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

LiDAR Surveys and Flood Mapping of Balantian River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of the Philippines Cebu

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

This research project is supported by the Department of Science and Technology (DOST) as part of its Grants-in-Aid (GIA) Program and is to be cited as:

E.C. Paringit, J. Sinogaya, L.P. Balicanta, C. Cruz, L.G. Acuña, G. Hipolito, J.P.S. Mars, R.A.C. Felismino, M.R.C.O. Ang, J.L.D. Fabila, S.J.D. Samalburo, G.M. Apat, J.F. Prieto, M.A.L. Olanda, A.R.V. Araneta, C.J.P. Añonuevo, F.D. Maraya, C.B. de Guzman, J.S. Caballero, P.M.P. dela Cruz, D.T. Lozano, D.R.P.C. Tajora, E.B. Salvador, R.C. Alberto, C.C. Atacador, L.R. Taguse, A.M. Lagmay, C. Uichanco, S. Sueno, M. Moises, H. Ines, M. del Rosario, K. Punay, N. Tingin, N.C. Tan, M. Arias (2017), LiDAR Surveys and Flood Mapping of Balantian River, in Enrico C. Paringit, (Ed.), Flood Hazard Mapping of the Philippines using LIDAR, Quezon City: University of the Philippines Training Center on Geodesy and Photogrammetry-200pp.

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CONTENTS

List of Tables v
List of Figures vii
List of Acronyms and Abbreviations ix
CHAPTER 1: OVERVIEW OF THE PROGRAM AND BALANTIAN RIVER 1
1.1 Background of the Phil-LiDAR 1 Program 1
1.2 Overview of the Balantian River Basin 1
CHAPTER 2: LIDAR DATA ACQUISITION OF THE BALANTIAN FLOODPLAIN 3
2.1 Flight Plans 3
2.2 Ground Base Stations 5
2.3 Flight Missions 10
2.4 Survey Coverage 11
CHAPTER 3: LIDAR DATA PROCESSING OF THE BALANTIAN FLOODPLAIN 13
3.1 Overview of the LIDAR Data Pre-Processing 13
3.2 Transmittal of Acquired LiDAR Data 14
3.3 Trajectory Computation 14
3.4 LiDAR Point Cloud Computation 17
3.5 LiDAR Data Quality Checking 17
3.6 LiDAR Point Cloud Classification and Rasterization 23
3.7 LiDAR Image Processing and Orthophotograph Rectification 25
3.8 DEM Editing and Hydro-Correction 27
3.9 Mosaicking of Blocks 28
3.10 Calibration and Validation of Mosaicked LiDAR DEM 31
3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model 35
3.12 Feature Extraction 37
3.12.1 Quality Checking of Digitized Features' Boundary 37
3.12.2 Height Extraction 38
3.12.3 Feature Attribution 38
3.12.4 Final Quality Checking of Extracted Features 39
CHAPTER 4: LIDAR VALIDATION SURVEY AND MEASUREMENTS OF THE BALANTIAN RIVER BASIN 41
4.1 Summary of Activities 41
4.2 Control Survey 43
4.3 Baseline Processing 48
4.4 Network Adjustment 48
4.5 Cross-section and Bridge As-Built Survey and Water Level Marking 50
4.6 Validation Points Acquisition Survey 56
4.7 Bathymetric Survey 58
CHAPTER 5: FLOOD MODELING AND MAPPING 61
5.1 Data Used for Hydrologic Modeling 61
5.1.1 Hydrometry and Rating Curves 61
5.1.2 Precipitation 61
5.1.3 Rating Curves and River Outflow 62
5.2 RIDF Station 64
5.3 HMS Model 66
5.4 Cross-section Data 71
5.5 Flo 2D Model 72
5.6 Results of HMS Calibration 74
5.7 Calculated outflow hydrographys and Discharge values for different rainfall return periods 76
5.7.1 Hydrograph using the Rainfall Runoff Model 76
5.7.2 Discharge data using Dr. Horritt's recommended hydrologic method 78
5.8 River Analysis (RAS) Model Simulation 81
5.9 Flow Depth and Flood Hazard 82
5.10 Inventory of Areas Exposed to Flooding of Affected Areas 89
5.11 Flood Validation 121
REFERENCES 124
ANNEXES 125
Annex 1. Technical Specifications of the Gemini LiDAR Sensor used in the Balantian Floodplain Survey 125
Annex 2. NAMRIA Certification of Reference Points used in the LiDAR Survey 127
Annex 3. Baseline Processing Reports of Control Points used in the LiDAR Survey 130
Annex 4. The LiDAR Survey Team Composition 132

Annex 5. Data Transfer Sheets for the Balantian Floodplain Flights.......... 133
Annex 6. Flight Logs for the Flight Missions.......... 134
Annex 7. Flight Status Reports.......... 139
Annex 8. Mission Summary Reports.......... 145
Annex 9. Balantian Model Basin Parameters.......... 190
Annex 10. Balantian Model Reach Parameters.......... 192
Annex 11. Balantian Field Validation Points.......... 193
Annex 12. Educational Institutions Affected by Flooding in Balantian Floodplain.......... 197
Annex 13. Medical Institutions Affected by Flooding in Balantian Floodplain.......... 200

LIST OF TABLES

Table 1. Flight planning parameters for the Gemini LiDAR system 3
Table 2. Details of the recovered NAMRIA horizontal control point ILO-78, used as a base station for the LiDAR acquisition 6
Table 3. Details of the recovered NAMRIA horizontal control point ILO-3134, used as a base station for the LiDAR acquisition 7
Table 4. Details of the recovered NAMRIA horizontal control point ILO-97, used as a base station for the LiDAR acquisition 8
Table 5. Details of the recovered NAMRIA horizontal control point ILO-104, used as a base station for the LiDAR acquisition 9
Table 6. Ground control points used during the LiDAR data acquisition 10
Table 7. Flight missions for the LiDAR data acquisition in the Balantian floodplain 10
Table 8. Actual parameters used during the LiDAR data acquisition 10
Table 9. List of municipalities and cities surveyed during the Balantian floodplain LiDAR survey 11
Table 10. Self-calibration results for the Balantian flights 17
Table 11. List of LiDAR blocks for the Balantian floodplain 19
Table 12. Balantian classification results in TerraScan 23
Table 13. LiDAR blocks with their corresponding areas 27
Table 14. Shift values of each LiDAR block of the Balantian floodplain 29
Table 15. Calibration statistical measures 33
Table 16. Validation statistical measures 34
Table 17. Quality checking ratings for the Balantian building features 38
Table 18. Building features extracted for the Balantian floodplain 38
Table 19. Total length of extracted roads for the Balantian floodplain 39
Table 20. Number of extracted water bodies for the Balantian floodplain 39
Table 21. List of Reference and Control points occupied in the Balantian River survey (Source: NAMRIA and UP-TCAGP) 43
Table 22. Baseline processing report for the Balantian River Basin static survey 48
Table 23. Constraints applied to the adjustments of the control points 48
Table 24. Adjusted grid coordinates for the control points used in the Balantian floodplain survey 49
Table 25. Adjusted geodetic coordinates for control points used in the Balantian River floodplain validation 50
Table 26. Reference and control points used in the Balantian River Static Survey, with their corresponding locations (Source: NAMRIA and UP-TCAGP) 50
Table 27. RIDF values for the Roxas Rain Gauge, computed by PAGASA 64
Table 28. Range of calibrated values for Balantian 75
Table 29. Efficiency Test of the Balantian HMS Model 76
Table 30. Peak values of the Balantian HEC-HMS Model outflow, using the Roxas RIDF 77
Table 31. Summary of Balantian River (1) discharge, generated in HEC-HMS 78
Table 32. Validation of river discharge estimates 78
Table 33. Summary of Balantian River (1) discharge generated in HEC-HMS 79
Table 34. Validation of river discharge estimates 79
Table 35. Summary of Balantian River (3) discharge generated in HEC-HMS 80
Table 36. Validation of river discharge estimates 80
Table 37. Municipalities affected in the Balantian floodplain 82
Table 38. Affected areas in Balasan, Iloilo during a 5-year rainfall return period 90
Table 39. Affected areas in Batad, Iloilo during a 5-year rainfall return period 92
Table 40. Affected areas in Estancia, Iloilo during a 5-year rainfall return period 94
Table 41. Affected areas in Pilar, Capiz during a 5-year rainfall return period 96
Table 42. Affected areas in San Dionisio, Iloilo during a 5-year rainfall return period 98
Table 43. Affected areas in Sara, Iloilo during a 5-year rainfall return period 99
Table 44. Affected areas in Balasan, Iloilo during a 25-year rainfall return period 100
Table 45. Affected areas in Batad, Iloilo during a 25-year rainfall return period 102
Table 46. Affected areas in Estancia, Iloilo during a 25-year rainfall return period 104
Table 47. Affected areas in Pilar, Capiz during a 25-year rainfall return period 106
Table 48. Affected areas in San Dionisio, Iloilo during a 25-year rainfall return period 108
Table 49. Affected areas in Sara, Iloilo during a 25-year rainfall return period 109
Table 50. Affected areas in Balasan, Iloilo during a 100-year rainfall return period 110
Table 51. Affected areas in Batad, Iloilo during a 100-year rainfall return period 112
Table 52. Affected areas in Estancia, Iloilo during a 100-year rainfall return period 114
Table 53. Affected areas in Pilar, Capiz during a 100-year rainfall return period 116

Table 54. Affected areas in San Dionisio, Iloilo during a 100-year rainfall return period....................... 118
Table 55. Affected areas in Sara, Iloilo during a 100-year rainfall return period 119
Table 56. Area covered by each warning level, with respect to the rainfall scenario............................ 120
Table 57. Actual flood depth vs. simulated flood depth, at different levels in the Balantian River Basin.. 123
Table 58. Summary of Accuracy Assessment in the Balantian River Basin survey 123

LIST OF FIGURES

Figure 1. Location map of the Balantian River Basin (in brown)....2
Figure 2. Flight plans and base stations used to cover the Balantian floodplain survey....4
Figure 3. (a) GPS set-up over ILO-78 in Barangay Batad Viejo, Batad, Iloilo; and (b) NAMRIA reference point ILO-78, as recovered by the field team....6
Figure 4. (a) GPS set up over ILO-3134, located at the first bridge after Balasan National High School in Barangay Balanti-an, Balasan, Iloilo; and (b) NAMRIA reference point ILO-3134, as recovered by the field team....7
Figure 5. (a) GPS set-up over ILO-97, situated over an irrigation canal near the national road in Barangay Tabunan, Lemery, Iloilo; and (b) NAMRIA reference point ILO-97, as recovered by the field team....8
Figure 6. (a) GPS set-up over ILO-104, located in an irrigation canal near Ajuy High School in Barangay Poblacion, Ajuy, Iloilo; and (b) NAMRIA reference point ILO-104, as recovered by the field team....9
Figure 7. Actual LiDAR survey coverage of the Balantian floodplain....12
Figure 8. Schematic diagram for the Data Pre-Processing Component....14
Figure 9. Smoothed Performance Metric Parameters of Balantian Flight 2778G....15
Figure 10. Solution Status Parameters of Balantian Flight 2778G....16
Figure 11. The best estimated trajectory conducted over the Balantian floodplain....17
Figure 12. Boundaries of the processed LiDAR data over the Balantian floodplain....18
Figure 13. Image of data overlap for the Balantian floodplain....20
Figure 14. Pulse density map of merged LiDAR data for the Balantian floodplain....21
Figure 15. Elevation difference map between flight lines for the Balantian floodplain....22
Figure 16. Quality checking for Balantian Flight 2778G, using the Profile Tool of QT Modeler....23
Figure 17. (a) Tiles for Balantian floodplain, and (b) classification results in TerraScan....24
Figure 18. Point cloud (a) before and (b) after classification....24
Figure 19. The production of (a) last return DSM and (b) DTM, (c) first return DSM and (d) secondary DTM in some portion of Balantian floodplain....25
Figure 20. The Balantian floodplain, with available orthophotographs....26
Figure 21. Sample orthophotograph tiles for the Balantian floodplain....26
Figure 22. Portions in the DTM of the Balantian floodplain – bridges (a) before and (b) after manual editing; a paddy field (c) before and (d) after data retrieval....28
Figure 23. Map of processed LiDAR data for the Balantian floodplain....30
Figure 24. Map of the Balantian floodplain, with the validation survey points in green....32
Figure 25. Correlation plot between the calibration survey points and the LiDAR data....33
Figure 26. Correlation plot between the validation survey points and the LiDAR data....34
Figure 27. Map of the Balantian floodplain, with bathymetric survey points shown in blue....36
Figure 28. Blocks (in blue) of Balantian building features that were subjected to QC....37
Figure 29. Extracted features for the Balantian floodplain....40
Figure 30. Extent of the bathymetric survey (in blue line) in the Balantian River and the LiDAR data validation survey (in red)....42
Figure 31. GNSS network covering the Balantian River....44
Figure 32. Trimble® SPS 882 set-up at ILO-1, located at the rooftop of the St. Clemente Church bell tower in Barangay La Paz, Iloilo City....45
Figure 33. Trimble® SPS 852 set-up at IL-39A, located in Barangay JT Bretaña, Municipality of Barotac Nuevo, Iloilo....45
Figure 34. Trimble® SPS 882 set-up at UP-SIB located at the Sibalom Bridge in Barangay Anonang, Leon, Iloilo....46
Figure 35. Trimble® SPS 852 set-up at BRV-1, located on the rooftop of Hollywood Star Inn in Barangay Poblacion, Municipality of Barotac Viejo, Iloilo....46
Figure 36. Trimble® SPS 852 set-up at ILO-3135, located at the Balasan Bridge in Barangay Poblacion Sur, Municipality of Balasan, Iloilo....47
Figure 37. Trimble® SPS 882 set-up at ILO-66, located inside Dingle Elementary School, Barangay Camambugan, Municipality of Dingle, Iloilo....47
Figure 38. (a) Panoramic View of the Balasan Bridge facing upstream; and (b) as-built and cross section survey of the Balasan Bridge....51
Figure 39. Balasan Bridge location map....52
Figure 40. Balasan Bridge cross-sectional diagram....53
Figure 41. Balasan Bridge data form....54
Figure 42. Water level markings on the cord of the Balantian Bridge....55
Figure 43. Validation points acquisition set-up for the Balantian River Basin....56

Figure 44. Extent of the validation points acquisition survey covering the length of the Balantian River Basin ... 57
Figure 45. Bathymetric survey in the Balantian River in Barangay Poblacion Sur, Municipality of Balasan, Iloilo ... 58
Figure 46. Extent of the bathymetric survey of the Balantian River ... 59
Figure 47. Riverbed profile of the Balantian River ... 60
Figure 48. The location map of Balantian HEC-HMS model, which was used for calibration ... 62
Figure 49. Cross-section plot of the Balasan Bridge ... 63
Figure 50. The rating curve at the Balasan Bridge, Balasan, Iloilo ... 63
Figure 51. Rainfall and outflow data at Balantian, which were used for modeling ... 64
Figure 52. Location of Roxas RIDF station, relative to Balantian River Basin ... 65
Figure 53. Synthetic storm generated from a 24-hour period rainfall, for various return periods ... 66
Figure 54. Soil map of the Balantian River Basin (Source: DA) ... 67
Figure 55. Land cover map of the Balantian River Basin (Source: NAMRIA) ... 68
Figure 56. Slope map of the Balantian River Basin ... 69
Figure 57. Stream delineation map of Balantian River Basin ... 70
Figure 58. The Balantian River Basin model, generated using HEC-HMS ... 71
Figure 59. River cross-section of the Balantian River, generated through ArcMap HEC GeoRAS tool ... 72
Figure 60. Screenshot of a sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro) ... 73
Figure 61. Generated 100-year rain return hazard map from FLO-2D Mapper ... 73
Figure 62. Generated 100-year rain return flow depth map from FLO-2D Mapper ... 74
Figure 63. Outflow Hydrograph of Balantian produced by the HEC-HMS model, compared with observed outflow ... 75
Figure 64. Outflow hydrograph at the Balantian Station generated using the Iloilo RIDF, simulated in HEC-HMS ... 77
Figure 65. Balantian River (1) generated discharge using 5-, 25-, and 100-year Roxas City RIDF in HEC-HMS ... 78
Figure 66. Balantian River (2) generated discharge using 5-, 25-, and 100-year Roxas City RIDF in HEC-HMS ... 79
Figure 67. Balantian River (3) generated discharge using 5-, 25-, and 100-year Roxas City RIDF in HEC-HMS ... 80
Figure 68. Sample output map of the Balantian RAS Model ... 81
Figure 69. 100-year flood hazard map for the Balantian floodplain, overlaid on Google Earth imagery ... 83
Figure 70. 100-year flow depth map for the Balantian floodplain, overlaid on Google Earth imagery ... 84
Figure 71. 25-year flood hazard map for the Balantian floodplain, overlaid on Google Earth imagery ... 85
Figure 72. 25-year flow depth map for the Balantian floodplain, overlaid on Google Earth imagery ... 86
Figure 73. 5-year flood hazard map for the Balantian floodplain, overlaid on Google Earth imagery ... 87
Figure 74. 5-year flow depth map for the Balantian floodplain, overlaid on Google Earth imagery ... 88
Figure 75. Affected areas in Balasan, Iloilo during a 5-year rainfall return period ... 91
Figure 76. Affected areas in Batad, Iloilo during a 5-year rainfall return period ... 93
Figure 77. Affected areas in Estancia, Iloilo during a 5-year rainfall return period ... 95
Figure 78. Affected areas in Pilar, Capiz during a 5-year rainfall return period ... 97
Figure 79. Affected areas in San Dionisio, Iloilo during a 5-year rainfall return period ... 98
Figure 80. Affected areas in Sara, Iloilo during a 5-year rainfall return period ... 99
Figure 81. Affected areas in Balasan, Iloilo during a 25-year rainfall return period ... 101
Figure 82. Affected areas in Batad, Iloilo during a 25-year rainfall return period ... 103
Figure 83. Affected areas in Estancia, Iloilo during a 25-year rainfall return period ... 105
Figure 84. Affected areas in Pilar, Capiz during a 25-year rainfall return period ... 107
Figure 85. Affected areas in San Dionisio, Iloilo during a 25-year rainfall return period ... 108
Figure 86. Affected areas in Sara, Iloilo during a 25-year rainfall return period ... 109
Figure 87. Affected areas in Balasan, Iloilo during a 100-year rainfall return period ... 111
Figure 88. Affected areas in Batad, Iloilo during a 100-year rainfall return period ... 113
Figure 89. Affected areas in Estancia, Iloilo during a 100-year rainfall return period ... 115
Figure 90. Affected areas in Pilar, Capiz during a 100-year rainfall return period ... 117
Figure 91. Affected areas in San Dionisio, Iloilo during a 100-year rainfall return period ... 118
Figure 92. Affected areas in Sara, Iloilo during a 100-year rainfall return period ... 119
Figure 93. Validation points for the 25-year flood depth map of the Balantian floodplain ... 122
Figure 94. Flood map depth vs. actual flood depth ... 122

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
BSWM	Bureau of Soils and Water Management
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DA	Department of Agriculture
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]
IMU	Inertial Measurement Unit
kts	knots
LAS	LiDAR Data Exchange File format
LC	Low Chord
LGU	local government unit
LiDAR	Light Detection and Ranging
LMS	LiDAR Mapping Suite
m AGL	meters Above Ground Level
MMS	Mobile Mapping Suite
MSL	mean sea level
NAMRIA	National Mapping and Resource Information Authority
NSO	National Statistics Office
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
RBCO	River Basin Control Office
RIDF	Rainfall-Intensity-Duration-Frequency
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
SRS	Science Research Specialist
SSG	Special Service Group
TBC	Thermal Barrier Coatings
UPC	University of the Philippines Cebu
UP-TCAGP	University of the Philippines – Training Center for Applied Geodesy and Photogrammetry
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER 1: OVERVIEW OF THE PROGRAM AND BALANTIAN RIVER

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

1.1 Background of the Phil-LiDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program in 2014 entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1, supported by the Department of Science and Technology (DOST) Grants-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at a 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.

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for a 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 the 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 Cebu (UPC). UPC is in charge of processing LiDAR data and conducting data validation reconnaissance, cross section, bathymetric survey, validation, river flow measurements, flood height and extent data gathering, flood modeling, and flood map generation for the twenty-two (22) river basins in the Central Luzon Region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Balantian River Basin

The Balantian River Basin is located in the northeastern point of the province of Iloilo, specifically at the east of the Panay Island in Visayas. The basin covers the Municipalities of Balasan, Batad, Estancia, and San Dionisio in Iloilo; as well as the Municipality of Pilar in the province of Capiz. According to the Department of Environment and Natural Resources - River Basin Control Office (DENR-RBCO), it has an approximate land area of 50 square kilometers, with an estimated run-off of 64 million cubic meters (MCM) (RBCO, 2015).
The basin's main stem, the Balantian River, is approximately 8.07 kilometers in length, and drains towards the West Philippine Sea. The river stream network traverses the Barangays Tupaz, Mamhut Norte, and Poblacion Sur; all of which are in the Municipality of Balasan.

The Balantian floodplain area of 138.66 square kilometers covers the Municipalities of Balasan, Batad, San Dionisio, Carles, Estancia , and Pilar .

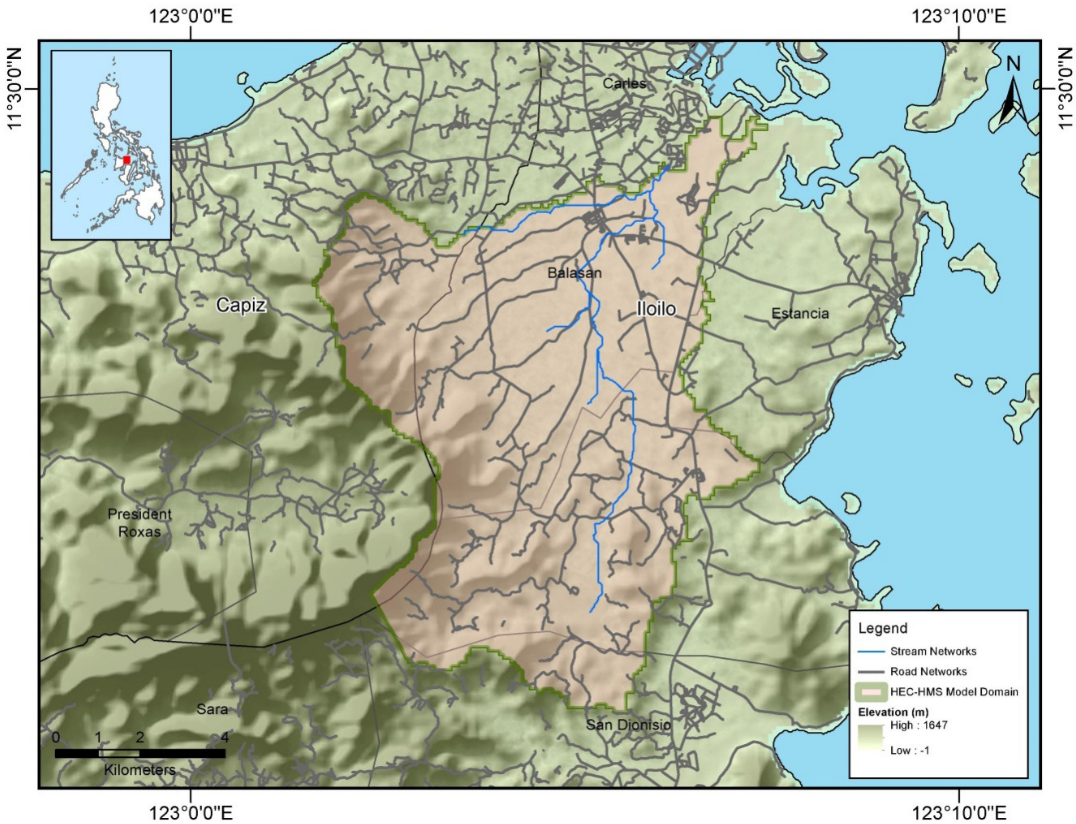

Figure 1. Location map of the Balantian River Basin (in brown)

According to the 2010 census conducted by the National Statistics Office (NSO), the total population of residents within the immediate vicinity of the river is 4,979, distributed among the three (3) barangays.

Parts of the areas covered by the basin are cultivated for agricultural products; such as, coconut, cereal, and sugar. At the same time, the coastal areas thrive with aquaculture, through fishing and the cultivation of oysters.

On October 7, 2015, flash floods occurred near the riverside when Typhoon Lando made landfall in the Western Visayas, carrying intermittent rainfall.

The Phil-LiDAR 1 Program hopes to contribute to the mitigation of the impact of such flooding events, which are caused by typhoons that take place in the country every year. In the conduct of the Program, the Balantian floodplain was 99.8% covered with LiDAR data, which compromises nine (9) blocks. The LiDAR data was calibrated, mosaicked with an RMSE value of -0.39, and then bathy burned. The bathy survey conducted reached a total length of 7.99 kilometers, with 6,026 points surveyed; starting at the Bangon Bridge in Barangay Poblacion Sur, Balasan, until the mouth of the river. There were 21,746 buildings, 348-kilometer roads, 585 water bodies, and 16 bridges that were digitized in the floodplain, based on the LiDAR data. Feature extraction attribution was conducted among the said building features, comprised of 20,581 residential structures, 428 schools, and 25 medical institutions.

The flood hazard maps produced for the Balantian floodplain covers 44.35 square kilometers, 46.12 square kilometers, and, 58.39 square kilometers for the 5-year, 25-year, and 100-year rainfall return periods, respectively. The flood hazard maps encompass twenty-three (23) barangays in Balasan; twenty-four (24) barangays in Batad; five (5) barangays in San Dionisio; four (4) barangays in Carles; ten (10) barangays, in Pilar; and twenty-two (22) barangays in Estancia. A flood depth validation was conducted using one hundred and eighty-seven (187) randomly generated points in the 25-year rainfall flood depth map, which were spread throughout the six (6) ranges of flood depths – 0-0.2 meters, 0.21-0.5 meters, 0.51-1 meter, 1.01-2 meters, 2.10-5 meters, and more than 5 meters. The validation yielded an RMSE value of 0.766 meters.

The HEC-HMS model of the Balantian River basin still requires calibration. Several flow data gathering activities were performed at the Bangon Bridge in the Municipality of Balasan, Iloilo. However, the onset of the El Niño phenomenon, characterized by the lack of rain events and minimal precipitation, coincided with the project duration and consequently prevented the acquisition of sufficient flow and rainfall data.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE BALANTIAN FLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Balantian floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in Iloilo. These missions were planned for twelve (12) lines that ran for at most four and a half (4.5) hours, including take-off, landing, and turning time. The Gemini LiDAR system was utilized for the missions (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR system are found in Table 1. Figure 2 illustrates the flight plans for the Balantian floodplain survey.

Table 1. Flight planning parameters for the Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK37A	1000	30	50	125	30	130	5
BLK37B	800	40	50	125	50	130	5
BLK37C	1000	30	50	125	30	130	5
BLK37D	1000	30	50	125	30	130	5

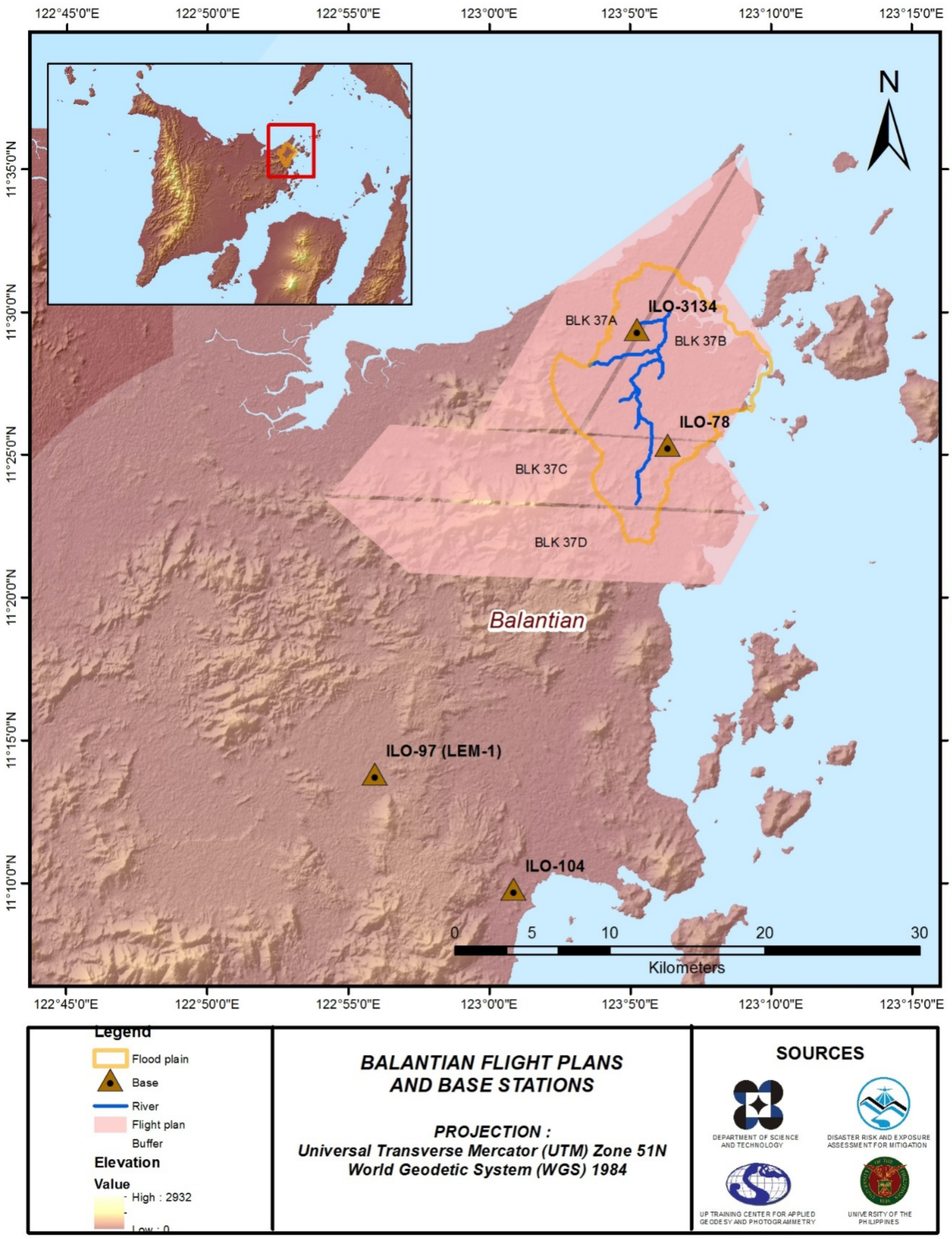


Figure 2. Flight plans and base stations used to cover the Balantian floodplain survey

2.2 Ground Base Stations

The field team for this undertaking was able to recover four (4) NAMRIA reference points: ILO-78, ILO-97, ILO-104, and ILO-3134, which are of second (2^{nd}) order accuracy. Fourth (4^{th}) order ground control points where then re-processed to obtain the coordinates of the reference points of second (2^{nd}) order accuracy. The certifications for the NAMRIA reference points are found in Annex 2; while the baseline processing report for the re-processed control point is found in Annex 3. These were used as the base stations during the flight operations for the entire duration of the survey, held on February 9, 2015, and on September 27-29, 2015. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. The flight plans and locations of the base stations used during the aerial LiDAR acquisition in the Balantian floodplain are shown in Figure 2. The composition of the full project team is given in Annex 4. Figure 3 to Figure 6 exhibit the recovered NAMRIA control stations within the area. Table 2 to Table 5 provide the details of the NAMRIA control stations and established point. Table 6 lists all of the ground control points occupied during the acquisition, along with the corresponding dates of utilization.

(a)

(b)

Figure 3. (a) GPS set-up over ILO-78 in Barangay Batad Viejo, Batad, Iloilo; and (b) NAMRIA reference point ILO-78, as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point ILO-78, used as a base station for the LiDAR acquisition

Station Name	ILO-78	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 25’ 25.75892” 123° 06’ 14.81238” 39.177 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	511361.438 meters 1263207.627 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 25’ 21.28384” North 123° 06’ 19.96798” East 96.312 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	511357.46 meters 1262765.48 meters

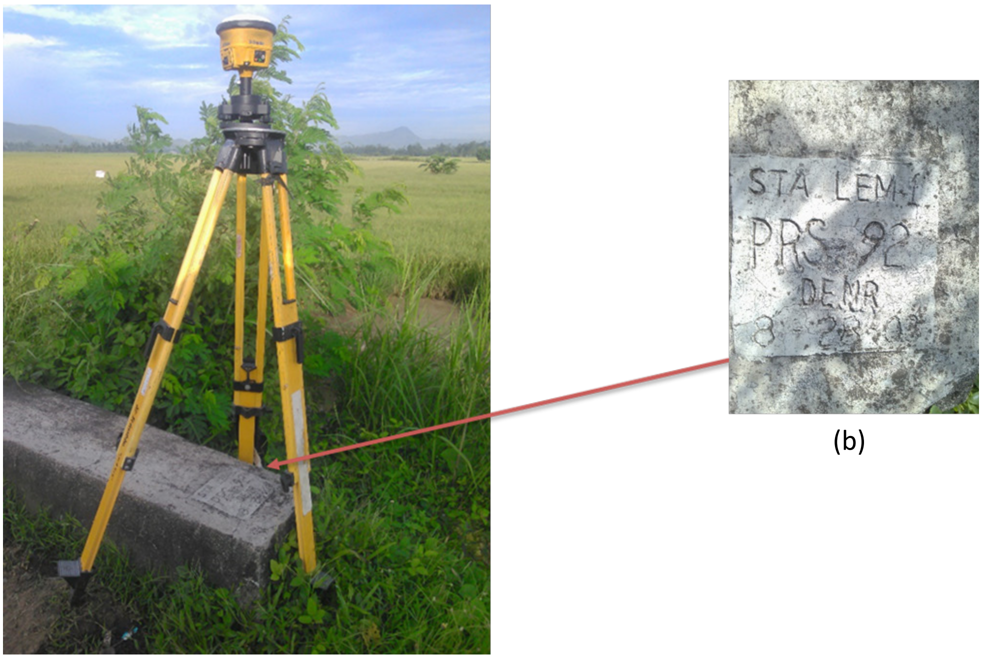
(a)

(b)

Figure 4. (a) GPS set up over ILO-3134, located at the first bridge after Balasan National High School in Barangay Balanti-an, Balasan, Iloilo; and (b) NAMRIA reference point ILO-3134, as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point ILO-3134, used as a base station for the LiDAR acquisition

Station Name	ILO-3134	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 29’ 28.52507” North 123° 05’ 09.67199” East 9.732 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	509253.537 meters 1270730.971 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 29’ 24.03156” North 123° 05’ 14.82183” East 66.656 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	509381.371 meters 1270220.950 meters



(a) (b)

Figure 5. (a) GPS set-up over ILO-97, situated over an irrigation canal near the national road in Barangay Tabunan, Lemery, Iloilo; and (b) NAMRIA reference point ILO-97, as recovered by the field team

Table 4. Details of the recovered NAMRIA horizontal control point ILO-97, used as a base station for the LiDAR acquisition

Station Name	ILO-97	
Order of Accuracy	2ND	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS92)	Latitude Longitude Ellipsoidal Height	11° 13' 54.08920" 122° 55' 50.84966" 88.56000 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone PRS92)	Easting Northing	1241955.878 m 492442.632 m
Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 13' 49.64749" 122° 55' 56.02324" 145.73700 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	1241521.17 492445.28

(a) (b)

Figure 6. (a) GPS set-up over ILO-104, located in an irrigation canal near Ajuy High School in Barangay Poblacion, Ajuy, Iloilo; and (b) NAMRIA reference point ILO-104, as recovered by the field team

Table 5. Details of the recovered NAMRIA horizontal control point ILO-104, used as a base station for the LiDAR acquisition

Station Name	ILO-104	
Order of Accuracy	2ND	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS92)	Latitude Longitude Ellipsoidal Height	11° 9’ 53.30263” 123° 0’ 46.92545” 11.59700 m
Grid Coordinates, Philippine Transverse Mercator Zone 4 (PTM Zone PRS92)	Easting Northing	501423.696 m 1234557.253 m
Grid Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 9’ 48.88466” 123° 0’ 52.10452” 69.13900 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	501,423.20 m 1,234,125.14

Table 6. Ground control points used during the LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
February 9, 2015	2538G	2BLK37A04A	ILO-78 and ILO-3134
February 9, 2015	2540G	2BLK37BC040B	ILO-78 and ILO-3134
September 27, 2015	2778G	2BLK37AC270A	ILO-97(LEM-1) and ILO-104
September 29, 2015	2786G	2BLK37AB272A	ILO-97(LEM-1) and ILO-104
September 29, 2015	2788G	2BLK37BCD272B	ILO-97(LEM-1) and ILO-104

2.3 Flight Missions

A total of five (5) flight missions were conducted to complete the LiDAR data acquisition in the Balantian floodplain, for a total of twenty-one hours and thirty-one minutes (21+31) of flying time for RP-C9122. All missions were acquired using the Gemini LiDAR system. The flight logs for the missions are provided in Annex 6. Table 7 indicates the total area of actual coverage and the corresponding flying hours per mission; while Table 8 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight missions for the LiDAR data acquisition in the Balantian floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
February 9, 2015	2538G	91.05	140.86	45.83	95.03	774	4	23
February 9, 2015	2540G	109.26	146.63	74.01	72.62	675	4	17
September 27, 2015	2778G	176.10	204.34	52.14	152.20	764	4	17
September 29, 2015	2786G	176.10	142.32	47.79	94.53	739	4	17
September 29, 2015	2788G	176.10	182.07	40.18	182.07	930	4	17
TOTAL		728.61	816.22	259.95	596.45	3,882	21	31

Table 8. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (KHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
2538G	1000	30	50	125	30	130	5
2540G	1000	30	50	125	30	130	5
2778G	850	30	50	125	50	125	5
2786G	1000	30	50	125	50	130	5
2788G	800	40	50	125	30	125	5

2.4 Survey Coverage

The Balantian floodplain is located in the provinces of Iloilo and Capiz, with majority of the floodplain situated within the Municipalities of Balasan and Pilar. The Municipality of Balasan is fully covered by the survey. The municipalities and cities surveyed, with at least one (1) square kilometer coverage, are enumerated in Table 9. The actual coverage of the LiDAR acquisition for the Balantian floodplain is illustrated in Figure 7. See Annex 7 for the flight status report of the survey coverage.

Table 9. List of municipalities and cities surveyed during the Balantian floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed
Iloilo	Balasan	51.11	51.11	100%
	Batad	48.05	46.17	96%
	Estancia	29.44	28.41	96%
	Carles	103.84	46.66	45%
	San Dionisio	108.56	25.72	24%
Capiz	Pilar	120.51	100.19	83%
	President Roxas	76.29	36.39	48%
	Pontevedra	95.28	13.68	14%
Total		633.08	348.33	55.02%

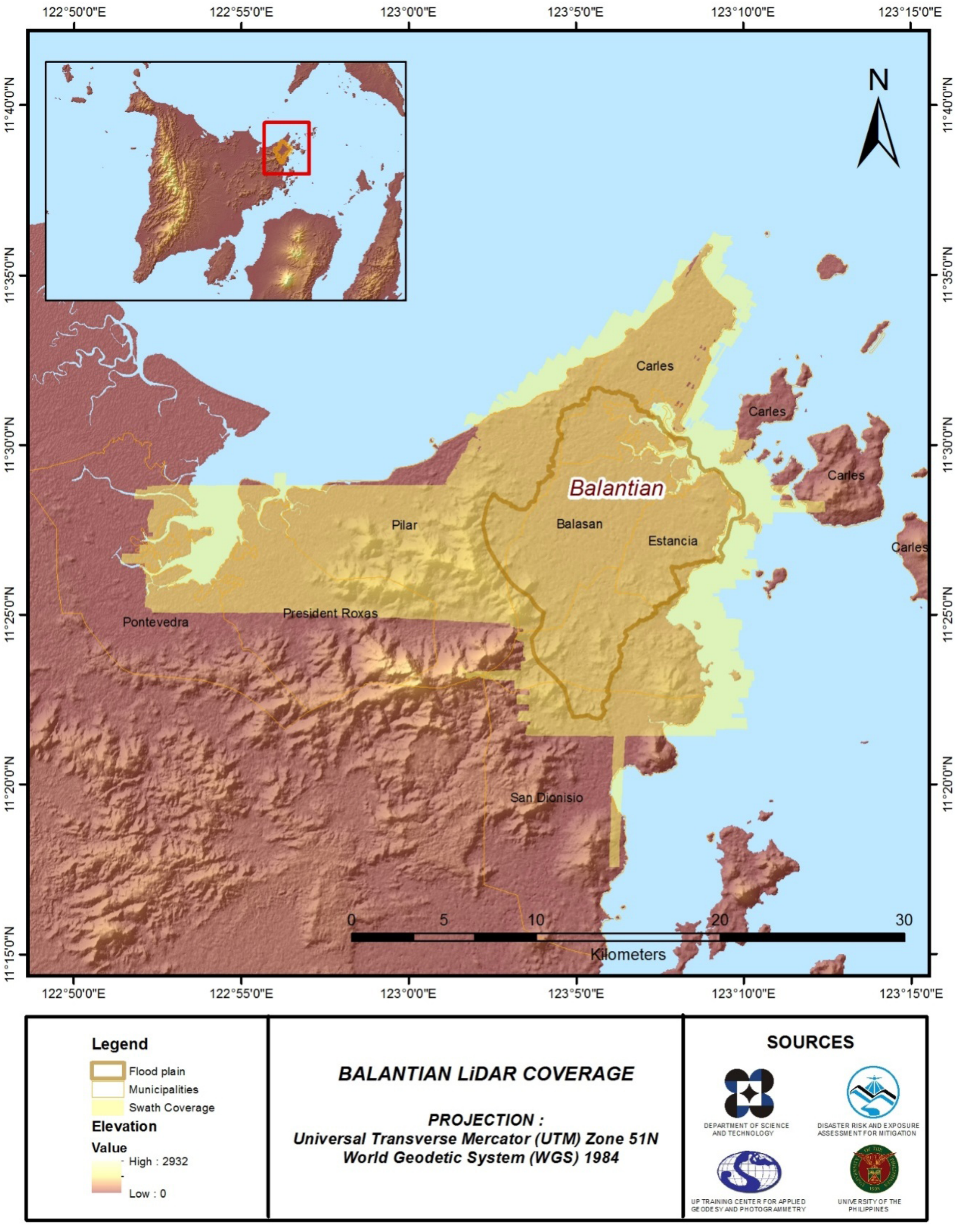


Figure 7. Actual LiDAR survey coverage of the Balantian floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE BALANTIAN FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

Using the elevation of points gathered from the field, the LiDAR-derived digital models were calibrated. Portions of the river that were barely penetrated by the LiDAR system were replaced by the actual river geometry, measured from the field by the Data Validation and Bathymetry Component (DVBC). LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was accomplished through the help of the georectified point clouds, and the metadata containing the time the image was captured. These processes are summarized in the diagram in Figure 8.

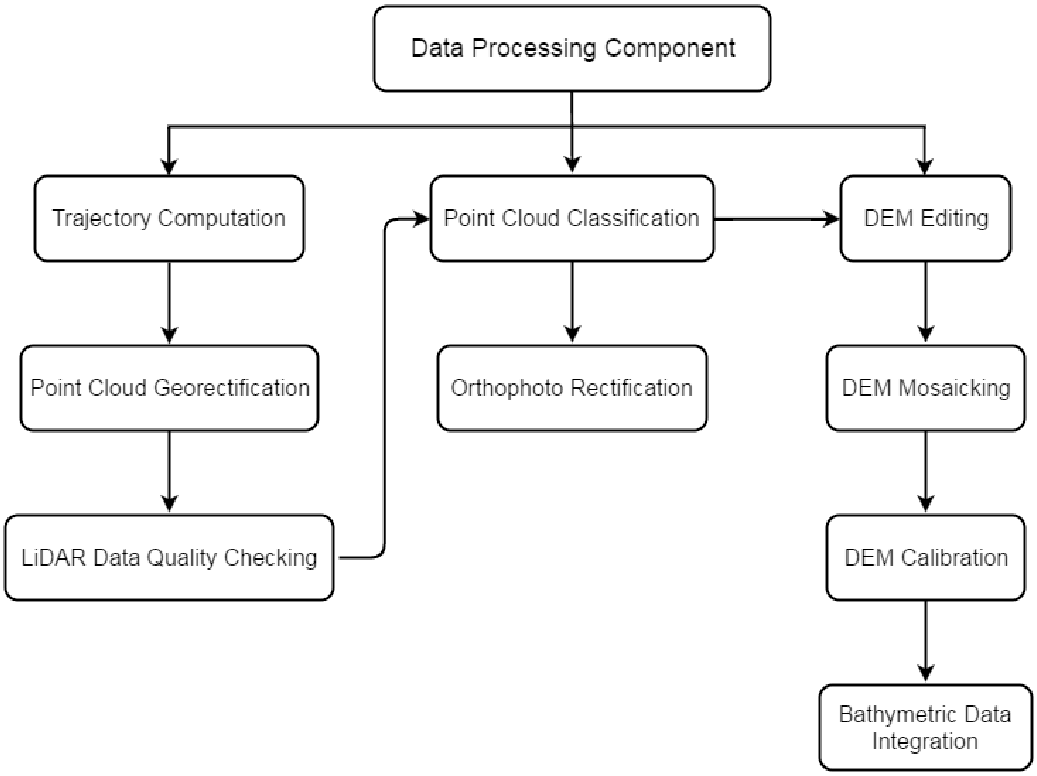


Figure 8. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all the LiDAR missions for the Balantian floodplain are found in Annex 5. Missions flown over Balasan, Iloilo during the surveys conducted in February and September 2015 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system. The DAC transferred a total of 151.8 Gigabytes of Range data, 1.49 Gigabytes of POS data, 442 Megabytes of GPS base station data, and 290.9 Gigabytes of raw image data to the data server on February 18, 2015 for the first survey, and on November 3, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Balantian survey was fully transferred on November 9, 2015, as indicated on the data transfer sheets for the Balantian floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for Flight 2778G, one of the Balantian flights, which are the North, East, and Down position RMSE values, are presented in Figure 9. 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 fell on September 27, 2015 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

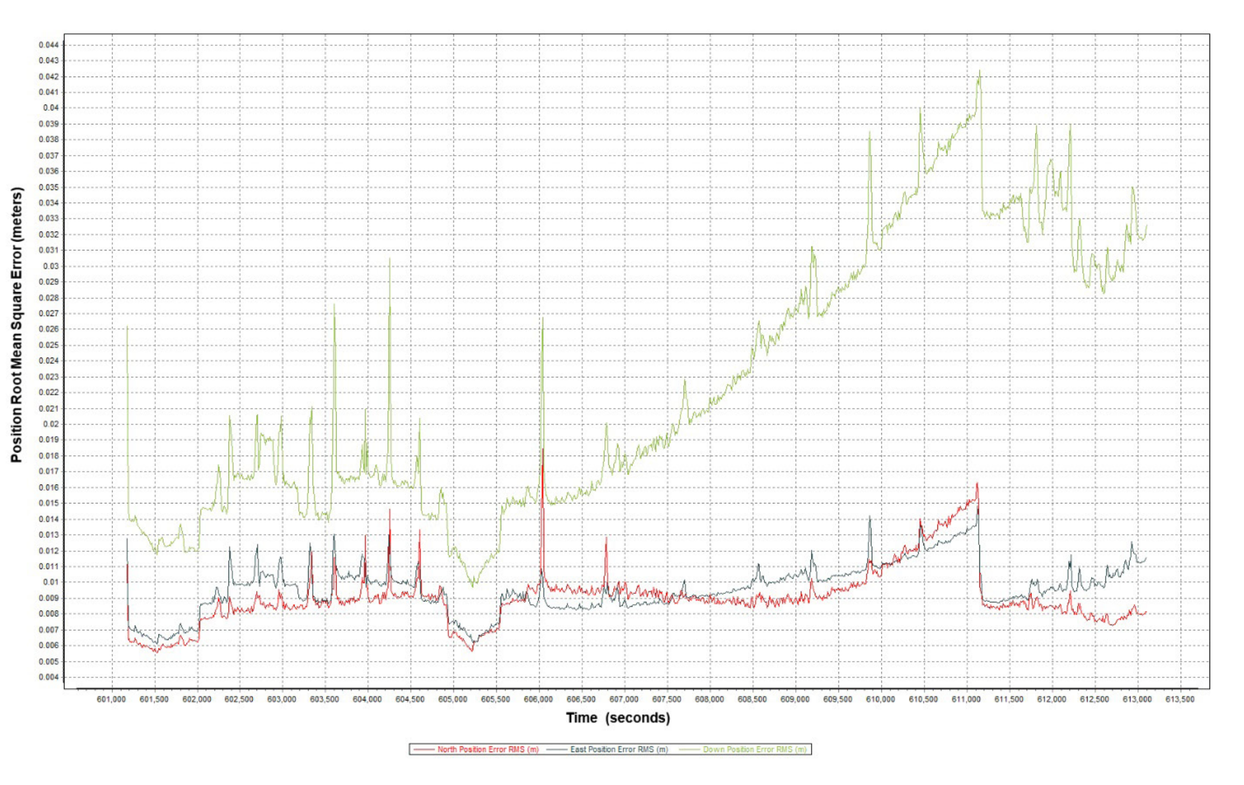


Figure 9. Smoothed Performance Metric Parameters of Balantian Flight 2778G

The time of flight was from 601000 seconds to 613500 seconds, which corresponds to the afternoon of September 27, 2015. The initial spike reflected on the data indicates the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE values of the positions. The periodic increase in RMSE values from an otherwise smoothly curving set of RMSE values signifies the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 9 demonstrates that the North position RMSE peaked at 1.86 centimeters, the East position RMSE peaked at 1.30 centimeters, and the Down position RMSE peaked at 3.05 centimeters, which are within the prescribed accuracies described in the methodology.

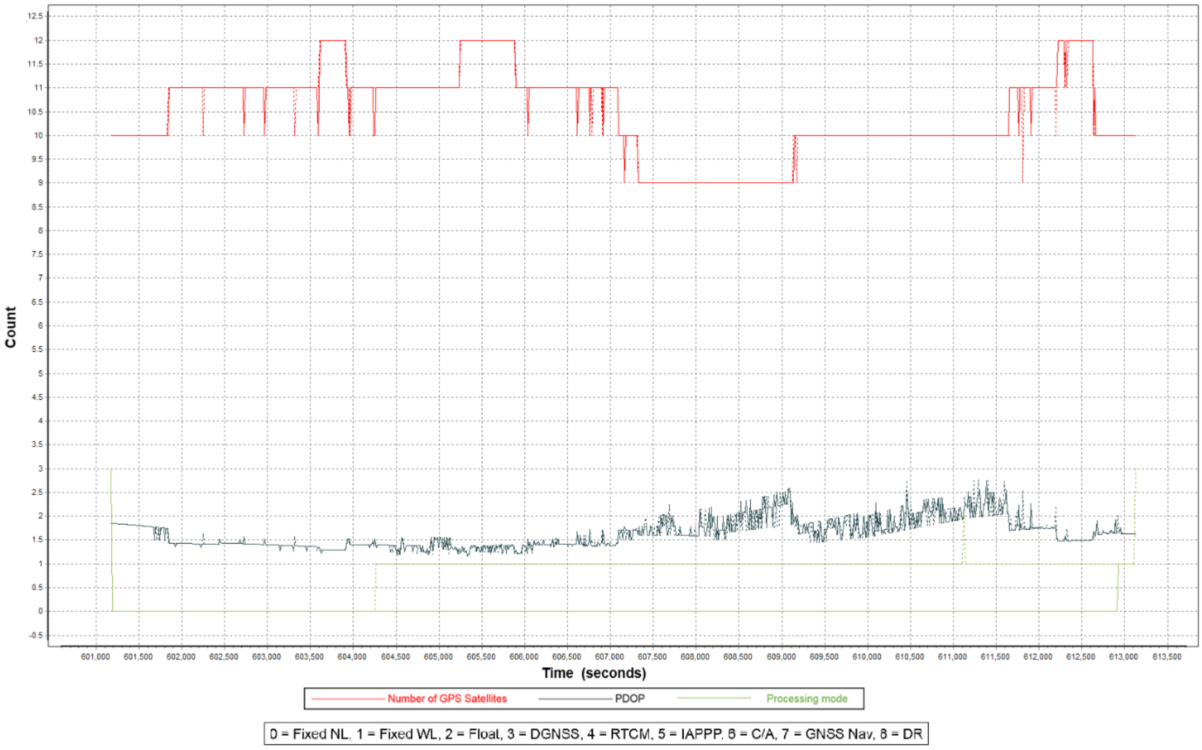


Figure 10. Solution Status Parameters of Balantian Flight 2778G

The Solution Status parameters of Flight 2778G, one of the Balantian flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are exhibited in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 9. Majority of the time, the number of satellites tracked was between 9 and 12. The PDOP value did not go above the value of 3, which indicates optimal GPS geometry. The processing mode remained at the value of 0 for majority of the survey. The value of 0 represents a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Balantian flights is depicted in Figure 11.

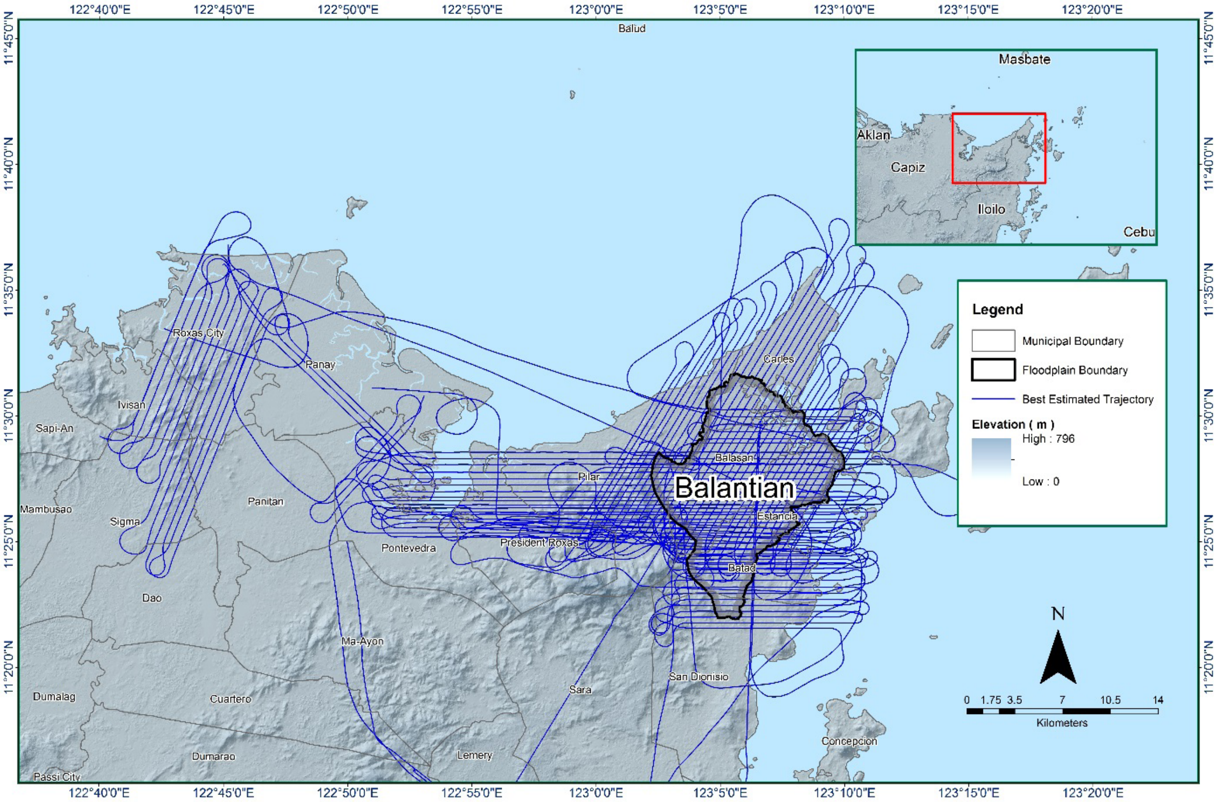


Figure 11. The best estimated trajectory conducted over the Balantian floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains one hundred and twenty-nine (129) flight lines, with each flight line containing one (1) channel, since the Gemini system contains only one (1) channel. The summary of the self-calibration results for all flights over the Balantian floodplain, obtained through LiDAR processing in the LiDAR Mapping Suite (LMS) software, is given in Table 10.

Table 10. Self-calibration results for the Balantian flights

Parameter	Absolute Value	Computed Value
Boresight Correction stdev	(<0.001degrees)	0.000404
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000779
GPS Position Z-correction stdev	(<0.01meters)	0.0034

Optimum accuracy was obtained for all Balantian flights, based on the computed standard deviations of the corrections of the orientation parameters. The standard deviation values for the individual blocks are available in Annex 8: Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Balantian floodplain are represented in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

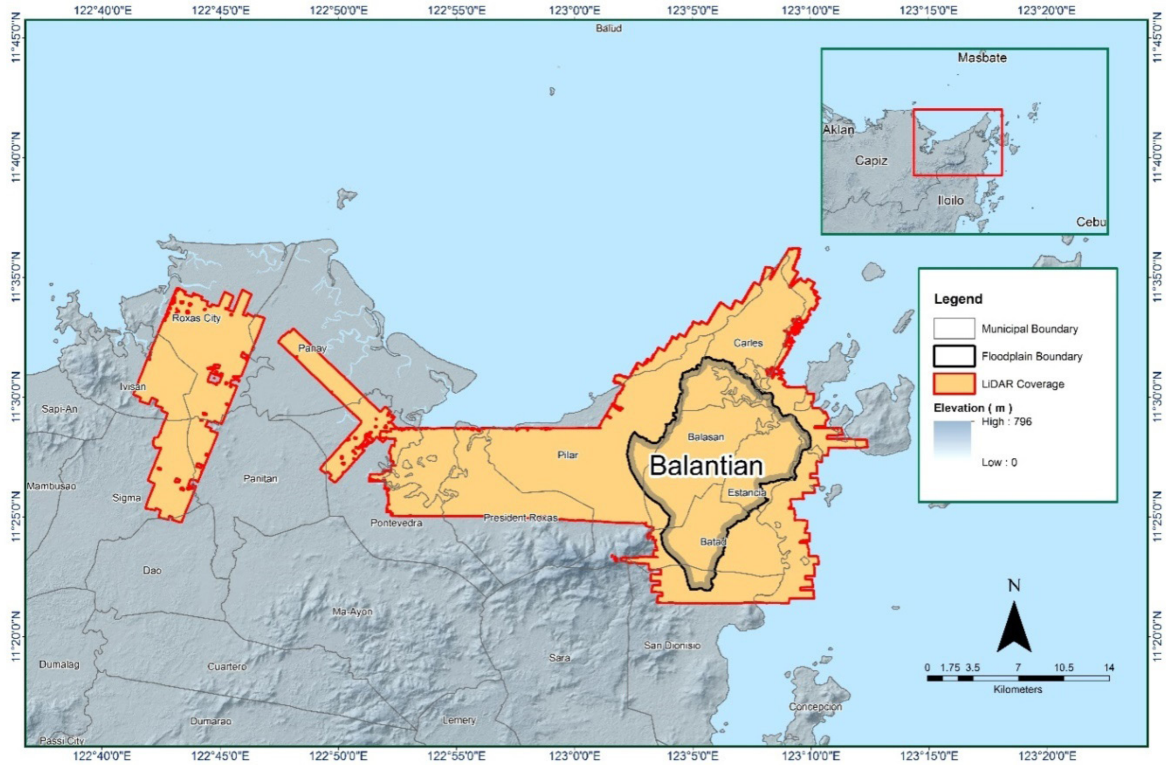


Figure 12. Boundaries of the processed LiDAR data over the Balantian floodplain

The total area covered by the Balantian missions is 735.9 square kilometers, comprised of six (6) flight acquisitions that are grouped and merged into nine (9) blocks, as outlined in Table 11.

Table 11. List of LiDAR blocks for the Balantian floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Iloilo_Blk37A	2538G	127.2
Iloilo_Blk37B	2540G	81.53
Iloilo_Blk37C	2540G	51.58
Capiz_Aklan_Blk37A	2778G	129.8
Capiz_Aklan_Blk37A_supplement	2786G	130.7
Capiz_Aklan_Blk37B	2778G	71.18
Capiz_Aklan_Blk37D	2788G	27.39
Capiz_Aklan_Blk38K	2762G	90.82
Capiz_Aklan_Blk38K_supplement	2762G	25.7
TOTAL		**735.9 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is exhibited in Figure 13. Since the Gemini systems employs one (1) channel, it is expected to have 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.

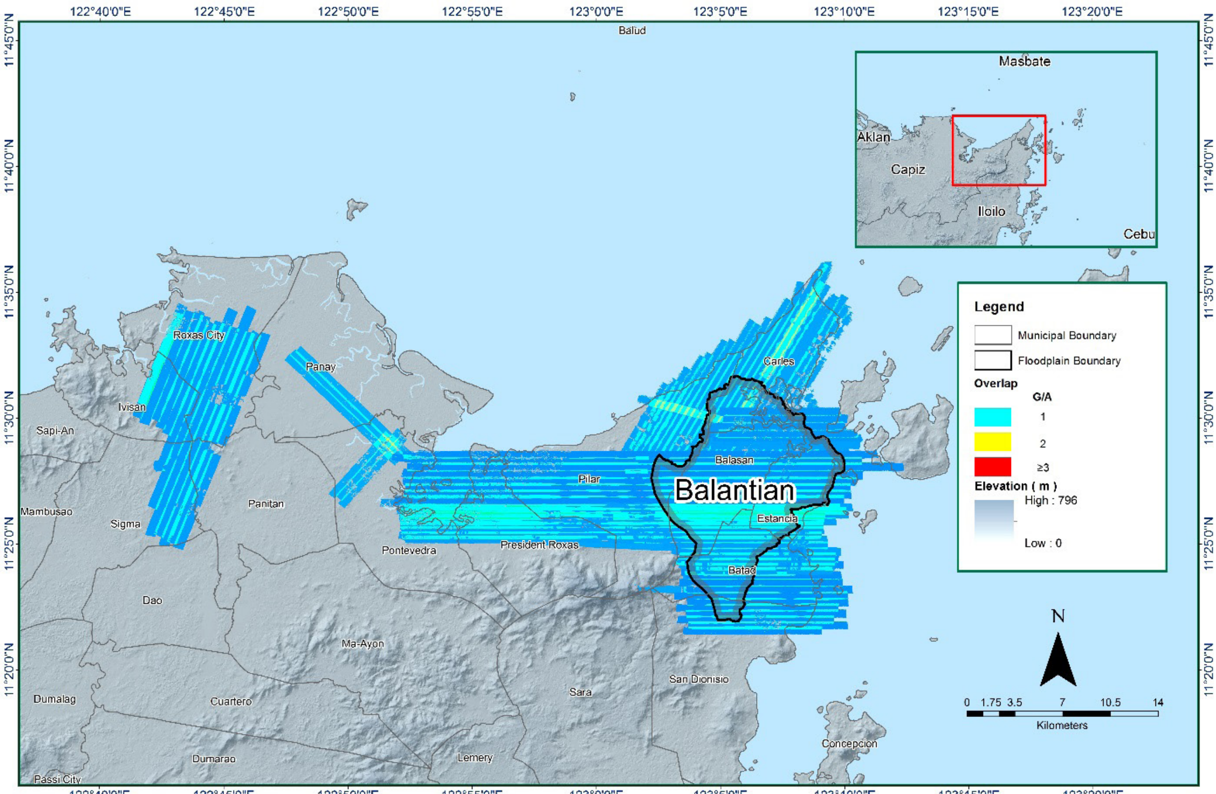


Figure 13. Image of data overlap for the Balantian floodplain

The overlap statistics per block for the Balantian floodplain can be found in Annex 8. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 33.08% and 51.06%, respectively, which satisfied 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 displayed in Figure 14. It was determined that all LiDAR data for the Balantian floodplain satisfy the point density requirement, and that the average density for the entire survey area is 4.88 points per square meter.

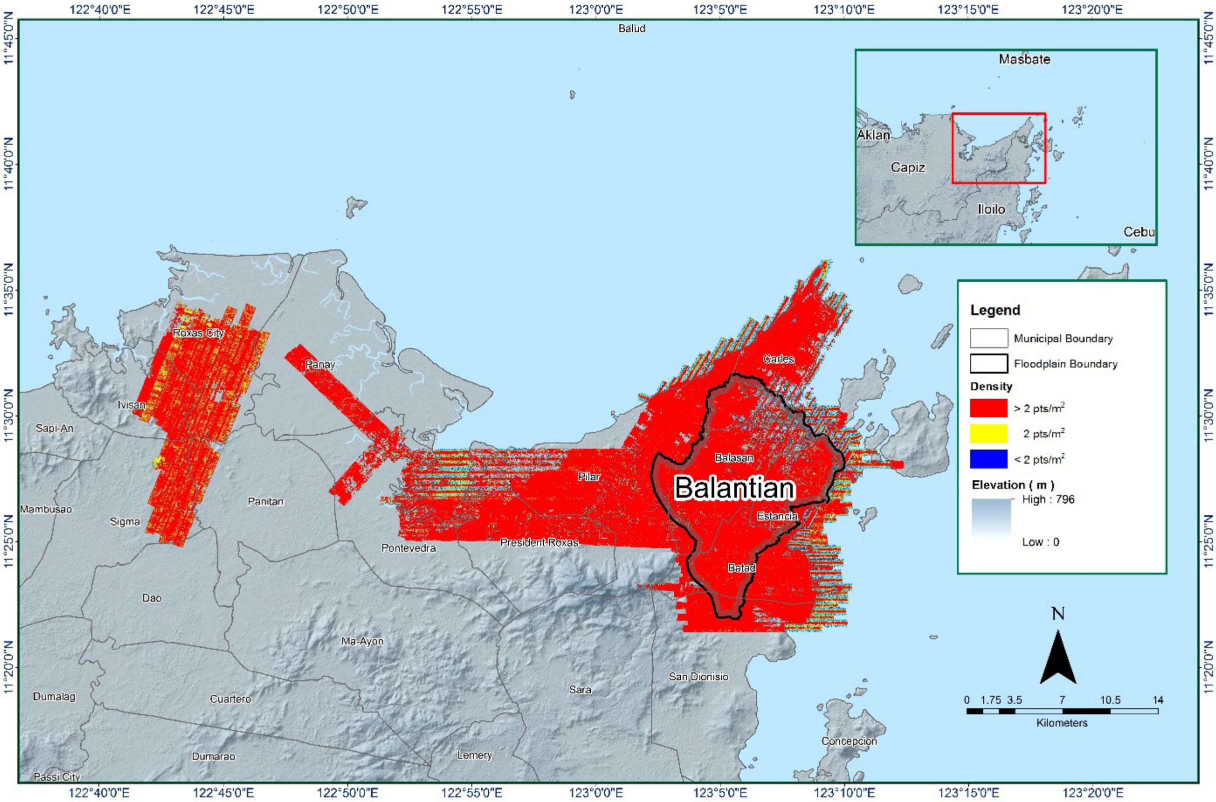


Figure 14. Pulse density map of merged LiDAR data for the Balantian floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 15. The default color range is from blue to red. Bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 meters relative to the elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.20 meters relative to the elevations of its adjacent flight line. Areas marked with bright red or bright blue were investigated further using the Quick Terrain (QT) Modeler software.

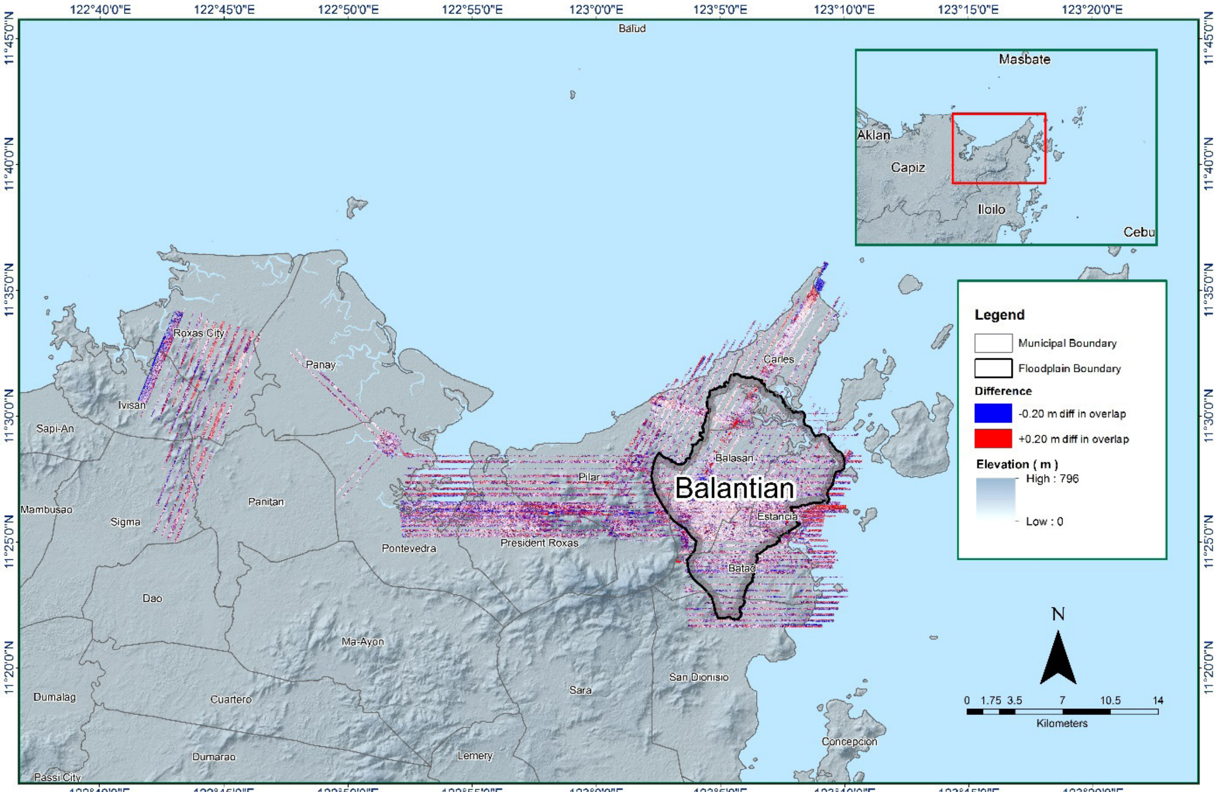


Figure 15. Elevation difference map between flight lines for the Balantian floodplain

A screen capture of the processed LAS data from Balantian Flight 2778G loaded in the QT Modeler is provided in Figure 16. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis represents the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

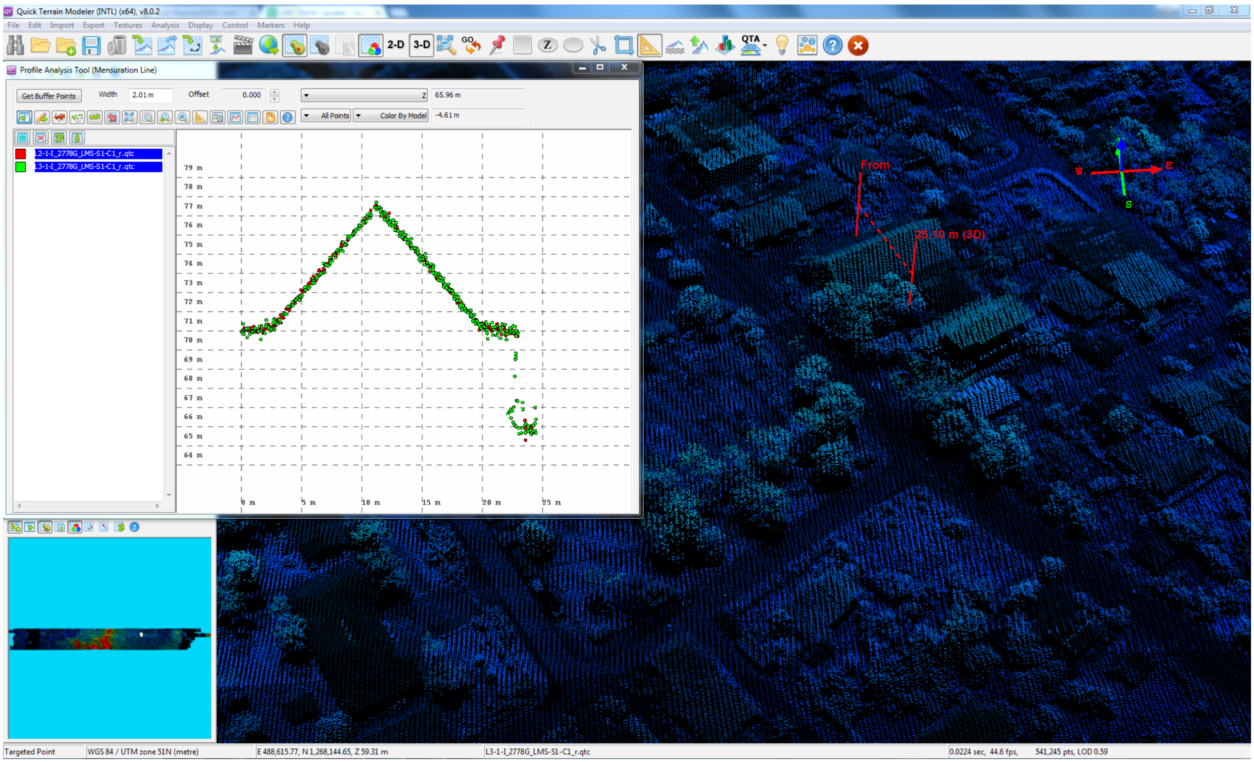


Figure 16. Quality checking for Balantian Flight 2778G, using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 12. Balantian classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	353,193,340
Low Vegetation	366,710,679
Medium Vegetation	1,518,308,123
High Vegetation	560,360,890
Building	11,984,035

The tile system that TerraScan employed for the LiDAR data, as well as the final classification image for a block in the Balantian floodplain, are presented in Figure 17. A total of 1,143 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 12. The point cloud had a maximum and minimum height of 743.71 meters and 54.64 meters, respectively.

