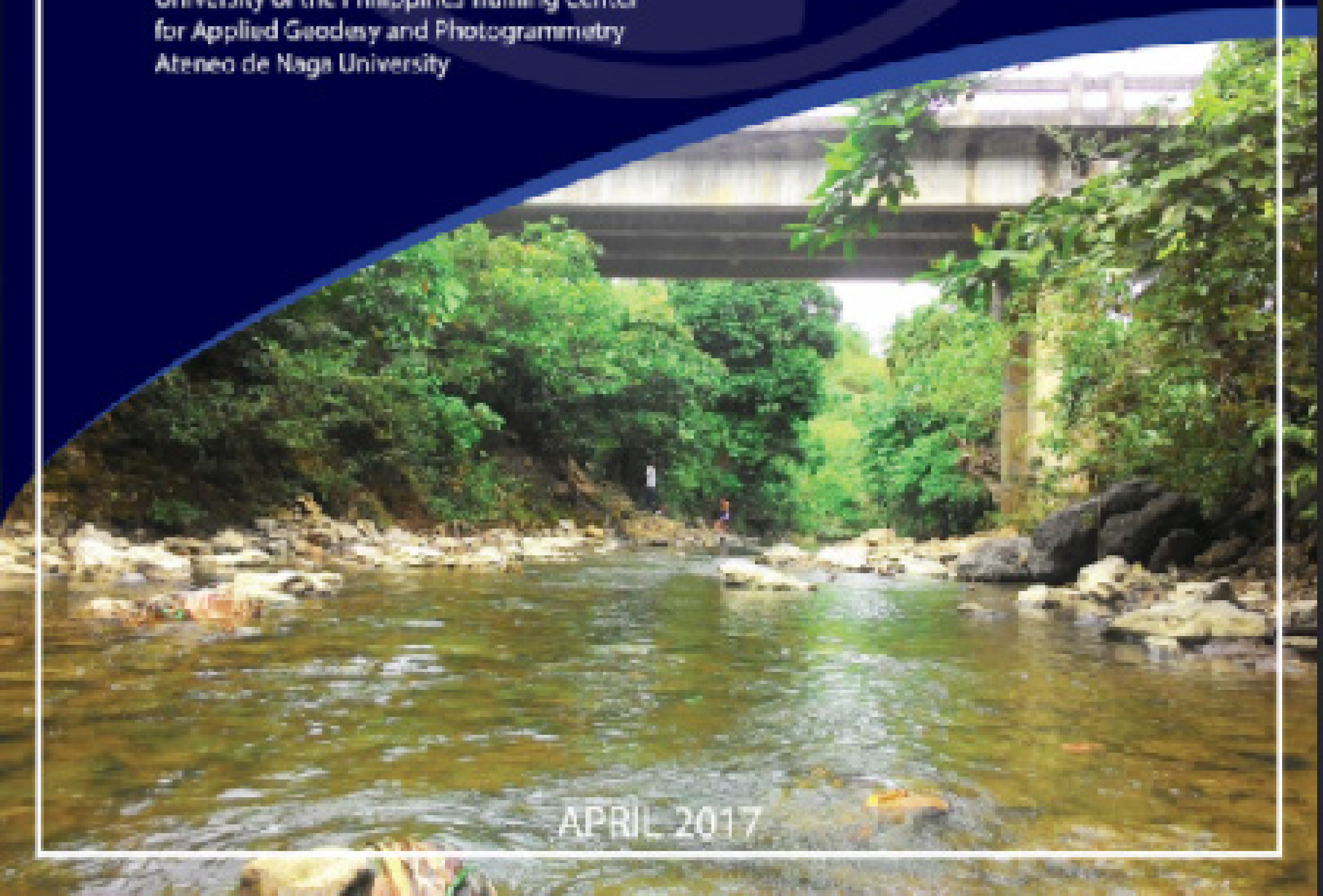
Hazard Mapping of the Philippines Using LIDAR (Phil-LIDAR 1)

LiDAR Surveys and Flood Mapping of Nainday River

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



APRIL 2017

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LIDAR SURVEYS AND FLOOD MAPPING OF NAINDAY RIVER

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND NAINDAY RIVER

Ms. Joanaviva Plopenio and Enrico C. Paringit, Dr. Eng.

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 in 2014" 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 methods applied in this report are thoroughly described in a separate publication entitled "FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et. al. 2017) available separately.

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 Nainday River Basin

The Nainday River Basin is under two (2) second class towns: Cawayan and Placer and two (2) fourth class towns: Palanas and Dimasalang. In the 2015 census, Cawayan has 67,033 population distributed in 37 barangays, Placer has 55,826 residents in 35 barangays, Palanas has 26,222 in its 24 barangays and Dimasalang with 26,192 in 20 barangays.

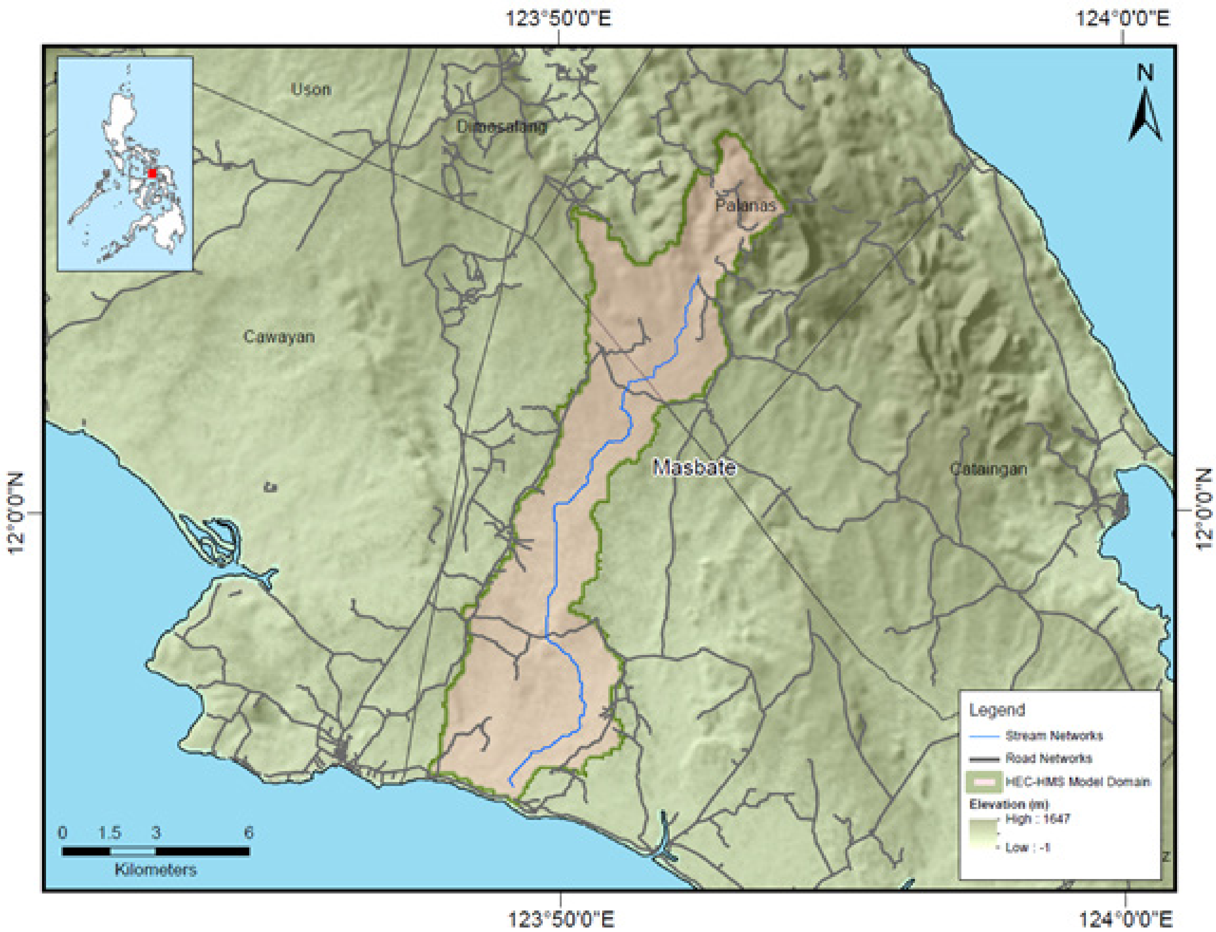

Figure 1. Map of Nainday River Basin (in brown).

The Nainday River with its estuarine in Placer, drains the basin out to the Visayan Sea. The headwater is coming from the northeast where there is a low mountain range in the towns of Palanas and Dimasalang. The Nainday River is about 72 km long. The surrounding areas are gently rolling low hills and is used for agricultural practices. There are two (2) wildlife sanctuaries in Cawayan, albeit these are islands. These are Chico Island and Naro Island Wildlife Sanctuaries. The Visayan tarictic hornbill (Penelopides panini), an endangered hornbill, is known to be distributed in four (4) islands: Panay, Guimaras, Masbate and Negros.

The area receives a relatively evenly distributed rainfall throughout the year except from November to April when it is relatively dry. This is Type III climate of the modified Corona classification of climate in the Philippines.

Almost half of the land area of the basin is cultivated while a small portion is dedicated to fishponds, particularly near the sea. Mangroves are also thriving at the estuarine. The rest of the area is brushland with some dedicated to tree plantation.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE NAINDAY 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

To initiate the LiDAR acquisition survey of the Nainday floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Nainday Floodplain in Masbate. These flight missions were planned for 10 lines and ran for at most three hours and twenty minutes (3.33 hours) including take-off, landing and turning time. The flight planning parameters for the LiDAR system are outlined in Table 1. Figure 2 shows the flight plan for Nainday floodplain survey.

Table 1. Flight planning parameters for the 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)
BLK32H	600/800	25/30	40/50	200/250	30/36	130	5
BLK32I	1000/1200	25/40	50	200	30	130	5
BLK32J	800/1000/ 1200	25	50	200	30	130	5
BLK32K	800	25	50	200	30	130	5
BLK32L	800	25	50	200	30	130	5

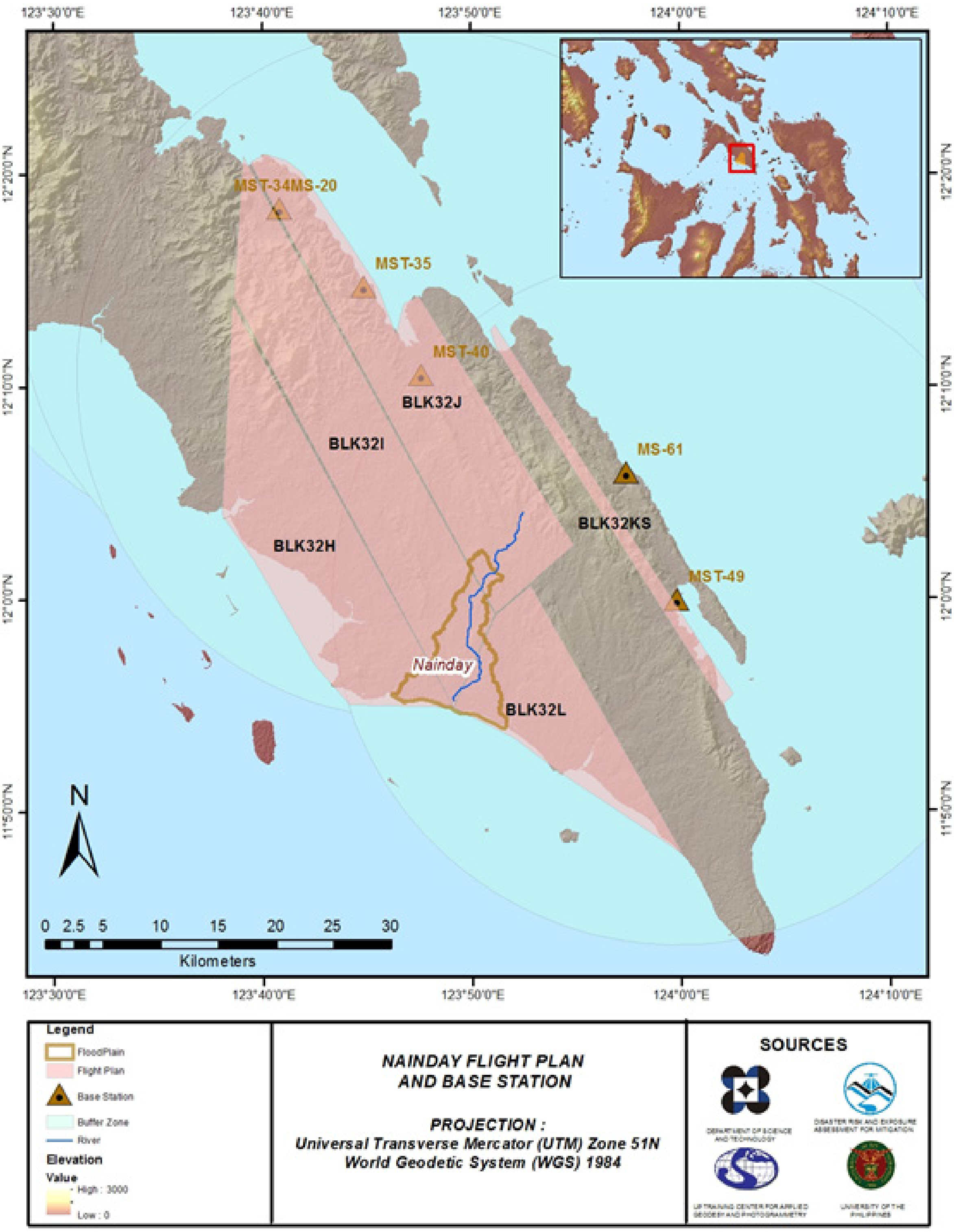

Figure 2. Flight Plan and base stations used for the Nainday Floodplain survey using Pegasus sensor.

2.2 Ground Base Stations

The field team was able to recover five (5) NAMRIA ground control points: MST-34, MST-35, MST-40 and MST-49 which are of second (2nd) order accuracy, also, MS-20 and MS-61, two (2) benchmarks which are of 1st order vertical accuracy.

The certifications for the base stations are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey from March 20 to April 1, 2014. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882 and SPS 852. Flight plans and location of base stations used during the aerial LiDAR acquisition in Nainday floodplain are shown in Figure 2.

The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Nainday Floodplain LiDAR Survey. Figure 3 to Figure 8 show the recovered NAMRIA reference points and established point within the area of the floodplain, while Table 2 and Table 7 show the details about the following NAMRIA control stations and established points. Table 8, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

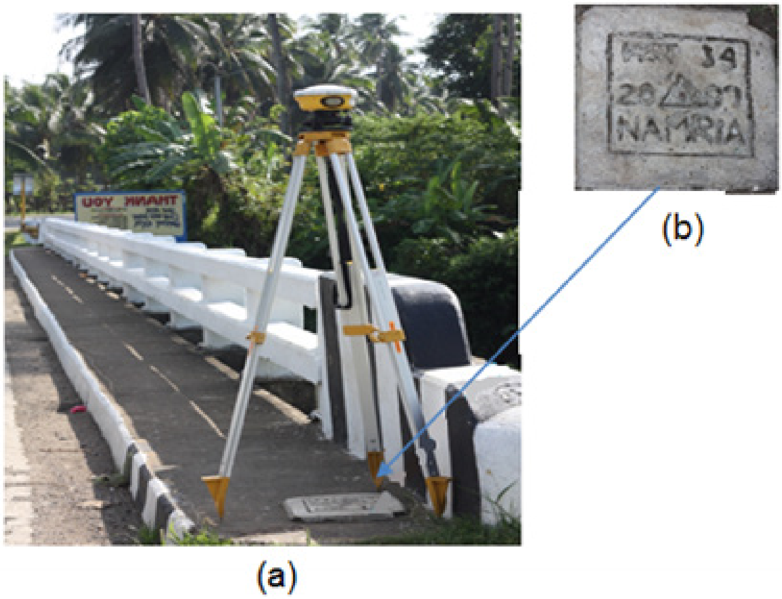

Figure 3. GPS set-up over MST-34 (a) as recovered in Sagawsawan Bridge, Brgy. Umabay Exterior, municipality of Mobo, Masbate and NAMRIA reference point MST-34 (b) as recovered by the field team.

Table 2. 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	12° 18' 29.18323" North
	Longitude	123° 40' 46.86556" East
	Ellipsoidal Height	11.91000 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	573933.177 meters
	Northing	1361109.053 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	12° 18' 24.53692" North
	Longitude	123° 40' 51.93952" East
	Ellipsoidal Height	68.23000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	573907.30 meters
	Northing	1360632.64 meters

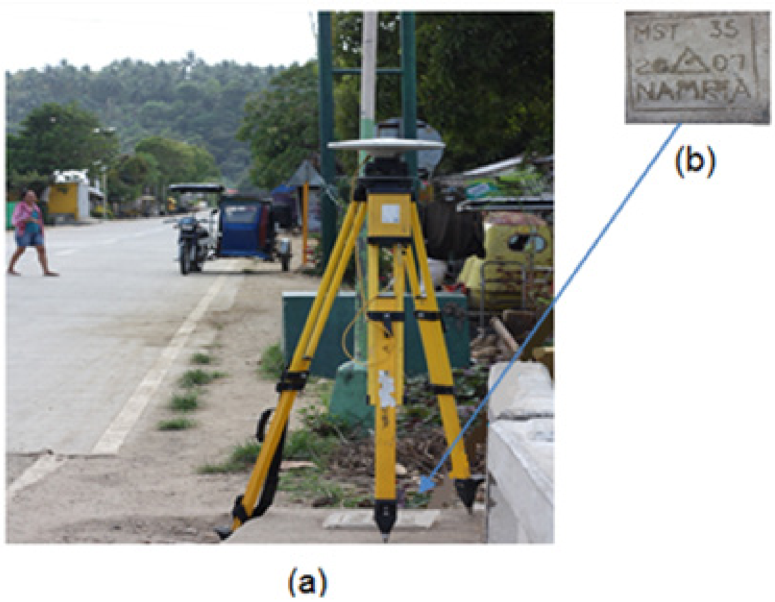

Figure 4. GPS set-up over MST-35 (a) as recovered in Marcella Bridge in Brgy. Cagay, City of Masbate, Province of Masbate; NAMRIA reference point MST-35 (b) as recovered by the field team.

Table 3. 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 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12° 14' 48.14863" North
	Longitude	123° 44' 47.51779" East
	Ellipsoidal Height	5.31500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	581223.775 meters
	Northing	1354336.379 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	12° 14' 43.52314" North
	Longitude	123° 44' 52.59656" East
	Ellipsoidal Height	61.95700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	581195.35 meters
	Northing	1353862.34 meters

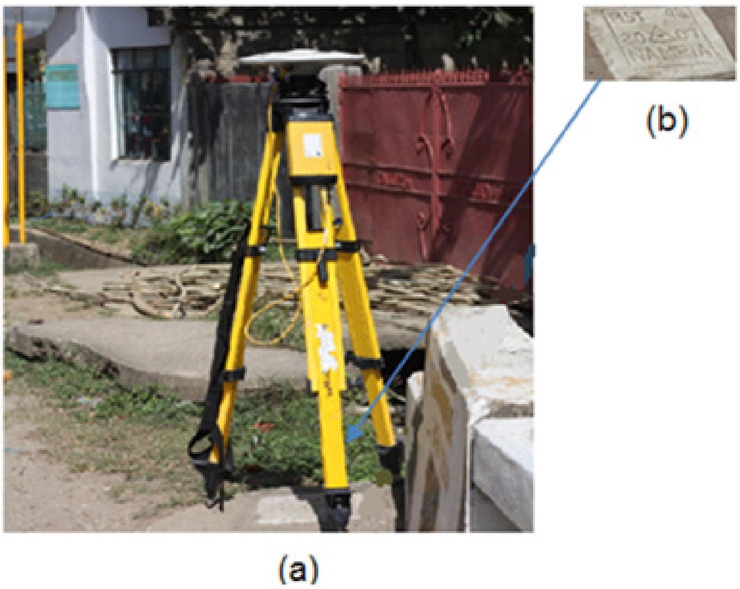

Figure 5. GPS set-up over MST-40 (a) as recovered in Buenavista Bridge in Brgy. Buenavista, municipality of Uson, Masbate; NAMRIA reference point MST-40 (b) as recovered by the field team.

Table 4. Details of the recovered NAMRIA vertical control point MST-40 used as base station for the LiDAR acquisition with established coordinates.

Station Name	MST-40	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12° 10' 39.45274" North
	Longitude	123° 47' 33.62147" East
	Ellipsoidal Height	4.72600 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	586266.511 meters
	Northing	1346708.7 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	12° 10' 34.84826" North
	Longitude	123° 47' 38.70589" East
	Ellipsoidal Height	61.65900 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	586236.32 meters
	Northing	1346237.33 meters

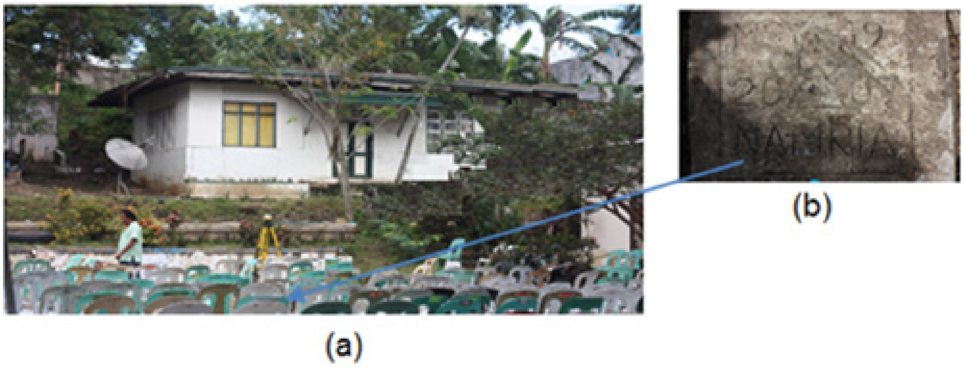

Figure 6. GPS set-up over MST-49 (a) as recovered in front of the Cataingan Municipal Hall, municipality of Cataingan, Masbate; NAMRIA reference point MST-49 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA vertical control point MST-49 used as base station for the LiDAR acquisition with established coordinates.

Station Name	MST-49	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12° 00' 01.41677"
	Longitude	123° 59' 46.24265"
	Ellipsoidal Height	21.25500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	608487.281 meters
	Northing	1327175.1 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	11° 59' 56.87354" North
	Longitude	123° 59' 51.34085" East
	Ellipsoidal Height	79.14000 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	608449.31 meters
	Northing	1326710.57 meters

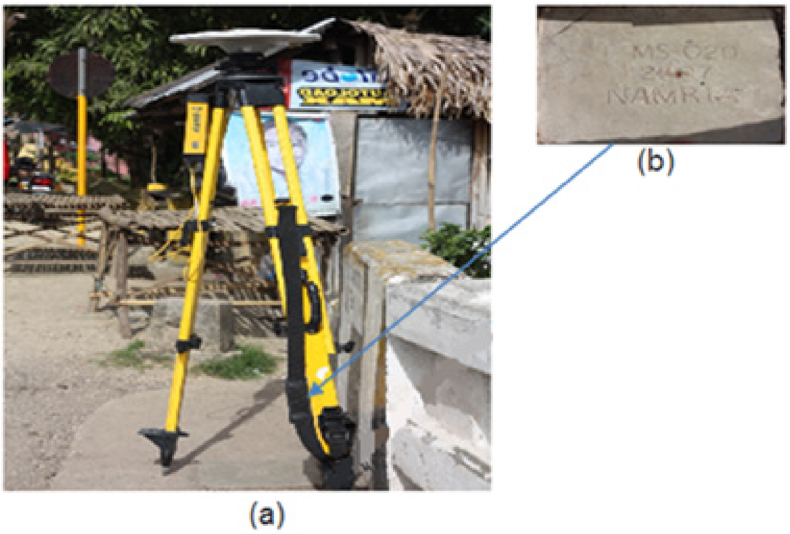

Figure 7. GPS set-up over MS-20 (a) as recovered in Manaswang Bridge in Brgy. Marcella, municipality of Uson, Masbate; NAMRIA reference point MS-20 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point MS-20 used as base station for the LiDAR acquisition.

Station Name	MS-20	
Order of Accuracy	2nd order	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	12° 18' 29.18317" North
	Longitude	123° 40' 46.86570" East
	Ellipsoidal Height	11.92 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	12° 18' 24.53692" North
	Northing	123° 40' 51.93952" East
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	68.230 meters
	Longitude	574059.995 meters
	Ellipsoidal Height	1360574.929 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	586236.32 meters
	Northing	1346237.33 meters

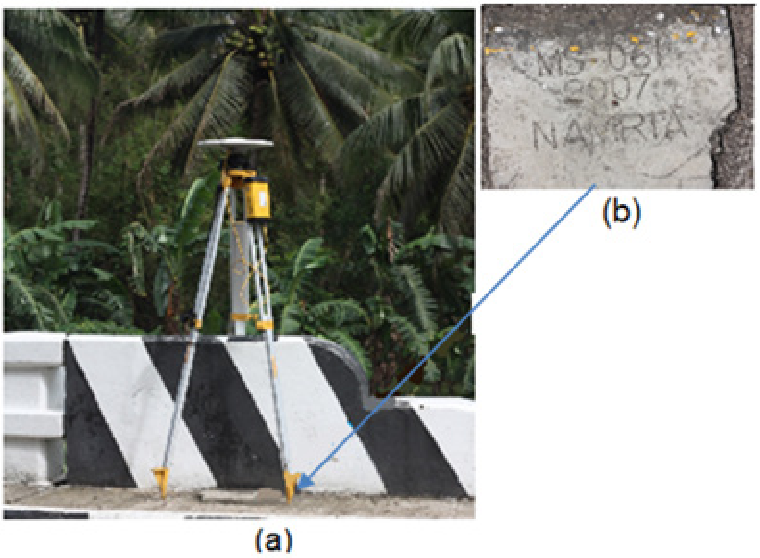

Figure 8. GPS set-up over MS-61 (a) as recovered in Nabangig Bridge, Brgy. Nabangig, municipality of Palanas, Masbate; NAMRIA reference point MS-61 (b) as recovered by the field team.

Table 7. Details of the recovered NAMRIA horizontal control point MS-61 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	12° 06' 1.51238"
	Longitude	123° 57' 21.24483"
	Ellipsoidal Height	4.74 meters
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone 4 PRS 92)	Easting	12° 05' 56.94091" North
	Northing	123° 57' 26.33451" East
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	65.257 meters
	Longitude	604178.664 meters
	Ellipsoidal Height	1337699.951 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 92)	Easting	586236.32 meters
	Northing	1346237.33 meters

Table 8. Ground control points used during the LiDAR data acquisition.

Date Surveyed	Flight Number	Mission Name	Ground Control Points
March 20, 2014	1245P	1BLK32J079B	MS-20, MST-34 and MST-40
March 21, 2014	1247P	1BLK32IJ080A	MST-34 and MST-40
March 27, 2014	1271P	1BLK32H086A	MST-49 and MS-61
March 28, 2014	1275P	1BLK32HI087A	MST-40 and MST-49
March 29, 2014	1281P	1BLK32I088B	MST-40 and MST-49
April 1, 2014	1291P	1BLK32KL091A	MST-49 and MS-61
April 1, 2014	1293P	1BLK32H091B	MST-40 and MST-49

2.3 Flight Missions

A total of seven (7) missions were conducted to complete the LiDAR data acquisition in Nainday floodplain, for a total of of twenty two hours and forty two minutes (22+42) of flying time for RP-C9022 (See Annex 6). All missions were acquired using the Pegasus system. As shown below, the total area of actual coverage per mission and the corresponding flying hours are depicted in Table 9, while the actual parameters used during the LiDAR data acquisition are presented in Table 10.

Table 9. Flight missions for the LiDAR data acquisition of the Nainday Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within Floodplain (km^2)	Area Surveyed Outside Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
March 20, 2014	1245P	276.40	143.44	0	143.44	721	3	5
March 21, 2014	1247P	559.60	326.96	16.41	310.55	846	4	0
March 27, 2014	1271P	267.86	169.487	1.07	168.417	1184	4	23
March 28, 2014	1275P	267.86	126.674	18.29	108.384	620	2	53
March 29, 2014	1281P	283.20	126.996	25.43	101.566	0	1	53
April 1, 2014	1291P	193.72	186.16	2.91	183.25	666	4	23
April 1, 2014	1293P	267.86	82.521	0	82.521	423	2	5
TOTAL		2116.5	1162.238	64.11	1098.128	4460	22	42

Table 10. Actual parameters used during the LiDAR data acquisition of the Nainday Floodplain.

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1245P	800	25	50	200	30	130	5
1247P	1000, 1200	25	50	200	30	130	5
1271P	800, 600	25, 30	50	200	30	130	5
1275P	800	25	40	250	36	130	5
1281P	1000	40	50	200	30	130	5
1291P	800	30	50	200	30	130	5
1293P	800	25	40	250	36	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Nainday floodplain (See Annex 7). It is located in the province of Masbate, with majority of the floodplain situated within the municipalities of Placer. Municipalities of Cawayan and Uson are mostly covered by the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage is shown in Table 11. Figure 9, on the other hand, shows the actual coverage of the LiDAR acquisition for the Nainday floodplain.

Table 11. The list of municipalities and cities surveyed of the Nainday Floodplain LiDAR acquisition.

Province	Municipality/City	Area of Municipality/ City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Masbate	Cawayan	261.38	245.246	94%
	Uson	183.758	168.156	92%
	Placer	253.547	200.439	79%
	Mobo	143.029	108.830	76%
	Dimasalang	100.442	52.422	57%
	Palanas	138.167	62.137	45%
	Cataingan	191.694	30.130	16%
	Milagros	530.431	83.025	16%
	Esperanza	62.754	8.799	14%
	Pio V. Corpuz	95.643	1.113	1%
Total		1960.845	960.297	49%

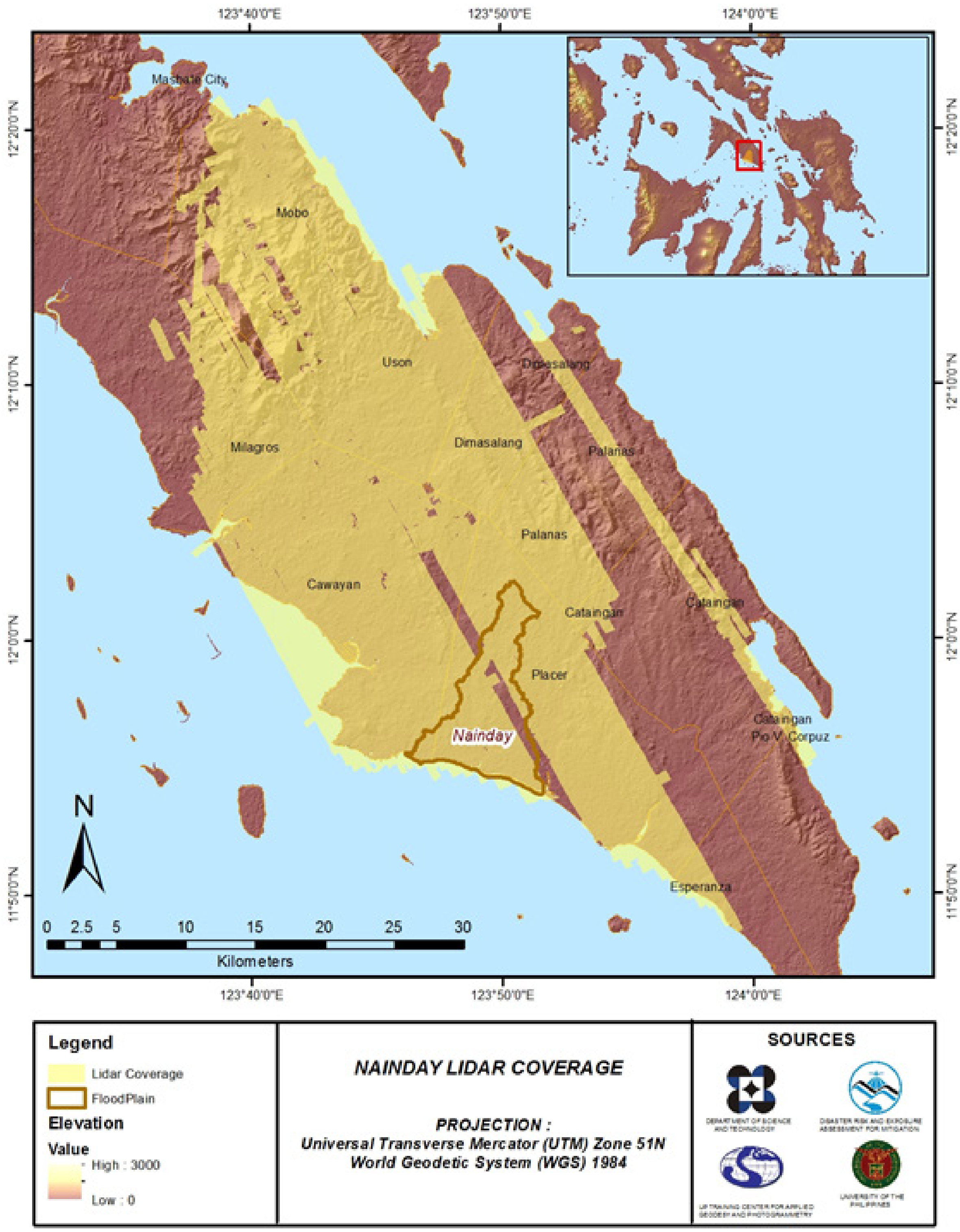

Figure 9. Actual LiDAR survey coverage of the Nainday Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE NAINDAY FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

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

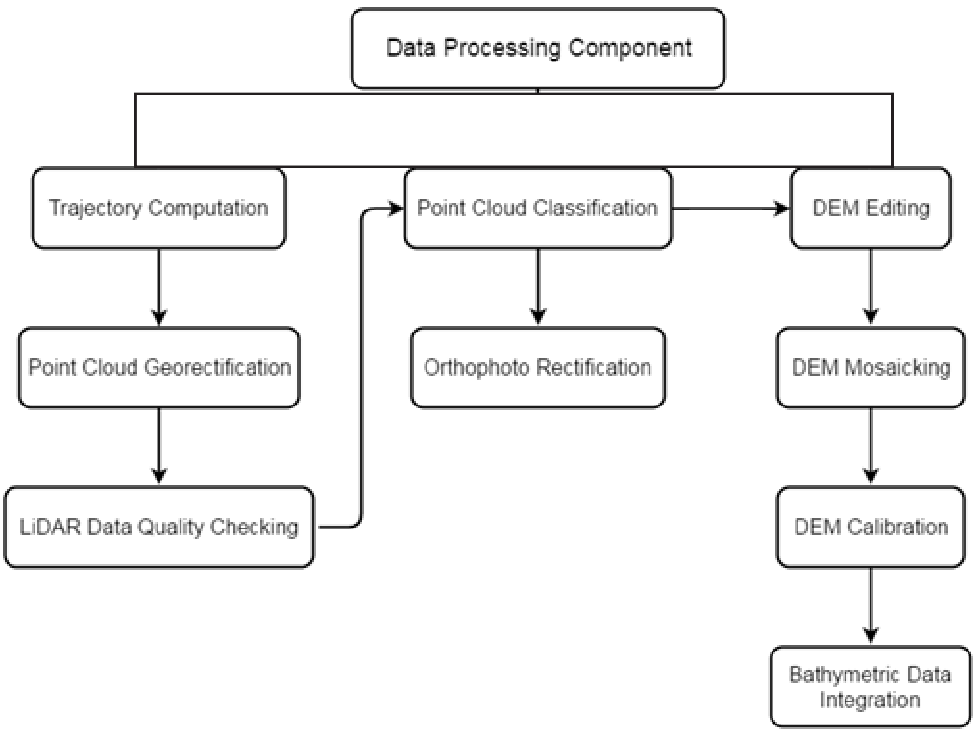


Figure 10. Schematic diagram for the data pre-processing.

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions of the Nainday Floodplain can be found in Annex 5. The missions flown during the conduct of the first survey in April 2014 utilized the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system over Placer, Masbate.

The Data Acquisition Component (DAC) transferred a total of 177.60 Gigabytes of Range data, 1.33 Gigabytes of POS data, 46.11 Megabytes of GPS base station data, and 285.90 Gigabytes of raw image data to the data server on April 22, 2014 for the first survey, which was verified for accuracy and completeness by the DPPC. The whole dataset for the Nainday Floodplain was fully transferred on April 23, 2014, as indicated on the Data Transfer Sheets for the Nainday floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for Flight 1245P, one of the Nainday flights, which is the North, East, and Down position RMSE values are shown in Figure 11. The x-axis corresponds to the time of the 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 3, 2014 00:00AM. The y-axis, on the other hand, represents the RMSE value for that particular position.

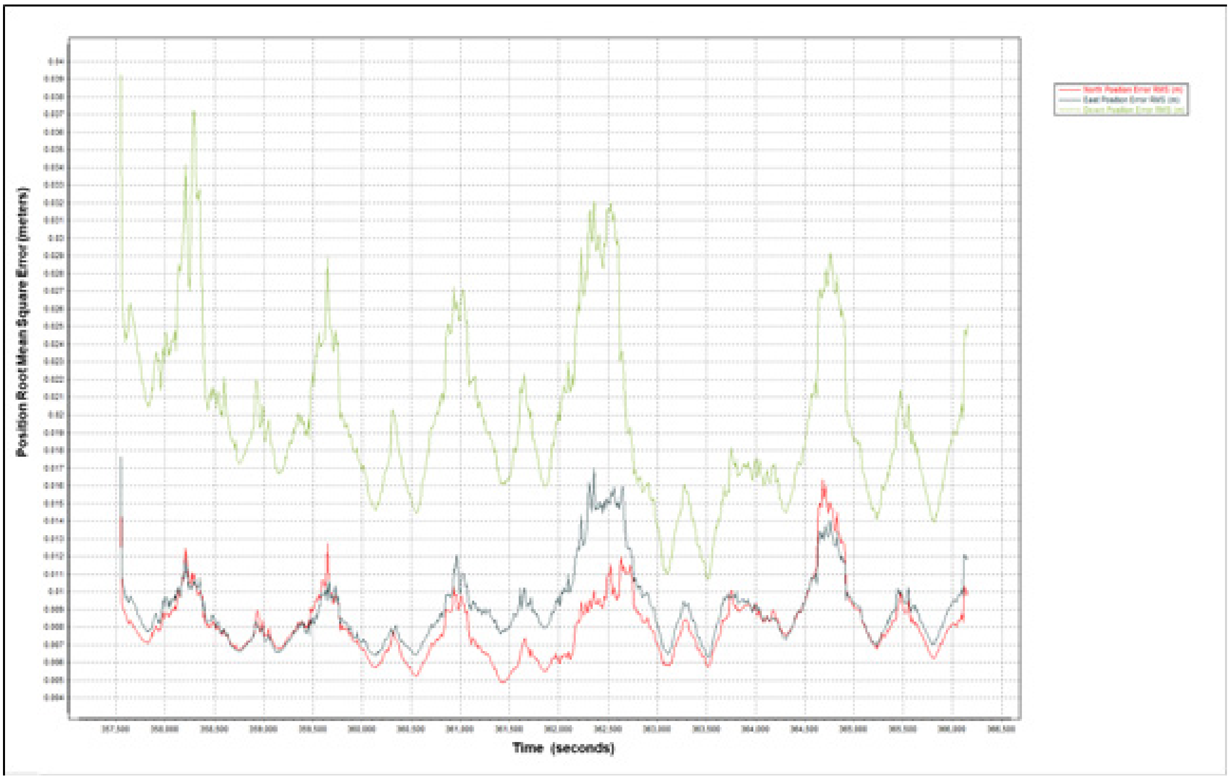


Figure 11. Smoothed Performance Metrics of Nainday Flight 1245P.

The time of flight was from 357,500 seconds to 366,100 seconds, which corresponds to morning of April 3, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimize the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 11 shows that the North position RMSE peaks at 1.60 centimeters, the East position RMSE peaks at 1.70 centimeters, and the Down position RMSE peaks at 3.70 centimeters, which are within the prescribed accuracies described in the methodology.

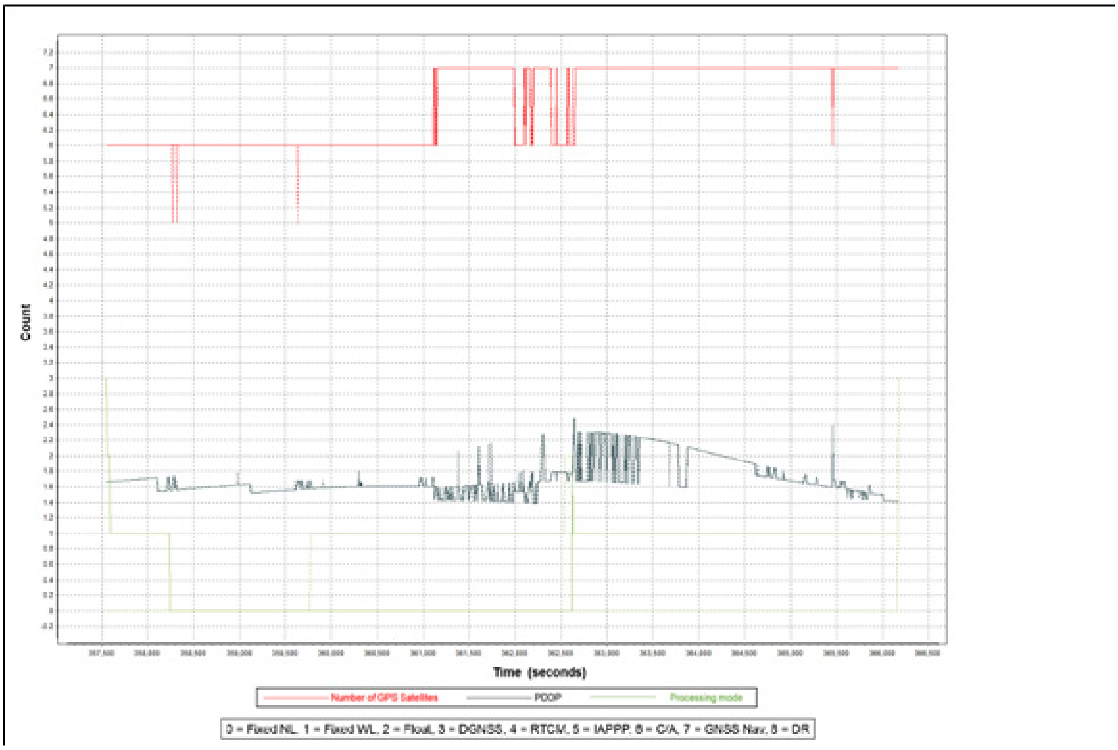


Figure 12. Solution Status Parameters of Nainday Flight 1245P.

The Solution Status parameters, which indicate the number of GPS satellites; Positional Dilution of Precision (PDOP); and the GPS processing mode used for Nainday Flight 1245P are shown in Figure 12. For the Solution Status parameters, the figure above signifies that the number of satellites utilized and tracked during the acquisition were between 6 and 7, not going lower than 6. Similarly, the PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode also remained at 0 for the majority of the survey stayed at the value of 0 with some peaks up to 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane Mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for the POSPAC MMS. Fundamentally, 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 Nainday flights is shown in Figure 13.

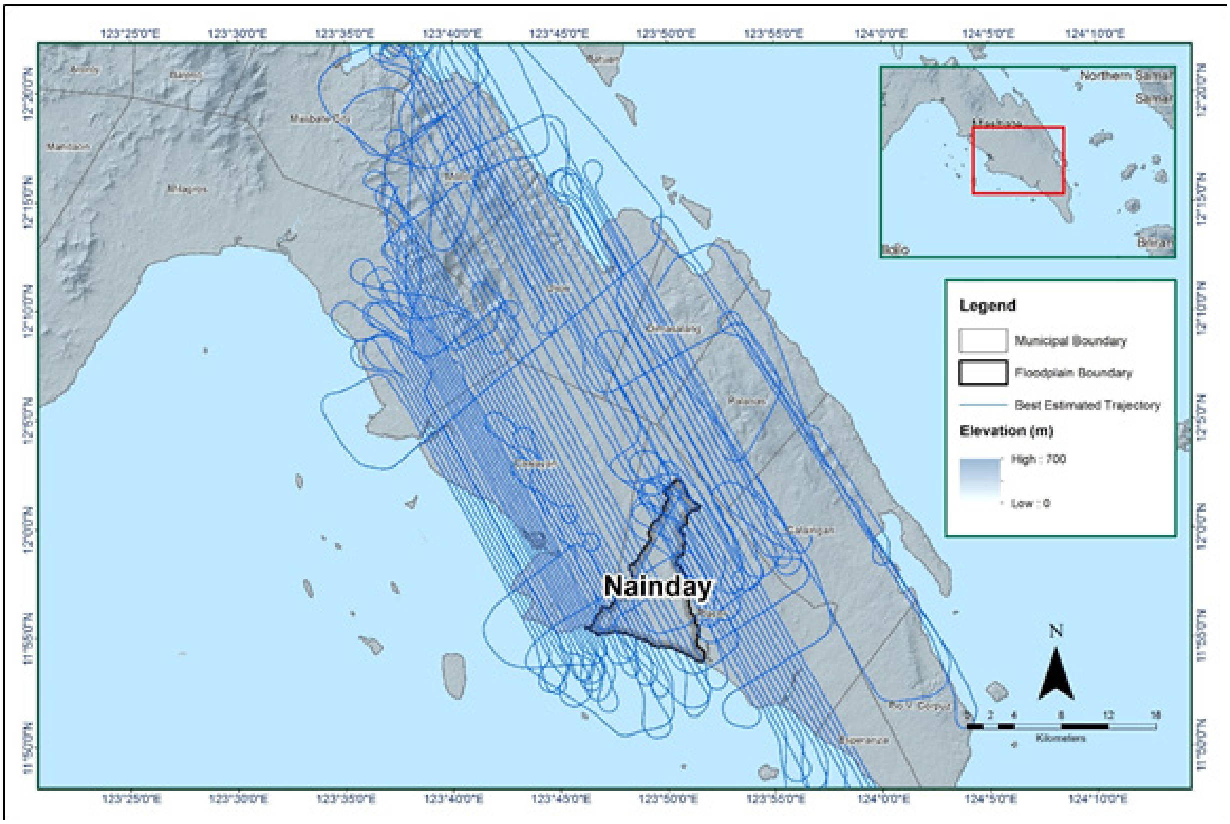


Figure 13. Best estimated trajectory of the LiDAR missions conducted over the Nainday Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 54 flight lines, with each flight line containing two channels, since the Pegasus system contains two channels. The summary of the self-calibration results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over the Nainday floodplain are given in Table 12.

Table 12. Self-calibration Results values for Nainday flights.

Parameter	Value	
Boresight Correction stdev	<0.001degrees	0.000398
IMU Attitude Correction Roll and Pitch Corrections stdev	<0.001degrees	0.000675
GPS Position Z-correction stdev	<0.01meters	0.0074

The optimum accuracy values for all Nainday flights were also calculated, which are based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for individual blocks are presented in the Mission Summary Reports (Annex 8).

