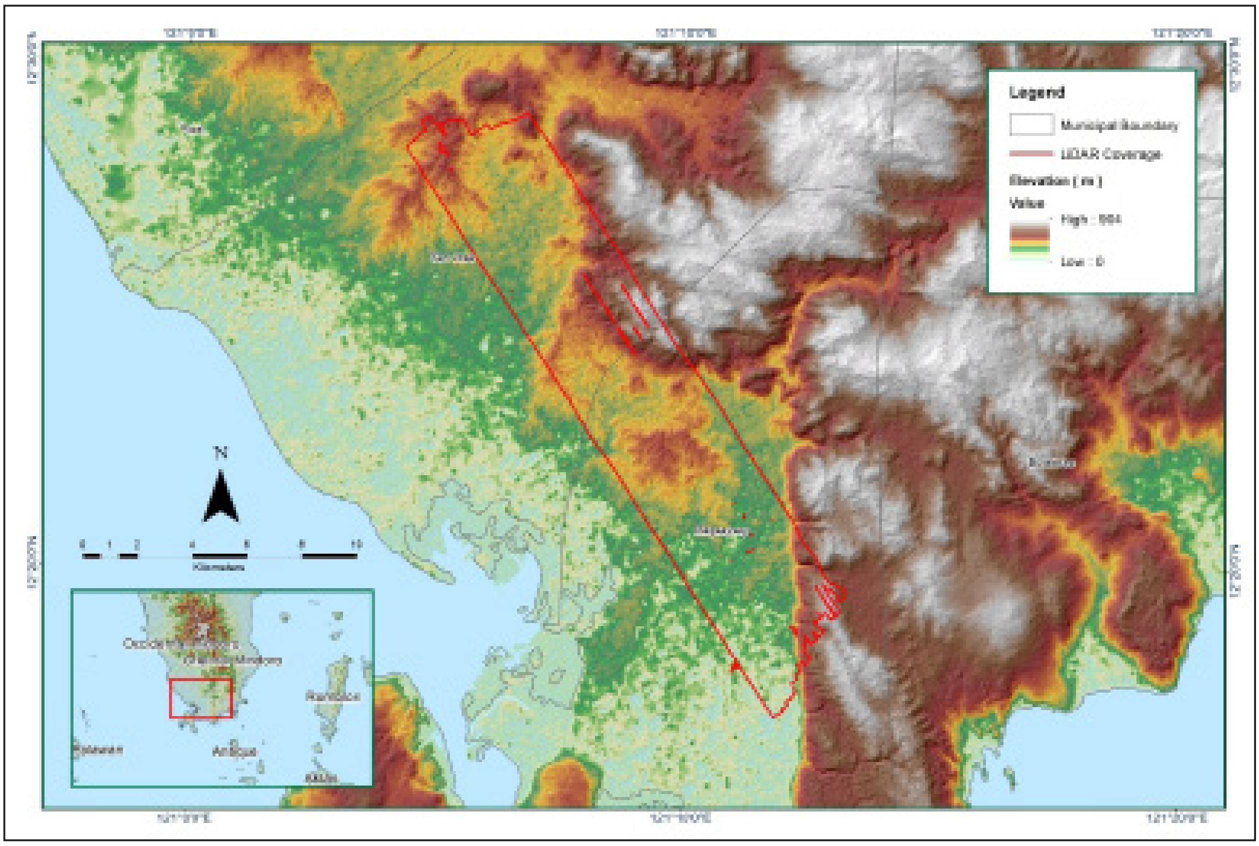


Figure A-8.18. Coverage of LiDAR data

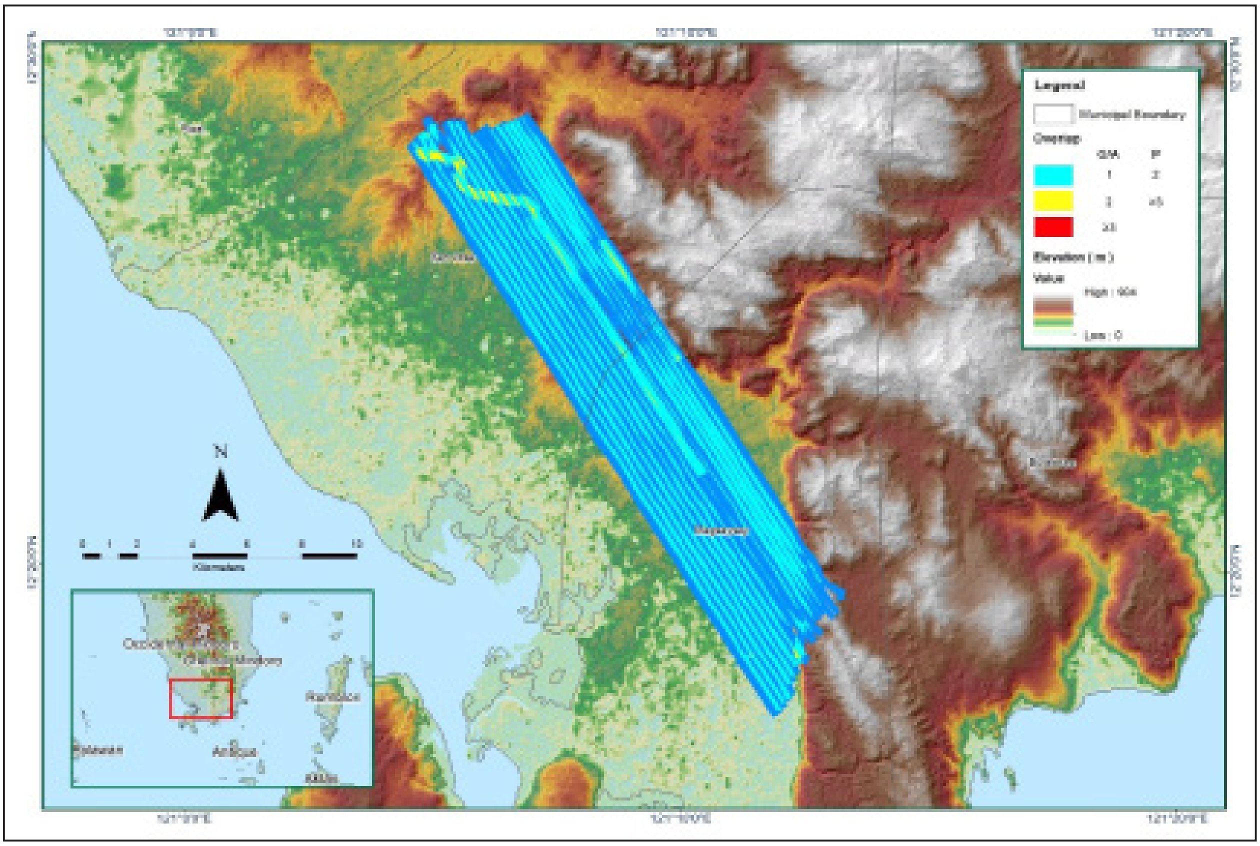


Figure A-8.19. Image of data overlap

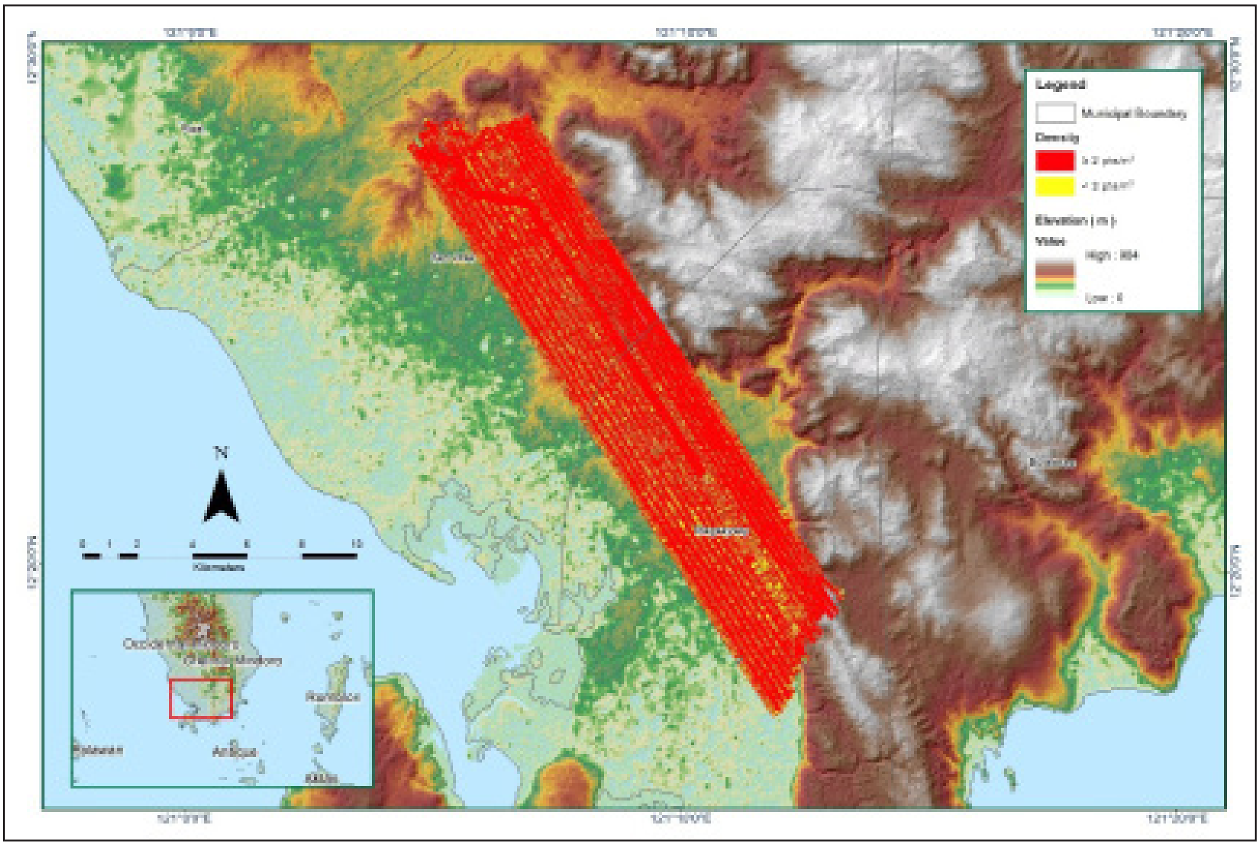


Figure A-8.20. Density map of merged LiDAR data

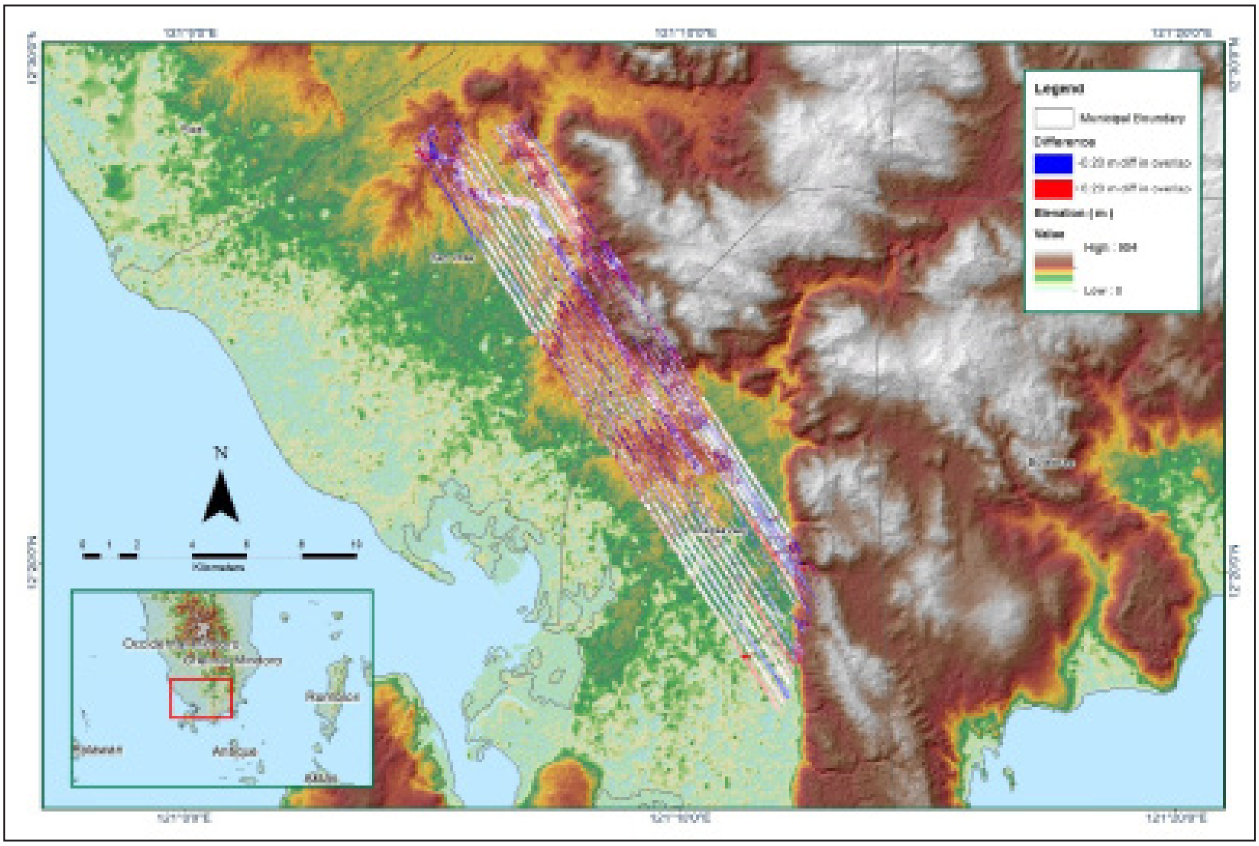


Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Mission Blk29A_additional

Flight Area	Davao Oriental
Mission Name	Blk29A_additional
Inclusive Flights	3078P
Range data size	6.2GB
POS	167MB
Image	12.9MB
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.01
RMSE for East Position (<4.0 cm)	1.16
RMSE for Down Position (<8.0 cm)	4.25
Boresight correction stdev (<0.001deg)	0.359804
IMU attitude correction stdev (<0.001deg)	0.083211
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	
Ave point cloud density per sq.m. (>2.0)	
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	40
Maximum Height	231.12 m
Minimum Height	50.50 m
Classification (# of points)	
Ground	15,453,565
Low vegetation	10,246,556
Medium vegetation	13,004,794
High vegetation	17,341,456
Building	271,742
Orthophoto	Yes
Processed by	Engr. Abigail Ching, Engr. Harmond Santos, Engr. Melissa Fernandez

