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

LiDAR Surveys and Flood Mapping of Danao River

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

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

AAC	Asian Aerospace Corporation
Ab	abutment
ALTM	Airborne LiDAR Terrain Mapper
ARG	automatic rain gauge
ATQ	Antique
AWLS	Automated Water Level Sensor
BA	Bridge Approach
BM	benchmark
CAD	Computer-Aided Design
CN	Curve Number
CSRS	Chief Science Research Specialist
DAC	Data Acquisition Component
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
DPPC	Data Pre-Processing Component
DREAM	Disaster Risk and Exposure Assessment for Mitigation [Program]
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVBC	Data Validation and Bathymetry Component
FMC	Flood Modeling Component
FOV	Field of View
GiA	Grants-in-Aid
GCP	Ground Control Point
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HC	High Chord
IDW	Inverse Distance Weighted [interpolation method]

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND THE DANAO RIVER

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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 sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

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

The implementing partner university for the Phil-LiDAR 1 Program is the University of the 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 22 river basins in the Western Visayas Region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Danao River Basin

Danao River Basin is located in Escalante City in the province of Negros Occidental located at the north of Negros Island. The floodplain and drainage area of 156.37 km2 and 135.027 km2 respectively covers the municipality of Toboso and the cities of Sagay and Escalante. According to the River Basin Control Office of the DENR, it has an estimated annual run-off of 170 million cubic meters (MCM).

Its main stem, Danao River is part of the river systems in the Negros Island. According to the 2010 census, the total population of the barangays nearby the upstream and downstream portion of Danao River is 42,769. Sugarcane, being the primary agricultural product of the city, occupies most of the land of the northern side of the province. During this study, it was noted that Danao River is heavily silted and mangroves grow at its riverbanks. Locals were also quarrying at the upstream of the river. Northern Negros Occidental had scenes of devastation as the floods receded during the fall of Tropical Storm Uring from November 2 to 7, 1991. The province was also identified to have high landslide vulnerability.

The floodplain is 99.47% covered with LiDAR data which compromises 8 blocks. The LiDAR data was calibrated then mosaicked with an RMSE of 0.15 and then bathy burned. The bathy survey conducted reached a total length of 19.95 km starting from Tanquinto Bridge, Jonob-Jonob, Escalante City up to the river mouth with 5601 points surveyed. There are 19272 buildings, 317.58km roads, 655 waterbodies and 19 bridges digitized based from the LiDAR data. Feature Extraction Attribution was conducted and among the building features, 18532 of them are Residential, 370 are schools and 23 are Medical Institutions.

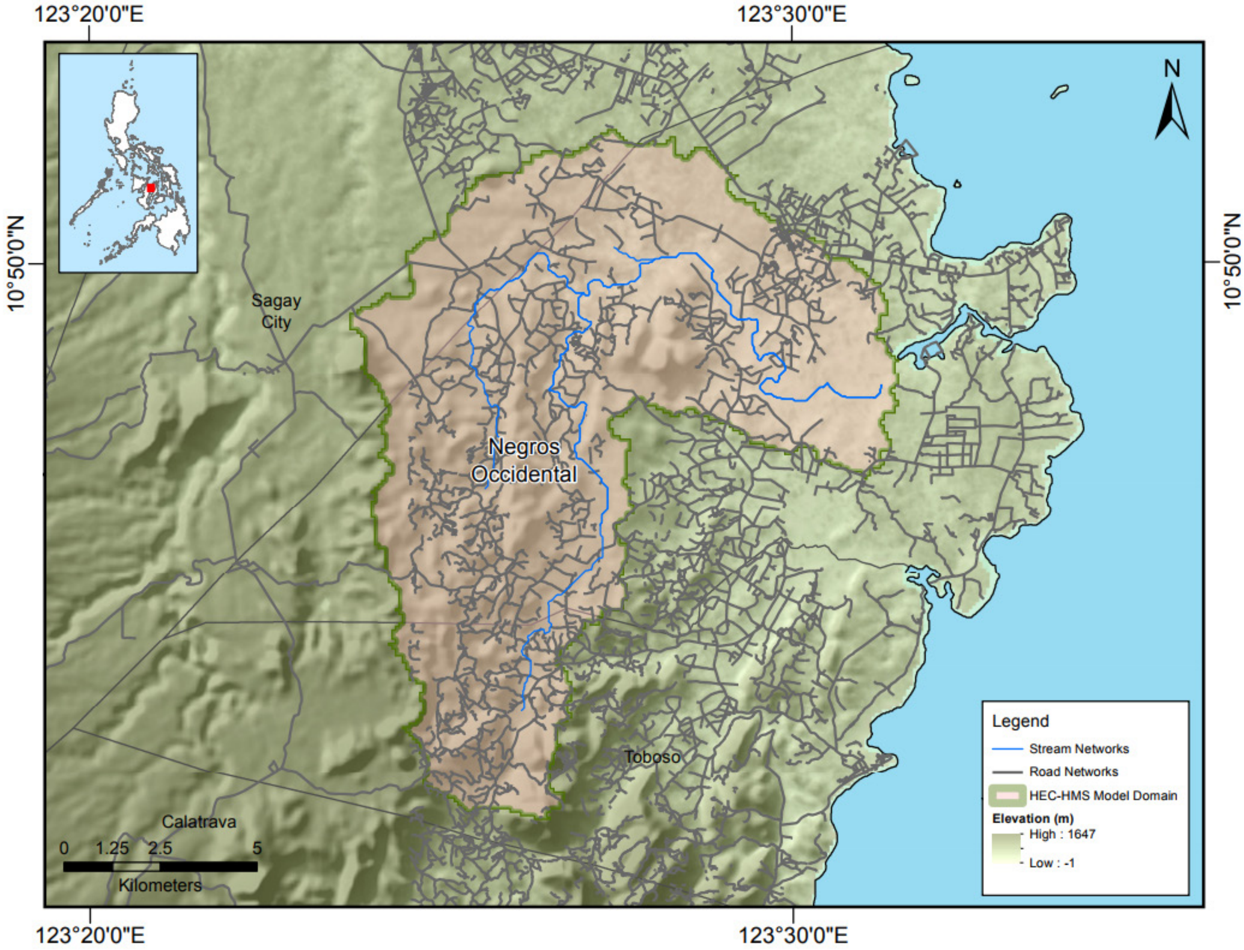

Figure 1. Map of Danao River Basin (in brown)

The flood hazard map produced covers the 11.49 km2, 14.66 km2, 16.04 km2 for the 5-year, 25-year, and 100-year rainfall return period Escalante City which affects 12 barangays. A flood depth validation was conducted using 203 randomly generated points which is spread throughout the 6 ranges namely 0m-0.2m, 0.21m-0.5m, 0.51m-1m, 1.01m-2m, 2.10m-5m, 5m+ depth using the 25-year rainfall flood depth map. It yielded a 0.784m RMSE.

A rating curve was developed at Danao Footbridge Bridge, Escalante City, Negros Occidental, which shows the relationship between the observed water levels at Danao Footbridge and outflow of the watershed at this location. The rating curve is as shown in Figure 3. This rating curve equation, expressed as Q = 0.0644e5.6329x, was used to compute the river outflow at Danao Footbridge for the calibration of the HEC-HMS model. The resulting outflow was used to simulate the flooded areas using HEC-RAS. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE DANAO FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Danao floodplain in Negros Occidental. These missions were planned for 14 lines and ran for at most four and a half (4.5) hours including take-off, landing and turning time. The flight planning parameters for the LiDAR system can be found in Table 1 and Table 2. Figure 2 shows the flight plan and base station for Danao floodplain.

Table 1. Flight planning parameters for Aquarius LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK44 A	600	30	36	70	50	120	5

Table 2. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (AGL)	Overlap (%)	Field of View	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency	Average Speed	Average Turn Time (Minutes)
BLK44 D	1800	30	40	200	50	130	5
BLK44 E	1800	30	40	200	50	130	5
BLK44 F	1800	30	40	200	50	130	5
BLK44 G	1800	30	50	200	40	130	5
BLK44 H	1800	30	50	200	40	130	5
BLK44 I	1800	30	40	200	50	130	5
BLK44 J	1800	30	40	200	40	130	5

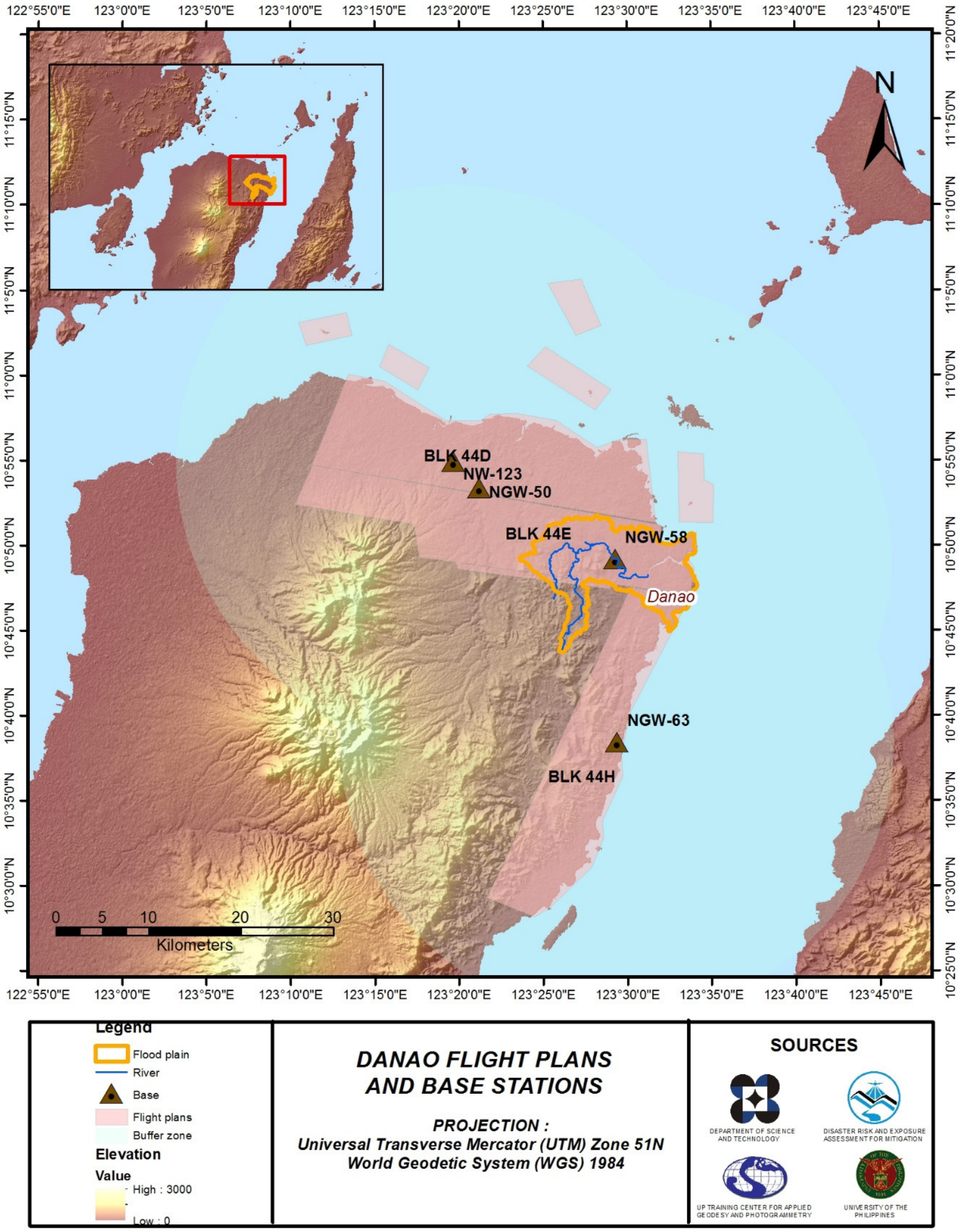


Figure 2. Flight plan and base stations used for Danao floodplain.

2.2 Ground Base Station

The project team was able to recover three (3) NAMRIA reference points: NGW-50, NGW-58, NGW-63, which are of second (2nd) order accuracy. The team also reprocessed one (1) benchmark NW-123. These benchmarks were used as vertical reference points and were also established as ground control points. The certification for the NAMRIA reference points and benchmarks are found in Annex 2 while the baseline processing reports for the established control points are found in Annex 3. These were used as base stations during flight operations for the entire duration of the survey (April to May 2014 and April to May

2016). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. Flight plans and location of base stations used during the aerial LiDAR acquisition in Danao floodplain are shown in Figure 1.

Figure 3 to Figure 6 shows the recovered NAMRIA control station within the area. In addition, Table 3 to Table 6 shows the details about the following NAMRIA control stations and established points, while Table 7 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

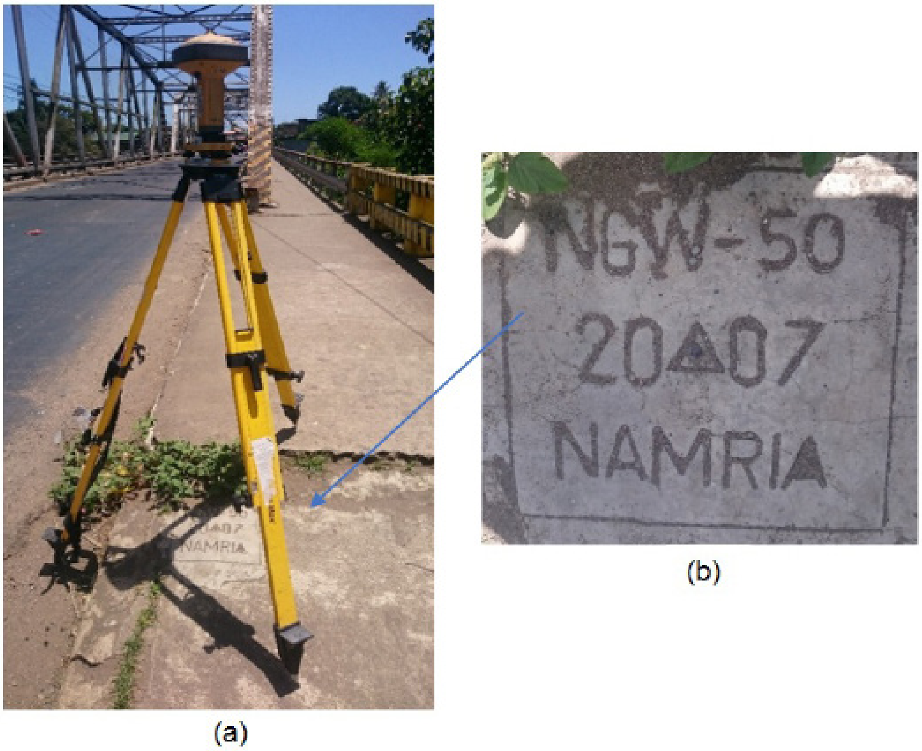


Figure 3. GPS set-up over NGW-50 in Sagay, Negros Occidental (a) NAMRIA reference point NGW-50 (b) as recovered by the field team.

Table 3. Details of the recovered NAMRIA horizontal control point NGW-50 used as base station for the LiDAR Acquisition.

Station Name	NGW-50	
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	10° 53' 26.84456" 123° 21' 06.66798" 15.386 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	538465.927 m 1204272.594 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 53' 26.84456" North 123° 21' 06.66798" East 15.386 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	538452.463 meters 1203851.077 meters

(a)

Figure 4. GPS set-up over NGW-58 in Brgy. Jonobjonob, Sitio Labarca, Escalante, Negros Occidental. It is on top of embedded benchmark NW-100.

Table 4. Details of the recovered NAMRIA horizontal control point NGW-58 used as base station for the LiDAR Acquisition.

Station Name	NGW-58	
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	10° 49' 16.43235" 123° 29' 11.51295" 8.72200 m
Grid Coordinates PTM	Easting Northing	553202.195 m 1196599.363 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 49' 12.14178" 123° 29' 16.71871" 68.25600 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	553,183.57 1,196,180.53

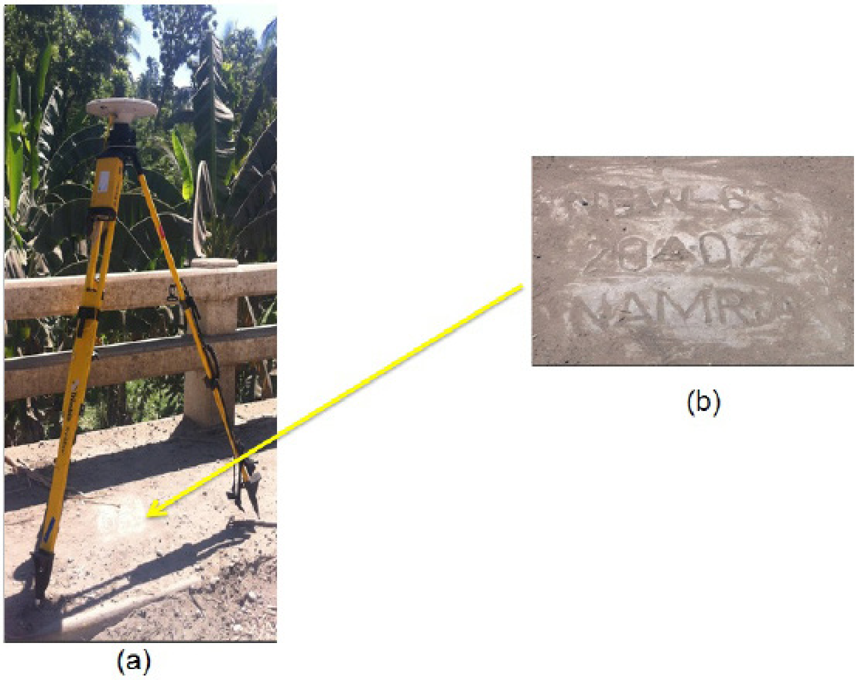
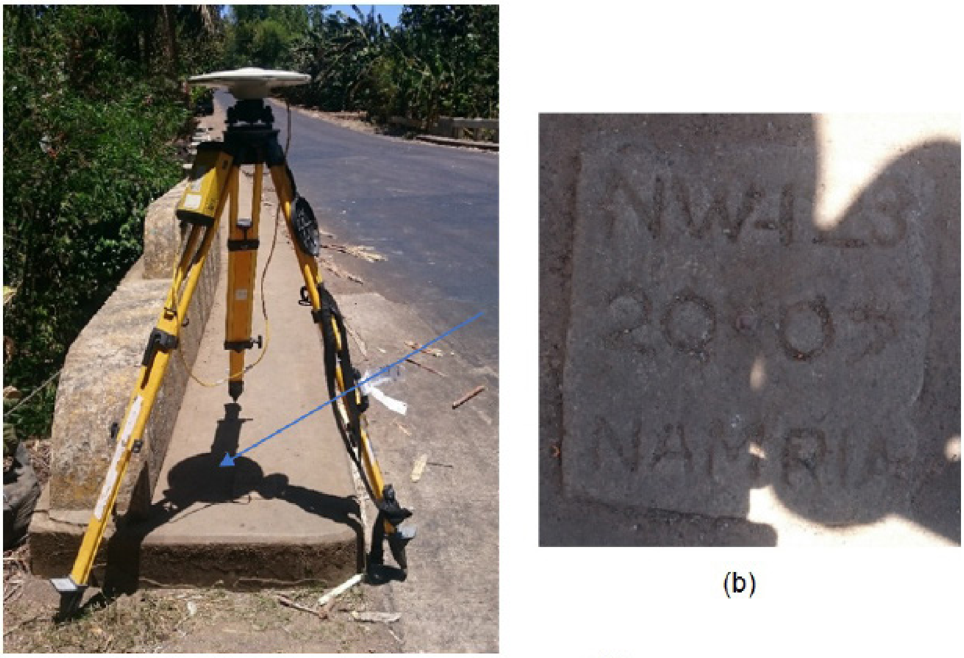


Figure 5. GPS set-up over NGW-63 in Brgy. Lemery, Calatrava, Negros Occidental and NAMRIA reference point NGW-63 (b) as recovered by the field team.

Table 5. Details of the recovered NAMRIA horizontal control point NGW-63 used as base station for the LiDAR Acquisition.

Station Name	NGW-63	
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	10° 38’ 30.18023” 123° 29’ 18.57332” 10.15500 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	553448.18 m 1176744.618 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 38’ 25.93535” 123° 29’ 23.79491” 70.11800 m
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	553429.47 m 1176332.74 m



(b)

(a)

Figure 6. GPS set-up over NW-123 in Cadiz, Negros Occidental going to San Carlos, along the national road (a) and NAMRIA reference point NW-123 (b) as recovered by the field team.

Table 6. Details of the recovered NAMRIA horizontal control point NW-123 used as base station for the LiDAR Acquisition.

Station Name	NW-123	
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	10° 54' 55.44193" 123° 19' 39.85851" 29.402 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	Latitude Longitude Ellipsoidal Height 10° 54' 51.11386" North 123° 19' 45.05716" East 88.320 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	535814.201 meters 1206569.167 meters

Table 7. Ground control points used during LiDAR Data Acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
May 1, 2014	1411P	1BLK44D121A	NGW-50 and NGW-58
May 2, 2014	1415P	1BLK44H122A	NGW-50 and NGW-58
May 6, 2014	1431P	1BLK44GHS126A	NGW-58 and NGW-63
May 6, 2014	1433P	1BLK44FGS126B	NGW-58 and NGW-63
May 7, 2014	1435P	1BLK44DS127A	NGW-58 and NGW-63
April 22, 2016	8453AC	3BLK44AS113A	NGW-50 and NW-123
April 23, 2016	8455AC	3BLK44AS114A	NGW-50 and NW-123
April 25, 2016	8459AC	3BLK44AS11A	NGW-50 and NW-123

2.3 Flight Missions

Eight (8) missions were conducted to complete LiDAR data acquisition in Danao floodplain, for a total of 34 hours and 14 minutes of flying time for RP-C9022 and RP-C9322. All missions were acquired using the Aquarius and Pegasus LiDAR systems. Table 8 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 9 presents the actual parameters used during the LiDAR data acquisition.

Table 8. Flight missions for LiDAR data acquisition in Danao Floodplain.

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
May 1, 2014	1411P	584.55	358.76	20.50	338.26	519	3	47
May 2, 2014	1415P	501.27	405.08	62.00	343.08	686	4	23
May 6, 2014	1431P	501.27	217.96	39.89	178.07	727	4	21
May 6, 2014	1433P	341.79	196.81	9.37	187.44	973	4	29
May 7, 2014	1435P	843.06	303.80	14.20	289.60	NA	4	53
April 22, 2016	8453AC	276.43	104.46	50.20	54.26	NA	4	11
April 23, 2016	8455AC	276.43	60.01	26.26	33.75	NA	3	53
April 25, 2016	8459AC	49.41	76.85	0.17	76.68	NA	4	17
Total		2596.51	1723.73	222.59	1501.14	2905	34	14

Table 9. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes
1411P	1200	30	40	200	50	120	5
1415P	1200	30	40	200	50	120	5
1431P	800	30	40	200	50	125	5
1433P	800	30	40	200	50	130	5
1435P	800	30	40	200	50	125	5
8453AC	500	30	36	50	45	125	5
8455AC	500	30	36	50	45	125	5
8459AC	500	30	36	50	45	125	5

2.4 Survey Coverage

Danao floodplain is located in the province of Negros Occidental with majority of the floodplain situated within the municipality of Escalante City. Municipalities of Sagay City and Calatrava are mostly covered by the survey. The list of municipalities and cities surveyed, with at least one (1) square kilometer coverage, is shown in Table 10. The actual coverage of the LiDAR acquisition for Danao floodplain is presented in Figure 7.

Table 10. List of Municipalities/Cities Surveyed in Negros Occidental

Province	Municipality/City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Negros Occidental	Escalante City	193.4	193.17	100%
	Toboso	118.52	118.51	100%
	Sagay City	304.62	280.17	92%
	Calatrava	344.54	251.47	73%
	Cadiz City	516.18	244.23	47%
	San Carlos City	408.97	84.81	21%
	Manapala	99.18	3.17	3%

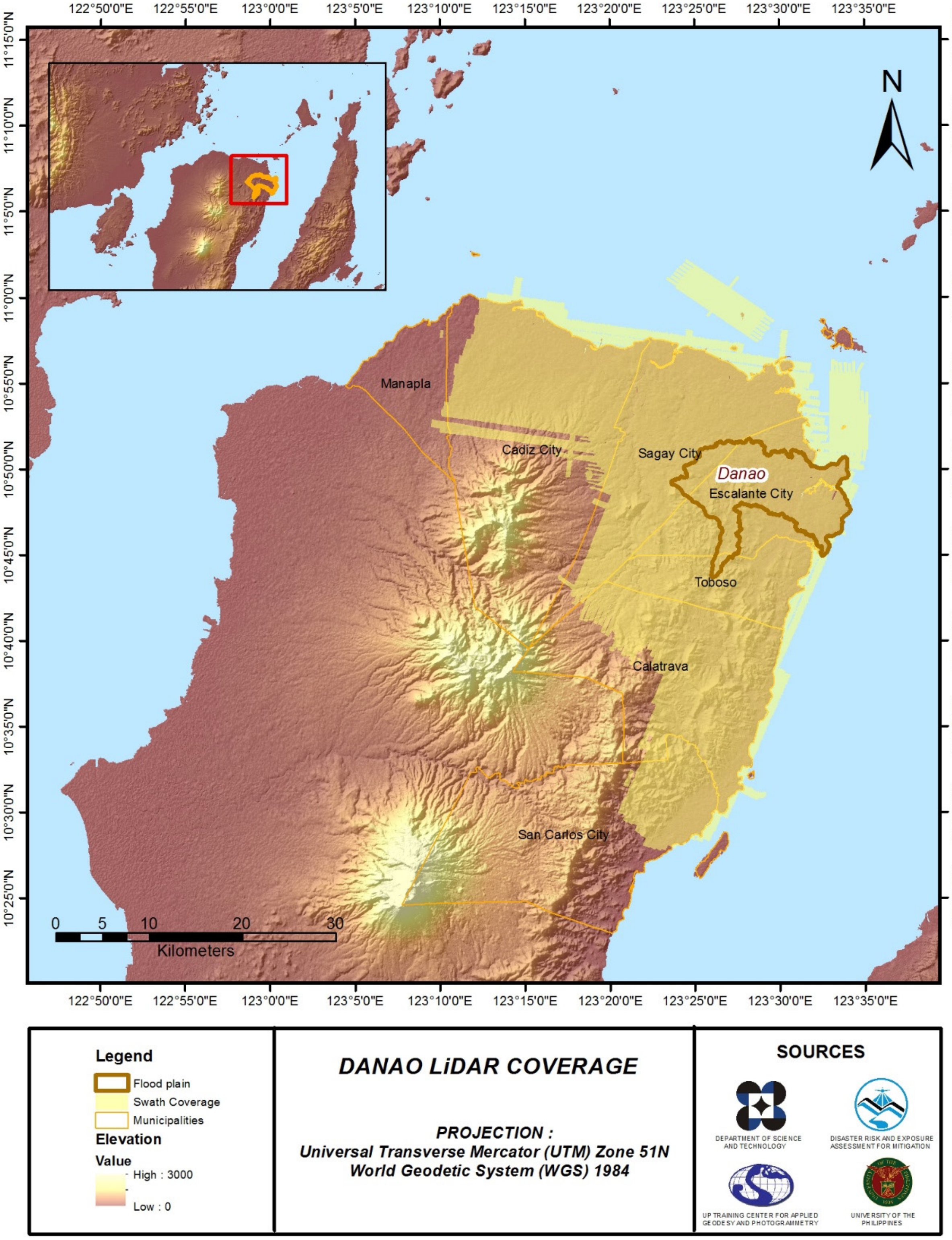


Figure 7. Actual LiDAR data acquisition for Danao Floodplain.

CHAPTER 3: LIDAR DATA PROCESSING OF THE DANAO 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 LiDAR Data Pre-Processing

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

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

These processes are summarized in the flowchart shown in Figure 8.

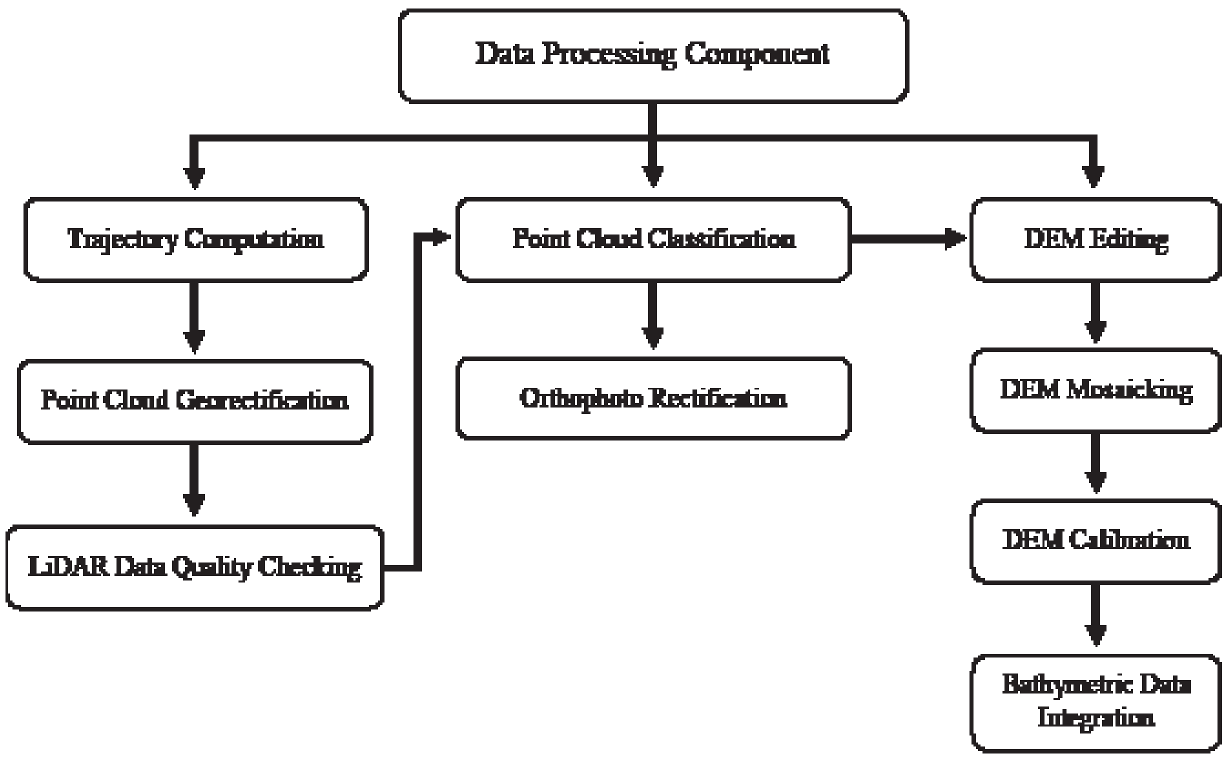


Figure 8. Schematic Diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Danao floodplain can be found in Annex 5. Missions flown during the first survey conducted on May 2014 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus while missions acquired during the second survey on May 2016 were flown using the Aquarius system over Escalante, Negros Occidental. The Data Acquisition Component (DAC) transferred a total of 182.89 Gigabytes of Range data, 2.41 Gigabytes of POS data, 605.10 Megabytes of GPS base station data, and 303.18 Gigabytes of raw image data to the data server on May 19, 2014 for the first survey and May 18, 2016 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Danao was fully transferred May 20, 2016, as indicated on the Data Transfer Sheets for Danao floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for flight 1451P, one of the Danao flights, which is the North, East, and Down position RMSE values are shown 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 on that week fell on June 19, 2014 00:00AM. The y-axis is the RMSE value for that particular position.

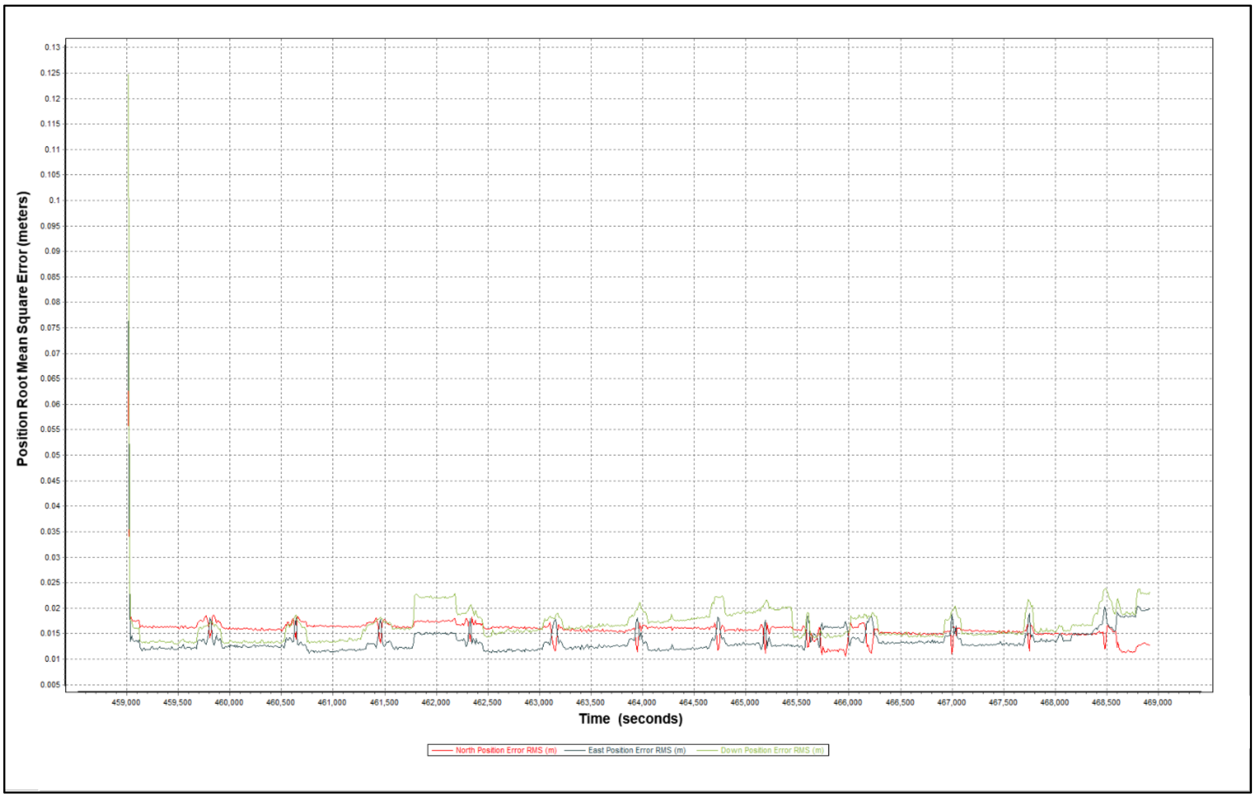


Figure 9. Smoothed Performance Metrics of a Danao Flight 1451P.

The time of flight was from 459,000 seconds to 468,900 seconds, which corresponds to morning of May 19, 2014. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 10 shows that the North position RMSE peaks at 1.80 centimeters, the East position RMSE peaks at 1.60 centimeters, and the Down position RMSE peaks at 2.40 centimeters, which are within the prescribed accuracies described in the methodology.

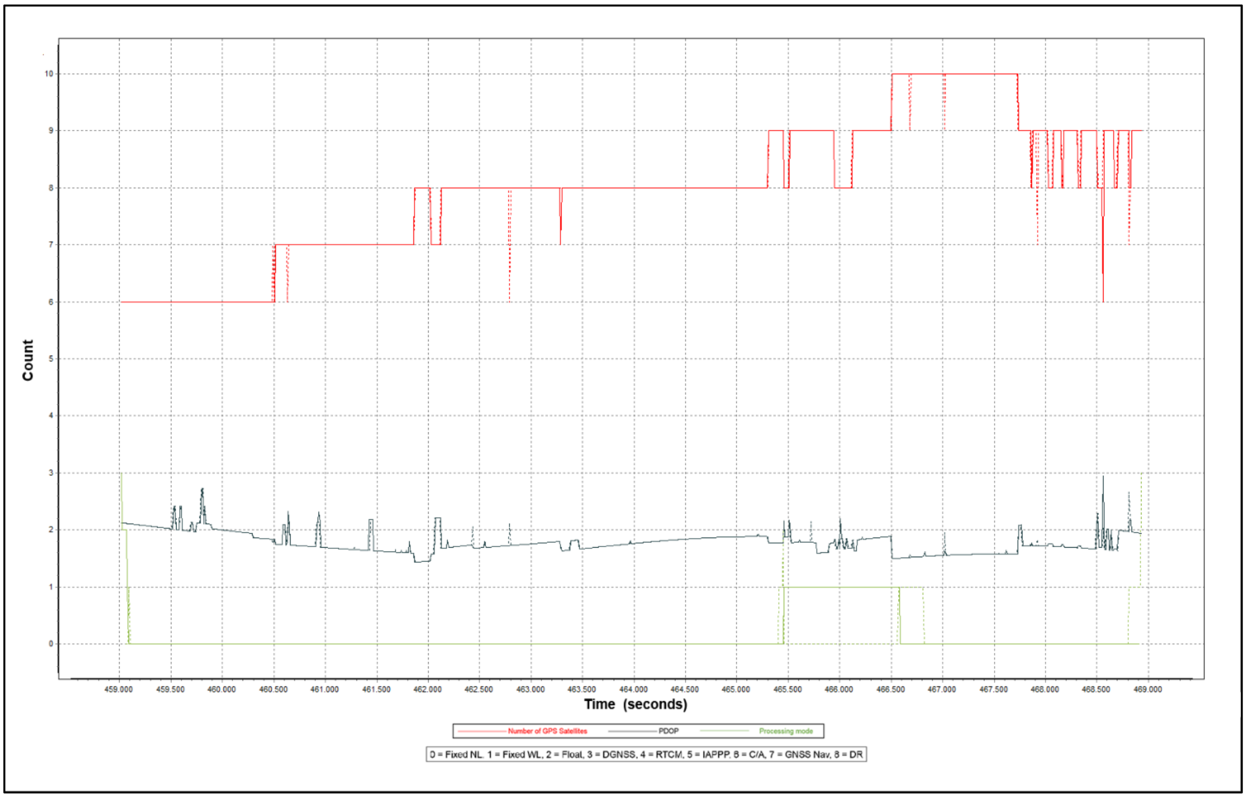


Figure 10. Solution Status Parameters of Danao Flight 1451P.

The Solution Status parameters of flight 1451P, one of the Danao flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 10. The graphs indicate that the number of satellites during the acquisition did not go down to 6. Majority of the time, the number of satellites tracked was between 6 and 10. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey with some peaks up to 2 attributed to the turns performed by the aircraft. The value of 0 corresponds to a Fixed, Narrow-Lane mode, which is the optimum carrier-cycle integer ambiguity resolution technique available for POSPAC MMS. All of the parameters adhered to the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Danao flights is shown in Figure 11.

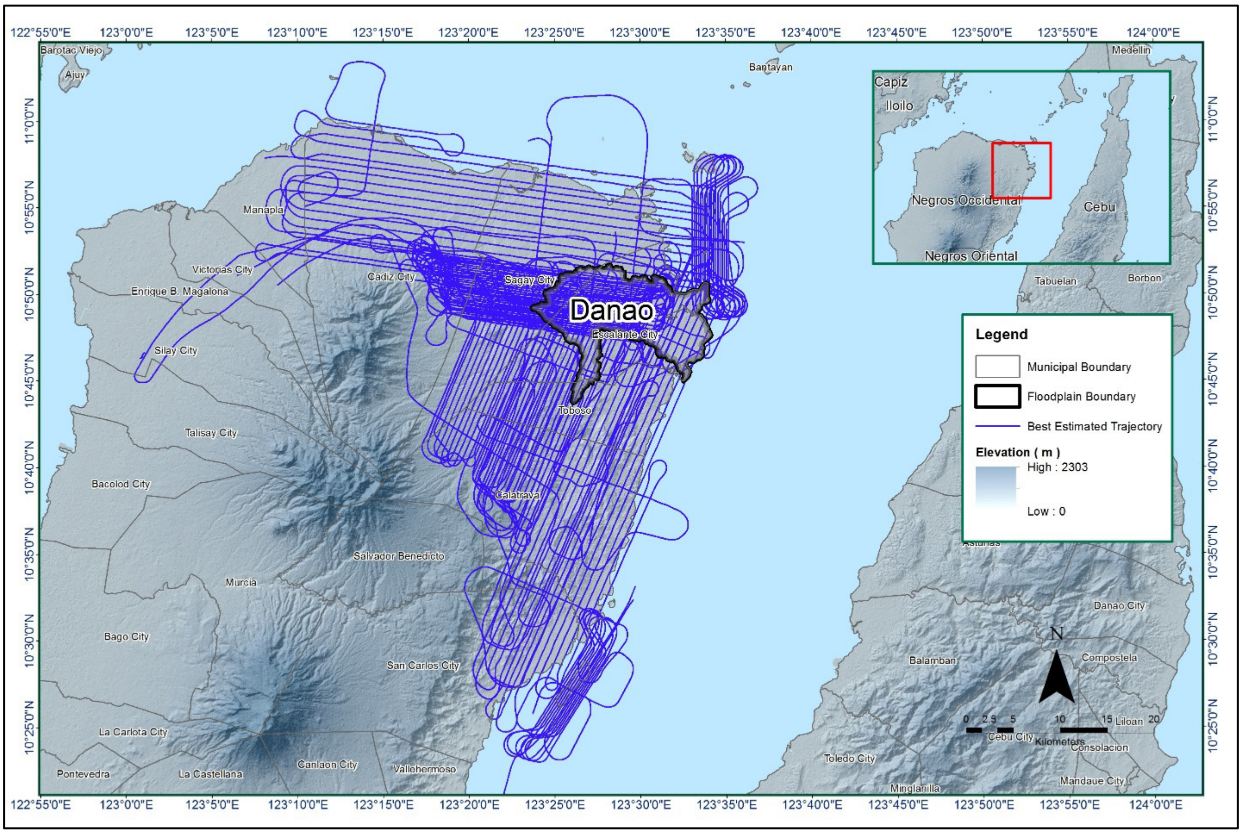


Figure 11. The best estimated trajectory of the LiDAR missions conducted over the Danao floodplain.

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 164 flight lines, with each flight line containing two channels for Pegasus system and one channel for Aquarius system. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Danao floodplain are given in Table 11.

Table 11. Self-Calibration Results values for Danao flights.

Parameter	Acceptable Value	Value
Boresight Correction stdev	(<0.001degrees)	0.000218
IMU Attitude Correction Roll and Pitch Corrections stdev	(<0.001degrees)	0.000903
GPS Position Z-correction stdev	(<0.01meters)	0.0027

The optimum accuracy is obtained for all Danao flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in Annex 8: Mission Summary Reports.

3.5 LiDAR Data Quality Checking

The boundary of the processed LiDAR data on top of a SAR Elevation Data over Danao Floodplain is shown in Figure 12. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

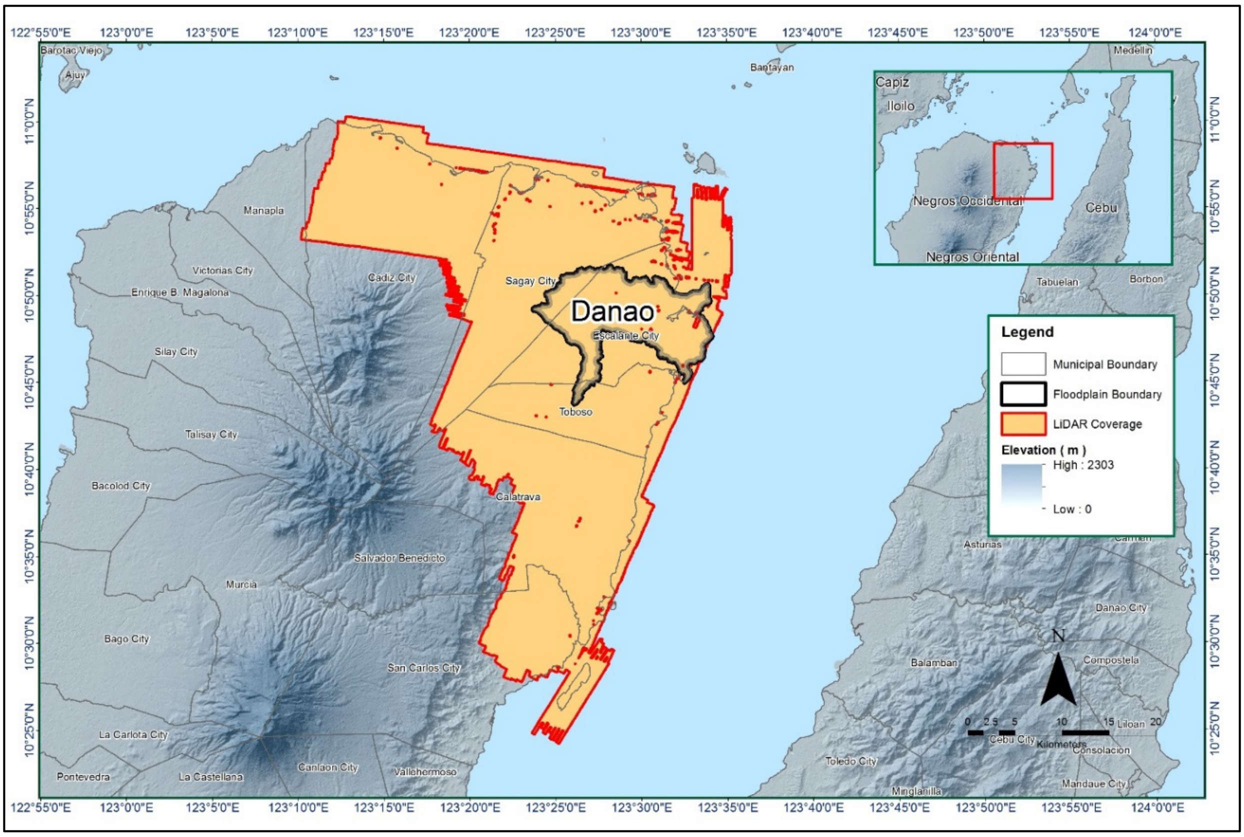


Figure 12. Boundary of the processed LiDAR data over Danao Floodplain

The total area covered by the Danao missions is 1494.22 sq.km which comprised of thirteen (13) flight acquisitions that were grouped and merged into eight (8) blocks as shown in Table 12.

Table 12. List of LiDAR blocks for Danao Floodplain.

LiDAR Blocks	Flight Numbers	Area (sq. km)
Negros_Blk44D	1411P	475.20
	1435P	
Negros_Blk44FG	1433P	283.70
	1435P	
	1431P	
Negros_Blk44H	1415P	511.86
	1431P	
Negros_Blk44H_additional	1415P	3.09
Bacolod_Blk44E	8453A	101.60
Bacolod_Blk44E_additional	8455A	54.26
Bacolod_Blk44N	8459A	35.00
Bacolod_Blk44O	8462A	29.51
	8464A	
TOTAL		**1,494.22 sq.km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location is shown in Figure 13. Since the Gemini system employs one channel, we would expect an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines. While for the Pegasus system which employs two channels, we would expect an average value of 2 (blue) for areas where there is limited overlap and a value of 3 (yellow) or more (red) for areas with three or more overlapping flight lines.

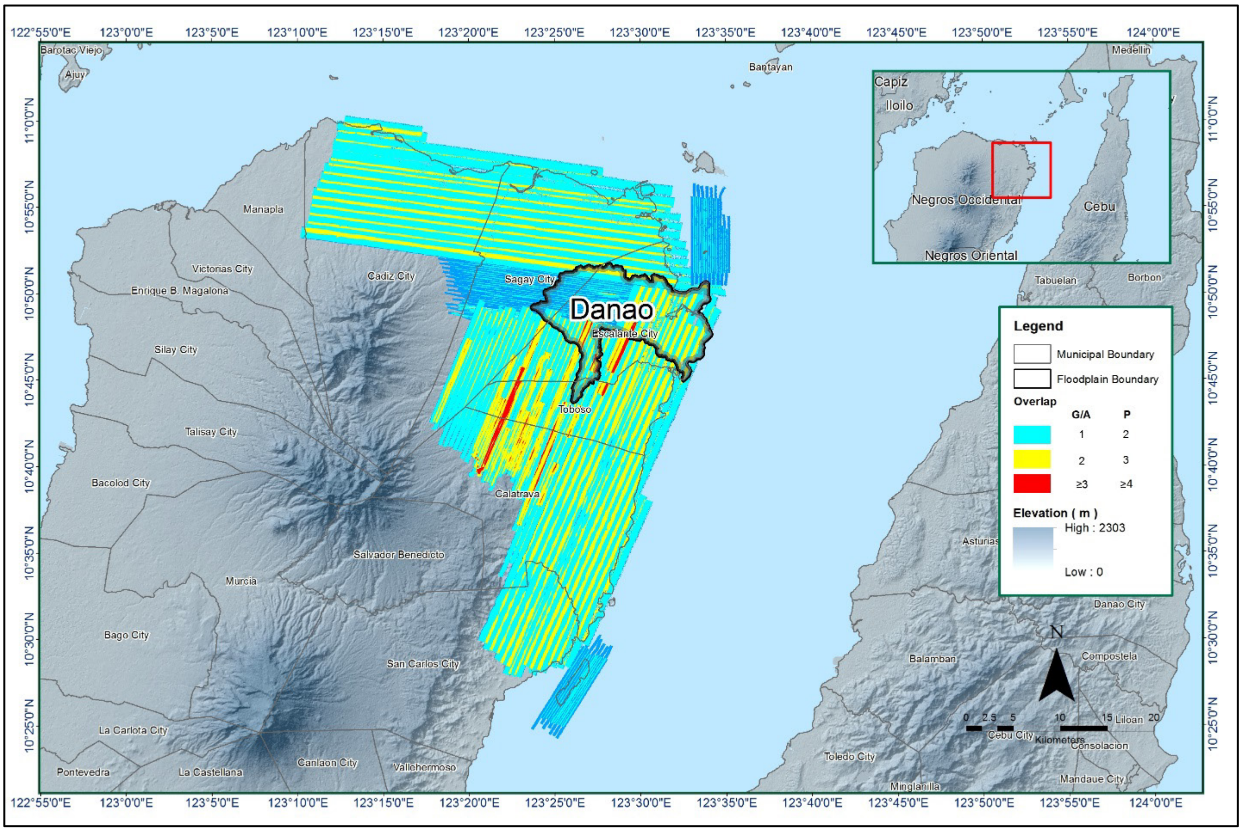


Figure 13. Image of data overlap for Danao floodplain.

The overlap statistics per block for the Danao floodplain can be found in Annex B-1. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 27.44% and 43.01% respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 14. It was determined that all LiDAR data for Danao floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.28 points per square meter.

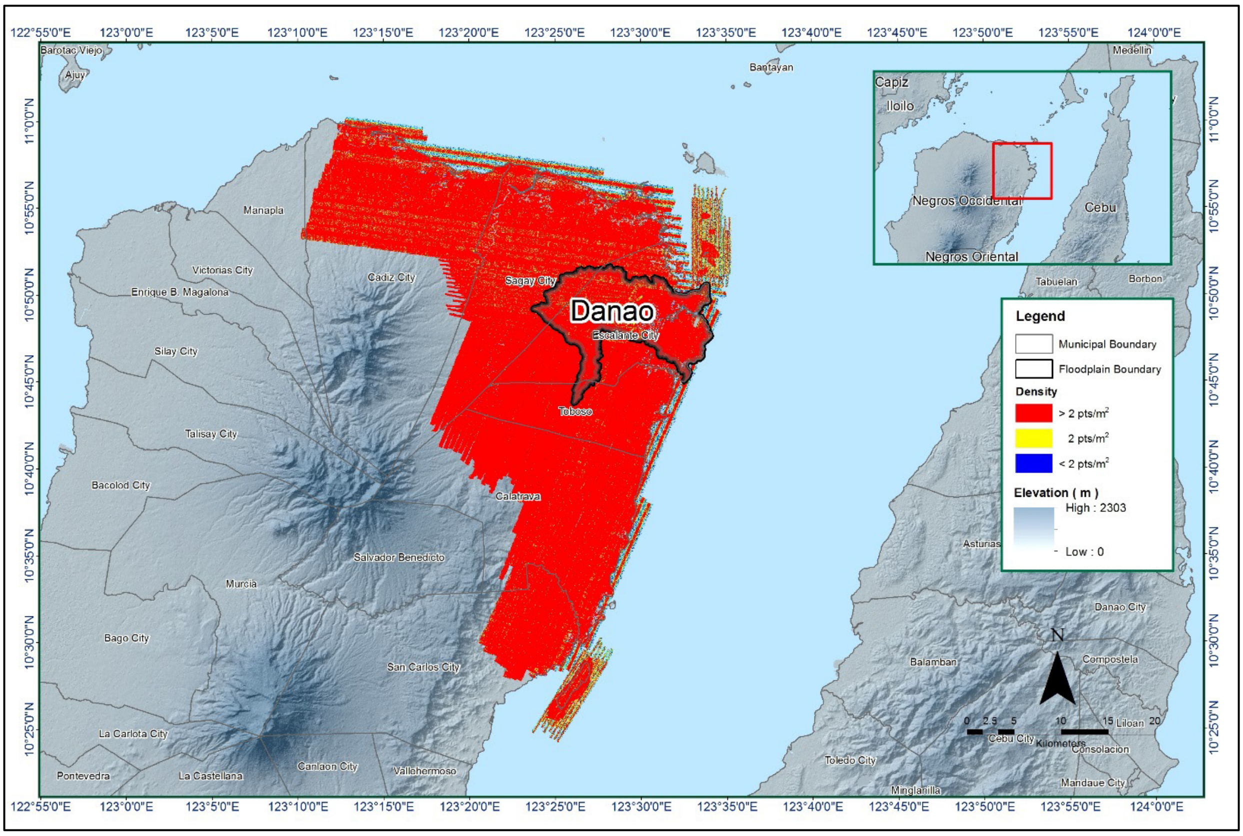


Figure 14. Pulse density map of merged LiDAR data for Danao floodplain.

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

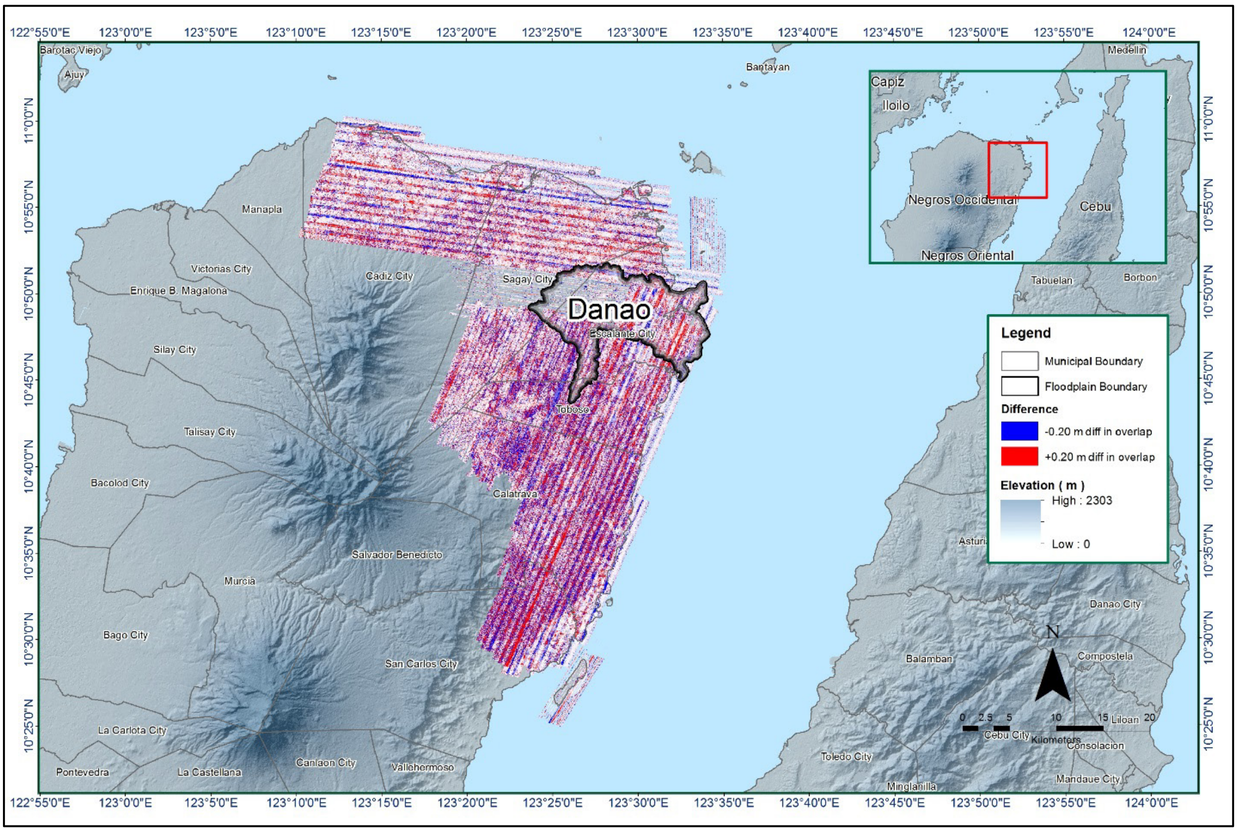


Figure 15. Elevation difference map between flight lines for Danao Floodplain.

A screen capture of the processed LAS data from a Danao flight 1451P loaded in QT Modeler is shown in Figure 16. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

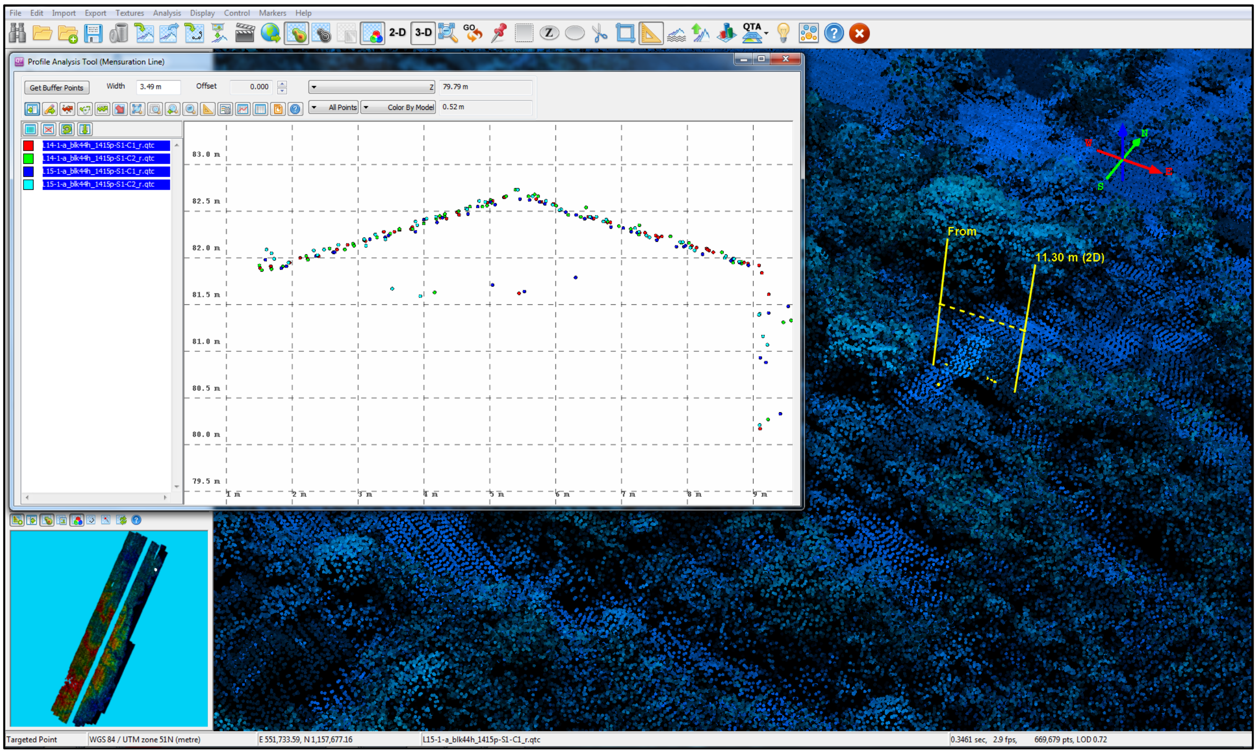


Figure 16. Quality checking for a Danao flight 1451P using the Profile Tool of QT Modeler.

3.6 LiDAR Point Cloud Classification and Rasterization

Table 13. Danao classification results in TerraScan.

Pertinent Class	Total Number of Points
Ground	1,556,347,583
Low Vegetation	1,421,189,351
Medium Vegetation	2,288,600,815
High Vegetation	716,492,720
Building	34,743,581

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Danao floodplain is shown in Figure 17. A total of 1,876 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 13. The point cloud has a maximum and minimum height of 696.44 meters and 9.98 meters respectively.

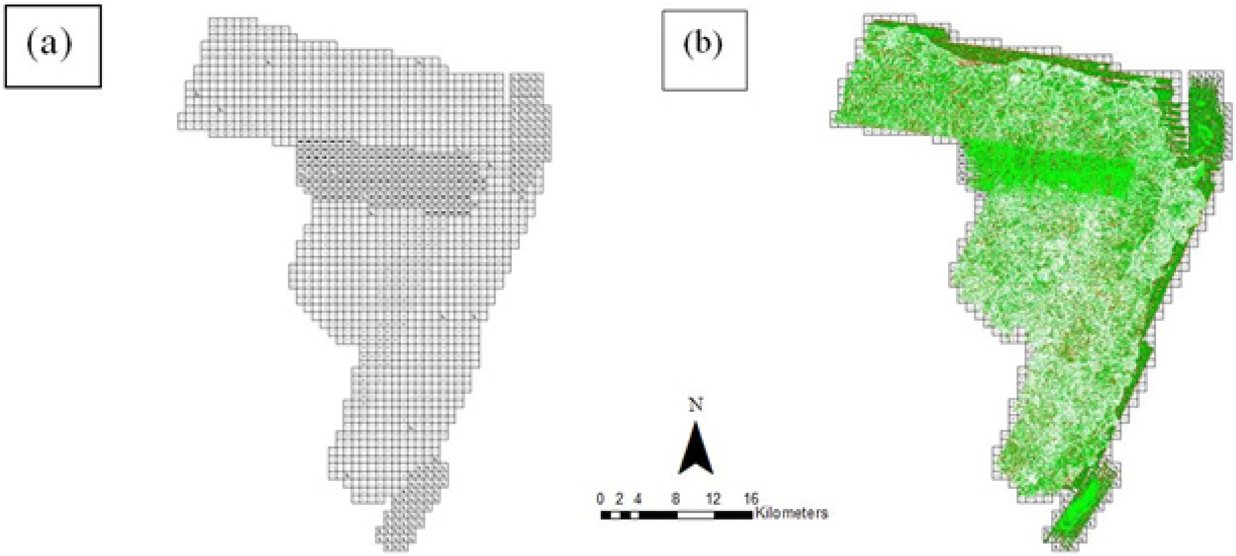


Figure 17. Tiles for Danao floodplain (a) and classification results (b) in TerraScan.

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

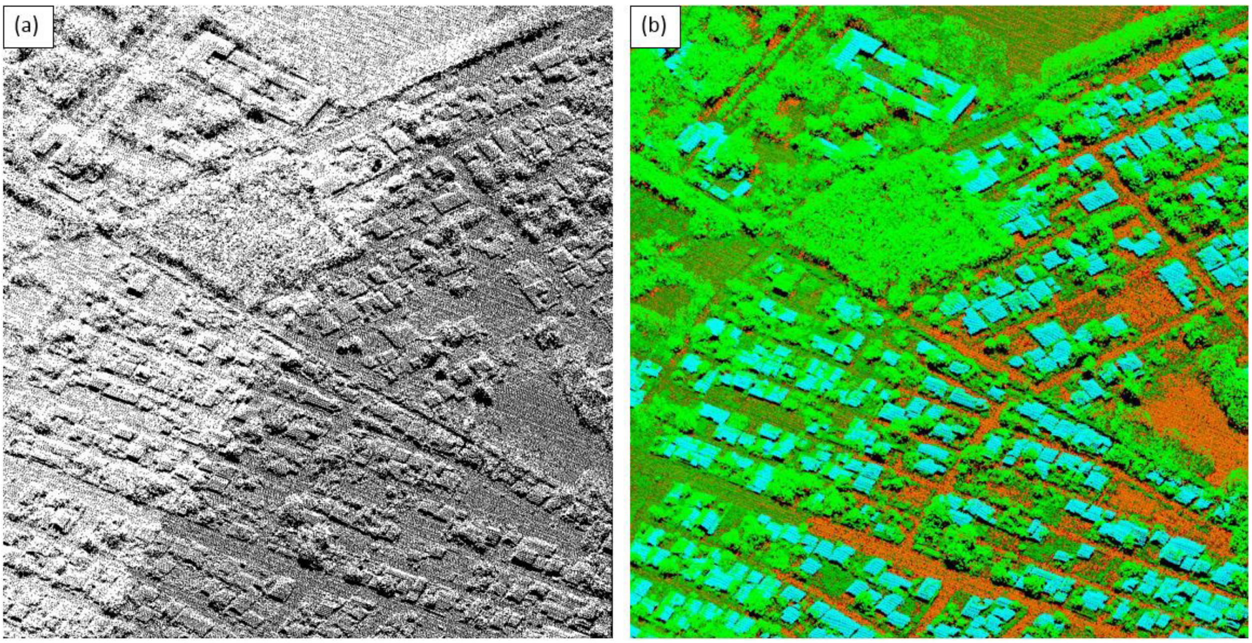


Figure 18. Point cloud before (a) and after (b) classification.

