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

LiDAR Surveys and Flood Mapping of Abatan River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
University of San Carlos

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LIST OF ACRONYMS AND ABBREVIATIONS

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND ABATAN RIVER

Enrico C. Paringit, Dr. Eng., Dr. Roland S. Otadoy, and Engr. Aure Flo Oraya

1.1 Background of the Phil-LiDAR 1 Program

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

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for a 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through the DOST. The methods applied in this report are thoroughly described in a separate publication entitled "Flood Mapping of Rivers in the Philippines Using Airborne LiDAR: Methods" (Paringit, et. al., 2017), available separately.

The implementing partner university for the Phil-LiDAR 1 Program is the University of San Carlos (USC). USC 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 seventeen (17) river basins in the Central Visayas Region. The university is located in Cebu City in the province of Cebu.

1.2 Overview of the Abatan River Basin

The Abatan River Basin covers the Municipalities of Balilihan, Cortes, Antequera, San Isidro, Corella, and Catigbian, and small portions of eight (8) other municipalities in the Province of Bohol. The Department of Environment and Natural Resources (DENR) River Basin Control Office (RBCO) identified the basin to have a drainage area of 352 km^2, and an estimated annual runoff of 211 million cubic meters (MCM) (RBCO, 2015). The basin's main stem, the Abatan River, is part of the seventeen (17) river systems in the Central Visayas Region.

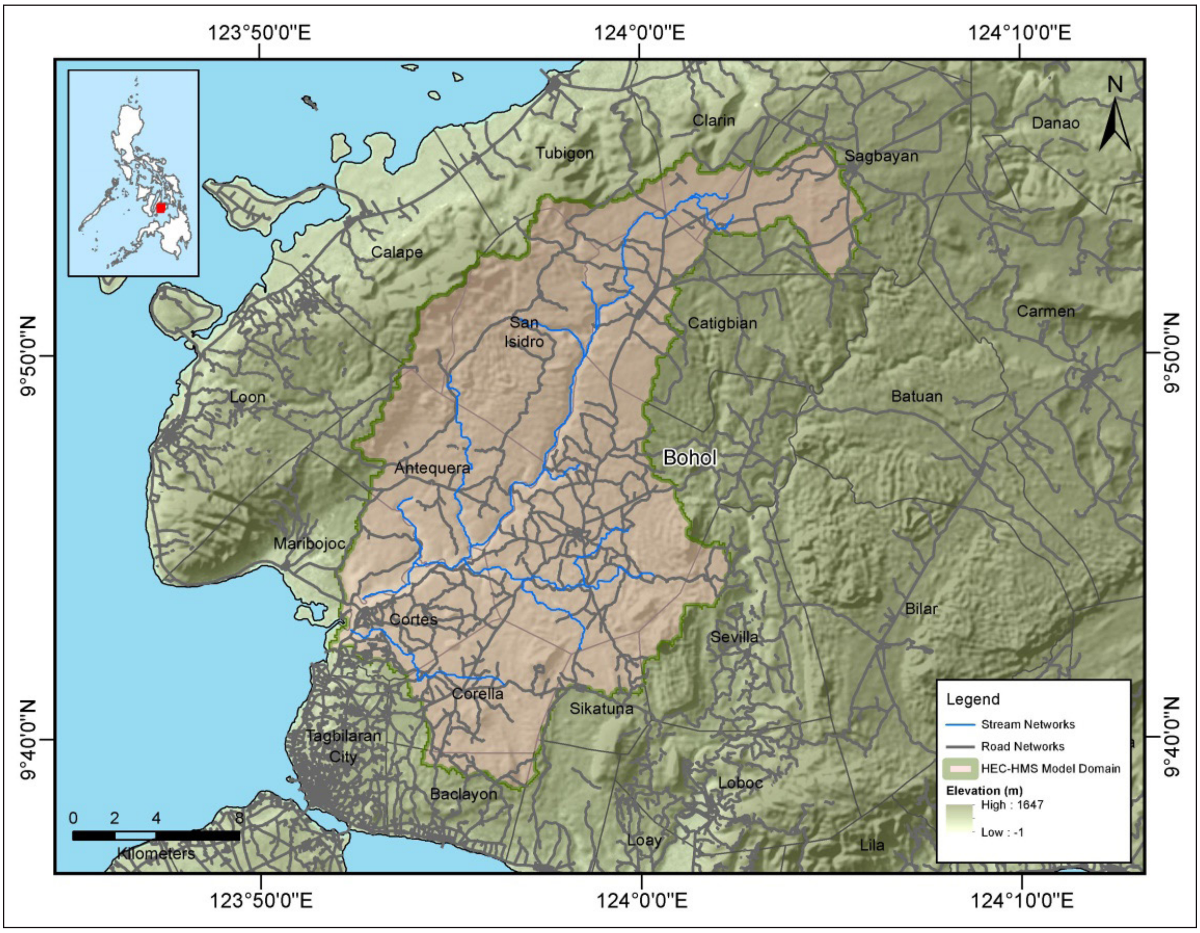

Figure 1. Location map of the Abatan River Basin (in brown)

According to the 2015 national census of the National Statistics Office (NSO), the total population within the immediate vicinity of the river is 11,173. These residents are distributed among three (3) barangays in the Municipality of Antequera, four (4) barangays in the Municipality of Cortes, and three (3) barangays in the Municipality of Maribojoc, in the province of Bohol.

The Municipality of Cortes is known for its industrial products; such as, handmade paper crafts, and iron that is used for roofing. Locals in Cortes harvest sand from the Abatan River for shipment to construction sites, as a source of income. Recently, the local government unit (LGU) of Cortes has been developing a River Cruise on the Abatan River, which will be utilized for boosting tourism, and also for transportation purposes. This will create more employment opportunities for the community (Source: http://www.bohol-philippines.com/cortes.html).

The most recent, severe flooding event in the area of the Abatan River occurred on December 30, 2014, during the landfall of Typhoon Seniang (internationally known as *Jangmi*). The typhoon killed eleven (11) people and displaced 1,700 others, which placed the province under a state of calamity (Source: http://www.rappler.com/nation/79373-bohol-seniang-death-toll).

CHAPTER 2: LIDAR DATA ACQUISITION OF THE ABATAN FLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Abatan floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the floodplain in the province of Bohol. These missions were planned for sixteen (16) lines that ran for at most four and a half (4.5) hours, including take-off, landing, and turning time. The Pegasus LiDAR system was utilized for the missions (See Annex 1 for the sensor specifications). The flight planning parameters for the LiDAR system is found in Table 1. Figure 2 illustrates the flight plans for the Abatan floodplain.

Table 1. Flight planning parameters for Pegasus LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK51M	1000/1100/1200	30	50	200	30	130	5
BLK51H	1000/1100/1200	30	50	200	30	130	5

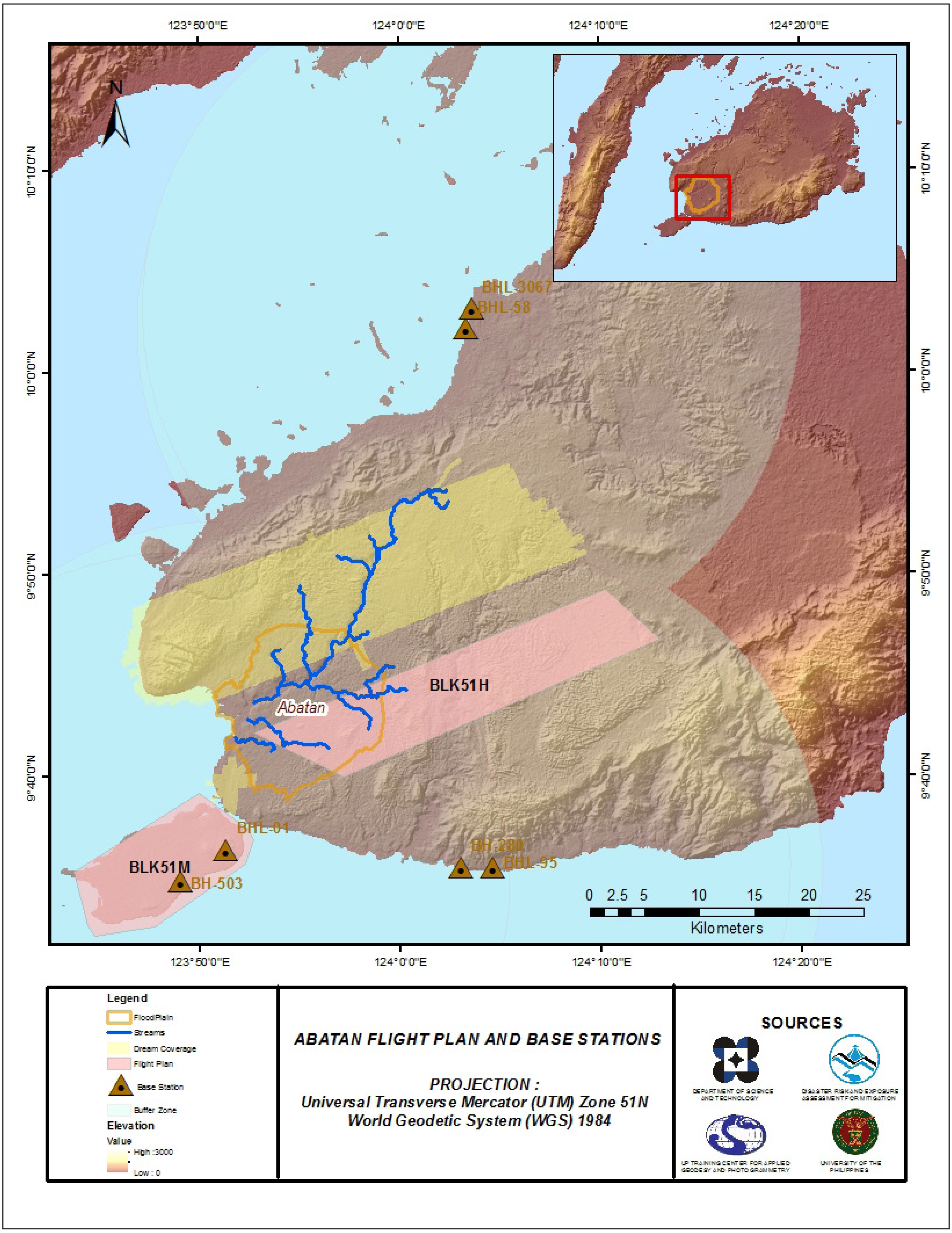
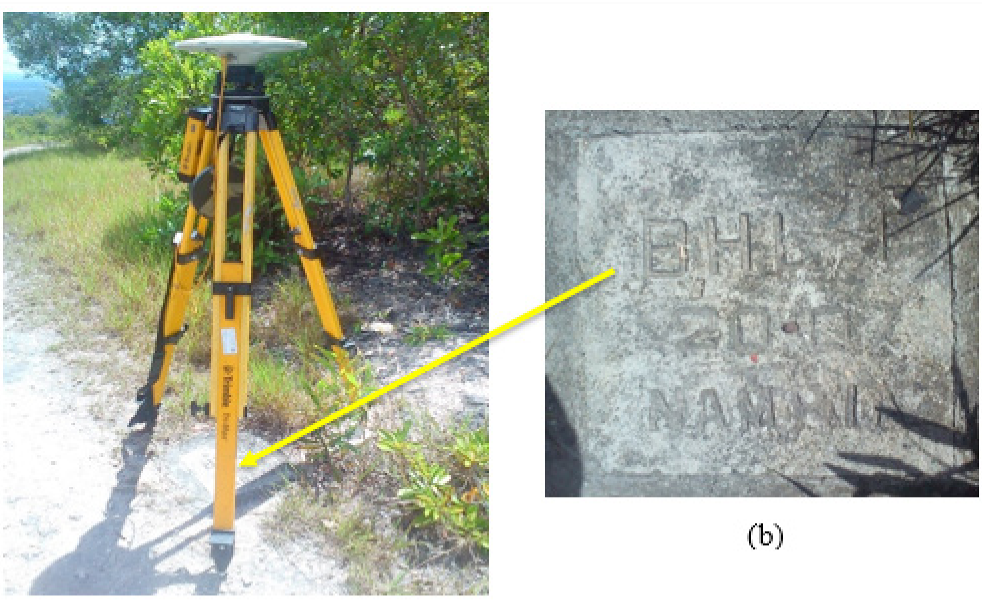


Figure 2. Flight plans and base stations used to cover the Abatan floodplain survey

2.2 Ground Base Stations

The field team for this undertaking was able to recover four (4) NAMRIA ground control points: BHL-01, BHL-95, BHL-58, and BHL-3067, which are of first (1st) and second (2nd) order accuracy. The field team also recovered two (2) benchmark points: BMBH-280 and BMBH-503. The certifications for the NAMRIA reference points and the baseline processing reports for the established points are found in Annexes 2 and 3, respectively. These were used as the base stations during the flight operations for the entire duration of the survey, held on August 22-23, 2014, and on September 21, 2015. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 882, SPS 852, and SPS 985. The locations of the base stations used during the aerial LiDAR acquisition in the Abatan floodplain are also shown in Figure 2, along with the flight plans. The composition of the full project team is given in Annex 4.

Figure 3 to Figure 8 exhibit the recovered NAMRIA control stations within the area. In addition, Table 2 to Table 7 provide the details about the NAMRIA control stations and established points. Table 8 lists all of the ground control points occupied during the acquisition, with the corresponding dates of utilization.



(a) (b)

Figure 3. (a) GPS set-up over BHL-01 in Barangay Mayacabac, Dauis in Bohol; and (b) NAMRIA reference point BHL-01,as recovered by the field team

Table 2. Details of the recovered NAMRIA horizontal control point BHL-01, used as a base station for the LiDAR acquisition

Station Name	BHL-01	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	9° 36' 26.3953"
	Longitude	123° 51' 10.6019"
	Ellipsoidal Height	184.35 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	374086.36320 meters
	Northing	1062513.68434 meters

Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	9° 36' 22.44746" North
	Longitude	123° 51' 15.91243" East
	Ellipsoidal Height	247.564 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	593754.44681 meters
	Northing	1061993.66019 meters

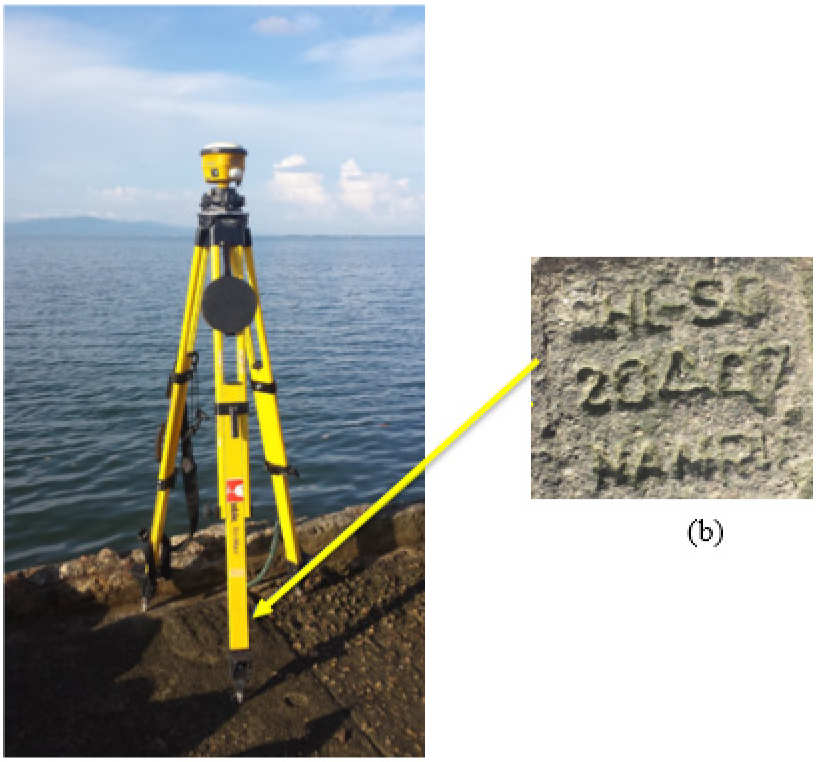
(b)

(a)

Figure 4. (a) GPS set-up over BHL-95 in Barangay Tiguis, Lila, Bohol; and (b) NAMRIA reference point BHL-95, as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point BHL-95, used as a base station for the LiDAR acquisition

Station Name	BHL-95	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	9° 35' 30.9568"
	Longitude	124° 04' 30.0216"
	Ellipsoidal Height	19.00 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	398459.94396 meters
	Northing	1060736.81055 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	9° 35' 27.03243" North
	Longitude	124° 04' 35.33150" East
	Ellipsoidal Height	82.798 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	618128.686 meters
	Northing	1060360.033 meters