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data is shown in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

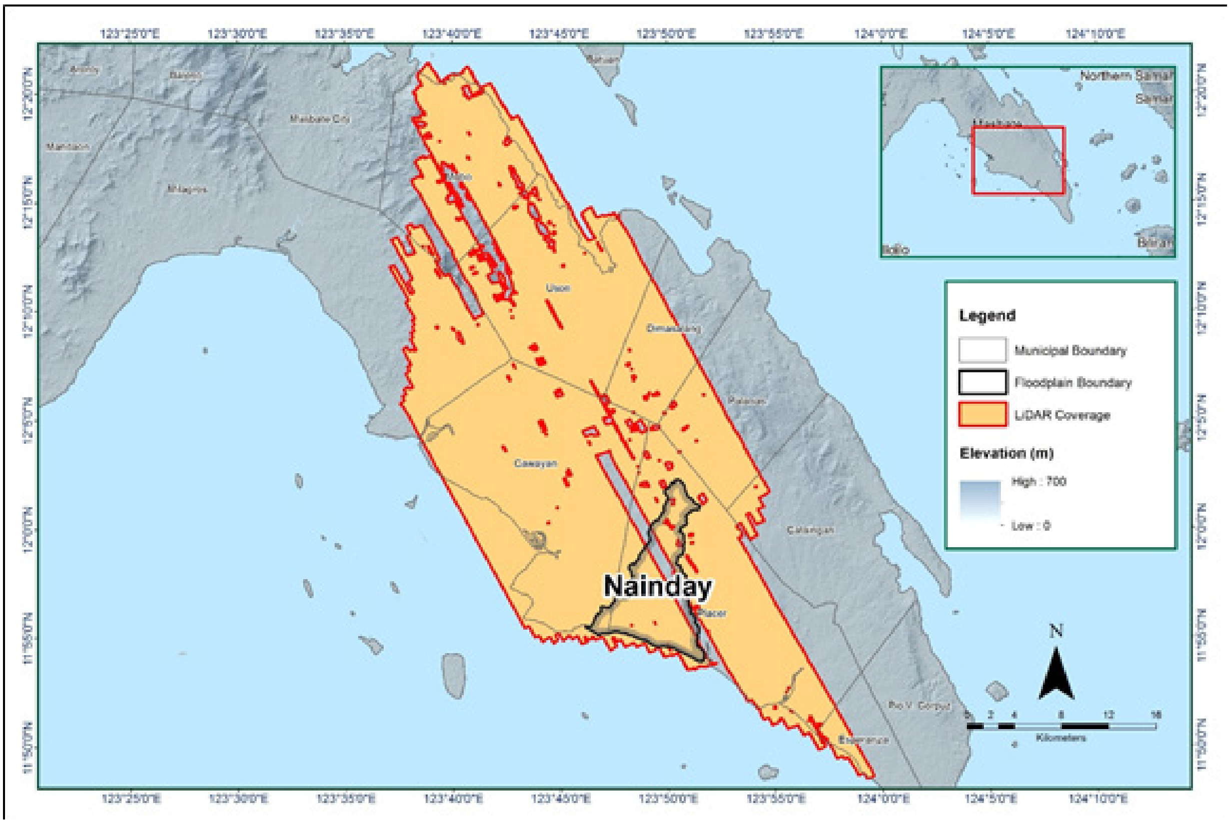


Figure 14. Boundary of the processed LiDAR data on top of the SAR Elevation Data over the Nainday Floodplain.

A total area of 978.31 square kilometers (sq. kms.) were covered by the Nainday flight missions as a result of seven (7) flight acquisitions, which were grouped and merged into three (3) blocks accordingly, as portrayed in Table 13.

Table 13. List of LiDAR blocks for the Nainday floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Masbate Blk32L	1291P	122.45
Masbate Blk32IJ	1245P	540.53
	1247P	
	1281P	
Masbate Blk32H	1293P	315.33
	1275P	
	1271P	
	TOTAL	**828.67 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 15. Since the Pegasus system employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap, and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

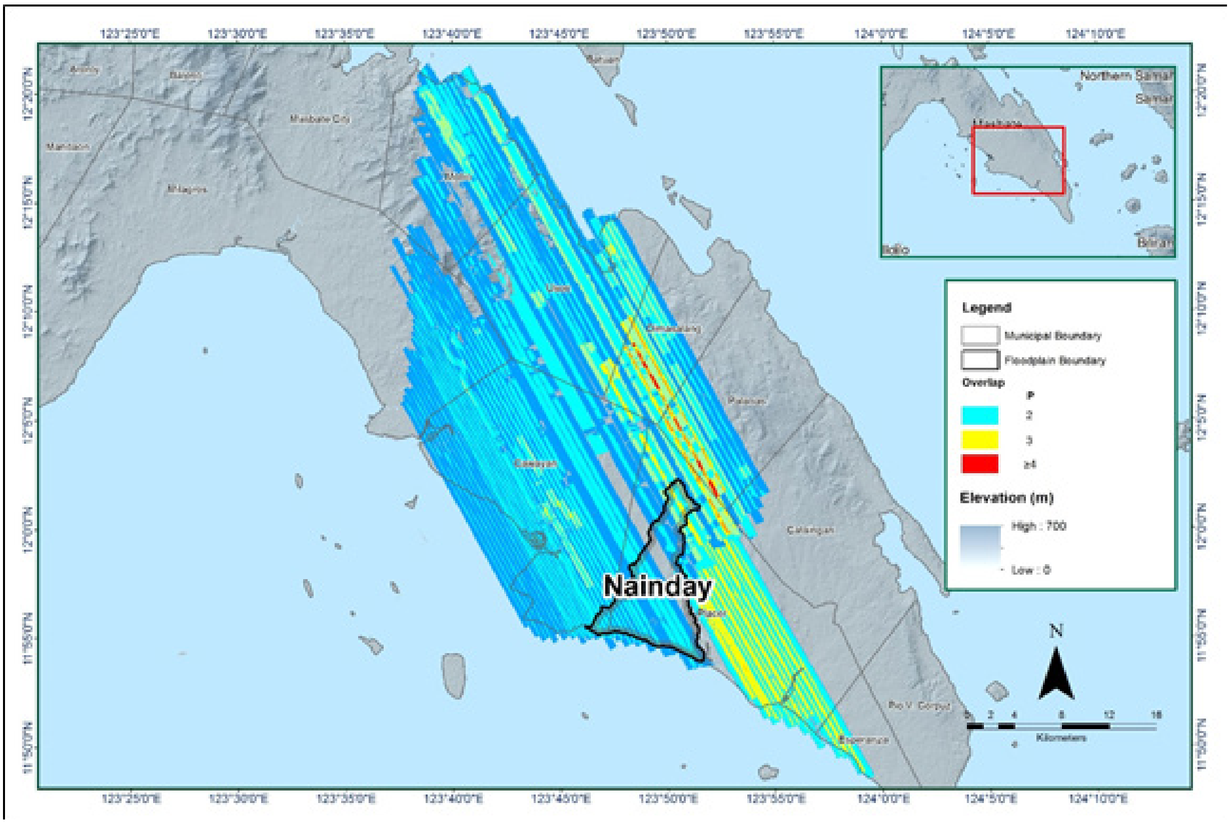


Figure 15. Image of data overlap for Nainday floodplain.

The overlap statistics per block for the Nainday floodplain can be found in the Mission Summary Reports (Annex 8). One pixel corresponds to 25.0 square meters on the ground. For this area, the maximum percent overlap is 46.57, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the two (2) points per square meter criterion is shown in Figure 16. As seen in the figure below, it was determined that all LiDAR data for the Nainday Floodplain Survey satisfy the point density requirement, as the average density for the entire survey area is 3.11 points per square meter.

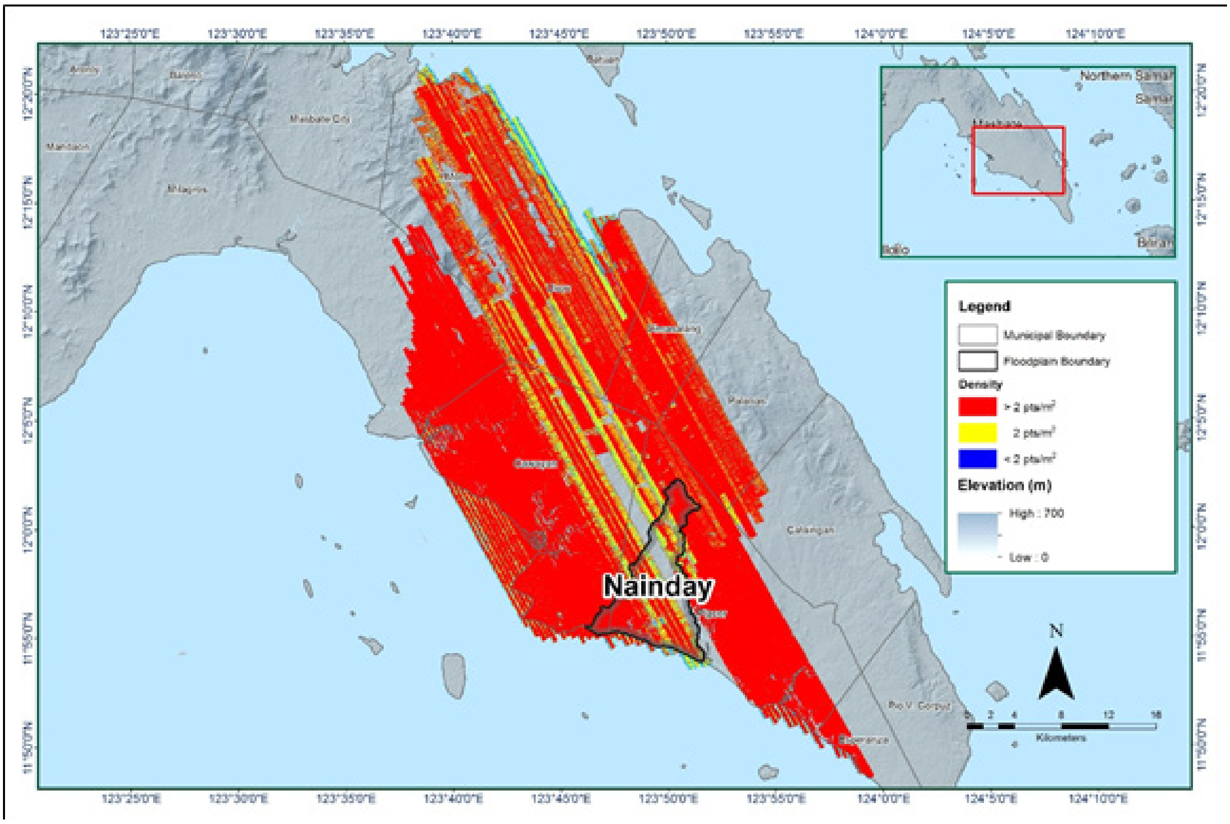


Figure 16. Pulse density map of the merged LiDAR data for Nainday floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. The default color range is blue to red, where bright blue areas correspond to portions where elevations of a previous flight line are higher by more than 0.20m, as identified by its acquisition time; which is relative to the elevations of its adjacent flight line. Similarly, bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m, relative to the elevations of its adjacent flight line. Areas highlighted in bright red or bright blue necessitate further investigation using the Quick Terrain Modeler software.

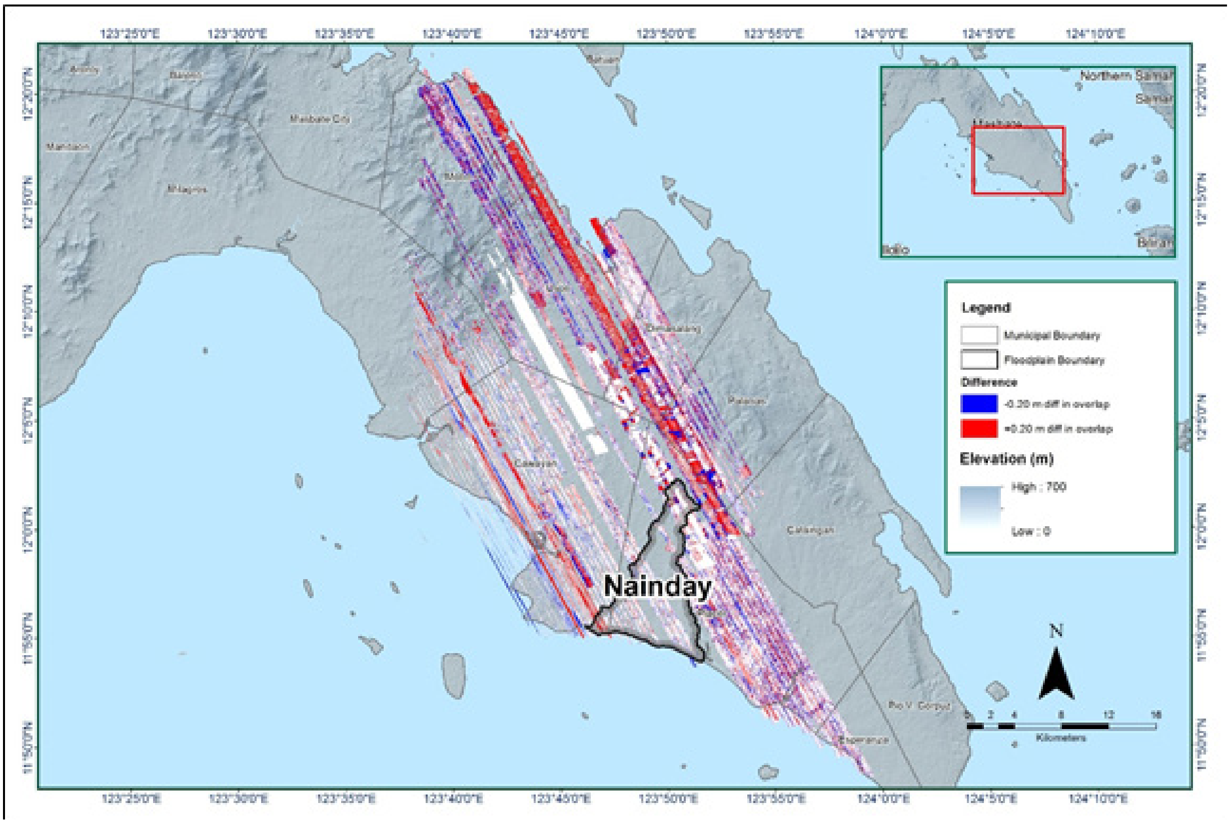


Figure 17. Elevation difference Map between flight lines for the Nainday Floodplain Survey.

A screen-capture of the processed LAS data from Nainday flight 1245P loaded in QT Modeler is shown in Figure 18. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data generated satisfactory results. No reprocessing was done for this LiDAR dataset.

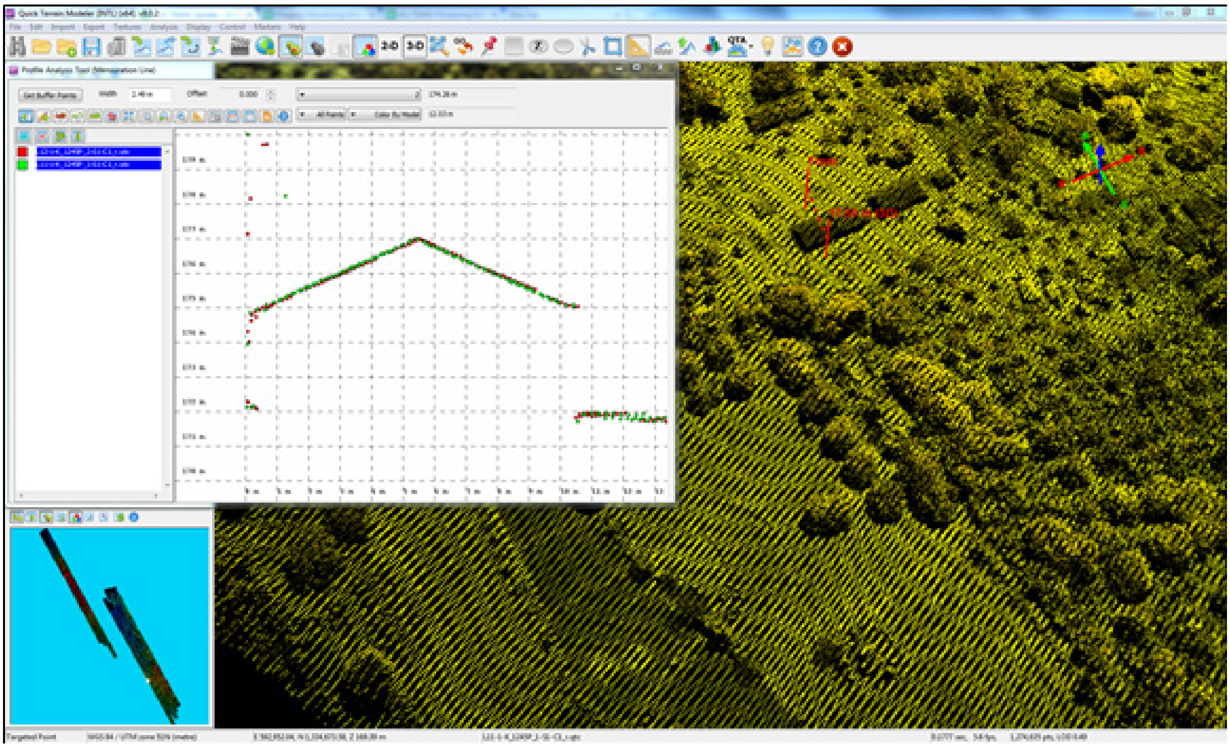


Figure 18. Quality checking for Nainday flight 1245P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Nainday classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	1,223,186,626
Low Vegetation	831,471,744
Medium Vegetation	924,639,156
High Vegetation	589,616,582
Building	252,553,166

The tile system that TerraScan employed for the LiDAR data as well as the final classification image for a block of the Nainday floodplain is shown in Figure 19. A total of 1,238 tiles with 1 km. X 1 km. (one kilometer by one kilometer) size were produced. Correspondingly, Table 14 summarizes the number of points classified to the pertinent categories. The point cloud has a maximum and minimum height of 603.95 meters and 42.31 meters, respectively.

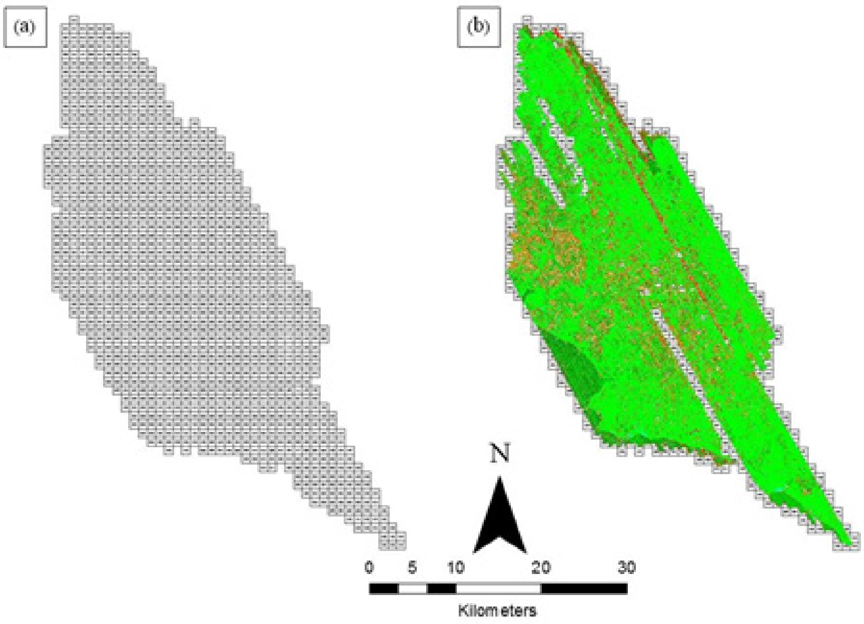


Figure 19. Tiles for Nainday floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 20. The ground points are highlighted 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 the canopy are classified correctly, due to the density of the LiDAR data.

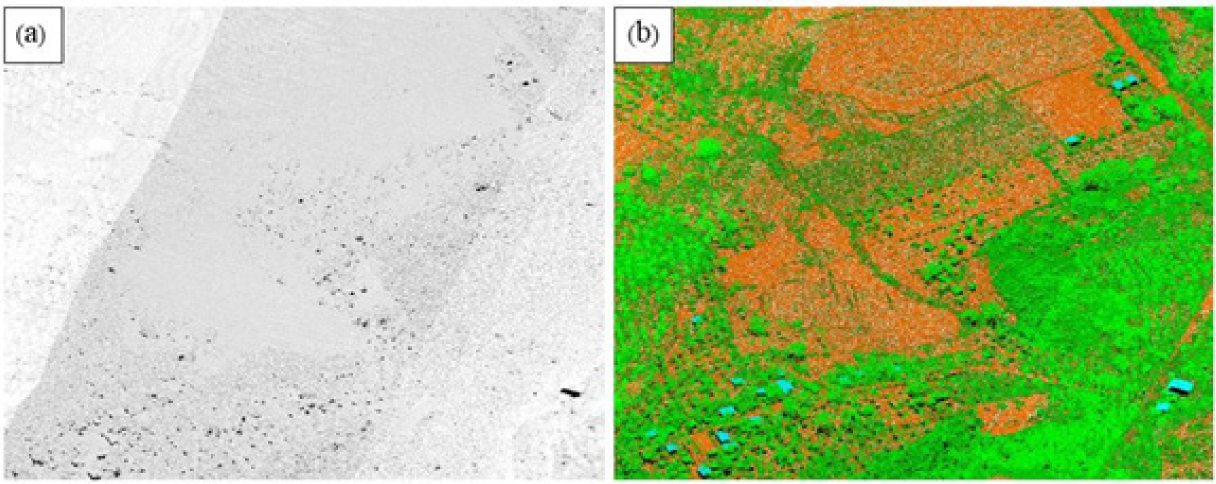


Figure 20. Point cloud before (a) and after (b) classification.

The production of the last return (V_ASCII) and secondary (T_ ASCII) DTM as well as the first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are shown in Figure 21. It shows that DTMs are the representation of the bare earth, while on the DSM, all features are present such as buildings and vegetation.

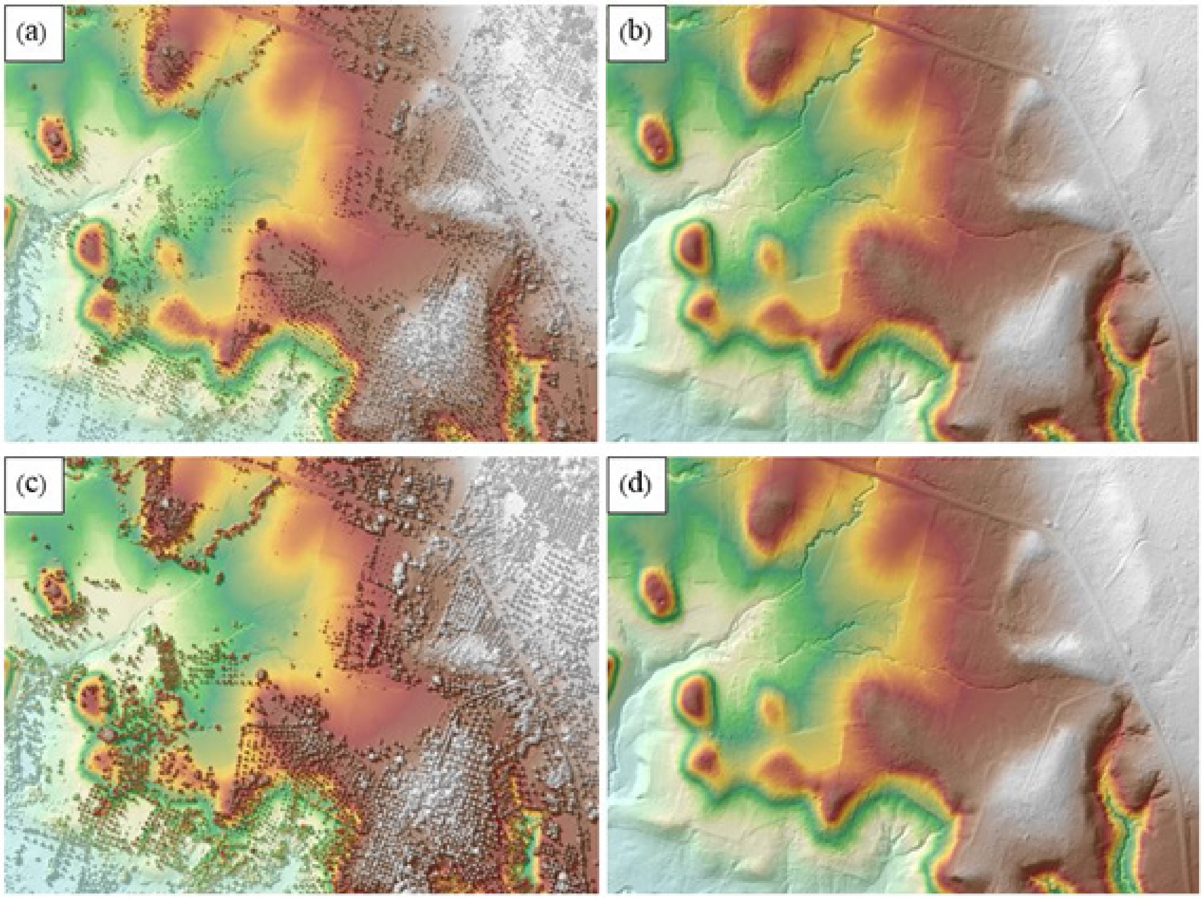


Figure 21. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Nainday floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,059 1km by 1km tiles area covered by the Nainday floodplain is shown in Figure 22. After the tie point selection to fix photo misalignments, color points were added to smooth out visual inconsistencies along the seam lines where photos overlap. The Nainday floodplain attained a total of 856.41 sq. kms. in orthophotograph coverage comprised of 4,139 images. A zoomed-in version of sample orthophotographs named in reference to its tile number is shown in Figure 23.

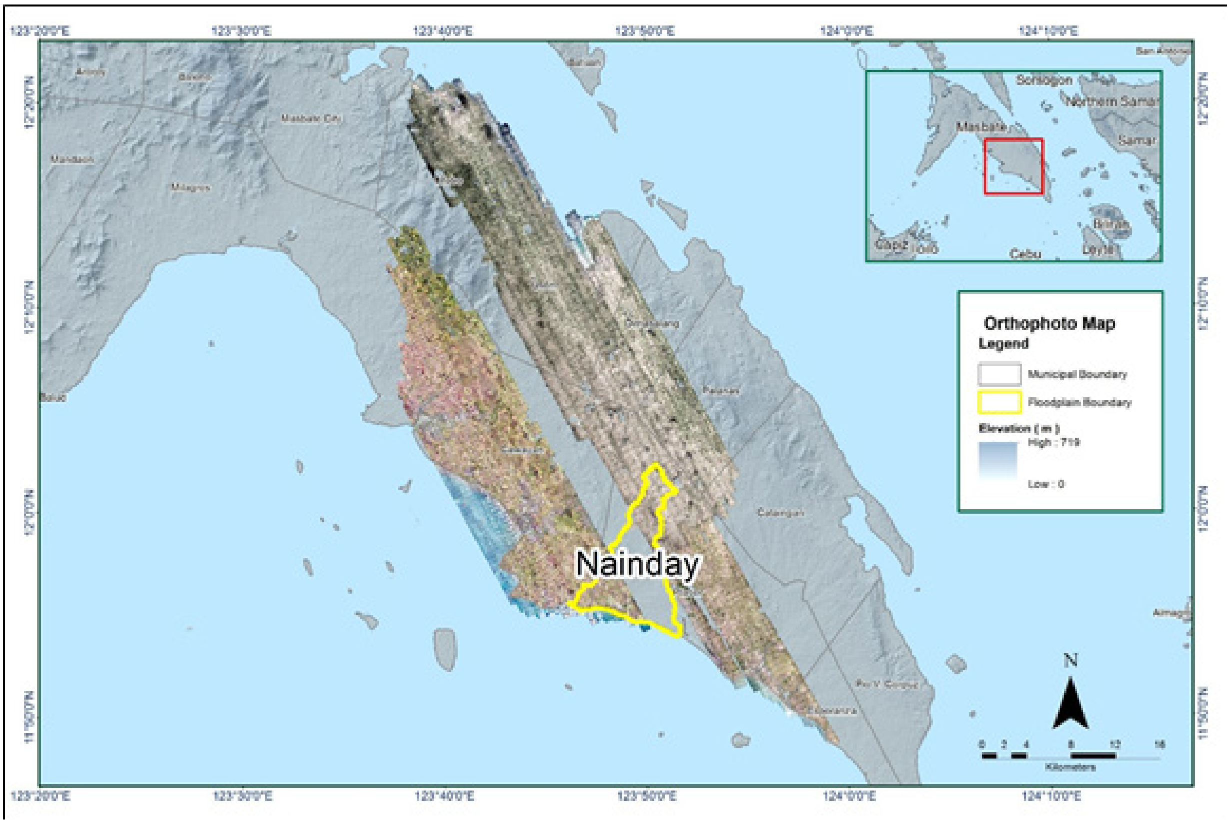


Figure 22. Nainday Floodplain with the available orthophotographs.

Figure 23. Sample orthophotograph tiles for the Nainday Floodplain.

3.8 DEM Editing and Hydro-Correction

Three (3) mission blocks were processed for the Nainday Floodplain Survey. These blocks are composed of Masbate blocks with a total area of 978.31 square kilometers. Table 15 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with its corresponding areas.

LiDAR Blocks	Area (sq.km)
Masbate Blk32L	122.45
Masbate Blk32IJ	540.53
Masbate Blk32H	315.33
TOTAL	978.31 sq.km

Figure 24 shows portions of a DTM before and after manual editing. As evident in the figure, the bridge (Figure 24a) has obstructed the flow of water along the river. To correct the river hydrologically, the bridge was removed through manual editing (Figure 24b). Likewise, a depression visible on the terrain (Figure 24c) which resulted from misclassified points during the classification process. To complete the surface, the depression (Figure 24d) was interpolated through manual editing to allow the correct water flow. As well, a lone building (Figure 24e) was still present in the DTM after the classification process. To correct this, the building was removed through manual editing (Figure 24f).

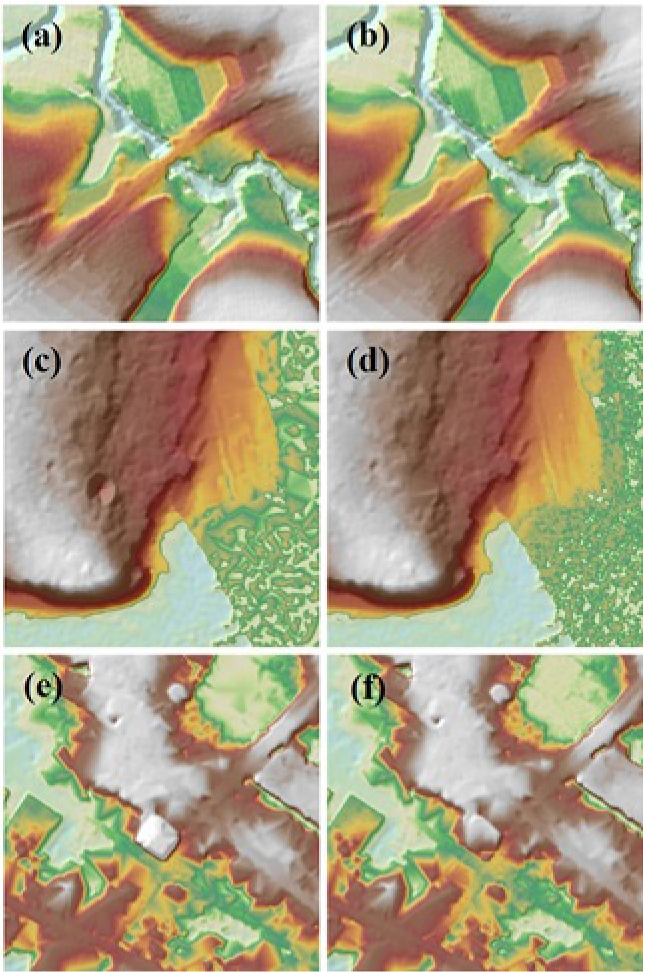


Figure 24. Portions in the DTM of the Nainday Floodplain – a bridge before (a) and after (b) manual editing; a depression before (c) and after (d) data retrieval; and a building before (e) and after (f) manual editing.

3.9 Mosaicking of Blocks

Masbate_Blk32D was used as the reference block at the start of mosaicking because it was referred to a base station with an acceptable order of accuracy. Table 16 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Nainday Floodplain is shown in Figure 25. It can be seen that the entire Nainday floodplain is 86.20% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 16. Shift values of each LiDAR block of Nainday Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Masbate_Blk32L	0.00	0.00	1.63
Masbate_Blk32IJ	0.00	0.00	1.67
Masbate_Blk32H	0.00	0.00	1.64

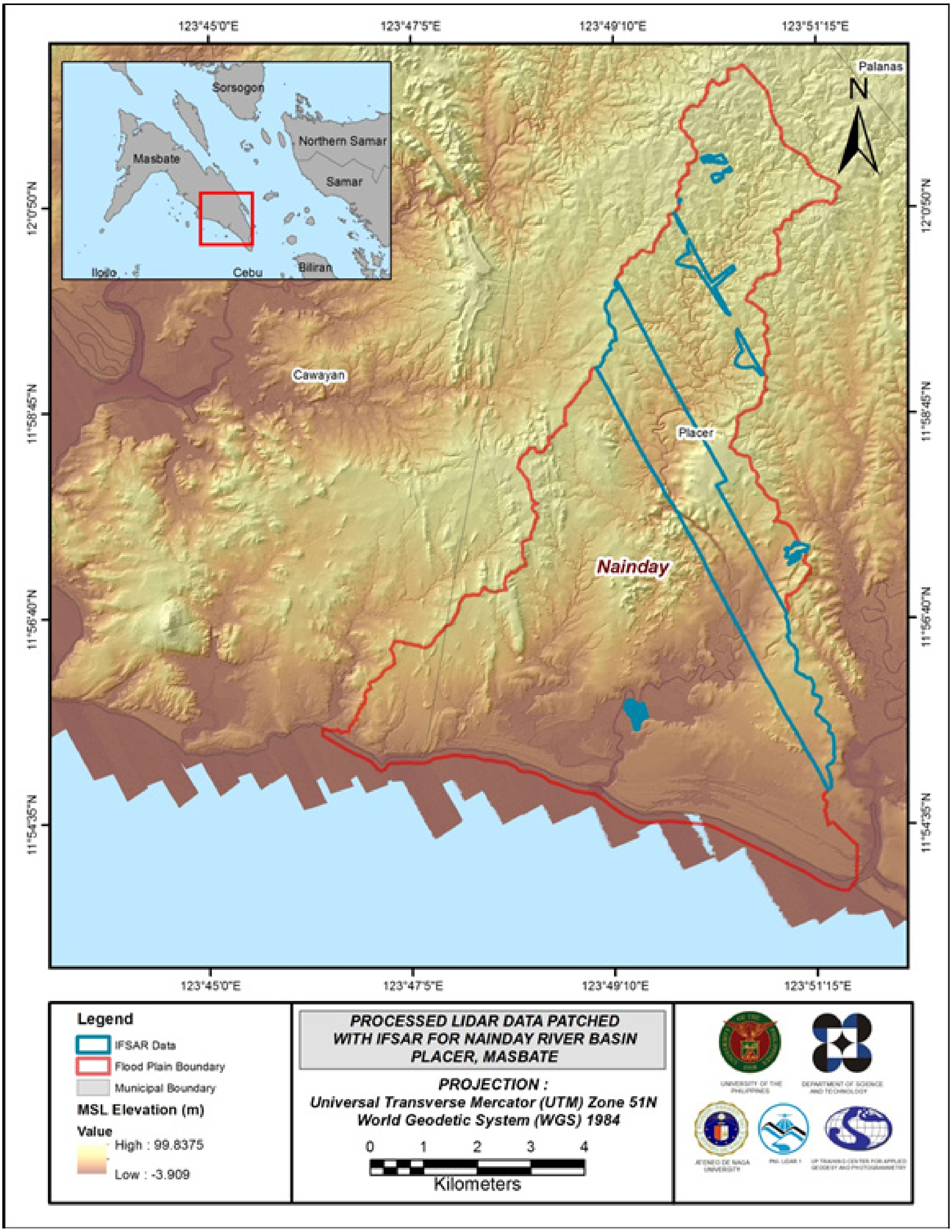


Figure 25. Map of processed LiDAR data for the Nainday Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Nainday to collect points with which the LiDAR dataset is validated is shown in Figure 26, with the validation survey points highlighted in green. A total of 2,639 survey points from Asid floodplain were used for calibration and validation of Nainday LiDAR data. Random selection of 80% of the survey points, resulting to 2,591 points, were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR DTM and the ground survey elevation values is shown in Figure 27. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of the data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 3.22 meters, with a standard deviation of 0.158 meters. The calibration of the Nainday LiDAR data was accomplished by subtracting the height difference value of 3.22 meters to the Nainday mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between the Nainday LiDAR data and the calibration data.

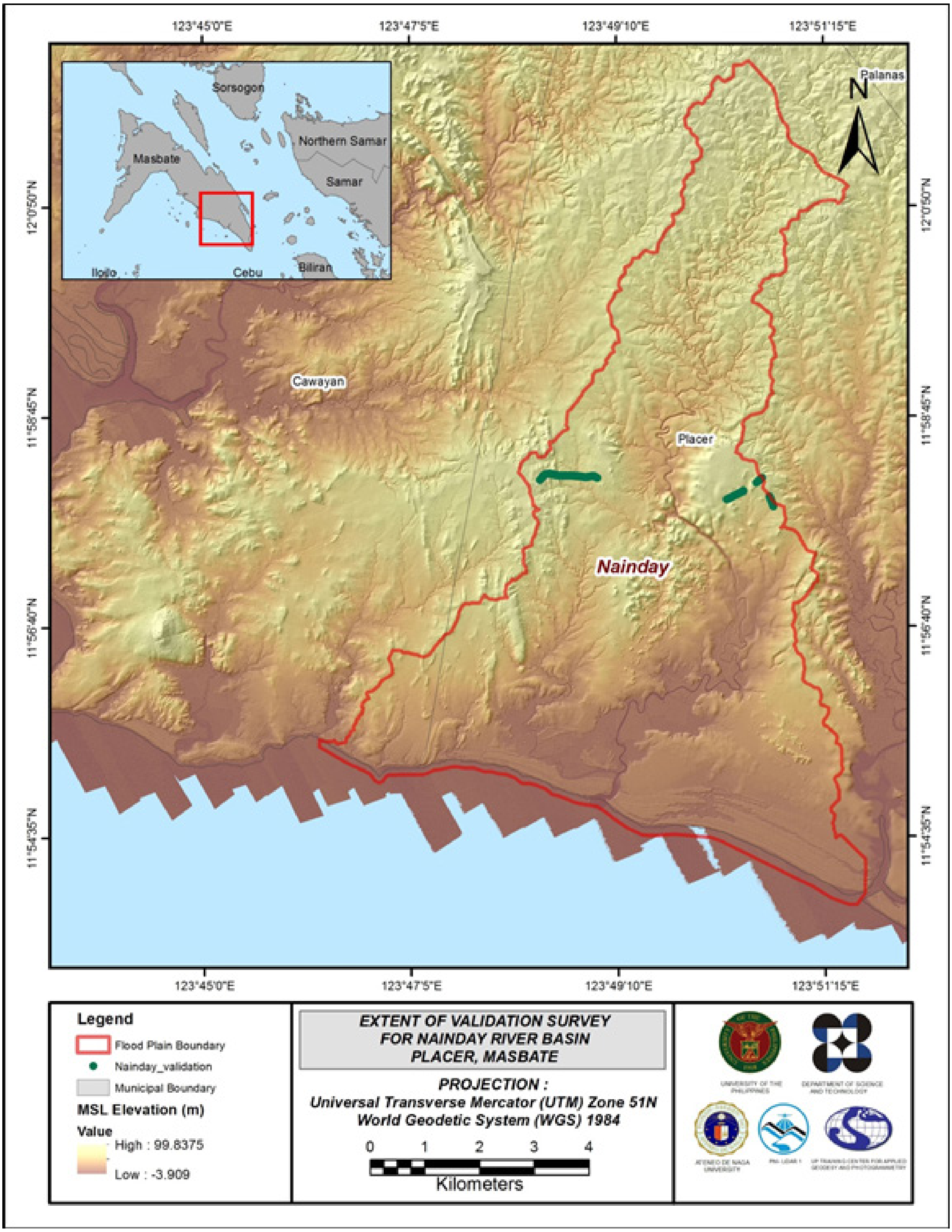


Figure 26. Map of Nainday Floodplain with validation survey points in green.

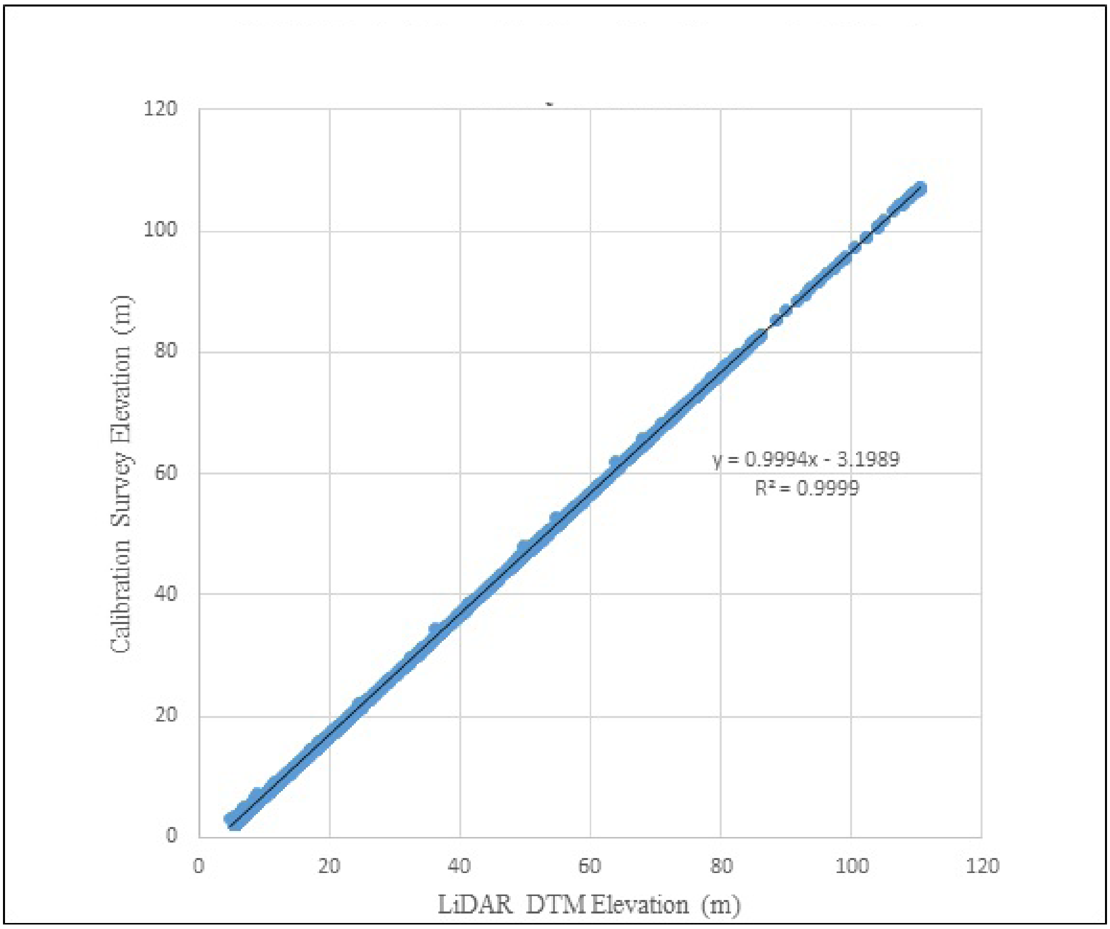


Figure 27. Correlation plot between calibration survey points and LiDAR data.

Table 17. Calibration Statistical Measures

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

A total of 2,105 survey points were collected by DVBC for Nainday floodplain. Random selection of points within the boundaries of the floodplain, resulting to 218 points, were used for the validation of the calibrated Nainday DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.13 meters with a standard deviation of 0.06 meters, as shown in Table 18.

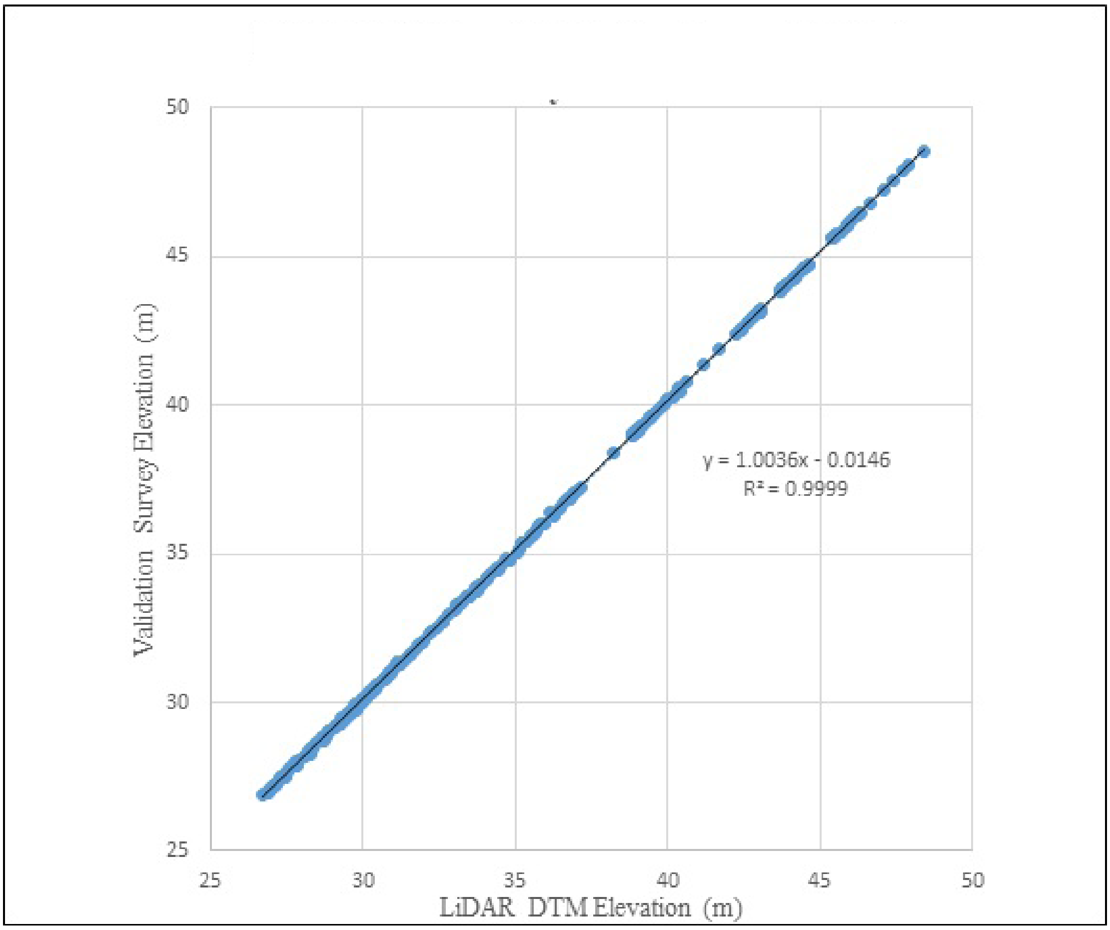


Figure 28. Correlation plot between validation survey points and LiDAR data.

Table 18. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.13
Standard Deviation	0.06
Average	0.12
Minimum	-0.03
Maximum	0.21

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Nainday with a total of 4,280 bathymetric survey points. The resulting raster surface produced was done by Kernel interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.36 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Nainday integrated with the processed LiDAR DEM is shown in Figure 29.

