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

LiDAR Surveys and Flood Mapping of Batang-batang River

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

APRIL 2017

Published by the UP Training Center for Applied Geodesy and Photogrammetry (TCAGP)
College of Engineering
University of the Philippines – Diliman
Quezon City
1101 PHILIPPINES

E.C. Paringit and E.R Abucay (Eds.) (2017), LiDAR Surveys and Flood Mapping of Batang-batang River. Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry-154pp

For questions/queries regarding this report, contact:

Asst. Prof. Edwin R. Abucay
Project Leader Phil-LiDAR 1 Program
University of the Philippines, Los Banos
Los Banos, Laguna, Philippines 4031
E-mail: erabucay@up.edu.ph

Enrico C. Paringit, Dr. Eng.
Program Leader, Phil-LiDAR 1 Program
University of the Philippines Diliman
Quezon City, Philippines 1101
E-mail: ecparingit@up.edu.ph

National Library of the Philippines
ISBN: 978-621-430-127-0

TABLE OF CONTENTS

LIST OF FIGURES v
LIST OF TABLES vii
LIST OF ACRONYMS AND ABBREVIATIONS viii
CHAPTER 1: OVERVIEW OF THE PROGRAM AND BATANG-BATANG RIVER 1
1.1 Background of the Phil-LIDAR 1 Program 1
1.2 Overview of the Batang-batang River Basin 1
CHAPTER 2: LIDAR ACQUISITION IN BATANG-BATANG FLOODPLAIN 3
2.1 Flight Plans 3
2.2 Ground Base Station 5
2.3 Flight Missions 7
2.4 Survey Coverage 8
CHAPTER 3: LIDAR DATA PROCESSING FOR BATANG-BATANG FLOODPLAIN 10
3.1 Overview of LiDAR Data Pre-Processing 10
3.2 Transmittal of Acquired LiDAR Data 11
3.3 Trajectory Computation 11
3.4 LiDAR Point Cloud Computation 13
3.5 LiDAR Data Quality Checking 14
3.6 LiDAR Point Cloud Classification and Rasterization 18
3.7 LiDAR Image Processing and Orthophotograph Rectification 20
3.8 DEM Editing and Hydro-Correction 21
3.9 Mosaicking of Blocks 22
3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model 24
3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model 27
3.12 Feature Extraction 29
3.12.1 Quality Checking (QC) of Digitized Features' Boundary 29
3.12.2 Height Extraction 30
3.12.3 Feature Attribution 30
3.12.4 Final Quality Checking of Extracted Features 32
CHAPTER 4: DATA VALIDATION SURVEY AND MEASUREMENTS IN THE BATANG-BATANG RIVER BASIN 33
4.1 Summary of Activities 33
4.2 Control Survey 34
4.3 Baseline Processing 38
4.4 Network Adjustment 38
4.5 Cross-section and Bridge As-Built survey and Water Level Marking 41
4.6 Validation Points Acquisition Survey 46
4.7 Bathymetric Survey 49
CHAPTER 5: FLOOD MODELING AND MAPPING 53
5.1 Data Used for Hydrologic Modeling 53
5.1.1 Hydrometry and Rating Curves 53
5.1.2 Precipitation 53
5.2 RIDF Station 53
5.3 HMS Model 55
5.4 Cross-section Data 59
5.5 Flo 2D Model 60
5.6 HEC-HMS Model Values (Uncalibrated) 61
5.7 River Analysis Model Simulation 62
5.8 Flood Hazard and Flow Depth Map 62
5.9 Inventory of Areas Exposed to Flooding 69
5.10 Flood Validation 72
REFERENCES 74
Annex 1. Optech Technical Specification of the Sensor 75
Annex 2. NAMRIA Certificates of Reference Points Used 79
Annex 3. Baseline Processing Report of Reference Points Used 84
Annex 4. The LiDAR Survey Team Composition 86
Annex 5. Data Transfer Sheet For Batang-batang Floodplain 87
Annex 6. Flight Logs 89

Annex 7. Flight Status 97
Annex 8. Mission Summary Reports..106
Annex 9. Batang-batang Model Basin Parameters..136
Annex 10. Batang-batang Model Reach Parameters 139
Annex 11. Batang-batang Field Validation Data..141
Annex 12. Phil-LiDAR 1 UPLB Team Composition 146

LIST OF FIGURES

Figure 1. Map of Batang-batang River Basin (in brown)....2
Figure 2. Flight plans and base stations used for Batang-batang floodplain using the Gemini sensor.....4
Figure 3. GPS set-up over PVP-1 (a) located on the ground beside Puerto Princesa Airport Fire Station; and NAMRIA reference point PVP-1 (b) as recovered by the field team.....6
Figure 4. Actual LiDAR data acquisition for Batang-batang floodplain.....9
Figure 5. Schematic Diagram for Data Pre-Processing Component....10
Figure 6. Smoothed Performance Metric Parameters of a Batang-batang Flight 3555G.....11
Figure 7. Solution Status Parameters of Batang-batang Flight 3555G.....12
Figure 8. Best Estimated Trajectory of the LiDAR missions conducted over the Batang-batang Floodplain. . 13
Figure 9. Boundaries of the processed LiDAR data over the Batang-batang Floodplain.....14
Figure 10. Image of data overlap for Batang-batang floodplain.....15
Figure 11. Pulse density map of the merged LiDAR data for Batang-batang floodplain.....16
Figure 12. Elevation difference Map between flight lines for the Batang-batang Floodplain Survey.....17
Figure 13. Quality checking for aBatang-batang flight 3555G using the Profile Tool of QT Modeler....18
Figure 14. Tiles for Batang-batang Floodplain (a) and classification results (b) in TerraScan.....19
Figure 15. Point cloud before (a) and after (b) classification.....19
Figure 16. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Batang-batang floodplain.....20
Figure 17. Portions in the DTM of the Batang-batang Floodplain – a portion of a waterway before (a) and after (b) manual editing; and a data gap before (c) and after (d) filling.....21
Figure 18. Map of Processed LiDAR Data for Batang-batang Flood Plain.....23
Figure 19. Map of Batang-batang Flood Plain with validation survey points in green.....25
Figure 20. Correlation plot between calibration survey points and LiDAR data.....26
Figure 21. Correlation plot between validation survey points and LiDAR data.....27
Figure 22. Map of Batang-batang Flood Plain with bathymetric survey points shown in blue.....28
Figure 23. QC Blocks (in blue) of Batang-batang building features that was subjected to QC.....29
Figure 24. Extracted features for Inagauan Floodplain.....32
Figure 25. Batang-batang River Survey Extent....33
Figure 27. Figure 27. GNSS receiver set up, Trimble® SPS 882, at PL-432, located at the approach of Maasin Bridge in Brgy. Maasin, Brookes Point, Province of Palawan.....35
Figure 26. Figure 26. GNSS base set up, Trimble® SPS 852 at PLW-122, located in an open lot beside the house of Ms. Liza Jamili in Brgy. Calasaguen, Brookes Point, Province of Palawan.....35
Figure 28. GNSS receiver set up, Trimble® SPS SPS 882, at UP_BAT-1, located near the approach of Batang-batang Bridge in Brgy. Princesa Urduja, Narra, Province of Palawan.....36
Figure 29. GNSS receiver set up, Trimble® SPS 985, at UP_PUL-1, located at the approach of Pulot Bridge, In Brgy. Pulot Shore, Sofronio Española, Province of Palawan.....36
Figure 30. Figure 30. GNSS receiver set up, Trimble® SPS 985, at UP_TIG-1, located at the approach of Tigaplan Bridge in Brgy. Tigaplan, Brookes Point, Province of Palawan.....37
Figure 31. Downstream of Batang-batang Bridge.....41
Figure 32. Bridge As-Built Survey of Batang-batang Bridge.....41
Figure 33. Location Map of Batang-batang Bridge River Cross-Section survey....43
Figure 34. The Batang-batang Bridge cross-section survey drawn to scale.....44
Figure 35. The Batang-batang Bridge as-built survey data.....45
Figure 36. Water level markings on Batang-batang Bridge.....46
Figure 37. GNSS Receiver Trimble® SPS 882 installed on a vehicle for Ground Validation Survey.....47

Figure 38. The extent of the LiDAR ground validation survey (in red) for Batang-batang River Basin. 48
Figure 39. Set up of the bathymetric survey of ABSD at Batang-batang River using Horizon™ Total Station. 49
Figure 40. The extent of the Batang-batang River Bathymetry Survey...50
Figure 41. Batang-batang centerline riverbed profile (Upstream) 51
Figure 42. Batang-batang centerline riverbed profile (Downstream)...52
Figure 43. Location of Puerto Princesa RIDF Station relative to Batang-batang River Basin. 54
Figure 44. Synthetic storm generated for a 24-hr period rainfall for various return periods 54
Figure 45. Soil Map of Batang-batang River Basin..55
Figure 46. Land Cover Map of Batang-batang River Basin...56
Figure 47. Slope Map of the Batang-batang River Basin. 57
Figure 48. Stream Delineation Map of Batang-batang River Basin..58
Figure 49. Batang-batang river basin model generated in HEC-HMS. 59
Figure 50. 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)..60
Figure 51. Sample output map of the Batang-batang RAS Model..62
Figure 52. 100-year Flood Hazard Map for Batang-batang Floodplain overlaid in Google Earth imagery .63
Figure 53. 100-year Flow Depth Map for Batang-batang Floodplain overlaid in Google Earth imagery 64
Figure 54. 25-year Flood Hazard Map for Batang-batang Floodplain overlaid in Google Earth imagery ...65
Figure 55. 25-year Flow Depth Map for Batang-batang Floodplain overlaid in Google Earth imagery 66
Figure 56. 5-year Flood Hazard Map for Batang-batang Floodplain overlaid in Google Earth imagery 67
Figure 57. 5-year Flow Depth Map for Batang-batang Floodplain overlaid in Google Earth imagery 68
Figure 58. Affected areas in Narra, Palawan during a 5-Year Rainfall Return Period. 69
Figure 59. Affected areas in Narra, Palawan during a 25-Year Rainfall Return Period. 70
Figure 60. Affected areas in Narra, Palawan during a 100-Year Rainfall Return Period. 71
Figure 61. Validation Points for a 25-year Flood Depth Map of the Batang-batang Floodplain. 72
Figure 62. Flood map depth vs. actual flood depth...73

LIST OF TABLES

Table 1. Flight planning parameters for Gemini LiDAR system. 3
Table 2. Details of the reprocessed NAMRIA horizontal control point PLW-3043 used as base station for the LiDAR acquisition. 5
Table 3. Details of the recovered NAMRIA vertical control point PL-318 with processed coordinates used as base station for the LiDAR acquisition. 5
Table 4. Details of the reprocessed NAMRIA horizontal control point PVP-1 used as base station for the LiDAR Acquisition. 6
Table 6. Ground control points used during LiDAR data acquisition 7
Table 5. Details of the recovered NAMRIA horizontal control point MRE-24 used as base station for the LiDAR Acquisition. 7
Table 8. Flight missions for LiDAR data acquisition in Batang-batang Floodplain....8
Table 7. Actual parameters used during LiDAR data acquisition. 8
Table 9. List of municipalities and cities surveyed during Batang-batang floodplain LiDAR survey....8
Table 10. Self-Calibration Results values for Batang-batang flights. 13
Table 11. List of LiDAR blocks for the Batang-batang floodplain. 14
Table 12. Batang-batang classification results in TerraScan....18
Table 13. LiDAR blocks with its corresponding area. 21
Table 14. Shift Values of each LiDAR Block of Batang-batang floodplain....22
Table 15. Calibration Statistical Measures. 26
Table 16. Validation Statistical Measures. 27
Table 17. Details of the quality checking ratings for the building features extracted for the Batang-batang River Basin 29
Table 18. Building Features Extracted for Inagauan Floodplain....31
Table 19. Total Length of Extracted Roads for Inagauan Floodplain. 31
Table 20. Number of Extracted Water Bodies for Inagauan Floodplain....31
Table 21. List of reference and control points used during the survey in Batang-batang River (Source: NAMRIA, UP-TCAGP). 34
Table 22. Baseline Processing Report for Batang-batang River Static Survey (Source: NAMRIA, UP-TCAGP) 38
Table 23. Control Point Constraints 39
Table 24. Adjusted grid coordinates for the control points used in the Batang-batang River flood plain survey. 39
Table 25. Adjusted geodetic coordinates for control points used in the Batang-batang River Flood Plain validation. 40
Table 26. The reference and control points utilized in the Batang-batang River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TCAGP) 40
Table 27. values for Romblon Rain Gauge computed by PAGASA 53
Table 28. Range of values for the Batang-batang River Basin. 61
Table 29. Municipalities affected in Batang-batang floodplain 62
Table 30. Affected areas in Narra, Palawan during a 5-Year Rainfall Return Period. 69
Table 31. Affected areas in Narra, Palawan during a 25-Year Rainfall Return Period. 70
Table 32. Affected areas in Narra, Palawan during a 100-Year Rainfall Return Period. 71
Table 33. Actual Flood Depth versus Simulated Flood Depth at different levels in the Batang-batang River Basin. 73
Table 34. Summary of Accuracy Assessment in Batang-batang 73

LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND BATANG-BATANG RIVER

Enrico C. Paringit, Dr. Eng., Asst. Prof. Edwin R. Abucay, and Asst. Prof. Efraim D. Roxas

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) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

Also, the program was aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication entitled "FLOOD MAPPING OF RIVERS IN THE PHILIPPINES USING AIRBORNE LIDAR: METHODS (Paringit, et. al. 2017) available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the University of the Philippines Los Banos (UPLB). UPLB is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the 45 river basins in the MIMAROPA Region. The university is located at Los Banos, Laguna.

1.2 Overview of the Batang-batang River Basin

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

Batang-batang River basin is a 15,633 located in Palawan. It covers barangay Batang-batang, Bato-bato, Calategas, Malinao, Princess Urduja, and Teresa in the municipality of Narra; Aramaywan and Berong in Quezon. Its geologic classification includes Cretaceous-Paleogene and Recent.

The basin area has gently sloping to moderately steep slopes and with elevation ranging from 10 to more than 200 meters above sea level (masl). Soil types that can be found in the area include Brooke's clay and San Manuel clay loam. The rest of the area is still unclassified (rough mountainous land). Lush forest can still be found in the basin area dominated mostly by closed forest (broadleaved) and open forest (broadleaved).

Batang-batang river passes through Bato-bato, Princess Urduja, Teresa, and Batang-batang. The 2010 NSO Census of Population and Housing showed that Princess Urduha is the most populated barangay in the area.

The study conducted by the Mines and Geosciences Bureau showed that barangay Princess Urduja, Batang-batang and Teresa has moderate to high flood susceptibility. Based on the field surveys conducted by the PHIL-LiDAR 1 validation team, there were only two notable weather disturbances that caused flooding in 2013 (Yolanda), and 2016 (Lawin). For landslide, barangay Berong has high susceptibility while Aramaywan and Bato-bato has moderate to high susceptibility.

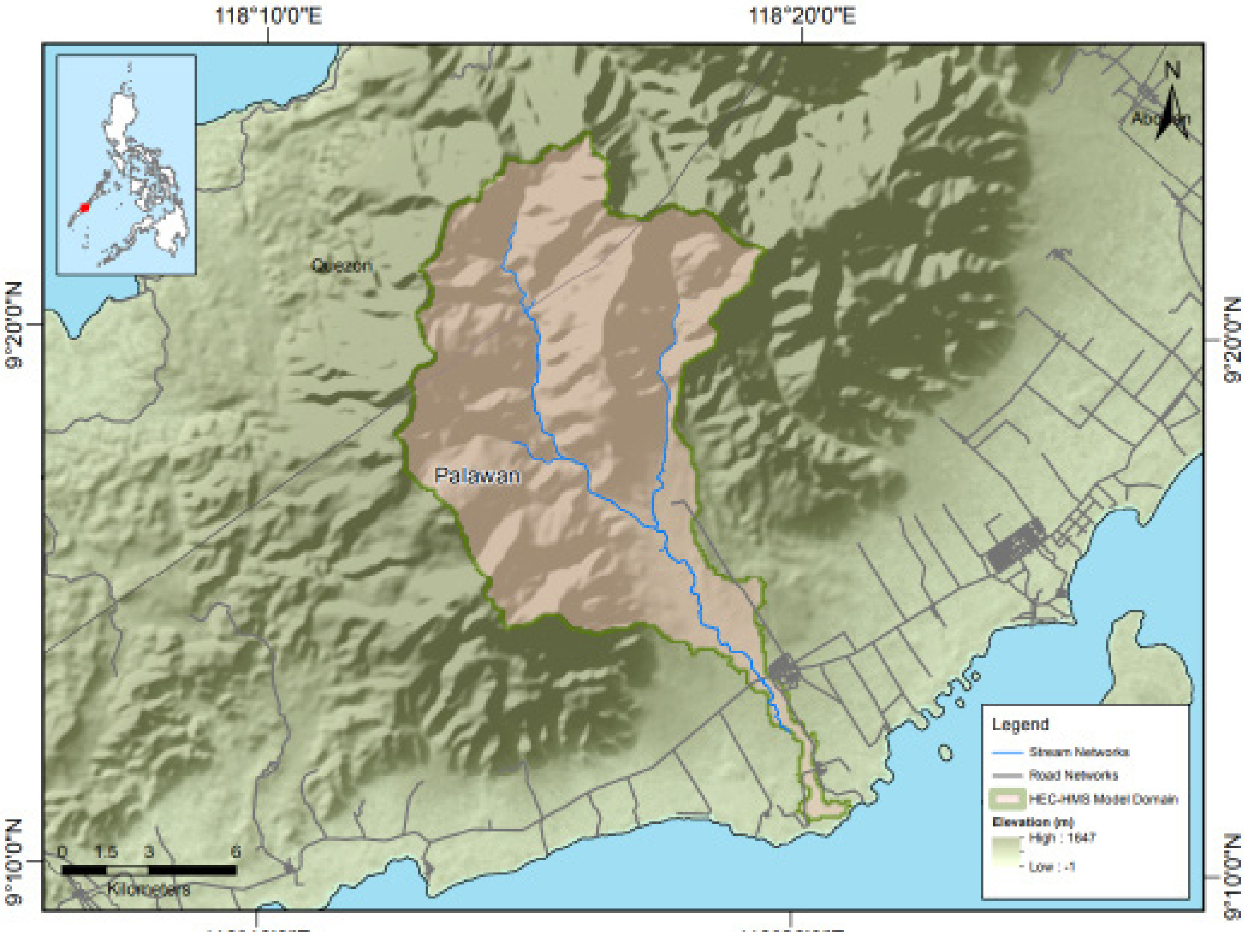


Figure 1. Map of Batang-batang River Basin (in brown)

CHAPTER 2: LIDAR ACQUISITION IN BATANG-BATANG FLOODPLAIN

Engr. Louie P. Balicanta, Engr. Christopher Cruz, Lovely Gracia Acuña, Engr. Gerome Hipolito, Engr. Christopher L. Joaquin, and Ms. Jasmin M. Domingo

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).

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Batang-batang floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for Batang-batang Floodplain in Palawan. These flight missions were planned for 14 lines and ran for at most four and a half hours (4.5) including take-off, landing and turning time using one sensor – the Gemini (see Annex 1 for sensor specifications). The flight planning parameters for the LiDAR system are outlined in Table 1. Figure 2, on the other hand, shows the flight plan for Batang-batang floodplain survey.

Table 1. Flight planning parameters for Gemini LiDAR system.

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK 42H	1100/1000/850	30	26/30/40	100/125	50	130	5
BLK 42I	850	30	50	125	40	130	5
BLK 42J	1000	30	26	100	50	130	5
BLK 42K	1000	30	26	100	50	130	5

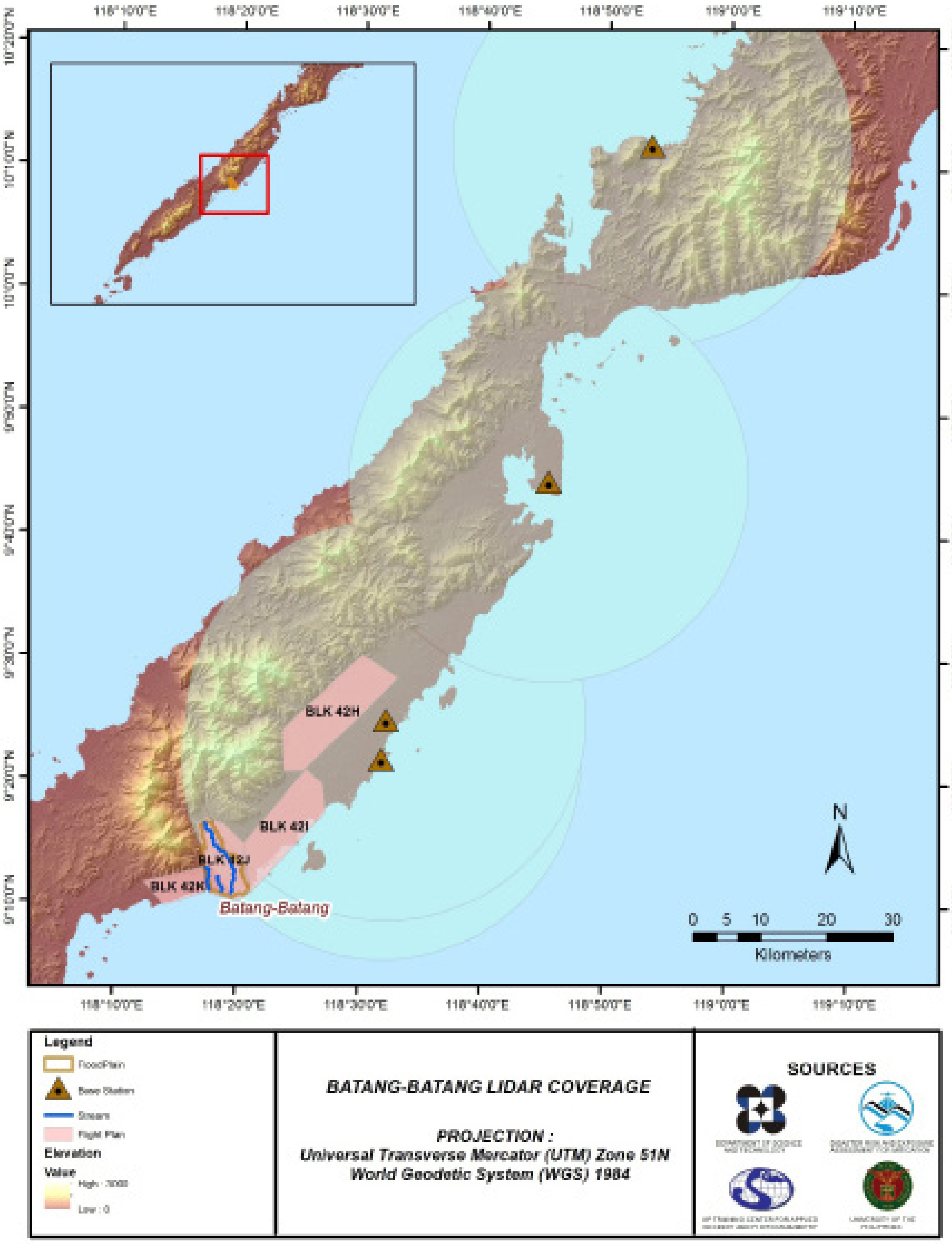


Figure 2. Flight plans and base stations used for Batang-batang floodplain using the Gemini sensor.

2.2 Ground Base Station

The project team was able to recover one (1) NAMRIA ground control point, PLW-3043 which is of fourth (4th) order accuracy and one (1) benchmark, BM PL-318.

The certification for the NAMRIA reference points and benchmarks 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 November 26 to 30, 2015. Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and TRIMBLE SPS 882. Flight plans and location of base stations used during the aerial LiDAR acquisition in Batang-batang floodplain are shown in Figure 2.

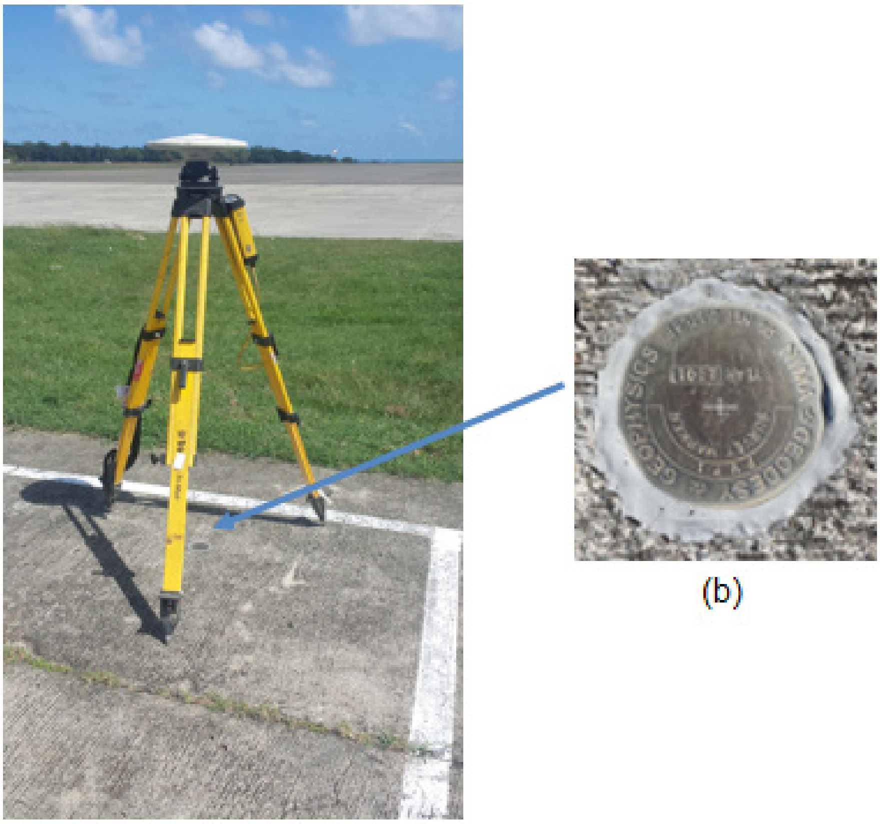
The succeeding sections depict the sets of reference points, control stations and established points, and the ground control points for the entire Batang-batang Floodplain LiDAR Survey. Figure 3 shows the recovered NAMRIA reference points within the area of the floodplain, while Table 2 to Table 5 show the details about the following NAMRIA control stations and established points. Table 6, on the other hand, shows the list of all ground control points occupied during the acquisition together with the corresponding dates of utilization.

Table 2. Details of the reprocessed NAMRIA horizontal control point PLW-3043 used as base station for the LiDAR acquisition.

Station Name	PLW-3043	
Order of Accuracy (benchmark)	4th order	
Elevation (horizontal positioning)	1:10000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°21’42.33800” North 118°31’50.87908” East 8.199 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°21’37.98382” North 118°31’56.23900” East 58.756 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	8789.146 m 1037903.794 m

Table 3. Details of the recovered NAMRIA vertical control point PL-318 with processed coordinates used as base station for the LiDAR acquisition.

Station Name	PL-318	
Order of Accuracy (benchmark)	1st Order	
Elevation (horizontal positioning)	1:100000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°24’58.86852” North 118°32’06.39402” East 16.365 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°24’54.50099” North 118°32’11.74904” East 66.814 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	9340.850 m 1043950.552 m



(b)

(a)

Figure 3. GPS set-up over PVP-1 (a) located on the ground beside Puerto Princesa Airport Fire Station; and NAMRIA reference point PVP-1 (b) as recovered by the field team.

Table 4. Details of the reprocessed NAMRIA horizontal control point PVP-1 used as base station for the LiDAR Acquisition.

Station Name	PVP-1	
Order of Accuracy (benchmark)	**1st order**	
Elevation (horizontal positioning)	**1:100000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°44’31.66247” North 118°45’13.60677” East 17.172 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°44’27.23233” North 118°45’18.93228” East 61.835 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	33860.371 m 1079760.689 m

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

Station Name	PVP-1A	
Order of Accuracy (benchmark)	1st order	
Elevation (horizontal positioning)	1:100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9°44’32.50133” North 118°45’13.64985” East 17.110 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9°44’28.07113” North 118°45’18.97534” East 67.394 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	33862.011 m 1079786.501 m

Table 6. Ground control points used during LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
November 26, 2015	3537G	2BLK42HJ330A	PL-318 and PLW-3043
November 27, 2015	3541G	2BLK42I331A	PVP1 and PVP-1A
November 30, 2015	3553G	2BLK42HJ334A	PL-318 and PLW-3043
November 30, 2015	3555G	2BLK42JsK334B	PL-318 and PLW-3043

2.3 Flight Missions

A total of four (4) missions were conducted to complete the LiDAR data acquisition in Batang-batang floodplain, for a total of fourteen hours and forty two minutes (14+42) of flying time for RP-C9022 (See Annex 6). All missions were acquired using the Gemini LiDAR system. As shown below, the total area of actual coverage per mission and the corresponding flying hours are depicted in Table 7, while the actual parameters used during the LiDAR data acquisition are presented in Table 8.

Table 8. Flight missions for LiDAR data acquisition in Batang-batang Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 25, 2014	3537G	198.52	81.61	0.81	80.8	0	3	30
February 25, 2014	3541G	100.22	133.5	5.22	128.28	0	3	50
February 26, 2014	3553G	130.23	108.93	12.12	96.81	0	3	29
February 27, 2014	3555G	100.19	98.97	38.45	60.52	0	3	53
TOTAL		529.16	423.01	56.6	366.41	0	14	42

Table 7. Actual parameters used during LiDAR data acquisition.

Flight Number	Flying Height (AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
3537G	1100 /1000 /850	30	26/30/40	100/125	50	130	5
3541G	850	30	50	125	40	130	5
3553G	1000	30	26	100	50	130	5
3555G	1000	30	26	100	50	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Batang-batang floodplain (See Annex 7). It is situated within the municipality of Narra, Palawan. The municipalities of Narra and Aborlan were mostly covered by the survey. The list of municipalities and cities surveyed with at least one (1) square kilometer coverage, is shown in Table 9. Figure 4, on the other hand, shows the actual coverage of the LiDAR acquisition for the Batang-batang floodplain.

Table 9. List of municipalities and cities surveyed during Batang-batang floodplain LiDAR survey.

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Palawan	Narra	831.1903	271.3524	32.65%
	Aborlan	645.1105	87.74085	13.60%
Total		1476.3	359.093	23.12%

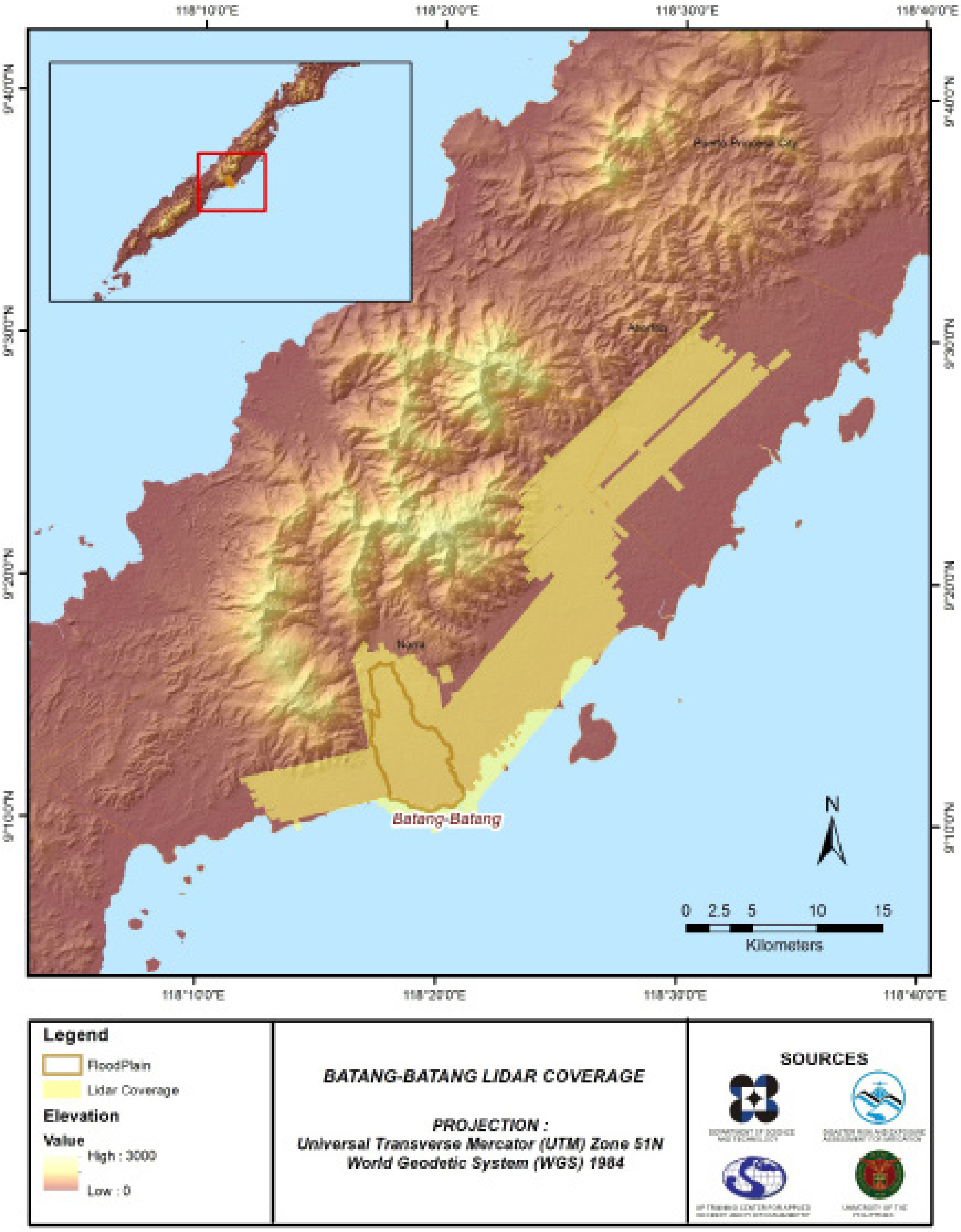


Figure 4. Actual LiDAR data acquisition for Batang-batang floodplain.

CHAPTER 3: LIDAR DATA PROCESSING FOR BATANG-BATANG FLOODPLAIN

Engr. Ma. Rosario Concepcion O. Ang, Engr. John Louie D. Fabila, Engr. Sarah Jane D. Samalburo , Engr. Harmond F. Santos , Engr. Angelo Carlo B. Bongat , Engr. Ma. Ailyn L. Olanda, Engr. Melanie C. Hingpit, Marie Denise V. Bueno , Engr. Regis R. Guhiting, Engr. Merven Matthew D. Natino, Gillian Katherine L. Inciong, Gemmalyn E. Magnaye, Leendel Jane D. Punzalan, Sarah Joy A. Acepcion, Ivan Marc H. Escamos, Allen Roy C. Roberto, and Jan Martin C. Magcale

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

3.1 Overview of LiDAR Data Pre-Processing

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 5.

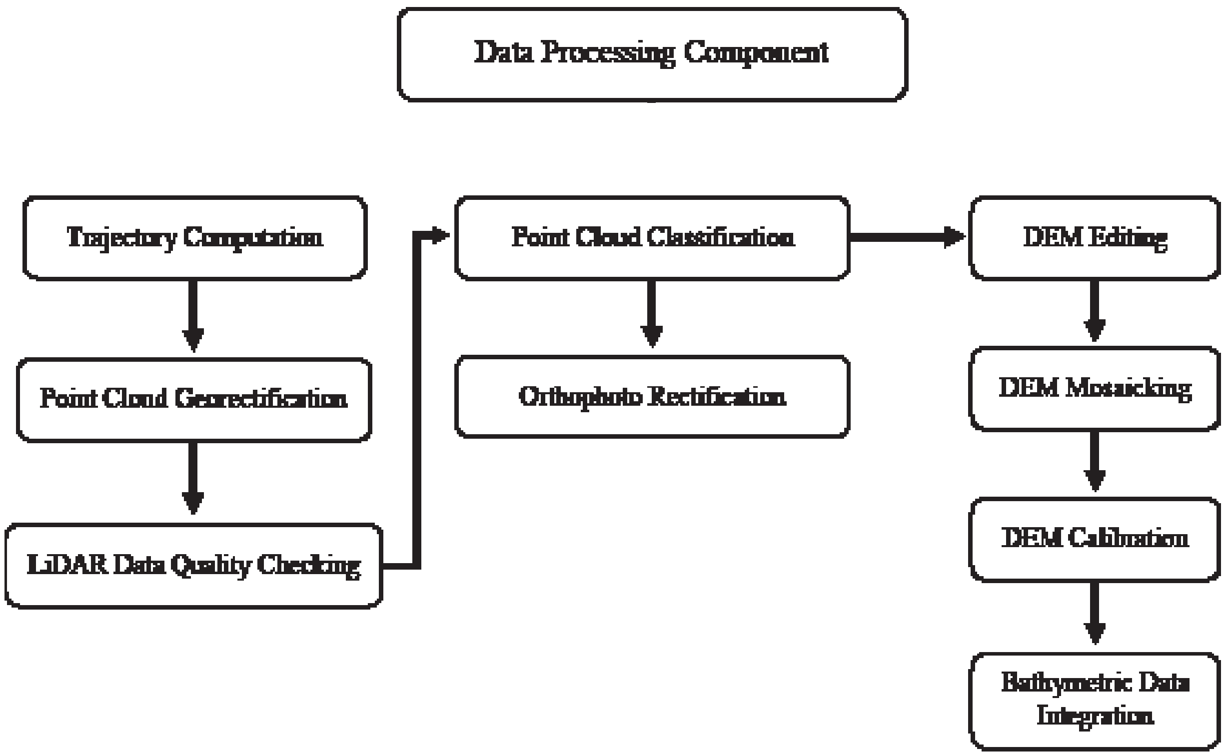


Figure 5. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Batang-batang floodplain can be found in Annex 5. Missions flown during the first survey conducted on November 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system over Narra, Palawan.

The Data Acquisition Component (DAC) transferred a total of 59.8 Gigabytes of Range data, 654 Megabytes of POS data, 22.51 Megabytes of GPS base station data, and no raw image data to the data server on December 8, 2015. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Batang-batang was fully transferred on December 8, 2015, as indicated on the Data Transfer Sheets for Batang-batang floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 3555G, one of the Batang-batang flights, which is the North, East, and Down position RMSE values are shown in Figure 6. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on November 30, 2015 00:00AM. The y-axis is the RMSE value for that particular position.

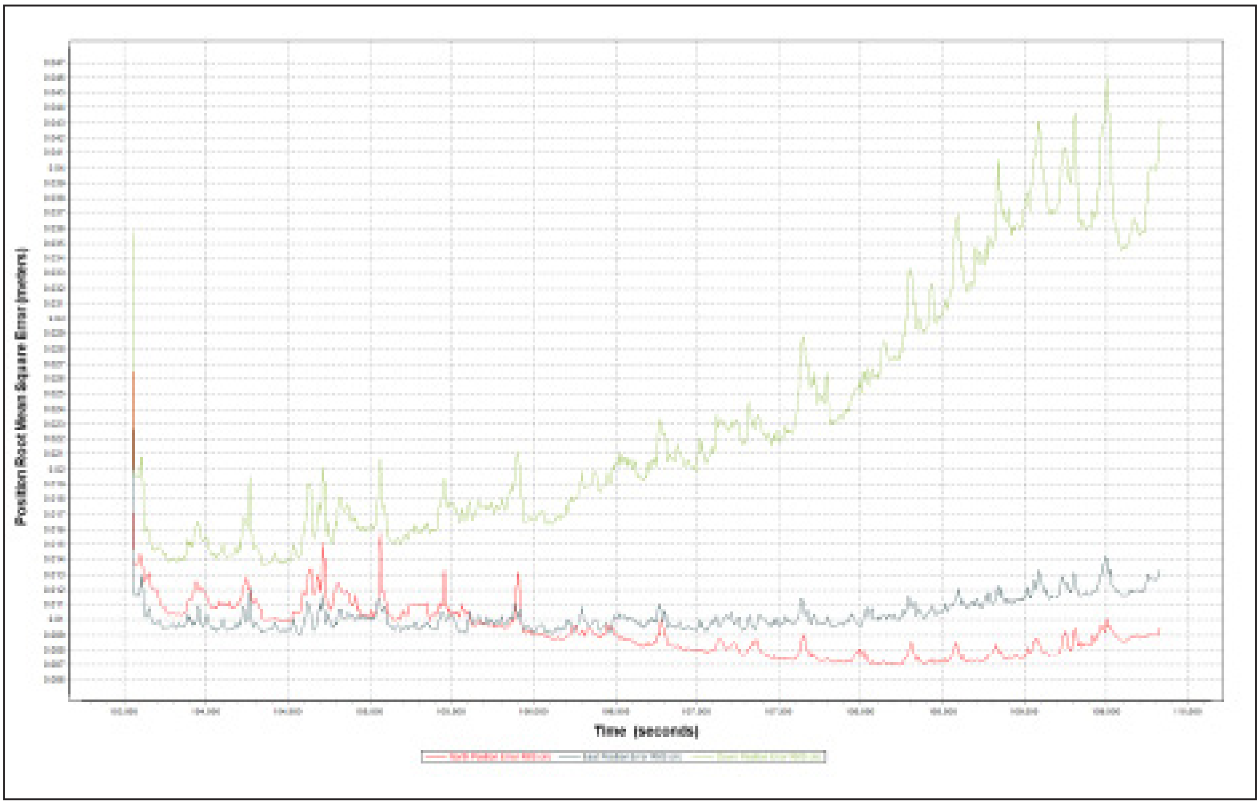


Figure 6. Smoothed Performance Metrics of Batang-batang Flight 3555G.

The time of flight was from 103500 seconds to 110000 seconds, which corresponds to afternoon of November 30, 2015. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft.

Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 6 shows that the North position RMSE peaks at 1.32 centimeters, the East position RMSE peaks at 1.14 centimeters, and the Down position RMSE peaks at 2.88 centimeters, which are within the prescribed accuracies described in the methodology.

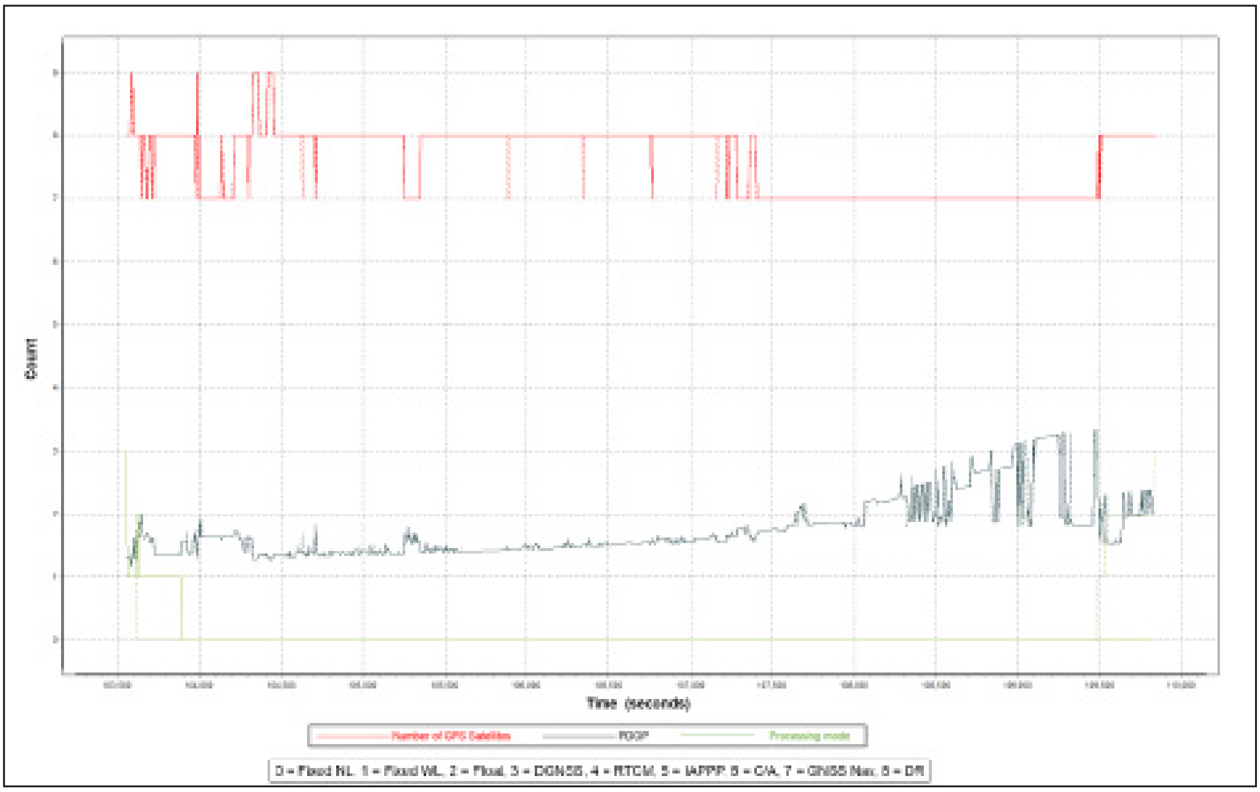


Figure 7. Solution Status Parameters of Batang-batang Flight 3555G.

The Solution Status parameters of flight 3555G, one of the Batang-batang flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 7. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 1 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Batang-batang flights is shown in Figure 8.

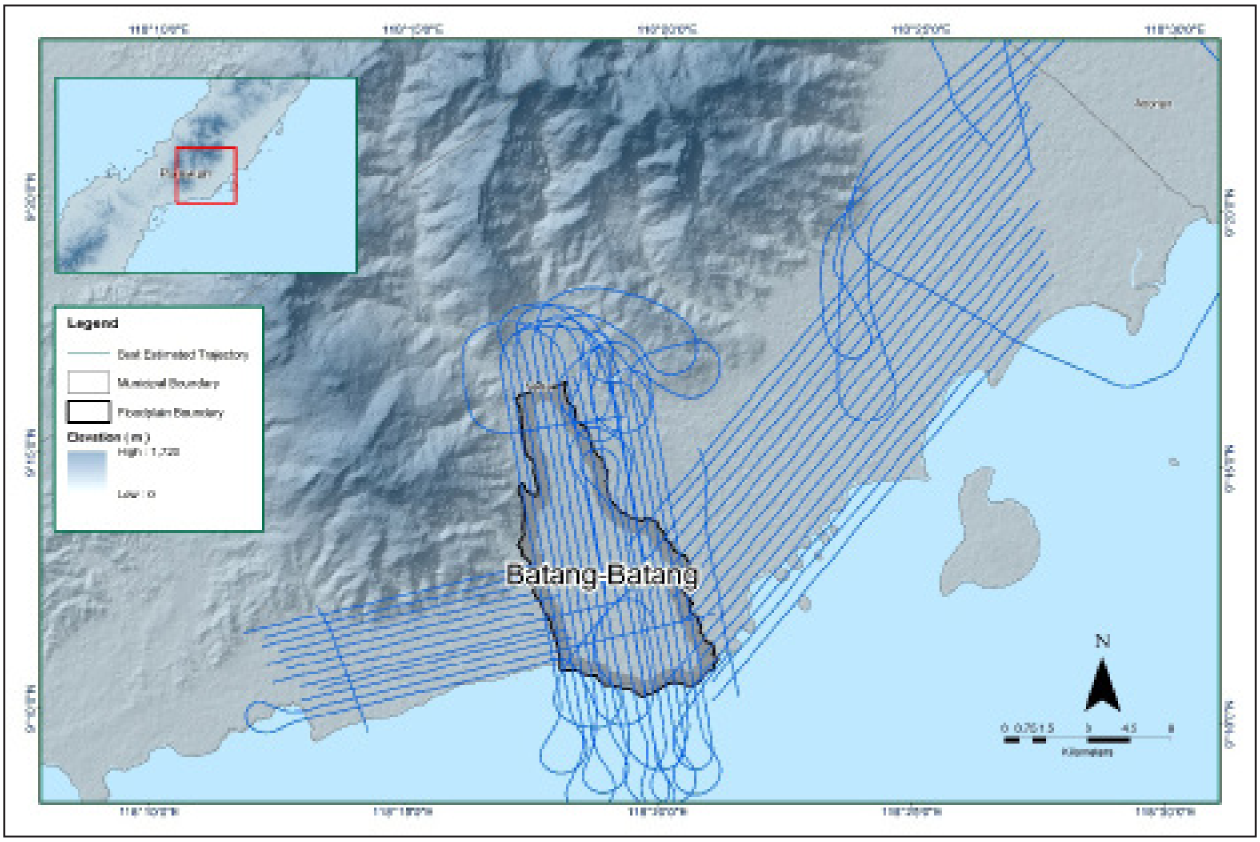


Figure 8. Best Estimated Trajectory of the LiDAR missions conducted over the Batang-batang Floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS contains 48 flight lines, with each flight line containing one channel, since the Gemini system contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over the Batang-batang floodplain are given in Table 10.

Table 10. Self-Calibration Results values for Batang-batang flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev	(<0.001degrees)	0.000914
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000954
GPS Position Z-correction stdev	(<0.01meters)	0.0089

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

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of the SAR Elevation Data over the Batang-batang Floodplain is shown in Figure 9. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

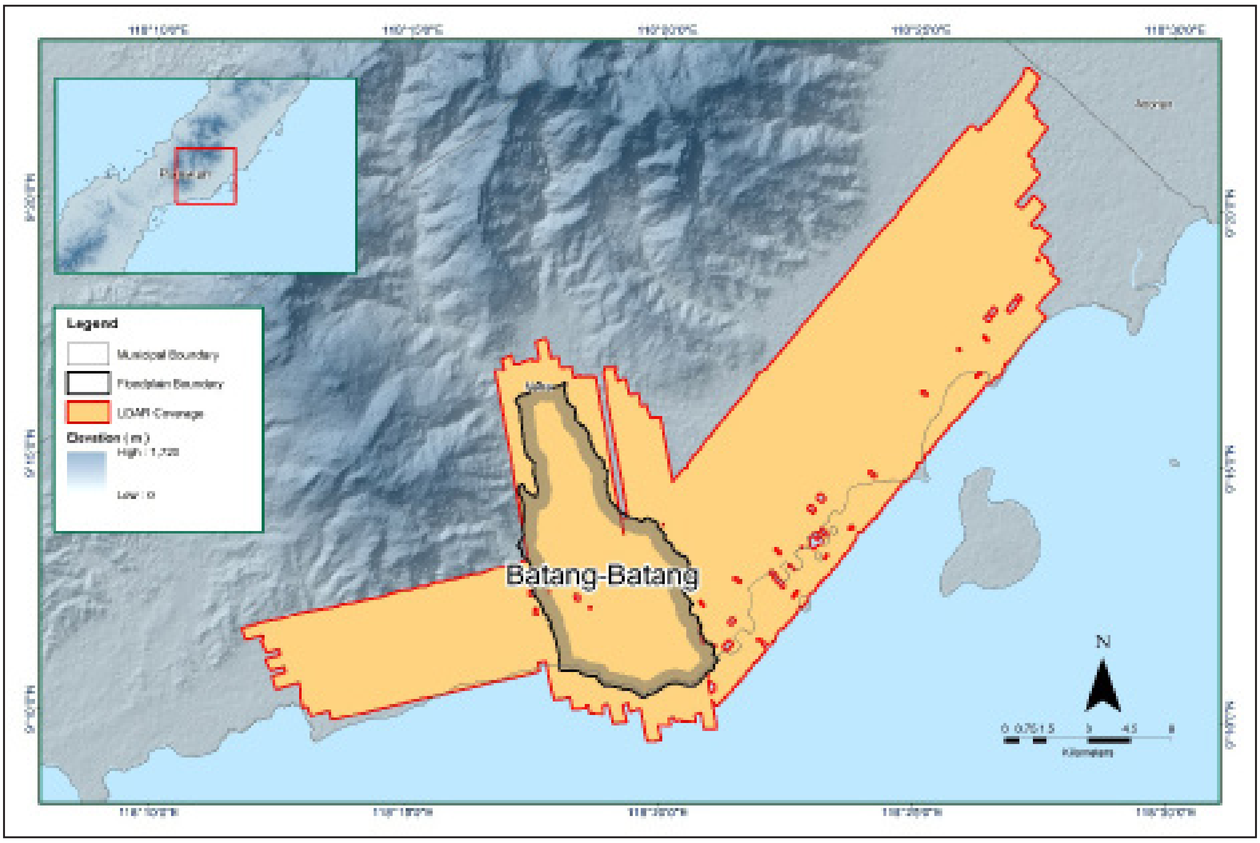


Figure 9. Boundaries of the processed LiDAR data over the Batang-batang Floodplain.

The total area covered by the Batang-batang missions is 242.18 square kilometers (sq. kms.) that is comprised of three (3) flight acquisitions grouped and merged into four (4) blocks as shown in Table 11.