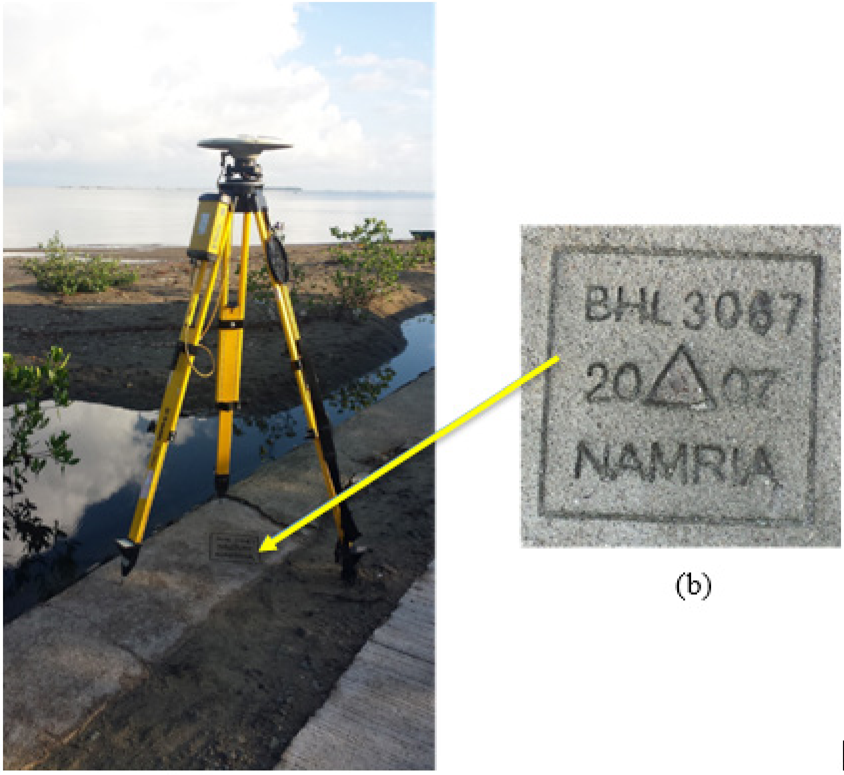


(a) (b)

Figure 5. (a) GPS set-up over BHL-58 at the pier in Barangay Tungod, Inabanga, Bohol; and (b) NAMRIA reference point BHL-58, as recovered by the field team

Table 4. Details of the established control point BLH-58, used as a base station for the LiDAR acquisition

Station Name	BHL-58	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	10° 2' 12.58586"
	Longitude	124° 03' 14.58015"
	Ellipsoidal Height	3.13800 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	396297.833 meters
	Northing	1109952.503 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	10° 02’ 8.54469” North
	Longitude	124° 03’ 19.85079” East
	Ellipsoidal Height	65.89700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	615513.67 meters
	Northing	1109600.04 meters



(a)

Figure 6. (a) GPS set-up over BHL-3067 on the seawall in Barangay Ondol, Inabanga, Bohol; and (b) NAMRIA reference point BHL-3067, as recovered by the field team

Table 5. Details of the established control point BHL-3067, used as a base station for the LiDAR acquisition

Station Name	BHL-3067	
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° 03’ 10.47434”North 124° 03’ 30.07070”East 3.679 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	615979.548 meters 1111379.617 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10° 03’ 06.42941” North 124° 03’ 35.33988” East 66.412 meters

(b)

(a)

Figure 7. (a) GPS set-up over BMBH-503 in Barangay Dao, Dauis, Bohol; and (b) NAMRIA reference point BMBH-503, as recovered by the field team

Table 6. Details of the established control point BMBH-503, used as a base station for the LiDAR acquisition

Station Name	BMBH-503	
Order of Accuracy	1st	
Relative Error (horizontal positioning)	1 in 100,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	9° 34’ 53.54895”North 123° 48’ 54.10112”East 22.564 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	589439.266 meters 1059186.111 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 34’ 49.60419” North 123° 48’ 59.41428” East 85.755 meters

(a) (b)

Figure 8. (a) GPS set-up over BMBH-280 in Barangay Tocdog Dacu, Loay, Bohol; and (b) NAMRIA benchmark point, as recovered by the field team

Table 7. Details of the established control point BMBH-280, used as a base station for the LiDAR acquisition

Station Name	BMBH-280	
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	9° 35' 33.32448"North 124° 02' 54.62703"East 3.860 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N WGS 1984)	Easting Northing	615059.442 meters 1060477.159 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	9° 35' 29.39739" North 124° 02' 59.93729" East 67.604 meters

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

Date Surveyed	Flight Number	Mission Name	Ground Control Points
August 22, 2014	1867P	1BLK51M234A	BHL-1 and BMBH-503
August 23, 2014	1871P	1BLK51H235A	BHL-95 and BMBH-280
September 21, 2015	3445P	1BLK51S264A	BHL-58 and BHL-3067

2.3 Flight Missions

Four (4) flight missions under the DREAM program covered around 49 km^2 (Table 9) within the Abatan floodplain. Three (3) flight missions were conducted under the Phil-LiDAR 1 Program to complete the LiDAR data acquisition in the Abatan floodplain, for a total of eight hours and fifty-two minutes (8+52) of flying time for RP-C9022. All missions were acquired using the Pegasus LiDAR system. The flight logs for the missions are found in Annex 6. Table 10 indicates the total area of actual coverage for each mission, and the corresponding flying hours. Table 11 presents the actual parameters used during the LiDAR data acquisition.

Table 9. Flight missions under the DREAM Program, which covers the Abatan floodplain

Flight Number	Mission Name	Area Surveyed within the Floodplain (km^2)
755P	1LMSBHL1HS319A	19.82
757P	1BHL1G319B	1.48
759P	1BHL1HS320A	17.99
795P	1BHL1GS329A	3.58
825P	1BHL1GS336A	6.13
TOTAL		49

Table 10. Flight missions for the LiDAR data acquisition in the Abatan floodplain

Date Surveyed	Flight Number	Flight Plan Area (km^2)	Surveyed Area (km^2)	Area Surveyed within the Floodplain (km^2)	Area Surveyed Outside the Floodplain (km^2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
August 22, 2014	1867P	122.97	147.57	_	147.57	384	3	12
August 23, 2014	1871P	391.11	265.95	57.07	208.88	795	3	35
September 21, 2015	3445P	298	45.38	_	45.38	NA	2	05
TOTAL		812.08	458.9	57.07	401.83	1179	8	52

Table 11. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1867P	1000/1100/1200	30	50	200	30	130	5
1871P	1000/1100/1200	30	50	200	30	130	5
3445P	1000/1100/1200	30	50	200	30	130	5

2.4 Survey Coverage

The Abatan floodplain is located in the province of Bohol, situated within the Municipalities of Antequera, Baclayon, Balilihan, Corella, Cortes, Maribojoc, Sikatuna, and Tagbilaran City. The municipalities and cities surveyed with at least one (1) square kilometer coverage are outlined in Table 12. The actual coverage of the LiDAR acquisition for the Abatan floodplain is presented in Figure 9. Annex 7 provides the flight status report for the survey coverage.

Table 12. List of Municipalities and Cities Surveyed in Abatan

Province	Municipality /City	Area of Municipality/ City (km²)	Total Area Surveyed (km²)	Percentage of Area Surveyed
Bohol	Baclayon	31.22	1.58	5%
	Balilihan	123.46	39.78	32%
	Batuan	90.27	41.22	46%
	Bilar	137.93	52.5	38%
	Carmen	221.41	60.75	27%
	Catigbian	84.38	12.62	15%
	Corella	40.09	29.73	74%
	Cortes	30.52	11.47	38%
	Dauis	43.6	43.6	100%
	Panglao	48.09	47.85	99%
	Sevilla	68.37	44.85	66%
	Sikatuna	21.88	16.7	76%
	Tagbilaran	30.72	5.35	17%
Total		971.94	408	41.98%

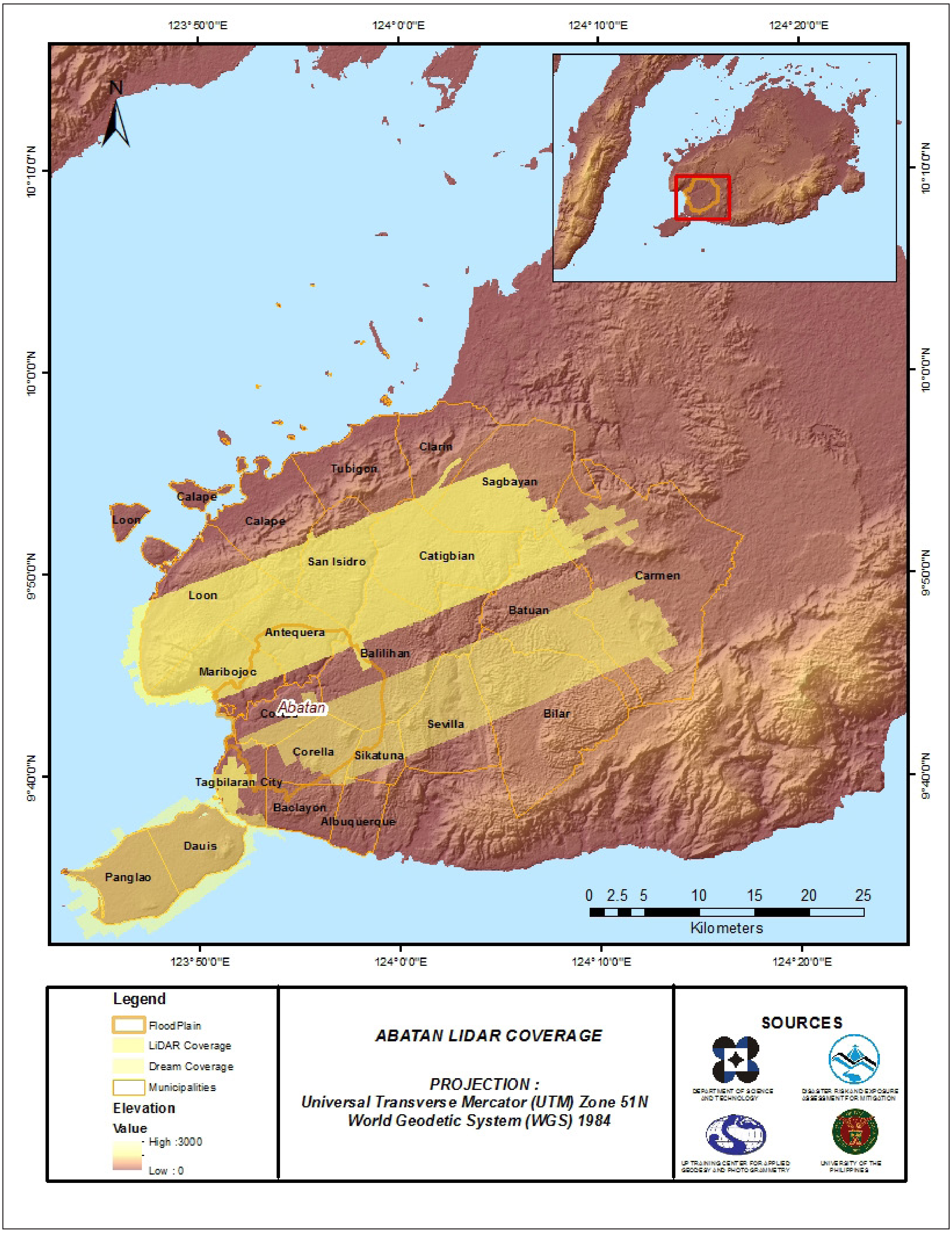


Figure 9. Actual LiDAR survey coverage of the Abatan floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE ABATAN FLOODPLAIN

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

3.1 Overview of the LIDAR Data Pre-Processing

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

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

These processes are summarized in the diagram in Figure 10.

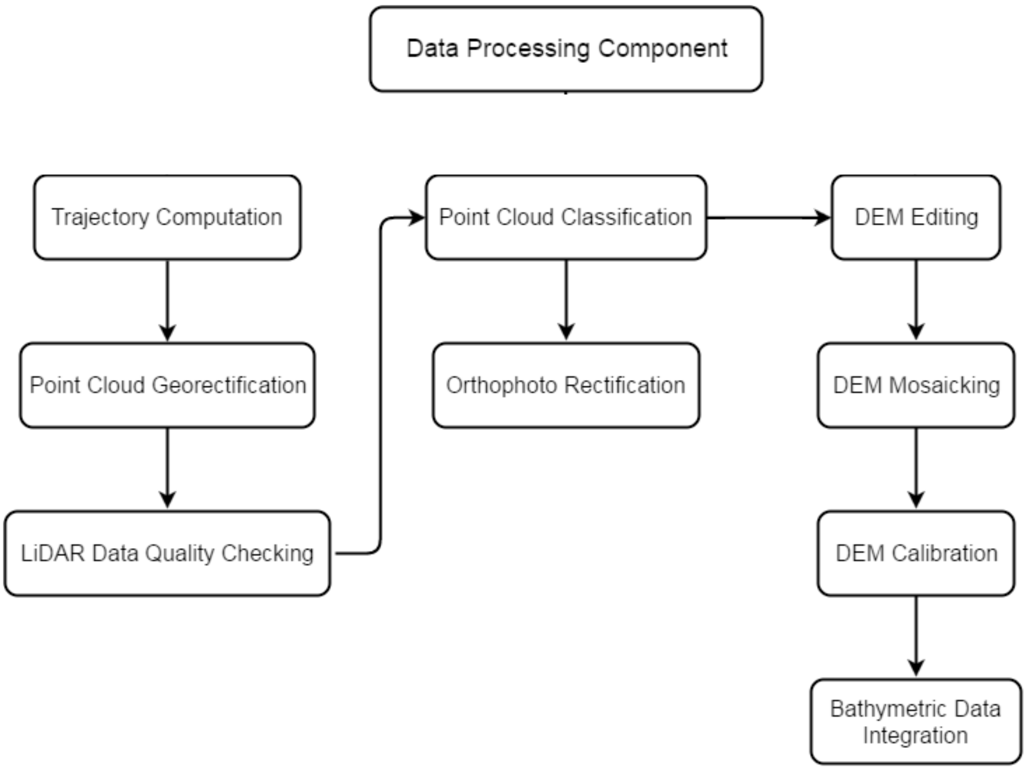


Figure 10. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

The data transfer sheets for all of the LiDAR missions for the Abatan floodplain can be found in Annex 5. Missions flown during the first survey conducted in November 2013 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Pegasus system. Missions acquired during the second survey were flown in October 2015 over Maribojoc, Bohol using the same system. The DAC transferred a total of 142.34 Gigabytes of Range data, 1.60 Gigabytes of POS data, 99.47 Megabytes of GPS base station data, and 77.80 Gigabytes of raw image data to the data server on November 20, 2013 for the first survey, and on October 1, 2015 for the second survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for the Abatan survey was fully transferred on October 28, 2015, as indicated on the data transfer sheets for the Abatan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metrics of the computed trajectory for Flight 757P, one of the Abatan flights, which are the North, East, and Down position RMSE values, are exhibited in Figure 11. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which fell on November 15, 2013 at 00:00 hrs. on that week. The y-axis represents the RMSE value for that particular position.

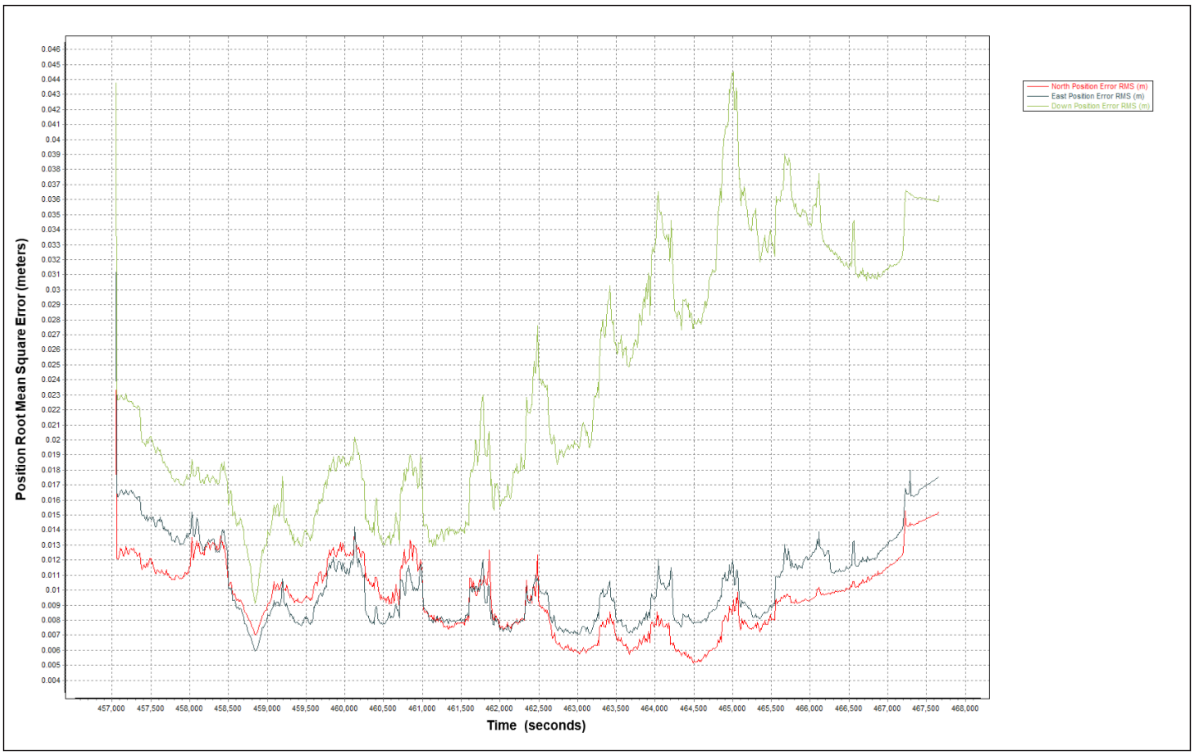


Figure 11. Smoothed Performance Metrics of Abatan Flight 757P

The time of flight was from 457000 seconds to 468000 seconds, which corresponds to the afternoon of November 15, 2013. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE values of the positions. The periodic increase in RMSE values from an otherwise smoothly curving set of RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 11 depicts that the North position RMSE peaked at 1.30 centimeters, the East position RMSE peaked at 1. 80 centimeters, and the Down position RMSE peaked at 4.40 centimeters, which are within the prescribed accuracies described in the methodology.