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

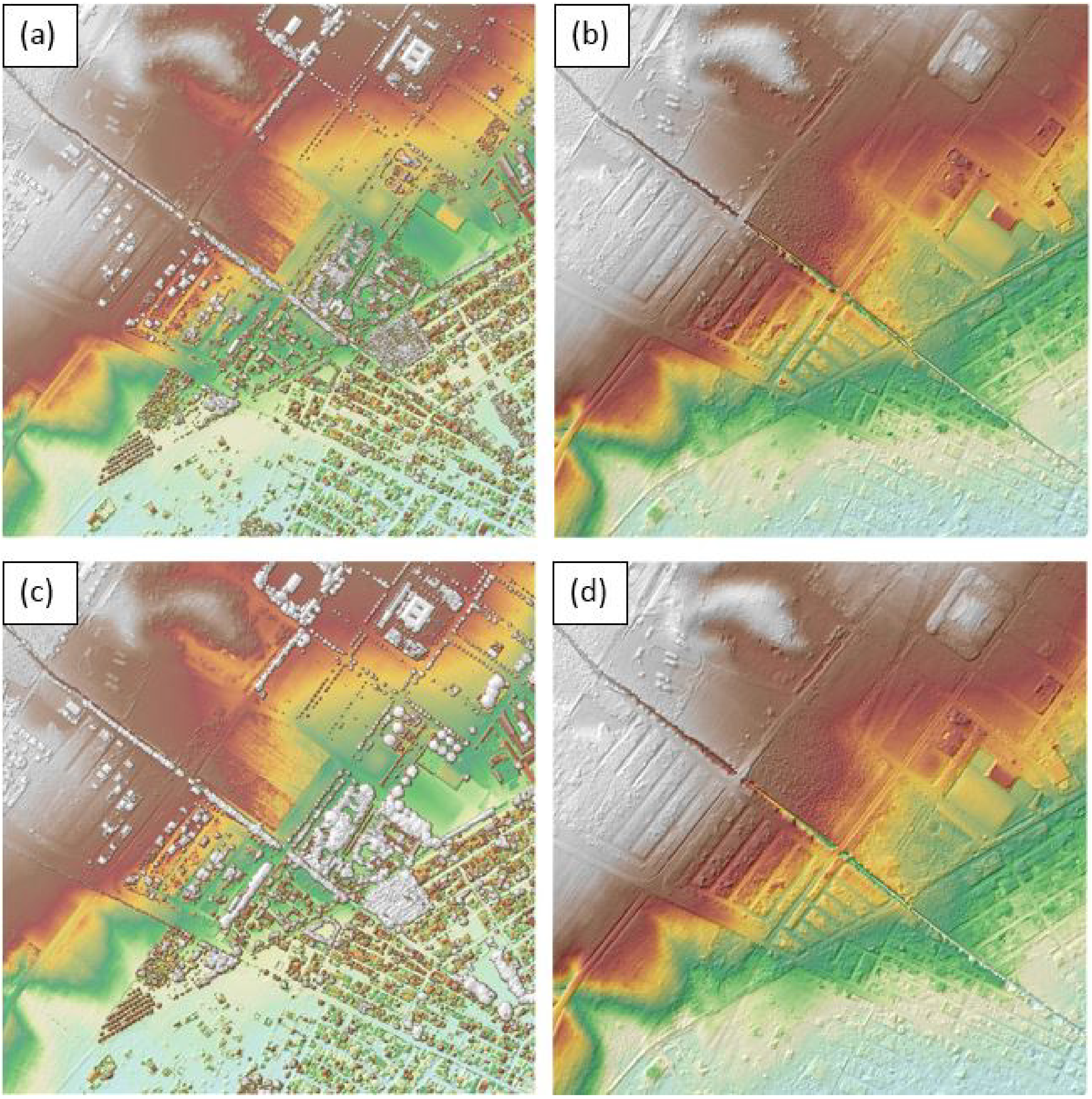


Figure 19. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Danao floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 1,191 of 1 km by 1 km tiles area covered by Danao floodplain is shown in Figure 20. After tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Danao floodplain survey attained a total of 930.47 sq.km orthophotogaph coverage comprised of 3,018 images. A zoomed in version of sample orthophotographs named in reference to its tile number is shown in Figure 21.

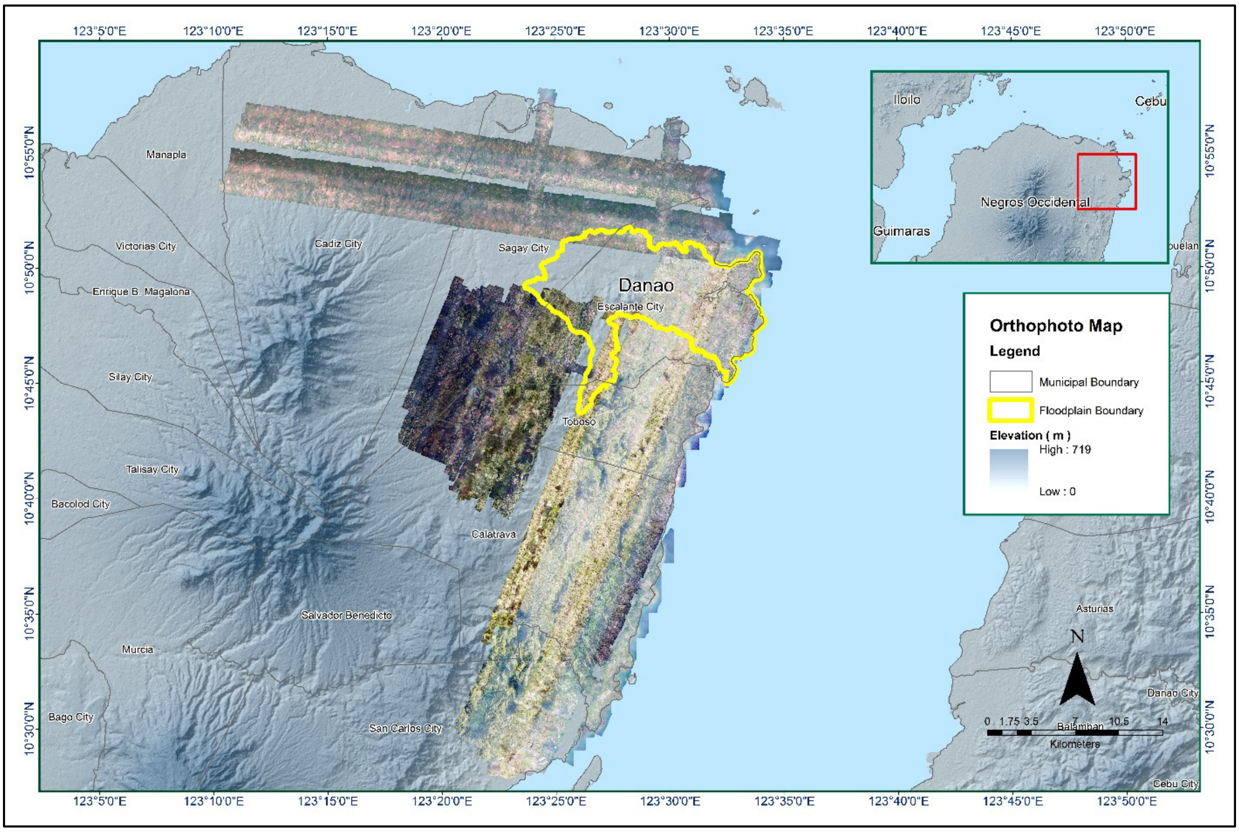


Figure 20. Danao Floodplain with available orthophotographs.

Figure 21. Sample orthophotograph tiles for Danao Floodplain.

3.8 DEM Editing and Hydro-Correction

Eight (8) mission blocks were processed for Danao flood plain. These blocks are composed of Negros and Bacolod blocks with a total area of 1494.22 square kilometers. Table 14 shows the name and corresponding area of each block in square kilometers.

Table 14. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Negros_Blk44D	475.20
Negros_Blk44FG	283.70
Negros_Blk44H	511.86
Negros_Blk44H_additional	3.09
Bacolod_Blk44E	101.60
Bacolod_Blk44E_additional	54.26
Bacolod_Blk44N	35.00
Bacolod_Blk44O	29.51
TOTAL	**1,494.22 sq.km**

Portions of DTM before and after manual editing are shown in Figure 22. It shows that the paddy field (Figure 22a) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 22b). The bridges (Figure 22c) would be an impedance to the flow of water along the river and have to be removed (Figure 22d) in order to hydrologically correct the river.

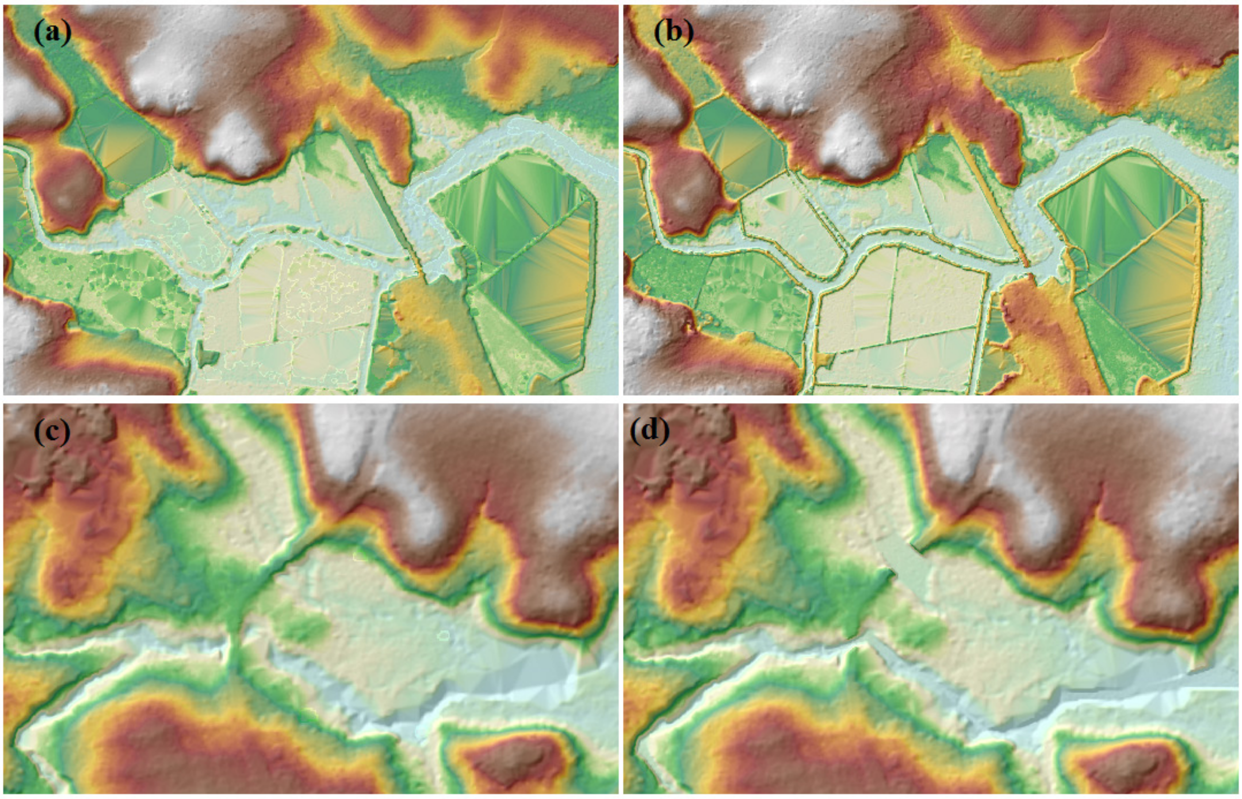


Figure 22. Portions in the DTM of Danao Floodplain – a paddy field before (a) and after (b) data retrieval; bridges before (c) and after (d) manual editing

3.9 Mosaicking of Blocks

Negros_Blk44AB 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 15 shows the area of each LiDAR block and the shift values applied during mosaicking.

Mosaicked LiDAR DTM for Danao floodplain is shown in Figure 23. It can be seen that the entire Danao floodplain is 99.47% covered by LiDAR data.

Table 15. Shift Values of each LiDAR Block of Danao Floodplain.

Mission Blocks	Shift Values (meters)		
	x	y	z
Negros_Blk44D	0.00	0.00	0.66
Negros_Blk44FG	0.00	0.00	0.57
Negros_Blk44H	0.00	0.00	0.51
Negros_Blk44H_additional	0.00	0.00	0.41
Bacolod_Blk44E	0.00	0.00	1.39
Bacolod_Blk44E_additional	0.00	0.00	1.45
Bacolod_Blk44N	0.00	0.00	1.55
Bacolod_Blk44O	0.00	0.00	0.00

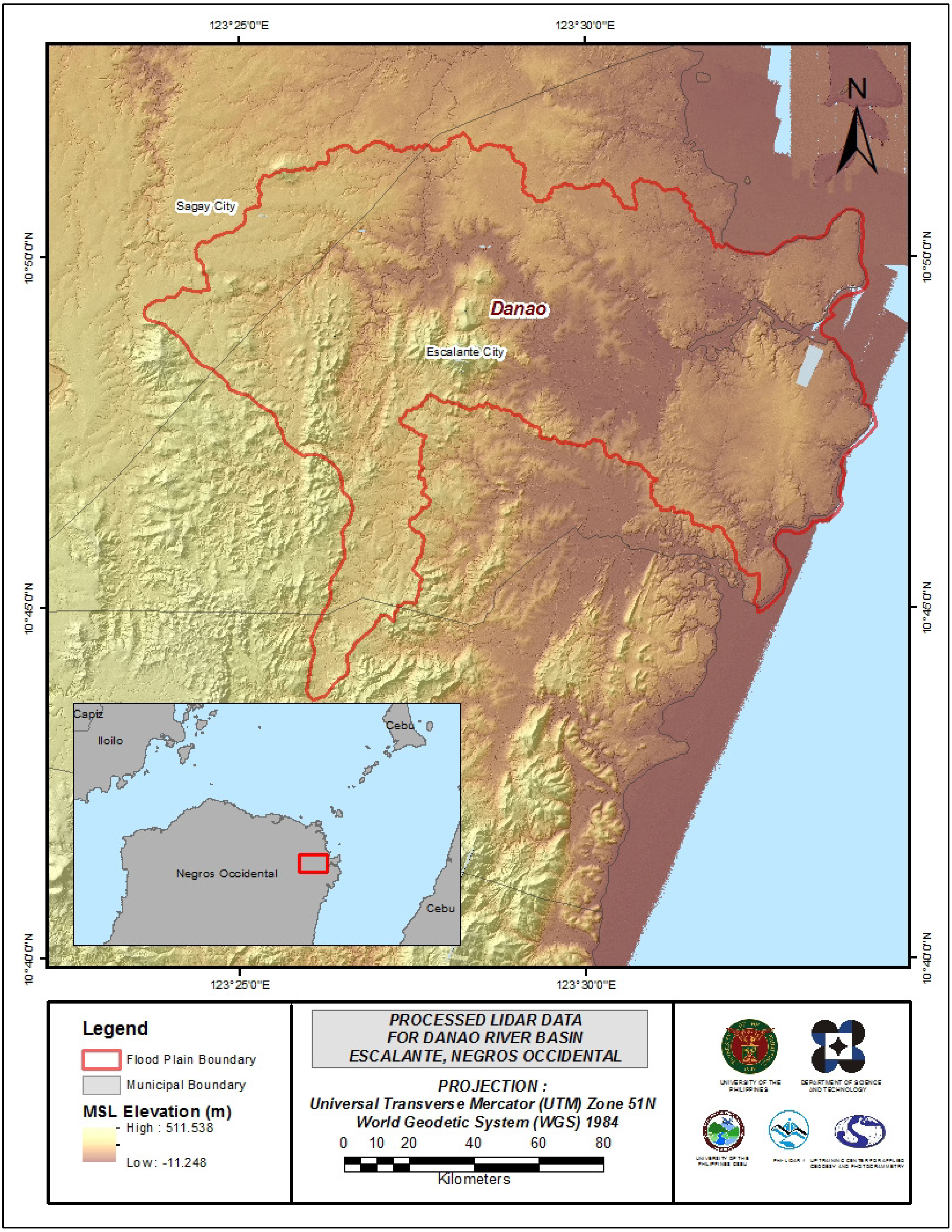


Figure 23. Map of Processed LiDAR Data for Danao Floodplain.

3.10 Calibration and Validation of Mosaicked LiDAR Digital Elevation Model

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Danao to collect points with which the LiDAR dataset is validated is shown in Figure 24. A total of 4141 survey points were used for calibration and validation of Danao LiDAR data. Random selection of 80% of the survey points, resulting to 3312 points were used for calibration.

A good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 25. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.94 meters with a standard deviation of 0.15 meters. Calibration of Danao LiDAR data was done by subtracting the height difference value, 0.94 meters, to the mosaicked LiDAR data for Danao. Table 16 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

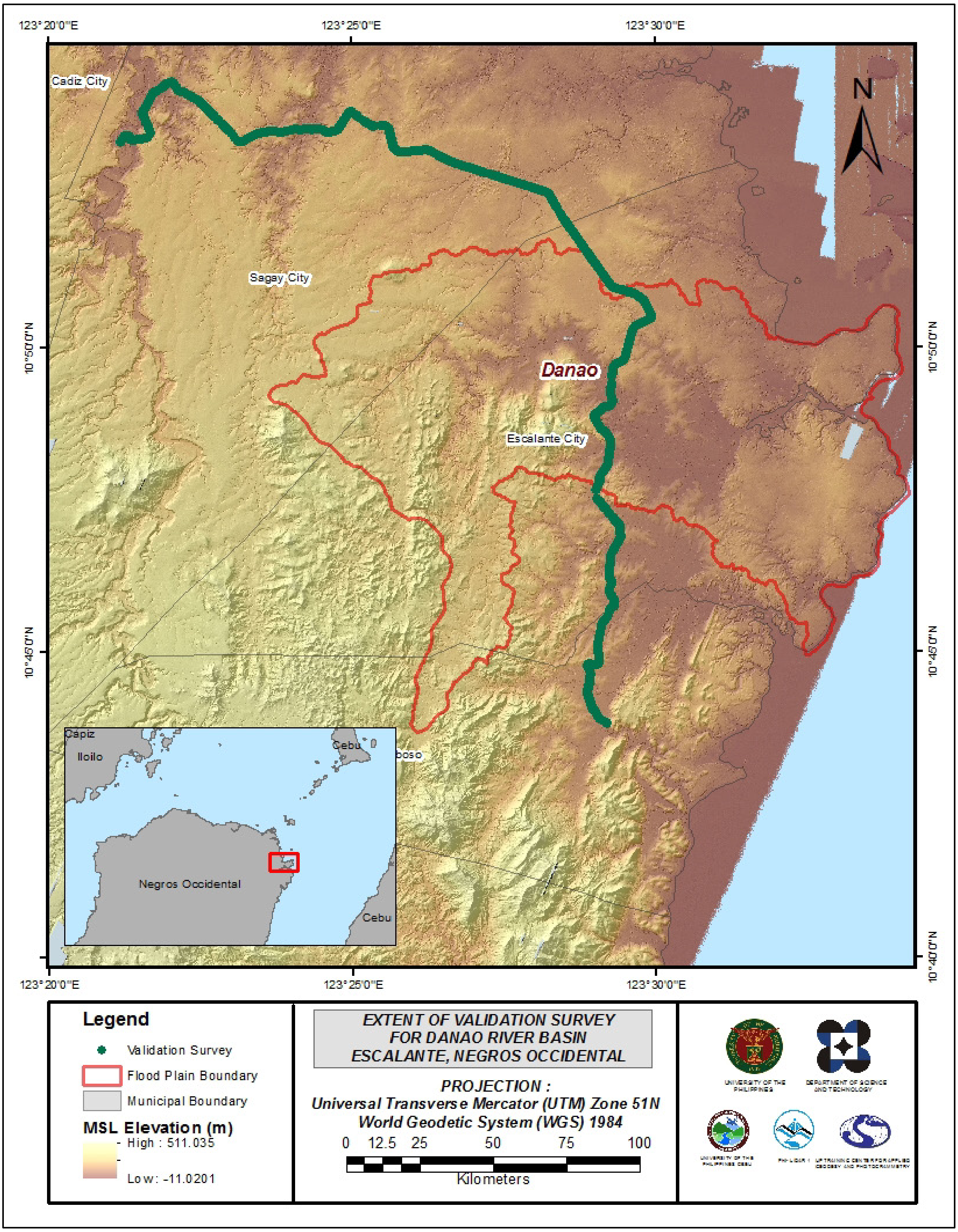


Figure 24. Map of Danao Flood Plain with validation survey points in green.

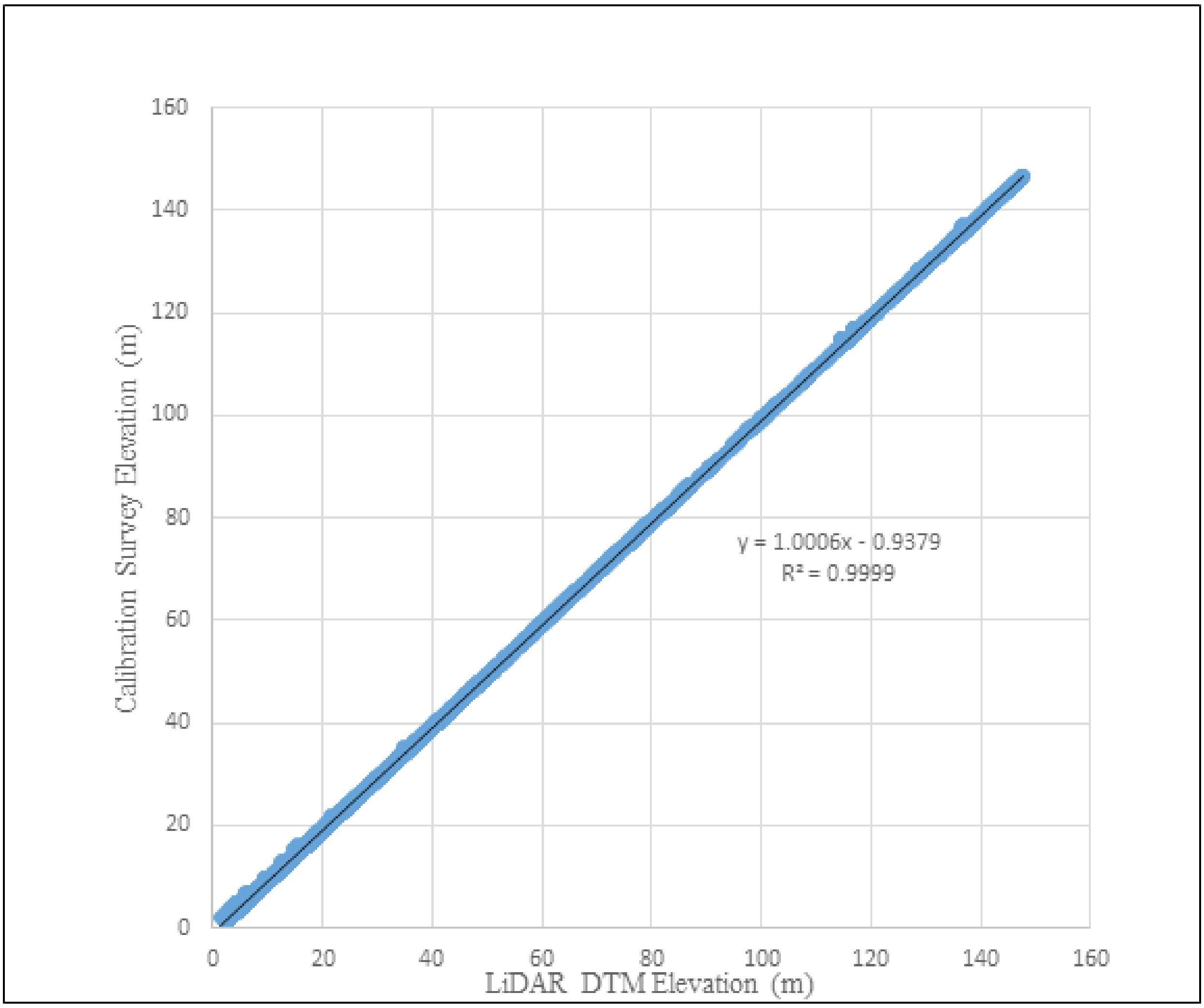


Figure 25. Correlation plot between calibration survey points and LiDAR data.

Table 16. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.94
Standard Deviation	0.15
Average	-0.93
Minimum	-1.21
Maximum	0.89

A total of 219 survey points that are within Danao flood plain were used for the validation of the calibrated Danao DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 26. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.11 meters with a standard deviation of 0.10 meters, as shown in Table 17.

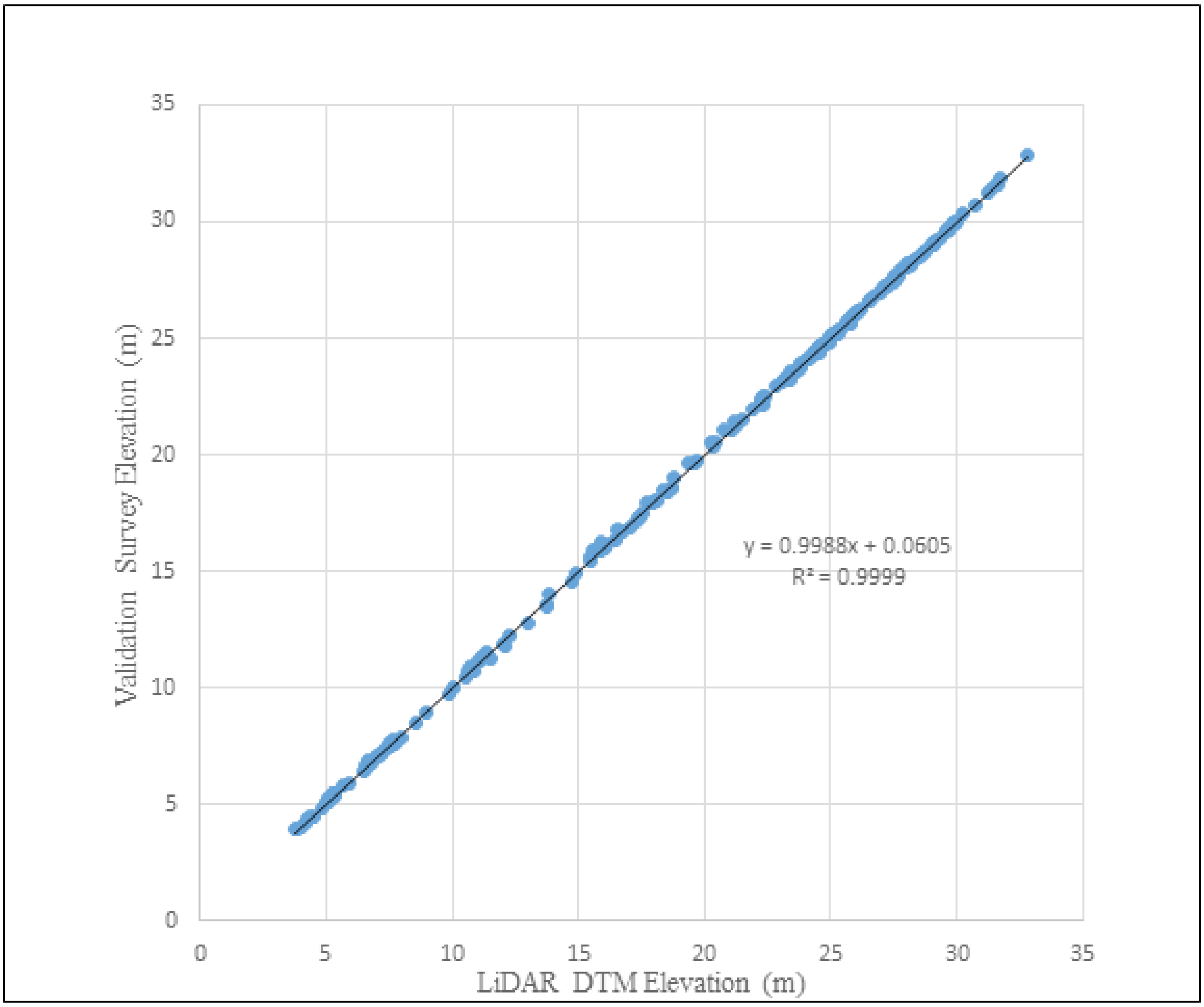


Figure 26. Correlation plot between validation survey points and LiDAR data.

Table 17. Validation Statistical Measures.

Validation Statistical Measures	Value (meters)
RMSE	0.11
Standard Deviation	0.10
Average	0.04
Minimum	-0.32
Maximum	0.37

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline data was available for Danao with 5,245 bathymetric survey points. The resulting raster surface produced was done by Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.07 meters. The extent of the bathymetric survey done by the Data Validation and Bathymetry Component (DVBC) in Danao integrated with the processed LiDAR DEM is shown in Figure 27.

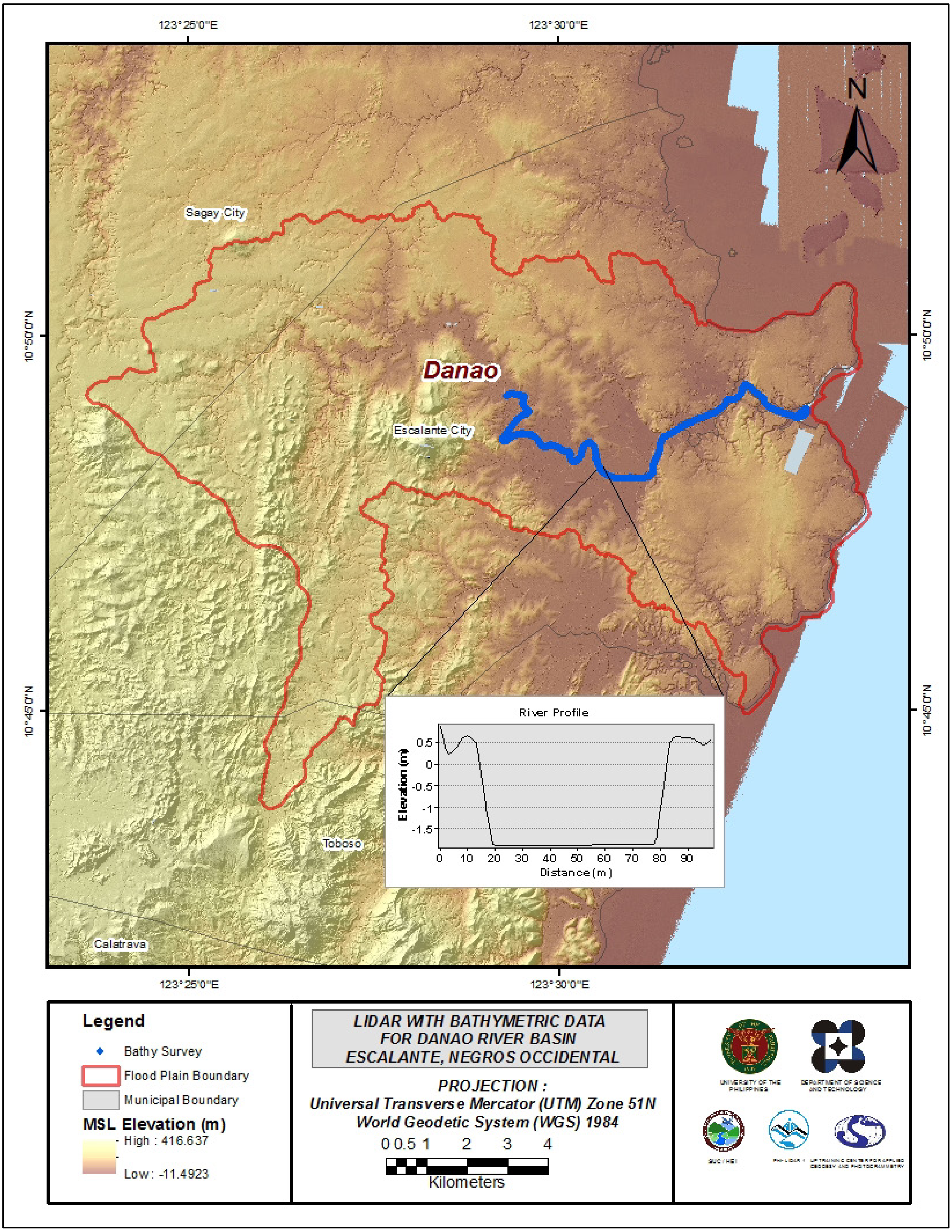


Figure 27. Map of Danao Floodplain with bathymetric survey points shown in blue.

3.12 Feature Extraction

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

3.12.1 Quality Checking (QC) of Digitized Features' Boundary

Danao floodplain, including its 200 m buffer, has a total area of 151.17 sq. km. For this area, a total of 5.0 sq km, corresponding to a total of 1060 building features, are considered for QC. Figure 28 shows the QC blocks for Danao floodplain.

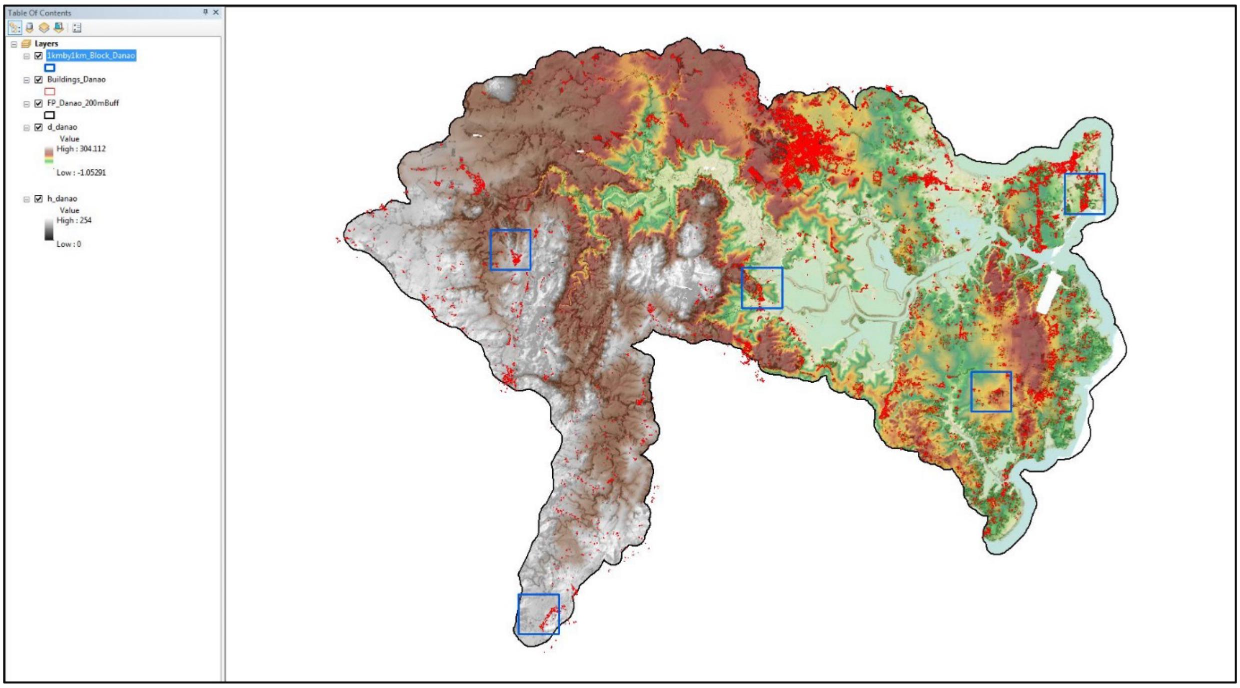


Figure 28. QC blocks for Danao building features.

Quality checking of Danao building features resulted in the ratings shown in Table 18.

Table 18. Quality Checking Ratings for Danao Building Features.

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Danao	100.00	100.00	98.94	PASSED

3.12.2 Height Extraction

Height extraction was done for 20,982 building features in Danao floodplain. Of these building features, 1710 was filtered out after height extraction, resulting to 19,272 buildings with height attributes. The lowest building height is at 2.0 m, while the highest building is at 12.10 m.

3.12.3 Feature Attribution

The feature attribution survey was conducted through a participatory community-based mapping in coordination with the Local Government Units of the Municipality/City. The research associates of Phil-LiDAR 1 team visited local barangay units and interviewed local key personnel and officials who possessed expert knowledge of their local environments to identify and map out features.

Maps were displayed on a laptop and were presented to the interviewees for identification. The displayed map includes the orthophotographs, Digital Surface Models, existing landmarks, and extracted feature shapefiles. Physical surveys of the barangay were also done by the Phil-LiDAR 1 team every after interview for 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 flood plain of the river basin.

Table 19 summarizes the number of building features per type. On the other hand, Table 20 shows the total length of each road type, while Table 21 shows the number of water features extracted per type.

Table 19. Building Features Extracted for Danao Floodplain.

Facility Type	No. of Features
Residential	18,532
School	370
Market	10
Agricultural/Agro-Industrial Facilities	1
Medical Institutions	23
Barangay Hall	16
Military Institution	22
Sports Center/Gymnasium/Covered Court	8
Telecommunication Facilities	5
Transport Terminal	10
Warehouse	12
Power Plant/Substation	1
NGO/CSO Offices	2
Police Station	1
Water Supply/Sewerage	5
Religious Institutions	44
Bank	3
Factory	5
Gas Station	8
Fire Station	1
Other Government Offices	22
Other Commercial Establishments	167
Others	4
Total	**19272**

Table 20. Total Length of Extracted Roads for Danao Floodplain.

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Danao	269.54	24.85	2.78	20.42	0	317.58

Table 21. Number of Extracted Water Bodies for Danao Floodplain.

Floodplain	Water Body Type						Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	Others	
Danao	22	5	0	0	628	0	655

A total of 19 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 29 shows the Digital Surface Model (DSM) of Danao floodplain overlaid with its ground features.

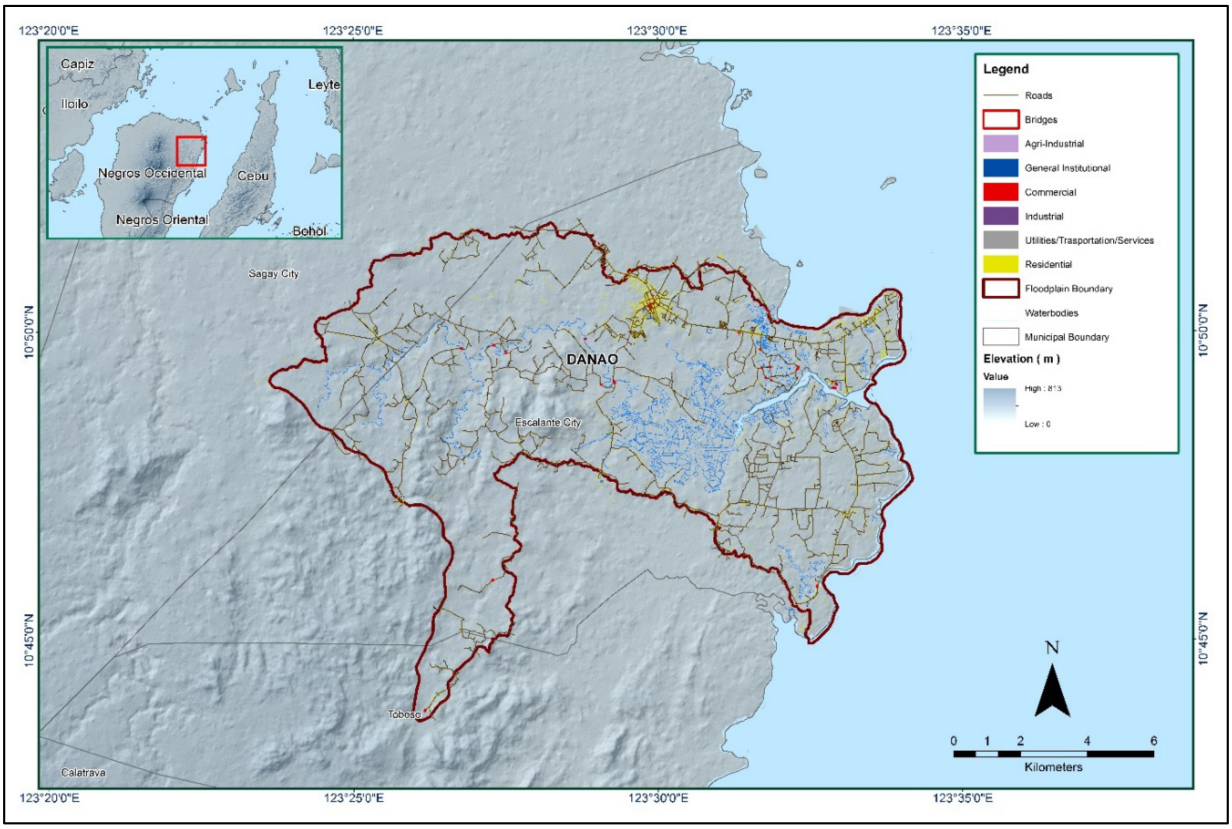


Figure 29. Extracted features for Danao Floodplain.

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

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

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

In line with this, DVBC conducted a field survey in Danao River from December 4 to 16, 2014 with the following scope of work: reconnaissance survey to determine the viability of traversing the planned routes for bathymetric survey; courtesy call to the barangays near the survey area for information dissemination of the team's activities and to ask for a boat and local aide's assistance; control survey for the establishment of a control point; cross-section; bridge as-built and water level marking in MSL of Danao Bridge piers; ground validation data acquisition survey of about 37 km; and bathymetric survey from Danao Bridge down to the mouth of the river in Brgy. Buenavista, with an estimated length of 13 k using an Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882 utilizing GNSS PPK survey technique.

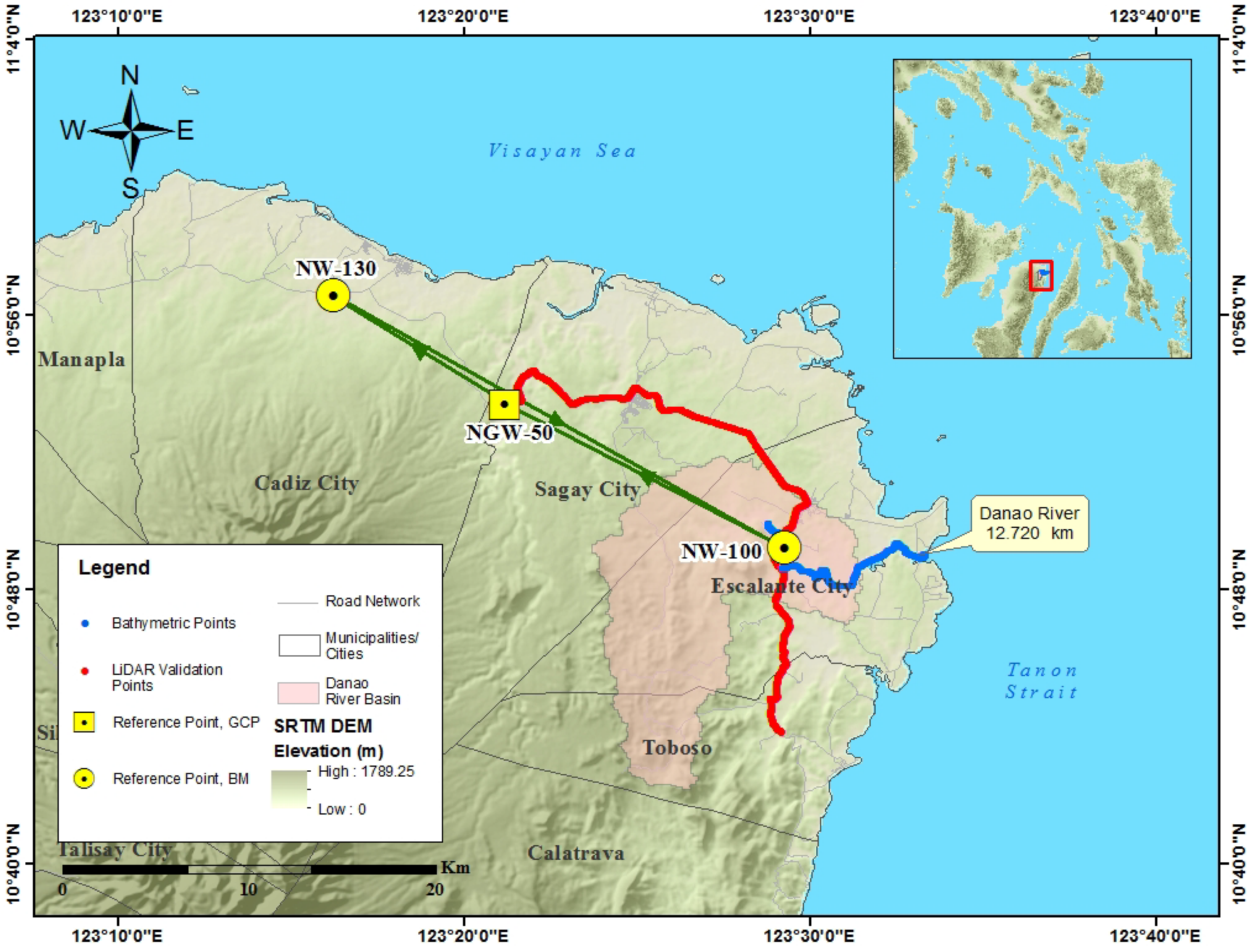


Figure 30. Danao River survey extent

4.2 Control Survey

The GNSS network used for Danao River survey is composed of a single loop established on September 9, 2014 occupying the following reference points: NGW-50, a second order GCP in Brgy. Paraiso, Sagay City; and NW-100, a first order BM in Brgy. Jonobjonob, Escalante City, Negros Occidental.

The point NW-130, a NAMRIA established control point, along the approach of Trozo Bridge in Brgy. Daga, Cadiz City, was also occupied to use by the DVBC survey team as marker during the survey.

The summary of reference and control points is shown in Table 22, while the GNSS network established is illustrated in Figure 31.

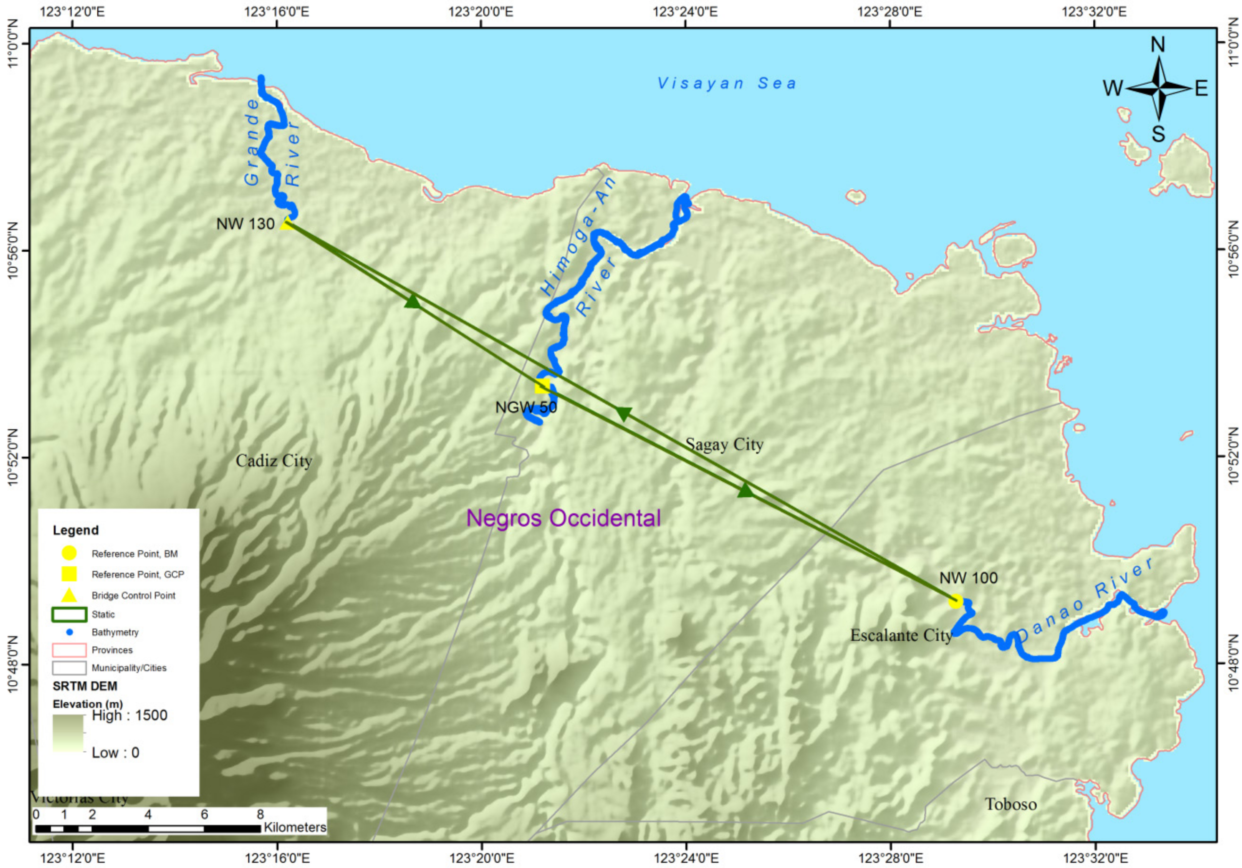


Figure 31. GNSS network of Danao River field survey

Table 22. List of references and control points occupied in Negros Occidental survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
NGW-50	2nd order, GCP	10°53'22.52478"	123°21'11.86863"	74.422	13.0512	2013
NW-100	1st order, BM	-	-	68.325	7.2272	2007
NW-130	Used as Marker	-	-	-	-	2017

The GNSS set-ups on recovered reference points and established control points in Danao River are shown in Figure 32 to Figure 34.

Figure 32. GNSS base receiver setup, Trimble® SPS 852, at NGW-50 in Himoga-An Bridge, Brgy. Paraiso, Sagay City, Negros Occidental

Figure 33. GNSS base receiver setup, Trimble® SPS 852, at NW-100 in Danao Bridge, Brgy. Jonobjonob, Escalante City, Negros Occidental

Figure 34. GNSS base receiver setup, Trimble® SPS 852, over NW-130 in Troso Bridge, Brgy. Daga, Cadiz City, Negros Occidental

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking is performed. Masking is done by removing/masking portions of these 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, resurvey is initiated. The Baseline processing result of control points in Danao River Basin is summarized in Table 23, as generated by TBC software.

Table 23. Baseline Processing Report for Danao River Survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
NGW 50 --- NW 130 (B4)	09-11-2014	Fixed	0.005	0.008	302°49'33"	10801.487	-2.613
NW 130 --- NW 100 (B5)	9-11-2014	Fixed	0.185	0.037	119°37'31"	27388.571	-3.542
NGW 50 --- NW 100 (B6)	9-11-2014	Fixed	0.004	0.006	117°34'16"	16614.558	-6.178

4.4 Network Adjustment

After the baseline processing procedure, network adjustment is performed using TBC. Looking at the Adjusted Grid Coordinates, Table 25 of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation from:

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 24 to 27 for complete details. The three control points, NGW-50, NW-100, and NW-130 were occupied and observed simultaneously to form a GNSS loop. Coordinates and elevation values of NGW-50 were held fixed during the processing of the control points as presented in Table 24. The offset for MSL value of NW-100 was then applied to all the control points after the processing. Through these reference points, the coordinates and elevation of the unknown control points will be computed.

Table 24. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
NGW 50	Global	Fixed	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 25. The fixed control NGW-50 has no values for and elevation error yet.

Table 25. Adjusted grid coordinates.

Point ID	Easting	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
NGW 50	538610.026	?	1203793.905	?	13.070	?	LLh
NW 100	553341.183	0.013	1196123.819	0.007	7.170	0.020	
NW 130	529529.956	0.017	1209636.397	0.008	10.639	0.024	

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

a. NGW-50

horizontal accuracy	=	Fixed
vertical accuracy	=	Fixed

b. NW-100

horizontal accuracy	=	$\sqrt{((1.3)^2 + (0.7)^2}$
	=	$\sqrt{(1.69 + 0.49)}$
	=	1.48 < 20 cm
vertical accuracy	=	2.0 cm < 10 cm

c. NW-130

horizontal accuracy	=	$\sqrt{((1.7)^2 + (0.8)^2}$
	=	$\sqrt{(2.89 + 0.64)}$
	=	1.88 < 20 cm
vertical accuracy	=	2.4 cm < 10 cm

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

Table 26. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
NGW 50	N10°53'22.52478"	E123°21'11.86863"	74.422	?	LLh
NW 130	N10°56'33.04992"	E123°16'12.93293"	71.819	0.024	
NW 100	N10°49'12.14033"	E123°29'16.71793"	68.325	0.020	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 26. Based on the result of the computation, the equation is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 27.

Table 27. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	MSL Elevation (m)
NGW-50	2nd order, GCP	10°53'22.52478"	123°21'11.86863"	74.422	1203793.905	538610.026	13.051
NW-100	1st order BM	10°49'12.14033"	123°29'16.71793"	68.325	1196123.819	553341.183	7.227
NW-130	Used as Marker	10°56'33.04992"	123°16'12.93293"	71.819	1209636.397	529529.956	10.643

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

Cross-section and bridge as-built surveys were conducted on September 12 and 16, 2014 at the downstream side of Danao Bridge in Brgy. Jonobjonob, Escalante City using the GNSS receiver Trimble® SPS 882 utilizing GNSS PPK survey technique as shown in Figure 35.

Figure 35. Cross-section survey at Danao Bridge in Escalante City

The cross-section line is about 70.28 m with 79 points acquired using NW-100 as GNSS base station. Figure 36 to Figure 38 show the bridge cross-section diagram, planimetric map, and as-built data form, respectively.

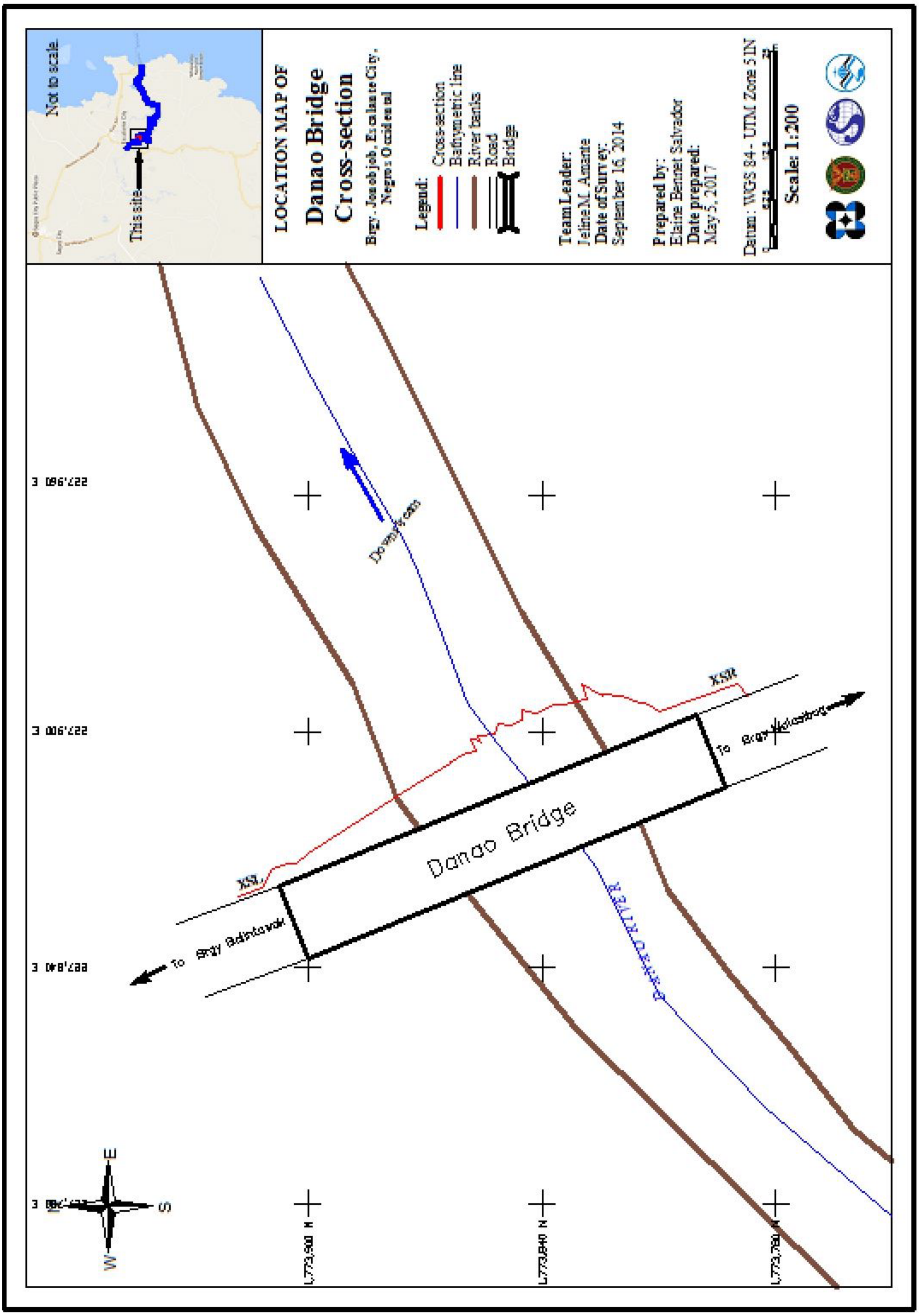


Figure 36. Danao bridge cross-section location map

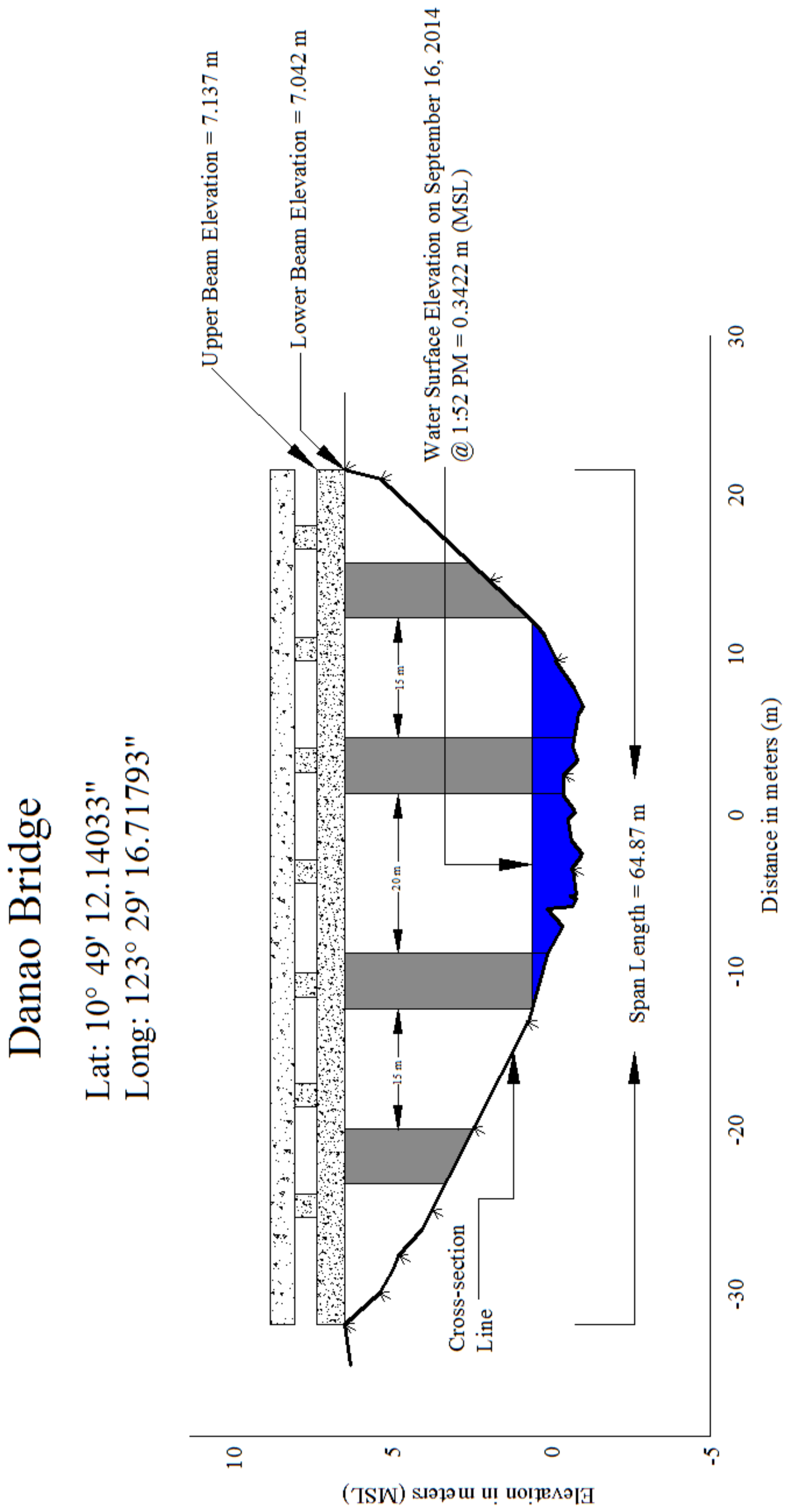


Figure 37. Danao Bridge cross-section diagram

Bridge Data Form

Bridge Name: Danao Bridge **Date:** September 12 & 16, 2014

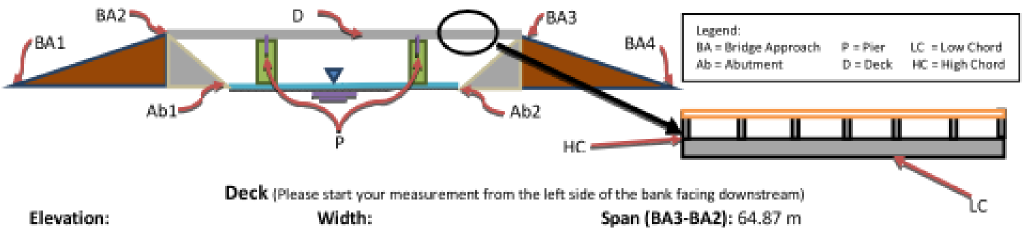
River Name: Danao River **Time:** 1:30 PM

Location (Brgy, City,Region): Escalante, Negros Occidental

Survey Team: Negros Occidental Survey Team

Flow condition: low <u>normal</u> high **Weather Condition:** <u>fair</u> rainy

Latitude: 10d49'12.14033"N **Longitude:** 123d29'16.71793" E



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

Elevation: **Width:** **Span (BA3-BA2):** 64.87 m

	Station	High Chord Elevation	Low Chord Elevation
1		7.1372m	7.0422m
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**	n/a	**BA3**	64.87 m	7.2172 m
BA2	0	7.2942 m	**BA4**	70.28 m	6.9912 m

Abutment: Is the abutment sloping? <u>Yes</u> 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: (Pier 4) rectangular & (Pier 1-3) circular Number of Piers: 4 Height of column footing:

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	7.15	7.4042	
Pier 2	22.28	7.4202	
Pier 3	42.3	7.4212	
Pier 4	57.29	7.3922	
Pier 5			
Pier 6			

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

Figure 38. Danao Bridge Data Form

The water surface elevation of Danao Bridge on the left and right banks was acquired using GNSS receiver Trimble® SPS 882 in GNSS PPK survey technique on September 16, 2014 at 1:52 PM. The resulting water surface elevation data is 0.3244 m above MSL. There is an existing water level mark on one of the piers of Danao Bridge as shown in Figure 39. The water level marking shall serve as a reference for flow data gathering and depth gauge deployment of UP Cebu PHIL-LIDAR 1.