Table 11. List of LiDAR blocks for the Batang-batang floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Palawan_reflights_Blk42eI	3541G	125.57
Palawan_reflights_Blk42eJ	3555G	60.06
Palawan_reflights_Blk42eJ_additional	3553G	17.32
Palawan_reflights_Blk42eK	3555G	39.23
TOTAL		242.18 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 10. Since the Gemini system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

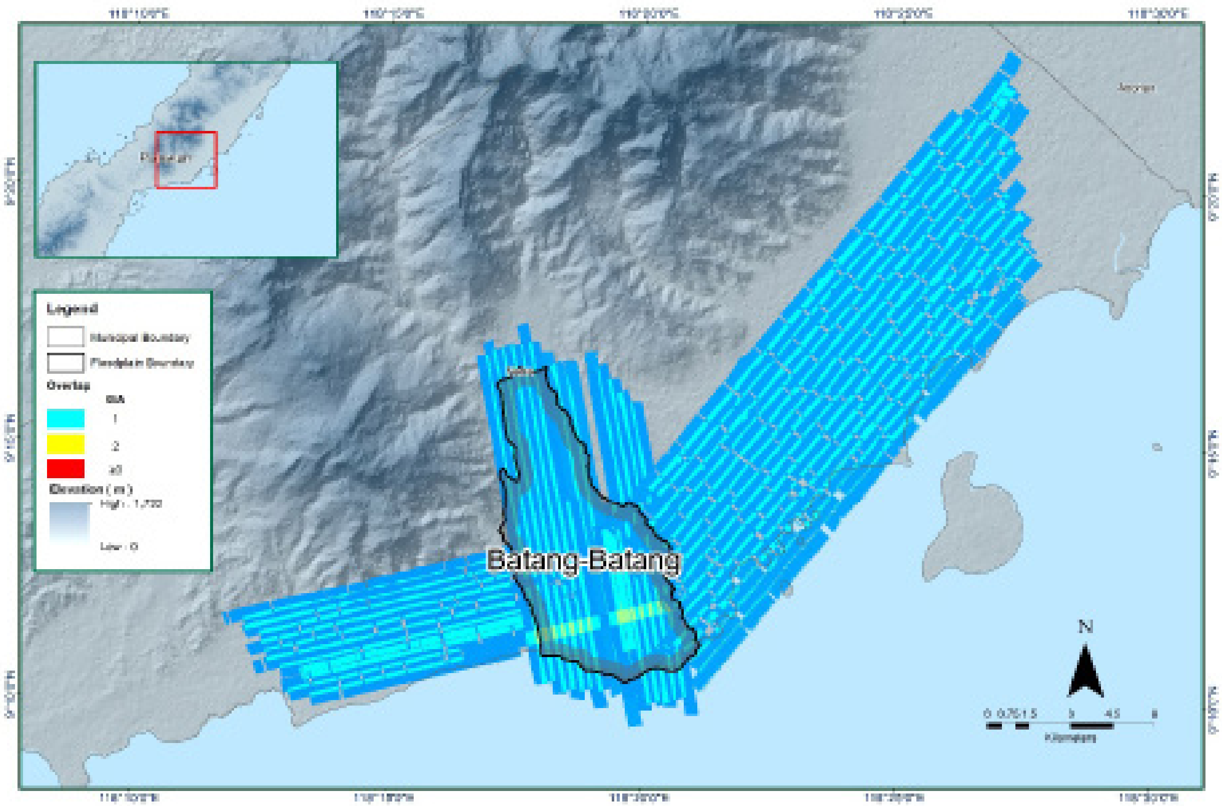


Figure 10. Image of data overlap for Batang-batang floodplain.

The overlap statistics per block for the Batang-batang 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 minimum and maximum percent overlaps are 26.16% and 35.51% 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 11. It was determined that all LiDAR data for the Batang-batang floodplain satisfy the point density requirement, and the average density for the entire survey area is 4.96 points per square meter.

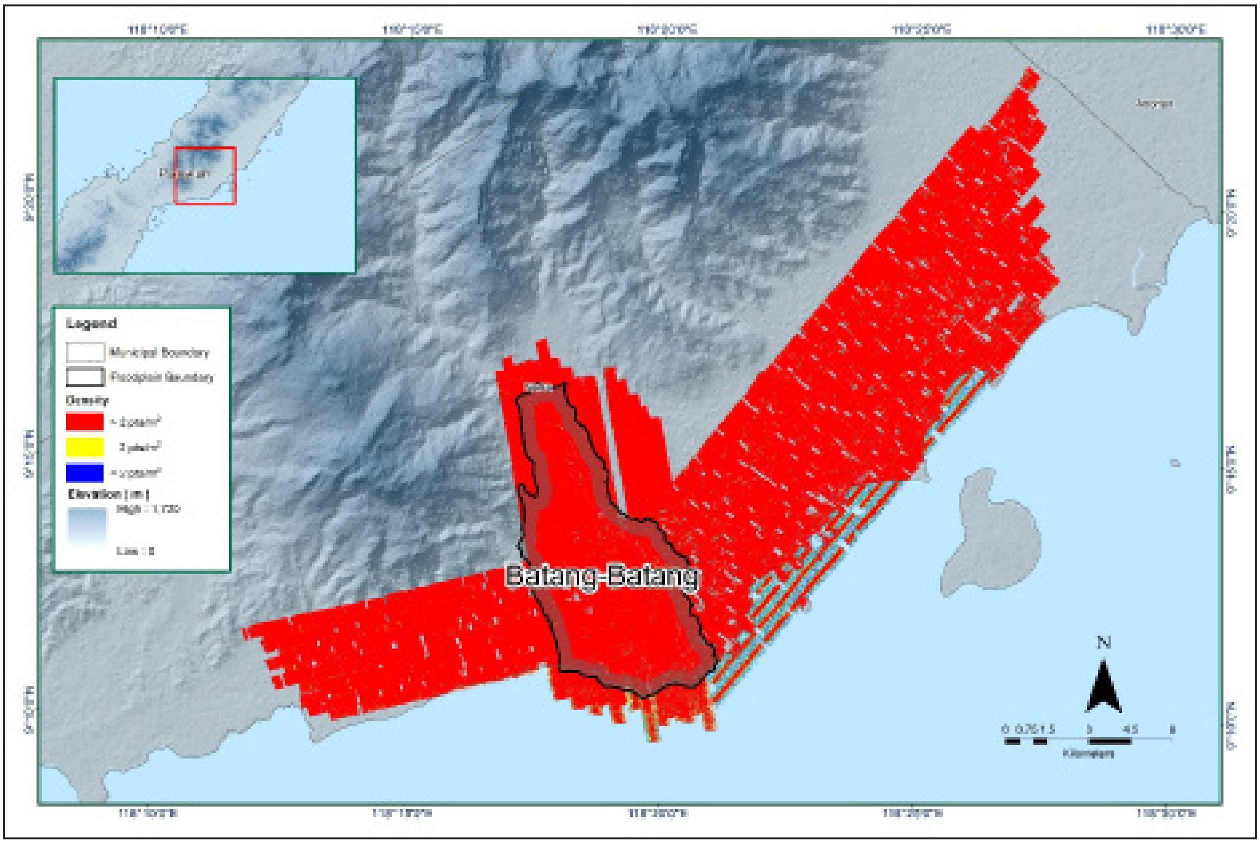


Figure 11. Pulse density map of the merged LiDAR data for Batang-batang floodplain.

The elevation difference between overlaps of adjacent flight lines is shown in Figure 12. The default color range is from blue to red, where bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20m relative to elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20m relative to elevations of its adjacent flight line. Areas with bright red or bright blue need to be investigated further using Quick Terrain Modeler software.

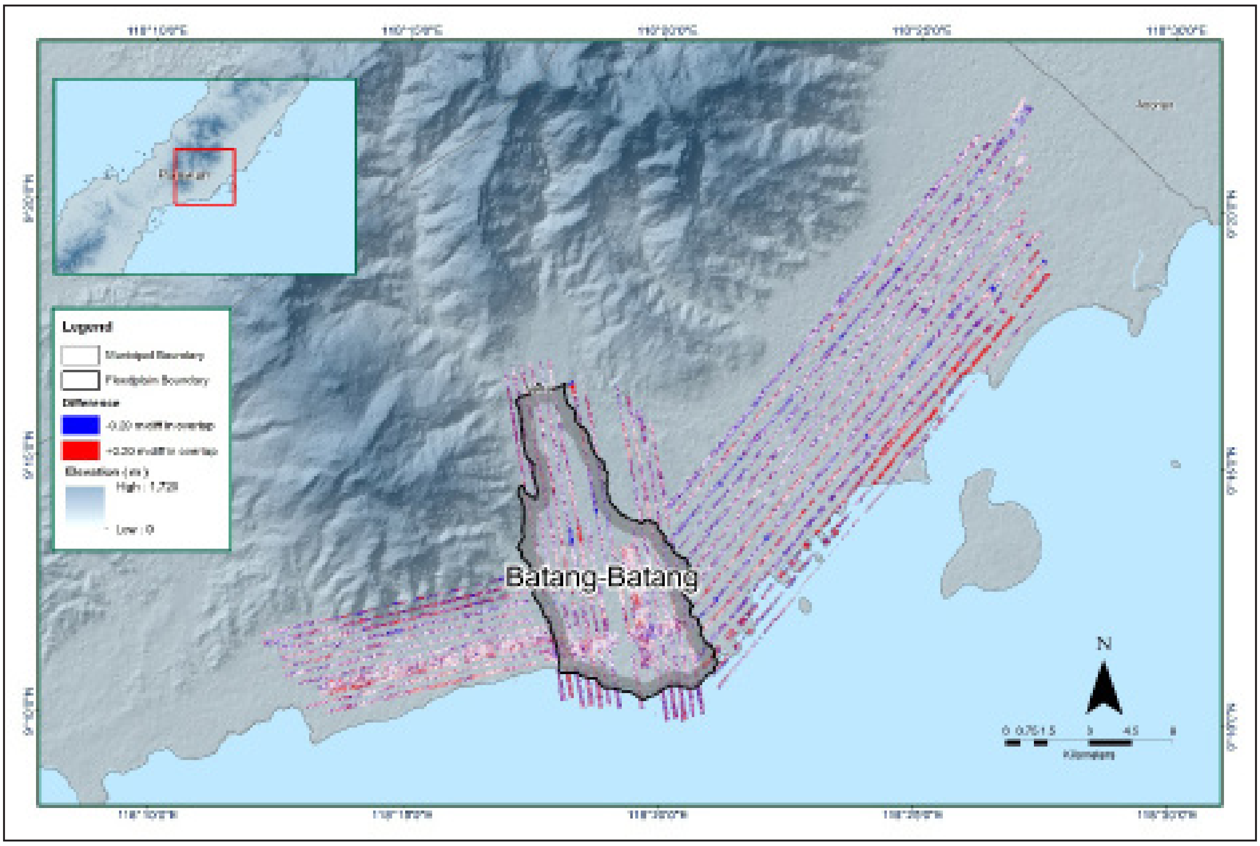


Figure 12. Elevation difference Map between flight lines for the Batang-batang Floodplain Survey.

A screen capture of the processed LAS data from a Batang-batang flight 3555G loaded in QT Modeler is shown in Figure 13. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

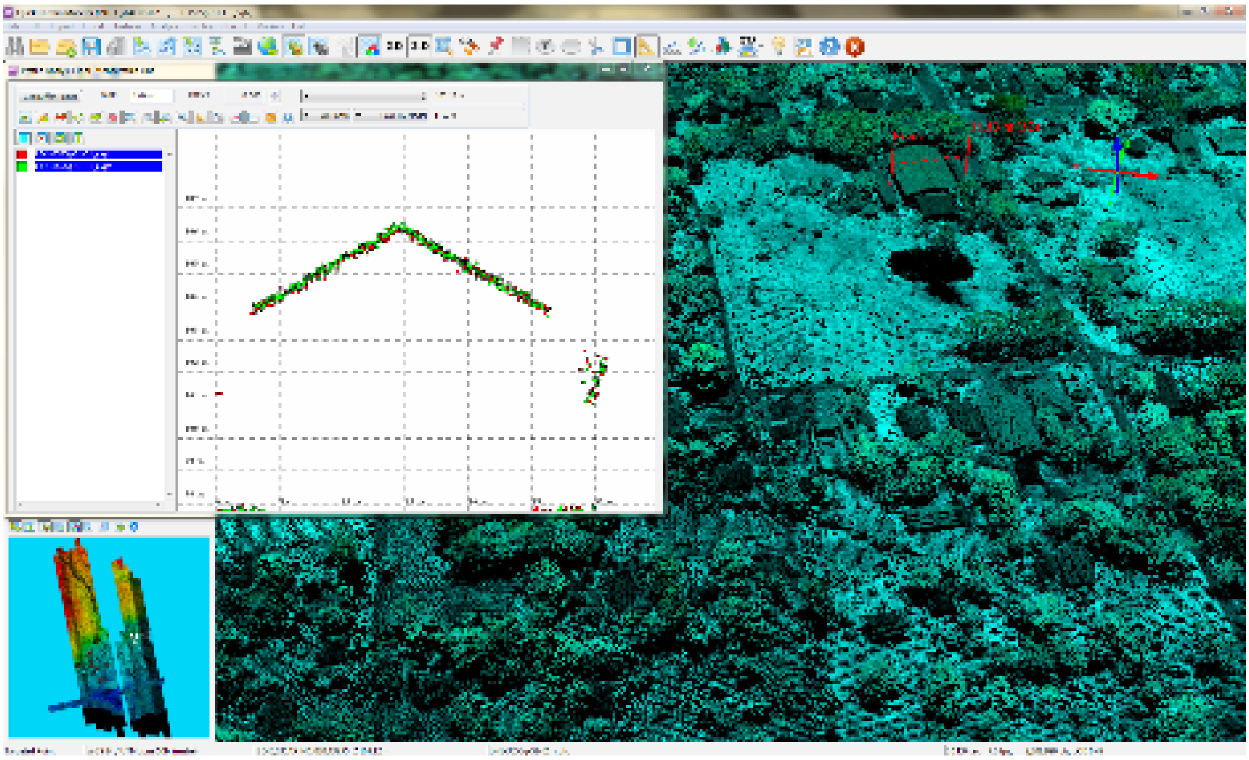


Figure 13. Quality checking for aBatang-batang flight 3555G using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Batang-batang classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	130,251,049
Low Vegetation	158,721,948
Medium Vegetation	529,555,022
High Vegetation	242,605,215
Building	4,402,229

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Batang-batang floodplain is shown in Figure 14. A total of 370 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 12. The point cloud has a maximum and minimum height of 505.92 meters and 45.93 meters, respectively.

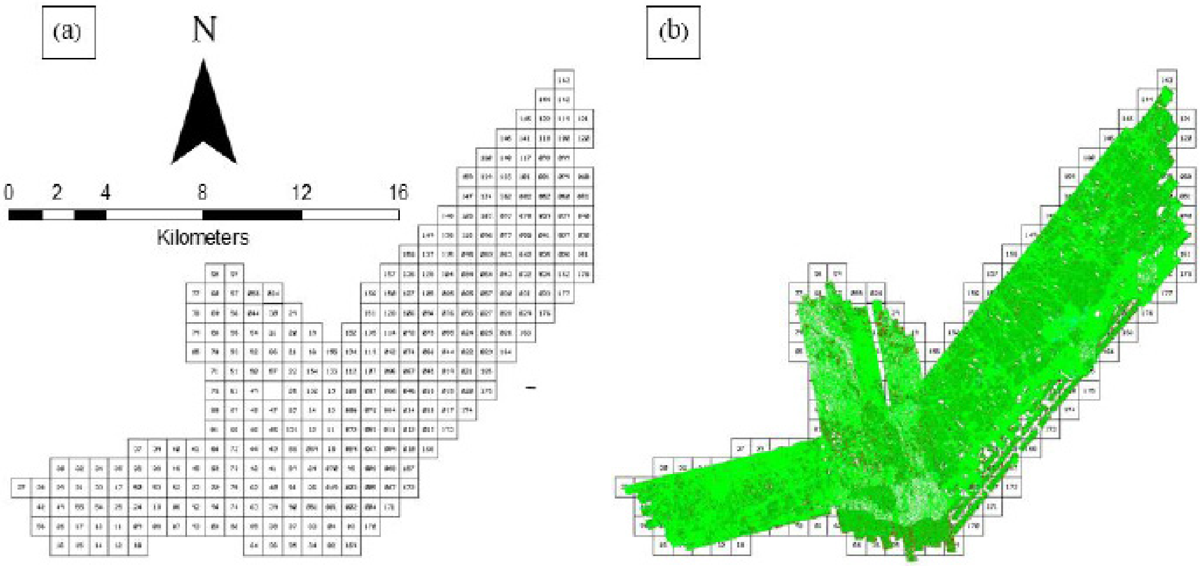


Figure 14. Tiles for Batang-batang Floodplain (a) and classification results (b) in TerraScan.

An isometric view of an area before and after running the classification routines is shown in Figure 15. The ground points are in orange, while the vegetation is in different shades of green, and the buildings are in cyan. It can be seen that residential structures adjacent or even below the canopy are classified correctly, due to the density of the LiDAR data.

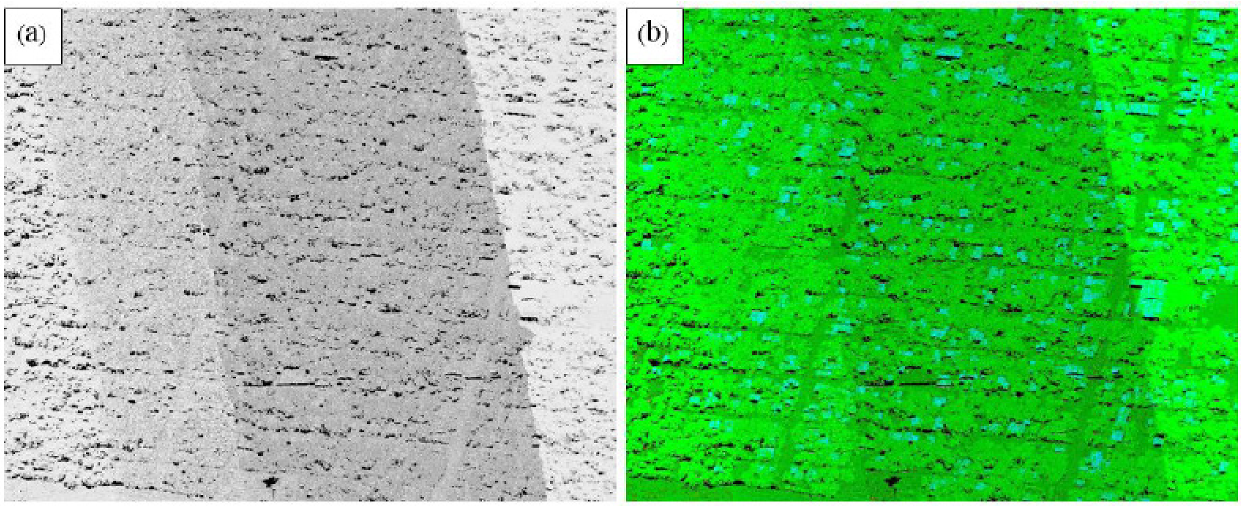


Figure 15. Point cloud before (a) and after (b) classification.

The production of the last return (V_ASCII) and the secondary (T_ ASCII) DTM, first (S_ ASCII) and last (D_ ASCII) return DSM of the area in top view display are show in Figure 16. It shows that DTMs are the representation of the bare earth, while on the DSMs, all features are present, such as buildings and vegetation.

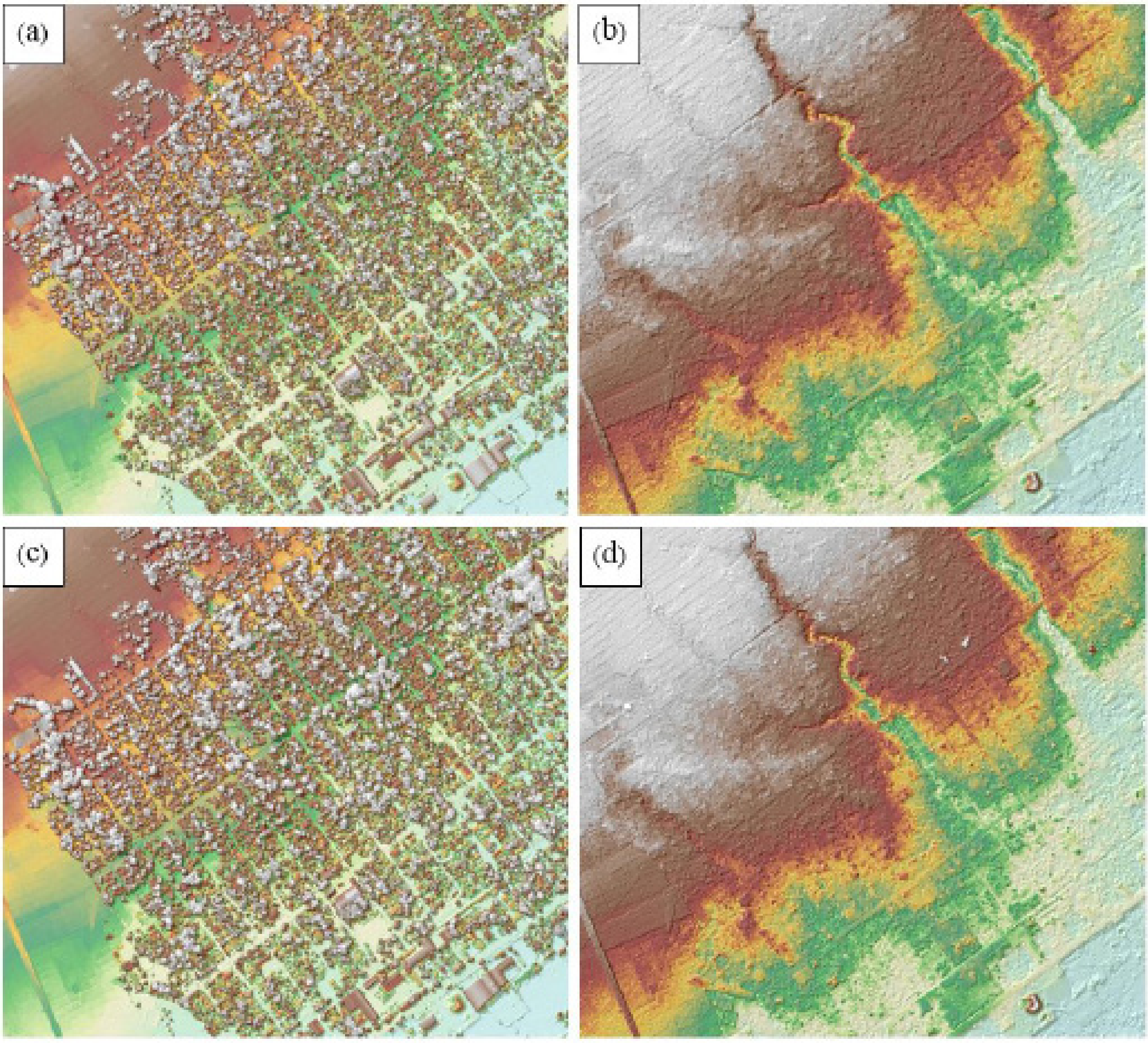


Figure 16. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Batang-batang floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Batang-batang floodplain.

3.8 DEM Editing and Hydro-Correction

Four (4) mission blocks were processed for Batang-batang flood plain. These blocks are composed of Palawan_reflight blocks with a total area of 242.18 square kilometers. Table 13 shows the name and corresponding area of each block in square kilometers.

Table 13. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Palawan_reflights_Blk42eI	125.57
Palawan_reflights_Blk42eJ	60.06
Palawan_reflights_Blk42eJ_additional	17.32
Palawan_reflights_Blk42eK	39.23
TOTAL	242.18 sq.km

Figure 17 shows portions of a DTM before and after manual editing. As evident in the figure, a portion of a waterway (Figure 17a) has obstructed the flow of water along the river. To correct the river hydrologically, it was removed through manual editing (Figure 17b). The data gap (Figure 17c) has been filled to complete the surface (Figure 17d) to allow the correct flow of water.

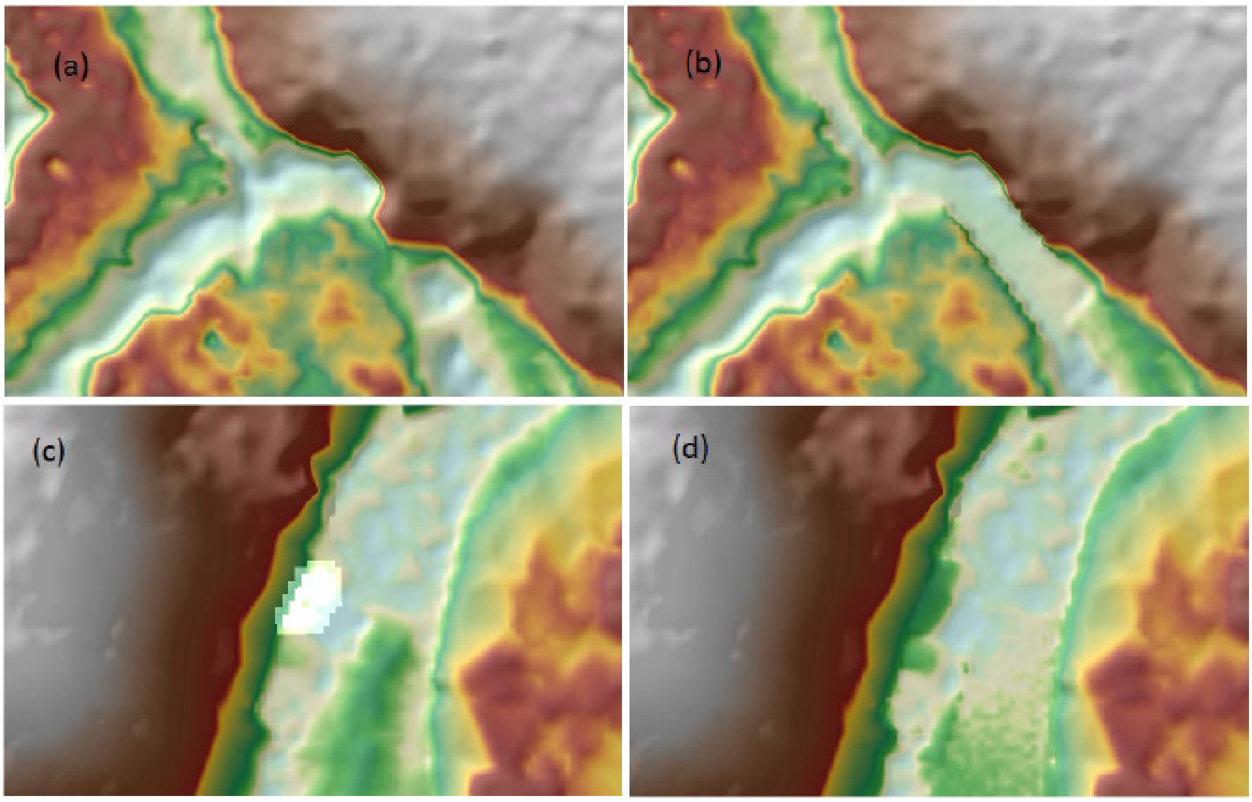


Figure 17. Portions in the DTM of the Batang-batang Floodplain – a portion of a waterway before (a) and after (b) manual editing; and a data gap before (c) and after (d) filling.

3.9 Mosaicking of Blocks

Palawan_Blk42Aa was used as the reference block at the start of mosaicking because it was the first block mosaicked to the larger DTM of West Coast Palawan. Table 14 shows the shift values applied to each LiDAR block during mosaicking.

.

Mosaicked LiDAR DTM for Batang-batang floodplain is shown in Figure 18. It can be seen that the entire Batang-batang floodplain is 99.23% covered by LiDAR data while portions with no LiDAR data were patched with the available IFSAR data.

Table 14. Shift Values of each LiDAR Block of Batang-batang floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Palawan_reflights_Blk42eI	0.00	0.00	0.05
Palawan_reflights_Blk42eJ	0.00	2.02	-1.51
Palawan_reflights_Blk42eJ_additional	-2.00	1.00	5.51
Palawan_reflights_Blk42eK	0.00	2.02	-1.45

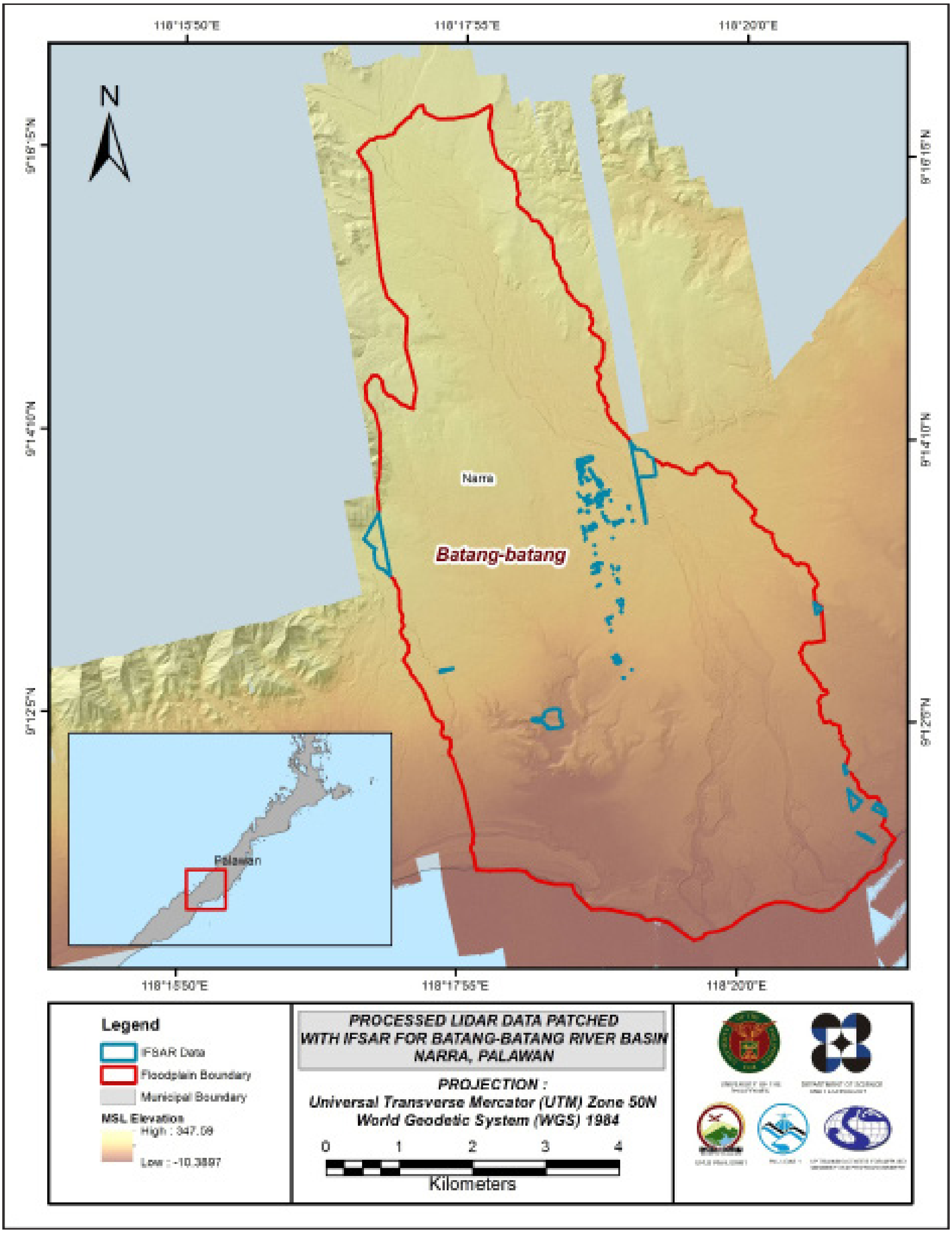


Figure 18. Map of Processed LiDAR Data for Batang-batang Flood Plain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Batang-batang to collect points with which the LiDAR dataset is validated is shown in Figure 19, with the validation survey points highlighted in green. A total of 3,080 survey points were used for calibration and validation of Batang-batang LiDAR data. Random selection of 80% of the survey points, resulting to 2,464 points, was used for calibration.

A good correlation between the uncalibrated Batang-batang LiDAR DTM and ground survey elevation values is shown in Figure 20. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 9.86 meters with a standard deviation of 0.20 meters. Calibration of Batang-batang LiDAR data was done by adding the height difference value, 9.86 meters, to Batang-batang mosaicked LiDAR data. Table 15 shows the statistical values of the compared elevation values between Batang-batang LiDAR data and calibration data.

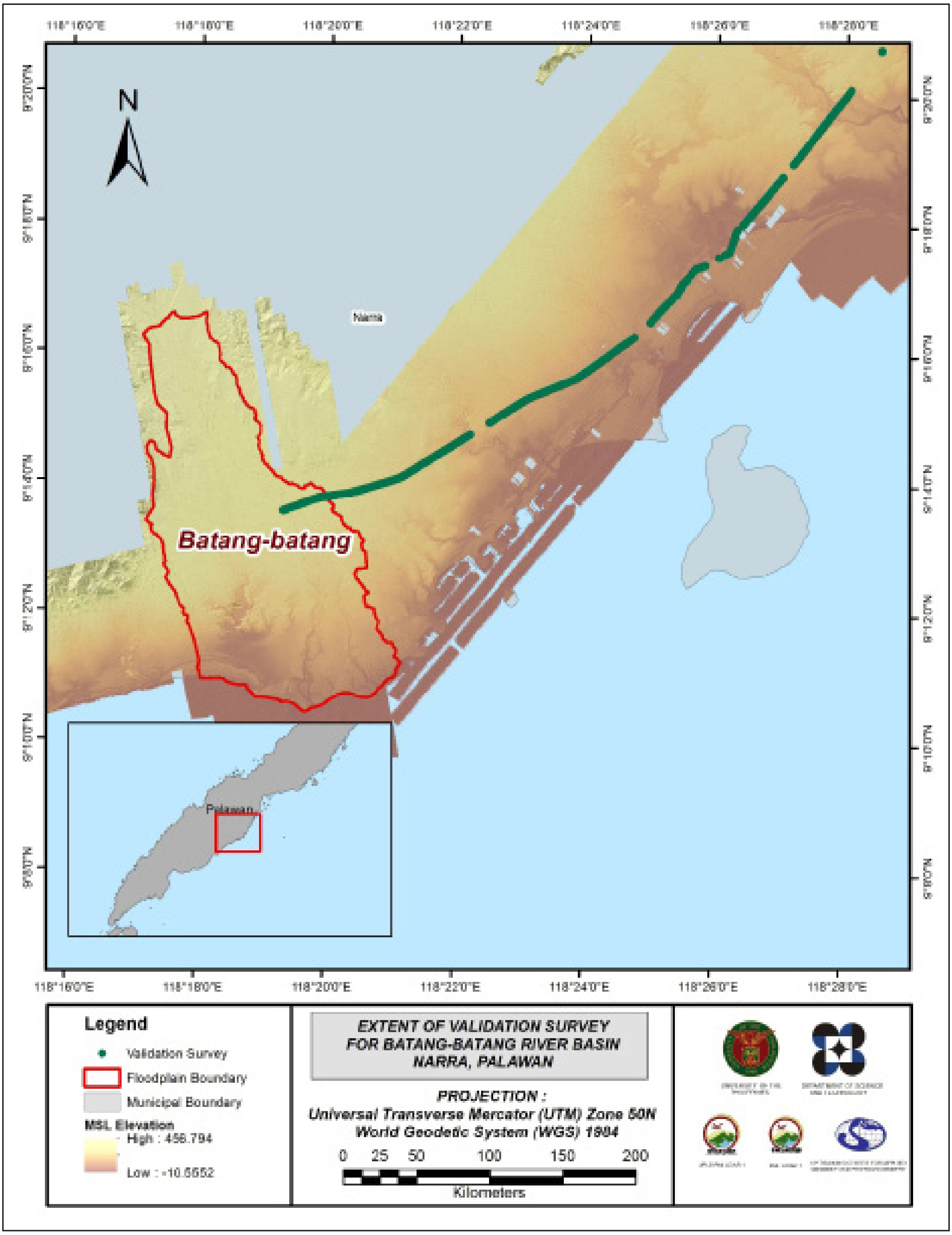


Figure 19. Map of Batang-batang Flood Plain with validation survey points in green.

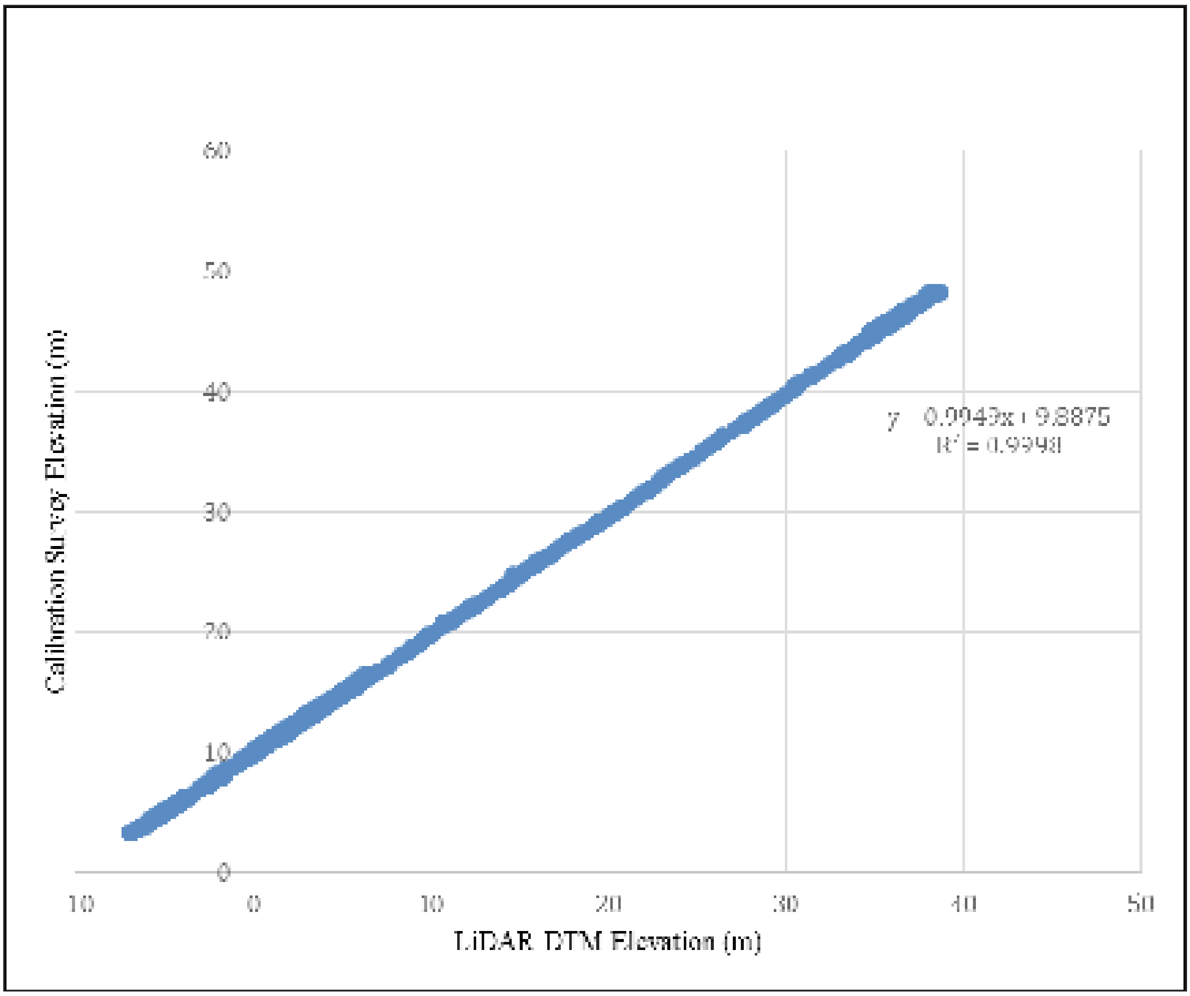


Figure 20. Correlation plot between calibration survey points and LiDAR data.

Table 15. Calibration Statistical Measures.

Calibration Statistical Measures	Value (meters)
Height Difference	9.86
Standard Deviation	0.20
Average	9.85
Minimum	9.45
Maximum	10.25

A total of 616 points were used for the validation of calibrated Batang-batang 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 21. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.16 meters with a standard deviation of 0.16 meters, as shown in Table 16.

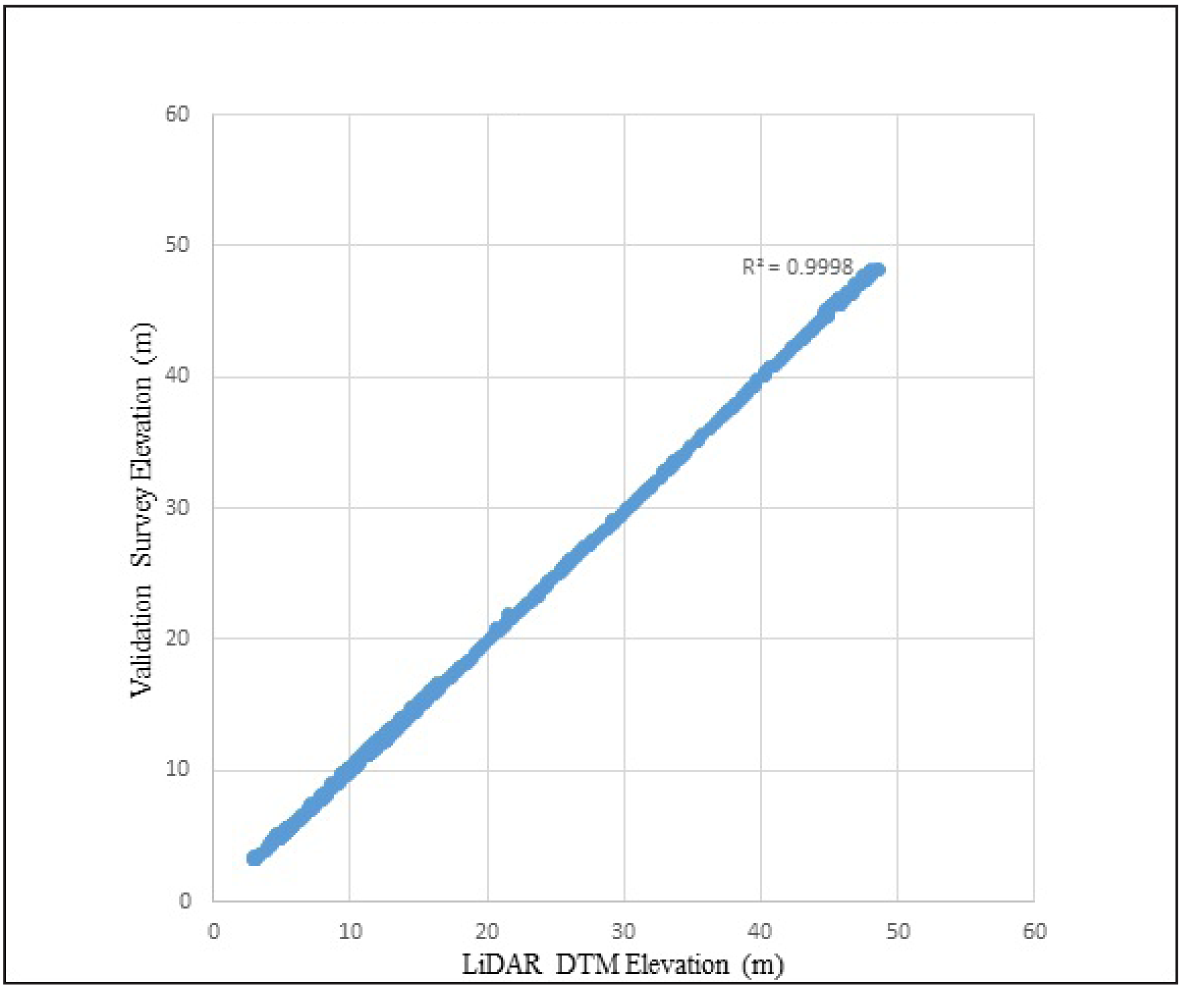


Figure 21. Correlation plot between validation survey points and LiDAR data.

Table 16. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.20
Average	-0.004
Minimum	-0.40
Maximum	0.40

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only cross-section data was available for Batang-batang with 2,115 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barrier method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.05 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Batang-batang integrated with the processed LiDAR DEM is shown in Figure 22.

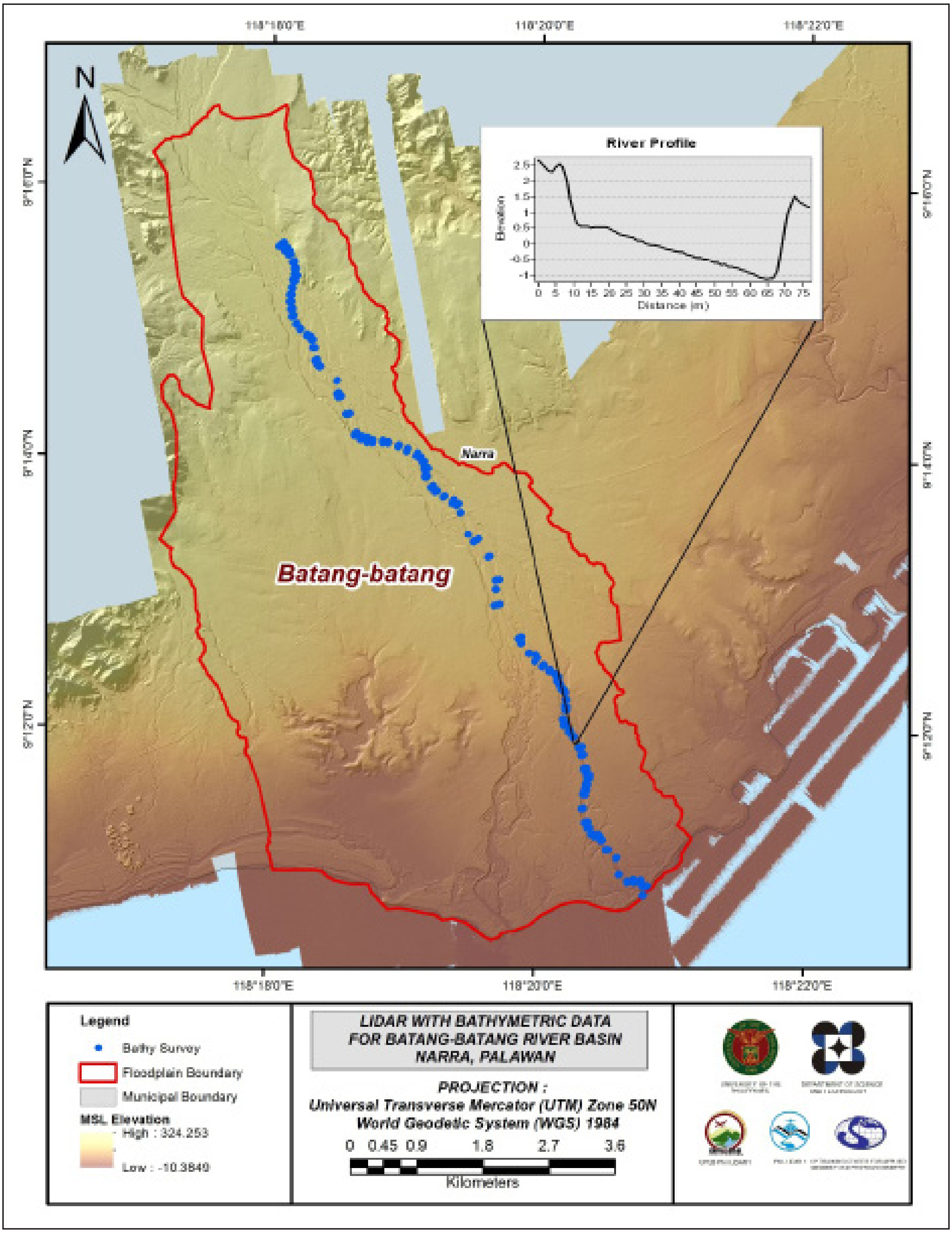


Figure 22. Map of Batang-batang Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

The features salient in flood hazard exposure analysis include buildings, road networks, bridges, and water bodies within the floodplain area with 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 (QC) of Digitized Features' Boundary

Batang-Batang floodplain, including its 200 m buffer, has a total area of 51.31 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 441 building features, are considered for QC. Figure 23 shows the QC blocks for Batang-Batang floodplain.

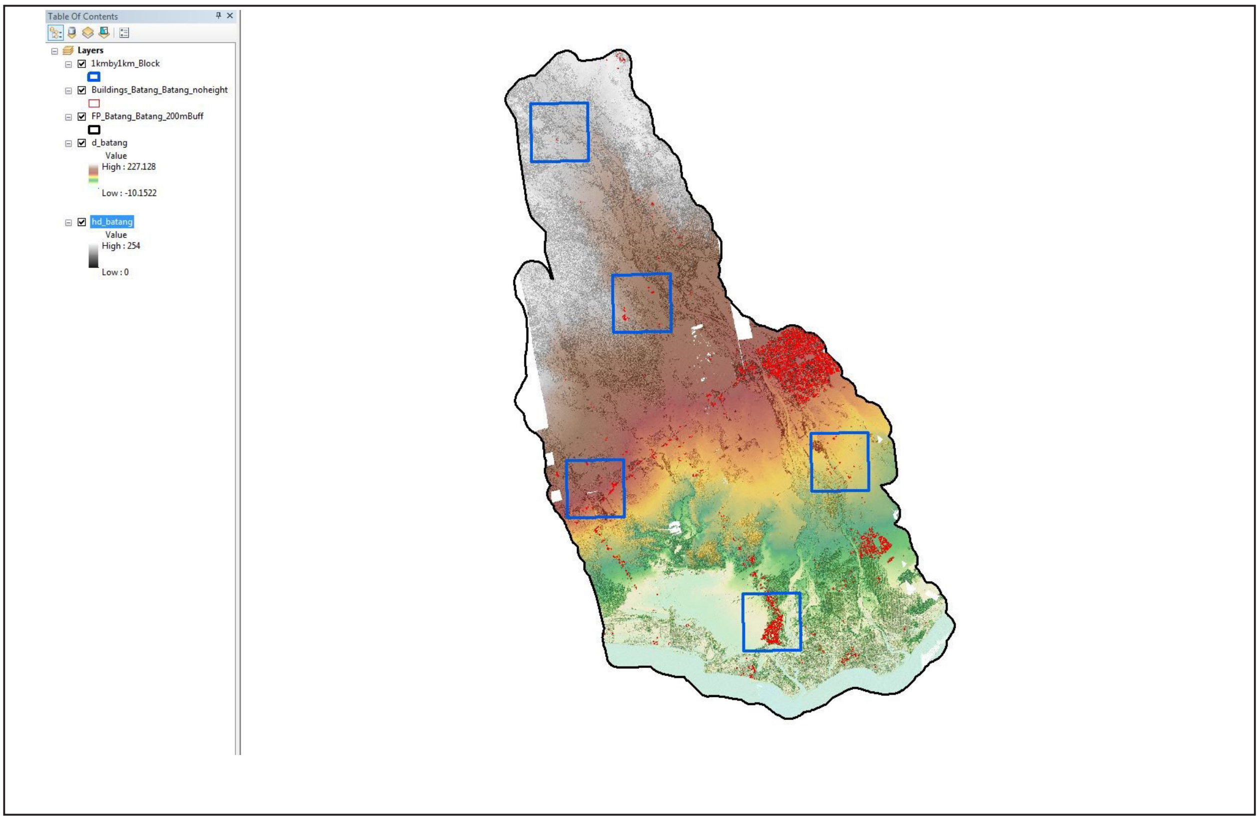


Figure 23. QC Blocks (in blue) of Batang-batang building features that was subjected to QC.

Quality checking of Batang-batang building features resulted in the ratings shown in Table 17.

Table 17. Details of the quality checking ratings for the building features extracted for the Batang-batang River Basin

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Batang-batang	98.87	98.87	96.15	PASSED

3.12.2 Height Extraction

Height extraction was done for 51,234 building features in Batang-batang floodplain. Of these building features, 843 were filtered out after height extraction, resulting to 50,391 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 14.87 meters.

3.12.3 Feature Attribution

A field team was deployed to the floodplain areas to gather attribute data for the features. Point features in .gpx format were generated from the feature shapefiles. These were loaded into OsmAnd, a mobile mapping application that uses OpenStreetMap (OSM) data as base map. Attributes of feature points of interest (POIs) such as government institutions, social service facilities, agro-industrial facilities, commercial buildings, and transportation and utility offices were recorded. These attributes include building types and names. Names and types of roads were also noted. For water bodies and bridges, only the names were recorded.