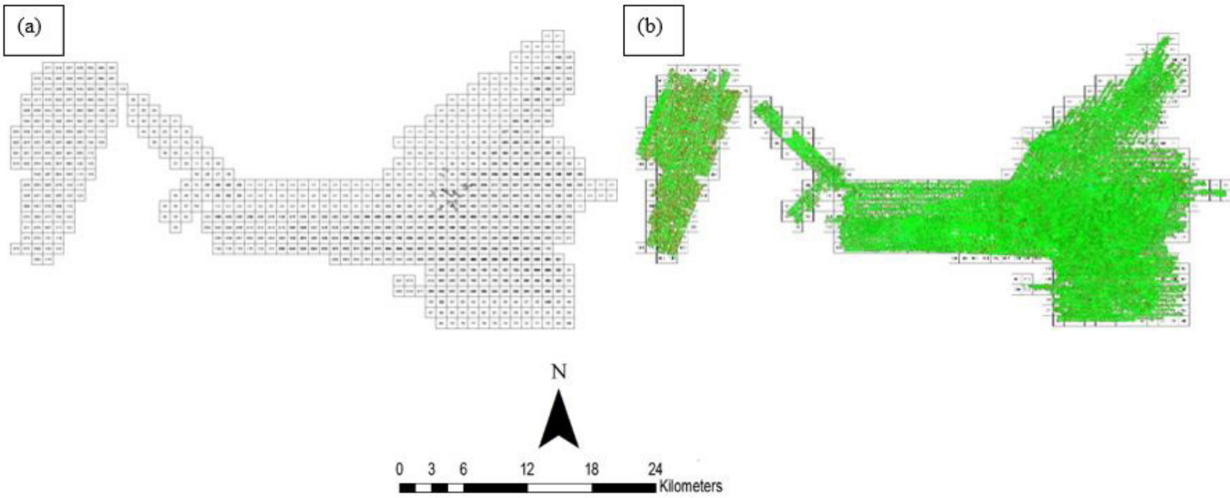


Figure 17. (a) Tiles for Balantian floodplain, and (b) classification results in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 18. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It is visible that the residential structures adjacent or even below canopy were classified correctly, due to the density of the LiDAR data.

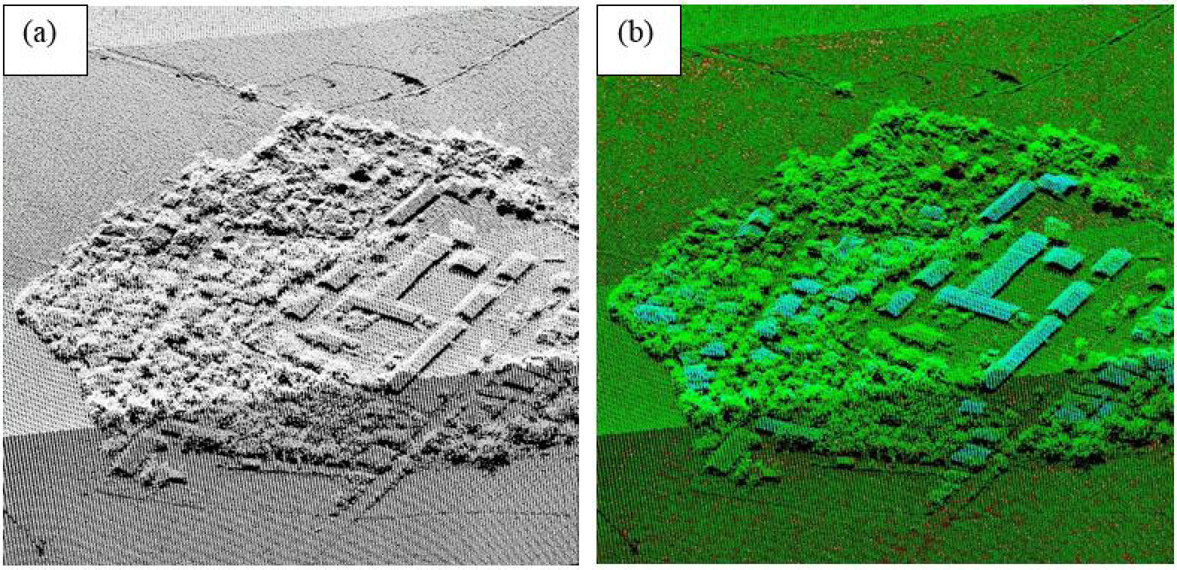


Figure 18. Point cloud (a) before and (b) after classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the area are illustrated in Figure 19, in top view display. The images convey that the DTMs are a representation of the bare earth; while the DSMs reflect all features that are present, such as buildings and vegetation.

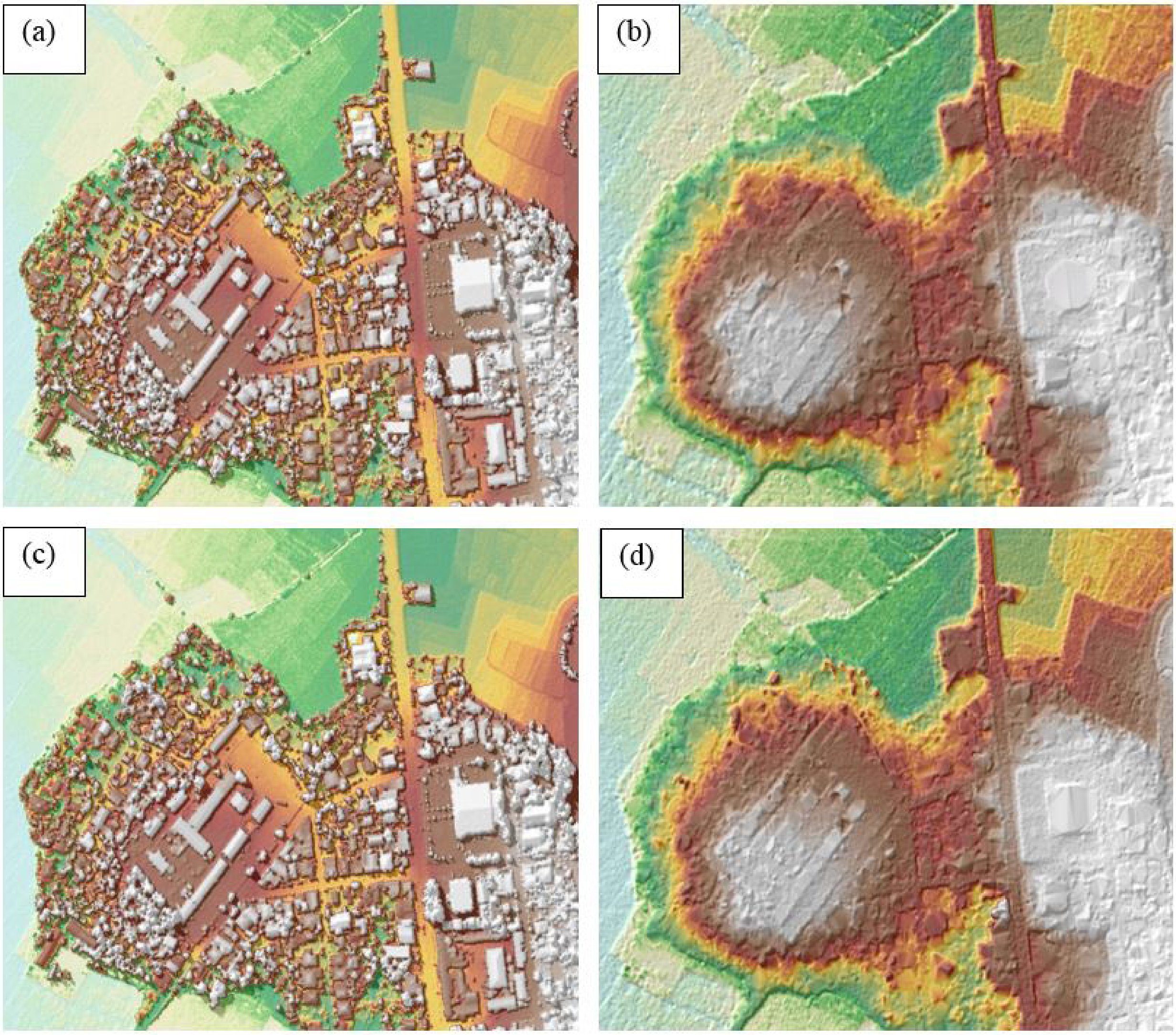


Figure 19. The production of (a) last return DSM and (b) DTM, (c) first return DSM and (d) secondary DTM in some portion of Balantian floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 647 1km by 1km tiles area covered by the Balantian floodplain is presented in Figure 20. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Balantian floodplain survey attained a total of 453.37 square kilometers in orthophotographic coverage, comprised of 2,249 images. Zoomed-in in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 21.

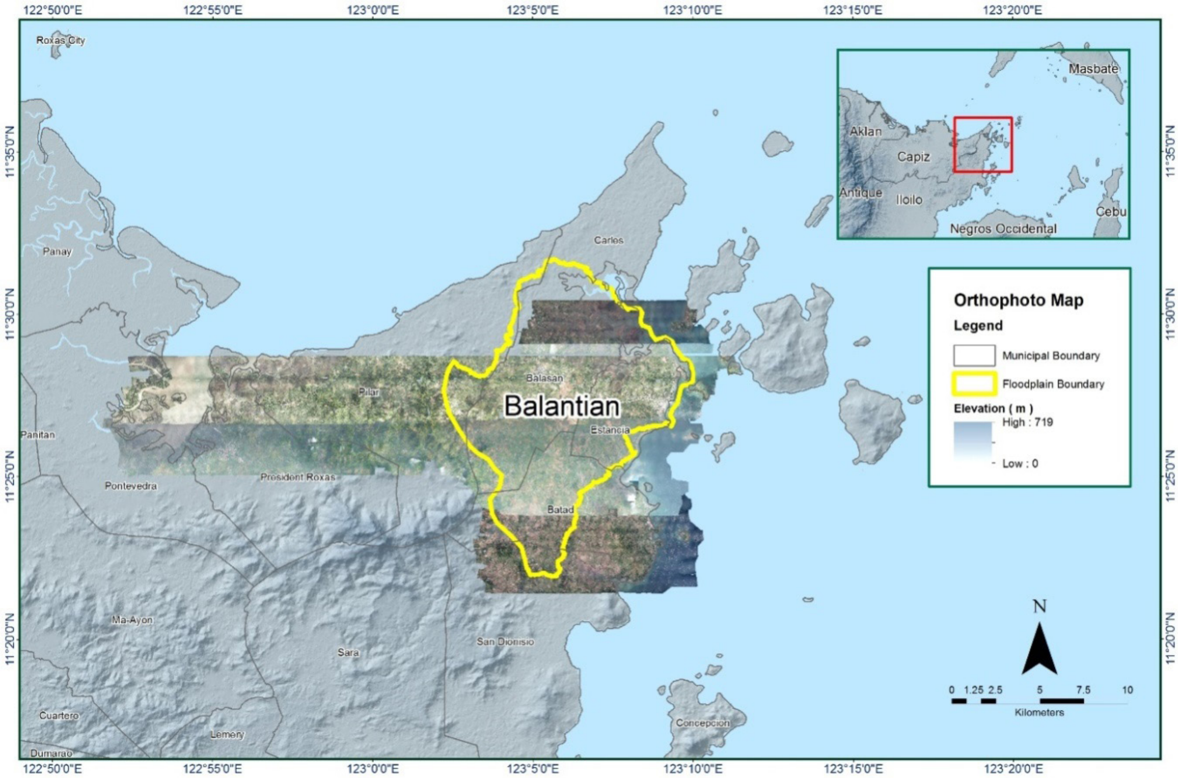


Figure 20. The Balantian floodplain, with available orthophotographs

Figure 21. Sample orthophotograph tiles for the Balantian floodplain

3.8 DEM Editing and Hydro-Correction

Nine (9) mission blocks were processed for the Balantian floodplain. These blocks are composed of Samar-Leyte and Leyte blocks, with a total area of 735.9 square kilometers. Table 13 summarizes the names and corresponding areas of the blocks, in square kilometers.

Table 13. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
Iloilo_Blk37A	127.2
Iloilo_Blk37B	81.53
Iloilo_Blk37C	51.58
Capiz_Aklan_Blk37A	129.8
Capiz_Aklan_Blk37A_supplement	130.7
Capiz_Aklan_Blk37B	71.18
Capiz_Aklan_Blk37D	27.39
Capiz_Aklan_Blk38K	90.82
Capiz_Aklan_Blk38K_supplement	25.7
TOTAL	**735.9 sq.km**

Portions of the DTM before and after manual editing are exhibited in Figure 22. The bridges (Figure 22a) would be an obstruction to the flow of water along the river, and had to be removed (Figure 22b) in order to hydrologically correct the river. The images also show that structures around paddy fields (Figure 22c) were misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 22d).

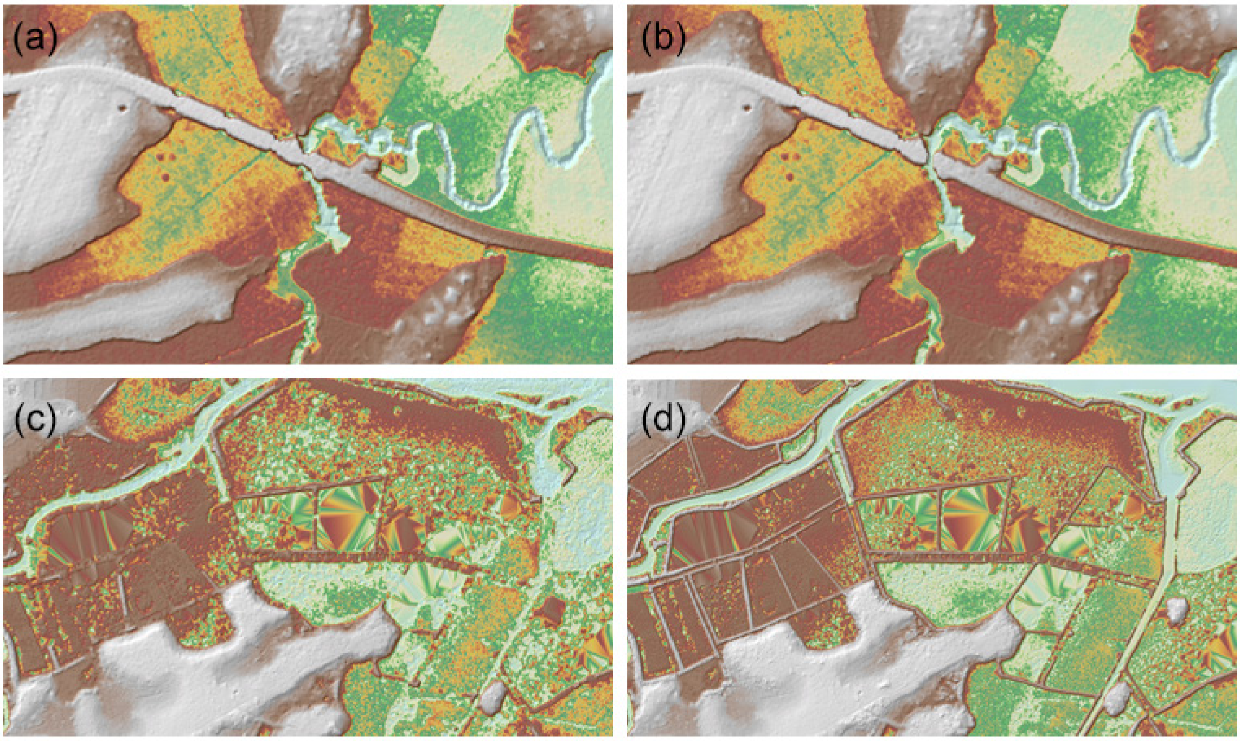


Figure 22. Portions in the DTM of the Balantian floodplain – bridges (a) before and (b) after manual editing; a paddy field (c) before and (d) after data retrieval

3.9 Mosaicking of Blocks

The Iloilo_Blk37B block was used as the reference block at the start of mosaicking, because it was referred to a base station with an acceptable order of accuracy. Table 14 specifies the area of each LiDAR block and the shift values applied during mosaicking.

The mosaicked LiDAR DTM for the Balantian floodplain is represented in Figure 23. It conveys that the entire Balantian floodplain is 99.82% covered by LiDAR data.

Table 14. Shift values of each LiDAR block of the Balantian floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Iloilo_Blk37A	1.00	0.00	2.19
Iloilo_Blk37B	0.00	0.00	0.00
Iloilo_Blk37C	0.00	1.00	0.07
Capiz_Aklan_Blk37A	108.00	169	1.33
Capiz_Aklan_Blk37A_supplement	157.00	1.00	0.46
Capiz_Aklan_Blk37B	0.00	1.00	0.06
Capiz_Aklan_Blk37D	0.00	0.00	0.14
Capiz_Aklan_Blk38K			
Capiz_Aklan_Blk38K_supplement			

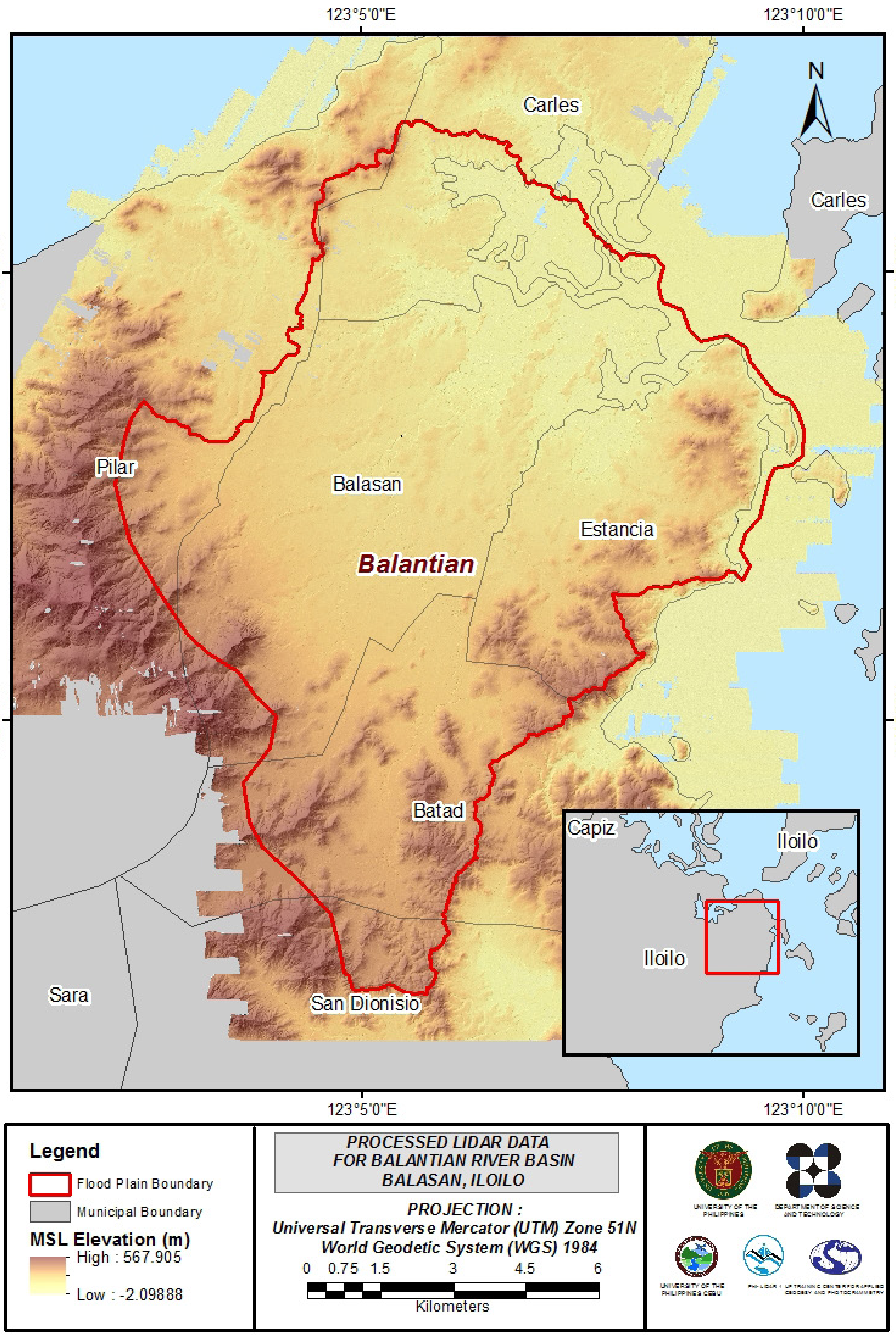


Figure 23. Map of processed LiDAR data for the Balantian floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

To undertake the data validation of the mosaicked LiDAR DEMs, the DVBC conducted a validation survey along the Balantian floodplain. The extent of the validation survey done in Balantian to collect points with which the LiDAR dataset was validated is shown in Figure 24, with the validation survey points highlighted in green. A total of 7,162 survey points were used for the calibration and validation of the Balantian LiDAR data.

Random selection of 80% of the survey points resulted in 5,482 points, which were used for calibration. A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is reflected in Figure 25. Statistical values were computed from the extracted LiDAR values using the selected points, to assess the quality of the data and to obtain the values for vertical adjustment. The computed height difference between the LiDAR DTM and the calibration elevation values is 0.09 meters, with a standard deviation of 0.09 meters. Calibration of the Balantian LiDAR data was executed by subtracting the height difference value, 0.09 meters, from the Balantian mosaicked LiDAR data. Table 15 indicates the statistical values of the compared elevation values between the LiDAR data and the calibration data.

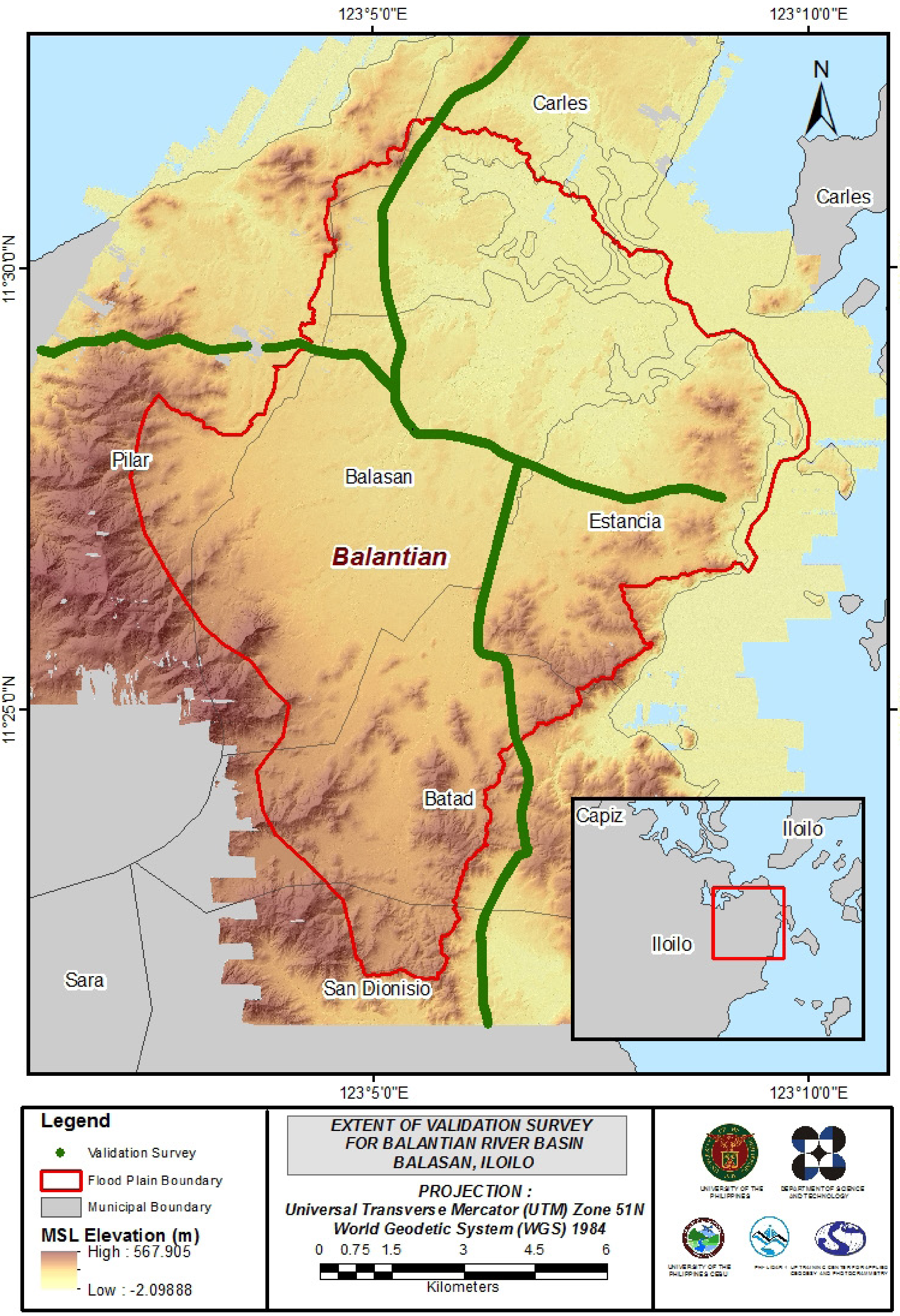


Figure 24. Map of the Balantian floodplain, with the validation survey points in green

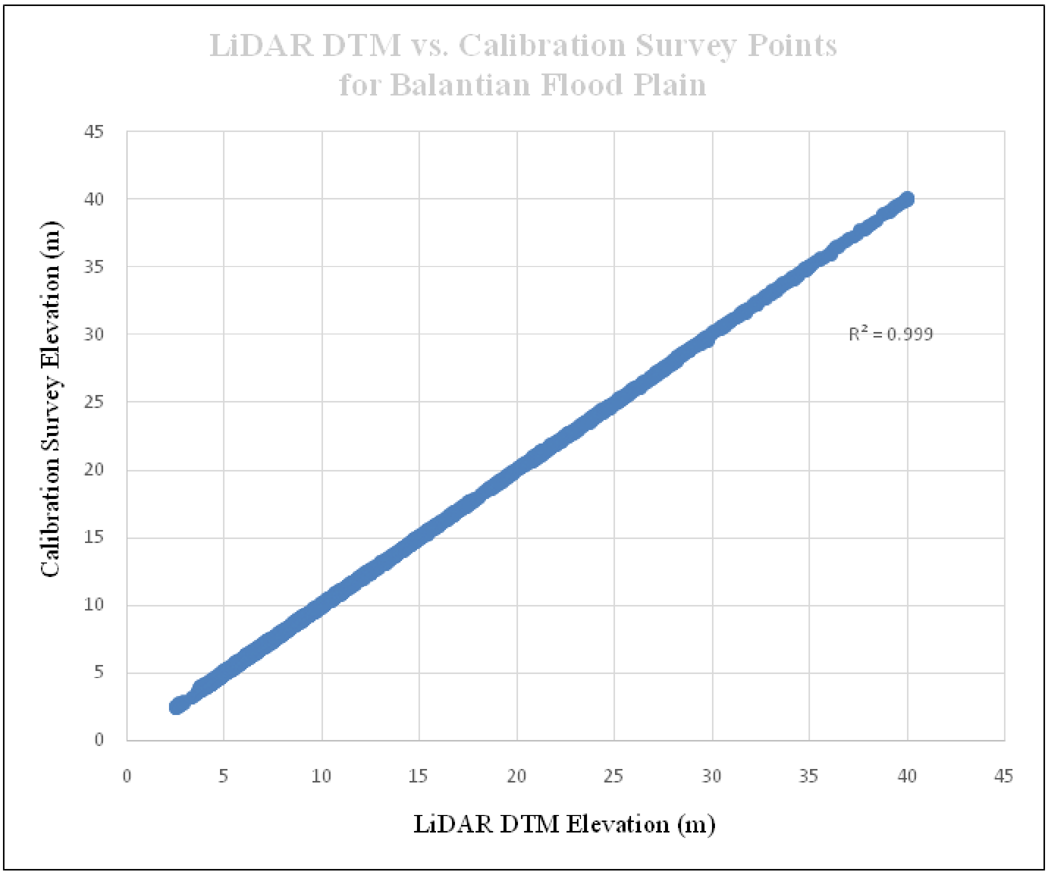


Figure 25. Correlation plot between the calibration survey points and the LiDAR data

Table 15. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.09
Standard Deviation	0.09
Average	-0.02
Minimum	-0.24
Maximum	0.21

The remaining 20% of the total survey points, resulting in 1,362 points were used for the validation of the calibrated Balantian 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 demonstrated in Figure 26. The computed RMSE between the calibrated LiDAR DTM and the validation elevation values is 0.12 meters, with a standard deviation of 0.09 meters, as shown in Table 16.

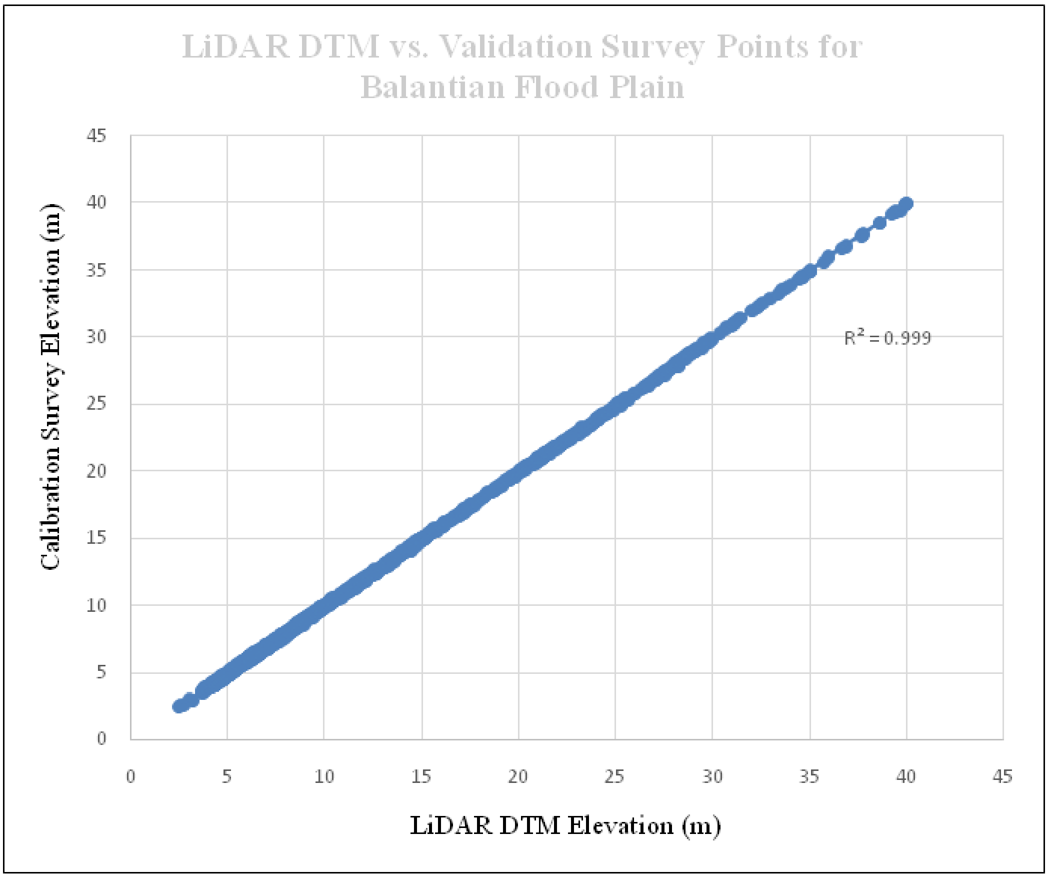


Figure 26. Correlation plot between the validation survey points and the LiDAR data

Table 16. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.12
Standard Deviation	0.09
Average	0.08
Minimum	-0.14
Maximum	0.30

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For the bathy integration, centerlines and zigzag data were available for Balantian, with 6,026 bathymetric survey points. Due to the significant difference in the river width of some portions of the Balantian River, the raster was divided into two (2) parts. Bathymetric burning was performed on these two parts separately. The resulting raster surface produced was obtained through the Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE values of 0.3 meters and 0.29 meters for the two raster surfaces. The bathymetric-burned raster surfaces were mosaicked afterwards. The extent of the bathymetric survey done by DVBC in Balantian, integrated with the processed LiDAR DEM, is illustrated in Figure 27.

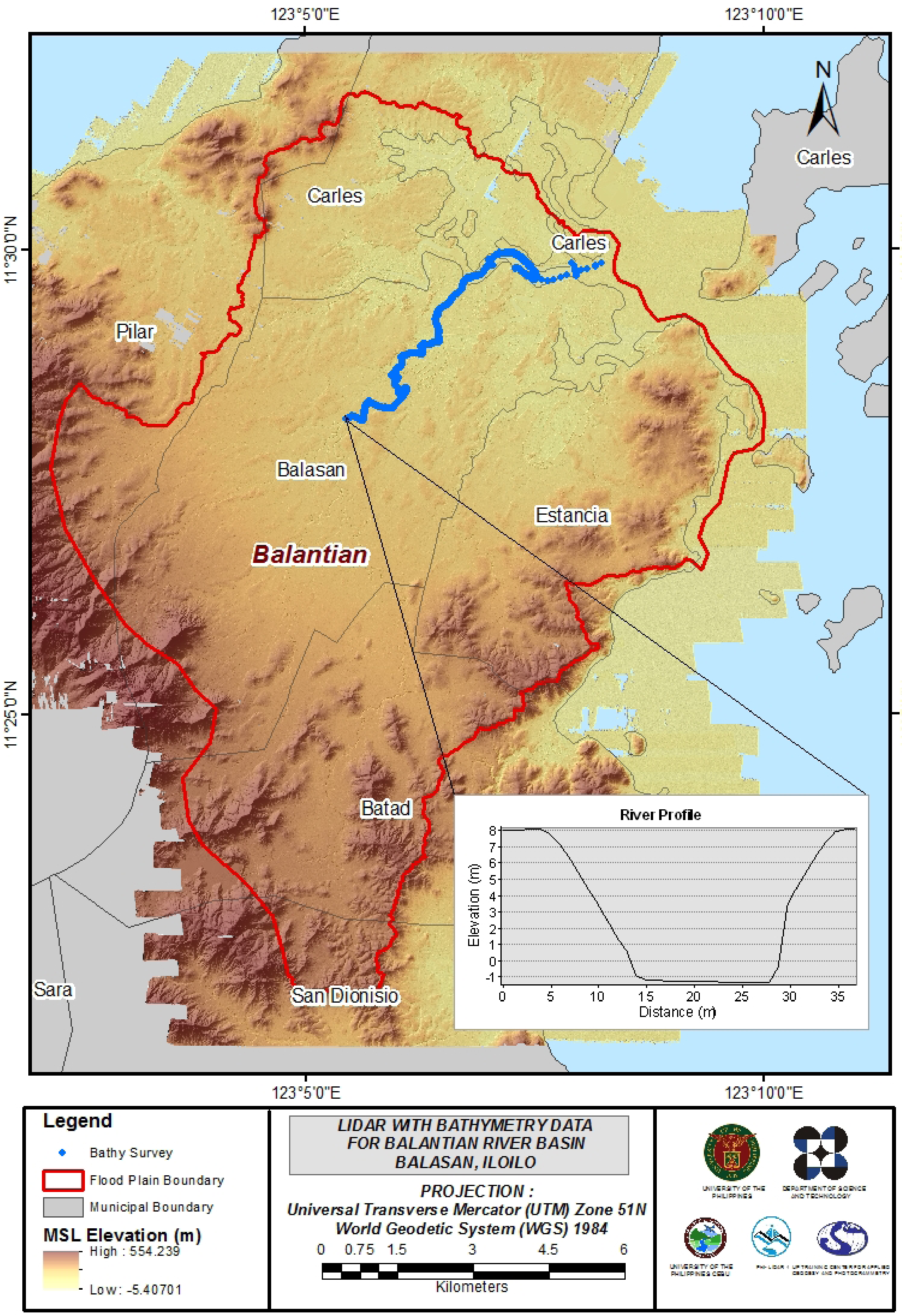


Figure 27. Map of the Balantian floodplain, with bathymetric survey points shown in blue

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 DEM with a 1-meter resolution was used to delineate footprints of building features, which consist of residential buildings, government offices, medical facilities, religious institutions, and commercial establishments, among others. Road networks – comprised of main thoroughfares, such as highways, and municipal and barangay roads – are essential for routing disaster response efforts. These features are represented by a network of road centerlines.

3.12.1 Quality Checking of Digitized Features' Boundary

The Balantian floodplain, including its 200-meter buffer zone, has a total area of 140.98 square kilometers. For this area, a total of 5.00 square kilometers, corresponding to a total of 1,346 building features, were considered for quality checking (QC). Figure 28 presents the QC blocks for the Balantian floodplain.

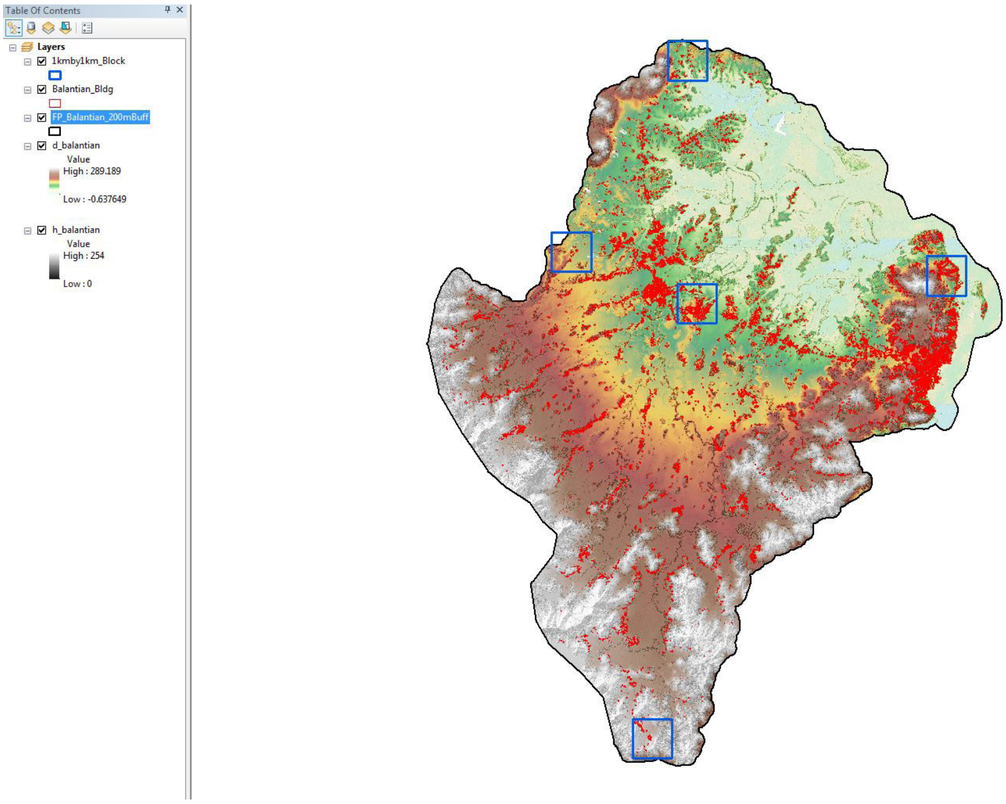


Figure 28. Blocks (in blue) of Balantian building features that were subjected to QC

Quality checking of the Balantian building features resulted in the ratings given in Table 17.

Table 17. Quality checking ratings for the Balantian building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Balantian	92.14	96.73	54.31	PASSED

3.12.2 Height Extraction

Height extraction was done for 23,358 building features in the Balantian floodplain. Of these building features, 1,612 were filtered out after height extraction, resulting in 21,746 buildings with height attributes. The lowest building height is at 2.0 meters, while the highest building is at 9.4 meters.

3.12.3 Feature Attribution

The feature attribution survey was conducted through a participatory community-based mapping, in coordination with the local government units (LGUs) of the covered municipalities. The research associates of the Phil-LiDAR 1 team visited the local barangay units and interviewed key local personnel and officials who possessed expert knowledge of their local environments, in order to identify and map out features in the floodplain.

Maps were displayed on a laptop, and were presented to the interviewees for identification. The displayed maps include the orthophotographs, Digital Surface Models, existing landmarks, and extracted feature shapefiles. Physical surveys of the barangay were also performed by the Phil-LiDAR 1 team after each interview, for the purposed of validation. The number of days by which the survey was conducted was dependent on the number of features and number of barangays included in the floodplain of the river basin.

Table 18 summarizes the number of building features per type. Table 19 indicates the total length of each road type, and Table 20 specifies the number of water features extracted per type.

Table 18. Building features extracted for the Balantian floodplain

Facility Type	No. of Features
Residential	20,581
School	428
Market	63
Agricultural/Agro-Industrial Facilities	37
Medical Institutions	25
Barangay Hall	54
Military Institution	0
Sports Center/Gymnasium/Covered Court	25
Telecommunication Facilities	5
Transport Terminal	5
Warehouse	4
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	2
Water Supply/Sewerage	2
Religious Institutions	96
Bank	6
Factory	0
Gas Station	19

Fire Station	2
Other Government Offices	53
Other Commercial Establishments	287
Others	51
Total	**21,746**

Table 19. Total length of extracted roads for the Balantian floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Munici-pal Road	Provincial Road	National Road	Others	
Balantian	281	18	8	6	35	**348**

Table 20. Number of extracted water bodies for the Balantian floodplain

Floodplain	Water Body Type						Total
	Rivers/ Streams	Lakes/ Ponds	Sea	Dam	Fish Pen	Others	
Balantian	3	0	0	0	582	0	**585**

A total of sixteen (16) 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 Balantian floodplain. This completes the feature extraction phase of the project.

Figure 29 displays the Digital Surface Model (DSM) of the Balantian floodplain, overlaid with its ground features.

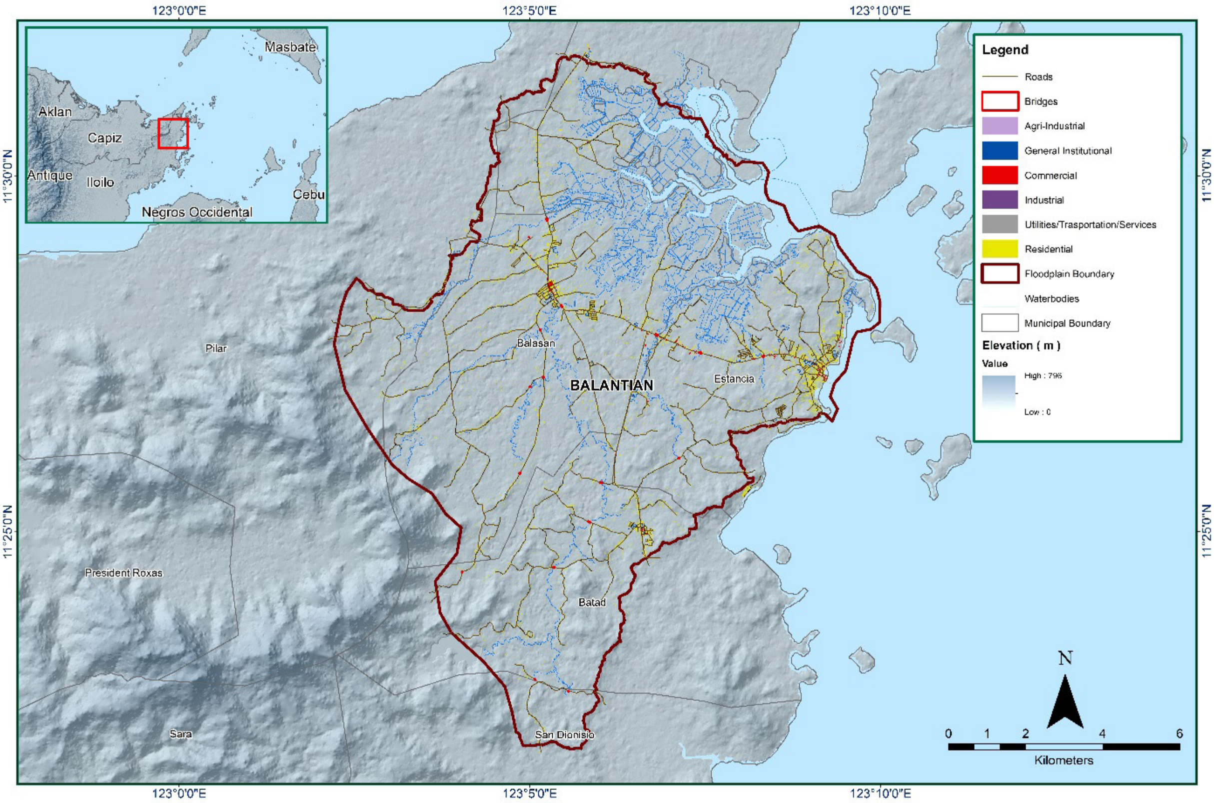


Figure 29. Extracted features for the Balantian floodplain

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

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

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

4.1 Summary of Activities

The DVBC conducted field surveys in three (3) river basins in the province of Iloilo, including Balantian River Basin, on July 22-26, 2014 and on October 10-21, 2015. The scope of work was comprised of the following: (i.) initial reconnaissance; (ii.) cross-section and bridge as-built surveys, and water level marking in MSL of the Balasan Bridge; (iii.) validation point acquisition in the province of Iloilo, which covers the Balantian River Basin; and (iv.) bathymetric survey of the Balantian River, starting from the upstream in Barangay Poblacion Sur down to the mouth of the river in Barangay Tupaz; both of which are in the Municipality of Balasan. The survey had an approximate length of 8 kilometers, using a Trimble® GNSS in PPK survey technique and an OHMEX™ single beam echo sounder. See Figure 30 for the illustration of the extent of the surveys.

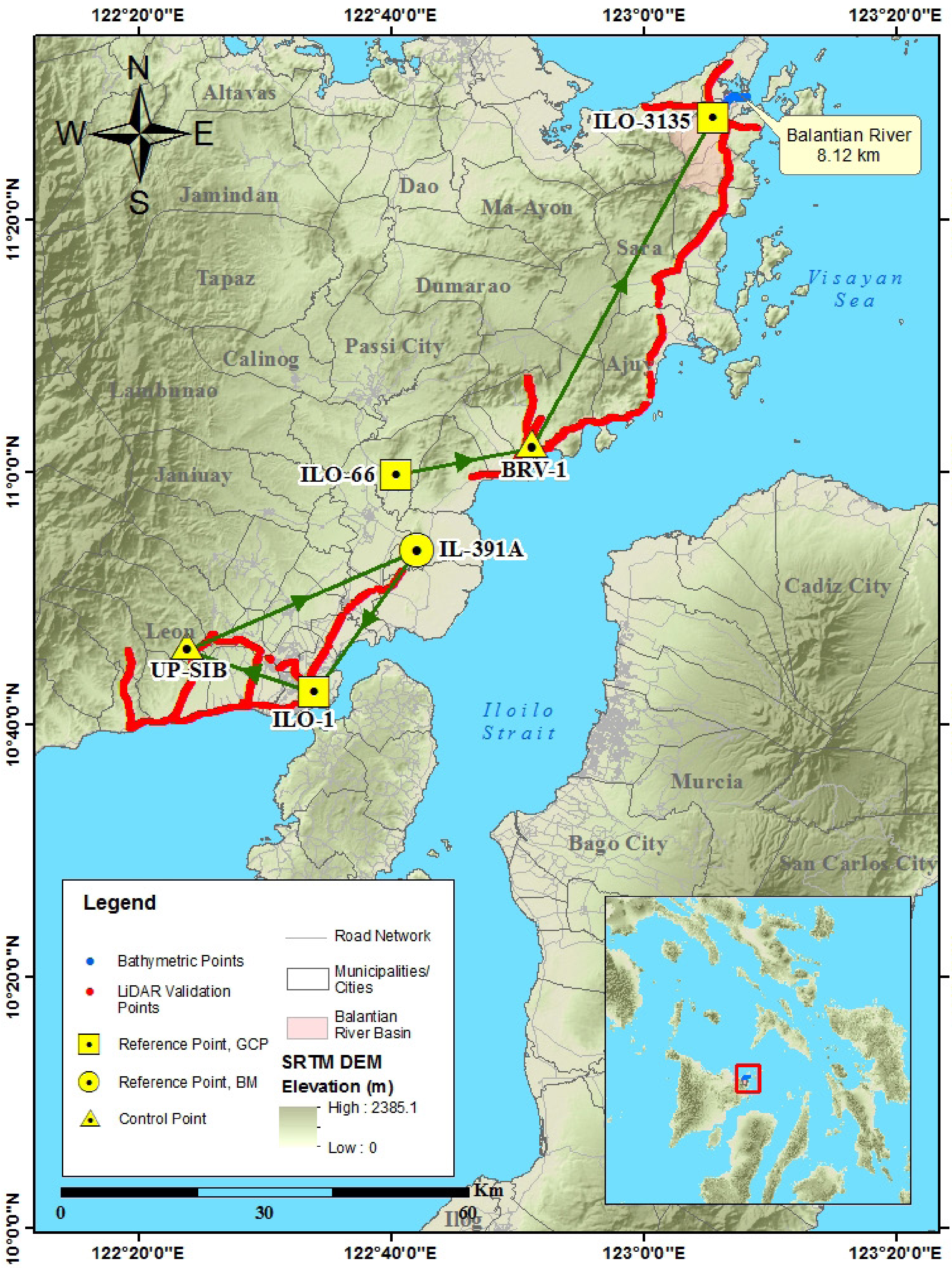


Figure 30. Extent of the bathymetric survey (in blue line) in the Balantian River and the LiDAR data validation survey (in red)

4.2 Control Survey

A GNSS baseline was established on July 22, 2014, occupying the following reference points: (i.) ILO-3135, an LMS marker used as a GCP in Barangay Poblacion Sur, Municipality of Balasan; and (ii.) ILO-66, a second-order GCP in Barangay Camambugan, Municipality of Dingle.

The GNSS network used for the Balantian River Basin is composed of a single loop established on October 21, 2015, occupying the following reference points: (i.) ILO-1, a first order GCP in Barangay La Paz in Iloilo City; and (ii.) IL-39A, a first-order BM in Barangay JT Bretaña in the Municipality of Barotac Nuevo. A control point, UP-SIB, was established along the approach of the Sibalom Bridge in Barangay Anonang in the Municipality of Leon.

The summary of reference and control points and their corresponding locations is given in Table 21; while the established GNSS network is illustrated in Figure 31.

Table 21. List of Reference and Control points occupied in the Balantian River survey (Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height, (m)	BM Ortho in MSL (m)	Date Established
Control Survey on July 22-26, 2014						
ILO-66	2nd Order, GCP	10°59'51.7441"N	122°40'23.8767"E	84.815	25.655	2005
ILO-3135	2nd Order, GCP	11°28'10.9134"N	123°05'27.1359"E	67.655	8.0823	2007
BRV-1	UP-established	11°02'19.3210"N	122°51'07.2894"E	74.417	14.337	2014
Control Survey on Oct 10 -21, 2016						
IL-319A	1st order, BM	-	-	70.755	12.159	2012
ILO-1	1st order, GCP	10°42'36.4676"N	122°33'53.5929"E	82.696	-	1989
UP-SIB	UP established	-	-	-	-	2015

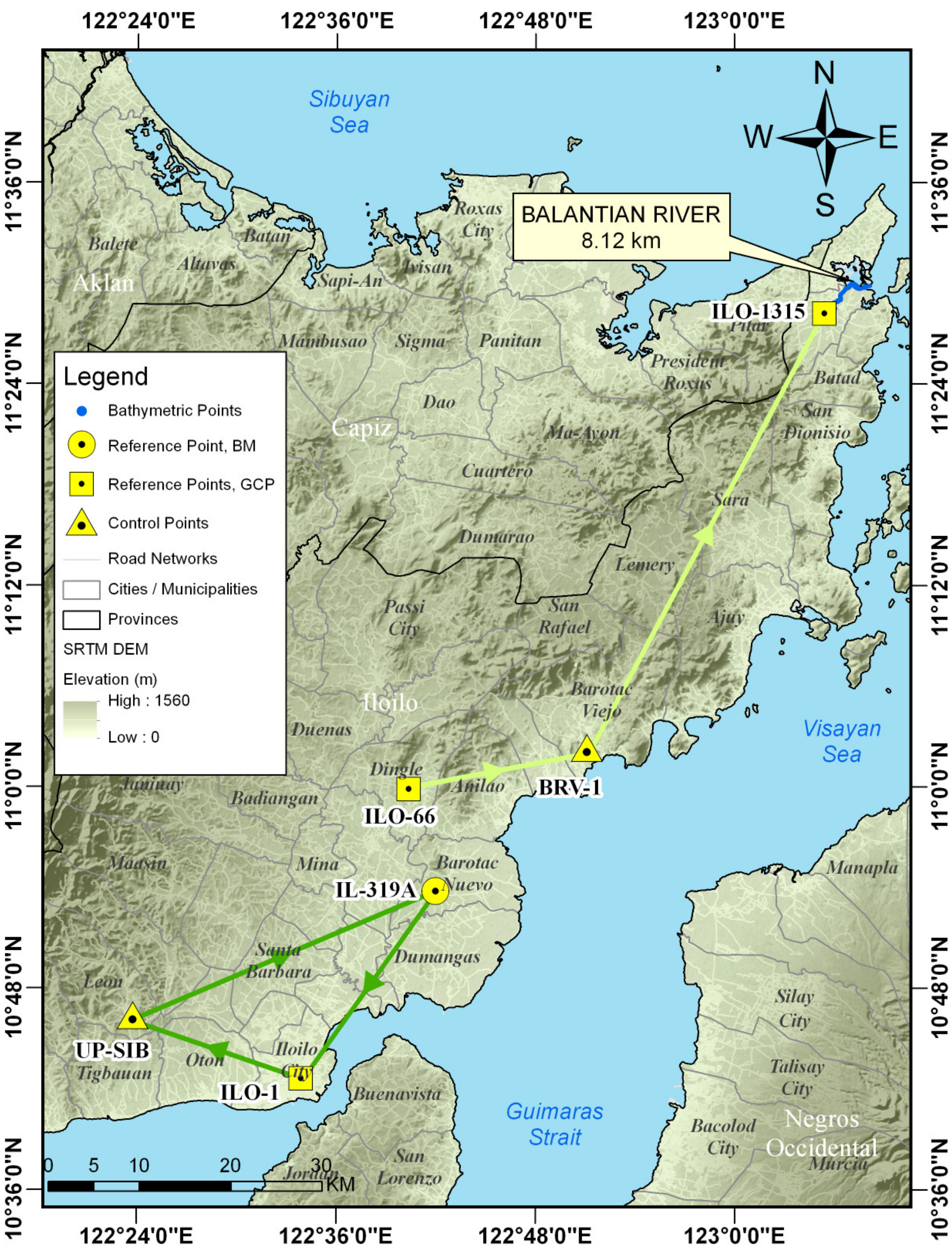


Figure 31. GNSS network covering the Balantian River

The GNSS set-ups in the reference points and established control points in the Iloilo survey are exhibited in Figure 32 to Figure 37.

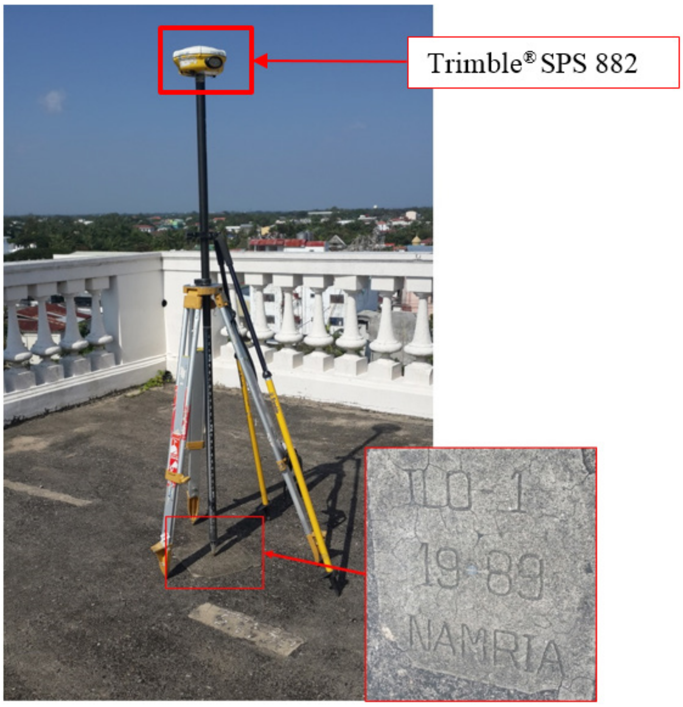


Figure 32. Trimble® SPS 882 set-up at ILO-1, located at the rooftop of the St. Clemente Church bell tower in Barangay La Paz, Iloilo City

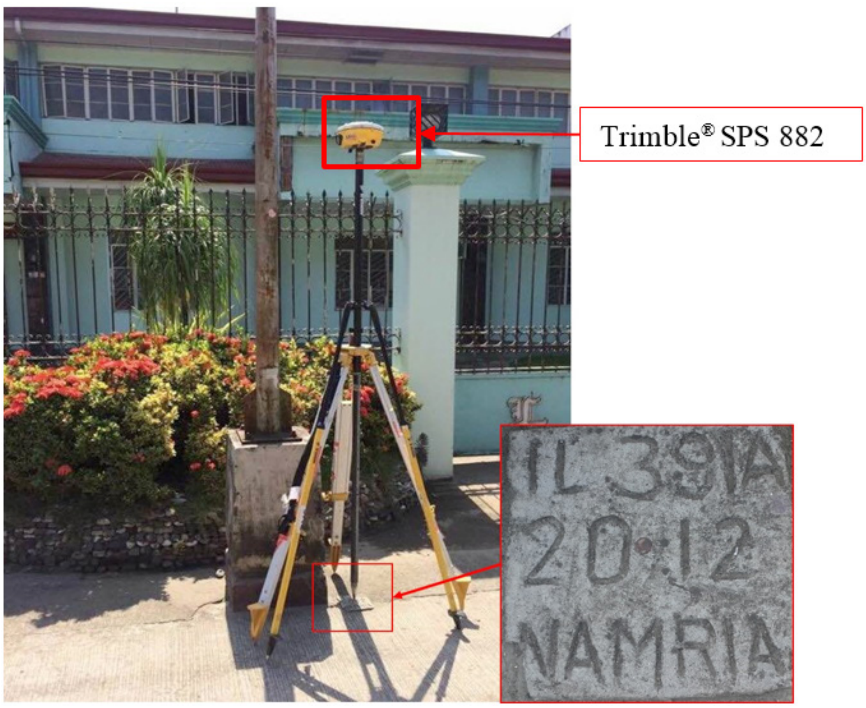


Figure 33. Trimble® SPS 852 set-up at IL-39A, located in Barangay JT Bretaña, Municipality of Barotac Nuevo, Iloilo

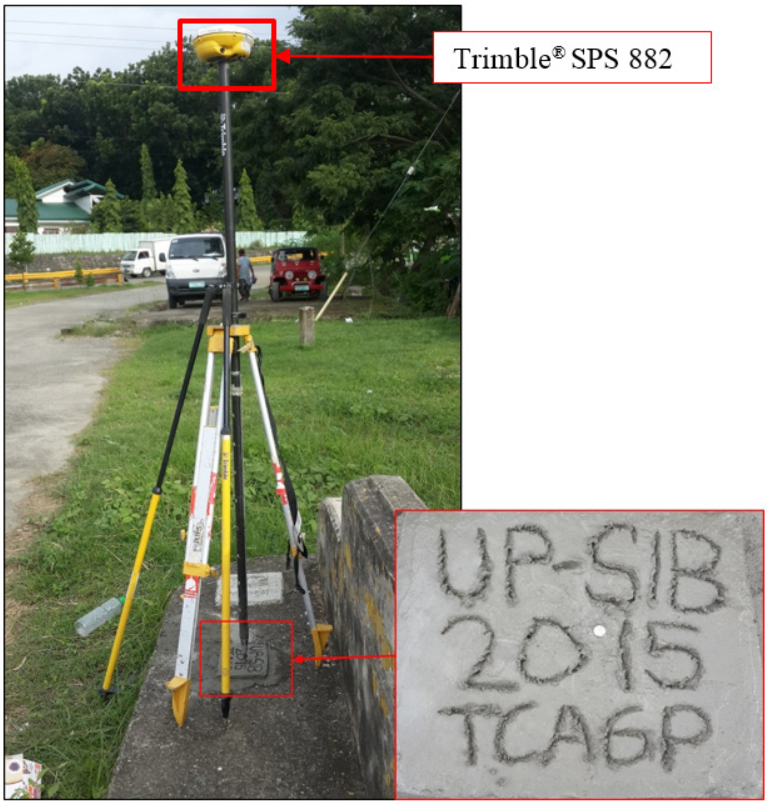


Figure 34. Trimble® SPS 882 set-up at UP-SIB located at the Sibalom Bridge in Barangay Anonang, Leon, Iloilo

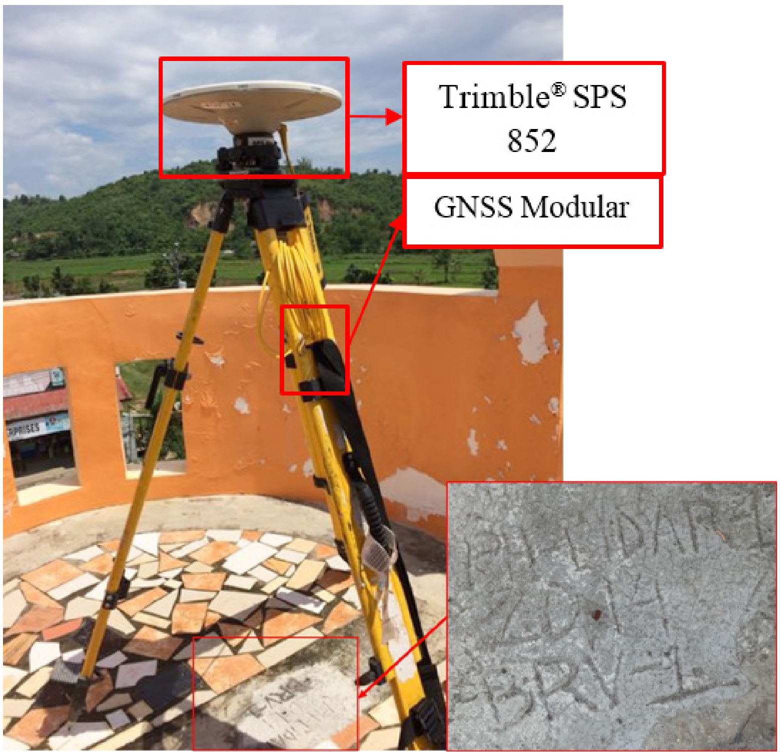


Figure 35. Trimble® SPS 852 set-up at BRV-1, located on the rooftop of Hollywood Star Inn in Barangay Poblacion, Municipality of Barotac Viejo, Iloilo

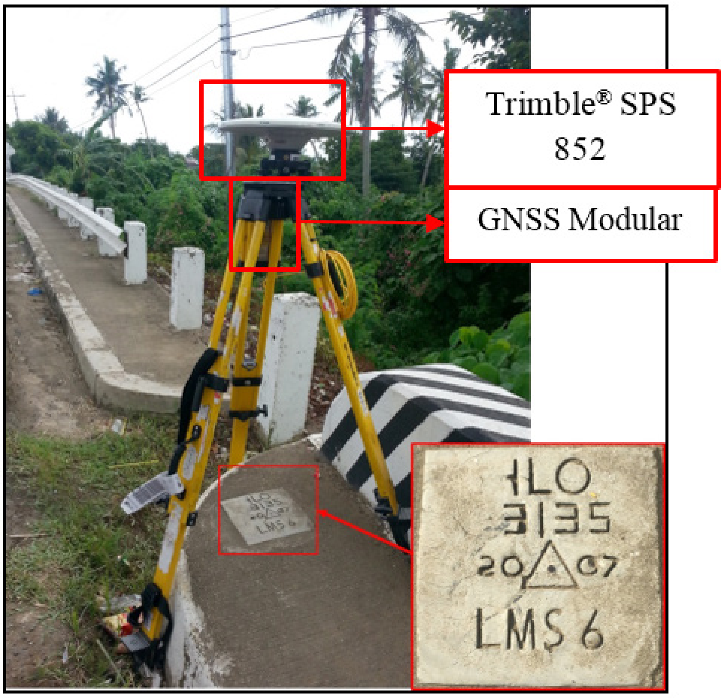


Figure 36. Trimble® SPS 852 set-up at ILO-3135, located at the Balasan Bridge in Barangay Poblacion Sur, Municipality of Balasan, Iloilo

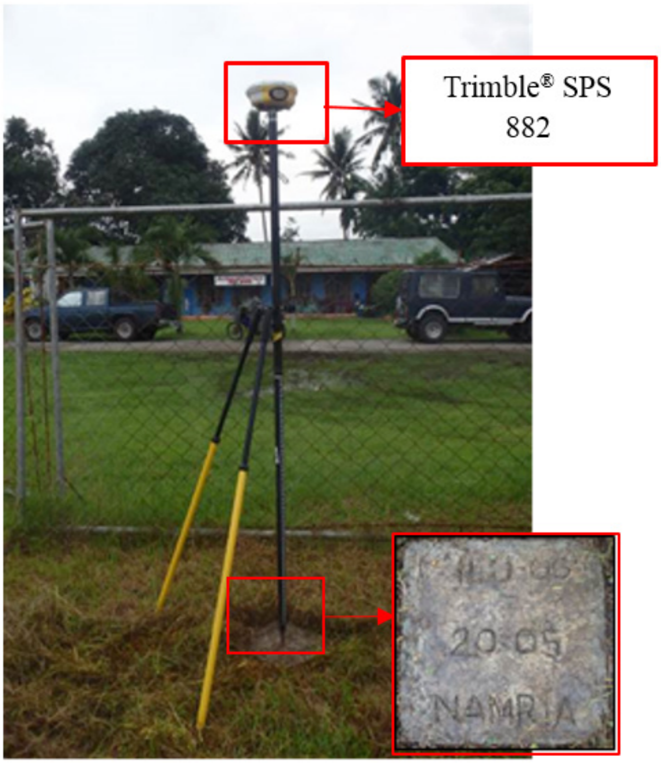


Figure 37. Trimble® SPS 882 set-up at ILO-66, located inside Dingle Elementary School, Barangay Camambugan, Municipality of Dingle, Iloilo

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 the +/- 20-centimeter and +/- 10-centimeter requirement, respectively. In cases where one or more of the baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a re-survey is initiated. The baseline processing results of the control points in the Balantian River Basin, generated by TBC software, are summarized in Table 22.

Table 22. Baseline processing report for the Balantian River Basin static survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
UP-SIB --- ILO-1	10-21-2015	Fixed	0.004	0.020	290°35’49”	19718.694	29.558
ILO-1 --- IL-39A	10-21-2015	Fixed	0.007	0.042	35°35’00”	25376.998	-11.945
UP-SIB --- IL-39A	10-21-2015	Fixed	0.008	0.008	67°33’28”	35939.016	-41.499

As shown in Table 22, a total of four (4) baselines were processed, with reference point ILO-1 held fixed. All of the baselines satisfied the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the adjusted grid coordinates table of the TBC-generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 centimeters, and z less than 10 centimeters, or in equation form:

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

Where:

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

for each control point. See the Network Adjustment Report in Tables 23 to 26 for complete details.

The control point ILO-1 was held fixed during the processing of the control point, as presented in Table 23. Through these reference points, the coordinates of the unknown control points were computed.

Table 23. Constraints applied to the adjustments of the control points

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
IL391A	Grid				Fixed
ILO1	Global	Fixed	Fixed		
Fixed = 0.000001(Meter)					

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 24. The fixed control point ILO-1 did not yield values for standard errors.

Table 24. Adjusted grid coordinates for the control points used in the Balantian floodplain survey

Point ID	Easting (Meter)	East-ing Error (Meter)	Northing (Meter)	Northing Error (Meter)	Eleva-tion (Meter)	Eleva-tion Error (Meter)	Con-straint
L391A	467210.564	0.008	1204571.737	0.009	12.159	?	e
ILO1	452420.308	?	1183962.237	?	24.280	0.067	LL
UPSIB	433978.543	0.006	1190922.753	0.005	55.063	0.069	

With the mentioned equation for horizontal accuracy, and for vertical accuracy, the computations for accuracy are as follows:

a. ILO-1

Horizontal Accuracy = fixed

Vertical Accuracy = 6.7 < 10 cm

b. IL-39A

Horizontal Accuracy $= \sqrt{((0.8)^2 + (0.9)^2}$

$= \sqrt{(0.64 + 0.81)}$

= 1.20 cm < 20 cm

Vertical Accuracy = fixed

c. UP-SIB

Horizontal Accuracy $= \sqrt{((0.6)^2 + (0.5)^2}$

$= \sqrt{(0.36 + 0.25)}$

= 0.78 cm < 20 cm

Vertical Accuracy = 6.9 < 10 cm

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

Table 25. Adjusted geodetic coordinates for control points used in the Balantian River floodplain validation

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
IL391A	N10°53'48.05371"	E122°41'59.84243"	70.755	?	e
ILO1	N10°42'36.46758"	E122°33'53.59289"	82.696	0.067	LL
UPSIB	N10°46'22.07056"	E122°23'46.02755"	112.253	0.069	

The corresponding geodetic coordinates of the observed points are within the required accuracy, as demonstrated 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 Balantian River GNSS Static Survey are indicated in Table 26.

Table 26. Reference and control points used in the Balantian River Static Survey, with their corresponding locations (Source: NAMRIA and UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates WGS 84			UTM Zone 51 N		
		Latitude	Longitude	Ellipsoidal Height, (m)	Northing (m)	Easting (m)	BM Ortho (m)
Control Survey on July 22-26, 2014							
ILO-66	2nd Order	10°59'51.7441"N	122d40'23.8767"E	84.815	1215745.274	464309.479	25.655
ILO-3135	2nd Order	11°28'10.9134"N	123d05'27.1359"E	67.655	1267916.553	509911.061	8.0823
BRV-1	UP Established	11°02'19.3210"N	122°51'07.2894"E	74.417	1220262.792	483836.720	14.337
Control Survey on Oct 10 -21, 2016							
IL-319A	1st Order, BM	10°53'48.05371"	122°41'59.84243"	70.755	1204572	467210.6	12.159
ILO-1	1st Order, GCP	10°42'36.46758"	122°33'53.59289"	82.696	1183962	452420.3	24.28
UP-SIB	UP Established	10°46'22.07056"	122°23'46.02755"	112.253	1190923	433978.5	55.063

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

Cross-section and bridge as-built surveys were conducted on July 23, 2014 along the upstream side of the Balasan Bridge, located in Barangay Poblacion Sur, Municipality of Balasan. A Trimble® SPS 882 GNSS receiver in PPK survey technique was utilized for the survey, as depicted in Figure 38.

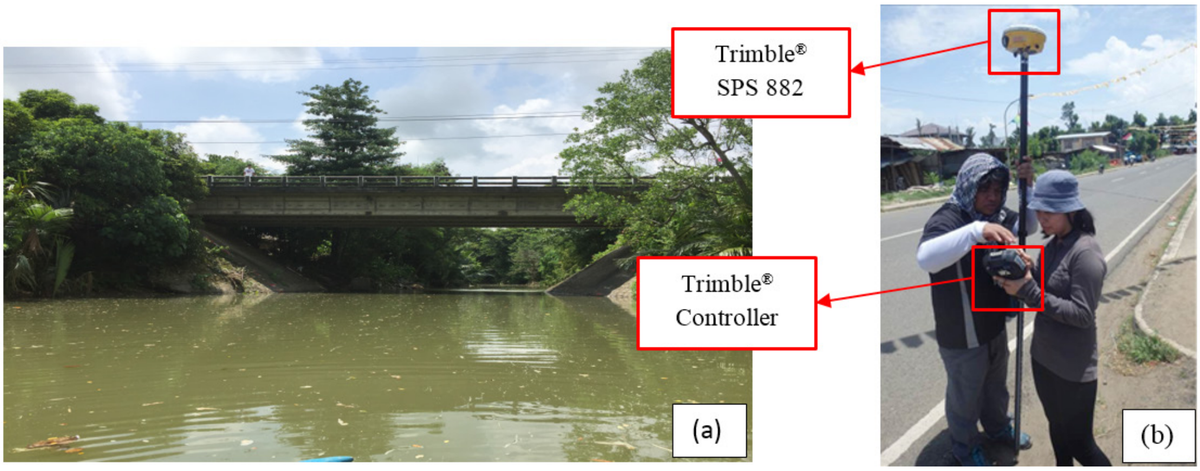


Figure 38. (a) Panoramic View of the Balasan Bridge facing upstream; and (b) as-built and cross section survey of the Balasan Bridge

The length of the cross-sectional line surveyed in the Balasan Bridge is 308.949 meters with a total of twenty (20) points acquired, using the control point ILO-3135 as the base station. The location map, cross-section diagram, and the bridge data form are presented in Figure 39 to Figure 41.