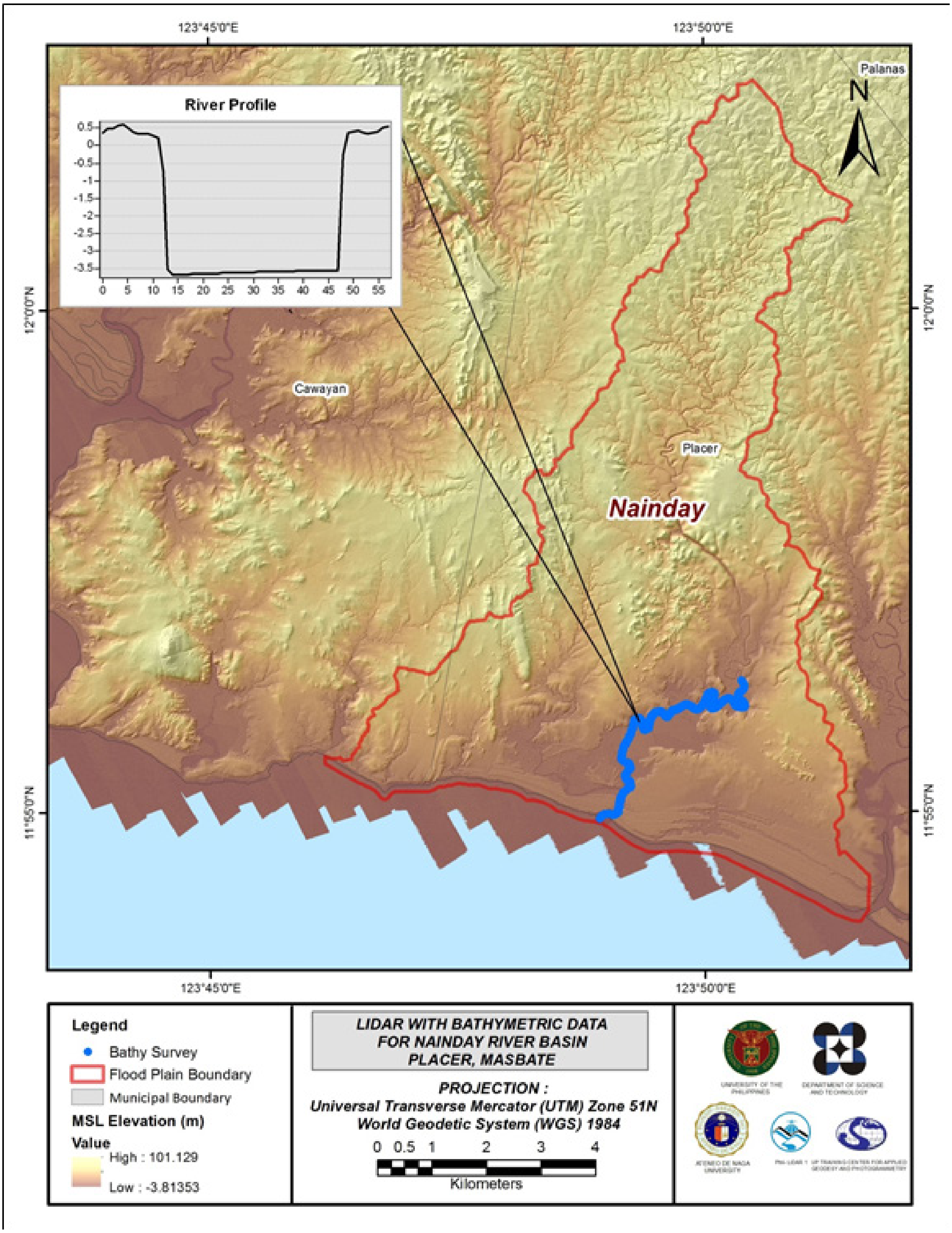


Figure 29. Map of Nainday floodplain with bathymetric survey points in blue.

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 a 200-meter buffer zone. Mosaicked LiDAR DEMs with a 1-m resolution were used to delineate footprints of building features, which comprised 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 the routing of disaster response efforts. These features are represented by network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

Nainday floodplain, including its 200-m buffer, has a total area of 72.46 sq km. For this area, a total of 5.0 sq. km., corresponding to a total of 1,087 building features, were considered for QC. Figure 30 shows the QC blocks for the Nainday floodplain.

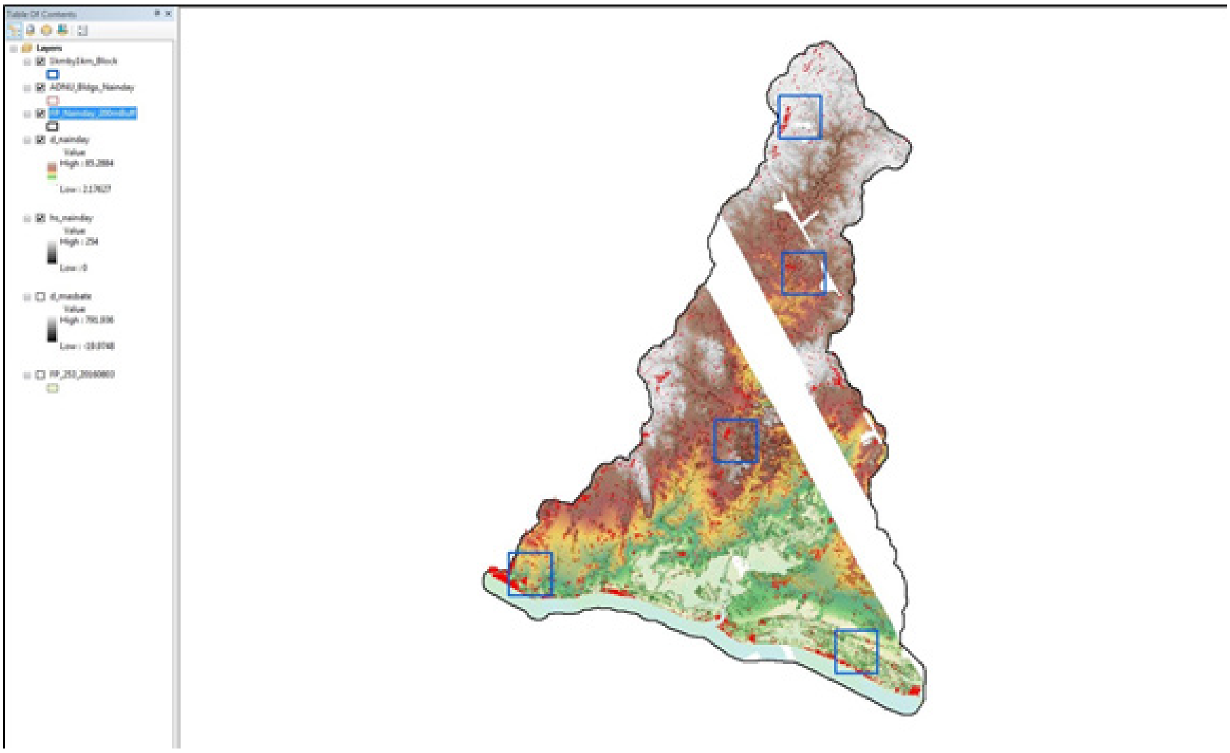


Figure 30. Blocks (in blue) of Nainday building features that were subjected to QC.

Quality checking of Nainday building features resulted in the ratings shown in Table 19.

Table 19. Details of the quality checking ratings for the building features extracted for the Nainday River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Nainday	99.20	99.73	98.83	PASSED

3.12.2 Height Extraction

Height extraction was done for 6,114 building features in Nainday floodplain. Of these building features, 1,904 was filtered out after height extraction, resulting to 4,510 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 11.05 meters.

3.12.3 Feature Attribution

Feature Attribution was done for 4,510 building features in Nainday Floodplain with the use of participatory mapping and innovations. The approach used in participatory mapping undergoes the creation of feature extracted maps in the area and presenting spatial knowledge to the community with the premise that the local community in the area are considered experts in determining the correct attributes of the building features in the area.

The innovation used in this process is the creation of an android application called reGIS. The Resource Extraction for Geographic Information System (reGIS)[1] app was developed to supplement and increase the field gathering procedures being done by the AdNU Phil-LiDAR 1. The Android application allows the user to automate some procedures in data gathering and feature attribution to further improve and accelerate the geotagging process. The 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. This effectively allows unified and standardized sets of data.

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

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

Table 20. Building features extracted for Nainday Floodplain.

Facility Type	No. of Features
Residential	4378
School	90
Market	4
Agricultural/Agro-Industrial Facilities	0
Medical Institutions	12
Barangay Hall	10
Military Institution	0
Sports Center/Gymnasium/Covered Court	0
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	1
Power Plant/Substation	0
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	1
Religious Institutions	10
Bank	0
Factory	0
Gas Station	3
Fire Station	0
Other Government Offices	1
Other Commercial Establishments	0
Total	4,510

Table 21. Total length of extracted roads for Nainday Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Nainday	79.92	0	0	0	0	**79.92**

Table 22. Number of extracted water bodies for Nainday Floodplain.

Floodplain	Water Body Type					Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	
Nainday	1	29	0	0	0	**30**

A total of 2 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

All extracted ground features were given the complete required attributes. Respectively, 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 31 shows the completed Digital Surface Model (DSM) of the Nainday floodplain overlaid with its ground features.

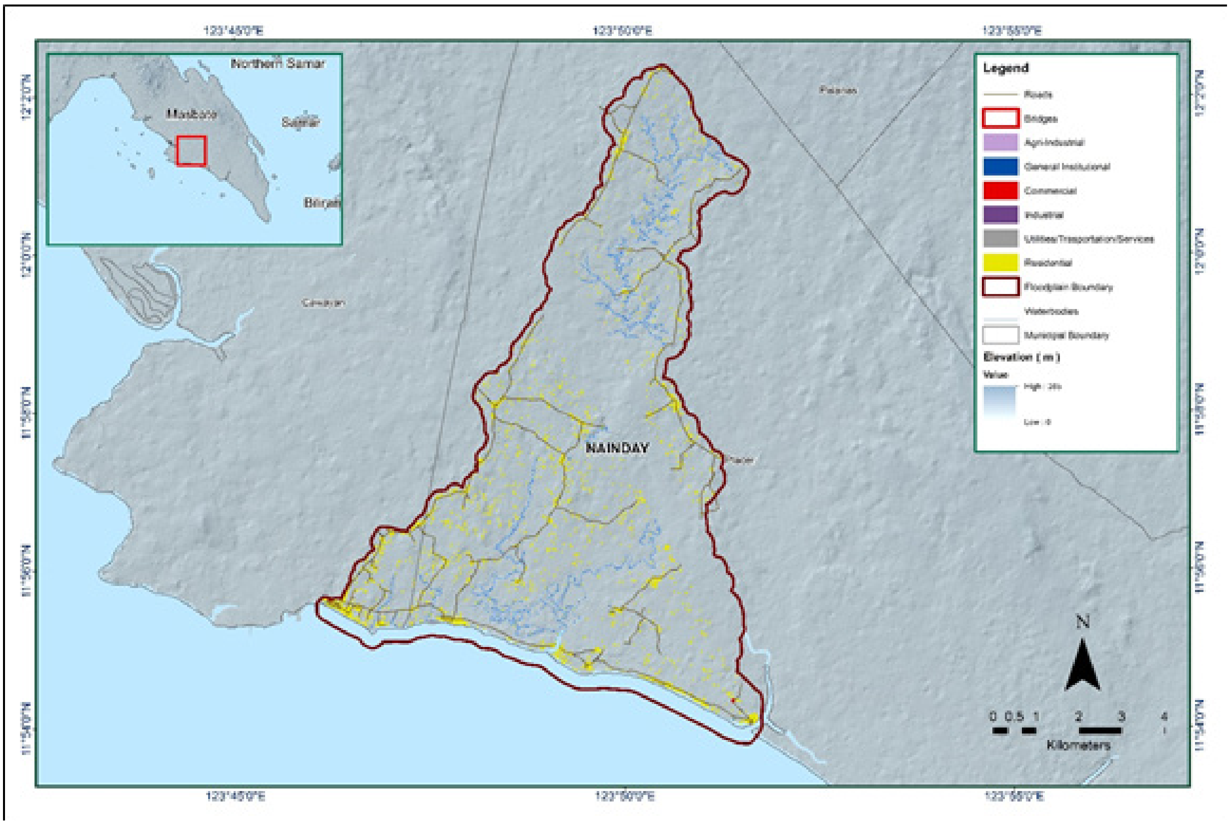


Figure 31. Extracted features of the Nainday Floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, For. Dona Rina Patricia C. Tajora, Elaine Bennet Salvador, For. Rodel C. Alberto

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 a field survey in Nainday River on February 5, 2017. Generally, the scope of work was comprised of (i) initial reconnaissance; (ii) control point survey for the establishment of a control point; (iii) the cross-section survey, bridge as-built survey, on the mouth of the river in Brgy. Taboc, Municipality of Placer, Masbate; and bathymetric survey, and water level marking in the Mean Sea Level (MSL); and (iv) the bathymetric survey of the Nainday River from Brgy. Manlut-Od to Brgy. Tubod where the mouth of the river is located; which reached an estimated length of 4.391 km using a dual frequency Topcon™ GR-5, a Hydrolite™ Single Beam Echo Sounder, and a Sokkia™ Set CX Total Station. Figure 32 illustrates the extent of the Nainday River Bathymetric Survey.

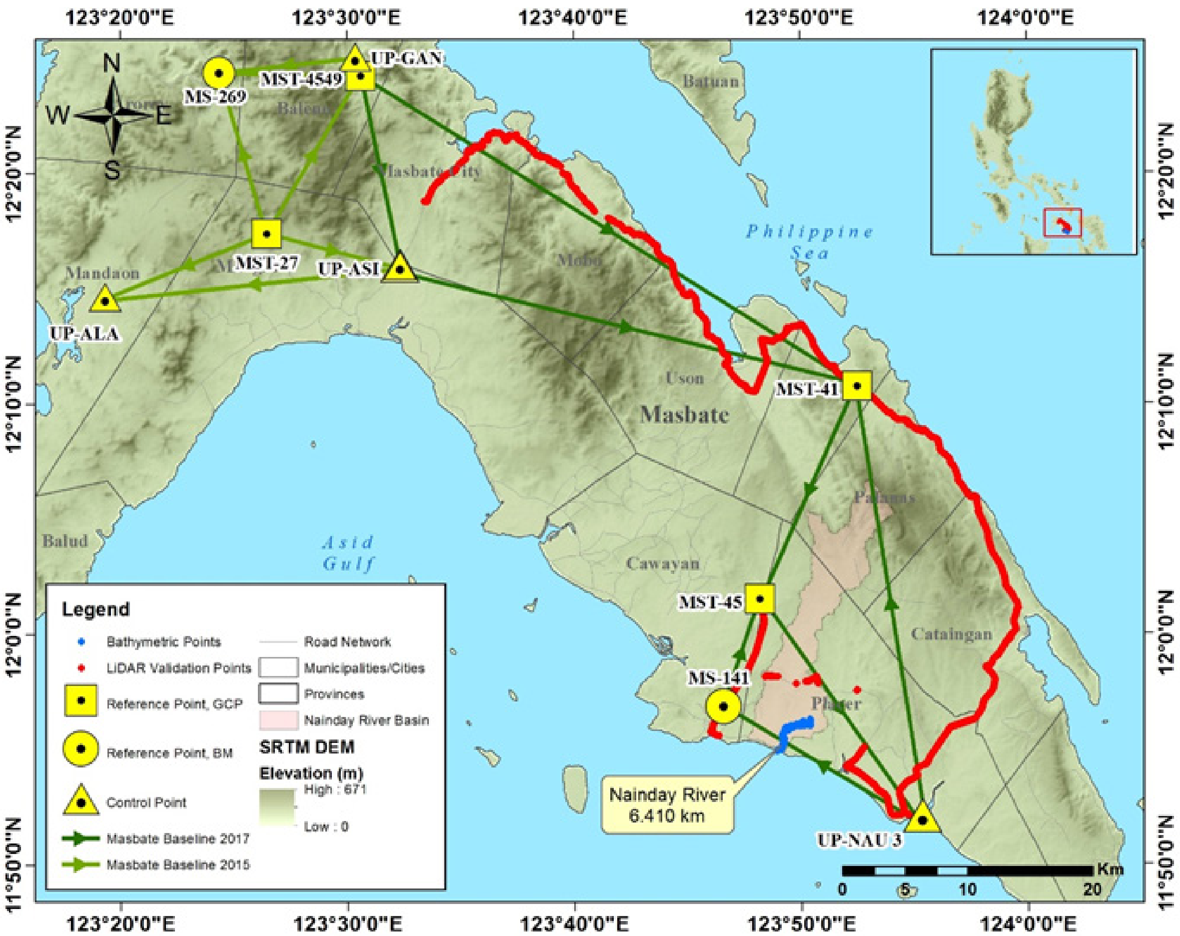


Figure 32. Extent of the bathymetric survey (in blue line) in Nainday River and the LiDAR data validation survey (in red).

4.2 Control Survey

The GNSS network used for Nainday River Basin is composed of three (3) loops established on January 27 and February 14, 2017, which occupied the following reference points: MST-4549, a fixed control from previous field survey in Lanang River located in Brgy. Canjunday, Municipality of Baleno, Masbate; UP-ASI, also a fixed control located in Brgy. Cayabon, Municipality of Milagros, Masbate; and MS-141, a first order BM located in Brgy. San Vicente, Municipality of Cawayan, Masbate.

A GNSS network was established for a previous PHIL-LIDAR 1 DVBC fieldwork in Mandaon, Baleno, and Asid Rivers in Masbate on December 12, 2015 occupying the reference and control points MST-27, a 2nd order GCP in Brgy. Matiporon, Municipality of Milagros; MS-269, a 1st order Benchmark in Brgy. Luy-A, Municipality of Aroroy; MST-4549, a 4th order GCP in Brgy. Canjunday, Municipality of Baleno; UP-ALA, a UP established control point in Brgy. Tagpu, Municipality of Mandaon; UP-ASI, a UP established control point in Brgy. Cayabon, Municipality of Milagros; and, UP-GAN, a UP established control point in Brgy. Gangao, Municpality of Baleno, all in the province of Masbate.

A control point was established namely UP-NAU-3 located near the mouth of the Nainday River in Brgy, Taboc, Municipality of Placer, Masbate. Alongside this, the respective NAMRIA established control points were also used as markers during the survey: MST-41 in Brgy. Gaid, Municipality of Dimasalang; and MST-45 in Brgy. Villahermosa, Municipality of Cawayan; both located in the province of Masbate.

Table 23 depicts the summary of reference and control points utilized, with their corresponding locations, while Figure 33 shows the GNSS network established in the Nainday River Survey.

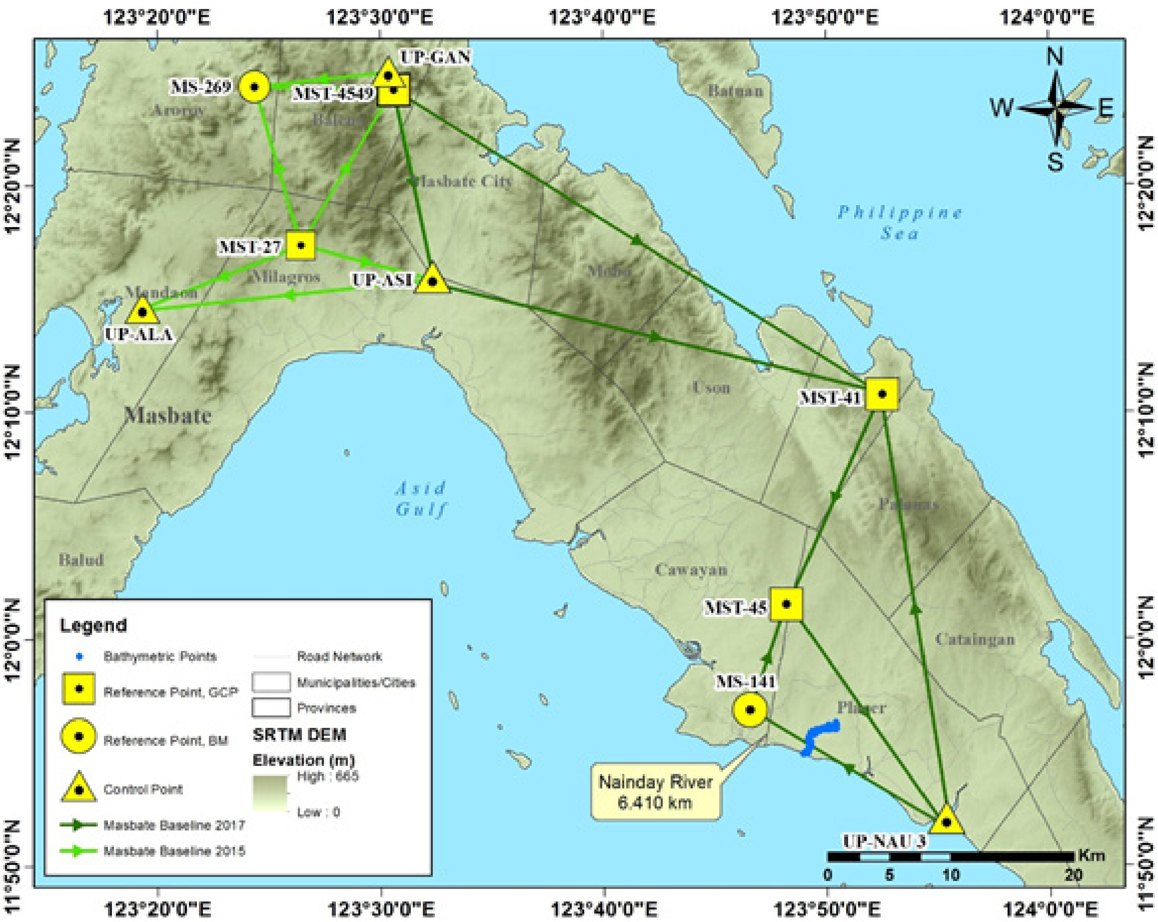


Figure 33. The GNSS Network established in the Nainday River Survey.

Table 23. References used and control points established in the Nainday River Survey (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84 N)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
MST-4549	4th order, GCP	12°24'13.29041"	123°30'36.98735"	76.969	21.829	2013
MST-41	Used as Marker	-	-	64.943	-	2007
MST-45	Used as Marker	-	-	73.746	-	2007
MS-141	1st order, BM	-	-	71.378	13.221	2007
UP-ASI	UP established	12°15'59.72358"	123°32'20.76940"	66.451	10.476	2015
UP-NAU3	UP established	-	-	60.4	-	2017

Figure 34 to Figure 39 depict the setup of the GNSS on recovered reference points and established control points in the Nainday River.

Figure 34. GNSS base set up, Trimble® SPS 985, at MST-4549, located in Brgy. Canjunday, Municipality of Baleno, Masbate.

Figure 35. GNSS receiver setup, Trimble® SPS 985, at MST-41, located in Brgy. Gaid, Municipality of Dimasalang, Masbate.

Figure 36. GNSS receiver setup, Trimble® SPS 985, at MST-45, located in Brgy. Villahermosa, Municipality of Cawayan, Masbate.

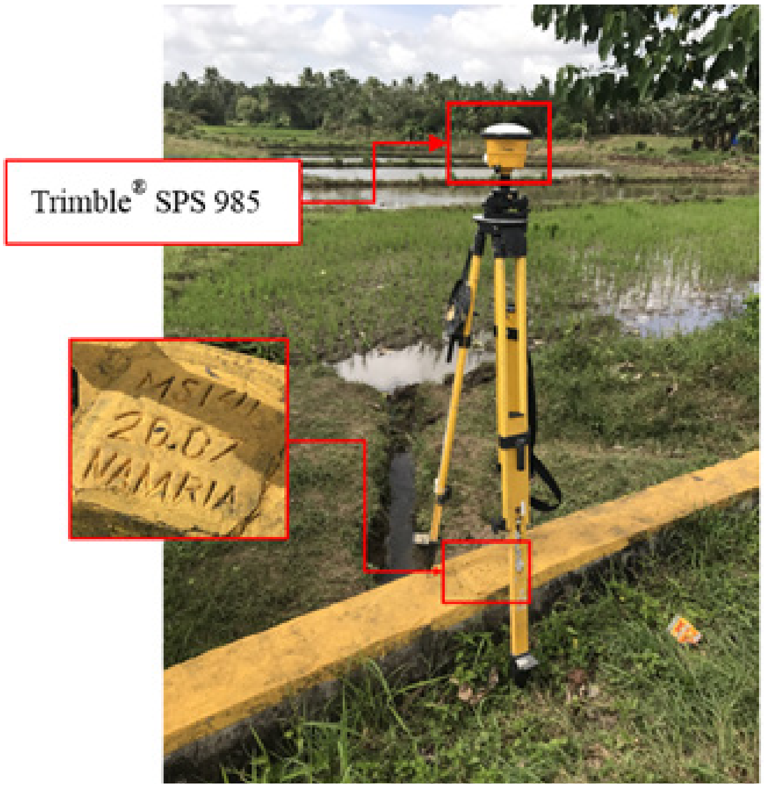


Figure 37. GNSS receiver setup, Trimble® SPS 985, at MS-141, located in Brgy. San Vicente, Municipality of Cawayan, Masbate.

Figure 38. GNSS receiver setup, Trimble® SPS 985, at UP-ASI, located Brgy. Cayabon, Municipality of Milagros, Masbate.

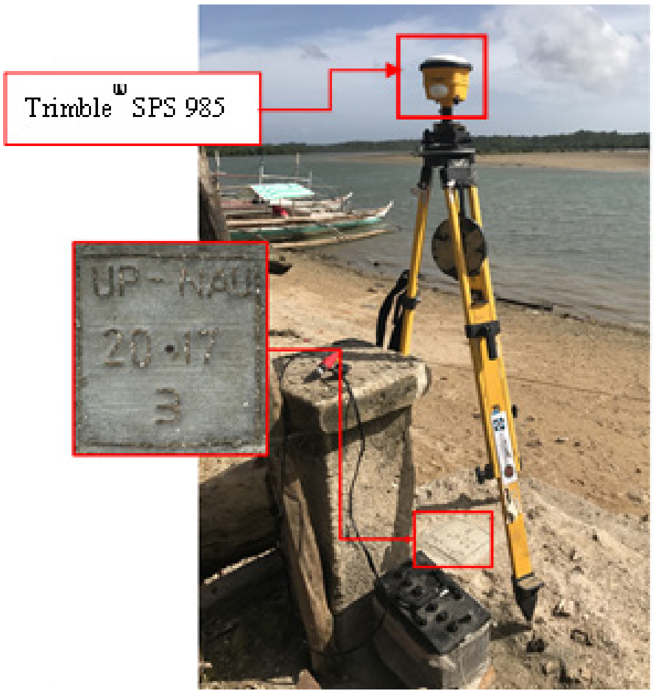


Figure 39. GNSS receiver setup, Trimble® SPS 985, at UP-NAU3, located in Brgy. Taboc, Municipality of Placer, Masbate.

4.3 Baseline Processing

The GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal or covering of portions of the 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 24 presents the baseline processing results of control points in the Nainday River Basin, as generated by the TBC software.

Table 24. The Baseline processing report for the Nainday River GNSS static observation survey.

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
UP-NAU 3 --- MS-141 (B6)	08-28-16	Fixed	0.004	0.019	298°53'38"	18166.522	11.403
MS-141 --- MST-45	12-05-2015	Fixed	0.007	0.04	263°57'41"	23763.75	-9.332
(B3)	08-28-16	Fixed	0.004	0.016	18°57'41"	9036.475	2.254
MST-4549 --- UPASI	12-05-2015	Fixed	0.013	0.019	271°18'18"	11347.5	5.154
(B8)	08-28-16	Fixed	0.003	0.014	168°18'59"	15487.632	-10.554
UP-NAU 3 --- MST-41 (B10)	08-28-16	Fixed	0.003	0.015	351°30'42"	34736.682	4.574
MST-45 --- UP-NAU 3 (B4)	08-28-16	Fixed	0.003	0.014	143°09'49"	21636.574	-13.668
MST-41 --- MST-45	12-05-2015	Fixed	0.015	0.076	343°39'18"	13427.81	-26.942

As shown in Table 24, a total of eight (8) baselines were processed with reference points MST-4549 and UP-ASI held fixed for coordinate values; and, MST-4549, MS-ASI, and UP-ASI fixed for elevation values; it is apparent that all baselines passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, the 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 20 cm and z less than 10 cm for each control point; or in equation form:

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

Where:

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

For complete details, see the Network Adjustment Report shown in Table 25 to Table 28.

The six (6) control points, MST-4549, MST-41, MST-45, MS-141, UP-ASI, and, UP-NAU-3 were occupied and observed simultaneously to form a GNSS loop. Coordinates of MST-4549 and UP-ASI; and elevation values of MST-4549, MS-141, and UP-ASI were held fixed during the processing of the control points as presented in Table 25. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 25. Constraints applied to the adjustment of the control points.

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
MS-141	Grid				Fixed
MST-4549	Grid	Fixed	Fixed		Fixed
UP-ASI	**Grid**	**Fixed**	**Fixed**		**Fixed**
Fixed = 0.000001 (Meter)					

Likewise, the list of adjusted grid coordinates, i.e. Northing, Easting, Elevation and computed standard errors of the control points in the network is indicated in Table 26. The fixed controls MST-4549 and UP-ASI have no values for grid errors while MST-4549, MS-141, and UP-ASI have no value for elevation error.

Table 26. Adjusted grid coordinates for the control points used in the Nainday River flood plain survey.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MST-4549	555464.635	?	1371246.784	?	21.829	?	ENe
MST-41	595192.614	0.004	1346499.397	0.004	7.564	0.045	
MST-45	587415.558	0.005	1329444.427	0.004	15.819	0.017	
MS-141	584504.292	0.005	1320892.702	0.005	13.221	?	e
UP-ASI	558628.712	?	1356091.508	?	10.476	?	ENe
UP-NAU 3	600433.760	0.007	1312170.323	0.006	1.747	0.024	

With the mentioned equation, $\sqrt{((x_e)^2+(y_e)^2)}<20cm$ for horizontal and $z^e<10$ cm for the vertical; the computation for the accuracy are as follows:

a. MST-4549

horizontal accuracy = Fixed
vertical accuracy = Fixed

b. MST-41

horizontal accuracy = $\sqrt{((0.4)^2 + (0.4)^2}$
= $\sqrt{(0.16 + 0.16)}$
= 0.57 < 20 cm
vertical accuracy = 4.5 cm < 10 cm

c. MST-45

horizontal accuracy = $\sqrt{((0.5)^2 + (0.4)^2}$
= $\sqrt{(0.25 + 0.16)}$
= 0.64 < 20 cm
vertical accuracy = 1.7 cm < 10 cm

d. MS-141

horizontal accuracy = $\sqrt{((0.5)^2 + (0.5)^2}$
= $\sqrt{(0.25 + 0.25)}$
= 0.71 < 20 cm
vertical accuracy = Fixed

e. UP-ASI

horizontal accuracy = Fixed
vertical accuracy = Fixed

f. UP-NAU 3

horizontal accuracy = $\sqrt{((0.7)^2 + (0.6)^2}$
= $\sqrt{(0.49 + 0.36)}$
= 0.92 < 20 cm
vertical accuracy = 2.4 cm < 10 cm

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

Table 27. Adjusted geodetic coordinates for control points used in the Nainday River Flood Plain validation.

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
MST-4549	N12°24'13.29041"	E123°30'36.98735"	76.969	?	ENe
MST-41	N12°10'44.36122"	E123°52'30.02722"	64.943	0.045	
MST-45	N12°01'29.95768"	E123°48'11.03606"	73.746	0.017	
MS-141	N11°56'51.84368"	E123°46'33.96438"	71.378	?	e
UP-ASI	N12°15'59.72358"	E123°32'20.76940"	66.451	?	ENe
UP-NAU 3	N11°52'06.32015"	E123°55'19.63857"	60.400	0.024	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 27. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met. The computed coordinates of the reference and control points utilized in the Nainday River GNSS Static Survey are seen in Table 28.

Table 28. The reference and control points utilized in the Nainday River Static Survey, with their corresponding locations (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-4549	4th order, GCP	12°24'13.29041"	123°30'36.98735"	76.969	1371246.784	555464.635	21.829
MST-41	Used as Marker	12°10'44.36122"	123°52'30.02722"	64.943	1346499.397	595192.614	7.564
MST-45	Used as Marker	12°01'29.95768"	123°48'11.03606"	73.746	1329444.427	587415.558	15.819
MS-141	1st order, BM	11°56'51.84368"	123°46'33.96438"	71.378	1320892.702	584504.292	13.221
UP-ASI	UP established	12°15'59.72358"	123°32'20.76940"	66.451	1356091.508	558628.712	10.476
UP-NAU3	UP established	11°52'06.32015"	123°55'19.63857"	60.4	1312170.323	600433.760	1.747

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

The bridge cross-section and as-built surveys were conducted on February 9, 2017 at the downstream side of Nainday Bridge in Brgy. Tan-Awan, Municipality of Placer, Masbate, using Trimble® SPS 882 GNSS in PPK Survey Technique (Figure 40 and Figure 41).

Figure 40. Nainday Bridge facing upstream.

Figure 41. The Bridge As-Built Survey using PPK Survey Technique.

The length of the cross-sectional line surveyed on Nainday Bridge is about 76.219 meters with 25 cross-sectional points acquired using the control point MST-45 as the GNSS base station. The location map, the cross-section diagram, and the bridge data form are shown in Figure 42 to Figure 44, respectively.

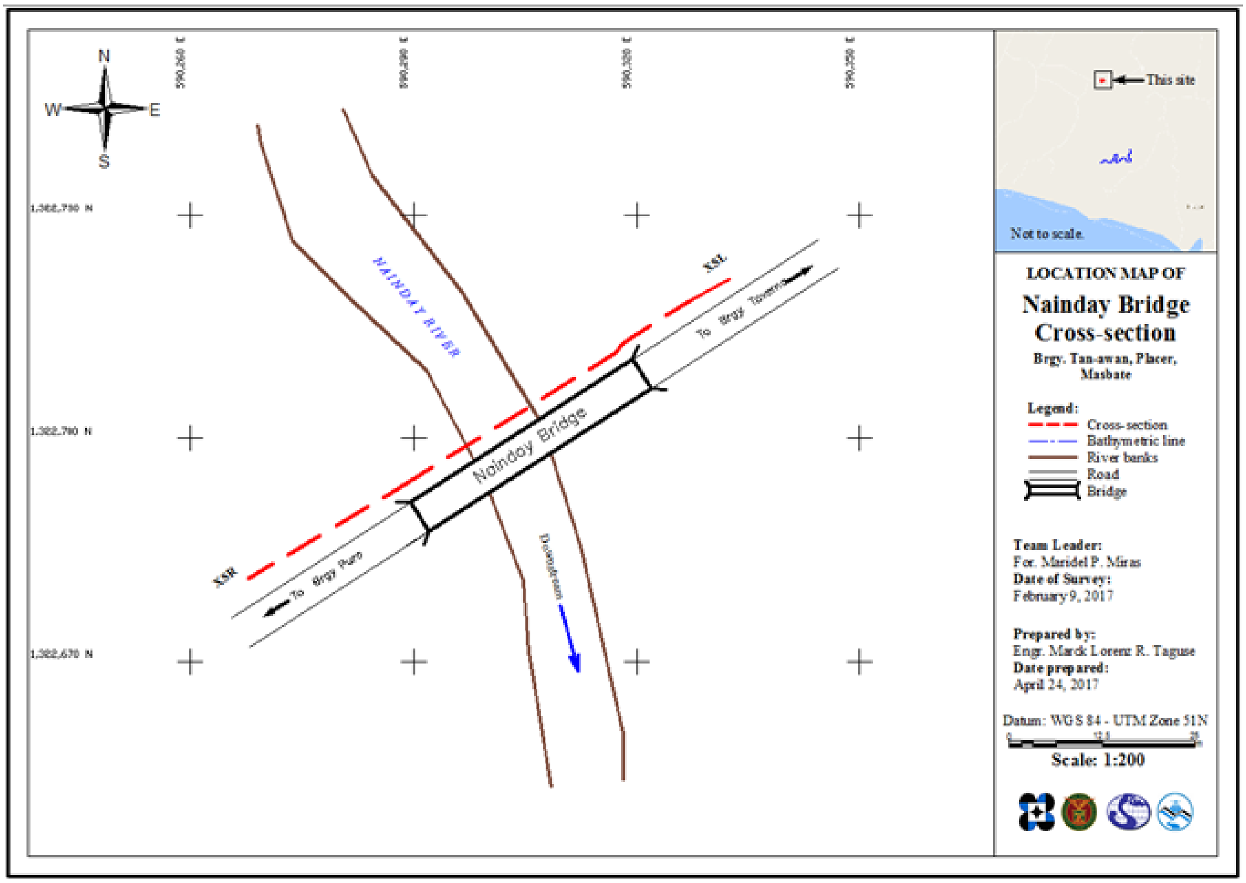


Figure 42. Location map of the Nainday Bridge cross-section survey.

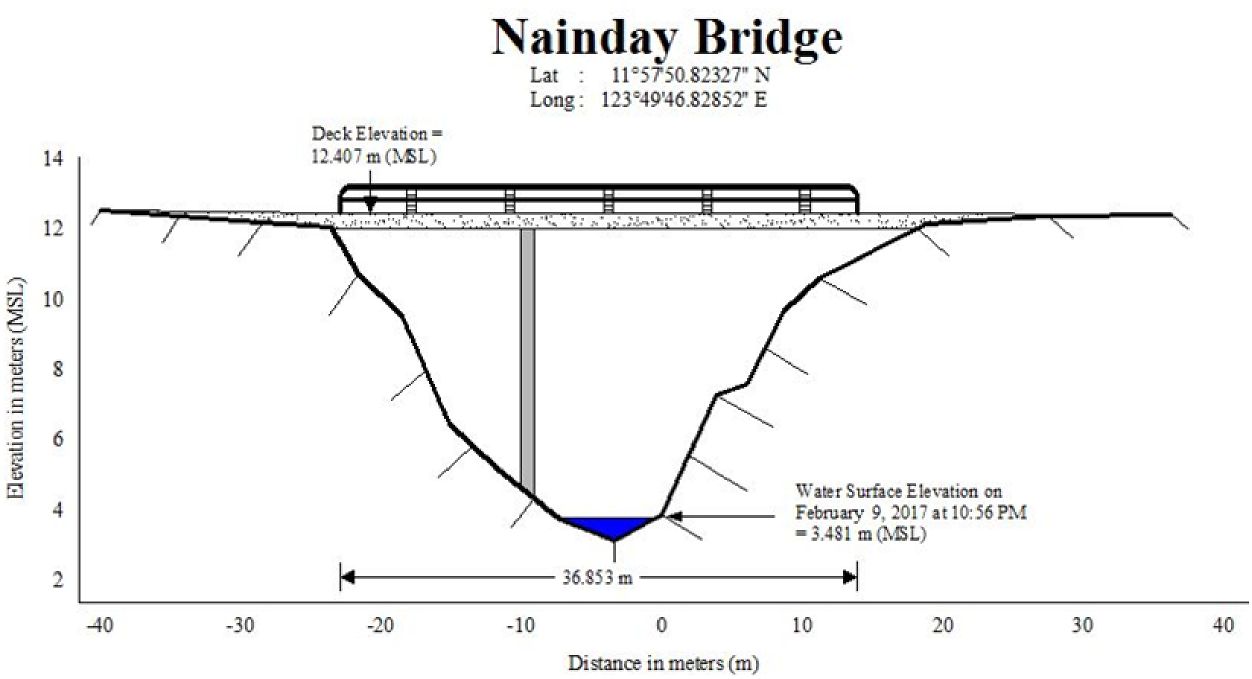


Figure 43. The Nainday Bridge cross-section survey drawn to scale.

Bridge Data Form

Bridge Name: Nainday Bridge — Date: February 9, 2017

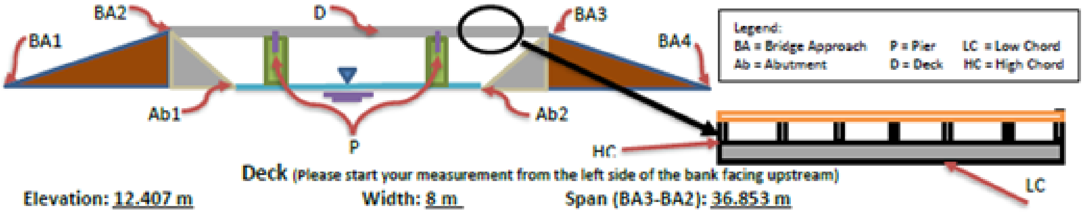
River Name: Nainday River — Time: 10:56 AM

Location (Brgy, City,Region): Brgy. Tan-Awan, Placer, Masbate

Survey Team: Maridel Miras, Marla Tricia Morris, Randell Pabroquez

Flow condition: average — Weather Condition: fair

Latitude: 11°57'50.82327"N — Longitude: 123°49'46.82852"E



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

Elevation: 12.407 m — Width: 8 m — Span (BA3-BA2): 36.853 m

	Station	High Chord Elevation	Low Chord Elevation
1	Not available	Not available	Not available

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	12.509 m	BA3	53.907 m	12.415 m
BA2	17.054 m	12.407 m	BA4	76.219 m	12.378 m

Abutment: Is the abutment sloping? ; If yes, fill in the following information:

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: round — Number of Piers: 1 — Height of column footing: Not available

	Station (Distance from BA1)	Elevation	Pier Diameter
Pier 1	30.445 m	12.413 m	1 m

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure 44. The Nainday Bridge as-built survey data.

The water surface elevation of Nainday River was determined using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique on February 9, 2017 at 10:56 AM with a value of 3.481 m in MSL as shown in Figure 44. This was translated into marking on the Nainday Bridge's deck using the same technique shown in Figure 45. The marking will serve as reference for flow data gathering and depth gauge deployment of the partner HEI responsible for Nainday River, the Ateneo de Naga University.

Figure 45. Water level markings along Nainday River.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on January 28, February 7 and 13, 2017 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on top of a vehicle. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced as shown in Figure 46. The antenna height was 1.884 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP-NAU3, MST-41, and UP-ASI occupied as the GNSS base stations in the conduct of the survey.

Figure 46. The validation point acquisition survey setup using a GNSS receiver fixed in a van along the Nainday River Basin.

The conducted survey on January 28, 2017 started from Brgy. Libas, Municipality of Placer going east, traversing the Municipality of Cataingan. On February 7, 2017 the survey continued from the Municipality of Cataingan going west to the Municipality of Mobo; and on February 13, 2017, the survey started in Masbate City going east to the Municipality of Mobo until it ended in Brgy. Marintoc, Municipality of Mobo. A total of 16,824 points, with approximate length of 122.19 km, were gathered for the entire extent of validation points acquisition survey, as illustrated in the map in Figure 47.

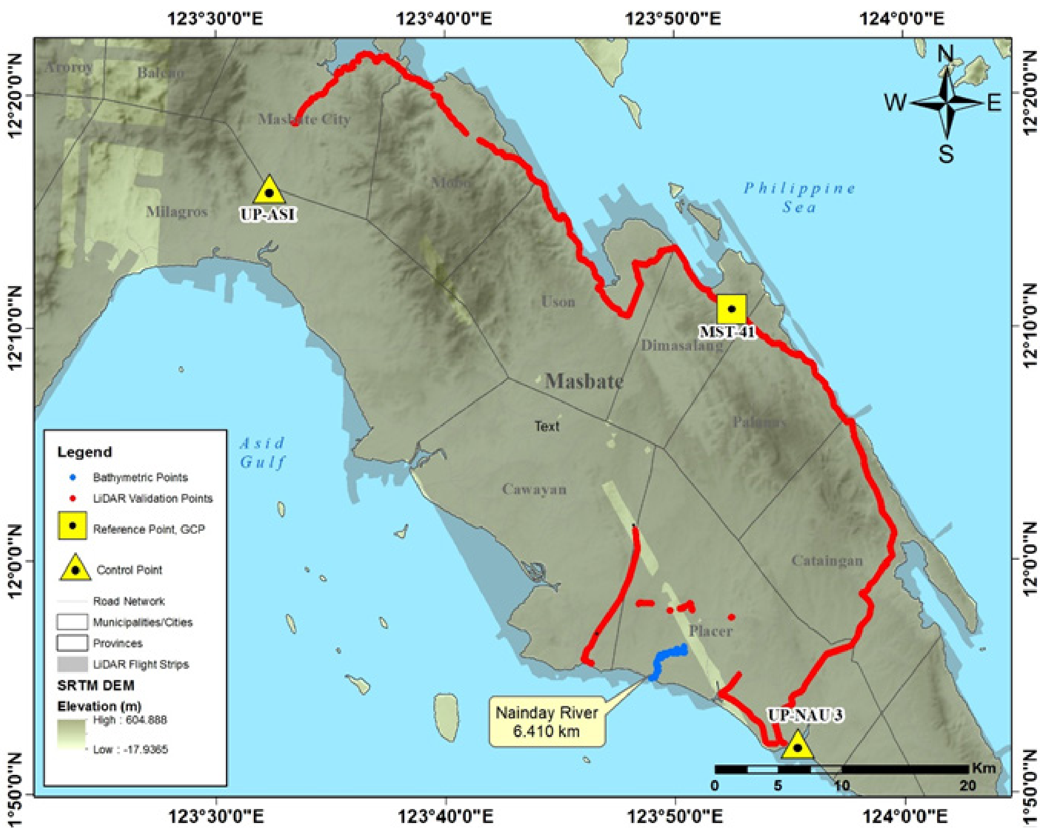


Figure 47. The extent of the LiDAR ground validation survey (in red) for Nainday River Basin.

4.7 Bathymetric Survey

Bathymetric survey was conducted on February 8, 2017 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode as shown in Figure 48. The survey started in the upstream part of the river in Brgy. Nainday, Municipality of Placer with coordinates 11°56'18.13511"N, 123°50'22.12322"E, and ended at the mouth of the river with coordinates 11°54'55.79921"N, 123°48'55.99941"E in the same Barangay. The control UP-NAU3 was used as GNSS base station all throughout the bathymetric survey.

Figure 48. Set-up of the bathymetric survey using Ohmex™ single beam echo sounder in Nainday River.

Overall, the bathymetric survey for the Nainday River gathered a total of 4,458 points, covering 6.41 km of the river, traversing Brgy. Nainday, Municipality of Placer, Masbate downstream (Figure 49). To further illustrate this, a CAD drawing of the riverbed profile of Nainday River was produced. As shown in Figure 50, the highest and lowest elevation has a 3.778-m difference for Nainday River. The highest elevation observed was –0.358 m below MSL located at the downstream part of Nainday river; while the lowest was –4.136 m below MSL located at the downstream portion of the river.

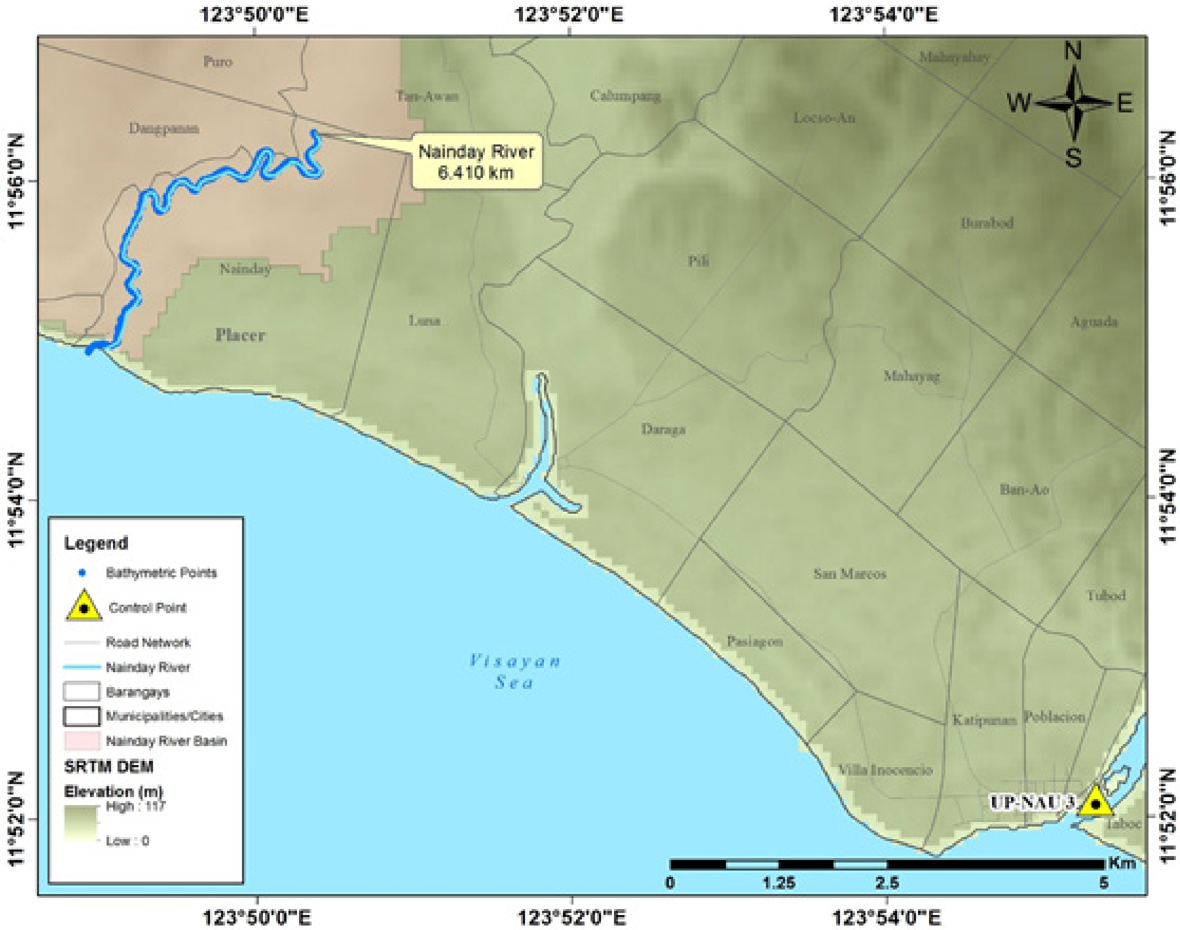


Figure 49. The extent of the Nainday River Bathymetry Survey.

