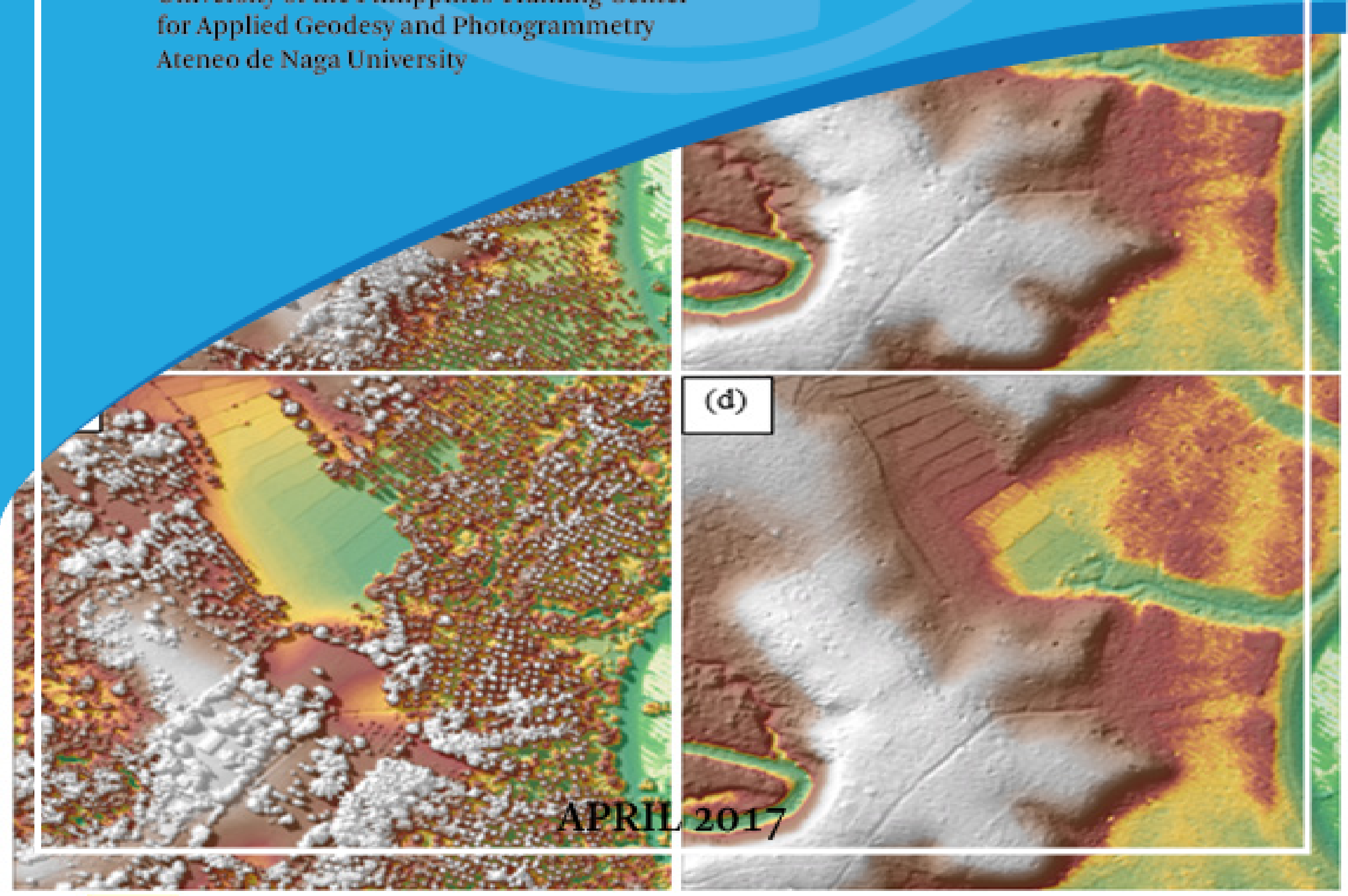
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Mandaon River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Ateneo de Naga University



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LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ADNU	Ateneo de Naga University
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
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
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND MANDAON RIVER

Enrico C. Paringit, Dr. Eng., Dr. George Puno, and Eric Bruno

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 in 2014 entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grant-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Phiippines Cebu (UPC). UPC is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 22 river basins in the Bicol Region . The university is located in Naga City in the province of Camarines Sur.

2.2 Overview of Mandaon River Basin

Mandaon river basin is under two (2) municipalities: Milagros a first class town and Mandaon, a third class municipality (both located in the province of Masbate). Mandaon is populated with 41,262 residents in its 26 barangays, and Milagros has 57,473 in its 27 barangays according to the 2015 census.

Mandaon River is the major stream that drains the Mandaon River Basin. It is about 67 km long and empties out to Nin Bay and eventually out to the Sibuyan Sea west of the Island of Masbate. Low hills bound the basin to the north and to the east. There is also a low mountain to the southwest that is not more than 400 mASL. The areas upstream show poor vegetation cover and thus may produce sedimentation. The areas around the outlet of the basin are mostly dedicated to agriculture. And the areas immediately near the estuarine are dedicated to fisheries with extensive fishponds.

The climate type that governs the area is Type III. It is relatively dry during November to April and wet but not pronounced rain period the rest of the year. In the whole Region V, Masbate has the lowest average rainfall.

Products are minerals from Milagros, particularly manganese which is being exported to Japan. Gold, copper and silver along with white clay are also found in the area. Fisheries is another economic source particularly in Mandaon. Agricultural output in the area is dominated by rice production.

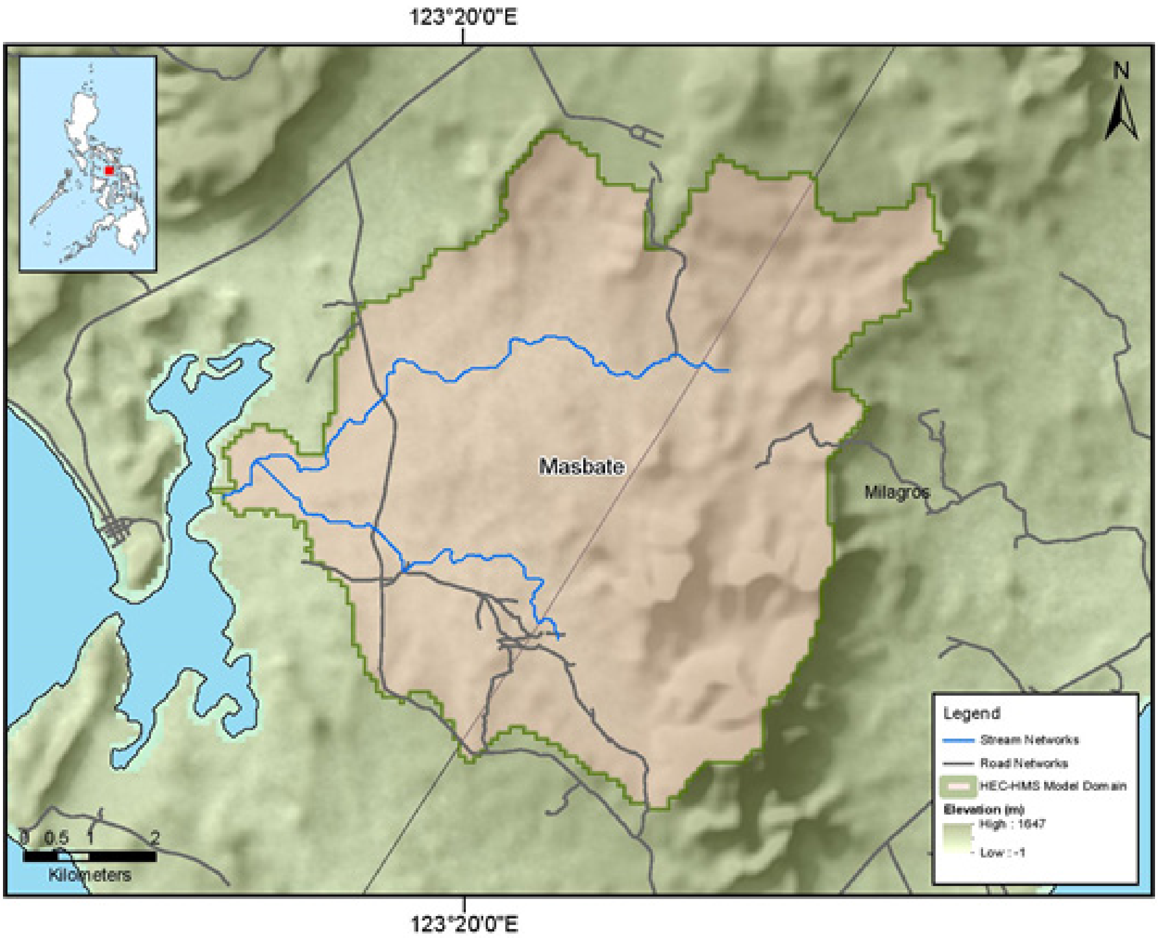

Figure 1. Map of Mandaon River

CHAPTER 2: LIDAR DATA ACQUISITION OF THE MANDAON 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 Mandaon Floodplain in Masbate. These missions were planned for 12 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 shows the flight plan for Mandaon Floodplain.

Table 1. Flight planning parameters for the Aquarius LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK32A	1000,1200	25, 30	50	200	30	130	5
BLK32B	800, 900,						
1000, 1200	30, 35	50	200	30	130	5	
BLK32F	800, 1200	25, 30	50	200	30	130	5
BLK32G	1200	25, 30	50	200	30	130	5

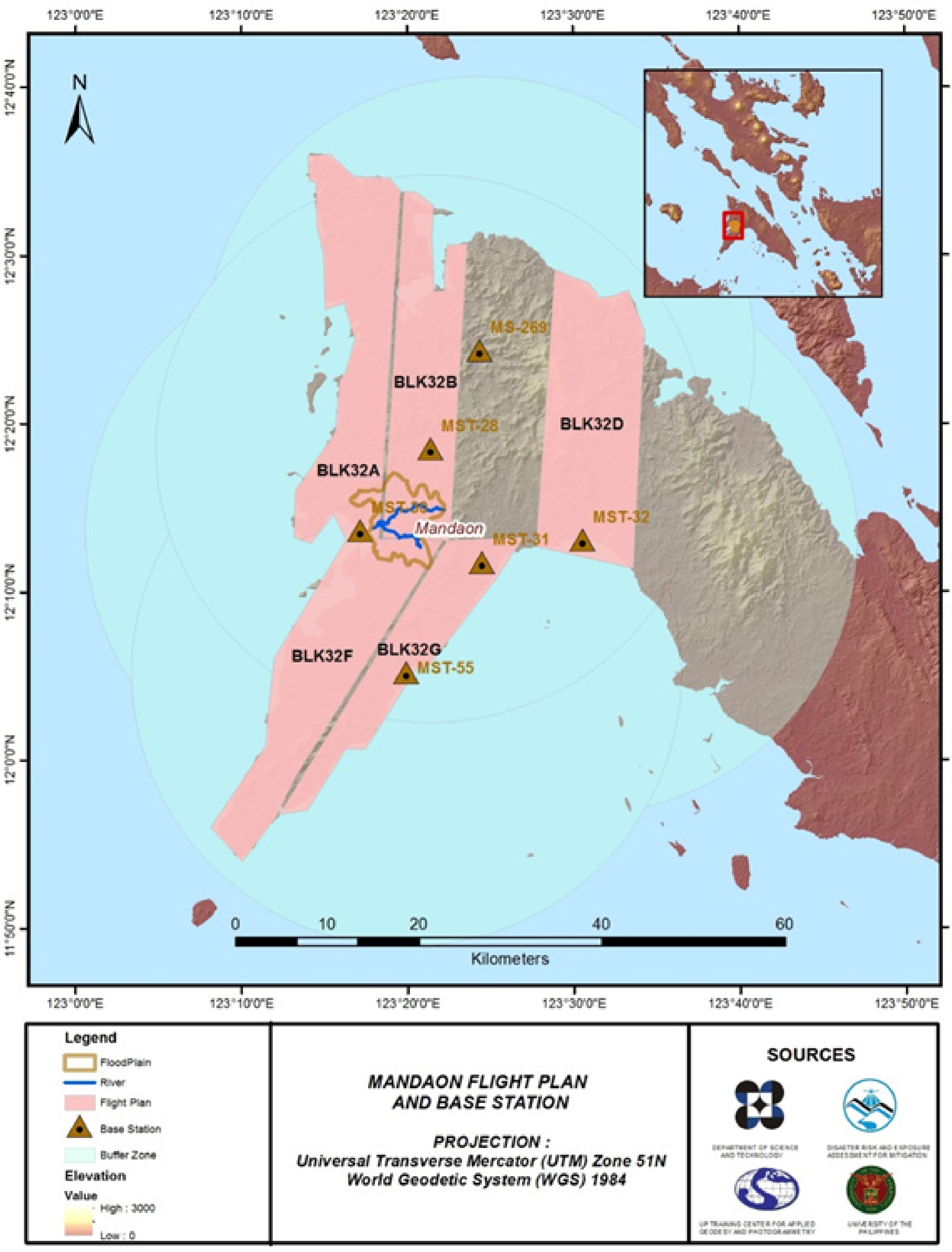

Figure 2 Flight plans and base stations for Mandaon floodplain

2.2 Ground Base Stations

The project team recovered five (5) NAMRIA ground control points: MST-28, MST-30, MST-31, MST-32 and MST-55 which are of second (2nd) order accuracy and one (1) NAMRIA benchmark: MS-269 which is of first (1st) order accuracy. The benchmark was used as vertical reference point and was established as ground control point. The certifications for the NAMRIA reference points and benchmark are found in Annex 2. These were used as base stations during flight operations for the entire duration of the survey (April 3 - 11, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Mandaon Floodplain are shown in Figure 2.

Figure 3 to Figure 8 show the recovered NAMRIA reference points within the area. In addition, Table 2 to Table 7 show the details about the following NAMRIA control stations, while Table 8 shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

(a)

(b)

Figure 3 GPS set-up over MST-28 in Mambog Bridge, Barangay Bat-ongan, municipality of Mandaon, Masbate (a) and NAMRIA reference point MST-28 (b) as recovered by the field team

Table 2 Details of the recovered NAMRIA horizontal control point MST-28 used as base station for the LiDAR acquisition

Station Name	MST-28	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 18' 35.15371" North 123° 21' 19.21293" East 49.12800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	538651.166 meters 1361224.57 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 18' 30.47973" North 123° 21' 24.28923" East 104.64900 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	538637.64 meters 1360748.12 meters

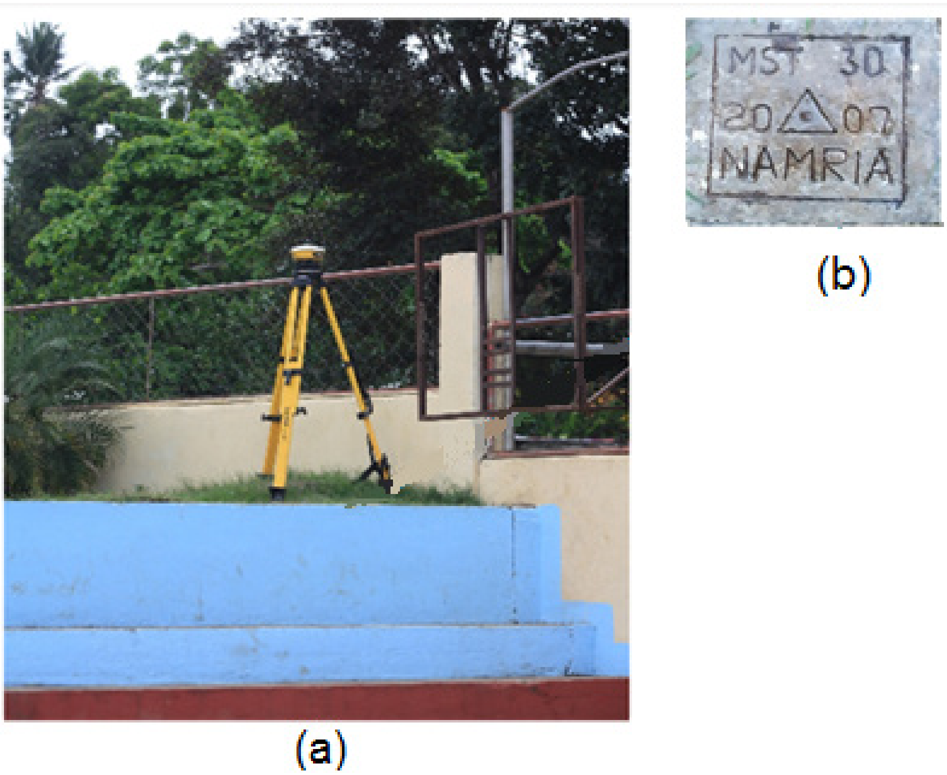

Figure 4 GPS set-up over MST-30 inside compound of plaza stage of Brgy. Poblacion, Mandaon, Masbate (a) and NAMRIA reference point MST-30 (b) as recovered by the field team

Table 3 Details of the recovered NAMRIA horizontal control point MST-30 used as base station for the LiDAR acquisition

Station Name	**MST-30**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1 in 50, 000**	
Geographic Coordinates, Philippine Reference Of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 13' 42.50852" North 123° 17' 3.56592" East 9.63700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	530936.259 meters 1352223.558 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 13' 37.84860" North 123° 17' 8.64987" East 65.19300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	530925.43 meters 1351750.26 meters

(a)

(b)

Figure 5 GPS set-up over MST-31 in Boracay Bridge, Barangay Bangad, municipality of Milagros, Masbate (a) and NAMRIA reference point MST-31 (b) as recovered by the field team

Table 4 Details of the recovered NAMRIA horizontal control point MST-31 used as base station for the LiDAR Acquisition

Station Name	**MST-31**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 11' 50.29728" 123° 24' 24.05419" 18.45000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Latitude Longitude Ellipsoidal Height	544254.929 meters 1384892.732 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 11' 45.65539" North 123° 24' 29.13992" East 74.38600 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992	Easting Northing	544239.44 meters 1348320.63 meters

(a) (b)

Figure 6 GPS set-up over MST-32 inside the compound of the Milagros Municipal Hall, Masbate (a) and NAMRIA reference point MST-32 (b) as recovered by the field team

Table 5 Details of the recovered NAMRIA horizontal control point MST-32 used as base station for the LiDAR acquisition

Station Name	**MST-32**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 13' 7.66936" North 123° 30' 26.72479" East 3.78300 meters
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Easting Northing	555213.396 meters 1351188.593 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 13' 3.03064" North 123° 30' 31.80788" East 59.91100 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	555194.07 meters 1350715.65 meters

Figure 7 GPS set-up over MST-55 inside the compound of Casamongan Brgy. Hall, municipality of Balud, Masbate. (a) and NAMRIA reference point MST-55 (b) as recovered by the field team

Table 6 Details of the recovered NAMRIA horizontal control point MST-55 used as base station for the LiDAR acquisition

Station Name	**MST-32**	
Order of Accuracy	**2nd**	
Relative Error (horizontal positioning)	**1 in 50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 05' 16.28892" North 123° 19' 50.73333" East 3.33300 meters
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Easting Northing	536007.686 meters 1336676.257 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 5' 11.66770" North 123° 19' 55.82918" East 59.36300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	535995.08 meters 1336207.40 meters

(b)

(a)

Figure 8 GPS set-up over MS-269 in Luy-a Bridge in Aroroy, Masbate (a) and NAMRIA benchmark MS-269 (b) as recovered by the field team

Table 7 Details of the recovered NAMRIA vertical control point MS-269 used as base station for the LiDAR acquisition with established coordinates

Station Name	**MS-269**	
Order of Accuracy	**1st**	
Relative Error (Horizontal positioning)	**1 in 100,000**	
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 24' 21.62786" North 123° 24' 21.40082" East 83.308 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	544123.868 meters 1,902,971.42 meters
Elevation (mean sea level)	27.4076 meters	

Table 8 Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
April 3, 2014	1299P	1BLK32FG093A	MST-30 &MST-31
April 3, 2014	1301P	1BLK32F093B	MST-30 &MST-31
April 4, 2014	1303P	1BLK32A094A	MS-269 & MST-28
April 4, 2014	1305P	1BLK32A094B	MS-269 & MST-28
April 5, 2014	1307P	1BLK32DG095A	MST 31 & MST 55
April 8, 2014	1319P	1BLK32B098A	MST-28 & MST-32
April 11, 2014	1331P	1BLK32B101A	MST-28 & MST-32

2.3 Flight Missions

Seven (7) missions were conducted to complete LiDAR data acquisition in Mandaon Floodplain, for a total of twenty four hours and thirty five minutes (24+35) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR systems. Table 9 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 9 Flight Missions for LiDAR data acquisition in Mandaon 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
April 3, 2014	1299P	449.02	317.043	14.461	302.582	528	3	53
April 3, 2014	1301P	278.49	168.543	9.603	158.94	695	2	41
April 4, 2014	1303P	287.82	301.884	7.39	294.494	800	3	41
April 4, 2014	1305P	287.82	239.52	12.28	227.24	326	2	59
April 5, 2014	1307P	477.28	344.804	4.621	340.183	326	4	29
April 8, 2014	1319P	247.35	254.693	34.08	220.613	294	4	17
April 11, 2014	1331P	247.35	127.611	3.901	123.71	460	2	35
TOTAL		**2275.13**	**1754.10**	**86.34**	**1667.762**	**3429**	**24**	**35**

Table 10 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)
1299P	1200	30	50	200	30	130	5
1301P	800	25	50	200	30	130	5
1303P	1200, 1000	30	50	200	30	130	5
1305P	1000	25	50	200	30	130	5
1307P	1000	25, 30	50	200	30	130	5
1319P	900	35	50	200	30	130	5
1331P	800	35	50	200	30	130	5

2.4 Survey Coverage

Mandaon floodplain is located in the province of Masbate, with majority of the floodplain situated within the municipality of Mandaon and Milagros. Most of Balud, Mandaon and Aroroy were covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 11. The actual coverage of the LiDAR acquisition for Mandaon Floodplain is presented in Figure 9.

ble 11 List of municipalities and cities surveyed during Mandaon Floodplain LiDAR survey

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Eastern Samar	Balud	217.54	211.64	97%
	Mandaon	267.43	255.97	96%
	Aroroy	403.62	345.45	86%
	Masbate City	192.96	109.87	57%
	Milagros	530.43	238.95	45%
	Baleno	200.24	48.54	24%
Total		1812.22	1210.42	67.47%

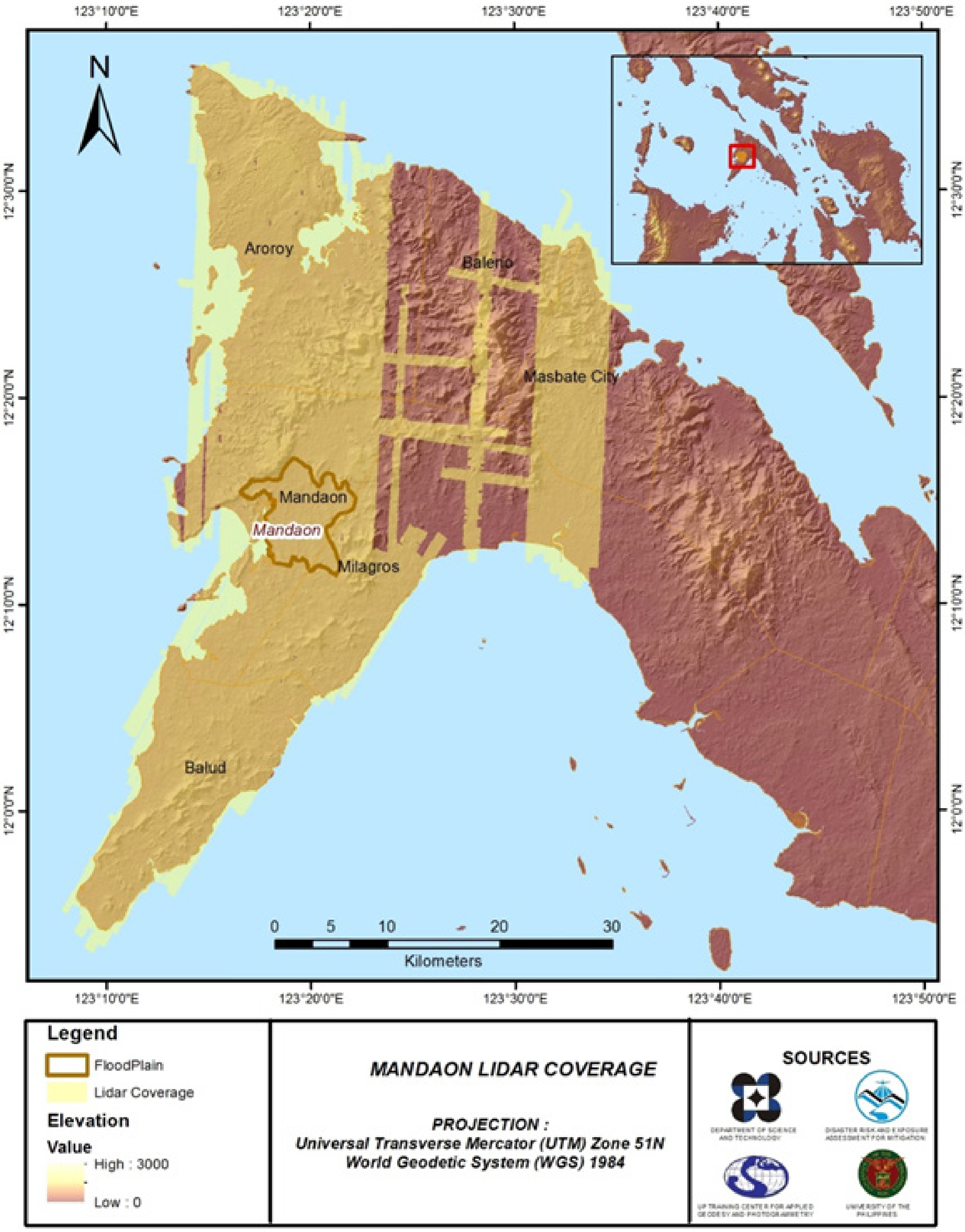

Figure 9 Actual LiDAR survey coverage for Mandaon Floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE MANDAON FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

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

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

These processes are summarized in the flow chart shown in Figure 10.

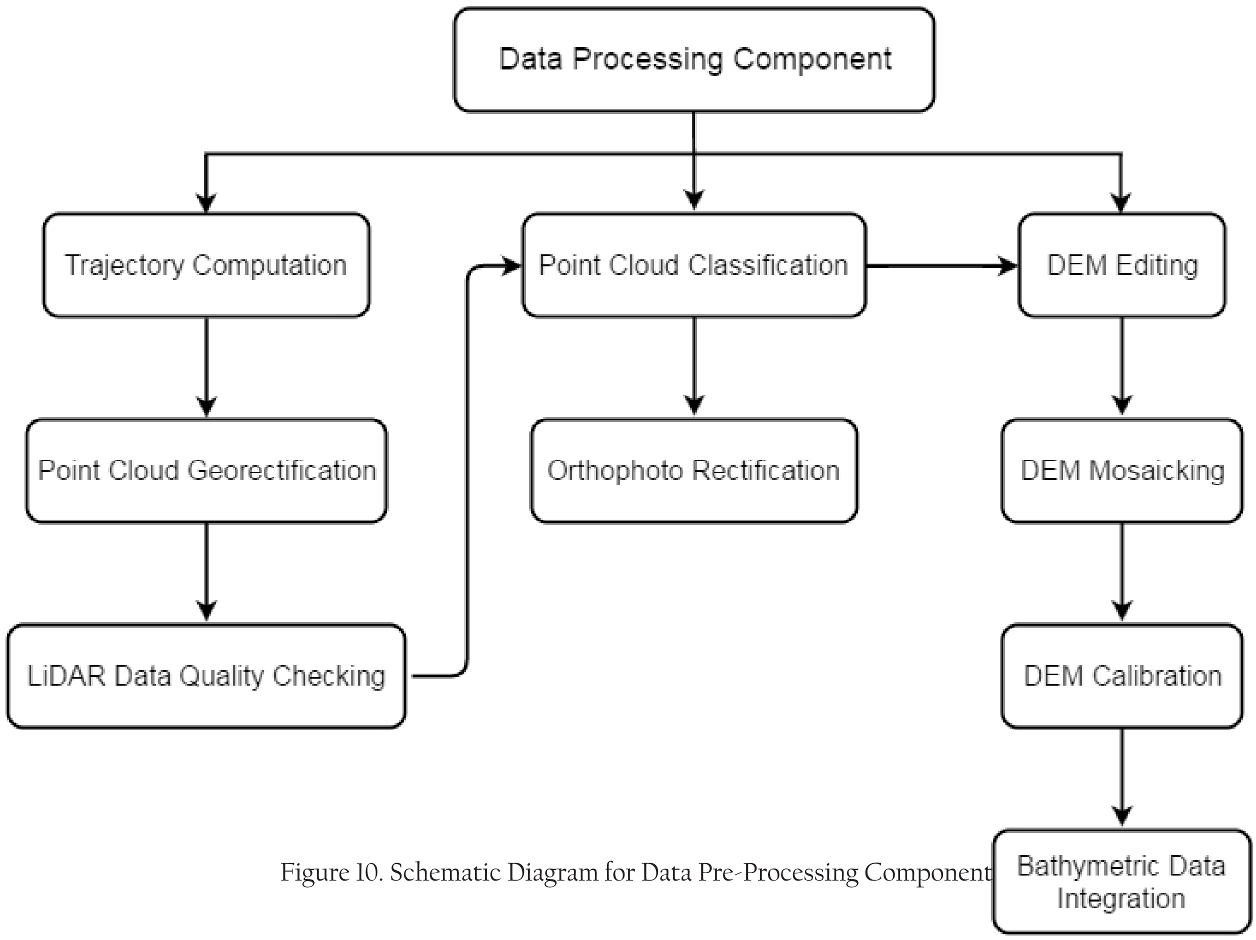


Figure 10. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Mandaon floodplain can be found in Annex 5. Data Transfer Sheets. Missions flown during the first survey conducted on April 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Municipality of Mandaon, Masbate.The Data Acquisition Component (DAC) transferred a total of 190.8 Gigabytes of Range data, 1.39 Gigabytes of POS data, 44.05 Megabytes of GPS base station data, and 289.5 Gigabytes of raw image data to the data server on April 23, 2014. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Mandaon was fully transferred on April 23, 2014, as indicated on the Data Transfer Sheets for Mandaon floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1331P, one of the Mandaon 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 was measured by the number of seconds from the midnight of the start of the GPS week, which fell on April 11, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

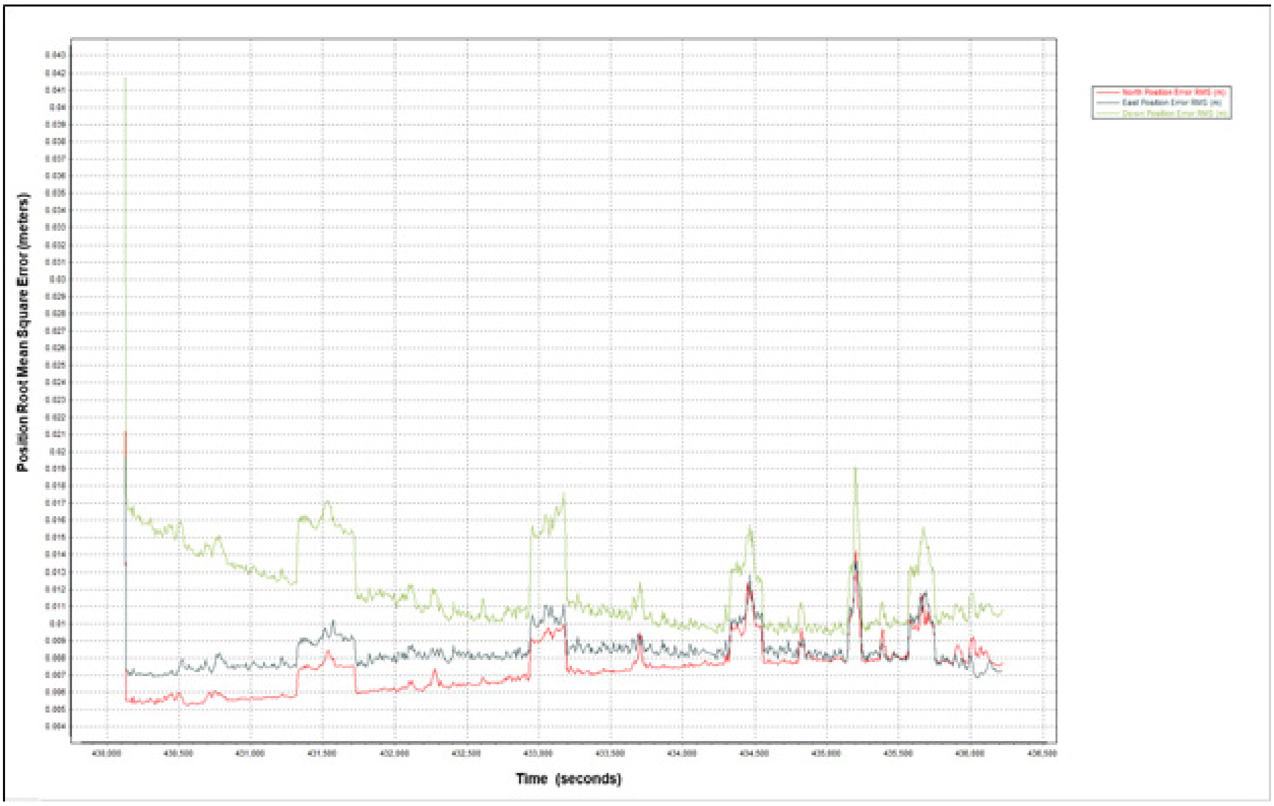


Figure 11. Smoothed Performance Metrics of a Mandaon Flight 1331P

The time of flight was from 430000 seconds to 436250 seconds, which corresponds to morning of April 11, 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 started 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 peaked at 1.24 centimeters, the East position RMSE peaked at 1.29 centimeters, and the Down position RMSE peaked at 1.76 centimeters, which are within the prescribed accuracies described in the methodology.

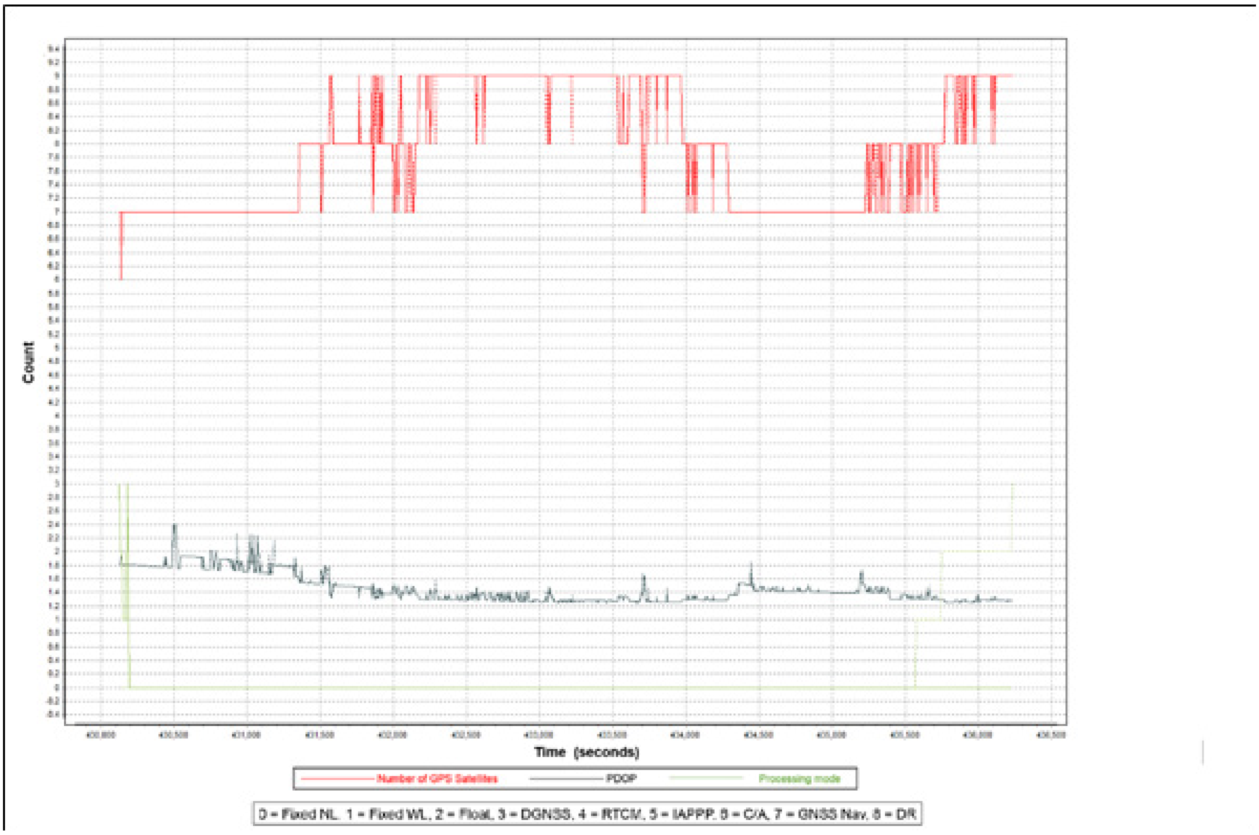


Figure 12. Solution Status Parameters of Mandaon Flight 1331P

The Solution Status parameters of flight 1331P, one of the Mandaon flights, which indicate 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. Most of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Mandaon flights is shown in Figure 13.

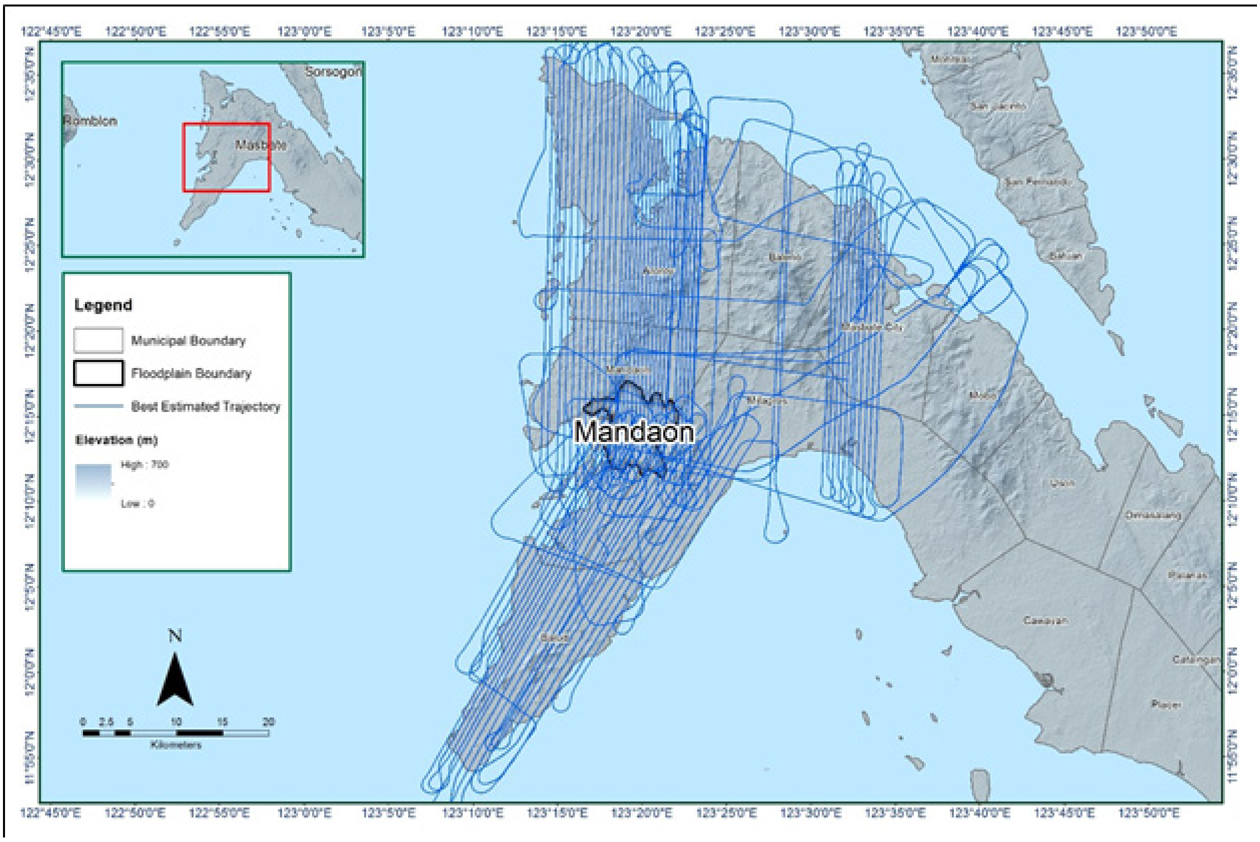


Figure 13. Best estimated trajectory for Mandaon Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 90 flight lines, with each flight line containing two channels, since the Pegasus system has two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Mandaon floodplain are given in Table 12.

Table 12. Self-Calibration Results values for Mandaon Flights.

Parameter	Acceptable Value	Computed Value
Boresight Correction stdev)	<0.001degrees	0.000351
IMU Attitude Correction Roll and Pitch Corrections stdev)	<0.001degrees	0.000991
GPS Position Z-correction stdev)	<0.01meters	0.0089

The optimum accuracy was obtained for all Mandaon 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 is shown in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

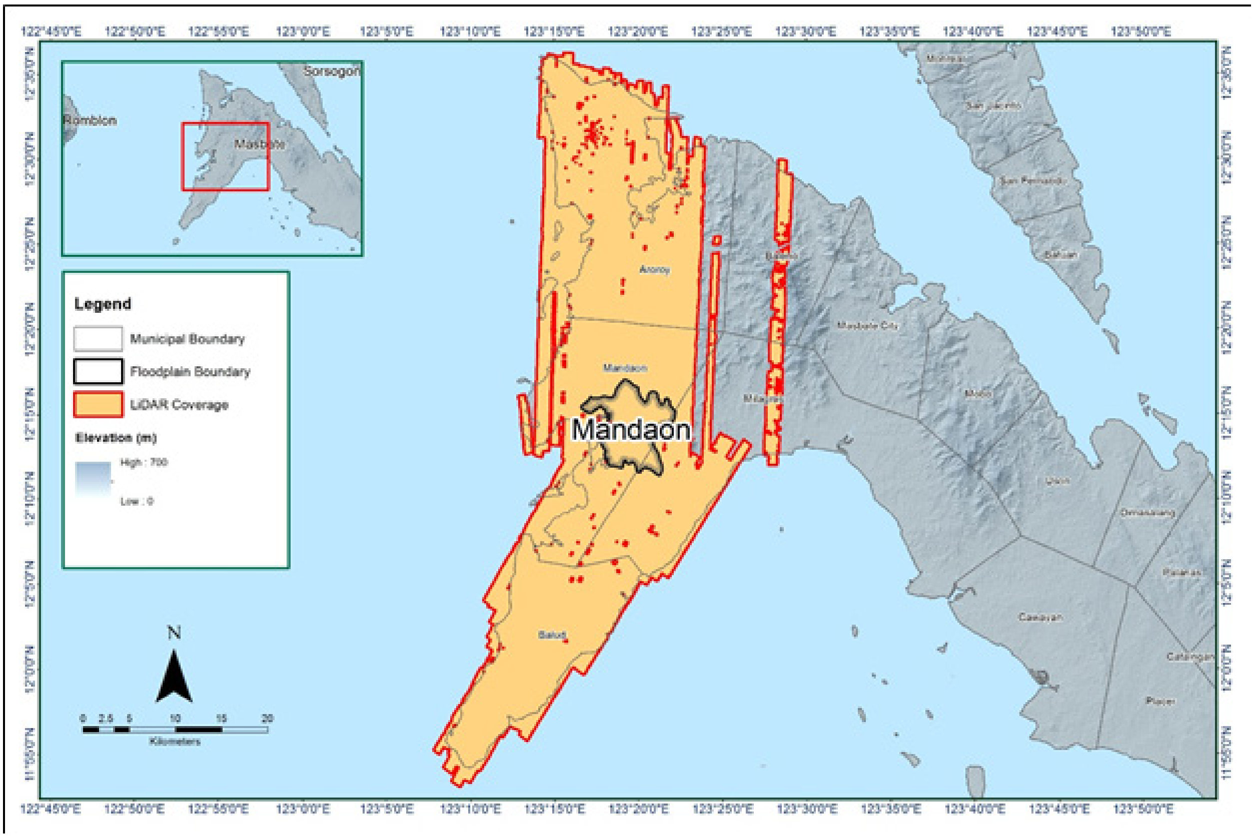


Figure 14. Boundary of the processed LiDAR data on top of a SAR Elevation Data over Mandaon Floodplain.

The total area covered by the Mandaon missions is 1482.40 sq.km that is comprised of seven (7) flight acquisitions grouped and merged into five (5) blocks as shown in Table 13.

Table 13. List of LiDAR blocks for the Mandaon floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Masbate_Blk32A	1303P	476.01
	1305P	
Masbate_Blk32A_additional	1305P	13.19
Masbate_Blk32B	1303P	327.12
	1319P	
	1331P	
Masbate_Blk32F	1299P	307.28
	1301P	
Masbate_Blk32G	1299P	358.80
TOTAL		**1482.4 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 Pegasus system employs two channels 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 is expected.

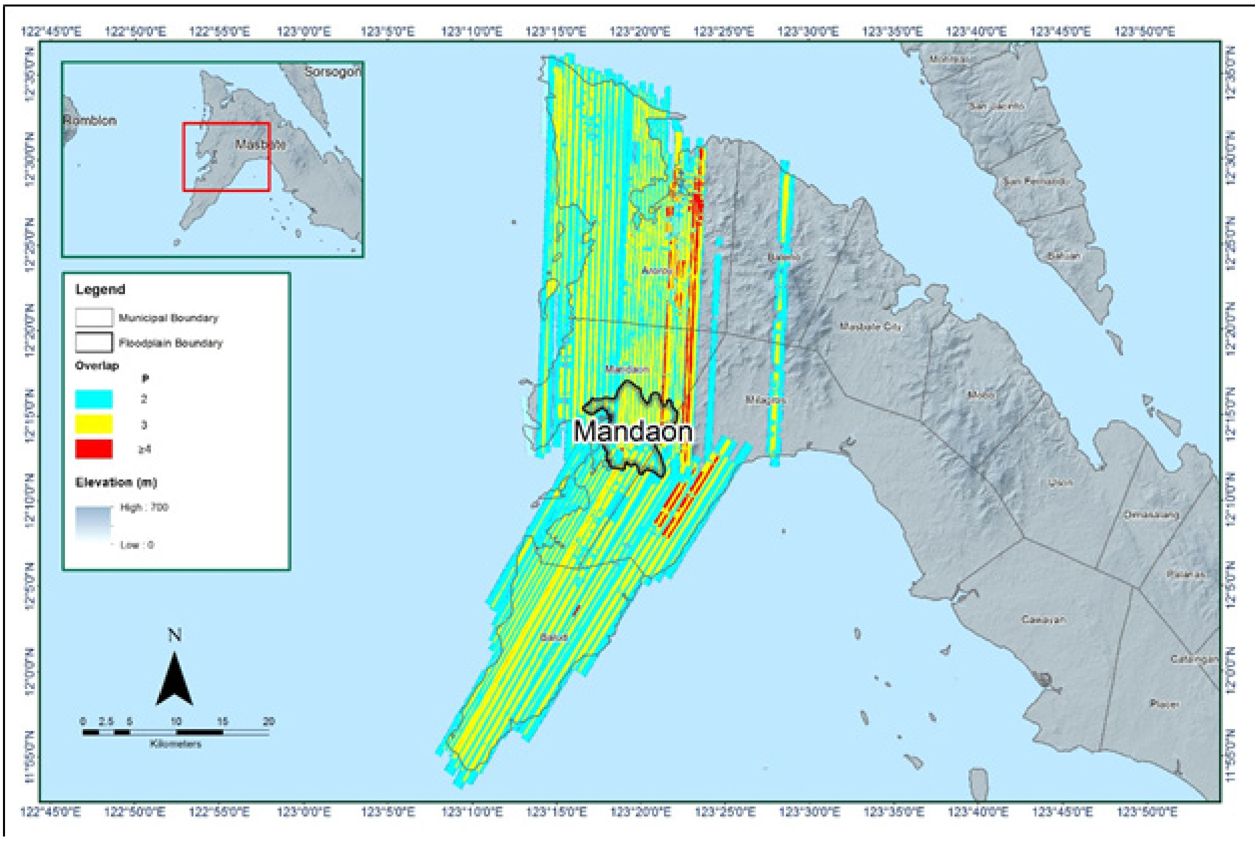


Figure 15. Image of data overlap for Mandaon Floodplain

The overlap statistics per block for the Mandaon Floodplain can be found in Annex 8. Mission Summary Reports. It should be noted that one pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 35.60% and 61.52% respectively, which passed the 25% requirement.

The density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 16. It was determined that all LiDAR data for Mandaon Floodplain satisfy the point density requirement, and the average density for the entire survey area is 2.86 points per square meter.

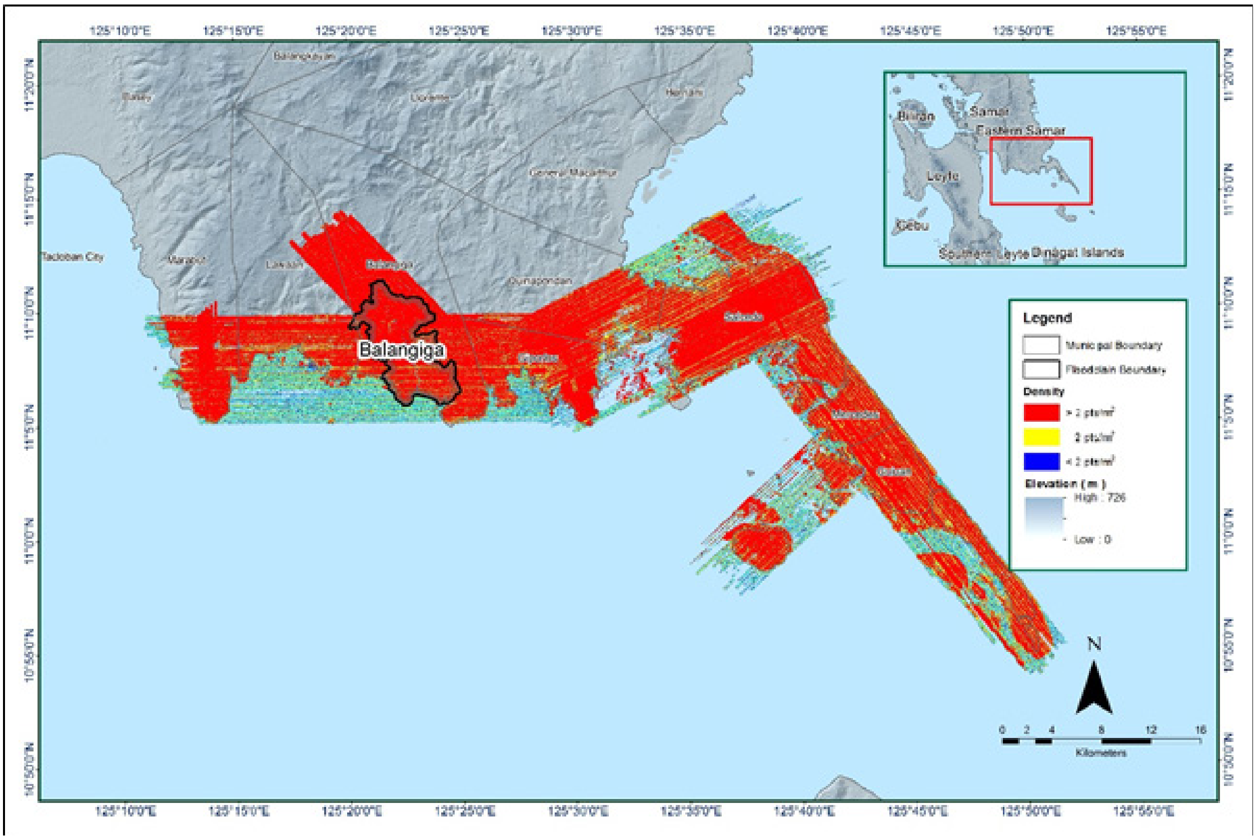


Figure 16. Pulse density map of merged LiDAR data for the Mandaon floodplain

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.