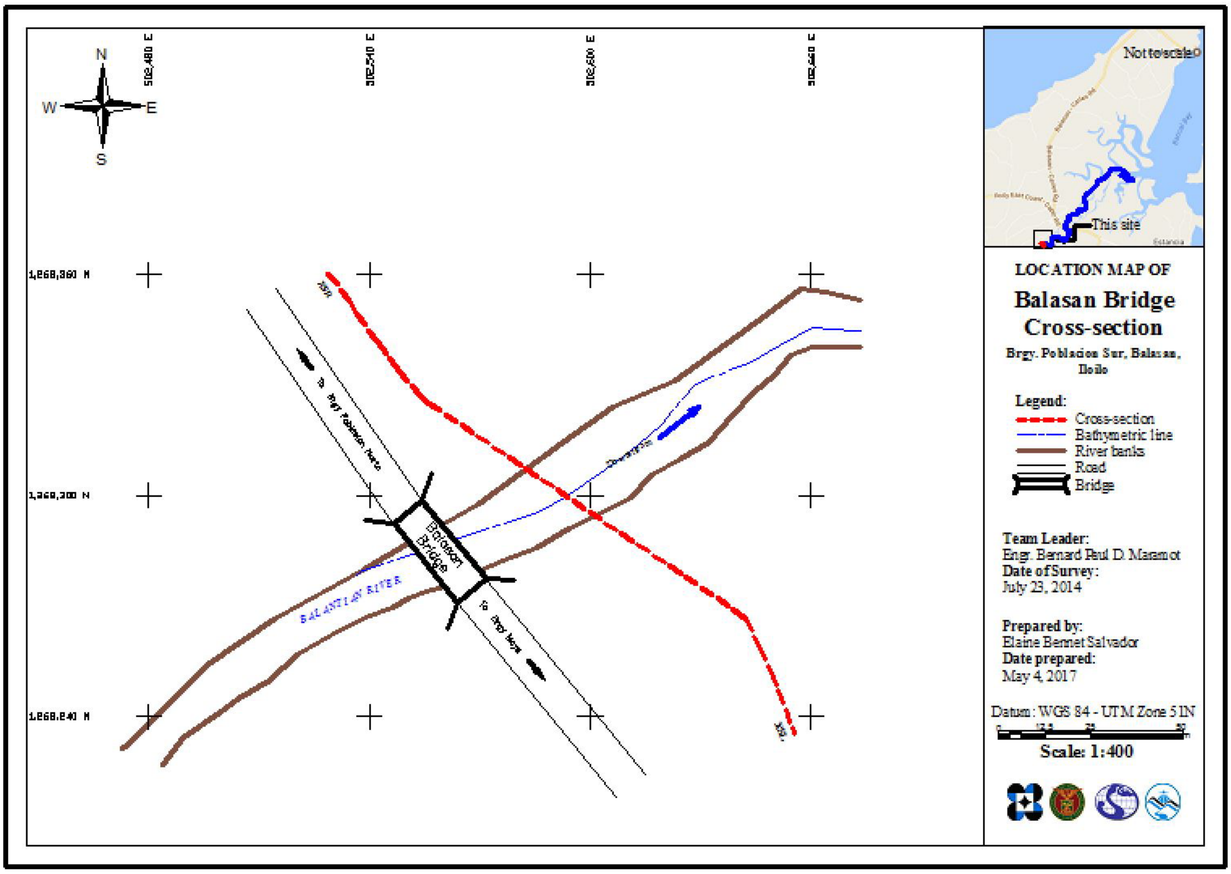


Figure 39. Balasan Bridge location map

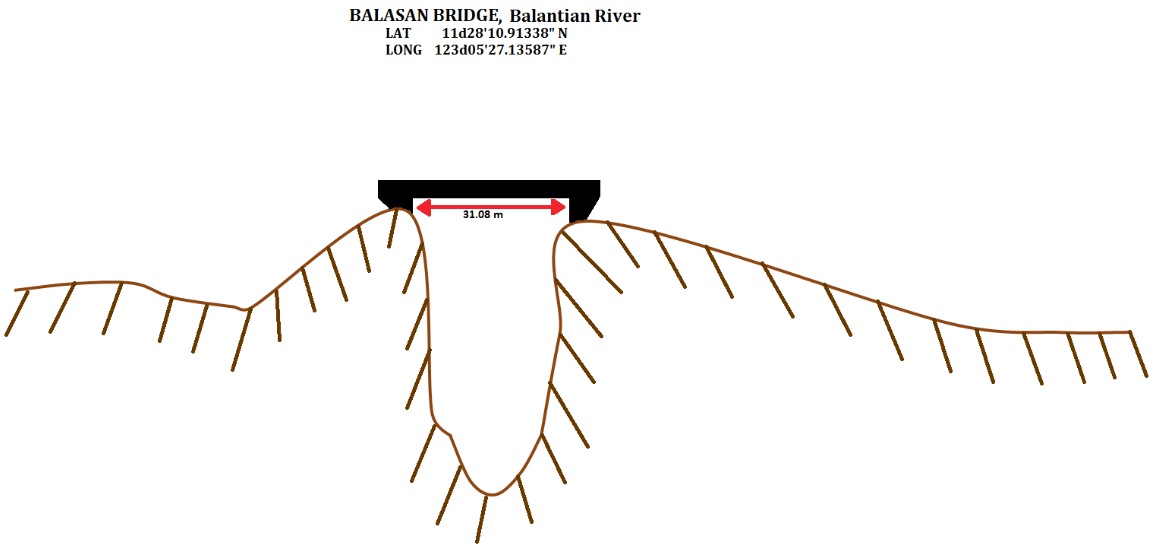


Figure 40. Balasan Bridge cross-sectional diagram

Bridge Data Form

Bridge Name: Balasan Bridge **Date:** July 23, 2014

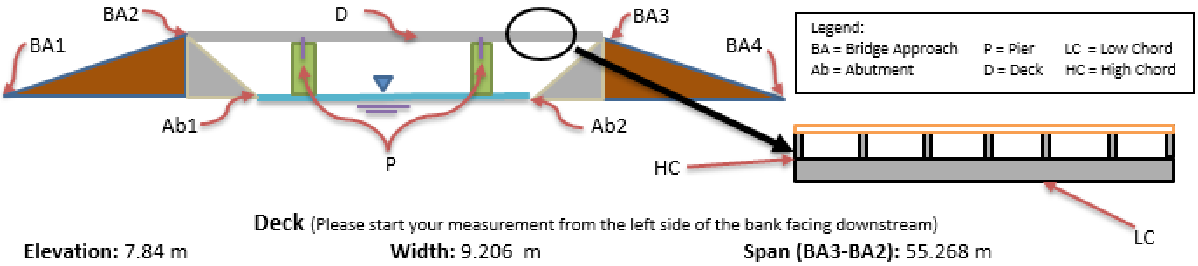
River Name: Balantian River **Time:** 11: 50 AM

Location (Brgy, City,Region): Poblacion Sur, Balasan, Iloilo

Survey Team: DVBC Iloilo Survey Team

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

Latitude: 11d28'10.91338"N **Longitude:** 123d05'27.13587" E



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

Elevation: 7.84 m **Width:** 9.206 m **Span (BA3-BA2):** 55.268 m

	Station	High Chord Elevation	Low Chord Elevation
1	BA 3	8.0633 m	6.1633 m
2			
3			
4			
5			

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	5.4283 m	**BA3**	165.0642 m	8.0633 m
BA2	130.856 m	8.0683 m	**BA4**	308.949 m	4.7873 m

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

	Station (Distance from BA1)	Elevation
Ab1	140.994 m	0.5903 m
Ab2	165.0642 m	0.6243 m

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

Shape: NA Number of Piers: NA Height of column footing: NA

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1			
Pier 2			
Pier 3			
Pier 4			
Pier 5			
Pier 6			

Figure 41. Balasan Bridge data form

The water surface elevation of the Balantian River was determined using a Trimble® 882 GNSS receiver in PPK survey technique on July 23, 2014. The water surface elevation had an MSL value of 8.25 meters, which was translated into markings on the bridge's post using the same technique, as displayed in Figure 42. The markings served as a reference for flow data gathering and depth gauge deployment by the UPC Phil-LiDAR 1 team.

Figure 42. Water level markings on the cord of the Balantian Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on October 11, 12, 13, 14, 17, 18, and 19 of the year 2015 using a survey-grade GNSS rover receiver, Trimble® SPS 882. The receiver was mounted on a pole attached in front of a vehicle, as demonstrated in Figure 43. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height of 2.53 meters was measured from the ground up to the bottom of the notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode, with ILO-3135, BRV-1, and UP-SIB occupied as the GNSS base stations.

Figure 43. Validation points acquisition set-up for the Balantian River Basin

The validation points acquisition survey for the Balantian River Basin traversed twenty (20) municipalities and Iloilo City in the province of Iloilo. The ground survey traversed a route that was perpendicular to the LiDAR flight strips across the basin. A total of 26,620 points with an approximate length of 223.38 kilometers were acquired for the validation points acquisition survey, as shown in the map in Figure 44.

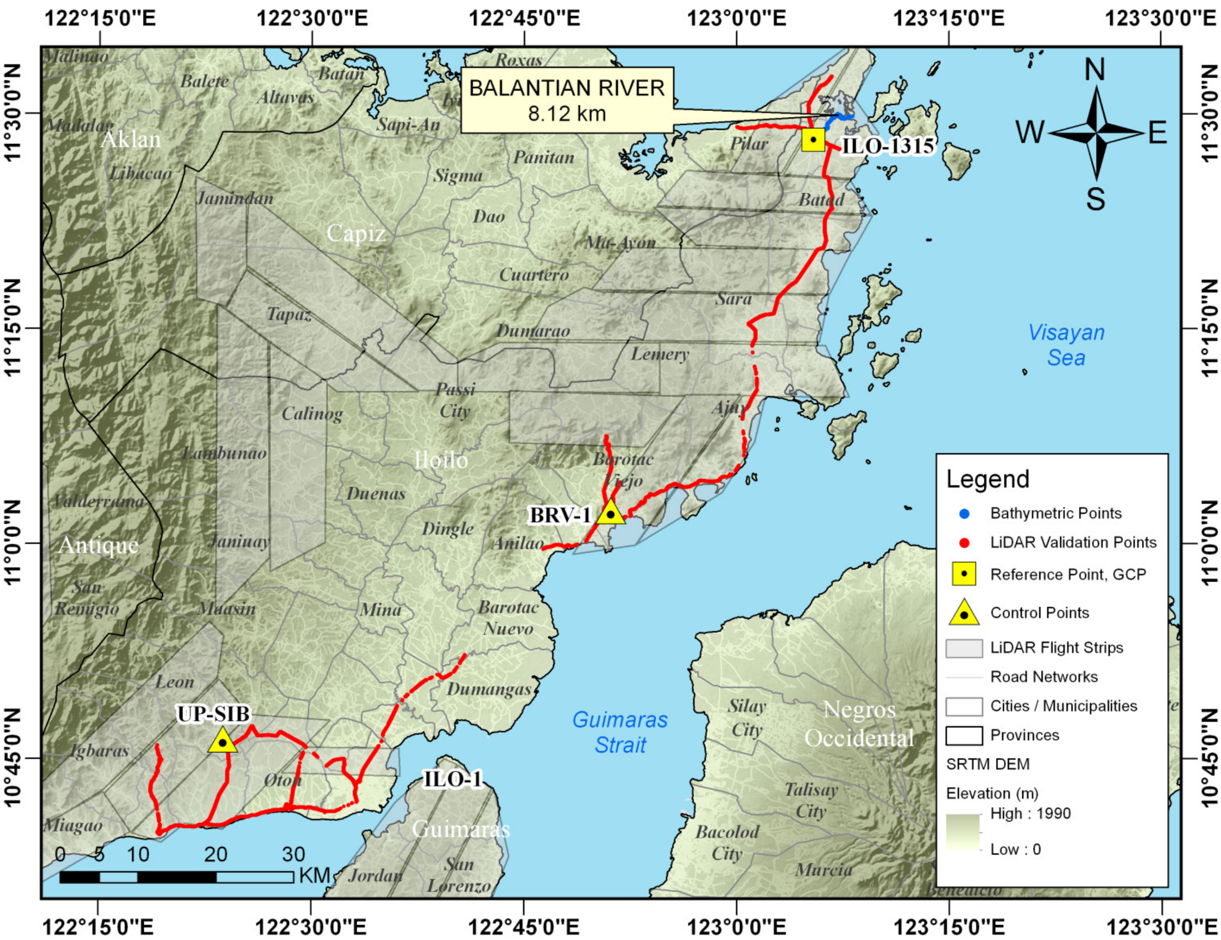


Figure 44. Extent of the validation points acquisition survey covering the length of the Balantian River Basin

4.7 Bathymetric Survey

A bathymetric survey of the Balantian River was conducted on October 11, 2015 using an Ohmex™ single-beam echo sounder and a Trimble® SPS 882 GNSS Rover receiver attached to a pole on the side of the boat, as depicted in Figure 45. The survey began at the upstream part of the river in Barangay Poblacion Sur, with coordinates 11°28'10.22143" 123°05'26.67410"; traversed down to the mouth of the river towards the Visayan Sea; and ended in Barangay Tupaz, Municipality of Carles, with coordinates 11°29'50.83544" 123°08'13.88877". The control point ILO-3135 was used as the base station for the duration of the bathymetric survey.

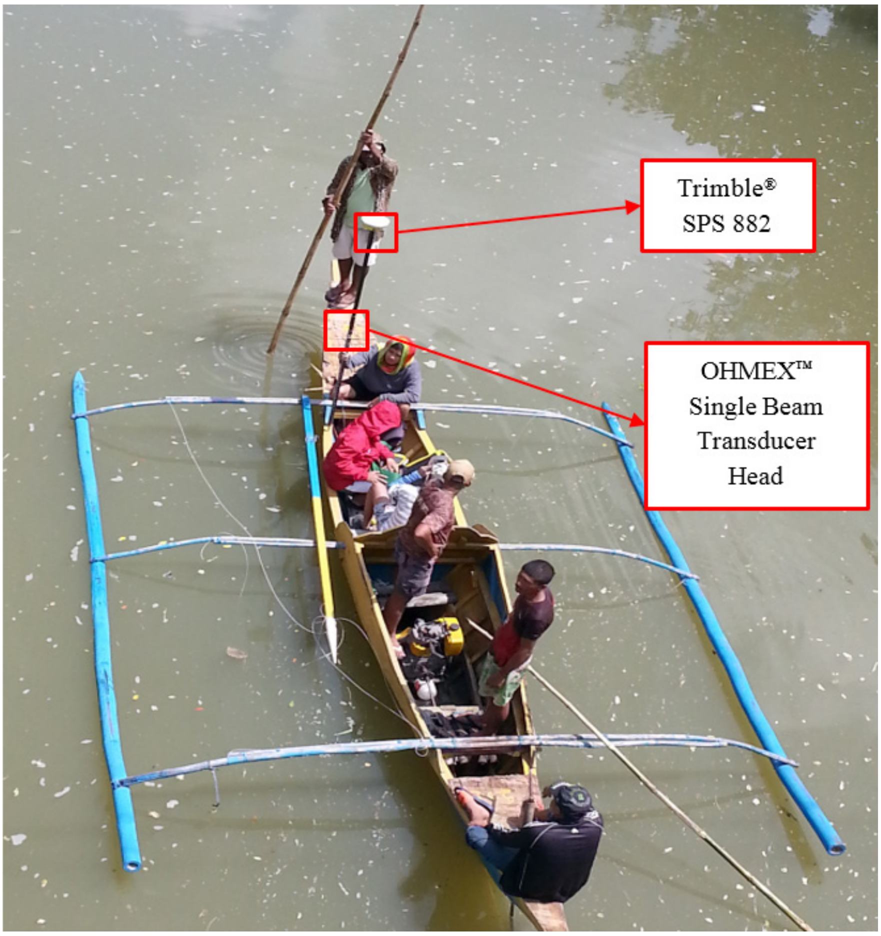


Figure 45. Bathymetric survey in the Balantian River in Barangay Poblacion Sur, Municipality of Balasan, Iloilo

The bathymetric survey for the Balantian River gathered a total of 6,198 bathymetric points, with an approximate length of 8.07 kilometers, as illustrated in the map in Figure 46.

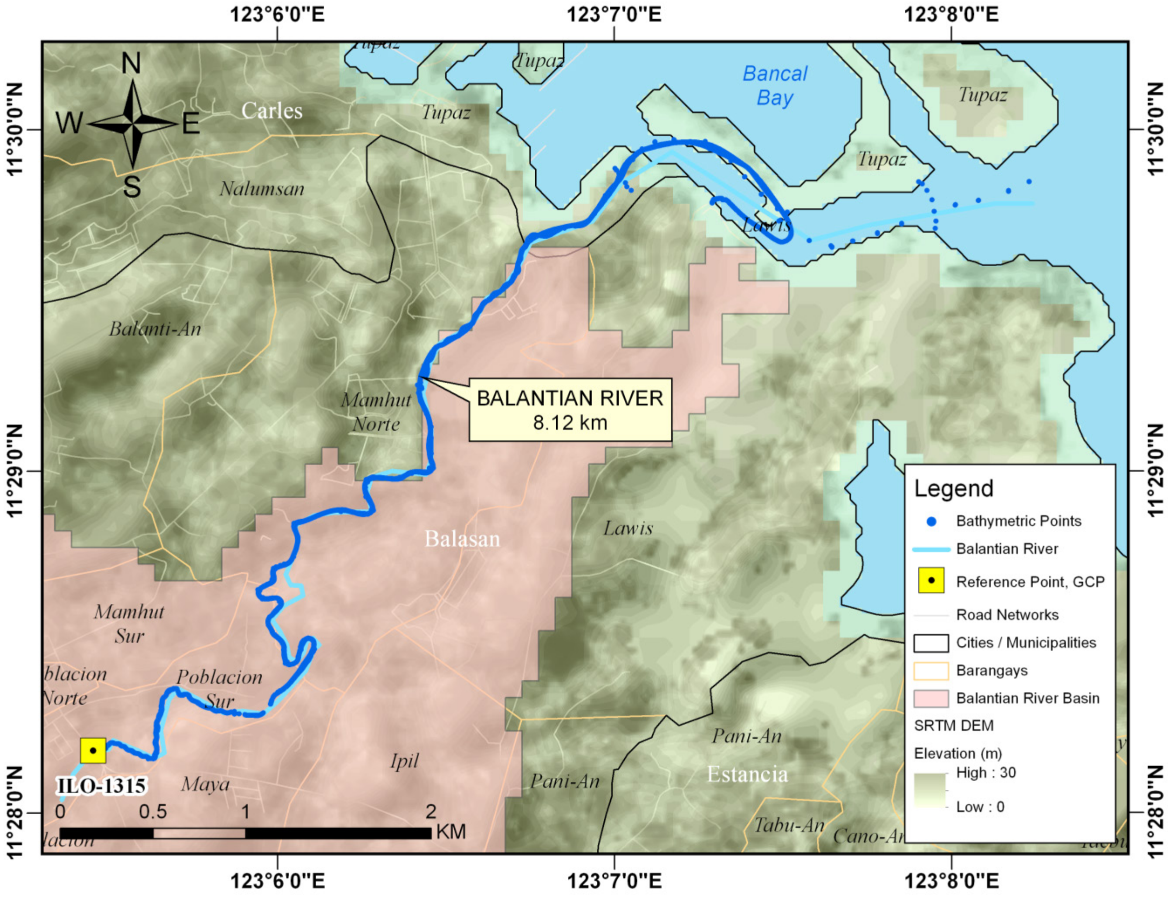


Figure 46. Extent of the bathymetric survey of the Balantian River

A CAD drawing was also produced to illustrate the Balantian riverbed centerline profile, presented in Figure 47. The profile shows that a rise in elevation of 0.92 meters with respect to MSL was observed within the 8.07-kilometer acquired data, with the lowest elevation at -4.825 meters located in Barangay Tupaz, Municipality of Balasan.

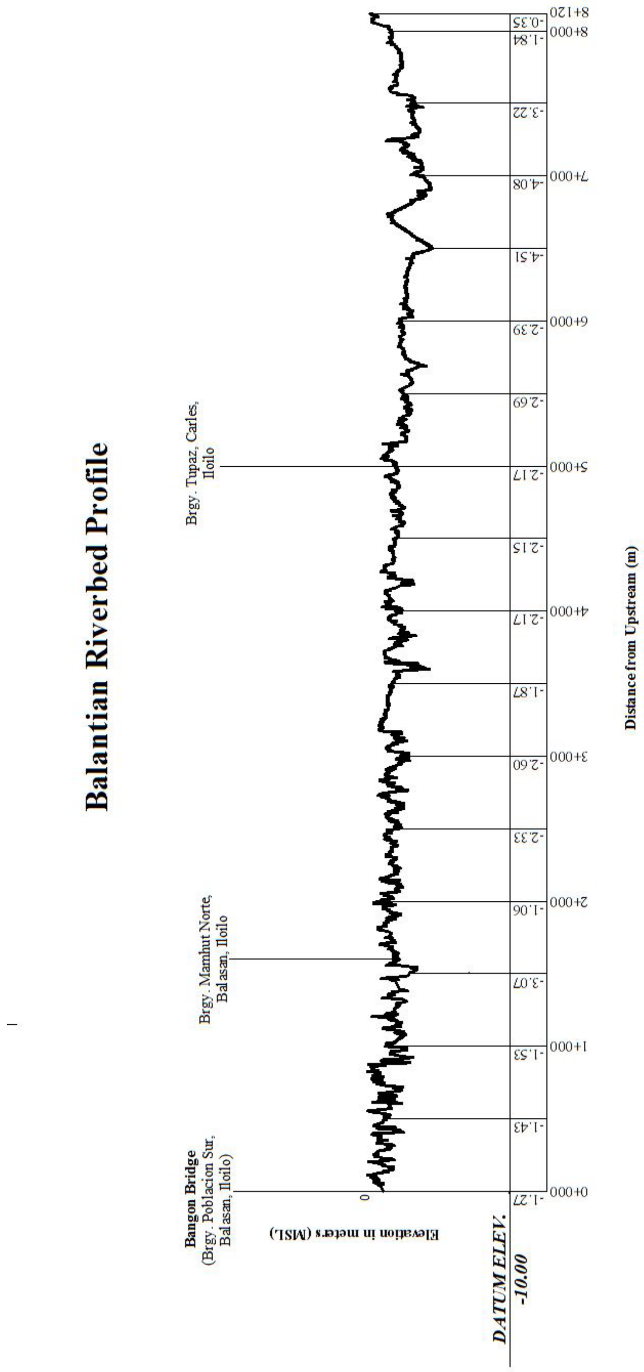


Figure 47. Riverbed profile of the Balantian River

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, Neil Tingin, Narvin Clyd Tan, and Marvin Arias

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

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the UPC Flood Modeling Component (FMC) team. The ARG was installed at Barangay Abuanan, Bago City, Negros Occidental (Figure 48). The precipitation data collection was held on January 9, 2017 at 02:30 hrs. until 14:10 hrs., with a recording interval of ten (10) minutes.

The total precipitation for this event in the Barangay Abuanan ARG was 59.3 millimeters, with a peak rainfall of 2.80 millimiters on January 16, 2017 at 05:35 hrs. The lag time between the peak rainfall and discharge was eleven (11) hours and fifty (50) minutes.

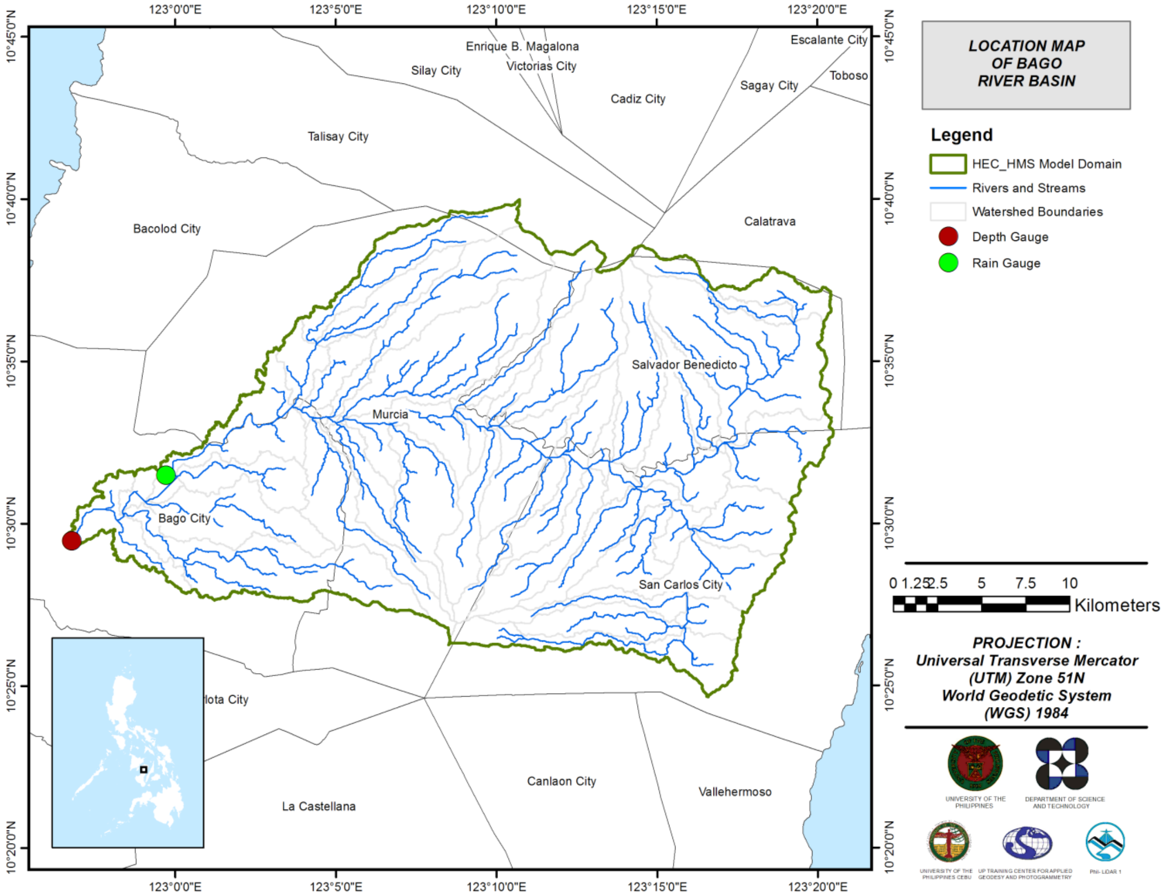


Figure 48. The location map of Balantian HEC-HMS model, which was used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 49) at the Balasan Bridge, Balasan Iloilo to establish the relationship between the observed water levels (H) and outflow (Q) of the watershed at this location.

For the Balasan Bridge, the rating curve is expressed as Q = 13.641x-134.27, as illustrated in Figure 50.

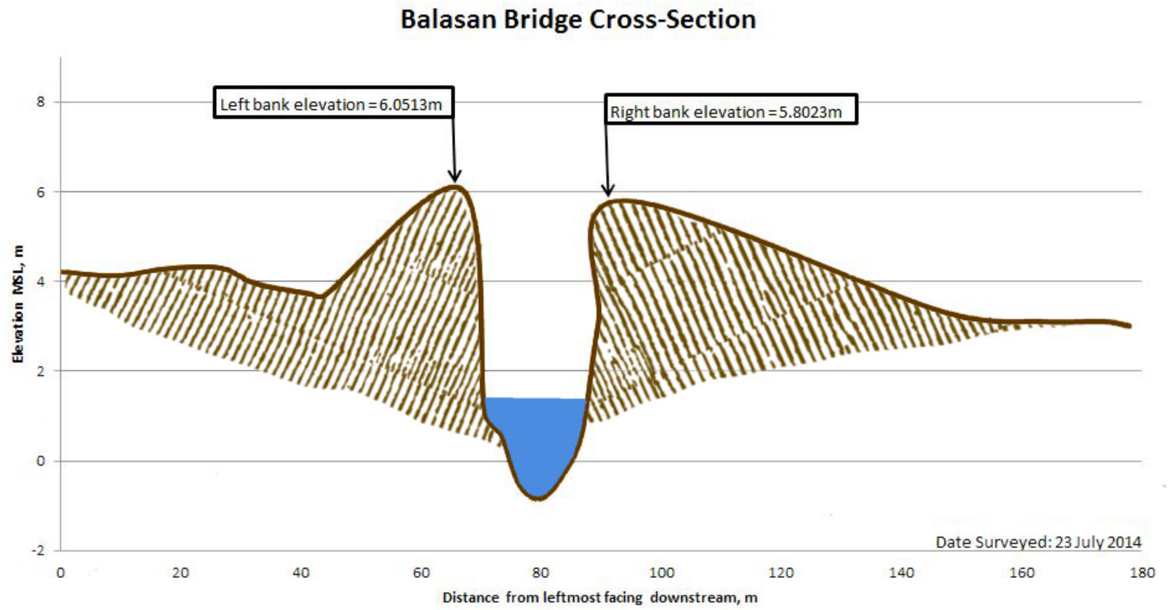


Figure 49. Cross-section plot of the Balasan Bridge

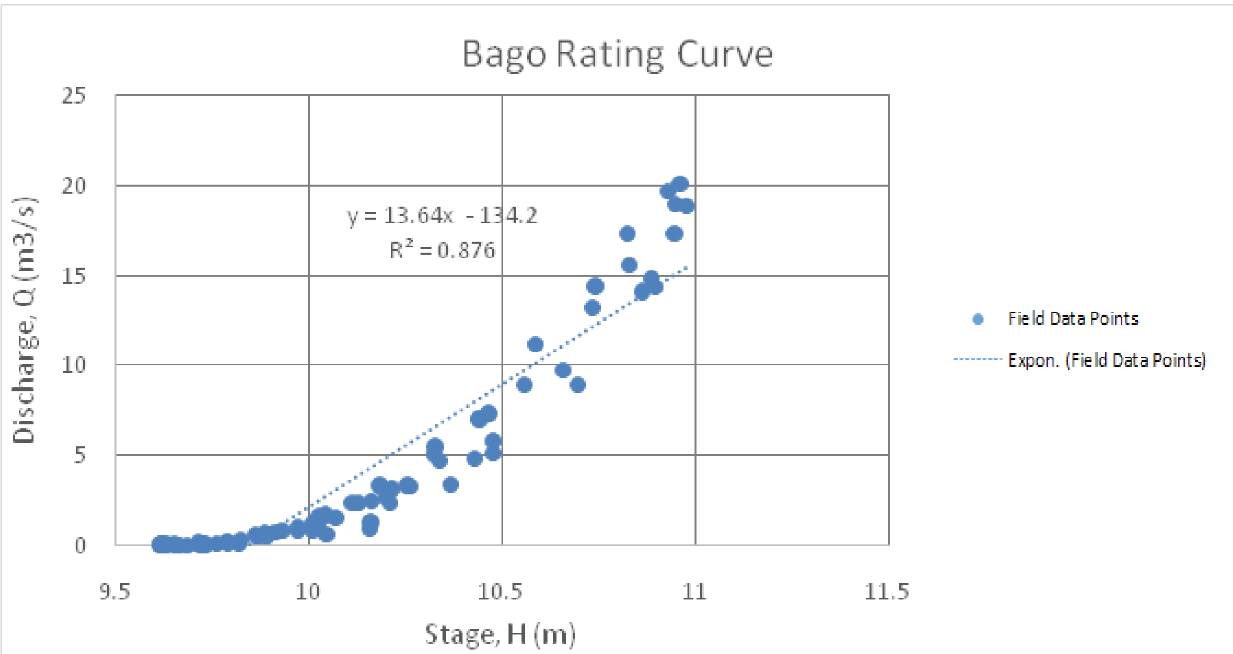


Figure 50. The rating curve at the Balasan Bridge, Balasan, Iloilo

This rating curve equation was used to compute for the river outflow at the Balasan Bridge for the calibration of the HEC-HMS model presented in Figure 51. The total rainfall for this event was 43.8 millimeters; and the peak discharge was 20.1 cubic meters (m^3) on January 16, 2017 at 15:50 hrs..

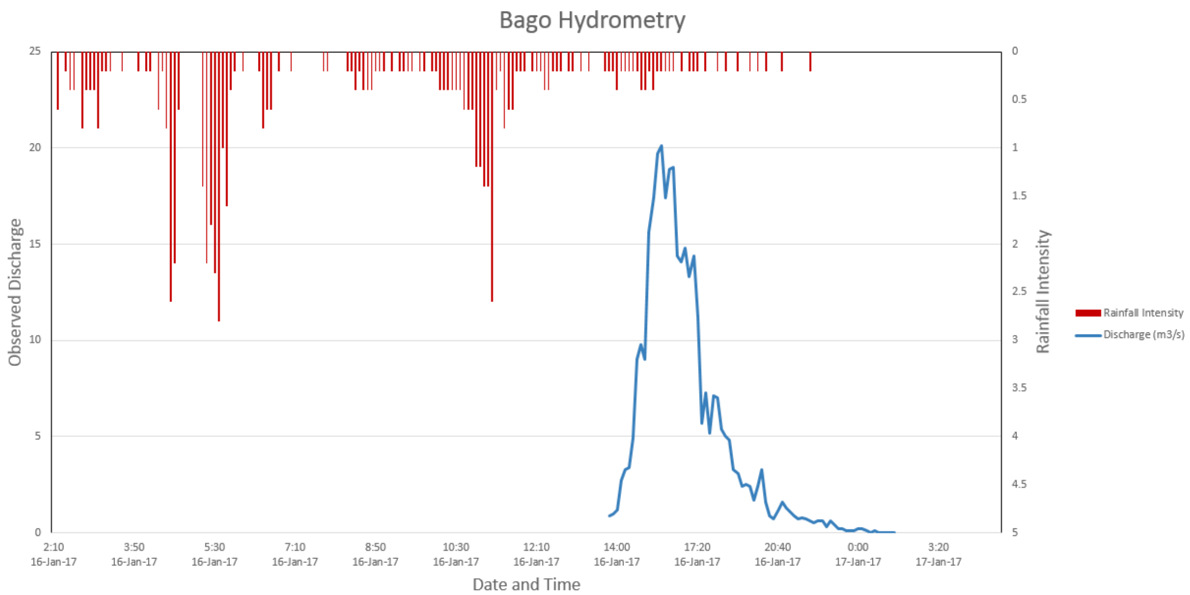


Figure 51. Rainfall and outflow data at Balantian, which were used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Roxas Rain Gauge (Table 27). This station was selected based on its proximity to the Balantian watershed (Figure 52). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values such that certain peak values were attained at a certain time. The extreme values for this watershed were computed based on a 59-year record.

Table 27. RIDF values for the Roxas 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**
5	26.6	40.5	51.3	72.1	98	115.5	142.8	165.9	186.2
10	31.3	47.8	60.7	86.2	118	139.4	172.3	200.1	224.6
25	37.4	57	72.5	104	143.1	169.6	209.7	243.4	273
50	41.8	63.8	81.3	117.2	161.8	192	237.4	275.4	308.9
100	46.2	70.5	90	130.2	180.3	214.2	264.9	307.2	344.6

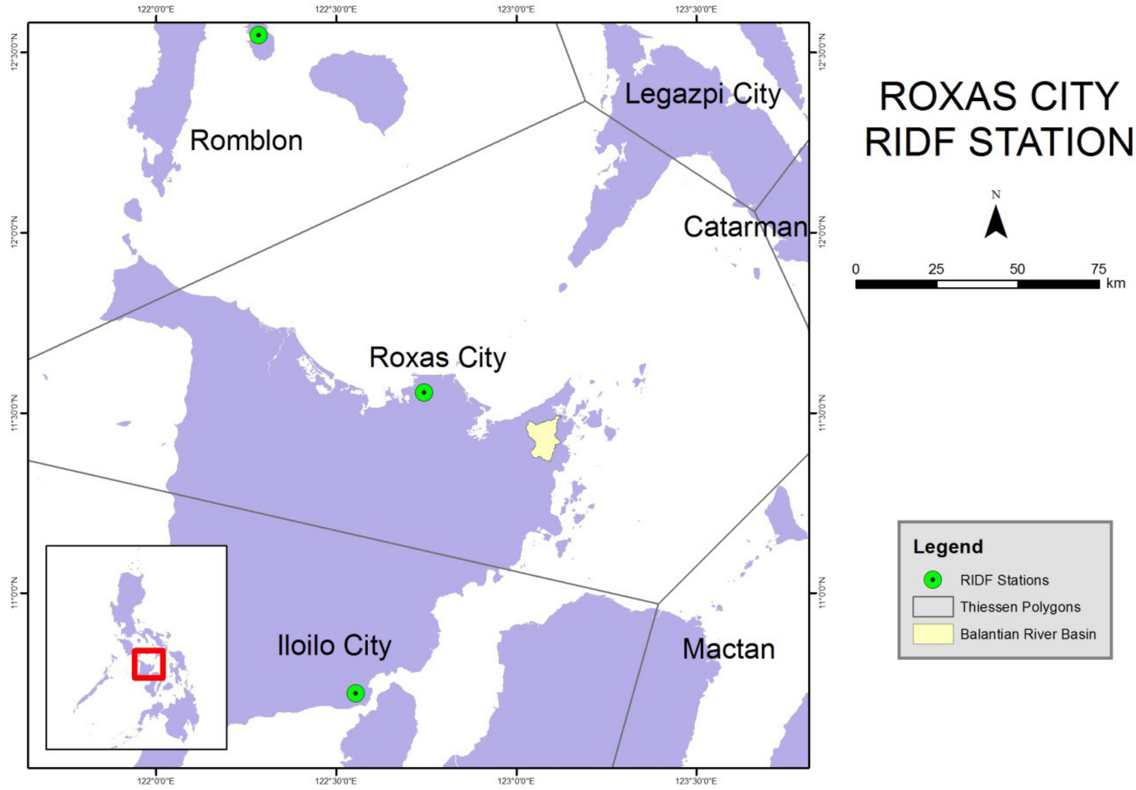


Figure 52. Location of Roxas RIDF station, relative to Balantian River Basin

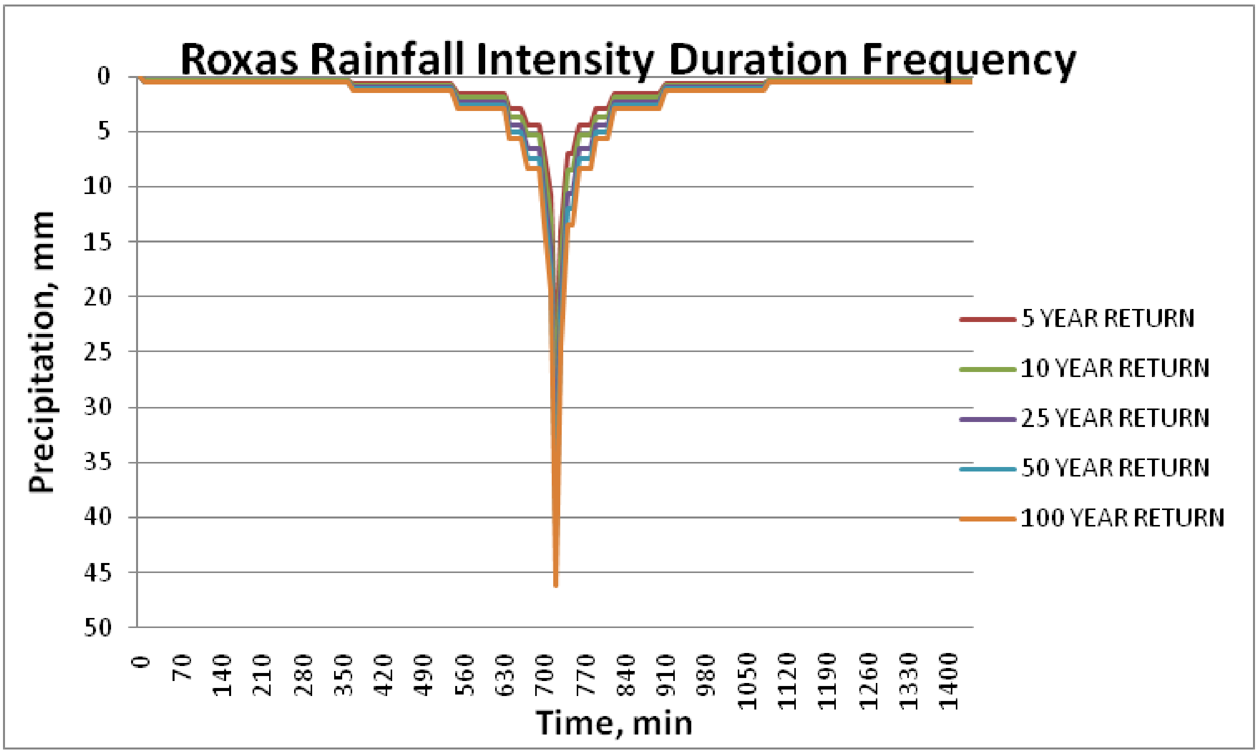


Figure 53. Synthetic storm generated from a 24-hour period rainfall, for various return periods

5.3 HMS Model

The soil shapefile was taken in 2004 from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover maps of the Balantian River Basin are presented in Figures 54 and 55, respectively.

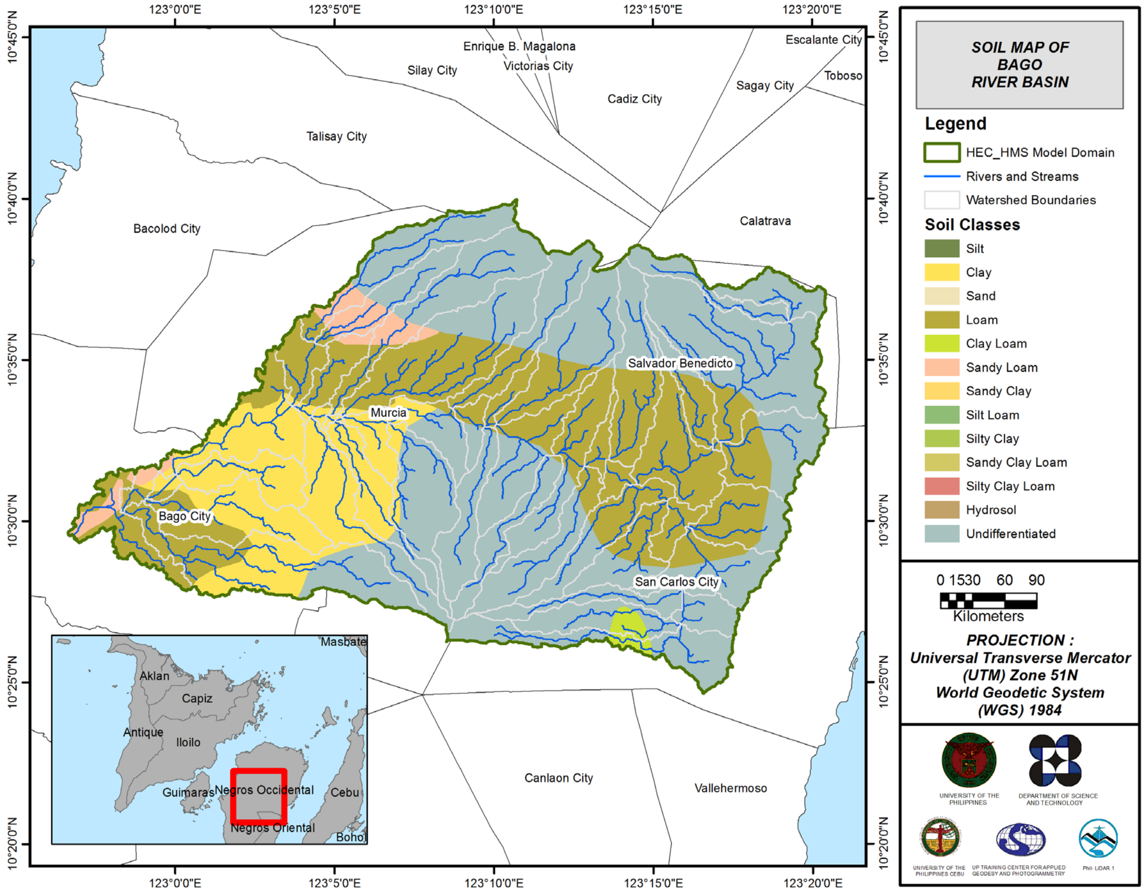


Figure 54. Soil map of the Balantian River Basin (Source: DA)

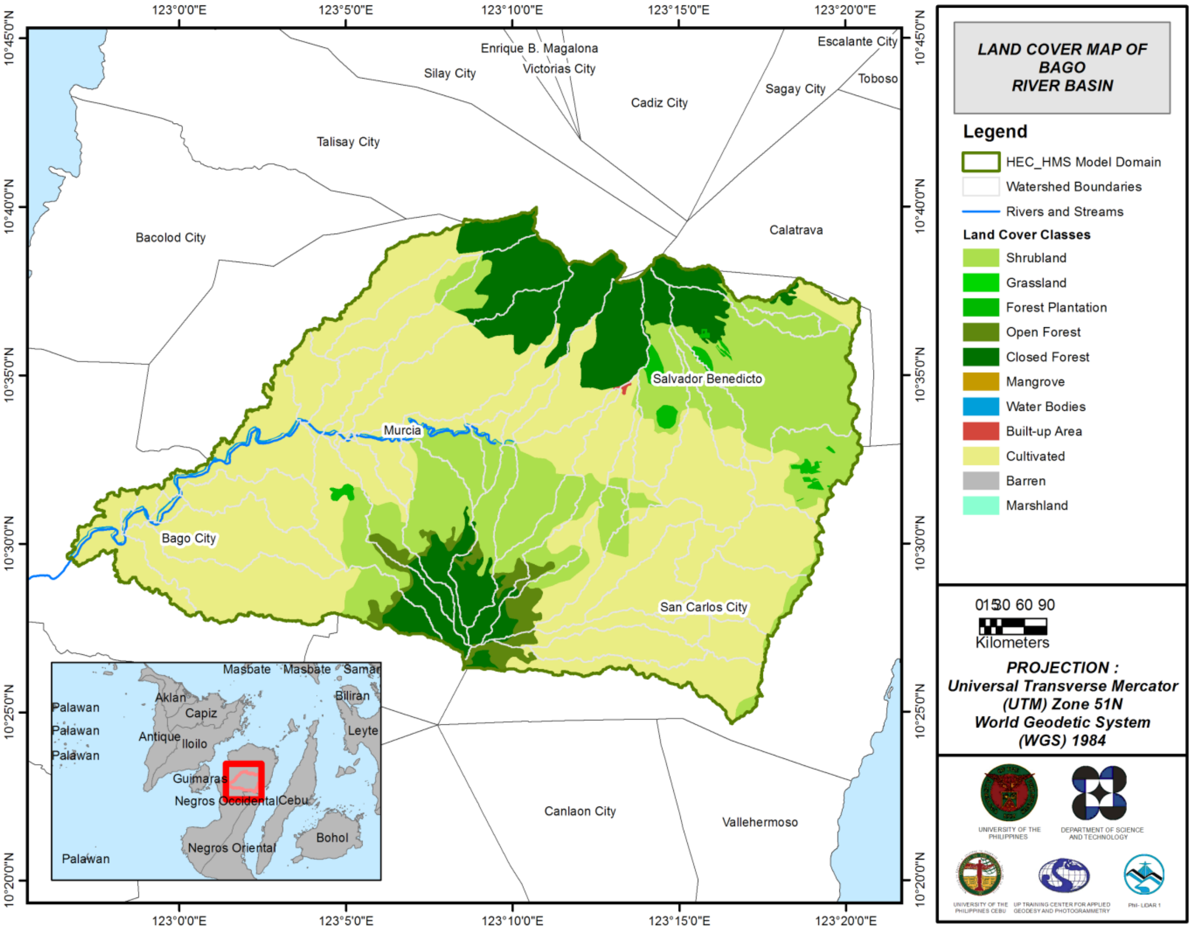


Figure 55. Land cover map of the Balantian River Basin (Source: NAMRIA)

Five (5) soil classes were identified in the Balantian River Basin. These are loam, sandy loam, clay, clay loam, and undifferentiated soil. Moreover, five (5) land cover classes were identified. These are open and closed forests, shrub lands, forest plantations, and built-up areas.

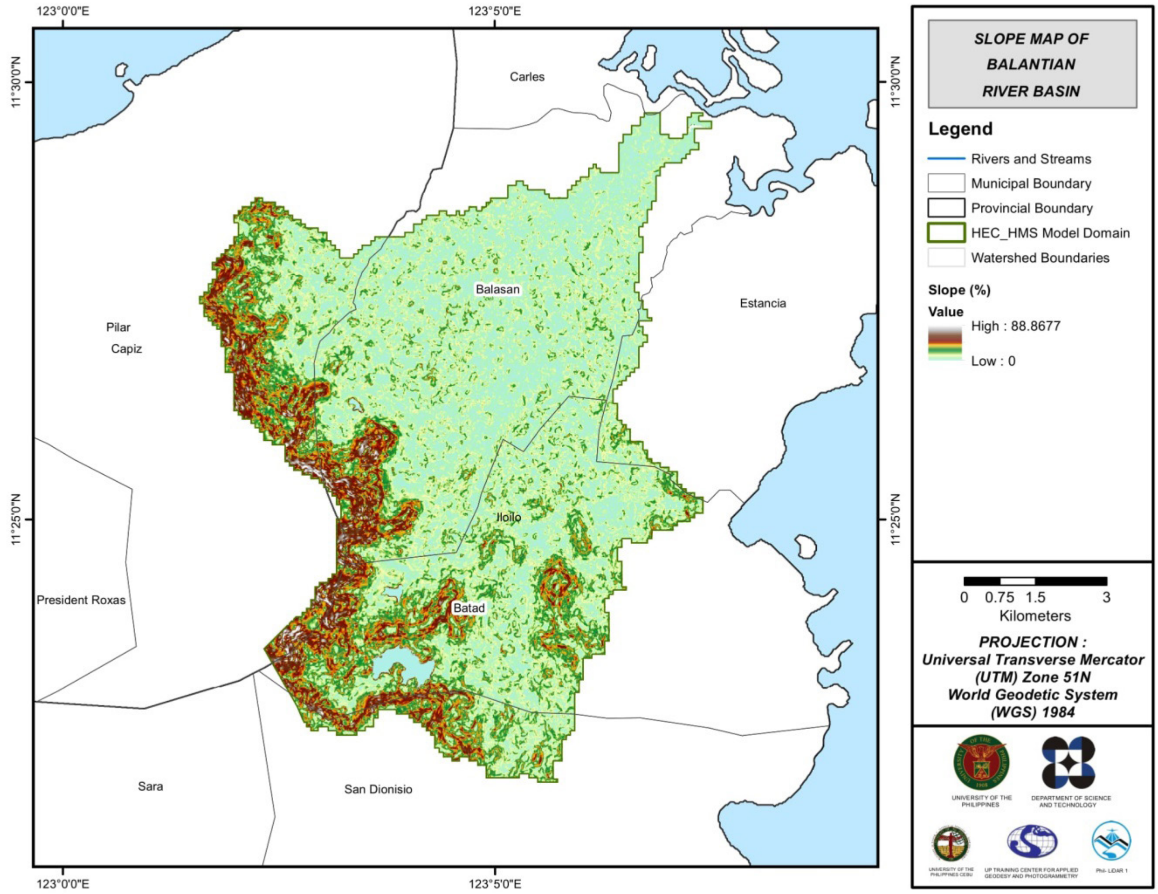


Figure 56. Slope map of the Balantian River Basin

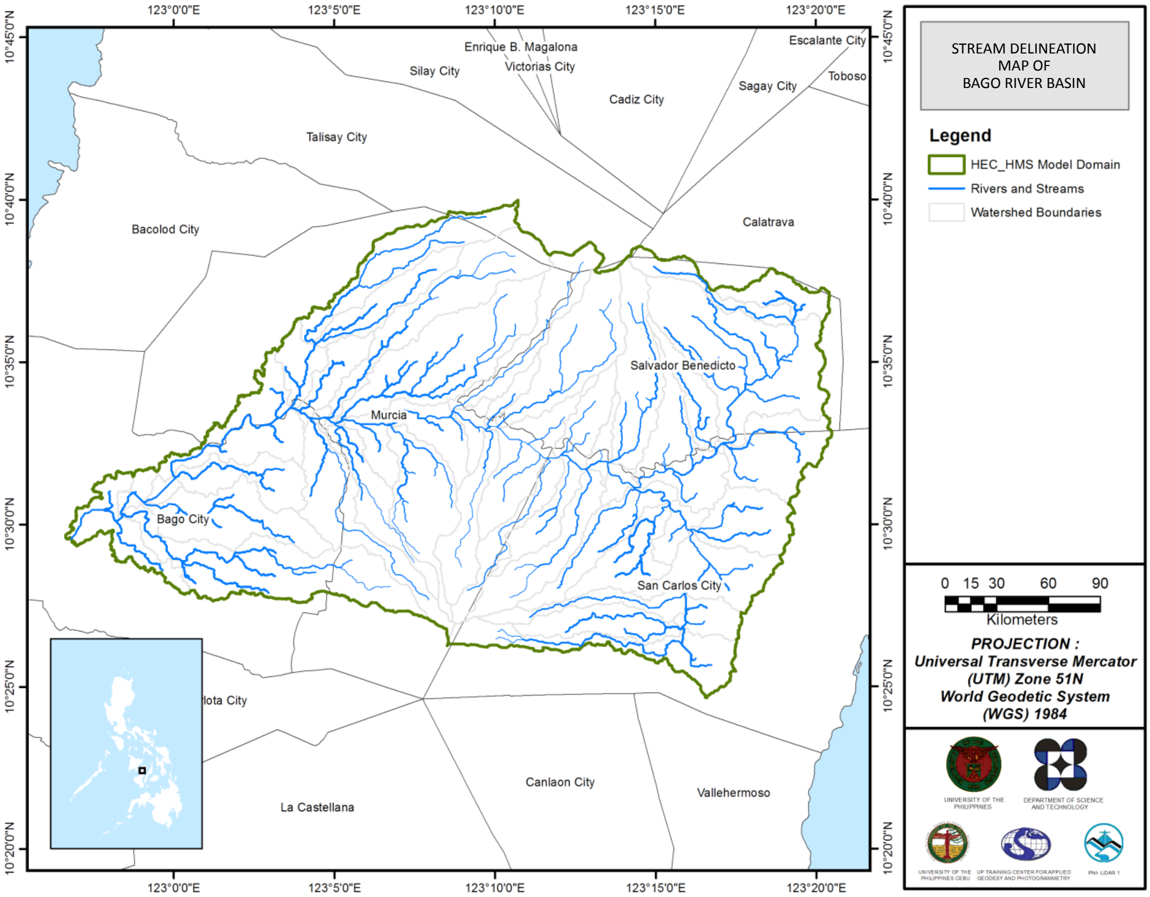


Figure 57. Stream delineation map of Balantian River Basin

Using the SAR-based DEM, the Balantian basin was delineated and further subdivided into sub-basins. The model consists of forty-seven (47) sub basins, twenty-three (23) reaches, and twenty-three (23) junctions, as illustrated in Figure 58. The main outlet is at the Balasan Bridge. See Annex 10 for the Balantian Model Reach Parameters

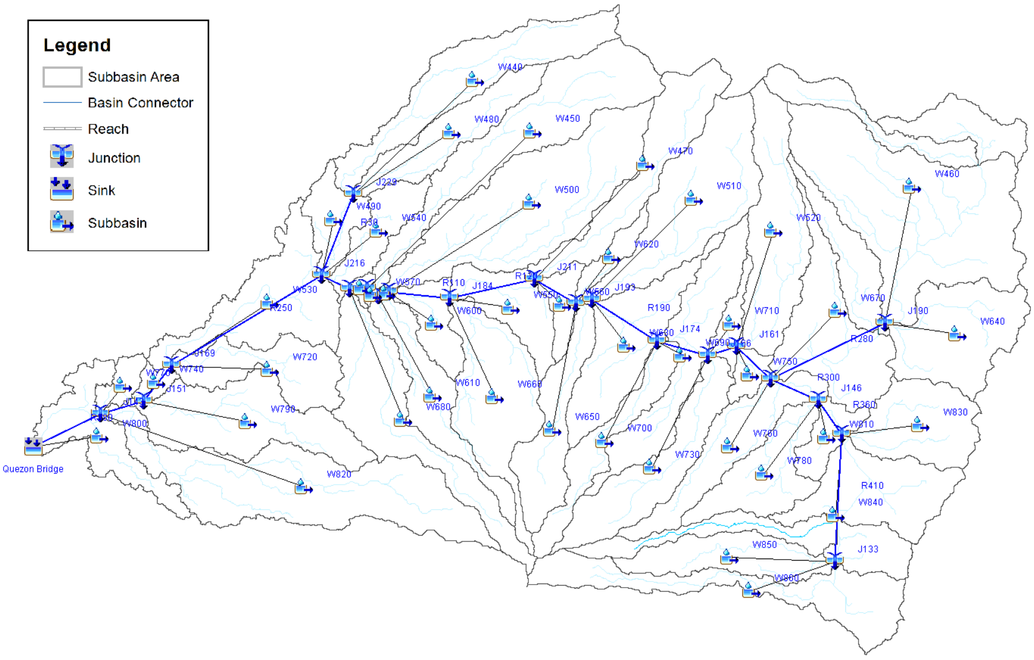


Figure 58. The Balantian River Basin model, generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool, and was post-processed in ArcGIS (Figure 59).

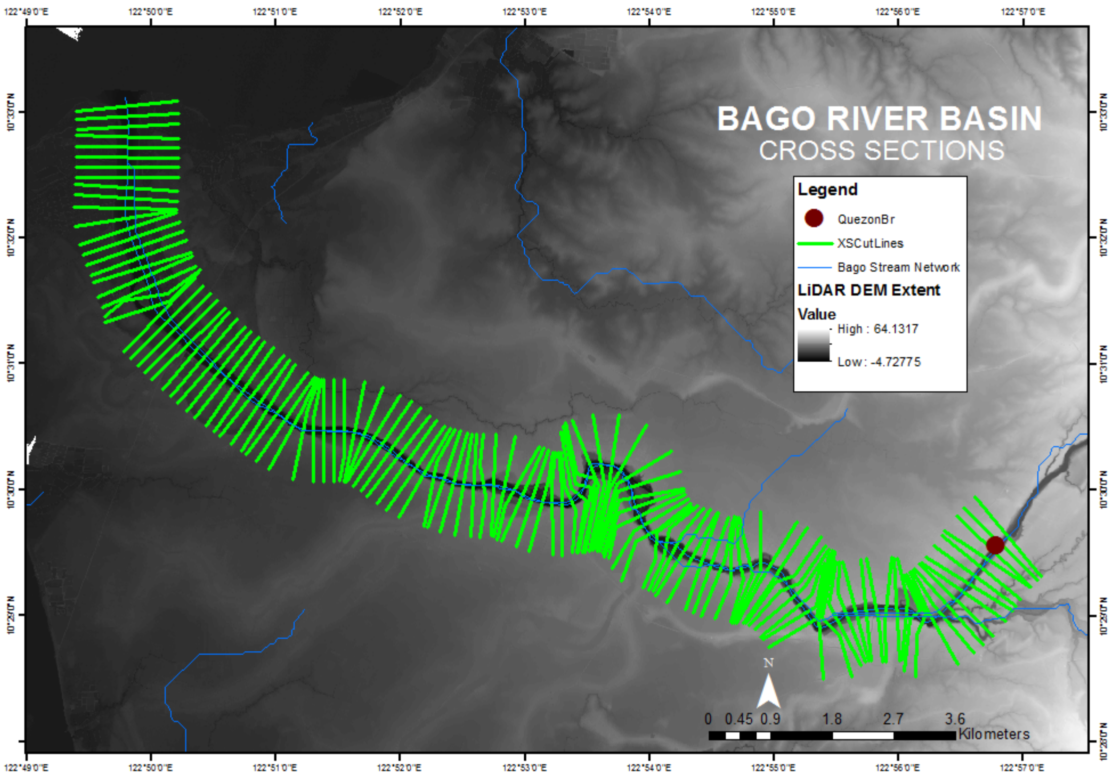


Figure 59. River cross-section of the Balantian River, generated through ArcMap HEC GeoRAS tool

5.5 Flo 2D Model

The automated modeling process allowed 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 was divided into square grid elements, 10 meters by 10 meters in size. Each element was assigned a unique grid element number, which served as its identifier. The elements were then attributed with the parameters required for modeling, such as x- and y-coordinates of centroid, names of adjacent grid elements, Manning's coefficient of roughness, infiltration, and elevation values. The elements were arranged spatially to form the model, allowing the software to simulate the flow of water across the grid elements in eight (8) directions (i.e., north, south, east, west, northeast, northwest, southeast, and southwest).

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

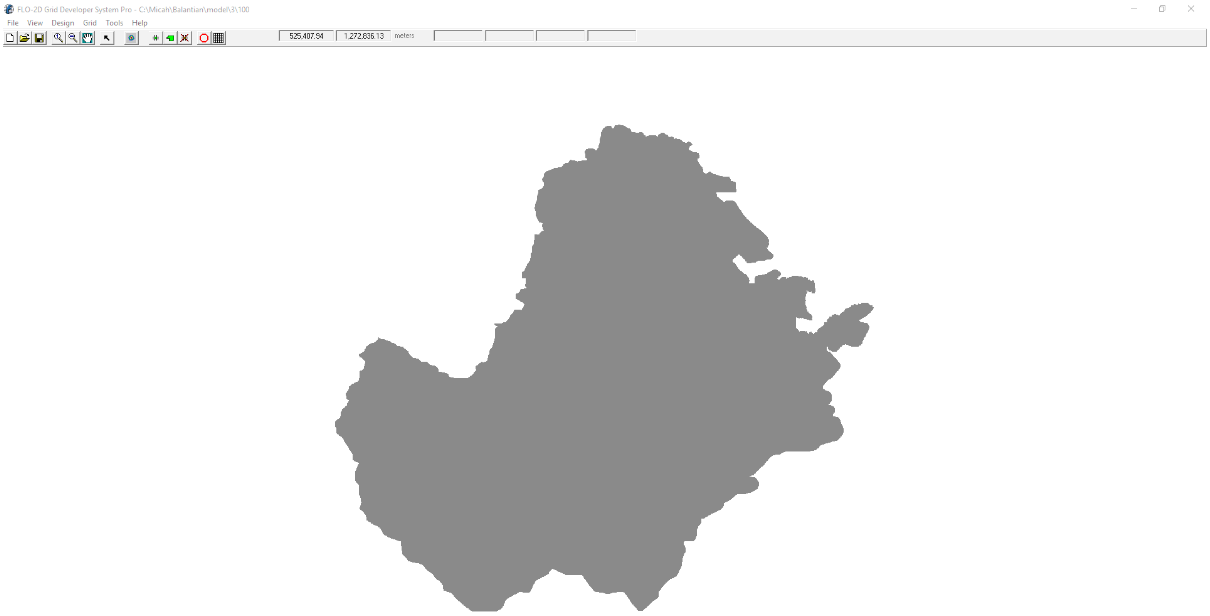


Figure 60. Screenshot of a sub-catchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

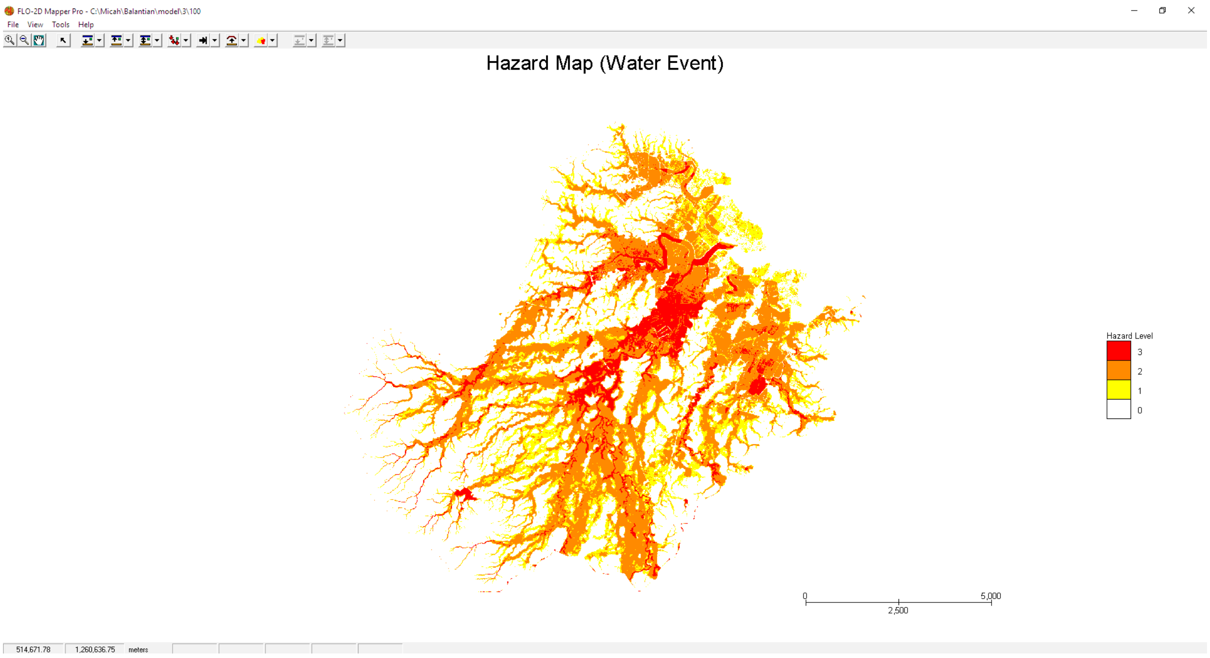


Figure 61. Generated 100-year rain return hazard map from FLO-2D Mapper

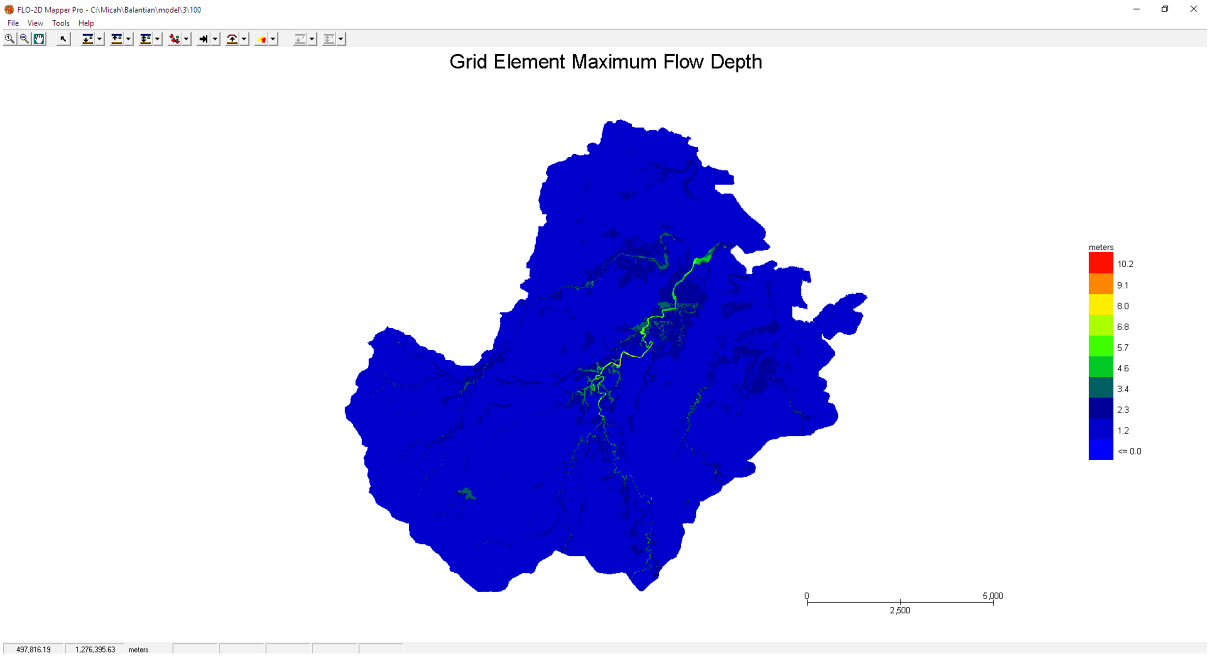


Figure 62. Generated 100-year rain return flow depth map from FLO-2D Mapper

Insert last 3 paragraphs for the Flo 2D report here.

5.6 Results of HMS Calibration

After calibrating the Balantian HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 63 depicts the comparison between the two discharge data. The Balantian Model Basin Parameters are available in Annex 9.

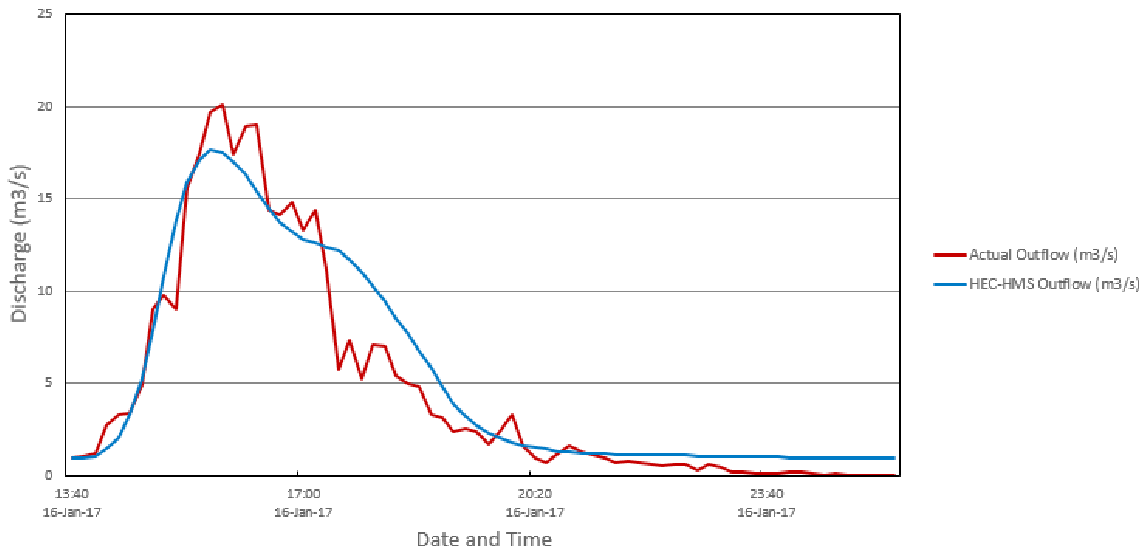


Figure 63. Outflow Hydrograph of Balantian produced by the HEC-HMS model, compared with observed outflow

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

Table 28. Range of calibrated values for Balantian

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	5-20
			Curve Number	65-90
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	4-12
			Storage Coefficient (hr)	2-7
	Baseflow	Recession	Recession Constant	0.9
			Ratio to Peak	0.2
Reach	Routing	Muskingum-Cunge	Slope	0.001-0.006
			Manning's Coefficient	0.0001

The Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. A range of values of 5 - 20 millimeters signifies a minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range of 65 to 90 for the curve number is advisable for Philippine watersheds, depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Balantian, the basin mostly consists of closed and open forests, shrub lands, forest plantations, and cultivated areas; and the soil consists of clay, sandy loam, loam, clay loam, and undifferentiated soils

The time of concentration and storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. The range of calibrated values from 4 hours to 12 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; and ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 0.9 indicates that the basin is unlikely to quickly return to its original discharge, and will be higher instead. A ratio to peak of 0.2 implies a slightly steeper receding limb of the outflow hydrograph.

A Manning's roughness coefficient of 0.0001 for the Balantian river basin is lower than the usual Manning's n value in the Philippines (Brunner, 2010).

Table 29. Efficiency Test of the Balantian HMS Model

RMS Error	1.8
r^2	0.9595
NSE	0.91
RSR	0.30
PBIAS	-11.00

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 1.8 m^3/s.

The Pearson correlation coefficient (r^2) assesses the strength of the linear relationship between the observations and the model. A coefficient value close to 1 represents an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it was measured as 0.9595.

The Nash-Sutcliffe (E) method was also used to assess the predictive power of the model. Here, the optimal value is 1. The model attained an efficiency coefficient of 0.91.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is -11.

The Observation Standard Deviation Ratio (RSR) is an error index. A perfect model attains a value of 0 when the error units of the values are quantified. The model attained an RSR value of 0.30.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 64) illustrates the Balantian outflow using the Roxas RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods – from 186.2 cubic meters in a 5-year return period, to 344.6 cubic meters for a 100-year return period.

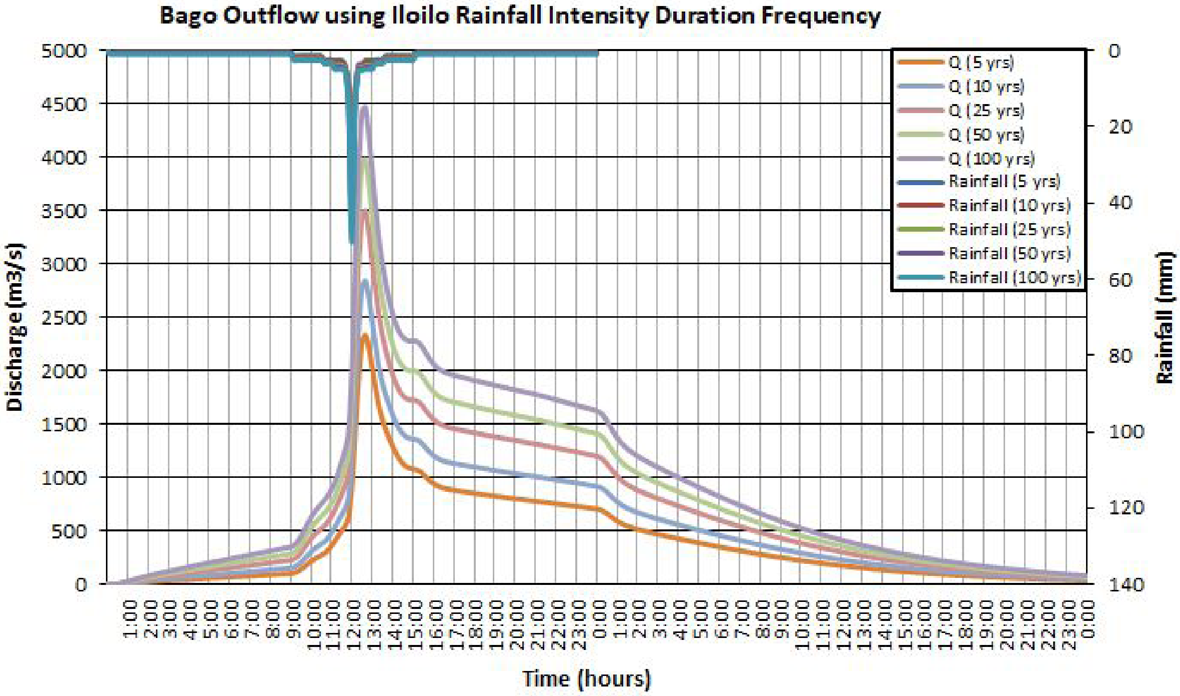


Figure 64. Outflow hydrograph at the Balantian Station generated using the Iloilo RIDF, simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Balantian discharge using the Roxas RIDF curves in five (5) different return periods is outlined in Table 30.

Table 30. Peak values of the Balantian HEC-HMS Model outflow, using the Roxas RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	186.2	26.6	28.89	50 minutes
10-Year	224.6	31.3	32.12	50 minutes
25-Year	273	37.4	36.19	50 minutes
50-Year	308.9	41.8	39.22	50 minutes
100-Year	344.6	46.2	42.2	50 minutes

5.7.2 Discharge data using Dr. Horritt's recommended hydrologic method

The river discharges entering the floodplain are shown in Figure 65 to Figure 67; and the peak values are summarized in Tables 31, 33, 35.