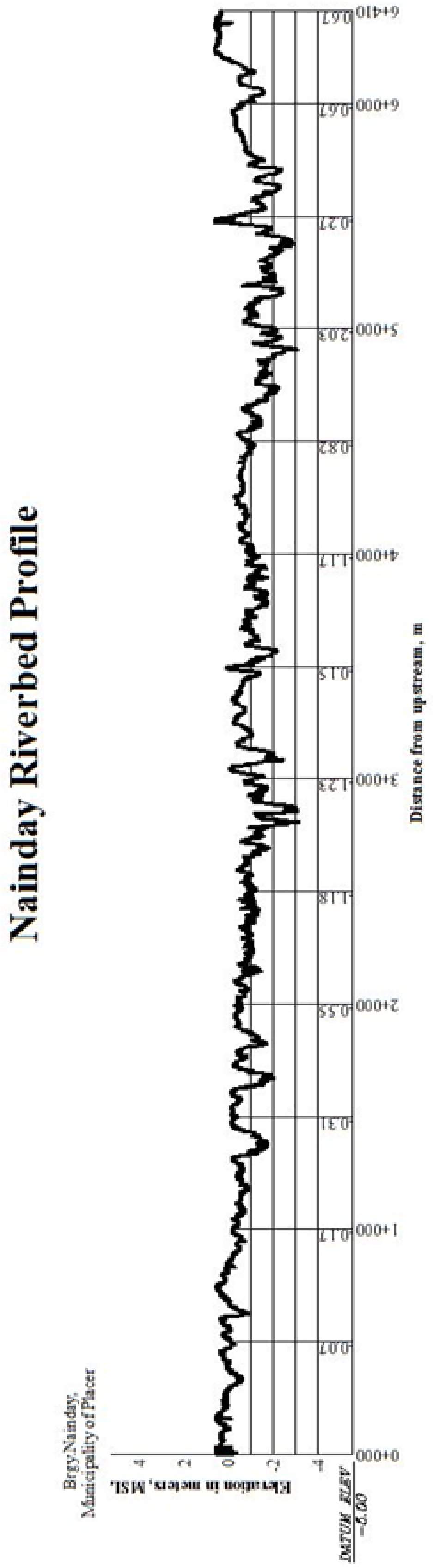


Figure 50. The Nainday Riverbed Profile.

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Gianni Sumajit

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, such as rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Nainday River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute as illustrated in Figure 51. The precipitation data collection started from December 06, 2014 at 12:00 AM to December 09, 2014 at 4:00 PM with a 10-minute recording interval.

The total precipitation for this event in Tagaytay Bridge ARG is 26.6mm. It has a peak rainfall of 5mm on December 08, 2014 at 11:30 AM. The lag time between the peak rainfall and discharge is 14 hours.

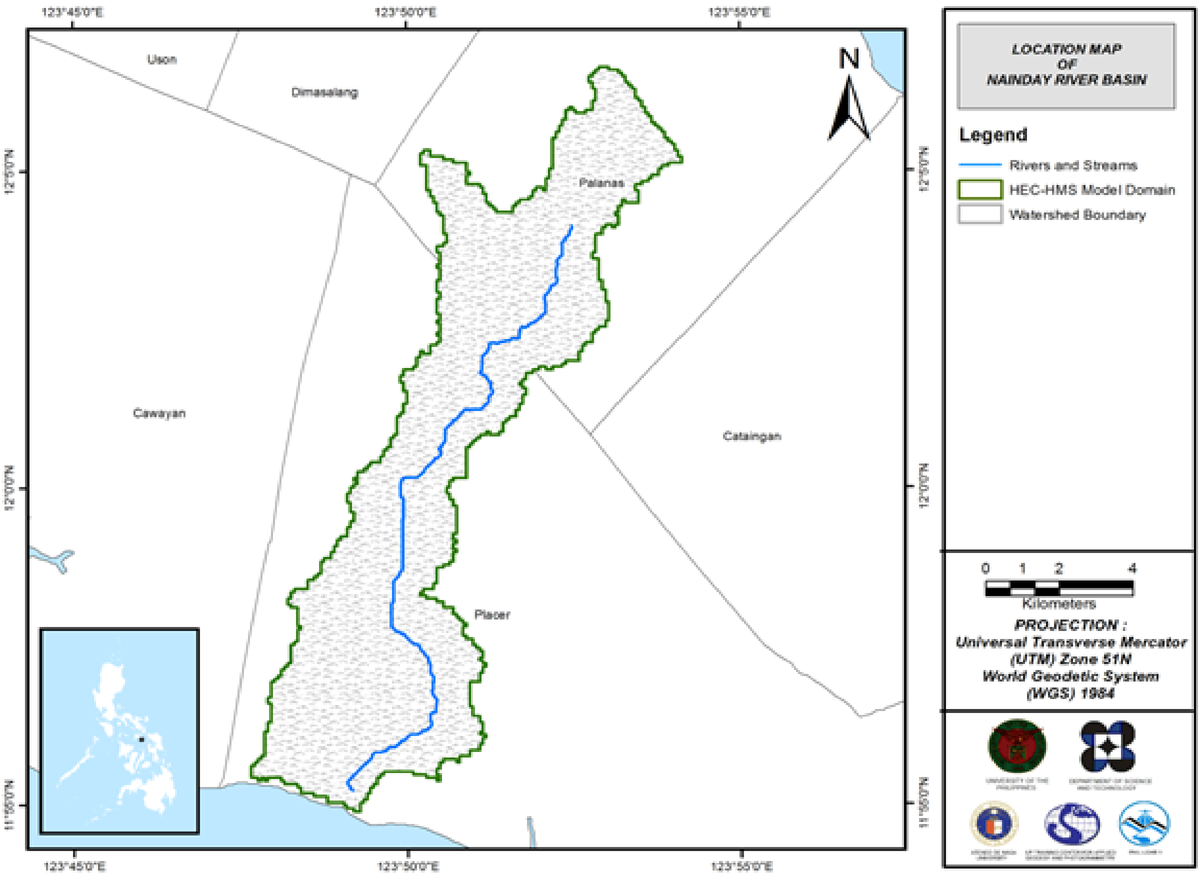


Figure 51. Location Map of the Nainday HEC-HMS model used for calibration.

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 52) at Nainday Bridge, Nainday, Masbate (13°49’14.6”N, 122°47’41.3”E) to establish the relationship between the observed water levels (H) at Nainday Bridge and outflow (Q) of the watershed at this location.

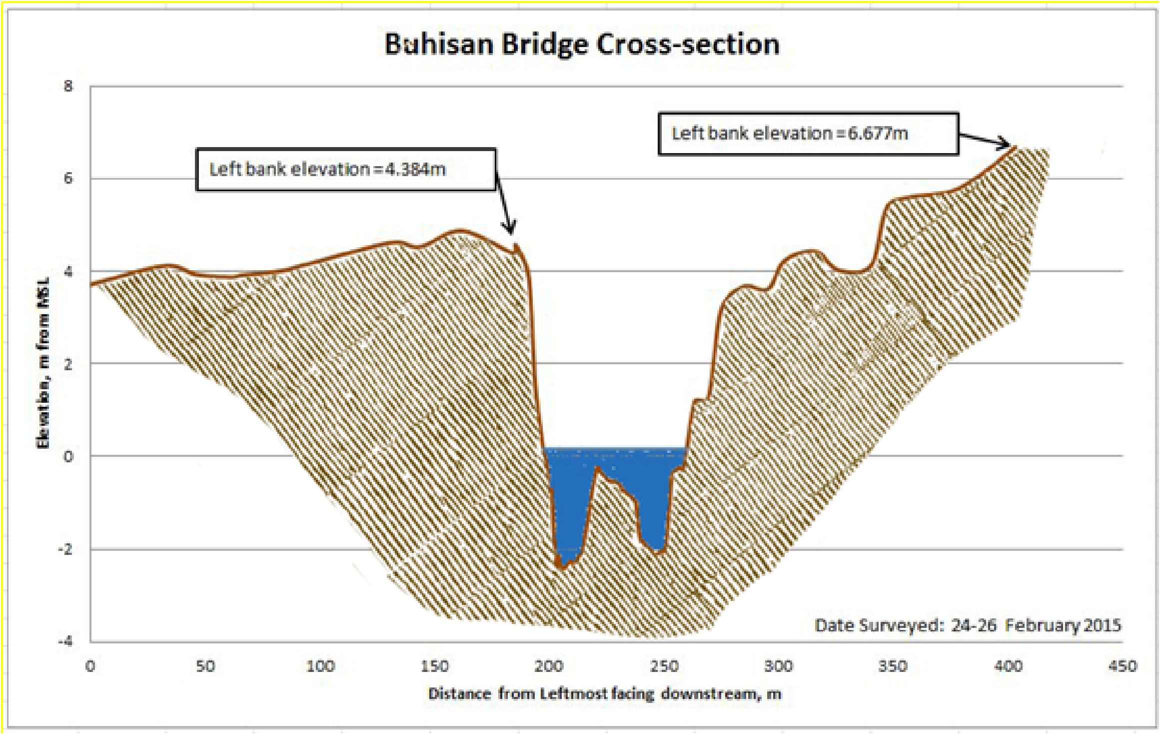


Figure 52. The cross-section plot of the Buhisan Bridge.

The rating curve for Nainday Bridge is unnavailable

Figure 53. The rating curve of Nainday Bridge in Nainday, Masbate.

This rating curve equation was used to compute the river outflow at Nainday Bridge for the calibration of the HEC-HMS model shown in Figure 51. The total rainfall for this event is 27.8mm and the peak discharge is 51.2 m3/s at 2:30 AM, December 26, 2016.

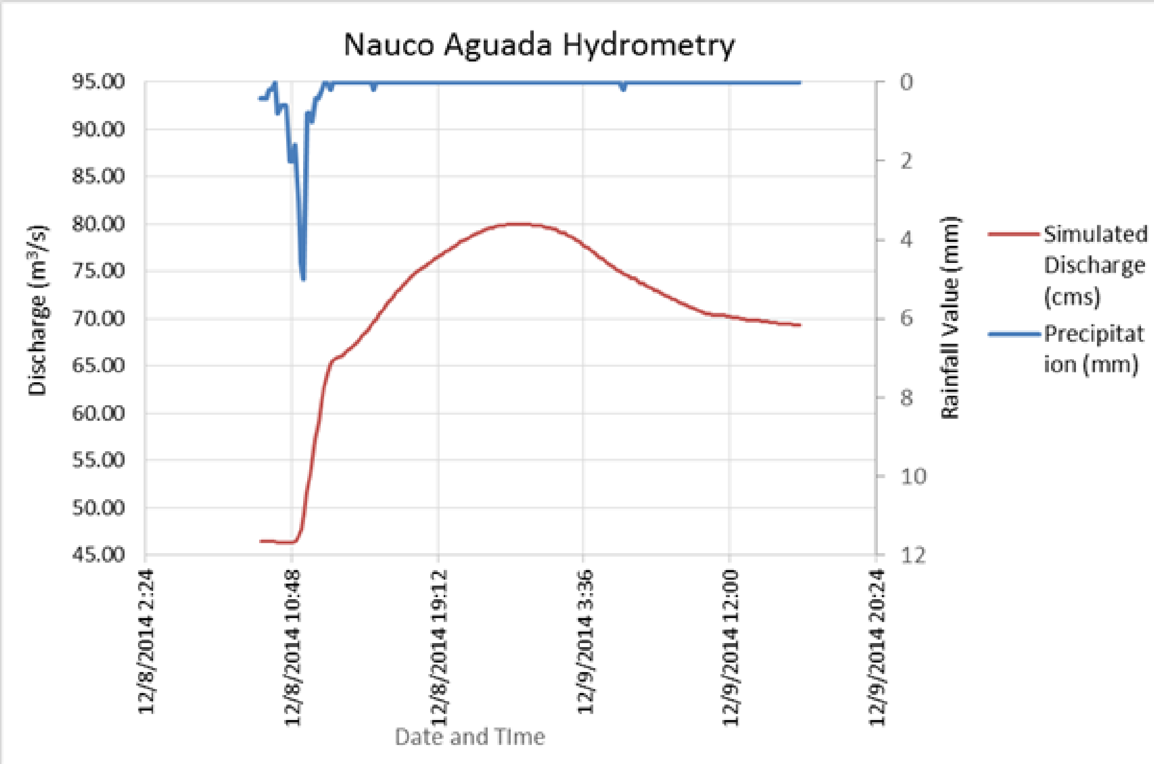


Figure 54. Rainfall and outflow data at the Nainday Bridge of the Nainday River Basin, which was used for modeling.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Catarman RIDF (Table 29). The RIDF rainfall amount for 24 hours was converted into a synthetic storm by interpolating and re-arranging the values in such a way that certain peak values will be attained at a certain time (Figure 54). This station was selected based on its proximity to the Nainday watershed. The extreme values for this watershed were computed based on a 26-year record.

Table 29. RIDF values for the Nainday River Basin as computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	22.5	34.2	42.4	57.5	80.9	96.4	125.2	156.6	180
5	29.9	45.4	56.2	77	110.3	135.9	183.5	229.5	255.4
10	34.7	52.8	65.4	90	129.7	162	222.1	277.8	305.4
15	37.5	57	70.5	97.3	140.7	176.7	243.9	305.1	333.6
20	39.4	60	74.2	102.4	148.4	187.1	259.1	324.1	353.3
25	40.9	62.2	76.9	106.3	154.3	195	270.9	338.8	368.5
50	45.5	69.2	85.5	118.4	172.6	219.5	307.1	384.1	415.3
100	50	76.1	94	130.5	190.7	243.8	343	429	461.8

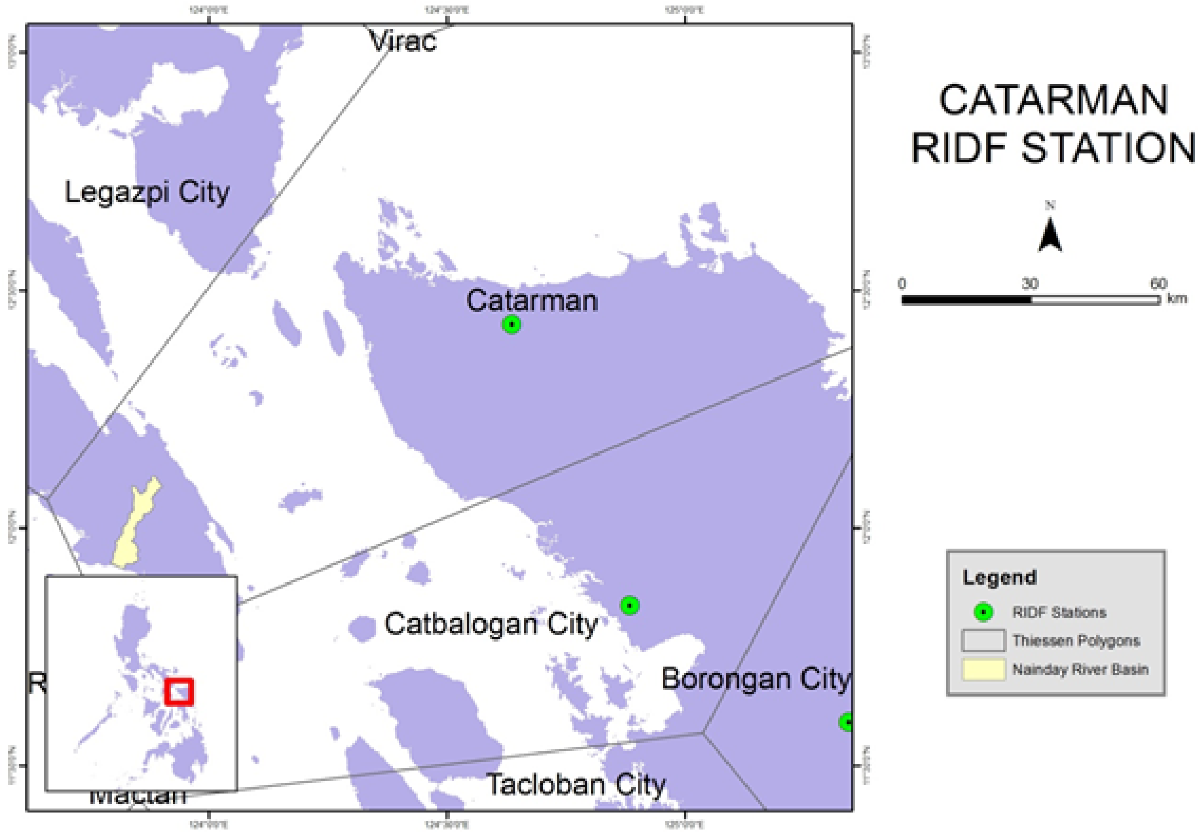


Figure 55. The location of the Catarman RIDF station relative to the Nainday River Basin.

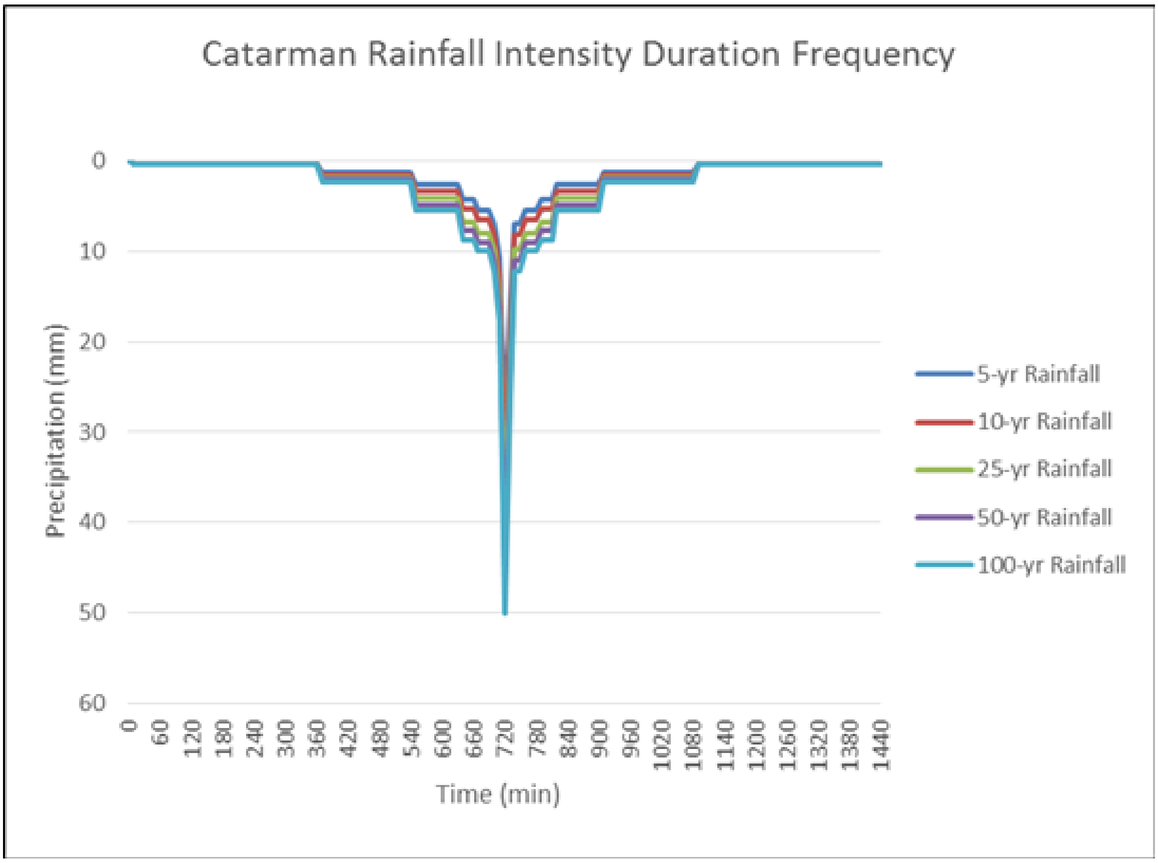


Figure 56. The synthetic storm generated for a 24-hour period rainfall for various return periods.

5.3 HMS Model

These soil dataset was taken on 2004 from the Bureau of Soils and Water Management (BSWM). It is 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 Nainday River Basin are shown in Figure 57 and Figure 58, respectively.

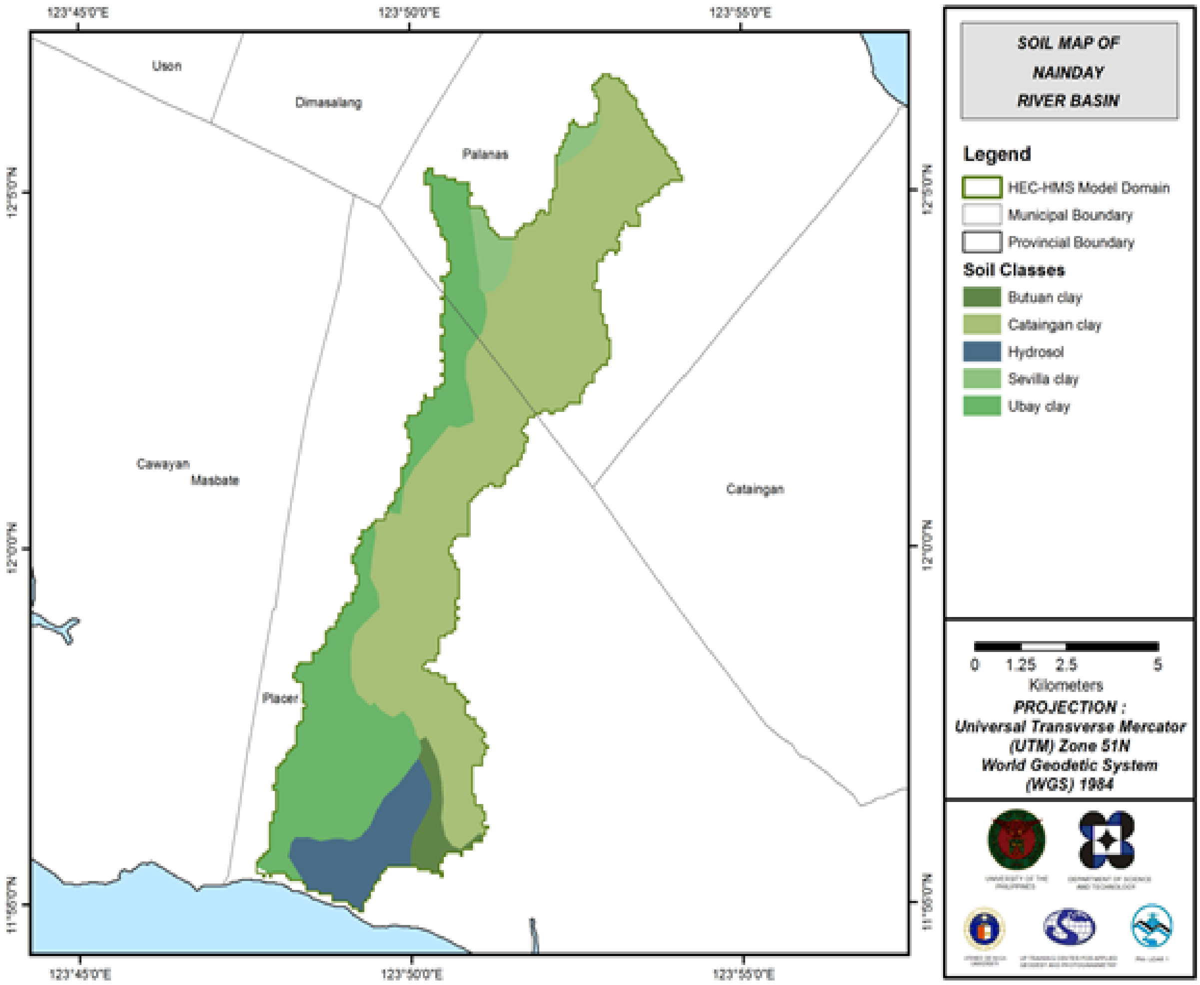


Figure 57. Soil Map of Nainday River Basin.

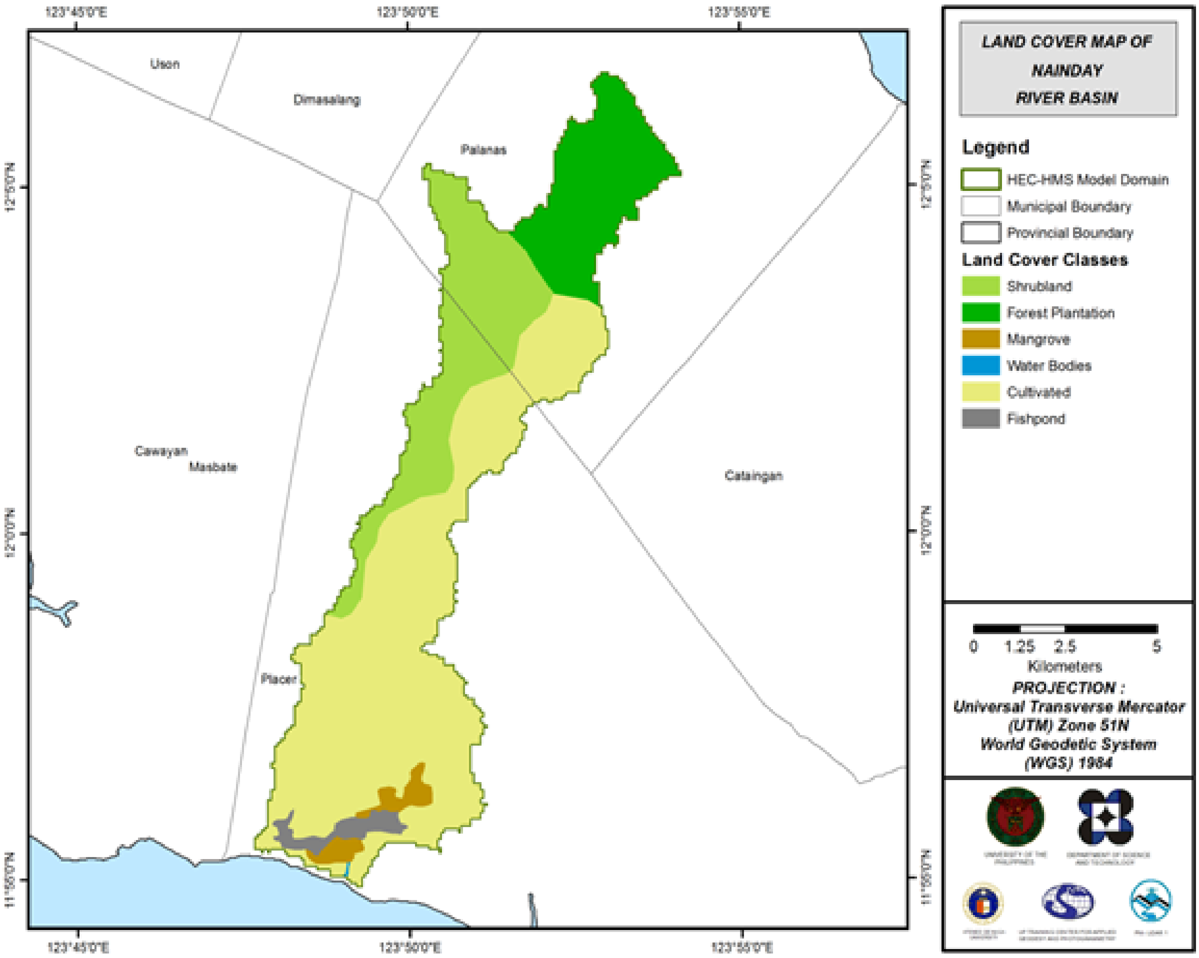


Figure 58. Land Cover Map of Nainday River Basin.

For Nainday, six soil classes were identified. These are Sevilla clay, Annam clay loam, Panganiran clay, and Nainday sandy clay. Moreover, three land cover classes were identified. These are shrubland, mangrove, and barren areas.

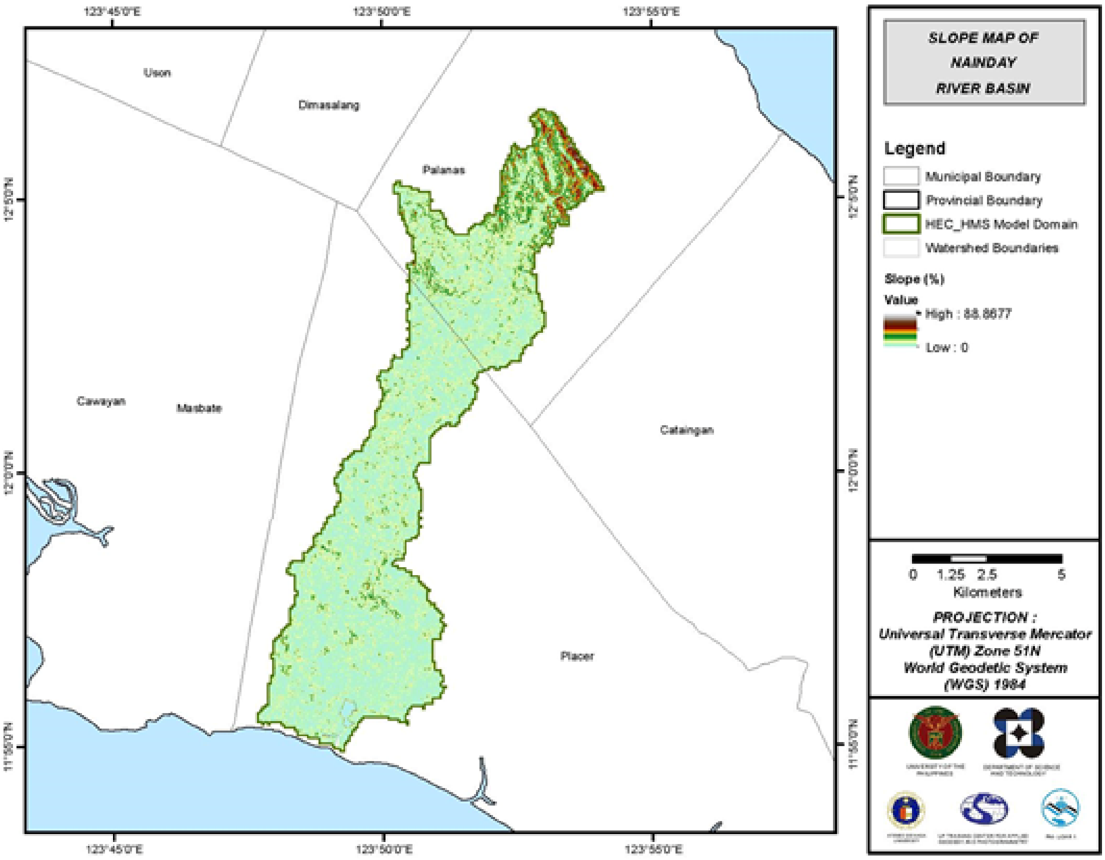


Figure 59. Slope Map of the Nainday River Basin.

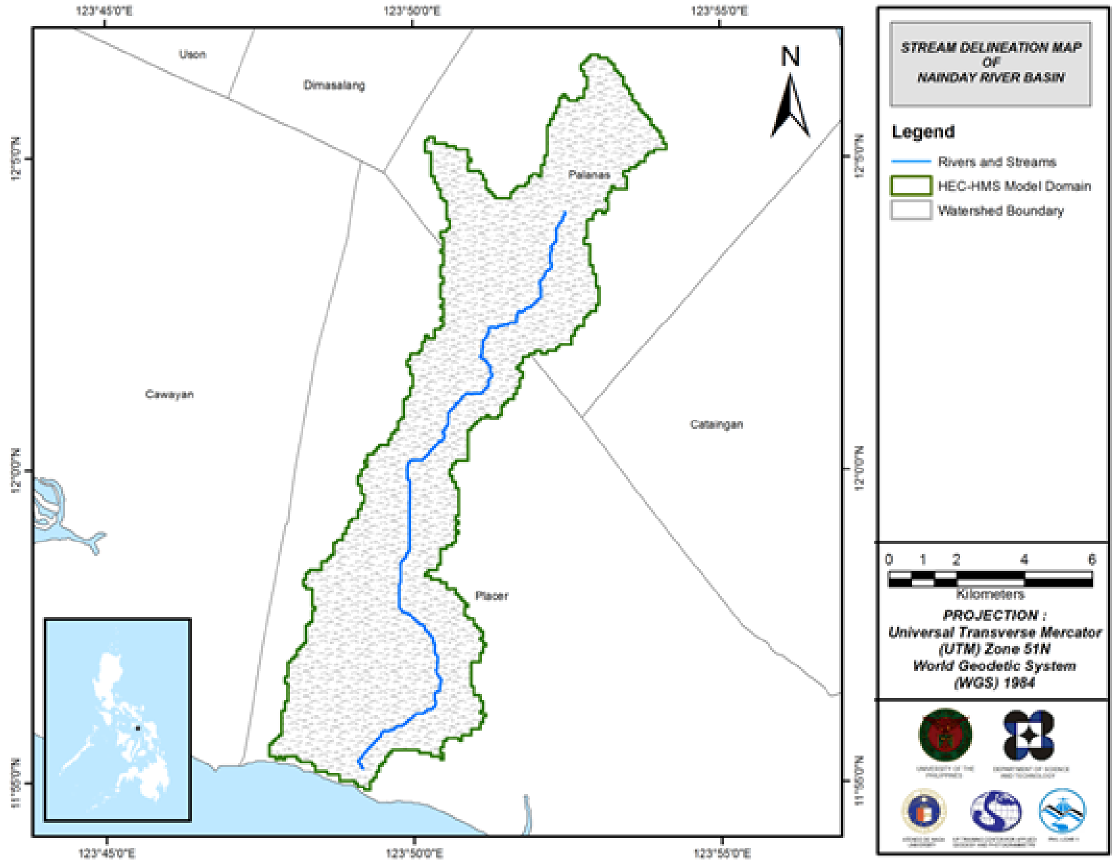


Figure 60. Stream Delineation Map of Nainday River Basin.

Using the SAR-based DEM, the Nainday basin was delineated and further subdivided into subbasins. The model consists of 17 sub basins, 8 reaches, and 8 junctions as shown in Figure 59. The main outlet is at Nainday Bridge.

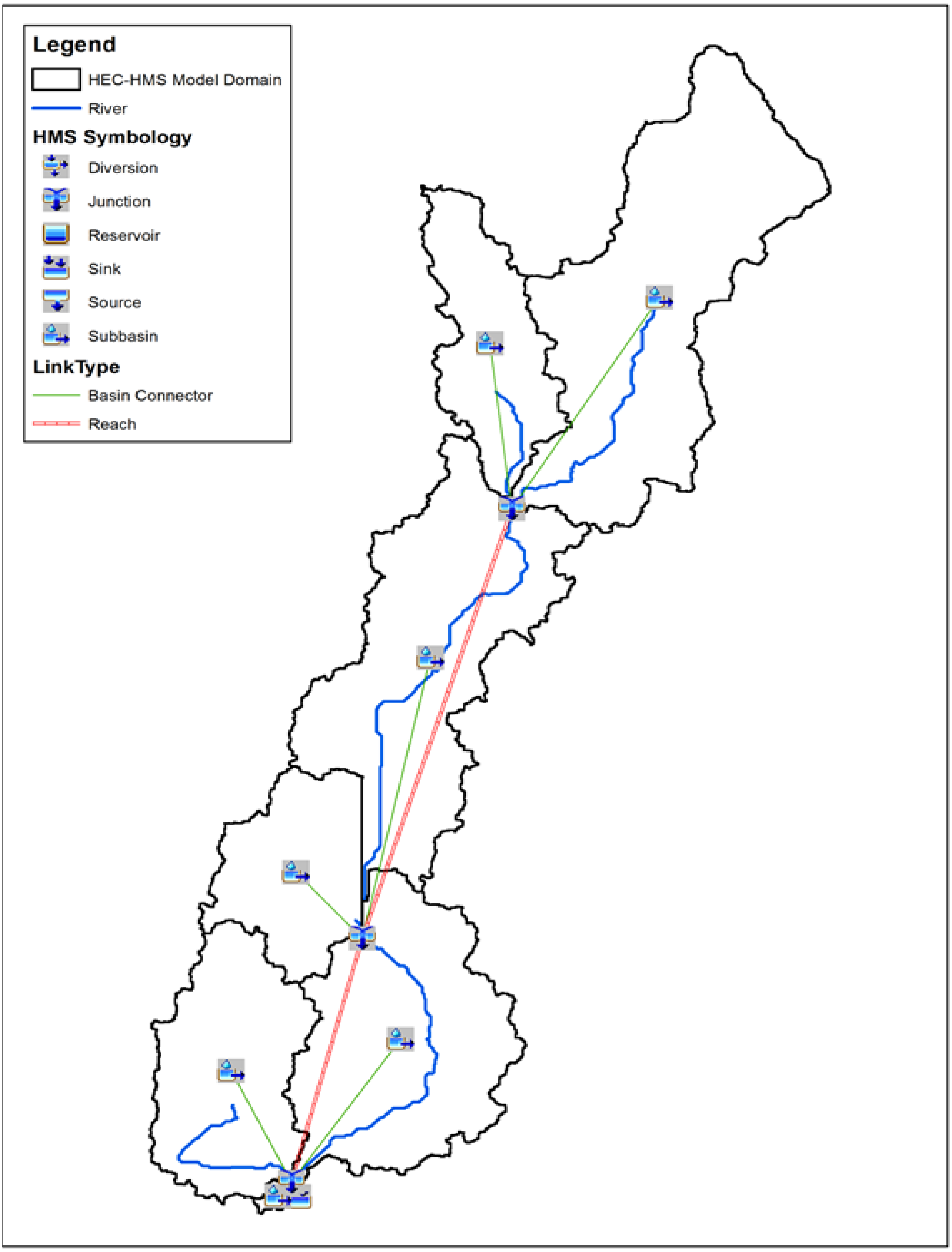


Figure 61. The Nainday river basin model generated using HEC-HMS.

5.4 Cross-section Data

The riverbed cross-sections of the watershed were necessary in the HEC-RAS model setup. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data, which was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 62).

The River cross-section of the Nainday River through the ArcMap HEC GeoRas tool is unnavailable

Figure 62. River cross-section of the Nainday River through the ArcMap HEC GeoRas tool.

5.5 Flo 2D Model

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

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

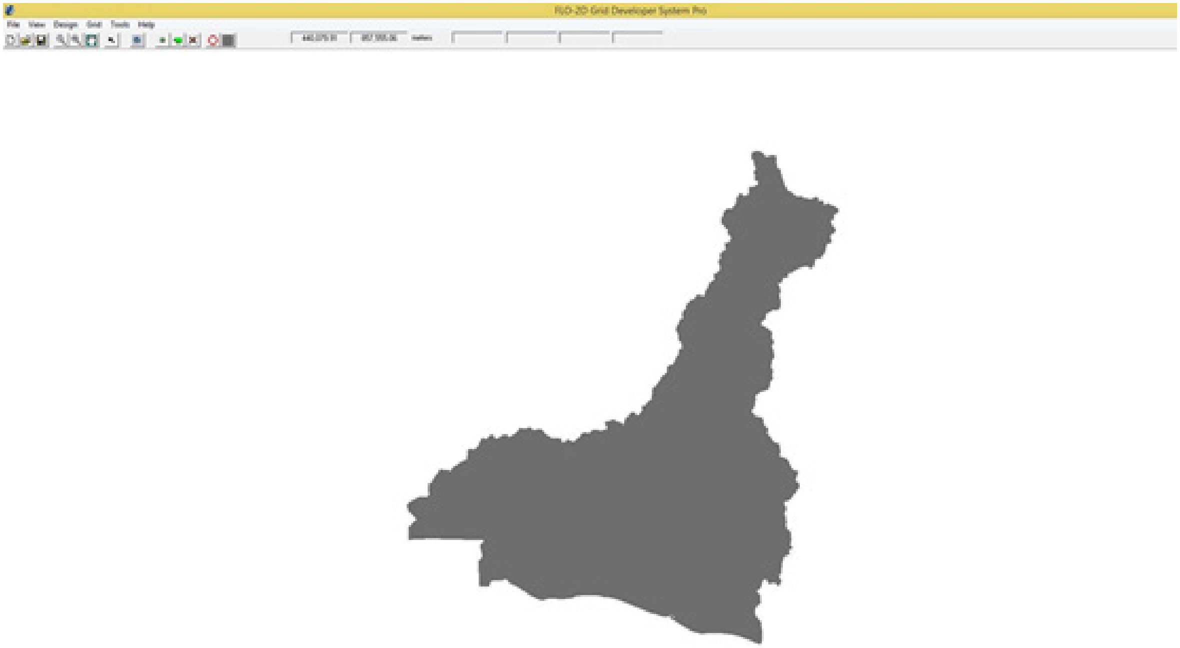


Figure 63. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro).

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 80.99707 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0m2/s. The generated hazard maps for Nainday are in Figure 67, 69, and 71.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 80,066,112.00m2. The generated flood depth maps for Nainday are in Figure 68, 70, and 72.

There is a total of 31,607,439.81 m3 of water entering the model. Of this amount, 24,777,912.56 m3 is due to rainfall while 6,829,527.24 m3 is inflow from other areas outside the model. 6,612,736.00 m3 of this water is lost to infiltration and interception, while 14,389,995.94 m3 is stored by the flood plain. The rest, amounting up to 10,604,650.44 m3, is outflow.

5.6 Results of HMS Calibration

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

The Outflow Hydrograph of Nainday produced by the HEC-HMS model compared with observed outflow is unavailable

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

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

Table 30. Range of calibrated values for the Nainday River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.001-2
			Curve Number	53-99
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.02-0.5
			Storage Coefficient (hr)	0.02-8
	Baseflow	Recession	Recession Constant	0.0004-0.02
			Ratio to Peak	0.01-0.7
Reach	Routing	Muskingum-Cunge	Slope	0.0002-0.008
			Manning's Coefficient	0.004-1

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 0.0001mm to 2mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 53 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 Nainday, the basin mostly consists of grassland and the soil consists of Alimodian clay loam, Luisiana clay loam, and Faraon clay.

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 8 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 Nainday, 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 Nainday watershed, which is determined to be mangrove forest with trees with heavy stand that flow into branches (Brunner, 2010).

Table 31. Summary of the Efficiency Test of the Nainday HMS Model,

Accuracy Measure	Value
RMSE	2.39
r2	0.82
NSE	0.82
PBIAS	1.05
RSR	0.42

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 2.39 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.82.

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 0.82.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 1.05.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 65) shows the Nainday outflow using the Catarman 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 (PAGASA) data. The simulation results reveal show increasing outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

The Outflow hydrograph at the Nainday Station, generated using the Romblon RIDF simulated in HEC-HMS is unavailable

Figure 65. The Outflow hydrograph at the Nainday Station, generated using the Romblon RIDF simulated in HEC-HMS.

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Nainday discharge using the Catarman Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 32.

Table 32. The peak values of the Nainday HEC-HMS Model outflow using the Catarman RIDF.

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	277.54	31.8	657.2	4 hours
10-Year	335.77	38.5	828.3	2 hours
25-Year	409.33	46.9	1070.9	2 hours
50-Year	463.87	53.2	1270.2	2 hours
100-Year	518.02	59.4	1429	1 hour and 50 minutes

5.8 River Analysis (RAS) Model Simulation

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

The sample output map of the Nainday RAS Model is unavalable

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

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 67 to Figure 72 show the 5-, 25-, and 100-year rain return scenarios of the Nainday flood plain. The flood plain, with an area of 205.73km2, covers three (3) municipalities, namely Cawayan, Palanas, and Placer. Table 33 shows the percentage of area affected by flooding per municipality.

Table 33. Municipalities affected in Nainday floodplain.

Municipality	Total Area (km2)	Area Flooded (km2)	% Flooded
Cawayan	261.38	117.18	44.83
Palanas	138.17	2.31	1.67
Placer	253.55	85.03	33.53

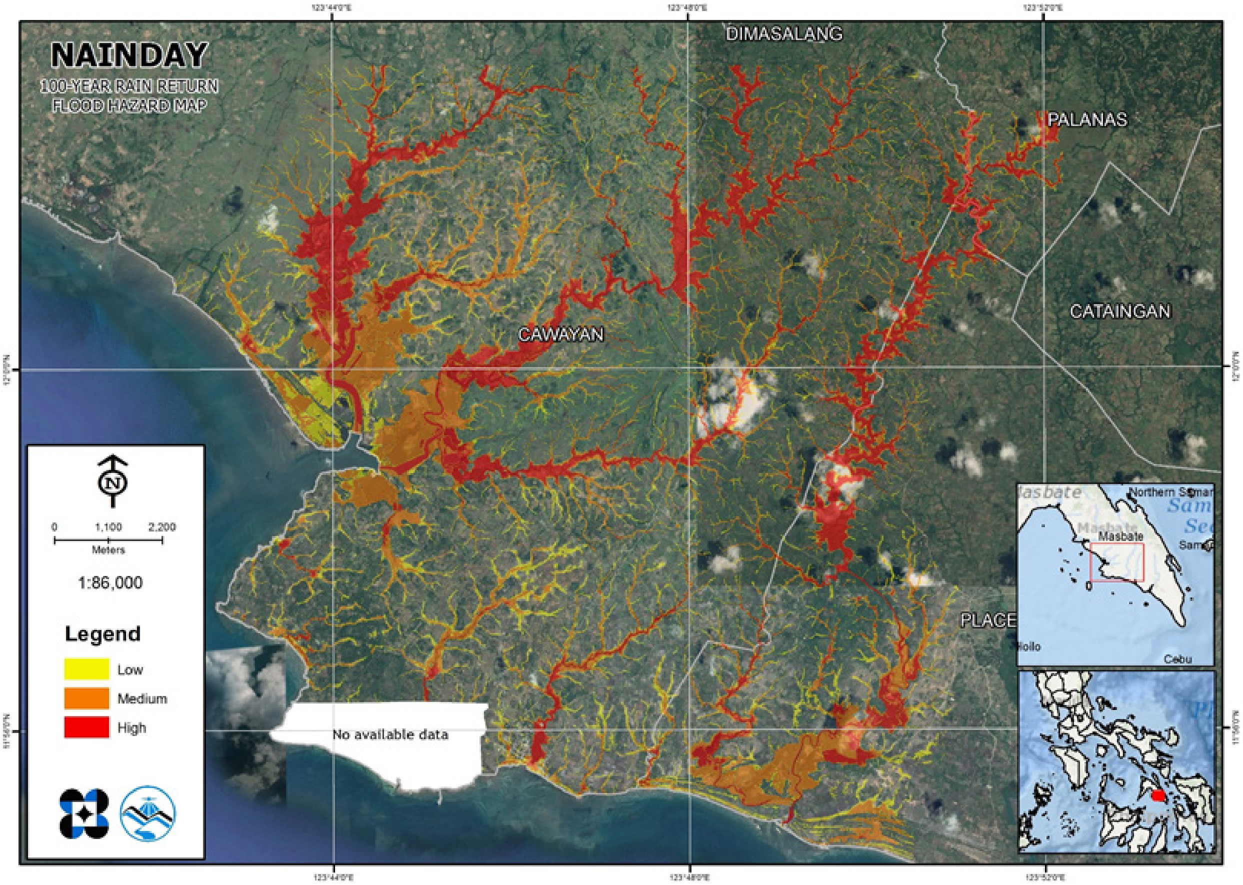


Figure 67. 100-year flood hazard map for the Nainday flood plain overlaid on Google Earth imagery.

