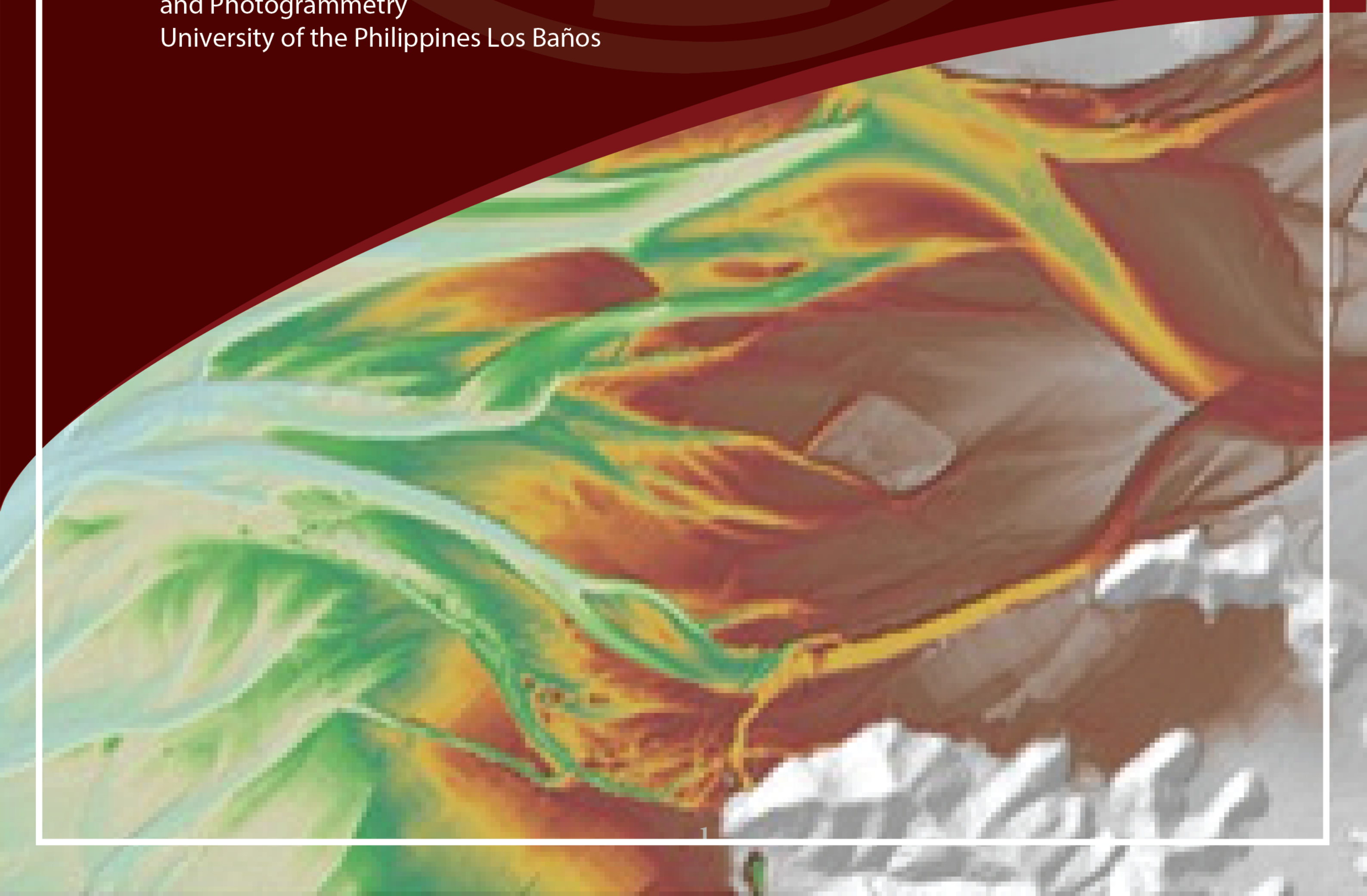
Hazard Mapping of the Philippines Using LIDAR (Phil-LiDAR 1)

LiDAR Surveys and Flood Mapping of Magbando River

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



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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
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 MAGBANDO RIVER

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

1.1 Background of the Phil-LIDAR 1 Program

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

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

The methods applied in this report are thoroughly described in a separate publication entitled “Flood Mapping of Rivers in the Philippines using Airborne LiDAR: Methods” (Paringit, et. Al. 2017).

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 Magbando River Basin

The Magbando River Basin, a 53,800-hectare watershed, covers major portions of the municipalities of, Sablayan, Calintaan, Rizal and San Jose in Occidental Mindoro; and minor portions of Mansalay and Bongabong in Oriental Mindoro. The DENR River Basin Control Office (RCBO) states that the Magbando River Basin has a drainage area of 578 km^2 with estimated annual run-off of 925 million cubic meter (MCM).

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

The basin area has four geological classifications with Jurrasic, Paleocene-Eocene, Recent and Oligocene-Miocene as the most dominant while others are Basement Complex, Oligocene, Cretaceous-Paleogene, Upper Miocene-Pliocene, Neogene and Pliocene-Pleistocene. The river basin is generally characterized by undulating to rolling and steep slopes. The elevation in the area generally has more than 300 meters above mean sea level. Eight soil types covers the area including Maranlig gravelly sandy clay loam, Quingua clay loam, San Manuel sandy loam, Faraon clay/river wash, Quingua sandy loam, Magsaysay clay, San Manuel loam, and San Manuel loamy sand. Beach sand and rough mountain land (unclassified) can also be found in the area. The river basin is also dominated by natural grassland, broadleaved open forests, cultivated areas with annual and perennial crops, barren lands, built-up areas, and wooded lands with wooded and non-wooded shrubs.

Magbando River passes through San Agustin, Central, San Isidro, Batasan and Monte Carlo in San Jose; Adela, San Pedro, Pitogo, Aguas, Manoot and Santo Niño in Rizal; Tanyag, Poypoy and Malpalon in Calintaan; and, Tuban and Ligaya in Sablayan. Per record in the 2010 NSO Census of Population and Housing, among the municipalities, San Jose is the most populated area.

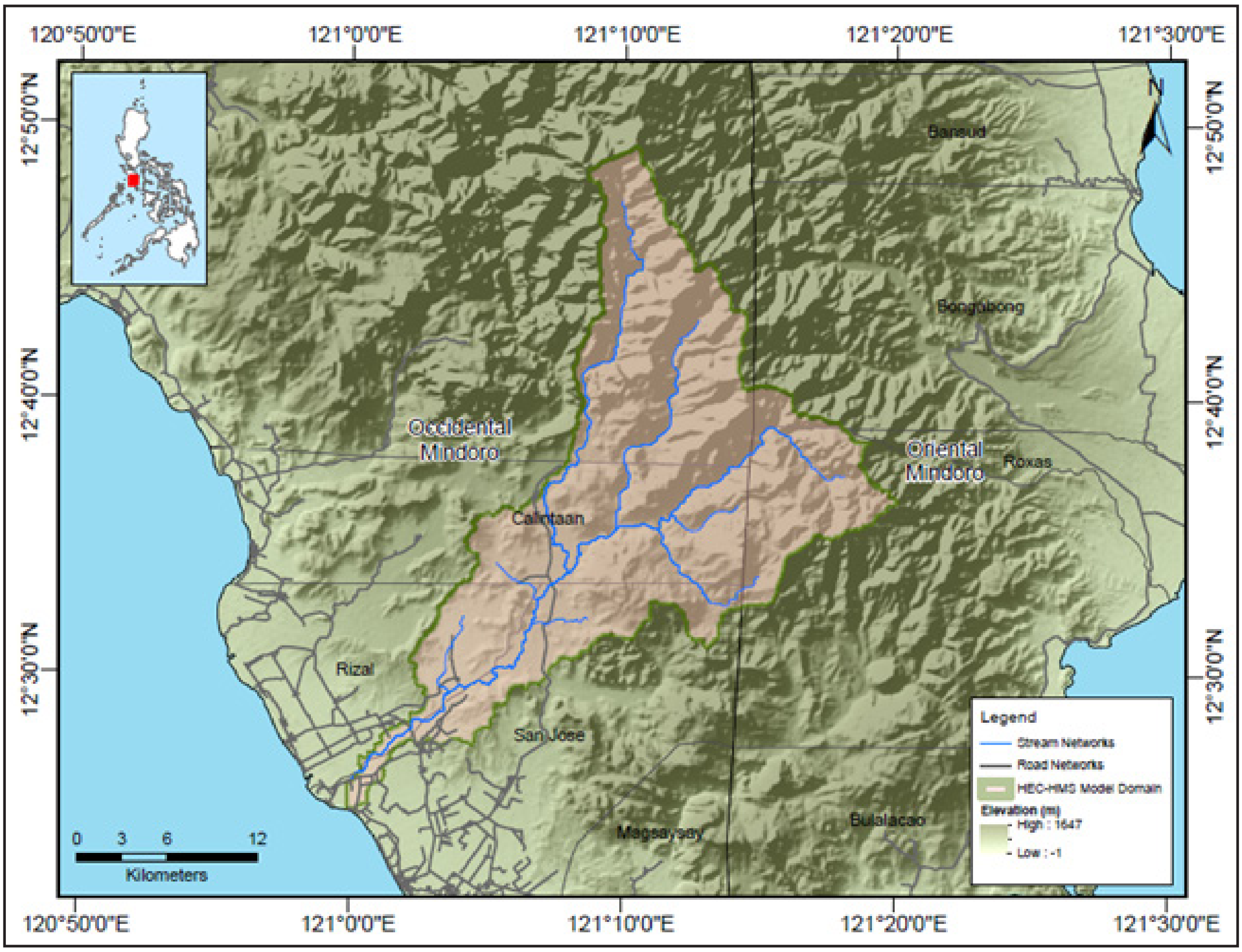

Figure 1. Map of the Magbando River Basin in brown

Based on the studies conducted by the Mines and Geosciences Bureau, the barangays within the Magbando River Basin have varying risk levels in terms of flooding and landslides. Batasan is the only barangay in San Jose that has a low flood risk; Monte Carlo and Murtha in San Jose, Santo Niño, Manoot, Pitogo and Aguas in Rizal, Tanyag, Poypoy and Malpalon in Calintaan are at low to high risk level; while San Agustin and Central in San Jose, San Pedro, and Adela in Rizal at moderate to high risk level; leaving Tuban and Ligaya in Sablayan at high flood risk level. The field surveys conducted by the PHIL-LiDAR 1 validation team showed the are has experience flooding brought by weather disturbance in 2009 (Ondoy), 2013 (Yolanda), and 2014 (Glenda). Heavy rains caused by southwest monsoon also caused flooding in 2013 affecting barangays Adela, Pitogo and Rizal. When it comes to landslide susceptibilty, San Agustin and Central in San Jose, and San Pedro and Adela in Rizal are the only ones included under low risk areas; Murtha in San Jose, Santo Niño, Manoot and Aguas in Rizal under low to moderate risks; San Isidro, Monte Carlo and Batasan in San Jose, Pitogo in Rizal, Tanyag, Poypoy and Malpalon in Calintaan, and Tuban falling to low to high risk levels; leaving Ligaya and Malisbong in Sablayan at moderate to high risk levels.

Its main stem, Magbando River, transverses along Barangays Batasan, San Isidro, Central and San Agustin in the Municipality of San Jose and Barangays Aguas, San Pedro, Pitogo and Adela in the Municipality of Rizal. According to the municipal profile of San Jose, Magbando River is locally known as Busuanga River and it serves as a natural boundary between the municipalities of Rizal and San Jose. The river is also the major source of irrigation for the barangays of both municipalities along the river. An estimated 31,681 people are residing within the immediate vicinity of the river which is distributed among the 9 barangays as of 2010 according to the Philippine Statistics Authority Census. The latest flooding recorded was on Dec. 25, 2015 where Typhoon Nona hit Occidental Mindoro causing knee-deep floods in the Municipality of San Jose.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE MAGBANDO 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 Magbando floodplain in Occidental Mindoro. These missions were planned for 15 lines that run for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameter used for the LiDAR system is found in Table 1 and Table 2. Figure 2 shows the flight plan for Magbando floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Max Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK29O	1100	30	50	200	30	130	5

Table 2. Flight planning parameters used for Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Max Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK29A	300	30	36	50	40	130	5
BLK29B	300	30	36	50	40	130	5
BLk29C	300	30	36	50	40	130	5
BLK29D	300	30	36	50	40	130	5
BLK29E	300	30	36	50	40	130	5
BLK29F	300	30	36	50	40	130	5
BLK29G	300	30	36	50	40	130	5

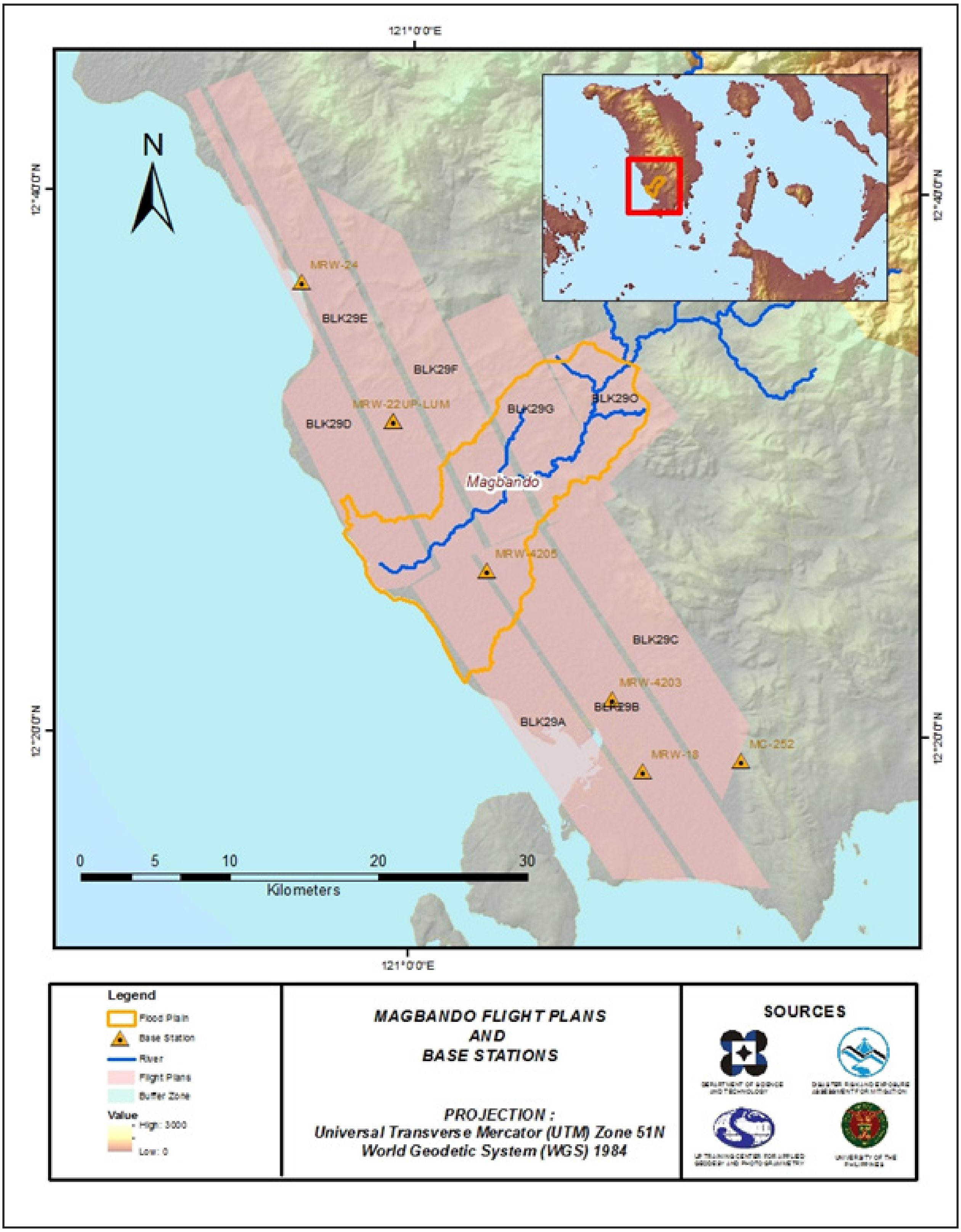


Figure 2. Flight plans and base stations used for Magbando floodplain.

2.2 Ground Base Stations

The project team was able to recover three (3) NAMRIA ground control points: MRW-18, MRW-22, MRW-24, which are of second (2nd) order accuracy. The project team also re-processed two (2) NAMRIA ground control points: MRW-4203 and MRW-4203 which are of third (3rd) order accuracy. One (1) NAMRIA benchmark was recovered MC-252. This benchmark was used as vertical reference point and was also established as ground control point. The project team also established one ground control point, UP-LUM. The certifications for the NAMRIA reference points are found in Annex 2, while the baseline processing report for NAMRIA benchmark and established points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (February 24 - March 3, 2014 and December 10 - 11, 2015). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, TRIMBLE SPS 852, and TRIMBLE SPS985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Magbando floodplain are shown in Figure 2.

Figure 3 to Figure 8 show the recovered NAMRIA reference point within the area. In addition, Table 3 to Table 9 show the details about the NAMRIA control stations and the established point while Table 10 shows the list of all GCPs occupied during the acquisition together with the corresponding dates of utilization.

(b)

(a)

Figure 3. GPS set-up over MRW-18 inside the municipal compound of Magsaysay, Occidental Mindoro (a) and NAMRIA reference point MRW-18 (b) as recovered by the field team.

Table 3. 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°8'35.92441" East 21.29500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 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 PRS 1992)	Easting Northing	298113.89 meters 1361734.74 meters

(a) (b)

Figure 4. GPS set-up over MRW-22 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 4. 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 3 (PTM Zone 3 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 1992)	Easting Northing	281265.62 meters 1385563.72 meters

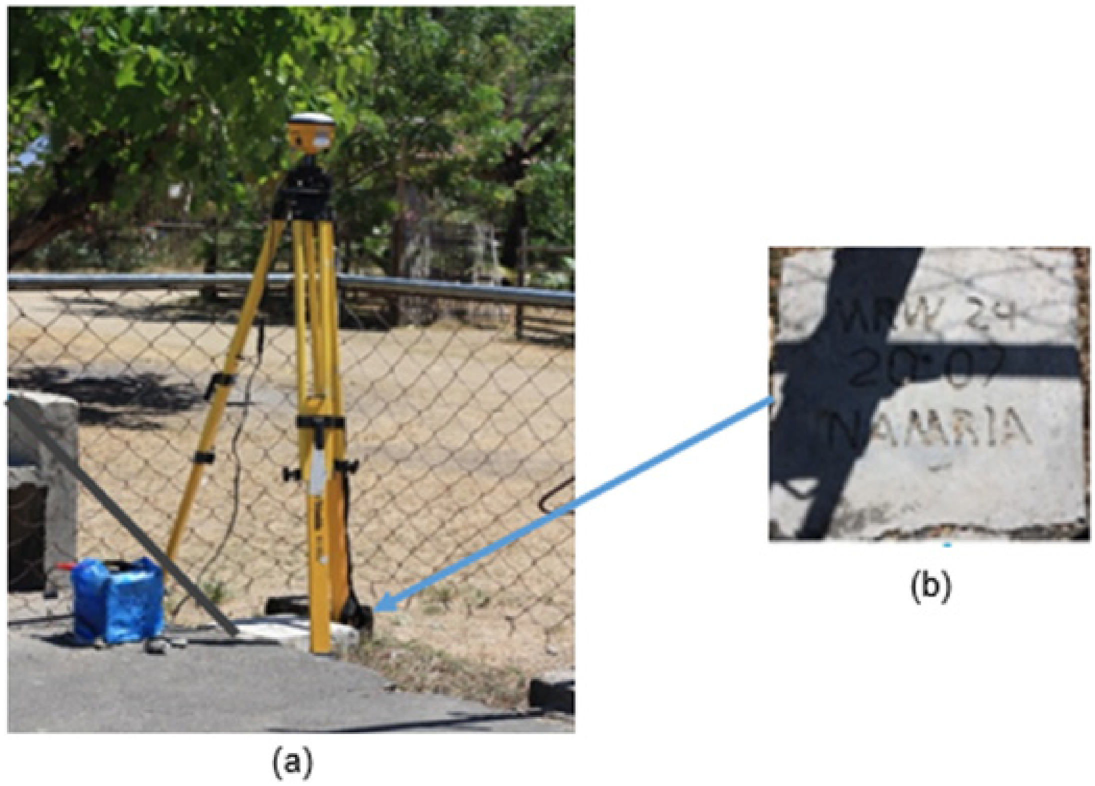
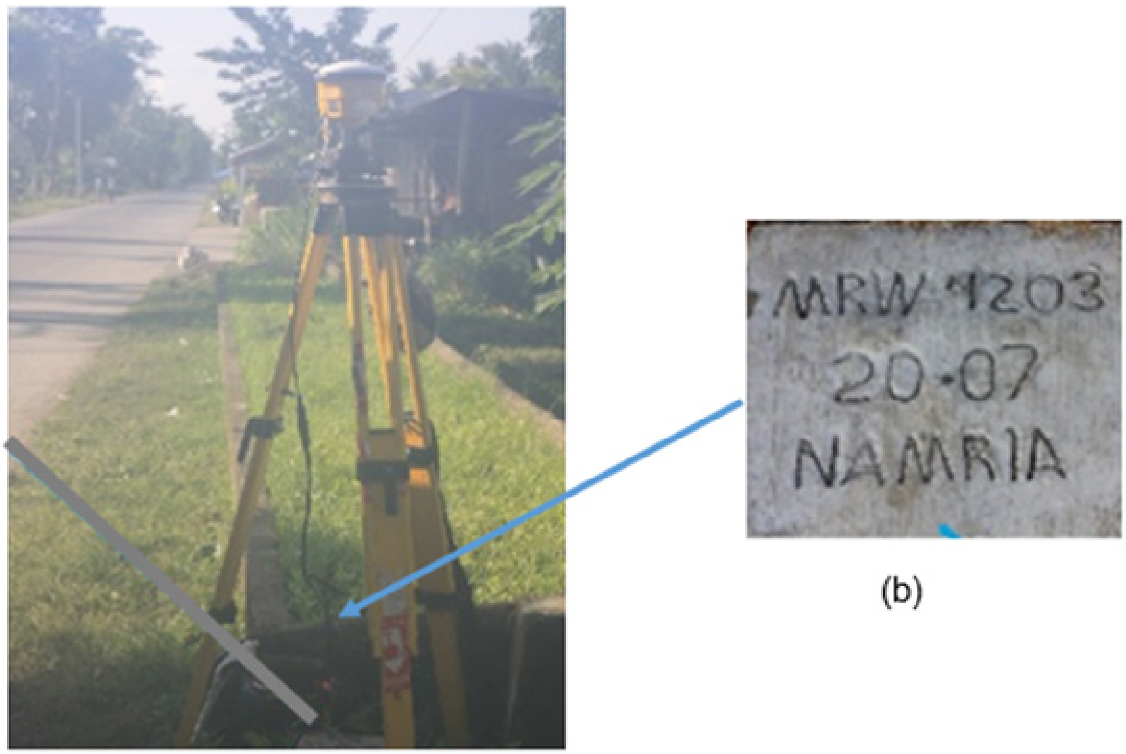


Figure 5. GPS set-up over MRW-24 in the basketball court in Brgy. Iriron, municipality of Calintaan, Occidental Mindoro (a) and NAMRIA reference point MRW-24 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point MRW-24 used as base station for the LiDAR acquisition.

Station Name	**MRW-34**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12°36’42.98691” North 120°55’49.01762” East 5.69500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 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 PRS 1992)	Easting Northing	275166.05 meters 1395022.71 meters

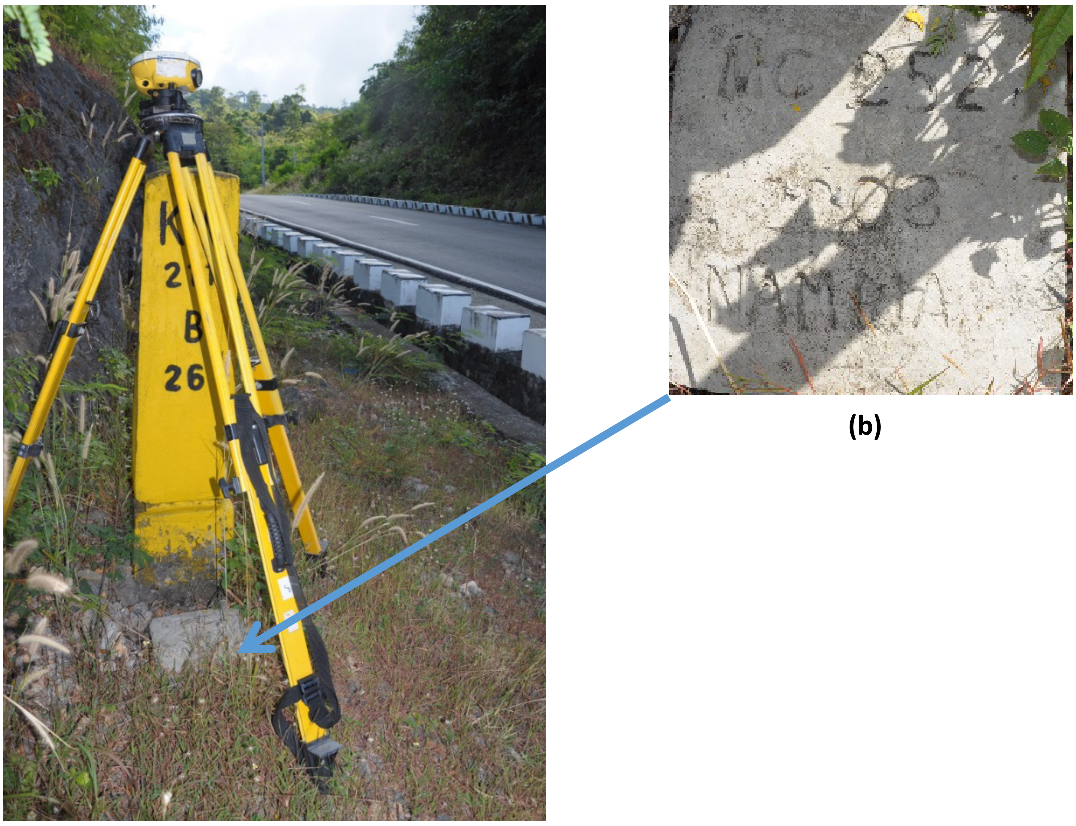


(a)

Figure 6. GPS set-up over MRW-4203 in 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 6. Details of the recovered NAMRIA horizontal control point MRW-4203 used as base station for the LiDAR acquisition.

Station Name	MRW-4203	
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°21’24.45294” North 121°07’26.92407” East 7.40100 meters
Grid Coordinates, Philippine Transverse Mercator Zone 3 (PTM Zone 3 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 PRS 1992)	Easting Northing	296032.79 meters 1366637.32 meters



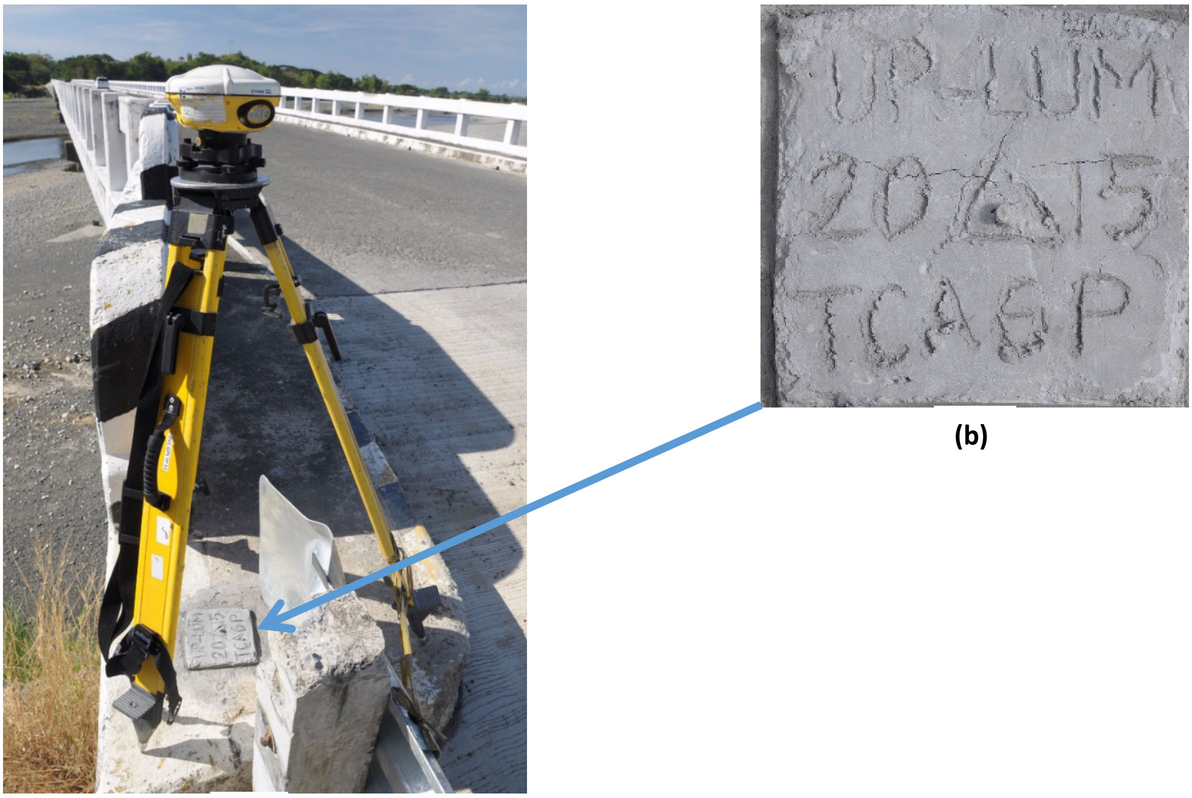
(b)

(a)

Figure 7. GPS set-up over MC-252 along National road beside KM post 211 in the municipality of Magsaysay, Occidental Mindoro (a) and NAMRIA reference point MC-252 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA vertical control point MC-252 used as base station for the LiDAR Acquisition with the re-processed coordinates.

Station Name	MC-252	
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°19'10.66357" North 121°12'17.05287" East 76.241 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°19'05.80624" North 121°12'22.14215" East 126.454 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	304770.876 meters 1362466.012 meters



(b)

(a)

Figure 8. GPS set-up over UP-LUM in the municipality of Rizal, Occidental Mindoro (a) and reference point UP-LUM (b) as established by the field team.

Table 8. Details of the horizontal control point UP-LUM used as base station for the LiDAR Acquisition with the re-processed coordinates.

Station Name	UP-LUM	
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°31'36.65200" North 120°59'13.78049" East 35.185 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12°31'31.72599" North 120°59'18.85291" East 84.296 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	281275.130 meters 1385560.055 meters

Table 9. 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	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 26' 08.33883" North 121° 02' 46.62885" East 12.555 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 26' 03.43990" North 121° 02' 51.70890" East 62.080 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	287627.814 m 1375422.160 m

Table 10. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
24-Feb-14	1140A	3BLK29ES55A (3BLK29ES+G55A)	MRW-22, MRW-24
24-Feb-14	1142A	3BLK29P55B	MRW-22, MRW-24
27-Feb-14	1152A	3BLK29GSD58A (3BLK29D+GS58A)	MRW-22, MRW-24
27-Feb-14	1154A	3BLK29DS58B	MRW-22, MRW-24
28-Feb-14	1156A	3BLK29F59A	MRW-22, MRW-24
28-Feb-14	1158A	3BLK29A59B	MRW-22, MRW-24, MRW-4205
1-Mar-14	1160A	3BLK29C60A	MRW-22, MRW-4205
01-Mar-14	1162A	3BLK29AS60B (3BLK29AS+DV60B)	MRW-22, MRW-4205
03-Mar-14	1164A	3BLK29N61A	MRW-4203, MRW-22
2-Mar-14	1166A	3BLK29BS62A	MRW-22, MRW-4203

3-Mar-14	1168A	3BLK29BS+AB+DB+CV+KV62B	MRW-22, MRW-4203
10-Dec-15	3074P	1BLK29KLMO344A	MRW-24, UP-LUM
10-Dec-15	3076P	1BLK29P344B	MRW-24, UP-LUM
11-Dec-15	3078P	1BLK29NQRS345A	MRW-18, MC-252

2.3 Flight Missions

Fourteen (14) missions were conducted to complete LiDAR data acquisition in Magbando floodplain, for a total fifty-four hours and fifty-two minutes (54+52) of flying time for RP-C9022 and RP-C9122. All missions were acquired using the Pegasus and Aquarius LiDAR systems. Table 11 shows the total area of actual coverage and the corresponding flying hours per mission while Table 12 presents the actual parameters used during the LiDAR data acquisition.

Table 11. Flight Missions for LiDAR data acquisition in Magbando 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
24-Feb-14	1140A	189.5	72.50	18.82	53.69	796	4	11
24-Feb-14	1142A	89.72	110.31	25.58	84.73	1061	3	59
27-Feb-14	1152A	155.58	89.81	37.24	52.57	1077	4	23
27-Feb-14	1154A	81.39	78.54	22.86	55.67	616	3	53
28-Feb-14	1156A	89.72	114.55	33.66	80.89	1312	4	29
28-Feb-14	1158A	72.02	66.28	21.66	44.62	650	3	41
1-Mar-14	1160A	97.59	107.85	5.36	102.49	194	4	35
01-Mar-14	1162A	191.43	87.17	21.78	65.39	594	3	41
03-Mar-14	1164A	162.96	28.43	2.74	25.70	311	4	53
2-Mar-14	1166A	85.08	115.93	17.64	98.29	N/A	3	59
3-Mar-14	1168A	90.69	154.79	2.37	152.42	N/A	4	29
10-Dec-15	3074P	47.18	84.97	35.11	49.86	454	4	5
10-Dec-15	3076P	26.32	28.50	16.15	12.35	67	1	47
11-Dec-15	3078P	221.86	60.91	18.80	42.12	211	2	47
TOTAL		**1601.04**	**1200.54**	**279.77**	**920.79**	**7343**	**54**	**52**

Table 11. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1140A	600	30	36	50	40	130	5
1142A	600	30	36	50	40	130	5
1152A	600	30	30	50	40	130	5
1154A	600	30	36	50	40	130	5
1156A	600	30	36	50	40	130	5
1158A	600	30	36	50	40	130	5
1160A	600	30	36	50	40	130	5
1162A	600	30	36	50	40	130	5
1164A	600	30	36	50	40	130	5
1166A	600	30	36	50	40	130	5
1168A	600	30	36	50	40	130	5
3074P	1100	30	50	200	32	130	5
3076P	1000	30	50	200	32	130	5
3078P	850	30	50	250	32	130	5

2.4 Survey Coverage

Magbando floodplain is located in the province of Occidental Mindoro, with majority of the floodplain within the municipality of Rizal. The municipalities of Rizal, Magsaysay, and San Jose are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 13. The actual coverage of the LiDAR acquisition for Magbando floodplain is presented in Figure 9.

Table 13. List of municipalities and cities surveyed during Magbando floodplain LiDAR survey.

Province	Municipality/ City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Occidental Mindoro	Rizal	184.98	184.73	100%
	Magsaysay	256.56	154.69	60%
	San Jose	449.82	246.04	55%
	Calintaan	282.31	134.22	48%
	Sablayan	2350.46	113.64	5%
	Bulalacao	365.58	6.29	2%
	Santa Cruz	709.53	10.01	1%
TOTAL		**4599.24**	**849.62**	**18.47%**

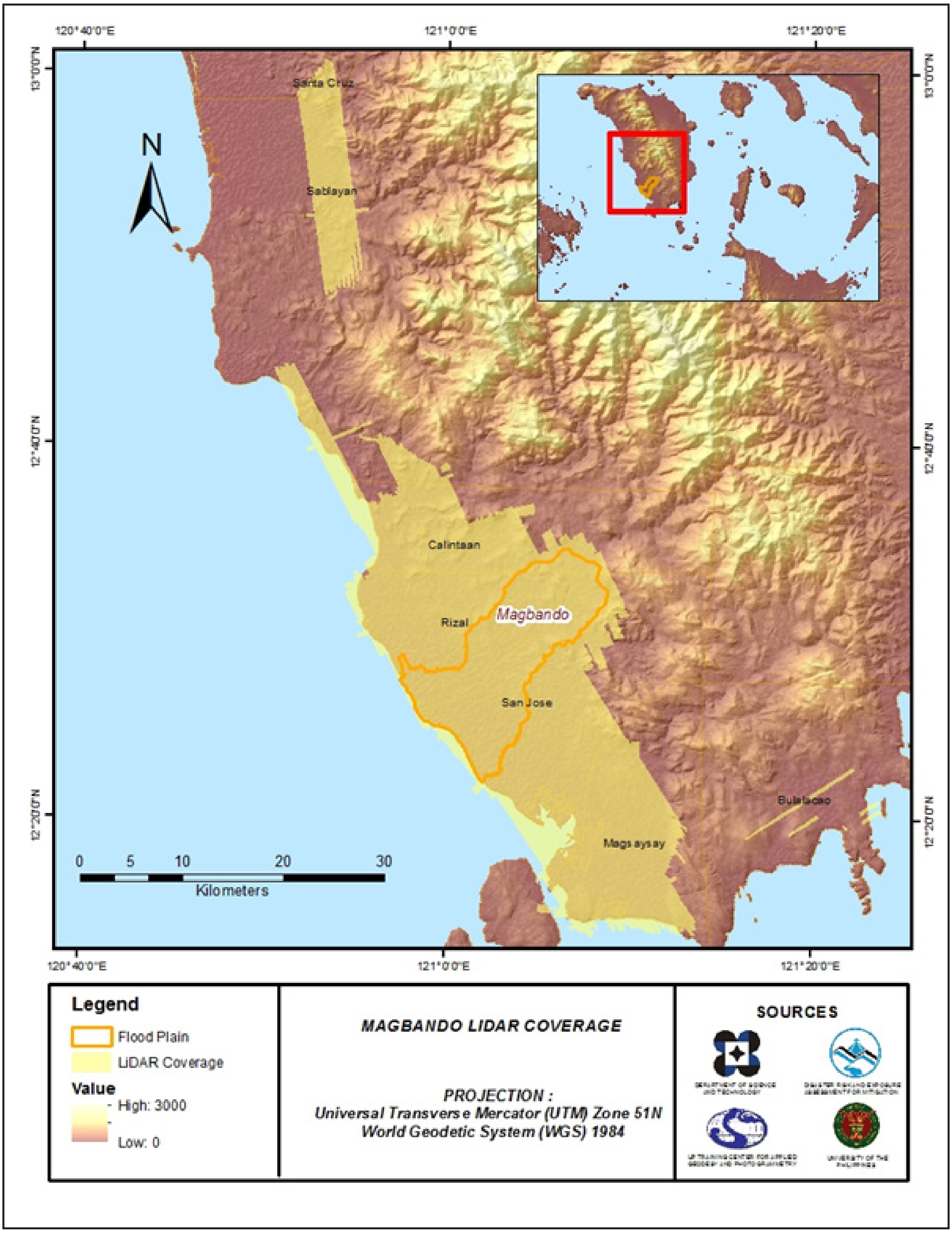


Figure 9. Actual LiDAR survey for Magbando Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE MAGBANDO FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 10.

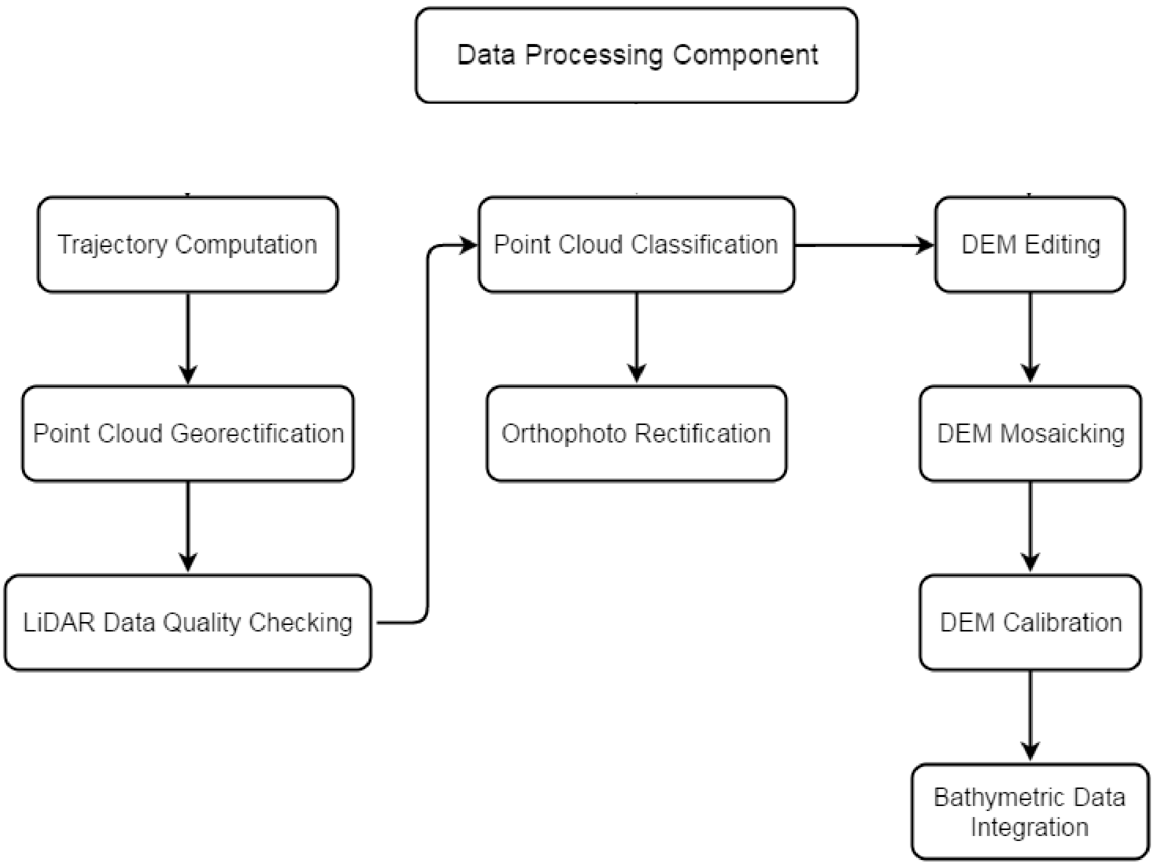

Figure 10.Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Magbando floodplain can be found in Annex 5. Missions flown during the first survey conducted on February 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 San Jose, Occidental Mindoro.

The Data Acquisition Component (DAC) transferred a total of 184.48 Gigabytes of Range data, 2.93 Gigabytes of POS data, 196.52 Megabytes of GPS base station data, and 420.82 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 Magbando was fully transferred on January 15, 2016, as indicated on the Data Transfer Sheets for Magbando floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1160A, one of the Magbando flights, which is the North, East, and Down position RMSE values are shown in Figure 11. 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 1, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

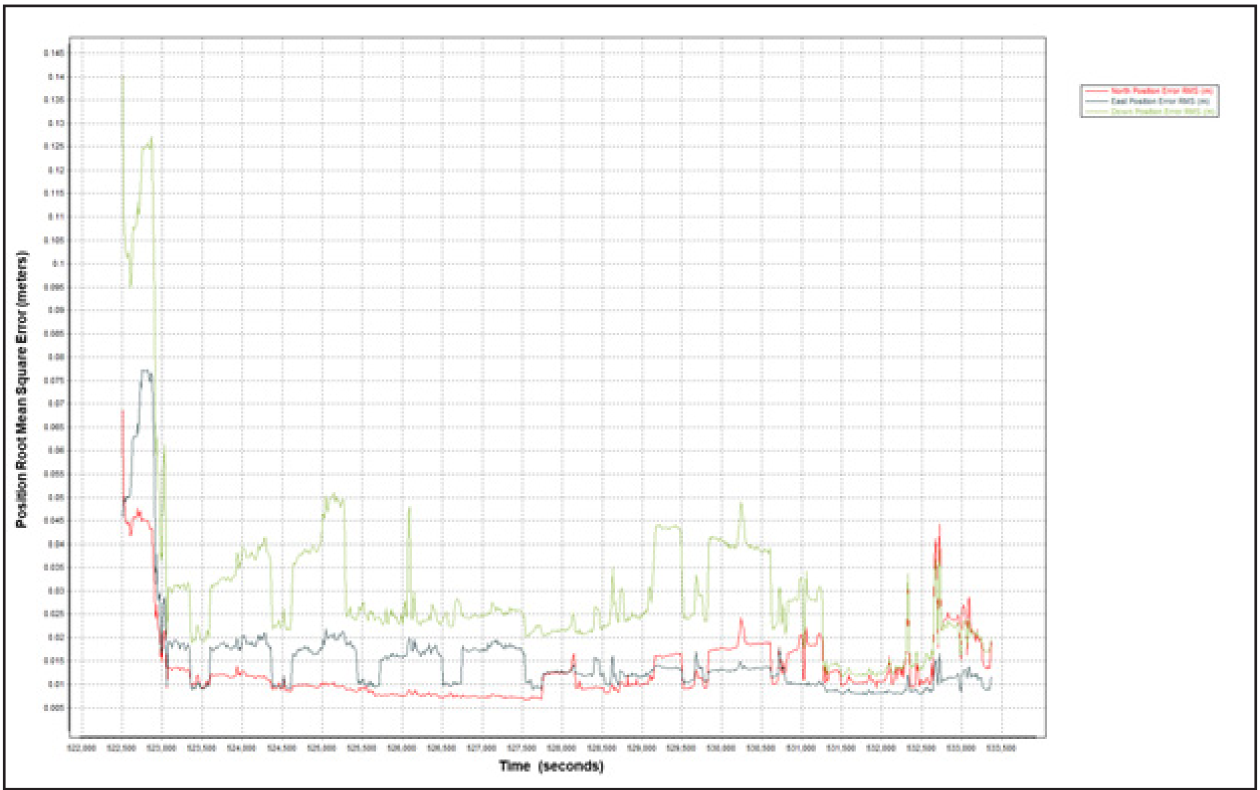

Figure 11. Smoothed Performance Metrics of a Magbando Flight 1160A.

The time of flight was from 522000 seconds to 533500 seconds, which corresponds to morning of March 1, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 11 shows that the North position RMSE peaks at 0.025 centimeters, the East position RMSE peaks at 0.02 centimeters, and the Down position RMSE peaks at 0.05 centimeters, which are within the prescribed accuracies described in the methodology.

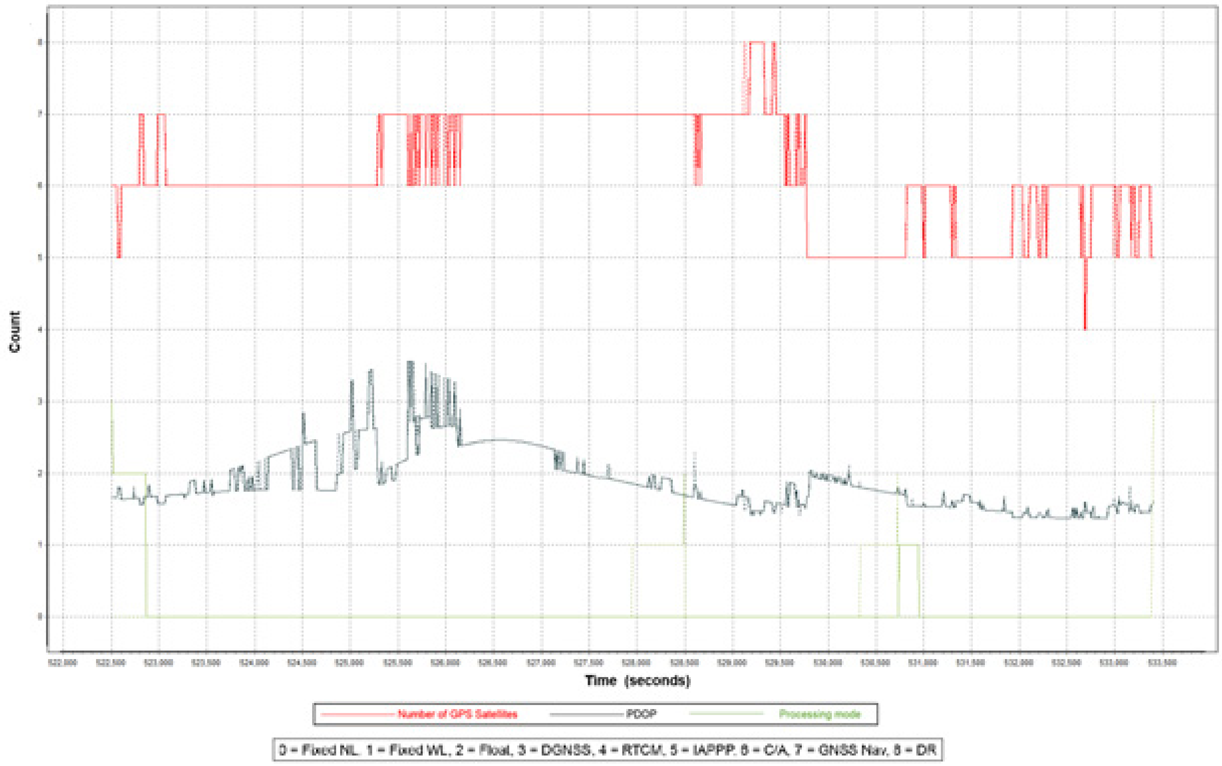

Figure 12. Solution Status Parameters of Magbando Flight 1160A.

The Solution Status parameters of flight 1160A, one of the Magbando flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 5 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 Magbando flights is shown in Figure 13.

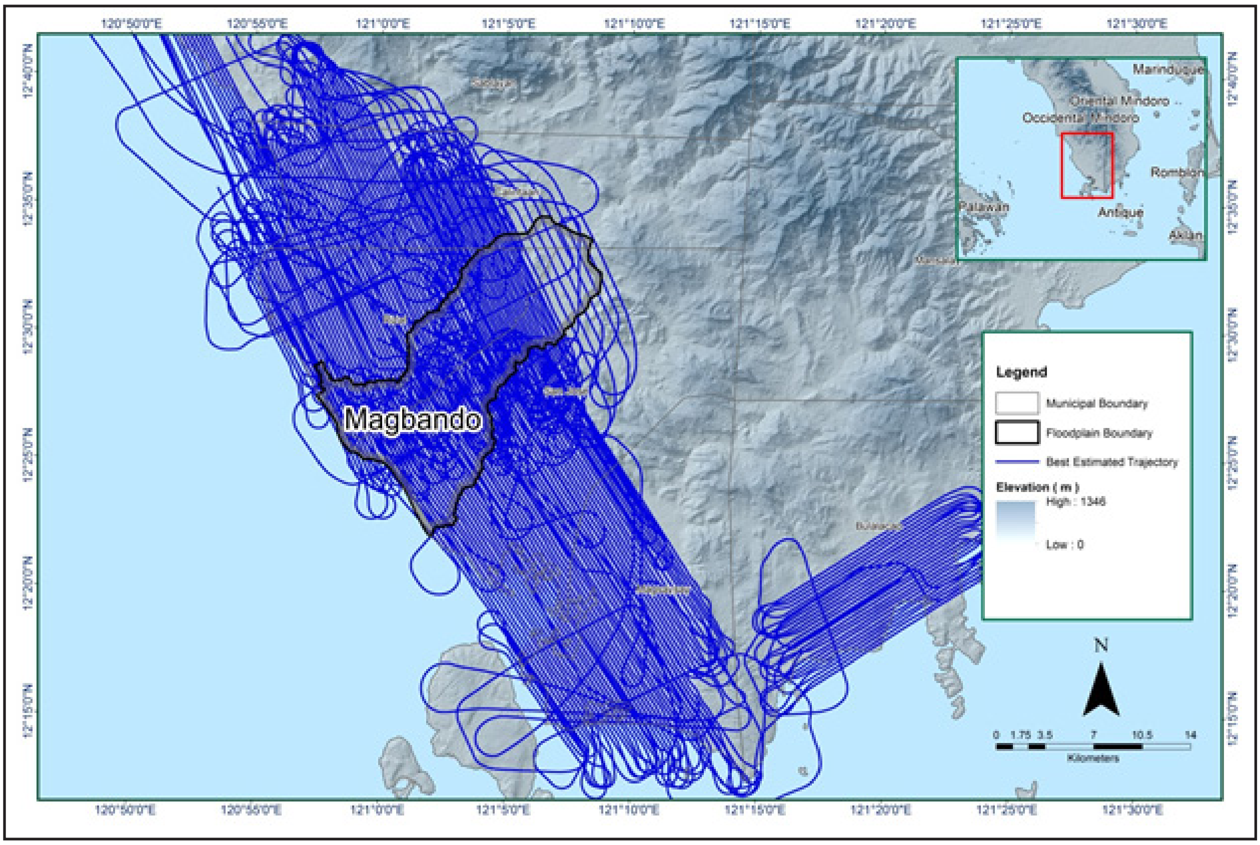

Figure 13. The best estimated trajectory of the LiDAR missions conducted over the Magbando floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 185 flight lines, with 151 lines containing one channel and 34 lines containing two channels, since the Aquarius and Pegasus systems contain one and two channels respectively. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Magbando floodplain are given in Table 14.

Table 14. Self-Calibration Results values for Magbando flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev)	<0.001degrees	0.000373
IMU Attitude Correction Roll and Pitch Correction stdev)	<0.001degrees	0.000922
GPS Position Z-correction stdev)	<0.01meters	0.0025

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Magbando Floodplain is shown in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

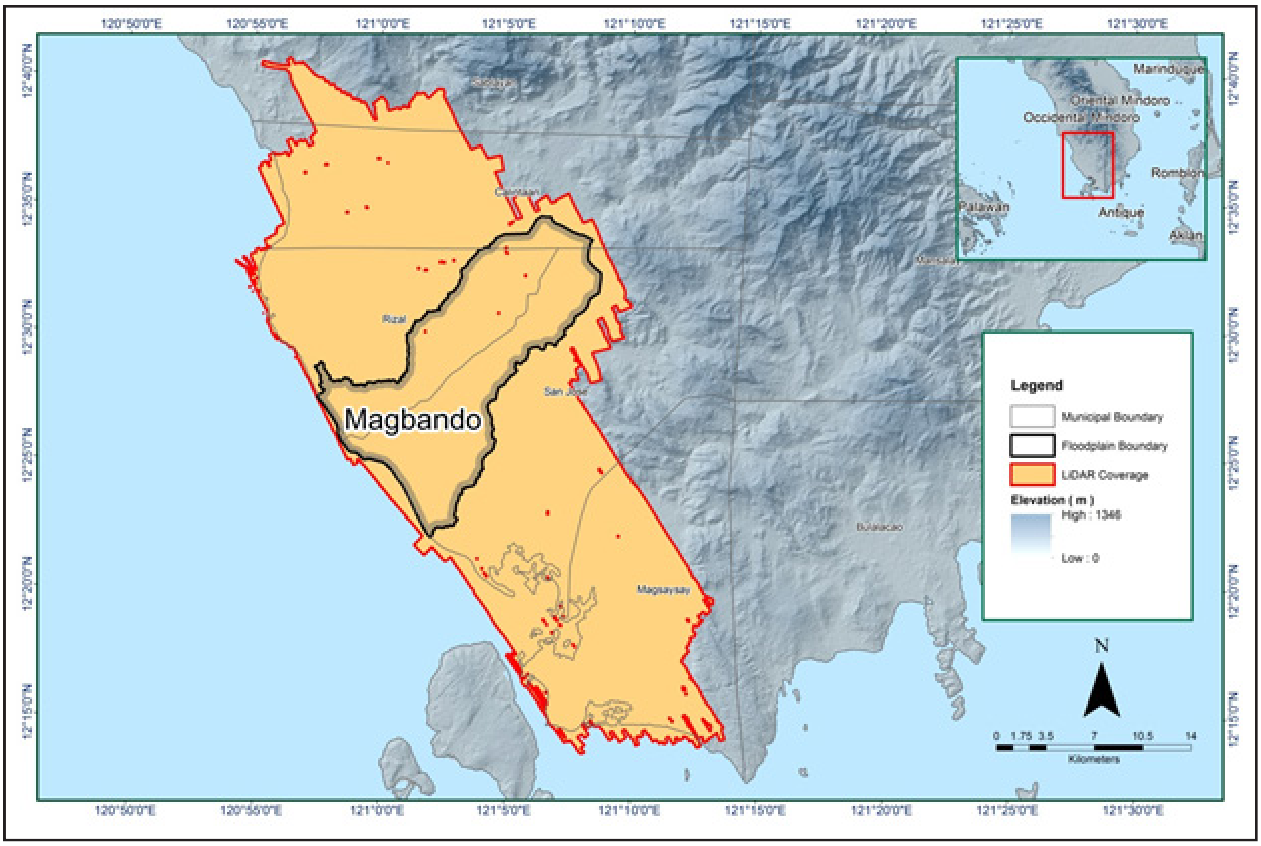

Figure 14. Boundary of the processed LiDAR data over Magbando Floodplain

The total area covered by the Magbando missions is 1042.89 sq.km that is comprised of twelve (12) flight acquisitions grouped and merged into thirteen (13) blocks as shown in Table 15.

Table 14. List of LiDAR blocks for Pagbahan Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
OccidentalMindoro_Blk29A	1158A	140.61
	1162A	
	1168A	
OccidentalMindoro_Blk29B	1166A	146.16
	1164A	
	1168A	
OccidentalMindoro_Blk29C	1160A	102.42
OccidentalMindoro_Blk29D	1154A	89.07
	1152A	
	1162A	
OccidentalMindoro_Blk29D_additional	1152A	11.05
	1168A	
OccidentalMindoro_Blk29F	1156A	112.31
OccidentalMindoro_Blk29G	1152A	65.98

OccidentalMindoro_Blk29G_supplement	1160A	30.22
OccidentalMindoro_Blk29P	1142A	106.52
OccidentalMindoro_reflights_Blk29A	3076P	28.04
OccidentalMindoro_reflights_Blk29F	3078P	24.57
OccidentalMindoro_reflights_Blk29G	3074P	62.40
OccidentalMindoro_reflights_Blk29G_ additional	3074P	123.54
TOTAL		**1042.89 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 15. Since the Aquarius system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus system which employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

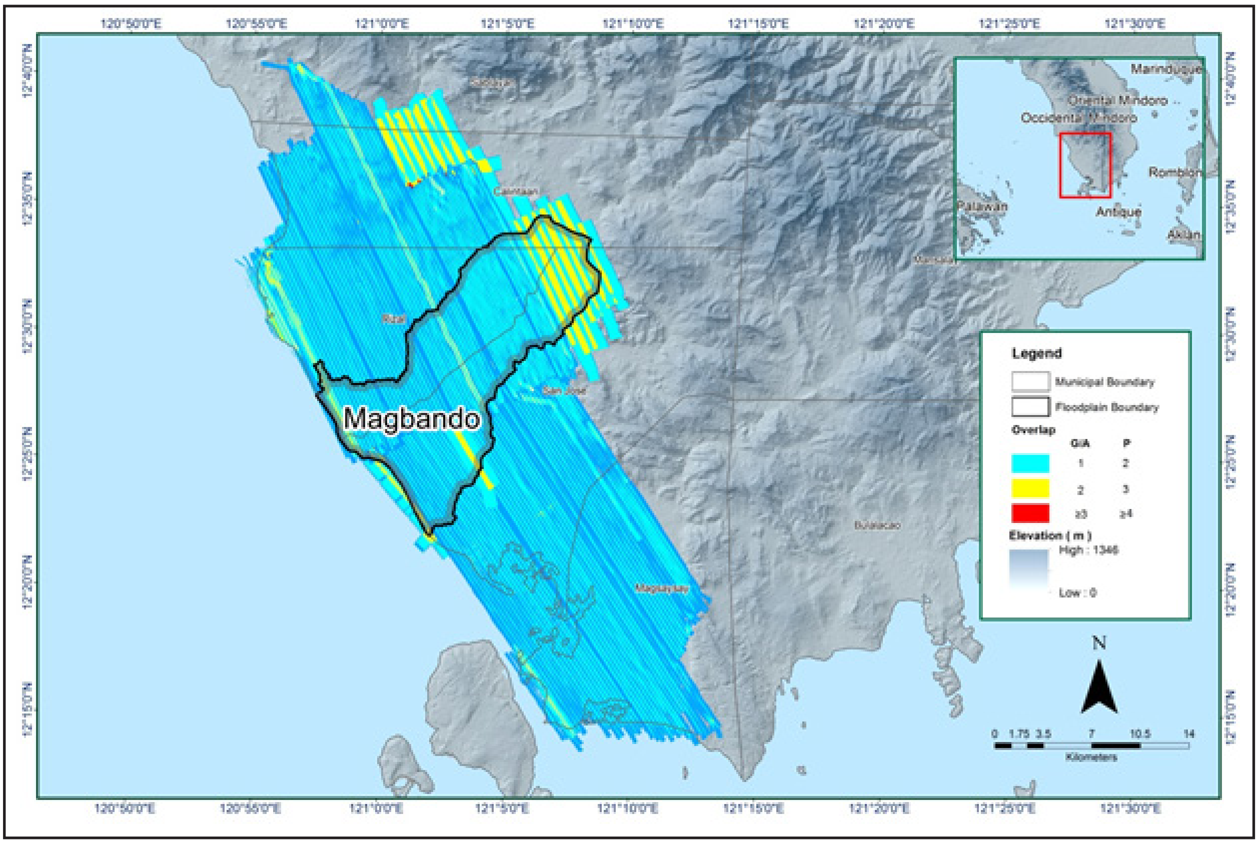

Figure 15. Image of data overlap for Magbando floodplain.