Figure 39. Existing water level mark at one of the piers of Danao Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on September 12, 2014 using a survey GNSS rover receiver Trimble® SPS 882 mounted on a pole, which was attached in front of the vehicle as shown in Figure 40. It was secured with a steel rod and tied with cable ties to ensure that it was horizontally and vertically balanced. The antenna height was measured from the ground up to the bottom of the notch of the GNSS rover receiver with a value of 2.10 m.

The base was setup at the NAMRIA established reference point, NGW-50, in Himoga-an Bridge on September 12, 2014 and the gathering of validation points started from Brgy. Poblacion, Toboso to Himoga-An Bridge, Sagay City. The ground validation line is approximately 37 km in length and with overall gathered points of 4,238. Figure 41 shows the length of the acquired points for the survey.

Figure 40. (A) Occupied base station, NGW-50 in Himoga-An Bridge, Sagay City and (B) Installation of GNSS Receiver Trimble® SPS882 on the van prior the conduct of ground validation points

Figure 41. Validation Points Acquisition Survey from Himoga-An Bridge to Brgy. Poblacion Toboso

4.7 River Bathymetric Survey

An Ohmex™ Single Beam Echo Sounder integrated with a roving GNSS receiver, Trimble® SPS 882, installed on the boat to gather the riverbed elevation was utilized for bathymetric survey on December 11, 2014 as shown in Figure 42. The survey began at the upstream part of the river in Brgy. Malasibog, Escalante City with coordinates 10˚49'12.62871" 123˚29'20.11589", down to the mouth of the river in Brgy. Old Poblacion, Escalante City with coordinates 10°49'00.36612" 123°33'19.39701". The reference point NW-100, located in Danao Bridge in Brgy. Jonobjonob, Escalante City, served as the base station in conducting the bathymetric survey.

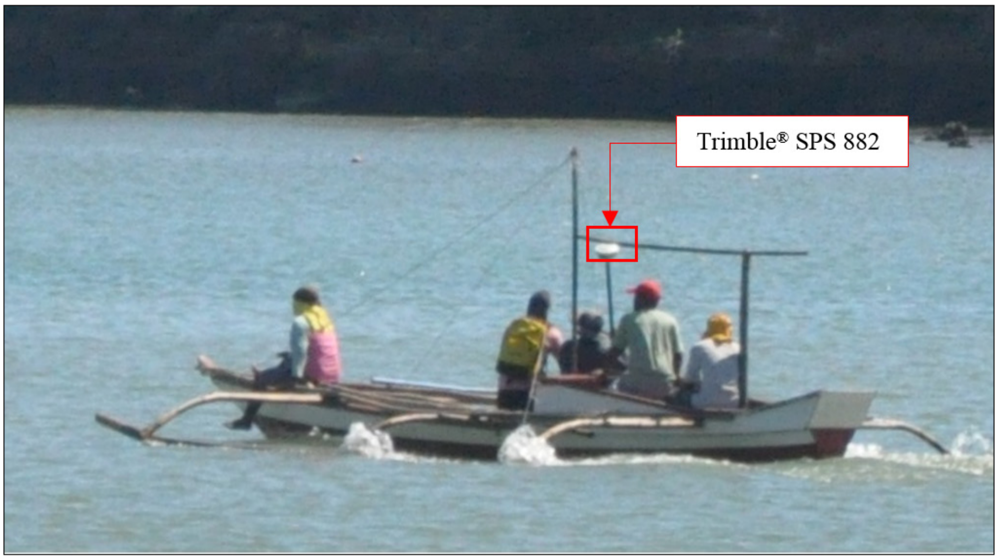


Figure 42. Execution of bathymetric survey using Ohmex™ Single Beam Echo Sounder along Danao River

Bathymetric line is approximately 12.8 km in length and with a total of 6,765 bathymetric points starting from Brgy. Buenavista going upstream to Danao Bridge, Brgy. Jonobjonob, Escalante City as shown in Figure 43.

Figure 43. Bathymetric points gathered at Danao River

A CAD drawing was also produced to illustrate the Danao riverbed profile. As shown in Figure 44, the lowest elevation recorded was at -5.84 m below MSL about 10,500 m of Danao Bridge, and the highest elevation was -0.488 m in MSL located at the upstream part of the river.

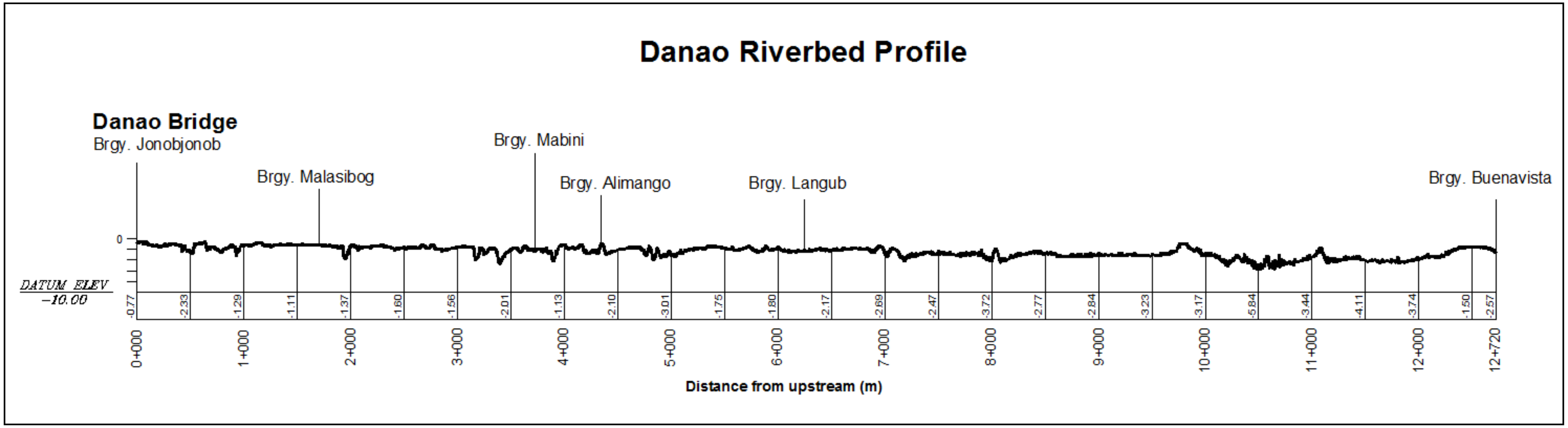


Figure 44. Riverbed profile of Danao River

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, 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

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

5.1.2 Precipitation

Precipitation data was taken from an automatic rain gauge (ARG) deployed by the UP Cebu Flood Modeling Component (FMC) team. The ARG was installed at Brgy. Malasibog, Escalante City, Negros Occidental (Figure 45). The precipitation data collection started from January 11, 2017 at 7:20 AM to January 12, 2017 at 2:00 with 5 minutes recording interval.

The total precipitation for this event in Brgy. Malasibog ARG was 14.6 mm. It has a peak rainfall of 1.4 mm. on January 11, 2017 at 8:35 in the morning. The lag time between the peak rainfall and discharge is 12 hours and 25 minutes.

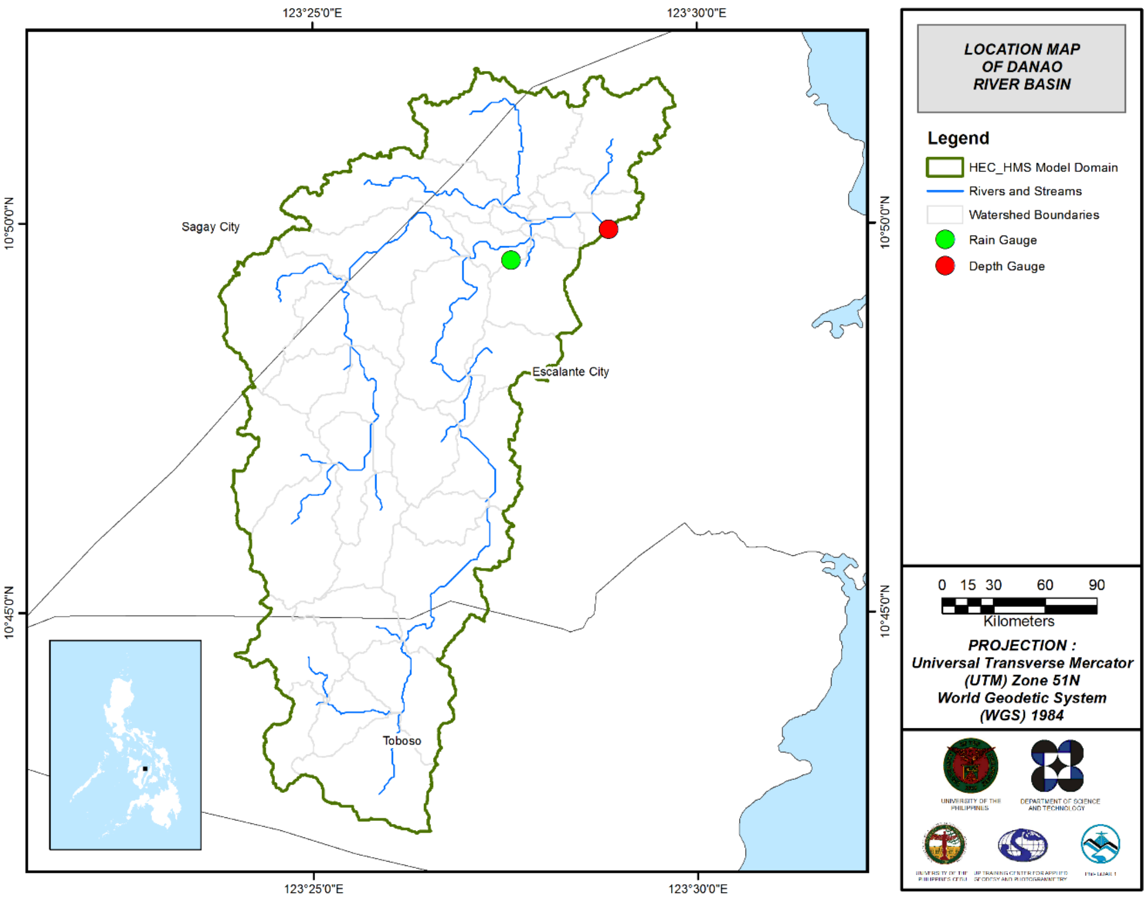


Figure 45. The location map of Danao HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 46) at Danao Footbridge Bridge, Escalante City, Negros Occidental (10°49'53.44"N, 123°28'48.27"E). It gives the relationship between the observed water levels at Danao Footbridge Bridge and outflow of the watershed at this location.

For Danao Footbridge, the rating curve is expressed as Q = 0.0644e5.6329x as shown in Figure 47.

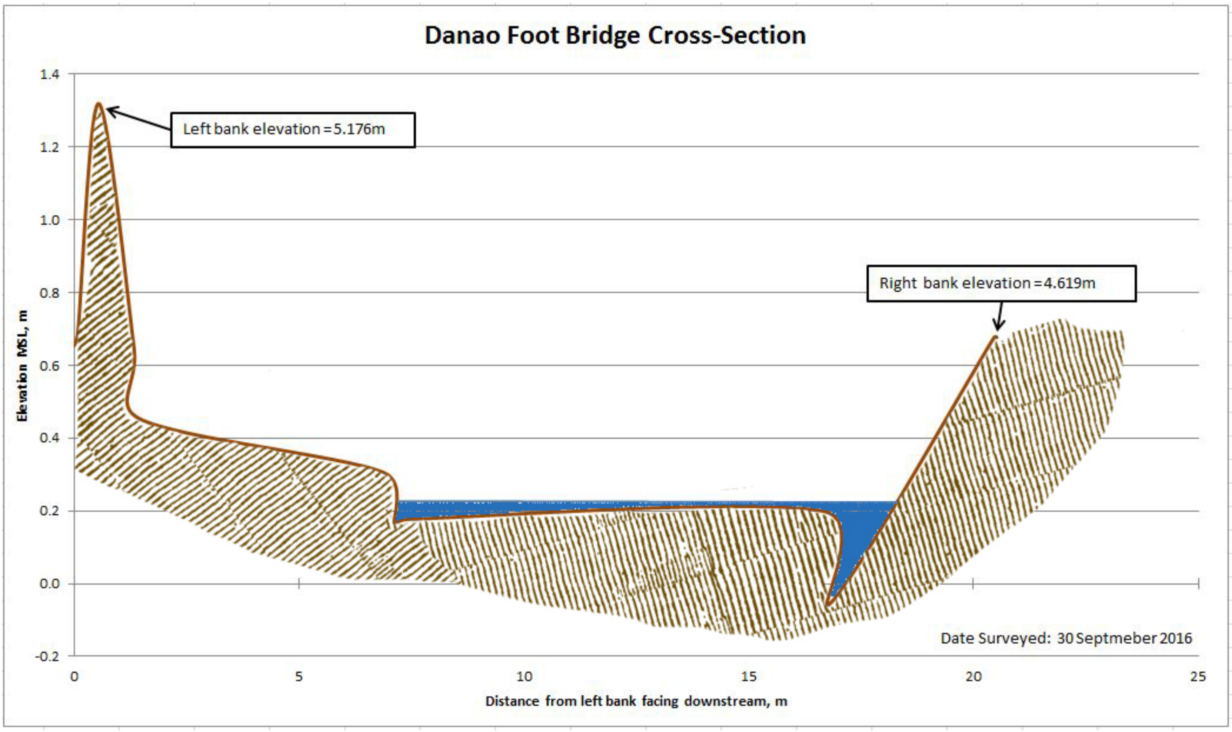


Figure 46. Cross-Section Plot of Danao Footbridge

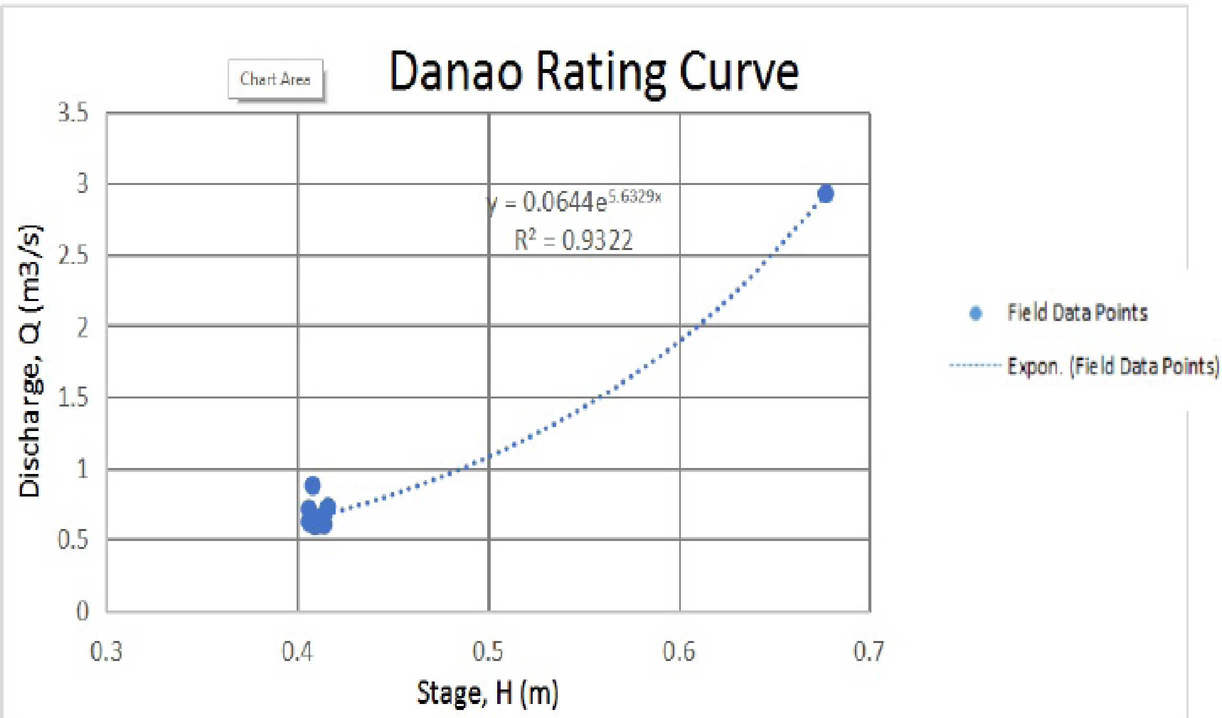


Figure 47. Rating Curve at Danao Footbridge, Escalante City

This rating curve equation was used to compute the river outflow at Danao Footbridge for the calibration of the HEC-HMS model shown in Figure 48. The total rainfall for this event was 14.6mm and the peak discharge is 0.04683 m3 at 9:00 PM, January 11, 2017.

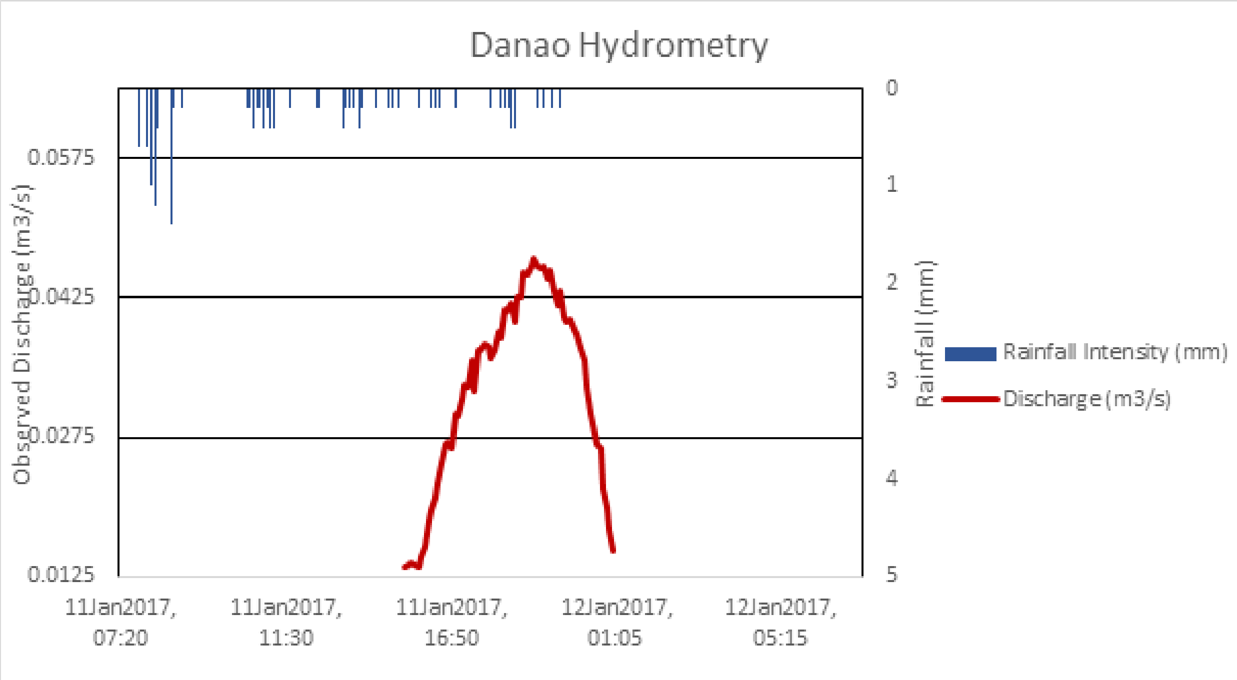


Figure 48. Rainfall and outflow data at Danao used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Mactan Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value will be attained at a certain time. This station chosen based on its proximity to the Danao watershed. The extreme values for this watershed were computed based on a 59-year record.

Table 28. RIDF values for Mactan 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	21.9	34	43.2	58.4	74.9	84	105.2	122.6	139.1
10	25.8	40.2	51.1	69.7	88.9	99.6	126.3	148.6	169.7
25	30.9	48	61	83.9	106.6	119.3	153.1	181.4	208.5
50	34.6	53.8	68.3	94.4	119.7	133.9	173	205.8	237.2
100	38.3	59.5	75.6	104.9	132.7	148.4	192.7	237.2	265.7

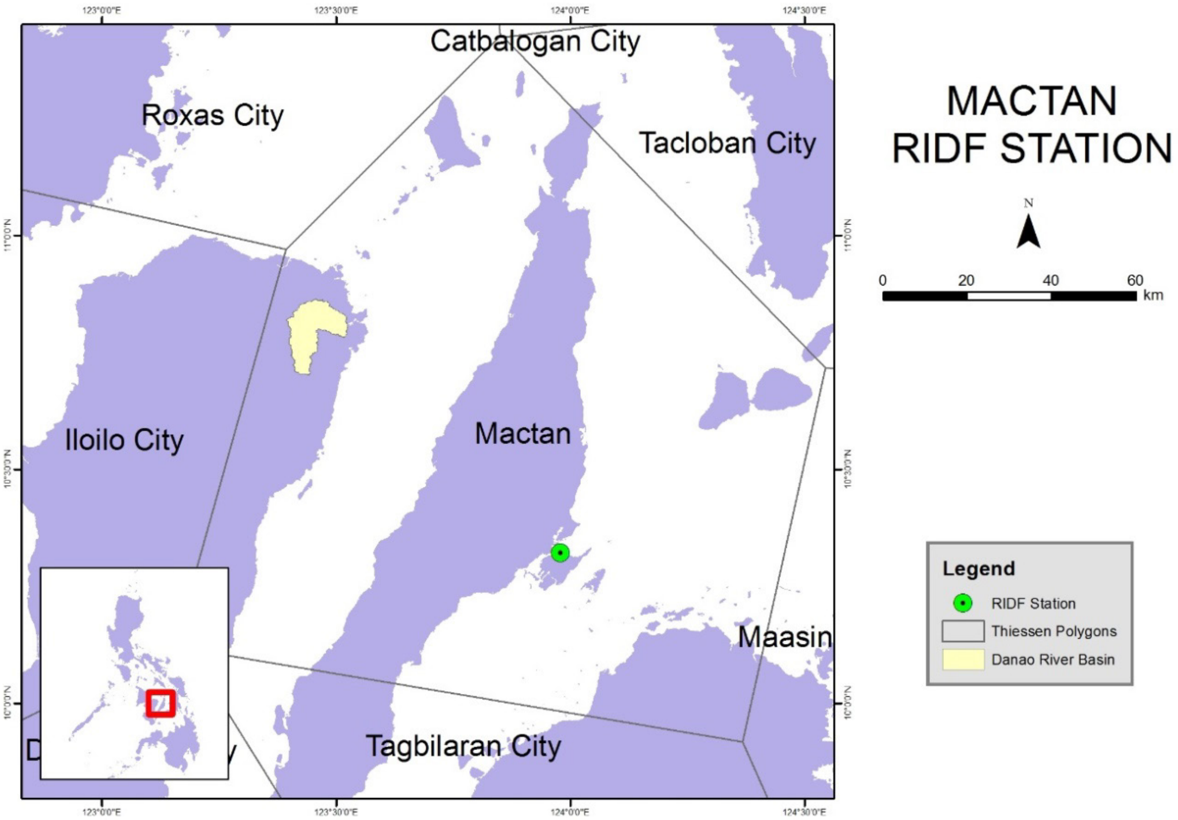


Figure 49. Location of Iloilo RIDF station relative to Danao River Basin

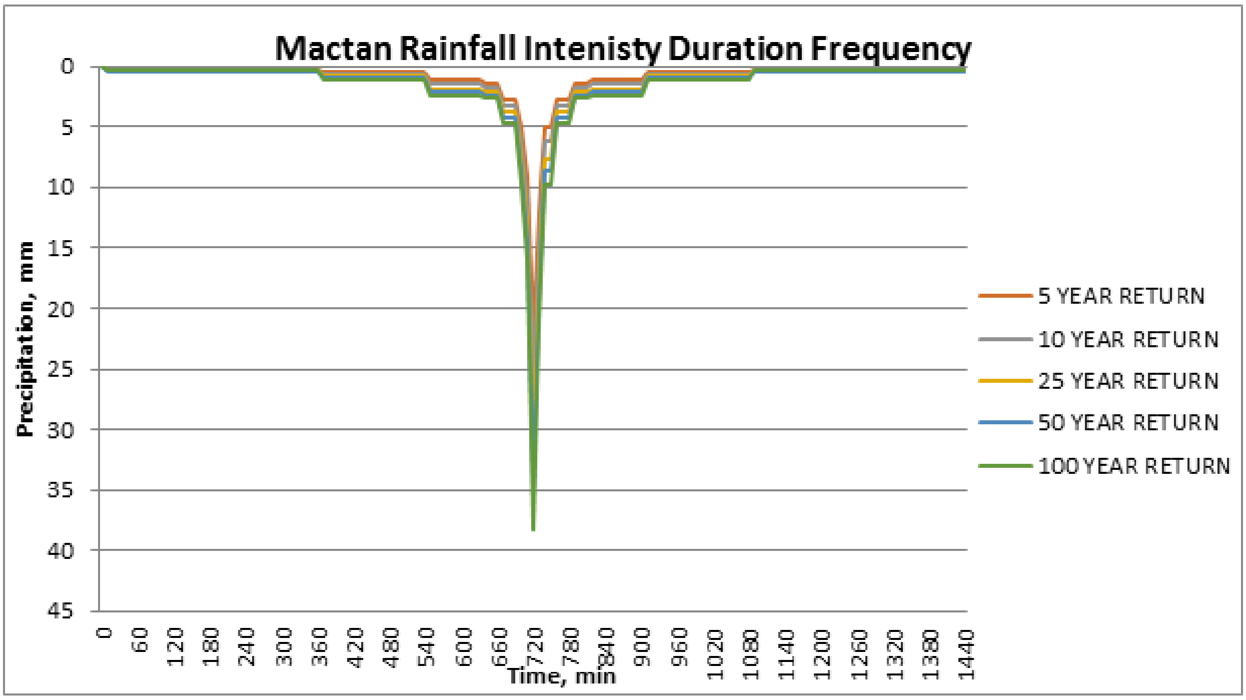


Figure 50. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken on 2004 from the Bureau of Soils; this is under the Department of Environment and Natural Resources Management. The land cover shape file is from the National Mapping and Resource Information Authority (NAMRIA). The soil and land cover of the Danao River Basin are shown in Figures 51 and 52, respectively.

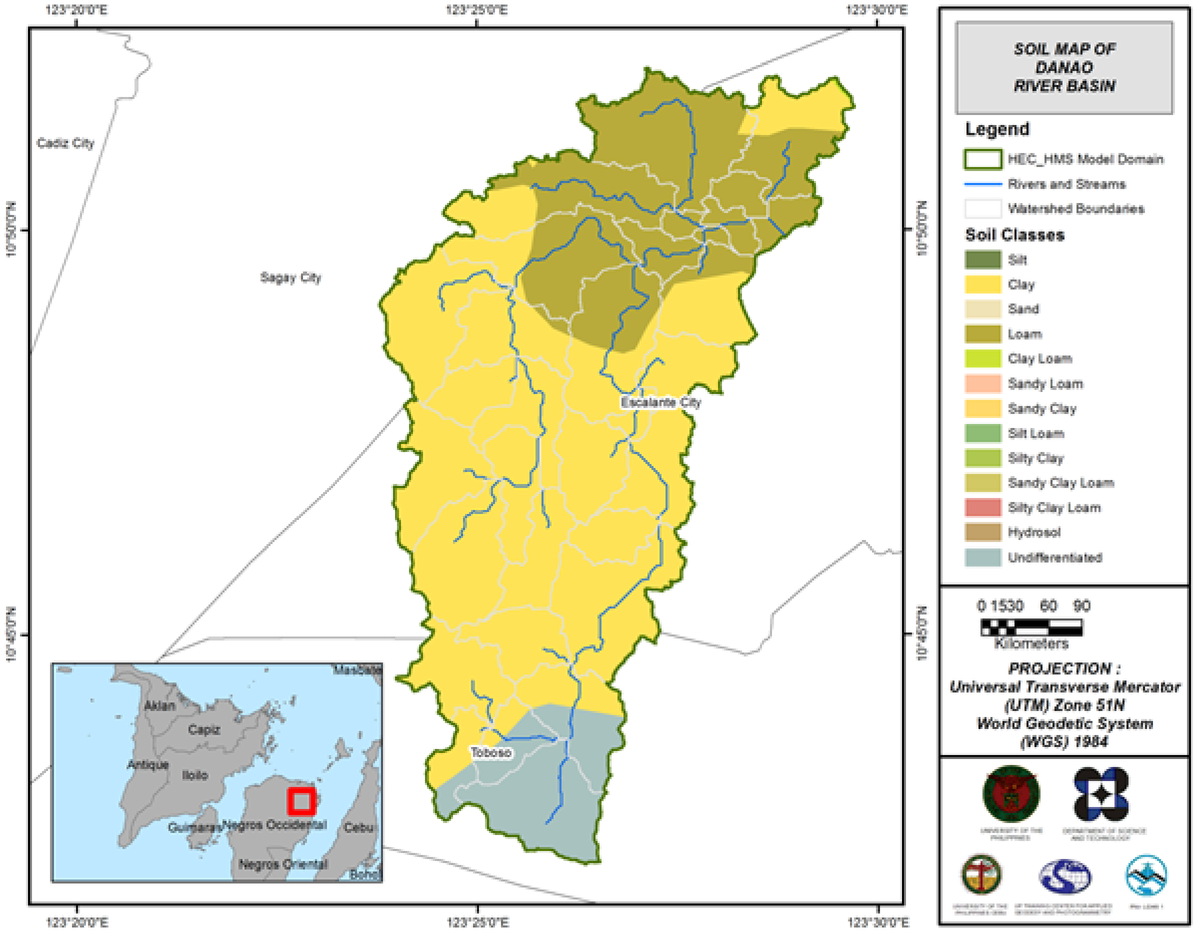


Figure 51. Soil map of the Danao River Basin

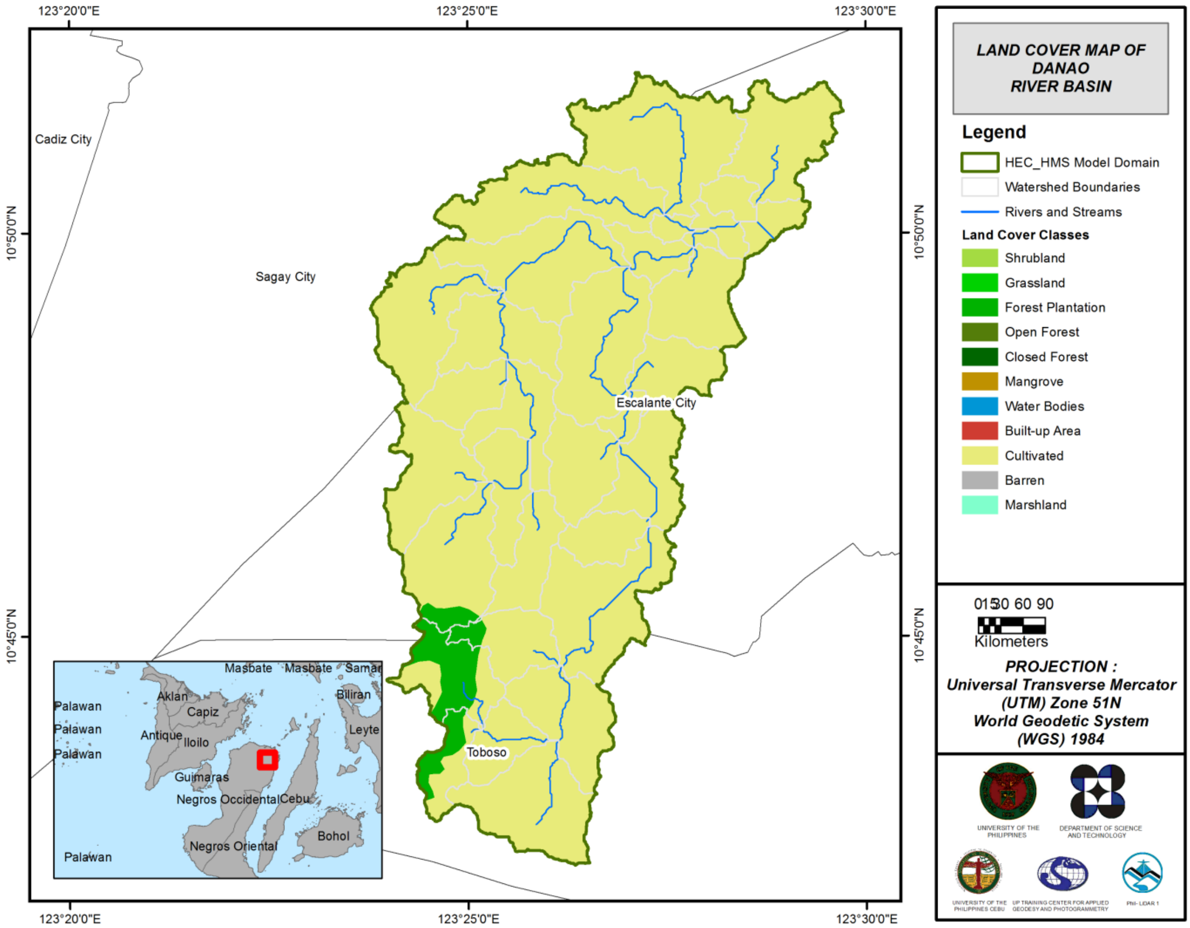


Figure 52. Land cover map of the Danao River Basin

For Danao, three soil classes were identified. These are loam, clay, and undifferentiated soil. Moreover, two land cover classes were identified. These are cultivated areas and forest plantations.

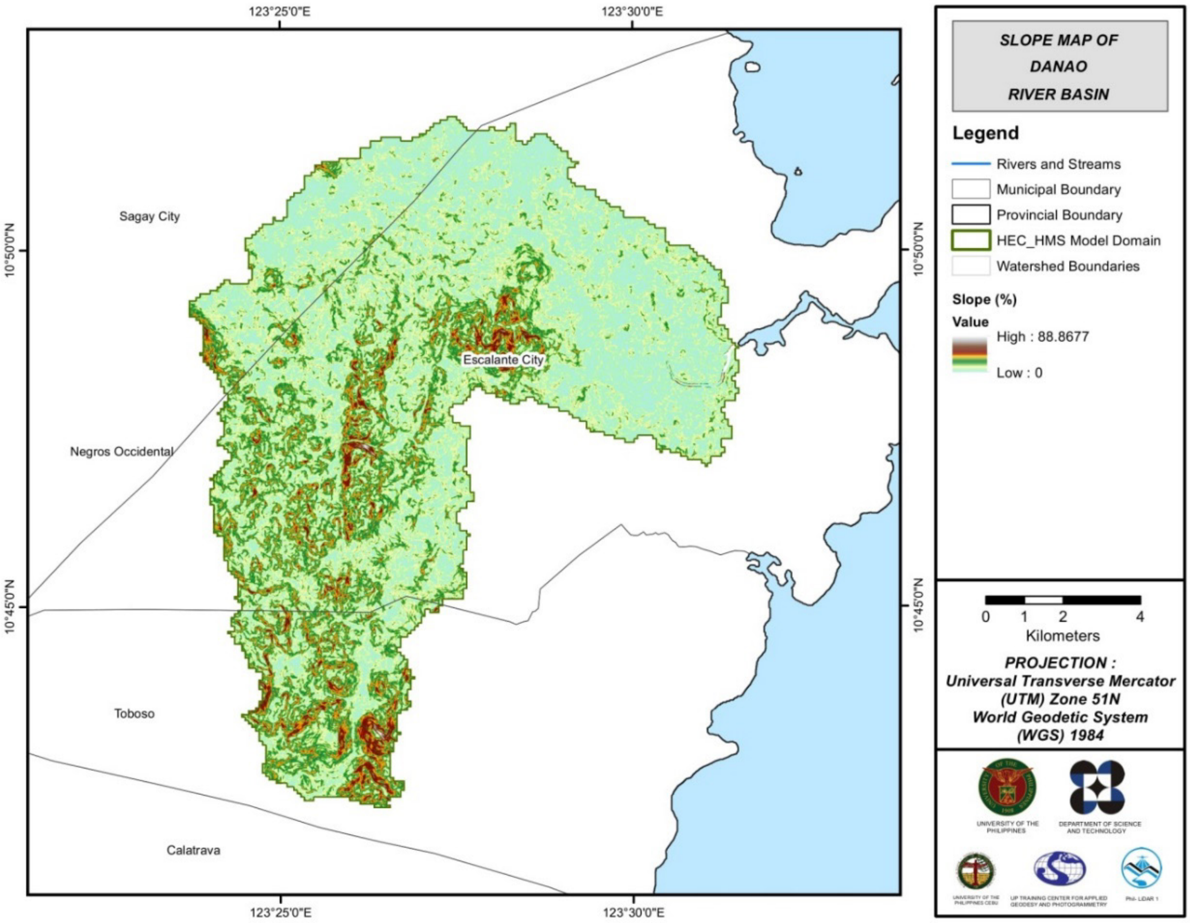


Figure 53. Slope map of the Danao River Basin

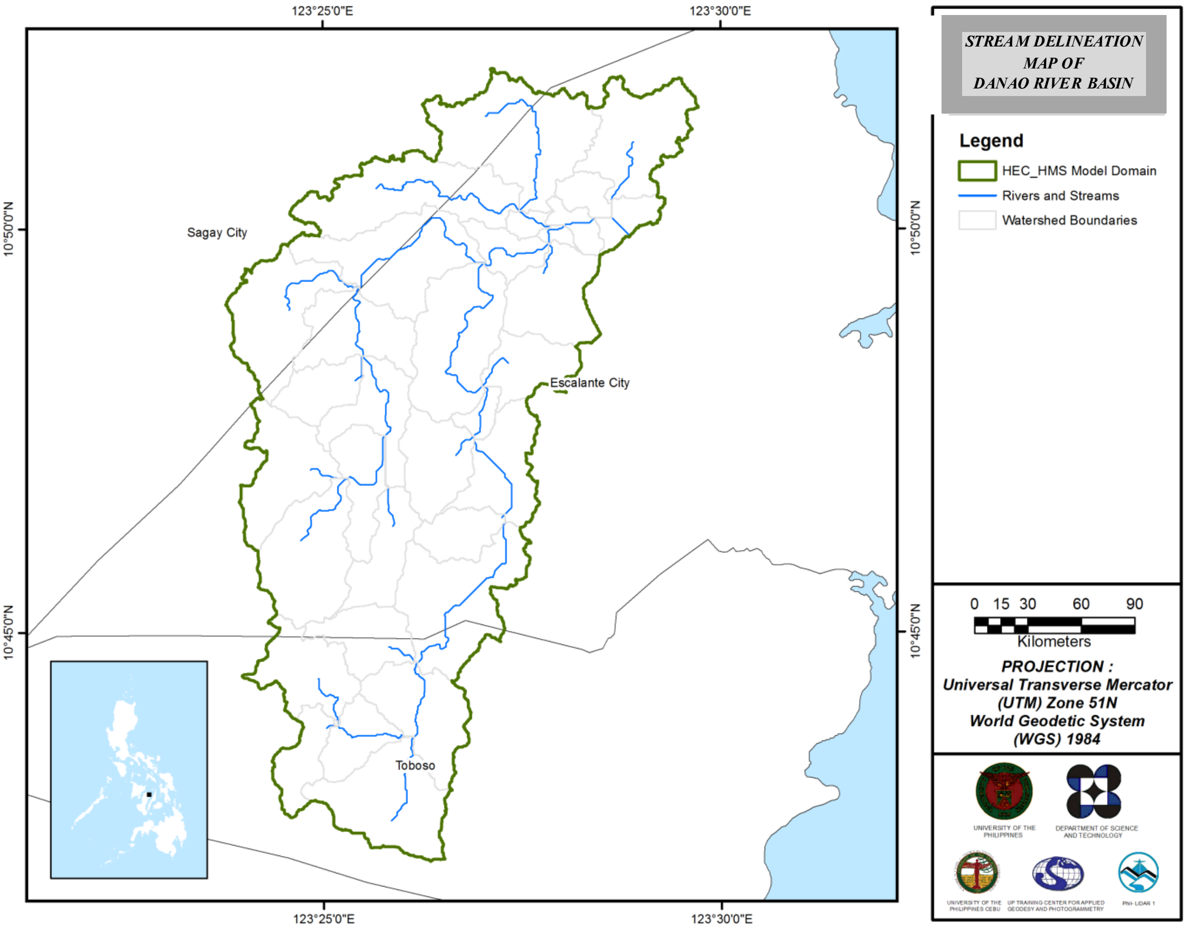


Figure 54. Stream delineation map of Danao river basin

Using the SAR-based DEM, the Danao basin was delineated and further subdivided into sub-basins. The model consists of 31 sub basins, 15 reaches, and 15 junctions as shown in Figure 7. The main outlet is at Danao Footbridge.

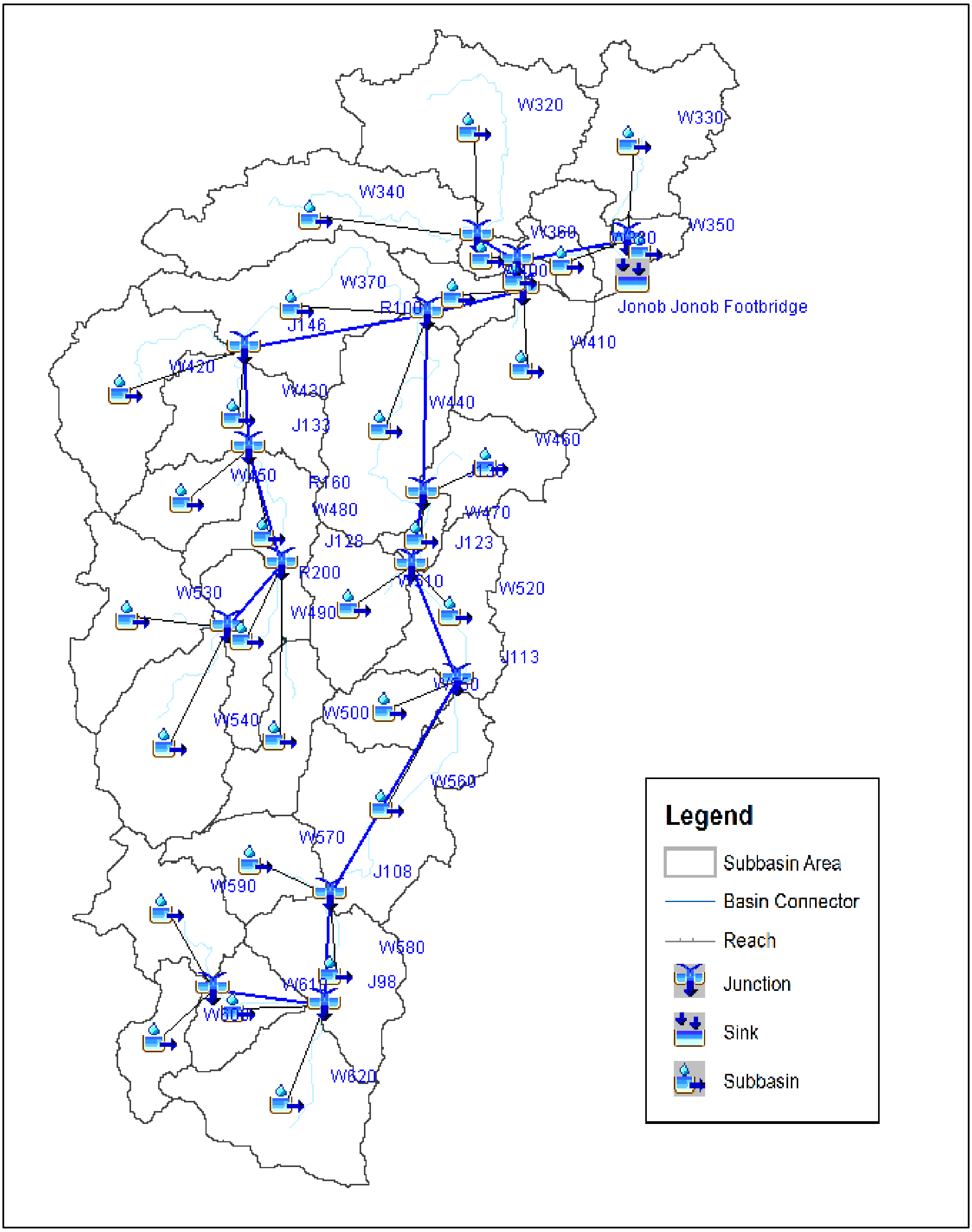


Figure 55. The Danao river basin model generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were crucial in the HEC-RAS model setup. 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.

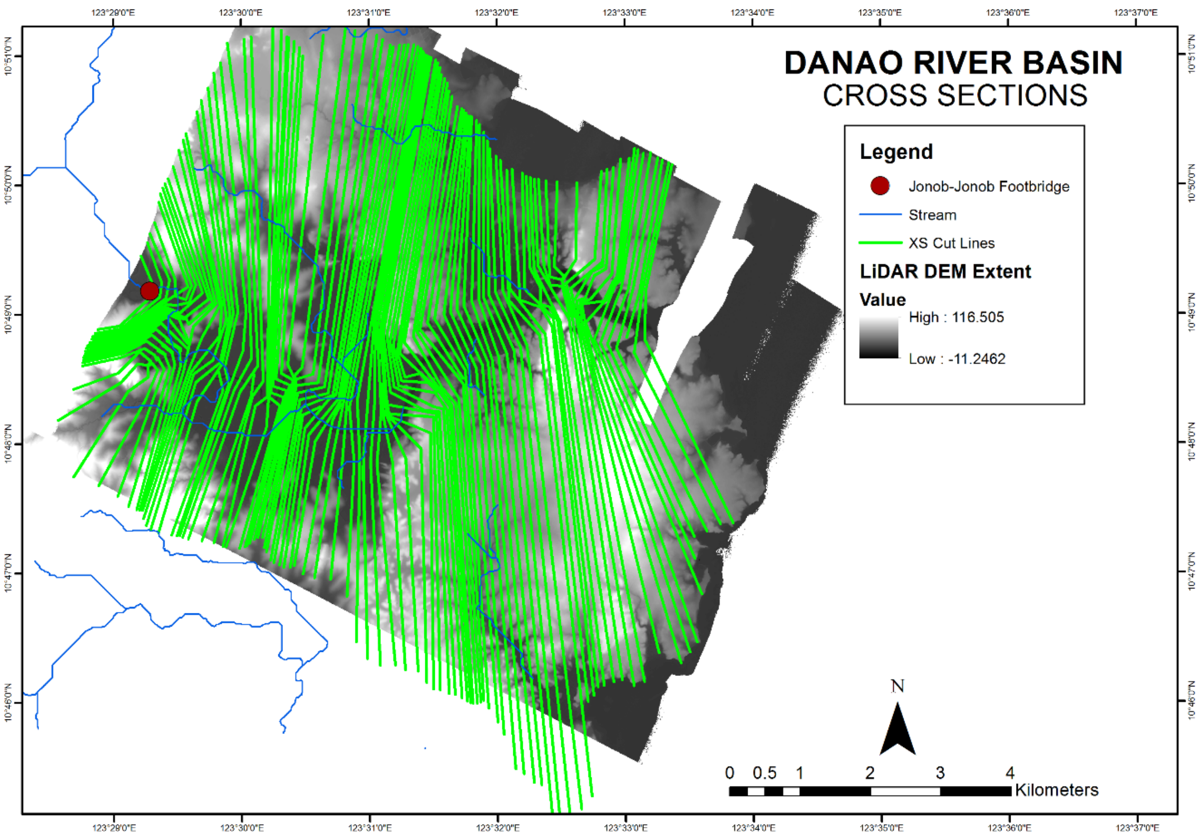


Figure 56. River cross-section of Danao River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

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

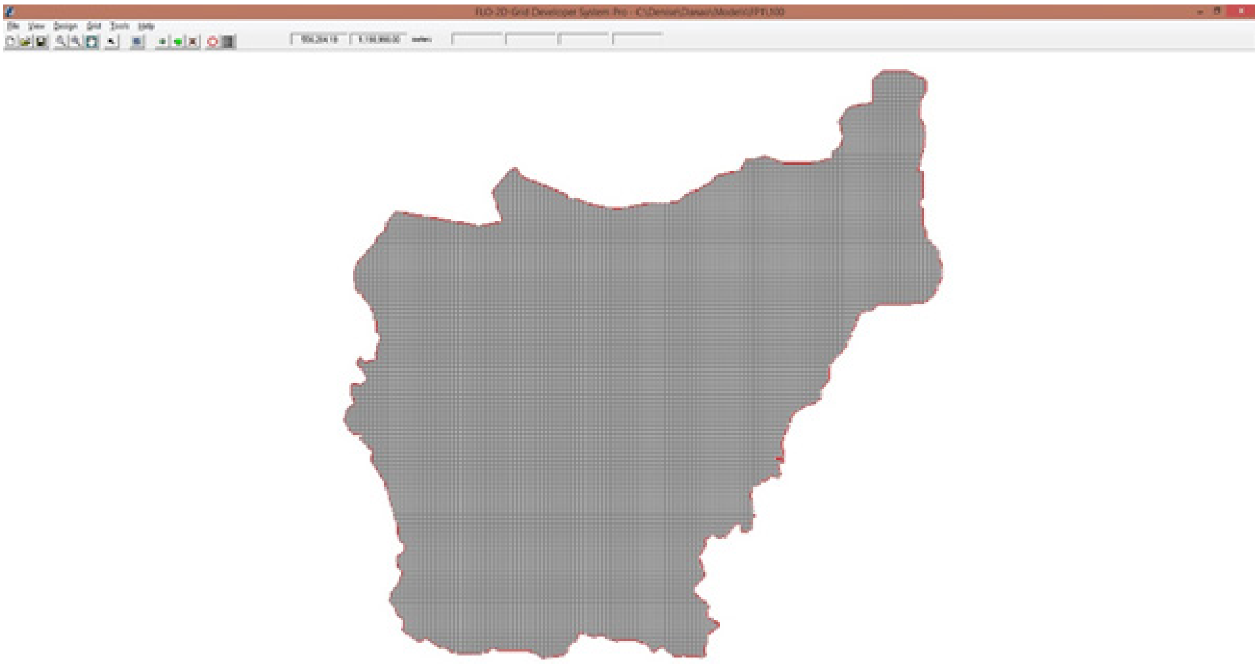


Figure 57. Screenshot of subcatchment with the computational area to be modeled in FLO-2D Grid Developer System Pro (FLO-2D GDS Pro)

The simulation is then run through FLO-2D GDS Pro. This particular model had a computer run time of 11.43066 hours. After the simulation, FLO-2D Mapper Pro is used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High creates the following food hazard map. Most of the default values given by FLO-2D Mapper Pro are used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s.

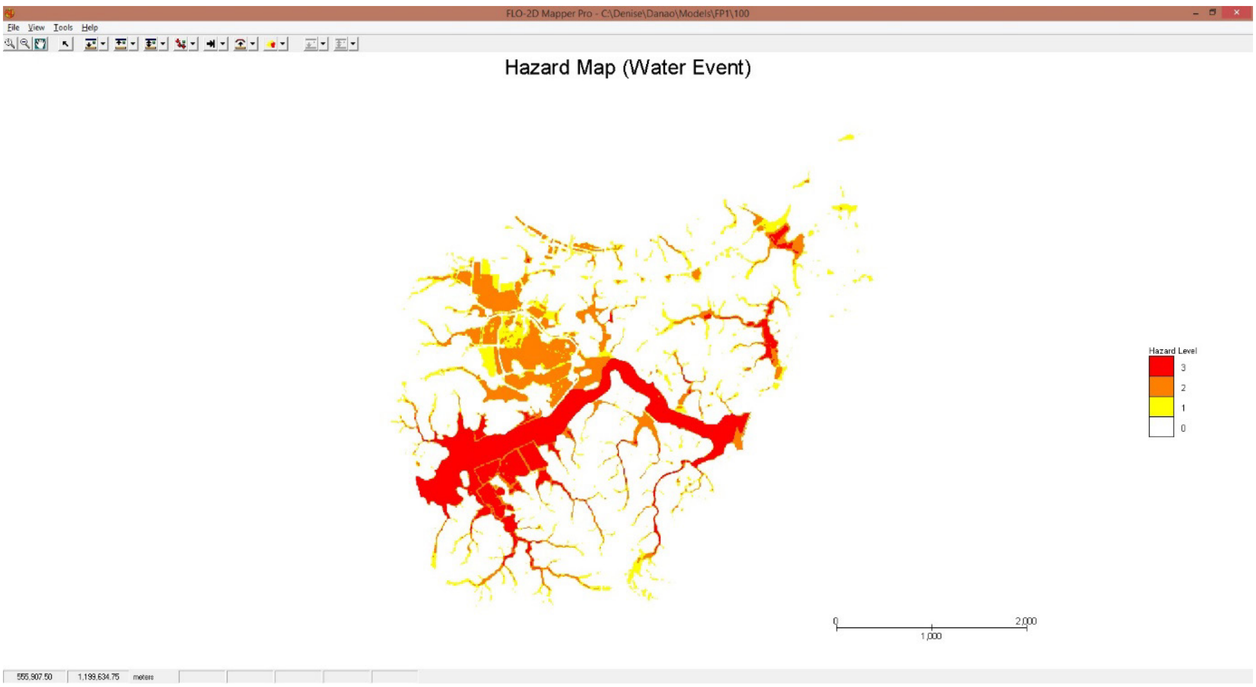


Figure 58. Generated 100-year rain return hazard map from FLO-2D Mapper

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 15705300.00 m2.

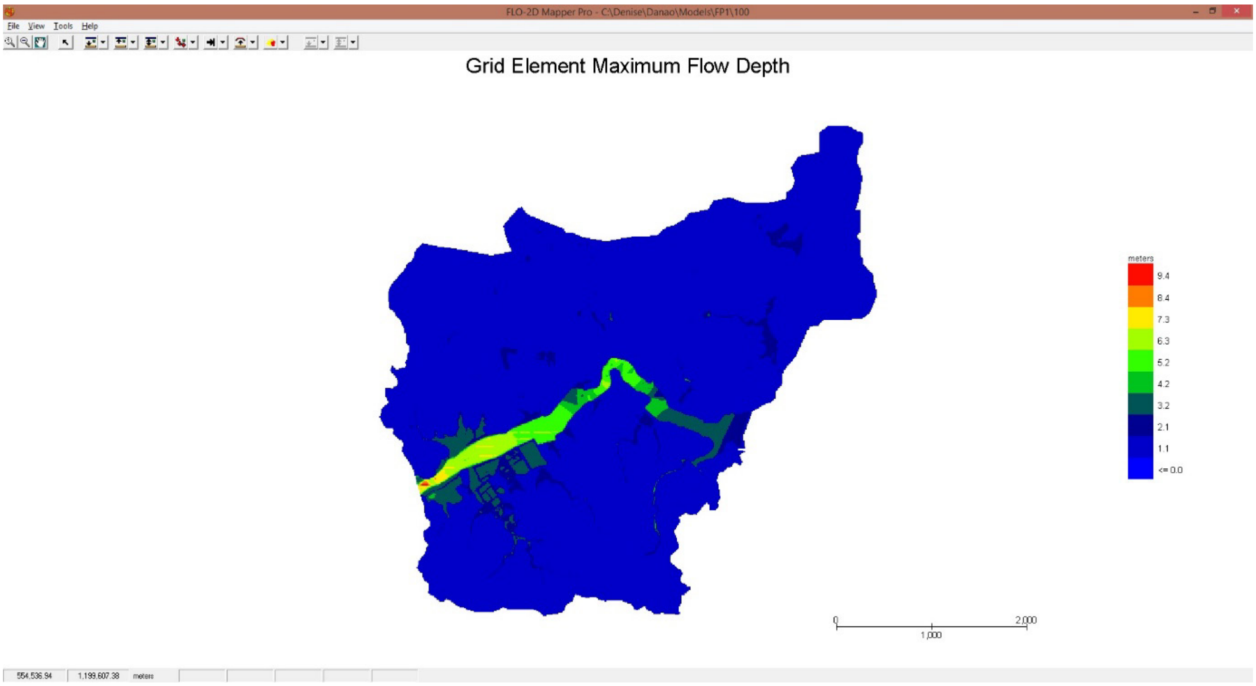


Figure 59. The Danao Hydrologic Model generated in HEC-GeoHMS

There is a total of 14986300.36 m3 of water entering the model. Of this amount, 4135168.99 m3 is due to rainfall while 10851131.37 m3 is inflow from other areas outside the model. 1872651.12 m3 of this water is lost to infiltration and interception, while 5463852.34 m3 is stored by the flood plain. The rest, amounting up to 7649796.67 m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Danao HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 60 shows the comparison between the two discharge data.

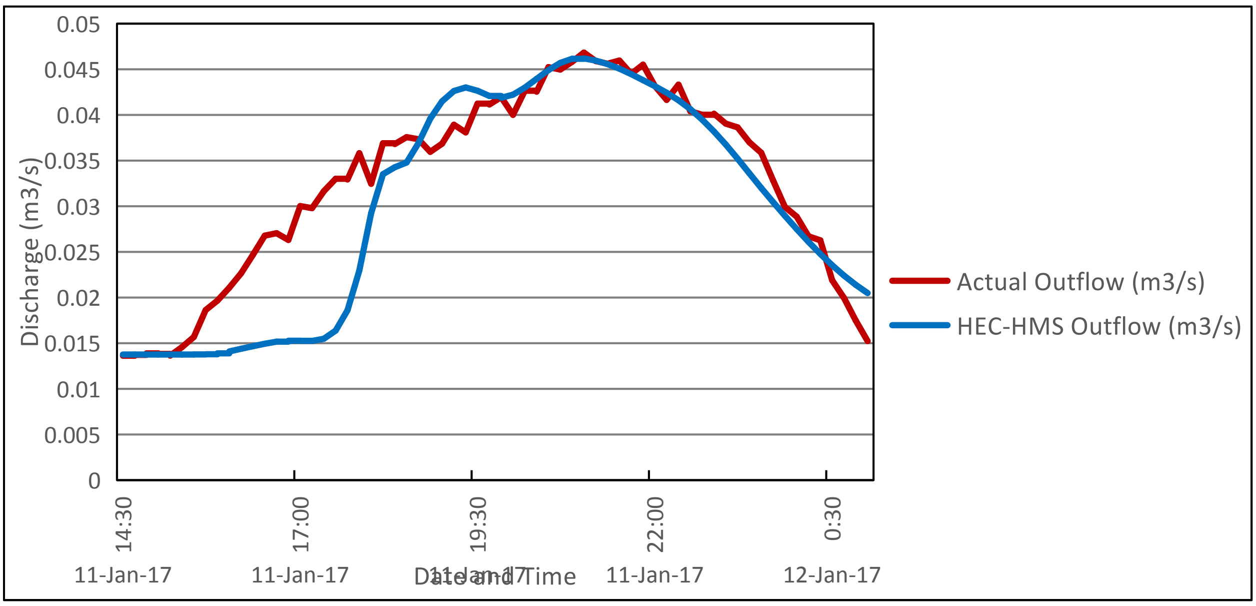


Figure 60. Outflow Hydrograph of Danao produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 29 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 29. Range of Calibrated Values for Danao

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	0.35-6.4
			Curve Number	51.9-89
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.16-6.6
			Storage Coefficient (hr)	1.04-1.29
	Baseflow	Recession	Recession Constant	1
			Ratio to Peak	0.07
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.0001-0.0022

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 0.35 mm to 6.4 mm means that there is minimal to average amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 51.9 to 89 for curve number is advisable for Philippine watersheds depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Danao, the basin mostly consists of cultivated areas, and the soil consists of clay, loam, and undifferentiated soil.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.16 hours to 6.6 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 1 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.07 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.0001 to 0.0022 for the Danao river basin is lower than the usual Manning's n value in the Philippines (Brunner, 2010).

Table 30. Summary of the Efficiency Test of Danao HMS Model

Accuracy Measure	Value
RMS Error	6.822906
r2	0.954382
NSE	0.879895
RSR	0.346561
PBIAS	-1.4088

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 0.0 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9016.

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 0.67.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 8.52.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.57.

Calculated Outflow hydrographs and Discharge Values for different Rainfall Return Periods
Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 61) shows the Danao outflow using the Mactan Rainfall Intensity-Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods from 139.1m3 in a 5-year return period to 265.7m3 for a 100-year return period.

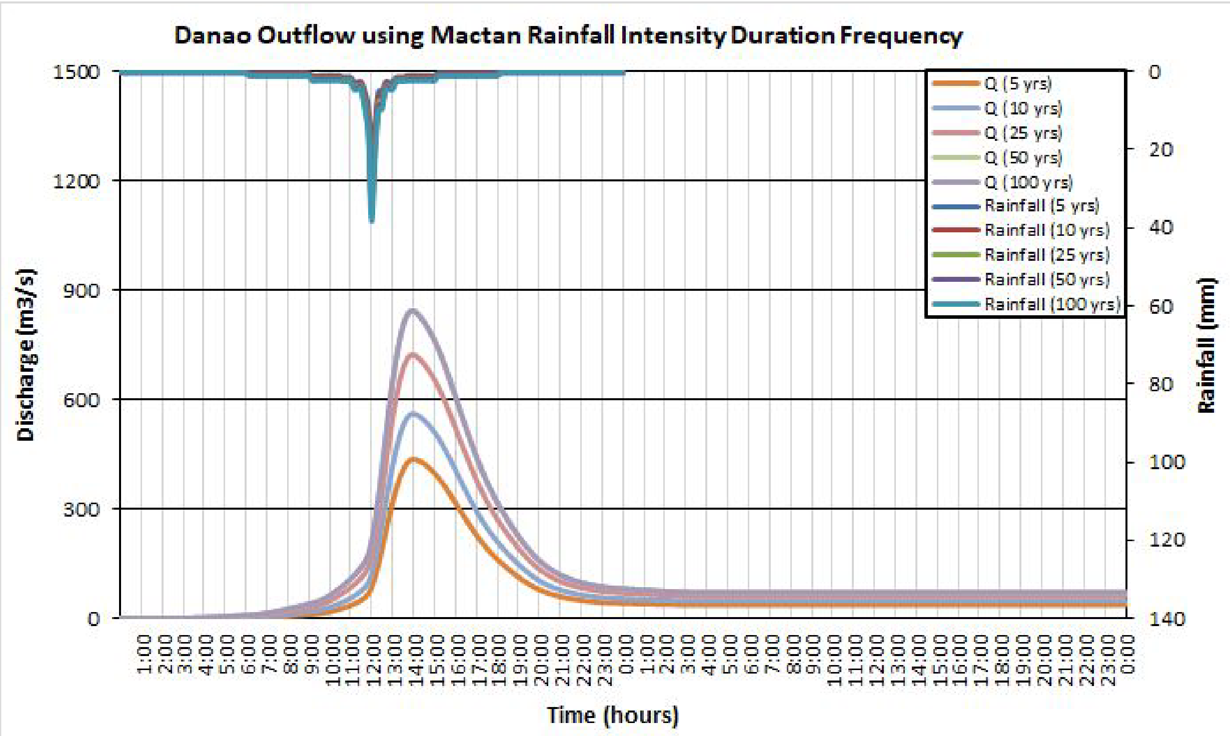


Figure 61. Outflow hydrograph at Danao Station generated using Mactan RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Danao discharge using the Mactan Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 31.

Table 31. Peak values of the Danao HEC-HMS Model outflow using the Mactan RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	139.1	21.9	436.28657	2 hours
10-Year	169.7	25.8	561.42163	2 hours
25-Year	208.5	30.9	722.69811	2 hours
50-Year	237.2	34.6	843.42321	2 hours
100-Year	265.7	38.3	965.03739	2 hours

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The river discharges entering the floodplain are shown in to and the peak values are summarized in Table 32 to Table 34.