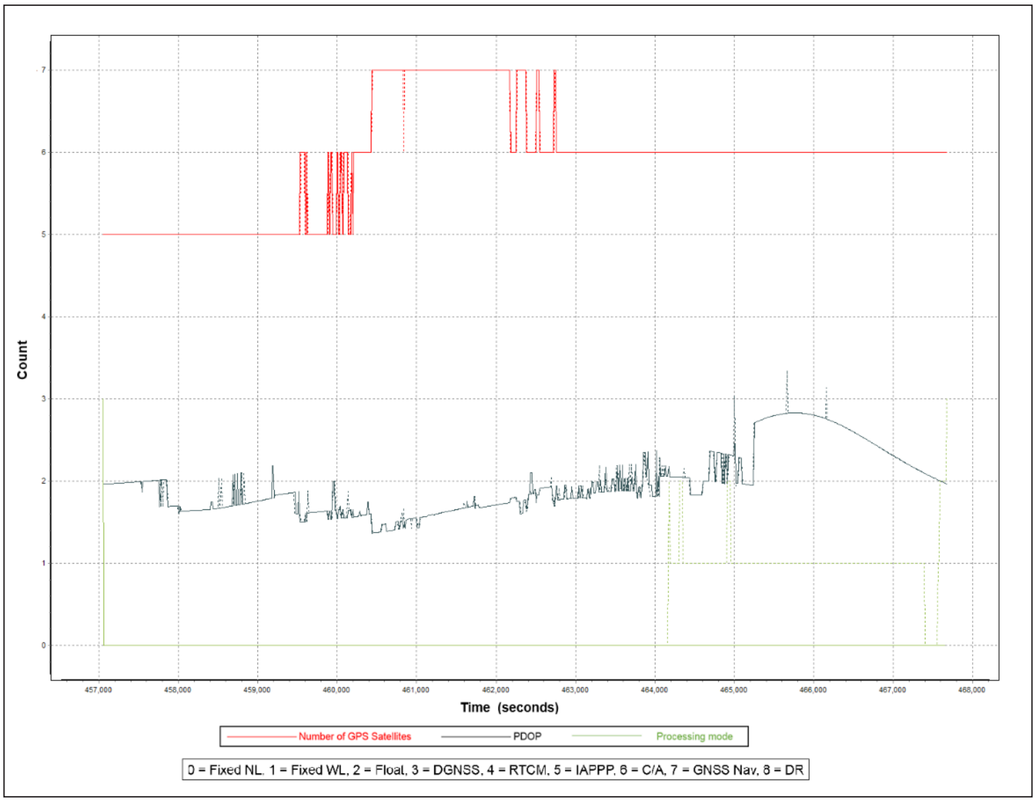


Figure 12. Solution Status Parameters of Abatan Flight 757P

The Solution Status parameters of Flight 757P, one of the Abatan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are illustrated in Figure 12. The graphs indicate that the number of satellites during the acquisition did not go down to 5. Majority of the time, the number of satellites tracked was between 5 and 7. The PDOP value did not go above the value of 3.4, which indicates optimal GPS geometry. The processing mode remained at the value of 0 for majority of the survey, with some peaks to 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 Abatan flights is presented in Figure 13.

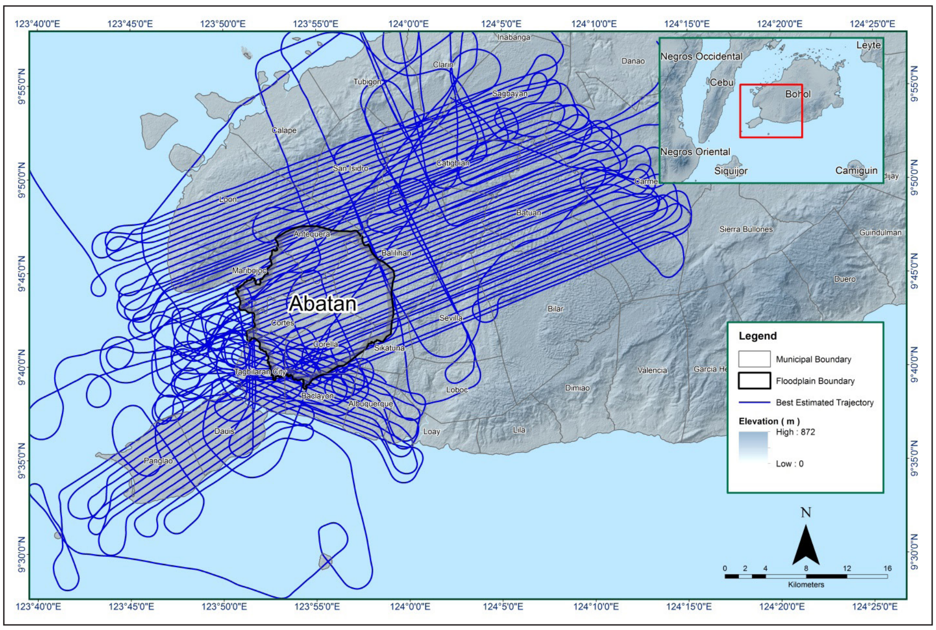


Figure 13. The best estimated trajectory conducted over the Abatan floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains seventy-five (75) flight lines, with each flight line containing two (2) channels, since the Pegasus system contains two (2) channels. The summary of the self-calibration results for all flights over the Abatan floodplain, obtained through LiDAR processing in the LiDAR Mapping Suite (LMS) software, is given in Table 13.

Table 13. Self-calibration results for the Abatan flights

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000539
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000832
GPS Position Z-correction stdev (<0.01meters)	0.0023

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

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of an SAR Elevation Data over the Abatan floodplain are represented in Figure 14. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

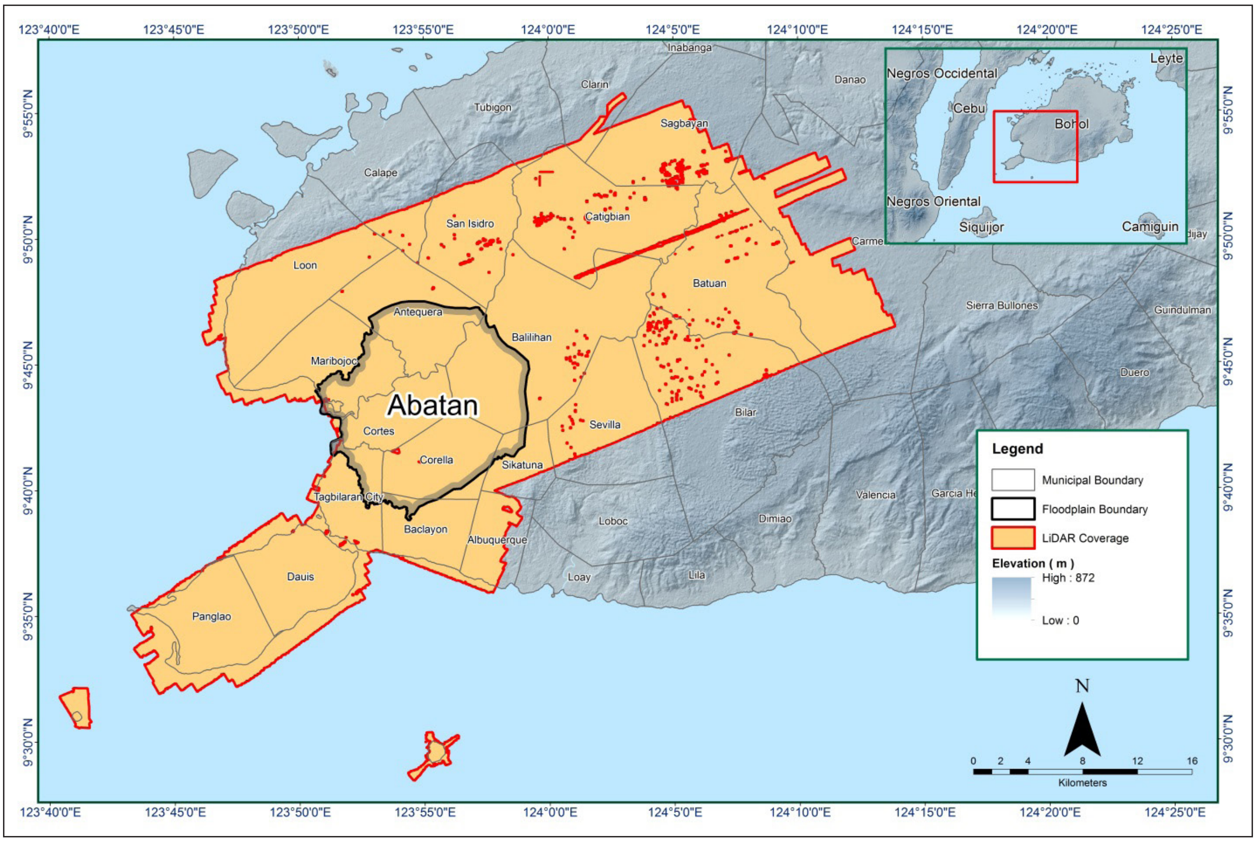


Figure 14. Boundaries of the processed LiDAR data over the Abatan floodplain

The total area covered by the Abatan missions is 1195.46 square kilometers, comprised of nine (9) flight acquisitions that were grouped and merged into nine (9) blocks, as indicated in Table 14.

Table 14. List of LiDAR blocks for the Abatan floodplain

LiDAR Blocks	Flight Numbers	Area (sq.km)
Bohol_Blk51M	1871P	144.31
Bohol_Blk51H	1867P	258.01
Bohol_Blk1H_additional	3445P	42.56
Bohol_Blk1H	755P	158.38
Bohol_Blk51H_supplement	759P	148.08
Bohol_Blk51G	757P	151.20
Bohol_Blk51G_supplement1	795P	20.92
Bohol_Blk51G_supplement2	825P	171.91
Bohol_Tagbilaran	741P	100.09
TOTAL		1195.46 sq.km

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

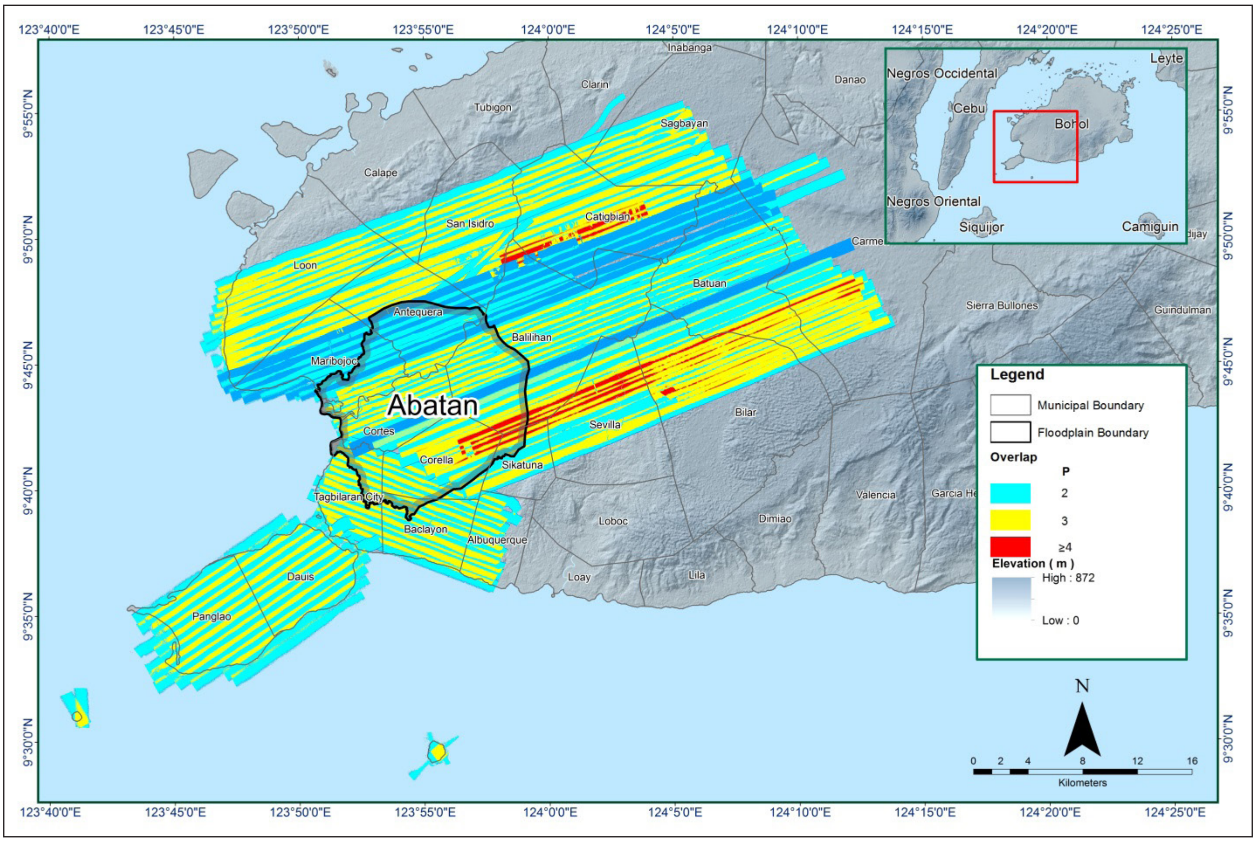


Figure 15. Image of data overlap for the Abatan floodplain

The overlap statistics per block for the Abatan floodplain can be found in Annex 8. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps were 37.27% and 59.98%, 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 (2) points per square meter criterion, is illustrated in Figure 16. It was determined that all LiDAR data for the Abatan floodplain satisfy the point density requirement, and that the average density for the entire survey area is 4.14 points per square meter.

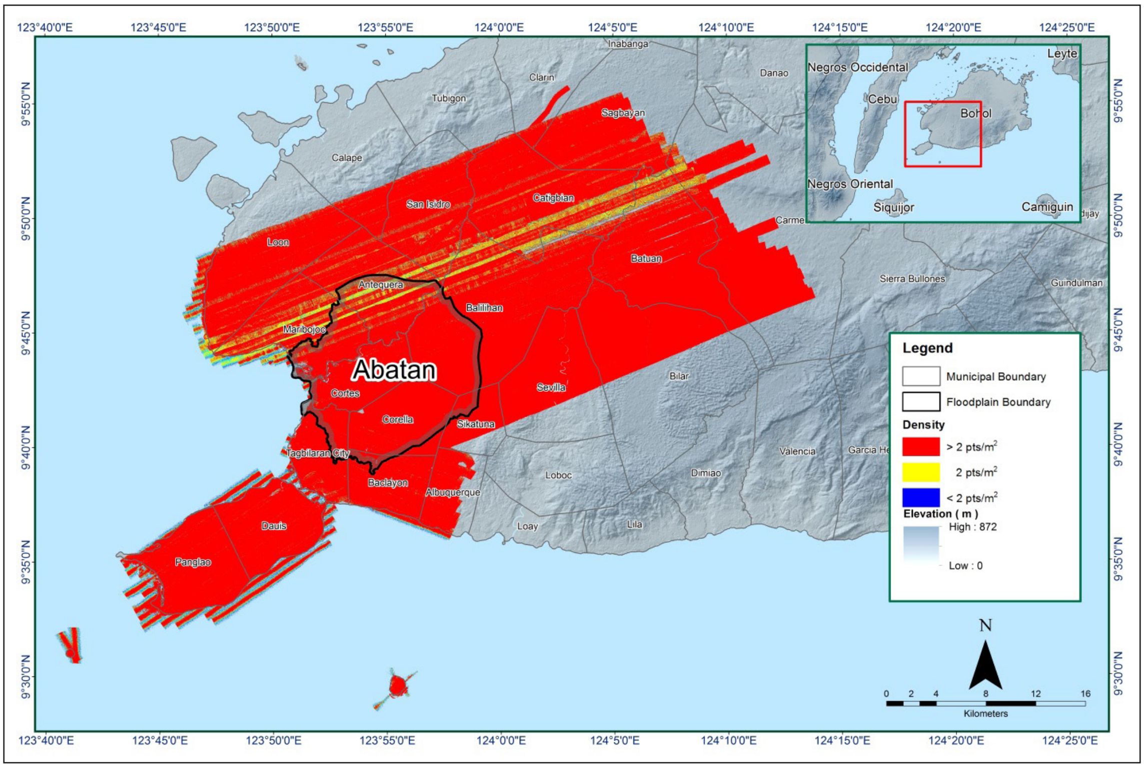


Figure 16. Pulse density map of merged LiDAR data for the Abatan floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 17. The default color range is from blue to red. Bright blue areas correspond to portions where elevations of a previous flight line, identified by its acquisition time, are higher by more than 0.20 meters relative to the elevations of its adjacent flight line. Bright red areas indicate portions where elevations of a previous flight line are lower by more than 0.2 meters relative to the elevations of its adjacent flight line. Areas with bright red or bright blue colors were investigated further using the Quick Terrain (QT) Modeler software.