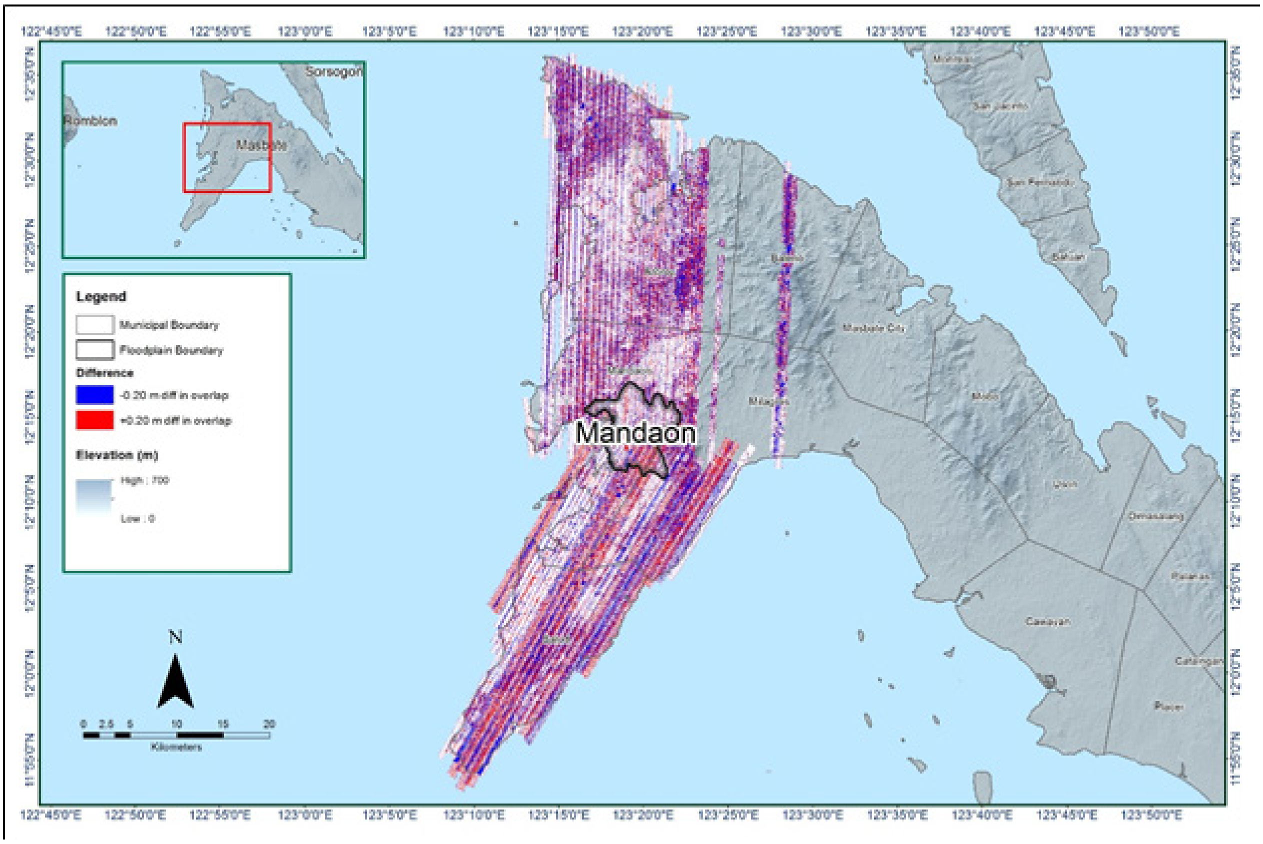


Figure 17. Elevation difference map between flight lines for Mandaon Floodplain

A screen capture of the processed LAS data from a Mandaon flight 1331P 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 were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

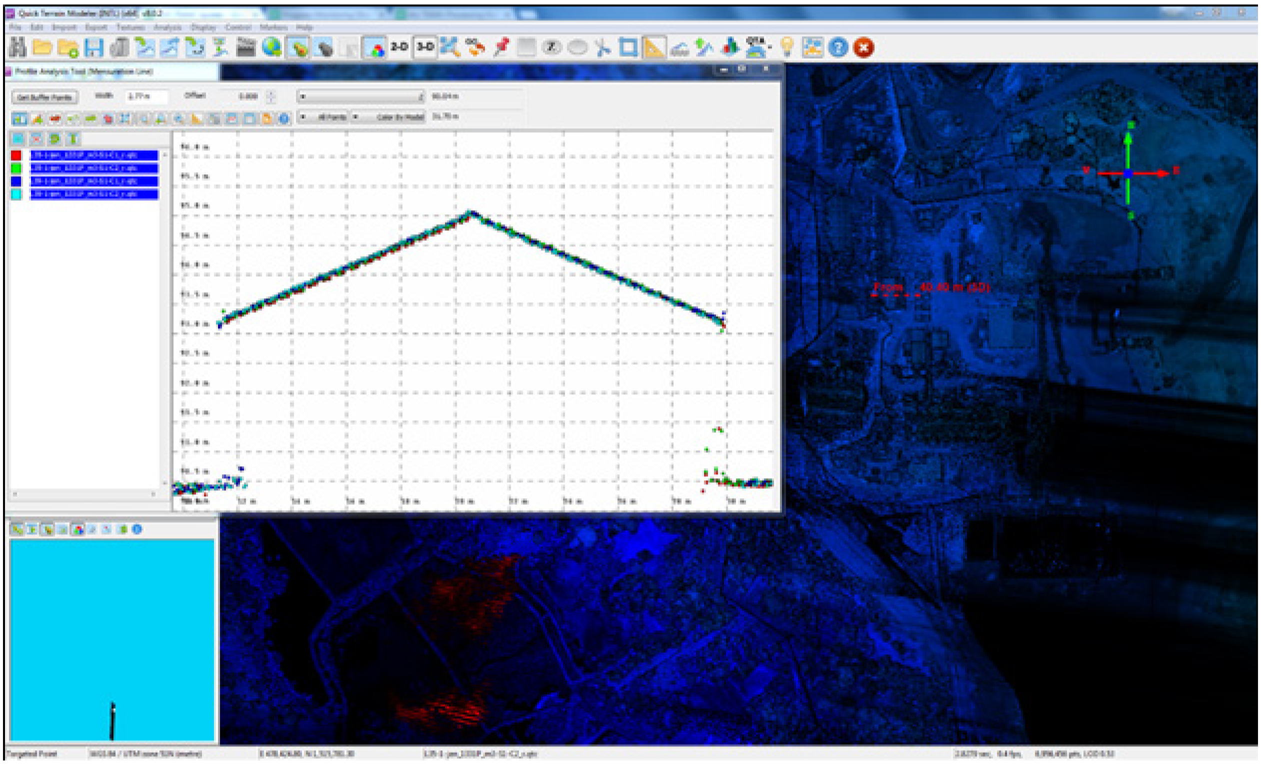


Figure 18. Quality checking for a Mandaon flight 1331P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Mandaon classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	980,995,752
Low Vegetation	1,136,355,402
Medium Vegetation	1,291,015,184
High Vegetation	438,208,948
Building	9,869,689

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Mandaon Floodplain is shown in Figure 19. A total of 1,9371km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 14. The point cloud has a maximum and minimum height of 710.95 meters and 57.15 meters respectively.

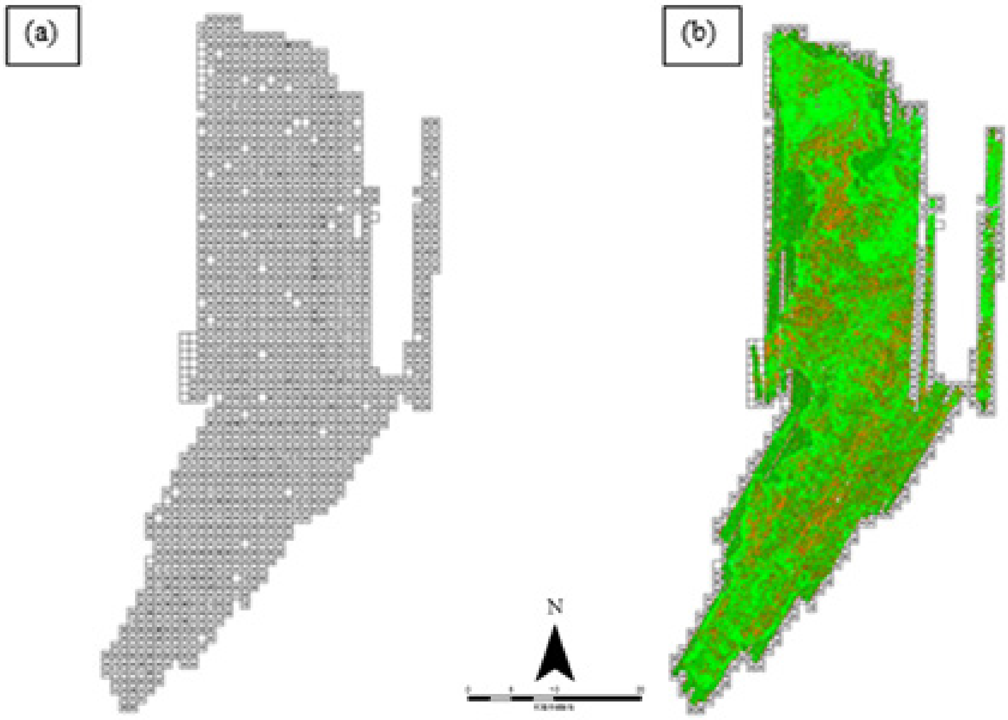


Figure 19. Tiles for Mandaon floodplain (a) and classification results (b) in TerraScan

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.

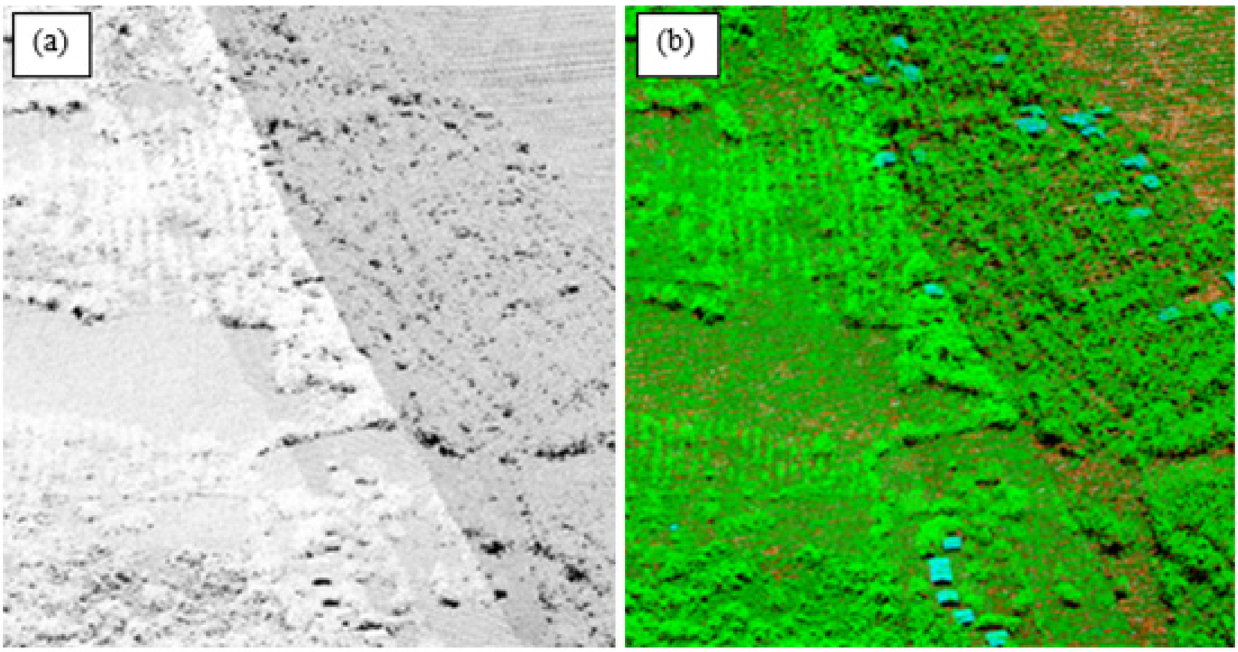


Figure 20. Point cloud before (a) and after (b) classification

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.

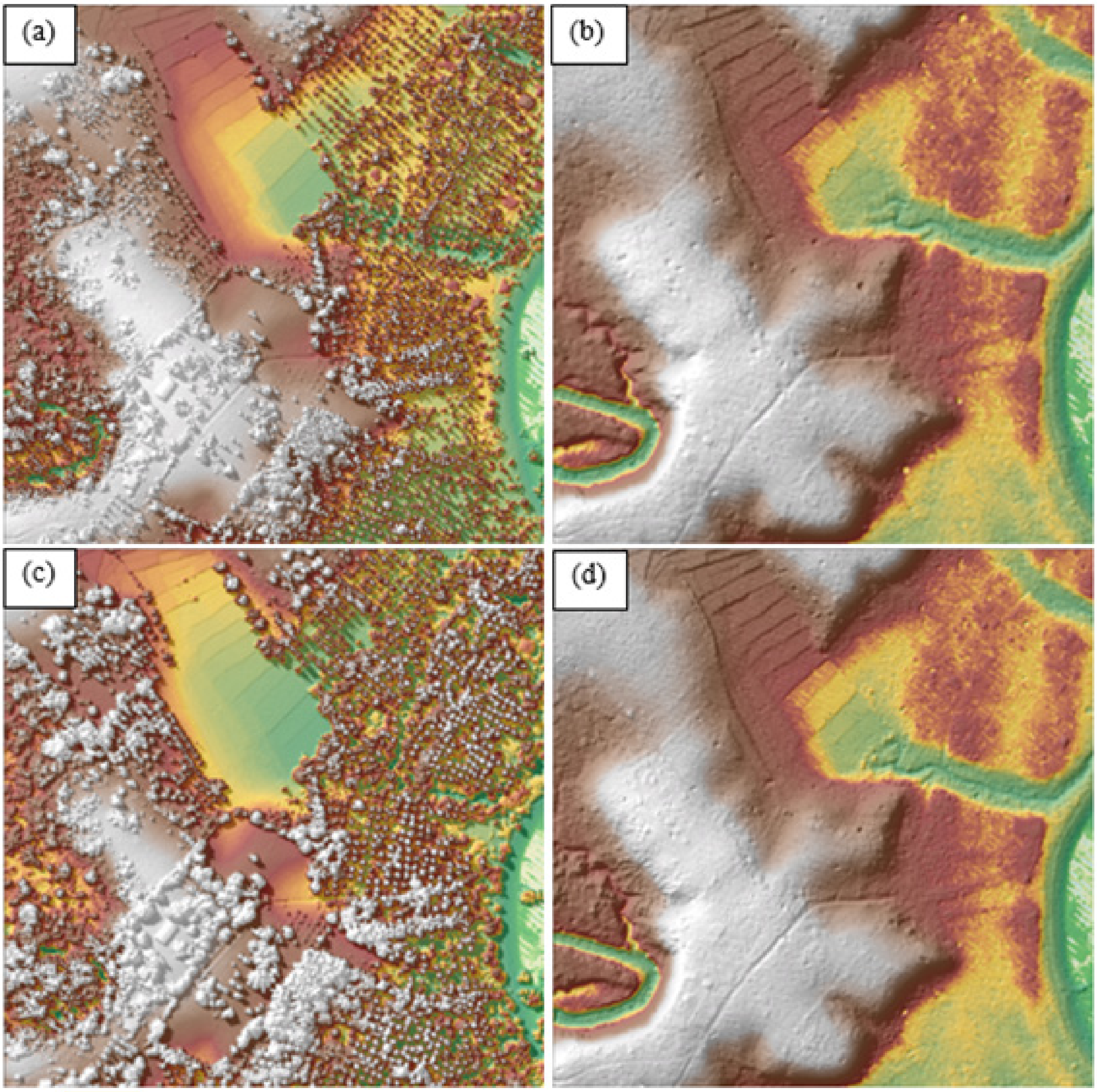


Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Mandaon Floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,4561km by 1km tiles area covered by Mandaon 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 Mandaon Floodplain has a total of 325.02 sq.km orthophotogaph coverage comprised of3,124images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

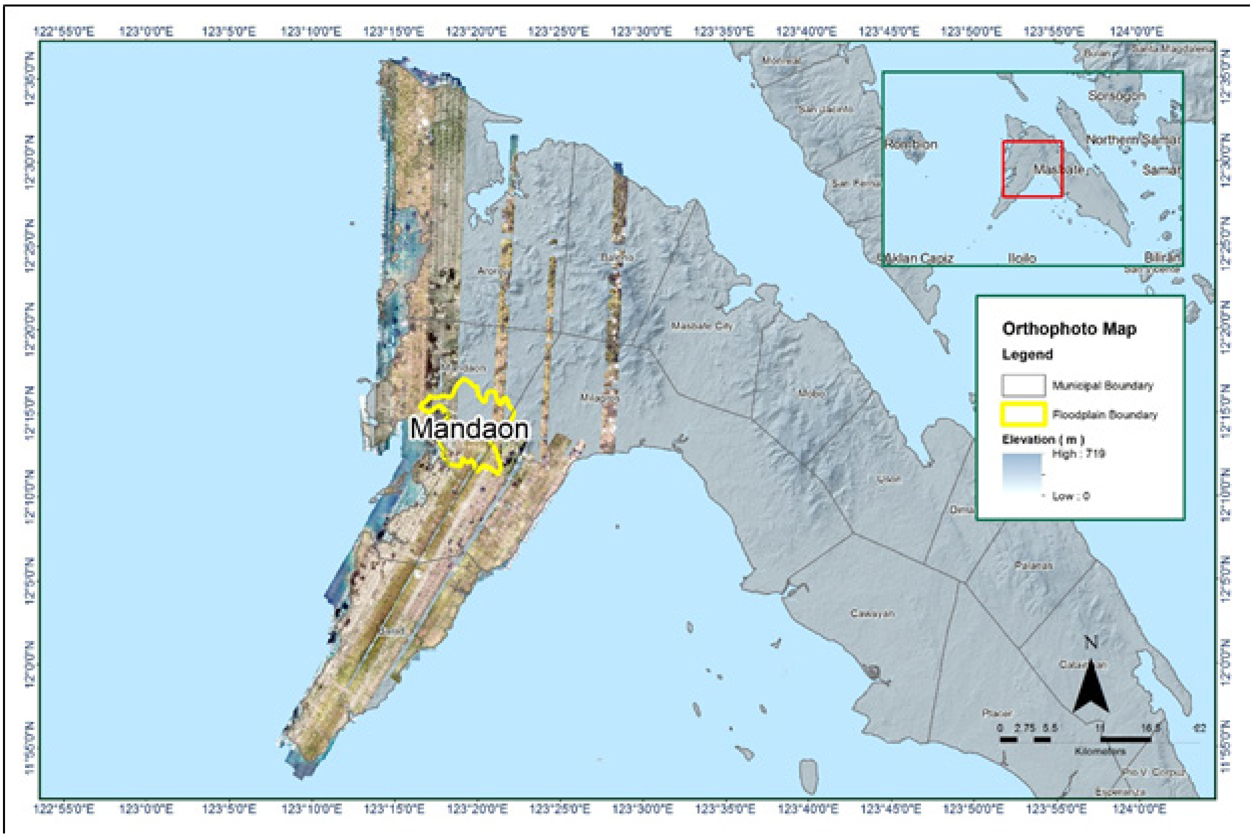


Figure 22. Mandaon Floodplain with available orthophotographs.

Figure 23. Sample orthophotograph tiles for Mandaon Floodplain.

3.8 DEM Editing and Hydro-Correction

Five (5) mission blocks were processed for Mandaon Floodplain. These blocks are composed of Masbate blocks with a total area of 1,482.40 square kilometers. Table 15 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Masbate_Blk32G	358.80
Masbate_Blk32F	307.28
Masbate_Blk32B	327.12
Masbate_Blk32A	476.01
Masbate_Blk32A_additional	13.19
TOTAL	1482.40 sq.km

Portions of DTM before and after manual editing are shown in Figure 24. The bridge (Figure B-24a) is considered to be an impedance to the flow of water along the river and had to be removed (Figure 24b) in order to hydrologically correct the river. This was done through interpolation process wherein a specific polygon determines the upstream and downstream elevation values to generate an interpolated portion of a river and eventually remove the bridge footprint. Portion of ridge also (Figure B-24c) had been misclassified that needed to be retrieved to retain the correct terrain (Figure B-24d). Object retrieval used the secondary DTM (t_layer) to fill in these areas.

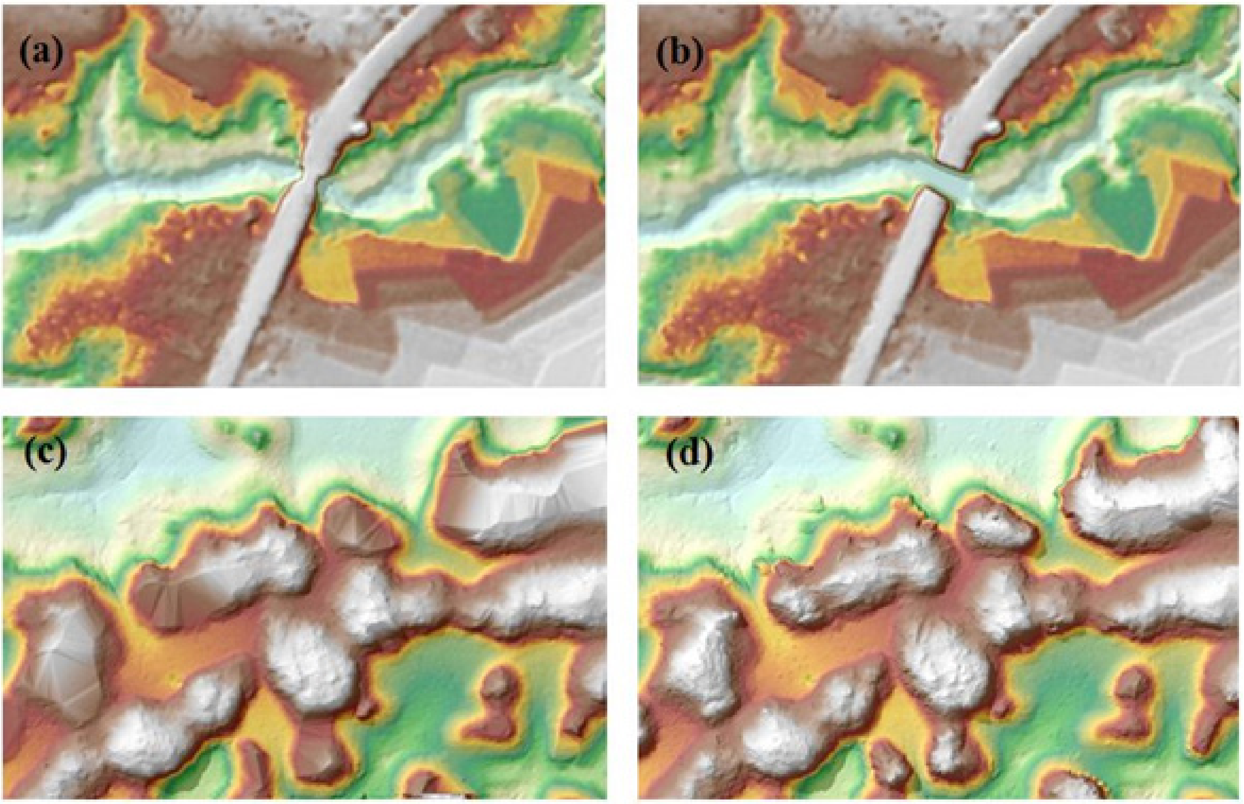


Figure 24 Portions in the DTM of Mandaon Floodplain – a bridge before (a) and after (b) manual editing; a misclassified hill before (c) and after (d) data retrieval

3.9 Mosaicking of Blocks

Masbate_Blk32A 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 16 shows the shift values applied to each LiDAR block during mosaicking.

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

Table 16. Shift Values of each LiDAR Block of Mandaon Floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Masbate_Blk32G	0.00	0.00	0.00
Masbate_Blk32F	0.00	0.00	0.00
Masbate_Blk32B	0.00	0.00	0.00
Masbate_Blk32A	0.00	0.00	1.70
Masbate_Blk32A_additional	0.00	0.00	0.24

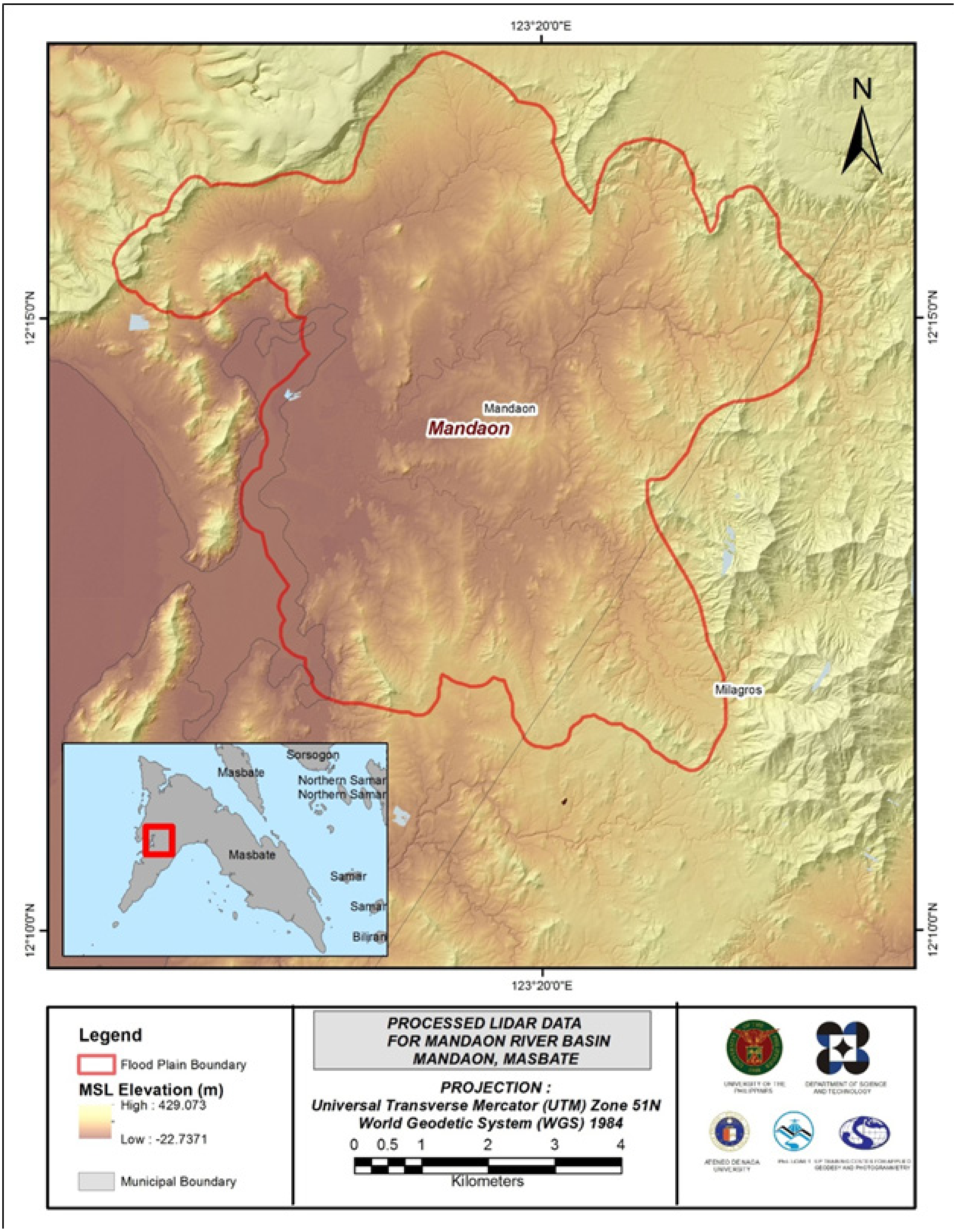


Figure 25. Map of Processed LiDAR Data for Mandaon Floodplain

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 Mandaon to collect points with which the LiDAR dataset was validated is shown in Figure 26. A total of1,135 survey points were used for calibration and validation of Mandaon LiDAR data. Random selection of 80% of the survey points, resulting to 1,087 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 was 5.33 meters with a standard deviation of 0.15 meters. Calibration of Mandaon LiDAR data was done by subtracting the height difference value, 5.33 meters, to Mandaon mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between LiDAR data and calibration data.
`

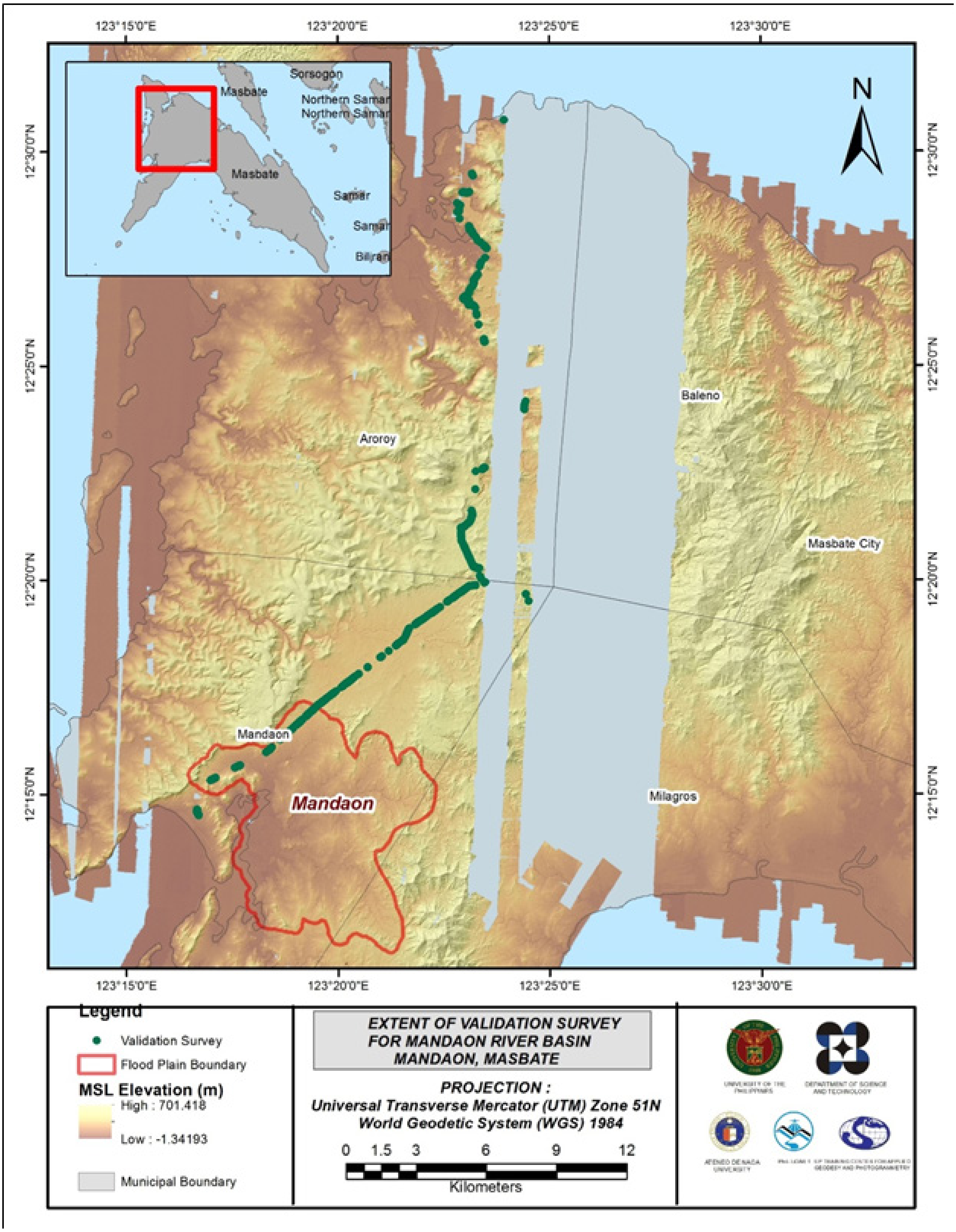


Figure 26. Map of Mandaon Floodplain with validation survey points in green

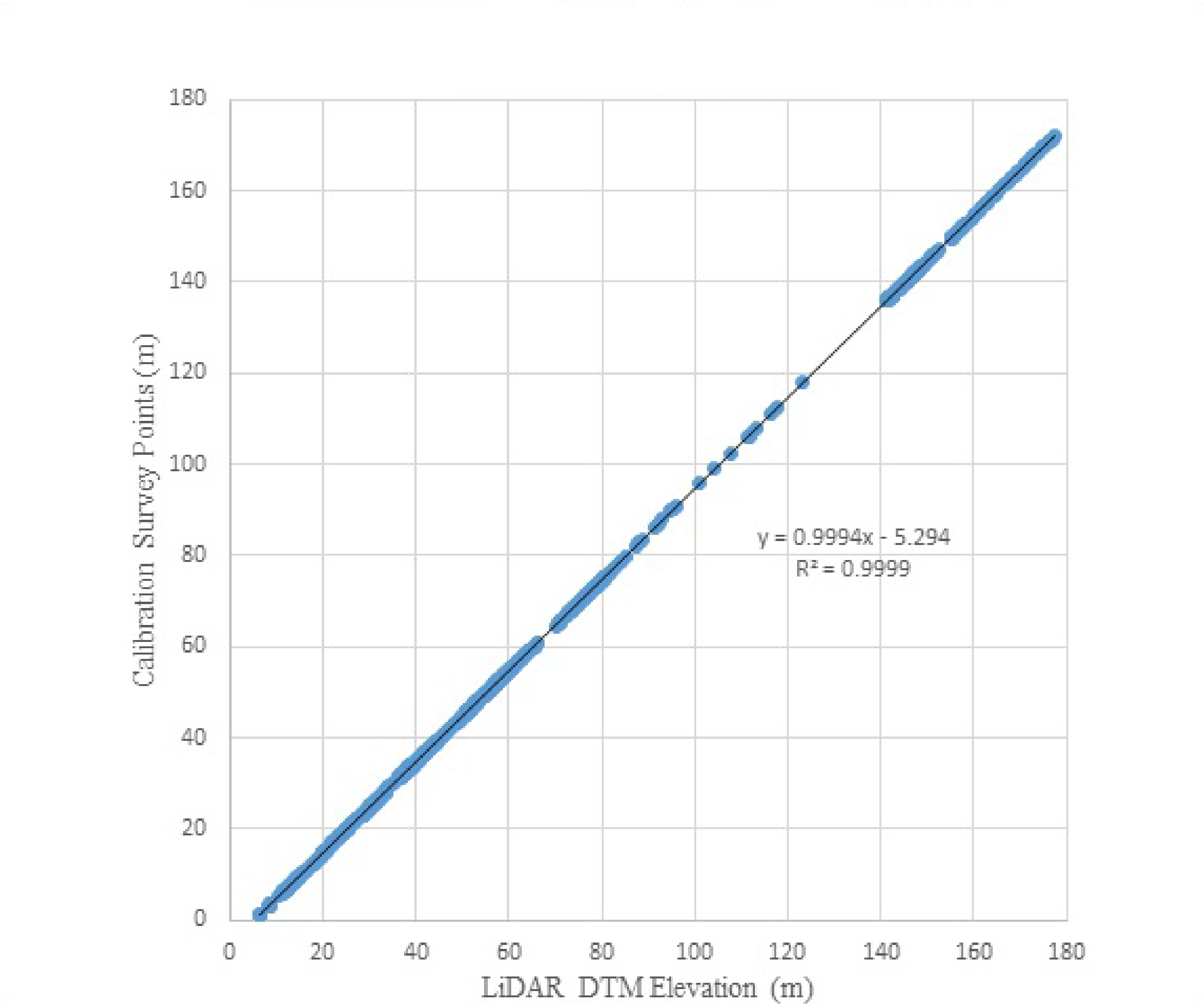


Figure 27. Correlation plot between calibration survey points and LiDAR data

Table 17. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	5.33
Standard Deviation	0.15
Average	-5.33
Minimum	-5.63
Maximum	-5.03

The remaining 20% of the total survey points, resulting to 227 points, were used for the validation of calibrated Mandaon 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 0.12 meters with a standard deviation of 0.12 meters, as shown in Table 18.

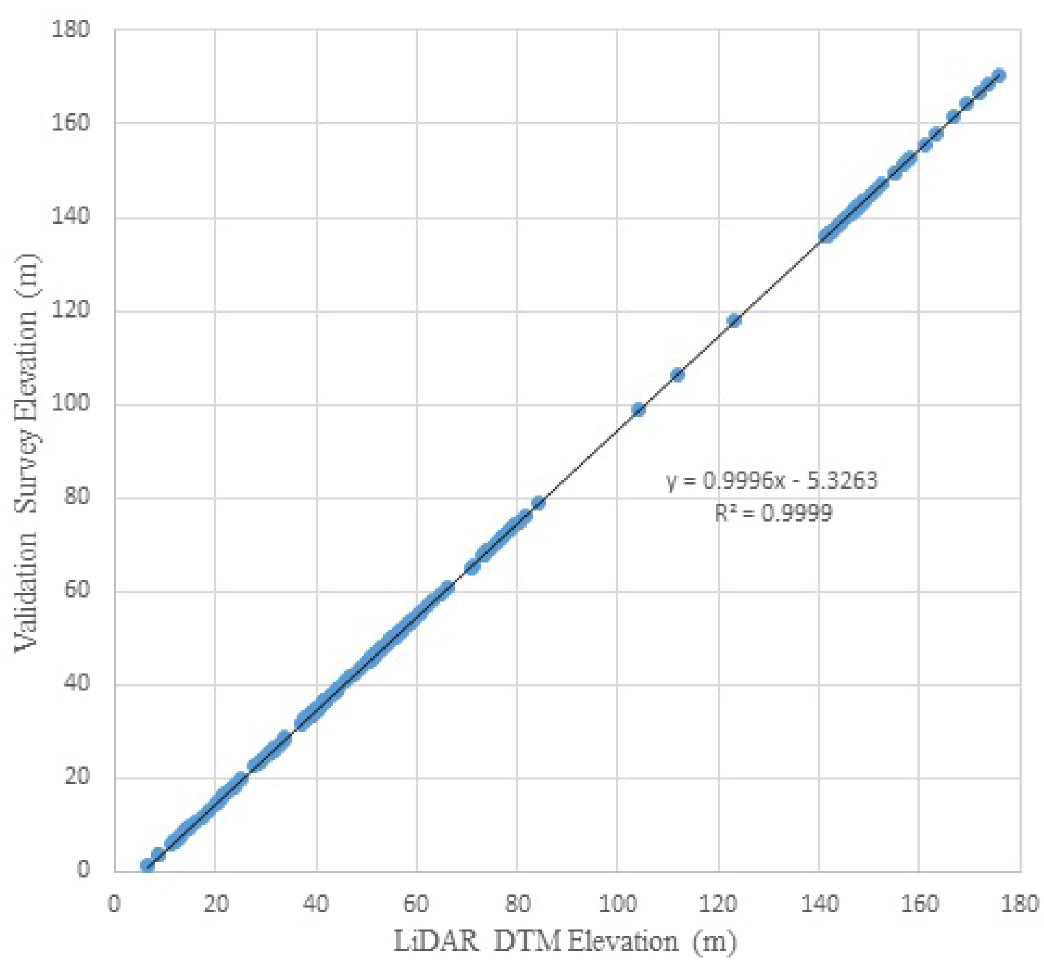


Figure 28. Correlation plot between validation survey points and LiDAR data

Table 18. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.12
Standard Deviation	0.12
Average	-0.02
Minimum	-0.26
Maximum	0.23

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Mandaon with 3,893 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.12 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Mandaon

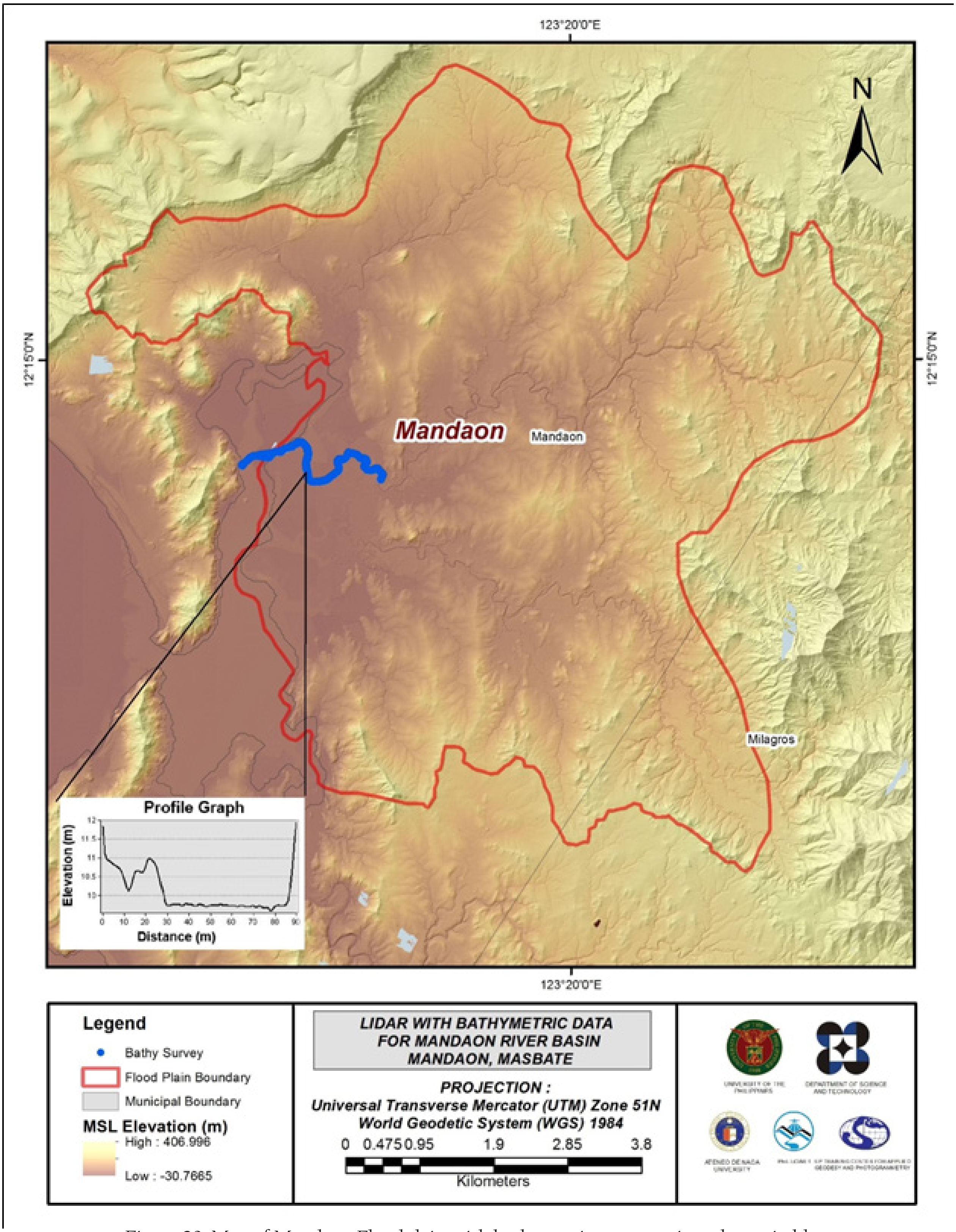


Figure 29. Map of Mandaon Floodplain with bathymetric survey points shown in blue

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges and water bodies within the floodplain area with 200 m buffer zone. Mosaicked LiDAR DEM with 1 m resolution was used to delineate footprints of building features, which consist of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks comprise of main thoroughfares such as highways and municipal and barangay roads essential for routing of disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

Mandaon Floodplain, including its 200 m buffer, has a total area of 63.59 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 919 building features, are considered for QC. Figure 30 shows the QC blocks for Mandaon floodplain.

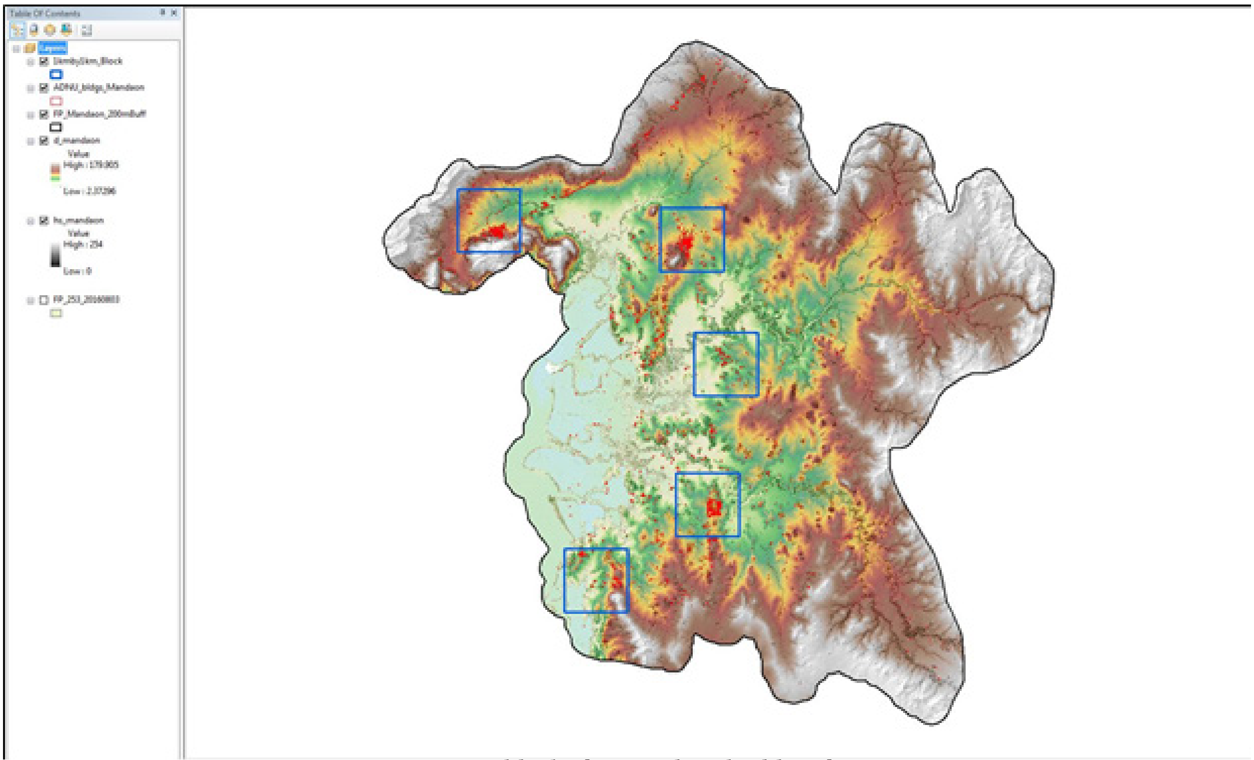


Figure 30. QC blocks for Mandaon building features

Quality checking of Mandaon building features resulted in the ratings shown in Table B-8.

Table 19. Quality Checking Ratings for Mandaon Building Features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Mandaon	100.00	100.00	99.78	PASSED

3.12.2 Height Extraction

Height extraction was done for 2,261 building features in Mandaon floodplain. Of these building features, 25 were filtered out after height extraction, resulting to 2,236 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 9.04 m.

3.12.3 Feature Attribution

Feature Attribution was done for 2,236 building features in Mandaon Floodplain with the use of participatory mapping and innovations. The approach used in participatory mapping underwent the creation of feature extracted maps in the area and presenting spatial knowledge to the community with the premise that the local community in the area were considered experts in determining the correct attributes of the building features in the area.

The innovation used in this process is the creation of an android application called reGIS. The Resource Extraction for Geographic Information System (reGIS)[1] app was developed to supplement and increase the field gathering procedures being done by the AdNU Phil-LiDAR 1. The Android application allows the user to automate some procedures in data gathering and feature attribution to further improve and accelerate the geotagging process. The applicatoin lets the user record the current GPS location together with its corresponding exposure features, code, timestamp, accuracy and additional remarks. This was all done by a few swipes with the help of the device's pre-defined list of exposure features. This effectively allowed unified and standardized sets of data

Table 20 summarizes the number of building features per type. On the other hand, Table B-21 shows the total length of each road type, while Table 22 shows the number of water features extracted per type.

[1]Resource Extraction for Geographic Information System (reGIS), March 17,2015.

Table 20. Building features extracted for the Mandaon floodplain

Facility Type	No. of Features
Residential	2,183
School	29
Market	0
Agricultural/Agro-Industrial Facilities	4
Medical Institutions	4
Barangay Hall	4
Military Institution	0
Sports Center/Gymnasium/Covered Court	0
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	0
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	1
Religious Institutions	11
Bank	0
Factory	0
Gas Station	0
Fire Station	0
Other Government Offices	0
Other Commercial Establishments	0
Total	2,236

Table 21. Total Length of Extracted Roads for Mandaon Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Mandaon	37.95	0	0	6.18	0.00	37.95

Table 22. Number of Extracted Water Bodies for Mandaon Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Mandaon	1	80	1	0	0	82

A total of 4 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 31 shows the Digital Surface Model (DSM) of Mandaon Floodplain overlaid with its ground features.

