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

LiDAR Surveys and Flood Mapping of Asid River

University of the Philippines Training Center
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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
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NAMRIA	National Mapping and Resource Information Authority
NSTC	Northern Subtropical Convergence
PAF	Philippine Air Force
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PDOP	Positional Dilution of Precision
PPK	Post-Processed Kinematic [technique]
PRF	Pulse Repetition Frequency
PTM	Philippine Transverse Mercator
QC	Quality Check
QT	Quick Terrain [Modeler]
RA	Research Associate
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UPC	University of the Philippines Cebu
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND ASID RIVER

Enrico C. Paringit, Dr. Eng., Ms. Joanaviva C. Plopenio, and Engr. Ferdinand Bien

1.1 Background of the Phil-LiDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the Ateneo de Naga University (ADNU). ADNU 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 24 river basins in the Bicol region. The university is located in Naga City in the province of Camarines Sur.

1.2 Overview of the Asid River Basin

Asid River Basin is in Masbate and under the jurisdiction of the component city of Masbate, another first class municipality, Milagros, and a fourth class town, Mobo. According to DENR – River Basin Control Office, it has a drainage area of 140 km2 and an estimated 189 million cubic meter (MCM) annual run-off. Based on the 2015 census, Masbate City has a population of 95,359, Milagros is populated with 57,473 residents and Mobo with 38,813 residents.

Its main stem, Asid River, is part of the 24 river systems in Bicol Region.The Asid River is around 18 km long and drains south in the Asid Gulf which is part of the Visayan Sea through its mouth near the town of Milagros. Low lying hills bracketed the river basin to the east and west. The City of Masbate lies to the north facing Ticao Island.

According to the 2010 national census of NSO, a total of 9,630 locals are residing in the immediate vicinity of the river. Aside from providing water in the nearby areas, it serves as a major source of income because of the quarrying activities in the river. Asid River is identified to be rich in gold and silver deposits due to erosion in the mountainous area upstream. Water carrying eroded soils with minerals transport these minerals until they are deposited in the riverbed.

This river basin is governed with the type III Philippine climate. The months from November to April are considered dry and the rest is wet. Its maximum temperature reached 37^{o}C last May 2016. Several small islands in the Asid Gulf is proclaimed as Wilderness Areas. These are the islands of Guinauyan, Naro, Chico and Pobre.

The major products from this area include minerals such as manganese, gold, copper and silver, including white clay for porcelain products. Masbate is also famous for its rodeo. Rodeo competitions are also held in Masbate with competitors coming from Northern and Central Luzon and Mindanao. Fishing is also a source of income for the fisherfolks in the coastal town of Milagros whether in the Visayan Sea or through fishponds. The fishponds are concentrated near the mouth of the river and with more fishponds even 5 km upstream.

According to the locals, flooding is very usual in the area because the province is situated relatively near the Pacific Ocean. Among the recent weather disturbances which caused significant flooding events include Super Typhoon Frank in 2008 where transport of relief goods was paralyzed in the province. The City Government was urged to build a new Asid Bridge because the old one was reached by raging flood waters. Waist-deep floods were experienced by the province caused by torrential rains and storm surges brought by Super Typhoon Ruby on December 6, 2014.

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

CHAPTER 2: LIDAR DATA ACQUISITION OF THE ASID 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 Asid Floodplain in Masbate. These missions were planned for 10 lines that run for at most three and a half (3.5) 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 Asid Floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK32D	1000/1200	25/30/35/40	50	200	30	130	5
BL32E	800 / 1000	25,30	50	200	30	130	5
BLK32G,	1000	25, 30	50	200	30	130	5
BLK32H	600/800	25, 30	40/50	250/200	30/36	130	5

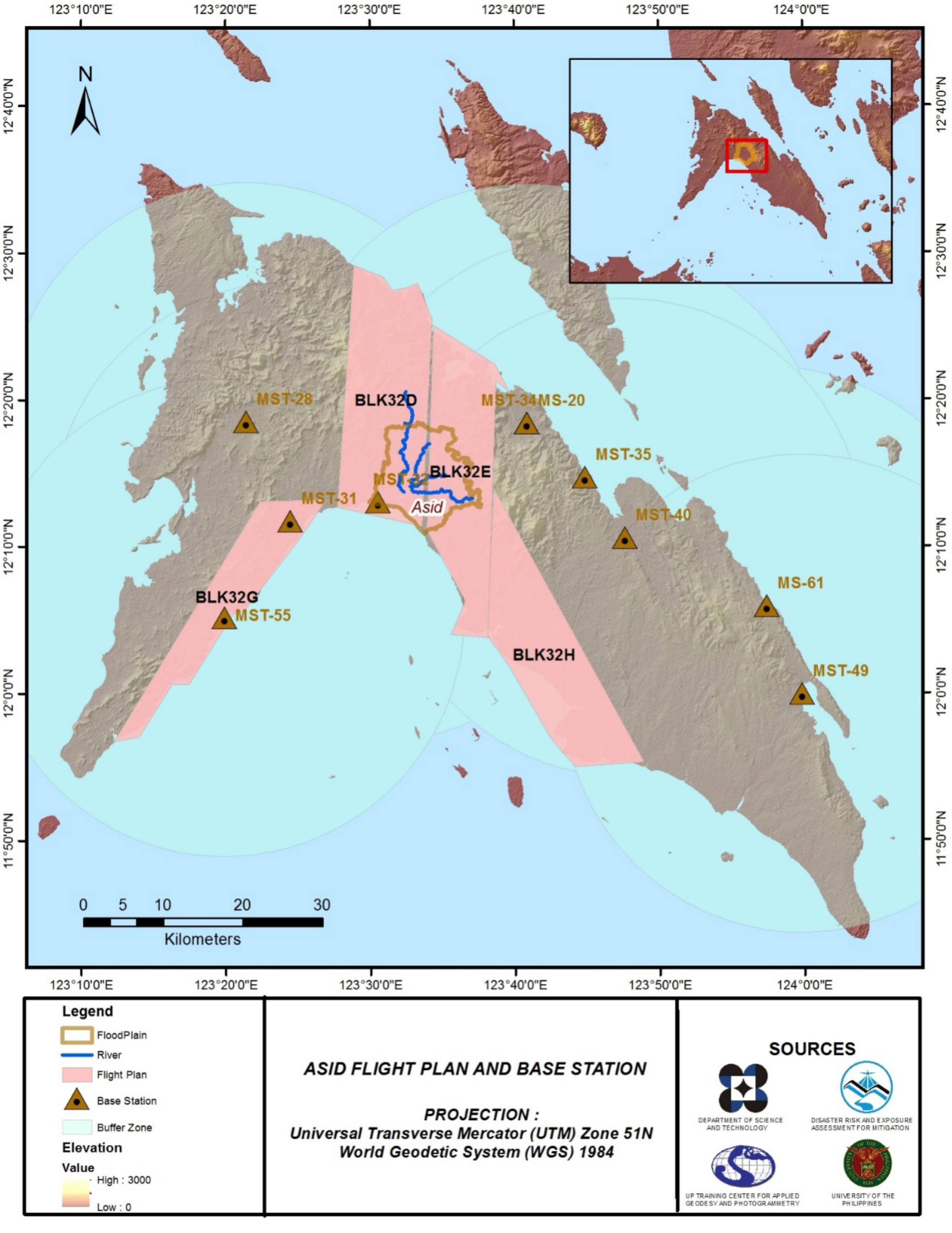

Figure 2. Flight plan and base stations for Asid Floodplain.

2.2 Ground Base Stations

The project team was able to recover eight (8) NAMRIA ground control points: MST-28, MST-31, MST-32, MST-34, MST-35, MST-40, MST-49 and MST-55 which are of second (2nd) order accuracy, also, MS-20 and MS-61, two (2) benchmarks which are of 1st order accuracy. The certifications for the NAMRIA reference points are found in Annex B. These were used as base stations during flight operations for the entire duration of the survey (March 18- April 14, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Asid Floodplain are shown in Figure 2.

Figure 3 to Figure 12 show the recovered NAMRIA reference points within the area.In addition Table 2 to Table 11 show the details about the following NAMRIA control stations and established points. Table 12 shows the list of all ground control points occupied during the acquisition together with the dates they are utilized during the survey.

(b)

(a)

Figure 3. a) GPS set-up over MST-28 as recovered in Mambog Bridge, Barangay Bat-ongan, municipality of Mandaon, Masbate. b) NAMRIA reference point MST-28 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 of 1992 Datum (PRS 92)	Latitude	12° 18’ 35.15371” North
	Longitude	123° 21’ 19.21293” East
	Ellipsoidal Height	49.12800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	538651.166 meters
	Northing	1361224.57 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	12° 18’ 30.47973” North
	Longitude	123° 21’ 24.28923” East
	Ellipsoidal Height	104.64900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	538637.64 meters
	Northing	1360748.12 meters

(b)

(a)

Figure 4. a) GPS set-up over MST-31 as recovered in Boracay Bridge, Barangay Bat-ongan, municipality of Mandaon, Masbate. b) NAMRIA reference point MST-31 as recovered by the field team.

Table 3. 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" North 123° 24' 24.05419" East 18.45000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	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)

Figure 5. a) GPS set-up over MST-32 as recovered inside the compound of Milagros Municipal Hall, Masbate. b) NAMRIA reference point MST-32 as recovered by the field team.

Table 4. 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
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 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

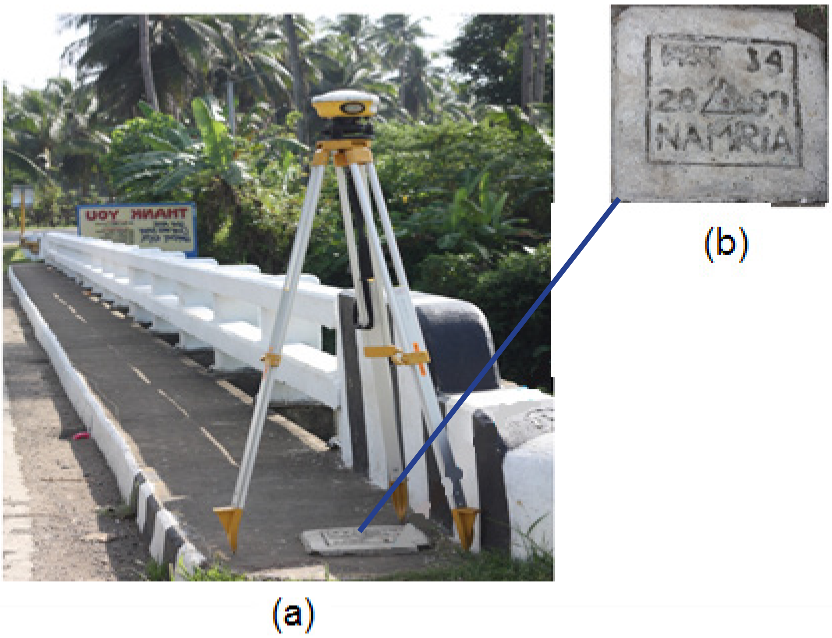

Figure 6. a) GPS set-up over MST-34 as recovered in Sagawsawan Bridge, Brgy. Umabay Exterior, municipality of Mobo, Masbate b) NAMRIA reference point MST-34 as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point MST-34 used as base station for the LiDAR Acquisition.

Station Name	MST-34	
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° 18' 29.18323" North 123° 40' 46.86556" East 11.91000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	573933.177 meters 1361109.053 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 18' 24.53692" North 123° 40' 51.93952" East 68.23000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	573907.30 meters 1360632.64 meters

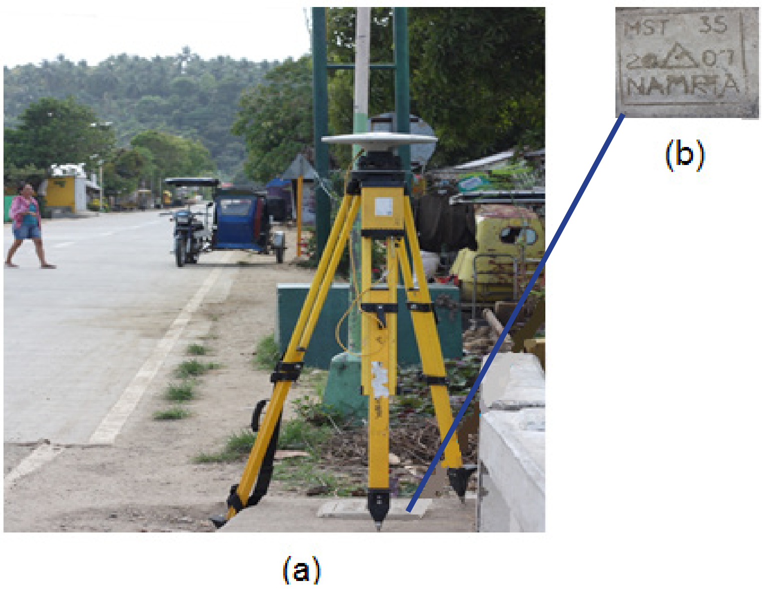

Figure 7. a) GPS set-up over MST-35 as recovered in Marcella Bridge in Brgy. Cagay, City of Masbate, Province of Masbate b) NAMRIA reference point MST-35 as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point MST-35 used as base station for the LiDAR Acquisition.

Station Name	MST-35	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 14' 48.14863" North 123° 44' 47.51779" East 5.31500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	581223.775 meters 1354336.379 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 14' 43.52314" North 123° 44' 52.59656" East 61.95700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	581195.35 meters 1353862.34 meters

(a)

Figure 8. a) GPS set-up over MST-40 as recovered in Buenavista Bridge in Brgy. Buenavista, Municipality of Uson, Masbate. b) NAMRIA reference point MST-40 as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point MST-40 used as base station for the LiDAR Acquisition.

Station Name	MST-40	
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° 10' 39.45274" North 123° 47' 33.62147" East 4.72600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	586266.511 meters 1346708.7 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 10' 34.84826" North 123° 47' 38.70589" East 61.65900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	586236.32 meters 1346237.33 meters

(b)

(a)

Figure 9. a) GPS set-up over MST-49 as recovered in front of the Cataingan Municipal Hall, municipality of Cataingan, Masbate b) NAMRIA reference point MST-49 as recovered by the field team.

Table 8. Details of the recovered NAMRIA horizontal control point MST-49 used as base station for the LiDAR Acquisition.

Station Name	MST-49	
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° 00' 01.41677" 123° 59' 46.24265" 21.25500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting Northing	608487.281 meters 1327175.1 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 59' 56.87354" North 123° 59' 51.34085" East 79.14000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	608449.31 meters 1326710.57 meters

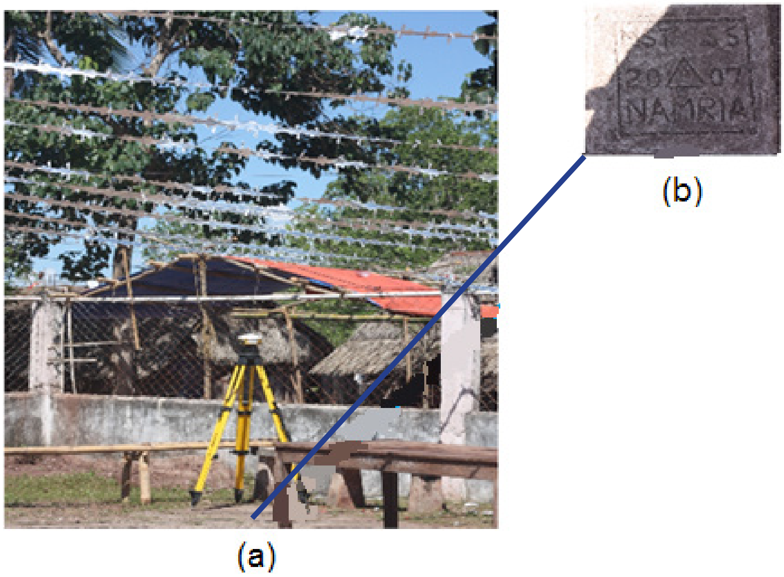

Figure 10. a) GPS set-up over MST-55 as recovered inside the compound of Casamongan Brgy. Hall, Municipality of Balud, Masbate. b) NAMRIA reference point MST-55 as recovered by the field team.

Table 9. Details of the recovered NAMRIA horizontal control point MST-55 used as base station for the LiDAR Acquisition.

Station Name	MST-55	
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
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 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 11. a) GPS set-up over MS-20 as recovered in Manaswang Bridge in Brgy. Marcella, Municipality of Uson, Masbate b) NAMRIA reference point MS-20 as recovered by the field team.

Table 10. Details of the recovered NAMRIA benchmark point MS-20 with processed coordinates used as base station for the LiDAR Acquisition.

Station Name	MS-20	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 18’ 29.18317” North 123° 40’ 46.86570” East 11.92 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 18’ 24.53692” North 123° 40’ 51.93952” East 68.230 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	574059.995 meters 1360574.929 meters

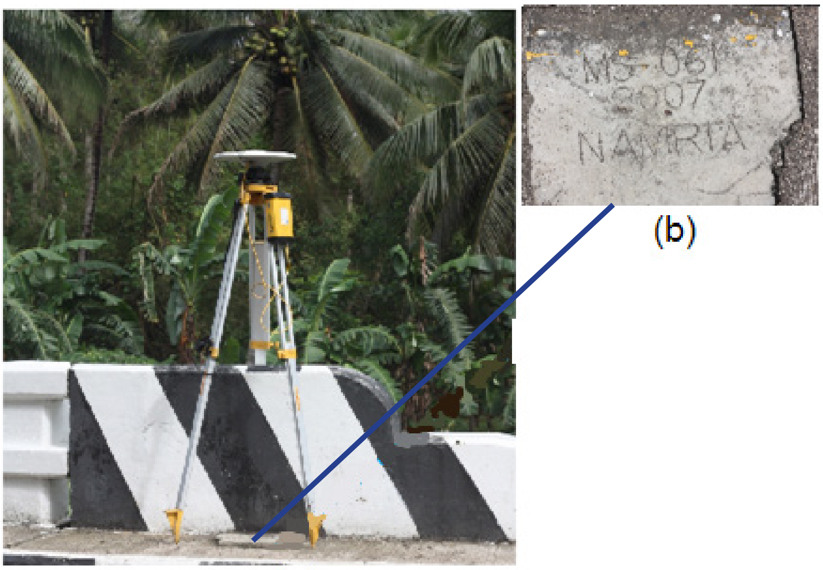

Figure 12. a) GPS set-up over MS-61 as recovered in Nabangig Bridge, Brgy. Nabangig, Municipality of Palanas, Masbate b) NAMRIA reference point MS-61 as recovered by the field team.

Table 11. Details of the recovered NAMRIA benchmark point MS-61 with processed coordinates used as base station for the LiDAR Acquisition.

Station Name	MS-61	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	12° 06' 1.51238" 123° 57' 21.24483" 4.74 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	12° 05' 56.94091" North 123° 57' 26.33451" East 65.257 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	604178.664 meters 1337699.951 meters

Table 12. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
March 19, 2014	1241P	1BLK32E078A	MST-34 and MST-35
March 20, 2014	1243P	1BLK32E079A	MS-20 and MST-34
March 27, 2014	1271P	1BLK32H086A	MS-61 and MST-49
March 28, 2014	1275P	1BLK32HI087A	MST-40 and MST-49
April 1, 2014	1293P	1BLK32H091B	MST-40 and MST-49
April 2, 2014	1295P	1BLK32E092A	MST-32
April 5, 2014	1307P	1BLK32DG095A	MST-31 AND MST-55
April 10, 2014	1327P	1BLK32D100A	MST-28 AND MST-32

2.3 Flight Missions

A total of eight (8) missions were conducted to complete the LiDAR data acquisition in Asid Floodplain, amounting to twenty seven hours and fifty two minutes (27+52) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. As depicted below, Table 13 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 14 presents the actual parameters used during the LiDAR data acquisition.

Table 13. Flight missions for LiDAR Data Acquisition in Asid floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
March 19, 2014	1241P	256.41	146.522	8.984	137.538	587	4	29
March 20, 2014	1243P	256.41	157.137	33.447	123.69	339	2	59
March 27, 2014	1271P	267.86	169.487	0	169.487	1184	4	23
March 28, 2014	1275P	267.86	126.674	0	126.674	620	2	53
April 1, 2014	1293P	269.6	82.521	0.595	81.926	423	2	5
April 2, 2014	1295P	256.41	197.562	37.688	159.874	828	3	59
April 5, 2014	1307P	477.29	339.433	67.0721	272.3609	326	4	29
April 10, 2014	1327P	306.75	201.168	6.905	194.263	460	2	35
TOTAL		2358.59	1420.50	154.69	1265.81	4767	27	52

Table 14. 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)
1241P	800,1000	25	50	200	30	130	5
1243P	800	25	50	200	30	130	5
1271P	800, 600	25, 30	50	200	30	130	5
1275P	800	25	40	250	36	130	5
1293P	800	25	40	250	36	130	5
1295P	800,1000	30, 25	50	200	30	130	5
1307P	1000	25, 30	50	200	30	130	5
1327P	1000,1200	30, 35, 40	50	200	30	130	5

2.4 Survey Coverage

Asid Floodplain is located in the Province of Masbate with majority of the floodplain situated within the Municipality of Milagros and Masbate City. Masbate City is fully covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 15, while the actual coverage of the LiDAR acquisition for Asid Floodplain is presented in Figure 13.

Table 15. List of municipalities and cities surveyed during Asid floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City	Total Area Surveyed	Percentage of Area Surveyed
Masbate	Masbate City	192.96	192.75	100%
	Milagros	530.43	364.58	69%
	Cawayan	261.38	178.71	68%
	Baleno	200.24	103.82	52%
	Mobo	143.03	56.45	39%
	Balud	217.54	45.67	21%
	Placer	253.55	18.09	7%
	Dimasalang	100.44	3.77	4%
	Uson	183.76	2.97	2%
Total		2083.33	966.81	40.20%

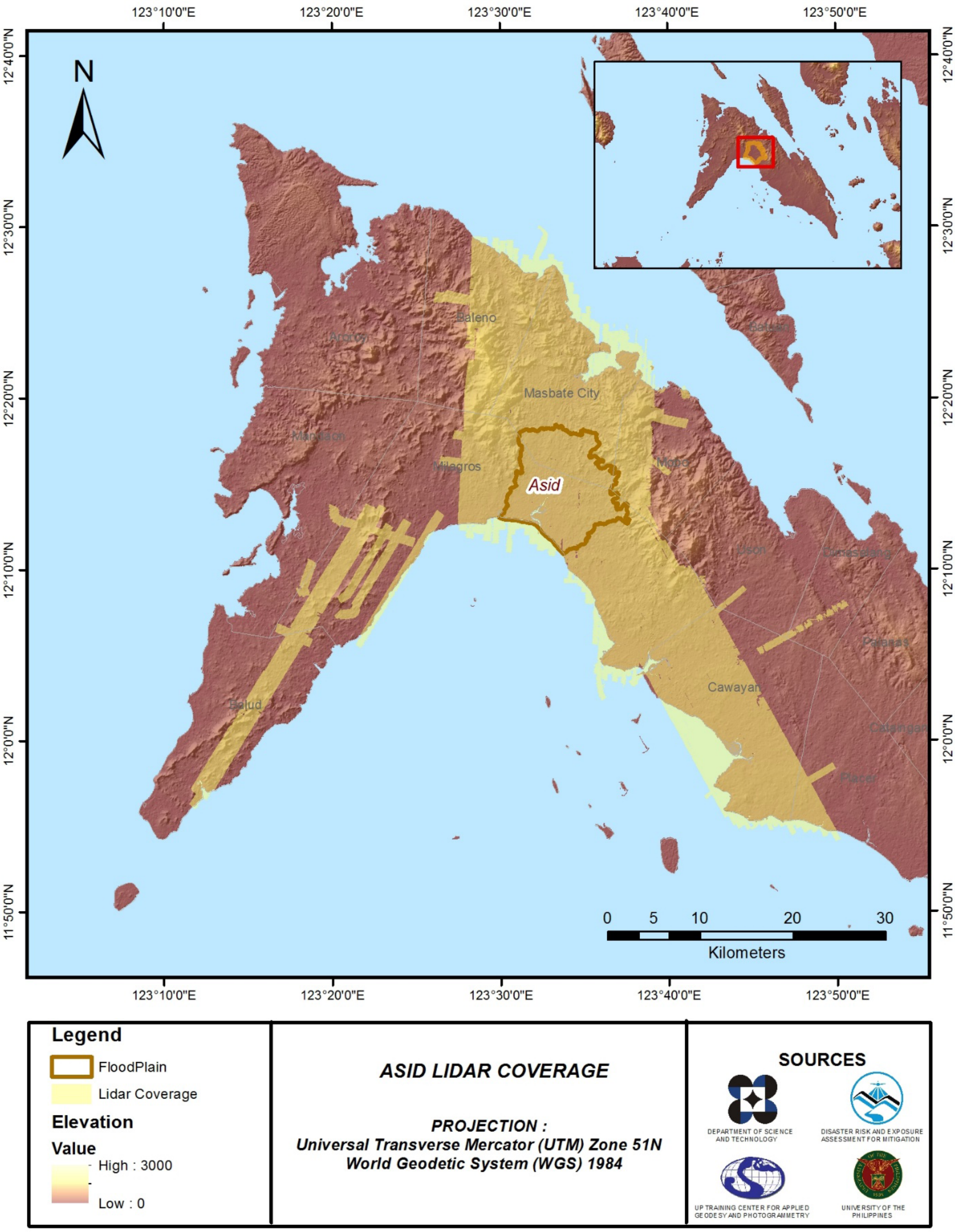

Figure 13. Actual LiDAR survey coverage for Asid floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE ASID 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

After the acquisition of LiDAR data, the latter is transmitted to the DPPC. Upon acceptance of the field data, the DPPC checks it for completeness and accuracy based on the list of raw files needed to proceed with its pre-processing. After which, the flight trajectory is georeferenced to obtain the exact location of the LiDAR sensor when the laser was shot.

Subsequently, the point cloud georectification is performed to incorporate the correct position and orientation for each point acquired. The georectified LiDAR point clouds are then subjected to a quality check to ensure that the required accuracies of the program, namely the minimum point density and vertical and horizontal accuracies, are met. These point clouds are then classified into various classes, which are integral in the generation of Digital Elevation Models (DEMs) such as the Digital Terrain Model (DTM) and the Digital Surface Model (DSM).

After this, the LiDAR-derived digital models are calibrated using the elevation of points gathered in the field. Parts of the river basin that were barely penetrated by the LiDAR system are then replaced by the actual river geometry measured from the field by the DVBC. Temporally acquired LiDAR data are then mosaicked to completely cover the target river systems in the Philippines. Images acquired from the field are orthorectified simultaneously with the LiDAR data through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in the flowchart shown in Figure 14.

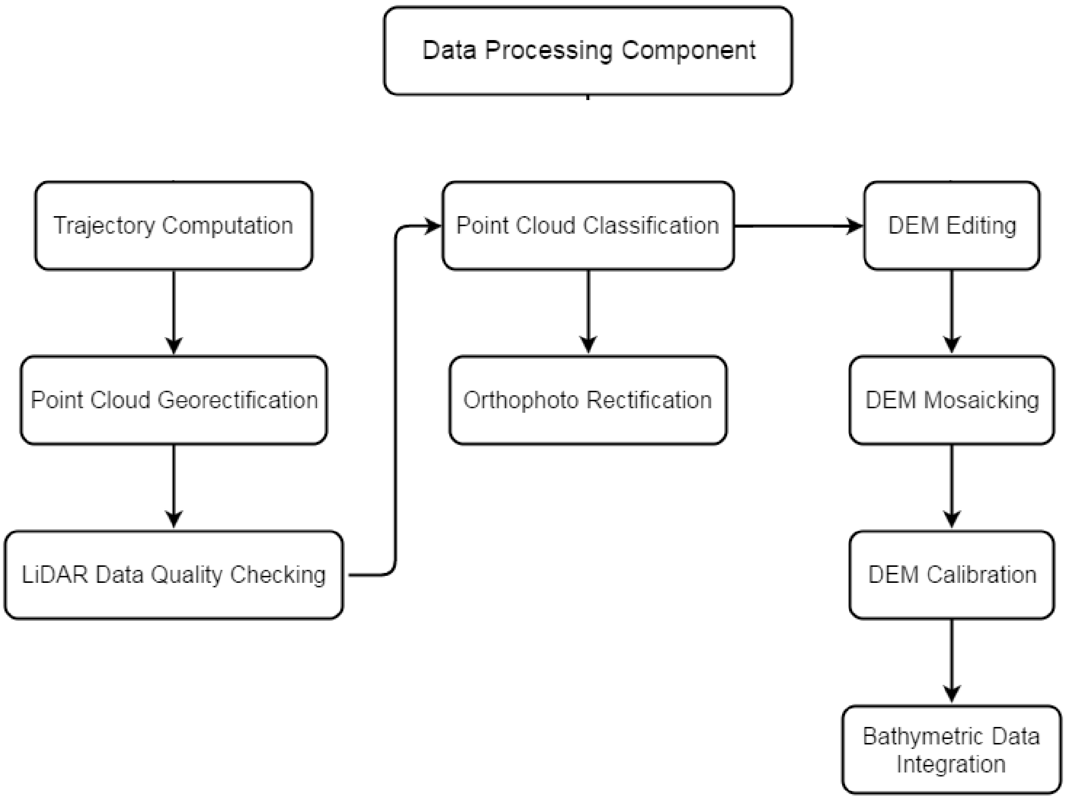

Figure 14. Schematic diagram for Data Pre-processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Asid Floodplain can be found in ANNEX5. Missions flown during the first and second surveys conducted in March 2014 and February 2016 respectively used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus System over the Municipality of Milagros and Masbate City.

In total, the DAC transferred 186.40 Gigabytes of range data, 1.659 Gigabytes of POS data, 43.577 Megabytes of GPS base station data, and 370.60 Gigabytes of raw image data to the data server on April 22, 2014, which was verified for accuracy and completeness by the DPPC. The entiredataset for Asid was fully transferred on April 23, 2014 as indicated on the Data Transfer Sheets for the Asid Floodplain Survey.

3.3 Trajectory Computation

Figure 15 shows the Smoothed Performance Metrics of the computed trajectory for flight 1295P, one of the Asidflights. It substantiates that the Root Mean Square Error (RMSE) values areNorth, East, and Down position. 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**the date and time of** April 02, 2014 00:00AM. The y-axis on the other hand represents the RMSE value for that particular position.

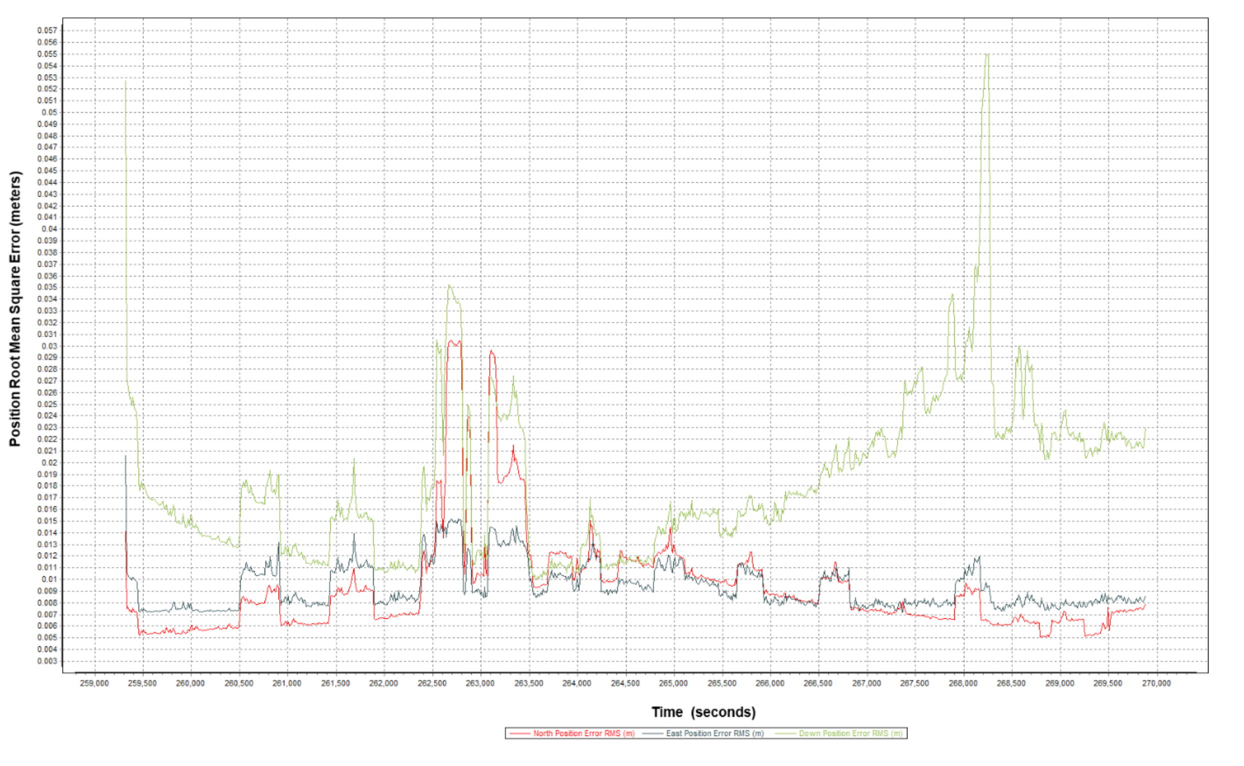

Figure 15. Smoothed Performance Metrics of Asid Flight 1295P.

The time of flight was from 259000 seconds to 270000 seconds, which corresponds to the morning of April 02, 2014. The initial spike seen in the diagram abovecorresponds to the time that the aircraft was getting into position to start the acquisition, then the POS system starts computing for the position and orientation of the aircraft. Additionally, 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 12 shows that the North position RMSE peaks at 3.05 cm, the East position RMSE peaks at 1.52 cm, and the Down position RMSE peaks at 5.50 cm, which are within the prescribed accuracies described in the methodology.

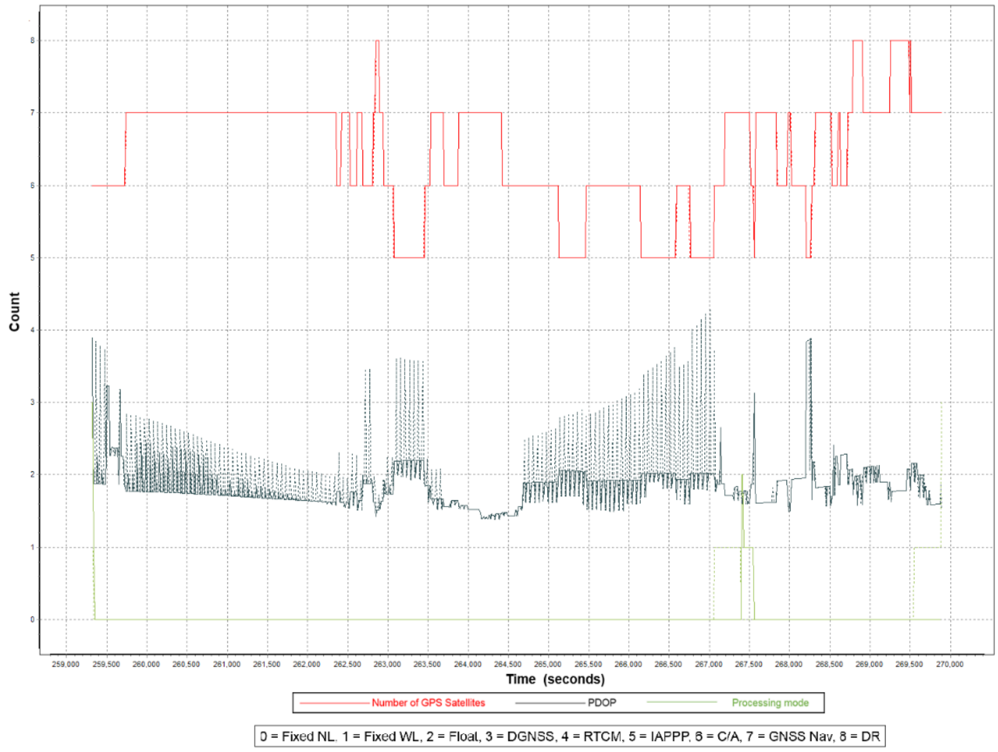

Figure 16. Solution Status Parameters of Asid Flight 1295P.

The Solution Statusparameters of flight 1295P, indicating the number of GPS satellites, Positional Dilution of Precision, and the GPS processing mode used, are presentedin Figure 16. The graphs showthat the number of satellites utilized and trackedwere between 6 and 8, not going lower than 5. Likewise, the PDOP value did not go above the value of 3, except on minimal sudden spikes above 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for almost the entire survey time with sudden peak up to 2 attributed to the turn 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. Essentially, 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 Asid flights is shown in Figure 17.

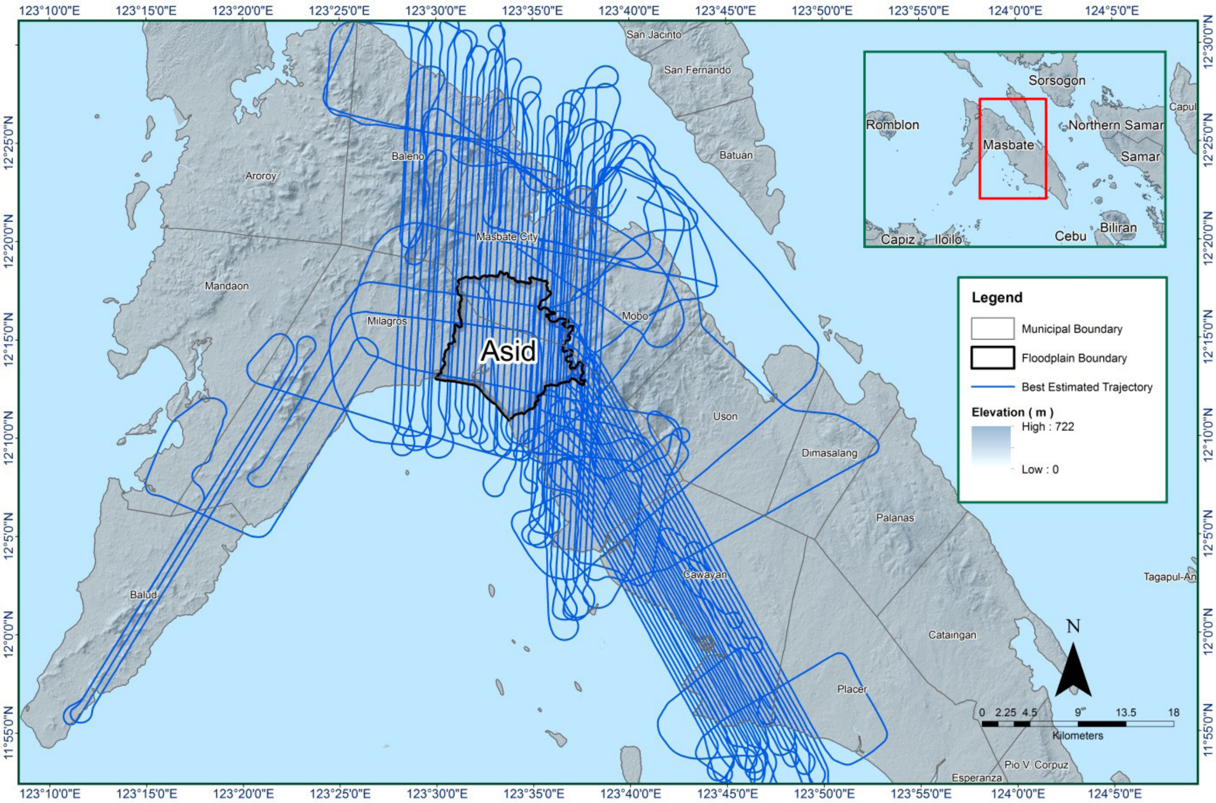

Figure 17. Best Estimated Trajectory for Asid floodplain

3.4 LiDAR Point Cloud Computation

The data generated inLAS contains 99flight lines, with each flight line comprised oftwo channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Asid Floodplain are presentedin Table 16.

Table 16. Self-Calibration Results values for Asid flights.

Parameter	Computed Value	Estimated Value
Boresight Correction stdev	(<0.001degrees)	0.000626
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000906
GPS Position Z-correction stdev	(<0.01meters)	0.0098

The optimum accuracy values for all Asid flights are alsoobtained, based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are givenin Mission Summary Reports (ANNEX 7).

3.5 LiDAR Data Quality Checking

Figure 18 presents the boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Asid Floodplain. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

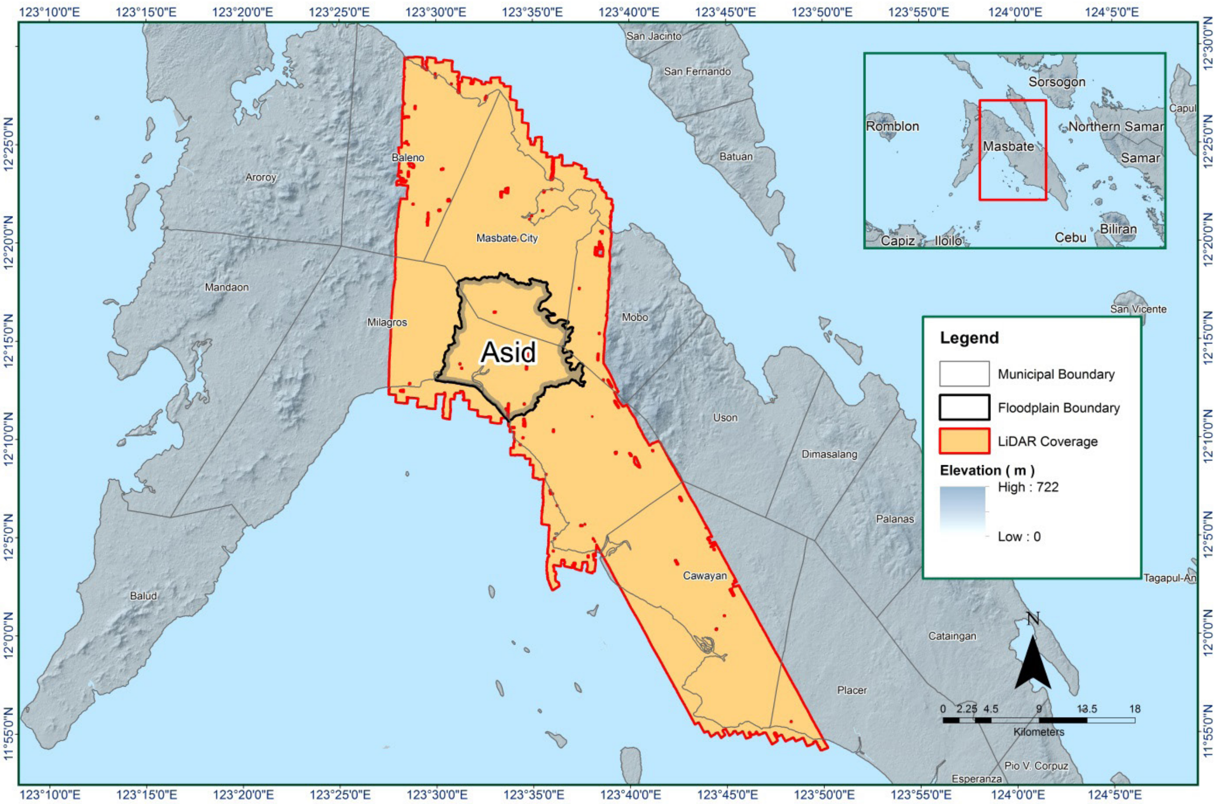

Figure 17. Boundary of the processed LiDAR data over Asid Floodplain

The total area of 967.08 km2 (sq.kms)were covered by the Asid flight missions as a result of eight (8) flight acquisitions, grouped and merged into three (3) blocks as shown in Table 17.

Table 17. List of LiDAR blocks for Asid floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Masbate_Blk32H	1293P	313.84
	1275P	
	1271P	
Masbate_Blk32D	1327P	364.68
	1307P	
Masbate_Blk32E	1241P	288.56
	1243P	
	1295P	
TOTAL		**967.08 sq.km**

Figure 19 depicts the overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location. Since the Pegasus system employs two channels, an average value of 2 (blue) is expected for areas with limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

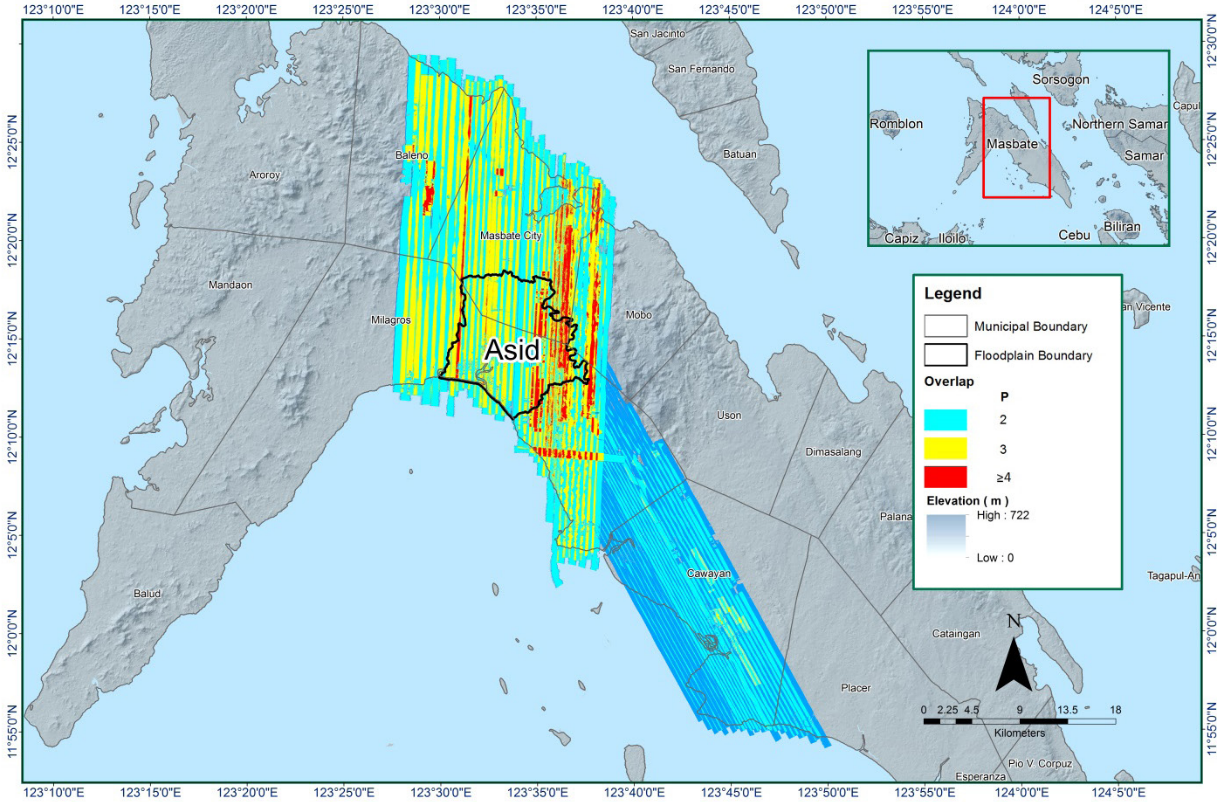

Figure 19. Image of data overlap for Asid Floodplain.

The overlap statistics per block for the Asid floodplain can be found in Mission Summary Reports (Annex 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 53.97% and 54.63% respectively, which passed the 25% requirement.

Figure 20 shows the density map for the merged LiDAR data, where portions of the data that satisfy the two (2) points per square meter criterion are highlighted in red. It was determined that all LiDAR data for Asid floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.70 points per square meter.