Table 18 summarizes the number of building features per type. On the other hand, Table 19 shows the total length of each road type, while Table 20 shows the number of water features extracted per type.

Table 18. Building Features Extracted for Batang-batang Floodplain.

Facility Type	No. of Features
Residential	2369
School	47
Market	10
Agricultural/Agro-Industrial	7
Medical Institutions	4
Barangay Hall	8
Military Institution	0
Sports Center/Gymnasium/Covered Court	5
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	14
Power Plant/Substation	4
NGO/CSO Offices	0
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	10
Bank	0
Factory	2
Gas Station	2
Fire Station	0
Other Government Offices	12
Other Commercial Establishments	25
Total	**2519**

Table 19. Total Length of Extracted Roads for Batang-batang Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Batang-batang	38.36	0.00	0.00	1.03	0.00	39.39

Table 20. Number of Extracted Water Bodies for Batang-batang Floodplain.

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Batang-batang	1	0	1	0	0	2

A total of 7 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 24 shows the completed Digital Surface Model (DSM) of the Batang-batang floodplain overlaid with its ground features.

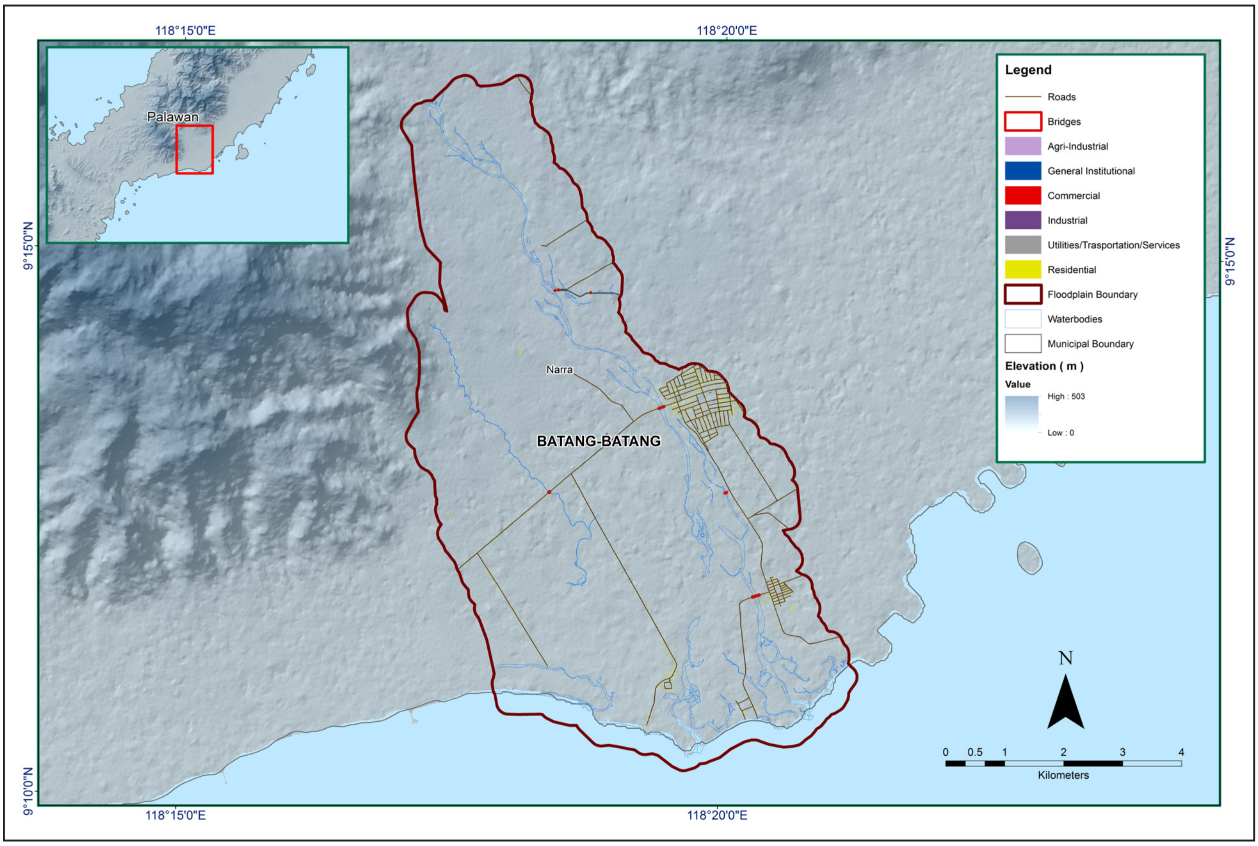


Figure 24. Extracted features for Batang-batang Floodplain.

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo Ms. Jeline M. Amante, Marie Angelique R. Estipona, Charie Mae V. Manliguez, Engr. Janina Jupiter, and Vie Marie Paola M. Rivera

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 AB Surveying and Development (ABSD) conducted a field survey in Batang-batang River on November 28, 2015, January 26, 27, 31, February 1, 2016. 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 and bridge as-built survey, and water level marking in the Mean Sea Level (MSL) of the Batang-batang Bridge; (iv) validation points acquisition of about 82 km covering the Batang-batang River Basin area; and (v) manual bathymetric survey from the mouth of the river in Brgy. Batang-Batang to the upstream in Brgy. Princess Urduja both in the Municipality of Narra using GNSS survey technique and Horizon® Total Station. Figure 25 illustrates the extent of the entire survey in Batang-batang River.

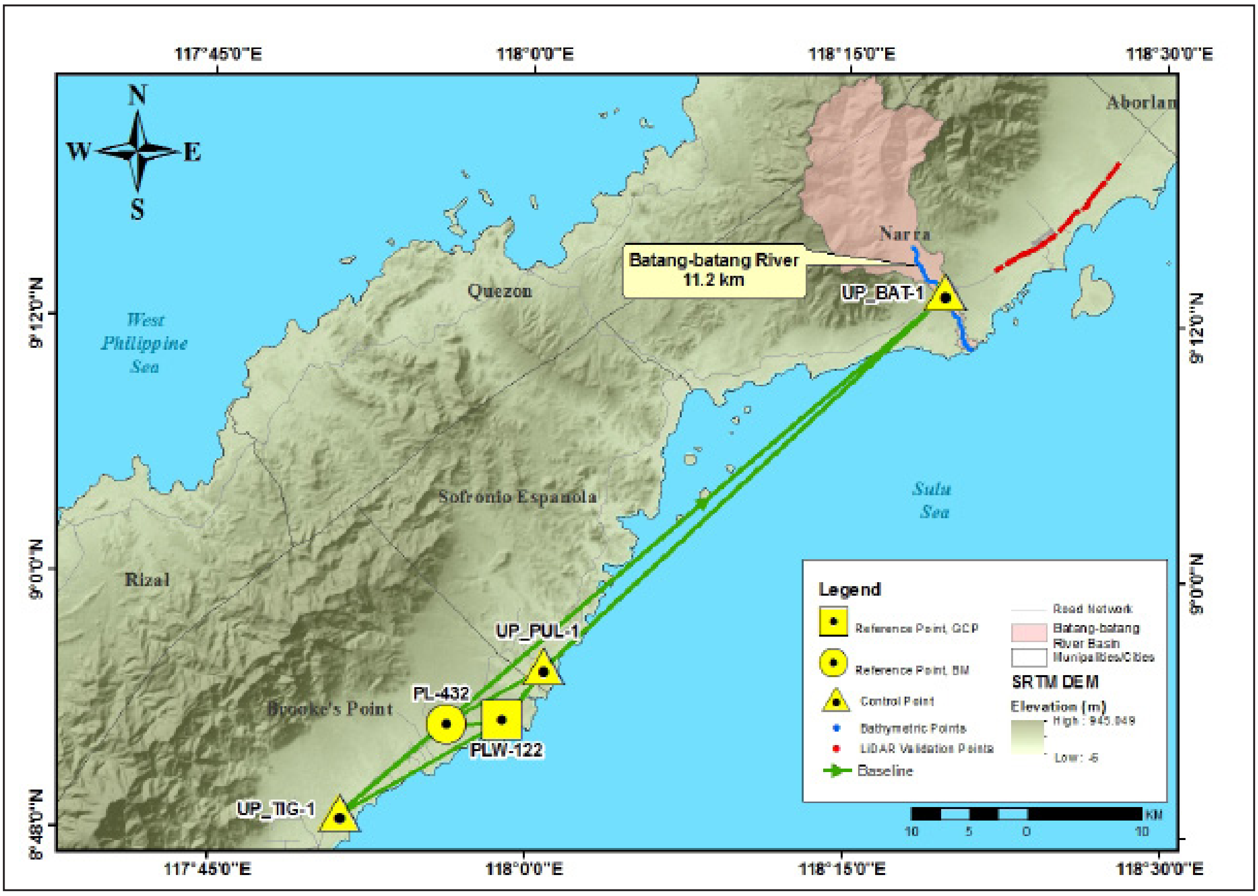


Figure 25. Batang-batang River Survey Extent

4.2 Control Survey

The GNSS network utilized for the Batang-batang River Basin is composed of two (2) loops established on August 23, 2016, which occupied the following reference points: PLW-122, a second-order GCP, in Brgy. Calasaguen, Brookes Point, Palawan and PL-432, a first-order BM, in Brgy. Maasin, Brookes Point, Palawan.

Three (3) control points were established in the area by ABS, namely: UP_BAT-1 at the approach of Batang-batang Bridge in Brgy. Batang-batang, Narra, Province of Palawan, UP_PUL-1 at the approach of Pulot Bridge in Brgy. Pulot Shore, Sofronio Española, Palawan, and UP_TIG-1 located at the approach of Tigaplan Bridge in Brgy. Barong-barong, Brookes Point, Palawan.

Table 21 depicts the summary of reference and control points utilized, with their corresponding locations.

Table 21. List of reference and control points used during the survey in Batang-batang River (Source: NAMRIA, UP-TCAGP).

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
PLW-122	2nd order, GCP	8°53'15.04059"N	117°58'54.93380"E	62.283	0.061	2007
PL-432	1st order, BM	8°53'00.38663"N	117°56'15.64298"E	68.495	0.042	2008
UP_BAT-1	Established	9°13'36.17513"	118°19'28.44057"E	99.128	48.319	12-07-15
UP_PUL-1	Established	8°56'59.82715"N	117°59'27.45211"E	61.711	0.064	12-17-15
UP_TIG-1	Established	8°48'46.72587"N	117°51'10.83488"E	60.057	0.086	11-30-15

Figure 26 to Figure 30 depict the setup of the GNSS on recovered reference points and established control points in the Batang-batang River.

Figure 26. GNSS base set up, Trimble® SPS 852 at PLW-122, located in an open lot beside the house of Ms. Liza Jamili in Brgy. Calasaguen, Brookes Point, Province of Palawan.

Figure 27. GNSS receiver set up, Trimble® SPS 882, at PL-432, located at the approach of Maasin Bridge in Brgy. Maasin, Brookes Point, Province of Palawan.

Figure 28. GNSS receiver set up, Trimble® SPS SPS 882, at UP_BAT-1, located near the approach of Batang-batang Bridge in Brgy. Princesa Urduja, Narra, Province of Palawan.

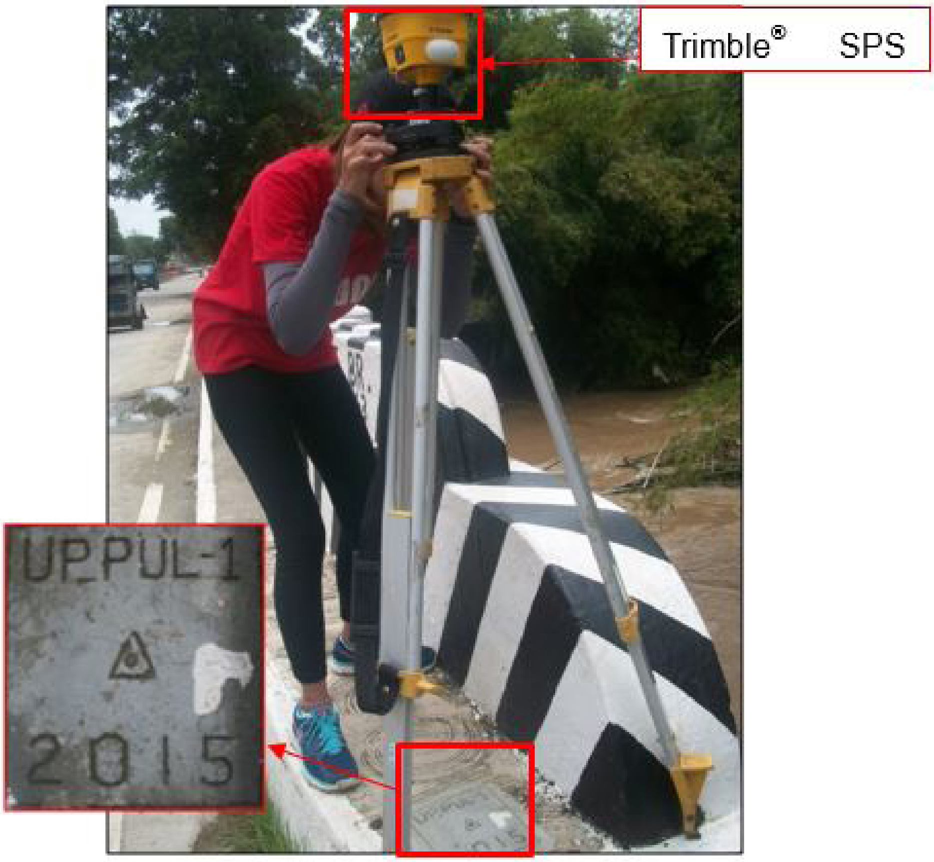


Figure 29. GNSS receiver set up, Trimble® SPS 985, at UP_PUL-1, located at the approach of Pulot Bridge, In Brgy. Pulot Shore, Sofronio Española, Province of Palawan.

Figure 30. Figure 30. GNSS receiver set up, Trimble® SPS 985, at UP_TIG-1, located at the approach of Tigaplan Bridge in Brgy. Tigaplan, Brookes Point, Province of Palawan.

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 22 presents the baseline processing results of control points in the Batang-batang River Basin, as generated by the TBC software.

Table 22. Baseline Processing Report for Batang-batang River Static Survey
(Source: NAMRIA, UP-TCAGP)

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
UP_PUL-1--- UP_BAT-1	8-23-2016	Fixed	0.034	0.034	230°10'32"	27770.125	-11.807
PL-432 --- UP_BAT-1	8-23-2016	Fixed	0.024	0.024	228°16'42"	57014.957	55.240
UP_TIG-1 --- UP_PUL-1	8-23-2016	Fixed	0.019	0.019	45°02'06"	21441.510	55.249
UP_TIG-1 --- PL-432	8-23-2016	Fixed	0.026	0.026	50°04'25"	12144.165	-35.515
PLW-122 --- UP_PUL-1	8-23-2016	Fixed	0.012	0.012	8°11'07"	6977.113	14.631
PLW-122 --- PL-432	8-23-2016	Fixed	0.020	0.020	264°43'06"	4887.669	2.872

As shown in Table 22, a total of six(6) baselines were processed with the coordinate and ellipsoidal height values of PLW-122 held fixed; 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:

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

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 23 to Table 26

The five (5) control points, PL-432, PLW-122, UP-BAT-1, UP_PUL-1, and UP-TIG-1 were occupied and observed simultaneously to form a GNSS loop. The coordinates and ellipsoidal height of PLW-122 were held fixed during the processing of the control points as presented in Table 23. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 23. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
PLW-122	Global	Fixed	Fixed		
UP_BAT-1	Grid				Fixed
UP_BAT-1	Global	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 24.

Table 24. Adjusted grid coordinates for the control points used in the Batang-batang River flood plain survey.

Point ID	Easting	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
PLW-122	607965.609	?	982558.716	?	11.971	0.061	LL
PL-432	603101.186	0.014	982096.040	0.014	18.317	0.042	
UP_BAT-1	645509.020	?	1020187.067	?	48.319	?	LLe
UP_PUL-1	608940.379	0.010	989465.589	0.008	11.454	0.064	
UP_TIG-1	593808.679	0.017	974282.799	0.017	10.210	0.086	

The results of the computation for accuracy are as follows:

a. PLW-122
horizontal accuracy = Fixed
vertical accuracy = Fixed

b. PL-432
horizontal accuracy = $\sqrt{((1.4)^2 + (1.4)^2}$
= $\sqrt{(1.96 + 1.96)}$
= 1.98 < 20 cm
vertical accuracy = 4.2 < 10 cm

c. UP_BAT-1
horizontal accuracy = Fixed
vertical accuracy = Fixed

d. UP_PUL-1
horizontal accuracy = $\sqrt{((1.0)^2 + (0.8)^2}$
= $\sqrt{(1.0 + 0.64)}$
= 1.28 < 20 cm
vertical accuracy = 6.4 < 10 cm

e. UP_TIG-1
horizontal accuracy = $\sqrt{((1.7)^2 + (1.7)^2}$
= $\sqrt{(2.89 + 2.89)}$
= 2.40 < 20 cm
vertical accuracy = 8.6 < 10 cm

Following the given formula, the horizontal and vertical accuracy result of the four (4) occupied control points are within the required precision.

Table 25. Adjusted geodetic coordinates for control points used in the Batang-batang River Flood Plain validation.

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
PLW-122	8°53'15.04059"N	117°58'54.93380"E	62.283	0.061	LL
PL-432	8°53'00.38663"N	117°56'15.64298"E	68.495	0.042	
UP_BAT-1	9°13'36.17513"N	118°19'28.44057"E	99.128	?	LLe
UP_PUL-1	8°56'59.82715"N	117°59'27.45211"E	61.711	0.064	
UP_TIG-1	8°48'46.72587"N	117°51'10.83488"E	60.057	0.086	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 25. 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 Batang-batang River GNSS Static Survey are seen in Table 26.

Table 26. The reference and control points utilized in the Batang-batang 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	Easting	MSL Elevation (m)
PLW-122	2nd order, GCP	8°53'15.04059"N	117°58'54.93380"E	85.647	982558.716	607965.609	0.061
PL-432	1st order, BM	8°53'00.38663"N	117°56'15.64298"E	63.739	982096.040	603101.186	0.042
UP_BAT-1	Established	9°13'36.17513"N	118°19'28.44057"E	48.751	1020187.067	645509.020	48.319
UP_PUL-1	Established	8°56'59.82715"N	117°59'27.45211"E	52.045	989465.589	608940.379	0.064
UP_TIG-1	Established	8°48'46.72587"N	117°51'10.83488"E	48.192	974282.799	593808.679	0.086

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

The bridge cross-section and as-built survey were conducted on November 28, 2015 at the downstream side of Batang-batang Bridge in Brgy. Batang-Batang, Municipality of Narra using a total station (Figure 31 and Figure 32).

Figure 31. Downstream of Batang-batang Bridge.

Figure 32. Bridge As-Built Survey of Batang-batang Bridge.

The length of the cross-sectional line surveyed at Batang-batang Bridge is about 160.211 m with forty-seven (47) cross-sectional points using the control points UP_BAT-1 and UP_BAT-2 as the GNSS base stations. The location map, cross-section diagram, and the accomplished bridge data form are shown in Figure 33 to Figure 35.

Gathering of random points for the checking of ABSD's bridge cross-section and bridge points data was performed by DVBC on August 25, 2016 using a survey grade GNSS Rover receiver attached to a 2-m pole. Linear square correlation (R2) and RMSE analysis were performed on the two (2) datasets. The linear square coefficient range is determined to ensure that the submitted data of the contractor is within the accuracy standard of the project which is ±20 cm and ±10 cm for horizontal and vertical, respectively. The R2 value must be within 0.85 to 1. An R2 approaching 1 signifies a strong correlation between the vertical (elevation values) of the two datasets. A computed R2 value of 0.1318 was obtained was obtained by comparing the data of the contractor and DVBC, which is not within the required R2 range. However, since the checking points were gathered on the paved area of the bridge, the value has been deemed acceptable.

In addition to the Linear Square correlation, Root Mean Square (RMSE) analysis is also performed in order to assess the difference in elevation between the DVBC checking points and the contractor's. The RMSE value should only have a maximum radial distance of 5 m and the difference in elevation within the radius of 5 meters should not be beyond 0.50 m. For the bridge cross-section data, a computed value of 0.3710 m, this is within the program's requirement.

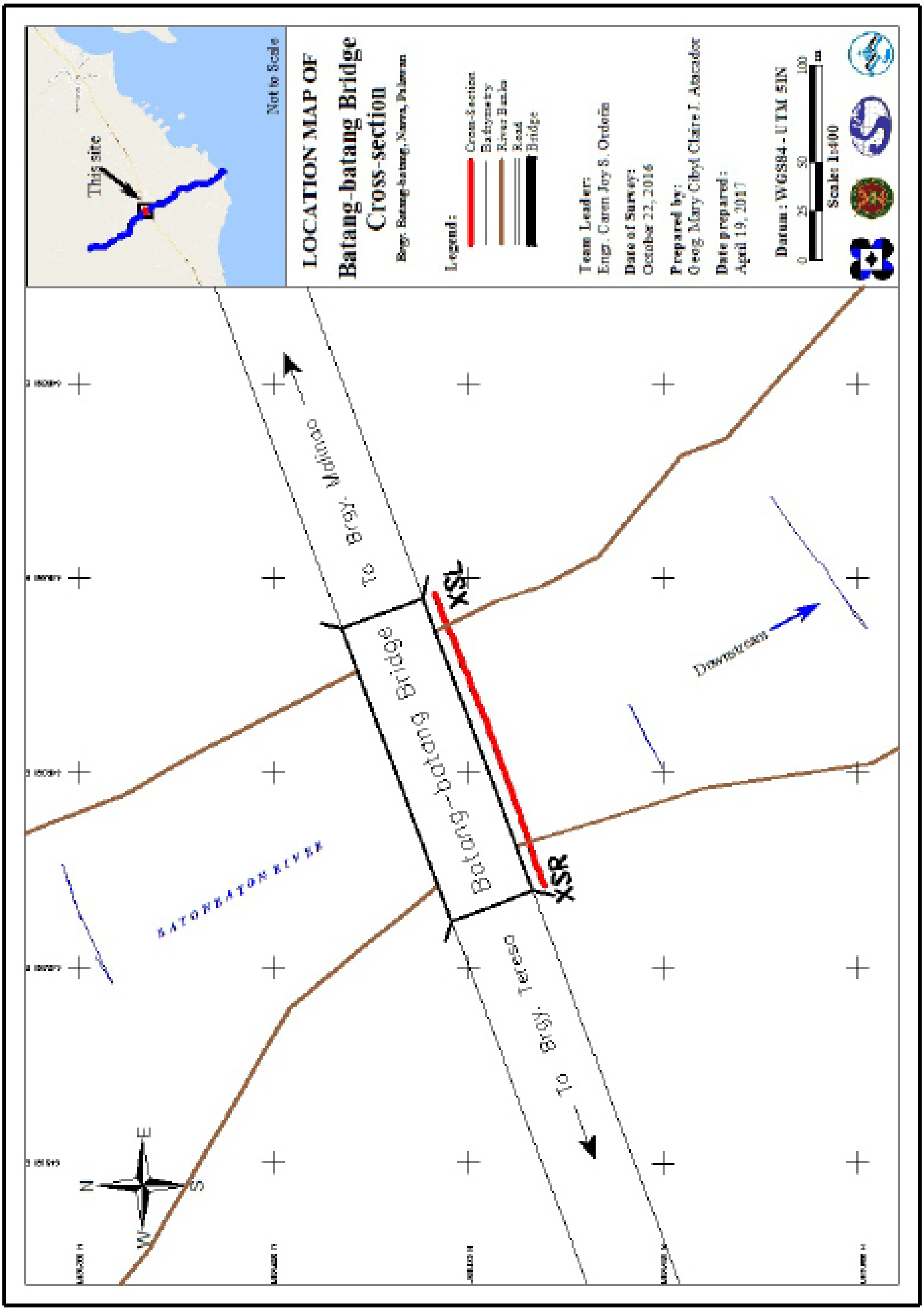


Figure 33. Location Map of Batang-batang Bridge River Cross-Section survey

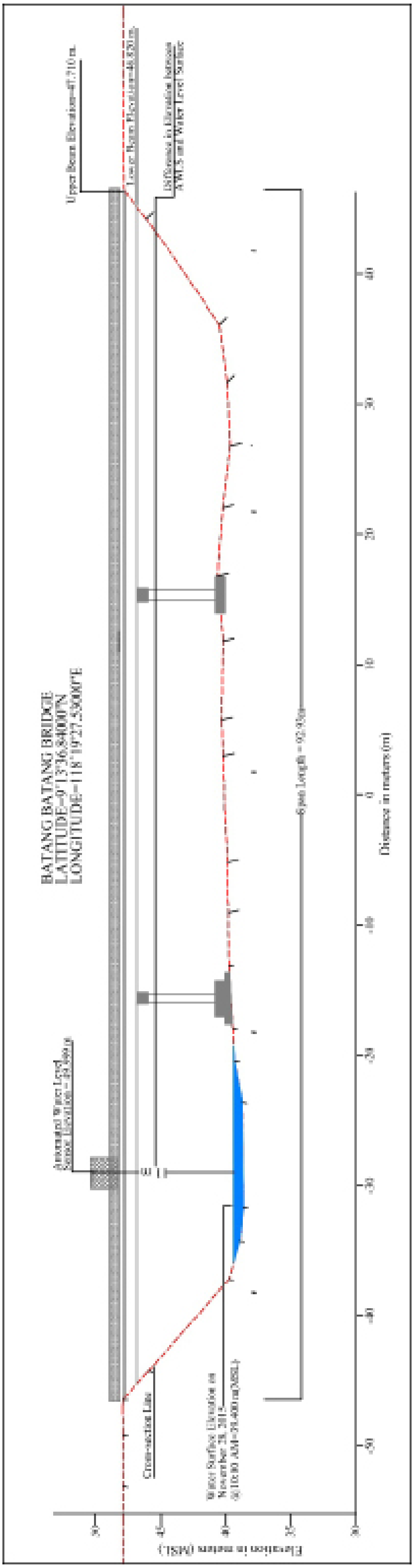


Figure 34. The Batang-batang Bridge cross-section survey drawn to scale.

Bridge Name: BATANG-BATANG BRIDGE

River Name: BATANG-BATANG RIVER

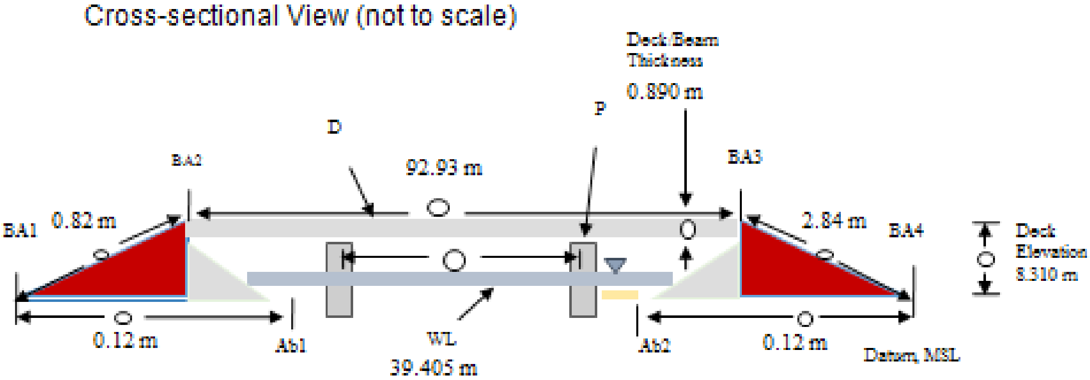
Location (Brgy, City, Region): Brgy. Batang-Batang, Narra, Palawan

Survey Team: William Mamaril, Bernard Burcia

Date and Time: November 28, 2015, 10:00AM

Flow Condition:	low	✔ normal	high
Weather Condition:	✔ fair	rainy	

Cross-sectional View (not to scale)



Legend:
BA = Bridge Approach
P = Pier
Ab = Abutment
D = Deck
WL = Water Level/Surface
MSL = Mean Sea Level
◯ = Measurement Value

Line Segment	Measurement (m)	Remarks
1. BA1-BA2	0.82 m	
2. BA2-BA3	92.93 m	
3. BA3-BA4	2.84 m	
4. BA1-Ab1	0.12 m	
5. Ab2-BA4	0.12 m	
6. Deck/beam thickness	0.890 m	
7. Deck elevation	8.310m	

Note: Observer should be facing downstream

Figure 35. The Batang-batang Bridge as-built survey data.

The water surface elevation of Batang-batang River was determined using a Horizon® Total Station on November 28, 2015 at 10:00 AM with a value of 39.405 m (MSL) as shown in Figure 36. This was translated into marking on the bridge's pier using the same technique as shown in Figure 36. It now serves as the reference for flow data gathering and depth gauge deployment of the University of the Philippines Los Baños (UPLB), the partner HEI responsible for the monitoring of Batang-batang River.

Figure 36. Water level markings on Batang-batang Bridge.

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted by DVBC from August 16 to 28, 2016 using a survey grade GNSS Rover receiver, Trimble® SPS 985, mounted on a range pole which was attached on the side of the vehicle as shown in Figure 37. It was secured with cable ties and ropes to ensure that it was horizontally and vertically balanced. The antenna height was 1.361 m and measured from the ground up to the bottom of the quick release of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with UP_BAT-1 occupied as the GNSS base station in the conduct of the survey.

Figure 37. GNSS Receiver Trimble® SPS 882 installed on a vehicle for Ground Validation Survey.

The survey started from Brgy. Malatgao, Municipality of Narra, Palawan going northwest along the national highway, covering four (4) barangays in the Municipality of Brookes Point, and ended in Brgy. Malinao, Municipality of Narra, Palawan. The survey gathered a total of 1,725 points with approximate length of 14.67 km using UP_BAT-1 as GNSS base station for the entire extent validation points acquisition survey as illustrated in the map in Figure 38.

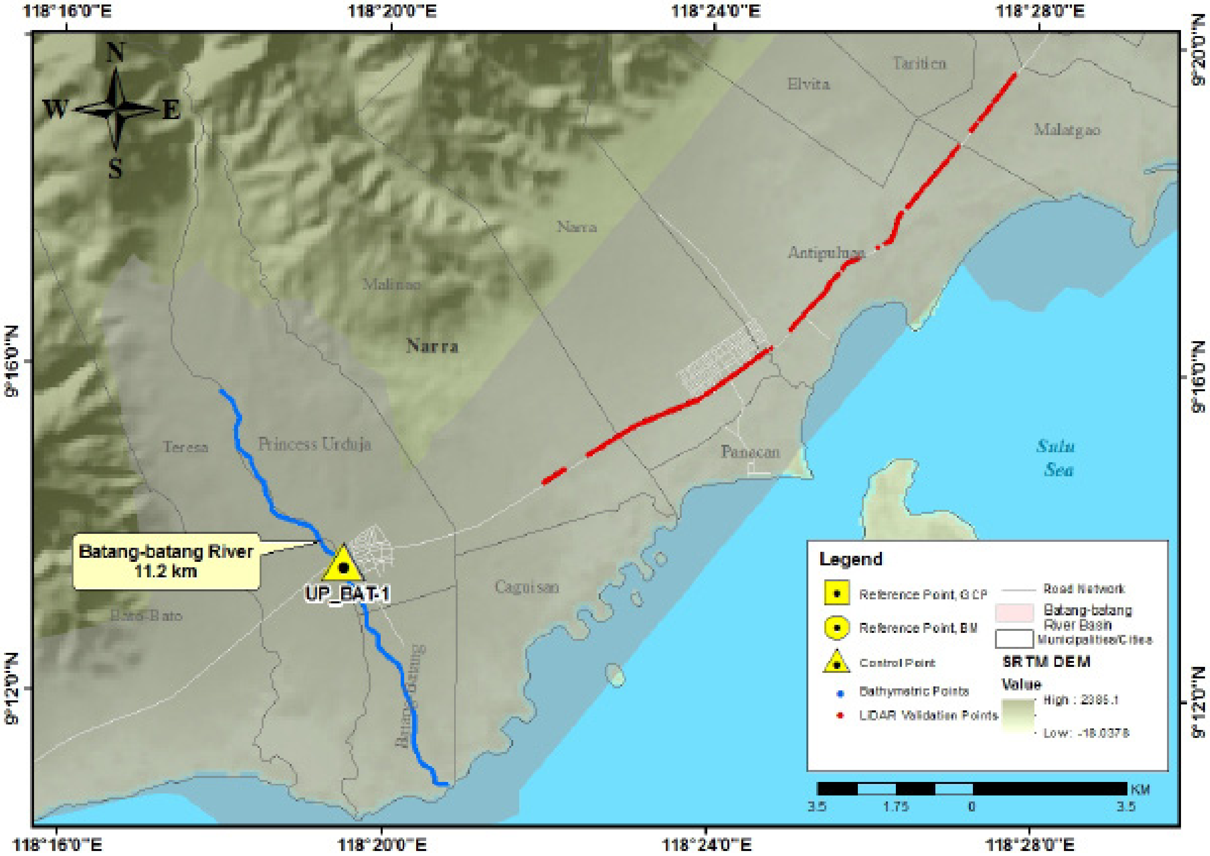


Figure 38. The extent of the LiDAR ground validation survey (in red) for Batang-batang River Basin.

4.7 Bathymetric Survey

A bathymetric survey was performed on January 26, 27, 31 and February 1, 2016 using a Horizon™ Total Station, as illustrated in Figure 39. The survey started from the mouth of the river in Brgy. Batang-batang in Municipality of Bataraza, Palawan with coordinates 9°10'48.66790"N, 118°20'52.94360"E and ended at the upstream of the river in Brgy. Princess Urduja, Municipality of Narra, with coordinates 9°15'35.88840"N, 118°18'7.26189"E, as shown in the map in Figure 40. The control points UP_BAT-1 and UP_BAT-2 were used as GNSS base stations all throughout the entire survey.

Linear square correlation (R2) and RMSE analysis were also performed on the two (2) datasets. The computed R2 value of 0.9972 is within the required range for R2, which is 0.85 to 1. Additionally, an RMSE value of 0.1034 was obtained. Both the computed R2 and RMSE values are within the accuracy required by the program.

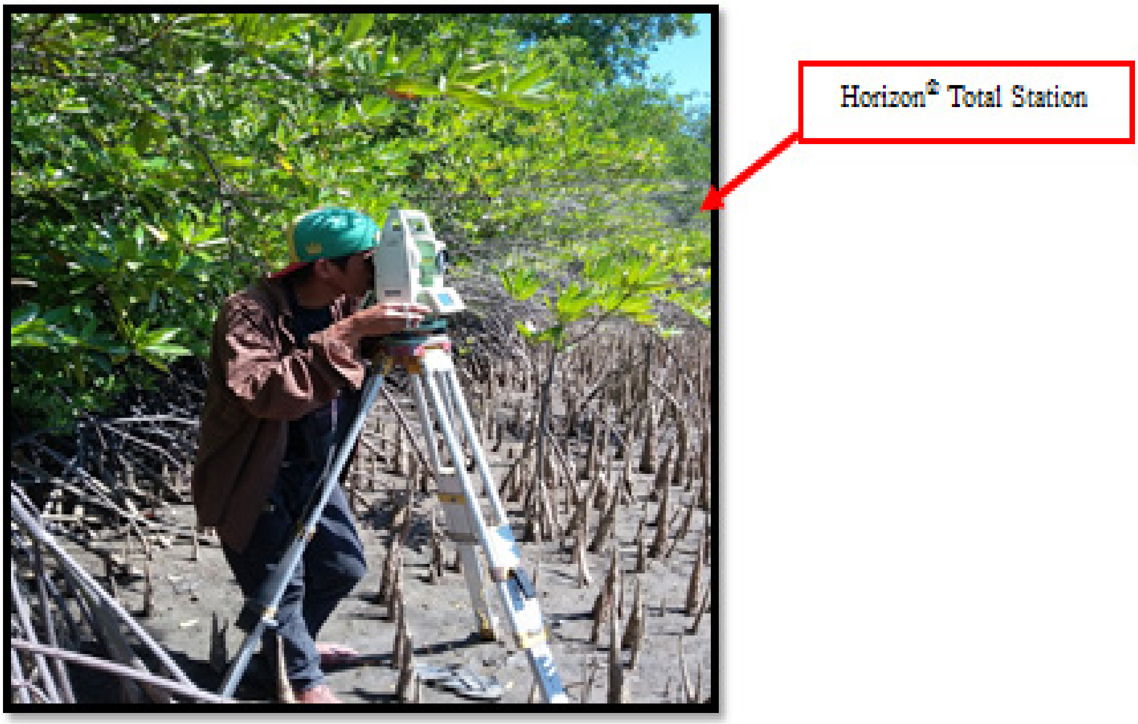


Figure 39. Set up of the bathymetric survey of ABSD at Batang-batang River using Horizon™ Total Station.

To further illustrate this, a CAD drawing of the riverbed profile of the Batang-batang River was produced. As seen in Figure 42, an elevation drop of 96.64 m was observed within the distance of approximately 10.835 km.

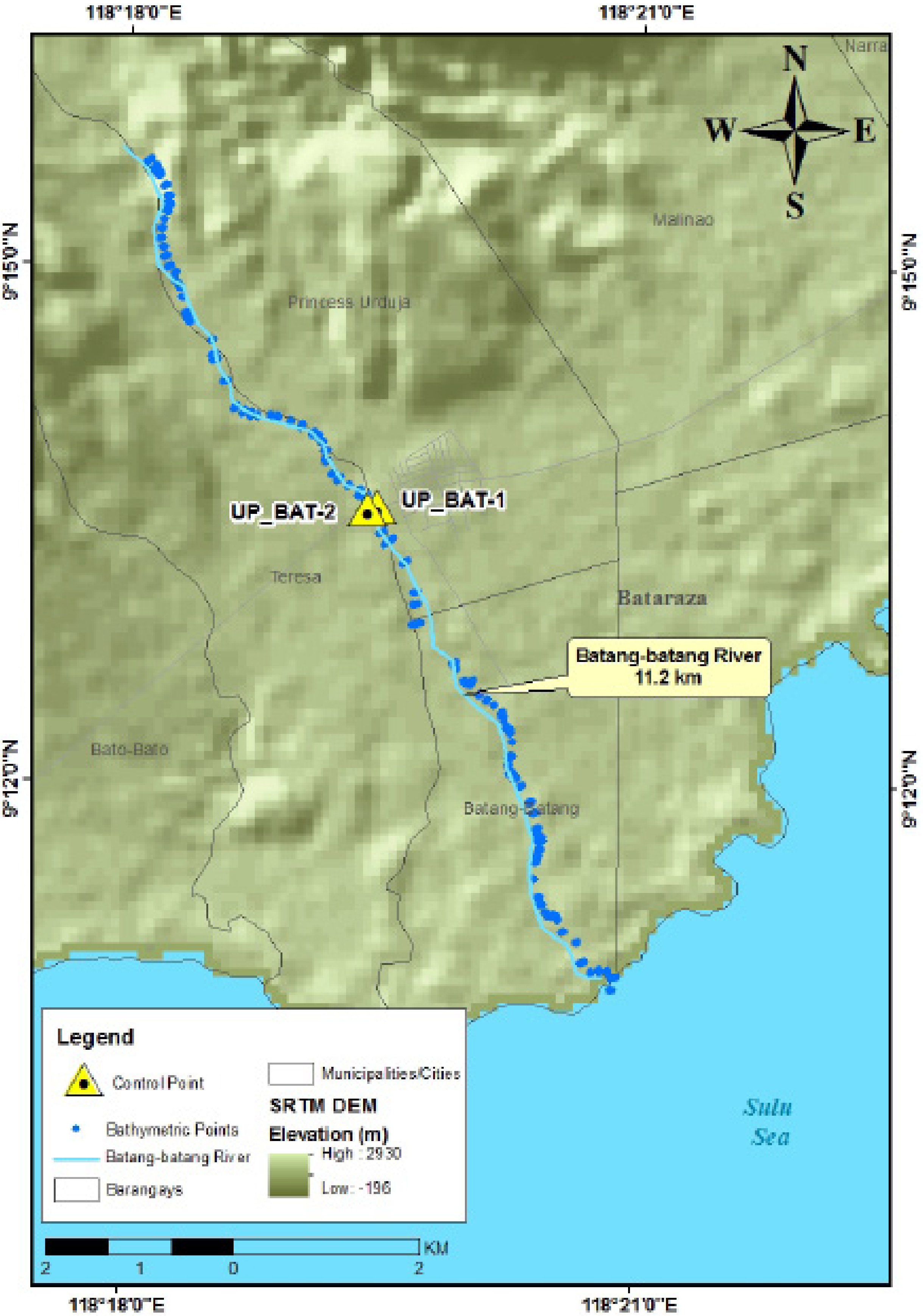


Figure 40. The extent of the Batang-batang River Bathymetry Survey.

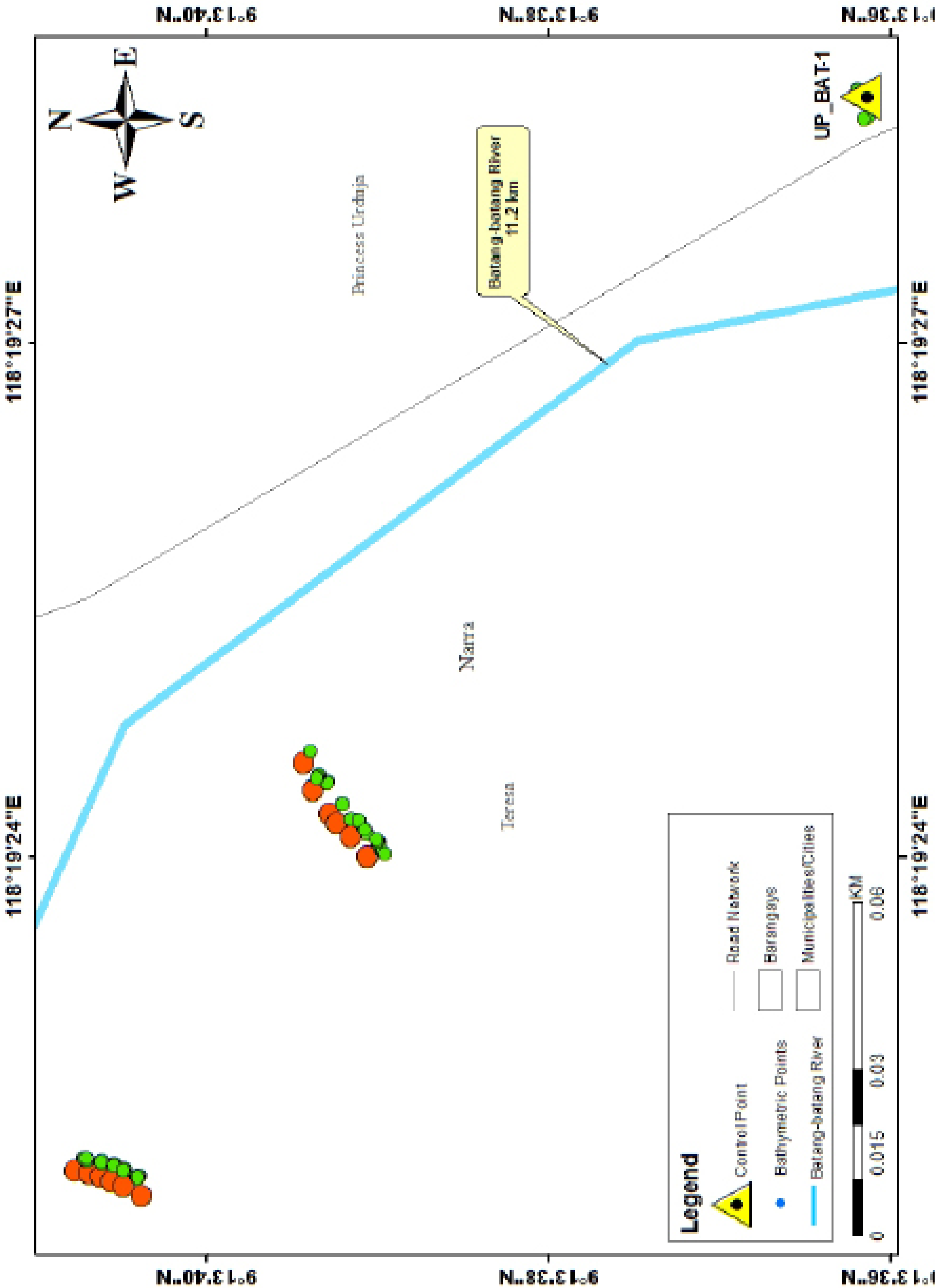


Figure 41. Batang-batang centerline riverbed profile (Upstream)

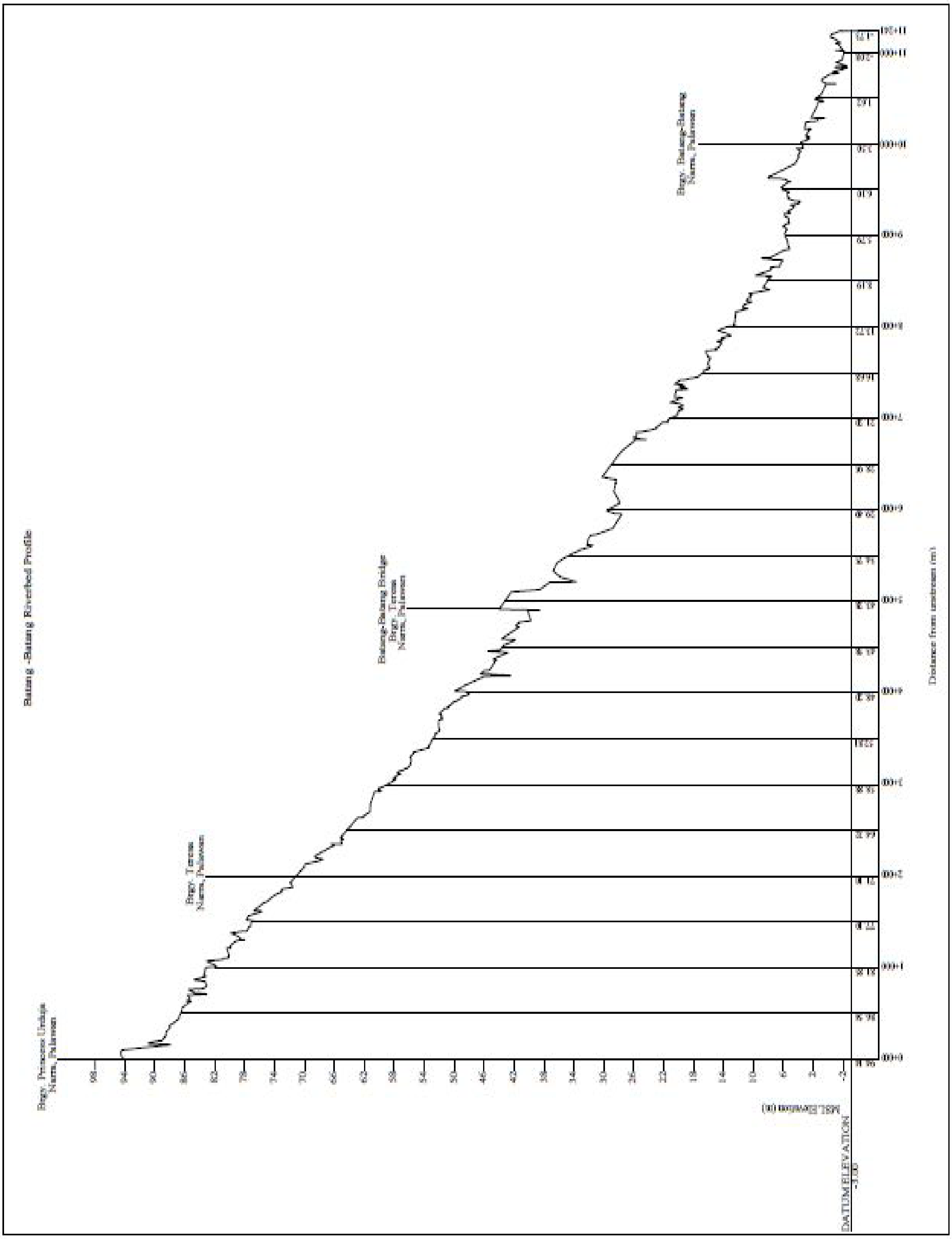


Figure 42. Batang-batang centerline riverbed profile (Downstream)

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

All components and data, such as rainfall, water level, and flow in a certain period of time, which may affect the hydrologic cycle of the Batang-batang River Basin were monitored, collected, and analyzed.

5.1.2 Precipitation

There is no gathered rainfall data for Batang-Batang River Basin. The HMS model is not calibrated. The values generated HMS model is set to default.

5.2 RIDF Station

PAGASA computed the Rainfall Intensity Duration Frequency (RIDF) values for the Puerto Princesa Rain Gauge (Table 27). 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 43). This station was selected based on its proximity to the Batang-batang watershed. The extreme values for this watershed were computed based on a 58-year record.

Table 27. values for Romblon Rain Gauge computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	14.8	22	27.3	36.2	49.8	58.8	75.1	88	104.1
5	21.3	31.9	39.7	52.3	73	86.9	112.8	135.4	156.4
10	25.6	38.5	48	63	88.4	105.5	137.8	166.8	191.1
15	28.1	42.2	52.6	69	97	116	151.9	184.5	210.6
20	29.8	44.7	55.9	73.3	103.1	123.4	161.7	196.8	224.3
25	31.1	46.7	58.4	76.5	107.8	129.1	169.3	206.4	234.9
50	35.2	52.9	66.1	86.5	122.2	146.5	192.7	235.8	267.3
100	39.2	59	73.7	96.4	136.5	163.8	216	265	299.6

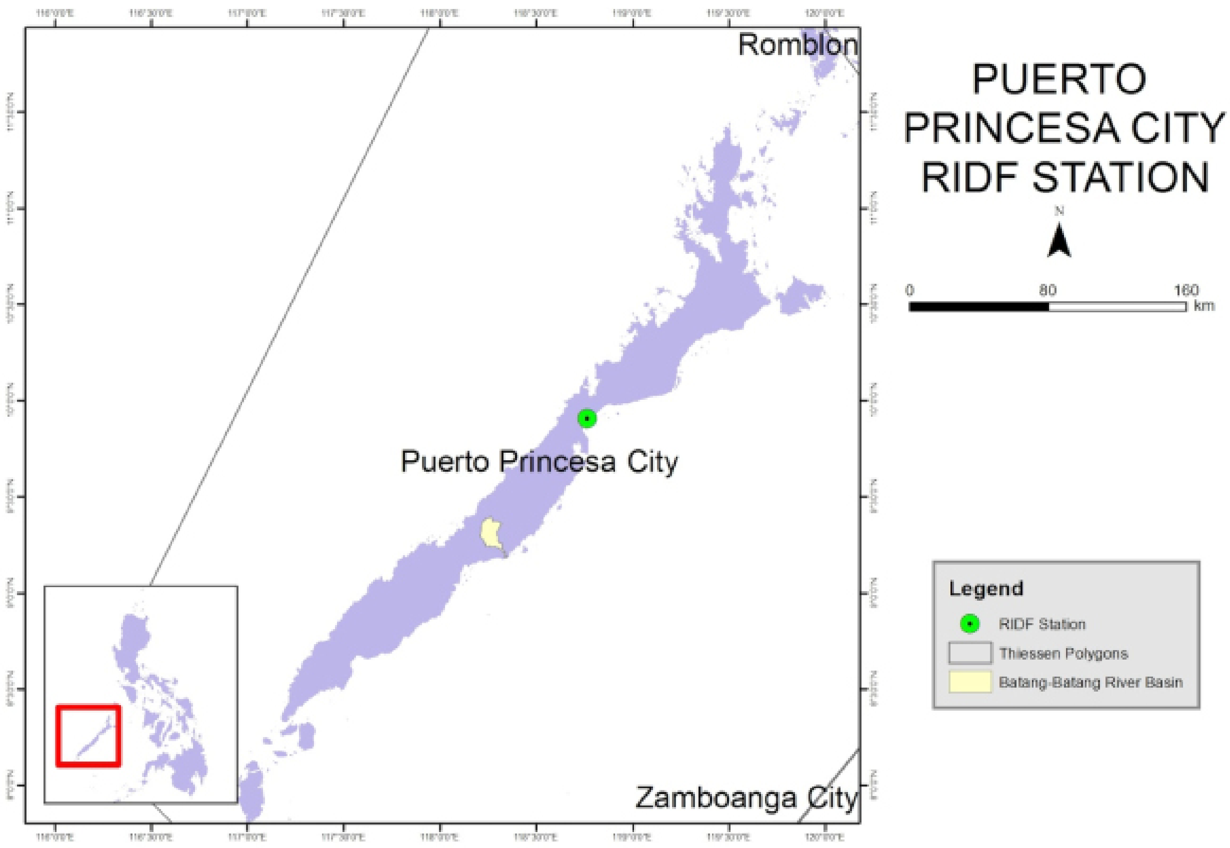


Figure 43. Location of Puerto Princesa RIDF Station relative to Batang-batang River Basin.