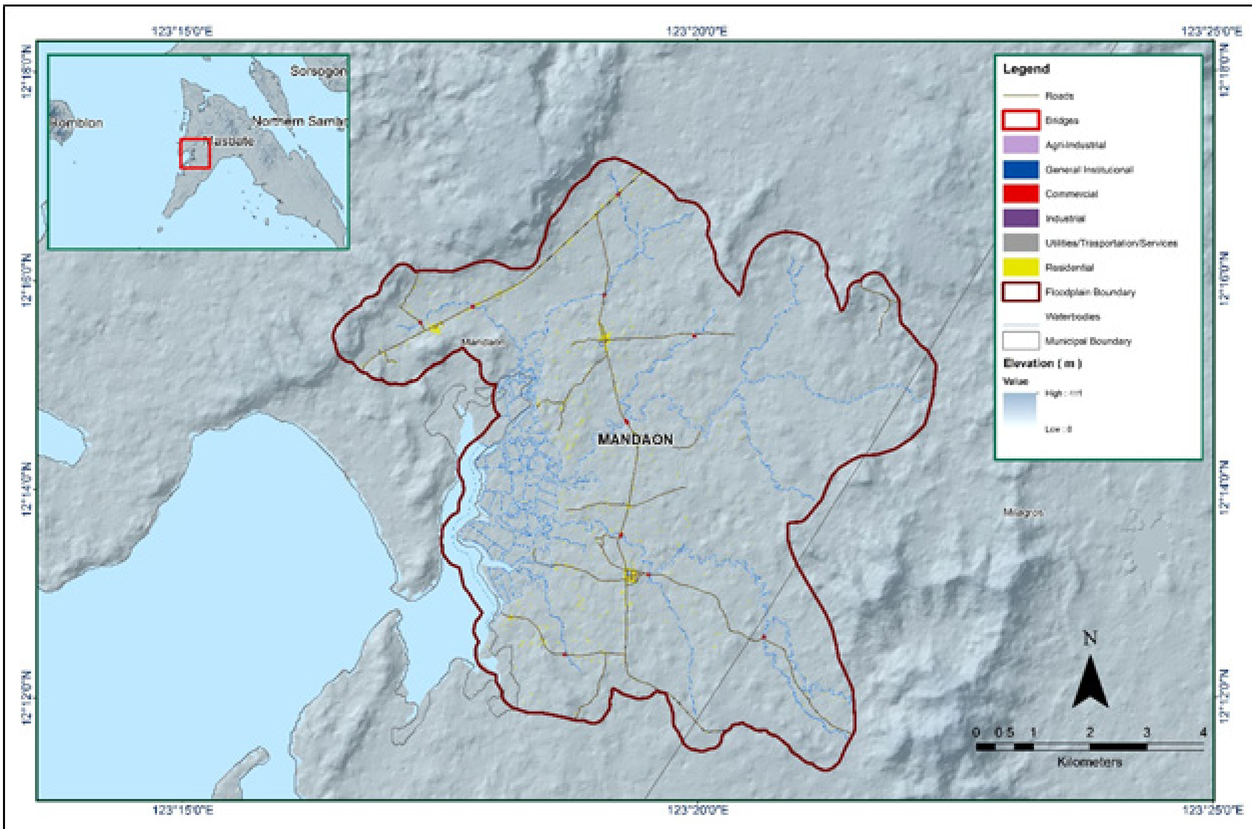


Figure 31. Extracted features for Mandaon Floodplain

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

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

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

4.1 Summary of Activities

Mandaon River Basin is situated in the province of Masbate, covering the Municipalities of Mandaon and Milagros. According to DENR – River Basin Control Office, it has a drainage area of 58 km2 and an estimated 78 million cubic meter (MCM) annual run-off.

Its main stem, Mandaon River, is part of the 24 river systems under the PHIL-LiDAR 1 partner HEI, Ateneo de Naga University. According to the 2010 national census of NSO, a total of 4,561 locals are residing in the immediate vicinity of the river. Farmers use the river for irrigation and also for the needs of the carabao to quench its thirst, to clean itself and to dispose its waste. The risk of water contamination in Mandaon River is very high, yet residents utilize it for bathing and washing clothes. Source of clean water has been a problem of the municipality since then. The LGU of Mandaon is taking action to resolve this by setting distribution pipes to make clean water accessible to its constituents.

According to the locals, swelling of Mandaon River due to torrential rains is usual but no households are reached by flood waters. However, culverts that connect the roads in the areas are mostly submerged to flood, hence, travel and the provision of relief goods and aids to residents would be very difficult in case of flooding .

In line with this, DVBC conducted field survey in Mandaon River on December 3-17, 2015 with the following scope of work: reconnaissance; control survey for the establishment of a control point; cross-section and as-built survey; validation points acquisition survey; and bathymetric survey from Alas Bay to Brgy. Tagpu, Mandaon - 2.41 km from the mouth of the river using an OHMEX™ Single Beam Echo Sounder and GNSS PPK survey technique.

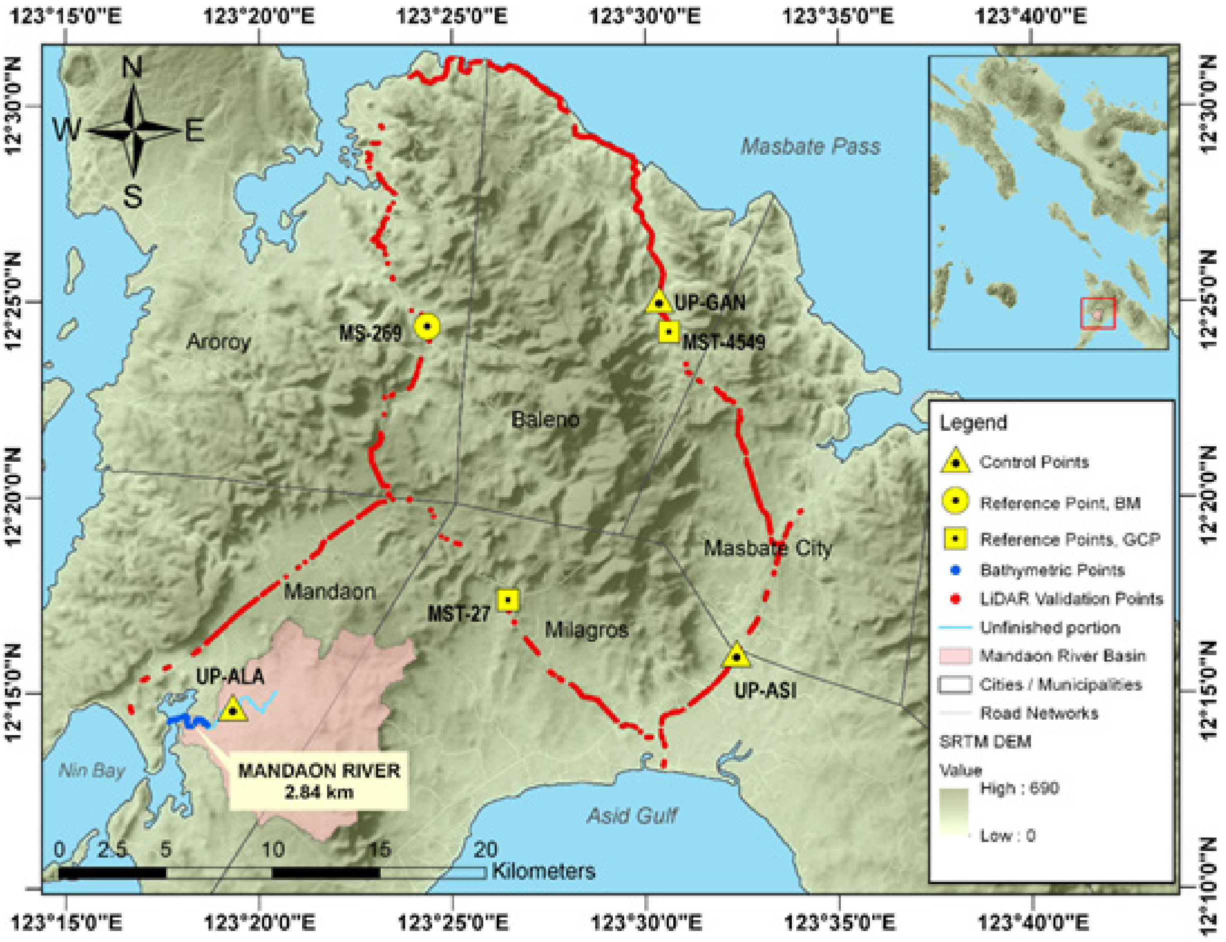


Figure 32 Survey extent for Mandaon River Basin

4.2 Control Survey

The GNSS network used for Mandaon River Basin is composed of four (4) loops established on December 4, 5, 6 and 13, 2015 occupying the following reference points: MST-27, a second order GCP in Brgy. Matiporon, Municipality of Milagros; andMS-269, a first order benchmark in Brgy. Luy-A, Municipality of Aroroy.

Three (3) control points were established along the approach of bridges, namely: UP-ALA at Alas Bridge in Brgy. Alas, Municipality of Mandaon; UP-ASI at Asid Bridge in Brgy. Asid, Masbate City; and UP-GAN near Gangao Bridge, in Brgy. Gangao, Municipality of Baleno. The control point established by DENR, MST-4945, in Brgy. Gangao, also in Baleno was occupied to use as a marker for the network.

The summary of reference and control points and its location is summarized in Table 24.List of reference and control points occupied for Mandaon River Survey.while GNSS network established is illustrated in Figure 33.

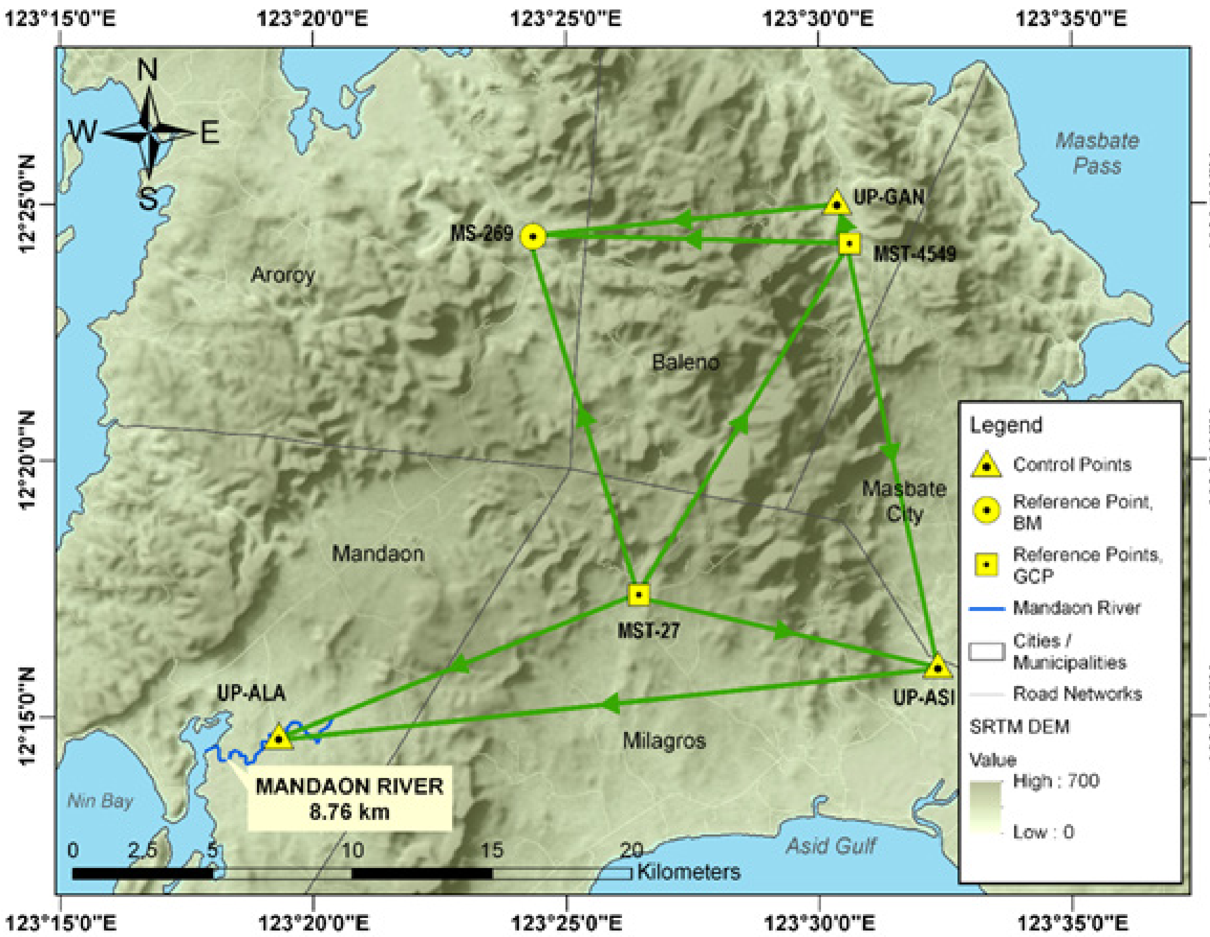


Figure 33 GNSS Network of Masbate field survey

Table 23 List of reference and control points occupied for Mandaon River Survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
MS-269	1st order, BM	-	-	82.132	27.408	2008
MST-27	2nd order, GCP	12°17'22.32360"N	123°26'26.50548"E	109.123	-	2007
MST-4549	Used as Marker	-	-	-	-	Sep 13, 2014
	Used as Marker	-	-	-	-	2013
UP-ALA	Used as Marker	-	-	-	-	Sep 13, 2014
	UP Established	-	-	-	-	Dec. 12, 2015
UP-ASI						
	UP Established	-	-	-	-	Dec. 5, 2015
UP-GAN	UP Established	-	-	-	-	Sep 19, 2014
	UP Established	-	-	-	-	Dec. 4, 2015

The GNSS set up made in the location of the reference and control points are exhibited in Figure 34 to Figure 39.

Figure 34 GNSS base set-up, Trimble® SPS 852at MS-269, located at Lanang Bridge, along Central Nautical Highway in Brgy. Luy-A, Aroroy, Masbate

Figure 36. GNSS receiver, Trimble® SPS 882, at SE-85, located at the approach of the Llorente Bridge in Barangay 11, Municipality of Llorente, Eastern Samar

Figure 36 Trimble® SPS 852 base set-up at MST-4945, a DENR-established control point located at the approach of Cancahorao Bridge along Central Nautical Highway in Brgy. Gangao, Baleno, Masbate

Figure 37 Trimble®SPS 882 set-up at UP-ALA, located at Alas Bridge in Brgy. Alas, Mandaon, Masbate

Figure 38 GNSS receiver set-up, Trimble® SPS 882, at UP-ASI, located at Asid Bridge, along Central Nautical Highway, Brgy. Asid, Masbate City

Figure 39 GNSS receiver set-up, Trimble® SPS 882, at UP-GAN, located on top of a riprap near Gangao Bridge, along Central Nautical Highway, Brgy. Gangao, Baleno, Masbate

4.3 Baseline Processing

GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of 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, a re-survey is initiated. The baseline processing results of control points in the Mandaon River Basin generated by the TBC software is summarized in Table 25.

Table 24 Baseline Processing Report for Mandaon River Basin static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP-GAN --- MS-269	12-04-2015	Fixed	0.064	0.077	263°25'15"	10958.94	8.902
UP-ASI --- UP-ALA	12-05-2015	Fixed	0.007	0.04	263°57'41"	23763.75	-9.332
MST-4549 --- UP-ASI	12-05-2015	Fixed	0.007	0.034	168°18'59"	15487.62	-10.509
MST-4549 --- MS-269	12-05-2015	Fixed	0.013	0.019	271°18'18"	11347.5	5.154
MST-4549 --- UP-GAN	12-04-2015	Fixed	0.003	0.005	343°10'30"	1581.606	-3.725
MST-27 --- UP-ALA	12-12-2015	Fixed	0.006	0.046	248°40'43"	13874.51	-52.04
MST-27 --- UP-ASI	12-05-2015	Fixed	0.005	0.019	103°19'39"	11002.41	-42.67
MST-27 --- MS-269	12-05-2015	Fixed	0.015	0.076	343°39'18"	13427.81	-26.942
MST-4549 ---MST-27	12-05-2015	Fixed	0.006	0.023	30°55'25"	14722.42	-32.154

As shown in Table 24, the accuracies of the processed baselines are within the precision requirement of the program.

4.4 Network Adjustment

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

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

where:

x_e is the Easting Error,
y_e is the Northing Error, and
z_e is the Elevation Error

for each control point. See the Network Adjustment Report provided in Table 26 to Table 29 for the complete details.

The six (6) control points, MST-27, MST-4549, MS-269. UP-ALA, UP-ASI, UP-GAN were occupied and observed simultaneously to form a GNSS loop. Coordinates of MST-27 and elevation values of MS-269 were held fixed during the processing of the control points as presented in Table 25. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 25 Control Point Constraints

Point ID	**Type**	**East σ (Meter)**	**North σ (Meter)**	**Height σ (Meter)**	**Elevation σ (Meter)**
MST-27	Global	Fixed	Fixed	Fixed	
MS-269	Grid				Fixed
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 26. All fixed control points have no values for grid and elevation errors.

Table 27. Adjusted grid coordinates for the control points used in the Mandaon floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MS-269	544123.788	0.018	1371483.424	0.013	27.408	?	e
MST-27	547922.386	?	1358609.337	?	53.606	0.063	LL
MST-4549	555464.635	0.009	1371246.784	0.006	21.829	0.043	
UP-ALA	535010.665	0.009	1353545.355	0.008	1.754	0.100	
UP-ASI	558628.712	0.007	1356091.508	0.006	10.476	0.069	
UP-GAN	555004.108	0.011	1372759.259	0.008	18.209	0.045	

The network is fixed at reference points. The list of adjusted grid coordinates of the network is shown in Table 27.Using the equation $\sqrt{((x_e)^2+(y_e)^2)}<20cm$ for horizontal and $z_e<10$ cm for the vertical; below is the computation for accuracy that passed the required precision:

a. a. MST-27

horizontal accuracy	=	Fixed
vertical accuracy	=	6.3 cm < 10 cm

b. MS-269

horizontal accuracy	=	$\sqrt{((1.8)^2 + (1.3)^2)}$
	=	$\sqrt{(3.24+ 1.69)}$
	=	2.2 cm< 20 cm
vertical accuracy	=	Fixed

c. MST-4549

horizontal accuracy	=	$\sqrt{((0.9)^2 + (0.6)^2)}$
	=	$\sqrt{(0.81 + 0.36)}$
	=	1.08 cm < 20 cm
vertical accuracy	=	4.30 cm < 10 cm

d. UP-ALA

horizontal accuracy	=	$\sqrt{((0.9)^2 + (0.8)^2)}$
	=	$\sqrt{(0.81 + 0.64)}$
	=	1.20 cm < 20 cm
vertical accuracy	=	10 cm < 10 cm

e. UP-ASI

horizontal accuracy	=	$\sqrt{((0.70)^2 + (0.60)^2)}$
	=	$\sqrt{(0.49 + 0.36)}$
	=	0.92 cm < 20 cm
vertical accuracy	=	6.90 cm < 10 cm

f. UP-GAN

horizontal accuracy	=	$\sqrt{((1.1)^2 + (0.8)^2)}$
	=	$\sqrt{(1.21 + 0.64)}$
	=	1.36 cm < 20 cm
vertical accuracy	=	4.5 cm < 10 cm

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

Table 28. Adjusted geodetic coordinates for control points used in the Mandaon River floodplain validation

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
MS-269	N12°24'21.62817"	E123°24'21.39816"	82.132	?	e
MST-27	N12°17'22.32360"	E123°26'26.50548"	109.123	0.063	LL
MST-4549	N12°24'13.29041"	E123°30'36.98735"	76.970	0.043	
UP-ALA	N12°14'38.06086"	E123°19'18.85903"	57.103	0.100	
UP-ASI	N12°15'59.72358"	E123°32'20.76940"	66.451	0.069	
UP-GAN	N12°25'02.55601"	E123°30'21.83023"	73.244	0.045	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 27. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 28.

Table 28 Reference and Control points and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
MST-27	2nd order, GCP	12°17'22.32360"	123°26'26.50548"	109.123	1358609.337	547922.386	53.606
MS-269	1st order, BM	12°24'21.62817"	123°24'21.39816"	82.132	1371483.424	544123.788	27.408
MST-4549	Used as Marker	12°24'13.29041"	123°30'36.98735"	76.970	1371246.784	555464.635	21.829
UP-ALA	UP Established	12°d14'38.06086"	123°19'18.85903"	57.103	1353545.355	535010.665	1.754
UP-ASI	UP Established	12°15'59.72358"	123°32'20.76940"	66.451	1356091.508	558628.712	10.476
UP-GAN	UP Established	12°25'02.55601"	123°30'21.83023"	73.244	1372759.259	555004.108	18.209

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

Cross-section, as-built survey and water-level marking was conducted on December 16, 2015at Alas Bridge in Brgy. Alas, Mandaon, Masbate. The survey was conducted using Trimble® SPS 882 in GNSS PPK survey technique along the downstream side of the bridge as shown in Figure 40.

Figure 40. The Mandaon Bridge facing upstream

As-built features of the bridge were determined to get the distance of spillway and abutments from the bridge approach. Cross-section data were incorporated with as-built data to create a cross-section diagram of Alas Bridge illustrated in Figure 41. The cross-sectional length of the bridge is 47 m with twelve (12) cross-sectional points acquired using UP-ALA as GNSS base station.

The water surface elevation of Mandaon River was acquired using PPK survey technique on December 16, 2015 at 11:23 pm. The resulting water surface elevation data with a value of 0.535 m MSL.was translated to the bridge

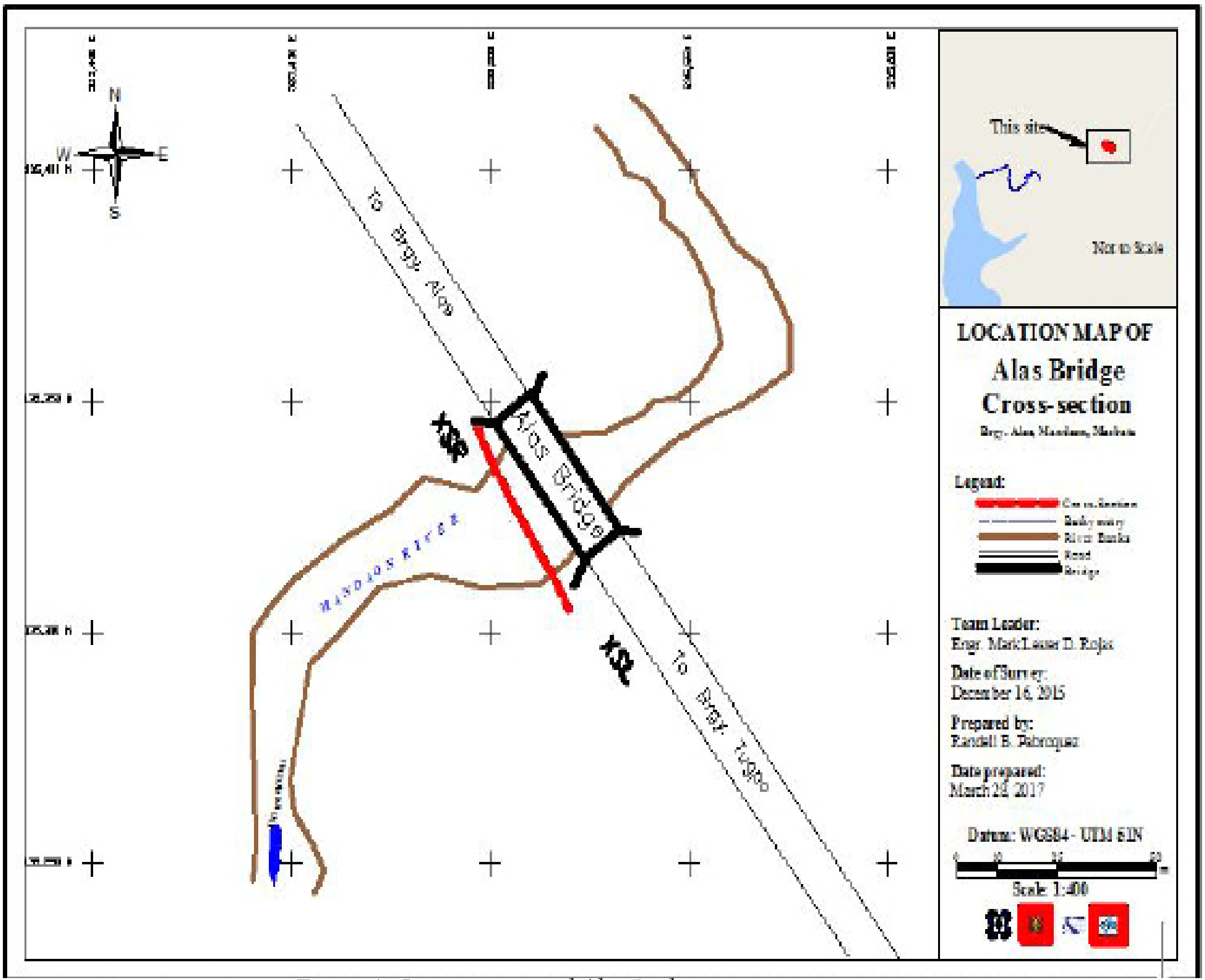


Figure 41. Location map od Alas Bridge cross section survey

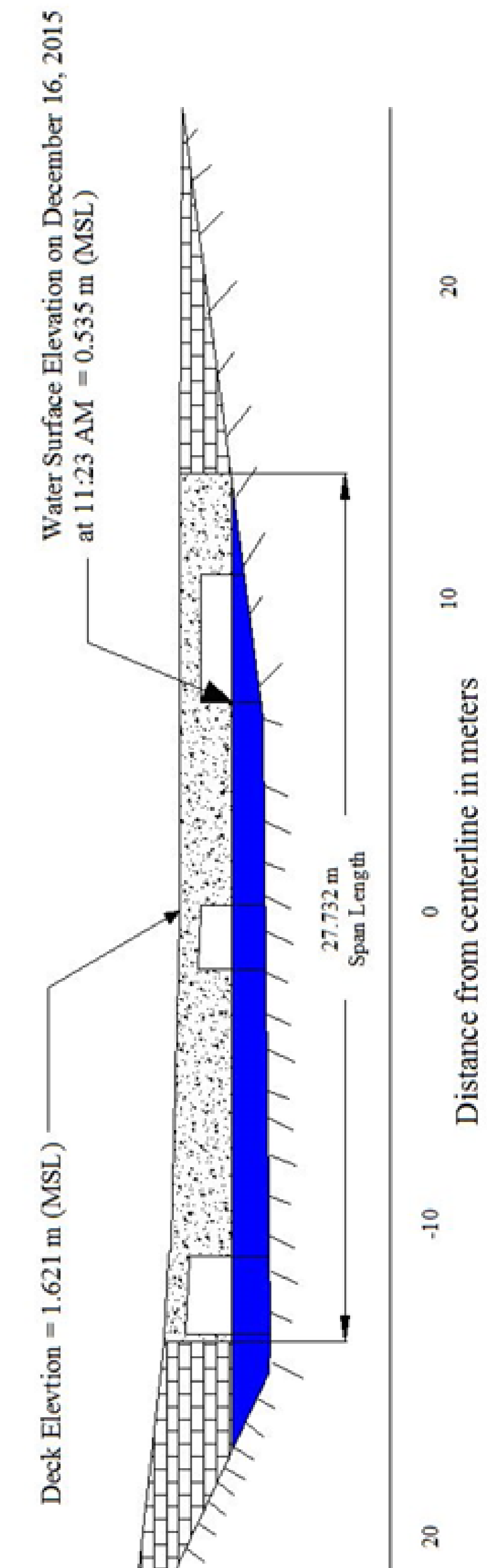


Figure 42. Alas Bridge cross-section diagram

Culvert Data Form

Culvert Name: ALAS BRIDGE — Date: December 16, 2015

River Name: MANDAON RIVER — Time: 11:23 am

Location (Brgy, City, Region): Brgy. Alas, Mandaon, Masbate

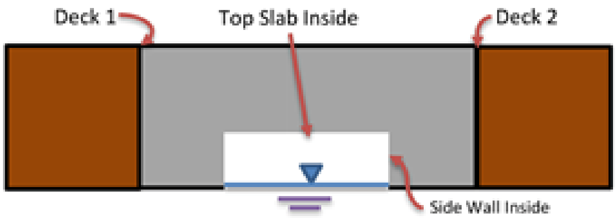
Survey Team: Team Masbate field survey / Team Mark

Flow condition: low normal high (circled: high)

Weather Condition: fair raining (circled: fair)

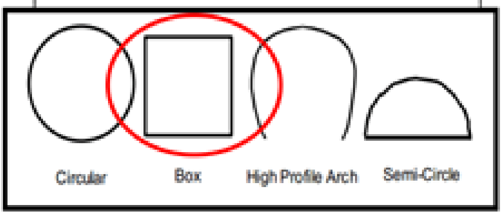
Latitude: 12d14'38.57107" N Longitude: 123d19'18.58825" E

Profile View



Culvert Shape:

Encircle the shape of the culvert



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

Elevation: 1.381 m — Width (# of lanes): 4.07 m.

Span (D2-D1): 27.732 m. — Number of Barrels: 3

Fill information needed below.

SHAPE	Diameter	Rise	Span
Circular			
Box		Approximately 1m	2.45 m
Arch			
Semi-circular			

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 43 Alas Bridge Culvert data form

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on December 5 to 6, 2015. A Trimble® SPS 882 was attached in front of a vehicle, as shown in Figure 43, to measure points utilizing continuous topo method in a PPK survey technique. The height of instrument was measured and noted a 1.902-meter distance from the ground up to the bottom of notch. Points were gathered along major concrete roads with the aid of a vehicle which moved at a speed of 20-40 kph, cutting across the flight strips of the DAC with the aid of available topographic maps and Google EarthTM images.

On December 05, validation points acquisition survey ran from Mabuaya Bridge in Brgy. Matiporon, Milagros to Brgy. Poblacion, Aroroy via Baleno in an almost semi-circumferential route .The reference point MST-4549 was utilized as the GNSS base station during this survey. The second day of this survey also started in Mabuayan Bridge going to Brgy. Poblacion in Aroroy via Mandaon, the other half of the circumferential road. This survey also covered Mandaon Road which started from Brgy. Mabatobato going southwest towards Brgy. Nailaban, both in the Municipality of Mandaon using MST-27 as the GNSS base station.

Figure 44 Validation points acquisition survey set-up: A Trimble® SPS 882, mounted on top of the vehicle

The map in Figure 44 shows the extent of the validation points acquisition survey which acquired a total of 4,709 ground validation points with an approximate length of 112km.

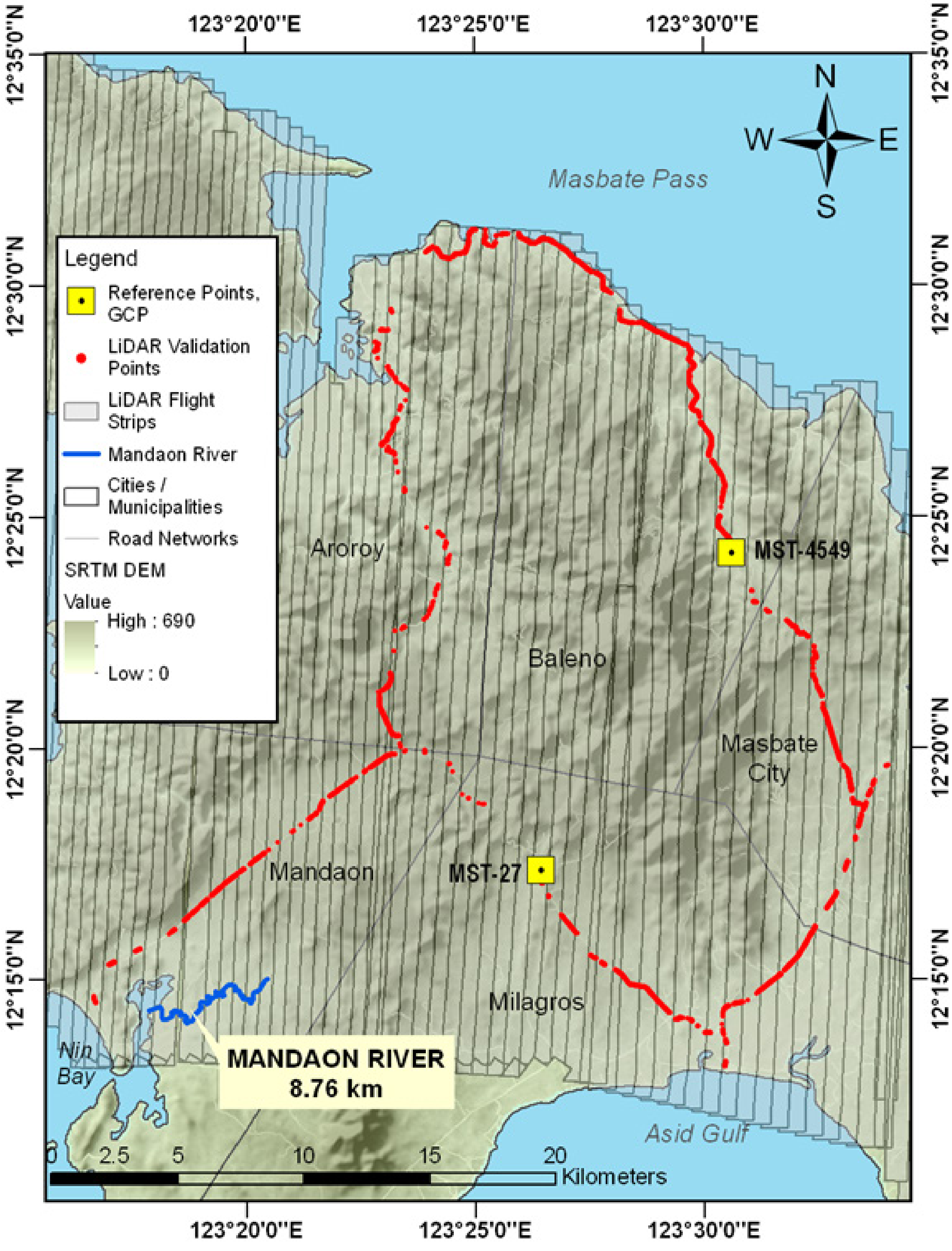


Figure 45 Validation points acquisition survey in Masbate

4.7 River Bathymetric Survey

Bathymetric survey was conducted on December 16, 2015 at Mandaon River. A boat with an installed Ohmex™ single beam echo sounder and a mounted Trimble® SPS 882 GNSS receiver was used in this survey as shown in Figure 45. The survey started in Brgy. Tagpu, Municipality of Mandaon with coordinates 12°14'09.79379"123°18'39.35782" and ended at the mouth of the river which is also at the same barangay but with coordinates 12°14'15.49862"123°17'40.52118". The bathymetric survey was supposed to cover 8.76 km of Mandaon River but the boat did not make it any further upstream because of the strong current of the river after Typhoon 'Nona' traversed the province of Masbate on December 14-15, 2015.

Figure 46 Bathymetric survey set-up using OHMEX™ single beam echo sounder and amounted with a Trimble® SPS 882

The bathymetric survey gathered a total of 4,529 points and produced a centerline profile of 2.84 km covering just a part of Brgy. Tagpu as shown in Figure 46.A CAD drawing was also produced to illustrate the Mandaon riverbed profile. As shown in Figure 47, the highest and lowest elevation has a 3-meter difference. The highest elevation observed was 1.040 m below MSL while the lowest was 4.443 m below MSL, both located in Brgy. Tagpu, Mandaon, Masbate.

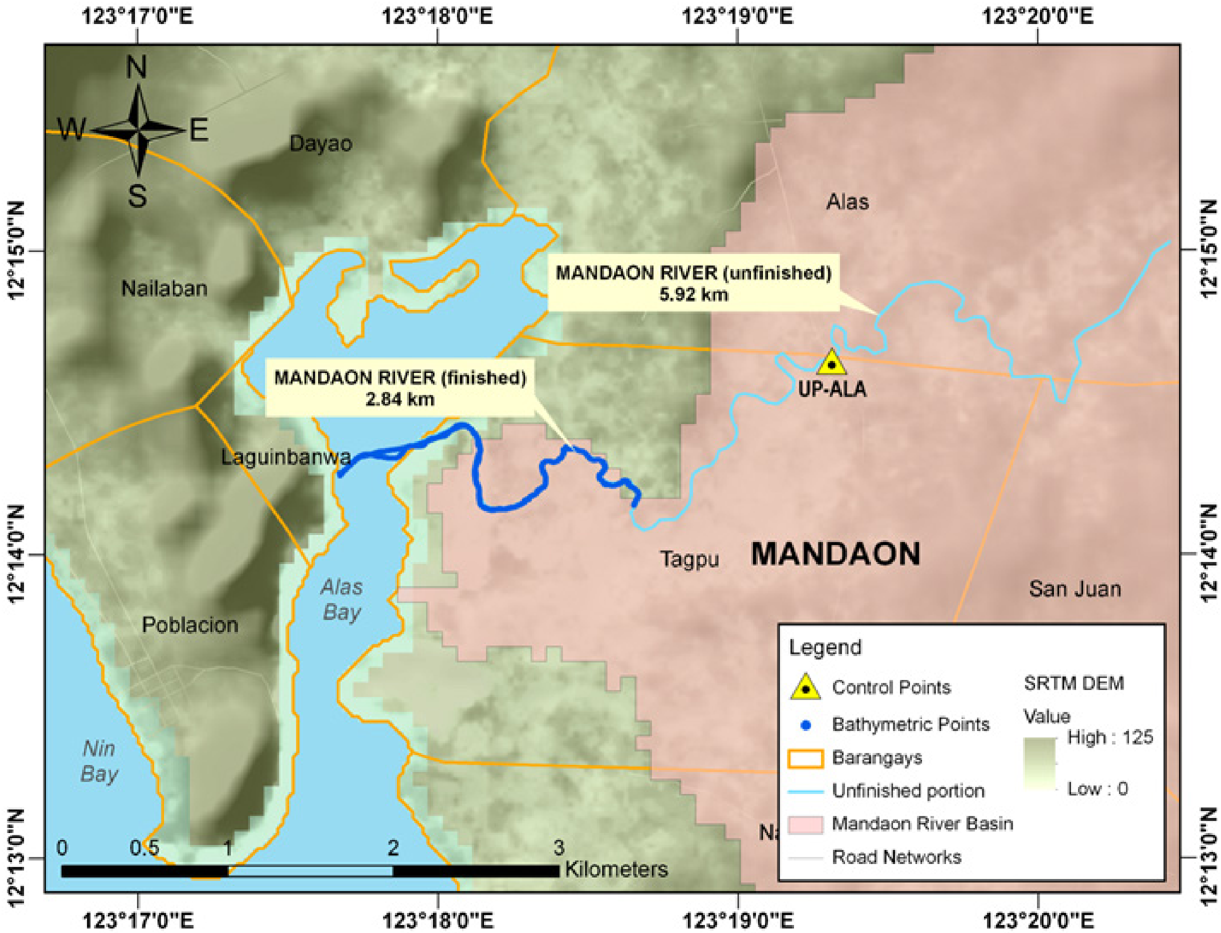


Figure 47 Bathymetric survey along Mandaon River

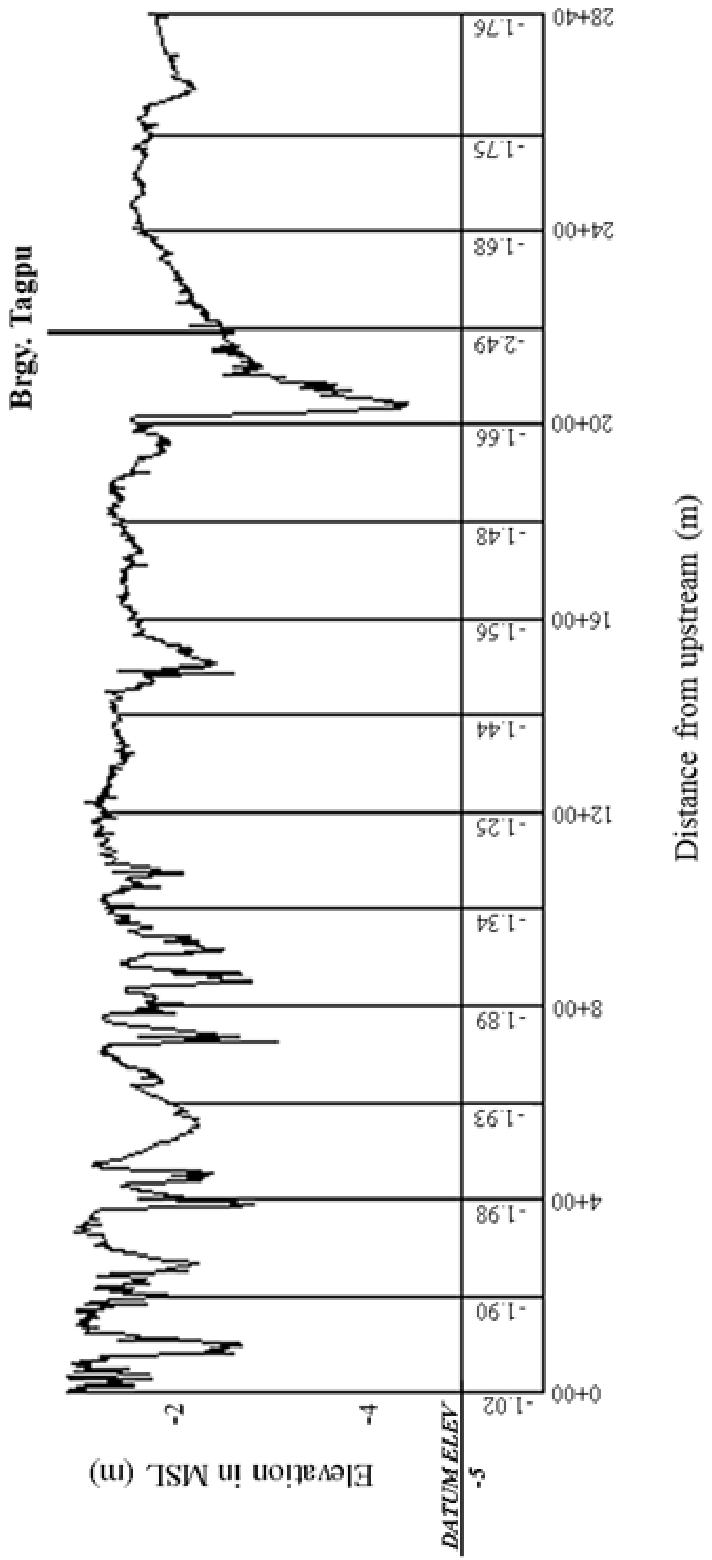


Figure 48. Extent of the bathymetric survey of the Mandaon River

CHAPTER 5: FLOOD MODELING AND MAPPING

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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

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

5.1.2 Precipitation

Precipitation data was taken from one automatic rain gauge (ARGs) installed by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). The rain gauge was installed at Mandaon Municipal Hall (Figure 48).The precipitation data collection started from January 16, 2017 at 12:00 AM to January 16, 2017 at 11:50PM with a 10-minute recording interval.

The total precipitation for this event in Mandaon Municipal Hall ARG is 89.4mm. It had a peak rainfall of 7.4mm on January 16, 2017 at6:50 AM. The lag time between the peak rainfall and discharge was 10 minutes.

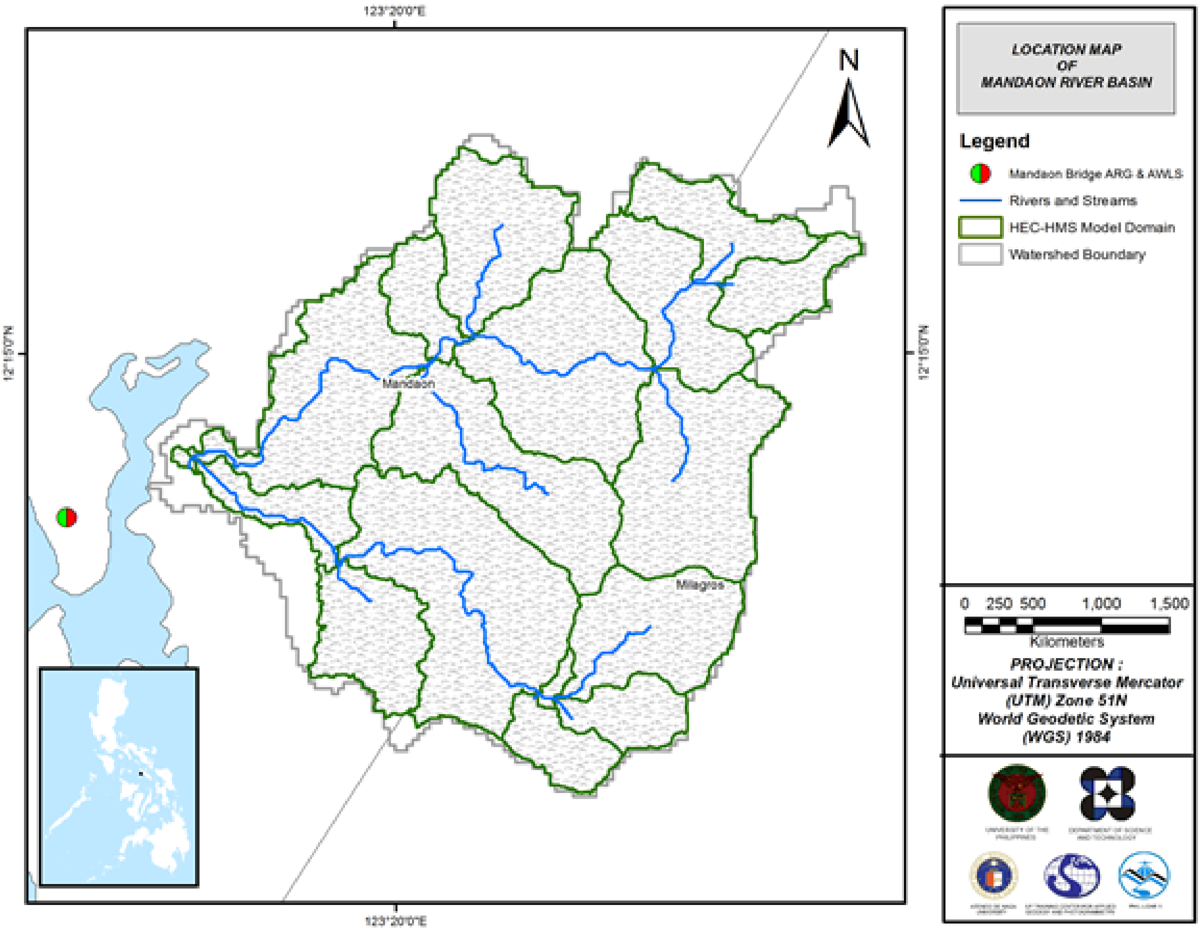

Figure 49 The location map of Mandaon HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Tagpu Box Culvert, Mandaon, Masbate (12°13’36.33"N, 123°17'9.0"E). It gives the relationship between the observed water levels at Tagpu Box Culvert and outflow of the watershed at this location.

For Tagpu Box Culvert, the rating curve is expressed as Q = 1.9334e2.2702has shown in Figure 50.

Thus river basin has no cross-section plot of Tagpu Box Culvert

Figure 50 This report has no cross-section plot of Tagpu Box Culvert

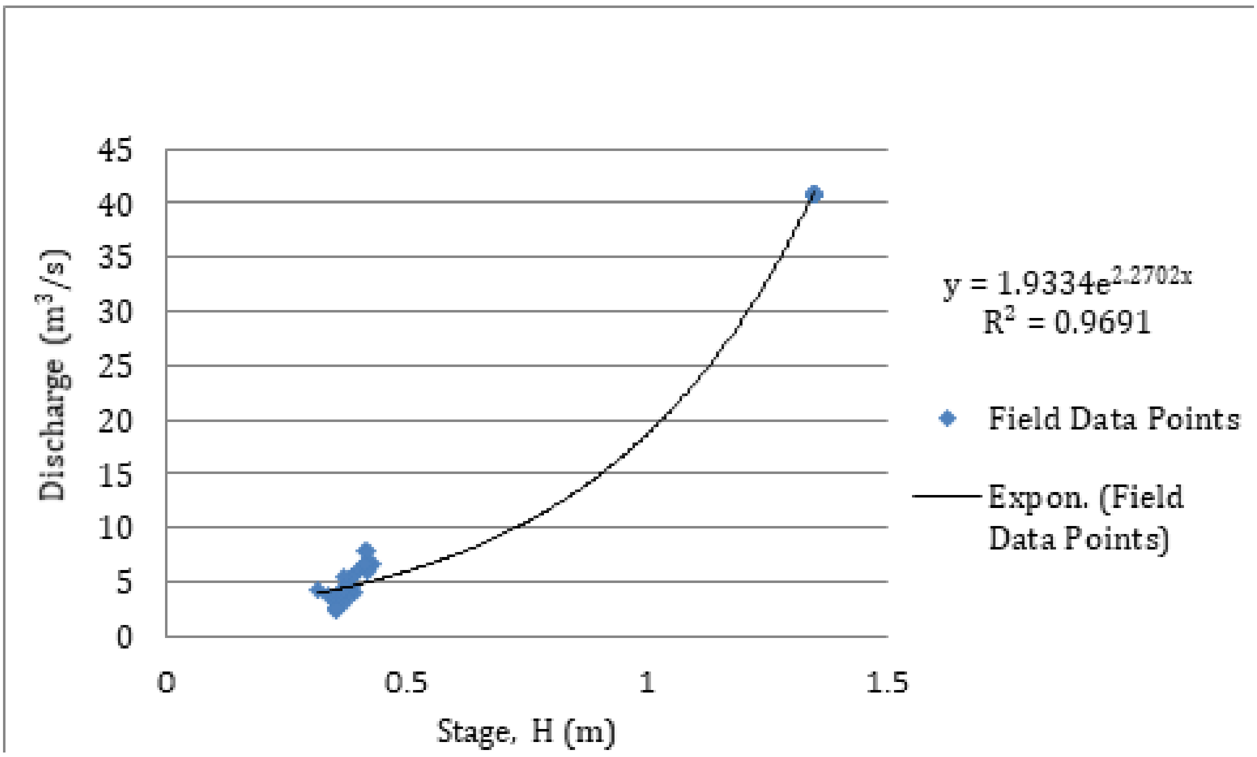

Figure 51 The rating curve of Tagpu Box Culvert in Mandaon, Masbate

This rating curve equation was used to compute the river outflow at Tagpu Box Culvert for the calibration of the HEC-HMS model shown in Figure 51. The total rainfall for this event was 89.4mm and the peak discharge was 580.4m3/s at 6:50 AM, January 16, 2017.