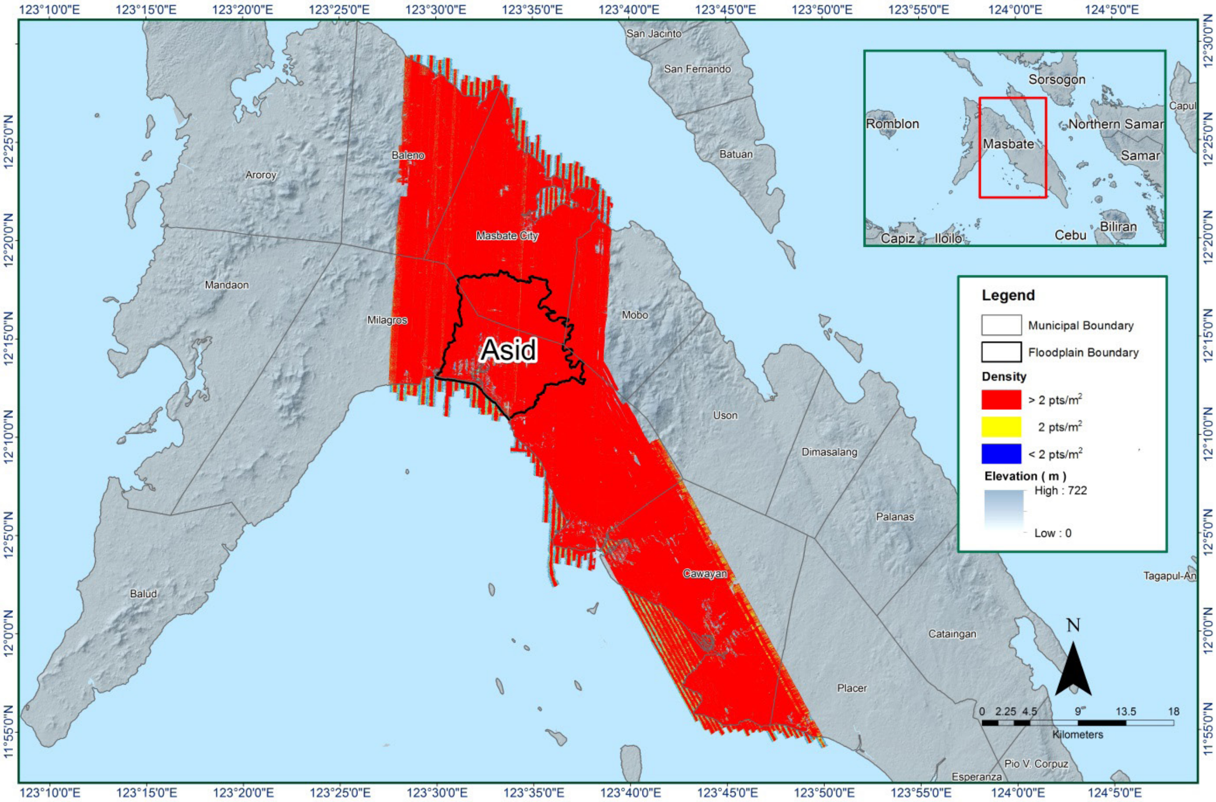

Figure 20. Density map of merged LiDAR data for Asid Floodplain.

Figure 21 however shows the elevation difference between overlaps of adjacent flight lines. 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.

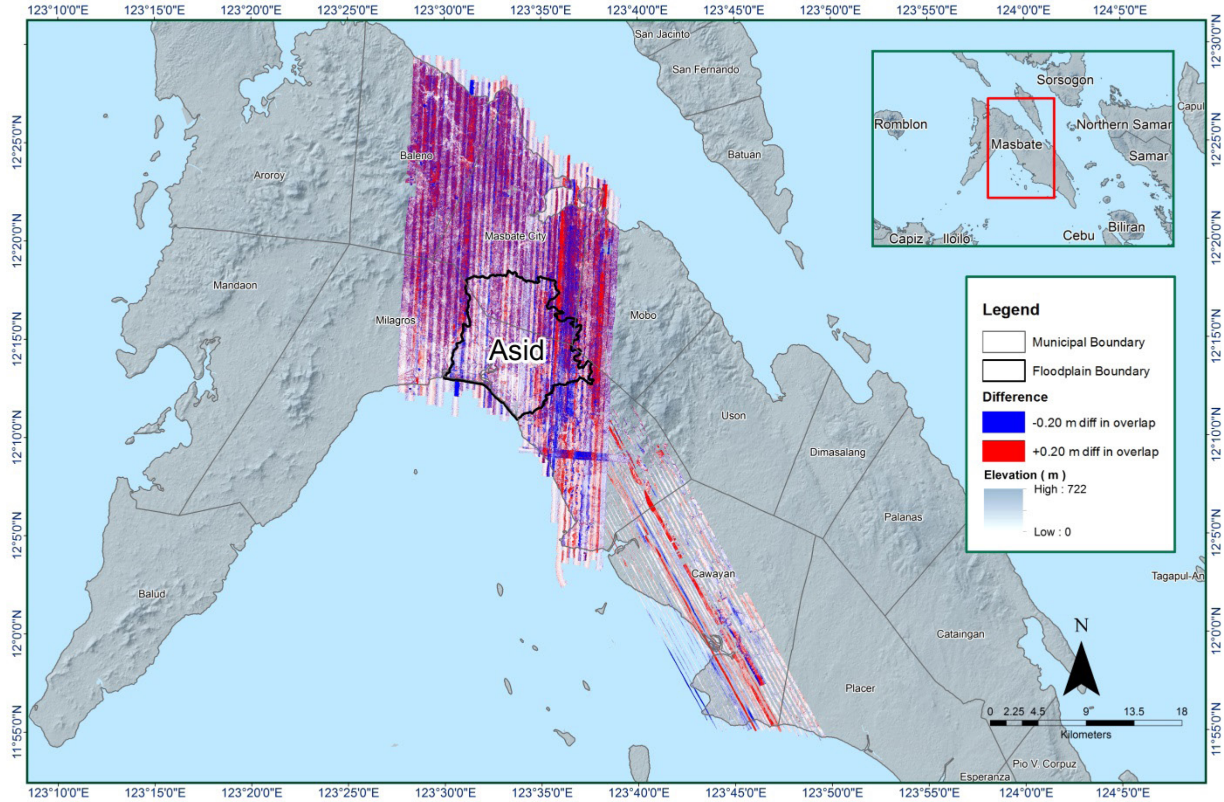

Figure 21. Elevation difference map between flight lines for Asid Floodplain.

Figure 22 shows a screen capture of the processed LAS data from Asid flight 1295P loaded in QT Modeler. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory results. No reprocessing was done for this LiDAR dataset.

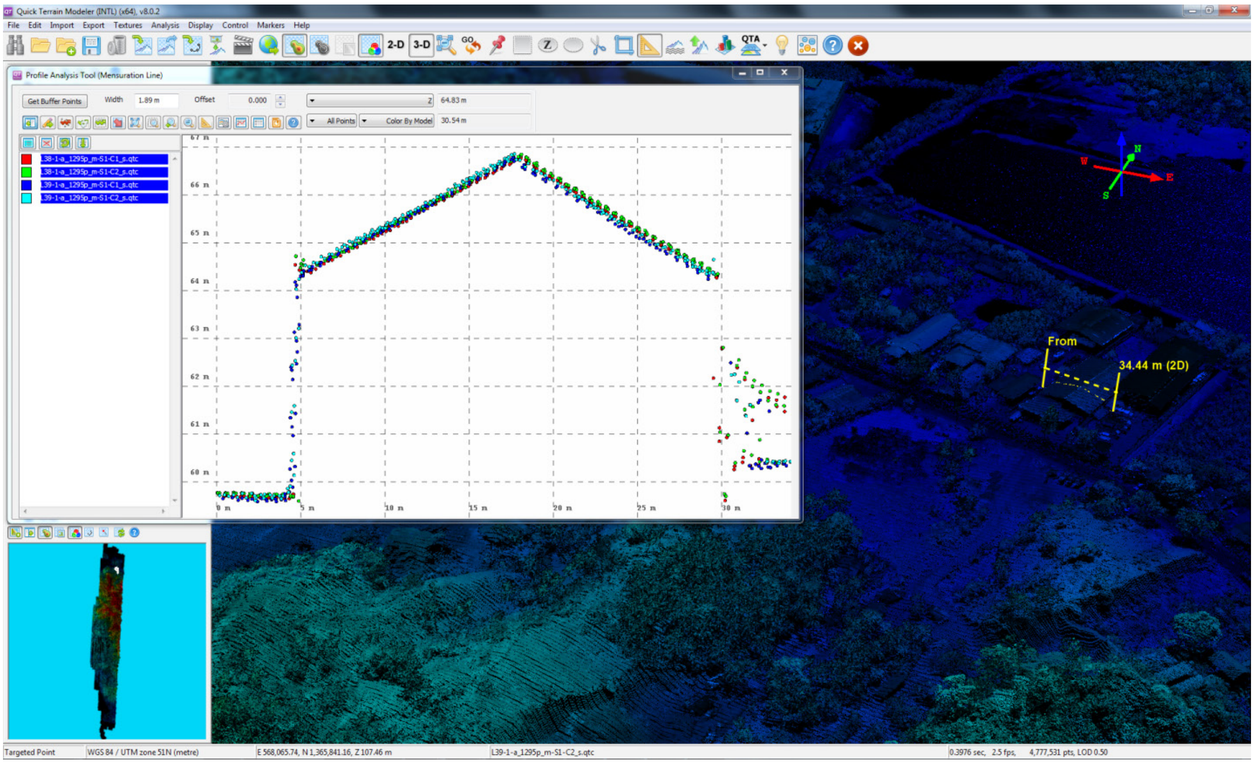

Figure 22. Quality checking for Asid flight 1295P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 18. Summary of point cloud classification results in TerraScan for Asid River Floodplain.

Pertinent Class	Total Number of Points
Ground	1,269,702,308
Low Vegetation	1,109,185,198
Medium Vegetation	1,443,327,696
High Vegetation	771,508,371
Building	16,153,169

Figure 23 illustrates the tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Asid Floodplain. A total of 1,157 tiles with 1km.X1km.(one kilometer by one kilometer) sizewere produced. Correspondingly, Table 18 shows the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 847.76 meters and 31.30 meters respectively.

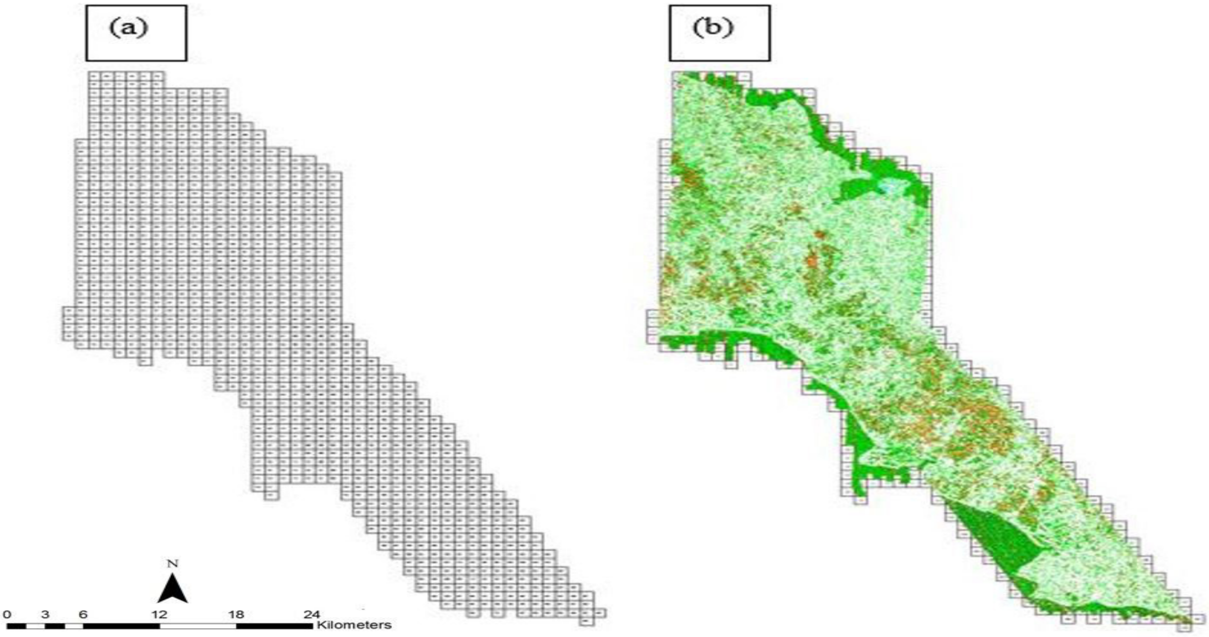

Figure *23*. Tiles for Asid floodplain (a) and classification results (b) in TerraScan.

Figure 24 illustrates an isometric view of an area before and after running the classification routines. The ground points are in orange, while 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.

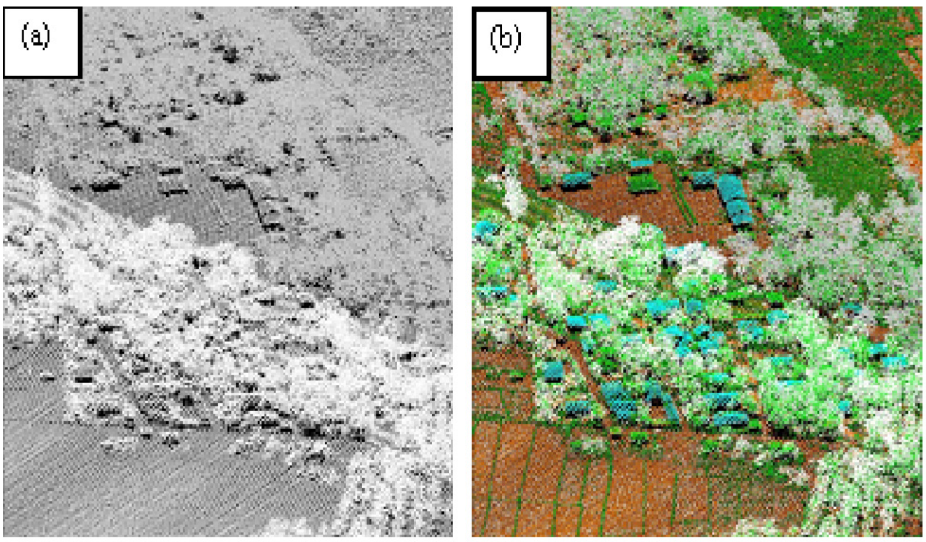

Figure 24. Point cloud before (a) and after (b) classification.

Correspondingly, Figure 25 shows the production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, as well as the first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display. It suggeststhat DTMs are the representation of the bare earth while on the DSMs, all features are present such as buildings and vegetation.

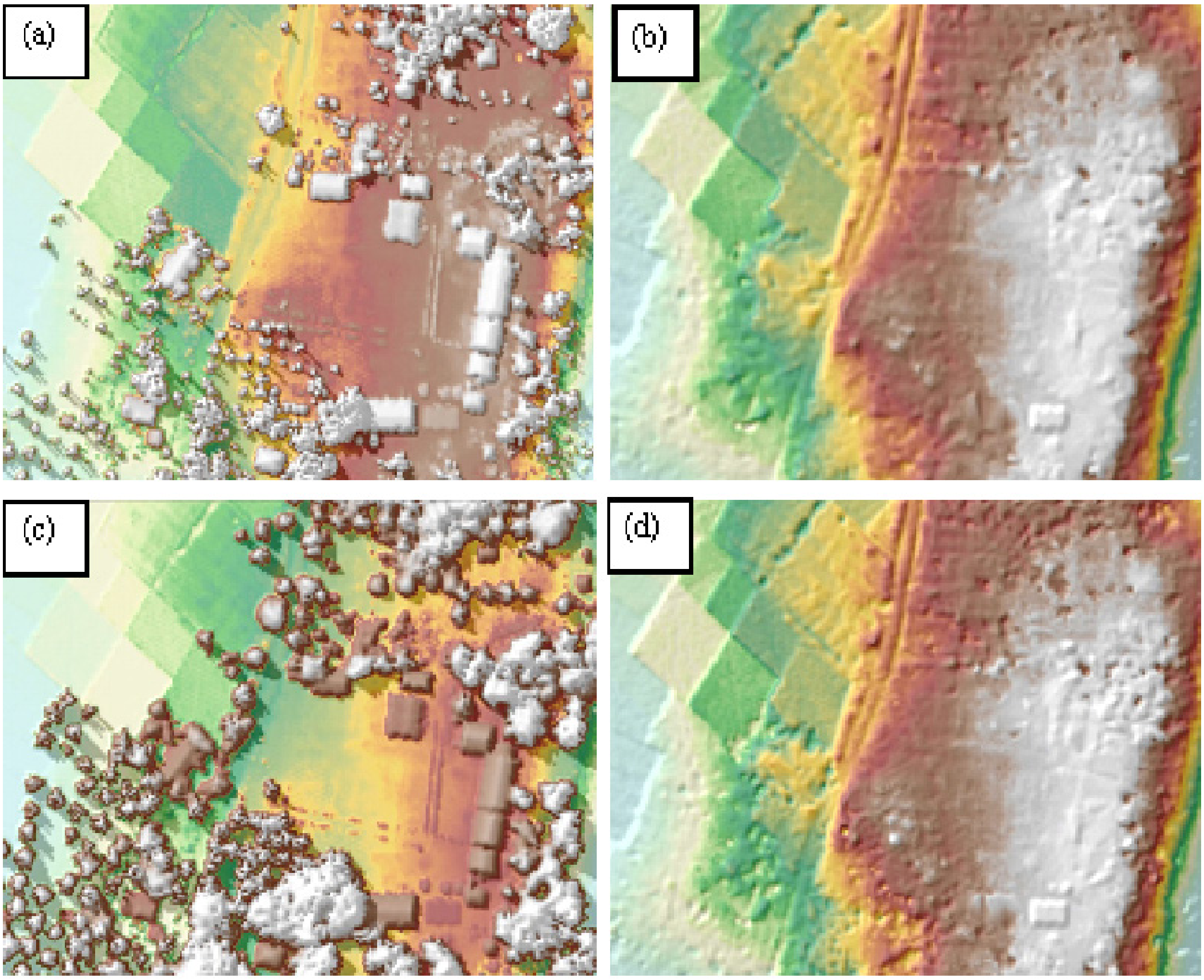

Figure 25. The Production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Asid floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

to fix photo misalignments, tie point selection was done. Color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. Overall, the Asid Floodplain Survey reached a total of 913.44 sq.km in orthophotogaph coverage, comprised of 2,861 images. Figure 26 shows the area covered by Asid Floodplain featuring 1,085 1km. by 1km. tiles.Figure 27 on the other hand illustrates a zoomed in version of sample orthophotographs named in reference to its tile number.

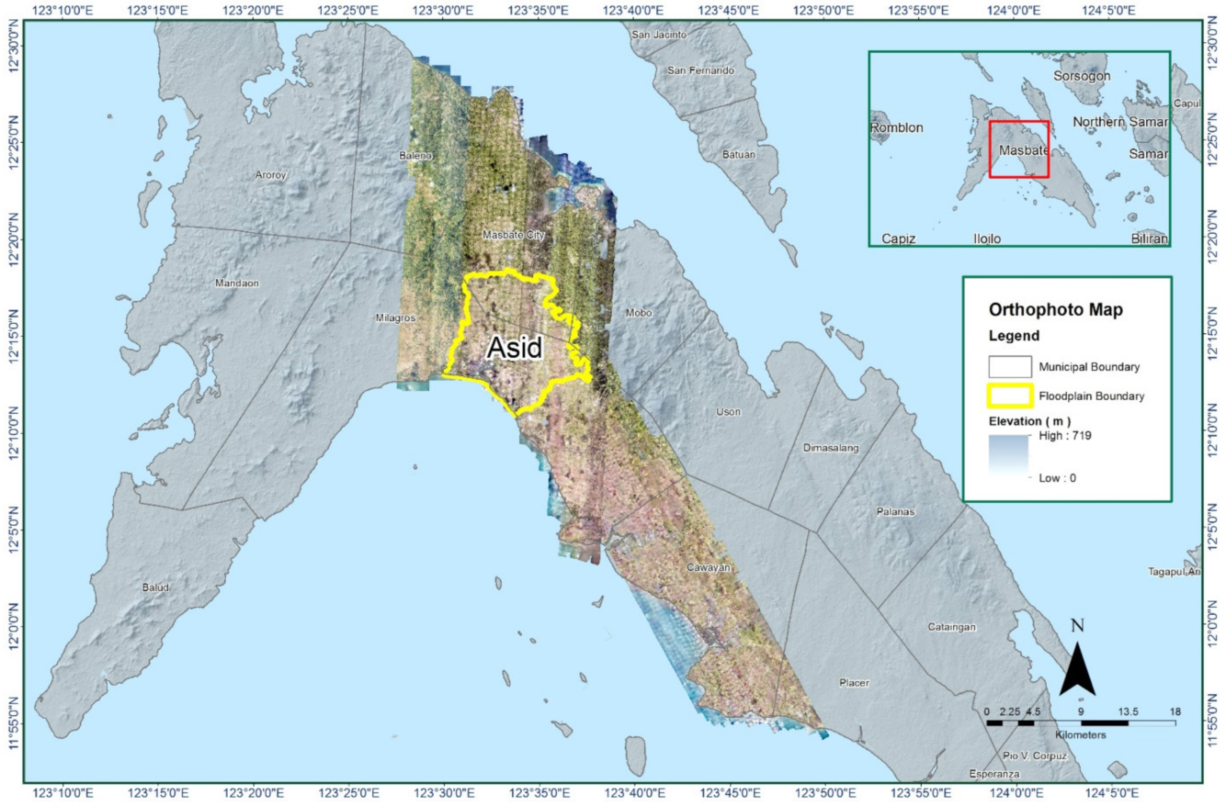

Figure 26. Asid Floodplain with available orthophotographs.

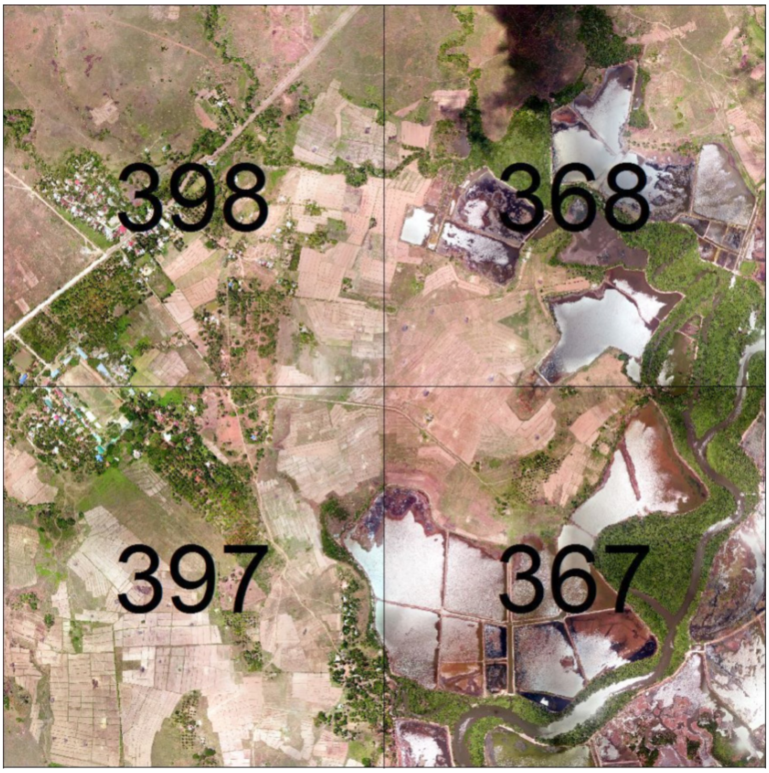

Figure 27. Sample orthophotograph tiles for Asid Floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for Asid Floodplain. These blocks are composed of Masbate blocks with a total area of 967.08 square kilometers. Correspondingly, Table 19 shows the name and corresponding area of each block in square kilometers.

Table 19. LiDAR blocks with its corresponding area

LiDAR Blocks	Area (sq. km)
Masbate_Blk32H	313.84
Masbate_Blk32D	364.88
Masbate_Blk32E	288.56
TOTAL	**967.08 sq. km**

Figure 28 shows the portions of DTM before and after manual editing. As illustrated in the figure, the bridge (Figure 28a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 28b) in order to hydrologically correct the river. Also, the embankment (Figure 28c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 28d) to allow the correct flow of water.

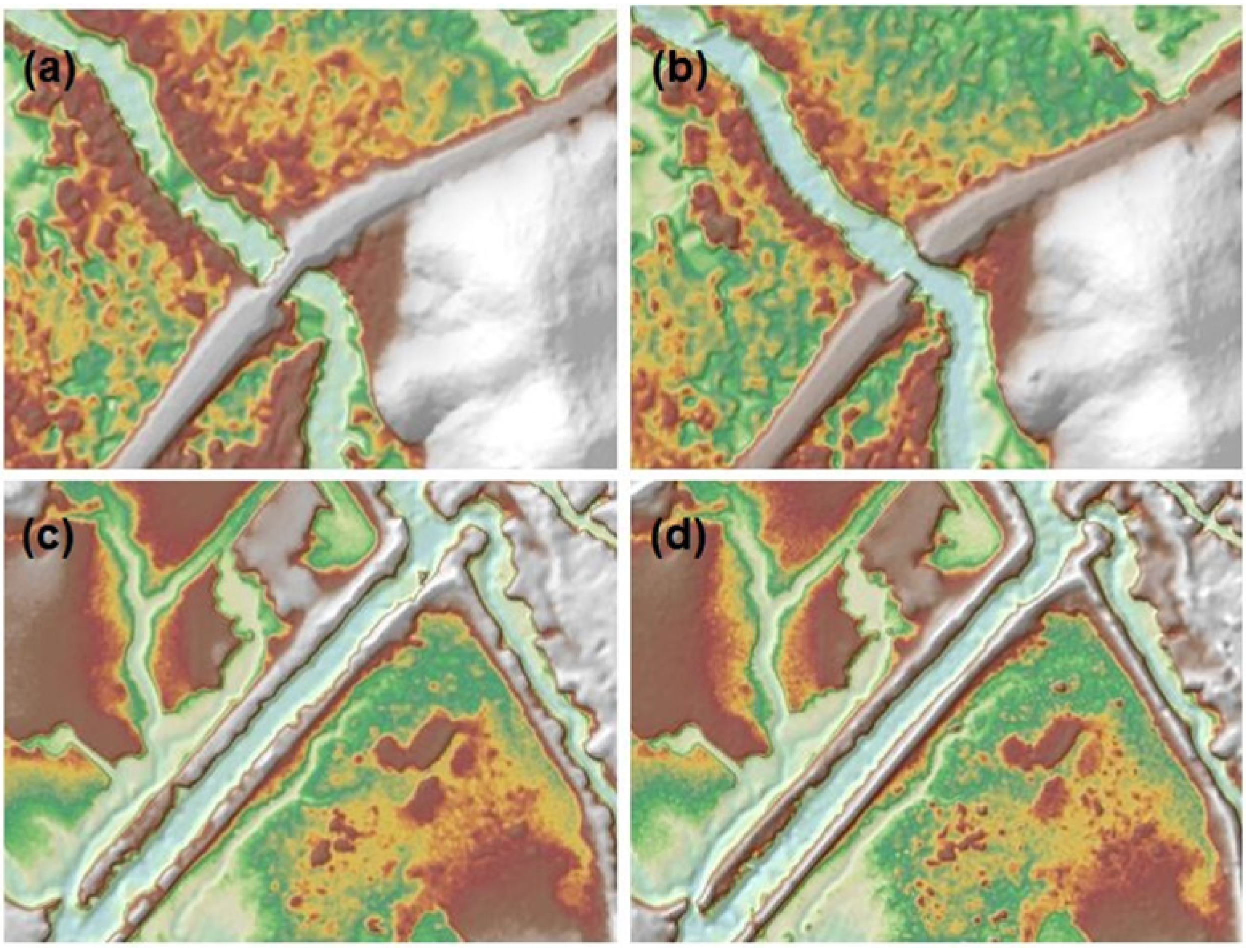

Figure 28. Portions in the DTM of Asid Floodplain – a bridge before (a) and after (b) manual editing; and anembankment before (c) and after (d) data retrieval

3.9 Mosaicking of Blocks

Masbate_Blk32D was used as the reference block at the start of mosaicking sinceit was referred to a base station with an acceptable order of accuracy. Table 20presentsthe shift values applied to each LiDAR block during mosaicking.

Table 20. Shift Values of each LiDAR Block of Asid floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Masbate_Blk32D	0.00	0.00	0.00
Masbate_Blk32E	0.00	0.00	1.61
Masbate_Blk32H	0.00	0.00	1.64

Mosaicked LiDAR DTM for Asid Floodplain is shown in Figure 29. It can be seen that the entire Asid Flood-plain is 99.64% covered by LiDAR data.

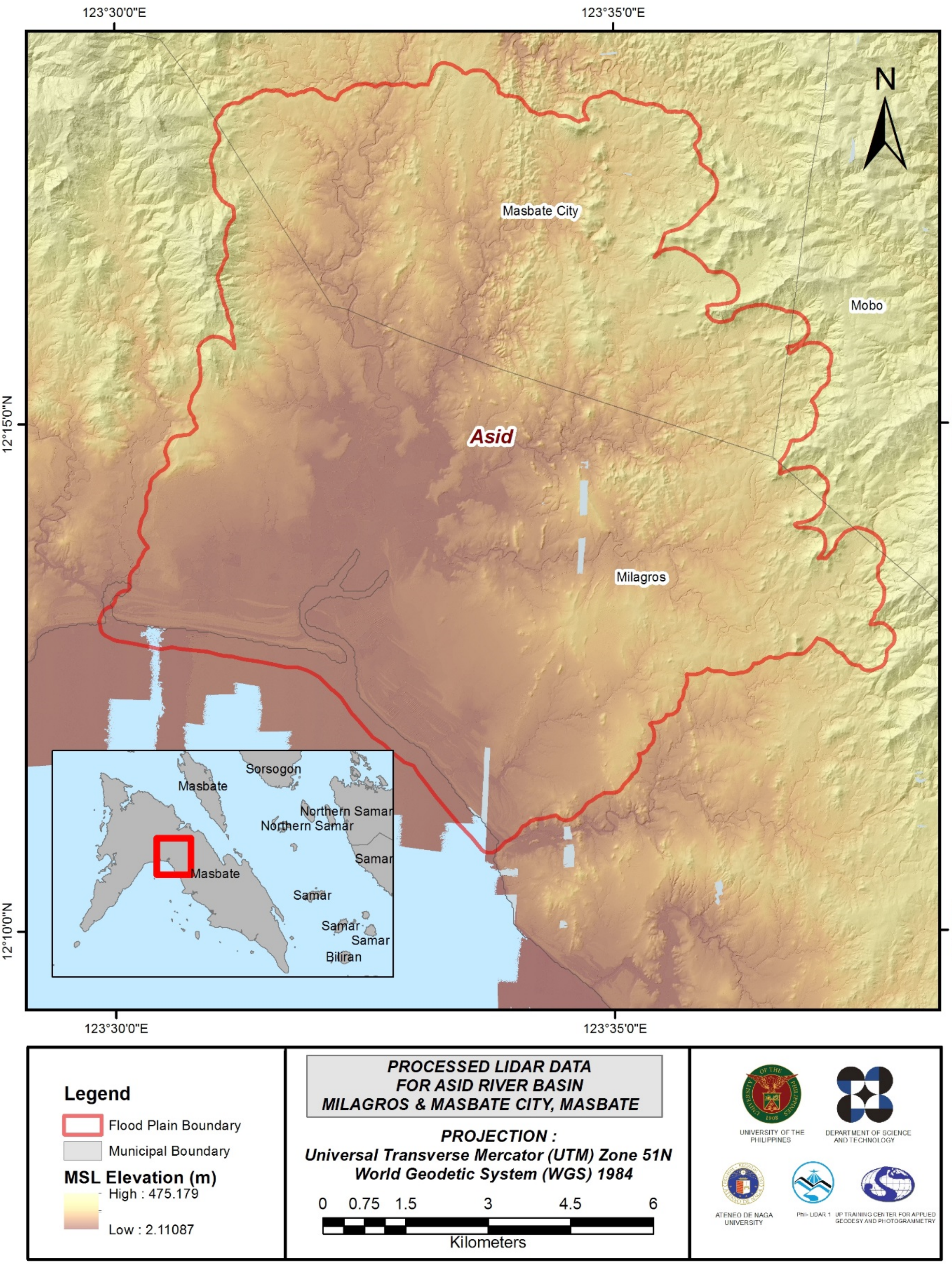

Figure 29. Map of Processed LiDAR Data for Asid Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

Figure 30 shows the extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Asid. Essentially, its purpose is to collect points with which the LiDAR dataset is validated. A total of 2,639 survey points were used for calibration and validation of Asid LiDAR data. Consequently, a random selection of 80% of the survey points, resulting to 2,591 points, were used for the calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 31. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 3.22 meters with a standard deviation of 0.16 meters. Calibration of Asid LiDAR data was done by subtracting the height difference value, 3.22 meters, to Asid mosaicked LiDAR data. Table 21 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

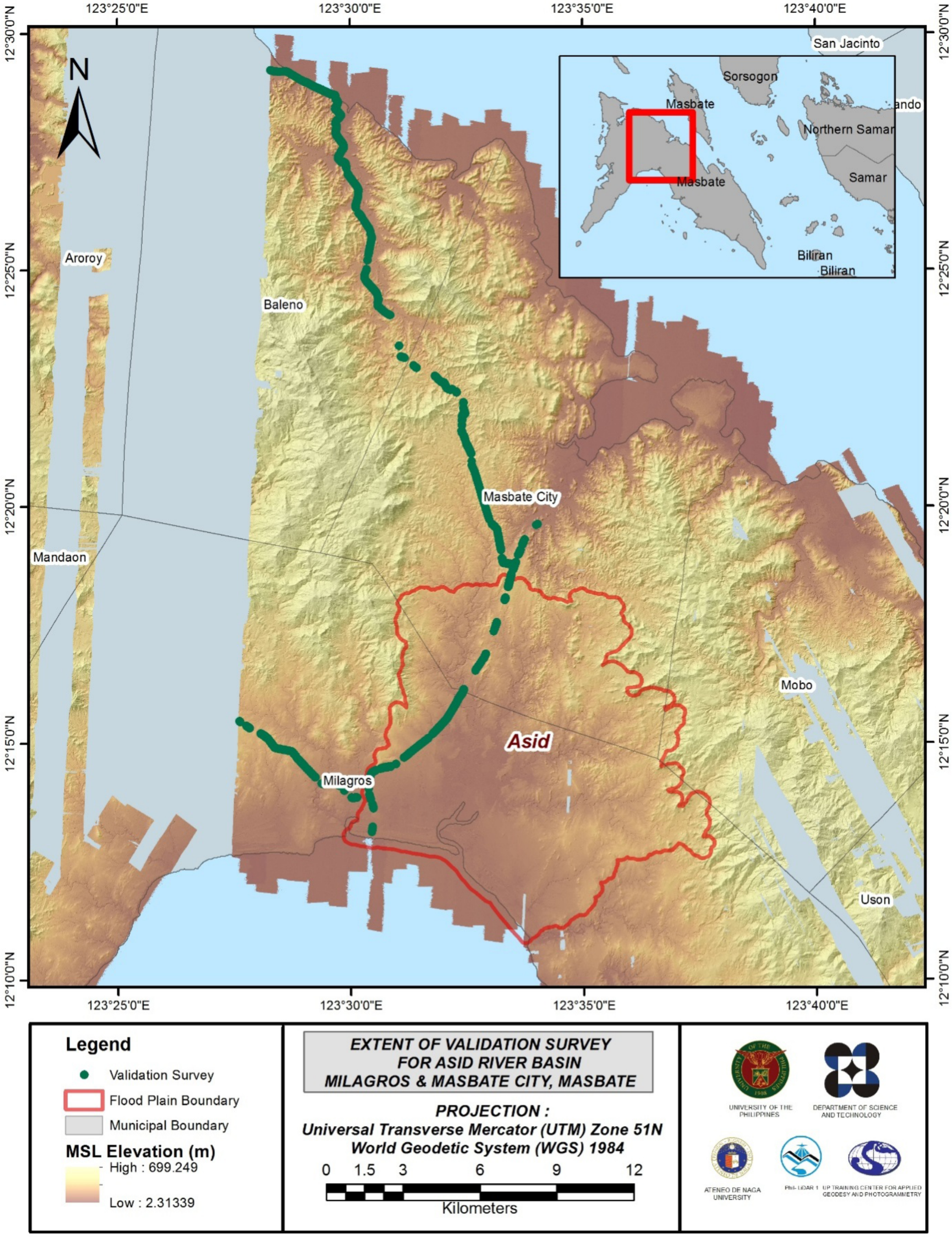

Figure 30. Map of Asid Floodplain with validation survey points in green.

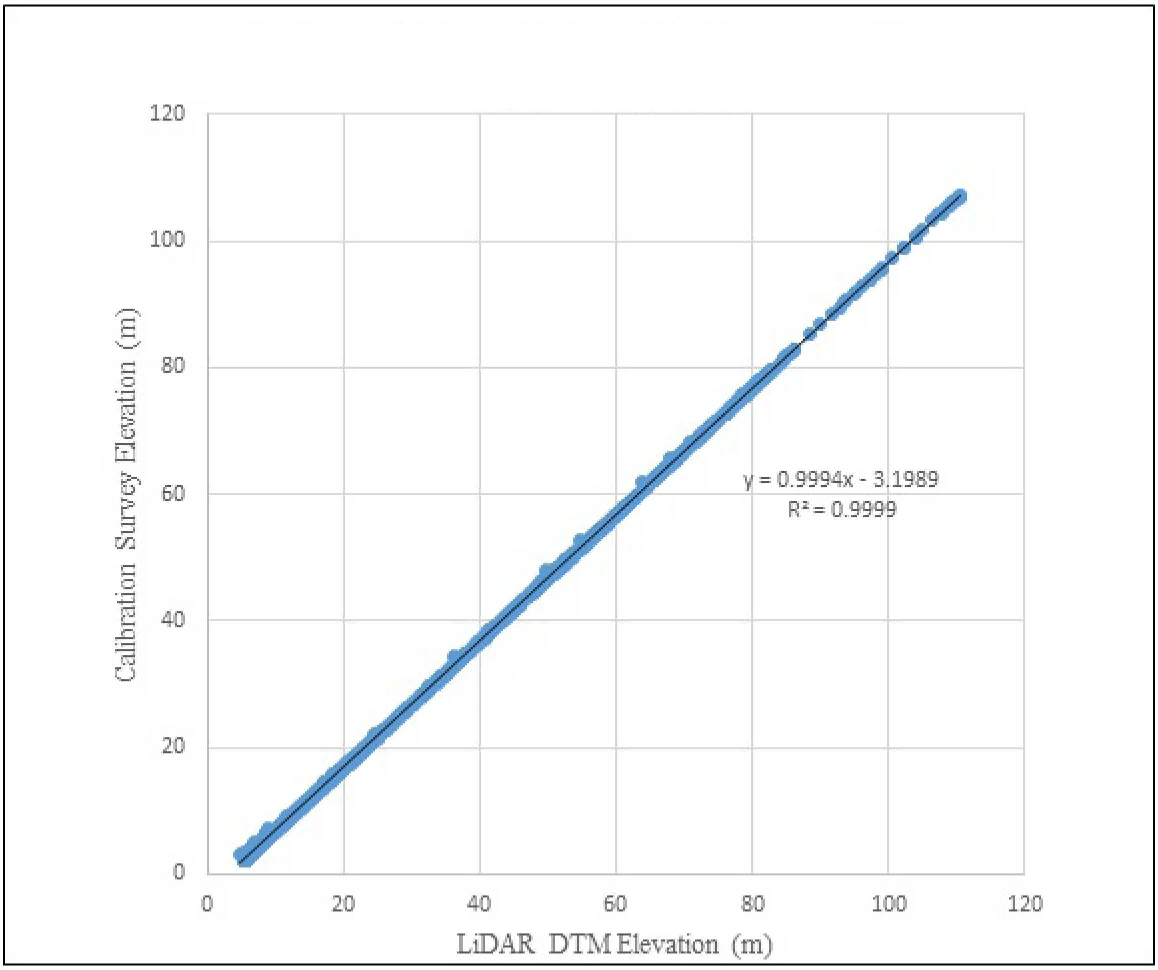

Figure 31. Correlation plot between calibration survey points and LiDAR data.

Table 21. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	3.22
Standard Deviation	0.16
Average	-3.22
Minimum	-3.53
Maximum	-1.66

The remaining 20% of the total survey points, resulting to 528 points, were used for the validation of calibrated Asid 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 32. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.07 meters with a standard deviation of 0.07 meters, as shown in Table 22.

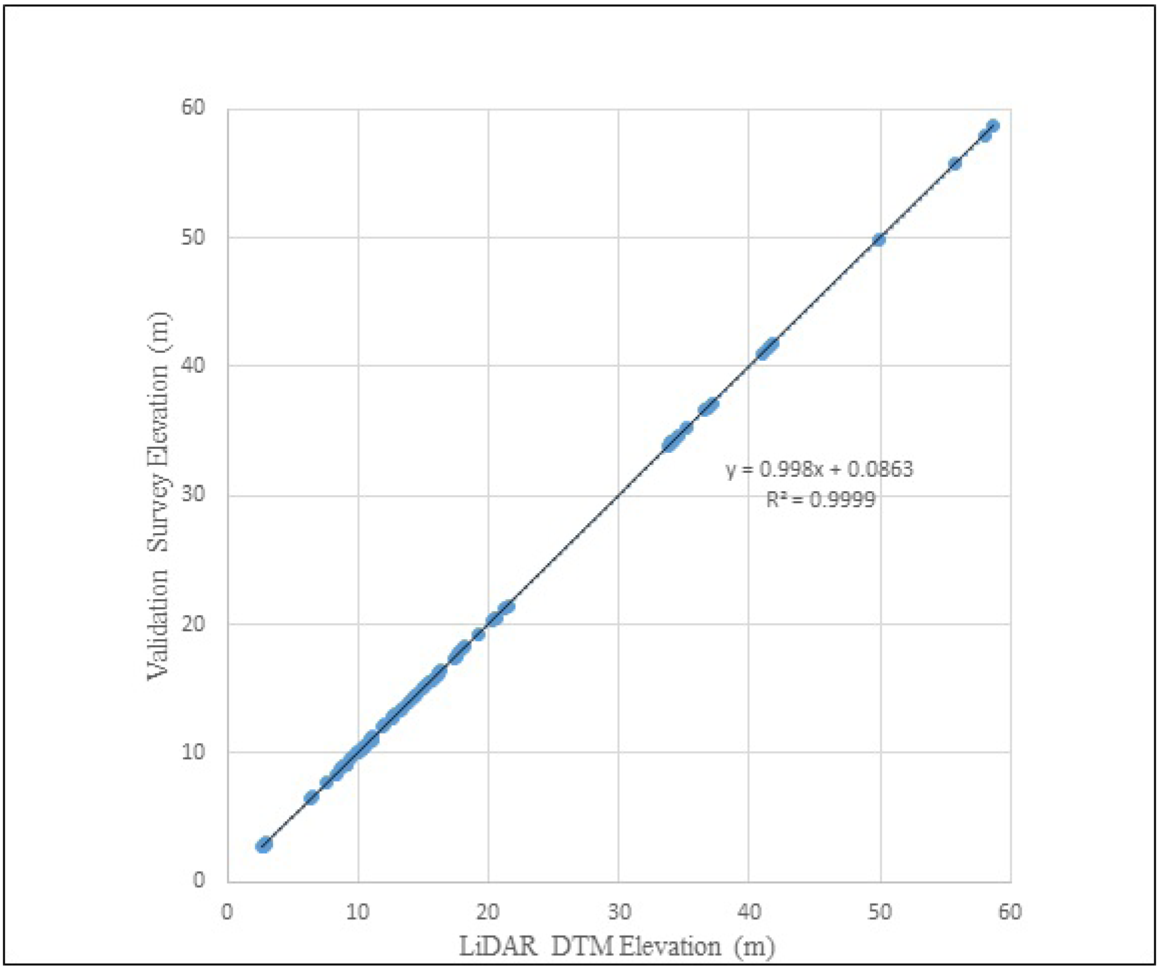

Figure 32. Correlation plot between validation survey points and LiDAR data.

Table 22. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.07
Standard Deviation	0.06
Average	0.05
Minimum	-0.06
Maximum	0.16

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline and zigzag data wereavailable for Asid with 11,680 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 0.09 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Asid integrated with the processed LiDAR DEM is shown in Figure 33.

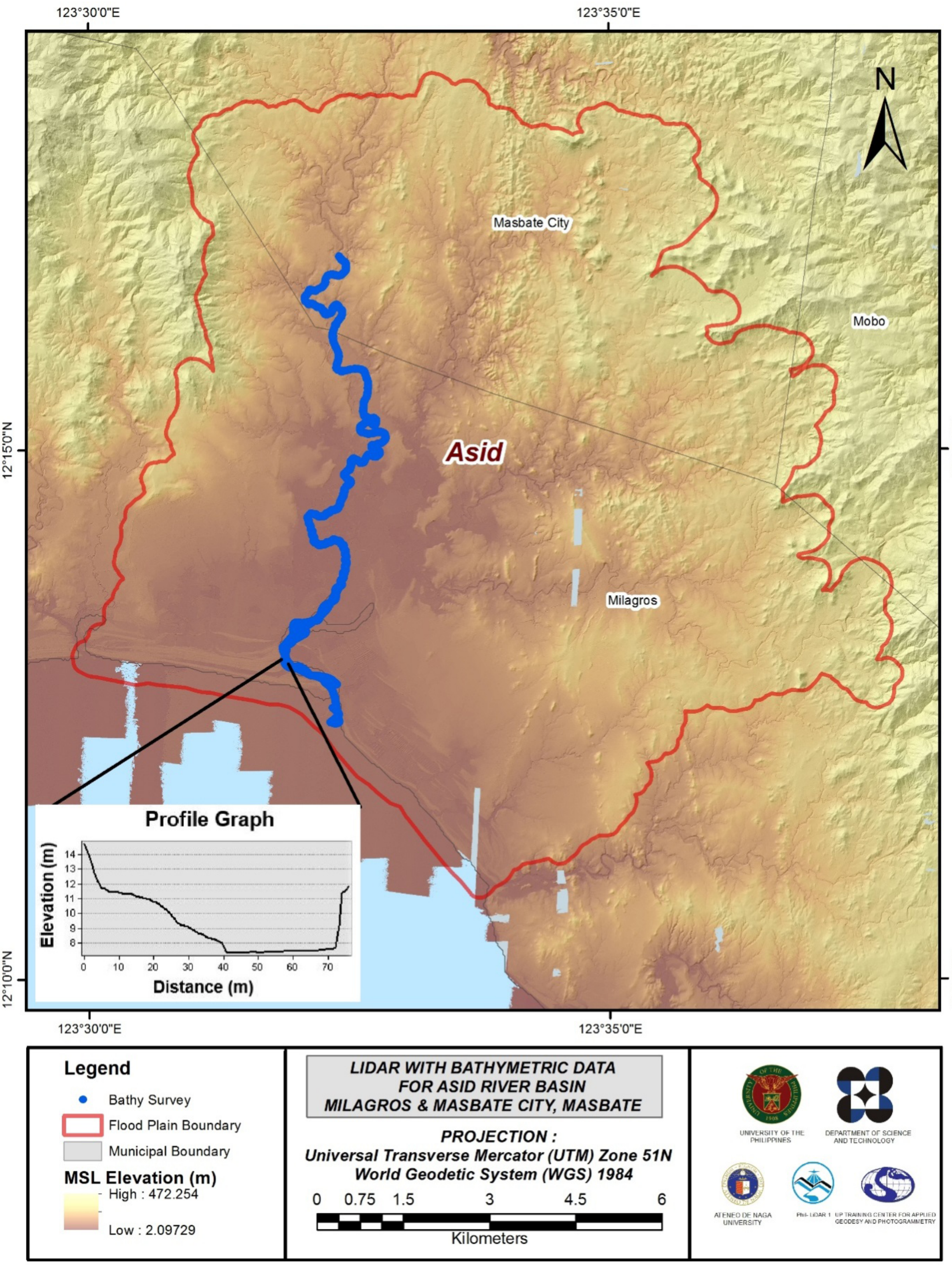

Figure 33. Map of Asid Flood Plain with bathymetric survey points shown in blue.

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-meter 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

Asid Floodplain, including its 200-meter buffer, has a total area of 126.89 sq km. Ofthis area, a total of 5.00 sq km, which correspondsto a total of 2,576 building features, wereconsidered for QC. Figure 34 shows the QC blocks for Asid Floodplain, while Table 23 outlines the quality checking of the Asid building features.