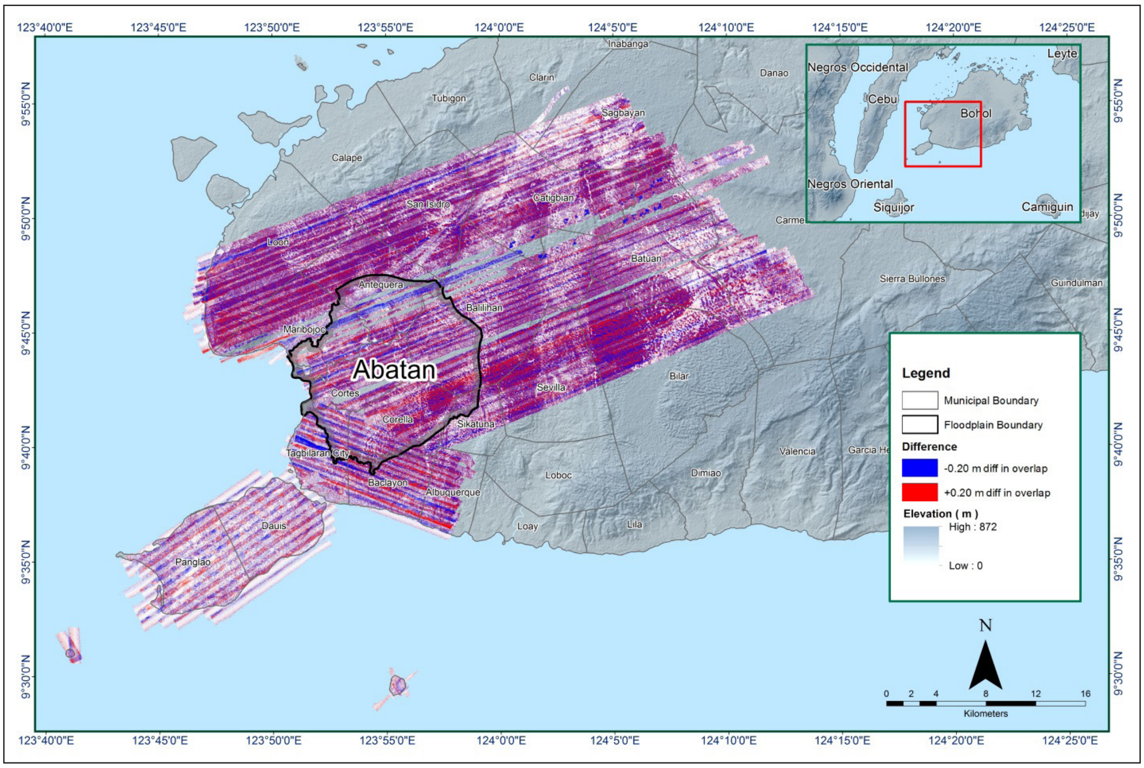


Figure 17. Elevation difference map between flight lines for the Abatan floodplain

A screen capture of the processed LAS data from Abatan Flight 757P loaded in the QT Modeler is provided in Figure 18. The upper left image shows the elevations of the points from two (2) overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

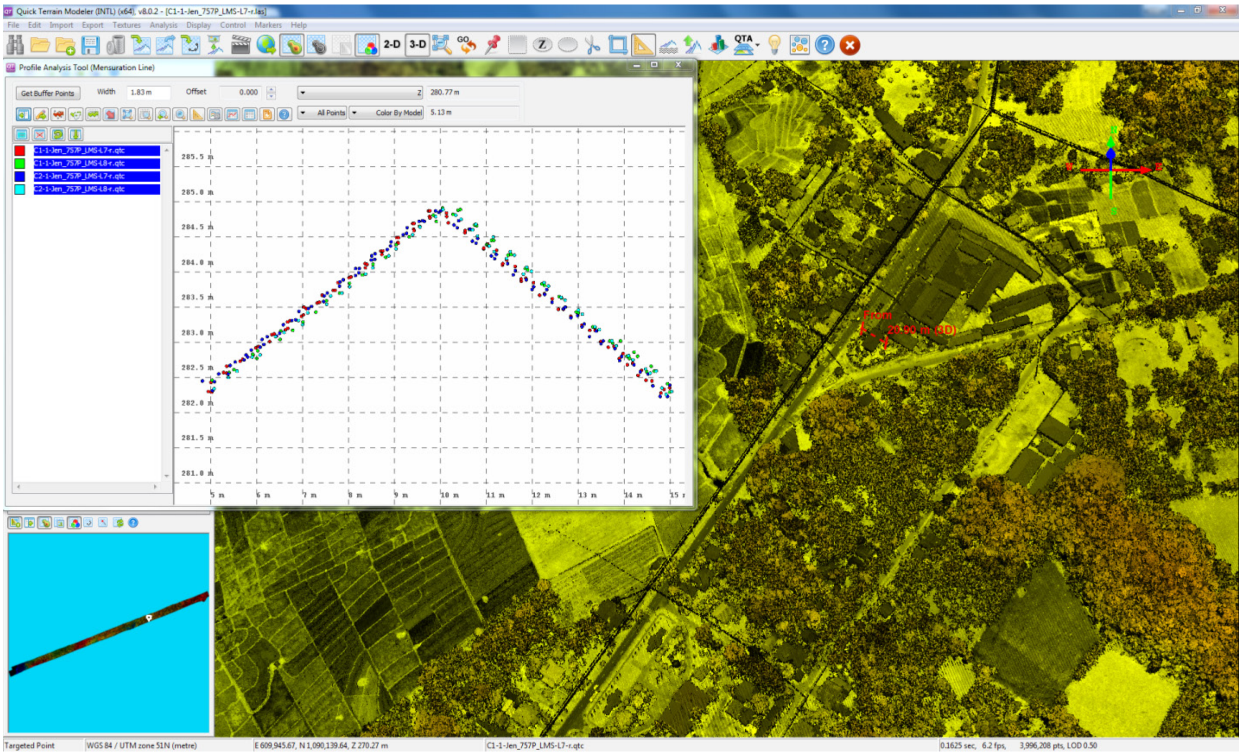


Figure 18. Quality checking for Abatan Flight 757P, using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Abatan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	685,557,645
Low Vegetation	571,060,984
Medium Vegetation	1,319,531,042
High Vegetation	1,394,649,477
Building	47,537,366

The tile system that TerraScan employed for the LiDAR data, as well as the final classification image for a block in the Abatan floodplain, are presented in Figure 19. A total of 1,794 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 15. The point cloud had a maximum and minimum height of 569.16 meters and 49.56 meters, respectively.

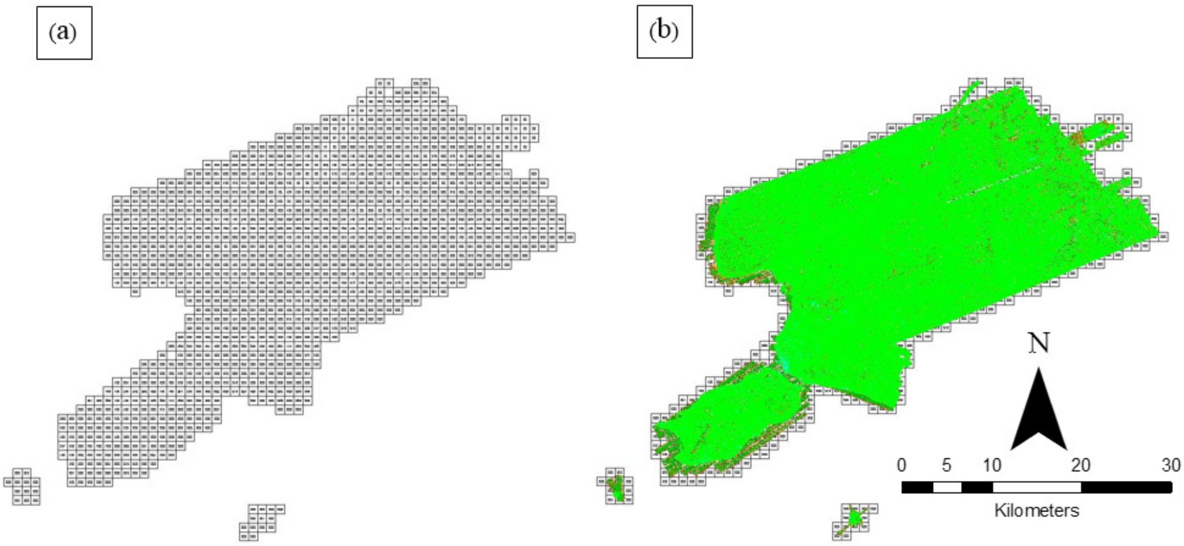


Figure 19. (a) Tiles for the Abatan floodplain; and (b) classification results in TerraScan

An isometric view of an area before and after running the classification routines is shown in Figure 20. The ground points are in orange, the vegetation is in different shades of green, and the buildings are in cyan. It is visible that the residential structures adjacent or even below canopy were classified correctly, due to the density of the LiDAR data.

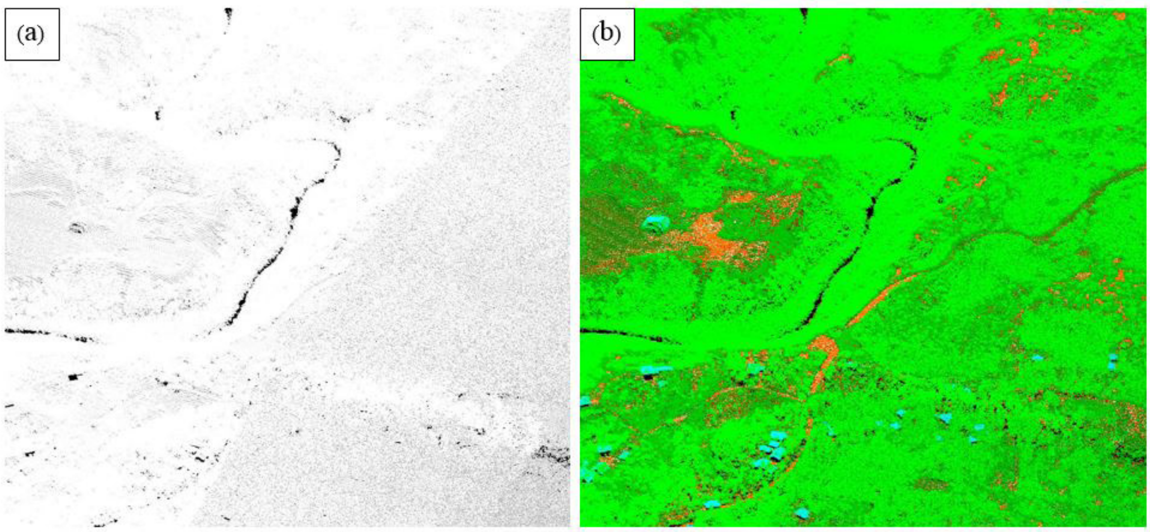


Figure 20. Point cloud (a) before and (b) after classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the area are illustrated in Figure 21, in top view display. The images convey that the DTMs are a representation of the bare earth; while the DSMs reflect all features that are present, such as buildings and vegetation.

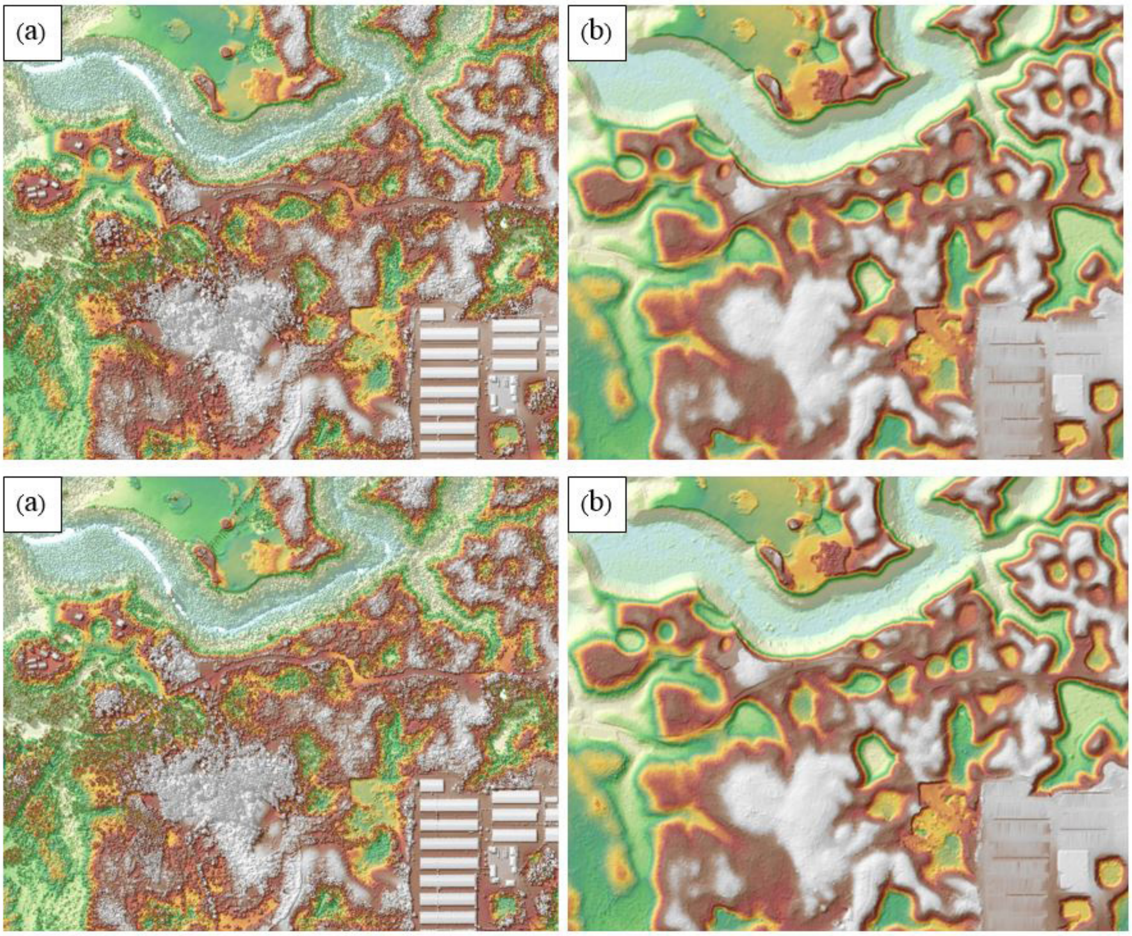


Figure 21. The production of (a) last return DSM and (b) DTM; (c) first return DSM, and (d) secondary DTM in some portion of the Abatan floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 486 1km by 1km tiles area covered by the Abatan floodplain is shown in Figure 22. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Abatan floodplain survey attained a total of 400.35 square kilometers in orthophotographic coverage, comprised of 1,166 images. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are provided in Figure 23.