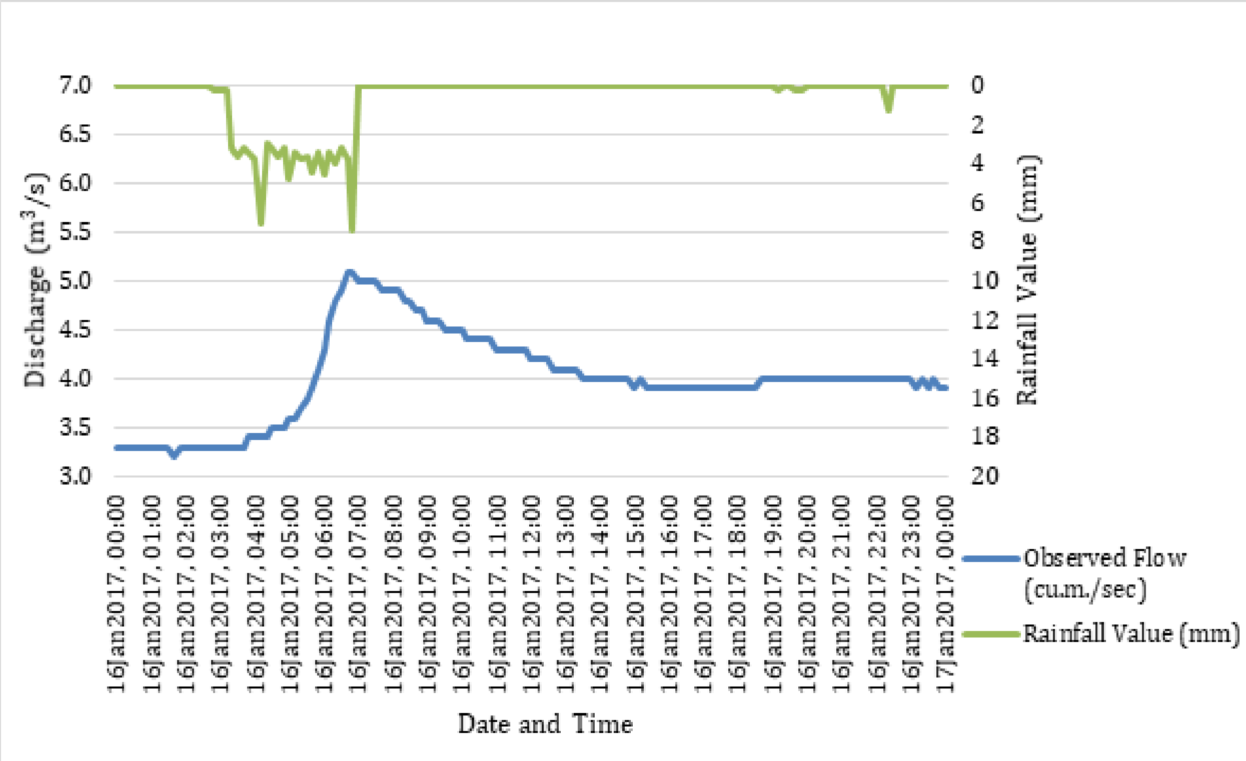

Figure 52. Rainfall and outflow data at the Mandaon Bridge used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Legazpi RIDF. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station was chosen based on its proximity to the Mandaon watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 29 RIDF values for Mandaon Rain Gauge computed by PAG-ASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	**10 mins**	**20 mins**	**30 mins**	**1 hr**	**2 hrs**	**3 hrs**	**6 hrs**	**12 hrs**	**24 hrs**
2	21	31.9	39.6	53.4	74.5	89.3	119.2	145.5	176.4
5	29.1	43.8	54.5	76.7	113.4	138.5	189.8	228.7	260.5
10	34.5	51.6	64.3	92.2	139.1	171.1	236.6	283.8	316.1
15	37.5	56	69.8	100.9	153.6	189.4	263	314.8	347.5
20	39.6	59.1	73.7	107	163.7	202.3	281.5	336.6	369.5
25	41.3	61.5	76.7	111.7	171.6	212.2	295.7	353.4	386.4
50	46.3	68.9	85.9	126.2	195.7	242.7	339.6	405	438.6
100	51.3	76.2	95.1	140.5	219.6	273.1	383.1	456.2	490.3

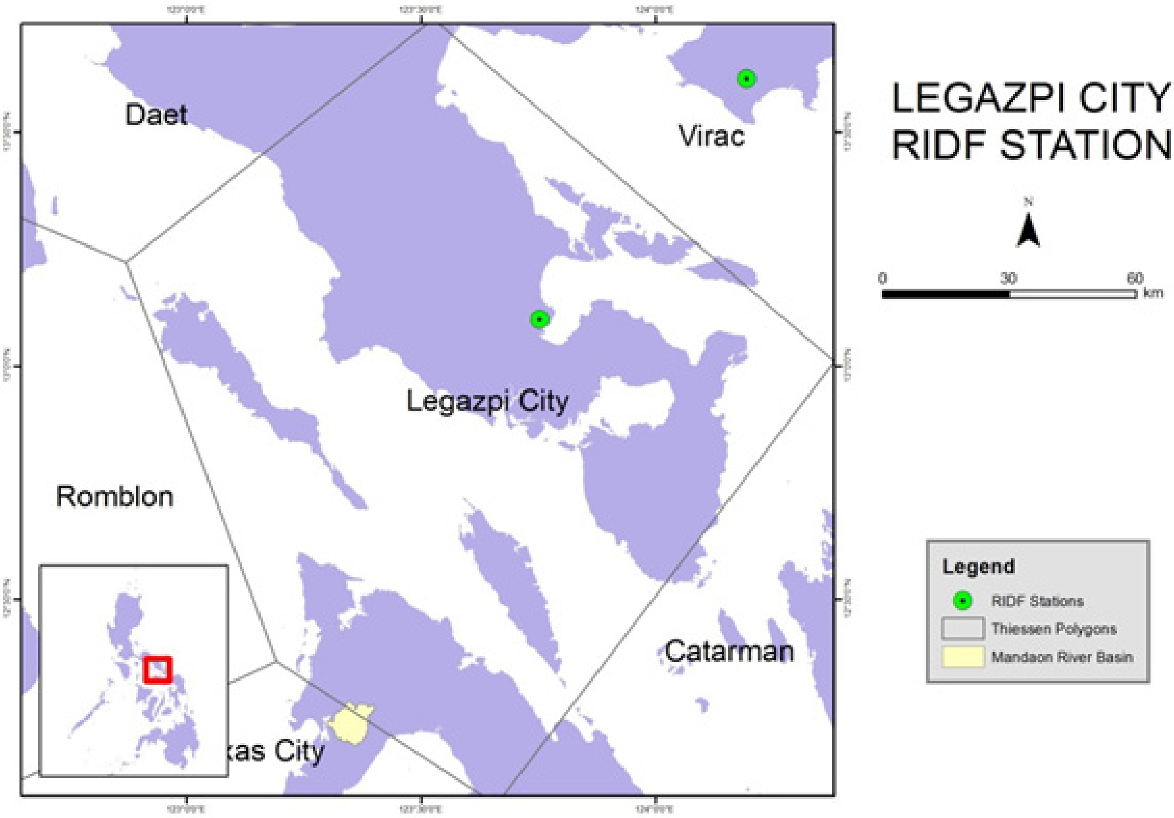

Figure 53 The location of the Legazpi City RIDF station relative to the Mandaon River Basin

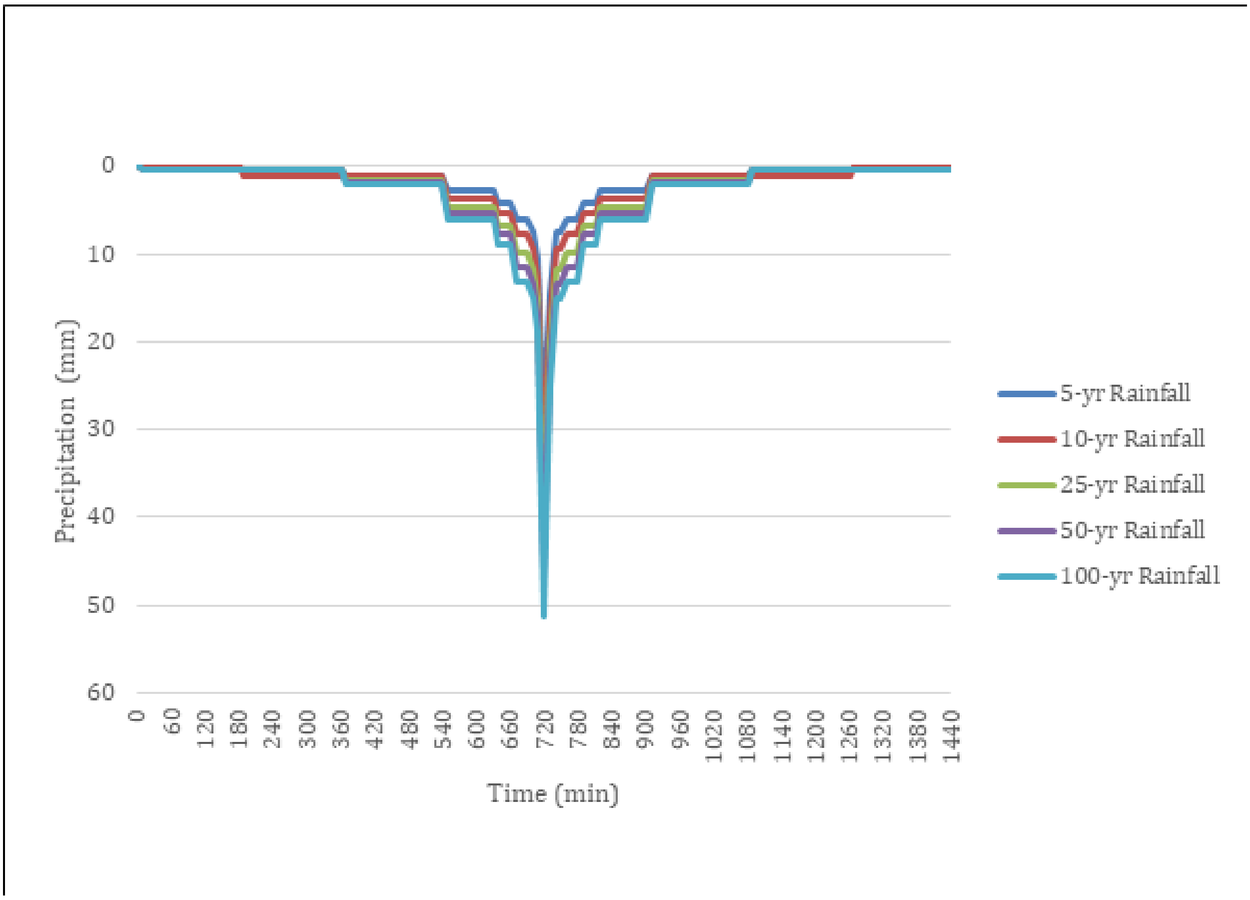

Figure 54 The synthetic storm generated for a 24-hour period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 by the Bureau of Soils under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Mandaon River Basin are shown in Figures 54 and 55, respectively.

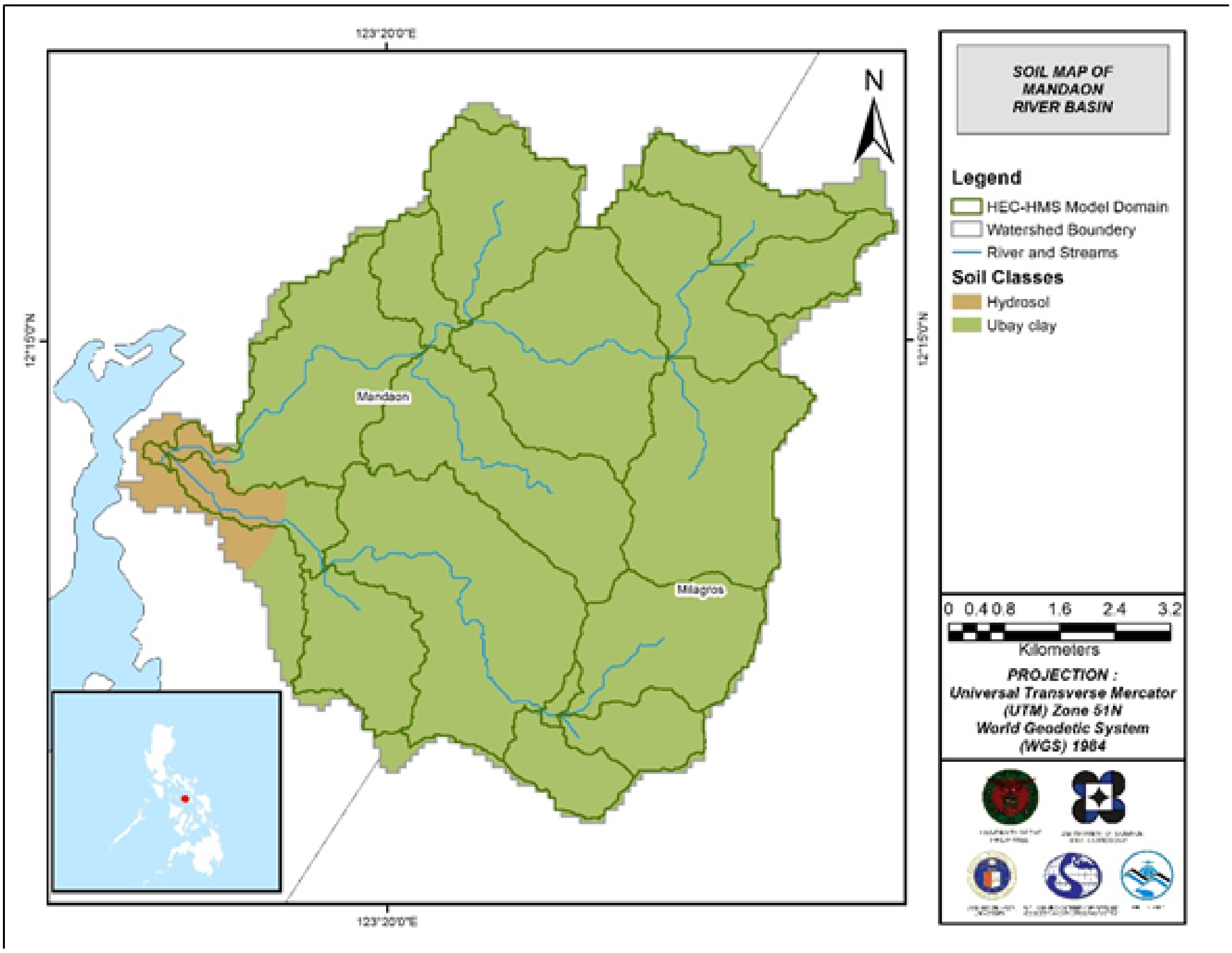

Figure 55 Soil map of Mandaon River Basin

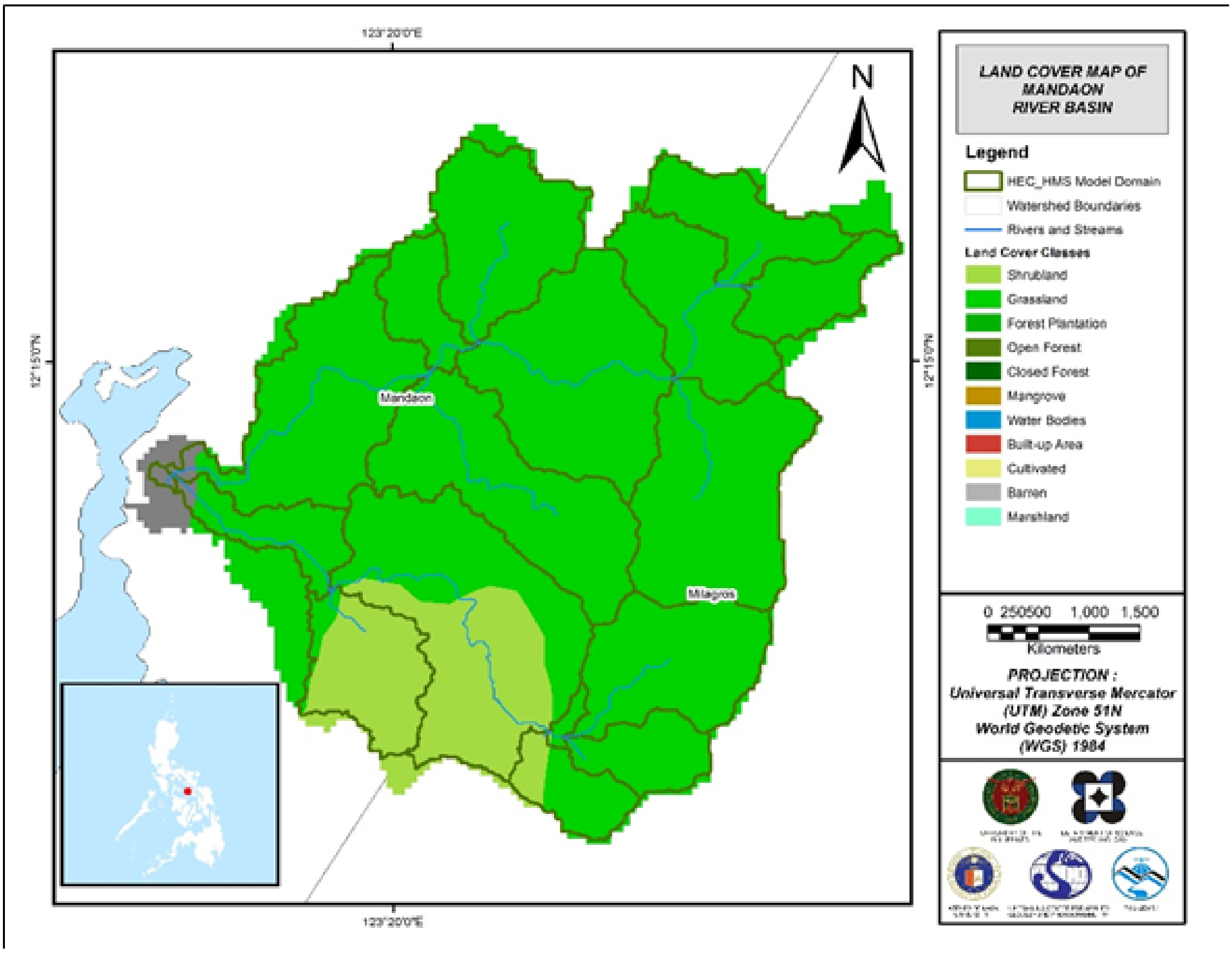

Figure 56 Land cover map of Mandaon River Basin

For Mandaon, two soil classes were identified. These are Ubay clay and hydrosol. Moreover, three land cover classes were identified. These are grassland, shrubland, and barren areas.

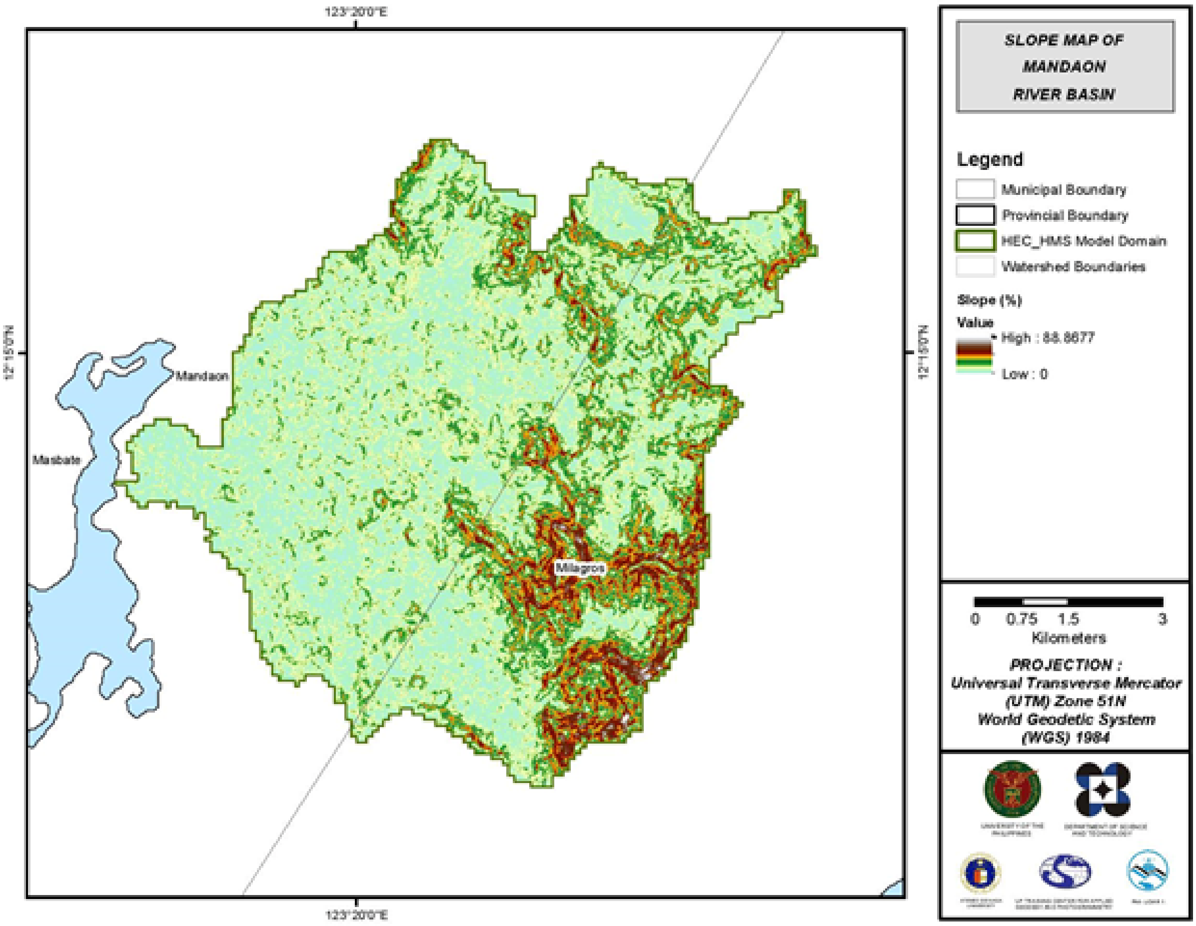

Figure 57 Slope map of Mandaon River Basin

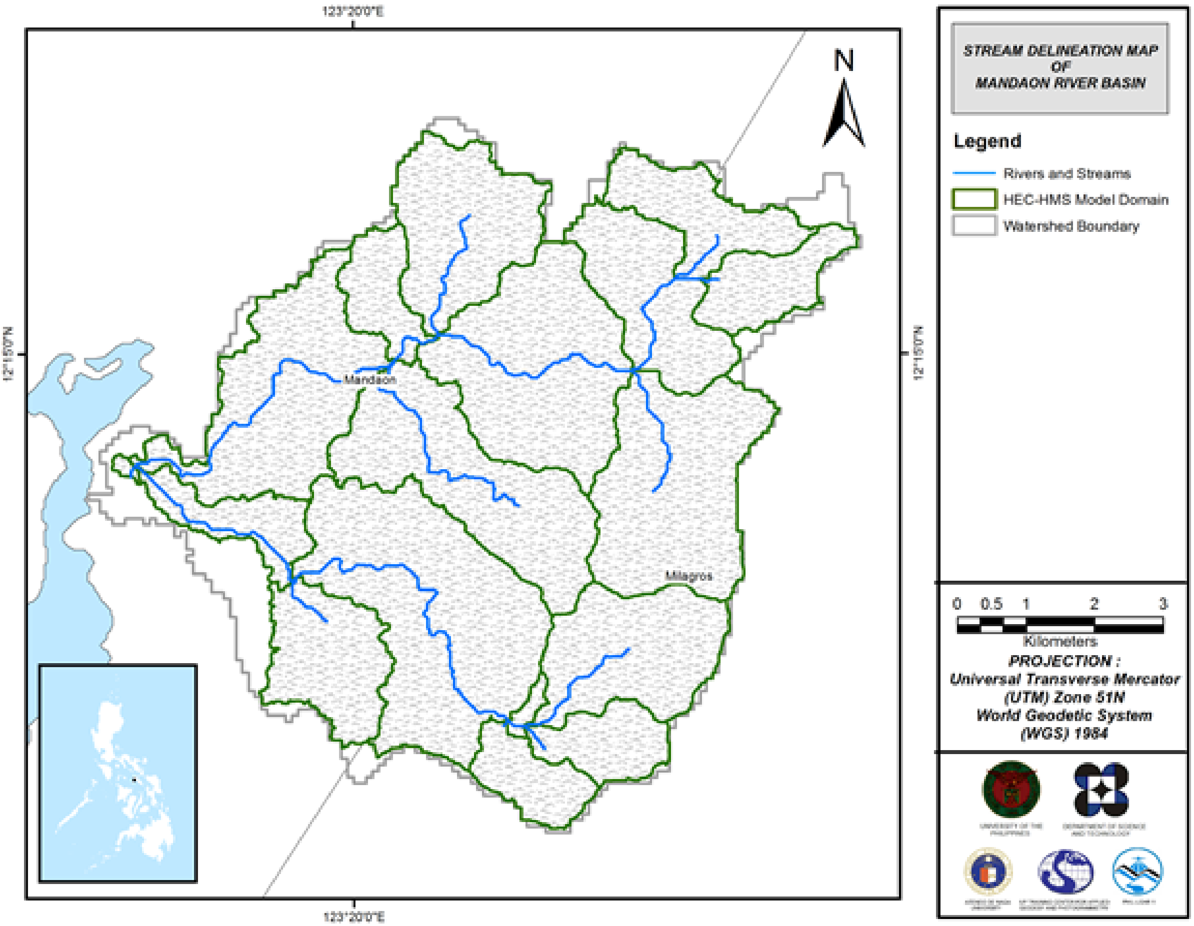

Figure 58 Stream delineation map of Mandaon River Basin

Using the SAR-based DEM, the Mandaon basin was delineated and further divided into subbasins. The model consists of 21 sub basins, 10 reaches, and 10 junctions, as shown in Figure 58. The main outlet is Tagpu Box Culvert.

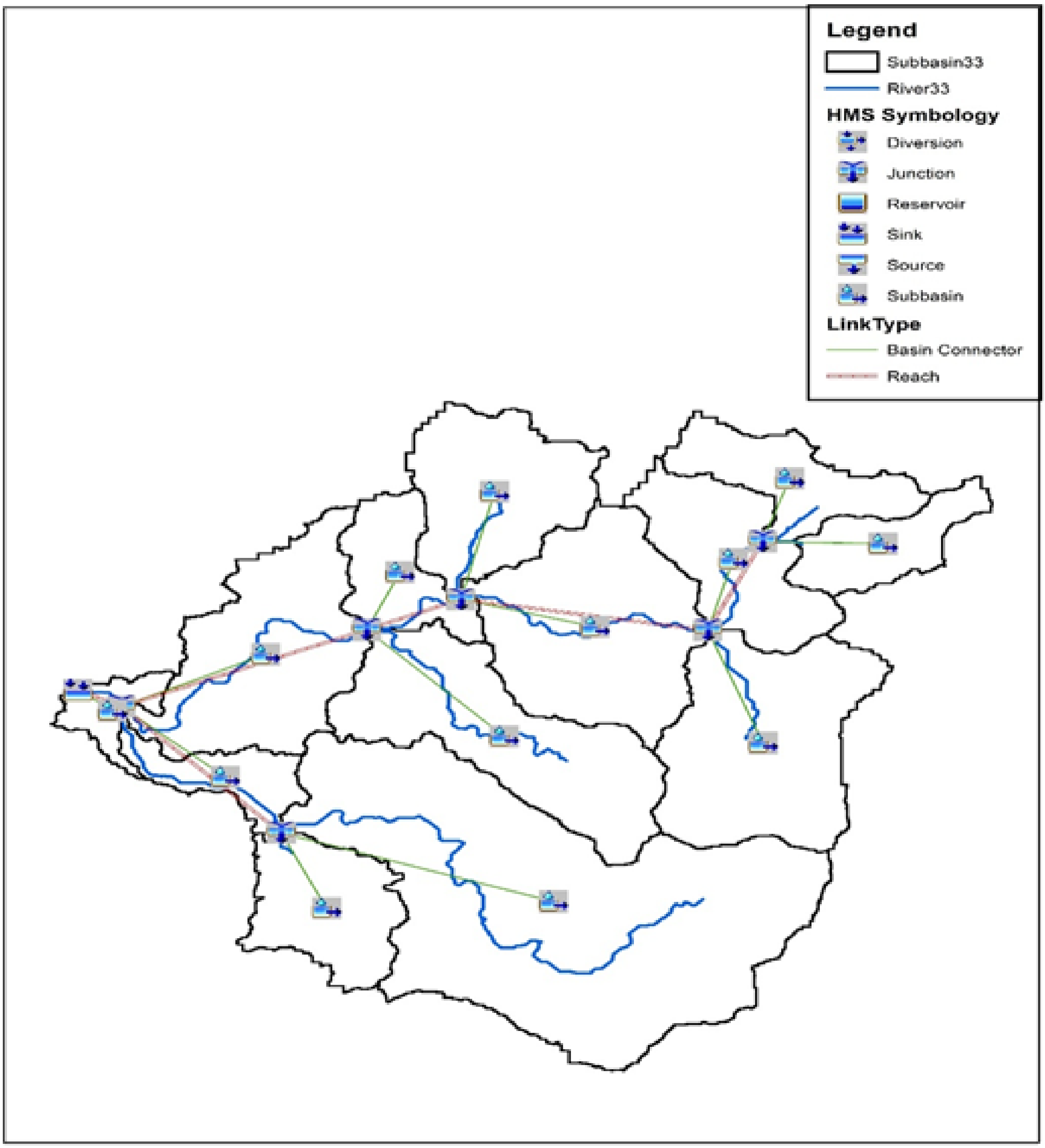

Figure 59 The Mandaon River Basin model generated in HEC-HMS

5.4 Cross-section Data

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

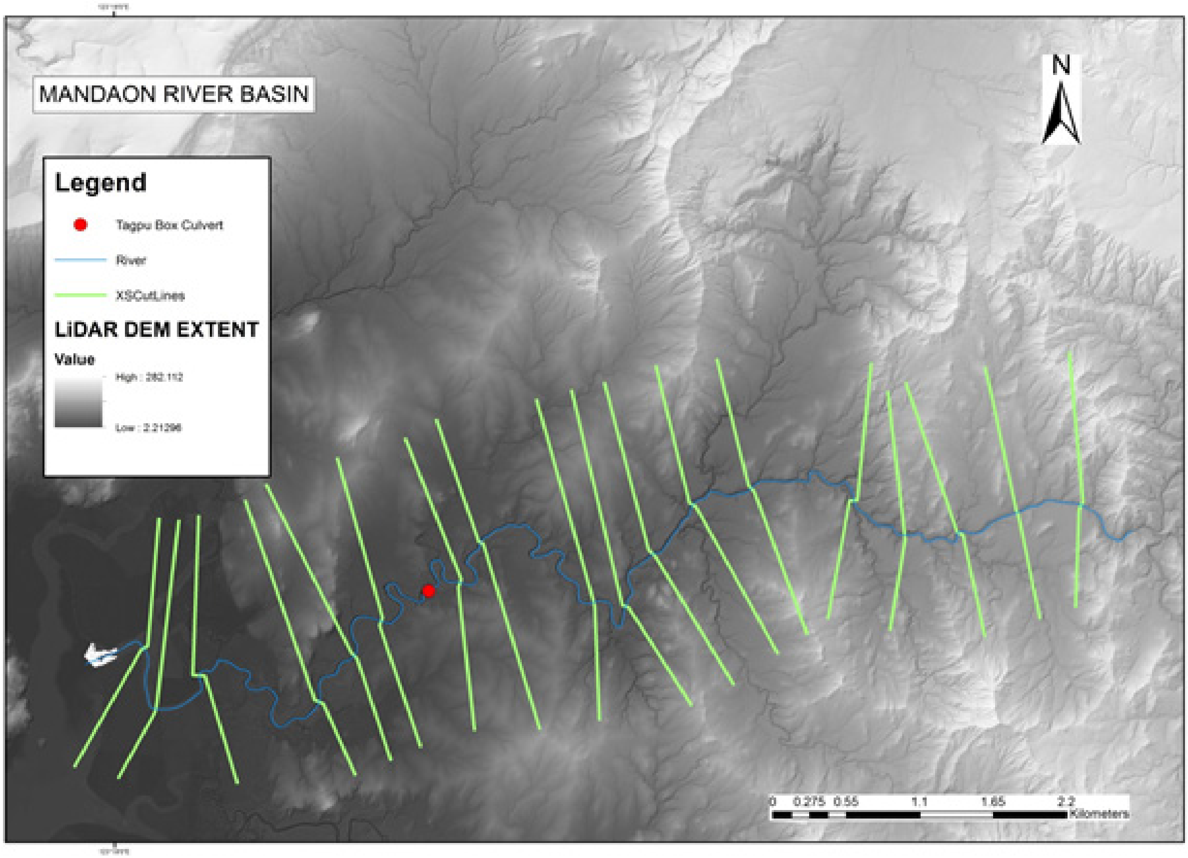

Figure 60 River cross-section of Alas River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

Figure 61 Screenshot of subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 29.44629 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 48,622,000.00 m2.

There is a total of 12,899,636.39 m3 of water entering the model. Of this amount, 12,899,636.39 m3 is due to rainfall while 0.00 m3 is inflow from other areas outside the model. 3,928,841.50 m3 of this water is lost to infiltration and interception, while 3,321,255.42 m3 is stored by the flood plain. The rest, amounting up to 5,649,538.15

5.6 Results of HMS Calibration

After calibrating the Mandaon HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 61 shows the comparison between the two discharge data.

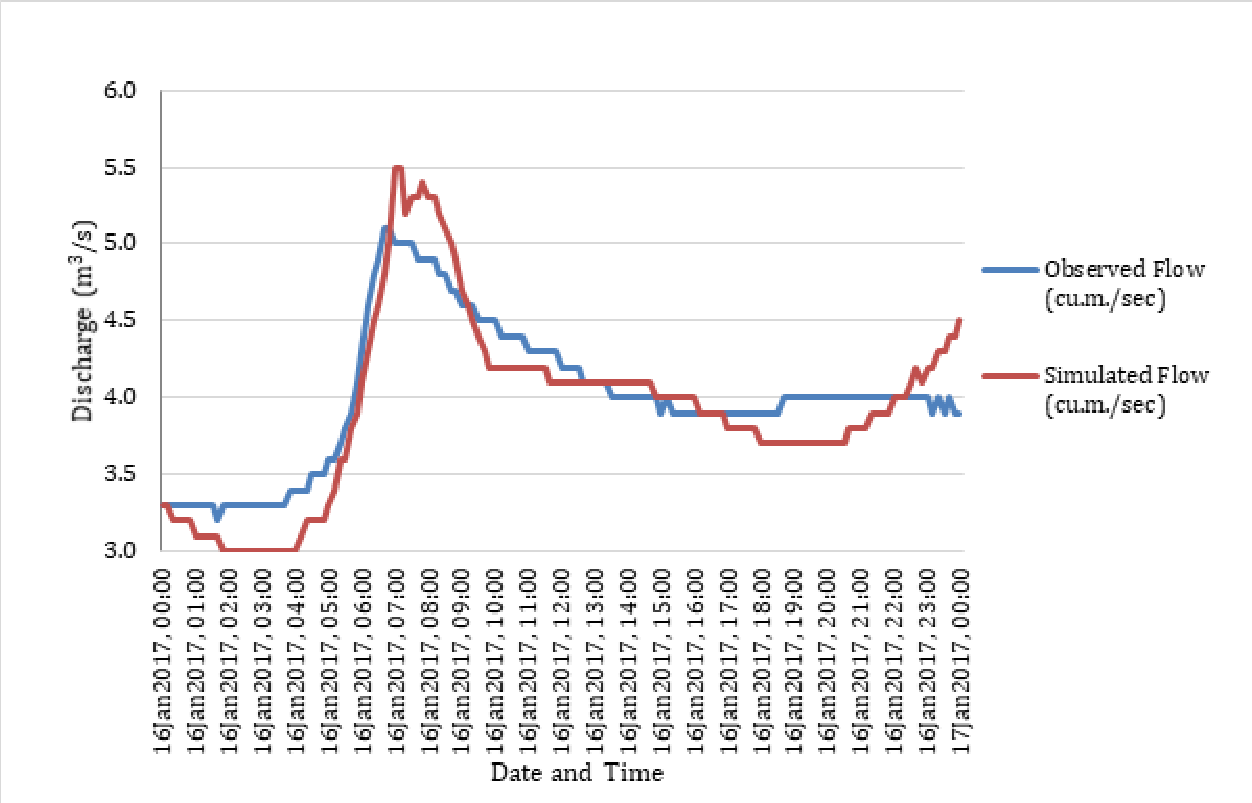

Figure 62 Outflow hydrograph of Mandaon River Basin produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 30 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 30 Range of calibrated values for the Mandaon River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.001-121
			Curve Number	35-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02-144
			Storage Coefficient (hr)	0.06-70
	Baseflow	Recession	Recession Constant	0.00001
			Ratio to Peak	0.0001-0.2
Reach	Routing	Muskingum-Cunge	Slope	0.001-0.02
			Manning's Coefficient	0.0001-1

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.001mm to 121mm means that there is minimal to high 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 35 to 99 for curve number is wider than the advisable for Philippine watersheds (70-80), depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Mandaon, the basin mostly consists of grassland and the soil consists of Ubay clay and hydrosol.

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 0.02 hours to 144 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. For Mandaon, it will take 13 hours from the peak discharge to go back to the initial discharge.

Manning's roughness coefficient of 0.0001 corresponds to the common roughness of Mandaon watershed, which was determined to be built-up area that is concrete and float-finished (Brunner, 2010).

Table 31 Summary of the Efficiency Test of Mandaon HMS Model

Accuracy measure	Value
RMSE	0.23
r2	0.89
NSE	0.75
PBIAS	1.74
RSR	0.50

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 0.89.

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 0.75.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 1.74.

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 0.50.

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 62) shows the Mandaon outflow using the synthetic storm events using the Legazpi Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results revealed significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods from 36.3m3/s in a 5-year return period to 108.3m3/s in a 100-year return period.

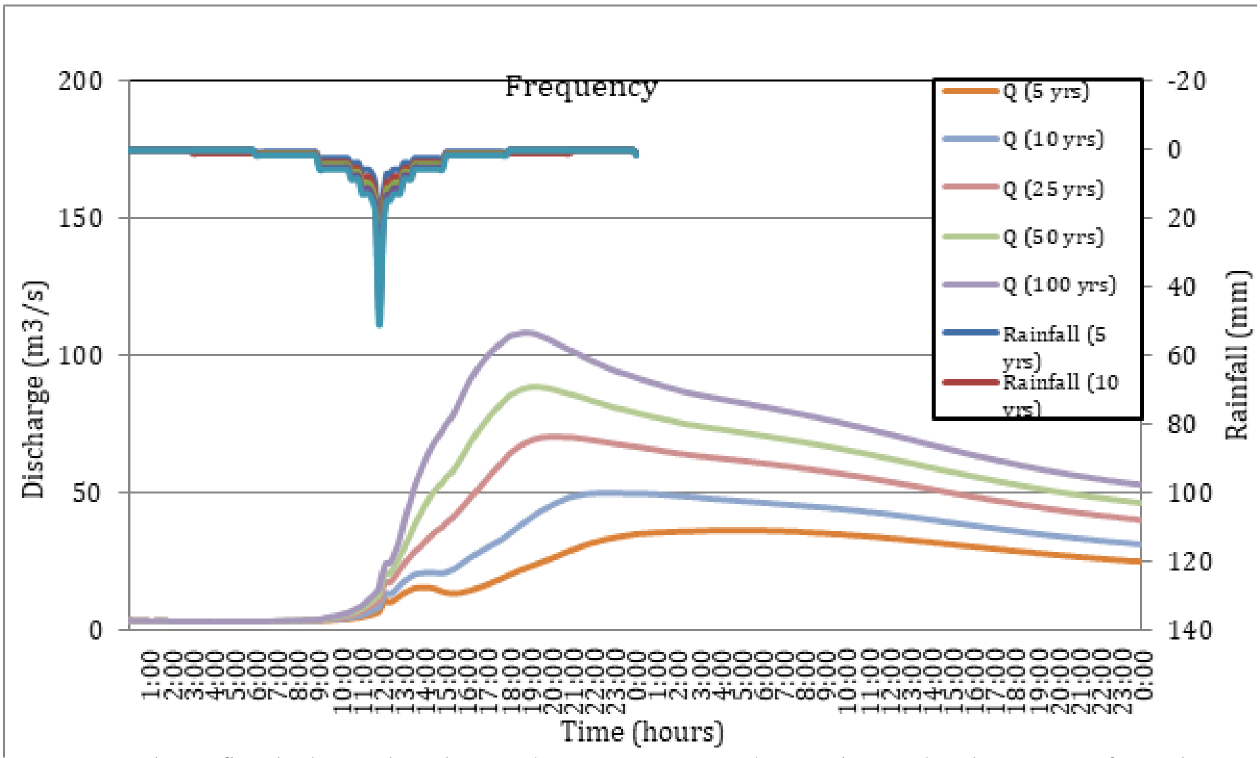

Figure 63 The outflow hydrograph at the Mandaon Basin, generated using the simulated rain events for 24-hour period for Legazpi station

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Mandaon discharge using the Tacloban RIDF curves in five (5) different return periods is outlined in Table 33.

Table 32 Peak values of the Mandaon HEC-HMS Model outflow using the Legazpi RIDF 24-hour values

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	260.50	29.1	36.3	16 hours
10-Year	316.10	34.5	50.2	10hours, 20minutes
25-Year	386.40	41.3	70.2	8 hours
50-Year	438.40	46.3	88.9	7 hours, 10 minutes
100-Year	490.30	51.3	108.3	6 hours, 50 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river is shown, since only the ADNU-DVC base flow was calibrated. The sample generated map of Mandaon River using the calibrated HMS base flow is shown in Figure 63.

Figure 64 The sample output map of the Mandaon RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figures 64 to 69 show the 5-, 25-, and 100-year rain return scenarios of the Mandaon floodplain. The flood plain, with an area of 74.97km2, covers two (2) municipalities, namely Mandaon and Milagros. Table 33 shows the percentage of area affected by flooding per municipality.

Table 33 Municipalities affected in Mandaon Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Mandaon	220.76	55.45	25.12
Milagros	530.43	9.55	1.8

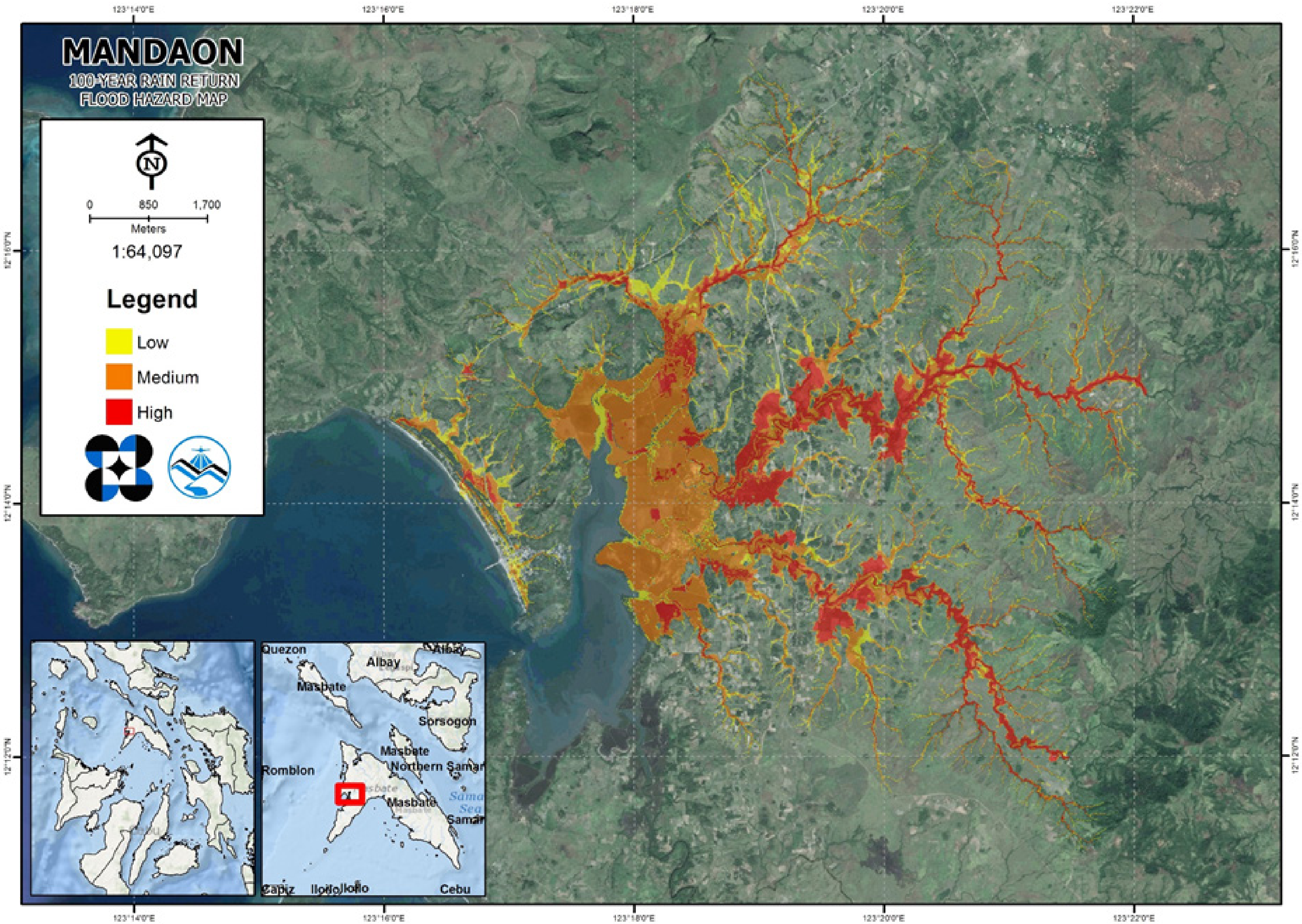

Figure 65 100-year flood hazard map for the Mandaon flood plain overlaid on Google Earth imagery

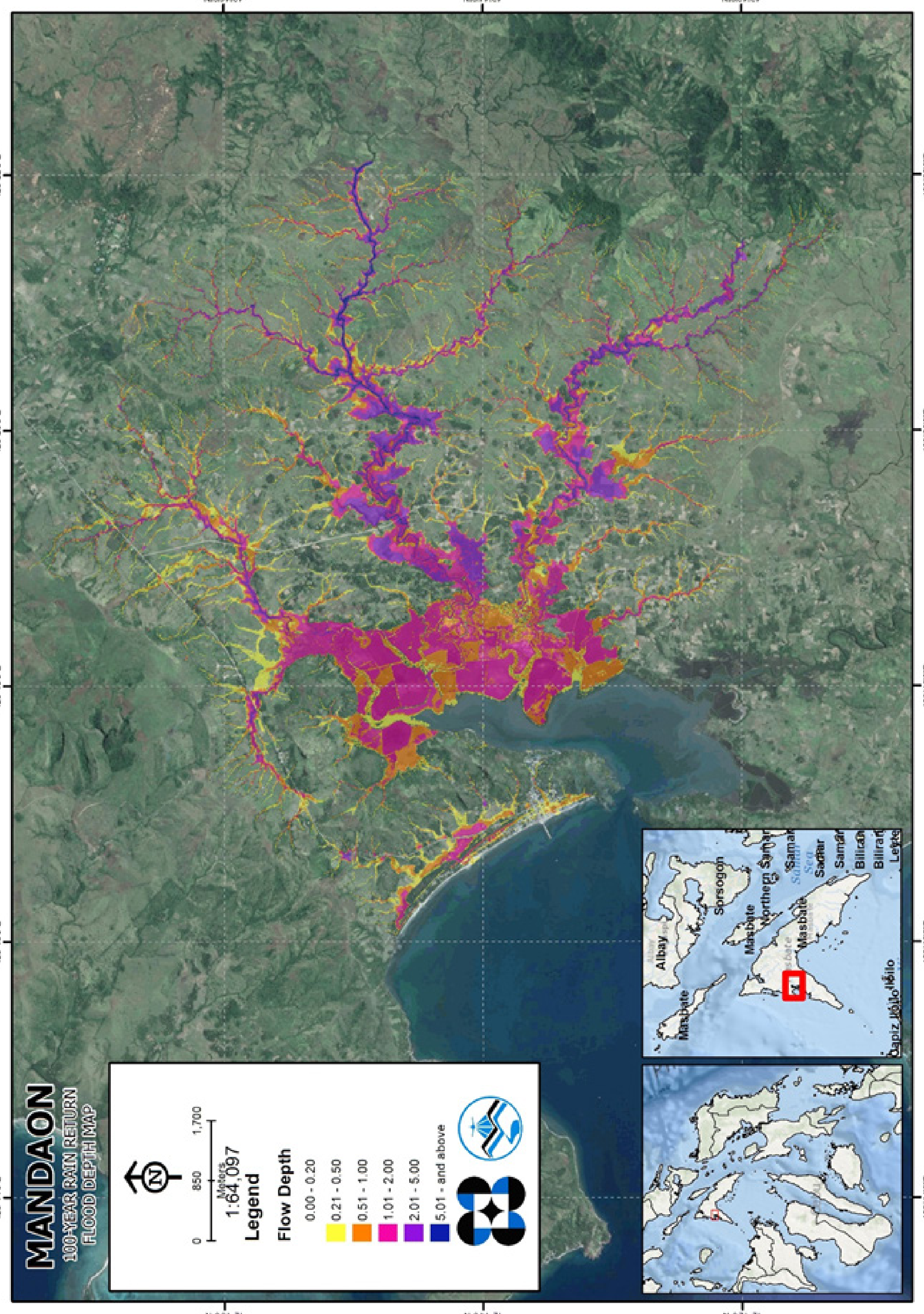

Figure 66 100-year flow depth map for the Mandaon flood plain overlaid on Google Earth imagery

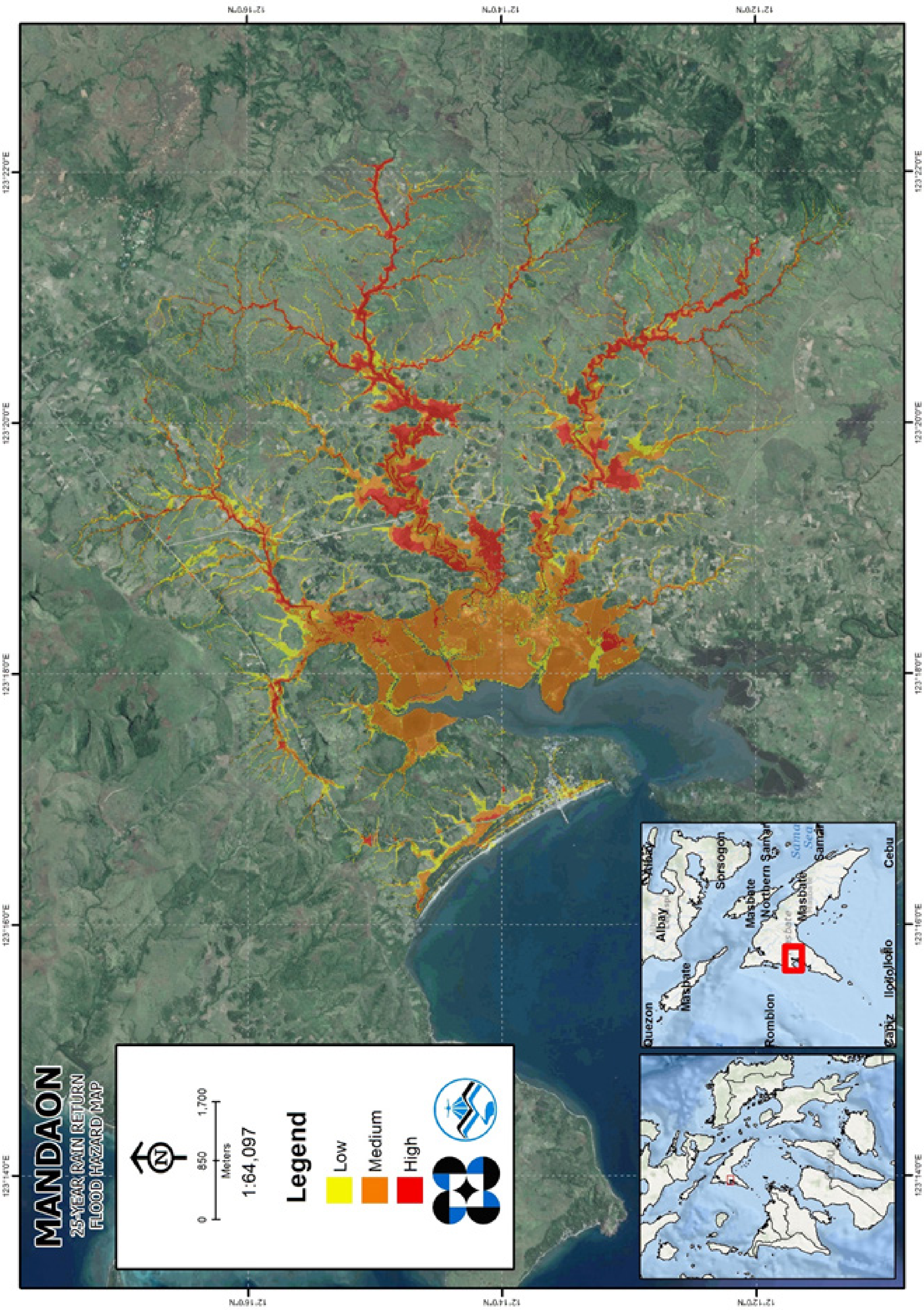

Figure 67. 25-year flood hazard map for the Mandaon flood plain overlaid on Google Earth imagery