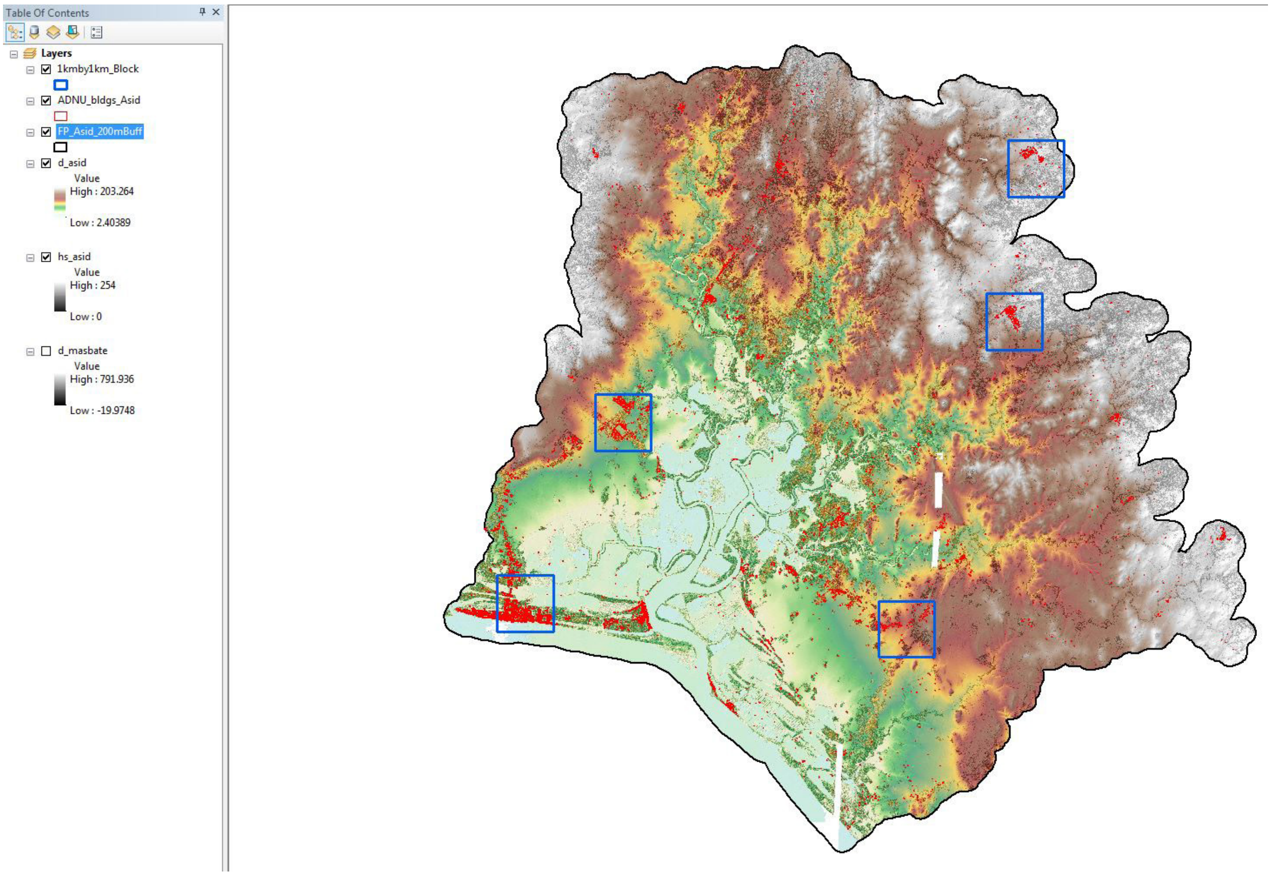

Figure 34. QC blocks for Asid building features.

Table 23. Quality Checking Ratings for Asid Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Asid	96.19	99.96	95.96	PASSED

3.12.2 Height Extraction

A total of 9,094 building features in the Asid Floodplain underwent a height extraction. Of these building features, 438 werefiltered out after height extraction, resulting to 8,656 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 13.87 meters.

3.12.3 Feature Attribution

Feature Attribution was done for 7,278 building features in Asid Floodplain through participatory mapping and innovations. The approach used in participatory mapping undergoes the creation of feature extracted maps. It also includes presentation of spatial knowledge to the community with the premise that the people in the area are considered experts in determining the correct attributes of the building features.

The innovation used in this process was the creation of an android application called reGIS. The Resource Extraction for Geographic Information System or 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 app lets the user record the current GPS location together with its corresponding exposure features, code, timestamp, accuracy and additional remarks. This is all done by a few swipes with the help of the device's pre-defined list of exposure features, which effectively allows unified and standardized sets of data.

Table 24 summarizes the number of building features that were extracted for the Asid Floodplain. On the other hand, Table 25 shows the total length of each road type, while Table 26presents the number of water features extracted per type.

Table 24. Number of Building Features Extracted for Asid Floodplain.

Facility Type	No. of Features
Residential	8,316
School	163
Market	32
Agricultural/Agro-Industrial Facilities	9
Medical Institutions	13
Barangay Hall	13
Military Institution	2
Sports Center/Gymnasium/Covered Court	3
Telecommunication Facilities	3
Transport Terminal	0
Warehouse	2
Power Plant/Substation	0
NGO/CSO Offices	2
Police Station	1
Water Supply/Sewerage	3
Religious Institutions	30
Bank	1
Factory	0
Gas Station	3
Fire Station	0
Other Government Offices	17
Other Commercial Establishments	43
Total	**8,656**

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

Table 25. Total Length of Extracted Roads for Asid Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Asid	59.30	9.10	0	10.74	0.00	**79.14**

Table 26. Number of Extracted Water Bodies for Asid Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Asid	1	341	0	0	0	**342**

A total of 32 bridges and culverts over small channels that are part of the river network were also extracted fromthe floodplain.

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were given the complete required attributes. Consequently, all these output features comprise the flood hazard exposure database for the floodplain. The final quality checking completes the feature extraction phase of the project.

Figure 35 shows the Digital Surface Model (DSM) of Asid Floodplain, overlaid with its ground features.

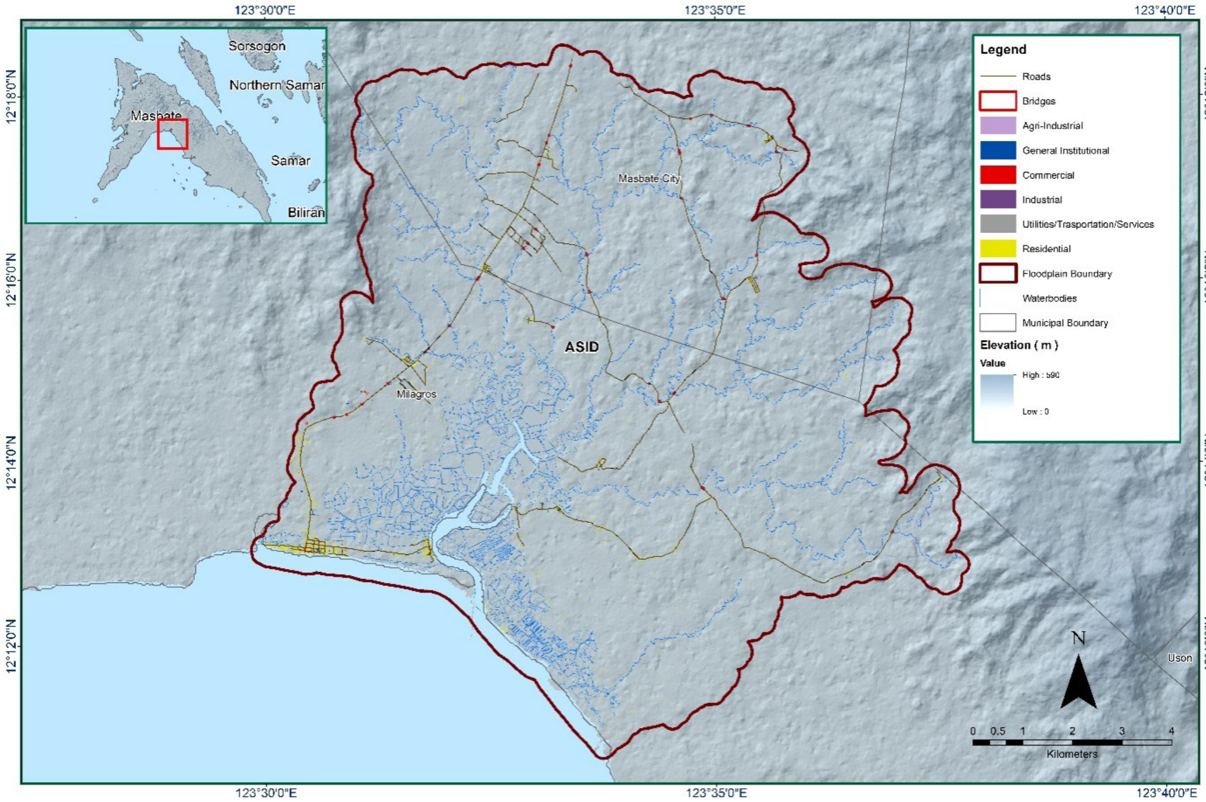

Figure 35. Extracted features for Asid Floodplain.

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

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

4.1 Summary of Activities

The Data Validation and Bathymetry Component (DVBC) conducted field survey in Asid River on December 3-17, 2015 with the following scope of work: (i) reconnaissance; (ii) control survey for the establishment of a control point; (iii) cross-section and as-built survey; (iv) validation points acquisition survey; and (v) bathymetric survey. The survey started from Brgy. Asid down to the mouth of the river in Brgy. Calasuche, with an estimated length of 13.00 km using an OHMEX™ Single Beam Echo Sounder and GNSS PPK survey technique.

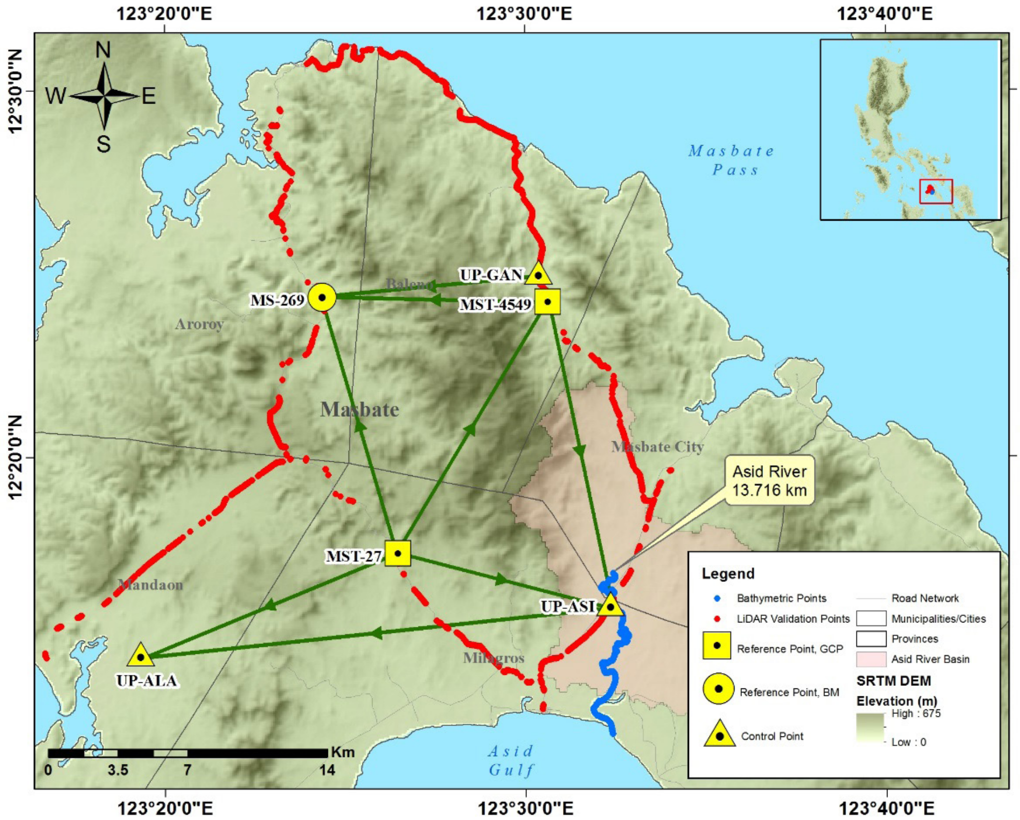


Figure 36.The extent of theAsid River Bathymetric Survey

4.2 Control Survey

The GNSS network used for Asid 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; and MS-269, a first order benchmark in Brgy. Luy-A, Municipality of Aroroy.

Three (3) control points were established along the approach of three 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.

Table 27 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 37 shows the GNSS network established in Asid River Survey.

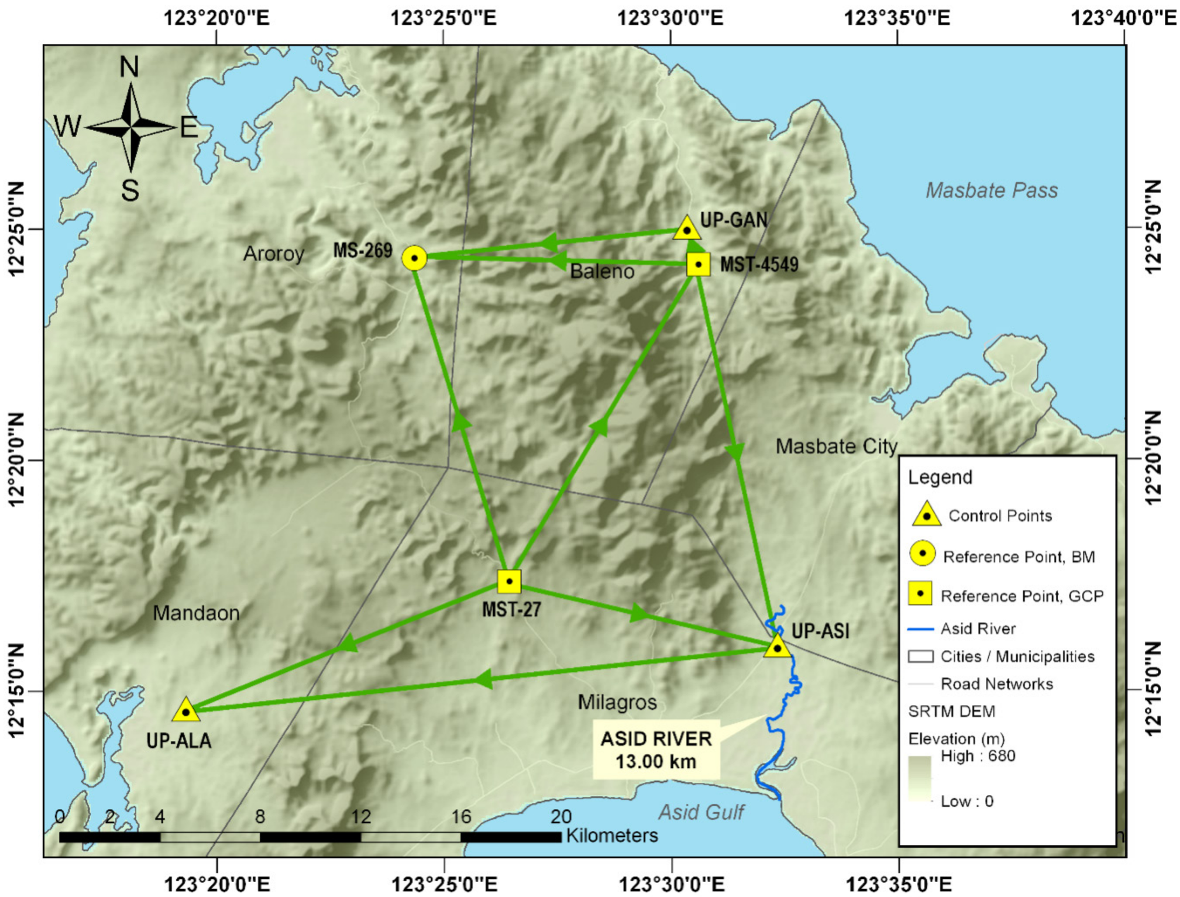


Figure 37.GNSS Network of Asid River field survey

Table 27.List of Reference and Control Points used in Masbate fieldwork on December 3-17 2015 (Source: NAMRIA and UP-TCAGP)

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

Figure 38 to Figure 43 show the GNSS set up made in the location of the reference and control points.

Figure 38. GNSS base set up, Trimble® SPS 852 at MS-269 benchmark located at Lanang Bridge, along Central Nautical Highway in Brgy. Luy-A, Aroroy, Masbate

Figure 39. GNSS receiver set up, Trimble® SPS 882 at MST-27, a second order GCP located at Mabuaya Bridge along Central Nautical Highway in Brgy. Matiporon, Milagros, Masbate

Figure 40. Trimble® SPS 852 base setup 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 41. Trimble® SPS 882 setup at UP-ALA, an established control point located at Alas Bridge in Brgy. Alas, Mandaon, Masbate

Figure 42. GNSS receiver setup, Trimble® SPS 882, at UP-ASI, an established control point located at Asid Bridge, along Central Nautical Highway, Brgy. Asid, Masbate City

Figure 43. GNSS receiver setup, Trimble® SPS 882, at UP-GAN, an established control point located on the 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 +/-20cm and +/-10cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking wasperformed. Masking isthe removal or covering of portions of these baseline data using the same processing software. The data is then repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a resurvey is initiated. Table 28 presents the baseline processing results of control points in the Asid River Basin, as generated by the TBC software.

Table 28.Baseline Processing Report for Asid 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 28, 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 is performed using the TBC software. 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:

Xe is the Easting error,
Ye is the Northing error, and
Ze is the Elevation error

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 29. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 29. 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 30. All fixed control points have no values for grid and elevation errors.

Table 30. Adjusted grid coordinates

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	0.1	
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 31. Using the equation for horizontal and for the vertical; below is the computation for accuracy that passed the required precision:

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 two occupied control points are within the required precision.

Table 31.Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	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 C-5. 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 32.

Table 32. 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 Estab-lished	12°d14’38.06086”	123°19’18.85903”	57.103	1353545.355	535010.665	1.754
UP-ASI	UP Estab-lished	12°15’59.72358”	123°32’20.76940”	66.451	1356091.508	558628.712	10.476
UP-GAN	UP Estab-lished	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 and as-built survey was conducted on December 7, 2015 at Asid Bridge in Brgy. Asid, Masbate City. The survey was conducted along the downstream side of the bridge with the application of PPK technique using a survey grade GPS, Trimble® SPS 882 as shown in Figure 44.

Figure 44.As-built survey using Trimble® SPS 882

The cross-sectional line length of Asid bridge is 95.056 meters with 36 points acquired using UP-ASI as the GNSS base station. The location map, cross-section diagram, and bridge as-built form are shown in Figure 45 to Figure 47, respectively.

The water surface elevation of Asid River was acquired using PPK survey technique on December 11, 2015 at 12:53 with a value of 0.827 meter MSL. The resulting water surface elevation data was translated to the bridge pier to serve as basis for the partner HEI, Ateneo De Naga University.

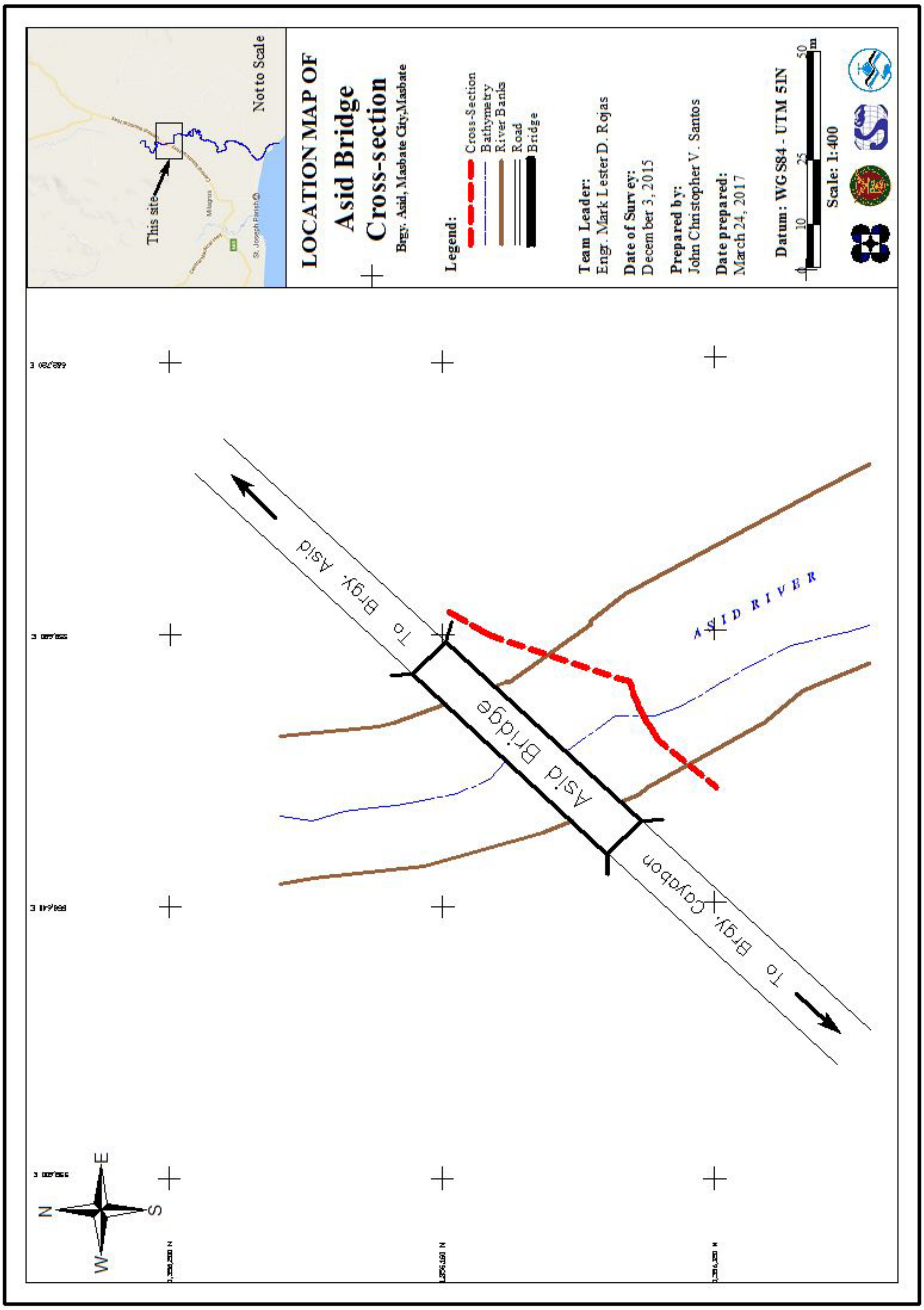


Figure 45. Asid Bridge cross-section location map

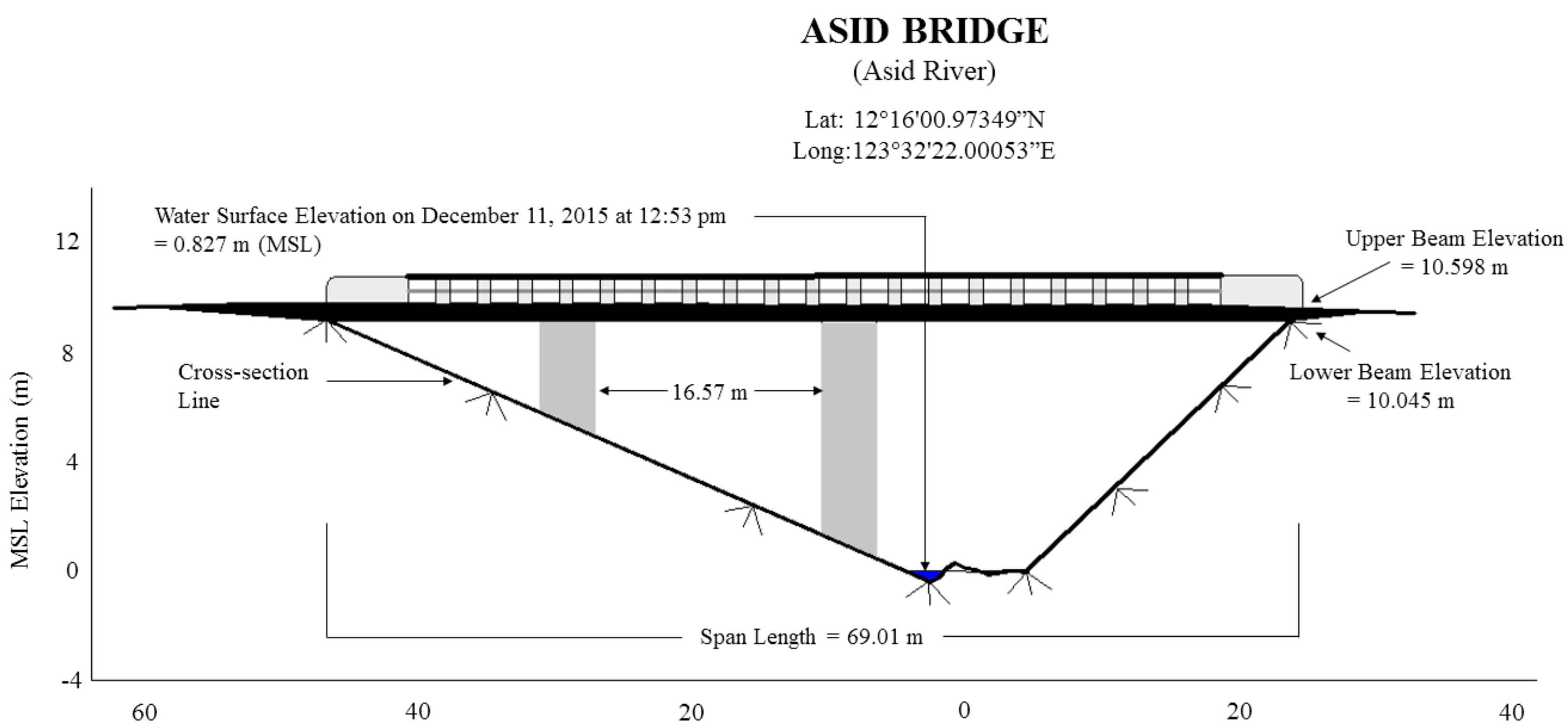


Figure 46. Asid Bridge cross-section diagram

Bridge Data Form

Bridge Name: ASID BRIDGE **Date:** December 11, 2015

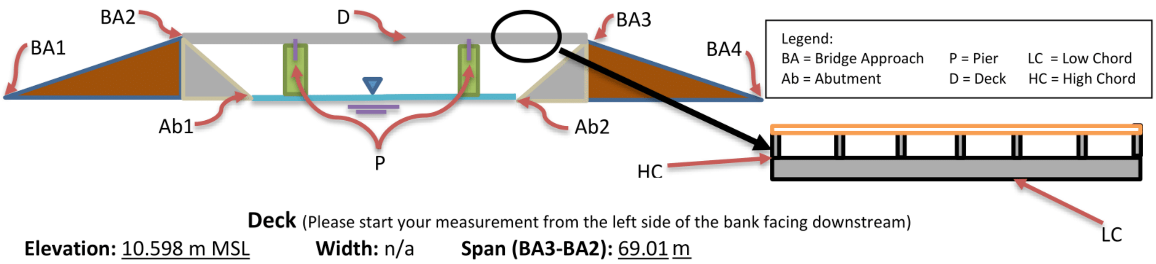
River Name: ASID RIVER **Time:** 12:53 pm

Location (Brgy, City, Region): Brgy. Asid, Masbate City, Masbate

Survey Team: DVBC/DVC Masbate Survey – Team Mark

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

Latitude: 12°16'00.97349" **Longitude:** 123°32'22.00053



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

Elevation: 10.598 m MSL **Width:** n/a **Span (BA3-BA2):** 69.01 m

	Station	High Chord Elevation	Low Chord Elevation
1	Pier 1	10.602	
2	Pier 2	10.561	
3			
4			
5			
6			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	10.500	**BA3**	78.88904	10.598
BA2	9.878239	10.677	**BA4**	95.05559	10.355

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

	Station (Distance from BA1)	Elevation
Ab1	12.16995793	10.045
Ab2		

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

Shape: ____________ **Number of Piers:** 2 **Height of column footing:** n/a

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	Pier 1	10.602	
Pier 2	Pier 2	10.561	
Pier 3			

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

Figure 47.Asid Bridge data form

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on December 5 to 6, 2015. As shown in Figure 48, a Trimble® SPS 882 was attached in front of a vehicleto 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 Earth™ 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 during this survey. The second day of the validation survey also started in Mabuayan Bridge going to Brgy. Poblacion in Aroroy via Mandaon, which is the other half of the circumferential road. This survey covered Mandaon Road which started from Brgy. Mabatobato going southwest towards Brgy. Nailaban, both in the Municipality of Mandaon. The reference point MST-27 was used as base for the last route.

Figure 48. Validation points acquisition survey setup: A Trimble® SPS 882, mounted on top of the vehicle

The map in Figure 49 shows the extent of the ground validation survey, which acquired a total of 4,709 ground validation points with an approximate length of 112 km.

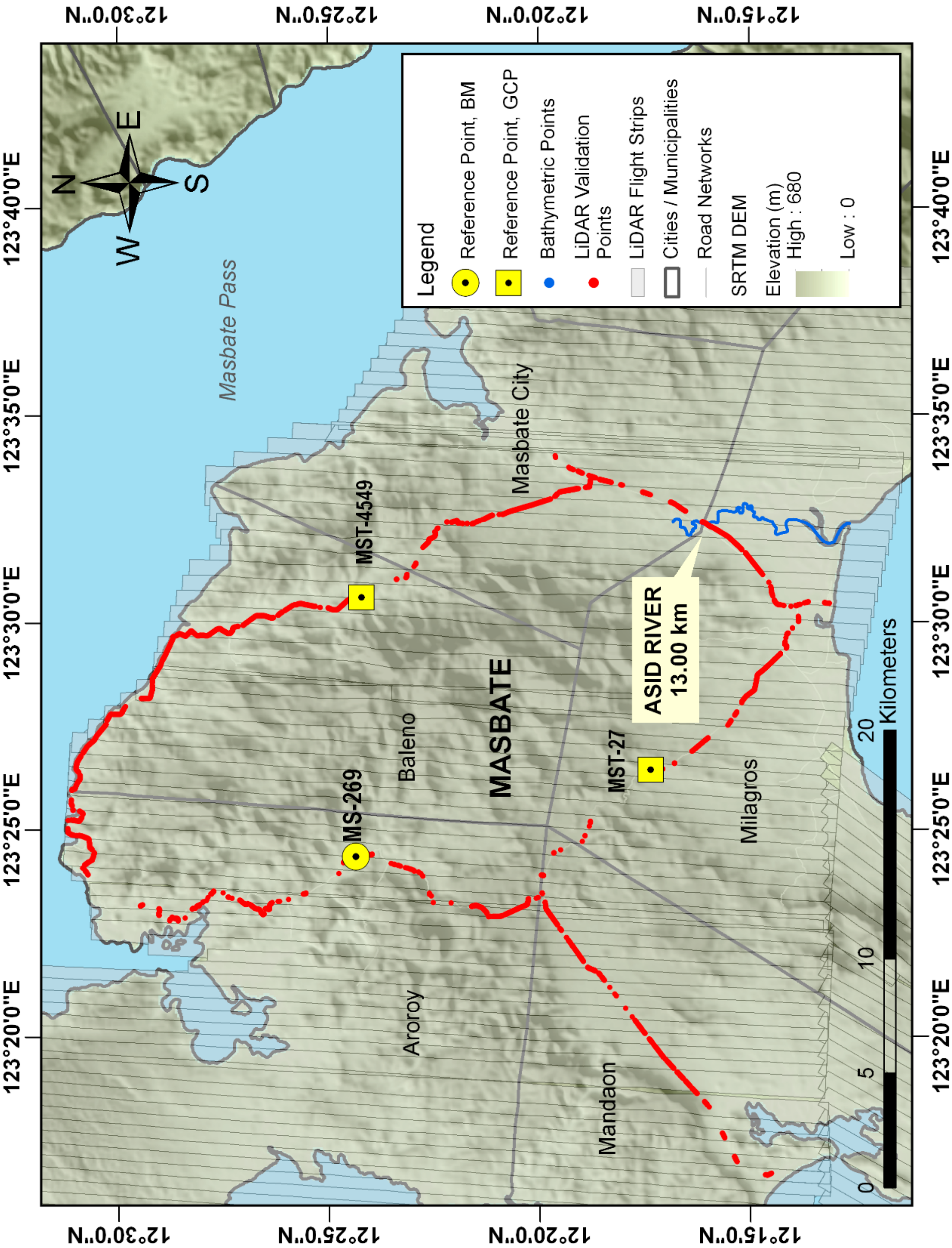


Figure 49. Validation points acquisition survey along Asid River Basin

4.7 River Bathymetric Survey

The bathymetric survey was conducted on December 15, 2015 using a boat with an installed Ohmex™ single beam echo sounder and a mounted Trimble® SPS 882 GNSS receiver in PPK survey technique as shown in Figure 50. The survey started in Brgy. Calsauche, Municipality of Milagros with coordinates 12°15'14.37290" 123°32'43.97507" down to the mouth of the river in the same barangay with coordinates 12°12'25.01229" 123°32'22.55337".

Another set manual bathymetry survey was then conducted on December 9 and 11, 2015, using Trimble® SPS 882 GNSS receiver in PPK survey technique as seenin Figure 51. The survey started at the upstream part of the river in Brgy. Asid, Masbate City with coordinates 12°16'49.41621" 123°32'24.60538", traversed down by foot and ended at the starting point of bathymetric survey using boat. The control point UP-ASI was used as the GNSS base station all throughout the survey.

Figure 50. Bathymetric survey set-up using OHMEX™ single beam echo sounder and a mounted with Trimble® SPS 882

Figure 51. Manual bathymetry in Asid River

The bathymetric line survey has an estimated length of 13.00 km with 12,231 bathymetric points acquired covering barangays Asid, Cayabon, and Calasuche as shown in the map in Figure 52. To further illustrate this, a CAD drawing of the Asid riverbed profile was produced. As shown in Figure 53 and Figure 54, the highest and lowest elevation has a 6-meter difference. The highest elevation observed was 3.382 m above MSLlocated in Brgy. Asid, Masbate City while the lowest was 7.374 m below MSL located in Brgy. Cala-suche, Milagros, Masbate.

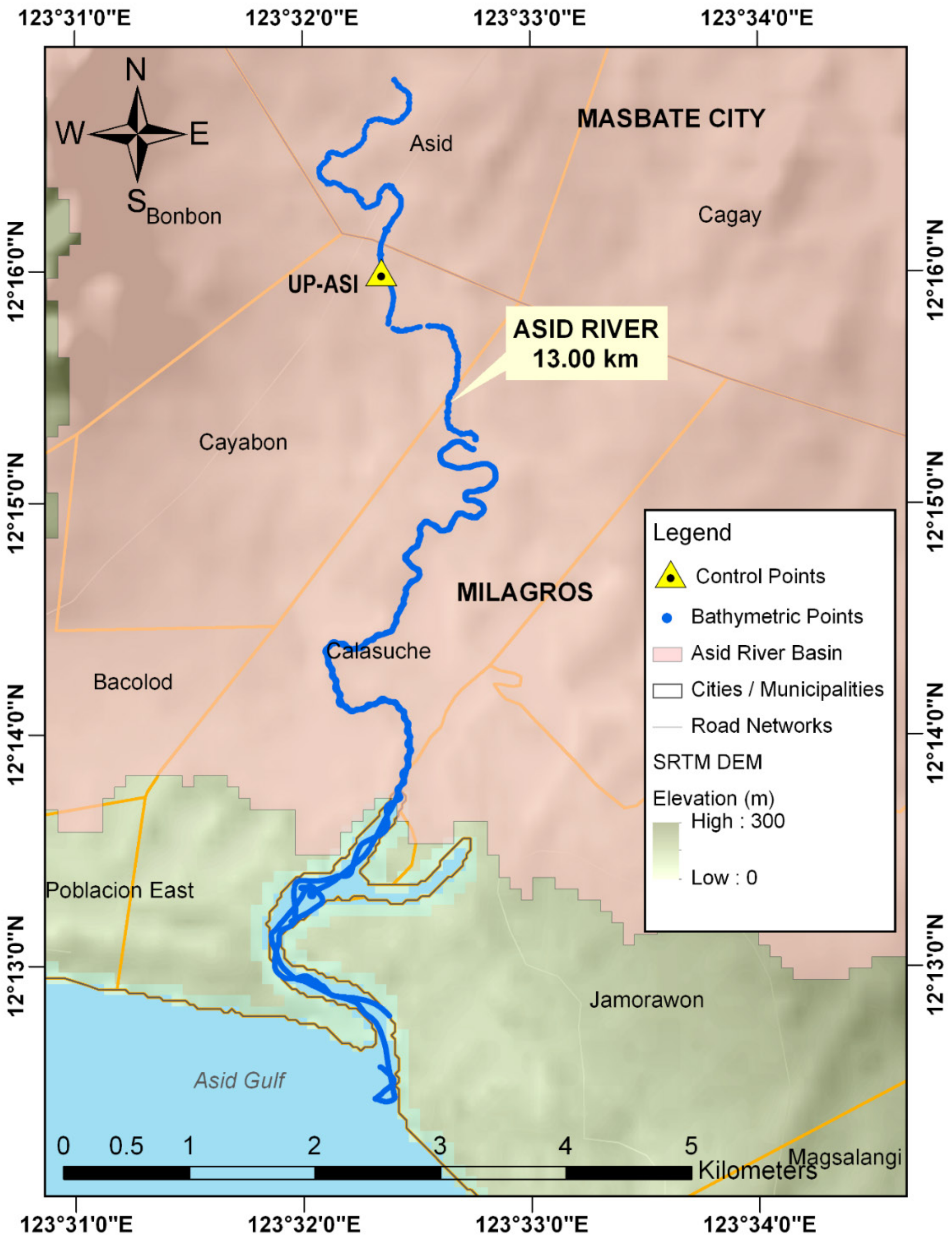


Figure 52. Bathymetric survey along Asid River

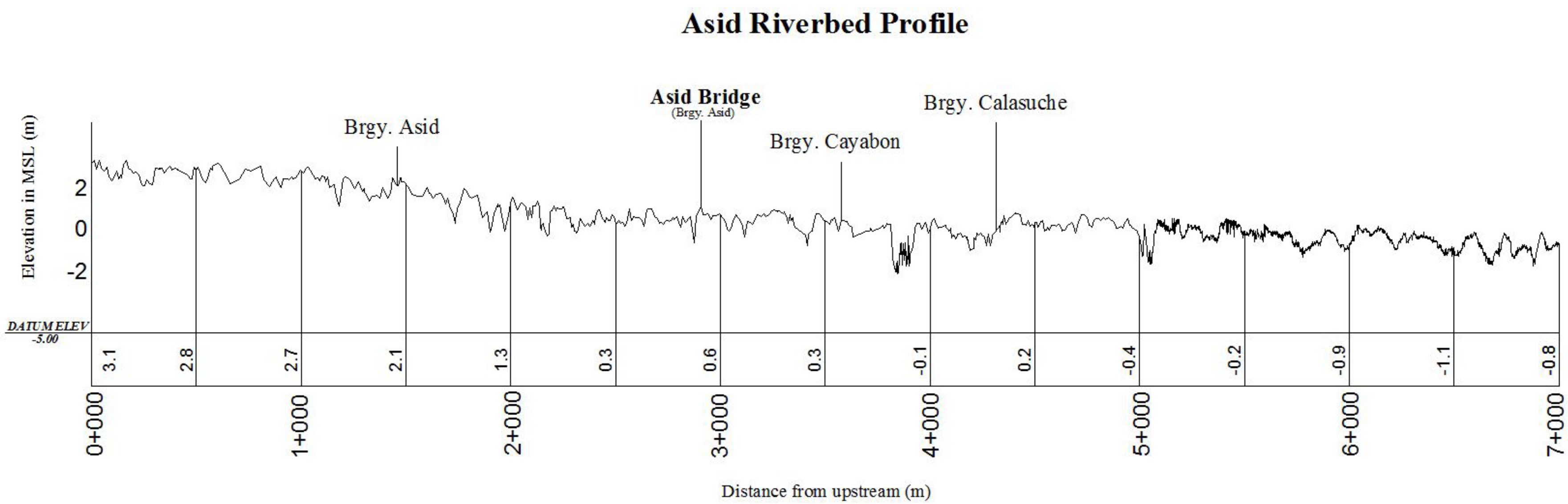


Figure 53. Riverbed profile of Asid River (1 of 2)

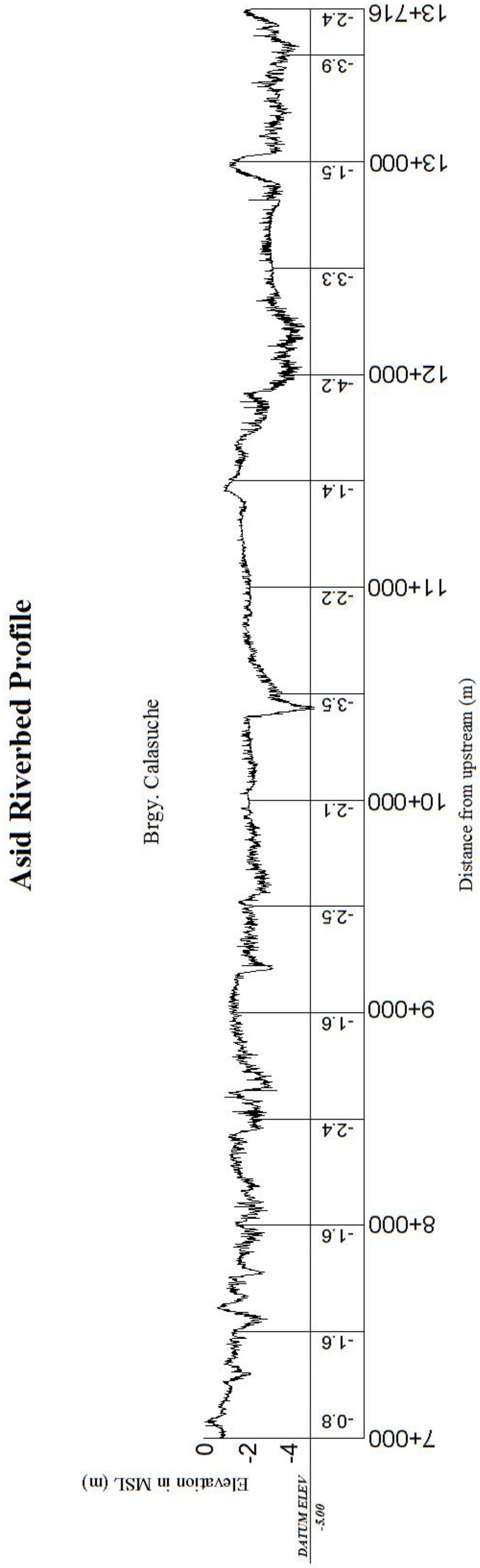


Figure 54. Riverbed profile of Asid River (2 of 2)

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

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

5.1.2 Precipitation

Precipitation data was taken from anAutomatic Rain Gauge (ARGs) installed by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). The rain gauge was installed at the PAG-ASA Weather Station (Figure 55). The precipitation data collection started from December 13, 2015 at 1:00 PM to December 15, 2015 at 1:00 PM with a 10-minute recording interval.

The total precipitation for this event in PAG-ASA weather station ARG is 185mm. It has a peak rainfall of 50.4mm on December 14, 2015 at 12:00 PM. The lag time between the peak rainfall and discharge is 18 hours and 10 minutes.

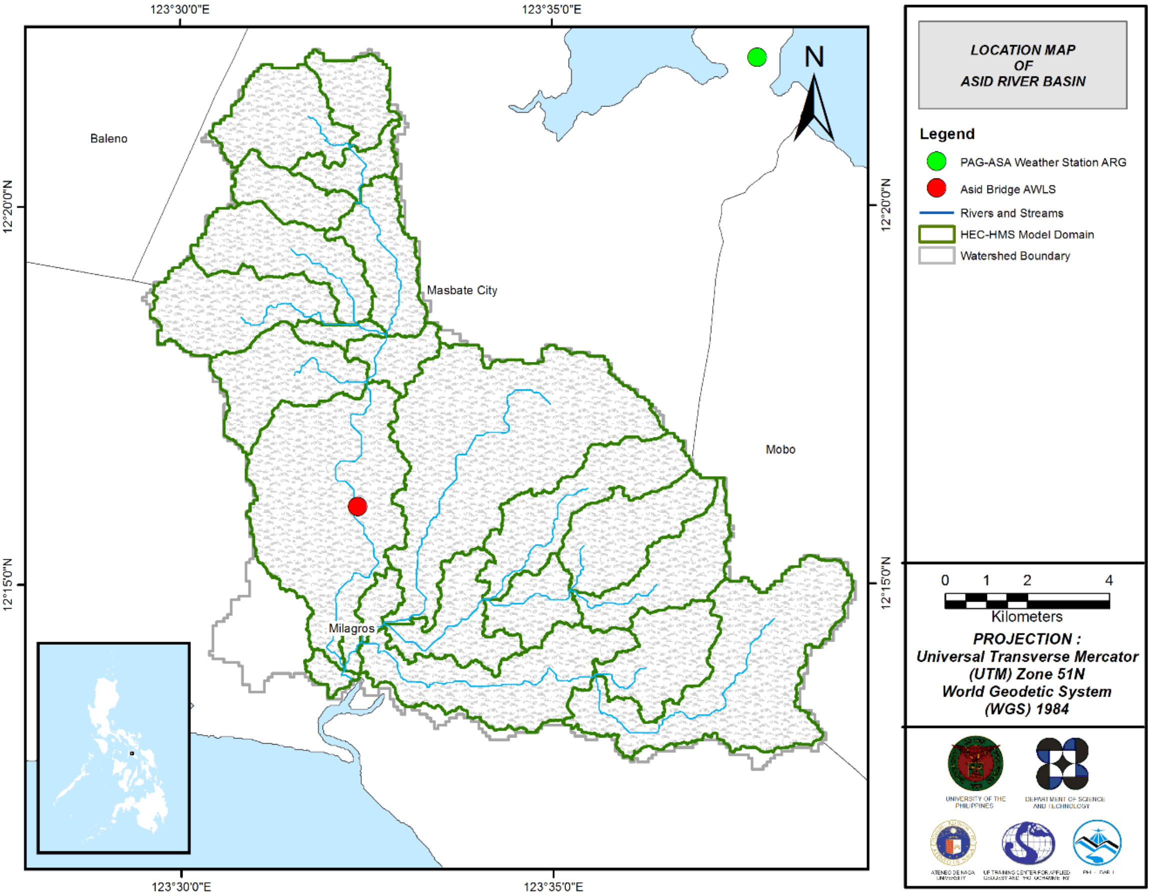

Figure 55. The location map of Asid HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Asid Bridge, Brgy. Asid, Masbate City (12°16’1.8”N, 123°32’22.5”Eto establish a relationship between the observed water levels at Asid Bridge and outflow of the watershed at this location.

For Asid Bridge, the rating curve is expressed as $Q = 0.0842e^{1.908h}$ as shown in Figure 57.