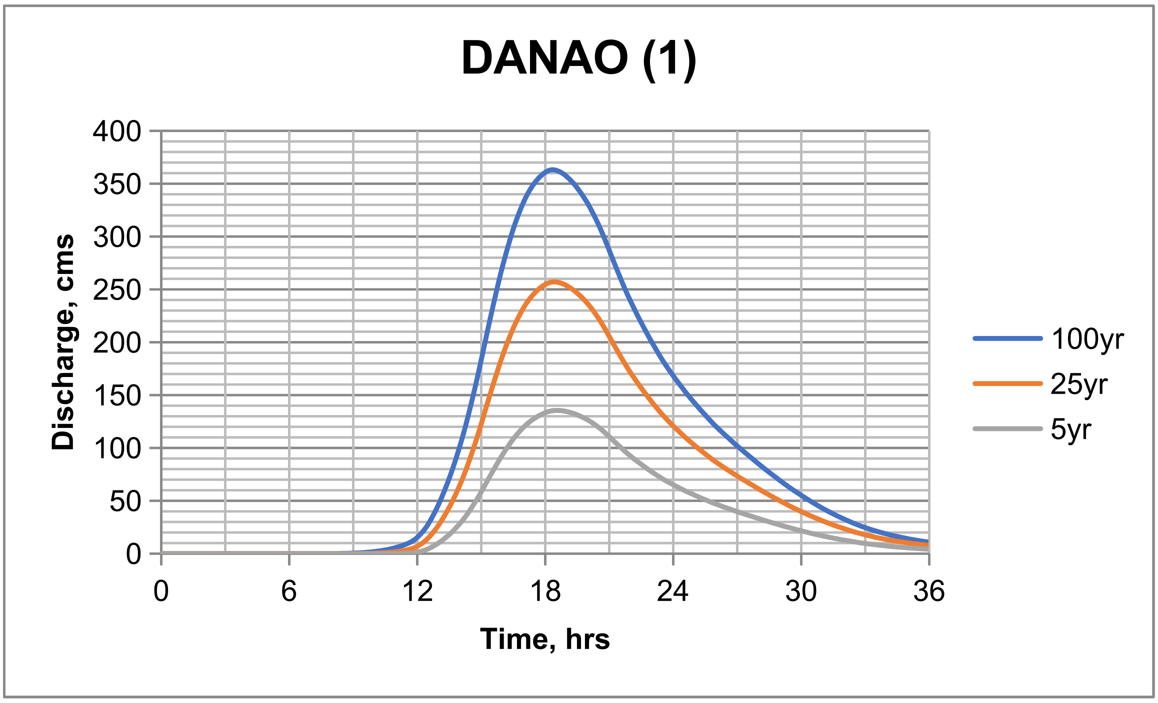


Figure 62. Danao river (1) generated discharge using 5-, 25-, and 100-year Iloilo and Butuan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS

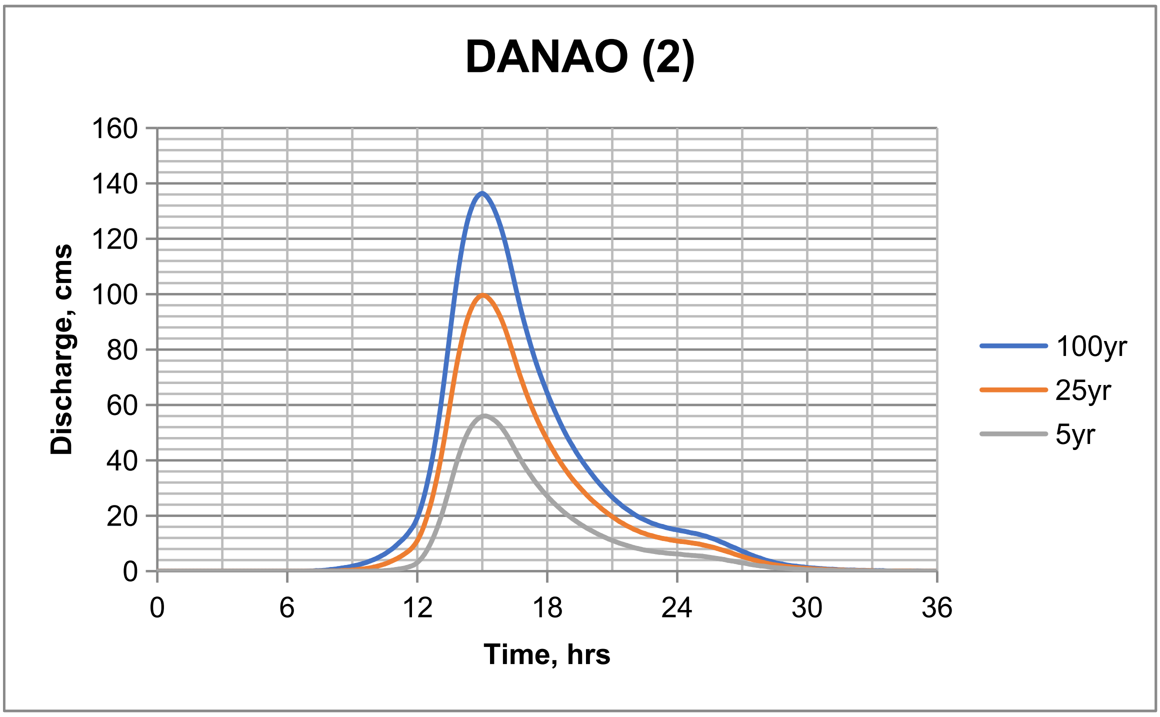


Figure 63. Danao river (2) generated discharge using 5-, 25-, and 100-year Iloilo and Butuan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS

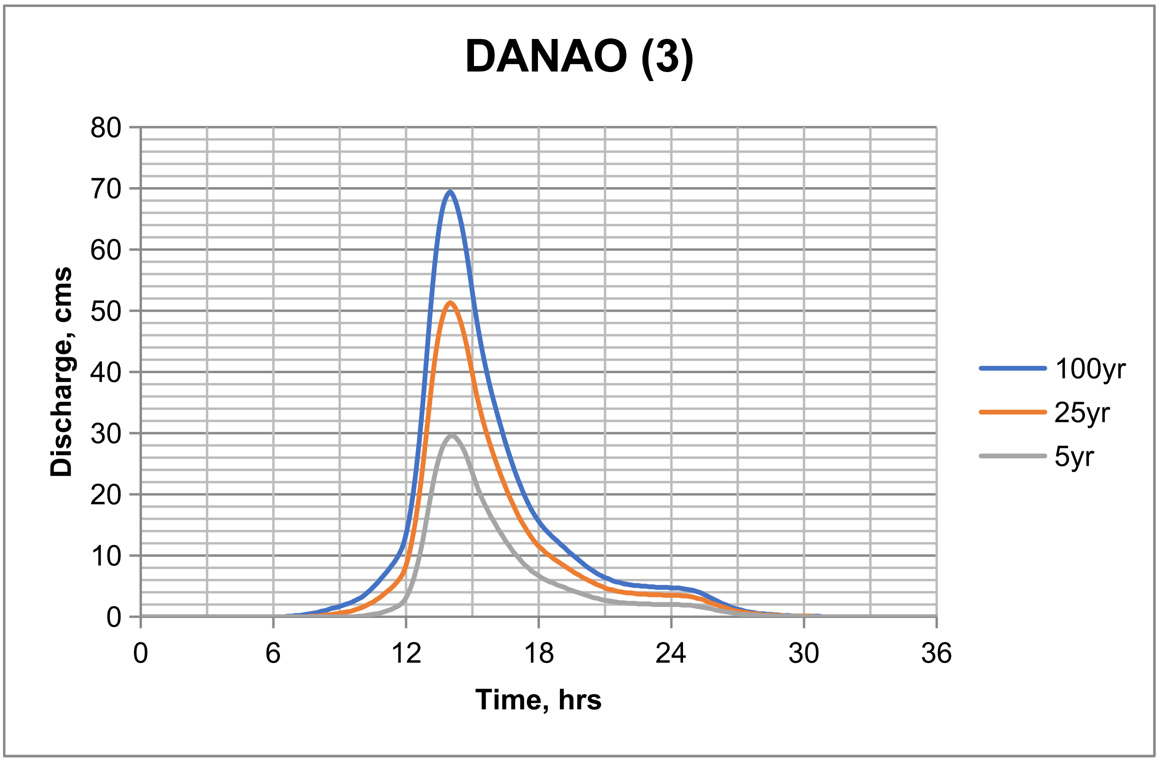


Figure 64. Danao river (3) generated discharge using 5-, 25-, and 100-year Iloilo and Butuan stations' rainfall intensity-duration-frequency (RIDF) in HEC-HMS

Table 32. Summary of Danao river (1) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	363.2	18 hours, 20 minutes
25-Year	257.0	18 hours, 20 minutes
5-Year	135.5	18 hours, 20 minutes

Table 33. Summary of Danao river (2) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	136.4	15 hours
25-Year	99.6	15 hours
5-Year	56.0	15 hours

Table 34. Summary of Danao river (3) discharge generated in HEC-HMS

RIDF Period	Peak discharge (cms)	Time-to-peak
100-Year	69.4	14 hours
25-Year	51.3	14 hours
5-Year	29.5	14 hours

The comparison of the discharge results using Dr. Horritt's recommended hydrological method against the bankful and specific discharge estimates is shown in Table 35.

Table 35. Validation of river discharge estimates

Discharge Point	QMED(SCS), cms	QBANKFUL, cms	QMED(SPEC), cms	VALIDATION	
				Bankful Discharge	Specific Discharge
Danao (1)	119.240	109.101	206.252	Pass	Pass
Danao (2)	49.280	83.831	68.112	Pass	Pass
Danao (3)	25.960	19.599	31.368	Pass	Pass

All three values from the HEC-HMS river discharge estimates were able to satisfy the conditions for validation using the bankful and specific discharge methods. The calculated values are based on theory but are supported using other discharge computation methods so they were good to use flood modeling. However, 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 Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every time step for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample generated map of Danao River using the calibrated HMS event flow is shown in Figure 65.

Figure 65. Sample output of Danao RAS Model

5.9 Flood Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 66 to Figure 71 shows the 5-, 25-, and 100-year rain return scenarios of the Danao floodplain. The floodplain, with an area of 57.19 sq.km., covers one municipality namely, Escalante City.

Table 36. Summary of Dipolog river (1) discharge generated in HEC-HMS

City / Municipality	Total Area	Area Flooded	% Flooded
Escalante City	192.144	56.32662	29.3148

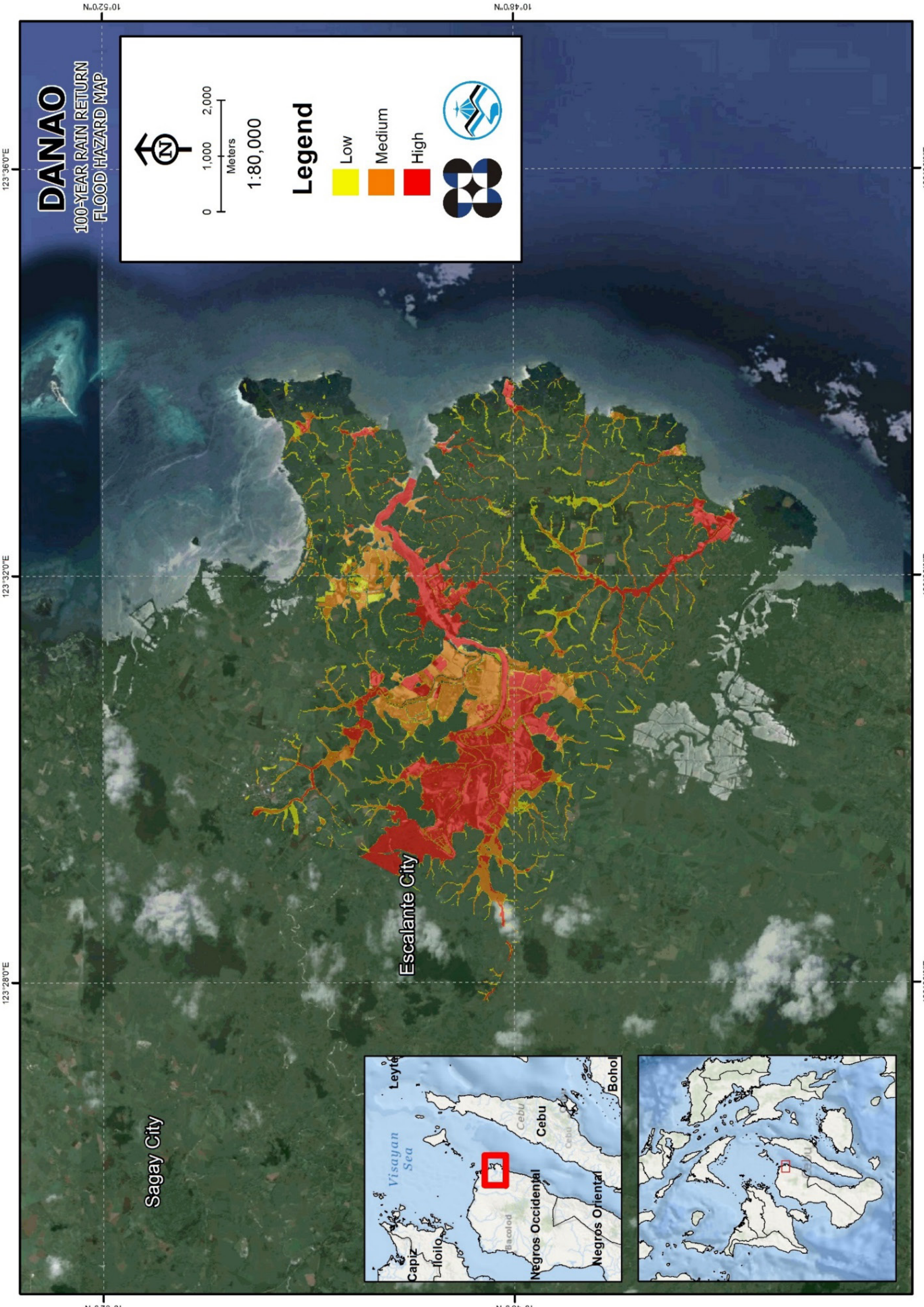


Figure 66. 100-year Flood Hazard Map for Danao Floodplain overlaid on Google Earth imagery

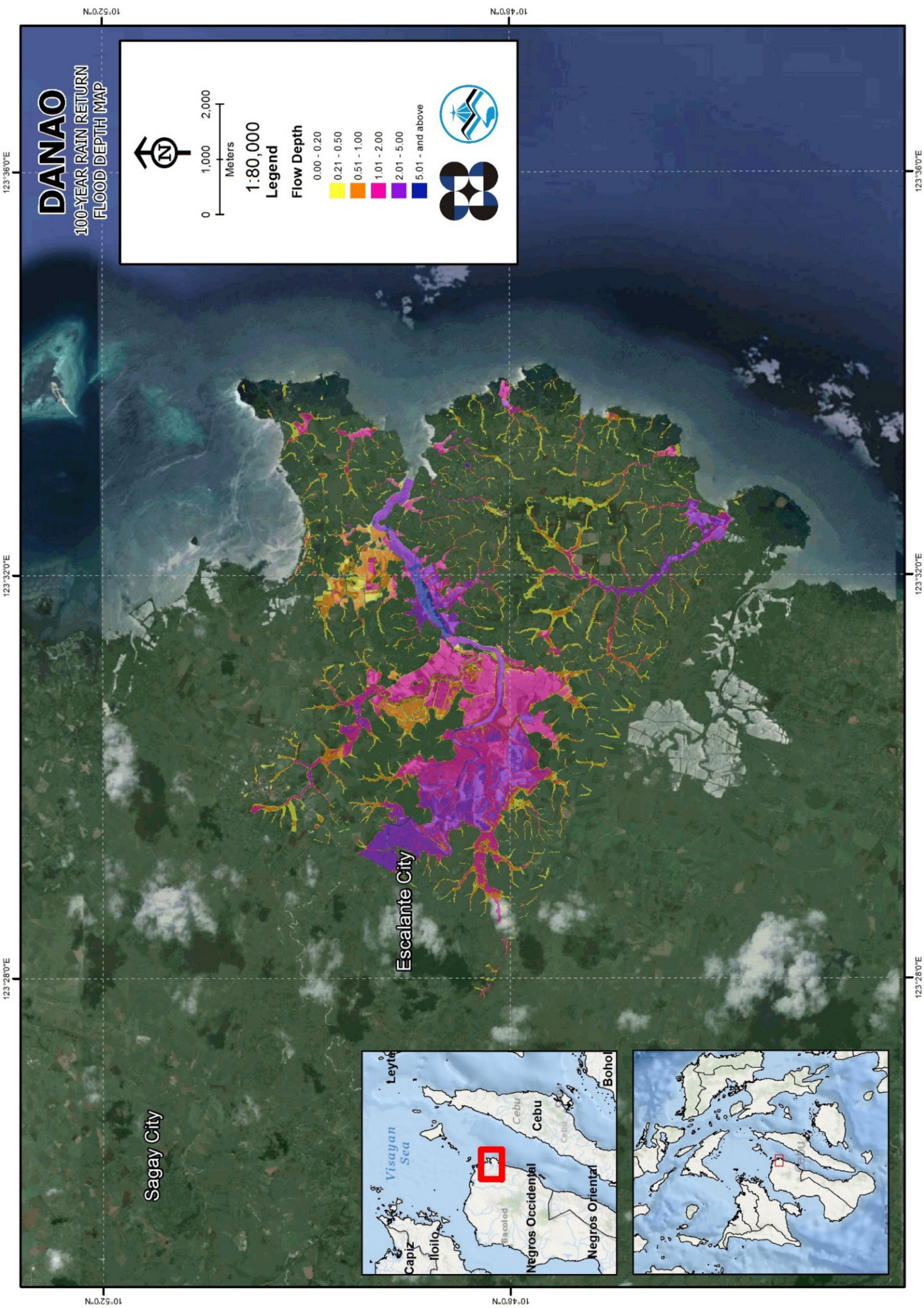


Figure 67. 100-year Flow Depth Map for Danao Floodplain overlaid on Google Earth imagery

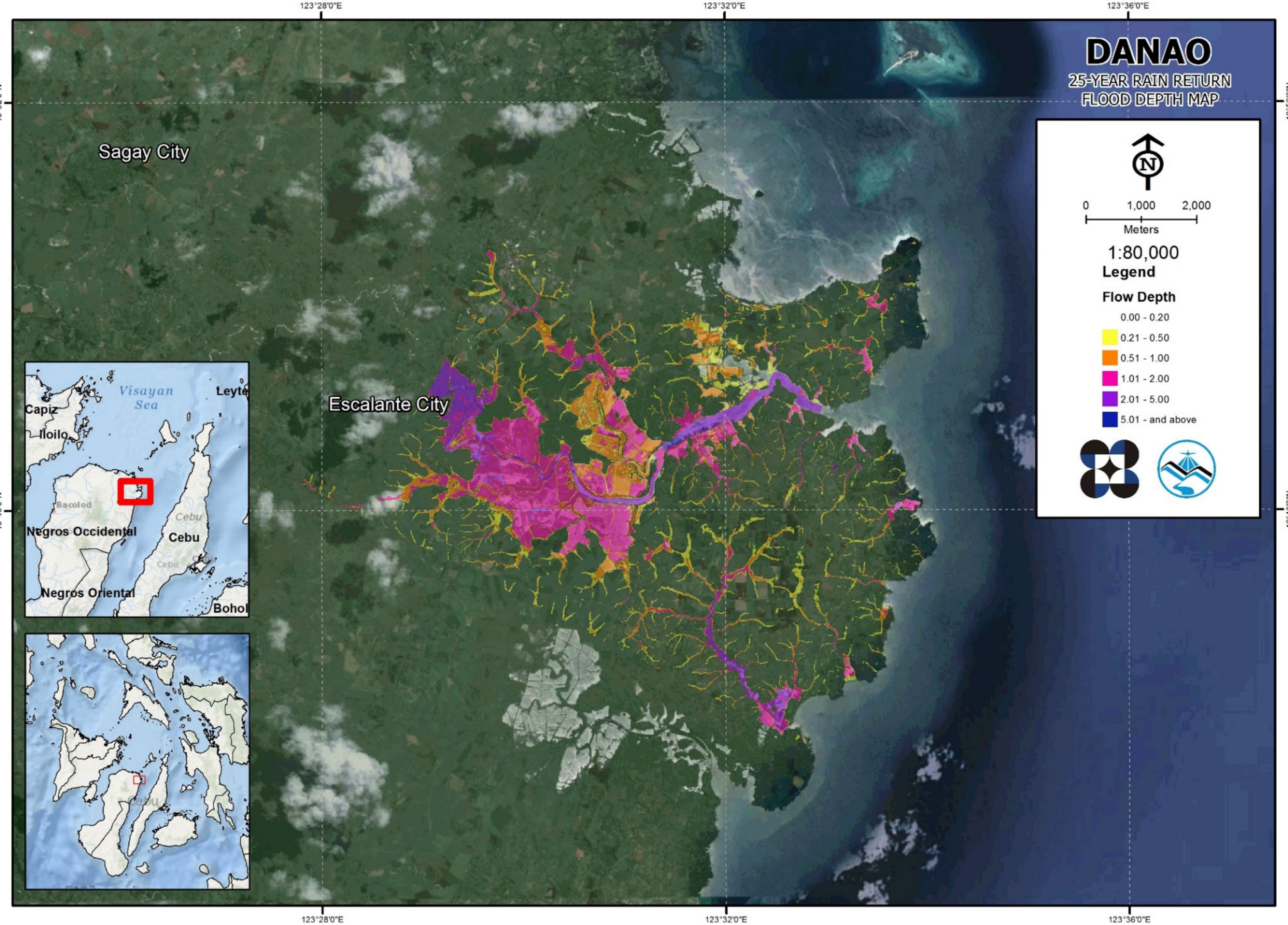


Figure 68. 25-year Flood Hazard Map for Danao Floodplain overlaid on Google Earth imagery

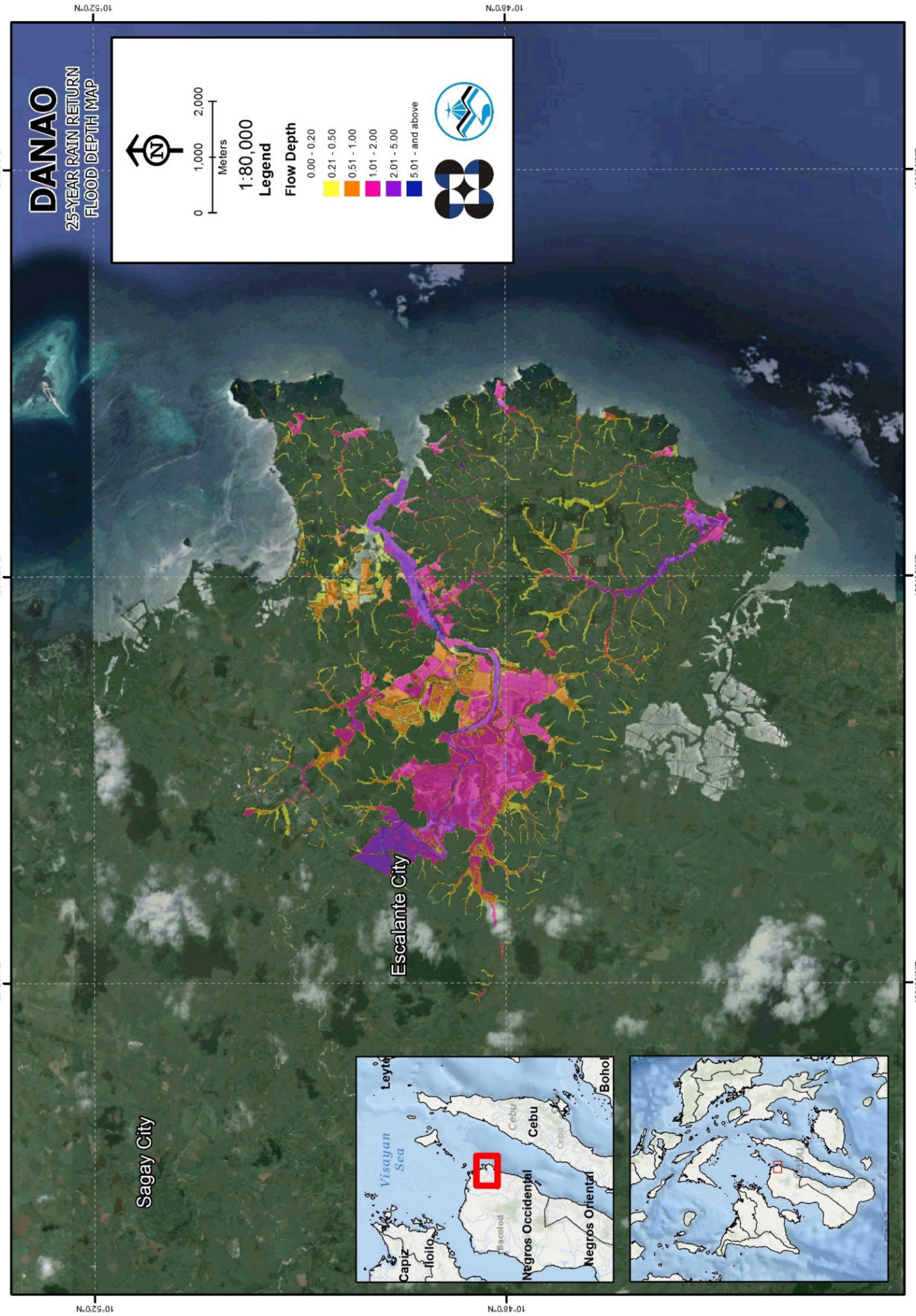


Figure 69. 25-year Flow Depth Map for Danao Floodplain overlaid on Google Earth imagery

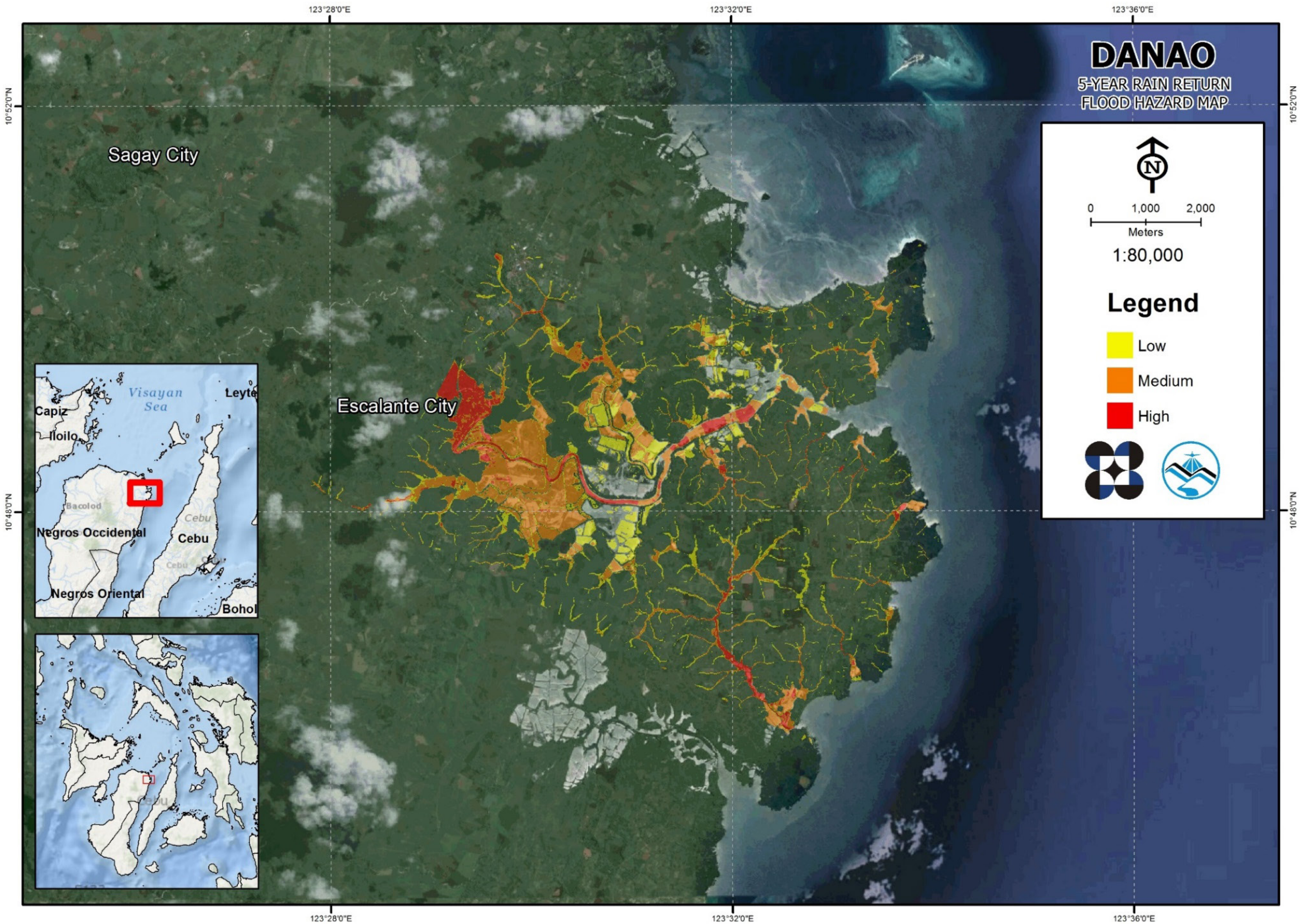


Figure 70. 5-year Flood Hazard Map for Danao Floodplain overlaid on Google Earth imagery

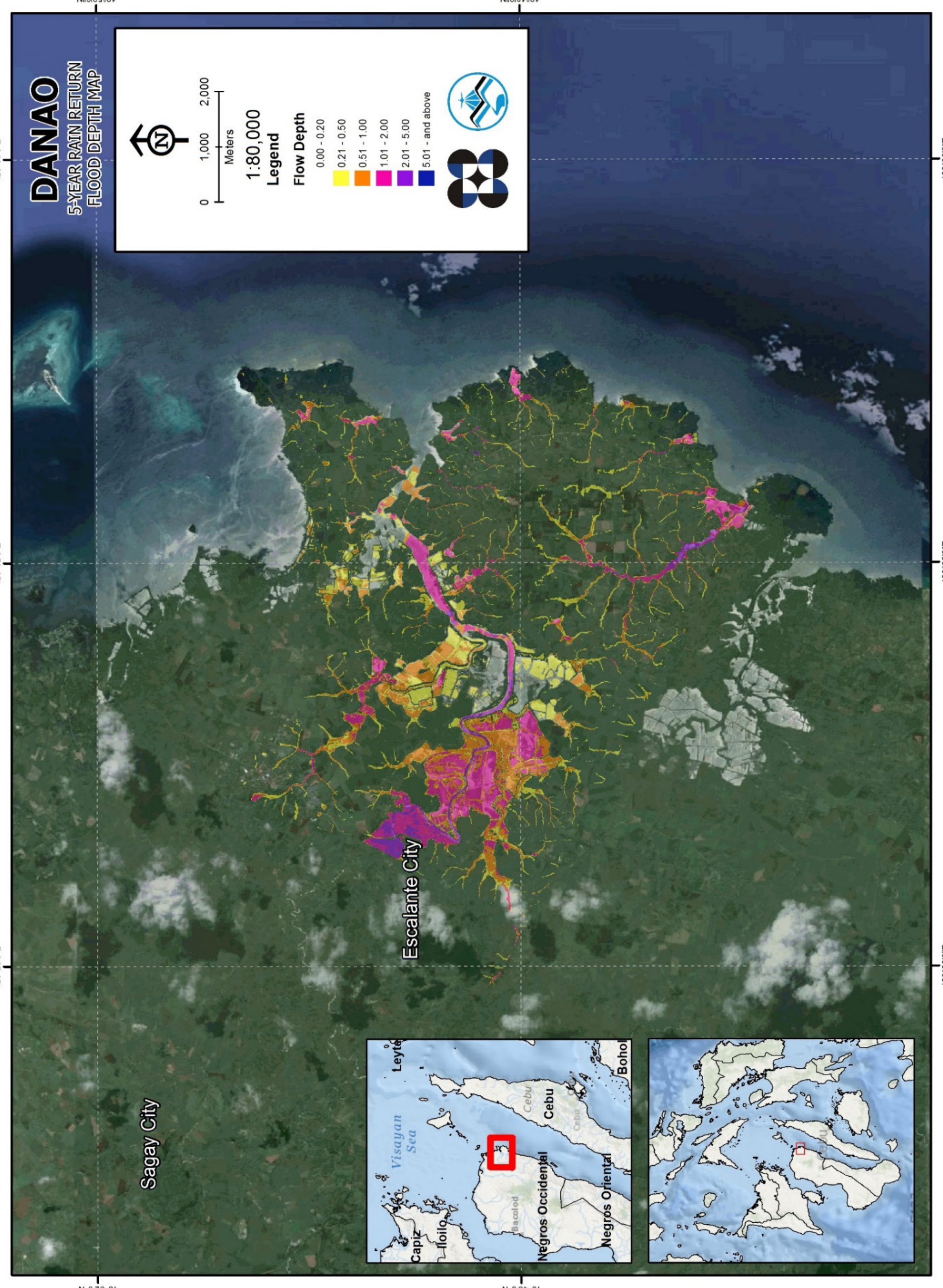


Figure 71. 5-year Flood Depth Map for Danao Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Danao river basin, grouped by municipality, are listed below. For the said basin, one city consisting of 12 barangays is expected to experience flooding when subjected to 5-yr rainfall return period.

For the 5-year return period, 23.46% of the city of Escalante with an area of 192.144 sq. km. will experience flood levels of less 0.20 meters. 2.12% of the area will experience flood levels of 0.21 to 0.50 meters while 1.87%, 1.56%, 0.30%, and 0.004% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 are the affected areas in square kilometres by flood depth per barangay.

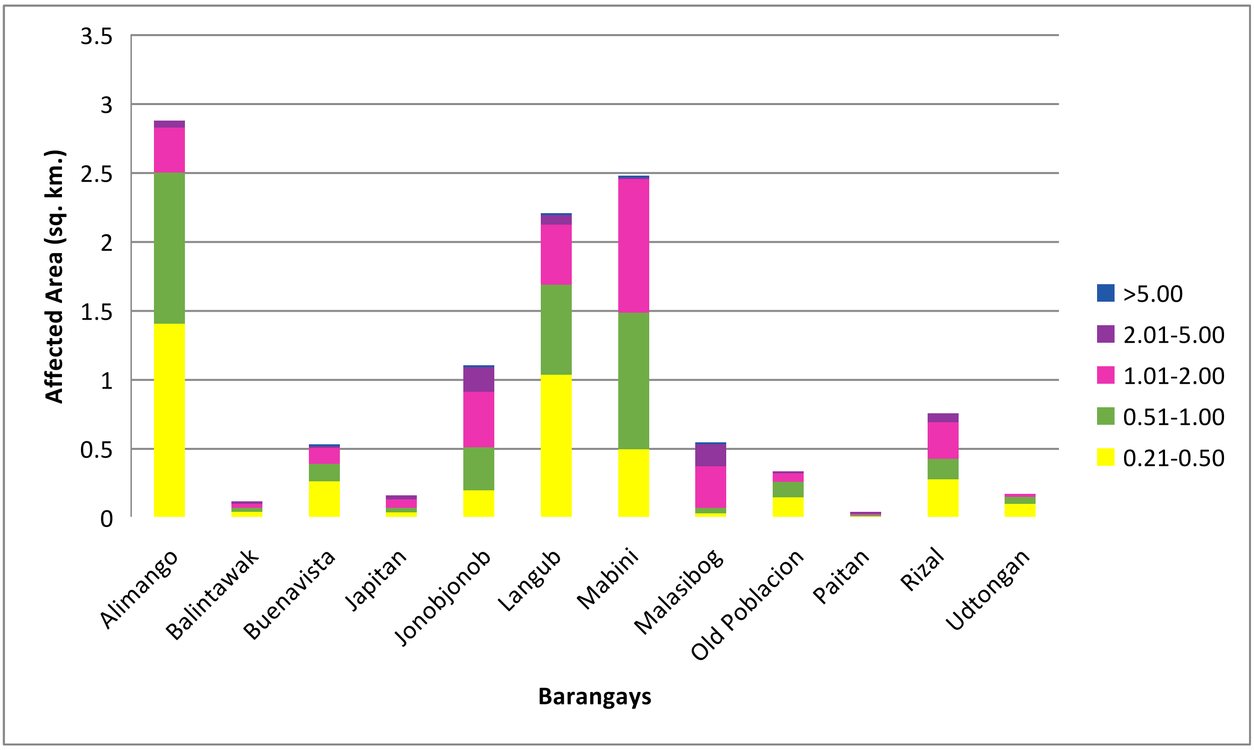


Figure 72. Affected Areas in Escalante City, Negros Occidental during 5-Year Rainfall Return Period

Table 37. Affected Areas in Escalante City, Negros Occidental during 5-Year Rainfall Return Period

Affected area (sq.km.)	Area of affected barangays in Dapitan City (in sq. km.)					
	Alimango	**Balintawak**	**Buenavista**	**Japitan**	**Jonobjonob**	**Langub**
0.03-0.20	9.05	0.86	6.56	0.65	2.81	8.29
0.21-0.50	1.41	0.044	0.27	0.042	0.2	1.04
0.51-1.00	1.1	0.031	0.13	0.034	0.31	0.65
1.01-2.00	0.33	0.03	0.12	0.06	0.41	0.44
2.01-5.00	0.048	0.0038	0.0086	0.026	0.18	0.07
> 5.00	0	0	0.0012	0	0.0027	0.0001

Affected area (sq.km.)	Area of affected barangays in Dapitan City (in sq. km.)					
	Mabini	**Malasibog**	**Old Poblacion**	**Paitan**	**Rizal**	**Udtongan**
0.03-0.20	4.64	0.59	4.16	0.41	5.25	1.81
0.21-0.50	0.5	0.035	0.15	0.014	0.28	0.1
0.51-1.00	0.99	0.037	0.11	0.0081	0.15	0.049
1.01-2.00	0.97	0.3	0.065	0.0098	0.27	0.01
2.01-5.00	0.014	0.16	0.0016	0.00039	0.063	0
> 5.00	0.0005	0.0024	0	0	0	0

For the 25-year return period, 21.81% of the city of Escalante with an area of 192.144 sq. km. will experience flood levels of less 0.20 meters. 1.75% of the area will experience flood levels of 0.21 to 0.50 meters while 1.94%, 3.04%, 0.75%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas in square kilometres by flood depth per barangay.

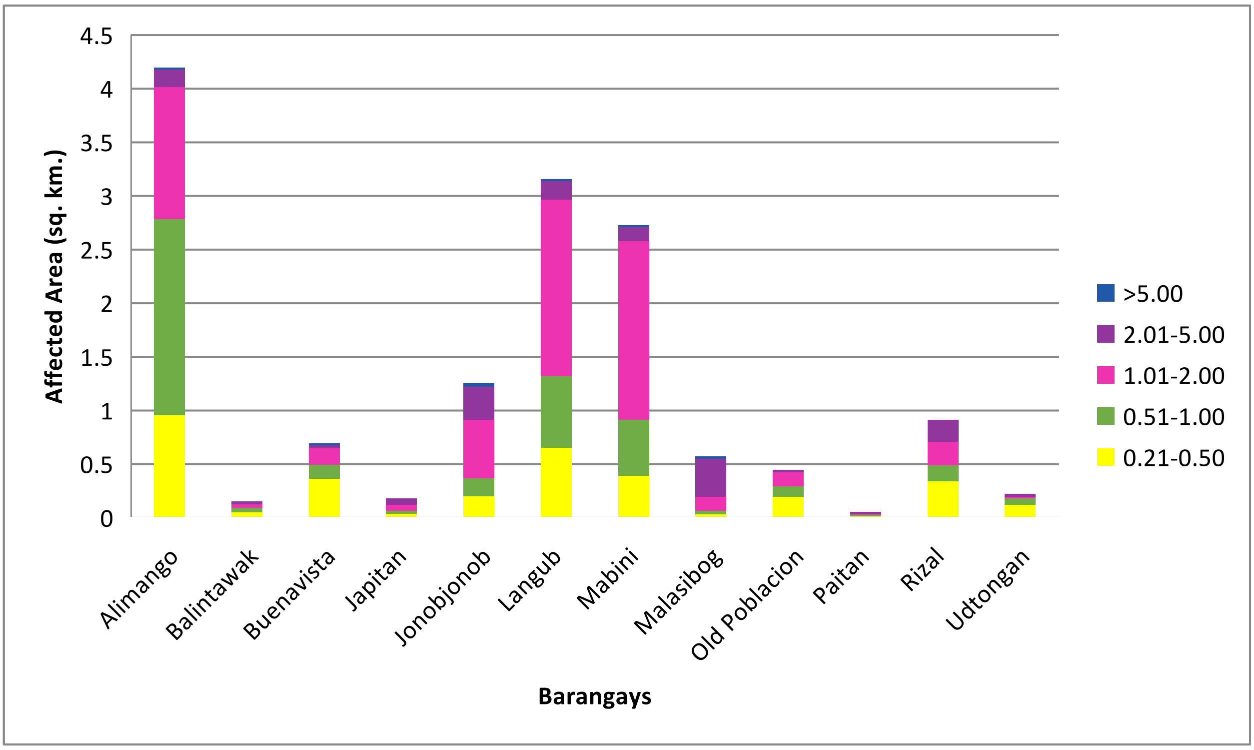


Figure 73. Affected Areas in Escalante City, Negros Occidental during 25-Year Rainfall Return Period

Table 38. Affected Areas in Escalante City, Negros Occidental during 25-Year Rainfall Return Period

Affected area (sq.km.)	Area of affected barangays in Dapitan City (in sq. km.)					
	Alimango	Balintawak	Buenavista	Japitan	Jonobjonob	Langub
0.03-0.20	7.74	0.83	6.4	0.63	2.67	7.35
0.21-0.50	0.95	0.05	0.37	0.037	0.2	0.65
0.51-1.00	1.83	0.042	0.13	0.028	0.17	0.67
1.01-2.00	1.23	0.037	0.16	0.056	0.55	1.65
2.01-5.00	0.16	0.012	0.027	0.059	0.31	0.17
> 5.00	0.018	0	0.0025	0	0.013	0.0006

Affected area (sq.km.)	Area of affected barangays in Dapitan City (in sq. km.)					
	Mabini	Malasibog	Old Poblacion	Paitan	Rizal	Udtongan
0.03-0.20	4.4	0.57	4.05	0.4	5.1	1.77
0.21-0.50	0.4	0.033	0.2	0.017	0.34	0.12
0.51-1.00	0.52	0.031	0.098	0.0092	0.15	0.059
1.01-2.00	1.66	0.13	0.13	0.012	0.22	0.015
2.01-5.00	0.14	0.35	0.0064	0.0025	0.2	0.0086
> 5.00	0.0014	0.0058	0	0	0	0

For the 100-year return period, 21.1% of the city of Escalante with an area of 192.144 sq. km. will experience flood levels of less 0.20 meters. 1.76% of the area will experience flood levels of 0.21 to 0.50 meters while 1.69%, 3.02%, 1.71%, and 0.04% 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 39 are the affected areas in square kilometres by flood depth per barangay.

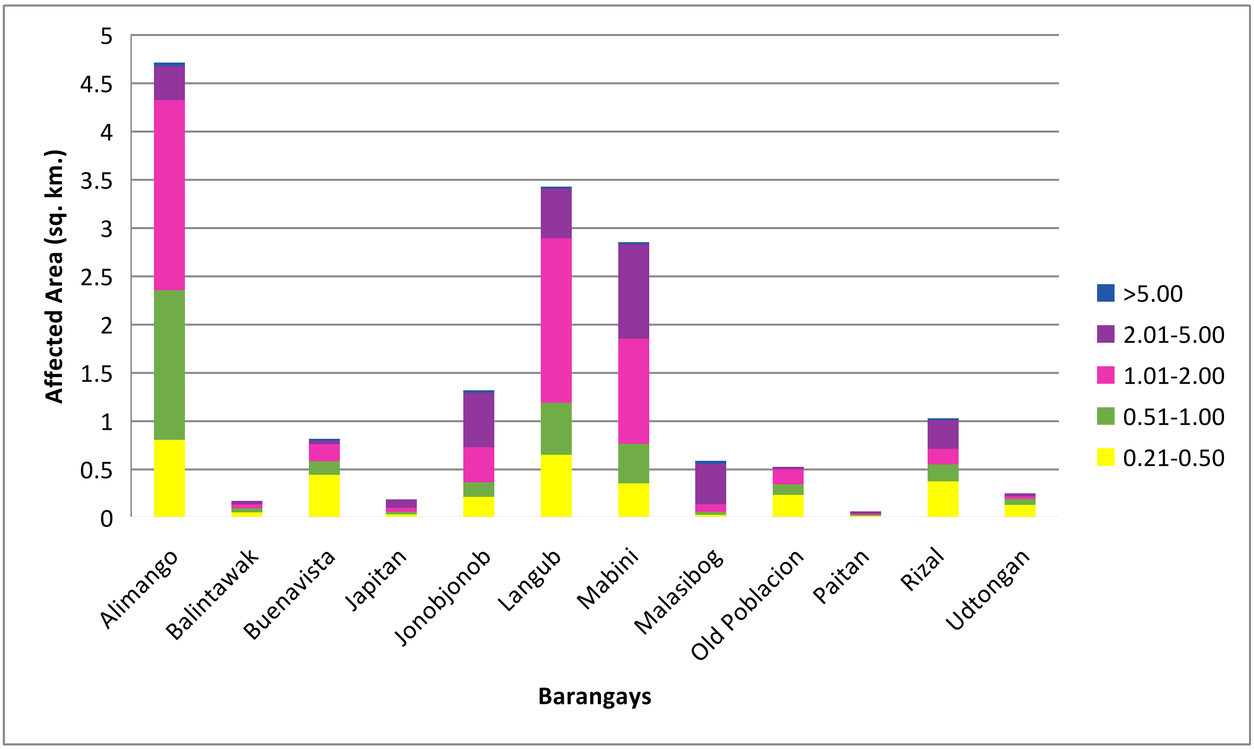


Figure 74. Affected Areas in Escalante City, Negros Occidental during 100-Year Rainfall Return Period

Table 39. Affected Areas in Escalante City, Negros Occidental during 100-Year Rainfall Return Period

Affected area (sq.km.)	Area of affected barangays in Dapitan City (in sq. km.)					
	Alimango	**Balintawak**	**Buenavista**	**Japitan**	**Jonobjonob**	**Langub**
0.03-0.20	7.22	0.81	6.27	0.62	2.59	7.08
0.21-0.50	0.81	0.056	0.44	0.037	0.22	0.65
0.51-1.00	1.54	0.044	0.14	0.026	0.15	0.54
1.01-2.00	1.97	0.042	0.17	0.039	0.36	1.71
2.01-5.00	0.35	0.016	0.041	0.087	0.56	0.51
> 5.00	0.035	0	0.0029	0	0.022	0.0034

Affected area (sq.km.)	Area of affected barangays in Dapitan City (in sq. km.)					
	Mabini	**Malasibog**	**Old Poblacion**	**Paitan**	**Rizal**	**Udtongan**
0.03-0.20	4.28	0.56	3.97	0.39	5	1.74
0.21-0.50	0.36	0.031	0.24	0.02	0.38	0.13
0.51-1.00	0.41	0.029	0.1	0.011	0.17	0.067
1.01-2.00	1.08	0.082	0.15	0.0085	0.16	0.023
2.01-5.00	0.98	0.42	0.0084	0.0086	0.29	0.013
> 5.00	0.0021	0.013	0	0	0.0004	0

Among the barangays in the city of Escalante, Alimango is projected to have the highest percentage of area that will experience flood levels at 6.21%. Meanwhile, Langub posted the second highest percentage of area that may be affected by flood depths at 5.46%.

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

Table 40. 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	4.29	3.51	3.50
Medium	6.24	7.05	6.27
High	1.48	4.83	7.03
TOTAL	**12.01**	**15.39**	**16.8**

Of the 39 identified education institutions in the Danao floodplain, 2 schools were assessed to be exposed to the Low-level flooding during a 5-year scenario. In the 25-year scenario, 6 schools were assessed to be exposed to the Low-level flooding. For the 100-year scenario, 7 schools were assessed to be exposed to the High-level flooding.

Lastly, no medical or health institutions were assessed to be exposed to all flooding scenarios.

5.11 Flood Validation

In order to check and validate the extent of flooding in different river systems, there is a need to perform validation survey work. Field personnel gather secondary data regarding flood occurrence in the area within the major river system in the Philippines.

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

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

The flood validation points were obtained on November 6, 2015. The actual data from the field were compared to the simulated data to assess the accuracy of the Flood Depth Maps produced and to improve on the results of the flood map. The points in the flood map versus its corresponding validation depths are shown in Figure 75.

The flood validation consists of 203 points randomly selected all over Danao flood plain. Comparing it with the flood depth map of the nearest storm event, the map has an RMSE value of 0.78m. Table 41 shows a contingency matrix of the comparison.

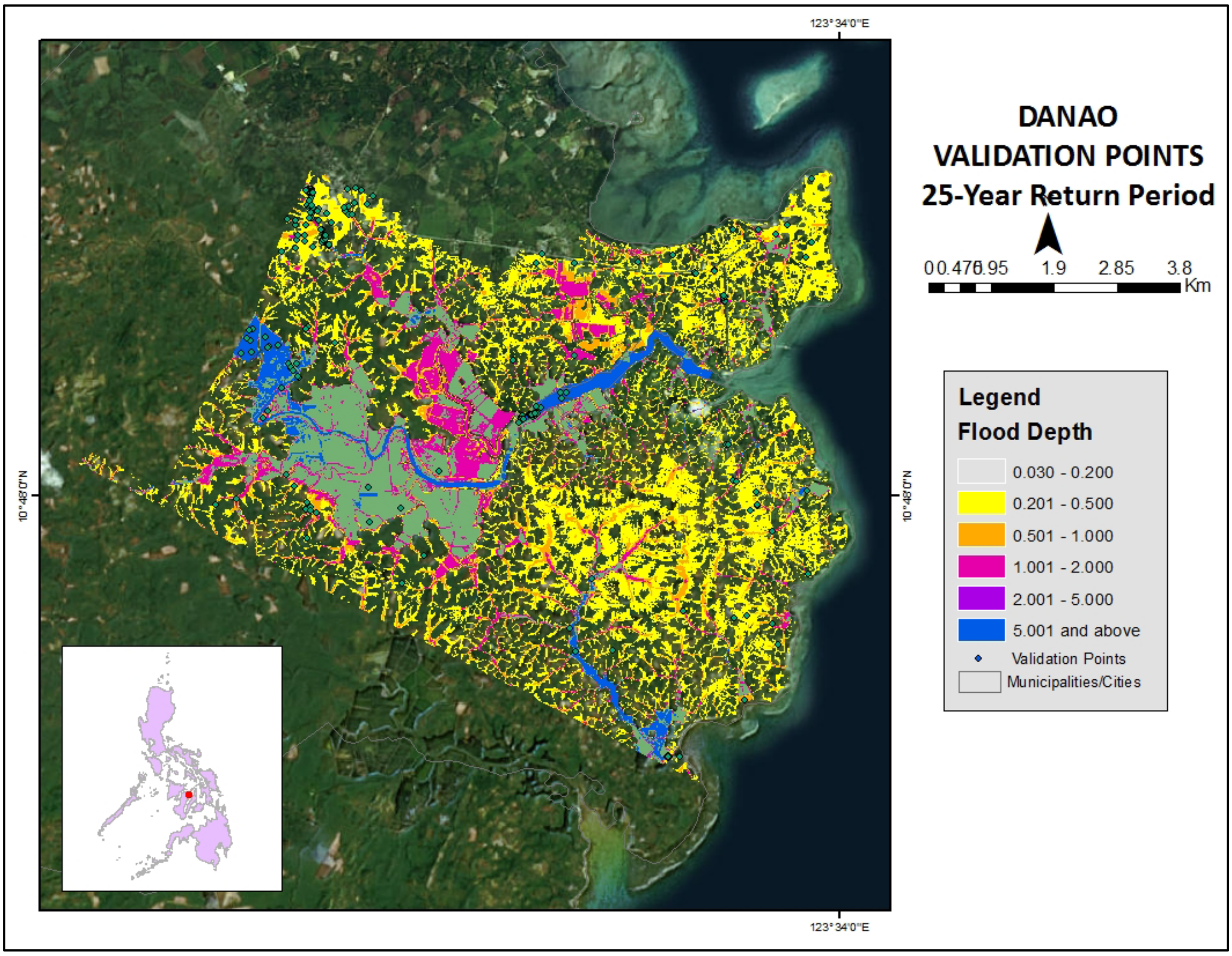


Figure 75. Validation points for 25-year Flood Depth Map of Danao Floodplain

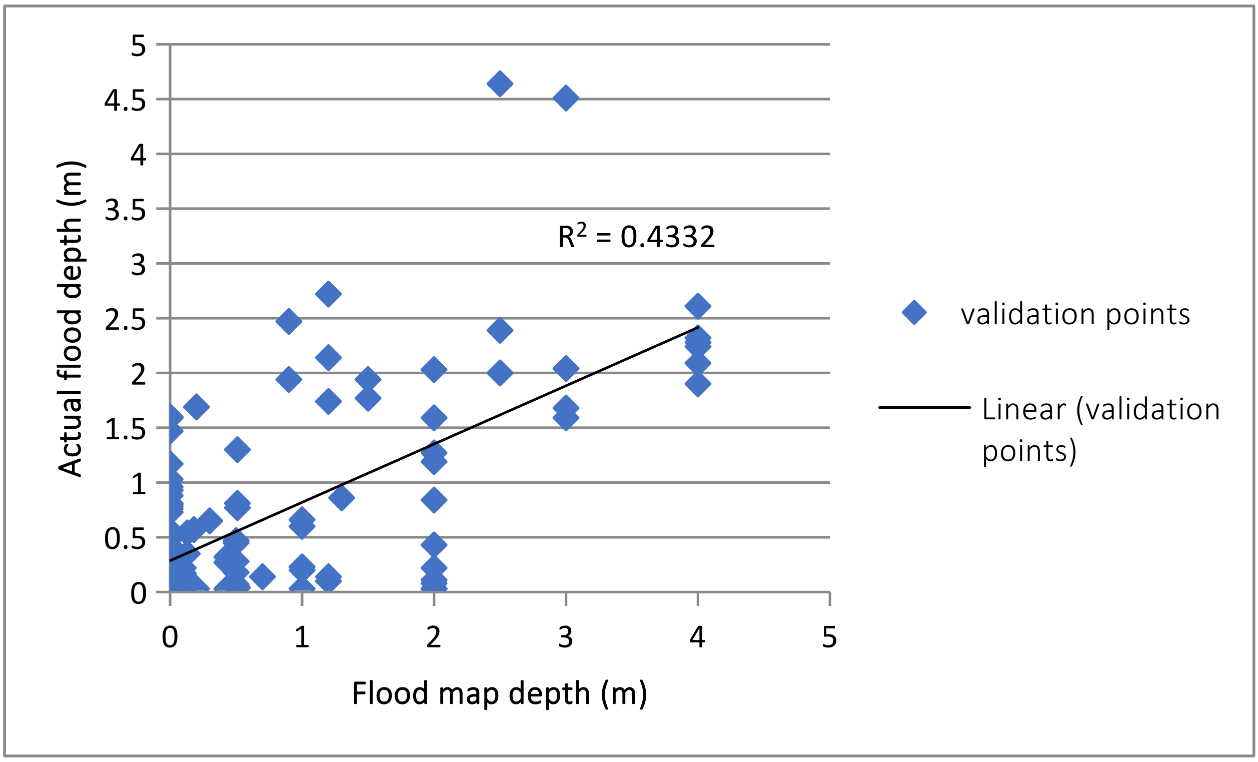


Figure 76. Flood map depth vs actual flood depth

Table 41. Actual Flood Depth vs Simulated Flood Depth at different levels in the Danao River Basin

Actual Flood Depth (m)	Modeled Flood Depth (m)						
	0-0.20	**0.21-0.50**	**0.51-1.00**	**1.01-2.00**	**2.01-5.00**	**> 5.00**	**Total**
0-0.20	64	12	13	6	1	0	96
0.21-0.50	9	5	1	0	0	0	15
0.51-1.00	4	1	4	2	1	1	13
1.01-2.00	15	2	2	6	4	0	29
2.01-5.00	24	1	3	11	9	0	48
> 5.00	0	0	0	1	1	0	2
Total	116	21	23	26	16	1	203

The overall accuracy generated by the flood model is estimated at 43.35%, with 88 points correctly matching the actual flood depths. In addition, there were 43 points estimated one level above and below the correct flood depths while there were 24 points and 23 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 68 points were overestimated while a total of 69 points were underestimated in the modelled flood depths of Danao. Table 42 depicts the summary of the Accuracy Assessment in the Danao River Basin Survey.

Table 42. Summary of Accuracy Assessment in Danao River Basin Survey

	No. of Points	**%**
Correct	88	43.35
Overestimated	41	20.20
Underestimated	74	36.45
Total	203	100

REFERENCES

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

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

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

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

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

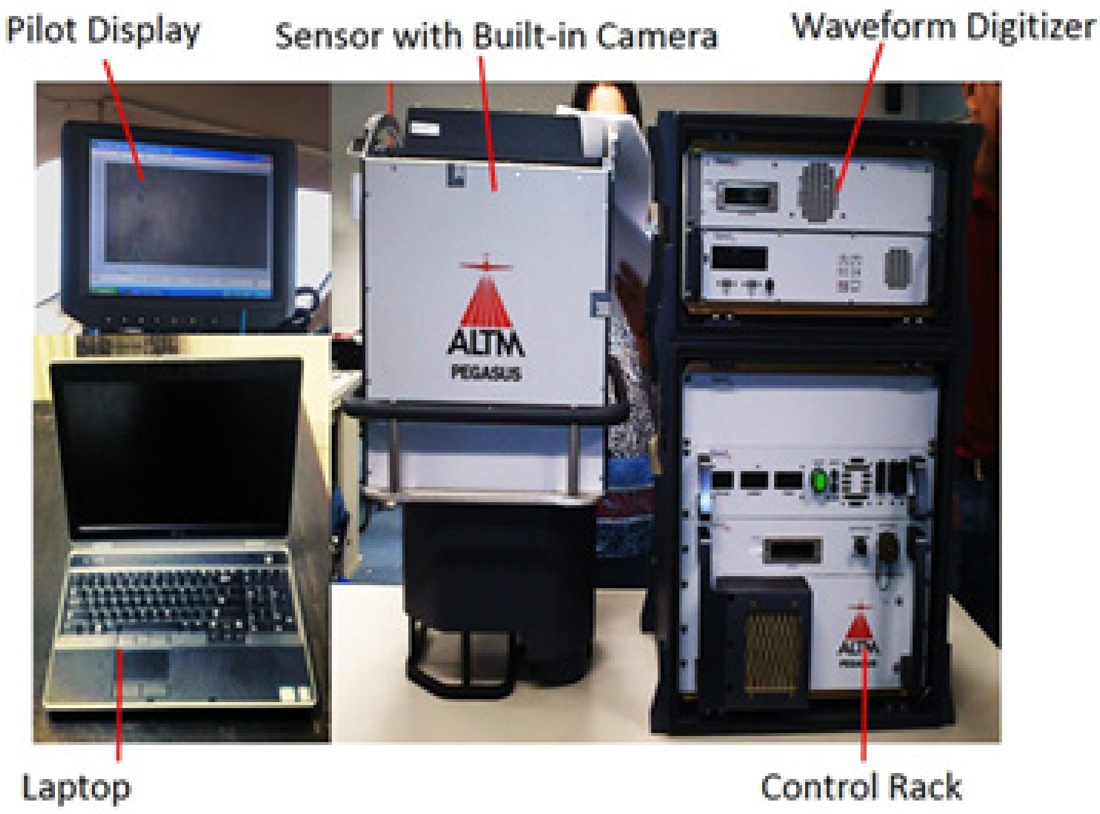
Sarmiento C., Paringit E.C., et al. 2014. DREAM Data Acquisition Component Manual. Quezon City, Philippines: UP Training Center for Applied Geodesy and Photogrammetry.

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

ANNEXES

Annex 1. Technical Specification of the LiDAR Sensor used in the Danao Floodplain Survey

1. GEMINI SENSOR



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

OPTECH TECHNICAL SPECIFICATION OF THE D-8900 AERIAL DIGITAL CAMERA

Parameter	Specification
Camera Head	
Sensor type	60 Mpix full frame CCD, RGB
Sensor format (H x V)	8, 984 x 6, 732 pixels
Pixel size	6µm x 6 µm
Frame rate	1 frame/2 sec.
FMC	Electro-mechanical, driven by piezo technology (patented)
Shutter	Electro-mechanical iris mechanism 1/125 to 1/500++ sec. f-stops: 5.6, 8, 11, 16
Lenses	50 mm/70 mm/120 mm/210 mm
Filter	Color and near-infrared removable filters
Dimensions (H x W x D)	200 x 150 x 120 mm (70 mm lens)
Weight	~4.5 kg (70 mm lens)
Controller Unit	
Computer	Mini-ITX RoHS-compliant small-form-factor embedded
	computers with AMD TurionTM 64 X2 CPU
	4 GB RAM, 4 GB flash disk local storage
	IEEE 1394 Firewire interface
Removable storage unit	~500 GB solid state drives, 8,000 images
Power consumption	~8 A, 168 W
Dimensions	2U full rack; 88 x 448 x 493 mm
Weight	~15 kg
Image Pre-Processing Software	
Capture One	Radiometric control and format conversion, TIFF or JPEG
Image output	8,984 x 6,732 pixels
	8 or 16 bits per channel (180 MB or 360 MB per image)

2. AQUARIUS SENSOR

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

ITRES TECHNICAL SPECIFICATIONS OF CASI

Sensor Type	
VNIR Push-broom Sensor	
(Compact Airborne Spectrographic Imager)	
Performance	
Spectral Range (Continuous Coverage)	380-1050 nm
# Spectral Channels	Up to 288
#Across-Track Pixels	1500
Total Field of View	40 deg
IFOV	0.49 mRad
t/#	t/3.5
Spectral Width Sampling Row	2.4 nm
Spectral Resolution (FWHM)	<3.5 nm
Pixel Size	20x20 microns
Dynamic Range	14-bits (16384:1)
Sustained Date Rate (Mpix/Second)	9.6 Mpix/Sec
Spectral Smile/Keystone Distortion	±0.35 pixels
Peak Signal Noise Ration	SNR models for various radiance conditions are available
Relative humidity	0-95% no-condensing

Annex 2. NAMRIA Certificates of Reference Points Used

1. NGW-50

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

May 09, 2014

CERTIFICATION

To whom it may concern:

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

Province: **NEGROS OCCIDENTAL**
Station Name: **NGW-50**
Order: **2nd**

Island: **VISAYAS**
Municipality: **SAGAY**
Barangay: **FABRICA**

PRS92 Coordinates

Latitude: **10° 53' 26.84456"** Longitude: **123° 21' 6.66799"** Ellipsoidal Hgt: **15.38600 m.**

WGS84 Coordinates

Latitude: **10° 53' 22.52478"** Longitude: **123° 21' 11.86863"** Ellipsoidal Hgt: **74.42200 m.**

PTM Coordinates

Northing: **1204272.594 m.** Easting: **538465.927 m.** Zone: **4**

UTM Coordinates

Northing: **1,203,851.08** Easting: **538,452.46** Zone: **51**

Location Description

NGW-50
The station is on the NW sidewalk of Himoga-an bridge at km. 73+545 along the Sagay-Bacolod national highway. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on top of the concrete sidewalk with inscriptions "NGW-50; 2007; NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8796117 A**
T.N.: **2014-1064**

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

9905092014100502

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

2. NGW-58

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

May 09, 2014

CERTIFICATION

To whom it may concern:

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

Province: **NEGROS OCCIDENTAL**
Station Name: **NGW-58**
Order: **2nd**

Island: **VISAYAS**
Municipality: **ESCALANTE**
Barangay: **ONOBONOB, SITIO LABARCA**

	PRS92 Coordinates	
Latitude: **10° 49' 16.43235"**	Longitude: **123° 29' 11.51295"**	Ellipsoidal Hgt: **8.72200 m.**
	WGS84 Coordinates	
Latitude: **10° 49' 12.14178"**	Longitude: **123° 29' 16.71871"**	Ellipsoidal Hgt: **68.25600 m.**
	PTM Coordinates	
Northing: **1196599.363 m.**	Easting: **553202.195 m.**	Zone: **4**
	UTM Coordinates	
Northing: **1,196,180.53**	Easting: **553,183.57**	Zone: **51**

Location Description

NGW-58
The station is on the NE sidewalk of Danao bridge. It is about 2.4 km. from Escalante City proper. Mark is the head of a 4" copper nail flushed at the center of an existing benchmark embedded on the concrete sidewalk with inscriptions "NW-100; 2007; NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8796117 A**
T.N.: **2014-1066**

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

9 9 0 5 0 9 2 0 1 4 1 0 0 6 0 6

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

3. NGW-63

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

May 09, 2014

CERTIFICATION

To whom it may concern:

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

Province: **NEGROS OCCIDENTAL**
Station Name: **NGW-63**
Order: **2nd**

Island: **VISAYAS**
Municipality: **CALATRAVA**
Barangay: **LEMERY**

PRS92 Coordinates

Latitude: **10° 38' 30.18023"**	Longitude: **123° 29' 18.57332"**	Ellipsoidal Hgt: **10.15500 m.**

WGS84 Coordinates

Latitude: **10° 38' 25.93535"**	Longitude: **123° 29' 23.79491"**	Ellipsoidal Hgt: **70.11800 m.**

PTM Coordinates

Northing: **1176744.618 m.**	Easting: **553448.18 m.**	Zone: **4**

UTM Coordinates

Northing: **1,176,332.74**	Easting: **553,429.47**	Zone: **51**

Location Description

NGW-63
The station is on the NE end of the sidewalk. It is located at Daan-Lunsod bridge at km.124+077 along San Carlos-Bacolod national highway. The station is about 10.1 km. from Calatrava town proper. Mark is the head of a 4" copper nail drilled and grouted at the center of a 30 x 30 cm. cement putty embedded on top of the concrete sidewalk with inscriptions "NGW-63; 2007; NAMRIA".