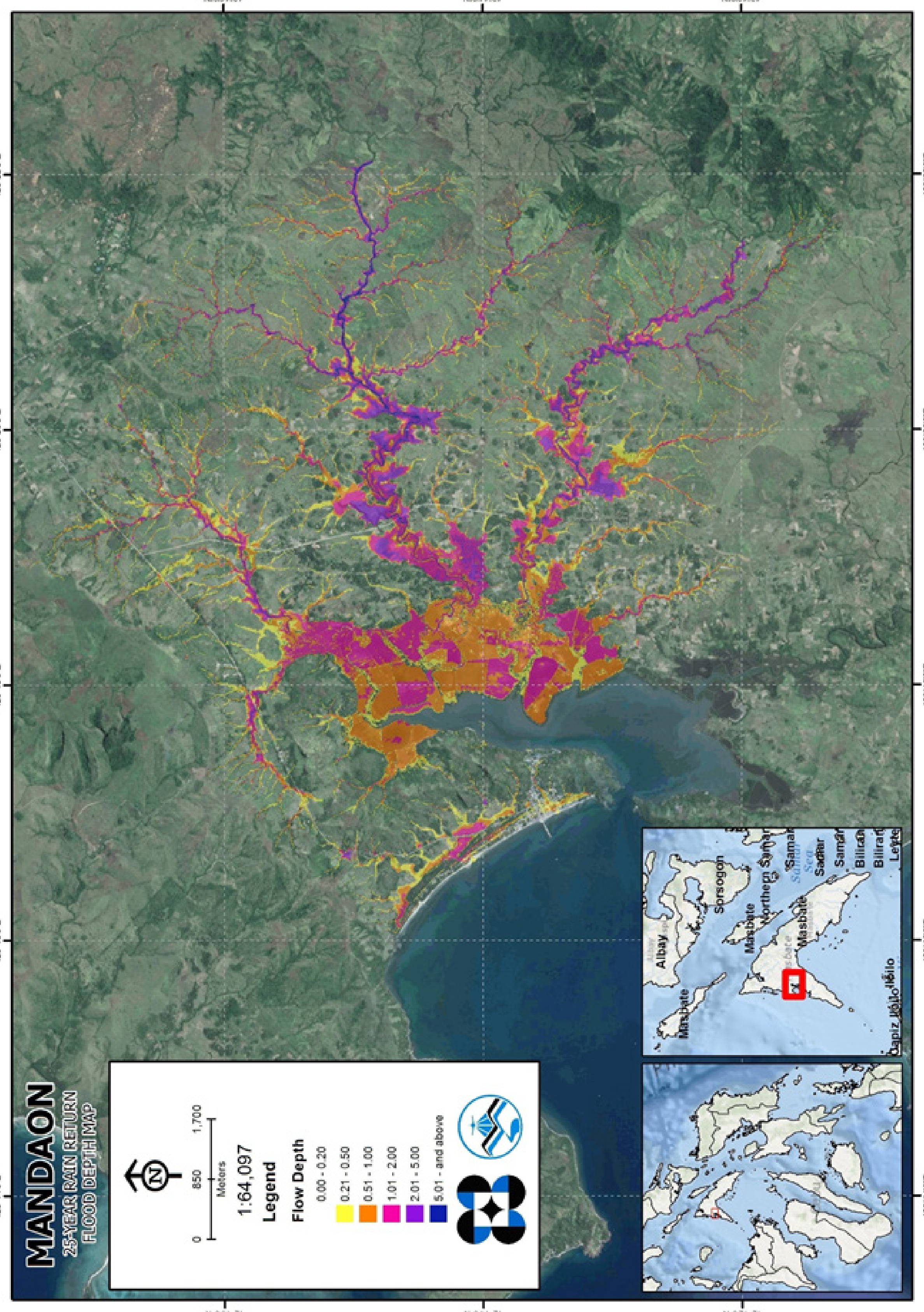

Figure 68 25-year flow depth map for the Mandaon flood plain overlaid on Google Earth imagery

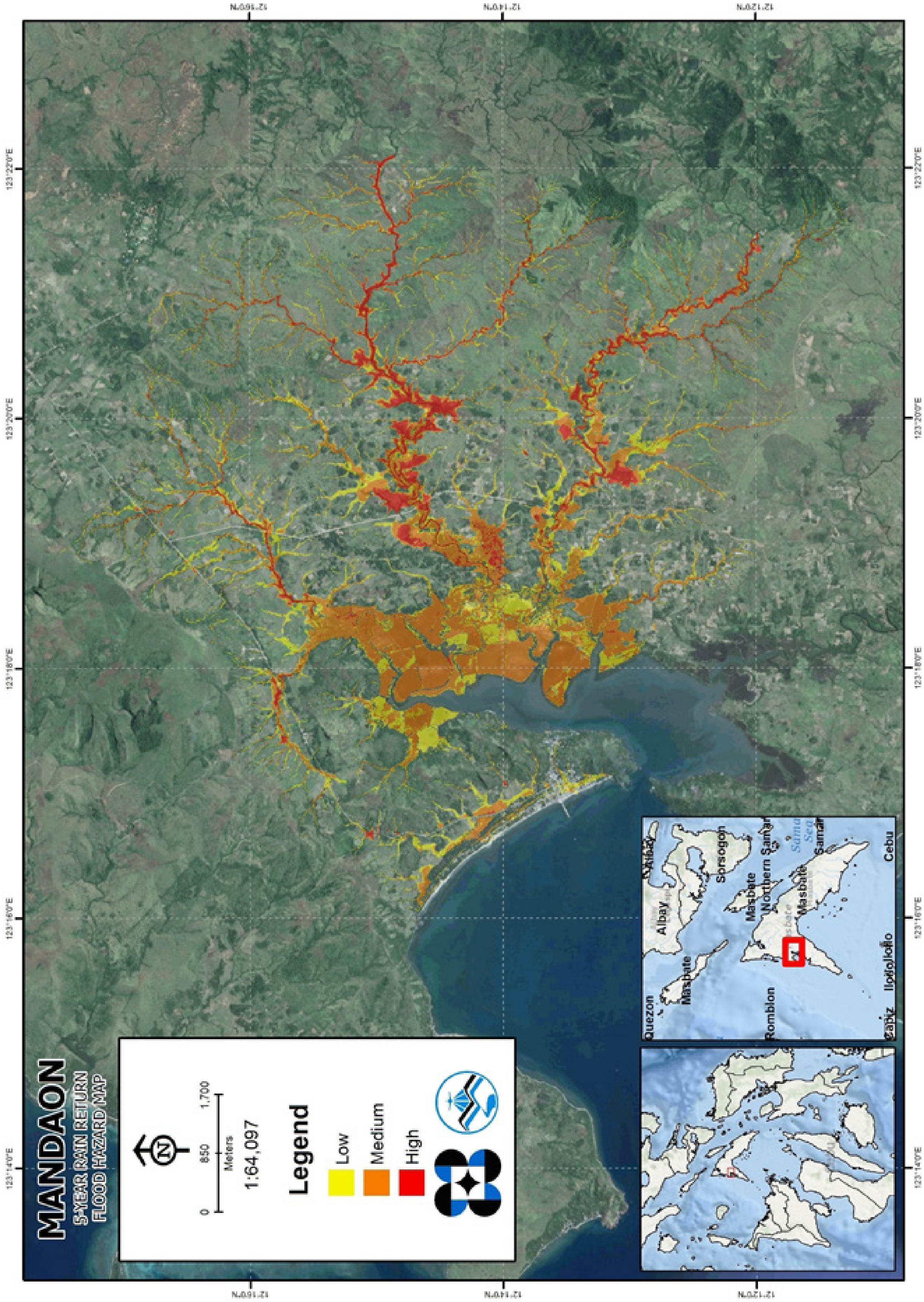

Figure 69 5-year flood hazard map for the Mandaon flood plain overlaid on Google Earth imagery

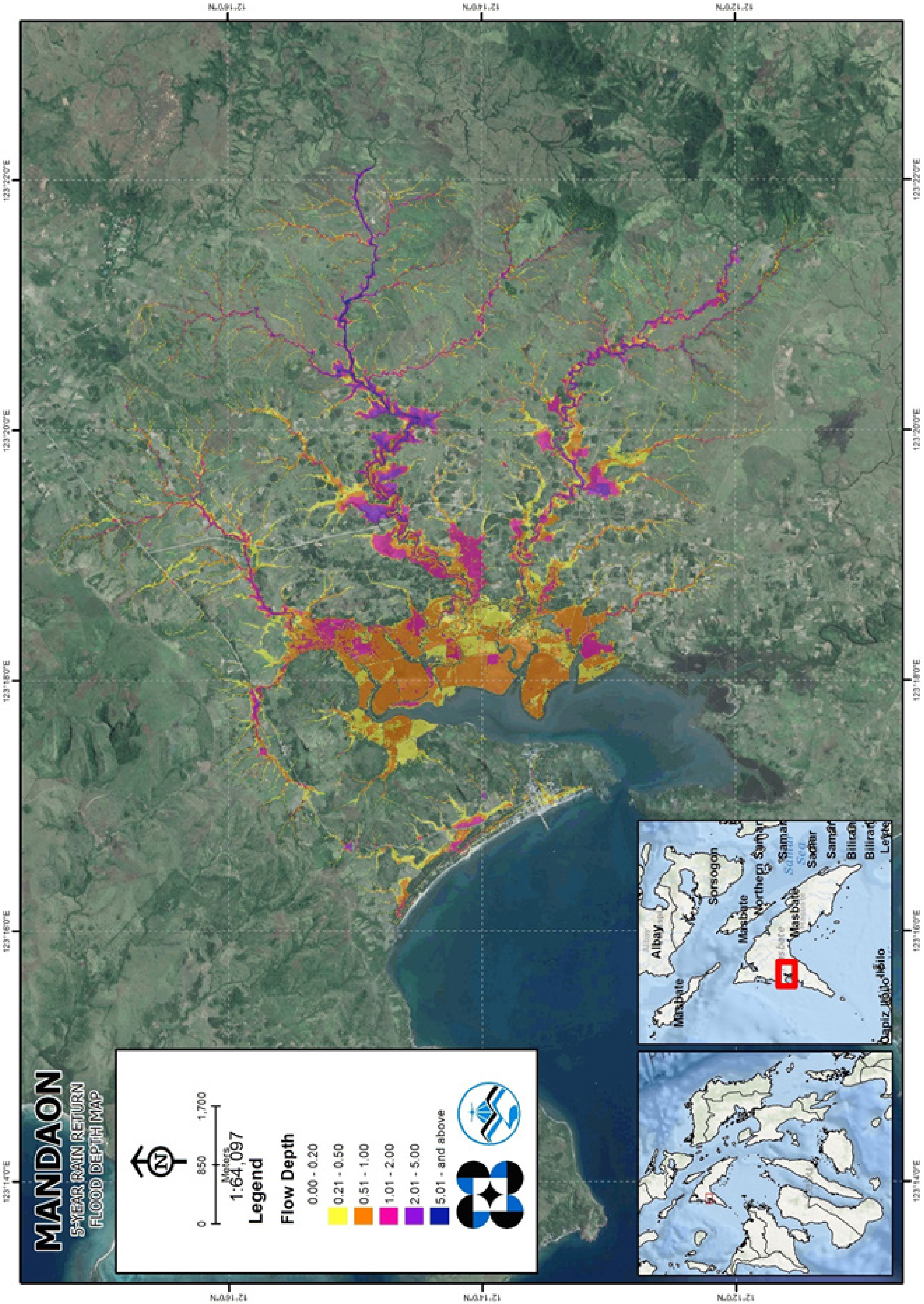

Figure 70 5-year flow depth map for the Mandaon flood plain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Listed below are the barangays affected by the Mandaon River Basin, grouped accordingly by municipality. For the said basin, two (2) municipalities consisting of 11 barangays are expected to experience flooding when subjected to the three rainfall return period scenarios.

For the 5-year rainfall return period, 23.19% of the municipality of Mandaon with an area of 220.76 sq. km. will experience flood levels of less than 0.20 meters. 2.05% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.18%, 1.09%, 0.41%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 34 depicts the areas affected in Mandaon in square kilometers by flood depth per barangay.

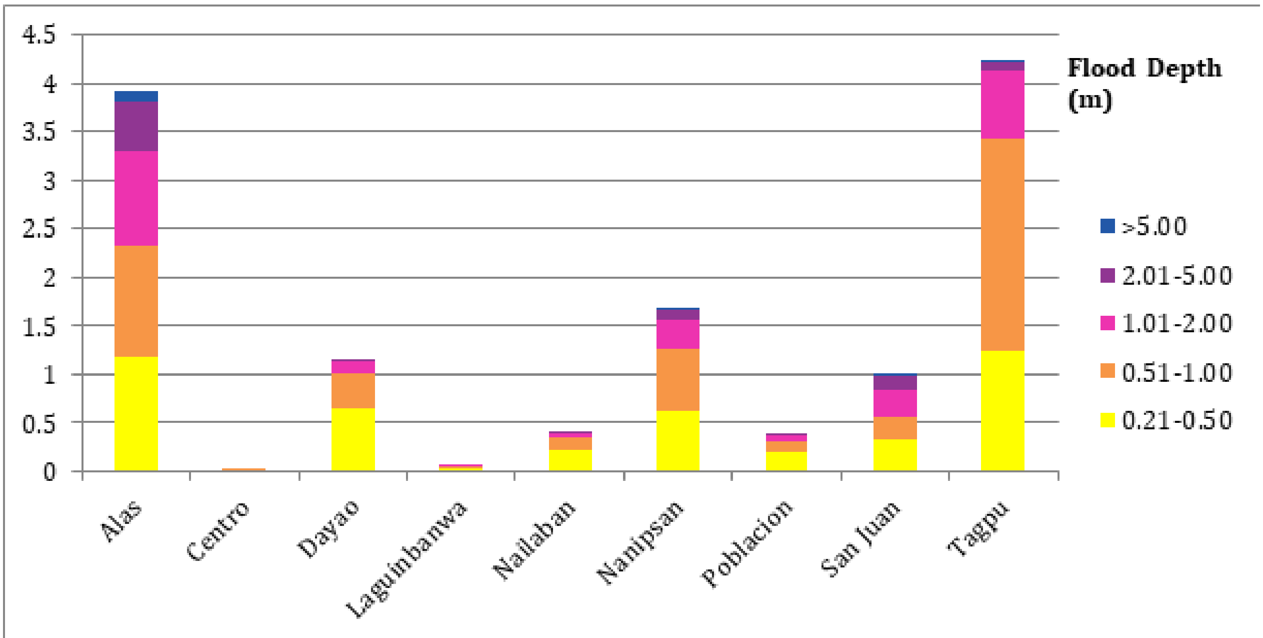

Figure 71 Affected Areas in Mandaon, Masbate during the 5-Year Rainfall Return Period

Table 34. Affected Areas in Mandaon Masbate during 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mandaon								
	Alas	Centro	Dayao	Laguin-banwa	Naila-ban	Na-nipsan	Pobla-cion	San Juan	Tagpu
0.03-0.20	17.82	0.12	9.54	0.44	3.31	7.09	2.53	6.03	4.3
0.21-0.50	1.18	0.0022	0.65	0.039	0.23	0.63	0.2	0.33	1.25
0.51-1.00	1.15	0.00013	0.36	0.0055	0.12	0.63	0.11	0.24	2.19
1.01-2.00	0.96	0	0.12	0.0001	0.029	0.3	0.058	0.26	0.69
2.01-5.00	0.52	0	0.022	0	0.0075	0.11	0.0028	0.16	0.087

For the municipality of Milagros with an area of 530.43 sq. km., 1.63% will experience flood levels of less than 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.05%, 0.05%, 0.02%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 35 depicts the areas affected in Milagros in square kilometers by flood depth per barangay.

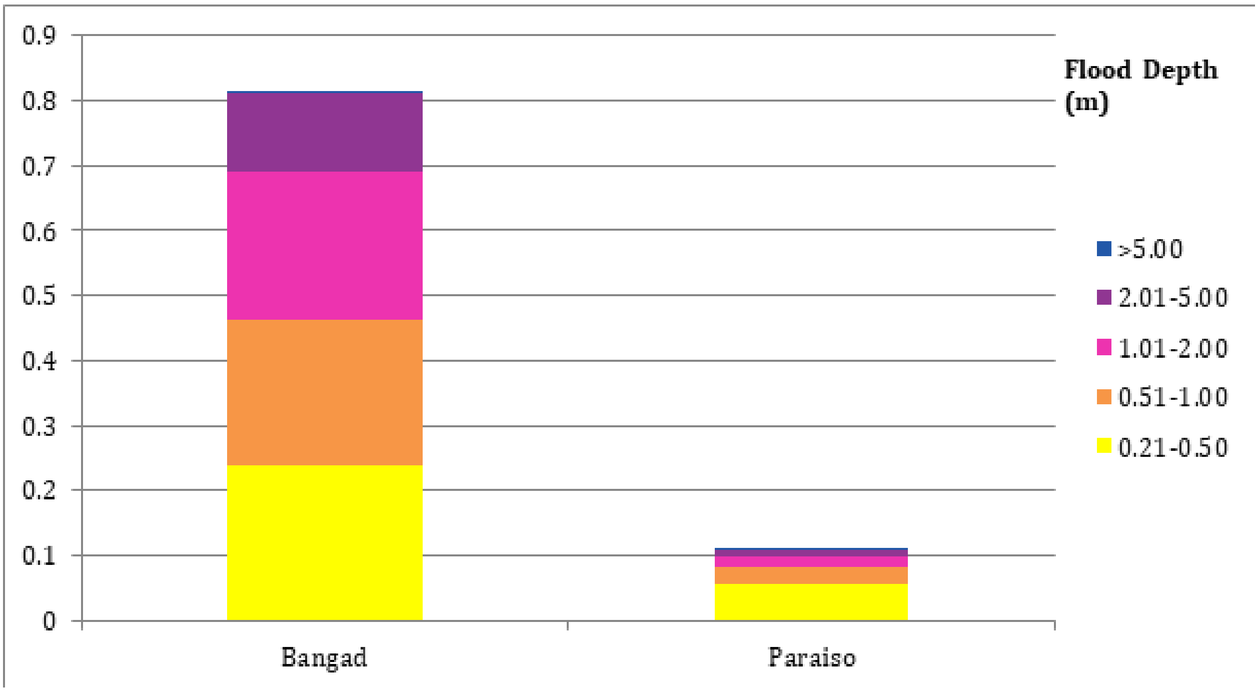

Figure 72 Affected Areas in Milagros, Masbate during the 5-Year Rainfall Return Period

Table 35 Affected Areas in Milagros, Masbate during the 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Milagros	
	Bangad	Paraiso
0.03-0.20	7.13	1.49
0.21-0.50	0.24	0.055
0.51-1.00	0.22	0.028
1.01-2.00	0.23	0.015
2.01-5.00	0.12	0.0096
>5.00	0.0031	0.0038

For the 25-year rainfall return period, 22.18% of the municipality of Mandaon with an area of 220.76 sq. km. will experience flood levels of less than 0.20 meters. 1.9% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.27%, 1.88%, 0.67%, 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 greater than 5 meters, respectively. Table 36 depicts the areas affected in Mandaon in square kilometers by flood depth per barangay.

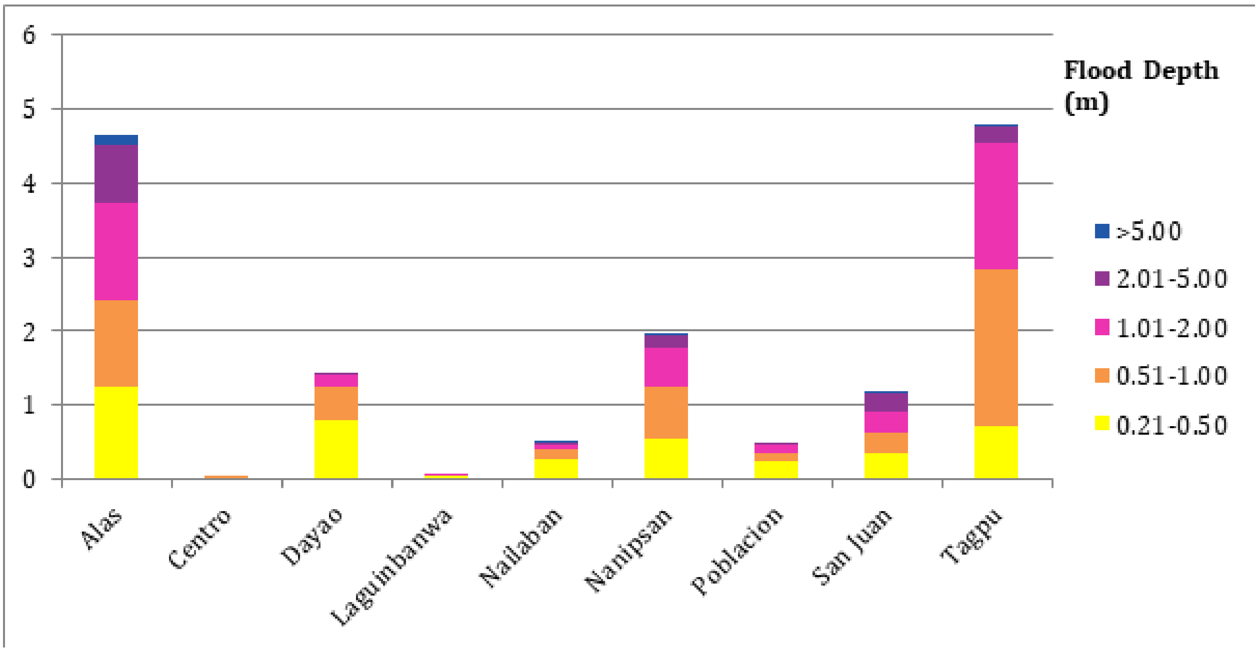

Figure 73 Affected Areas in Mandaon, Masbate during the 25-Year Rainfall Return Period

Table 36. Affected Areas in Mandaon Masbate during 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mandaon								
	Alas	Centro	Dayao	Laguin-banwa	Naila-ban	Na-nipsan	Pobla-cion	San Juan	Tagpu
0.03-0.20	17.1	0.12	9.24	0.43	3.22	6.81	2.44	5.85	3.76
0.21-0.50	1.24	0.0023	0.79	0.036	0.26	0.56	0.24	0.35	0.71
0.51-1.00	1.17	0.00033	0.45	0.017	0.16	0.69	0.12	0.27	2.12
1.01-2.00	1.32	0.00000071	0.18	0.0002	0.052	0.51	0.11	0.29	1.69
2.01-5.00	0.77	0	0.034	0	0.01	0.18	0.003	0.25	0.23

For the municipality of Milagros with an area of 530.43 sq. km., 1.6% will experience flood levels of less than 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.04%, 0.05%, 0.04%, and 0.003% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 37 depicts the areas affected in Milagros in square kilometers by flood depth per barangay.

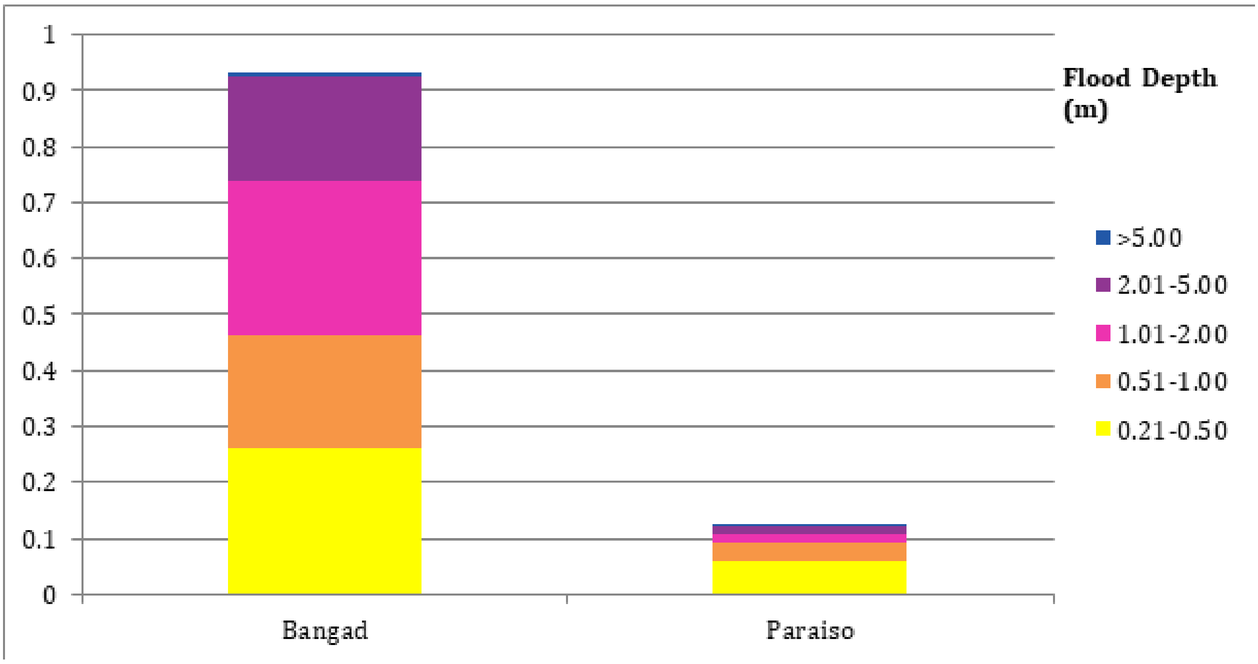

Figure 74 Affected Areas in Milagros, Masbate during the 25-Year Rainfall Return Period

Table 37 Affected Areas in Milagros, Masbate during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Milagros	
	Bangad	Paraiso
0.03-0.20	7.02	1.47
0.21-0.50	0.26	0.058
0.51-1.00	0.2	0.034
1.01-2.00	0.27	0.017
2.01-5.00	0.19	0.012
>5.00	0.0073	0.0062

For the 100-year rainfall return period, 21.45% of the municipality of Mandaon with an area of 220.76 sq. km. will experience flood levels of less than 0.20 meters. 1.88% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.01%, 2.55%, 0.98%, and 0.11% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 38 depicts the areas affected in Mandaon in square kilometers by flood depth per barangay.

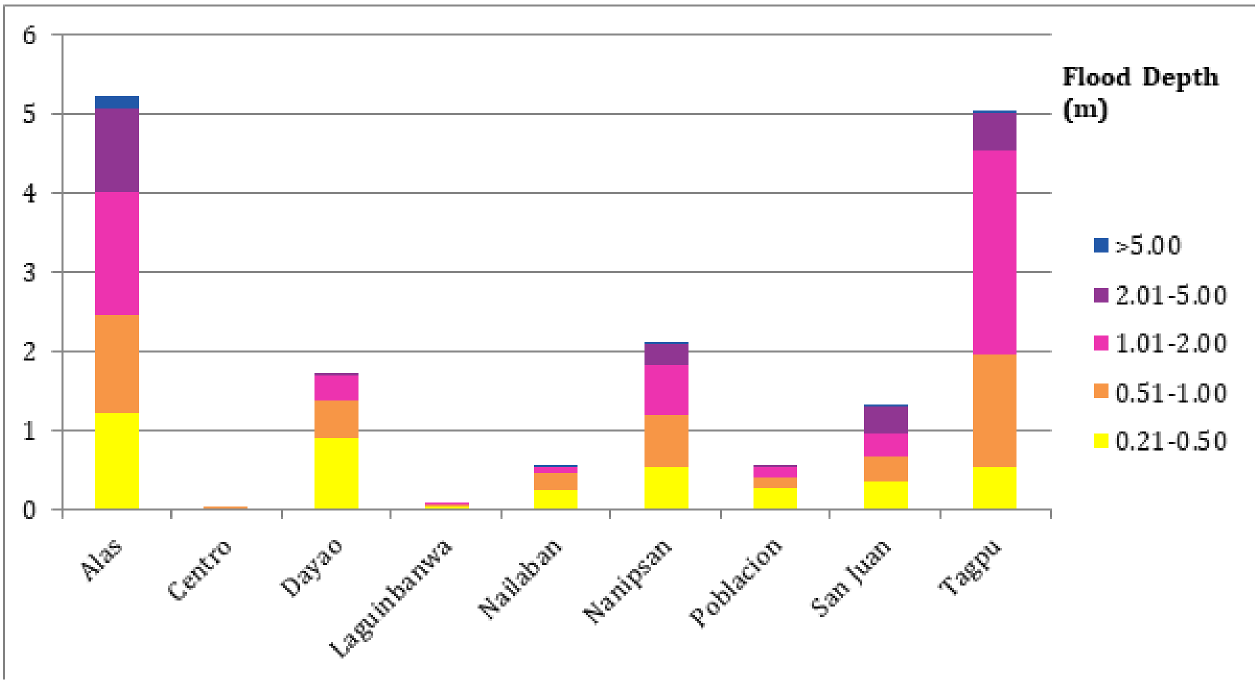

Figure 75 Affected Areas in Mandaon, Masbate during the 100-Year Rainfall Return Period

Table 38 Affected Areas in Mandaon, Masbate during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mandaon								
	Alas	Centro	Dayao	Laguin-banwa	Naila-ban	Na-nipsan	Pobla-cion	San Juan	Tagpu
0.03-0.20	0	0.12	8.95	0.43	3.15	6.65	2.36	5.7	3.5
0.21-0.50	1.23	0.0025	0.92	0.031	0.26	0.53	0.27	0.36	0.55
0.51-1.00	1.22	0.00054	0.47	0.027	0.19	0.67	0.15	0.3	1.41
1.01-2.00	1.57	0.00000071	0.3	0.0023	0.084	0.63	0.12	0.31	2.6
2.01-5.00	1.04	0	0.046	0	0.012	0.26	0.0031	0.33	0.46

For the municipality of Milagros with an area of 530.43 sq. km., 1.6% will experience flood levels of less than 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.05%, 0.06%, 0.05%, and 0.004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 39 depicts the areas affected in Milagros in square kilometers by flood depth per barangay.

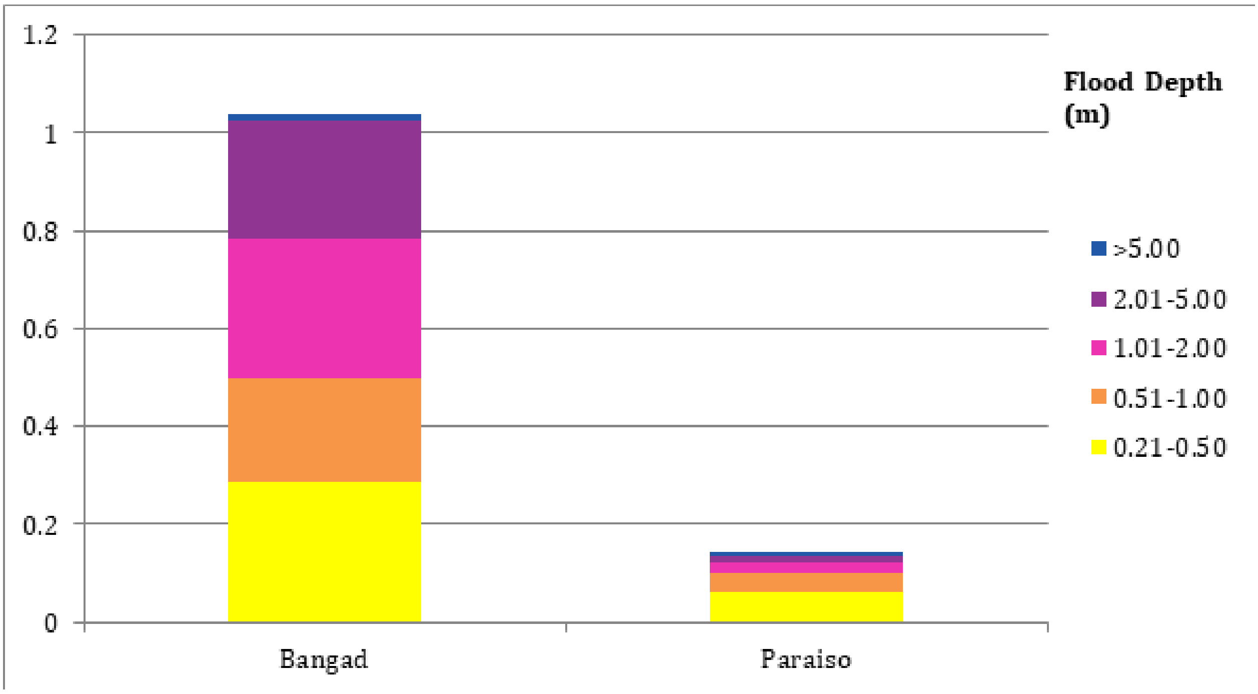

Figure 76 Affected Areas in Milagros, Masbate during the 100-Year Rainfall Return Period

Table 39 Affected Areas in Milagros, Masbate during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Milagros	
	Bangad	Paraiso
0.03-0.20	6.91	1.46
0.21-0.50	0.29	0.062
0.51-1.00	0.21	0.04
1.01-2.00	0.28	0.019
2.01-5.00	0.24	0.014
>5.00	0.012	0.0085

Among the barangays in the municipality of Mandaon, Alas is projected to have the highest percentage of area that will experience flood levels at 9.85%. Meanwhile, Dayao posted the second highest percentage of area that may be affected by flood depths at 4.84%.

Among the barangays in the municipality of Milagros, Bangad is projected to have the highest percentage of area that will experience flood levels at 3.6%. Meanwhile, Paraiso posted the second highest percentage of area that may be affected by flood depths at 0.72%.

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

Table 40 Area covered by each warning level with respect to rainfall scenario

Warning Level	**Area Covered in sq. km.**		
	5 year	25 year	100 year
Low	5.19	4.63	4.65
Medium	7.89	9.58	10
High	2.09	3.34	4.70

Of the 12 identified Educational Institutions in Mandaon Floodplain, none was assessed to be exposed to all flood levels (low, medium, and high) in all the flood hazard scenarios (5, 25, and 100 yr).

Of the 3 identified Medical Institutions in Mandaon Floodplain, none was assessed to be exposed to all flood levels (low, medium, and high) in all the flood hazard scenarios (5, 25, and 100 yr).

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed.

The flood validation consists of 53 points randomly selected all over the Mandaon Floodplain. It has an RMSE value of 0.855257878.

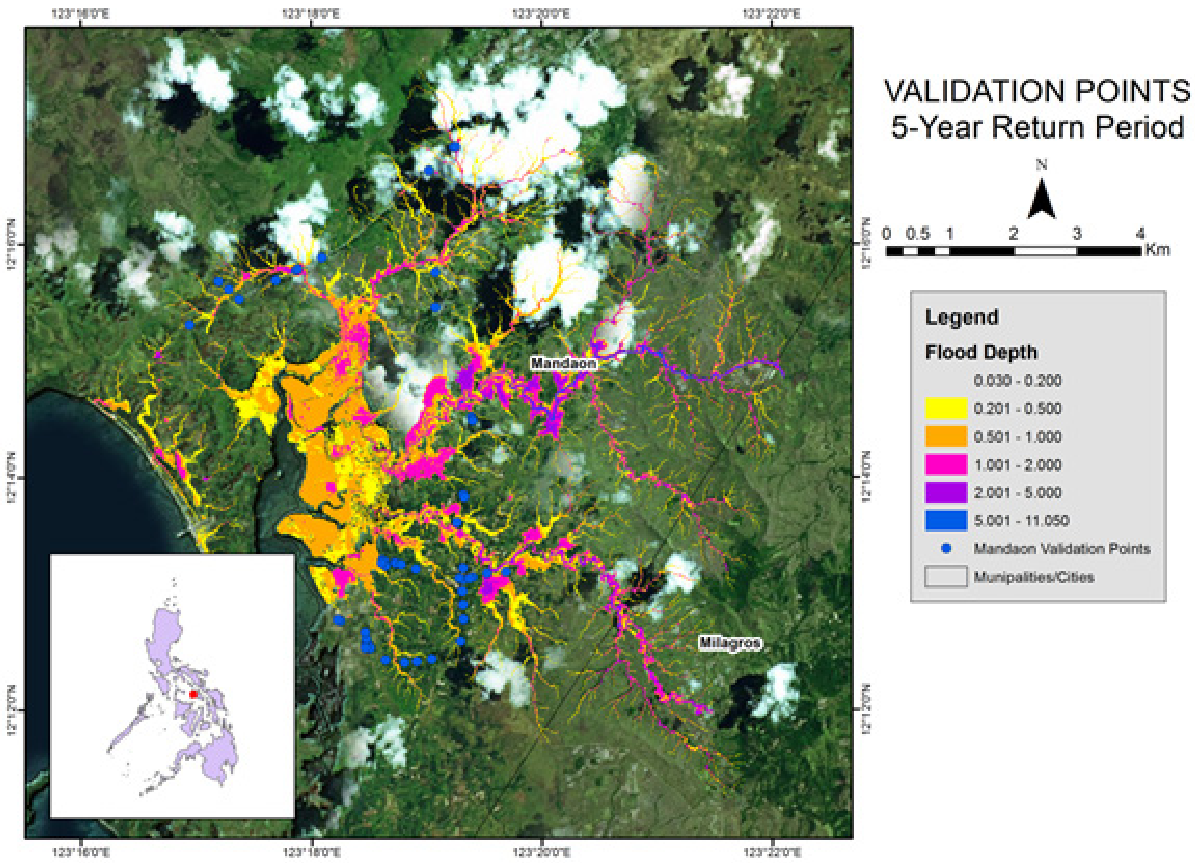

Figure 78 Flood validation points for Mandaon Floodplain

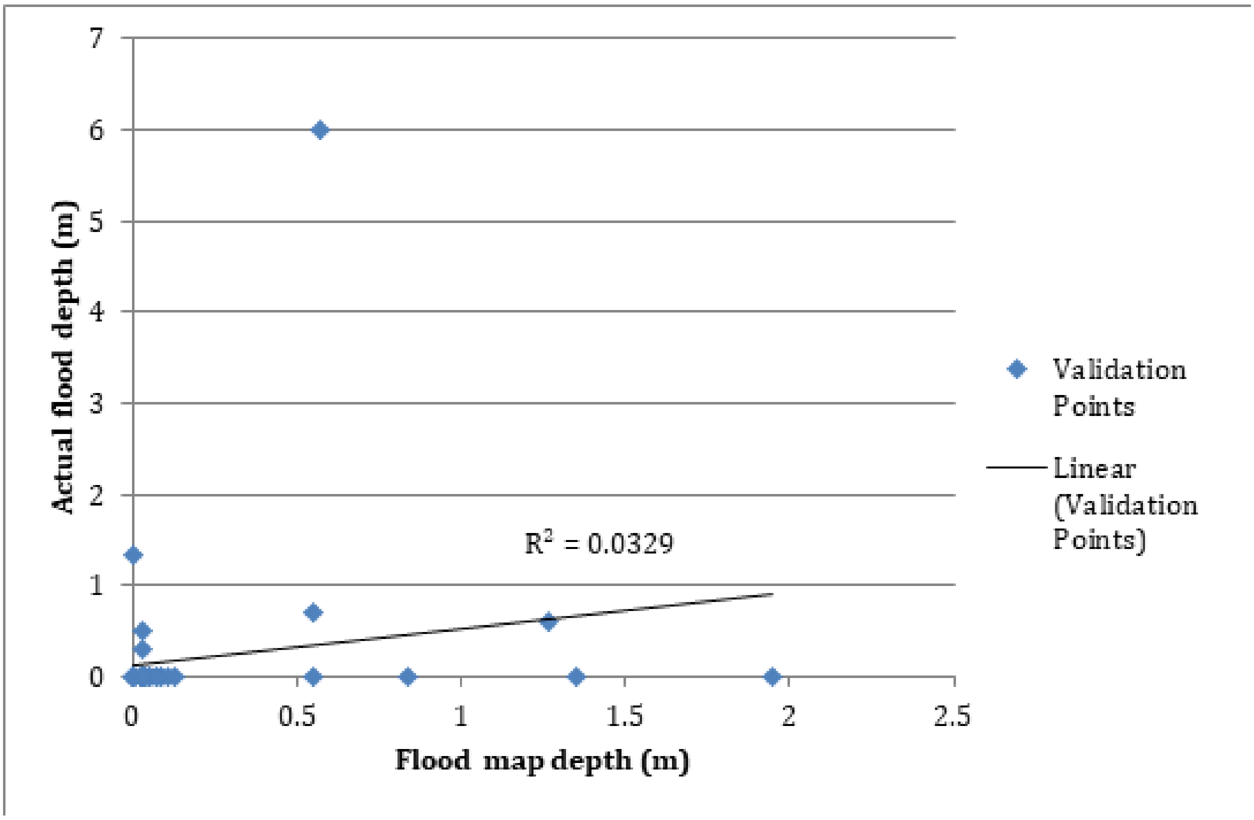

Figure 77 Flood map depth vs. Actual flood depth

Table 41 Actual flood vs. Simulated flood depth at different levels in the Mandaon River Basin

HIMOGAANTANAO BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	43	0	2	2	0	0	47
	0.21-0.50	2	0	0	0	0	0	2
	0.51-1.00	0	0	1	1	0	0	2
	1.01-2.00	1	0	0	0	0	0	1
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00		0	1	0	0	0	1
Total		46	0	4	3	0	0	53

the overall accuracy generated by the flood model is estimated at 83.02%, with 44 points correctly matching the actual flood depths. In addition, there were 3 points estimated one level above and below the correct flood depths, 2 points estimated two levels above and below, and 4 points estimated three or more levels above and below the correct flood depths. A total of 5 points were overestimated while a total of 4 points were underestimated in the modelled flood depths of Mandaon. Table 42 depicts the summary of the accuracy assessment in the Mandaon River Basin survey.

Table 42 The Summary of Accuracy Assessment in the Mandaon River Basin Survey

	No. of Points	**%**
Correct	44	83.02
Overestimated	5	9.43
Underestimated	4	7.55
Total	53	100

REFERENCES

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

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

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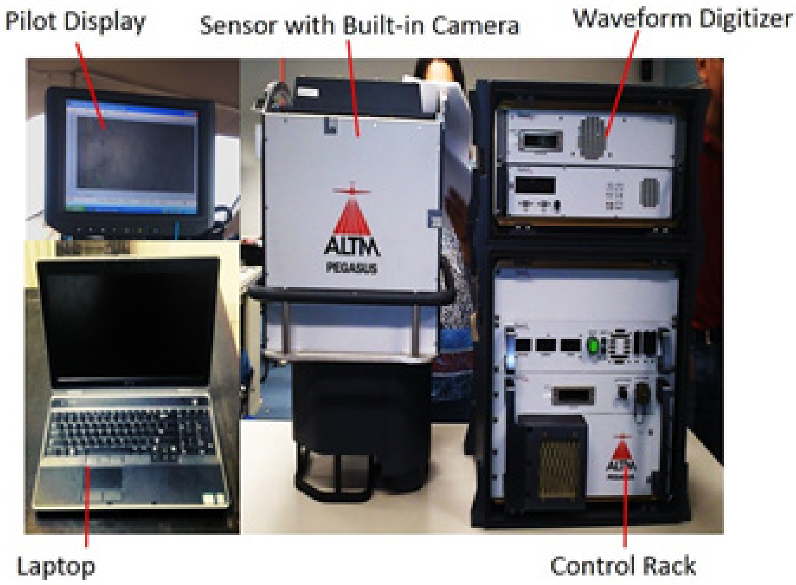
Paringit E.C, Balicanta L.P., Ang, M.O., Sarmiento, C. 2017. Flood Mapping of Rivers in the Philippines Using Airborne Lidar: Methods. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

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

ANNEXES

ANNEX 1. OPTECH TECHNICAL SPECIFICATION OF THE PEGASUS SENSOR



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

ANNEX 2 NAMRIA CERTIFICATES OF REFERENCE POINTS USED

1. MST-28

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MST-28**
Order: **2nd**

Island: **LUZON**
Municipality: **MANDAON**
Barangay: **BAT-ONGAN**

		PRS92 Coordinates			
Latitude:	**12° 18' 35.15371"**	Longitude:	**123° 21' 19.21293"**	Ellipsoidal Hgt:	**49.12800 m.**
		WGS84 Coordinates			
Latitude:	**12° 18' 30.47973"**	Longitude:	**123° 21' 24.28923"**	Ellipsoidal Hgt:	**104.64900 m.**
		PTM Coordinates			
Northing:	**1361224.57 m.**	Easting:	**538651.166 m.**	Zone:	**4**
		UTM Coordinates			
Northing:	**1,360,748.12**	Easting:	**538,637.64**	Zone:	**51**

Location Description

MST-28
From Masbate City Proper, travel for about 50.6 km. along the Nat'l. Highway going to Mambog Bridge at Brgy. Bat-ongan, Mandaon Town. Station is located at the right side wing of the said bridge. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block protruding 0.05 m. above the ground surface, with inscriptions "MST-28 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-829**

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

9904102014140223

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. MST-30

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MST-30**
Order: **2nd**

Island: **LUZON** Municipality: **MANDAON**		Barangay: **POBLACION**
	PRS92 Coordinates	
Latitude: **12° 13' 42.50852"**	Longitude: **123° 17' 3.56592"**	Ellipsoidal Hgt: **9.63700 m.**
	WGS84 Coordinates	
Latitude: **12° 13' 37.84860"**	Longitude: **123° 17' 8.64987"**	Ellipsoidal Hgt: **65.19300 m.**
	PTM Coordinates	
Northing: **1352223.558 m.**	Easting: **530936.259 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,351,750.26**	Easting: **530,925.43**	Zone: **51**

Location Description

MST-30
From Masbate City Proper, travel for about 64 km. along the Nat'l. Highway going to Mandaon Town Proper. Station is located at the compound of Pob. Mandaon, 15 m. NW of the stage and 10 m. NE of the basketball court. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block, with inscriptions "MST-30 2007 NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795949 A**
T.N.:	**2014-828**

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

9904102014140207

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Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. MST-31

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **MASBATE**	
	Station Name: **MST-31**	
	Order: **2nd**	
Island: **LUZON**		Barangay: **BANGAD**
Municipality: **MILAGROS**		
	PRS92 Coordinates	
Latitude: **12° 11' 50.29728"**	Longitude: **123° 24' 24.05419"**	Ellipsoidal Hgt: **18.45000 m.**
	WGS84 Coordinates	
Latitude: **12° 11' 45.65539"**	Longitude: **123° 24' 29.13992"**	Ellipsoidal Hgt: **74.38600 m.**
	PTM Coordinates	
Northing: **1348792.732 m.**	Easting: **544254.929 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,348,320.63**	Easting: **544,239.44**	Zone: **51**

Location Description

MST-31
From Masbate City Proper, travel for about 38 km. along the Nat'l. Highway going to Balud Town Proper until reaching Brgy. Bangad, Milagros Town. Station is located at the right side wing of Boracay Bridge. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block, with inscriptions "MST-31 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-827**

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

9904102014140150

CERTIFICACION INTERNACIONAL 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
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

4. MS-32

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MST-32**
Order: **2nd**

Island: **LUZON**
Municipality: **MILAGROS**
Barangay:

	PRS92 Coordinates	
Latitude: **12° 13' 7.66936"**	Longitude: **123° 30' 26.72479"**	Ellipsoidal Hgt: **3.78300 m.**
	WGS84 Coordinates	
Latitude: **12° 13' 3.03064"**	Longitude: **123° 30' 31.80788"**	Ellipsoidal Hgt: **59.91100 m.**
	PTM Coordinates	
Northing: **1351188.593 m.**	Easting: **555213.396 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,350,715.65**	Easting: **555,194.07**	Zone: **51**

Location Description

MST-32
From Masbate City Proper, travel for about 26 km. along the Nat'l. Highway going to Pob. Milagros. Station is located at the compound of the Milagros Mun. Hall, 30 m. NW, 2 m. E of the concrete fence, 5 m. SW of the basketball court and 10 m. W of the volleyball court. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete, with inscriptions "MST-32 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-838**

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

9904102014140542

NAMRIA OFFICES:
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

5. MST-55

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

	Province: **MASBATE**	
	Station Name: **MST-55**	
	Order: **2nd**	
Island: **LUZON**		Barangay: **CASAMONGAN**
Municipality: **BALUD**		
	PRS92 Coordinates	
Latitude: **12° 5' 16.28892"**	Longitude: **123° 19' 50.73333"**	Ellipsoidal Hgt: **3.33300 m.**
	WGS84 Coordinates	
Latitude: **12° 5' 11.66770"**	Longitude: **123° 19' 55.82918"**	Ellipsoidal Hgt: **59.36300 m.**
	PTM Coordinates	
Northing: **1336675.257 m.**	Easting: **536007.686 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,336,207.40**	Easting: **535,995.08**	Zone: **51**

Location Description

MST-55
From Masbate City Proper, travel for about 56 km. along the Nat'l. Highway going to Balud Town Proper to reach the crossing going to Brgys. Casamongan and Villa Alvarez. From Brgy. Villa Alvarez, continue traveling for at least 8.5 km. to reach Brgy. Casamongan. Station is located at the compound of Casamongan Brgy. Hall, beside the basketball court, 10 m. NE of the stage, 30 m. E from the brgy. hall and 2 m. SW from the concrete fence. Mark is the head of a 4 in. copper nail centered on a triangle on a 0.3 m. x 0.3 m. concrete block protruding 0.05 m. above the ground surface, with inscriptions "MST-55 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-830**

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

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

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

NAMRIA OFFICES:
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ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

6. MS-269

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

April 10, 2014

CERTIFICATION

To whom it may concern:

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

Province: **MASBATE**
Station Name: **MS-269**

Island: **LUZON**	Municipality: **AROROY**	Barangay: **LUY-A**
Elevation: **27.4076 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

MS-269

Station is in the Island / Province of Masbate, Municipality of Aroroy, along the road linking Aroroy with the town of Milagros, Barangay Luy-a, at the top of a concrete bridge. A diesel station is located nearby. Mark is the head of a 3" copper nail embedded into the bridge walkway / pavement with cement putty and inscription "MS-269; 2008; NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795949 A**
T.N.:	**2014-841**

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

9904102014140638

CIP/4701/12/09/814

NAMRIA OFFICES:
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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

ANNEX 3 BASELINE PROCESSING REPORTS OF REFERENCE POINTS USED

MS-269 - MST-28 (6:36:44 AM-10:31:44 AM) (S1)

Baseline observation:	MS-269 --- MST-28 (B1)
Processed:	5/13/2014 3:15:01 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.009 m
Vertical precision:	0.024 m
RMS:	0.004 m
Maximum PDOP:	2.923
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	4/4/2014 6:37:04 AM (Local: UTC+8hr)
Processing stop time:	4/4/2014 10:31:44 AM (Local: UTC+8hr)
Processing duration:	03:54:40
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	MST-28				
Grid		Local		Global	
Easting	538790.668 m	Latitude	N12°18'30.47973"	Latitude	N12°18'30.47973"
Northing	1360689.389 m	Longitude	E123°21'24.28923"	Longitude	E123°21'24.28923"
Elevation	49.498 m	Height	104.649 m	Height	104.649 m

To:	MS-269				
Grid		Local		Global	
Easting	544123.868 m	Latitude	N12°24'21.62786"	Latitude	N12°24'21.62786"
Northing	1371483.415 m	Longitude	E123°24'21.40082"	Longitude	E123°24'21.40082"
Elevation	28.584 m	Height	83.308 m	Height	83.308 m

Vector					
ΔEasting	5333.200 m	NS Fwd Azimuth	26°22'11"	ΔX	-3185.907 m
ΔNorthing	10794.025 m	Ellipsoid Dist.	12044.246 m	ΔY	-4889.699 m
ΔElevation	-20.914 m	ΔHeight	-21.341 m	ΔZ	10536.100 m

ANNEX 4. The LIDAR Survey Team Composition

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

FIELD TEAM

LiDAR Operation	Supervising SRS	GEROME B. HIPOLITO	UP-TCAGP
	Senior Science Research Specialist (SSRS)	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
		ENGR. IRO NIEL ROXAS	UP-TCAGP
Ground Survey, Data Download and Transfer		GRACE SINADJAN	UP-TCAGP
LiDAR Operation	Airborne Security	SSG MARLON TORRE	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. JEFFREY JEREMY ALAJAR	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. BRYAN DONGUINES	AAC