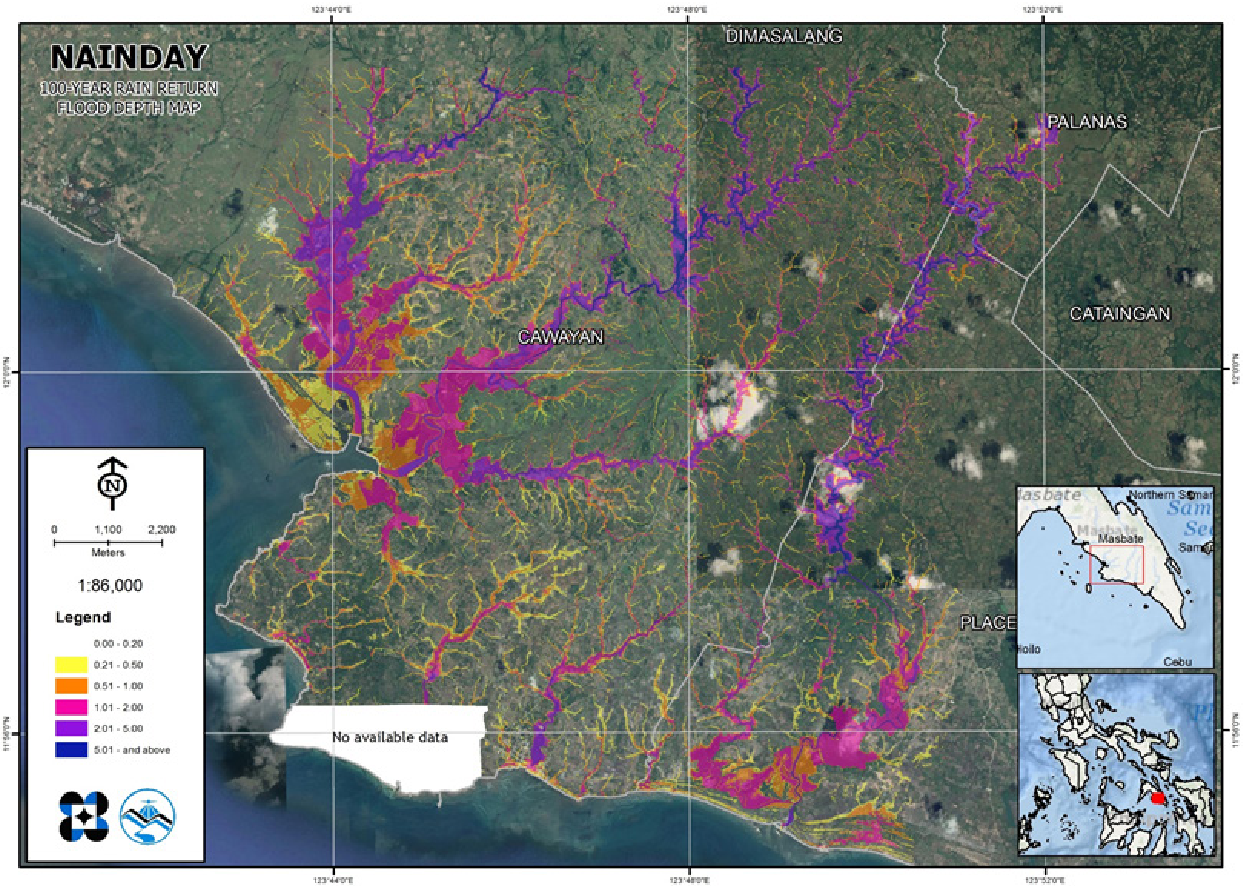


Figure 68. 100-year flow depth map for the Nainday flood plain overlaid on Google Earth imagery.

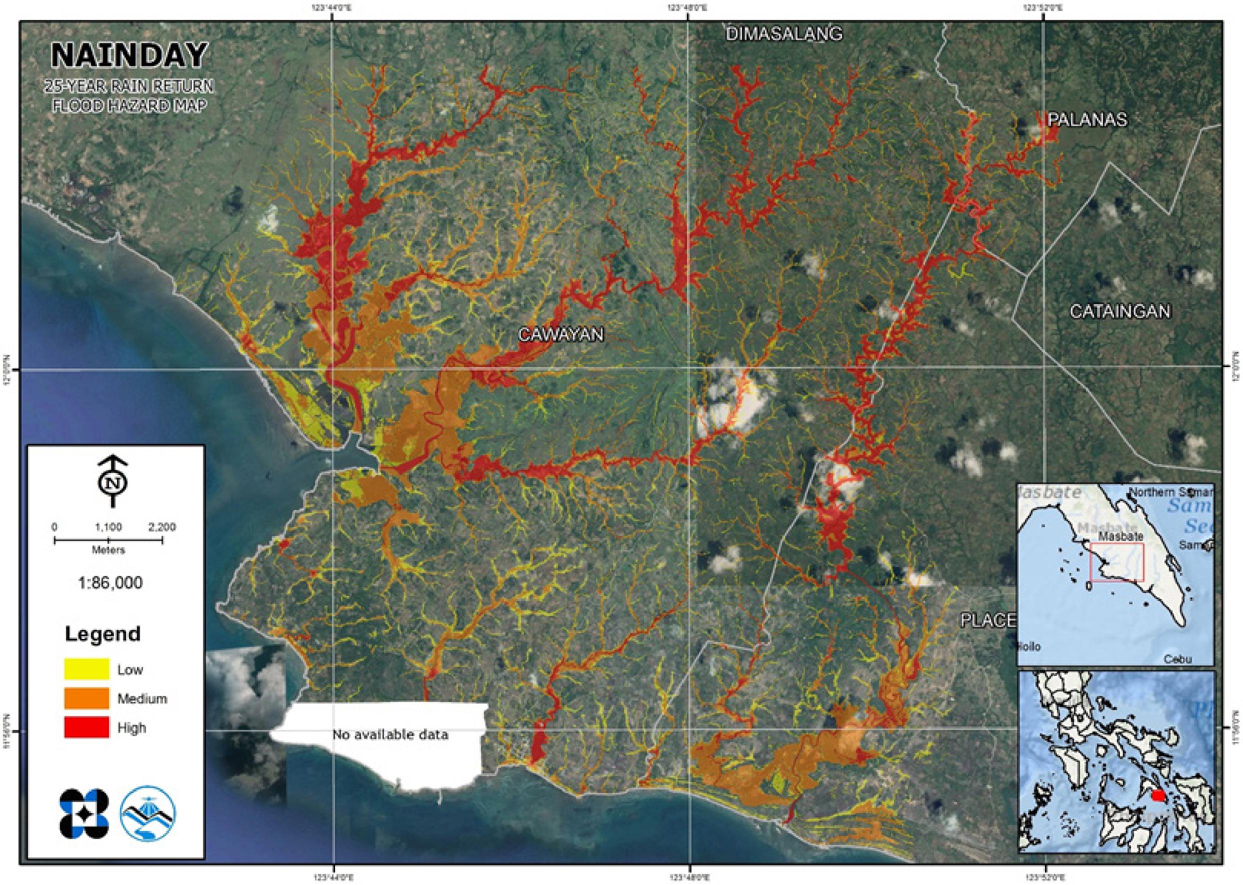


Figure 69. 25-year flood hazard map for the Nainday flood plain overlaid on Google Earth imagery.

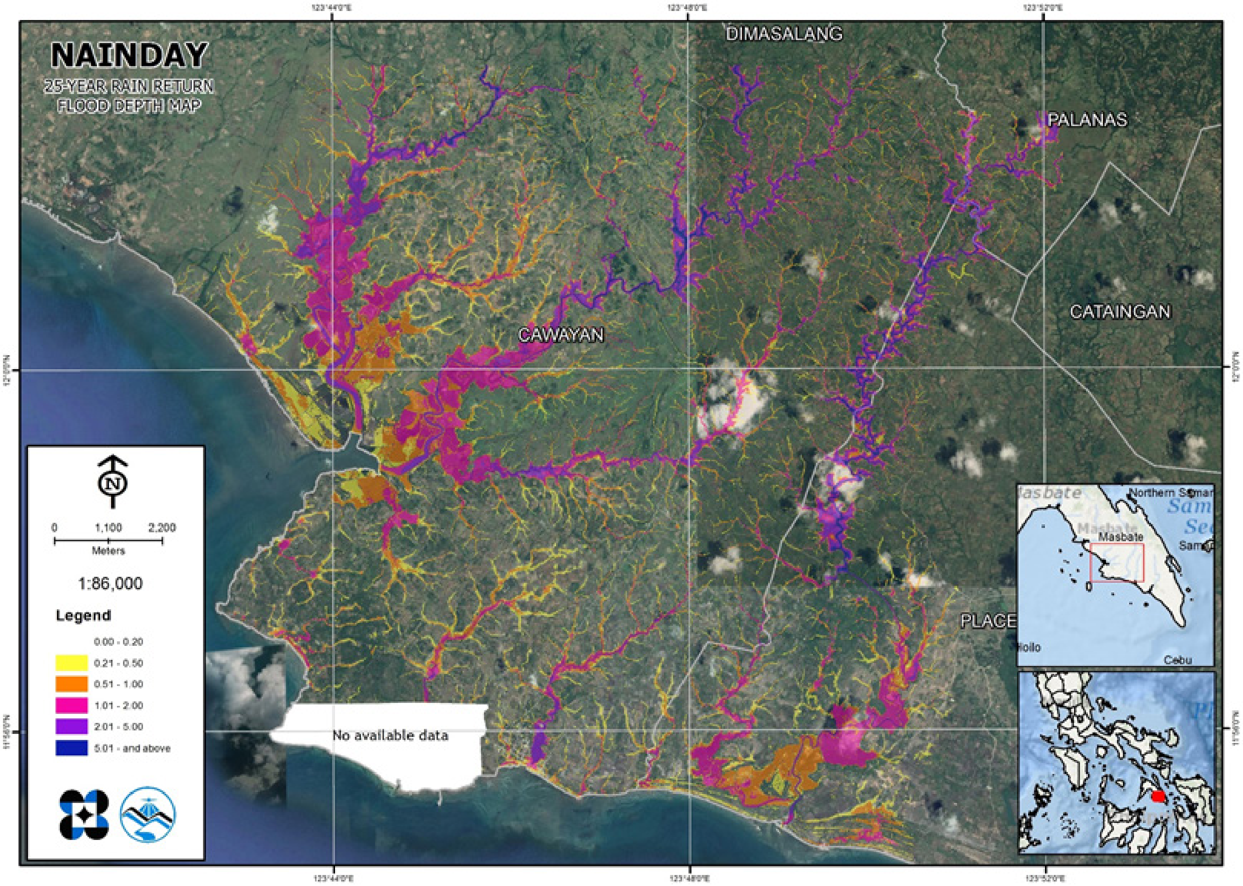


Figure 70. 25-year flow depth map for the Nainday flood plain overlaid on Google Earth imagery.

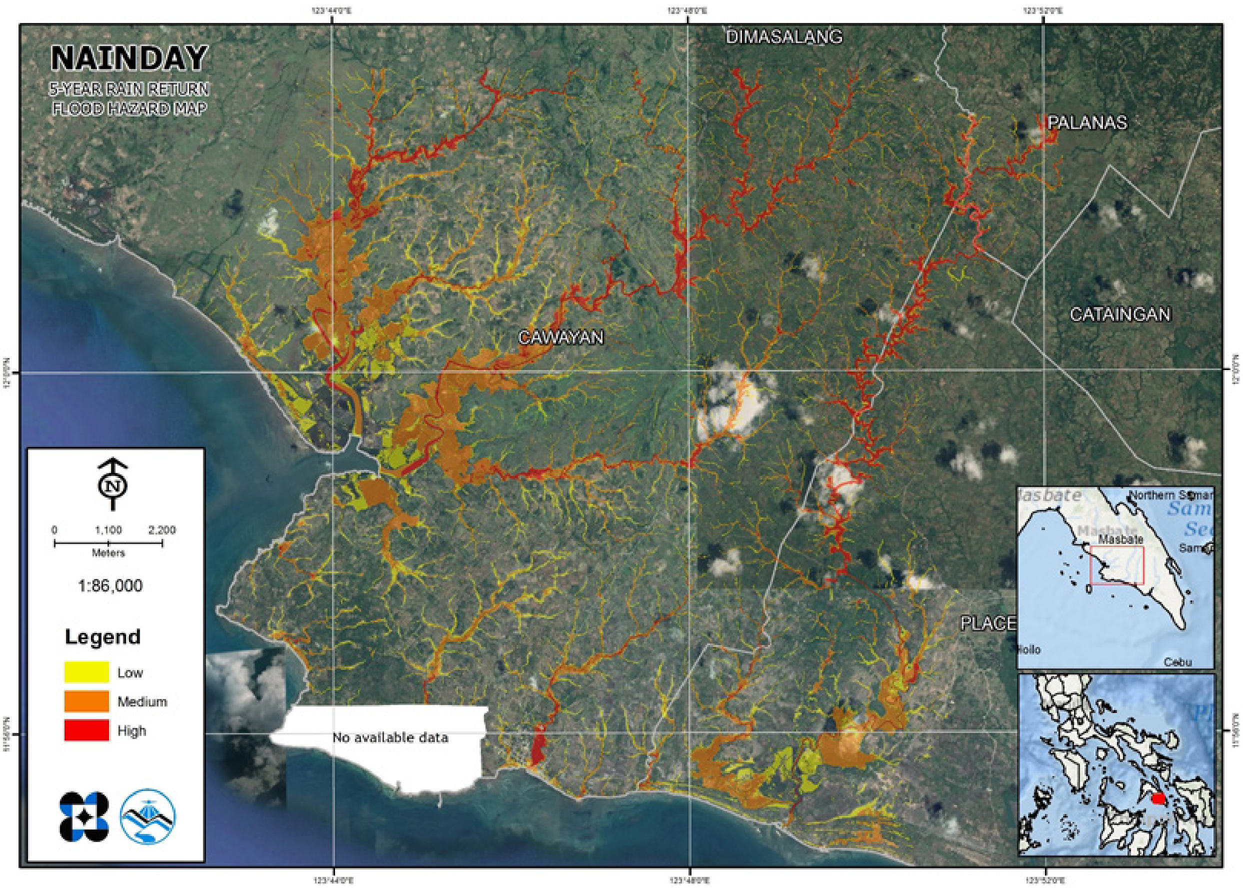


Figure 71. 5-year flood hazard map for the Nainday flood plain overlaid on Google Earth imagery.

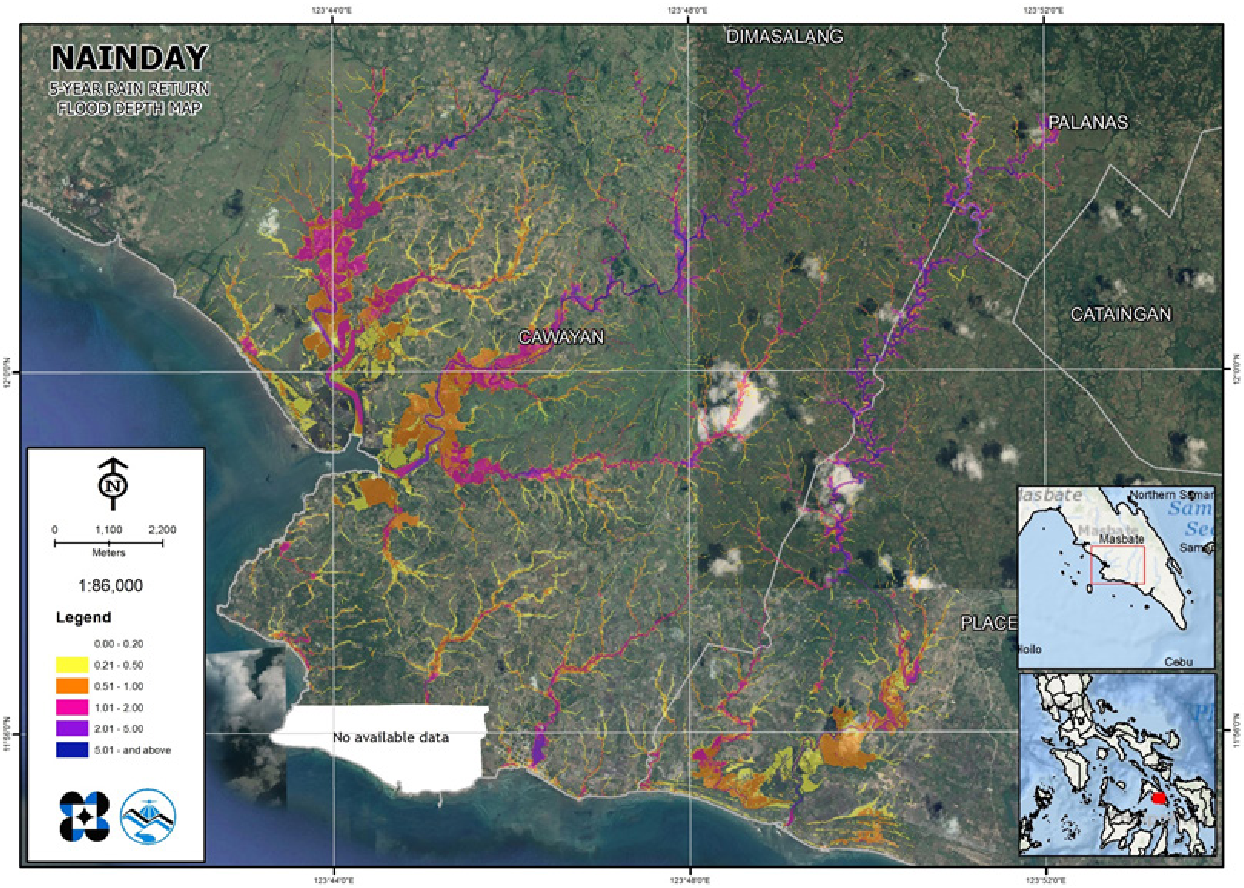


Figure 72. 5-year flow depth map for the Nainday flood plain overlaid on Google Earth imagery.

5.10 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Nainday River Basin, grouped accordingly by municipality. For the said basin, three (3) municipalities consisting of 33 barangays are expected to experience flooding when subjected to the three rainfall return period scenarios.

For the 5-year rainfall return period, 36.12% of the municipality of Cawayan with an area of 261.38 sq. km. will experience flood levels of less than 0.20 meters. 3.03% of the area will experience flood levels of 0.21 to 0.50 meters, while 3%, 2.02%, 0.58%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 34 depicts the areas affected in Cawayan in square kilometers by flood depth per barangay. Annex 12 and Annex 13

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

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Cawayan							
	Begia	Cabayugan		Calapayan	Calumpang	Dalipe	Divisoria	Guiom
0.03-0.20	4.45	1.36	4.21	6.49	7.51	3.54	2.84	5.63
0.21-0.50	0.21	0.044	0.19	0.33	0.54	1.09	0.22	0.64
0.51-1.00	0.068	0.019	0.17	0.29	0.49	0.77	0.11	0.72
1.01-2.00	0.0014	0.0014	0.15	0.23	0.24	0.55	0.11	0.22
2.01-5.00	0	0.0002	0.14	0.21	0.2	0.037	0.13	0.031
>5.00	0	0	0.013	0.056	0.042	0	0	0
	Iraya	Itombato	Madbad	Mahayahay	Maihao	Pananawan	Pin-As	Poblacion
0.03-0.20	3.36	4.99	4.05	0.098	2.41	4.88	1.69	5.64
0.21-0.50	0.35	0.44	0.19	0.0043	0.29	0.63	0.49	0.46
0.51-1.00	0.81	0.55	0.14	0.0075	1.21	0.53	0.39	0.33
1.01-2.00	1.25	0.58	0.14	0.011	0.42	0.4	0.017	0.09
2.01-5.00	0.13	0.1	0.016	0.0002	0.12	0.019	0	0.008
>5.00	0	0.0079	0	0	0	0	0	0
	R.M. Magbalon	Recodo	San Jose	San Vicente	Tubog	Tuburan	Villahermosa	
0.03-0.20	6.57	5.52	0.2	9.33	2.31	3.82	3.49	
0.21-0.50	0.34	0.32	0.014	0.71	0.15	0.14	0.14	
0.51-1.00	0.25	0.21	0.0074	0.4	0.16	0.091	0.14	
1.01-2.00	0.16	0.14	0.005	0.22	0.15	0.029	0.18	
2.01-5.00	0.081	0.0009	0	0.06	0.017	0.0053	0.22	
>5.00	0.009	0	0	0	0	0	0.071	

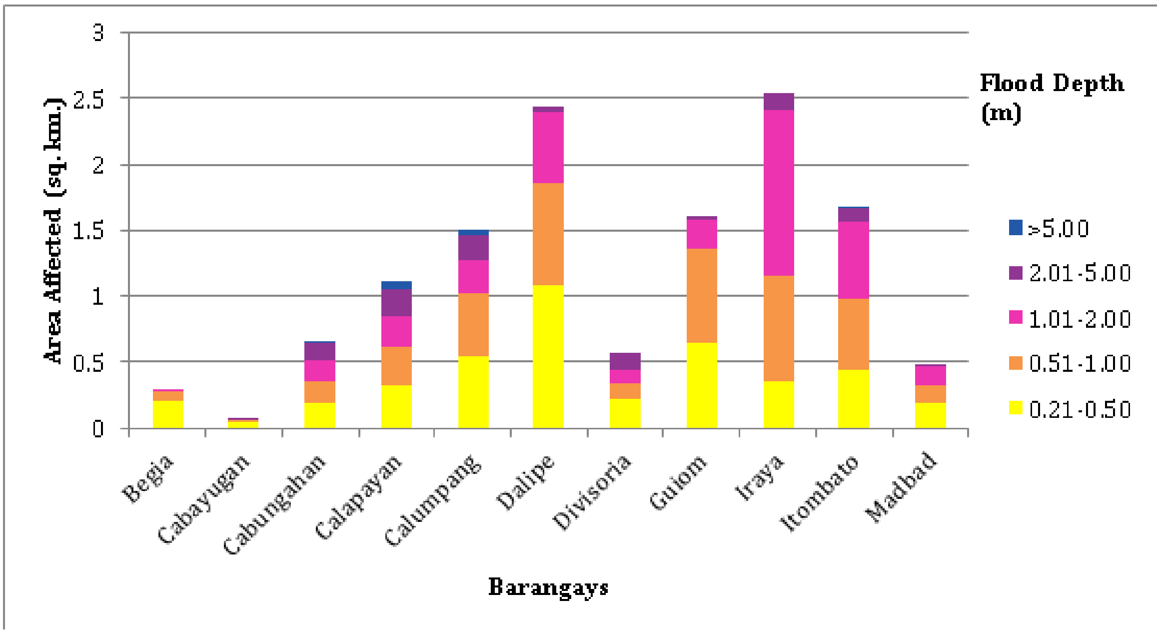


Figure 73. Affected Areas in Cawayan, Masbate during the 5-Year Rainfall Return Period.

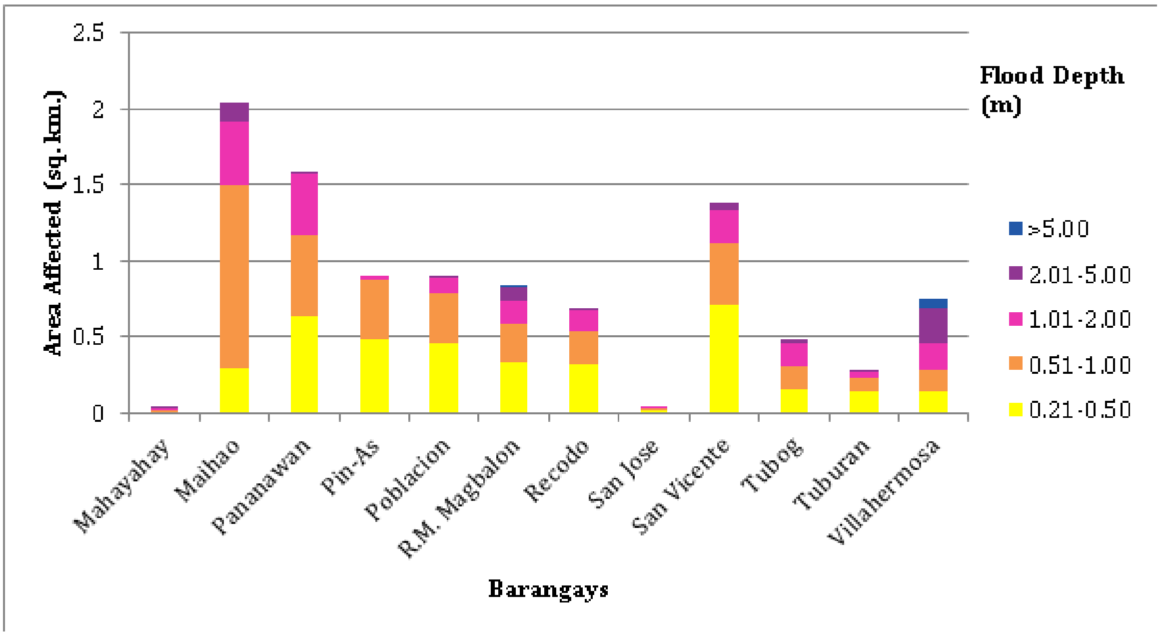


Figure 74. Affected Areas in Cawayan, Masbate during the 5-Year Rainfall Return Period.

For the municipality of Palanas with an area of 138.17 sq. km., 1.31% will experience flood levels of less than 0.20 meters. 0.07% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.07%, 0.11%, 0.1%, and 0.001% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 35 depicts the areas affected in Palanas in square kilometers by flood depth per barangay.

Table 35. Affected Areas in Palanas, Masbate during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Palanas	
	Antipolo	Malatawan
0.03-0.20	1.17	0.65
0.21-0.50	0.068	0.031
0.51-1.00	0.085	0.018
1.01-2.00	0.14	0.016
2.01-5.00	0.12	0.011
>5.00	0.0019	0

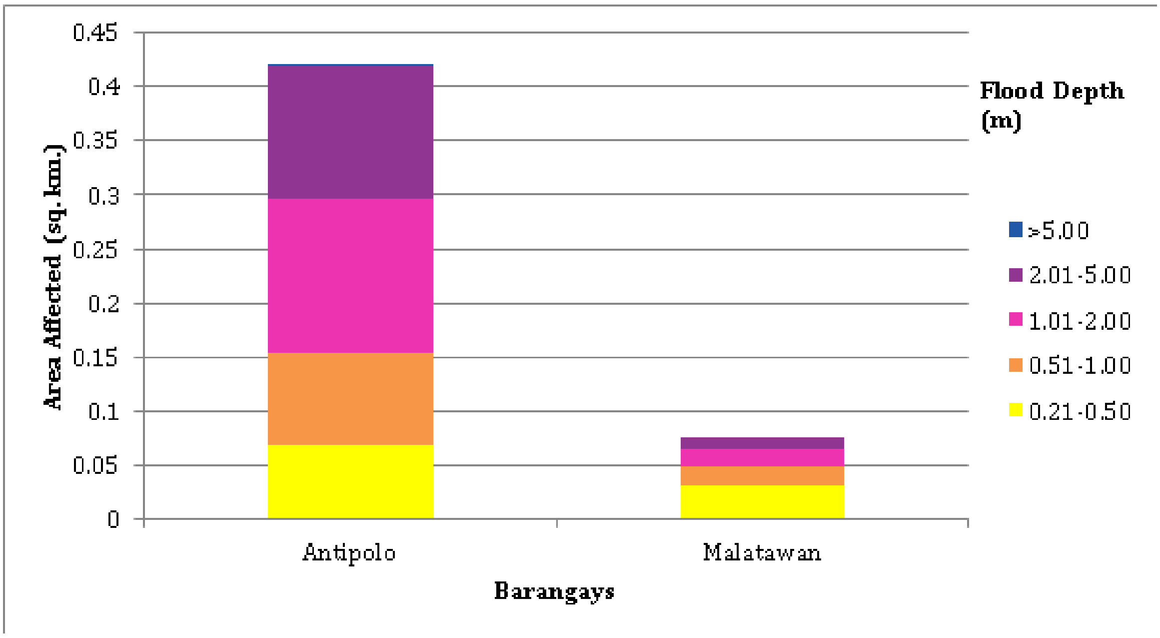


Figure 75. Affected Areas in Palanas, Masbate during the 5-Year Rainfall Return Period.

For the municipality of Placer with an area of 253.55 sq. km., 28.04% will experience flood levels of less than 0.20 meters. 1.95% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.76%, 1.03%, 0.63%, 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. Table 36 depicts the areas affected in Pio V. Corpuz in square kilometers by flood depth per barangay.

Table 36. Affected Areas in Placer, Masbate during 5-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Placer							
	Camayabsan	Dangpanan	Libas	Luna	Nainday	Puro	Santa Cruz	Tan-Awan
0.03-0.20	5.22	4.12	19.98	0.077	5.55	15.38	13.89	6.86
0.21-0.50	0.49	0.62	0.96	0.0004	1.02	0.73	0.64	0.47
0.51-1.00	0.43	0.67	0.8	0.0009	1.13	0.47	0.56	0.41
1.01-2.00	0.14	0.3	0.72	0.0002	0.13	0.37	0.65	0.31

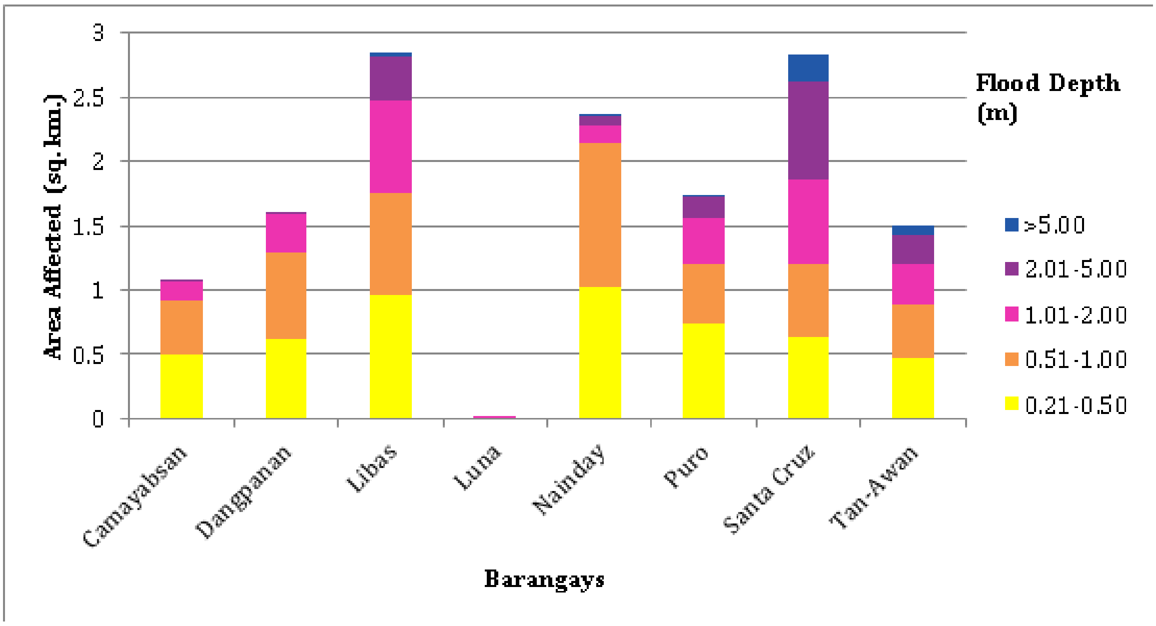


Figure 76. Affected Areas in Placer, Masbate during the 5-Year Rainfall Return Period.

For the 25-year rainfall return period, 34.22% of the municipality of Cawayan with an area of 261.38 sq. km. will experience flood levels of less than 0.20 meters. 2.9% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.94%, 3.3%, 1.3%, and 0.17% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 37 depicts the areas affected in Cawayan in square kilometers by flood depth per barangay.

Table 37. Affected Areas in Cawayan, Masbate during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Cawayan							
	Begia	Cabayugan		Calapayan	Calumpang	Dalipe	Divisoria	Guiom
0.03-0.20	4.36	1.34	4.05	6.22	7.19	2.86	2.69	5.34
0.21-0.50	0.25	0.057	0.19	0.33	0.52	0.55	0.28	0.62
0.51-1.00	0.11	0.025	0.18	0.33	0.57	1.41	0.14	0.74
1.01-2.00	0.006	0.0026	0.2	0.27	0.3	0.97	0.11	0.5
2.01-5.00	0	0.0002	0.19	0.36	0.36	0.18	0.19	0.042
>5.00	0	0	0.058	0.1	0.08	0	0.0002	0

	Iraya	Itombato	Madbad	Mahayahay	Maihao	Pananawan	Pin-As	Poblacion
0.03-0.20	3.11	4.73	3.92	0.096	2.27	4.57	1.28	5.41
0.21-0.50	0.25	0.38	0.2	0.0023	0.19	0.63	0.55	0.52
0.51-1.00	0.38	0.44	0.15	0.0058	0.45	0.45	0.5	0.37
1.01-2.00	1.59	0.82	0.16	0.012	1.38	0.68	0.26	0.21
2.01-5.00	0.58	0.27	0.091	0.005	0.16	0.14	0.0068	0.021
>5.00	0	0.017	0.0007	0	0	0	0	0

	R.M. Magbalon	Recodo	San Jose	San Vicente	Tubog	Tuburan	Villahermosa
0.03-0.20	6.38	5.37	0.19	8.95	2.18	3.76	3.18
0.21-0.50	0.34	0.37	0.016	0.83	0.17	0.16	0.15
0.51-1.00	0.3	0.25	0.0087	0.46	0.15	0.12	0.14
1.01-2.00	0.22	0.2	0.0068	0.27	0.22	0.041	0.21
2.01-5.00	0.13	0.01	0	0.19	0.062	0.012	0.4
>5.00	0.033	0	0	0.0028	0	0	0.16

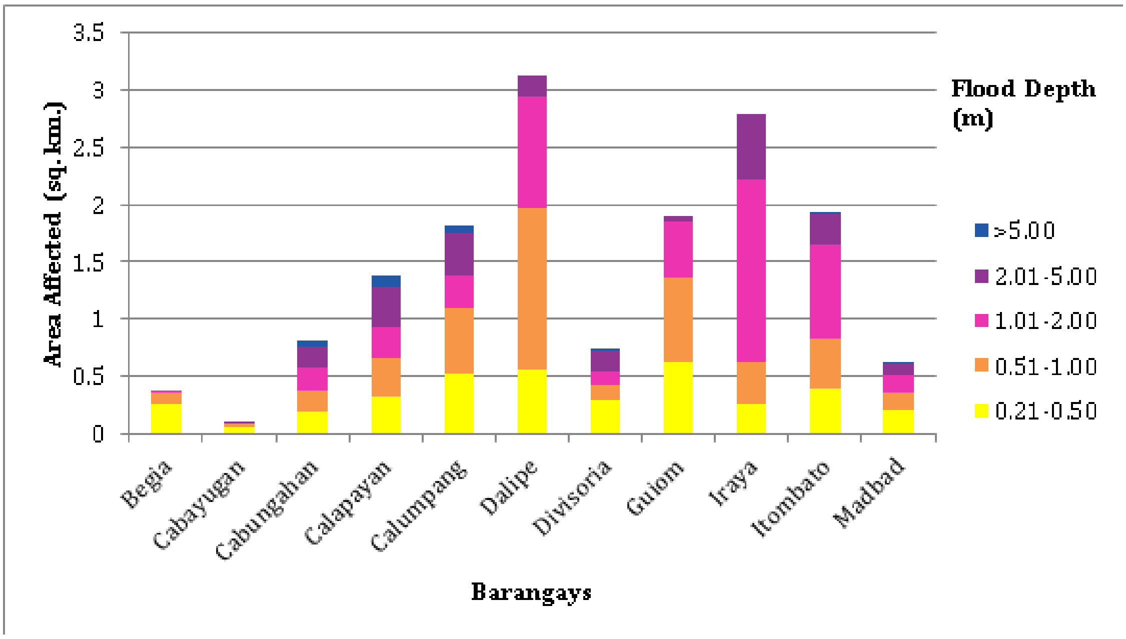


Figure 77. Affected Areas in Cawayan, Masbate during the 25-Year Rainfall Return Period.

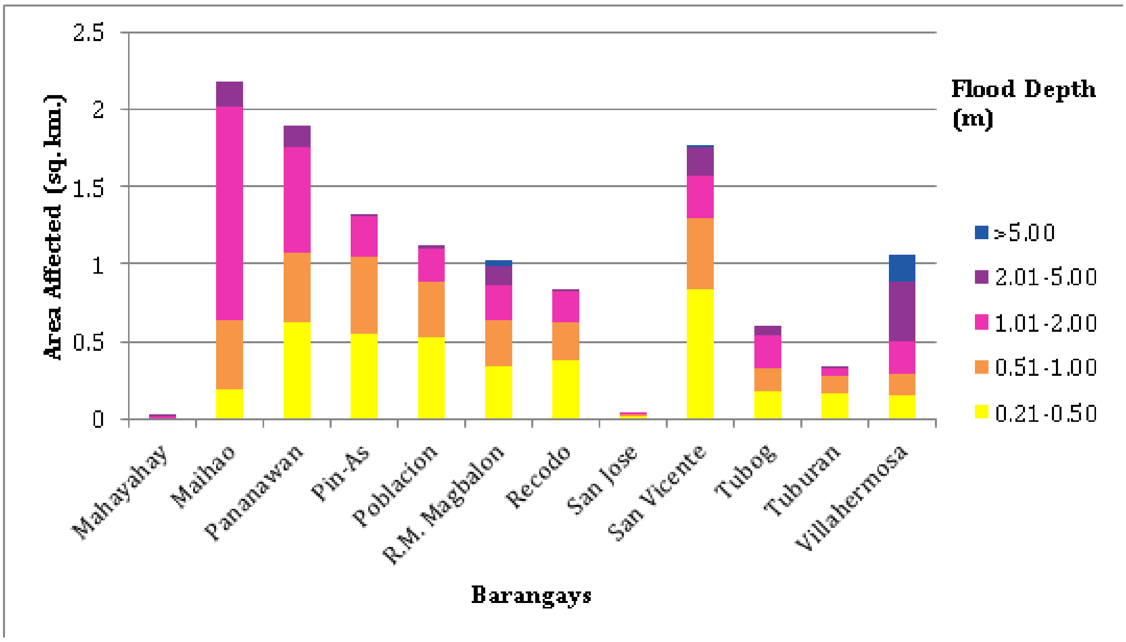


Figure 78. Affected Areas in Cawayan, Masbate during the 25-Year Rainfall Return Period.

For the municipality of Palanas with an area of 138.17 sq. km., 1.21% will experience flood levels of less than 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.08%, 0.12%, 0.18%, and 0.003% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 38 depicts the areas affected in Palanas in square kilometers by flood depth per barangay.

Table 38. Affected Areas in Palanas, Masbate during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Palanas			
	Banquerohan	Cabahug	Magsaysay	Tiglawigan
0.03-0.20	0.553186	2.42144	2.90551	3.80156
0.21-0.50	0.024227	0.070052	0.092574	0.195424
0.51-1.00	0.004834	0.077707	0.09597	0.138611
1.01-2.00	0.002354	0.145686	0.059252	0.121554
2.01-5.00	0	0.594736	0.025961	0.0092
>5.00	0	0.085987	0.113777	0

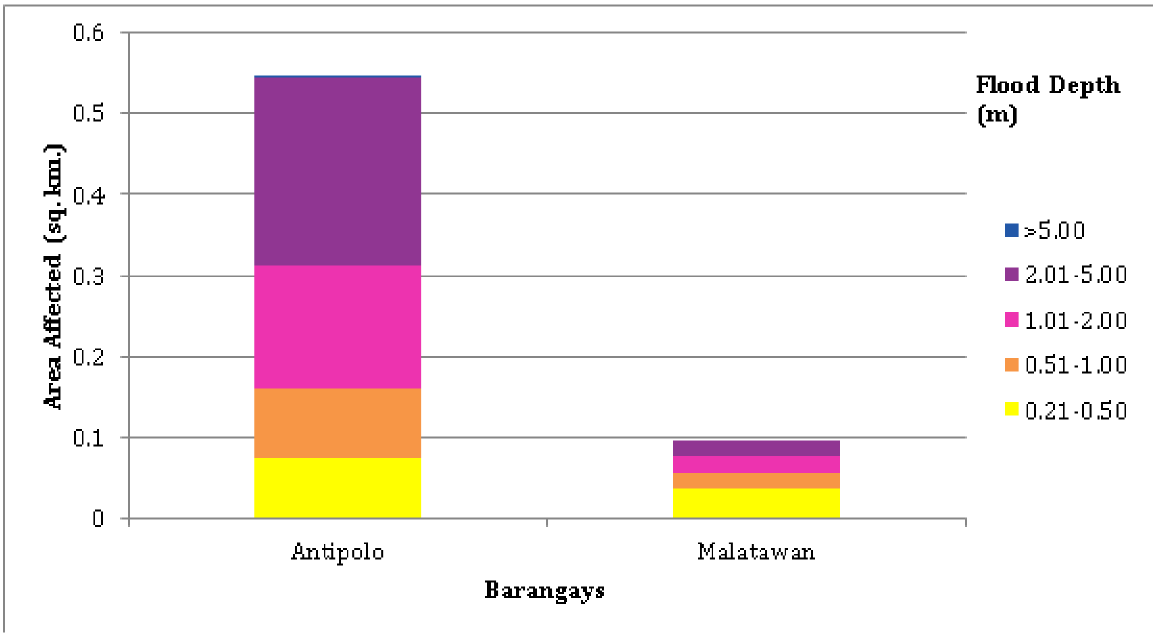


Figure 79. Affected Areas in Palanas, Masbate during the 25-Year Rainfall Return Period.

For the municipality of Placer with an area of 253.55 sq. km., 26.5% will experience flood levels of less than 0.20 meters. 1.87% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.86%, 1.95%, 1.1%, and 0.26% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 39 depicts the areas affected in Pio V. Corpuz in square kilometers by flood depth per barangay.

Table 39. Affected Areas in Placer, Masbate during 25-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Palanas	
	Antipolo	Malatawan
0.03-0.20	1.04	0.63
0.21-0.50	0.076	0.036
0.51-1.00	0.085	0.021
1.01-2.00	0.15	0.02
2.01-5.00	0.23	0.02
>5.00	0.0042	0

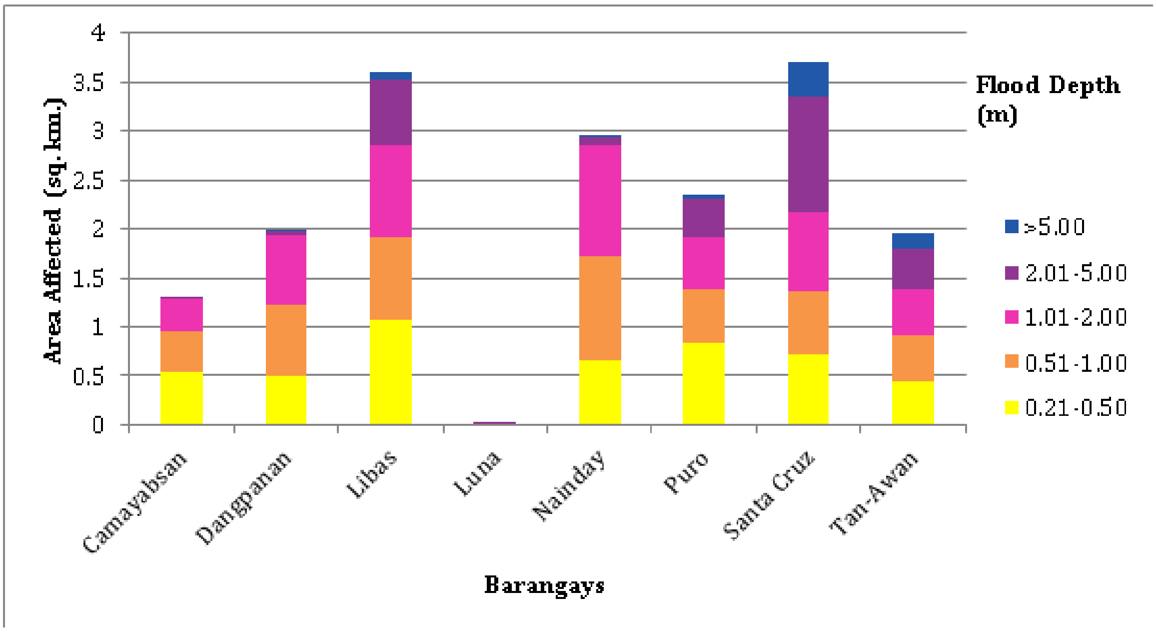


Figure 80. Affected Areas in Placer, Masbate during the 25-Year Rainfall Return Period.

For the 100-year rainfall return period, 33.2% of the municipality of Cawayan with an area of 261.38 sq. km. will experience flood levels of less than 0.20 meters. 2.89% of the area will experience flood levels of 0.21 to 0.50 meters, while 2.82%, 3.57%, 2.08%, and 0.27% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 40 depicts the areas affected in Cawayan in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Placer							
	Camayabsan	Dangpanan	Libas	Luna	Nainday	Puro	Santa Cruz	Tan-Awan
0.03-0.20	4.98	3.74	19.22	0.077	4.95	14.78	13.01	6.41
0.21-0.50	0.55	0.51	1.06	0.00067	0.65	0.83	0.71	0.43
0.51-1.00	0.4	0.72	0.86	0.0007	1.05	0.55	0.66	0.48
1.01-2.00	0.35	0.7	0.93	0.0006	1.15	0.54	0.8	0.47

Table 41. Affected Areas in Cawayan, Masbate during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Affected Barangays in Cawayan							
	Begia	Cabayugan		Calapayan	Calumpang	Dalipe	Divisoria	Guiom
0.03-0.20	4.3	1.32	3.96	6.05	7	2.69	2.6	5.22
0.21-0.50	0.28	0.068	0.2	0.34	0.51	0.41	0.33	0.53
0.51-1.00	0.14	0.028	0.19	0.33	0.59	1.11	0.16	0.65
1.01-2.00	0.012	0.0042	0.22	0.28	0.39	1.49	0.12	0.76
2.01-5.00	0	0.0002	0.23	0.45	0.42	0.28	0.2	0.09
>5.00	0	0	0.083	0.15	0.1	0	0.0003	0

	Iraya	Itombato	Madbad	Mahayahay	Maihao	Pananawan	Pin-As	Poblacion
0.03-0.20	2.98	4.59	3.85	0.095	2.21	4.37	1.07	5.27
0.21-0.50	0.22	0.39	0.2	0.0022	0.16	0.65	0.52	0.56
0.51-1.00	0.3	0.41	0.17	0.0043	0.25	0.51	0.58	0.39
1.01-2.00	1.05	0.67	0.16	0.012	1.56	0.62	0.41	0.28
2.01-5.00	1.34	0.58	0.14	0.0079	0.27	0.32	0.014	0.033
>5.00	0	0.027	0.0014	0	0	0	0	0.0005

	R.M. Magbalon	Recodo	San Jose	San Vicente	Tubog	Tuburan	Villahermosa
0.03-0.20	6.25	5.27	0.19	8.7	2.1	3.72	2.98
0.21-0.50	0.34	0.4	0.016	0.93	0.19	0.18	0.14
0.51-1.00	0.33	0.27	0.011	0.51	0.15	0.13	0.15
1.01-2.00	0.27	0.23	0.0085	0.29	0.25	0.054	0.21
2.01-5.00	0.17	0.025	0.0002	0.29	0.1	0.018	0.46
>5.00	0.041	0	0	0.0048	0	0	0.3

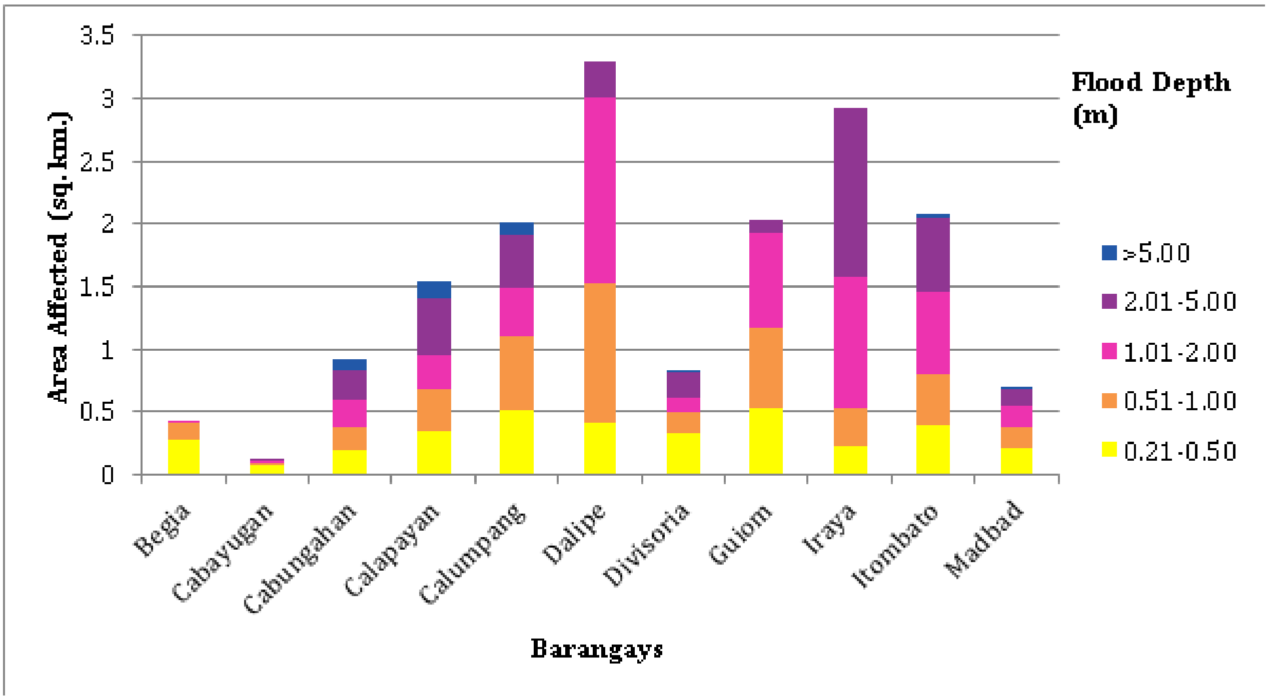


Figure 81. Affected Areas in Cawayan, Masbate during the 100-Year Rainfall Return Period.