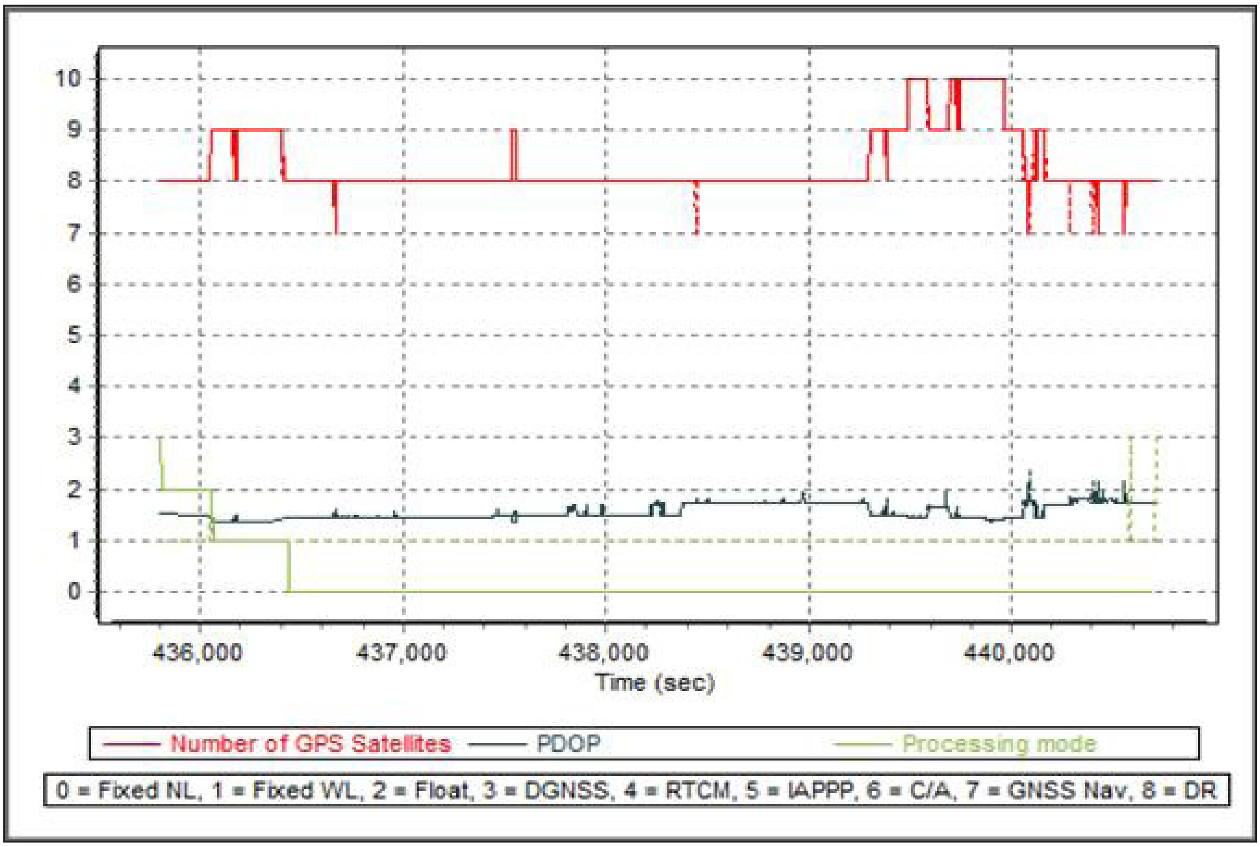


Figure A-8.22. Solution Status

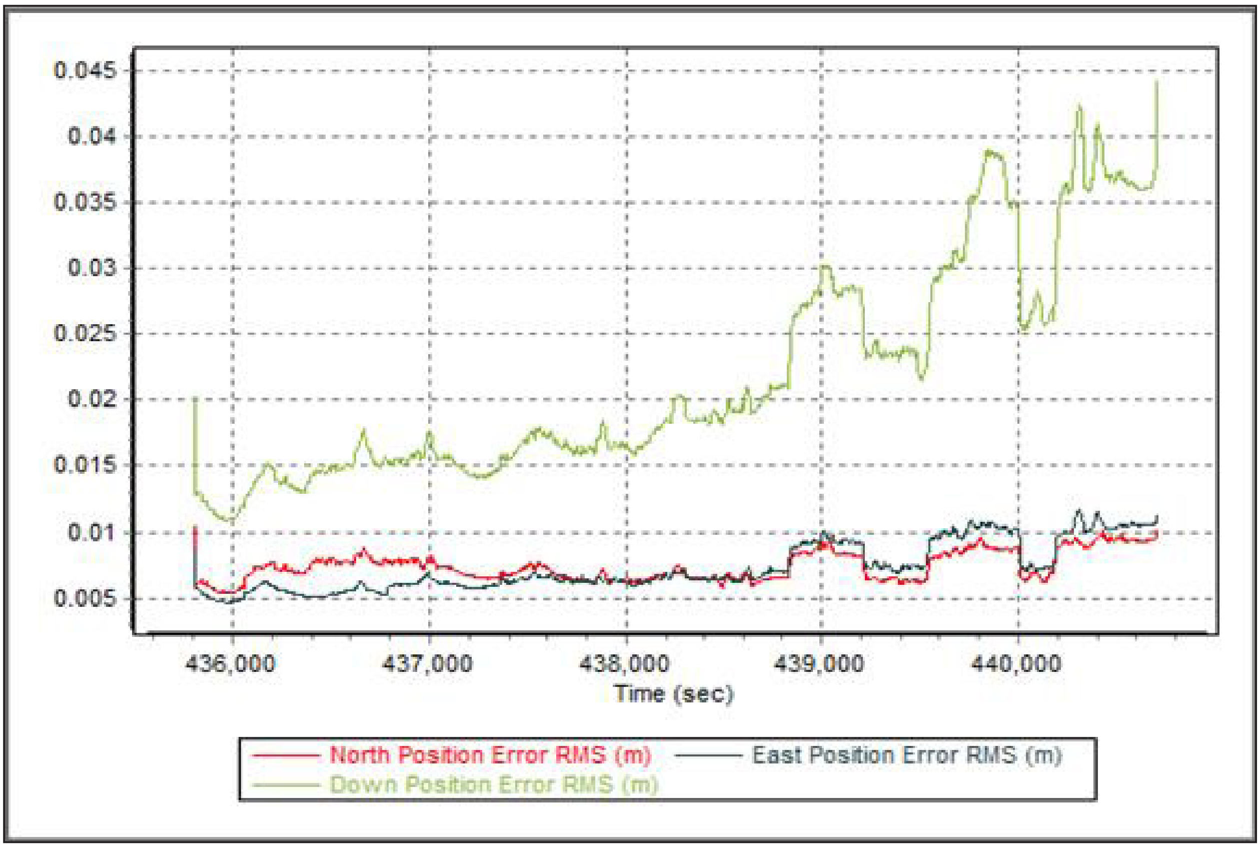


Figure A-8.23. Smoothed Performance Metric Parameters

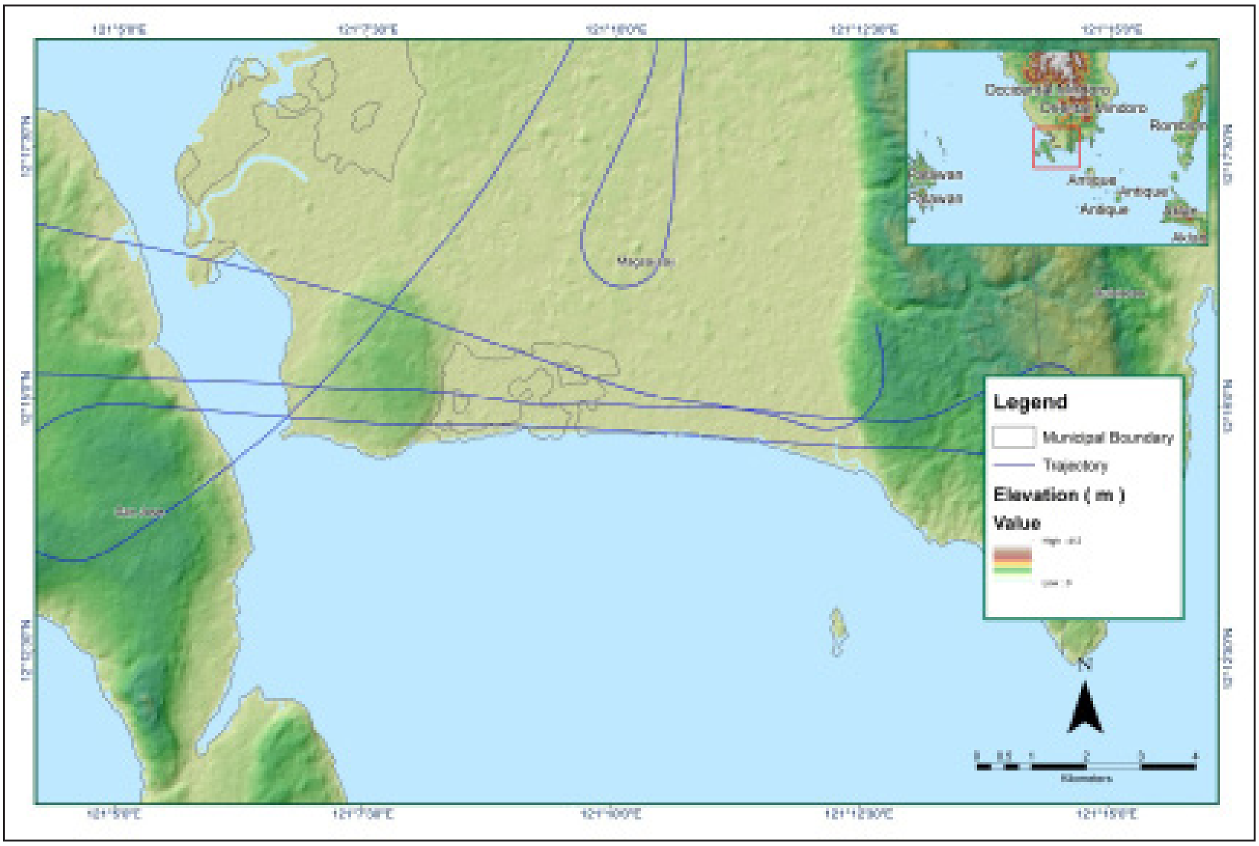


Figure A-8.24. Best Estimated Trajectory

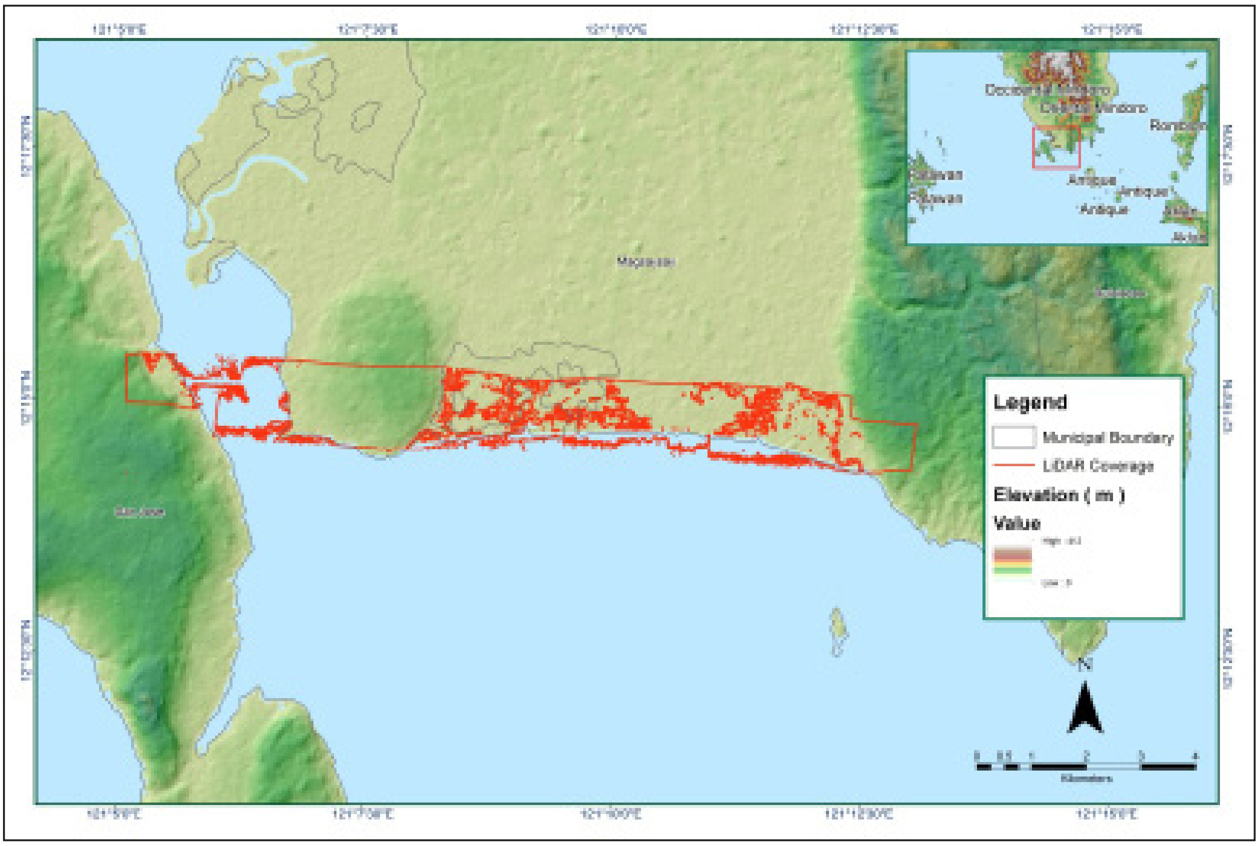


Figure A-8.25. Coverage of LiDAR data

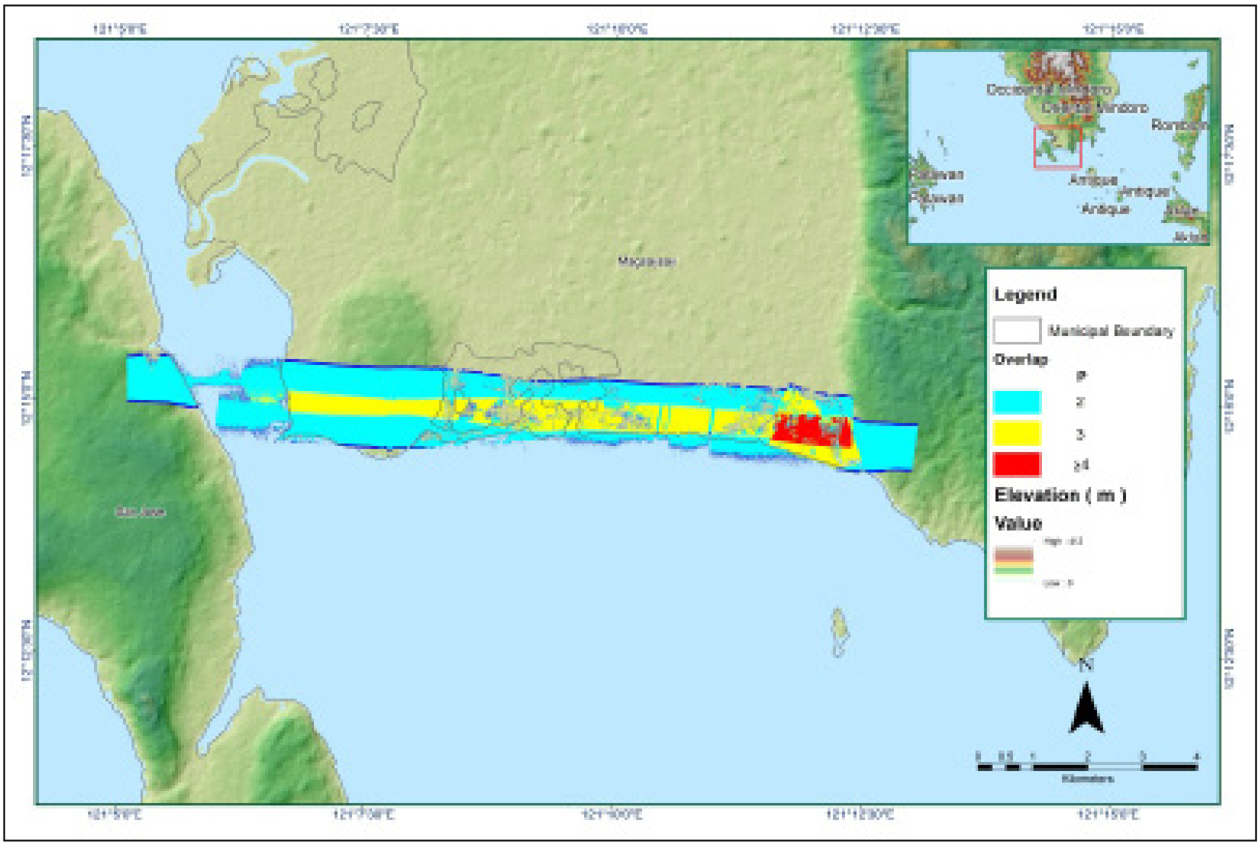


Figure A-8.26. Image of data overlap

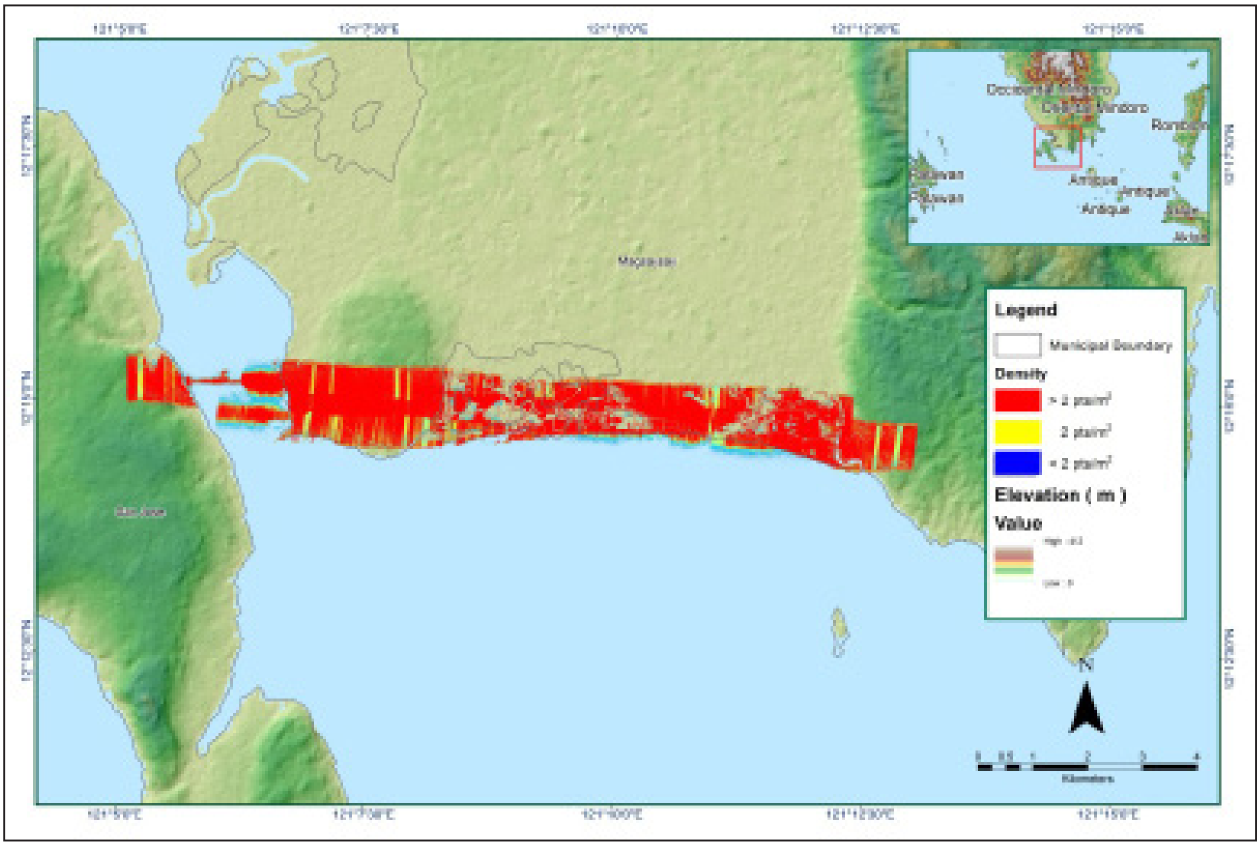


Figure A-8.27. Density map of merged LiDAR data

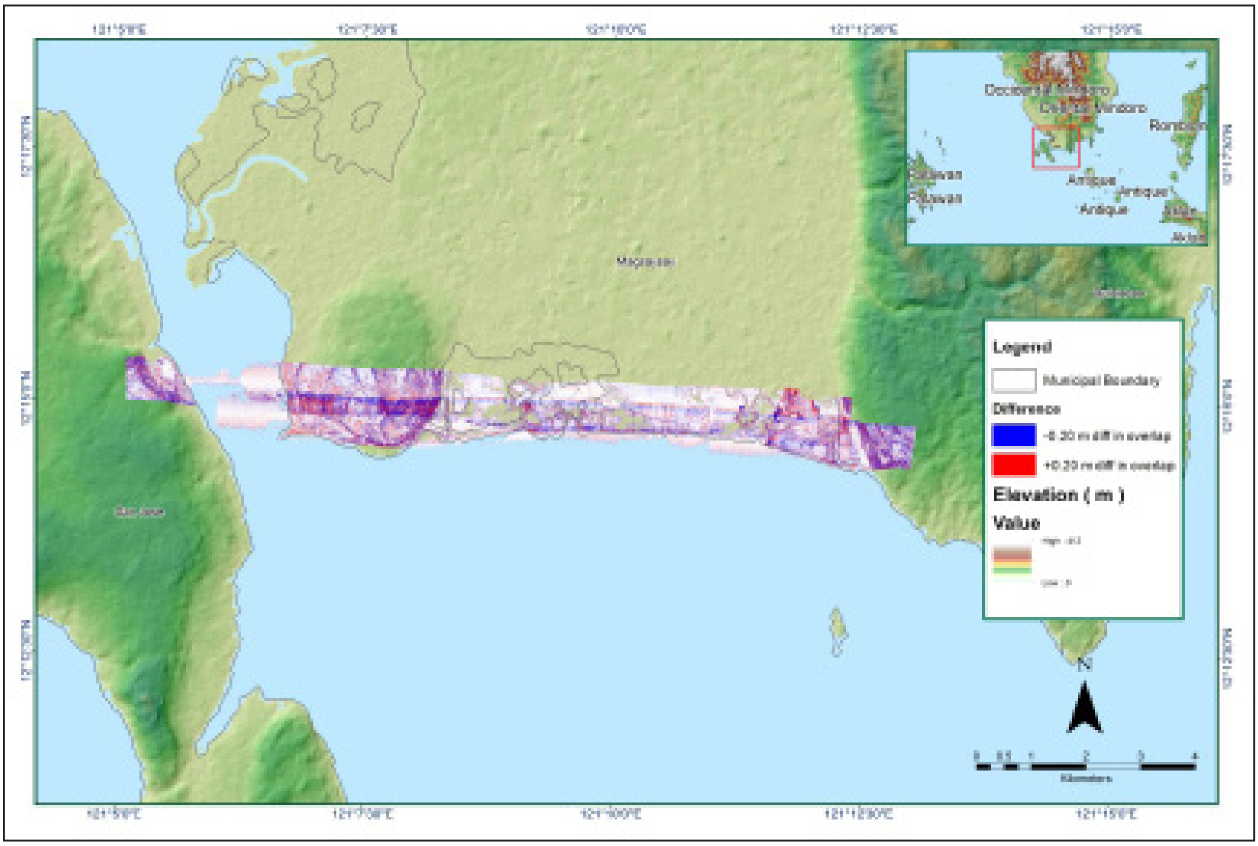


Figure A-8.28. Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Mission Blk29B_additional

Flight Area	Davao Oriental
Mission Name	Blk29B_additional
Inclusive Flights	3078P
Range data size	6.2GB
Base data size	7.02MB
POS	167MB
Image	12.9MB
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.01
RMSE for East Position (<4.0 cm)	1.16
RMSE for Down Position (<8.0 cm)	4.25
Boresight correction stdev (<0.001deg)	0.359804
IMU attitude correction stdev (<0.001deg)	0.083211
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	17.73%
Ave point cloud density per sq.m. (>2.0)	1.81
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	18
Maximum Height	322.24 m
Minimum Height	53.37 m
Classification (# of points)	
Ground	13,137,914
Low vegetation	6,256,653
Medium vegetation	4,588,390
High vegetation	8,091,371
Building	187,119
Orthophoto	Yes
Processed by	Engr. Abigail Ching, Engr. Harmond Santos, Engr. Melissa Fernandez