ANNEX 6 FLIGHT LOGS FOR THE FLIGHT MISSIONS

1. Flight Log for 1299P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1299P

1 LiDAR Operator: I. Roxas	2 ALTM Model: PEG	3 Mission Name: 1BLK32FG093A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: JJ Alcasar	8 Co-Pilot: BJ Dongui{n}es	9 Route: RPVJ			
10 Date: 03 April 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0652	14 Engine Off: 1045	15 Total Engine Time: 3+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					
20 Remarks: Surveyed 7 lines at Blk 32F and 7 lines at Blk 32G					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Marvon Tabar Signature over Printed Name (PAF Representative)	JJ Alcasar Signature over Printed Name	I. Roxas Signature over Printed Name

2. Flight Log for 1301P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1301P

1 LiDAR Operator: MCE BALICUAS	2 ALTM Model: PEG	3 Mission Name: 1BLK32F093B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: JJ ALAJAR	8 Co-Pilot: BJ DONGUINES	9 Route:			
10 Date: 03 APRIL 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 1130	14 Engine Off: ~~1406~~ 1411	15 Total Engine Time: 2+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Partly cloudy				

20 Remarks:

Completed BLK 32F

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G HIPOLITO	MARYSON TORIGE	JJ ALAJAR	CATHERINE BALICUAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

3. Flight Log for 1303P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1303P

1 LiDAR Operator: I. Roxas	2 ALTM Model: PEG	3 Mission Name: 1BLK32AC04A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: JJ ALAJAR	8 Co-Pilot: BJ DONGUINES	9 Route:			
10 Date: 04 APRIL 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0456	14 Engine Off: 1037	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					

20 Remarks:

Surveyed 7 lines at BLK 32A, 2 lines at BLK 32C and 2 lines BLK 32B

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
C HIROLITO	MARIUSZ TURNE	JJ ALAJAR	I. RO ROXAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

4. Flight Log for 1305P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1305P

1 LiDAR Operator: ACE BALIGUAS	2 ALTM Model: PEG	3 Mission Name: 1BLK32A094B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: JJ ALVADAA	8 Co-Pilot: BJ DONGUINES	9 Route:			
10 Date: 04 APRIL 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 1122	14 Engine Off: 1421	15 Total Engine Time: 2+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					

20 Remarks:

completed BLK 32A

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G HILARIO	MARLON TORRES	JJ ALVARAR	CATHERINE BALIGUAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

5. Flight Log for 1307P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1307P

1 LiDAR Operator: MCE Balicuas	2 ALTM Model: Peg	3 Mission Name: 1BLK32G097SA	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: JJ Alajar	8 Co-Pilot: BJ Dongwines	9 Route:			
10 Date: 05 April 2014	12 Airport of Departure (Airport, City/Province): RPVS		12 Airport of Arrival (Airport, City/Province): RPVS		
13 Engine On: 0925	14 Engine Off: 1354	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Completed BLK 32G and surveyed 13 lines at BLK 32D

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
C. Alconcel (signed)	Marilyn Tirado (signed)	JJ Alajar (signed)	Catherine Balicuas (signed)
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

6. Flight Log for 1319P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1319P

1 LiDAR Operator: PKE BAUTISTA	2 ALTM Model: PEG	3 Mission Name: 1BLK32B098A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: JJ ALAJAR	8 Co-Pilot: BJ DONGUINES	9 Route:			
10 Date: 08 APRIL 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0811	14 Engine Off: 1228	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	cloudy				

20 Remarks:

Surveyed 13 lines at BLK 32B and 1 line at BLK 32C

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G HIPOLITO	MARVIN TORRO	JJ ALAJAR	CATHERINE BALICUAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

7. Flight Log for 1331P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1331P

1 LiDAR Operator: MCE BALIGUAS	2 ALTM Model: PEG	3 Mission Name: 1BLK32B,idA	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: JJ ALAJAR	8 Co-Pilot: BJ DONGUINES	9 Route:			
10 Date: 11 APRIL 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0701	14 Engine Off: 0936	15 Total Engine Time: 2+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Cloudy				

20 Remarks:

Surveyed 5 lines at BLK 32B and covered voids within the area

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[signature]	[signature] MARLYN FORRO	[signature] JJ ALAJAR	[signature] CATHERINE BALIGUAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

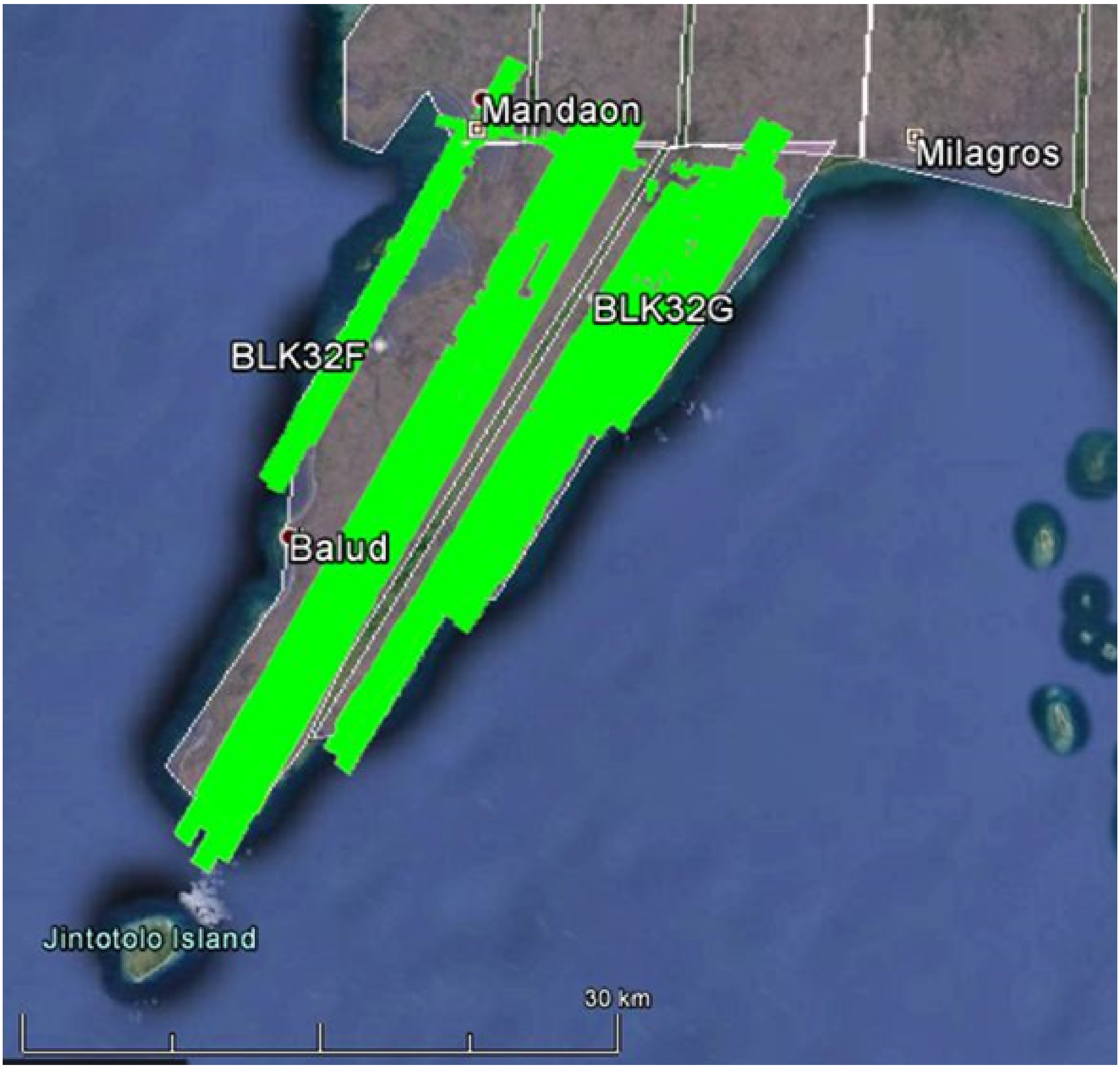
FLIGHT STATUS REPORTS

FLIGHT STATUS REPORT
MASBATE
MARCH 18, 2014-APRIL 14,2014

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1299P	BLK32F & BLK32G	1BLK32FG093A	I. ROXAS	03 APR 14	SURVEYED 7 LINES AT BLK32F AND 7 LINES AT BLK32G
1301P	BLK32F	1BLK32F093B	MCE. BALIGUAS	03 APR 14	COMPLETED BLK32F
1303P	BLK32A	1BLK32A094A	I. ROXAS	04 APR 14	SURVEYED 7 LINES AT BLK32A, 2 LINES AT BLK32C AND 2 LINES BLK32B
1305P	BLK32A	1BLK32A094B	MCE. BALIGUAS	04 APR 14	COMPLETED BLK32A
1307P	BLK32D & BLK32G	1BLK32DG095A	MCE. BALIGUAS	05 APR 14	COMPLETED BLK32G AND SURVEYED 13 LINES AT BLK32D
1319P	BLK32B	1BLK32B098A	MCE. BALIGUAS	08 APR 14	SURVEYED 5 LINES AT BLK32B AND COVERED VOIDS WITHIN THE AREA
1331P	BLK32B	1BLK32B101A	MCE. BALIGUAS	11 APR 14	SURVEYED 5 LINES AT BLK32B AND COVERED VOIDS WITHIN THE AREA

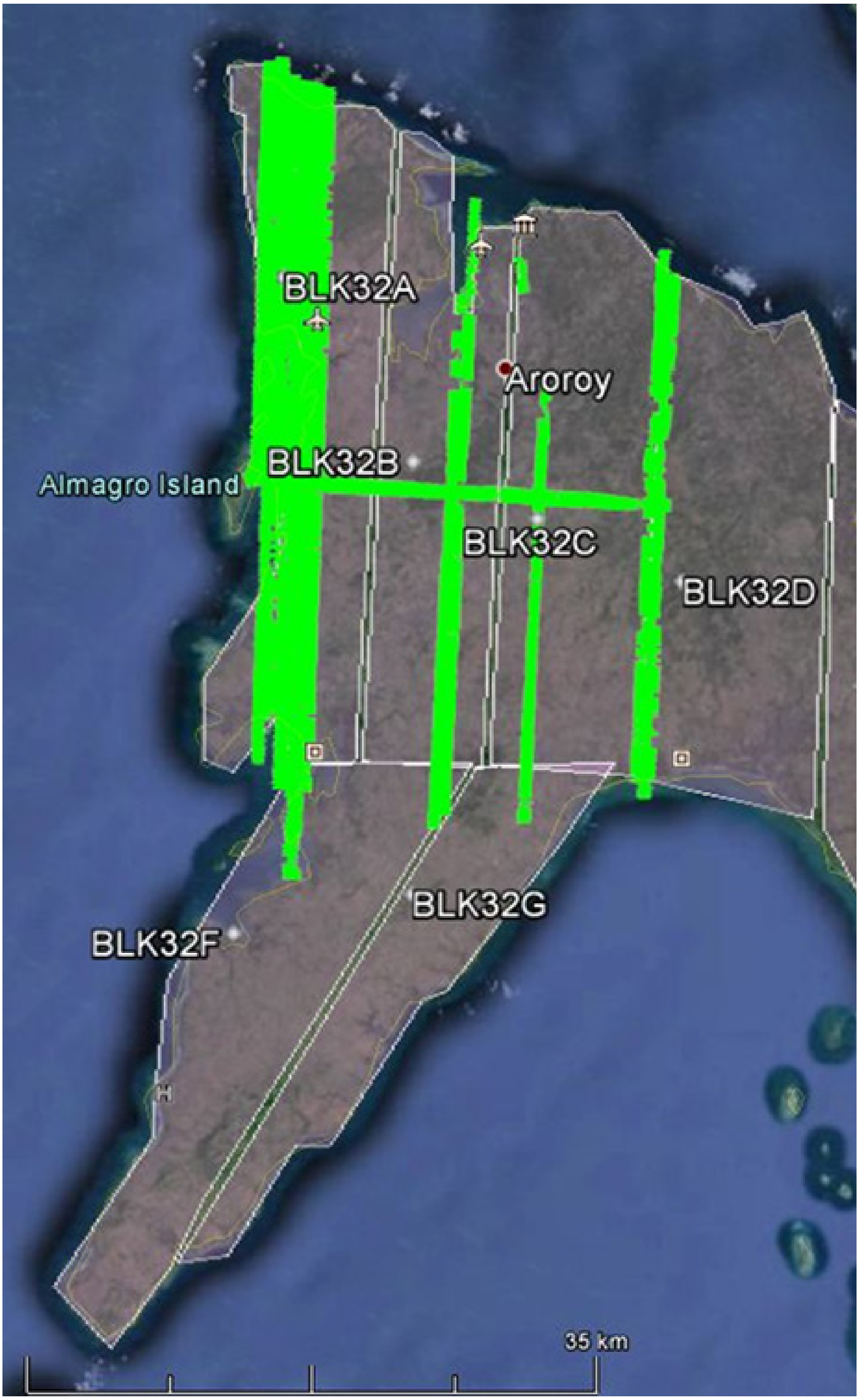
LAS/SWATH BOUNDARIES PER FLIGHT

Flight No.: 1299P
Area: BLK32F & BLK32G
Mission Name: 1BLK32G093A
Parameters: Altitude: 1200m; Scan Frequency: 30Hz;
Scan Angle: 50deg; Overlap: 30%

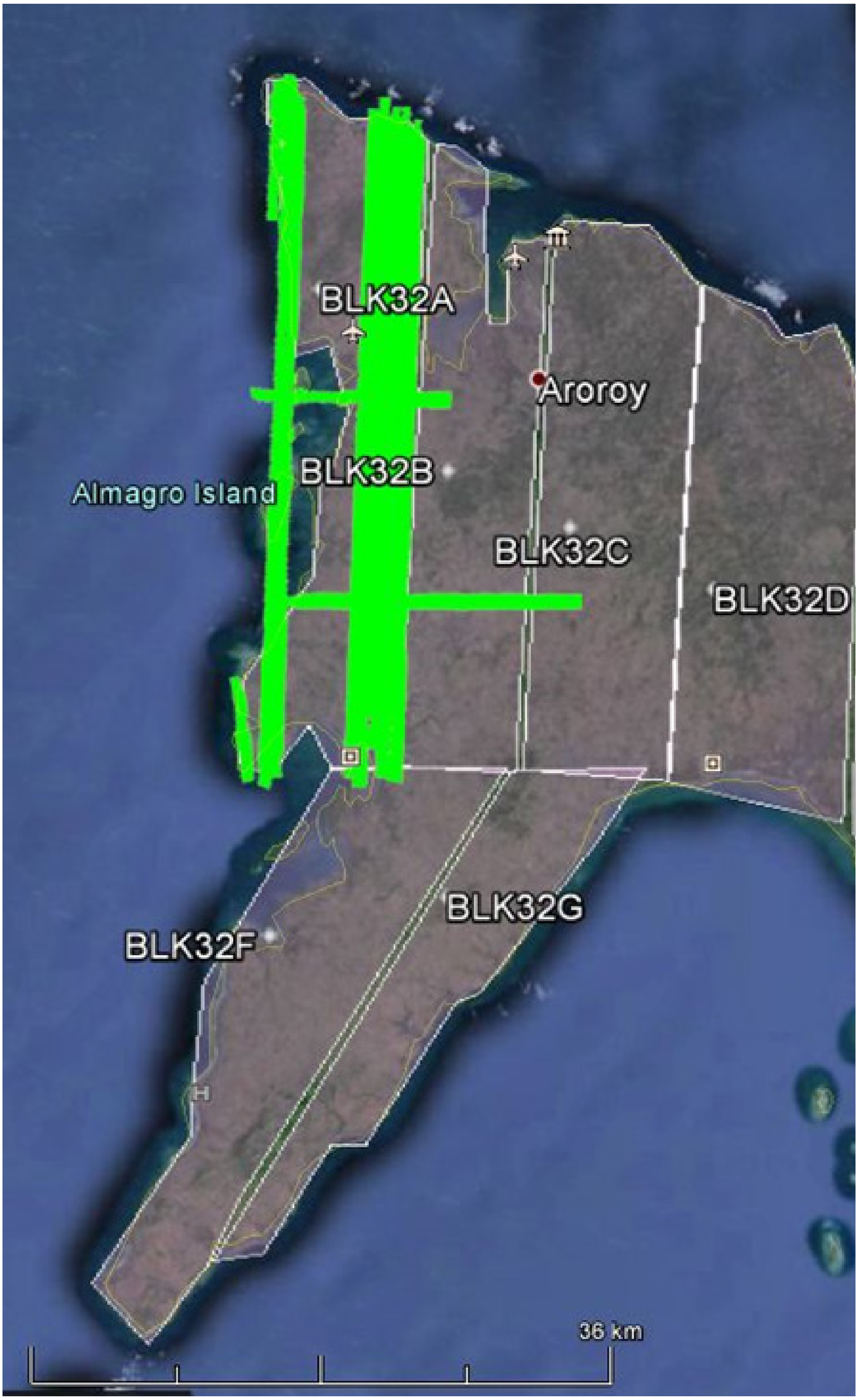


Flight No.: 1301P
Area: BLK32F
Mission Name: 1BLK32F093B
Parameters: Altitude: 800m; Scan Frequency: 30Hz;
Scan Angle: 50deg; Overlap: 25%

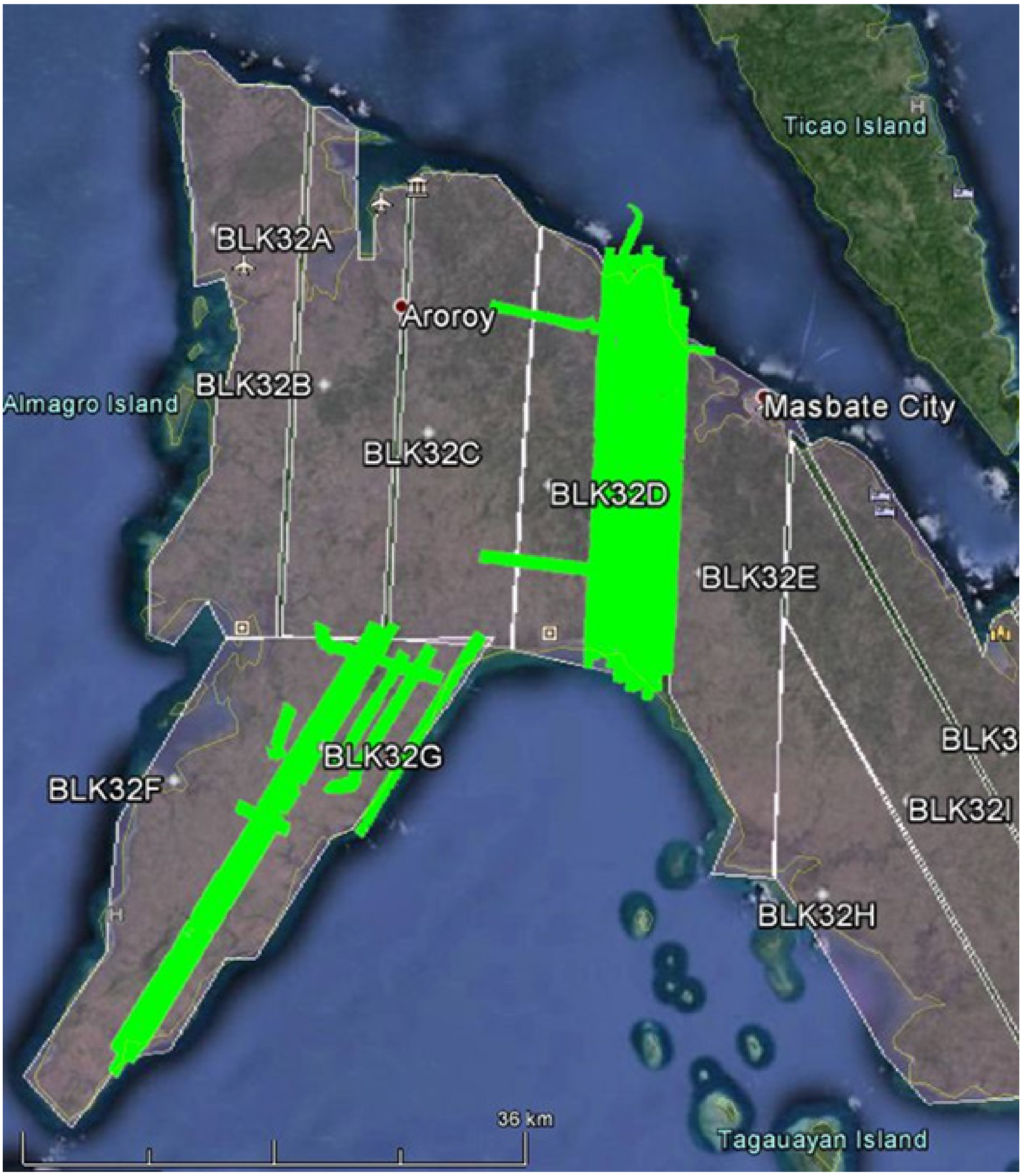
Flight No. : 1303P
Area: BLK32A
Mission Name: 1BLK32A094A
Parameters: Altitude: 1200m and 1000m; Scan Frequency: 30Hz;
Scan Angle: 50deg; Overlap: 30%



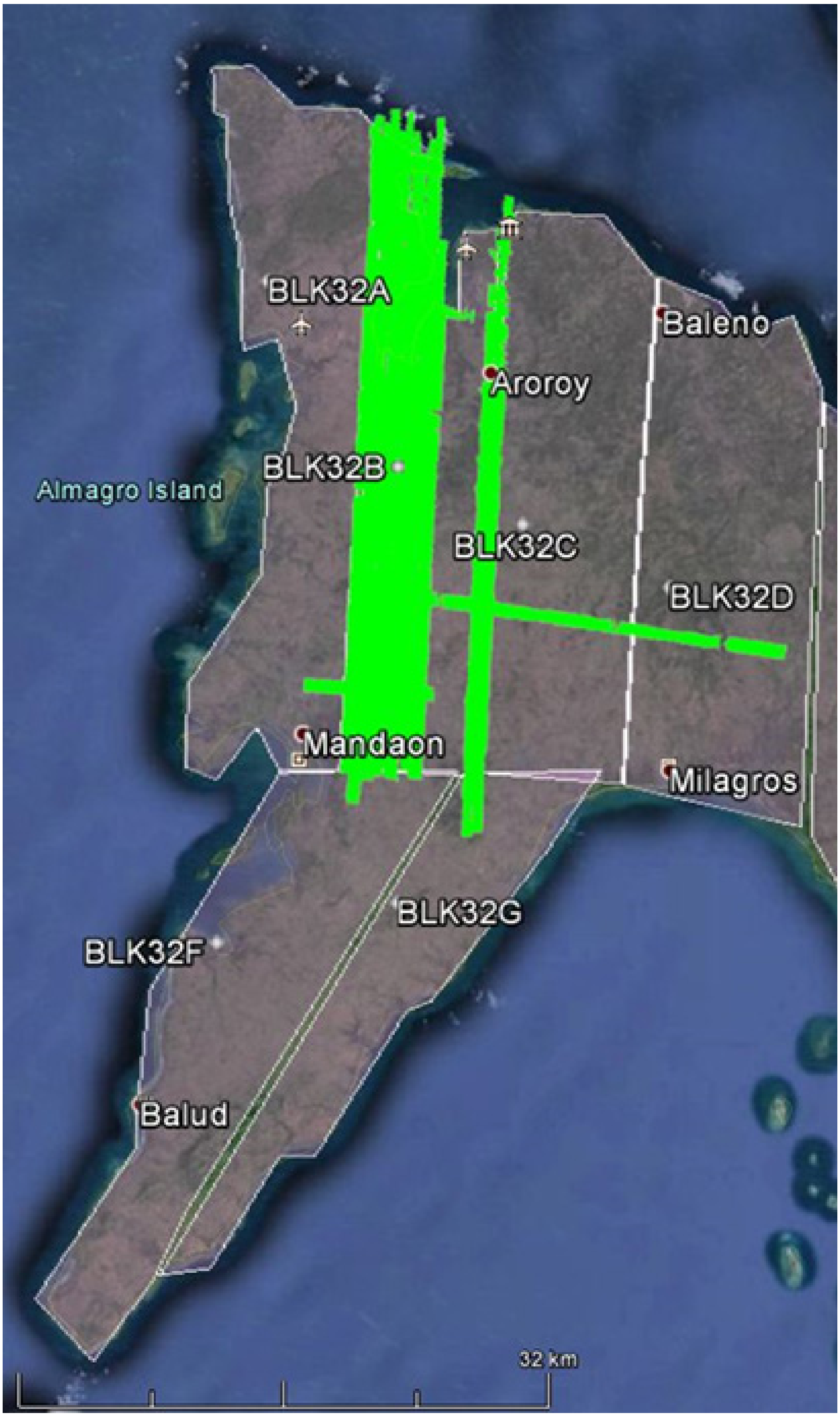
Flight No. : 1305P
Area: BLK32A
Mission Name: 1BLK32A094B
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle: 50deg; Overlap: 25%



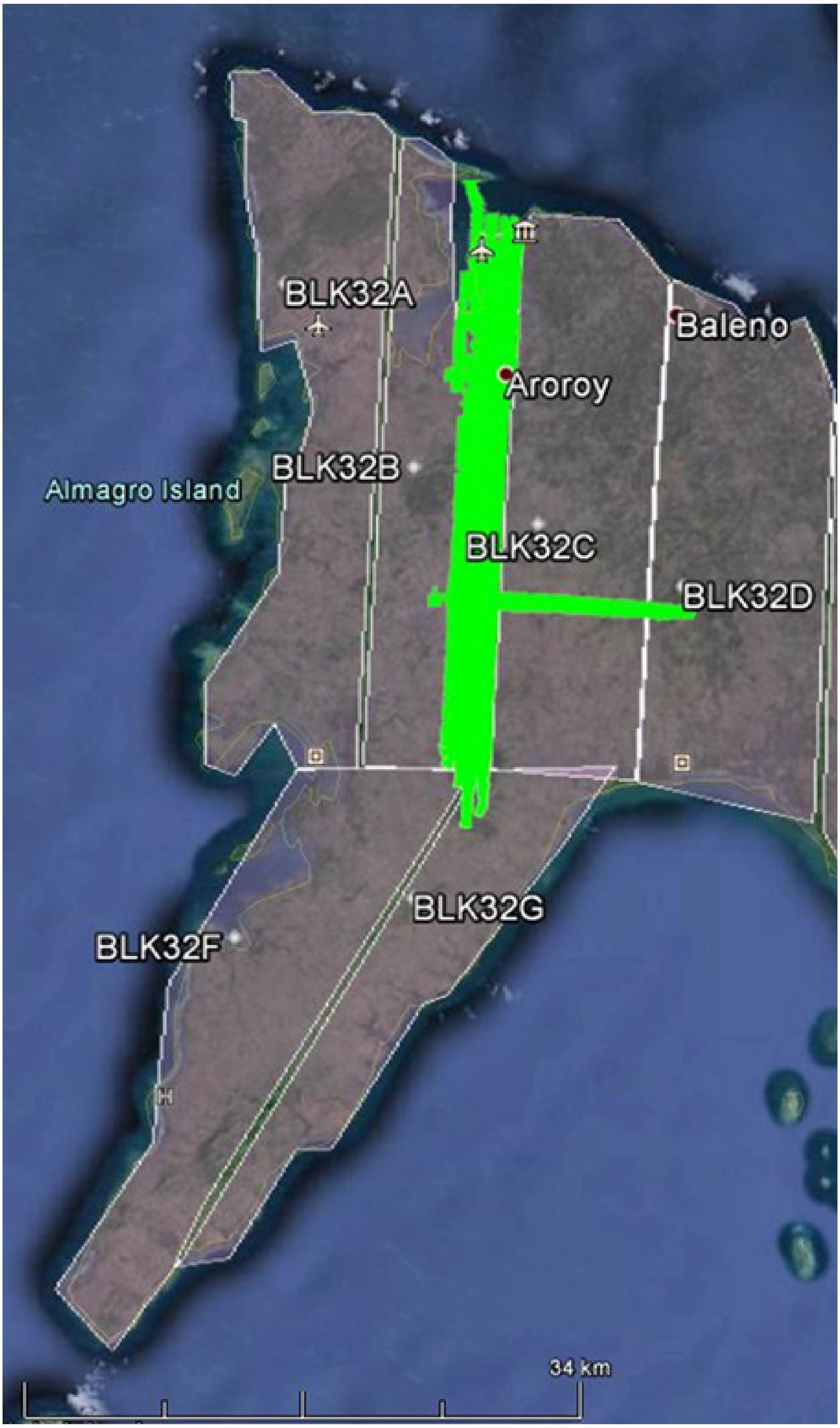
Flight No. : 1307P
Area: BLK32D & BLK32G
Mission Name: 1BLK32DG095A
Parameters: Altitude: 1000m; Scan Frequency: 30Hz;
Scan Angle: 50deg; Overlap: 25% and 30%



Flight No. : 1319P
Area: BLK32B
Mission Name: 1BLK32B098A
Parameters: Altitude: 900m; Scan Frequency: 30Hz;
Scan Angle: 50deg; Overlap: 35%

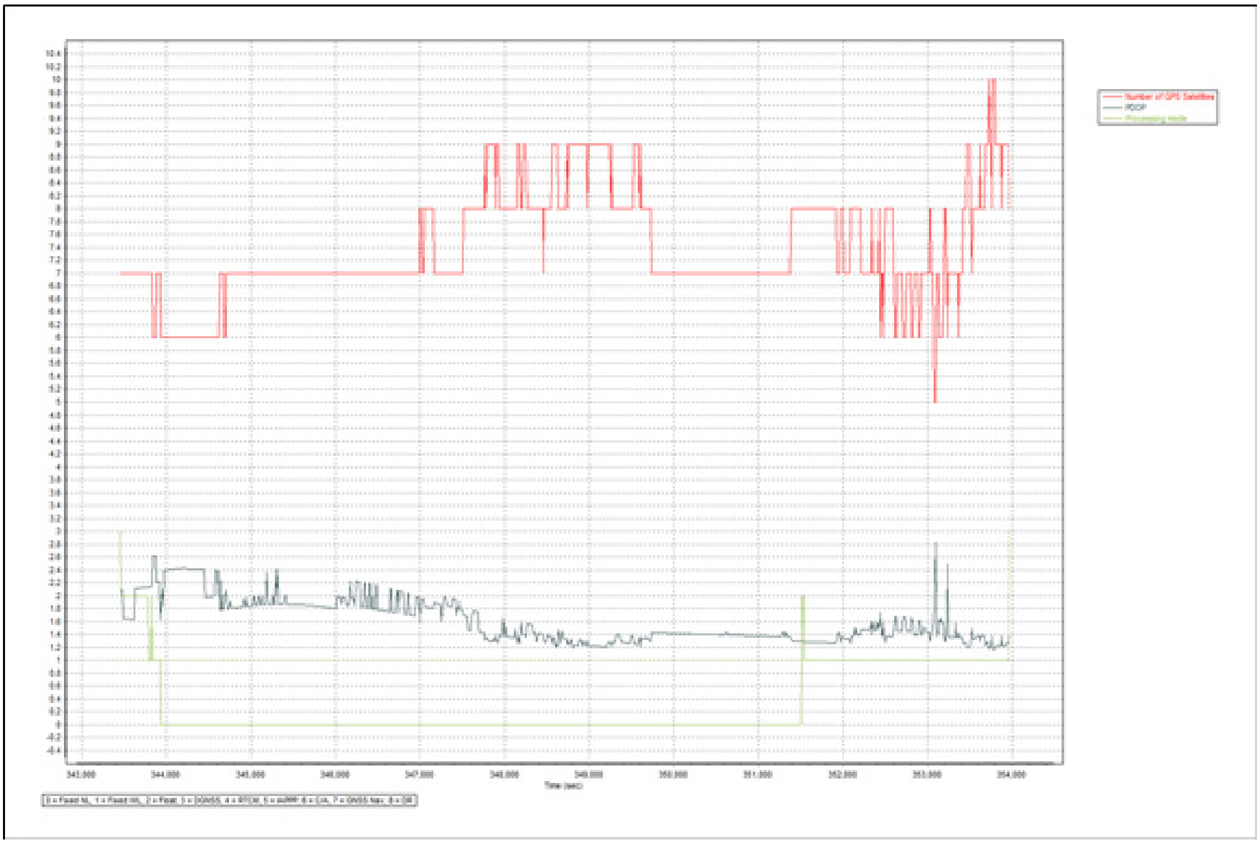


Flight No. : 1331P
Area: BLK32B
Mission Name: 1BLK32B101A
Parameters: Altitude: 800m; Scan Frequency: 30Hz;
Scan Angle: 50deg; Overlap: 35%



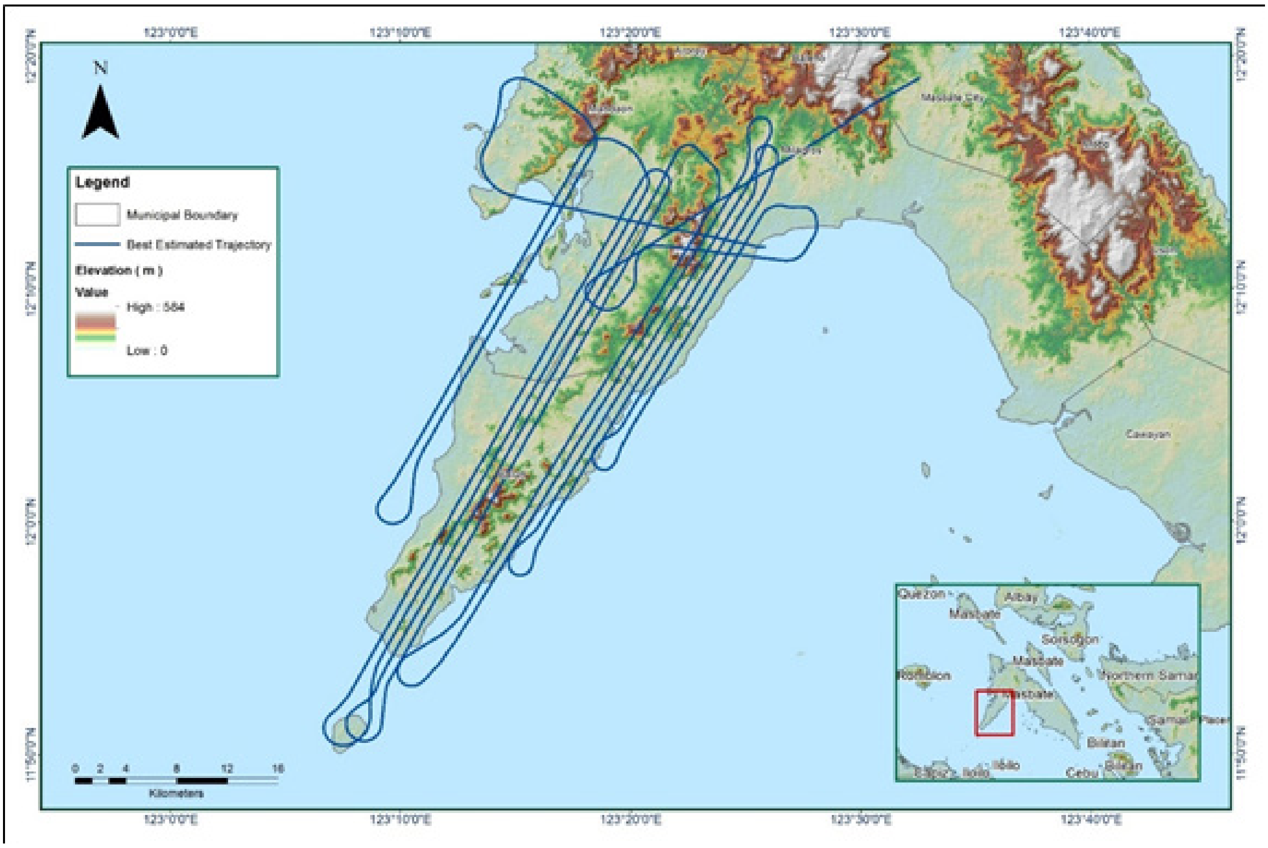
ANNEX 8 MISSION SUMMARY REPORTS

Flight Area	Masbate
Mission Name	Blk32G
Inclusive Flights	1299P, 1307P
Mission Name	1BLK32FG093A, 1BLK32DG095A
Range data size	64.5 GB
POS	503 MB
Base data size	14.08 MB
Image	100.6 GB
Transfer date	April 23, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.20
RMSE for East Position (<4.0 cm)	1.50
RMSE for Down Position (<8.0 cm)	3.00
Boresight correction stdev (<0.001deg)	0.000370
IMU attitude correction stdev (<0.001deg)	0.001180
GPS position stdev (<0.01m)	0.009
Minimum % overlap (>25)	45.31
Ave point cloud density per sq.m. (>2.0)	2.50
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	451
Maximum Height	486.11m
Minimum Height	56.37m
Classification (# of points)	
Ground	413,161,256
Low vegetation	357,001,223
Medium vegetation	465,190,528
High vegetation	93,258,337
Building	2,337,065
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Jennifer Saguran,Engr. Melanie Hingpit, JovyNarisma

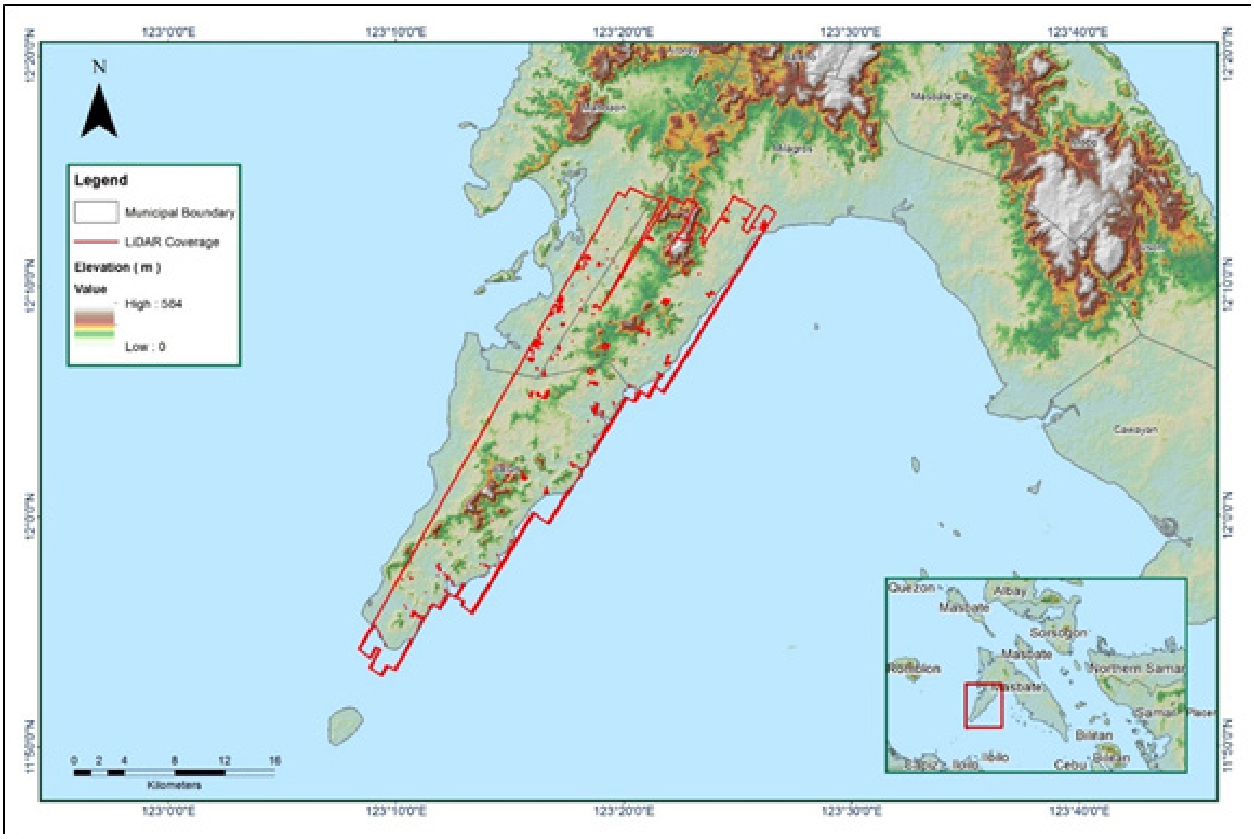


Solution Status

Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

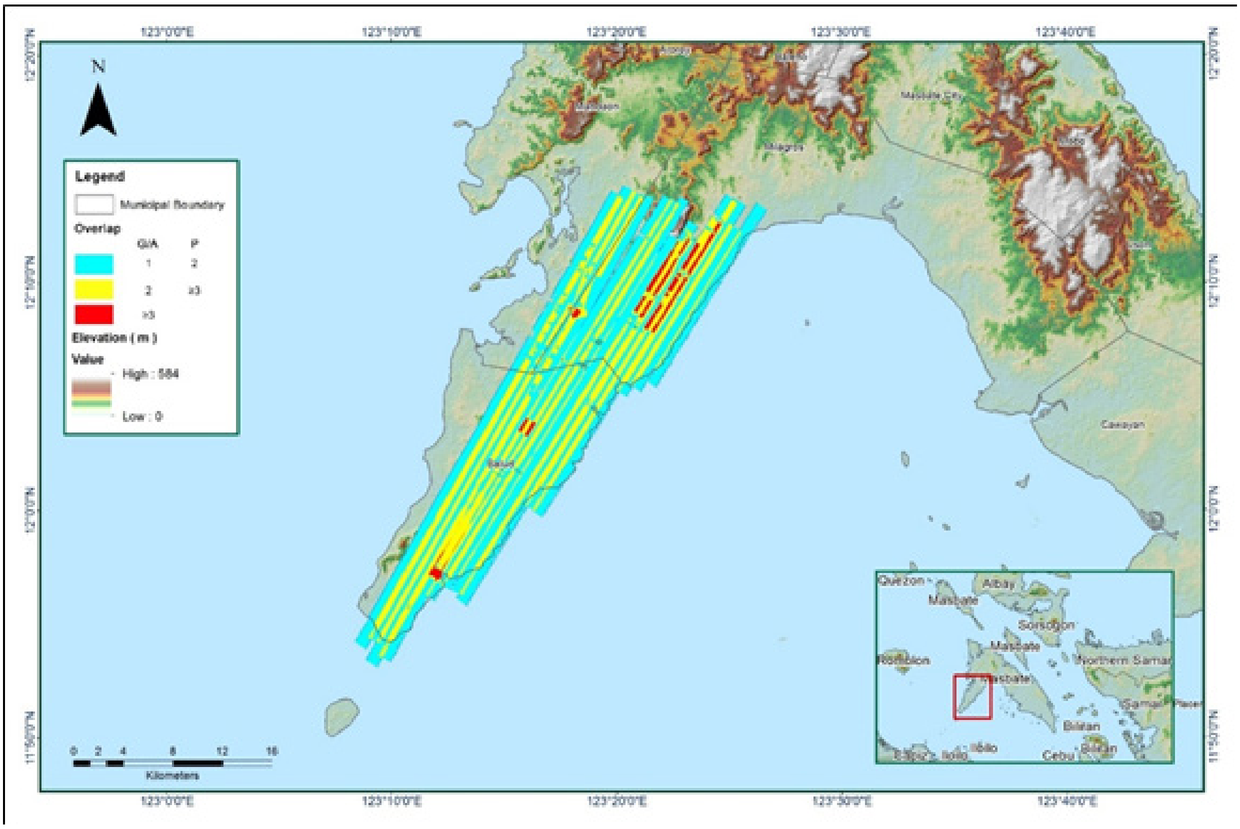
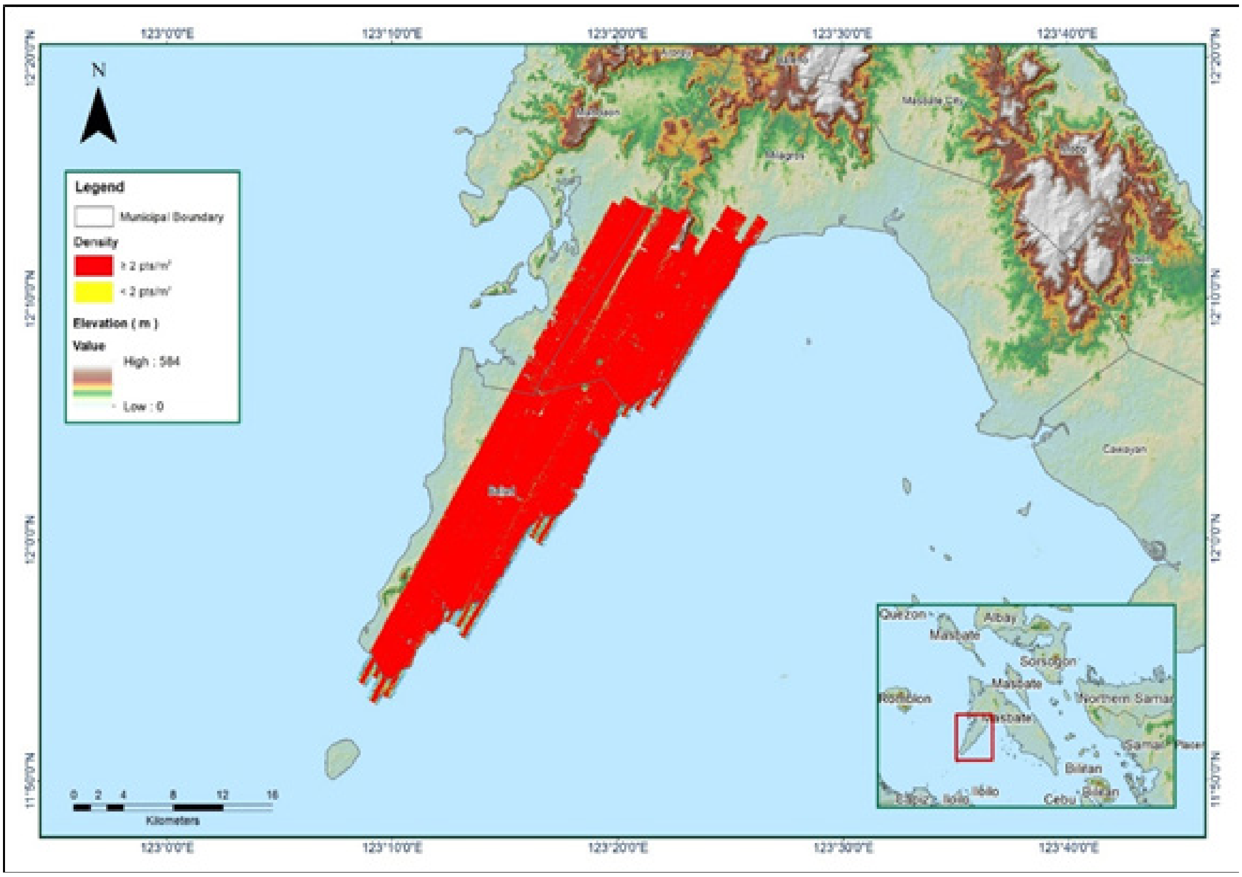
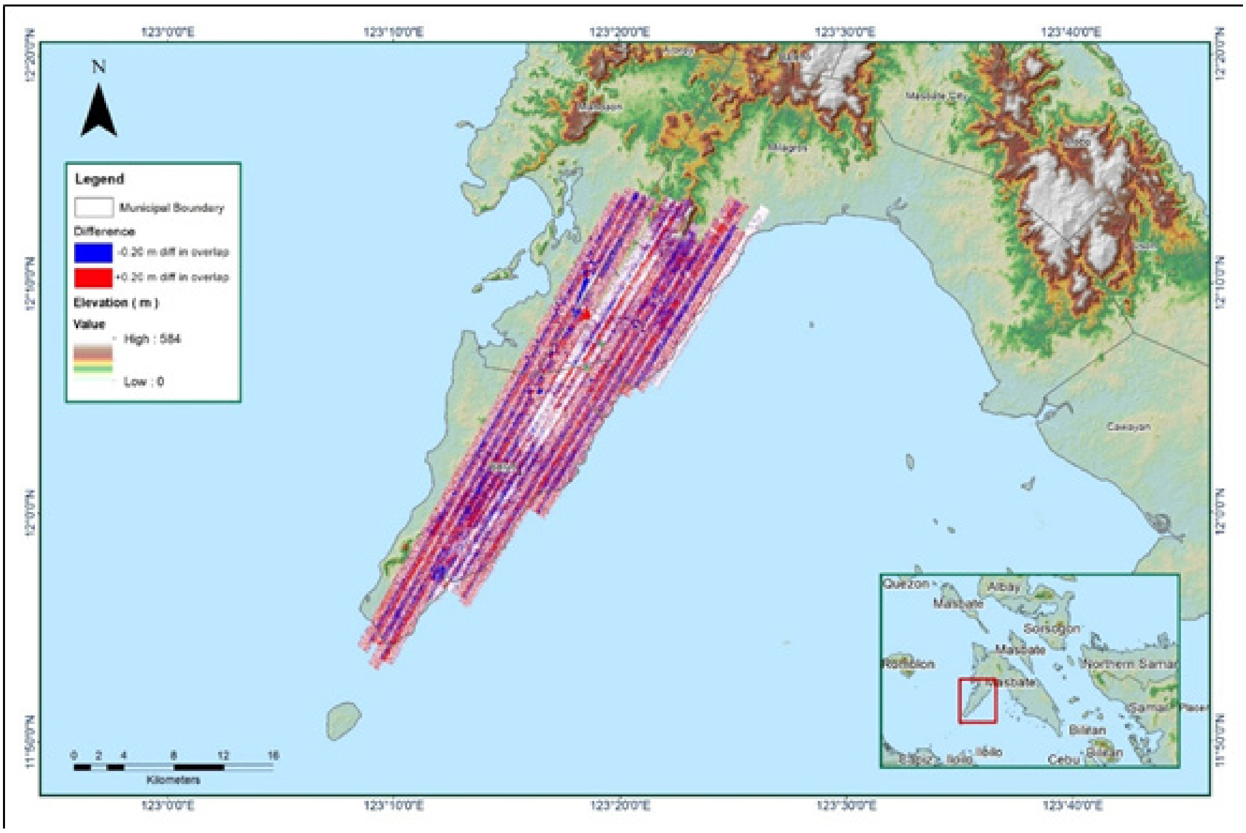