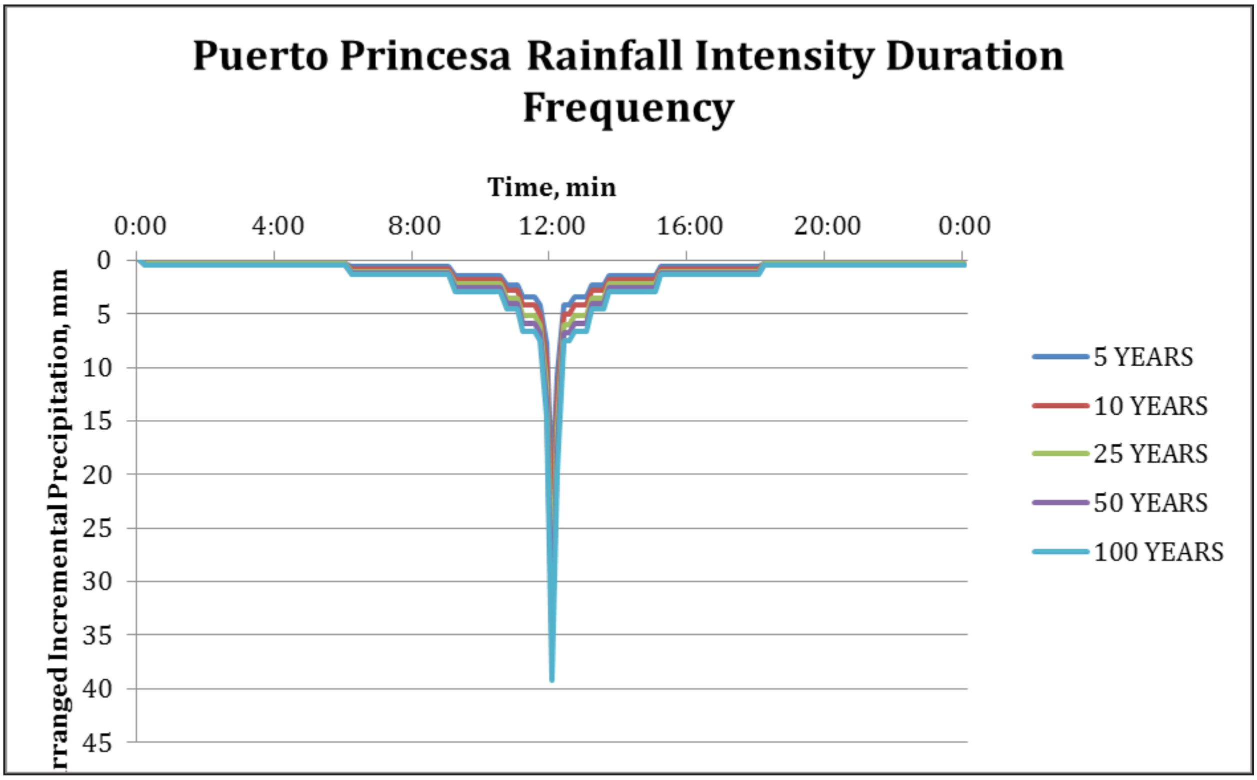


Figure 44. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was generated before 2004 from the Bureau of Soils under the Department of Environment and Natural Resources Management. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Batang-batang River Basin are shown in Figure 45 and Figure 46, respectively.

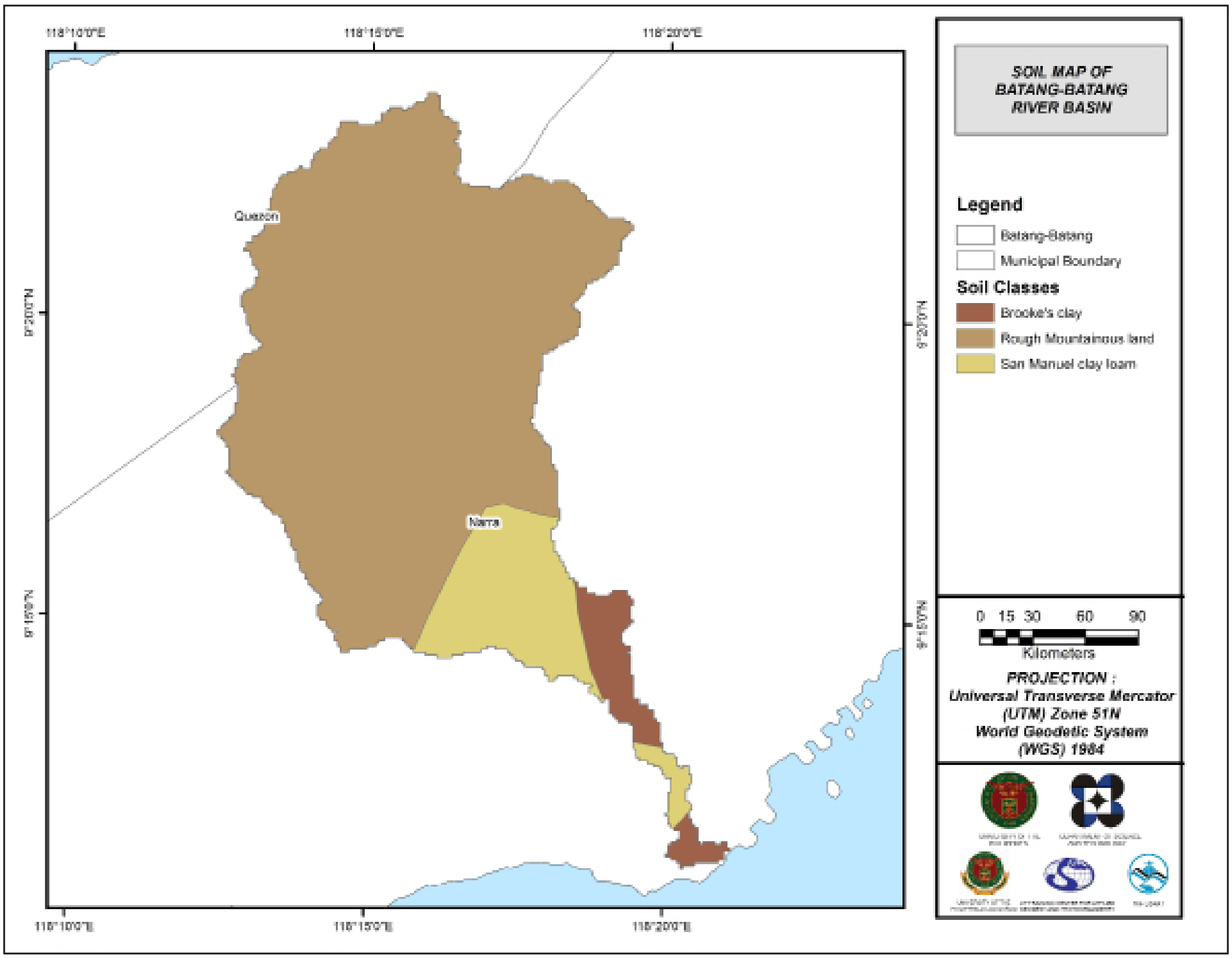


Figure 45. Soil Map of Batang-batang River Basin.

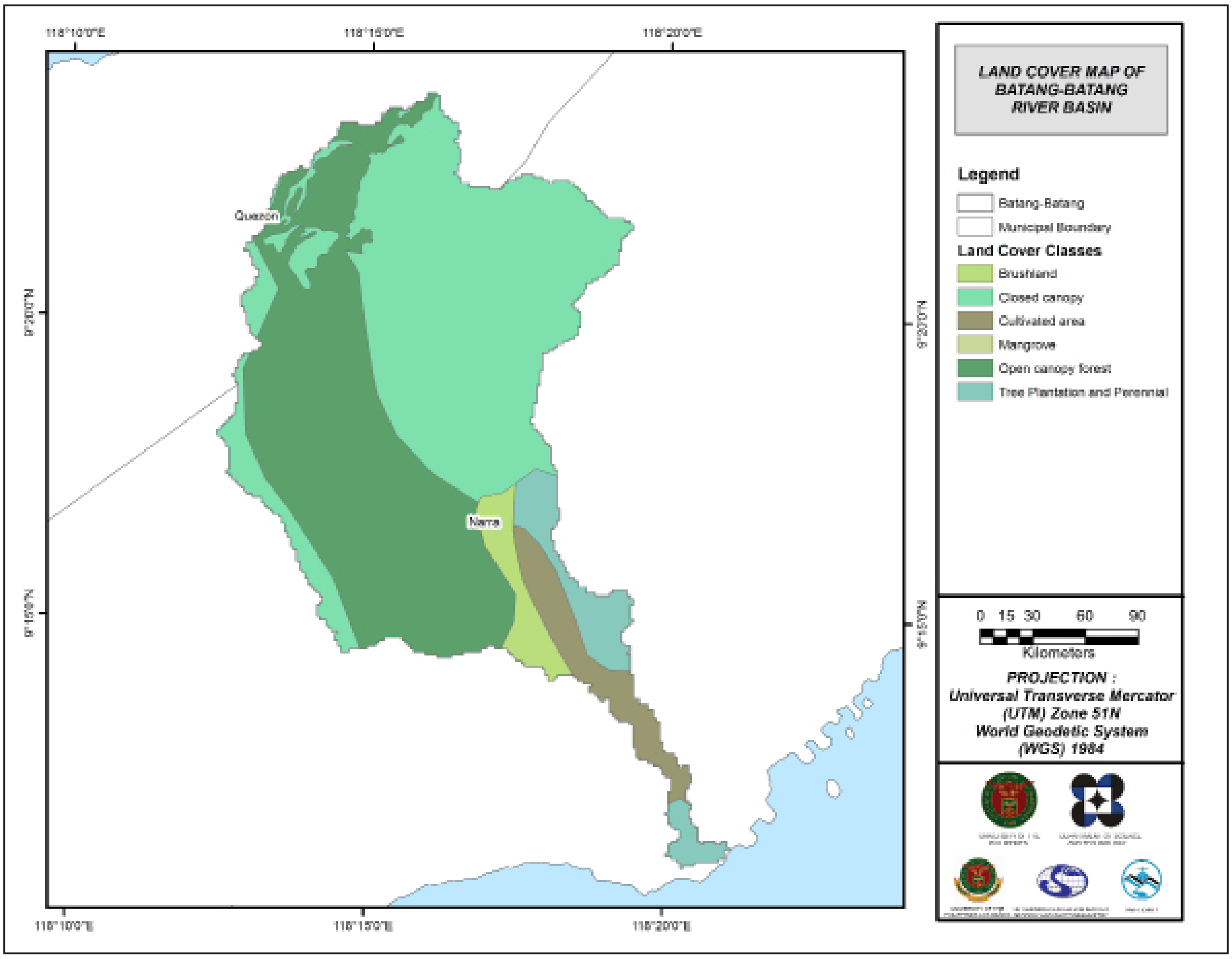


Figure 46. Land Cover Map of Batang-batang River Basin.

For Batang-batang, four (4) soil classes were identified. These are clay, clay loam, silt loam and undifferentiated land. Moreover, seven (7) land cover classes were identified. These are brushlands, built-up areas, cultivated areas, inland water, open areas, open canopy forests, and tree plantations.

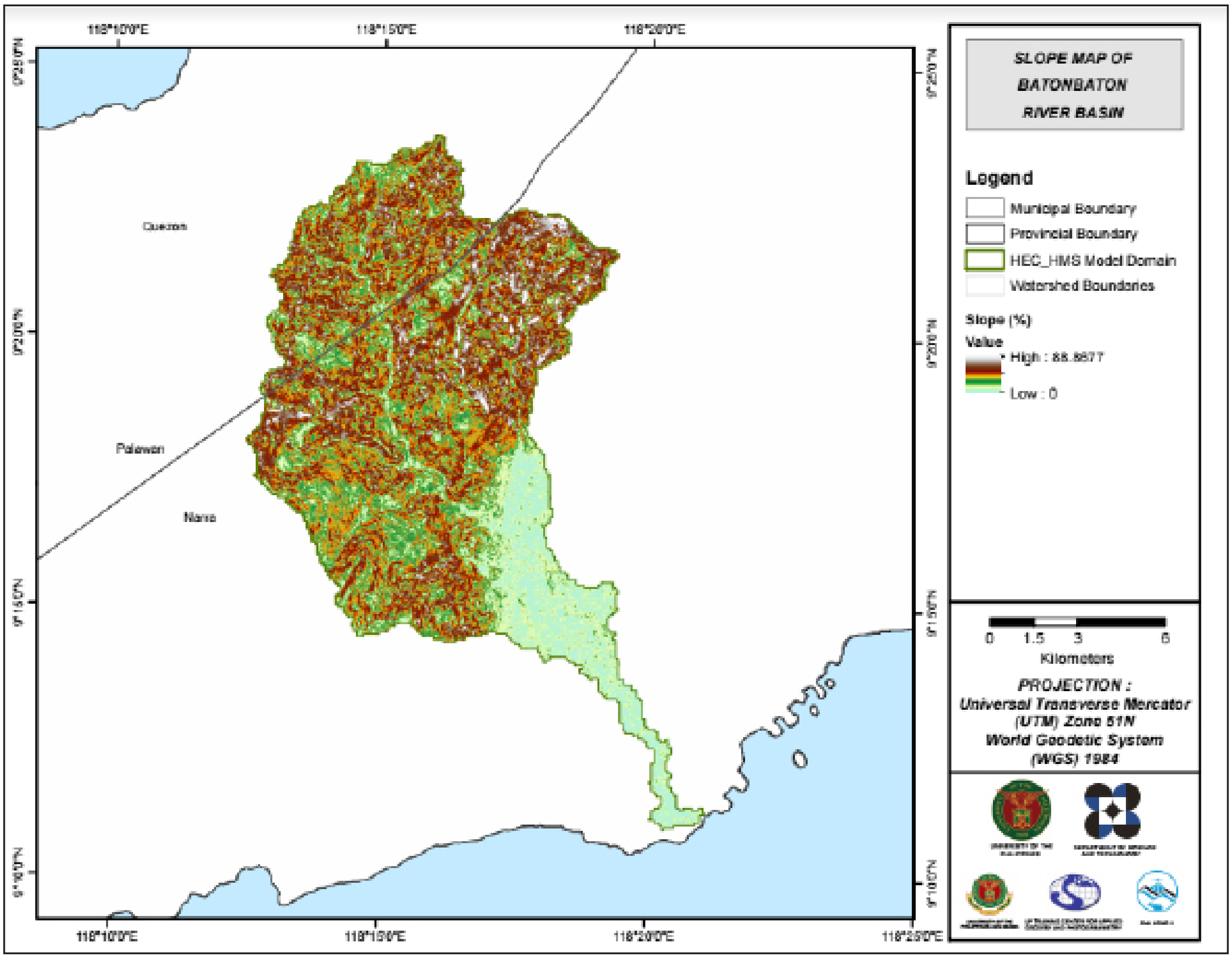


Figure 47. Slope Map of the Batang-batang River Basin.

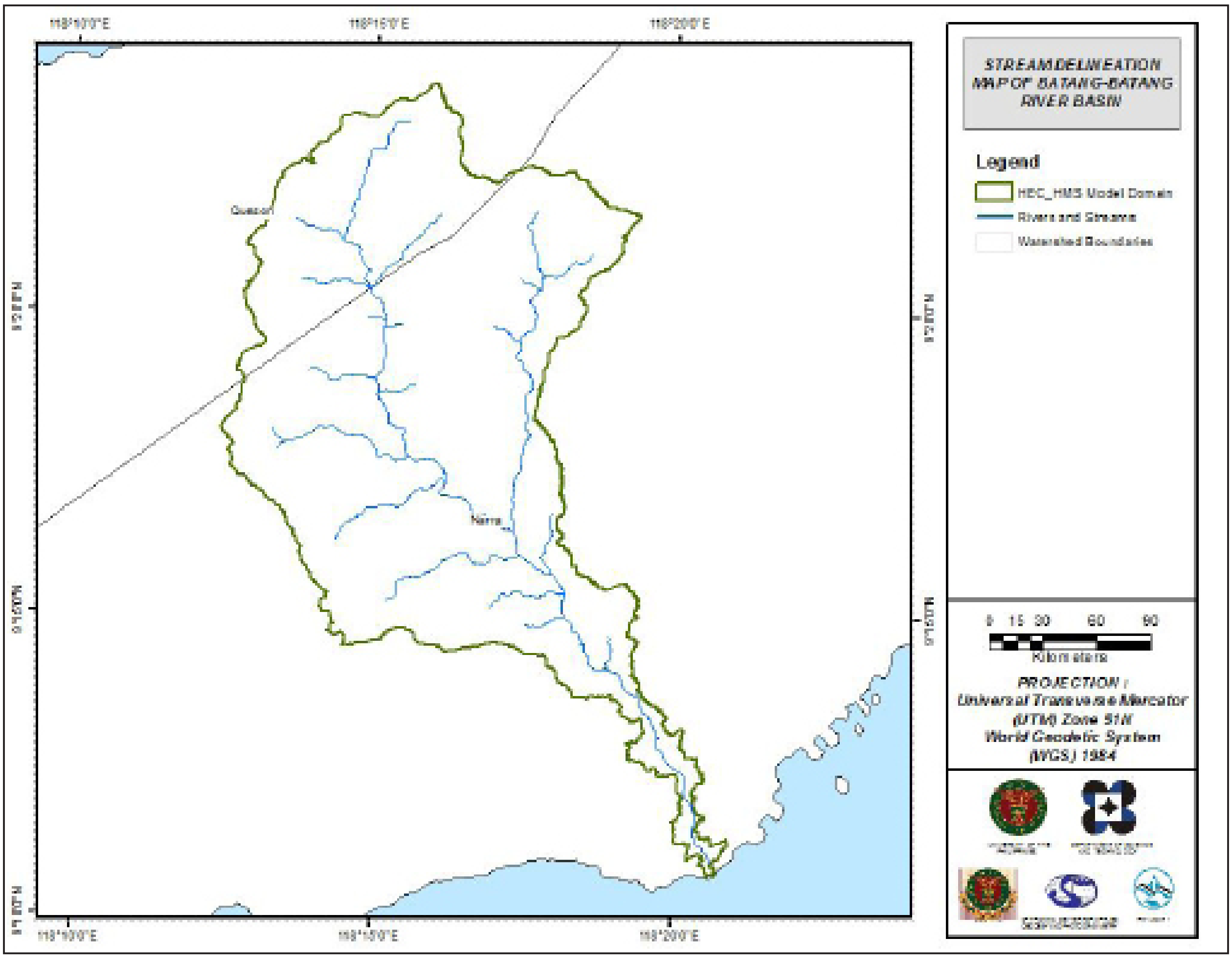


Figure 48. Stream Delineation Map of Batang-batang River Basin.

Using the SAR-based DEM, the Batang-batang basin was delineated and further subdivided into subbasins. The model consists of 48 sub basins, 23 reaches, and 21 junctions as shown in Figure 49 (See Annex 10). The main outlet is labelled as Batonbaton_outlet.

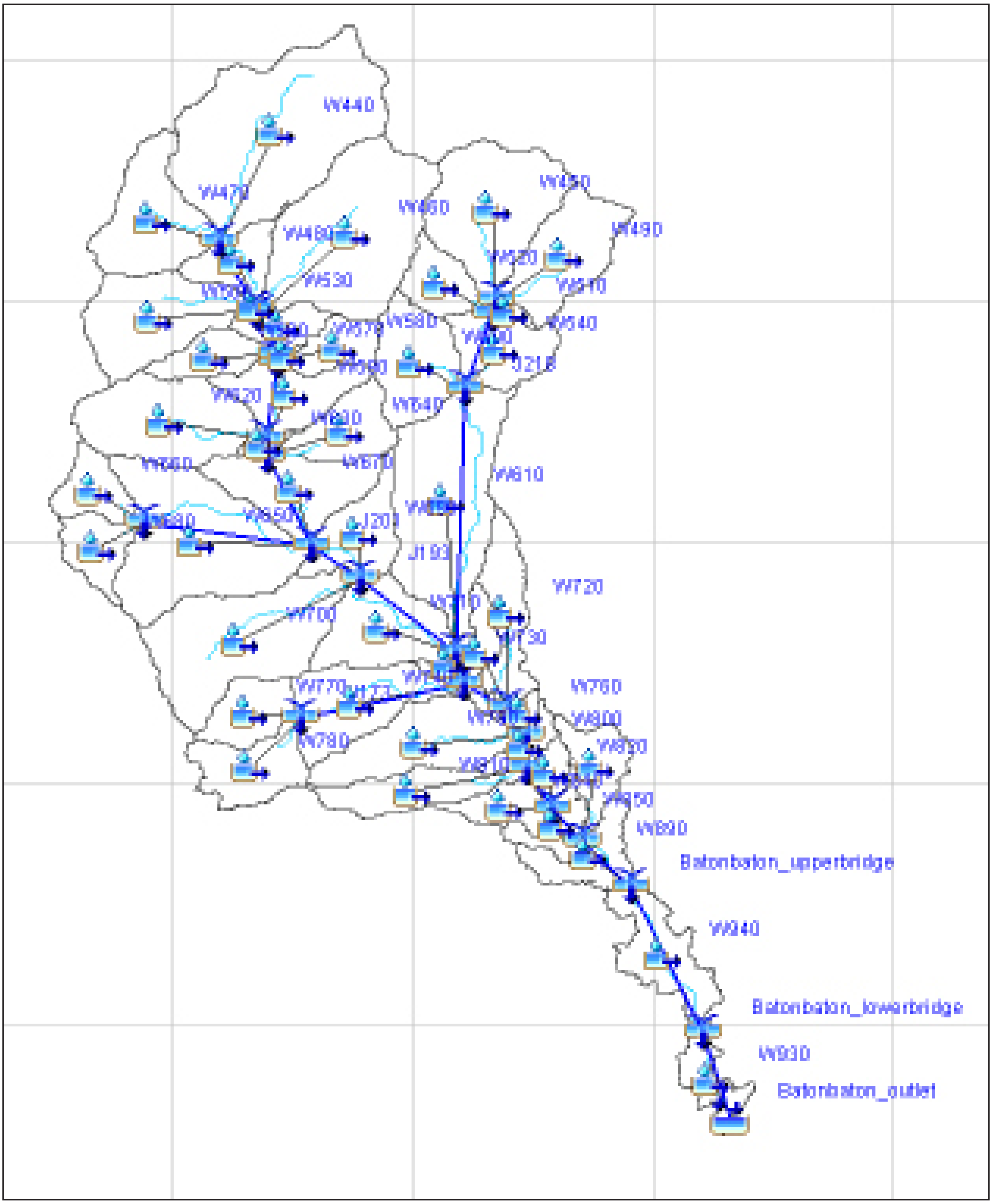


Figure 49. Batang-batang river basin model generated in HEC-HMS.

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.

5.5 Flo 2D Model

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

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

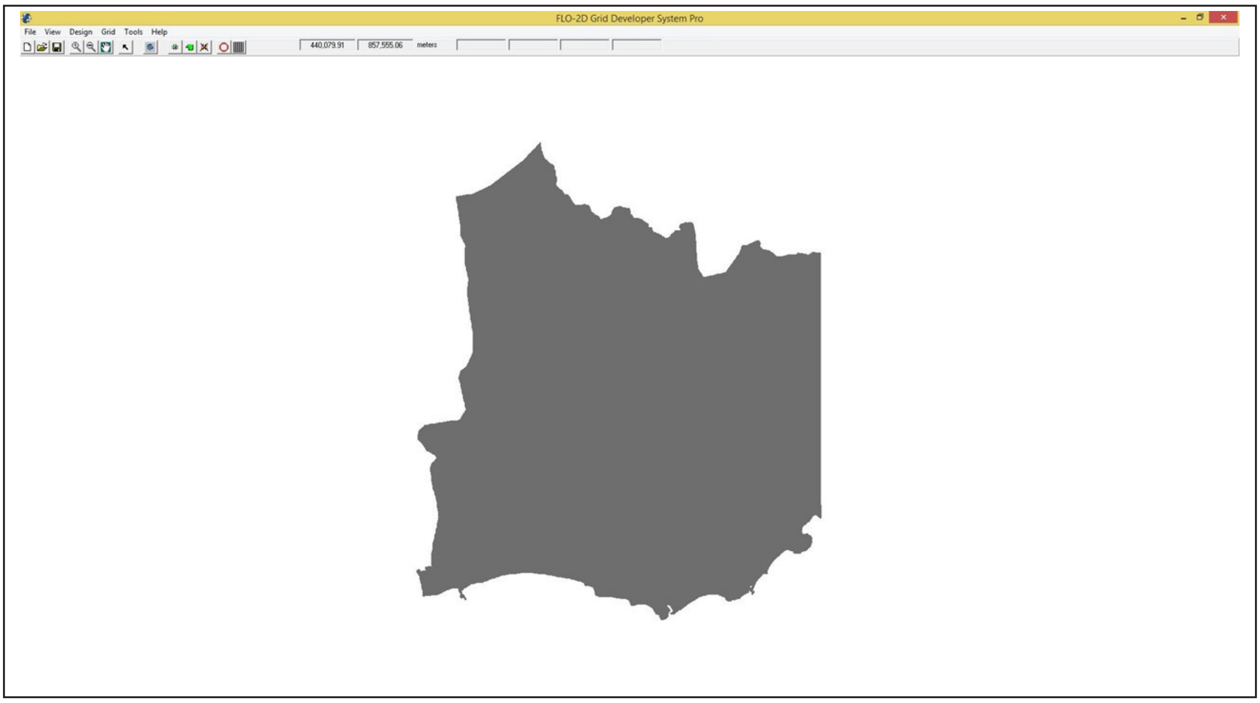


Figure 50. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro).

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 49.64783 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 71,875,680.00 m2.

There is a total of 53,948,279.52 m3 of water entering the model. Of this amount, 21,253,123.09 m3 is due to rainfall while 32,695,156.43 m3 is inflow from other areas outside the model. 7,294,501.50 m3 of this water is lost to infiltration and interception, while 3,439,606.72m3 is stored by the flood plain. The rest, amounting up to 43,214,165.81 m3, is outflow.

5.6 HEC-HMS Model Values (Uncalibrated)

Table 28 shows the range of values of the parameters in the model.

Table 28. Range of values for the Batang-batang River Basin.

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	2 - 10
			Curve Number	45 - 55
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.3 - 3
			Storage Coefficient (hr)	0.4 - 5

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 2 to 10mm means that there is minimal 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 45 to 55 for curve number is lower than advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012).

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.3 hours to 5 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.

5.7 River Analysis Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river was to be shown. Figure 51 shows a generated sample map of the Batang-batang River using the calibrated HMS base flow.

Figure 51. Sample output map of the Batang-batang RAS Model.

5.8 Flood Hazard and Flow Depth Map

The resulting hazard and flow depth maps have a 10m resolution. Figure 52 to Figure 57 show the 5-, 25-, and 100-year rain return scenarios of the Batang-batang floodplain. The floodplain, with an area of 77.81 sq. km., covers one municipality named Narra. Table 29 shows the percentage of area affected by flooding per municipality.

Table 29. Municipalities affected in Batang-batang Floodplain

City / Municipality	Municipality	Total Area	Area Flooded	% Flooded
Palawan	Narra	831.19	77.72	9.35

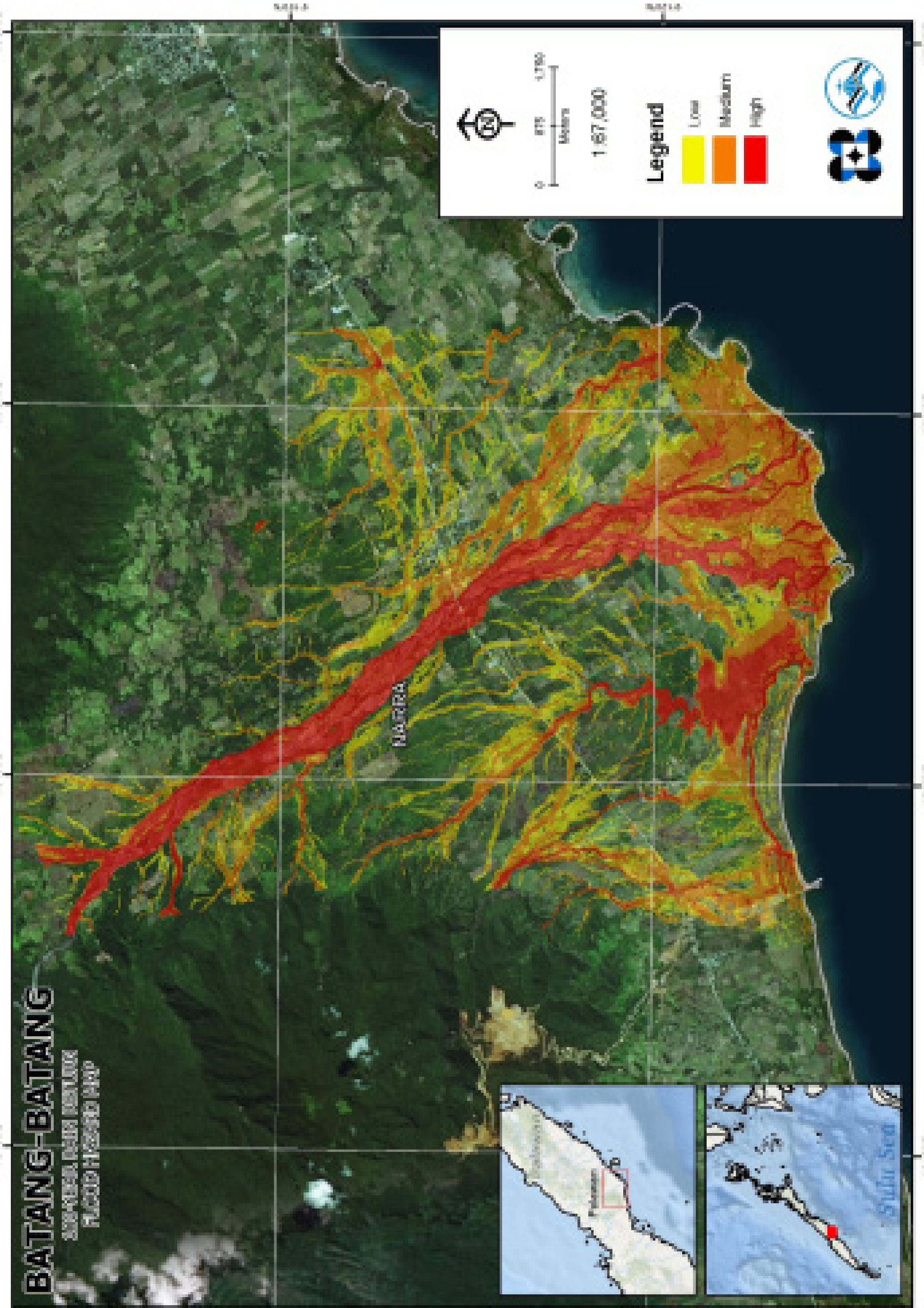


Figure 52. 100-year Flood Hazard Map for Batang-batang Floodplain overlaid in Google Earth imagery

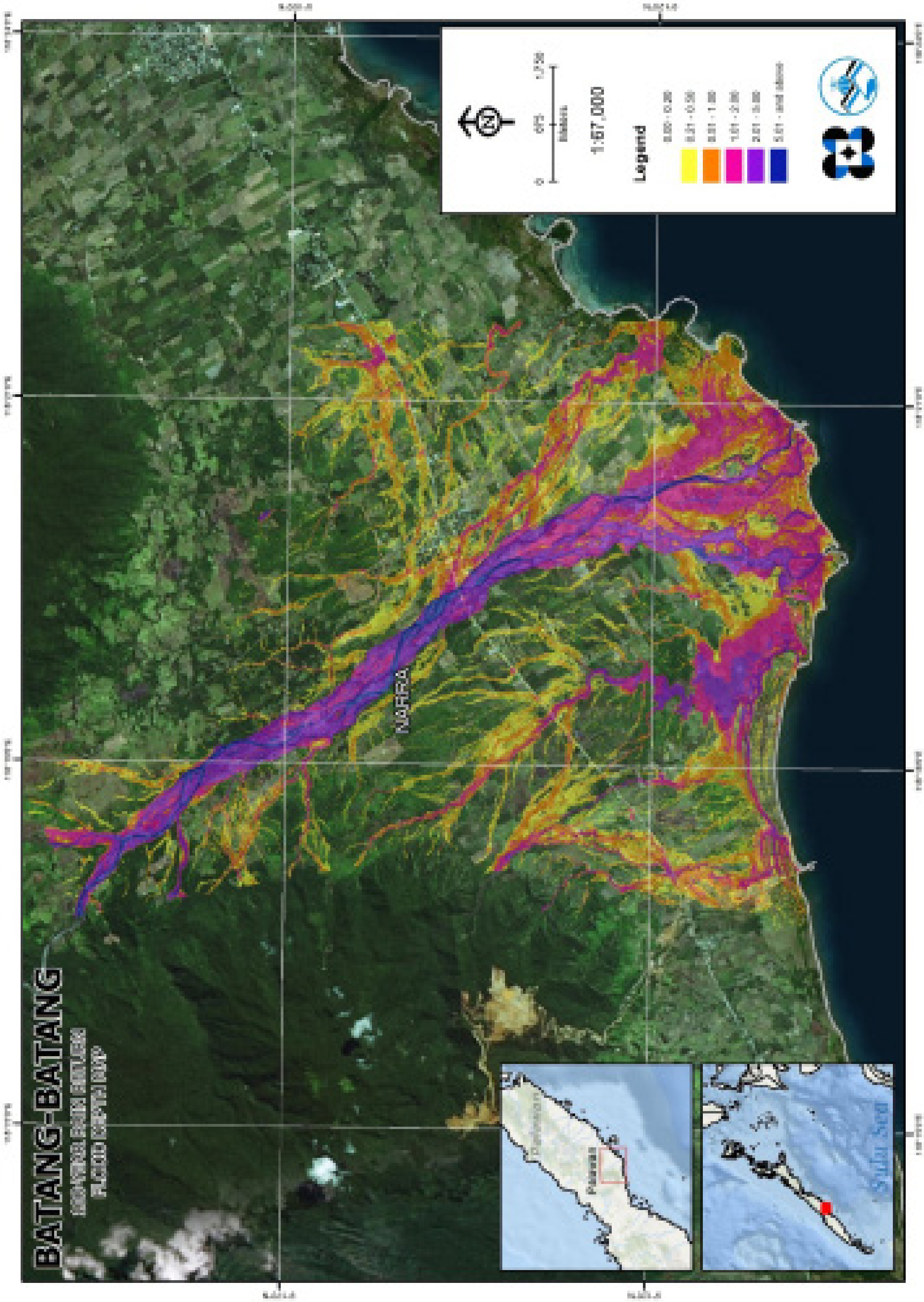


Figure 53. 100-year Flow Depth Map for Batang-batang Floodplain overlaid in Google Earth imagery

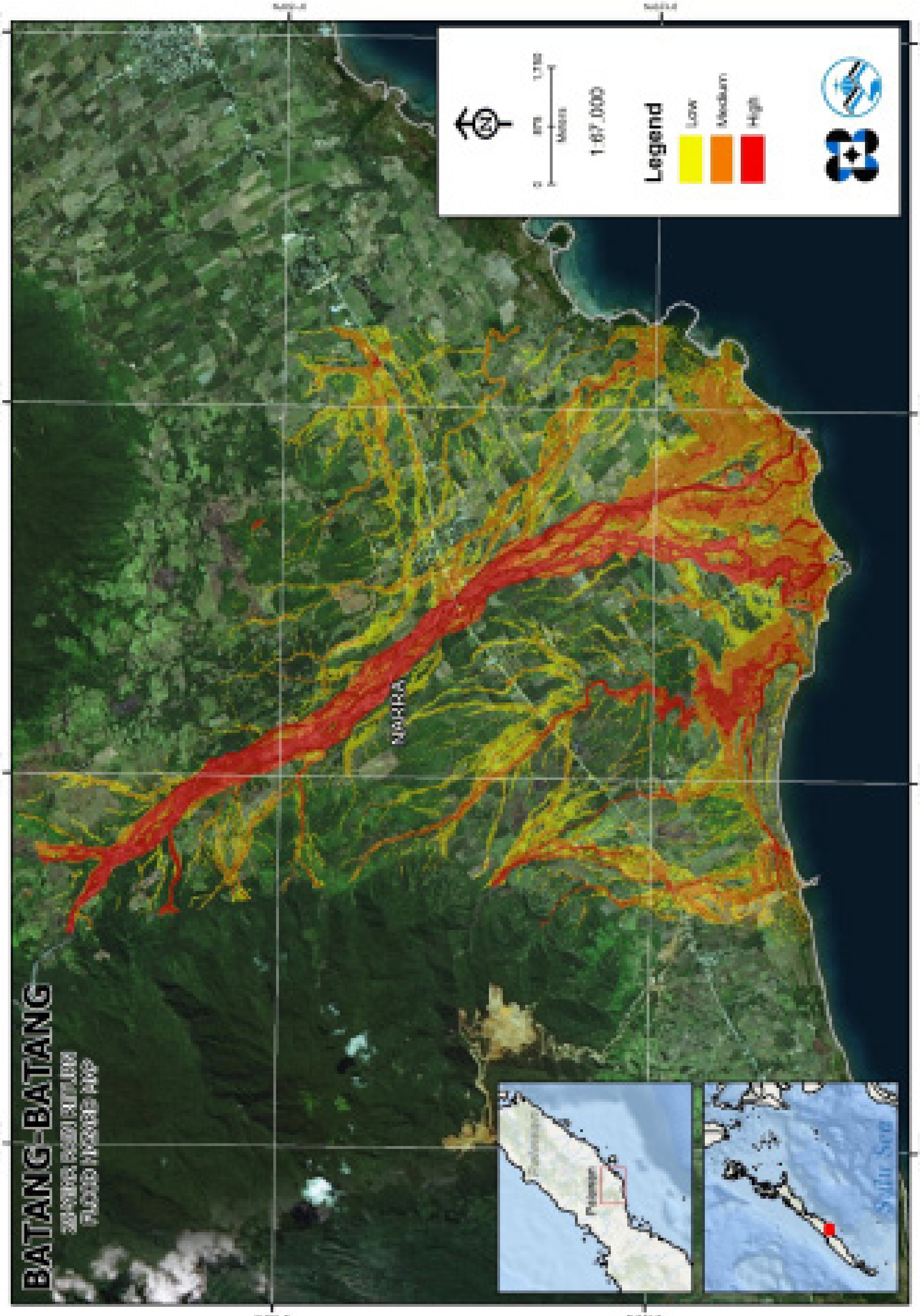


Figure 54. 25-year Flood Hazard Map for Batang-batang Floodplain overlaid in Google Earth imagery

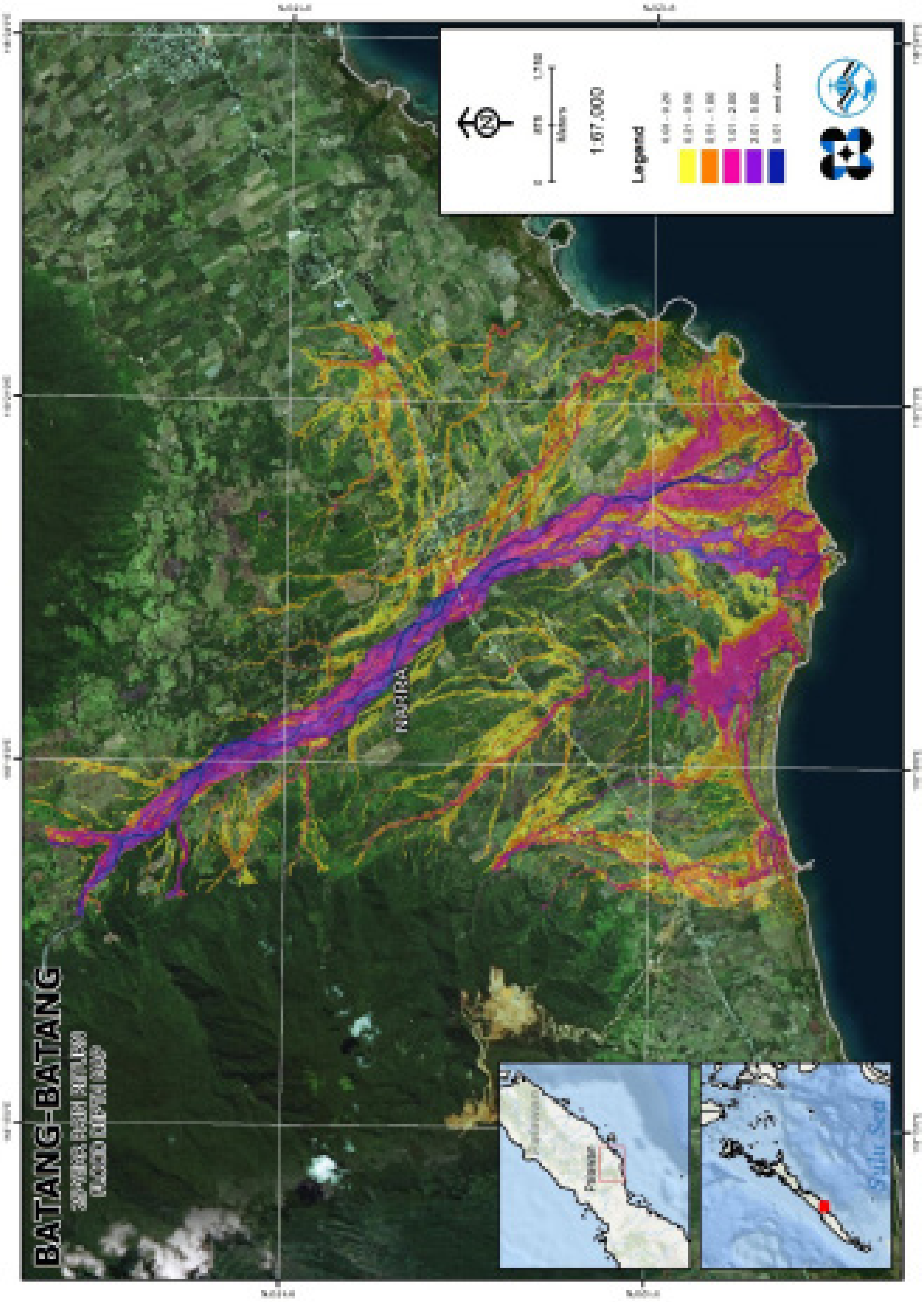


Figure 55. 25-year Flow Depth Map for Batang-batang Floodplain overlaid in Google Earth imagery

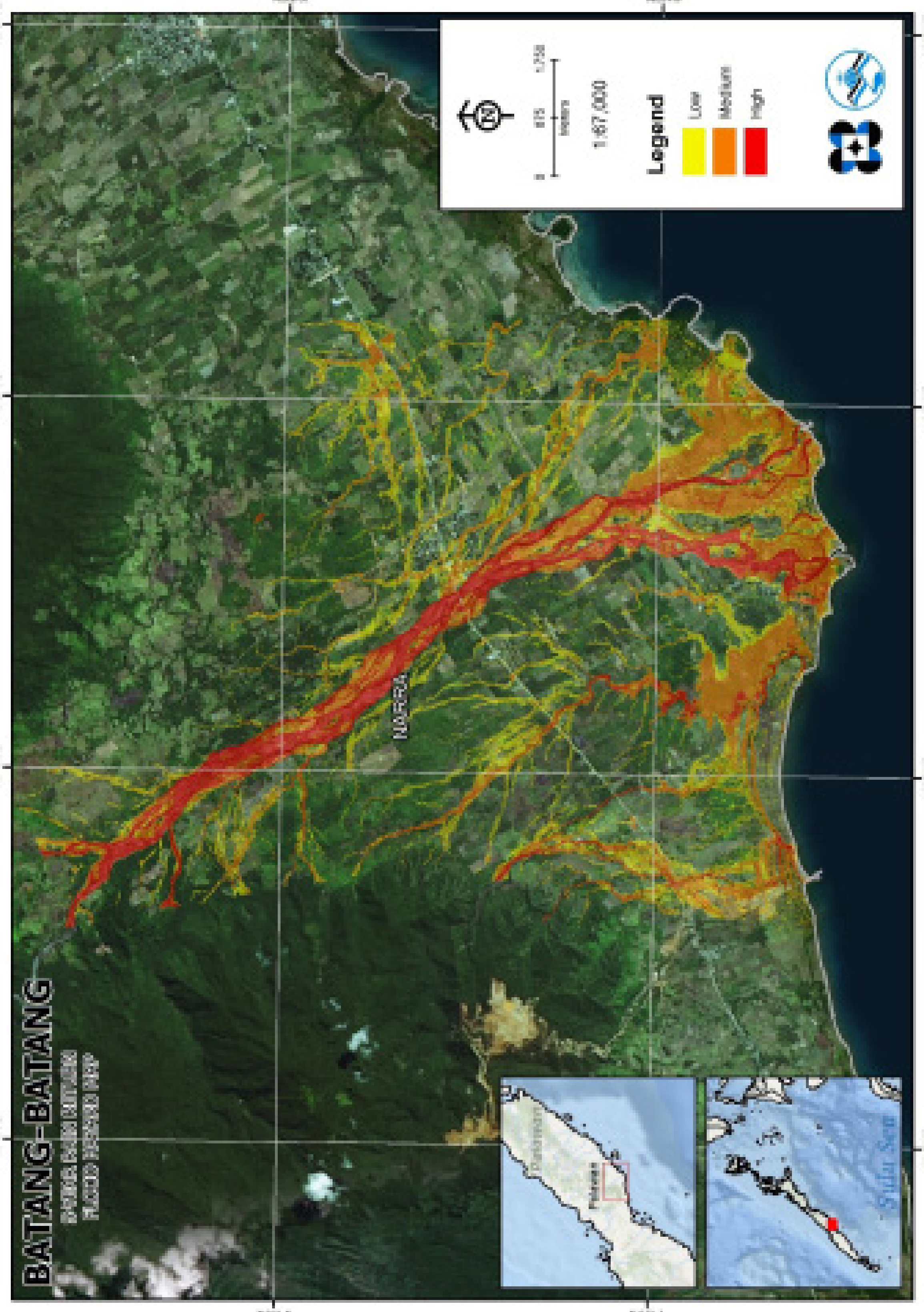


Figure 56. 5-year Flood Hazard Map for Batang-batang Floodplain overlaid in Google Earth imagery

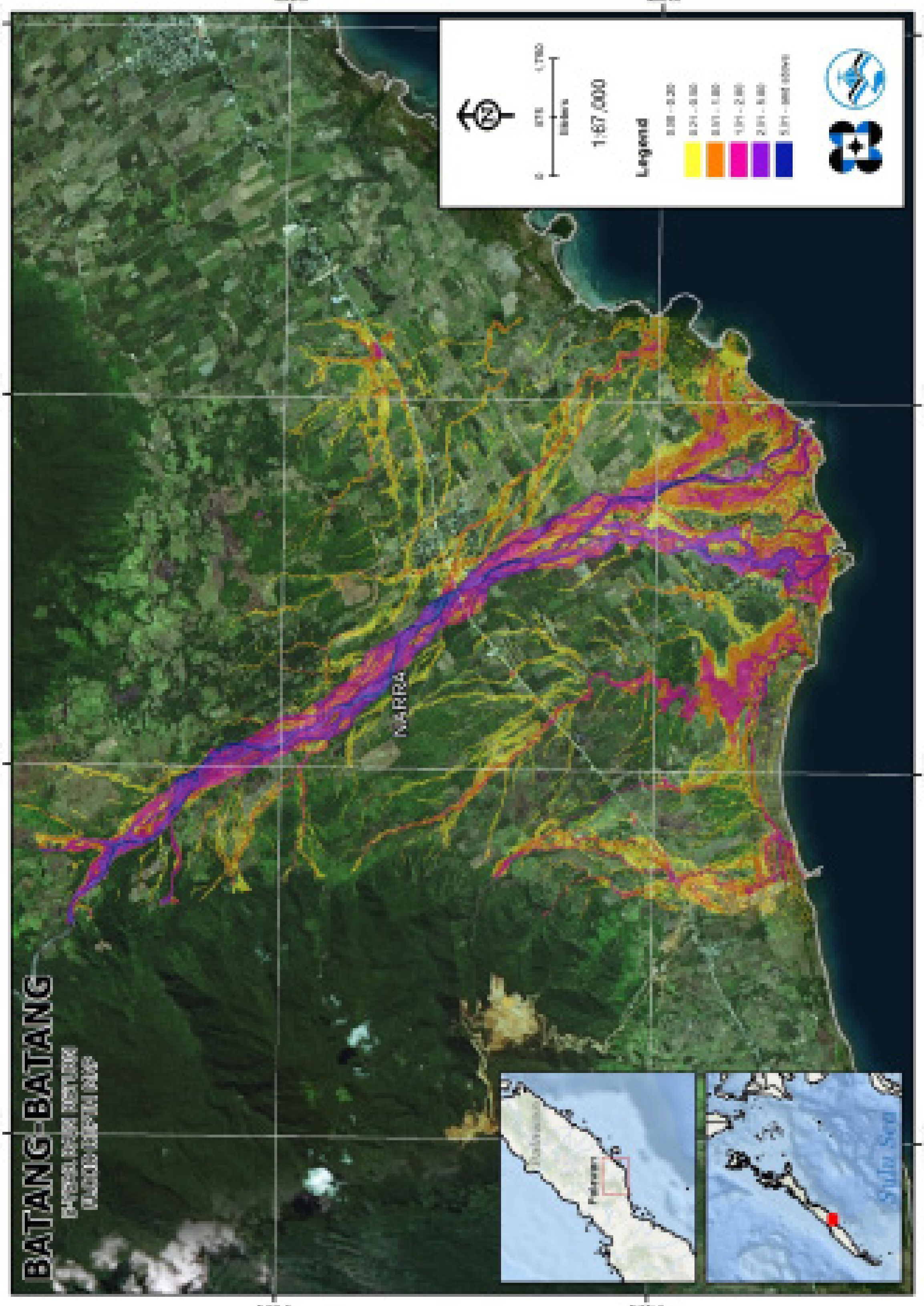


Figure 57. 5-year Flow Depth Map for Batang-batang Floodplain overlaid in Google Earth imagery

5.9 Inventory of Areas Exposed to Flooding

Listed below are the affected barangays in the Batang-batang River Basin, grouped accordingly by municipality. For the said basin, one (1) municipality consisting of six (6) barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 6.36% of the municipality of Narra with an area of 831.19 sq. km. will experience flood levels of less 0.20 meters, while 0.13% of the area will experience flood levels of 0.21 to 0.50 meters; 0.84%, 0.61%, 0.36%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Table 30 depicts the areas affected in Narra in square kilometers by flood depth per barangay.