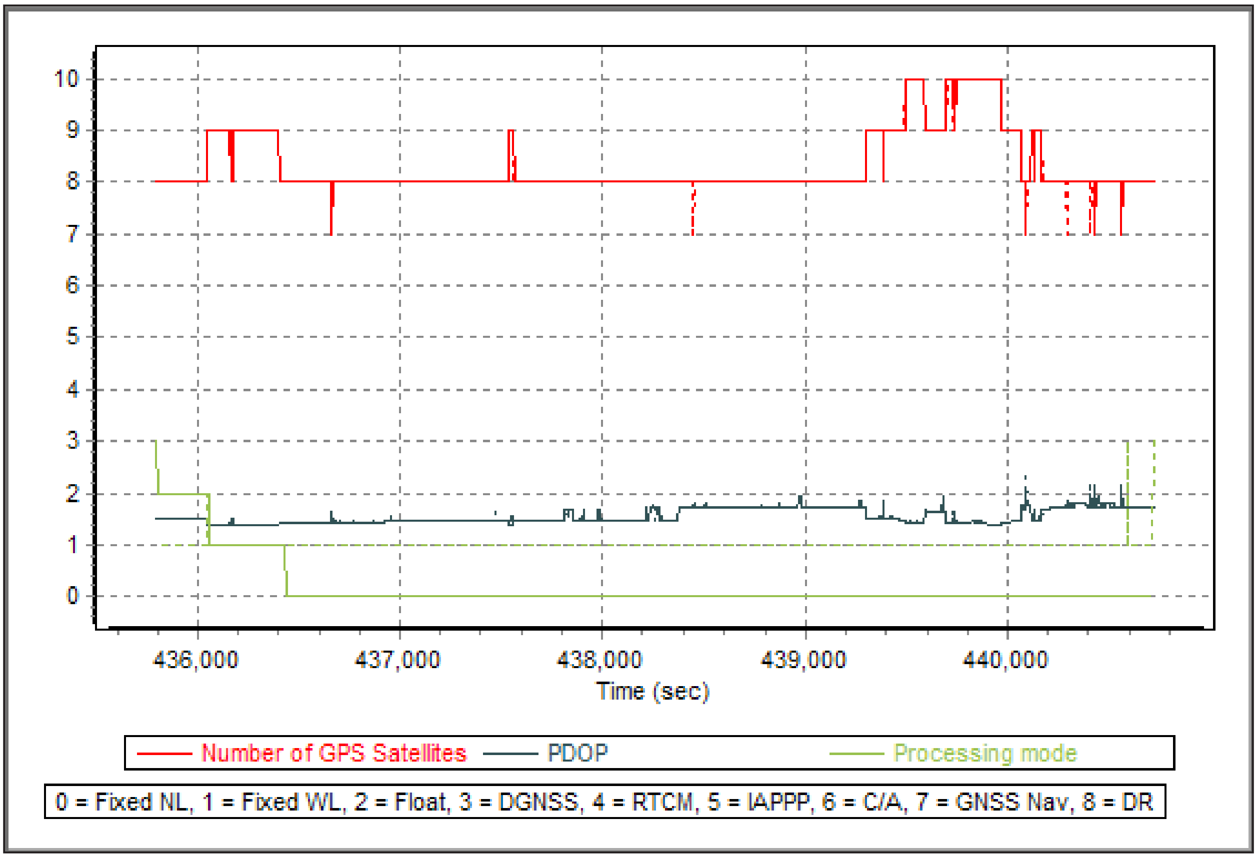


Figure A-8.29. Solution Status

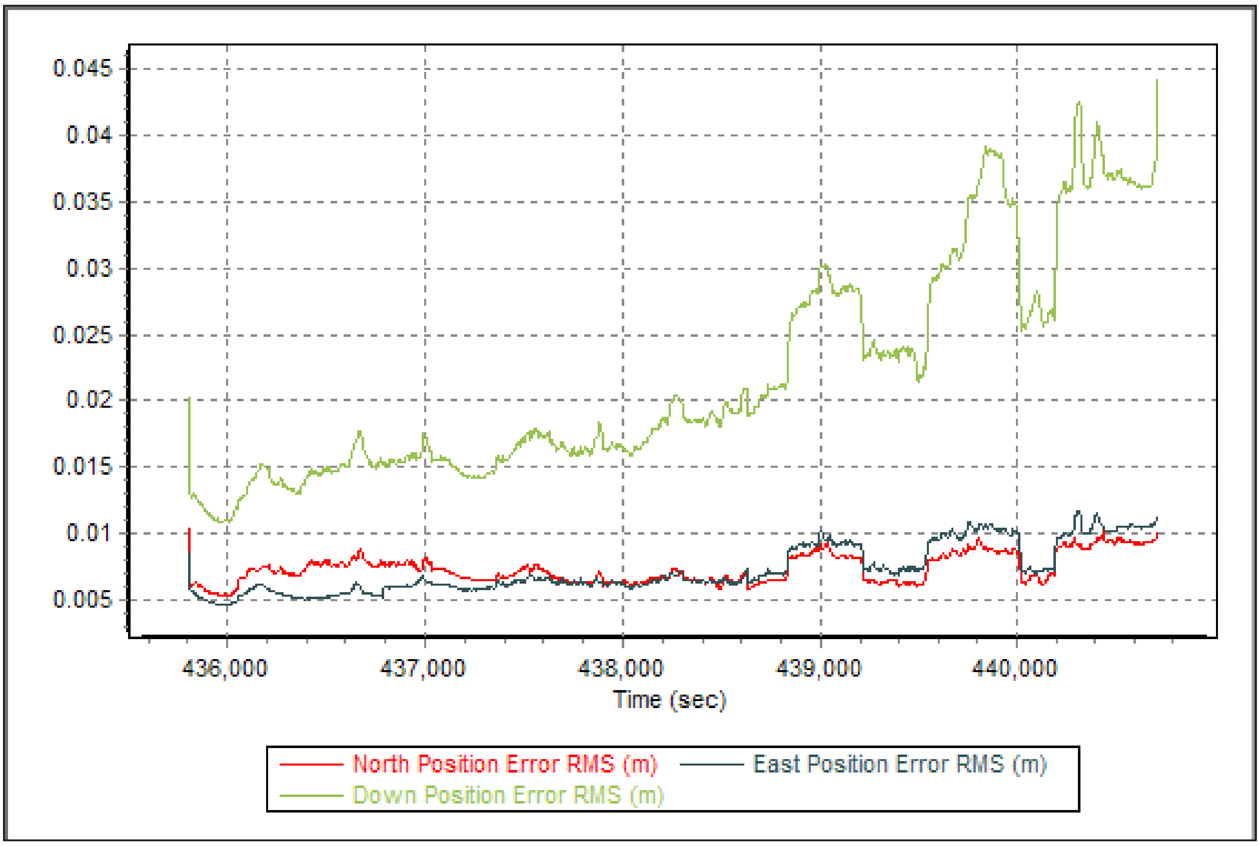


Figure A-8.30. Smoothed Performance Metric Parameters

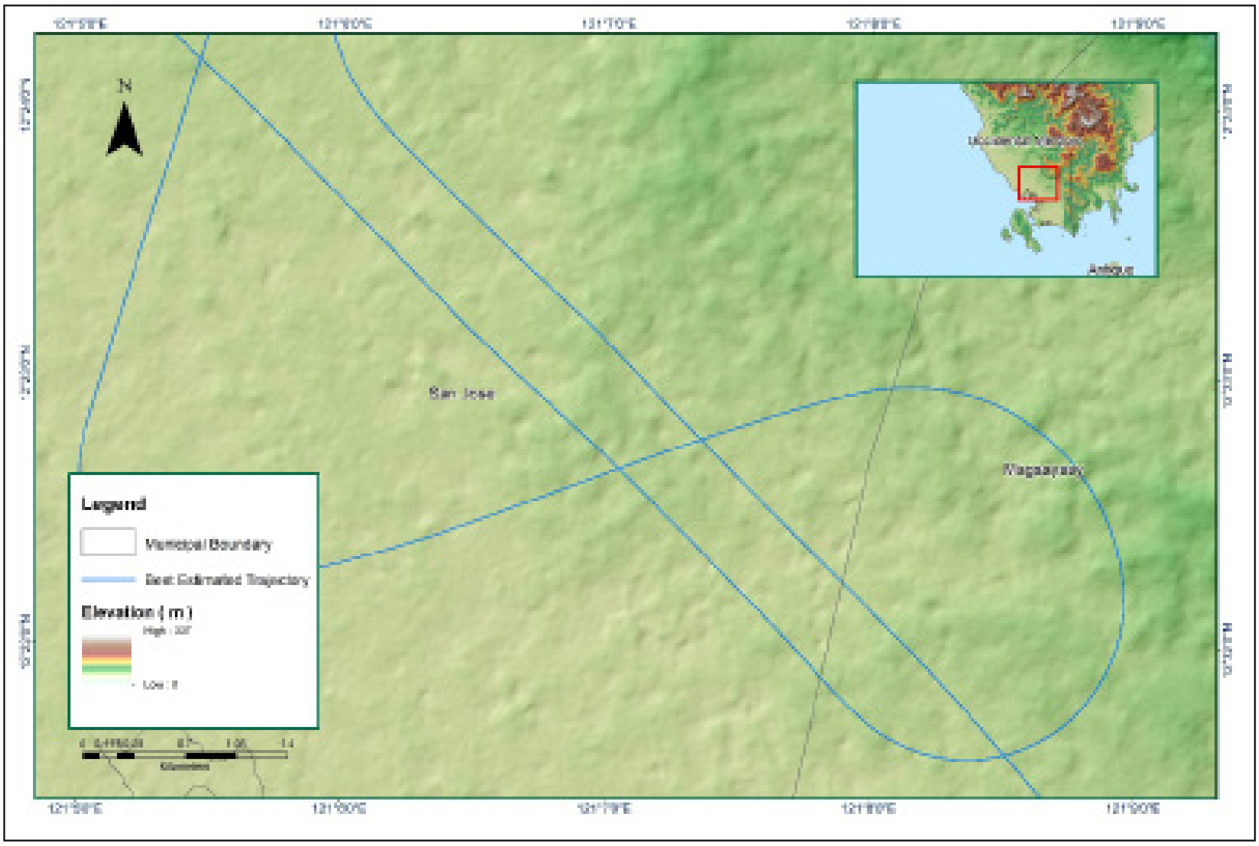


Figure A-8.31. Best Estimated Trajectory

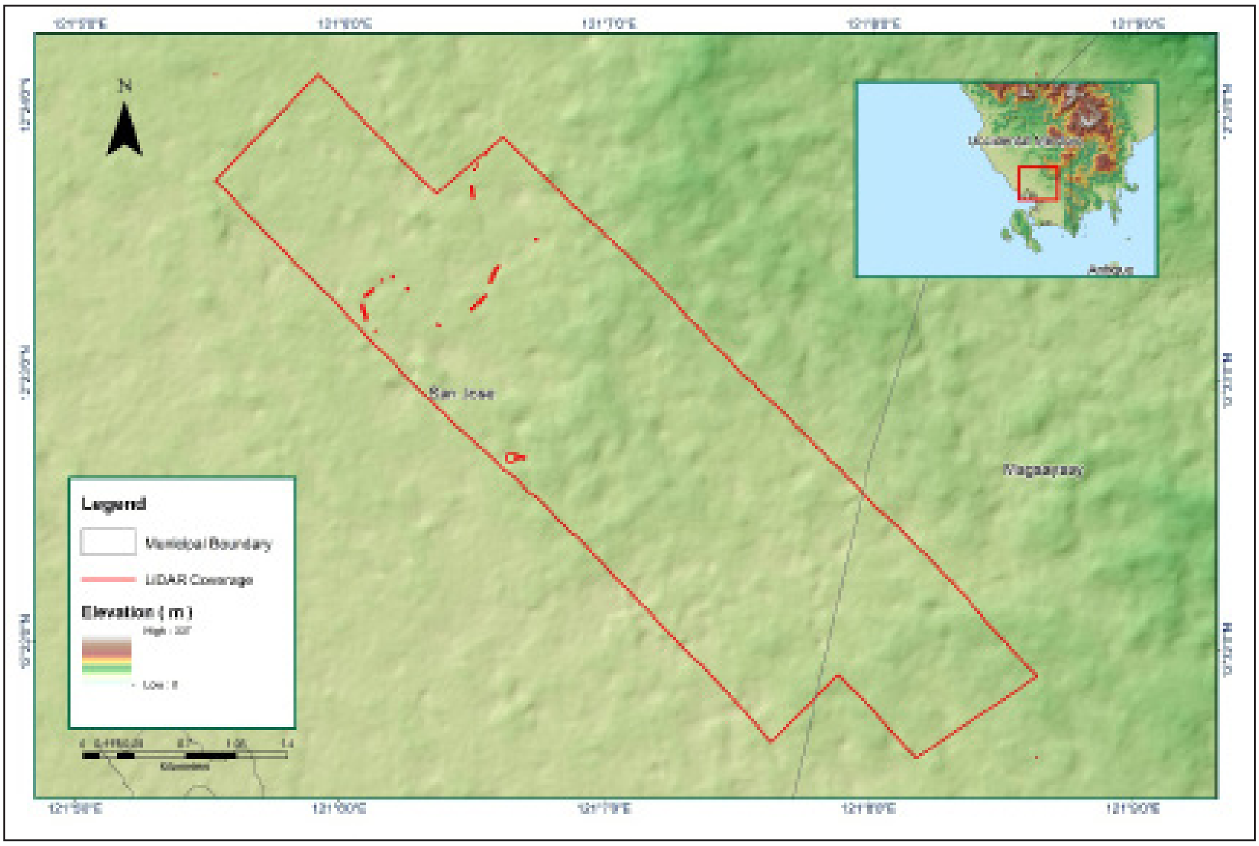


Figure A-8.32. Coverage of LiDAR data

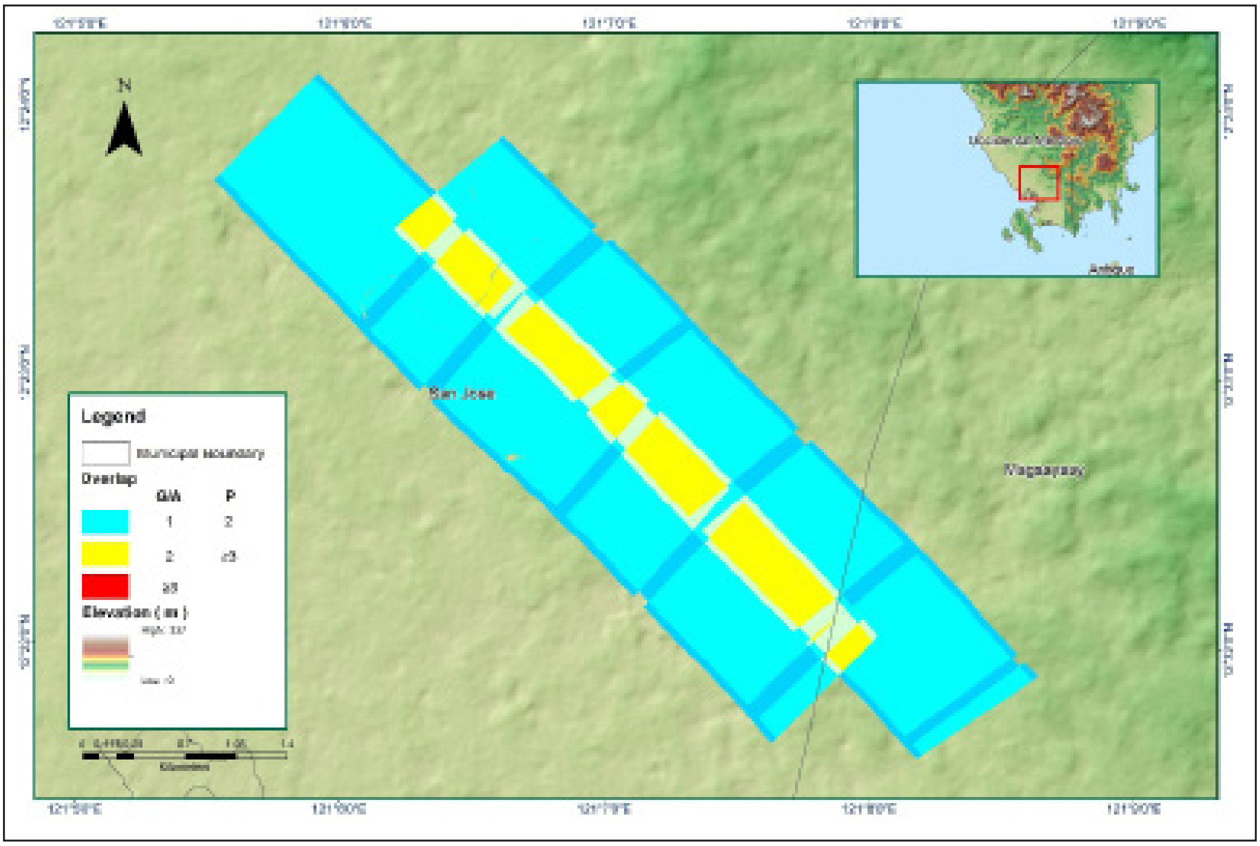


Figure A-8.33. Image of data overlap

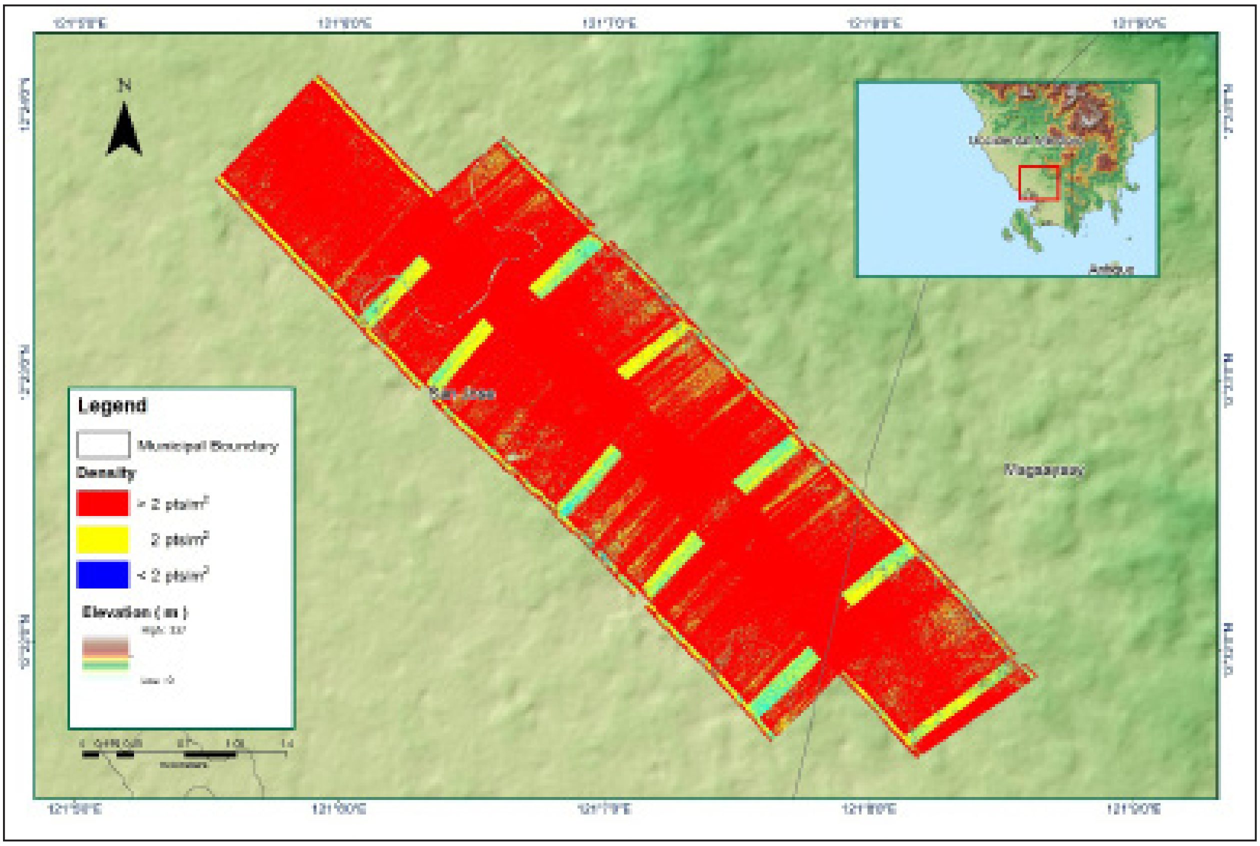


Figure A-8.34. Density map of merged LiDAR data

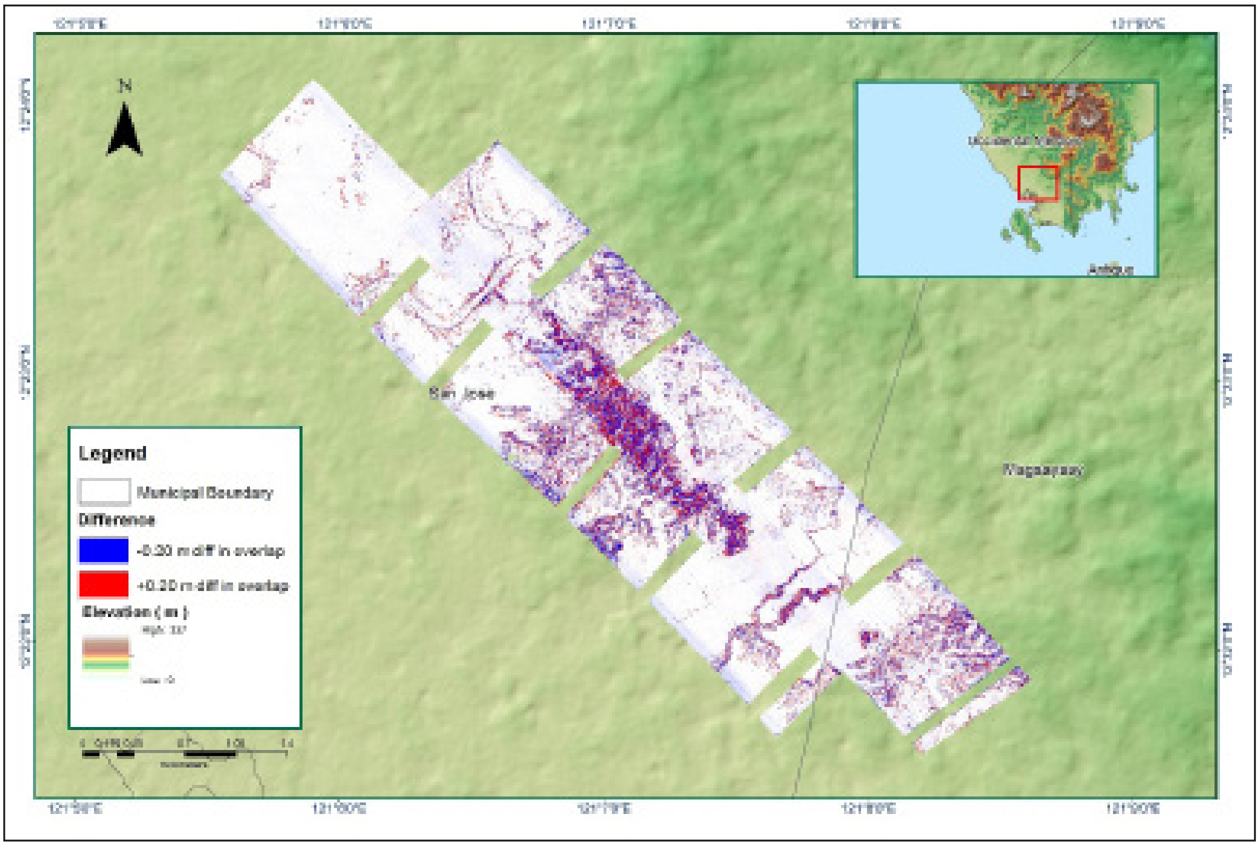


Figure A-8.35. Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Mission Blk29C_additional

Flight Area	Davao Oriental
Mission Name	Blk29C_additional
Inclusive Flights	3078P, 3082P
Range data size	15.42GB
POS	341MB
Image	26MB
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)	0.79
RMSE for East Position (<4.0 cm)	0.78
RMSE for Down Position (<8.0 cm)	1.67
Boresight correction stdev (<0.001deg)	0.359804
IMU attitude correction stdev (<0.001deg)	0.083211
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	40.31
Ave point cloud density per sq.m. (>2.0)	2.10
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	108
Maximum Height	521.55 m
Minimum Height	51.07 m
Classification (# of points)	
Ground	132,379,761
Low vegetation	125,752,184
Medium vegetation	199,077,351
High vegetation	599,574,573
Building	15,255,571
Orthophoto	Yes
Processed by	Engr. Abigail Ching, Engr. Harmond Santos, Kathryn Claudyn Zarate