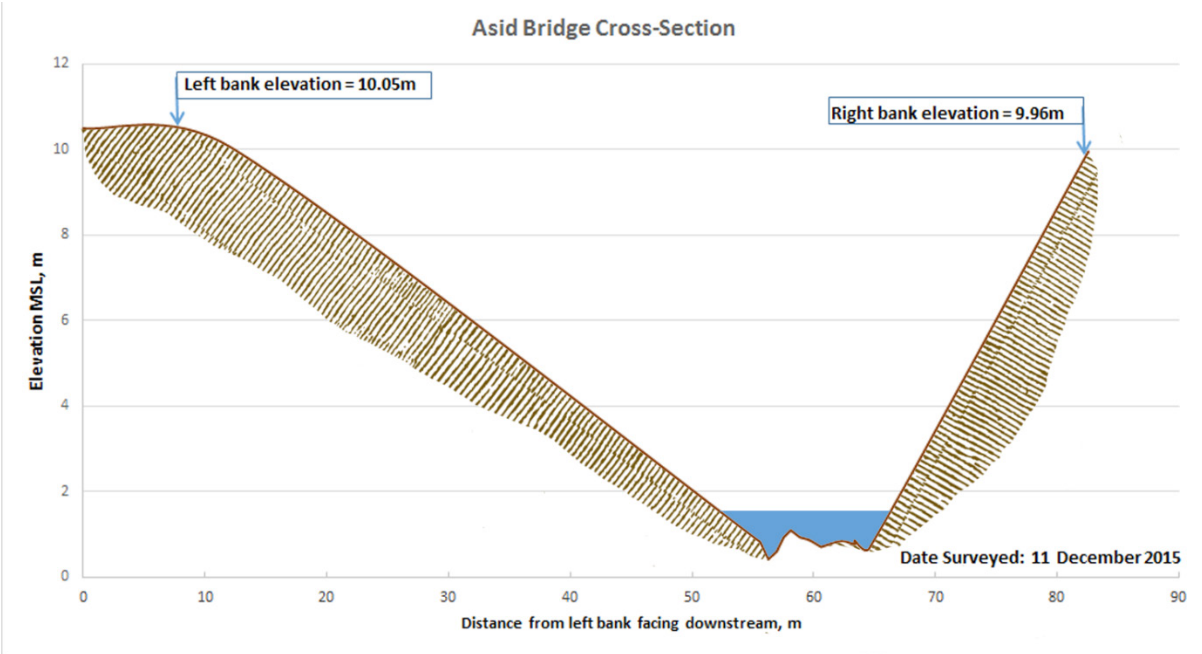

Figure 56. Cross-Section Plot of Asid Bridge

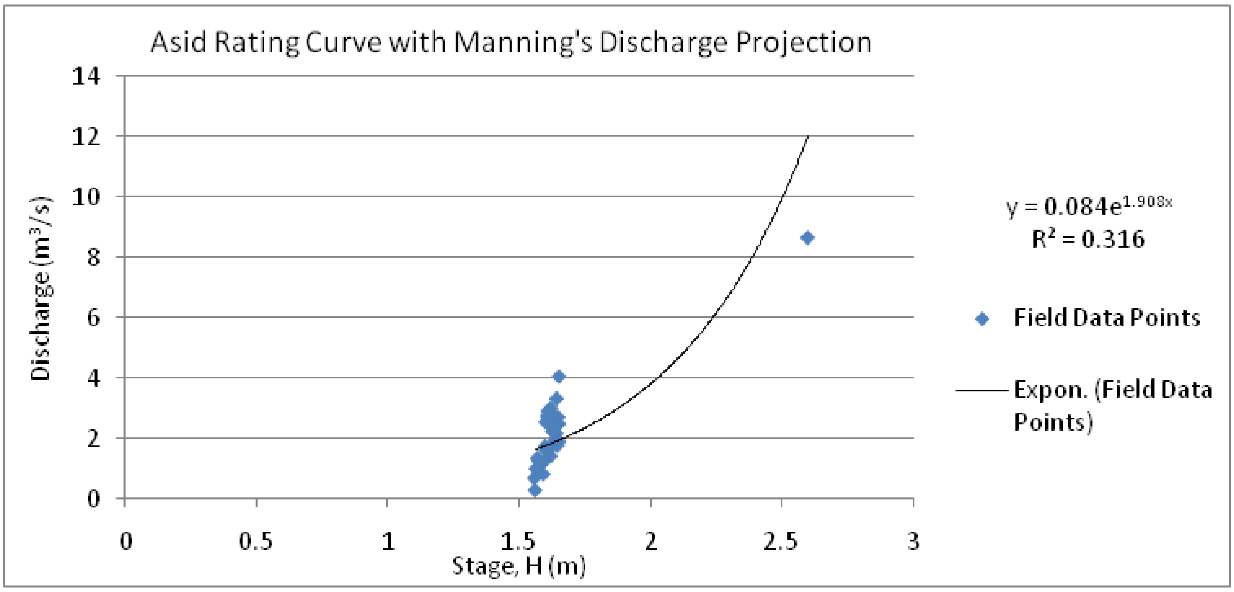

Figure 57. Rating Curve at Asid Bridge, Masbate City

This rating curve equation was used to compute the river outflow at Asid Bridge for the calibration of the HEC-HMS model shown in Figure 58. The total rainfall for this event is 50.4mm and the peak discharge is 7.1733 m^3/s at 6:10 AM, December 15, 2015.

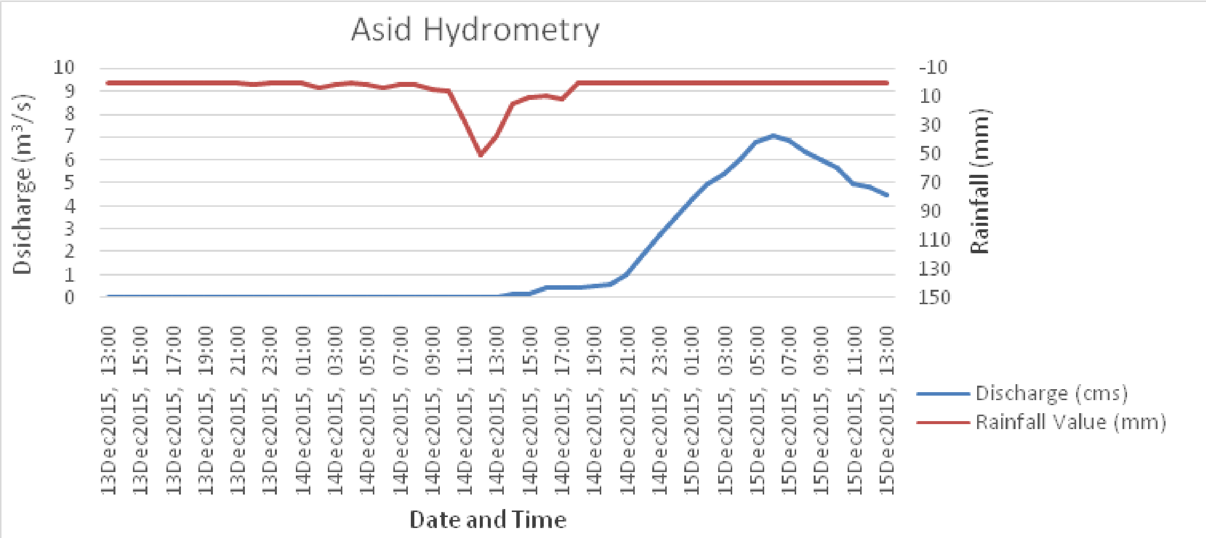

Figure 55. Rainfall and outflow data of the Asid River Basin, which was used for modeling

5.2 RIDF Station

PAGASA computed the 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 Asid watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 33. RIDF values for Asid 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

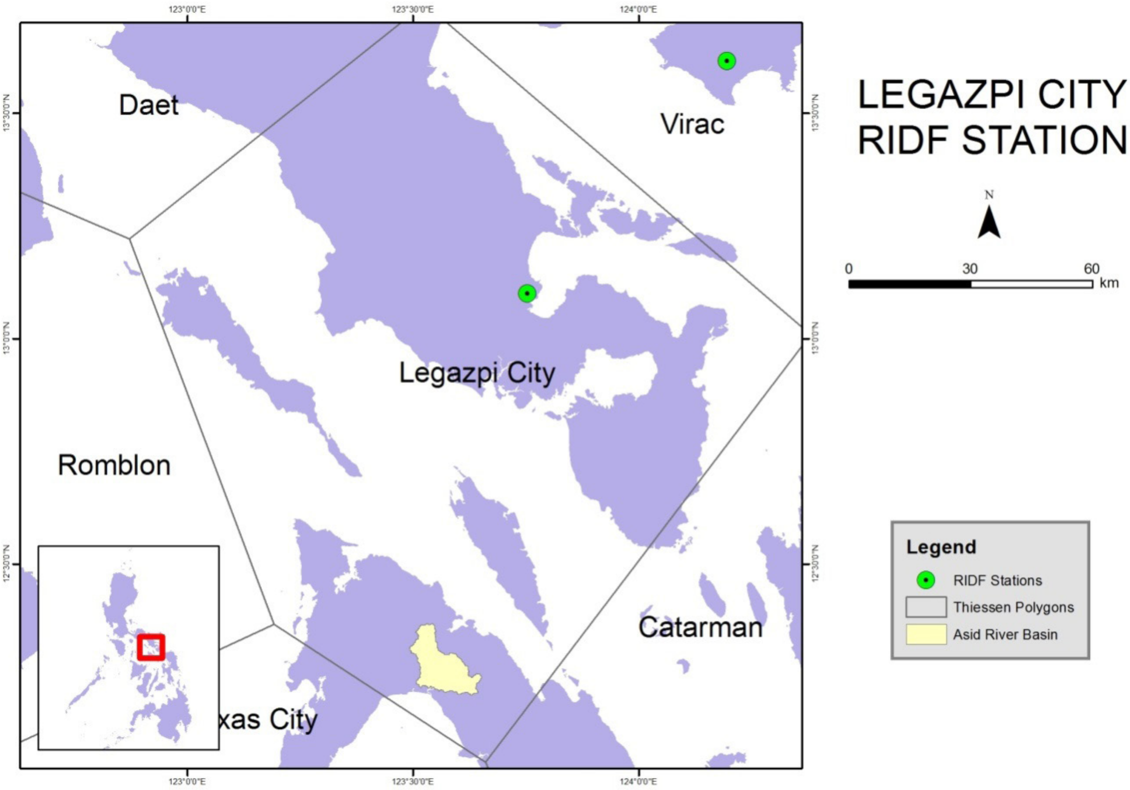

Figure 56. The location of the Legazpi City RIDF station relative to Asid River Basin

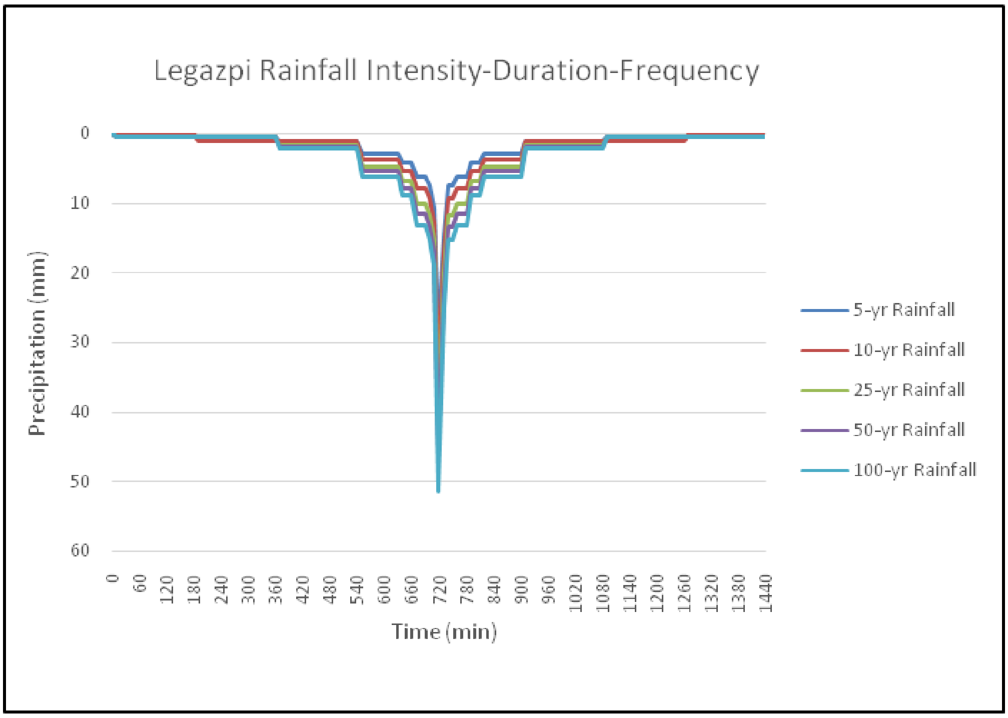

Figure 57. The synthetic storm generated for a 24-hour period rainfall for various return periods

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 Asid River Basin are shown in Figures 58 and 59, respectively.

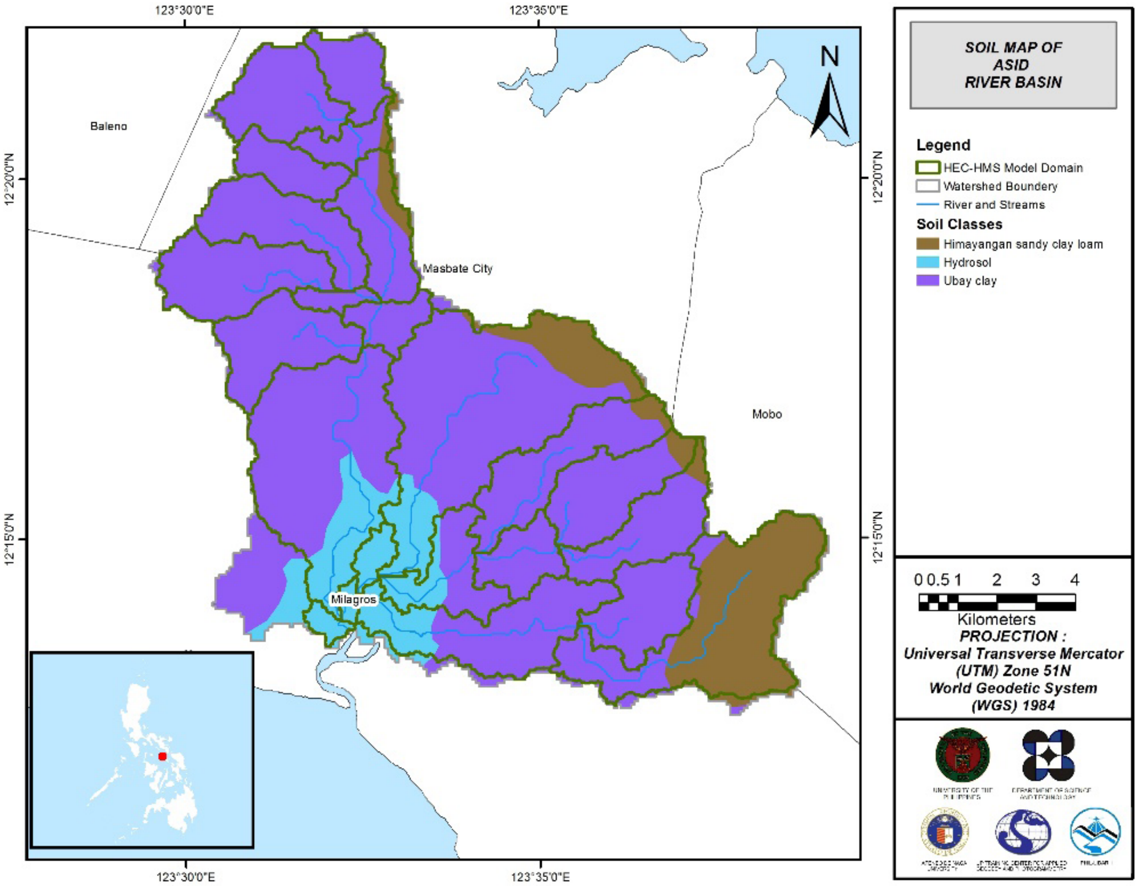

Figure 58. Soil map of Asid River Basin

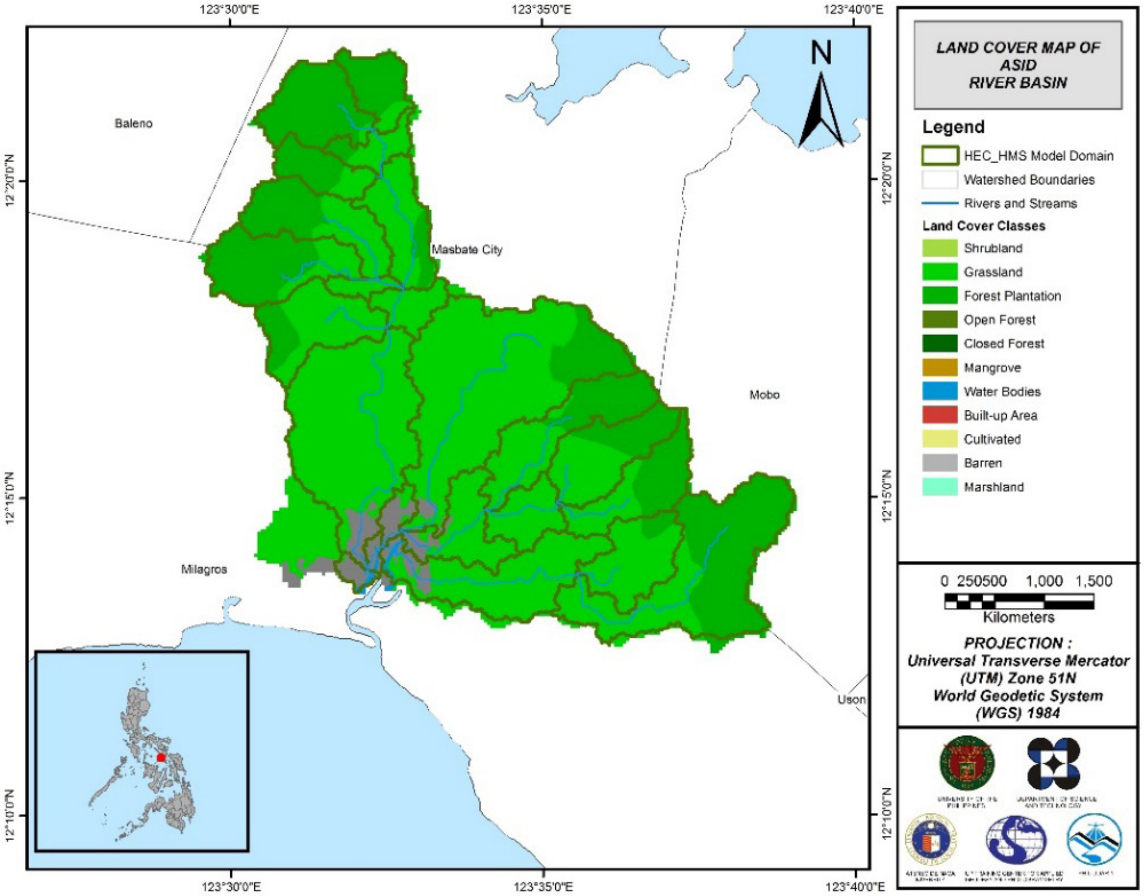

Figure 59. Land cover map of Asid River Basin

For Asid, three soil classes were identified. These are Himayangan sandy clay loam, Ubay clay, and hydrosol. Moreover, three land cover classes were identified. These are grassland, forest plantation, and barren areas.

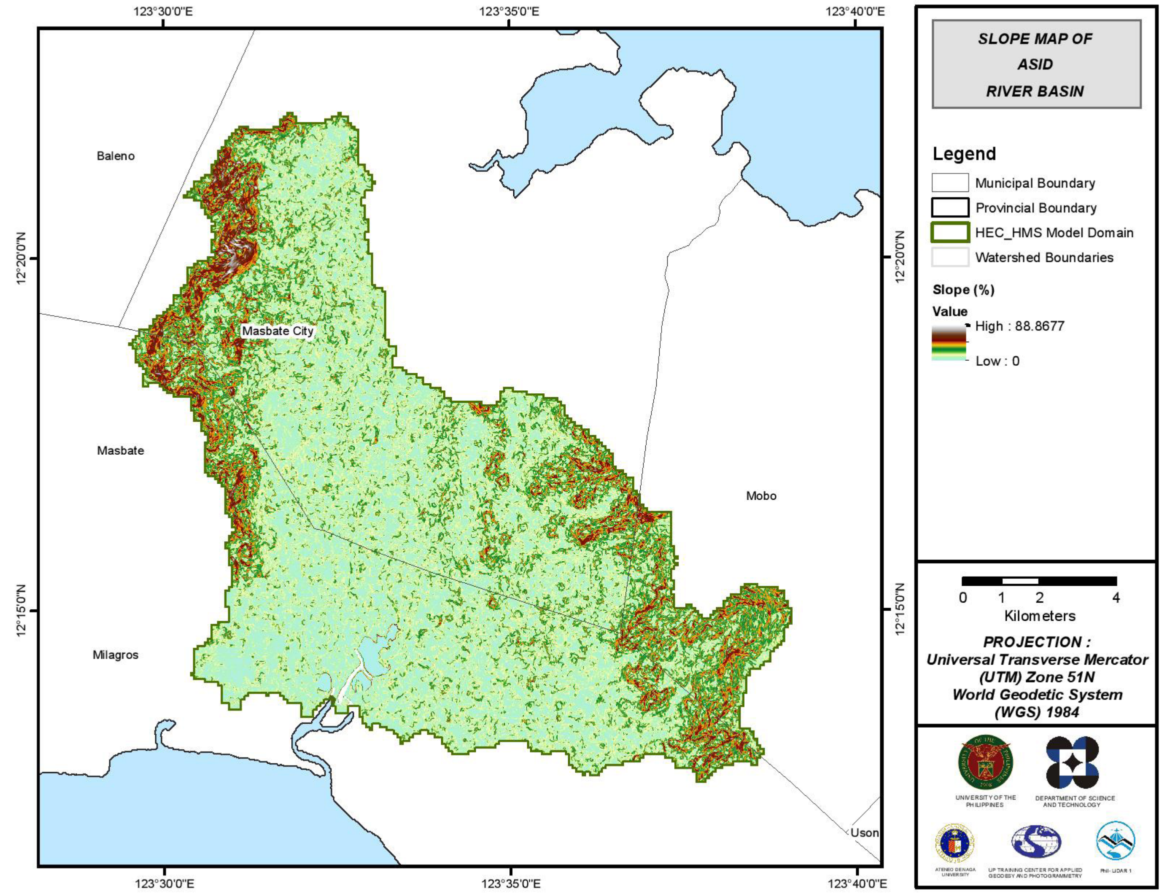

Figure 60. Slope map of Asid River Basin

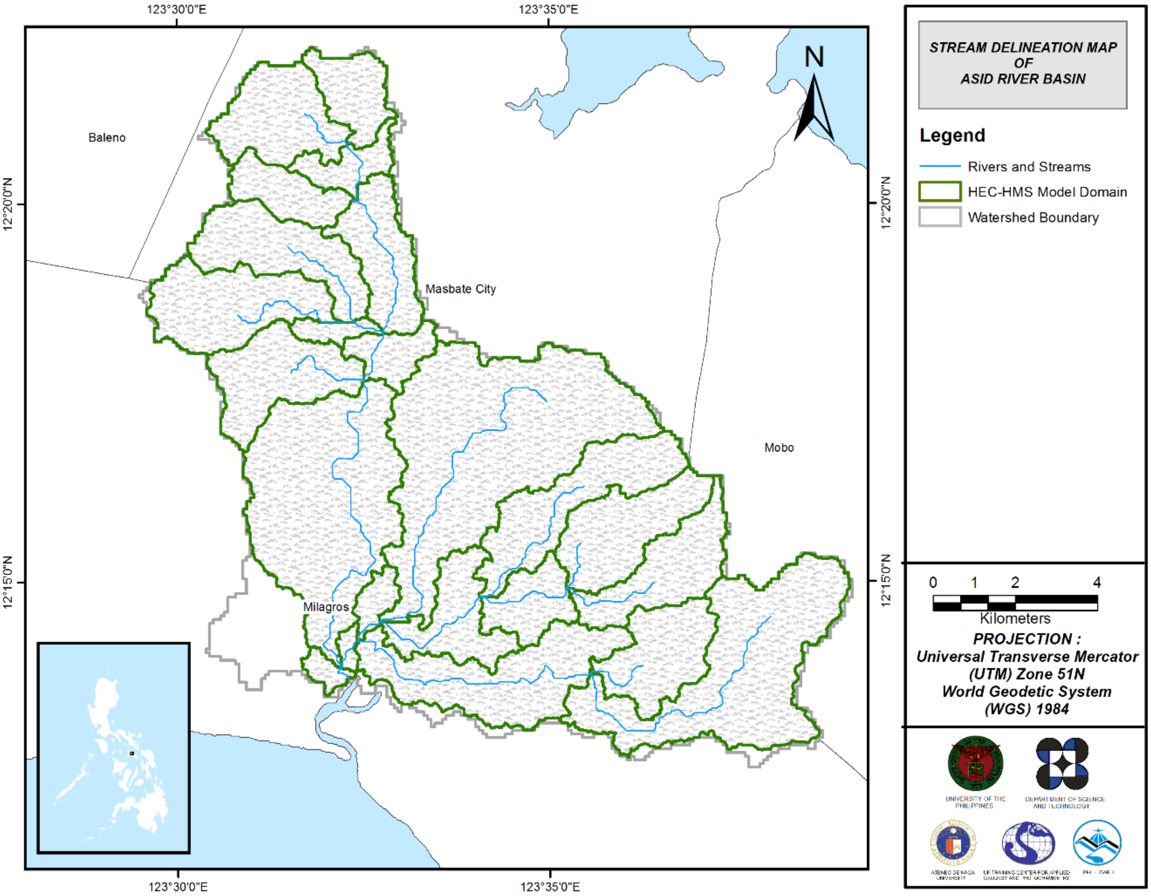

Figure 61. Stream delineation map of Asid River Basin

Using the SAR-based DEM, the Asid basin was delineated and further divided into subbasins. The model consists of 23 sub basins, 11 reaches, and 11 junctions, as shown in Figure 62. The main outlet is Asid Bridge.

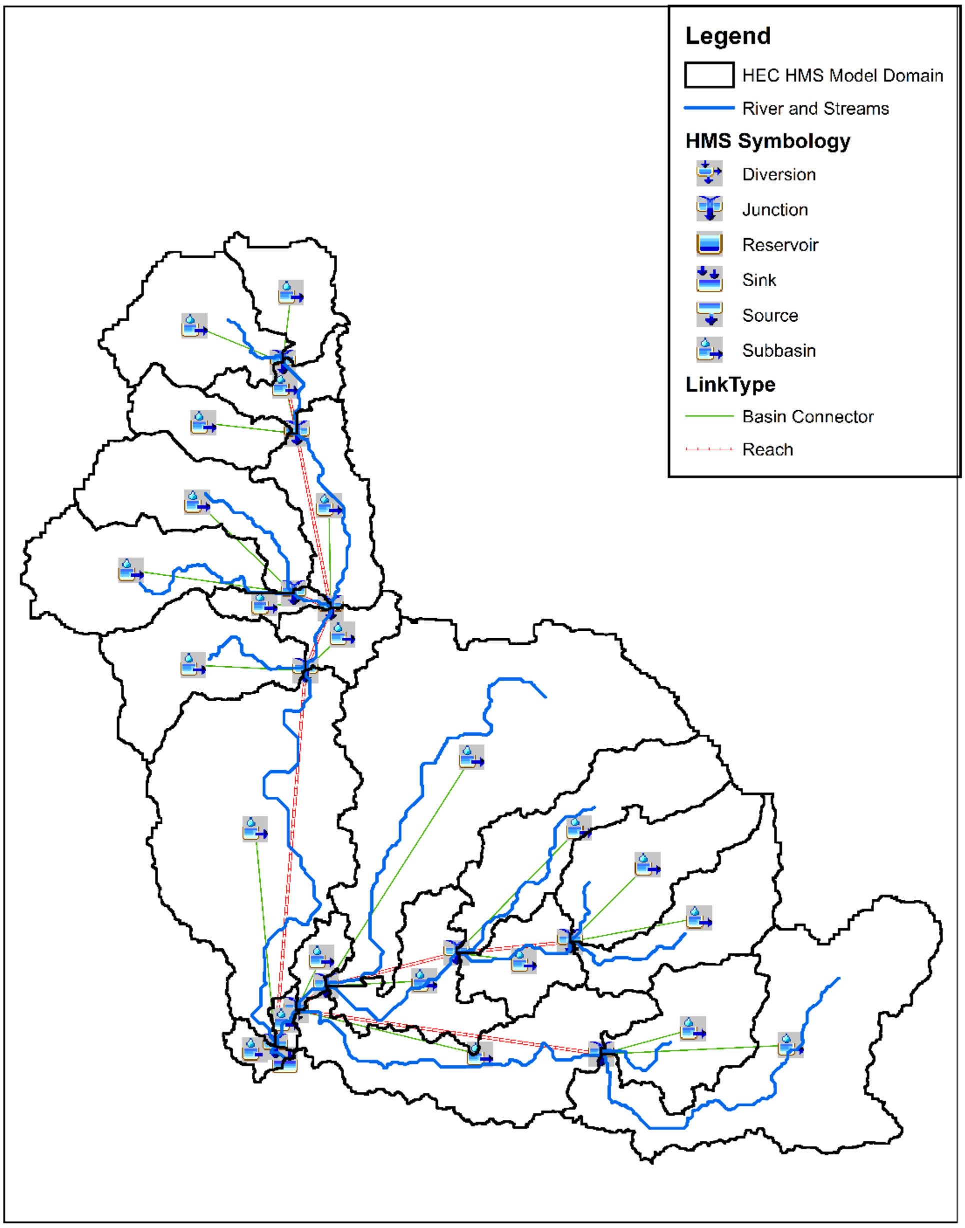

Figure 62. The Asid River Basin model generated in HEC-HMS

5.4 Cross-Section Data

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

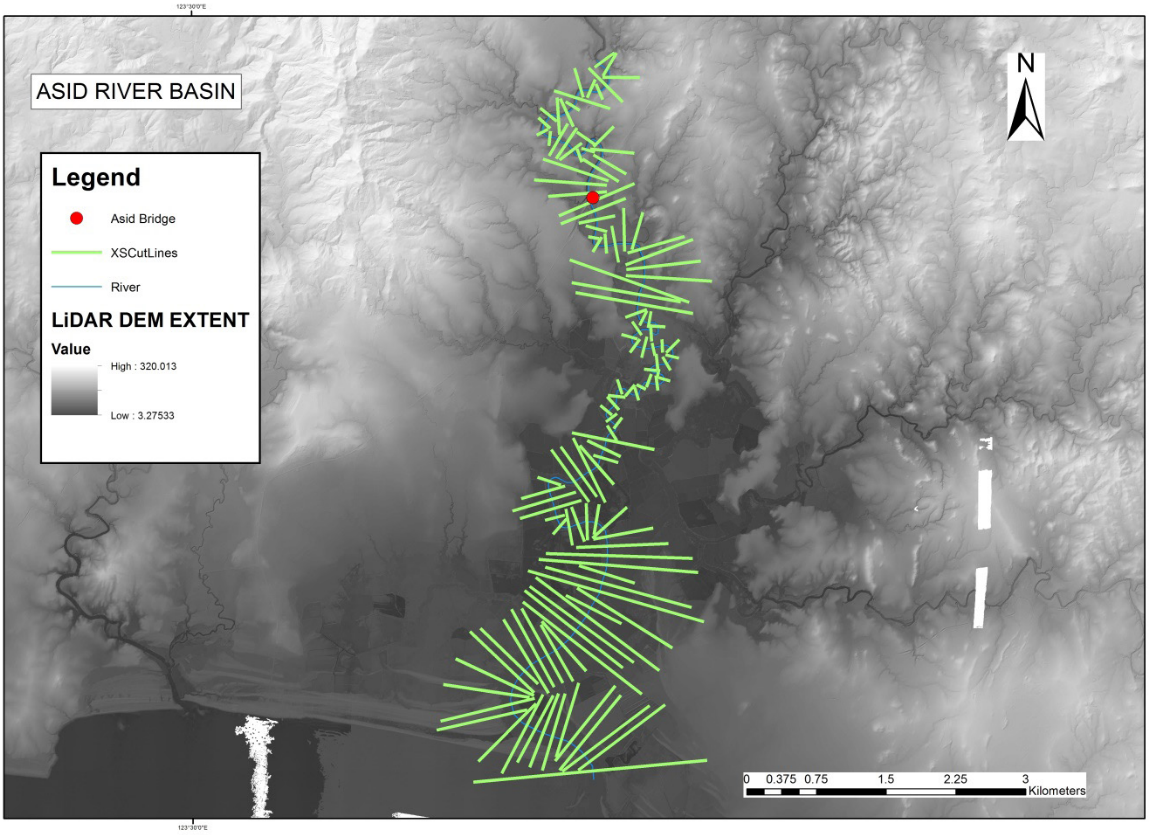

Figure 63. River cross-section of Asid River generated through Arcmap HEC GeoRAS tool

5.5 FLO-2D Model

[Insert 2D report]

Figure 13. Screenshot of subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

5.6 Results of HMS Calibration

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

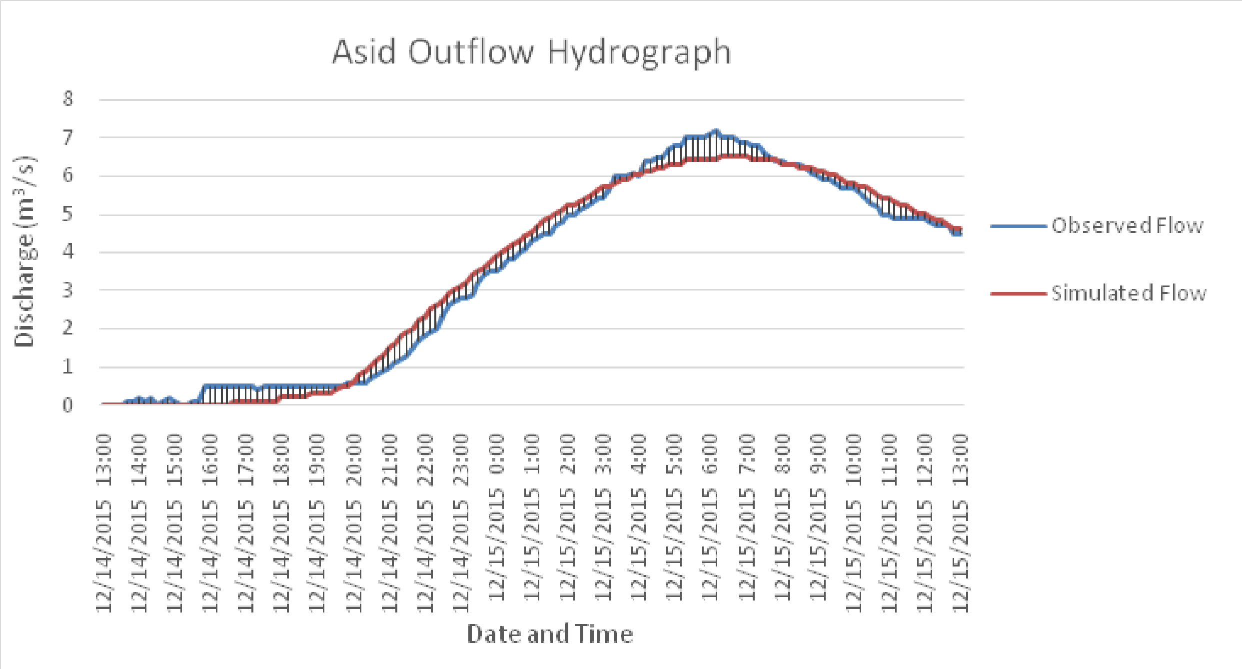

Figure 64. Outflow hydrograph of Asid River Basin produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 34 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 34. Range of Calibrated Values for Asid River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.01 - 19
			Curve Number	40 - 99
	Transform	Clark Unit Hydro-graph	Time of Concentration (hr)	0.02 - 49
			Storage Coefficient (hr)	0.02 - 121
	Baseflow	Recession	Recession Constant	0.00001 - 1
			Ratio to Peak	0.6 - 1
Reach	Routing	Muskingum-Cunge	Slope	0.001 - 0.007
			Manning's n	0.08 - 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 0.01 mm to 19 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

The 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 40 to 99 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Asid, the basin mostly consists of grassland and the soil consists of Ubay clay, Himayangan sandy clay loam, and hydrosol.

The 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 49 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 Asid, it will take at least 6 hours from the peak discharge to go back to the initial discharge.

Manning's roughness coefficient of 1 corresponds to the common roughness in Asid watershed, which is determined to be forest with trees with heavy stand that flow into branches (Brunner, 2010).

Table 35. Summary of the Efficiency Test of Asid HMS Model

Accuracy Measure	Value
r^2	0.98
NSE	0.98
PBIAS	0.08
RSR	0.13

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.33 (m^3/s).

The Pearson Correlation Coefficient (r^2) 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 0.98.

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 0.98.

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 0.08.

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 0.13.

5.7 Calculated outflow Hydrographys and discharge values for different Rainfall Return Periods

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 65) shows the Asid 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 reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods from 394.3m^3/s in a 5-year return period to 907.8m^3/s in a 100-year return period.

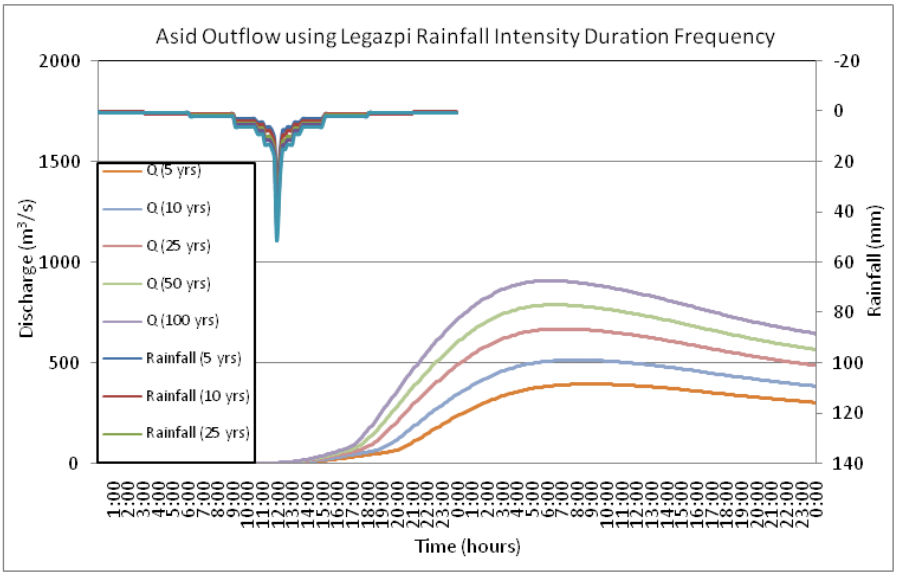

Figure 65. The outflow hydrograph at Asid Basin, generated using the simulated rain events for 24-hour period for Legazpi station

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Asid discharge using the Legazpi Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 35.

Table 35. Peak values of the Asid 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	394.3	20 hours, 40 minutes
10-Year	316.10	34.5	513.8	20 hours
25-Year	386.40	41.3	668.6	19 hours
50-Year	438.40	46.3	788.1	18 hours, 30 minutes
100-Year	490.30	51.3	907.8	18 hours, 10 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 was to be shown, since only the ADNU-DVC base flow was calibrated. Figure 66 shows a generated sample map of the Asid River using the calibrated HMS base flow.

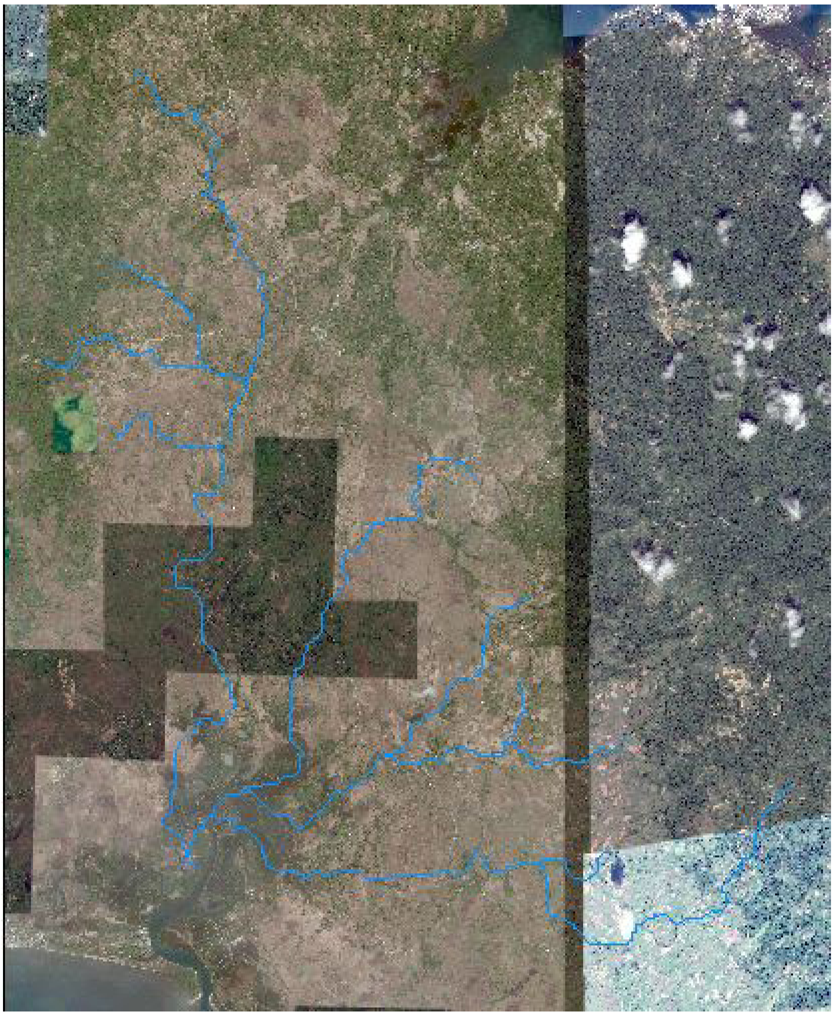

Figure 66. The sample output map of the Asid RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figures 67 to 72 show the 5-, 25-, and 100-year rain return scenarios of the Asid flood plain. The floodplain, with an area of 151.49km^2, covers three (3) municipalities, namely Masbate City, Milagros, and Mobo. Table 36 shows the percentage of area affected by flooding per municipality.

Table 36. Municipalities affected in Asid Floodplain

Municipality	Total Area (km^2)	Area Flooded (km^2)	% Flooded
Masbate City	192.96	48.21	24.99
Milagros	530.43	95.96	18.09
Mobo	143.03	6.5	4.54

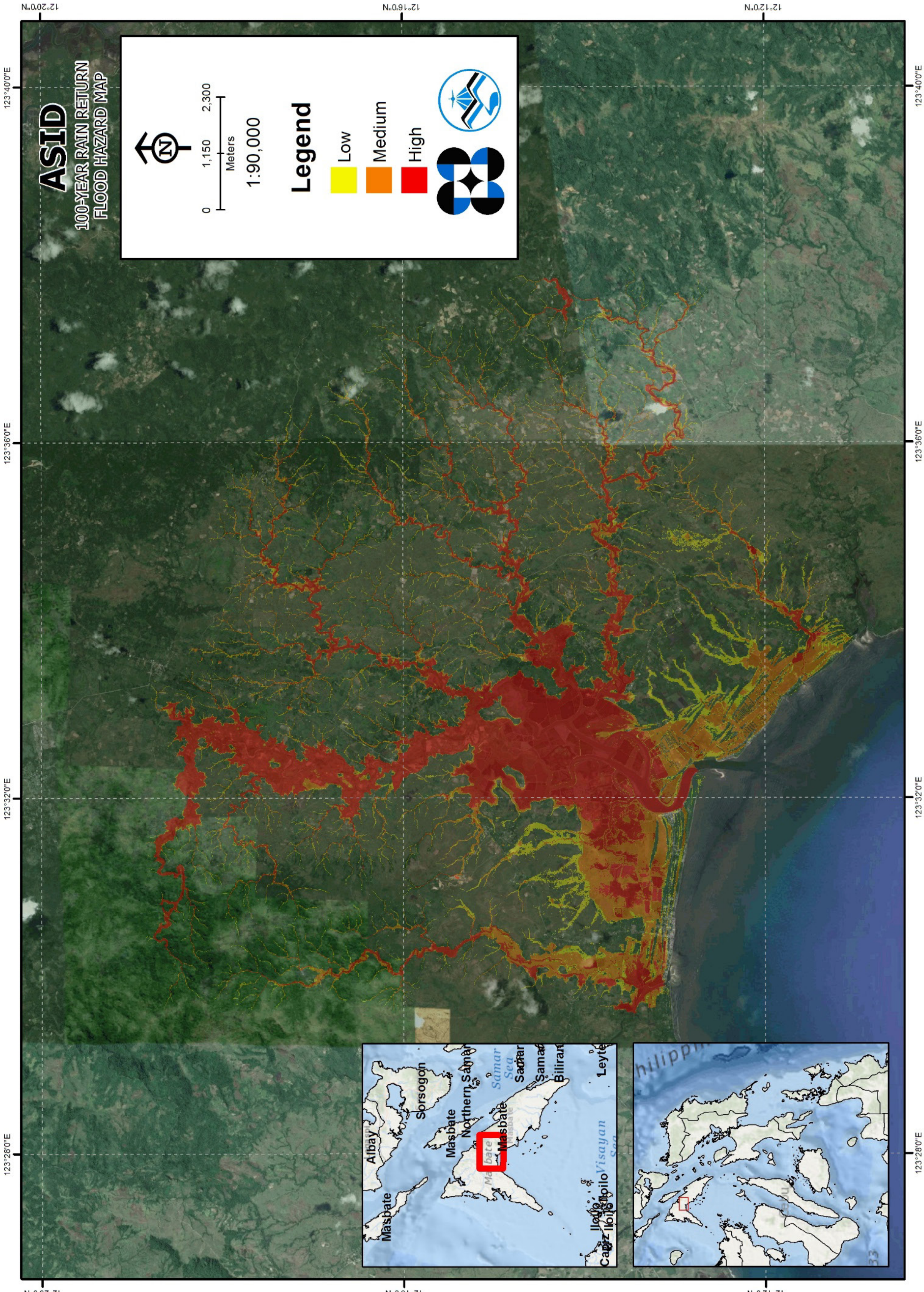

Figure 67.100-year flood hazard map for the Asid flood plain overlaid on Google Earth imagery

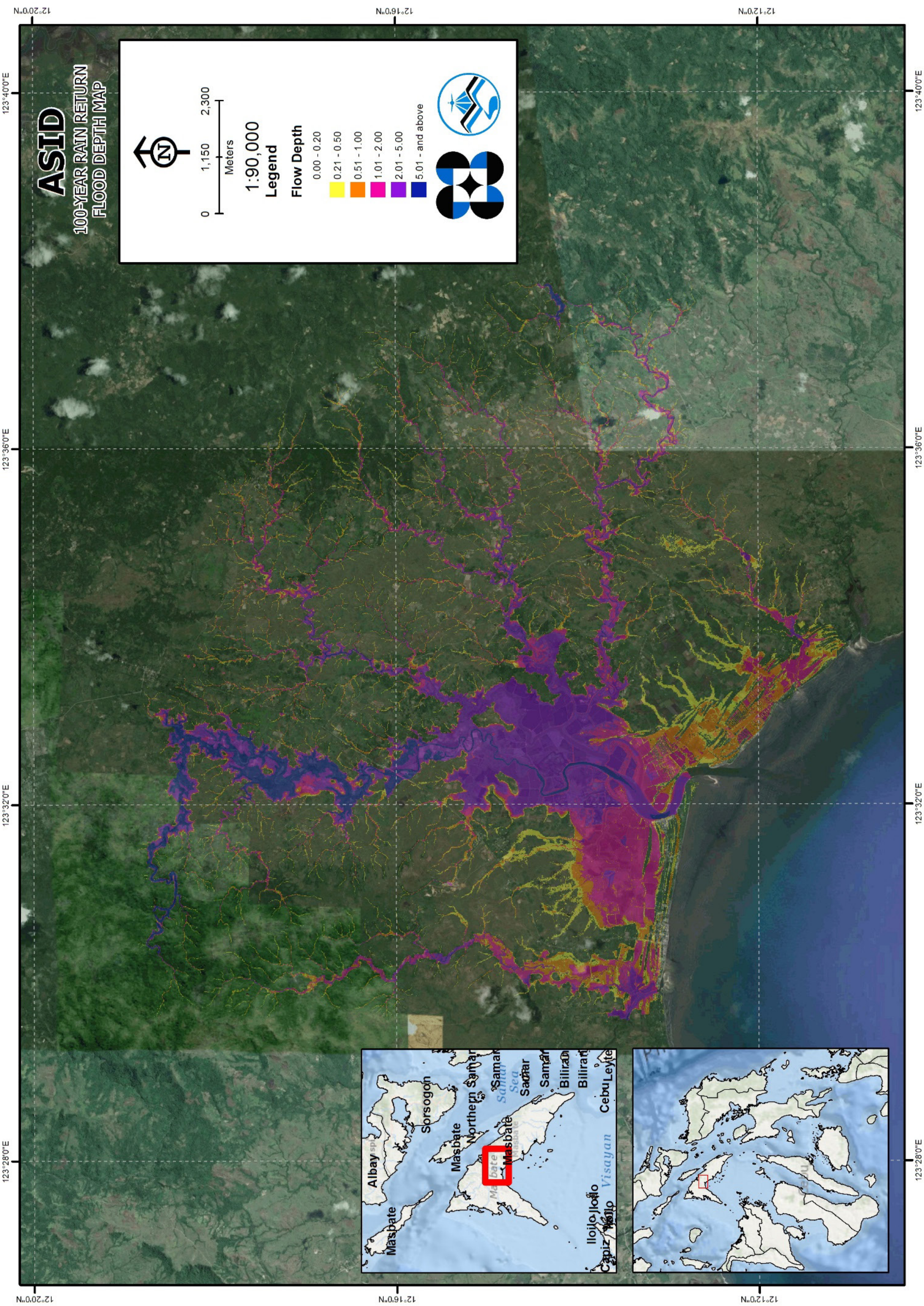

Figure 68. 100-year flow depth map for the Asid flood plain overlaid on Google Earth imagery