Requesting Party: **UP DREAM**
Pupose: **Reference**
OR Number: **8796117 A**
T.N.: **2014-1067**

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

9905092014100625

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

Annex 3. Baseline Processing Report of Reference Points Used

Project information		Coordinate System	
Name:	C:\Users\Windows User\Documents \Business Center - HCE\NW-123.vce	Name:	UTM
Size:	752 KB	Datum:	PRS 92
Modified:	4/22/2016 8:06:07 PM (UTC:8)	Zone:	51 North (123E)
Time zone:	China 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)
NGW-50 --- NW-123 (B1)	NGW-50	NW-123	Fixed	0.021	0.057	315°55'13"	3789.388	13.992
NGW-50 --- NW-123 (B2)	NGW-50	NW-123	Fixed	0.019	0.064	315°55'14"	3789.385	14.045

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

NGW-50 - NW-123 (8:46:55 AM-2:12:55 PM) (S1)

Baseline observation:	NGW-50 --- NW-123 (B1)
Processed:	4/22/2016 8:33:29 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.021 m
Vertical precision:	0.057 m
RMS:	0.008 m
Maximum PDOP:	4.126
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	4/22/2016 8:46:55 AM (Local: UTC+8hr)
Processing stop time:	4/22/2016 2:12:55 PM (Local: UTC+8hr)
Processing duration:	05:26:00
Processing interval:	1 second

Annex 4.The LiDAR Survey Team Composition

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

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
		CHRISTOPHER JOAQUIN	UP-TCAGP
	Research Associate (RA)	DC ALDOVINO	UP-TCAGP
		RENAN PUNTO	
		MA. VERLINA TONGA,	
		JONALYN GONZALES	
Ground Survey, Data Download and Transfer	RA	LANCE CINCO	UP-TCAGP
		KENNETH QUISADO	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
		SSG. LEE JAY PUNZALAN	
	Pilot	CAPT. JEFFREY JEREMY ALAJAR;	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. RANDY LAGCO	AAC
		CAPT. BRYAN DONGUINES	AAC
		CAPT. JERICHO JECIEL	AAC

Annex 5. Data Transfer Sheet for Danao Floodplain

DATA TRANSFER SHEET
5/19/2014(Bacolod Ready)

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	
4/29/2014	1403P	1BLK44DE119A	PEGASUS	2.89GB	2078KB	13.3	550	54.5	431	57.1	NA	7.14MB	1KB	1KB	92/75/52/56	NA	Z:\Airborne_Raw\1403P
5/1/2014	1411P	1BLK44D121A	PEGASUS	NA	88KB	10.9	221	31.5	264	26.5	NA	6.74MB	1KB	1KB	82/69/56	NA	Z:\Airborne_Raw\1411P
5/2/2014	1415P	1BLK44H122A	PEGASUS	3.27GB	2121KB	14.1	266	40.3	346	32.8	NA	7.32MB	1KB	1KB	37/38/46	NA	Z:\Airborne_Raw\1415P
5/5/2014	1427P	1BLK45E125A	PEGASUS	2.73GB	661KB	10.6	219	NA	NA	25.7	NA	6.12	1KB	1KB	30.9	NA	Z:\Airborne_Raw\1427P
5/6/2014	1431P	1BLK44GHS126A	PEGASUS	3.11	1612KB	13	254	51.3	370	29.2	NA	14.4	1KB	1KB	144/137/110	NA	Z:\Airborne_Raw\1431P
5/6/2014	1433P	1BLK44FGS126B	PEGASUS	3.04	1652	12.8	271	59	495	27.8	NA	14.4	1KB	1KB	144/137/110	NA	Z:\Airborne_Raw\1433P
5/7/2014	1435P	1BLK44DS127A	PEGASUS	2.94	712	14	285	NA	NA	19.6	NA	7.14	1KB	1KB	114	NA	Z:\Airborne_Raw\1435P
5/10/2014	1447P	1BLK45FG130A	PEGASUS	3.45	1382	14.4	294	NA	NA	32.3	NA	6.21	1KB	1KB	43	NA	Z:\Airborne_Raw\1447P
5/11/2014	1451P	1BLK45S132A	PEGASUS	2.42	500	11.5	243	NA	NA	27.2	NA	11.4	1KB	1KB	53	NA	Z:\Airborne_Raw\1451P
5/11/2014	1453P	1BLK45DFGS133A	PEGASUS	1.6	581	7.34	170	21.5	171	16.6	NA	11.4	1KB	1KB	49.3	NA	Z:\Airborne_Raw\1453P
5/12/2014	1455P	1IHLS134A	PEGASUS	3.05	530	13.2	298	NA	NA	26.3	NA	8.9	1KB	1KB	81/82/33/23	NA	Z:\Airborne_Raw\1455P
5/13/2014	1459P	1IHLS136A	PEGASUS	3.23	577	14.6	287	NA	NA	31.1	NA	7.18	1KB	1KB	88	NA	Z:\Airborne_Raw\1459P
5/14/2014	1463P	1IHLX137A	PEGASUS	782MB	249	5.69	148	NA	NA	8.26	NA	6.42	1KB	1KB	119	NA	Z:\Airborne_Raw\1463P

Received from
Name C - Jokorome
Position PA
Signature [signature]

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature [signature] 5/26/2014

DATA TRANSFER SHEET
BACOLOD 5/18/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	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	
April 22,2016	8453AC	3BLK44AS113A	AQUA/CASI	NA	343	769	246	NA	NA	13.9	101	99.1	1KB	1KB	6	14	Z:\DAC\RAW DATA
April 23,2016	8455AC	3BLK44AS114A	AQUA/CASI	NA	247	663	233	38.5	43	10.2	85.3	91	1KB	1KB	20	30	Z:\DAC\RAW DATA
April 24,2016	8457AC	3BLK44EDS115A	AQUA/CASI	NA	197	544	222	39.6	221	8.64	66.9	94	1KB	1KB	40	22	Z:\DAC\RAW DATA
April 25,2016	8459AC	3BLK44US116A	AQUA/CASI	NA	240	603	262	43.4	248	10.3	66.5	100	1KB	1KB	18	38	Z:\DAC\RAW DATA
April 26,2016	8462AC	3BLK46AS117B	AQUA/CASI	NA	194	502	229	37.4	187	8.59	67.4	107	1KB	1KB	8	20	Z:\DAC\RAW DATA
April 27,2016	8464AC	3BLK46AS118B	AQUA/CASI	NA	81	209	143	9.78	3.23	4	23.9	158	1KB	1KB	8	20	Z:\DAC\RAW DATA
May 1,2016	8471AC	3BLK44FGHS122A	AQUA/CASI	NA	191	541	241	45.3	263	8.33	139	90.5	1KB	1KB	10	22	Z:\DAC\RAW DATA
May 2,2016	8473AC	3BLK46AS123A	AQUA/CASI	NA	88	320	206	5.45	3.7	4.59	55.3	64.6	1KB	NA	16	22	Z:\DAC\RAW DATA

Received from

Name R. PUNTO
Position RA
Signature [signature]

Received by

Name AC Bongat
Position SSRS
Signature [signature] 5/20/16

Annex 6. Flight logs for the flight missions

1. Flight Log for 1441P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1411P

1 LiDAR Operator: D. Aldovino	2 ALTM Model: Pegasus	3 Mission Name: 1BLK44D121A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Donguines	9 Route: Bacolod			
10 Date: May 1, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 1505 H	14 Engine Off: 1852 H	15 Total Engine Time: 3+47	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					

20 Remarks:

Mission successful at 1200 m ; surveyed BLK 44D and parts of BLK 44E

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
J. Alajar	Dave Gumban	J J Alajar	D. Aldovino
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

2. Flight Log for 1415P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1415P

1 LiDAR Operator: R. Punto	2 ALTM Model: Pegasus	3 Mission Name: 1BLK44H124A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. Alajar	8 Co-Pilot: B. Donguines	9 Route: Bacolod			
10 Date: May 2, 2014	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 1446H	14 Engine Off: 1909H	15 Total Engine Time: 4+23	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: Partly cloudy					

20 Remarks:

Mission successful at 1200m; surveyed BLK44H; gap in the middle

21 Problems and Solutions:

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

DREAM
Disaster Risk and Exposure Assessment for Mitigation

3. Flight Log for 1431P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1431P

1 LiDAR Operator: D. ALDOVINO	2 ALTM Model: PEGASUS	3 Mission Name: 1BLK44G	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. ALAJAR	8 Co-Pilot: B. DONGUINES	9 Route: NEGROS OCC.			
10 Date: MAY 6, 2014	12 Airport of Departure (Airport, City/Province): BACOLOD		12 Airport of Arrival (Airport, City/Province): BACOLOD		
13 Engine On: 8+10	14 Engine Off: 12+51	15 Total Engine Time: 4+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: very cloudy					
20 Remarks: Mission successful @ 800 m; filled gaps in BLK44H + BLK44G					

21 Problems and Solutions:

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

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

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

Lidar Operator
DAN ALDOVINO
Signature over Printed Name

4. Flight Log for 1433P Mission

DREAM Data Acquisition Flight Log — Flight Log No.: 1433P

1 LiDAR Operator: R. PUNTO	2 ALTM Model: PEGASUS	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. ALAJAR	8 Co-Pilot: B. [illegible]	9 Route: NEGROS OCC.			
10 Date: MAY 6, 2014	12 Airport of Departure (Airport, City/Province): BACOLOD		12 Airport of Arrival (Airport, City/Province): BACOLOD		
13 Engine On: 14+4	14 Engine Off: 18+33	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: very cloudy					
20 Remarks: Mission successful @ 800 m ; gaps due to diminished overlap, high terrain, low cloud ceiling					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	Dave Gamban	J. ALAJAR	R. PUNTO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

5. Flight log for 1435P Mission

DREAM Data Acquisition Flight Log

Flight Log No.: 1435P

1 LiDAR Operator: D. ALDOVINO	2 ALTM Model: PEGASUS	3 Mission Name: [illegible]	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: J. ALAJAR	8 Co-Pilot: B. DONGUINES	9 Route: NEGROS OCCIDENTAL			
10 Date: MAY 7, 2014	12 Airport of Departure (Airport, City/Province): BACOLOD		12 Airport of Arrival (Airport, City/Province): BACOLOD		
13 Engine On: 13+7	14 Engine Off: 18+0	15 Total Engine Time: 4+53	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	partly cloudy				
20 Remarks:	Mission successful in BLK44D @ 1200m + filled up gaps in BLK44 @ 800m				

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Jasmine Alviar	Dave Dumban	J. ALAJAR	DAN ALDOVINO
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

6. Flight Log for 8453AC Mission

DREAM Program's Data Acquisition Flight Log

Flight Log No.: 8453

1 LIDAR Operator: JW Tonga	2 ALTM Model: Aq. (CAS)	3 Mission Name: 3BLK44A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Leojo	8 Co-Pilot: Jeciel	9 Route:			
10 Date: April 22, 2016	12 Airport of Departure (Airport, City/Province): Bacolod		12 Airport of Arrival (Airport, City/Province): Bacolod		
13 Engine On: 9:40	14 Engine Off: 13:51	15 Total Engine Time: 4+11	16 Take off: 9:45	17 Landing: 13:46	18 Total Flight Time: 4+01
19 Weather: partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Covered parts of BLK44AS

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
Chris Sanchez	Lee Jay E. Punzalan	[signature]	Ro Vryann T. Bage	
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

7. Flight Log for 8455AC Mission


DREAM Program's Data Acquisition Flight Log

Flight Log No.: 8455

1 LiDAR Operator: J. Gonzales	2 ALTM Model: Aqua 1CAS	3 Mission Name: 2BLK44A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9322
7 Pilot: Laguio	8 Co-Pilot: Ruiz	9 Route:			
10 Date: April 23, 2016	12 Airport of Departure (Airport, City/Province): Bacolod-Silay		12 Airport of Arrival (Airport, City/Province): Bacolod-Silay		
13 Engine On: 1020	14 Engine Off: 1413	15 Total Engine Time: 3153	16 Take off: 1025	17 Landing: 1408	18 Total Flight Time: 3143
19 Weather: fair					

20 Flight Classification

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

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

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

21 Remarks

Completed BLK 44A and some voids

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

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

Acquisition Flight Certified by: LEE JAY A. PUNZALAN, Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

Lidar Operator: Signature over Printed Name

Aircraft Mechanic/ Technician: Signature over Printed Name

8. Flight Log for 8459AC Mission


DREAM Program's Data Acquisition Flight Log

Flight Log No.: 8459

1 LIDAR Operator: J. Gonzales	2 ALTM Model: Aqua 10AS	3 Mission Name: 3BLK49S116A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Hugo	8 Co-Pilot: Jeziel	9 Route:			
10 Date: April 25, 2016	12 Airport of Departure (Airport, City/Province): Bancalod - Silay		12 Airport of Arrival (Airport, City/Province): Bacolod - Silay		
13 Engine On: 1040	14 Engine Off: 1457	15 Total Engine Time: 4+17	16 Take off: 1045	17 Landing: 1452	18 Total Flight Time: 4+07
19 Weather: fair					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK49IS and BLK49JS

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

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

Acquisition Flight Certified by: LEE JAY E. PUNZALAN Signature over Printed Name (PAF Representative)

Pilot-in-Command: [signature] Signature over Printed Name

Lidar Operator: JONATHAN E. GONZALES Signature over Printed Name

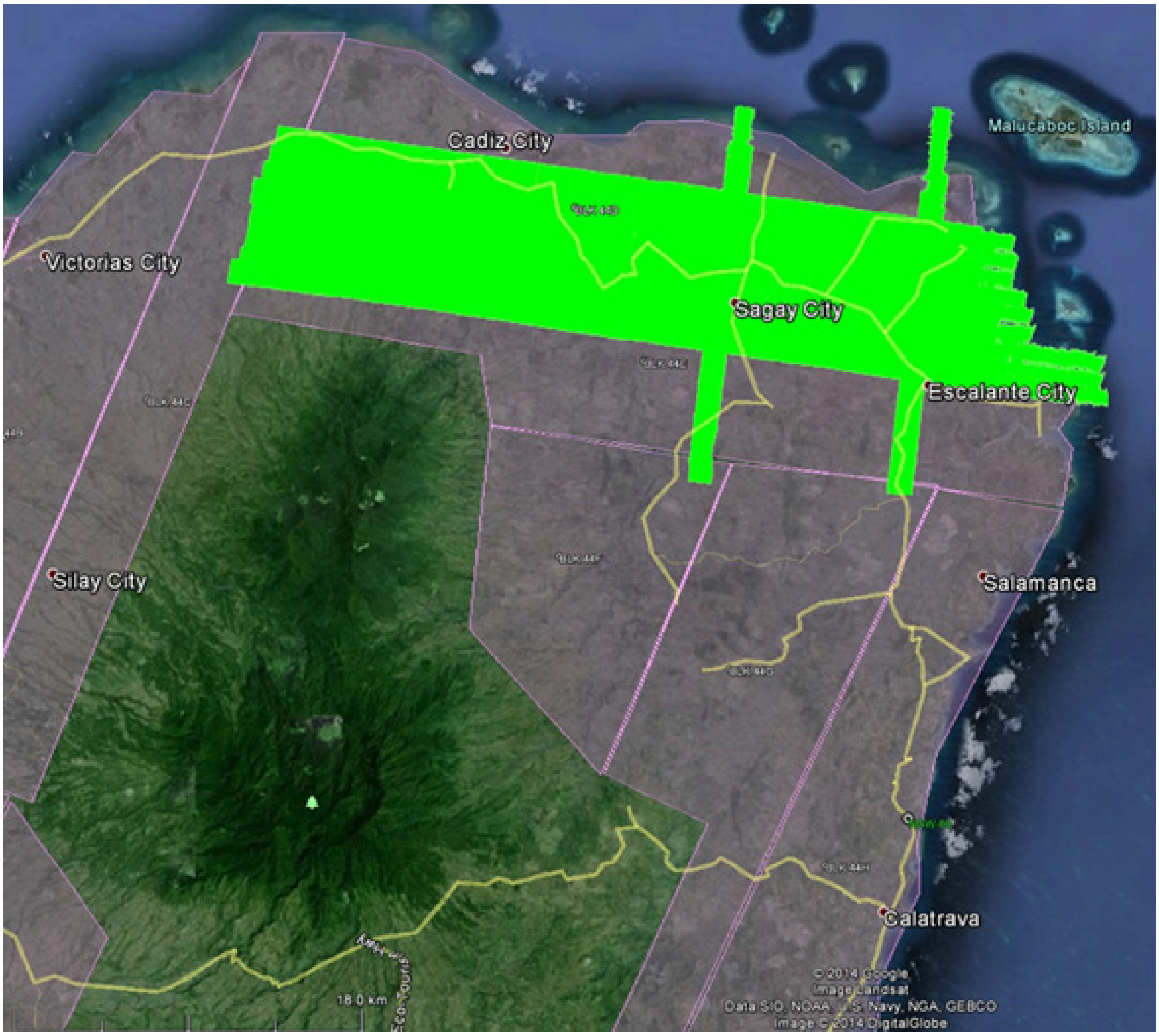
Aircraft Mechanic/ Technician: Signature over Printed Name

Annex 7. Flight Status

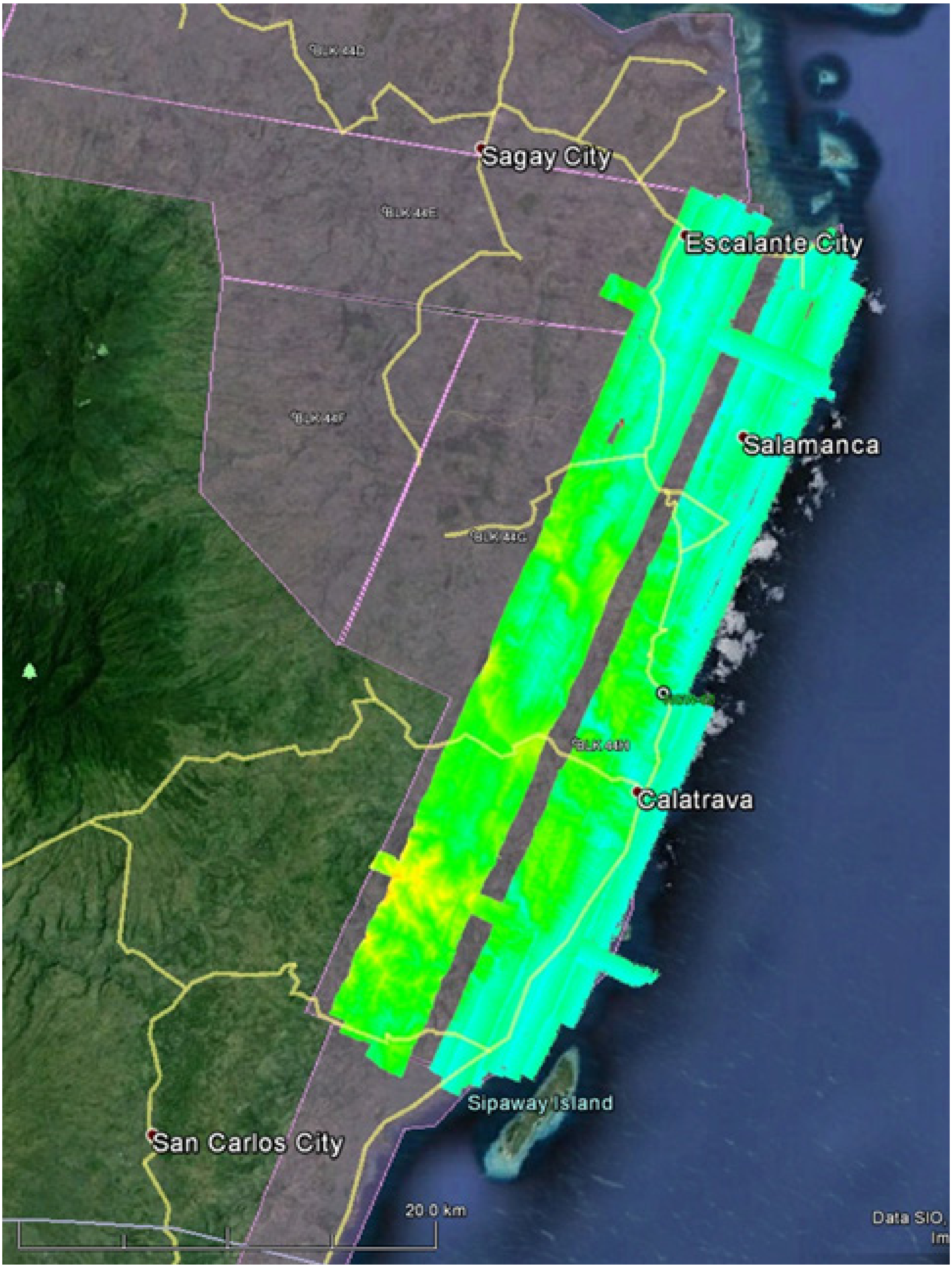
FLIGHT STATUS REPORT
DANAO
April to May 2014 and 2016

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1411P	BLK 44DE	1BLK44D121A	D. Aldovino	May 1, 2014	Mission successful at 1200m; surveyed BLK 44D and parts of BLK 44E
1415P	BLK 44H	1BLK44H122A	R. Punto	May 2, 2014	Mission successful at 1200m; 2-3 lines gap in the middle
1431P	BLK 44G, BLK 44H, BLK 44F	1BLK44GHS126A	D. Aldovino	May 6, 2014	Mission successful at 800m; filled gaps in BLK 44H and BLK 44G and some parts of BLK 44F
1433P	BLK 44G, BLK 44F	1BLK44FGS126B	R. Punto	May 6, 2014	Mission successful at 800m; filled gaps in BLK 44H; gaps due to diminished overlap (high terrain, low cloud ceiling)
1435P	BLK 44D, 44E, 44F, 44G	1BLk44DS127A	D. Aldovino	May 7, 2014	Mission successful in BLK 44D at 1200m and filled up gaps in BLK 44 at 800m.
8453AC	BLK44As Danao, Himogaan FP	3BLK44AS113A	V. TONGA	APR 22, 2016	SURVEYED PARTS OF BLK44AS
8455AC	BLK44As Danao, Himogaan FP	3BLK44As114A	J. GONZALES	APR 23, 2016	SURVEYED REST OF BLK44AS
8459AC	BLK44IS, BLK44JS	3BLK44IJS116A	J. GONZALES	APR 25	SURVEYED BLK44IS AND BLK44JS

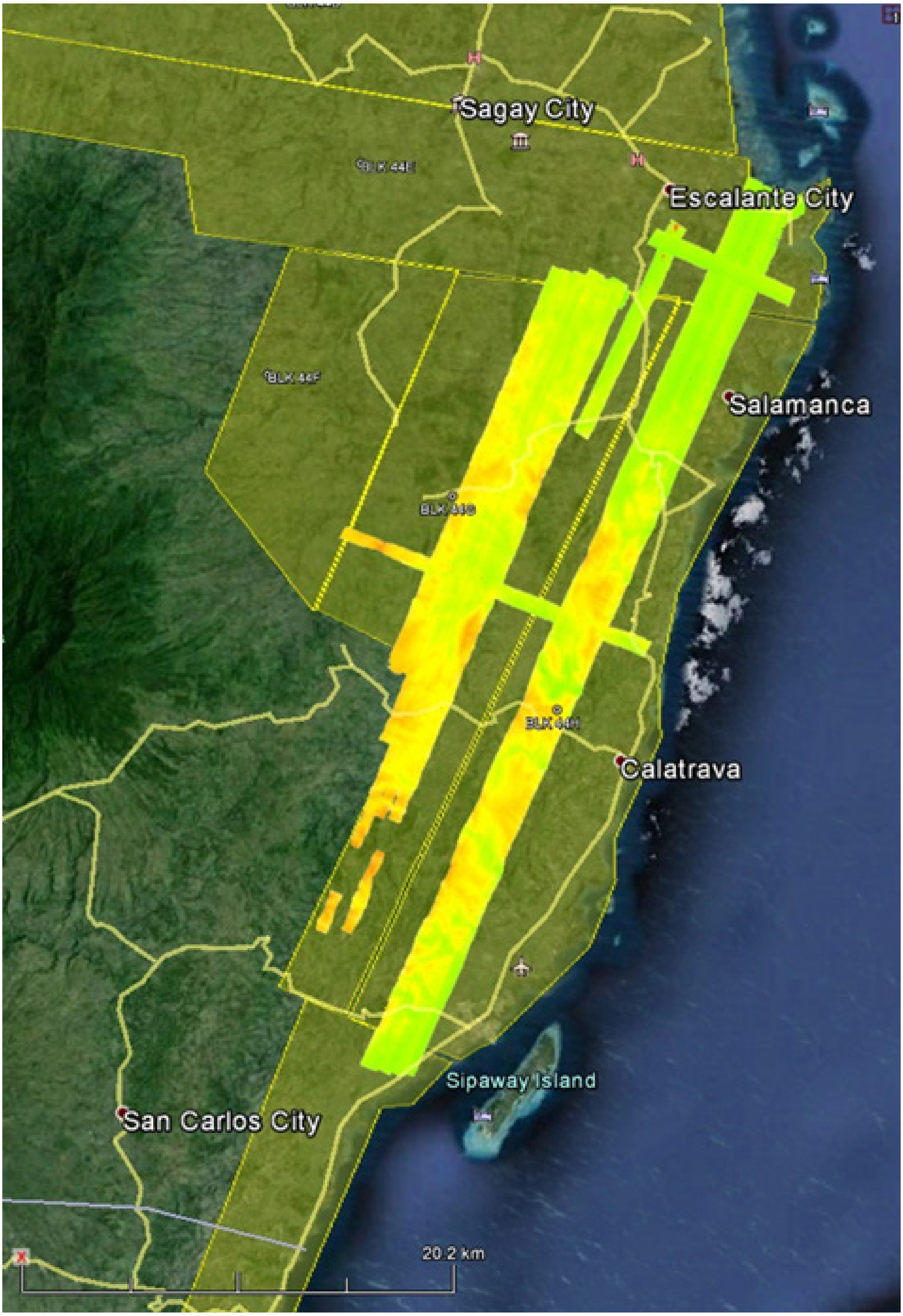
Flight No.:	1411P
Area:	BLK 44DE
Mission Name:	1BLK44D121A
Area Surveyed:	356.01 sq.km.



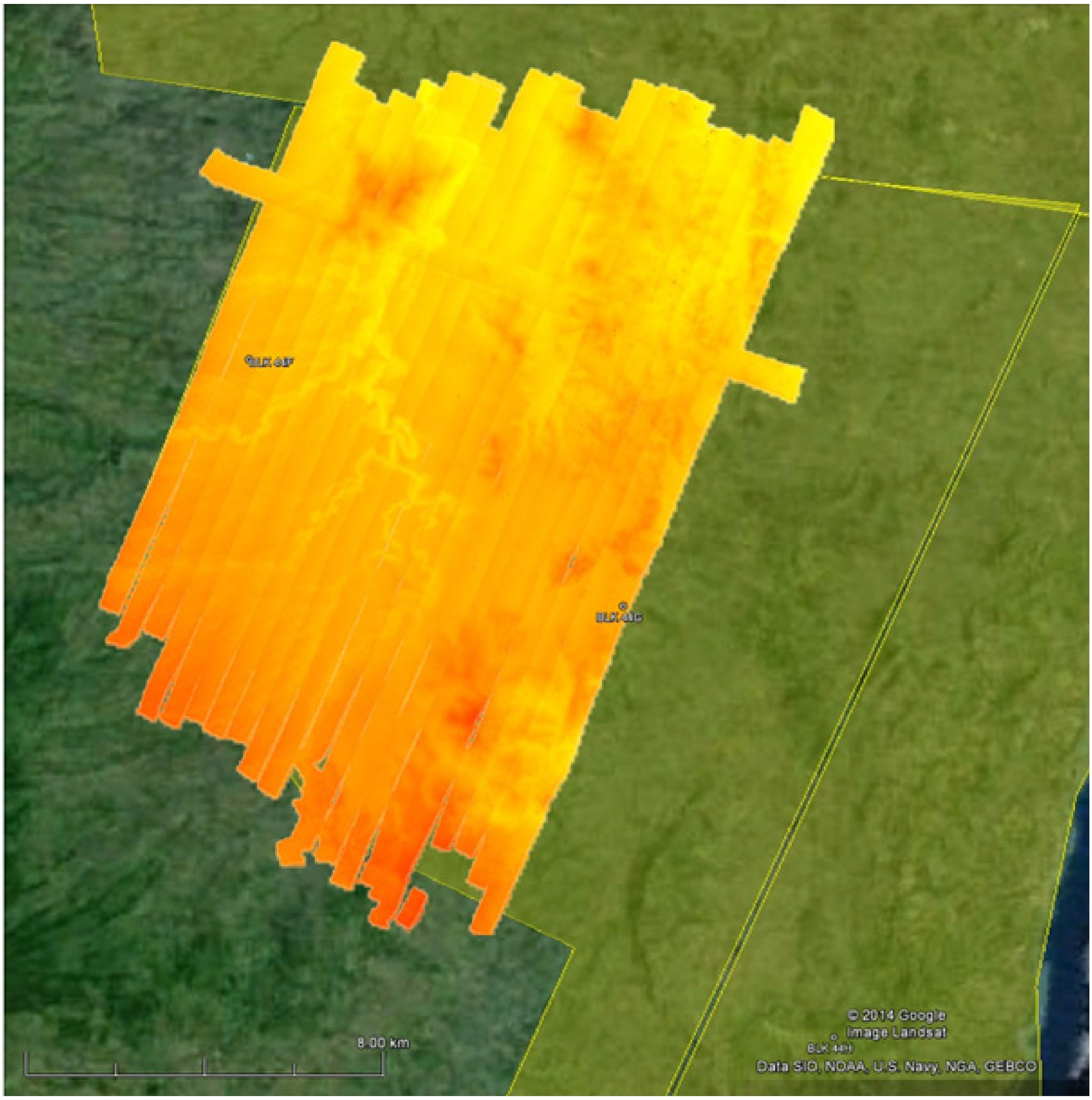
Flight No.:	1415P
Area:	BLK 44H
Mission Name:	1BLK44H122A
Area Surveyed:	371.6 sq.km



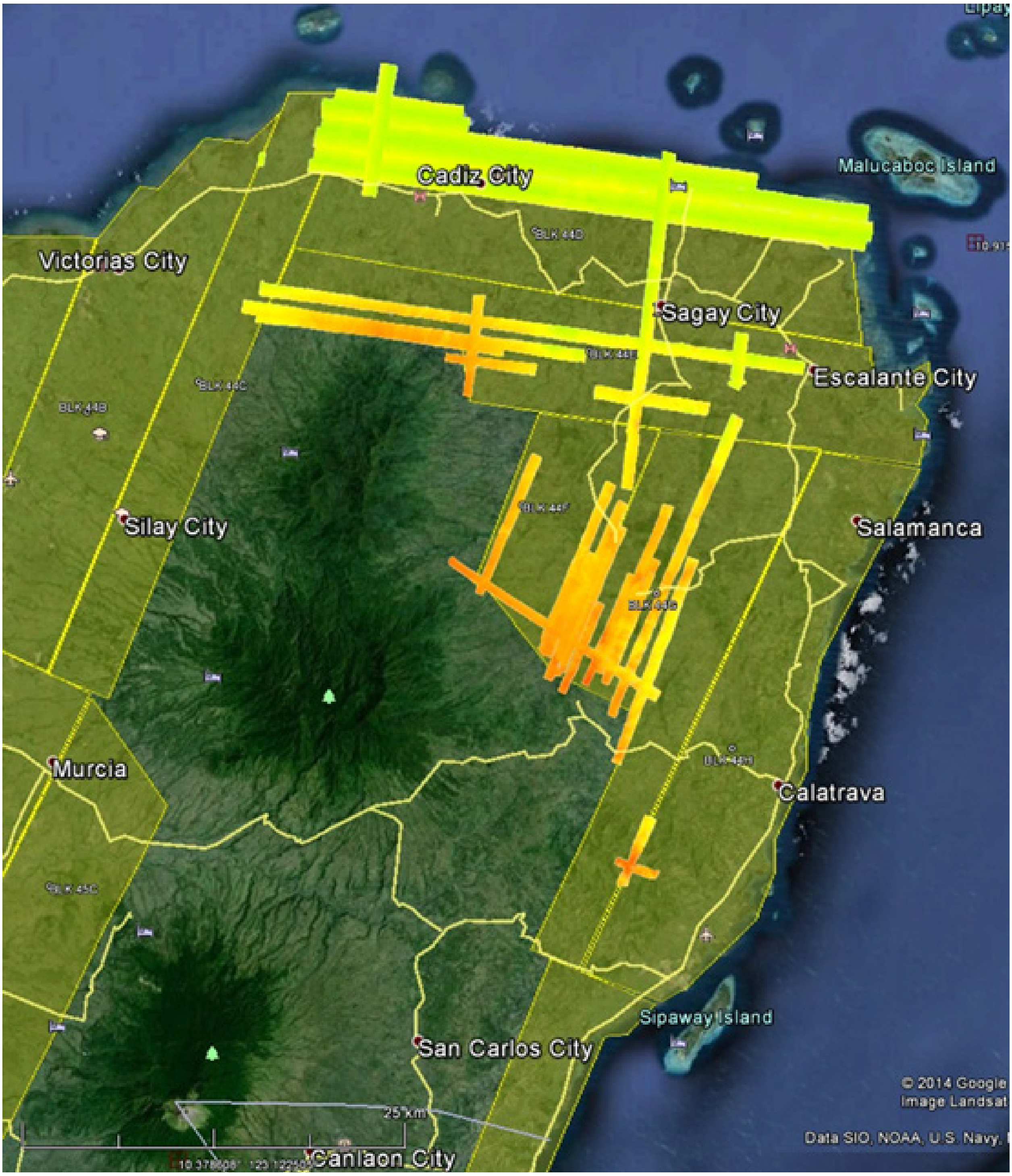
Flight No.:	1431P
Area:	BLK 44G, 44H, 44F
Mission Name:	1BLK44GHS126A
Area Surveyed:	230.5 sq.km



Flight No.:	1433P
Area:	BLK 44G, 44F
Mission Name:	1BLKFGS126B
Area Surveyed:	204.44 sq.km.



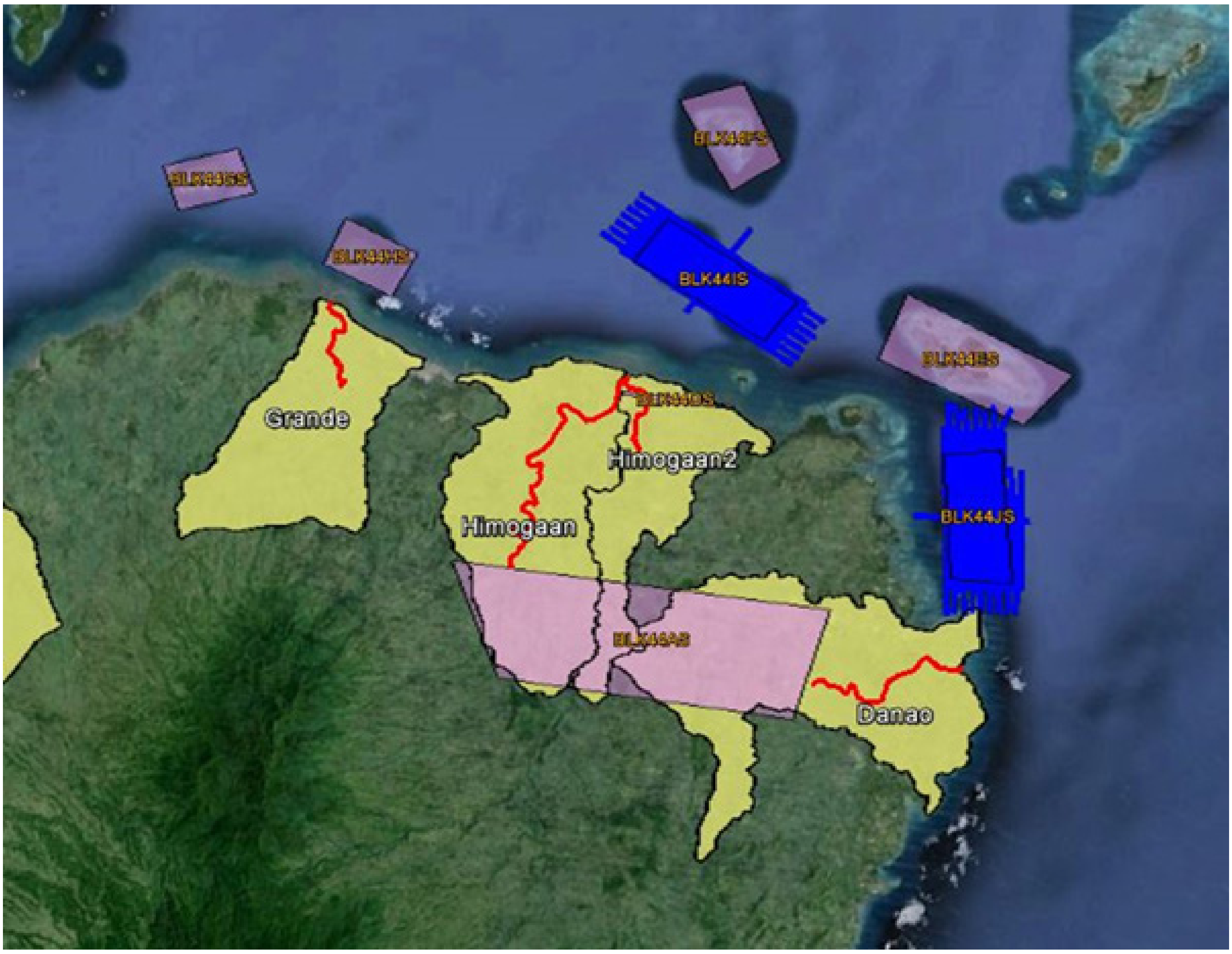
Flight No.:	1435P
Area:	BLK 44D, 44E, 44F, 44G
Mission Name:	1BLK44DS127A
Area Surveyed:	139.55 sq.km new area; 131.307 gap filling



Flight No.:	8453AC
Area:	BLK44AS
Mission Name:	3BLK44As113A
Parameters:	Altitude: 500m; Scan Frequency: 45; Scan Angle: 18; Overlap: 30 %; PRF: 50kHz
Total Area Surveyed:	98.3 sq km

Flight No.:	8455AC
Area:	BLK44AS
Mission Name:	3BLK44AS114A
Parameters:	Altitude: 500m; Scan Frequency: 45; Scan Angle: 18; Overlap: 30 %; PRF: 50kHz
Total Area Surveyed:	35 sq km

Flight No.:	8459AC
Area:	BLK44IS, BLK44JS
Mission Name:	3BLK44IJS116A
Parameters:	Altitude: 500m; Scan Frequency: 45; Scan Angle: 18; Overlap: 50 %; PRF: 50kHz
Total Area Surveyed:	70 sq km



Annex 8. Mission Summary Reports

Flight Area	Negros
Mission Name	Blk44D
Inclusive Flights	1411P, 1435P
Range data size	75.2 GB
POS data size	728 MB
Base data size	13.9 MB
Image	31.5 GB
Transfer date	May 26, 2014
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)	1.04
RMSE for East Position (<4.0 cm)	1.26
RMSE for Down Position (<8.0 cm)	2.51
Boresight correction stdev (<0.001deg)	0.000446
IMU attitude correction stdev (<0.001deg)	0.005774
GPS position stdev (<0.01m)	0.0134
Minimum % overlap (>25)	27.44%
Ave point cloud density per sq.m. (>2.0)	3.51
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	552
Maximum Height	395.70 m
Minimum Height	50.84 m
Classification (# of points)	
Ground	387,844,370
Low vegetation	324,638,606
Medium vegetation	458,253,579
High vegetation	120,361,293
Building	9,453,151
Orthophoto	Yes
Processed by	Engr. Jommer Medina, Engr. Carlyn Ibañez, Engr. Melanie Hingpit, Engr. Gladys Mae Apat

Figure A-8.1. Solution Status

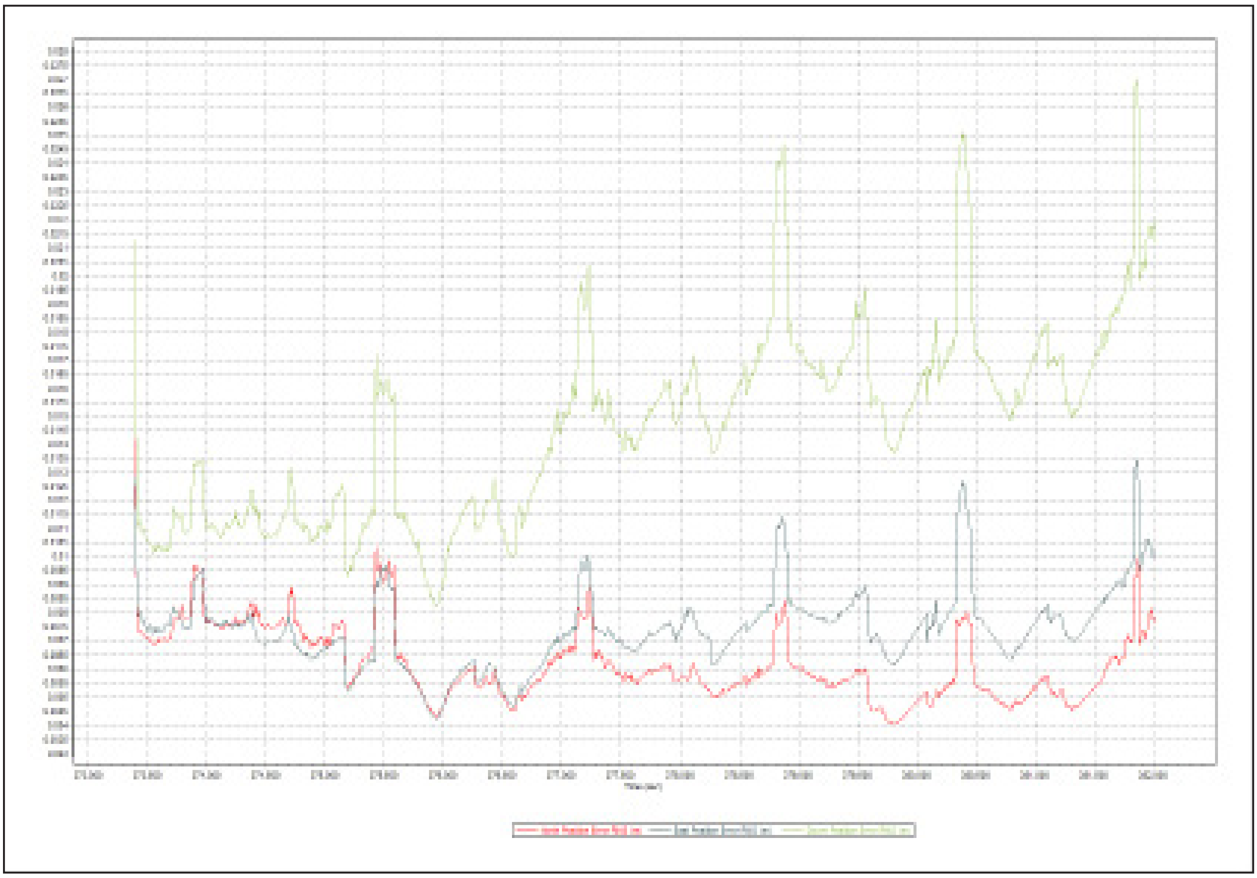


Figure A-8.2. Smoothed Performance Metric Parameters

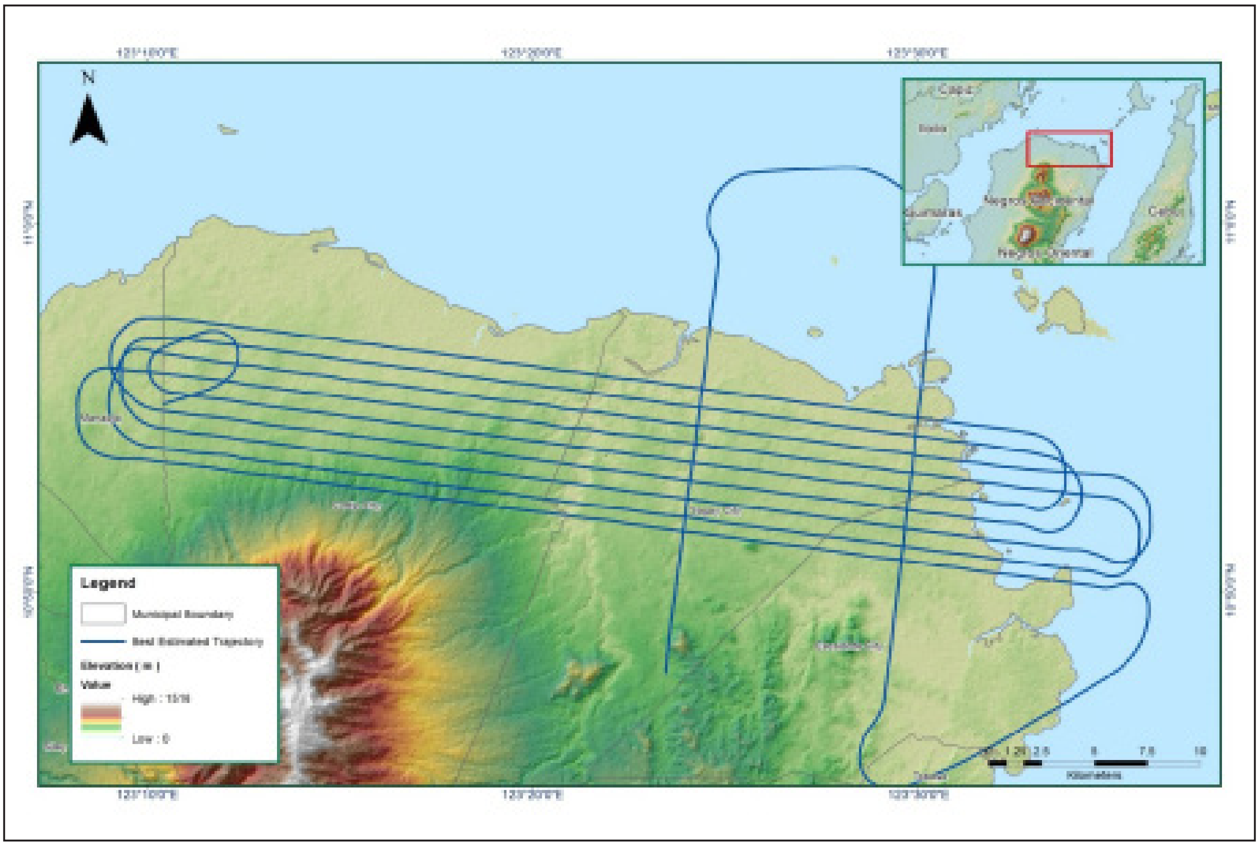


Figure A-8.3. Best Estimated Trajectory

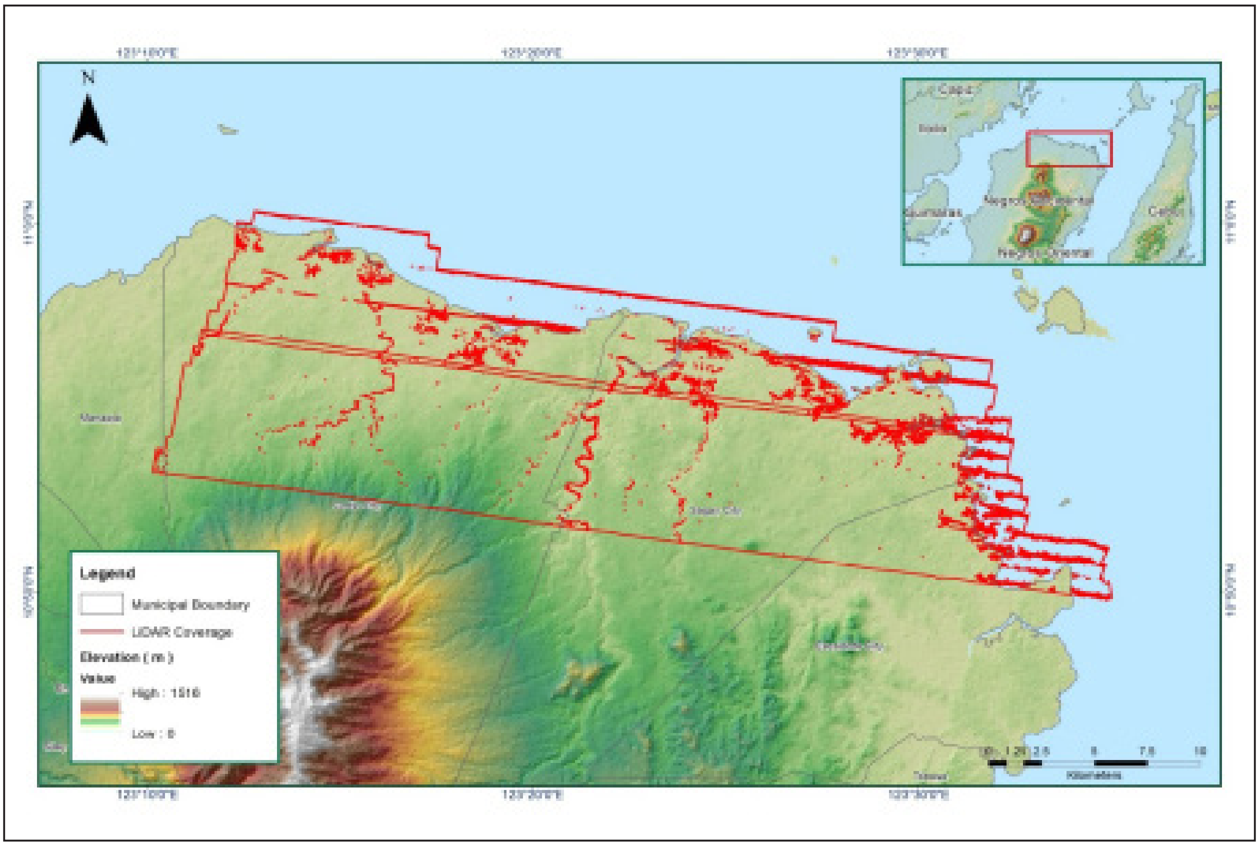


Figure A-8.4. Coverage of LiDAR data

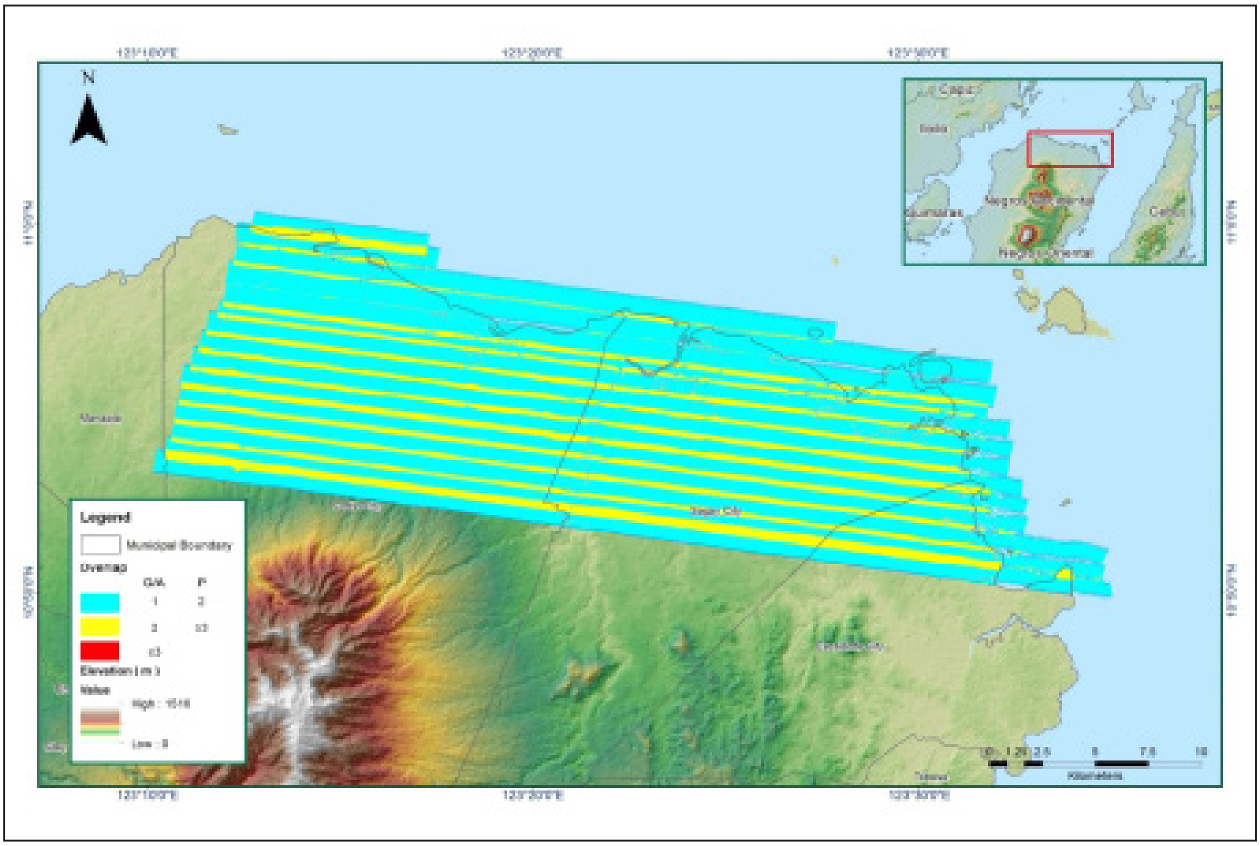


Figure A-8.5. Image of data overlap

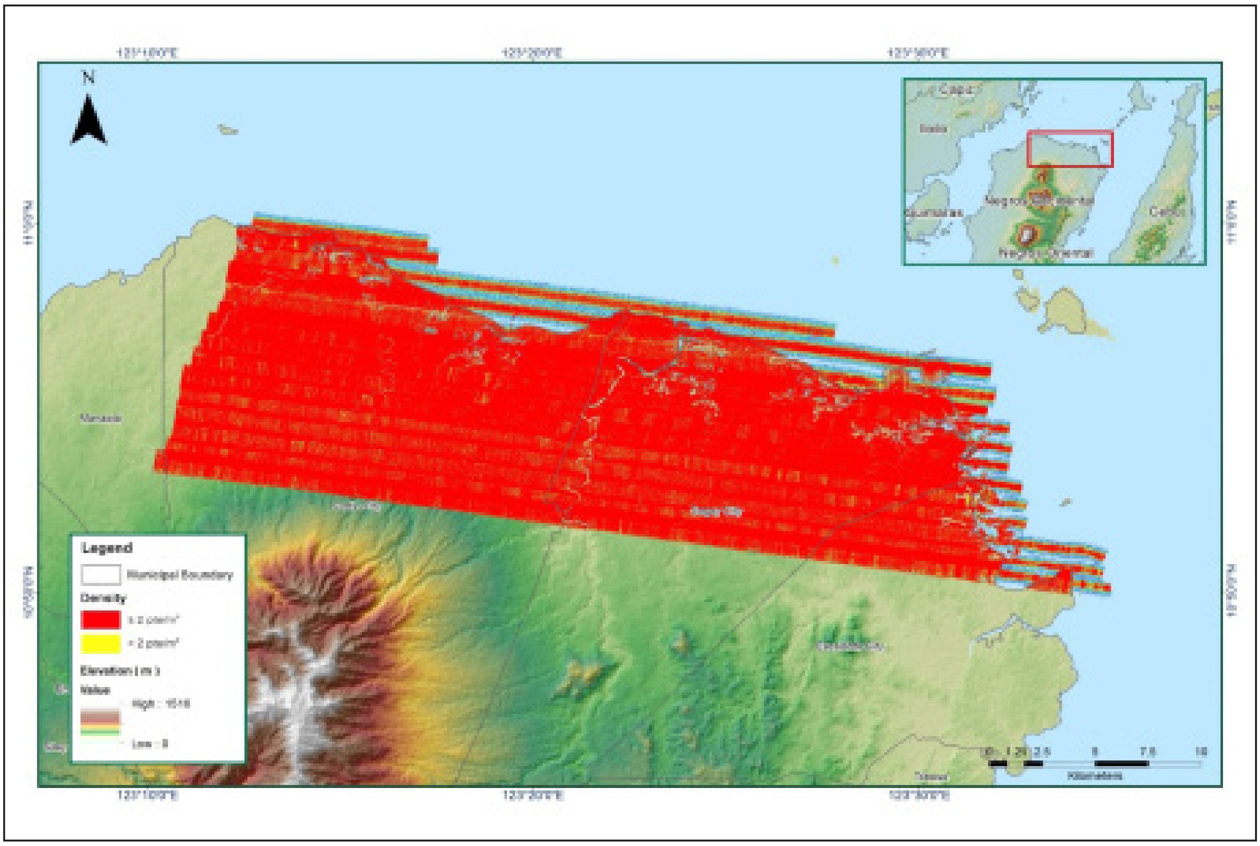


Figure A-8.6. Density map of merged LiDAR data

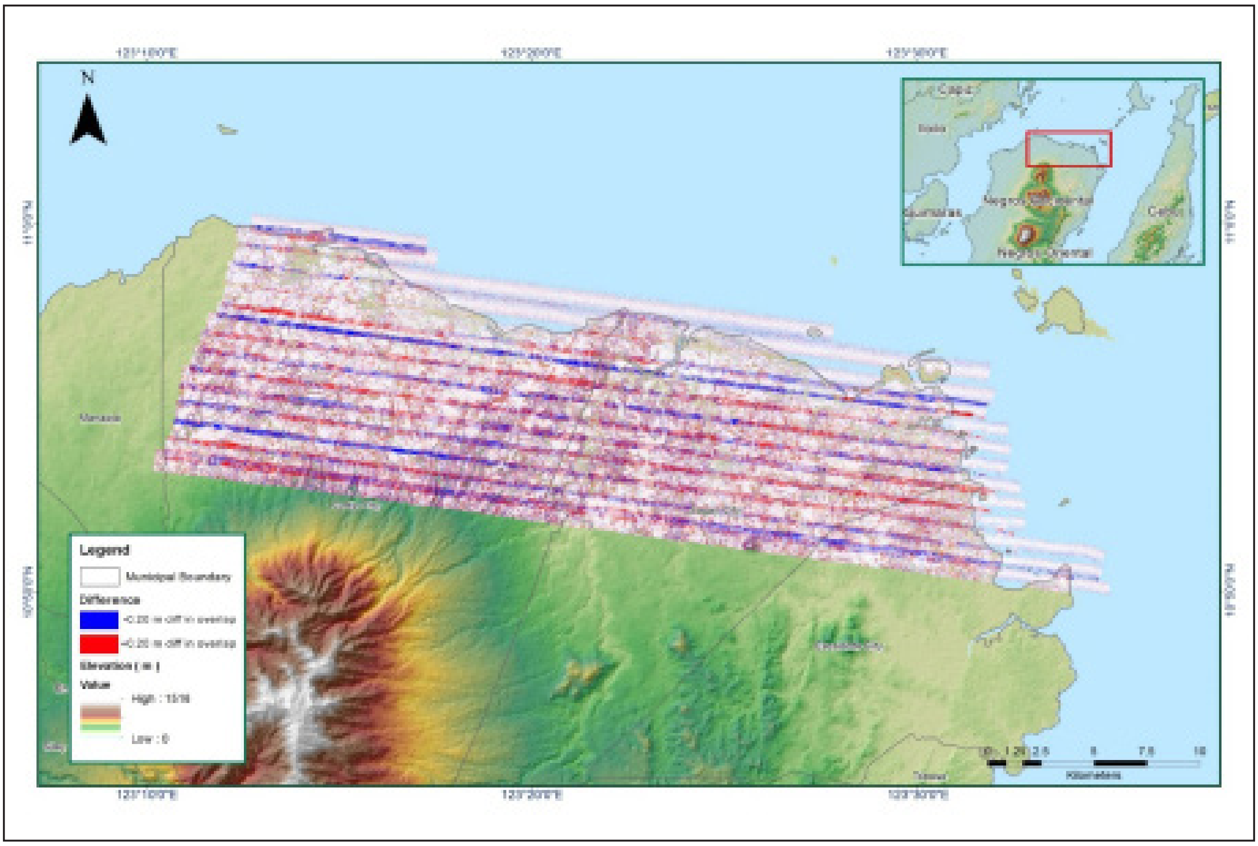


Figure A-8.7. Elevation difference between flight lines

Flight Area	Negros
Mission Name	Blk44FG
Inclusive Flights	1431P, 1433P, 1435P
Range data size	105.7 GB
POS data size	810 MB
Base data size	35.9 MB
Image	110.3 GB
Transfer date	May 26, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.24
RMSE for East Position (<4.0 cm)	1.41
RMSE for Down Position (<8.0 cm)	2.62
Boresight correction stdev (<0.001deg)	0.000248
IMU attitude correction stdev (<0.001deg)	0.001112
GPS position stdev (<0.01m)	0.0062
Minimum % overlap (>25)	43.01%
Ave point cloud density per sq.m. (>2.0)	9.26
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	347
Maximum Height	584.11 m
Minimum Height	72.76 m
Classification (# of points)	
Ground	445,025,694
Low vegetation	463,475,098
Medium vegetation	838,129,177
High vegetation	234,468,284
Building	6,471,602
Orthophoto	Yes
Processed by	Engr. Carlyn Ibañez, Engr. Christy Lubiano, Engr. Gladys Mae Apat