Image of Data Overlap

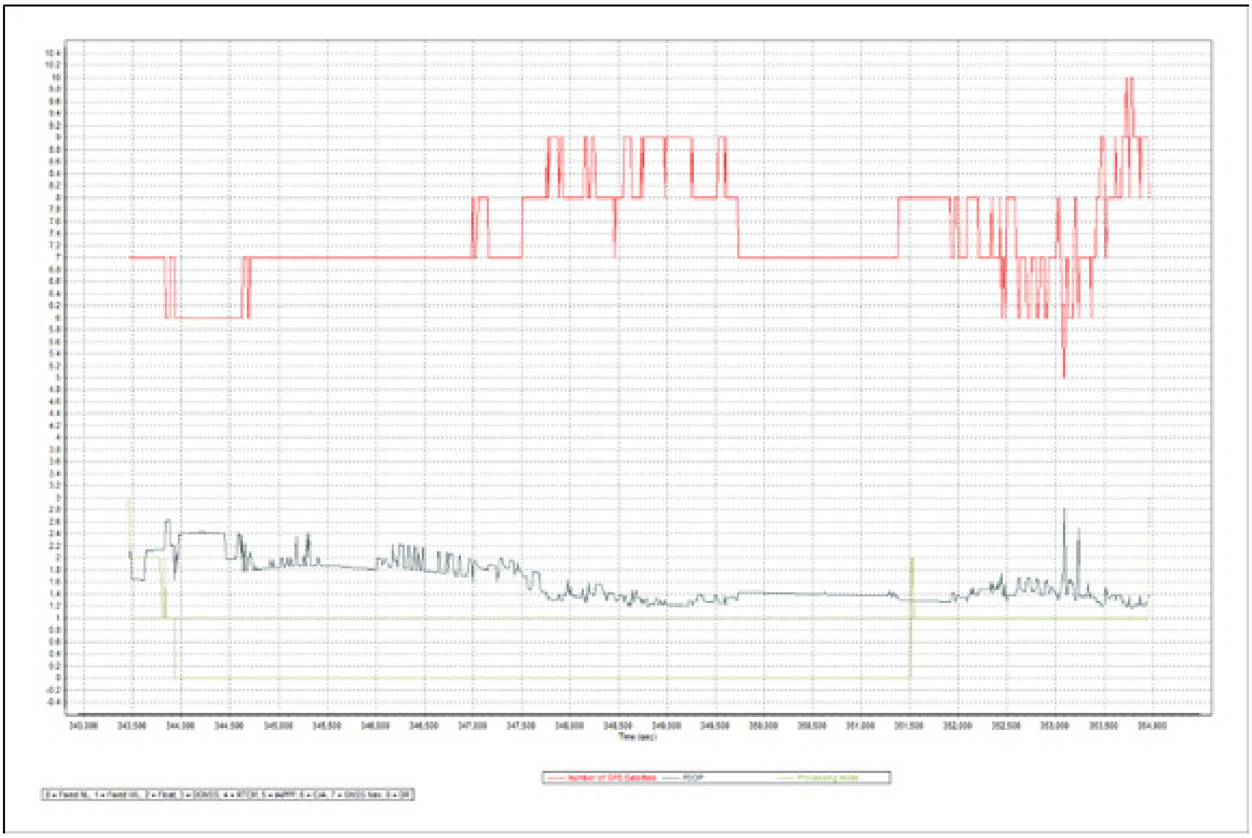


Density map of merged LiDAR data

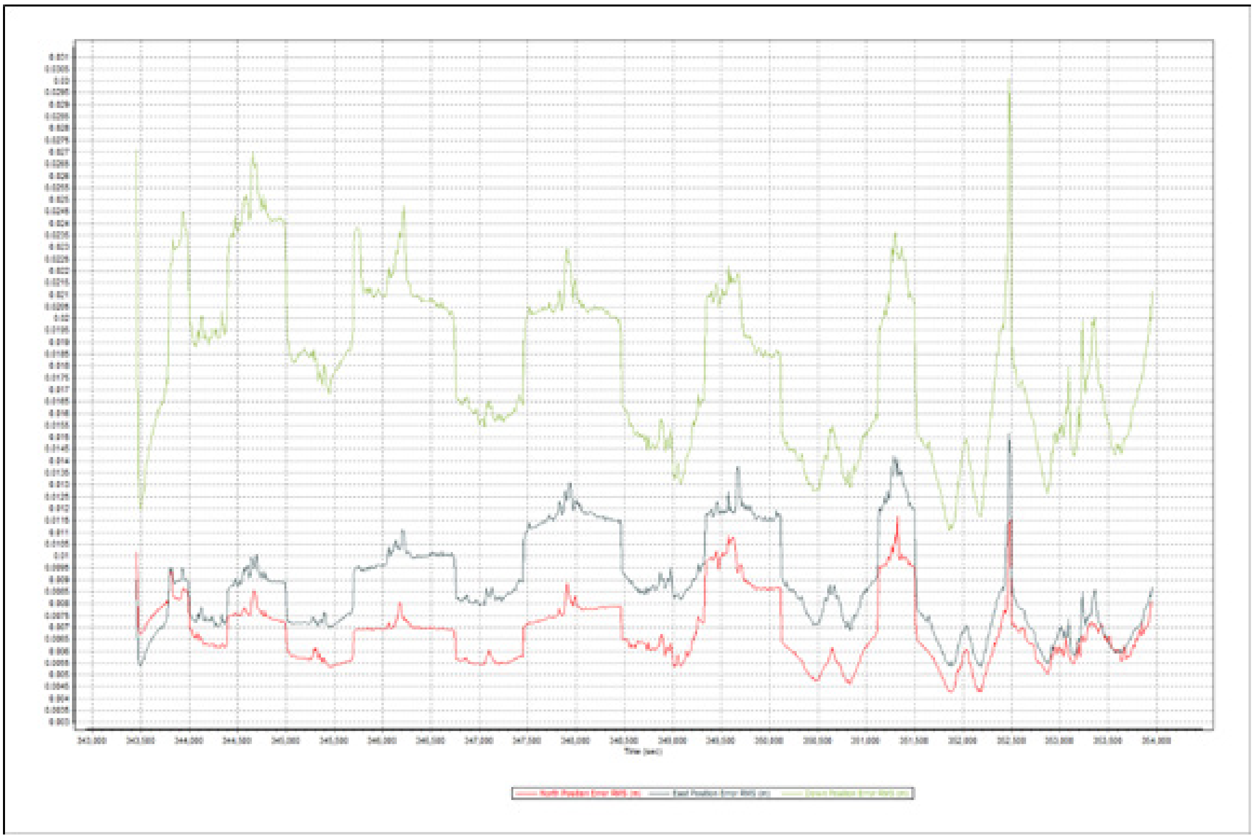


Elevation difference between flight lines

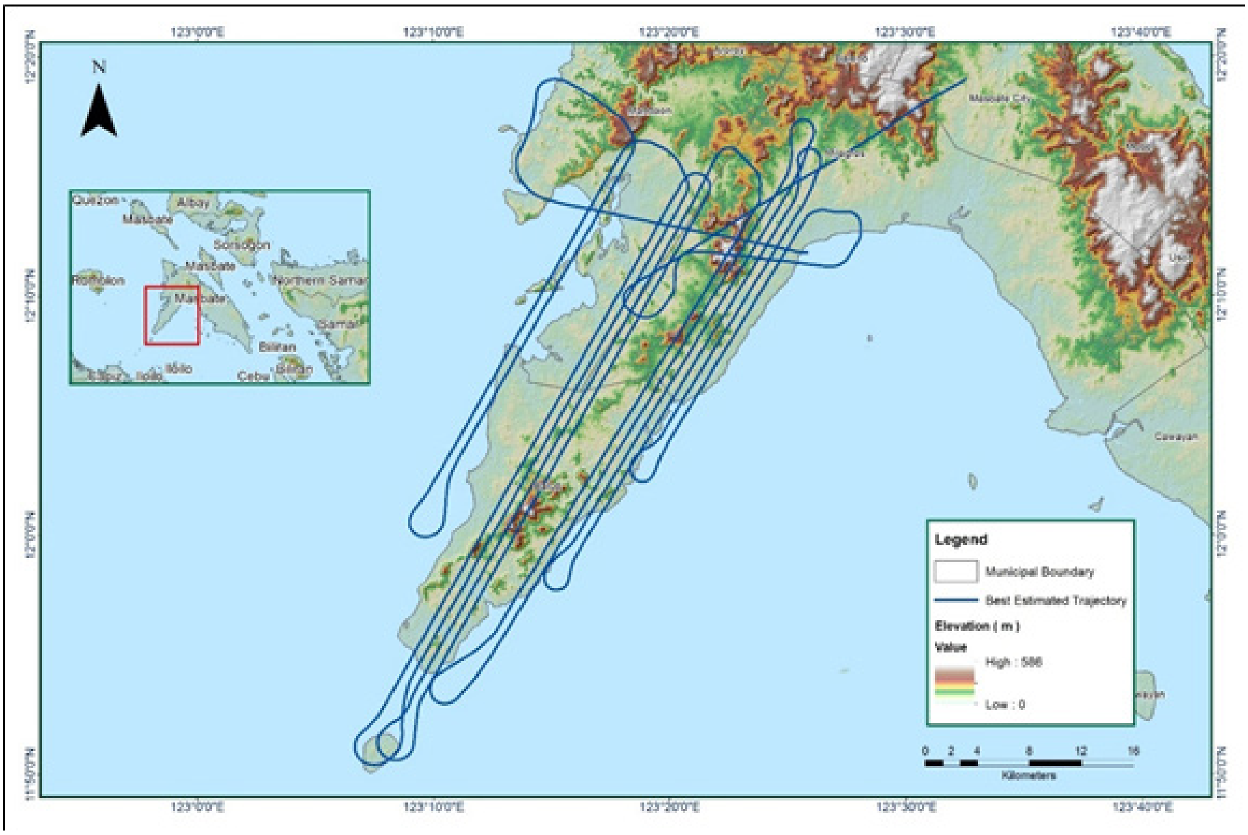
Flight Area	MASBATE
Mission Name	Blk 32F
Inclusive Flights	1299P, 1301P
Mission Name	1BLK32FG093A, 1BLK32F093B
Range data size	46.4 GB
POS	381 MB
Base data size	15.18 MB
Image	78.0 GB
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	0.000370
IMU attitude correction stdev (<0.001deg)	0.005504
GPS position stdev (<0.01m)	0.0124
Minimum % overlap (>25)	48.39
Ave point cloud density per sq.m. (>2.0)	2.73
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	387
Maximum Height	426.26 m
Minimum Height	55.13 m
Classification (# of points)	
Ground	403,066,762
Low vegetation	350,935,852
Medium vegetation	381,784,263
High vegetation	81,996,696
Building	2,586,509
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Melanie Hingpit, Engr. Melissa Fernandez



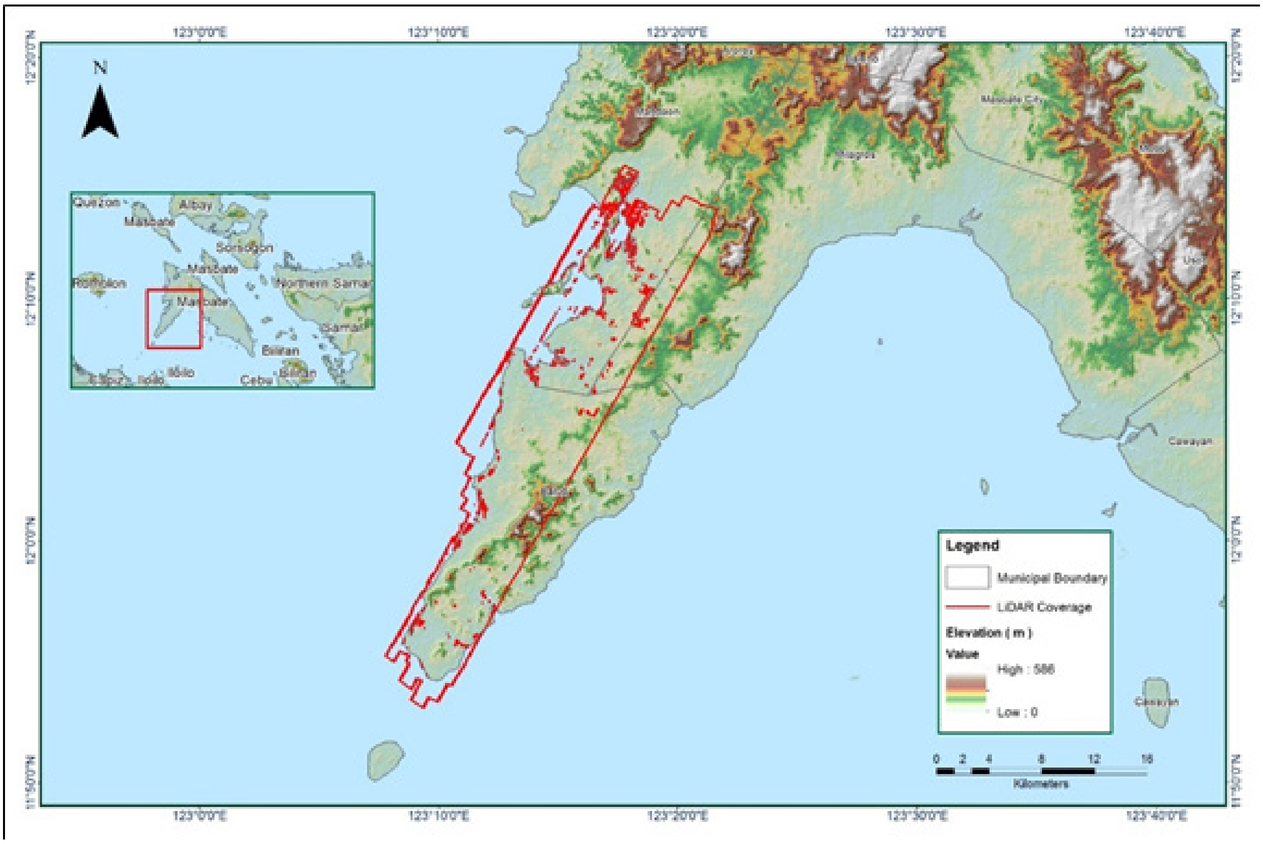
Solution Status Parameters



Smoothed Performance Metrics Parameters



Best Estimated Trajectory



Coverage of LiDAR data

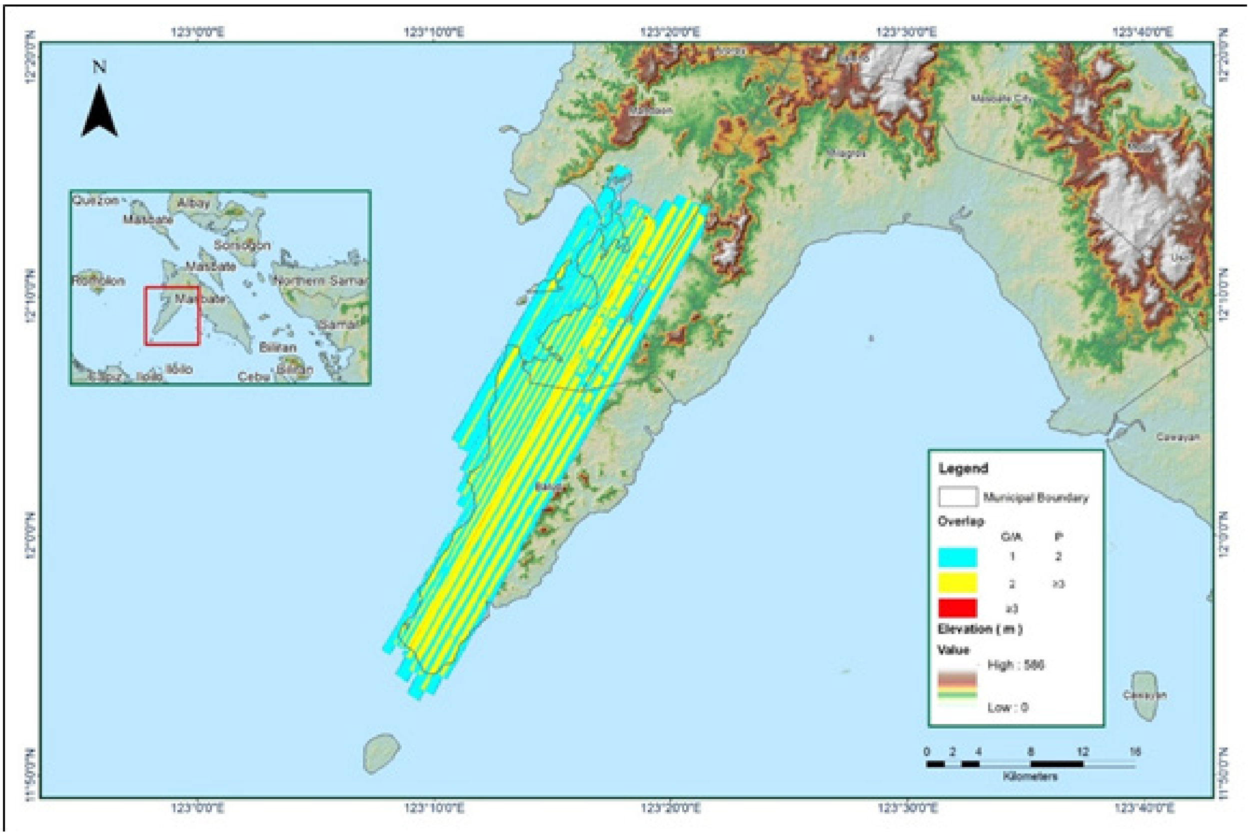
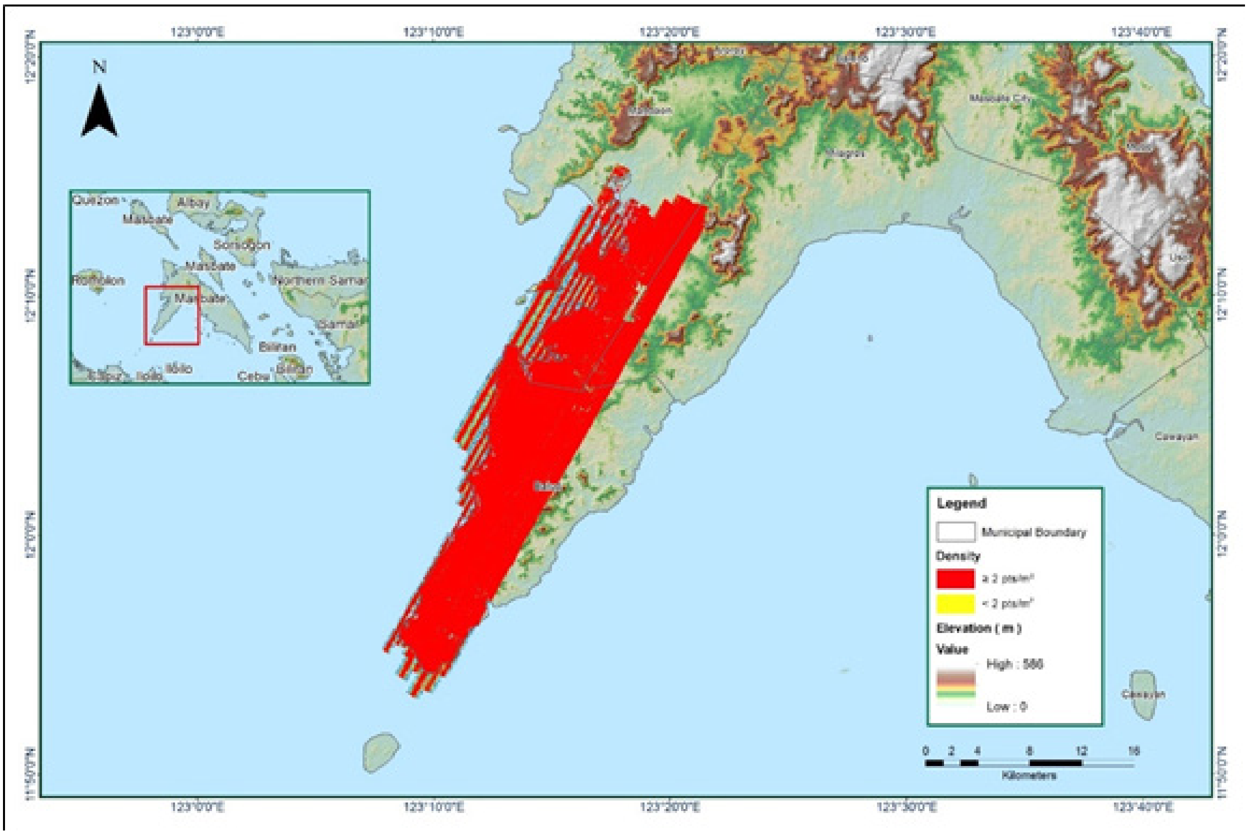
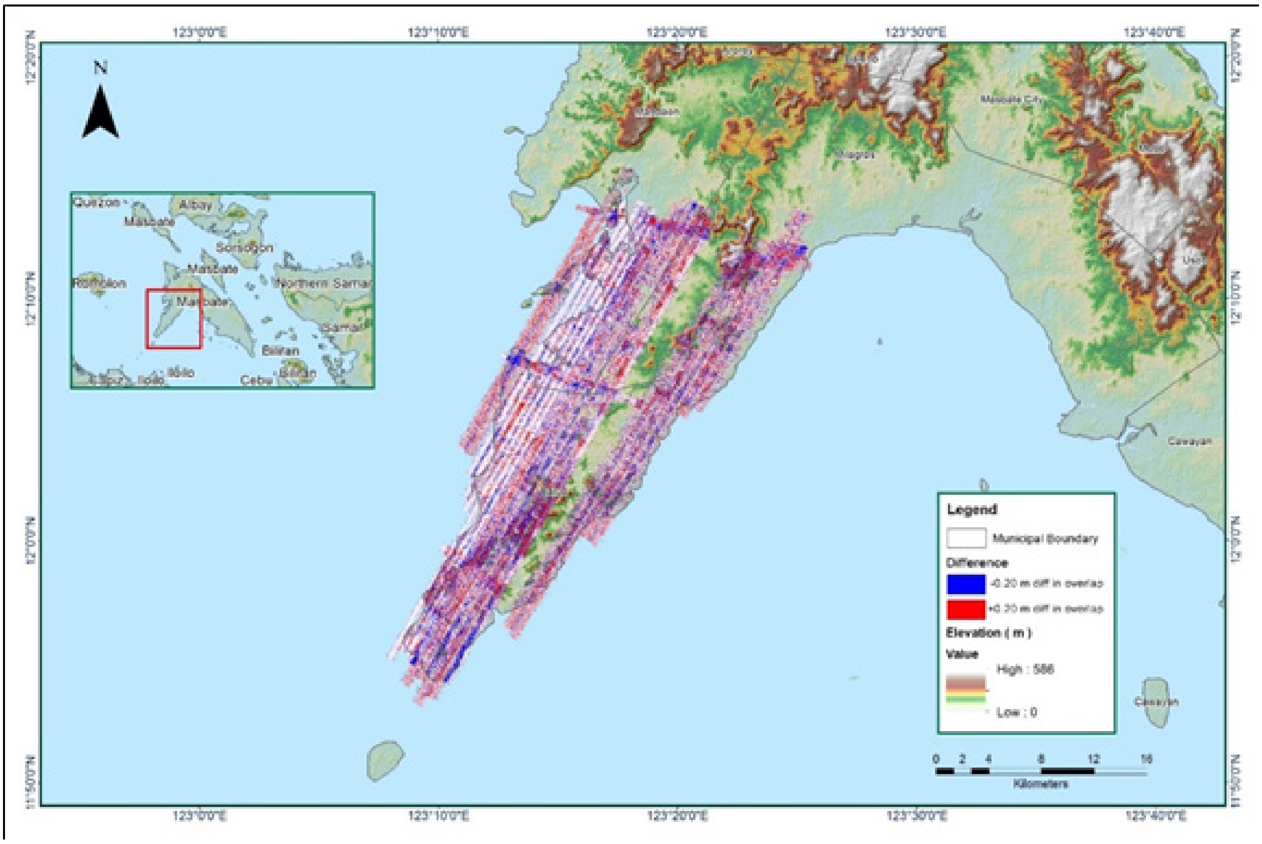


Image of Data Overlap

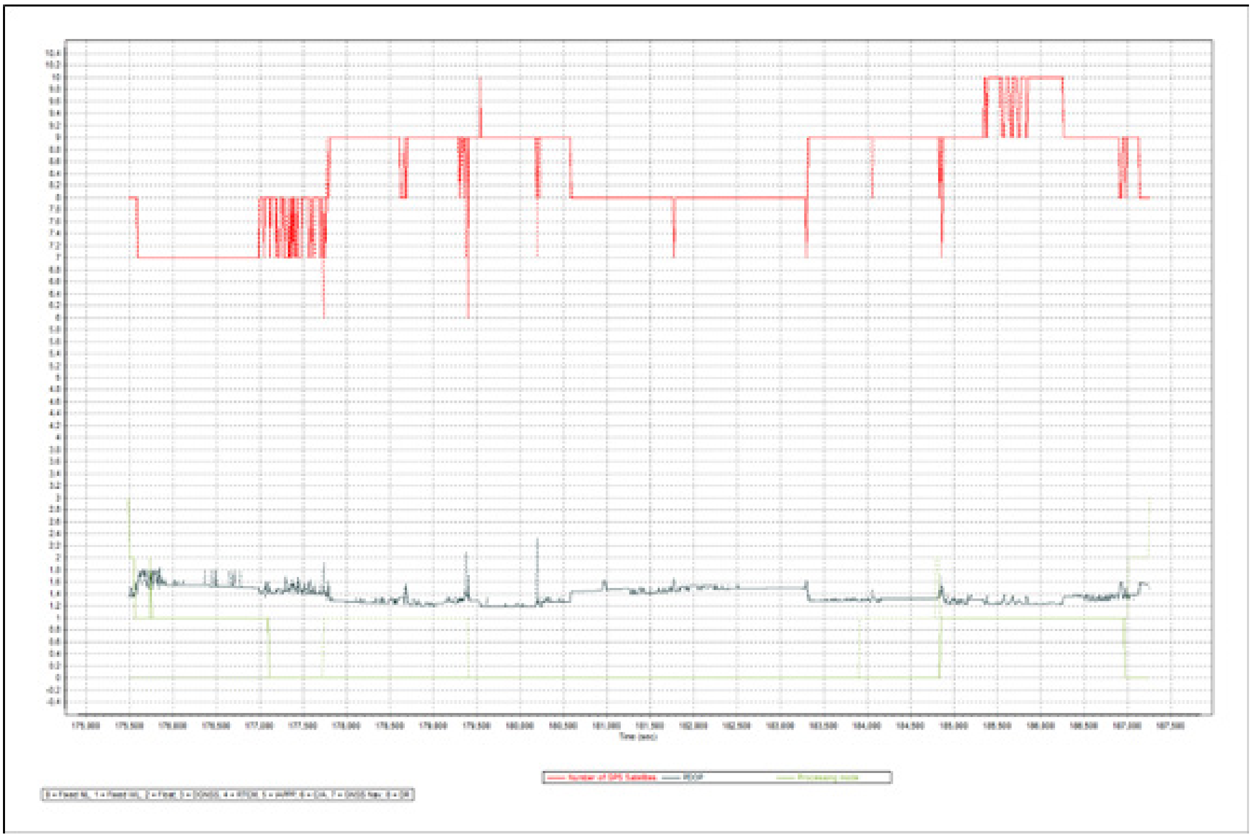


Density map of merged LiDAR data

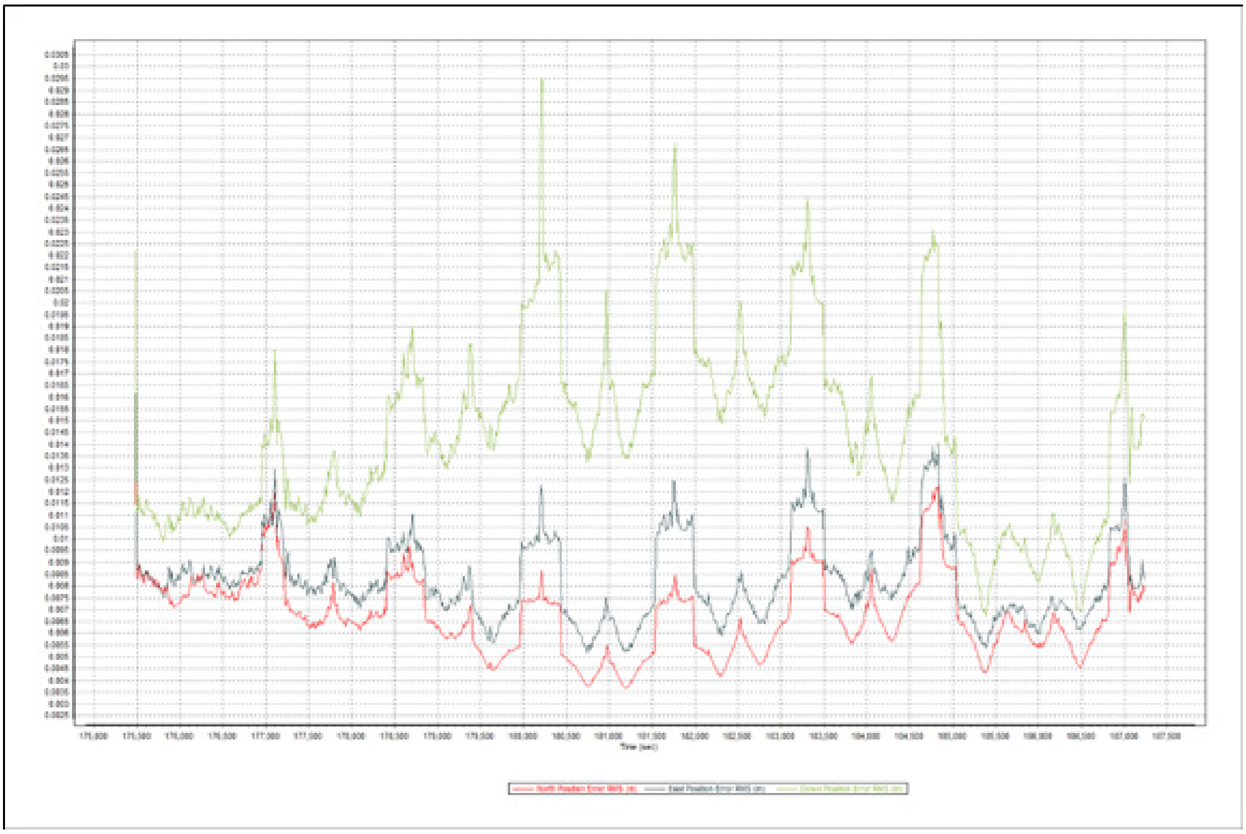


Elevation difference between flight lines

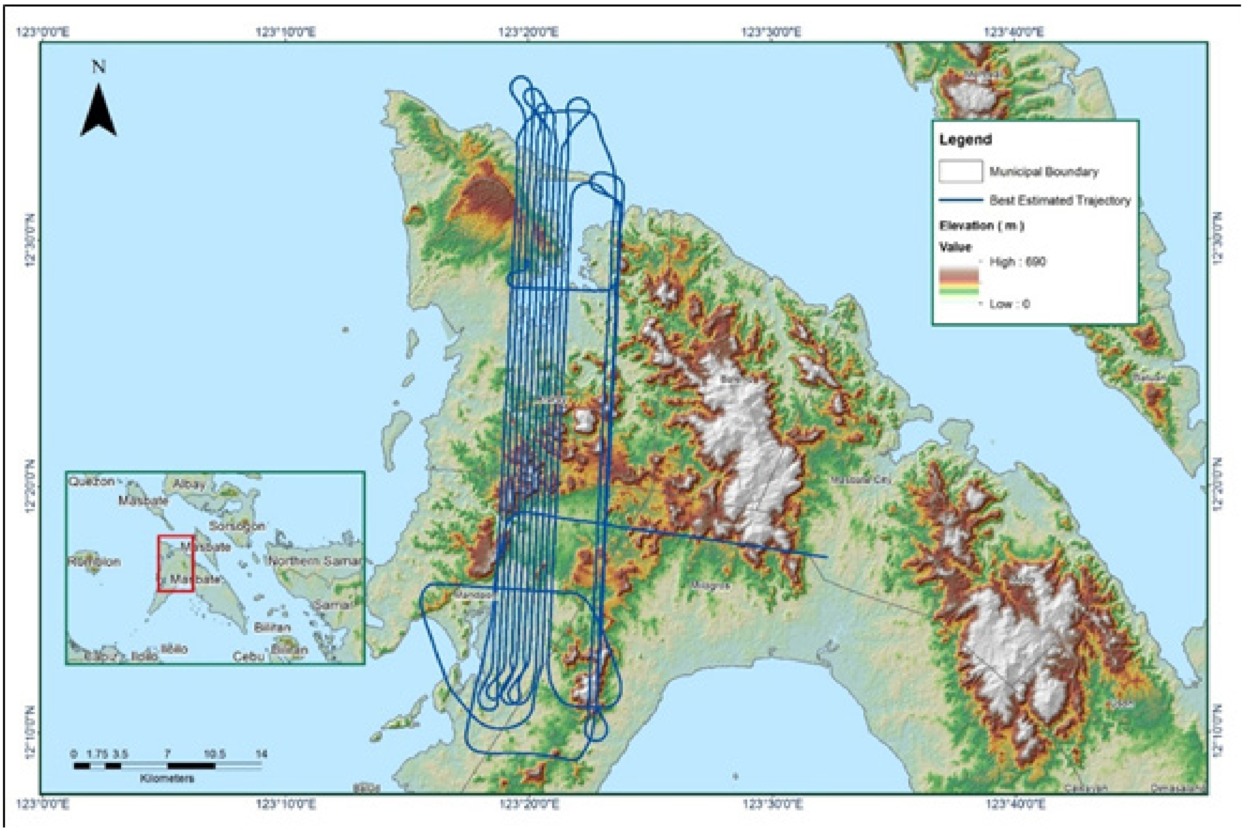
Flight Area	**MASBATE**
Mission Name	Blk 32B
Inclusive Flights	1319P, 1331P
Mission Name	1BLK32B098A, 1BLK32B101A
Range data size	54.0 GB
POS	388 MB
Base data size	9.04 MB
Image	47.5 GB
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.4
RMSE for Down Position (<8.0 cm)	2.9
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	61.52%
Ave point cloud density per sq.m. (>2.0)	4.66
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	394
Maximum Height	146.13m
Minimum Height	57.15m
Classification (# of points)	
Ground	1,946,372
Low vegetation	504,134
Medium vegetation	342,053
High vegetation	127,814
Building	7,547
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Jennifer Saguran, Engr. Mark Joshua Salvacion, Ryan James Nicholai Dizon



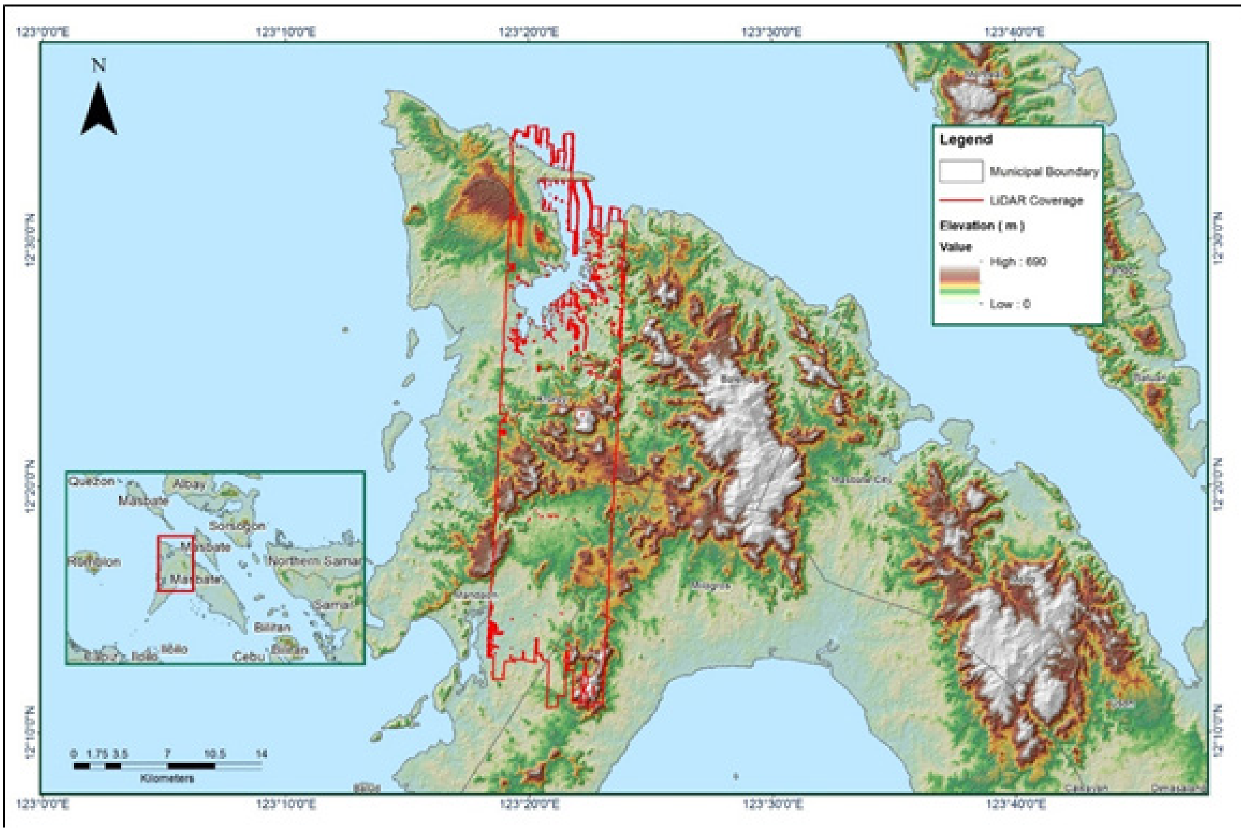
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

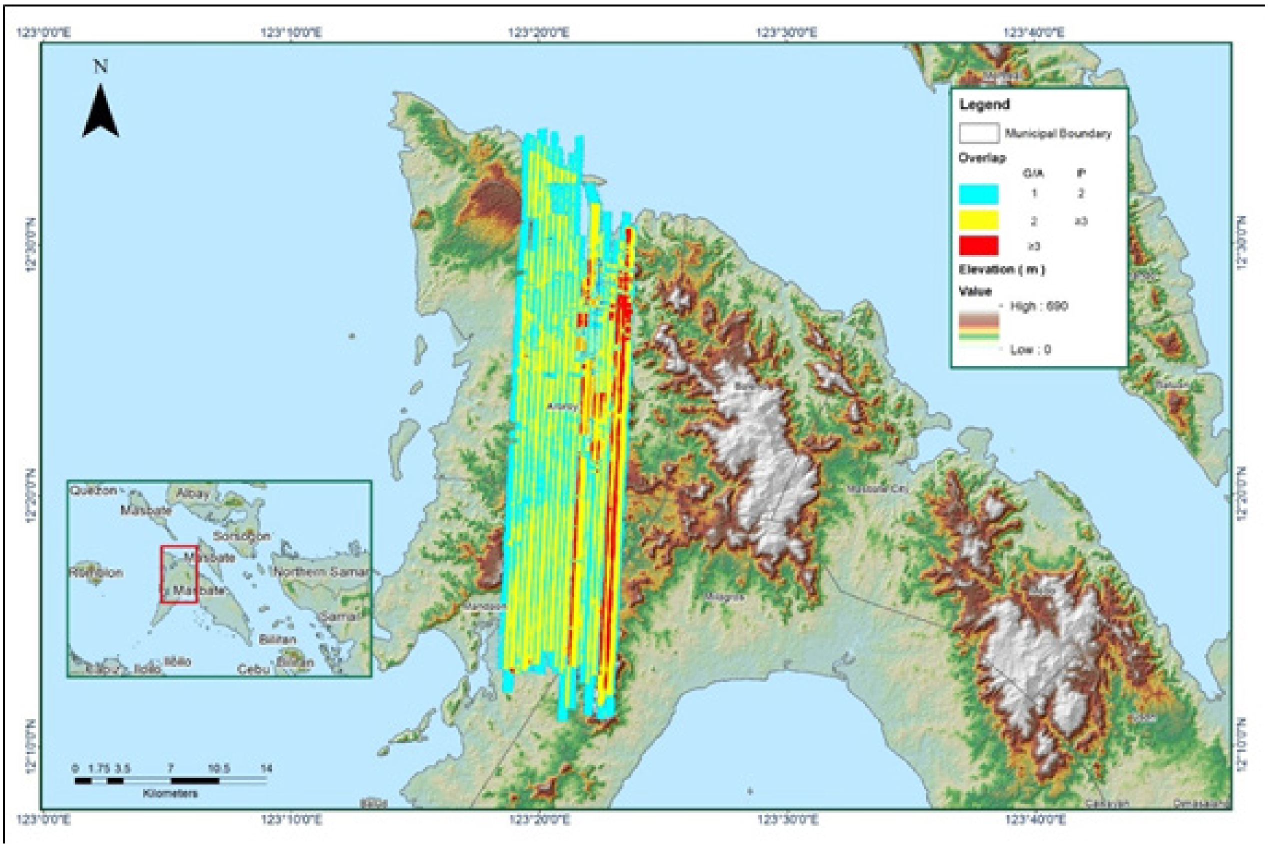
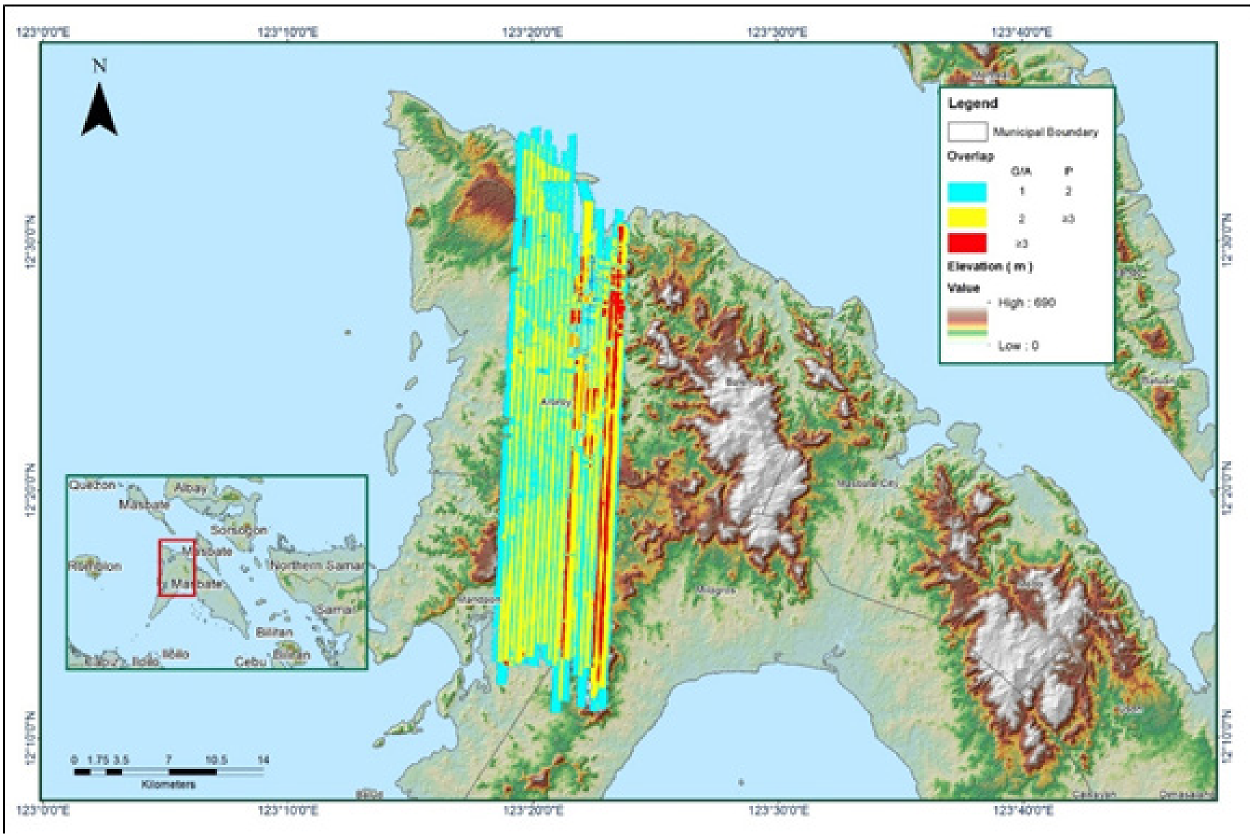
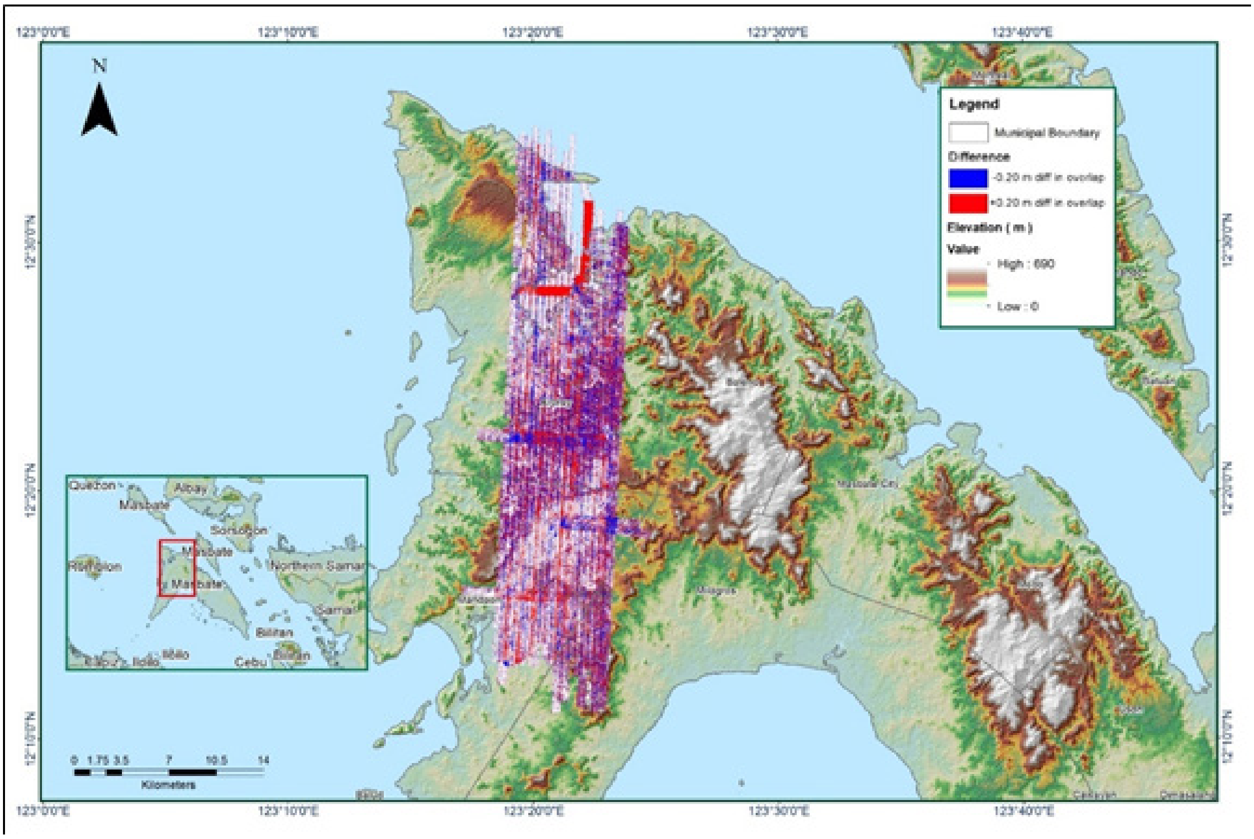