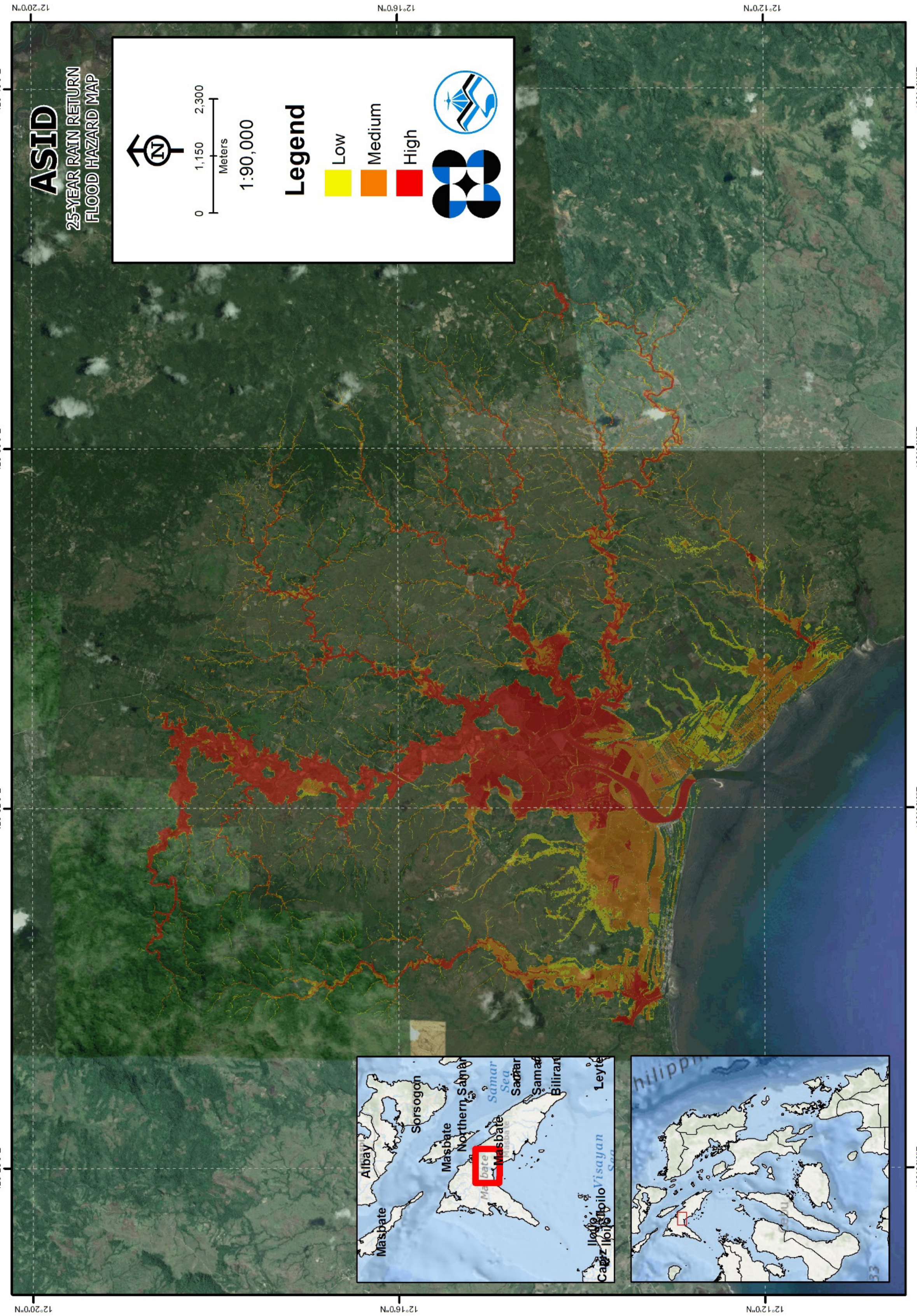

Figure 69. 25-year flood hazard map for the Asid flood plain overlaid on Google Earth imagery

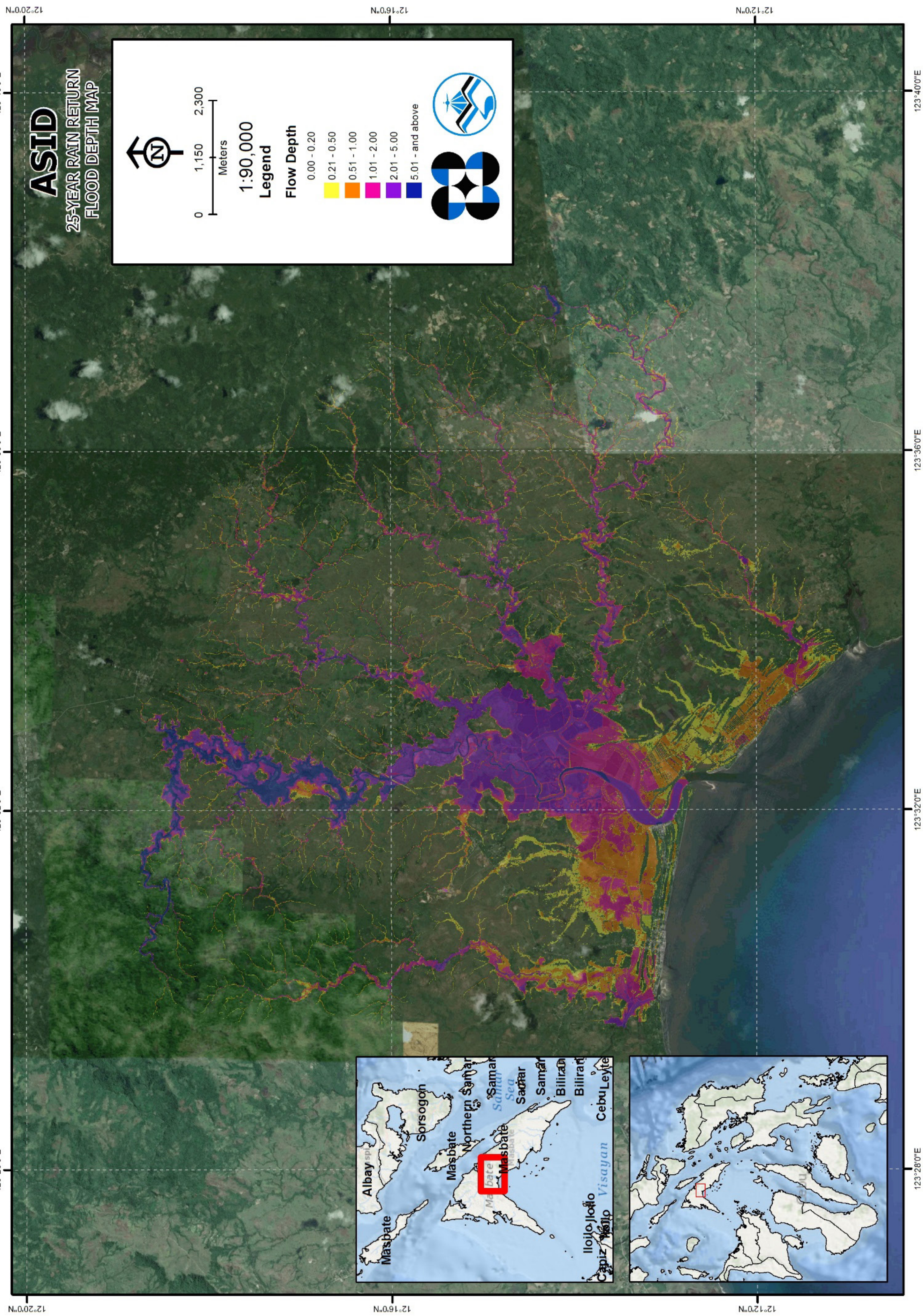

Figure 70.25-year flow depth map for the Asid flood plain overlaid on Google Earth imagery

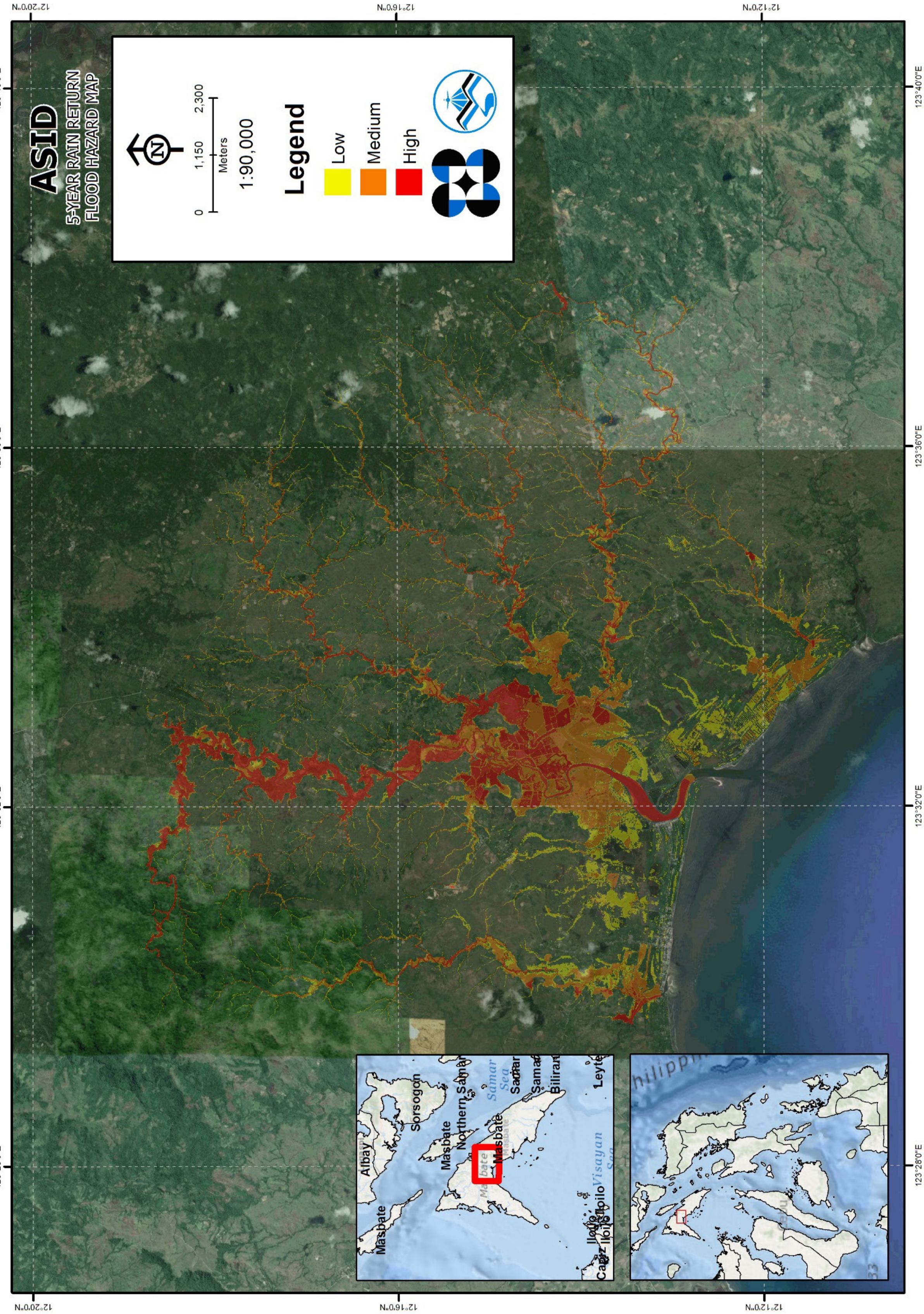

Figure 71. 5-year flood hazard map for the Asid flood plain overlaid on Google Earth imagery

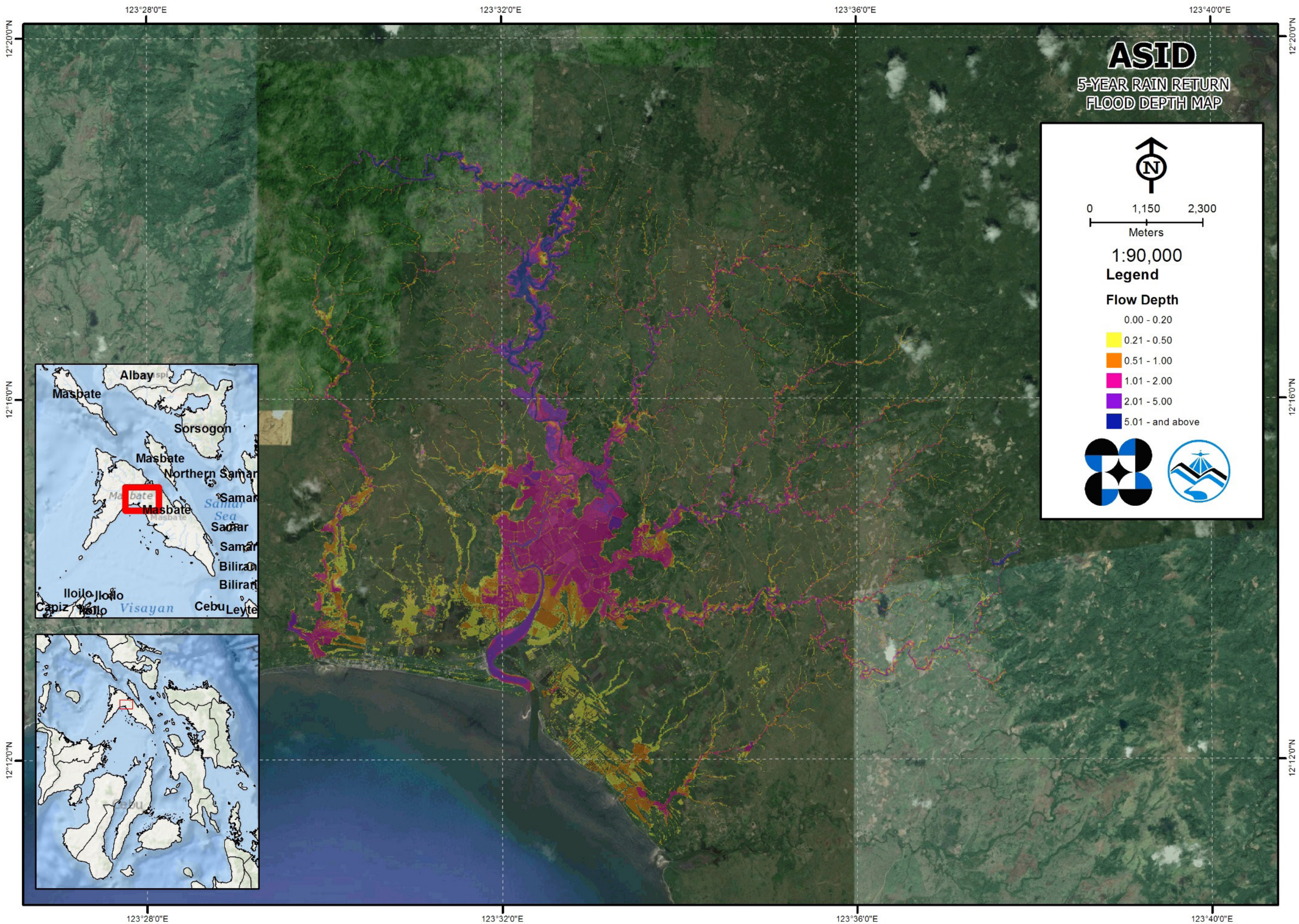

Figure 72.5-year flow depth map for the Asid flood plain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

Listed below are the barangays affected by the Asid River Basin, grouped accordingly by municipality. For the said basin, three (3) municipalities consisting of 20 barangays are expected to experience flooding when subjected to the three rainfall return period scenarios.

For the 5-year rainfall return period, 21.82% of Masbate City with an area of 192.96 sq. km. will experience flood levels of less than 0.20 meters. 0.74% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.63%, 0.66%, 0.66%, and 0.48% 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. Figure 73 depicts the areas affected in Masbate City in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Masbate City during the 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Masbate City				
	Asid	Cagay	Igang	Malinta	Sinalongan
0.03-0.20	8.57	26.01	1.19	4.32	2.01
0.21-0.50	0.3	0.86	0.032	0.18	0.056
0.51-1.00	0.26	0.72	0.026	0.17	0.036
1.01-2.00	0.33	0.65	0.043	0.24	0.014
2.01-5.00	0.62	0.23	0.11	0.32	0.001
>5.00	0.55	0.013	0.092	0.28	0

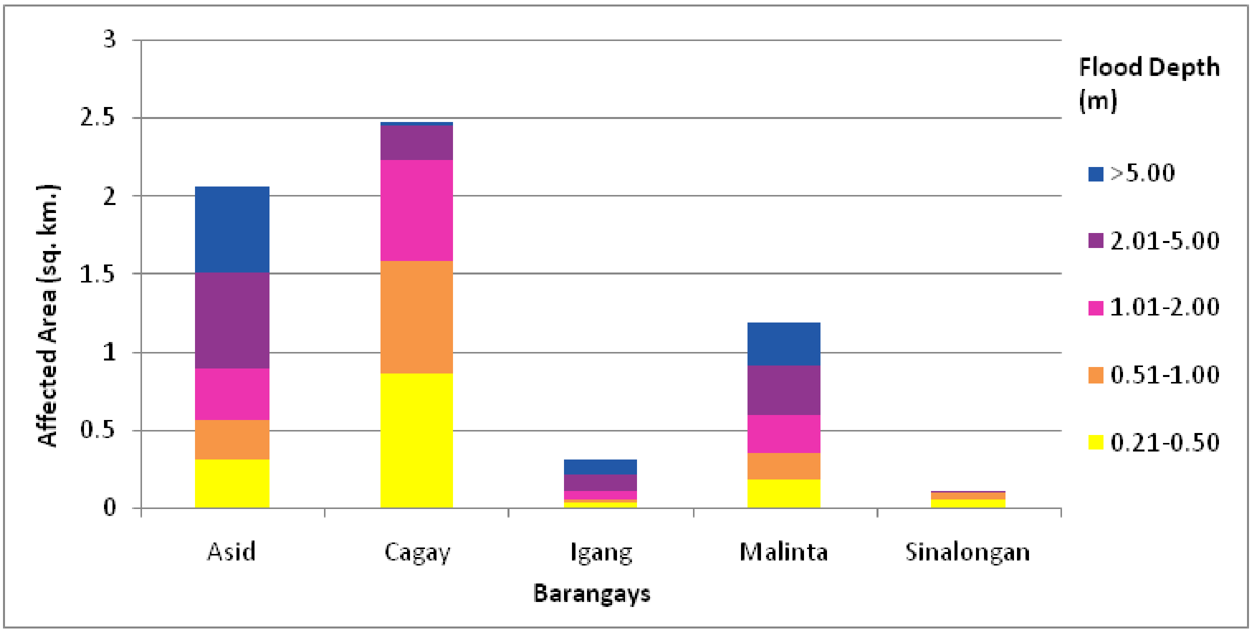

Figure 73. Affected Areas in Masbate City during the 5-Year Rainfall Return Period

For the municipality of Milagros with an area of 530.43 sq. km., 14.27% will experience flood levels of less than 0.20 meters. 1.18% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.94%, 1.37%, 0.31%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 74 depicts the areas affected in Milagros in square kilometers by flood depth per barangay.

Table 38. 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										
	Bacolod	Bonbon	Cala-suche	Cayabon	Jamorawon	Magsalangi	Poblacion East	Poblacion West	San Carlos	Tagbon	Tinaclipan
0.03-0.20	5.55	19.42	4.16	5.08	12.99	6.71	1.24	0.61	0.0028	19.76	0.16
0.21-0.50	0.9	0.54	0.91	0.35	1.71	0.48	0.35	0.13	0.000056	0.87	0.024
0.51-1.00	0.46	0.43	1.03	0.28	1.12	0.47	0.044	0.15	0	1	0.023
1.01-2.00	0.21	0.29	3.39	0.44	0.89	0.2	0.016	0.071	0	1.73	0.052
2.01-5.00	0.046	0.12	0.47	0.43	0.1	0.0023	0	0.0019	0	0.42	0.046
>5.00	0.0002	0.0094	0.0014	0.036	0.01	0.00074	0	0	0	0.027	0

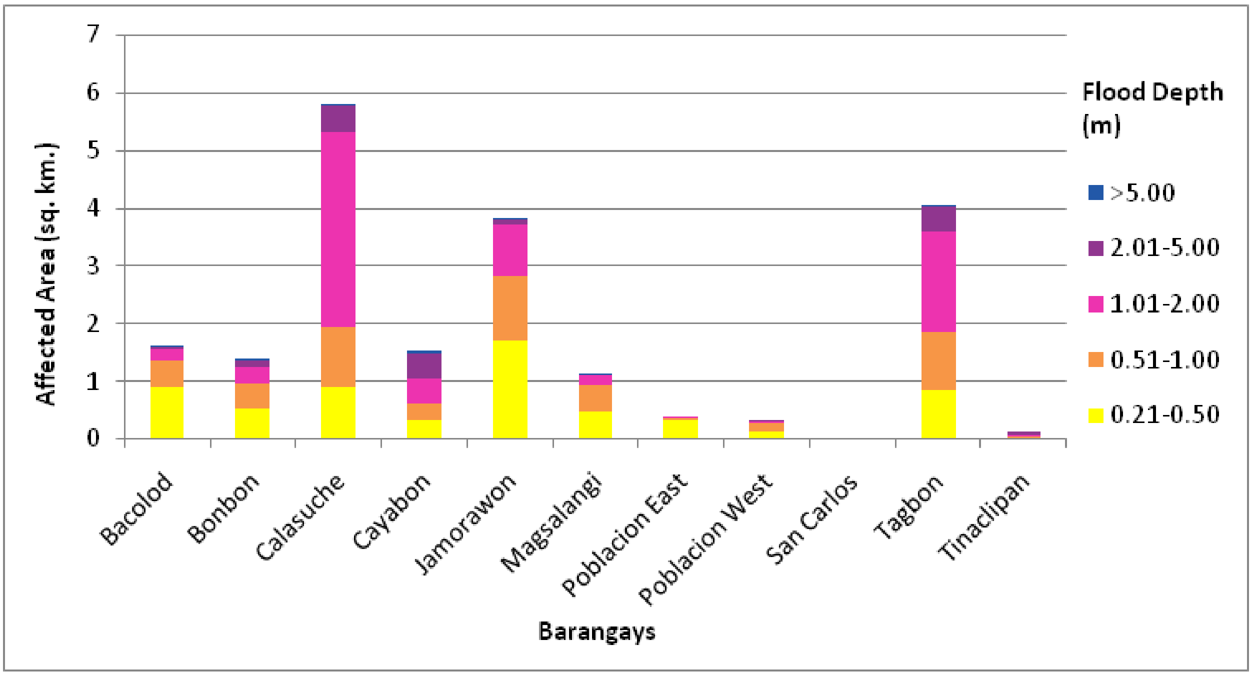

Figure 74. Affected Areas in Milagros, Masbate during the 5-Year Rainfall Return Period

For the municipality of Mobo with an area of 143.03 sq. km., 4.32% will experience flood levels of less than 0.20 meters. 0.1% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.05%, 0.03%, 0.02%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 75 depicts the areas affected in Mobo in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Mobo, Masbate during the 5-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mobo			
	Guintorelan	Mabuhay	Sambulawan	Santa Maria
0.03-0.20	3.81	1.8	0.56	0.011
0.21-0.50	0.082	0.044	0.012	0
0.51-1.00	0.045	0.027	0.0039	0
1.01-2.00	0.024	0.021	0.0015	0
2.01-5.00	0.0043	0.019	0.0001	0
>5.00	0	0.03	0	0

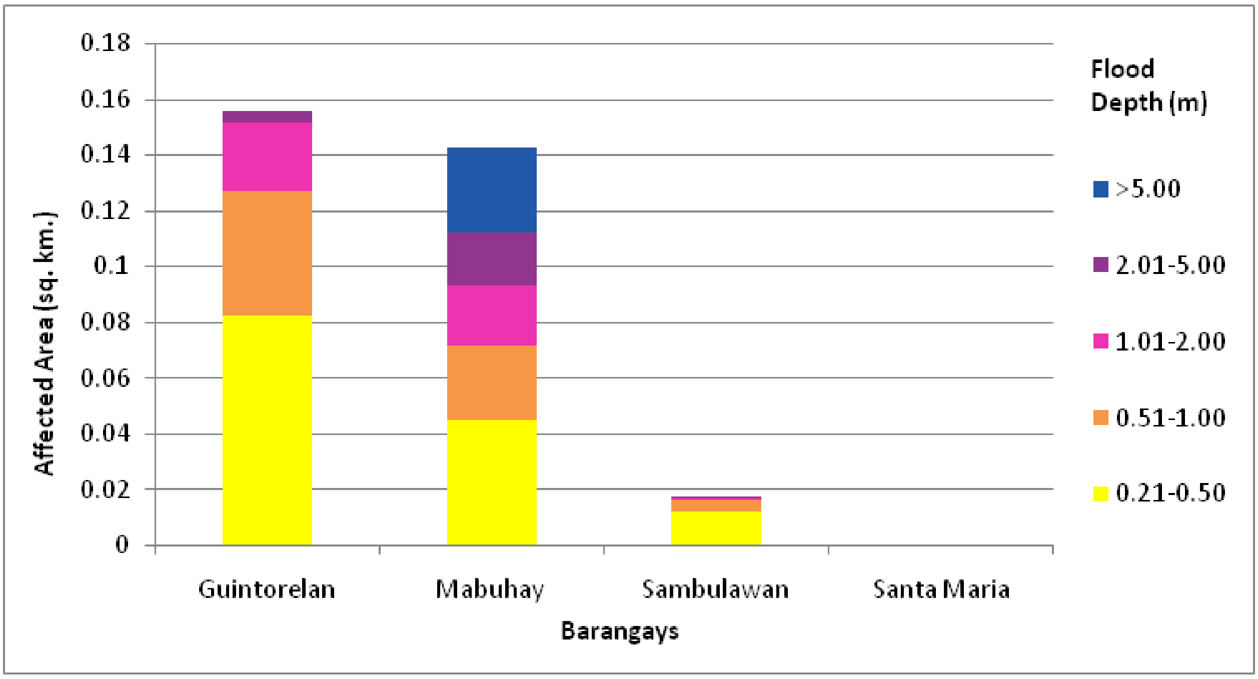

Figure 75. Affected Areas in Mobo, Masbate during the 5-Year Rainfall Return Period

For the 25-year rainfall return period, 20.92% of Masbate City with an area of 192.96 sq. km. will experience flood levels of less than 0.20 meters. 0.78% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.69%, 0.76%, 0.96%, and 0.87% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 76depicts the areas affected in Masbate City in square kilometers by flood depth per barangay.

Table 40. Affected Areas in Masbate City, Masbate during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Masbate City				
	Asid	Cagay	Igang	Malinta	Sinalongan
0.03-0.20	7.84	25.5	1.13	3.91	1.99
0.21-0.50	0.33	0.91	0.031	0.17	0.058
0.51-1.00	0.33	0.76	0.026	0.17	0.044
1.01-2.00	0.35	0.82	0.047	0.25	0.019
2.01-5.00	0.72	0.46	0.11	0.56	0.0022
>5.00	1.05	0.03	0.16	0.45	0

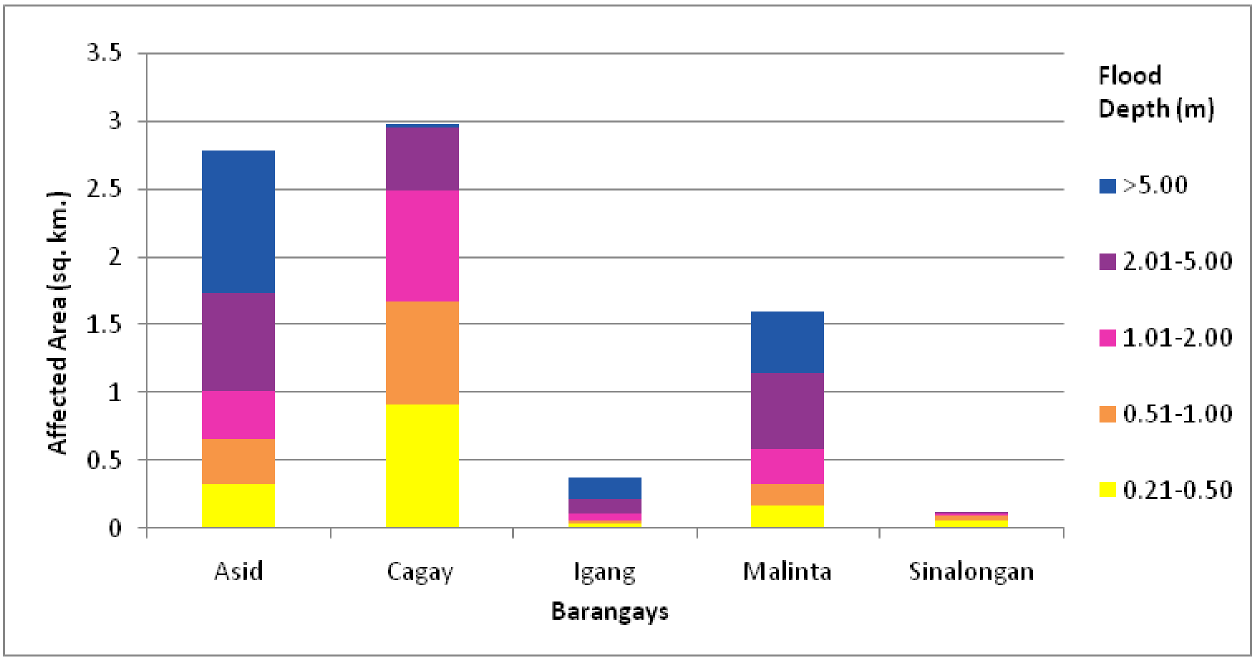

Figure 76. Affected Areas in Masbate City, Masbate during the 25-Year Rainfall Return Period

For the Municipality of Milagros with an area of 530.43 sq. km., 13.06% will experience flood levels of less than 0.20 meters. 1.07% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.07%, 1.38%, 1.3%, 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. Figure 77 depicts the areas affected in Milagros in square kilometers by flood depth per barangay.

Table 41. 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										
	Bacolod	Bonbon	Cala-suche	Cayabon	Jamorawon	Magsalangi	Poblacion East	Poblacion West	San Carlos	Tagbon	Tinaclipan
0.03-0.20	4.79	19.19	2.8	4.78	11.13	6.36	0.53	0.44	0.0028	19.12	0.11
0.21-0.50	0.99	0.55	0.31	0.37	1.8	0.53	0.19	0.12	0.000056	0.79	0.033
0.51-1.00	0	0.44	1.3	0.25	1.57	0.56	0.54	0.15	0	0.81	0.036
1.01-2.00	0.44	0.4	2.01	0.28	1.63	0.37	0.39	0.22	0	1.53	0.043
2.01-5.00	0.09	0.21	3.41	0.84	0.67	0.064	0.0006	0.03	0	1.5	0.086
>5.00	0.0009	0.029	0.13	0.091	0.025	0.0017	0	0	0	0.06	0.002

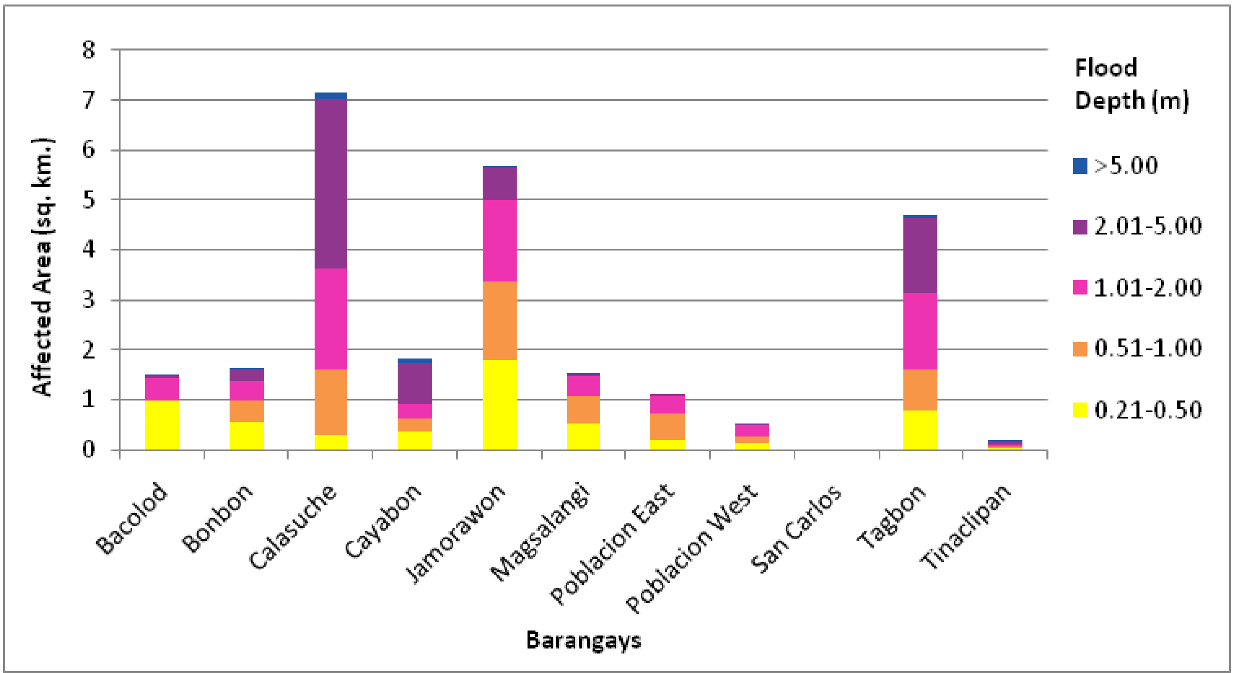

Figure 77. Affected Areas in Milagros, Masbate during the 25-Year Rainfall Return Period

For the Municipality of Mobo with an area of 143.03 sq. km., 4.27% will experience flood levels of less than 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.06%, 0.04%, 0.03%, and 0.03% 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. Figure 78depicts the areas affected in Mobo in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Mobo, Masbate during the 25-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mobo			
	Guintorelan	Mabuhay	Sambulawan	Santa Maria
0.03-0.20	3.78	1.76	0.56	0.011
0.21-0.50	0.093	0.048	0.013	0
0.51-1.00	0.051	0.029	0.0055	0
1.01-2.00	0.033	0.027	0.0019	0
2.01-5.00	0.0065	0.033	0.0001	0
>5.00	0	0.047	0	0

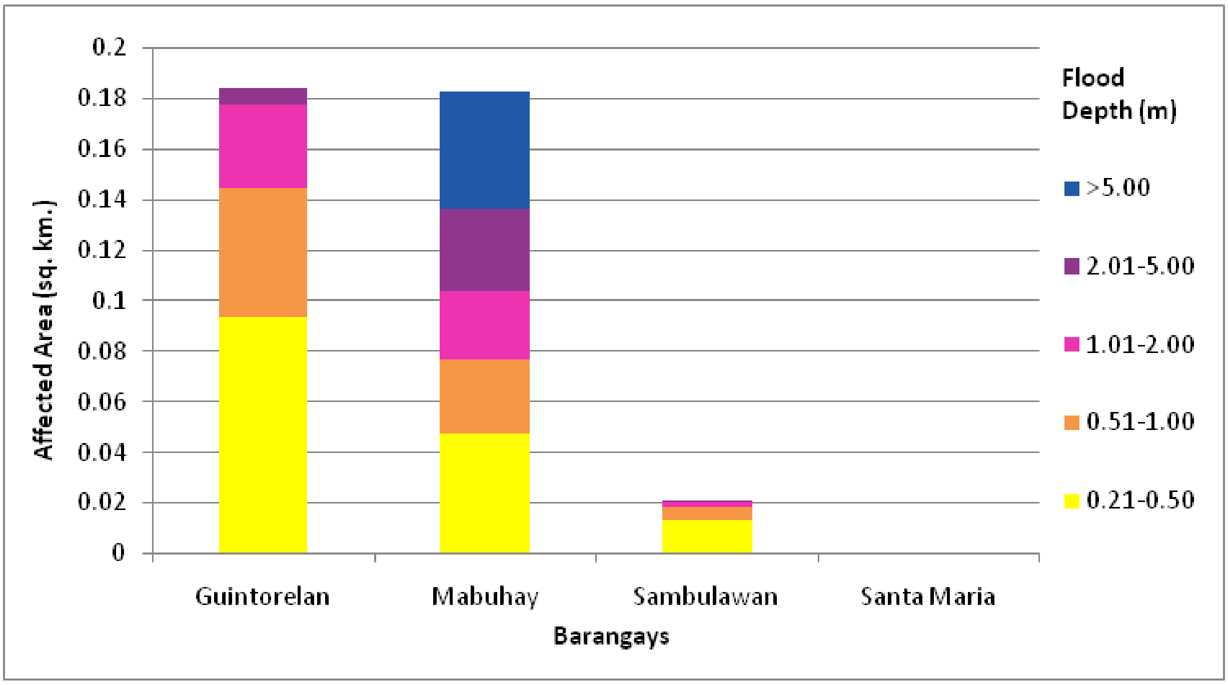

Figure 78. Affected Areas in Mobo, Masbate during the 25-Year Rainfall Return Period

For the 100-year rainfall return period, 20.36% of Masbate City with an area of 192.96 sq. km. will experience flood levels of less than 0.20 meters. 0.81% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.68%, 0.84%, 1.15%, and 1.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 79 depicts the areas affected in Masbate City in square kilometers by flood depth per barangay.

Table 43. Affected Areas in Masbate City, Masbate during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Masbate City				
	Asid	Cagay	Igang	Malinta	Sinalongan
0.03-0.20	7.44	25.13	1.07	3.66	1.98
0.21-0.50	0.32	0.98	0.029	0.18	0.061
0.51-1.00	0.3	0.78	0.028	0.17	0.047
1.01-2.00	0.44	0.89	0.043	0.22	0.025
2.01-5.00	0.79	0.66	0.12	0.65	0.0029
>5.00	1.33	0.056	0.21	0.63	0

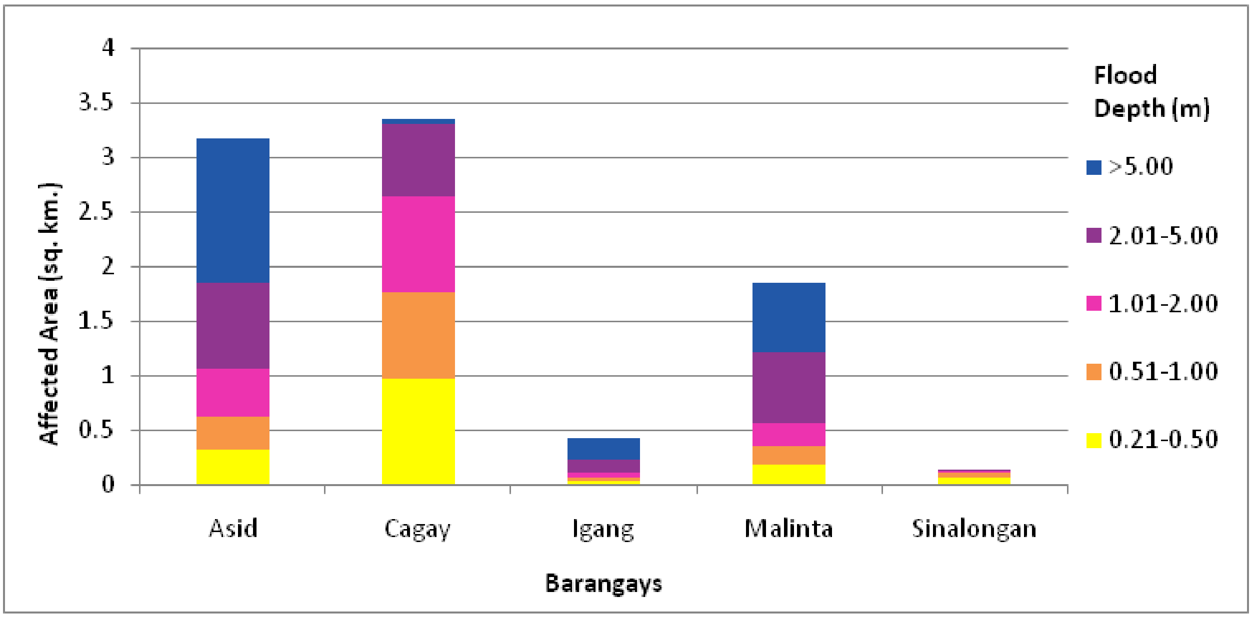

Figure 79. Affected Areas in Masbate City, Masbate during the 100-Year Rainfall Return Period

For the Municipality of Milagros with an area of 530.43 sq. km., 12.5% will experience flood levels of less than 0.20 meters. 1% of the area will experience flood levels of 0.21 to 0.50 meters, while 1%, 1.59%, 1.87%, and 0.13% 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. Figure 80 depicts the areas affected in Milagros in square kilometers by flood depth per barangay.

Table 44. 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										
	Bacolod	Bonbon	Cala-suche	Cayabon	Jamorawon	Magsalangi	Poblacion East	Poblacion West	San Carlos	Tagbon	Tinaclipan
0.03-0.20	4.36	19.03	2.46	4.51	10.3	6.08	0.4	0.33	0.0028	18.73	0.075
0.21-0.50	0.84	0.57	0.26	0.41	1.6	0.59	0.1	0.11	0.000063	0.82	0.025
0.51-1.00	0.92	0.43	0.29	0.25	1.74	0.52	0.18	0.18	0	0.77	0.049
1.01-2.00	0.91	0.44	2.13	0.26	1.63	0.58	0.93	0.27	0	1.21	0.058
2.01-5.00	0.13	0.28	4.62	0.85	1.52	0.1	0.04	0.063	0	2.2	0.095
>5.00	0.002	0.053	0.18	0.33	0.033	0.0023	0	0	0	0.082	0.0043

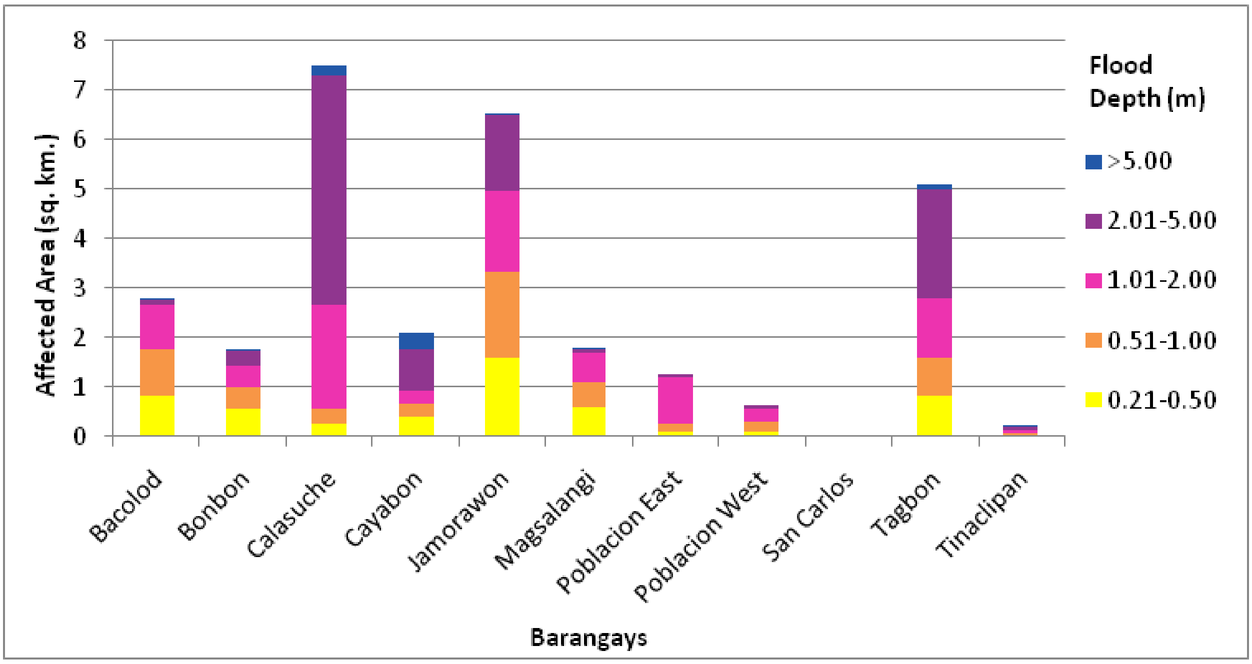

Figure 80. Affected Areas in Milagros, Masbate during the 100-Year Rainfall Return Period

For the Municipality of Mobo with an area of 143.03 sq. km., 4.23% will experience flood levels of less than 0.20 meters. 0.11% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.06%, 0.05%, 0.03%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Figure 81 depicts the areas affected in Mobo in square kilometers by flood depth per barangay.

Table 45. Affected Areas in Mobo, Masbate during the 100-Year Rainfall Return Period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Mobo			
	Guintorelan	Mabuhay	Sambulawan	Santa Maria
0.03-0.20	3.76	1.73	0.56	0.011
0.21-0.50	0.1	0.049	0.012	0
0.51-1.00	0.054	0.034	0.0071	0
1.01-2.00	0.04	0.028	0.0021	0
2.01-5.00	0.0091	0.038	0.0002	0
>5.00	0	0.065	0	0

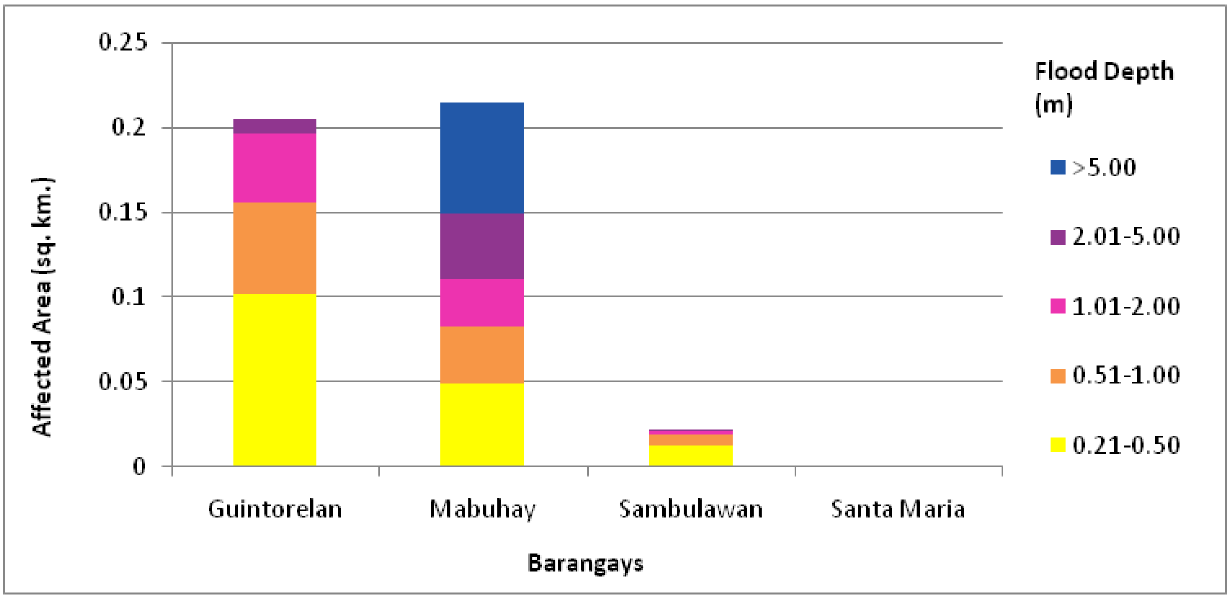

Figure 81. Affected Areas in Mobo, Masbate during the 100-Year Rainfall Return Period

Among the barangays in Masbate City, Cagay is projected to have the highest percentage of area that will experience flood levels at 14.76%. Meanwhile, Asid posted the second highest percentage of area that may be affected by flood depths at 5.5%.

Among the barangays in the Municipality of Milagros, Bonbon is projected to have the highest percentage of area that will experience flood levels at 3.92%. Meanwhile, Jamorawon posted the second highest percentage of area that may be affected by flood depths at 3.17%.
Among the barangays in the Municipality of Mobo, Guinatorelan is projected to have the highest percentage of area that will experience flood levels of at 2.77%. Meanwhile, Mabuhay posted the second highest percentage of area that may be affected by flood depths of at 1.36%.

Moreover, the generated flood hazard maps for the Asid 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 46. Area covered by each warning level with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	8.08	7.42	7.16
Medium	11.56	12.98	12.24
High	8.22	15.68	20.83
TOTAL	**27.86**	**36.08**	**40.23**

Of the 36 identified Educational Institutions in Asid Floodplain, none was assessed to be exposed to both low and high, while one (1) was assessed to be exposed to medium level flooding during the 5-year scenario. In the 25-year scenario, two (2) were assessed to be exposed to low, one (1) to medium, and none to high level flooding. In the 100-year scenario, two (2) were assessed to be exposed to low, two (2) to medium, and one (1) to high level flooding.