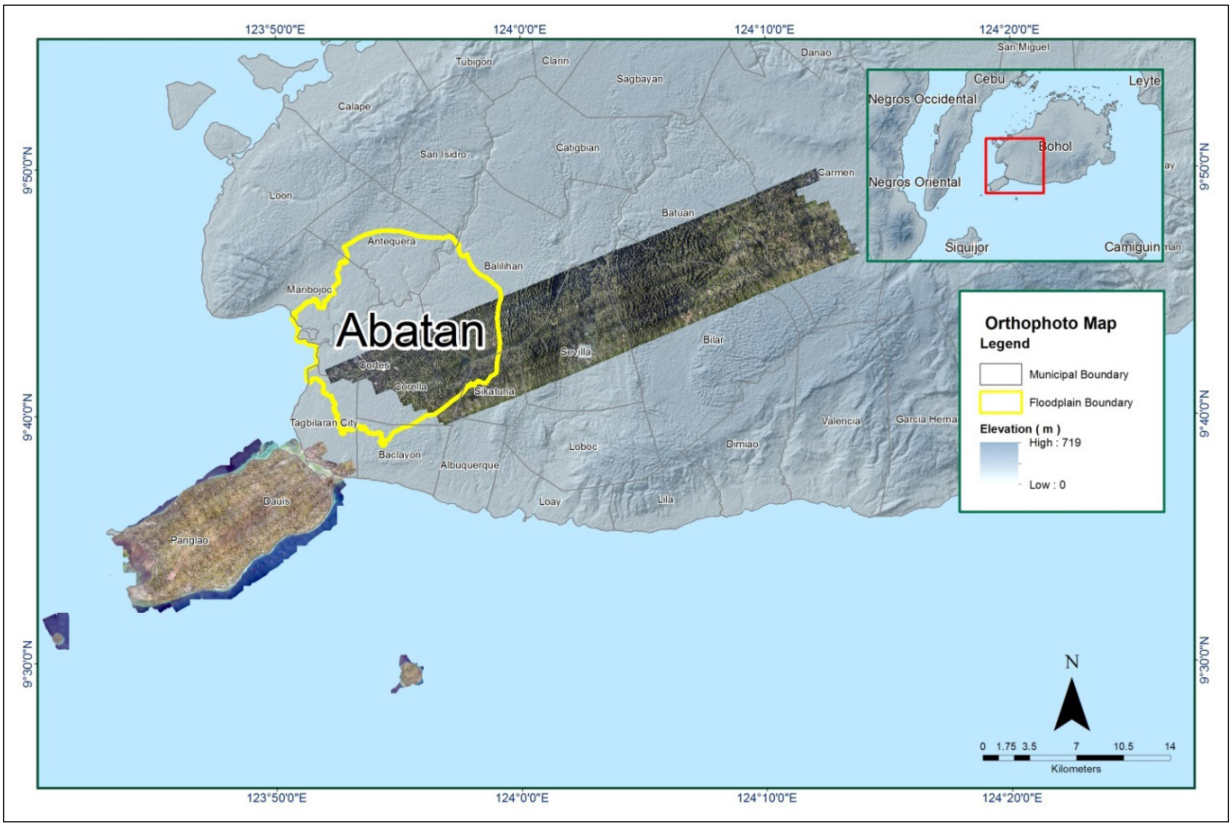


Figure 22. The Abatan floodplain, with available orthophotographs

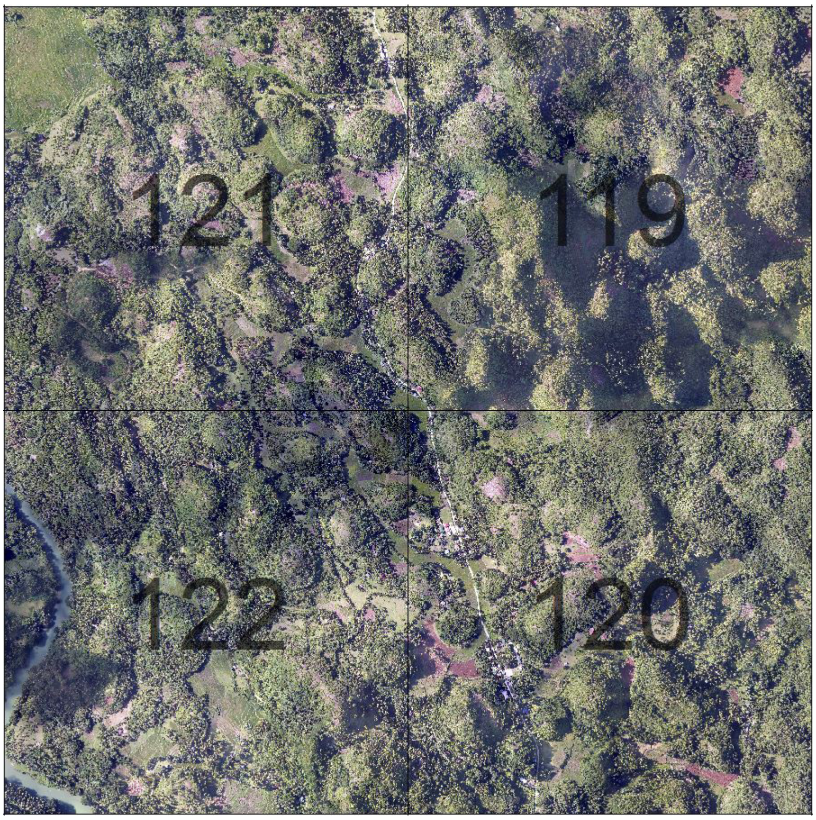


Figure 23. Sample orthophotograph tiles for the Abatan floodplain

3.8 DEM Editing and Hydro-Correction

Nine (9) mission blocks were processed for the Abatan floodplain. These blocks are composed of Bohol blocks, with a total area of 1195.46 square kilometers. Table 16 summarizes the names and corresponding areas of the blocks, in square kilometers.

Table 16. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
Bohol_Blk51M	144.31
Bohol_Blk51H	258.01
Bohol_Blk1H_additional	42.56
Bohol_Blk1H	158.38
Bohol_Blk51H_supplement	148.08
Bohol_Blk51G	151.20
Bohol_Blk51G_supplement1	20.92
Bohol_Blk51G_supplement2	171.91
Bohol_Tagbilaran	100.09
TOTAL	1195.46 sq.km

Portions of the DTM before and after manual editing are exhibited in Figure 24. The bridge (Figure 24a) was considered to be an obstruction to the flow of water along the river, and had to be removed (Figure 24b) in order to hydrologically correct the river. The mountain (Figure 24c) was misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 24d). These are represented in the images below.

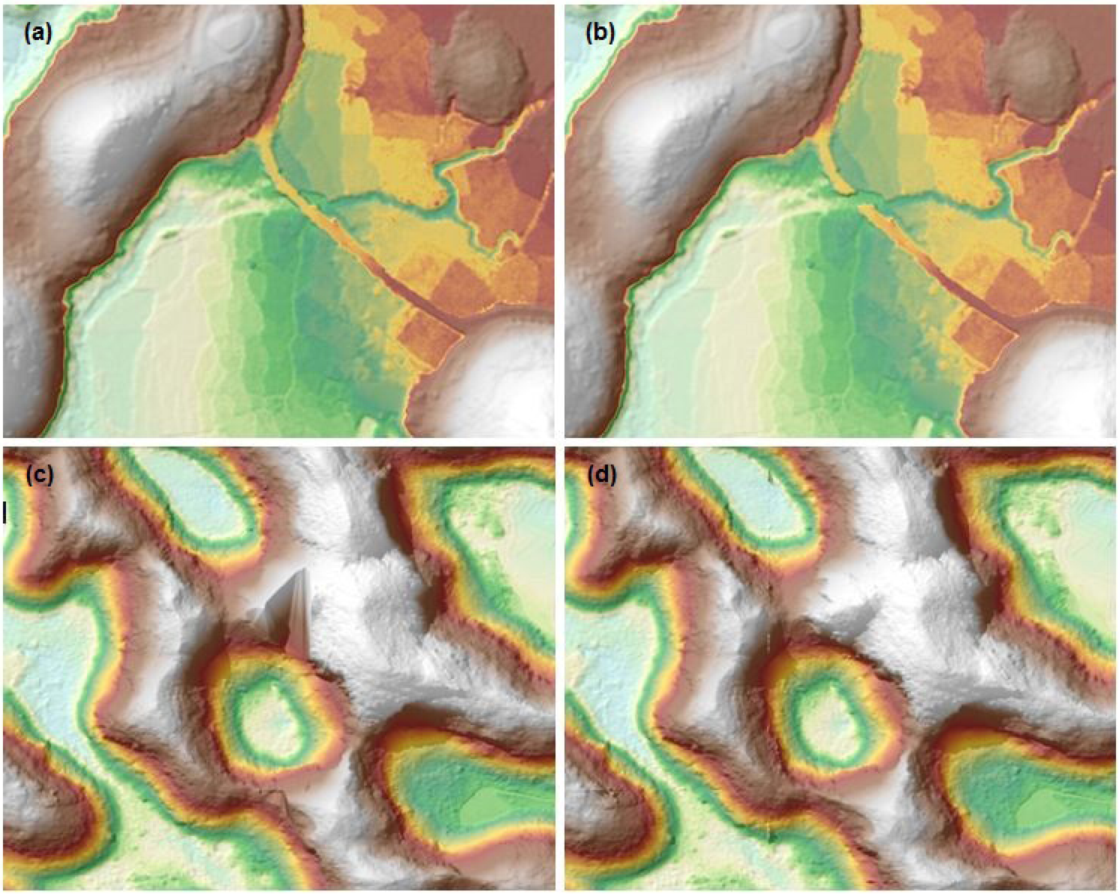


Figure 24. Portions in the DTM of the Abatan floodplain – a bridge (a) before and (b) after manual editing; and a mountain (c) before and (d) after data retrieval

3.9 Mosaicking of Blocks

The Bohol_Blk1A block was used as the reference block at the start of mosaicking process, because it was one of the first available post-processed blocks in the Bohol area. Table 17 specifies the shift values applied to each LiDAR block during mosaicking.

The mosaicked LiDAR DTM for the Abatan floodplain is shown in Figure 25. It demonstrates that the entire Abatan floodplain is 100% covered by LiDAR data.

Table 17. Shift values of each LiDAR block of the Abatan floodplain

Mission Blocks	Shift Values (meters)		
	x	y	z
Bohol_Blk51M	0.00	0.00	0.00
Bohol_Blk51H	1.10	0.14	-1.17
Bohol_Blk1H_additional	0.00	0.00	0.00
Bohol_Blk1H	0.00	18.00	0.10
Bohol_Blk1H_supplement	0.00	0.00	0.14
Bohol_Blk1G	0.00	0.00	0.37
Bohol_Blk1G_supplement1	0.00	0.00	-0.15
Bohol_Blk1G_supplement2	0.00	0.00	0.52
Bohol_Tagbilaran	0.00	0.00	1.17

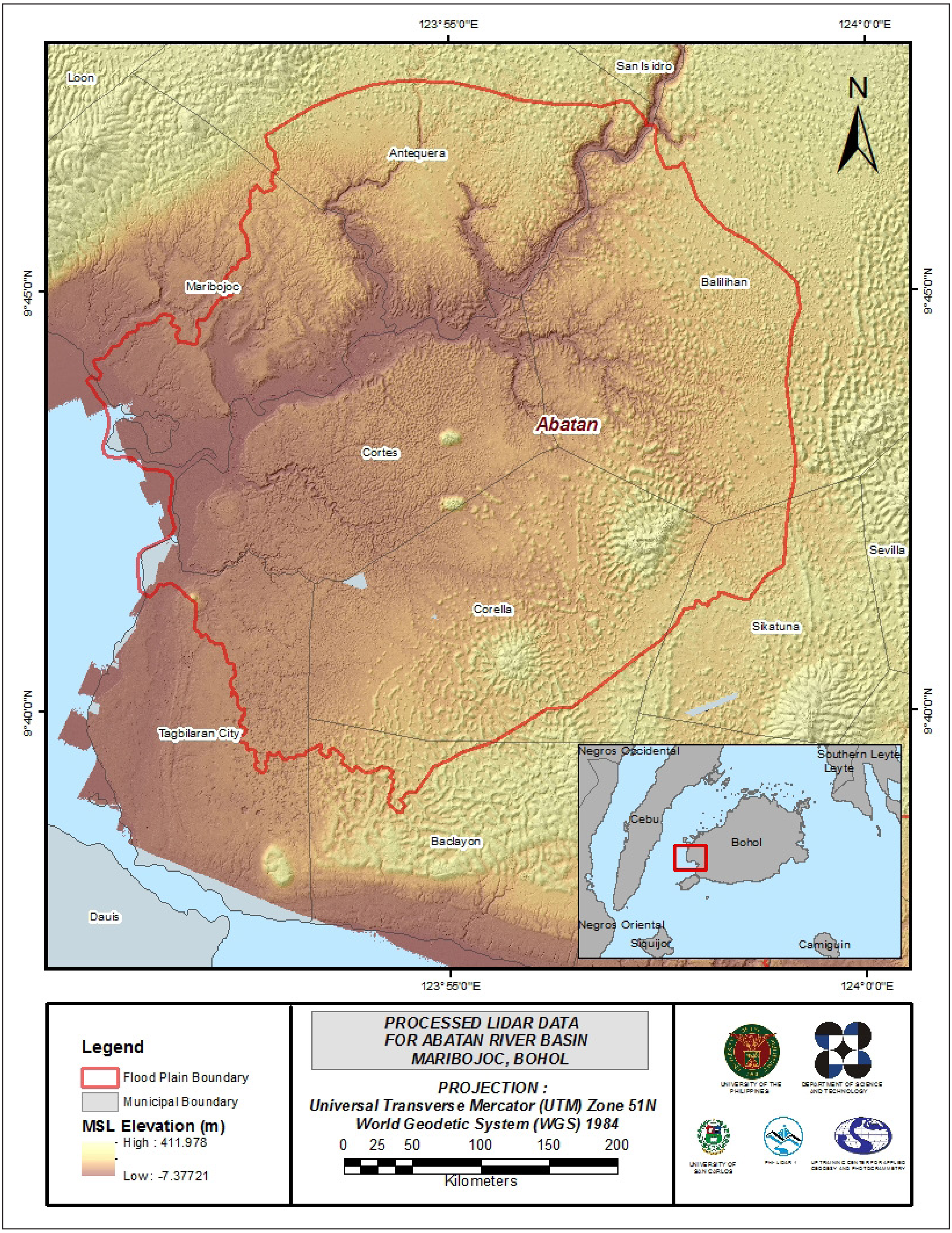


Figure 25. Map of the processed LiDAR data for the Abatan floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

The extent of the validation survey done by the Data Validation and Bathymetry Component (DVBC) in Abatan to collect points with which the LiDAR dataset is validated is shown in Figure 26. A total of 1001 survey points were gathered for calibration and validation of Abatan LiDAR data. However, the point dataset was not used for the calibration of the LiDAR data for Abatan because during the mosaicking process, each LiDAR block was referred to the calibrated Bohol DEM. Therefore, the mosaicked DEM of

Abatan can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Bohol LiDAR DTM and ground survey elevation values is shown in Figure 27. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 1.29 meters with a standard deviation of 0.19 meters. Calibration of Bohol LiDAR data was done by subtracting the height difference value, 1.29 meters, to Bohol mosaicked LiDAR data. Table 18 shows the statistical values of the compared elevation values between Bohol LiDAR data and calibration data. These values were also applicable to the Abatan DEM.

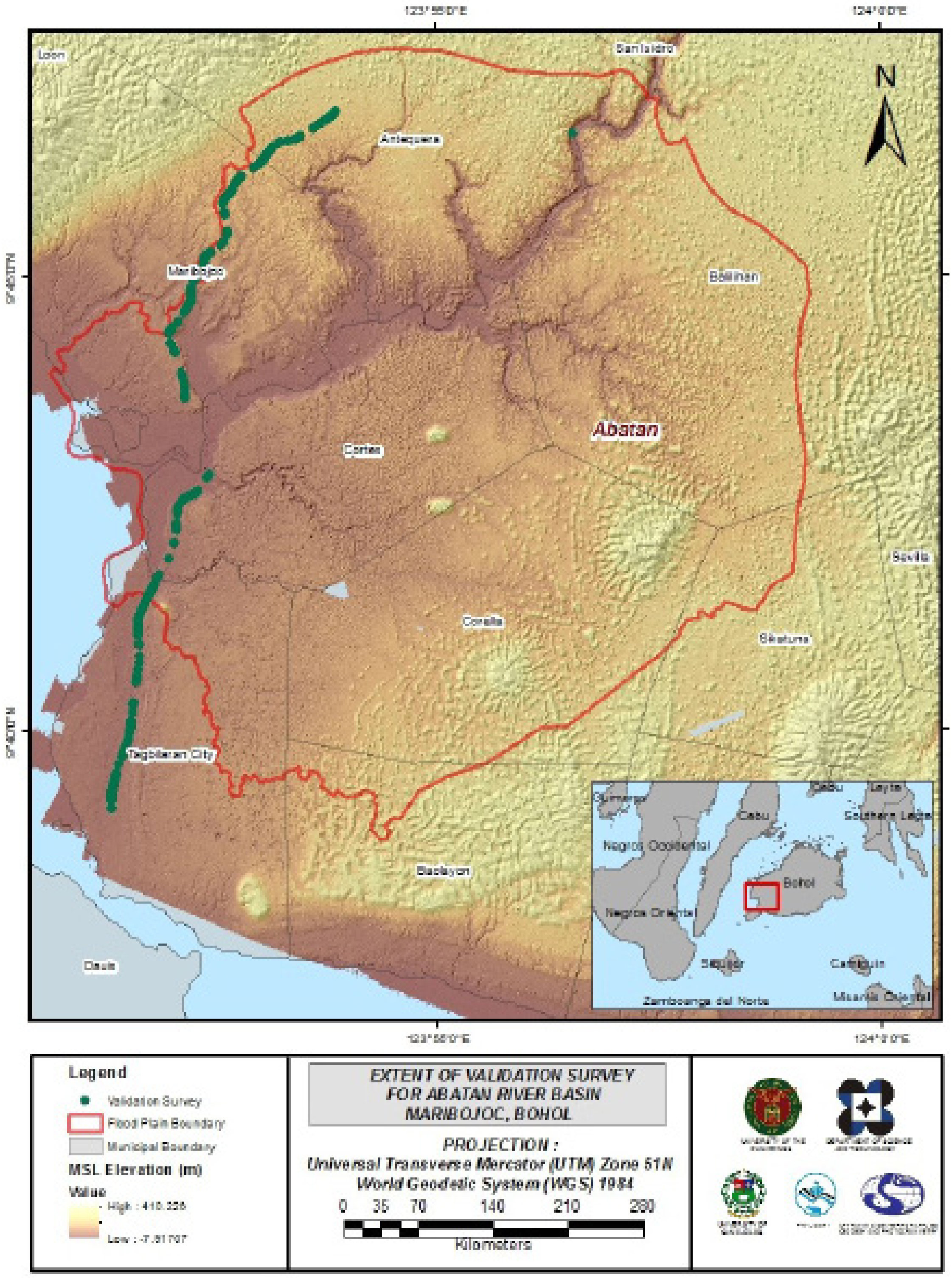


Figure 26. Map of the Abatan floodplain, with the validation survey points in green