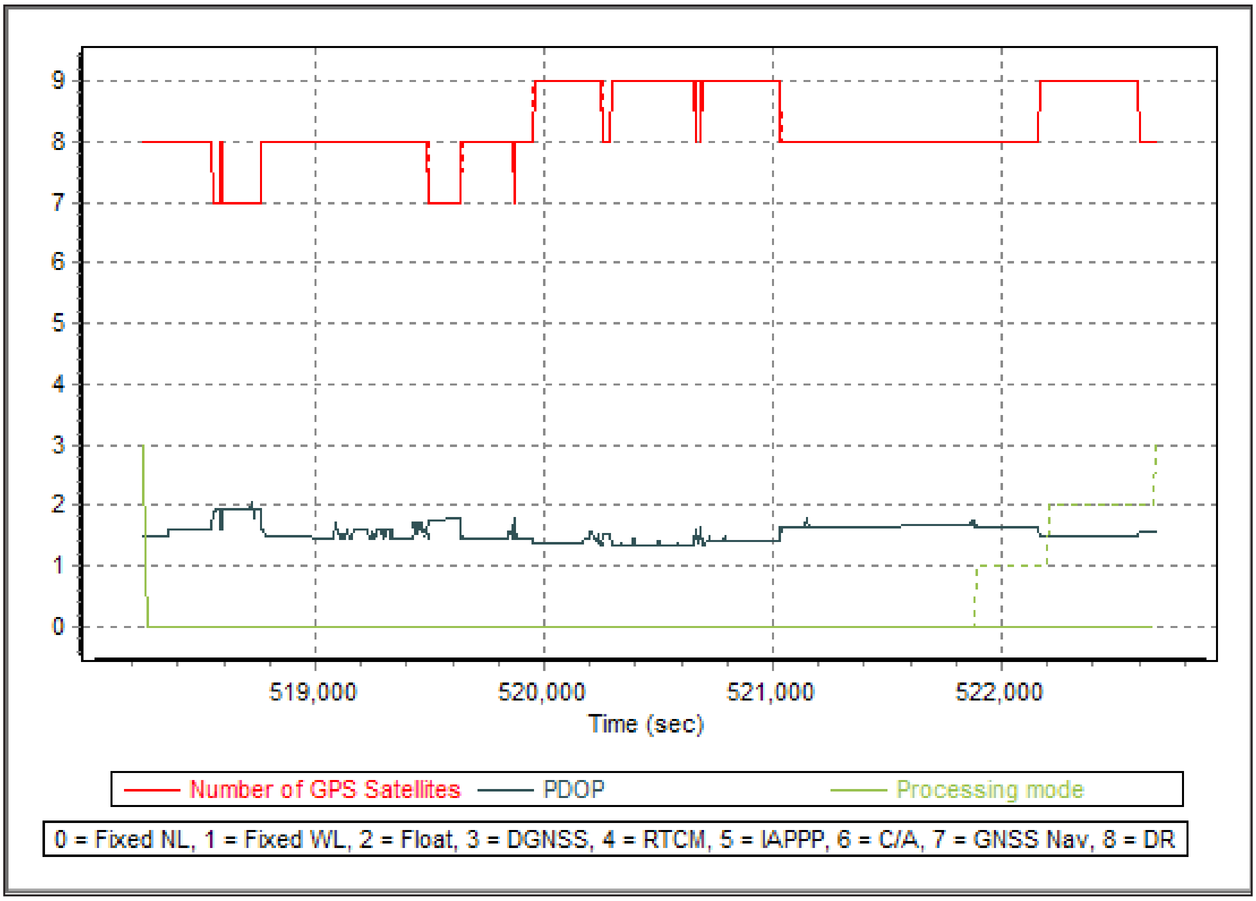


Figure A-8.36. Solution Status

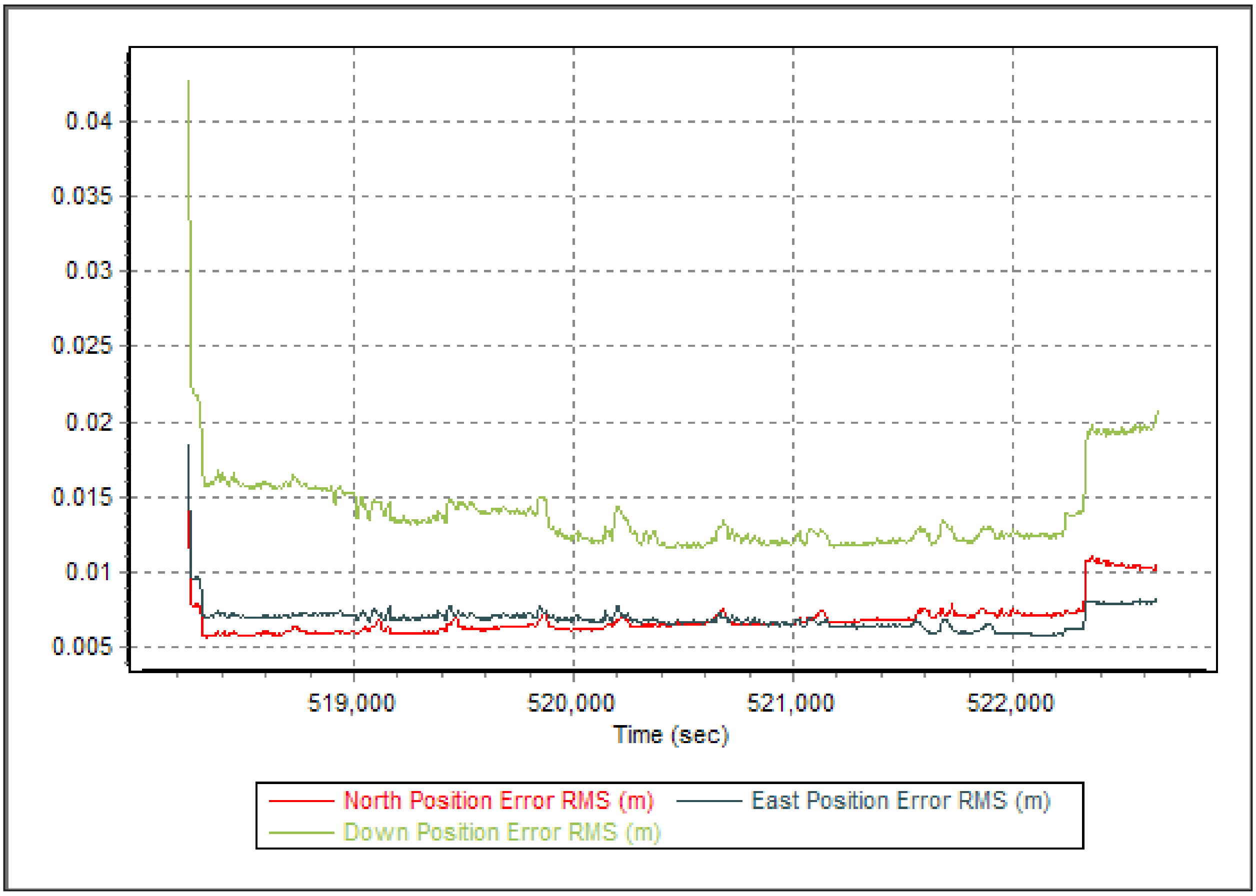


Figure A-8.37. Smoothed Performance Metric Parameters

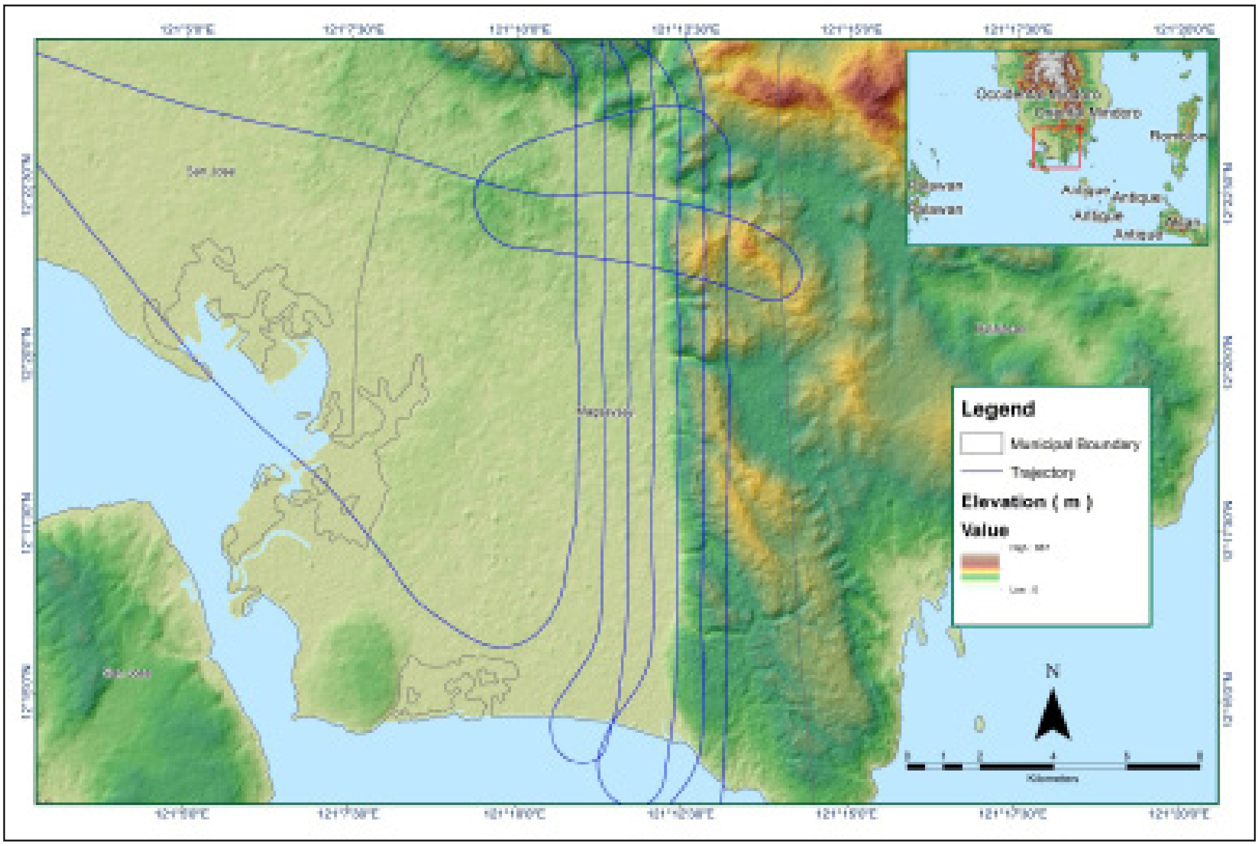


Figure A-8.38. Best Estimated Trajectory

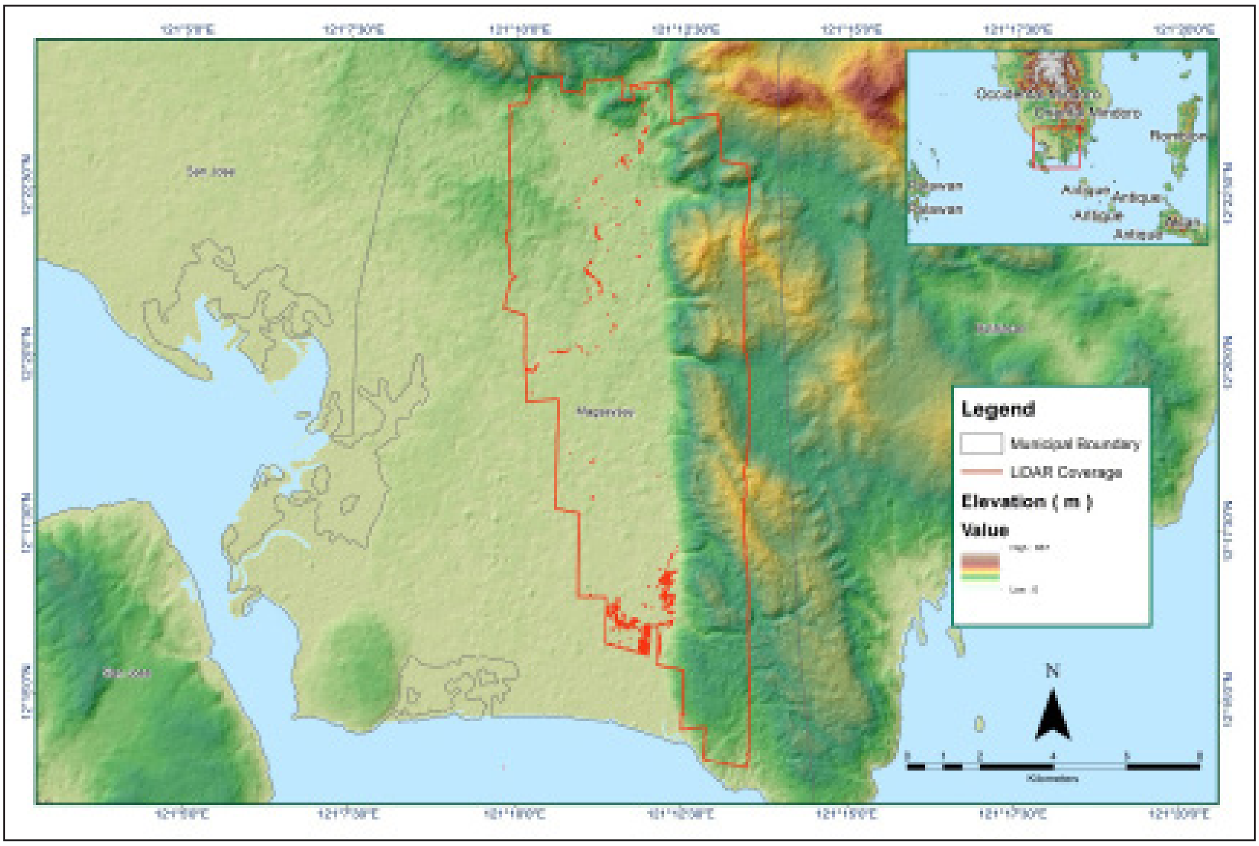


Figure A-8.39. Coverage of LiDAR data

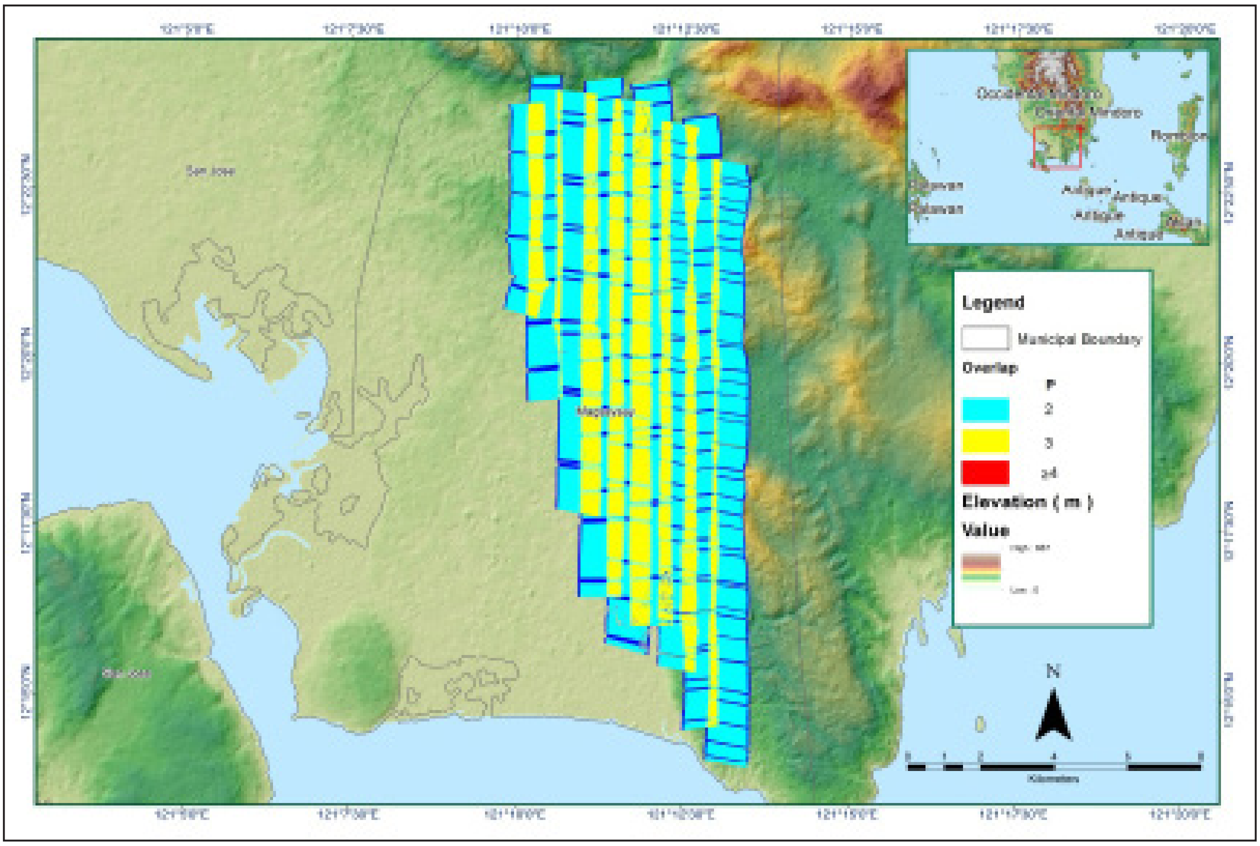


Figure A-8.40. Image of data overlap

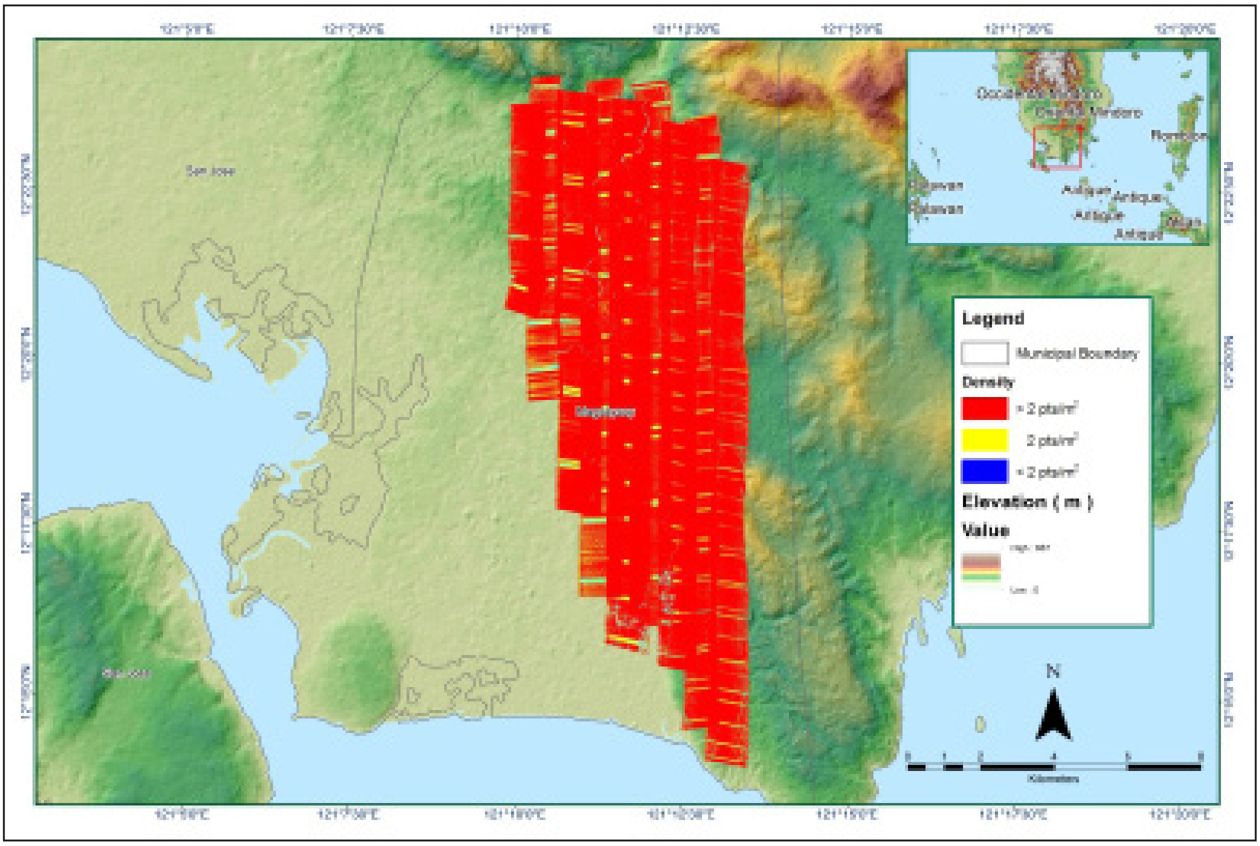


Figure A-8.41. Density map of merged LiDAR data

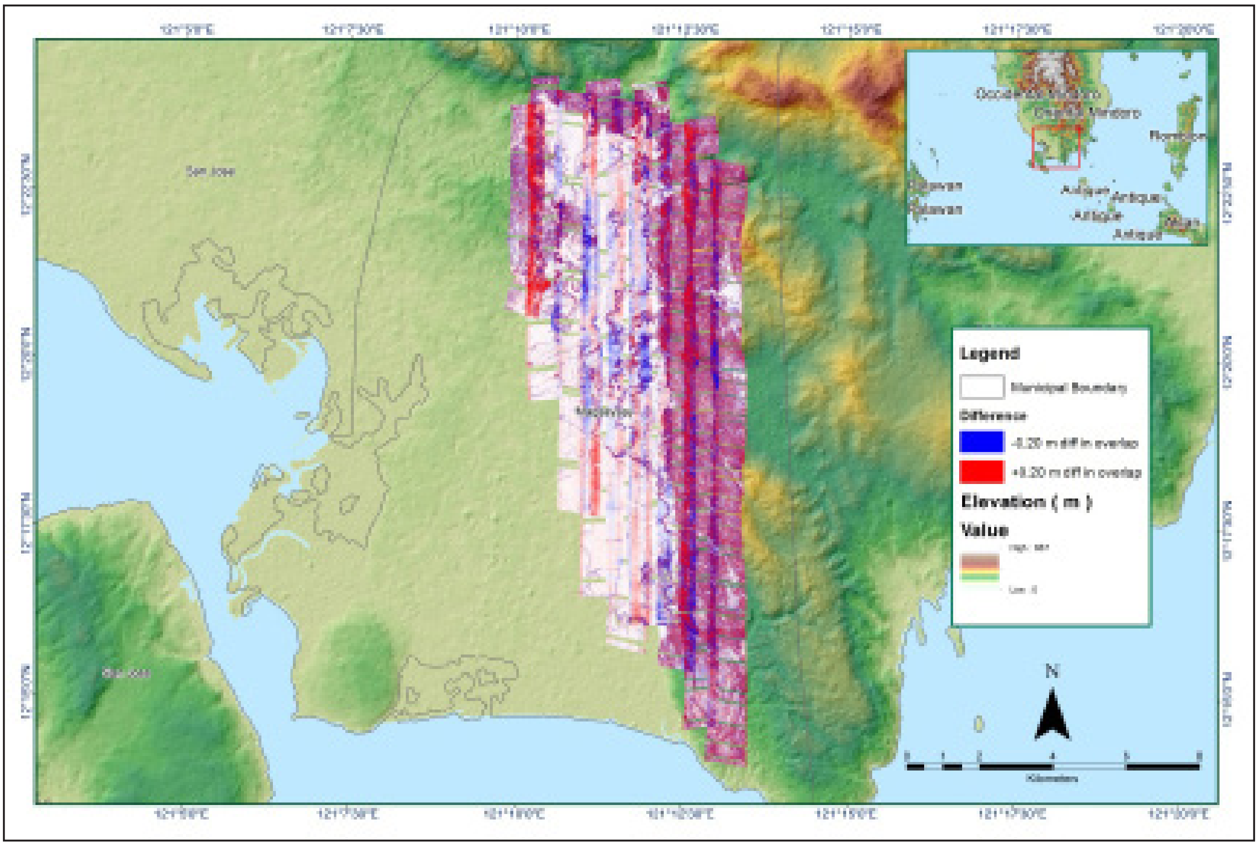


Figure A-8.42. Elevation difference between flight lines

Annex 9. Caguray Model Basin Parameters

Sub-basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (M3/S)	Recession Constant	Ratio to Peak
W1000	0.1458	68.331	0.0	0.1253	60.304	0.27230	1	0.5000
W1010	0.1294	68.331	0.0	0.11321	80.099	0.10504	1	0.5000
W1040	20.272	61.1743	0.0	1.6278	39.849	0.31144	1	0.5000
W1050	0.1964	99	0.0	0.54572	345.89	0.29530	1	0.5
W520	0.5432	92.532	0.0	0.42315	60.121	0.23650	1	0.5
W530	1.2222	92.532	0.0	0.92922	88.414	0.34808	1	0.5
W540	0.472	99	0.0	0.65115	138.48	0.68559	1	0.5
W550	0.5432	92.532	0.0	3.1593	89.84	0.44300	1	0.5
W560	0.5432	94.421	0.0	1.3939	102.05	0.35383	1	0.5
W570	0.816	96.885	0.0	2.8	174.69	0.75110	1	0.5
W580	0.5432	92.532	0.0	1.8204	116.46	0.28501	1	0.5
W590	0.5432	93.802	0.0	2.9157	124.93	0.54392	1	0.5
W600	1.2086	96.965	0.0	0.64102	92.767	0.36002	1	0.5
W610	0.5352	97.234	0.0	2.2193	141.25	0.72187	1	0.5
W620	0.5076	95.826	0.0	1.3338	127.79	0.78438	1	0.5
W630	0.5432	97.208	0.0	0.80972	76.951	0.22689	1	0.5
W640	2.334	68.331	0.0	1.4139	138.78	0.61288	1	0.5
W650	0.5432	62.946	0.0	0.17336	37.838	0.0169690	1	0.5
W660	0.5432	62.946	0.0	0.64138	94.004	0.10105	1	0.5
W670	0.7986	92.532	0.0	0.094735	22.522	.000663181	1	0.4802
W680	0.5432	92.532	0.0	0.86797	84.578	0.43717	1	0.5
W690	0.5432	99	0.0	0.68016	97.427	0.26251	1	0.5
W700	0.4816	99	0.0	1.0836	155.19	0.62682	1	0.5

Sub-basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (M3/S)	Recession Constant	Ratio to Peak
W710	0.3454	99	0.0	0.21805	45.486	0.18063	1	0.5
W720	0.4316	99	0.0	0.38721	84.853	0.35507	1	0.5
W730	1.2222	94.809	0.0	2.1907	139.43	0.65987	1	0.5
W740	0.5106	64.992	0.0	0.24921	79.963	0.21583	1	0.5
W750	0.5432	62.946	0.0	0.42364	62.246	0.0578862	1	0.5