Table 30. Affected areas in Narra, Palawan during a 5-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Narra (in sq. km.)					
	Batang-Batang	Bato-Bato	Caguisan	Malinao	Princess Urduja	Teresa
0.03-0.20	3.53	11.58	4.79	3.15	13.06	16.76
0.21-0.50	1.42	2.26	1.05	0.78	1.7	2.21
0.51-1.00	2.16	1.36	0.76	0.27	0.93	1.49
1.01-2.00	1.72	0.66	0.19	0.04	0.82	1.62
2.01-5.00	1.1	0.1	0.0022	0.00062	0.63	1.14
> 5.00	0.067	0.0001	0	0.00022	0.11	0.27

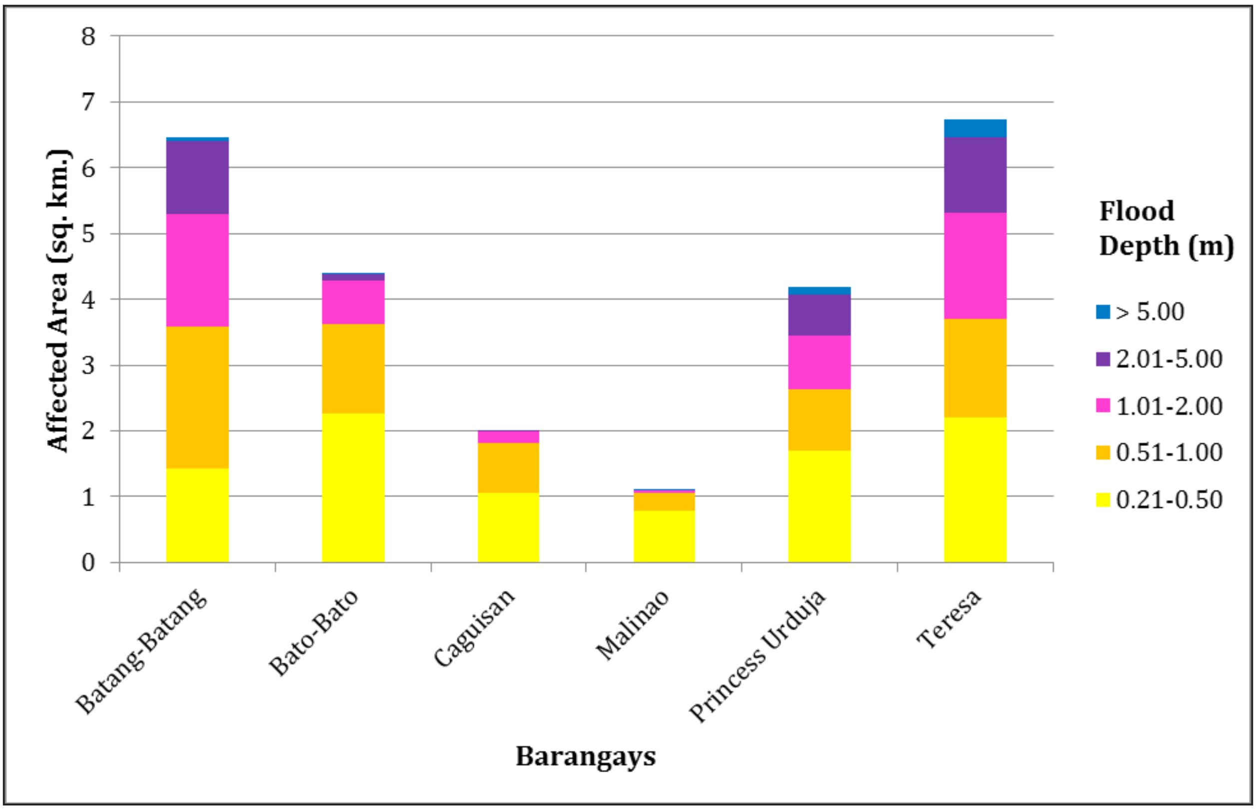


Figure 58. Affected areas in Narra, Palawan during a 5-Year Rainfall Return Period.

For the 25-year return period, 6.36% of the municipality of Narra with an area of 831.19 sq. km. will experience flood levels of less 0.20 meters, while 0.13% of the area will experience flood levels of 0.21 to 0.50 meters; 0.84%, 0.61%, 0.36%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Table 31 depicts the areas affected in Narra in square kilometers by flood depth per barangay.

Table 31. Affected areas in Narra, Palawan during a 25-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Narra (in sq. km.)					
	Batang-Batang	Bato-Bato	Caguisan	Malinao	Princess Urduja	Teresa
0.03-0.20	2.53	10.26	4.22	2.81	12.15	15.35
0.21-0.50	1.29	2.72	1.12	0.89	2.03	2.75
0.51-1.00	2.13	1.78	1.01	0.46	1.11	1.36
1.01-2.00	2.58	1	0.44	0.082	0.91	2.08
2.01-5.00	1.36	0.22	0.0084	0.0011	0.92	1.57
> 5.00	0.095	0.0006	0	0.00036	0.15	0.39

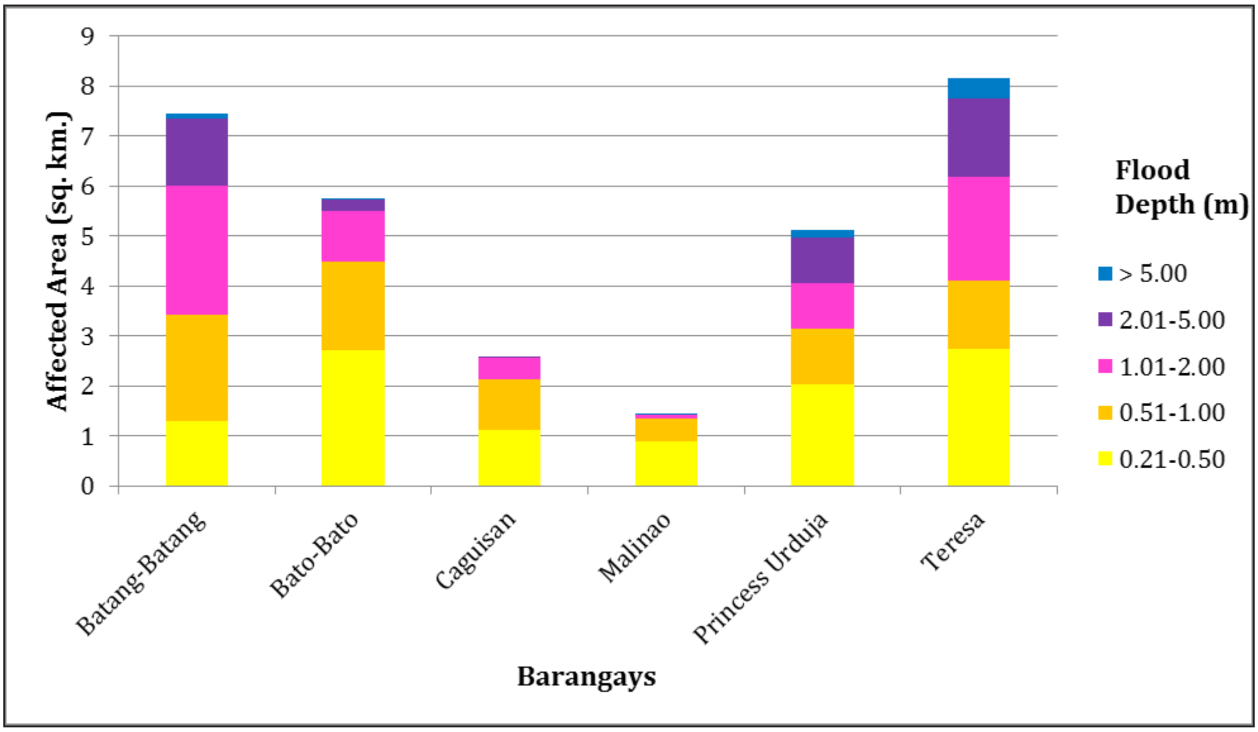


Figure 59. Affected areas in Narra, Palawan during a 25-Year Rainfall Return Period.

For the 100-year return period, 5.25% of the municipality of Narra with an area of 831.19 sq. km. will experience flood levels of less 0.20 meters, while 1.36% of the area will experience flood levels of 0.21 to 0.50 meters; 1.03%, 0.95%, 0.66%, and 0.10% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters respectively. Table 32 depicts the areas affected in Narra in square kilometers by flood depth per barangay.

Table 32. Affected areas in Narra, Palawan during a 100-Year Rainfall Return Period.

Affected area (sq.km.) by flood depth (in m.)	Area of affected barangays in Narra (in sq. km.)					
	Batang-Batang	Bato-Bato	Caguisan	Malinao	Princess Urduja	Teresa
0.03-0.20	1.9	9.47	3.78	2.59	11.48	14.39
0.21-0.50	1.16	2.89	1.1	0.94	2.25	2.98
0.51-1.00	1.89	2.12	1.17	0.58	1.28	1.55
1.01-2.00	3.28	1.11	0.72	0.12	0.84	1.79
2.01-5.00	1.64	0.38	0.029	0.0021	1.22	2.24
> 5.00	0.12	0.0014	0	0.00047	0.2	0.54

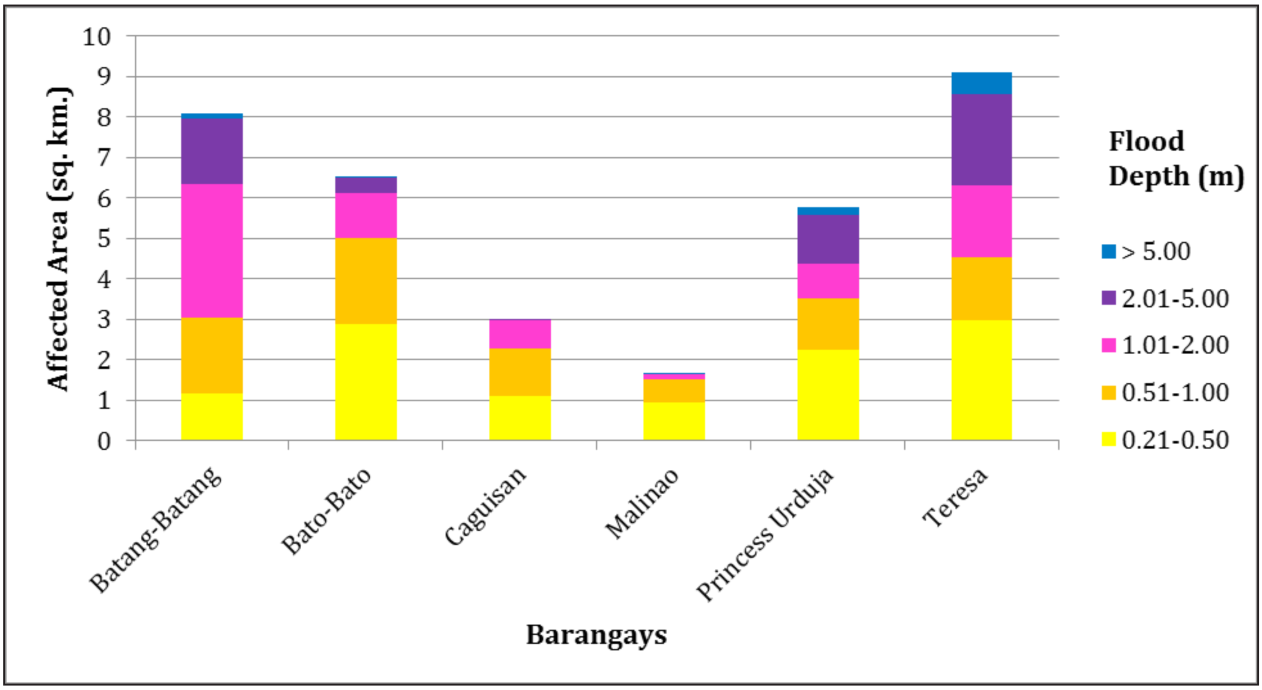


Figure 60. Affected areas in Narra, Palawan during a 100-Year Rainfall Return Period.

Among the barangays in the municipality of Narra, Teresa is projected to have the highest percentage of area that will experience flood levels of at 2.83%. On the other hand, Princesa Urduja posted the percentage of area that may be affected by flood depths of at 2.08%.

5.10 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 were 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.

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 62.

The flood validation consists of 105 points randomly selected all over the Batang-Batang flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.79m. Table 34 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

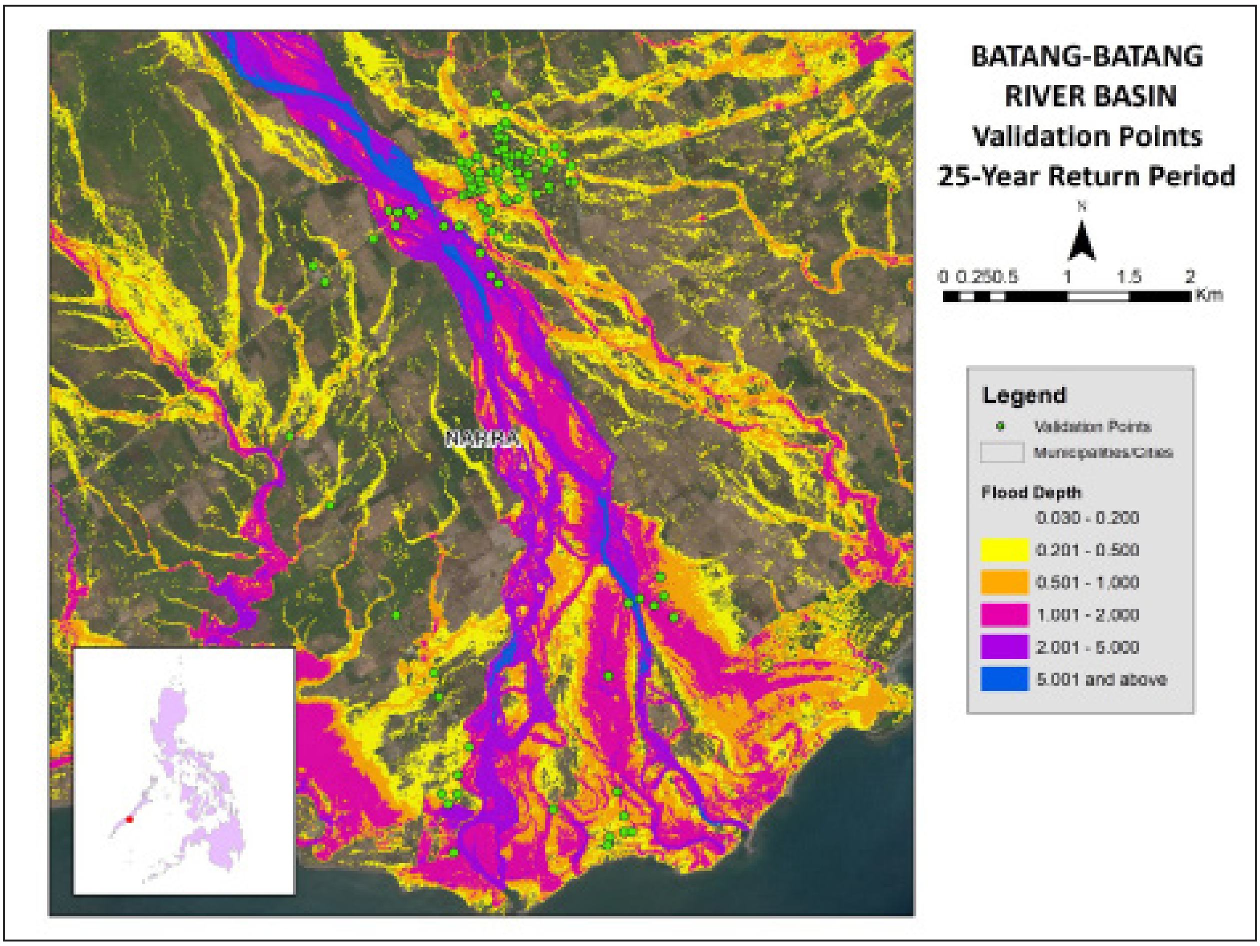


Figure 61. Validation Points for a 25-year Flood Depth Map of the Batang-batang Floodplain.

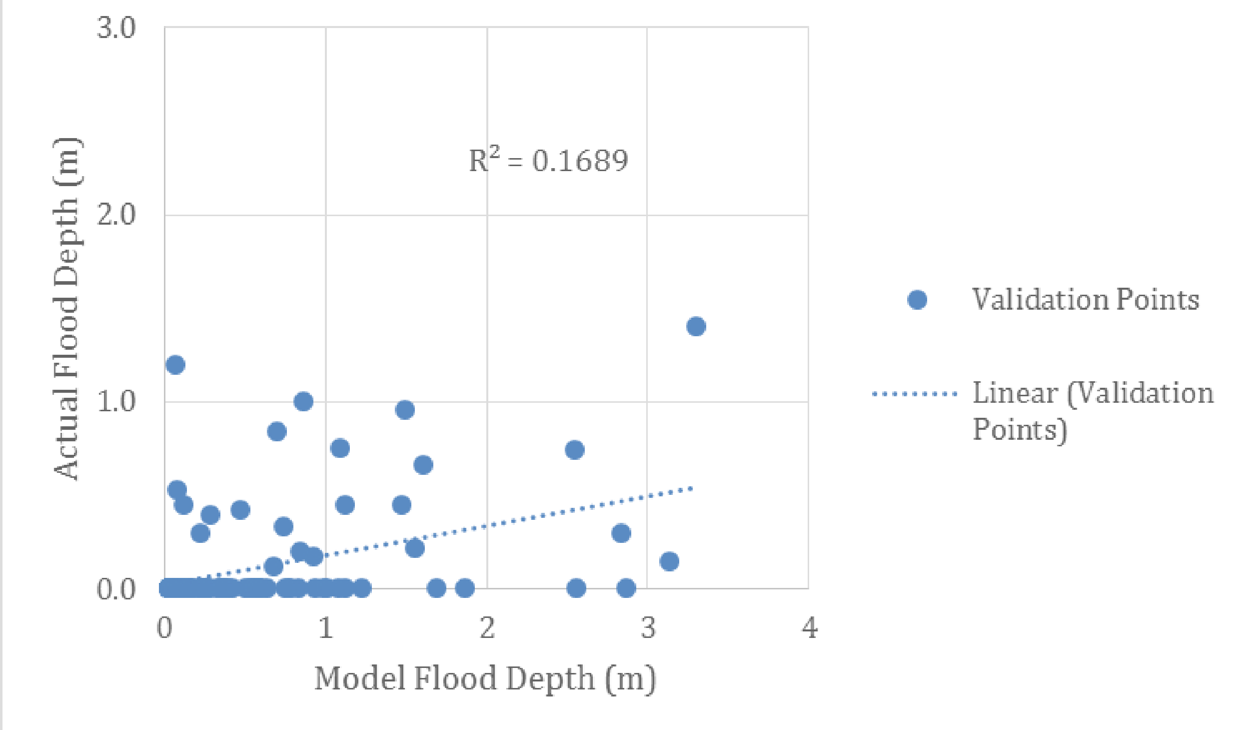


Figure 62. Flood map depth vs. actual flood depth

Table 33. Actual Flood Depth versus Simulated Flood Depth at different levels in the Batang-batang River Basin.

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
0-0.20	39	18	21	6	3	0	87
0.21-0.50	1	3	1	3	1	0	9
0.51-1.00	1	0	2	3	1	0	7
1.01-2.00	1	0	0	0	1	0	2
2.01-5.00	0	0	0	0	0	0	0
> 5.00	0	0	0	0	0	0	0
Total	42	21	24	12	6	0	105

On the whole, the overall accuracy generated by the flood model is estimated at 41.90%, with 44 points correctly matching the actual flood depths. In addition, there were 24 points estimated one level above and below the correct flood depths while there were 26 points and 11 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 4 points were overestimated while a total of 3 points were underestimated in the modelled flood depths of Batang-Batang.

Table 35 depicts the summary of the Accuracy Assessment in the Batang-batang River Basin Flood Depth Map.

Table 34. Summary of Accuracy Assessment in Batang-batang River Basin Survey

	No. of Points	%
Correct	9	6.67
Overestimated	37	27.41
Underestimated	89	65.93
Total	135	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.

Annex 1. Optech Technical Specification of the Sensor

1. AQUARIUS SENSOR

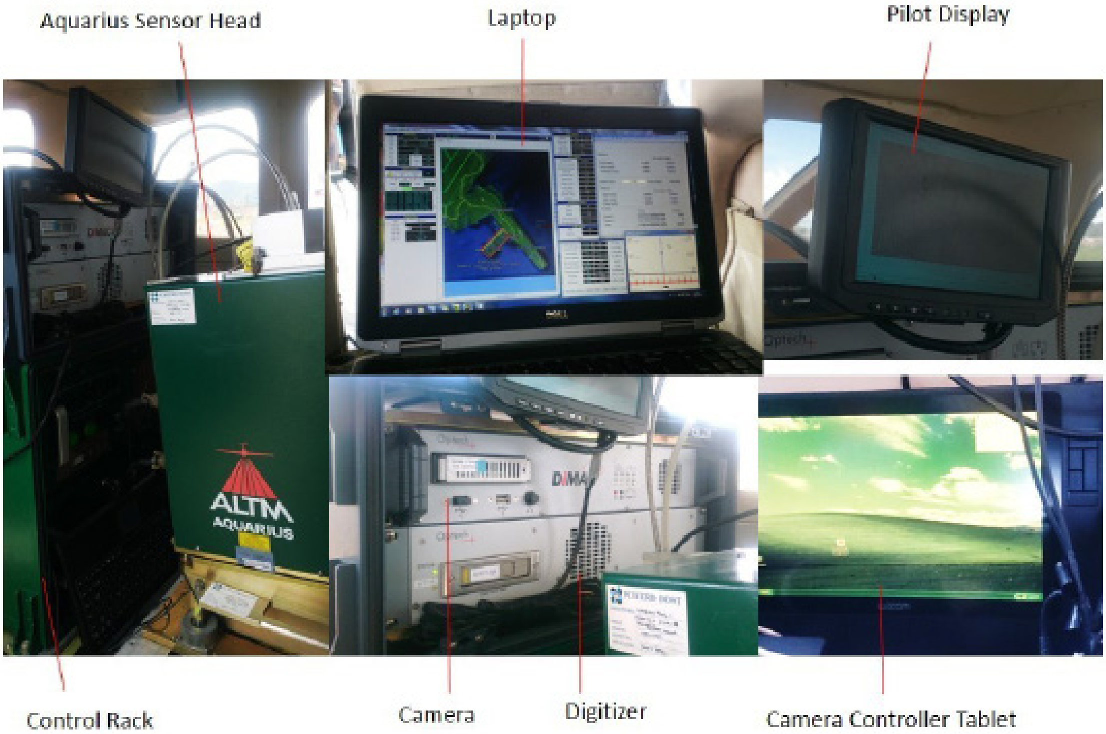


Figure A-1.1 Aquarius Sensor

2. PARAMETERS AND SPECIFICATIONS OF THE AQUARIUS SENSOR

Figure A-1.1 Parameters and Technical Specifications of the Aquarius Sensor

Parameter	Specification
Operational altitude	300-600 m AGL
Laser pulse repetition rate	33, 50. 70 kHz
Scan rate	0-70 Hz
Scan half-angle	0 to ± 25 ˚
Laser footprint on water surface	30-60 cm
Depth range	0 to > 10 m (for k < 0.1/m)
Topographic mode	
Operational altitude	300-2500
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	12-bit dynamic measurement range
Position and orientation system	POS AVTM 510 (OEM) includes embedded 72-channel GNSS receiver (GPS and GLONASS)
Data Storage	Ruggedized removable SSD hard disk (SATA III)
Power	28 V, 900 W, 35 A
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Dimensions and weight	Sensor:250 x 430 x 320 mm; 30 kg; Control rack: 591 x 485 x 578 mm; 53 kg
Operating temperature	0-35˚C
Relative humidity	0-95% no-condensing
Relative humidity	0-95% non-condensing

3. PEGASUS SENSOR

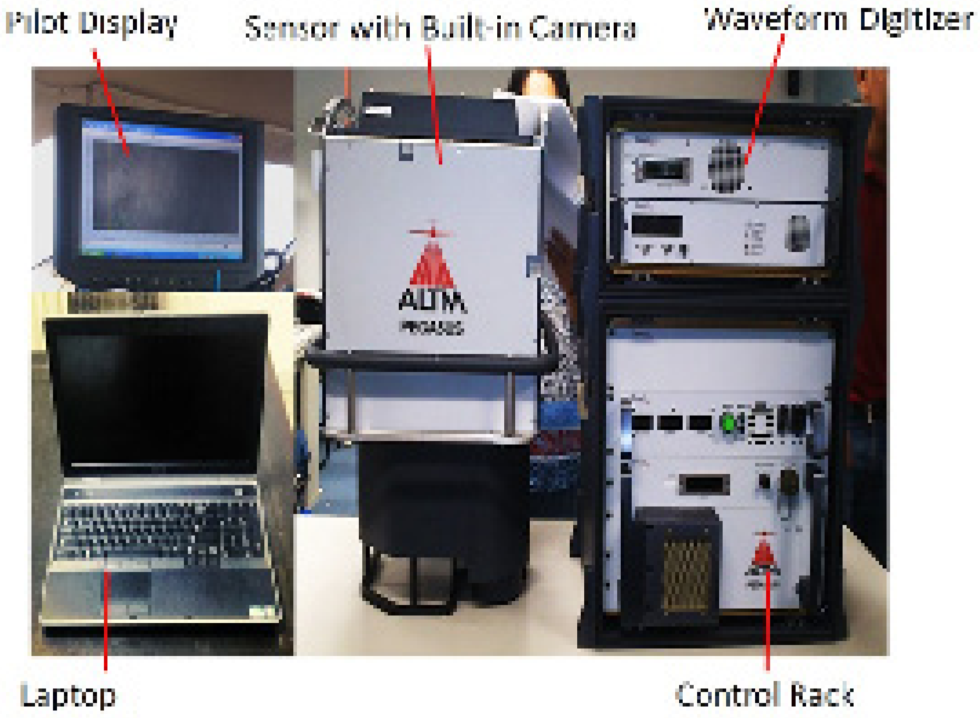


Figure A-1.2 Pegasus Sensor

4. PARAMETERS AND SPECIFICATIONS OF THE PEGASUS SENSOR

Figure A-1.2 Parameters and Technical Specifications of the Pegasus Sensor

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

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

Annex 2. NAMRIA Certificates of Reference Points Used

1. MRW-18

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

December 11, 2015

CERTIFICATION

To whom it may concern:

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

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

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

Location Description

MRW-18

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1 MRW-18

2. MRW-22

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-22**
Order: **2nd**

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

Location Description

MRW-22

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

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

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

CIP/4701/12/09/814

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

Figure A-2.2 MRW-22

3. MRE-56

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

October 28, 2015

CERTIFICATION

To whom it may concern:

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

	Province: **ORIENTAL MINDORO**	
	Station Name: **MRE-56**	
	Order: **2nd**	
Island: **LUZON**	Barangay:	
Municipality: **MANSALAY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **12° 31' 25.76362"**	Longitude: **121° 26' 25.21109"**	Ellipsoidal Hgt: **7.87000 m.**
	WGS84 Coordinates	
Latitude: **12° 31' 20.87629"**	Longitude: **121° 26' 30.28143"**	Ellipsoidal Hgt: **58.13600 m.**
	PTM / PRS92 Coordinates	
Northing: **1384916.657 m.**	Easting: **547957.861 m.**	Zone: **3**
	UTM / PRS92 Coordinates	
Northing: **1,384,892.31**	Easting: **330,530.08**	Zone: **51**

Location Description

MRE-56

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

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

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

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

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-2.3 MRE-56

4. MRW-4203

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

March 25, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-4203**
Order: **3rd**

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

PRS92 Coordinates

Latitude: **12° 21' 24.45294"**	Longitude: **121° 7' 26.92407"**	Ellipsoidal Hgt: **7.40100 m.**

WGS84 Coordinates

Latitude: **12° 21' 19.57973"**	Longitude: **121° 7' 32.01059"**	Ellipsoidal Hgt: **57.32000 m.**

PTM Coordinates

Northing: **1366404.003 m.**	Easting: **513501.246 m.**	Zone: **3**

UTM Coordinates

Northing: **1,366,637.32**	Easting: **296,032.79**	Zone: **51**

Location Description

MRW-4203

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.4 MRW-4203

5. MRW-4205

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

March 04, 2014

CERTIFICATION

To whom it may concern:

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

Province: **OCCIDENTAL MINDORO**
Station Name: **MRW-4205**
Order: **3rd**

Island: **LUZON**		Barangay: **CENTRAL**
Municipality: **SAN JOSE**		
	PRS92 Coordinates	
Latitude: **12° 26' 8.33964"**	Longitude: **121° 2' 46.62783"**	Ellipsoidal Hgt: **12.56900 m.**
	WGS84 Coordinates	
Latitude: **12° 26' 3.44072"**	Longitude: **121° 2' 51.70789"**	Ellipsoidal Hgt: **62.09500 m.**
	PTM Coordinates	
Northing: **1375124 m.**	Easting: **506032.188 m.**	Zone: **3**
	UTM Coordinates	
Northing: **1,375,422.19**	Easting: **287,627.78**	Zone: **51**

Location Description

MRW-4205

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

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

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

9903042014140315

CERTIFICATION INTERNATIONAL ISO 9001:2008
CP/4001/12/08/654

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

Figure A-2.5 MRW-4205

Annex 3. Baseline Processing Report of Reference Points Used

Project information		Coordinate System	
Name:	C:\Users\qwerty\Documents\Business Center - HCE\mrw18-mrw18a.vce	Name:	UTM
Size:	156 KB	Datum:	PRS 92
Modified:	12/21/2015 2:56:44 PM (UTC:8)	Zone:	51 North (123E)
Time zone:	Taipei Standard Time	Geoid:	EGMPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
MRW-18 --- MRW-18a (B1)	MRW-18	MRW-18a	Fixed	0.001	0.002	312°48'54"	6.566	0.551

Acceptance Summary

Processed	Passed	Flag	Fail
1	1	0	0

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

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

1

Figure A-3.1 Baseline Processing Report - A

Vector Components (Mark to Mark)

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

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

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

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

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

2

Figure A-3.2 Baseline Processing Report - B

Annex 4. The LiDAR Survey Team Composition

Figure A-4.1 LiDAR Survey Team Composition

<table>
<tr><th>Data Acquisition Component Sub -Team</th><th>Designation</th><th>Name</th><th>Agency / Affiliation</th></tr>
<tr><td>PHIL-LIDAR 1</td><td>Program Leader</td><td>ENRICO C. PARINGIT, D.ENG</td><td>UP-TCAGP</td></tr>
<tr><td>Data Acquisition Component Leader</td><td>Data Component Project Leader – I</td><td>ENGR. CZAR JAKIRI SARMIENTO</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="3">Survey Supervisor</td><td>Chief Science Research Specialist (CSRS)</td><td>ENGR. CHRISTOPHER CRUZ</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Supervising Science Research Specialist (Supervising SRS)</td><td>LOVELY GRACIA ACUÑA</td><td>UP-TCAGP</td></tr>
<tr><td>LOVELYN ASUNCION</td><td>UP-TCAGP</td></tr>
</table>

FIELD TEAM

<table>
<tr><td rowspan="5">LiDAR Operation</td><td>Senior Science Research Specialist (SSRS)</td><td>PAULINE JOANNE ARCEO</td><td>UP-TACGP</td></tr>
<tr><td>Research Associate (RA)</td><td>PATRICIA YSABEL ALCANTARA</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>ENGR. LARAH KRISELLE PARAGAS</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>ENGR. MILLIE SHANE REYES</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>GRACE SINADJAN</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="2">Ground Survey, Data Download and Transfer</td><td>RA</td><td>ENGR. FRANK NICOLAS ILEJAY</td><td>UP-TCAGP</td></tr>
<tr><td>RA</td><td>GRACE SINADJAN</td><td>UP-TCAGP</td></tr>
<tr><td rowspan="6">LiDAR Operation</td><td rowspan="2">Airborne Security</td><td>SSG. ERIC CACANINDIN</td><td>PHILIPPINE AIR FORCE (PAF)</td></tr>
<tr><td>SSG. BENJAMIN CARBOLLEDO</td><td>PAF</td></tr>
<tr><td rowspan="4">Pilot</td><td>CAPT. JEFFREY JEREMY ALAAR</td><td>ASIAN AEROSPACE CORPORATION (AAC)</td></tr>
<tr><td>CAPT. JACKSON JAVIER</td><td>AAC</td></tr>
<tr><td>CAPT. SHERWIN ALFONSO III</td><td>AAC</td></tr>
<tr><td>CAPT. JUSTINE JOYA</td><td>AAC</td></tr>
</table>

Annex 5. Data Transfer Sheet For Batang-batang Floodplain

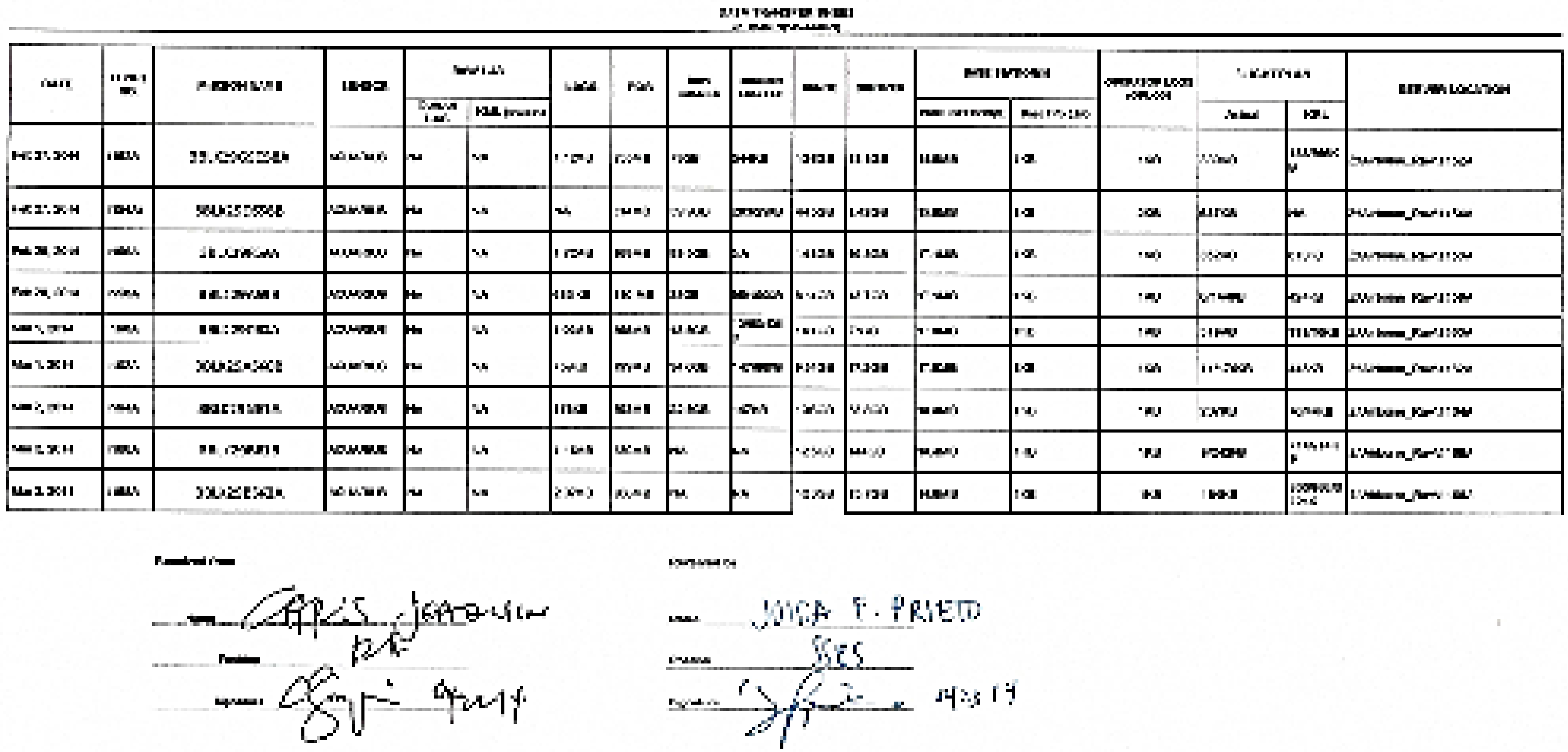


Figure A-5.1 Data Transfer Sheet for Batang-batang Floodplain - A

DATA TRANSFER SHEET
Occ. Mindoro 1/13/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
6-Dec-15	3058P	1BLK29C340A	pegasus	732	109	5.09	120	8.79	74	7.26	na	10.4	1KB	1KB	40	na	Z:\DAC\RAW DATA
6-Dec-15	3060P	1BLK29DE340B	pegasus	480	108	5.83	118	6.06	48	4.79	na	10.4	1KB	1KB	284/284/30	na	Z:\DAC\RAW DATA
7-Dec-15	3062P	1BLK29BCS341A	pegasus	1.40	430	9.18	208	20.8	100	14.4	na	7.01	1KB	1KB	100/88/98	na	Z:\DAC\RAW DATA
8-Dec-15	3066P	1BLK29ACDS342A	pegasus	982	278	7.18	177	57	121	8.79	na	18	1KB	1KB	140/150	na	Z:\DAC\RAW DATA
8-Dec-15	3068P	1BLK29GJ342B	pegasus	6	67	2.7	114	4.83	37	2.77	na	15	1KB	1KB	140/156	na	Z:\DAC\RAW DATA
9-Dec-15	3070P	1BLK29GHS343A	pegasus	953	217	5.7	140	14.3	na	0.37	na	6.98	1KB	1KB	148/168	na	Z:\DAC\RAW DATA
10-Dec-15	3074P	1BLK29KLMOS344A	pegasus	2.39	272	9.12	225	30.9	224	20.7	na	14.1	1KB	1KB	313	na	Z:\DAC\RAW DATA
10-Dec-15	3076P	1BLK29P344B	pegasus	258	73	3.5	102	4.32	34	3.2	na	14.1	1KB	1KB	366/316/320/315/146/158	na	Z:\DAC\RAW DATA
11-Dec-15	3078P	1BLK29NQRS345A	pegasus	641	171	5.29	167	12.9	105	8.2	na	7.02	1KB	1KB	47/394/344/313/140	na	Z:\DAC\RAW DATA
12-Dec-15	3082P	1BLK29R346A	pegasus	802	208	6.85	174	15.1	96	6.32	na	7.41	1KB	1KB	47/140	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position
Signature

Received by

Name AC Bongat
Position SSRA
Signature 1/13/16

Figure A-5.2 Data Transfer Sheet for Batang-batang Floodplain - B

Annex 6. Flight Logs

1. Flight Log for 3BLK29A59B Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1157

1 LiDAR Operator: L Ascuncion	2 ALTM Model: AQUA	3 Mission Name: 3BLK29A59B	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: J Alajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 2/28/14	12 Airport of Departure (Airport, City/Province): Mambusao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1433	14 Engine Off: 1814	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

Completed 10 lines in area A

21 Problems and Solutions:

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

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

Pilot-in-Command
Jeffrey Alajar
Signature over Printed Name

Lidar Operator
Signature over Printed Name

Figure A-6.1 Flight Log for Mission 3BLK29A59B

2. Flight Log for 3BLK29C60A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1160

1 LiDAR Operator: I.R. Pangga	2 ALTM Model: AGUA	3 Mission Name: 3BLK29C60A	4 Type: VFR	5 Aircraft Type: Cessna T206H	6 Aircraft Identification:
7 Pilot: J. Javier	8 Co-Pilot: J. Alajar	9 Route:			
10 Date: 3/1/14	12 Airport of Departure (Airport, City/Province): Mambucao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 822	14 Engine Off: 1257	15 Total Engine Time: 4+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission Completed					

21 Problems and Solutions:

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

Figure A-6.2 Flight Log for Mission 3BLK29C60A

3. Flight Log for 3BLK29AS60B Mission

Flight Log No.: 1162

REAM Data Acquisition Flight Log

1 LiDAR Operator: L Asuncion	2 ALTM Model: AQUA	3 Mission Name: 3BLK29AS60B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Javier	8 Co-Pilot: J Alajar	9 Route:			
10 Date: 3/1/14	12 Airport of Departure (Airport, City/Province): Mamburao		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1438	14 Engine Off: 1819	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission completed					

21 Problems and Solutions:

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

Figure A-6.3 Flight Log for Mission 3BLK29AS60B

4. Flight Log for 3BLK29N61A Mission

EAM Data Acquisition Flight Log

Flight Log No.: 1164

1 LiDAR Operator: LK Paragas	2 ALTM Model: AQUA	3 Mission Name: 3BLK29N61A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J Alajar	8 Co-Pilot: J Javier	9 Route:			
10 Date: 3/2/14	12 Airport of Departure (Airport, City/Province): Nambuan		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0812	14 Engine Off: 1305	15 Total Engine Time: 4 + 53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Mission Completed					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
	TEC CACANINDIN	JEFFREY ALAJAR	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.4 Flight Log for Mission 3BLK29N61A

5. Flight Log for 3BLK29B61B Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1166

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

21 Problems and Solutions:

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

Figure A-6.5 Flight Log for Mission 3BLK29B61B

6. Flight Log for 3BLK29BS62A Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1168

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

20 Remarks:

Mission completed

21 Problems and Solutions:

Acquisition Flight Approved by

Signature over Printed Name
(End User Representative)

Acquisition Flight Certified by

JEC CADAPAN

Signature over Printed Name
(PAF Representative)

Pilot-in-Command

J Javier

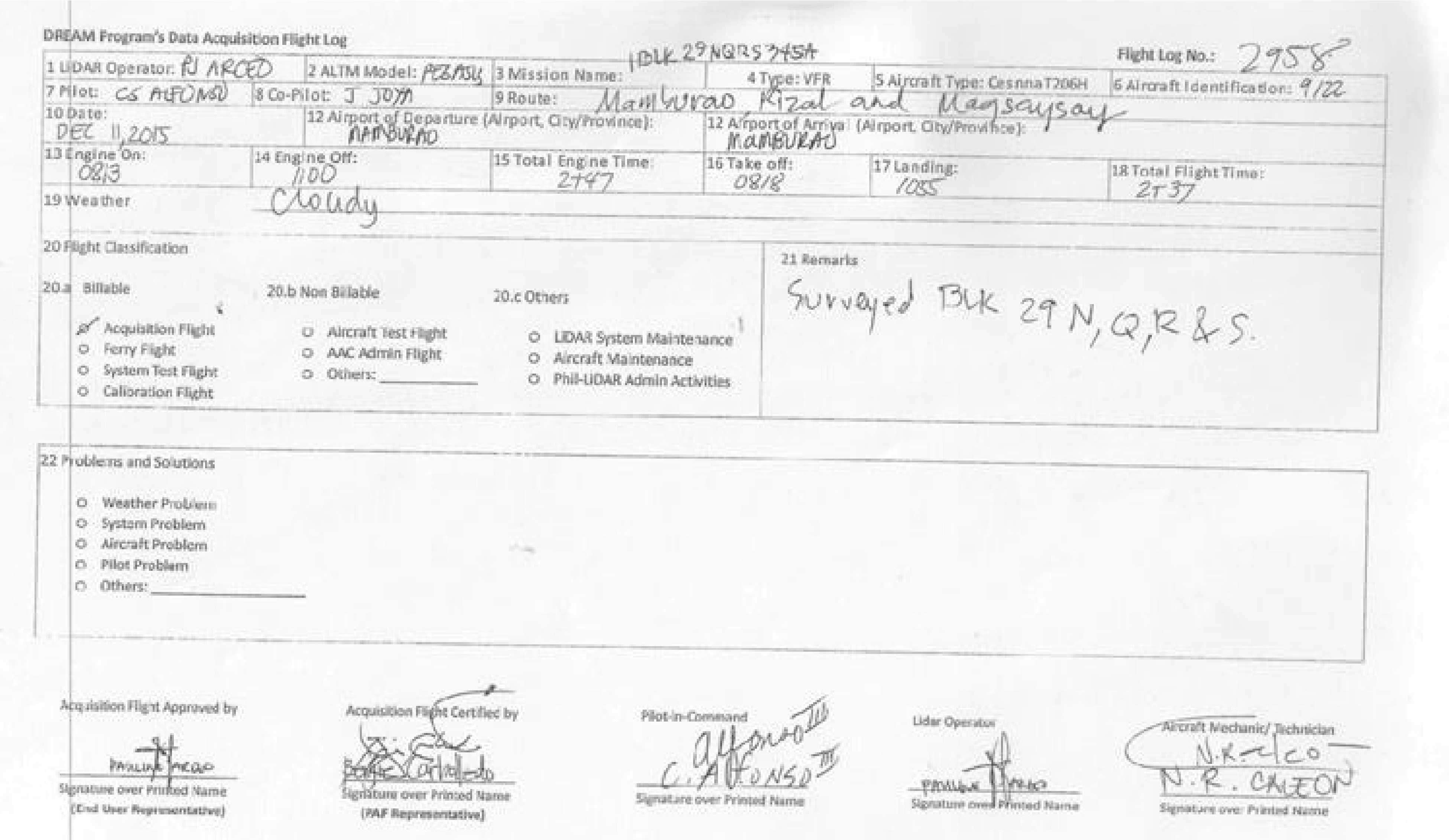
Signature over Printed Name

Lidar Operator

Signature over Printed Name

Figure A-6.6 Flight Log for Mission 3BLK29BS62A

7. Flight Log for 1BLK29NQRS345A Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 2958

1 LiDAR Operator: PJ ARCEO | 2 ALTM Model: PEGASUS | 3 Mission Name: 1BLK29NQRS345A | 4 Type: VFR | 5 Aircraft Type: CesnnaT206H | 6 Aircraft Identification: 9122

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

10 Date: DEC 11, 2015 | 12 Airport of Departure (Airport, City/Province): MAMBURAO | 12 Airport of Arrival (Airport, City/Province): MAMBURAO

13 Engine On: 0813 | 14 Engine Off: 1100 | 15 Total Engine Time: 2+47 | 16 Take off: 0818 | 17 Landing: 1055 | 18 Total Flight Time: 2+37

19 Weather: Cloudy

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 29N,Q,R & S.

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

Acquisition Flight Approved by: PAULINE ARCEO, Signature over Printed Name (End User Representative)

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

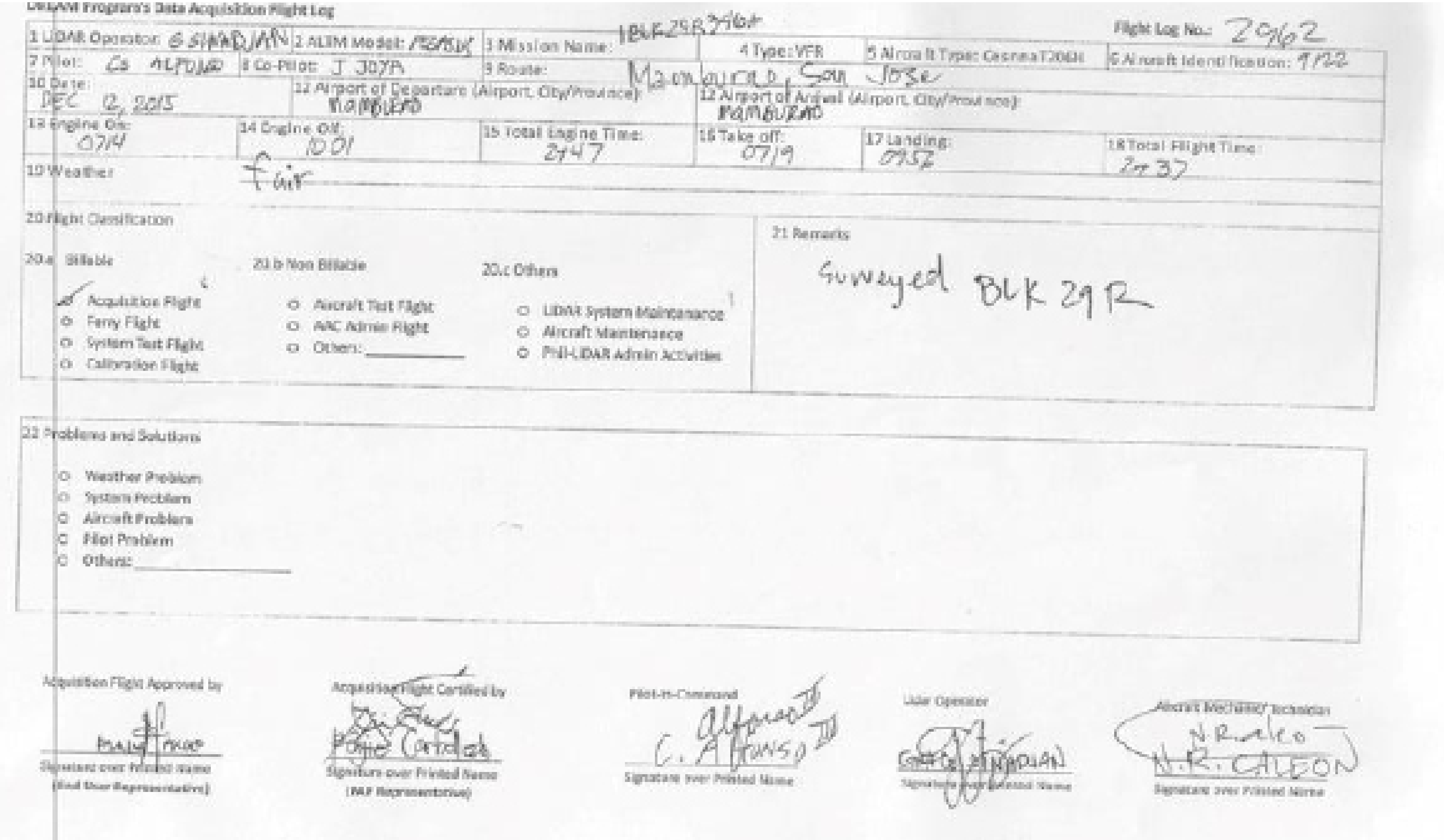
Pilot-in-Command: C. ALFONSO III, Signature over Printed Name

Lidar Operator: PAULINE ARCEO, Signature over Printed Name

Aircraft Mechanic/ Technician: N.R. CAJEON, Signature over Printed Name

Figure A-6.7 Flight Log for Mission 1BLK29NQRS345A

8. Flight Log for 1BLK29R346A Mission



DREAM Program's Data Acquisition Flight Log

Flight Log No.: 20962

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

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 29R

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

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

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

Pilot-in-Command: C. ALFONSO III — Signature over Printed Name

Lidar Operator: G SINADJAN — Signature over Printed Name

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

Figure A-6.8 Flight Log for Mission 1BLK29R346A

Annex 7. Flight Status

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

Table A-7.1 Flight Status Report

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

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

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

SURVEY COVERAGE:

Figure A-7.1 Swath for Flight No. 1158A

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

SURVEY COVERAGE:

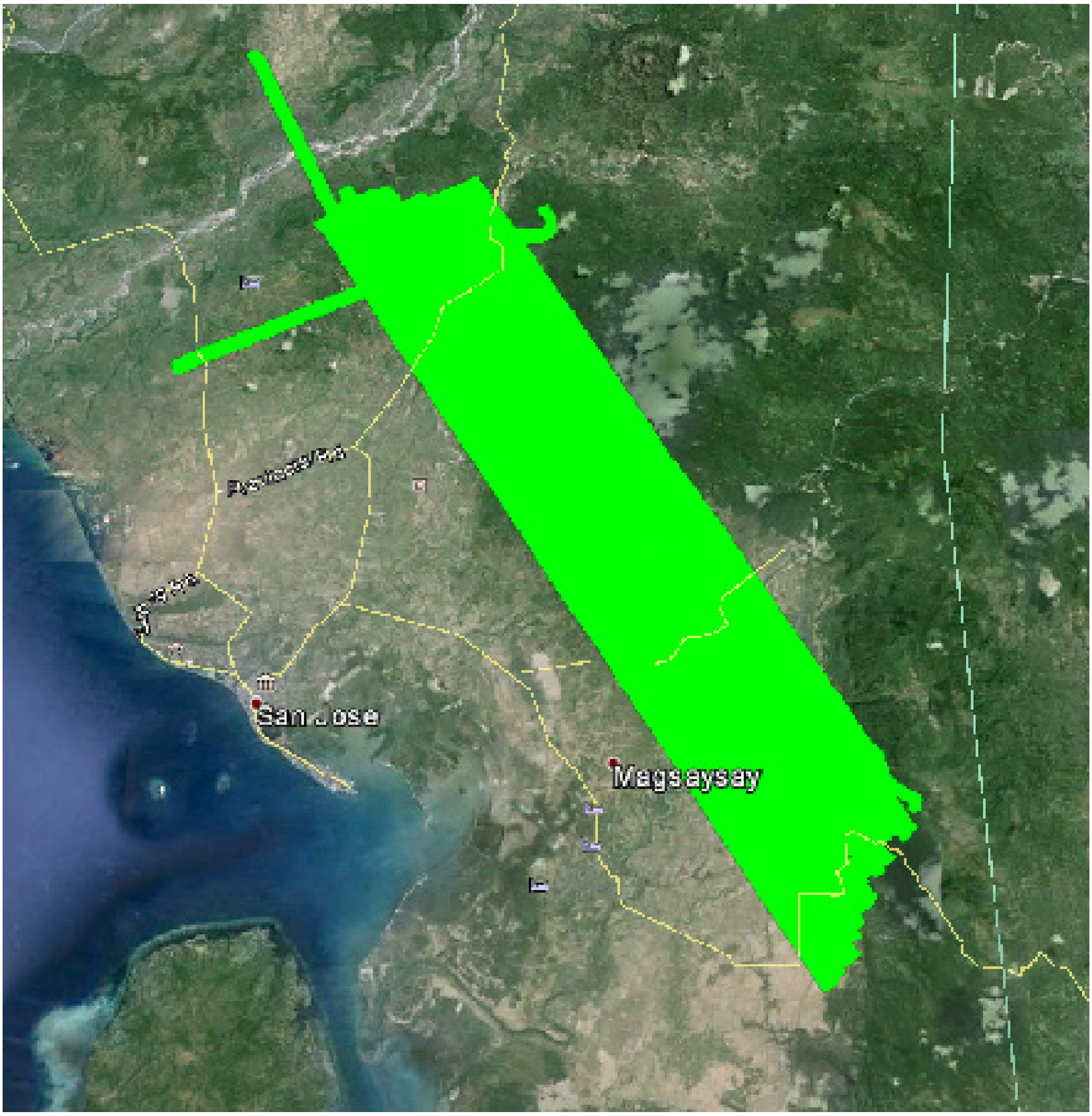


Figure A-7.2 Swath for Flight No. 1160A

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

SURVEY COVERAGE:

Figure A-7.3 Swath for Flight No. 1162A

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

SURVEY COVERAGE:

Figure A-7.4 Swath for Flight No. 1164A

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

SURVEY COVERAGE:

Figure A-7.5 Swath for Flight No. 1166A

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

SURVEY COVERAGE:

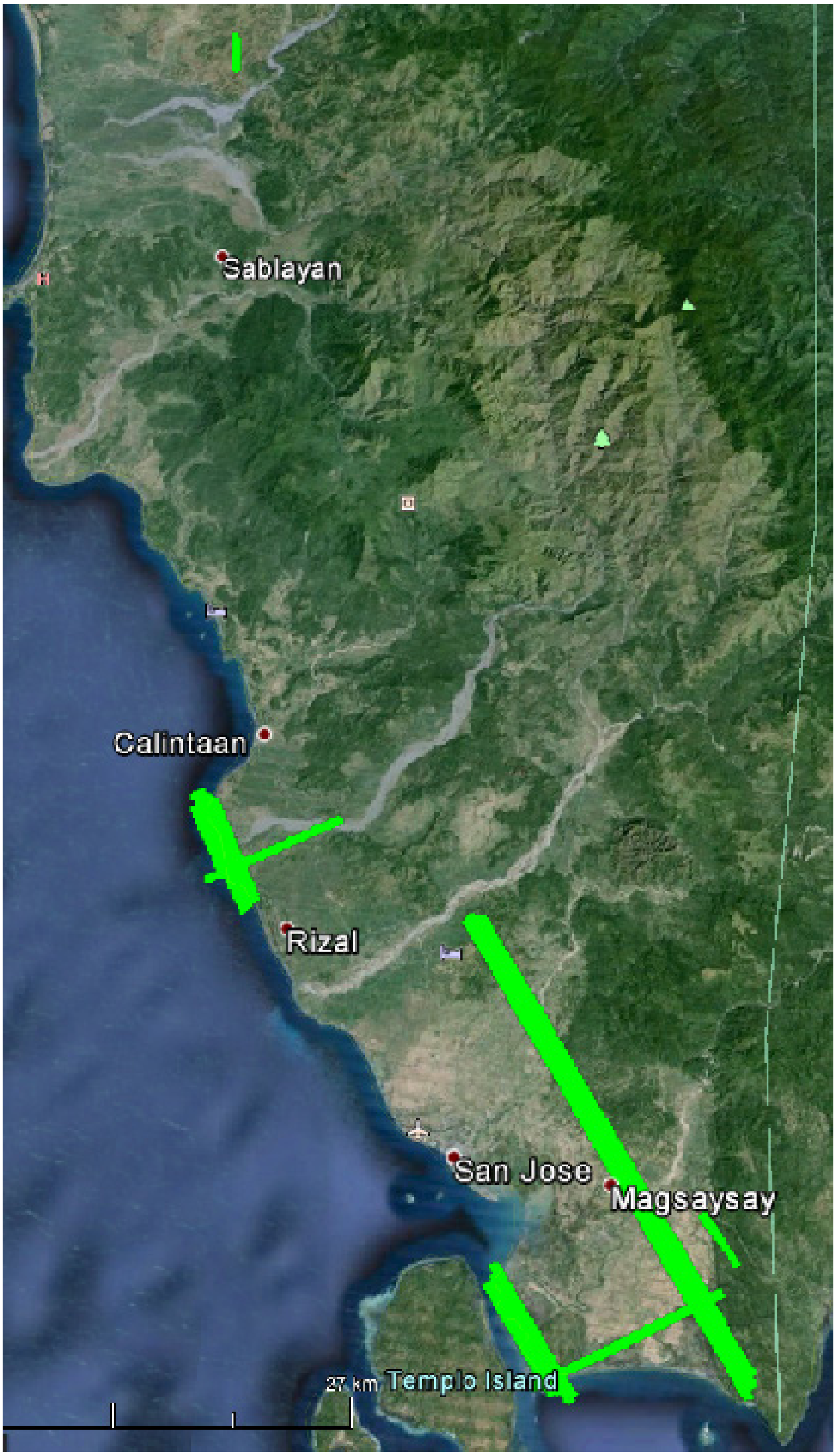


Figure A-7.6 Swath for Flight No. 1168A

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

SURVEY COVERAGE:

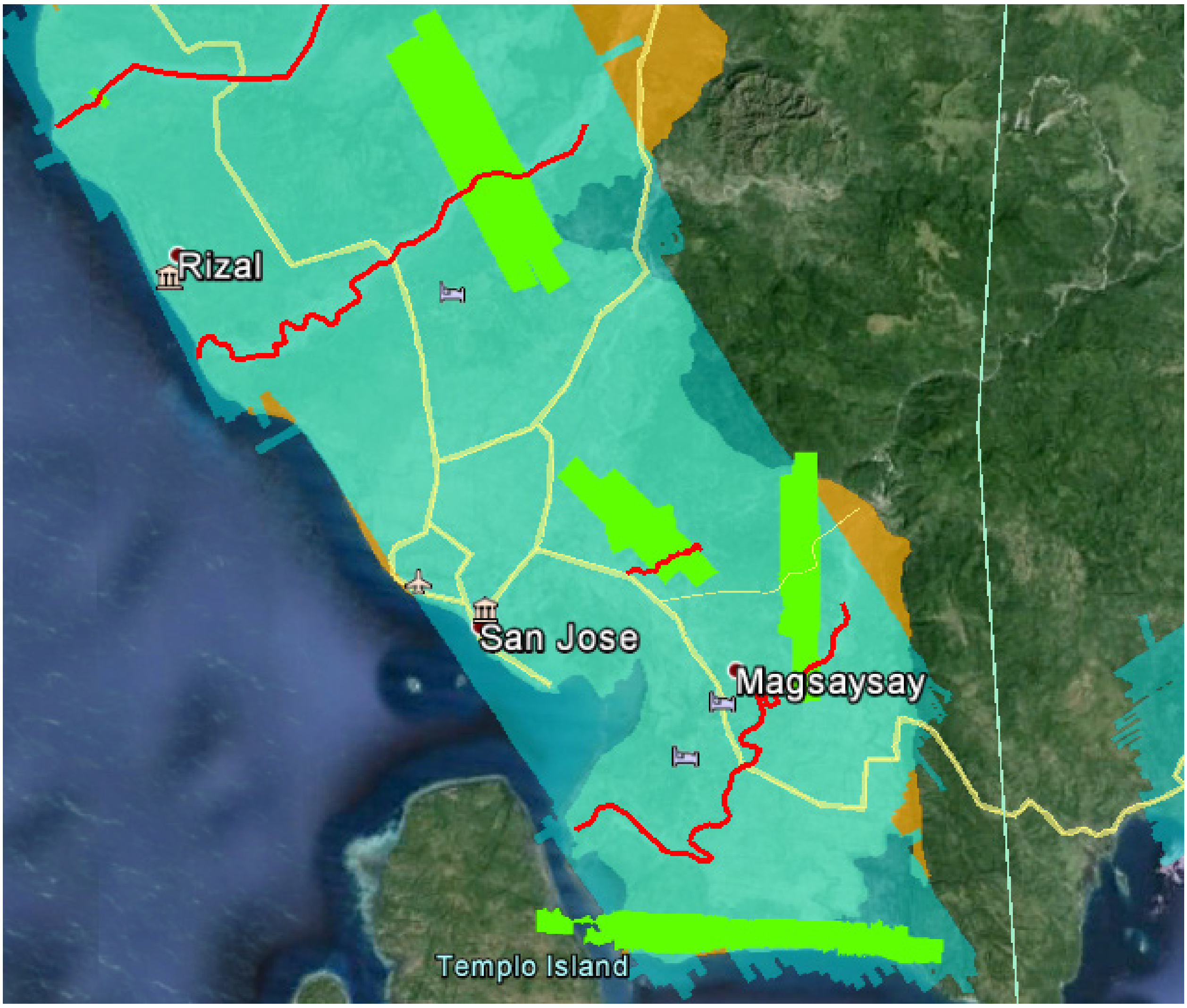


Figure A-7.7 Swath for Flight No. 3078P

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

SURVEY COVERAGE:

Figure A-7.8 Swath for Flight No. 3082P

Annex 8. Mission Summary Reports

Table A-8.1 Mission Summary Report for Blk29A

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

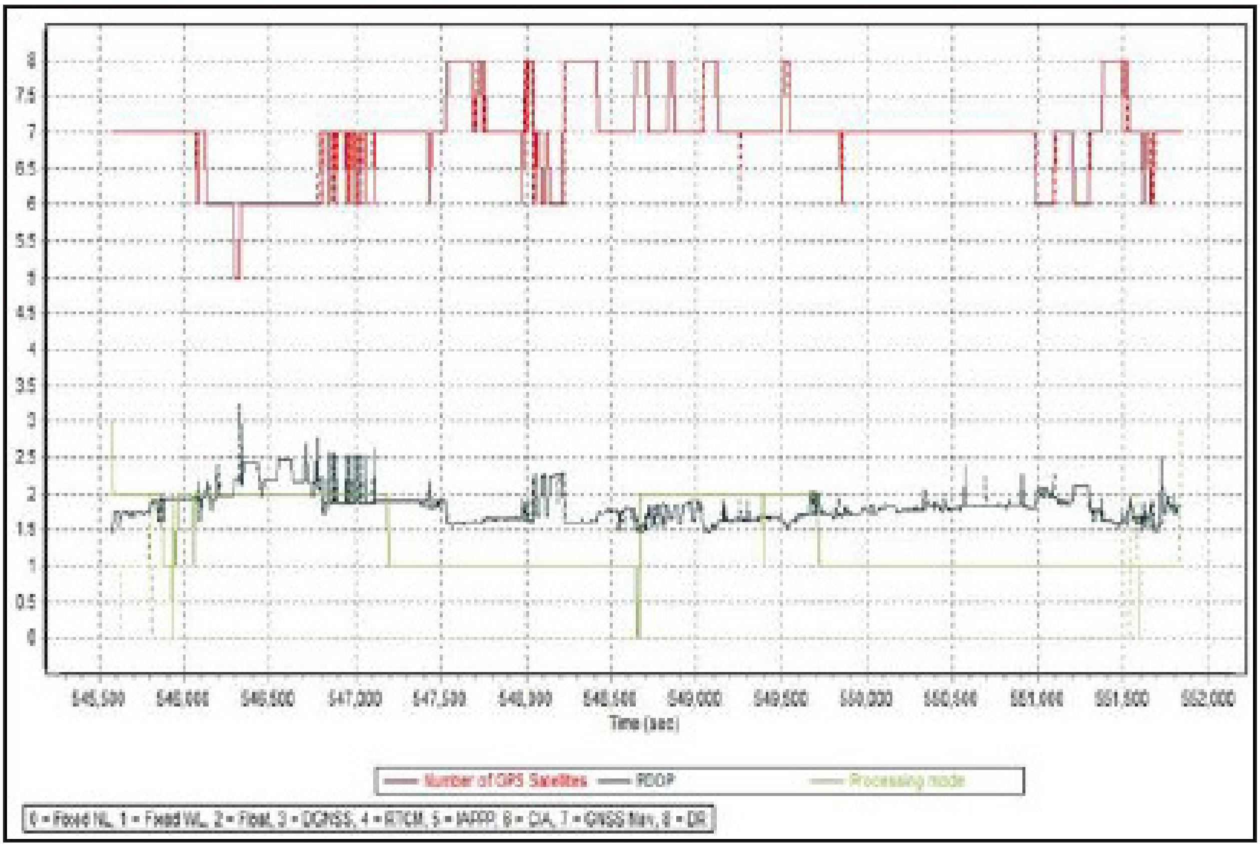


Figure A-8.1. Solution Status

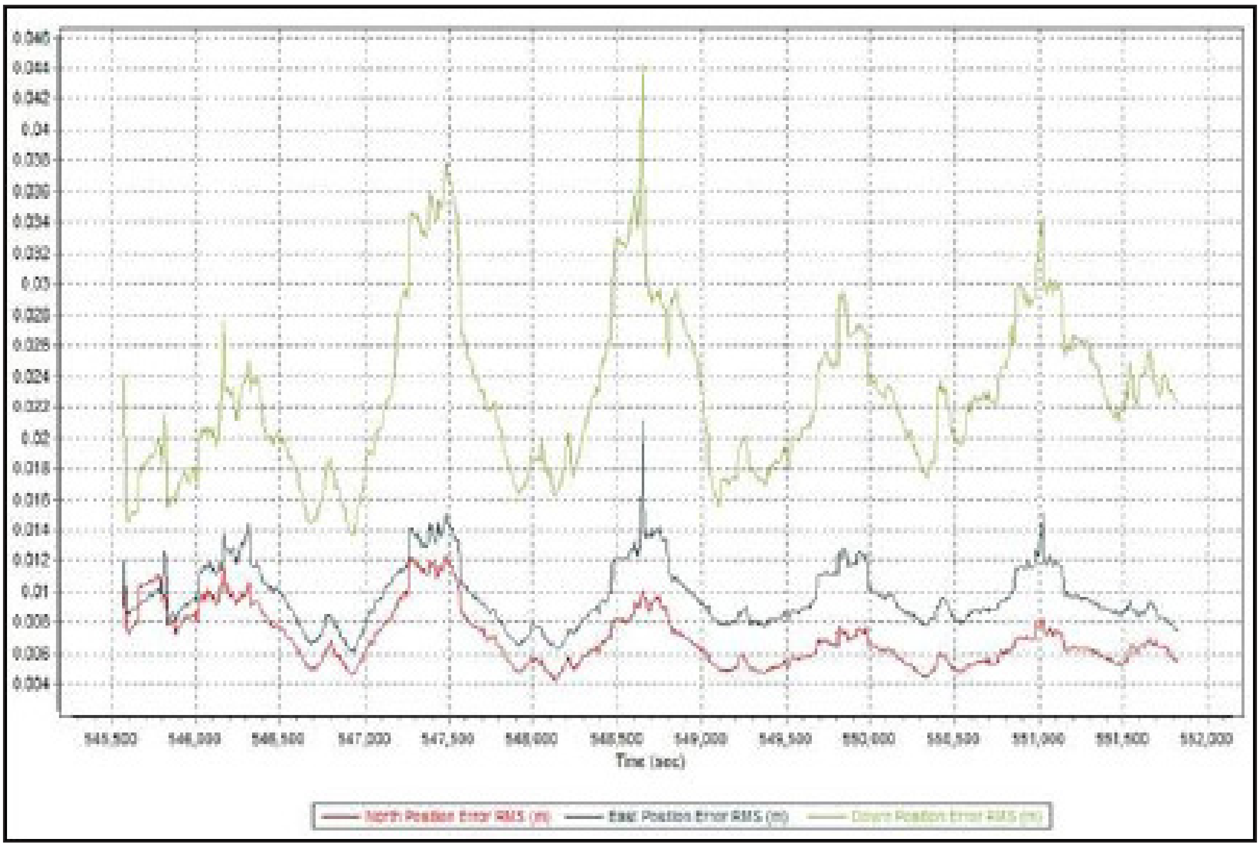


Figure A-8.2. Smoothed Performance Metric Parameters

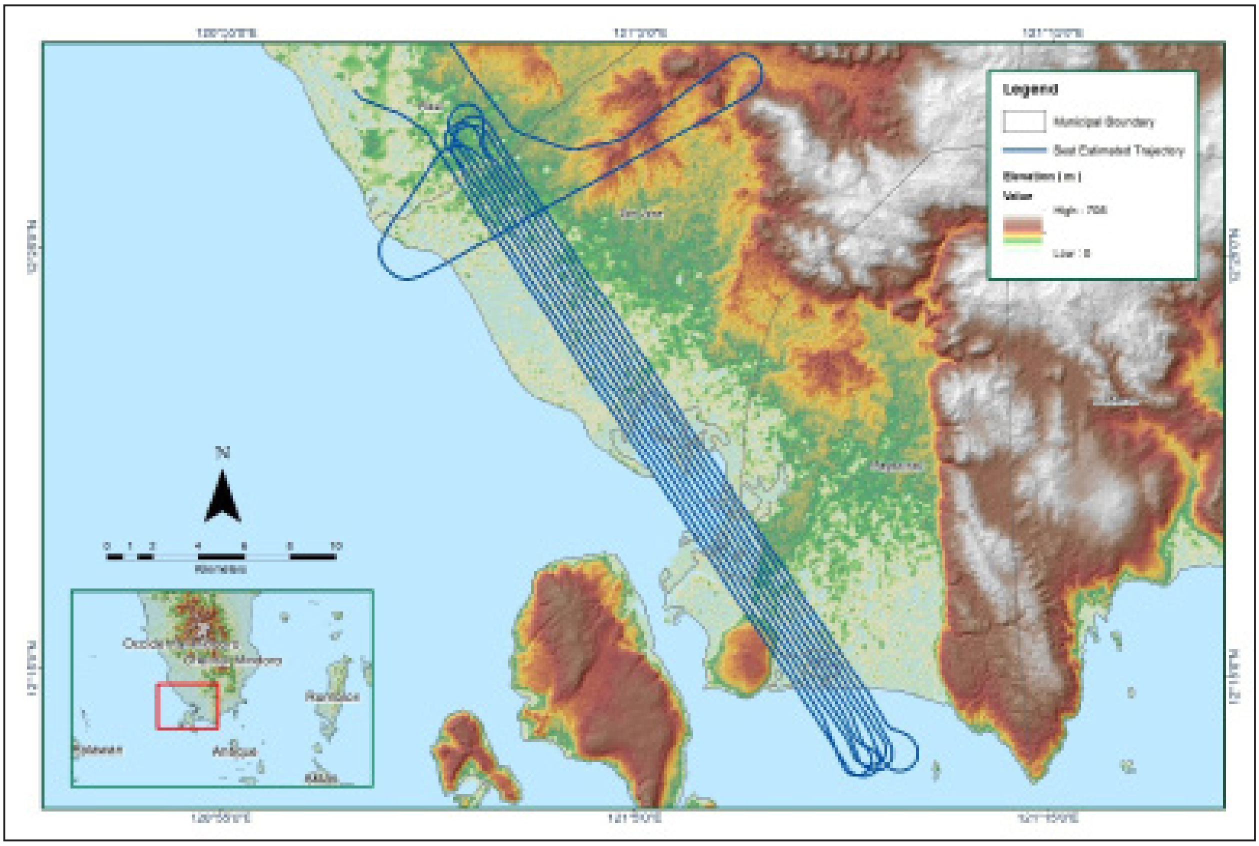


Figure A-8.3. Best Estimated Trajectory

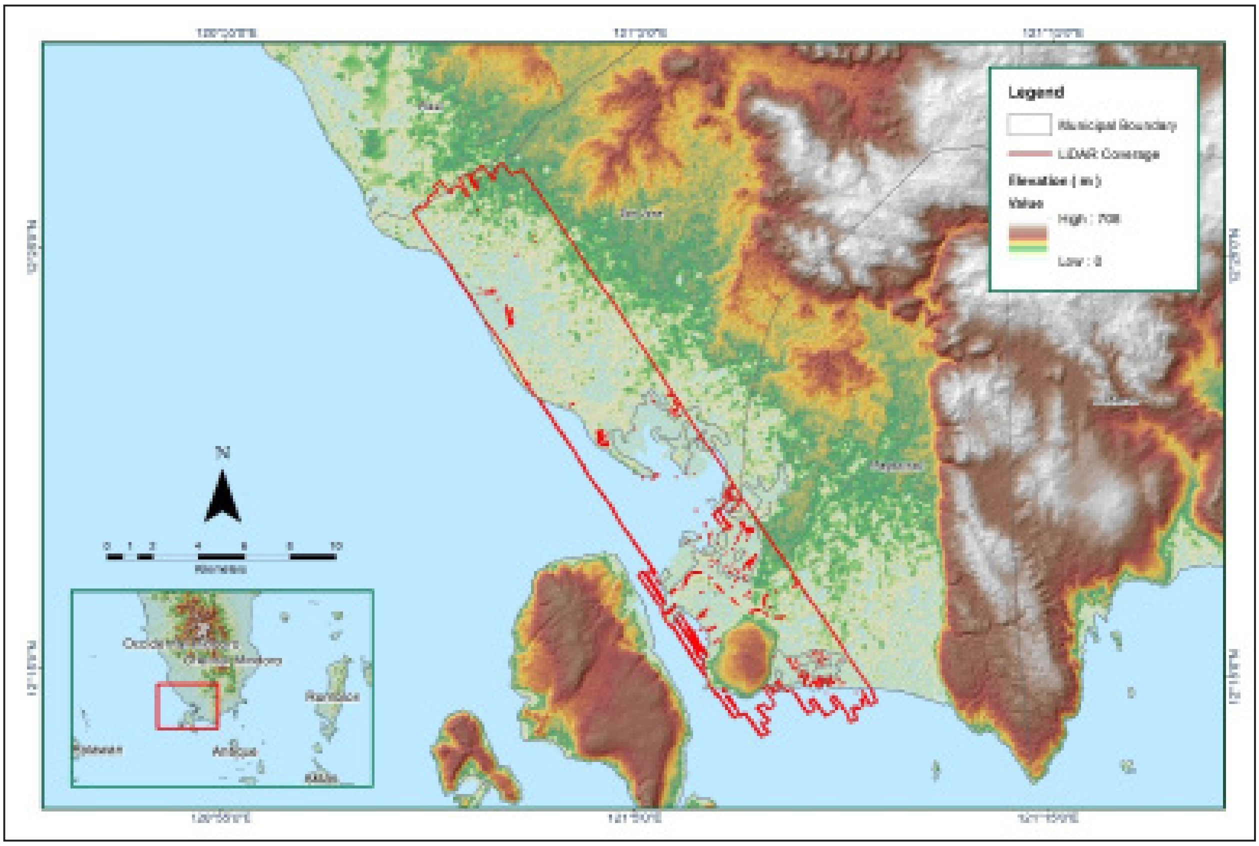


Figure A-8.4. Coverage of LiDAR data

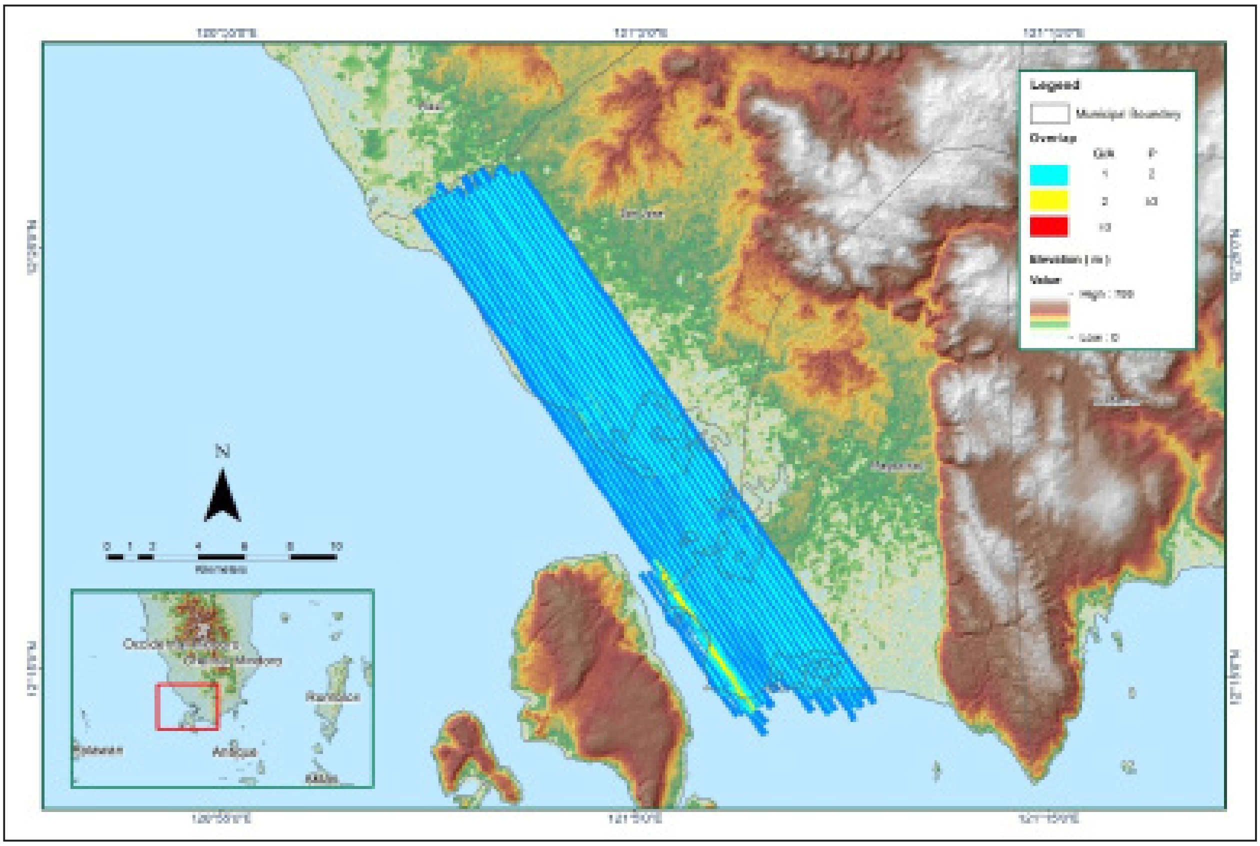


Figure A-8.5. Image of data overlap

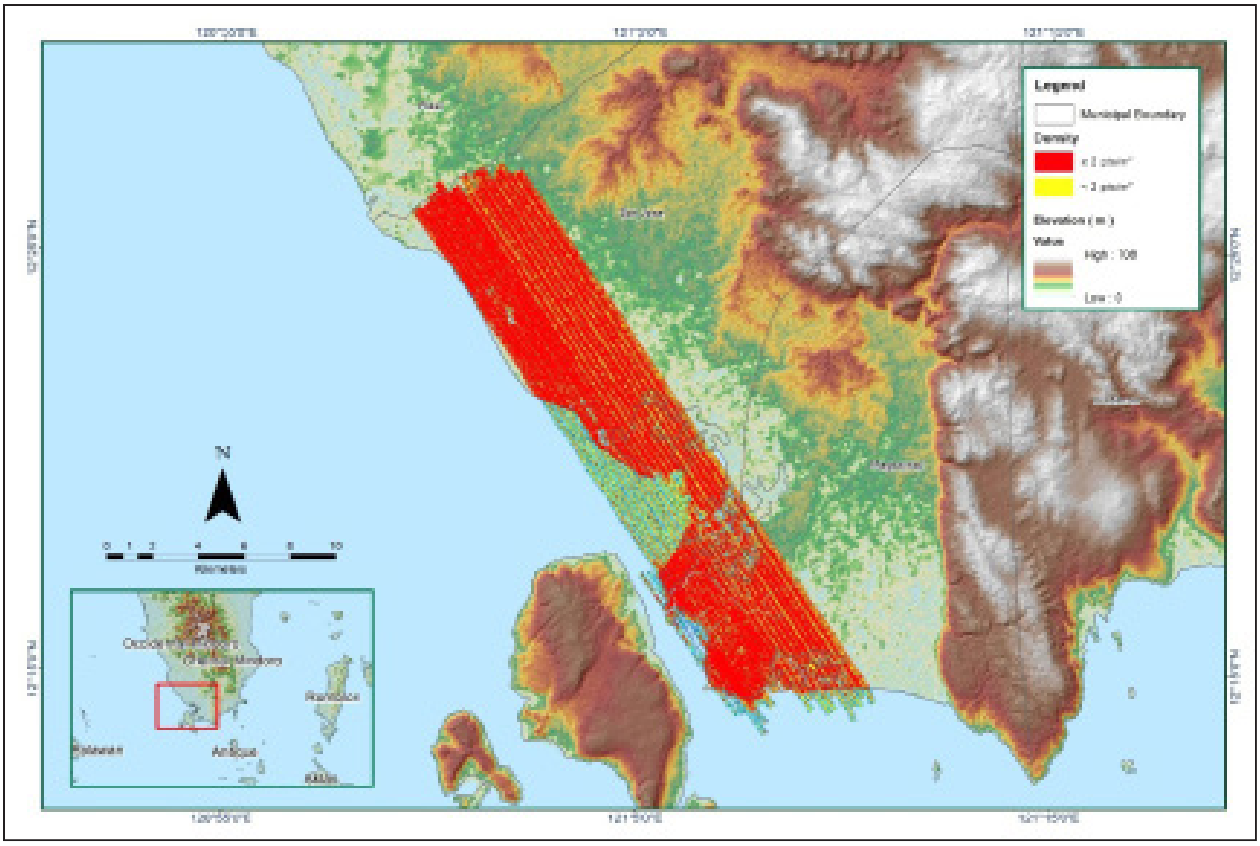


Figure A-8.6. Density map of merged LiDAR data

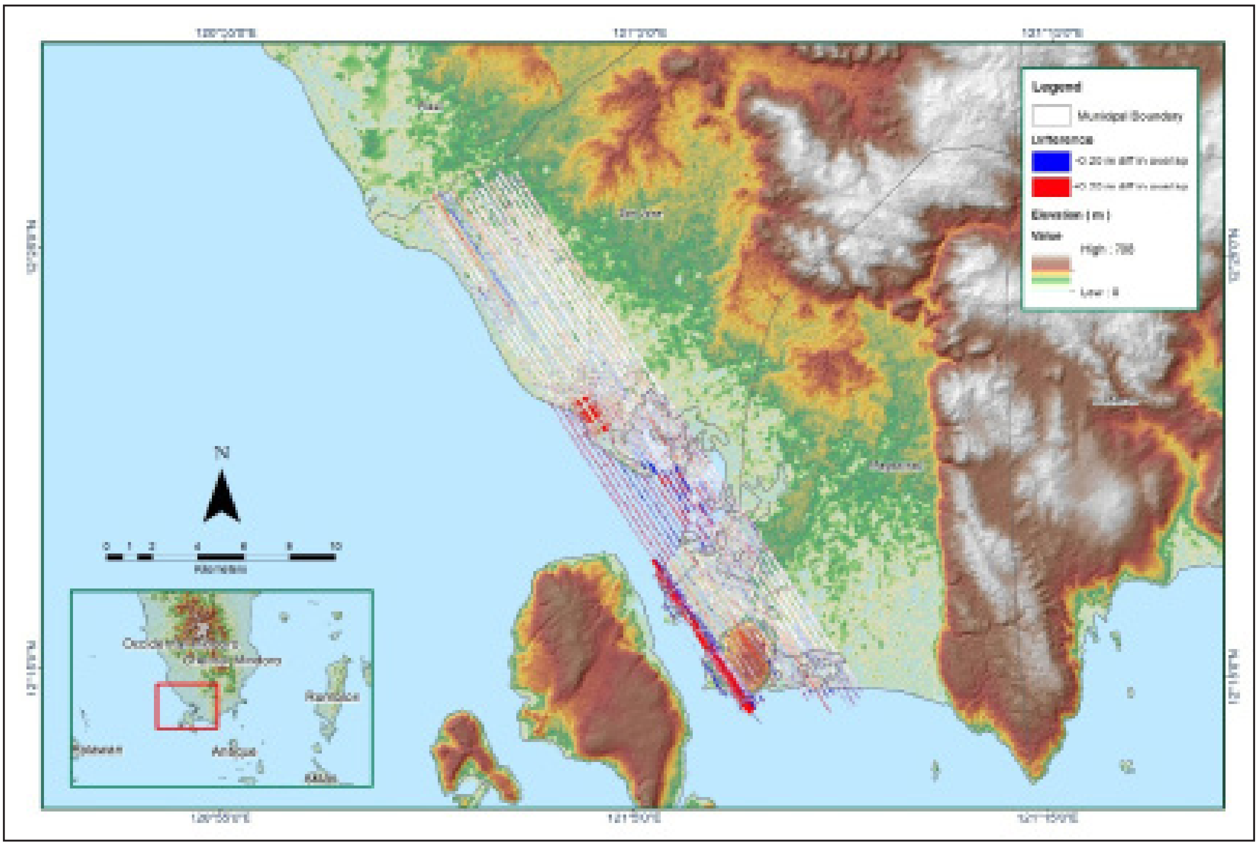


Figure A-8.7. Elevation difference between flight lines

Table A-8.2 Mission Summary Report for Blk29B

Flight Area	Davao Oriental
Mission Name	Blk29B
Inclusive Flights	1164A. 1166A, 1168A
Range data size	38.4 GB
POS	791 MB
Image	22.5 GB
Transfer date	04/23/2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.6
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000629
IMU attitude correction stdev (<0.001deg)	0.002510
GPS position stdev (<0.01m)	0.0158
Minimum % overlap (>25)	43.01%
Ave point cloud density per sq.m. (>2.0)	3.09
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	197
Maximum Height	258.38 m
Minimum Height	46.77 m
Classification (# of points)	
Ground	115,311,089
Low vegetation	138,979,099
Medium vegetation	95,318,939
High vegetation	30,819,969
Building	2,104,153
Orthophoto	Yes
Processed by	Ma. Victoria Rejuso, Engr. Harmond Santos, Engr. John Dill Macapagal