The overlap statistics per block for the Magbando floodplain can be found in Annex 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 36.55% and 60.10% 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 16. It was determined that all LiDAR data for Magbando floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.37 points per square meter.

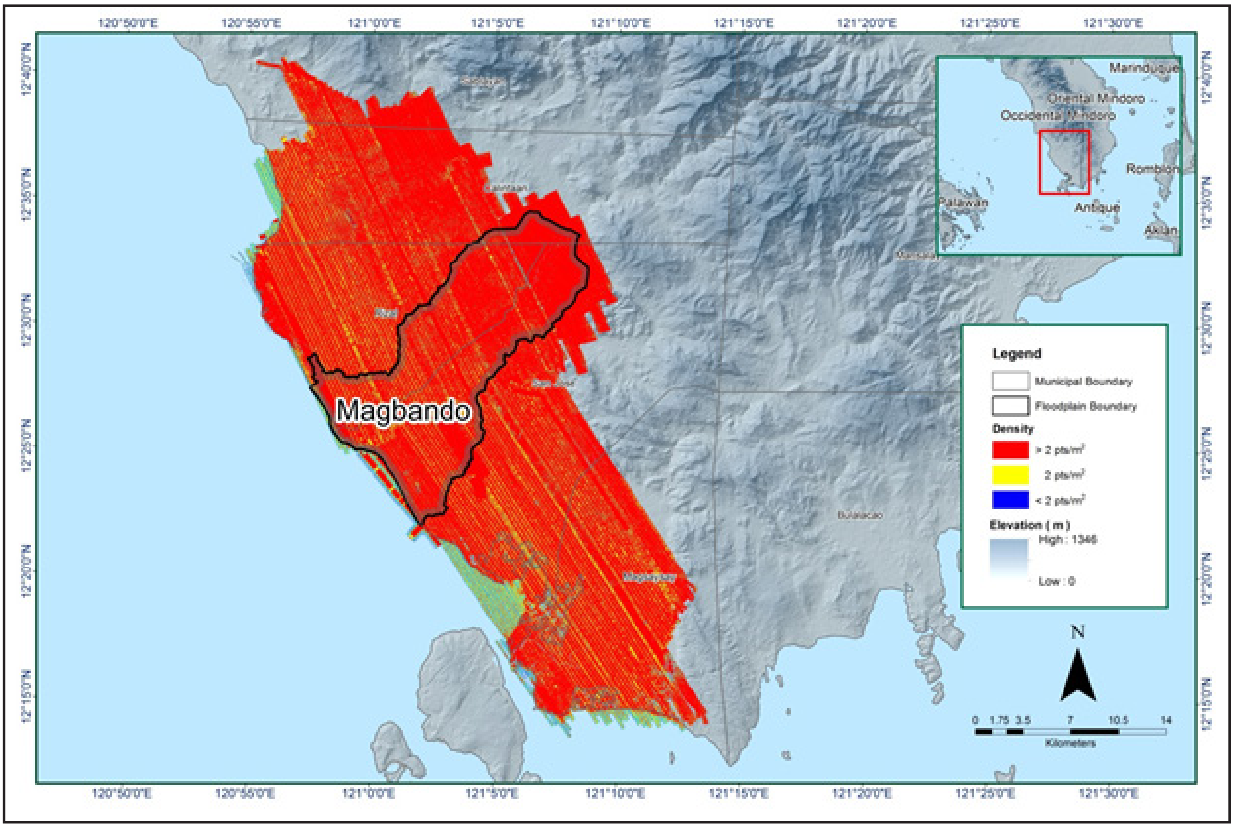

Figure 16. Pulse density map of merged LiDAR data for Magbando Floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. 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.

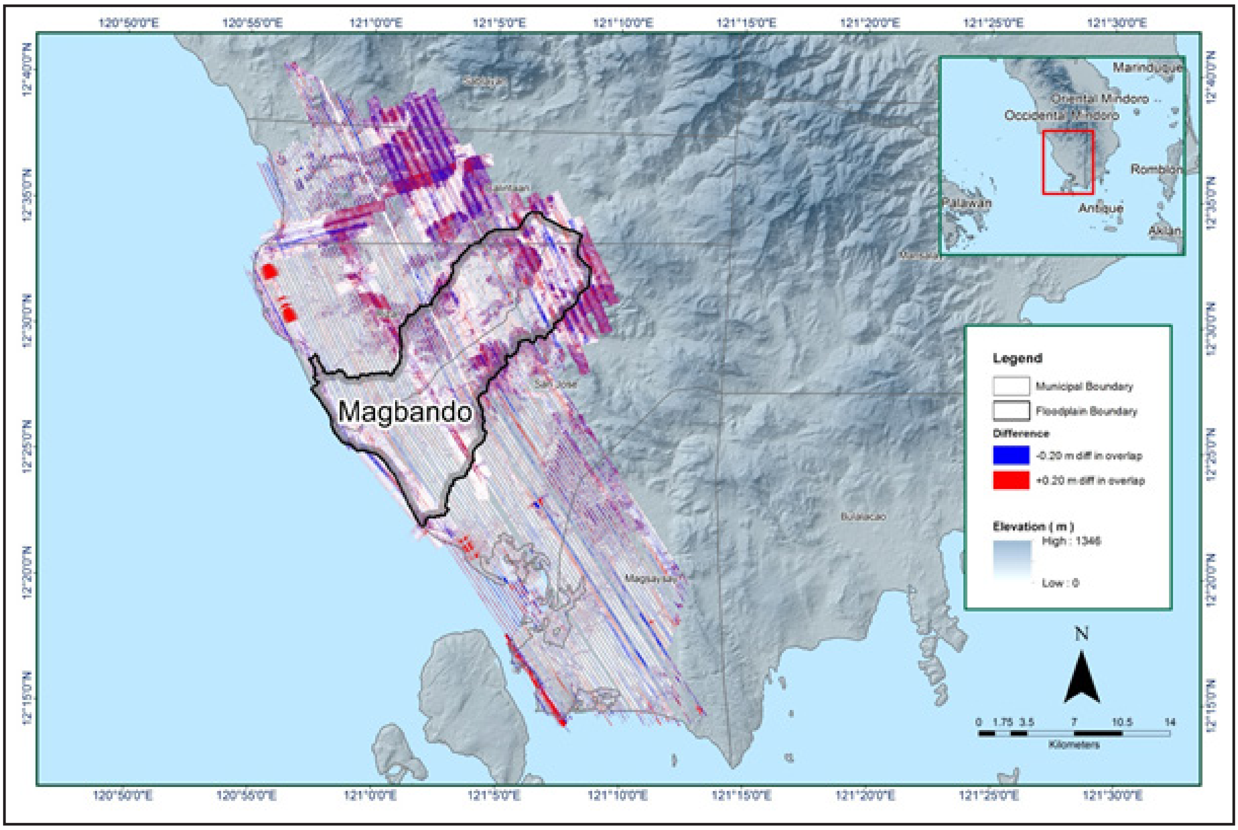

Figure 17. Elevation difference map between flight lines for Magbando floodplain.

A screen capture of the processed LAS data from a Magbando flight 1160A loaded in QT Modeler is shown in Figure 18. 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.

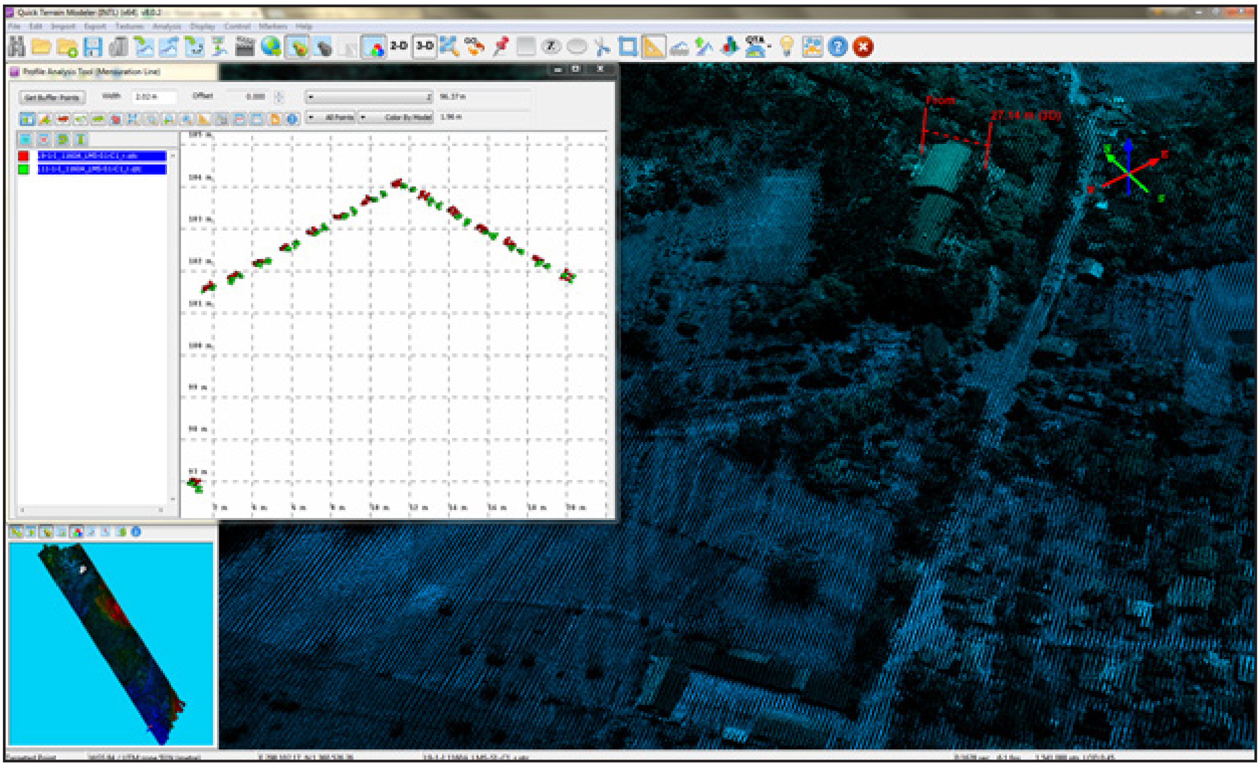

Figure 18. Quality checking for a Magbando flight 1160A using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 16. Magbando classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	914,281,565
Low Vegetation	961,138,360
Medium Vegetation	768,896,111
High Vegetation	1,072,426,468
Building	33,021,020

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Magbando floodplain is shown in Figure 19. A total of 1,544 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 623.42 meters and 50.35 meters respectively.

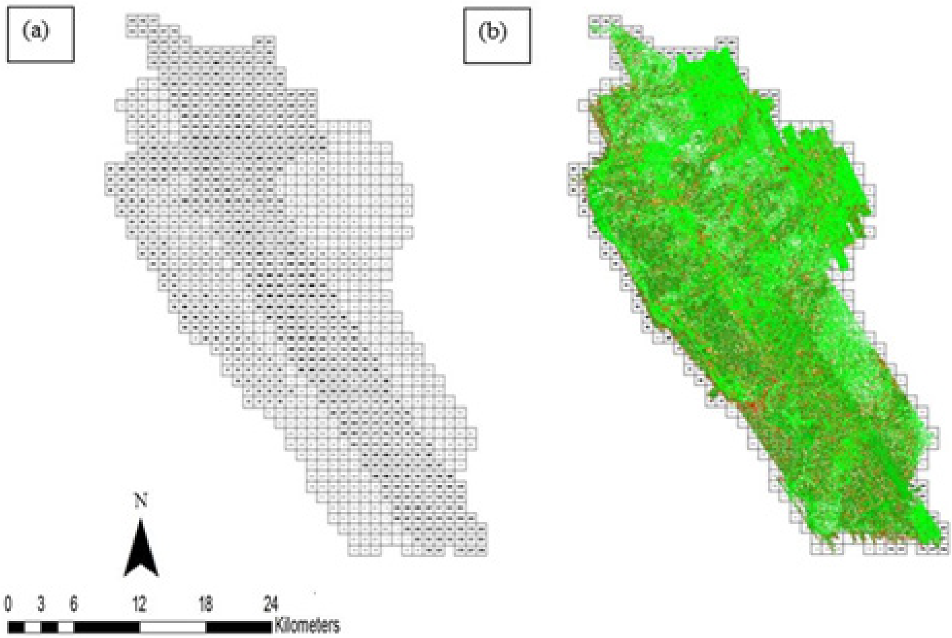

Figure 19. Tiles for Magbando Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 20. 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.

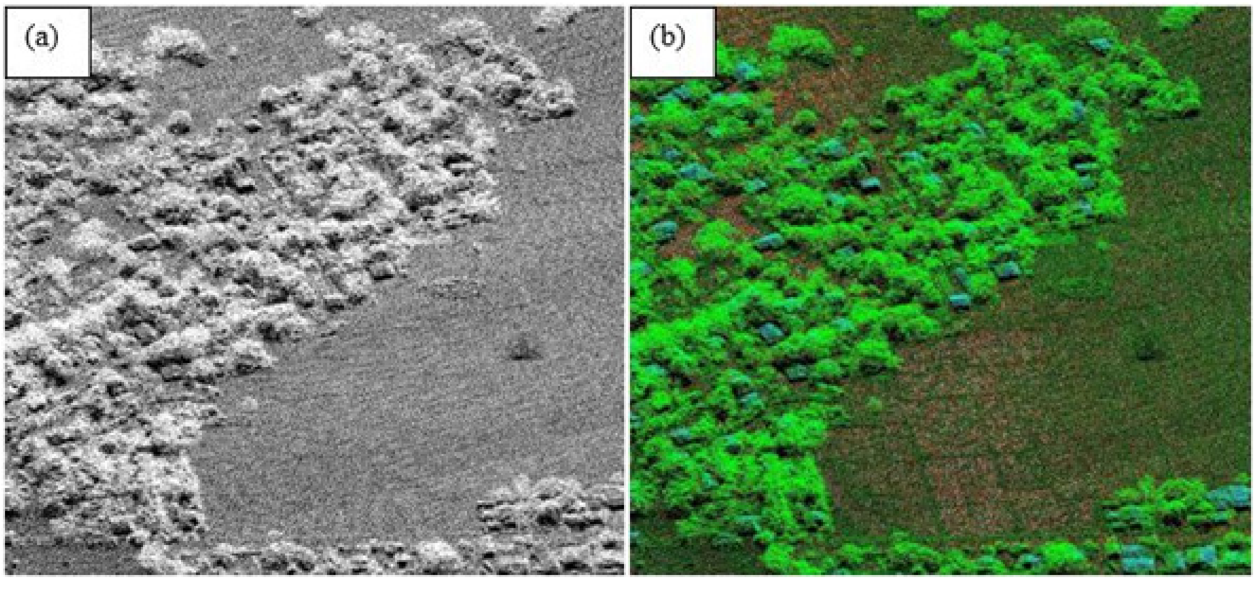

Figure 20. Point cloud before (a) and after (b) classification.

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

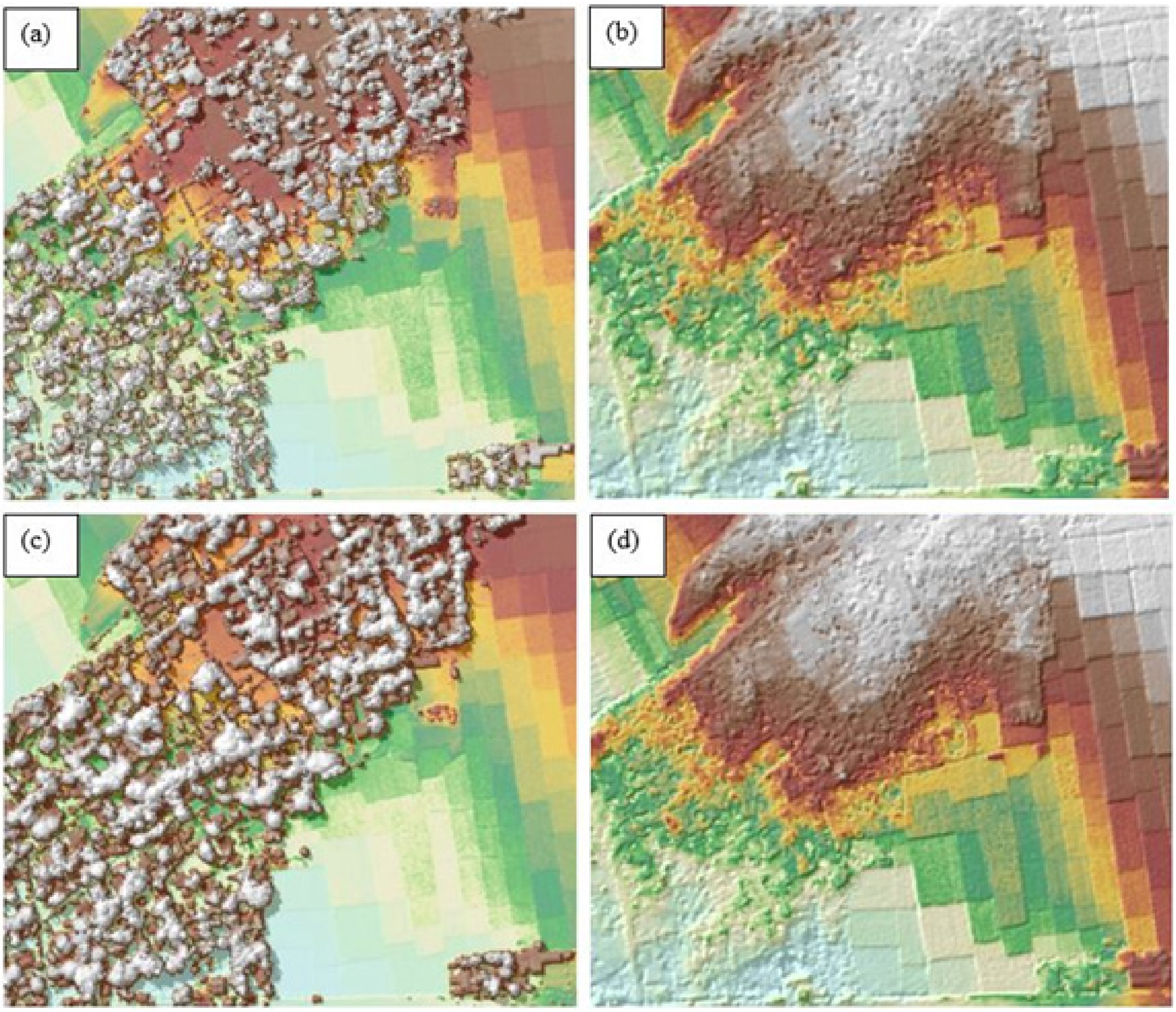

Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Magbando floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,176 1km by 1km tiles area covered by Magbando floodplain is shown in Figure 22. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Magbando floodplain survey attained a total of 510.44 km2 in orthophotogaph coverage comprised of 5,377 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

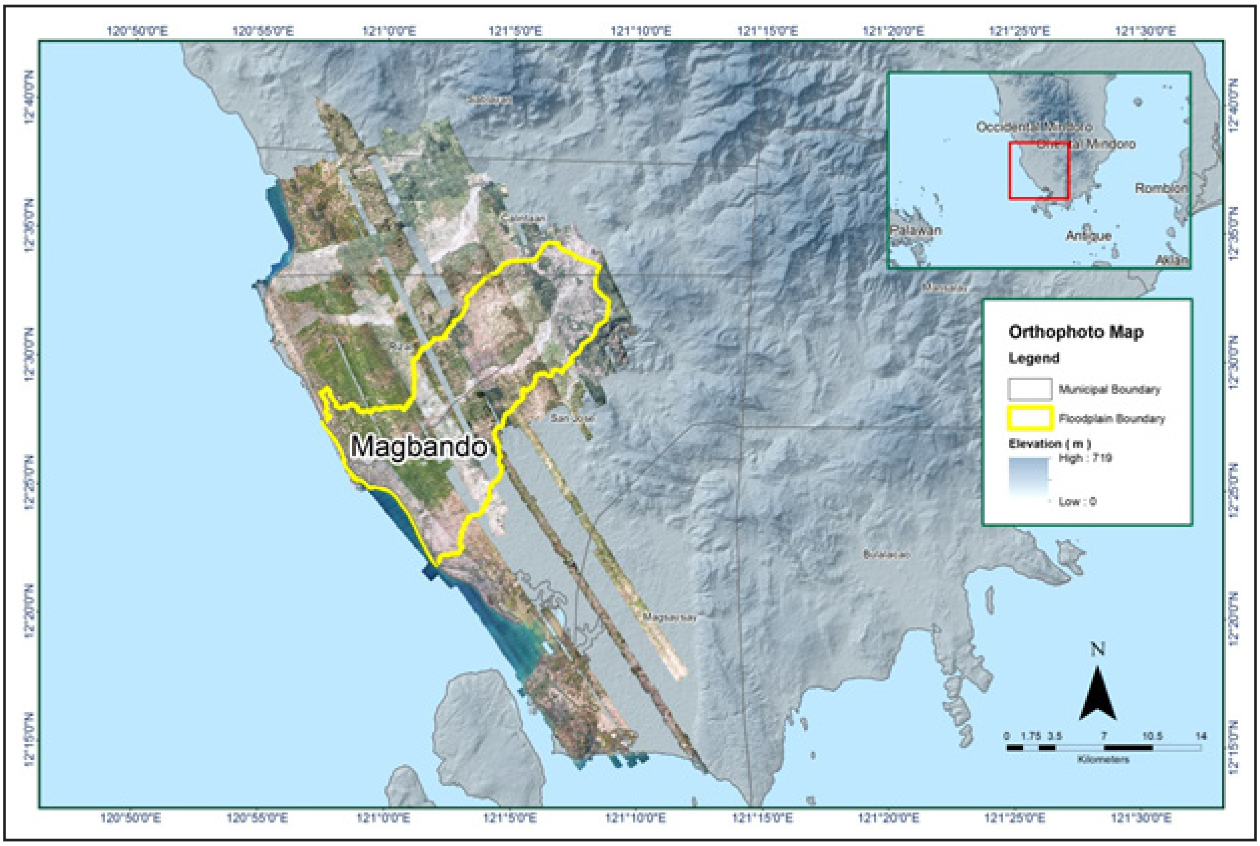

Figure 22. Magbando floodplain with available orthophotographs.

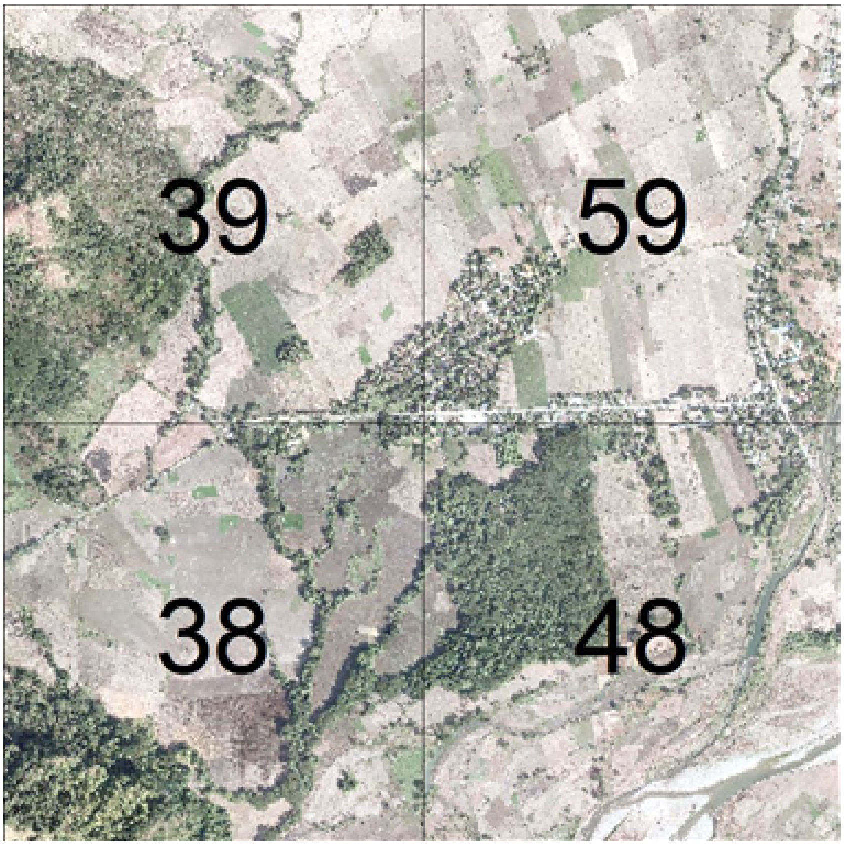

Figure 23. Sample orthophotograph tiles for Magbando floodplain.

3.8 DEM Editing and Hydro-Correction

Thirteen (13) mission blocks were processed for Magbando floodplain. These blocks are composed of OccidentalMindoro and OccidentalMindoro_reflights blocks with a total area of 1,070.01 square kilometers. Table 17 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_Blk29D	89.07
OccidentalMindoro_Blk29D_additional	11.05
OccidentalMindoro_Blk29F	112.31
OccidentalMindoro_Blk29G	65.98
OccidentalMindoro_Blk29G_supplement	30.22
OccidentalMindoro_Blk29P	106.52
OccidentalMindoro_reflights_Blk29A	28.04
OccidentalMindoro_reflights_Blk29F	24.57
OccidentalMindoro_reflights_Blk29G	62.40
OccidentalMindoro_reflights_Blk29G_ additional	123.54
TOTAL	**1042.89 sq.km**

Portions of DTM before and after manual editing are shown in Figure 24. The bridge in Figure 24a would be an impedance to the flow of water along the river and was removed in order to hydrologically correct the river, as done in Figure 24b. Another portion of the DTM presented in Figure 24c shows the part of the river which needed to be filled in order to allow the correct flow of water which resulted to the output in Figure 24d.

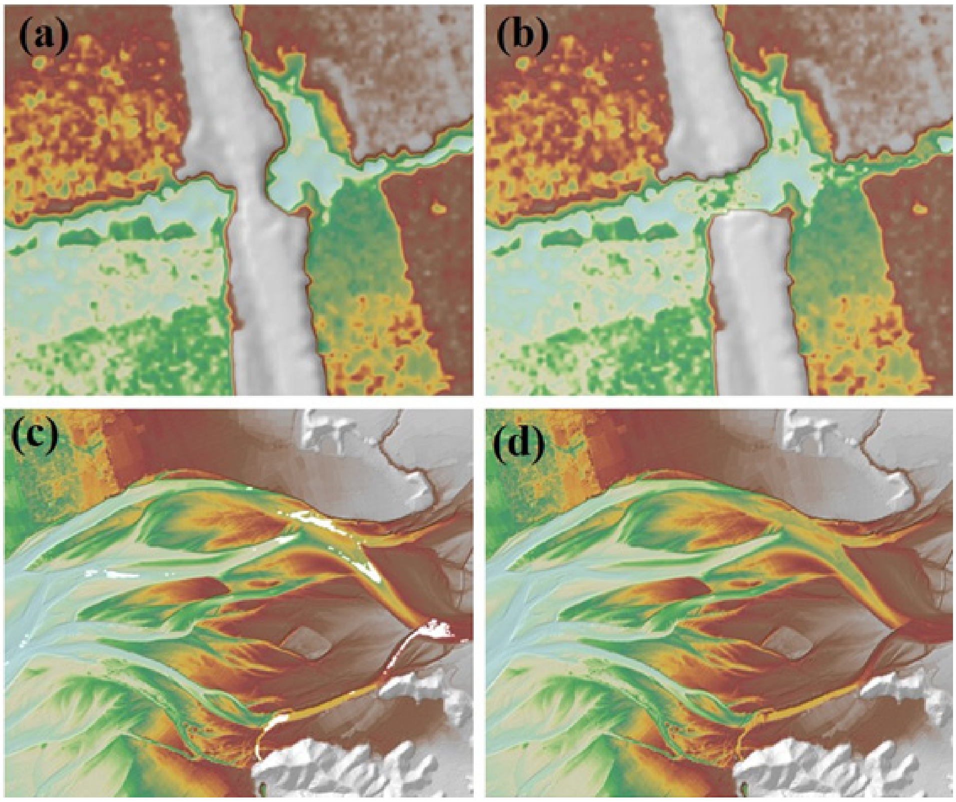

Figure 24. Portions in the DTM of Magbando Floodplain – a bridge before (a) and after (b) manual editing; a pit before (c) and after (d) data fill; and a mountain before (e) and after (f) data retrieval.

3.9 Mosaicking of Blocks

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

Mosaicked LiDAR DTM for Magbando floodplain is shown in Figure 25. It can be seen that the entire Magbando floodplain is 100% covered by LiDAR data.

Table 18. Shift Values of each LiDAR Block of Magbando 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	0.65	-0.68
OccidentalMindoro_Blk29D	0.00	0.00	-0.76
OccidentalMindoro_Blk29D_additional	-0.04	0.00	-0.68
OccidentalMindoro_Blk29F	0.00	0.00	-0.55
OccidentalMindoro_Blk29G	0.00	0.00	-0.40
OccidentalMindoro_Blk29G_supplement	0.00	0.00	-0.76
OccidentalMindoro_Blk29P	0.00	0.00	-0.65
OccidentalMindoro_reflights_Blk29A	0.00	0.00	-1.72
OccidentalMindoro_reflights_Blk29F	0.00	0.00	-1.41
OccidentalMindoro_reflights_Blk29G	0.00	0.00	-2.26
OccidentalMindoro_reflights_Blk29G_additional	0.00	0.00	-1.51

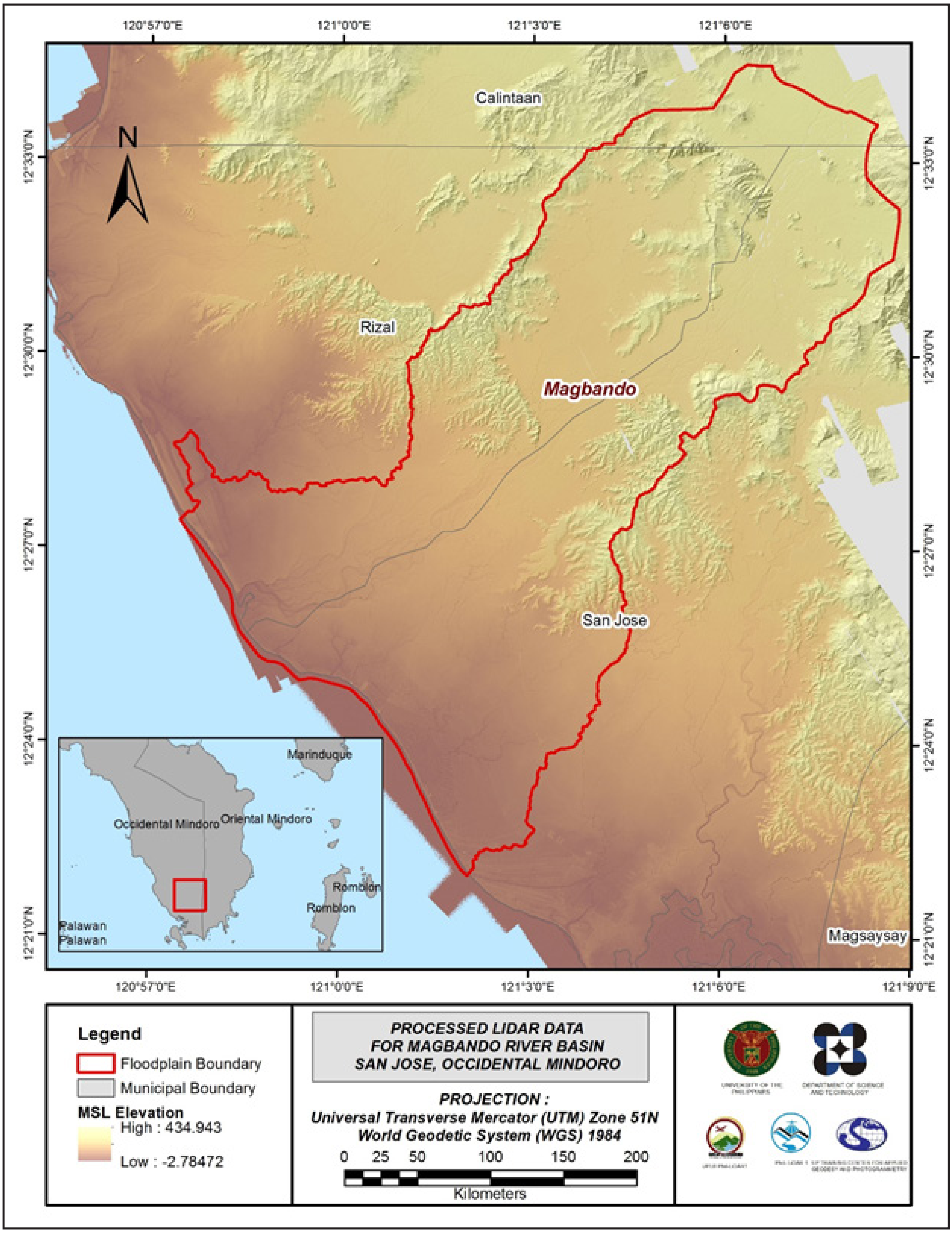

Figure 25. Map of Processed LiDAR Data for Magbando Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Magbando to collect points with which the LiDAR dataset is validated is shown in Figure 26. A total of 28,494 survey points were gathered for all the flood plains within Occidental Mindoro wherein the Magbando 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 27. 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 Magbando LiDAR data was done by adding the height difference value, 0.23 meters, to Magbando mosaicked LiDAR data. Table 19 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

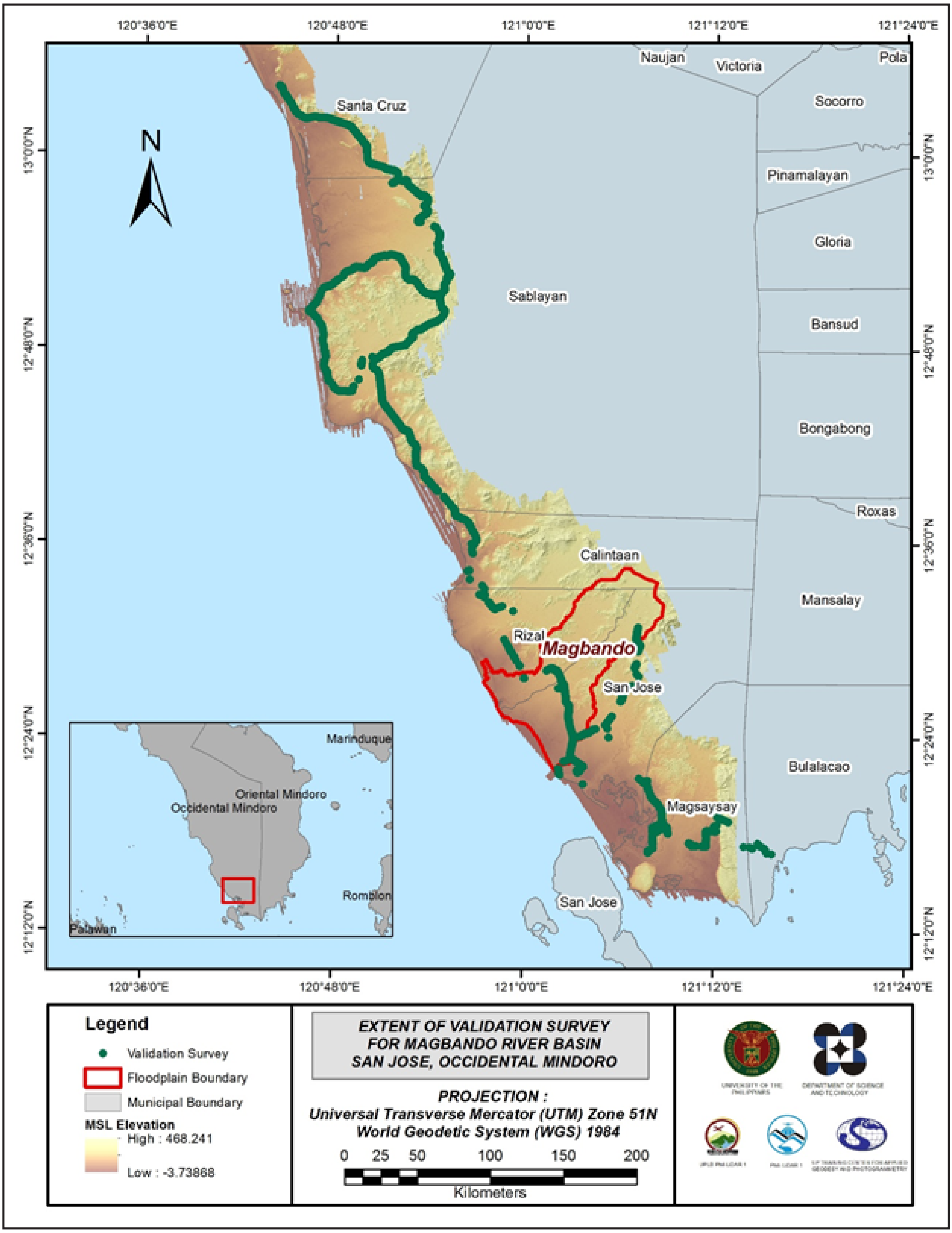

Figure 26. Map of Magbando Floodplain with validation survey points in green.

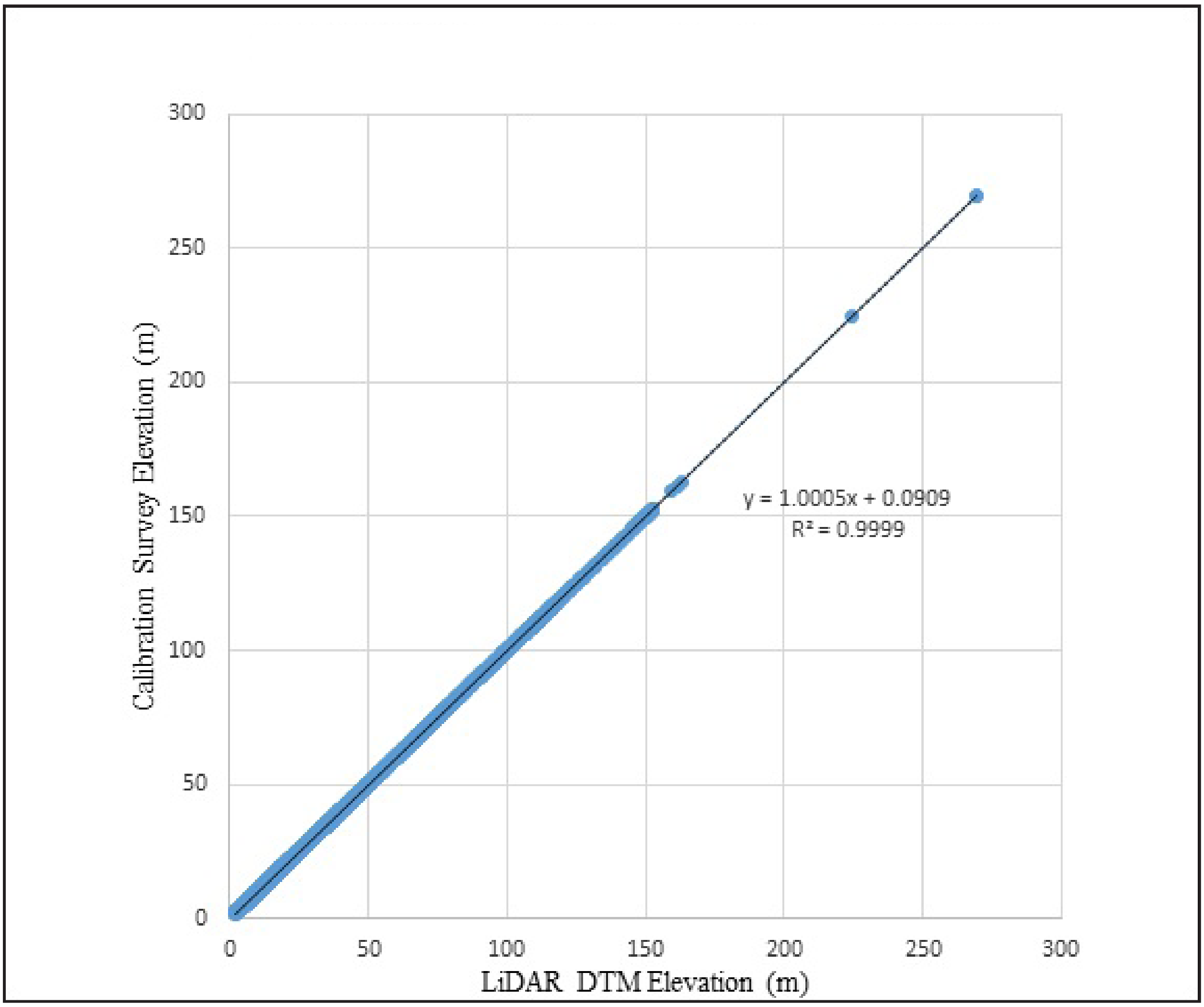

Figure 27. Correlation plot between calibration survey points and LiDAR data.

Table 19. Calibration Statistical Measures.

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

A total of 833 survey points lie within Magbando flood plain and were used for the validation of the calibrated Magbando 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 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.15 meters with a standard deviation of 0.15 meters, as shown in Table 20.

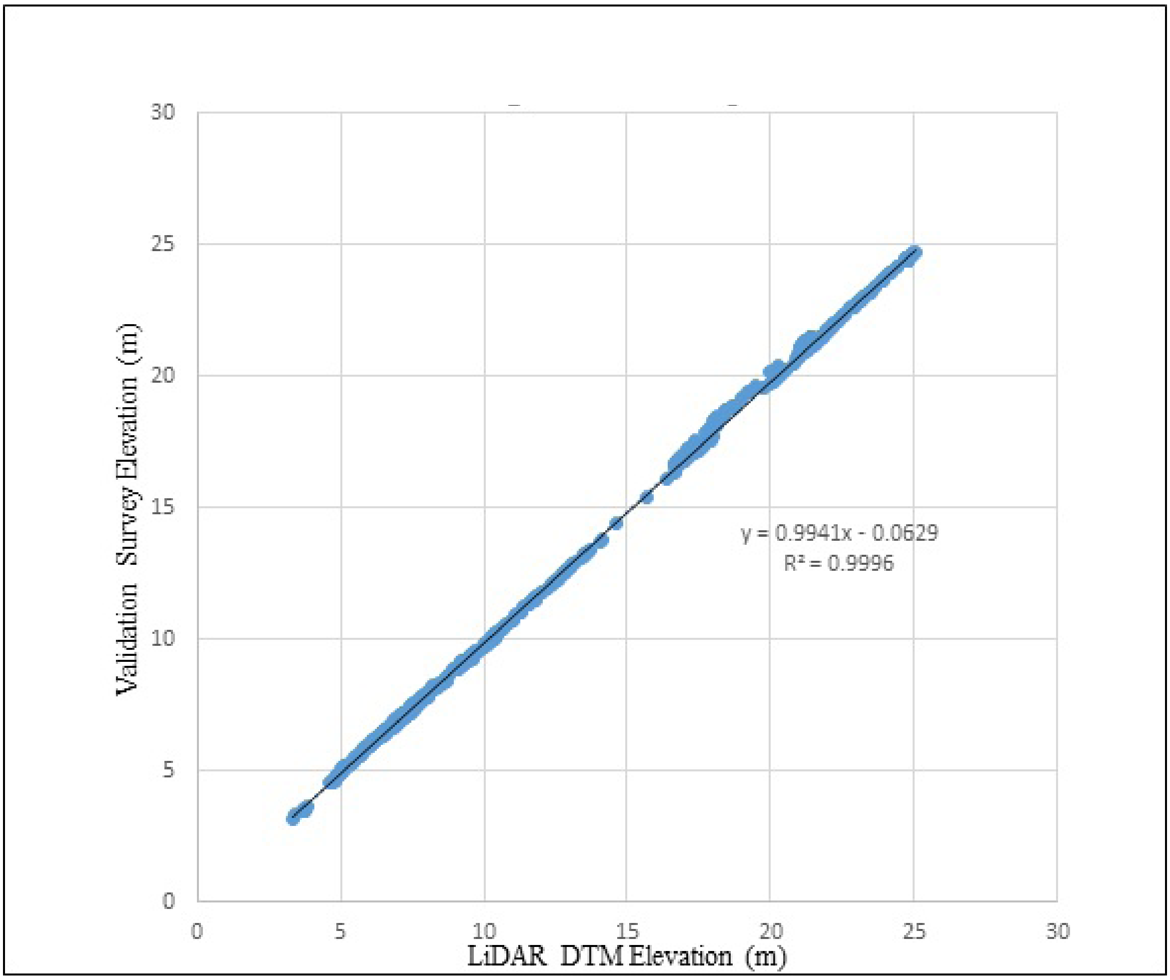

Figure 28. Correlation plot between validation survey points and LiDAR data.

Table 20. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.15
Average	-0.14
Minimum	-0.35
Maximum	0.30

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Magbando with 32,487 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barrier method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 1.27 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Magbando integrated with the processed LiDAR DEM is shown in Figure 29.

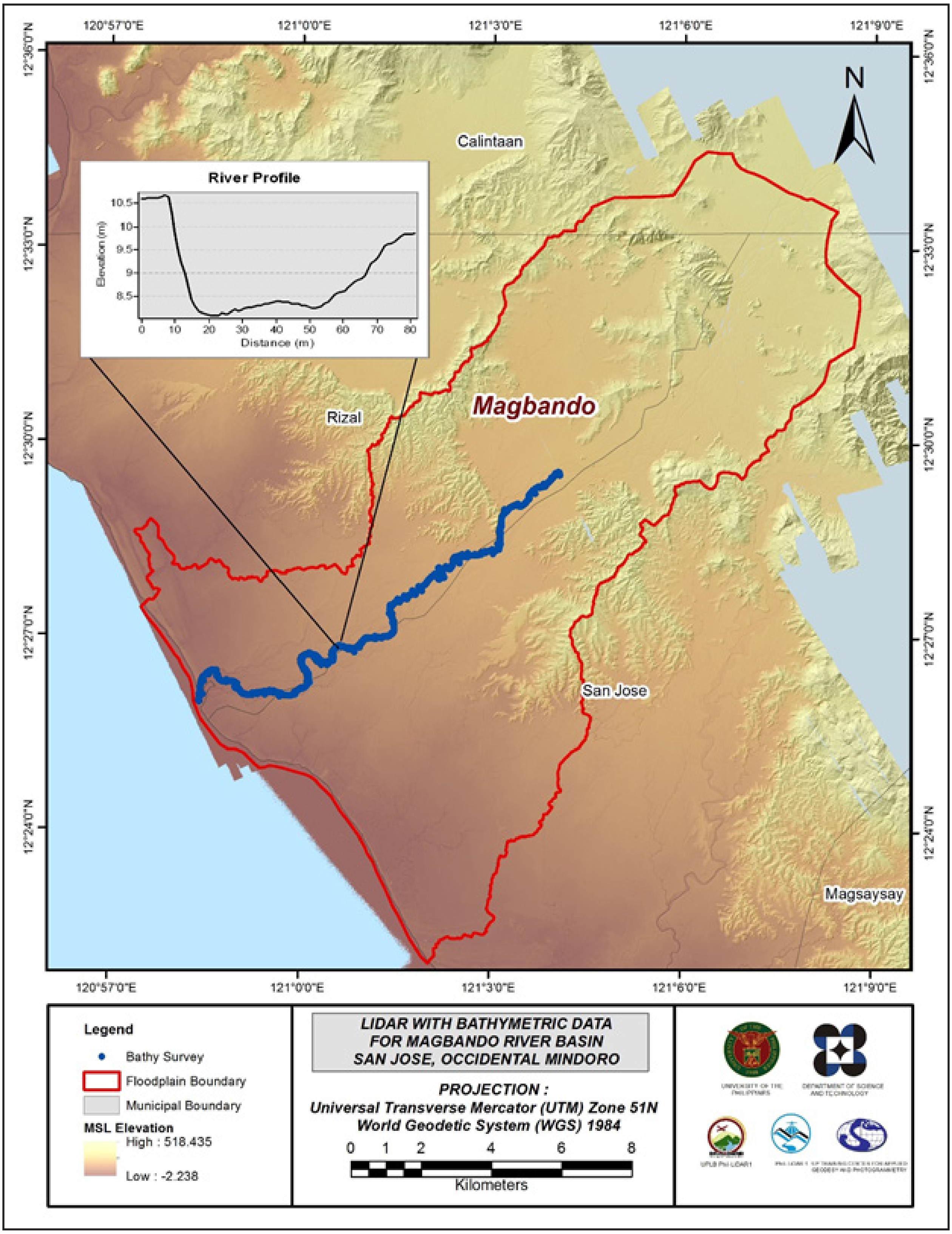

Figure 29. Map of Magbando Floodplain with bathymetric survey points shown in blue.

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

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

4.1 Summary of Activities

The project team conducted field survey in Magbando 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 in Brgy. San Pedro, Rizal, Occidental Mindoro; 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. Batasan, San Jose Municipality down to the mouth of the river in Brgy. Adela, Rizal Municipality with an approximate length of 16.842 km using GNSS PPK survey technique.

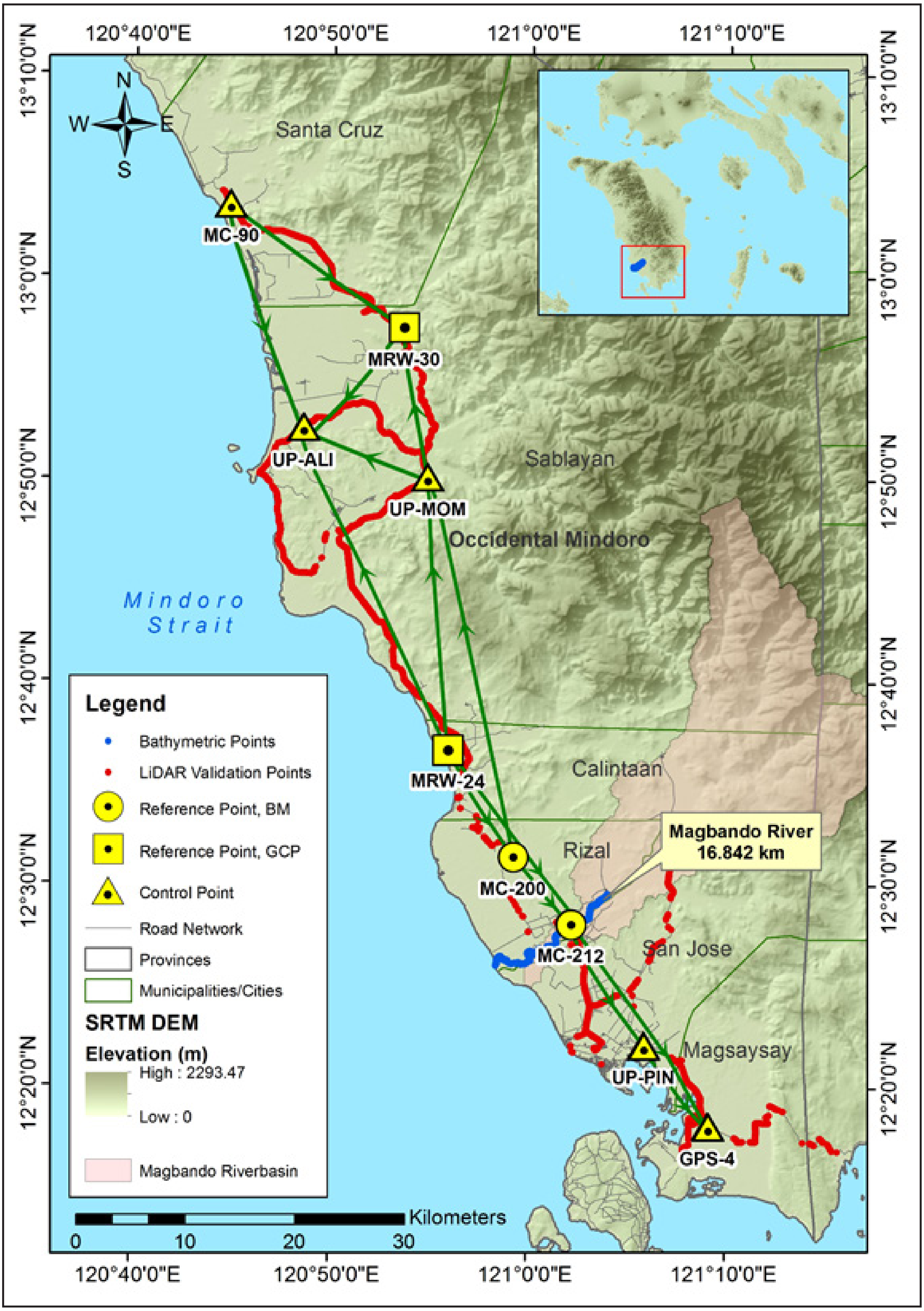


Figure 30. Extent of the bathymetric survey (blue line) in Magbando River and the LiDAR data validation survey (red)

4.2 Control Survey

The GNSS network used for Magbando 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 21 while the GNSS network established is illustrated in Figure 31.

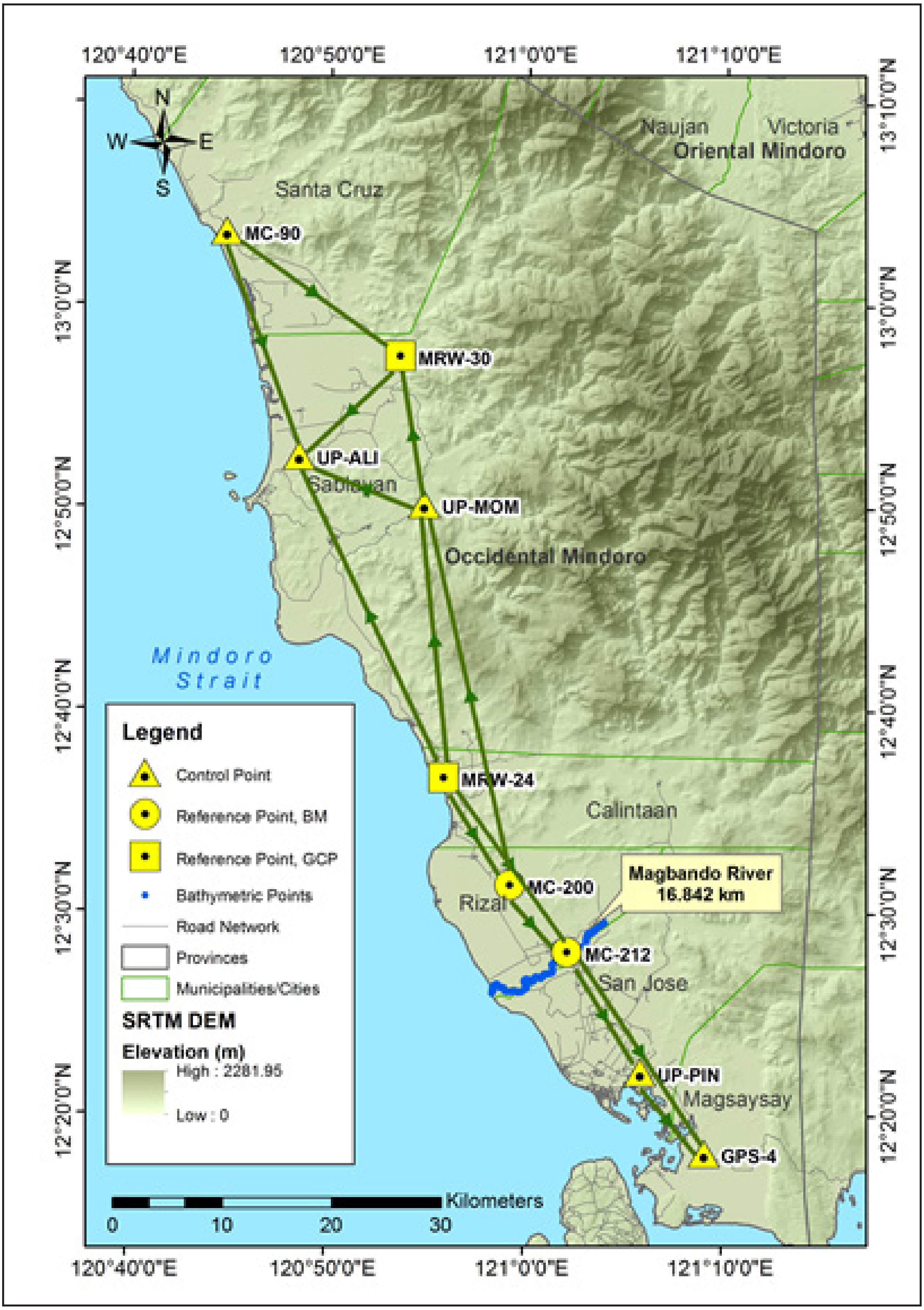


Figure 31. GNSS Network covering Magbando River

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

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 Figures 32 to 40.