Of the 10 identified Medical Institutions in Asid Floodplain, one (1) was assessed to be exposed to low, while none was assessed to be exposed to both medium and high level flooding in the 5-year scenario. In the 25-year scenario, none was assessed to be exposed to both low and high, while one (1) was assessed to be exposed to medium level flooding. In the 100-year scenario, none was assessed to be exposed to both low and high, while two (2) were assessed to be exposed to medium level flooding.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there is a need to perform validation on survey work. Field personnel gathered secondary data regarding flood occurrences in the respective areas within the major river systems in the Philippines.

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

The validation personnel went to the specified points identified in the 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 of some residents with knowledge of or have had experienced flooding in a particular area.

The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on what is needed. The points in the flood map versus its corresponding validation depths are shown in Figure 83.

The flood validation consists of 143 points randomly selected all over the Asid Floodplain. It has an RMSE value of 0.797996188.

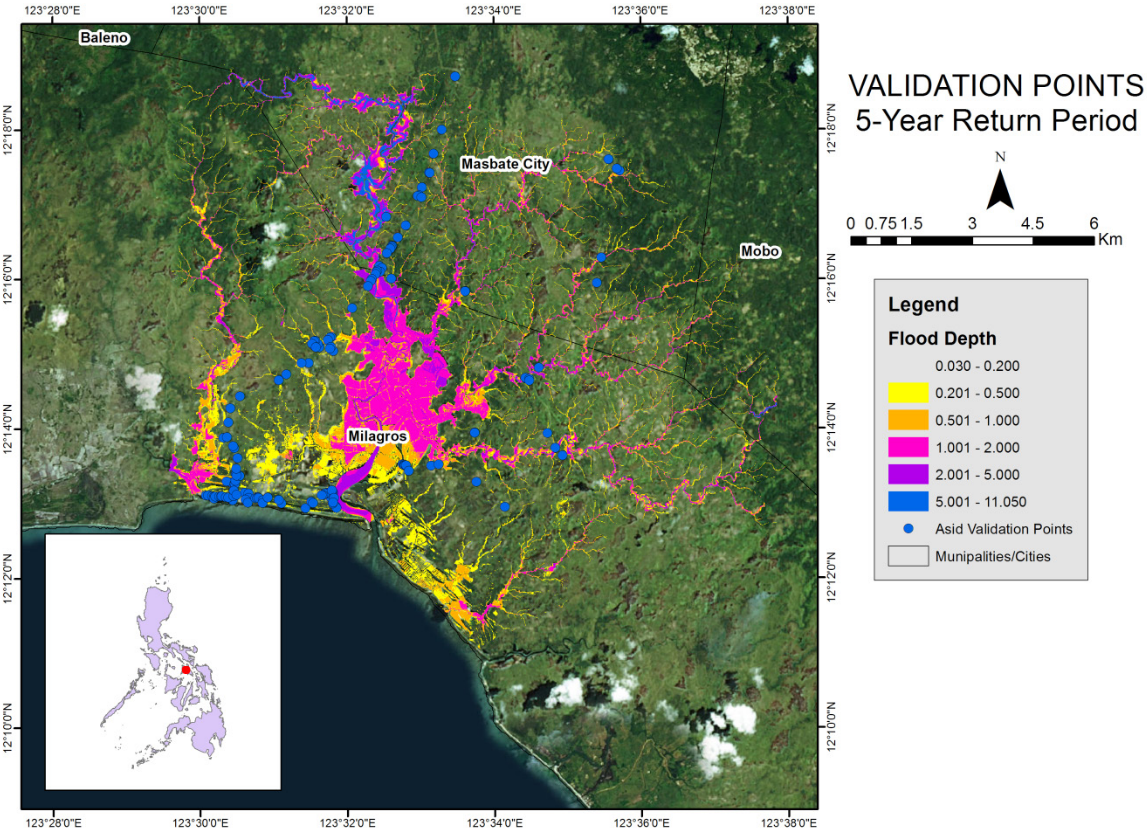

Figure 82. The validation points for the 5-Year flood depth map of the Asid Floodplain

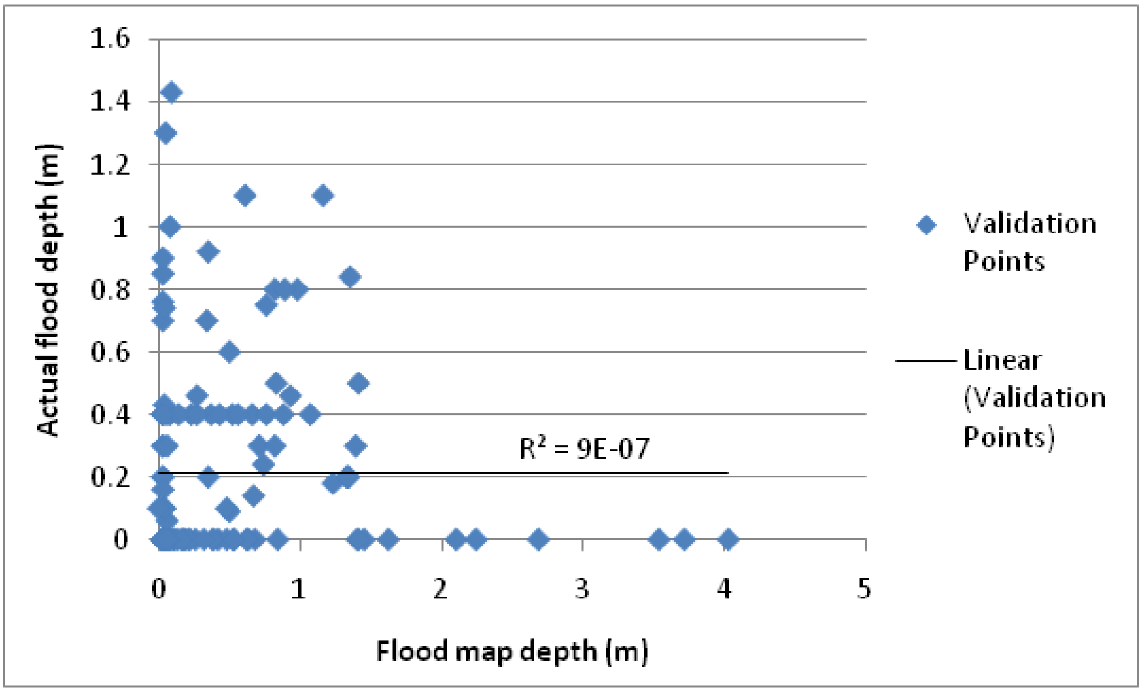

Figure 83. Flood map depth vs. Actual flood depth

Table 47. Actual flood vs. Simulated flood depth at different levels in the Asid River Basin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total	
0-0.20	56	11	9	8	6	0	90
0.21-0.50	12	5	10	3	0	0	30
0.51-1.00	6	3	4	1	0	0	14
1.01-2.00	2	0	1	1	0	0	4
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	76	19	24	13	6	0	138

The overall accuracy generated by the flood model is estimated at 47.83%, with 66 points correctly matching the actual flood depths. In addition, there were 38 points estimated one level above and below the correct flood depths, 18 points estimated two levels above and below, and 16 points estimated three or more levels above and below the correct flood depths. A total of 48 points were overestimated while a total of 24 points were underestimated in the modelled flood depths of Asid.

Table 48. Summary of Accuracy Assessment in the Asid River Basin Survey

	No. of Points	%
Correct	66	**47.83**
Overestimated	48	34.78
Underestimated	24	17.39
Total	138	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.

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the Pegasus Sensor

Table A-1.1. Parameters and Specifications of the Pegasus Sensor

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

1 Target reflectivity ≥20%

2 Dependent on selected operational parameters using nominal FOV of up to 40° in standard atmospheric conditions with 24-km visibility

3 Angle of incidence ≤20°

4 Target size ≥ laser footprint5 Dependent on system configuration

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

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

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CIP/4701/12/09/814

Figure A-2.1. MST-28

2. MST-31

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April 10, 2014

CERTIFICATION

To whom it may concern:

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Province: **MASBATE**
Station Name: **MST-31**
Order: **2nd**

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

	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**

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Figure A-2.2. MST-31

3. MST-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**			Barangay:	
Municipality:	**MILAGROS**				
		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

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Figure A-2.3. MST-32

4. MST-34

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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-34**
Order: **2nd**

Island: **LUZON**
Municipality: **MOBO**
Barangay: **UMABAY EXTERIOR**

PRS92 Coordinates

Latitude: **12º 18' 29.18323"**	Longitude: **123º 40' 46.86556"**	Ellipsoidal Hgt: **11.91000 m.**

WGS84 Coordinates

Latitude: **12º 18' 24.53692"**	Longitude: **123º 40' 51.93952"**	Ellipsoidal Hgt: **68.23000 m.**

PTM Coordinates

Northing: **1361109.053 m.**	Easting: **573933.177 m.**	Zone: **4**

UTM Coordinates

Northing: **1,360,632.64**	Easting: **573,907.30**	Zone: **51**

Location Description

MST-34
From Masbate City Proper, travel for about 9.5 km. along the Nat'l. Highway going to Uson Town Proper until reaching Brgy. Umabay Ext., Mobo Town. Station is located at the left wing of Sagawsawan Bridge, 12 m. NE of a signboard and 20 m. SE of a store. 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-34 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-823**

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Figure A-2.4. MST-34

5. MST-35

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-35**
Order: **2nd**

Island: **LUZON**
Municipality: **CITY OF MASBATE (CAPITAL)**
Barangay: **CAGAY**

PRS92 Coordinates

Latitude: **12º 14' 48.14863"** Longitude: **123º 44' 47.51779"** Ellipsoidal Hgt: **5.31500 m.**

WGS84 Coordinates

Latitude: **12º 14' 43.52314"** Longitude: **123º 44' 52.59656"** Ellipsoidal Hgt: **61.95700 m.**

PTM Coordinates

Northing: **1354336.379 m.** Easting: **581223.775 m.** Zone: **4**

UTM Coordinates

Northing: **1,353,862.34** Easting: **581,195.35** Zone: **51**

Location Description

MST-35
From Masbate City Proper, travel for about 20.2 km. along the Nat'l. Highway going to Brgy. Marcella, Uson Town. Station is located at the right side wing of Marcella Bridge, 7 m. NW of Cristela Bravo Store, 20 m. N of Abaja Store and 5 m. NW of Marcella Brgy. Welcome Arch. 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-35 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-824**

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Figure A-2.5. MST-35

6. MST-40

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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-40**
Order: **2nd**

Island: **LUZON**
Municipality: **USON**
Barangay: **BUENAVISTA**

PRS92 Coordinates

Latitude:	**12º 10' 39.45274"**	Longitude:	**123º 47' 33.62147"**	Ellipsoidal Hgt:	**4.72600 m.**

WGS84 Coordinates

Latitude:	**12º 10' 34.84826"**	Longitude:	**123º 47' 38.70589"**	Ellipsoidal Hgt:	**61.65900 m.**

PTM Coordinates

Northing:	**1346708.7 m.**	Easting:	**586266.511 m.**	Zone:	**4**

UTM Coordinates

Northing:	**1,346,237.33**	Easting:	**586,236.32**	Zone:	**51**

Location Description

MST-40
From Masbate City Proper, travel for about 32.6 km. along the Nat'l. Highway going to Uson Town Proper until reaching Brgy. Buenavista. Station is located at the right wing of Buenavista Bridge, 11 m. from the "15 T" signboard. 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-40 2007 NAMRIA".

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-825**

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Figure A-2.6. MST-40

7. MST-49

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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-49**
Order: **2nd**

Island: **LUZON**		Barangay: **QUEZON**
Municipality: **CATAINGAN**		
	PRS92 Coordinates	
Latitude: **12° 0' 1.41677"**	Longitude: **123° 59' 46.24265"**	Ellipsoidal Hgt: **21.25500 m.**
	WGS84 Coordinates	
Latitude: **11° 59' 56.87354"**	Longitude: **123° 59' 51.34085"**	Ellipsoidal Hgt: **79.14000 m.**
	PTM Coordinates	
Northing: **1327175.1 m.**	Easting: **608487.281 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,326,710.57**	Easting: **608,449.31**	Zone: **51**

Location Description

MST-49
From Masbate City Proper, travel for about 74.8 km. along the Nat'l. Highway going to Placer Town Proper to reach Brgy. Quezon, Cataingan Town. Station is located in front (17 m. SE) of Cataingan Mun. Hall, 10 N of the Mun. Trial Court and 15 m. E of the COMELEC Bldg. 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-49 2007 NAMRIA".

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795949 A**
T.N.:	**2014-826**

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Director, Mapping And Geodesy Branch

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Figure A-2.7. MST-49

8. 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

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Figure A-2.8. MST-55

9. MS-20

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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-20**

Island: **Luzon**	Municipality: **USON**	Barangay: **MARCELLA**
Elevation: **4.4091 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

Station is in the Municipality of Uson, along the national Highway going to the town of Dimasalang at Barangay Marcella at Manaswang Bridge, just before crossing Brgy. Welcome arc.

Mark i sthe head of a 3"copper nail embedded in the bridge walkway with cement putty and the standard NAMRIA name designation on it.

Requesting Party: **UP-DREAM**
Pupose: **Reference**
OR Number: **8795949 A**
T.N.: **2014-839**

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

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

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

Figure A-.2.9. MS-20

10. MS-61

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-61**

Island: **LUZON**	Municipality: **PALANAS**	Barangay: **NABANGIG**
Elevation: **7.0705 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

MS-061

Station is in the Municipality of Palanas, along National Highway leading to town of Cataingan, at Brgy. Nabangig, atop Nabangig Bridge (km 061+156). It is 55m from the Municipality's Boundary Arc. Mark is the head of a 3" copper nail set flush in cement putty with inscription "MS-061 2007 NAMRIA."

Requesting Party:	**UP-DREAM**
Pupose:	**Reference**
OR Number:	**8795949 A**
T.N.:	**2014-840**

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

9 9 0 4 1 0 2 0 1 4 1 4 0 6 2 2

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.10. MS-61

Annex 3. Baseline Processing Reports of Reference Points Used in the LIDAR Survey

1. MS–20

MS-20 - MST-34 (8:11:07 AM-8:58:19 AM) (S1)

Baseline observation:	MS-20 --- MST-34 (B1)
Processed:	5/13/2014 11:34:56 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.006 m
Vertical precision:	0.017 m
RMS:	0.003 m
Maximum PDOP:	2.504
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	3/20/2014 8:11:09 AM (Local: UTC+8hr)
Processing stop time:	3/20/2014 8:58:19 AM (Local: UTC+8hr)
Processing duration:	00:47:10
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	MST-34				
Grid		Local		Global	
Easting	574059.995 m	Latitude	N12°18'24.53692"	Latitude	N12°18'24.53692"
Northing	1360574.929 m	Longitude	E123°40'51.93952"	Longitude	E123°40'51.93952"
Elevation	11.764 m	Height	68.230 m	Height	68.230 m

To:	MS-20				
Grid		Local		Global	
Easting	581315.239 m	Latitude	N12°14'43.77974"	Latitude	N12°14'43.77974"
Northing	1353812.693 m	Longitude	E123°44'51.50748"	Longitude	E123°44'51.50748"
Elevation	4.956 m	Height	61.971 m	Height	61.971 m

Vector					
ΔEasting	7255.244 m	NS Fwd Azimuth	133°07'50"	ΔX	-6819.309 m
ΔNorthing	-6762.236 m	Ellipsoid Dist.	9921.211 m	ΔY	-2823.722 m
ΔElevation	-6.808 m	ΔHeight	-6.259 m	ΔZ	-6629.938 m

Figure A-3.1. Baseline Processing Report - A

2. MS–61

MS-61 - MST-49 (6:30:34 AM-11:24:24 AM) (S1)

Baseline observation:	MS-61 --- MST-49 (B1)
Processed:	5/13/2014 11:54:33 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.006 m
Vertical precision:	0.025 m
RMS:	0.009 m
Maximum PDOP:	3.505
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	3/26/2014 6:30:54 AM (Local: UTC+8hr)
Processing stop time:	3/26/2014 11:24:24 AM (Local: UTC+8hr)
Processing duration:	04:53:30
Processing interval:	5 seconds

Vector Components (Mark to Mark)

From:	MST-49				
Grid		Local		Global	
Easting	608602.644 m	Latitude	N11°59'56.87354"	Latitude	N11°59'56.87354"
Northing	1326654.175 m	Longitude	E123°59'51.34085"	Longitude	E123°59'51.34085"
Elevation	21.031 m	Height	79.140 m	Height	79.140 m

To:	MS-61				
Grid		Local		Global	
Easting	604178.664 m	Latitude	N12°05'56.94091"	Latitude	N12°05'56.94091"
Northing	1337699.951 m	Longitude	E123°57'26.33451"	Longitude	E123°57'26.33451"
Elevation	7.554 m	Height	65.257 m	Height	65.257 m

Vector					
ΔEasting	-4423.979 m	NS Fwd Azimuth	338°22'53"	ΔX	4935.367 m
ΔNorthing	11045.776 m	Ellipsoid Dist.	11901.865 m	ΔY	524.472 m
ΔElevation	-13.477 m	ΔHeight	-13.883 m	ΔZ	10817.803 m

Figure A-3.2. Baseline Processing Report - B

Annex 4. The LIDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub -Team	Designation	Name	Agency / Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	GEROME B. HIPOLITO	UP-TCAGP
	Research Associate (RA)	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
	RA	ENGR. IRO NIEL ROXAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	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 5. Data Transfer Sheet for Asid Floodplain

DATA TRANSFER SHEET
Apr 3, 2014

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
Mar 19, 2014	1241P	1BLK32E078A	PEGASUS	703MB	2.80MB	8.99MB	281MB	33.3GB	297KB	6.0GB	N/A	5.78MB	121B	825B	82.6KB	N/A	Z:\Airborne_Raw\1241P
Mar 20, 2014	1243P	1BLK32E079A	PEGASUS	1.14GB	2.37MB	6.18MB	169MB	41GB	335KB	21.3GB	N/A	5.45MB	225B	688B	80.3KB	N/A	Z:\Airborne_Raw\1243P
Mar 20, 2014	1245P	1BLK32J079B	PEGASUS	2.33GB	2.22MB	6.76MB	189MB	49.2GB	363KB	22.7GB	N/A	5.45MB	225B	377B	115KB	N/A	Z:\Airborne_Raw\1245P
Mar 21, 2014	1247P	1BLK32J080A	PEGASUS	4.09GB	3.96MB	9.60MB	244MB	55.2GB	426KB	40.8GB	N/A	5.78MB	95B	527B	137KB	N/A	Z:\Airborne_Raw\1247P
Mar 25, 2014	1263P	1BLK32K084A	PEGASUS	2.21GB	2.98MB	8.71MB	217MB	48.9GB	366KB	26.6GB	N/A	4.64MB	92B	936B	136KB	N/A	Z:\Airborne_Raw\1263P
Mar 26, 2014	1267P	1BLK32M085A	PEGASUS	3.67GB	4.25MB	10.8MB	283MB	58.2GB	451KB	36.4GB	N/A	5.94MB	92B	758B	254KB	N/A	Z:\Airborne_Raw\1267P
Mar 27, 2014	1271P	1BLK32H086A	PEGASUS	3.43GB	3.99MB	11.1MB	259MB	74.8GB	585KB	33.8GB	N/A	5.24MB	92B	678B	156KB	N/A	Z:\Airborne_Raw\1271P
Mar 28, 2014	1275P	1BLK32H087A	PEGASUS	2.18GB	2.11MB	6.13MB	164MB	38.4GB	315KB	21.1GB	N/A	6.67MB	93B	350B	145KB	N/A	Z:\Airborne_Raw\1275P
Mar 29, 2014	1281P	1BLK32O088B	PEGASUS	1.45GB	1.58MB	3.74MB	102MB	N/A	N/A	13.8GB	N/A	7.37MB	93B	455B	26.5KB	N/A	Z:\Airborne_Raw\1281P
Mar 31, 2014	1289P	1BLK32X090A	PEGASUS	1.45GB	1.63MB	4.32MB	116MB	22.6GB	162KB	14.1GB	N/A	8.08MB	93B	253B	31.9KB	N/A	Z:\Airborne_Raw\1289P

Received from

Name Faith Joy Sabio
Position
Signature

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature

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

DATA TRANSFER SHEET
4/22/2014(MASBATE)

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS (mb)	POS (mb)	RAW IMAGES	MISSION LOG FILE	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
4/1/2014	1291P	1BLK32KL091A	PEGASUS	2.91	3.36	9.99	256	43.6	332	29.8	NA	7.81	1KB	602	376	NA	Z:\Airborne_Raw\1291P
4/1/2014	1293P	1BLK32H091B	PEGASUS	1.75	1.46	3.85	115	24.7	213	15.6	NA	7.81	1KB	221	68.5	NA	Z:\Airborne_Raw\1293P
4/2/2014	1295P	1BLK32I092A	PEGASUS	2.93	3.42	8.9	225	54.2	404	29.2	NA	887KB	1KB	512	137	NA	Z:\Airborne_Raw\1295P
4/3/2014	1299P	1BLK32FG093A	PEGASUS	2.68	3.23	8.65	232	33.4	267	26.8	NA	7.59	1KB	358	113	NA	Z:\Airborne_Raw\1299P
4/3/2014	1301P	1BLK32F093B	PEGASUS	1.95	2.42	5.95	149	44.6	352	19.6	NA	7.59	1KB	538	201	NA	Z:\Airborne_Raw\1301P
4/4/2014	1303P	1BLK32A094A	PEGASUS	2.77	3.48	2.99	218	52.5	404	29.4	NA	6.67	1KB	694	186	NA	Z:\Airborne_Raw\1303P
4/4/2014	1305P	1BLK32A094B	PEGASUS	2.41	2.85	6.88	161	44.3	324	23.3	NA	6.67	1KB	400	2.41	NA	Z:\Airborne_Raw\1305P
4/5/2014	1307P	1BLK32DG095A	PEGASUS	3.84	4.49	4.12	271	67.2	514	37.7	NA	6.49	1KB	523	270	NA	Z:\Airborne_Raw\1307P
4/8/2014	1319P	1BLK32B098A	PEGASUS	3.66	4.32	9.93	254	17.7	526	36.2	NA	4.95	1KB	731	382	NA	Z:\Airborne_Raw\1319P
4/10/2014	1327P	1BLK32D100A	PEGASUS	2.16	2.47	6.99	175	37	277	21.7	NA	5.27	1KB	747	243	NA	Z:\Airborne_Raw\1327P
4/11/2014	1331P	1BLK32B101A	PEGASUS	1.76	1.9	5.09	134	29.8	232	17.6	NA	4.09	1KB	574	316	NA	Z:\Airborne_Raw\1331P

Received from

Name CARLOS JOAQUIN
Position RA
Signature 4/23/14

Received by

Name JOIDA F. PRIETO
Position SSRS
Signature 4/23/14

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

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 1241P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1241P

1 LiDAR Operator: I. ROXAS	2 ALTM Model: PEG	3 Mission Name: 1BLK32E0924A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot:	9 Route:			
10 Date: Nov. 19, 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0920	14 Engine Off: 1349	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					
20 Remarks: Surveyed BLK32E					
21 Problems and Solutions:					

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. ALIPANTO	MARVIN DUQUE	M. TANGONAN	I. ROXAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.1. Flight Log for Mission 1241P

2. Flight Log for 1243P Mission

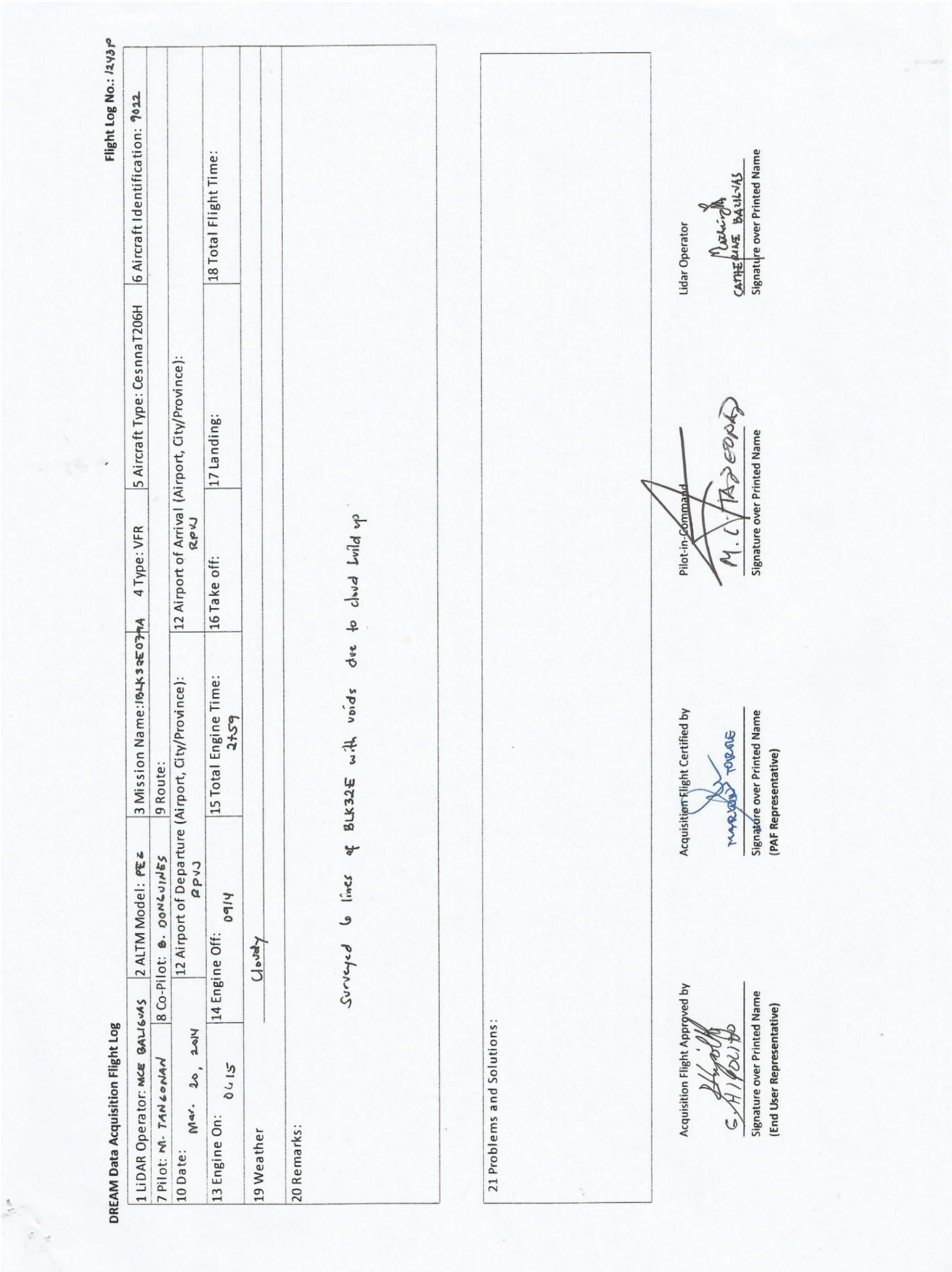


Figure A-6.2. Flight Log for Mission 1243P

3. Flight Log for 1271P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1271P

1 LiDAR Operator: NKE BALIGUAS	2 ALTM Model: PE2	3 Mission Name: 1BLK32H08C A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: M. TANGONAN	8 Co-Pilot: B. DONGUINES	9 Route:			
10 Date: Mar. 27, 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0827	14 Engine Off: 1250	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

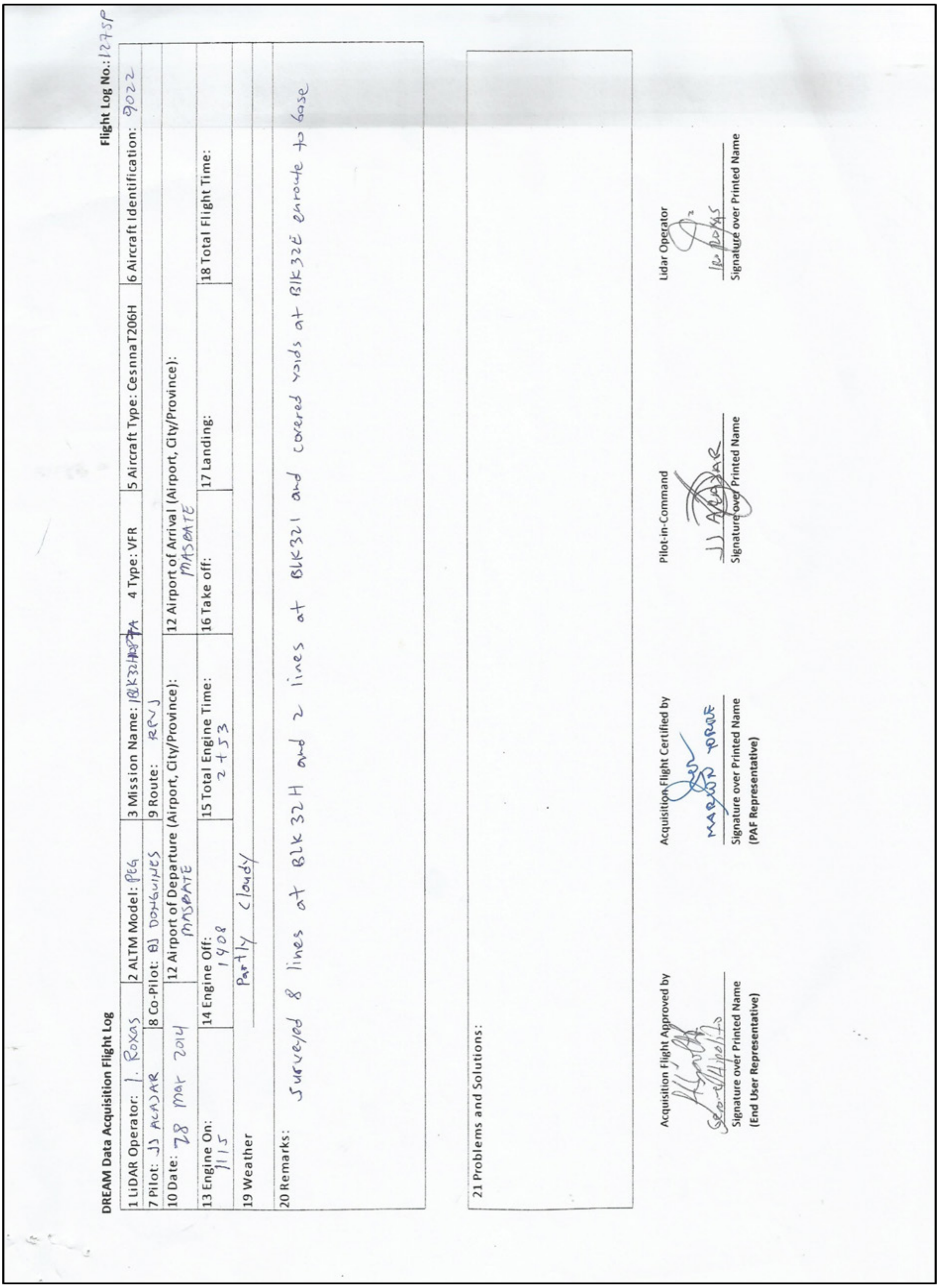
Finish lines of BLK 32H; without digitizer.

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. HIPOLITO	MARLON TORRES	M.L. TANGONAN	CATHERINE BALIGUAS
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.3. Flight Log for Mission 1271P

4. Flight Log for 1275P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1275P

1 LiDAR Operator: J. Roxas	2 ALTM Model: Peg	3 Mission Name: 1BLK32H[illegible]	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: JJ Alajar	8 Co-Pilot: BJ Donguines	9 Route: RPVJ			
10 Date: 28 Mar 2014	12 Airport of Departure (Airport, City/Province): Masbate		12 Airport of Arrival (Airport, City/Province): Masbate		
13 Engine On: 1115	14 Engine Off: 1408	15 Total Engine Time: 2+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					

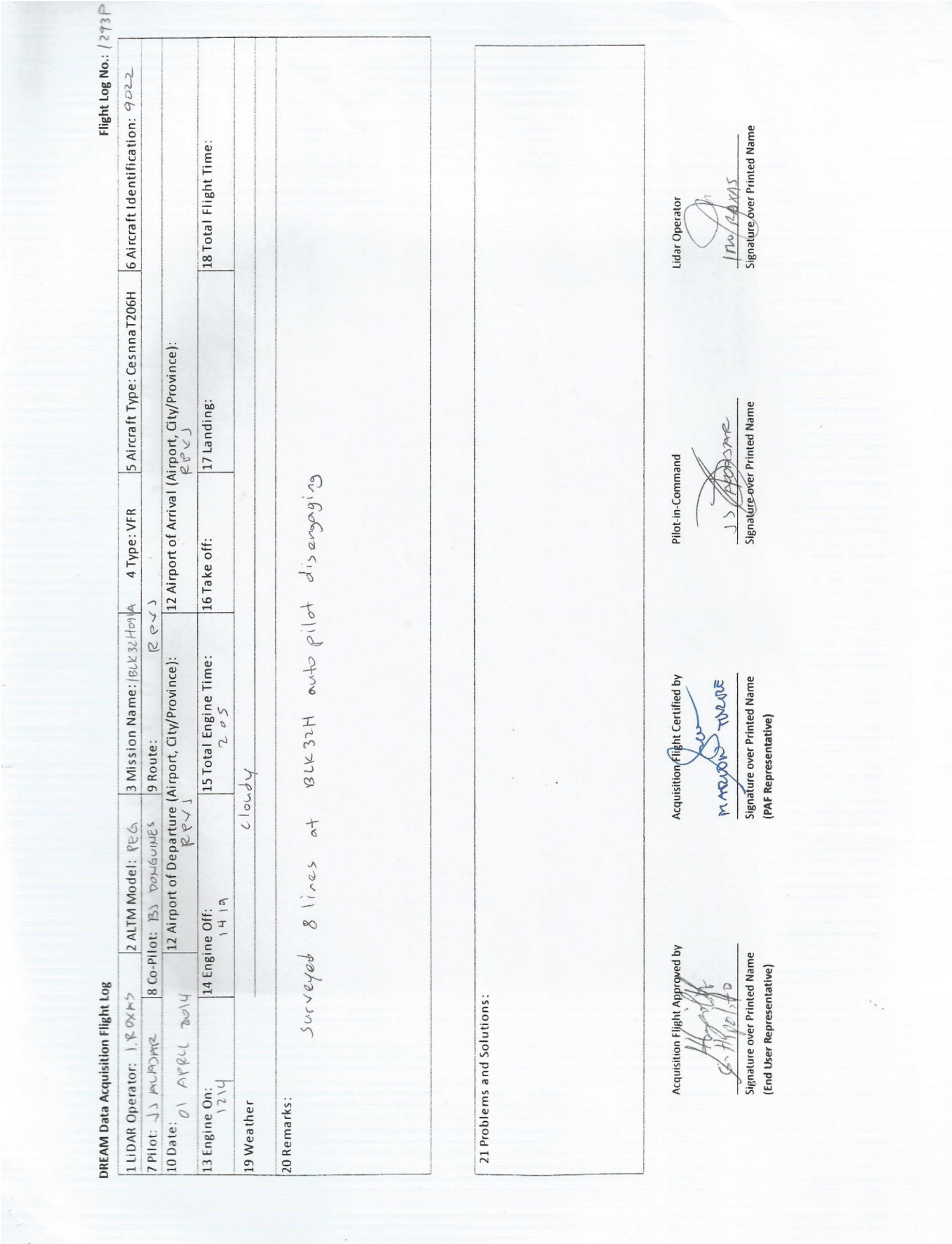
20 Remarks: Surveyed 8 lines at BLK 32H and 2 lines at BLK32I and covered voids at BLK32E enroute to base

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[illegible]	Marjun Torre	JJ Alajar	JR Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.4. Flight Log for Mission 1275P

5. Flight Log for 1293P Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1293P

1 LiDAR Operator: I. ROXAS	2 ALTM Model: PEG	3 Mission Name: 1BLK32H091A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: JJ ALAJAR	8 Co-Pilot: BJ DONGUINES	9 Route: RPVJ			
10 Date: 01 APRIL 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 1214	14 Engine Off: 1419	15 Total Engine Time: 205	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Remarks:

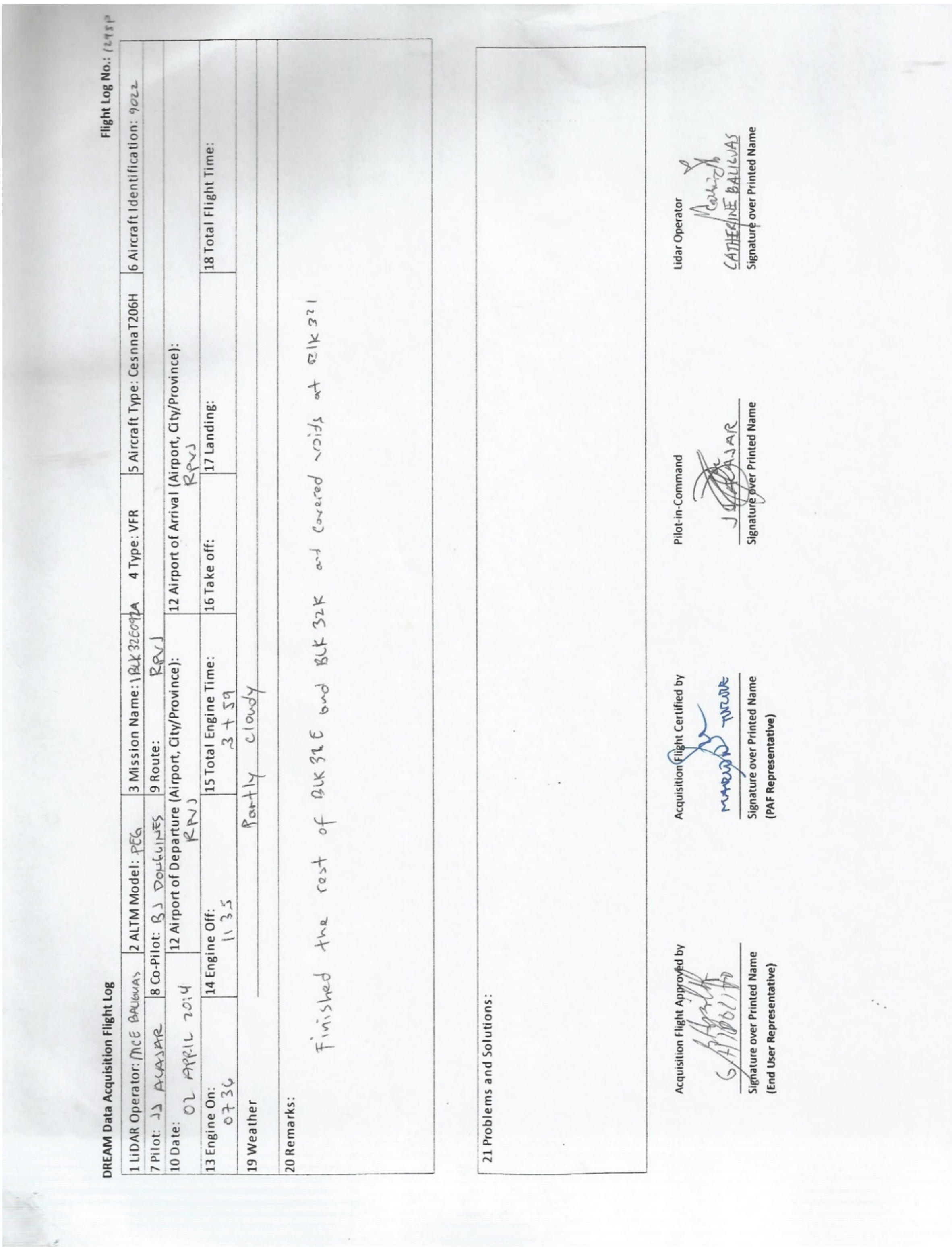
Surveyed 8 lines at BLK32H auto pilot disengaging

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
G. Hipolito	Marlon Tavere	JJ Alajar	Ino Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.5. Flight Log for Mission 1293P

6. Flight Log for 1295P Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 1295P

1 LiDAR Operator: MCE BALICAS	2 ALTM Model: PEG	3 Mission Name: 1BLK32C092A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: JJ ALAJAR	8 Co-Pilot: BJ DONGUINES	9 Route: RPVJ			
10 Date: 02 APRIL 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0736	14 Engine Off: 1135	15 Total Engine Time: 3+59	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Partly cloudy				

20 Remarks:

Finished the rest of BLK 32E and BLK 32K and covered voids at BLK 32I

21 Problems and Solutions:

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

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

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

Lidar Operator — CATHERINE BALICAS — Signature over Printed Name

Figure A-6.6. Flight Log for Mission 1295P

7. Flight Log for 1307P Mission

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

1 LiDAR Operator: MCE BALGUAS	2 ALTM Model: PEG	3 Mission Name: 1BLKAG095A	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: 05 APRIL 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
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 326 and surveyed 13 lines at BLK 320					
21 Problems and Solutions:					

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

Figure A-6.7. Flight Log for Mission 1307P

8. Flight Log for 1327P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1327P

1 LiDAR Operator: MCE Balguas	2 ALTM Model: PEG	3 Mission Name: 1BLK32D100A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: JJ Alajar	8 Co-Pilot: BJ Donguines	9 Route: —			
10 Date: 10 April 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On:	14 Engine Off:	15 Total Engine Time:	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					
20 Remarks: Surveyed 11 lines at BLK 32D. change overlap from 30-35-40					
21 Problems and Solutions:					

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	JJ Alajar Signature over Printed Name	Catherine Balguas Signature over Printed Name

Figure A-6.8. Flight Log for Mission 1327P

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Reports

MASBATE MARCH 18, 2014-APRIL 14,2014					
FLIGHT NO	**AREA**	**MISSION**	**OPERATOR**	**DATE FLOWN**	**REMARKS**
1241P	BLK32E	1BLK32E078A	I. ROXAS	19 MAR 14	Surveyed BLK32E but needs reflight due to problematic swath with area 146.522 km^2
1243P	BLK32E	1BLK32E079A	MCE. BALIGUAS	20 MAR 14	Surveyed 6 lines of BLK32E with voids due to heavy cloud build up with area of 152.126 km^2
1271P	BLK32H	1BLK32H086A	MCE. BALIGUAS	27 MAR 14	Surveyed 18 lines at BLK32H with area 169.487 km^2; without digitizer
1275P	BLK32H	1BLK32HI087A	I. ROXAS	28 MAR 14	Surveyed 8 lines at BLK32H and 2 lines at BLK32I and covered voids at BLK32E en route to base with area 126.674 km^2
1293P	BLK32H	1BLK32H091B	I. ROXAS	01 APR 14	Surveyed 8 lines at BLK32H with area 82.521 km^2; auto pilot disengaging
1295P	BLK32E	1BLK32E092A	MCE. BALIGUAS	02 APR 14	Finished the rest of BLK32 E and BLK32K and covered voids at BLK32I with area of 199.643 km^2
1307P	BLK32D & BLK32G	1BLK32DG095A	MCE. BALIGUAS	05 APR 14	Completed BLK32G and surveyed 13 lines at BLK32D with area of 344.804 km^2
1327P	BLK32D	1BLK32D100A	MCE. BALIGUAS	10 APR 14	Surveyed 11 lines at BLK32D with area 202.254 km^2. Changed overlap from 30-35-40.