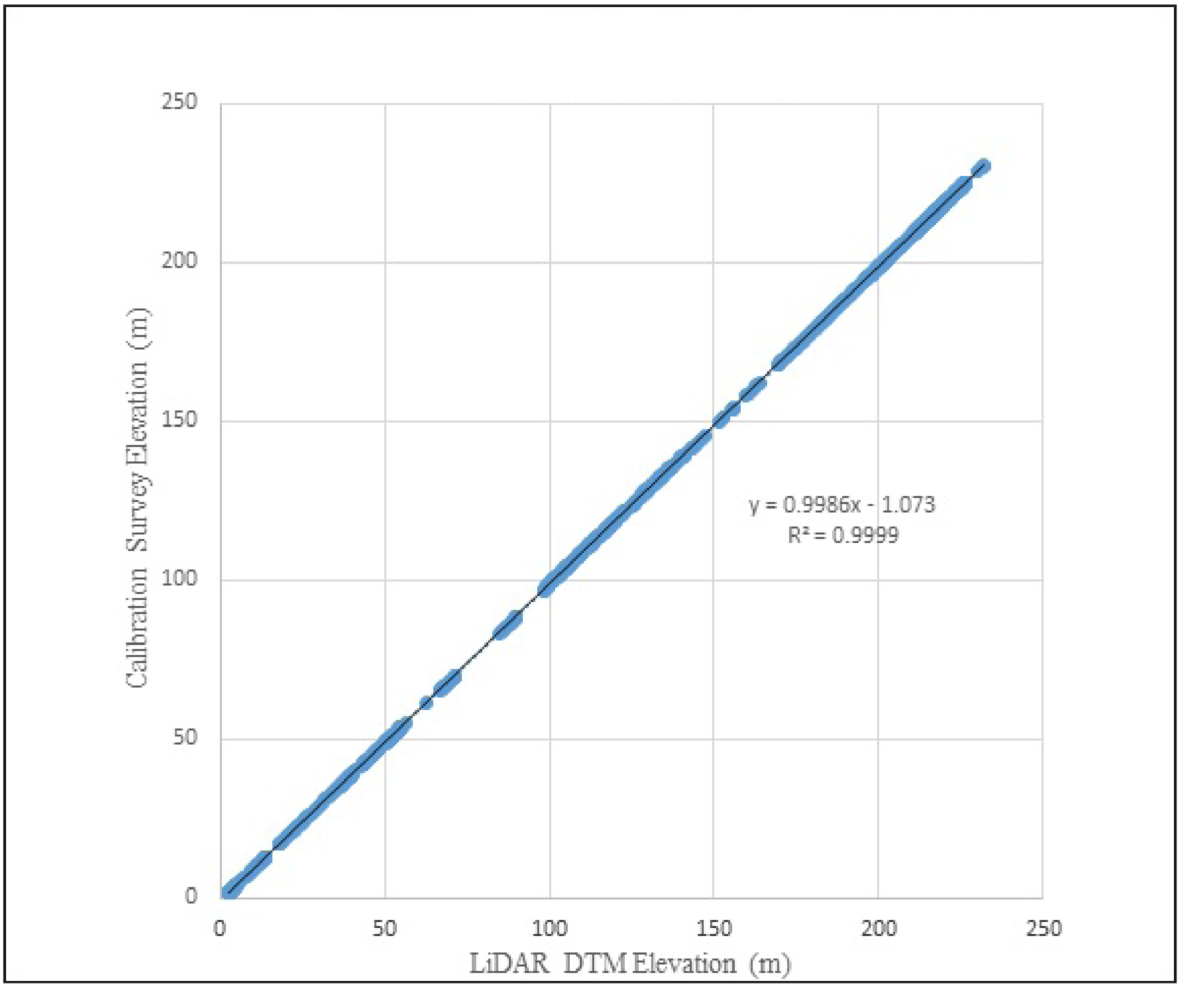


Figure 27. Correlation plot between the calibration survey points and the LiDAR data

Table 18. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	1.29
Standard Deviation	0.19
Average	-1.28
Minimum	-1.65
Maximum	-0.86

All survey points were used for the validation of calibrated Abatan DTM. The good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM is shown in Figure 28. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.17 meters with a standard deviation of 0.15 meters, as shown in Table 19.

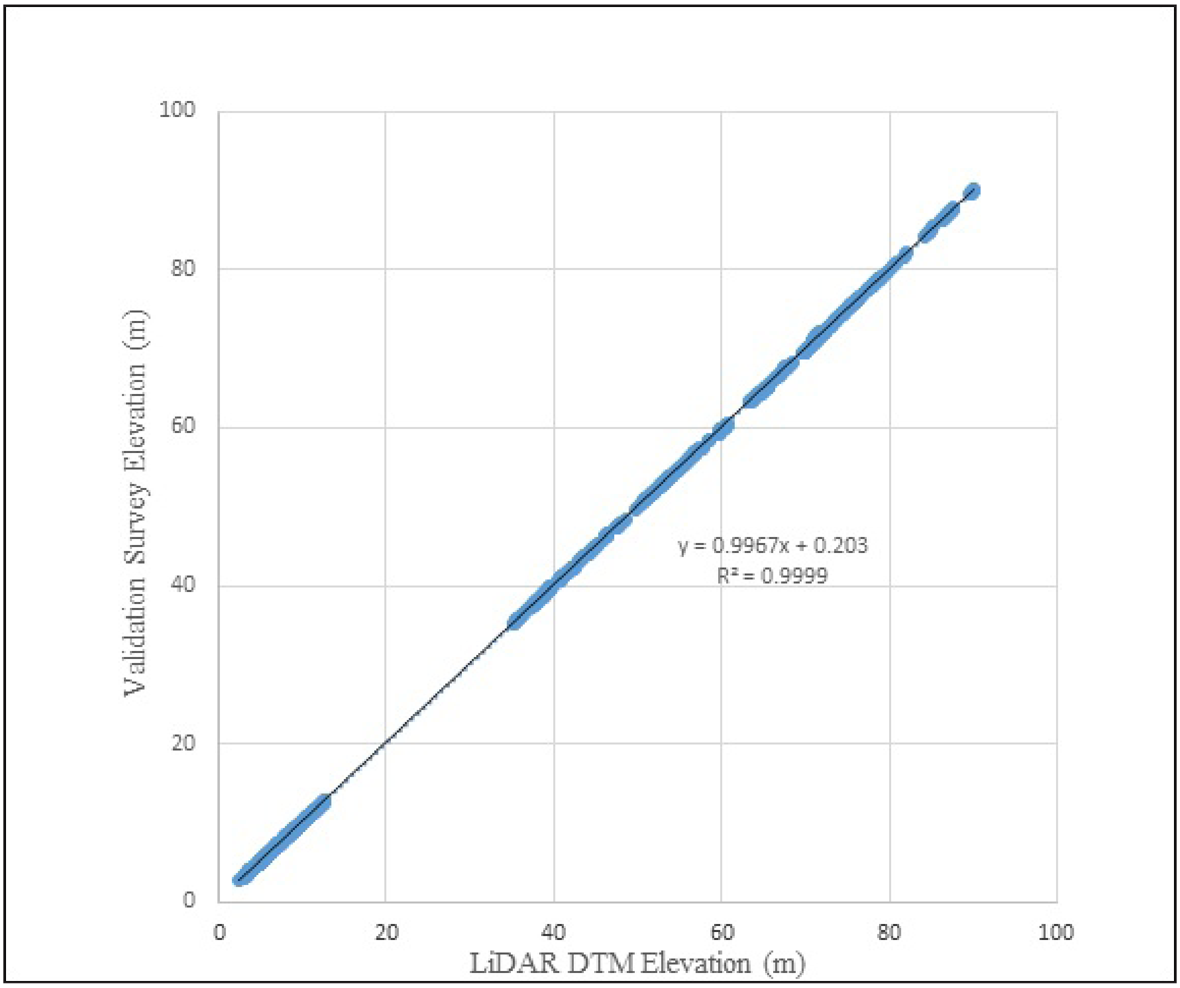


Figure 28. Correlation plot between the validation survey points and the LiDAR data

Table 19. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.17
Standard Deviation	0.15
Average	0.09
Minimum	-0.43
Maximum	0.47

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Abatan, with 4,521 bathymetric survey points. The resulting raster surface produced was obtained through the Inverse Distance Weighted (IDW) interpolation method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.02 meters. The extent of the bathymetric survey executed by the DVBC in the Abatan floodplain, integrated with the processed LiDAR DEM, is illustrated in Figure 29.

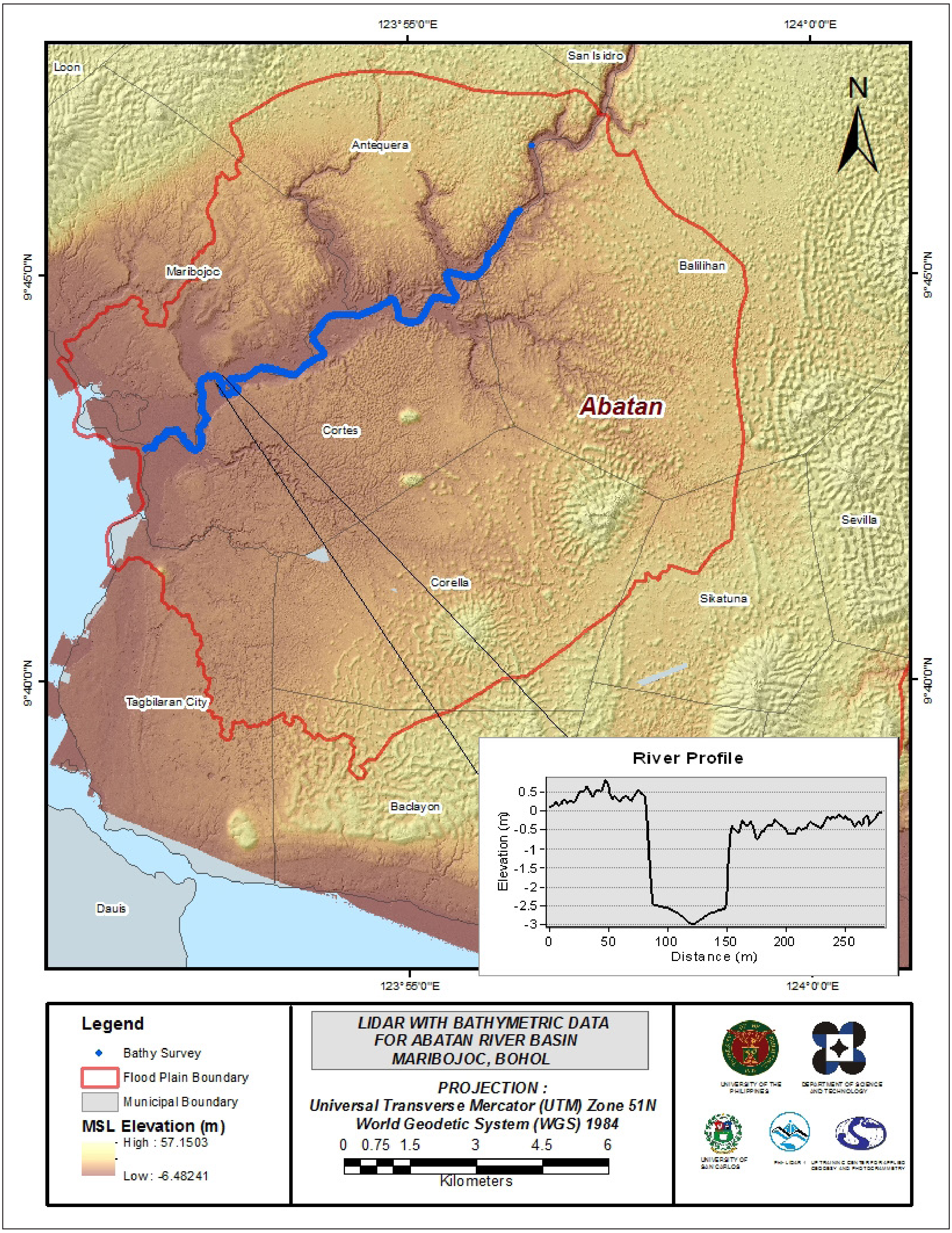


Figure 29. Map of the Abatan floodplain, with the bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

The Abatan floodplain, including its 200-meter buffer zone, has a total area of 178.83 square kilometers. Of this area, a total of 6.0 square kilometers, corresponding to a total of 978 building features, were considered for quality checking (QC). Figure 30 presents the QC blocks for the Abatan floodplain.

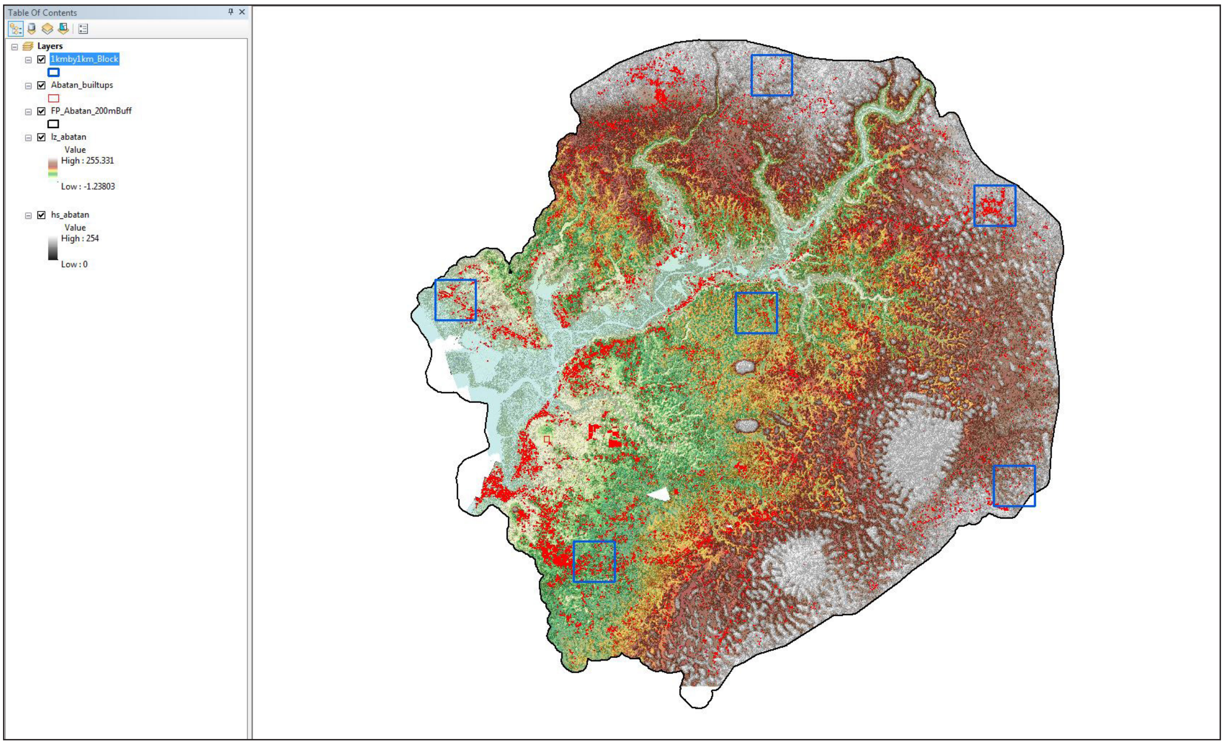


Figure 30. Blocks (in blue) of Abatan building features that were subjected to QC

Quality checking of the Abatan building features resulted in the ratings shown in Table 20.

Table 20. Quality checking ratings for the Abatan building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Abatan	99.90	100.00	98.47	PASSED

3.12.2 Height Extraction

Height extraction was done for 18,667 building features in the Abatan floodplain. Of these building features, 2,443 were filtered out after height extraction, resulting in 16,224 buildings with height attributes. The lowest building height is at 2.00 meters, while the highest building is at 18.33 meters.

3.12.3 Feature Attribution

In the attribution procedure, a combination of participatory mapping and actual field validation were employed. Representatives from the LGUs were invited to assist in the determination of the features. The remaining unidentified features were then validated on the field.

Table 21 summarizes the number of building features per type. Table 22 indicates the total length of each road type, and Table 23 specifies the number of water features extracted per type.

Table 21. Building features extracted for the Abatan floodplain

Facility Type	No. of Features
Residential	15,572
School	280
Market	21
Agricultural/Agro-Industrial Facilities	98
Medical Institutions	6
Barangay Hall	22
Military Institution	0
Sports Center/Gymnasium/Covered Court	0
Telecommunication Facilities	0
Transport Terminal	0
Warehouse	5
Power Plant/Substation	0
NGO/CSO Offices	12
Police Station	0
Water Supply/Sewerage	0
Religious Institutions	34
Bank	0
Factory	0
Gas Station	6
Fire Station	1
Other Government Offices	59
Other Commercial Establishments	82
Total	16,224

Table 22. Total length of extracted roads for the Abatan floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Abatan	155.65	31.855	59.28	32.689	0.00	289.47

Table 23. Number of extracted water bodies for the Abatan floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Abatan	3	0	0	0	0	3

A total of five (5) 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 31 displays the Digital Surface Model (DSM) of the Abatan floodplain, overlaid with its ground features.