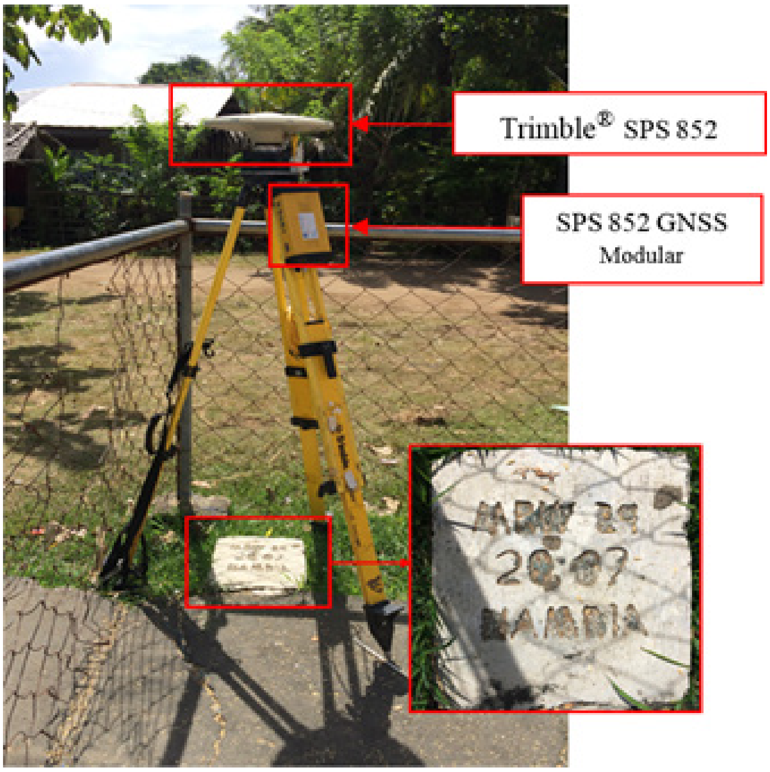


Figure 32. GNSS base set-up, Trimble® SPS 882, at MRW-24 in front of Iriron Elementary School in Brgy. Iriron, Municipality of Calintaan, Occidental Mindoro

Figure 33. GNSS receiver setup, Trimble® SPS 882, at MRW- 30 Amnay Bridge approach in Sitio Kabangkalan, Brgy. Pinagturilan, Municipality of Santa Cruz, Occidental Mindoro

Figure 34. GNSS receiver set-up, Trimble® SPS 882, at MC-200, Lumintao Bridge approach in Brgy. Magsikap, Municipality of Rizal, Occidental Mindoro

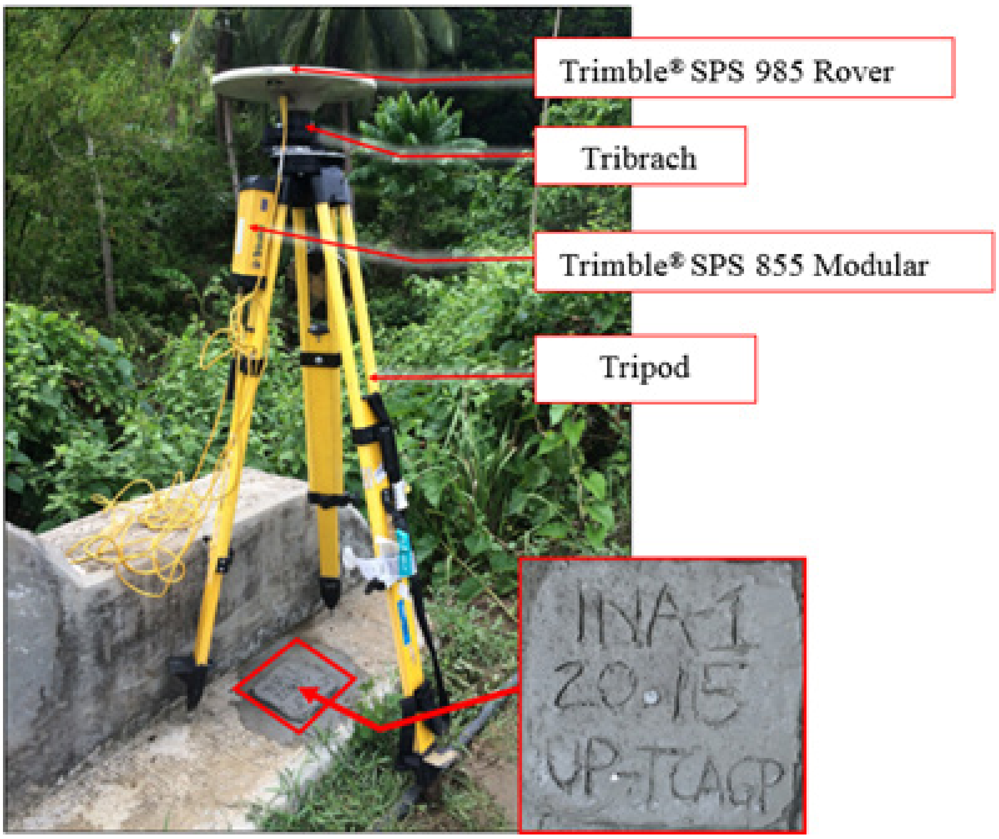


Figure 35. GNSS receiver set-up, Trimble® SPS 882, at MC-212, Busuanga Bridge approach in Bgry. Sto Niño, Municipality of Rizal, Occidental Mindoro

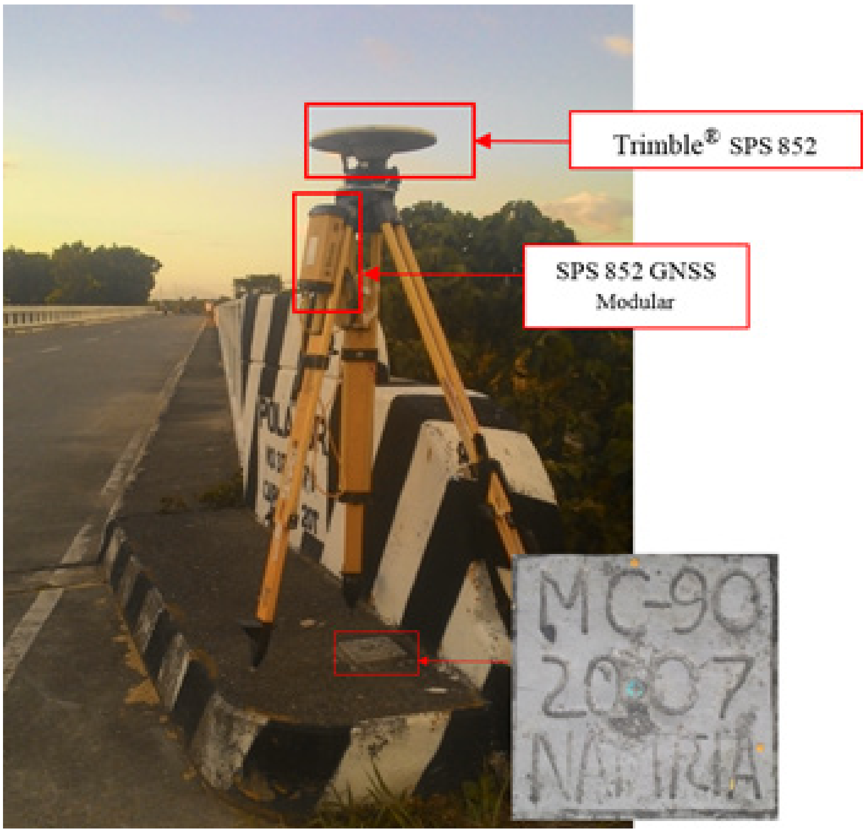


Figure 36. GNSS base, Trimble® SPS 852, at MC-90, used as marker, located at the Pola Bridge approach in Brgy. Barahan, Municipality of Santa Cruz, Occidental Mindoro

Figure 37. 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 38. GNSS base receiver set-up, Trimble® SPS 882, at UP-PIN Pinamanaan Bridge approach in Brgy. Mapaya, Municipality of San Jose, Occidental Mindoro

Figure 39. GNSS receiver set-up, Trimble® SPS 882, at UP-MOM, Mompong Bridge approached in Brgy. Lumang Bato, Municipality of Sablayan, Occidental Mindoro

Figure 40. 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 Magbando River Basin is summarized in Table 22 generated TBC software.

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

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MC-212 --- GPS-4	11-05-2015	Fixed	0.003	0.015	145°21'06"	22241.566	-11.807
MRW-30 --- UP-MOM	11-17-2015	Fixed	0.011	0.017	170°24'13"	13704.513	55.240
MRW-30 --- UP-MOM	11-17-2015	Fixed	0.003	0.023	170°24'12"	13704.541	55.249
MRW-30 --- MC-90	11-17-2015	Fixed	0.010	0.018	305°24'12"	19473.086	-35.515
UP-PIN --- MC-212	11-05-2015	Fixed	0.003	0.007	328°11'40"	12856.399	14.631
UP-PIN --- GPS-4	11-05-2015	Fixed	0.003	0.006	141°30'11"	9422.221	2.872
MC-200 --- UP-PIN	11-05-2015	Fixed	0.003	0.022	144°37'57"	20841.368	-23.356
MC-200 --- UP-MOM	11-05-2015	Fixed	0.009	0.014	346°57'26"	35544.301	60.755
MC-200 --- UP-MOM	11-05-2015	Fixed	0.004	0.014	346°57'27"	35544.309	60.692
MC-200 --- MC-212	11-05-2015	Fixed	0.003	0.006	138°58'31"	8048.668	-8.741
UP-ALI --- UP-MOM	11-15-2015	Fixed	0.008	0.013	110°57'37"	12258.370	88.024
UP-MOM --- UP-ALI	11-15-2015	Fixed	0.004	0.036	110°57'37"	12258.373	88.139
UP-ALI --- MRW-30	11-17-2015	Fixed	0.009	0.012	45°05'52"	12929.488	32.865
MRW-30 --- UP-ALI	11-17-2015	Fixed	0.004	0.017	45°05'52"	12929.476	32.850
MRW-30 --- UP-ALI	11-17-2015	Fixed	0.004	0.007	45°05'51"	12929.529	32.747
MC-90 --- UP-ALI	11-17-2015	Fixed	0.004	0.008	341°46'30"	21480.592	-2.784
MRW-24 --- UP-PIN	11-05-2015	Fixed	0.003	0.006	145°50'52"	32317.096	6.413
MRW-24 --- MC-200	11-05-2015	Fixed	0.005	0.007	148°04'31"	11489.166	29.777
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 form:

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

where:

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

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

Table 23. 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)					

Table 24. Adjusted Grid Coordinates

Point ID	Easting (Meter)	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 25. With the mentioned equation, $\sqrt{((x_e)^2+(y_e)^2)}<20cm$ for horizontal and $z_e<10\ cm$ for the vertical; the computation for the accuracy are as follows:

a. **GPS-4**

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

b. **MC-200**

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

c. **MC-212**

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

d. **MC-90**

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

e. **MRW-24**

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

f. **MRW-30**

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

g. **UP-ALI**

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

h. **UP-MOM**

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

i. **UP-PIN**

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

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

Table 25. Adjusted Geodetic Coordinates

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

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

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

Table 26. References and Control Points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
MC-200	1st order, BM	12°31'20.68883"	120°59'15.31614"	83.225	1385155.121	281320.527	34.024
MC-212	1st order, BM	12°28'03.07504"	121°02'10.26310"	74.473	1379041.958	286558.124	24.884
MRW-24	2nd order, GCP	12°36'38.03550"	120°55'54.08297"	53.435	1394955.913	275320.607	4.746
MRW-30	2nd order, GCP	12°57'27.19115"	120°53'33.54441"	88.823	1433384.691	271390.777	41.752
MC-90	UP Established	13°03'34.14426"	120°44'46.70845"	53.232	1444800.407	255607.924	8.195
UP-ALI	UP Established	12°52'30.24358"	120°48'29.69148"	55.998	1424334.041	262152.459	9.503
UP-MOM	UP Established	12°50'07.47192"	120°54'49.30854"	144.013	1419850.456	273564.872	96.192
UP-PIN	UP Established	12°22'07.55000"	121°05'54.64323"	59.843	1368066.413	293256.669	9.659
GPS-4	DPWH Established	12°18'07.55700"	121°09'08.74194"	62.706	1360649.962	299069.894	12.062

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

Bridge As-built and Cross-section survey were conducted on November 6 and 7, 2015 using GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in 41 at the downstream side of Busuanga Bridge in Brgy. San Pedro, Rizal, Occidental Mindoro as shown in Figure 42.

Figure 41. Busuanga Bridge facing downstream

Figure 42. Bridge as-built and cross-section survey at the downstream side of Busuanga Bridge, Brgy. San Pedro, Municipality of Rizal

The cross-sectional line length in Busuanga bridge is about 369.28 with 408 cross-sectional points acquired using MC-212 as the GNSS base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 43 to Figure 45, respectively.

On the other hand, water surface elevation in MSL of Magbando River was determined using Trimble® SPS 882 in PPK mode technique on November 23, 2015 at 04:25 PM with a value of 16.822 m in MSL. This was translated onto marking on the bridge's pier using a digital level. The value of 18.493 m is still an assumed elevation and yet to be changed to the computed 17.449 m in MSL by UP Los Baños. They shall update the marked pier to reflect its corresponding MSL value. The marked pier will serve as their reference for flow data gathering and depth gauge deployment for Magbando River

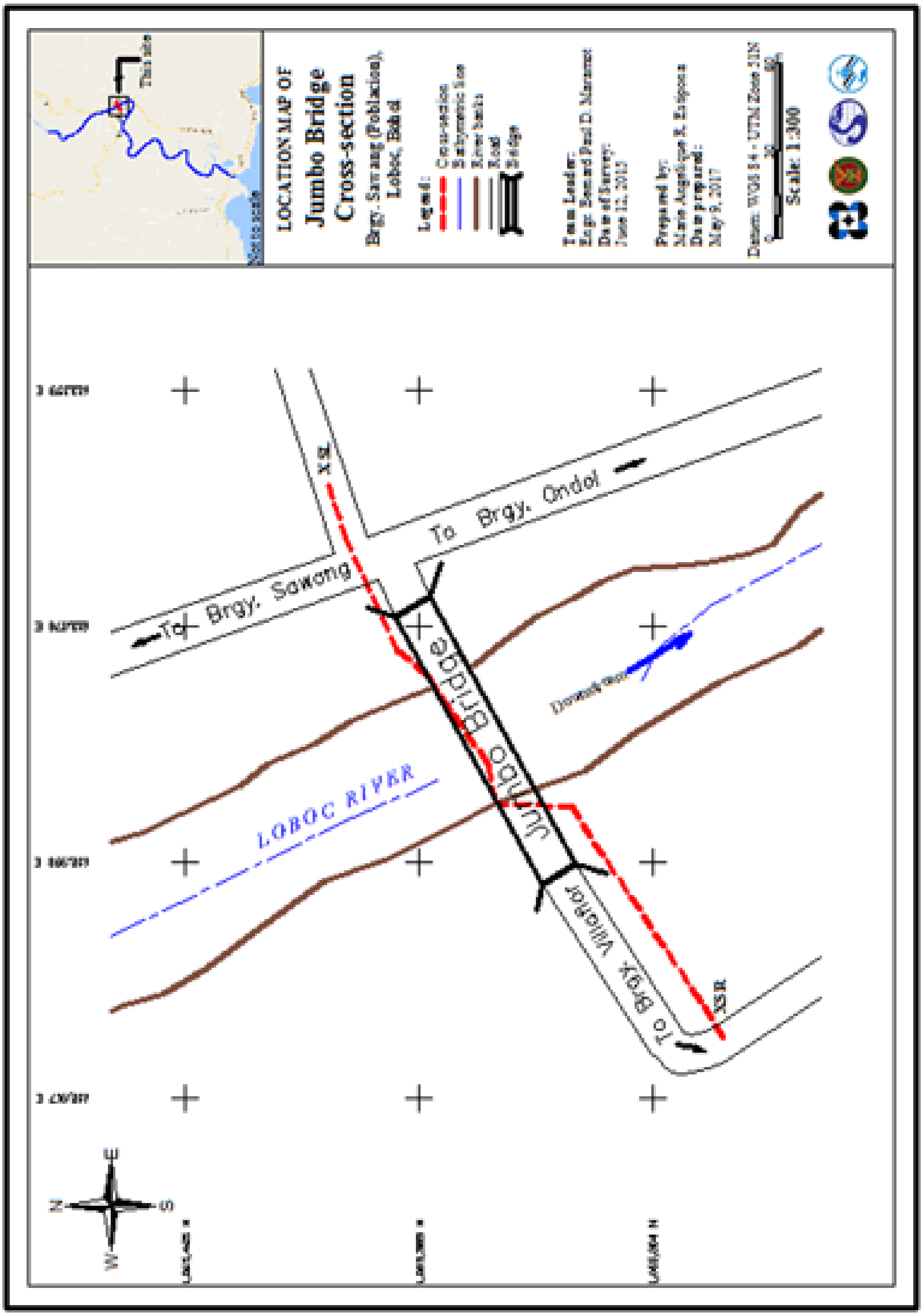


Figure 43. Magbando bridge cross-section location map

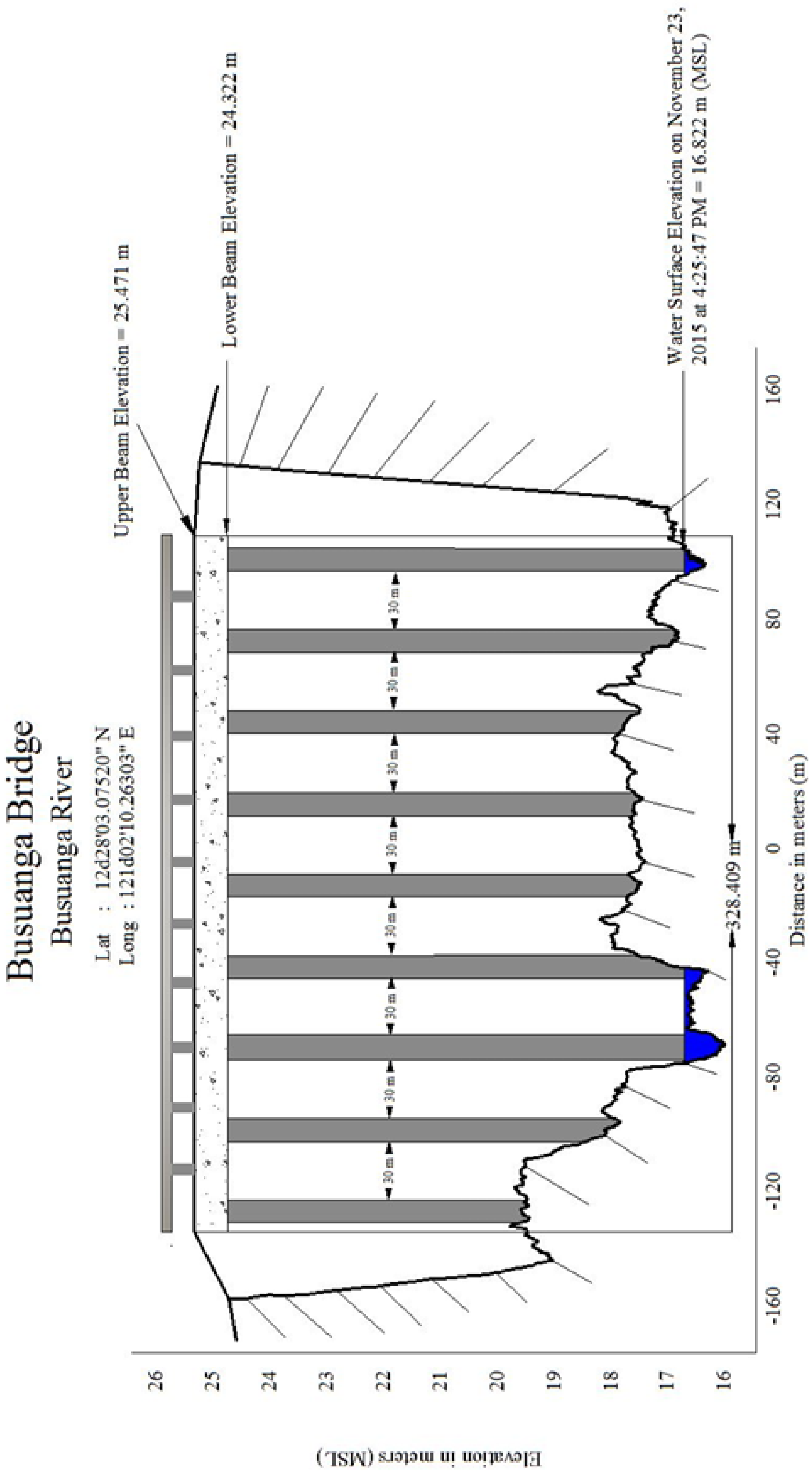


Figure 43. Magbando bridge cross-section location map

Bridge Name: Busuanga Bridge **Date:** November 06-07, 2015

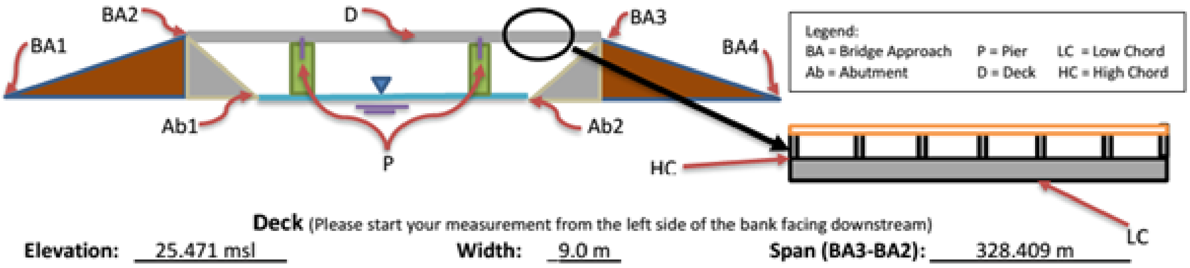
River Name: Busuanga River **Time:** 10:58 AM and 3:00 PM

Location (Brgy, City, Region): Brgy. San Pedro, Rizal, Occidental Mindoro

Survey Team: Team Mady and Team Klyn

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

Latitude: 12d28'03.07520" N **Longitude:** 121d02'10.26303" E



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

Elevation: 25.471 msl **Width:** 9.0 m **Span (BA3-BA2):** 328.409 m

	Station	High Chord Elevation	Low Chord Elevation
1	BA2	24.855	24.322
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		BA3	353.178	24.863
BA2	24.781	24.854	BA4	369.280	24.418

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: ________ **Number of Piers:** ________ **Height of column footing:** ________

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	61.005	25.236	
Pier 2	92.923	25.474	
Pier 3	124.966	25.652	
Pier 4	156.945	25.767	
Pier 5	188.984	25.796	
Pier 6	220.954	25.759	
Pier 7	252.981	25.624	
Pier 8	284.993	25.456	
Pier 9	316.9981	25.236	

Figure 45. Magbando Bridge Data Form

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 46. 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 46. Trimble® SPS8 82 set-up for validation points acquisition survey for Magbando 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 47 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.

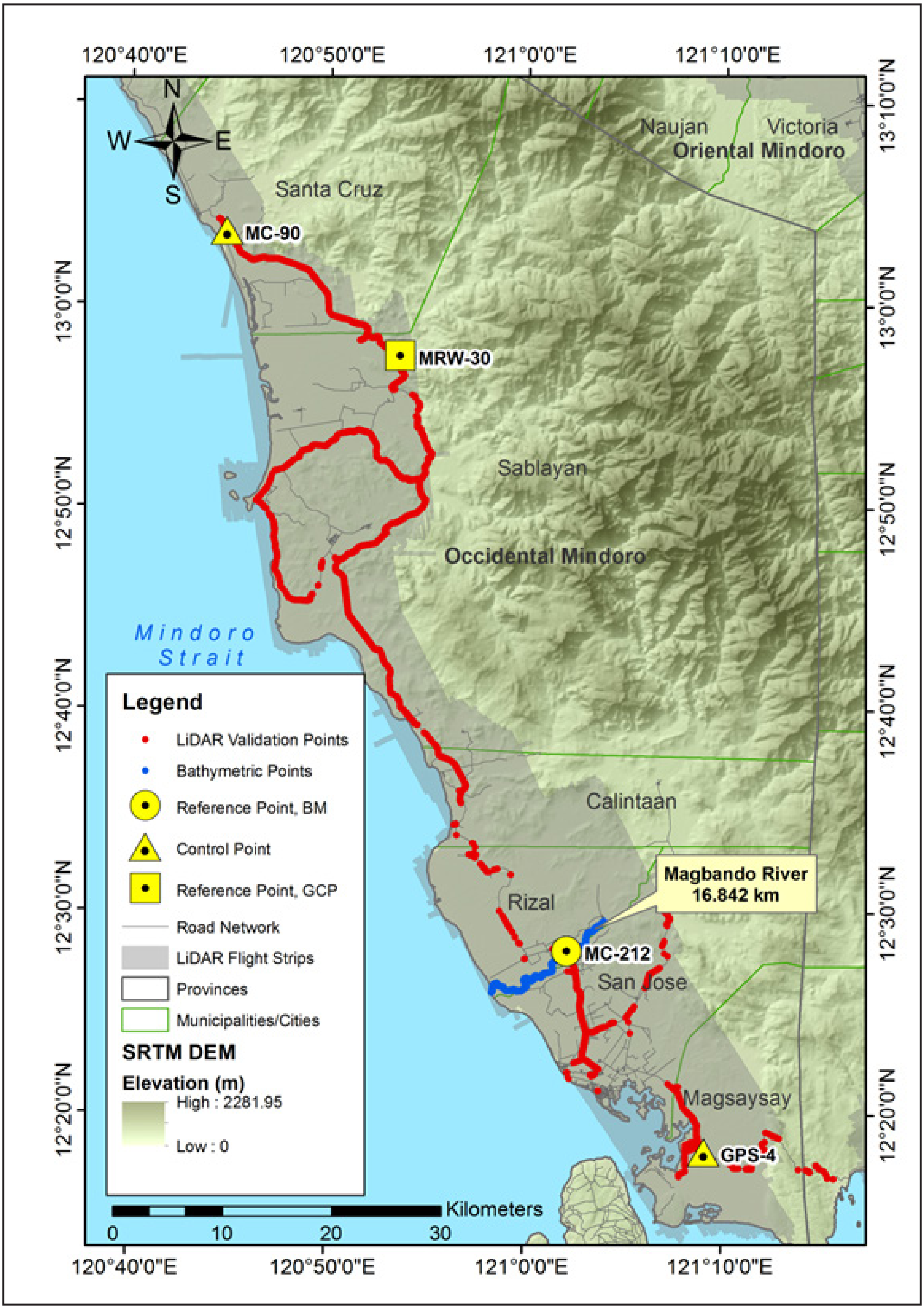


Figure 47. Validation point acquisition survey for the Magbando River Basin

4.7 River Bathymetric Survey

Manual bathymetric survey was executed on November 6 and 7, 2015 using Trimble® SPS 882 GNSS PPL technique as shown in Figure 48. The survey started at the upstream portion of Busuanga river in Brgy. Aguas, Municipality of Rizal with coordinates 12°29'29.40970" 121°04'04.18657", traversed down the river by foot to Brgy. Central, Municipality of San Jose and ended at the mouth of the river in Brgy. Adela in Municipality of Rizal with coordinates 12°25'58.83536" 120°58'24.62896".

Figure 48. Manual Bathymetry along Magbando River

The entire bathymetric data coverage for Magbando River is illustrated Figure 49. Bathymetric line length surveyed is approximately 16.842 km with a total of 65,534 bathymetric points covering three barangays in Rizal: Aguas, San Pedro and Adela; and three barangays in San Jose: San Isidro, Central and San Agustin. A CAD diagram was also produced to illustrate the Magbando riverbed profile.

As illustrated in Figure 50, there is an elevation drop of 32.42 meters within the total distance of Busuanga river. The highest elevation value observed was 32.382 m in MSL located at the upstream part and the lowest elevation value observed was -1.699 m below MSL located at the mouth of the river. There is a 3.5 km planned bathymetric line in the upstream part of San Isidro which was not covered because the area is not populated and not prone to flooding according to the courtesy call with LGU San Jose and upon reconnaissance of the area.

Figure 49. Bathymetric survey of Magbando River

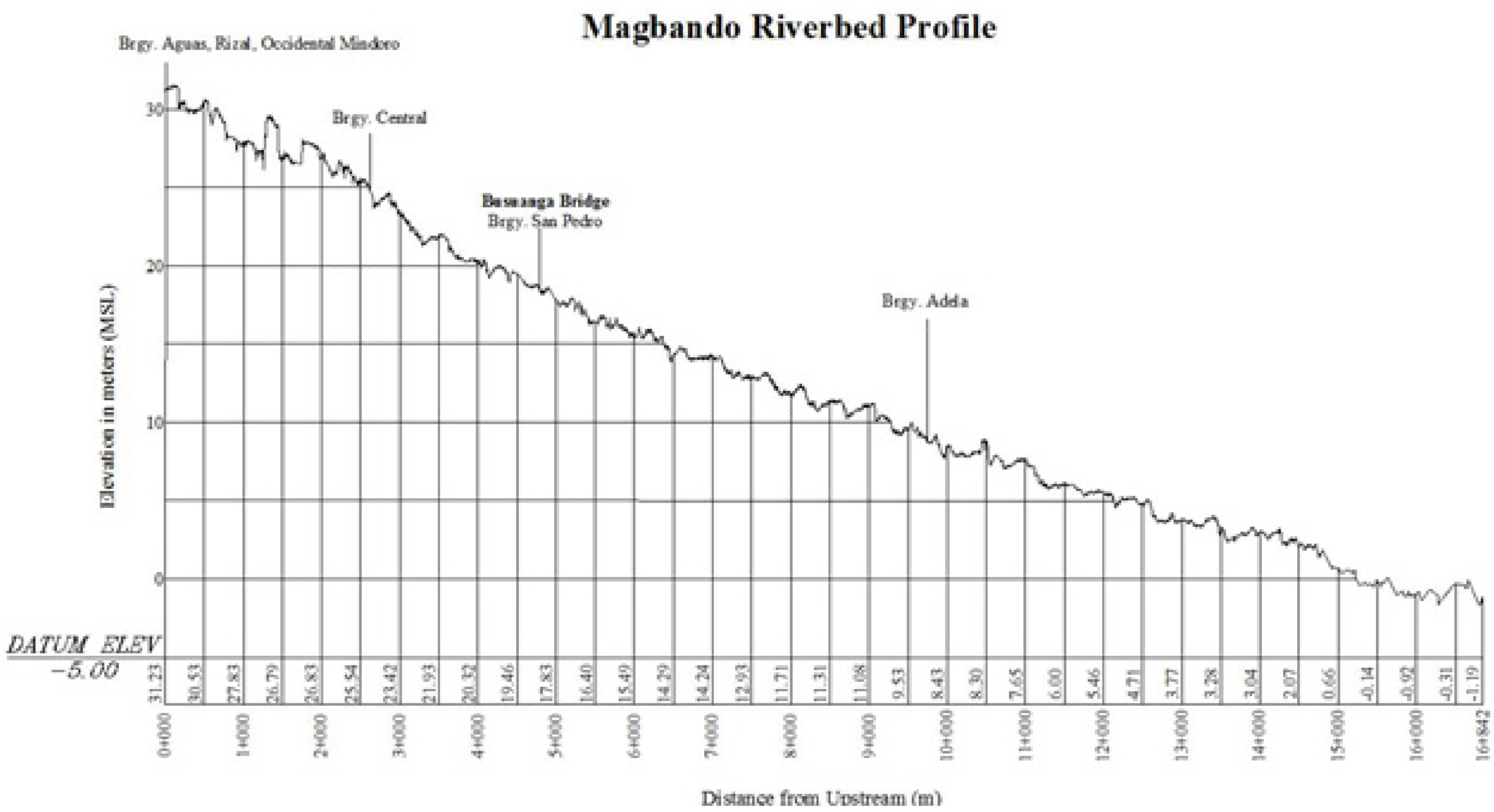


Figure 50. Riverbed profile of Magbando River

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, and Khristoffer Quinton, John Alvin B. Reyes, Alfi Lorenz B. Cura, Angelica T. Magpantay, Maria Michaela A. Gonzales Paulo Joshua U. Quilao, Jayson L. Arizapa, Raphael P. Gonzales, and Kevin M. Manalo

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from a portable rain gauge installed on a strategic location within the riverbasin (12.497851°N, 121.071038°E). The location of the rain gauge is seen in Figure 51.

The total precipitation for this event is 370.70 mm. It has a peak rainfall of 39.0 mm. on September 8, 2016 at 5:45 pm. The lag time between the peak rainfall and discharge is 2 hour and 25 minutes, as seen in Figure 53.

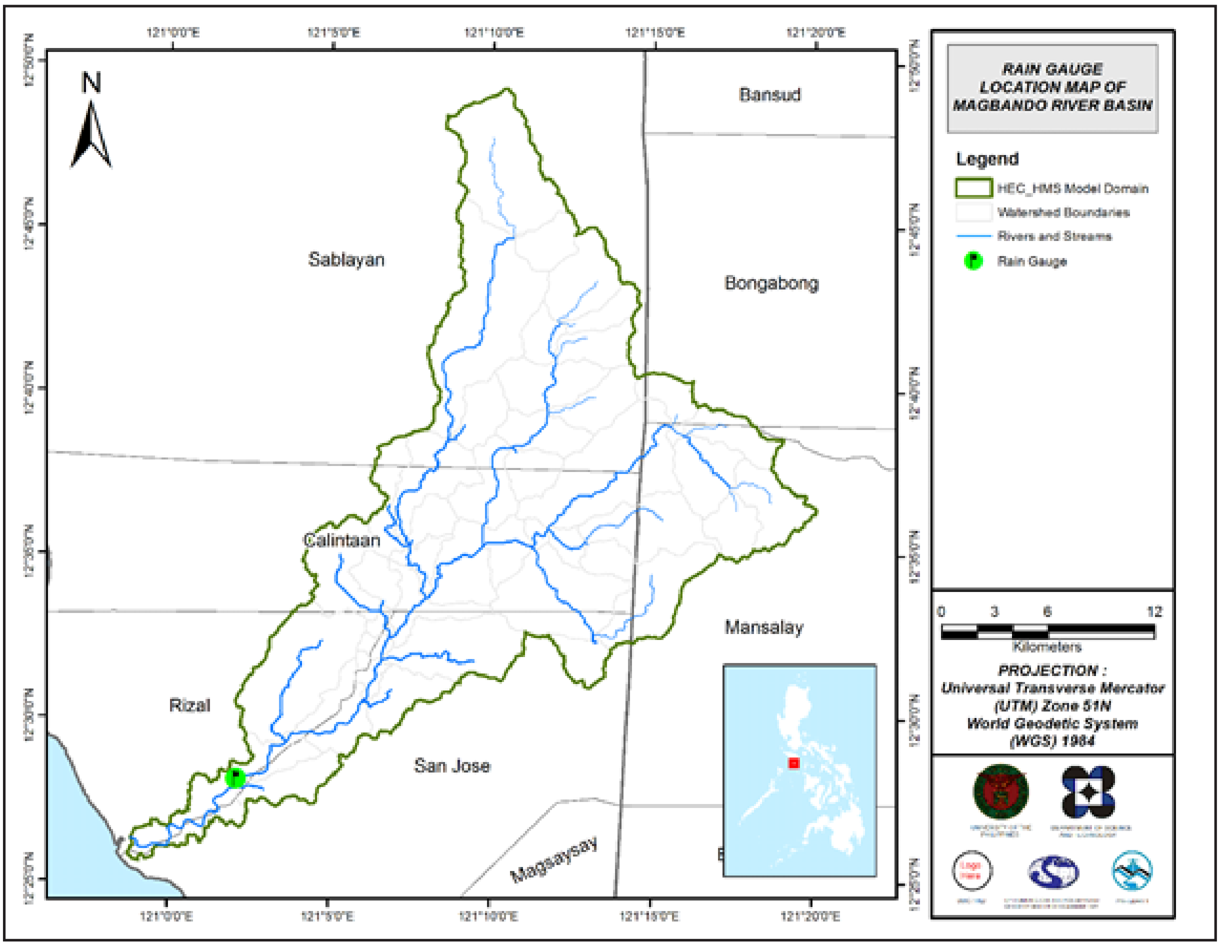


Figure 51. The location map of Magbando HEC-HMS model used for calibration

5.1.3 Rating Curve and River Outflow

A rating curve was developed at Busuanga Bridge, Occidental Mindoro (12.465189°N, 121.037486°E). It gives the relationship between the observed water levels from the Busuanga Bridge and outflow of the watershed at this location using Bankfull Method in Manning's Equation.

For Busuanga Bridge, the rating curve is expressed as Q = 0.0307exp(0.5315X) as shown in Figure 53.

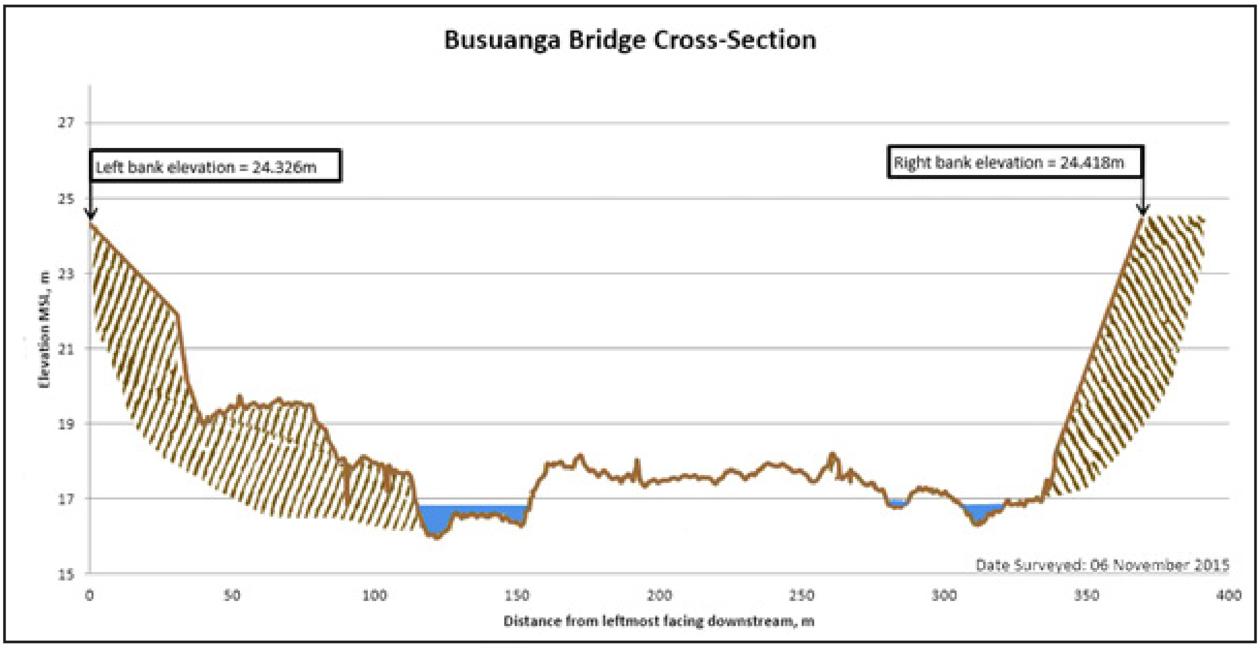


Figure 52. Cross-Section Plot of Busuanga Bridge

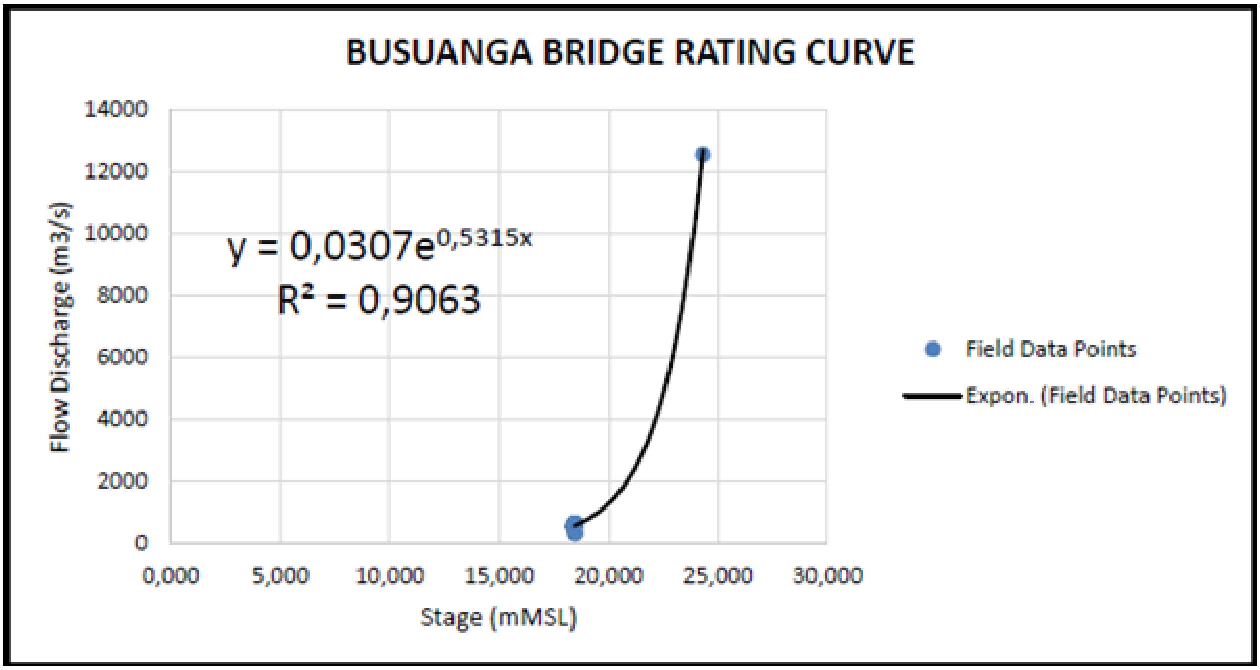


Figure 53. Rating Curve at Busuanga Bridge, Occidental Mindoro

For the calibration of the HEC-HMS model, shown in Figure 54, actual flow discharge during a rainfall event was collected in the Busuanga bridge. Peak discharge is 649.0 cu.m/s on September 9, 2016 at 8:10 pm.

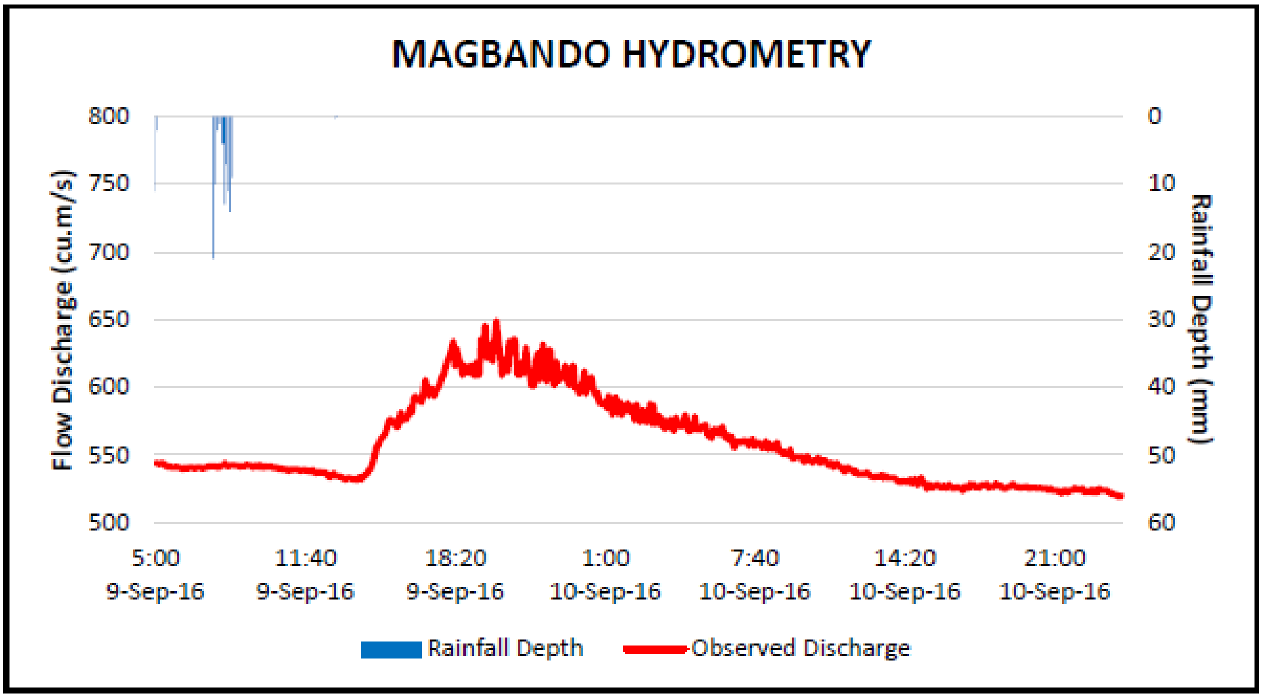


Figure 54. Rainfall and outflow data at Magbando used for modeling

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 Magbando watershed. The extreme values for this watershed were computed based on a 48-year record.

Table 27. 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

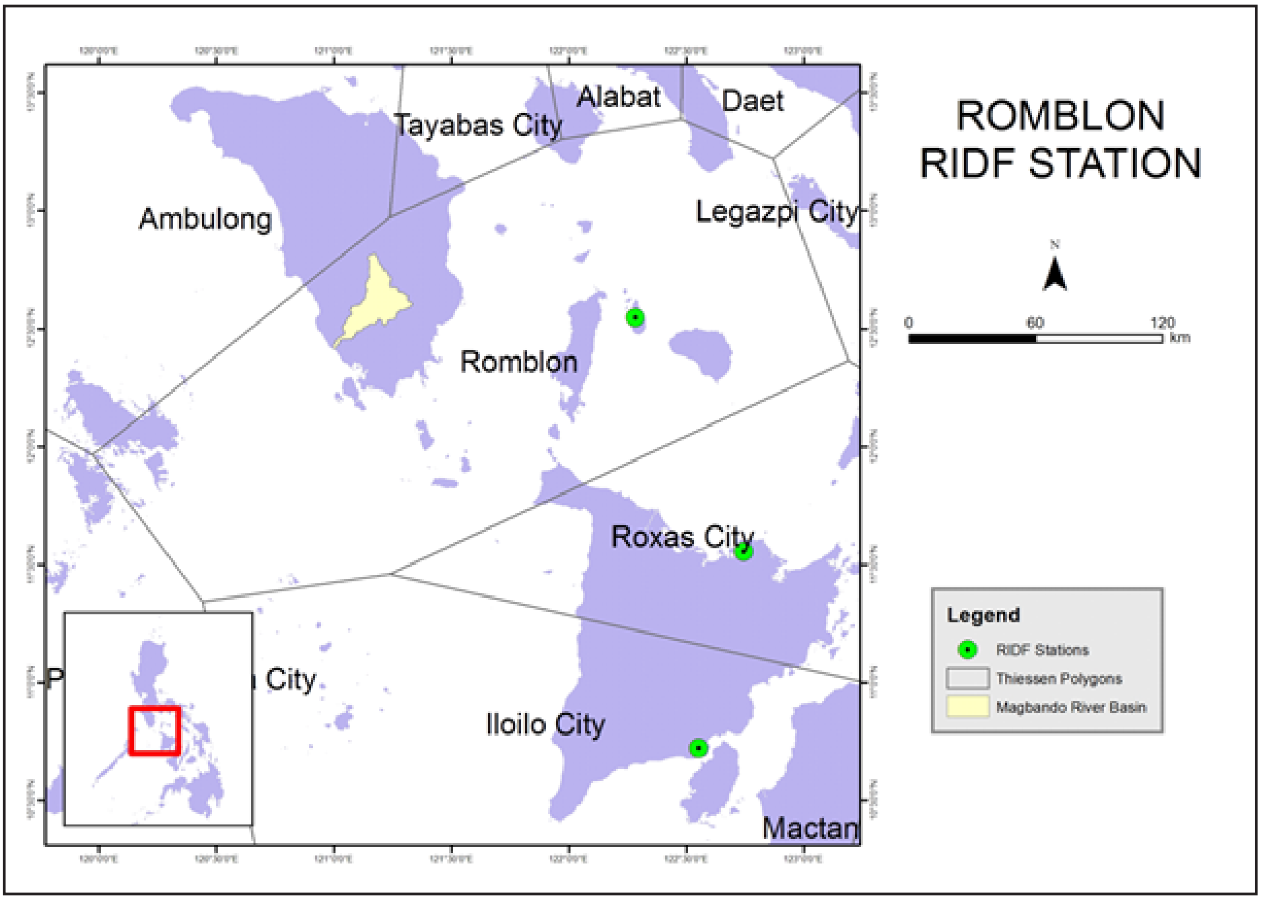


Figure 55. Location of Romblon RIDF station relative to Magbando River Basin

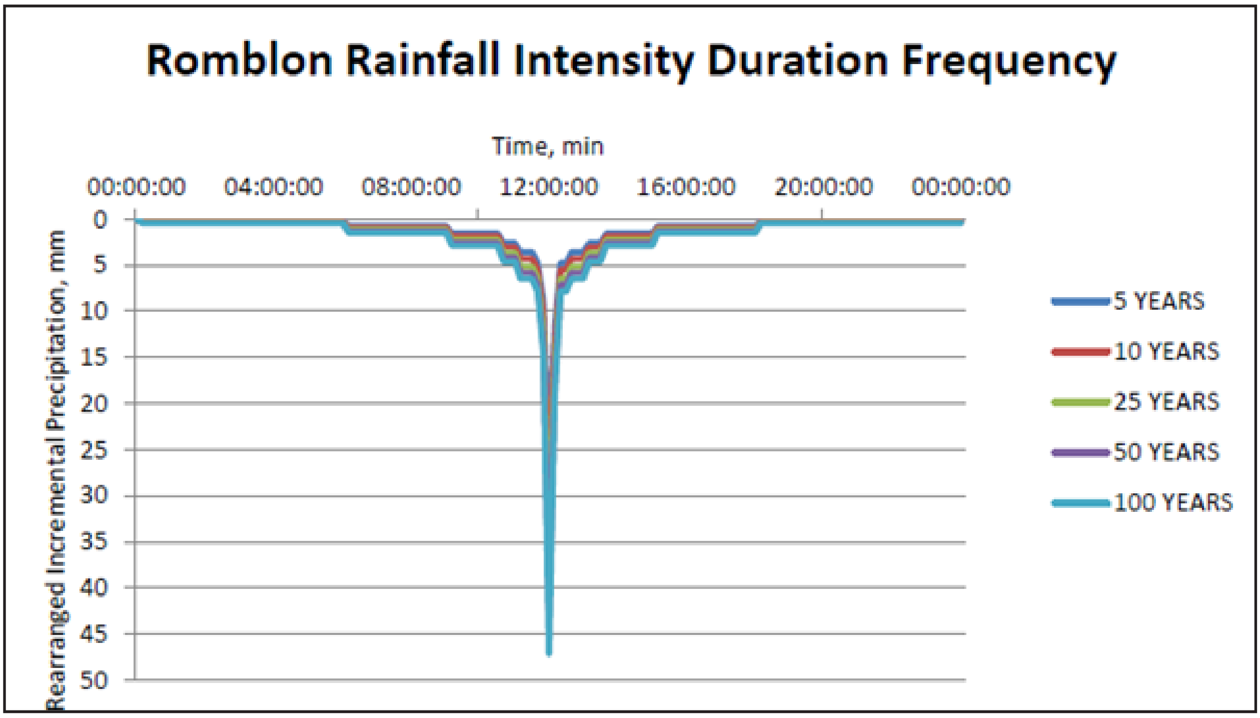


Figure 58. Synthetic storm generated for a 24-hr period rainfall for various return periods.

5.3 HMS Model

The soil shape file (dated pre-2004) was taken from the Bureau of Soils and Water Management under the Department of Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil map and land cover map can be found in Figures 57 and 58, respectively.

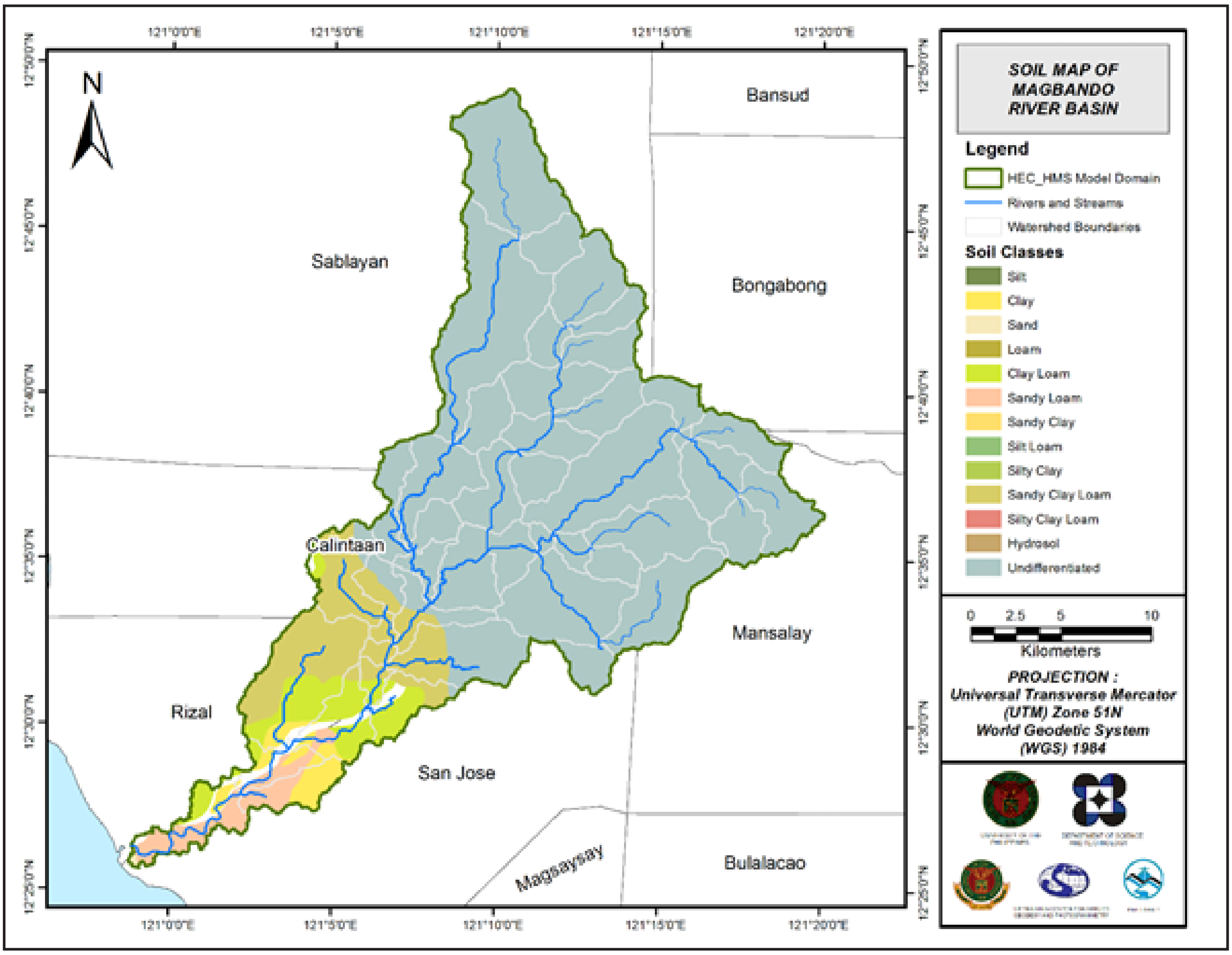


Figure 57. The soil map of the Magbando River Basin used for the estimation of the CN parameter. (Source of data: Digital soil map of the Philippines published by the Bureau of Soil and Water Management – Department of Agriculture)

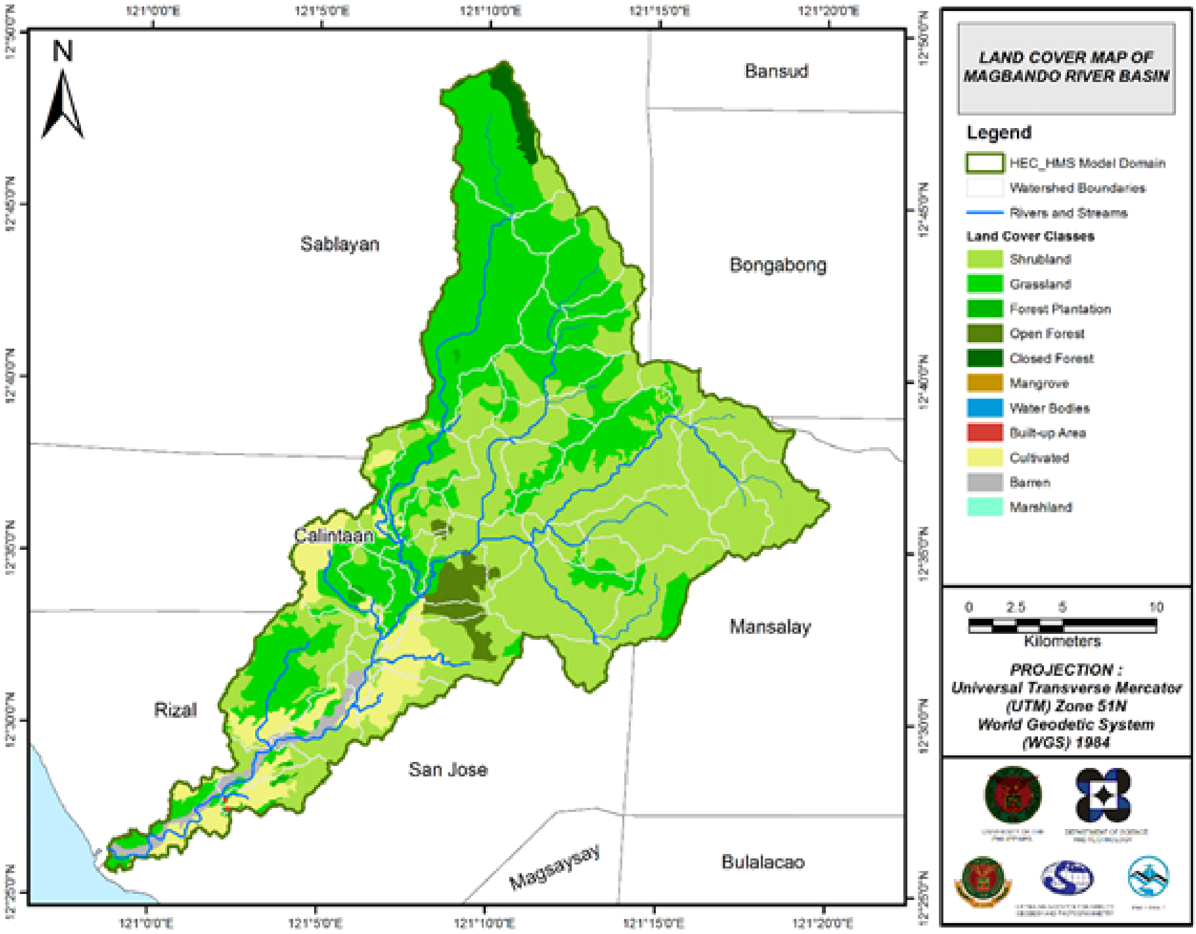


Figure 58. The land cover map of the Magbando River Basin used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model. (Source: NAMRIA)

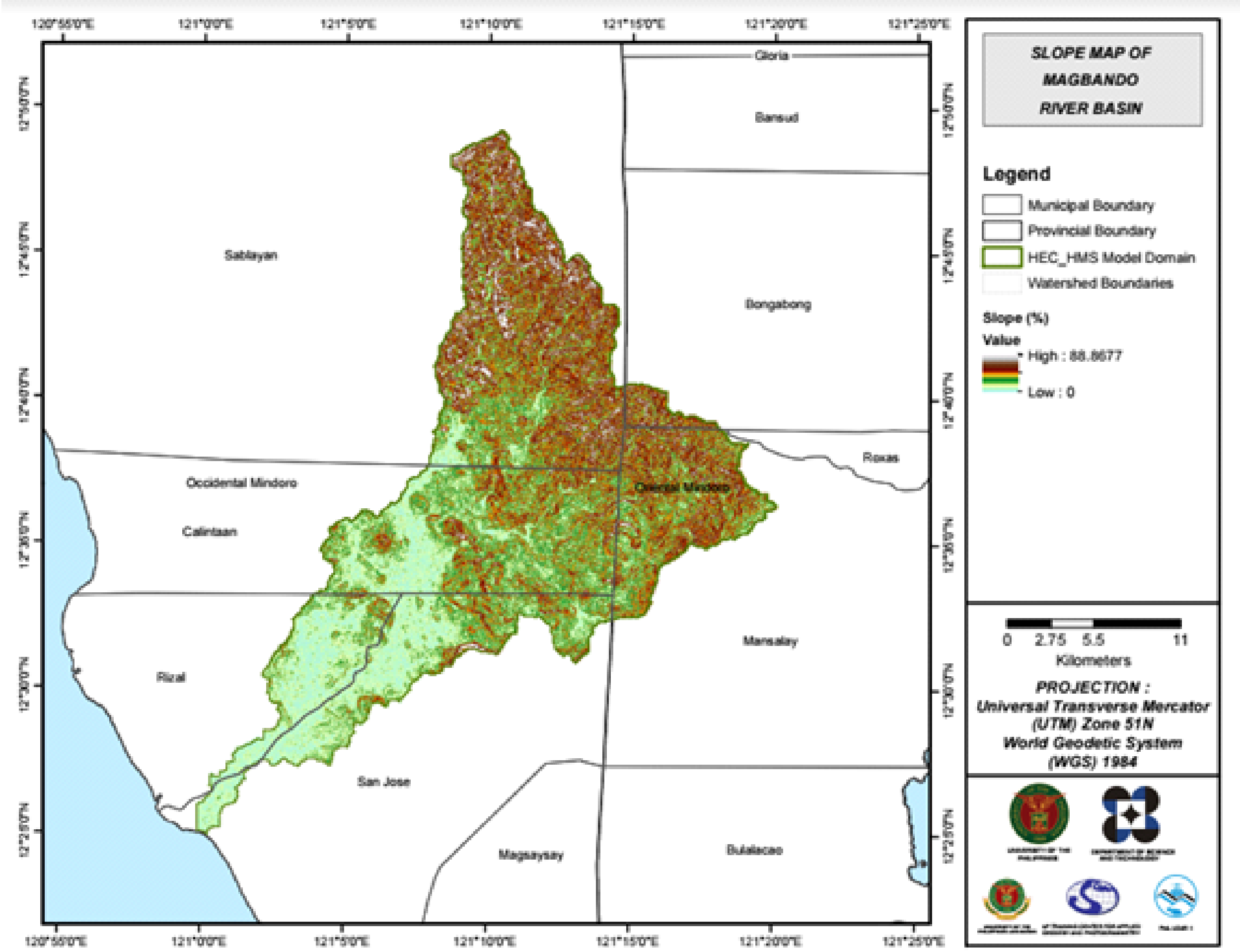


Figure 59. Slope Map of the Magbando River Basin

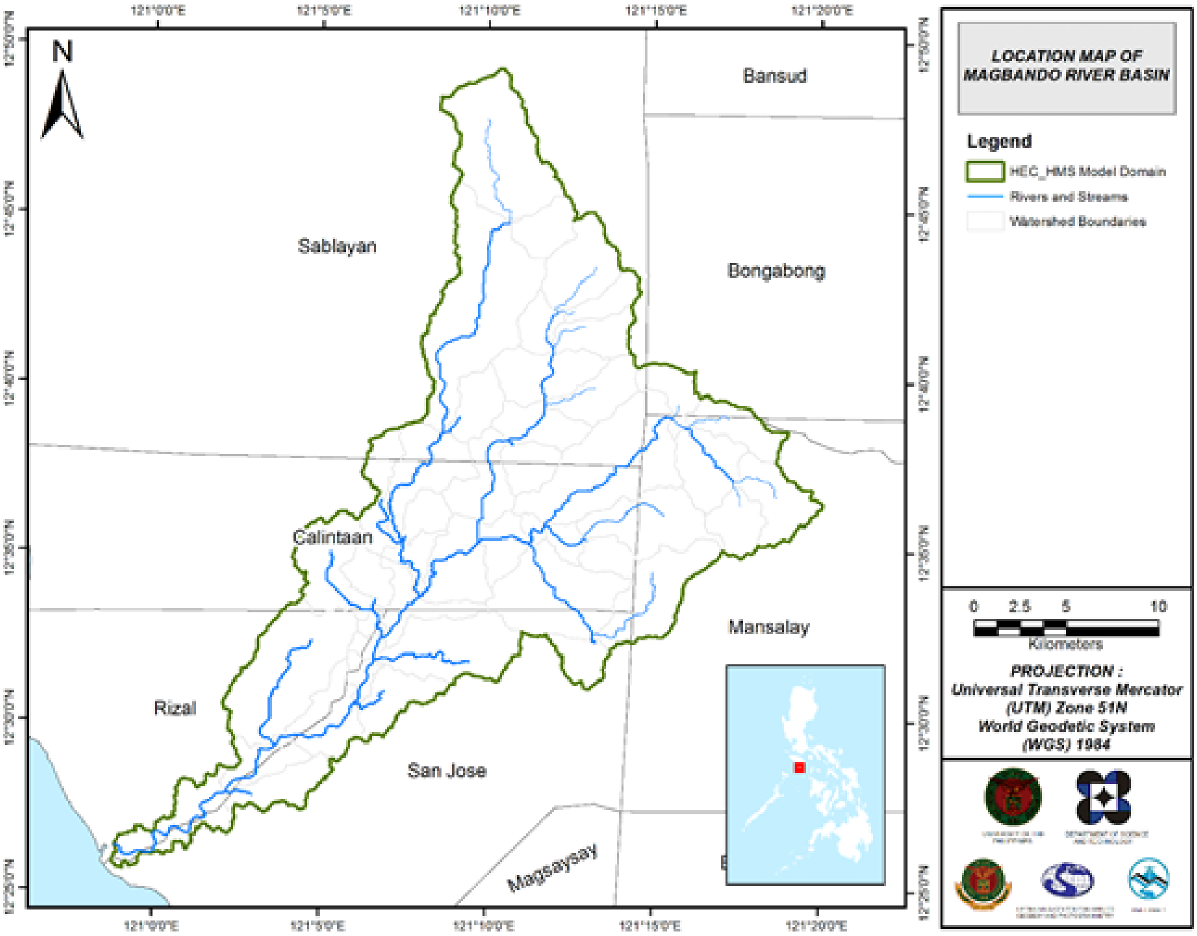


Figure 60. Stream Delineation Map of the Magbando River Basin

Using SAR-based DEM, the Magbando basin was delineated and further subdivided into subbasins. The model consists of 23 sub basins, 23 reaches, and 16 junctions as shown in Figure 61. The main outlet is at Busuanga Bridge.