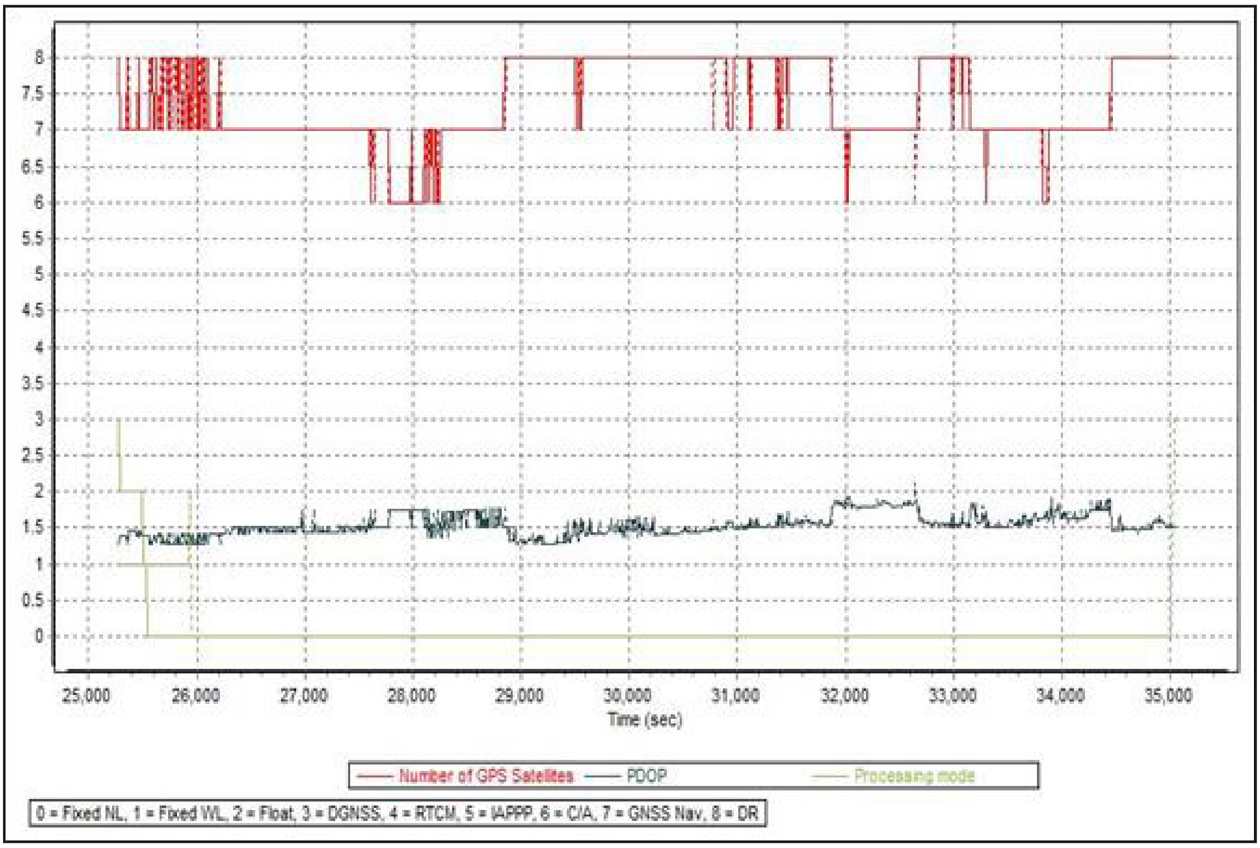


Figure A-8.8. Solution Status

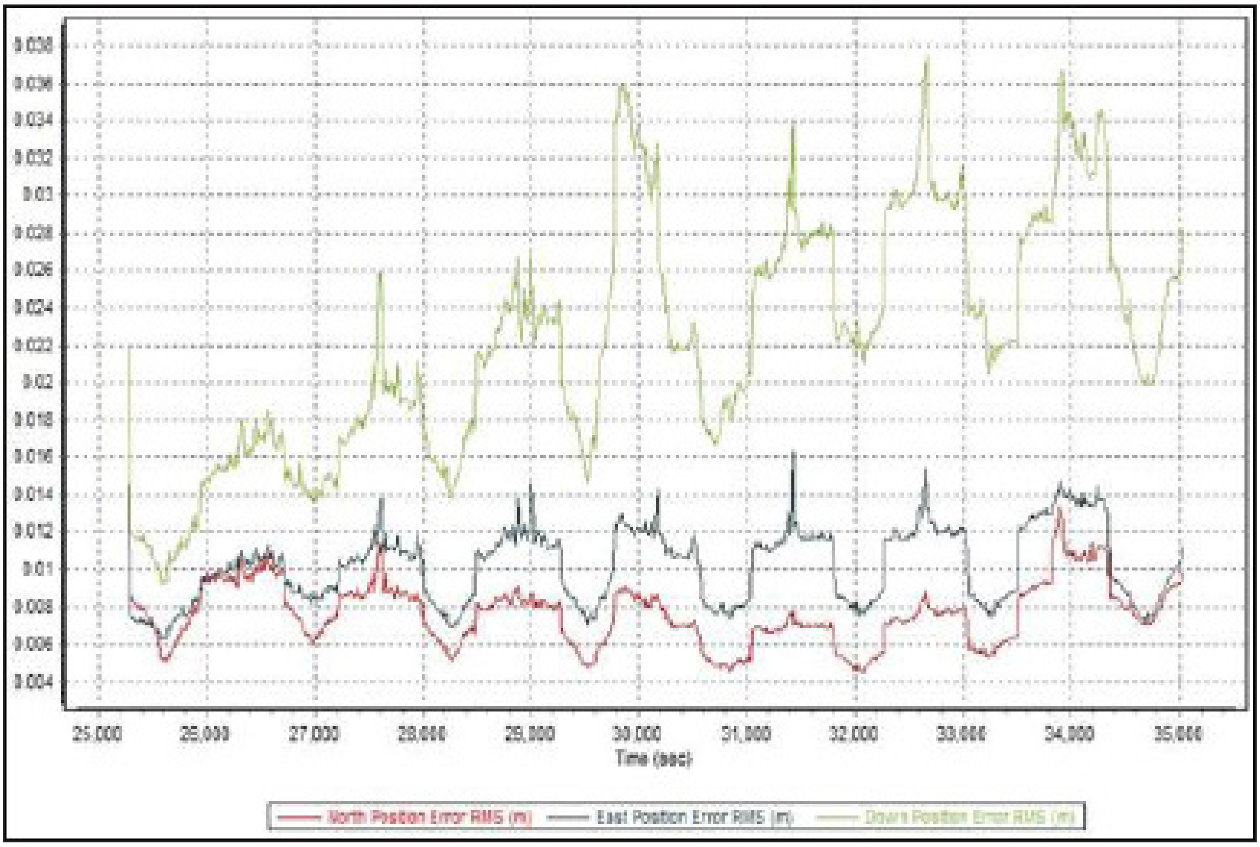


Figure A-8.9. Smoothed Performance Metric Parameters

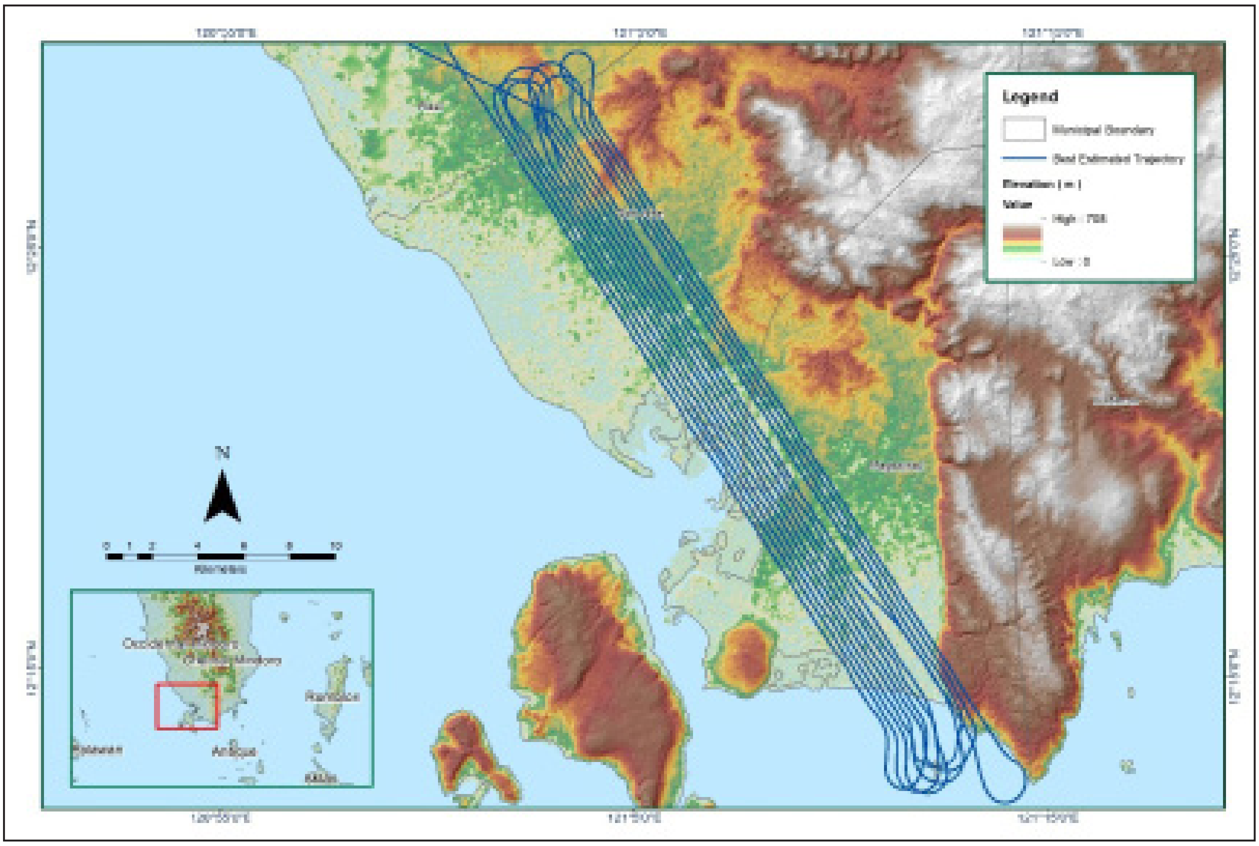


Figure A-8.10. Best Estimated Trajectory

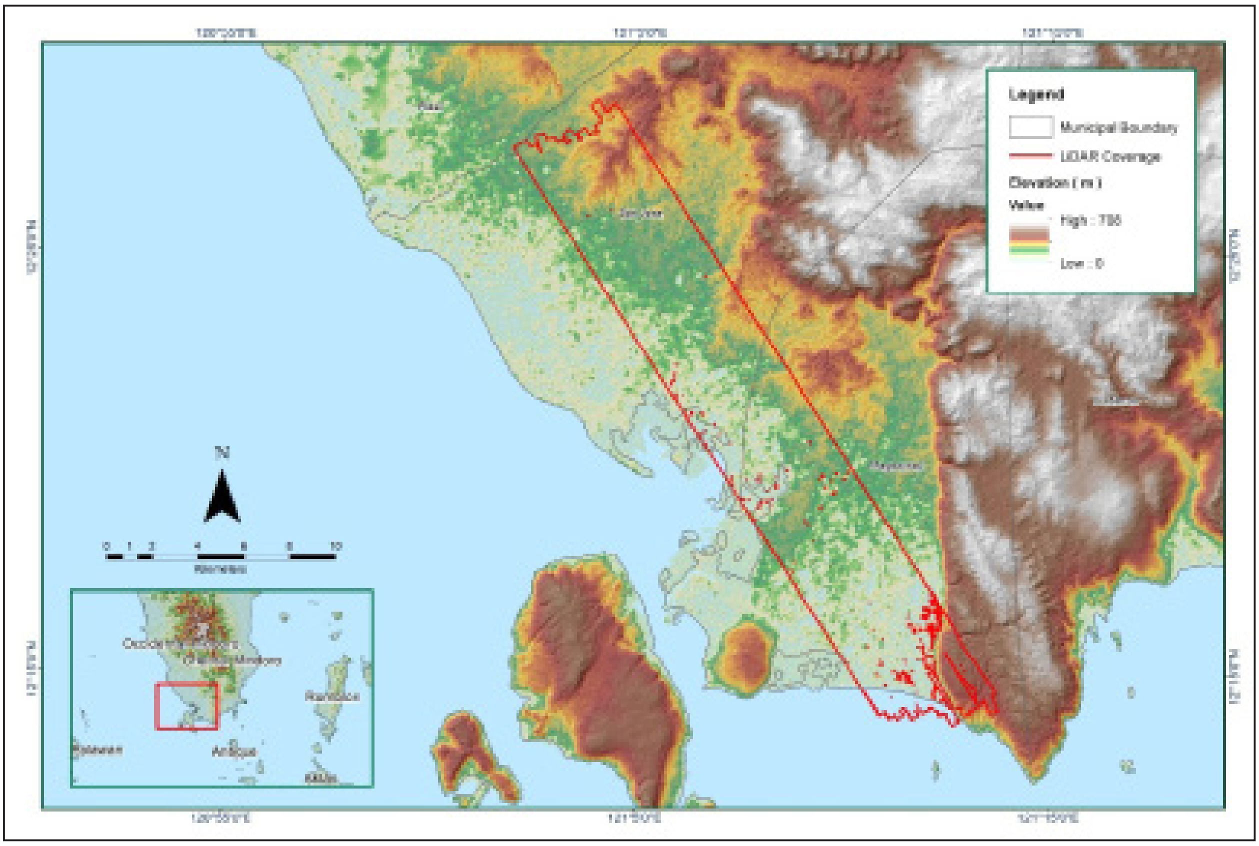


Figure A-8.11. Coverage of LiDAR data

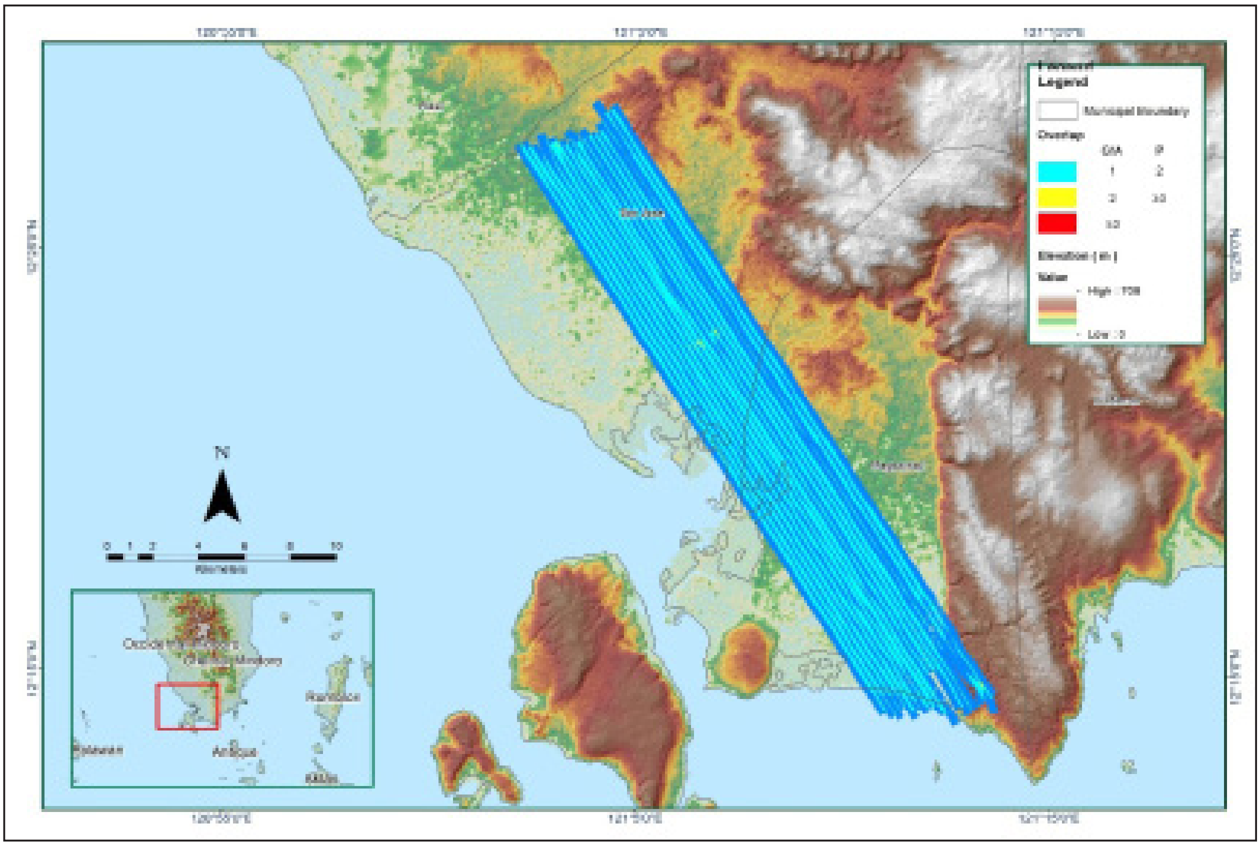


Figure A-8.12. Image of data overlap

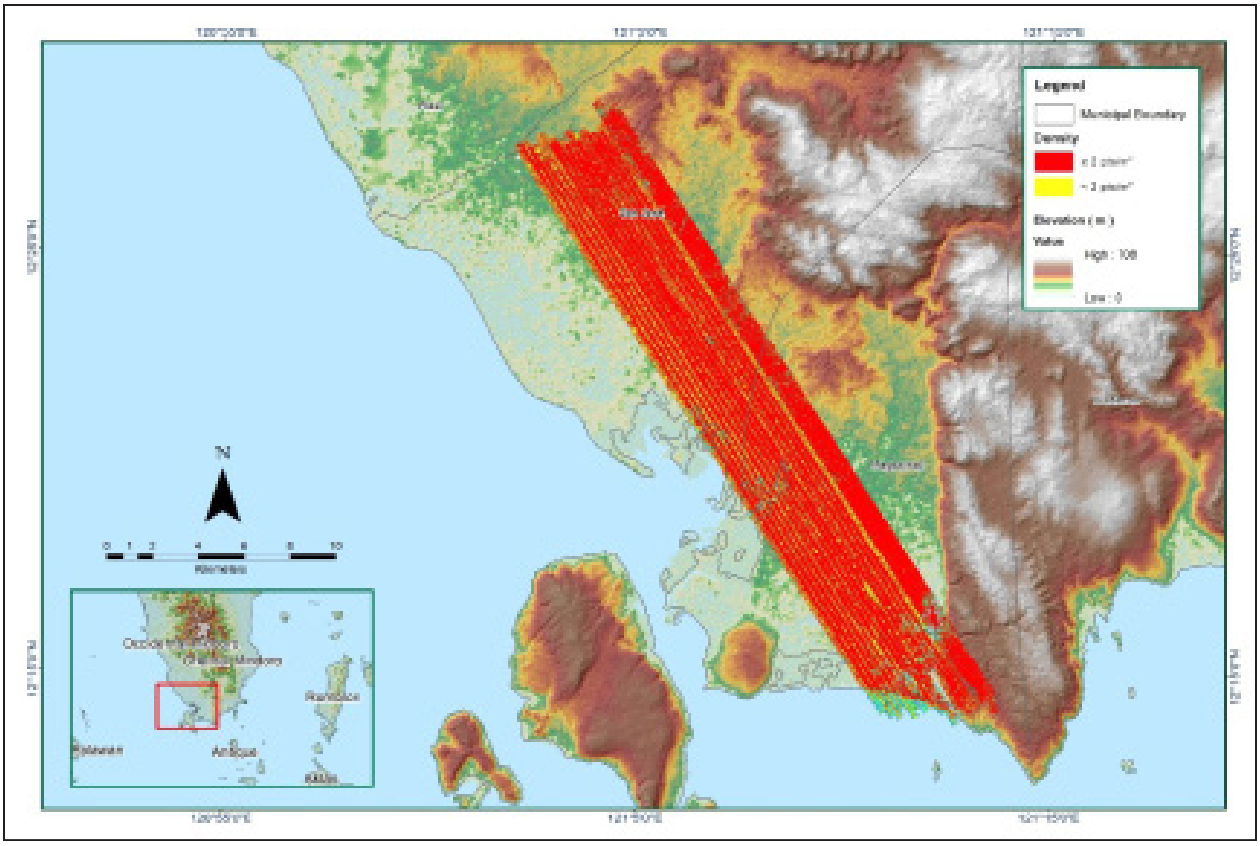


Figure A-8.13. Density map of merged LiDAR data

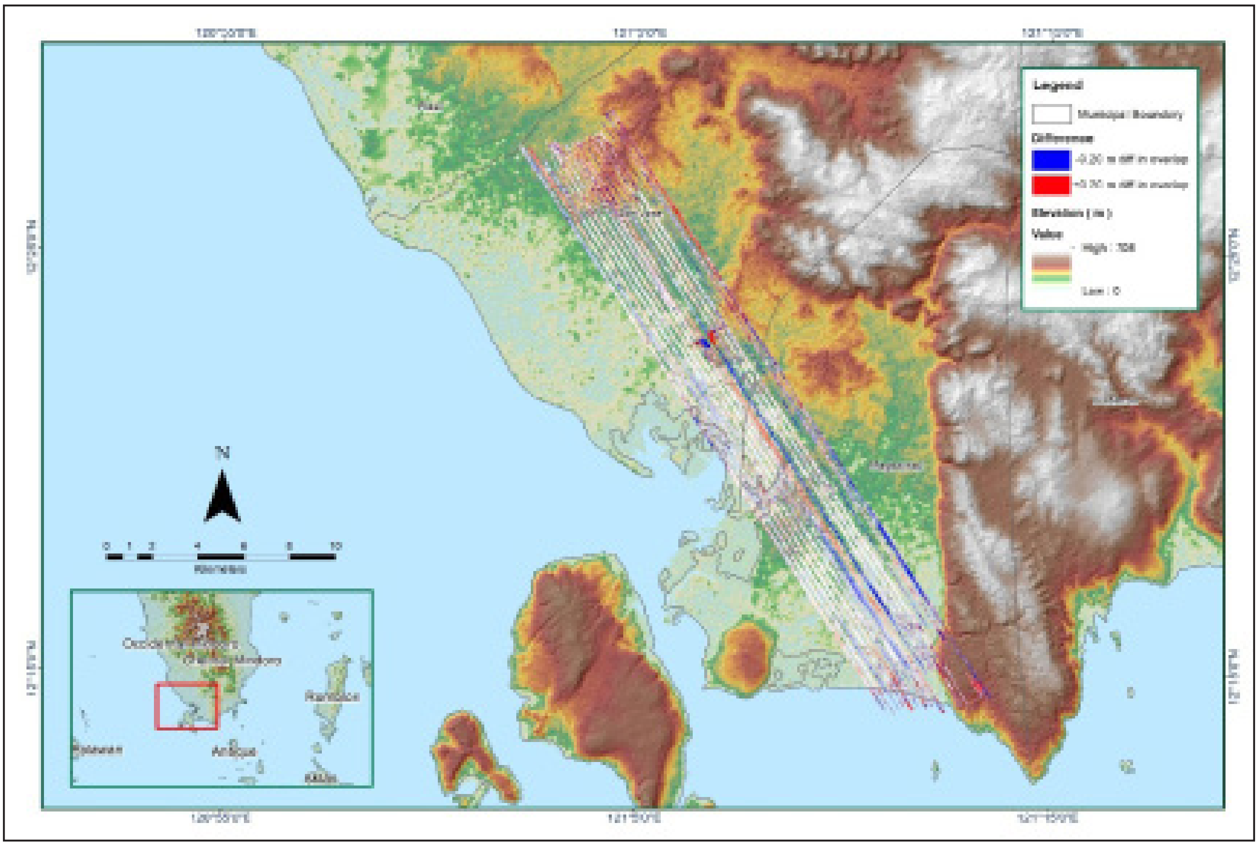


Figure A-8.14. Elevation difference between flight lines

Table A-8.3 Mission Summary Report for Blk29C

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

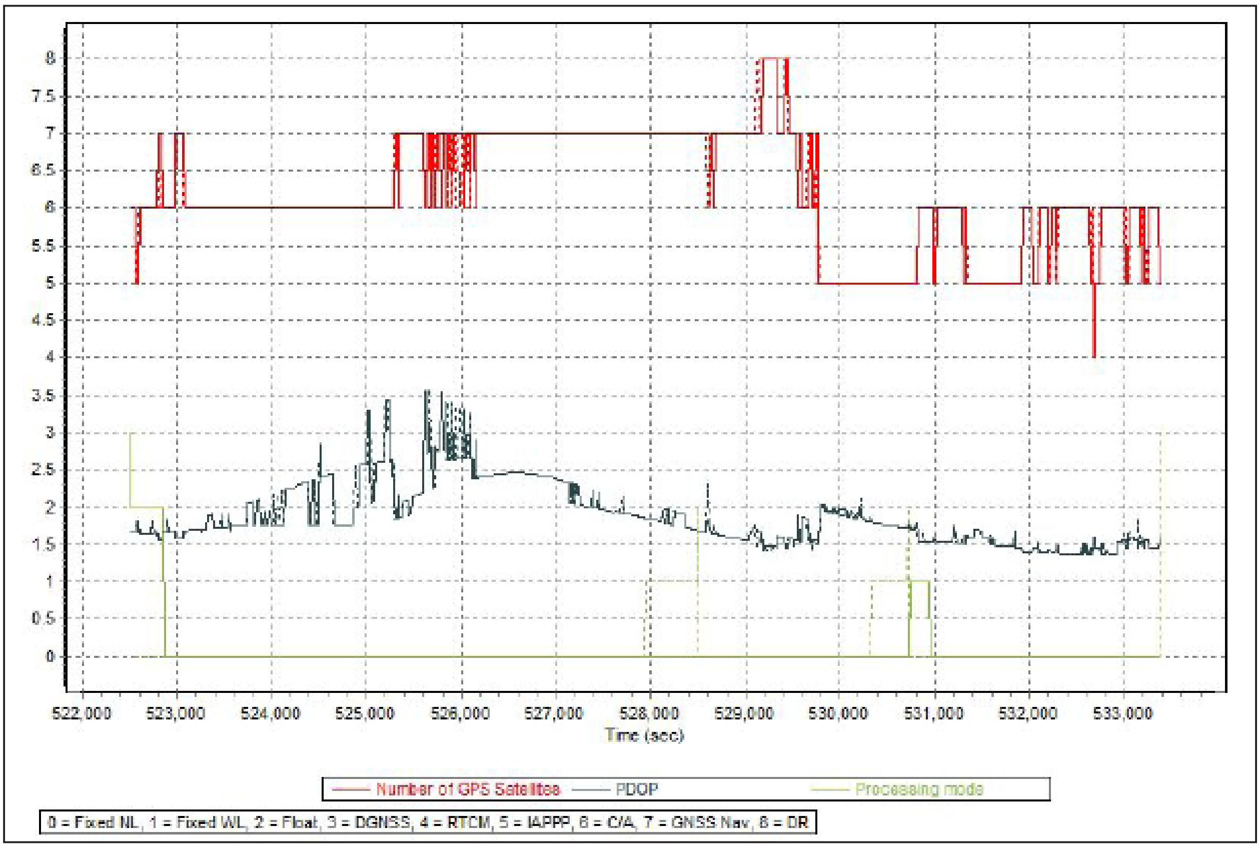


Figure A-8.15. Solution Status

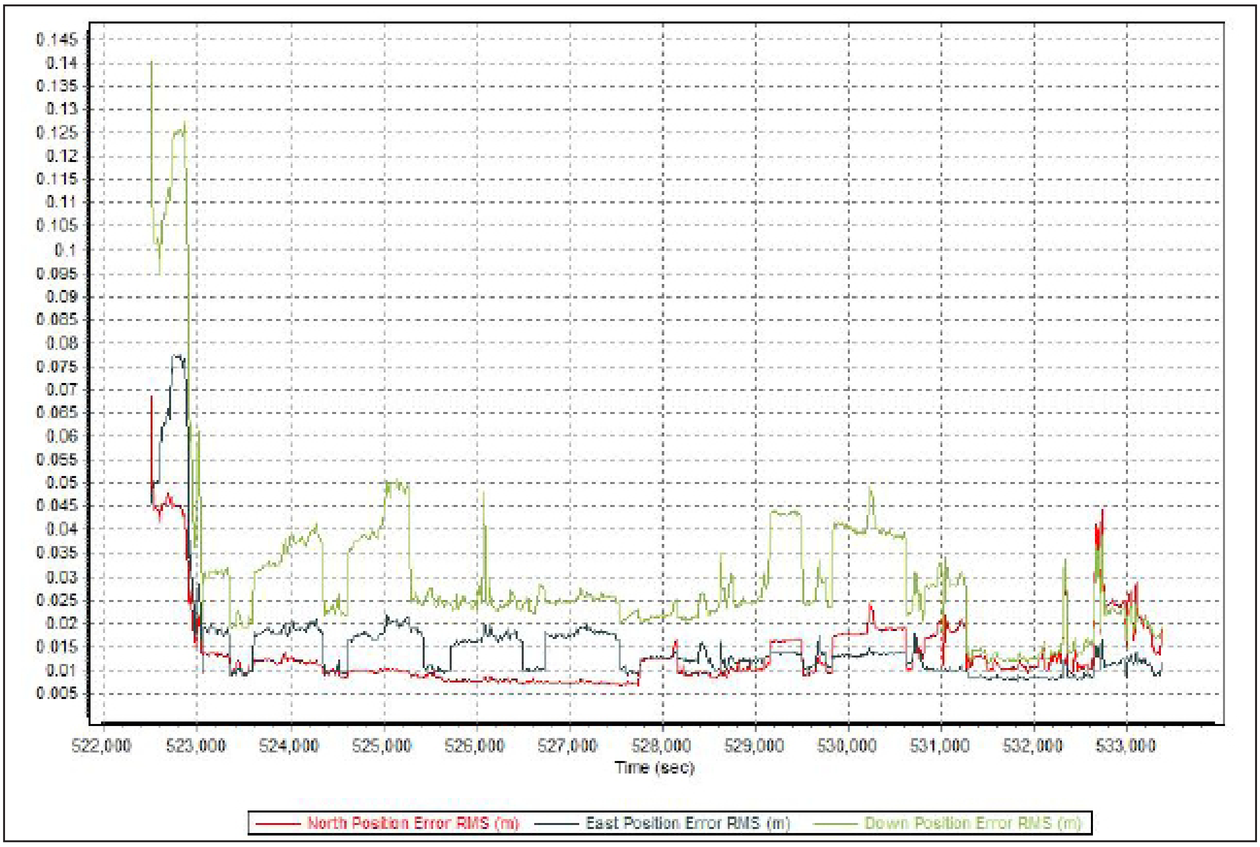


Figure A-8.16. Smoothed Performance Metric Parameters

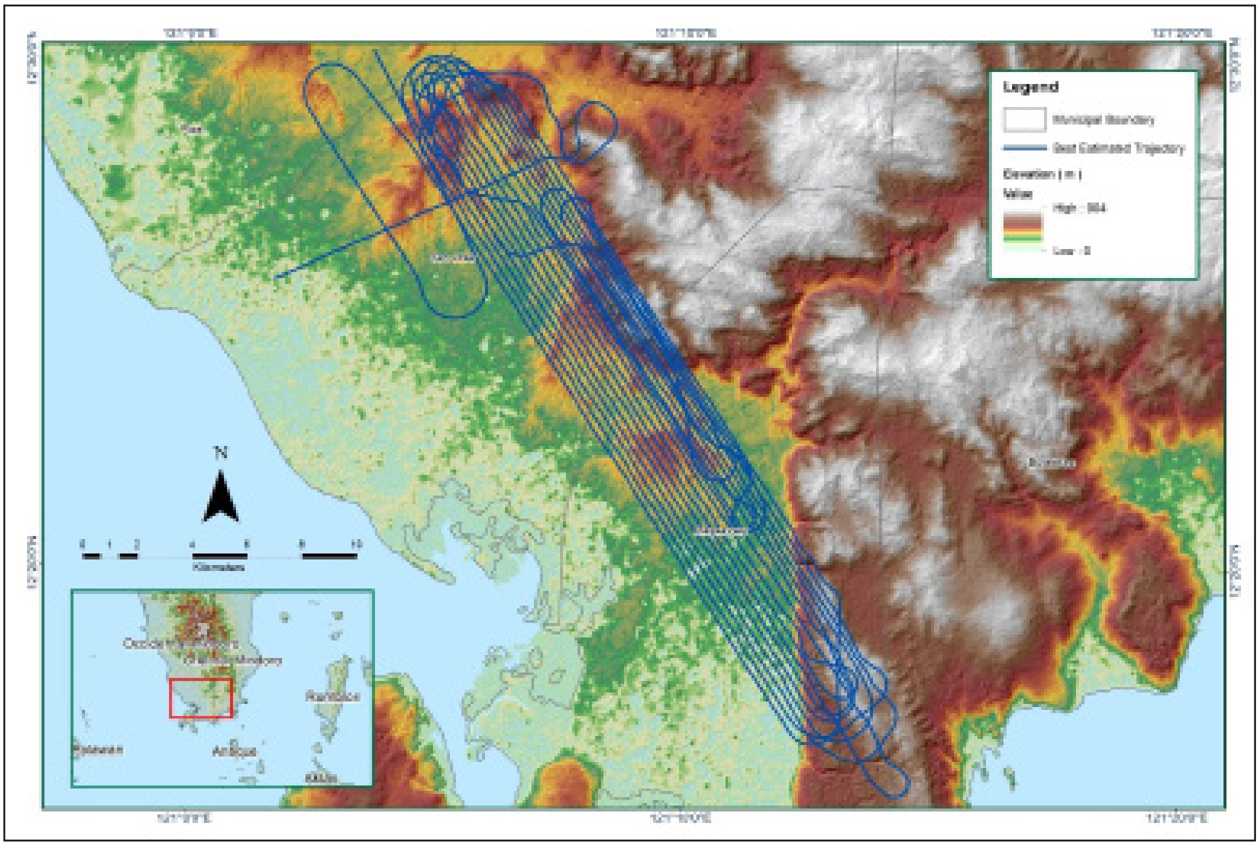


Figure A-8.17. Best Estimated Trajectory

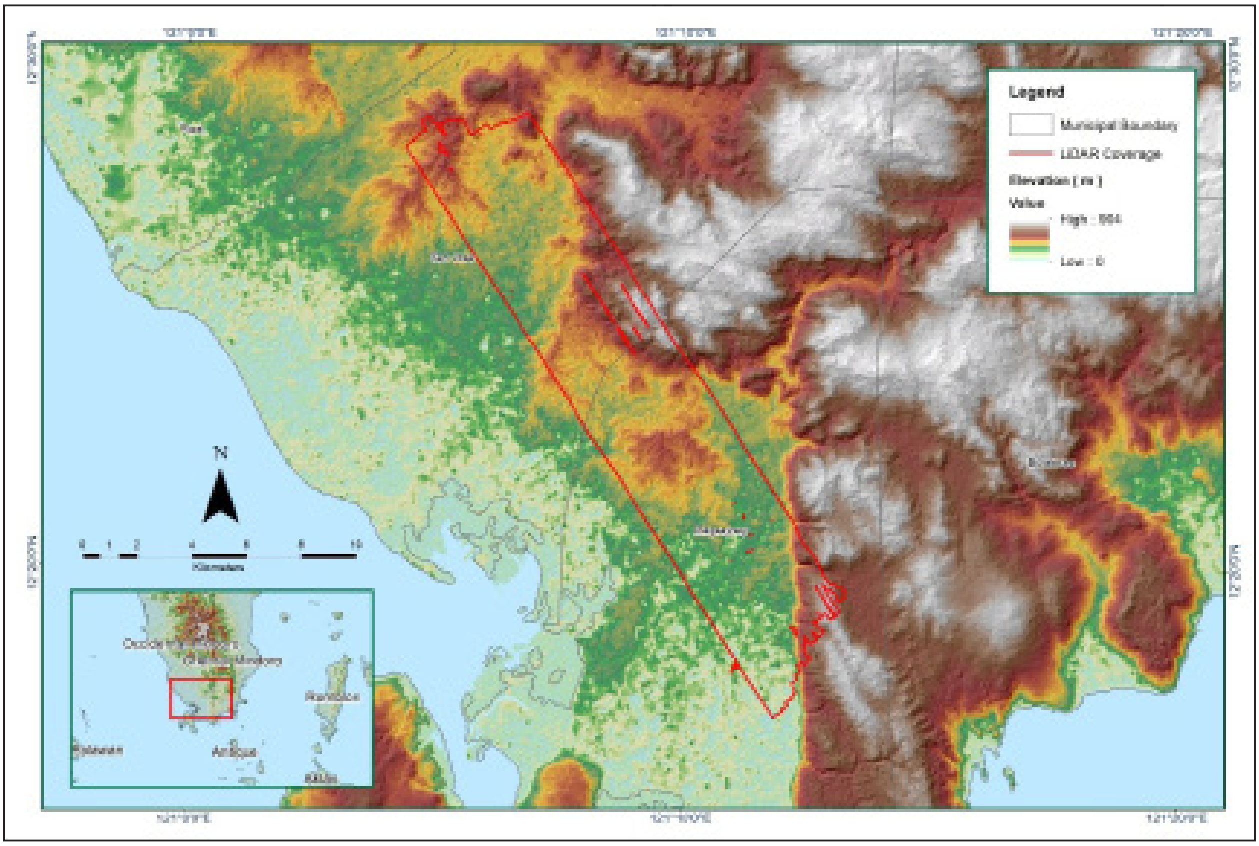


Figure A-8.18. Coverage of LiDAR data

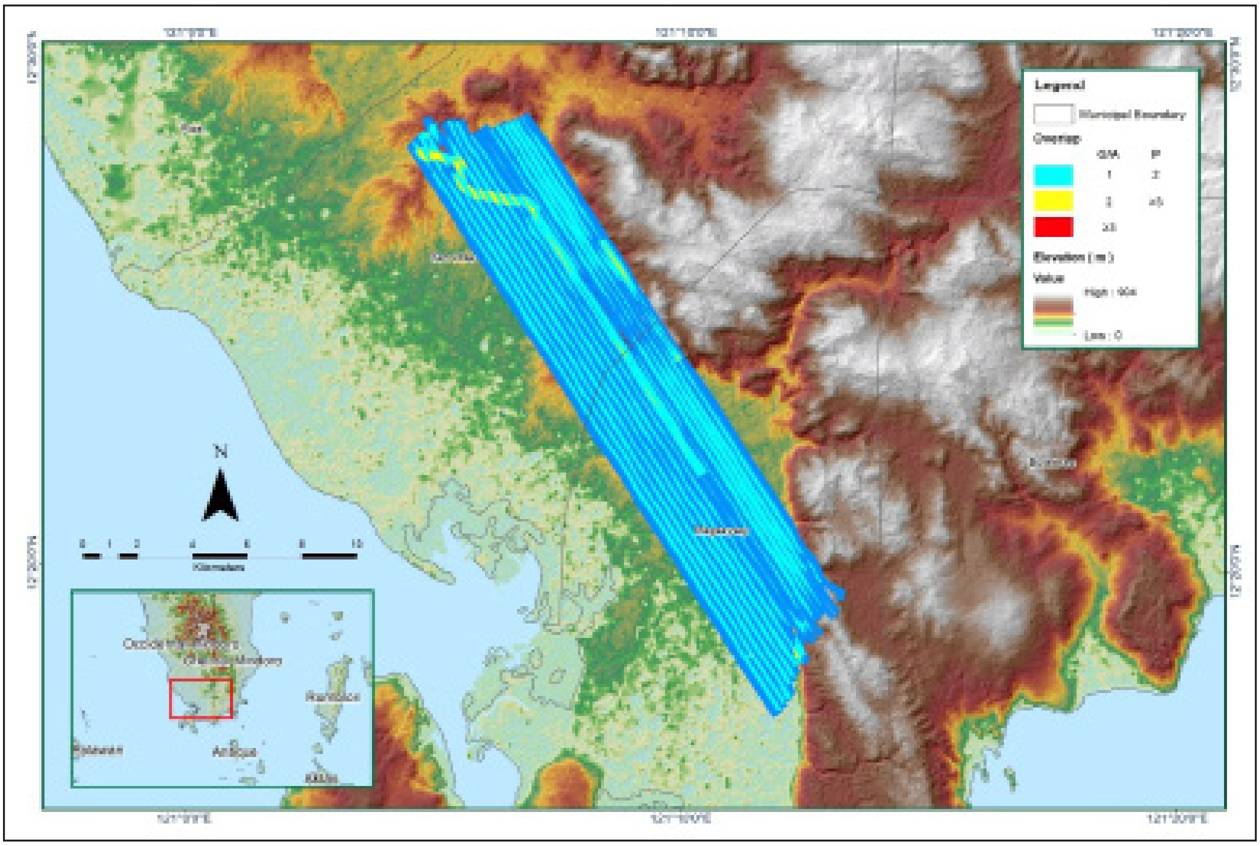


Figure A-8.19. Image of data overlap

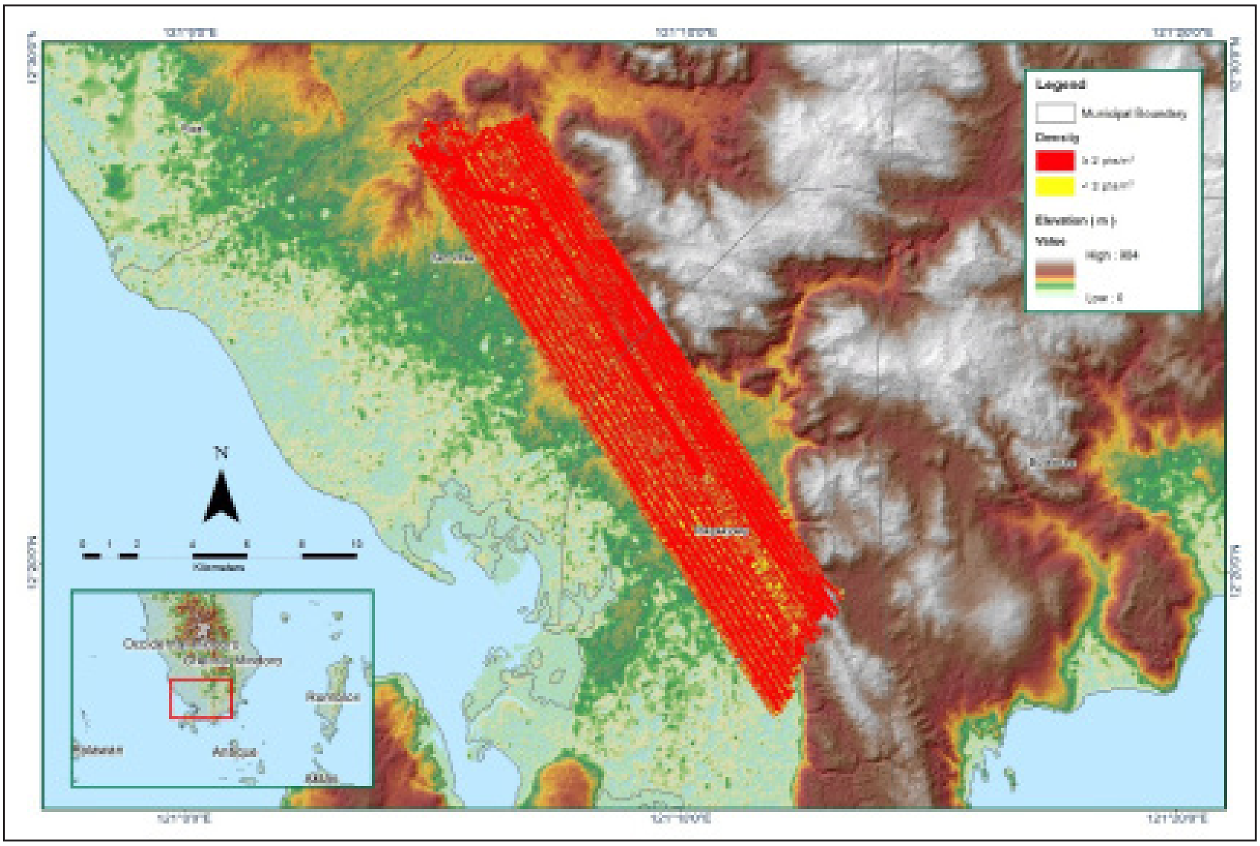


Figure A-8.20. Density map of merged LiDAR data

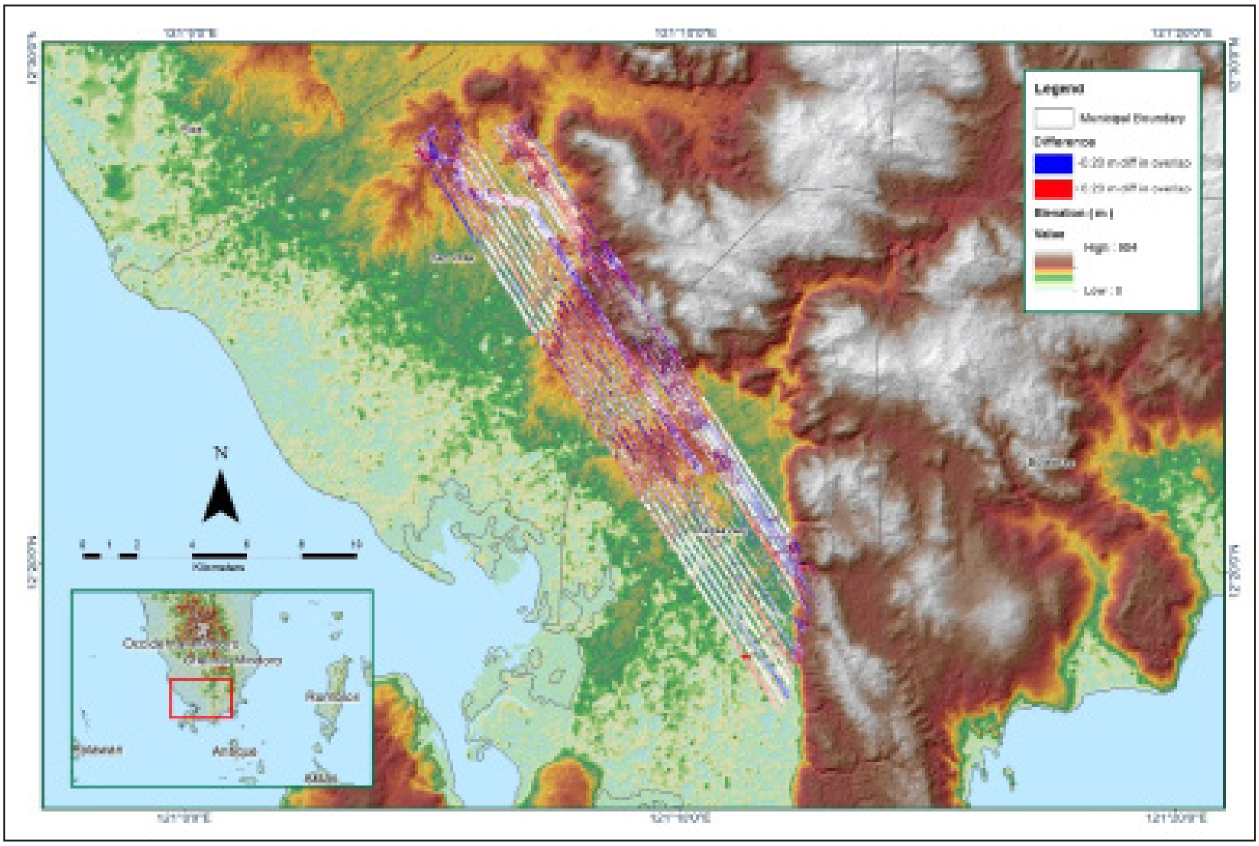


Figure A-8.21. Elevation difference between flight lines

Table A-8.4 Mission Summary Report for Blk29A_additional

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

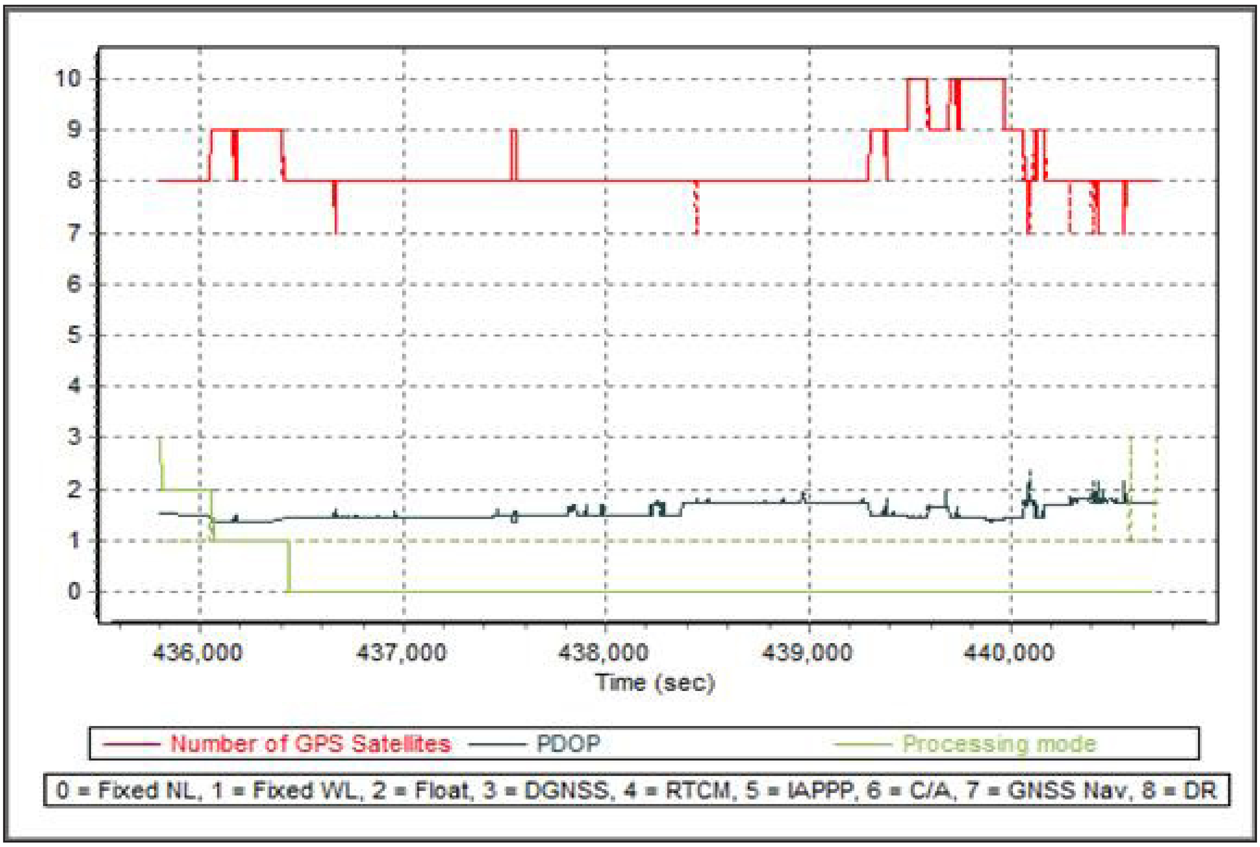


Figure A-8.22. Solution Status

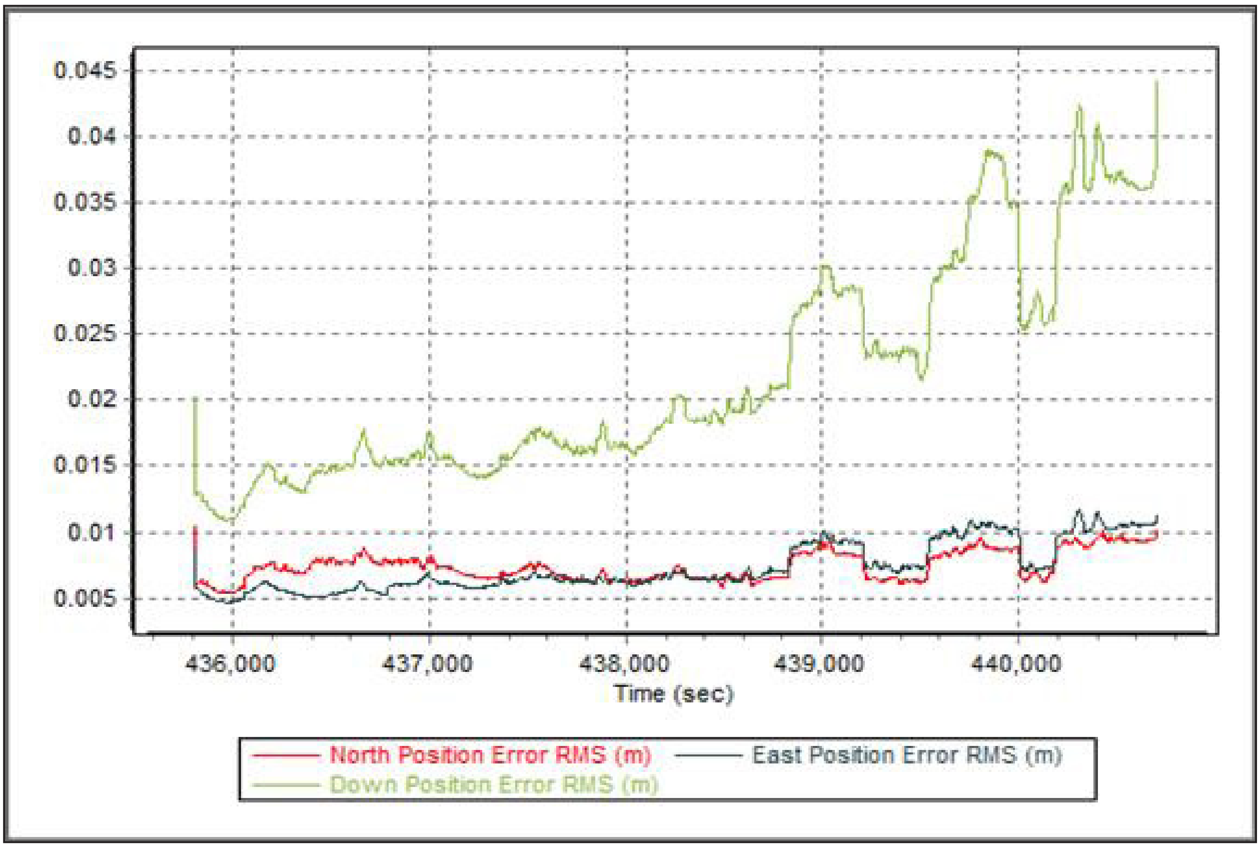


Figure A-8.23. Smoothed Performance Metric Parameters

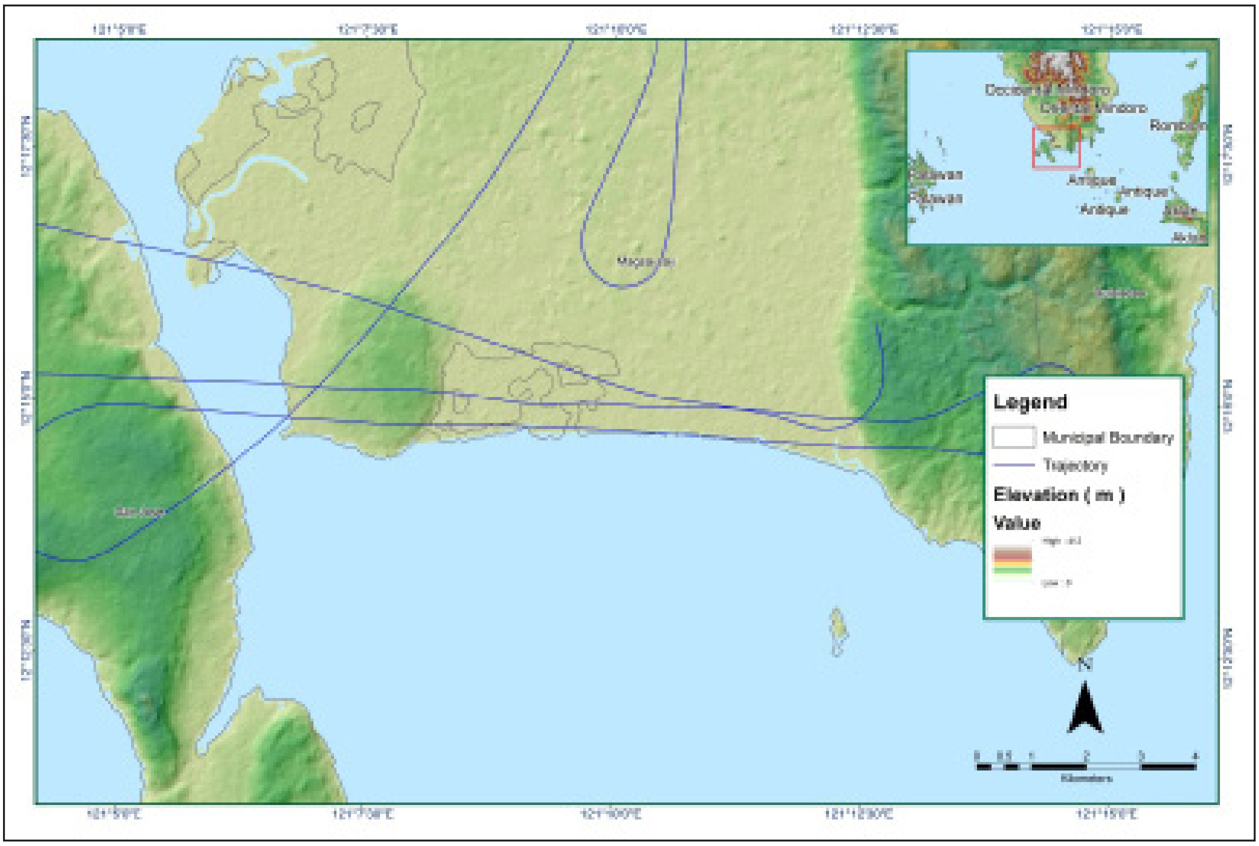


Figure A-8.24. Best Estimated Trajectory

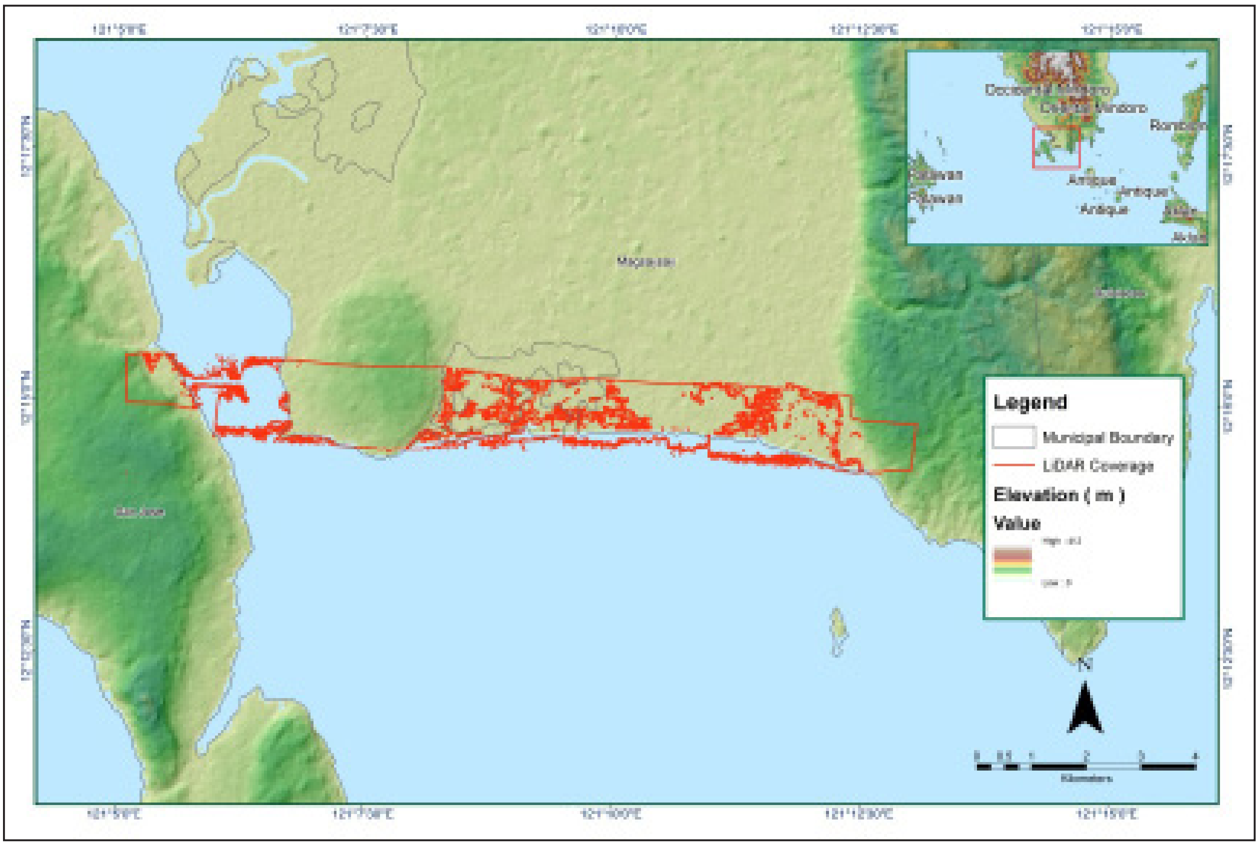


Figure A-8.25. Coverage of LiDAR data

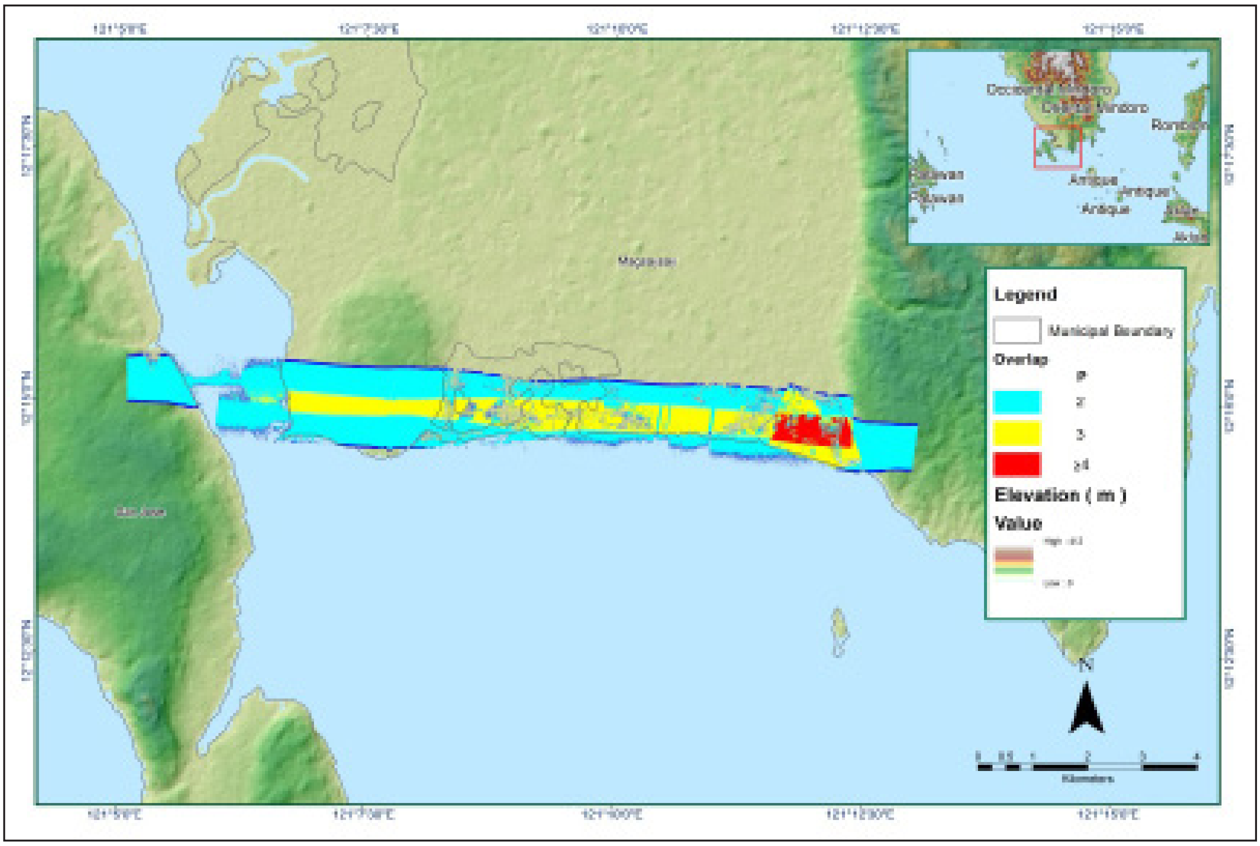


Figure A-8.26. Image of data overlap

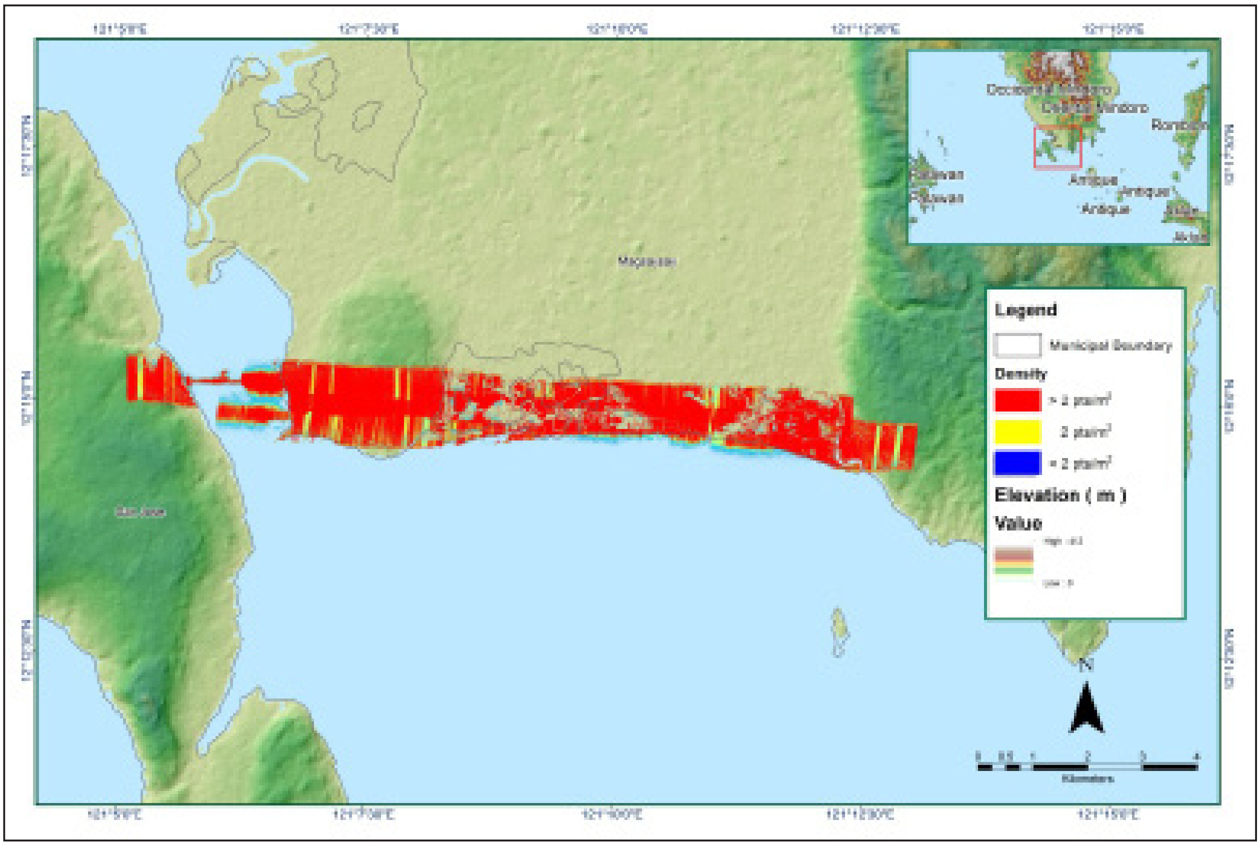


Figure A-8.27. Density map of merged LiDAR data

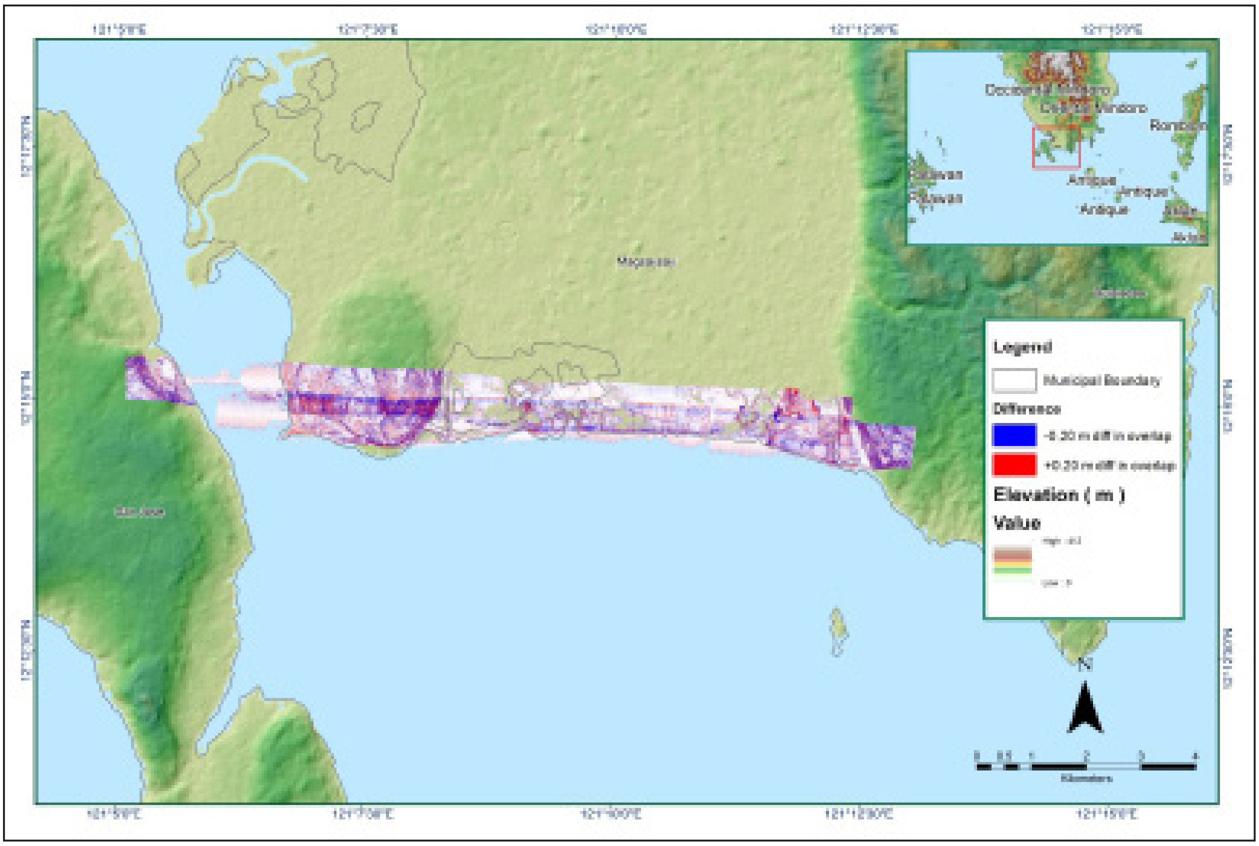


Figure A-8.28. Elevation difference between flight lines

Table A-8.5 Mission Summary Report for Blk29B_additional

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

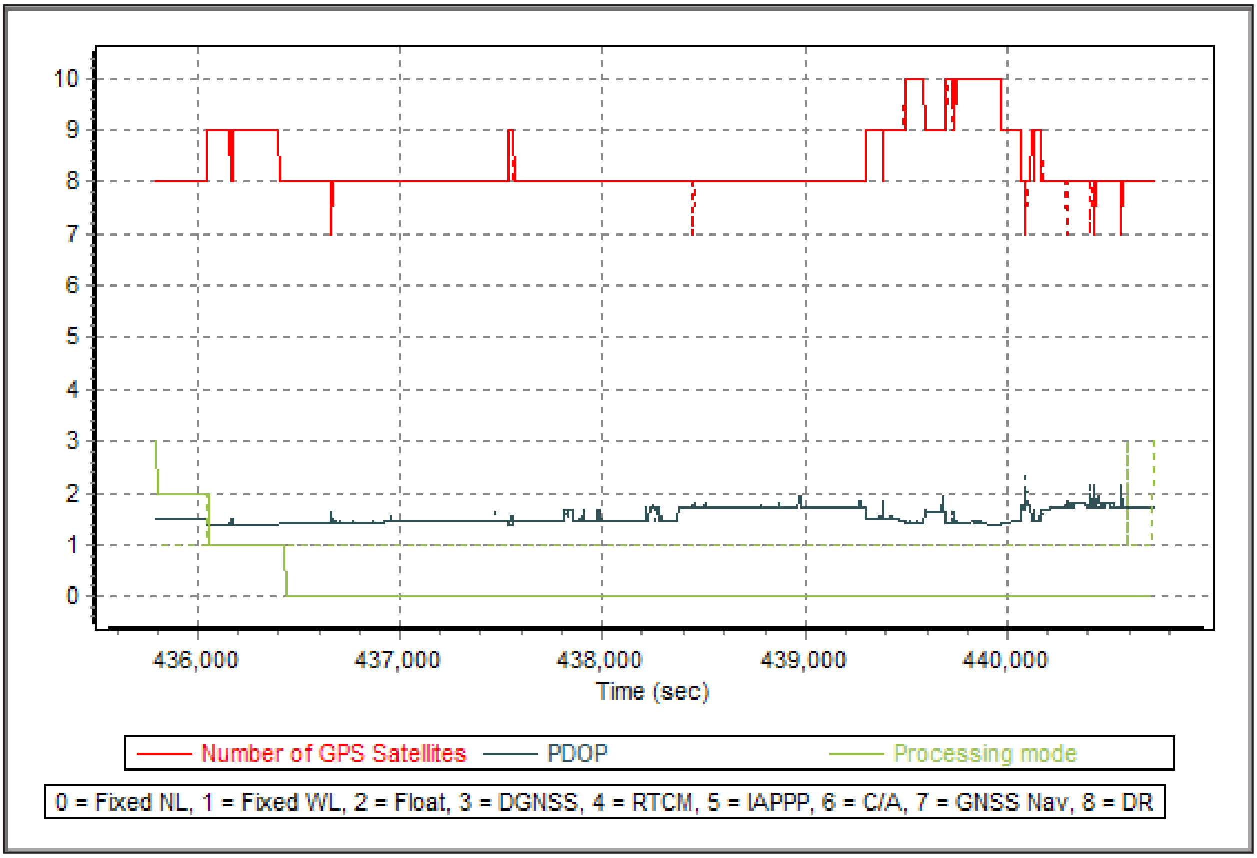


Figure A-8.29. Solution Status

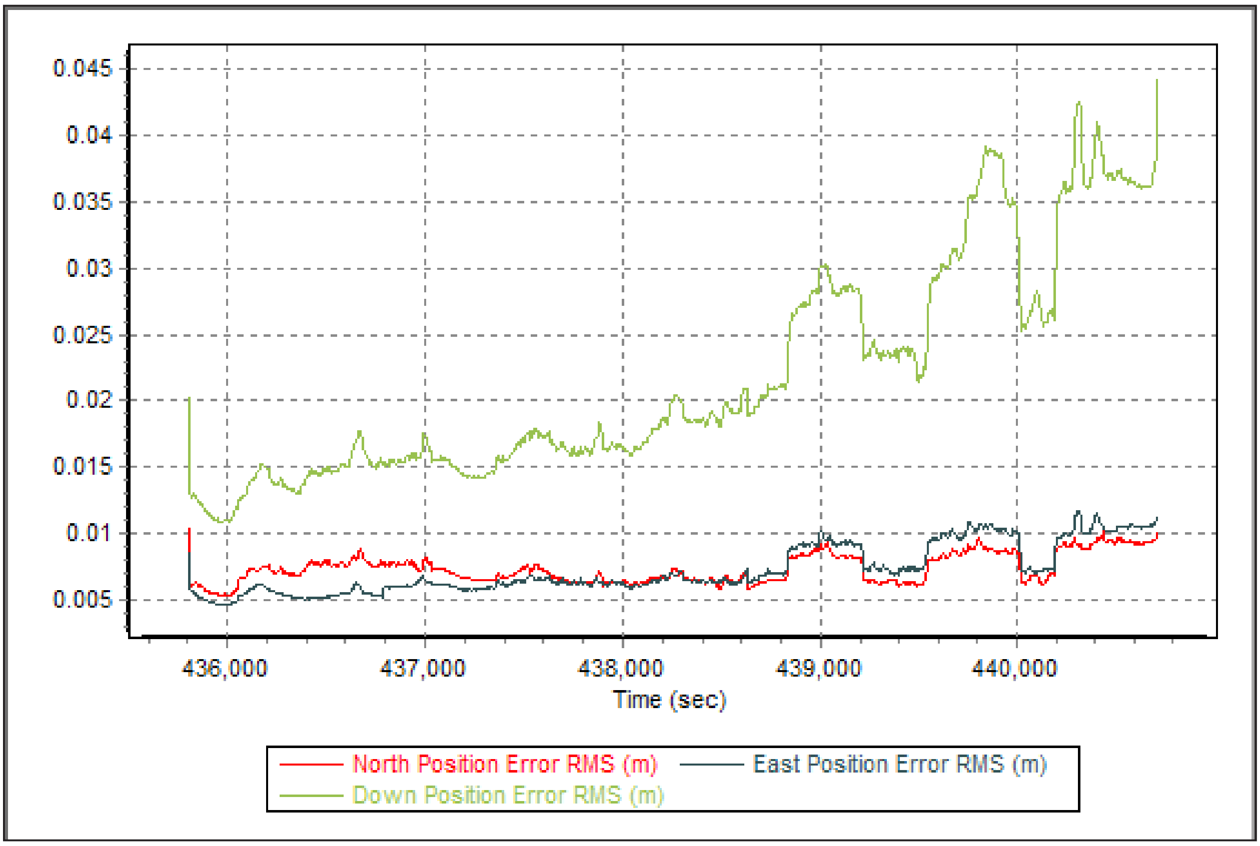


Figure A-8.30. Smoothed Performance Metric Parameters

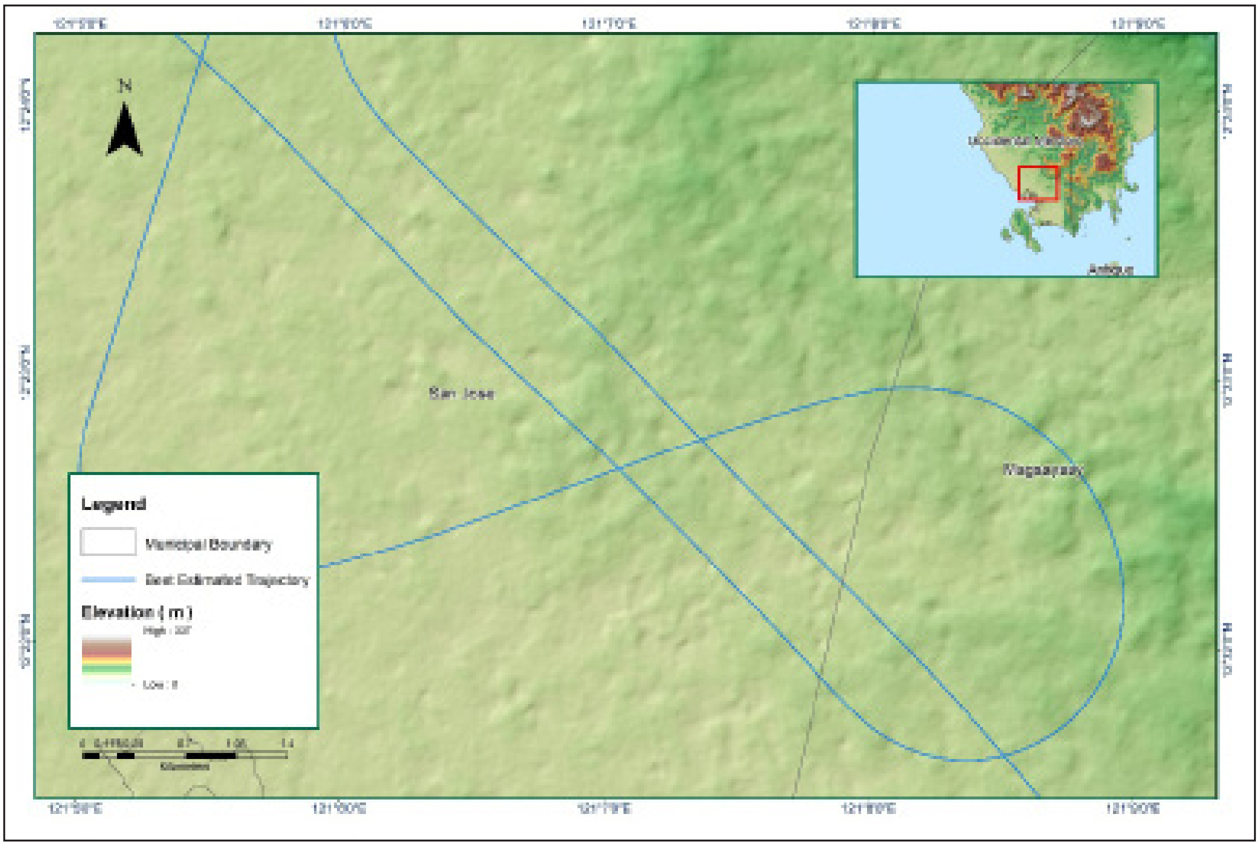


Figure A-8.31. Best Estimated Trajectory

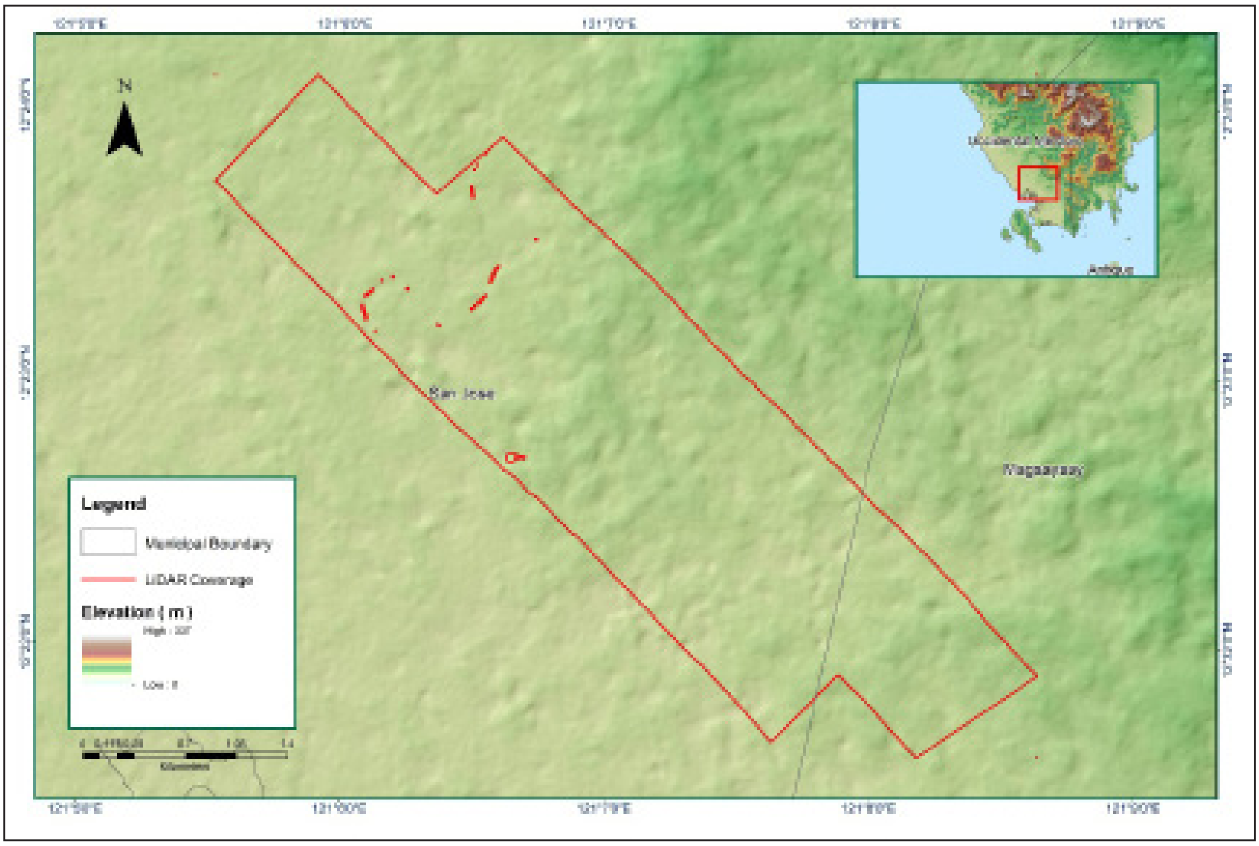


Figure A-8.32. Coverage of LiDAR data

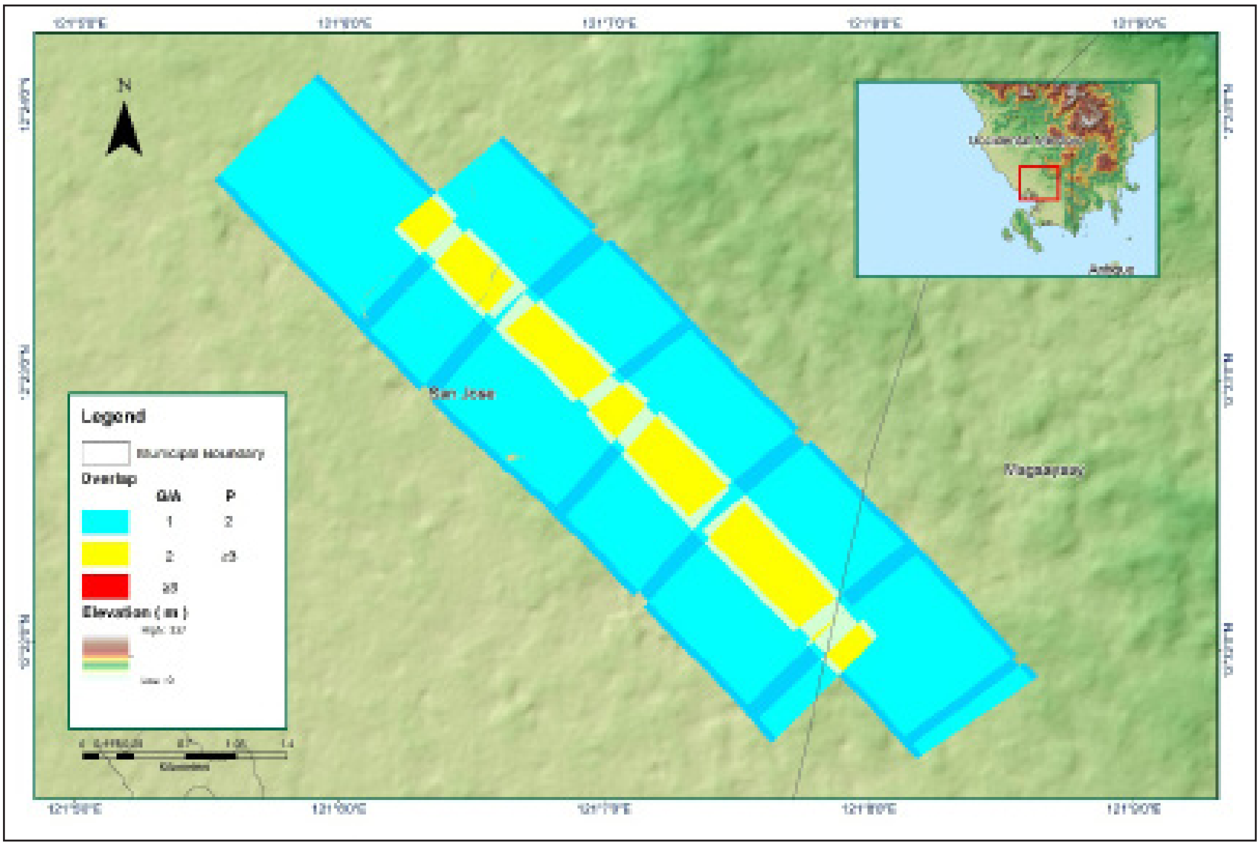


Figure A-8.33. Image of data overlap

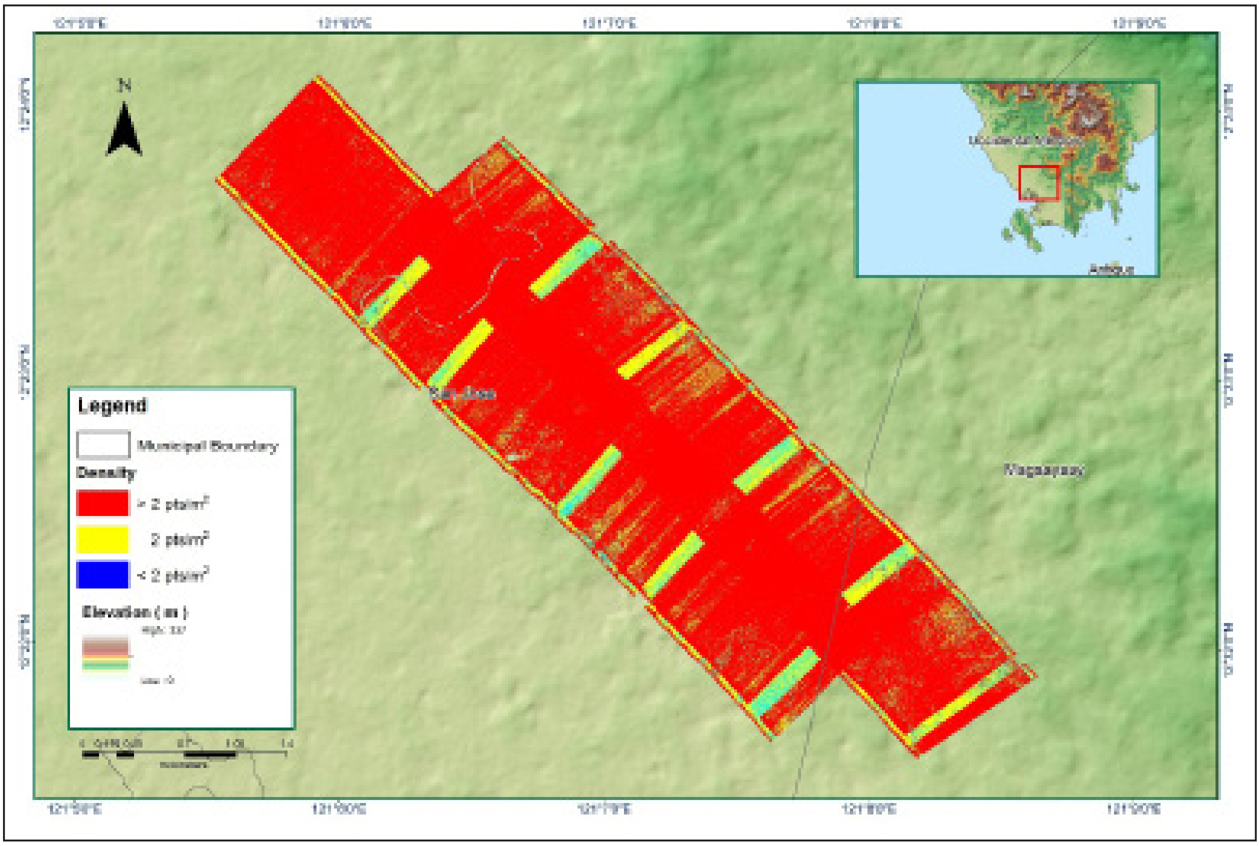


Figure A-8.34. Density map of merged LiDAR data

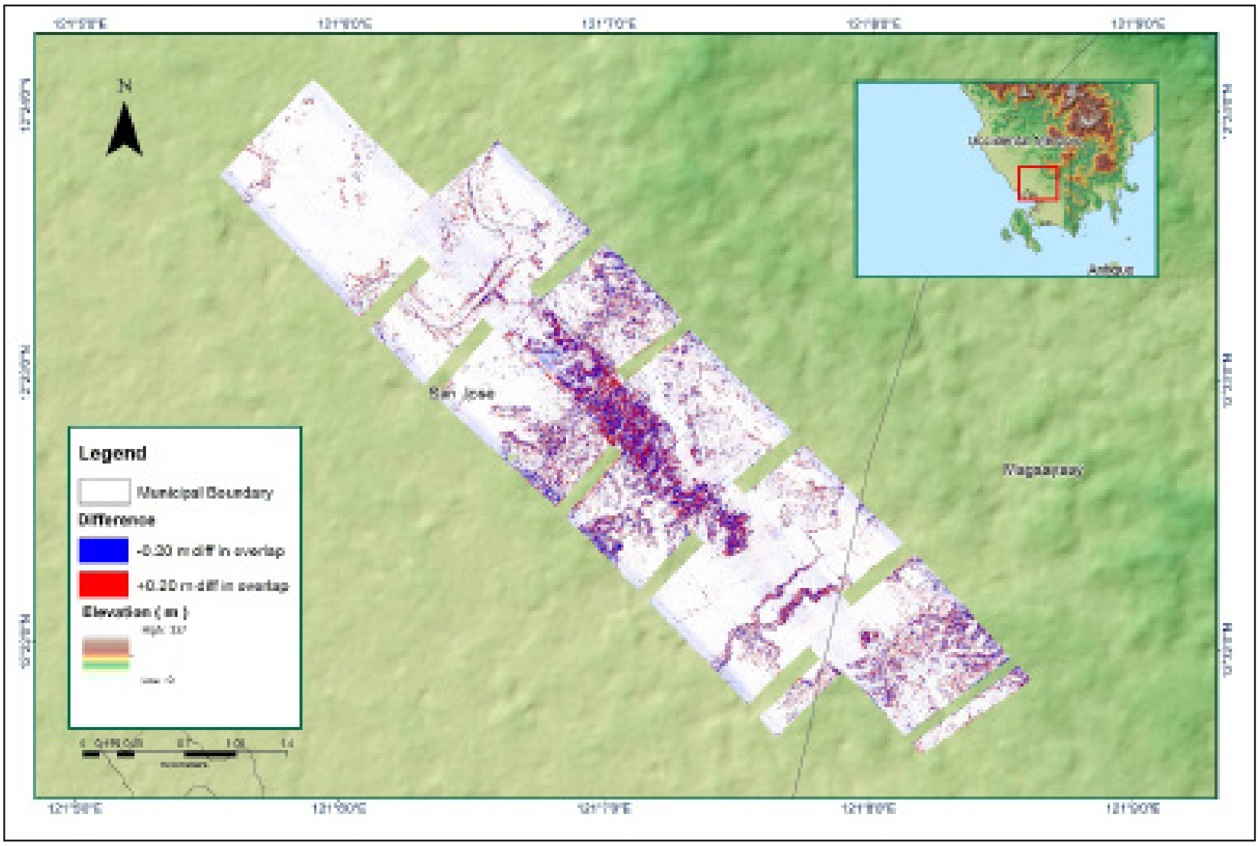


Figure A-8.35. Elevation difference between flight lines

Table A-8.6 Mission Summary Report for Blk29C_additional

Flight Area	Davao Oriental
Mission Name	Blk29C_additional
Inclusive Flights	3078P, 3082P
Range data size	15.42GB
POS	341MB
Image	26MB
Transfer date	January 15, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.79
RMSE for East Position (<4.0 cm)	0.78
RMSE for Down Position (<8.0 cm)	1.67
Boresight correction stdev (<0.001deg)	0.359804
IMU attitude correction stdev (<0.001deg)	0.083211
GPS position stdev (<0.01m)	0.0024
Minimum % overlap (>25)	40.31
Ave point cloud density per sq.m. (>2.0)	2.10
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	108
Maximum Height	521.55 m
Minimum Height	51.07 m
Classification (# of points)	
Ground	132,379,761
Low vegetation	125,752,184
Medium vegetation	199,077,351
High vegetation	599,574,573
Building	15,255,571
Orthophoto	Yes
Processed by	Engr. Abigail Ching, Engr. Harmond Santos, Kathryn Claudyn Zarate

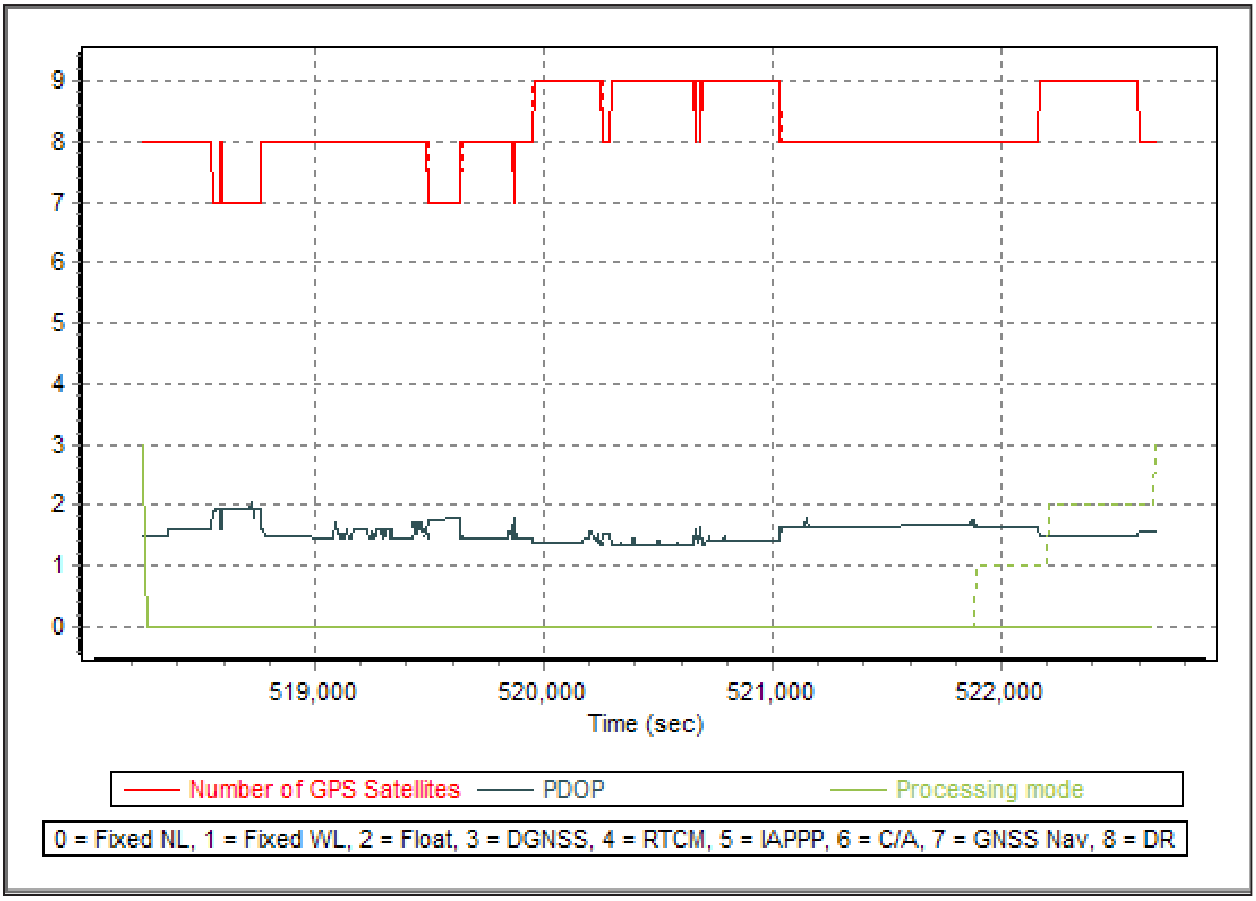


Figure A-8.36. Solution Status

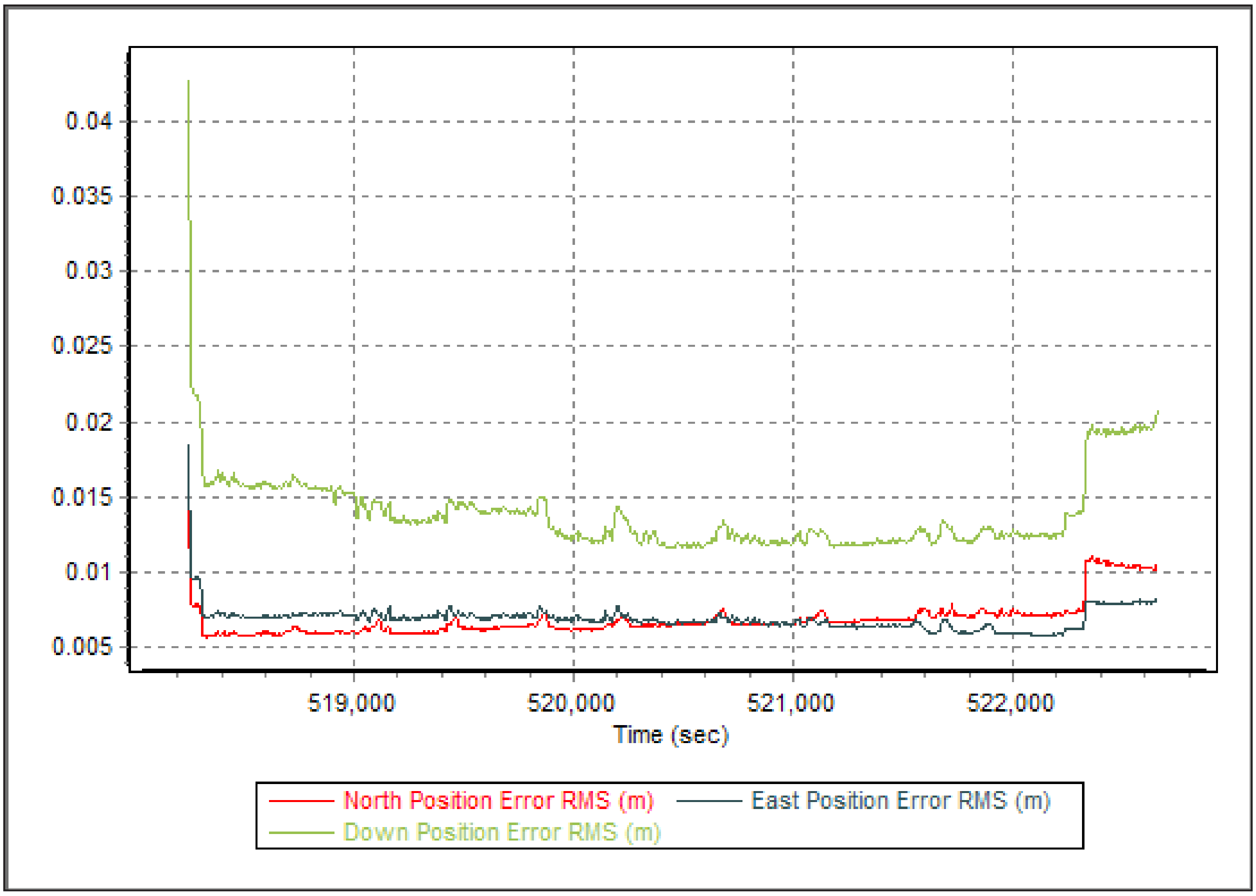