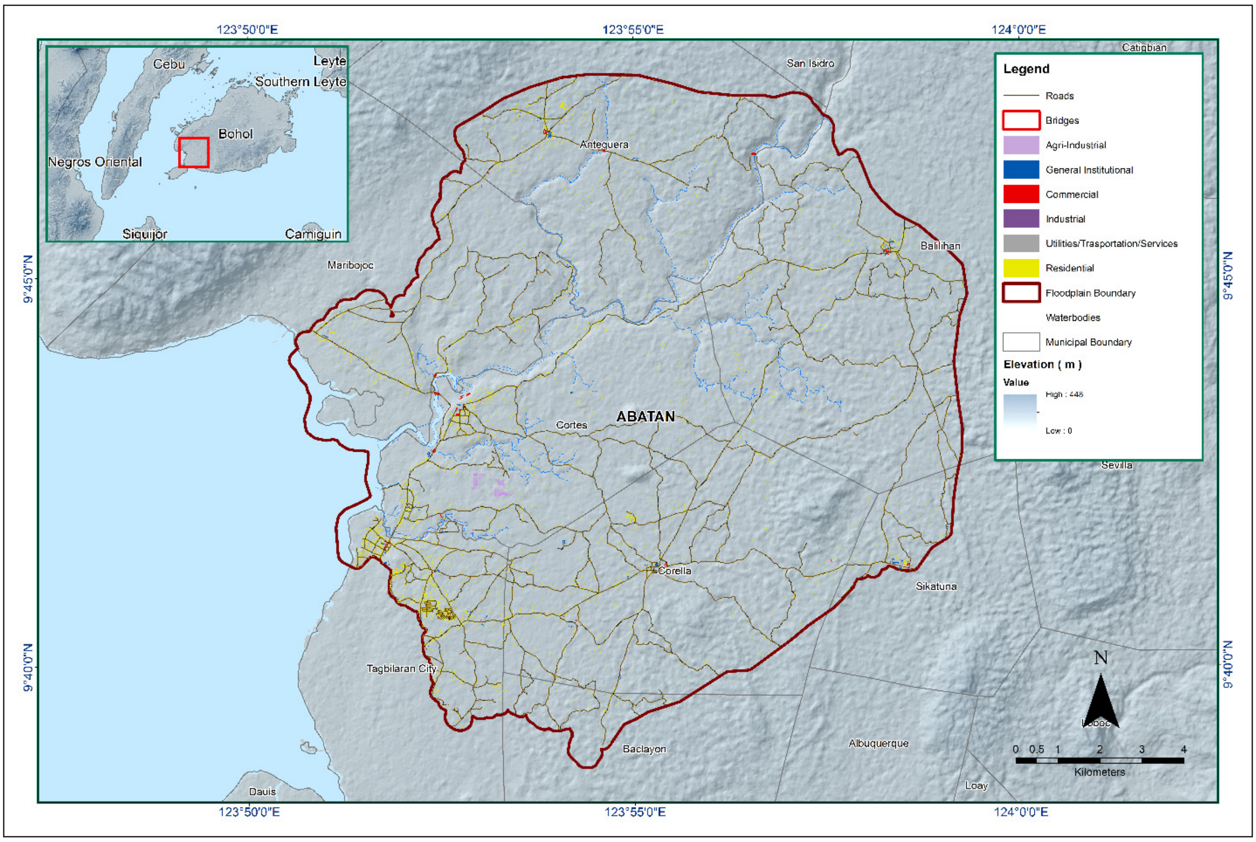


Figure 31. Extracted features for the Abatan floodplain

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

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

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

4.1 Summary of Activities

The DVBC conducted field surveys in the Abatan River on June 4 - 14, 2015. The scope of work was comprised of: (i.) courtesy calls with the LGUs of Abatan and the nearby municipalities; (ii.) static survey for the establishment of control point DOLOR at the approach of the bridge; (iii.) cross-section, bridge as-built and water level markings at the Dolor Bridge; (iv.) gathering of ground validation points along major roads, with an estimated length of 14.5 kilometers; and (v.) bathymetric survey of the river in the Municipalities of Antequera and Maribojoc, covering a distance of approximately 15.08 kilometers.

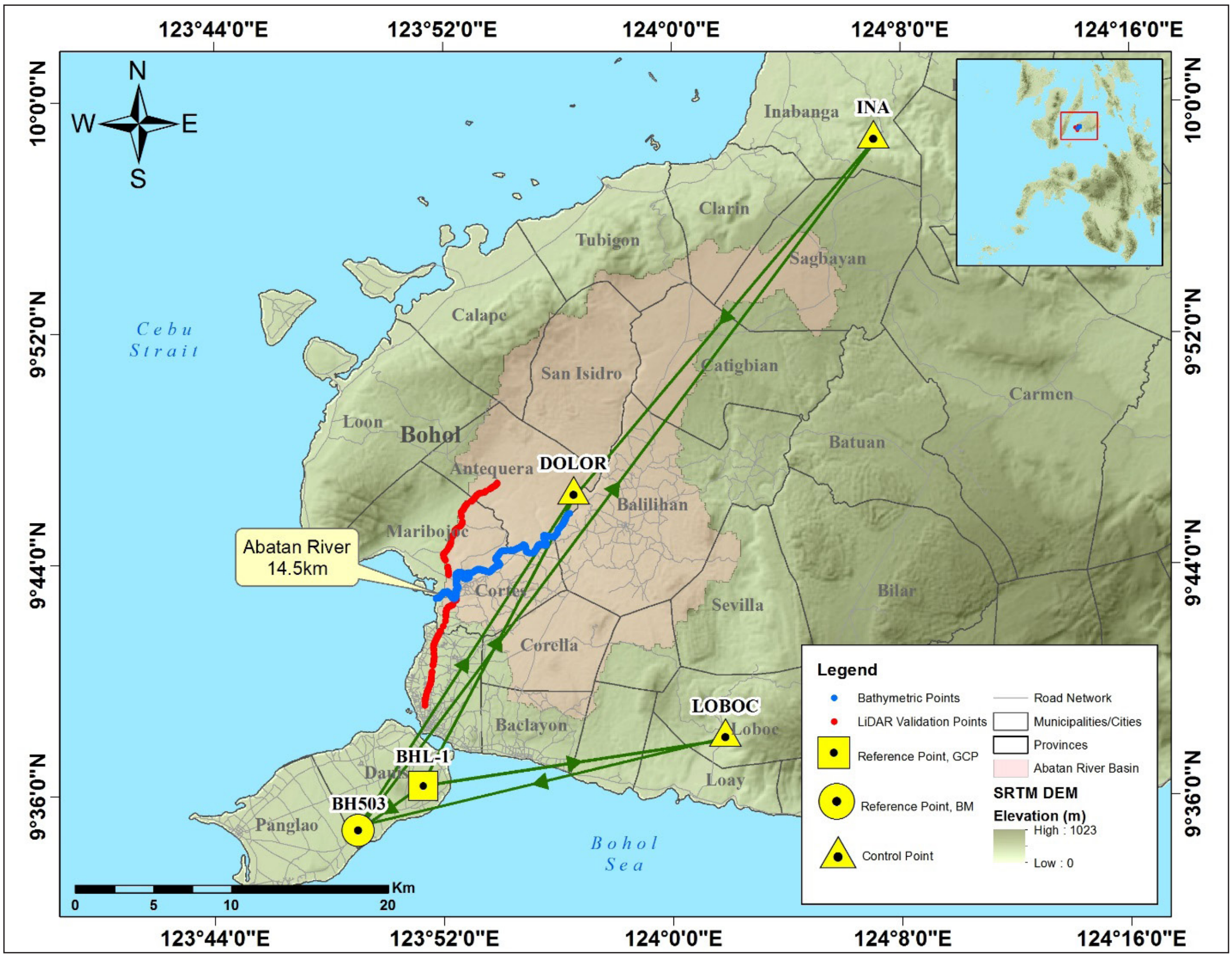


Figure 32. Extent of the bathymetric survey (in blue line) in the Abatan River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for the Abatan River Basin is composed of three (3) loops established on June 8, 2015, occupying the following reference points: (i.) BHL-1, a first-order GCP in Barangay Catarman, Municipality of Dauis; and (ii.) BH-503, a first-order BM in Barangay Dao, Municipality of Dauis. Both are located in the province of Bohol.

The following UP control points in the province of Bohol, were occupied and used as markers during the survey: (i.) DOLOR, located in Barangay Dolor, Municipality of Balilihan; (ii.) INA, located in Barangay Canlinte, Municipality of Inabanga; and (iii.) LOBOC, located in Barangay Poblacion Sawang, Municipality of Loboc.

The summary of reference and control points and their corresponding locations is provided in Table 24; while the established GNSS network is illustrated in Figure 33.

Table 24. List of reference and control points occupied during the Abatan River control survey (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
BHL-01	1st order, GCP	9°36'22.43560"N	123°51'15.91256"E	247.563	-	2007
BH-503	1st order, BM	-	-	85.726	22.328	2008
DOLOR	UP established	-	-	74.335	-	2015
INA	UP established	-	-	81.908	-	2015
LOBOC	UP established	-	-	73.769	-	2015

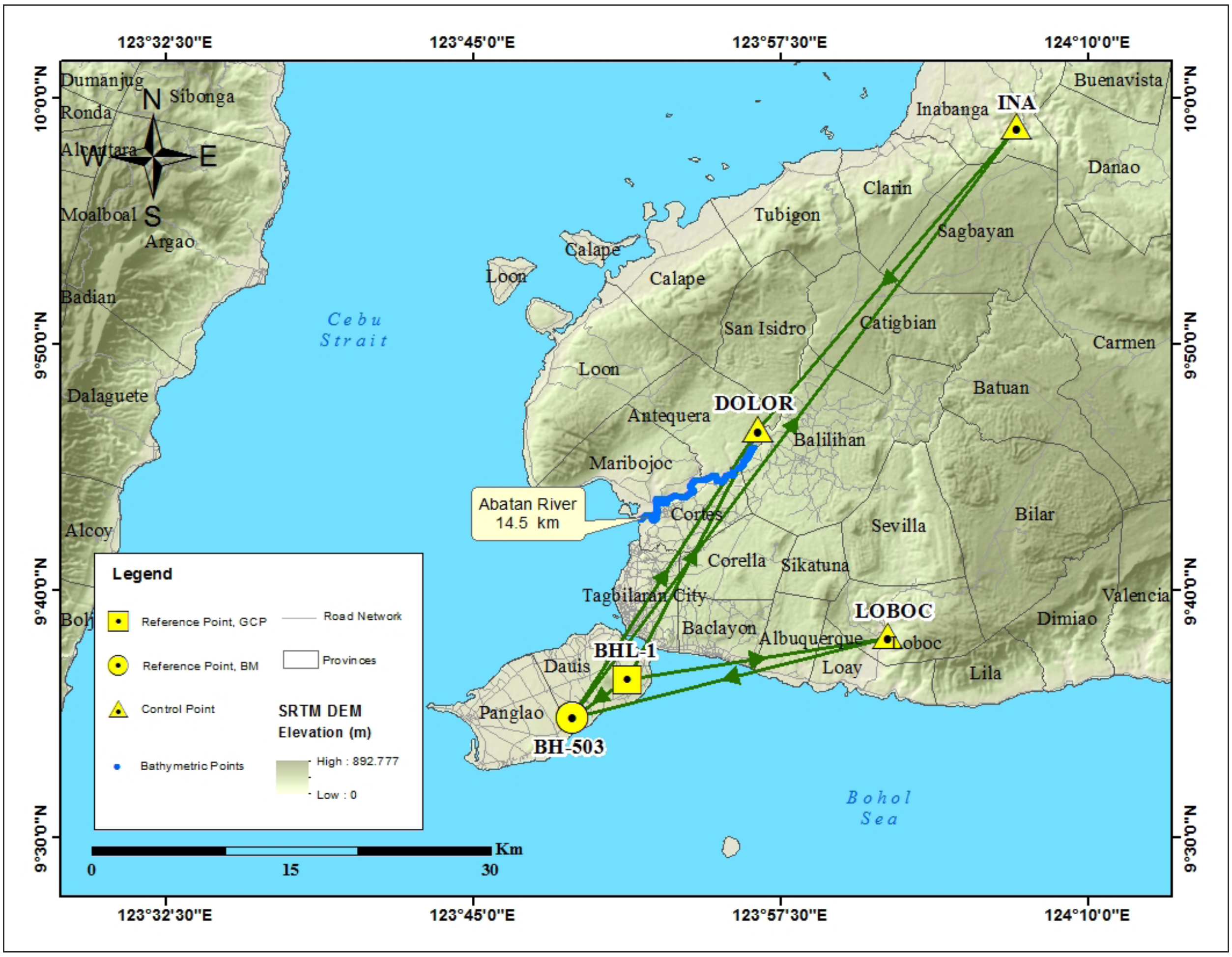


Figure 33. GNSS network covering the Abatan River

The GNSS set-ups on the recovered reference points, BHL-01 and BH-503, are exhibited in Figure 34 and Figure 35, respectively. The established control point, DOLOR, is presented in Figure 36.

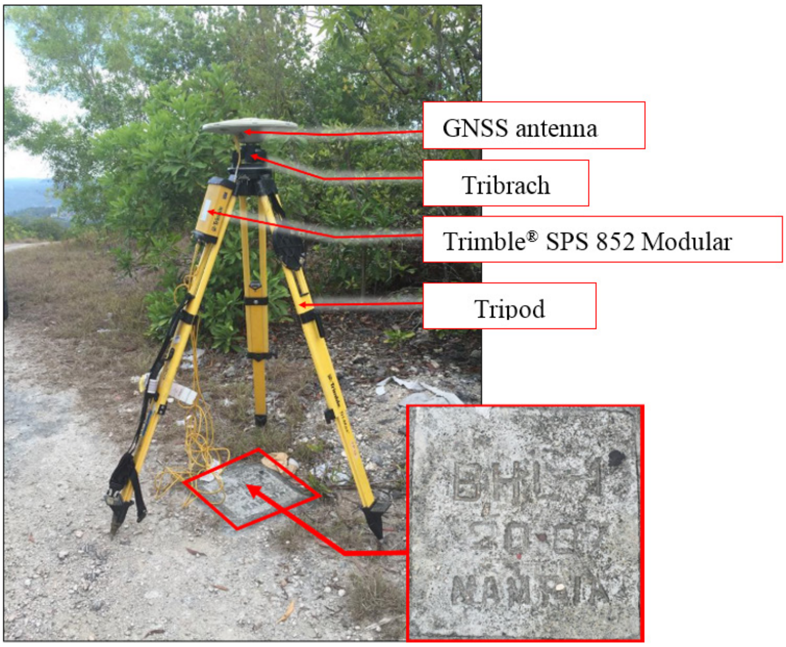


Figure 34. Trimble® SPS 852 GNSS Rover set-up at BHL-01, located on the highest hill in Sitio Dayo, Panglao Island, Bohol

Figure 35. Trimble® SPS 882 GNSS set-up at BH-503, located inside the campus of Dao Elementary School, Barangay Dao, Dauis, Bohol

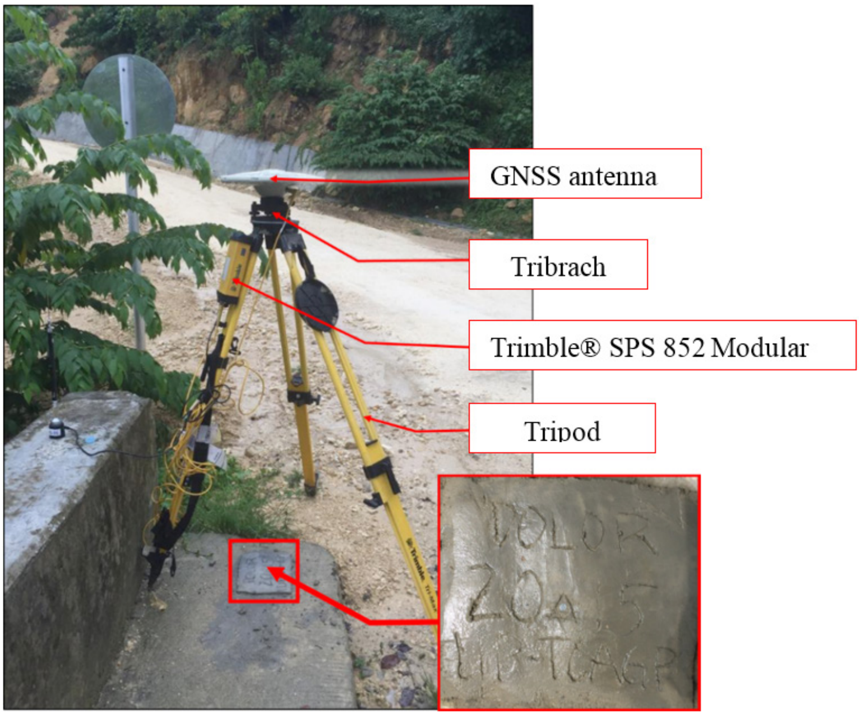


Figure 36. Trimble® SPS 852 GNSS receiver set-up on DOLOR, located at the leftmost approach of the Dolor Bridge (facing downstream), across the Abatan River in Barangay Dolor, Balilihan, Bohol

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with the horizontal and vertical precisions within the +/- 20-centimeter and +/- 10-centimeter requirement, respectively. In cases where one or more of the baselines did not meet all of these criteria, masking was performed. Masking is the removal of portions of baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, a re-survey is initiated. The baseline processing results of the control points used in the Abatan River Basin survey, generated by TBC software, are summarized in Table 25.

Table 25. Baseline processing generated report for the Abatan River control survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Height (Meter)
BHL1 --- BH503	06-08-15	Fixed	0.005	0.022	235°34'43"	5045.794	-161.828
BHL1 --- DOLOR	06-08-15	Fixed	0.006	0.039	27°08'58"	21145.711	-173.237
BH503 --- DOLOR	06-08-15	Fixed	0.010	0.064	32°30'26"	25695.545	-11.413
INA --- DOLOR	06-08-15	Fixed	0.010	0.060	220°21'08"	29699.597	-7.535
BHL1 --- INA	06-08-15	Fixed	0.009	0.027	34°50'24"	50519.954	-165.707
BH503 --- INA	06-08-15	Fixed	0.013	0.043	36°41'11"	55267.714	-3.844
BHL1 --- BH503	06-08-15	Fixed	0.004	0.038	235°34'43"	5045.804	-161.825
BHL1 --- LOBOC	06-08-15	Fixed	0.004	0.027	80°13'56"	19591.794	-173.810
LOBOC --- BH503	06-08-15	Fixed	0.006	0.076	255°17'11"	24269.112	11.864

Five (5) control points – BHL-01, BH-503 and DOLOR, INA, and LOBOC – were occupied simultaneously to form a GNSS loop. All three (3) baselines that formed the GNSS loop acquired fixed solutions, and passed the required ±20cm and ±10cm for horizontal and vertical precisions, respectively, as reflected in Table 25.

4.4 Network Adjustment

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

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

Where:

x_e is the Easting Error,

y_e is the Northing Error, and

z_e is the Elevation Error

for each control point. See the Network Adjustment Report presented in Table 26 to Table 29 for complete details.