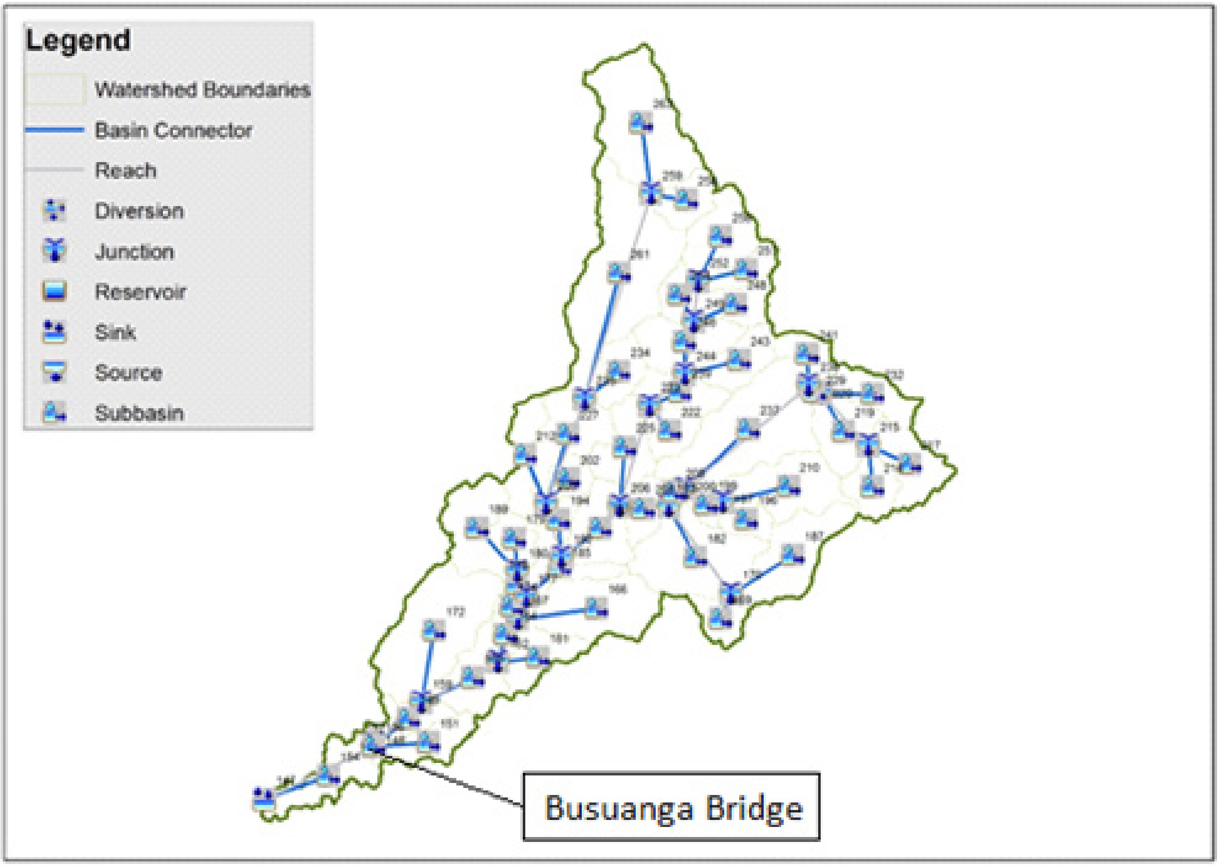


Figure 61. The Magbando river basin model generated using HEC-HMS

5.4 Cross-section Data

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

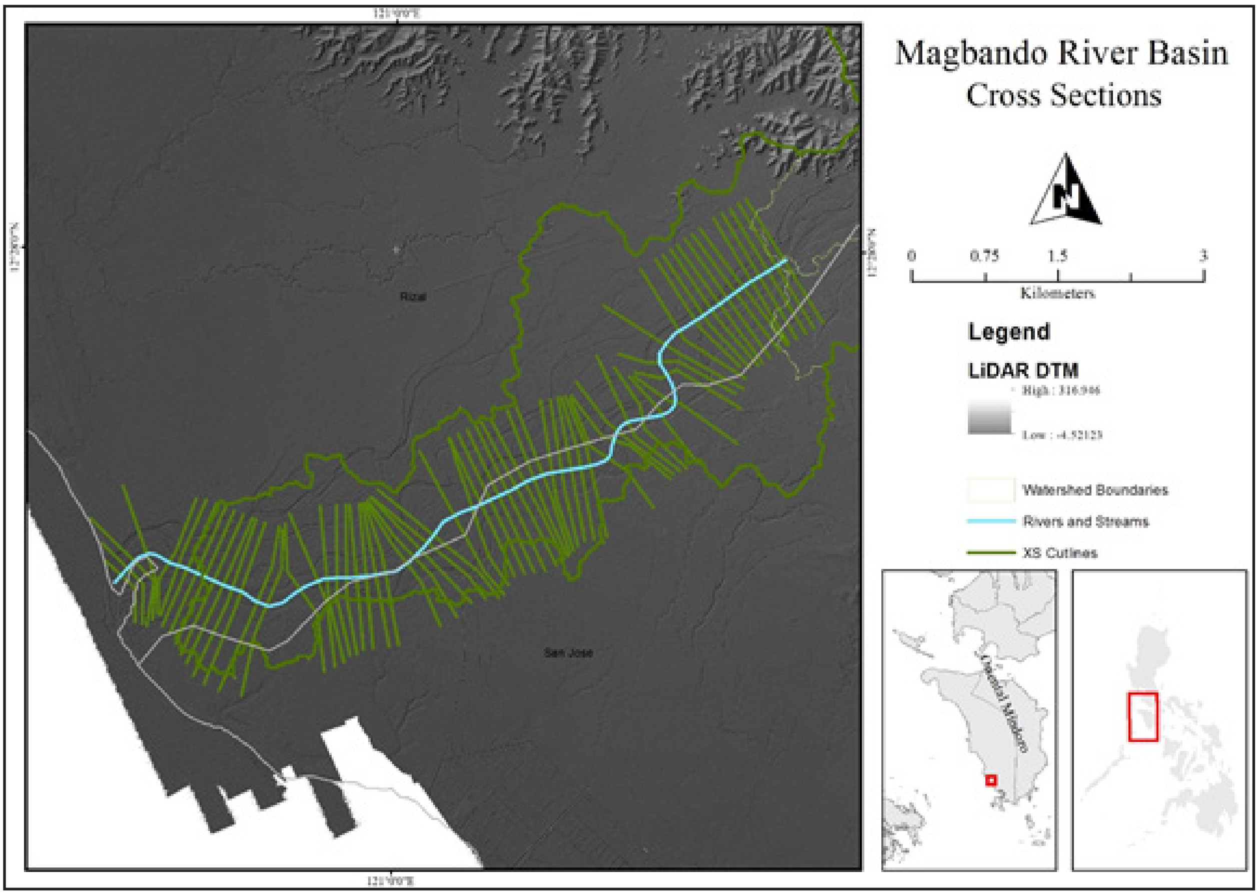


Figure 62. River cross-section of Pagbahan River generated through Arcmap HEC GeoRAS tool

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

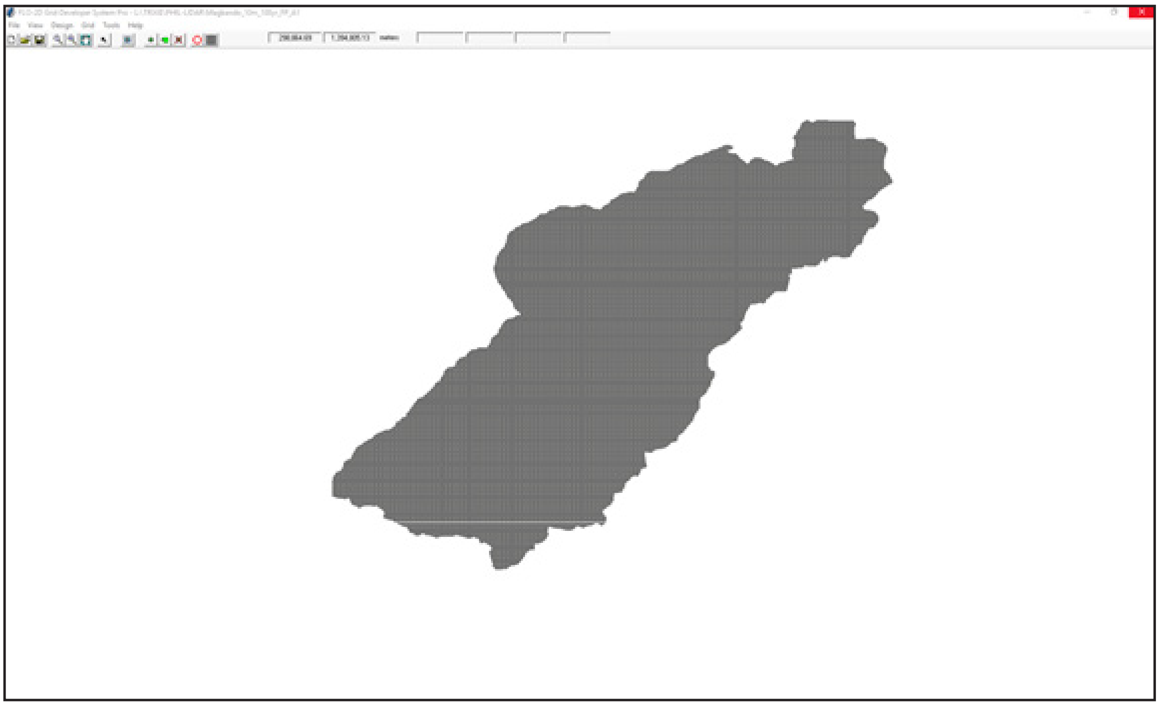


Figure 63. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 18.43164 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 m^2/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 27193300.00 m^2.

There is a total of 9387977.26 m^3 of water entering the model. Of this amount 9387977.26 m^3 is due to rainfall while 0.00 m^3 is inflow from other areas outside the model. 2515490.50 m^3 of this water is lost to infiltration and interception, while 1300206.70 m^3 is stored by the flood plain. The rest, amounting up to 5572280.96 m^3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Magbando HEC-HMS river basin model, its accuracy was measured against the observed values (see Annex 9: Magbando Model Basin Parameters). Figure 64 shows the comparison between the two discharge data.

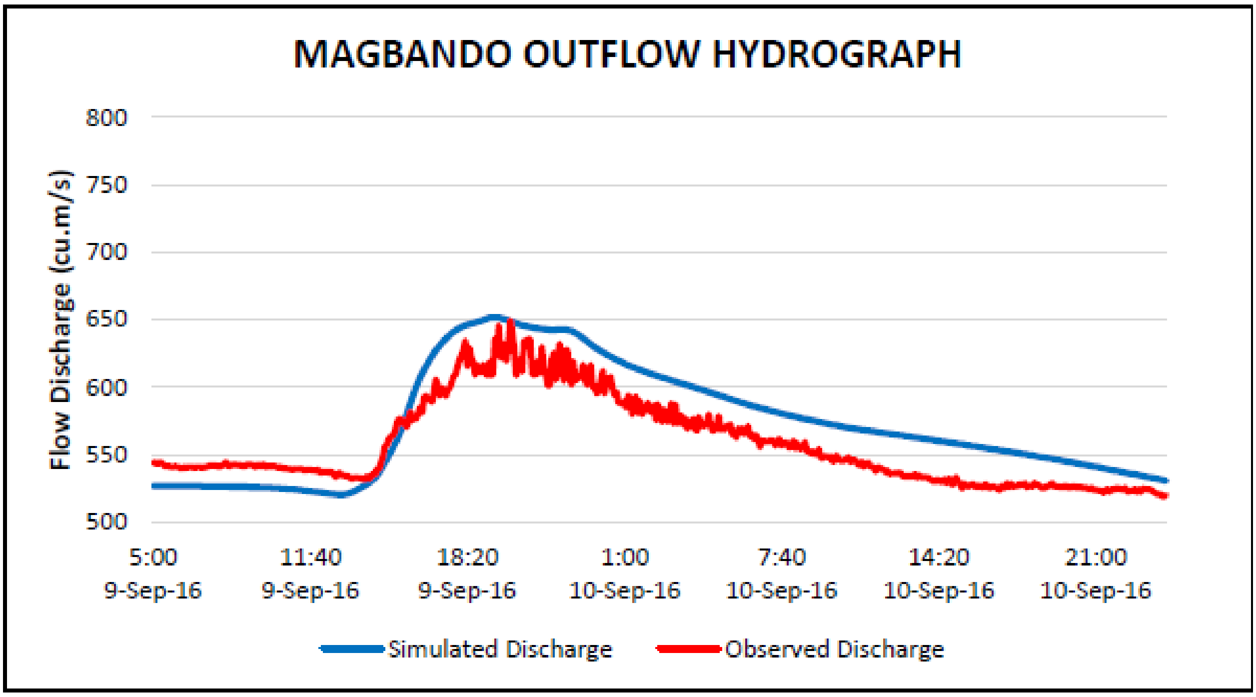


Figure 64. Outflow Hydrograph of Magbando produced by the HEC-HMS model compared with observed outflow

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

Table 28. Range of Calibrated Values for the Magbando River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	3 - 47
			Curve Number	39 - 99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.3 - 31
			Storage Coefficient (hr)	0.6 - 29
	Baseflow	Recession	Recession Constant	0.2 - 1
			Ratio to Peak	0.3 – 0.8
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.04

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 3 to 47mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 39 to 99 for curve number means that there is a diverse characteristic for this watershed depending on its subbasin.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.3 hours to 31 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. Same as the curve number, the characteristics of this watershed differs per reach.

Manning's roughness coefficient of 0.04 corresponds to the common roughness of Magbando watershed, which is determined to be cultivated with mature field crops (Brunner, 2010).

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

Accuracy measure	Value
RMSE	22.898
r2	0.917
NSE	0.492
PBIAS	-2.643
RSR	0.7129

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 22.898.

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 0.917.

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 0.492.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is -2.643.

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 0.7129.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 65) shows the Magbando 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.

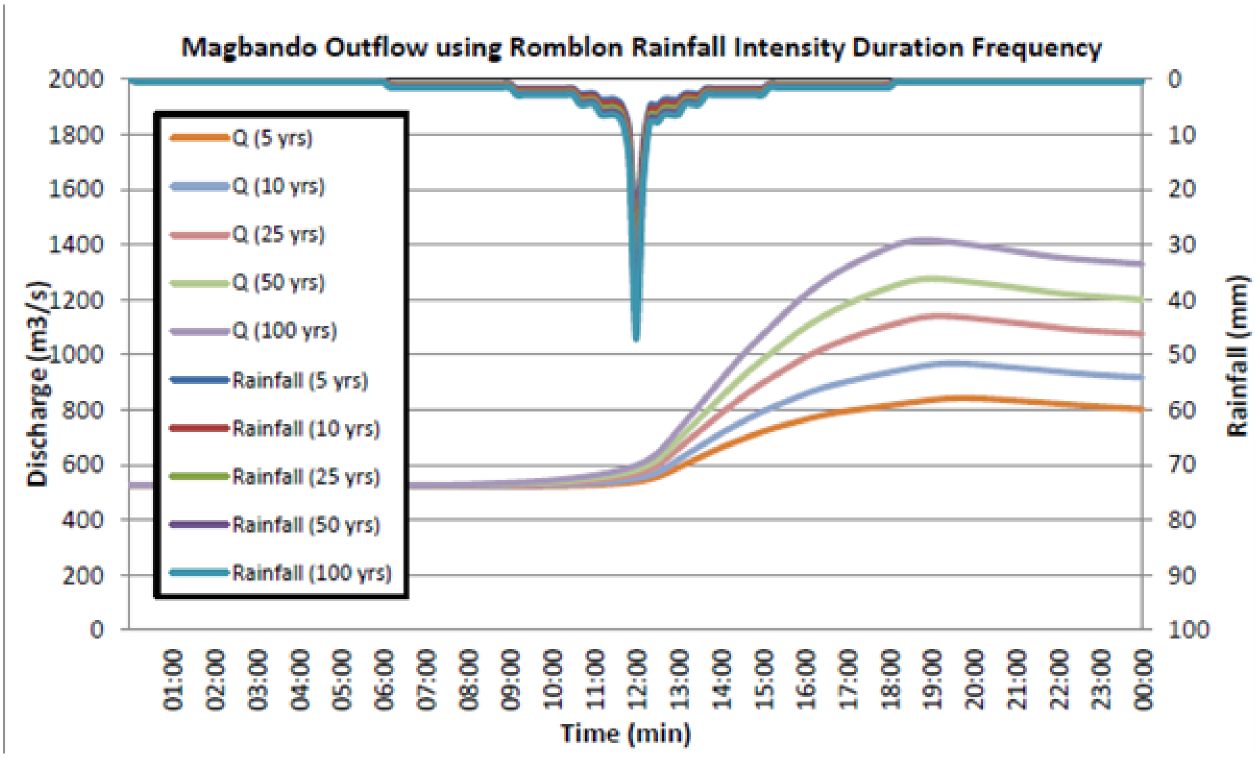


Figure 65. Outflow hydrograph at Magbando Station generated using Romblon RIDF simulated in HEC-HMS

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

Table 30. Peak values of the Magbando HECHMS Model outflow using the Romblon RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak Outflow (cu.m/s)	Time to Peak	Lag Time
5-yr	171.60	26.0	842.330	19 hours and 50 minutes	7 hours and 50 minutes
10-yr	205.90	31.1	967.834	19 hours and 30 minutes	7 hours and 30 minutes
25-yr	249.20	37.6	1139.835	19 hours and 10 minutes	7 hours and 10 minutes
50-yr	281.40	42.4	1275.736	19 hours	7 hours
100-yr	313.30	47.2	1415.901	18 hours and 50 minutes	6 hours and 50 minutes

5.7.2 Discharge Data Using Dr. Horritt's Recommended Hydrologic Method

The river discharges for the four rivers entering the floodplain are shown in Figure 66 to 69 and the peak values are summarized in Table 31 to 34.

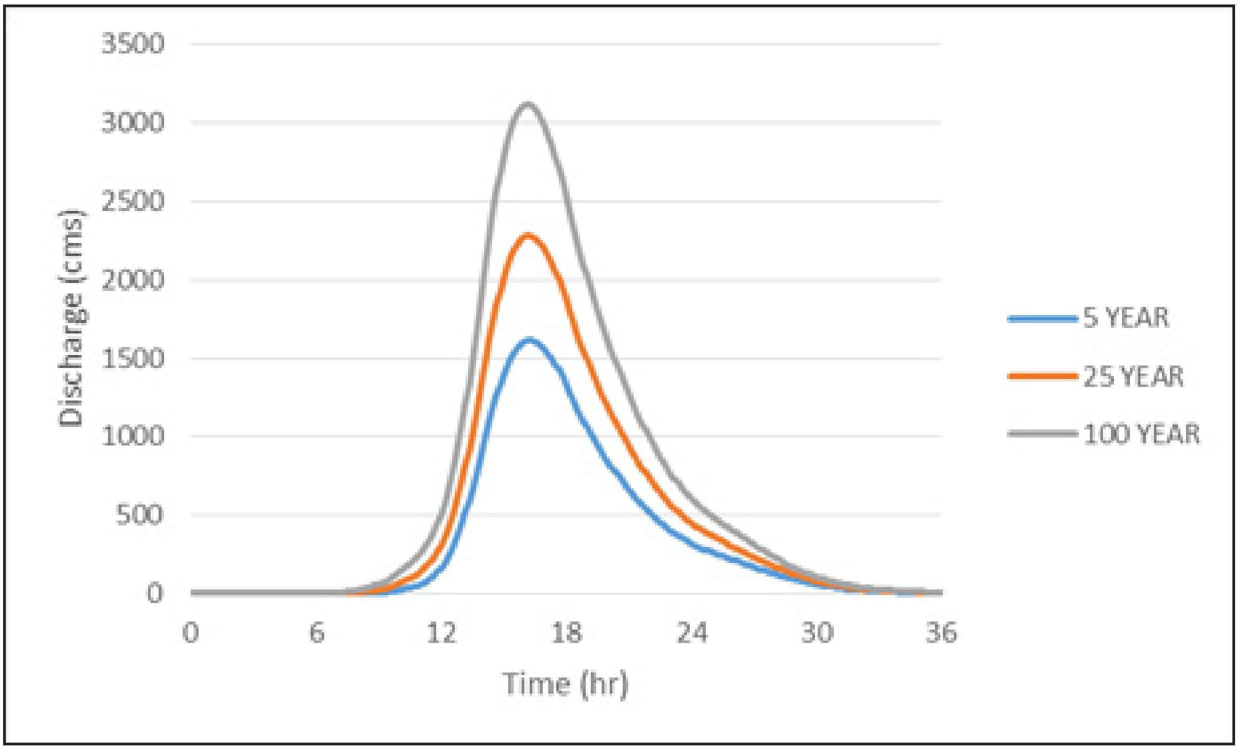


Figure 66. Magbando river (1) generated discharge using interpolated 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

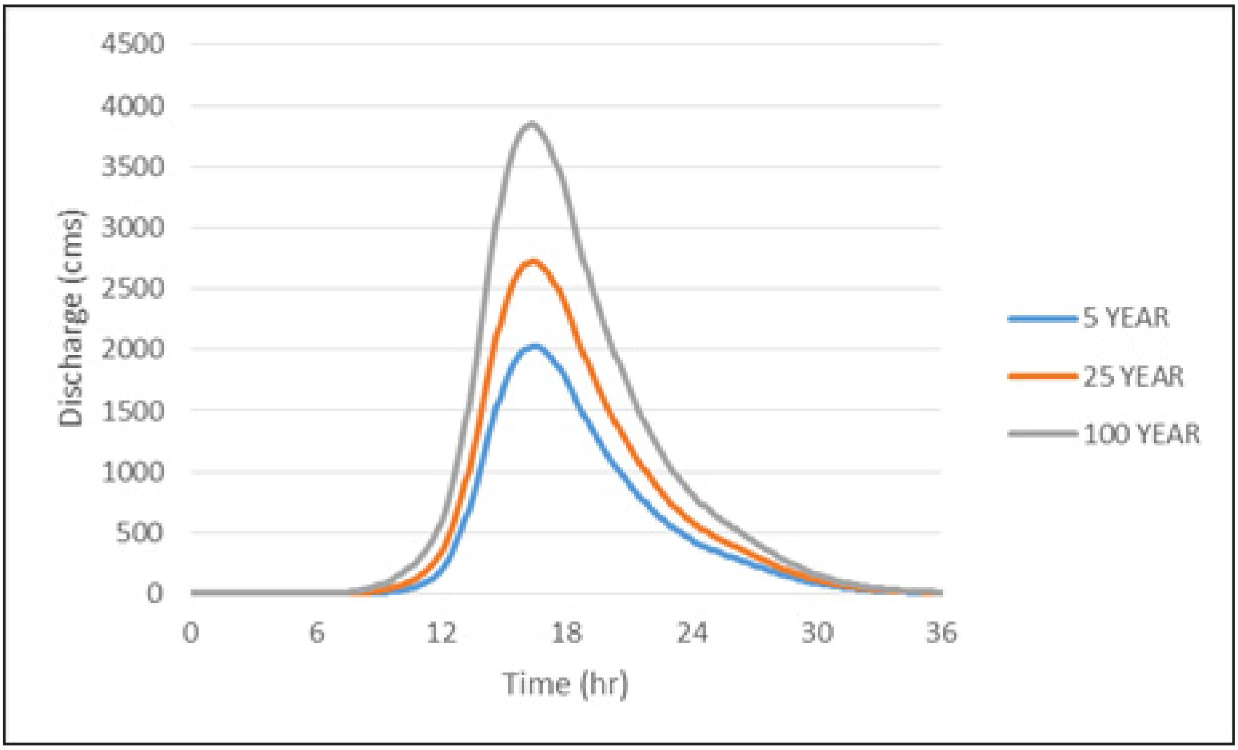


Figure 67. Magbando river (2) generated discharge using interpolated 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

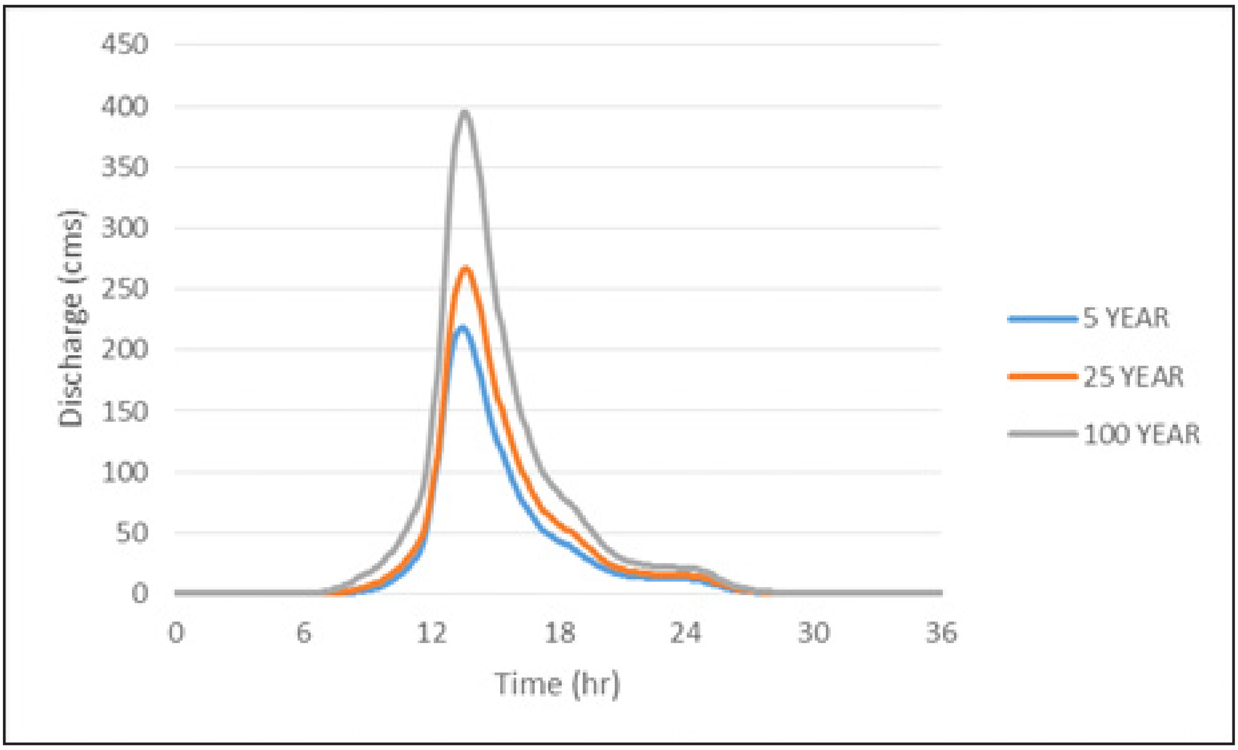


Figure 68. Magbando river (3) generated discharge using interpolated 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

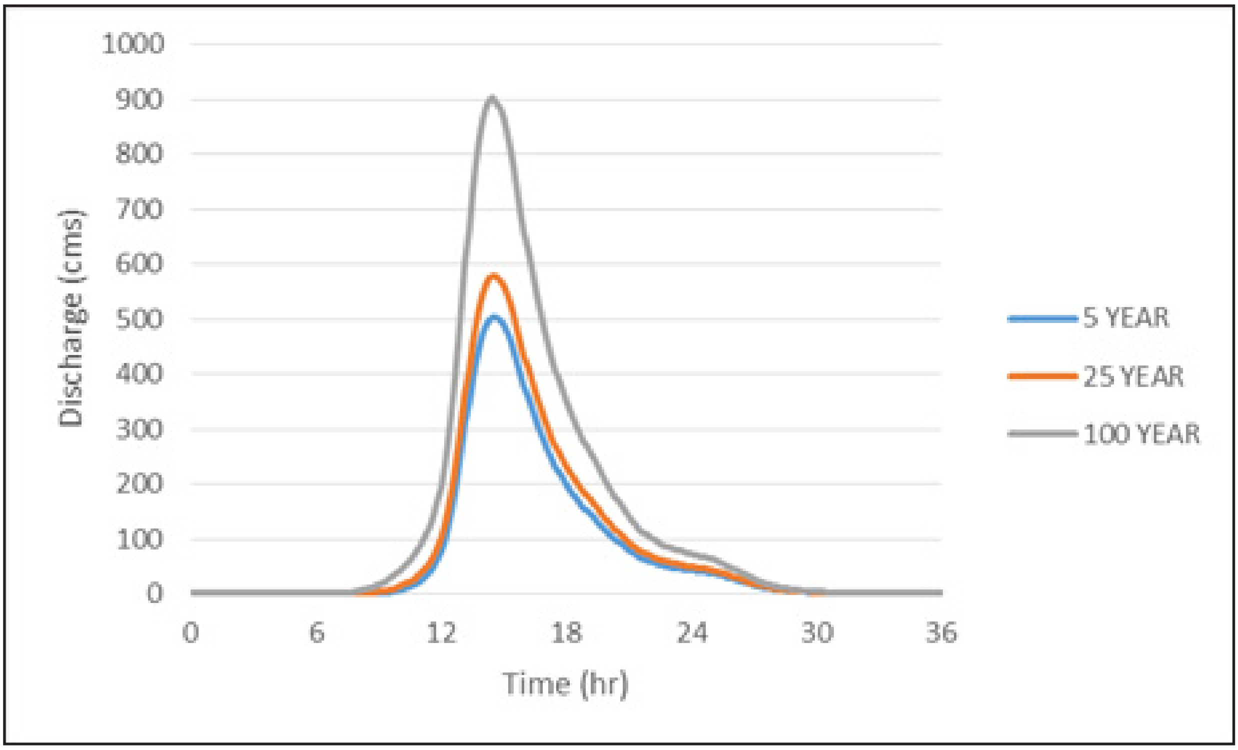


Figure 69. Magbando river (4) generated discharge using interpolated 5-, 25-, and 100-year rainfall intensity-duration-frequency (RIDF) in HEC-HMS

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

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	3 121.5	240.77 minutes
25-Year	2 283.9	240.77 minutes
5-Year	1 611.7	240.77 minutes

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

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	3 848.1	250.18 minutes
25-Year	2 727	250.18 minutes
5-Year	2 029.2	250.18 minutes

Table 33. Summary of Magbando river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	395	100.47 minutes
25-Year	267.6	100.47 minutes
5-Year	218.9	100.47 minutes

Table 34. Summary of Magbando river (4) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	903	146.31 minutes
25-Year	579	146.31 minutes
5-Year	504	146.31 minutes

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 35.

Table 35. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Magbando (1)	1418.296	78.173	1220.150	FALSE	TRUE
Magbando (2)	1785.696	1389.550	1409.025	TRUE	TRUE
Magbando (3)	192.632	132.820	247.134	TRUE	TRUE
Magbando (4)	443.520	443.482	544.574	TRUE	TRUE

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

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model 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 Magbando River using the HMS base flow is shown on Figure 70 below.

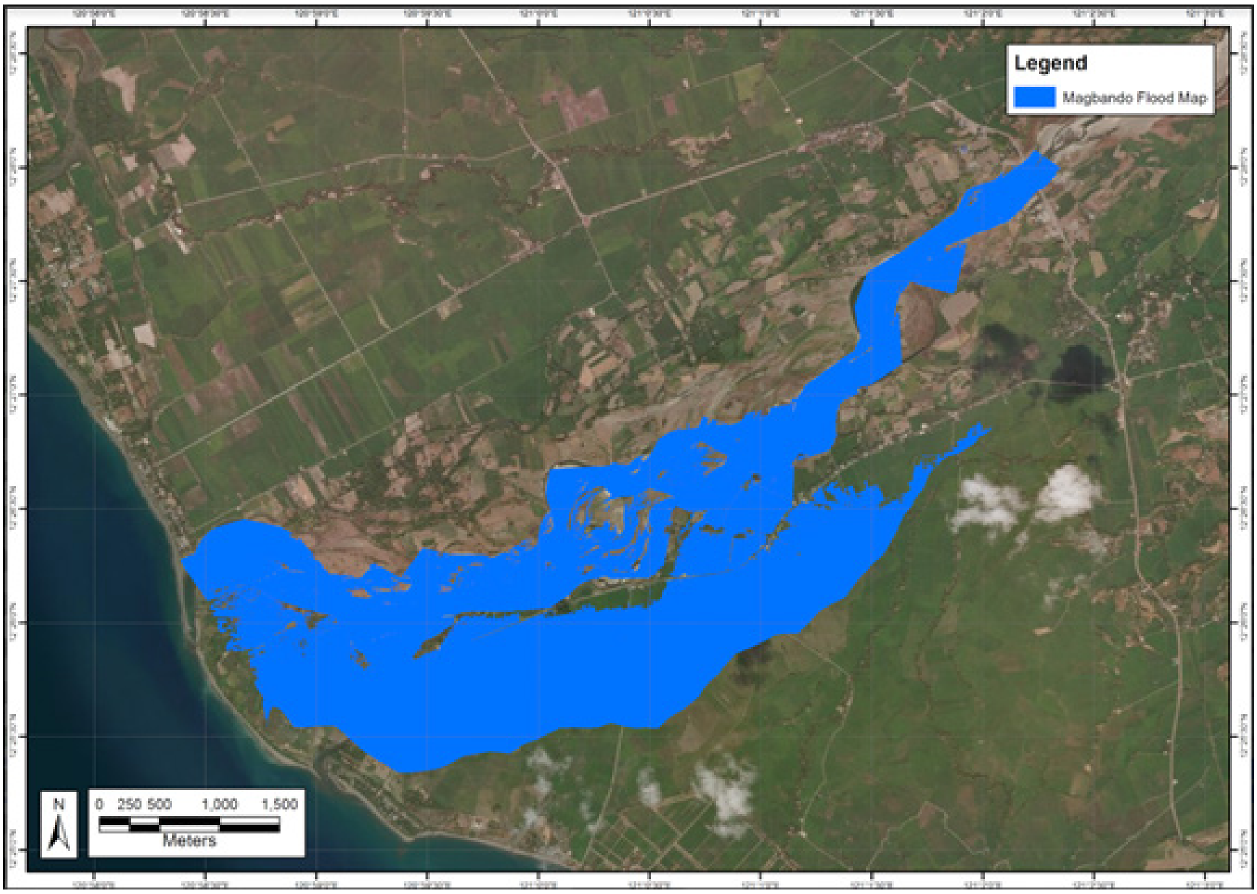


Figure 70. Magbando HEC-RAS Output

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps for 5-, 25-, and 100-year rain return scenarios of the Magbando floodplain are shown in Figure 71 to 76. The floodplain, with an area of 364.84 sq. km., covers four municipalities namely Calintaan, Magsaysay, Rizal, and San Jose. Table 36 shows the percentage of area affected by flooding per municipality.

Table 36. Municipalities affected in Magbando Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Calintaan	282.31	30.69	10.87
Magsaysay	256.56	5.96	2.32
Rizal	184.98	149.61	80.88
San Jose	449.82	178.42	39.67

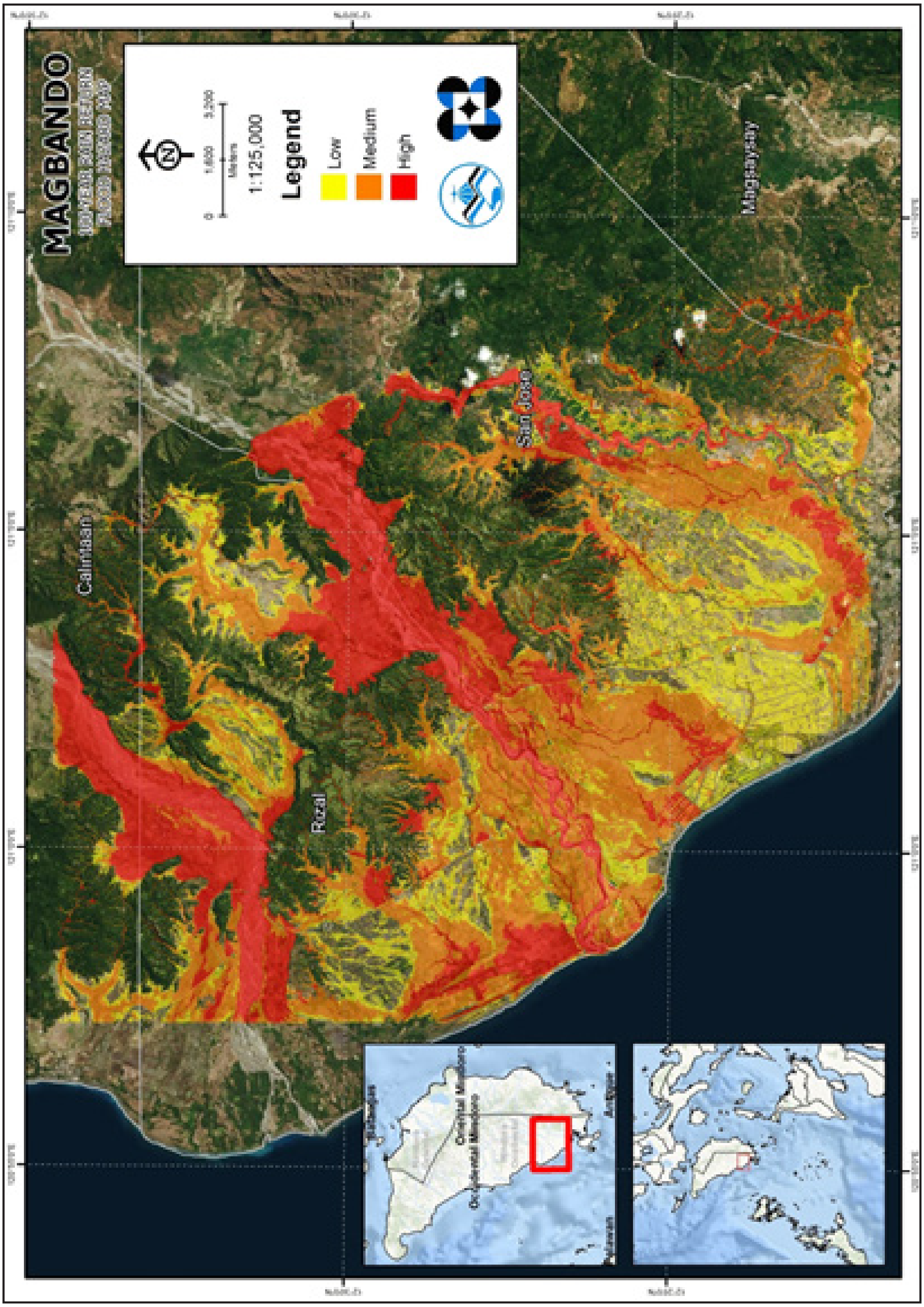


Figure 71. 100-year Flood Hazard Map for Magbando Floodplain

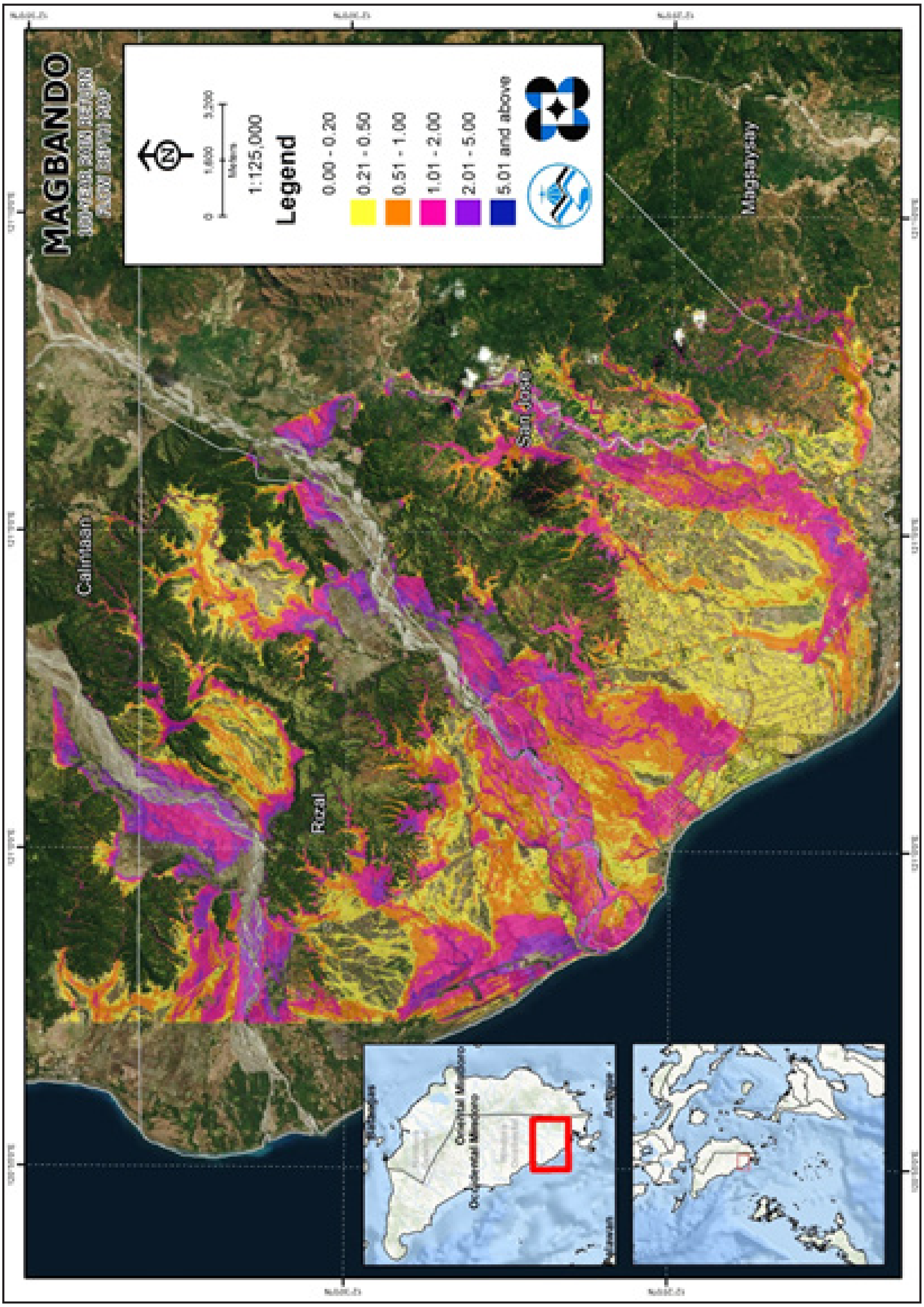


Figure 72. 100-year Flow Depth Map for Magbando Floodplain

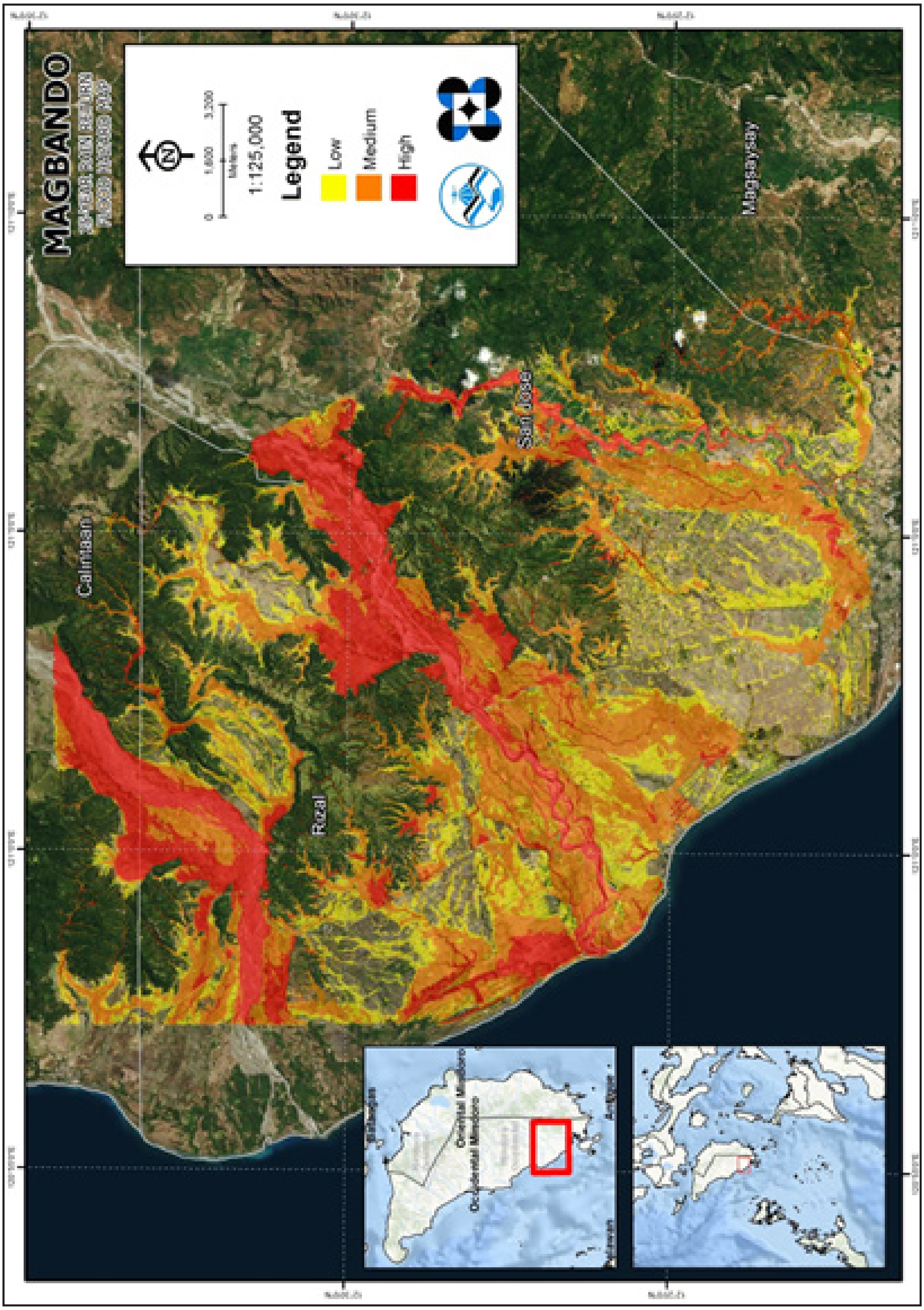


Figure 73. 25-year Flood Hazard Map for Magbando Floodplain

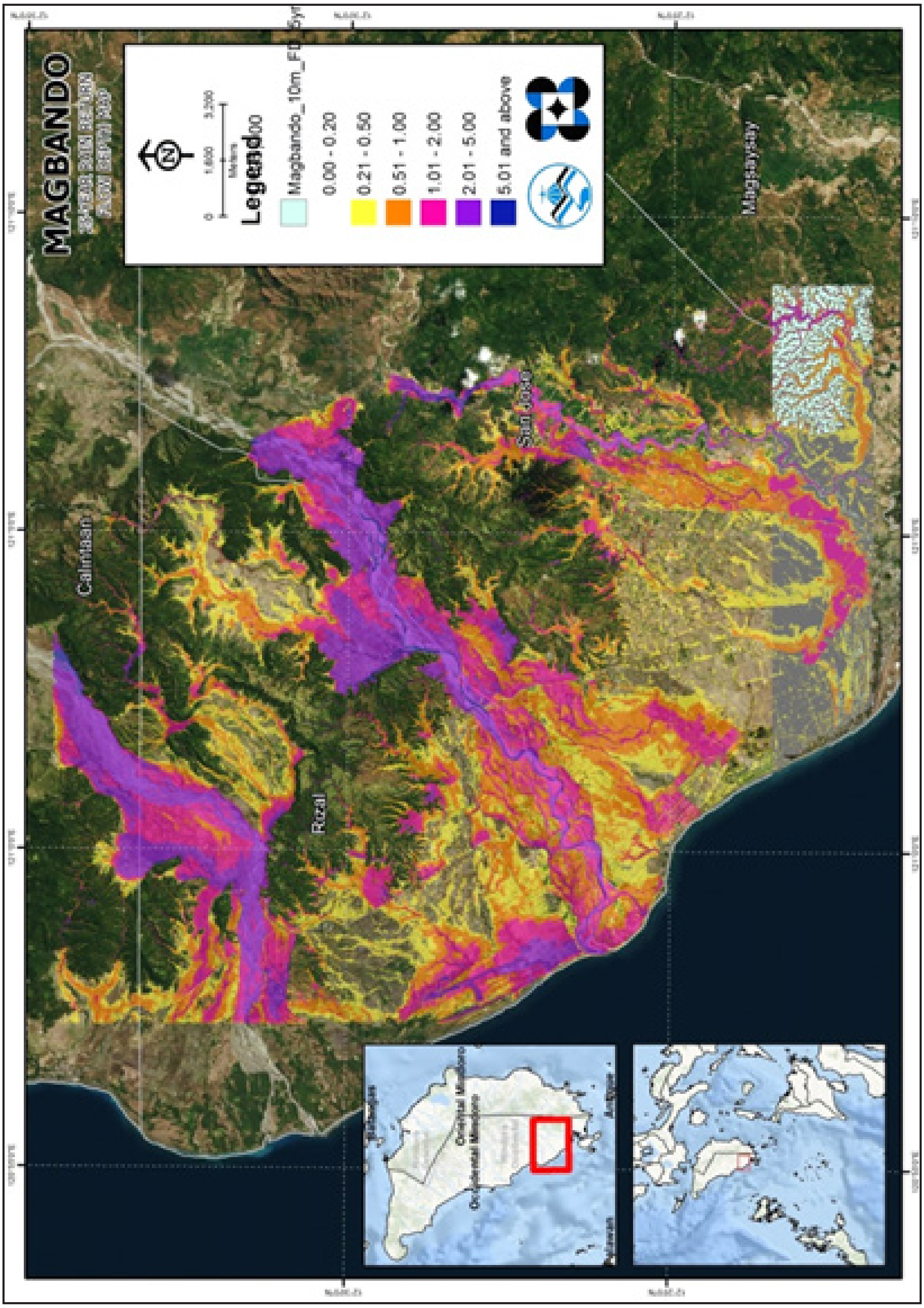


Figure 74. 25-year Flow Depth Map for Magbando Floodplain

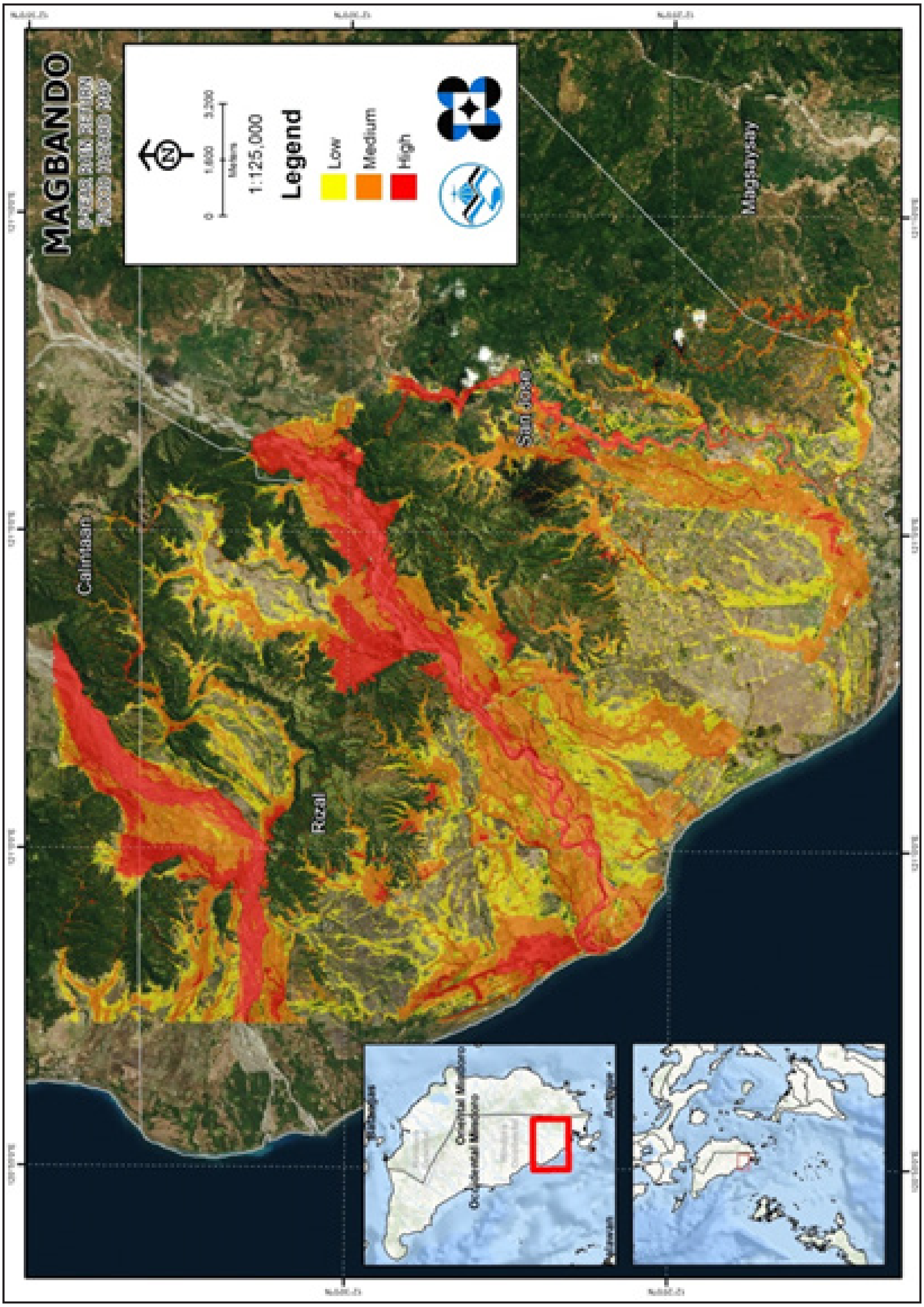


Figure 75. 5-year Flood Hazard Map for Magbando Floodplain

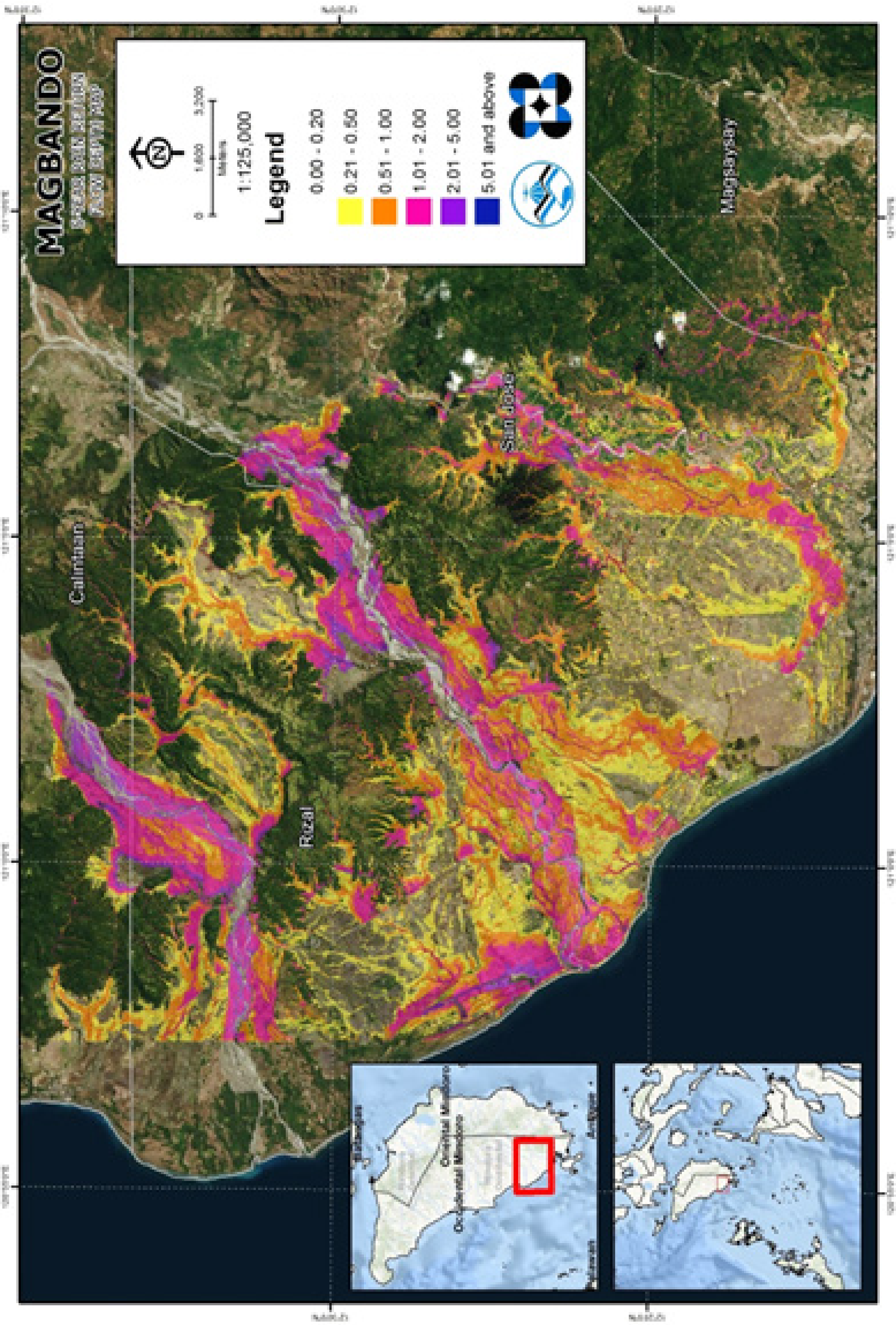


Figure 76. 5-year Flow Depth Map for Magbando Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Magbando river basin, grouped by municipality, are listed below. For the said basin, four municipalities consisting of 34 barangays are expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 7.86% of the municipality of Calintaan with an area of 282.31 sq. km. will experience flood levels of less 0.20 meters. 0.86% of the area will experience flood levels of 0.21 to 0.50 meters while 0.69%, 0.93%, 1.40%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table 37 are the affected areas in square kilometres by flood depth per barangay.