Figure A-8.37. Smoothed Performance Metric Parameters

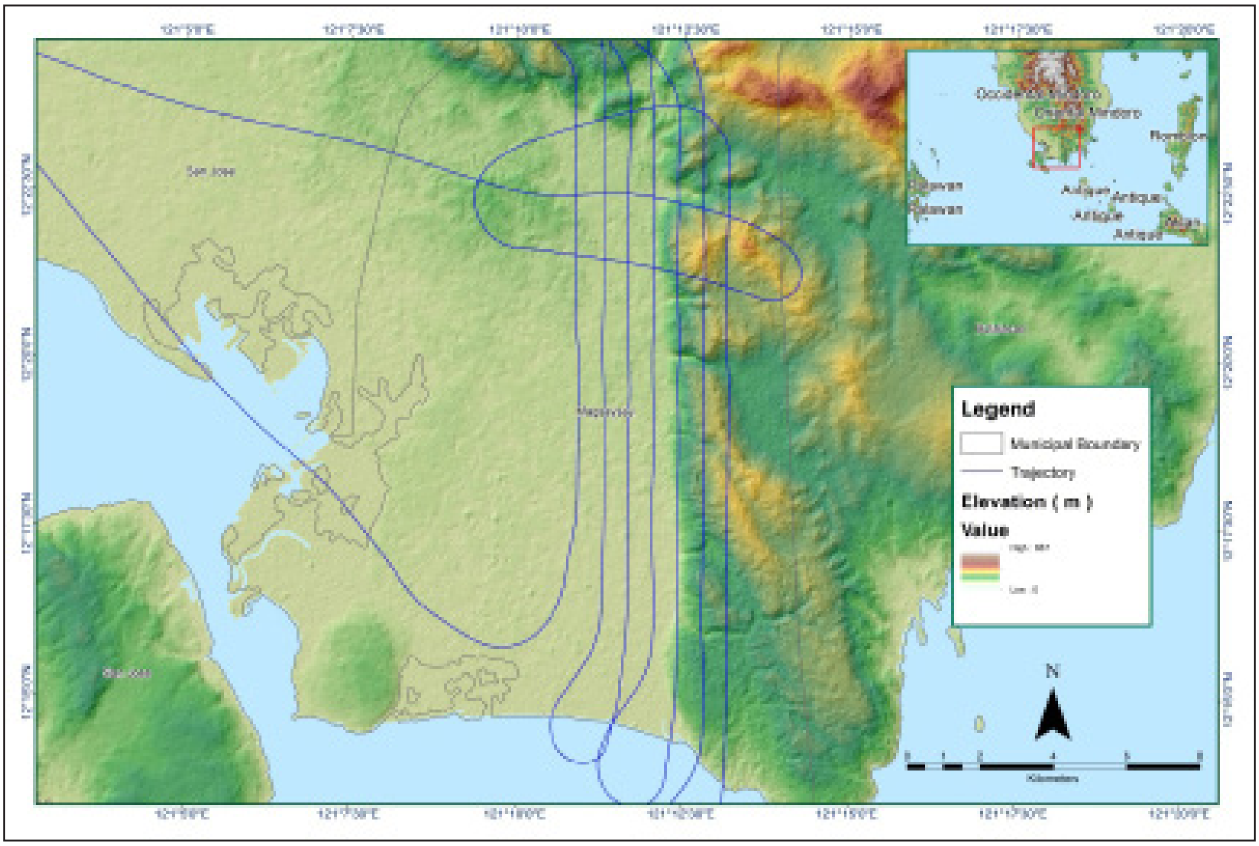


Figure A-8.38. Best Estimated Trajectory

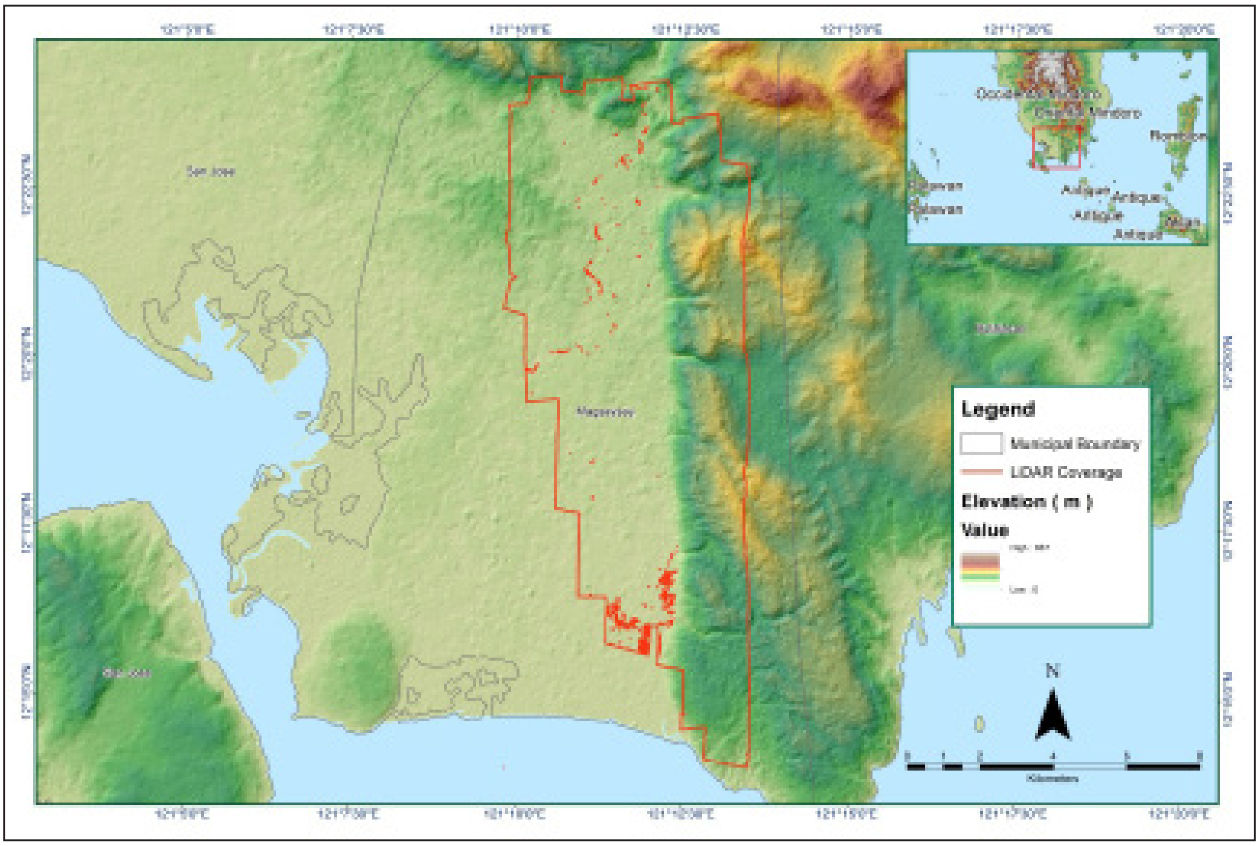


Figure A-8.39. Coverage of LiDAR data

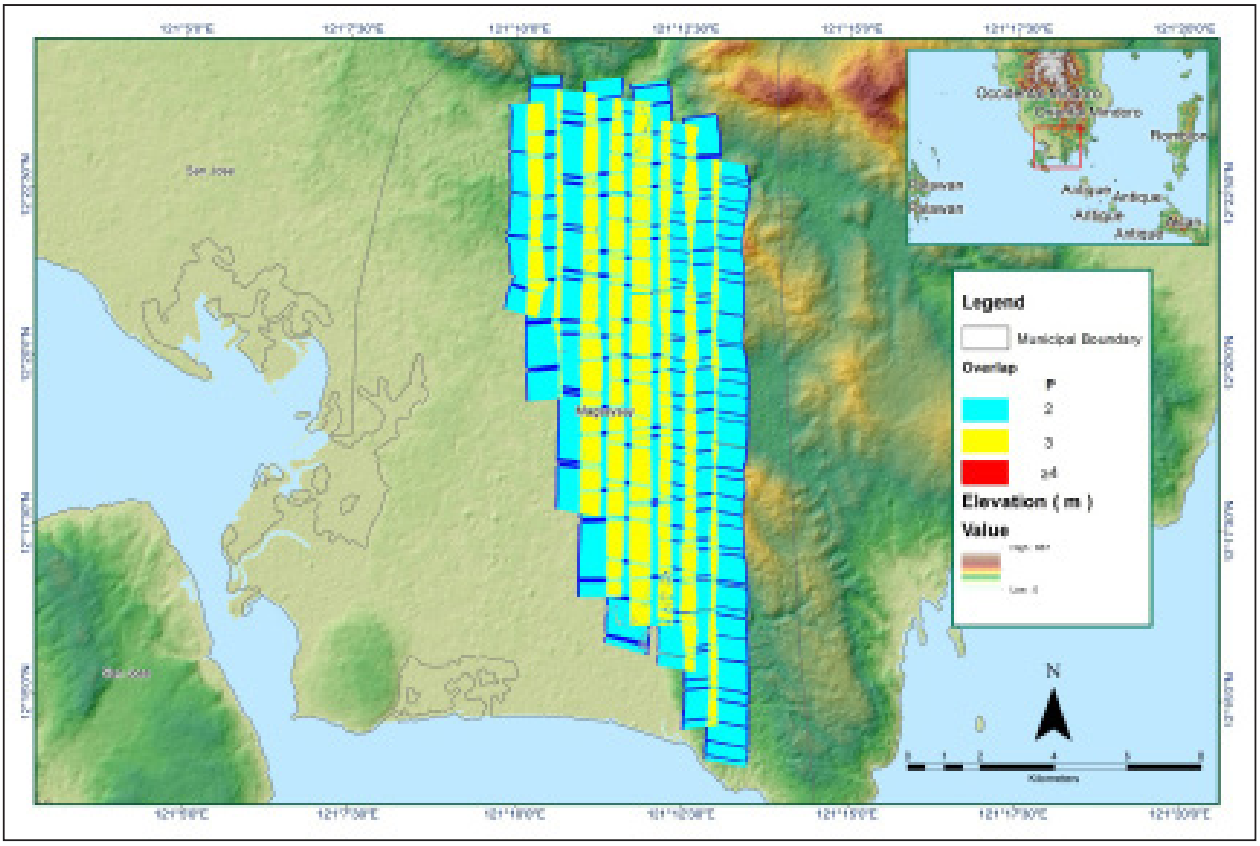


Figure A-8.40. Image of data overlap

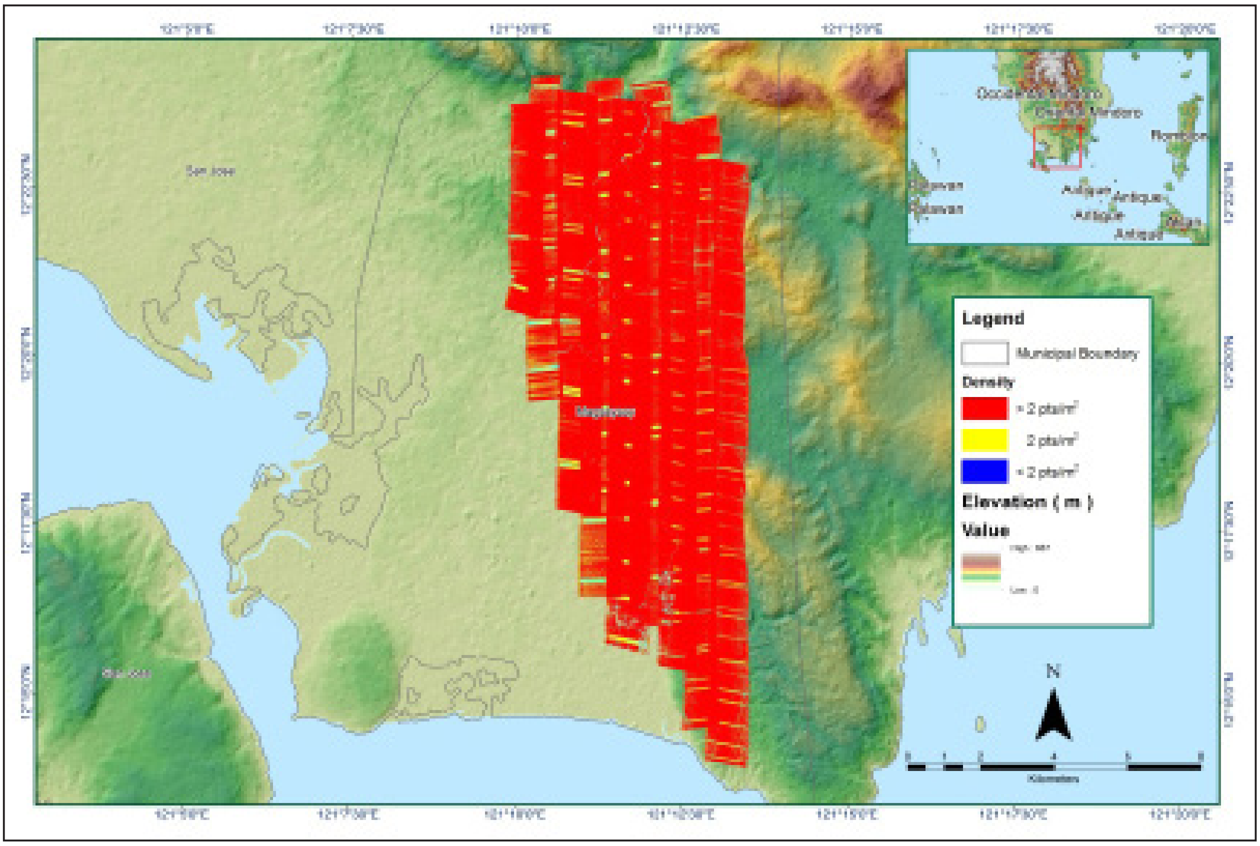


Figure A-8.41. Density map of merged LiDAR data

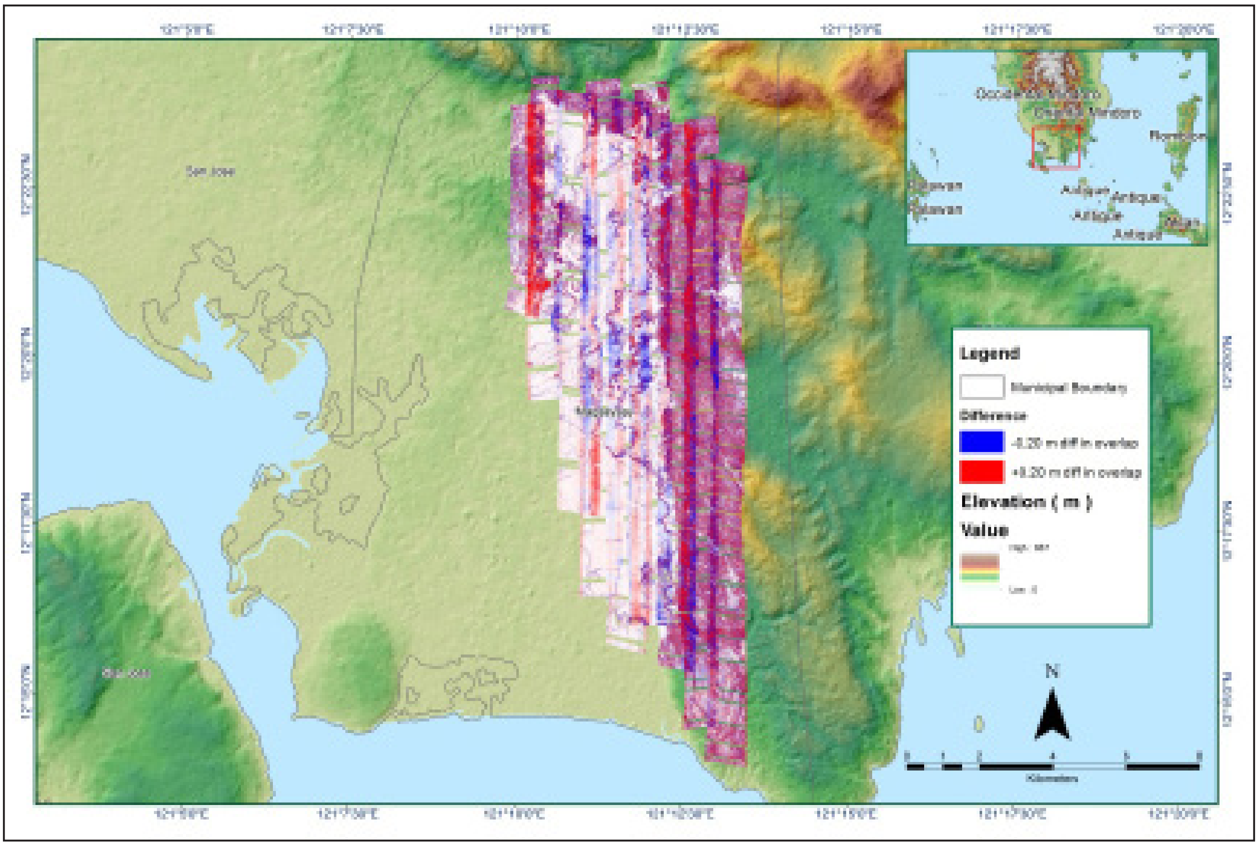


Figure A-8.42. Elevation difference between flight lines

Annex 9. Batang-batang Model Basin Parameters

Table A-9.1 Batang-batang Model Basin Parameters

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

Sub-basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (M3/S)	Recession Constant	Ratio to Peak
W700	0.4816	99	0.0	1.0836	155.19	0.62682	1	0.5
W710	0.3454	99	0.0	0.21805	45.486	0.18063	1	0.5
W720	0.4316	99	0.0	0.38721	84.853	0.35507	1	0.5
W730	1.2222	94.809	0.0	2.1907	139.43	0.65987	1	0.5
W740	0.5106	64.992	0.0	0.24921	79.963	0.21583	1	0.5
W750	0.5432	62.946	0.0	0.42364	62.246	0.0578862	1	0.5
W760	0.3502	99	0.0	0.63613	90.826	0.17837	1	0.5
W770	0.3946	99	0.0	0.37577	120.98	0.58995	1	0.5
W780	0.5432	99	0.0	0.09213	66.172	0.0154847	1	0.5
W790	0.5368	99	0.0	1.9798	189.93	0.55494	1	0.5
W800	1.1276	65.607	0.0	0.70668	102.24	0.26565	1	0.5
W810	0.5602	91.079	0.0	1.1138	159.5	0.95204	1	0.5
W820	1.2222	62.946	0.0	0.4252	93.245	0.30553	1	0.5
W830	1.1412	65.211	0.0	0.34601	75.888	0.25639	1	0.5
W840	2.75	42.821	0.0	0.2935	95.942	0.0912979	1	0.5
W850	0.4842	99	0.0	0.71624	69.124	0.36562	1	0.5
W860	1.1498	67.648	0.0	0.10129	74.201	0.28254	1	0.5
W870	0.7656	88.905	0.0	0.3824	125.18	0.52965	1	0.5
W880	0.5432	99	0.0	0.54271	116.51	0.25141	1	0.5
W890	0.7986	99	0.0	2.5252	105.07	0.27817	1	0.5
W900	0.9754	99	0.0	0.22251	158.37	0.79070	1	0.5
W910	0.403	99	0.0	0.14794	47.649	0.32253	1	0.5
W920	0.2732	99	0.0	0.07321	15.632	0.24728	1	0.2222
W930	0.3444	99	0.0	0.25243	287.16	0.19742	1	0.5
W940	0.5432	99	0.0	0.14816	163.49	0.37988	1	0.5

Sub-basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Discharge (M3/S)	Recession Constant	Ratio to Peak
W950	0.4394	99	0.0	0.15159	32.425	0.0517649	1	0.4917
W960	0.3936	99	0.0	0.14121	100.67	0.48522	1	0.5
W970	0.6004	99	0.0	0.11528	24.538	0.37268	1	0.3333
W980	0.8932	99	0.0	2.1041	456.64	1.2000	1	0.5
W990	0.6162	99	0.0	0.22157	161.37	0.60090	1	0.5

Annex 10. Batang-batang Model Reach Parameters

Table A-10.1 Batang-batang Model Reach Parameters

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

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

Annex 11. Batang-batang Field Validation Data

Table A-11.1 Batang-batang Field Validation Data

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

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

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

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

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

Annex 12. Phil-LiDAR 1 UPLB Team Composition

Project Leader
Asst. Prof. Edwin R. Abucay (CHE, UPLB)

Project Staffs/Study Leaders
Asst. Prof. Efraim D. Roxas (CHE, UPLB)
Asst. Prof. Joan Pauline P. Talubo (CHE, UPLB)
Ms. Sandra Samantela (CHE, UPLB)
Dr. Cristino L. Tiburan (CFNR, UPLB)
Engr. Ariel U. Glorioso (CEAT, UPLB)
Ms. Miyah D. Queliste (CAS, UPLB)
Mr. Dante Gideon K. Vergara (SESAM, UPLB)

Sr. Science Research Specialists
Gillian Katherine L. Inciong
For. John Alvin B. Reyes

Research Associates
Alfi Lorenz B. Cura
Angelica T. Magpantay
Gemmalyn E. Magnaye
Jayson L. Arizapa
Kevin M. Manalo
Leendel Jane D. Punzalan
Maria Michaela A. Gonzales
Paulo Joshua U. Quilao
Sarah Joy A. Acepcion
Ralphael P. Gonzales

Computer Programmers
Ivan Marc H. Escamos
Allen Roy C. Roberto

Information Systems Analyst
Jan Martin C. Magcale

Project Assistants
Daisili Ann V. Pelegrina
Athena Mercado
Kaye Anne A. Matre
Randy P. Porciocula