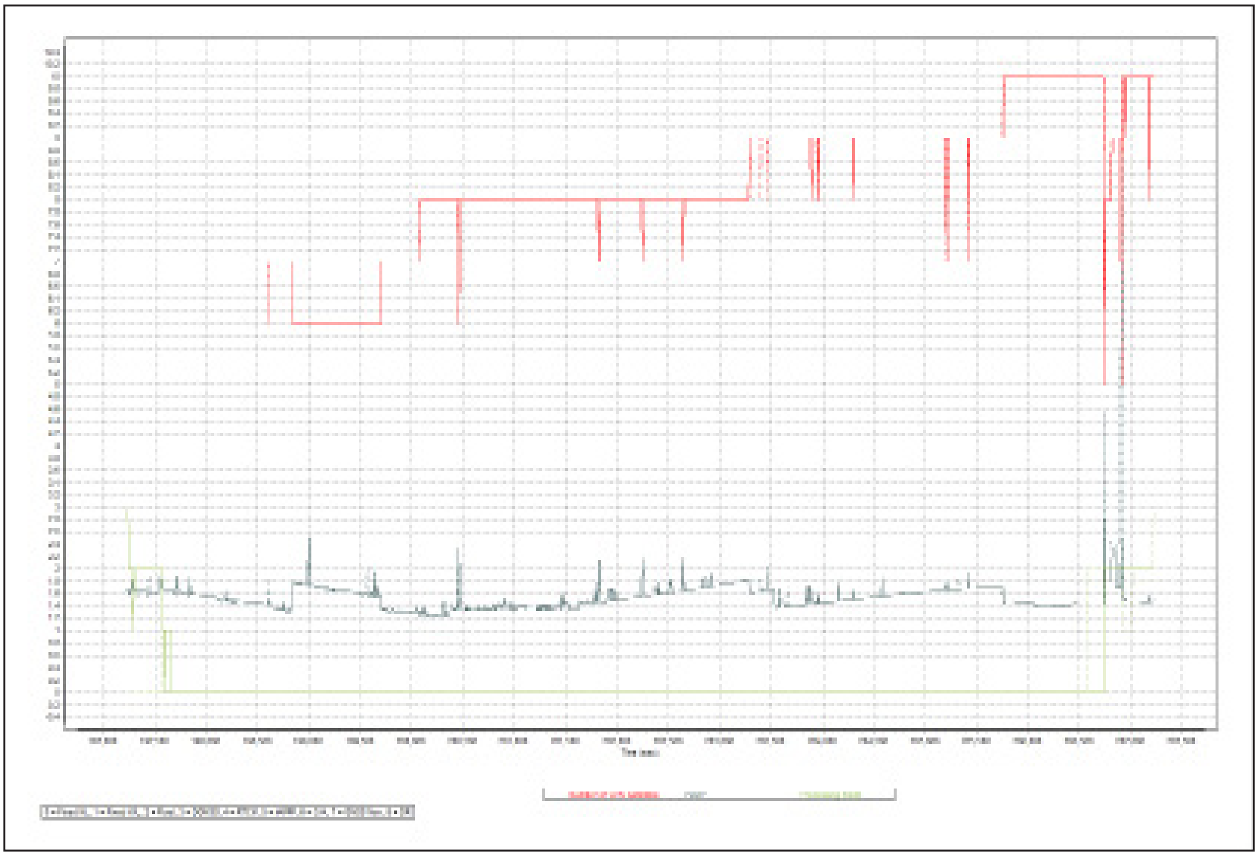


Figure A-8.8. Solution Status

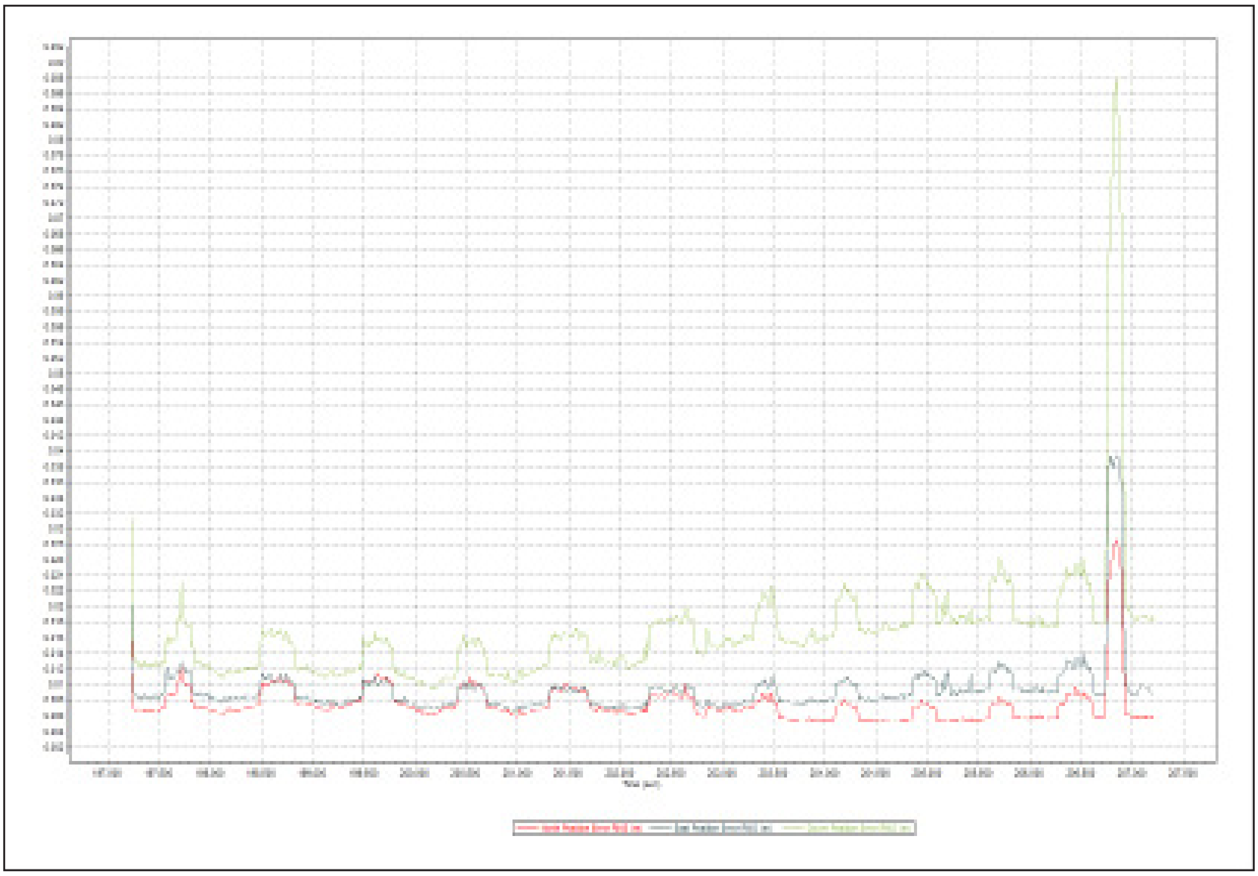


Figure A-8.9. Smoothed Performance Metric Parameters

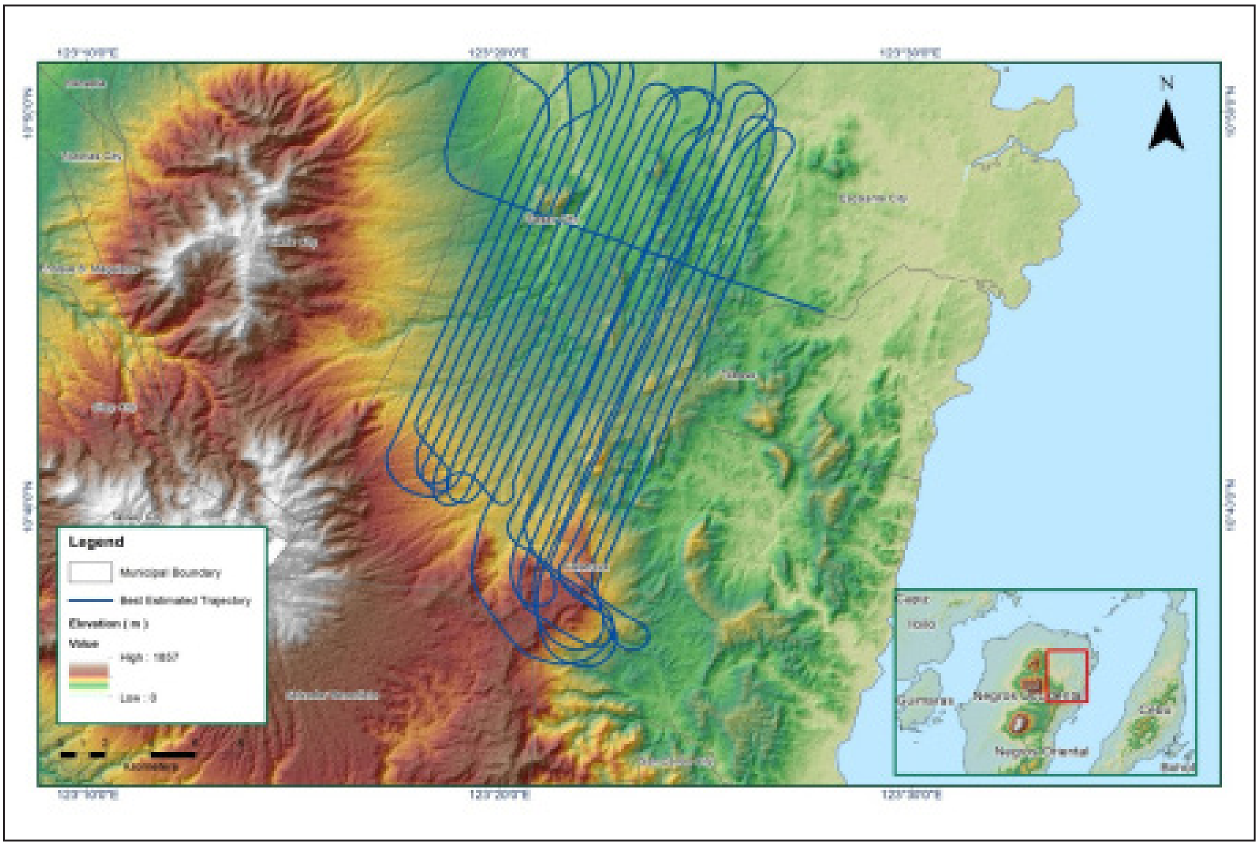


Figure A-8.10. Best Estimated Trajectory

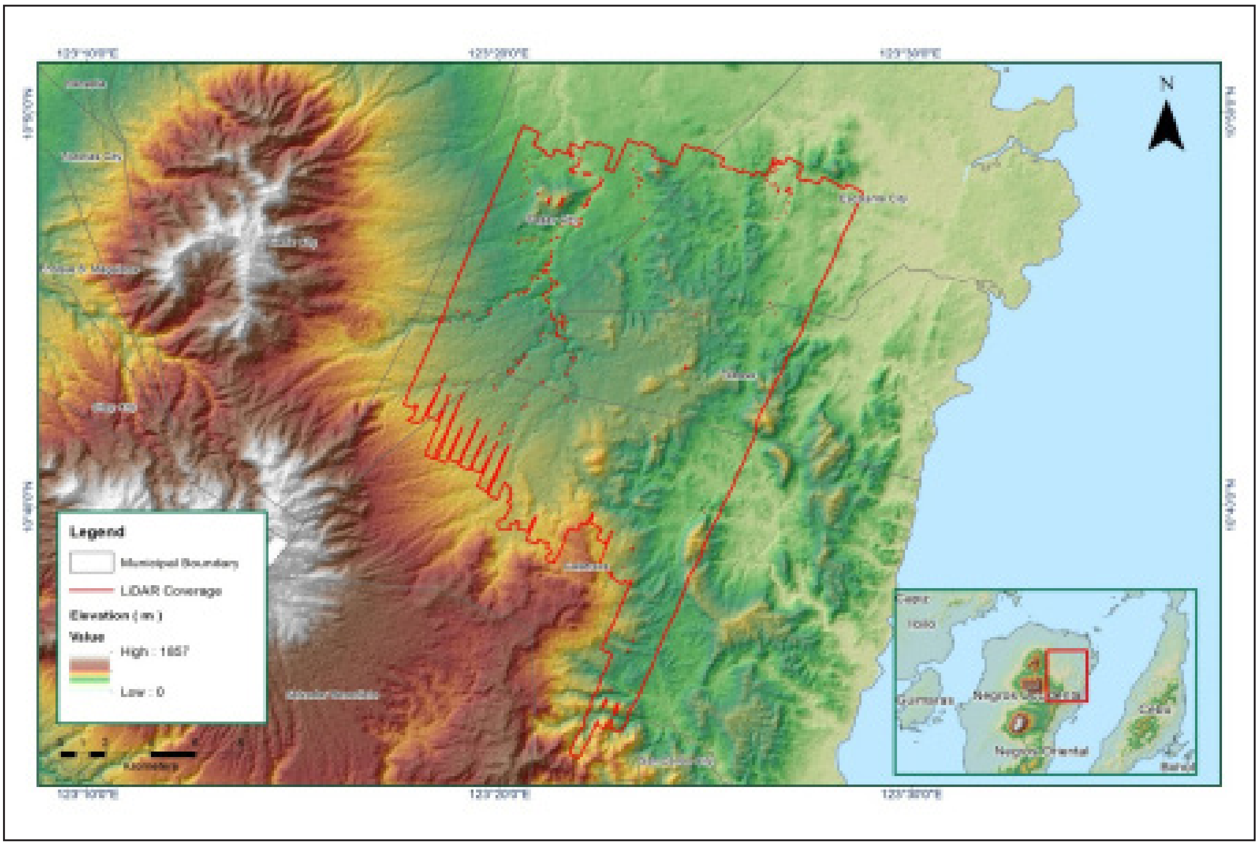


Figure A-8.11. Coverage of LiDAR data

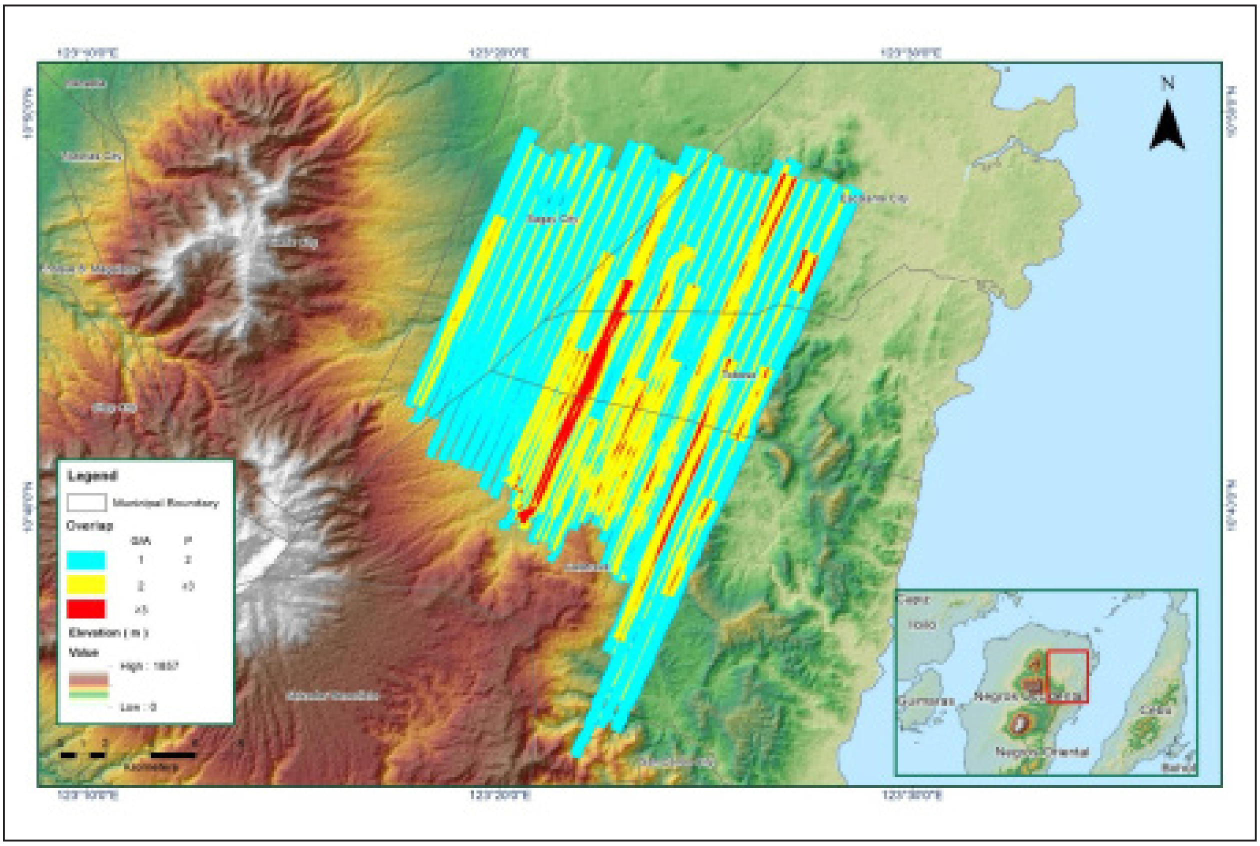


Figure A-8.12. Image of data overlap

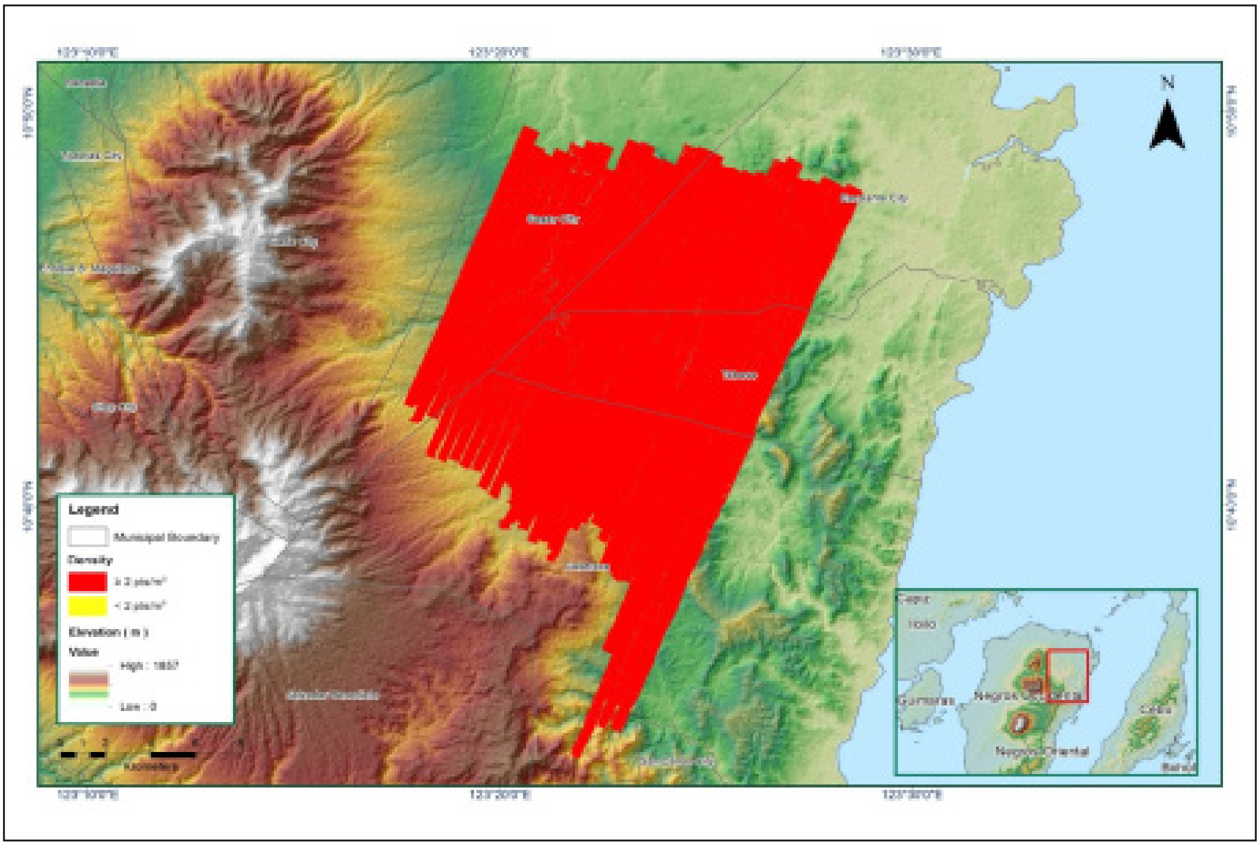


Figure A-8.13. Density map of merged LiDAR data

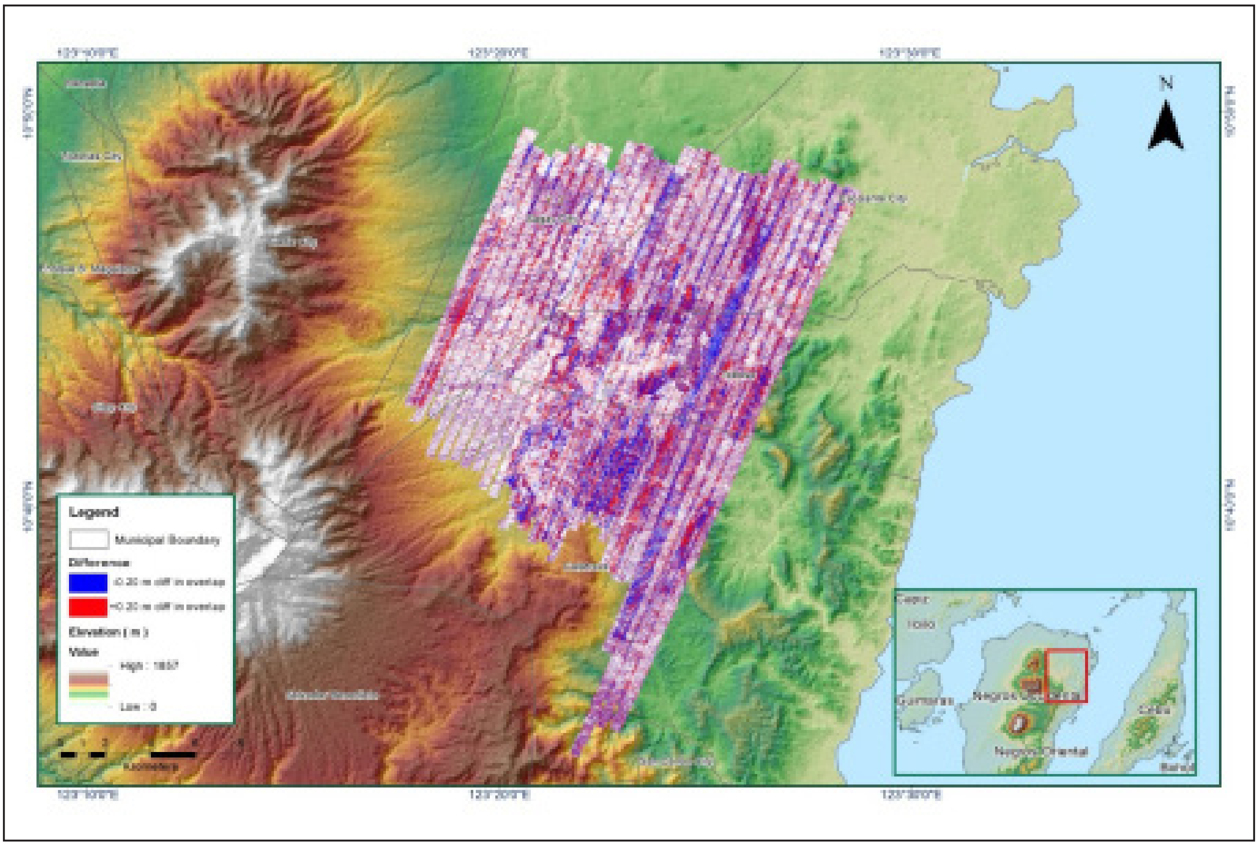


Figure A-8.14. Elevation difference between flight lines

Flight Area	**Negros**
Mission Name	Blk44H
Inclusive Flights	1415P, 1431P
Range data size	62 GB
POS data size	520 MB
Base data size	21.7 MB
Image	91.6 GB
Transfer date	May 26, 2014
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)	1.85
RMSE for East Position (<4.0 cm)	2.03
RMSE for Down Position (<8.0 cm)	2.28
Boresight correction stdev (<0.001deg)	0.000301
IMU attitude correction stdev (<0.001deg)	0.000639
GPS position stdev (<0.01m)	0.0125
Minimum % overlap (>25)	39.04%
Ave point cloud density per sq.m. (>2.0)	5.46
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	598
Maximum Height	696.44 m
Minimum Height	49.72 m
Classification (# of points)	
Ground	531,355,943
Low vegetation	420,470,931
Medium vegetation	791,130,506
High vegetation	281,524,864
Building	10,193,890
Orthophoto	Yes
Processed by	Engr. Carlyn Ibañez, Engr. Christy Lubiano, Engr. Gladys Mae Apat

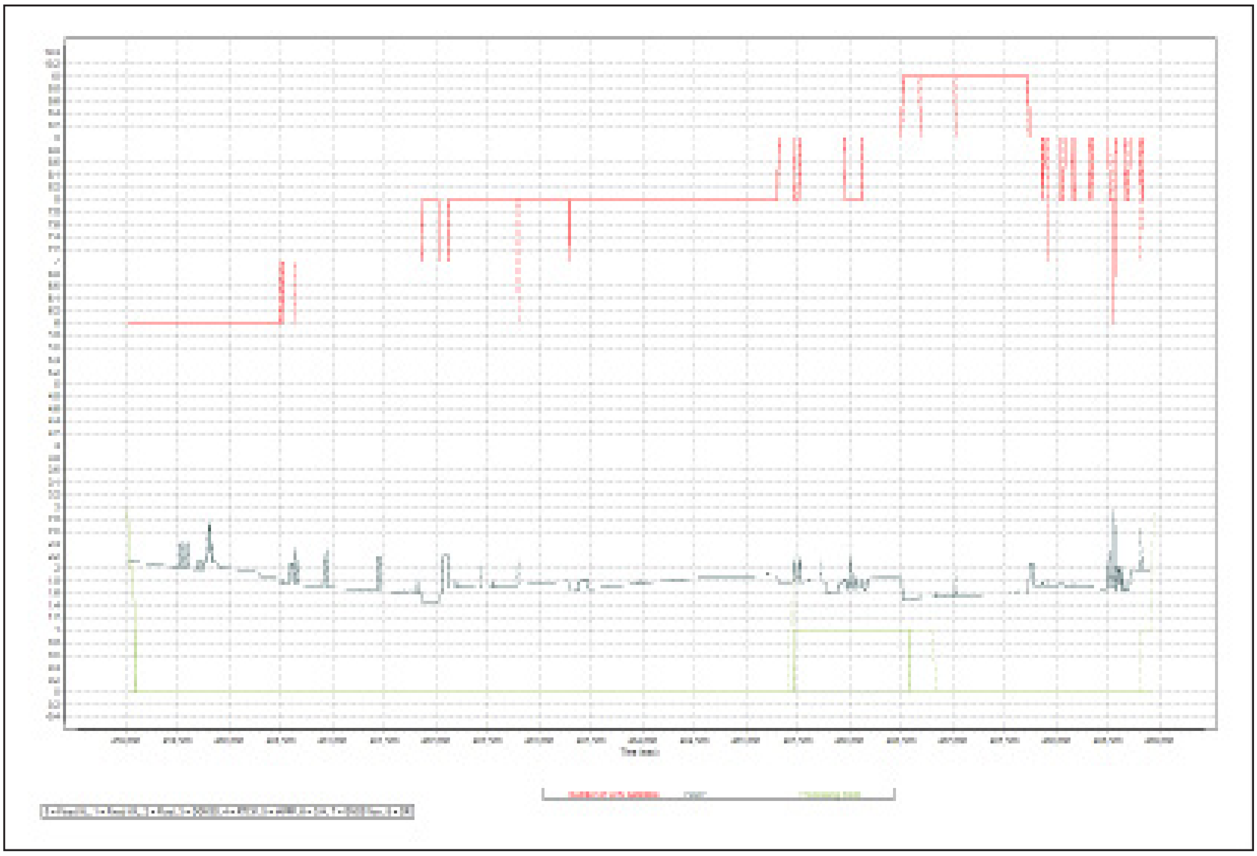


Figure A-8.15. Solution Status

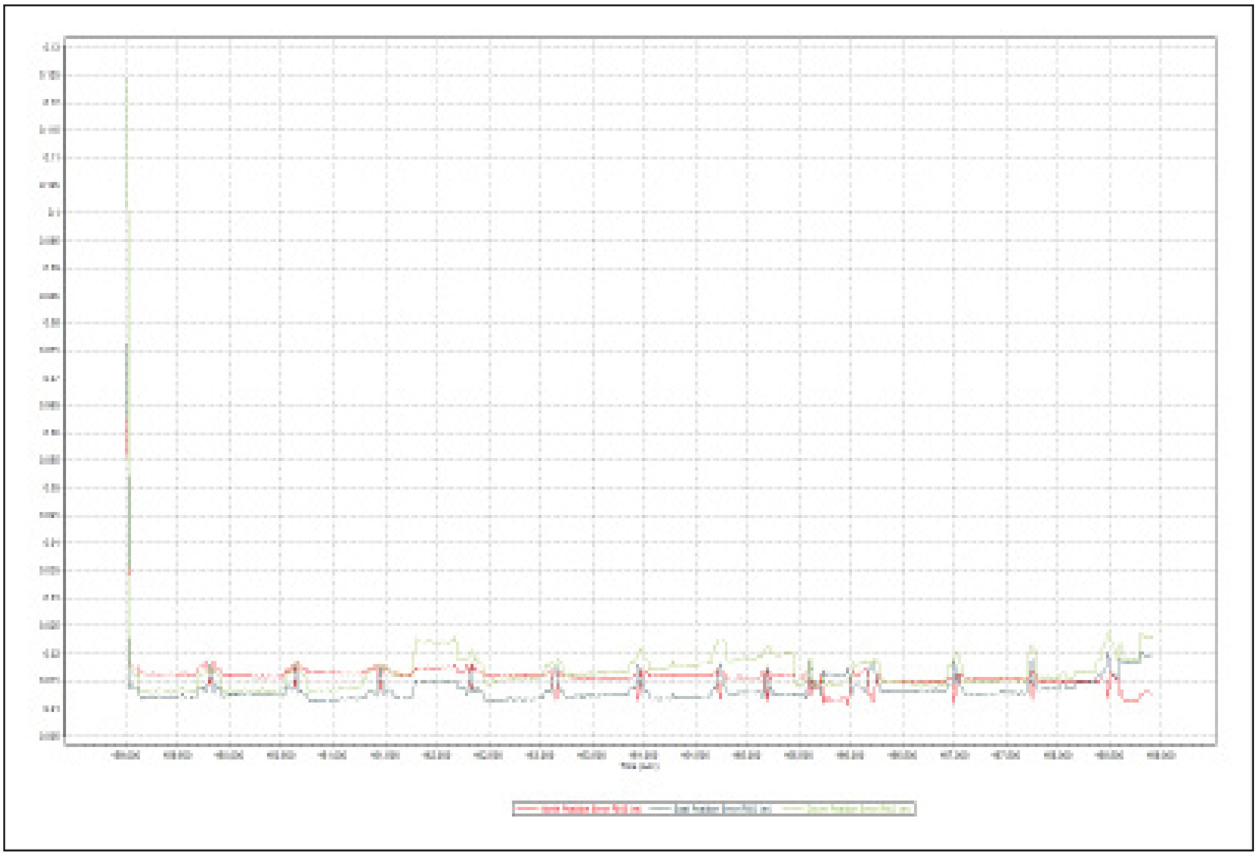


Figure A-8.16. Smoothed Performance Metric Parameters

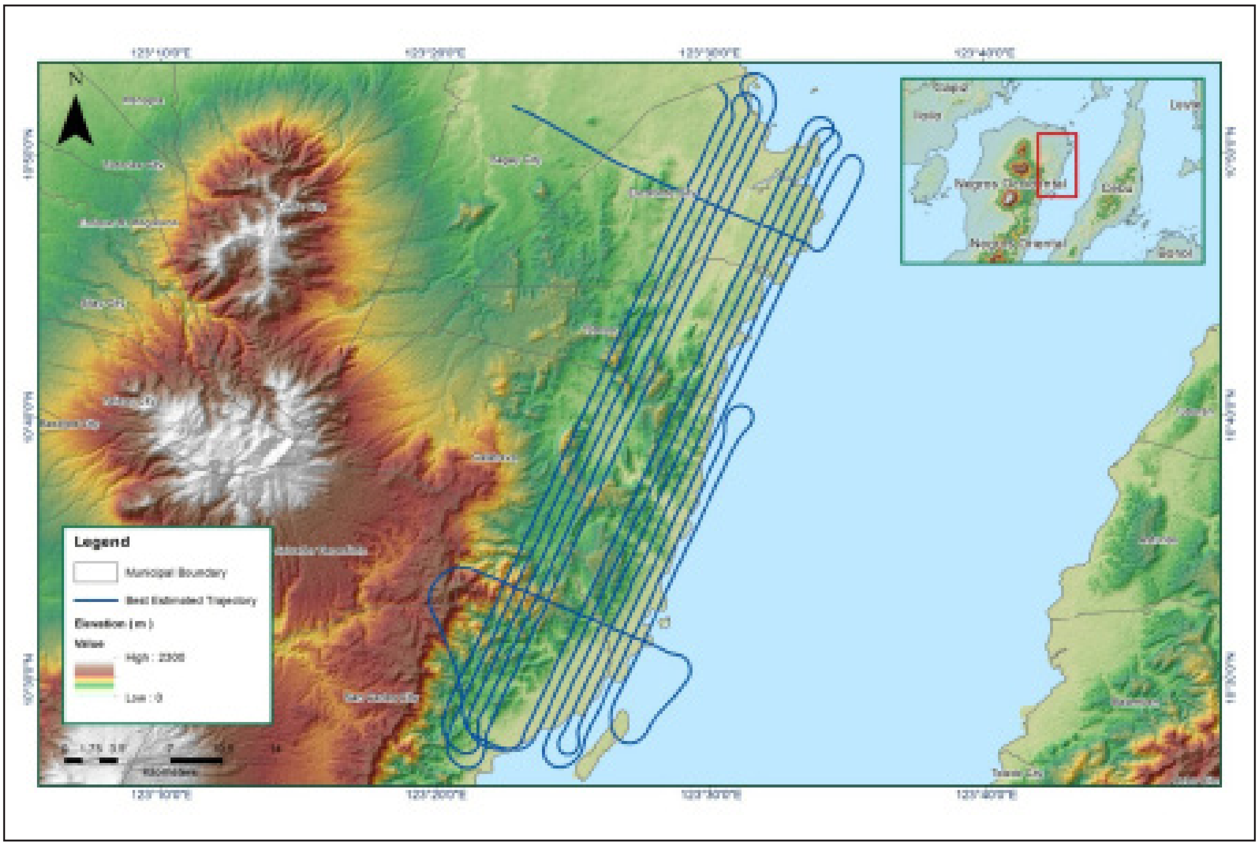


Figure A-8.17. Best Estimated Trajectory

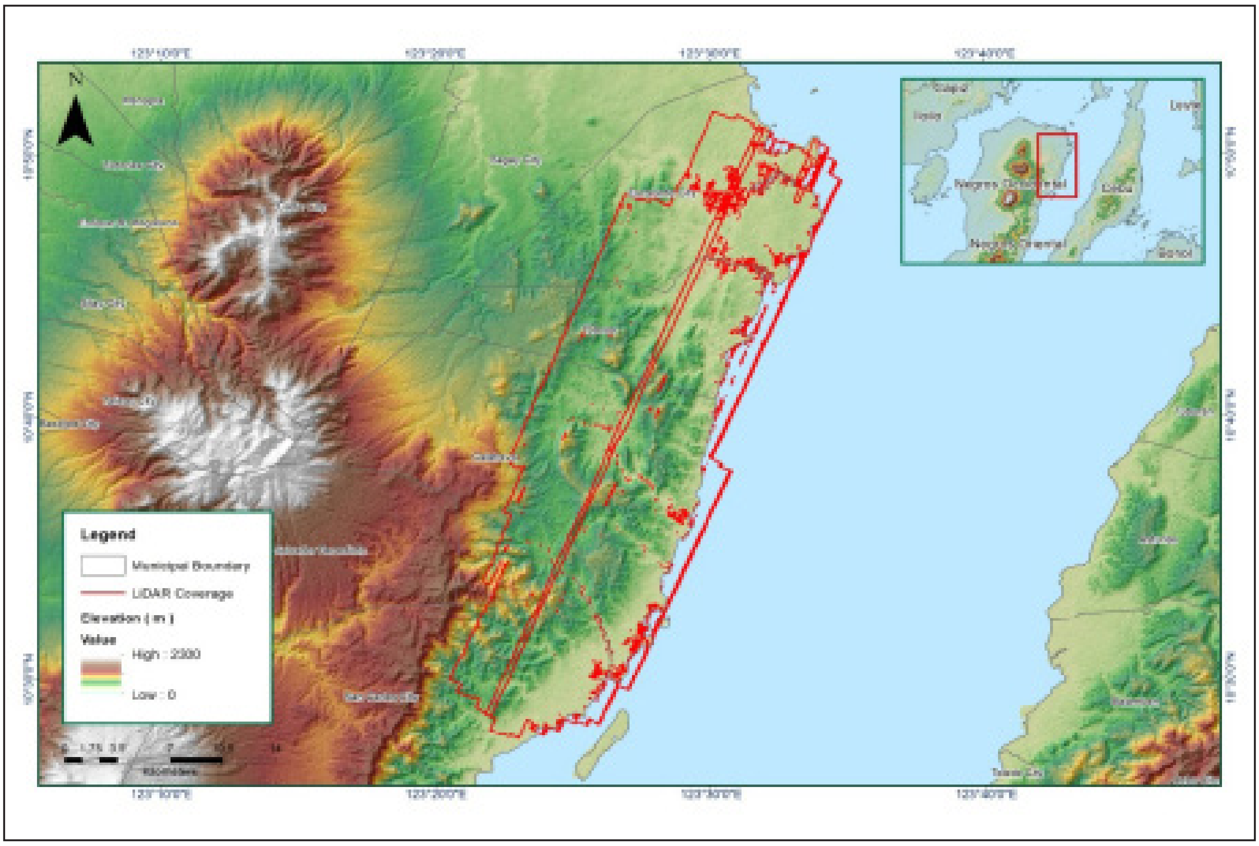


Figure A-8.18. Coverage of LiDAR data

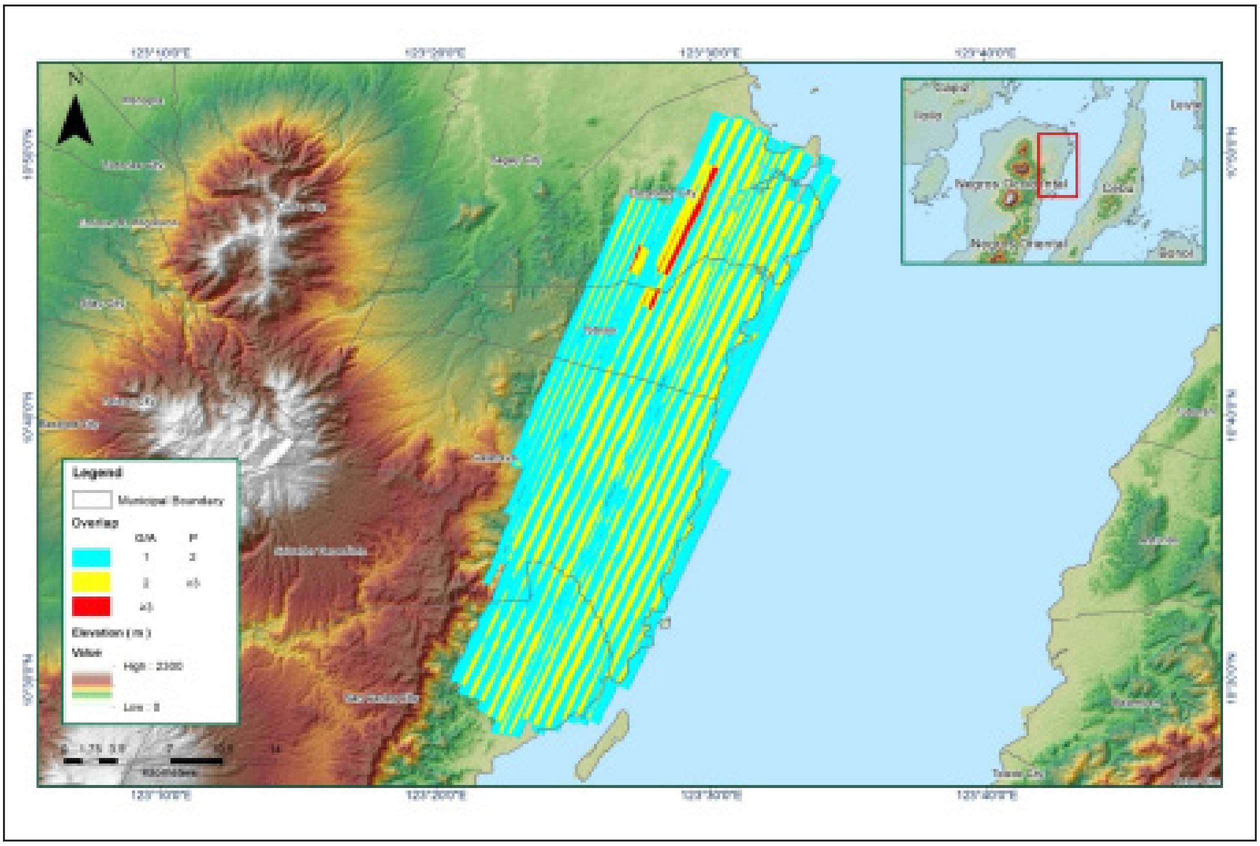


Figure A-8.19. Image of data overlap

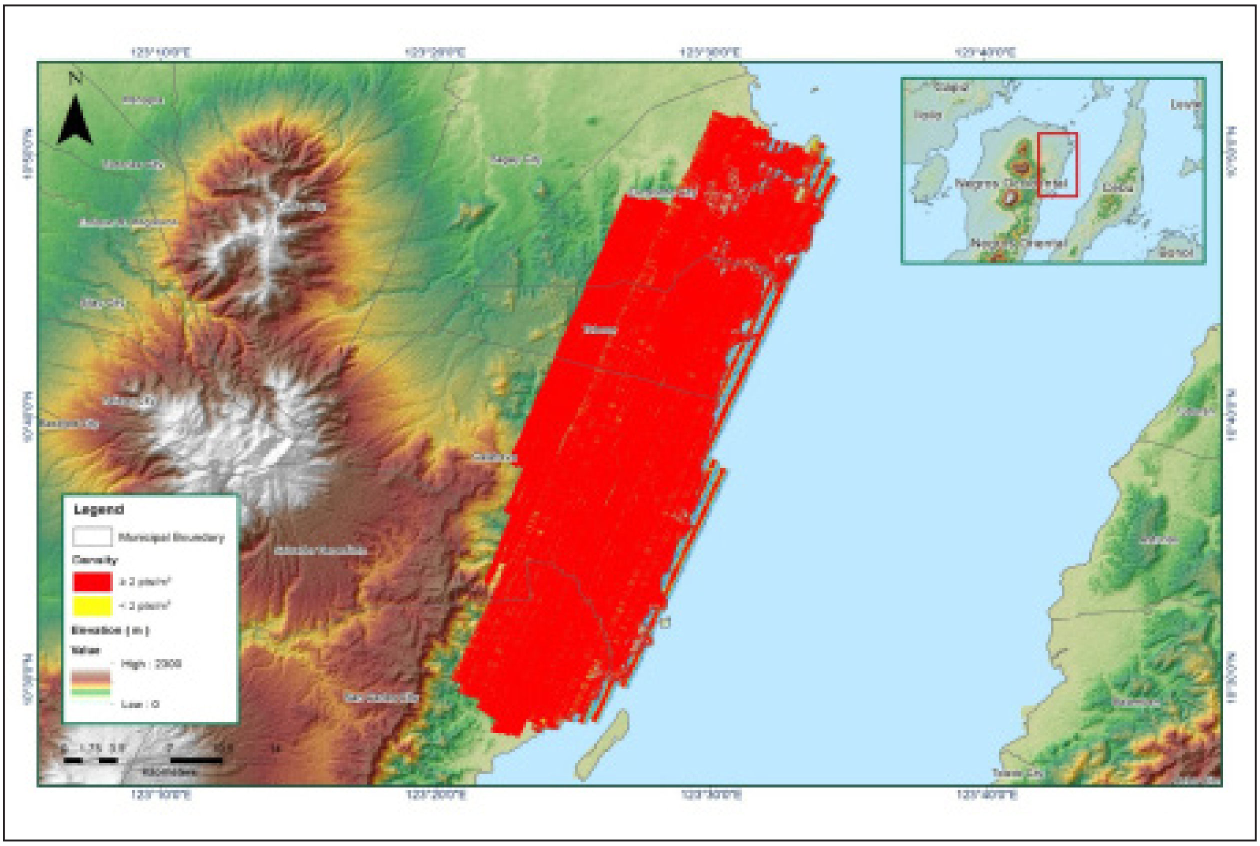


Figure A-8.20. Density map of merged LiDAR data

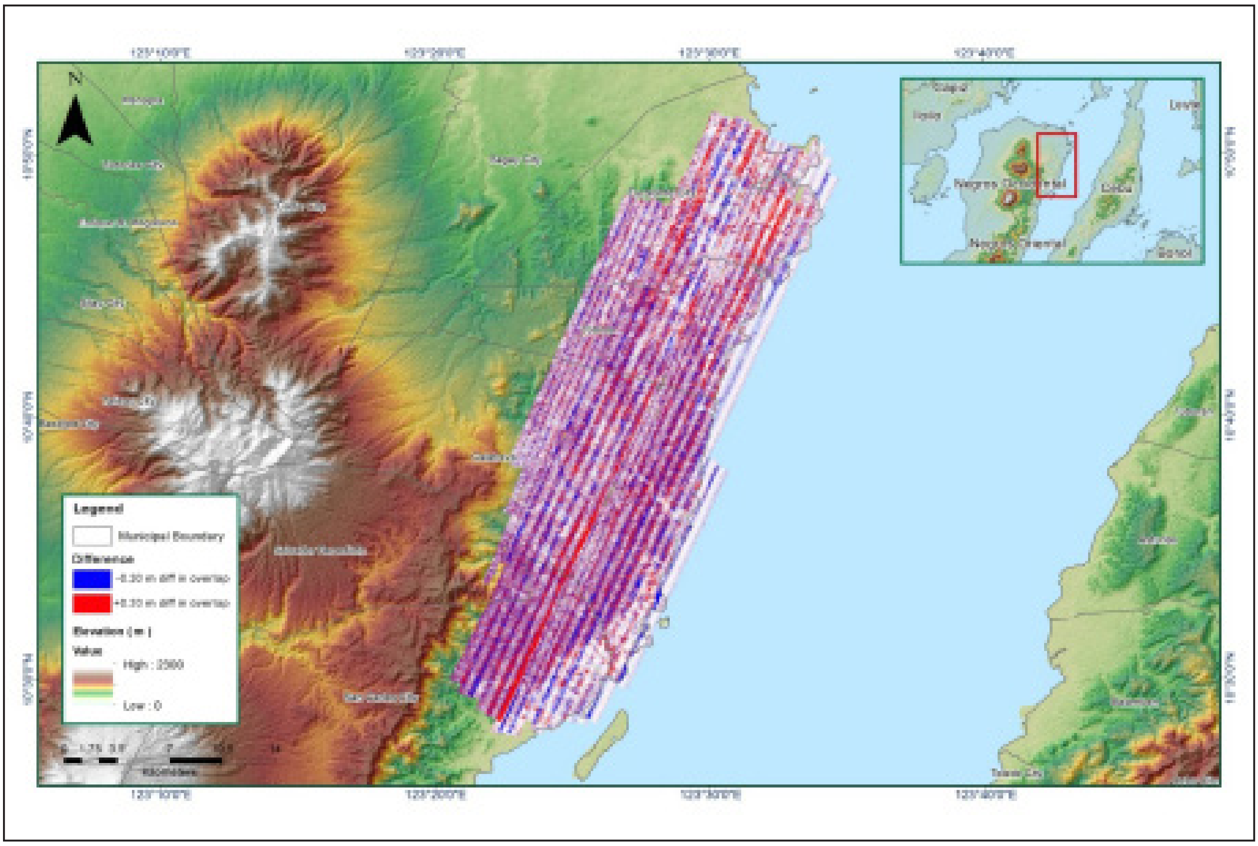


Figure A-8.21. Elevation difference between flight lines

Flight Area	Negros
Mission Name	Blk44H_additional
Inclusive Flights	1415P
Range data size	32.8 GB
POS data size	266 MB
Base data size	7.3 MB
Image	40.3 GB
Transfer date	May 26, 2014
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)	1.85
RMSE for East Position (<4.0 cm)	2.03
RMSE for Down Position (<8.0 cm)	2.28
Boresight correction stdev (<0.001deg)	0.000301
IMU attitude correction stdev (<0.001deg)	0.000639
GPS position stdev (<0.01m)	0.0125
Minimum % overlap (>25)	
Ave point cloud density per sq.m. (>2.0)	
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	11
Maximum Height	100.41 m
Minimum Height	60.30
Classification (# of points)	
Ground	2,563,917
Low vegetation	1,250,575
Medium vegetation	1,256,710
High vegetation	1,519,582
Building	66,247
Orthophoto	Yes
Processed by	Engr. Carlyn Ibañez, Engr. Harmond Santos, Engr. Ma. Ailyn Olanda

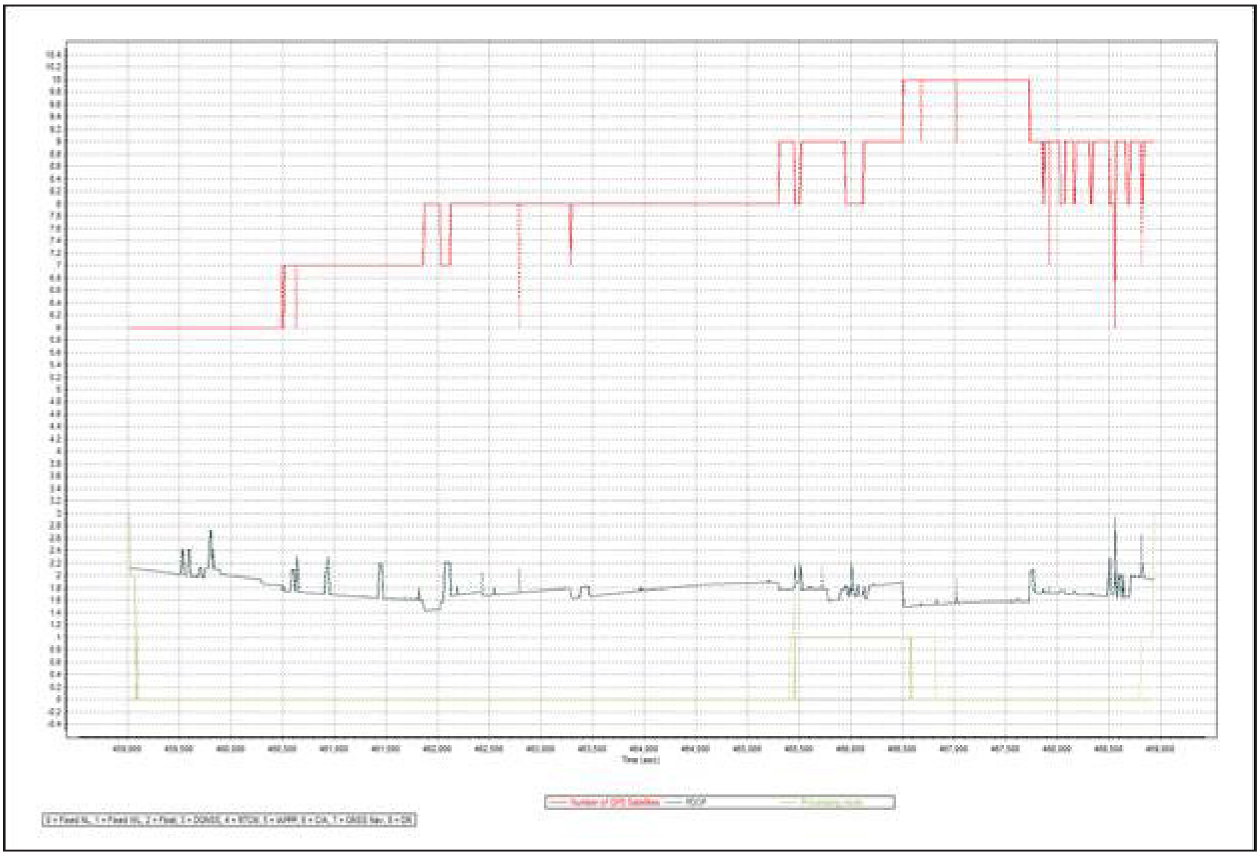


Figure A-8.22. Solution Status

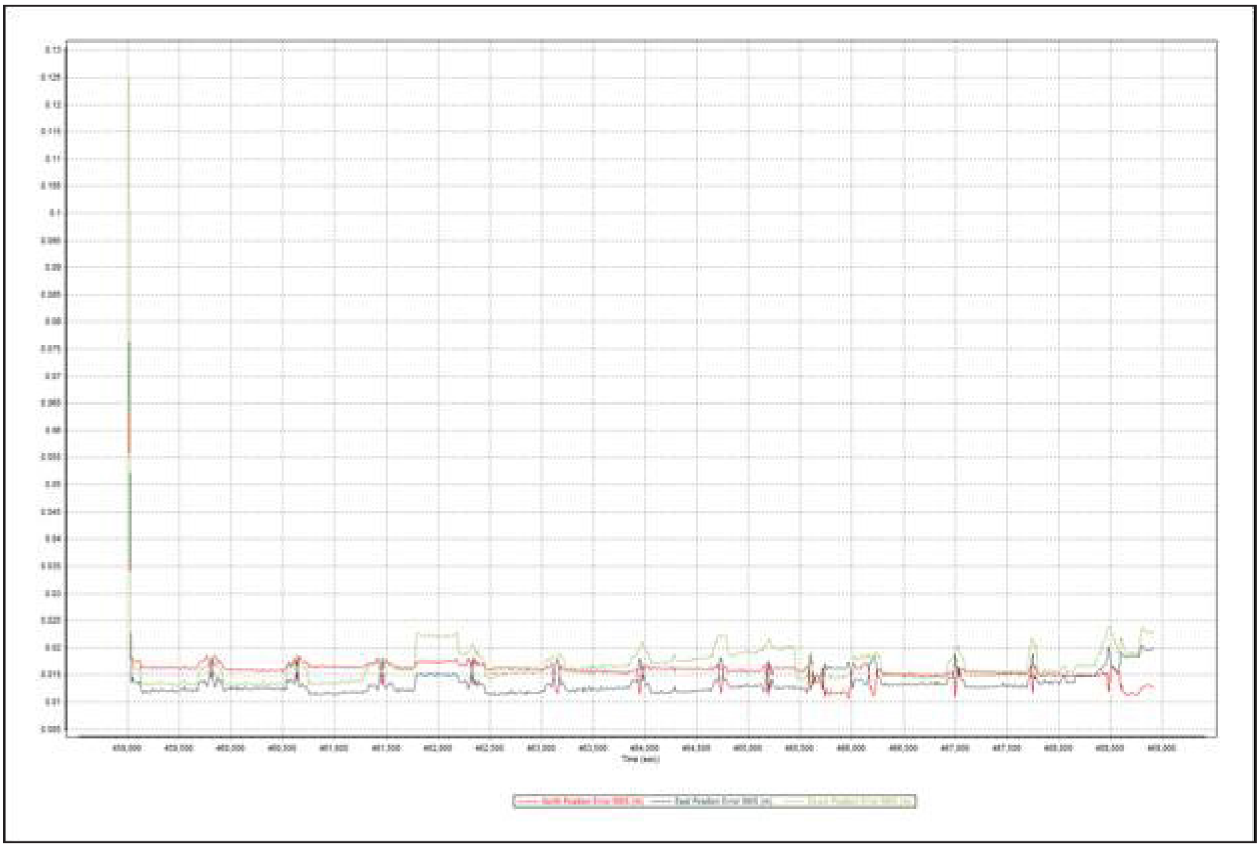


Figure A-8.23. Smoothed Performance Metric Parameters

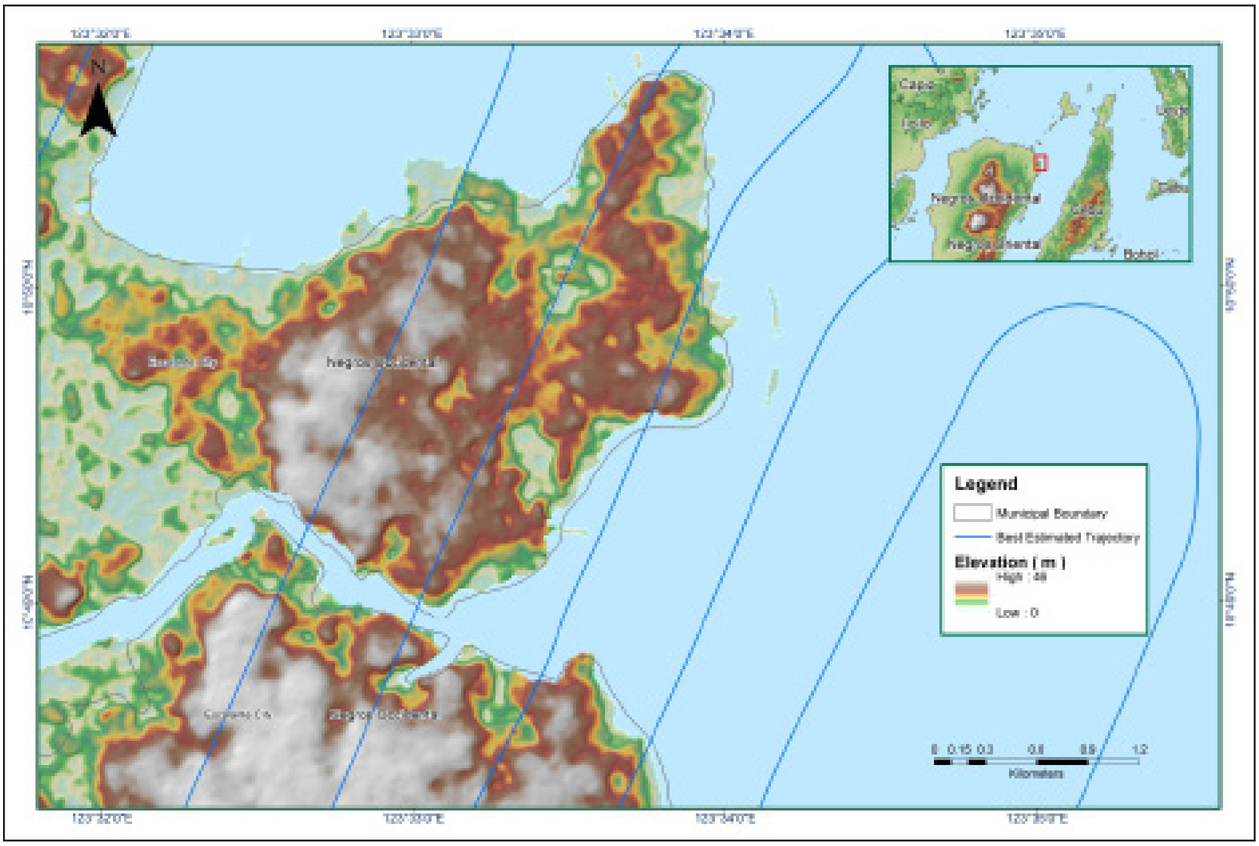


Figure A-8.24. Best Estimated Trajectory

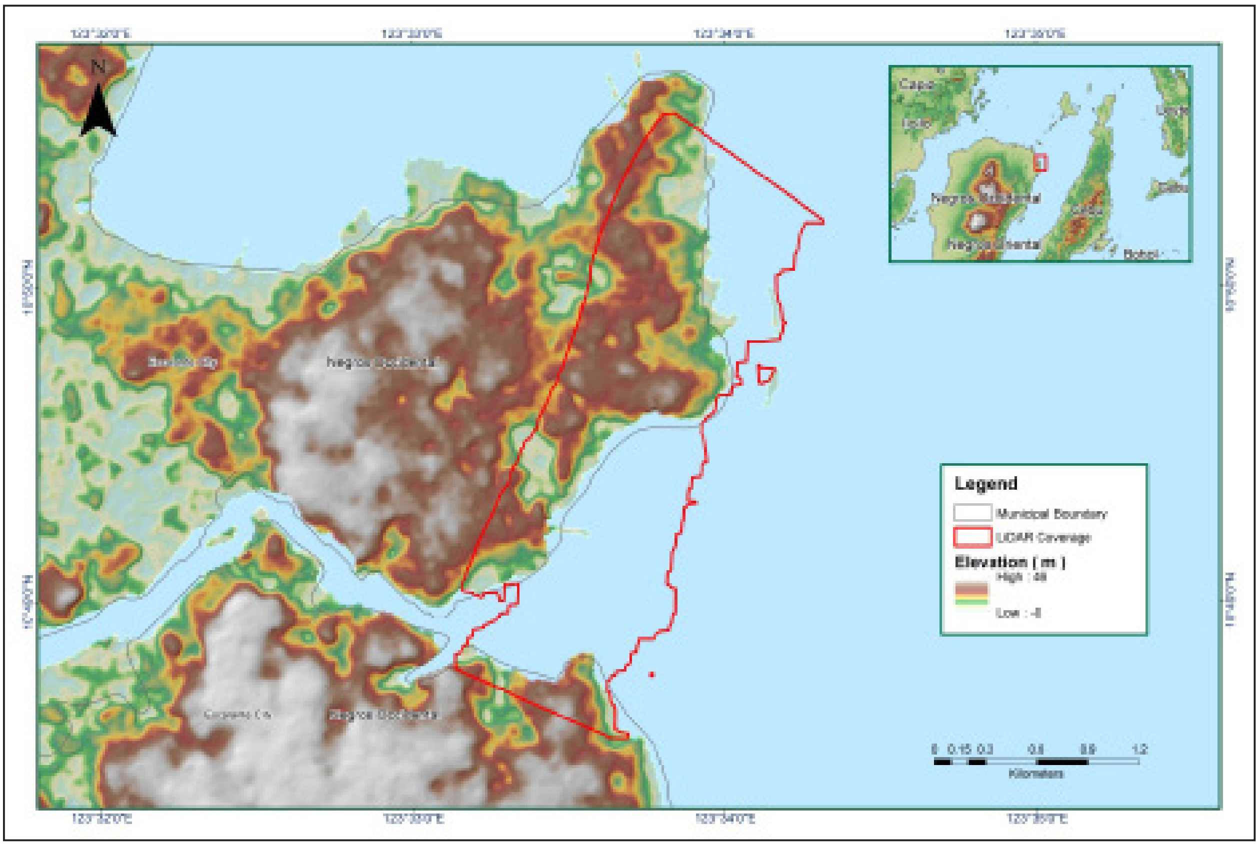


Figure A-8.25. Coverage of LiDAR data

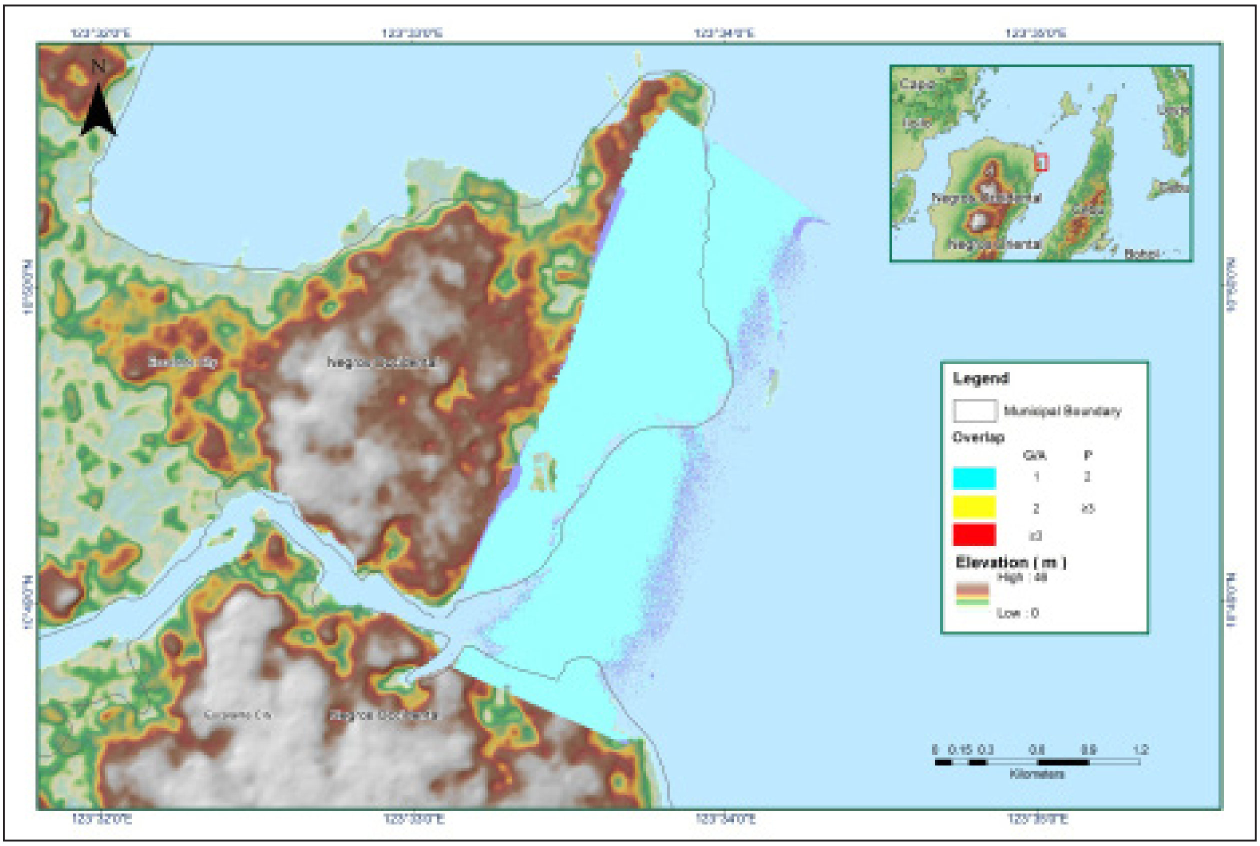


Figure A-8.26. Image of data overlap

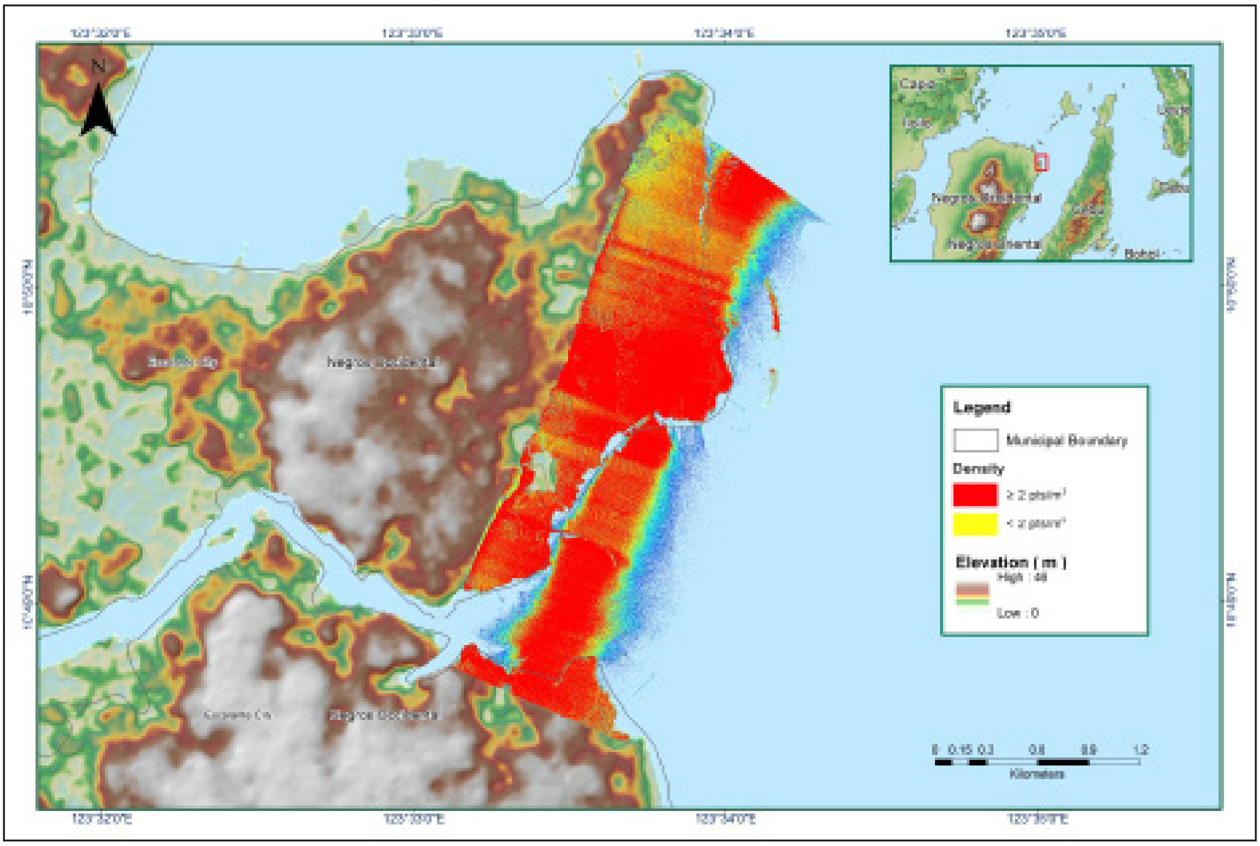


Figure A-8.27. Density map of merged LiDAR data

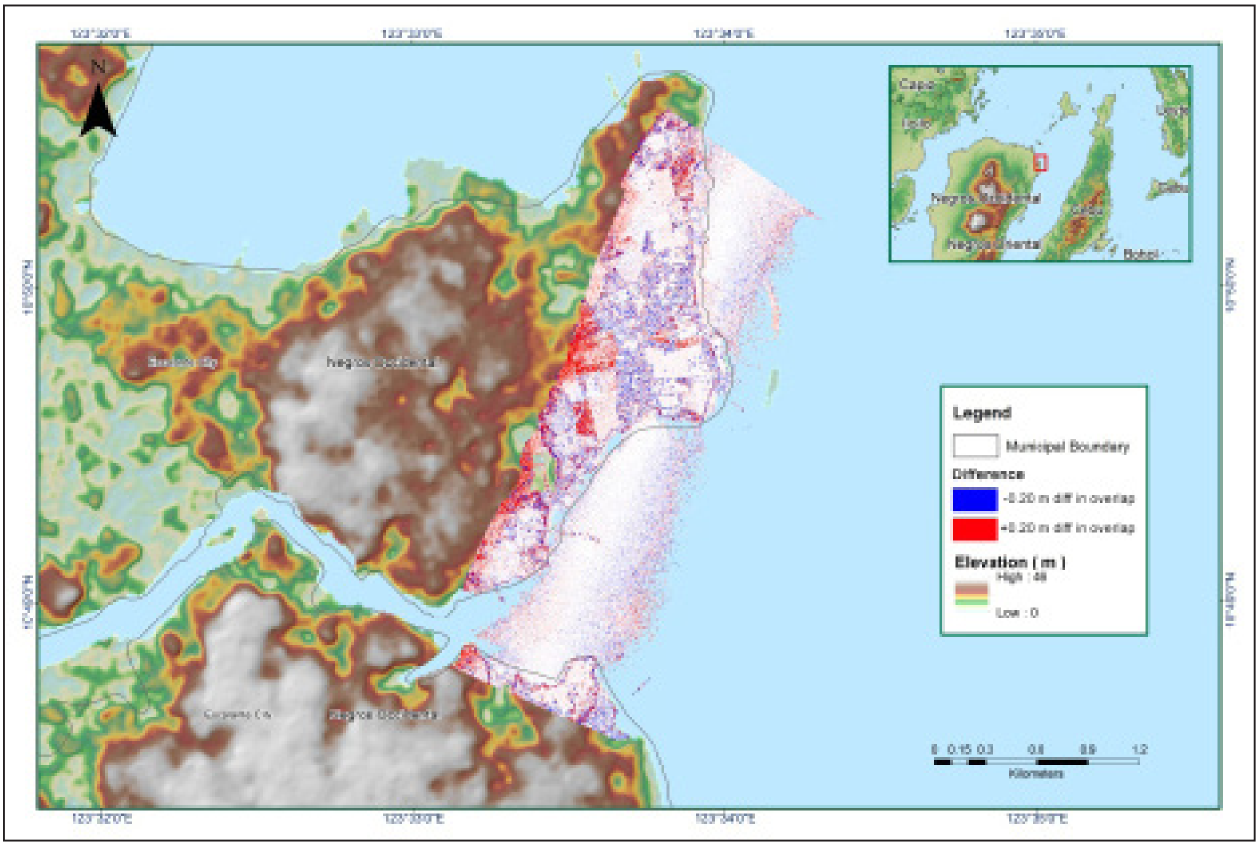


Figure A-8.28. Elevation difference between flight lines

Flight Area	Bacolod
Mission Name	Block 44E
Inclusive Flights	8453AC
Range data size	13.9 GB
POS data size	246 MB
Base data size	99.1 MB
Image	n/a
Transfer date	May 20, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.002
RMSE for East Position (<4.0 cm)	1.603
RMSE for Down Position (<8.0 cm)	5.037
Boresight correction stdev (<0.001deg)	0.000258
IMU attitude correction stdev (<0.001deg)	0.000791
GPS position stdev (<0.01m)	0.0016
Minimum % overlap (>25)	30.04
Ave point cloud density per sq.m. (>2.0)	3.95
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	139
Maximum Height	578.38
Minimum Height	60.03
Classification (# of points)	
Ground	93,527,454
Low vegetation	98,324,857
Medium vegetation	111,788,117
High vegetation	66,668,017
Building	3,363,991
Orthophoto	None
Processed by	Engr. Merven Matthew Natino, Engr. Elainne Lopez