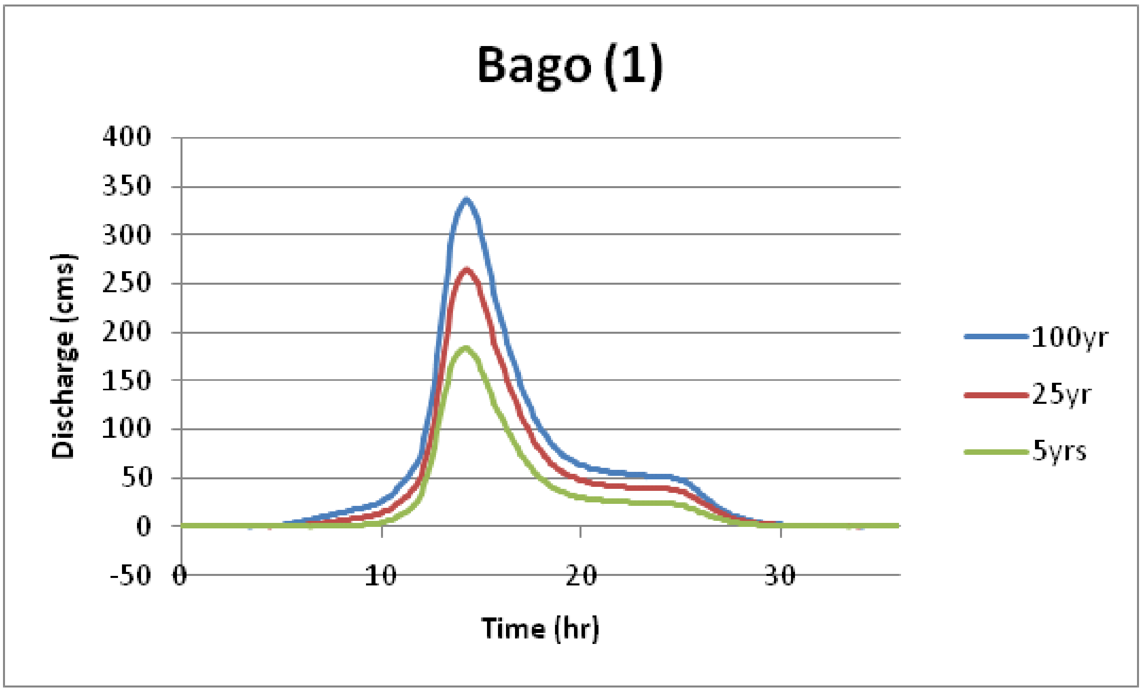


Figure 65. Balantian River (1) generated discharge using 5-, 25-, and 100-year Roxas City RIDF in HEC-HMS

Table 31. Summary of Balantian River (1) discharge, generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	184.2	14 hours, 20 minutes
25-Year	264.2	14 hours, 20 minutes
5-Year	335.5	14 hours, 10 minutes

Table 32. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Dis-charge	Specific Dis-charge
Bago (1)	162.096	128345.504	114.380	Fail	Pass

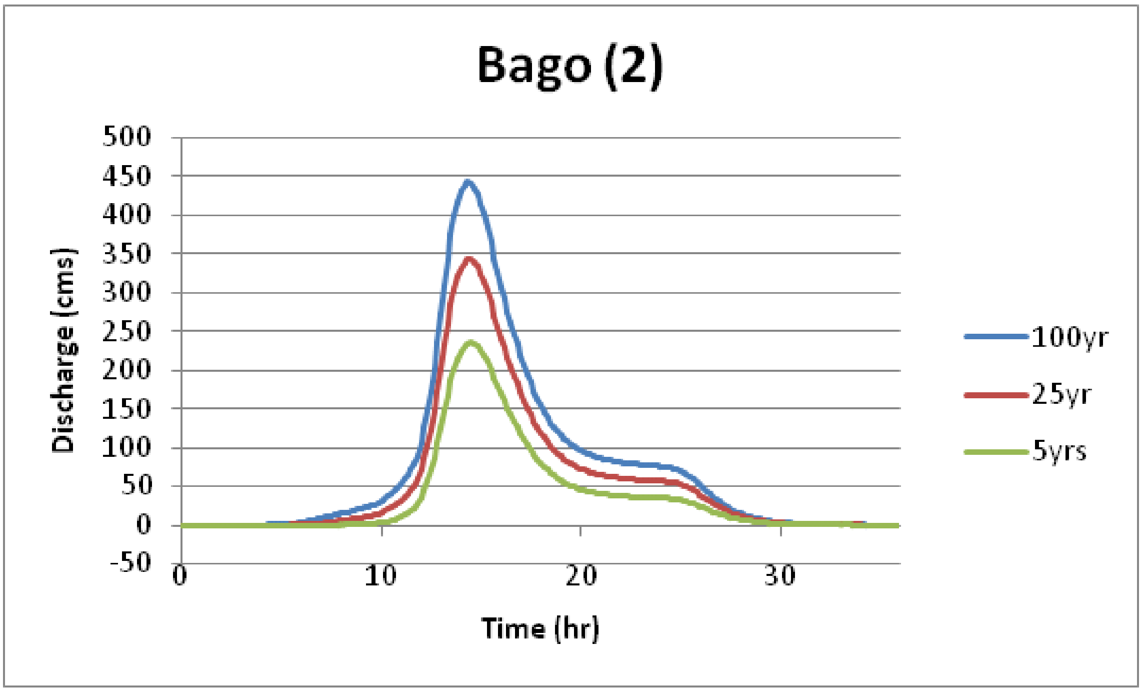


Figure 66. Balantian River (2) generated discharge using 5-, 25-, and 100-year Roxas City RIDF in HEC-HMS

Table 33. Summary of Balantian River (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	442.1	14 hours, 20 minutes
25-Year	343	14 hours, 20 minutes
5-Year	234.7	14 hours, 30 minutes

Table 34. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Dis-charge	Specific Dis-charge
Bago (2)	206.536	366838.592	147.979	Fail	Pass

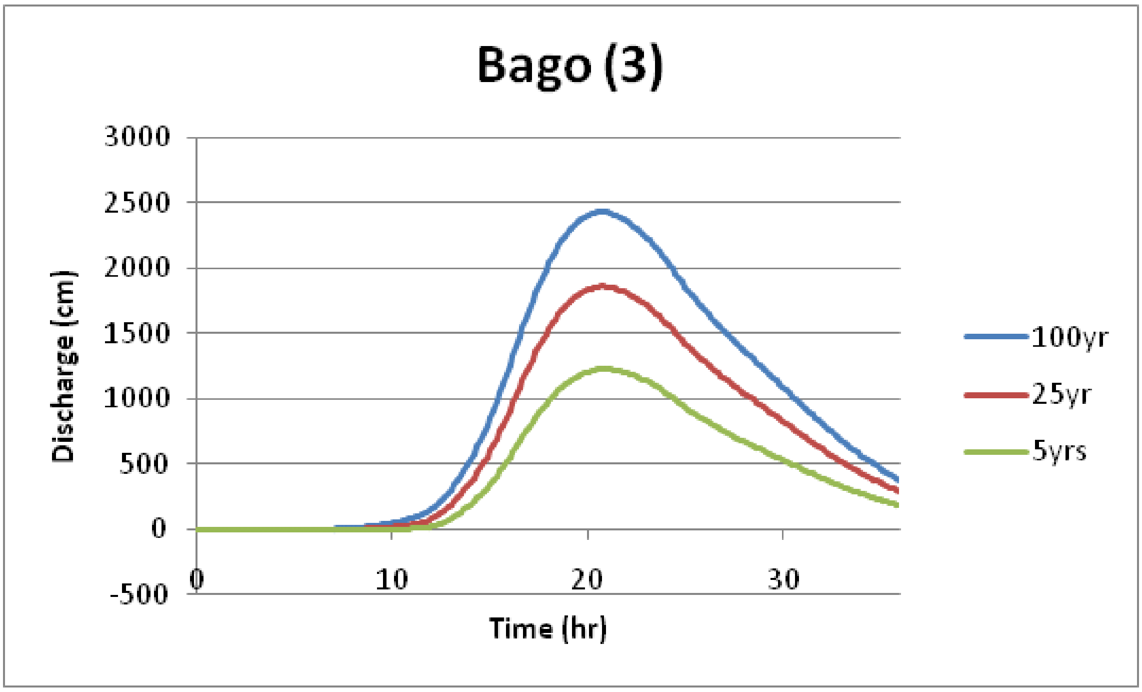


Figure 67. Balantian River (3) generated discharge using 5-, 25-, and 100-year Roxas City RIDF in HEC-HMS

Table 35. Summary of Balantian River (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	2431.5	19 hours, 40 minutes
25-Year	1861	20 hours, 50 minutes
5-Year	1228.4	20 hours, 50 minutes

Table 36. Validation of river discharge estimates

Discharge Point	$Q_{MED(SCS)}$, cms	$Q_{BANKFUL}$, cms	$Q_{MED(SPEC)}$, cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Bago (3)	1080.992	181004.323	681.025	Fail	Fail

Two (2) of the three (3) of the results from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the specific discharge methods, and failed in the bankful discharge method. One (1) result did not pass both, and will thus need further recalculation. The passing values are based on theory but are supported by other discharge computation methods; hence, they were appropriate for flood modeling. These values will need further investigation for the purpose of validation. It is therefore recommended to obtain actual values of the river discharges for higher-accuracy modeling.

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining the real-time flood inundation extent of the river, after it has been automated and uploaded on the DREAM website. The sample generated map of the Balantian River using the calibrated HMS event flow is presented in Figure 68.

Figure 68. Sample output map of the Balantian RAS Model

5.9 Flow Depth and Flood Hazard

The resulting flood hazard and flow depth maps have a 10-meter resolution. Figure 69 to Figure 74 exhibit the 5-year, 25-year, and 100-year rain return scenarios of the Balantian floodplain. The floodplain, with an area of 161.286 square kilometers, covers six (6) municipalities; namely, Balasan, Batad, Estancia, Pilar, San Dionisio, and Sara.

Table 37. Municipalities affected in the Balantian floodplain

Municipality	Total Area	Area Flooded	% Flooded
Balasan	56.356	50.84	90.21
Batad	44.94	43.20	96.13
Estancia	28.74	27.19	94.61
Pilar	117.9	16.19	13.73
San Dionisio	118.47	7.06	5.96
Sara	184.63	0.017	0.009

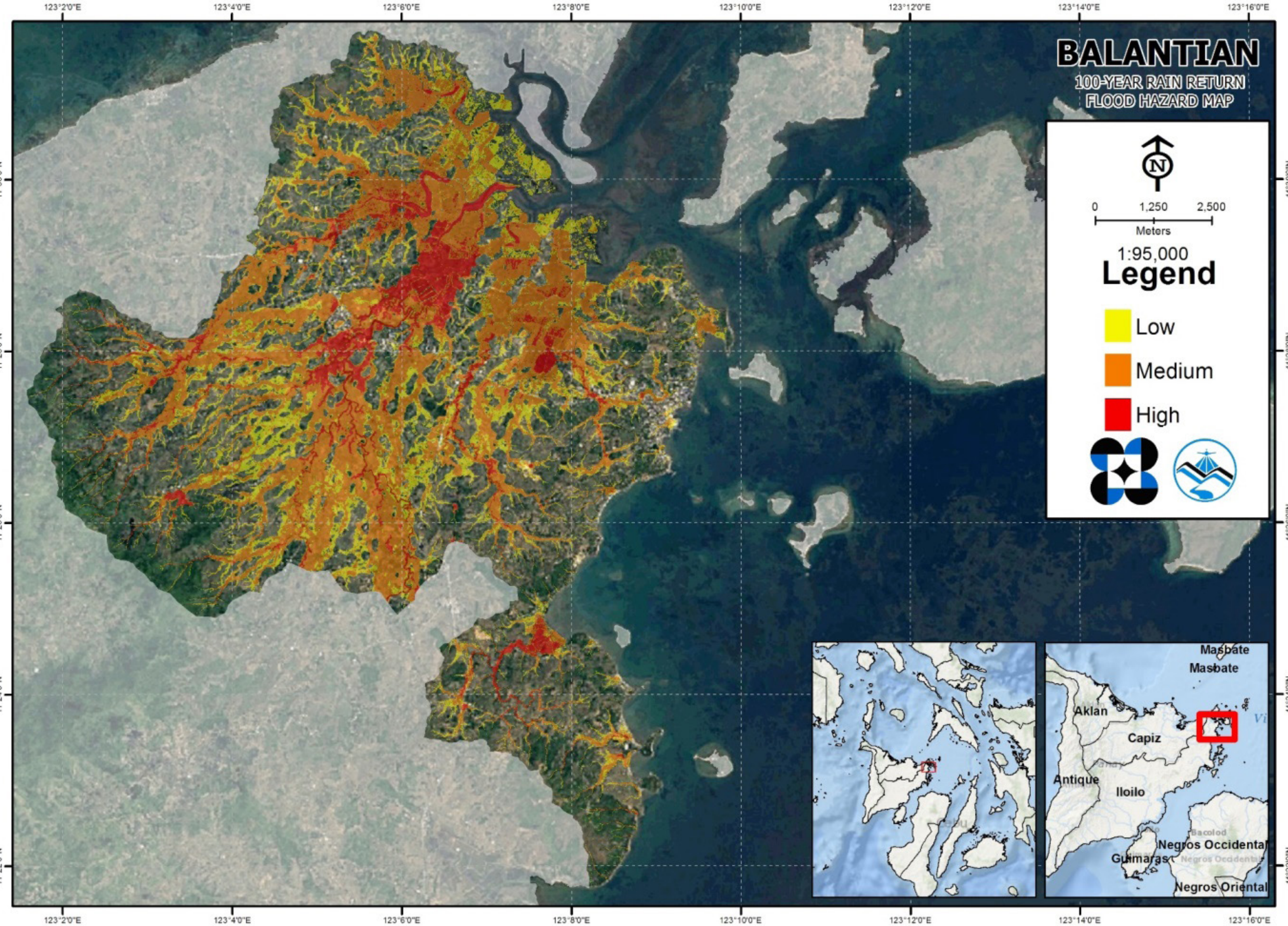


Figure 69. 100-year flood hazard map for the Balantian floodplain, overlaid on Google Earth imagery

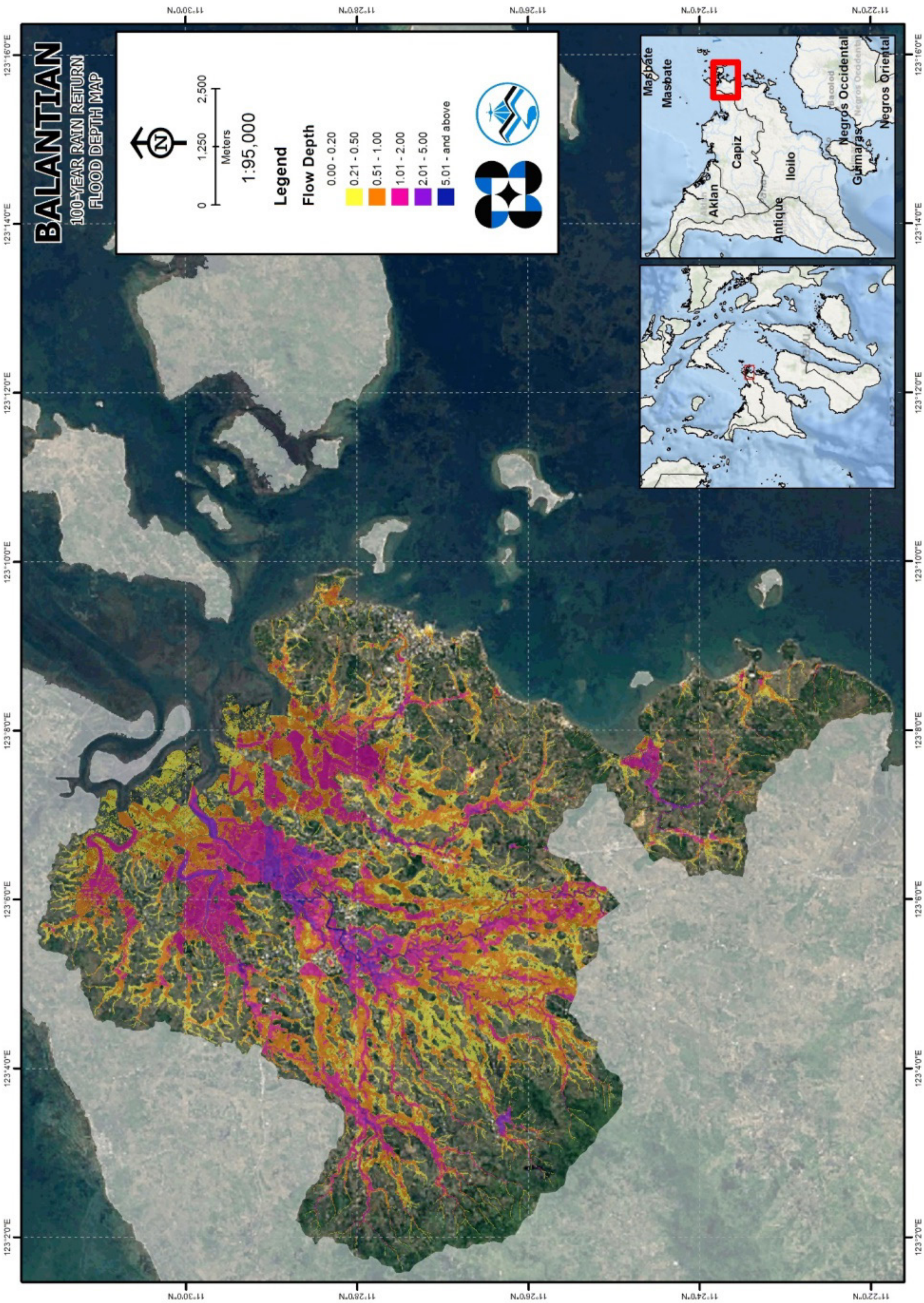


Figure 70. 100-year flow depth map for the Balantian floodplain, overlaid on Google Earth imagery

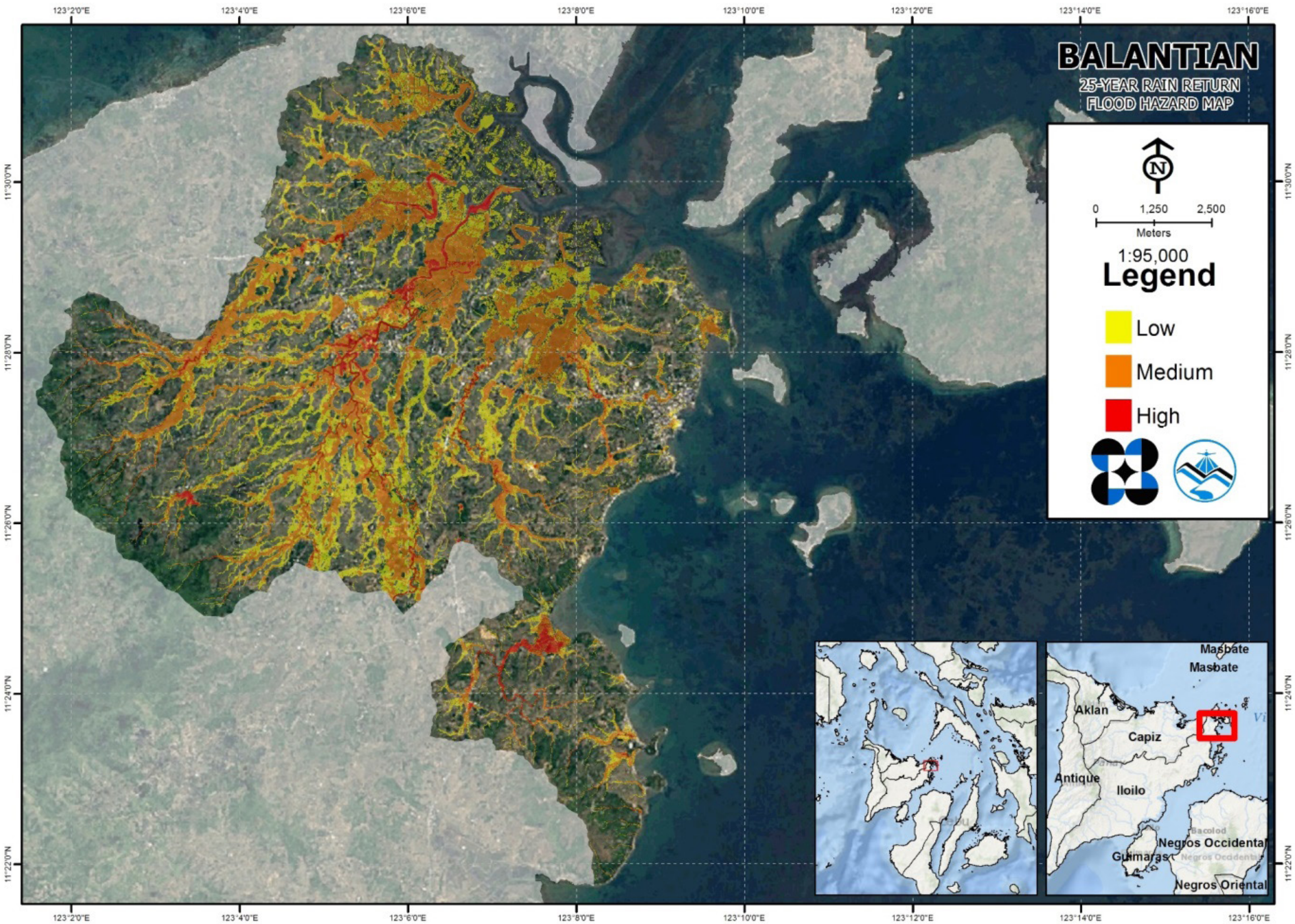


Figure 71. 25-year flood hazard map for the Balantian floodplain, overlaid on Google Earth imagery

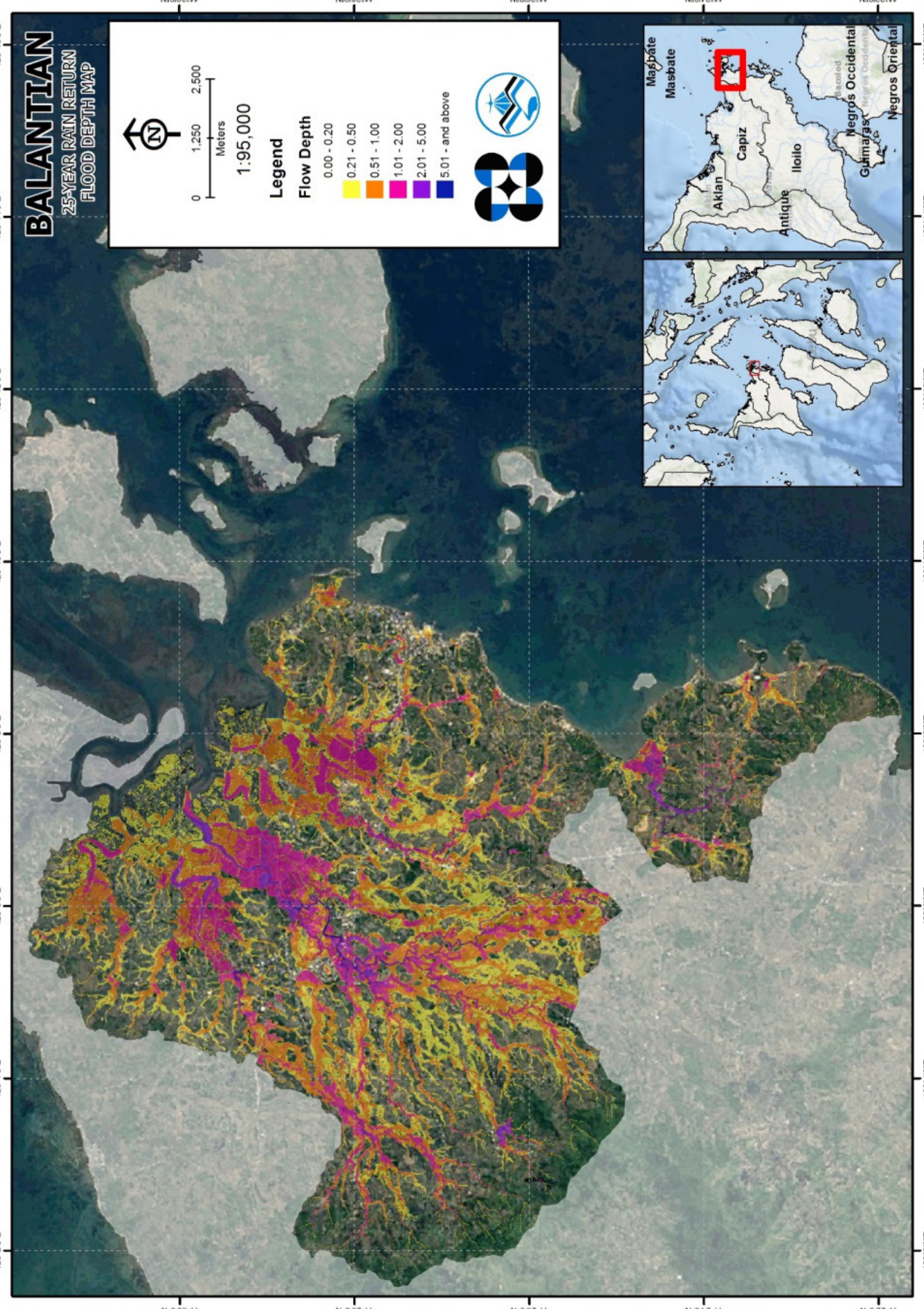


Figure 72. 25-year flow depth map for the Balantian floodplain, overlaid on Google Earth imagery

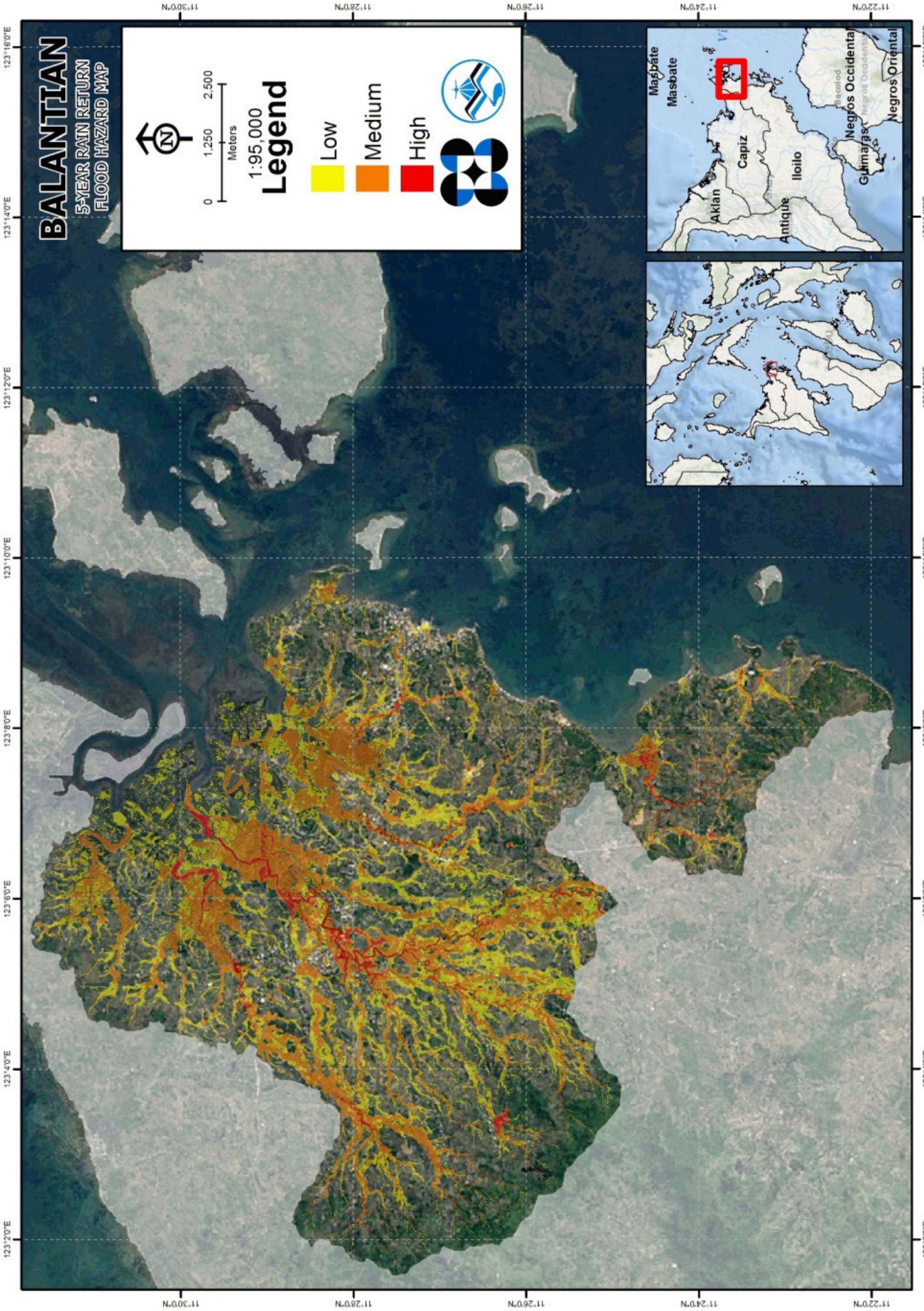


Figure 73. 5-year flood hazard map for the Balantian floodplain, overlaid on Google Earth imagery

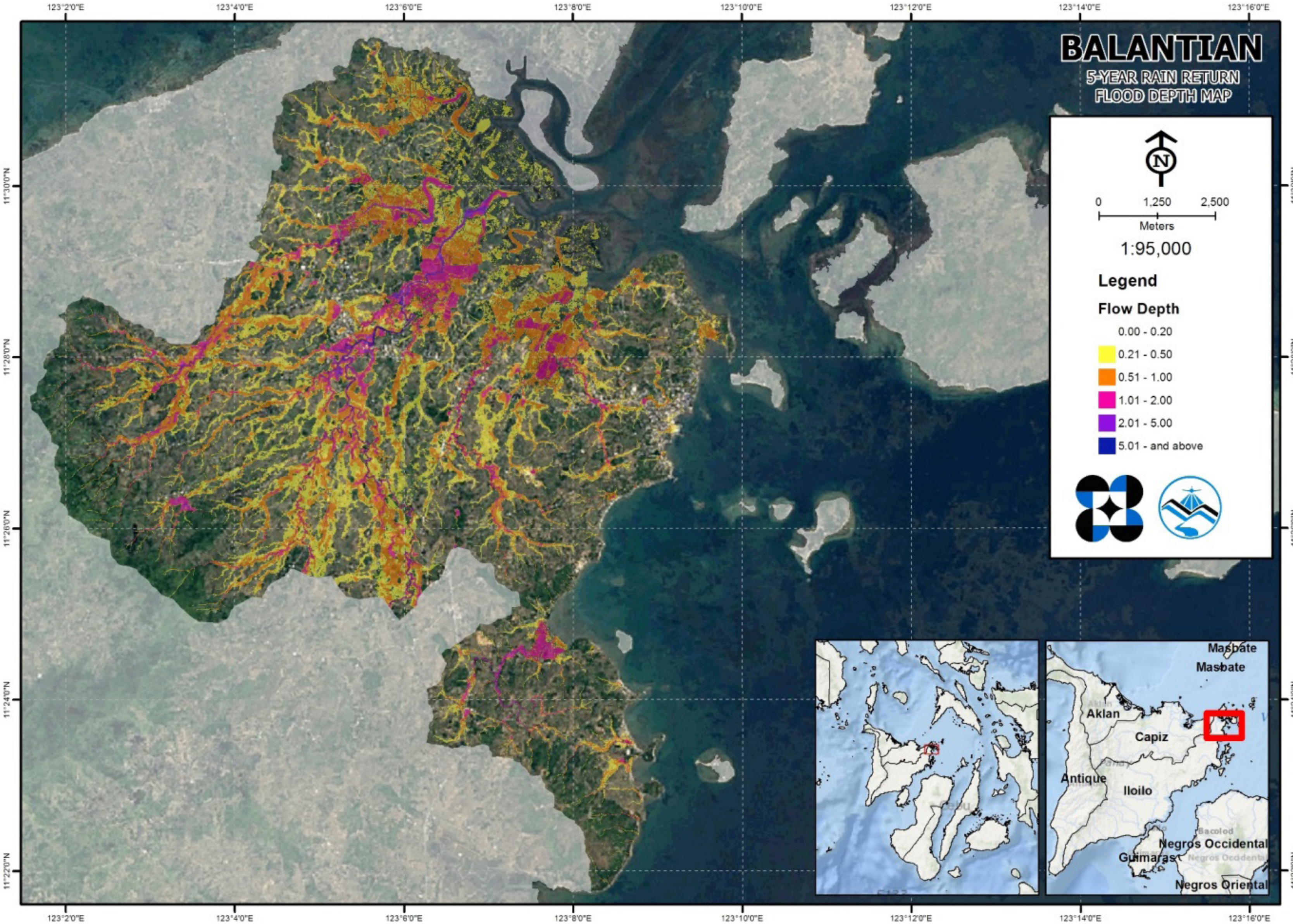


Figure 74. 5-year flow depth map for the Balantian floodplain, overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding of Affected Areas

The affected barangays in the Balantian River Basin, grouped by municipality, are listed below. For the said basin, six (6) municipalities consisting of eighty-five (85) barangays are expected to experience flooding when subjected to 5-year, 25-year, and 100-year rainfall return periods.

For the 5-year return period, 53.03% of the Municipality of Balasan, with an area of 56.36 square kilometers, will experience flood levels of less than 0.20 meters. 17.33% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 13.73%, 5.06%, 0.99%, and 0.073% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas, in square kilometers, by flood depth per barangay.

Table 38. Affected areas in Balasan, Iloilo during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balasan (in sq. km.)											
	Aranjuez	Bacolod	Balan-ti-An	Batuan	Cabalic	Camambugan	Dolores	Gimamanay	Ipil	Kinalkalan	Lawis	Malapoc
0.03-0.20	2.37	0.85	1.34	1.57	2.89	0.93	0.31	2.07	1.08	0.98	3.58	0.66
0.21-0.50	0.75	0.27	0.27	0.2	0.56	0.48	0.21	0.53	0.4	0.3	1.34	0.28
0.51-1.00	0.5	0.064	0.35	0.12	0.28	0.47	0.23	0.38	0.3	0.34	0.96	0.086
1.01-2.00	0.064	0.001	0.12	0.11	0.045	0.081	0.094	0.094	0.024	0.081	0.19	0.022
2.01-5.00	0.00085	0.000054	0.022	0.011	0.0061	0.0002	0.035	0.005	0	0.0044	0.00046	0.0018
> 5.00	0	0	0	0	0	0	0.0018	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balasan (in sq. km.)										
	Mamhut Norte	Mamhut Sur	Maya	Pani-An	Poblacion Norte	Poblacion Sur	Quiasan	Salong	Salvacion	Tin-gui-An	Zaragosa
0.03-0.20	1.2	0.23	0.9	0.95	0.21	0.48	1.02	1.82	1.68	1.48	1.3
0.21-0.50	0.7	0.17	0.13	0.21	0.034	0.24	0.99	0.23	0.27	0.96	0.24
0.51-1.00	0.97	0.11	0.2	0.18	0.032	0.36	0.77	0.19	0.17	0.52	0.16
1.01-2.00	0.83	0.099	0.19	0.08	0.0022	0.32	0.19	0.056	0.021	0.1	0.042
2.01-5.00	0.18	0.0015	0.048	0.02	0	0.15	0.024	0.0017	0.00014	0.051	0.0002
> 5.00	0.0012	0	0.00054	0	0	0.037	0	0	0	0.0001	0

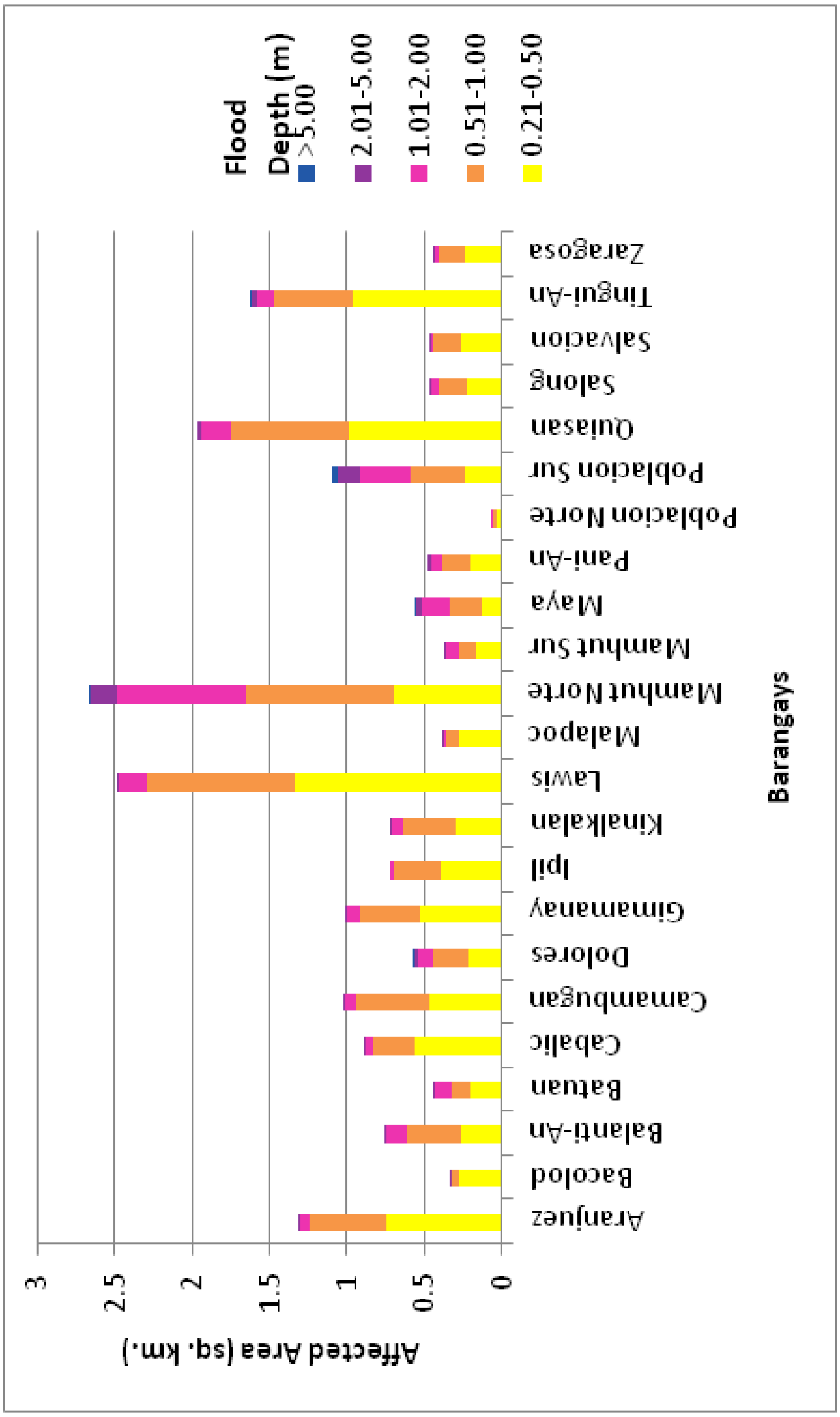


Figure 75. Affected areas in Balasan, Iloilo during a 5-year rainfall return period

For the Municipality of Batad, with an area of 44.94 square kilometers, 74.60% will experience flood levels of less than 0.20 meters. 10.21% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 6.87%, 3.53%, and 0.93% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 39 are the affected areas, in square kilometers, by flood depth per barangay.

Table 39. Affected areas in Batad, Iloilo during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Batad (in sq. km.)											
	Alapasco	Alinsolong	Banban	Batad Viejo	Bi-non-An	Bolhog	Bulak Norte	Bulak Sur	Cabagohan	Calangag	Caw-I	Drancalan
0.03-0.20	3.21	1.25	1.57	0.82	1.31	1.05	1.8	2.1	1.73	2.47	0.64	0.58
0.21-0.50	0.15	0.05	0.057	0.15	0.13	0.14	0.29	0.44	0.15	0.31	0.016	0.17
0.51-1.00	0.15	0.033	0.028	0.14	0.073	0.052	0.15	0.22	0.073	0.31	0.0077	0.091
1.01-2.00	0.39	0.023	0.033	0.037	0.018	0.0013	0.017	0.14	0.034	0.058	0.00093	0.019
2.01-5.00	0.042	0.0082	0.017	0.0075	0.0014	0	0.0082	0.01	0.0029	0.059	0.0001	0.013
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Batad (in sq. km.)											
	Embarcadero	Hamod	Malico	Nangka	Pasayan	Poblacion	Quiazan Flo-rete	Quiazan Lopez	Salong	Santa Ana	Tanao	Ta-pi-An
0.03-0.20	0.76	1.28	0.43	3.65	1.76	1.37	0.42	1.17	0.87	0.39	1.68	1.21
0.21-0.50	0.12	0.099	0.51	0.24	0.25	0.2	0.29	0.29	0.083	0.27	0.14	0.055
0.51-1.00	0.071	0.068	0.44	0.21	0.17	0.14	0.066	0.14	0.068	0.24	0.088	0.039
1.01-2.00	0.15	0.086	0.064	0.11	0.11	0.015	0.007	0.033	0.1	0.087	0.023	0.015
2.01-5.00	0.005	0.033	0.024	0.063	0.081	0.000018	0	0.0073	0.0074	0.025	0.0005	0.0016
> 5.00	0	0	0	0	0	0	0	0	0	0	0	0

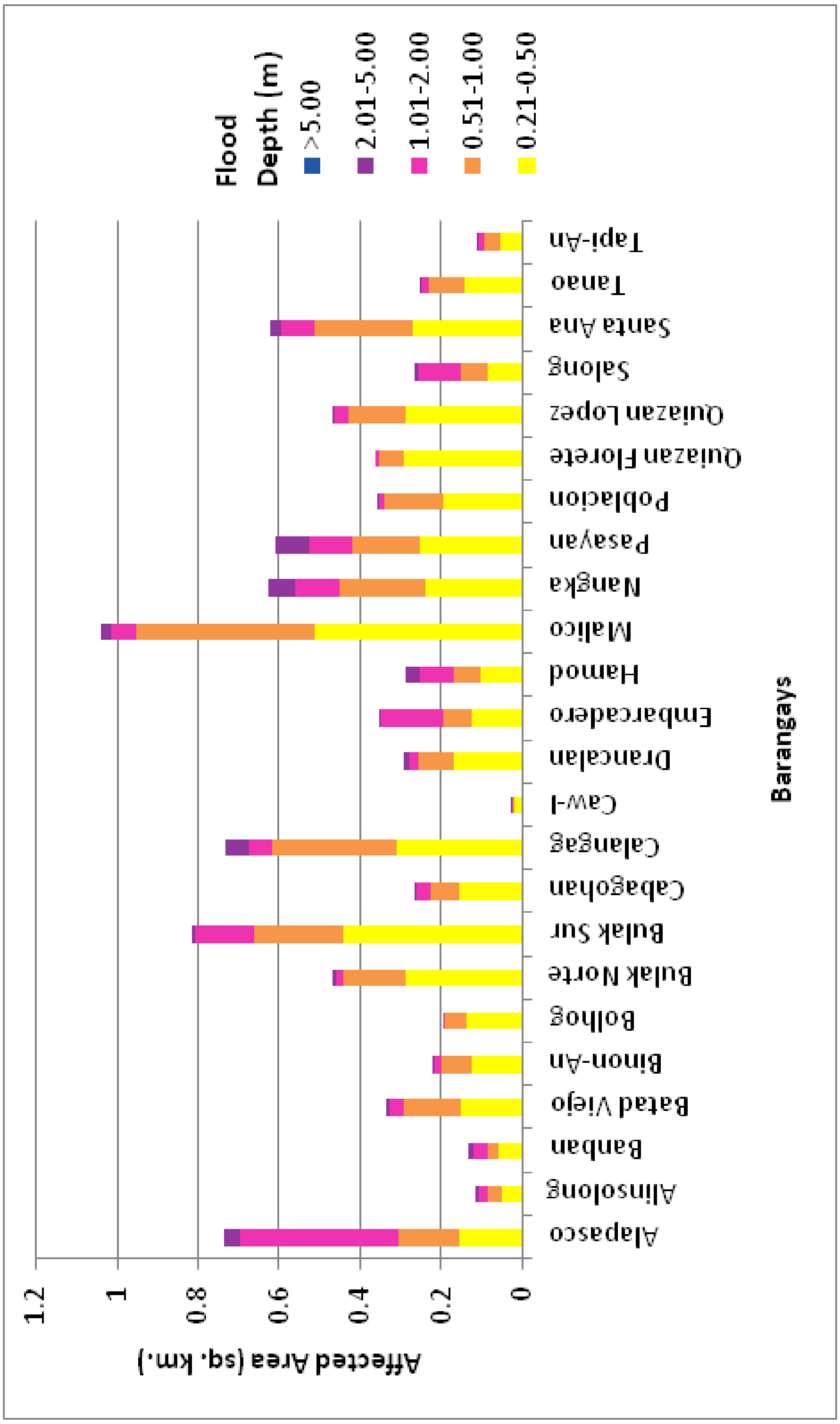


Figure 76. Affected areas in Batad, Iloilo during a 5-year rainfall return period

For the Municipality of Estancia, with an area of 28.74 square kilometers, 70.97% will experience flood levels of less than 0.20 meters. 11.93% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 8.62%, 2.98%, and 0.11% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 40 are the affected areas, in square kilometers, by flood depth per barangay.

Table 40. Affected areas in Estancia, Iloilo during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Estancia (in sq. km.)										
	Bayuyan	Botongan	Bu-laqueña	Calapdan	Cano-An	Daan Banua	Daculan	Gogo	Jolog	Lonoy	Lumbia
0.03-0.20	1.02	0.41	0.58	0.88	1.53	1.25	0.67	1.23	0.66	1.02	3.68
0.21-0.50	0.36	0.026	0.045	0.12	0.41	0.1	0.1	0.11	0.015	0.36	0.39
0.51-1.00	0.39	0.007	0.031	0.047	0.35	0.075	0.034	0.041	0.0023	0.086	0.35
1.01-2.00	0.1	0.0022	0.0036	0.0079	0.25	0.024	0.0017	0.0004	0.0009	0.015	0.096
2.01-5.00	0.008	0	0	0.0004	0.0016	0	0	0	0.0003	0.00072	0.005
> 5.00	0	0	0	0	0	0	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Estancia (in sq. km.)										
	Malbog	Pani-An	Pa-On	Poblacion Zone 1	Poblacion Zone II	Poblacion Zone III	San Roque	Santa Ana	Tabu-An	Tacbuyan	Tanza
0.03-0.20	0.29	0.91	0.48	0.58	0.18	0.071	0.86	1.67	0.54	0.99	0.89
0.21-0.50	0.15	0.23	0.037	0.11	0.027	0.002	0.19	0.18	0.33	0.076	0.059
0.51-1.00	0.1	0.4	0.0097	0.061	0.028	0.0003	0.12	0.025	0.24	0.042	0.041
1.01-2.00	0.05	0.2	0.001	0.012	0.0025	0	0.015	0.014	0.039	0.014	0.0098
2.01-5.00	0.0056	0.0067	0	0.00004	0	0	0	0.0023	0.0002	0	0.0001
> 5.00	0	0	0	0	0	0	0	0	0	0	0

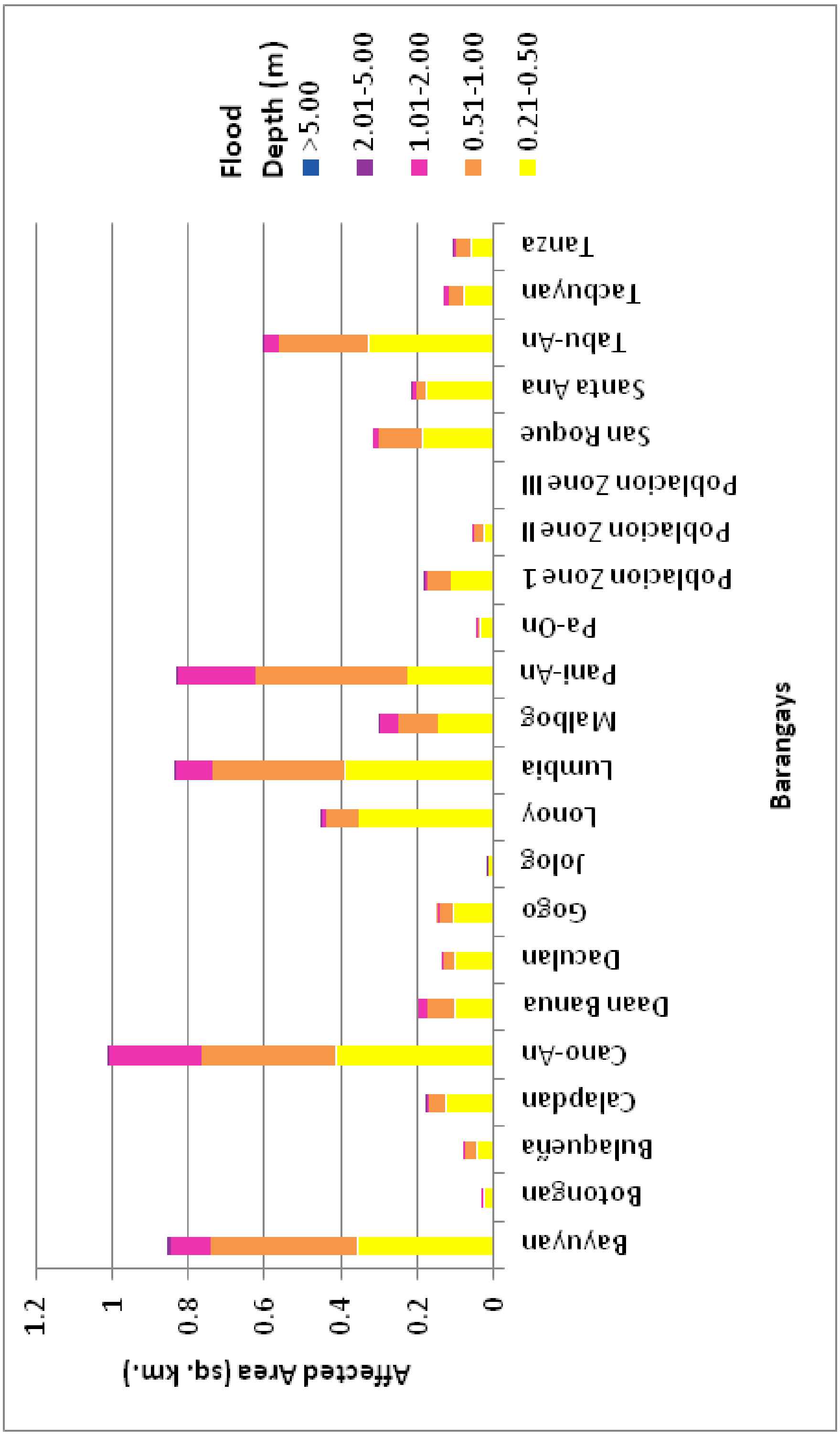


Figure 77. Affected areas in Estancia, Iloilo during a 5-year rainfall return period

For the Municipality of Pilar, with an area of 117.9 square kilometers, 11.59% will experience flood levels of less than 0.20 meters. 0.79% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.97%, 0.35%, and 0.028% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 41 are the affected areas, in square kilometers, by flood depth per barangay.

Table 41. Affected areas in Pilar, Capiz during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)									
	Balogo	Dayhagan	San Anto-nio	San Este-ban	San Nico-las	San Pedro	San Silves-tre	Sinamongan	Tabun-Acan	Yating
0.03-0.20	0.63	0.24	0.071	0.031	0.44	0.58	2.5	5.42	3.57	0.18
0.21-0.50	0.05	0.002	0.001	0.0001	0.12	0.079	0.085	0.52	0.076	0.0019
0.51-1.00	0.0085	0.0013	0.000009	0.00014	0.3	0.011	0.046	0.74	0.033	0
1.01-2.00	0	0.00097	0	0.000015	0.092	0.00024	0.018	0.28	0.021	0
2.01-5.00	0	0	0	0	0.0028	0	0.001	0.026	0.0034	0
> 5.00	0	0	0	0	0	0	0	0	0	0

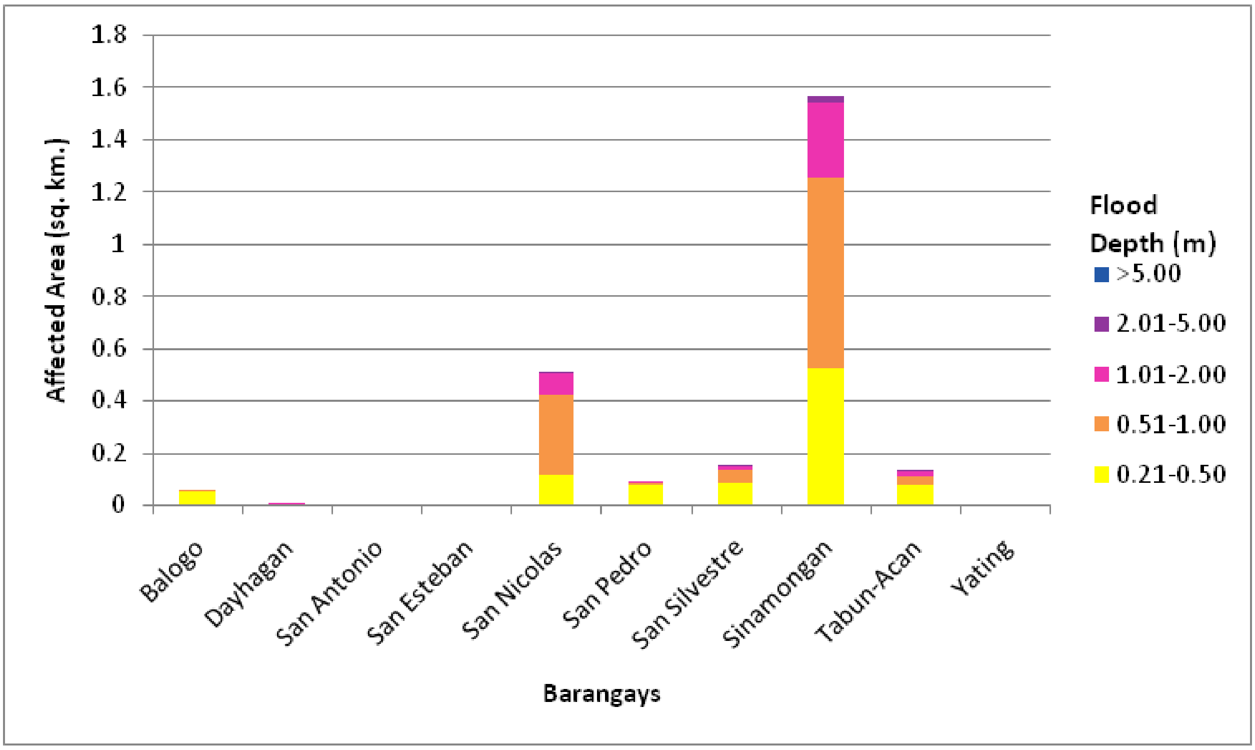


Figure 78. Affected areas in Pilar, Capiz during a 5-year rainfall return period

For the Municipality of San Dionisio, with an area of 118.47 square kilometers, 5.51% will experience flood levels of less than 0.20 meters. 0.19% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.16%, 0.083%, and 0.0046% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 42 are the affected areas, in square kilometers, by flood depth per barangay.

Table 42. Affected areas in San Dionisio, Iloilo during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Dionisio (in sq. km.)				
	Amayong	Batuan	Canas	Odiongan	Talo-Ato
0.03-0.20	2.89	0.14	0.99	1.26	1.26
0.21-0.50	0.13	0.0023	0.033	0.031	0.03
0.51-1.00	0.12	0.00011	0.037	0.016	0.016
1.01-2.00	0.057	0	0.03	0.0042	0.0076
2.01-5.00	0.0034	0	0.0012	0.0006	0.0003
> 5.00	0	0	0	0	0

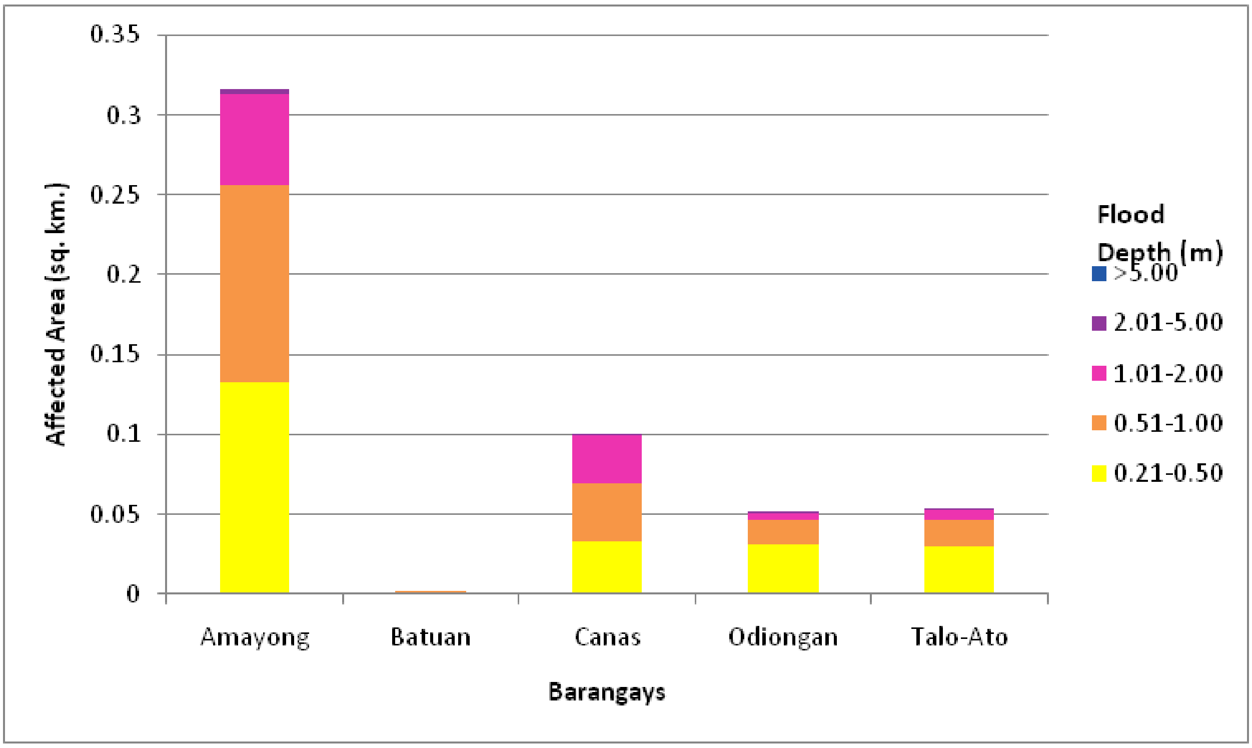


Figure 79. Affected areas in San Dionisio, Iloilo during a 5-year rainfall return period

For the Municipality of Sara, with an area of 184.63 square kilometers, 0.017% will experience flood levels of less 0.20 than meters. Listed in Table 43 are the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected areas in Sara, Iloilo during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sara (in sq. km.)
	Tady
0.03-0.20	0.017
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

Figure 80. Affected areas in Sara, Iloilo during a 5-year rainfall return period

For the 25-year return period, 39.29% of the Municipality of Balasan, with an area of 56.36 square kilometers, will experience flood levels of less than 0.20 meters. 12.97% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 19.67%, 14.63%, 3.48%, and 0.168% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 44 are the affected areas, in square kilometers, by flood depth per barangay.

Table 44. Affected areas in Balasan, Iloilo during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balasan (in sq. km.)											
	Aranjuez	Bacolod	Balan-ti-An	Batuan	Cabalic	Camambugan	Dolores	Gimamanay	Ipil	Kinalkalan	Lawis	Malapoc
0.03-0.20	1.47	0.6	1.18	1.38	2.44	0.66	0.16	1.85	0.62	0.87	2.12	0.36
0.21-0.50	0.74	0.37	0.2	0.22	0.63	0.31	0.059	0.36	0.26	0.13	1.05	0.35
0.51-1.00	1.05	0.21	0.23	0.21	0.53	0.68	0.25	0.63	0.52	0.46	1.53	0.25
1.01-2.00	0.41	0.012	0.45	0.11	0.16	0.3	0.33	0.23	0.39	0.22	1.23	0.079
2.01-5.00	0.0044	0.00021	0.05	0.088	0.015	0.0017	0.086	0.014	0.0081	0.021	0.13	0.0067
> 5.00	0	0	0	0	0	0	0.0035	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balasan (in sq. km.)										
	Mamhut Norte	Mamhut Sur	Maya	Pani-An	Poblacion Norte	Poblacion Sur	Quiasan	Salong	Salvacion	Tin-gui-An	Zaragosa
0.03-0.20	0.8	0.058	0.74	0.77	0.18	0.23	0.43	1.69	1.53	0.79	1.22
0.21-0.50	0.18	0.066	0.1	0.24	0.019	0.087	0.52	0.22	0.29	0.71	0.2
0.51-1.00	0.55	0.22	0.13	0.19	0.044	0.27	1.28	0.22	0.26	1.11	0.25
1.01-2.00	1.52	0.2	0.33	0.19	0.029	0.63	0.7	0.15	0.068	0.44	0.078
2.01-5.00	0.8	0.064	0.16	0.055	0	0.31	0.058	0.0068	0.00084	0.069	0.0034
> 5.00	0.028	0	0.0055	0	0	0.056	0	0	0	0.0019	0

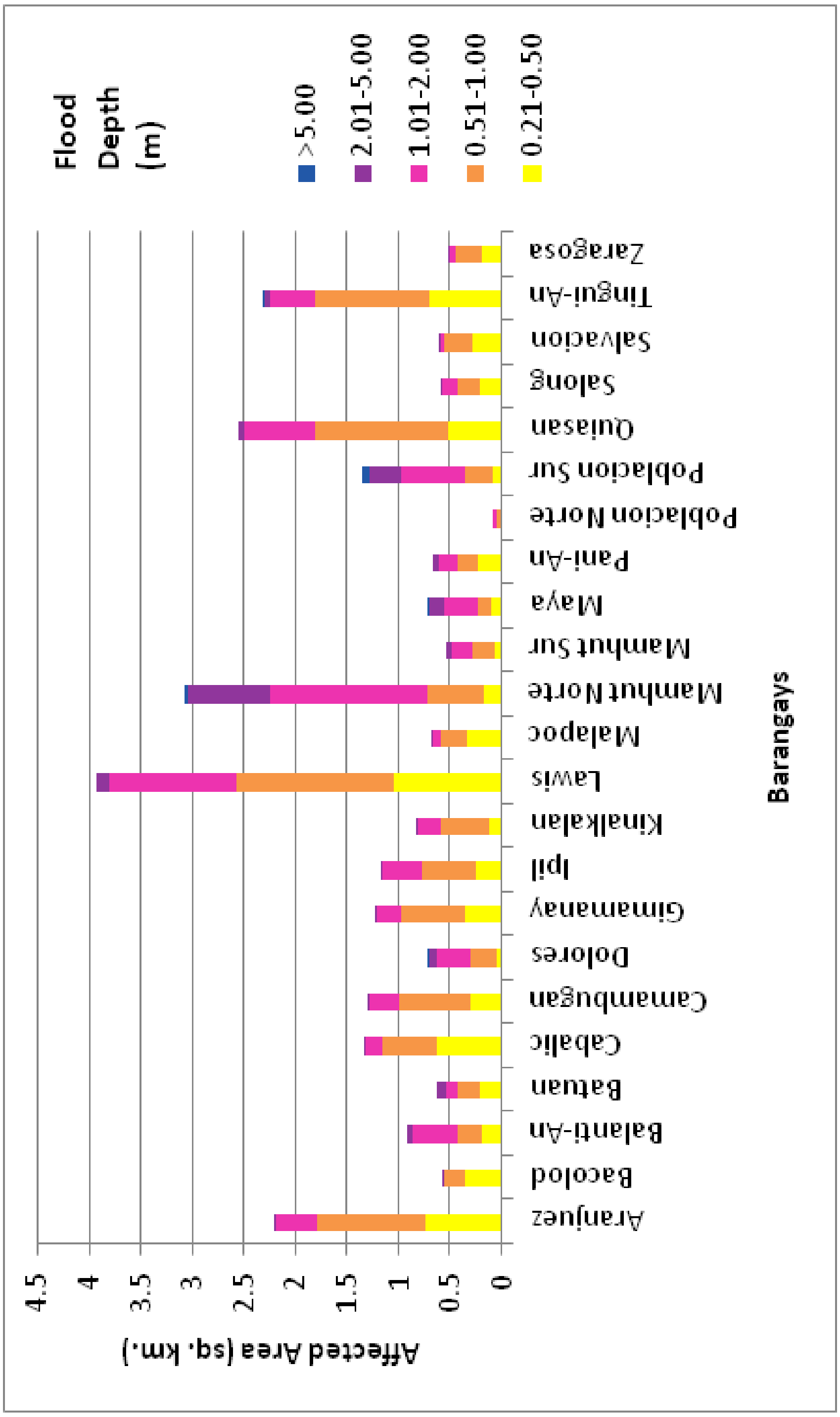


Figure 81. Affected areas in Balasan, Iloilo during a 25-year rainfall return period

For the Municipality of Batad, with an area of 44.94 square kilometers, 70.61% will experience flood levels of less than 0.20 meters. 8.63% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 9.79%, 4.82%, and 2.27% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 45 are the affected areas, in square kilometers, by flood depth per barangay.

Table 45. Affected areas in Batad, Iloilo during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Batad (in sq. km.)											
	Alapasco	Alinsolong	Banban	Batad Viejo	Bi-non-An	Bolhog	Bulak Norte	Bulak Sur	Cabagohan	Calangag	Caw-I	Drancalan
0.03-0.20	3.13	1.23	1.55	0.78	1.28	1.02	1.71	1.92	1.68	2.33	0.63	0.47
0.21-0.50	0.16	0.056	0.063	0.12	0.13	0.12	0.24	0.48	0.17	0.29	0.019	0.12
0.51-1.00	0.13	0.035	0.033	0.16	0.098	0.097	0.26	0.29	0.093	0.39	0.01	0.18
1.01-2.00	0.16	0.03	0.034	0.083	0.024	0.0065	0.054	0.14	0.045	0.13	0.0019	0.074
2.01-5.00	0.36	0.012	0.027	0.01	0.0021	0	0.0098	0.09	0.0068	0.067	0.0003	0.018
> 5.00	0	0.00052	0.00068	0	0	0	0	0	0	0.0001	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Batad (in sq. km.)											
	Embarcadero	Hamod	Malico	Nangka	Pasayan	Poblacion	Quiazan Flo-rete	Quiazan Lopez	Salong	Santa Ana	Tanao	Ta-pi-An
0.03-0.20	0.71	1.23	0.25	3.54	1.64	1.33	0.32	1.07	0.85	0.22	1.64	1.2
0.21-0.50	0.13	0.11	0.23	0.19	0.24	0.15	0.19	0.24	0.073	0.17	0.14	0.058
0.51-1.00	0.084	0.064	0.64	0.28	0.22	0.21	0.25	0.26	0.076	0.36	0.12	0.047
1.01-2.00	0.16	0.086	0.31	0.16	0.15	0.032	0.023	0.06	0.12	0.22	0.032	0.02
2.01-5.00	0.027	0.074	0.028	0.11	0.11	0.000018	0	0.012	0.017	0.033	0.0015	0.0035
> 5.00	0	0	0	0	0.0025	0	0	0	0	0	0	0

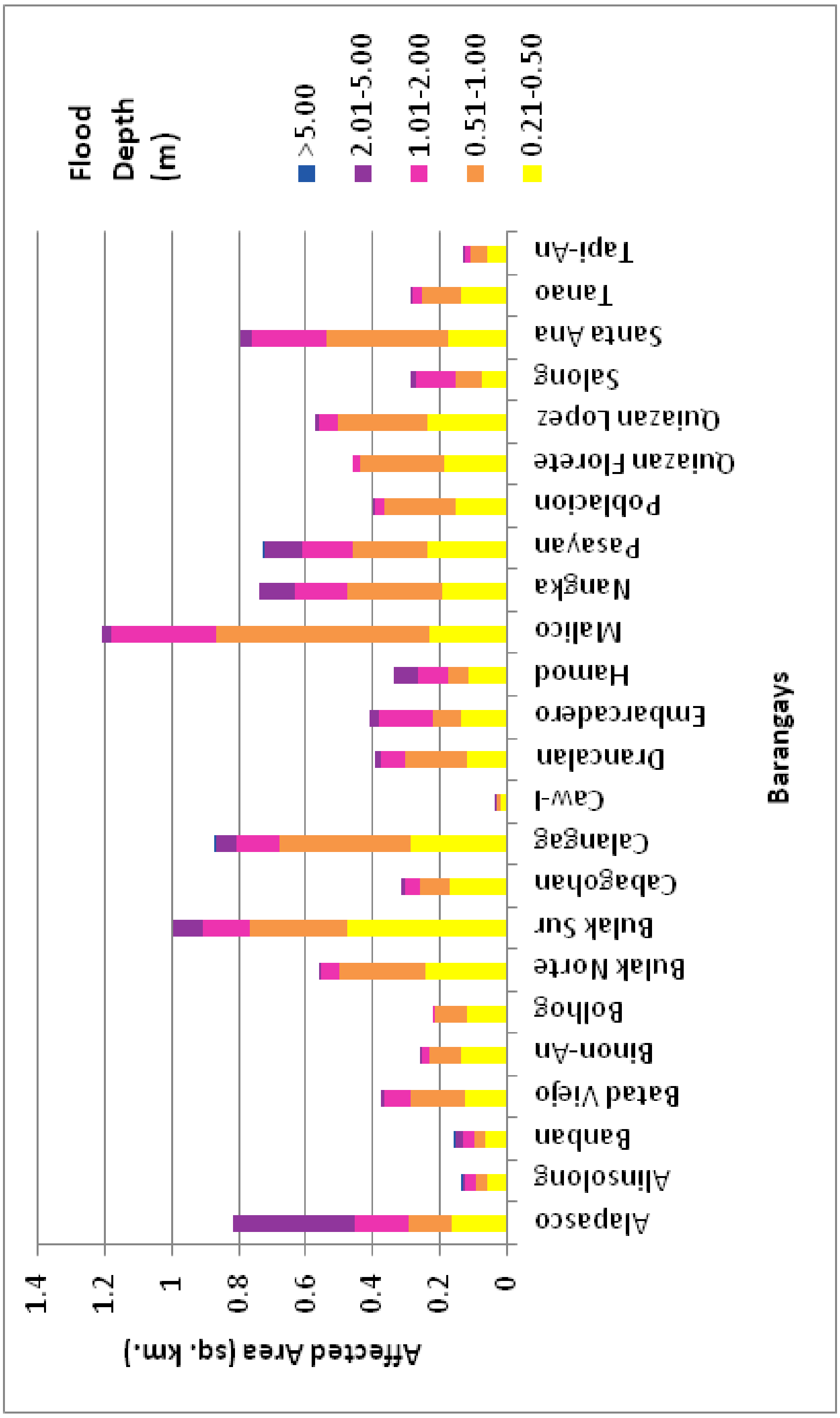


Figure 82. Affected areas in Batad, Iloilo during a 25-year rainfall return period

For the Municipality of Estancia, with an area of 28.74 square kilometers, 64.85% will experience flood levels of less than 0.20 meters. 11.17% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 11%, 7.23%, and 0.37% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 46 are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected areas in Estancia, Iloilo during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Estancia (in sq. km.)										
	Bayuyan	Boton-gan	Bu-laqueña	Calapdan	Cano-An	Daan Banua	Daculan	Gogo	Jolog	Lonoy	Lumbia
0.03-0.20	0.8	0.4	0.57	0.84	1.26	1.22	0.64	1.2	0.66	0.88	3.57
0.21-0.50	0.32	0.03	0.047	0.13	0.43	0.096	0.11	0.11	0.018	0.23	0.35
0.51-1.00	0.42	0.01	0.039	0.073	0.41	0.08	0.056	0.066	0.004	0.32	0.38
1.01-2.00	0.31	0.0028	0.0072	0.012	0.44	0.054	0.0038	0.0039	0.0011	0.044	0.2
2.01-5.00	0.028	0	0	0.0007	0.0075	0.0013	0	0	0.0003	0.0026	0.018
> 5.00	0	0	0	0	0	0	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Estancia (in sq. km.)										
	Malbog	Pani-An	Pa-On	Poblacion Zone 1	Poblacion Zone II	Poblacion Zone III	San Roque	Santa Ana	Tabu-An	Tacbuyan	Tanza
0.03-0.20	0.18	0.69	0.47	0.54	0.18	0.07	0.78	1.57	0.28	0.97	0.87
0.21-0.50	0.13	0.2	0.042	0.096	0.025	0.0029	0.19	0.23	0.28	0.07	0.062
0.51-1.00	0.19	0.3	0.016	0.094	0.033	0.0003	0.17	0.063	0.34	0.061	0.045
1.01-2.00	0.085	0.53	0.0015	0.038	0.0072	0	0.039	0.017	0.25	0.021	0.018
2.01-5.00	0.015	0.021	0	0.0033	0	0	0	0.0074	0.0011	0	0.0005
> 5.00	0	0	0	0	0	0	0	0	0	0	0

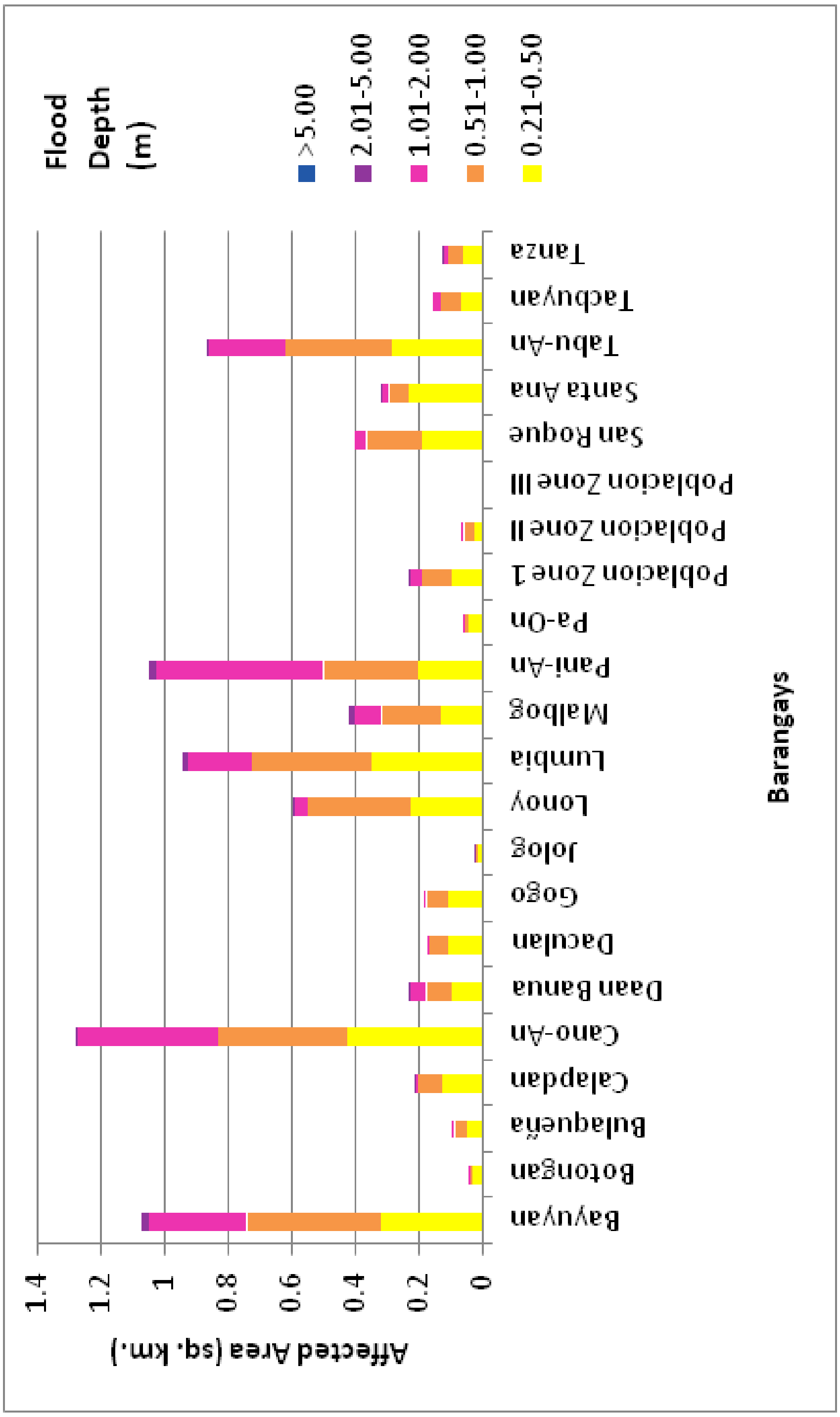


Figure 83. Affected areas in Estancia, Iloilo during a 25-year rainfall return period

For the Municipality of Pilar, with an area of 117.9 square kilometers, 11.19% will experience flood levels of less than 0.20 meters. 0.73% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.92%, 0.82%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 47 are the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected areas in Pilar, Capiz during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)									
	Balogo	Dayhagan	San Anto-nio	San Este-ban	San Nico-las	San Pedro	San Silves-tre	Sinamongan	Tabun-Acan	Yating
0.03-0.20	0.61	0.24	0.069	0.031	0.41	0.52	2.45	5.16	3.53	0.18
0.21-0.50	0.062	0.0037	0.0025	0.00014	0.056	0.12	0.1	0.42	0.089	0.0024
0.51-1.00	0.021	0.0018	0.000009	0.00026	0.26	0.034	0.058	0.67	0.043	0.000003
1.01-2.00	0.0003	0.00097	0	0.000015	0.22	0.00052	0.036	0.67	0.031	0
2.01-5.00	0	0.0001	0	0	0.0098	0.00022	0.0034	0.072	0.0093	0
> 5.00	0	0	0	0	0	0	0	0.00011	0	0

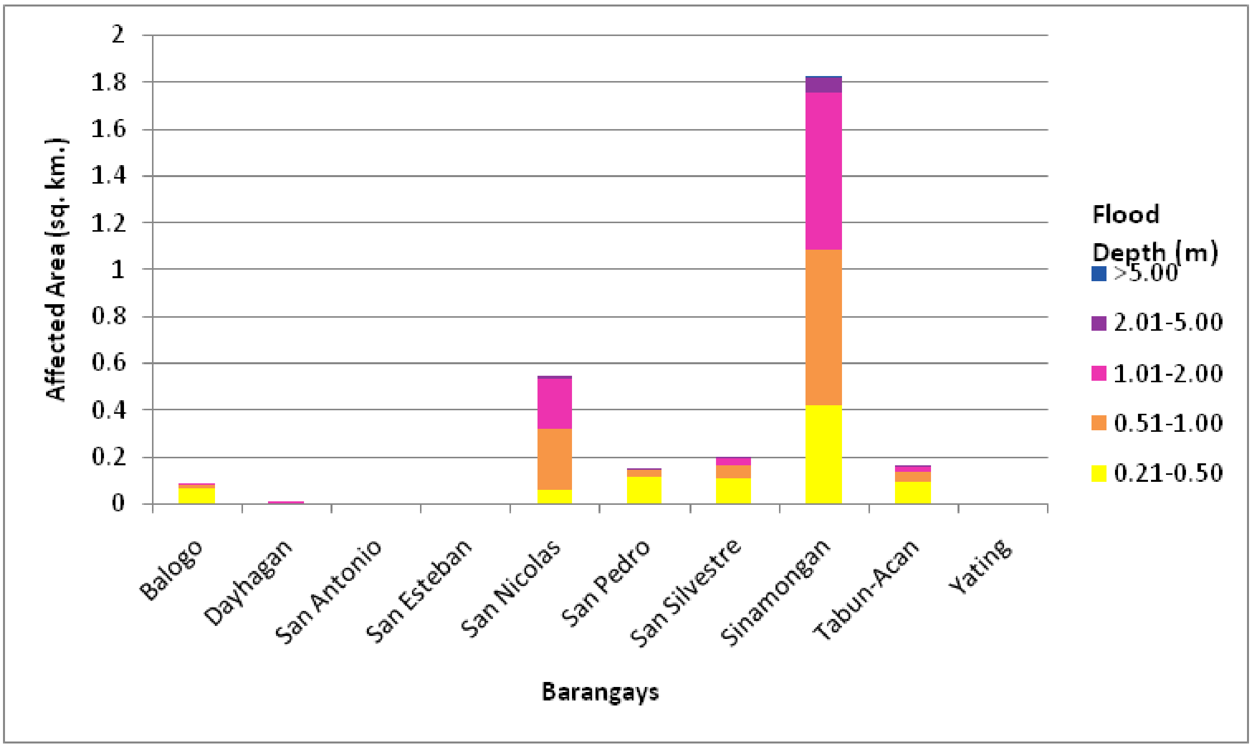


Figure 84. Affected areas in Pilar, Capiz during a 25-year rainfall return period

For the Municipality of San Dionisio, with an area of 118.47 square kilometers, 5.45% will experience flood levels of less than 0.20 meters. 0.21% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.17%, 0.12%, and 0.015% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 48 are the affected areas, in square kilometers, by flood depth per barangay.