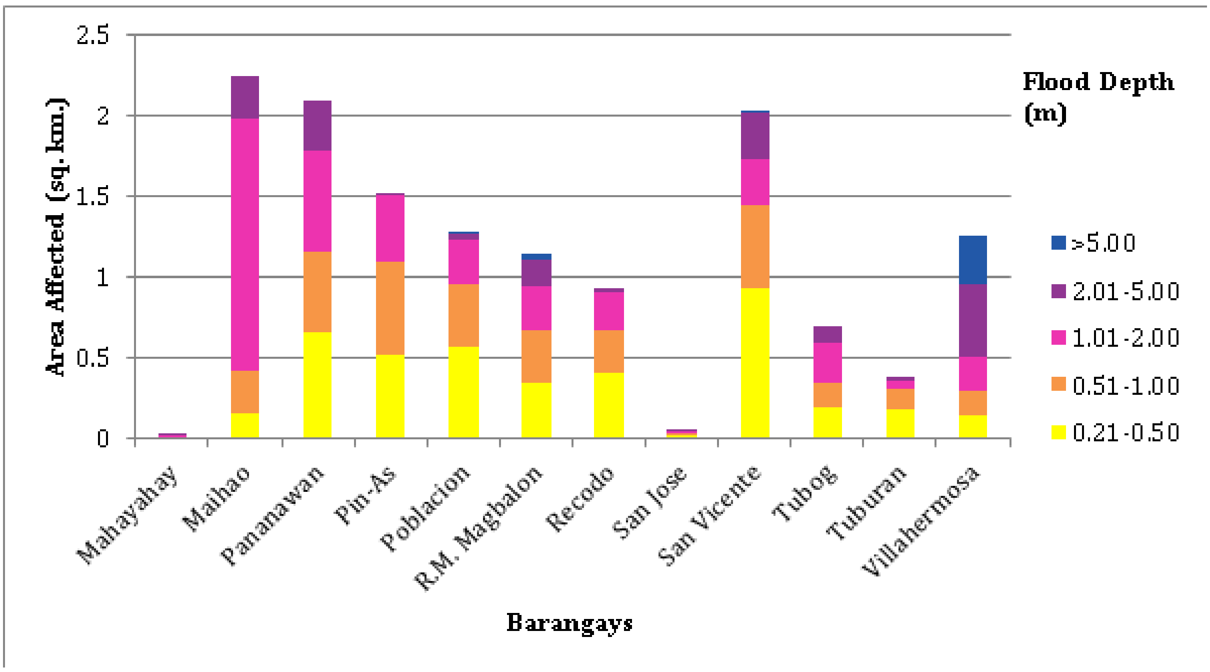


Figure 82. Affected Areas in Cawayan, Masbate during the 100-Year Rainfall Return Period.

For the municipality of Palanas with an area of 138.17 sq. km., 1.14% will experience flood levels of less than 0.20 meters. 0.08% of the area will experience flood levels of 0.21 to 0.50 meters, while 0.09%, 0.13%, 0.23%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 41 depicts the areas affected in Palanas in square kilometers by flood depth per barangay.

Table 42. Affected Areas in Palanas, Masbate during 100-Year Rainfall Return Period.

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Palanas	
	Antipolo	Malatawan
0.03-0.20	0.95	0.62
0.21-0.50	0.081	0.036
0.51-1.00	0.095	0.027
1.01-2.00	0.16	0.02
2.01-5.00	0.29	0.025
>5.00	0.016	0.00078

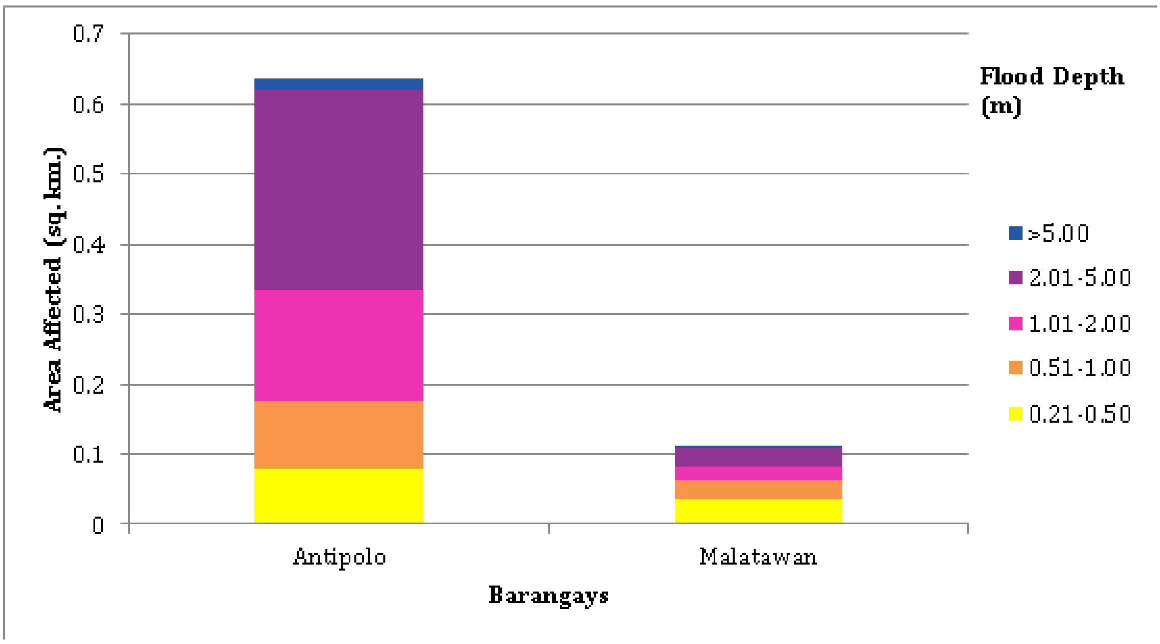


Figure 83. Affected Areas in Palanas, Masbate during the 100-Year Rainfall Return Period.

For the municipality of Placer with an area of 253.55 sq. km., 25.58% will experience flood levels of less than 0.20 meters. 1.95% of the area will experience flood levels of 0.21 to 0.50 meters, while 1.72%, 2.43%, 1.44%, and 0.42% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and greater than 5 meters, respectively. Table 42 depicts the areas affected in Pio V. Corpuz in square kilometers by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of barangays affected in Placer							
	Camayabsan	Dangpanan	Libas	Luna	Nainday	Puro	Santa Cruz	Tan-Awan
0.03-0.20	4.83	3.56	18.7	0.076	4.7	14.4	12.43	6.16
0.21-0.50	0.58	0.48	1.12	0.0011	0.73	0.9	0.7	0.43
0.51-1.00	0.37	0.55	0.92	0.00062	0.75	0.62	0.72	0.44
1.01-2.00	0.48	1.03	1.02	0.0009	1.6	0.56	0.91	0.57

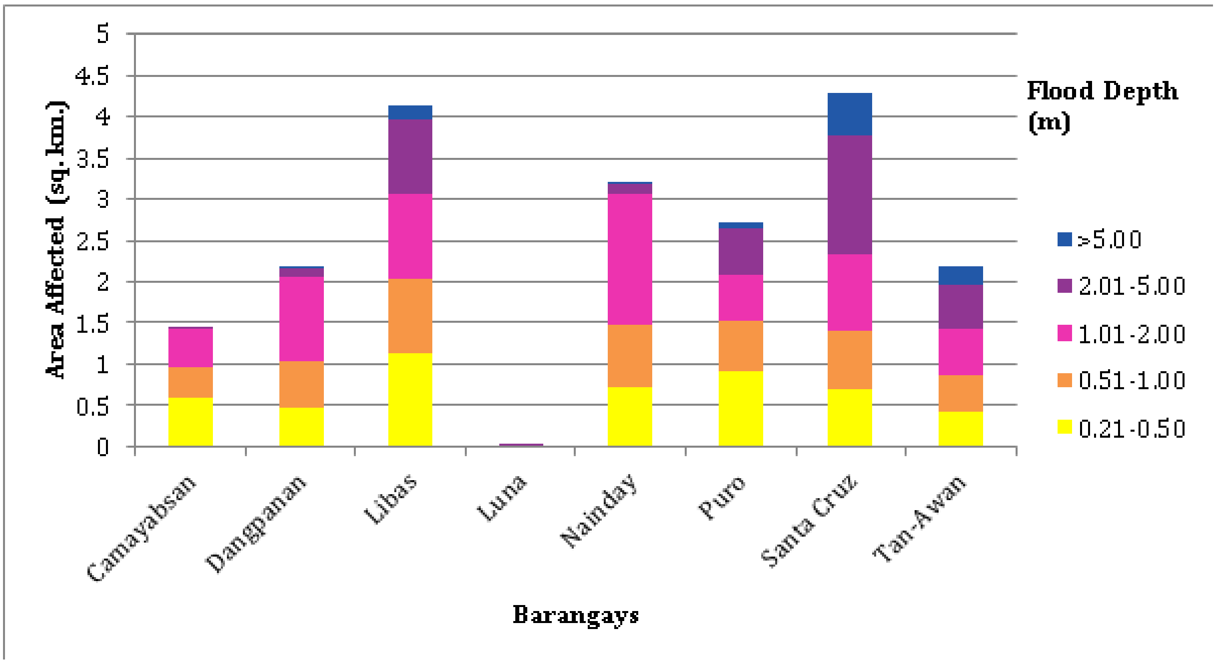


Figure 84. Affected Areas in Placer, Masbate during the 100-Year Rainfall Return Period.

Among the barangays in the municipality of Cawayan, San Vicente is projected to have the highest percentage of area that will experience flood levels at 4.1%. Meanwhile, Calumpang posted the second highest percentage of area that may be affected by flood depths at 3.45%.

Among the barangays in the municipality of Palanas, Antipolo is projected to have the highest percentage of area that will experience flood levels at 1.15%. Meanwhile, Malatawan posted the second highest percentage of area that may be affected by flood depths at 0.53%.

Among the barangays in the municipality of Placer, Libas is projected to have the highest percentage of area that will experience flood levels of at 9%. Meanwhile, Puro posted the second highest percentage of area that may be affected by flood depths at 6.76%.
Moreover, the generated flood hazard maps for the Nainday flood plain were used to assess the vulnerability of the educational and medical institutions in the flood plain. 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 44. 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	10.53	10.96	11.45
Medium	13.93	13.61	14.05
High	4.85	11.26	14.86

Of the 31 identified Educational Institutions in Nainday flood plain, 1 was assessed to be exposed to low, 2 to medium, and none to high level flooding during the 5-year scenario. In the 25-year scenario, 3 were assessed to be exposed to low, 2 to medium, and none to high level flooding. In the 100-year scenario, 3 were assessed to be exposed to low, 2 to medium, and none to high level flooding.

Of the 16 identified Medical Institutions in Nainday flood plain, 2 were 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, 3 were assessed to be exposed to low, 1 to medium, and none to high level flooding. In the 100-year scenario, 4 were assessed to be exposed to low, 1 to medium, and none to high 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 survey work. Field personnel gather secondary data regarding flood occurrence in the area within the major river system in the Philippines.

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 86.

The flood validation consists of 174 points randomly selected all over the Nainday flood plain (Figure 85). Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.014404. Table 44 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

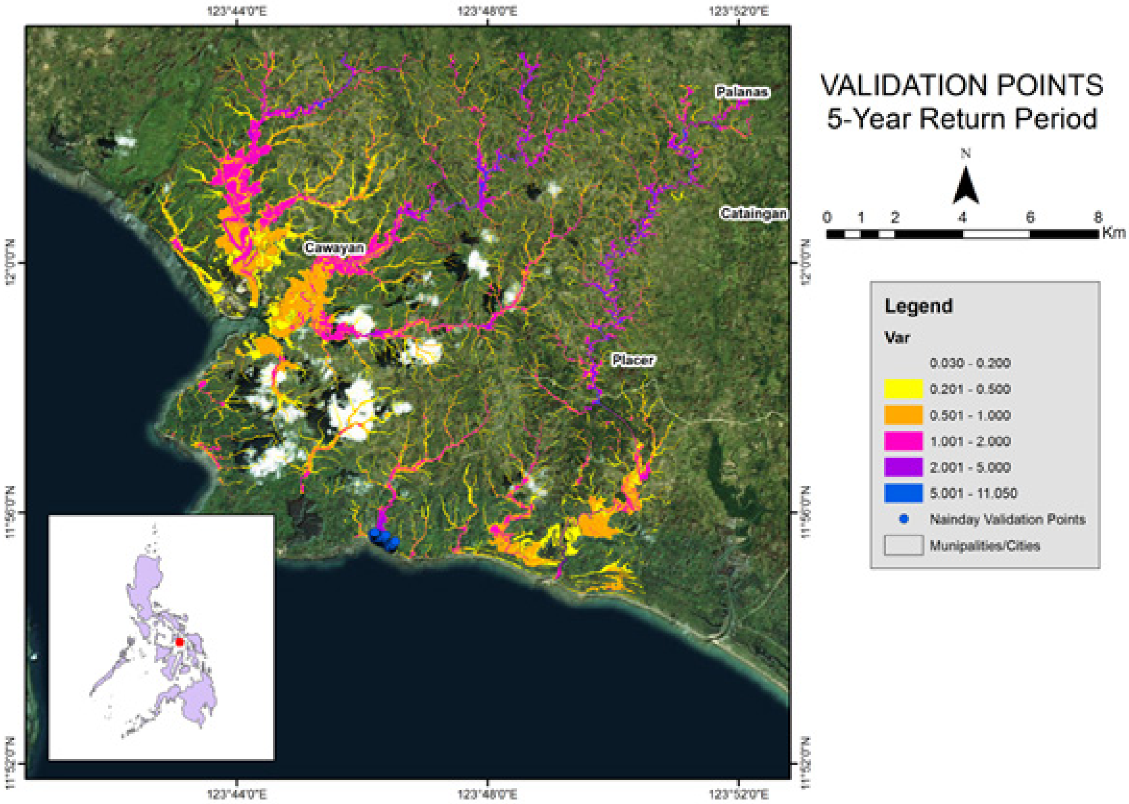


Figure 85. The Validation Points for a 5-year Flood Depth Map of the Nainday Floodplain.

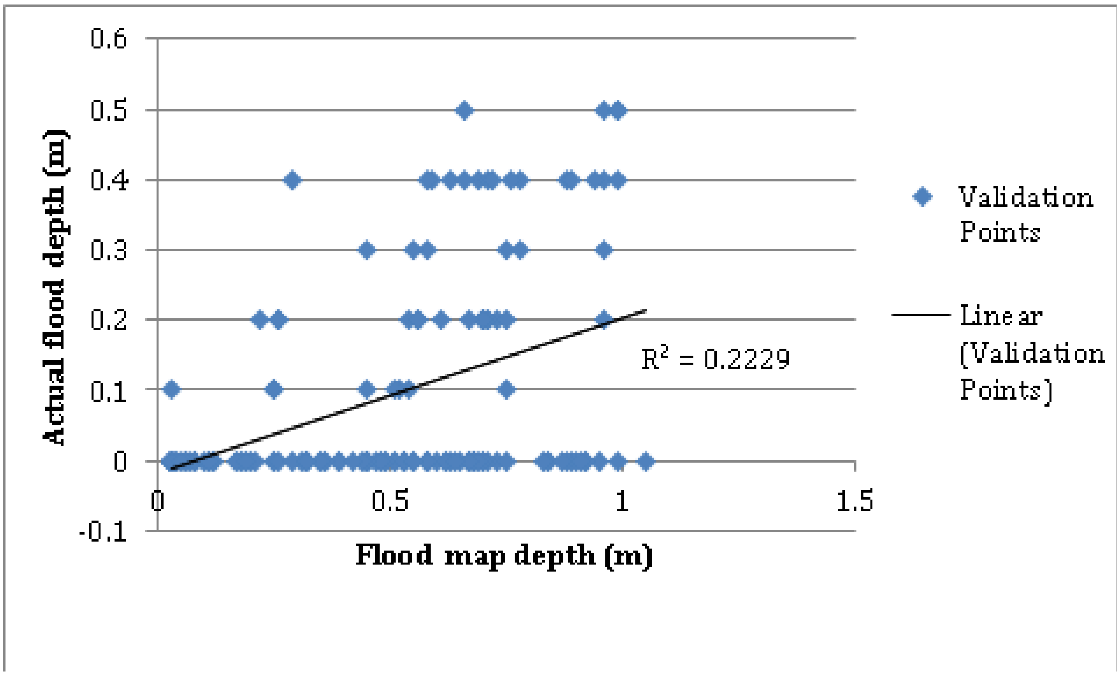


Figure 86. Flood map depth versus actual flood depth.

Table 45. Actual Flood Depth versuss Simulated Flood Depth at different levels in Nainday River Basin.

NAINDAY		Modeled Flood Depth (m)						
		0-0.20	**0.21-0.50**	**0.51-1.00**	**1.01-2.00**	**2.01-5.00**	**> 5.00**	Total
Actual Flood Depth (m)	**0-0.20**	52	37	59	1	0	0	149
	0.21-0.50	0	2	23	0	0	0	25
	0.51-1.00	0	0	0	0	0	0	0
	1.01-2.00	0	0	0	0	0	0	0
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	52	39	82	1	0	0	174

On the whole, the overall accuracy generated by the flood model is estimated at 31.03%, with 54 points correctly matching the actual flood depths. In addition, there were 60 points estimated one level above and below the correct flood depths, 59 points estimated two levels above and below, and 1 point estimated three or more levels above and below the correct flood depths. A total of 120 points were overestimated while a total of none was underestimated in the modelled flood depths of Nainday. Table 45 depicts the summary of the accuracy assessment in the Nainday River Basin survey.

Table 46. The summary of the Accuracy Assessment in the Nainday River Basin Survey.

LANANG	No. of Points	%
Correct	54	**31.03**
Overestimated	120	68.97
Underestimated	0	0.00
Total	174	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 LIDAR Sensors used in the Nainday Floodplain Survey

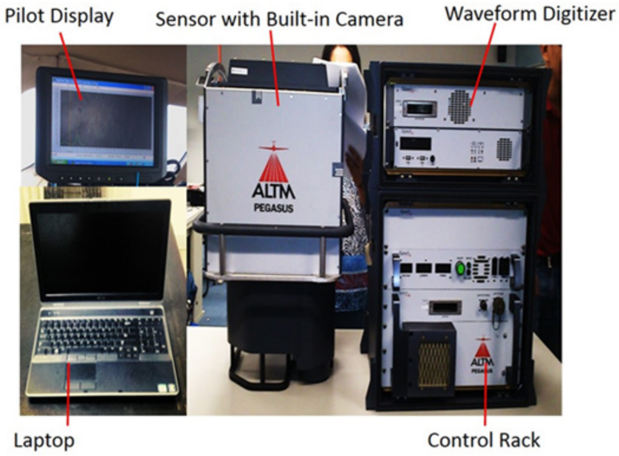


Figure A-1.1. Aquarious Sensor

Table A-1.1. Parameters and Specifications of the OPTECH 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, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
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)
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)
Video Camera	Internal video camera (NTSC or PAL)
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; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

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

1. MST-34

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

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

PRS92 Coordinates

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

WGS84 Coordinates

Latitude: **12° 18' 24.53692"**	Longitude: **123° 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**

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

9904102014140036

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 MST-34

2. 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: **12° 14' 48.14863"**	Longitude: **123° 44' 47.51779"**	Ellipsoidal Hgt: **5.31500 m.**

WGS84 Coordinates

Latitude: **12° 14' 43.52314"**	Longitude: **123° 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**

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

9904102014140101

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Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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Figure A-2.2 MST-35

3. MST-40

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**		Barangay: **CAGAY**
Municipality: **CITY OF MASBATE (CAPITAL)**		
	PRS92 Coordinates	
Latitude: **12° 14' 48.14863"**	Longitude: **123° 44' 47.51779"**	Ellipsoidal Hgt: **5.31500 m.**
	WGS84 Coordinates	
Latitude: **12° 14' 43.52314"**	Longitude: **123° 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**

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

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Figure A-2.3 MST-40

4. MST-49

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-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**

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

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

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Figure A-2.4 MST-49

5. MS-20

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-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

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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Figure A-2.5 MS-20

6. 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

9904102014140622

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Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
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Figure A-2.6 MS-61

Annex 3. Base Processing Reports of Control Points used in the LiDAR Survey

1. MS-20

Table A-3.1. 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

2. MS-61

Table A-3.2. 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

Annex 4. The LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
LiDAR Operation	Supervising Science Research Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA	UP-TCAGP
		LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Senior Science Research Specialist (SSRS)	ENGR. GEROME HIPOLITO	UP-TCAGP
	Research Associate (RA)	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
		ENGR. IRO NIEL ROXAS	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	ENGR. GRACE SINADJAN	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. MARLON TORRE	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. MARK TANGONAN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. JEFFREY ALAJAR	AAC
		CAPT. JOHN BRYAN DONGUINES	AAC

Annex 5. Data Transfer Sheet for Nainday 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	1BLK32U080A	PEGASUS	4.09GB	3.96MB	9.60MB	244MB	55.2GB	426KB	40.8GB	N/A	5.76MB	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	155KB	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	1BLK32K088B	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	1BLK32K090A	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 Sabile
Position
Signature

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature

Figure A-5.1. Transfer Sheet for Nainday 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	1.40	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	64.2	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	5.56	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	4.40	4.12	271	67.2	514	37.7	NA	6.49	1KB	623	270	NA	Z:\Airborne_Raw\1307P
4/8/2014	1319P	1BLK32BD98A	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

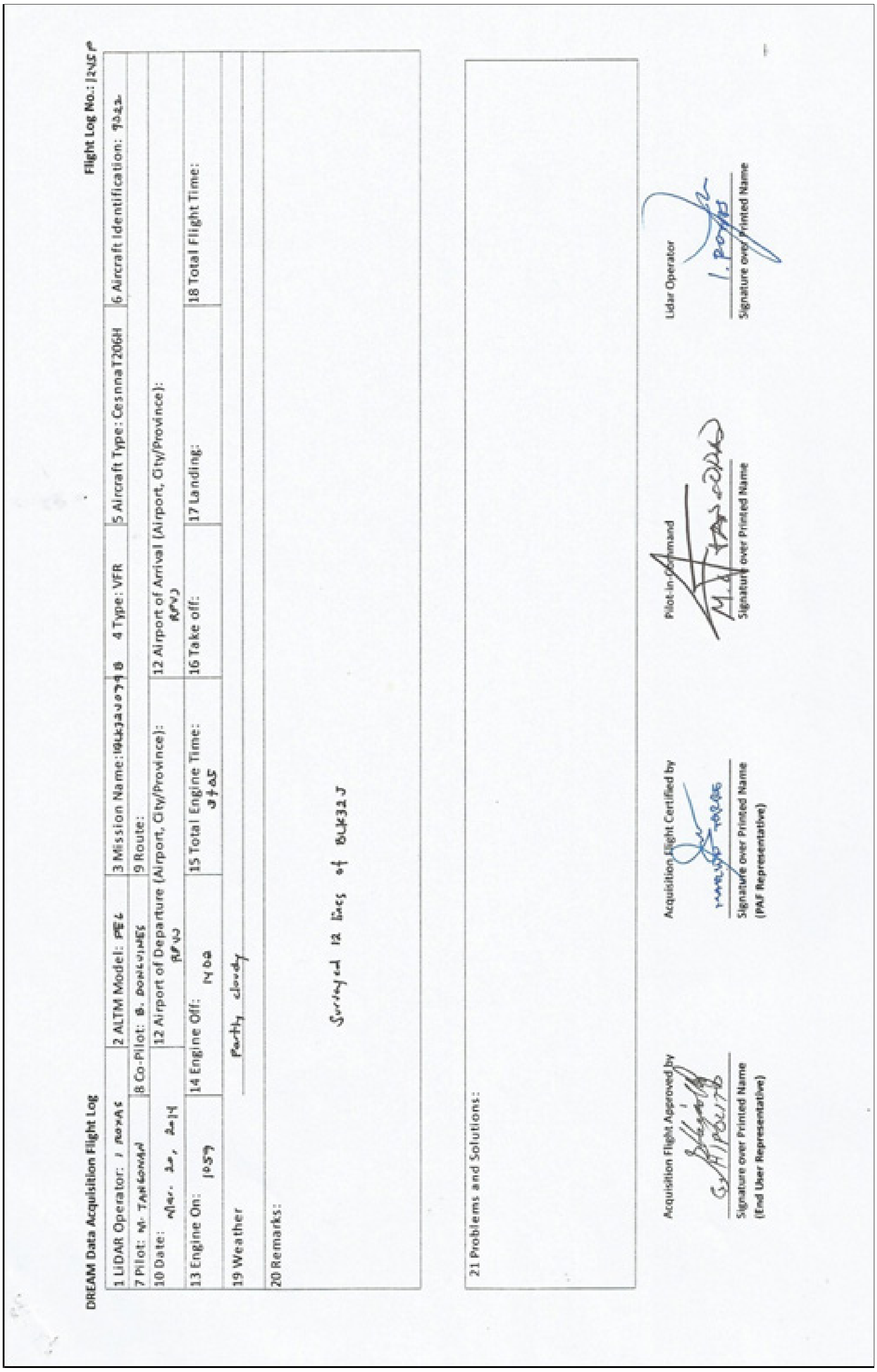
Received from
Name Carlos Joaquin
Position RA
Signature 4/23/14

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

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

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 1245P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1245P

1 LiDAR Operator: I. ROXAS	2 ALTM Model: PEG	3 Mission Name: 1BLK32J079B	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. 20, 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 1059	14 Engine Off: 1408	15 Total Engine Time: 3+05	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					

20 Remarks:

Surveyed 12 lines of BLK32J

21 Problems and Solutions:

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

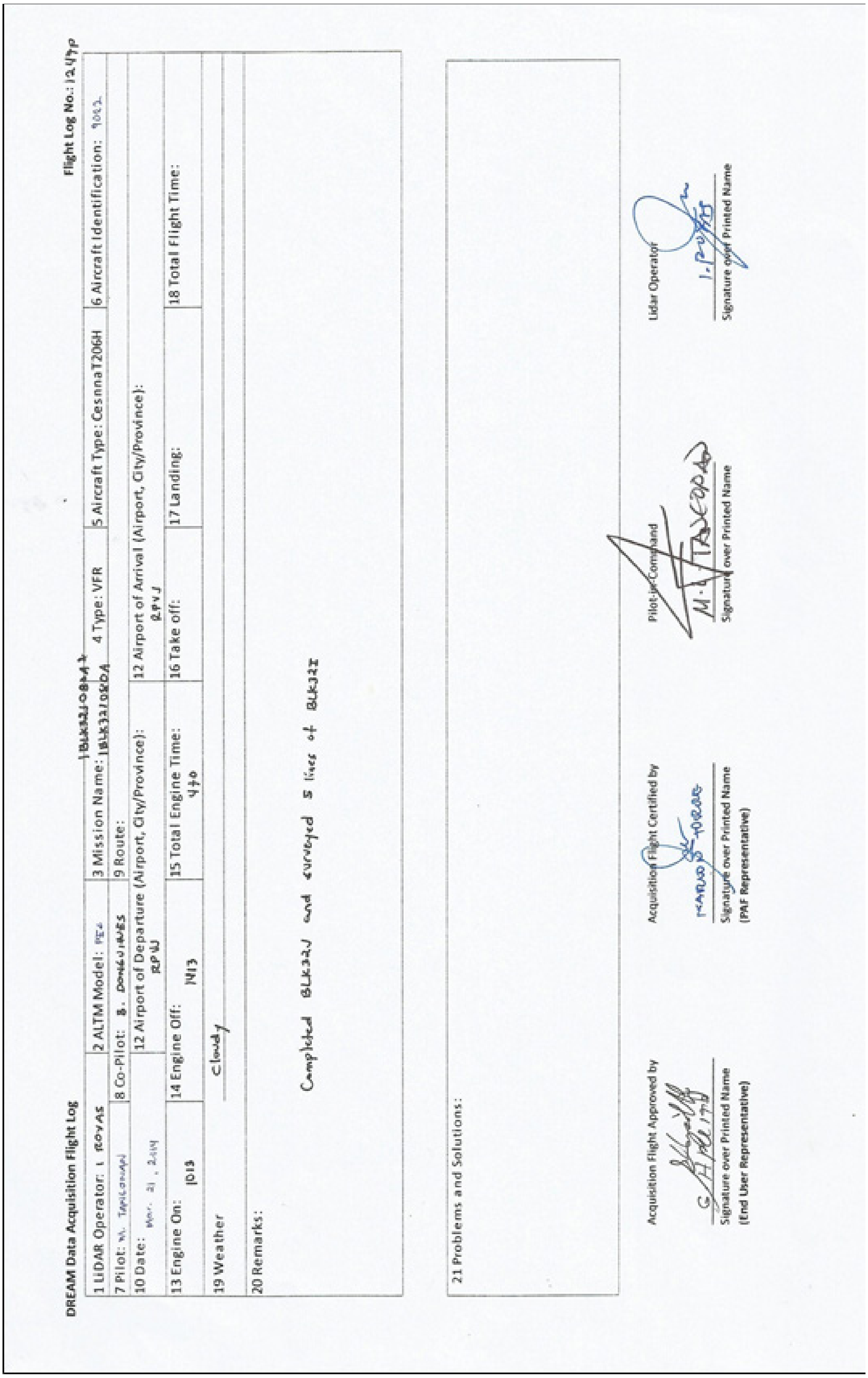
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — I. Roxas — Signature over Printed Name

Figure A-6.1. Flight Log for Mission 1245P

2. Flight Log for 1247P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1247P

1 LIDAR Operator: I. ROXAS	2 ALTM Model: Pe4	3 Mission Name: 1BLK32J081A+ 1BLK32J08DA	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. 21, 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 1013	14 Engine Off: 1413	15 Total Engine Time: 4+0	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					

20 Remarks:

Completed BLK32J and surveyed 5 lines of BLK32I

21 Problems and Solutions:

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

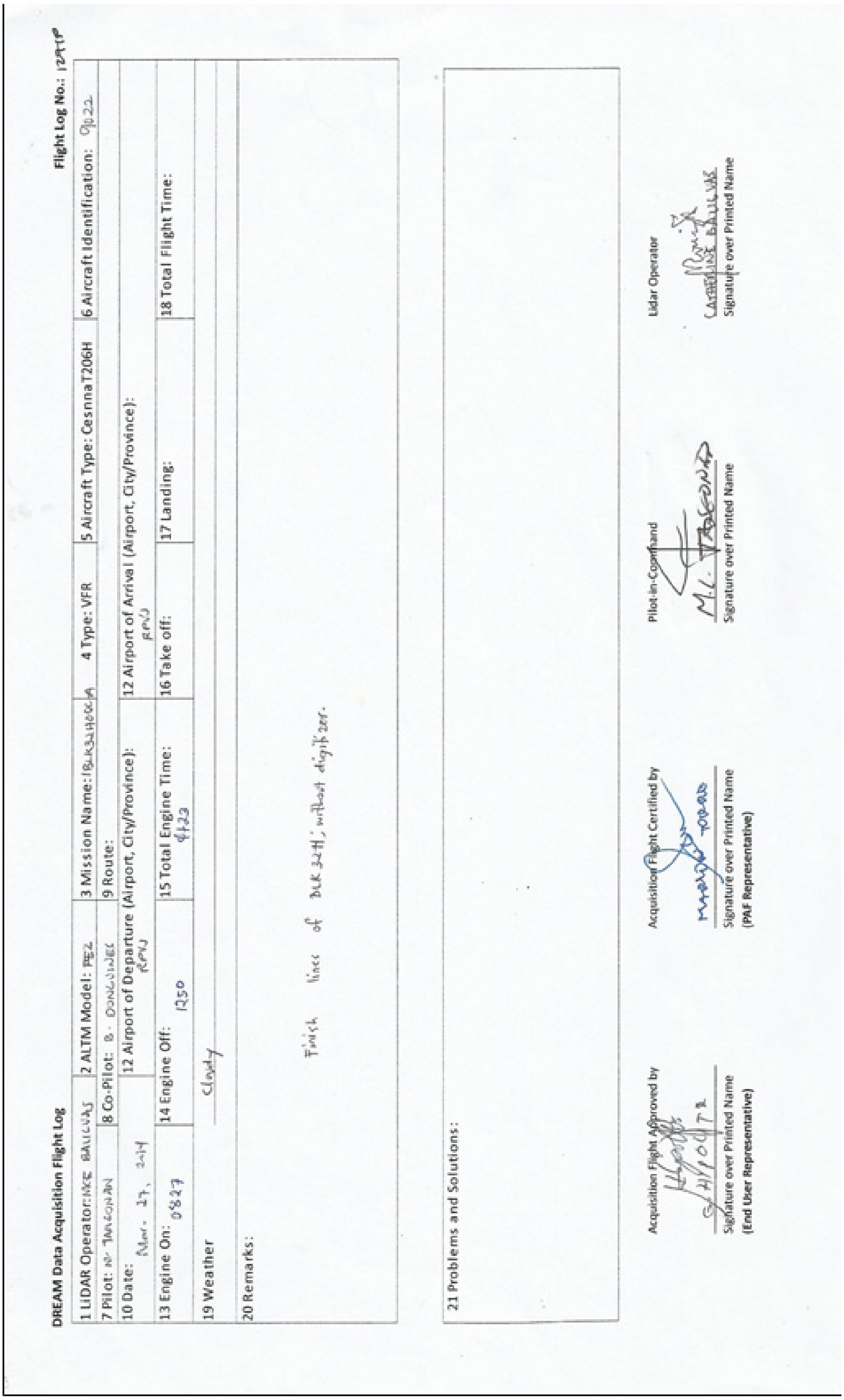
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — M. TANGONAN — Signature over Printed Name

Lidar Operator — I. ROXAS — Signature over Printed Name

Figure A-6.2. Flight Log for Mission 1247P

3. Flight Log for 1271P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1271P

1 LiDAR Operator: MCE BALICUAS	2 ALTM Model: PEG	3 Mission Name: 1BLK32H066A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	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 — Signature over Printed Name (End User Representative)

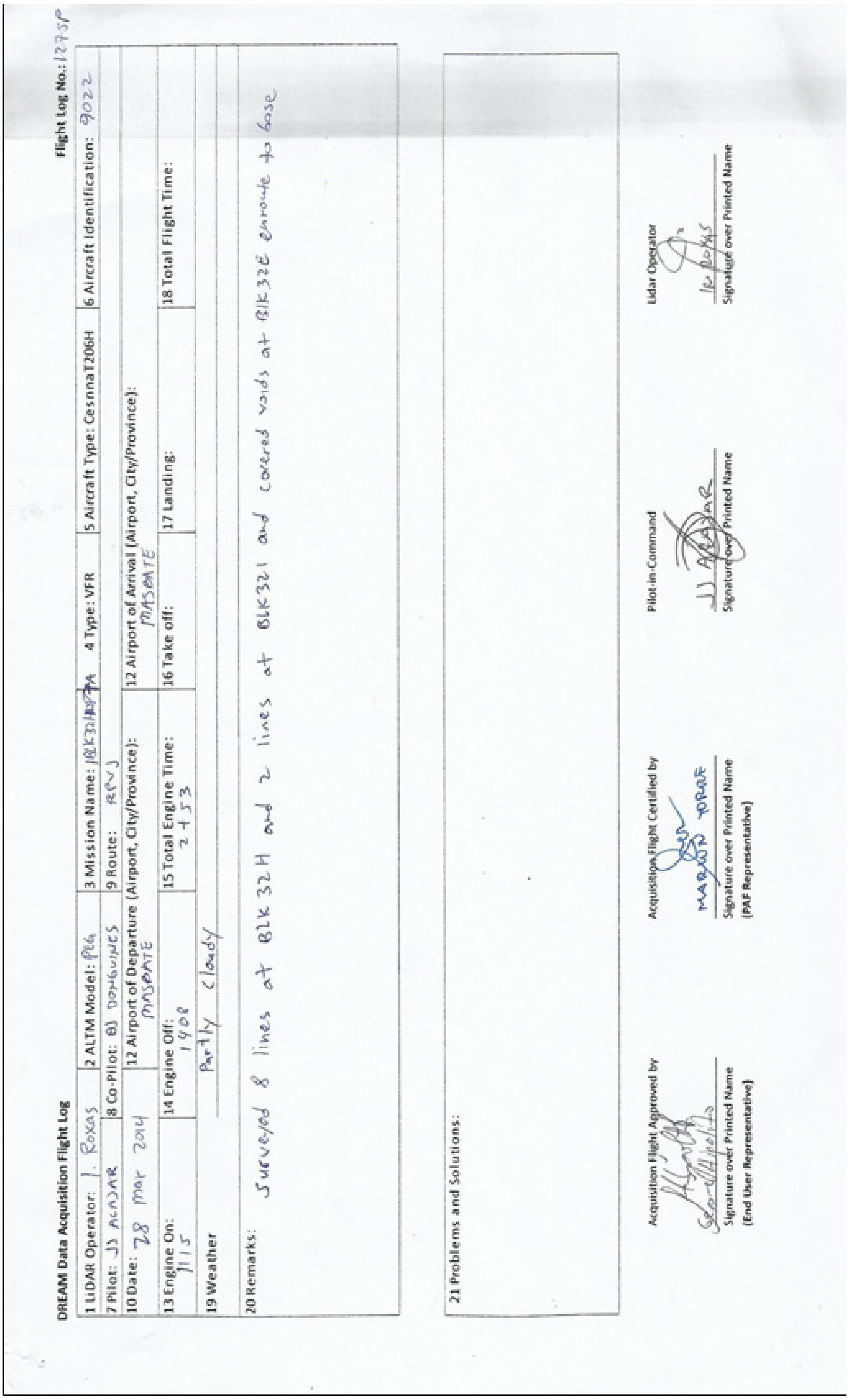
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — M. L. TANGONAN — Signature over Printed Name

Lidar Operator — CATHERINE BALICUAS — 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: BLK32	4 Type: VFR	5 Aircraft Type: Cesnna T206H	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 — Signature over Printed Name (End User Representative)

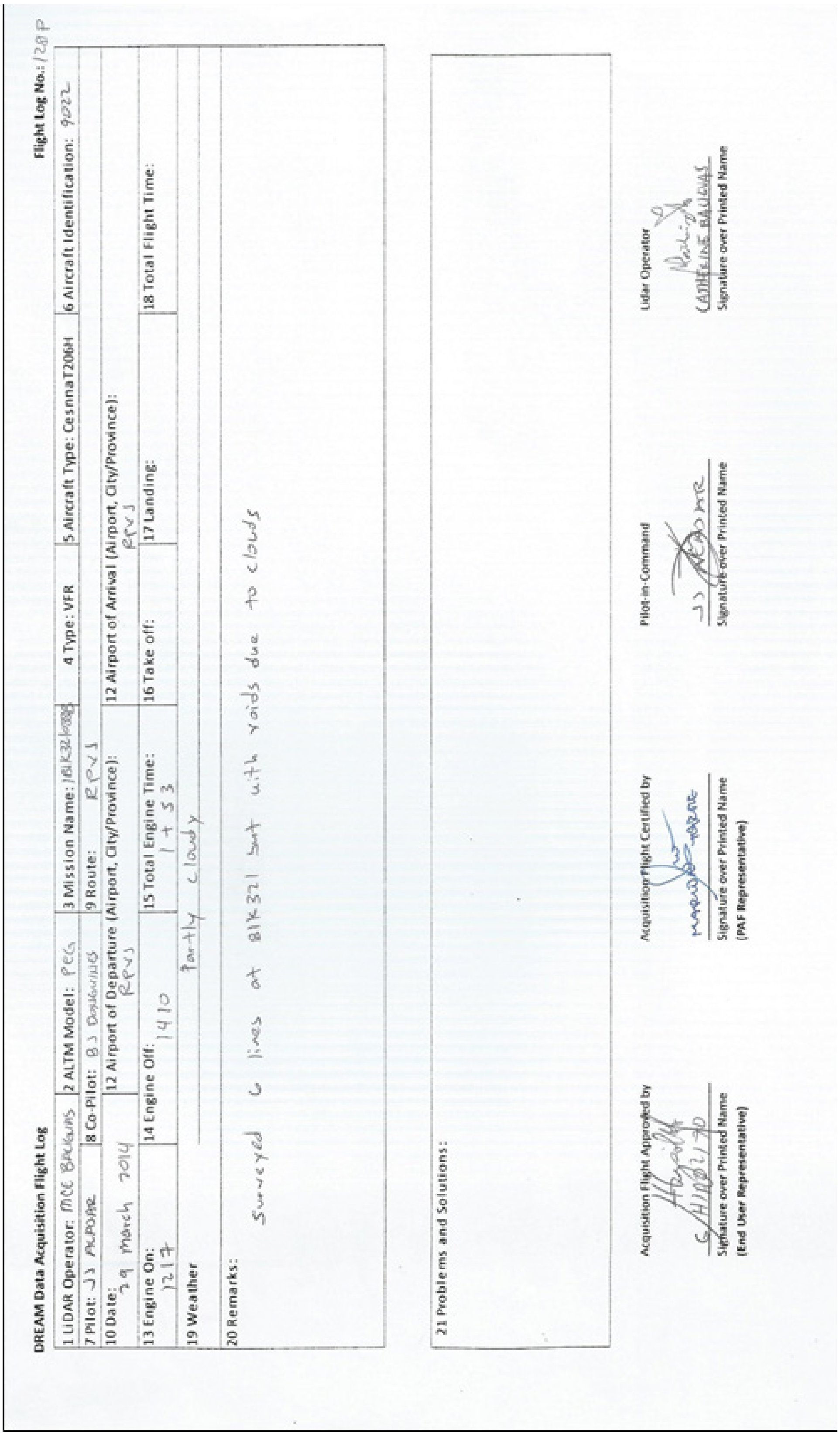
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — JJ Alajar — Signature over Printed Name

Lidar Operator — J. Roxas — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 1275P

5. Flight Log for 1281P Mission



DREAM Data Acquisition Flight Log — Flight Log No.: 1281P

1 LiDAR Operator: MCE Balicas	2 ALTM Model: Peg	3 Mission Name: 1BLK32I088B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: [illegible]	8 Co-Pilot: [illegible]	9 Route: RPVJ			
10 Date: 29 March 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 1217	14 Engine Off: 1410	15 Total Engine Time: 1+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					
20 Remarks: Surveyed 6 lines at BLK32I but with voids due to clouds					
21 Problems and Solutions:					

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

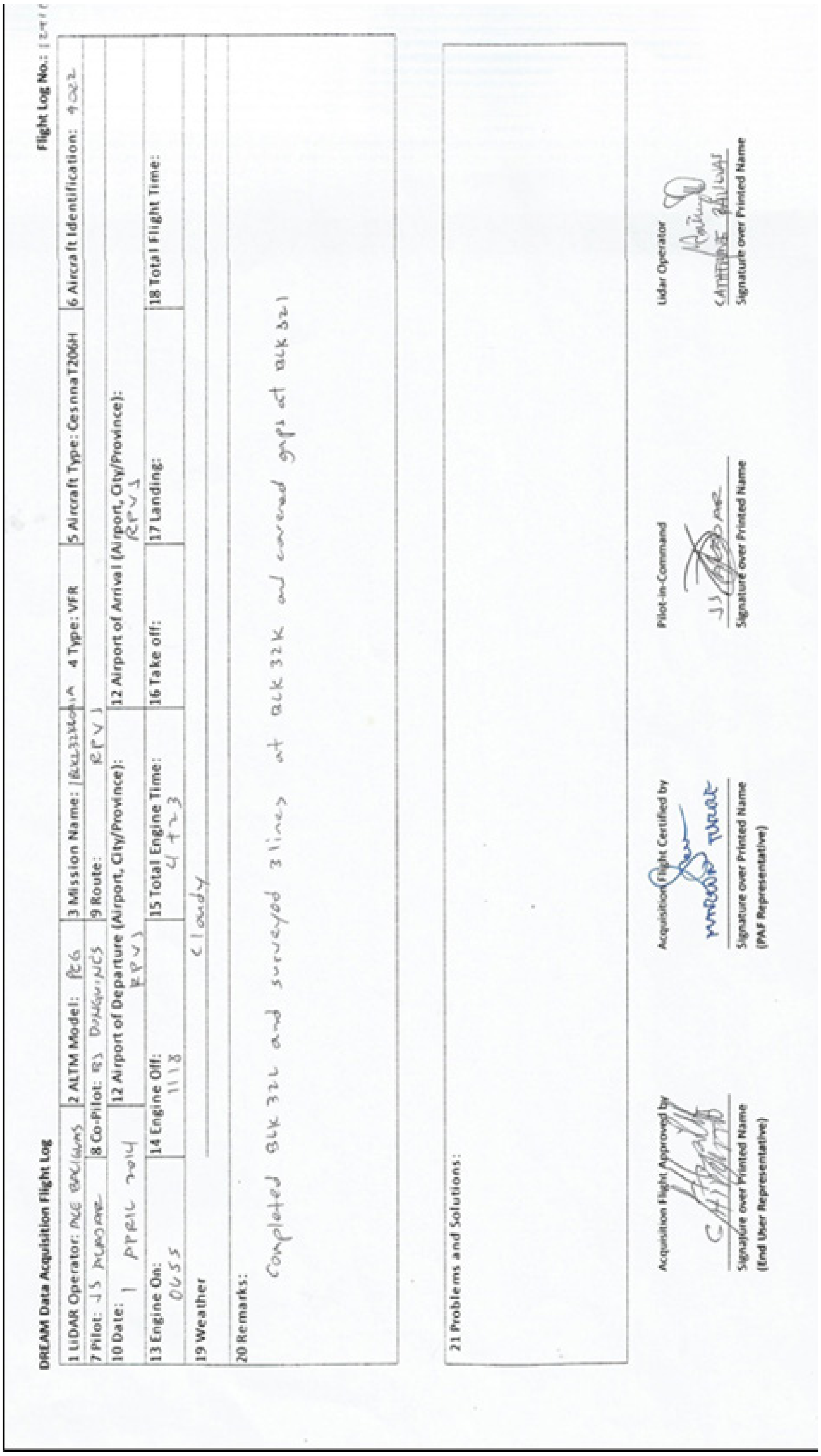
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — Signature over Printed Name

Lidar Operator — CATHERINE BALICAS — Signature over Printed Name

Figure A-6.5. Flight Log for Mission 1281P

6. Flight Log for 1291P Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1291P

1 LiDAR Operator: MCE Balicuas	2 ALTM Model: Peg	3 Mission Name: 1BLK32K091A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: JJ Munoz	8 Co-Pilot: RJ Dungingcs	9 Route: RPVJ			
10 Date: 1 April 2014	12 Airport of Departure (Airport, City/Province): RPVJ		12 Airport of Arrival (Airport, City/Province): RPVJ		
13 Engine On: 0655	14 Engine Off: 1118	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Cloudy					
20 Remarks: Completed BLK 32L and surveyed 3 lines at BLK 32K and covered gaps 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 — JJ Munoz — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.6. Flight Log for Mission 1291P