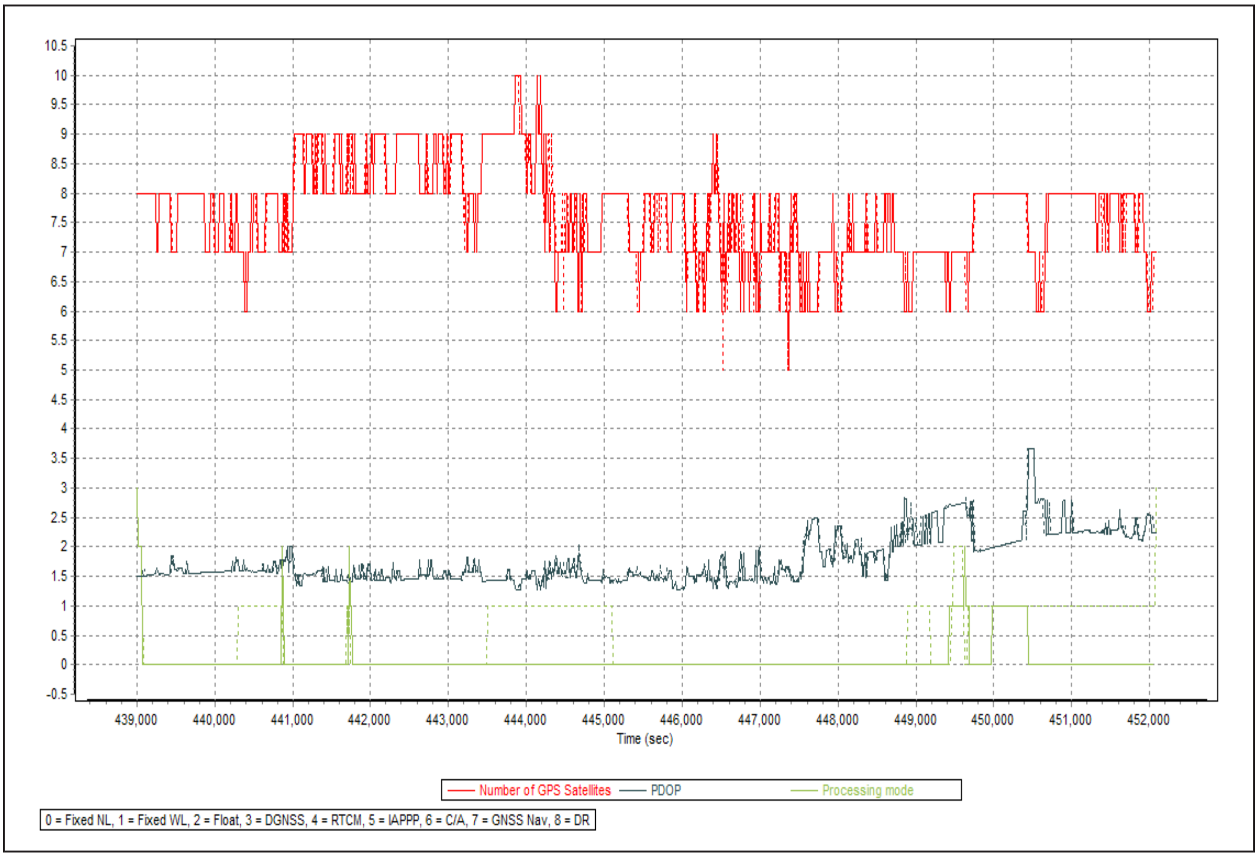


Figure A-8.29. Solution Status

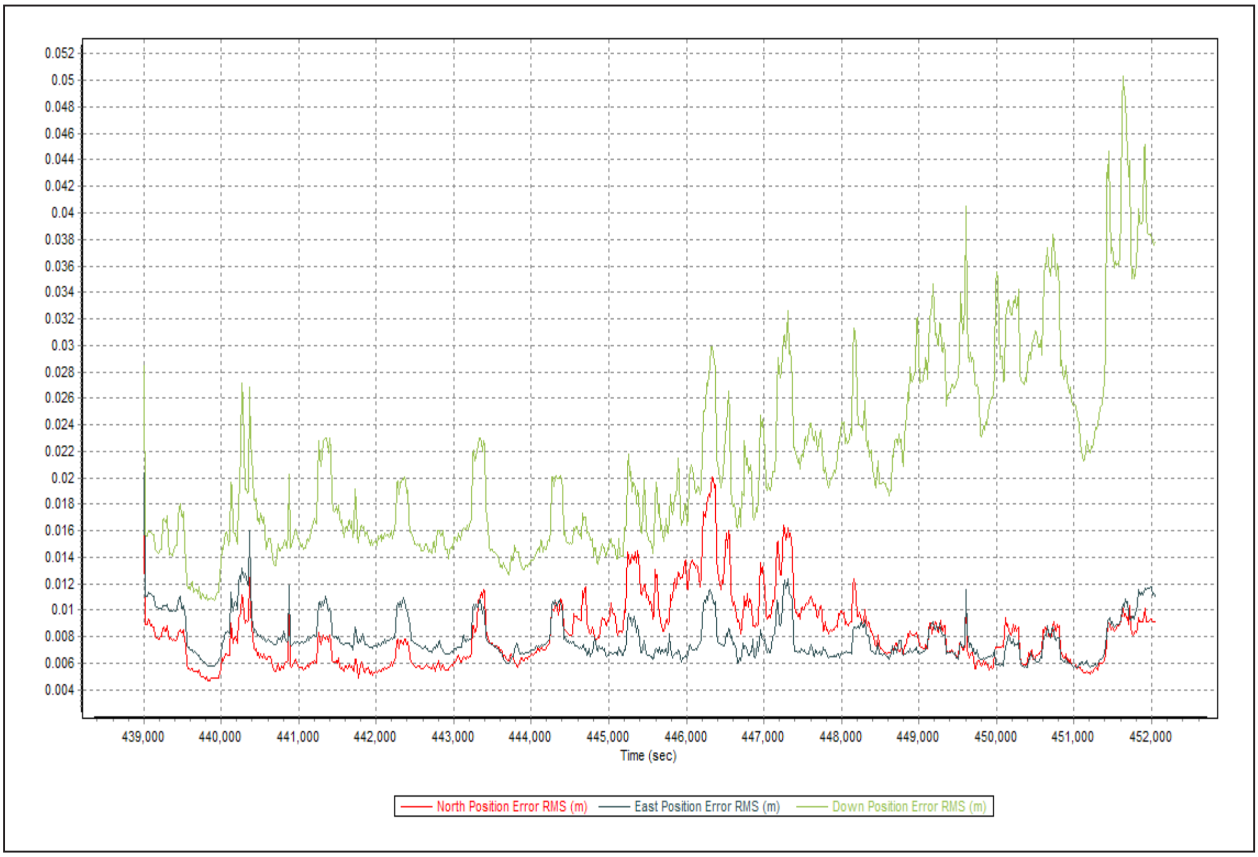


Figure A-8.30. Smoothed Performance Metric Parameters

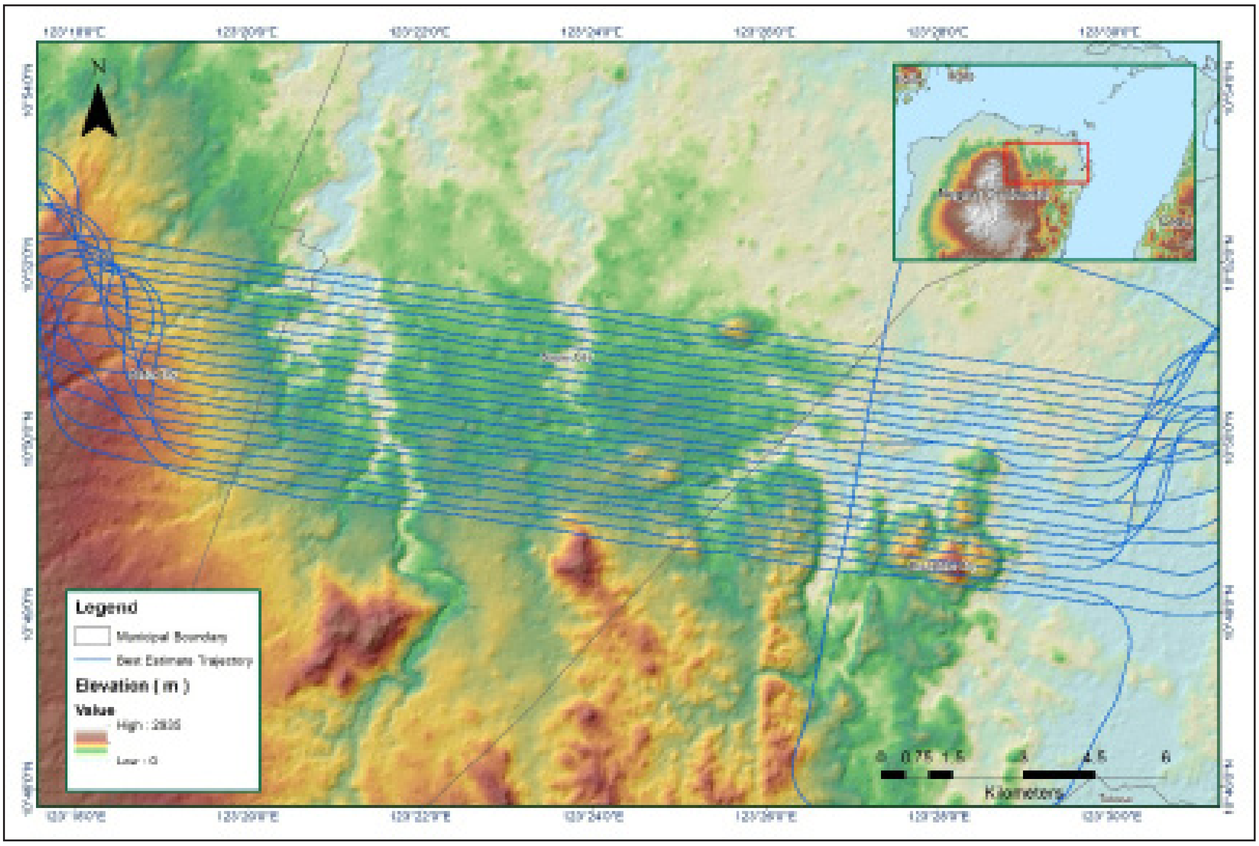


Figure A-8.31. Best Estimated Trajectory

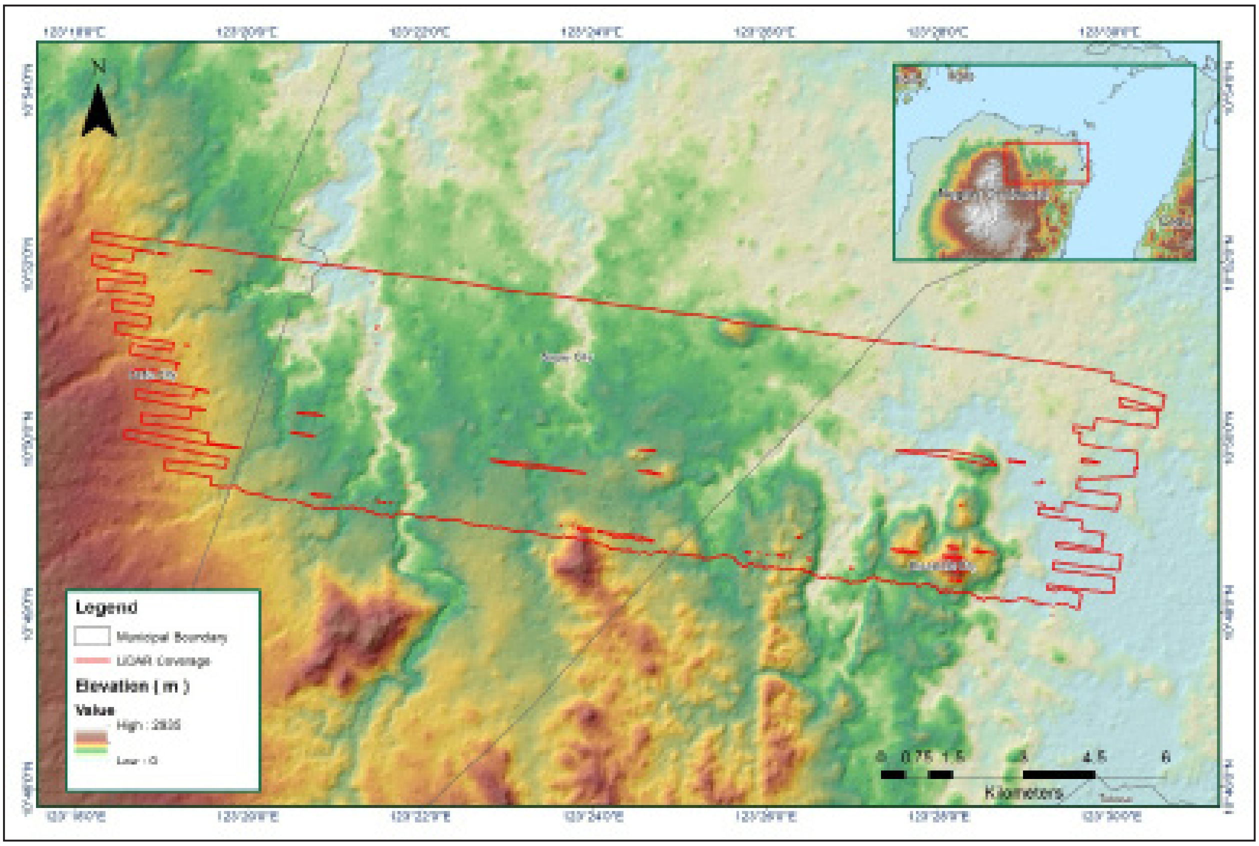


Figure A-8.32. Coverage of LiDAR data

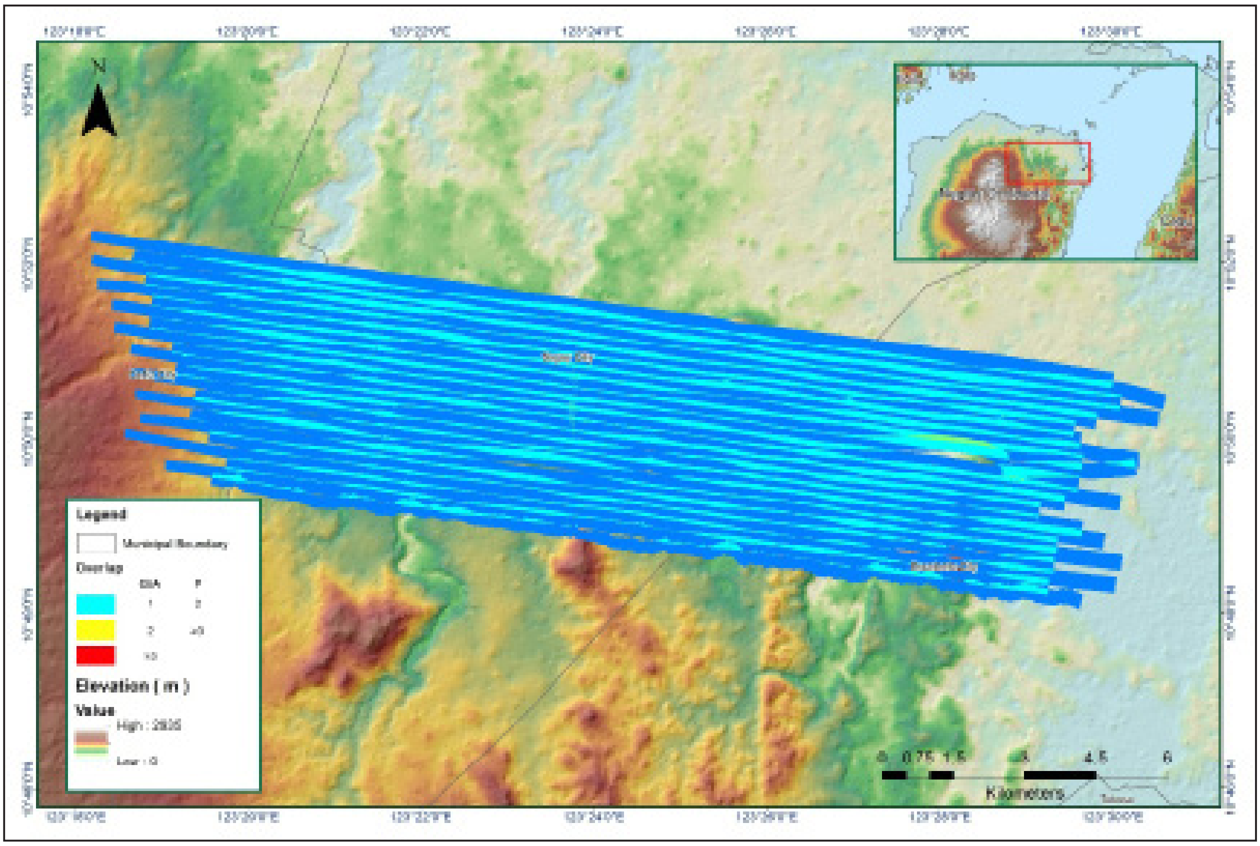


Figure A-8.33. Image of data overlap

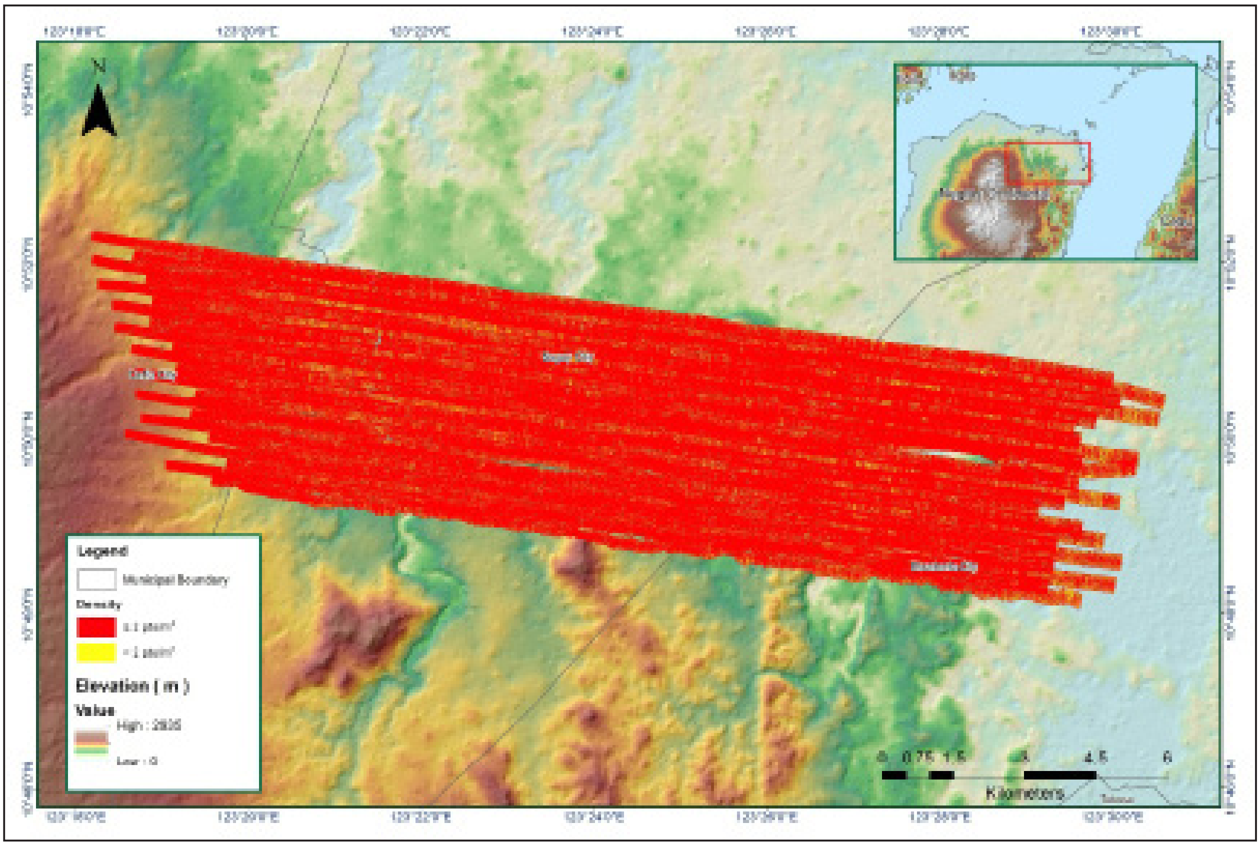


Figure A-8.34. Density map of merged LiDAR data

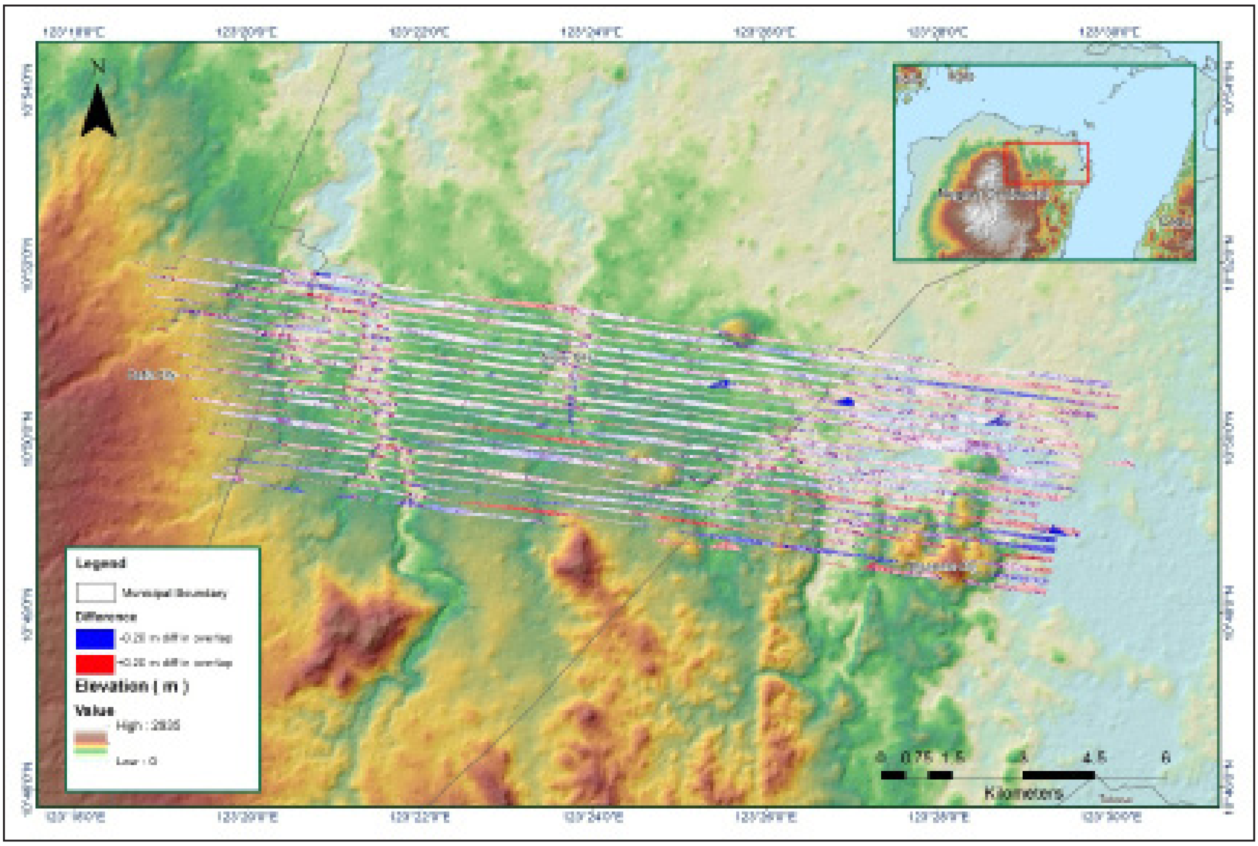


Figure A-8.35. Elevation difference between flight lines

Flight Area	Bacolod
Mission Name	Block 44E additional
Inclusive Flights	8455AC
Range data size	10.2 GB
POS data size	233 MB
Base data size	91 MB
Image	38.5 GB
Transfer date	May 20, 2016
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)	1.245
RMSE for East Position (<4.0 cm)	1.87
RMSE for Down Position (<8.0 cm)	4.065
Boresight correction stdev (<0.001deg)	0.000218
IMU attitude correction stdev (<0.001deg)	0.004166
GPS position stdev (<0.01m)	0.0027
Minimum % overlap (>25)	41.20
Ave point cloud density per sq.m. (>2.0)	4.92
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	120
Maximum Height	387.49
Minimum Height	59.77
Classification (# of points)	
Ground	53,625,771
Low vegetation	63,815,686
Medium vegetation	72,382,824
High vegetation	55,860,054
Building	2,859,236
Orthophoto	None
Processed by	Engr. Sheila Maye Santillan, Engr. Edgardo Gubatanga, Jr., Engr. Melissa Fernandez

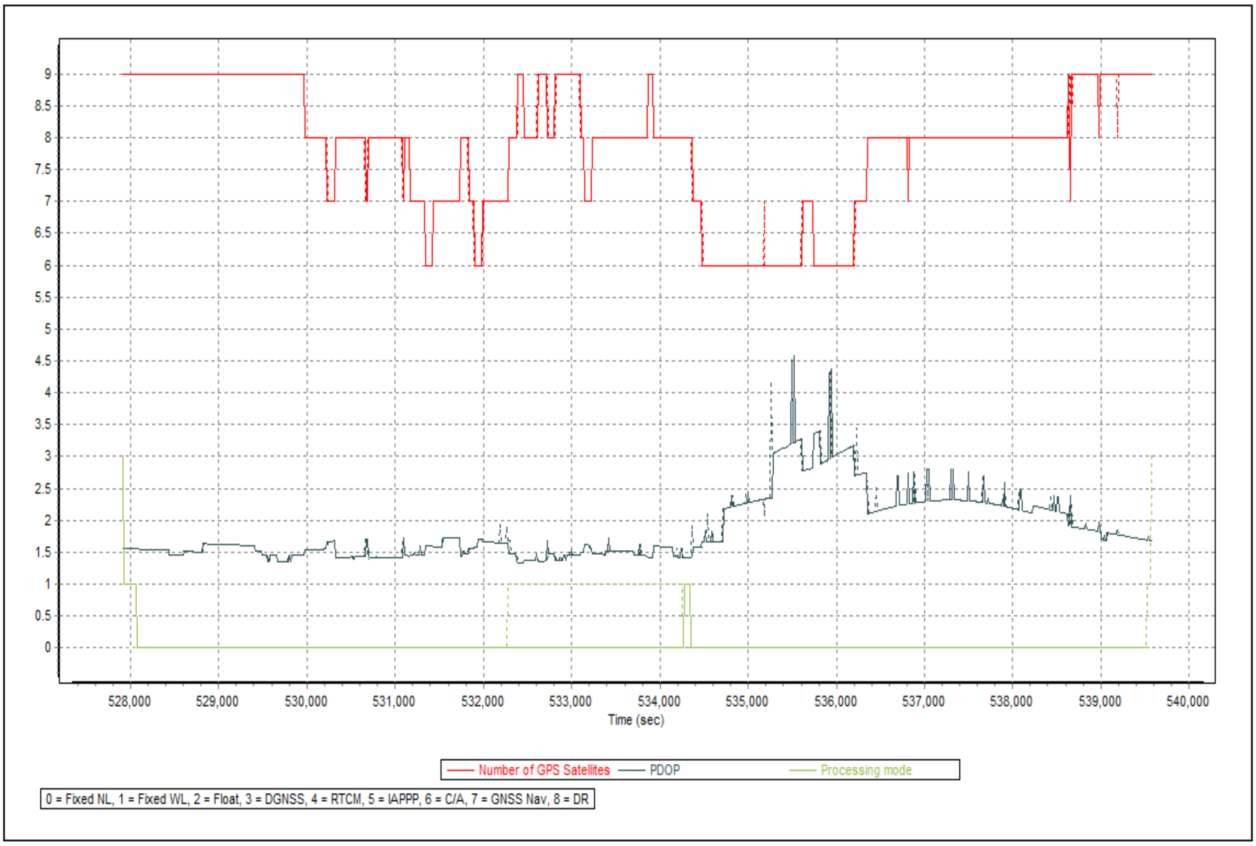


Figure A-8.36. Solution Status

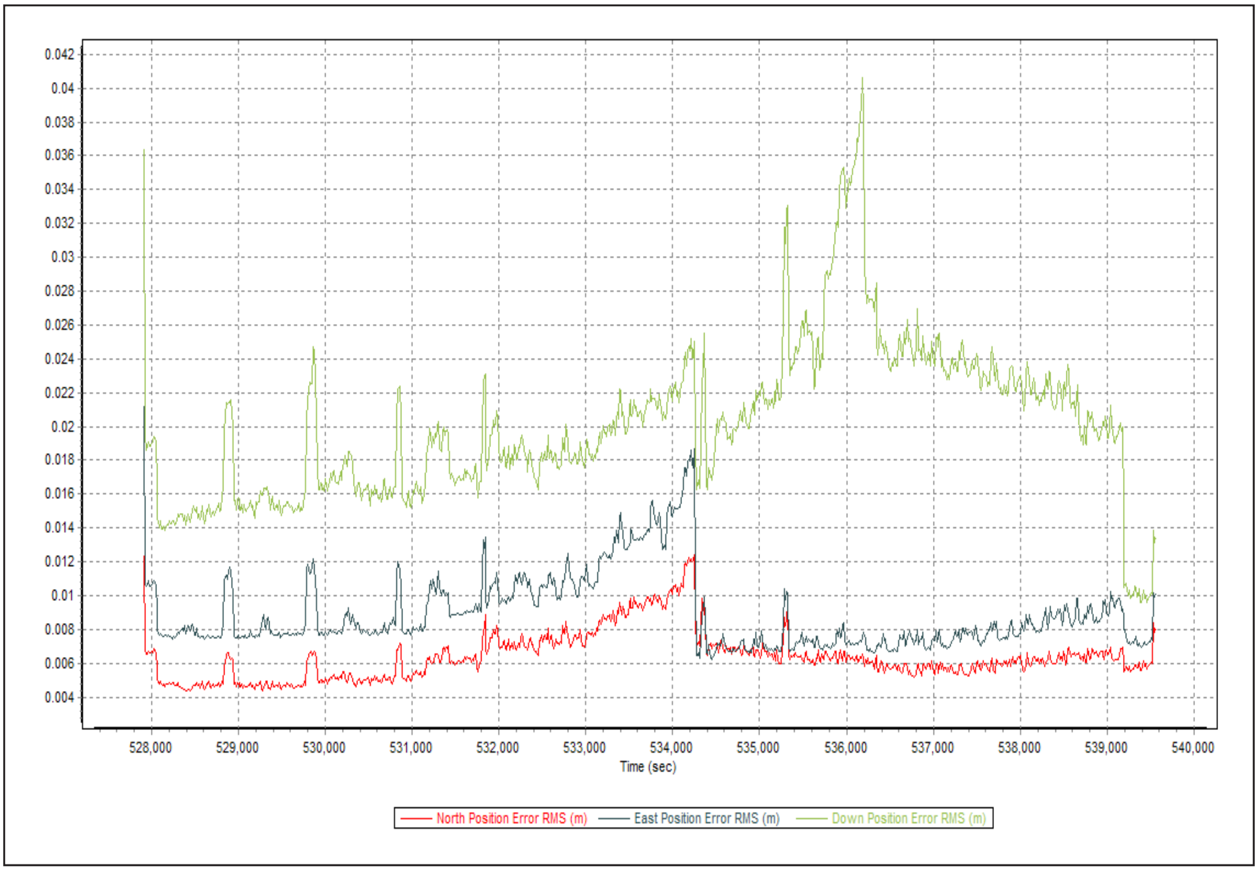


Figure A-8.37. Smoothed Performance Metric Parameters

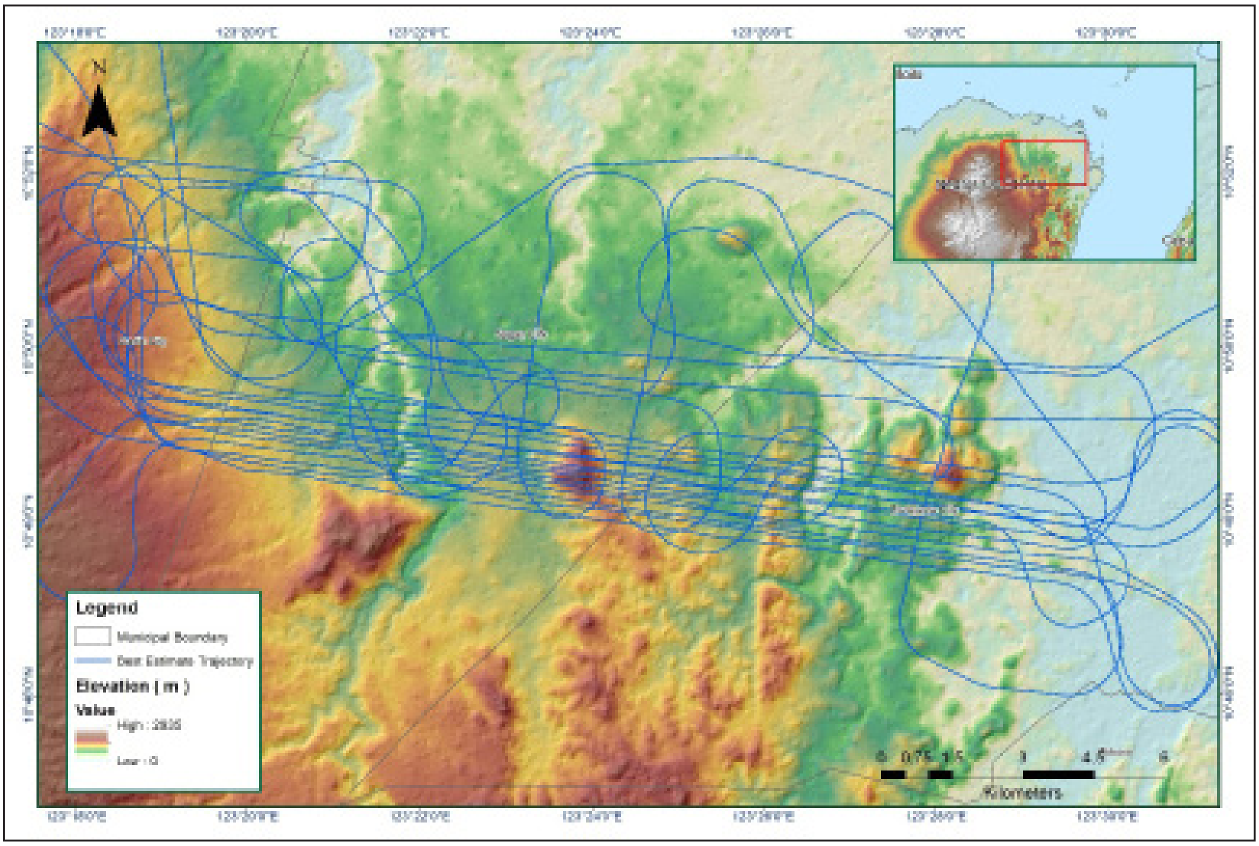


Figure A-8.38. Best Estimated Trajectory

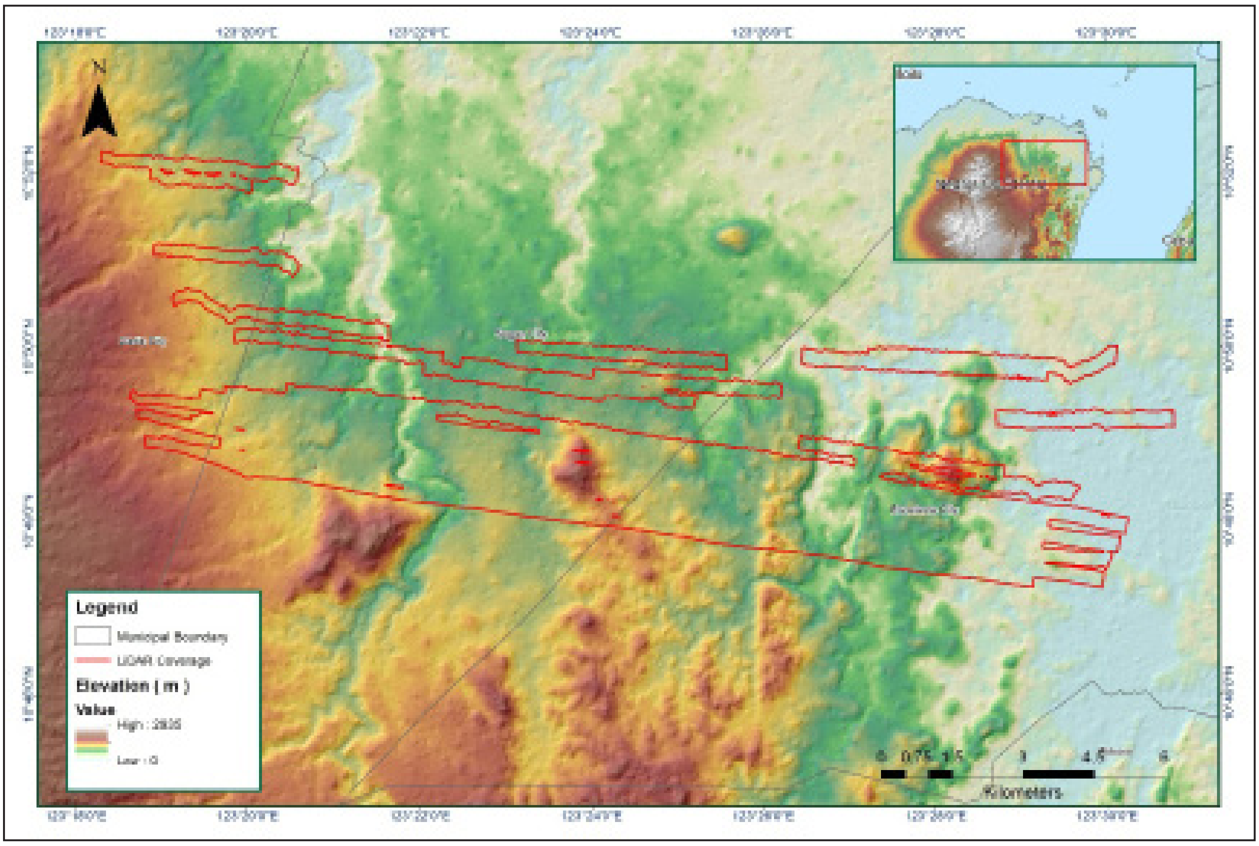


Figure A-8.39. Coverage of LiDAR data

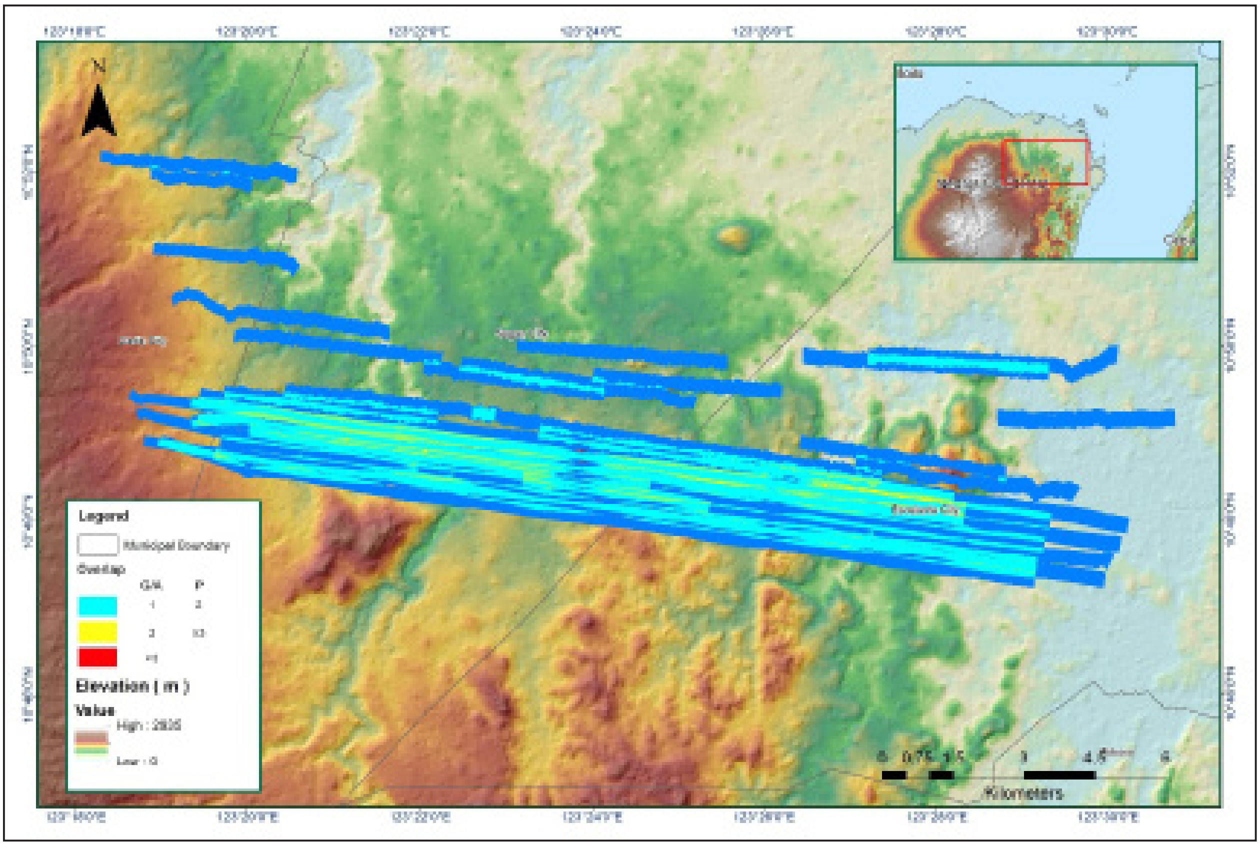


Figure A-8.40. Image of data overlap

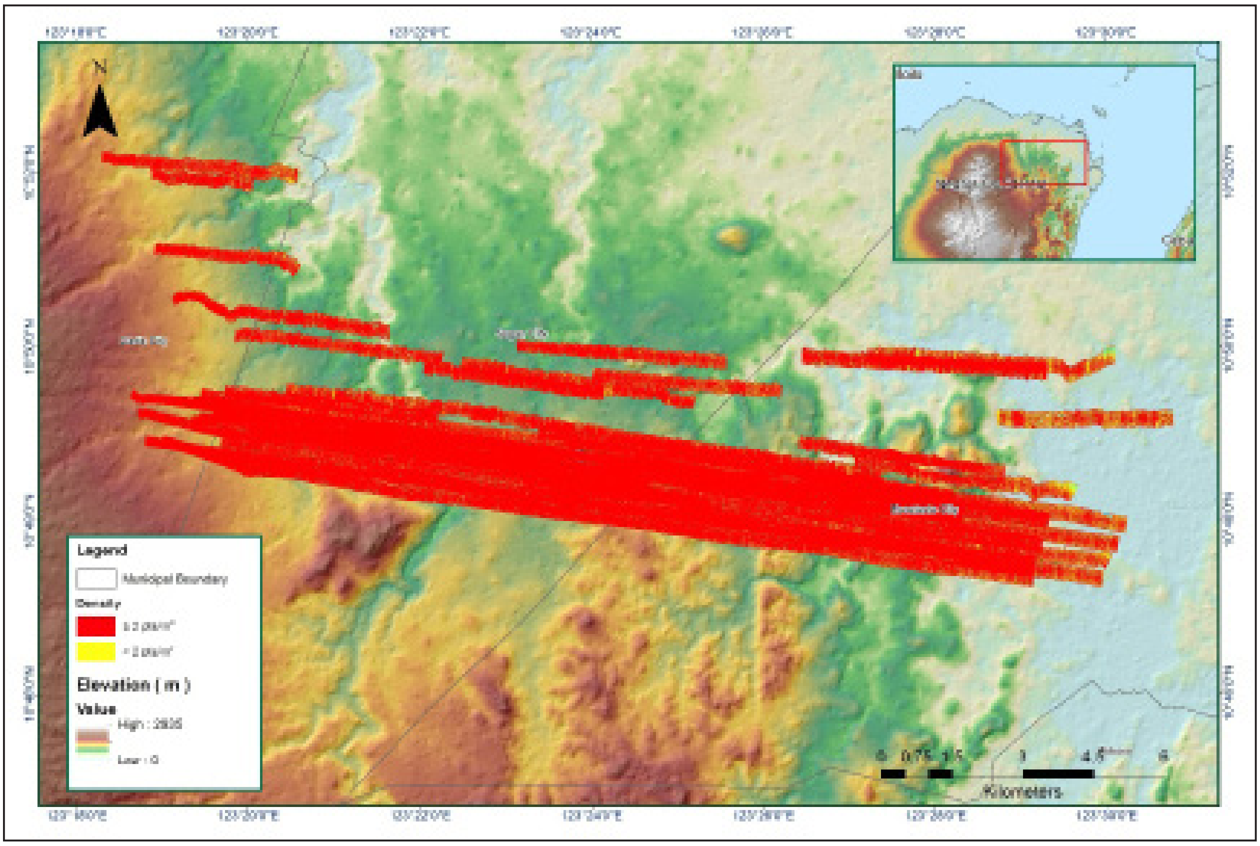


Figure A-8.41. Density map of merged LiDAR data

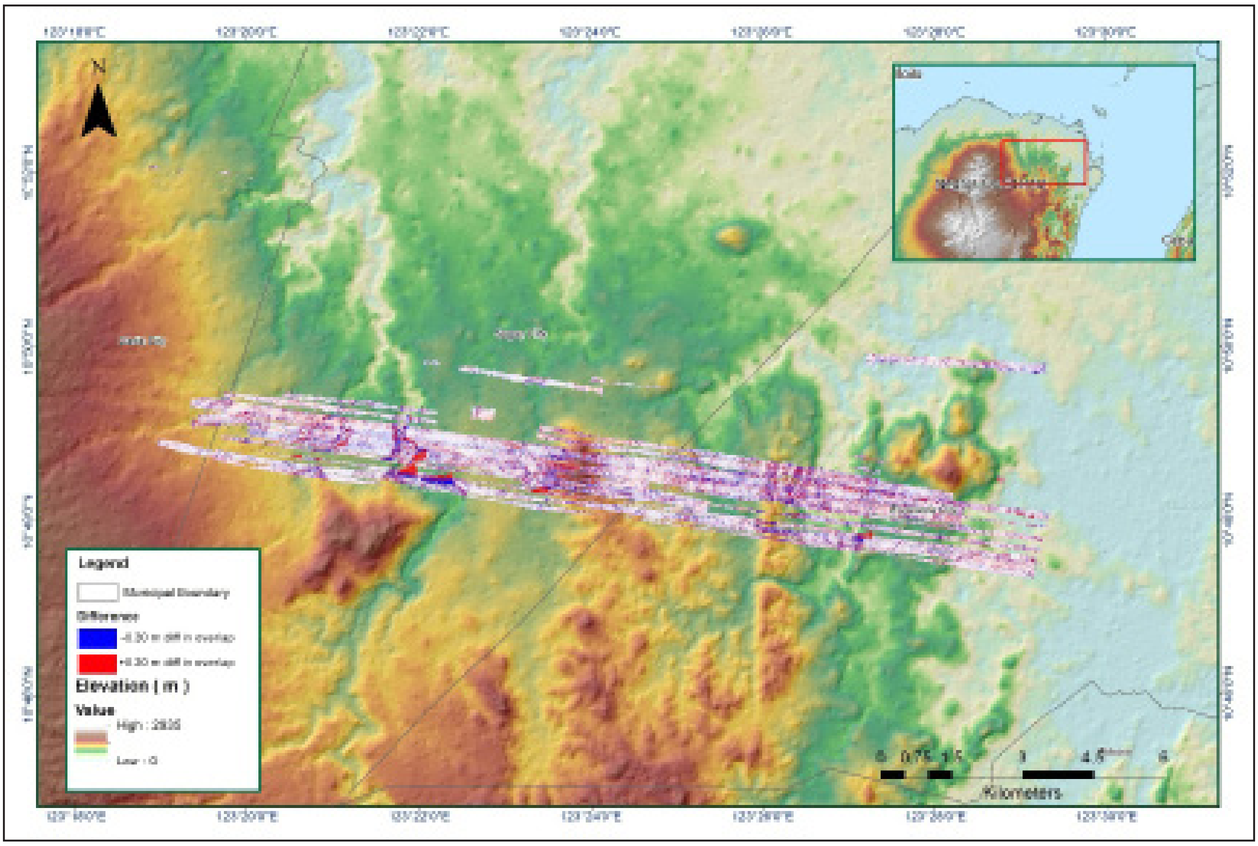


Figure A-8.42. Elevation difference between flight lines

Flight Area	Bacolod
Mission Name	Block 44N
Inclusive Flights	8459AC
Range data size	10.3 GB
POS data size	262 MB
Base data size	100 MB
Image	43.4 GB
Transfer date	May 20, 2016
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)	1.187
RMSE for East Position (<4.0 cm)	1.335
RMSE for Down Position (<8.0 cm)	5.753
Boresight correction stdev (<0.001deg)	0.000681
IMU attitude correction stdev (<0.001deg)	0.001561
GPS position stdev (<0.01m)	0.0236
Minimum % overlap (>25)	28.22
Ave point cloud density per sq.m. (>2.0)	1.99
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	55
Maximum Height	90.5
Minimum Height	46.36
Classification (# of points)	
Ground	21,396,247
Low vegetation	24,744,856
Medium vegetation	5,591,555
High vegetation	4,736,946
Building	1,212,863
Orthophoto	None
Processed by	Engr. Analyn Naldo, Engr. Edgardo Gubatanga, Jr., Vincent Louise Azucena