Table 48. Affected areas in San Dionisio, Iloilo during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Dionisio (in sq. km.)				
	Amayong	Batuan	Canas	Odiongan	Talo-Ato
0.03-0.20	2.89	0.14	0.99	1.26	1.26
0.21-0.50	0.13	0.0023	0.033	0.031	0.03
0.51-1.00	0.12	0.00011	0.037	0.016	0.016
1.01-2.00	0.057	0	0.03	0.0042	0.0076
2.01-5.00	0.0034	0	0.0012	0.0006	0.0003
> 5.00	0	0	0	0	0

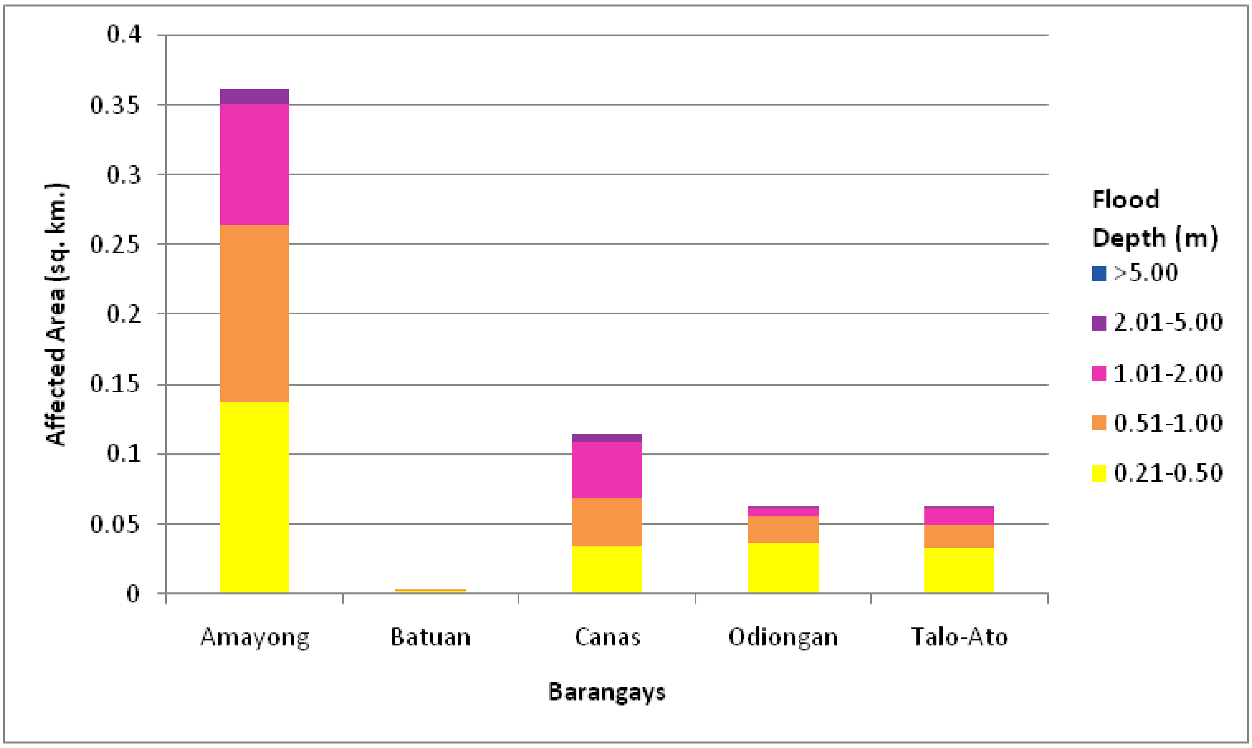


Figure 85. Affected areas in San Dionisio, Iloilo during a 25-year rainfall return period

For the Municipality of Sara, with an area of 184.63 square kilometers, 0.017% will experience flood levels of less than 0.20 meters. Listed in Table 49 are the affected areas, in square kilometers, by flood depth per barangay.

Table 49. Affected areas in Sara, Iloilo during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sara (in sq. km.)
	Tady
0.03-0.20	0.017
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

Figure 86. Affected areas in Sara, Iloilo during a 25-year rainfall return period

For the 100-year return period, 43.51% of the Municipality of Balasan, with an area of 56.36 square kilometers, will experience flood levels of less than 0.20 meters. 15.01% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 18.68%, 11%, 1.88%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 are the affected areas, in square kilometers, by flood depth per barangay.

Table 50. Affected areas in Balasan, Iloilo during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balasan (in sq. km.)											
	Aranjuez	Bacolod	Balan-ti-An	Batuan	Cabalic	Camambugan	Dolores	Gimamanay	Ipil	Kinalkalan	Lawis	Malapoc
0.03-0.20	1.79	0.68	1.24	1.44	2.59	0.75	0.2	1.9	0.79	0.9	2.58	0.47
0.21-0.50	0.81	0.36	0.23	0.23	0.66	0.37	0.091	0.42	0.36	0.17	1.18	0.37
0.51-1.00	0.84	0.15	0.25	0.18	0.42	0.64	0.32	0.57	0.44	0.47	1.43	0.16
1.01-2.00	0.24	0.0034	0.35	0.087	0.1	0.2	0.22	0.19	0.21	0.15	0.86	0.048
2.01-5.00	0.002	0.00021	0.036	0.072	0.011	0.00095	0.057	0.0091	0.00022	0.014	0.0091	0.0033
> 5.00	0	0	0	0	0	0	0.0028	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balasan (in sq. km.)										
	Mamhut Norte	Mamhut Sur	Maya	Pani-An	Poblacion Norte	Poblacion Sur	Quiasan	Salong	Salvacion	Tin-gui-An	Zaragosa
0.03-0.20	0.88	0.091	0.8	0.85	0.19	0.28	0.61	1.74	1.59	0.99	1.18
0.21-0.50	0.28	0.14	0.1	0.22	0.024	0.17	0.73	0.22	0.28	0.89	0.16
0.51-1.00	0.85	0.21	0.17	0.19	0.043	0.33	1.19	0.21	0.23	0.95	0.28
1.01-2.00	1.51	0.14	0.29	0.14	0.016	0.53	0.43	0.11	0.042	0.22	0.12
2.01-5.00	0.34	0.024	0.1	0.041	0	0.22	0.037	0.0038	0.00064	0.062	0.0071
> 5.00	0.013	0	0.0038	0	0	0.049	0	0	0	0.0006	0

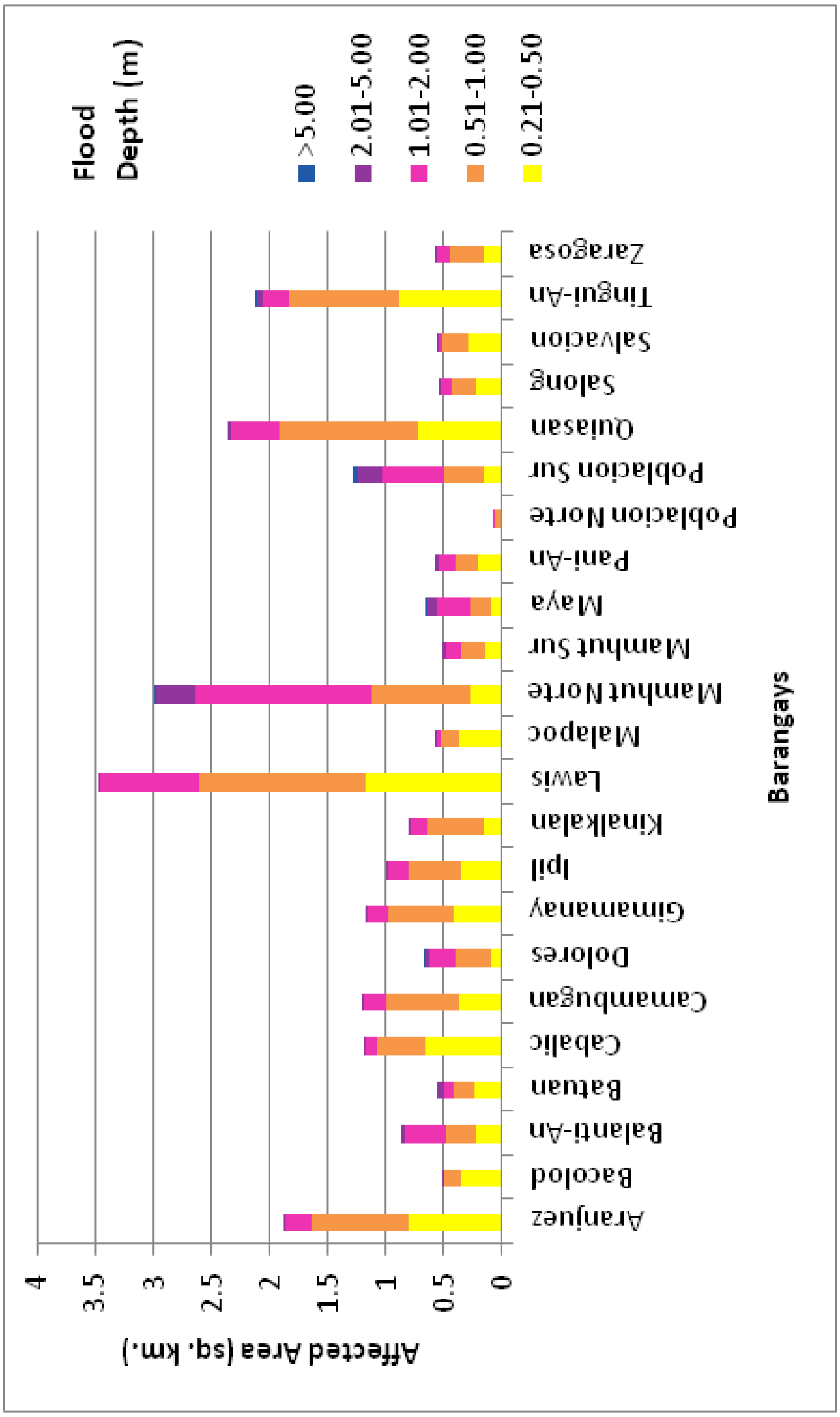


Figure 87. Affected areas in Balasan, Iloilo during a 100-year rainfall return period

For the Municipality of Batad, with an area of 44.94 square kilometers, 69.34% will experience flood levels of less than 0.20 meters. 8.71% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 9.96%, 5.39%, and 2.7% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 51 are the affected areas, in square kilometers, by flood depth per barangay.

Table 51. Affected areas in Batad, Iloilo during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Batad (in sq. km.)											
	Alapasco	Alinsolong	Banban	Batad Viejo	Bi-non-An	Bolhog	Bulak Norte	Bulak Sur	Cabagohan	Calangag	Caw-I	Drancalan
0.03-0.20	3.07	1.21	1.53	0.77	1.25	1.01	1.66	1.82	1.65	2.26	0.63	0.48
0.21-0.50	0.17	0.064	0.067	0.12	0.13	0.1	0.21	0.47	0.17	0.24	0.021	0.13
0.51-1.00	0.11	0.035	0.036	0.16	0.12	0.12	0.26	0.35	0.11	0.41	0.011	0.16
1.01-2.00	0.19	0.034	0.033	0.081	0.031	0.012	0.12	0.18	0.054	0.22	0.0027	0.071
2.01-5.00	0.4	0.015	0.035	0.0087	0.0024	0	0.012	0.1	0.01	0.076	0.0003	0.021
> 5.00	0	0.001	0.0027	0	0	0	0	0.000037	0	0.0011	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Batad (in sq. km.)											
	Embarcadero	Hamod	Malico	Nangka	Pasayan	Poblacion	Quiazan Flo-rete	Quiazan Lopez	Salong	Santa Ana	Tanao	Ta-pi-An
0.03-0.20	0.68	1.2	0.29	3.47	1.58	1.3	0.34	1.03	0.84	0.26	1.62	1.18
0.21-0.50	0.13	0.11	0.34	0.19	0.21	0.14	0.21	0.18	0.069	0.24	0.13	0.06
0.51-1.00	0.1	0.07	0.63	0.24	0.24	0.23	0.21	0.3	0.077	0.32	0.13	0.051
1.01-2.00	0.15	0.081	0.18	0.24	0.2	0.056	0.018	0.12	0.12	0.17	0.042	0.025
2.01-5.00	0.053	0.1	0.027	0.12	0.14	0.000018	0	0.017	0.031	0.03	0.003	0.0055
> 5.00	0	0.0002	0	0	0.0056	0	0	0	0	0	0	0

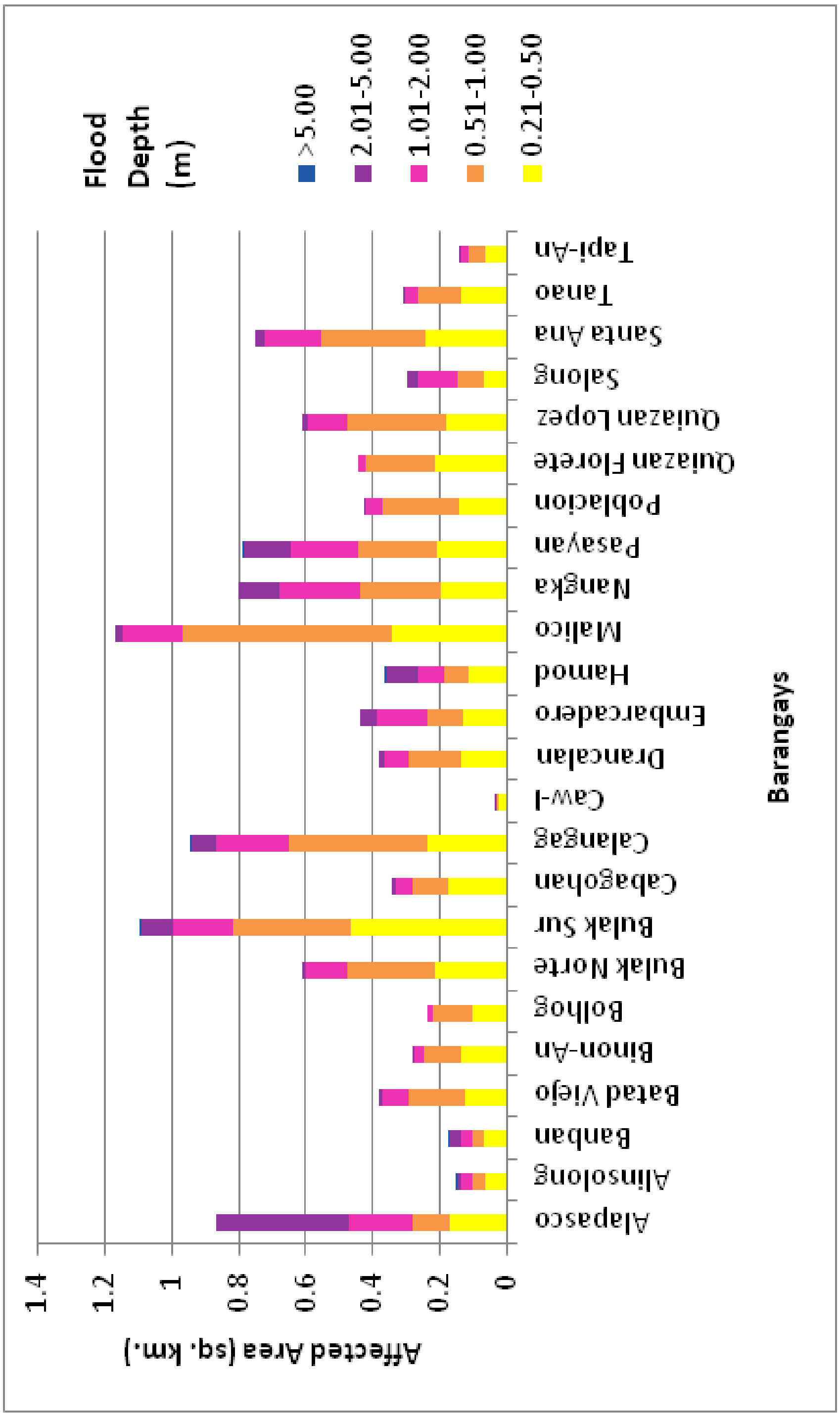


Figure 88. Affected areas in Batad, Iloilo during a 100-year rainfall return period

For the Municipality of Estancia, with an area of 28.74 square kilometers, 65.98% will experience flood levels of less than 0.20 meters. 11.68% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 10.71%, 5.99%, and 0.26% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 52 are the affected areas, in square kilometers, by flood depth per barangay.

Table 52. Affected areas in Estancia, Iloilo during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Estancia (in sq. km.)										
	Bayuyan	Boton-gan	Bu-laqueña	Calapdan	Cano-An	Daan Banua	Daculan	Gogo	Jolog	Lonoy	Lumbia
0.03-0.20	0.87	0.39	0.56	0.82	1.35	1.21	0.62	1.19	0.65	0.92	3.53
0.21-0.50	0.34	0.032	0.05	0.13	0.44	0.092	0.11	0.12	0.022	0.31	0.34
0.51-1.00	0.43	0.013	0.04	0.087	0.37	0.089	0.075	0.062	0.0048	0.23	0.4
1.01-2.00	0.21	0.003	0.012	0.013	0.38	0.063	0.0061	0.0021	0.0013	0.024	0.24
2.01-5.00	0.018	0	0	0.0005	0.0031	0.0015	0	0	0.0003	0.0018	0.015
> 5.00	0	0	0	0	0	0	0	0	0	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Estancia (in sq. km.)										
	Malbog	Pani-An	Pa-On	Poblacion Zone 1	Poblacion Zone II	Poblacion Zone III	San Roque	Santa Ana	Tabu-An	Tacbuyan	Tanza
0.03-0.20	0.21	0.77	0.47	0.54	0.17	0.069	0.81	1.6	0.37	0.96	0.86
0.21-0.50	0.15	0.21	0.043	0.11	0.024	0.0037	0.19	0.21	0.3	0.075	0.065
0.51-1.00	0.16	0.32	0.02	0.095	0.031	0.0004	0.16	0.046	0.35	0.061	0.045
1.01-2.00	0.071	0.43	0.002	0.026	0.014	0	0.026	0.017	0.13	0.026	0.024
2.01-5.00	0.011	0.014	0	0.00064	0	0	0	0.007	0.0003	0	0.0007
> 5.00	0	0	0	0	0	0	0	0	0	0	0

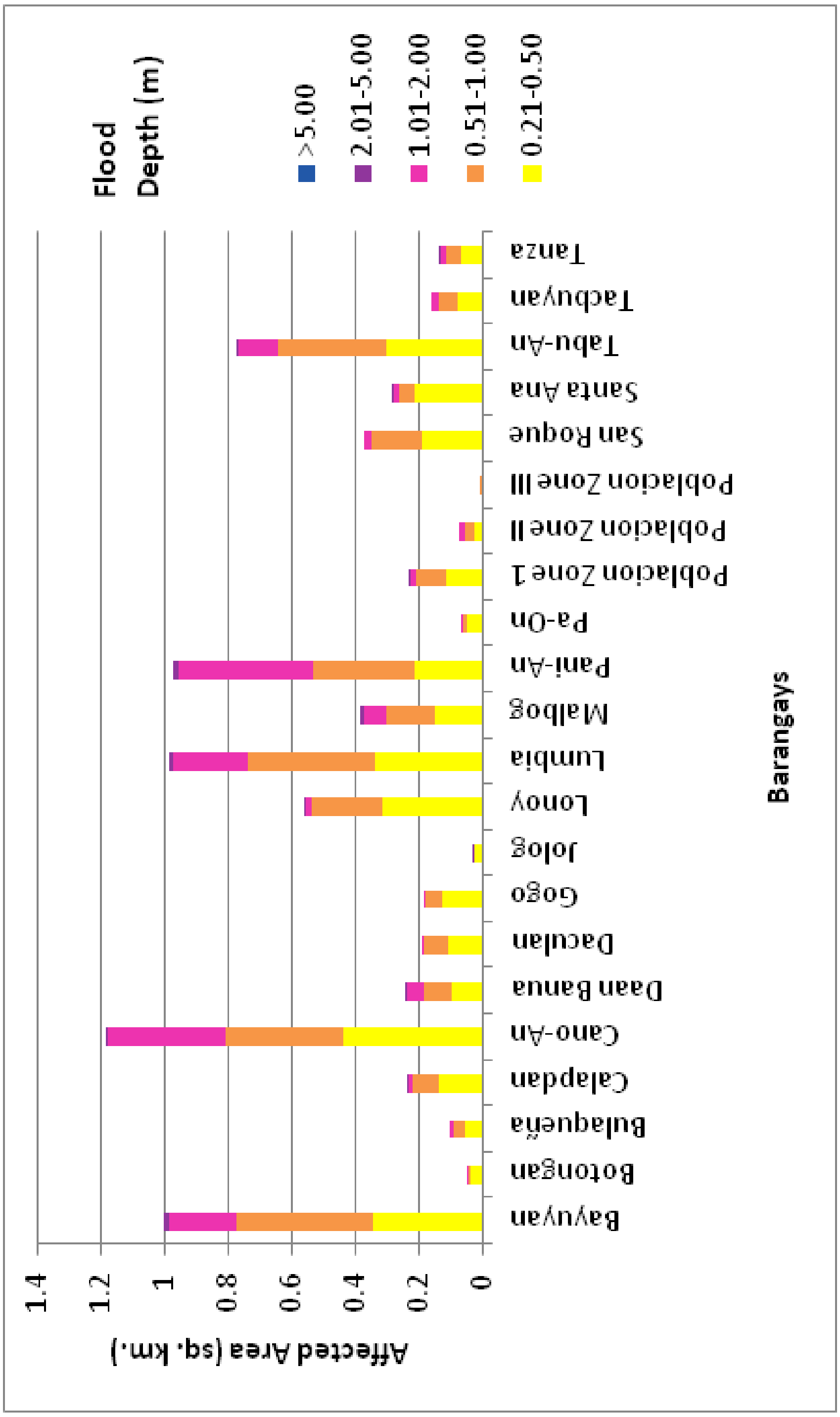


Figure 89. Affected areas in Estancia, Iloilo during a 100-year rainfall return period

For the Municipality of Pilar, with an area of 117.9 square kilometers, 11.34% will experience flood levels of less than 0.20 meters. 0.74% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.99%, 0.61%, and 0.052% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 53 are the affected areas, in square kilometers, by flood depth per barangay.

Table 53. Affected areas in Pilar, Capiz during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Pilar (in sq. km.)									
	Balogo	Dayhagan	San Anto-nio	San Este-ban	San Nico-las	San Pedro	San Silves-tre	Sinamongan	Tabun-Acan	Yating
0.03-0.20	0.62	0.24	0.07	0.031	0.42	0.55	2.47	5.26	3.54	0.18
0.21-0.50	0.056	0.0032	0.002	0.000076	0.073	0.1	0.096	0.45	0.093	0.0031
0.51-1.00	0.016	0.0016	0.000009	0.00025	0.3	0.026	0.055	0.73	0.041	0.000003
1.01-2.00	0.0001	0.00097	0	0.000015	0.16	0.00033	0.028	0.5	0.027	0
2.01-5.00	0	0	0	0	0.0064	0.00022	0.0019	0.047	0.0059	0
> 5.00	0	0	0	0	0	0	0	0.0001	0	0

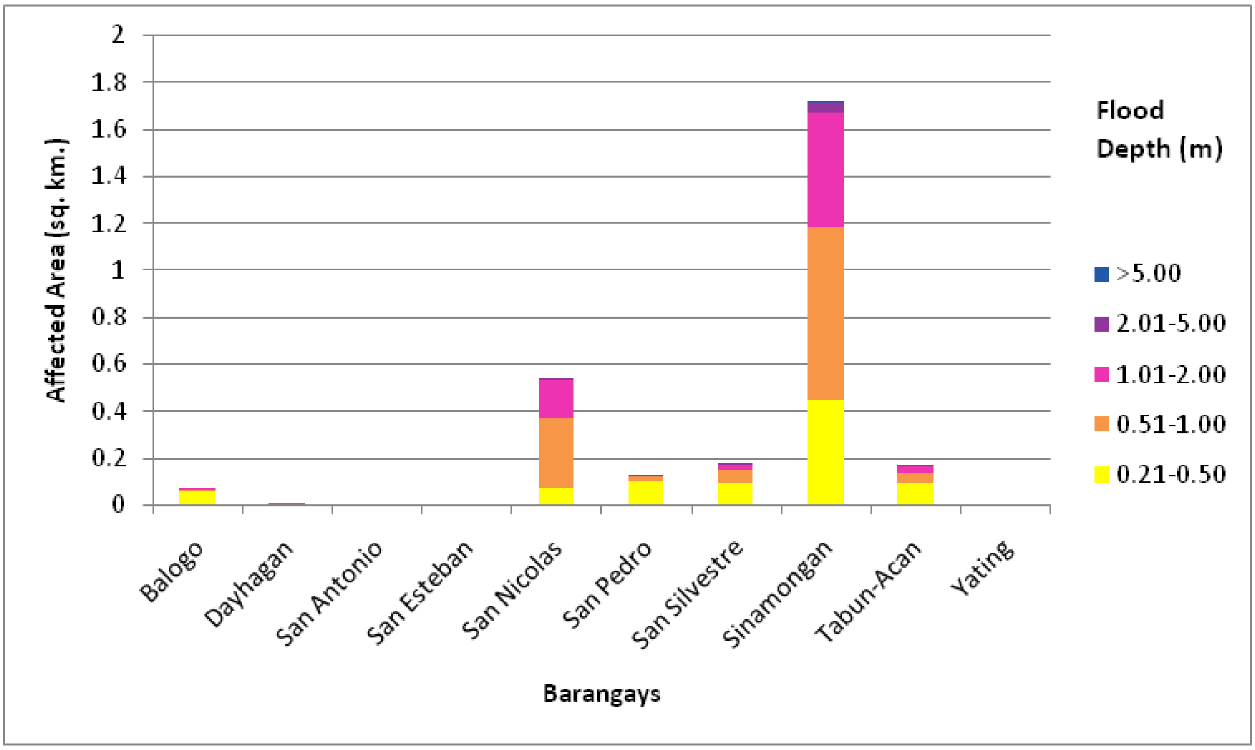


Figure 90. Affected areas in Pilar, Capiz during a 100-year rainfall return period

For the Municipality of San Dionisio, with an area of 118.47 square kilometers, 5.39% will experience flood levels of less than 0.20 meters. 0.22% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.17%, 0.15%, and 0.027% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and, 2.01 to 5 meters, respectively. Listed in Table 54 are the affected areas, in square kilometers, by flood depth per barangay.

Table 54. Affected areas in San Dionisio, Iloilo during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Dionisio (in sq. km.)				
	Amayong	Batuan	Canas	Odiongan	Talo-Ato
0.03-0.20	2.82	0.13	0.97	1.24	1.24
0.21-0.50	0.14	0.0038	0.036	0.041	0.036
0.51-1.00	0.13	0.00017	0.034	0.02	0.018
1.01-2.00	0.11	0	0.046	0.0079	0.014
2.01-5.00	0.021	0	0.0091	0.0007	0.0014
> 5.00	0	0	0	0	0

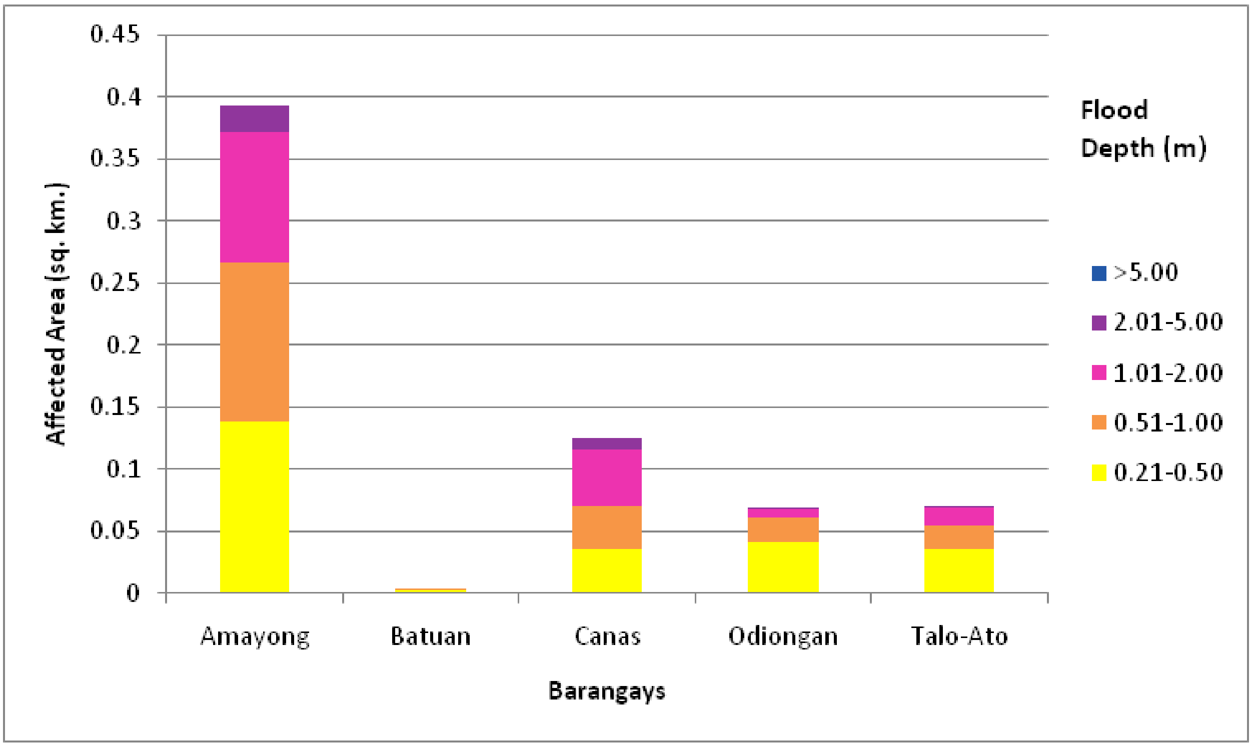


Figure 91. Affected areas in San Dionisio, Iloilo during a 100-year rainfall return period

For the Municipality of Sara, with an area of 184.63 square kilometers, 0.017% will experience flood levels of less than 0.20 meters. Listed in Table 55 are the affected areas, in square kilometers, by flood depth per barangay.

Table 55. Affected areas in Sara, Iloilo during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sara (in sq. km.)
	Tady
0.03-0.20	0.017
0.21-0.50	0
0.51-1.00	0
1.01-2.00	0
2.01-5.00	0
> 5.00	0

Figure 92. Affected areas in Sara, Iloilo during a 100-year rainfall return period

Among the barangays in the Municipality of Balasan, Lawis is projected to have the highest percentage of area that will experience flood levels, at 10.76%. Meanwhile, Aranjeuz posted the second highest percentage of area that may be affected by flood depths, at 6.53%.

Among the barangays in the Municipality of Batad, Nangka is projected to have the highest percentage of area that will experience flood levels, at 9.52%. Meanwhile, Alapasco posted the second highest percentage of area that may be affected by flood depths, at 8.78%.

Among the barangays in the Municipality of Estancia, Lumbia is projected to have the highest percentage of area that will experience flood levels, at 15.72%. Meanwhile, Cano-An posted the second highest percentage of area that may be affected by flood depths, at 8.85%.

Among the barangays in the Municipality of Pilar, Sinamongan is projected to have the highest percentage of area that will experience flood levels, at 5.92%. Meanwhile, Tabun-Acan posted the second highest percentage of area that may be affected by flood depths, at 3.14%.

Among the barangays in the Municipality of San Dionisio, Amayong is projected to have the highest percentage of area that will experience flood levels, at 2.71%. Meanwhile, Odiongan posted the second highest percentage of area that may be affected by flood depths, at 1.11%.

Among the barangays in the Municipality of Sara, Tady is projected to have the highest percentage of area that will experience flood levels, at 0.01%.

The generated flood hazard maps for the Balantian floodplain were also used to assess the vulnerability of the educational and medical institutions in the floodplain. Using the flood depth units of PAGASA for the hazard maps – “Low”, “Medium”, and “High” – the affected institutions were given their individual assessment for each flood hazard scenario (i.e., 5-year, 25-year, and 100-year).

Table 56. Area covered by each warning level, with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5-year	25-year	100-year
Low	22.32	22.09	18.24
Medium	21.50	23.00	35.62
High	3.03	3.54	8.49
TOTAL	**46.85**	**48.63**	**62.35**

Of the one hundred and six (106) identified educational institutions in the Balantian floodplain, three (3) were assessed to be exposed Low-level flooding during a 5-year scenario. Meanwhile, three (3) other schools were assessed to be exposed to Medium-level flooding in the same scenario. In the 25-year scenario, three (3) schools were found to be exposed to Low-level flooding, and another three (3) to Medium-level flooding. In the 100-year scenario, nine (9) schools were discovered to be exposed to Low-level flooding, and two (2) schools were assessed to be exposed to Medium-level flooding. Two (2) schools were projected to be exposed to High-level flooding in the same scenario. See Annex 12 for a detailed enumeration of the schools in the Balantian floodplain.

Of the twenty-three (23) medical institutions identified in the Balantian floodplain, two (2) were assessed to be exposed to Medium-level flooding during a 5-year scenario. In the 25-year scenario, two (2) centers were found to be exposed to Medium-level flooding. In the 100-year scenario, one (1) facility was discovered to be exposed to Low-level flooding, and three (3) to Medium-level flooding. See Annex 13 for a detailed enumeration of hospitals and clinics in the Balantian floodplain.

5.11 Flood Validation

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

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

The validation personnel then went to the specified points identified in a river basin to gather data regarding the actual flood levels in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents with knowledge or experience of flooding in a particular area.

After which, the actual data from the field were compared with 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 the corresponding validation depths are illustrated in Figure 94.

The flood validation consists of one hundred and fifty-four (154) points, randomly selected all over the Balantian floodplain. Comparing the validation with the flood depth map of the nearest storm event, the flood map attained an RMSE value of 0.77 meters. Table 57 presents a contingency matrix of the comparison. The validation points are found in Annex 11.

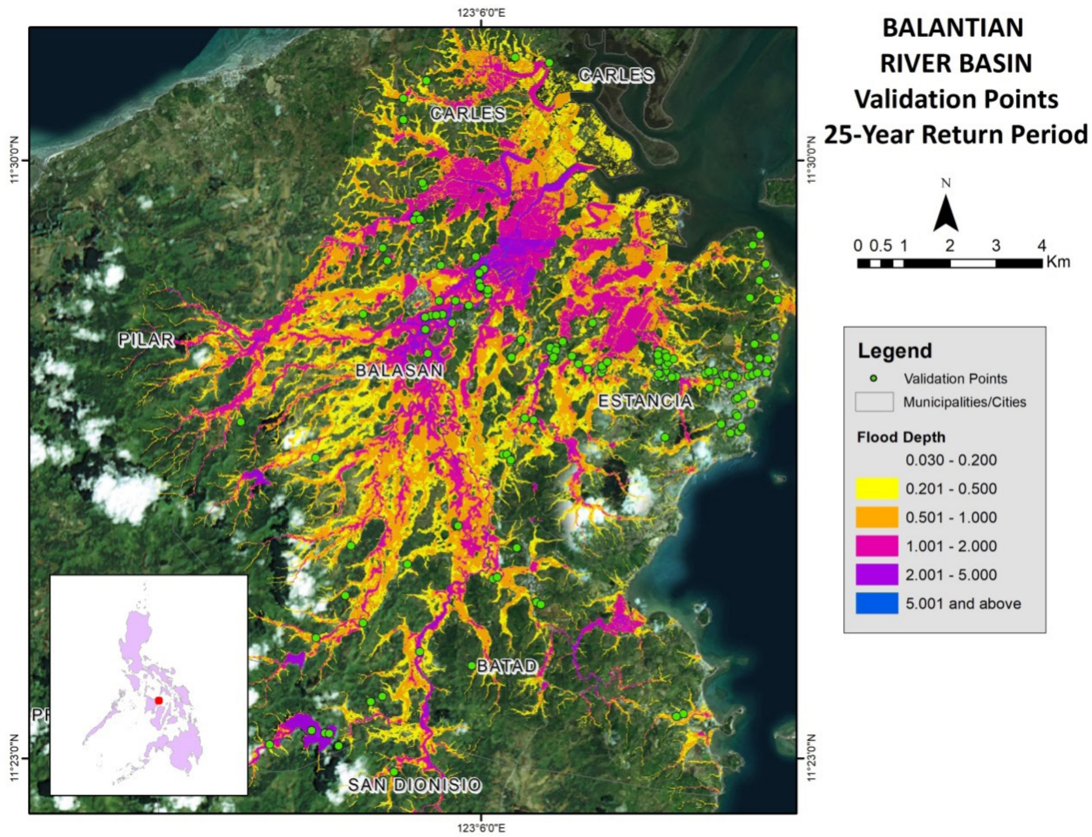


Figure 93. Validation points for the 25-year flood depth map of the Balantian floodplain

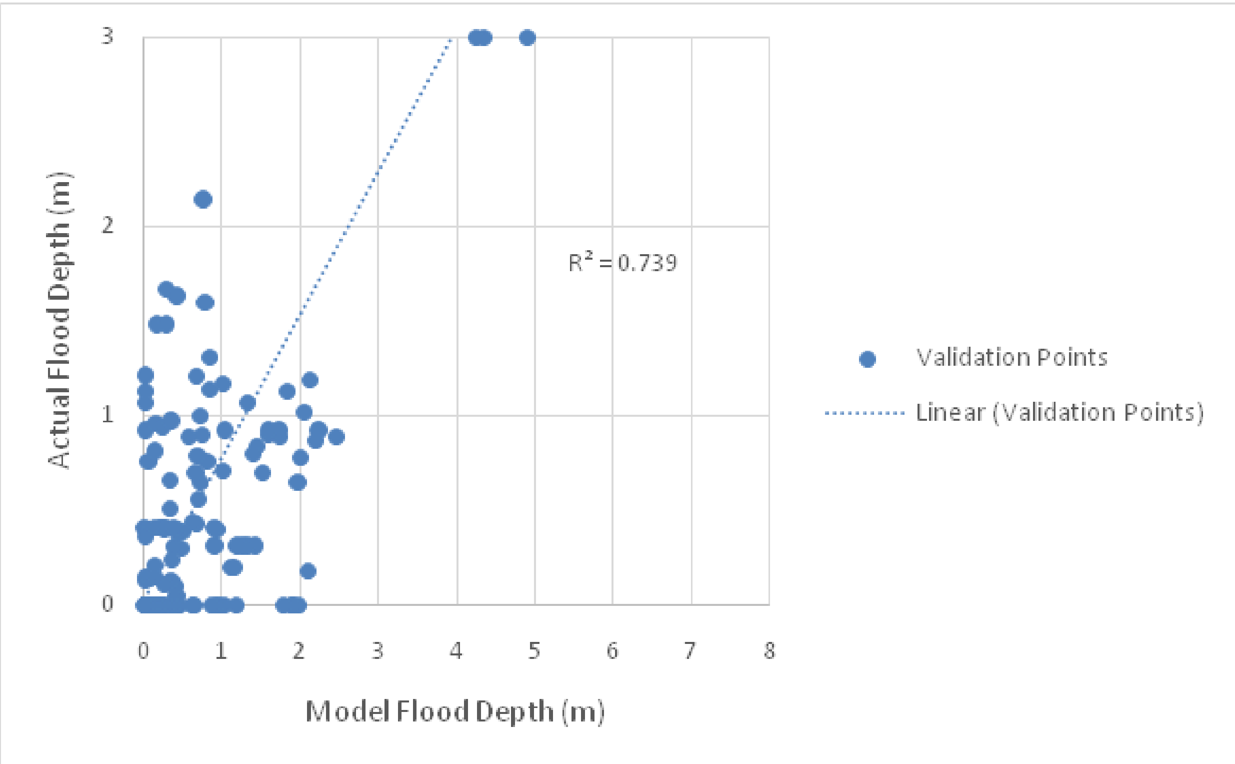


Figure 94. Flood map depth vs. actual flood depth

Table 57. Actual flood depth vs. simulated flood depth, at different levels in the Balantian River Basin

BALANTIAN BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	37	13	5	9	1	0	65
	0.21-0.50	6	11	6	4	0	0	27
	0.51-1.00	4	4	8	10	4	0	30
	1.01-2.00	4	3	4	3	2	0	16
	2.01-5.00	0	0	1	0	10	3	14
	> 5.00	0	0	0	0	0	2	2
	Total	51	31	24	26	17	5	154

The overall accuracy generated by the flood model is estimated at 46.10%, with seventy-one (71) points correctly matching the actual flood depths. In addition, there were forty-four (44) points estimated one (1) level above and below the correct flood depths. Meanwhile, there were twenty-one (21) points and fourteen (14) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood levels, respectively. A total of four (4) points were overestimated, while a total of twenty-six (26) points were underestimated in the modeled flood depths of Balantian. Table 58 depicts the summary of the Accuracy Assessment in the Balantian River Basin survey.

Table 58. Summary of Accuracy Assessment in the Balantian River Basin survey

No. of Points		%
Correct	71	**46.10**
Overestimated	57	**37.01**
Underestimated	26	**16.88**
Total	154	**100.00**

REFERENCES

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

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the Gemini LiDAR Sensor used in the Balantian Floodplain Survey

Figure A-1.1. Gemini Sensor

Table A-1.1. Technical specifications of the Gemini sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)

Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

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

1. ILO-78

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

February 05, 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: **ILOILO**
Station Name: **ILO-78**
Order: **2nd**

Island: **VISAYAS**	Barangay: **BATAD VIEJO**	
Municipality: **BATAD**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **11° 25' 25.75892"**	Longitude: **123° 6' 14.81238"**	Ellipsoidal Hgt: **39.17700 m.**
	WGS84 Coordinates	
Latitude: **11° 25' 21.28384"**	Longitude: **123° 6' 19.96798"**	Ellipsoidal Hgt: **96.31200 m.**
	PTM / PRS92 Coordinates	
Northing: **1263207.627 m.**	Easting: **511361.438 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,262,765.48**	Easting: **511,357.46**	Zone: **51**

Location Description

ILO-78
From the municipal hall, travel N for about 1 km. and turn W for 600 m. to Batad Natl. High School. It is located on the open ground inside the campus. It is found 41 m. NE of the flagpole, which is beside the stage, 55 m. N of the library room, 7 m. W of the MAPEH room (room 16) and 5 m. NW of the Vales Education room (room 14). Mark is the head of a 4 in. copper nail centered and embedded on a 30 cm. x 30 cm. x 4 cm. concrete monument, with inscriptions "ILO-78 2005 NAMRIA".

Requesting Party: **PHIL-LIDAR I**
Purpose: **Reference**
OR Number: **8077605 I**
T.N.: **2015-0223**

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

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

CIP/4701/12/09/814

Figure A-2.1. ILO-78

2. ILO-97

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: **ILOILO**	
	Station Name: **ILO-97 (LEM-1)**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **TABUNAN**	
Municipality: **LEMERY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **11° 13' 54.08920"**	Longitude: **122° 55' 50.84966"**	Ellipsoidal Hgt: **88.56000 m.**
	WGS84 Coordinates	
Latitude: **11° 13' 49.64749"**	Longitude: **122° 55' 56.02324"**	Ellipsoidal Hgt: **145.73700 m.**
	PTM / PRS92 Coordinates	
Northing: **1241955.878 m.**	Easting: **492442.632 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,241,521.17**	Easting: **492,445.28**	Zone: **51**

Location Description

ILO-97 (LEM-1)
From Iloilo City, travel NE to the Mun. of Lemery. Then from the town proper, go to Brgy. Tabunan along the Lemery-Sara Nat'l. Rd. Station is located on the headwall of an irrigation gate at the left side going to Sara. It is situated about 50 m. from a Duhat tree, 200 m. from the welcome arch of Pob. Lemery and about 210 m. and 300 m. NW of Km. Post No. 89 and Total Gas Station, respectively. Mark is the head of a 4 in. copper nail set flushed and centered on a 20 cm. x 20 cm. cement putty, with inscriptions "STA. LEM 1 PRS 92 DENR 08-282003".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8088472 I**
T.N.: **2015-3528**

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

9 9 1 0 2 8 2 0 1 5 1 3 4 9 5 6

CIP/4701/12/09/814

NAMRIA OFFICES:
Main : Lawton Avenue, Fort Bonifacio, 1634 Taguig City, Philippines Tel. No.: (632) 810-4831 to 41
Branch : 421 Barraca St. San Nicolas, 1010 Manila, Philippines, Tel. No. (632) 241-3494 to 98
www.namria.gov.ph
ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. ILO-97

3. ILO-104

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: **ILOILO**	
	Station Name: **ILO-104**	
	Order: **2nd**	
Island: **VISAYAS**	Barangay: **POBLACION**	
Municipality: **AJUY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **11° 9' 53.30263"**	Longitude: **123° 0' 46.92545"**	Ellipsoidal Hgt: **11.59700 m.**
	WGS84 Coordinates	
Latitude: **11° 9' 48.88466"**	Longitude: **123° 0' 52.10452"**	Ellipsoidal Hgt: **69.13900 m.**
	PTM / PRS92 Coordinates	
Northing: **1234557.253 m.**	Easting: **501423.696 m.**	Zone: **4**
	UTM / PRS92 Coordinates	
Northing: **1,234,125.14**	Easting: **501,423.20**	Zone: **51**

Location Description

ILO-104
From Iloilo City, travel NE to the Mun. of Ajuy. Then from the town proper, travel SW to Ajuy Nat'l. High School for about 1 km. Station is located on the headwall of an irrigation gate, at the left side of the road leading to the said school about 90 m. from the provincial road. Mark is the head of a 4 in. copper nail set flushed on top of a 30 cm. x 30 cm. concrete monument protruding 20 cm. above the ground, with inscriptions "ILO-104 2007 NAMRIA".

Requesting Party: **ENGR. CHRISTOPHER CRUZ**
Purpose: **Reference**
OR Number: **8088472 I**
T.N.: **2015-3527**

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

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

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

CP/4701/12/09/814

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.3. ILO-104

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

Table A-3.1.ILO-3134

Project information		Coordinate System	
Name:		Name:	UTM
Size:		Datum:	PRS 92
Modified:	10/12/2012 4:40:11 PM (UTC:-6)	Zone:	51 North (123E)
Time zone:	Mountain 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)
ILO-78 --- ILO-3134 (B1)	ILO-78	ILO-3134	Fixed	0.006	0.011	345°10'32"	7716.002	-29.415
ILO-78 --- ILO-3134 (B2)	ILO-78	ILO-3134	Fixed	0.004	0.014	345°10'32"	7715.965	-29.477

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

ILO-78 - ILO-3134 (2:14:52 PM-5:56:44 PM) (S1)

Baseline observation:	ILO-78 --- ILO-3134 (B1)
Processed:	2/11/2015 5:33:12 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.006 m
Vertical precision:	0.011 m
RMS:	0.003 m
Maximum PDOP:	3.202
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	2/9/2015 2:14:53 PM (Local: UTC+8hr)
Processing stop time:	2/9/2015 5:56:44 PM (Local: UTC+8hr)
Processing duration:	03:41:51

Vector Components (Mark to Mark)

From:	ILO-78				
Grid		Local		Global	
Easting	511357.462 m	Latitude	N11°25'25.75892"	Latitude	N11°25'21.28384"
Northing	1262765.482 m	Longitude	E123°06'14.81238"	Longitude	E123°06'19.96798"
Elevation	37.049 m	Height	39.177 m	Height	96.312 m

To:	ILO-3134				
Grid		Local		Global	
Easting	509381.363 m	Latitude	N11°29'28.52563"	Latitude	N11°29'24.03212"
Northing	1270220.967 m	Longitude	E123°05'09.67176"	Longitude	E123°05'14.82159"
Elevation	7.941 m	Height	9.763 m	Height	66.687 m

Vector					
ΔEasting	-1976.098 m	NS Fwd Azimuth	345°10'32"	ΔX	2479.078 m
ΔNorthing	7455.485 m	Ellipsoid Dist.	7716.002 m	ΔY	-187.237 m
ΔElevation	-29.108 m	ΔHeight	-29.415 m	ΔZ	7304.587 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.005 m
σ ΔElevation	0.006 m	σ ΔHeight	0.006 m	σ ΔZ	0.002 m

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000096165		
Y	-0.0000098941	0.0000290021	
Z	-0.0000027589	0.0000080866	0.0000035717

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Specialist (Supervising SRS)	LOVELY GRACIA ACUÑA; LOVELYN ASUNCION	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	GEROME HIPOLITO; LOVELYN ASUNCION	UP-TCAGP
LiDAR Operation	Research Associate (RA)	VERLINA TONGA; REGINA FELIS-MINO	UP-TCAGP
	RA	CATH BALIGUAS	UP-TCAGP
Ground Survey	RA	JONATHAN ALMALVEZ; KENNETH QUISADO; IRO NIEL ROXAS	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. LEE JAY PUNZALAN; SSG. JAYCO MANZANO	PHILIPPINE AIR FORCE (PAF)
LiDAR Operation	Pilot	CAPT. JEFFREY JEREMY ALAJAR; CAPT. BRYAN	ASIAN AEROSPACE CORPORATION (AAC)
LiDAR Operation	Pilot	CAPT. ALBERT LIM; CAPT. JERI-CHO JECIEL	AAC

Annex 5. Data Transfer Sheets for the Balantian Floodplain Flights

DATA TRANSFER SHEET
02/18/2015(ILOILO)

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	
9-Feb-15	2538G	2BLK37A040A	GEMINI	NA	980	1.58	261	55.5	220	24	2.41	18.1	1KB	1KB	8	25	Z:\DAC\RAW DATA
9-Feb-15	2540G	2BLK37B040B	GEMINI	NA	1044	1.67	231	37.5	339/424/424	24.5	2.6	18.1	1KB	1KB	3	NA	Z:\DAC\RAW DATA
10-Feb-15	2542G	2BLK37H041A	GEMINI	NA	1511	2.4	274	85.2	461	34.5	3.74	16.6	1KB	1KB	6/2	16	Z:\DAC\RAW DATA
10-Feb-15	2544G	2BLK37F041B	GEMINI	NA	1469	2.2	208	72.1	318	34.5	3.89	16.6	1KB	1KB	6	12	Z:\DAC\RAW DATA
11-Feb-15	2546G	2BLK37KV042A	GEMINI	NA	1148	1.86	255	61.9	451	26.5	2.85	11	1KB	1KB	3	9	Z:\DAC\RAW DATA
12-Feb-15	2550G	2BLK37GNOV43A	GEMINI	NA	1931	1.61	209	39.7	301	19.2	4.06	5.6	1KB	1KB	3	8	Z:\DAC\RAW DATA
13-Feb-15	2554G	2BLK37J044A	GEMINI	NA	1690	5.97	237	NA	NA	27.4	3	17.5	1KB	1KB	4	12	Z:\DAC\RAW DATA
13-Feb-15	2556G	2BLK37JSG044B	GEMINI	NA	3110	2.56	215	74.1	604	32.5	3.57	17.5	1KB	1KB	5	13	Z:\DAC\RAW DATA
14-Feb-15	2558G	2BLK43G045A	GEMINI	NA	2377	2.12	241	42.2	424/424/424/410	27.3	2.96	10.5	1KB	1KB	4	10	Z:\DAC\RAW DATA

Received from

Name C JOBONIN
Position
Signature

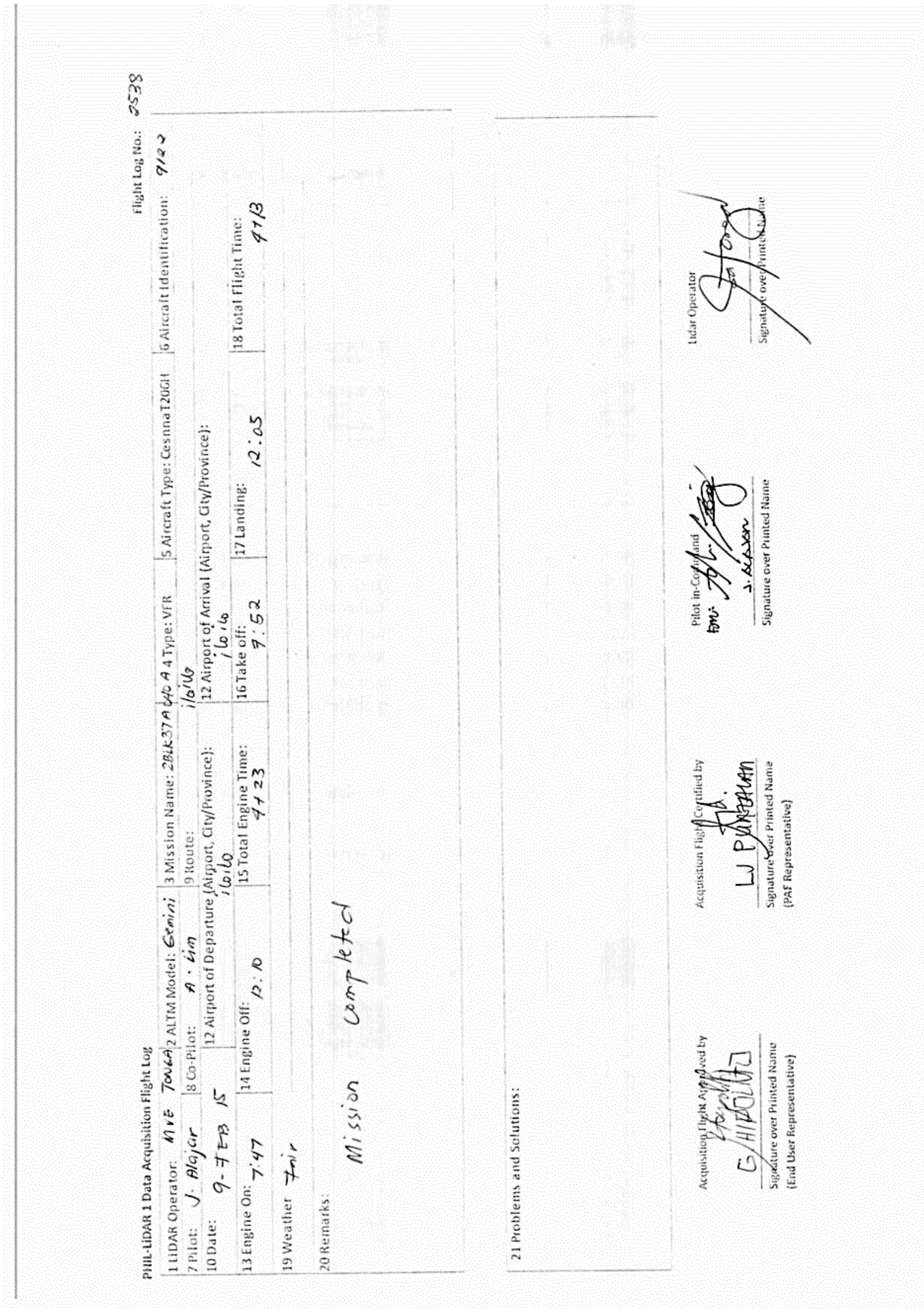
Received by

Name AC Bongat
Position SSRS
Signature

Figure A-5.1. Data Transfer Sheet for Balantian Floodplain

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 2538G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2538

1 LiDAR Operator: MVE Tonga	2 ALTM Model: Gemini	3 Mission Name: 2BLK37A040A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: 16/16			
10 Date: 9-FEB-15	12 Airport of Departure (Airport, City/Province): 16/16		12 Airport of Arrival (Airport, City/Province): 16/16		
13 Engine On: 7:47	14 Engine Off: 12:10	15 Total Engine Time: 4+23	16 Take off: 7:52	17 Landing: 12:05	18 Total Flight Time: 4+13
19 Weather: Fair					
20 Remarks: Mission Completed					
21 Problems and Solutions:					

Acquisition Flight Approved by: G. Hipolito, Signature over Printed Name (End User Representative)

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

Pilot-in-Command: J. Alajar, Signature over Printed Name

Lidar Operator: Signature over Printed Name

Figure A-6.1. Flight Log for Mission 2538G

2. Flight log for 2540G Mission

PHIL-LiDAR 1 Data Acquisition Flight Log — Flight Log No.: 2540

1 LiDAR Operator: R.A. Felismino	2 ALTM Model: Gemini	3 Mission Name: 2BLK37BC040B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: J. Alajar	8 Co-Pilot: A. Lim	9 Route: ILOILO			
10 Date: 9 Feb 15	12 Airport of Departure (Airport, City/Province): ILOILO		12 Airport of Arrival (Airport, City/Province): ILOILO		
13 Engine On: 13:56	14 Engine Off: 18:13	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Fair					

20 Remarks:

Mission completed for BLK 37B and covered 5 1/2 lines of BLK 37C

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[illegible]	SSG Punzalan	FB Docampo	RAC Felismino
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 2540G

3. Flight Log for 2778G Mission

Data Acquisition Flight Log

Flight Log No.: 2778G

1 LiDAR Operator: MCE BALICUAS	2 ALTM Model: GEM	3 Mission Name: 2BLK37AC270A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: A. LIM	8 Co-Pilot: J. VECIEL	9 Route:			
10 Date: 27 SEPT 15	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0623	14 Engine Off: 1040	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Cloudy / Scattered rainshowers				

20 Flight Classification

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

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

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

21 Remarks

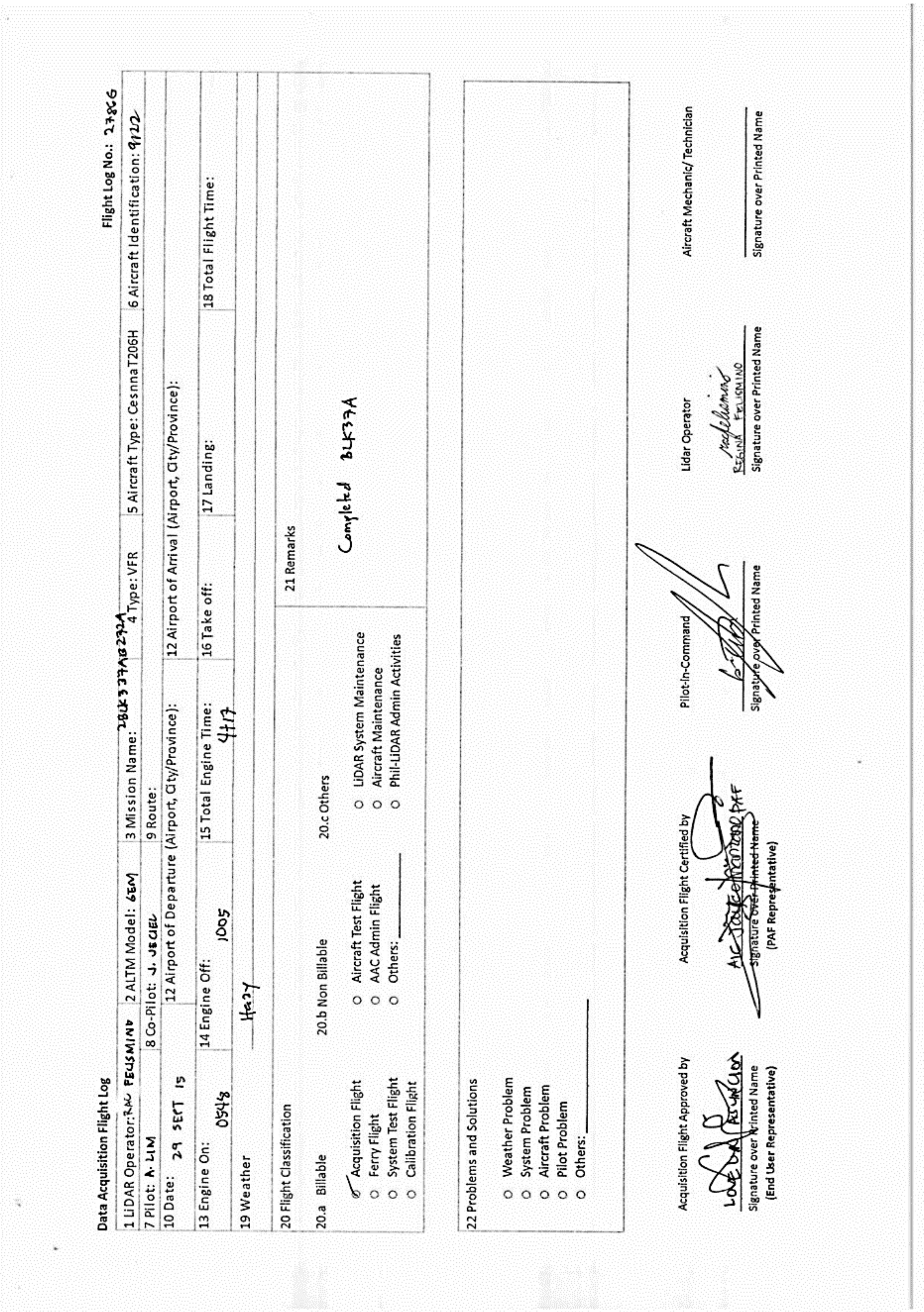
Covered 9 lines over BLK37C & 10 lines over BLK37A; POS turning red.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
LOVELYN ASUNCION	A1C JAYCOB MARZO PAF	A. LIM	MCE BALICUAS	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.3. Flight Log for Mission 2778G

4. Flight Log for 2786G Mission



Data Acquisition Flight Log

Flight Log No.: 2786G

1 LiDAR Operator: RAC FELISMINO	2 ALTM Model: GEM	3 Mission Name: 2BLK37AB272A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9122
7 Pilot: A. LIM	8 Co-Pilot: J. JECIEL	9 Route:			
10 Date: 29 SEPT 15	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 0548	14 Engine Off: 1005	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	Hazy				

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

Completed BLK37A

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

Acquisition Flight Approved by: LOVE DA ASUNCION — Signature over Printed Name (End User Representative)

Acquisition Flight Certified by: A1C JAYCE DIMORIONO PAF — Signature over Printed Name (PAF Representative)

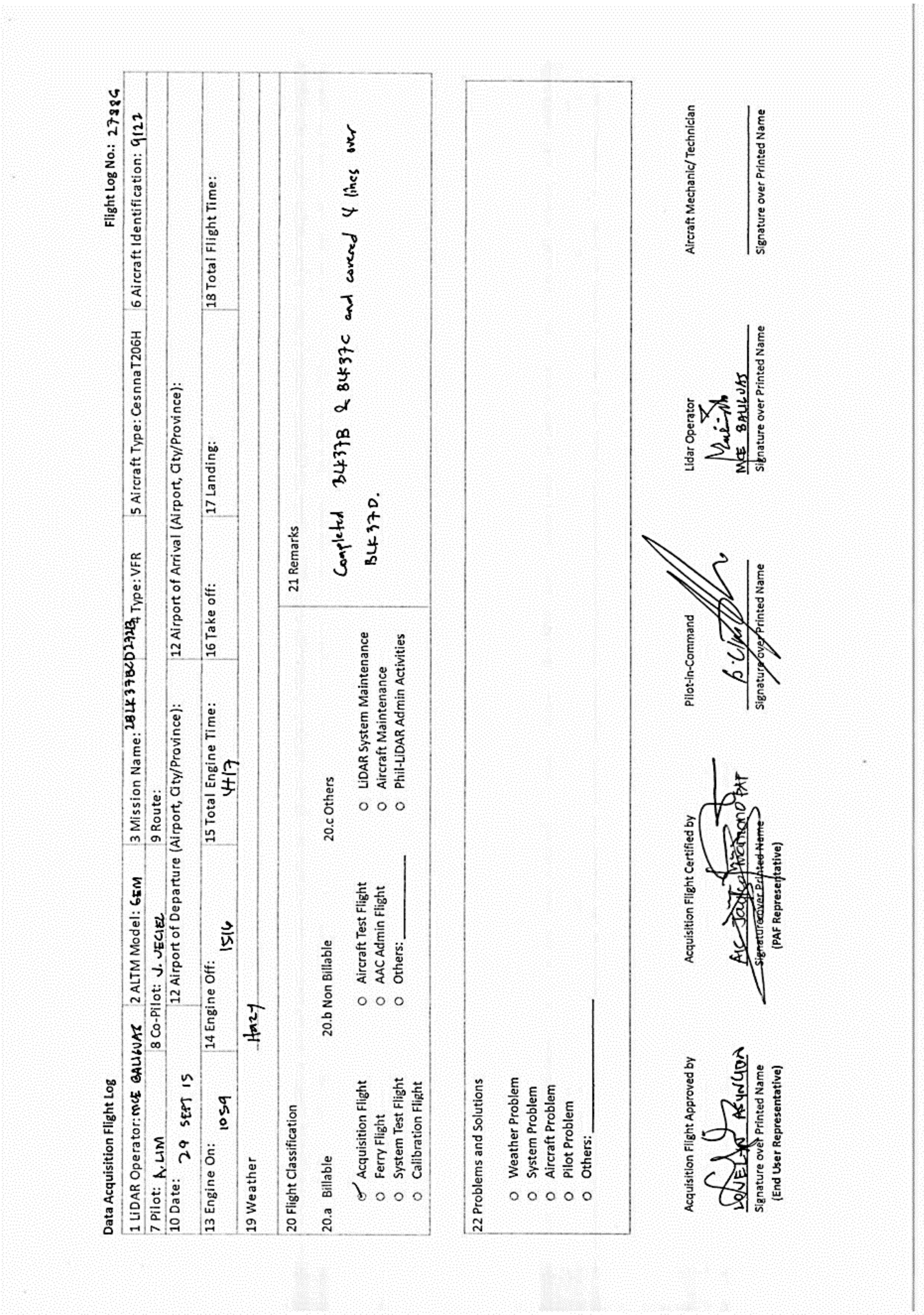
Pilot-in-Command: Signature over Printed Name

Lidar Operator: REGINA FELISMINO — Signature over Printed Name

Aircraft Mechanic/ Technician: Signature over Printed Name

Figure A-6.4. Flight Log for Mission 2786G

5. Flight Log for 2788G Mission



Data Acquisition Flight Log — Flight Log No.: 2788G

1 LiDAR Operator: MCE BALIGUAS	2 ALTM Model: GEM	3 Mission Name: 2BLK37BCD272B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot: A. LIM	8 Co-Pilot: J. JECIEL	9 Route:			
10 Date: 29 SEPT 15	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1059	14 Engine Off: 1516	15 Total Engine Time: 4+17	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Hazy					

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

Completed BLK37B & BLK37C and covered 4 lines over BLK37D.

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator	Aircraft Mechanic/ Technician
LOVELYN ASUNCION	A1C Jaykeo Raymond PAF	B. Uy	MCE BALIGUAS	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.5. Flight Log for Mission 2788G

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

FLIGHT STATUS REPORT CAPIZ, ANTIQUE AND ILOILO (FEBRUARY and SEPTEMBER 2015)					
FLIGHT NO	**AREA**	**MISSION**	**OPERATOR**	**DATE FLOWN**	**REMARKS**
2538G	BLK 37A	2BLK37A040A	MVE TONGA	FEB 09, 2015	Mission completed
2540G	BLK37B	2BLK37B040B	RA FELISMINO	09 FEB 15	Mission completed for BLK37B and covered 5.5 lines of BLK37C
2778G	BLK 37A	2BLK37AC270A	MCE BALIGUAS	SEP 27, 2015	Covered BLKs37 A & C, changed of altitudes because of cloud build up. Restarted ALTM twice, POS turning red. Bright images captured in most of the lines. No digitizer
2786G	BLK 37A & 37B	2BLK37AB272A	RA FELISMINO	SEP 29, 2015	Covered several lines of BLK37A and one line from C but lots of voids due to clouds. No images on the last line. No digitizer.
2788G	BLK 37B	2BLK37BCD272B	MCE BALIGUAS	SEP 29, 2015	Supplementary flight for BLKs 37 A and B. Also covered BLK37D. Mission completed. No digitizer.

LAS BOUNDARIES PER MISSION FLIGHT

Flight No. :	2538G	
Area:	BLK 37A	Base: ILO-78 & ILO-3134
Mission Name:	2BLK37A040A	
Total Area Surveyed:	140.86 sq. km	

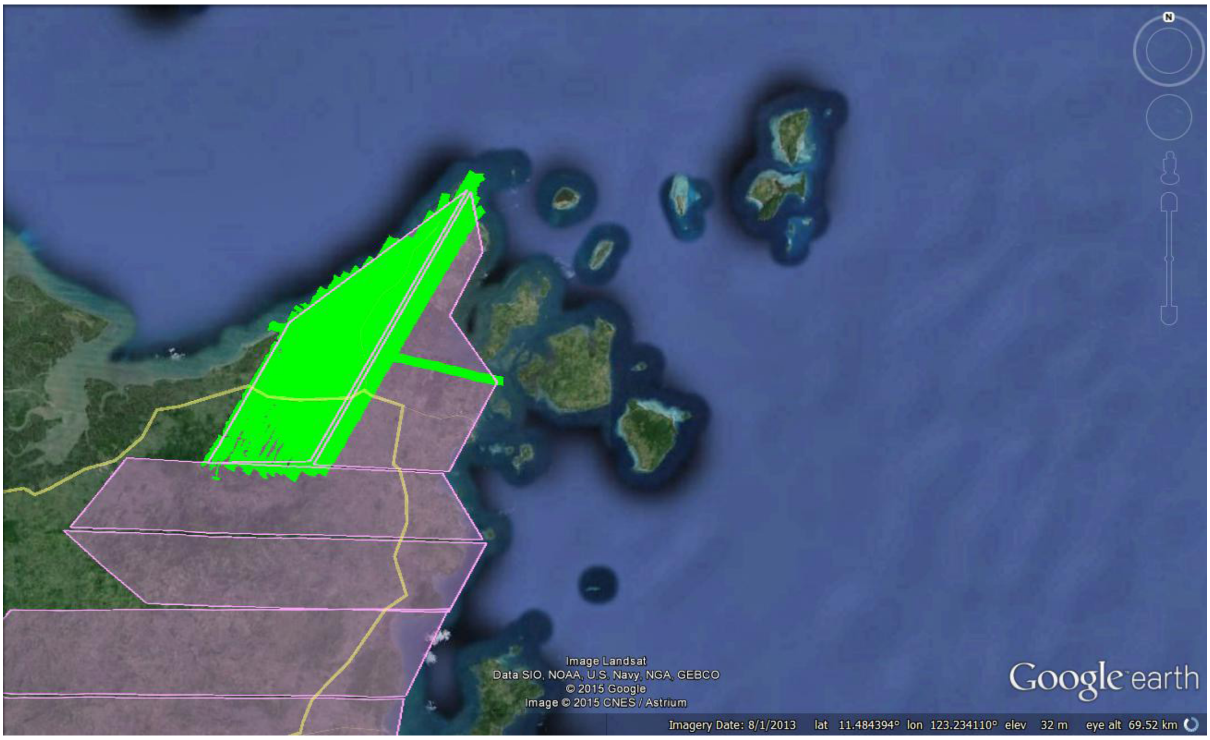


Figure A-7.1. Swath for Flight No. 2538G

Flight No. :	2540G	
Area:	BLK 37B	Base: ILO-78 & ILO-3134
Mission Name:	2BLK37BC040B	
Total Area Surveyed:	146.63 sq. km	

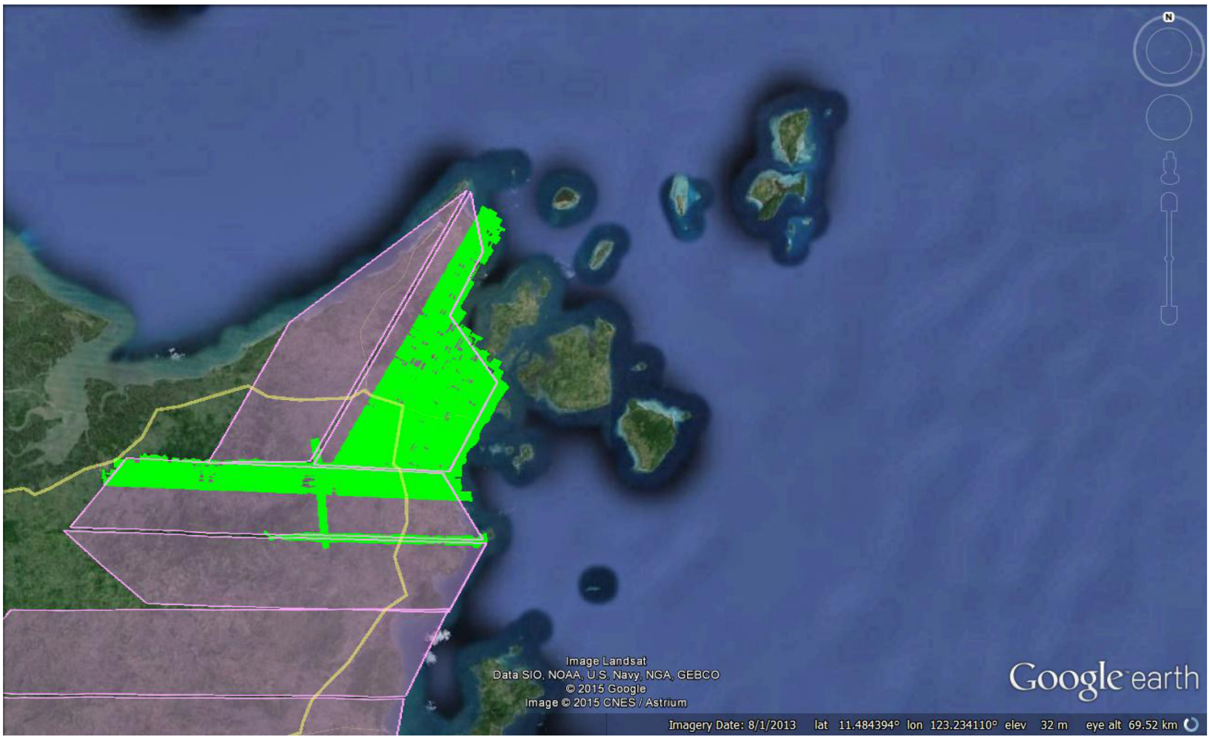


Figure A-7.2. Swath for Flight No. 2540G

Flight No. :	2778G
Area:	BLKs37 A & C
Mission Name:	2BLK37AC270A
Parameters:	FOR BLK37C: Alt: 1000m; Scan Fz: 50; Scan angle: 15; PRF: 100
	FOR BLK37A: Alt: 850m; Scan Fz: 50; Scan angle: 20; PRF: 125
Area surveyed:	187.46 sq. km.