7. 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 Alfonso	8 Co-Pilot: BS Dongiunes	9 Route: Revs			
10 Date: 01 April 2014	12 Airport of Departure (Airport, City/Province): Revs		12 Airport of Arrival (Airport, City/Province): Revs		
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 — Signature over Printed Name (End User Representative)

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

Pilot-in-Command — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.7. Flight Log for Mission 1293P

Annex 7. Flight Status Reports

Masbate Mission
March 20 to April 1, 2014

Table A-7.1. Flight Status Report

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1245P	BLK32J	1BLK32J079B	I. Roxas	20 MAR 14	Surveyed 12 lines of BLK32J
1247P	BLK32J	1BLK32IJ080A	I. Roxas	21 MAR 14	Completed BLK32J and surveyed 5 lines of BLK32I
1271P	BLK32H	1BLK32H086A	MCE. Baliguas	27 MAR 14	Surveyed 18 lines at BLK32H; 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
1281P	BLK32I	1BLK32I088B	MCE. Baliguas	29 MAR 14	Surveyed 6 lines at BLK32I but with voids due to clouds
1291P	BLK32K & BLK32L	1BLK32KL091A	MCE. BALIGUAS	01APR 14	Completed BLK32L and surveyed 3 lines at BLK32K and covered gaps at BLK32I
1293P	BLK32H	1BLK32H091B	I. Roxas	01APR 14	Surveyed 8 lines at BLK32H; auto pilot disengaging

LAS BOUNDARIES PER FLIGHT

Flight No. : 1245P
Area: BLK32J
Mission Name: 1BLK32J079B
Area Surveyed: 145.344 sq.km.
Altitude: 800m
PRF: 200 kHz
SCF: 30 Hz
Lidar FOV: 50 deg
Sidelap: 25%

Figure A-6.6. Flight Log for Mission 1291P

Flight No. : 1247P
Area: BLK32J
Mission Name: 1BLK32IJ080A
Area Surveyed: 333.843 sq.km.
Altitude: 1000m
PRF: 200 kHz SCF: 30 Hz
Lidar FOV: 50 deg Sidelap: 25%
Altitude: 1200m
PRF: 300 kHz SCF: 30 Hz
Lidar FOV: 50 deg Sidelap: 25%

Figure A-7.2. Swath for Flight No. 1247P

Flight No. : 1271P
Area: BLK32H
Mission Name: 1BLK32H086A
Area Surveyed: 173.31 sq.km.
Altitude: 800m
PRF: 200 kHz SCF: 30 Hz
Lidar FOV: 50 deg Sidelap:25%
Altitude: 600m
PRF: 200 kHz SCF: 30 Hz
Lidar FOV: 50 deg Sidelap:30%

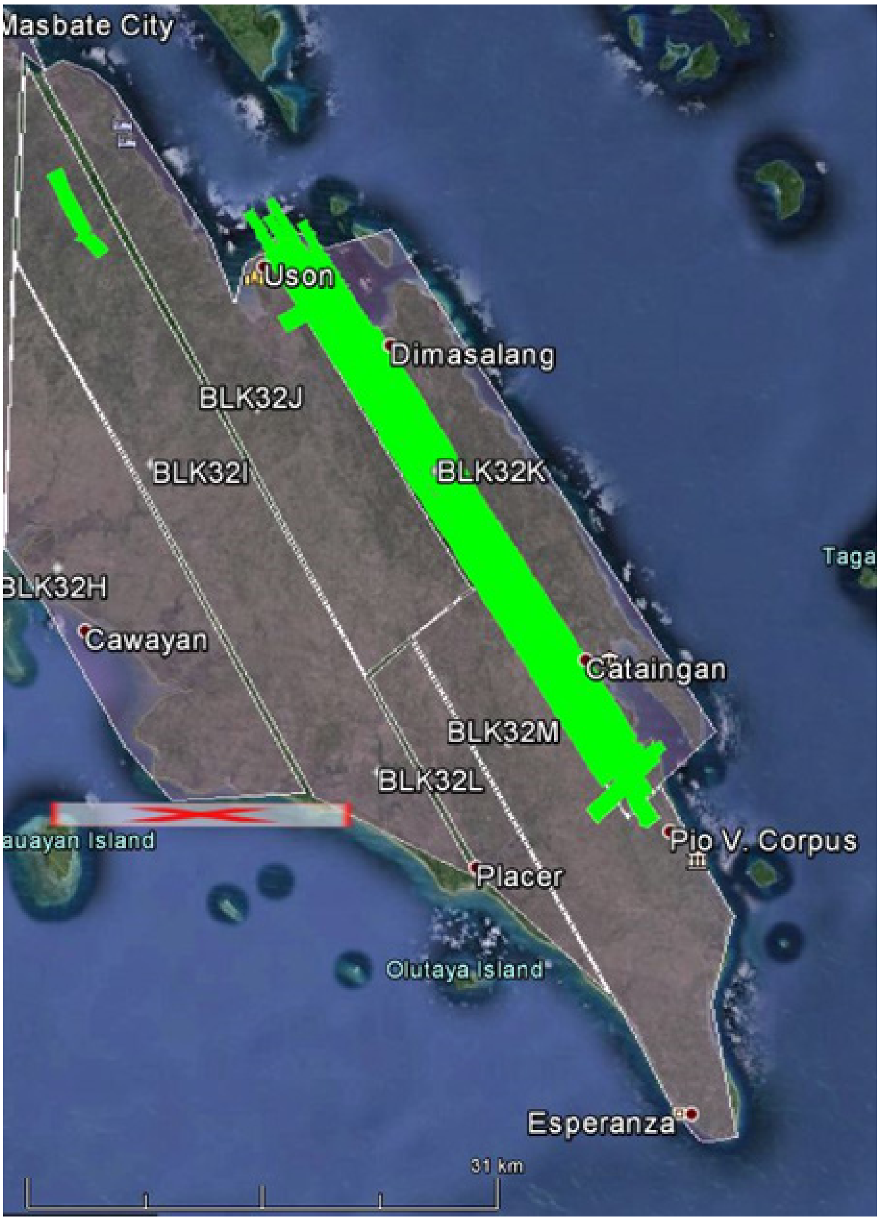


Figure A-7.3. Swath for Flight No. 1271P

Flight No. : 1275P
rea: BLK32H
Mission Name: 1BLK32HI087A
Area Surveyed: 127.76 sq.km.
Altitude: 800m
PRF: 250 kHz SCF: 36 Hz
Lidar FOV: 40 deg Sidelap: 25%

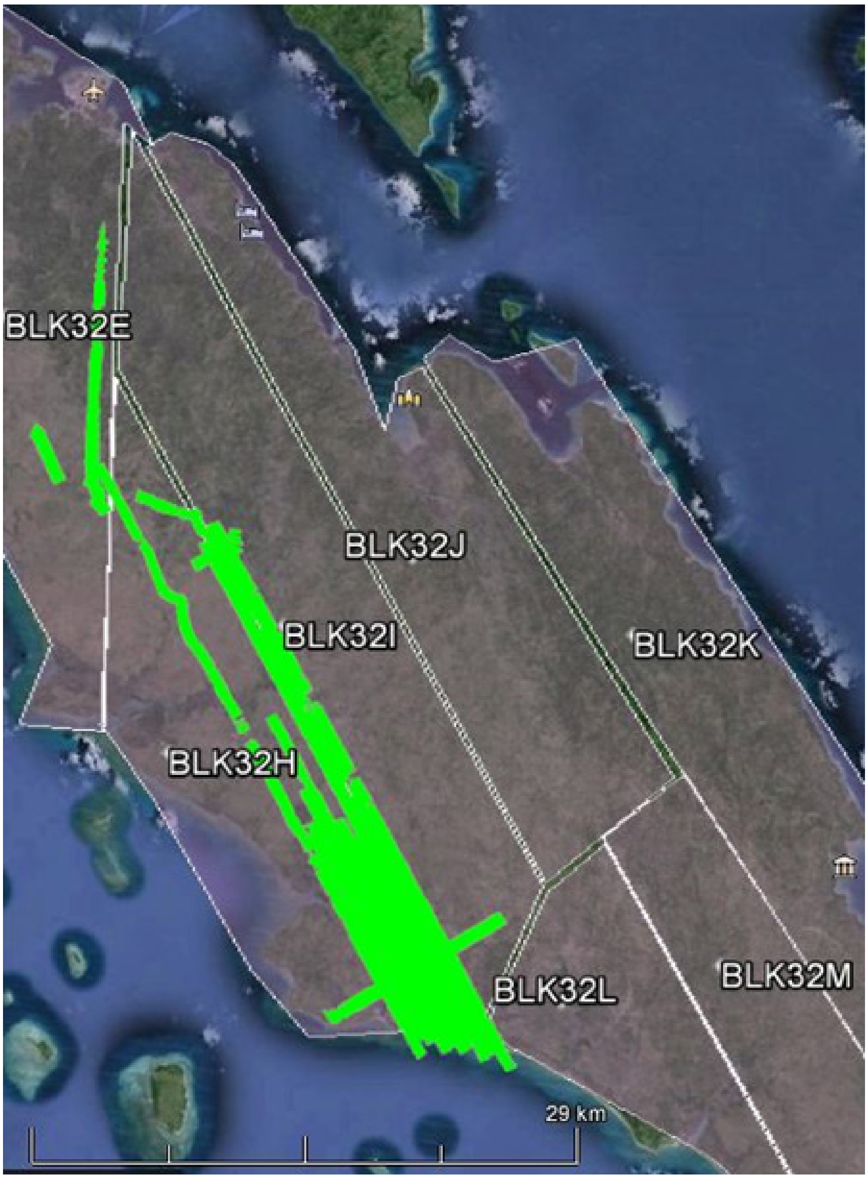


Figure A-7.4. Swath for Flight No. 1275P

Flight No. :	1281P	
Area:	BLK32I	
Mission Name:	1BLK32I088B	
Area Surveyed:	129.109 sq.km.	
Altitude:	1000m	
PRF:	200kHz	SCF:30Hz
Lidar FOV:	50deg	Sidelap: 40%

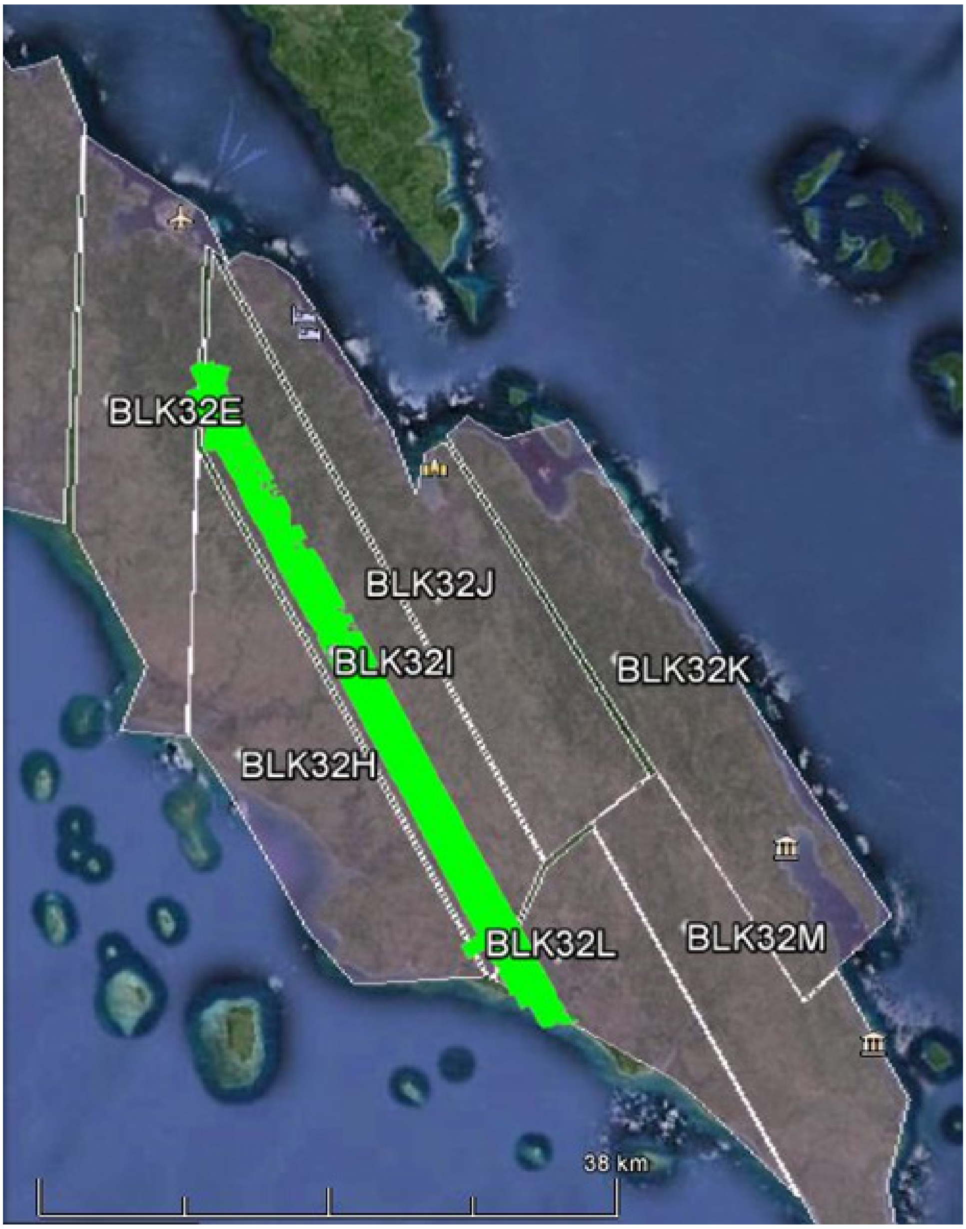


Figure A-7.5. Swath for Flight No. 1281P

Flight No. : 1291P
Area: BLK32K & BLK32L
Mission Name: 1BLK32KL091A
Area Surveyed: 173.14 sq.km.
BLK32L
Altitude: 800m
PRF: 200 kHz SCF: 30 Hz
Lidar FOV: 50 deg Overlap: 30%

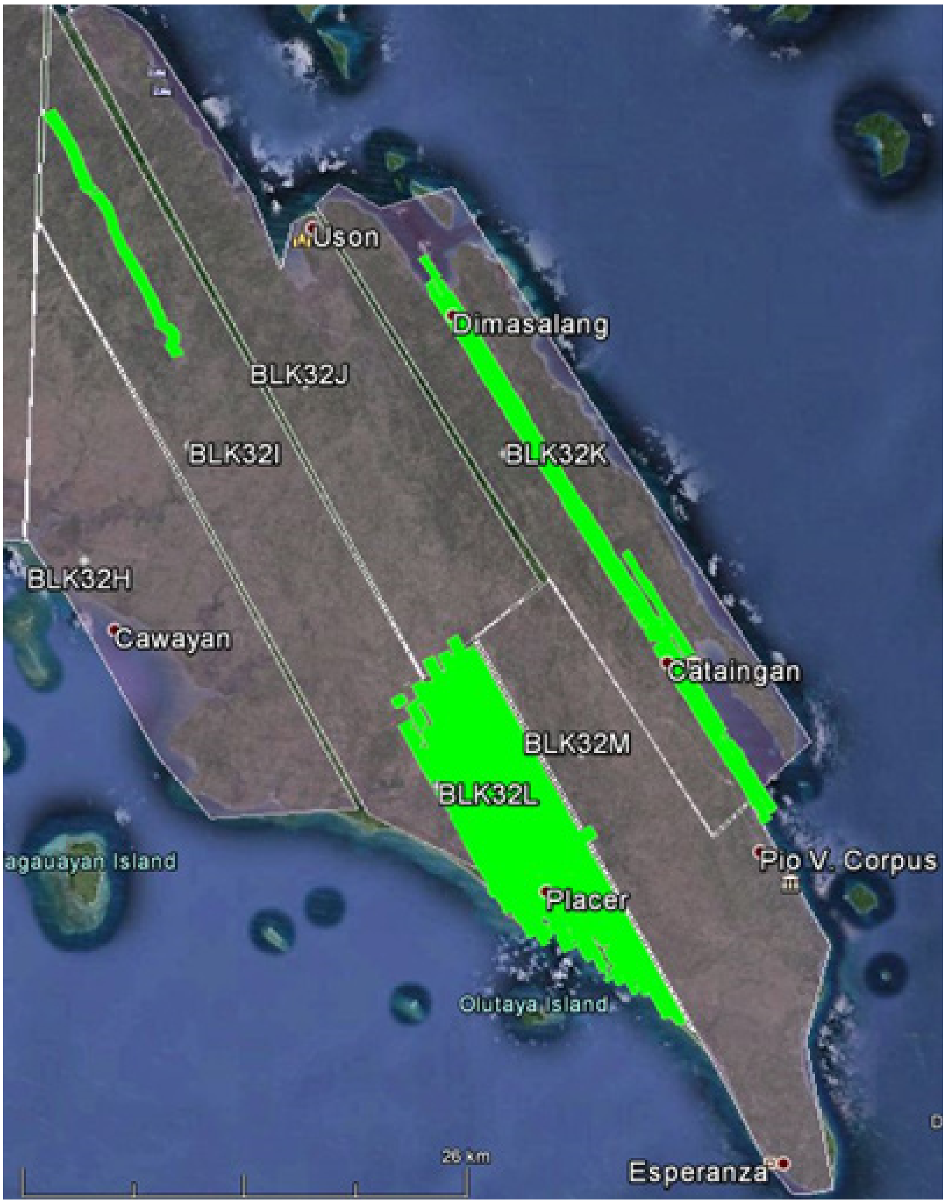


Figure A-7.6. Swath for Flight No. 1291P

Flight No. : 1293P
Area: BLK32H
Mission Name: 1BLK32H091B
Area Surveyed: 83.369 sq.km.
Altitude: 800m
PRF: 250 kHz SCF: 36 Hz
Lidar FOV: 40 deg Sidelap: 25%

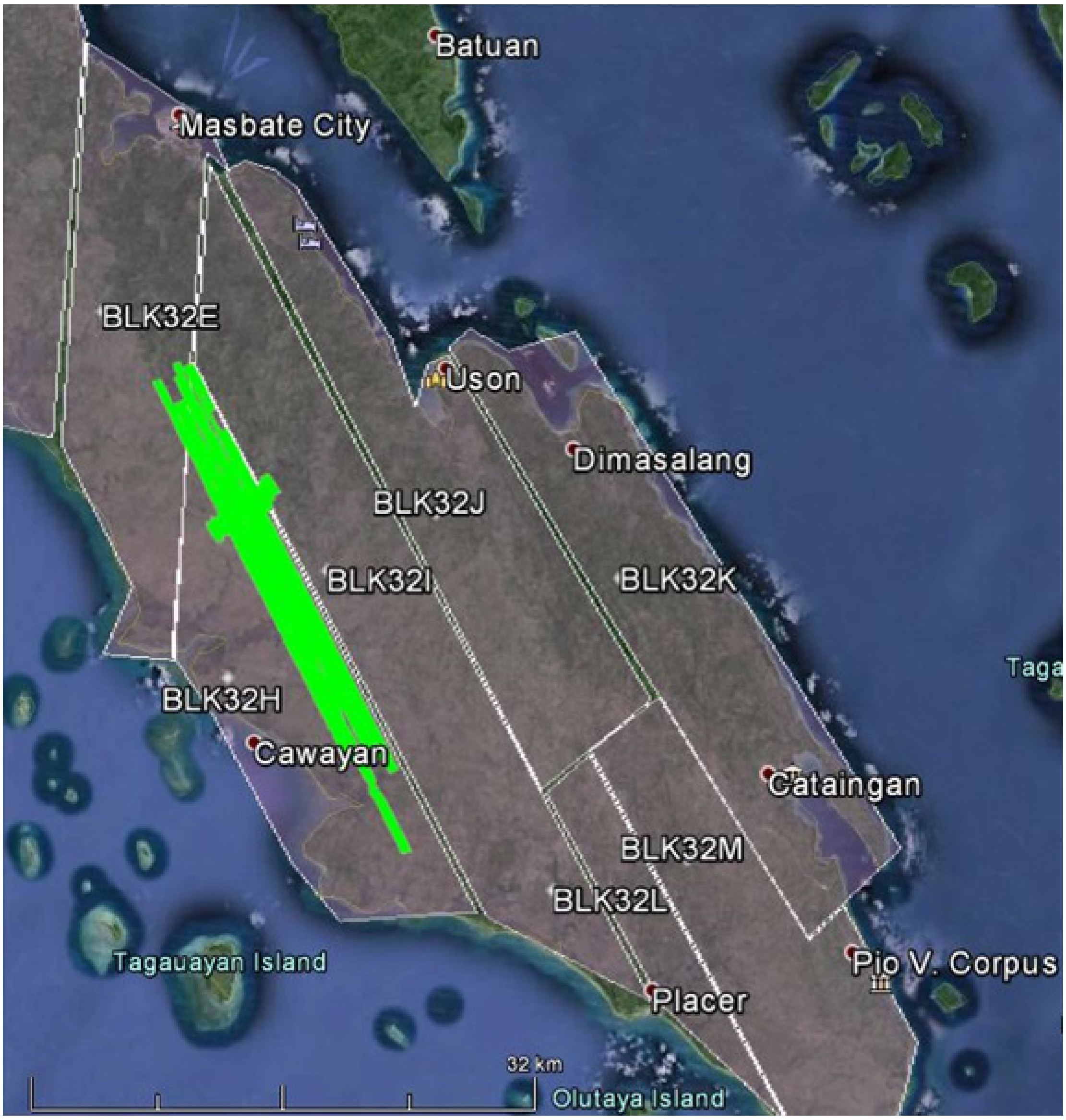


Figure A-7.6. Swath for Flight No. 1293P

Annex 8. Mission Summary Reports

Flight Area	Masbate
Mission Name	**Blk32L**
Inclusive Flights	1291P
Range data size	29.8 GB
POS	256 MB
Base data size	7.81 MB
Image	4.22 GB
Transfer date	April 23 2014
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.86
RMSE for East Position (<4.0 cm)	1.85
RMSE for Down Position (<8.0 cm)	3.45
Boresight correction stdev (<0.001deg)	0.000568
IMU attitude correction stdev (<0.001deg)	0.002429
GPS position stdev (<0.01m)	0.0021
Minimum % overlap (>25)	46.57%
Ave point cloud density per sq.m. (>2.0)	4.28
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	168
Maximum Height	187.1m
Minimum Height	47.37m
Classification (# of points)	
Ground	245,618,687
Low vegetation	177,742,884
Medium vegetation	166,437,529
High vegetation	74,107,542
Building	2,424,545
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Christy Lubiano, Jovy Narisma

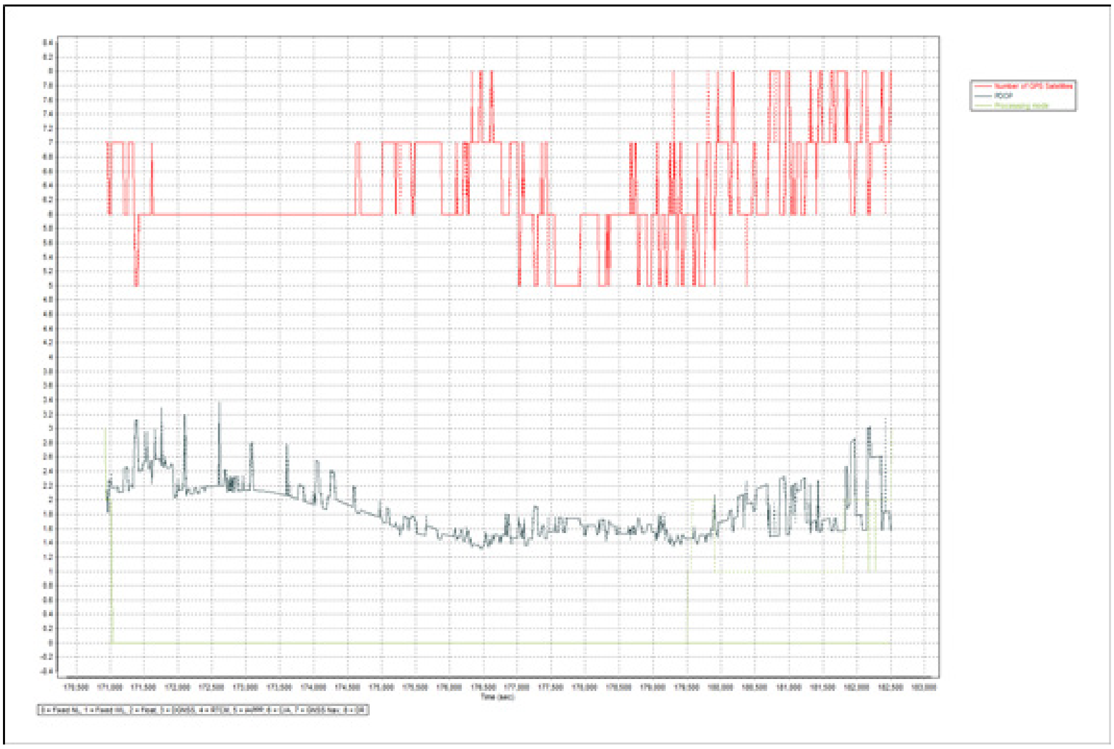


Figure A-8.1 Solution Status

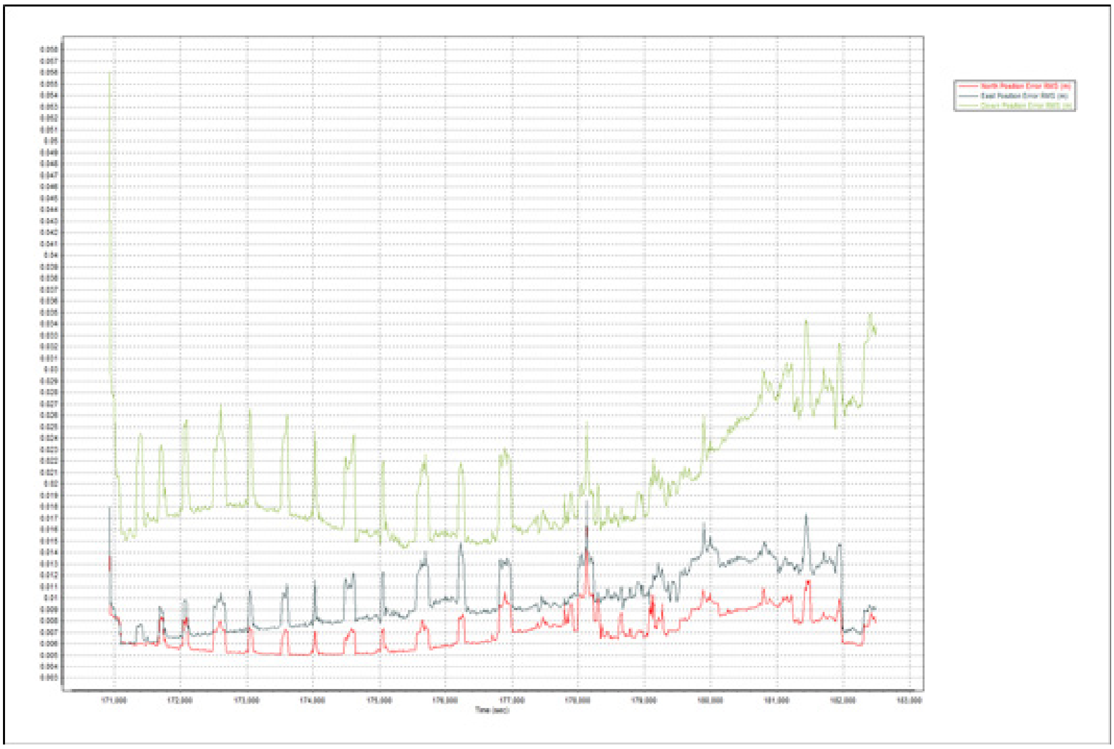


Figure A-8.2 Smoothed Performance Metric Parameters

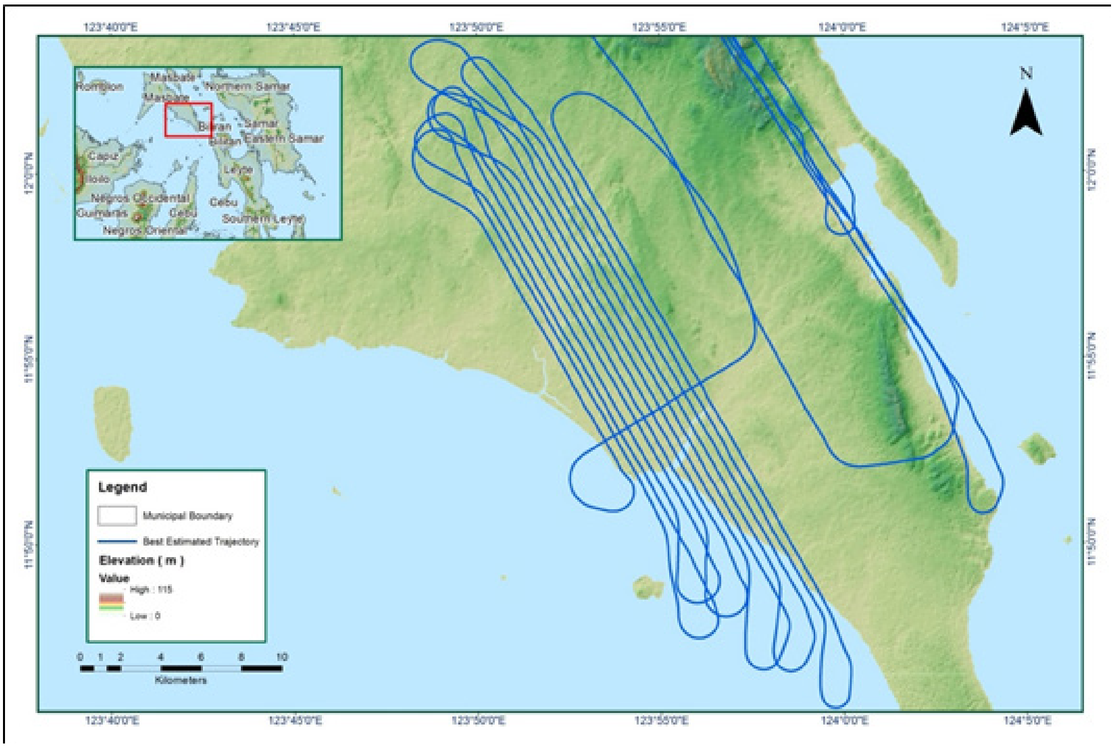


Figure A-8.3 Best Estimated Trajectory

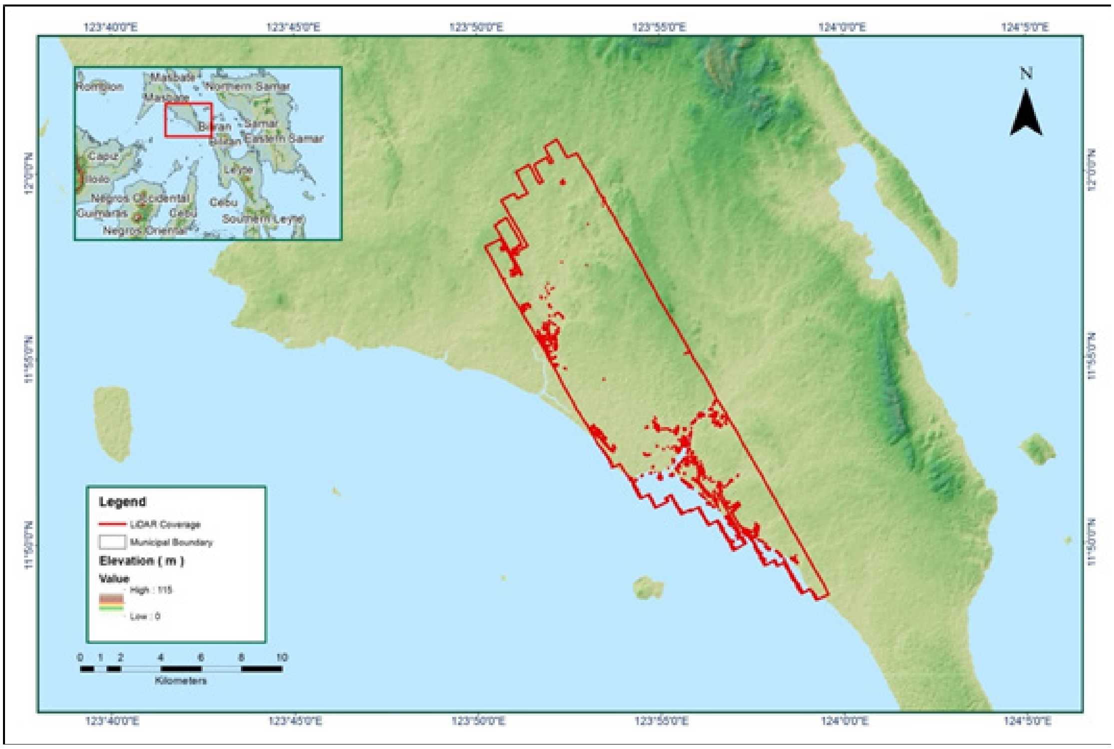


Figure A-8.4 Coverage of LiDAR data

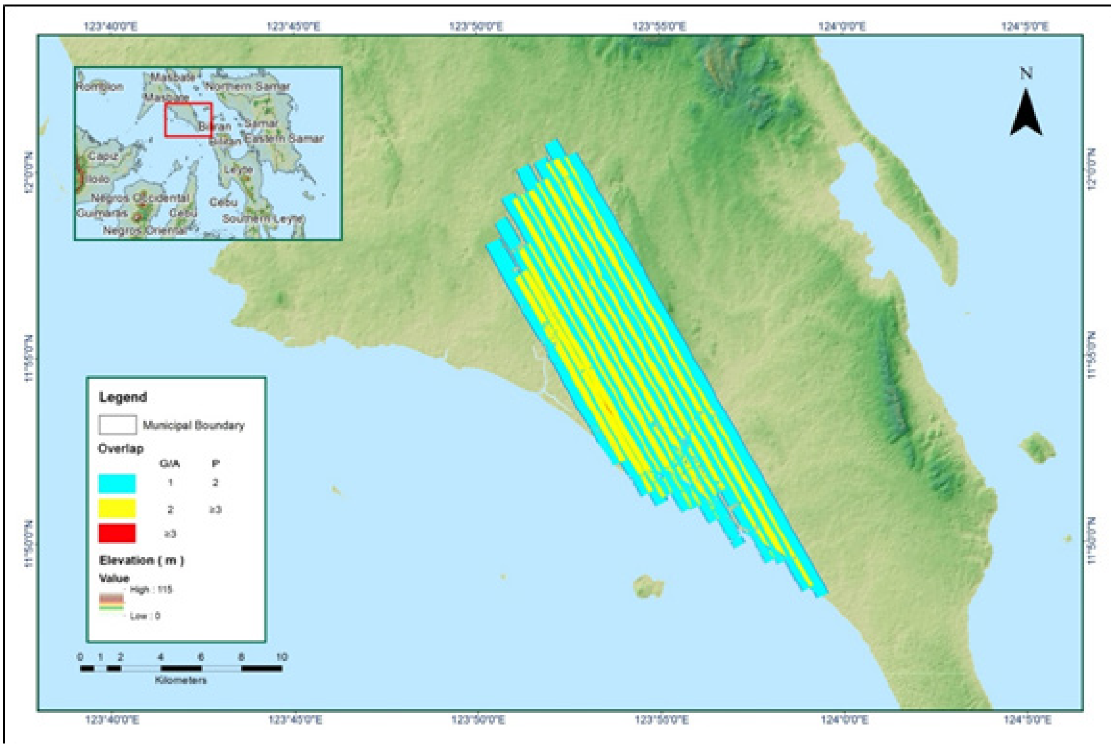


Figure A-8.5 Image of data overlap

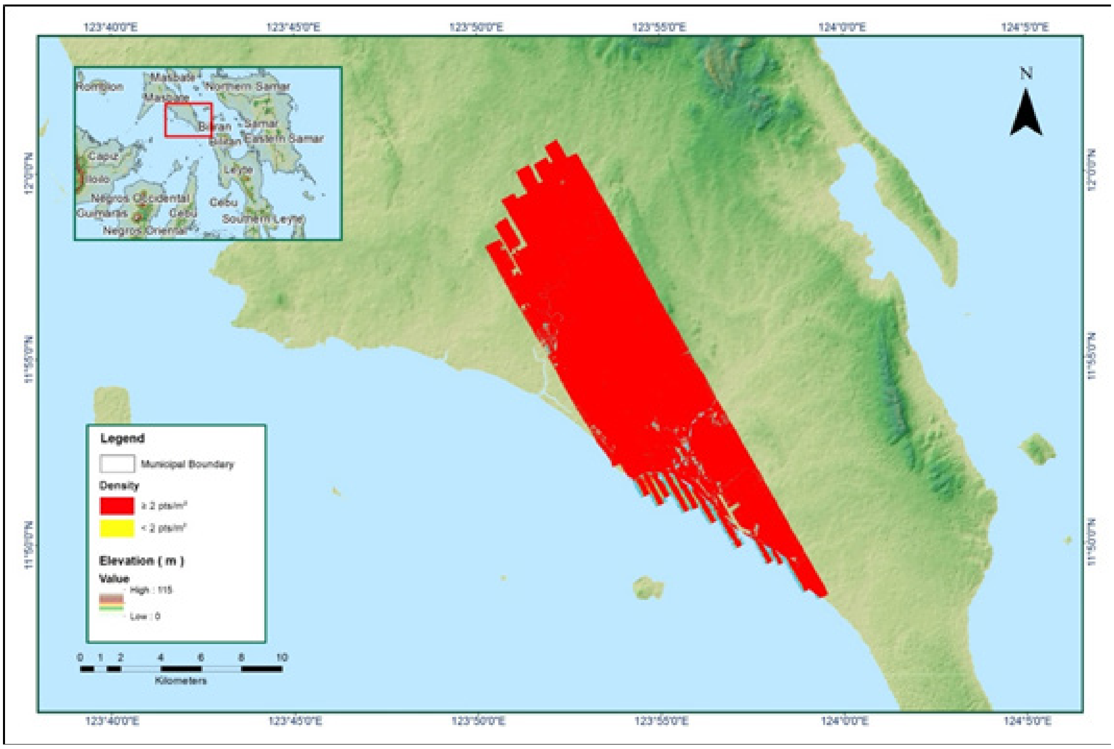


Figure A-8.6 Density map of merged LiDAR data

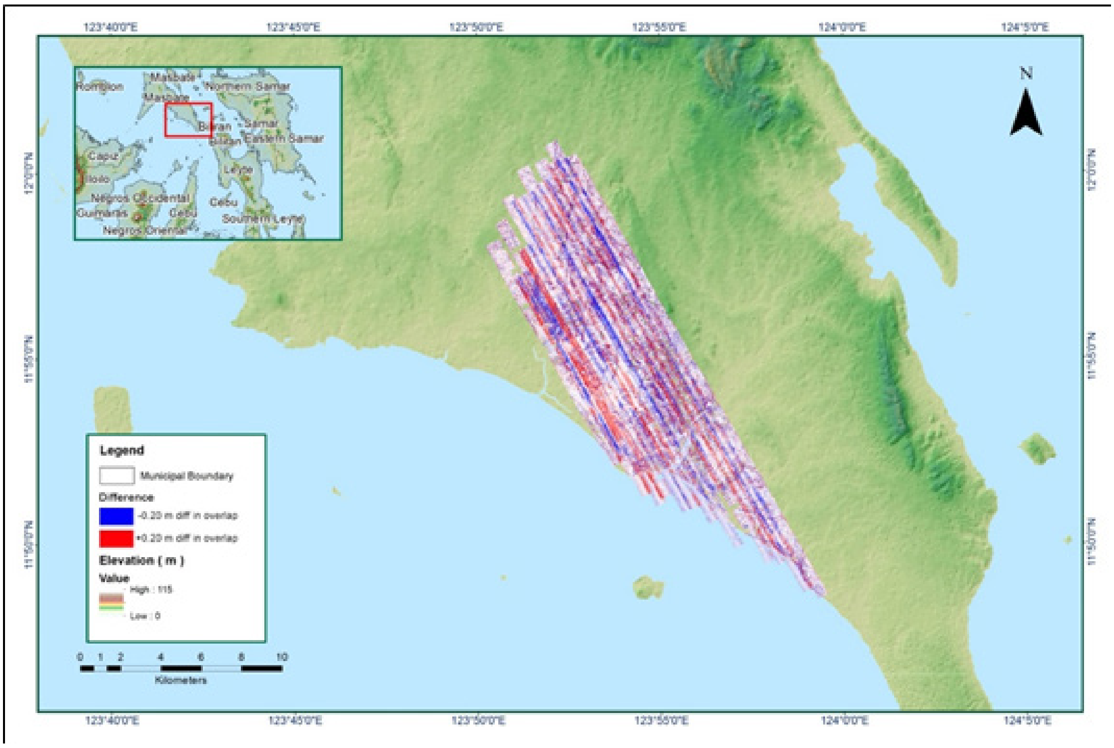


Figure A-8.7 Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Masbate_Blk32IJ

Flight Area	Masbate
Mission Name	Blk32IJ
Inclusive Flights	1245P, 1247P, 1281P
Range data size	77.3 GB
POS	535 MB
Base data size	18.58 MB
Image	104.4 GB
Transfer date	April 23 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.63
RMSE for East Position (<4.0 cm)	1.70
RMSE for Down Position (<8.0 cm)	3.20
Boresight correction stdev (<0.001deg)	0.000398
IMU attitude correction stdev (<0.001deg)	0.001191
GPS position stdev (<0.01m)	0.00270
Minimum % overlap (>25)	17.09%
Ave point cloud density per sq.m. (>2.0)	2.30
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	683
Maximum Height	603.95 m
Minimum Height	42.31 m
Classification (# of points)	
Ground	476,127,438
Low vegetation	250,199,416
Medium vegetation	363,150,463
High vegetation	265,574,430
Building	4,664,222
Orthophoto	Yes
Processed by	Engr. Kenneth Solidum, Engr. Harmond Santos, Engr. Roa Shalemar Redo, Engr. John Dill Macapagal