Table 37. Affected Areas in Calintaan, Occidental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calintaan (in sq. km.)		
	New Dagupan	**Poblacion**	**Tanyag**
0.03-0.20	0.33	0.0043	21.84
0.21-0.50	0.35	0.0018	2.06
0.51-1.00	0.23	0	1.71
1.01-2.00	0.0054	0	2.61
2.01-5.00	0	0	3.96
> 5.00	0	0	0.033

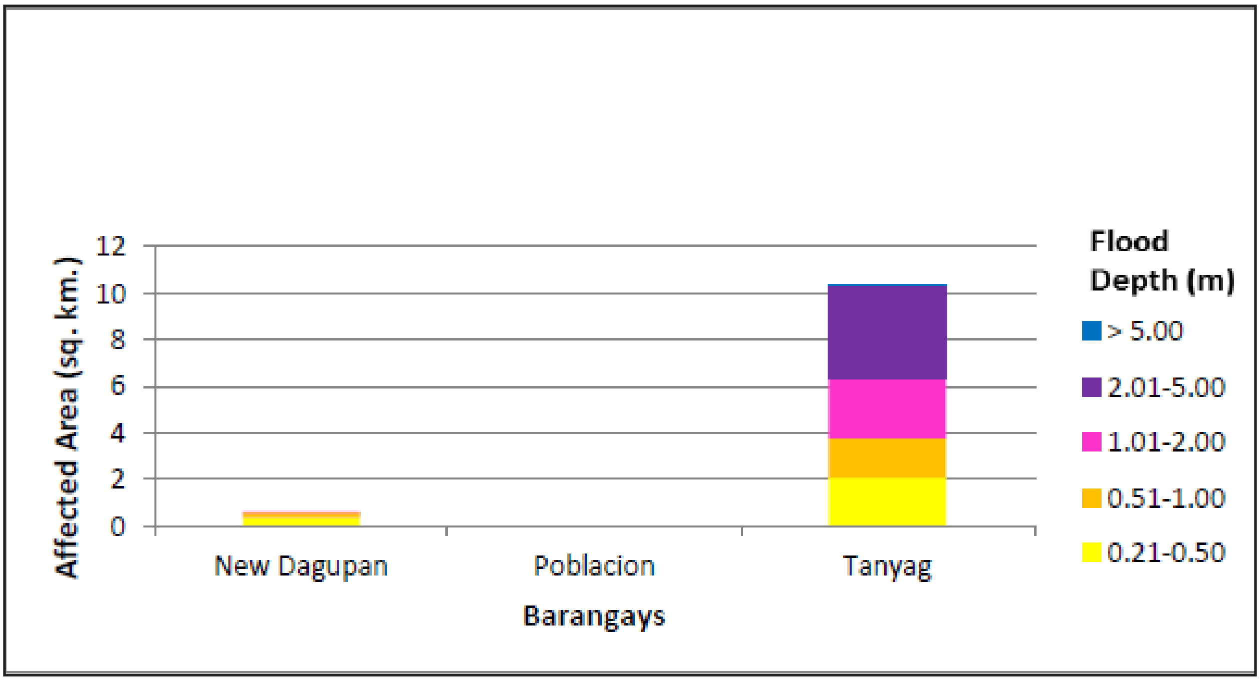


Figure 77. Affected Areas in Calintaan, Occidental Mindoro during 5-Year Rainfall Return Period

For the municipality of Magsaysay, with an area of 256.56 sq. km., 1.84% will experience flood levels of less 0.20 meters. 0.26% of the area will experience flood levels of 0.21 to 0.50 meters while 0.26%, 0.23%, 0.08%, and 0.005% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas in square kilometres by flood depth per barangay.

Table 38. 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.)	
	Lourdes	Paclolo
0.03-0.20	3.54	1.18
0.21-0.50	0.58	0.093
0.51-1.00	0.54	0.14
1.01-2.00	0.43	0.15
2.01-5.00	0.18	0.036
> 5.00	0.01	0.0021

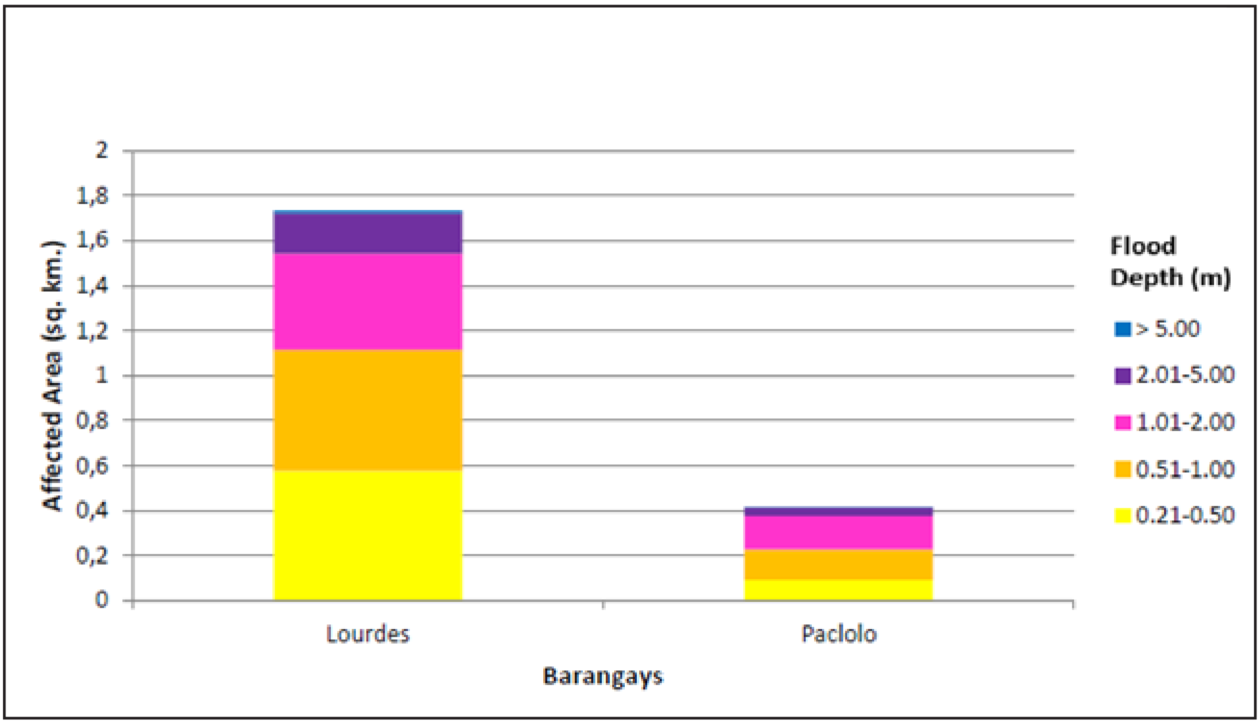


Figure 78. Affected Areas in Magsaysay, Occidental Mindoro during 5-Year Rainfall Return Period

For the municipality of Rizal, with an area of 184.98 sq. km., 42.94% will experience flood levels of less 0.20 meters. 12.45% of the area will experience flood levels of 0.21 to 0.50 meters while 10.49%, 11.58%, 7.18%, and 0.16% 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 Tables 39-40 are the affected areas in square kilometres by flood depth per barangay.

Table 39. Affected Areas in Rizal, Occidental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)					
	Adela	Aguas	Magsikap	Malawaan	Manoot	Pitogo
0.03-0.20	2.64	11.26	12	3.52	10.44	8.88
0.21-0.50	2.13	3.26	2.49	1.99	1.01	1.49
0.51-1.00	1.59	2.6	2.34	1.58	0.9	1.11
1.01-2.00	3.27	2.62	2.91	1.7	0.29	1.09
2.01-5.00	2.35	3.31	2.57	0.4	0.11	0.34
> 5.00	0.018	0.099	0.0009	0	0.0025	0.0011

Table 40. Affected Areas in Rizal, Occidental Mindoro during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)				
	Rizal	Rumbang	Salvacion	San Pedro	Santo Niño
0.03-0.20	6.8	2.64	3.45	3.52	14.27
0.21-0.50	2.68	2.13	0.89	1.95	3.01
0.51-1.00	2.79	1.54	0.16	2.41	2.38
1.01-2.00	4.1	1.16	0.099	2.77	1.41
2.01-5.00	1.21	0.3	0	1.86	0.84
> 5.00	0	0	0	0.18	0.00042

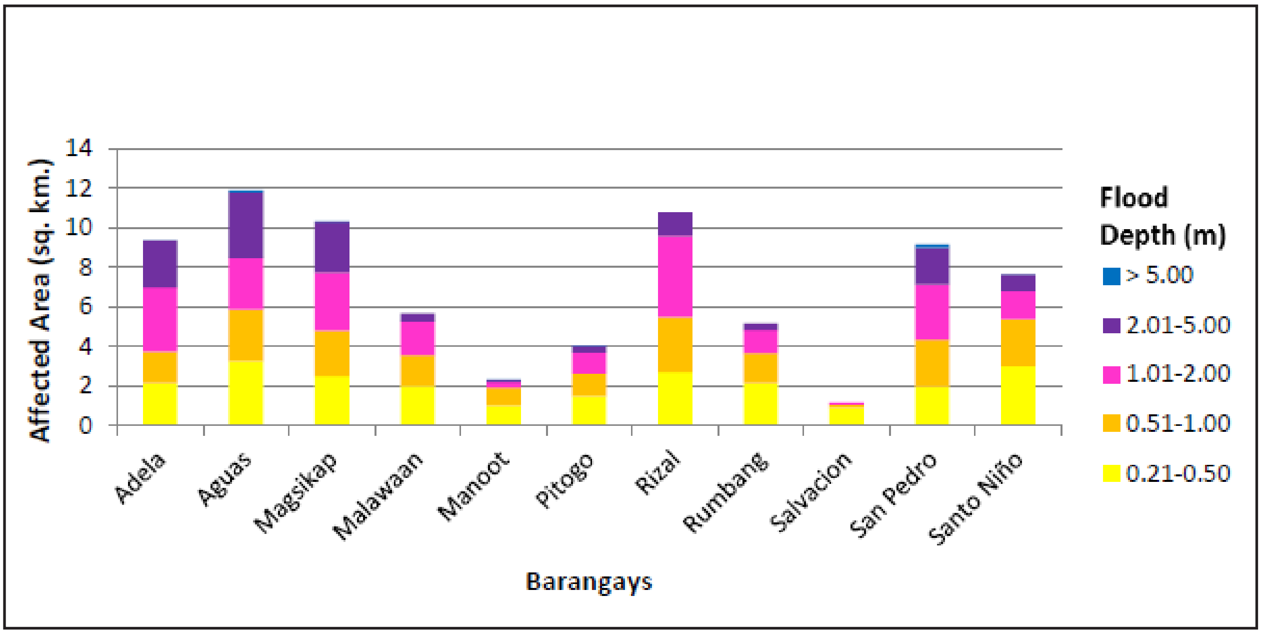


Figure 79. Affected Areas in Rizal, Occidental Mindoro during 5-Year Rainfall Return

For the municipality of San Jose, with an area of 449.82 sq. km., 23.57% will experience flood levels of less 0.20 meters. 5.47% of the area will experience flood levels of 0.21 to 0.50 meters while 5.26%, 4.71%, 2.29%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 41-42 are the affected areas in square kilometres by flood depth per barangay.

Table 41. 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.)								
	Bagong Sikat	Barangay 3	Batasan	Bayotbot	Bubog	Camburay	Central	La Curva	Labangan Poblacion
0.03-0.20	6.21	0.0091	0.45	14.52	4.26	6.35	4.02	1.93	0.055
0.21-0.50	1.78	0.00014	0.054	2.16	1.57	2.08	1.29	0.51	0.019
0.51-1.00	1.23	0.000013	0.26	2.35	0.29	1.57	2.72	1.83	0.069
1.01-2.00	0.83	0	1.72	2.09	0.32	0.72	4.81	2.59	0.12
2.01-5.00	0.0061	0	2.02	0.98	0.04	0.046	2	0.11	0.0001
> 5.00	0	0	0.012	0.005	0	0.0005	0.032	0	0

Table 42. 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.)								
	Mabini	Magbay	Mangarin	Mapaya	Monte Claro	Murtha	San Agustin	San Isidro	San Roque
0.03-0.20	12.06	16.46	1.38	1.18	9.53	12.07	5.19	8.81	1.53
0.21-0.50	4.46	3.27	0.42	1.1	0.97	1.07	2.45	0.62	0.76
0.51-1.00	2.42	4.09	0.21	0.95	1.45	1.41	1.62	1.04	0.13
1.01-2.00	1.71	1.21	0.082	0.051	1.16	0.58	2.18	1.02	0.0052
2.01-5.00	0.15	0.59	0.016	0.027	0.83	0.11	1.1	2.27	0.000085
> 5.00	0.0003	0.046	0	0.0009	0.14	0.0012	0.045	0.075	0

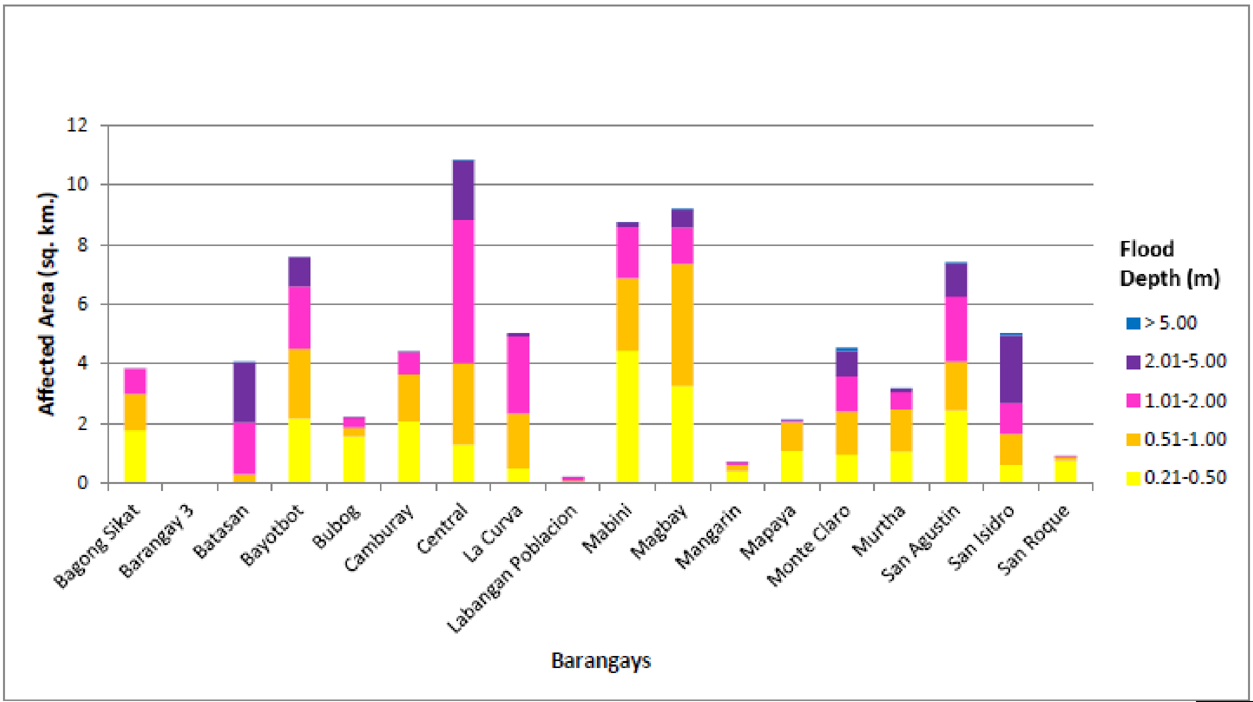


Figure 80. Affected Areas in San Jose, Occidental Mindoro during 5-Year Rainfall Return

For the 25-year return period, 7.59% of the municipality of Calintaan with an area of 282.31 sq. km. will experience flood levels of less 0.20 meters. 0.79% of the area will experience flood levels of 0.21 to 0.50 meters while 0.78%, 0.64%, 1.88%, and 0.09% 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 are the affected areas in square kilometres by flood depth per barangay. Listed in Table 43 are the affected areas in square kilometres by flood depth per barangay.

Table 43. Affected Areas in Calintaan, Occidental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calintaan (in sq. km.)		
	New Dagupan	Poblacion	Tanyag
0.03-0.20	0.27	0.0026	21.17
0.21-0.50	0.3	0.0035	1.93
0.51-1.00	0.34	0	1.77
1.01-2.00	0.01	0	1.79
2.01-5.00	0.0001	0	5.3
> 5.00	0	0	0.26

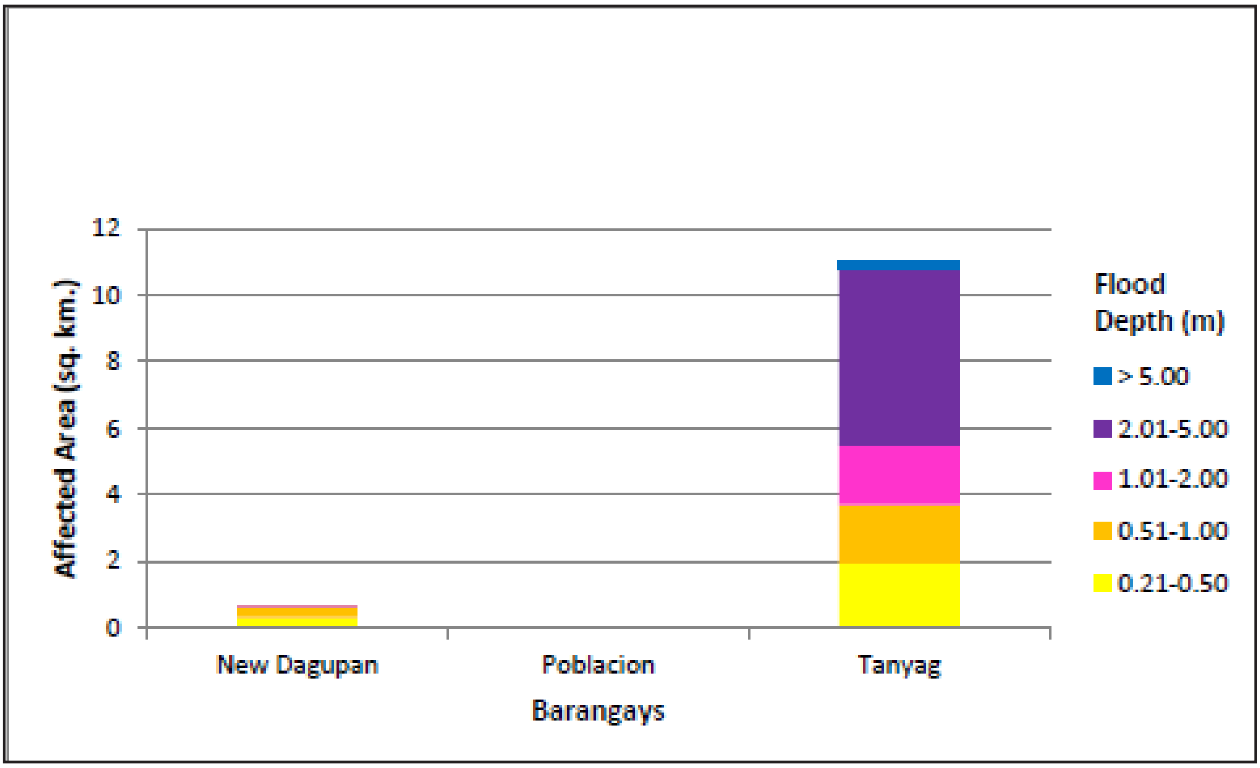


Figure 81. Affected Areas in Calintaan, Occidental Mindoro during 25-Year Rainfall Return Period

For the municipality of Magsaysay, with an area of 256.56 sq. km., 1.83% will experience flood levels of less 0.20 meters. 0.26% of the area will experience flood levels of 0.21 to 0.50 meters while 0.26%, 0.23%, 0.09%, and 0.005% 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 44 are the affected areas in square kilometres by flood depth per barangay.

Table 44. 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.)	
	Lourdes	Paclolo
0.03-0.20	3.53	1.18
0.21-0.50	0.57	0.092
0.51-1.00	0.54	0.13
1.01-2.00	0.44	0.15
2.01-5.00	0.18	0.037
> 5.00	0.011	0.0022

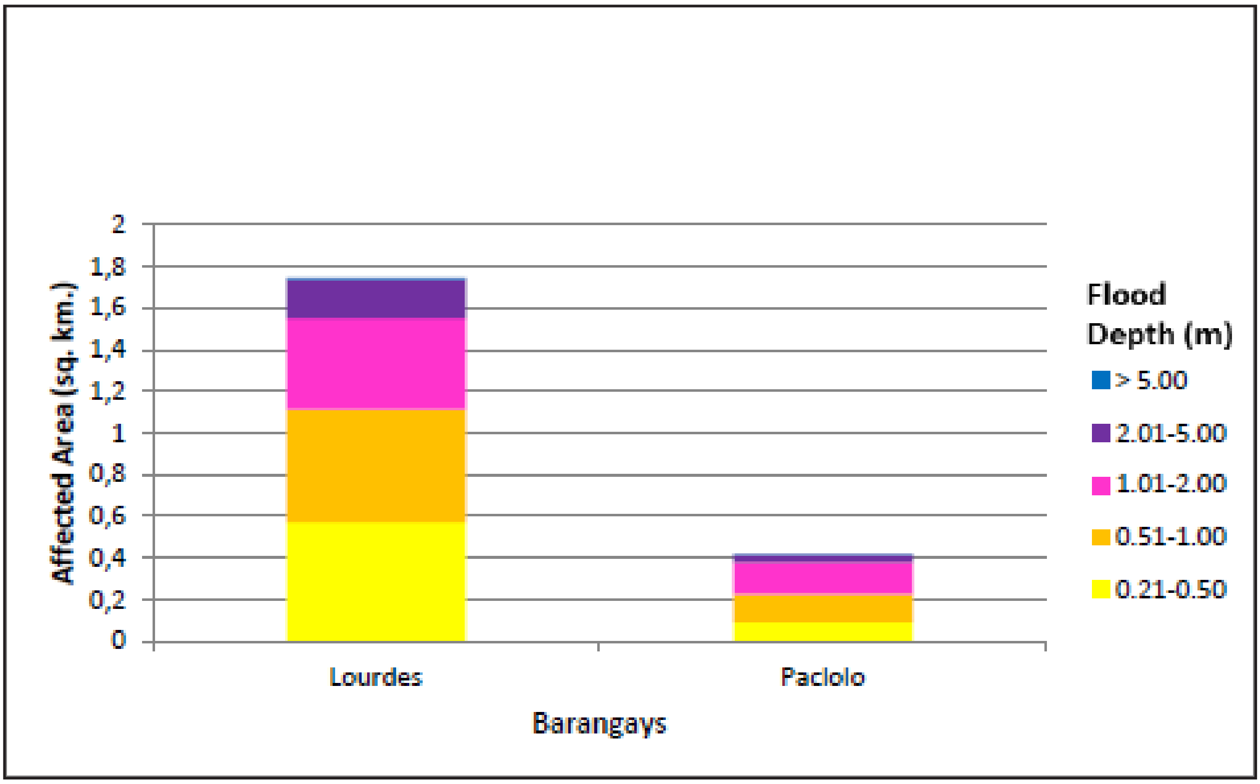


Figure 82. Affected Areas in Magsaysay, Occidental Mindoro during 25-Year Rainfall Return Period

For the municipality of Rizal, with an area of 184.98 sq. km., 7.31% will experience flood levels of less 0.20 meters. 1.57% of the area will experience flood levels of 0.21 to 0.50 meters while 1.42%, 1.002%, 0.51%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Tables 45-46 are the affected areas in square kilometres by flood depth per barangay.

Table 45. Affected Areas in Rizal, Occidental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)					
	Adela	Aguas	Magsikap	Malawaan	Manoot	Pitogo
0.03-0.20	2.22	10.47	10.75	2.62	10.16	8.54
0.21-0.50	1.84	2.94	2.56	1.47	1.01	1.57
0.51-1.00	1.71	2.67	2.12	2.1	0.99	1
1.01-2.00	3.2	2.18	3.13	1.96	0.45	0.86
2.01-5.00	3	4.65	3.7	1.04	0.14	0.94
> 5.00	0.026	0.25	0.035	0	0.0033	0.0016

Table 46. Affected Areas in Rizal, Occidental Mindoro during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)				
	Rizal	Rumbang	Salvacion	San Pedro	Santo Niño
0.03-0.20	6.06	1.63	2.77	3.07	13.53
0.21-0.50	2.62	1.53	1.19	1.71	2.9
0.51-1.00	2.1	2.27	0.44	2.57	2.62
1.01-2.00	4.34	1.8	0.19	3.02	1.85
2.01-5.00	2.46	0.54	0.0043	2.03	0.95
> 5.00	0	0	0	0.29	0.045

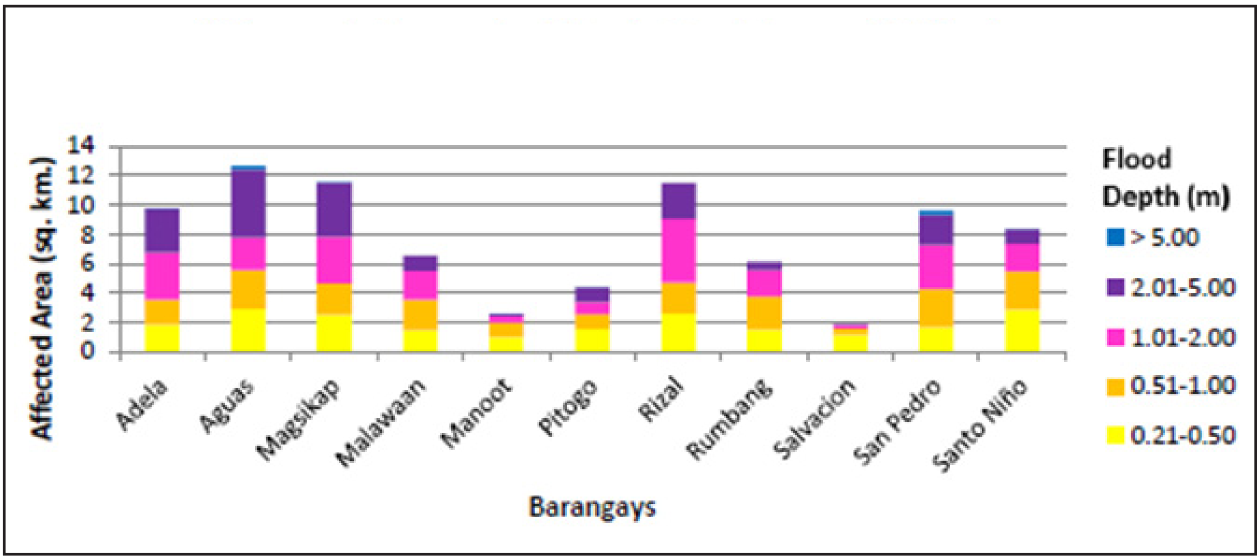


Figure 83. Affected Areas in Rizal, Occidental Mindoro during 25-Year Rainfall Return

For the municipality of San Jose, with an area of 449.82 sq. km., 22.67% will experience flood levels of less 0.20 meters. 5.34% of the area will experience flood levels of 0.21 to 0.50 meters while 4.72%, 5.17%, 3.33%, and 0.14% 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 Tables 47-48 are the affected areas in square kilometres by flood depth per barangay.

Table 47. 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.)								
	Bagong Sikat	Barangay 3	Batasan	Bayotbot	Bubog	Camburay	Central	La Curva	Labangan Poblacion
0.03-0.20	5.92	0.0091	0.4	14.3	4.03	5.69	3.72	1.69	0.054
0.21-0.50	1.89	0.00014	0.043	2.14	1.3	2.19	0.66	0.5	0.016
0.51-1.00	1.24	0.000013	0.1	2.32	0.4	1.35	1.71	1.04	0.056
1.01-2.00	0.99	0	0.93	2.2	0.6	1.39	4.65	3.2	0.14
2.01-5.00	0.015	0	3.01	1.14	0.17	0.15	4.06	0.54	0.00019
> 5.00	0	0	0.033	0.0051	0	0.0007	0.077	0	0

Table 48. 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.)								
	Mabini	Magbay	Mangarin	Mapaya	Monte Claro	Murtha	San Agus-tin	San Isidro	San Roque
0.03-0.20	11.41	16.25	1.35	1.16	9.15	11.96	4.58	8.83	1.48
0.21-0.50	4.75	3.12	0.42	1.07	0.89	1.01	2.6	0.64	0.79
0.51-1.00	2.52	4.28	0.22	1	1.16	1.45	1.57	0.67	0.15
1.01-2.00	1.95	1.36	0.094	0.056	1.6	0.69	2.43	0.96	0.0057
2.01-5.00	0.17	0.61	0.017	0.027	1.09	0.12	1.34	2.52	0.000085
> 5.00	0.0003	0.061	0	0.0009	0.2	0.0021	0.054	0.2	0

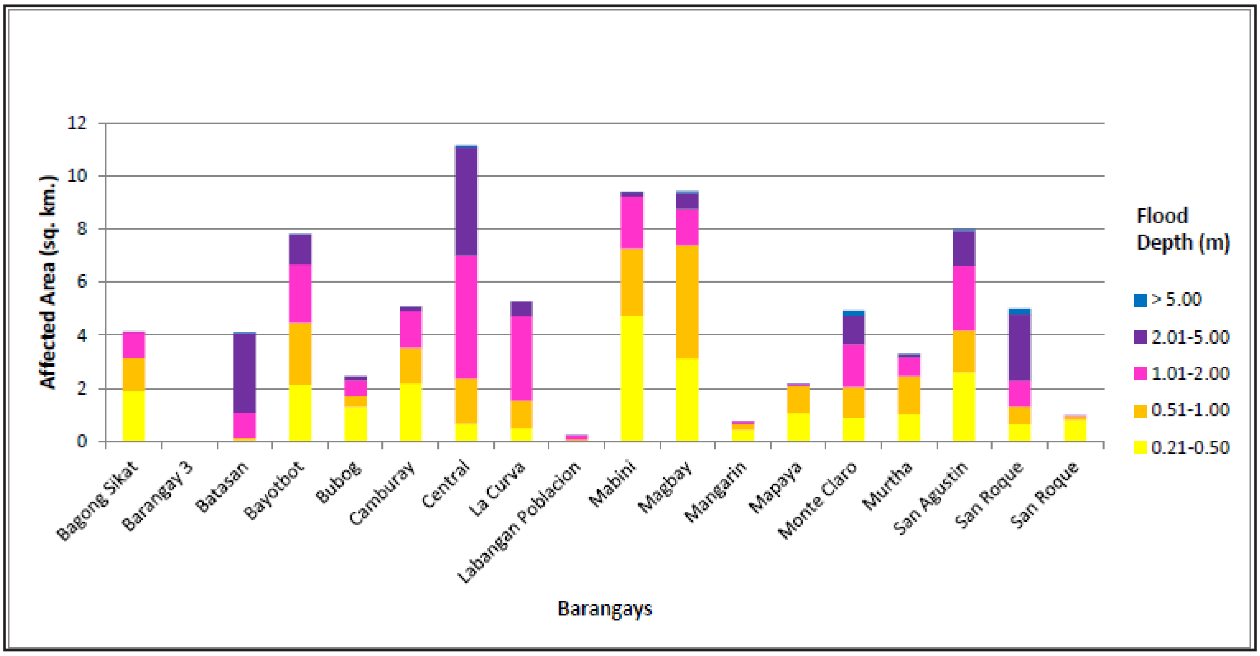


Figure 84. Affected Areas in San Jose, Occidental Mindoro during 25-Year Rainfall Return

For the 100-year return period, 7.33% of the municipality of Calintaan with an area of 282.31 sq. km. will experience flood levels of less 0.20 meters. 0.77% of the area will experience flood levels of 0.21 to 0.50 meters while 0.75%, 0.52%, 2.17%, and 0.22% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters and more than 5 meters, respectively. Listed in Table are the affected areas in square kilometres by flood depth per barangay. Listed in Table 49 are the affected areas in square kilometres by flood depth per barangay.

Table 49. Affected Areas in Calintaan, Occidental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Calintaan (in sq. km.)		
	New Dagupan	Poblacion	Tanyag
0.03-0.20	0.23	0.0011	20.45
0.21-0.50	0.27	0.005	1.9
0.51-1.00	0.41	0	1.7
1.01-2.00	0.021	0	1.44
2.01-5.00	0.0002	0	6.12
> 5.00	0	0	0.61

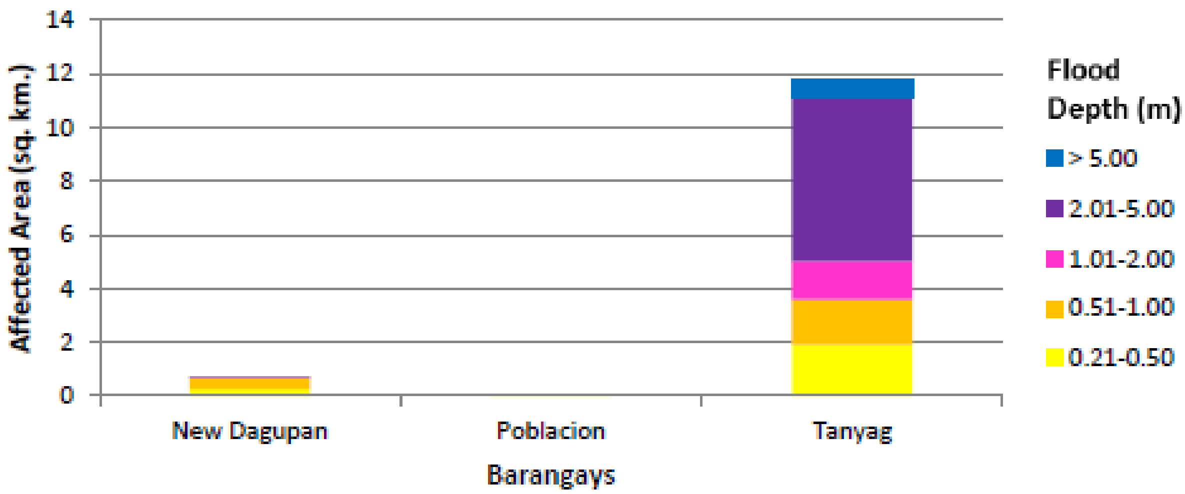


Figure 85. Affected Areas in Calintaan, Occidental Mindoro during 100-Year Rainfall Return Period

For the municipality of Magsaysay, with an area of 256.56 sq. km., 1.76% will experience flood levels of less 0.20 meters. 0.23% of the area will experience flood levels of 0.21 to 0.50 meters while 0.27%, 0.28%, 0.15%, and 0.009% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 are the affected areas in square kilometres by flood depth per barangay.

Table 50. 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.)	
	Lourdes	Paclolo
0.03-0.20	3.35	1.15
0.21-0.50	0.5	0.087
0.51-1.00	0.58	0.11
1.01-2.00	0.54	0.19
2.01-5.00	0.31	0.069
> 5.00	0.02	0.0028

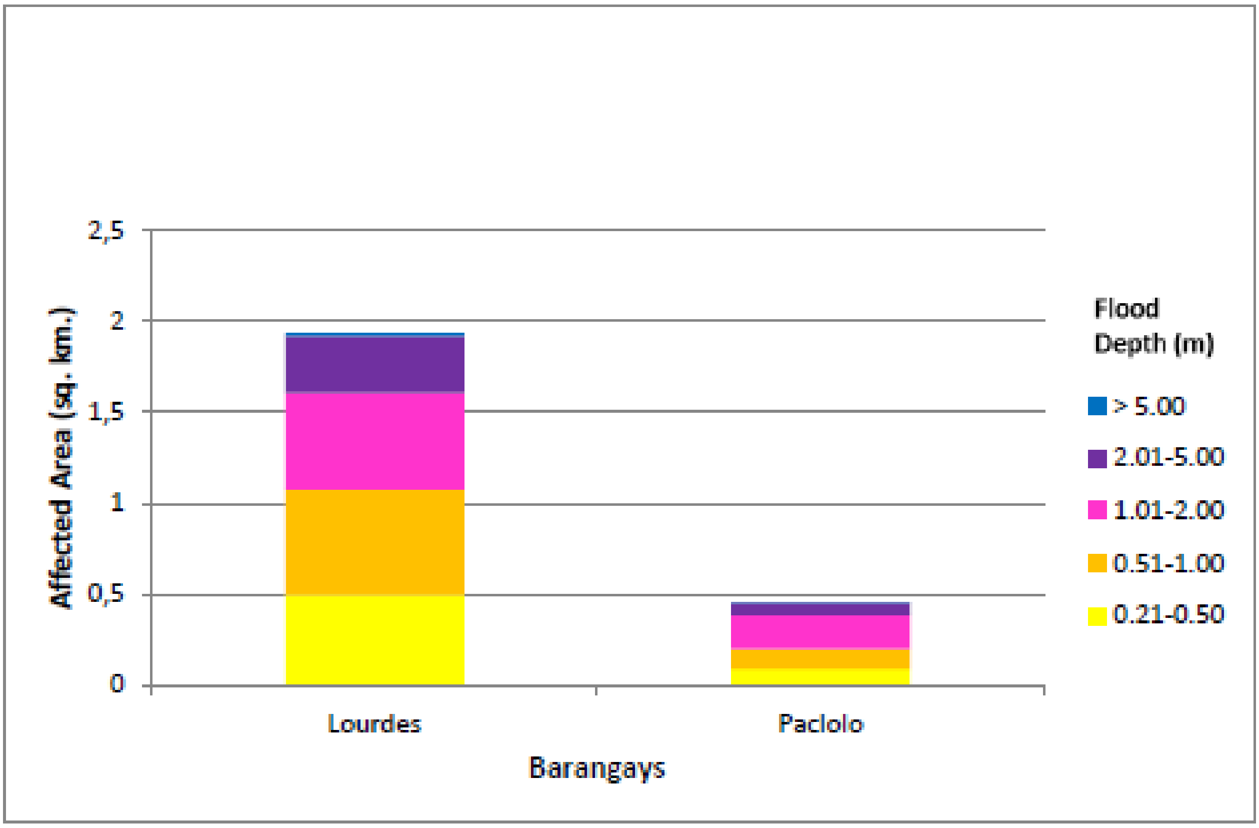


Figure 86. Affected Areas in Magsaysay, Occidental Mindoro during 100-Year Rainfall Return Period

For the municipality of Rizal, with an area of 184.98 sq. km., 34.07% will experience flood levels of less 0.20 meters. 10.16% of the area will experience flood levels of 0.21 to 0.50 meters while 11.75%, 13.16%, 14.33%, and 1.32% 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 Tables 51-52 are the affected areas in square kilometres by flood depth per barangay.

Table 51. Affected Areas in Rizal, Occidental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)					
	Adela	Aguas	Magsikap	Malawaan	Manoot	Pitogo
0.03-0.20	1.82	9.24	9.73	2.23	9.66	7.79
0.21-0.50	1.31	2.37	2.28	0.99	1	1.74
0.51-1.00	2.1	2.89	2.36	1.94	1.03	1.08
1.01-2.00	2.97	1.69	2.61	2.48	0.84	0.91
2.01-5.00	3.76	5.93	4.95	1.55	0.21	1.38
> 5.00	0.041	1.03	0.38	0.0001	0.0084	0.0027

Table 52. Affected Areas in Rizal, Occidental Mindoro during 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Rizal (in sq. km.)				
	Rizal	Rumbang	Salvacion	San Pedro	Santo Niño
0.03-0.20	4.91	0.94	2.06	2.53	12.1
0.21-0.50	2.48	0.92	1.42	1.44	2.84
0.51-1.00	2.25	1.85	0.75	2.54	2.96
1.01-2.00	3.57	3.09	0.32	3.39	2.48
2.01-5.00	4.37	0.98	0.038	2.32	1.01
> 5.00	0.0012	0	0	0.47	0.52

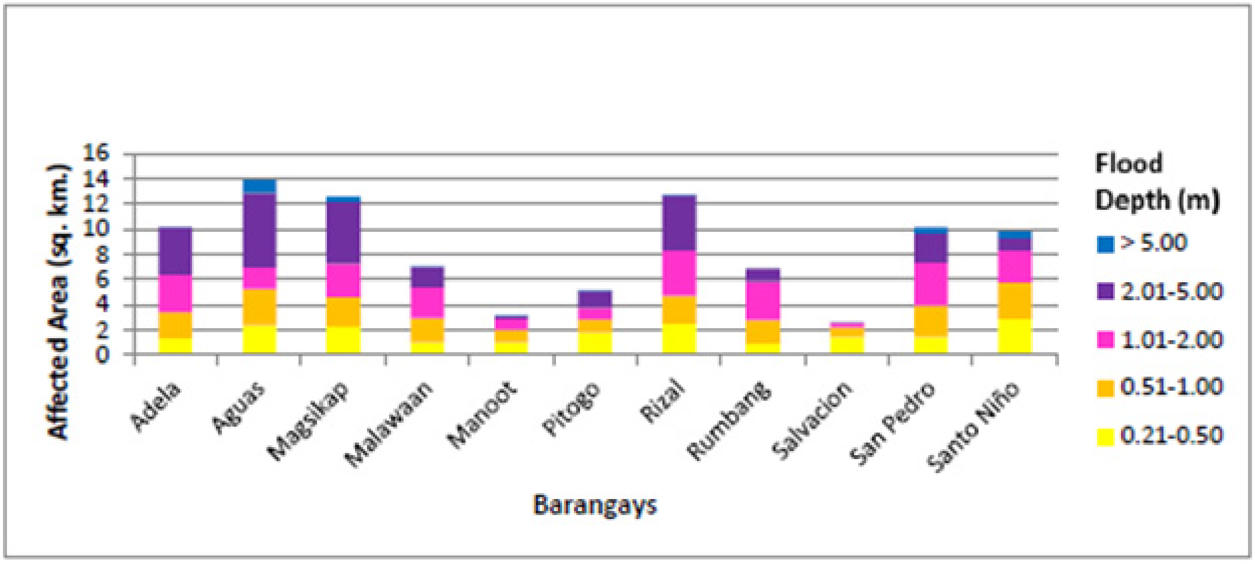


Figure 87. Affected Areas in Rizal, Occidental Mindoro during 100-Year Rainfall Return

For the municipality of San Jose, with an area of 449.82 sq. km., 18.65% will experience flood levels of less 0.20 meters. 6.53% of the area will experience flood levels of 0.21 to 0.50 meters while 4.62%, 5.95%, 5.28%, and 0.37% 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 Tables 53-54 are the affected areas in square kilometres by flood depth per barangay.

Table 53. 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.)								
	Bagong Sikat	Barangay 3	Batasan	Bayotbot	Bubog	Camburay	Central	La Curva	Labangan Poblacion
0.03-0.20	2.72	0.0089	0.38	13.45	1.91	3.37	3.35	0.72	0.044
0.21-0.50	3.81	0.00037	0.011	2.18	2.49	3.44	0.44	1.22	0.015
0.51-1.00	1.6	0.000013	0.059	1.94	0.53	1.54	0.74	0.5	0.024
1.01-2.00	1.86	0	0.51	2.51	0.56	1.9	3.12	2.99	0.18
2.01-5.00	0.065	0	3.42	2.03	0.99	0.52	7	1.53	0.0014
> 5.00	0	0	0.13	0.014	0	0.0018	0.23	0	0

Table 54. 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.)								
	Mabini	Magbay	Mangarin	Mapaya	Monte Claro	Murtha	San Agustin	San Isidro	San Roque
0.03-0.20	7.74	15.02	1.14	0.84	8.59	11.56	3.68	8.58	0.8
0.21-0.50	6.32	2.71	0.46	0.7	0.71	0.88	2.83	0.54	0.64
0.51-1.00	2.95	3.71	0.3	1.42	0.85	1.38	1.78	0.58	0.91
1.01-2.00	3.33	3.44	0.19	0.34	1.41	1.18	2.36	0.8	0.076
2.01-5.00	0.49	0.78	0.015	0.029	2.14	0.24	1.86	2.65	0.00084
> 5.00	0	0.14	0	0.0022	0.4	0.0058	0.069	0.69	0

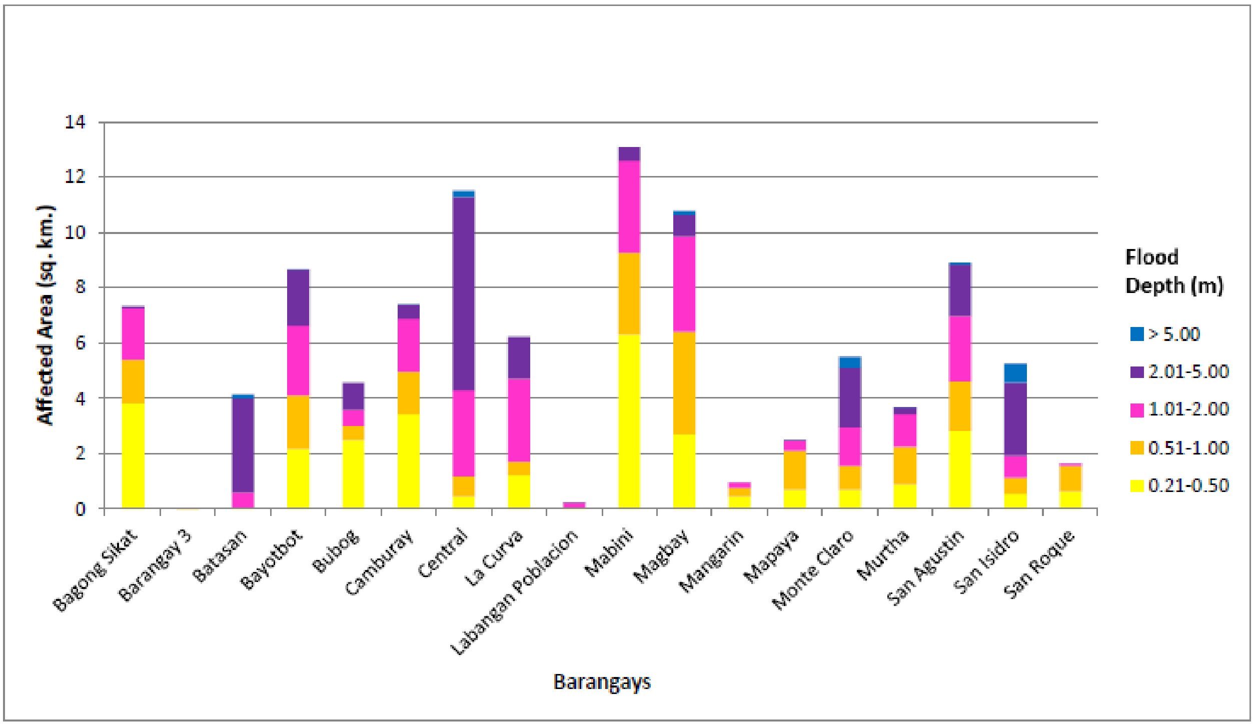


Figure 88. Affected Areas in San Jose, Occidental Mindoro during 100-Year Rainfall Return

Among the barangays in the municipality of Calintaan, Tanyag is projected to have the highest percentage of area that will experience flood levels at 11.41%. Meanwhile, New Dagupan posted the second highest percentage of area that may be affected by flood depths at 0.33%.

Among the barangays in the municipality of Magsaysay, Lourdes is projected to have the highest percentage of area that will experience flood levels at 2.06%. Meanwhile, Paclolo posted the second highest percentage of area that may be affected by flood depths at 0.62%.

Among the barangays in the municipality of Rizal, Aguas is projected to have the highest percentage of area that will experience flood levels at 12.52%. Meanwhile, Magsikap posted the second highest percentage of area that may be affected by flood depths at 12.06%.

Among the barangays in the municipality of San Jose, Magbay is projected to have the highest percentage of area that will experience flood levels at 5.70%. Meanwhile, Bayotbot posted the second highest percentage of area that may be affected by flood depths at 4.91%.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, a validation survey work was performed. Field personnel gathered 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 the help of a local DRRM office to obtain maps or situation reports about the past flooding events and through interviews with some residents with knowledge of or have had experienced flooding in a particular area.

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 90.

The flood validation consists of 119 points randomly selected all over the Magbando floodplain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 1.26m. Table 55 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

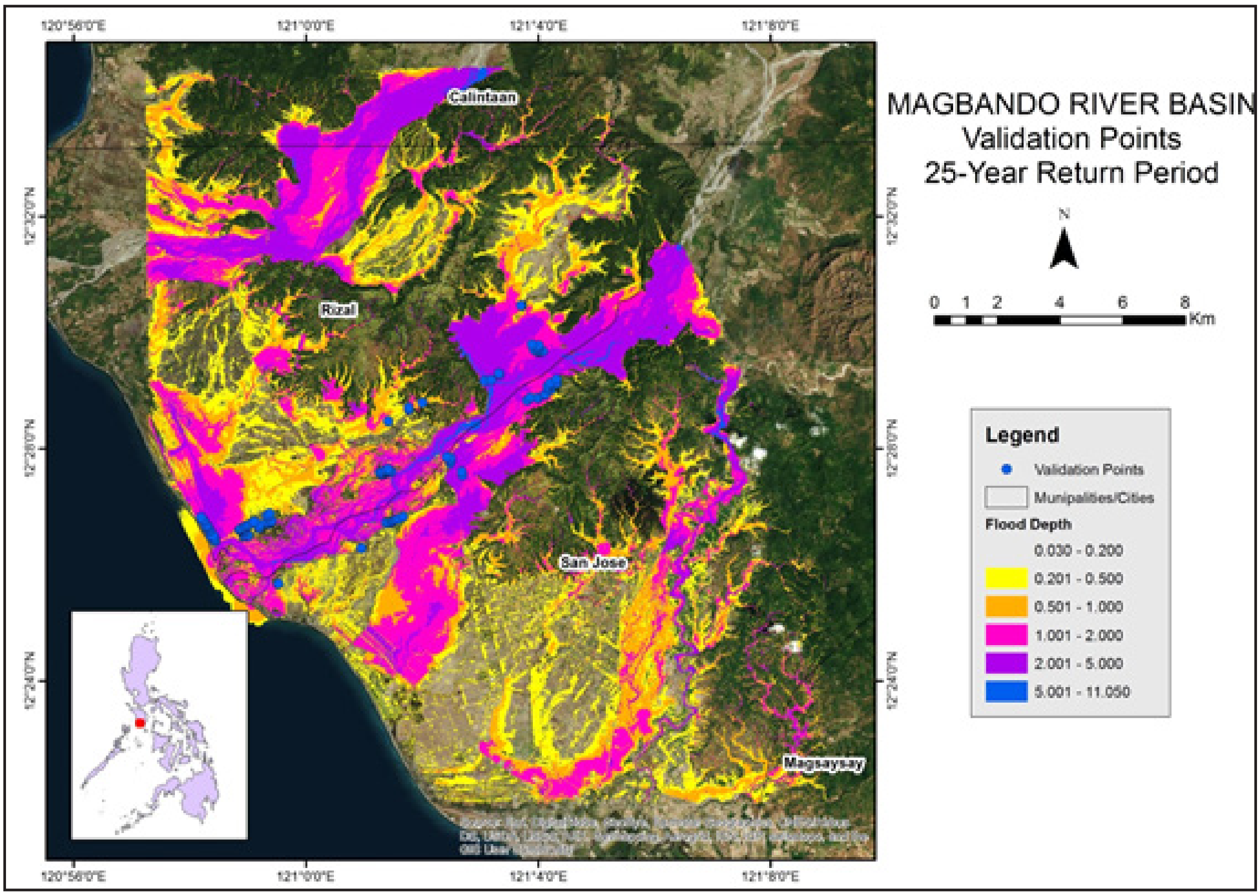


Figure 89. Validation points for 25-year Flood Depth Map of Magbando Floodplain

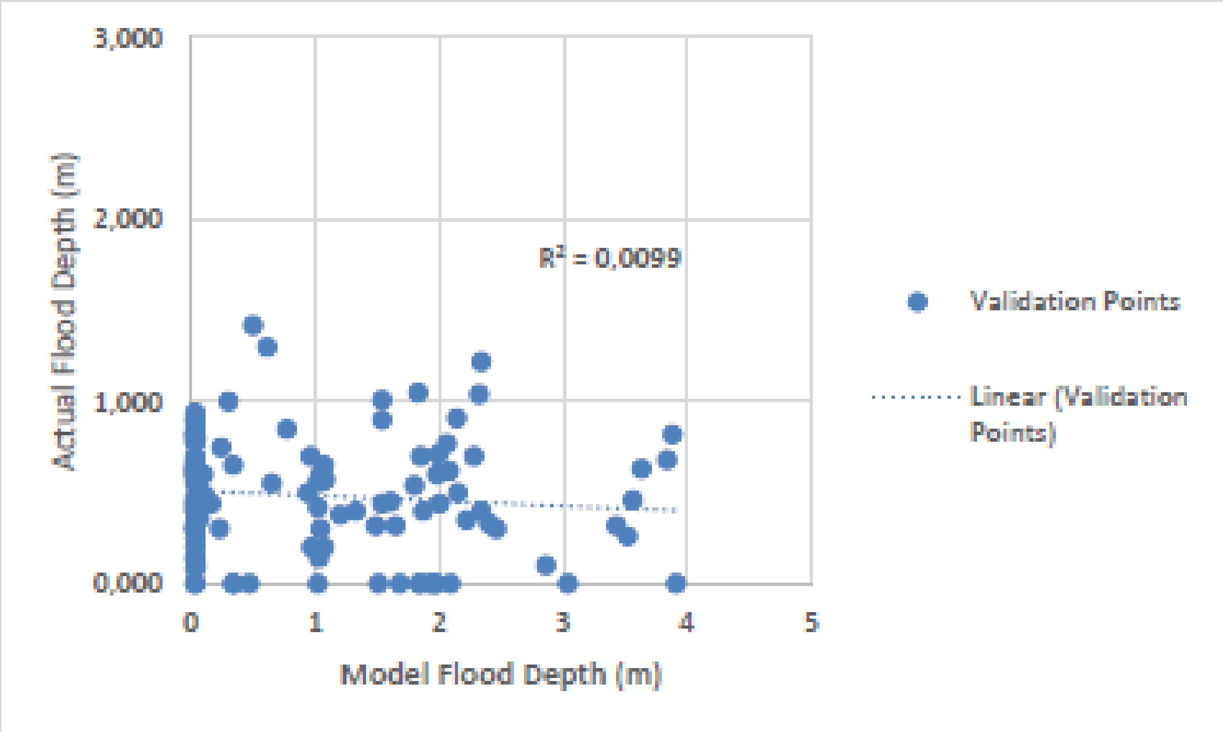


Figure 90. Flood map depth vs actual flood depth

Table 55. Actual Flood Depth vs Simulated Flood Depth at different levels in the Magbando 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	7	3	1	10	4	0	25
0.21-0.50	19	1	1	10	8	0	39
0.51-1.00	26	3	3	10	7	0	49
1.01-2.00	0	1	1	2	2	0	6
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	52	8	6	32	21	0	119

The overall accuracy generated by the flood model is estimated at 10.92% with 13 points correctly matching the actual flood depths. In addition, there were 36 points estimated one level above and below the correct flood depths while there were 45 points and 22 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 50 points were underestimated in the modelled flood depths of Magbando. Table 56 depicts the summary of the Accuracy Assessment in the Magbando River Basin Survey.

Table 56. Summary of Accuracy Assessment in the Magbando River Basin Survey

	No. of Points	%
Correct	13	10.92
Overestimated	56	47.06
Underestimated	50	42.02
Total	**119**	**100.00**

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LIDAR Sensors used in the Magbando Floodplain Survey

1. PEGASUS SENSOR

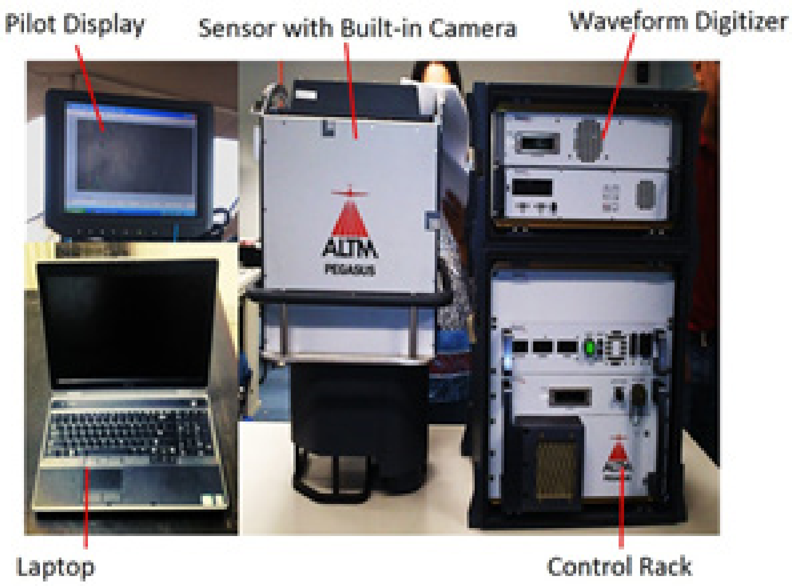


Figure A-1.1. Pegasus Sensor

Table A-1.1. Parameters and Specification of 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

2. AQUARIUS SENSOR

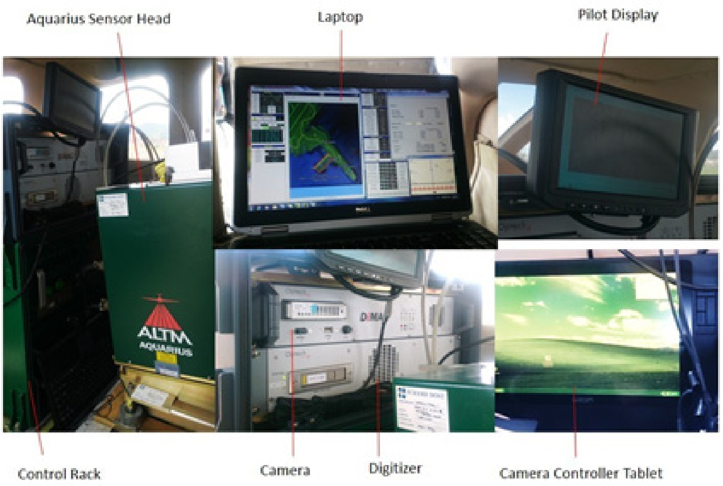


Figure A-1.2. Aquarius Sensor

Table A-1.2. Parameters and Specification of 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 altitiude	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

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. MRW-18

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**
Municipality: **CALINTAAN**
Barangay: **TANYAG**

	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: **1,385,563.72**	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

9903042014160150

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

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Figure A-2.2. MRW-22

3. MRW-24

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-24**
Order: **2nd**

Island: **LUZON**
Municipality: **CALINTAAN**
Barangay: **IRIRON**

PRS92 Coordinates

Latitude: **12° 36' 42.98691"**	Longitude: **120° 55' 49.01762"**	Ellipsoidal Hgt: **5.69500 m.**

WGS84 Coordinates

Latitude: **12° 36' 38.03549"**	Longitude: **120° 55' 54.08296"**	Ellipsoidal Hgt: **54.47900 m.**

PTM Coordinates

Northing: **1394624.897 m.**	Easting: **492425.435 m.**	Zone: **3**

UTM Coordinates

Northing: **1,395,022.71**	Easting: **275,166.05**	Zone: **51**

Location Description

MRW-24

From San Jose to Abra de Ilog, along Nat'l Road, approx. 9.2 Km. from Calintaan Proper, right side of the road located Evelyn's Welding Shop, left turn to Brgy. Road leading to Brgy. Iriron, approx. 1.9 Km. travel to reach Brgy. Plaza, in front of Iriron Elem. School located at Brgy. Iriron, Calintaan, Occ. Mindoro.Station is in NE corner of basketball court, about 10 m N of Goal. Mark is the head of a 4 in. copper nail flushed in a cement block embedded in the ground with inscriptions, "MRW-24, 2007, NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795470 A**
T.N.: **2014-447**

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

9903042014160207

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

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
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Figure A-2.3. MRW-24

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

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

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.4. MRW-4203

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**	
Island: **LUZON**	Order: **3rd**	Barangay: **CENTRAL**
Municipality: **SAN JOSE**		
	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: **505032.188 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

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

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

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

Figure A-2.5. MRW-4205

6. MC-252

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: **MC-252**

Island: **Luzon**	Municipality: **MAGSAYSAY**	Barangay: **NICOLAS (BULO)**
Elevation: **73.9140 +/- 0.11 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

Mark is the head of a 4" copper nail flushed in a cement block embedded in the groun with inscriptions "MC-252 2008 NAMRIA"

The station is situated beside KM post 211, 26 KM to Bulalacao, 11 KM from Magsaysay 2 KM from Nicolas Brgy. Hall. From Magsaysay located along National road beside KM post 211, Magsaysay Occidental Mindoro.