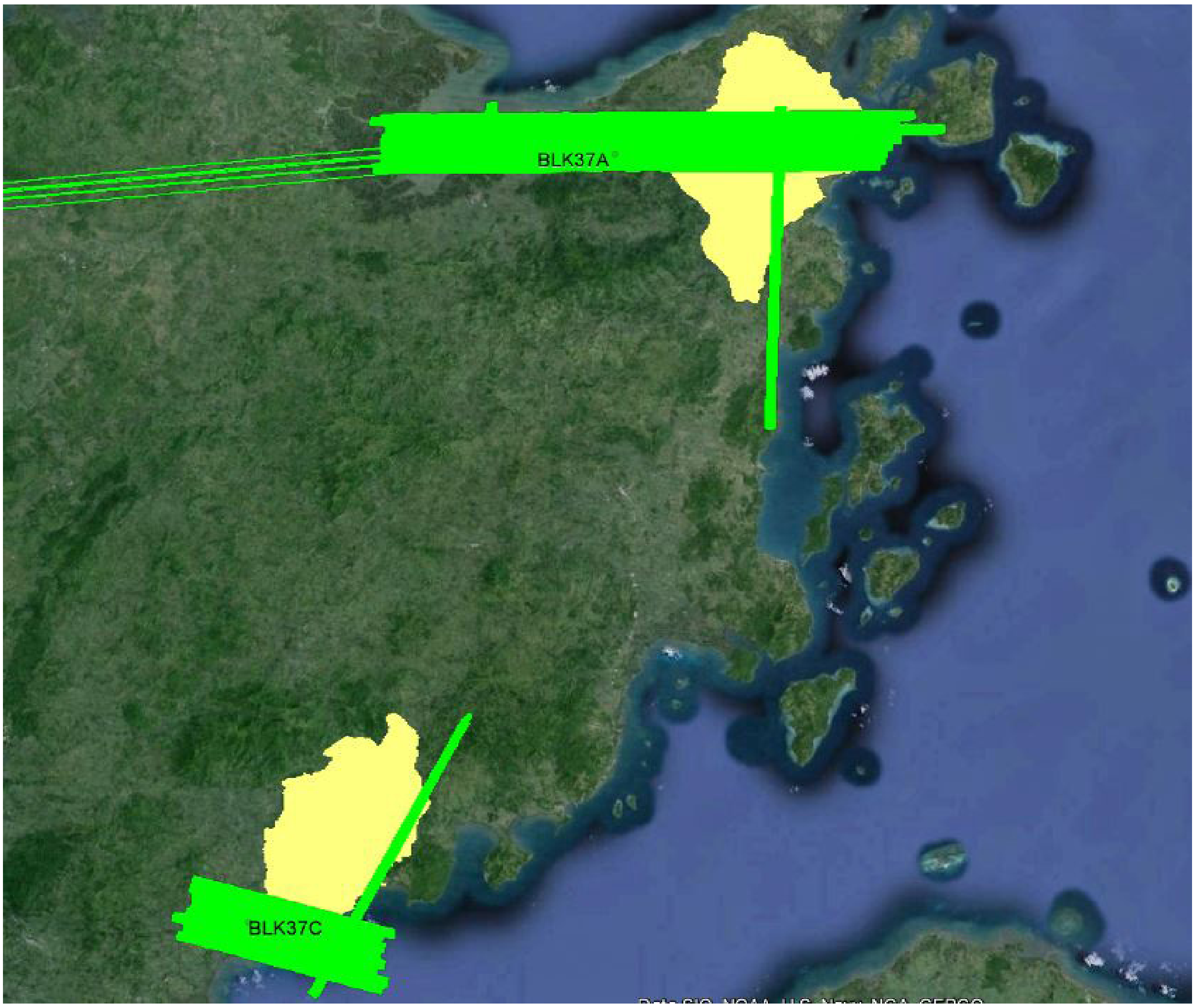


Figure A-7.3. Swath for Flight No. 2778G

Flight No. :	2786G
Area:	BLKs37 A & C
Mission Name:	2BLK37AB272A
Parameters:	Alt: 1000m; Scan Fz: 50; Scan angle: 15; PRF: 100
Area surveyed:	131.32 sq. km.

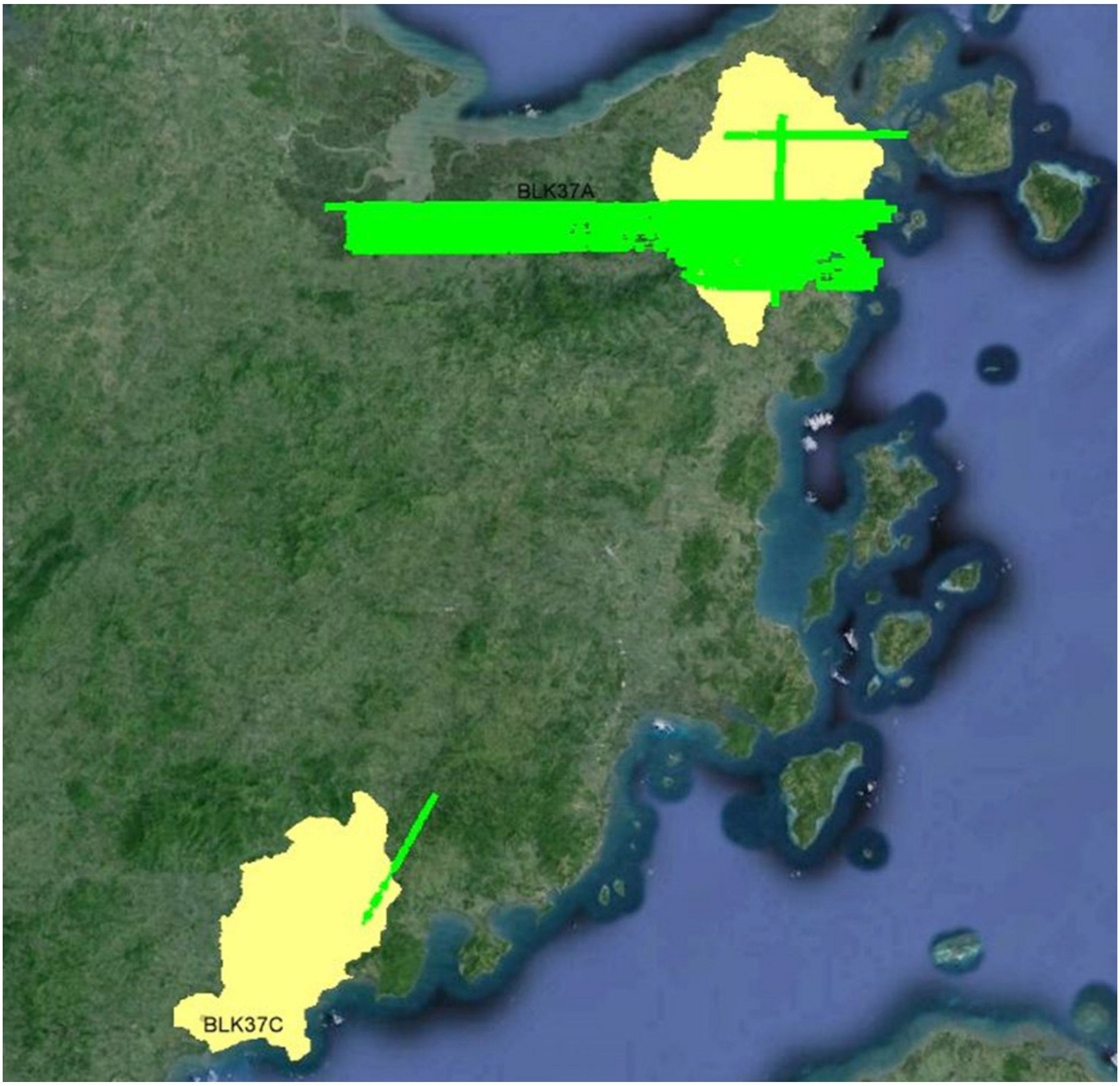


Figure A-7.4. Swath for Flight No. 2786G

Flight No. :	2788G
Area:	BLKs37 B, C & D
Mission Name:	2BLK37BCD272B
Parameters:	Alt: 800m; Scan Fz: 50; Scan angle: 20; PRF: 125
Area surveyed:	178.88 sq. km.

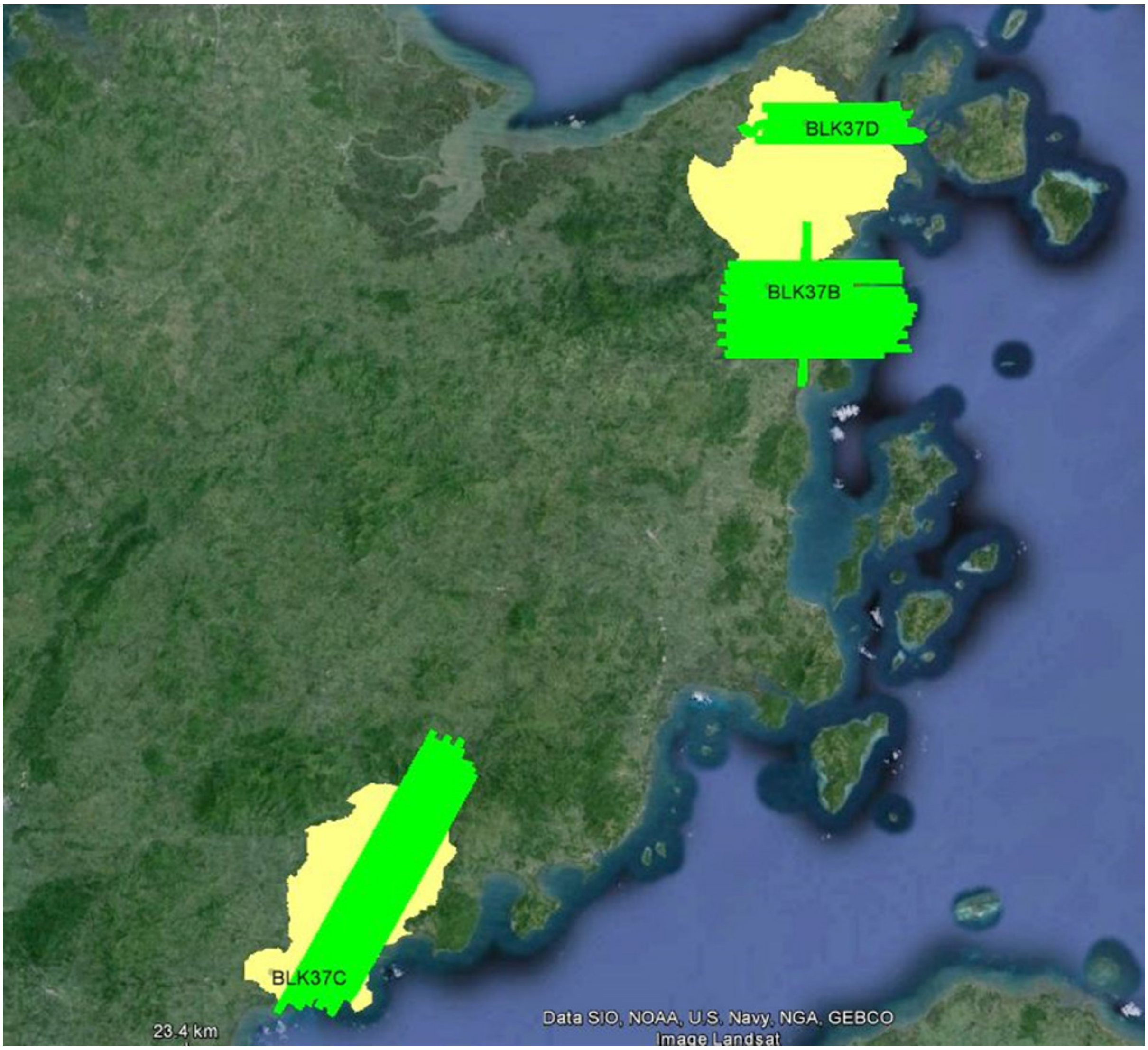


Figure A-7.5. Swath for Flight No. 2788G

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk37A

Flight Area	**Capiz_Aklan**
Mission Name	**Blk37A**
Inclusive Flights	2778G, 2786G
Range data size	29.3 GB
POS	242 MB
Base data size	240.7 MB
Image	53.8 GB
Transfer date	November 9, 2015
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)	1.633
RMSE for East Position (<4.0 cm)	1.457
RMSE for Down Position (<8.0 cm)	4.49
Boresight correction stdev (<0.001deg)	0.000404
IMU attitude correction stdev (<0.001deg)	0.006750
GPS position stdev (<0.01m)	0.0034
Minimum % overlap (>25)	24.93
Ave point cloud density per sq.m. (>2.0)	3.63
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	147
Maximum Height	517.07 m
Minimum Height	57.30 m
Classification (# of points)	
Ground	51,565,925
Low vegetation	45,243,218
Medium vegetation	296,746,020
High vegetation	100,133,685
Building	1,628,253
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Jovelle Anjeanette Canlas, Jovy Narisma

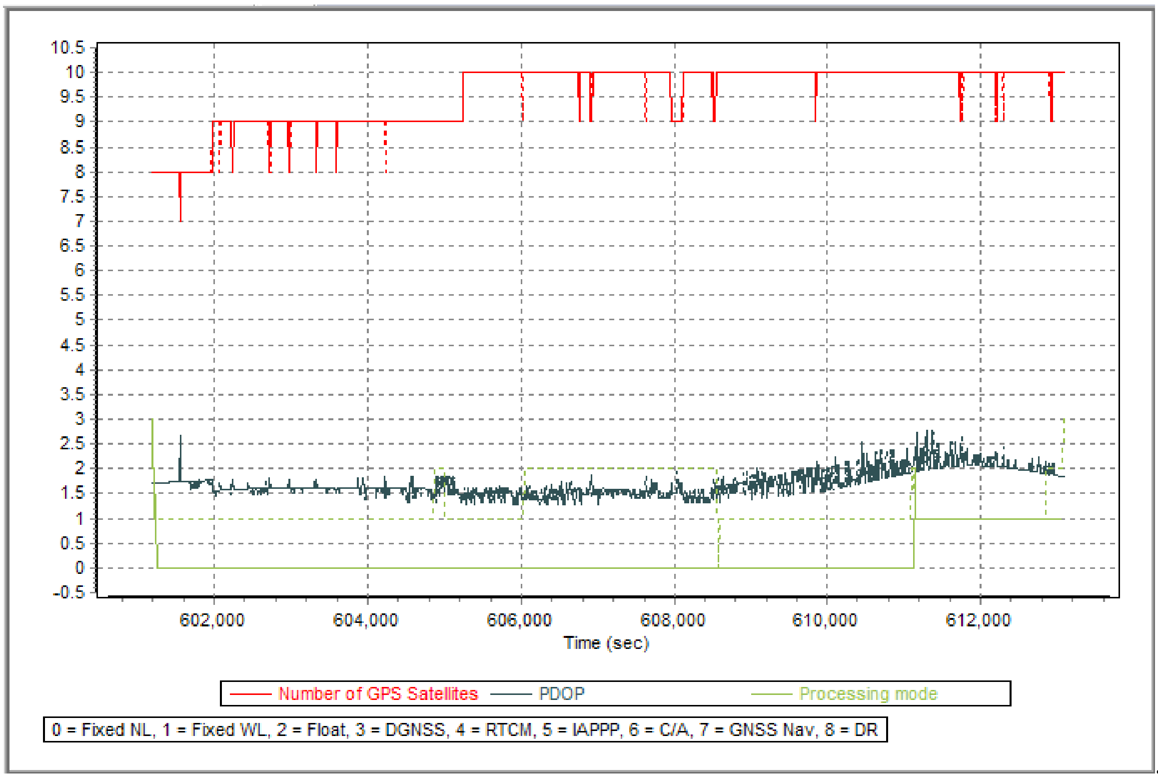


Figure A-8.1. Solution Status

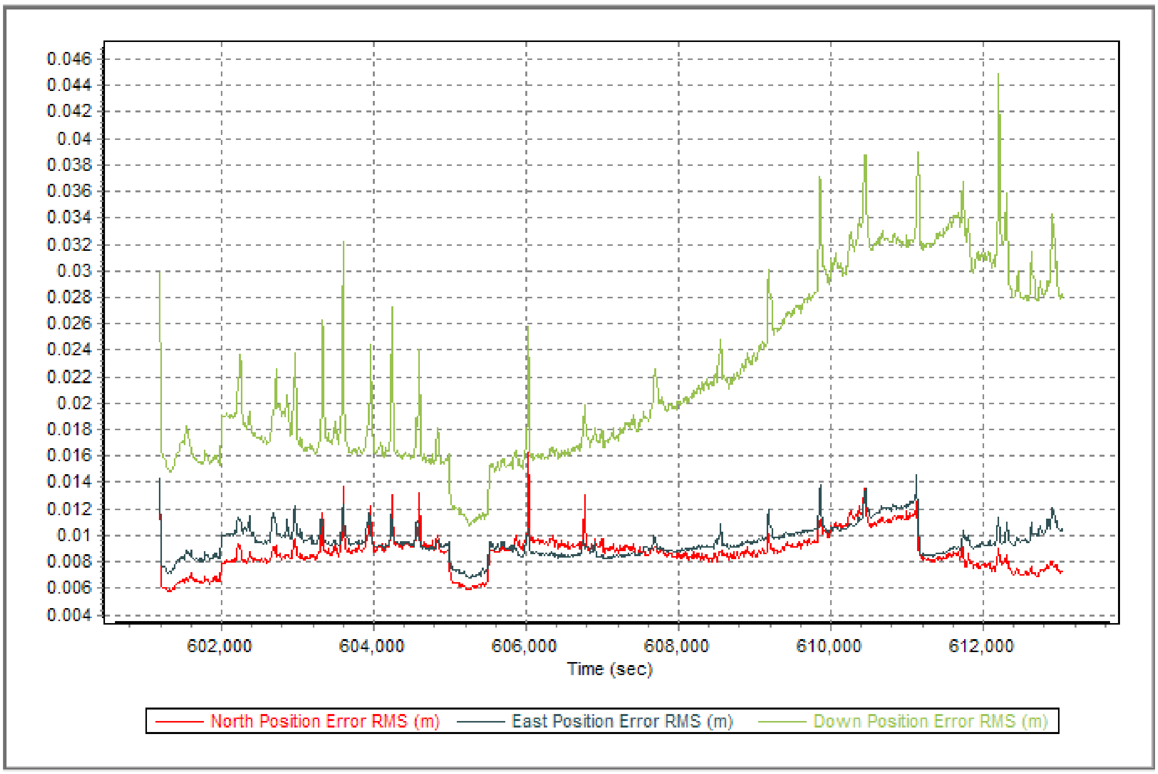


Figure A-8.2. Smoothed Performance Metric Parameters

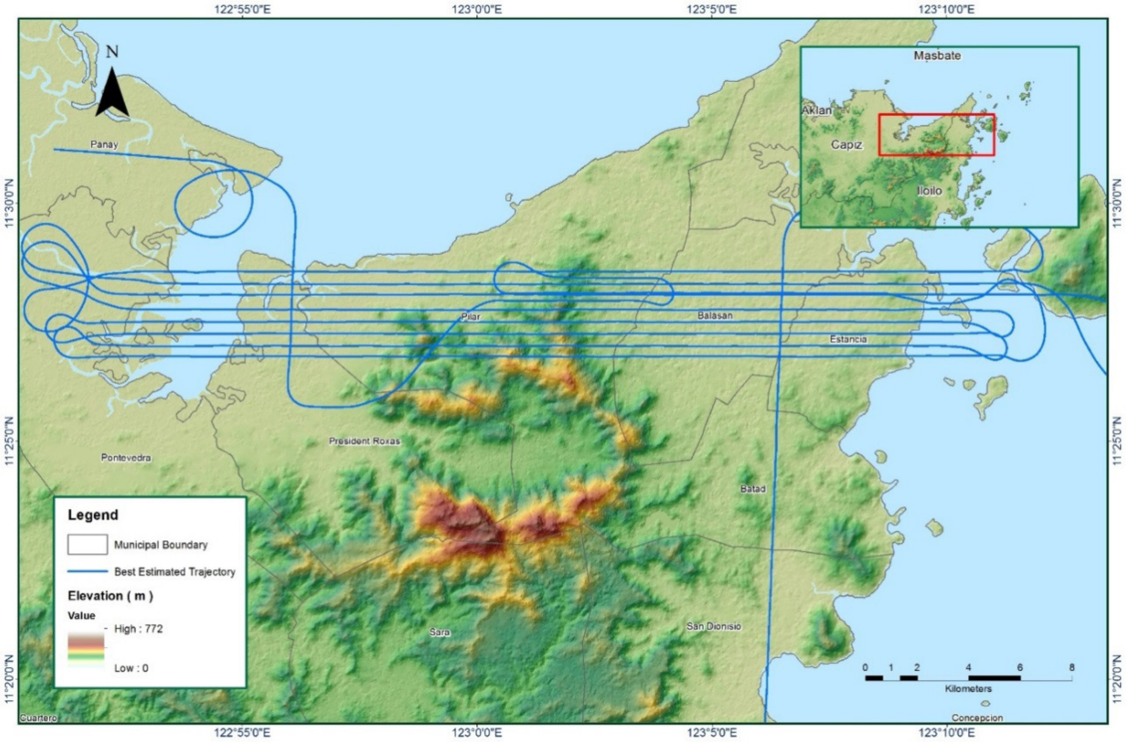


Figure A-8.3. Best Estimated Trajectory

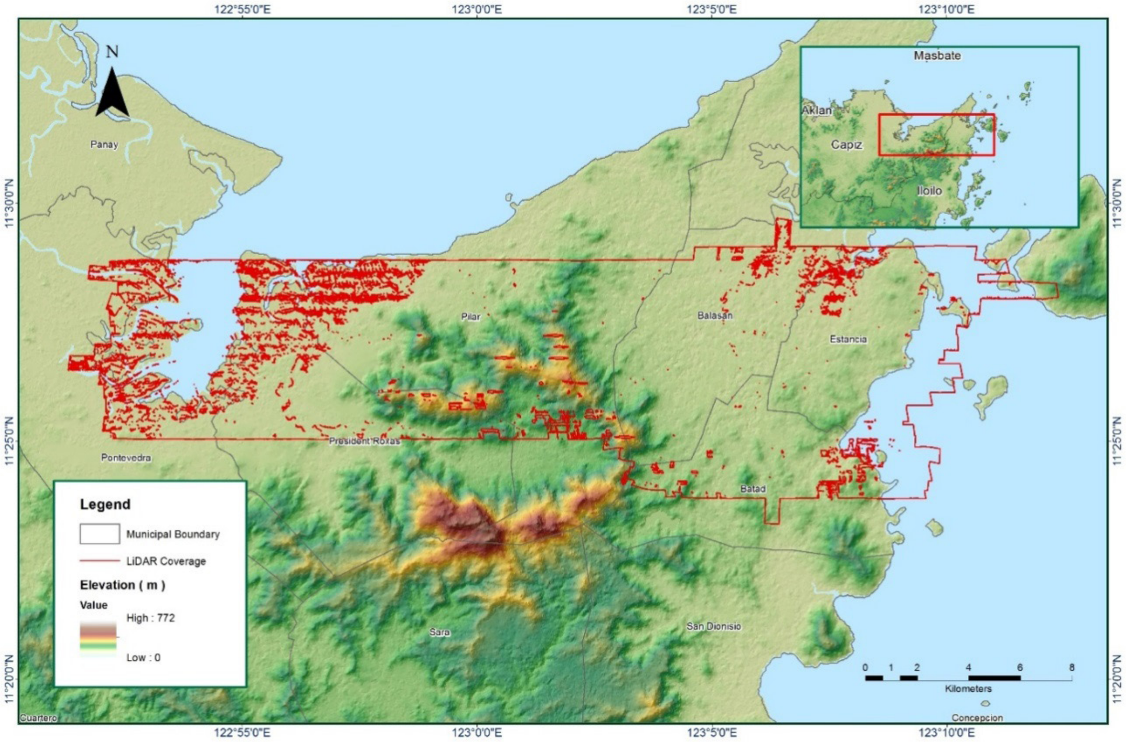


Figure A-8.4. Coverage of LiDAR data

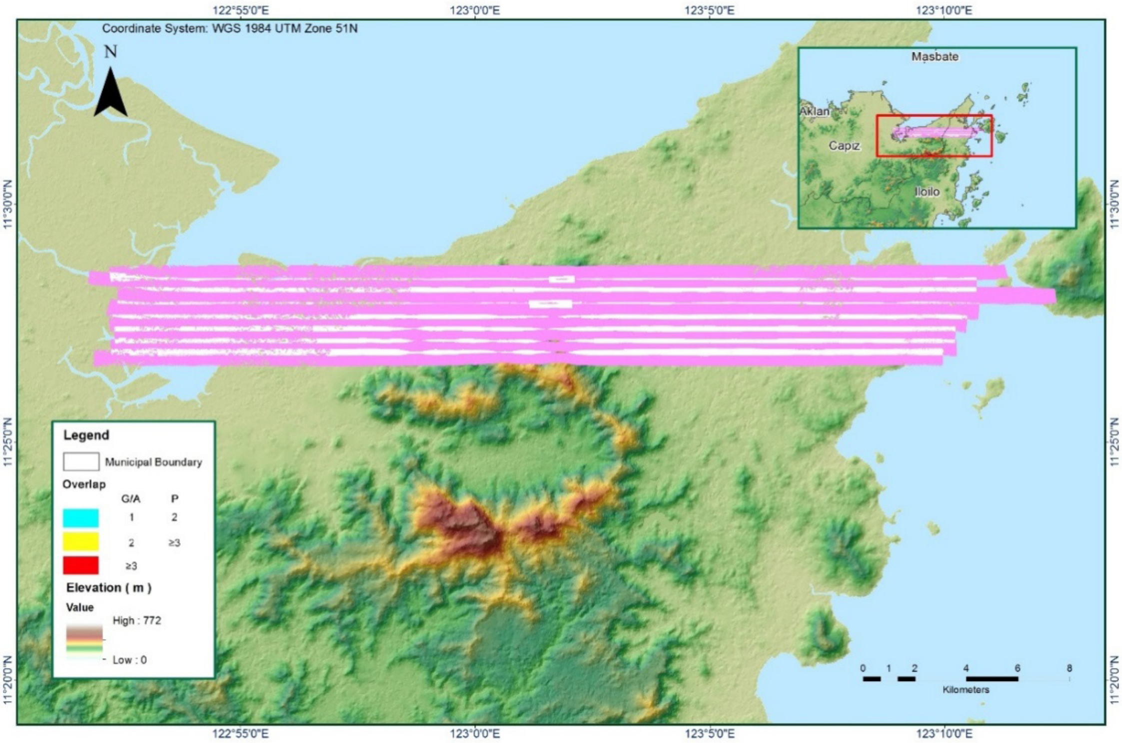


Figure A-8.5. Image of data overlap

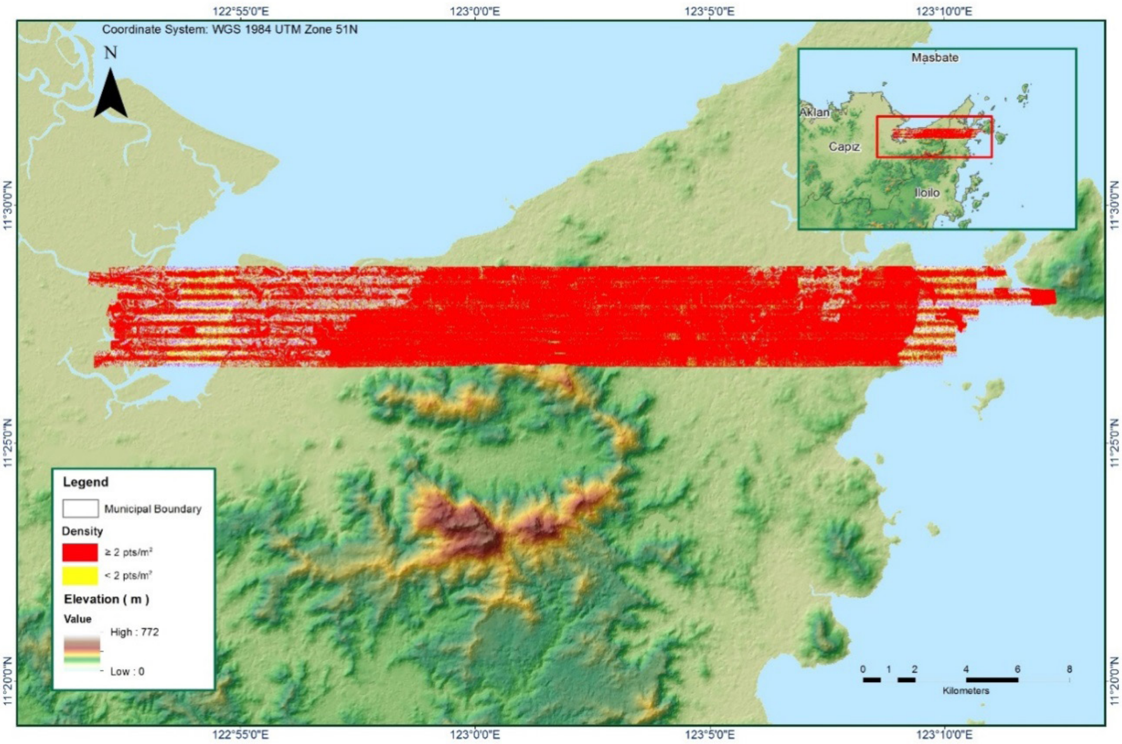


Figure A-8.6. Density map of merged LiDAR data

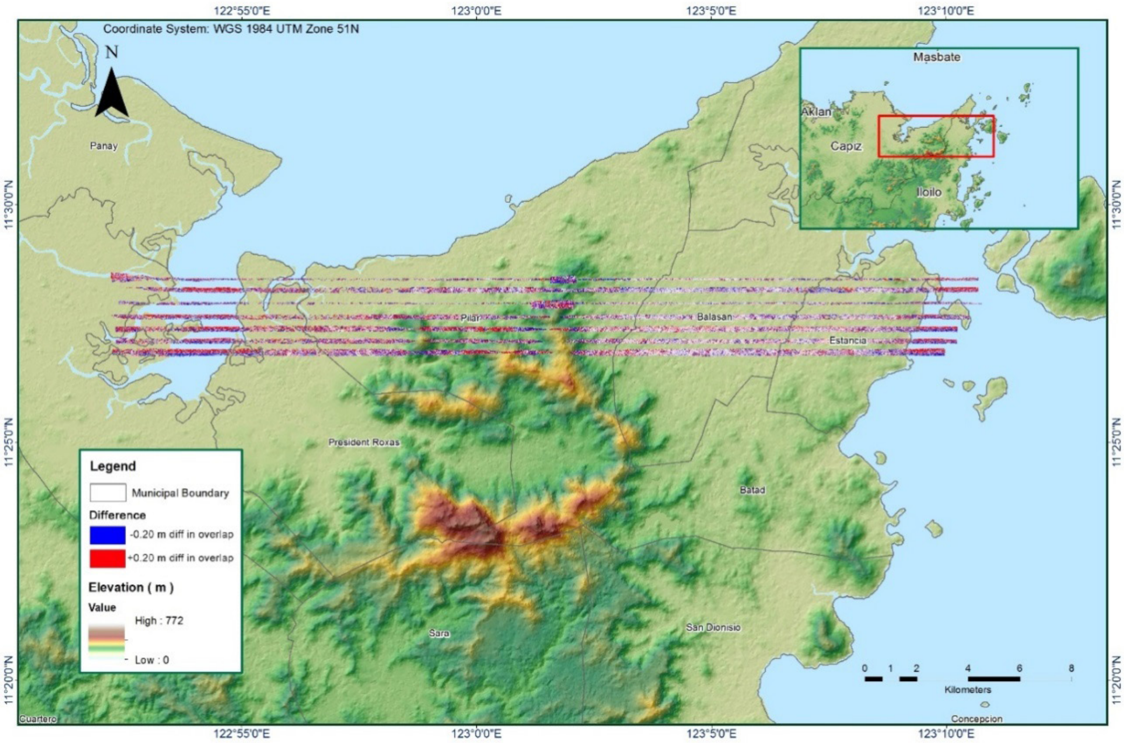


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk37B

Flight Area	Capiz_Aklan
Mission Name	**Blk37B**
Inclusive Flights	2788G
Range data size	30.7 GB
POS	255 MB
Base data size	89.7 MB
Image	59.1 GB
Transfer date	November, 9, 2015
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)	2.147
RMSE for East Position (<4.0 cm)	1.877
RMSE for Down Position (<8.0 cm)	4.287
Boresight correction stdev (<0.001deg)	0.001772
IMU attitude correction stdev (<0.001deg)	0.007061
GPS position stdev (<0.01m)	0.0022
Minimum % overlap (>25)	24.86
Ave point cloud density per sq.m. (>2.0)	4.17
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	93
Maximum Height	377.74 m
Minimum Height	59.28 m
Classification (# of points)	
Ground	26,635,685
Low vegetation	26,063,089
Medium vegetation	184,015,461
High vegetation	50,989,852
Building	131,726
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Ma. Joanne Balaga, Alex John Escobido

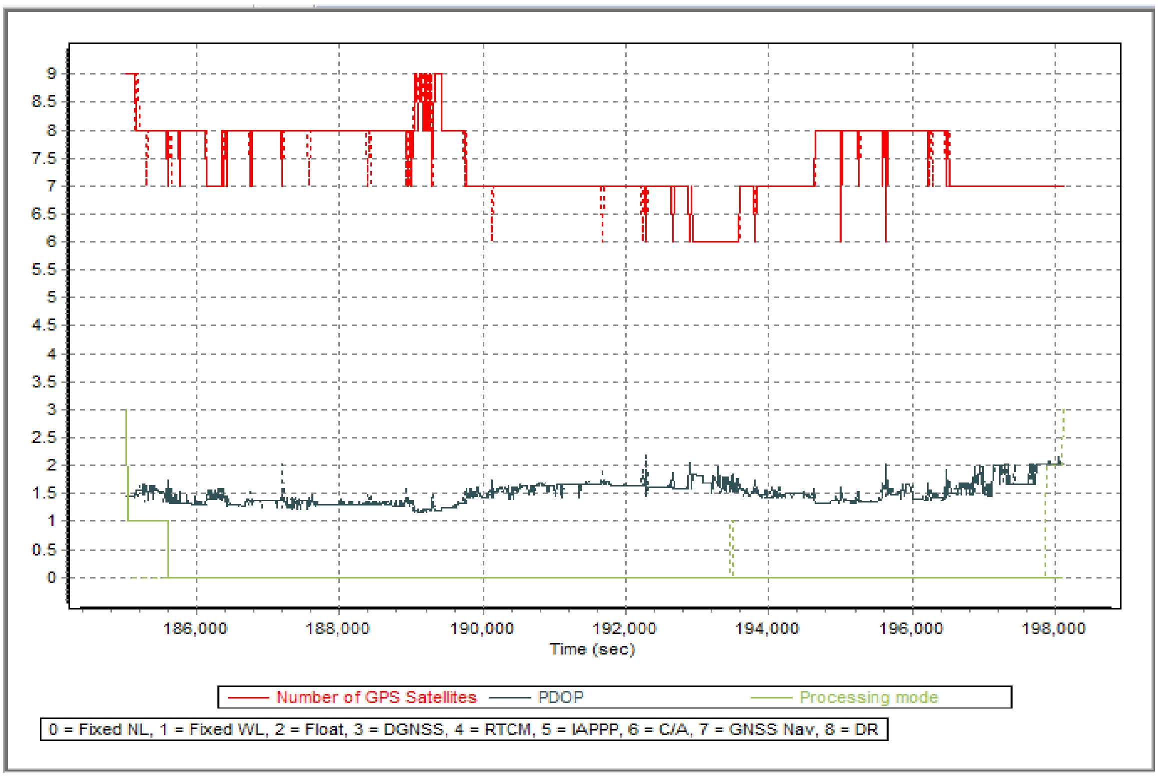


Figure A-8.8. Solution Status

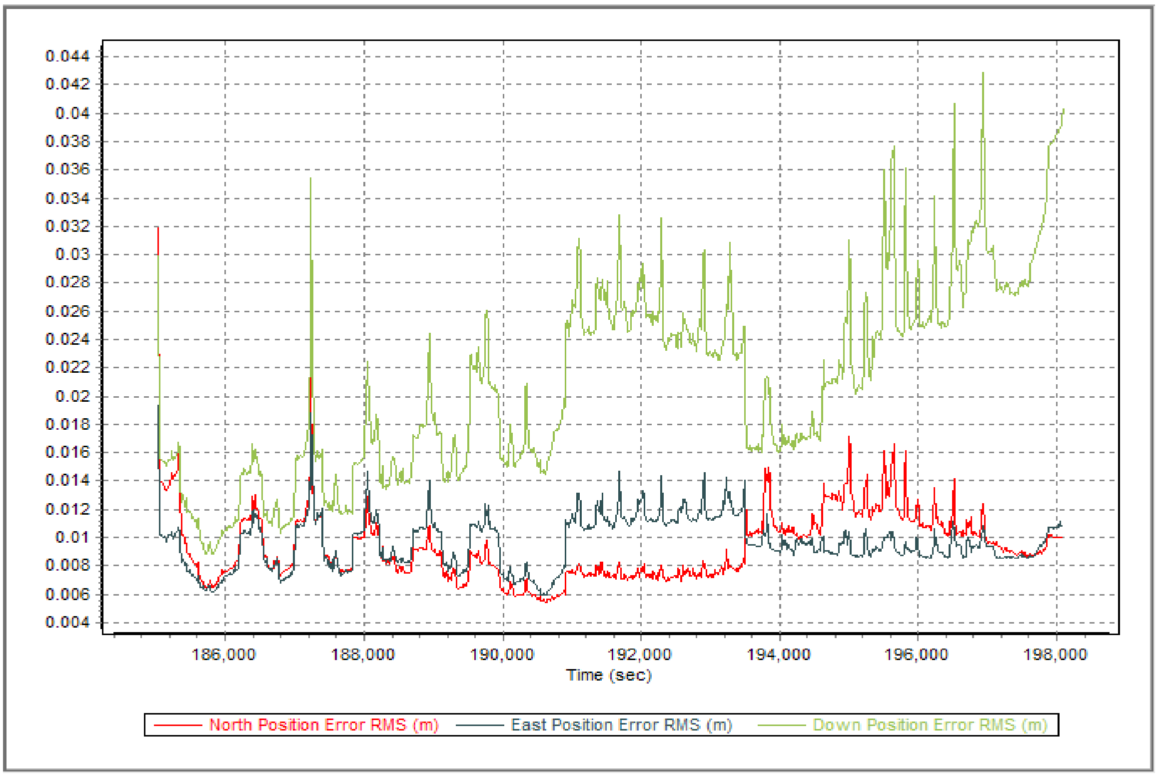


Figure A-8.9. Smoothed Performance Metric Parameters

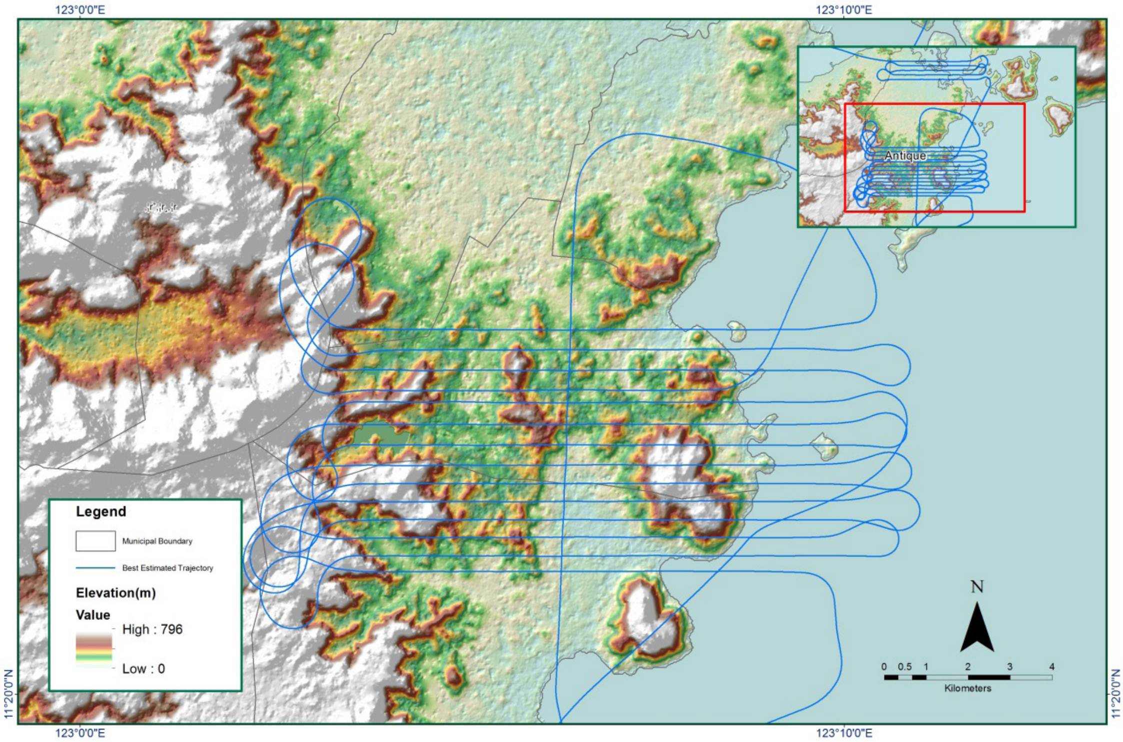


Figure A-8.10. Best Estimated Trajectory

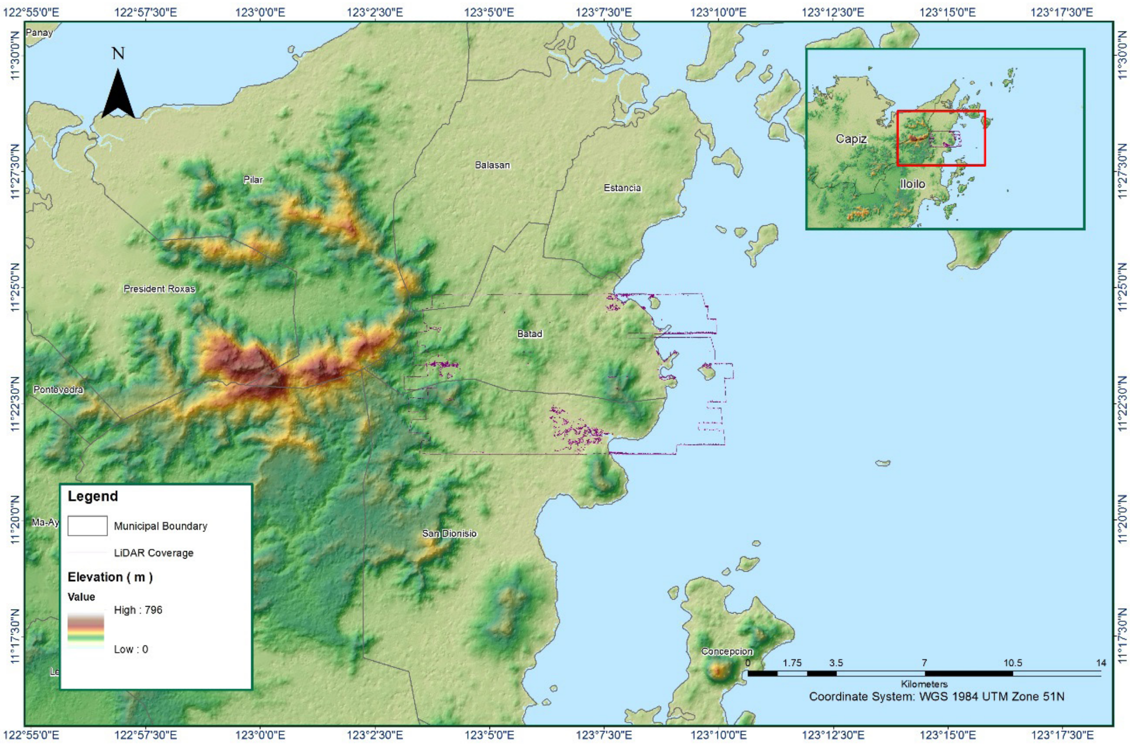


Figure A-8.11. Coverage of LiDAR data

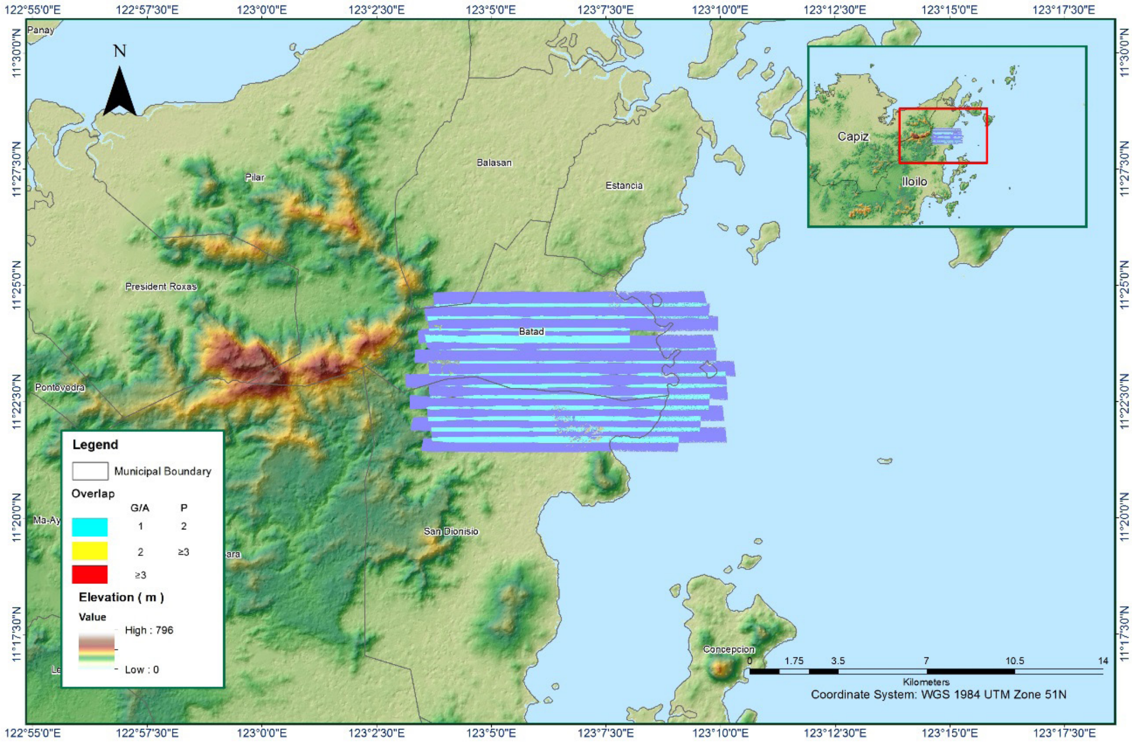


Figure A-8.12. Image of data overlap

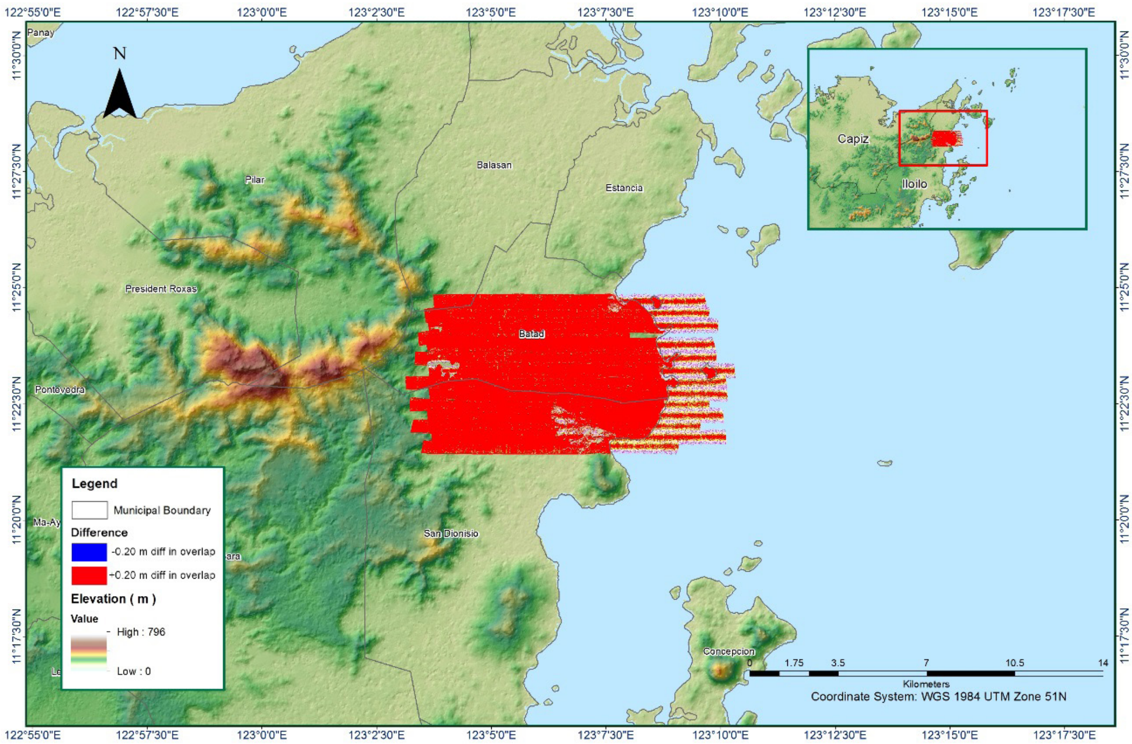


Figure A-8.13. Density map of merged LiDAR data

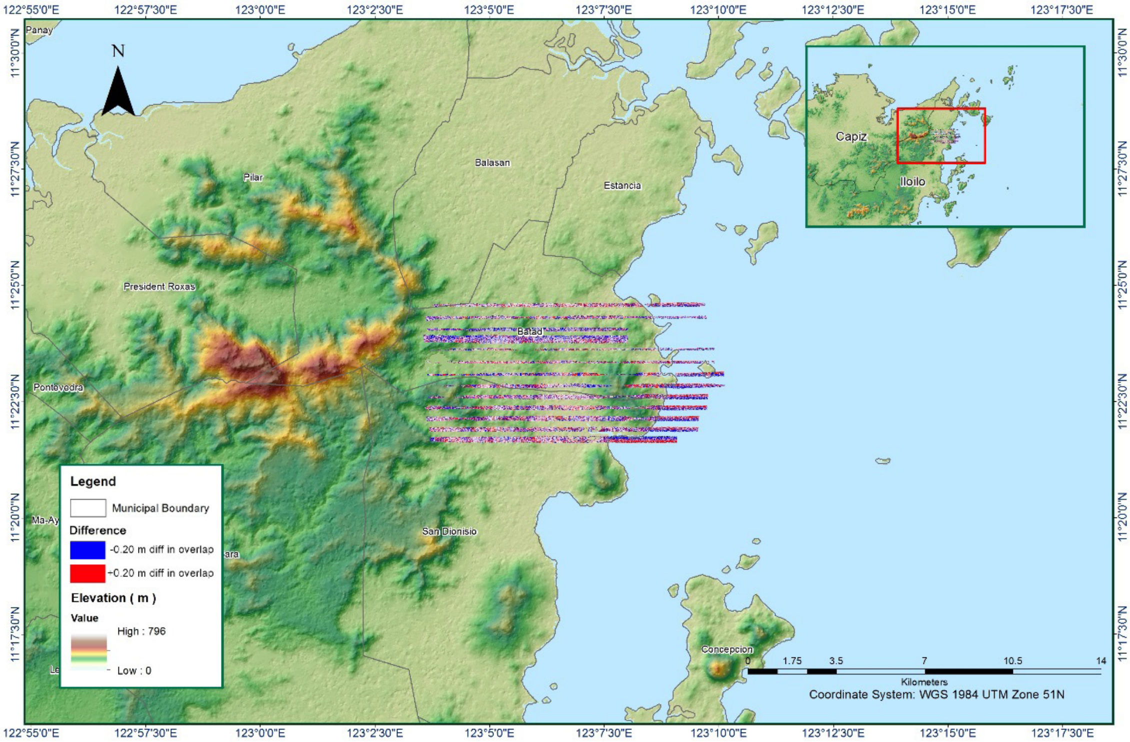


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk37D

Flight Area	**Capiz_Aklan**
Mission Name	**Blk37D**
Inclusive Flights	2788G
Range data size	30.7 GB
POS	255 MB
Base data size	89.7 MB
Image	59.1 GB
Transfer date	November, 9, 2015
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)	2.146
RMSE for East Position (<4.0 cm)	1.877
RMSE for Down Position (<8.0 cm)	4.286
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	6.51
Ave point cloud density per sq.m. (>2.0)	2.71
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	45
Maximum Height	151.09 m
Minimum Height	58.28 m
Classification (# of points)	
Ground	11,107,474
Low vegetation	5,635,834
Medium vegetation	32,466,973
High vegetation	6,113,824
Building	39,814
Orthophoto	Yes
Processed by	Engr. Sheila-Maye Santillan, Engr. Ma. Joanne Balaga, Jovy Narisma

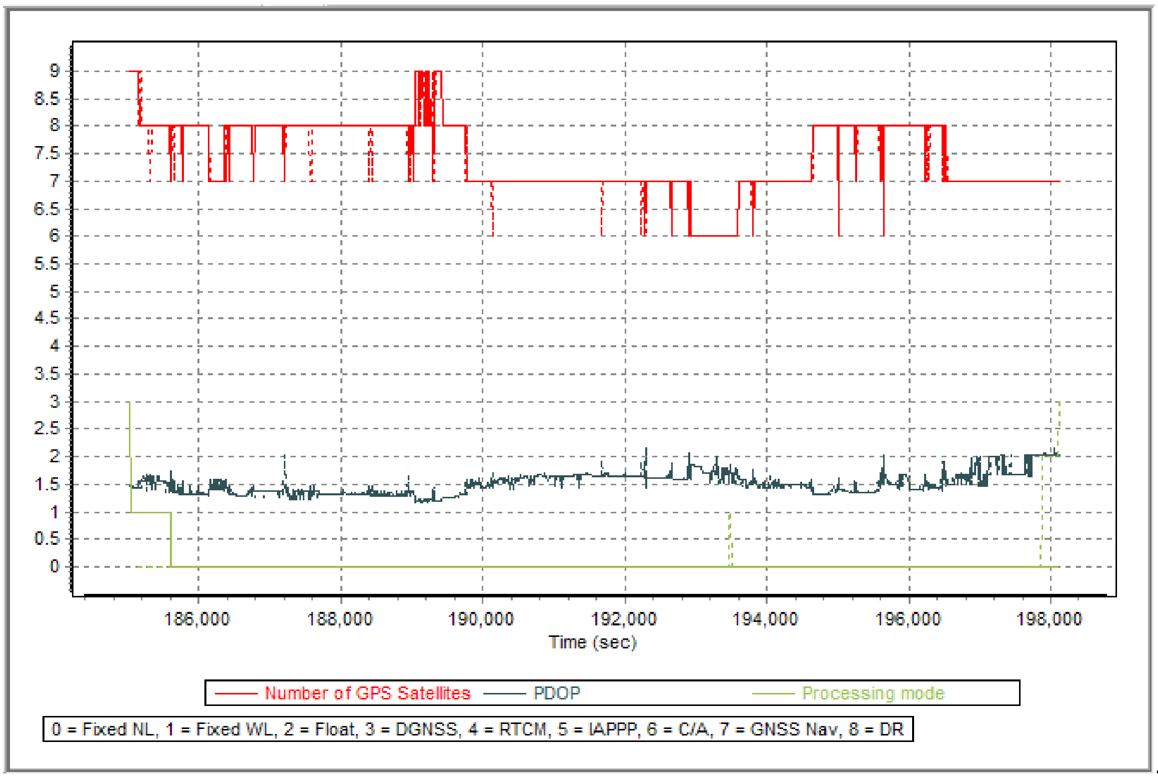


Figure A-8.15. Solution Status

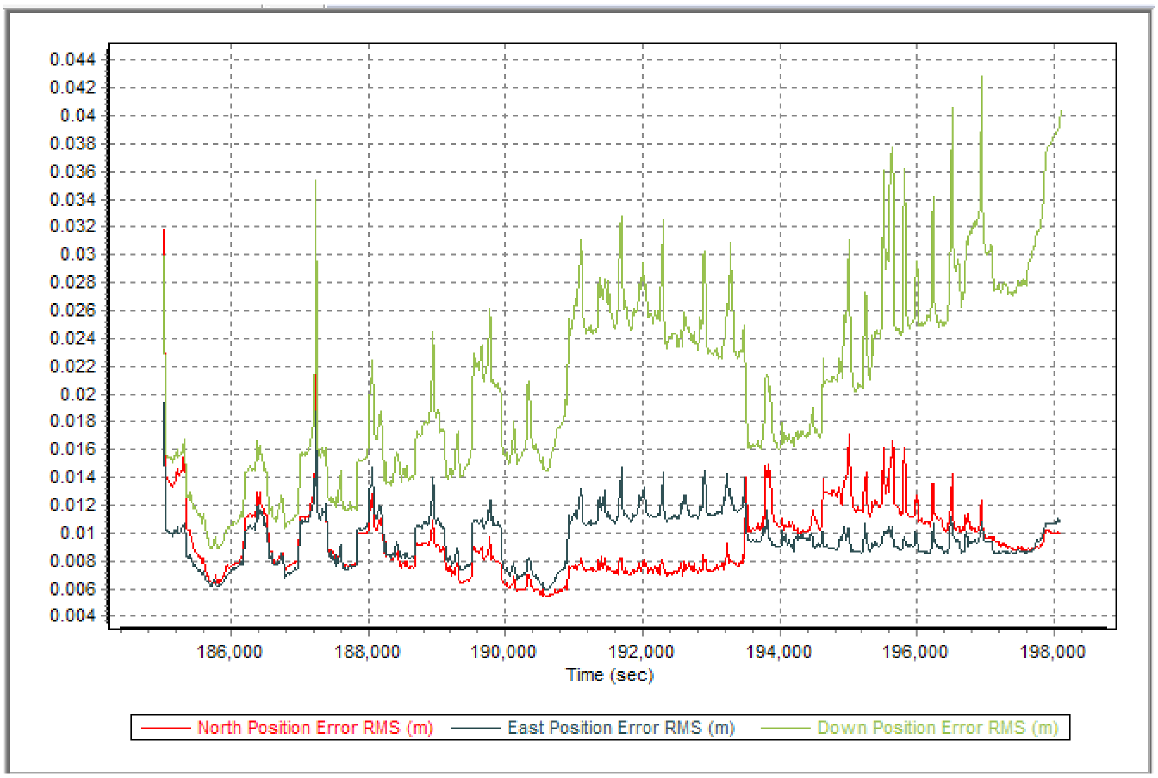


Figure A-8.16. Smoothed Performance Metric Parameters

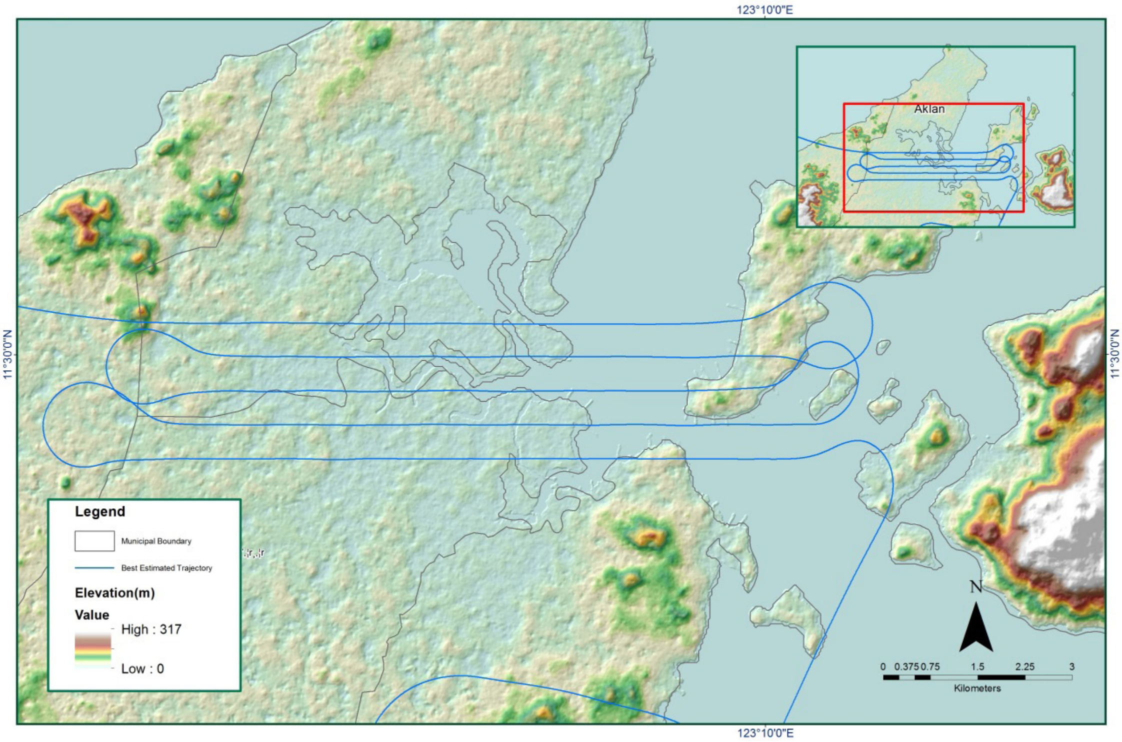


Figure A-8.17. Best Estimated Trajectory

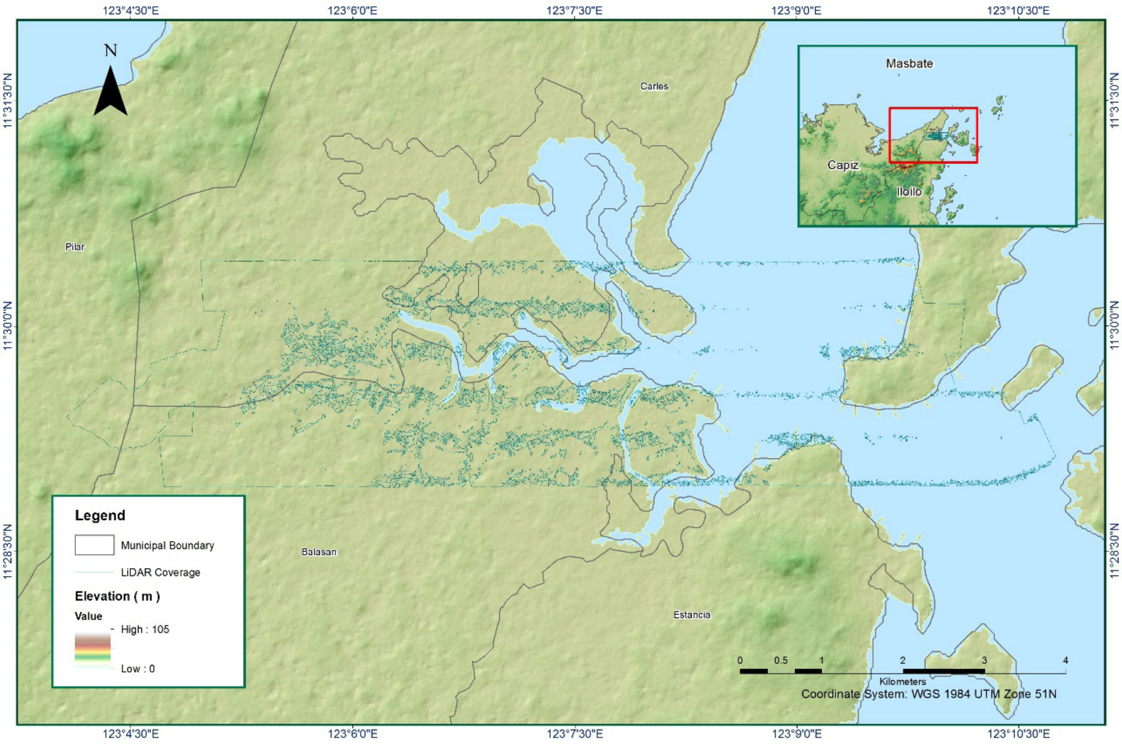


Figure A-8.18. Coverage of LiDAR data

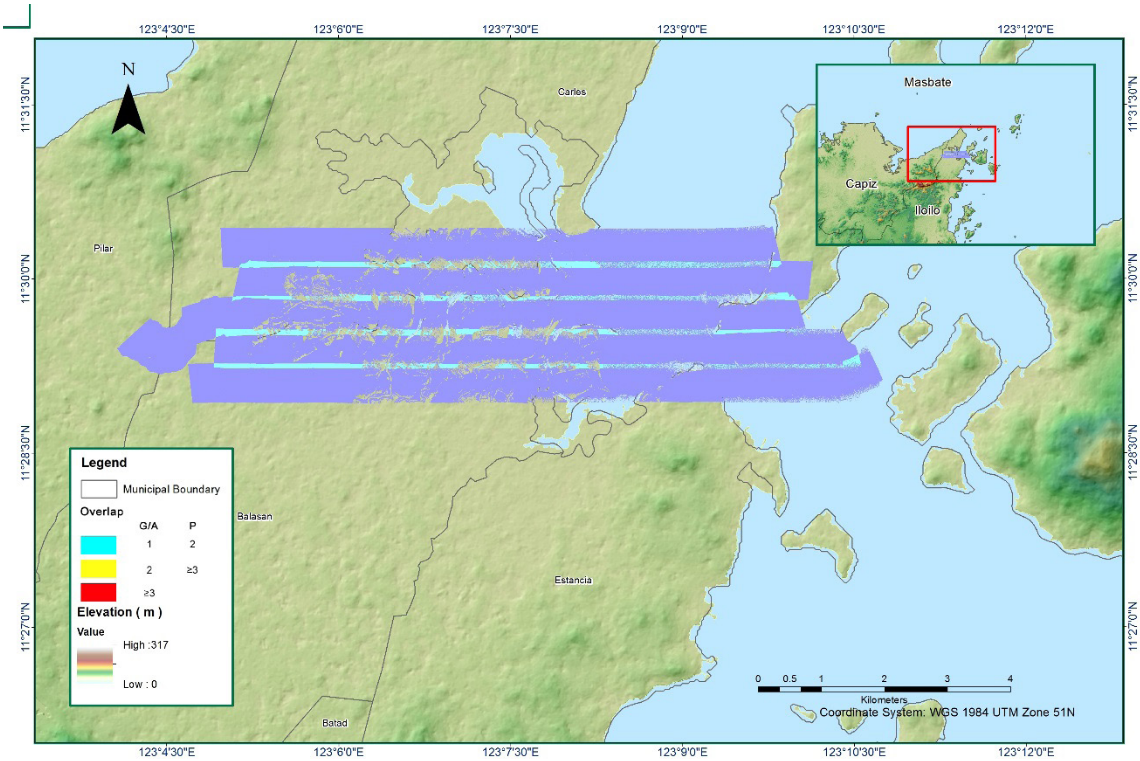


Figure A-8.19. Image of data overlap

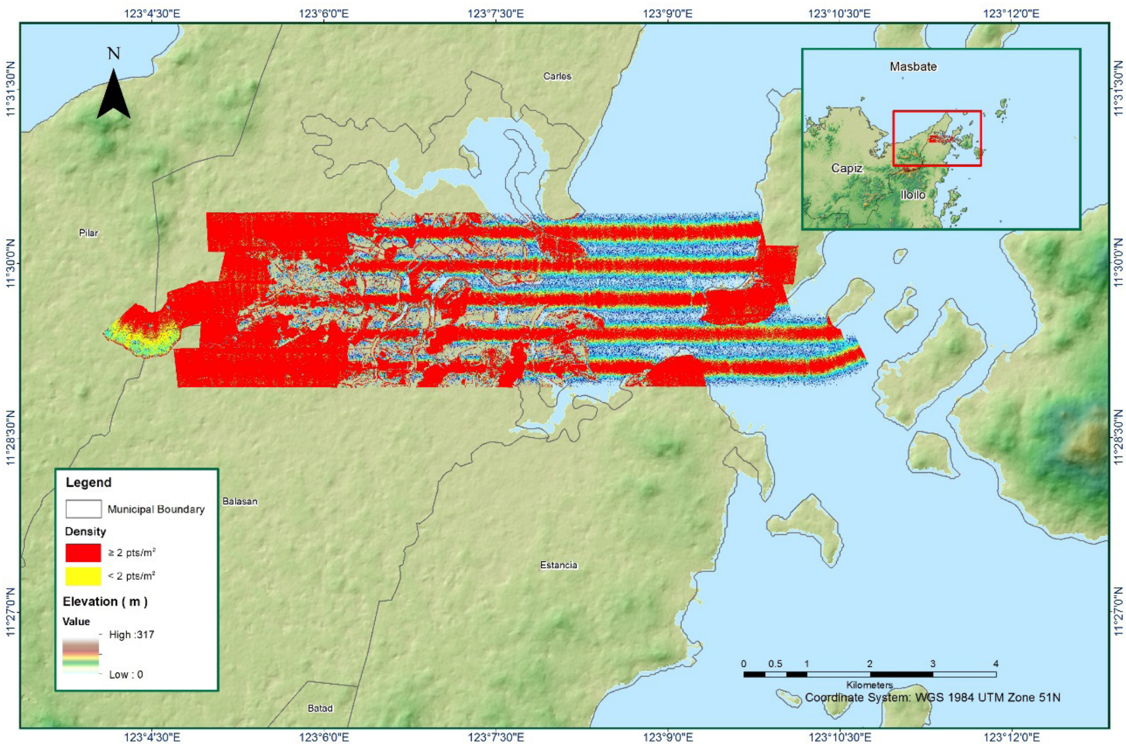


Figure A-8.20. Density map of merged LiDAR data

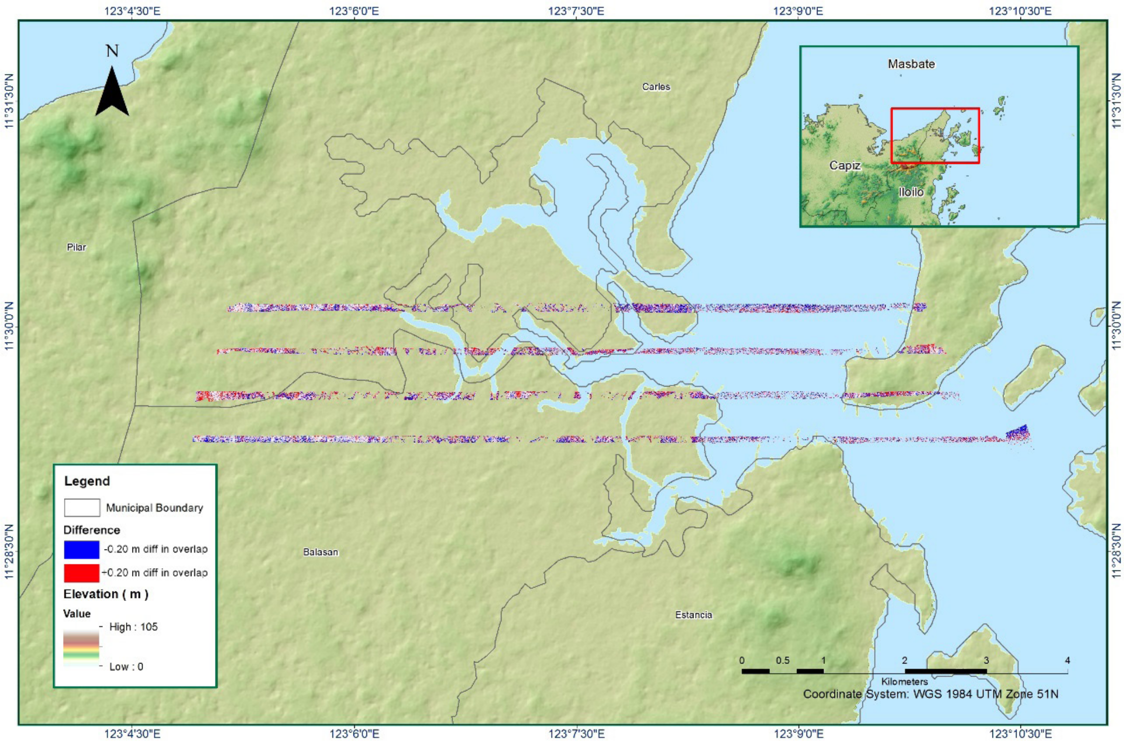


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk37A_supplement

Flight Area	Capiz_Aklan
Mission Name	**Blk37A_supplement**
Inclusive Flights	2786G
Range data size	25.5 GB
POS	262 MB
Base data size	89.7 MB
Image	44.6 GB
Transfer date	November 9, 2015
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)	3.892
RMSE for East Position (<4.0 cm)	5.836
RMSE for Down Position (<8.0 cm)	1.176
Boresight correction stdev (<0.001deg)	NA
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	NA
Minimum % overlap (>25)	51.06 %
Ave point cloud density per sq.m. (>2.0)	5.43
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	188
Maximum Height	637.47 m
Minimum Height	57.14 m
Classification (# of points)	
Ground	54,479,130
Low vegetation	65,242,359
Medium vegetation	339,729,055
High vegetation	147,719,576
Building	3,045,187
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Merven Matthew Natino, Engr. Gladys Mae Apat