Flight No.:		1241P	
Area:			BLK32E
Mission Name:	1BLK32E078A		
Parameters:	Altitude:	800, 1000m;	Scan Frequency: 30Hz;
Scan Angle:	50deg;	Overlap: 30%	

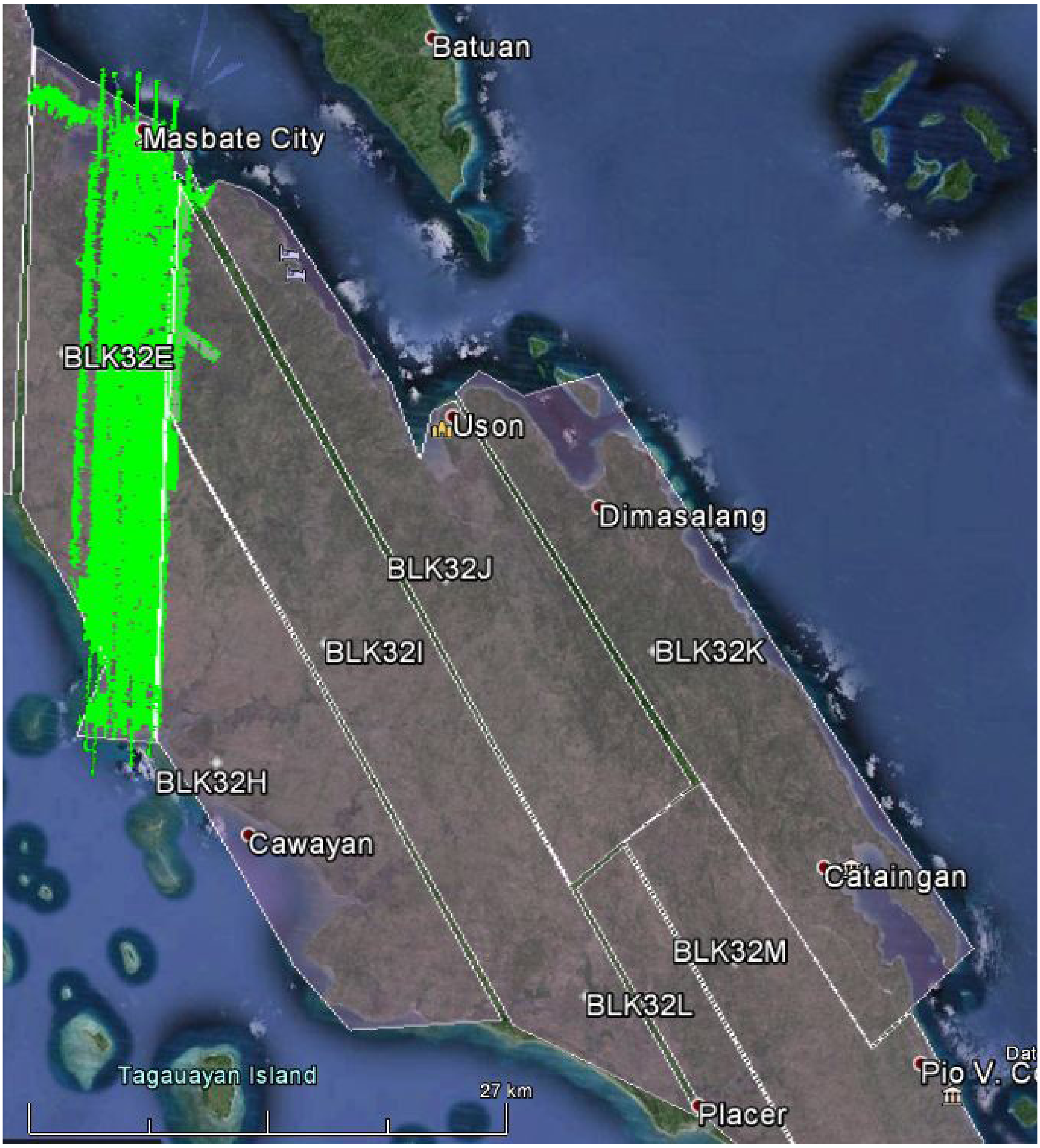


Figure A-7.1. Swath for Flight No. 1241P

Flight No.: 1243P
Area: BLK32E
Mission Name: 1BLK32E079A
Parameters: Altitude: 800m; Scan Frequency: 30Hz;
Scan Angle: 50deg; Overlap: 25%

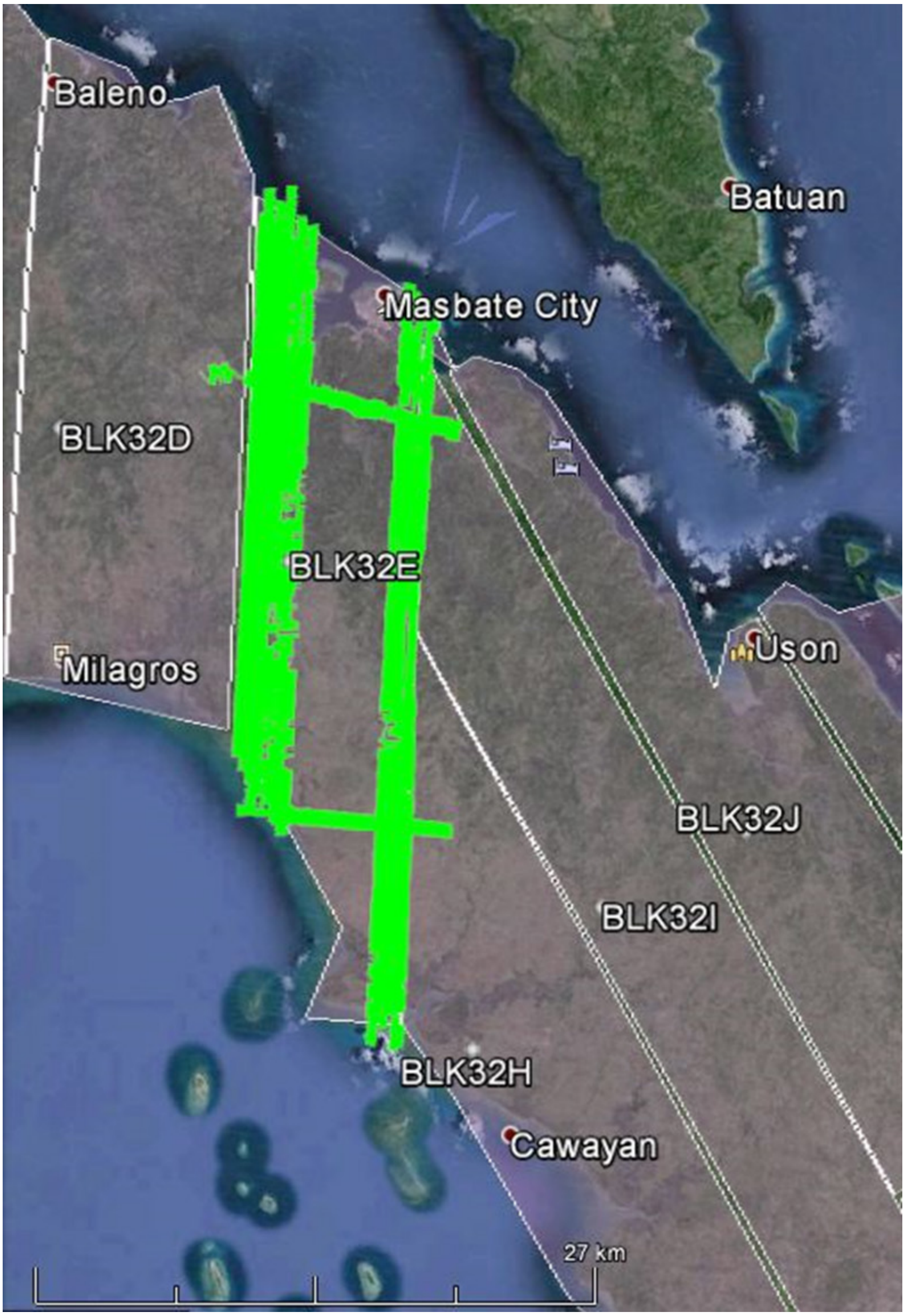


Figure A-7.2. Swath for Flight No. 1243P

Flight No. :		1271P		
Area:			BLK32H	
Mission Name:	1BLK32H086A			
Parameters:		Altitude:	600m, 800m;	Scan Frequency: 30Hz;
Scan Angle:	50deg;	Overlap: 25%, 30%		

Figure A-7.3. Swath for Flight No. 1271P

Flight No. : 1275P
Area: BLK32H
Mission Name: 1BLK32HI087A
Parameters: Altitude: 800m; Scan Frequency: 36Hz;
Scan Angle: 40deg; Overlap: 25%

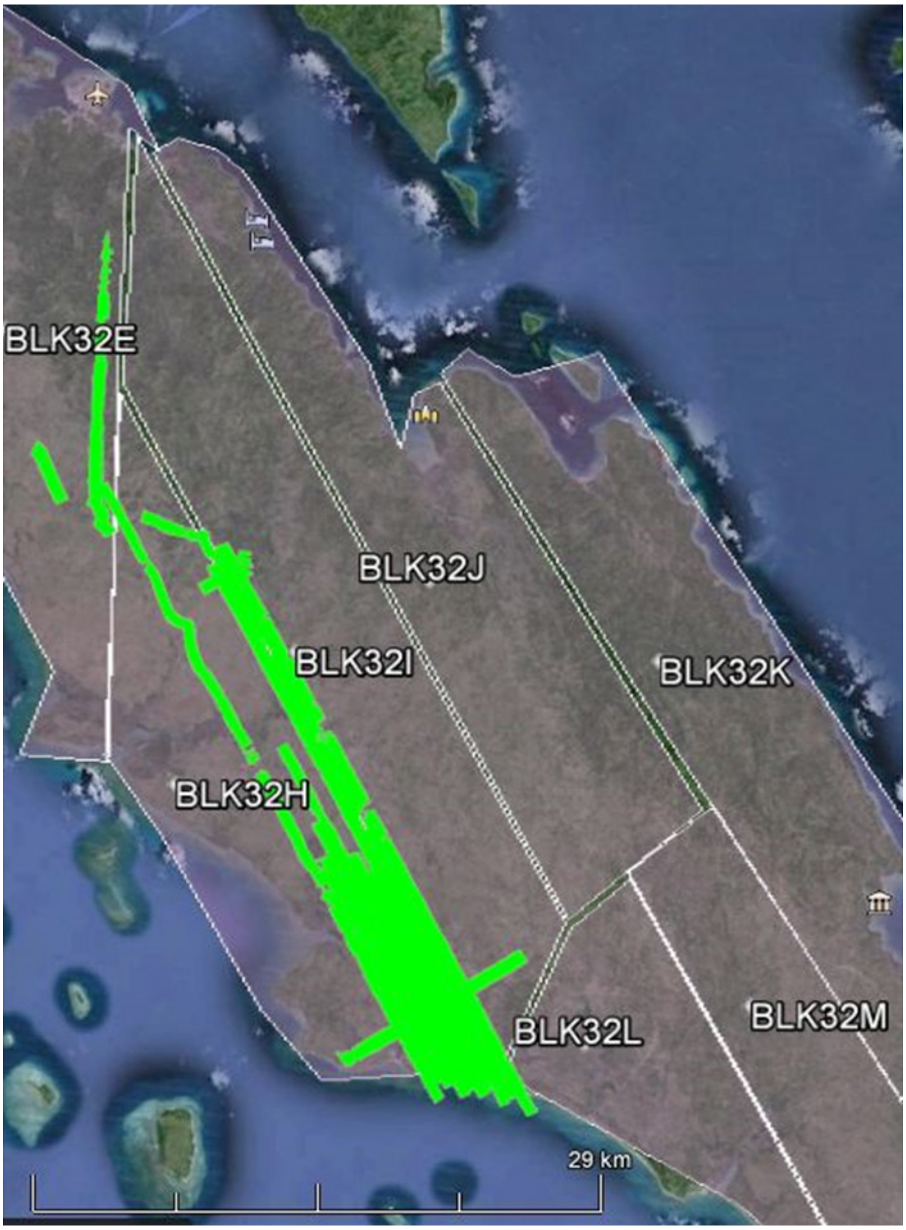


Figure A-7.4. Swath for Flight No. 1275P

Flight No. :		1293P		
Area:			BLK32H	
Mission Name:	1BLK32H091B			
Parameters:		Altitude:	800m;	Scan Frequency: 36Hz;
Scan Angle:	40deg;	Overlap: 25%		

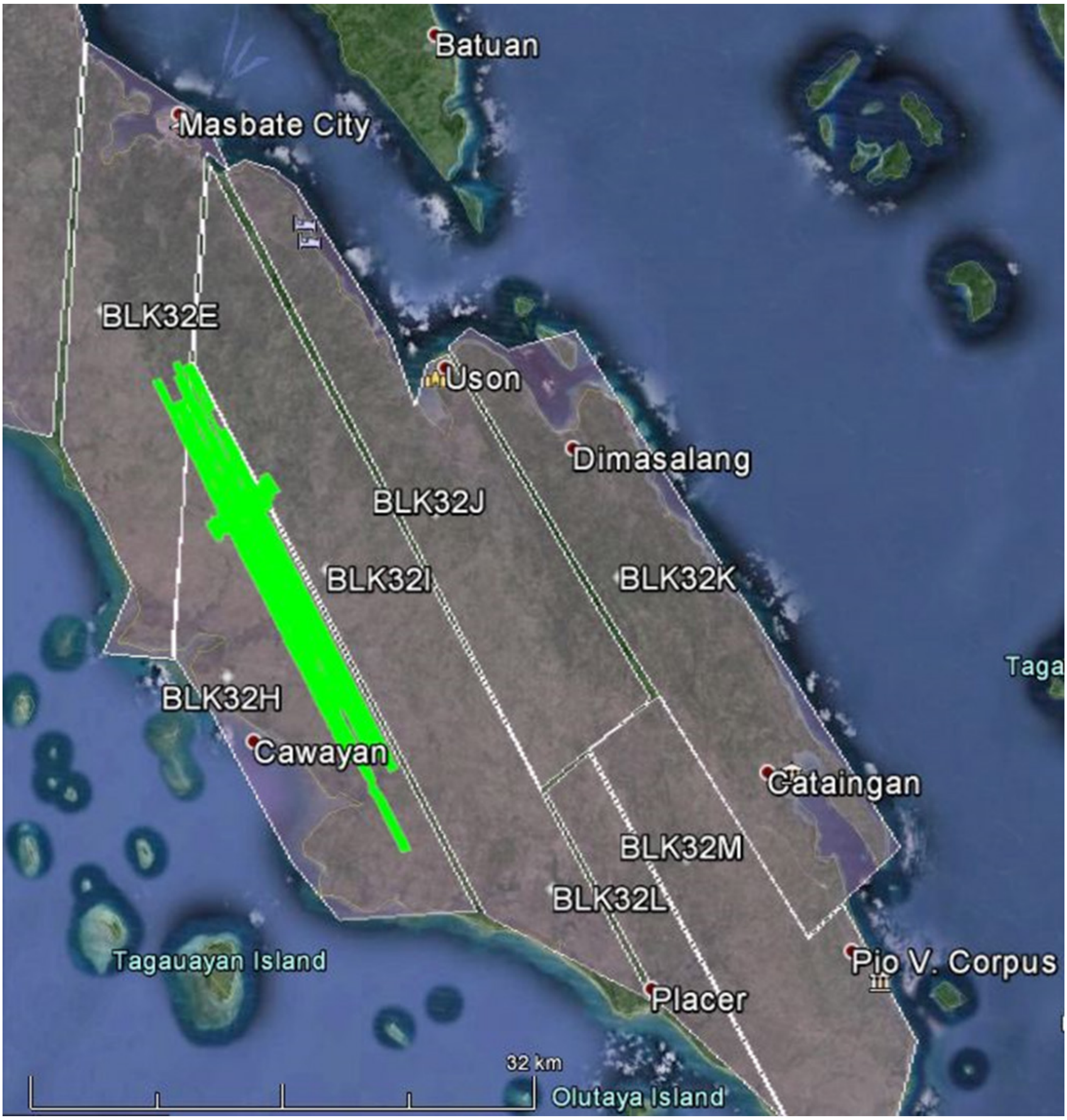


Figure A-7.5. Swath for Flight No. 1293P

Flight No. :		1295P	
Area:			BLK32E
Mission Name:	1BLK32E092A		
Parameters:		Altitude:	800m, 1000m; Scan Frequency: 30Hz;
Scan Angle:	50deg;		Overlap: 25%, 30%

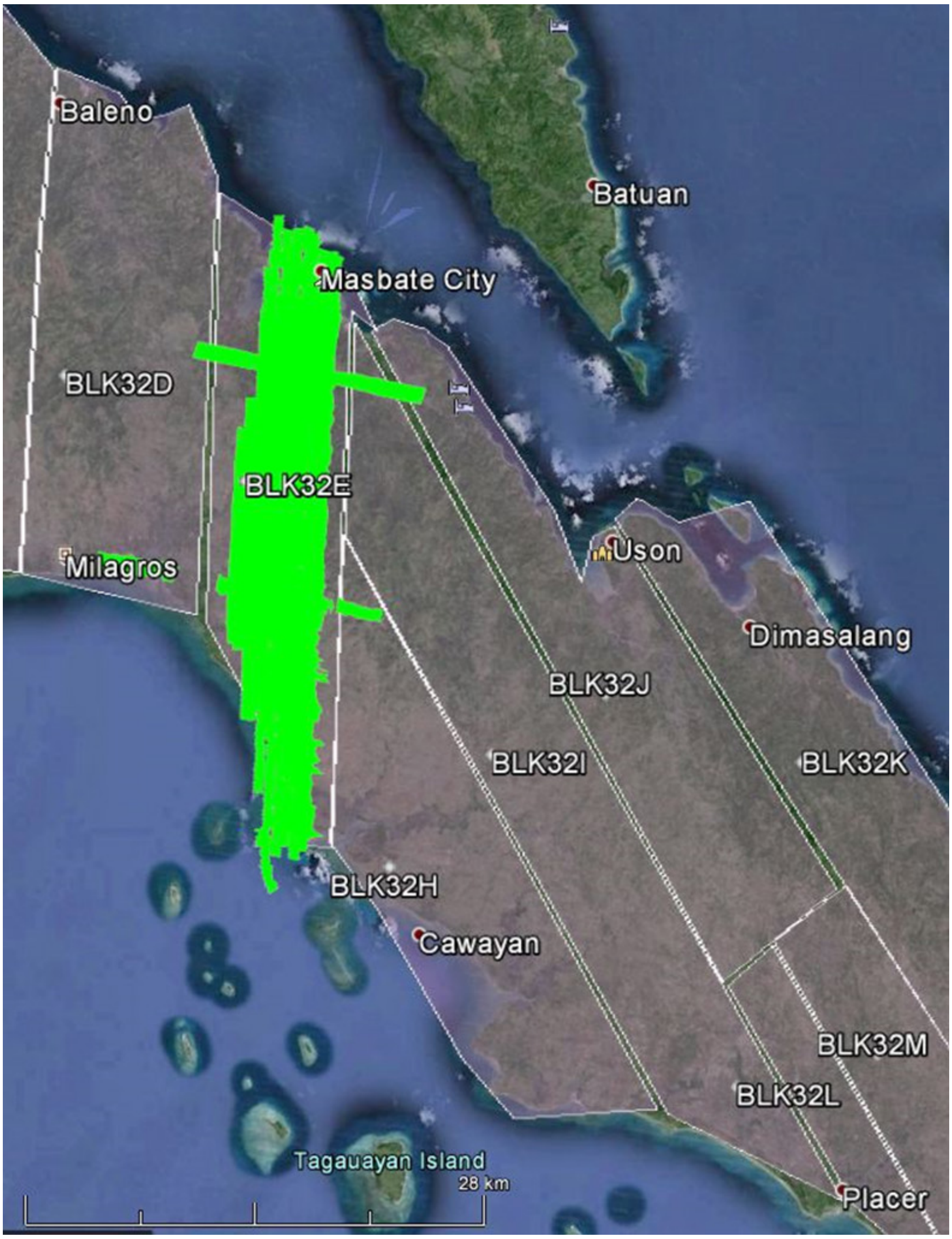


Figure A-7.6. Swath for Flight No. 1295P

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

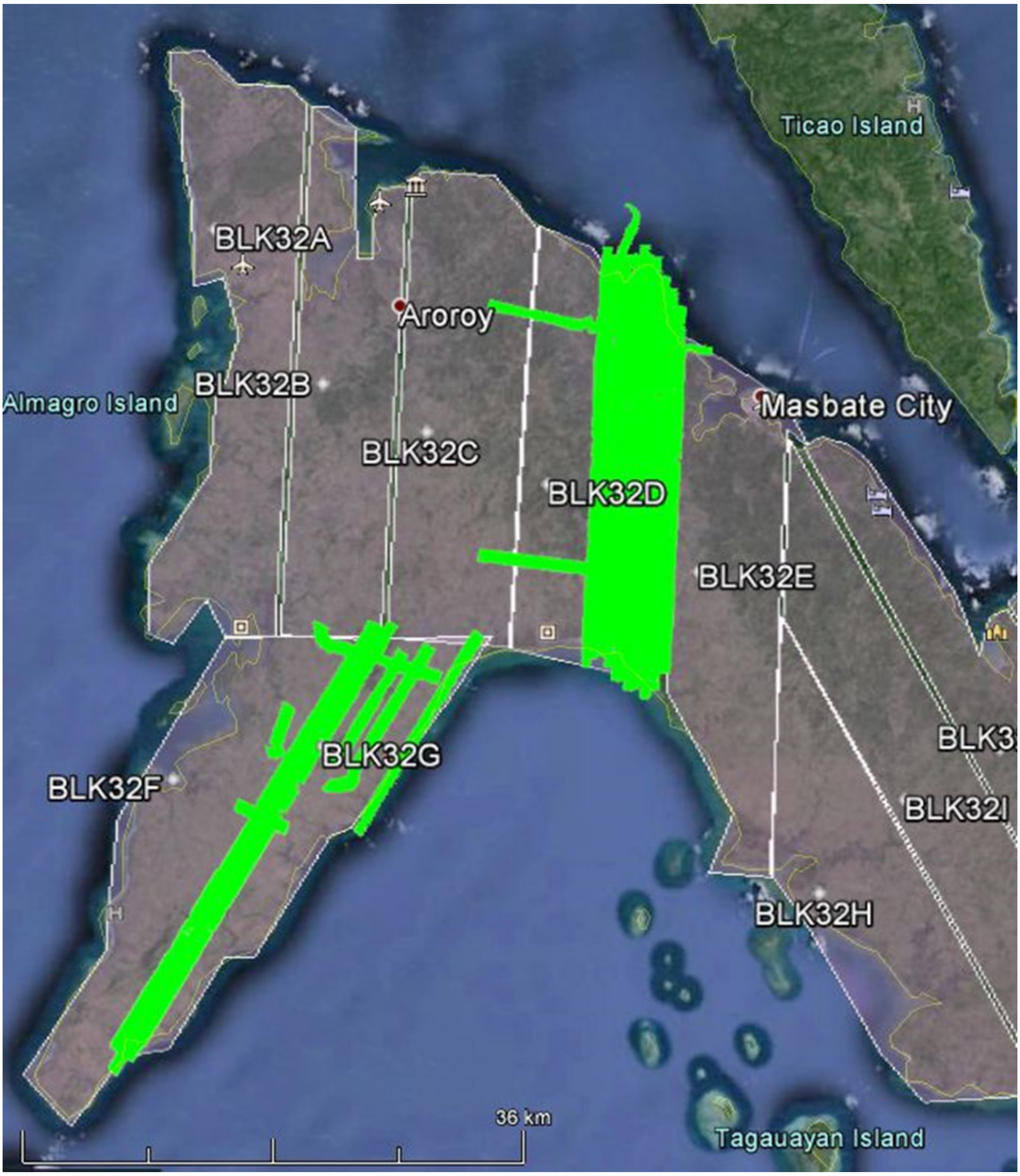


Figure A-7.7. Swath for Flight No. 1307P

Flight No. :		1327P	
Area:			BLK32D
Mission Name:	1BLK32D100A		
Parameters:		Altitude:	1000m,1200m; Scan Frequency: 30Hz;
Scan Angle:	50deg;		Overlap: 30%, 35%, 40%

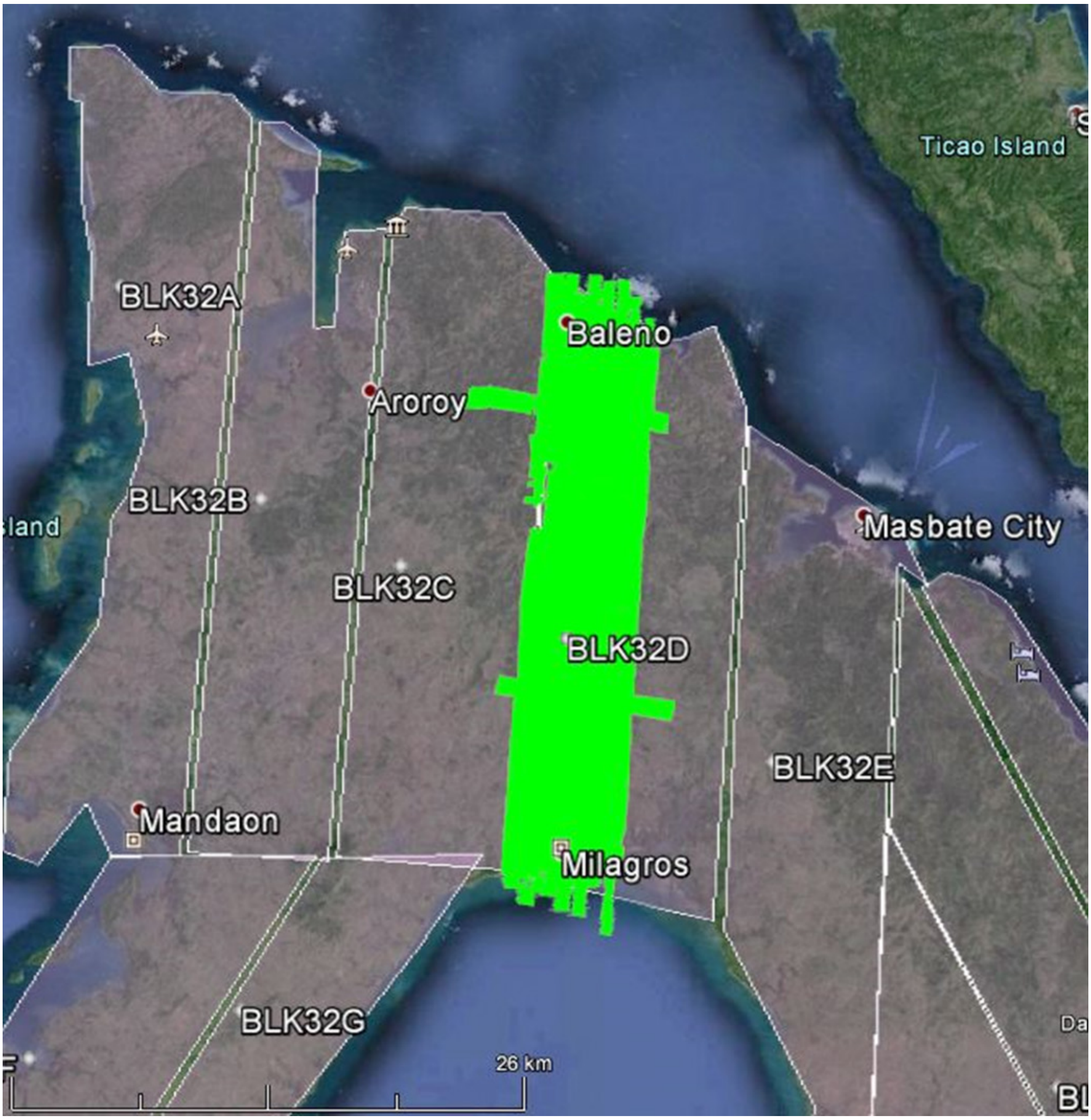


Figure A-7.8. Swath for Flight No. 1327P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk32H

Flight Area	Masbate
Mission Name	**Blk32H**
Inclusive Flights	1271P, 1275P, 1293P
Mission Name	1BLK32H086A, 1BLK32DG095A, 1BLK32H091B
Range data size	70.5 GB
Base data size	19.72 MB
POS	538 MB
Image	138.0 GB
Transfer date	April 23, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	5.04
RMSE for East Position (<4.0 cm)	3.40
RMSE for Down Position (<8.0 cm)	7.90
Boresight correction stdev (<0.001deg)	0.00058
IMU attitude correction stdev (<0.001deg)	0.00828
GPS position stdev (<0.01m)	0.00270
Minimum % overlap (>25)	2.25%
Ave point cloud density per sq.m. (>2.0)	2.74
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	387
Maximum Height	555.56m
Minimum Height	47.88m
Classification (# of points)	
Ground	501,440,501
Low vegetation	335,653,641
Medium vegetation	315,870,006
High vegetation	78,423,465
Building	2,270,257
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Gladys Mae Apat

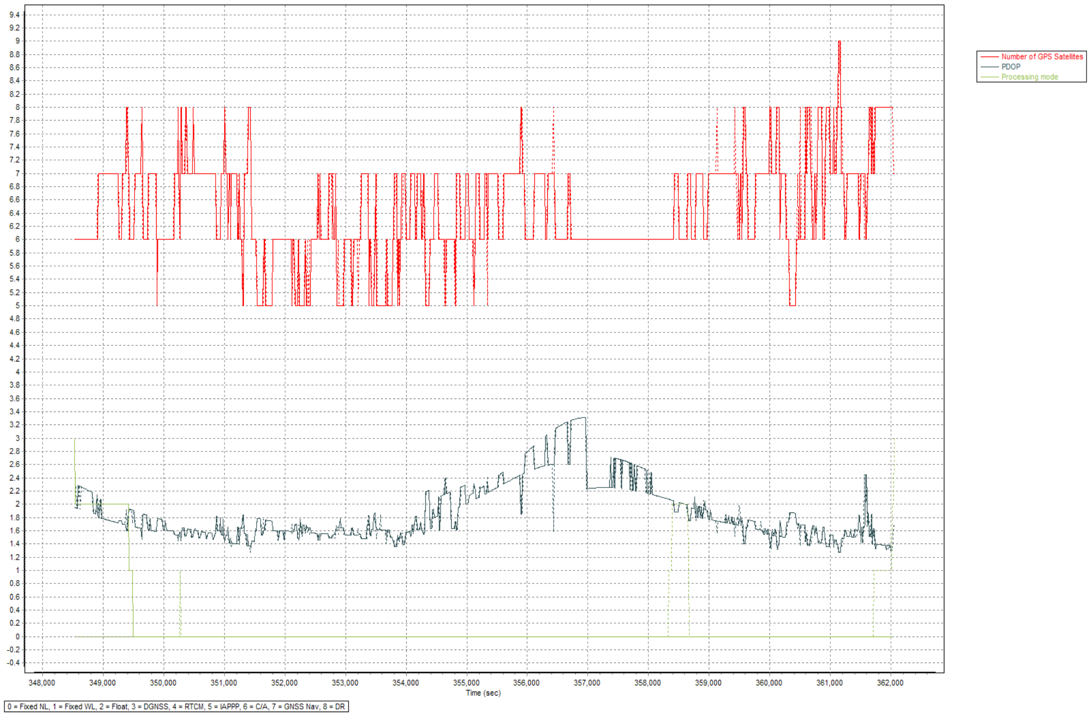


Figure A-8.1. Solution Status

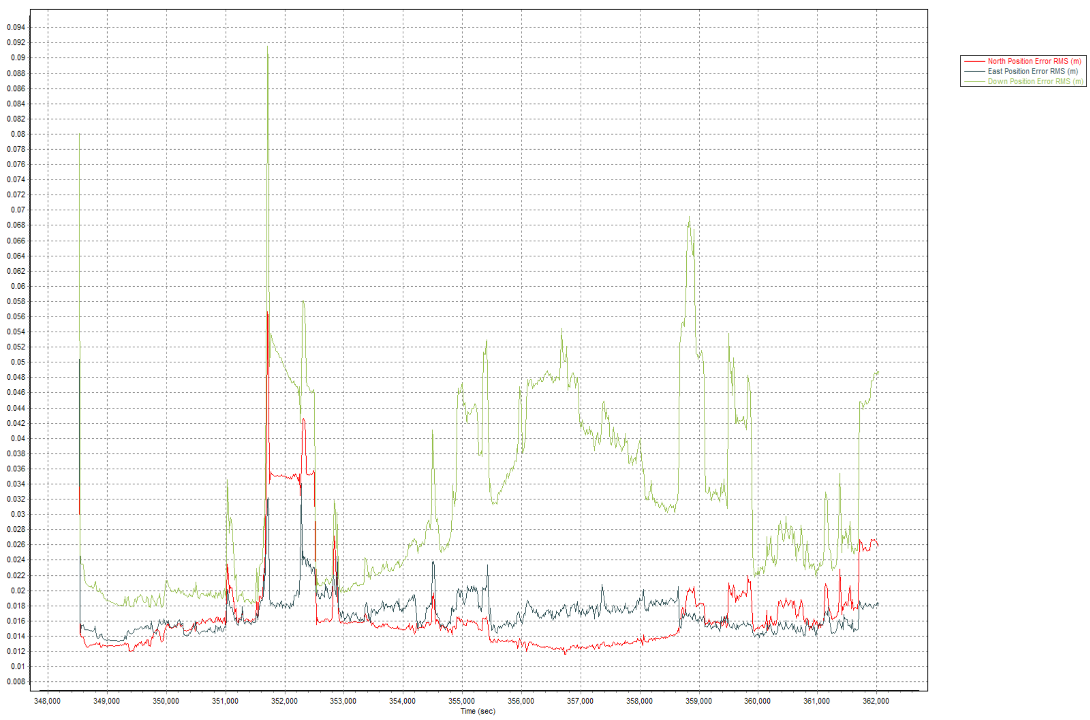


Figure A-8.2 ***Smoothed Performance Metric Parameters***

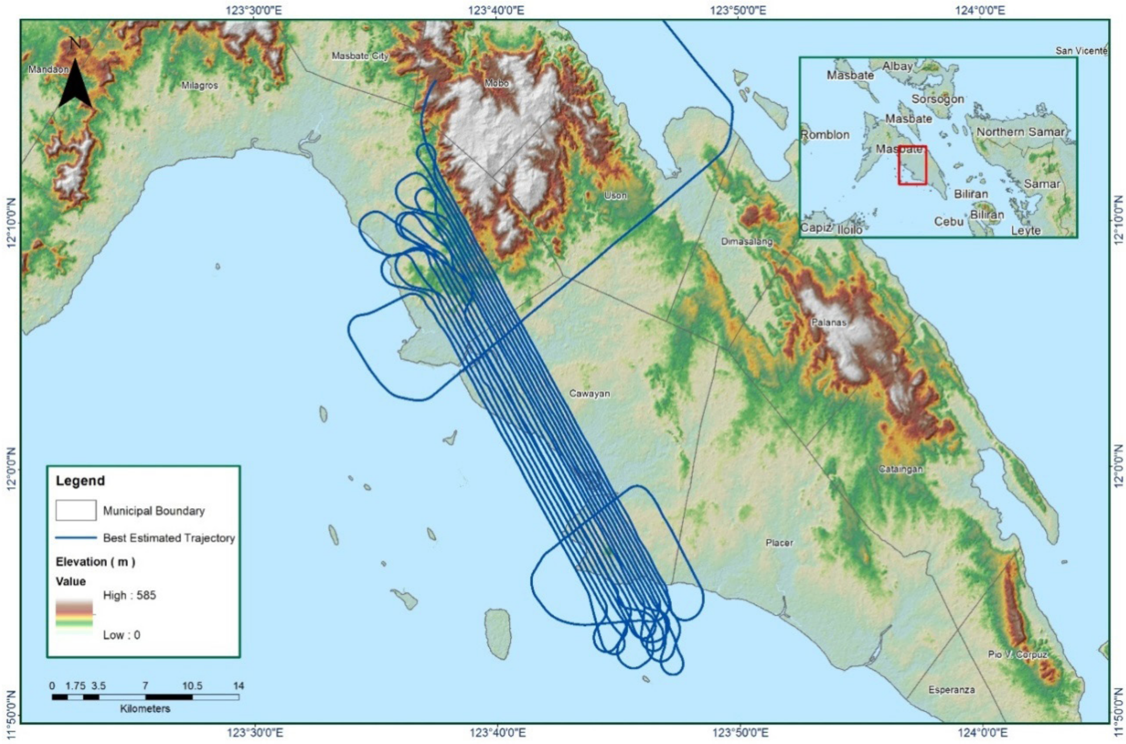


Figure A-8.3 Best Estimated Trajectory

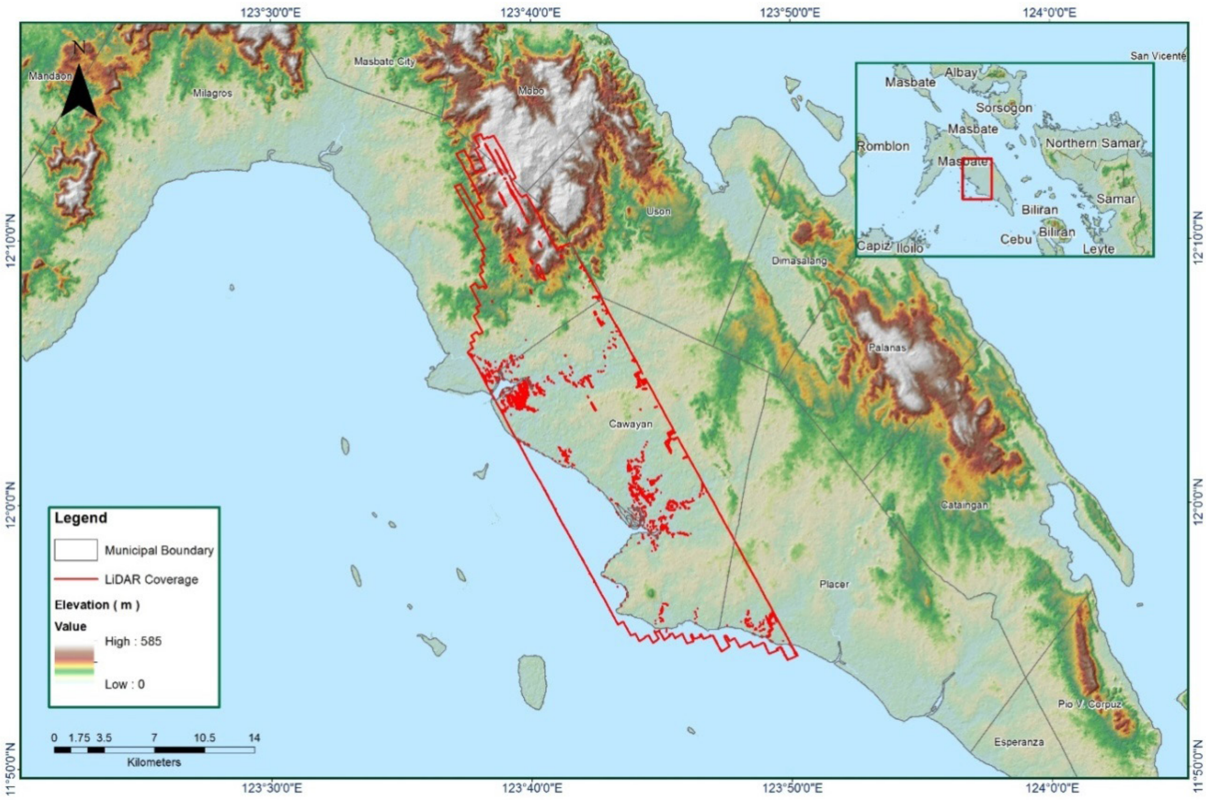


Figure A-8.4 Coverage of LiDAR data

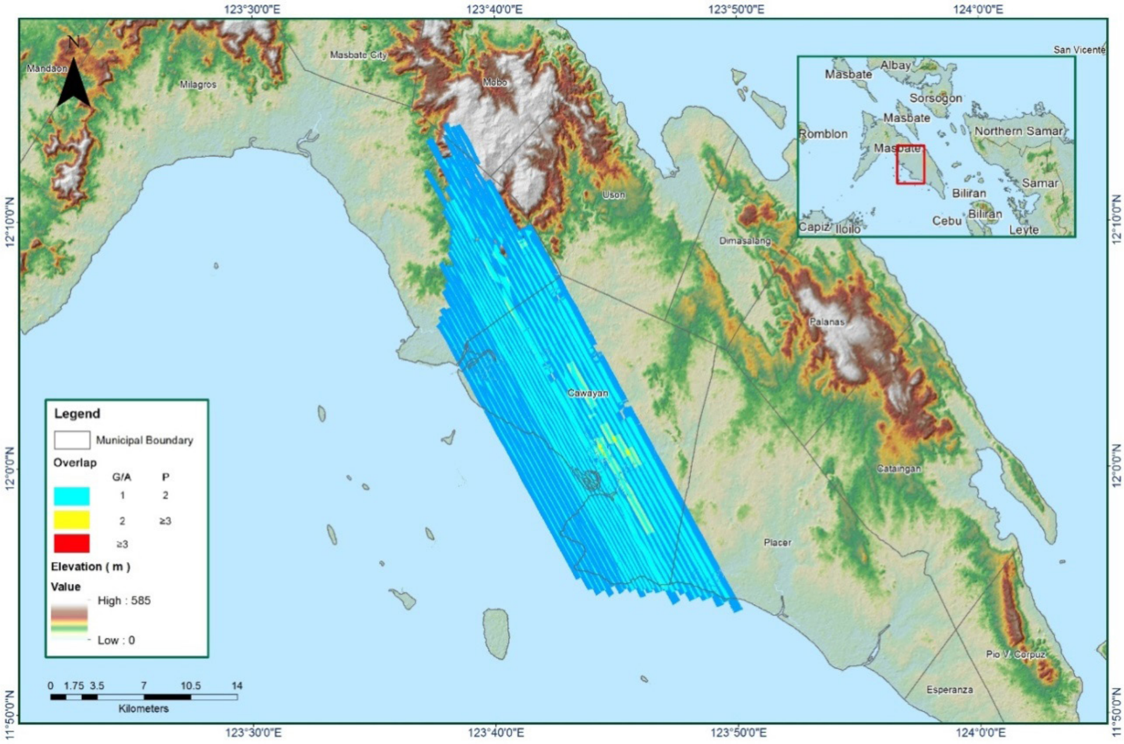


Figure A-8.5 Image of data overlap

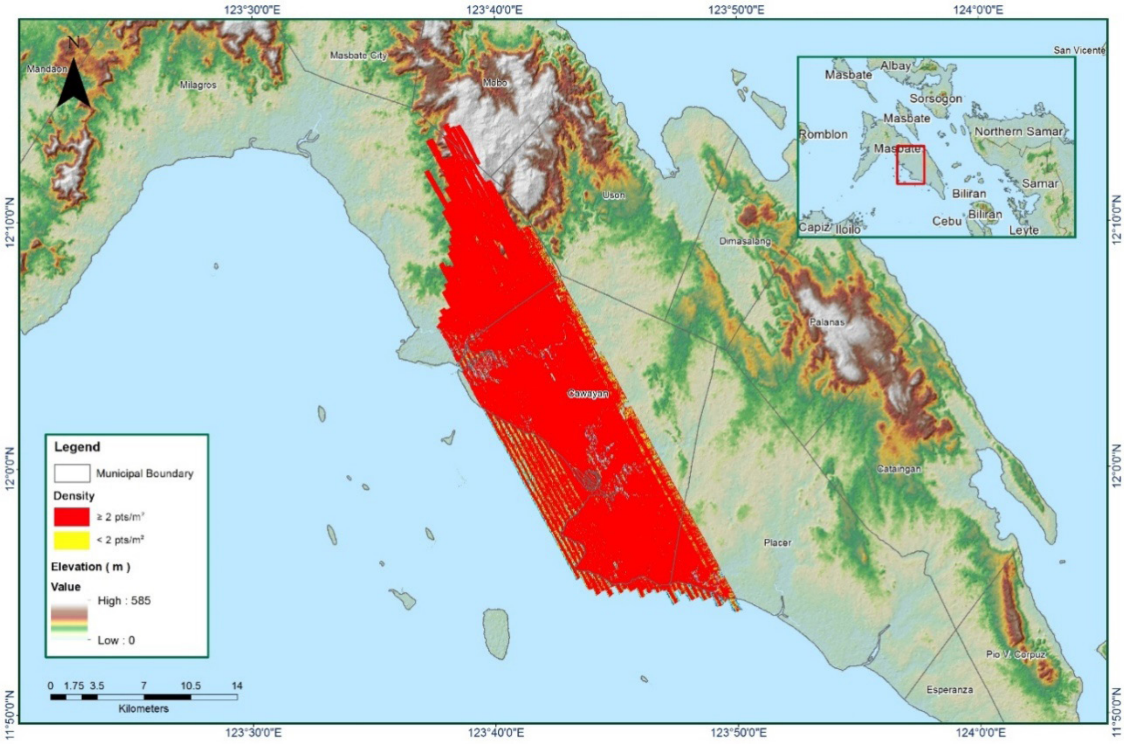


Figure A-8.6 ***Density map of merged LiDAR data***

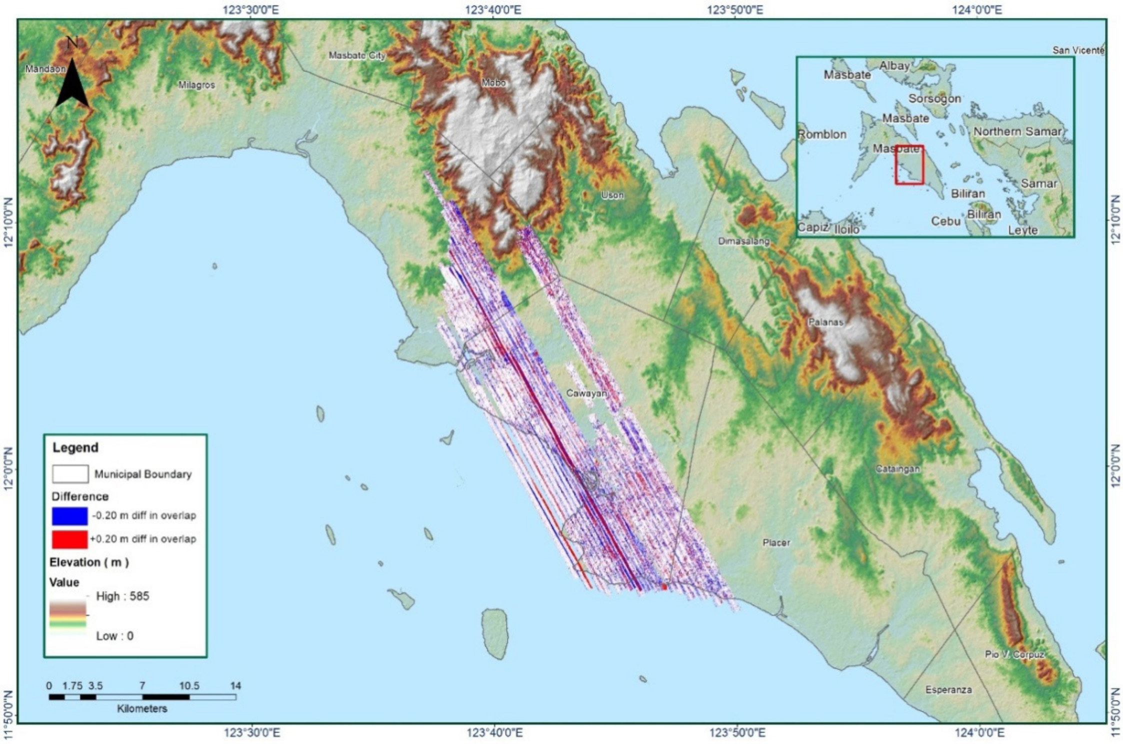


Figure A-8.7 ***Elevation difference between flight lines***

Table A-8.2 Mission Summary Report for Mission Blk 32D

Flight Area	Masbate
Mission Name	**Blk 32D**
Inclusive Flights	1307P, 1327P
Mission Name	1BLK32DG095A, 1BLK32D100A
Range data size	59.4 GB
Base data size	11.76 MB
POS	446 MB
Image	63.9 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)	1.07
RMSE for East Position (<4.0 cm)	1.65
RMSE for Down Position (<8.0 cm)	3.22
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)	53.97%
Ave point cloud density per sq.m. (>2.0)	3.54
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	421
Maximum Height	847.76
Minimum Height	47.46
Classification (# of points)	
Ground	408478727
Low vegetation	335594682
Medium vegetation	504152982
High vegetation	367118997
Building	5625146
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Regis Guhit-ing, Engr. Chelou Prado, Engr. Gladys Mae Apat