W760	0.3502	99	0.0	0.63613	90.826	0.17837	1	0.5
W770	0.3946	99	0.0	0.37577	120.98	0.58995	1	0.5
W780	0.5432	99	0.0	0.09213	66.172	0.0154847	1	0.5
W790	0.5368	99	0.0	1.9798	189.93	0.55494	1	0.5
W800	1.1276	65.607	0.0	0.70668	102.24	0.26565	1	0.5
W810	0.5602	91.079	0.0	1.1138	159.5	0.95204	1	0.5
W820	1.2222	62.946	0.0	0.4252	93.245	0.30553	1	0.5
W830	1.1412	65.211	0.0	0.34601	75.888	0.25639	1	0.5
W840	2.75	42.821	0.0	0.2935	95.942	0.0912979	1	0.5
W850	0.4842	99	0.0	0.71624	69.124	0.36562	1	0.5
W860	1.1498	67.648	0.0	0.10129	74.201	0.28254	1	0.5
W870	0.7656	88.905	0.0	0.3824	125.18	0.52965	1	0.5
W880	0.5432	99	0.0	0.54271	116.51	0.25141	1	0.5
W890	0.7986	99	0.0	2.5252	105.07	0.27817	1	0.5
W900	0.9754	99	0.0	0.22251	158.37	0.79070	1	0.5
W910	0.403	99	0.0	0.14794	47.649	0.32253	1	0.5
W920	0.2732	99	0.0	0.07321	15.632	0.24728	1	0.2222
W930	0.3444	99	0.0	0.25243	287.16	0.19742	1	0.5
W940	0.5432	99	0.0	0.14816	163.49	0.37988	1	0.5
W950	0.4394	99	0.0	0.15159	32.425	0.0517649	1	0.4917

Sub-basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (M3/S)	Recession Constant	Ratio to Peak
W960	0.3936	99	0.0	0.14121	100.67	0.48522	1	0.5
W970	0.6004	99	0.0	0.11528	24.538	0.37268	1	0.3333
W980	0.8932	99	0.0	2.1041	456.64	1.2000	1	0.5
W990	0.6162	99	0.0	0.22157	161.37	0.60090	1	0.5

Annex 10. Caguray Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R1060	Automatic Fixed Interval	8193.6	0.0046050	0.0669292	Trapezoid	40	1
R130	Automatic Fixed Interval	56.569	0.0141509	0.5452	Trapezoid	40	1
R140	Automatic Fixed Interval	1393.3	0.0067208	0.36539	Trapezoid	40	1
R150	Automatic Fixed Interval	5701.9	0.0133876	0.54531	Trapezoid	40	1
R160	Automatic Fixed Interval	3543.3	0.0141264	0.2448	Trapezoid	40	1
R190	Automatic Fixed Interval	2426.2	0.0077829	0.35627	Trapezoid	40	1
R220	Automatic Fixed Interval	3349.1	0.0091600	0.16238	Trapezoid	40	1
R230	Automatic Fixed Interval	2646.3	0.0061734	0.24238	Trapezoid	40	1
R240	Automatic Fixed Interval	2658.4	0.0065554	0.15835	Trapezoid	40	1
R250	Automatic Fixed Interval	1400.5	0.0110834	0.16076	Trapezoid	40	1
R260	Automatic Fixed Interval	118.28	0.0273725	0.15836	Trapezoid	40	1
R280	Automatic Fixed Interval	2263.1	0.0027761	0.23221	Trapezoid	40	1
R310	Automatic Fixed Interval	3547.5	0.0048115	0.23274	Trapezoid	40	1
R320	Automatic Fixed Interval	1758.5	0.0086590	0.10772	Trapezoid	40	1