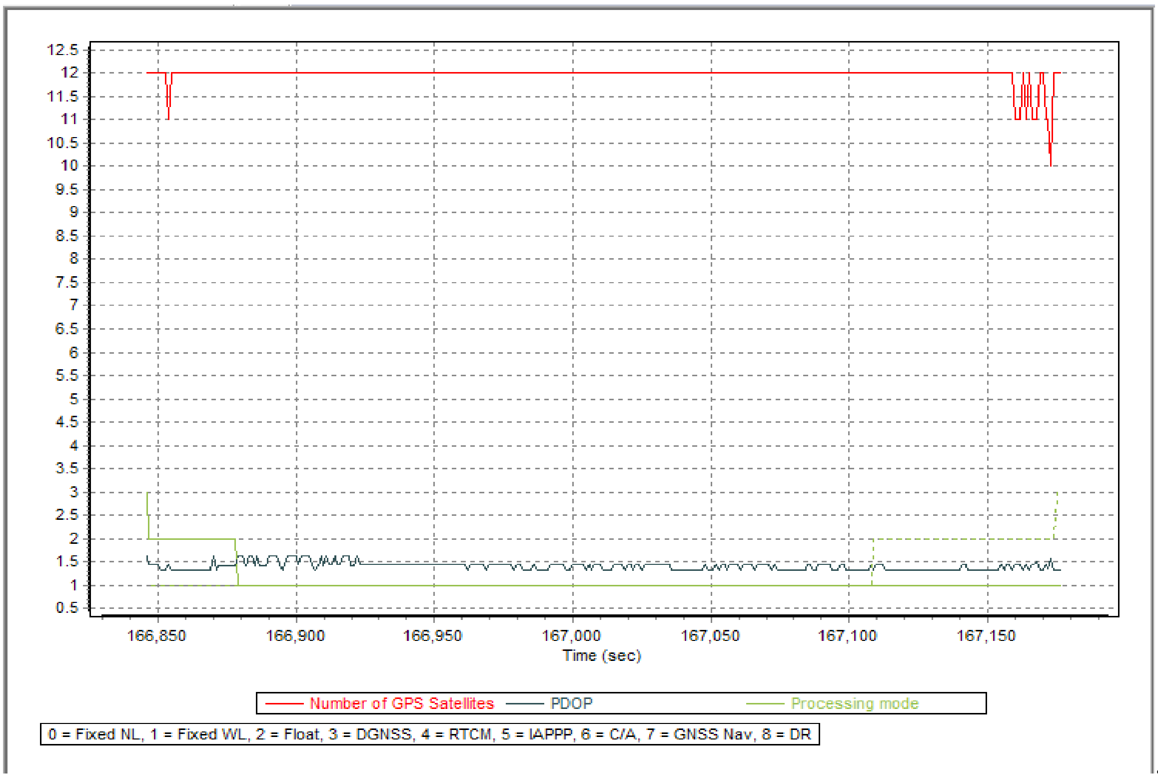


Figure A-8.22. Solution Status

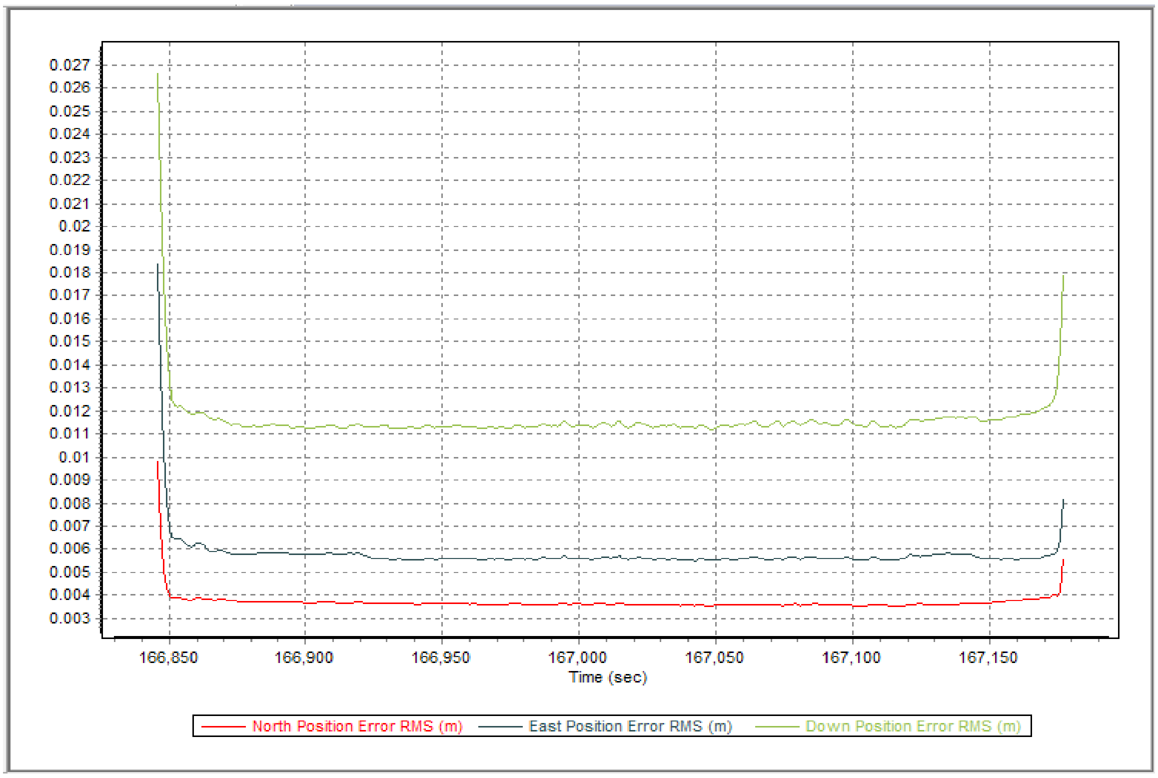


Figure A-8.23. Smoothed Performance Metric Parameters

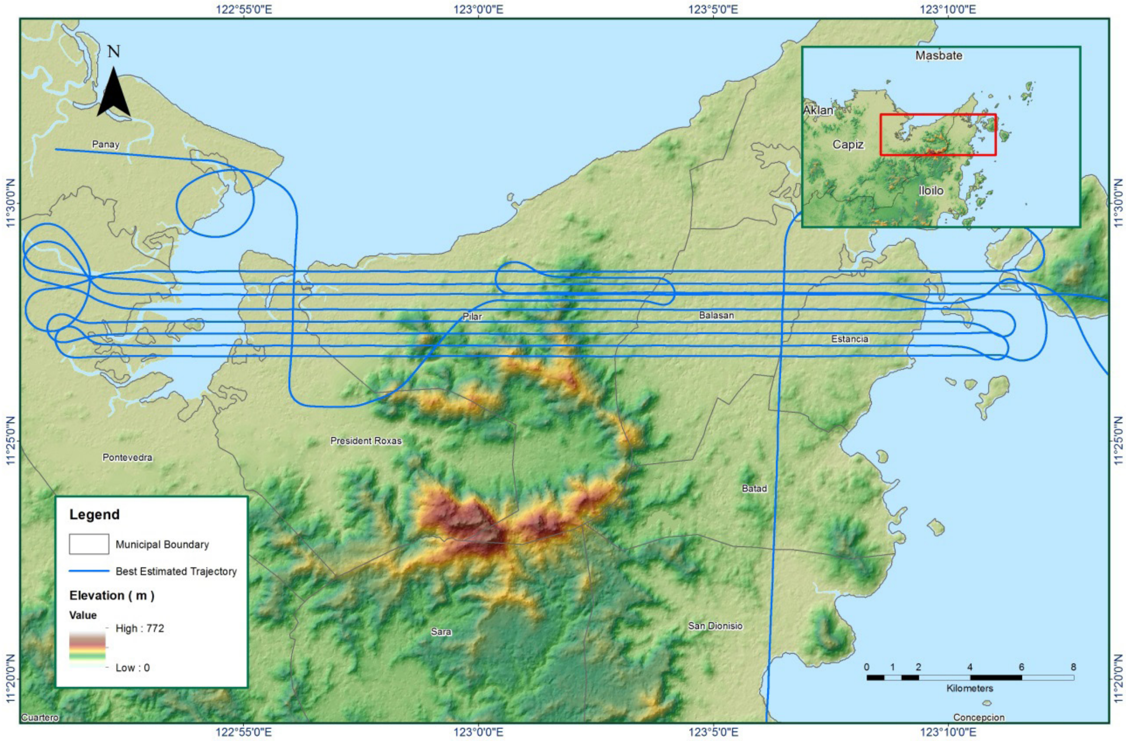


Figure A-8.24. Best Estimated Trajectory

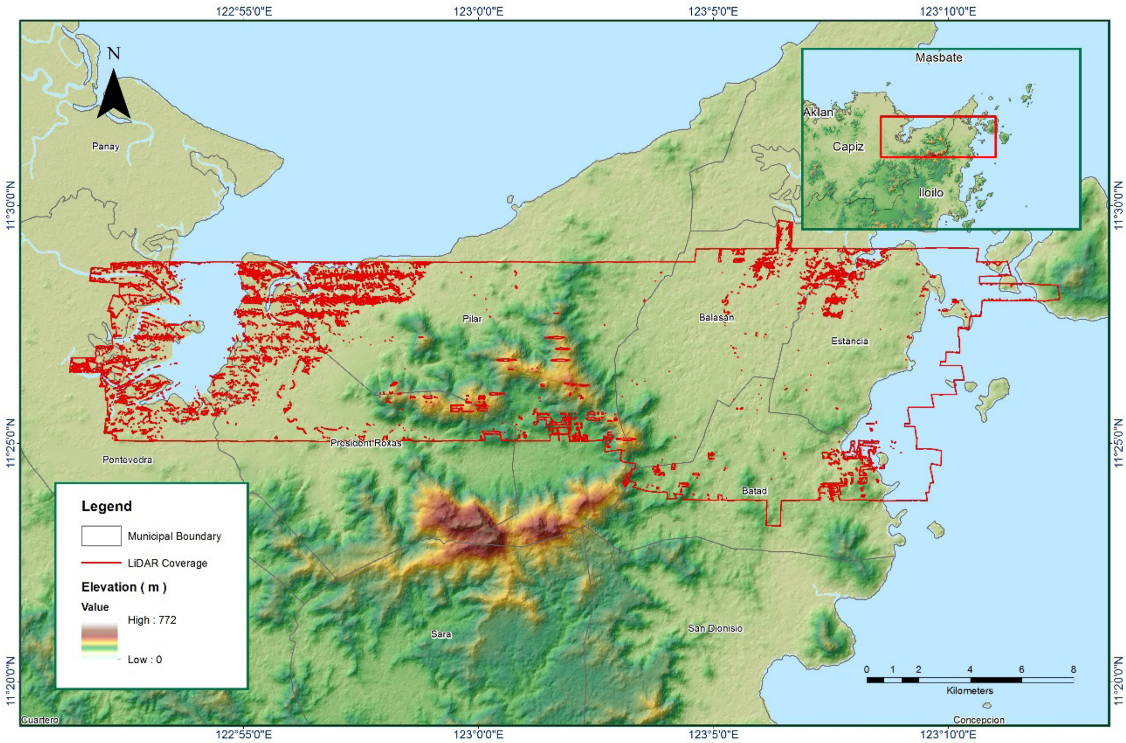


Figure A-8.25. Coverage of LiDAR data

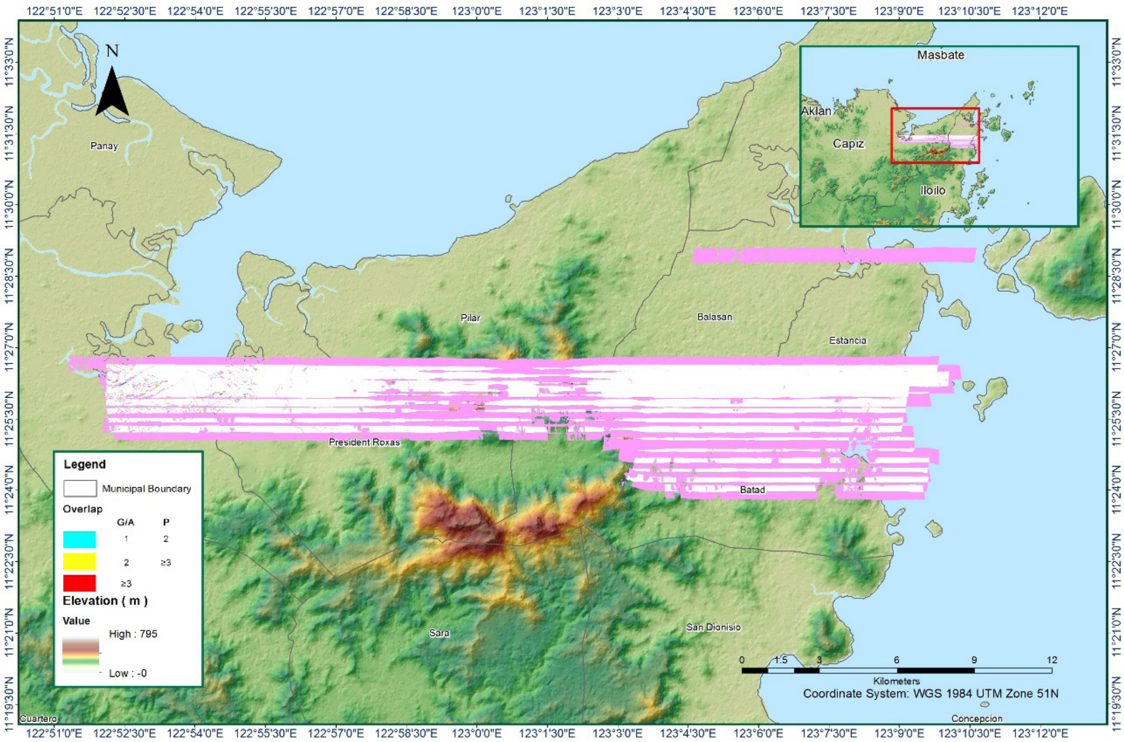


Figure A-8.26. Image of data overlap

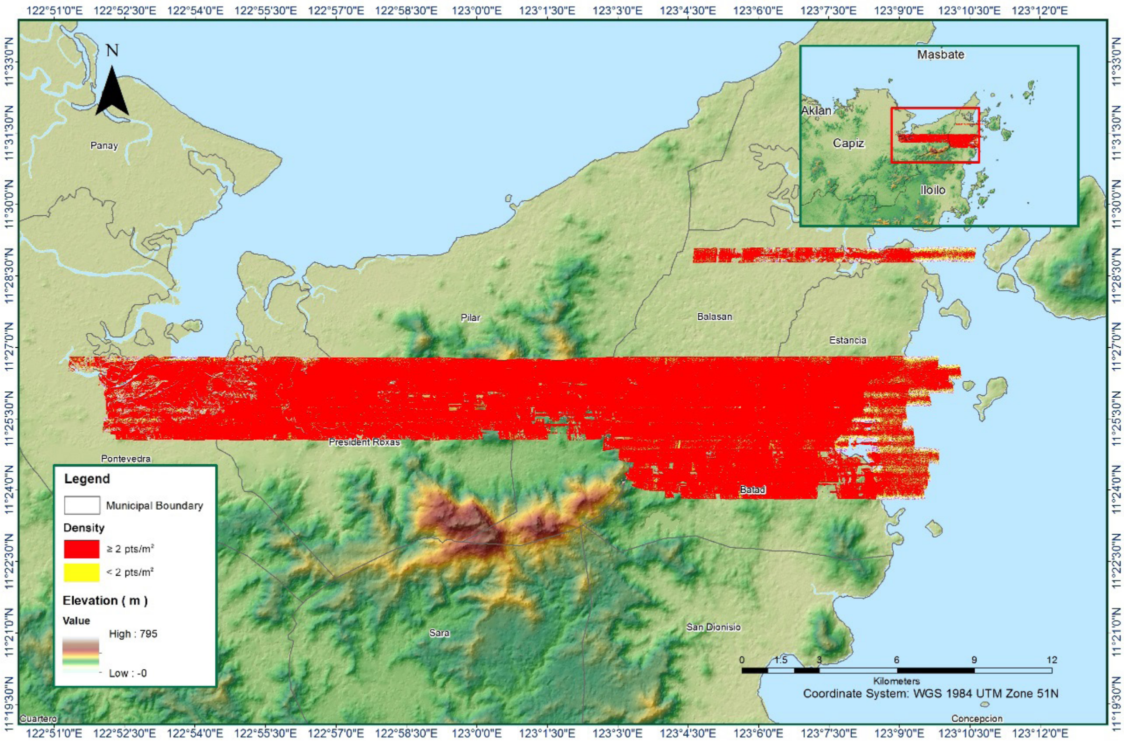


Figure A-8.27. Density map of merged LiDAR data

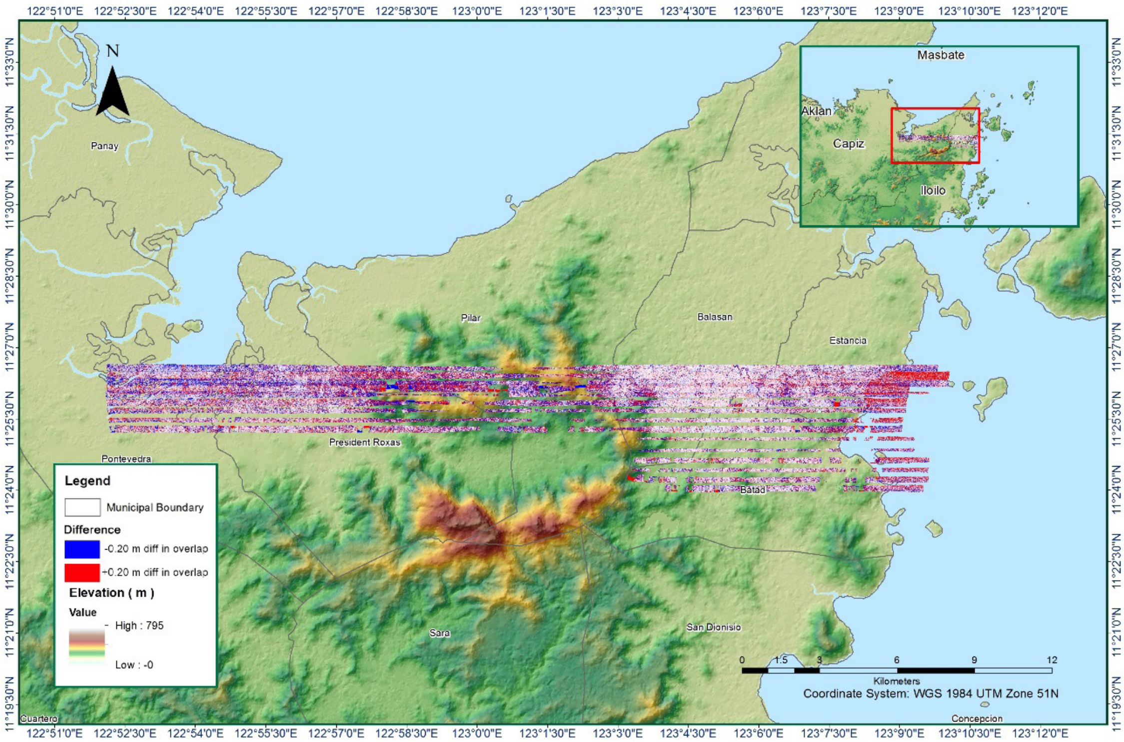


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk38K

Flight Area	Capiz_Aklan
Mission Name	**Blk38K**
Inclusive Flights	2762G
Range data size	17.8 GB
POS	243 MB
Image	40.4 MB
Transfer date	October 9, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.37
RMSE for East Position (<4.0 cm)	1.36
RMSE for Down Position (<8.0 cm)	2.96
Boresight correction stdev (<0.001deg)	0.001181
IMU attitude correction stdev (<0.001deg)	NA
GPS position stdev (<0.01m)	0.0325
Minimum % overlap (>25)	26.20
Ave point cloud density per sq.m. (>2.0)	3.27
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	129
Maximum Height	440.24 m
Minimum Height	40.44 m
Classification (# of points)	
Ground	72,914,645
Low vegetation	27,310,752
Medium vegetation	98,855,573
High vegetation	65,210,654
Building	1,620,581
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Mark Joshua Salvacion, Engr. Gladys Mae Apat

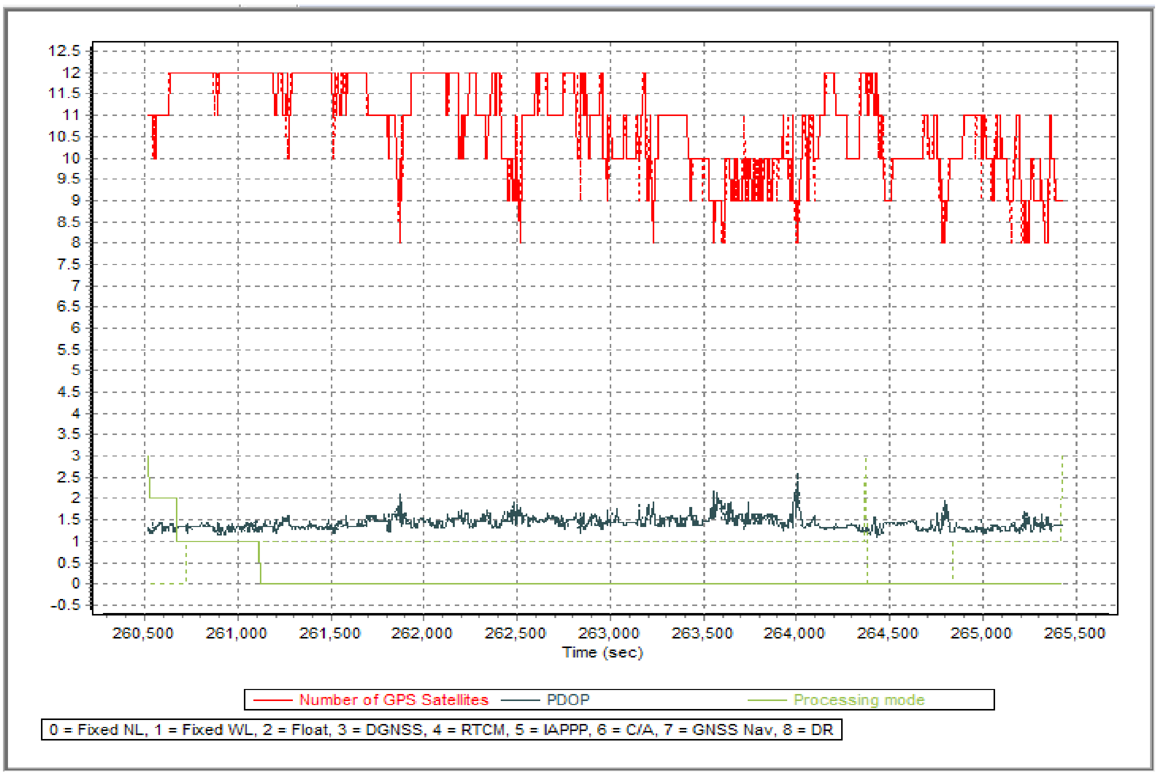


Figure A-8.29. Solution Status

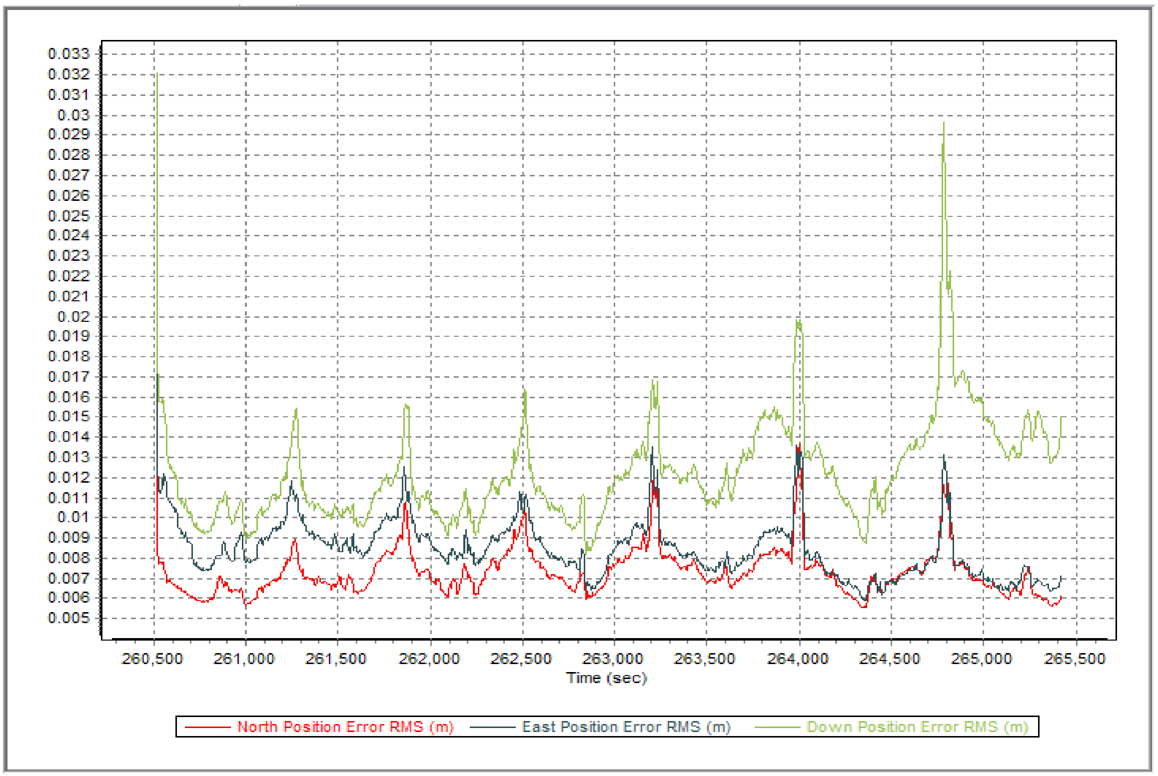


Figure A-8.30. Smoothed Performance Metric Parameters

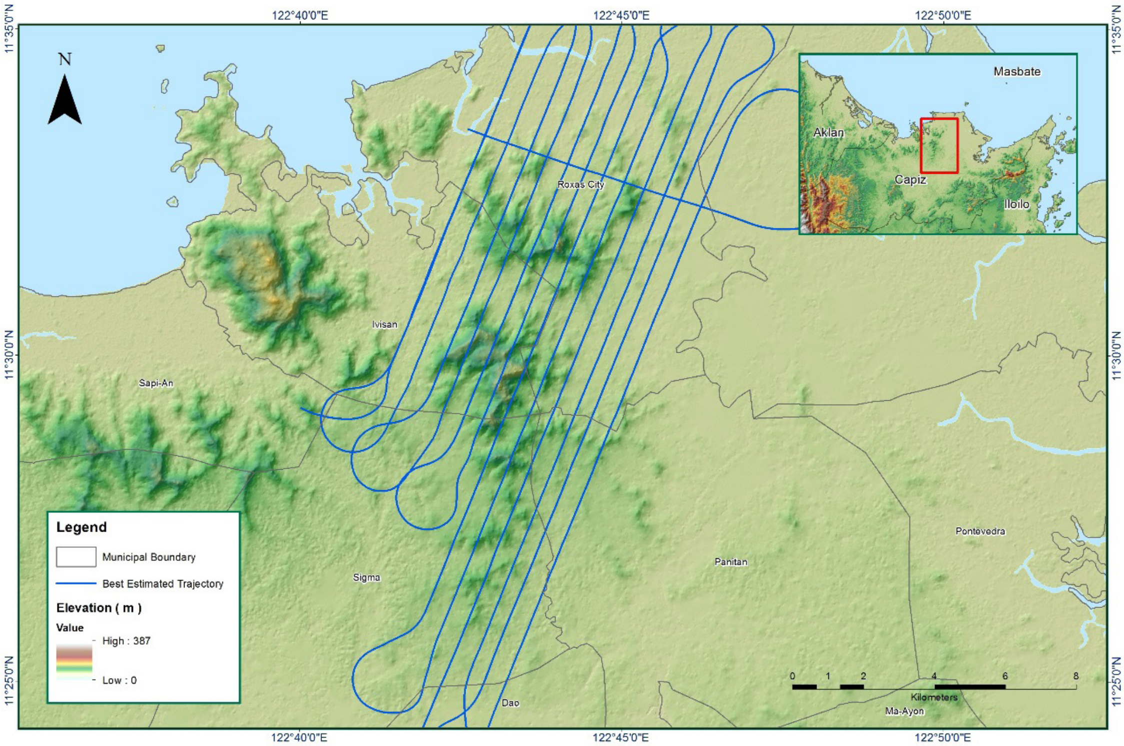


Figure A-8.31. Best Estimated Trajectory

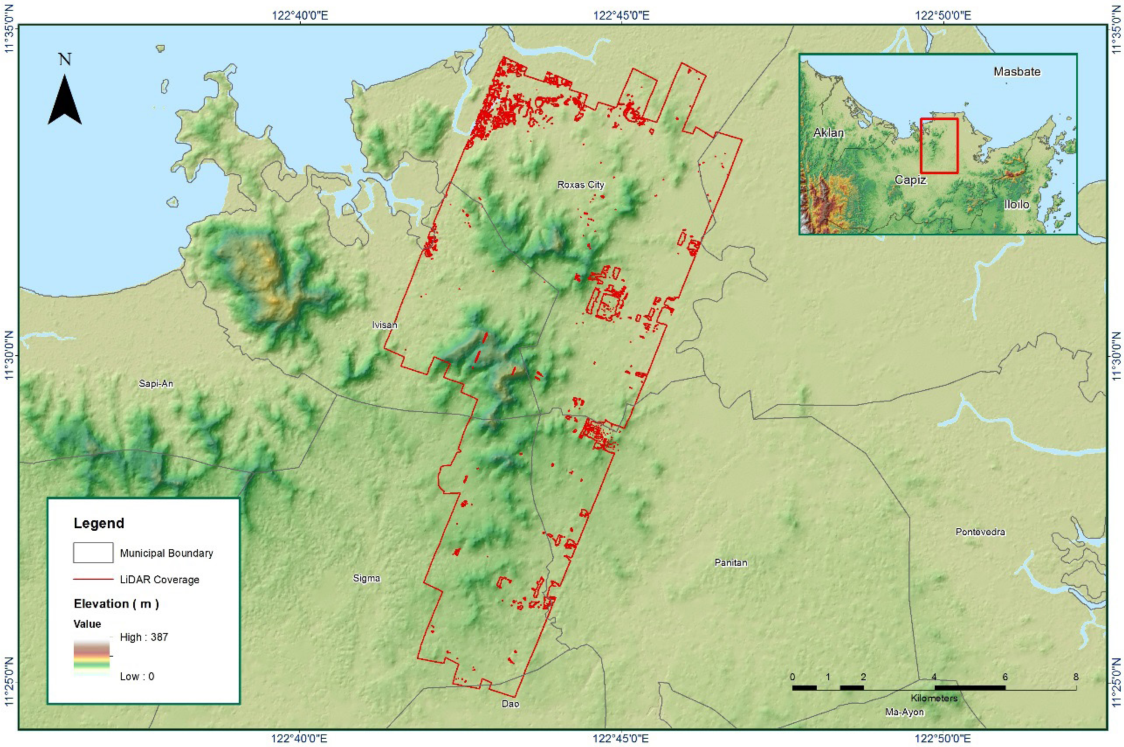


Figure A-8.32. Coverage of LiDAR data

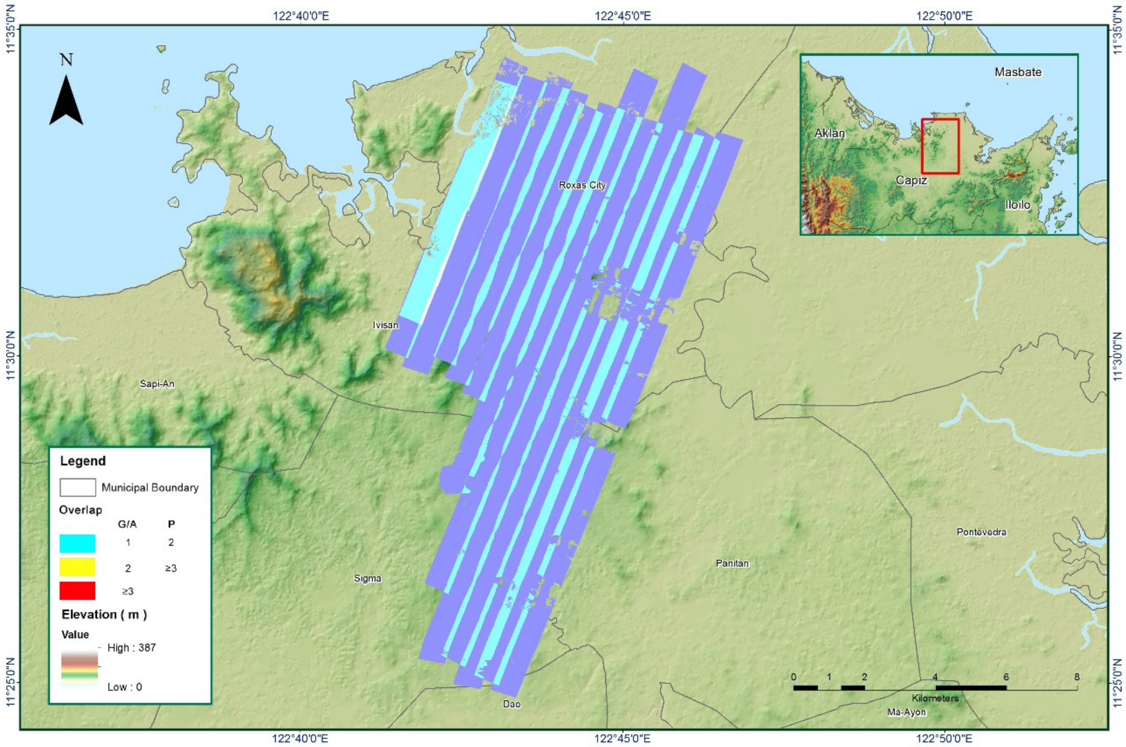


Figure A-8.33. Image of data overlap

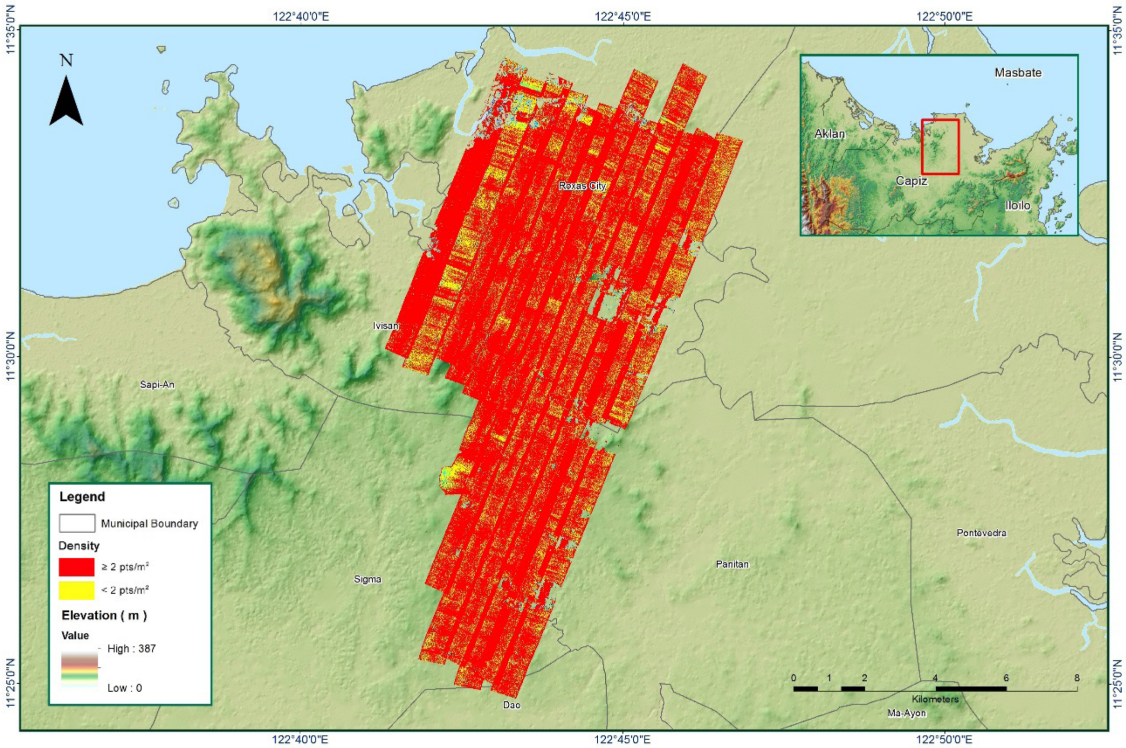


Figure A-8.34. Density of merged LiDAR data

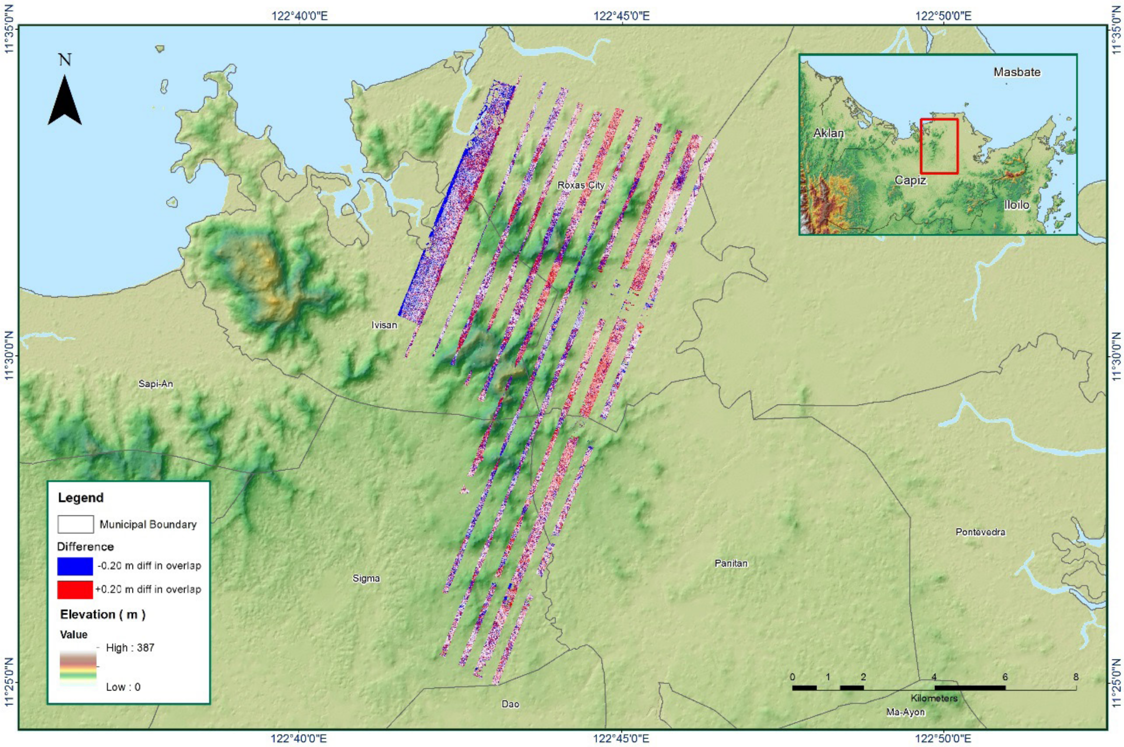


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk38K_supplement

Flight Area	**Capiz_Aklan**
Mission Name	**Blk38K_supplement**
Inclusive Flights	2762G
Range data size	17.8 GB
POS	243 MB
Image	40.4 MB
Transfer date	October 9, 2015
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)	0.82
RMSE for East Position (<4.0 cm)	0.92
RMSE for Down Position (<8.0 cm)	3.39
Boresight correction stdev (<0.001deg)	0.005466
IMU attitude correction stdev (<0.001deg)	0.000586
GPS position stdev (<0.01m)	0.0089
Minimum % overlap (>25)	20.69
Ave point cloud density per sq.m. (>2.0)	3.34
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	55
Maximum Height	156.63 m
Minimum Height	53.88 m
Classification (# of points)	
Ground	10,274,076
Low vegetation	14,770,601
Medium vegetation	29,506,932
High vegetation	18,215,600
Building	635,492
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Merven Matthew Natino, Engr. Gladys Mae Apat

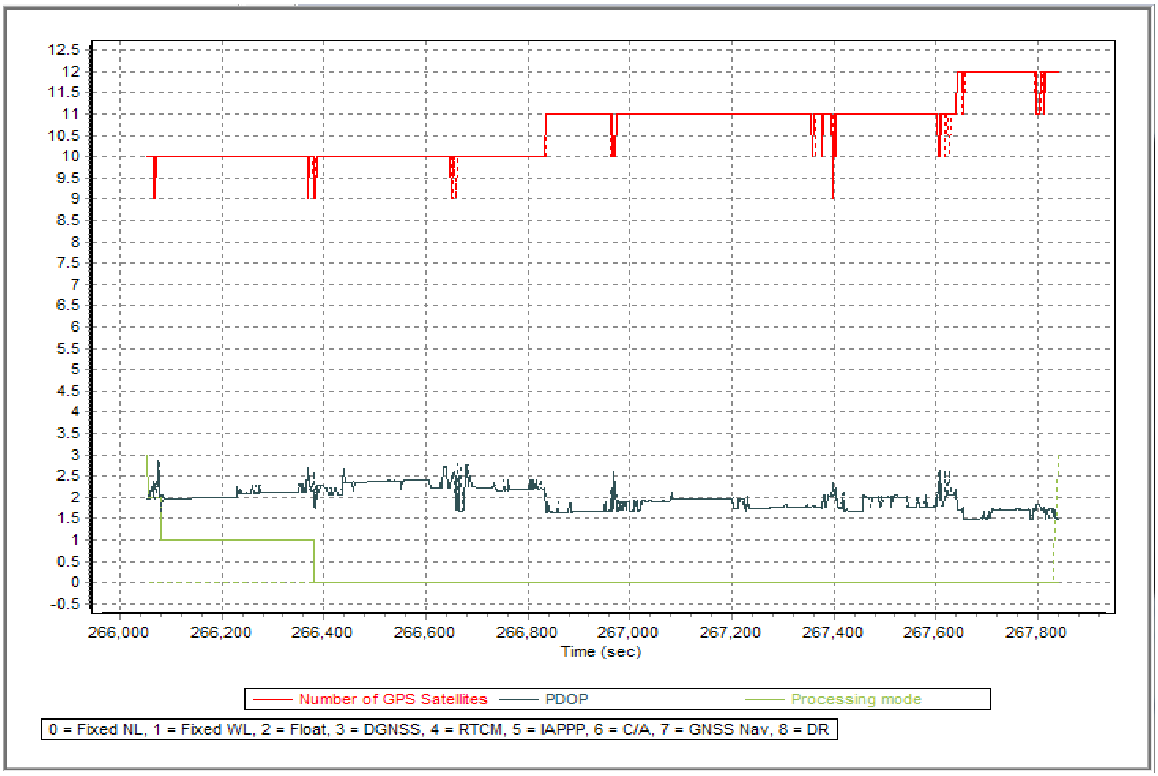


Figure A-8.36. Solution Status

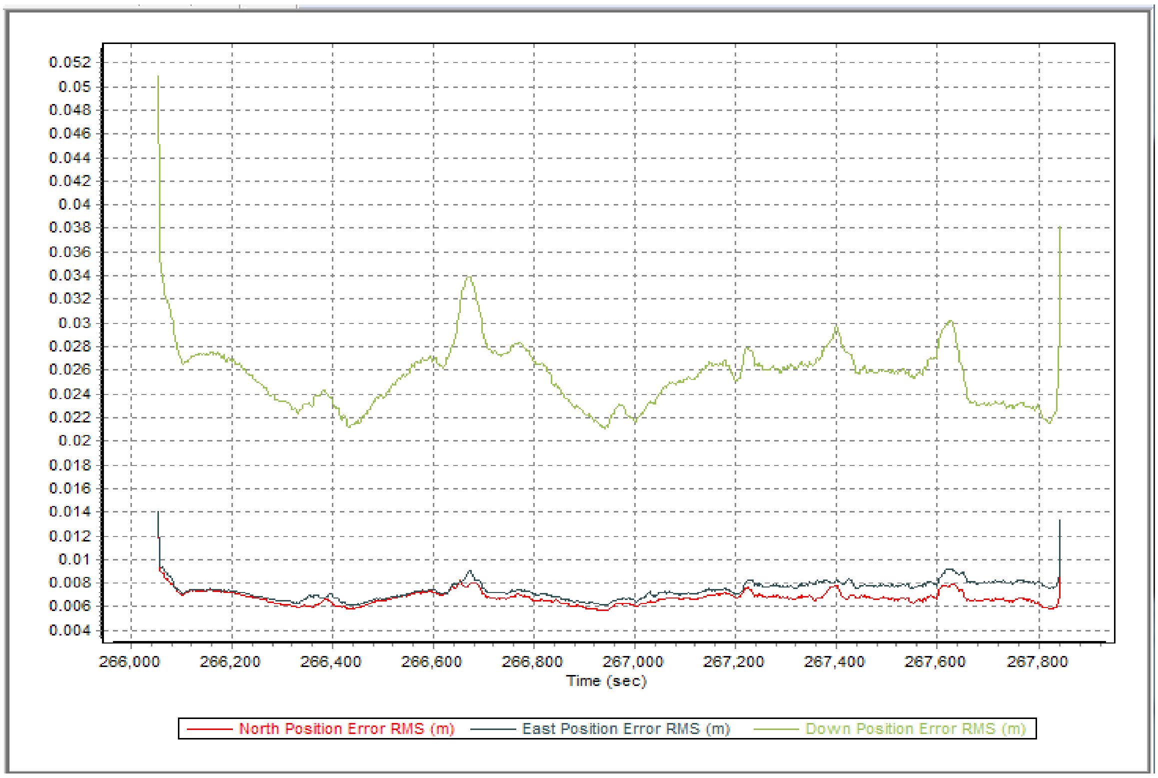


Figure A-8.37. Smoothed Performance Metric Parameters

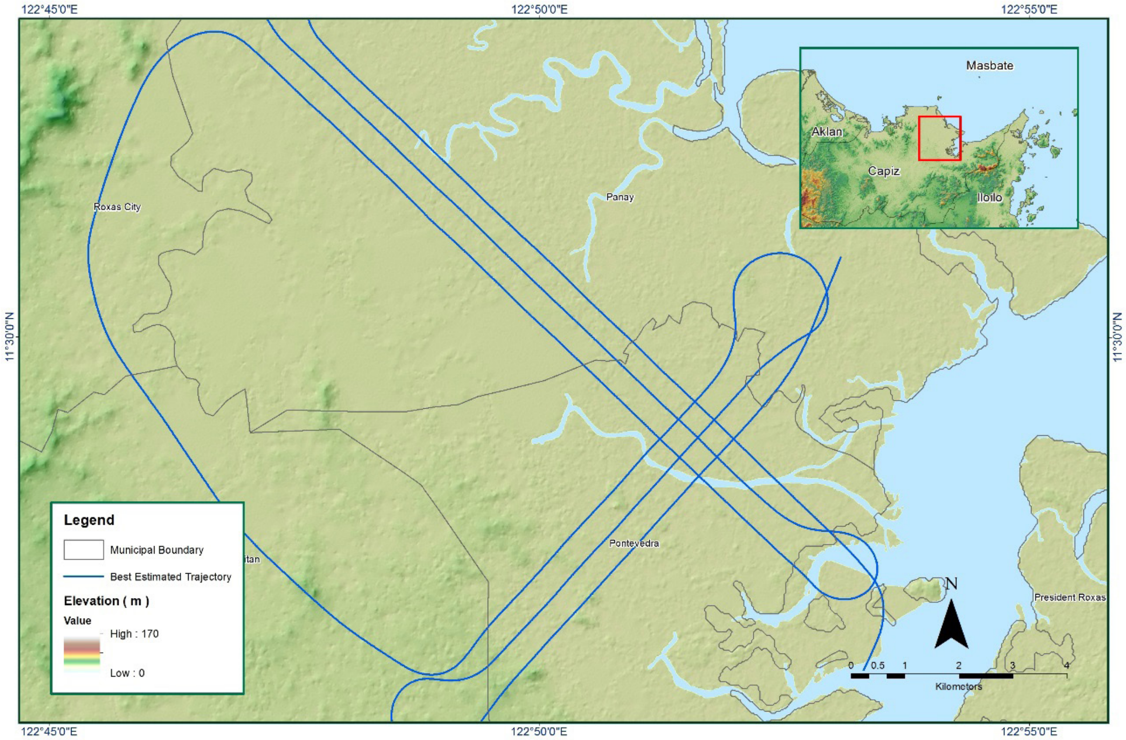


Figure A-8.38. Best Estimated Trajectory

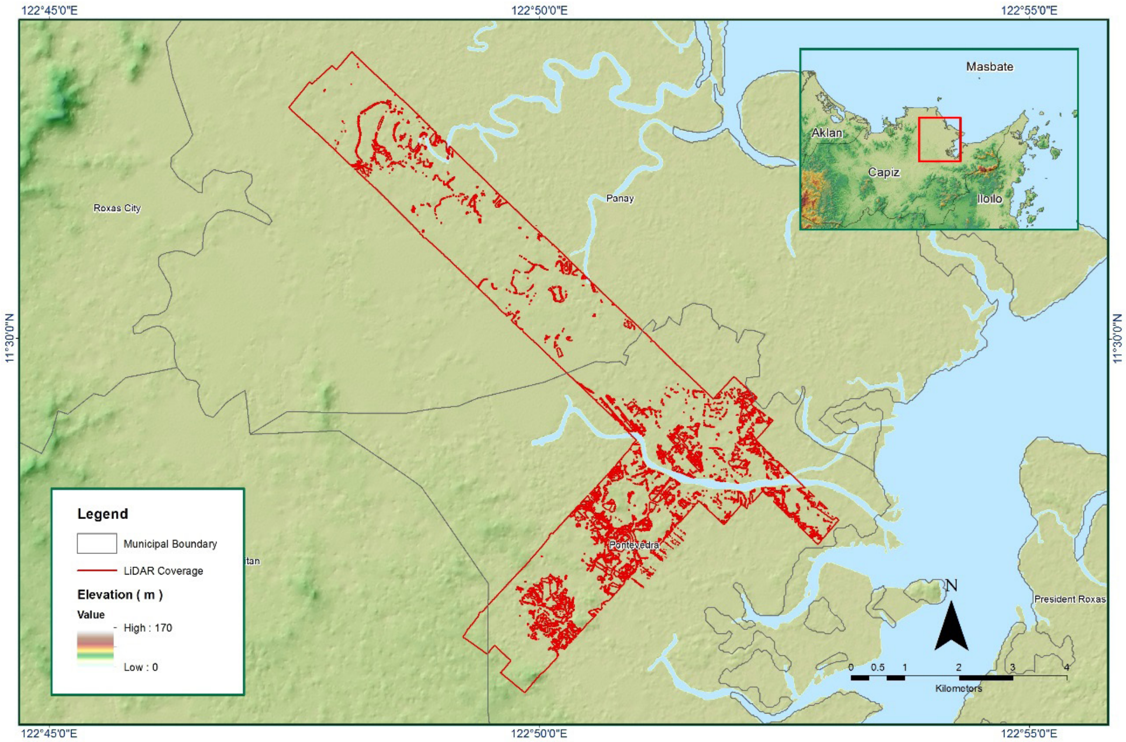


Figure A-8.39. Coverage of LiDAR data

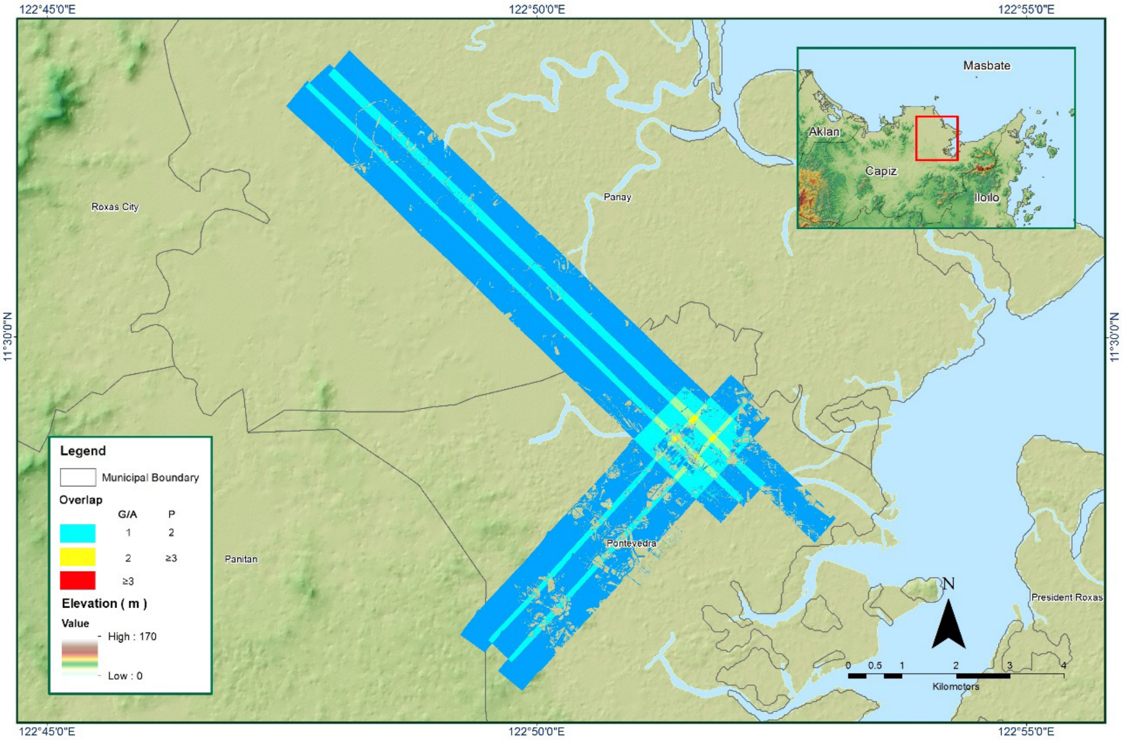


Figure A-8.40. Image of data overlap

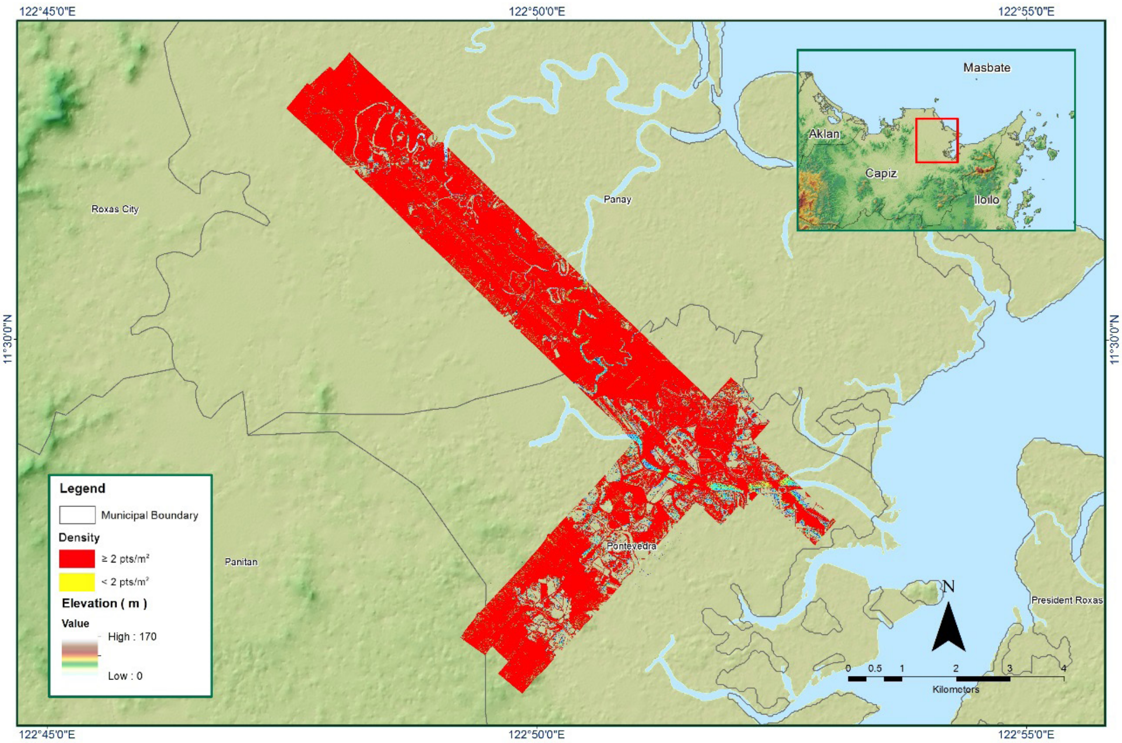


Figure A-8.41. Density of merged LiDAR data

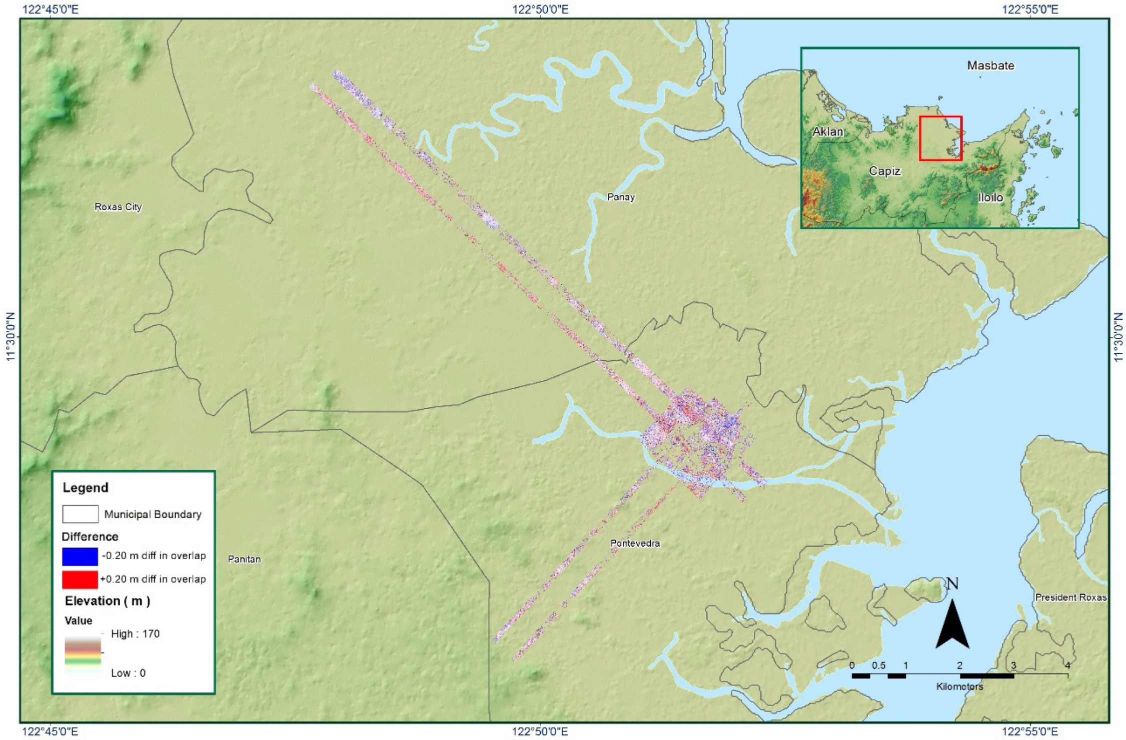


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk37A

Flight Area	Iloilo
Mission Name	**Blk37A**
Inclusive Flights	2538G
Range data size	24 GB
POS	261 MB
Base data size	18.1 MB
Image	55.5 GB
Transfer date	February 17, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.43
RMSE for East Position (<4.0 cm)	1.54
RMSE for Down Position (<8.0 cm)	4.63
Boresight correction stdev (<0.001deg)	0.000406
IMU attitude correction stdev (<0.001deg)	0.002891
GPS position stdev (<0.01m)	0.0019
Minimum % overlap (>25)	33.08%
Ave point cloud density per sq.m. (>2.0)	4.85
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	196
Maximum Height	679.76 m
Minimum Height	54.64 m
Classification (# of points)	
Ground	70,801,258
Low vegetation	106,924,939
Medium vegetation	321,385,872
High vegetation	106,055,712
Building	3,170,454
Orthophoto	
Processed by	Engr. Irish Cortez, Engr. Chelou Prado, Engr. Sueden Lyle Magtalas

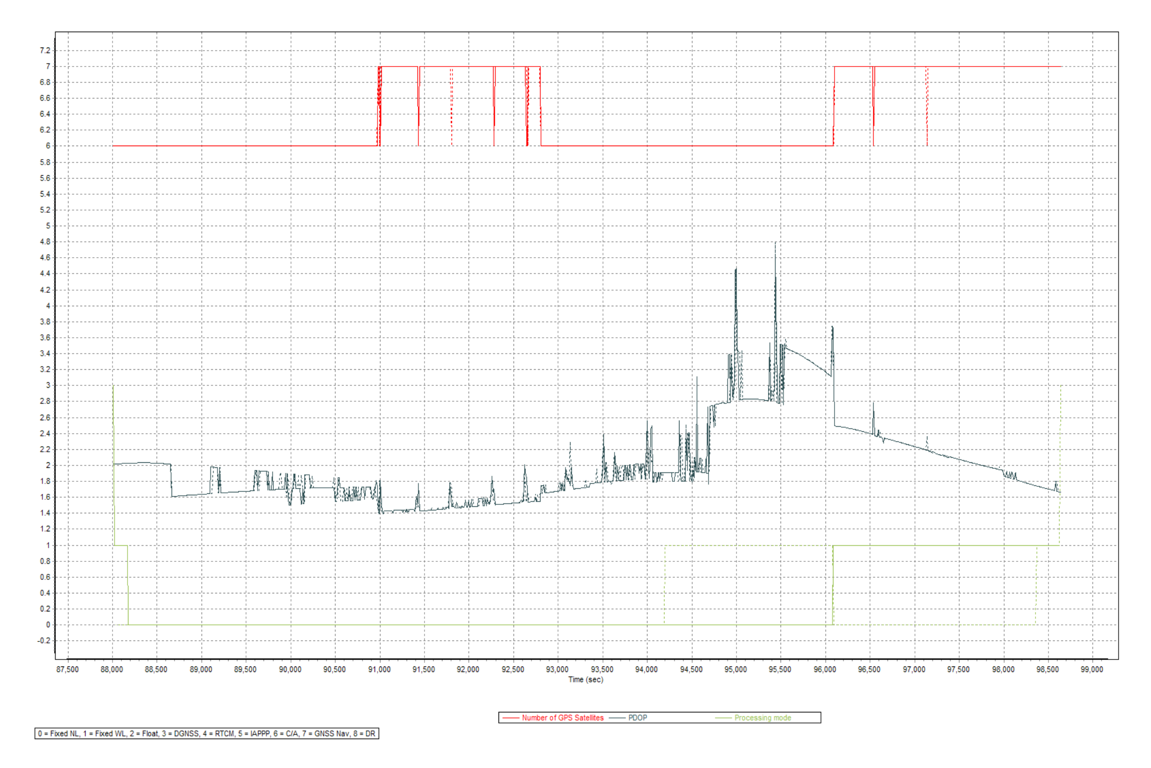


Figure A-8.43. Solution Status

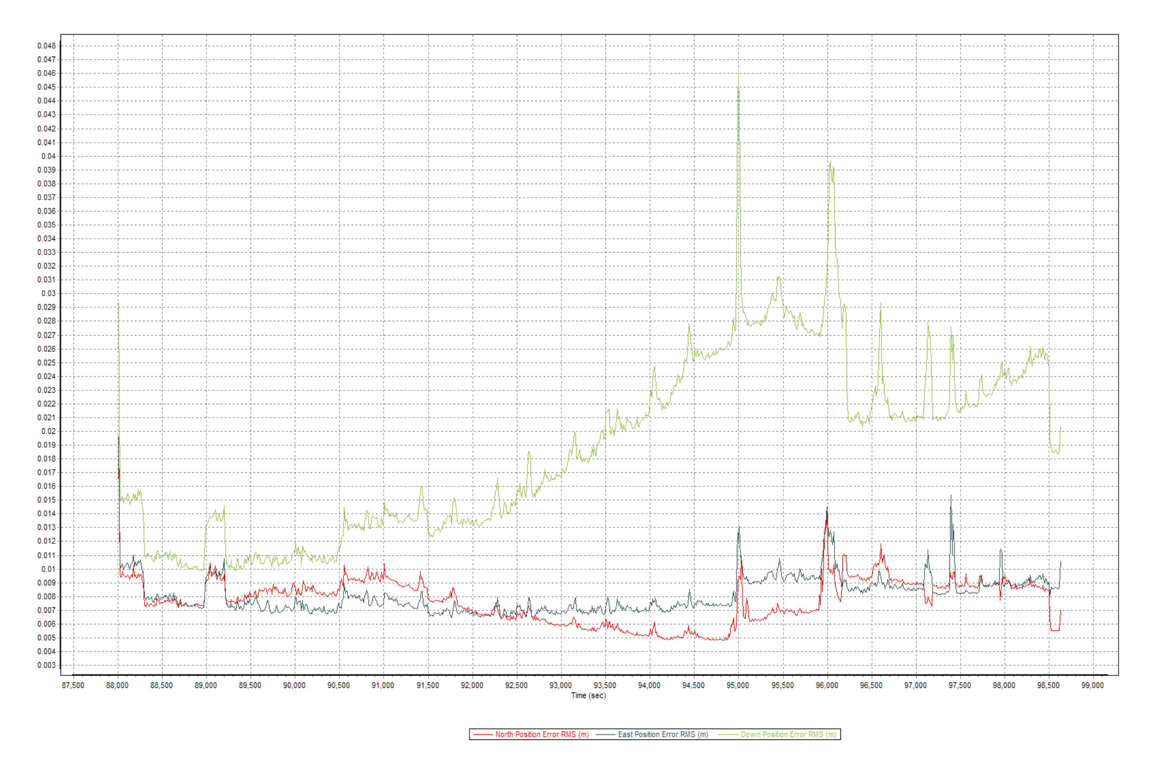


Figure A-8.44. Smoothed Performance Metric Parameters

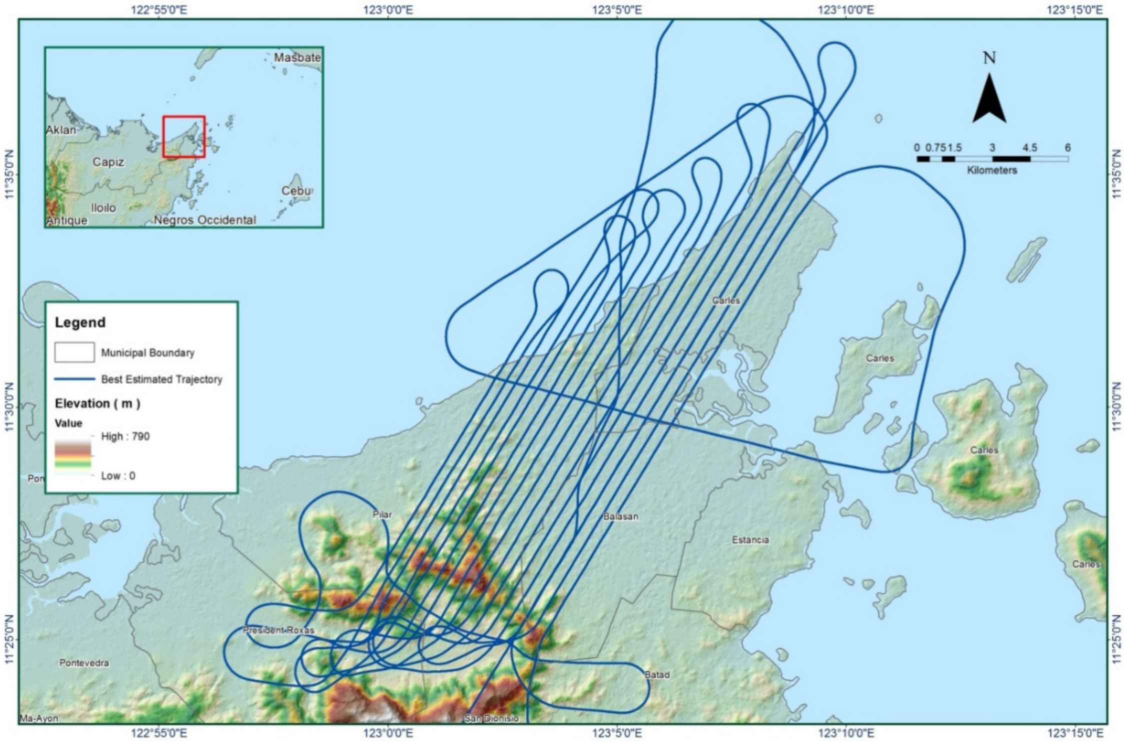


Figure A-8.45. Best Estimated Trajectory

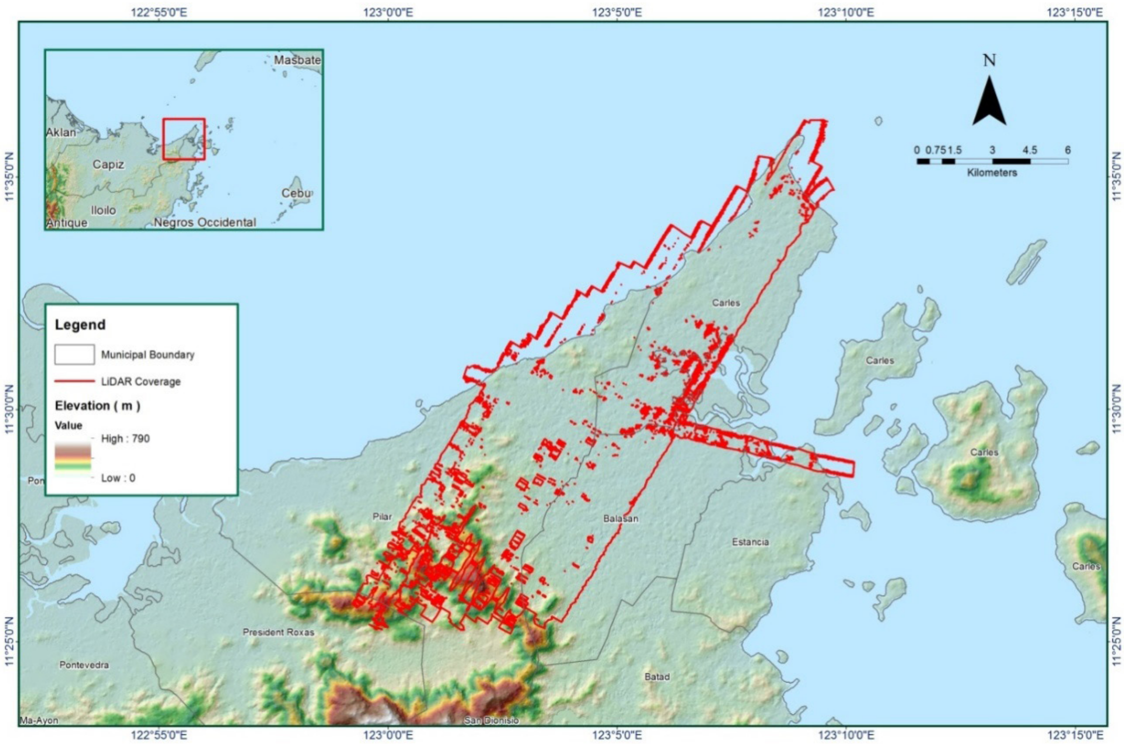


Figure A-8.46. Coverage of LiDAR data

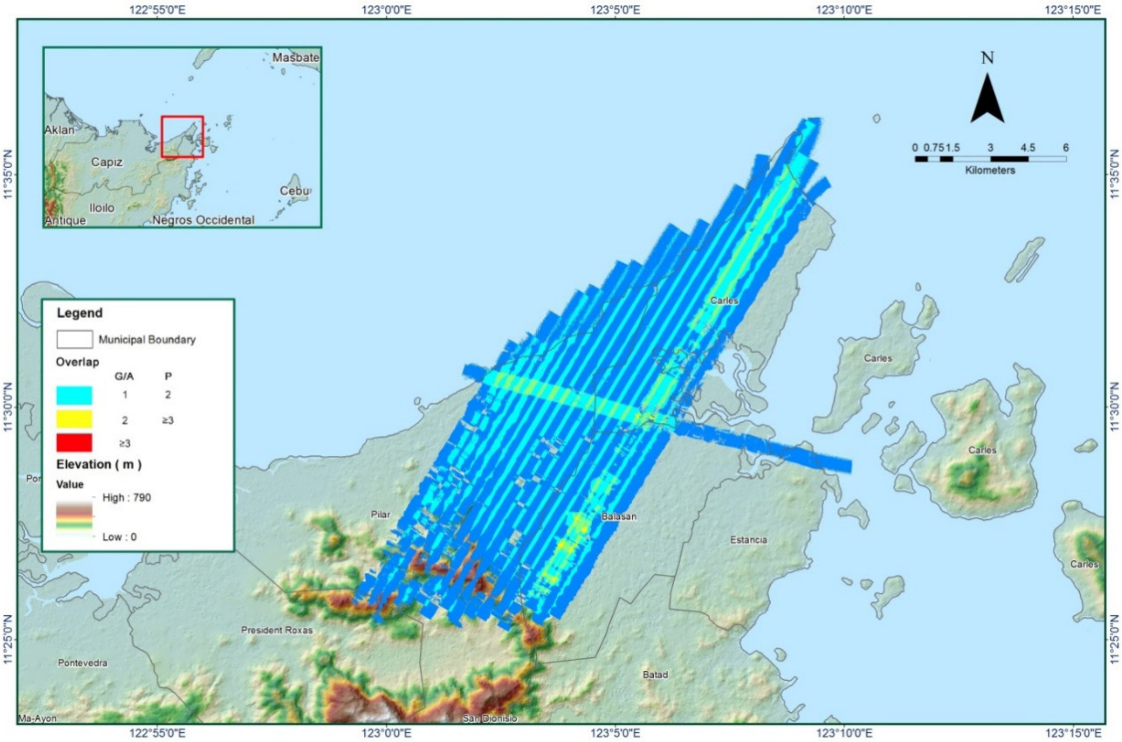


Figure A-8.47. Image of data overlap

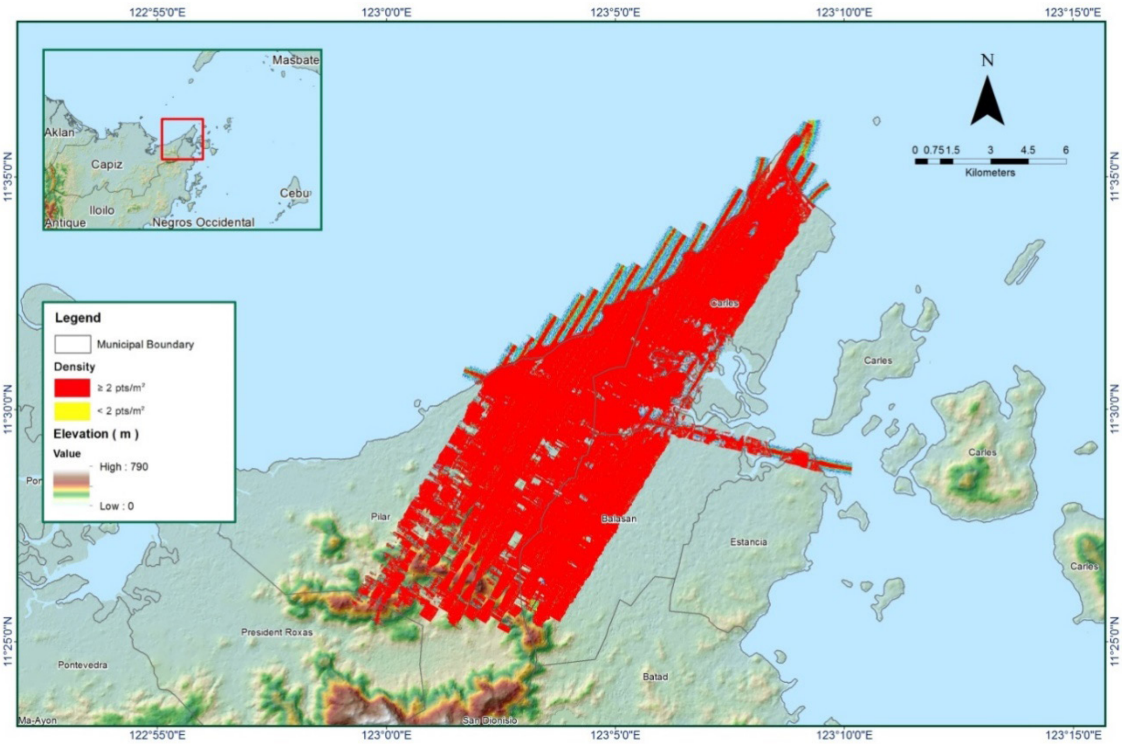


Figure A-8.48. Density map of merged LiDAR data

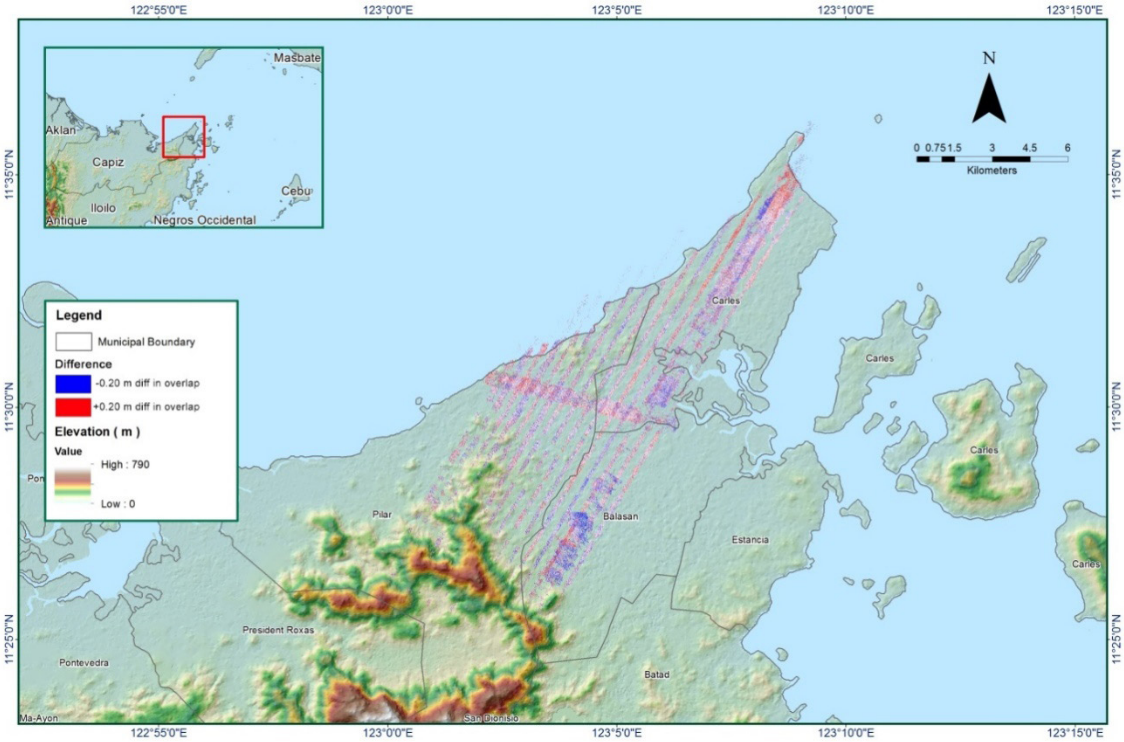


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk37B

Flight Area	Iloilo
Mission Name	**Blk37B**
Inclusive Flights	2540G
Range data size	24.5 GB
POS	231 MB
Base data size	18.1 MB
Image	37.5 GB
Transfer date	February 17, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.22
RMSE for East Position (<4.0 cm)	1.91
RMSE for Down Position (<8.0 cm)	3.43
Boresight correction stdev (<0.001deg)	0.000426
IMU attitude correction stdev (<0.001deg)	0.005063
GPS position stdev (<0.01m)	0.0157
Minimum % overlap (>25)	21.5%
Ave point cloud density per sq.m. (>2.0)	4.66
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	131
Maximum Height	229.91 m
Minimum Height	58.13 m
Classification (# of points)	
Ground	33,202,100
Low vegetation	46,142,935
Medium vegetation	118,439,186
High vegetation	29,204,855
Building	1,197,019
Orthophoto	
Processed by	Engr. Jommer Medina, Engr. Melanie Hing-pit, Kathryn Claudyn Zarate