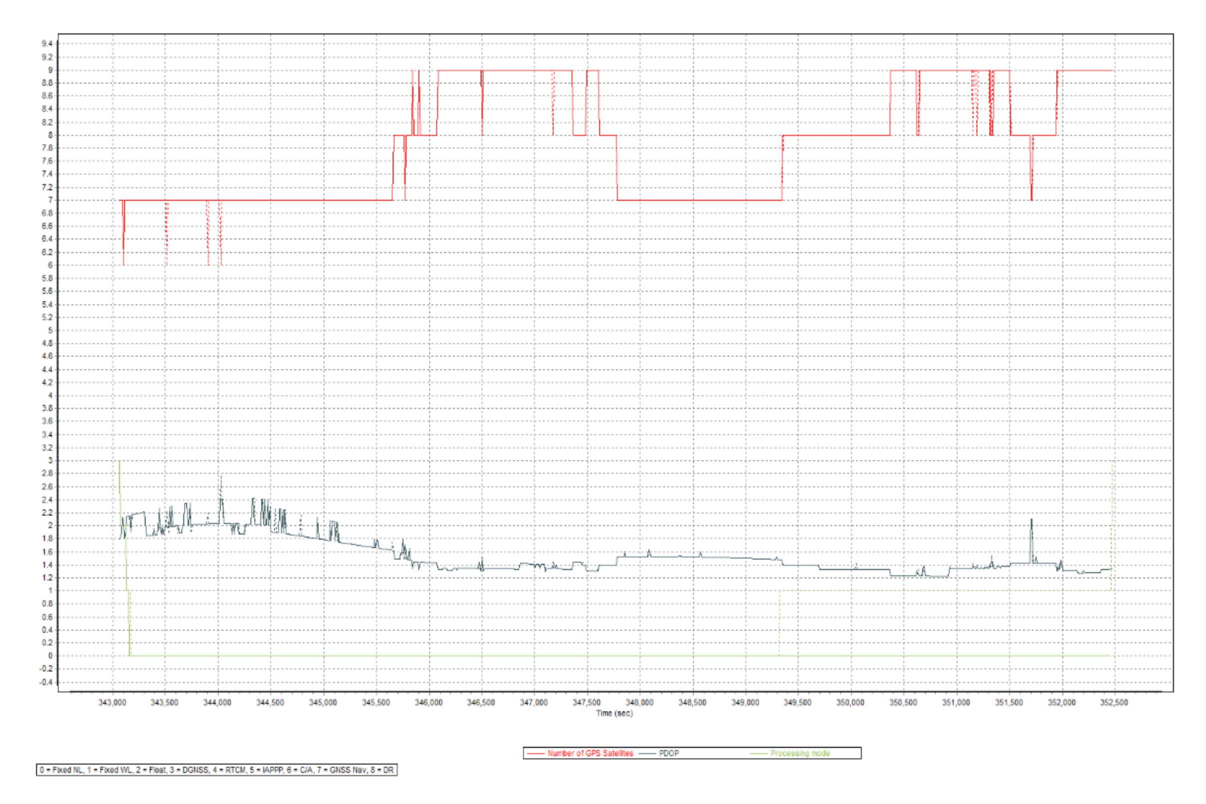


Figure A-8.8 Solution Status

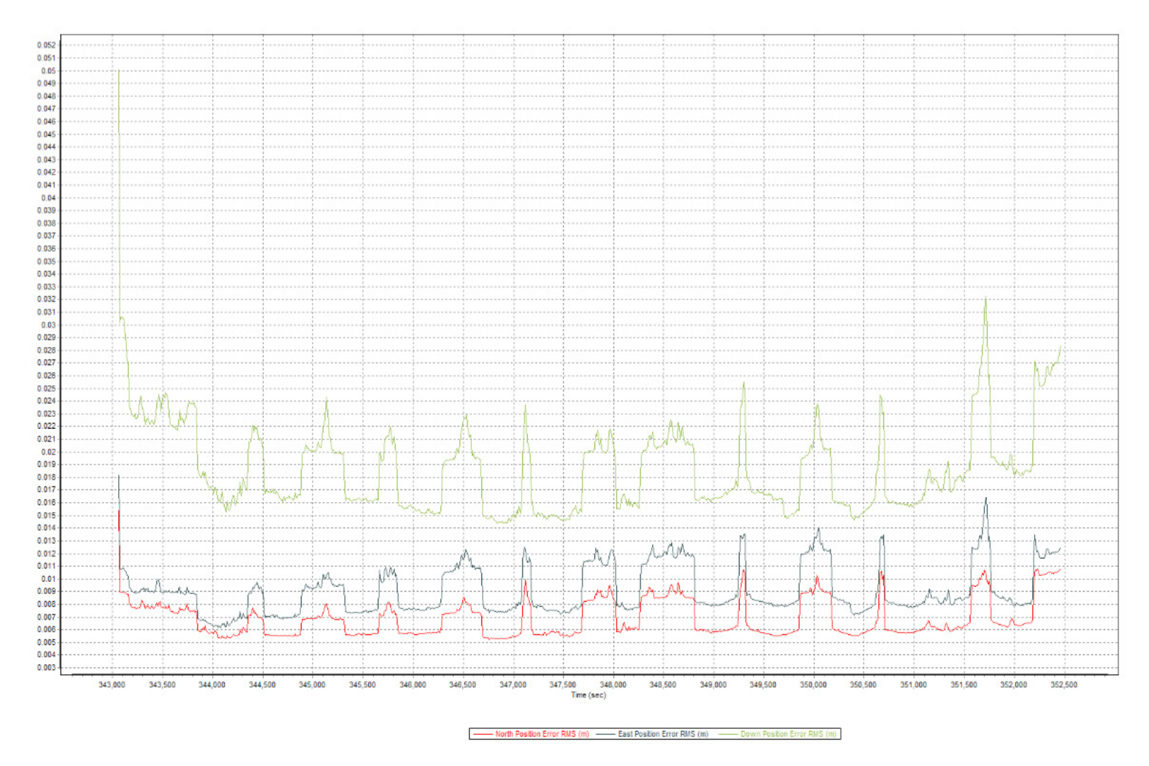


Figure A-8.9 ***Smoothed Performance Metric Parameters***

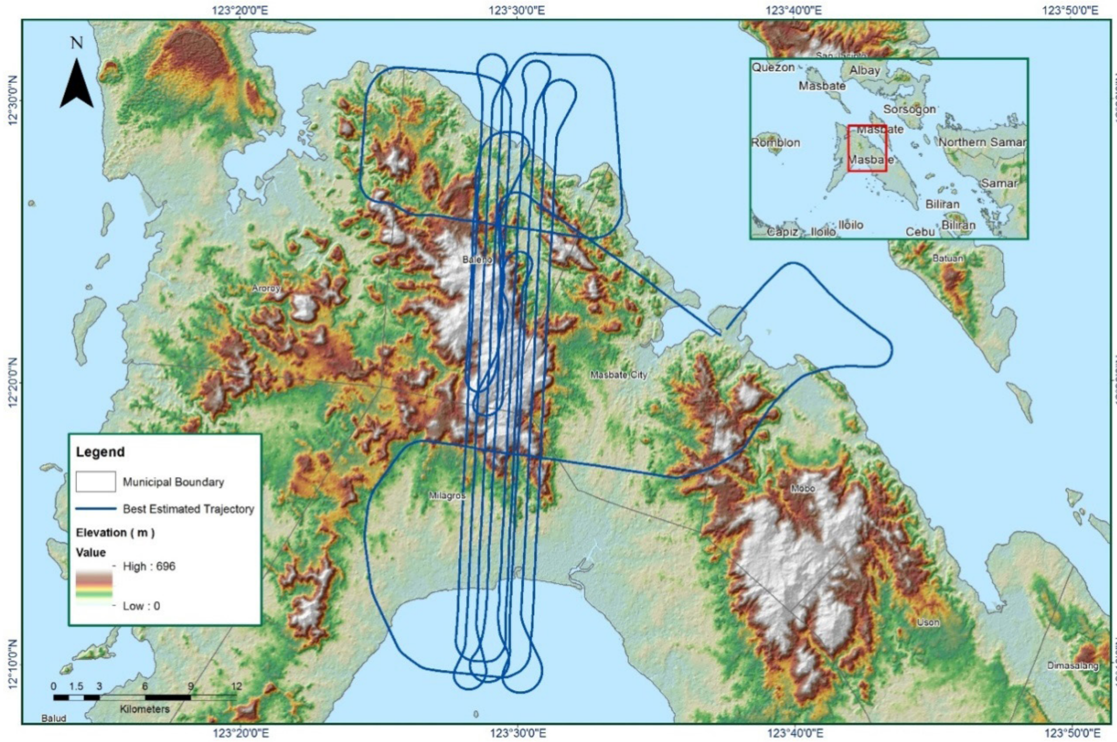


Figure A-8.10 ***Best Estimated Trajectory***

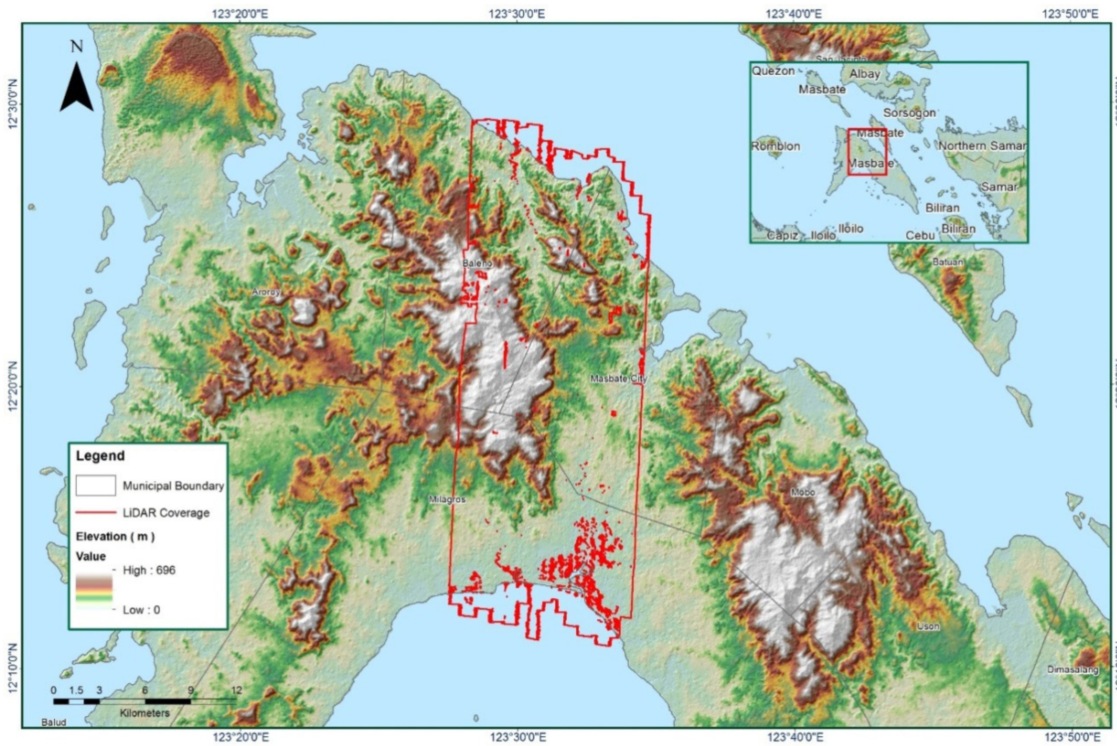


Figure A-8.11 ***Coverage of LiDAR data***

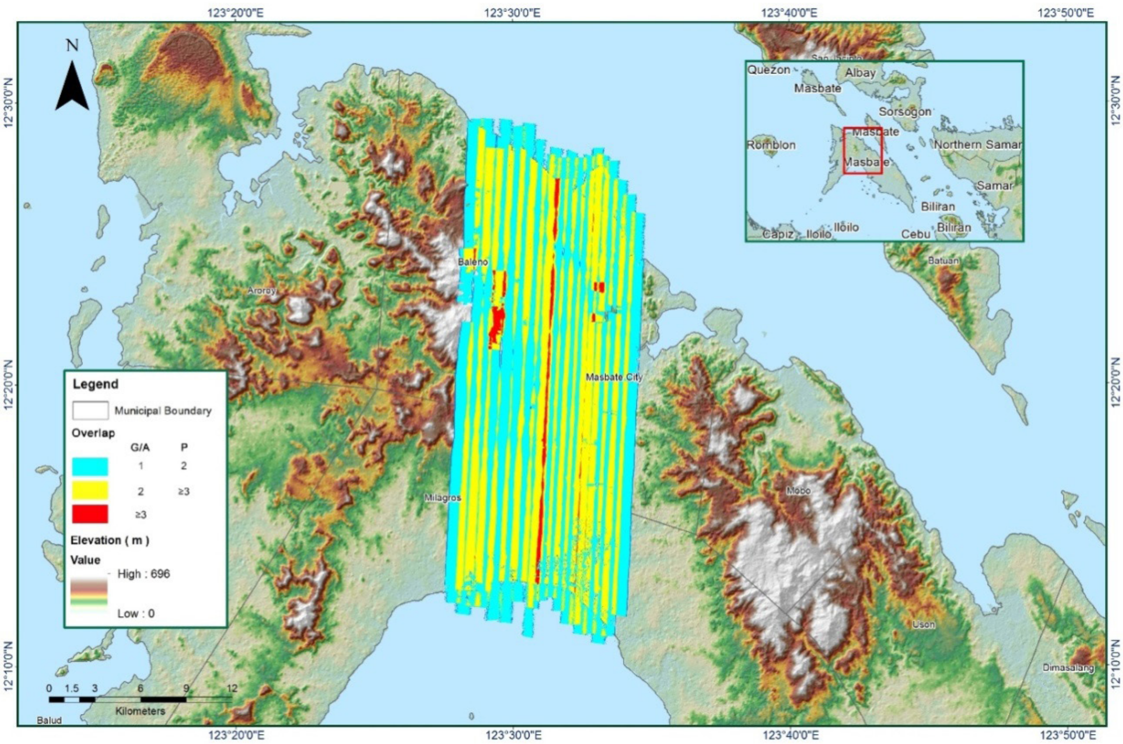


Figure A-8.12 ***Image of data overlap***

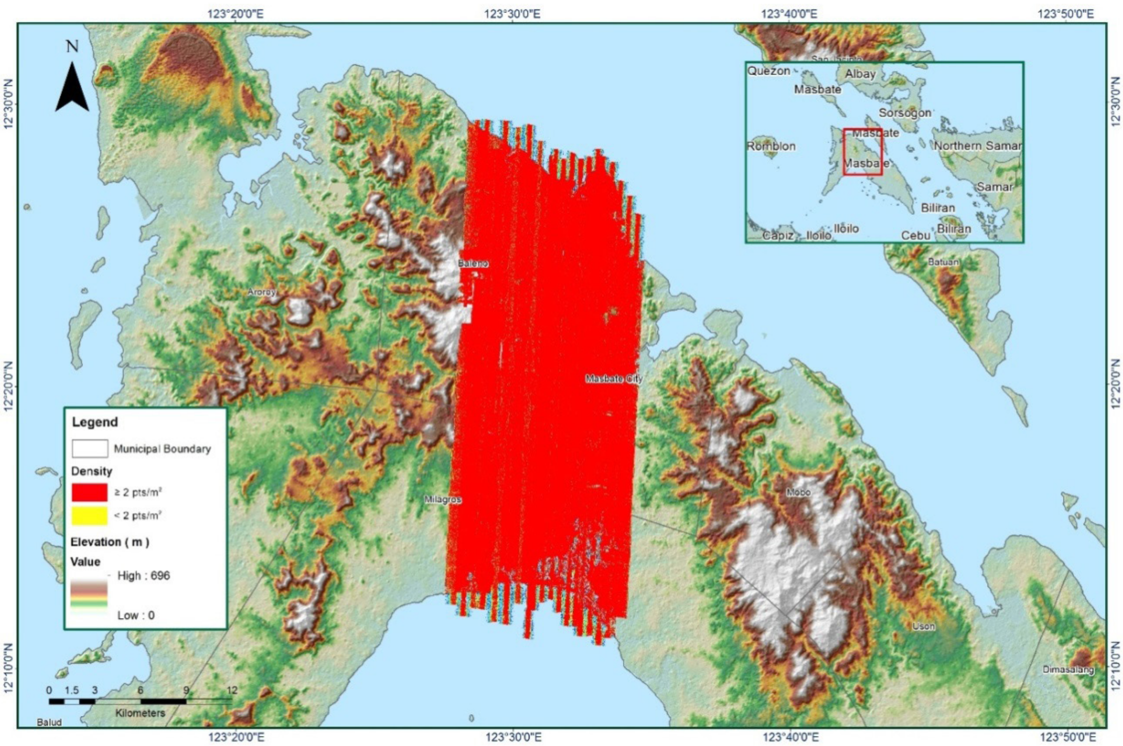


Figure A-8.13 ***Density map of merged LiDAR data***

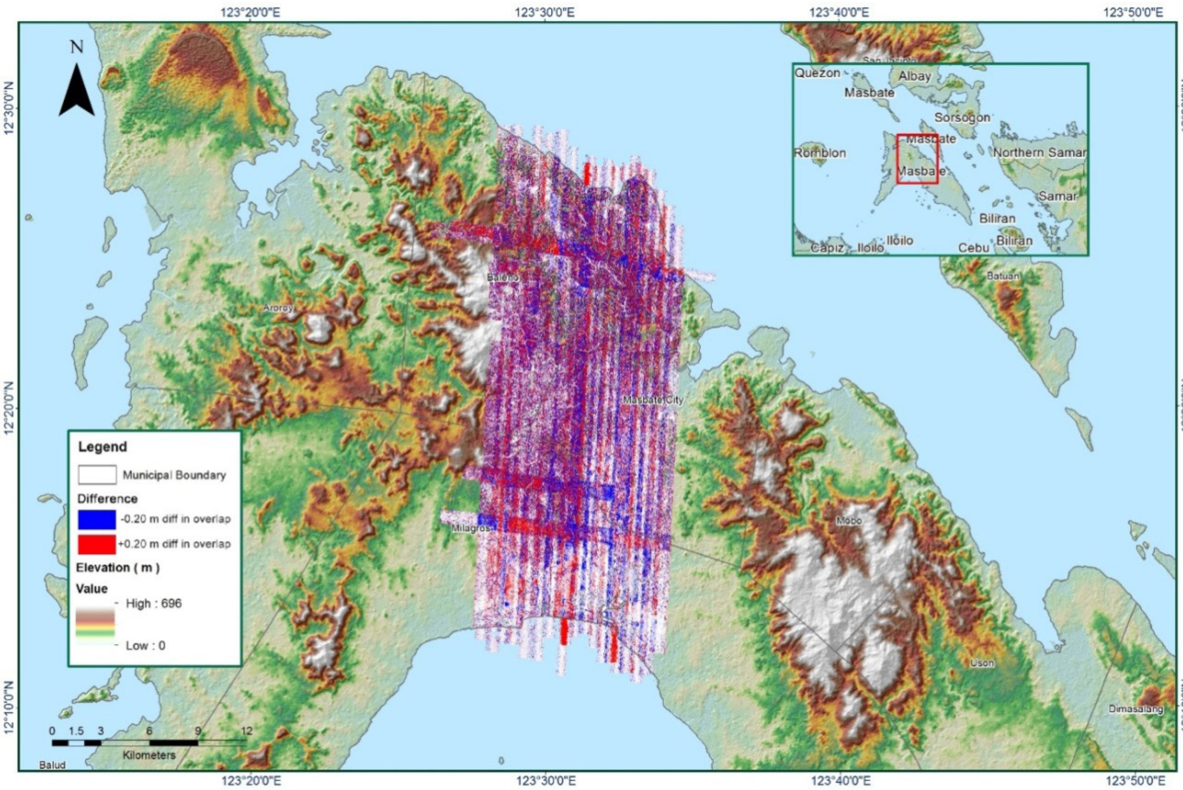


Figure A-8.14 Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Mission Blk 32E

Flight Area	Masbate
Mission Name	**Blk 32E**
Inclusive Flights	1241P, 1243P , 1275P, 1295P
Mission Name	1BLK32E078A, 1BLK32E079A, 1BLK32HI087A, 1BLK32E092A
Range data size	77.6 GB
Base data size	18.767 MB
POS	839 MB
Image	166.9 GB
Transfer date	April 22, 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	3.0
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	5.5
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)	54.63%
Ave point cloud density per sq.m. (>2.0)	4.83
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	349
Maximum Height	468.75m
Minimum Height	53.61m
Classification (# of points)	
Ground	445,560,056
Low vegetation	437,936,875
Medium vegetation	623,304,708
High vegetation	325,965,918
Building	8,257,766
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Irish Cortez, Engr. Melanie Hingpit, Engr. Gladys Mae Apat

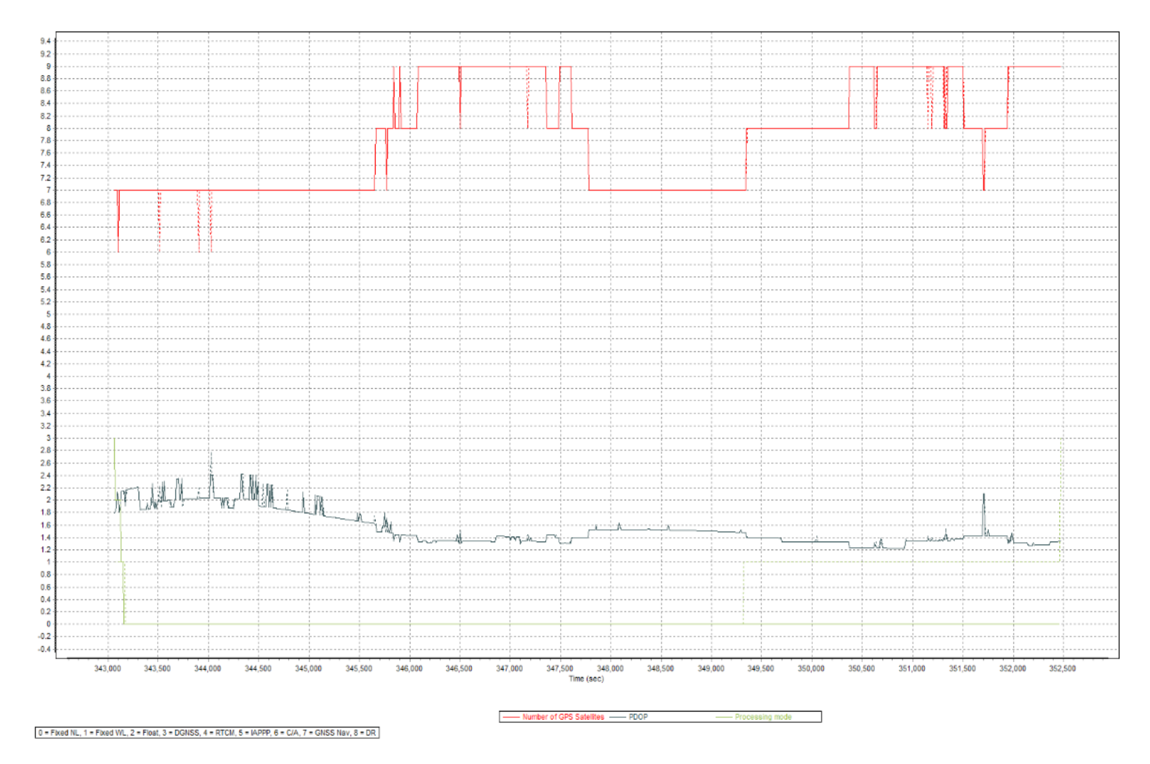


Figure A-8.15 Solution Status

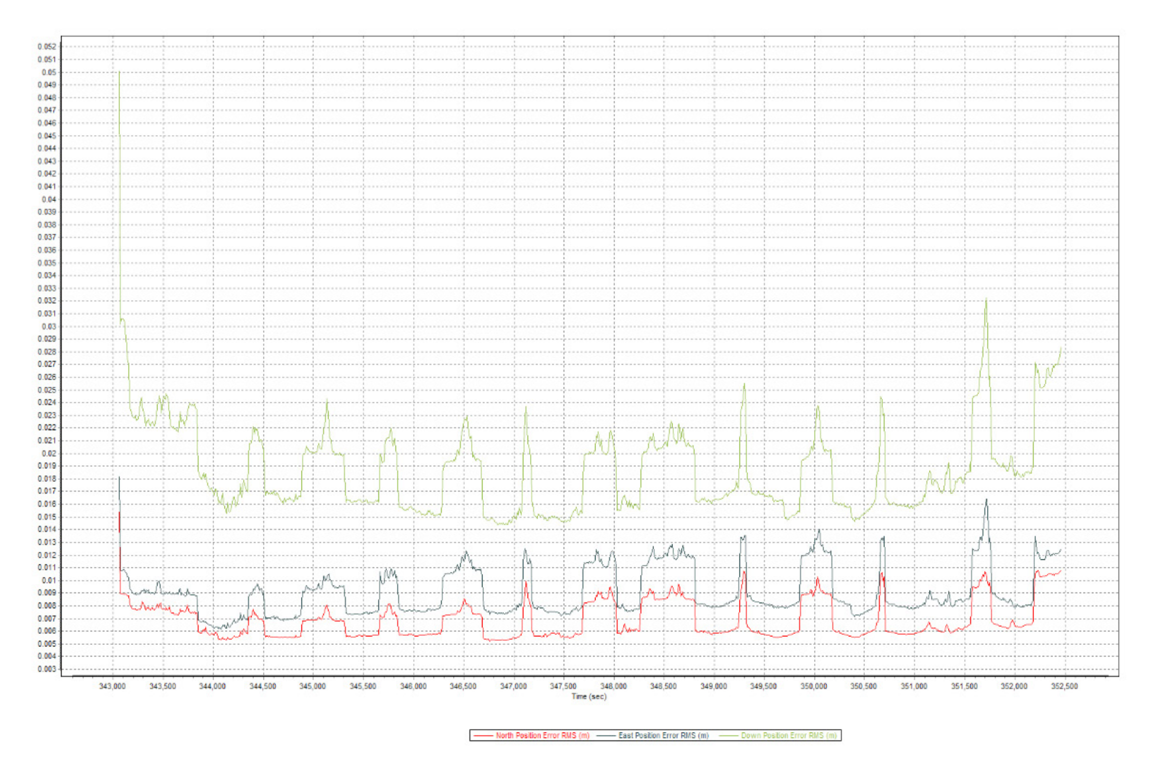


Figure A-8.16 ***Smoothed Performance Metric Parameters***

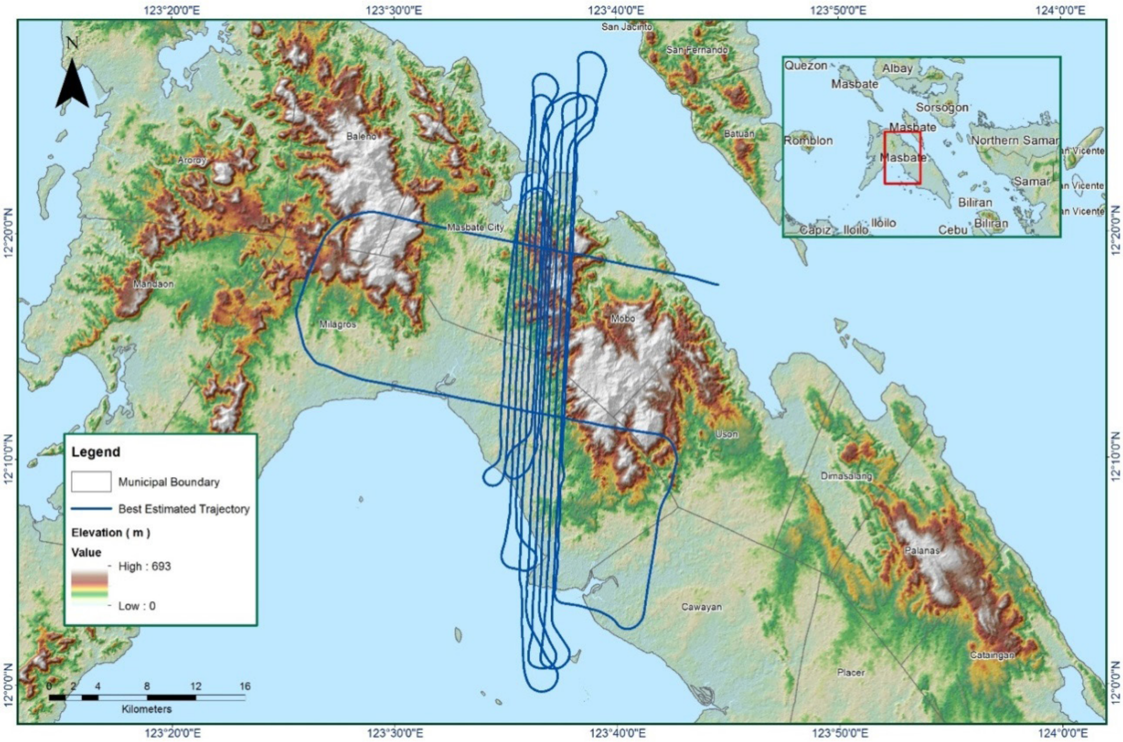


Figure A-8.17 ***Best Estimated Trajectory***

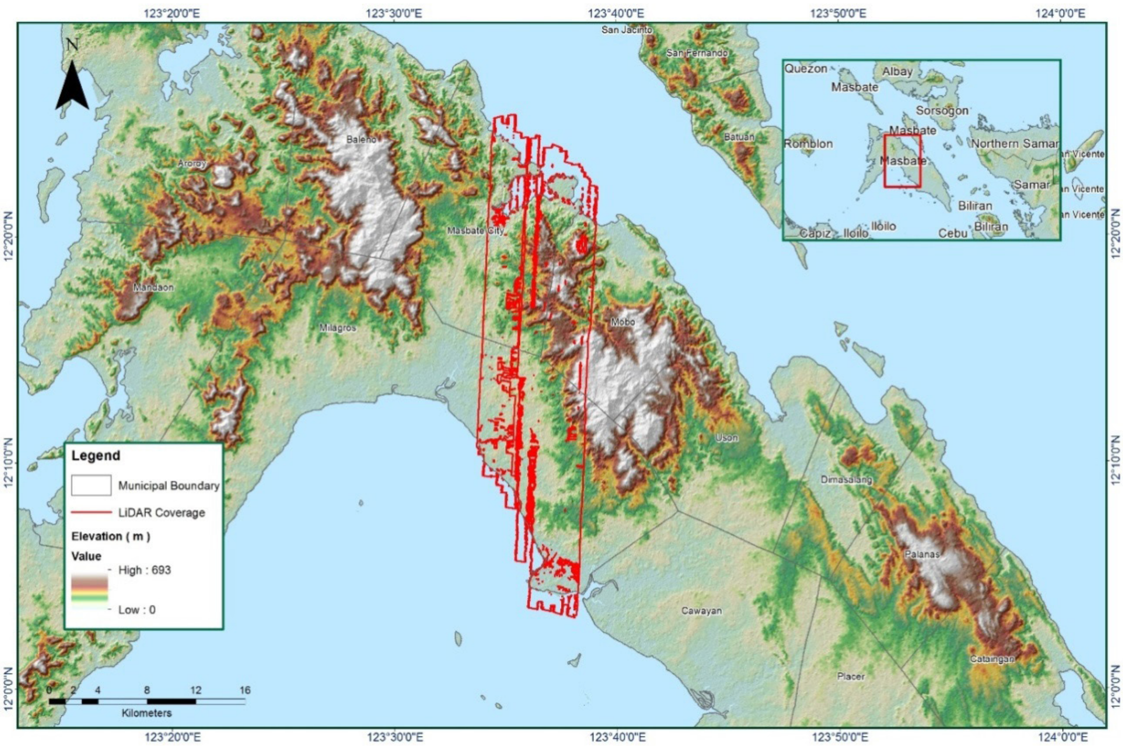


Figure A-8.18 ***Coverage of LiDAR data***

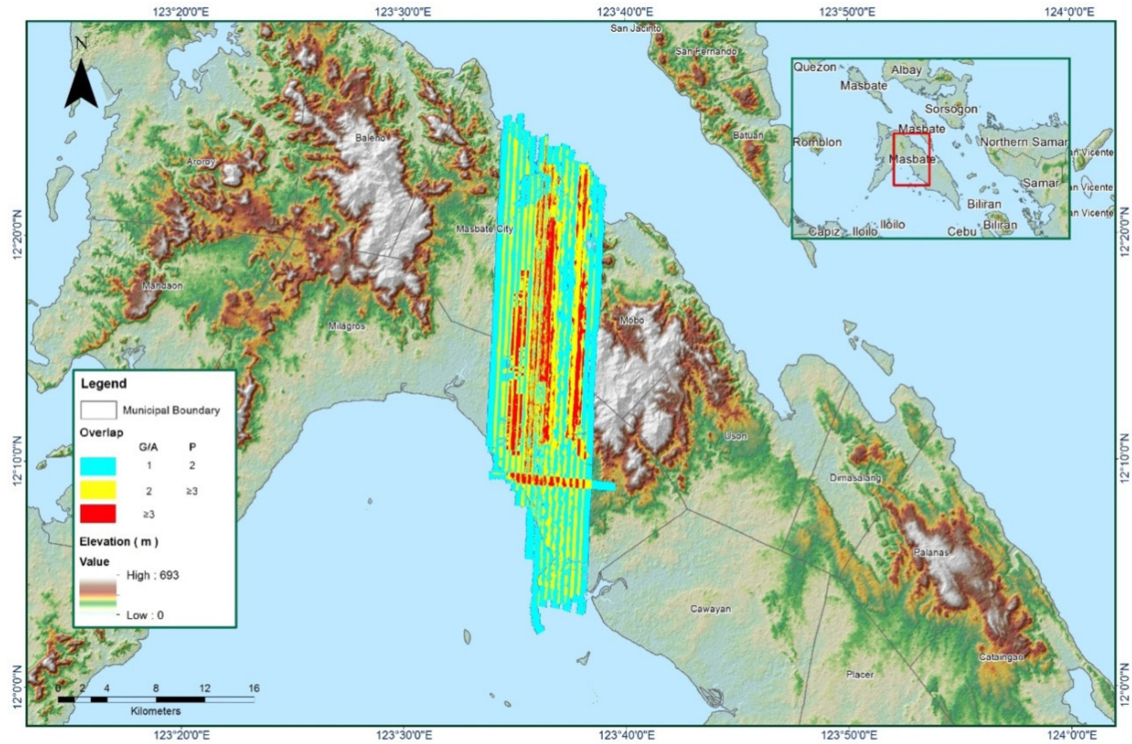


Figure A-8.19 ***Image of data overlap***

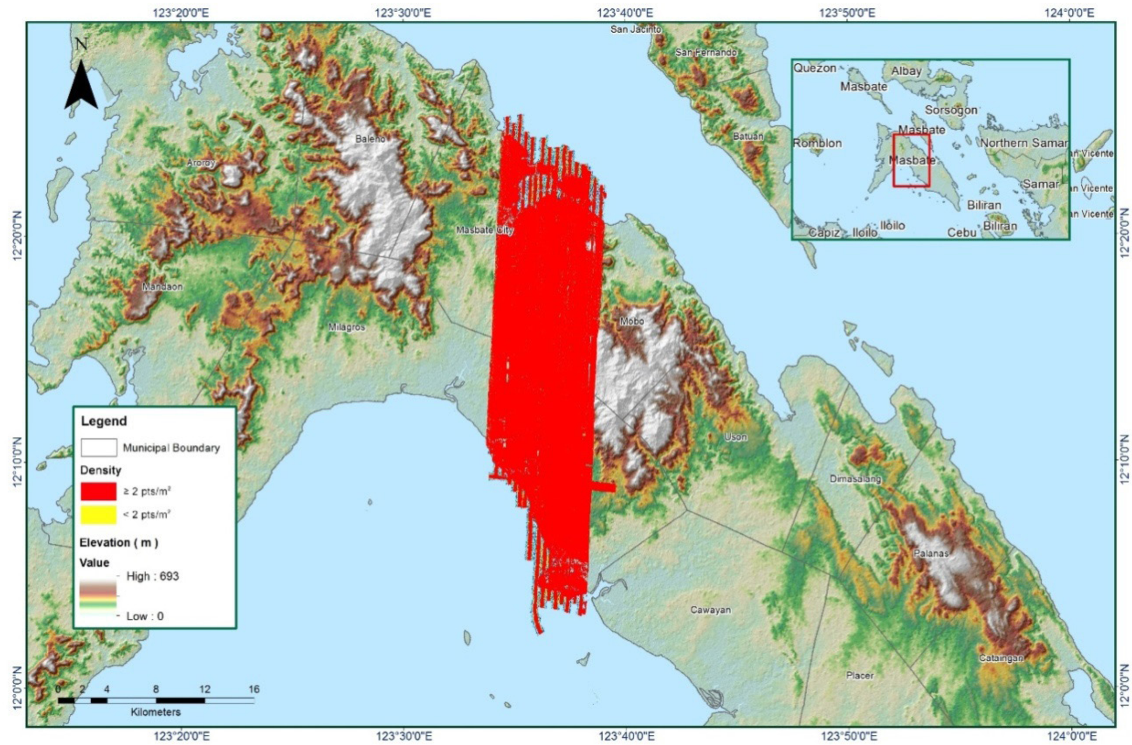


Figure A-8.20 ***Density map of merged LiDAR data***

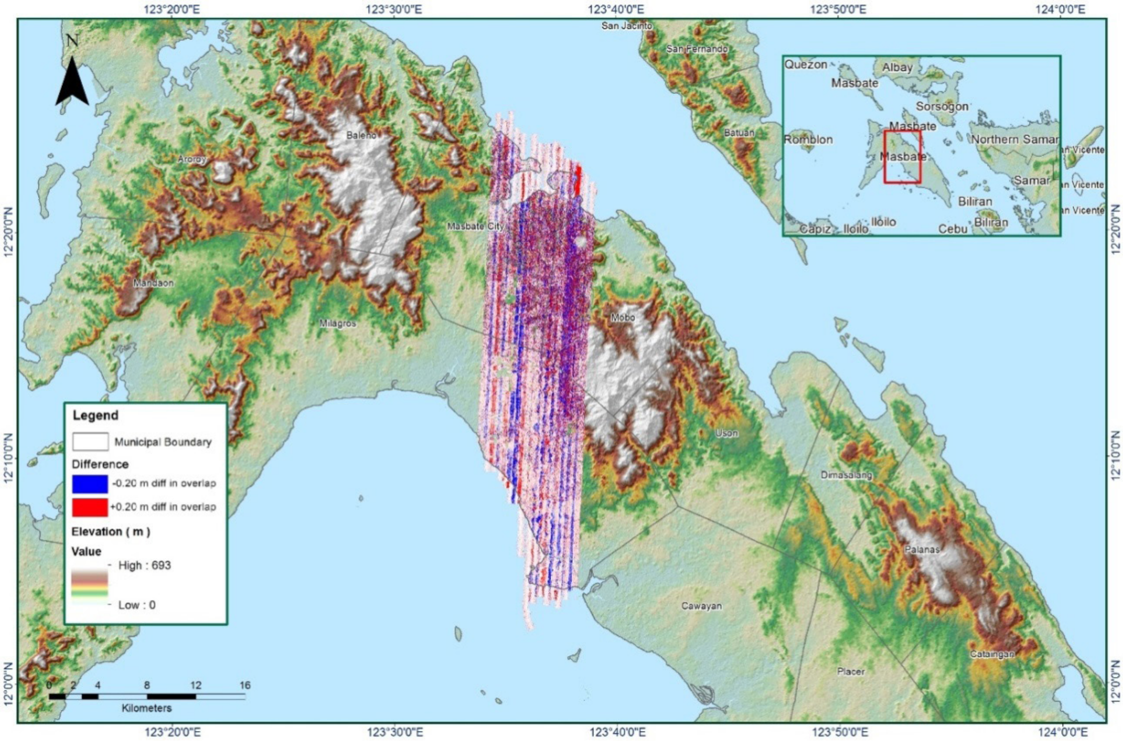


Figure A-8.21 ***Elevation difference between flight lines***

Annex 9. Asid Model Basin Parameters

Table A-9.1. Asid Model Basin Parameters

Basin Number	Curve Number Loss			Clark Unit Hydrograph Transform		Recession Base flow				
	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
W240	0.020	41.257	0	0.020	0.02000	Discharge	0.0010	0.62755	Ratio to Peak	0.96628
W250	6.469	44.749	0	0.017	0.01667	Discharge	0.0001	0.25081	Ratio to Peak	0.99500
W260	5.237	64.142	0	14.176	6.55030	Discharge	0.0002	0.00001	Ratio to Peak	0.68267
W270	0.013	71.999	0	0.020	0.02000	Discharge	0.0001	0.66002	Ratio to Peak	0.98000
W280	5.732	65.515	0	14.370	11.91700	Discharge	0.0002	0.18377	Ratio to Peak	0.62755
W290	3.314	98.821	0	5.860	4.10560	Discharge	0.0003	0.88200	Ratio to Peak	0.95082
W300	3.068	99.000	0	4.247	4.57430	Discharge	0.0005	0.93649	Ratio to Peak	0.99500
W310	12.058	96.525	0	17.269	6.24590	Discharge	0.0001	0.36665	Ratio to Peak	0.57624
W320	3.257	79.362	0	4.673	6.99060	Discharge	0.0002	0.99000	Ratio to Peak	0.99499
W330	3.532	73.648	0	1.943	3.47180	Discharge	0.0003	1.00000	Ratio to Peak	0.94603
W340	5.148	58.060	0	27.475	6.00900	Discharge	0.0009	0.00013	Ratio to Peak	0.99996
W350	4.305	64.766	0	16.774	11.14300	Discharge	0.0011	0.00001	Ratio to Peak	1.00000
W360	19.287	39.565	0	17.742	9.36500	Discharge	0.0004	0.01142	Ratio to Peak	1.00000
W370	3.202	41.645	0	29.466	0.01667	Discharge	0.0003	1.00000	Ratio to Peak	1.00000
W380	4.771	52.912	0	10.376	1000.000	Discharge	0.0003	1.00000	Ratio to Peak	1.00000
W390	14.648	41.848	0	16.425	33.26000	Discharge	0.0002	0.01719	Ratio to Peak	1.00000
W400	5.815	60.234	0	40.411	48.30200	Discharge	0.0002	0.00001	Ratio to Peak	1.00000
W410	19.273	40.577	0	188.080	120.8700	Discharge	0.0007	0.01599	Ratio to Peak	1.00000
W420	6.071	68.404	0	13.365	9.29370	Discharge	0.0001	0.00001	Ratio to Peak	0.99740
W430	0.234	55.231	0	16.760	26.39400	Discharge	0.0000	0.00030	Ratio to Peak	0.88254
W440	39.491	52.872	0	14.438	117.3000	Discharge	0.0003	0.00740	Ratio to Peak	0.69546
W450	3.395	68.745	0	16.895	3.17070	Discharge	0.0004	0.00001	Ratio to Peak	0.03747
W460	4.766	60.315	0	49.128	10.65800	Discharge	0.0000	0.00042	Ratio to Peak	0.99976

Annex 10. Asid Model Reach Parameters

Table A-10.1. Asid Model Reach Parameters

Muskingum-Cunge Channel Routing							
Reach Number	Time Step Method	Length (m)	Slope (m/m)	Man-ning's n	Shape	Width (m)	Side Slope
R40	Automatic Fixed Interval	1599.9	0.00740	0.18543	Trapezoid	20.168	1
R70	Automatic Fixed Interval	864.0	0.00540	1.00000	Trapezoid	20.168	1
R80	Automatic Fixed Interval	4087.9	0.00517	1.00000	Trapezoid	20.168	1
R100	Automatic Fixed Interval	1408.1	0.00133	0.32379	Trapezoid	20.168	1
R130	Automatic Fixed Interval	2571.8	0.00333	1.00000	Trapezoid	20.168	1
R160	Automatic Fixed Interval	808.1	0.00114	0.08359	Trapezoid	20.168	1
R170	Automatic Fixed Interval	3375.1	0.0028083	1	Trapezoid	20.168	1
R180	Automatic Fixed Interval	9761.6	0.0020538	0.90265	Trapezoid	20.168	1
R190	Automatic Fixed Interval	900.12	0.0011651	0.25955	Trapezoid	20.168	1
R200	Automatic Fixed Interval	475.19	0.001	0.12307	Trapezoid	20.168	1
R210	Automatic Fixed Interval	7319.8	0.0030878	0.995	Trapezoid	20.168	1

Annex 11. Asid Field Validation Points

Table A-11.1. Asid Field Validation Points

ASID				
ID	Latitude	Longitude	Flood Depth	Accuracy (m)
1	12.22133998	123.5072443	0.14	8
2	12.22136212	123.5070485	0.18	6
3	12.22164213	123.5059917		4
4	12.22106652	123.5078138	0.4	4
5	12.22100516	123.5078775	0	4
6	12.22173275	123.5080044	0	6
7	12.22284701	123.5089462	0	8
8	12.22318238	123.5080984		6
9	12.22289516	123.5082423	0	8
10	12.22445832	123.5081666	0	6
11	12.22680492	123.5084905	0	6
12	12.22899632	123.5077142	0.16	4
13	12.2294701	123.5074973	0	4
14	12.23129049	123.5052982	0	12
15	12.23148582	123.5060823	0.1	12
16	12.31178414	123.5580237		6
17	12.29996228	123.5549391	0	6
18	12.29460437	123.5530814		6
19	12.29036334	123.5520191	0.3	6
20	12.29030145	123.5521894	0	6
21	12.28714102	123.5504356	0	8
22	12.28532833	123.5497768	0.46	8
23	12.28522341	123.5494581	0.74	8
24	12.28489928	123.5503467	0	12
25	12.2786153	123.5467382	0	6
26	12.28056692	123.5423196	0	6
27	12.27594811	123.5449228	0	6
28	12.27415115	123.5436857	0	6
29	12.274025	123.543612	0	6
30	12.27375689	123.5434292	0.4	8
31	12.27345989	123.5432125	0	6
32	12.27246522	123.5424468	0	12
33	12.26962807	123.5407001	0	6
34	12.26912474	123.5413131	0	6
35	12.26676796	123.5434193		12
36	12.2682841	123.5408904	0	6
37	12.26852973	123.5402298	0	4
38	12.26821544	123.5400602	0	6
39	12.26773778	123.539867	0	4
40	12.26666091	123.5390397	0	6
41	12.266264	123.5387791	0	8

42	12.26505919	123.5381165	0	6
43	12.26016375	123.5345552	0	4
44	12.25379134	123.5297864	0	4
45	12.2535989	123.529528	0.7	4
46	12.25311993	123.5290319	0	4
47	12.25068066	123.5302342	0	8
48	12.25154666	123.5297159		8
49	12.25115386	123.5294646	0	4
50	12.25168668	123.5270503		8
51	12.25152335	123.5270904	0	6
52	12.25223575	123.5267631	0.3	12
53	12.25293161	123.5261108	0.92	8
54	12.25289695	123.525905	0.4	6
55	12.25183541	123.5259076	0.46	6
56	12.25228299	123.525473	0.43	8
57	12.25151133	123.5263031	0	8
58	12.2479618	123.5246602	0	6
59	12.24800758	123.5230475	0.4	4
60	12.24548288	123.5196236	0	8
61	12.24413086	123.5178523	0	12
62	12.240587	123.5090681	0	6
63	12.23793308	123.50693	0.76	8
64	12.23473935	123.5064176	0	6
65	12.21737333	123.50739	0	2.700000048
66	12.218445	123.501345	0.5	3.900000095
67	12.21844833	123.5018133	0.4	2.299999952
68	12.21831167	123.5027117	0	2.599999905
69	12.21825167	123.5032217	0.3	2.099999905
70	12.21777167	123.503115	0.4	3
71	12.21823333	123.50345	0.4	2.200000048
72	12.21827167	123.5043617	0	3.400000095
73	12.21821667	123.5047817	0.3	2.599999905
74	12.21833167	123.5049267	1.43	2
75	12.21809167	123.505835	0	2.5
76	12.21800333	123.5064183	0	2.200000048
77	12.218325	123.5075267	0.09	2.700000048
78	12.219565	123.5076183	0	2.5
79	12.21907333	123.5101233	0	2
80	12.21894	123.5110033	0	3.200000048
81	12.21789333	123.510945	0.4	2.299999952
82	12.21750833	123.5102433	0.3	4.300000191
83	12.21686167	123.5107883	0	2.5
84	12.21862	123.508265	0	2.099999905
85	12.21804667	123.51302	0	2.299999952
86	12.21784167	123.5125633	0	2.200000048
87	12.21785833	123.5129033	0	2.700000048

88	12.217935	123.5132067	0.06	4.599999905
89	12.21738333	123.5142617	0.2	3
90	12.21679833	123.5141633	0	2.900000095
91	12.21797167	123.5153183	0.4	4.599999905
92	12.21668333	123.5184817	0	3.700000048
93	12.21748333	123.5178133	0.85	2.599999905
94	12.21563833	123.5238533	0	3.299999952
95	12.21704	123.5252533	0	4.099999905
96	12.21673	123.5256133	0	2.700000048
97	12.21805667	123.5295733	0	2.299999952
98	12.21911	123.5301617	0.4	2.900000095
99	12.21914167	123.5299317	0	2.799999952
100	12.21924833	123.52983	0.4	2.700000048
101	12.21931833	123.52979	0.8	2.900000095
102	12.219265	123.5296567	0.8	2.099999905
103	12.219265	123.5295117	0.3	3
104	12.21900667	123.5288967	0	2.400000095
105	12.21887167	123.5286883	0.4	2.200000048
106	12.21889167	123.5283483	0.4	3
107	12.21852167	123.527895	0.8	2.400000095
108	12.21847333	123.527565	0.6	2.799999952
109	12.21956	123.5299217	0.4	2.900000095
110	12.21788333	123.53036	0.2	4.199999809
111	12.216075	123.5306867	0.4	2.5
112	12.21566167	123.5309183	0.2	2.400000095
113	12.21669833	123.5300733	0	2.599999905
114	12.21686333	123.530095	0.24	3.400000095
115	12.26394833	123.5602133	1.1	3.200000048
116	12.26393	123.56015	0.84	2.400000095
117	12.244415	123.5739067	1.1	2.400000095
118	12.24457667	123.5738617	0.75	2.400000095
119	12.244325	123.574705	1.3	2.599999905
120	12.24394833	123.57468	0.7	2.299999952
121	12.232405	123.5622667	0.1	2.799999952
122	12.23233667	123.562265	0	3
123	12.23225667	123.5787533	0	2.099999905
124	12.22899333	123.580565	1	2.200000048
125	12.22729333	123.5822317	0.1	2.5
126	12.21579833	123.5691167	0	2.099999905
127	12.221415	123.5626583	0	3.299999952
128	12.22532667	123.5459067	0	2.299999952
129	12.22524833	123.5462683	0.2	3.099999905
130	12.225115	123.5463017	0.4	3.299999952
131	12.22509	123.5463017	0.2	3.099999905
132	12.22507167	123.546385	0.2	2.5
133	12.22500167	123.54669	0.5	4.900000095

134	12.2251	123.5467217	0.1	4.800000191
135	12.22390833	123.5473583	0	2.400000095
136	12.22503167	123.5523683	0	2.099999905
137	12.22534333	123.5540633	0	2.599999905
138	12.246895	123.5768317	0.9	5.699999809
139	12.26574667	123.59005	0	3.099999905
140	12.27142833	123.5910483	0.1	3
141	12.29073333	123.59523	0	2.5
142	12.291205	123.59467	0	2
143	12.29331	123.59277	0	2.599999905

Annex 12. Educational Institutions Affected in Asid Floodplain

Table A-12.1. Educational Institutions in Masbate City and Milagros affected by Flooding in Asid Floodplain

Masbate				
Masbate City				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Antonio Dela Rosa Elem. School Asid	Asid			
Asid City Nursery	Asid			
Renet Malvar Elem School	Asid			
A. Delos Reyes Integrated School	Cagay			
Cagay Highschool	Cagay			
Sinalongan Elem School	Cagay			
Milagros				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Amazing Progress Learning Center Bacolod Milagros	Bacolod			
Bacolod Day Care Center Milagros	Bacolod			
Daycare Center Bacolod Milagros	Bacolod			
Liceo De San Jose Bacolod Milagros	Bacolod			
Asid Elem School	Calasuche			
Calasuche Daycare Center	Calasuche			
Calasuche Elem School	Calasuche			
Cayabon Elem School	Cayabon			
HS DedEd, Masbate School of fisheries, Tesda	Cayabon			
Clemente Bajar Elem School	Jamorawon			
Dominador Trabado Elem School	Jamorawon			
Jamorawon Elem School	Jamorawon			
Jamorawon High School	Jamorawon	Medium	Medium	High
Talisay Day Care Center	Jamorawon			
Colegio De San Jose	Poblacion East			
Day Care Poblacion East	Poblacion East			
Milagros East Central School	Poblacion East			
Milagros West Central School	Poblacion East			
Poblacion East Day Care 3	Poblacion East			
Inc. Poblacion West Milagros	Poblacion West			Low
Milagros West Central School	Poblacion West			
Mopeth Christian School	Poblacion West			Low
Poblacion West Daycare Center	Poblacion West		Low	Medium
Revila Bajar National Highschool	Poblacion West		Low	Medium
Brgy Tagbon Day Care Center	Tagbon			
Brgy Tagbon Elem School	Tagbon			
Floro De Medina Hs, Sta Maria	Tagbon			
Sta. Maria Day Care Center	Tagbon			
Sta. Maria Elem School	Tagbon			
Sta. Maria Elem School	Mabuhay			

Annex 13. Medical Institutions Affected in Asid Floodplain

Table A-13.1. Medical Institutions in Masbate City and Milagros affected by Flooding in Asid Floodplain

Masbate				
Masbate City				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Cagay Health Center	Cagay			
Milagros				
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Brgy Jamorawon Health Center	Jamorawon			
BemONC Center Poblacion West Milagros	Poblacion East			
Dubongco Medical Clinic	Poblacion East			
Health Center Poblacion East	Poblacion East			
Health Center Poblacion West Milagros	Poblacion East			
BemONC Center Poblacion West Milagros	Poblacion West			
Poblacion West Health Center	Poblacion West			Medium
Brgy Tagbon Health Center	Tagbon			
Sta. Maria Health Center	Tagbon	Low	Medium	Medium