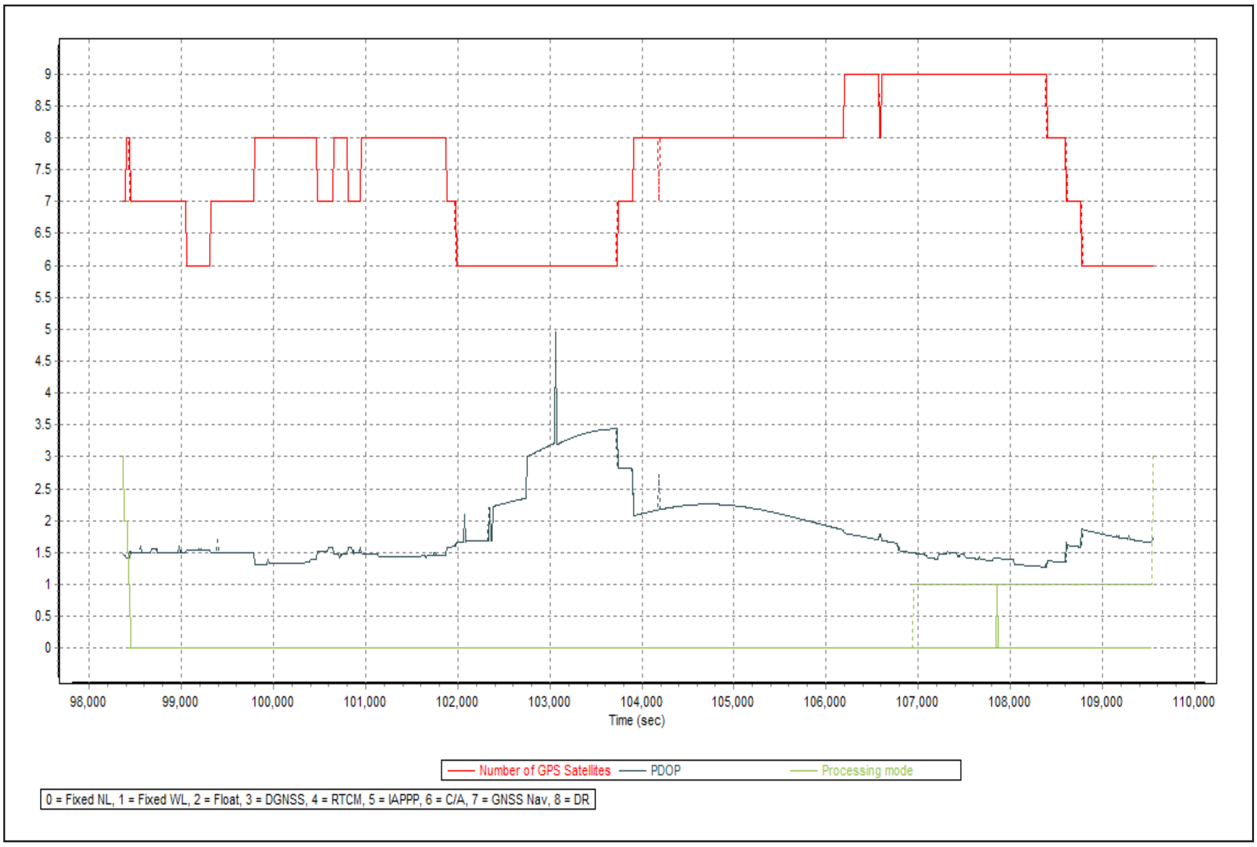


Figure A-8.43. Solution Status

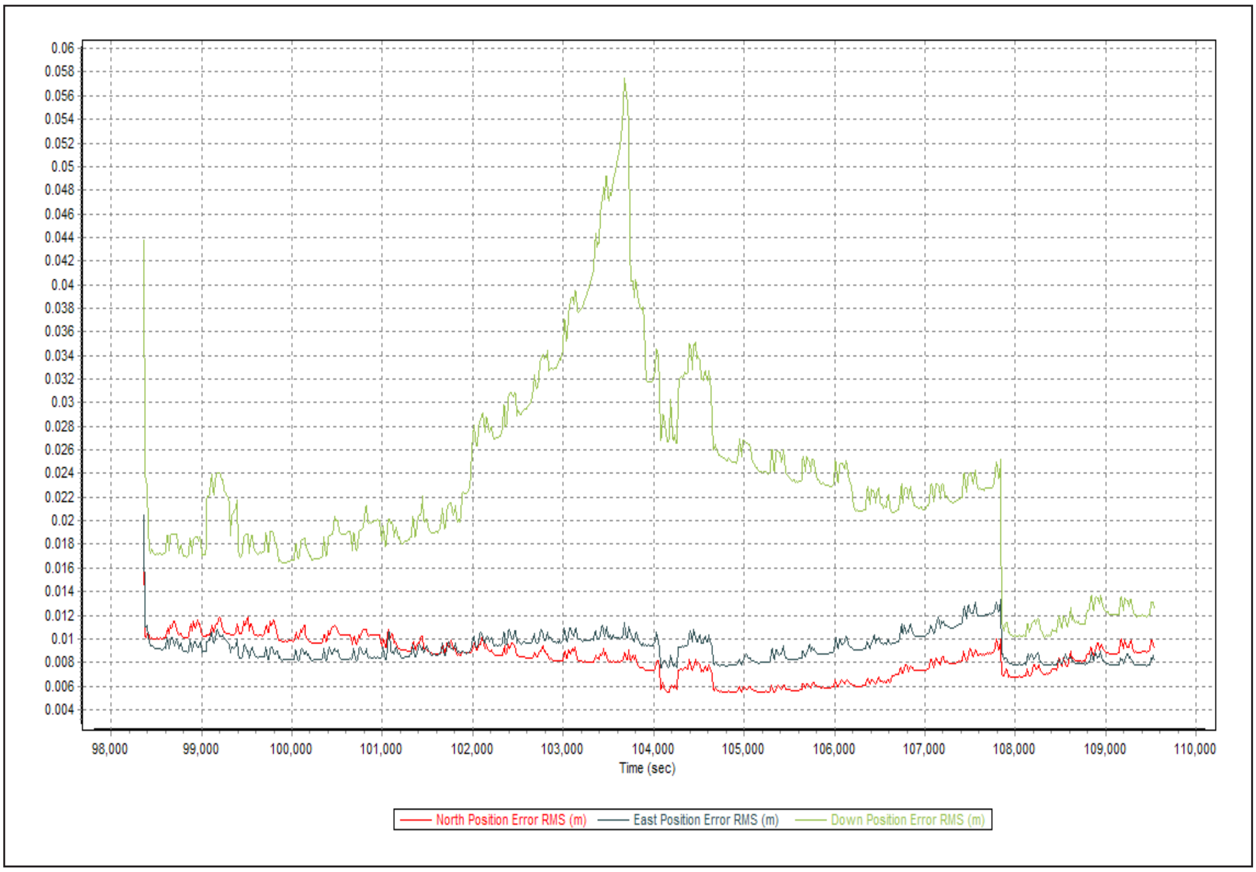


Figure A-8.44. Smoothed Performance Metric Parameters

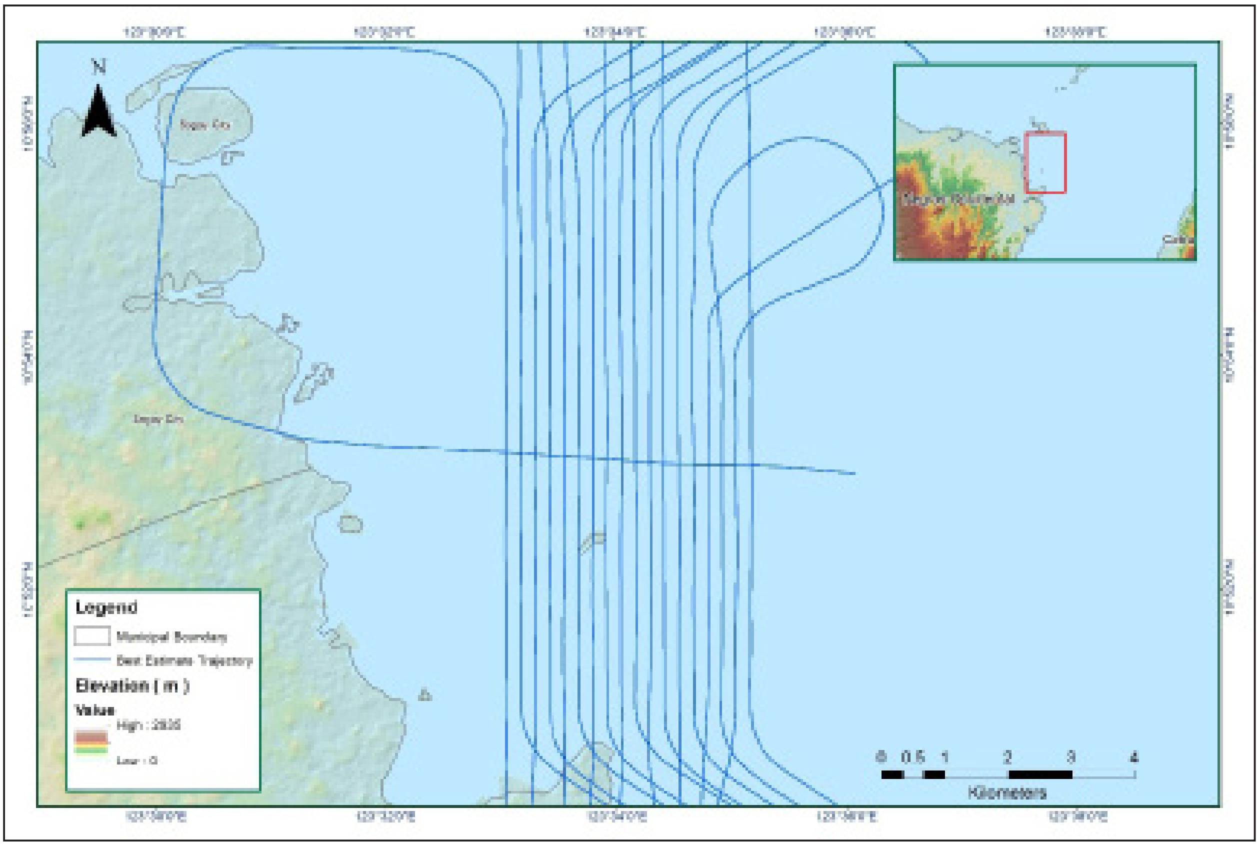


Figure A-8.45. Best Estimated Trajectory

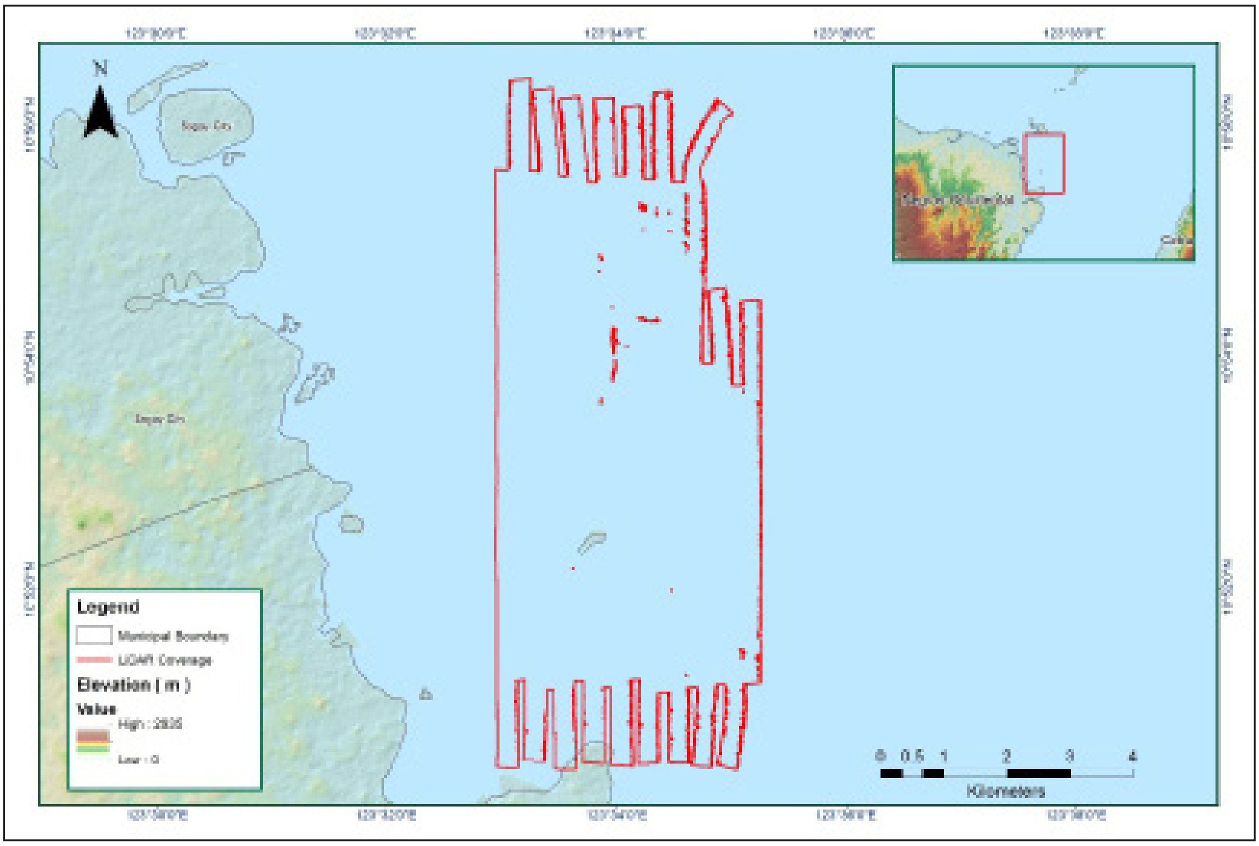


Figure A-8.46. Coverage of LiDAR data

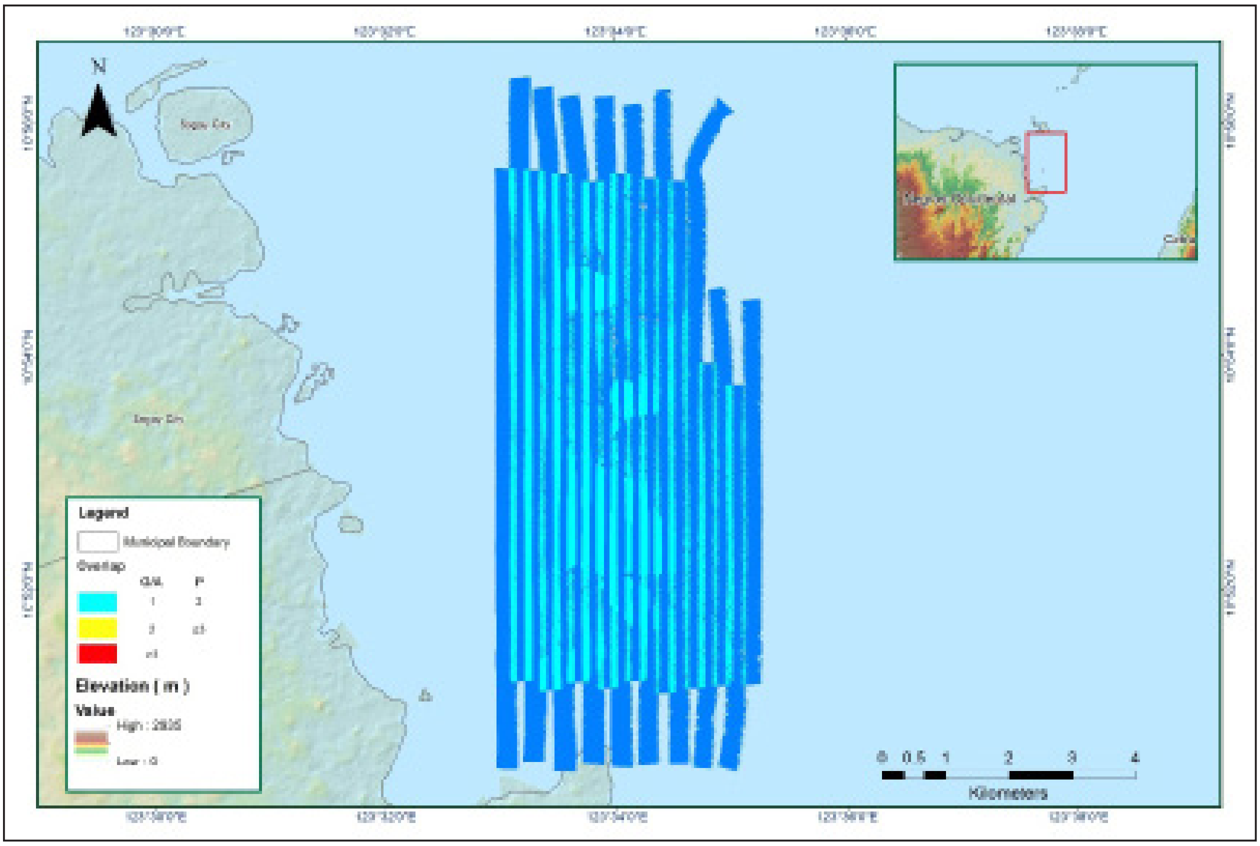


Figure A-8.47. Image of data overlap

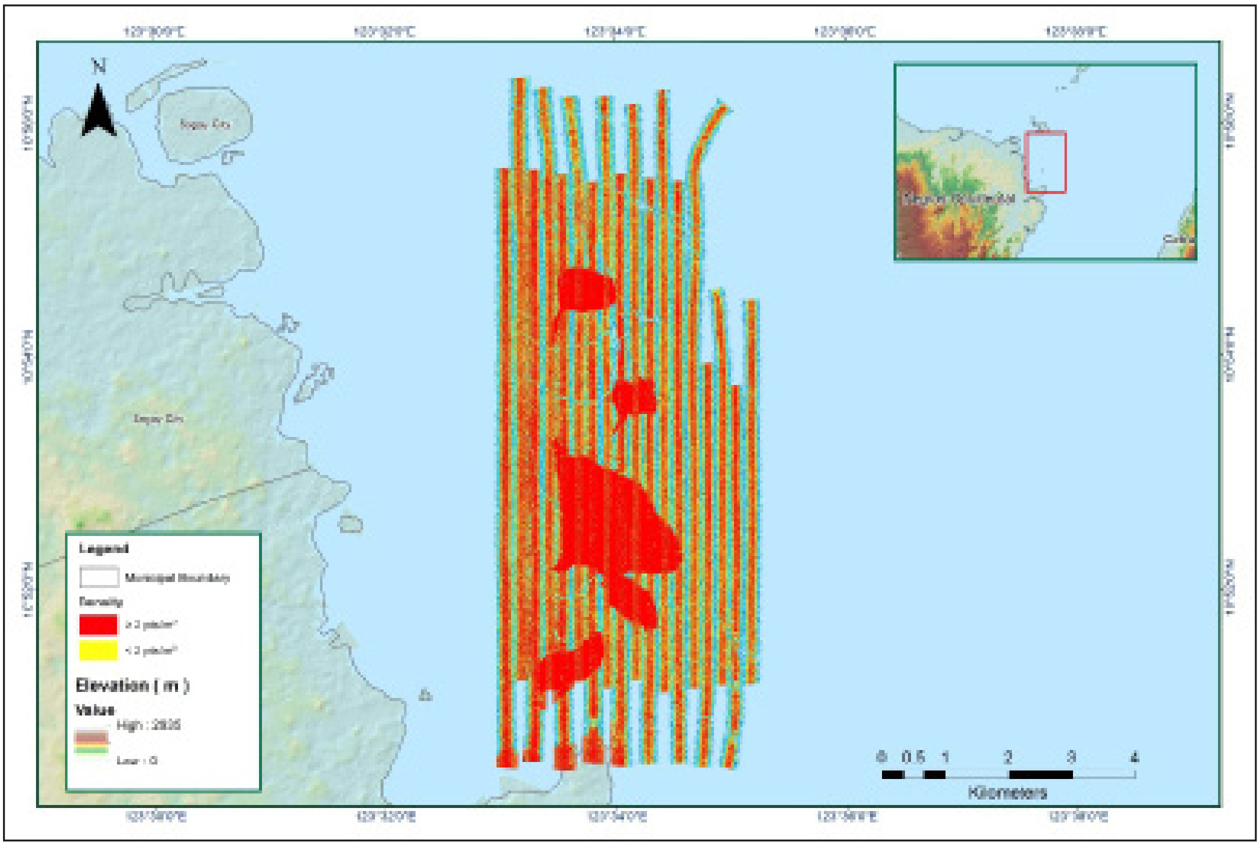


Figure A-8.48. Density map of merged LiDAR data

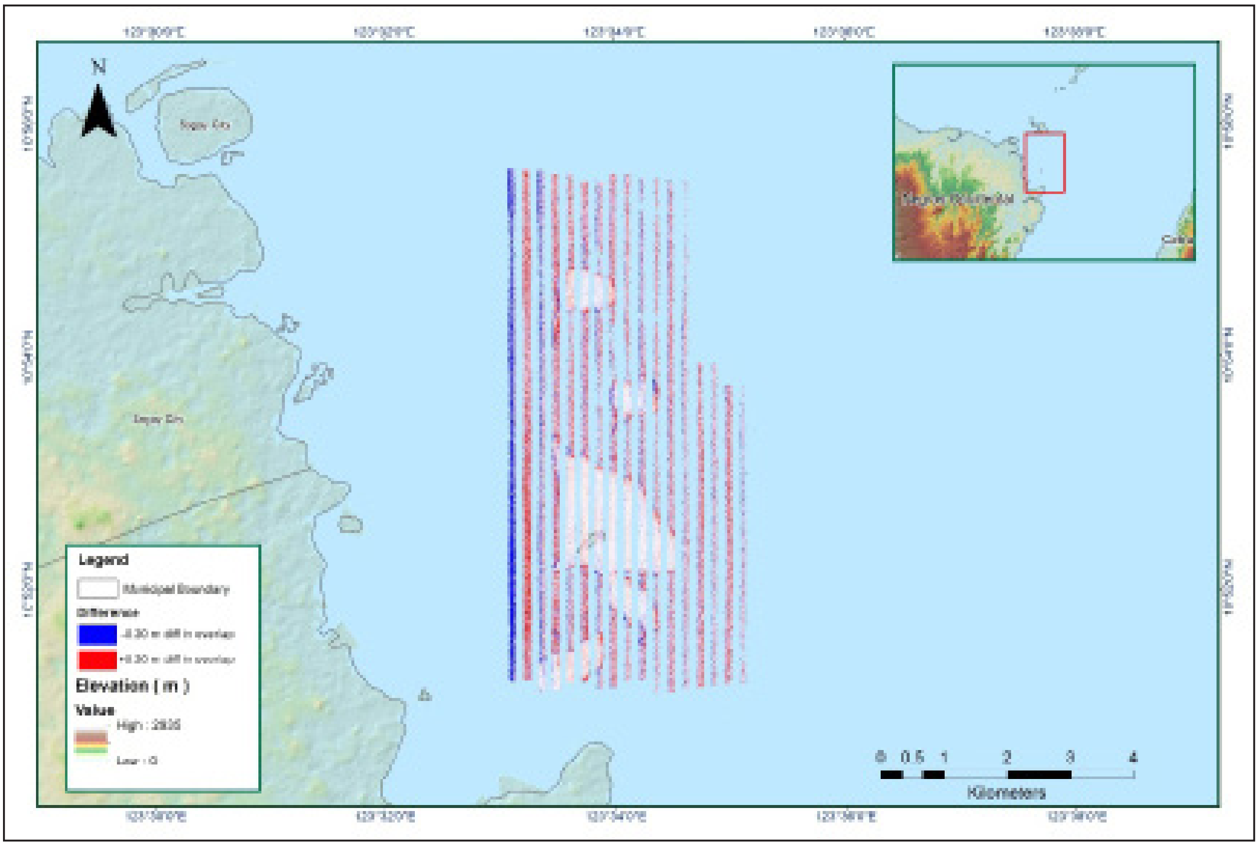


Figure A-8.49. Elevation difference between flight lines

Flight Area	Bacolod
Mission Name	Block 44O
Inclusive Flights	8462AC, 8464AC
Range data size	8.59 GB
POS data size	229 MB
Base data size	158
Image	37.4
Transfer date	May 20, 2016
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.538
RMSE for East Position (<4.0 cm)	1.988
RMSE for Down Position (<8.0 cm)	2.182
Boresight correction stdev (<0.001deg)	0.001075
IMU attitude correction stdev (<0.001deg)	0.013656
GPS position stdev (<0.01m)	0.0198
Minimum % overlap (>25)	35.11
Ave point cloud density per sq.m. (>2.0)	2.65
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	54
Maximum Height	99.71
Minimum Height	46.63
Classification (# of points)	
Ground	21,008,187
Low vegetation	24,468,742
Medium vegetation	10,068,347
High vegetation	11,353,680
Building	1,122,601
Orthophoto	None
Processed by	Engr. Kenneth Solidum, Engr. Harmond Santos, Engr. Gladys Mae Apat

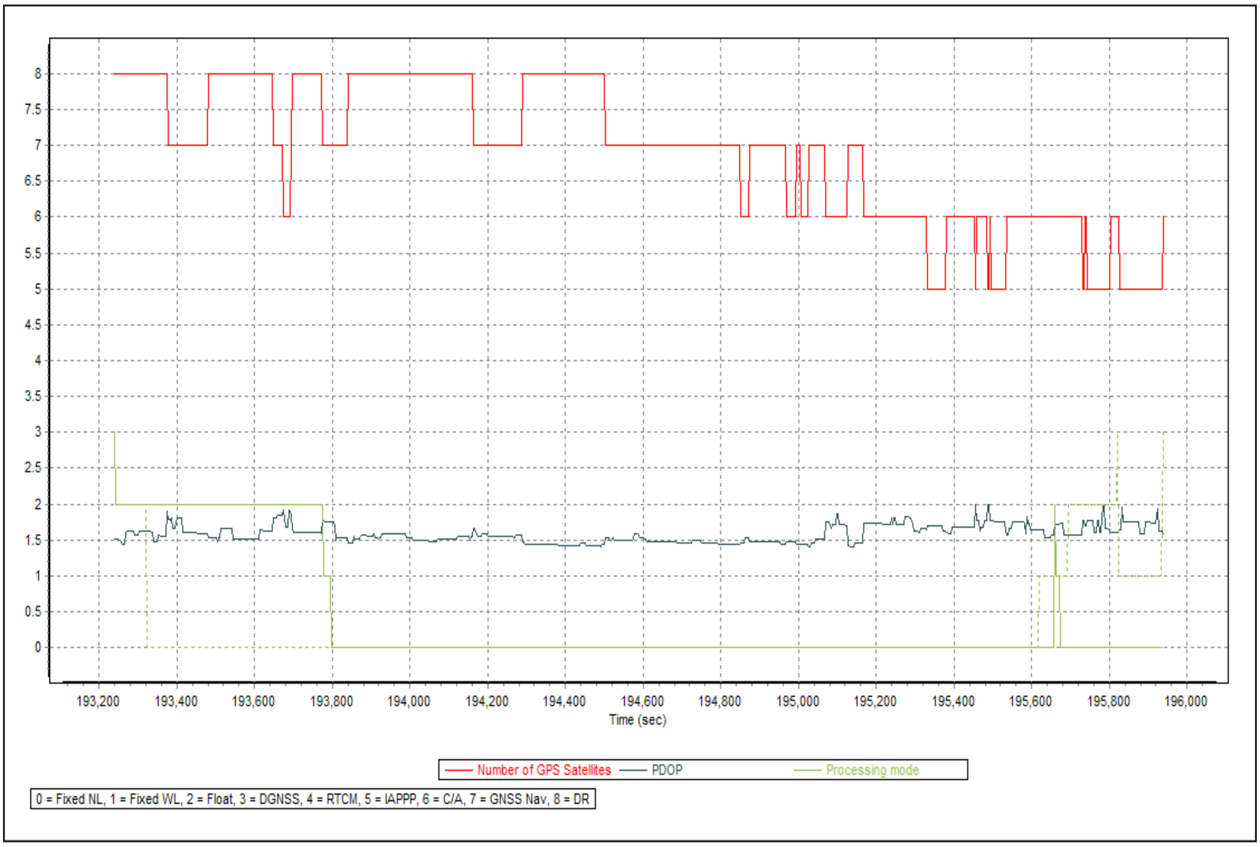


Figure A-8.50. Solution Status

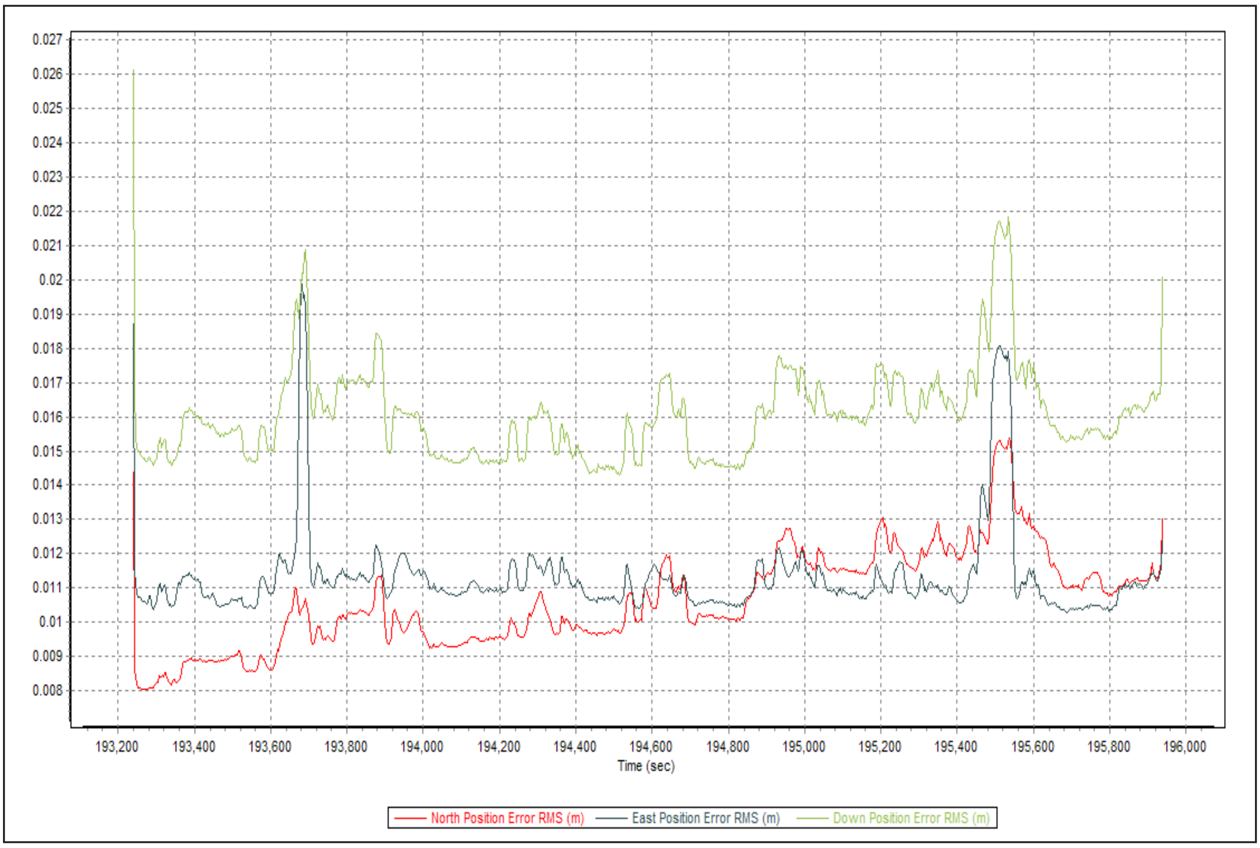


Figure A-8.51. Smoothed Performance Metric Parameters

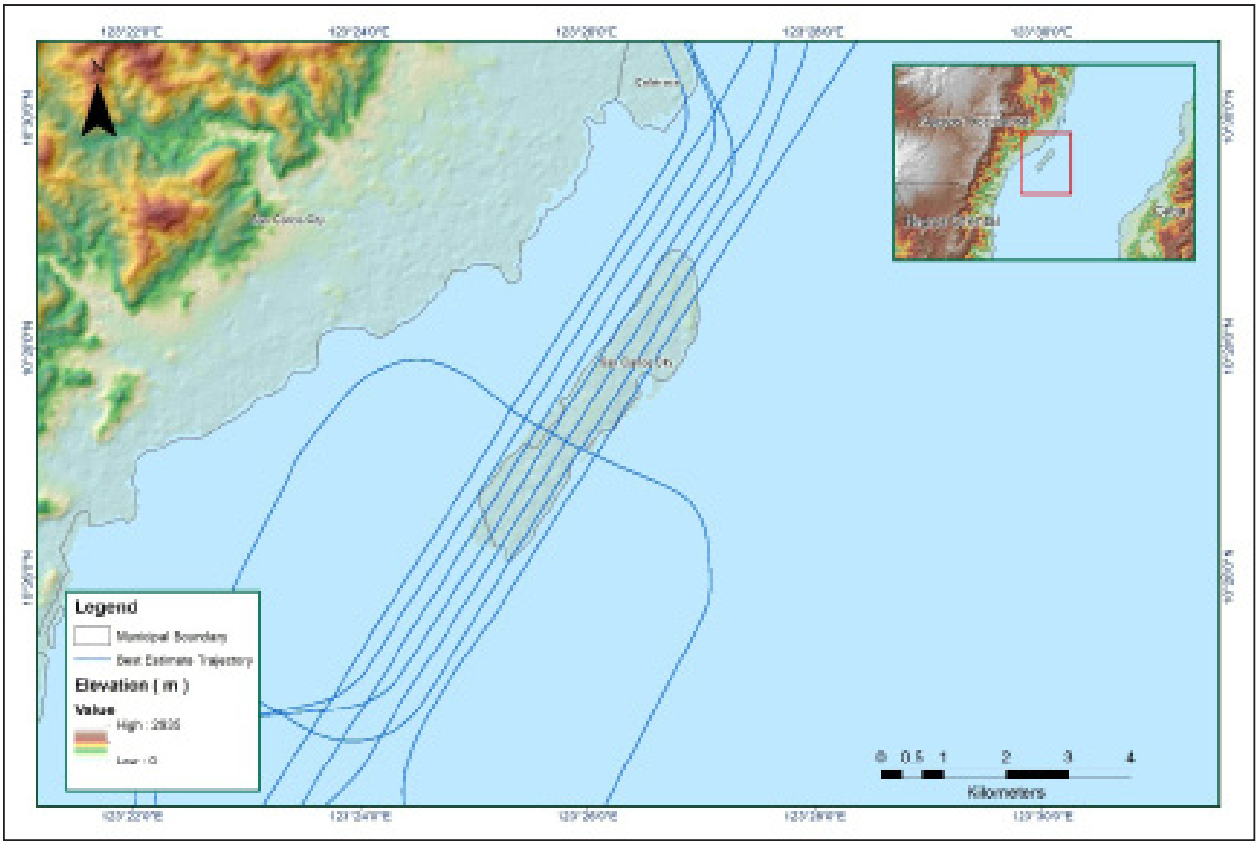


Figure A-8.52. Best Estimated Trajectory

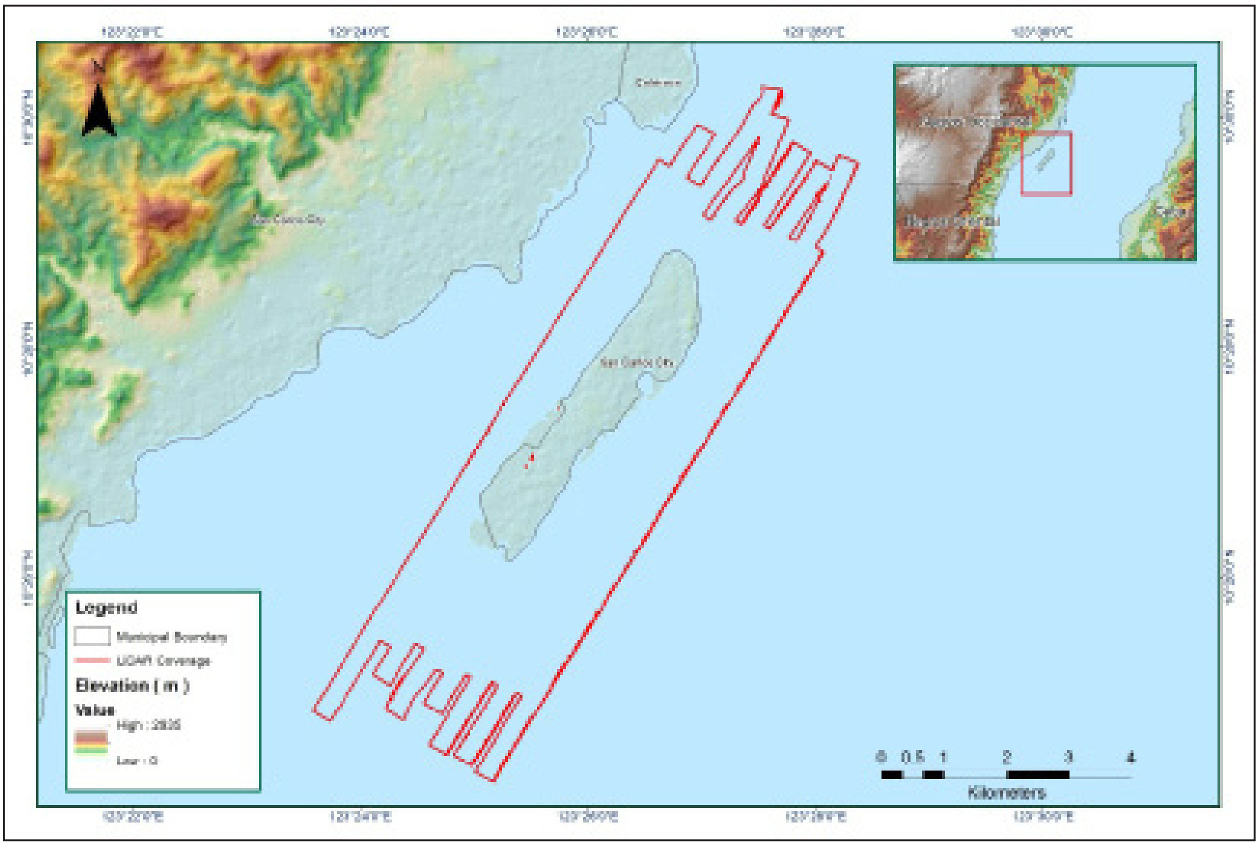


Figure A-8.53. Coverage of LiDAR data

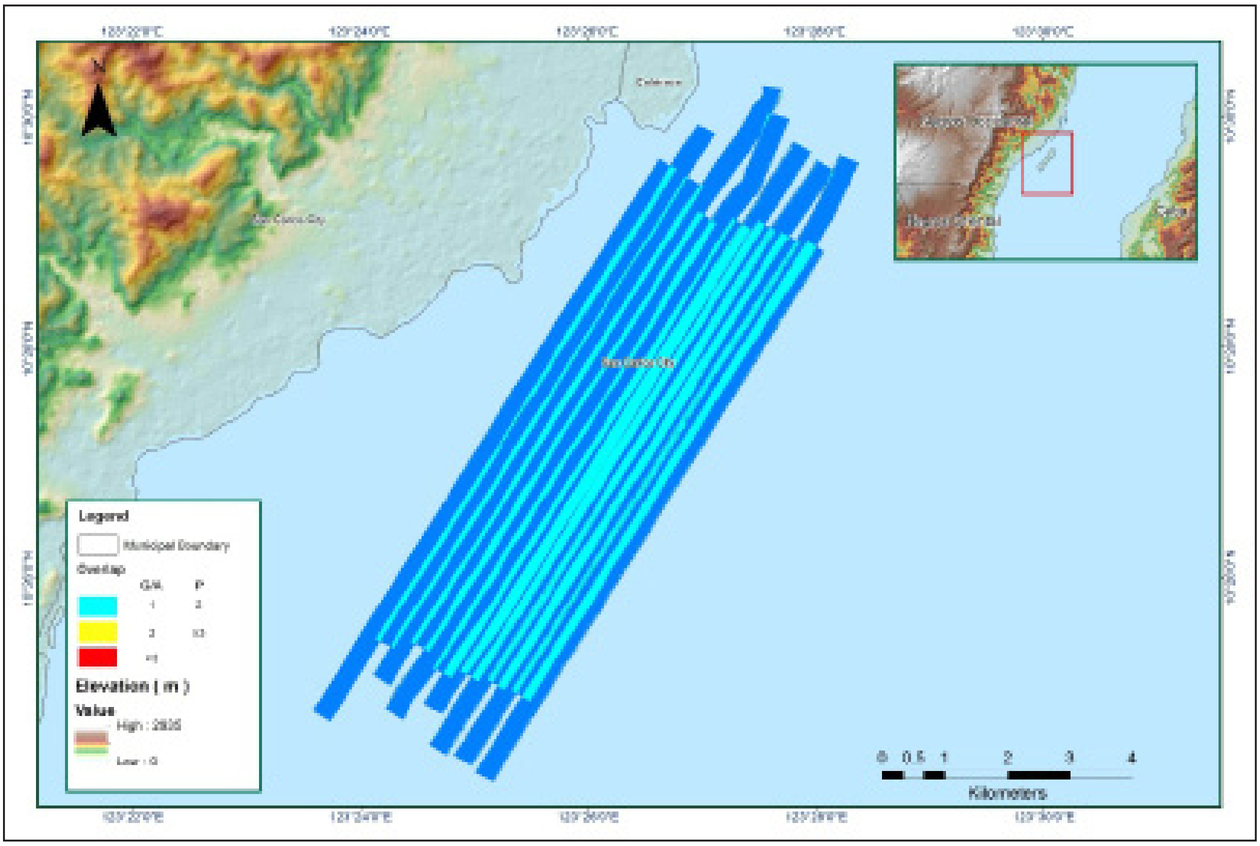


Figure A-8.54. Image of data overlap

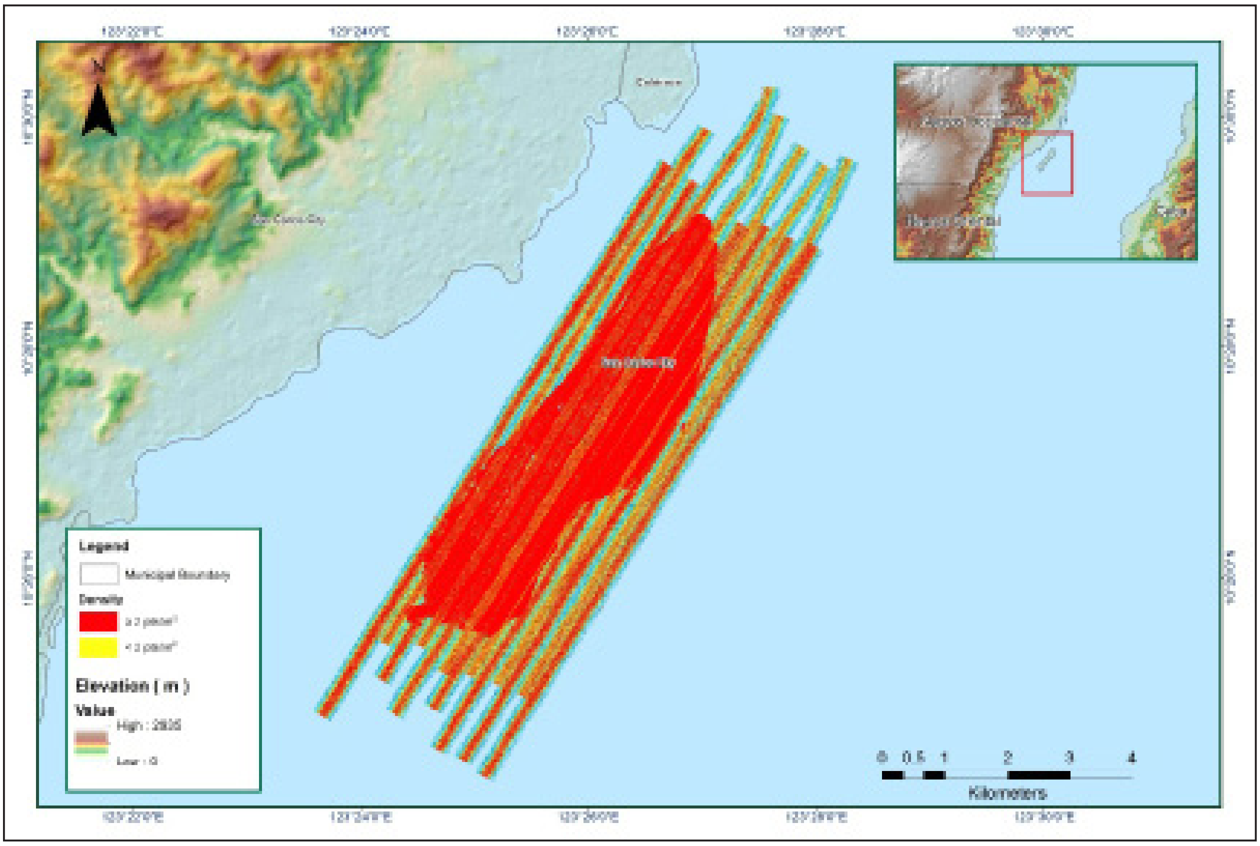


Figure A-8.55. Density map of merged LiDAR data

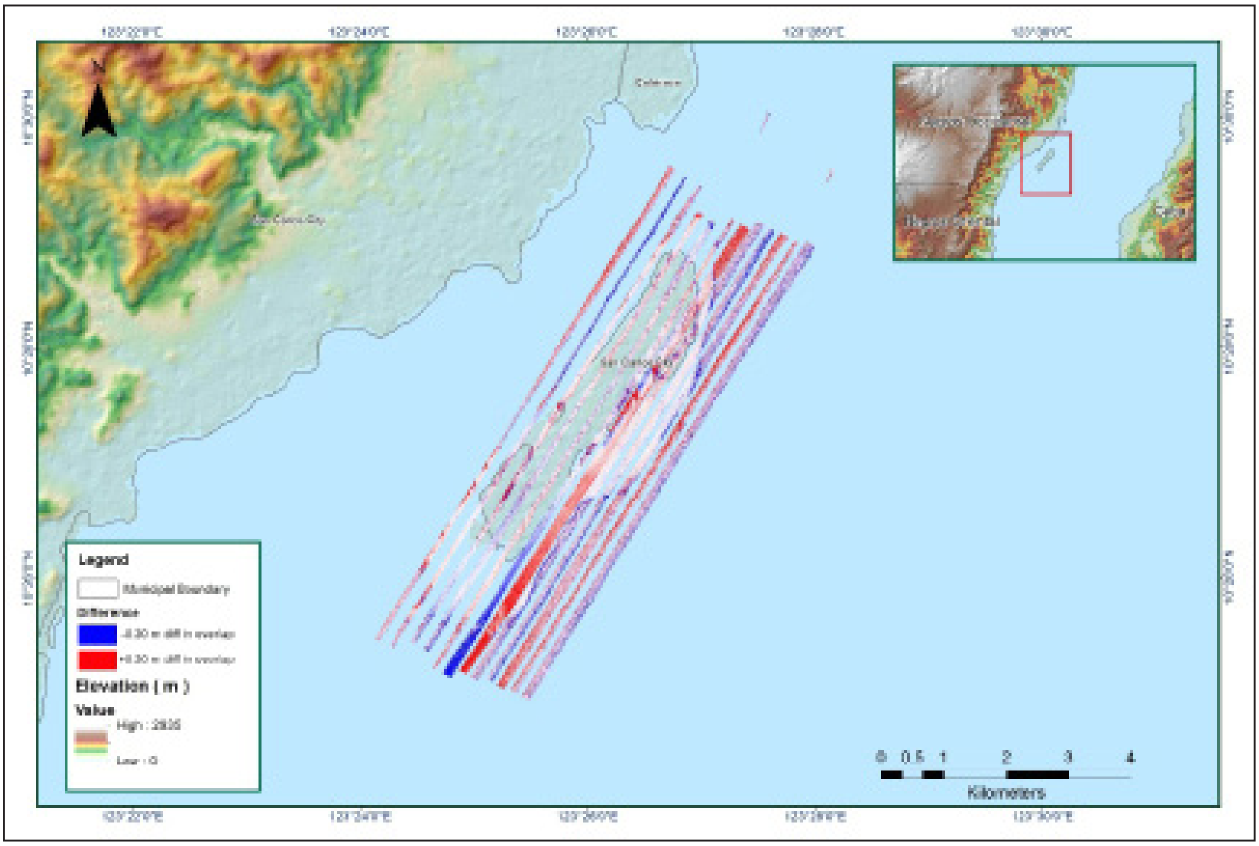


Figure A-8.56. Elevation difference between flight lines

Annex 9. Danao 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
W320	6.351722	72.8385	0	6.59313	1.24948	Discharge	0.000966411	1	Ratio to Peak	0.07
W330	5.059592	76.2812	0	5.03855	1.18084	Discharge	0.000781859	1	Ratio to Peak	0.07
W340	5.262942	75.7177	0	6.59313	1.24948	Discharge	0.000802757	1	Ratio to Peak	0.07
W350	6.3822	72.618	0	1.92958	1.04344	Discharge	0.000107637	1	Ratio to Peak	0.07
W360	6.3822	72.618	0	1.92958	1.04344	Discharge	6.39E-05	1	Ratio to Peak	0.07
W370	5.367312	75.4316	0	5.03855	1.18084	Discharge	0.000756709	1	Ratio to Peak	0.07
W380	6.3822	72.618	0	1.92958	1.04344	Discharge	0.0001815	1	Ratio to Peak	0.07
W390	6.3822	72.618	0	1.92958	1.04344	Discharge	1.77E-05	1	Ratio to Peak	0.07
W400	6.3822	72.618	0	3.906435	1.04344	Discharge	0.000194482	1	Ratio to Peak	0.07
W410	3.718266	80.2159	0	3.51893	1.04344	Discharge	0.00048795	1	Ratio to Peak	0.07
W420	1.835588	73.4	0	3.19726	1.06636	Discharge	0.000673662	1	Ratio to Peak	0.07
W430	2.014046	75.8667	0	5.669445	1.04344	Discharge	0.000478341	1	Ratio to Peak	0.07
W440	4.620748	77.5249	0	1.92958	1.11208	Discharge	0.000777981	1	Ratio to Peak	0.07
W450	0.3552392	74.8985	0	0.168584	1.04344	Discharge	0.000270052	1	Ratio to Peak	0.07
W460	2.83656	76.4263	0	1.41164	1.04344	Discharge	0.000327281	1	Ratio to Peak	0.07
W470	4.239626	82.859	0	4.94545	1.04344	Discharge	9.90E-05	1	Ratio to Peak	0.07
W480	2.54746	51.991	0	1.82147	1.28392	Discharge	0.000380647	1	Ratio to Peak	0.07
W490	2.768842	83.6959	0	4.38723	1.04344	Discharge	0.00033088	1	Ratio to Peak	0.07
W500	4.194644	82.8492	0	3.872805	1.1133	Discharge	0.000354604	1	Ratio to Peak	0.07
W510	4.24041	82.859	0	3.91546	1.04344	Discharge	0.000406317	1	Ratio to Peak	0.07
W520	2.88115	79.578	0	3.47314	1.04344	Discharge	0.000460974	1	Ratio to Peak	0.07
W530	2.483074	84.9023	0	3.067205	1.04344	Discharge	0.000544621	1	Ratio to Peak	0.07

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
W540	2.842048	76.7124	0	1.01853	1.1128	Discharge	0.000685378	1	Ratio to Peak	0.07
W550	2.866156	70.1876	0	4.79763	1.04344	Discharge	0.000243382	1	Ratio to Peak	0.07
W560	4.244428	82.859	0	1.932905	1.11268	Discharge	0.000825868	1	Ratio to Peak	0.07
W570	2.626644	88.9752	0	1.856525	1.04344	Discharge	0.000345247	1	Ratio to Peak	0.07
W580	4.665632	77.3955	0	1.92958	1.04344	Discharge	0.000533612	1	Ratio to Peak	0.07
W590	4.07969	79.1164	0	1.92958	1.04344	Discharge	0.000451352	1	Ratio to Peak	0.07
W600	5.985496	73.7822	0	1.92958	1.04344	Discharge	0.000246528	1	Ratio to Peak	0.07
W610	5.467958	75.1582	0	3.48416	1.04344	Discharge	0.000269332	1	Ratio to Peak	0.07
W620	6.3822	72.618	0	3.48416	1.11208	Discharge	0.000697866	1	Ratio to Peak	0.07

Annex 10. Danao Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R40	Automatic Fixed Interval	799.117	0.003988	0.001485	Trapezoid	5.61	1
R50	Automatic Fixed Interval	2469.95	0.002206	0.00027329	Trapezoid	5.61	1
R60	Automatic Fixed Interval	680.98	0.003868	0.00059056	Trapezoid	5.61	1
R70	Automatic Fixed Interval	772.426	0.002524	0.00040174	Trapezoid	5.61	1
R80	Automatic Fixed Interval	2200.95	0.003991	0.00059056	Trapezoid	5.61	1
R100	Automatic Fixed Interval	4575.29	0.006922	0.00015939	Trapezoid	5.61	1
R120	Automatic Fixed Interval	1979.24	0.015445	0.00060189	Trapezoid	5.61	1
R150	Automatic Fixed Interval	4642.45	0.00489	0.0016393	Trapezoid	5.61	1
R160	Automatic Fixed Interval	2385.51	0.007473	0.000954	Trapezoid	5.61	1
R170	Automatic Fixed Interval	1413.26	0.004999	0.0005288	Trapezoid	5.61	1
R200	Automatic Fixed Interval	1908.82	0.001708	0.0009673	Trapezoid	5.61	1
R210	Automatic Fixed Interval	2255.22	0.002933	0.0001	Trapezoid	5.61	1
R260	Automatic Fixed Interval	4968.31	0.005862	0.0021393	Trapezoid	5.61	1
R290	Automatic Fixed Interval	2056.1	0.0057	0.0001	Trapezoid	5.61	1
R300	Automatic Fixed Interval	2017.11	0.026075	0.001485	Trapezoid	5.61	1

Annex 11. Danao Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
0	10.83908226	123.4958957	0.04	0	0.000		
1	10.83967868	123.5024685	0.03	0	0.000		
2	10.83723248	123.4976477	0.03	0	0.000		
3	10.83463743	123.493964	0.05	0	0.000		
4	10.83487431	123.4929942	0.06	0	0.000		
5	10.78373368	123.5541744	0.11	0	0.000		
6	10.83851021	123.4969991	0.04	0	0.000		
7	10.78332741	123.5524374	0.03	0	0.000		
8	10.79822617	123.4941677	0.03	0.1	0.010	Yolanda	5-Year
9	10.83985285	123.5007569	0.03	0	0.000		
10	10.83693776	123.4928096	0.03	0	0.000		
11	10.8374519	123.495967	0.03	0	0.000		
12	10.83933571	123.5000259	0.03	0	0.000		
13	10.79798624	123.5546441	0.05	0.5	0.250	Auring	5-Year
14	10.78808555	123.5072044	0.03	0	0.000		
15	10.82090185	123.498069	0.07	0	0.000		
16	10.77890741	123.5358404	0.03	2	4.000	Yolanda	5-Year
17	10.7918362	123.5102446	0.03	0	0.000		
18	10.82303379	123.4945512	0.03	0	0.000		
19	10.79425087	123.4944085	0.03	1	1.000	Yolanda	5-Year
20	10.79857541	123.5554781	0.18	0.5	0.250	Auring	5-Year
21	10.83952144	123.4943935	0.22	0.1	0.010	Yolanda	5-Year
22	10.83838307	123.4949594	0.23	1	1.000	Ruping	5-Year
23	10.84165946	123.501725	0.03	0	0.000		
24	10.79873439	123.5555331		0.5	0.250	Auring	5-Year
25	10.80060378	123.5554493	0.13	0	0.000		
26	10.80207728	123.5522099	0.06	0.5	0.250	Yolanda	5-Year
27	10.83690462	123.4941953	0.09	0	0.000		
28	10.83541301	123.4931172	0.18	0	0.000		
29	10.7985261	123.4947713	0.04	0.1	0.010	Yolanda	5-Year
30	10.8020103	123.5526659	0.28	0.5	0.250	Yolanda	5-Year
31	10.8356159	123.5581129	0.16	0.1	0.010	Yolanda	5-Year
32	10.83385464	123.4950905	0.17	0.1	0.010	Yolanda	5-Year
33	10.79521867	123.5575403	0.15	0.1	0.010	Yolanda	5-Year
34	10.80134058	123.4926058	0.2	1	1.000	Yolanda	5-Year
35	10.78432683	123.5453961	0.28	0	0.000		
36	10.80295048	123.491493	0.6	1	1.000	Yolanda	5-Year
37	10.82277292	123.4942243	0.37	0	0.000		
38	10.84087008	123.5033449		0	0.000		

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
39	10.8378509	123.4949684	0.14	1.2	1.440	Yolanda	5-Year
40	10.83758491	123.4917149	0.3	0	0.000		
41	10.84173692	123.4997859	0.42	0	0.000		
42	10.83745198	123.492804	0.28	0	0.000		
43	10.83869567	123.4995636	0.05	0	0.000		
44	10.8385458	123.4947838	0.66	1	1.000	Ruping	5-Year
45	10.83785935	123.4947262	0.1	1.2	1.440	Yolanda	5-Year
46	10.83180138	123.5393784	0.14	0.7	0.490	Yolanda	5-Year
47	10.83917153	123.4945898	0.56	0	0.000		
48	10.79911965	123.4943868	0.11	0.1	0.010	Yolanda	5-Year
49	10.83497729	123.4967859	0.47	0.5	0.250	Yolanda	5-Year
50	10.83618175	123.5556542	0.38	0	0.000		
51	10.84191352	123.5010171	0.35	0	0.000		
52	10.83827037	123.499962	0.05	0	0.000		
53	10.83835794	123.4999443		0	0.000		
54	10.83034864	123.5469985	0.88	0	0.000		
55	10.81915981	123.5307492	0.49	0	0.000		
56	10.81060113	123.4883667	0.65	0.3	0.090	Yolanda	5-Year
57	10.84179751	123.4945849	1.6	0	0.000		
58	10.84168344	123.4945071	0.8	0	0.000		
59	10.84152033	123.4942673		0	0.000		
60	10.84095995	123.4949321	0.96	0	0.000		
61	10.83476659	123.496459	0.07	0.5	0.250	Yolanda	5-Year
62	10.83465705	123.4965218	0.45	0.5	0.250	Yolanda	5-Year
63	10.76455244	123.5435337	1.59	3	9.000	Yolanda	5-Year
64	10.84177623	123.4949195	1.47	0	0.000		
65	10.83452931	123.4965829		0.5	0.250	Yolanda	5-Year
66	10.83421989	123.4971981	0.03	0.2	0.040	Yolanda	5-Year
67	10.8408045	123.4950468		0	0.000		
68	10.83447434	123.4964071		0.5	0.250	Yolanda	5-Year
69	10.84168794	123.4948862	1.59	0	0.000		
70	10.84112692	123.4947586	0.76	0	0.000		
71	10.83476725	123.4965848		0.5	0.250	Yolanda	5-Year
72	10.76456	123.5435722		3	9.000	Yolanda	5-Year
73	10.84144785	123.4949474	0.73	0	0.000		
74	10.84145871	123.4945674		0	0.000		
75	10.83824815	123.5004591	0.78	0	0.000		
76	10.78200524	123.530083	0.03	2	4.000	Yolanda	5-Year
77	10.79840721	123.507042	1.17	0	0.000		
78	10.79639555	123.5029169	0.93	0	0.000		
79	10.80121251	123.5027608	1.03	0	0.000		

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
80	10.8266119	123.5510505	1.59	2	4.000	Ruping	5-Year
81	10.82663018	123.5510626		2	4.000	Ruping	5-Year
82	10.76443042	123.5435681		3	9.000	Yolanda	5-Year
83	10.76448012	123.5433459	1.68	3	9.000	Yolanda	5-Year
84	10.76443446	123.5433565		3	9.000	Yolanda	5-Year
85	10.82651497	123.5510435	0.03	2	4.000	Ruping	5-Year
86	10.82656043	123.5510586		2	4.000	Ruping	5-Year
87	10.82658354	123.5509943	1.27	2	4.000	Ruping	5-Year
88	10.83412393	123.4973421	1.69	0.2	0.040	Yolanda	5-Year
89	10.83408448	123.4973407		0.2	0.040	Yolanda	5-Year
90	10.76445671	123.5434048		3	9.000	Yolanda	5-Year
91	10.76459047	123.5434774		3	9.000	Yolanda	5-Year
92	10.76435659	123.5434076	0.78	3	9.000	Yolanda	5-Year
93	10.76450406	123.5434721		3	9.000	Yolanda	5-Year
94	10.82646521	123.5510721		2	4.000	Ruping	5-Year
95	10.76452426	123.5433695		3	9.000	Yolanda	5-Year
96	10.76459497	123.5434488		3	9.000	Yolanda	5-Year
97	10.76449842	123.5433631		3	9.000	Yolanda	5-Year
98	10.76453995	123.543425		3	9.000	Yolanda	5-Year
99	10.76455098	123.5433433		3	9.000	Yolanda	5-Year
100	10.83414128	123.4973559		0.2	0.040	Yolanda	5-Year
101	10.76443412	123.5434759		3	9.000	Yolanda	5-Year
102	10.77875385	123.5308005	1.19	2	4.000	Yolanda	5-Year
103	10.82274391	123.486881	1.77	1.5	2.250	Yolanda	5-Year
104	10.8216216	123.4887555	2.03	2	4.000	Yolanda	5-Year
105	10.8116084	123.4889895	0.86	1.3	1.690	Yolanda	5-Year
106	10.78870606	123.53304	2.66	0	0.000		
107	10.81804115	123.4929753	2.14	1.2	1.440	Yolanda	5-Year
108	10.81958072	123.4867377	1.94	0.9	0.810	Yolanda	5-Year
109	10.82044676	123.4904894	2	2.5	6.250	Yolanda	5-Year
110	10.82250125	123.4864115	1.94	1.5	2.250	Yolanda	5-Year
111	10.81406887	123.5287282	1.7	4	16.000	Yolanda	5-Year
112	10.81077624	123.5235217	2.28	4	16.000	Yolanda	5-Year
113	10.81081005	123.5249937	0.86	4	16.000	Yolanda	5-Year
114	10.82029501	123.4891658	2.39	2.5	6.250	Yolanda	5-Year
115	10.81104027	123.5245314	1.79	4	16.000	Yolanda	5-Year
116	10.81112288	123.5249693	2.61	4	16.000	Yolanda	5-Year
117	10.8132097	123.5289507	1.49	4	16.000	Yolanda	5-Year
118	10.81100253	123.525077	2.32	4	16.000	Yolanda	5-Year
119	10.81110531	123.5246959		4	16.000	Yolanda	5-Year
120	10.81106235	123.5252823		4	16.000	Yolanda	5-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
121	10.81613396	123.4932179	0.03	3	9.000	Yolanda	5-Year
122	10.82021858	123.4889762	4.64	2.5	6.250	Yolanda	5-Year
123	10.81083693	123.5236008		4	16.000	Yolanda	5-Year
124	10.81736974	123.4921386	1.74	1.2	1.440	Yolanda	5-Year
125	10.81795256	123.4919073	4.62	1.2	1.440	Yolanda	5-Year
126	10.81095446	123.525288		4	16.000	Yolanda	5-Year
127	10.81403707	123.5296437	1.75	4	16.000	Yolanda	5-Year
128	10.81040814	123.5237744	2.24	4	16.000	Yolanda	5-Year
129	10.81049589	123.5235336	1.85	4	16.000	Yolanda	5-Year
130	10.82012424	123.4889434		2.5	6.250	Yolanda	5-Year
131	10.81476118	123.490827	4.51	3	9.000	Yolanda	5-Year
132	10.81753363	123.4921146		1.2	1.440	Yolanda	5-Year
133	10.80691491	123.5513653	6.33	1	1.000	Yolanda	5-Year
134	10.81113426	123.5251997		4	16.000	Yolanda	5-Year
135	10.81104891	123.5248479		4	16.000	Yolanda	5-Year
136	10.81115779	123.5257246	0.1	4	16.000	Yolanda	5-Year
137	10.8120738	123.5261357	1.47	4	16.000	Yolanda	5-Year
138	10.81117255	123.5253664	2.09	4	16.000	Yolanda	5-Year
139	10.81047084	123.5237228		4	16.000	Yolanda	5-Year
140	10.81040988	123.5234518		4	16.000	Yolanda	5-Year
141	10.817078	123.492414	2.72	1.2	1.440	Yolanda	5-Year
142	10.81948677	123.4853958	2.47	0.9	0.810	Yolanda	5-Year
143	10.81212879	123.5255356	1.74	4	16.000	Yolanda	5-Year
144	10.81127162	123.5253881	1.9	4	16.000	Yolanda	5-Year
145	10.80990032	123.5231096	0.71	4	16.000	Yolanda	5-Year
146	10.81630392	123.4931451	2.04	3	9.000	Yolanda	5-Year
147	10.81044657	123.5238373		4	16.000	Yolanda	5-Year
148	10.80692633	123.5515716		0	0.000		
149	10.82117669	123.4865998	2.11	6	36.000	Ruby	5-Year
150	10.8213931	123.4861039	1.86	6	36.000	Ruby	5-Year
151	10.82691046	123.5509867	1.3	0.51	0.260		
152	10.83031045	123.5470719		0	0.000		
153	10.84053341	123.4948472	0.21	0	0.000		
154	10.83624537	123.4963492	0.81	0	0.000		
155	10.8362775	123.4962943		0	0.000		
156	10.83043792	123.5470601		0	0.000		
157	10.83028772	123.5471717		0	0.000		
158	10.83499804	123.4968091		2	4.000		
159	10.84147326	123.4945938		0	0.000		
160	10.83544524	123.4966534	0.84	2	4.000		
161	10.84163706	123.4943081		0	0.000		

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
162	10.83077851	123.5496888	0.35	0.13	0.017	Yolanda	5-Year
163	10.84161803	123.4941831	0.03	0	0.000		
164	10.83542028	123.4967877		2	4.000		
165	10.80334829	123.5122379	0.17	0	0.000		
166	10.83545456	123.4968726		2	4.000		
167	10.84016053	123.4946614	0.22	2	4.000		
168	10.83060367	123.5496849		0.13	0.017	Yolanda	5-Year
169	10.82710643	123.5510609	0.81	0.51	0.260		
170	10.84125294	123.4951244	0.93	0	0.000		
171	10.82720487	123.551027	0.77	0.51	0.260		
172	10.83057753	123.5497648	0.54	0.13	0.017	Yolanda	5-Year
173	10.83938835	123.4948258	0.43	2	4.000		
174	10.8393595	123.4948772		2	4.000		
175	10.80073381	123.5623536	0.03	0	0.000		
176	10.78256816	123.5576298	0.03	0	0.000		
177	10.81843059	123.5223192	0.57	0.18	0.032	Yolanda	5-Year
178	10.79964168	123.4847833	0.52	0	0.000		
179	10.76452324	123.5450261	0.03	0	0.000		
180	10.83923298	123.4993121	0.09	0	0.000		
181	10.83540277	123.4940501	0.2	0	0.000		
182	10.84165898	123.501664	0.03	0.43	0.185		
183	10.77977841	123.5583723	0.32	0.43	0.185	Yolanda	5-Year
184	10.83280609	123.5440511	0.27	0.43	0.185	Yolanda	5-Year
185	10.83916523	123.4950883	0.11	2	4.000		
186	10.79800605	123.494802	0.03	0	0.000		
187	10.83959941	123.4949442	0.08	2	4.000		
188	10.78928735	123.5625225	0.16	0	0.000		
189	10.79777697	123.4956748	0.31	3	9.000		
190	10.79872485	123.4819097	0.14	0	0.000		
191	10.77216165	123.5538167	0.22	0	0.000		
192	10.83881172	123.4957681	0.03	0	0.000		
193	10.83287343	123.5263029	0.07	0	0.000		
194	10.83370888	123.4927242	0.03	0	0.000		
195	10.8363058	123.5522933	0.04	0.51	0.260	Yolanda	5-Year
196	10.83680738	123.5596522	0.03	0	0.000		
197	10.83323971	123.4908623	0.03	0	0.000		
198	10.83445028	123.5628912	0.03	0	0.000		
199	10.84314233	123.5628895	0.03	0	0.000		
200	10.8317558	123.5254632	0.03	0	0.000		
201	10.83242928	123.5622179	0.08	0	0.000		
202	10.83170168	123.5307376	0.06	0	0.000		

Annex 12. Educational Institutions Affected by Flooding in Danao Floodplain

NEGROS OCCIDENTAL				
ESCALANTE CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Udtongan Barangay Health Center	Udtongan	Low	Low	Low
Balintawak Day Care Center	Alimango			
Cogon Day Care Center	Alimango			
Escalante National High School	Alimango			
Mercedes Alimani Pareno Elementary School	Alimango			
Nabutaan Child Development Center	Alimango			
Alternative Learning School(ALS)	Balintawak			
Balintawak Day Care Center	Balintawak			
Bible Baptist Learning Center	Balintawak			
Escalante Central Elementary School	Balintawak			
Escalante Central ES	Balintawak			
Escalante Kindergarten Elementary School	Balintawak			
Mount Carmel College	Balintawak			
Mt. Carmel	Balintawak			
Mt. Carmel ES	Balintawak			
Mt. Carmel HS and College	Balintawak			
Mt. Carmel Parish Church	Balintawak			
Buenavista Day Care Center	Buenavista			
Buenavista Elementary School	Buenavista			
Buenavista National High School	Buenavista		Low	Low
Sports Center	Buenavista			
Pagasa Child Development Center	Jonobjonob			Low
Private Kindergaten	Jonobjonob			
Buenavista-Langub Ext. High School	Langub			
Langub Day Care	Langub			
Langub Elementary School	Langub			
Amparo Day Care Center	Mabini			
Mabini Elementary School	Mabini			
Mabini National High School	Mabini			
URBASA DAY CARE CENTER	Mabini			
Danao Port Elementary School	Old Poblacion			
Escalante Elementary School	Old Poblacion	Low	Low	Low
Iglesia Ni Cristo	Old Poblacion			
Old Poblacion Day Care Center	Old Poblacion			
Old Poblacion National High School	Old Poblacion		L ow	Low
Buenavista High School - Japitan Extension	Rizal			
Rizal Day Care Center	Rizal		Low	Low
Udtongan Day Care Center	Udtongan	Low	Low	Low
Udtongan Elementary School	Udtongan			

Annex 12. Health Institutions Affected by Flooding in Danao Floodplain

NEGROS OCCIDENTAL				
ESCALANTE CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
DR. TANCINCO PEDIA CLINIC	Balintawak	Low	Low	Low
Blanco Clinic	Balintawak			
DR.LUMAYNO DENTAL CLINIC	Balintawak			
Hinolan Medical Clinic	Balintawak			
Buenavista Barangay Health Center	Buenavista			
Pagasa Health Center	Jonobjonob			
Barangay Health Center	Langub			
Old Poblacion Barangay Health Center	Old Poblacion			
Udtongan Barangay Health Center	Udtongan			

Annex 14. UPC Phil-LiDAR 1 Team Composition

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