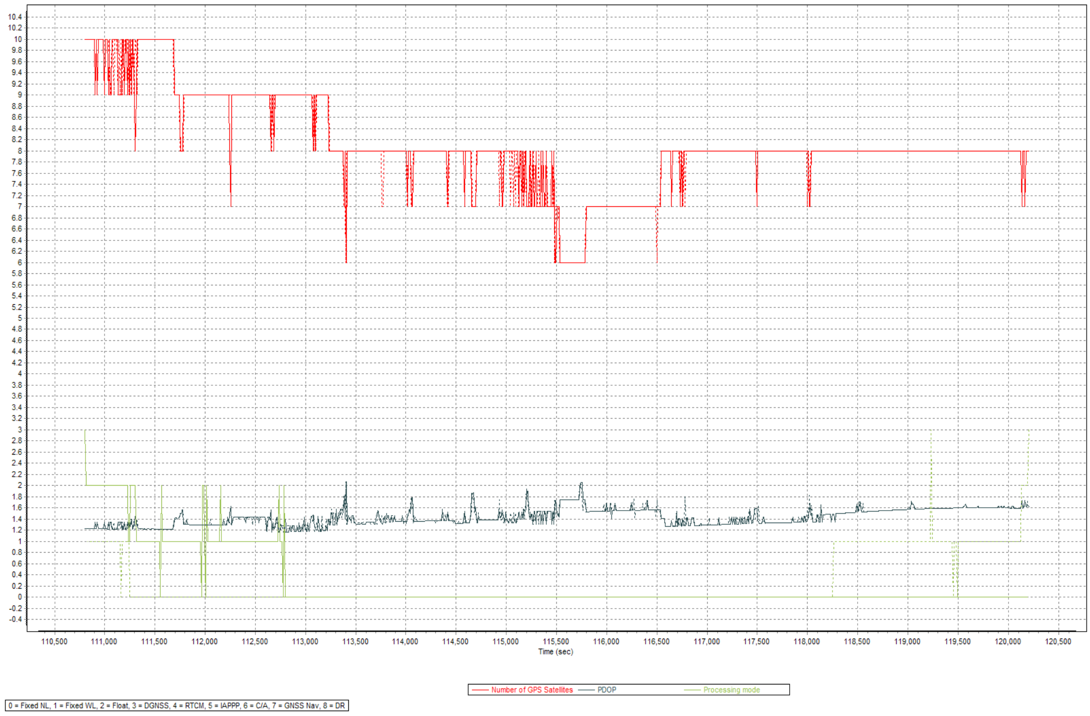


Figure A-8.50. Solution Status

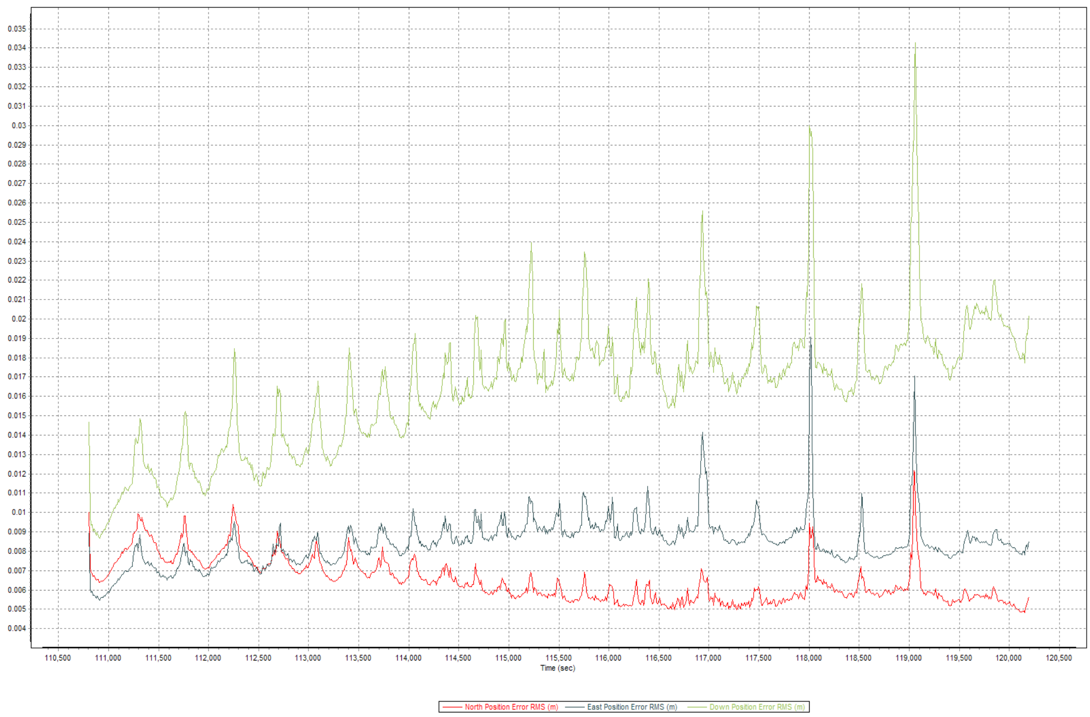


Figure A-8.51. Smoothed Performance Metric Parameters

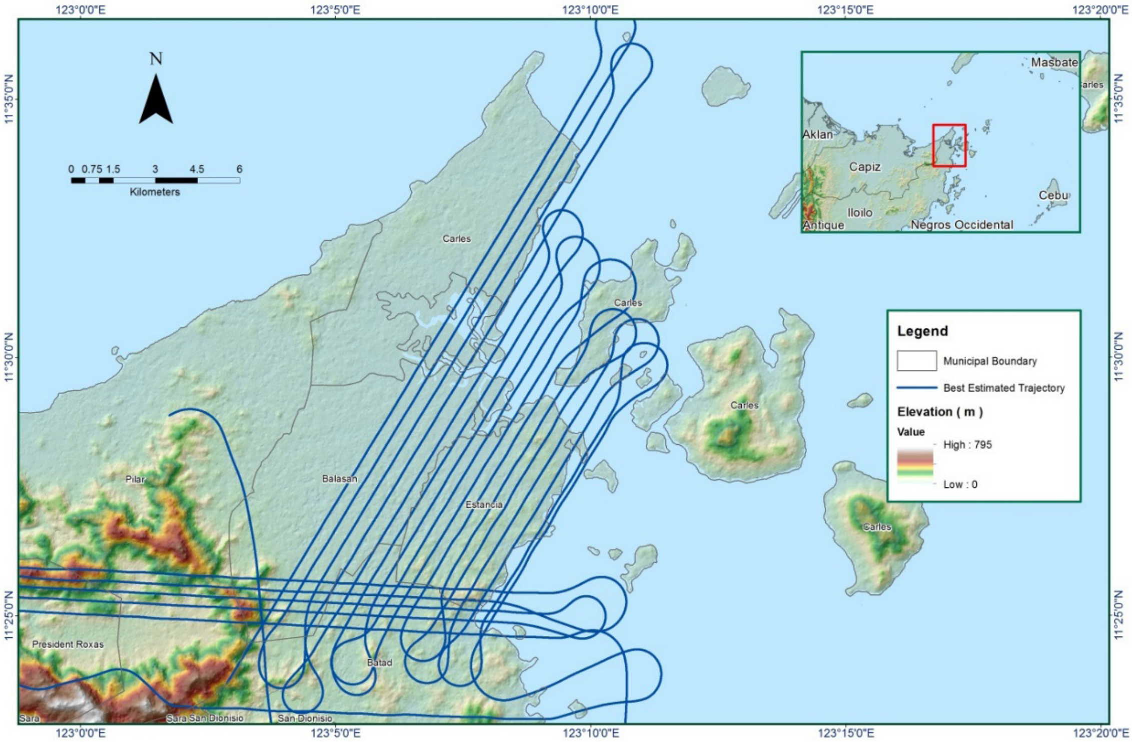


Figure A-8.52. Best Estimated Trajectory

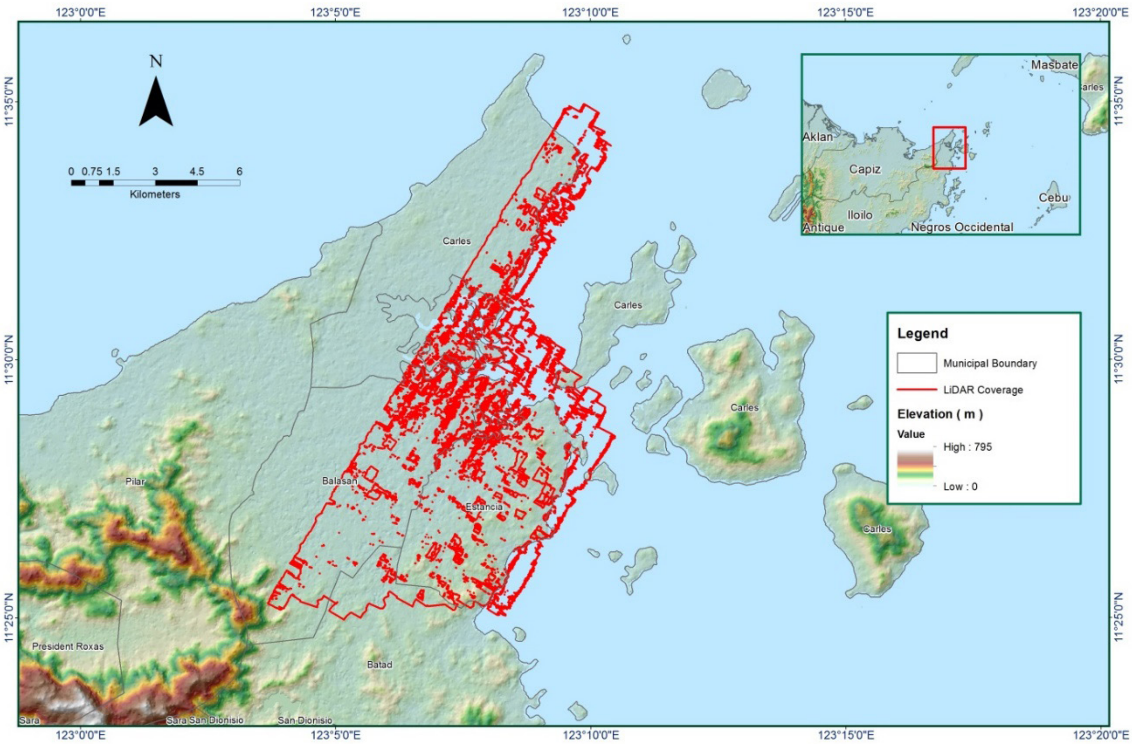


Figure A-8.53. Coverage of LiDAR data

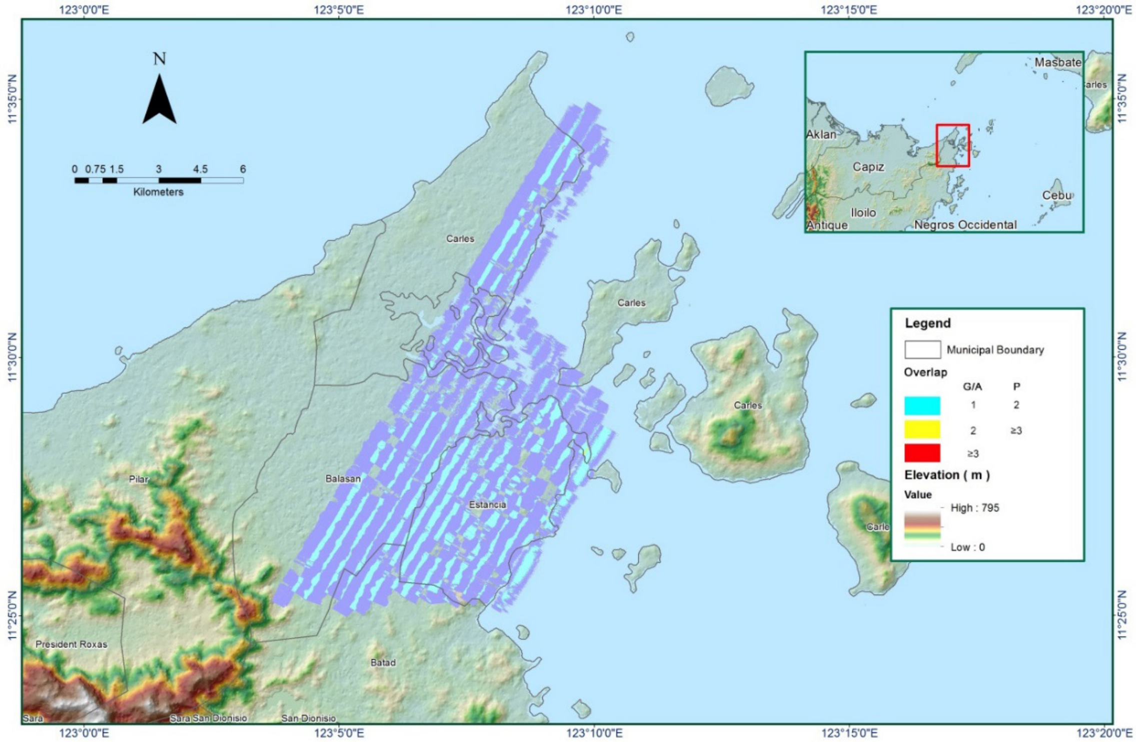


Figure A-8.54. Image of data overlap

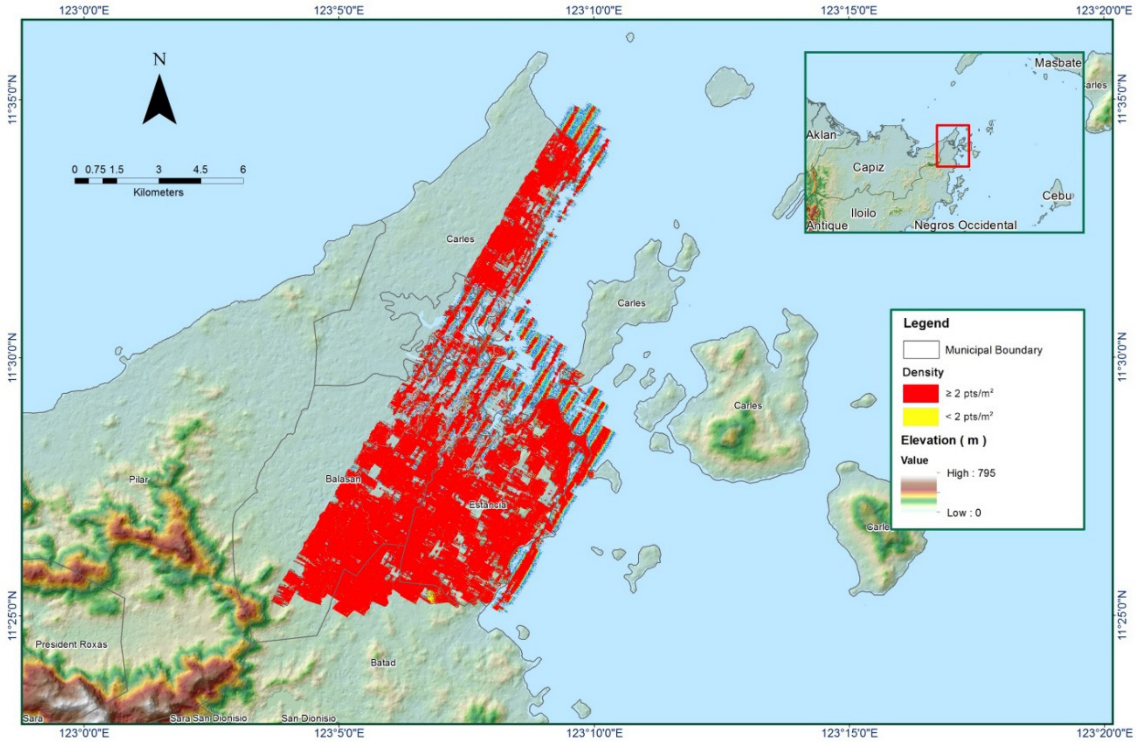


Figure A-8.55. Density map of merged LiDAR data

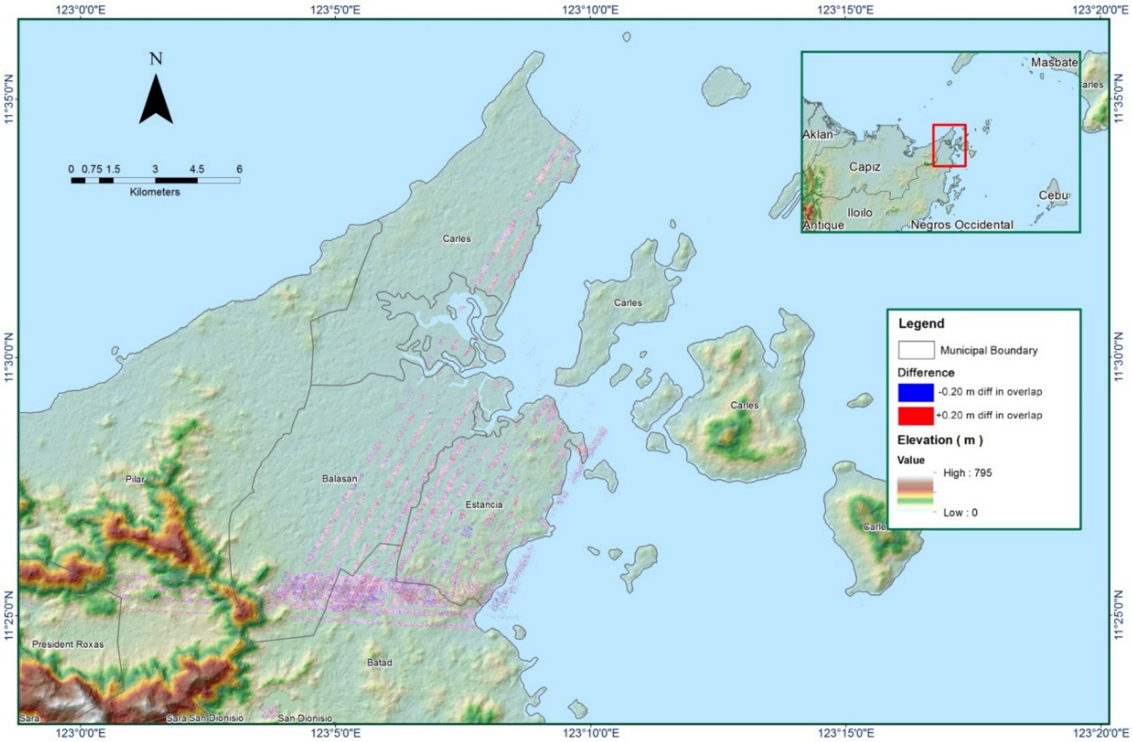


Figure A-8.56. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission Blk37C

Flight Area	Iloilo
Mission Name	**Blk 37C**
Inclusive Flights	2540G
Range data size	24.5 GB
POS	231 MB
Base data size	18.1 MB
Image	37.5 MB
Transfer date	February 9, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.215
RMSE for East Position (<4.0 cm)	1.91
RMSE for Down Position (<8.0 cm)	3.43
Boresight correction stdev (<0.001deg)	0.000426
IMU attitude correction stdev (<0.001deg)	0.005063
GPS position stdev (<0.01m)	0.0157
Minimum % overlap (>25)	22.87
Ave point cloud density per sq.m. (>2.0)	2.65
Elevation difference between strips (<0.20 m)	No
Number of 1km x 1km blocks	106
Maximum Height	742.48
Minimum Height	58.94
Classification (# of points)	
Ground	26,388,470
Low vegetation	31,862,891
Medium vegetation	105,278,592
High vegetation	42,034,983
Building	598,623
Orthophoto	None
Processed by	Engr. Jommer Medina, Engr. Edgardo Gubatanga Jr., Engr. Gladys Mae Apat

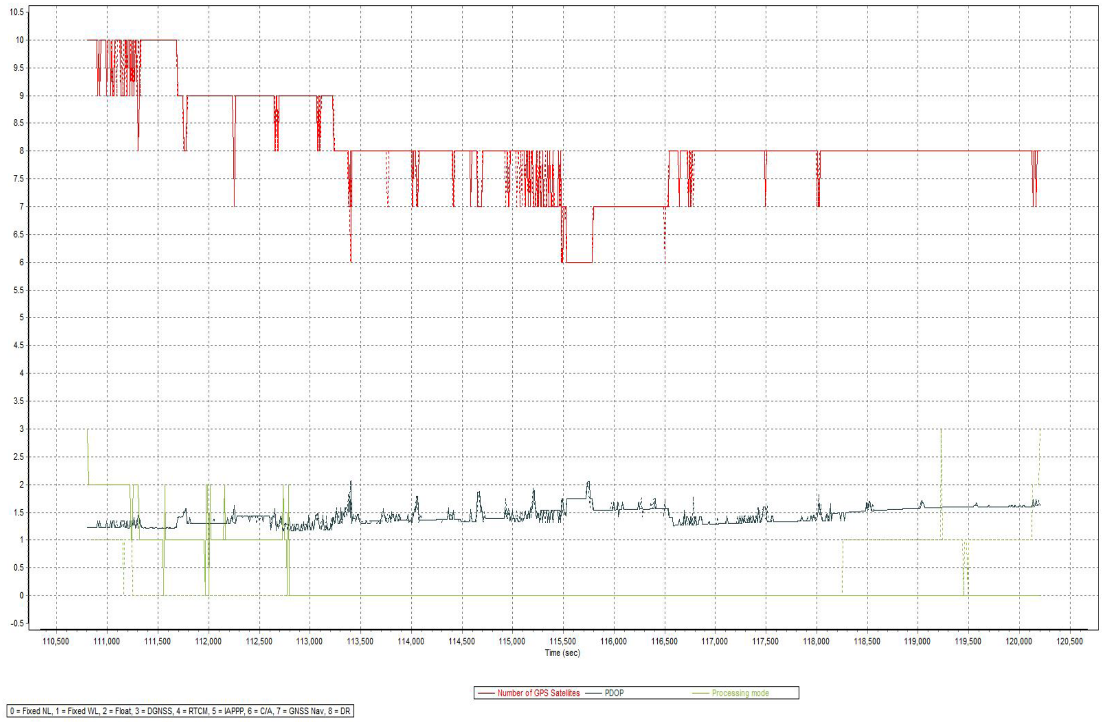


Figure A-8.57. Solution Status

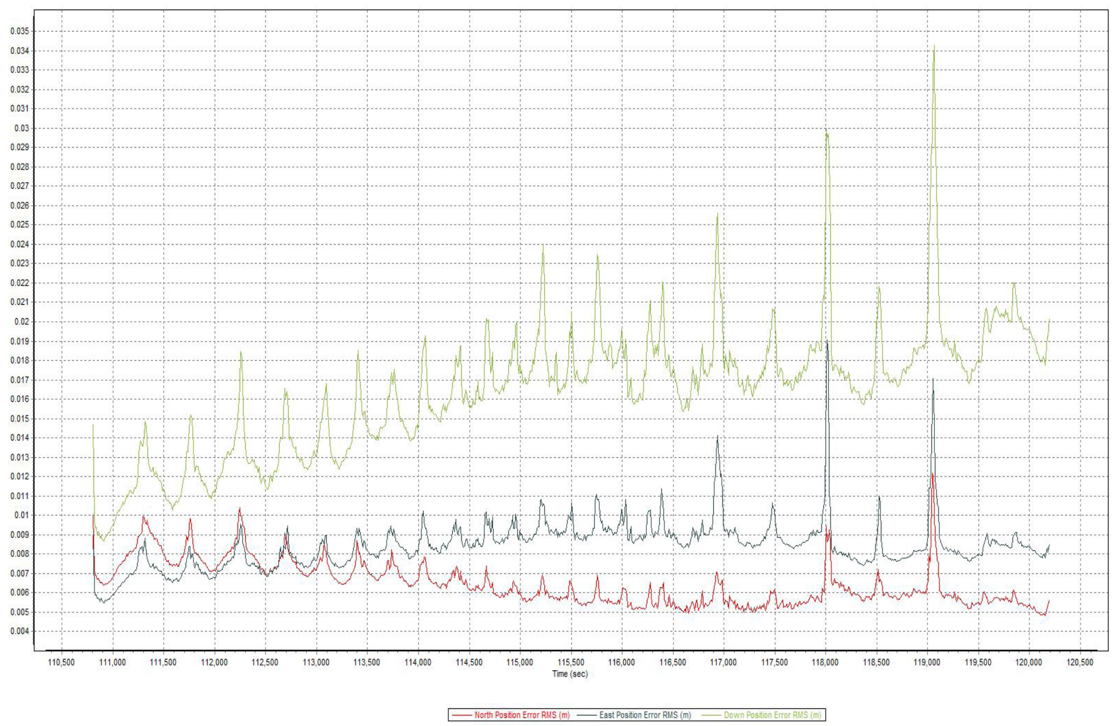


Figure A-8.58. Smoothed Performance Metric Parameters

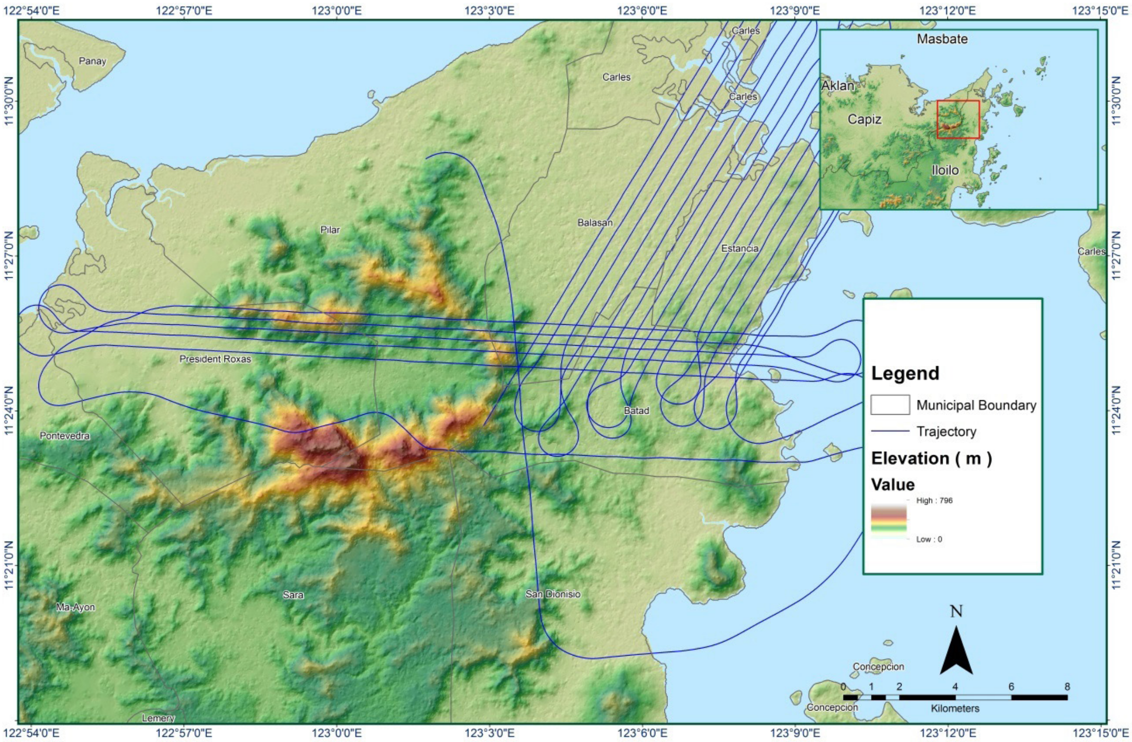


Figure A-8.59. Best Estimated Trajectory

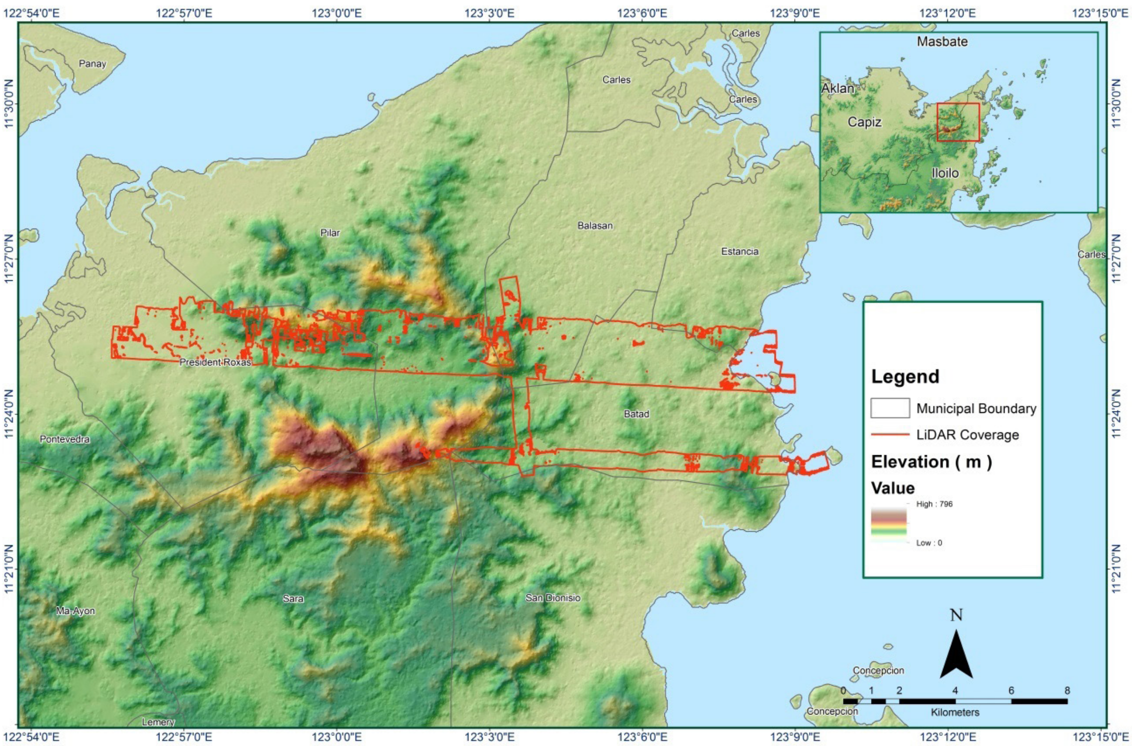


Figure A-8.60. Coverage of LiDAR data

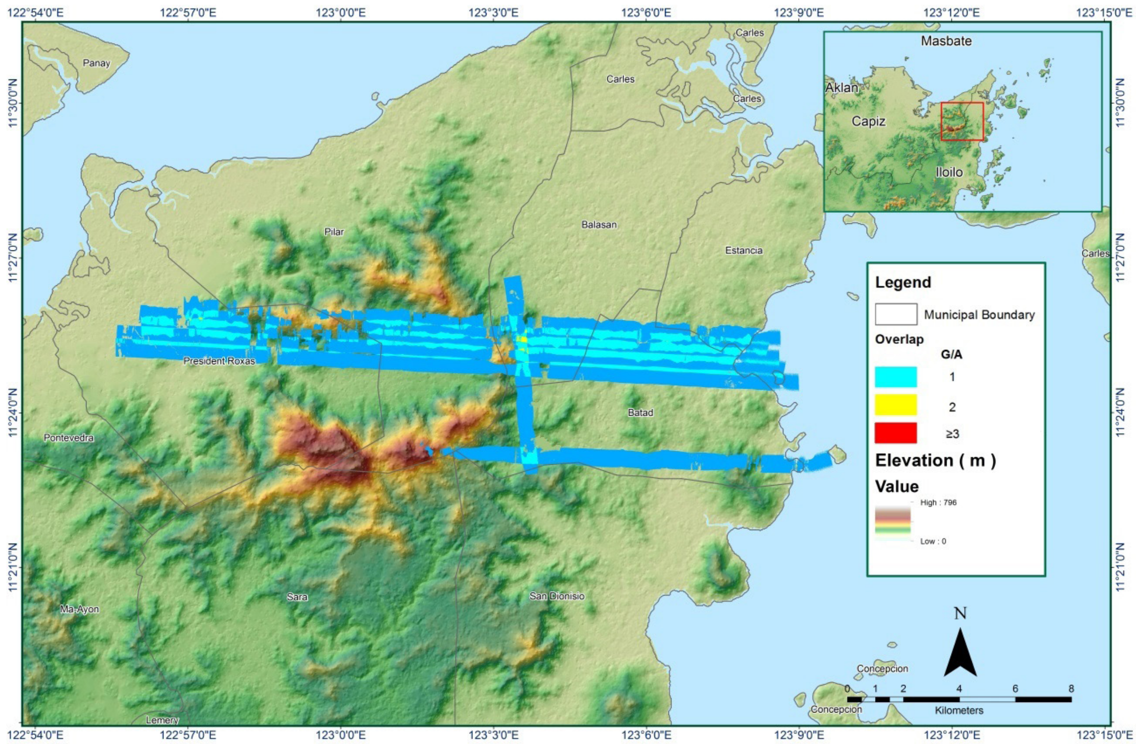


Figure A-8.61. Image of data overlap

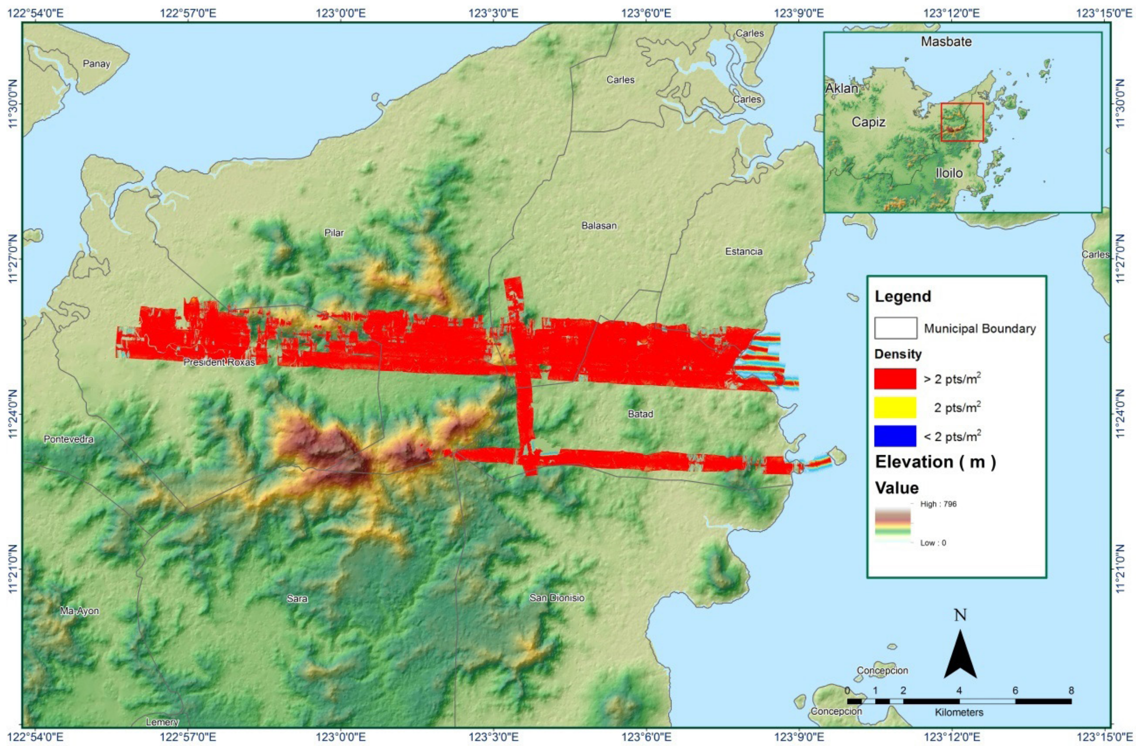


Figure A-8.62. Density map of merged LiDAR data

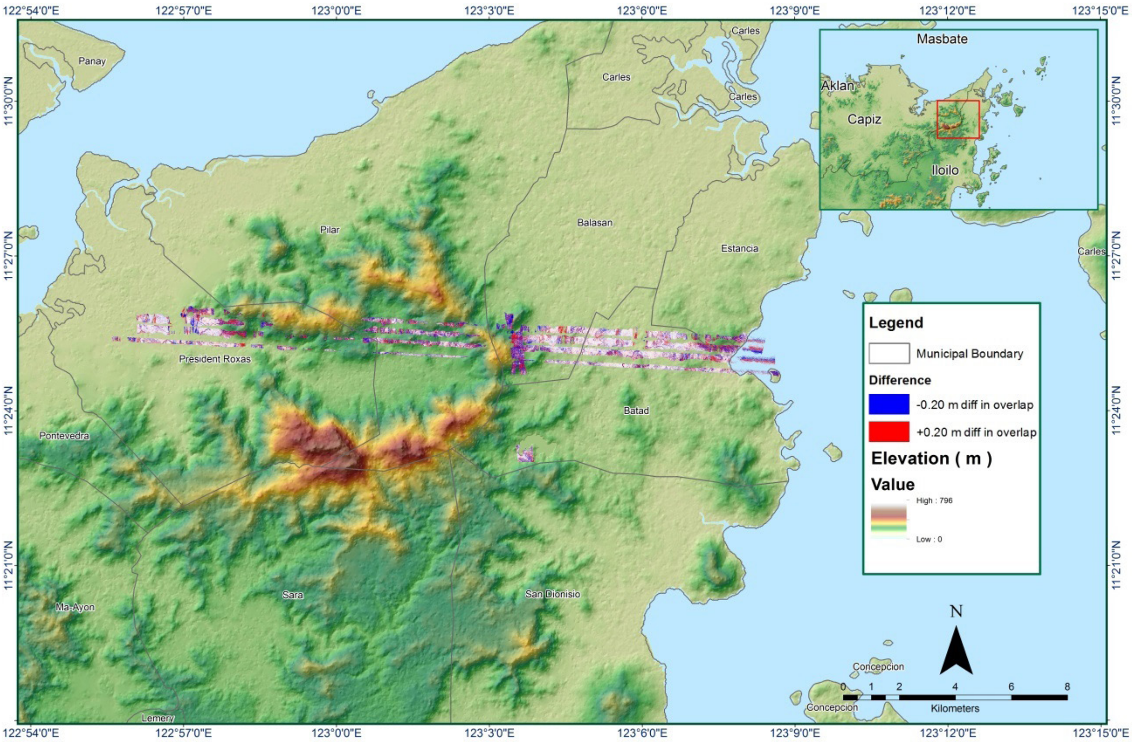


Figure A-8.63. Elevation difference between flight lines

Annex 9. Balantian Model Basin Parameters

Table A-9.1. Balantian Model Basin Parameters

Basin Number	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction (mm)	Curve Number	Impervious (%)	Time of Concentration (HR)	Storage Coefficient (HR)	Initial Type	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Ratio to Peak
W440	3.6193	70.088	0	19.452	5.7027	Discharge	0.0284584	0.00001	Ratio to Peak	0.0001
W450	3.6197	62.357	0	11.057	7.2687	Discharge	0.0358655	0.00001	Ratio to Peak	0.0001
W460	2.3747	52.853	0	18.013	7.9369	Discharge	0.0862123	0.00001	Ratio to Peak	0.0001
W470	2.098	65.66	0	11.312	3.4524	Discharge	0.0223259	0.00001	Ratio to Peak	0.0001
W480	3.2645	73.113	0	33.146	2.9387	Discharge	0.0166115	0.00001	Ratio to Peak	0.0001
W490	2.3758	79.505	0	0.70886	0.77214	Discharge	0.0095096	0.00001	Ratio to Peak	0.0001
W500	1.0036	70.107	0	0.44191	1.0353	Discharge	0.0493643	0.00001	Ratio to Peak	0.0001
W510	4.6791	65.587	0	5.459	3.5894	Discharge	0.0339394	0.00001	Ratio to Peak	0.0001
W520	1.6859	61.277	0	5.9316	8.6941	Discharge	0.028154	0.00001	Ratio to Peak	0.0001
W530	0.89043	79.399	0	9.0782	13.285	Discharge	0.027799	0.00001	Ratio to Peak	0.0001
W540	3.6649	78.957	0	4.833	3.1795	Discharge	0.0105641	0.00001	Ratio to Peak	0.0001
W550	5.1795	63.344	0	4.8788	3.2066	Discharge	0.0132725	0.00001	Ratio to Peak	0.0001
W560	0.29818	63.639	0	0.97992	0.72275	Discharge	0.0053229	0.00001	Ratio to Peak	0.0001
W570	0.16753	99	0	0.19258	0.28944	Discharge	0.000426448	0.00001	Ratio to Peak	0.0001
W580	0.21258	99	0	0.65983	0.29943	Discharge	0.0011075	0.00001	Ratio to Peak	0.0001
W590	0.26622	99	0	0.18092	0.26105	Discharge	0.000187145	0.00001	Ratio to Peak	0.0001
W600	0.19776	99	0	0.91514	0.39947	Discharge	0.0084785	0.00001	Ratio to Peak	0.0001
W610	0.22348	85.766	0	0.75871	0.41623	Discharge	0.0166028	0.00001	Ratio to Peak	0.0001
W620	0.45848	82.125	0	0.95631	0.26143	Discharge	0.0046303	0.00001	Ratio to Peak	0.0001
W630	3.872	60.65	0	4.813	3.1571	Discharge	0.0242959	0.00001	Ratio to Peak	0.0001
W640	4.0303	59.63	0	9.6244	4.2351	Discharge	0.0256199	0.00001	Ratio to Peak	0.0001
W650	5.2466	53.046	0	3.5329	7.7192	Discharge	0.0176086	0.00001	Ratio to Peak	0.0001
W660	2.0312	56.646	0	13.142	3.8755	Discharge	0.0274746	0.00001	Ratio to Peak	0.0001

W670	1.711	46.82	0	11.292	7.4117	Discharge	0.0378866	0.00001	Ratio to Peak	0.0001
W680	1.7557	72.649	0	1.115	0.55939	Discharge	0.0297976	0.00001	Ratio to Peak	0.0001
W690	2.7572	68.583	0	3.6082	2.3791	Discharge	0.0236694	0.00001	Ratio to Peak	0.0001
W700	5.3986	52.405	0	8.8739	5.8862	Discharge	0.0139659	0.00001	Ratio to Peak	0.0001
W710	0.39333	74.628	0	0.18859	0.63876	Discharge	0.0044033	0.00001	Ratio to Peak	0.0001
W720	0.1968	98.364	0	0.7986	0.52469	Discharge	0.0171293	0.00001	Ratio to Peak	0.0001
W730	3.6979	61.757	0	4.9829	7.2961	Discharge	0.0223483	0.00001	Ratio to Peak	0.0001
W740	0.16967	99	0	0.17585	0.28026	Discharge	0.0025183	0.00001	Ratio to Peak	0.0001
W750	0.30214	63.326	0	0.18784	0.44007	Discharge	0.0037516	0.00001	Ratio to Peak	0.0001
W760	0.28635	73.567	0	0.65074	0.47996	Discharge	0.0192934	0.00001	Ratio to Peak	0.0001
W770	0.34897	77.503	0	0.344	1.1847	Discharge	0.0042625	0.00001	Ratio to Peak	0.0001
W780	0.32543	70.105	0	0.6636	2.2853	Discharge	0.0172641	0.00001	Ratio to Peak	0.0001
W790	0.12742	88.765	0	1.0267	0.74206	Discharge	0.0291398	0.00001	Ratio to Peak	0.0001
W800	2.7349	77.013	0	6.2317	6.1123	Discharge	0.0173869	0.00001	Ratio to Peak	0.0001
W810	0.14025	82.801	0	0.39106	0.57874	Discharge	0.0066268	0.00001	Ratio to Peak	0.0001
W820	4.0747	77.046	0	4.3979	6.4455	Discharge	0.051334	0.00001	Ratio to Peak	0.0001
W830	0.21066	84.082	0	0.54788	0.58211	Discharge	0.0197129	0.00001	Ratio to Peak	0.0001
W840	2.6157	76.266	0	4.977	7.3027	Discharge	0.0425653	0.00001	Ratio to Peak	0.0001
W850	0.41076	81.693	0	0.55802	0.59288	Discharge	0.0164589	0.00001	Ratio to Peak	0.0001
W860	1.3056	51.377	0	23.982	3.1759	Discharge	0.026654	0.00001	Ratio to Peak	0.0001

Annex 10. Balantian Model Reach Parameters

Table A-10.1. Balantian Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R30	Automatic Fixed Interval	4579.31	0.013934	0.0001	Trapezoid	70.48	1
R60	Automatic Fixed Interval	1456.1	0.007061	0.0001	Trapezoid	70.48	1
R70	Automatic Fixed Interval	889.411	0.016001	0.0001	Trapezoid	70.48	1
R90	Automatic Fixed Interval	636.69	0.000118	0.0001	Trapezoid	70.48	1
R100	Automatic Fixed Interval	507.99	0.003275	0.0001	Trapezoid	70.48	1
R110	Automatic Fixed Interval	2839.53	0.007204	0.0001	Trapezoid	70.48	1
R120	Automatic Fixed Interval	5008.18	0.012202	0.0001	Trapezoid	70.48	1
R150	Automatic Fixed Interval	2289.36	0.018505	0.0001	Trapezoid	70.48	1
R160	Automatic Fixed Interval	770.416	0.013281	0.0001	Trapezoid	70.48	1
R190	Automatic Fixed Interval	3596.59	0.015821	0.0001	Trapezoid	70.48	1
R220	Automatic Fixed Interval	2607.65	0.005366	0.0001	Trapezoid	70.48	1
R230	Automatic Fixed Interval	1451.25	0.013598	0.0001	Trapezoid	70.48	1
R250	Automatic Fixed Interval	10359.9	0.004838	0.0001	Trapezoid	70.48	1
R270	Automatic Fixed Interval	2509.66	0.018178	0.0001	Trapezoid	70.48	1
R280	Automatic Fixed Interval	7315.95	0.010304	0.0001	Trapezoid	70.48	1
R300	Automatic Fixed Interval	3154.92	0.022818	0.0001	Trapezoid	70.48	1
R310	Automatic Fixed Interval	2156.64	0.000074	0.0001	Trapezoid	70.48	1
R320	Automatic Fixed Interval	3706.52	0.000489	0.0001	Trapezoid	70.48	1
R360	Automatic Fixed Interval	2200.66	0.00469	0.0001	Trapezoid	70.48	1
R380	Automatic Fixed Interval	5672.12	0.075335	0.0001	Trapezoid	70.48	1
R410	Automatic Fixed Interval	7115.36	0.00644	0.0001	Trapezoid	70.48	1

Annex 11. Balantian Field Validation Points

Table A-11.1. Balantian Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event	Date	Rain Return/Scenario
	Latitude	Longitude						
1	11.48845	123.0871	1.991	0	-1.991			25-Year
2	11.38872	123.0669	1.926	0	-1.926	Yolanda	Nov 1 2013	25-Year
3	11.46091	123.1359	2.102	0.1778	-1.9242	Frank	Jun-08	25-Year
4	11.38824	123.0696	1.923	0	-1.923	Yolanda	Nov 1 2013	25-Year
5	11.38819	123.0704	1.923	0	-1.923	Yolanda	Nov 1 2013	25-Year
6	11.47615	123.0997	4.919	3	-1.919	Yolanda	Nov 1 2013	25-Year
7	11.47259	123.095	5.621	3.75	-1.871	Frank	Jun-08	25-Year
8	11.48879	123.0873	1.791	0	-1.791			25-Year
9	11.47494	123.1003	5.539	3.9	-1.639	Yolanda	Nov 1 2013	25-Year
10	11.40413	123.0881	2.47	0.89	-1.58	Marce	Nov 1 2013	25-Year
11	11.39434	123.0784	0.3	1.67	1.37	Yolanda	Nov 1 2013	25-Year
12	11.4788	123.1005	4.355	3	-1.355	Yolanda	Nov 1 2013	25-Year
13	11.4614	123.1358	2.262	0.9144	-1.3476	Yolanda	Nov 1 2013	25-Year
14	11.45849	123.1235	1.997	0.65	-1.347	Yolanda	Nov 1 2013	25-Year
15	11.46325	123.1141	2.21	0.87	-1.34	Yolanda	Nov 1 2013	25-Year
16	11.38069	123.083	0.795	2.1336	1.3386	Yolanda	Nov 1 2013	25-Year
17	11.46261	123.1345	0.169	1.4732	1.3042	Yolanda	Nov 1 2013	25-Year
18	11.45791	123.1376	2.678	3.9624	1.2844	Frank	Jun-08	25-Year
19	11.45788	123.1375	2.678	3.9624	1.2844	Frank	Jun-08	25-Year
20	11.47798	123.0996	4.251	3	-1.251	Yolanda	Nov 1 2013	25-Year
21	11.48936	123.0875	2.008	0.78	-1.228	Yolanda	Nov 1 2013	25-Year
22	11.45844	123.1372	1.194	0	-1.194	Yolanda	Nov 1 2013	25-Year
23	11.46284	123.1347	0.298	1.4732	1.1752	Yolanda	Nov 1 2013	25-Year
24	11.51904	123.1133	0.03	1.205	1.175	Yolanda	Nov 1 2013	25-Year
25	11.46114	123.1363	0.458	1.6256	1.1676	Yolanda	Nov 1 2013	25-Year
26	11.45827	123.1471	1.436	0.3048	-1.1312	Yolanda	Nov 1 2013	25-Year
27	11.40141	123.0982	0.034	1.13	1.096	Marce	Nov 1 2013	25-Year
28	11.45879	123.136	1.059	0	-1.059			25-Year
29	11.39537	123.0807	0.032	1.07	1.038	Marce	Nov 1 2013	25-Year
30	11.48833	123.0869	2.056	1.02	-1.036	Yolanda	Nov 1 2013	25-Year
31	11.46362	123.1145	1.332	0.3048	-1.0272	Yolanda	Nov 1 2013	25-Year
32	11.45802	123.1474	1.303	0.3048	-0.9982	Yolanda	Nov 1 2013	25-Year
33	11.41833	123.1023	0.988	0	-0.988	Marce	Nov 1 2013	25-Year
34	11.45806	123.1373	2.986	3.9624	0.9764	Frank	Jun-08	25-Year
35	11.46228	123.0896	1.166	0.2	-0.966	Frank	Jun-08	25-Year
36	11.51205	123.0849	0.963	0	-0.963			25-Year
37	11.45767	123.15	1.155	0.2	-0.955	Frank	Jun-08	25-Year
38	11.38601	123.0587	2.136	1.19	-0.946	Marce	Nov 1 2013	25-Year
39	11.46277	123.1135	1.23	0.3048	-0.9252	Yolanda	Nov 1 2013	25-Year
40	11.47167	123.0976	5.418	4.5	-0.918	Yolanda	Nov 1 2013	25-Year
41	11.48349	123.1531	0.031	0.9144	0.8834	Yolanda	Nov 1 2013	25-Year

42	11.47387	123.1013	4.78	3.9	-0.88	Frank	Jun-08	25-Year
43	11.41865	123.1032	0.879	0	-0.879	Marce	Nov 1 2013	25-Year
44	11.45992	123.1361	1.75	0.889	-0.861	Yolanda	Nov 1 2013	25-Year
45	11.46126	123.1359	1.757	0.9144	-0.8426	Yolanda	Nov 1 2013	25-Year
46	11.467	123.0891	1.529	0.7	-0.829	Yolanda	Nov 1 2013	25-Year
47	11.40678	123.0678	0.818	1.6	0.782	Yolanda	Nov 1 2013	25-Year
48	11.46828	123.1218	0.19	0.96	0.77	Yolanda	Nov 1 2013	25-Year
49	11.45922	123.1208	1.849	1.13	-0.719	Frank	Jun-08	25-Year
50	11.47512	123.1	4.618	3.9	-0.718	Yolanda	Nov 1 2013	25-Year
51	11.47476	123.1013	4.614	3.9	-0.714	Yolanda	Nov 1 2013	25-Year
52	11.46429	123.116	1.607	0.9	-0.707	Yolanda	Nov 1 2013	25-Year
53	11.47973	123.1556	0.244	0.9398	0.6958	Frank	Jun-08	25-Year
54	11.4593	123.1238	1.594	0.914	-0.68	Frank	Jun-08	25-Year
55	11.46559	123.1573	0.09	0.762	0.672	Undang	30987	25-Year
56	11.46234	123.1359	0.671	0	-0.671			25-Year
57	11.44111	123.1058	0.158	0.805	0.647	Yolanda	Nov 1 2013	25-Year
58	11.46971	123.0902	0.632	0	-0.632	Yolanda	Nov 1 2013	25-Year
59	11.46346	123.1135	0.936	0.3048	-0.6312	Yolanda	Nov 1 2013	25-Year
60	11.45782	123.1381	1.463	0.8382	-0.6248	Frank	Jun-08	25-Year
61	11.47525	123.0999	4.51	3.9	-0.61	Yolanda	Nov 1 2013	25-Year
62	11.46467	123.1159	1.403	0.8	-0.603	Yolanda	Nov 1 2013	25-Year
63	11.44707	123.1503	0.379	0.9652	0.5862	Yolanda	Nov 1 2013	25-Year
64	11.46829	123.0944	0.961	0.4	-0.561	Yolanda	Nov 1 2013	25-Year
65	11.45826	123.1479	0.937	0.4064	-0.5306	Yolanda	Nov 1 2013	25-Year
66	11.4579	123.1522	0.686	1.21	0.524	Frank	Jun-08	25-Year
67	11.45059	123.1497	0.47	0	-0.47			25-Year
68	11.42868	123.0955	0.855	1.31	0.455	Marce	Nov 1 2013	25-Year
69	11.45884	123.1454	0.442	0	-0.442	Yolanda	Nov 1 2013	25-Year
70	11.45841	123.1438	0.454	0.0508	-0.4032	Frank	Jun-08	25-Year
71	11.48544	123.1545	0.032	0.4	0.368	Yolanda	Nov 1 2013	25-Year
72	11.46104	123.1345	0.041	0.4064	0.3654	Marce	Nov 1 2013	25-Year
73	11.46286	123.1146	0.363	0	-0.363			25-Year
74	11.51551	123.0894	0.362	0	-0.362			25-Year
75	11.41504	123.0735	0.055	0.4	0.345	Yolanda	Nov 1 2013	25-Year
76	11.46176	123.1177	0.426	0.1	-0.326	Yolanda	Nov 1 2013	25-Year
77	11.47276	123.1579	0.03	0.3556	0.3256	Yolanda	Nov 1 2013	25-Year
78	11.44974	123.1086	0.346	0.66	0.314	Frank	Jun-08	25-Year
79	11.45768	123.1372	1.021	0.7112	-0.3098	Frank	Jun-08	25-Year
80	11.46112	123.1139	0.588	0.89	0.302	Yolanda	Nov 1 2013	25-Year
81	11.50788	123.0849	0.29	0	-0.29			25-Year
82	11.40972	123.077	0.859	1.14	0.281	Marce	Nov 1 2013	25-Year
83	11.47259	123.0918	0.726	1	0.274	Yolanda	Nov 1 2013	25-Year
84	11.46158	123.1142	1.333	1.07	-0.263	Yolanda	Nov 1 2013	25-Year
85	11.44892	123.0531	0.259	0	-0.259	Yolanda	Nov 1 2013	25-Year
86	11.45878	123.1445	0.148	0.4064	0.2584	Yolanda	Nov 1 2013	25-Year
87	11.46468	123.1077	0.384	0.13	-0.254	Yolanda	Nov 1 2013	25-Year

88	11.46173	123.1349	0.253	0	-0.253			25-Year
89	11.45679	123.1461	0.678	0.4318	-0.2462	Yolanda	Nov 1 2013	25-Year
90	11.46055	123.1366	0.238	0	-0.238			25-Year
91	11.46989	123.0925	7.22	7	-0.22	Frank	Jun-08	25-Year
92	11.41374	123.1109	0.216	0	-0.216	Yolanda	Nov 1 2013	25-Year
93	11.45843	123.1493	0.492	0.3	-0.192	Yolanda	Nov 1 2013	25-Year
94	11.5201	123.1066	0.631	0.44	-0.191	Yolanda	Nov 1 2013	25-Year
95	11.45992	123.1523	0.176	0	-0.176	Yolanda	Nov 1 2013	25-Year
96	11.4543	123.1511	0.231	0.4064	0.1754	Frank	Jun-08	25-Year
97	11.42474	123.0746	0.173	0	-0.173	Yolanda	Nov 1 2013	25-Year
98	11.4426	123.1043	0.273	0.11	-0.163	Yolanda	Nov 1 2013	25-Year
99	11.44935	123.1103	0.353	0.51	0.157	Yolanda	Nov 1 2013	25-Year
100	11.45814	123.153	0.258	0.41	0.152	Marce	Nov 1 2013	25-Year
101	11.45985	123.1236	0.707	0.56	-0.147	Yolanda	Nov 1 2013	25-Year
102	11.48041	123.0817	0.753	0.9	0.147	Yolanda	Nov 1 2013	25-Year
103	11.4477	123.151	1.026	1.1684	0.1424	Yolanda	Nov 1 2013	25-Year
104	11.46977	123.0912	6.86	7	0.14	Frank	Jun-08	25-Year
105	11.42116	123.0856	0.525	0.39	-0.135	Yolanda	Nov 1 2013	25-Year
106	11.45789	123.1344	0.128	0	-0.128			25-Year
107	11.46068	123.1246	0.366	0.24	-0.126	Marce	Nov 1 2013	25-Year
108	11.46126	123.1376	0.124	0	-0.124			25-Year
109	11.46157	123.1363	1.038	0.9144	-0.1236	Frank	Jun-08	25-Year
110	11.45339	123.1496	0.031	0.1524	0.1214	Yolanda	Nov 1 2013	25-Year
111	11.44263	123.105	0.28	0.4	0.12	Yolanda	Nov 1 2013	25-Year
112	11.45239	123.1527	0.289	0.4064	0.1174	Marce	Nov 1 2013	25-Year
113	11.46998	123.0769	0.112	0	-0.112	Yolanda	Nov 1 2013	25-Year
114	11.45773	123.1352	0.108	0	-0.108			25-Year
115	11.45836	123.1349	0.299	0.4064	0.1074	Yolanda	Nov 1 2013	25-Year
116	11.49488	123.0889	0.105	0	-0.105			25-Year
117	11.46136	123.1543	0.032	0.127	0.095	Yolanda	Nov 1 2013	25-Year
118	11.46087	123.1347	0.063	0.1524	0.0894	Marce	Nov 1 2013	25-Year
119	11.46026	123.1191	0.399	0.31	-0.089	Yolanda	Nov 1 2013	25-Year
120	11.45816	123.1491	0.733	0.65	-0.083	Frank	Jun-08	25-Year
121	11.448	123.1509	0.837	0.762	-0.075	Frank	Jun-08	25-Year
122	11.46204	123.1345	0.075	0	-0.075			25-Year
123	11.44593	123.1359	0.073	0	-0.073			25-Year
124	11.44681	123.1487	0.716	0.7874	0.0714	Yolanda	Nov 1 2013	25-Year
125	11.39198	123.1395	0.449	0.38	-0.069	Yolanda	Nov 1 2013	25-Year
126	11.39151	123.1381	0.149	0.21	0.061	Yolanda	Nov 1 2013	25-Year
127	11.45616	123.1486	0.056	0	-0.056			25-Year
128	11.4556	123.1446	0.041	0	-0.041			25-Year
129	11.45796	123.1494	0.439	0.4	-0.039	Yolanda	Nov 1 2013	25-Year
130	11.39159	123.0395	0.036	0	-0.036	Marce	Nov 1 2013	25-Year
131	11.38576	123.0722	0.036	0	-0.036	Yolanda	Nov 1 2013	25-Year
132	11.45012	123.1501	0.035	0	-0.035			25-Year
133	11.44191	123.0677	0.035	0	-0.035	Marce	Nov 1 2013	25-Year

134	11.47319	123.1524	0.033	0	-0.033			25-Year
135	11.41329	123.1117	0.032	0	-0.032	Yolanda	Nov 1 2013	25-Year
136	11.44884	123.1469	0.032	0	-0.032			25-Year
137	11.46411	123.1534	0.032	0	-0.032	Yolanda	Nov 1 2013	25-Year
138	11.46122	123.1559	0.032	0	-0.032	Yolanda	Nov 1 2013	25-Year
139	11.45853	123.154	0.031	0	-0.031	Yolanda	Nov 1 2013	25-Year
140	11.47654	123.1544	0.031	0	-0.031			25-Year
141	11.4244	123.107	0.031	0	-0.031	Yolanda	Nov 1 2013	25-Year
142	11.48287	123.0808	0.031	0	-0.031	Yolanda	Nov 1 2013	25-Year
143	11.47949	123.0921	0.03	0	-0.03			25-Year
144	11.46156	123.106	0.03	0	-0.03	Yolanda	Nov 1 2013	25-Year
145	11.4956	123.0886	0.03	0	-0.03			25-Year
146	11.48122	123.099	0.03	0	-0.03			25-Year
147	11.48848	123.0881	0.03	0	-0.03			25-Year
148	11.44152	123.1058	0.03	0	-0.03	Yolanda	Nov 1 2013	25-Year
149	11.45853	123.1558	0.03	0	-0.03	Frank	Jun-08	25-Year
150	11.45364	123.1501	0.03	0	-0.03	Yolanda	Nov 1 2013	25-Year
151	11.44846	123.1469	0.03	0	-0.03			25-Year
152	11.45841	123.1347	0.395	0.4064	0.0114	Yolanda	Nov 1 2013	25-Year
153	11.4694	123.0891	0.692	0.7	0.008	Yolanda	Nov 1 2013	25-Year
154	11.46504	123.1078	0.155	0.15	-0.005	Yolanda	Nov 1 2013	25-Year

Annex 12. Educational Institutions Affected by Flooding in Balantian Floodplain

Table A-12.1. Educational Institutions Affected by Flooding in the Balantian Floodplain

Capiz				
Pilar				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Carlos Lopez Elementary School	San Nicolas			
San Nicolas National High School	San Nicolas			
Sinamongan Elementary School	Sinamongan			
Sinamongan Elementary School Stage	Sinamongan			Low

Iloilo				
Balasan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Pedro Bedez Elementary School	Aranjuez			
Bacolod Day Care Center	Bacolod			
Bacolod Preschool	Bacolod			
Bacolod Primary School	Bacolod			
Balantian Elementary School	Balanti-An			
Balasan National High School	Balanti-An			
Mamhut Sur Day Care Center	Balanti-An			
Mamhut Sur Elementary School	Balanti-An			
Batuan Day Care Center	Batuan			
Batuan Primary School	Batuan			
Cabalic Day Care Center	Cabalic			
Cabalic Elementary School	Cabalic			
Cabalic National High School	Cabalic			
Salvacion Day Care Center	Cabalic			
Camambugan Day Care Center	Camambugan			
Camambugan Elem. School	Camambugan			
Dolores Barangay Day Care Center	Dolores			
Gimamanay Day Care Center	Gimamanay			
Gimamanay Elementary School	Gimamanay			
Ipil Day Care Center	Ipil			
Panian-Ipil Elementary School	Ipil			Low
Kinalkalan Day Care Center	Kinalkalan			
Kinalkalan Elementary School	Kinalkalan			
Kinalkalan Elementary School Stage	Kinalkalan			
Lawis Elementary School	Lawis			
Mamhut Norte Day Care Center	Mamhut Norte			
Mamhut Norte Primary School	Mamhut Norte			
Mamhut Sur Elementary School	Mamhut Sur			
Leon Ganzon Polytechnic College	Maya			
Maya Day Care Center	Maya	Low	Low	Medium
Iloilo Christian School	Pani-An			

Balasan Central School	Poblacion Norte			
Poblacion Norte Day Care Center	Poblacion Norte			Low
Ansag Day Care Center	Poblacion Sur	Medium	Medium	High
Balasan Central School	Poblacion Sur			Low
Wakebridge Adventist Academy	Poblacion Sur	Medium	Medium	High
Quiasan Barangay Day Care Center	Quiasan			
Quiasan Elementary School	Quiasan			
Salong Elem. School	Salong			
Filipino Chamber of Commerce	Tingui-An			
St. Anne Catholic School of Balasan	Tingui-An			

Batad				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Batad National High School	Batad Viejo			
Batad Viejo Barangay Day Care Center	Batad Viejo			
Northern Iloilo Polytechnic State College - Batad Campus	Batad Viejo			
Barangay Calangag Daycare Center	Bolhog			
Calangag Primary School	Bolhog			
Barangay Bulak Norte Daycare Center	Bulak Norte			
Barangay Nangka Daycare Center	Bulak Norte			
Bulak Elementary School	Bulak Norte			
Bulak Elementary School	Bulak Sur			
Barangay Pasayan Daycare Center	Calangag			
Pasayan Primary School	Calangag			
Drancalan Barangay Daycare Center	Drancalan			
Malico Barangay Day Care Center	Malico			
Baptist School	Poblacion			
Batad Central School	Poblacion			
Batad Seventh Day Adventist Multi-grade School	Poblacion			
Poblacion Barangay Day Care Center 1	Poblacion			
Poblacion Barangay Day Care Center 2	Poblacion			
St. Vincent Catholic School	Poblacion			Low
Malico Primary School	Santa Ana			
Sta. Ana Barangay Day Care Center	Santa Ana			
Sta. Ana Primary School	Santa Ana			

Carles				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bolo Elementary School	Bolo			
Bolo Elementary School Stage	Bolo			
Cawayan Primary School	Cawayan			
Cawayan Sulod Daycare Center	Cawayan			Low
Mandulao Daycare Center	Cawayan			
Barangay bolo Daycare Center	Tupaz			

Barangay Tupaz Daycare Center	Tupaz			
Bolo Elementary School Stage	Tupaz			
Tupaz Elementary School	Tupaz			

Estancia				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BU Learning Center	Estancia			
Hijas de Jesus School	Estancia			
Botongon Elementary School	Estancia	Low	Low	Low
Bulaquena Day Care Center	Estancia			
Tacbuyan Day Care Center	Estancia			
Calapdan Day Care Center	Estancia			
Cano-An Elementary School	Estancia			
Tanza Elementary School	Estancia			
Daculan Barangay Day Care Center	Estancia	Medium	Medium	Medium
Pa-on Elementary School	Estancia			
Andres S. Ravena Elementary School	Estancia			
Lonoy Day Care Center	Estancia			
Brgy. Lumbia, Sitio Alimango Day Care Center	Estancia			
Lumbia Elem. School	Estancia			
Lumbia Proper Day Care Center	Estancia			
Barangay Day Care Center	Estancia			Low
Malbog Elementary School	Estancia			
Northern Iloilo Polytechnic State College - Main Campus	Estancia			
Pa-on Elementary School	Estancia			
Pani-an Barangay Day Care Center	Estancia	Low	Low	Low
Estancia Central School	Estancia			
Northern Iloilo Polytechnic State College - West Campus	Estancia			
Estancia Central School	Estancia			
Iloilo King of Glory Academy	Estancia			
Seventh Day Adventist Elementary School, Inc.	Estancia			
Northern Iloilo Polytechnic State College - Main Campus	Estancia			
San Roque Barangay Day Care Center	Estancia			
San Roque Elementary School	Estancia			
Santa Ana Day Care Center	Estancia			
Estancia National High School	Estancia			

Annex 13. Medical Institutions Affected by Flooding in Balantian Floodplain

Table A-13.1. Medical Institutions Affected by Flooding in the Balantian Floodplain

Iloilo				
Balasan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Mamhut Sur Barangay Health Center	Balanti-An			
Cabalic Barangay Health Center	Cabalic			
Aranjuez Day Care Center	Camambugan			
Camambugan Health Center	Camambugan			
Gimamanay Barangay Health Center	Gimamanay			
Ipil Barangay Health Center	Ipil			
Kinalkalan Health Center	Kinalkalan			
Tingui-an Health Center	Tingui-An			
Zaragosa Health Center	Zaragosa			

Batad				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Bulak Norte	Barangay Bulak Norte Health Center			
Malico	Malico Barangay Health Center			
Pasayan	Barangay Pasayan Health Center			
Santa Ana	Sta. Ana Barangay Health Center			

Carles				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Barangay Bolo Health Center	Bolo	Medium	Medium	Medium
Nalumsan Barangay Health Center	Nalumsan			
Barangay Bolo Health Center	Tupaz			Medium
Barangay Tupaz Health Station	Tupaz			

Estancia				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Cano-An Barangay Health Station	Cano-An			
Daculan Barangay Health Center	Daculan	Medium	Medium	Medium
Jolog Barangay Health Center	Jolog			
Jesus Colmenares District Hospital	Malbog			Low
Estancia Municipal Health Office	Poblacion Zone 1			
Estancia Municipal Health Office	Poblacion Zone II			