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8088861 I**
T.N.:	**2015-4115**

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

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

CIP/4701/12/09/814

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.6. MC-252

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

1. MC-252

Table A-3.1. MC-252

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 — MC-252 (B1)	MRW-18	MC-252	Fixed	0.011	0.042	83°20'06"	6696.437	54.946

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

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°08'36.92444"	Longitude	E121°08'42.01469"
Elevation	20.797 m	Height	21.295 m	Height	71.375 m

To:	MC-252				
Grid		Local		Global	
Easting	304770.876 m	Latitude	N12°19'10.66357"	Latitude	N12°19'05.80624"
Northing	1362466.012 m	Longitude	E121°12'17.05287"	Longitude	E121°12'22.14215"
Elevation	75.616 m	Height	76.241 m	Height	126.454 m

Vector					
ΔEasting	6656.981 m	NS Fwd Azimuth	83°20'06"	ΔX	-5632.860 m
ΔNorthing	731.267 m	Ellipsoid Dist.	6696.437 m	ΔY	-3538.801 m
ΔElevation	54.818 m	ΔHeight	54.946 m	ΔZ	770.489 m

Standard Errors

Vector errors:					
σ ΔEasting	0.005 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.011 m
σ ΔNorthing	0.003 m	σ Ellipsoid Dist.	0.005 m	σ ΔY	0.019 m
σ ΔElevation	0.021 m	σ ΔHeight	0.021 m	σ ΔZ	0.005 m

2. UP-LUM

Table A-3.2. UP-LUM

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRW-24 --- UP-LUM_2015_TCAGP (B1)	MRW-24	UP-LUM_2015_TCAGP	Fixed	0.005	0.018	146°42'11"	11260.986	29.457
MRW-24 --- UP-LUM_2015_TCAGP (B2)	MRW-24	UP-LUM_2015_TCAGP	Fixed	0.004	0.018	146°42'11"	11260.989	29.463

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	MRW-24				
Grid		Local		Global	
Easting	275166.053 m	Latitude	N12°36'42.98690"	Latitude	N12°36'38.03549"
Northing	1395022.712 m	Longitude	E120°55'49.01761"	Longitude	E120°55'54.08296"
Elevation	5.790 m	Height	5.694 m	Height	54.479 m

To:	UP-LUM_2015_TCAGP				
Grid		Local		Global	
Easting	281275.130 m	Latitude	N12°31'36.65200"	Latitude	N12°31'31.72599"
Northing	1385560.055 m	Longitude	E120°59'13.78049"	Longitude	E120°59'18.85291"
Elevation	35.101 m	Height	35.151 m	Height	84.296 m

Vector					
ΔEasting	6109.077 m	NS Fwd Azimuth	146°42'11"	ΔX	-6369.234 m
ΔNorthing	-9462.657 m	Ellipsoid Dist.	11260.986 m	ΔY	-1398.516 m
ΔElevation	29.311 m	ΔHeight	29.457 m	ΔZ	-9180.860 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.005 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.008 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.003 m

3. MRW-4203

Table A-3.3. MRW-4203

Vector Components (Mark to Mark)

From:	MRW-22				
Grid		Local		Global	
Easting	281265.629 m	Latitude	N12°31'36.76881"	Latitude	N12°31'31.84278"
Northing	1385563.717 m	Longitude	E120°59'13.46492"	Longitude	E120°59'18.53734"
Elevation	35.076 m	Height	35.127 m	Height	84.271 m

To:	MRW-4203				
Grid		Local		Global	
Easting	296032.858 m	Latitude	N12°21'24.45021"	Latitude	N12°21'19.57700"
Northing	1366637.239 m	Longitude	E121°07'26.92622"	Longitude	E121°07'32.01274"
Elevation	6.991 m	Height	7.414 m	Height	57.334 m

Vector					
ΔEasting	14767.230 m	NS Fwd Azimuth	141°36'12"	ΔX	-14844.540 m
ΔNorthing	-18926.478 m	Ellipsoid Dist.	24002.218 m	ΔY	-4238.929 m
ΔElevation	-28.085 m	ΔHeight	-27.712 m	ΔZ	-18378.800 m

4. MRW-4205

Table A-3.4. MRW-4205

Vector Components (Mark to Mark)

From:	MRW-22				
Grid		Local		Global	
Easting	281265.629 m	Latitude	N12°31'36.76881"	Latitude	N12°31'31.84278"
Northing	1385563.717 m	Longitude	E120°59'13.46492"	Longitude	E120°59'18.53734"
Elevation	35.076 m	Height	35.127 m	Height	84.271 m

To:	MRW-4205				
Grid		Local		Global	
Easting	287627.814 m	Latitude	N12°26'08.33883"	Latitude	N12°26'03.43990"
Northing	1375422.160 m	Longitude	E121°02'46.62885"	Longitude	E121°02'51.70890"
Elevation	12.319 m	Height	12.555 m	Height	62.080 m

Vector					
ΔEasting	6362.185 m	NS Fwd Azimuth	147°27'47"	ΔX	-6629.191 m
ΔNorthing	-10141.557 m	Ellipsoid Dist.	11969.898 m	ΔY	-1466.672 m
ΔElevation	-22.757 m	ΔHeight	-22.572 m	ΔZ	-9858.113 m

Standard Errors

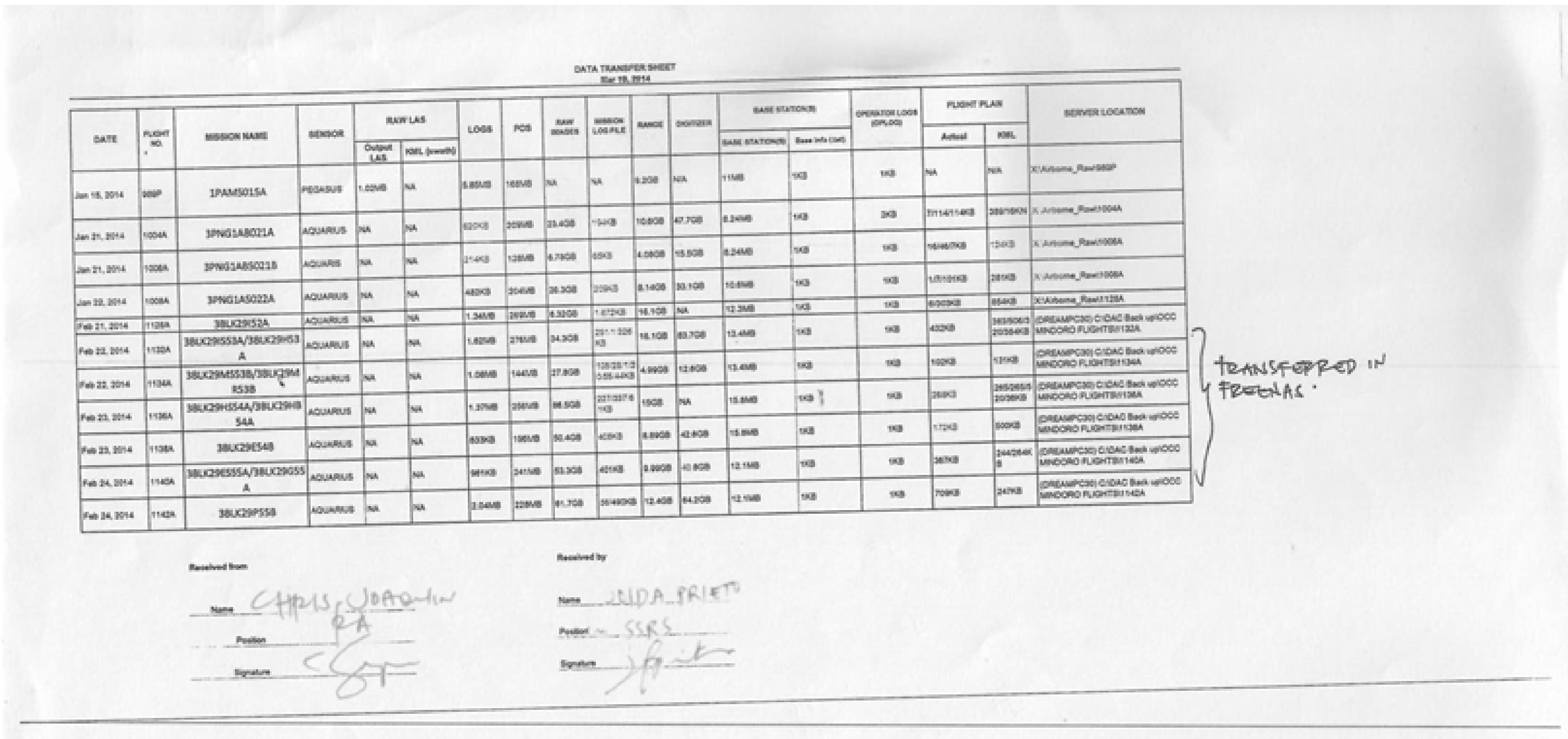
Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.006 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.002 m

ANNEX 4. The LIDAR Survey Team Composition

Table A-4.1. 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
		ENGR. LOUIE BALICANTA	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	
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. LARAH PARAGAS	UP-TCAGP
		PATRICIA YSABEL ALCANTARA	UP-TCAGP
		MILLIE SHANE REYES	UP-TCAGP
Ground Survey, Data Download and Transfer	Research Associate (RA)	GRACE SINADJAN	UP-TCAGP
		FRANK NICOLAS ILEJAY	UP-TCAGP
LiDAR Operation	Airborne Security	SGT. OLIVIER SACLOT	PHILIPPINE AIR FORCE (PAF)
		SSG. BENJAMIN CARBOLLEDO	
	Pilot	CAPT. JEFFREY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. CESAR SHERWIN ALFONSO	
		CAPT. JACKSON JAVIER	
		CAPT. JUSTIN REI JOYA	

ANNEX 5. Data Transfer Sheet for Magbando Floodplain



DATA TRANSFER SHEET
Mar 19, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Jan 15, 2014	989P	1PAM5015A	PEGASUS	1.02MB	NA	5.85MB	165MB	NA	NA	9.2GB	NA	11MB	1KB	1KB	NA	NA	X:\Airborne_Raw\989P
Jan 21, 2014	1004A	3PNG1A8021A	AQUARIUS	NA	NA	820KB	209MB	23.4GB	164KB	10.8GB	47.7GB	8.24MB	1KB	2KB	7/114/114KB	289/18KN	X:\Airborne_Raw\1004A
Jan 21, 2014	1008A	3PNG1A8S021B	AQUARIUS	NA	NA	214KB	128MB	6.79GB	55KB	4.08GB	15.5GB	8.24MB	1KB	1KB	16/46/7KB	124KB	X:\Airborne_Raw\1008A
Jan 22, 2014	1008A	3PNG1AS022A	AQUARIUS	NA	NA	482KB	204MB	26.3GB	209KB	8.14GB	30.1GB	10.6MB	1KB	1KB	1/31/101KB	281KB	X:\Airborne_Raw\1008A
Feb 21, 2014	1128A	3BLK29I52A	AQUARIUS	NA	NA	1.34MB	269MB	6.32GB	1.672KB	16.1GB	NA	12.3MB	1KB	1KB	8/303KB	854KB	X:\Airborne_Raw\1128A
Feb 22, 2014	1132A	3BLK29SS53A/3BLK29HS53A	AQUARIUS	NA	NA	1.62MB	276MB	34.3GB	281/1326KB	16.1GB	83.7GB	13.4MB	1KB	1KB	432KB	363/506/3 20/384KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1132A
Feb 22, 2014	1134A	3BLK29MS53B/3BLK29MR53B	AQUARIUS	NA	NA	1.08MB	144MB	27.8GB	108/28/112 /335/44KB	4.99GB	12.8GB	13.4MB	1KB	1KB	100KB	131KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1134A
Feb 23, 2014	1136A	3BLK29HS54A/3BLK29HS54A	AQUARIUS	NA	NA	1.37MB	256MB	66.5GB	221/337/6 1KB	15GB	NA	15.8MB	1KB	1KB	269KB	265/265/5 20/38KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1136A
Feb 23, 2014	1138A	3BLK29ES4B	AQUARIUS	NA	NA	603KB	196MB	50.4GB	403KB	8.89GB	42.6GB	15.8MB	1KB	1KB	172KB	500KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1138A
Feb 24, 2014	1140A	3BLK29ES55A/3BLK29GS55A	AQUARIUS	NA	NA	981KB	241MB	53.3GB	401KB	9.99GB	40.8GB	12.1MB	1KB	1KB	367KB	244/264KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1140A
Feb 24, 2014	1142A	3BLK29PS5B	AQUARIUS	NA	NA	2.04MB	228MB	61.7GB	35/490KB	12.4GB	64.2GB	12.1MB	1KB	1KB	709KB	247KB	(DREAMPC30) C:\DAC Back up\OCC MINDORO FLIGHTS\1142A

TRANSFERRED IN FREENAS.

Received from
Name CHRIS JOAQUIN
Position RA
Signature

Received by
Name LINDA PRIETO
Position SSRS
Signature

Figure A-5.1. Transfer Sheet for Magbando Floodplain - A

DATA TRANSFER SHEET
3/19/2014(CCCMIN)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base info (.txt)		Actual	KML	
Feb 27, 2014	1152A	3BLK29GSD58A	AQUARIUS	NA	NA	1.12MB	255MB	73GB	544KB	12.6GB	53.8GB	15.9MB	1KB	1KB	339KB	135/556KB	Z:\Airborne_Raw\1152A
Feb 27, 2014	1154A	3BLK29DS58B	AQUARIUS	NA	NA	NA	214MB	39.9GB	283/29KB	44.5GB	9.42GB	15.9MB	1KB	2KB	687KB	NA	Z:\Airborne_Raw\1154A
Feb 28, 2014	1156A	3BLK29FS9A	AQUARIUS	NA	NA	1.72MB	268MB	89.5GB	NA	14.3GB	69.6GB	17.1MB	1KB	1KB	352KB	813KB	Z:\Airborne_Raw\1156A
Feb 28, 2014	1158A	3BLK29AS9B	AQUARIUS	NA	NA	683 KB	210 MB	38GB	95/199KB	8.14GB	13.7GB	17.1MB	1KB	1KB	6/144KB	424KB	Z:\Airborne_Raw\1158A
Mar 1, 2014	1160A	3BLK29C60A	AQUARIUS	NA	NA	1.03MB	268MB	13.5GB	10/50/40KB	14.1GB	57GB	17.8MB	1KB	1KB	519KB	399/16KB	Z:\Airborne_Raw\1160A
Mar 1, 2014	1162A	3BLK29AS60B	AQUARIUS	NA	NA	759KB	199MB	34.6GB	147/88KB	9.54GB	87.2GB	17.8MB	1KB	1KB	11/176KB	445KB	Z:\Airborne_Raw\1162A
Mar 2, 2014	1164A	3BLK29N61A	AQUARIUS	NA	NA	879KB	293MB	22.5GB	147KB	13.6GB	73.8GB	18.4MB	1KB	1KB	237KB	76/44KB	Z:\Airborne_Raw\1164A
Mar 2, 2014	1166A	3BLK29B61B	AQUARIUS	NA	NA	1.16MB	230MB	NA	NA	12.5GB	144GB	18.4MB	1KB	1KB	9/242KB	714/714KB	Z:\Airborne_Raw\1166A
Mar 3, 2014	1168A	3BLK29BS62A	AQUARIUS	NA	NA	2.37MB	268MB	NA	NA	12.3GB	15.7GB	10.6MB	1KB	1KB	184KB	300/666/670KB	Z:\Airborne_Raw\1168A

Received from

Name: Chris Joaquin
Position: RA
Signature: [signature] 03/21/14

Received by

Name: JOIDA F. PRIETO
Position: SSRS
Signature: [signature] 3/23/14

Figure A-5.2. Transfer Sheet for Magbando Floodplain - B

DATA TRANSFER SHEET
Occ. Mindoro 1/13/16

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

Received from

Name
Position
Signature

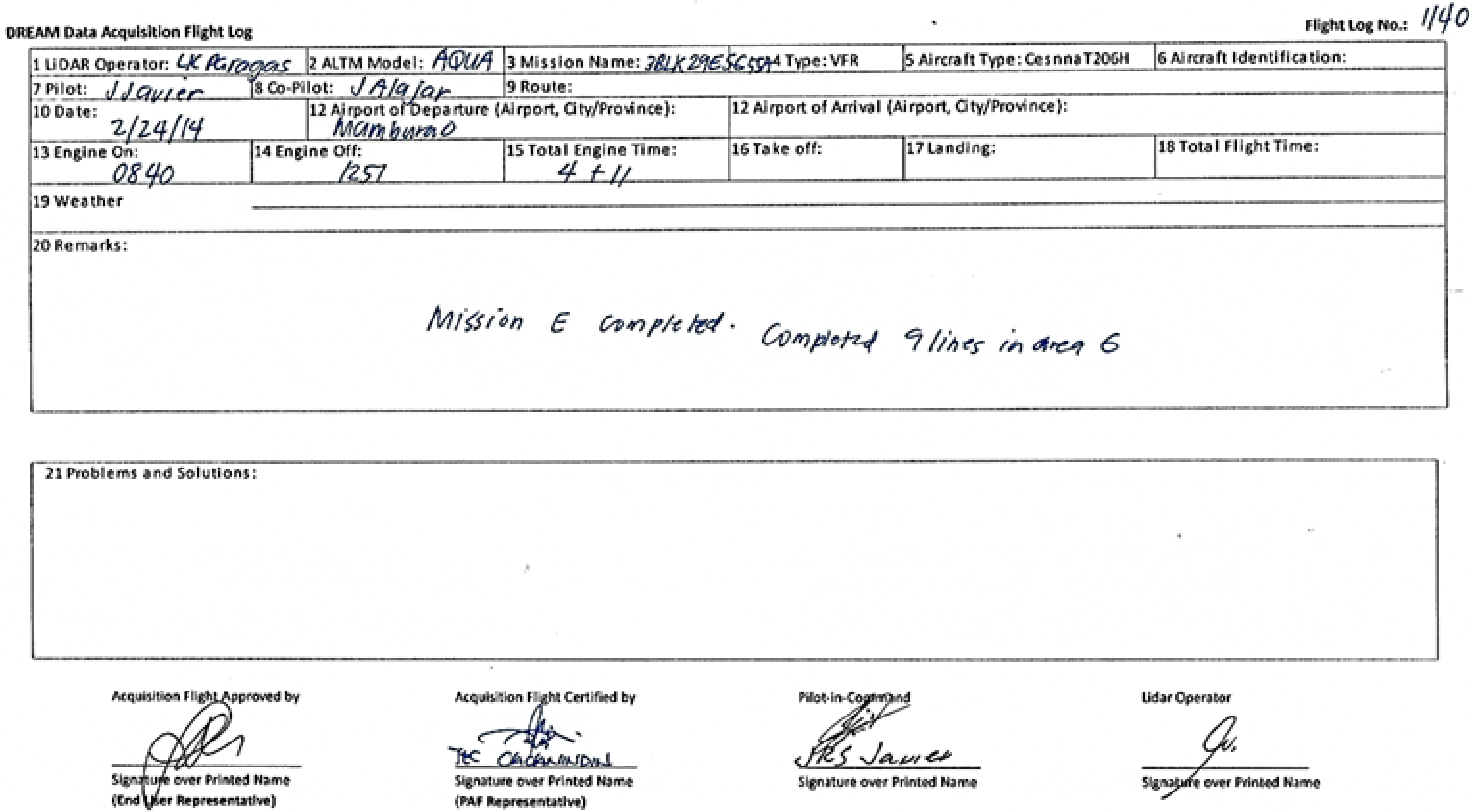
Received by

Name
Position
Signature

Figure A-5.3. Transfer Sheet for Magbando Floodplain - C

ANNEX 6. Flight logs for the Flight Missions

1. Flight Log for Mission 3BLK29ES55A



DREAM Data Acquisition Flight Log

Flight Log No.: 1140

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29ES55A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 2/24/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0840	14 Engine Off: 1257	15 Total Engine Time: 4+11	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission E completed. Completed 9 lines in area 6					

21 Problems and Solutions:

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

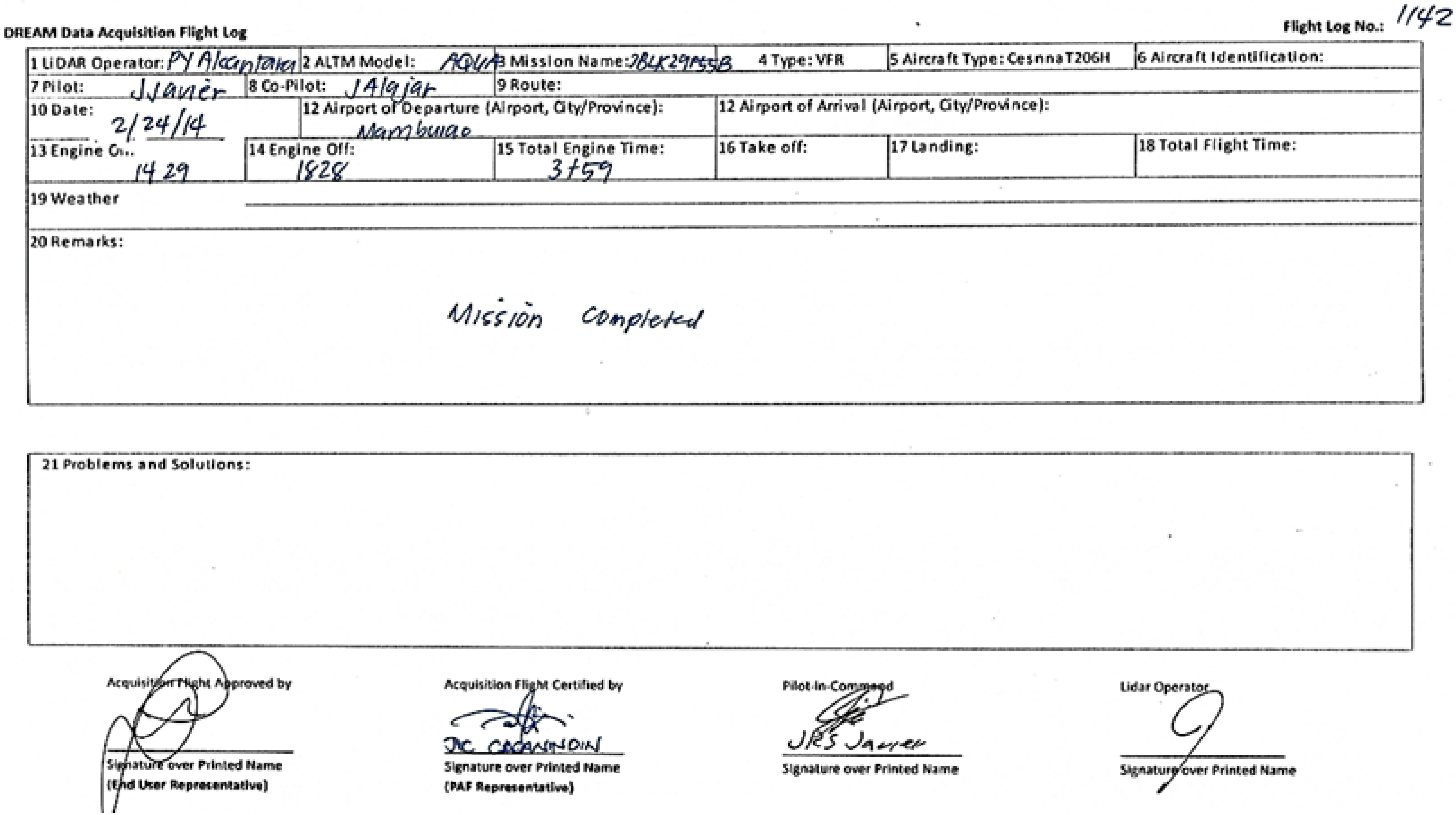
Acquisition Flight Certified by
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JRS Javier
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.1. Flight Log for Mission 3BLK29ES55A

2. Flight Log for Mission 3BLK29P55B



DREAM Data Acquisition Flight Log

Flight Log No.: 1142

1 LiDAR Operator: PY Alcantara	2 ALTM Model: AQUA	3 Mission Name: 3BLK29P55B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 2/24/14	12 Airport of Departure (Airport, City/Province): Nambuyao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1429	14 Engine Off: 1828	15 Total Engine Time: 3+59	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)

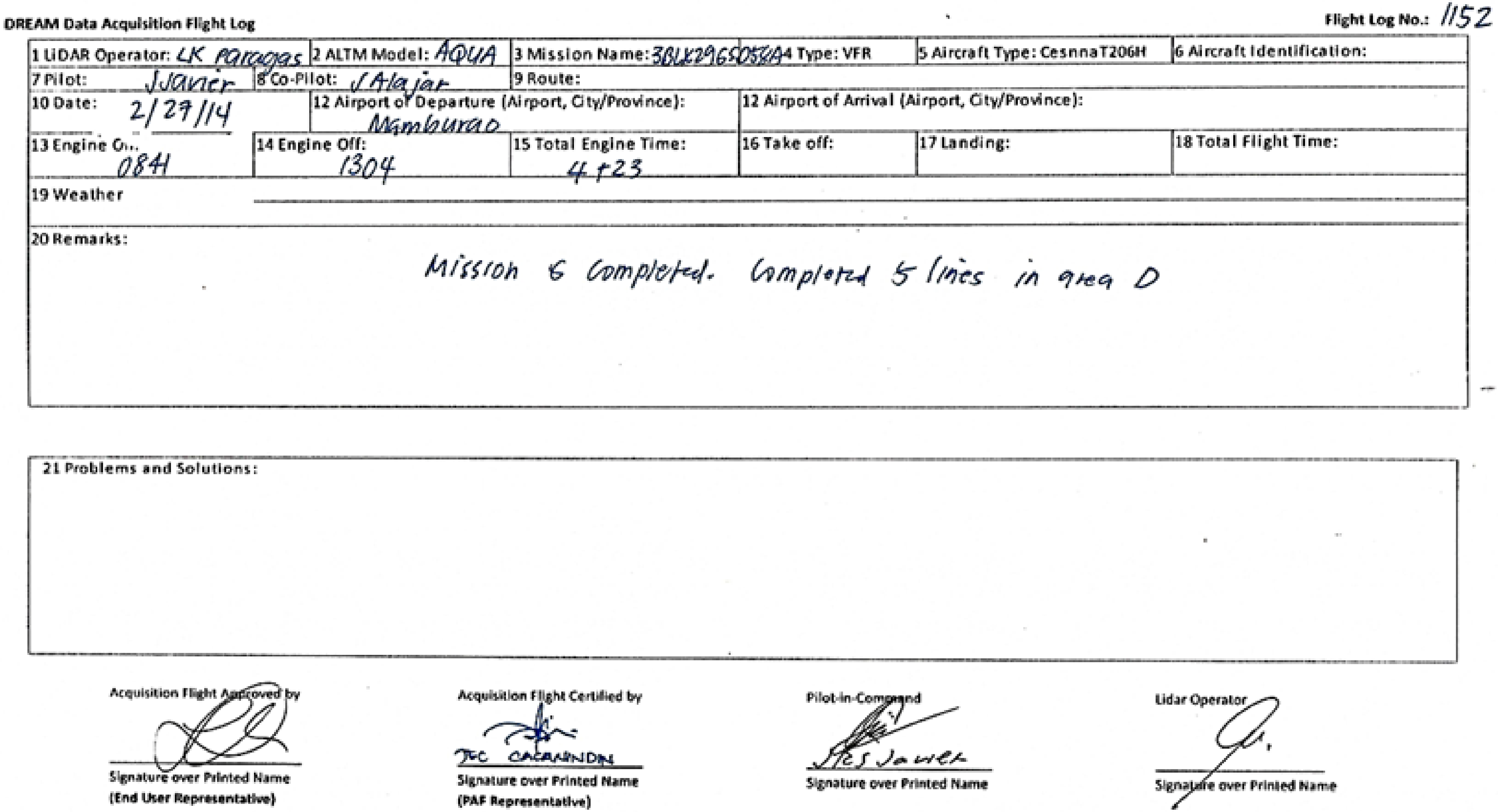
Acquisition Flight Certified by
JC Cagangdon
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JRS Javier
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.2. Flight Log for Mission 3BLK29P55B

3. Flight Log for Mission 3BLK29GSD58A (3BLK29D+GS58A)



DREAM Data Acquisition Flight Log — Flight Log No.: 1152

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29GSD58A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 2/27/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0841	14 Engine Off: 1304	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Mission 6 Completed. Completed 5 lines in area D

21 Problems and Solutions:

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

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

Pilot-in-Command
J. Javier
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.3. Flight Log for Mission 3BLK29GSD58A (3BLK29D+GS58A)

4. Flight Log for Mission 3BLK29DS58B

DREAM Data Acquisition Flight Log Flight Log No.: 1154

1 LiDAR Operator: L Asuncion	2 ALTM Model: AQUA	3 Mission Name: 3BLK29DS58B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 2/27/14	12 Airport of Departure (Airport, City/Province): Mambumo		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1414	14 Engine Off: 1807	15 Total Engine Time: 3+53	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 — Jec Cacanindin — Signature over Printed Name (PAF Representative)

Pilot-in-Command — J Javier — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 3BLK29DS58B

5. Flight Log for Mission 3BLK29F59A

DREAM Data Acquisition Flight Log

Flight Log No.: 1156

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29F59A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	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): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 819	14 Engine Off: 1248	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
Signature over Printed Name
(End User Representative)

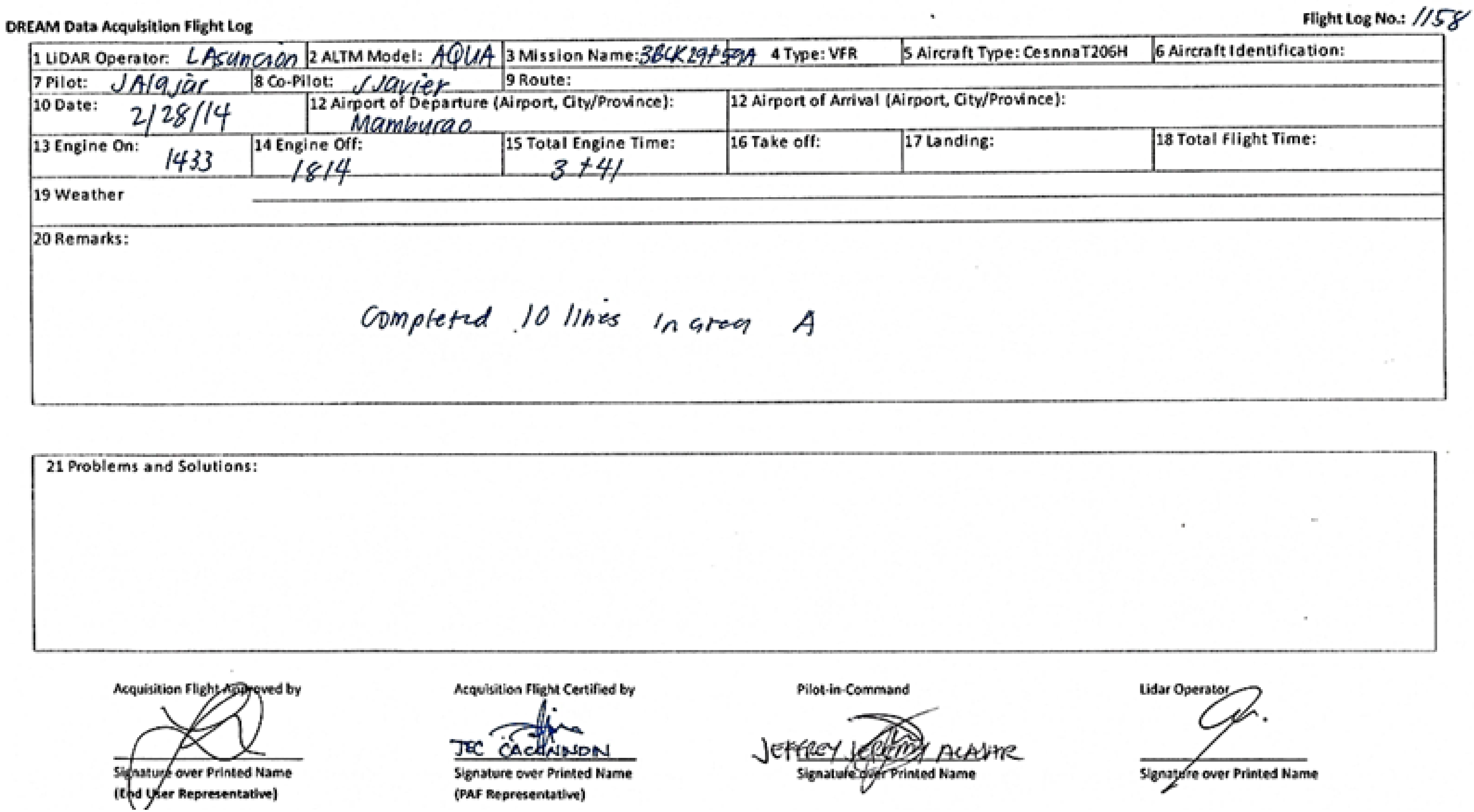
Acquisition Flight Certified by
JRC CACANINDIN
Signature over Printed Name
(PAF Representative)

Pilot-in-Command
JEFFREY JEREMY ALAJAR
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.5. Flight Log for Mission 3BLK29F59A

6. Flight Log for Mission 3BLK29A59B



DREAM Data Acquisition Flight Log — Flight Log No.: 1158

1 LiDAR Operator: L Asuncion	2 ALTM Model: AQUA	3 Mission Name: 3BLK29A59A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	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): Mamburao		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 — Signature over Printed Name (End User Representative)

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

Pilot-in-Command — JEFFREY JEREMY ALAJAR — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.6. Flight Log for Mission 3BLK29A59B

7. Flight Log for Mission 3BLK29C60A

DREAM Data Acquisition Flight Log

Flight Log No.: 1160

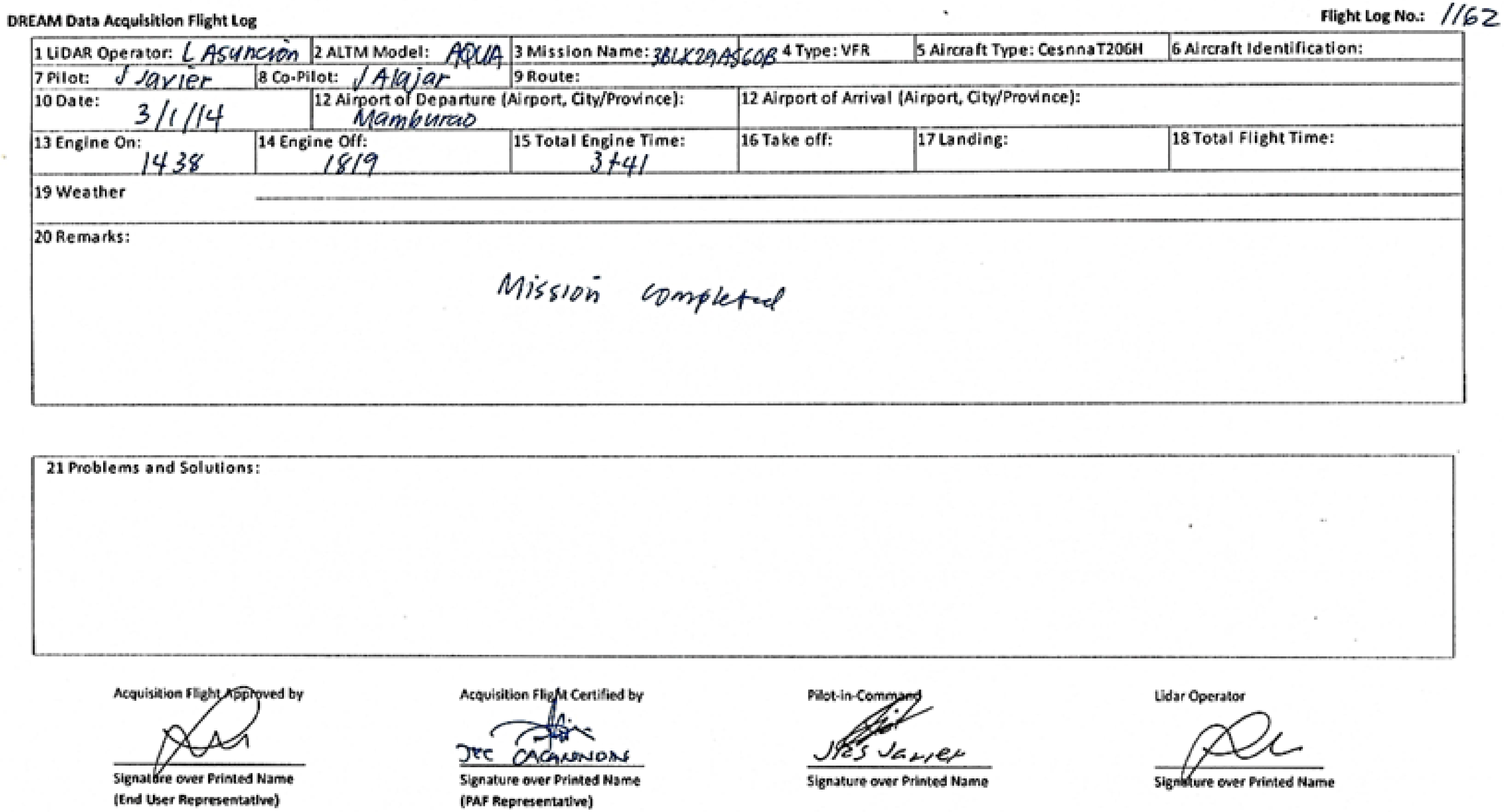
1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29C60A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 3/1/14	12 Airport of Departure (Airport, City/Province): Mambajao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 822	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	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
	Dec Caganinons	J. Javier	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.7. Flight Log for Mission 3BLK29C60A

8. Flight Log for Mission 3BLK29AS60B



DREAM 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
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
J. Javier
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.8. Flight Log for Mission 3BLK29AS60B

9. Flight Log for Mission 3BLK29N61A

DREAM Data Acquisition Flight Log

Flight Log No.: 1164

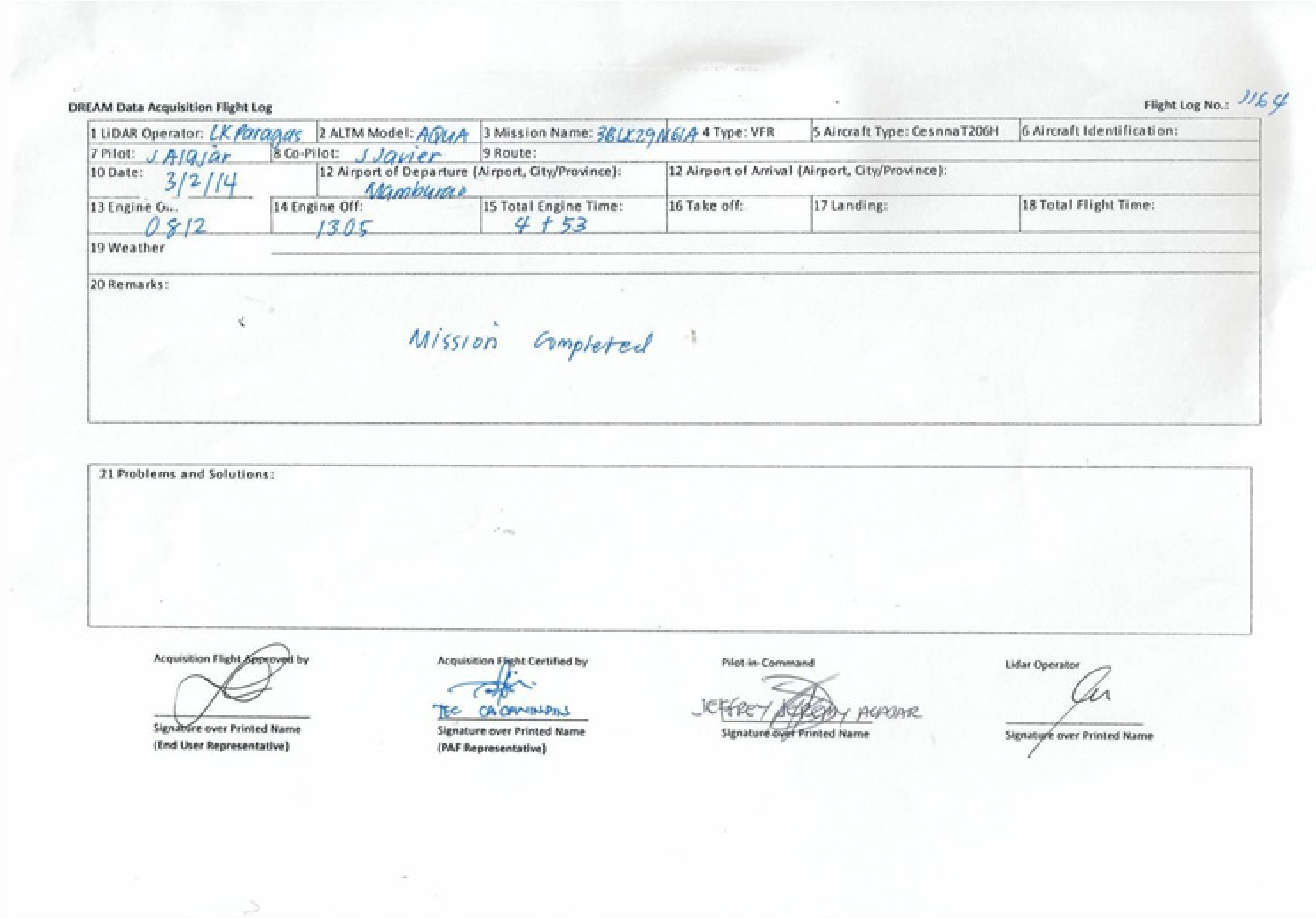
1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29N61A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Alajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 3/2/14	12 Airport of Departure (Airport, City/Province): Nambuwan		12 Airport of Arrival (Airport, 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

Figure A-6.9. Flight Log for Mission 3BLK29N61A

10. Flight Log for Mission 3BLK29BS62A



DREAM 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): Mambuao		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
Signature over Printed Name
(End User Representative)

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

Pilot-in-Command
JEFFREY ALAJAR
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.10. Flight Log for Mission 3BLK29BS62A

11. Flight Log for Mission 3BLK29BS+AB+DB+CV+KV62B

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: CesnnaT206H	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): Mamburao		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
	JEC CACANINDIN	J Javier	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.11. Flight Log for Mission 3BLK29BS+AB+DB+CV+KV62B

12. Flight Log for Mission 1BLK29KLMO344A

DREAM Program's Data Acquisition Flight Log — Flight Log No.: 2954

1 LiDAR Operator: G. SINADJAN | 2 ALTM Model: PEGASUS | 3 Mission Name: 1BLK29KLMO344A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9122

7 Pilot: CS ALFONSO | 8 Co-Pilot: J JOYA | 9 Route: Mamburao

10 Date: DEC 10, 2015 | 12 Airport of Departure (Airport, City/Province): MAMBURAO | 12 Airport of Arrival (Airport, City/Province): MAMBURAO

13 Engine On: 0752 | 14 Engine Off: 1157 | 15 Total Engine Time: 4+05 | 16 Take off: 0757 | 17 Landing: 1152 | 18 Total Flight Time: 3+55

19 Weather: Fair

20 Flight Classification

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

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

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

21 Remarks: Successful flight. Surveyed BLK 29K,L,M&O

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

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

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

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

Lidar Operator: Grace Sinadjan — Signature over Printed Name

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

Figure A-6.12. Flight Log for Mission 1BLK29KLMO344A

13. Flight Log for Mission 1BLK29P344B

DREAM Program's Data Acquisition Flight Log — Flight Log No.: 2956

1 LiDAR Operator: MS REYES	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK29P344B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: CS ALFONSO	8 Co-Pilot: J JOYA	9 Route:			
10 Date: DEC 10, 2015	12 Airport of Departure (Airport, City/Province): MAMBURAO		12 Airport of Arrival (Airport, City/Province): MAMBURAO		
13 Engine On: 1434	14 Engine Off: 1621	15 Total Engine Time: 1+47	16 Take off: 1439	17 Landing: 1616	18 Total Flight Time: 1+37
19 Weather: low lying clouds					

20 Flight Classification

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

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

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

21 Remarks

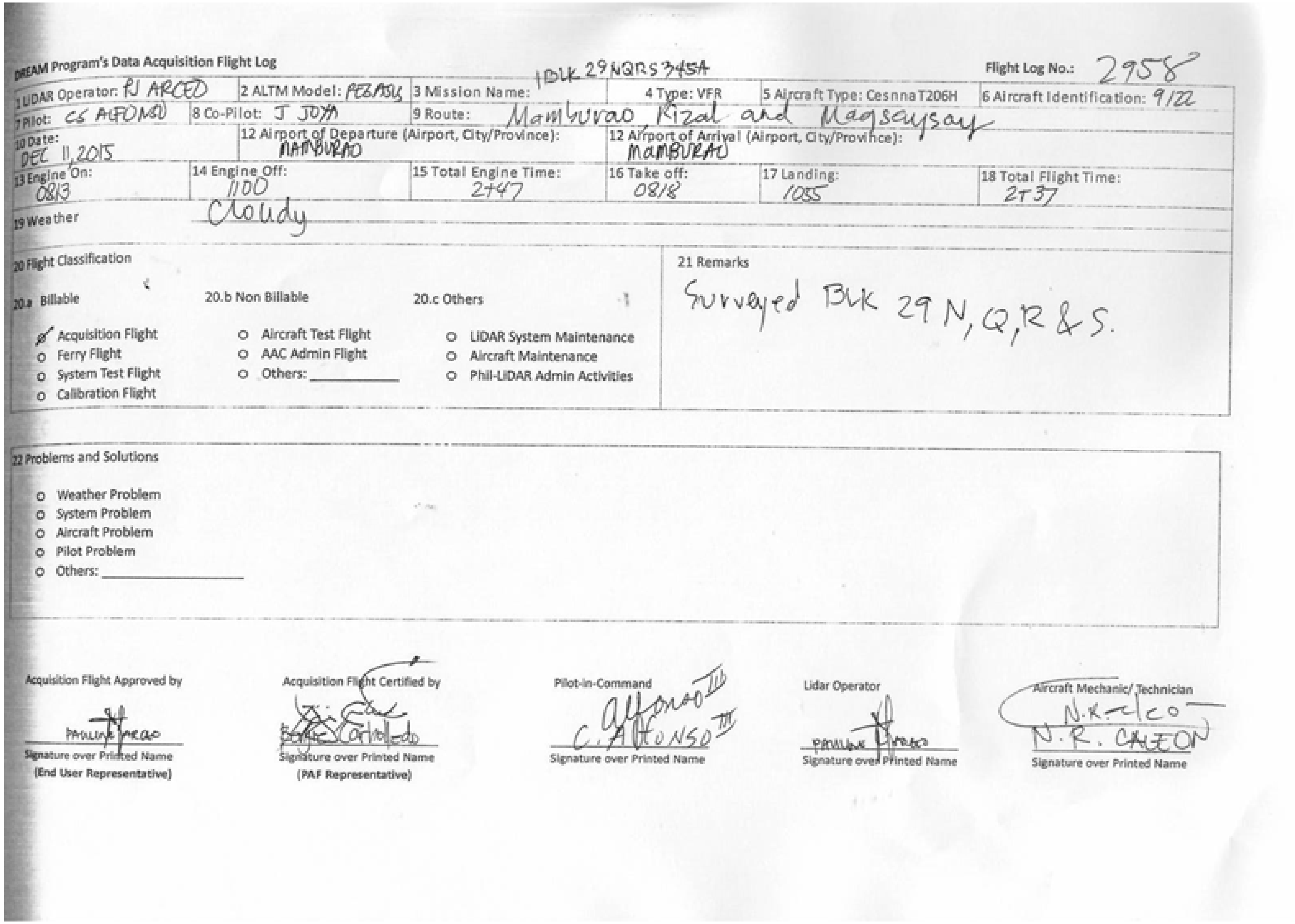
Surveyed BLK 29P

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
[illegible]	[illegible] Caballedo	C. ALFONSO III	MS REYES	N.R. 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

Figure A-6.13. Flight Log for Mission 1BLK29P344B

14. Flight Log for Mission 1BLK29NQRS345A



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
- o Ferry Flight
- o System Test Flight
- o Calibration Flight

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

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

21 Remarks

Surveyed BLK 29 N, Q, R & S.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
PAULINE ARCEO	[illegible] Cartolledo	C. ALFONSO III	PAULINE ARCEO	N.R. 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

Figure A-6.14. Flight Log for Mission 1BLK29NQRS345A

ANNEX 7. Flight status reports

OCCIDENTAL MINDORO
(February 24 – March 3, 2014 and December 10-11, 2015)

Table A-7.1. Flight Status Reports

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1140A	BLK29E & BLK29G	3BLK29ES55A (3BLK29ES+G55A)	LK PARAGAS	24-Feb-14	Completed the rest of area E and 5 lines of area G. 30 percent dropouts in line 20 of area G.
1142A	BLK29F	3BLK29P55B	PY ALCANTARA	24-Feb-14	Mission completed. Camera error in line 16, 100% dropouts in line 15
	BLK29D, E	1BLK29DE340B	MS REYES	6-Dec-15	Surveyed BLK29D & E
1152A	BLK29D & BLK29G	3BLK29GSD58A (3BLK29D+GS58A)	L. PARAGAS	27-Feb-14	Completed the rest of BLK29G and 5 lines of BLK29D.
1154A	BLK29D	3BLK29DS58B	L. ASUNCION	27-Feb-14	Completed the rest of BLK29D. Experienced dropouts over water. Camera assertion failed in line 15, restarted the camera. Also, cam error in line 18.
1156A	BLK29F	3BLK29F59A	L. PARAGAS	28-Feb-14	Mission completed. No camera mission logs.
1158A	BLK29A	3BLK29A59B	L. ASUNCION	28-Feb-14	Covered 10 lines.
1160A	BLK29C	3BLK29C60A	L. PARAGAS	01-Mar-14	Mission completed.
1162A	BLK29A & BLK29D	3BLK29AS60B (3BLK29AS+DV60B)	L. ASUNCION	01-Mar-14	Mission completed. Continuation of BLK29A and covered voids in BLK29D. Restarted the system due to high system temperature. Camera hanged in line 3, no images for half of the line while manually for the rest of the line and entire line 8 while no images for lines 1, 4 and 7.
1164A	BLK29B & BLK28N	3BLK29N+B61A	L. PARAGAS	02-Mar-14	Mission Complete
1166A	BLK29B	3BLK29B61B	L. ASUNCION	02-Mar-14	Covered gap in line 10 from the morning flight.

1168A	BLK29B, A, D, C AND K	3BLK29BS+AB+DB+ CV+KV62B	L. PARAGAS	March 3, 2014	Mission completed. Bathy in BLK29A and D but the digitizer hanged in line 2 of area A. Covered voids of BLK29 C and K.
3074P	BLK29K, L, M, O	1BLK29KLMO344A	G. Sinadjan	December 10, 2015	Surveyed BLK29K, L, M, and O
3076P	BLK29P	1BLK29P344B	MS. REYES	December 10, 2015	Surveyed BLK29P
3078P	BLK29N, Q, R, S	1BLK29NQRS345A	PJ. Arceo	December 11, 2015	Surveyed BLK29N, Q, R, and S

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

FLIGHT LOG NO. 1140A
AREA: BLK29E AND BLK29G
MISSION NAME: 3BLK29ES55A (3BLK29ES+G55A)

SURVEY COVERAGE:

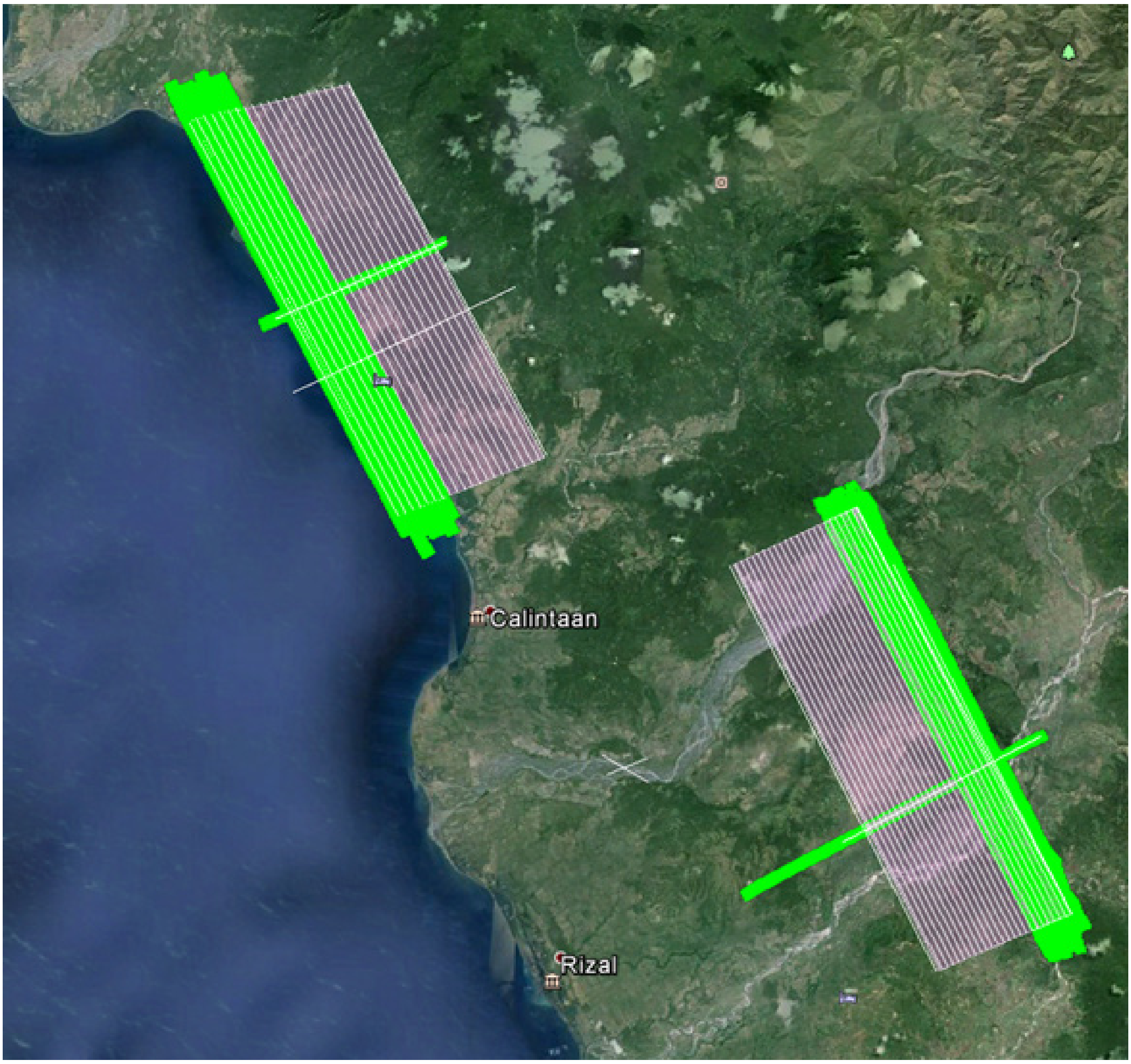


Figure A-7.1. Swath for Flight No. 1140A

FLIGHT LOG NO. 1142A
AREA: BLK29P
MISSION NAME: 3BLK29P55B

SURVEY COVERAGE:

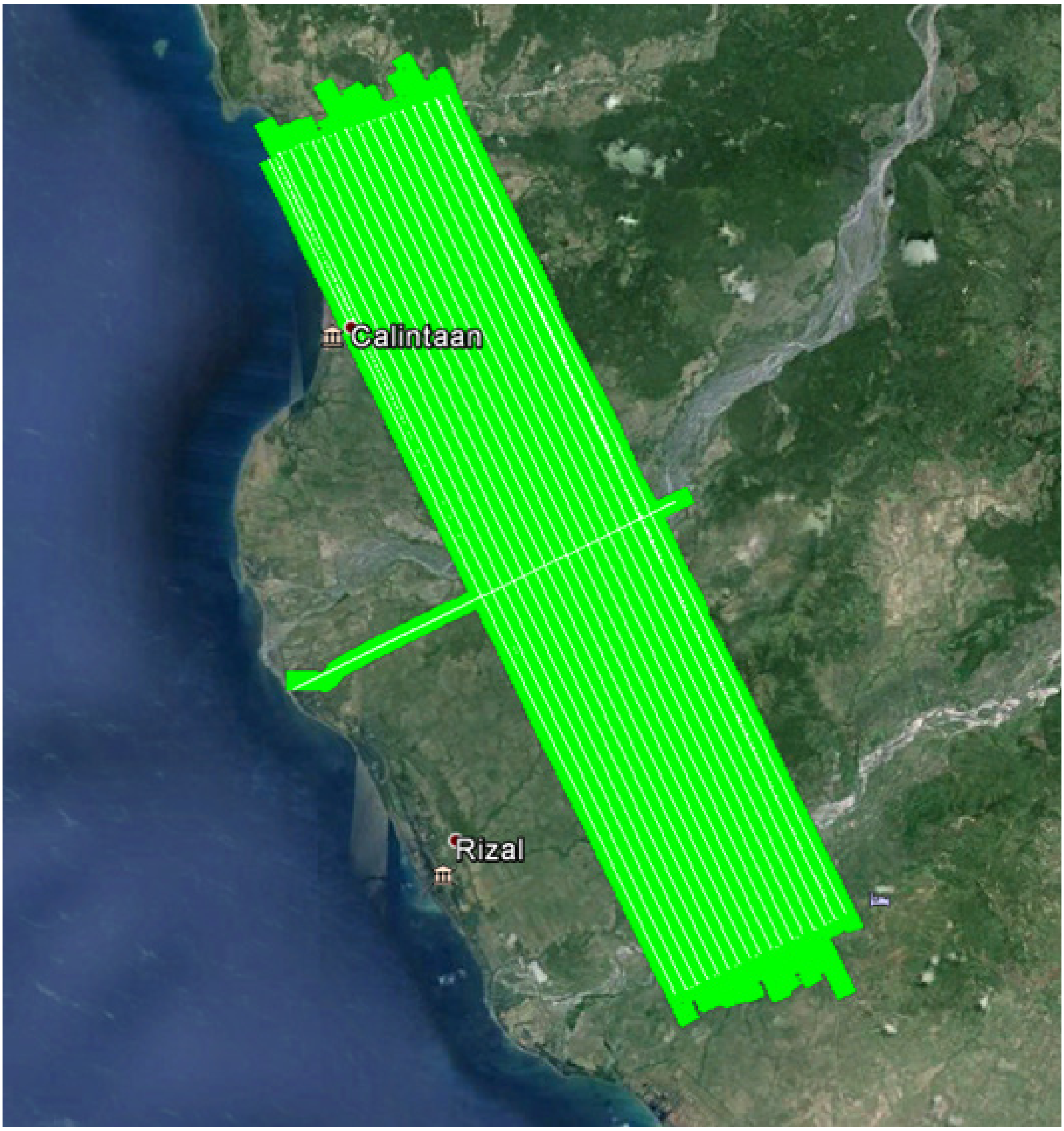


Figure A-7.2. Swath for Flight No. 1142A

FLIGHT LOG NO.	1152A
AREA:	BLK29D AND BLK29G
MISSION NAME:	3BLK29GSD58A (3BLK29D+GS58A)

SURVEY COVERAGE:

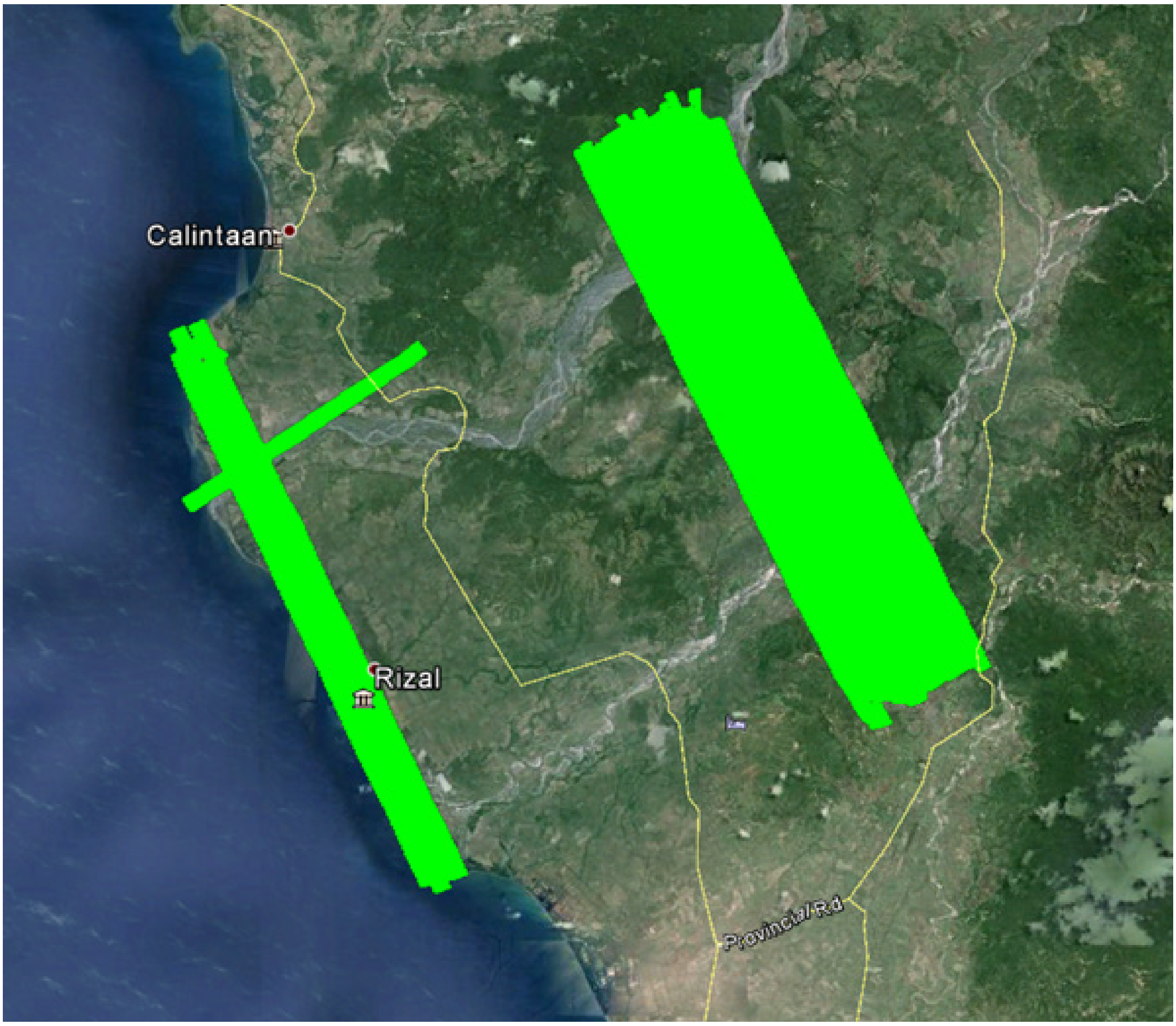


Figure A-7.3. Swath for Flight No. 1152A

FLIGHT LOG NO. 1154A
AREA: BLK29D
MISSION NAME: 3BLK29DS58B

SURVEY COVERAGE:

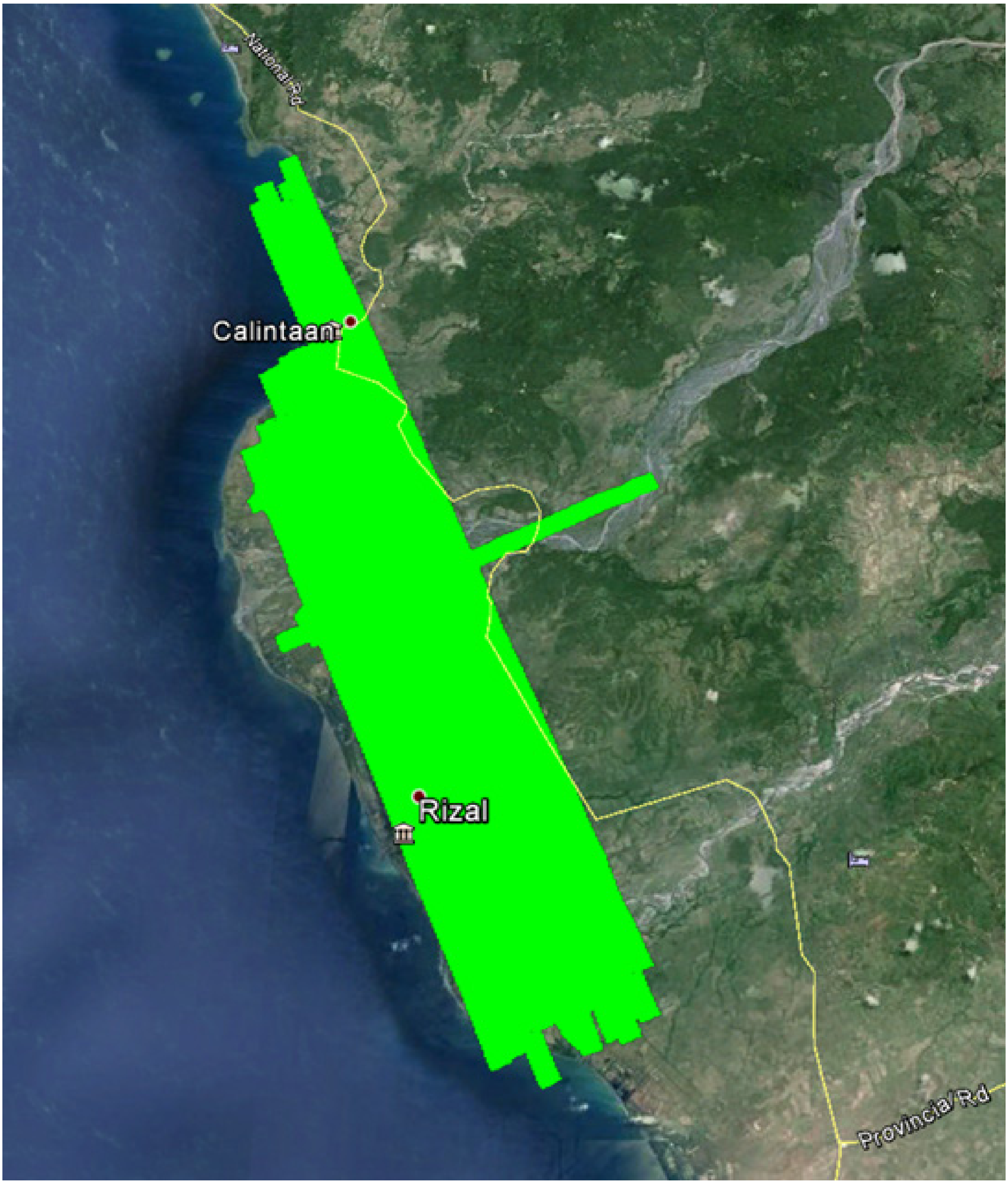


Figure A-7.4. Swath for Flight No. 1154A

FLIGHT LOG NO. 1156A
AREA: BLK29F
MISSION NAME: 3BLK29F59A

SURVEY COVERAGE:

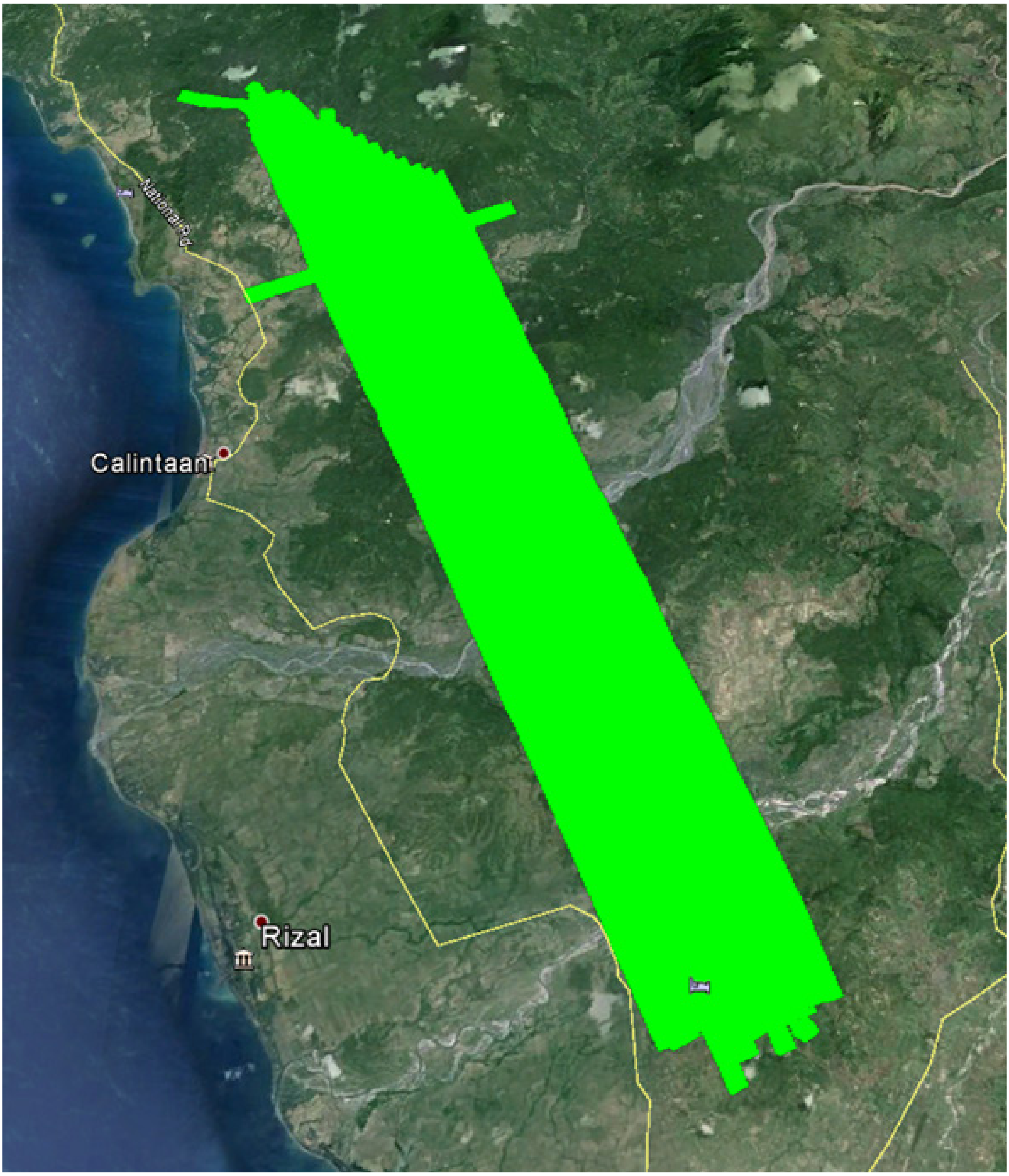


Figure A-7.5. Swath for Flight No. 1156A

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

SURVEY COVERAGE:

Figure A-7.6. Swath for Flight No. 1158A

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

SURVEY COVERAGE:

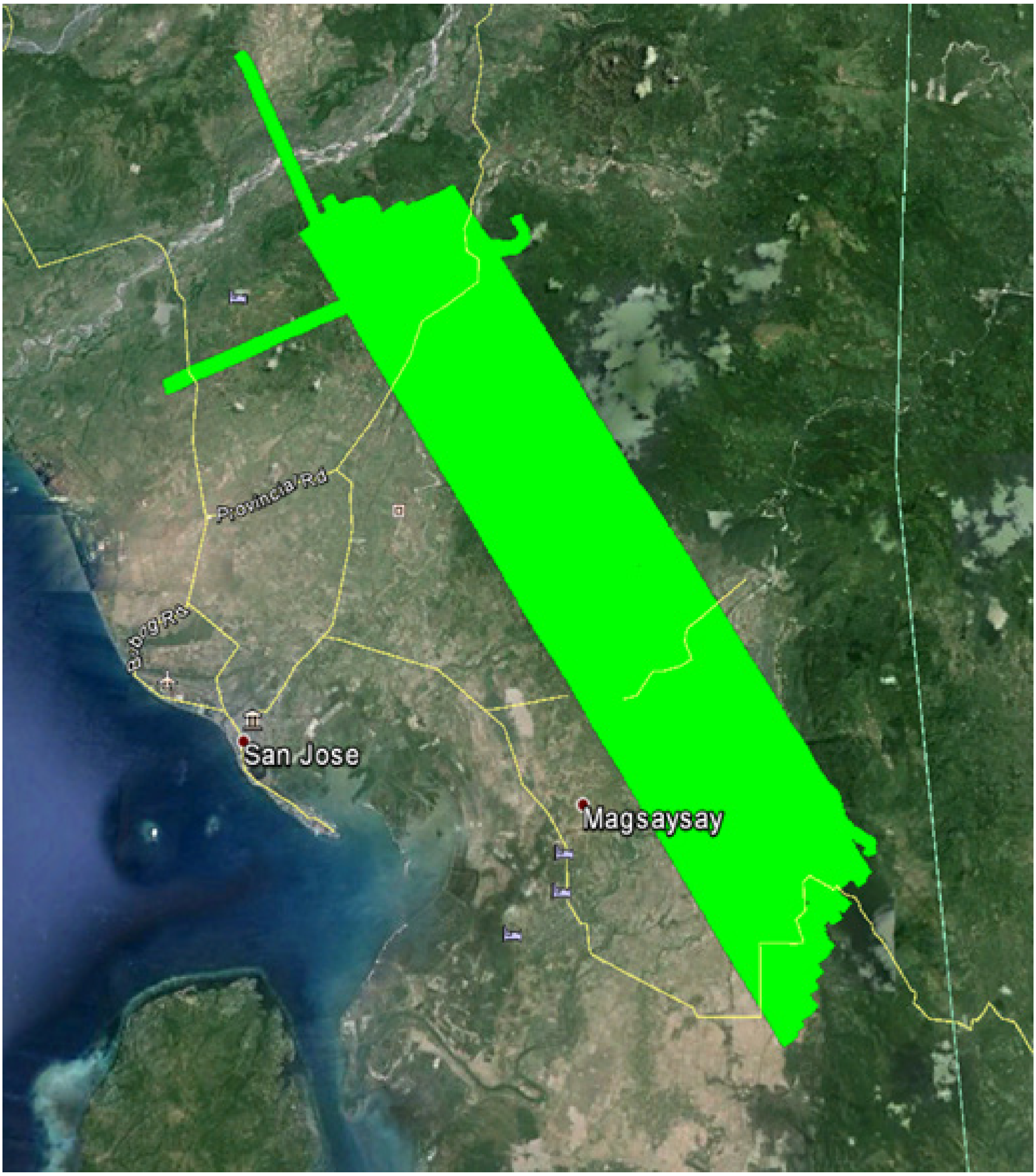


Figure A-7.7. Swath for Flight No. 1160A

FLIGHT LOG NO. 1162A
AREA: BLK29A AND BLK29D
MISSION NAME: 3BLK29AS60B (3BLK29AS+DV60B)

SURVEY COVERAGE:

Figure A-7.8. Swath for Flight No. 1162A

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:

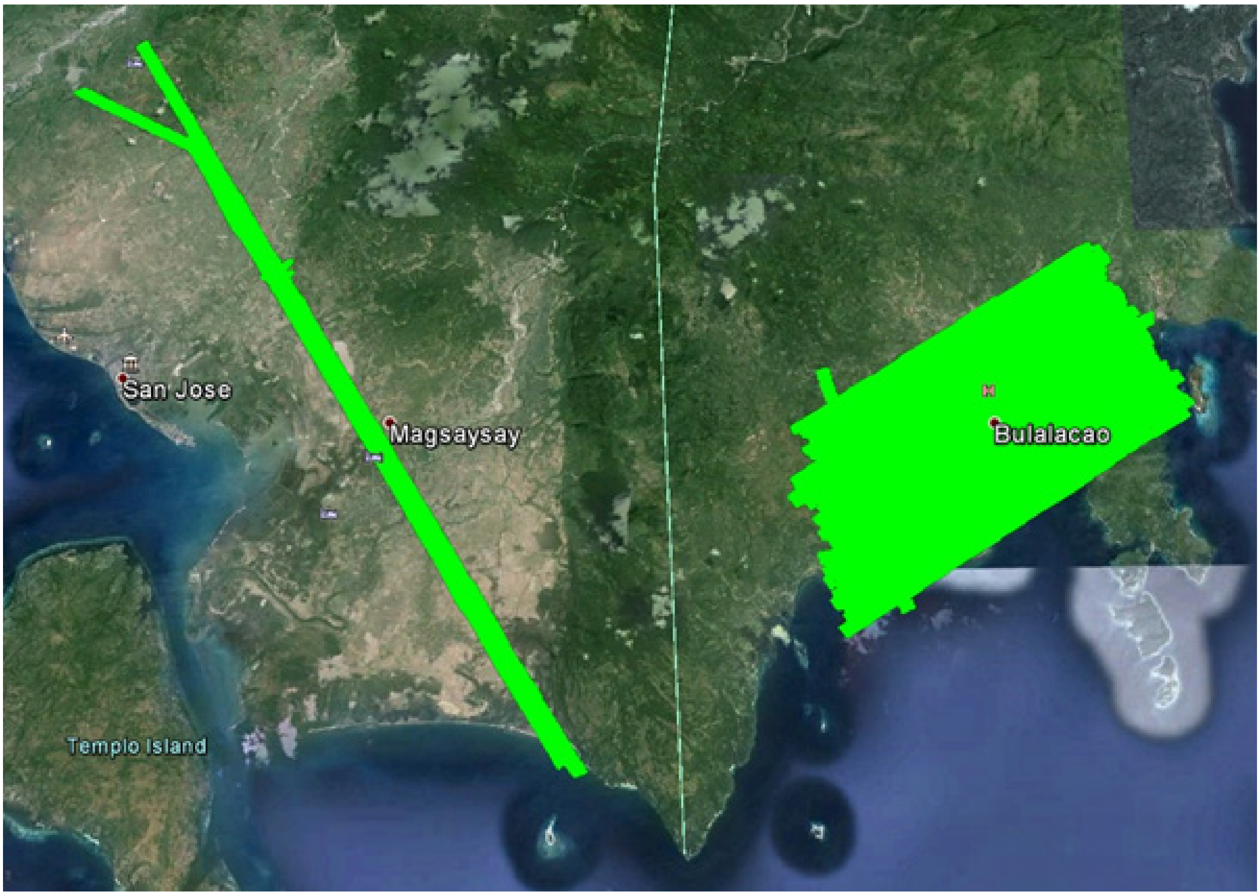


Figure A-7.9. Swath for Flight No. 1164A

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

SURVEY COVERAGE:

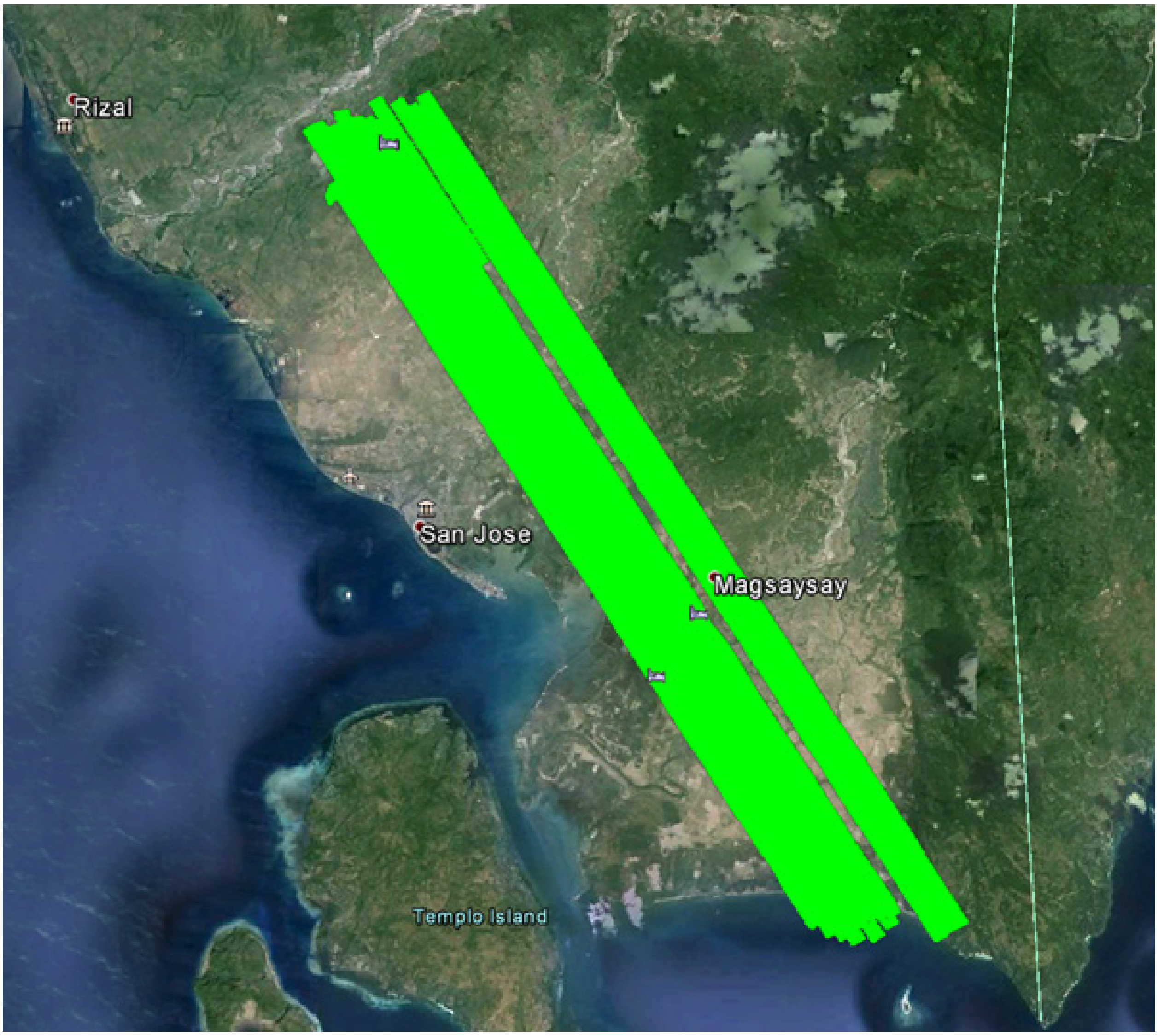


Figure A-7.10. Swath for Flight No. 1166A

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:

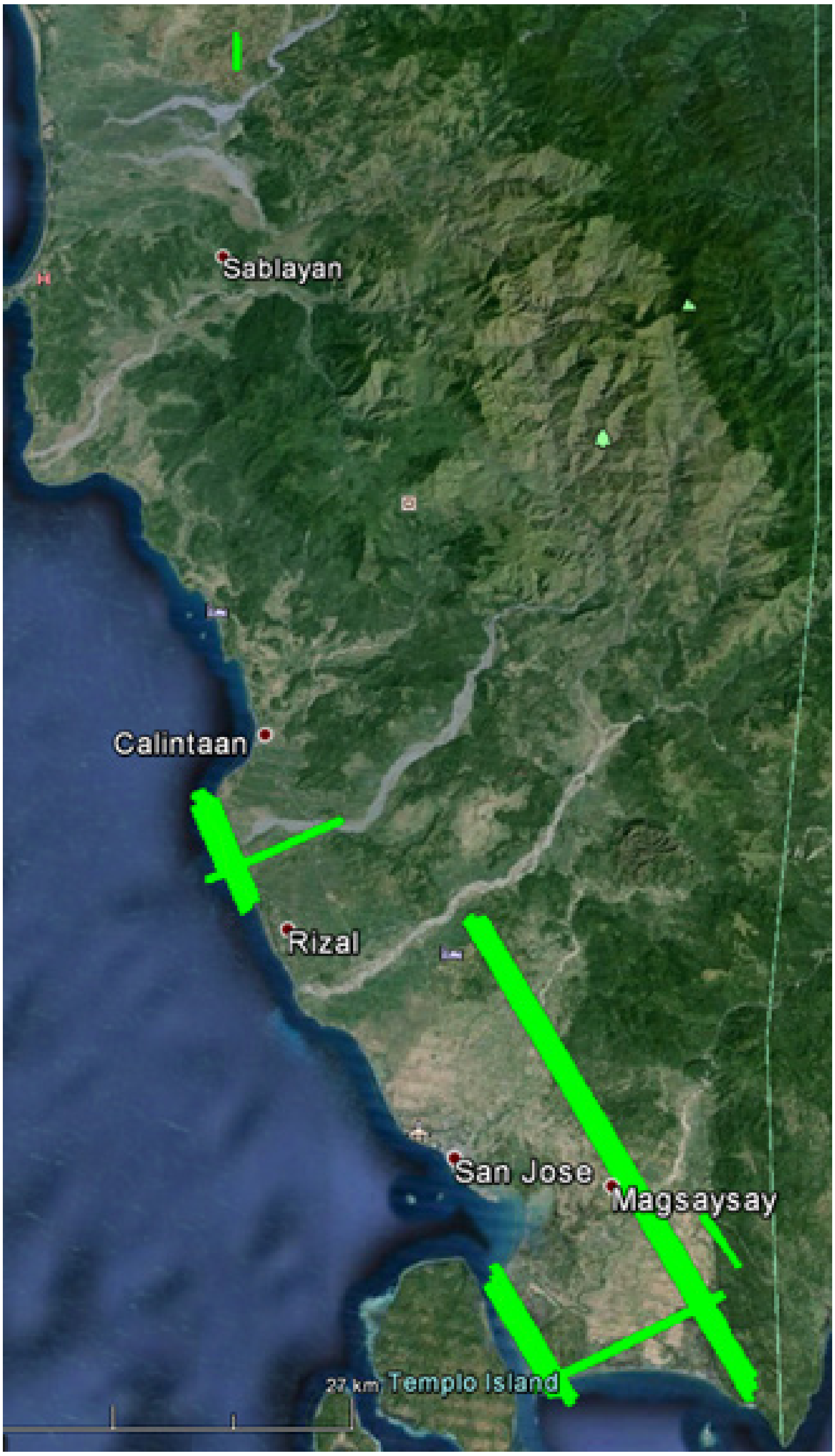


Figure A-7.11. Swath for Flight No. 1168A

Flight No.:	3074P			
Area:	BLK29K, L, M, O			
Mission Name:	1BLK29KLMO344A			
Parameters:	Altitude:	1100	Scan Frequency:	30
	Scan Angle:	50	Overlap:	30%

SWATH

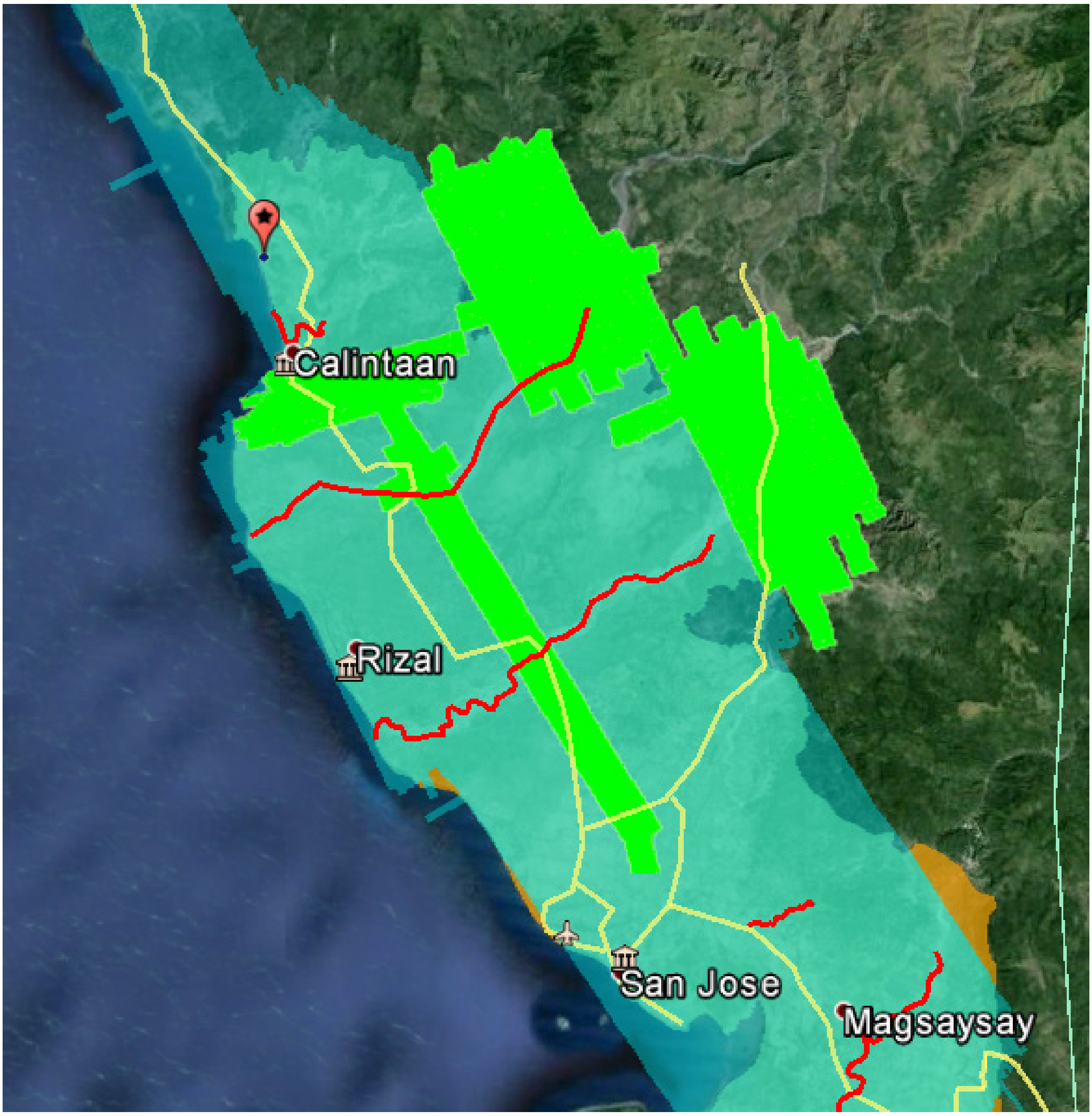


Figure A-7.12. Swath for Flight No. 3074P

Flight No.:	3076P			
Area:	BLK29P			
Mission Name:	1BLK29P344B			
Parameters:	Altitude:	1000	Scan Frequency:	32
	Scan Angle:	50	Overlap:	30%

SWATH

Figure A-7.13. Swath for Flight No. 3076P

Flight No.:	3078P			
Area:	BLK29N, Q, R, S			
Mission Name:	1BLK29NQRS345A			
Parameters:	Altitude:	850	Scan Frequency:	32
	Scan Angle:	50	Overlap:	30%

SWATH

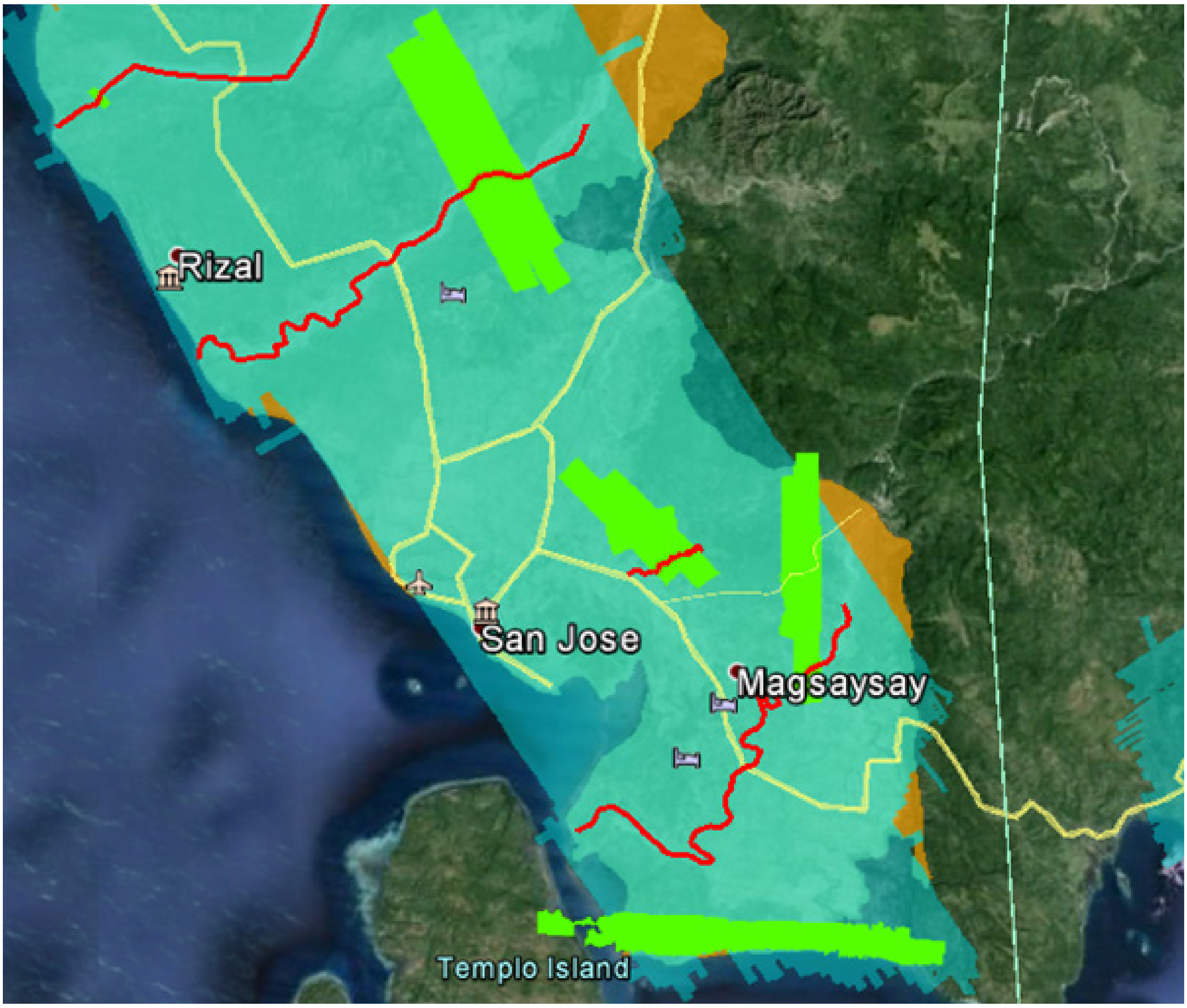


Figure A-7.14. Swath for Flight No. 3078P

ANNEX 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Mission Blk29O

Flight Area	Occidental Mindoro
Mission Name	Blk29O
Inclusive Flights	1122A, 1124A
Range data size	16.34 GB
POS	344.3 MB
Image	92.5 GB
Transfer date	03/07/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	3.2
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	68.31%
Ave point cloud density per sq.m. (>2.0)	3.68
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	140
Maximum Height	392.65 m
Minimum Height	39.47 m
Classification (# of points)	
Ground	77,532,897
Low vegetation	93,964,891
Medium vegetation	81,470,250
High vegetation	61,944,922
Building	2,711,988
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Celina Rosete, Ryan Nicholai Dizon

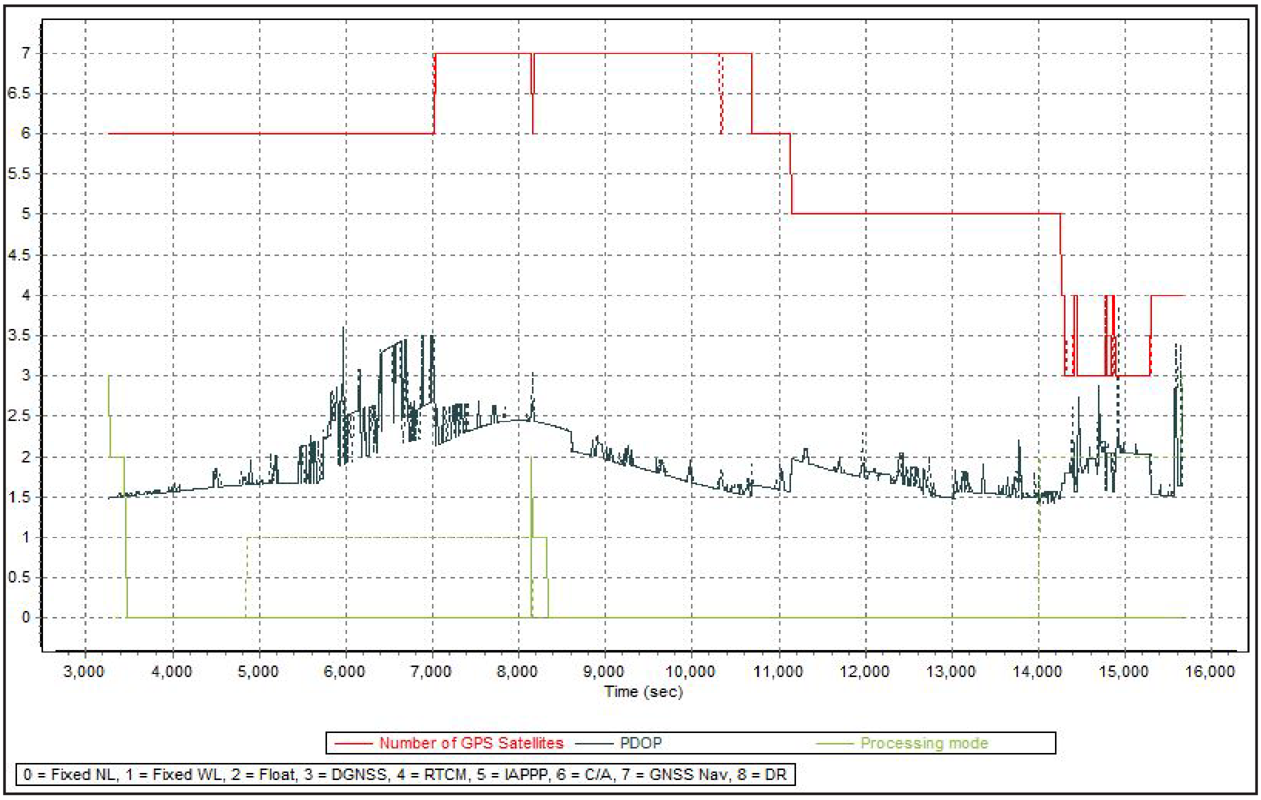


Figure A-8.1. Solution Status

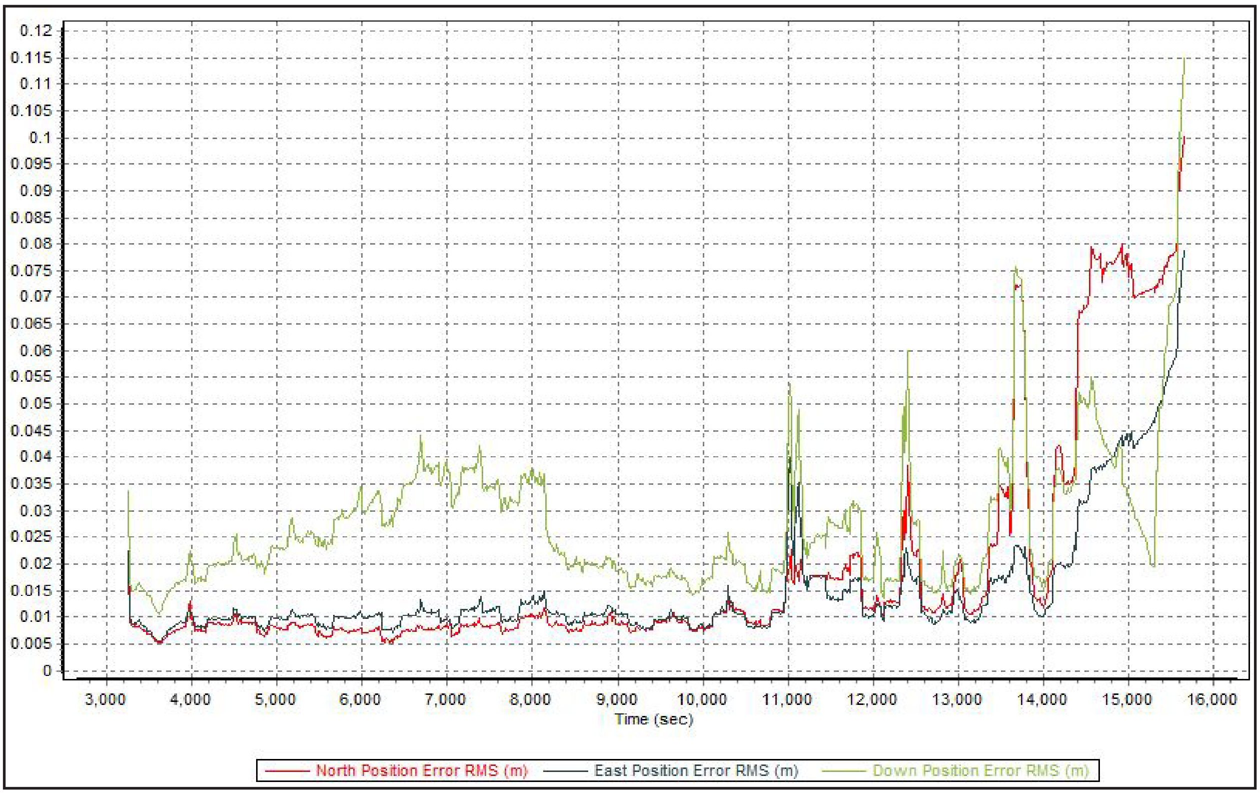


Figure A-8.2. Smoothed Performance Metrics Parameters

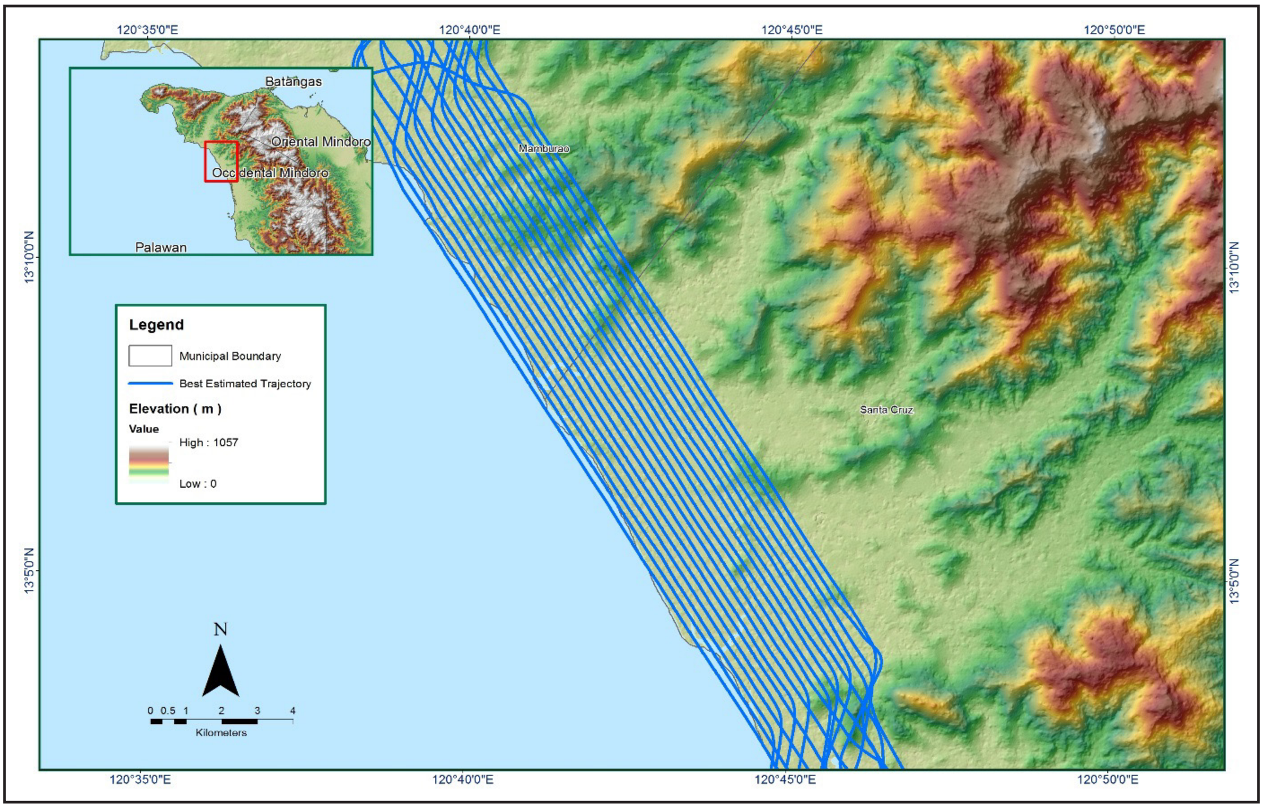


Figure A-8.3 Best Estimated Trajectory

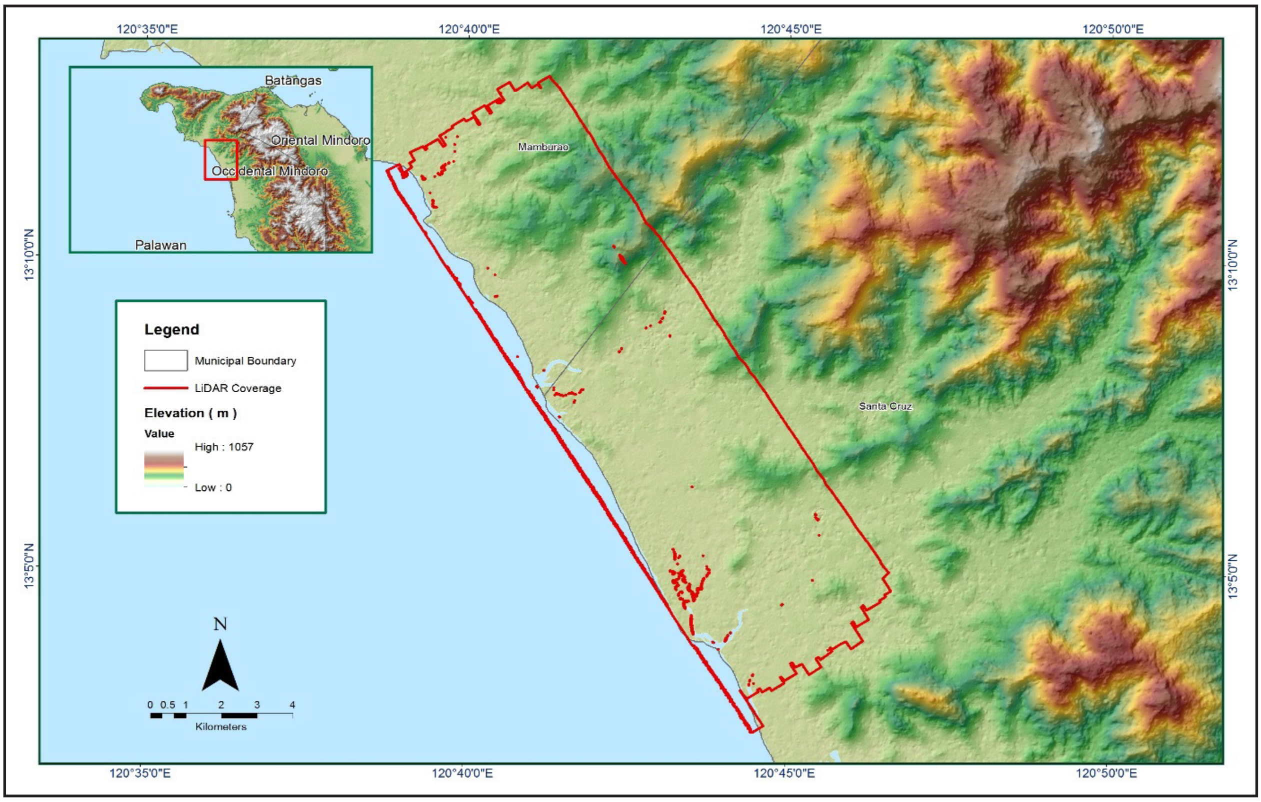


Figure A-8.4. Coverage of LiDAR data

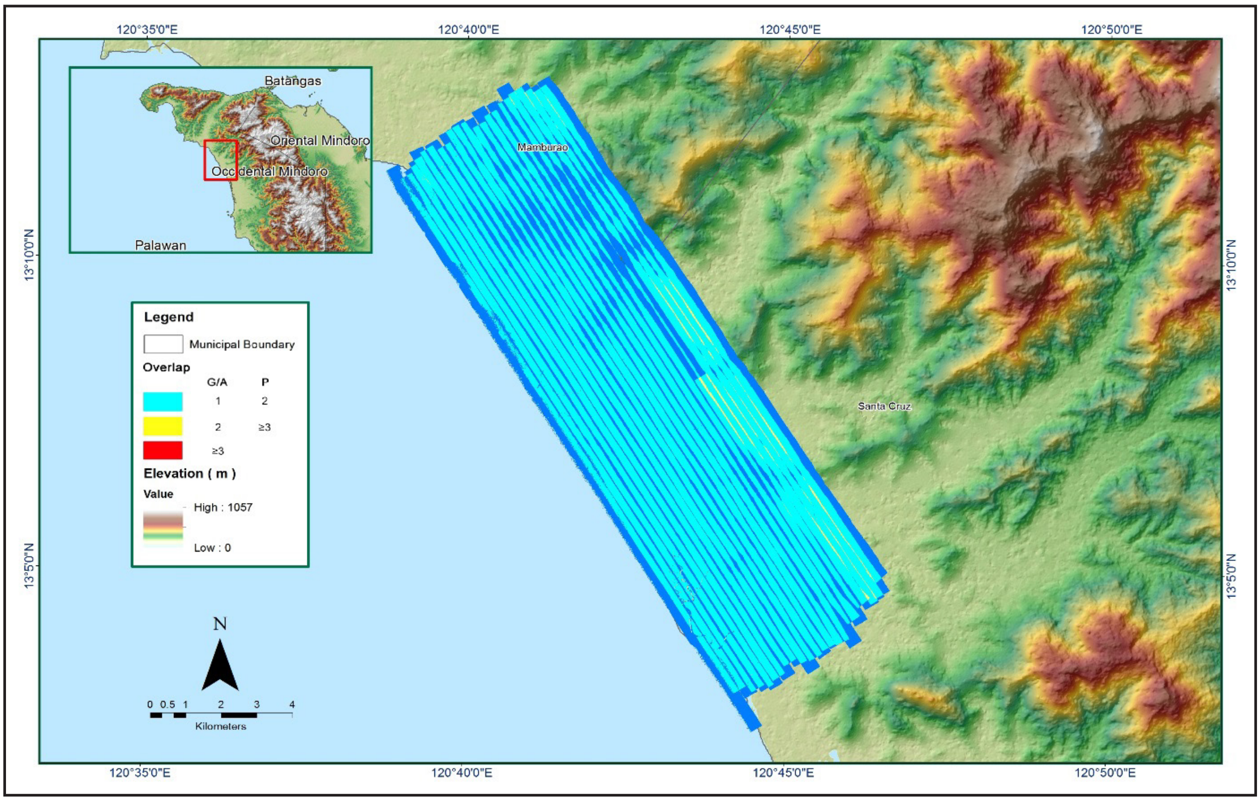


Figure A-8.5. Image of data overlap

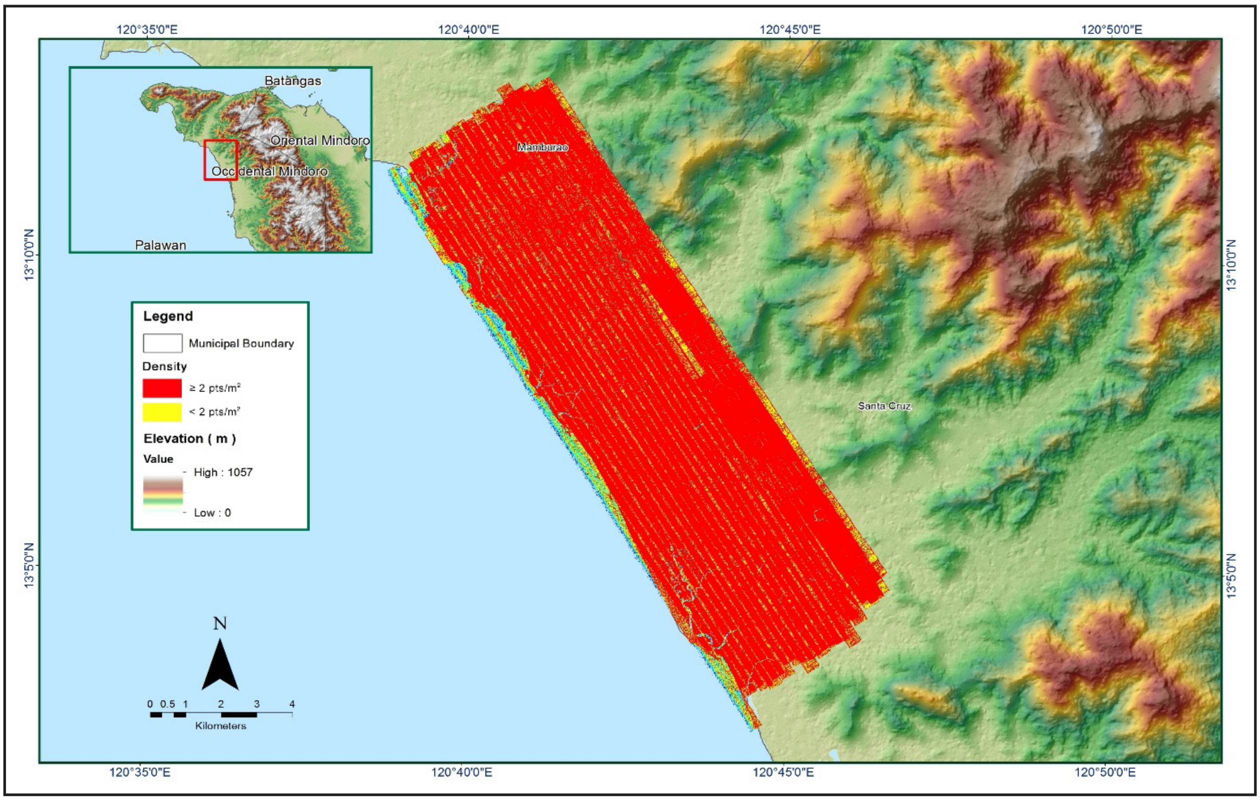


Figure A-8.6 Density of merged LiDAR data

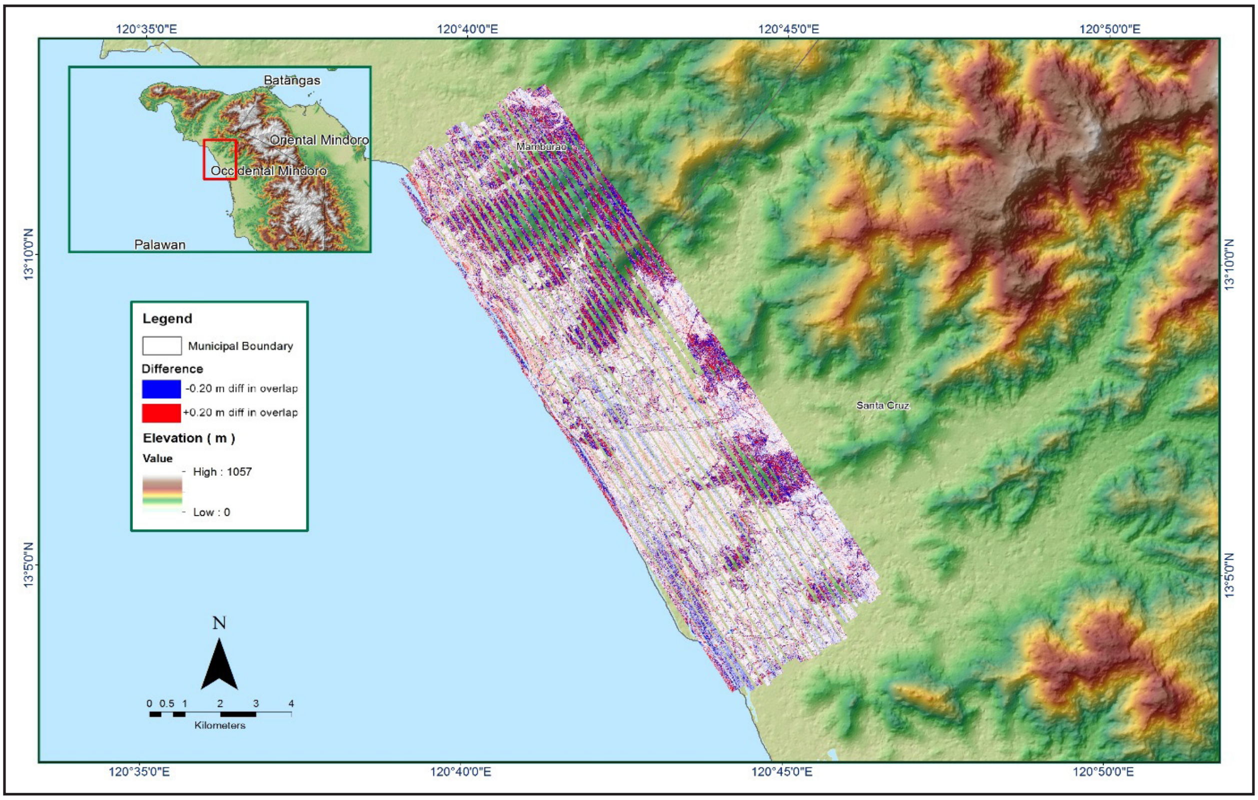


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Mission Blk29O

Flight Area	Occidental Mindoro Reflights
Mission Name	Blk29O
Inclusive Flights	3066P, 3060P, 3062P
Range data size	28.98GB
POS	498MB
Image	49.69MB
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)	1.11
RMSE for East Position (<4.0 cm)	1.13
RMSE for Down Position (<8.0 cm)	2.17
Boresight correction stdev (<0.001deg)	0.000442
IMU attitude correction stdev (<0.001deg)	0.004259
GPS position stdev (<0.01m)	0.0174
Minimum % overlap (>25)	30.09
Ave point cloud density per sq.m. (>2.0)	1.74
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	110
Maximum Height	562.67 m
Minimum Height	46.30 m
Classification (# of points)	
Ground	49,733,362
Low vegetation	34,970,589
Medium vegetation	71,641,806
High vegetation	114,102,370
Building	2,166,793
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Ma. Joanne Balaga, Marie Denise Bueno