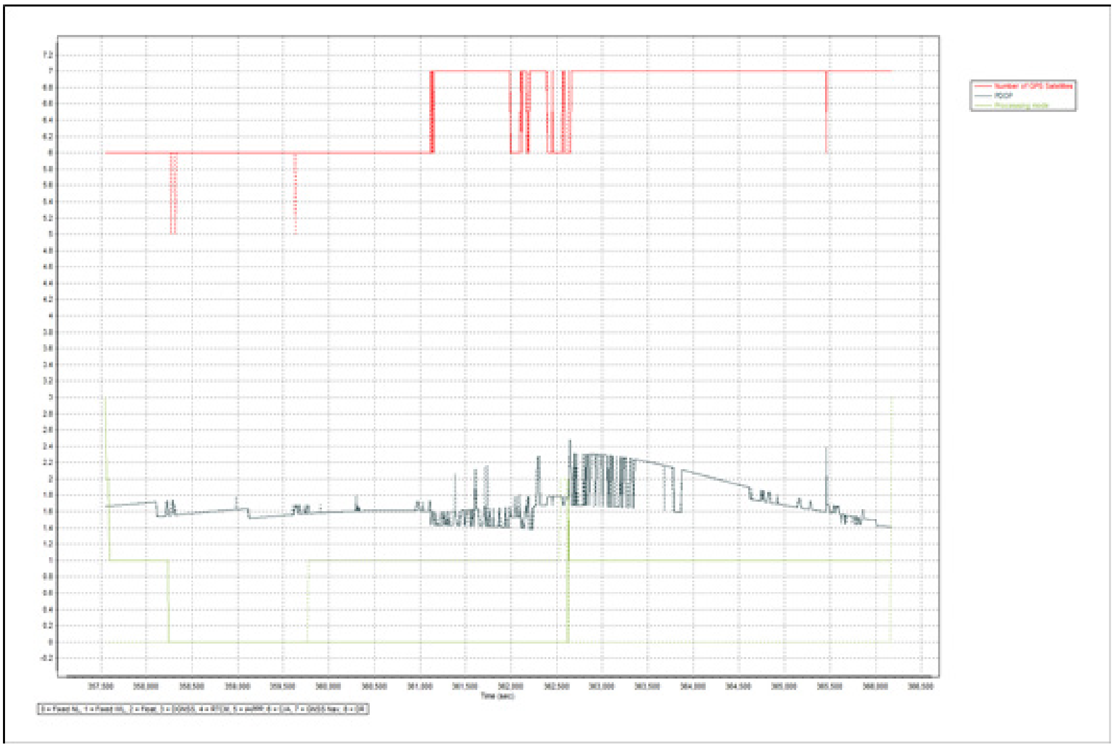


Figure A-8.8 Solution Status

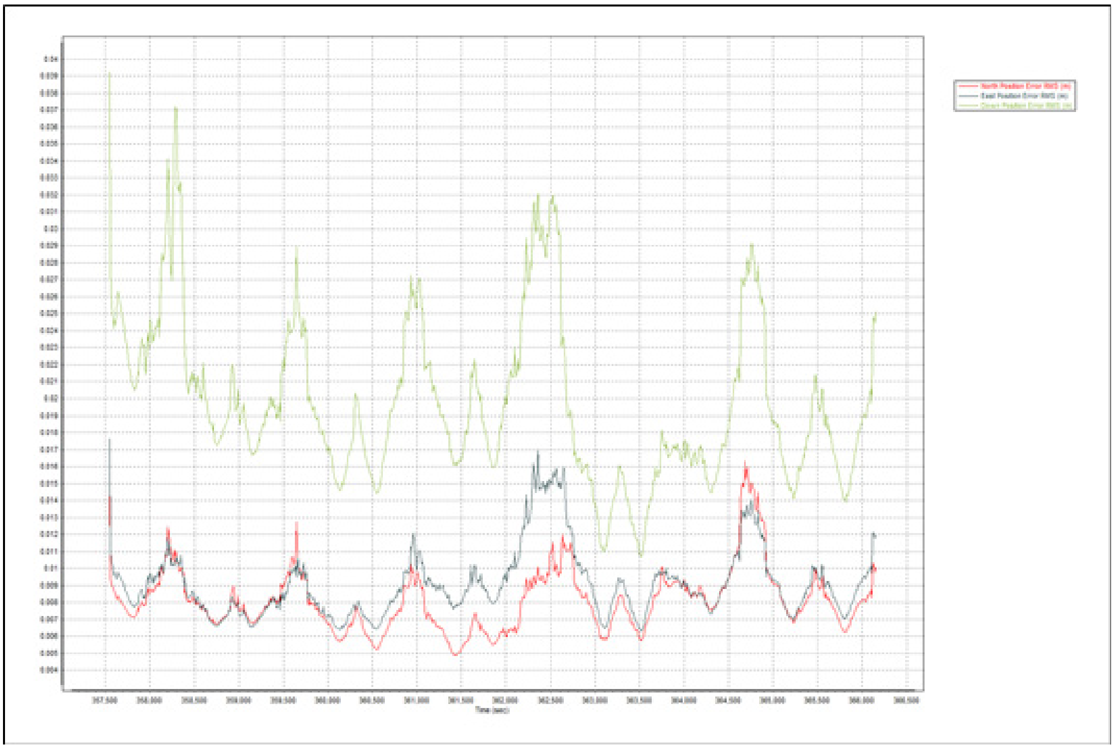


Figure A-8.9 Smoothed Performance Metric Parameters

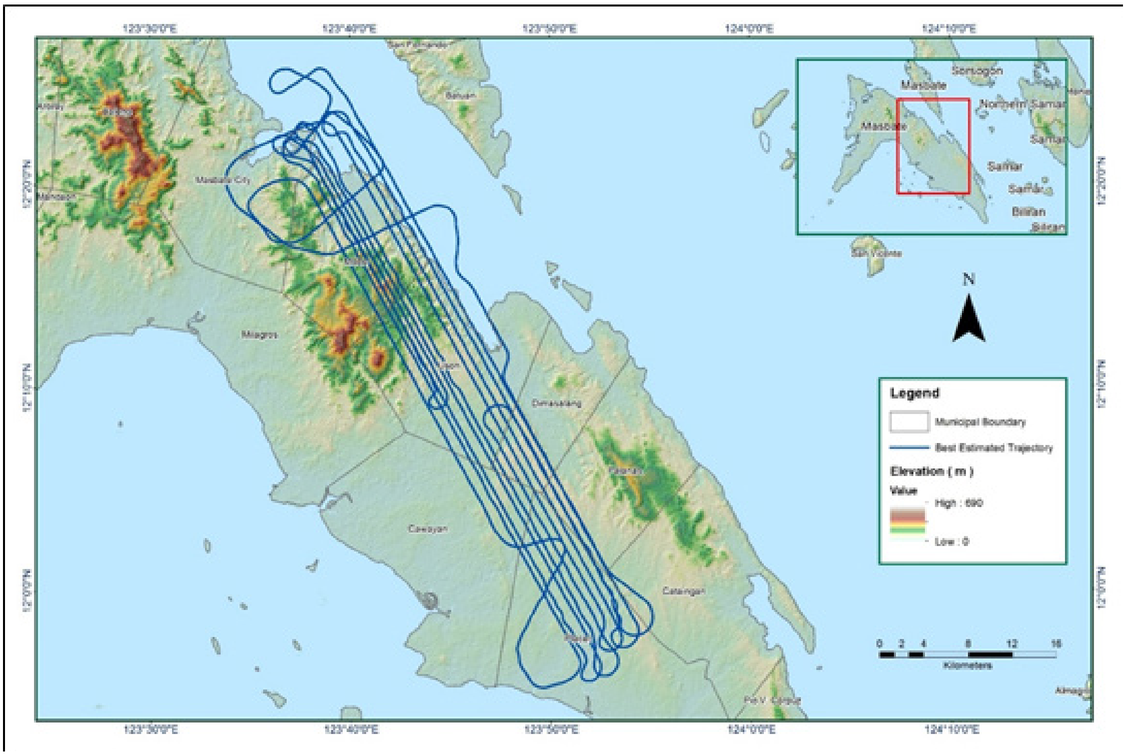


Figure A-8.10 Best Estimated Trajectory

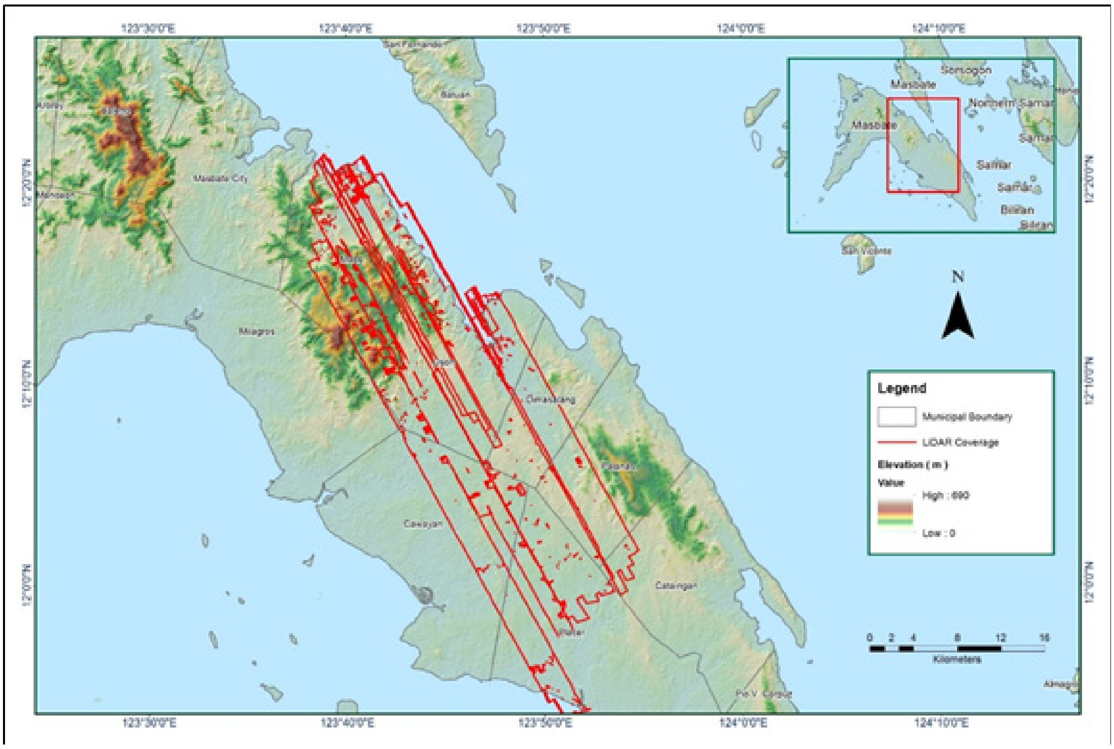


Figure A-8.11 Coverage of LiDAR data

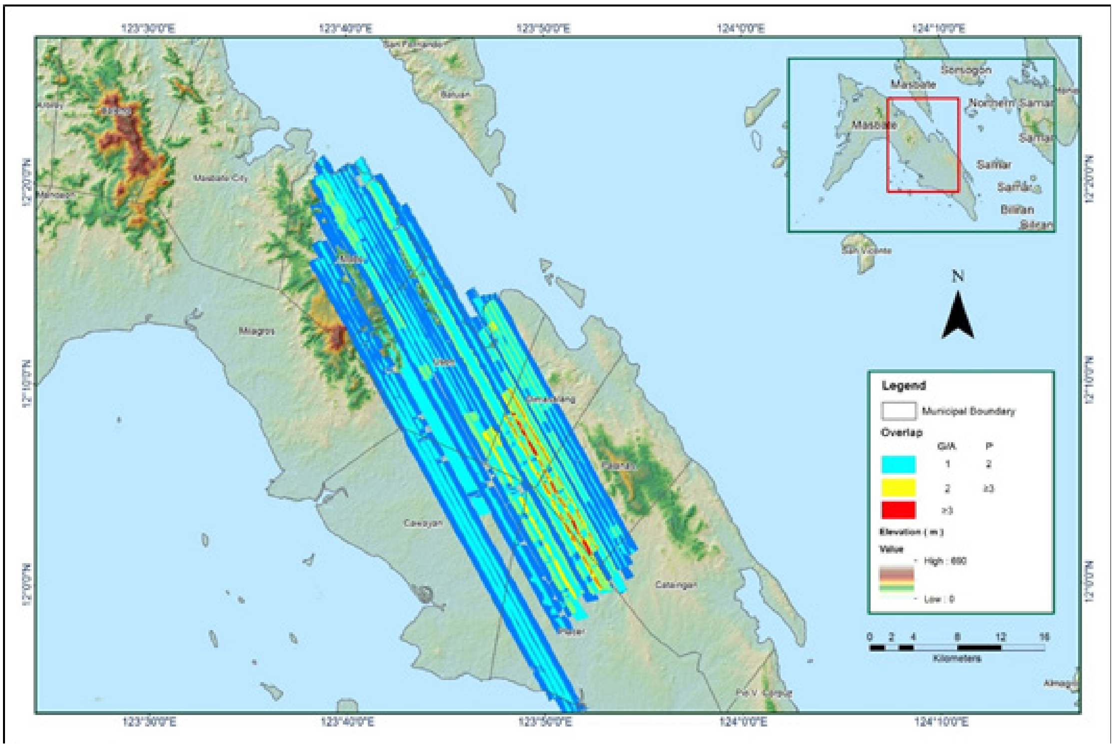


Figure A-8.12 Image of data overlap

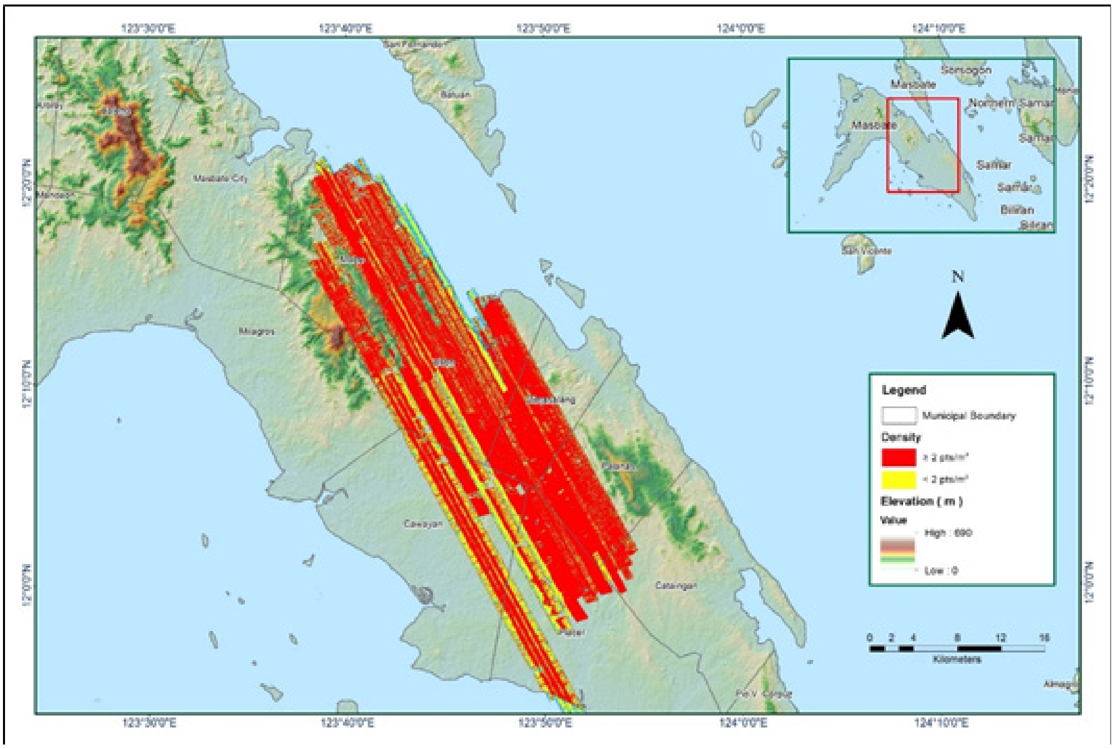


Figure A-8.13 Density map of merged LiDAR data

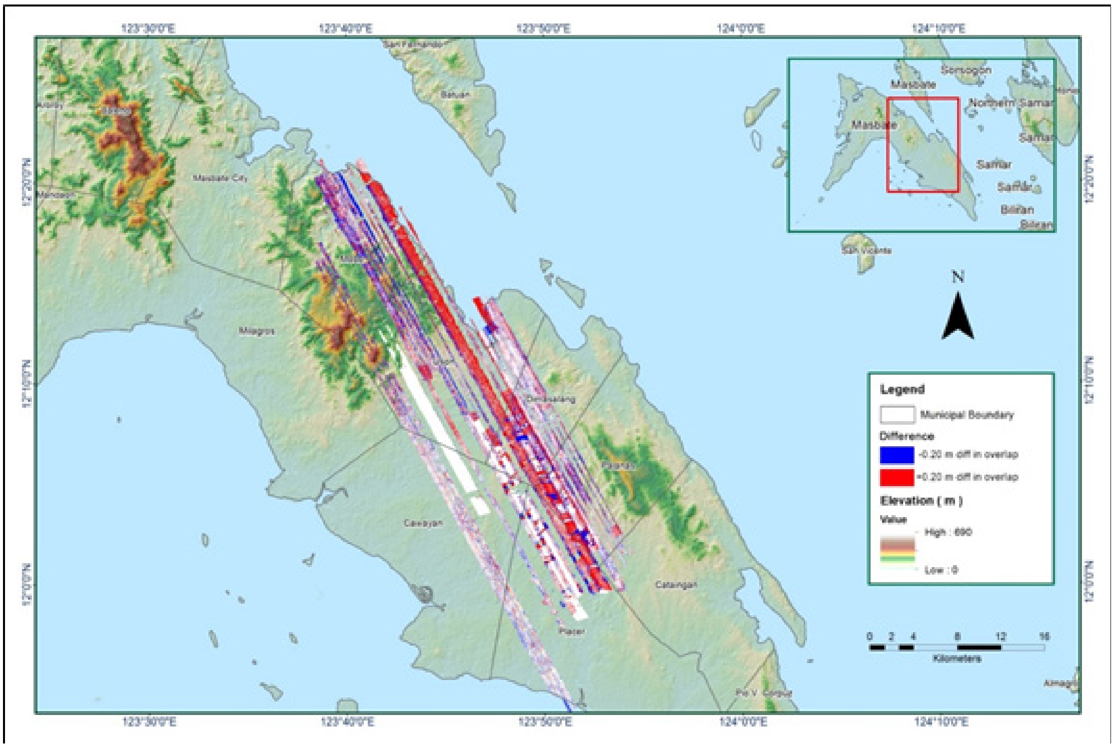


Figure A-8.14 Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Masbate_Blk32H

Flight Area	Masbate
Mission Name	Blk32H
Inclusive Flights	1271P, 1275P, 1293P
Range data size	70.5 GB
POS	538 MB
Base data size	19.72 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. Harmond Santos, Engr. Gladys Mae Apat

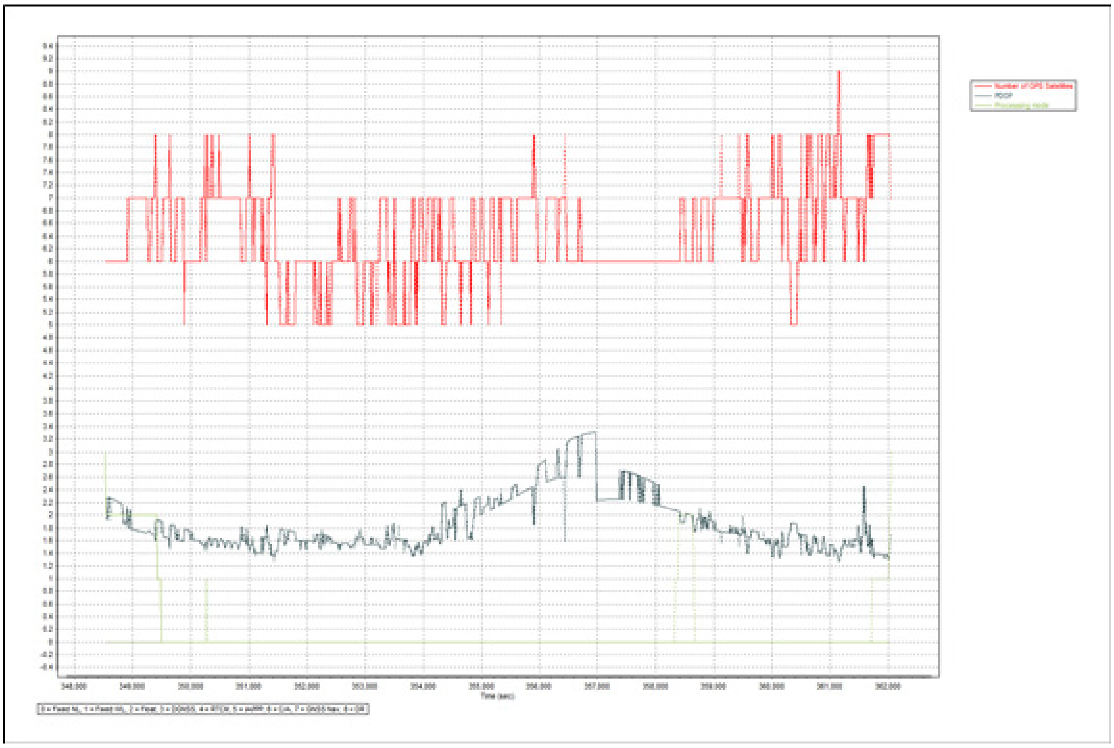


Figure A-8.15 Solution Status

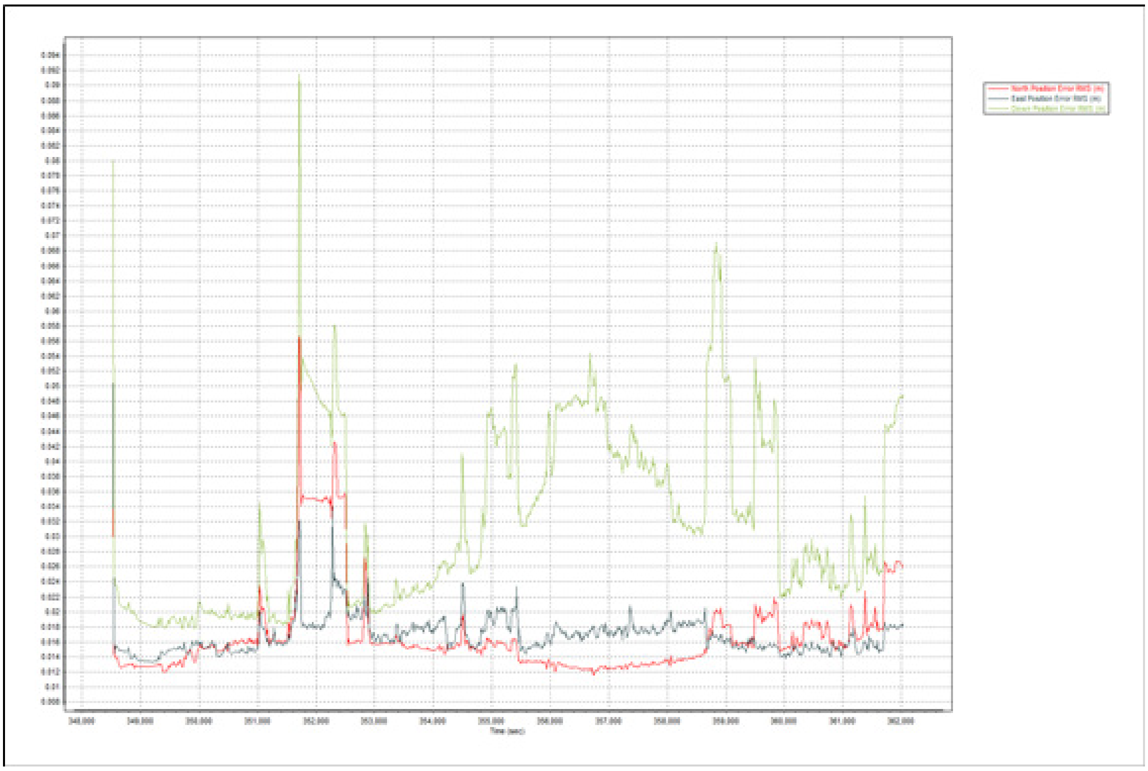


Figure A-8.16 Smoothed Performance Metric Parameters

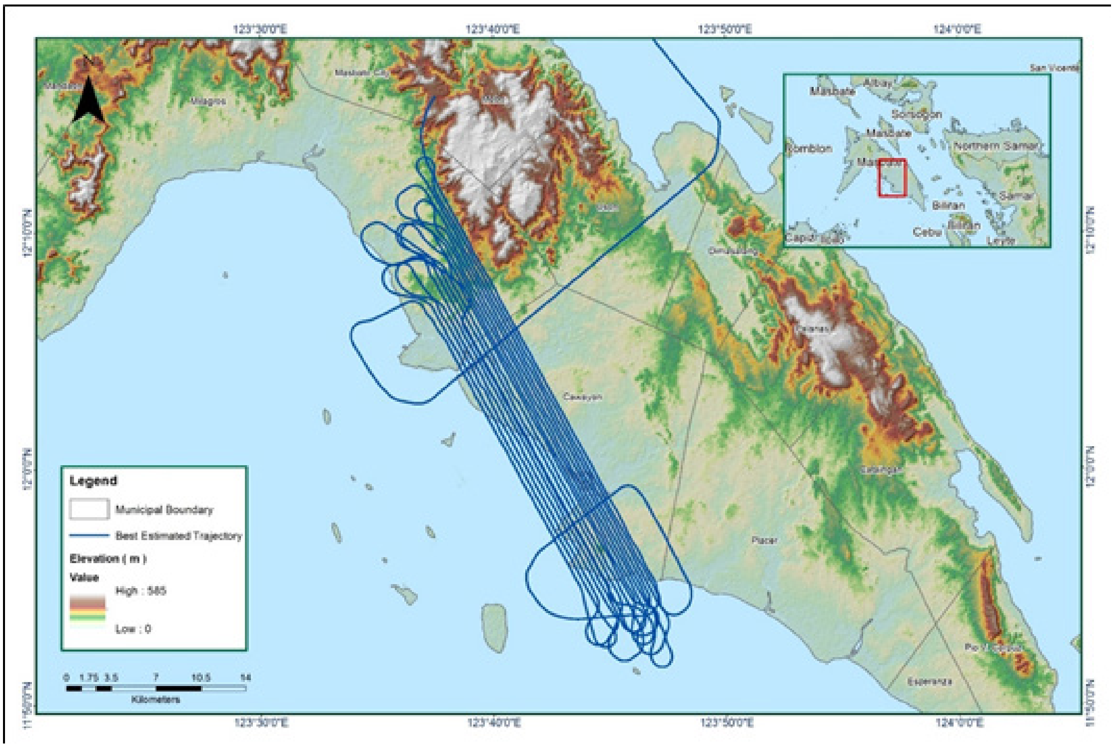


Figure A-8.17 Best Estimated Trajectory

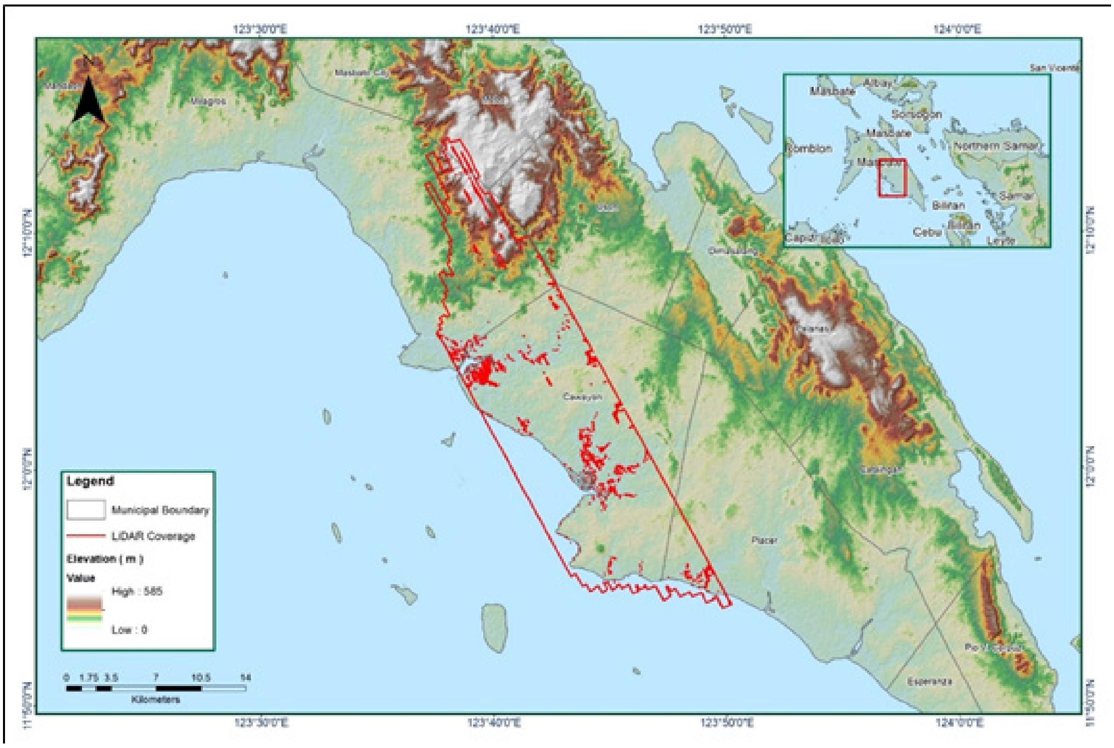


Figure A-8.18 Coverage of LiDAR data

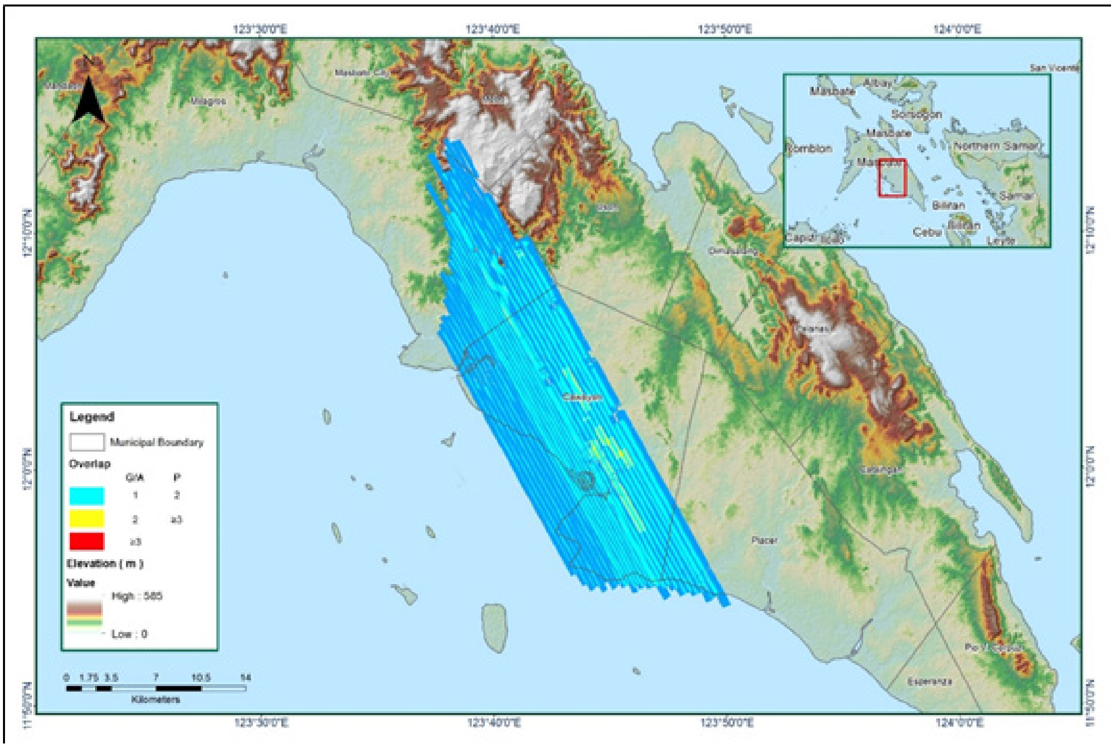


Figure A-8.19 Image of data overlap

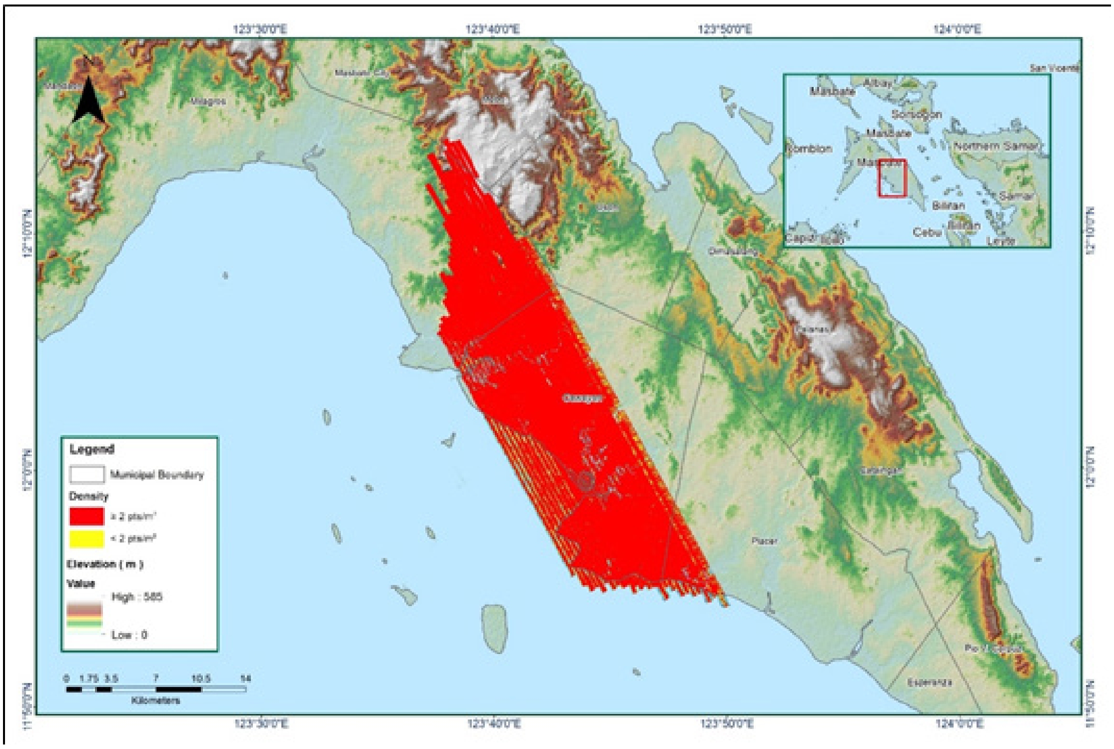


Figure A-8.20 Density map of merged LiDAR data

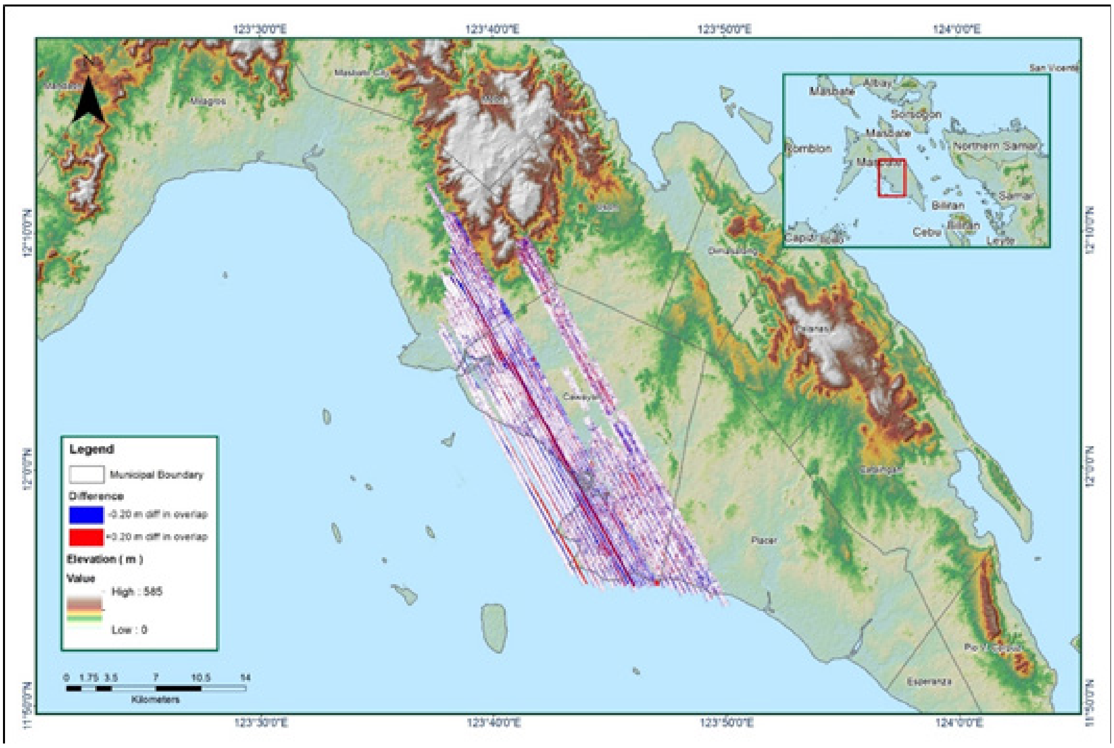


Figure A-8.21 Elevation difference between flight lines

Annex 9. Nainday Model Basin Parameters

Table A-9.1. Nainday Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform			
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Threshold Type	Ratio to Peak
			0			Ratio to Peak	1
W80	1.89770115	87	0	3.405928	5.558474	Ratio to Peak	1
W90	1.89770115	87	0	3.604764	5.882974	Ratio to Peak	1
W100	1.89770115	87	0	7.819576	12.76155	Ratio to Peak	1
W110	1.89770115	87	0	2.843685	4.640893	Ratio to Peak	1
W120	2.47134443	83.7104454	0	5.099622	8.322584	Ratio to Peak	1
W130	2.48443777	83.638263	0	4.806784	7.844672	Ratio to Peak	1
W140	4.93888889	72	0	0.742494	1.211751	Ratio to Peak	1
W360	1.2717375	76.194	0	0.60122	0.96275	Ratio to Peak	1
W370	0.84781	76.194	0	1.2146	0.8565765	Ratio to Peak	1
W380	15.2043375	79.7997	0	1.4101	3.397104	Ratio to Peak	1
W400	7.5169875	75.07098	0	0.78395	1.8887	Ratio to Peak	1
W410	8.267325	73.14318	0	0.88664	2.136024	Ratio to Peak	1

Annex 10. Lanang Model Reach Parameters

Table A-10.1. Labo Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R10	Automatic Fixed Interval	37660	12.23439	0.04	2521.87	29.25	1
R20	Automatic Fixed Interval	23240	7.091514	0.04	5658.22	29.25	1
R30	Automatic Fixed Interval	39640	4.394676	0.04	378.49	29.25	1
R40	Automatic Fixed Interval	17000	3.887717	0.04	9986.24	29.25	1
R50	Automatic Fixed Interval	26680	4.513697	0.04	3818.27	29.25	1
R60	Automatic Fixed Interval	21600	4.571291	0.04	6735.66	29.25	1
R70	Automatic Fixed Interval	3240	5.87595	0.04	345.06	29.25	1

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return/ Scenario
	Lat	Long					
1	11.92397825	123.7747099	0.59	0.4	0.19	STY Yolanda 2013	5-Year
2	11.92402808	123.7746137	0.69	0.4	0.29	STY Ruby 2014	5-Year
3	11.92412333	123.7745786	0.63	0.4	0.23	STY Yolanda 2013	5-Year
5	11.92414553	123.7744297	0.6	0	0.6		5-Year
4	11.92416373	123.7743361	0.73	0	0.73		5-Year
6	11.92419664	123.7744739	0.7	0.2	0.5		5-Year
7	11.92421069	123.7744687	0.7	0.2	0.5	STY Ruby 2014	5-Year
8	11.92422332	123.7743517	0.73	0.2	0.53	STY Yolanda 2013	5-Year
9	11.92426075	123.7743451	0.71	0.2	0.51	STY Ruby 2014	5-Year
29	11.92426406	123.7743222	0.71	0.4	0.31	STY Ruby 2014	5-Year
33	11.92426501	123.7742341	0.58	0.3	0.28	STY Ruby 2014	5-Year
42	11.92428111	123.7737244	0.32	0	0.32		5-Year
10	11.92428075	123.7743606	0.71	0	0.71		5-Year
35	11.92428845	123.7741396	0.54	0.2	0.34		5-Year
32	11.92429248	123.7742359	0.58	0.4	0.18		5-Year
41	11.92429575	123.7738569	0.48	0	0.48		5-Year
30	11.92430405	123.7743082	0.71	0.2	0.51		5-Year
34	11.92430696	123.7741535	0.54	0.1	0.44		5-Year
36	11.92432467	123.7740454	0.58	0	0.58		5-Year
37	11.9243264	123.7740125	0.53	0	0.53		5-Year
38	11.92432674	123.7739585	0.53	0	0.53		5-Year
40	11.92436394	123.7738106	0.04	0	0.04		5-Year
28	11.92439418	123.774344	0.7	0.2	0.5		5-Year
25	11.92443163	123.774358	0.45	0.1	0.35		5-Year
27	11.92446438	123.7741767	0.66	0.4	0.26		5-Year
26	11.92446829	123.7741796	0.66	0.5	0.16		5-Year
11	11.9244705	123.774373	0.45	0	0.45		5-Year
39	11.92450226	123.7738264	0.03	0	0.03		5-Year
31	11.92452754	123.7744329	0.45	0.3	0.15	STY Ruby 2014	5-Year
12	11.92453678	123.7744127	0.45	0	0.45		5-Year
15	11.92455985	123.7746922	0.75	0.1	0.65		5-Year
14	11.92458894	123.7746738	0.75	0.2	0.55		5-Year
13	11.92468073	123.7745218	0.68	0	0.68		5-Year
16	11.92471323	123.7746938	0.52	0.1	0.42	STY Ruby 2014	5-Year
24	11.92483048	123.7746331	0.26	0.2	0.06	STY Ruby 2014	5-Year
23	11.92485785	123.7746535	0.26	0.2	0.06		5-Year
21	11.92494905	123.774734	0.45	0	0.45		5-Year
22	11.92500539	123.7746364	0.22	0.2	0.02	STY Ruby 2014	5-Year

43	11.92503298	123.7732802	0.36	0	0.36		5-Year
44	11.92507686	123.7732352	0.58	0	0.58		5-Year
45	11.925091	123.773237	0.58	0	0.58		5-Year
46	11.92523038	123.7731359	0.35	0	0.35		5-Year
87	11.92533982	123.7721904	0.03	0	0.03		5-Year
86	11.92545595	123.7719274	0.07	0	0.07		5-Year
85	11.9254859	123.7715771	0.12	0	0.12		5-Year
20	11.92550441	123.7749912	0.7	0	0.7		5-Year
19	11.92551188	123.7750219	0.7	0	0.7		5-Year
51	11.9255292	123.7724138	0.25	0	0.25		5-Year
50	11.92556426	123.7724858	0.08	0	0.08		5-Year
52	11.92556587	123.7723762	0.25	0	0.25		5-Year
88	11.92556879	123.7724672	0.08	0	0.08		5-Year
49	11.92559706	123.7724933	0.08	0	0.08		5-Year
53	11.92560746	123.7723636	0.2	0	0.2		5-Year
84	11.92572252	123.7714772	0.03	0	0.03		5-Year
89	11.92573459	123.7722728	0.18	0	0.18		5-Year
48	11.92575017	123.7725916	0.03	0	0.03		5-Year
82	11.92577289	123.7711746	0.12	0	0.12		5-Year
90	11.92578656	123.7722749	0.18	0	0.18		5-Year
18	11.92577973	123.7753586	0.51	0.1	0.41		5-Year
47	11.92579011	123.7726187	0.03	0	0.03		5-Year
17	11.92578261	123.7754392	0.49	0	0.49		5-Year
91	11.92581966	123.7722183	0.03	0	0.03		5-Year
83	11.92583355	123.7712192	0.17	0	0.17		5-Year
92	11.92583452	123.7721013	0.2	0	0.2		5-Year
101	11.92584131	123.7717808	0.06	0	0.06		5-Year
100	11.92584885	123.7717927	0.06	0	0.06		5-Year
99	11.92589772	123.7718262	0.03	0	0.03		5-Year
54	11.92591665	123.7724682	0.03	0	0.03		5-Year
93	11.92594097	123.7719649	0.1	0	0.1		5-Year
119	11.9259653	123.770807	0.03	0	0.03		5-Year
55	11.92598557	123.7723817	0.03	0	0.03		5-Year
118	11.92601831	123.7707885	0.03	0	0.03		5-Year
94	11.92602502	123.7718182	0.03	0	0.03		5-Year
81	11.92606602	123.7710992	0.51	0	0.51		5-Year
117	11.92609338	123.7706468	0.19	0	0.19		5-Year
98	11.92609872	123.7716843	0.39	0	0.39		5-Year
95	11.92610238	123.7717096	0.39	0	0.39		5-Year
80	11.92611044	123.7711152	0.51	0	0.51		5-Year
65	11.92612823	123.772147	0.06	0	0.06		5-Year
97	11.9261394	123.7715804	0.49	0	0.49		5-Year
79	11.92617908	123.7711441	0.32	0	0.32		5-Year
66	11.92618458	123.772074	0.03	0	0.03		5-Year
96	11.92619533	123.7715435	0.36	0	0.36		5-Year

78	11.92621685	123.7711476	0.32	0	0.32		5-Year
77	11.926248	123.7714821	0.03	0	0.03		5-Year
121	11.92626812	123.7702708	0.11	0	0.11		5-Year
122	11.9262897	123.7702641	0.11	0	0.11		5-Year
56	11.92629052	123.7721442	0.17	0	0.17		5-Year
115	11.92635709	123.7705003	0.45	0	0.45		5-Year
116	11.92636336	123.7704778	0.45	0	0.45		5-Year
120	11.92638439	123.7708391	0.65	0	0.65		5-Year
76	11.92638544	123.7712959	0.68	0	0.68		5-Year
75	11.92640406	123.7712647	0.9	0	0.9		5-Year
67	11.9264068	123.7718488	0.03	0	0.03		5-Year
58	11.92642094	123.7721353	0.03	0.1	-0.07		5-Year
123	11.92643564	123.7699881	0.03	0	0.03		5-Year
114	11.92645343	123.7705502	0.67	0	0.67		5-Year
102	11.92646122	123.7711121	0.95	0	0.95		5-Year
57	11.92645918	123.7722562	0.21	0	0.21		5-Year
73	11.92646587	123.7713577	0.68	0	0.68		5-Year
74	11.92646892	123.7713542	0.68	0	0.68		5-Year
113	11.92648473	123.7705435	0.67	0	0.67		5-Year
124	11.92649577	123.769896	0.03	0	0.03		5-Year
105	11.92649981	123.7710343	0.92	0	0.92		5-Year
103	11.92650414	123.771067	0.92	0	0.92		5-Year
72	11.92654596	123.7713845	0.47	0	0.47		5-Year
125	11.92656082	123.7697991	0.31	0	0.31		5-Year
68	11.92656272	123.7716801	0.03	0	0.03		5-Year
104	11.92661046	123.7708853	0.69	0	0.69		5-Year
59	11.92660851	123.7721118	0.78	0.4	0.38		5-Year
112	11.92662648	123.7707162	0.84	0	0.84		5-Year
111	11.92662812	123.7707314	1.05	0	1.05		5-Year
127	11.92664342	123.7699314	0.48	0	0.48		5-Year
126	11.92665567	123.7698541	0.53	0	0.53		5-Year
69	11.92666175	123.771476	0.03	0	0.03		5-Year
64	11.92666589	123.7725638	0.03	0	0.03		5-Year
128	11.9266779	123.7700054	0.55	0	0.55		5-Year
129	11.92669207	123.7699952	0.55	0	0.55		5-Year
70	11.92672784	123.771381	0.03	0	0.03		5-Year
71	11.92672951	123.7713468	0.63	0	0.63		5-Year
130	11.92673382	123.7701613	0.62	0	0.62		5-Year
131	11.92677609	123.7702645	0.75	0	0.75		5-Year
132	11.92682306	123.7703765	0.99	0	0.99		5-Year
106	11.92682192	123.7711891	0.62	0	0.62		5-Year
107	11.92682359	123.7711742	0.84	0	0.84		5-Year
108	11.92684097	123.7710805	0.89	0	0.89		5-Year
63	11.92688313	123.7726587	0.03	0	0.03		5-Year
109	11.92689301	123.7710994	0.88	0	0.88		5-Year

133	11.92694275	123.7701986	0.03	0	0.03		5-Year
62	11.92694346	123.7727676	0.03	0	0.03		5-Year
144	11.92707441	123.7695237	0.75	0.3	0.45		5-Year
143	11.92714123	123.7694354	0.55	0.3	0.25		5-Year
61	11.92721215	123.772841	0.06	0	0.06		5-Year
134	11.92724033	123.7700896	0.83	0	0.83		5-Year
142	11.92739014	123.7694974	0.45	0	0.45		5-Year
135	11.92739057	123.7698456	0.91	0	0.91		5-Year
141	11.92739335	123.7694988	0.45	0	0.45		5-Year
136	11.92746905	123.7698865	0.67	0	0.67		5-Year
138	11.92748918	123.7697495	0.64	0	0.64		5-Year
137	11.92753169	123.7698508	0.35	0	0.35		5-Year
110	11.92753498	123.7713901	0.87	0	0.87		5-Year
165	11.92753888	123.7700905	0.29	0.4	-0.11		5-Year
60	11.92753823	123.7729898	0.06	0	0.06		5-Year
139	11.92759367	123.7696323	0.44	0	0.44		5-Year
140	11.92761991	123.7695936	0.11	0	0.11		5-Year
145	11.92767012	123.7697014	0.19	0	0.19		5-Year
146	11.92769293	123.7698507	0.26	0	0.26		5-Year
166	11.92771127	123.770159	0.25	0.1	0.15		5-Year
167	11.92774811	123.7701539	0.25	0.1	0.15		5-Year
149	11.92775655	123.7704016	0.96	0.4	0.56		5-Year
147	11.92776848	123.7704586	0.94	0.4	0.54		5-Year
150	11.92778749	123.7703848	0.76	0.4	0.36		5-Year
172	11.9277916	123.7696153	0.04	0	0.04		5-Year
170	11.92781703	123.7696782	0.29	0	0.29		5-Year
169	11.92782272	123.7698939	0.32	0	0.32		5-Year
148	11.92782762	123.7704613	0.72	0.4	0.32		5-Year
171	11.92783222	123.7697177	0.32	0	0.32		5-Year
173	11.92784702	123.7693982	0.03	0	0.03		5-Year
174	11.92784812	123.7693104	0.05	0	0.05		5-Year
162	11.92785321	123.7699213	0.56	0.2	0.36		5-Year
164	11.92786399	123.769916	0.56	0.2	0.36		5-Year
168	11.92786611	123.770139	0.42	0	0.42		5-Year
163	11.92789893	123.7699336	0.61	0.2	0.41		5-Year
151	11.92793629	123.7702768	0.78	0.3	0.48		5-Year
152	11.92802976	123.7700781	0.96	0.2	0.76		5-Year
157	11.92806791	123.7699142	0.96	0.5	0.46		5-Year
161	11.92808372	123.7696868	0.88	0.4	0.48		5-Year
158	11.92808734	123.7697702	0.99	0.5	0.49		5-Year
153	11.92809494	123.7700659	0.7	0.2	0.5		5-Year
159	11.92812816	123.7697701	0.99	0.5	0.49		5-Year
155	11.92812889	123.770096	0.67	0.2	0.47		5-Year
160	11.92813785	123.7697817	0.99	0.4	0.59		5-Year
156	11.92814274	123.7699884	0.96	0.3	0.66		5-Year

154	11.92824038	123.7700562	0.89	0.4	0.49	STY Ruby 2014	5-Year

Annex 12. Educational Institutions affected by flooding in Nainday Flood Plain

Table A-12.1. Educational Institutions affected by flooding in Nainday Floodplain

Masbate				
Cawayan	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Divisoria Day Care Center	Divisoria	Medium	Medium	Medium
Divisoria Day Care Center 1	Divisoria		Low	Low
Divisoria Highschool	Divisoria			Low
Tubog Elem School	Tubog			
Placer	Kiayap			
	Kiayap	Low	Medium	Medium
Name	Barangay	Rainfall Scenario	Medium	Medium
		5-YR	25-YR	100-YR
Camayabsan Day Care Center	Camayabsan			
Camayabsan Elem School	Camayabsan			
Camayabsan Elem School	Dangpanan			
Dangpanan Daycare Center	Dangpanan			
Luna Elem School Purok 2	Libas			
Nainday Daycare Center	Nainday			
Nainday Daycare Center Purok 3	Nainday			
Nainday Elem School	Nainday			
Nainday Highschool	Nainday			
Puro Daycare Center	Puro			
Puro Elem School	Puro			
Puro Highschool	Puro			
Luna Elem School Purok 2	Santa Cruz			
Santa Cruz Elem School	Santa Cruz			
Tanawan Daycare Center	Tan-Awan			
Tanawan Elem School	Tan-Awan			
Tanwan Daycare Center	Tan-Awan			

Annex 13. Health Institutions affected by flooding in Nainday Floodplain

Table A-12.1. Medical Institutions affected by flooding in Nainday Floodplain

Masbate				
Cawayan	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Divisoria Health Center	Divisoria	Medium	High	High
Tubog Health Center	Tubog			
Placer	Divisoria			Low
	Tubog			
Name	Barangay	Rainfall Scenario		
		5-YR	25-YR	100-YR
Camayabsan Health Center	Camayabsan	Low	Low	Low
Camayabsan Lying In	Camayabsan	Low	Low	Low
Camayabsan Health Center	Dangpanan			
Dangpanan Health Center	Dangpanan			
Nainday Health Center	Nainday			
Puro Health Center	Puro			
Tanawan Health Center	Tan-Awan			