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R330	Automatic Fixed Interval	5530.8	0.0156066	0.16029	Trapezoid	40	1
R350	Automatic Fixed Interval	3248.8	0.0051373	0.23636	Trapezoid	40	1
R410	Automatic Fixed Interval	1738.2	0.0017449	0.10244	Trapezoid	40	1
R420	Automatic Fixed Interval	7732.6	0.0042001	0.15442	Trapezoid	40	1
R440	Automatic Fixed Interval	905.69	0.0042001	0.10453	Trapezoid	40	1
R450	Automatic Fixed Interval	4671.6	0.0305024	0.0696889	Trapezoid	40	1
R460	Automatic Fixed Interval	4474.2	0.0016455	0.0696889	Trapezoid	40	1
R500	Automatic Fixed Interval	1767.8	0.0046050	0.0696889	Trapezoid	40	1
R510	Automatic Fixed Interval	9161.4	0.0046050	0.04	Trapezoid	40	1
R70	Automatic Fixed Interval	4911.4	0.0201613	0.54495	Trapezoid	40	1
R80	Automatic Fixed Interval	7061.7	0.0330236	0.36499	Trapezoid	40	1
R90	Automatic Fixed Interval	683.55	0.0141509	0.54533	Trapezoid	40	1

Annex 11. Caguray Field Validation Data

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	12.2677593	121.139577	0.052	0.00	-0.05		25-Year
2	12.26808239	121.1359749	0.096	0.00	-0.10		25-Year
3	12.26811462	121.1353353	0.042	0.00	-0.04		25-Year
4	12.26817205	121.1348946	0.056	0.00	-0.06		25-Year
5	12.2683501	121.1396667	0.178	0.00	-0.18		25-Year
6	12.26855913	121.139096	0.067	0.00	-0.07		25-Year
7	12.26867158	121.1358332	0.056	0.00	-0.06		25-Year
8	12.2687375	121.1369316	0.097	0.00	-0.10		25-Year
9	12.26890997	121.1370532	0.06	0.00	-0.06		25-Year
10	12.26898759	121.136709	0.072	0.00	-0.07		25-Year
11	12.26906449	121.1348371	0.078	0.00	-0.08		25-Year
12	12.26918658	121.1388668	0.119	0.00	-0.12		25-Year
13	12.26918873	121.1377438	0.138	0.00	-0.14		25-Year
14	12.26942876	121.1364042	0.162	0.00	-0.16		25-Year
15	12.26947415	121.1384567	0.247	0.00	-0.25		25-Year
16	12.26948678	121.1375942	0.278	0.00	-0.28		25-Year
17	12.26983985	121.1342523	0.202	0.00	-0.20		25-Year
18	12.26990337	121.1332585	0.074	0.00	-0.07		25-Year
19	12.27053581	121.1343376	0.293	0.00	-0.29		25-Year
20	12.27085968	121.1369329	0.081	0.30	0.22		25-Year
21	12.27101084	121.1333797	0.036	0.00	-0.04	Ruby / Dec. 2014	25-Year
22	12.27107064	121.1403548	0.035	0.60	0.57		25-Year
23	12.27104627	121.1365413	0.268	0.60	0.33	Ruby / Dec. 2014	25-Year
24	12.27130712	121.1420051	0.056	0.60	0.54	Ruby / Dec. 2014	25-Year
25	12.27148638	121.1399971	0.067	0.90	0.83	Ruby / Dec. 2014	25-Year
26	12.27155569	121.140664	0.032	0.60	0.57	Ruby / Dec. 2014	25-Year
27	12.27181344	121.1391873	0.03	0.60	0.57	Ruby / Dec. 2014	25-Year
28	12.27181687	121.1327829	0.061	0.00	-0.06	Ruby / Dec. 2014	25-Year
29	12.27199171	121.1365596	0.094	0.60	0.51		25-Year
30	12.27237603	121.1318774	0.077	0.00	-0.08	Ruby / Dec. 2014	25-Year
31	12.27389698	121.1320439	0.03	0.50	0.47		25-Year
32	12.27420119	121.1246051	0.216	1.00	0.78	Ruby / Dec. 2014	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
33	12.280456	121.140142	0.03	0.40	0.37	Ruby / Dec. 2014	25-Year
34	12.280598	121.140319	0.03	0.35	0.32	Ondoy / Sept. 2009	25-Year
35	12.2815	121.1406	0.199	0.24	0.04	Yolanda / Nov. 2013	25-Year
36	12.2824	121.141125	0.03	0.42	0.39	Glenda / July, 2014	25-Year
37	12.2826	121.1413	0.031	0.77	0.74	Nona / Dec. 2015	25-Year
38	12.28291	121.14136	0.268	0.50	0.23	Yolanda / Nov. 2013	25-Year
39	12.283027	121.142358	0.03	0.30	0.27	Yolanda / Nov. 2013	25-Year
40	12.28324598	121.1163547	0.03	0.30	0.27	Yolanda / Nov. 2013	25-Year
41	12.28343378	121.1168896	0.03	0.00	-0.03	Ruby / Dec. 2014	25-Year
42	12.28369153	121.1183253	0.03	0.00	-0.03		25-Year
43	12.28385491	121.1165601	0.03	0.30	0.27		25-Year
44	12.283971	121.115485	0.037	0.30	0.26	Ruby / Dec. 2014	25-Year
45	12.28404456	121.1149475	0.03	0.00	-0.03	Ruby / Dec. 2014	25-Year
46	12.2841044	121.1177292	0.056	0.30	0.244		25-Year
47	12.28436415	121.1161775	0.03	0.60	0.57	Ruby / Dec. 2014	25-Year
48	12.28454404	121.1174499	0.034	0.00	-0.034	Ruby / Dec. 2014	25-Year
49	12.28454459	121.1145975	0.075	0.00	-0.075		25-Year
50	12.28473556	121.1142957	0.054	0.00	-0.054		25-Year
51	12.28501068	121.1148755	0.038	0.00	-0.038		25-Year
52	12.28521985	121.1413016	0.03	0.90	0.87		25-Year
53	12.2852526	121.1149556	0.044	0.00	-0.044	Frank / June, 2008	25-Year
54	12.28541714	121.1146135	0.03	0.60	0.57		25-Year
55	12.28570751	121.1145189	0.049	0.70	0.651	Ruby / Dec. 2014	25-Year
56	12.28584209	121.1142662	0.031	1.00	0.969	Ruby / Dec. 2014	25-Year
57	12.28588312	121.1161351	0.048	0.30	0.252	Ruby / Dec. 2014	25-Year
58	12.28590879	121.1146586	0.03	0.90	0.87	Ruby / Dec. 2014	25-Year
59	12.28605087	121.1137754	0.054	1.00	0.946	Ruby / Dec. 2014	25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
60	12.28619179	121.1143164	0.037	1.00	0.963	Ruby / Dec. 2014	25-Year
61	12.286413	121.113646	0.03	0.70	0.67	Ruby / Dec. 2014	25-Year
62	12.28662187	121.1137243	0.03	1.00	0.97	Yolanda / Nov. 2013	25-Year
63	12.28713632	121.14006	0.03	0.00	-0.03	Ruby / Dec. 2014	25-Year
64	12.28713758	121.1152344	0.03	0.00	-0.03		25-Year
65	12.2874	121.1118	0.03	0.40	0.37		25-Year
66	12.287451	121.106806	0.123	1.30	1.177	Yolanda / Nov. 2013	25-Year
67	12.287451	121.106806	0.123	0.56	0.437	Yolanda / Nov. 2013	25-Year
68	12.287712	121.110859	0.033	0.10	0.067	Ruby / Dec. 2014	25-Year
69	12.2877	121.1076	0.149	0.77	0.621	Ruby / Dec. 2014	25-Year
70	12.288088	121.107628	0.343	1.00	0.657	Glenda / July, 2014	25-Year
71	12.288137	121.109273	0.259	0.85	0.591	Ruby / Dec. 2014	25-Year
72	12.2881785	121.1140012	0.03	0.00	-0.03	Aug. 2015	25-Year
73	12.288228	121.108309	0.363	0.95	0.587		25-Year
74	12.28826257	121.1078895	0.286	1.30	1.014	Yolanda / Nov. 2013	25-Year
75	12.28846631	121.1084624	0.296	1.30	1.004	Ruby / Dec. 2014	25-Year
76	12.288522	121.1095252	0.111	1.30	1.189	Ruby / Dec. 2014	25-Year
77	12.2888	121.1101	0.03	0.7	0.67	Ruby / Dec. 2014	25-Year
78	12.29604087	121.1485593	1.32	0.9	-0.42	Undang / 1984	25-Year
79	12.29769703	121.1368933	0.03	0	-0.03	Mario / Sept. 2014	25-Year
80	12.29790457	121.1465242	0.03	0	-0.03		25-Year
81	12.30016443	121.1466252	0.031	0	-0.031		25-Year
82	12.30080732	121.1466362	0.03	0	-0.03		25-Year
83	12.30216259	121.1493133	0.037	0	-0.037		25-Year
84	12.30300969	121.151692	0.858	0.9	0.042		25-Year
85	12.30471438	121.1514492	0.03	0	-0.03	Mario / Sept. 2014	25-Year
86	12.30694932	121.1511363	0.03	0	-0.03		25-Year
87	12.30704819	121.138254	0.03	0	-0.03		25-Year
88	12.30837591	121.1497059	0.03	0	-0.03		25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
89	12.30836425	121.1429956	0.03	0	-0.03		25-Year
90	12.3083822	121.1356902	0.03	0	-0.03		25-Year
91	12.30873982	121.1426897	0.036	0	-0.036		25-Year
92	12.30887093	121.1437328	0.031	0	-0.031		25-Year
93	12.30920466	121.1340459	0.03	0	-0.03		25-Year
94	12.30931966	121.1494876	0.031	0	-0.031		25-Year
95	12.30972792	121.1433471	0.031	0	-0.031		25-Year
96	12.30992565	121.147753	0.055	0	-0.055		25-Year
97	12.31063205	121.1464339	0.03	0	-0.03		25-Year
98	12.31175295	121.144631	0.03	0	-0.03		25-Year
99	12.31194925	121.1460993	0.03	0	-0.03		25-Year
100	12.31682036	121.1464441	0.03	0	-0.03		25-Year
101	12.31818137	121.1463399	0.03	0	-0.03		25-Year
102	12.31878966	121.1488838	0.03	0	-0.03		25-Year
103	12.31892575	121.1478403	0.03	0	-0.03		25-Year
104	12.31937536	121.1462643	0.03	0	-0.03		25-Year
105	12.31981115	121.1493826	0.03	0	-0.03		25-Year
106	12.3212637	121.1460699	0.031	0	-0.031		25-Year
107	12.32141748	121.1501692	0.03	0	-0.03		25-Year
108	12.3231649	121.1455786	0.03	0	-0.03		25-Year
109	12.32450852	121.1466509	0.03	0	-0.03		25-Year
110	12.32641608	121.1455303	0.031	0	-0.031		25-Year
111	12.32794347	121.1446483	0.03	0	-0.03		25-Year
112	12.33484516	121.1403739	0.631	0	-0.631		25-Year
113	12.33541404	121.1384496	0.03	0	-0.03		25-Year
114	12.33617703	121.1377899	0.066	0	-0.066		25-Year
115	12.337552	121.17735	2.251	0.6	-1.651		25-Year
116	12.3375274	121.137022	0.03	0	-0.03	Yolanda / Nov. 2013	25-Year
117	12.337885	121.17717	1.372	0.5	-0.872		25-Year
118	12.3382249	121.1352883	0.03	0	-0.03	Undang / 1984	25-Year
119	12.33915982	121.1346933	0.078	0	-0.078		25-Year
120	12.339481	121.17681	0.03	0	-0.03		25-Year
121	12.33981626	121.1342148	0.03	0	-0.03		25-Year
122	12.34130204	121.1338624	0.035	0	-0.035		25-Year
123	12.34160143	121.155423	0.03	0	-0.03		25-Year
124	12.342589	121.133367	0.036	0	-0.036		25-Year
125	12.343543	121.17839	0.03	0	-0.03		25-Year
126	12.34345954	121.133481	0.146	0	-0.146		25-Year
127	12.344377	121.1331039	0.03	0	-0.03		25-Year
128	12.34475837	121.1326007	0.089	0	-0.089		25-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
129	12.34692781	121.133061	0.288	0	-0.288		25-Year
130	12.34747038	121.1319442	0.607	0	-0.607		25-Year
131	12.34827659	121.1310979	0.467	0	-0.467		25-Year
132	12.35144908	121.1298895	0.052	0	-0.052		25-Year
133	12.3522015	121.1301683	0.284	0	-0.284		25-Year
134	12.35250501	121.1270408	0.03	0	-0.03		25-Year
135	12.35412972	121.1264919	0.031	0	-0.031		25-Year
136	12.35536653	121.1252275	0.03	0	-0.03		25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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