Image of Data Overlap

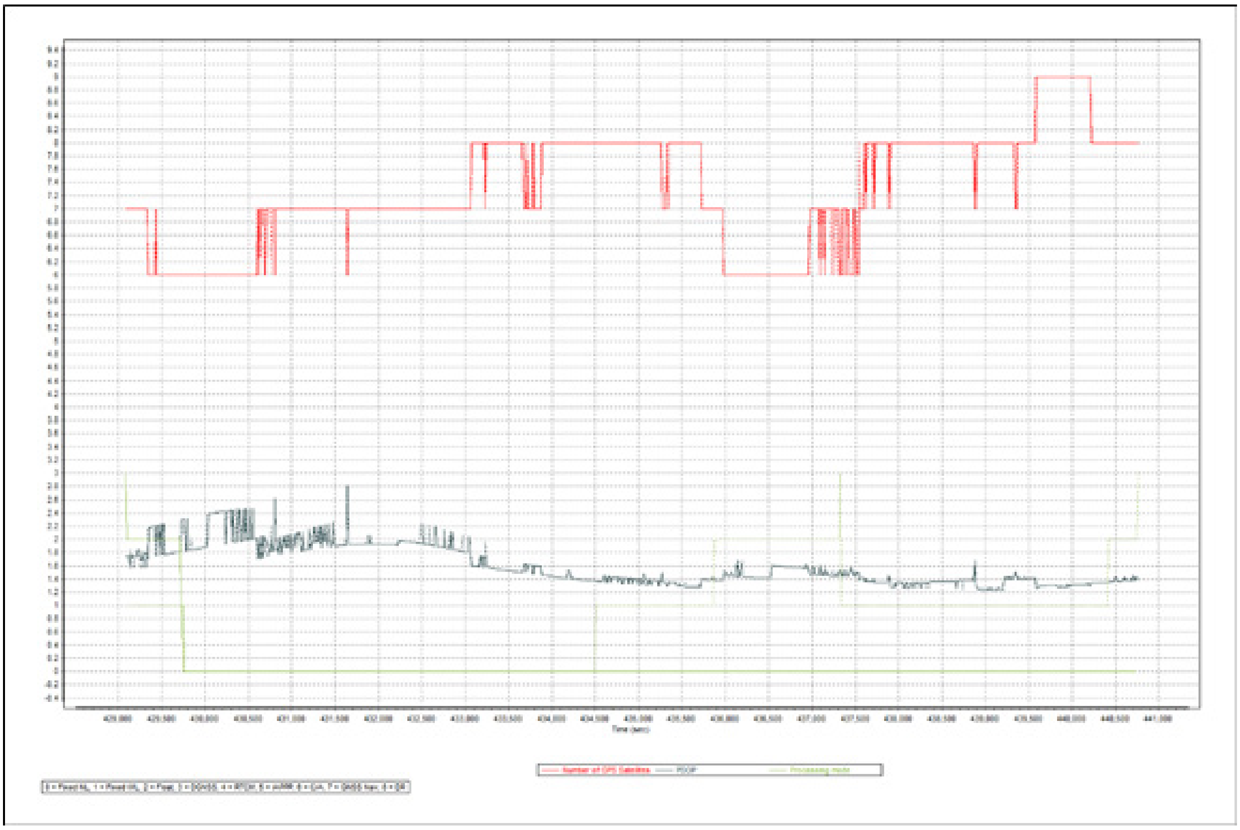


Density map of merged LiDAR data

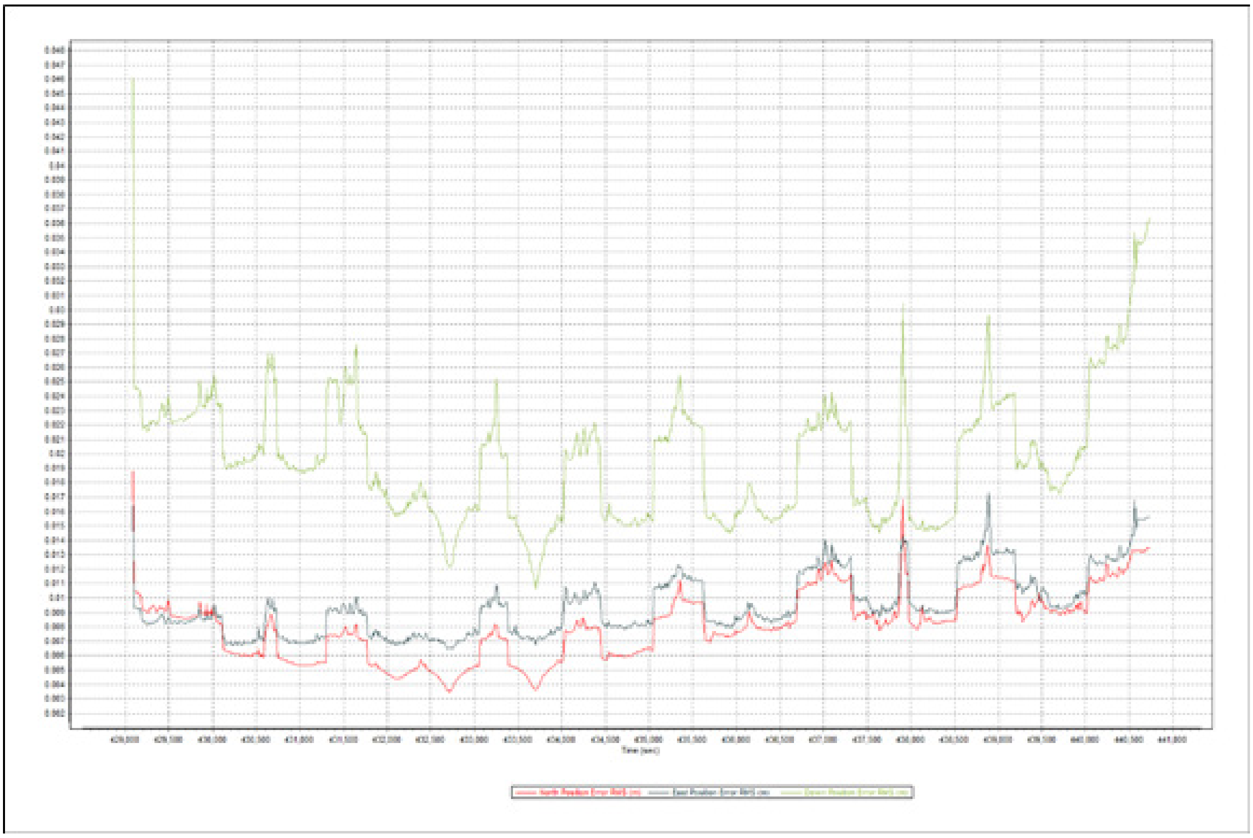


Elevation difference between flight lines

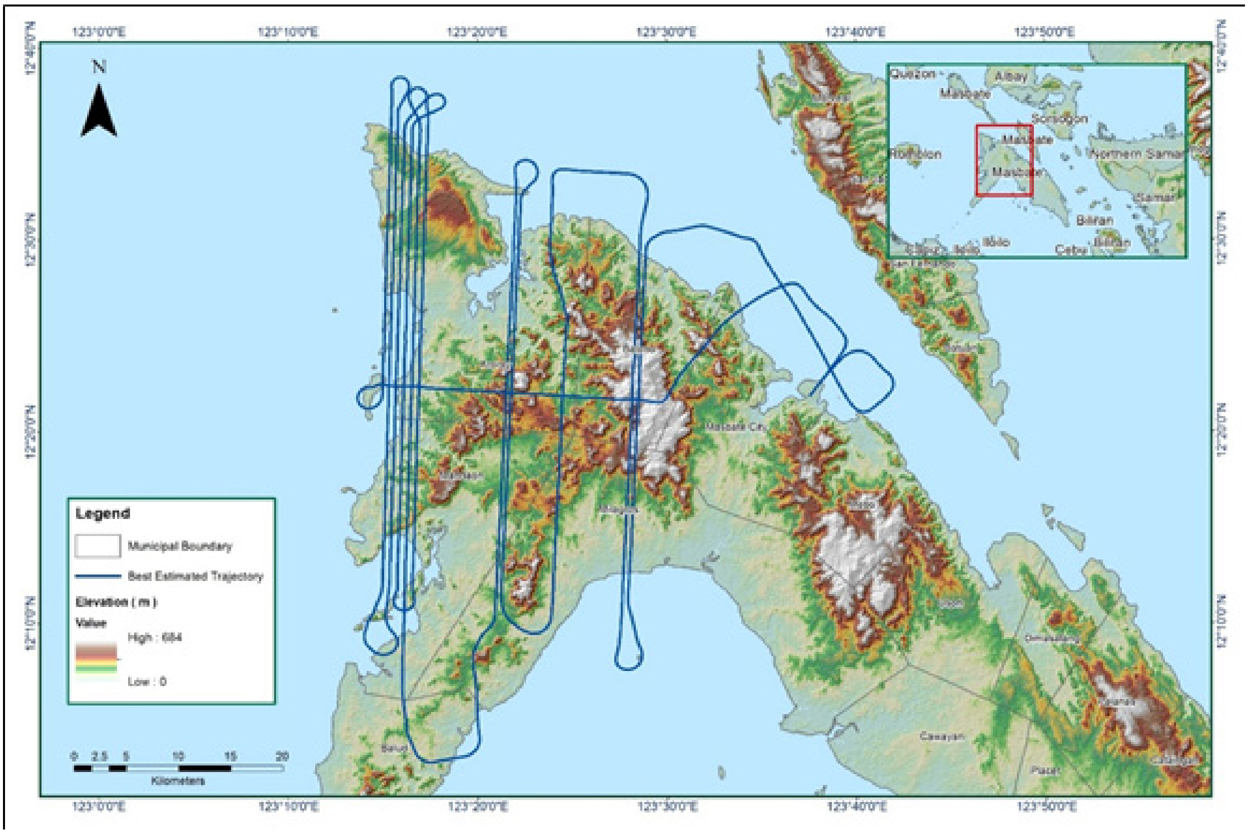
Flight Area	MASBATE
Mission Name	Blk 32A
Inclusive Flights	1303P, 1305P
Mission Name	1BLK32A094A, 1BLK32A094B
Range Data Size	52.7 GB
POS	379 MB
Base Data Size	13.34 MB
Image	96.8 GB
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.0
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	35.60%
Ave point cloud density per sq.m. (>2.0)	2.78
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	671
Maximum Height	710.95m
Minimum Height	55.95m
Classification (# of points)	
Ground	556,276,310
Low vegetation	419,293,403
Medium vegetation	439,040,885
High vegetation	260,239,514
Building	4,857,880
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Mark Joshua Salvacion, Engr. Jeffrey Delica



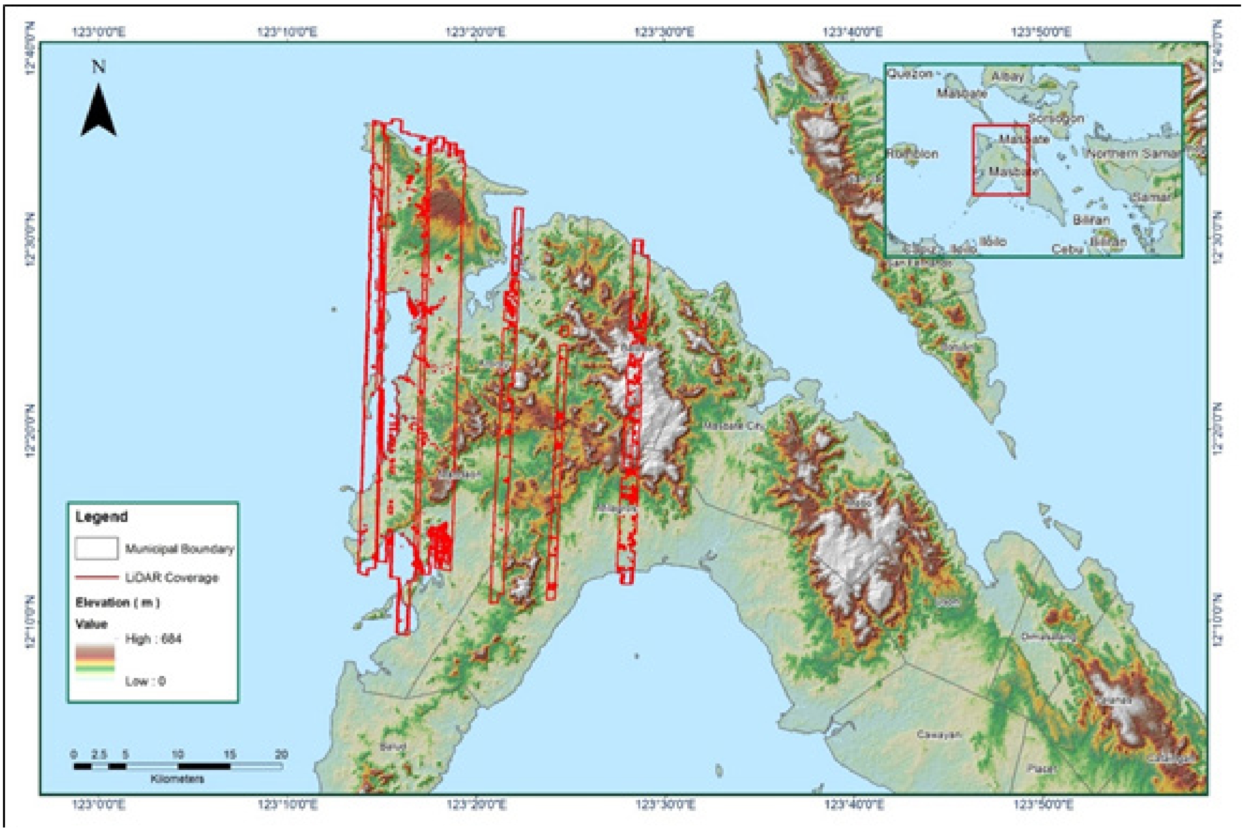
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

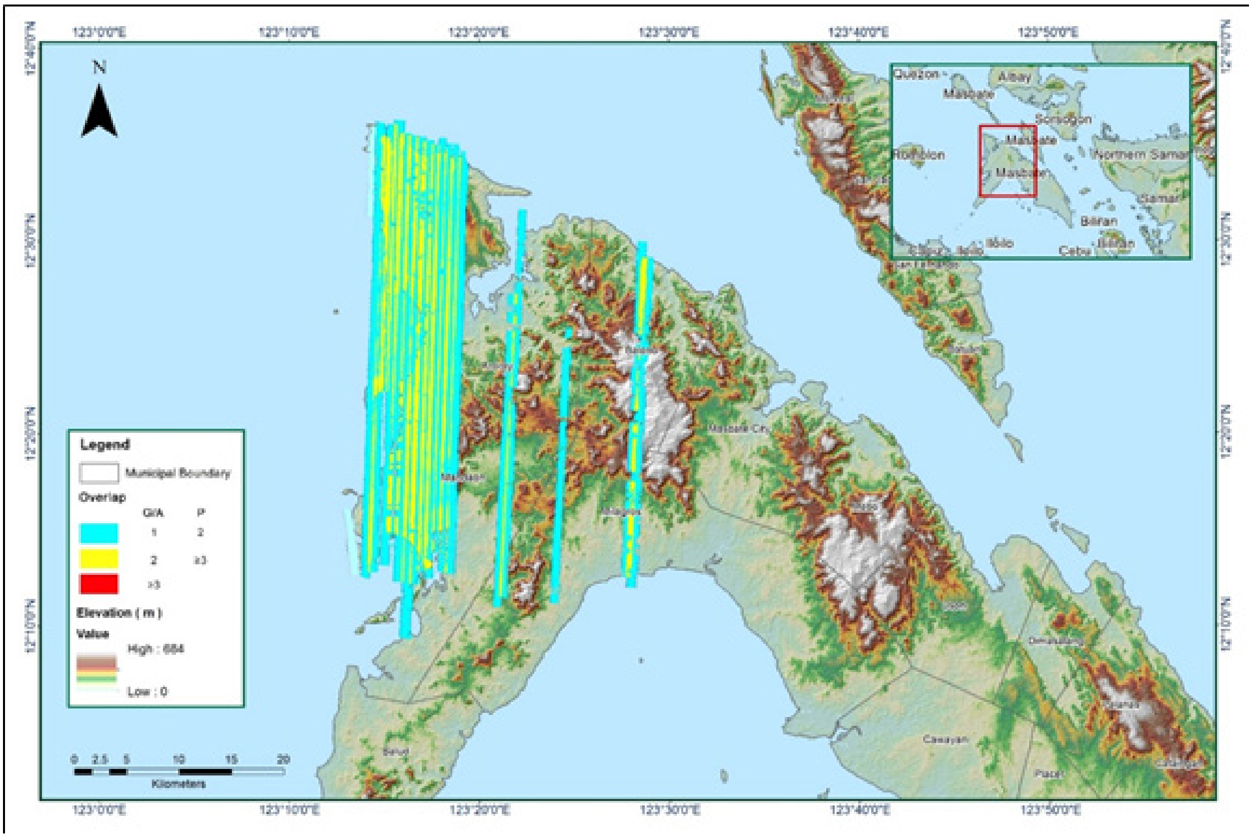
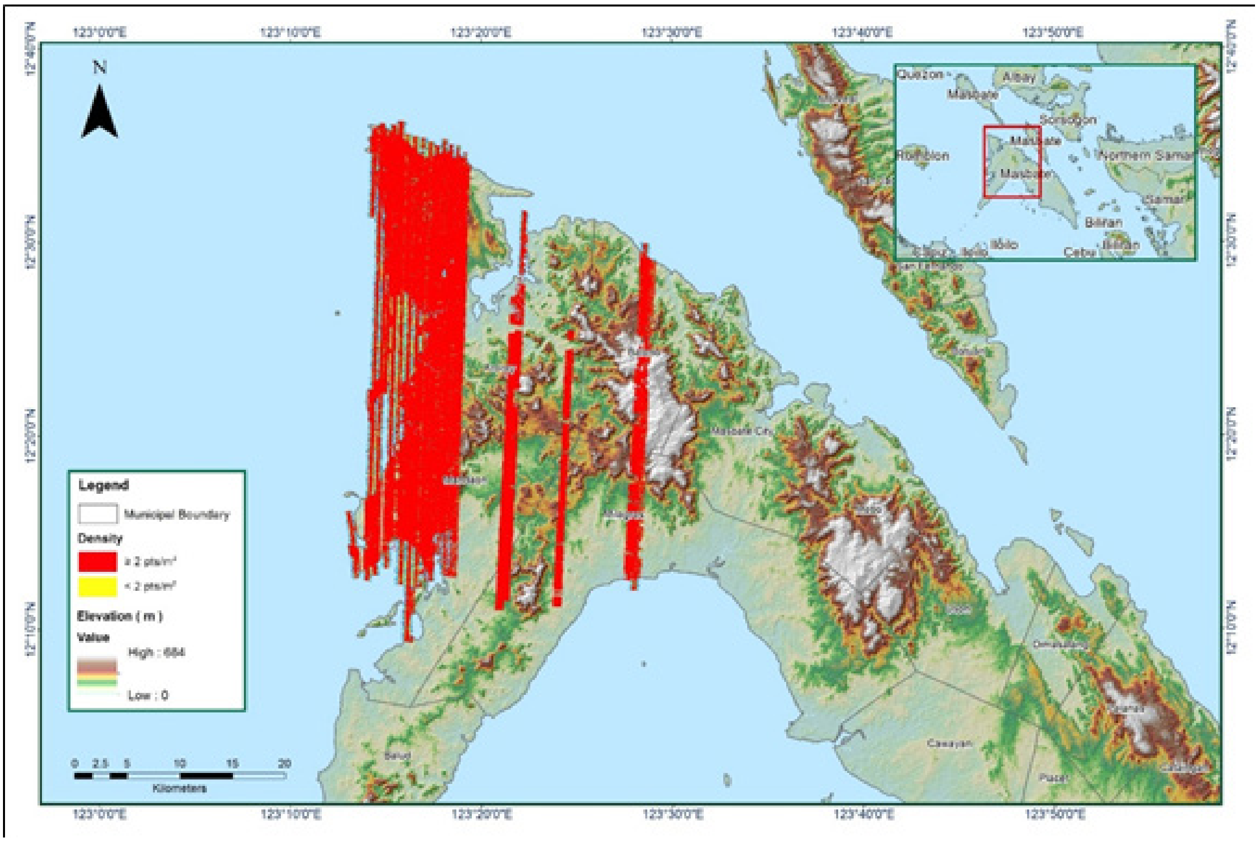
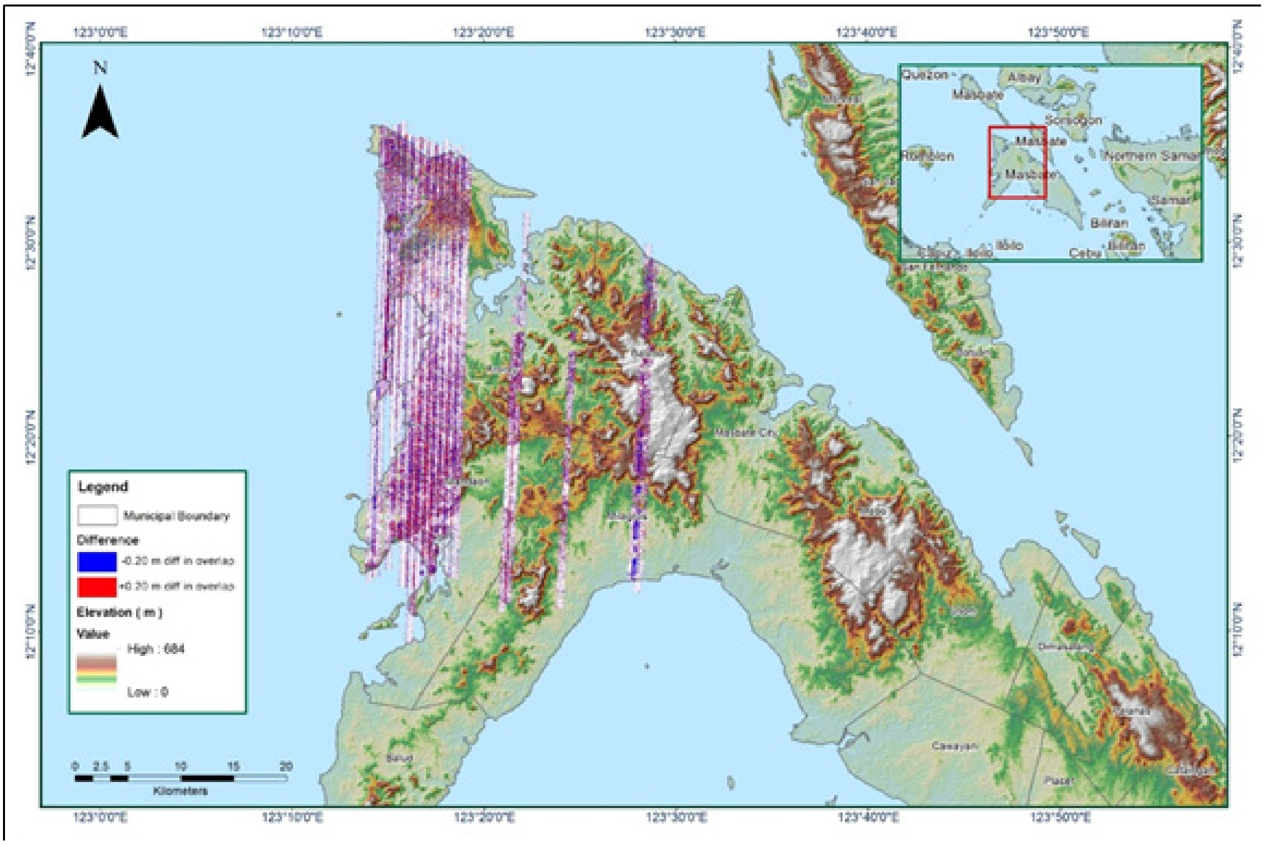


Image of Data Overlap

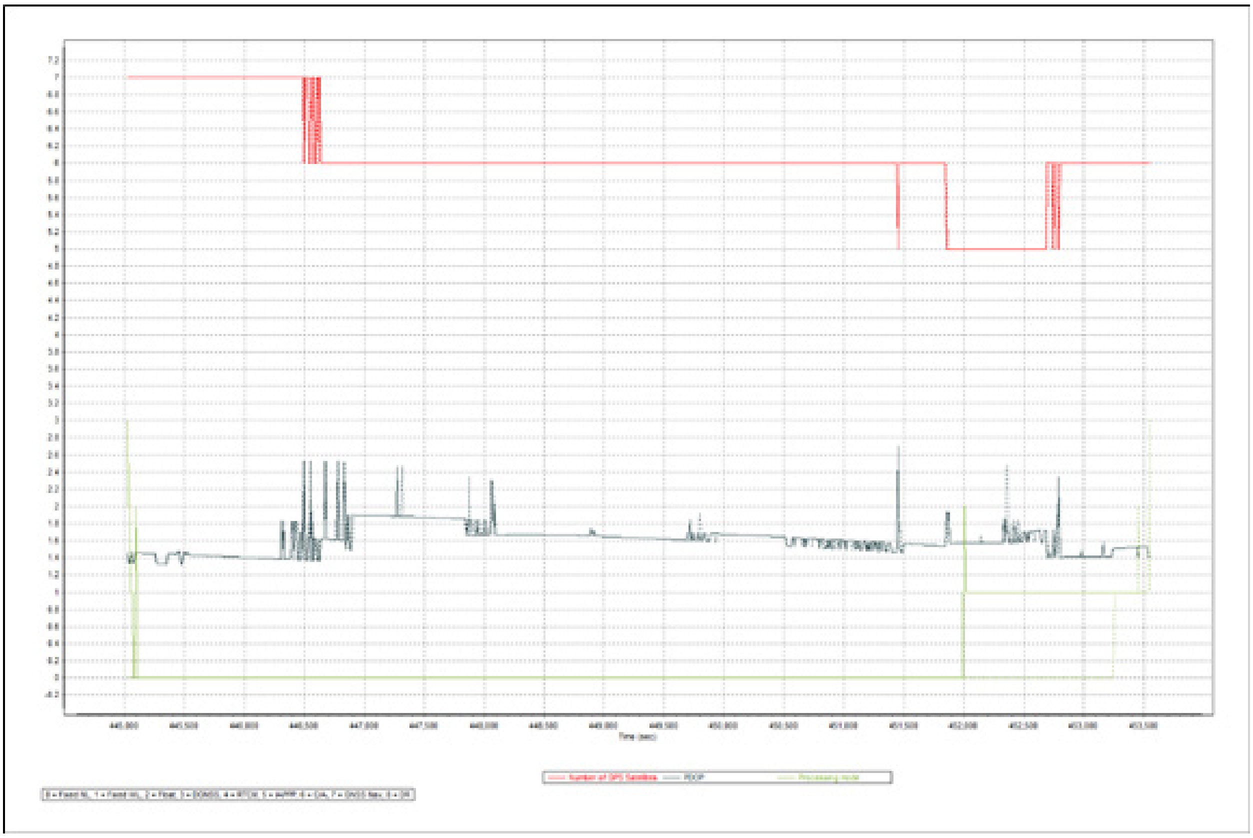


Density map of merged LiDAR data

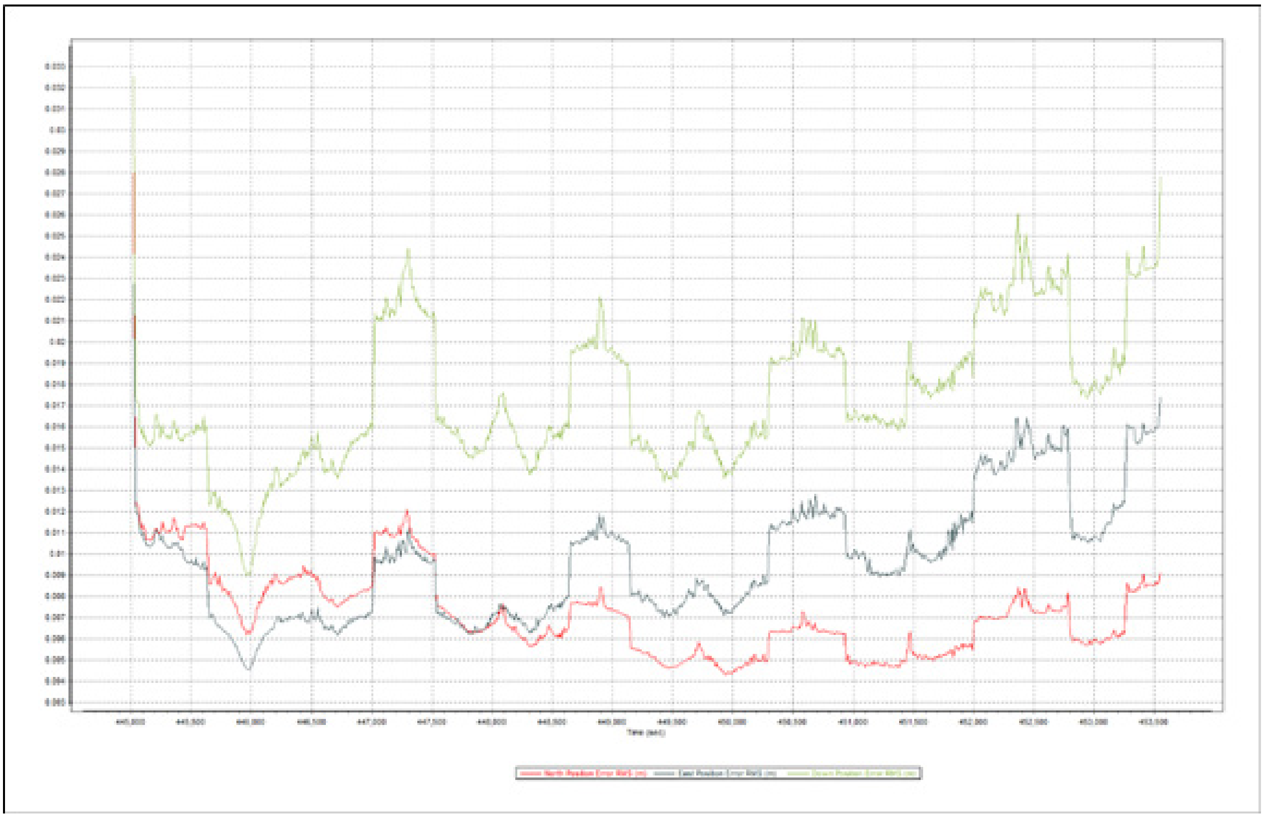


Elevation difference between flight lines

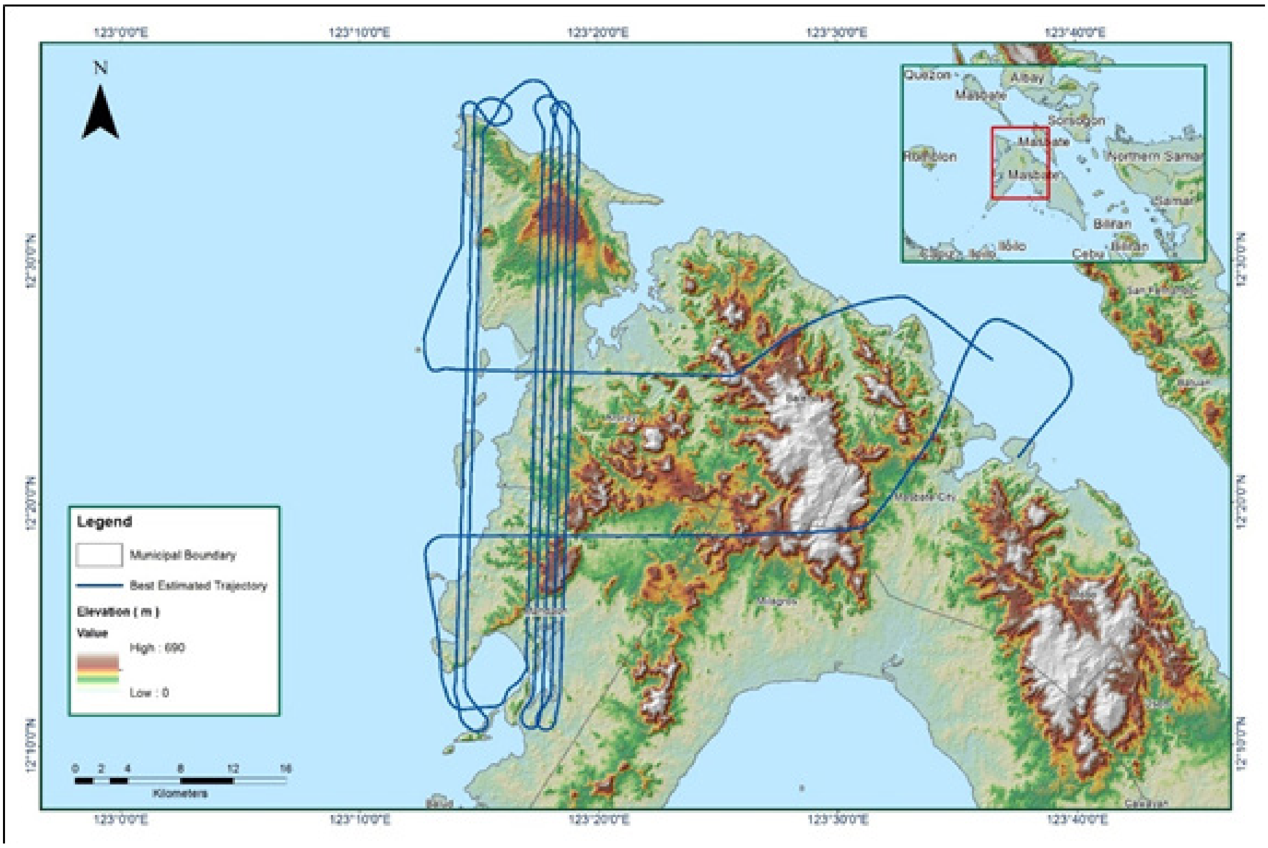
Flight Area	**MASBATE**
Mission Name	Blk 32A_Additional
Inclusive Flights	1305P
Mission Name	1BLK32A094B
Range data size	23.3 GB
POS	161 MB
Base data size	6.67 MB
Image	44.3 GB
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.2
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	2.6
Boresight correction stdev (<0.001deg)	N/A
IMU attitude correction stdev (<0.001deg)	N/A
GPS position stdev (<0.01m)	N/A
Minimum % overlap (>25)	N/A
Ave point cloud density per sq.m. (>2.0)	1.64
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	34
Maximum Height	143.57 m
Minimum Height	47.07 m
Classification (# of points)	
Ground	9,611,814
Low vegetation	8,620,790
Medium vegetation	4,657,455
High vegetation	2,586,587
Building	80,688
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Harmond Santos, Engr. Melissa Fernandez



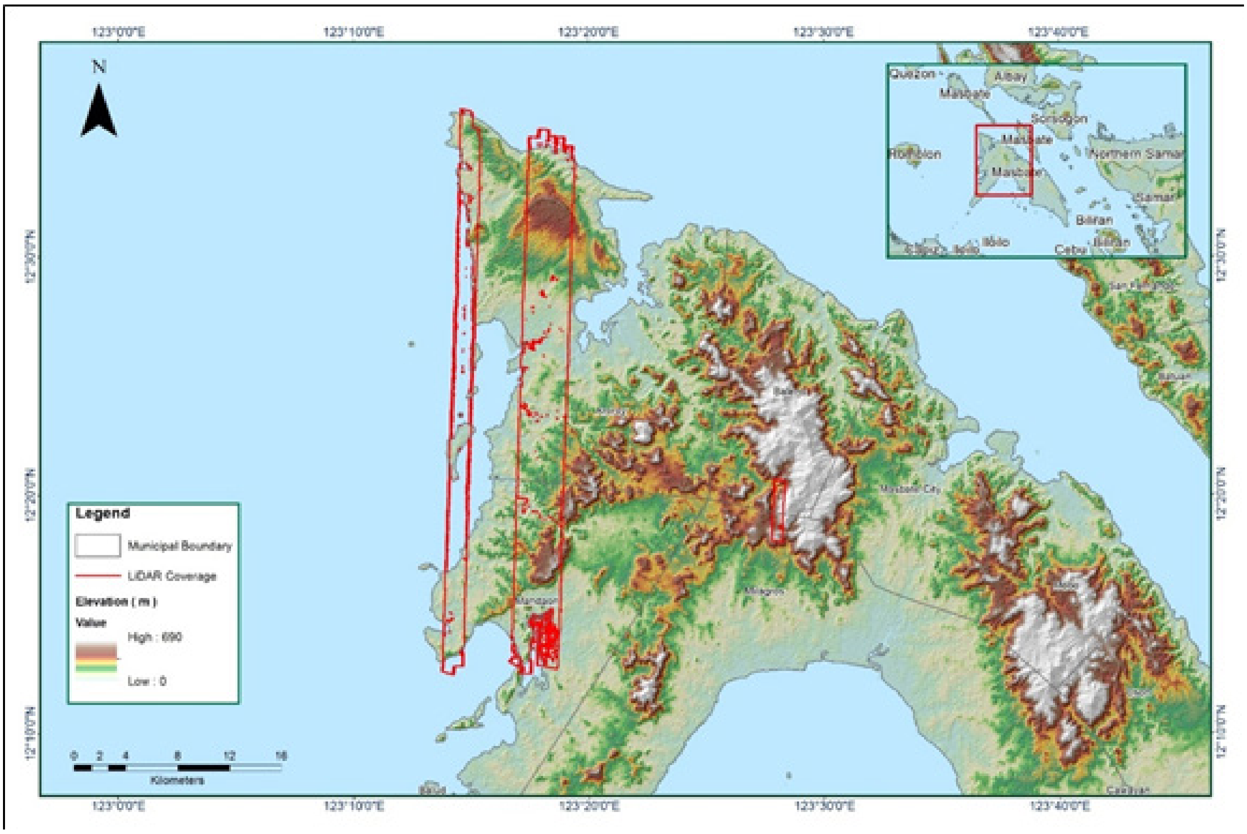
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

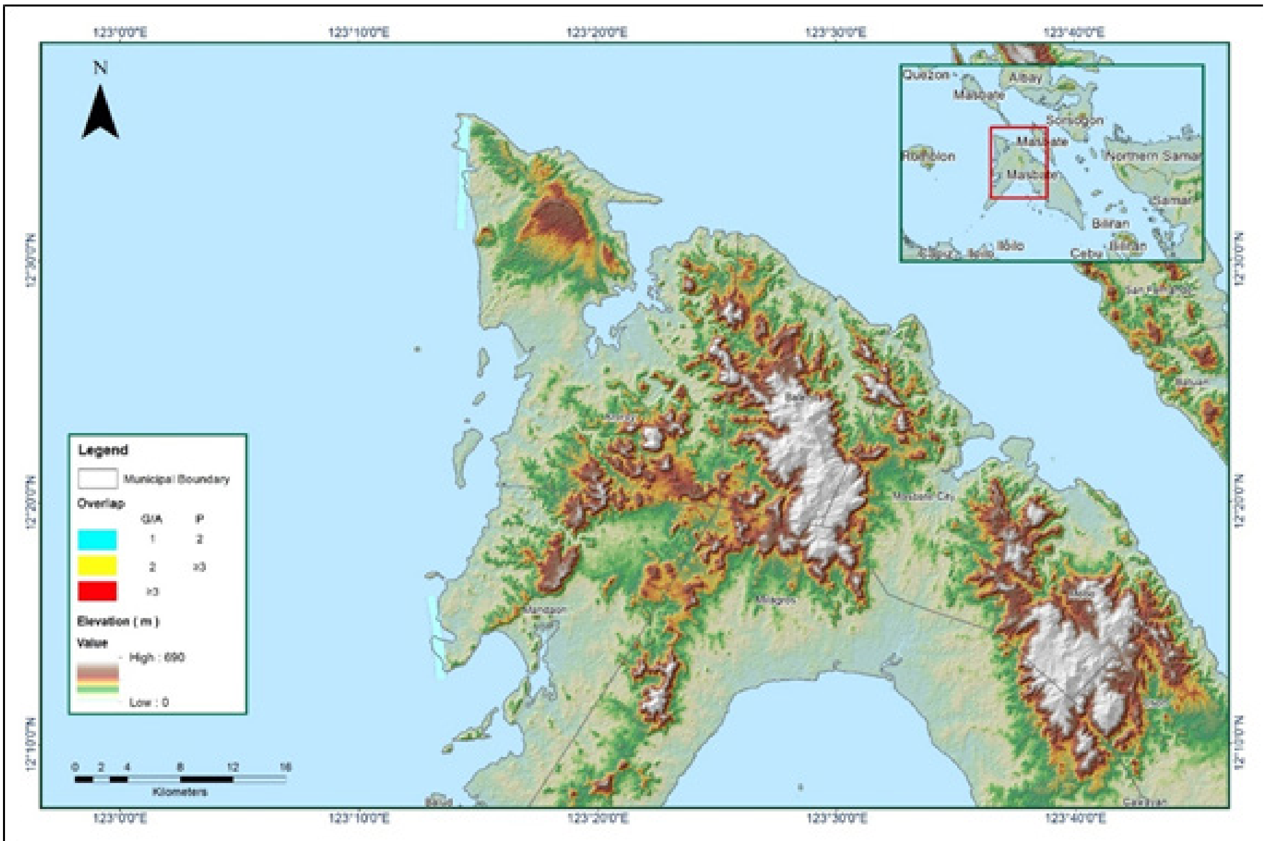
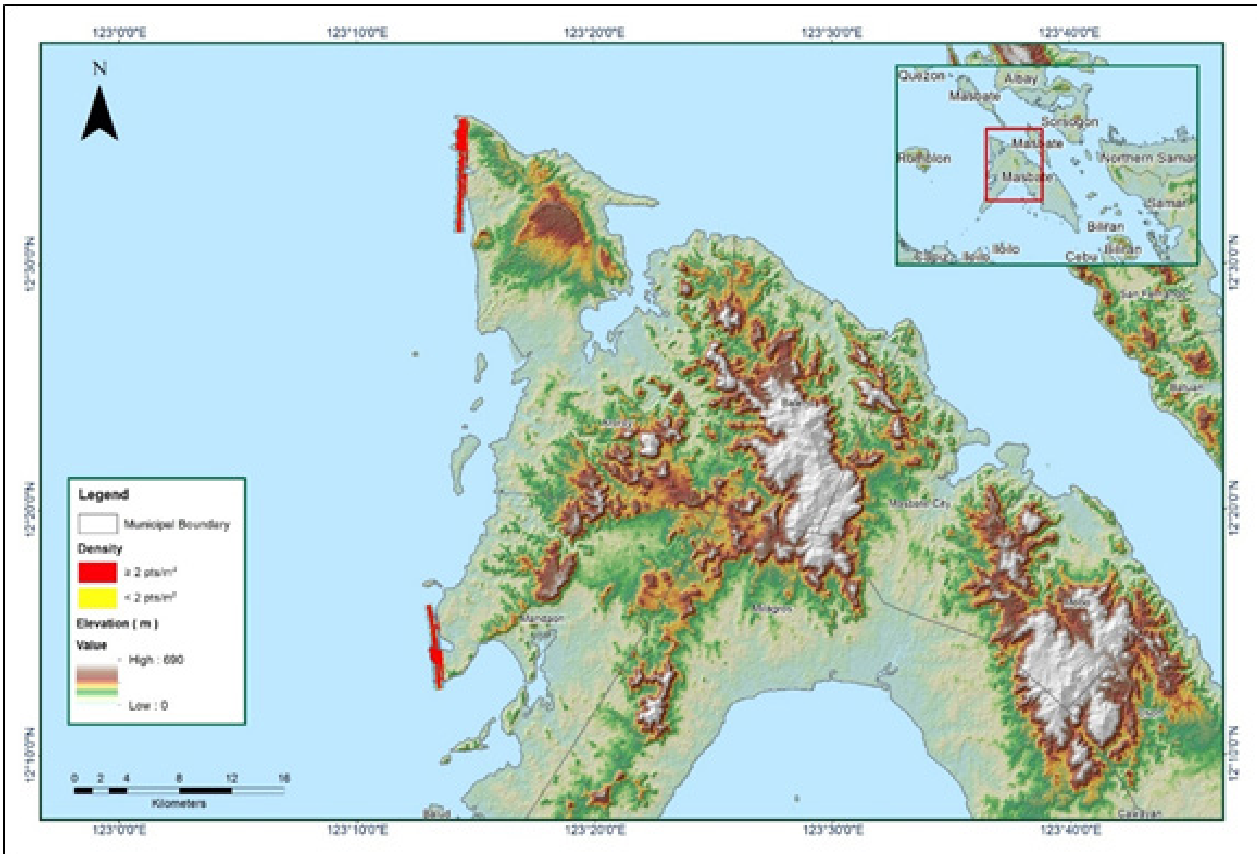
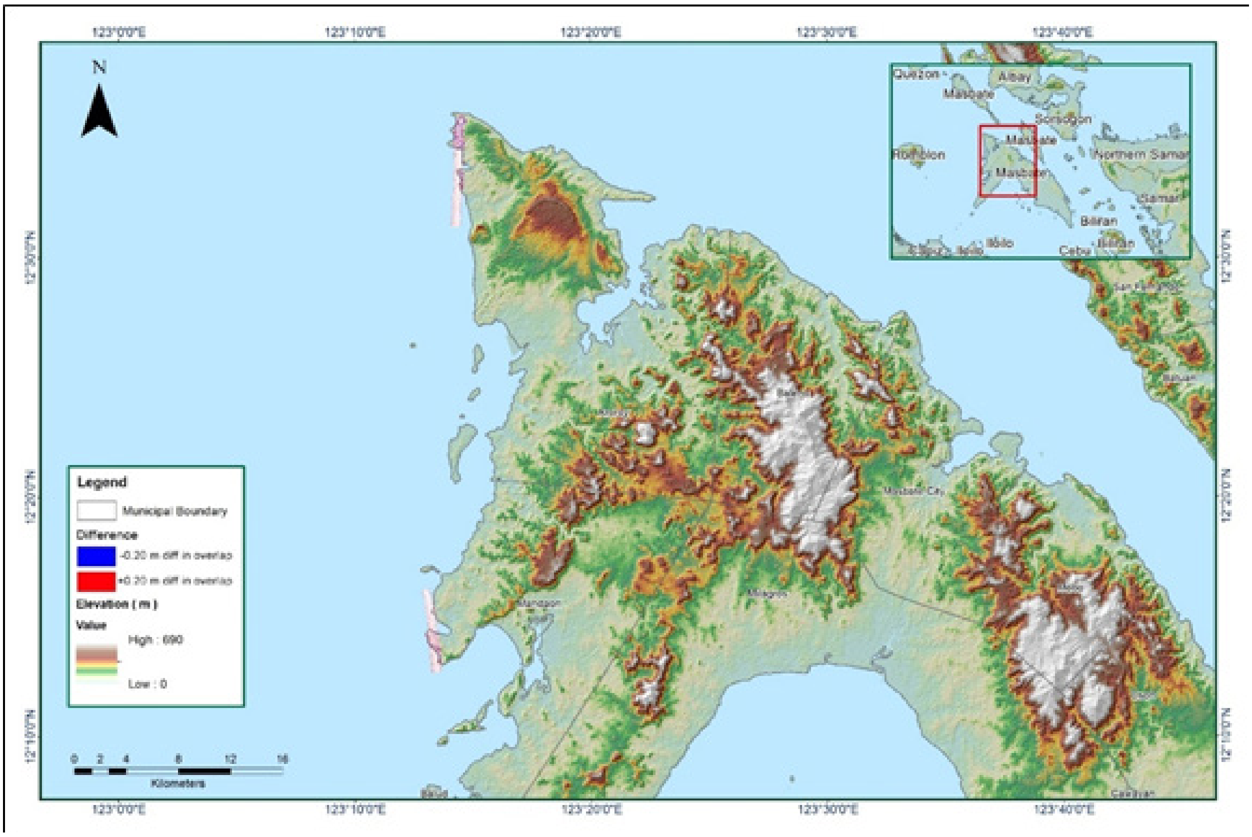


Image of Data Overlap



Density map of merged LiDAR data



Elevation difference between flight lines

ANNEX 9 MANDAON MODEL BASIN PARAMETERS

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W220	0.00167	99.000	0	18.121	15.62600	Discharge	0.2333	0.00001	Ratio to Peak	0.20117
W230	0.00616	35.100	0	78.390	10.71300	Discharge	0.1382	0.00001	Ratio to Peak	0.00023
W240	0.00618	47.933	0	80.737	12.97300	Discharge	0.1035	0.00001	Ratio to Peak	0.00033
W250	0.23039	46.815	0	128.980	23.32600	Discharge	0.1959	0.00001	Ratio to Peak	0.05784
W260	0.00124	99.000	0	60.642	4.61870	Discharge	0.0842	0.00001	Ratio to Peak	0.04913
W270	0.00608	41.090	0	70.922	12.74700	Discharge	0.0804	0.00001	Ratio to Peak	0.00149
W280	0.64870	35.289	0	4.365	14.45300	Discharge	0.3358	0.00001	Ratio to Peak	0.04084
W290	0.00407	60.321	0	144.610	11.07600	Discharge	0.0518	0.00001	Ratio to Peak	0.00539
W300	110.22000	66.000	0	34.516	69.66400	Discharge	0.3455	0.00001	Ratio to Peak	0.00820
W310	0.00125	99.000	0	64.432	10.13700	Discharge	0.2351	0.00001	Ratio to Peak	0.00016
W320	0.00101	65.484	0	0.166	0.06442	Discharge	0.0068	0.00001	Ratio to Peak	0.00387
W330	103.46000	38.079	0	0.017	0.07737	Discharge	0.3286	0.00001	Ratio to Peak	0.01668
W340	14.15800	35.309	0	2.789	0.06355	Discharge	0.0939	0.00001	Ratio to Peak	0.00014
W350	26.41200	37.469	0	0.138	0.07984	Discharge	0.0768	0.00001	Ratio to Peak	0.01181
W360	4.08230	91.868	0	0.149	0.07100	Discharge	0.0171	0.00001	Ratio to Peak	0.00185
W370	0.06261	59.908	0	12.369	8.75010	Discharge	0.3910	0.00001	Ratio to Peak	0.00243
W380	113.95000	52.924	0	0.153	0.07229	Discharge	0.1667	0.00001	Ratio to Peak	0.00023
W390	121.09000	52.921	0	0.153	0.06648	Discharge	0.2292	0.00001	Ratio to Peak	0.00907
W400	0.00214	46.946	0	124.540	6.13680	Discharge	0.0835	0.00001	Ratio to Peak	0.04279
W410	29.87100	35.203	0	0.017	0.06286	Discharge	0.0122	0.00001	Ratio to Peak	0.00515
W420	0.00282	49.588	0	47.468	40.82100	Discharge	0.0906	0.00001	Ratio to Peak	0.00049

ANNEX 10 MANDAON MODEL REACH PARAMETERS

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R40	Automatic Fixed Interval	1003.5	0.003227	0.67823	Trapezoid	20.952	1
R50	Automatic Fixed Interval	1230.6	0.0161085	0.0001	Trapezoid	20.952	1
R60	Automatic Fixed Interval	1853.1	0.0014719	0.0001	Trapezoid	20.952	1
R70	Automatic Fixed Interval	2298.5	0.0055529	0.0001	Trapezoid	20.952	1
R90	Automatic Fixed Interval	5540.9	0.0021391	0.64578	Trapezoid	20.952	1
R100	Automatic Fixed Interval	384.62	0.0038433	0.0001	Trapezoid	20.952	1
R140	Automatic Fixed Interval	665.57	0.0025086	1	Trapezoid	20.952	1
R150	Automatic Fixed Interval	3337.2	0.0025086	1	Trapezoid	20.952	1
R170	Automatic Fixed Interval	5074.7	0.0066991	0.13851	Trapezoid	20.952	1
R180	Automatic Fixed Interval	260.01	0.0015644	0.0001	Trapezoid	20.952	1

ANNEX 11 MANDAON FIELD VALIDATION POINTS

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
1	12.20944472	123.3082521	0	0	0		5-Year	
2	12.20968688	123.3078851	0	1.34	-1.34		5-Year	
3	12.20941383	123.3079051	0	0	0		5-Year	
4	12.20954168	123.308113	0	0	0		5-Year	
5	12.20888763	123.3085221	1.35	0	1.35		5-Year	
6	12.20979072	123.3216111	0.03	0	0.03		5-Year	
7	12.21703143	123.3217603	0.05	0	0.05		5-Year	
8	12.21861006	123.3220055	0.03	0	0.03		5-Year	
9	12.22147589	123.3102538	0.03	0	0.03		5-Year	
10	12.22128917	123.3105845	0.03	0	0.03	STY Yolanda 2013	5-Year	
11	12.22113537	123.3120841	0.03	0	0.03		5-Year	
12	12.208925	123.30778	0	0	0		5-Year	
13	12.21023333	123.3079517	0	0	0		5-Year	
14	12.21112333	123.3077967	0.03	0	0.03		5-Year	
15	12.21278333	123.3041933	0	0	0		5-Year	
16	12.21290333	123.3038367	0	0	0		5-Year	
17	12.20719833	123.31074	0.03	0	0.03		5-Year	
18	12.20682	123.3135033	0.03	0	0.03		5-Year	
19	12.20696	123.3152767	0.03	0	0.03		5-Year	
20	12.207355	123.3174183	0.05	0	0.05		5-Year	
21	12.21301167	123.3220267	0.03	0	0.03		5-Year	
22	12.2151	123.3219567	0.03	0	0.03		5-Year	
23	12.21701833	123.32187	0.03	0	0.03		5-Year	
24	12.22067	123.3107133	0.03	0	0.03		5-Year	
25	12.22109833	123.310155	0.84	0	0.84		5-Year	
26	12.22105167	123.3123083	0.03	0	0.03		5-Year	
27	12.22088333	123.3129983	0.03	0	0.03		5-Year	
28	12.22021	123.315095	0.55	0	0.55		5-Year	
29	12.2189	123.3213867	0.03	0	0.03		5-Year	
30	12.21896667	123.3233417	0.03	0	0.03		5-Year	
31	12.21885	123.3229033	0.03	0	0.03		5-Year	
32	12.219805	123.3281483	0.03	0	0.03		5-Year	
33	12.21961167	123.3254067	1.95	0	1.95		5-Year	
34	12.22035333	123.3219883	0.03	0	0.03		5-Year	
35	12.25519634	123.2824395	0.03	0.3	-0.27		5-Year	
36	12.26137943	123.2866096	0.04	0	0.04		5-Year	
37	12.26027271	123.2880803	0.03	0.5	-0.47		5-Year	
38	12.25884957	123.2896163	0.09	0	0.09		5-Year	
39	12.26151442	123.2949074	0.07	0	0.07		5-Year	

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return / Scenario
	Lat	Long						
40	12.2629925	123.2978194	0.55	0.7	-0.15		5-Year	
41	12.26312066	123.2980446	1.27	0.6	0.67	TY Mario 2014	5-Year	
42	12.26475051	123.3015682	0.03	0	0.03		5-Year	
43	12.27725306	123.3170813	0.05	0	0.05		5-Year	
44	12.26266899	123.3180005	0.09	0	0.09		5-Year	
45	12.24199533	123.3231791	0.11	0	0.11		5-Year	
46	12.24172609	123.3232824	0.04	0	0.04		5-Year	
47	12.23086833	123.3220009	0.04	0	0.04		5-Year	
48	12.22684436	123.3211243	0.03	0	0.03	STY Yolanda 2013	5-Year	
49	12.28058044	123.3206407	0.57	6	-5.43	TY Caloy 2006	5-Year	
50	12.2576182	123.3179795	0.07	0	0.07		5-Year	
51	12.24145256	123.3233263	0.03	0	0.03		5-Year	
52	12.23048946	123.3221468	0.03	0	0.03		5-Year	
53	12.28063252	123.3209201	0.13	0	0.13		5-Year	

ANNEX 12 EDUCATIONAL INSTITUTIONS AFFECTED BY FLODING IN MANDAON FLOODPLAIN

Masbate				
Mandaon				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Alas Day Care CenterMandaon	Alas			
Alas Elementary School Mandaon	Alas			
alas reading centermandaon	Alas			
Alas SMP Day Care CenterMandaon	Alas			
Calumpang Alas Day Care CenterMandaon	Alas			
Bon-Oco Day care centerDayaoMandaon	Dayao			
Dayao Day Care CenterMandaon	Dayao			
Dayao Elementary School Mandaon	Dayao			
Nanipsan elementary school mandaon	Nanipsan			
Tagpo Day Care CenterMandaon	Nanipsan			
Tagpo Elementary School mandaon	Nanipsan			

ANNEX 13 HEALTH INSTITUTIONS AFFECTED BY FLOODING IN MANDAON FLOODPLAIN

Masbate				
Mandaon	Barangay	Rainfall Scenario		
		5-year	25-year	100-year