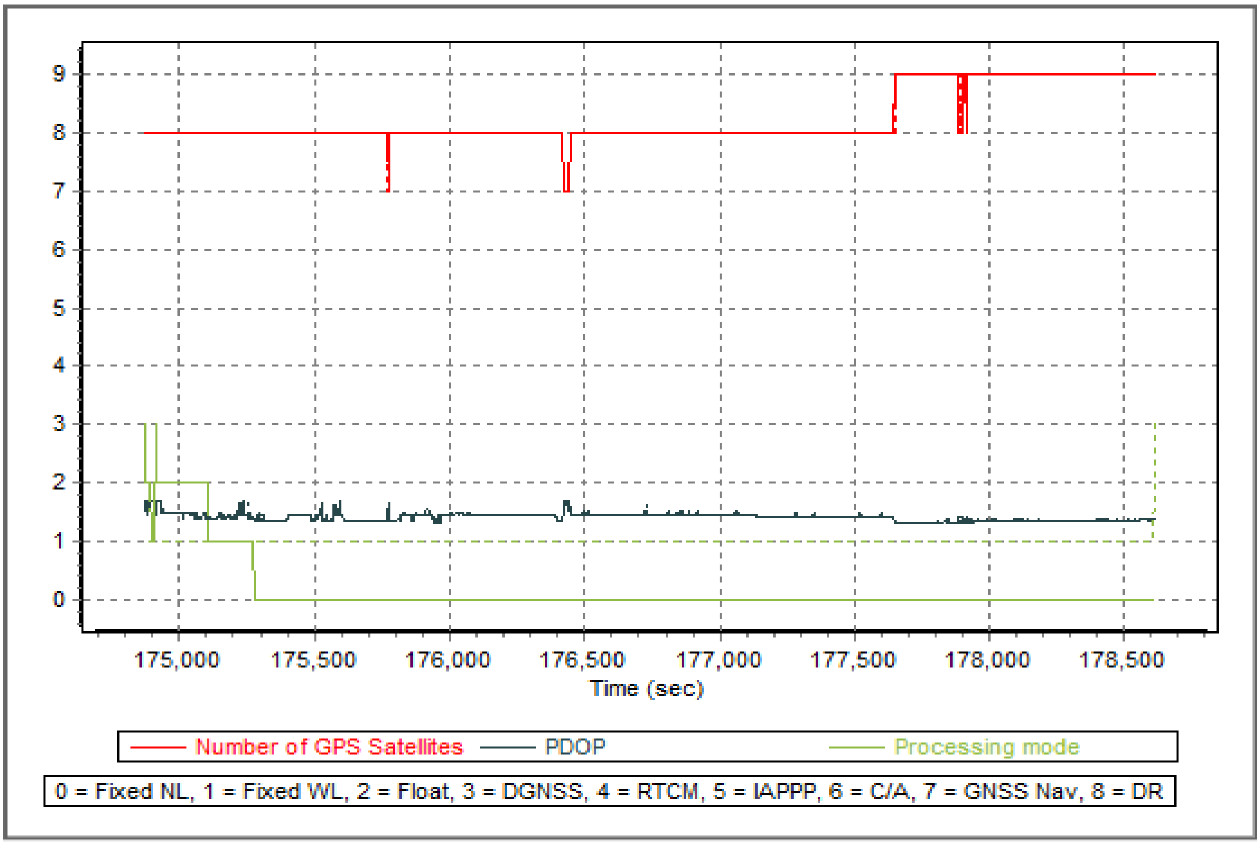


Figure A-8.8. Solution Status

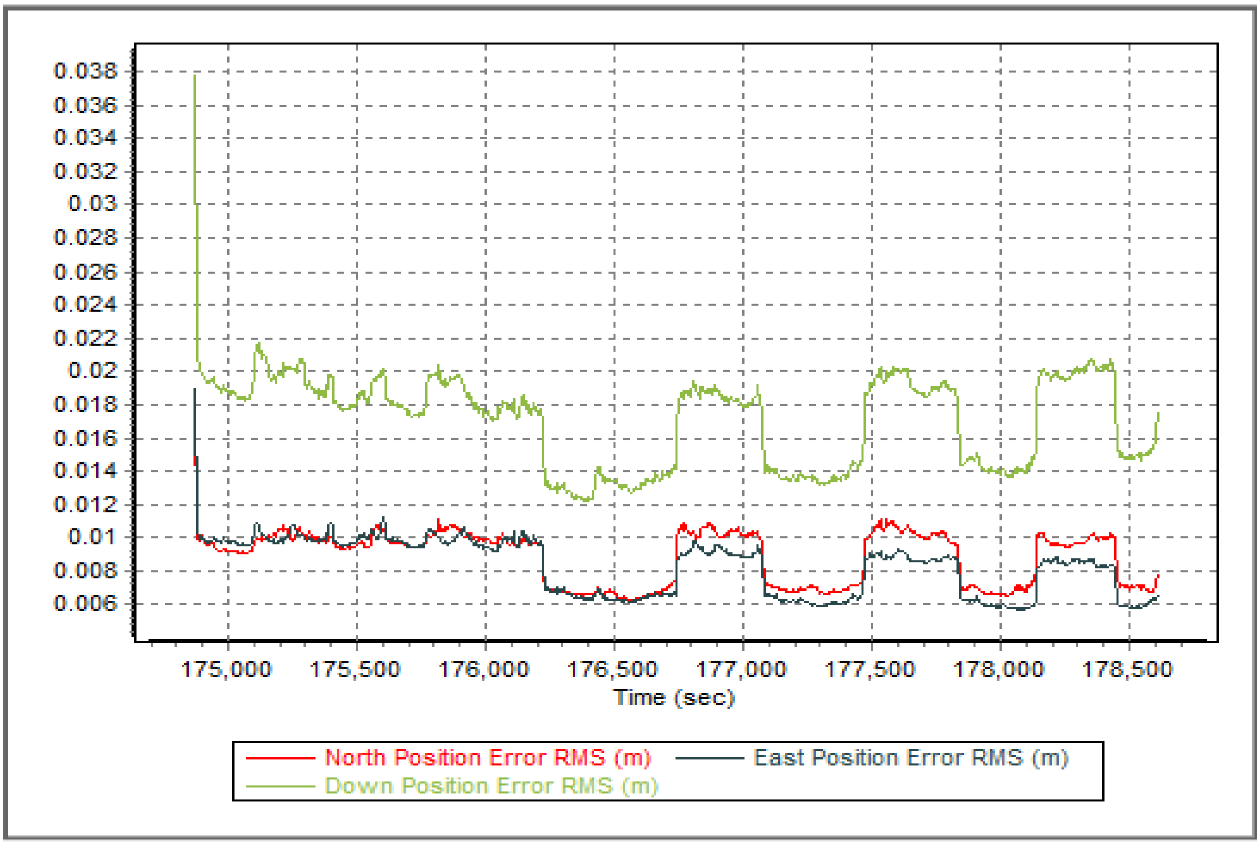


Figure A-8.9. Smoothed Performance Metrics Parameters

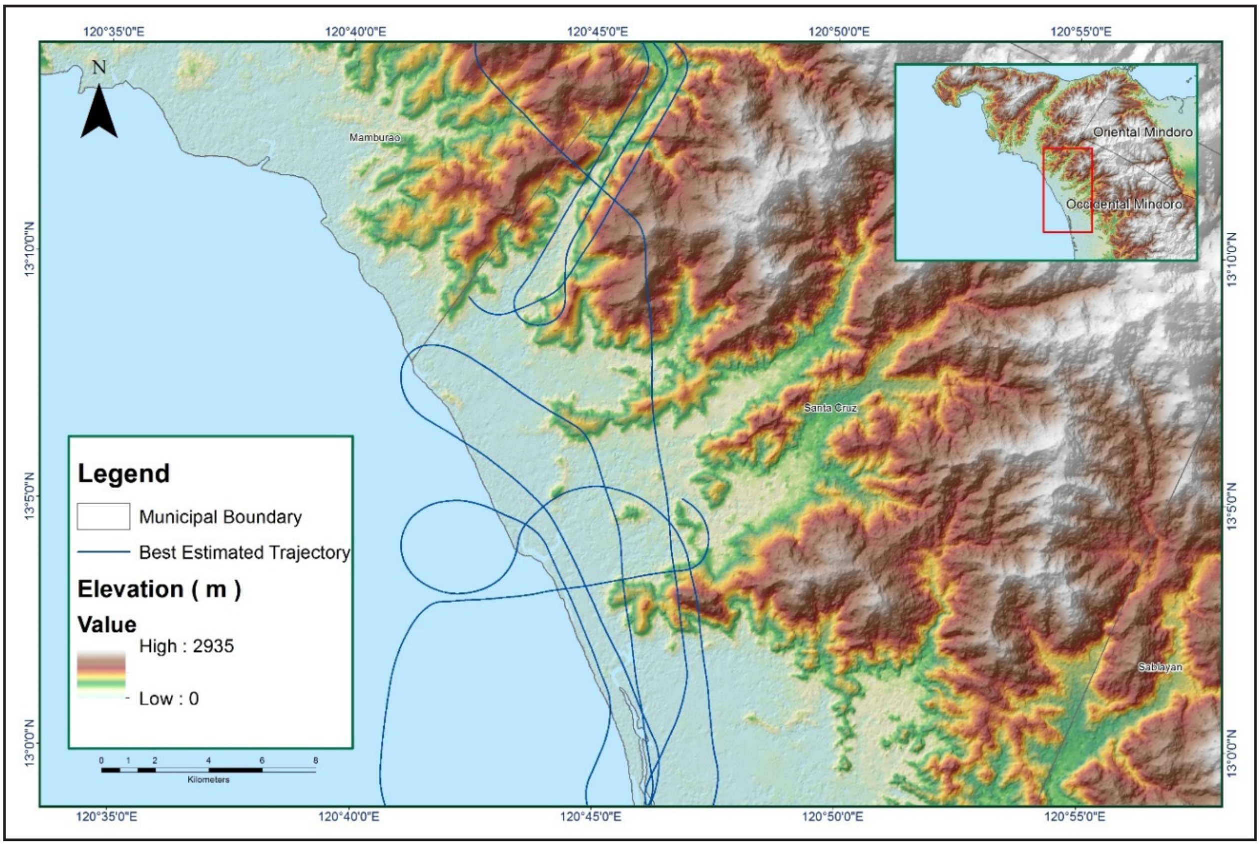


Figure A-8.10. Best Estimated Trajectory

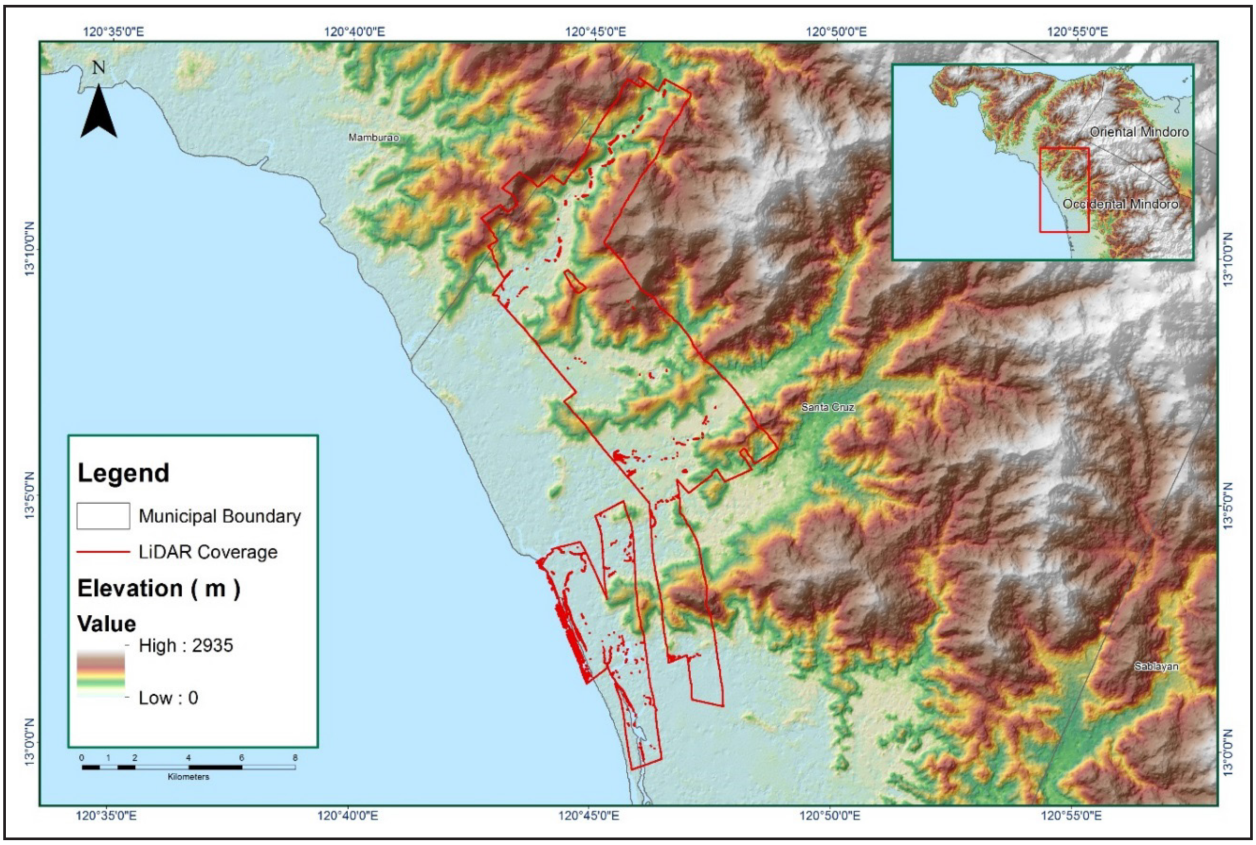


Figure A-8.11. Coverage of LiDAR data

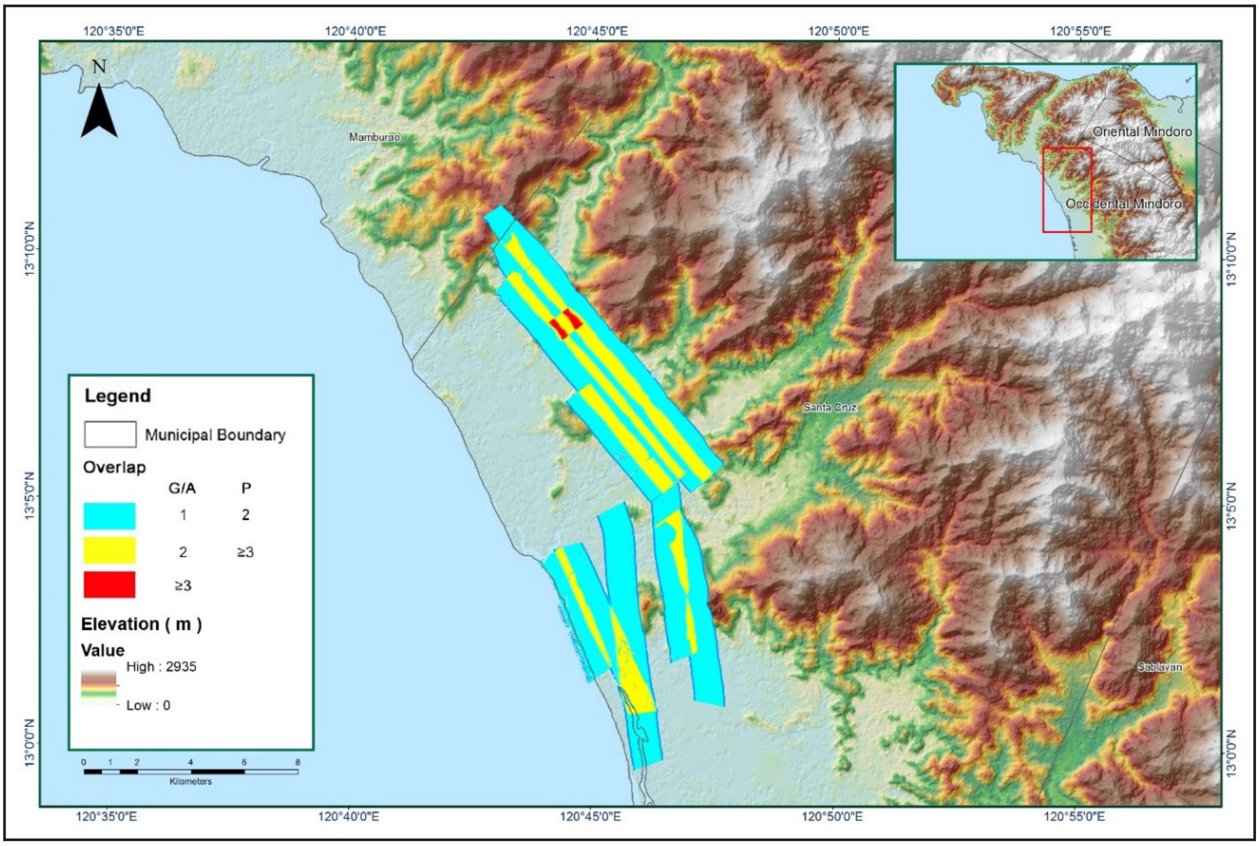


Figure A-8.12. Image of data overlap

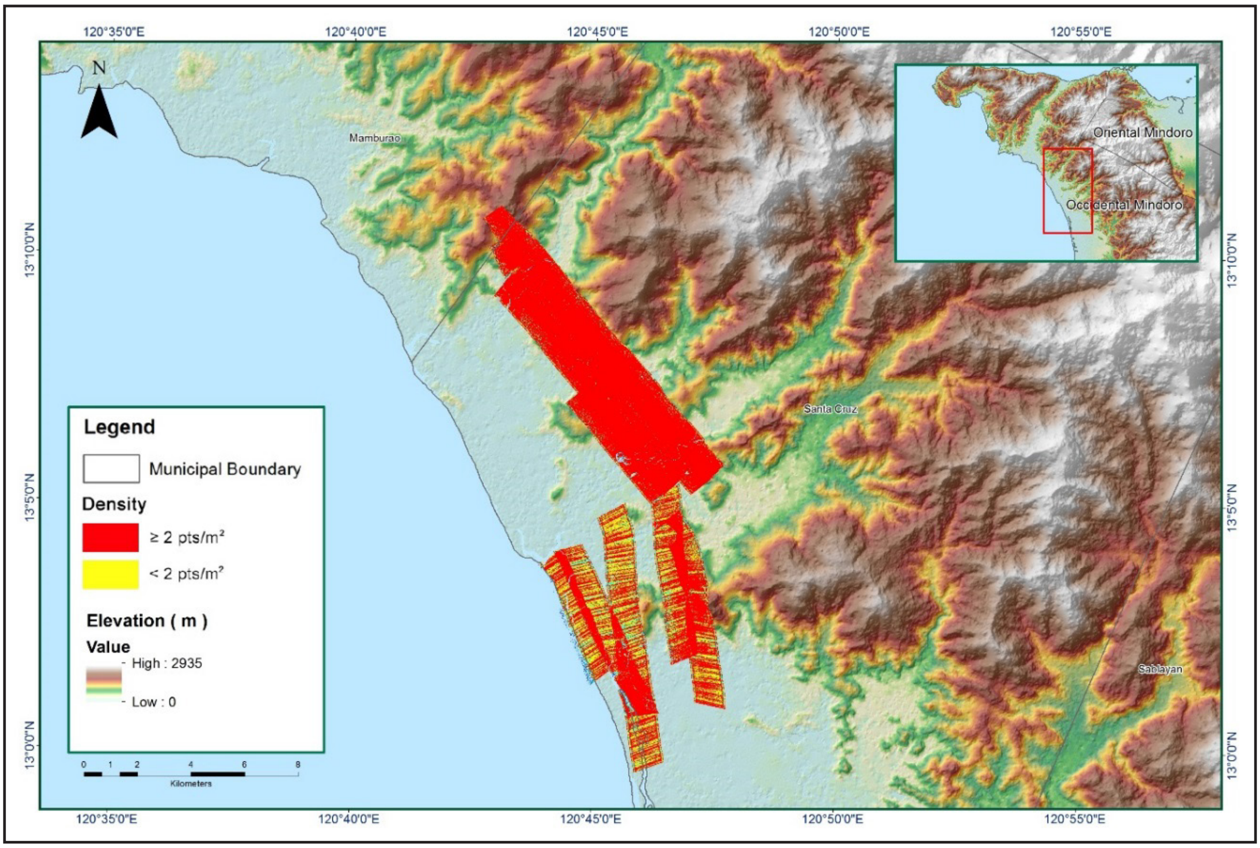


Figure A-8.9. Smoothed Performance Metrics Parameters

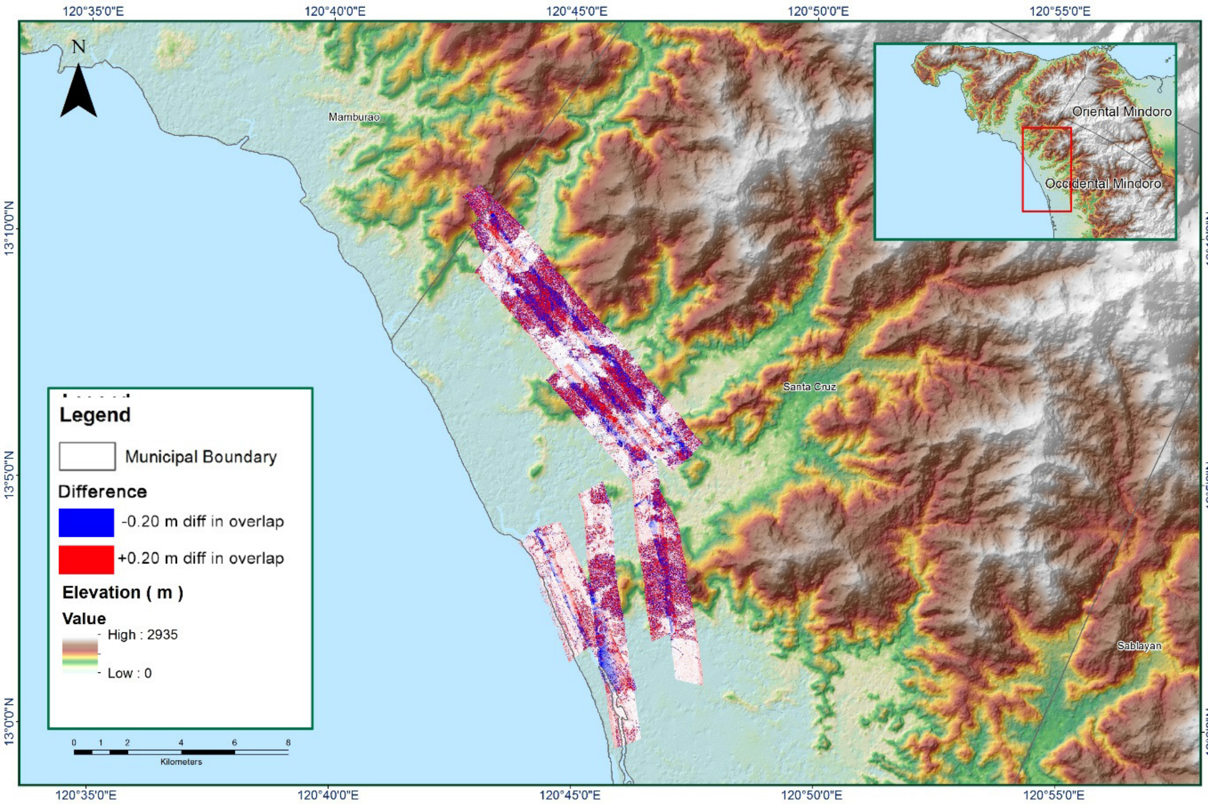


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk29O_additional

Flight Area	Occidental Mindoro Reflights
Mission Name	Blk29O_additional
Inclusive Flights	3062P, 3066P
Range data size	24.19 GB
POS	383 MB
Image	43.6 GB
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)	1.11
RMSE for East Position (<4.0 cm)	1.13
RMSE for Down Position (<8.0 cm)	2.17
Boresight correction stdev (<0.001deg)	0.000442
IMU attitude correction stdev (<0.001deg)	0.0174
GPS position stdev (<0.01m)	0.004259
Minimum % overlap (>25)	36.98%
Ave point cloud density per sq.m. (>2.0)	3.16
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	72
Maximum Height	612.98 m
Minimum Height	57.95 m
Classification (# of points)	
Ground	22,240,970
Low vegetation	11,751,518
Medium vegetation	55,505,386
High vegetation	126,638,244
Building	1,574,754
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Harmond Santos, Engr. Gladys Mae Apat

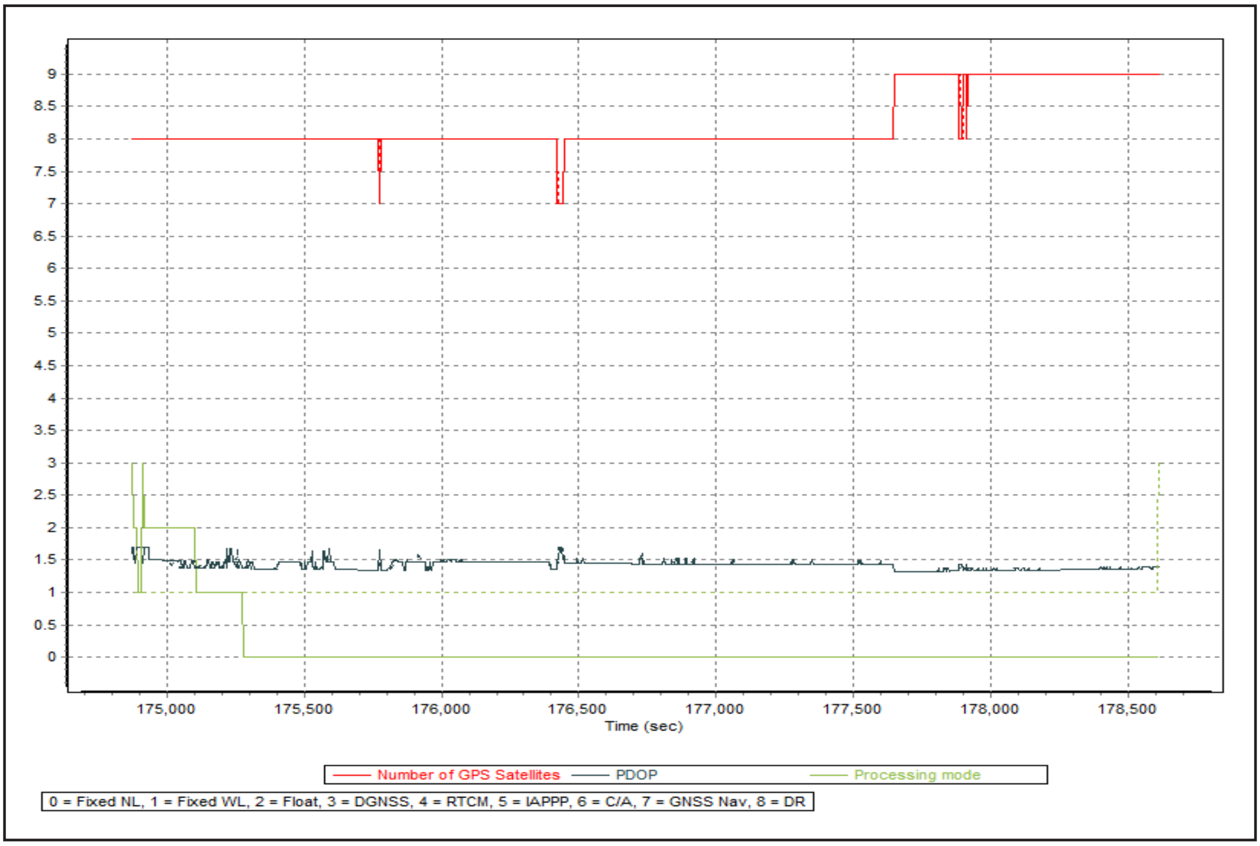


Figure A-8.15. Solution Status

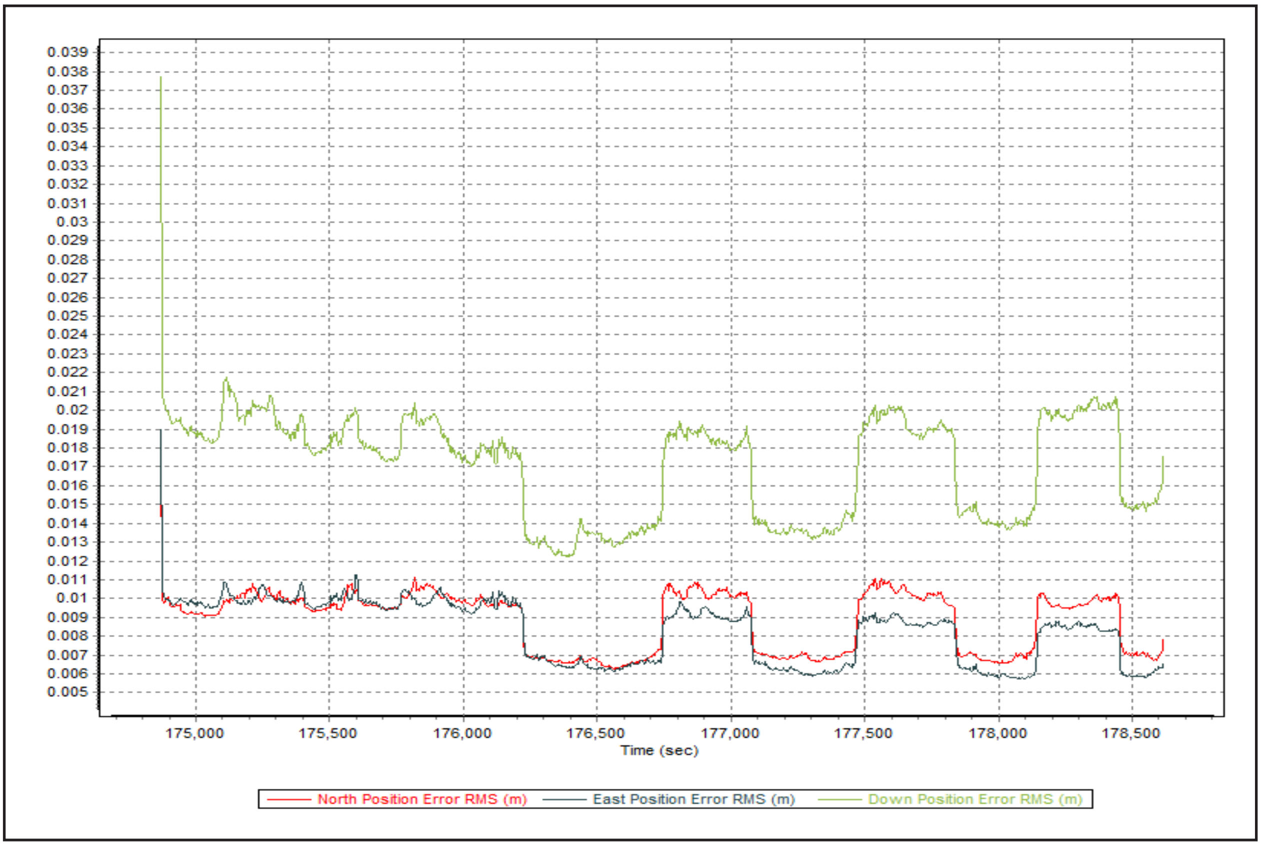


Figure A-8.16. Smoothed Performance Metrics Parameters

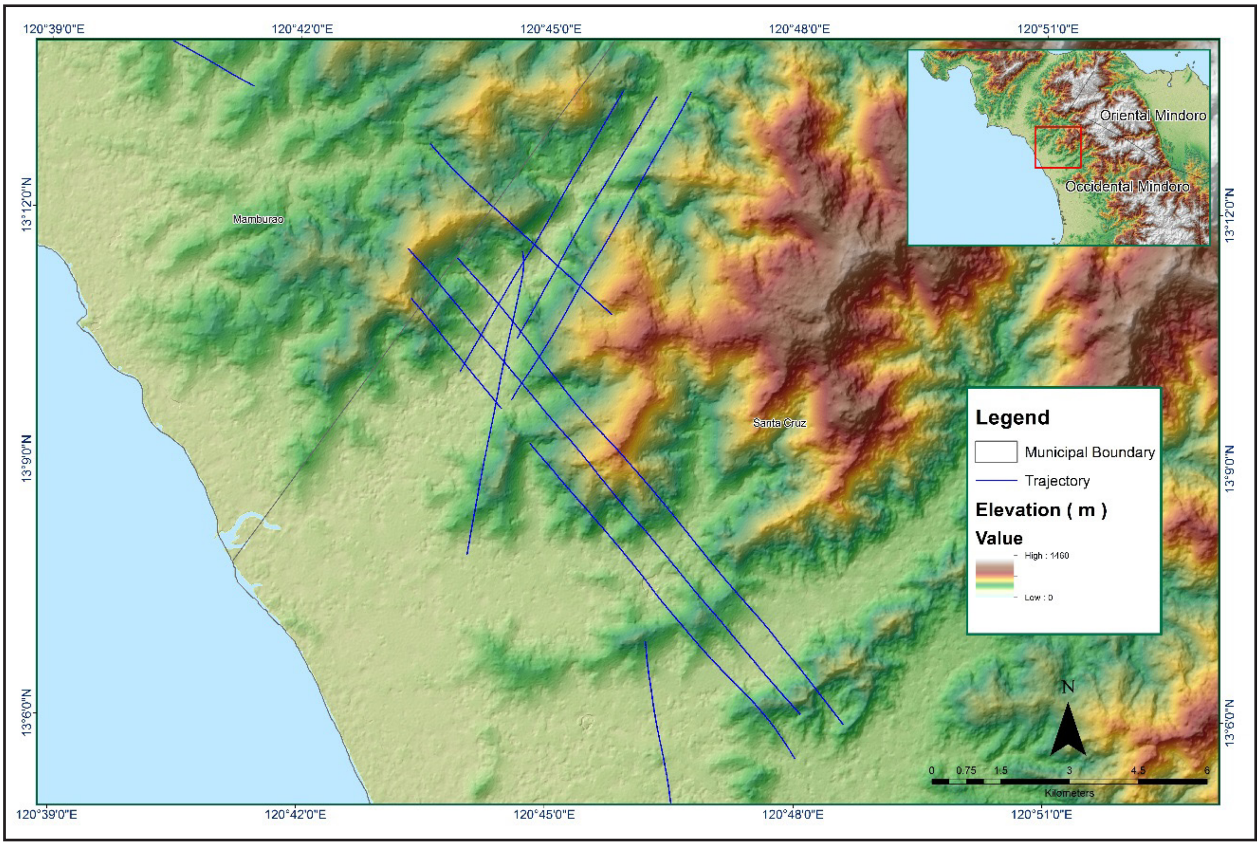


Figure A-8.17. Best Estimated Trajectory

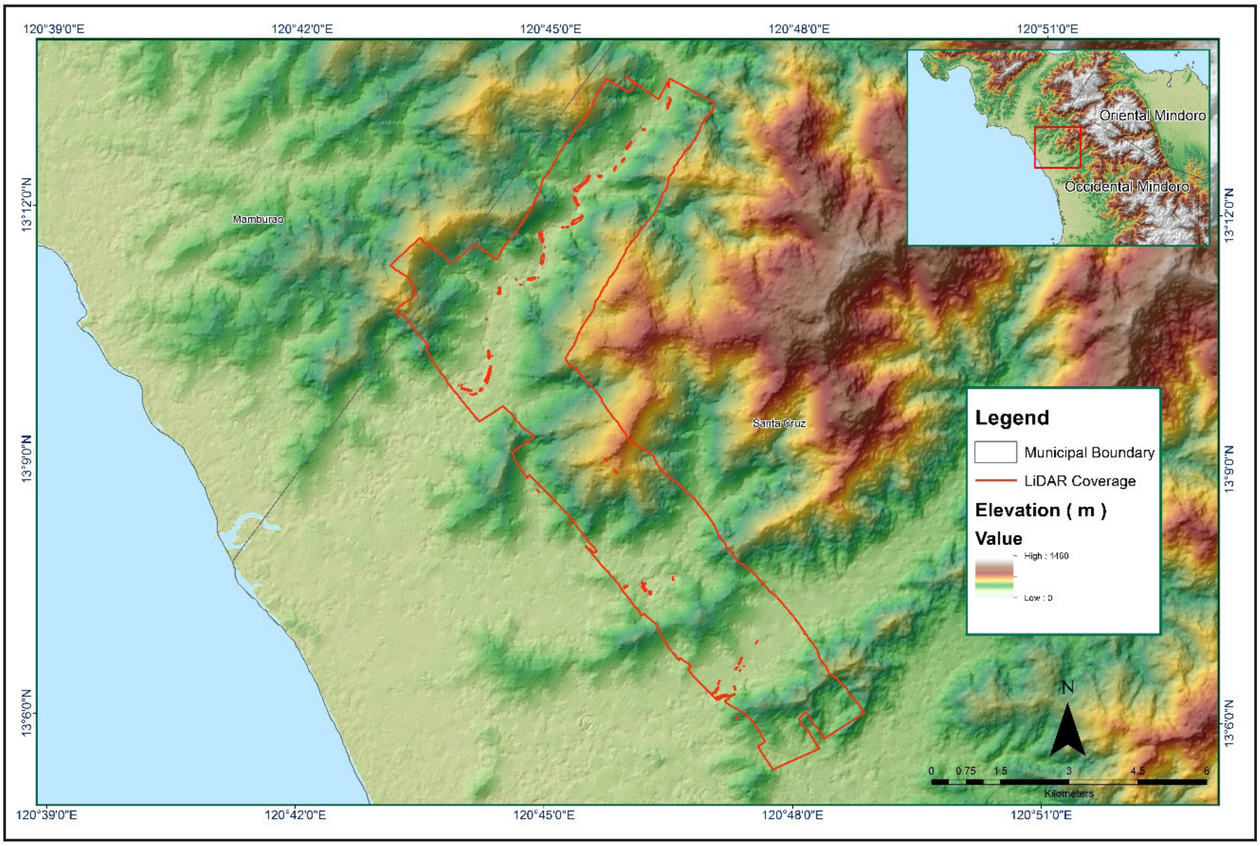


Figure A-8.18. Coverage of LiDAR data

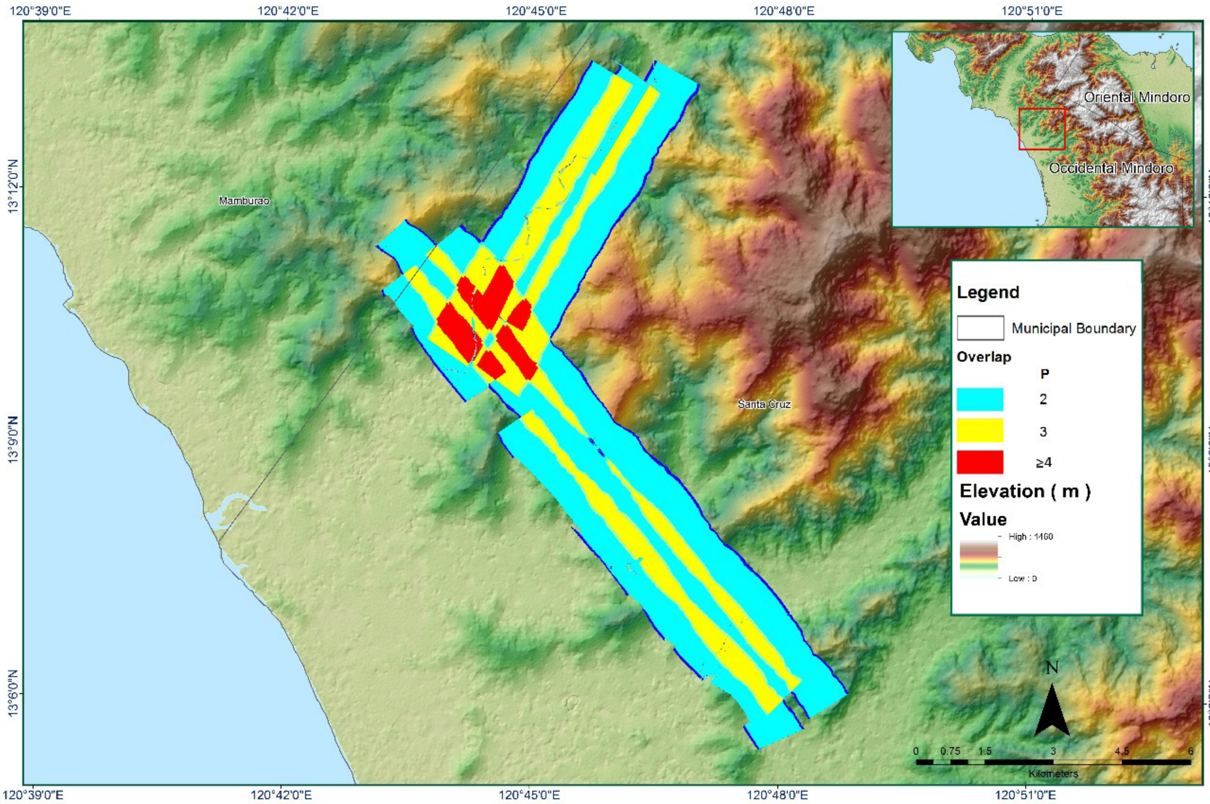


Figure A-8.19. Image of data overlap

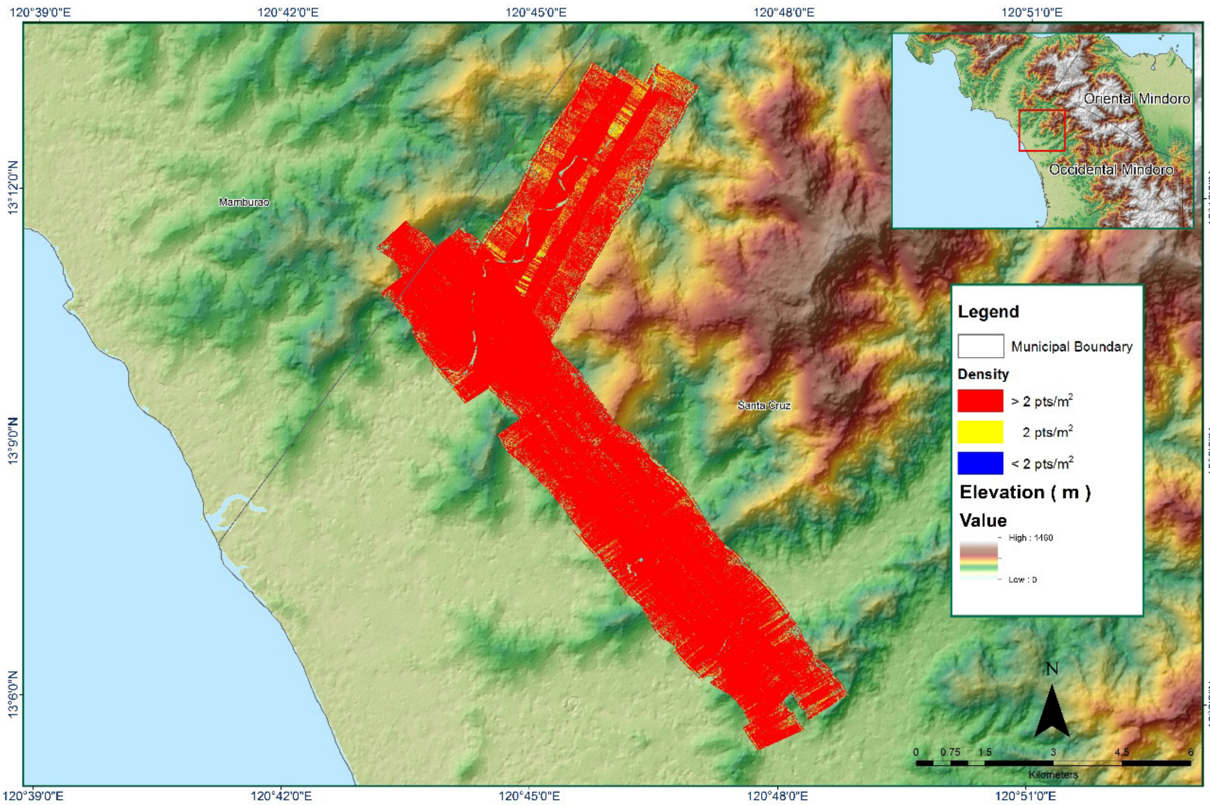


Figure A-8.20. Density of merged LiDAR data

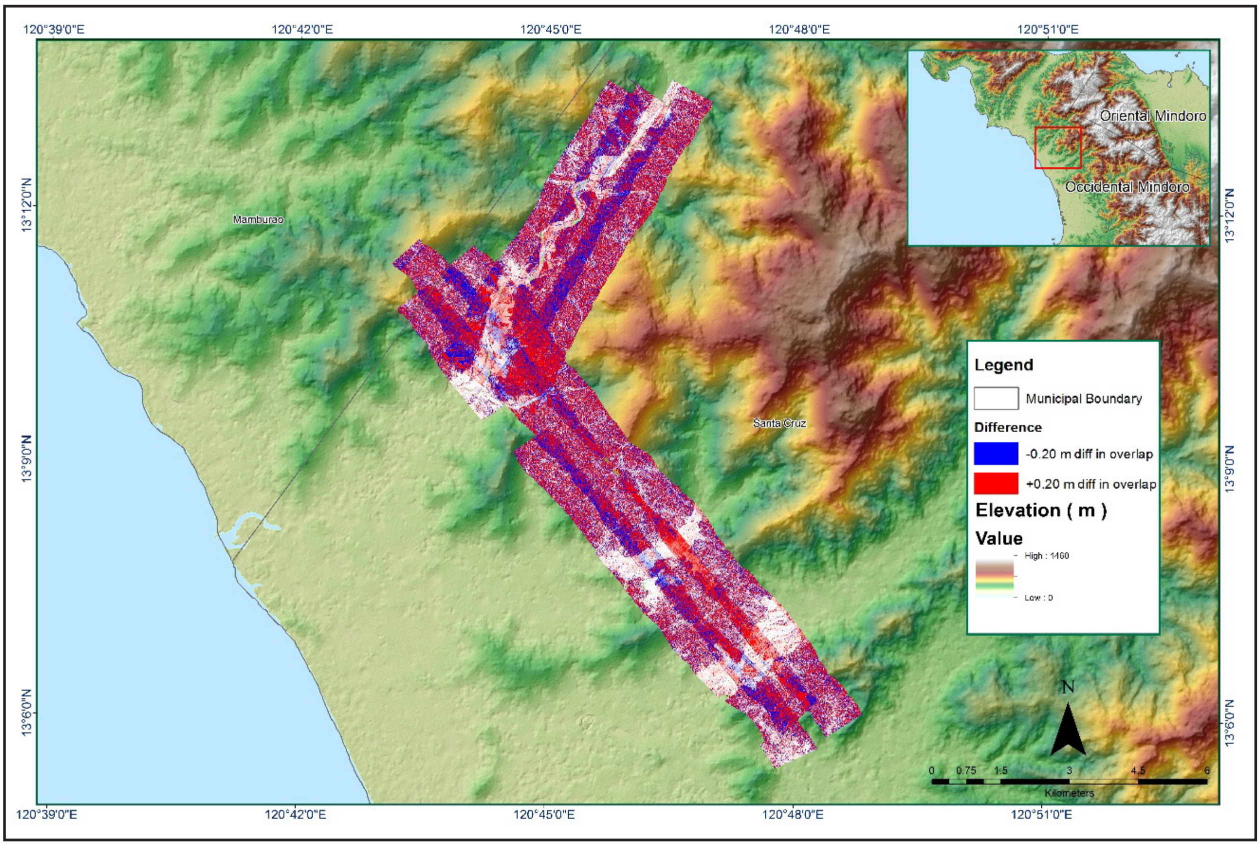


Figure A-8.19. Image of data overlap

ANNEX 9. Magbando Model Basin Parameters

Table A-9.1. Magbando Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		RECESSION BASEFLOW		
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (CU.M/S)	Recession Constant	Ratio to Peak
W470	22.228	50.251	0.0	7.6432	5.6055	33.65565	0.64027	0.69991
W480	9.4769	51.371	0.0	31.27	10.228	45.80835	1	0.5
W490	15.689	49.088	0.0	1.1411	2.4268	8.143065	1	0.44292
W500	23.323	49.176	0.0	2.4235	2.8272	10.25661	1	0.47426
W510	14.06	52.552	0.0	0.43736	18.751	5.843985	0.61779	0.54587
W520	24.305	49.287	0.0	0.46317	5.973	5.732475	0.63553	0.44292
W530	10.539	49.064	0.0	4.9295	8.3297	12.62625	0.61774	0.71187
W540	15.673	50.146	0.0	1.4469	12.882	14.2002	1	0.49217
W550	11.912	47.48	0.0	0.46922	20.633	6.9153	1	0.4826
W560	13.207	44.085	0.0	10.102	11.234	6.43146	0.42008	0.71022
W570	12.616	46.156	0.0	0.41268	3.3357	9.865695	0.98475	0.4536
W580	11.907	47.365	0.0	28.14	13.809	36.13785	0.97282	0.5
W590	17.157	47.155	0.0	29.688	6.5388	3.95997	1	0.49442
W600	14.166	39.049	0.0	12.698	9.5309	9.844905	1	0.50135
W610	47.094	39.066	0.0	2.6085	0.87025	0.852642	0.19937	0.3013
W620	11.061	48.002	0.0	26.828	13.159	15.8508	1	0.5
W630	13.48	44.702	0.0	1.9903	7.8844	12.2892	1	0.5
W640	19.617	45.294	0.0	2.0084	11.693	5.03832	0.62909	0.54391
W650	21.123	43.388	0.0	26.529	8.716	13.1985	0.2859	0.76436
W660	21.142	39.049	0.0	9.2713	15.276	12.79635	0.99219	0.5
W670	14.166	39.049	0.0	10.848	8.0223	8.35821	0.99356	0.49
W680	9.798	51.89	0.0	28.014	13.742	9.385635	1	0.5

W690	21.138	42.52	0.0	4.7623	11.828	18.43905	0.98786	0.5
W700	13.692	66.256	0.0	0.33437	4.1257	1.82679	0.64928	0.44292
W710	20.018	43.745	0.0	0.43144	28.324	7.54971	0.44041	0.47689
W720	10.862	49.516	0.0	1.1217	2.8885	5.45937	1	0.44314
W730	21.066	43.569	0.0	1.66	2.6199	3.511935	1	0.46118
W740	13.452	44.765	0.0	0.31103	4.0512	5.32014	1	0.52366
W750	15.388	51.456	0.0	0.562	3.2815	4.92513	1	0.45342
W760	10.866	48.397	0.0	1.2693	17.046	13.90935	1	0.5
W770	3.9671	70.956	0.0	1.1741	6.6155	16.296	1	0.48574
W780	19.81	43.975	0.0	5.3805	19.758	19.75365	0.98153	0.5
W790	10.43	60.116	0.0	0.49689	6.0836	9.391725	1	0.44292
W800	13.507	43.585	0.0	26.554	8.6839	27.3651	1	0.5
W810	7.4811	59.171	0.0	0.6498	5.1703	5.945625	0.88332	0.47293
W820	4.4785	99	0.0	0.26668	1.0695	1.8333	1	0.3013
W830	23.288	67.568	0.0	4.1331	2.0762	2.22348	1	0.44292
W840	4.9156	65.514	0.0	0.80169	22.687	34.314	0.98988	0.5
W850	24.191	42.52	0.0	0.44165	5.546	4.26342	1	0.56878
W860	7.959	55.079	0.0	0.55561	24.063	22.60545	1	0.5
W870	31.516	66.847	0.0	0.65769	28.925	2.98116	1	0.49232
W880	6.3328	75.339	0.0	0.26528	5.0436	10.59345	0.68239	0.44292
W890	3.659	71.015	0.0	0.53458	4.5085	13.22055	1	0.4535
W910	7.6822	62.309	0.0	14.178	0.55438	0.0231409	1	0.5
W920	5.6863	69.073	0.0	4.6362	23.139	14.822	1	0.5
W940	7.6544	62.394	0.0	0.3397	7.5662	9.6550	1	0.5
W950	14.713	99	0.0	0.91772	11.721	7.67046	1	0.575

ANNEX 10. Magbando Model Reach Parameters

Table A-10.1. Magbando Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (M)	Slope(M/M)	Manning's n	Shape	Width (M)	Side Slope (xH:1V)
R100	Automatic Fixed Interval	928.11	0.0388603	0.04	Trapezoid	369	1
R120	Automatic Fixed Interval	15323	0.0258930	0.04	Trapezoid	369	1
R140	Automatic Fixed Interval	3143.9	0.0206951	0.04	Trapezoid	369	1
R160	Automatic Fixed Interval	4405.7	0.0217125	0.04	Trapezoid	369	1
R190	Automatic Fixed Interval	11262	0.0225407	0.04	Trapezoid	369	1
R210	Automatic Fixed Interval	9031.2	0.0082446	0.04	Trapezoid	369	1
R250	Automatic Fixed Interval	2004.1	0.0140363	0.04	Trapezoid	369	1
R260	Automatic Fixed Interval	7282.4	0.0163284	0.04	Trapezoid	369	1
R270	Automatic Fixed Interval	3093.1	0.0060354	0.04	Trapezoid	369	1
R280	Automatic Fixed Interval	2871.2	0.0242662	0.04	Trapezoid	369	1
R290	Automatic Fixed Interval	4499.9	0.0069013	0.04	Trapezoid	369	1
R300	Automatic Fixed Interval	5900.1	0.0092513	0.04	Trapezoid	369	1
R330	Automatic Fixed Interval	6979.8	0.0228750	0.04	Trapezoid	369	1
R340	Automatic Fixed Interval	1856.8	0.0034543	0.04	Trapezoid	369	1
R350	Automatic Fixed Interval	3415.5	0.0029418	0.04	Trapezoid	369	1
R380	Automatic Fixed Interval	1442.3	0.0036484	0.04	Trapezoid	369	1
R400	Automatic Fixed Interval	2959.8	0.0025764	0.04	Trapezoid	369	1
R430	Automatic Fixed Interval	5936.7	0.0038813	0.04	Trapezoid	369	1
R440	Automatic Fixed Interval	148.99	0.0246198	0.04	Trapezoid	369	1
R460	Automatic Fixed Interval	10287	0.0015450	0.04	Trapezoid	369	1
R50	Automatic Fixed Interval	2942.1	0.0371152	0.04	Trapezoid	369	1
R70	Automatic Fixed Interval	3740.9	0.0220578	0.04	Trapezoid	369	1
R970	Automatic Fixed Interval	4385.0	0.0017364	0.04	Trapezoid	369	1

ANNEX 11. Magabando Field Validation Points

Table A-11.1. Magbando Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation points (m)	Error (m)	Event	Date	Rain Return/ Scenario
	Lat	Long						
1	12.44166	120.9832	0.03	0.25	0.22	Ondoy	Sept. 2009	25-Year
2	12.44177	120.9835	0.03	0	-0.03	Ondoy	Sept. 2009	25-Year
3	12.44184	120.9821	0.03	0.15	0.12	Glenda	July 2014	25-Year
4	12.44264	120.982	2.15	0.5	-1.65	Glenda	July 2014	25-Year
5	12.44286	120.9818	2.34	0.4	-1.94	Glenda	July 2014	25-Year
6	12.44362	120.9814	2.22	0.35	-1.87	Glenda	July 2014	25-Year
7	12.44344	120.9809	0.03	0.6	0.57	Yolanda	Nov. 2013	25-Year
8	12.4432	120.9813	0.09	0.5	0.41	Ondoy	Sept. 2009	25-Year
9	12.44343	120.9812	1.98	0.6	-1.38	Yolanda	Nov. 2013	25-Year
10	12.44383	120.9814	0.03	0.45	0.42	Habagat	2013	25-Year
11	12.44413	120.9823	2.28	0.7	-1.58	Yolanda	Nov. 2013	25-Year
12	12.44452	120.9828	0.04	0.4	0.36	Yolanda	Sept. 2009	25-Year
13	12.44467	120.9832	0.03	0.68	0.65	Yolanda	Nov. 2013	25-Year
14	12.44494	120.9837	0.11	0.45	0.34	Glenda	July 2014	25-Year
15	12.44549	120.9847	2.46	0.3	-2.16	Glenda	July 2014	25-Year
16	12.44573	120.9852	0.16	0.44	0.28	Yolanda	Nov. 2013	25-Year
17	12.45915	121.0216	0.03	0.8	0.77	Glenda	July 2014	25-Year
18	12.45935	121.0226	1.99	0.71	-1.28	Glenda	July 2014	25-Year
19	12.45974	121.0233	0.03	0.78	0.75	Glenda	July 2014	25-Year
20	12.45994	121.0244	0.77	0.85	0.08	Glenda	July 2014	25-Year
21	12.46022	121.0246	0.03	0.85	0.82	Glenda	July 2014	25-Year
22	12.46047	121.0239	1.85	0.7	-1.15	Glenda	July 2014	25-Year
23	12.4866	121.0719	0.03	0	-0.03	Yolanda	Nov. 2013	25-Year
24	12.48546	121.072	2.09	0	-2.09	Yolanda	Nov. 2013	25-Year
25	12.48552	121.0701	0.47	0	-0.47	Yolanda	Nov. 2013	25-Year
26	12.48354	121.0704	0.03	0.55	0.52	Ondoy	Sept. 2009	25-Year
27	12.48207	121.0685	1.92	0	-1.92	Ondoy	Sept. 2009	25-Year
28	12.4805	121.0636	0.03	0.2	0.17	Yolanda	Nov. 2013	25-Year
29	12.48139	121.0644	0.03	0.4	0.37	Yolanda	Nov. 2013	25-Year
30	12.45907	121.045	0.34	0	-0.34	Yolanda	Nov. 2013	25-Year
31	12.46255	121.0414	0.03	0.65	0.62	Yolanda	Nov. 2013	25-Year
32	12.46325	121.0413	0.03	0.65	0.62	Yolanda	Nov. 2013	25-Year
33	12.46427	121.0404	0.03	0.6	0.57		2013	25-Year
34	12.44637	121.0262	0.03	0.62	0.59	Yolanda	Nov. 2013	25-Year
35	12.44661	121.0267	0.03	0.34	0.31	Glenda	July 2014	25-Year
36	12.44718	121.028	0.04	0.1	0.06	Yolanda	Nov. 2013	25-Year
37	12.44627	121.0258	0.24	0.75	0.51	Yolanda	Nov. 2013	25-Year
38	12.44583	121.025	0.3	1	0.7	Yolanda	Nov. 2013	25-Year
39	12.44583	121.025	0.03	0.3	0.27	Yolanda	Nov. 2013	25-Year
40	12.42788	120.9921	0.03	0.3	0.27	Yolanda	Nov. 2013	25-Year

41	12.43819	121.016	0.03	0.13	0.1	Ondoy	Sept. 2009	25-Year
42	12.5078	121.0618	0.03	0.43	0.4	Yolanda	Nov. 2013	25-Year
43	12.50764	121.062	0.03	0.82	0.79	Yolanda	Nov. 2013	25-Year
44	12.49463	121.068	0.5	1.42	0.92	Yolanda	Nov. 2013	25-Year
45	12.4949	121.067	0.03	0.62	0.59	Yolanda	Nov. 2013	25-Year
46	12.4949	121.067	2.4	0.33	-2.07	Ondoy	Sept. 2009	25-Year
47	12.49471	121.0661	0.03	0.47	0.44	Glenda	July 2014	25-Year
48	12.49518	121.0655	1.49	0.32	-1.17	Yolanda	Nov. 2013	25-Year
49	12.49518	121.0655	0.03	0.82	0.79	Ondoy	Sept. 2009	25-Year
50	12.4966	121.0649	2.34	1.22	-1.12	Ondoy	Sept. 2009	25-Year
51	12.48829	121.0553	0.03	0.78	0.75	Yolanda	Nov. 2013	25-Year
52	12.48634	121.0532	2.32	1.04	-1.28	Ondoy	Sept. 2009	25-Year
53	12.47995	121.0335	0.03	0.44	0.41	Yolanda	Nov. 2013	25-Year
54	12.47848	121.0295	0.03	0.42	0.39	Yolanda	Nov. 2013	25-Year
55	12.44543	120.9896	0.03	0.6	0.57	Glenda	July 2014	25-Year
56	12.44557	120.9898	2	0.44	-1.56	Glenda	July 2014	25-Year
57	12.44579	120.9901	0.03	0.7	0.67	Glenda	July 2014	25-Year
58	12.44611	120.9902	0.34	0.65	0.31	Glenda	July 2014	25-Year
59	12.445	120.9895	0.03	0.89	0.86	Glenda	July 2014	25-Year
60	12.44588	120.989	0.61	1.3	0.69	Glenda	July 2014	25-Year
61	12.44717	120.9892	0.03	0.62	0.59	Glenda	July 2014	25-Year
62	12.44814	120.9896	1.02	0.56	-0.46	Glenda	July 2014	25-Year
63	12.44764	120.9889	0.03	0.08	0.05	Glenda	July 2014	25-Year
64	12.44484	120.9868	0.03	0.58	0.55	Glenda	July 2014	25-Year
65	12.44404	120.9867	0.03	0.3	0.27	Glenda	July 2014	25-Year
66	12.45942	121.0217	1.83	1.05	-0.78	Glenda	July 2014	25-Year
67	12.45981	121.0226	1.2	0.38	-0.82	Glenda	July 2014	25-Year
68	12.45993	121.023	2.06	0.77	-1.29	Glenda	July 2014	25-Year
69	12.46011	121.0229	0.03	0.91	0.88	Yolanda	Nov. 2013	25-Year
70	12.46022	121.0231	0.04	0.8	0.76	Glenda	July 2014	25-Year
71	12.4602	121.0235	0.03	0.82	0.79	Glenda	July 2014	25-Year
72	12.4945	121.0673	0.03	0.4	0.37	Ondoy	2009	25-Year
73	12.4944	121.0668	0.03	0.94	0.91			25-Year
74	12.4947	121.0668	1.07	0.65	-0.42			25-Year
75	12.495	121.0664	3.88	0.82	-3.06	Yolanda	Nov. 2013	25-Year
76	12.4956	121.0663	3.52	0.26	-3.26	Yolanda	Nov. 2013	25-Year
77	12.4959	121.0663	3.84	0.68	-3.16	Glenda	July 2014	25-Year
78	12.4963	121.0668	3.63	0.63	-3	Ondoy	Sept. 2009	25-Year
79	12.488	121.0555	3.91	0	-3.91			25-Year
80	12.486	121.0513	0.1	0.6	0.5	Habagat	2016	25-Year
81	12.4778	121.0296	0.34	0	-0.34			25-Year
82	12.4746	121.0237	0.07	0.36	0.29	Ondoy	Sept. 2009	25-Year
83	12.4401	120.9741	0.03	0.63	0.6	Habagat	2016	25-Year
84	12.4404	120.9738	1.54	0.44	-1.1	Yolanda	Nov. 2013	25-Year
85	12.4409	120.9737	1.08	0.57	-0.51	Yolanda	Nov. 2013	25-Year

86	12.4418	120.9734	1.65	0.32	-1.33	Yolanda	Nov. 2013	25-Year
87	12.4417	120.9727	1.33	0.4	-0.93	Yolanda	Nov. 2013	25-Year
88	12.4432	120.9725	1.04	0.3	-0.74	Yolanda	Nov. 2013	25-Year
89	12.4435	120.9721	1.07	0.2	-0.87	Yolanda	Nov. 2013	25-Year
90	12.444	120.9717	0.96	0.7	-0.26	Yolanda	Nov. 2013	25-Year
91	12.4444	120.9718	1.02	0.42	-0.6	Yolanda	Nov. 2013	25-Year
92	12.4447	120.9714	0.97	0.2	-0.77	Yolanda	Nov. 2013	25-Year
93	12.4459	120.9709	1.05	0.56	-0.49	Yolanda	Nov. 2013	25-Year
94	12.4463	120.9704	1.03	0.14	-0.89	Habagat	2016	25-Year
95	12.447	120.97	1.04	0.6	-0.44	Habagat	2016	25-Year
96	12.4598	121.0212	0.23	0.3	0.07	Glenda	July 2014	25-Year
97	12.4599	121.0214	1.02	0	-1.02	Ondoy	Sept. 2009	25-Year
98	12.4602	121.0222	3.43	0.32	-3.11	Glenda	July 2014	25-Year
99	12.4604	121.0231	3.56	0.46	-3.1	Glenda	July 2014	25-Year
100	12.4608	121.0237	0.65	0.55	-0.1	Yolanda	Nov. 2013	25-Year
101	12.5077	121.0619	2.86	0.1	-2.76	Habagat	2016	25-Year
102	12.48525	121.071	3.04	0	-3.04	Yolanda	Nov. 2013	25-Year
103	12.4849	121.071	1.68	0	-1.68	Yolanda	Nov. 2013	25-Year
104	12.48466	121.0699	1.87	0.4	-1.47	Yolanda	Nov. 2013	25-Year
105	12.48466	121.0694	1.84	0	-1.84	Yolanda	Nov. 2013	25-Year
106	12.48386	121.0696	1.84	0	-1.84	Yolanda	Nov. 2013	25-Year
107	12.48241	121.0688	1.51	0	-1.51	Yolanda	Nov. 2013	25-Year
108	12.48115	121.0666	1.97	0	-1.97	Yolanda	Nov. 2013	25-Year
109	12.48127	121.0663	1.97	0	-1.97	Yolanda	Nov. 2013	25-Year
110	12.46016	121.0448	1.8	0.54	-1.26	Yolanda	Nov. 2013	25-Year
111	12.46335	121.0417	1.54	1.01	-0.53	Glenda	July 2014	25-Year
112	12.464	121.0416	1.54	0.9	-0.64	Glenda	July 2014	25-Year
113	12.44603	121.0254	2.08	0.62	-1.46	Glenda	July 2014	25-Year
114	12.44568	121.0249	2.14	0.91	-1.23	Glenda	July 2014	25-Year
115	12.44539	121.0243	1.61	0.45	-1.16	Yolanda	Nov. 2013	25-Year
116	12.44557	121.024	0.94	0.5	-0.44	Glenda	July 2014	25-Year
117	12.44522	121.0236	0.03	0.31	0.28	Glenda	July 2014	25-Year
118	12.44542	121.0231	0.03	0.64	0.61	Glenda	July 2014	25-Year
119	12.42778	120.992	0.03	0.3	0.27	Glenda	July 2014	25-Year

Annex 12. Phil-LiDAR 1 UPLB Team Composition

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