The five (5) control points – BHL-1, BH-503, DOLOR, INA, and LOBOC – were occupied and observed simultaneously to form a GNSS loop. The coordinates of BHL-1 and the elevation values of BH-503 were held fixed during the processing of the control points, as demonstrated in Table 26. Through these reference points, the coordinates and elevation values of the unknown control points were computed.

Table 26. Constraints applied to the adjustments of the control points

Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
BH503	Grid			
BHL1	Global	Fixed	Fixed	
Fixed = 0.000001(Meter)				

The list of adjusted grid coordinates; i.e., Northing, Easting, Elevation, and computed standard errors of the control points in the network, is indicated in Table 27. The fixed controls BHL-1 and BH-503 did not yield values for grid errors and elevation errors, respectively.

Table 27. Adjusted grid coordinates for the control points used in the Abatan floodplain survey

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
BH503	589600.481	0.005	1059131.546	0.005	22.328	?	e
BHL1	593754.454	?	1061993.296	?	184.054	0.049	LL
DOLOR	603353.551	0.011	1080828.082	0.007	10.331	0.089	
INA	622503.084	0.018	1103520.295	0.011	17.794	0.093	
LOBOC	613048.755	0.007	1065364.372	0.007	9.787	0.083	

With the mentioned equation, for horizontal accuracy, and $z_e < 10\ cm$ for vertical accuracy, the computations for accuracy are as follows:

a. BHL-1

Horizontal Accuracy = Fixed

Vertical Accuracy = 1.9 cm < 10 cm

b. BH-503

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

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

= 0.707< 20 cm

Vertical Accuracy = Fixed

c. DOLOR

Horizontal Accuracy = $\sqrt{((1.1)^2 + (0.7)^2}$

= $\sqrt{(1.21 + 0.49)}$

= 1.303 < 20 cm

Vertical Accuracy = 8.9 cm < 10 cm

d. INA

Horizontal Accuracy = $\sqrt{((1.8)^2 + (1.1)^2}$

= $\sqrt{(3.24 + 1.21)}$

= 1.1 < 20 cm

Vertical Accuracy = 1.99.3 cm < 10 cm

e. LOBOC

Horizontal Accuracy = $\sqrt{((0.7)^2 + (0.7)^2}$

= $\sqrt{(0.49 + 0.49)}$

= 0.99 < 20 cm

Vertical Accuracy = 8.3 cm < 10 cm

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

Table 28. Adjusted geodetic coordinates for control points used in the Abatan River floodplain validation

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
BH503	N9°34'49.59212"	E123°48'59.41509"	85.726	?	e
BHL1	N9°36'22.43560"	E123°51'15.91256"	247.563	0.049	LL
DOLOR	N9°46'34.81522"	E123°56'32.52432"	74.335	0.089	
INA	N9°58'51.64572"	E124°07'03.51400"	81.908	0.093	
LOBOC	N9°38'10.45985"	E124°01'49.19123"	73.769	0.083	

The corresponding geodetic coordinates of the observed points are within the required accuracy as, shown in Table 28. Based on the results of the computation, the accuracy conditions are satisfied; hence, the required accuracy for the program was met.

The computed coordinates of the reference and control points utilized in the Abatan River GNSS Static Survey are indicated in Table 29.

Table 29. Reference and control points used in the Abatan River Static Survey, with their corresponding locations (Source: NAMRIA, UP-TACAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM Zone 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing	Easting	MSL Elevation (m)
BHL-01	1st order, GCP	9°36'22.43560"N	123°51'15.91256"E	247.563	1061993.296	593754.454	184.054
BH-503	1st order, BM	9°34'49.59212"N	123°48'59.41509"E	85.726	1059131.546	589600.481	22.328
DOLOR	UP established	9°46'34.81522"N	123°56'32.52432"E	74.335	1080828.082	603353.551	10.331
INA	UP established	9°58'51.64572"N	124°07'03.51400"E	81.908	1103520.295	622503.084	17.794
LOBOC	UP established	9°38'10.45985"N	124°01'49.19123"E	73.769	1065364.372	613048.755	9.787

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

The cross-section and bridge as-built surveys were conducted on June 11, 2015 at the downstream side of the Dolor Bridge in Barangay Anigilan, Municipality of Antequera, Bohol. A Trimble® SPS 885 GNSS in PPK survey technique was utilized, as depicted in Figure 37.

Figure 37. Bridge as-built survey using PPK Technique

The length of the cross-sectional line surveyed in the Dolor Bridge is about 48.728 meters with twenty-five (25) cross-sectional points, using the control point DOLOR as the GNSS base station. The location map, cross-section diagram, and bridge as-built data for the Dolor Bridge are illustrated in Figure 38 Figure 39, and Figure 40, respectively.

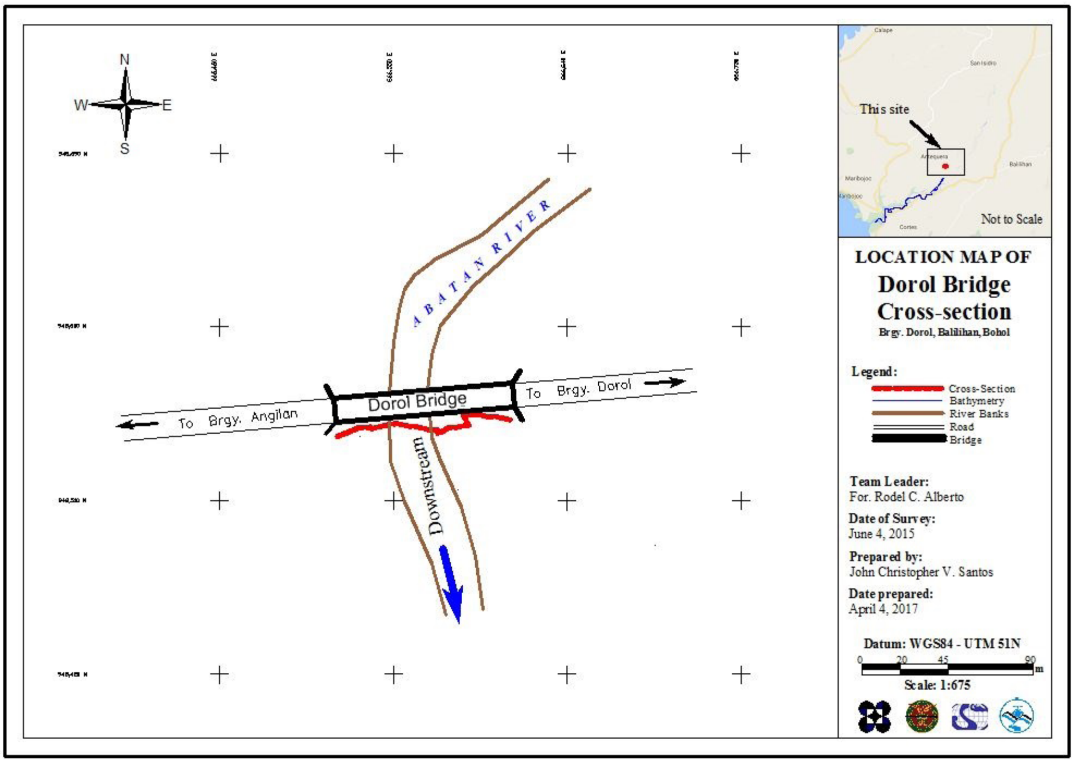


Figure 38. Dolor Bridge location map

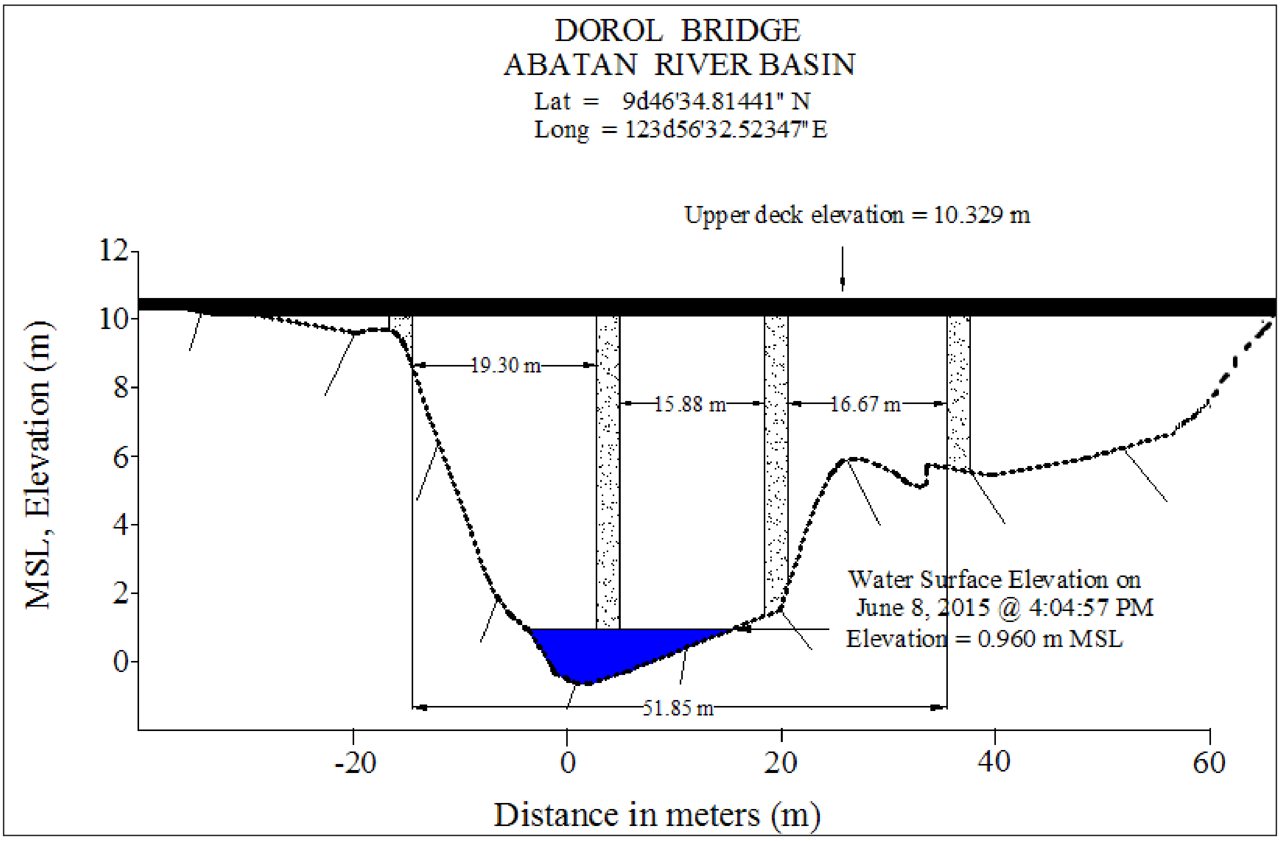


Figure 39. Dolor Bridge cross-sectional diagram

Bridge Data Form

Bridge Name: Dorol Bridge **Date:** June 11, 2015

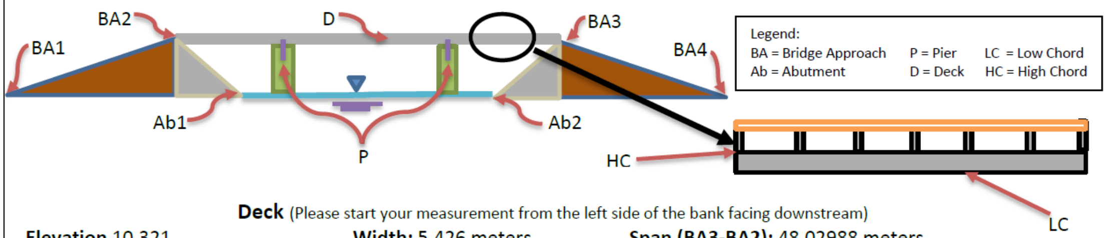
River Name: Abatan River **Time:** 4:30 P.M.

Location (Brgy, City, Region): Barangay Dorol, Municipality of Balilihan, Bohol

Survey Team: Bernard's Team

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

Latitude: 9d46'34.81441" N **Longitude:** 123d56'32.52347" E



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

Elevation 10.321 **Width:** 5.426 meters **Span (BA3-BA2):** 48.02988 meters

	Station	High Chord Elevation	Low Chord Elevation
1		11.478	10.334
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	10.329	**BA3**	76.3328	5.749
BA2	28.30292	10.595	**BA4**		

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

	Station (Distance from BA1)	Elevation
Ab1		
Ab2		

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

Shape: Rectangular **Number of Piers:** 2 **Height of column footing:**

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	38.6113	10.291	
Pier 2	59.6664	10.507	
Pier 3			
Pier 4			
Pier 5			
Pier 6			

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

Figure 40. Bridge as-built form of the Dolor Bridge

Figure 41. Water level markings on the post of the Dolor Bridge

The water surface elevation in MSL of the Abatan River was determined using a Trimble® SPS 882 in PPK mode on June 8, 2015 at 16:04:57 hrs. This was translated into markings on the bridge's pier, using a digital level. The marked pier, as displayed in Figure 41, served as reference for flow data gathering and depth gauge deployment by the USC Phil-LiDAR 1 Team.

4.6 Validation Points Acquisition Survey

The validation acquisition survey was conducted on June 12, 2015 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a range pole that was attached in front of a vehicle (Figure 42). The GNSS base station at DOLOR was utilized. The receiver secured with a cable-tie to ensure that it was horizontally and vertically balanced. The antenna height was measured and recorded to be 2.330 meters, from the ground up to the bottom of the notch of the GNSS rover receiver.

Figure 42. Validation points acquisition survey set-up along the Abatan River Basin

The survey was conducted using PPK technique set on a continuous topography mode, which started in Barangay Poblacion, Municipality of Antequera, and ended in Barangay Lincod, Municipality of Maribojoc. The survey gathered 1,024 validation points covering an approximate distance of 14.8 kilometers. The gaps in the validation line, as depicted in Figure 43, were due to some difficulties in acquiring satellite signals, such as dense canopies of trees along the roads.

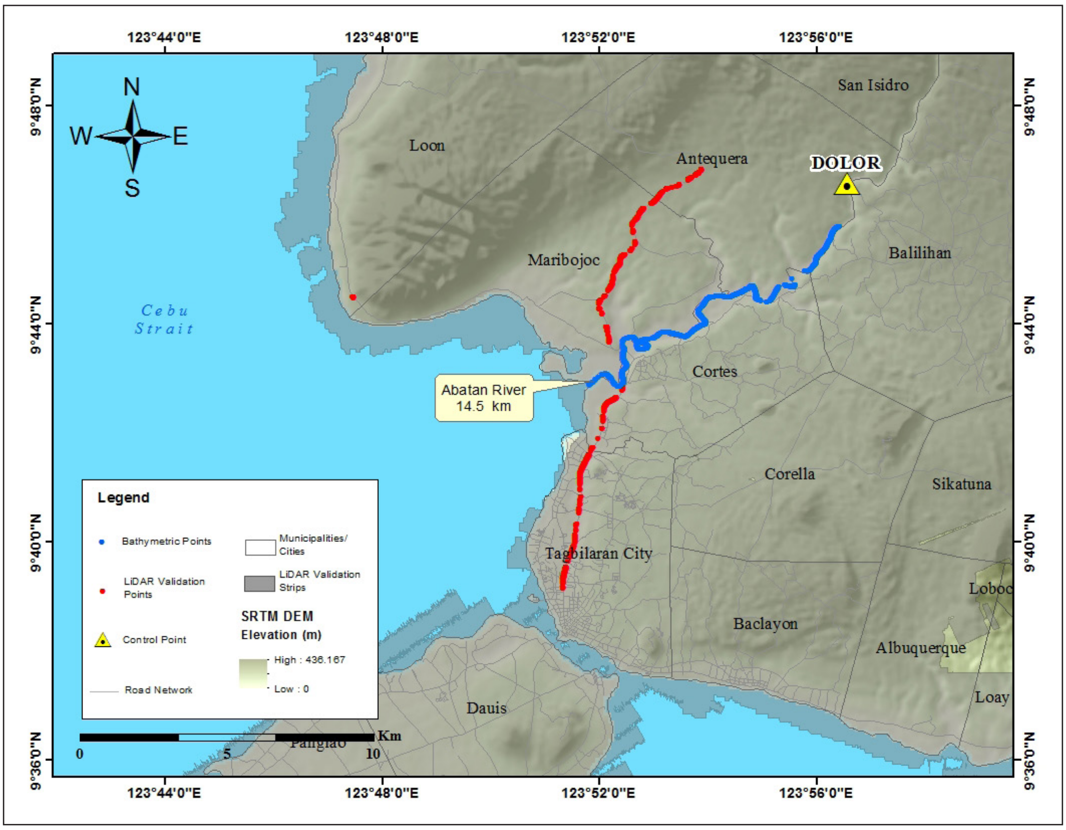


Figure 43. Extent of the LiDAR ground validation survey of the Abatan River Basin

4.7 Bathymetric Survey

A bathymetric survey was executed on June 8, 2015 using an Ohmex™ single beam echo sounder and Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode, as illustrated in Figure 44. The survey started in the upstream portion of the river in Barangay Angilan, Municipality of Antequera, with coordinates 9°45'47.14299"N, 123°56'23.68935"E; and ended at the mouth of the river in Barangay Lincod, Municipality of Maribojoc, with coordinates 9°42'52.78062"N, 123°51'48.11859"E. The control point DOLOR was used as the GNSS base station all throughout the survey.

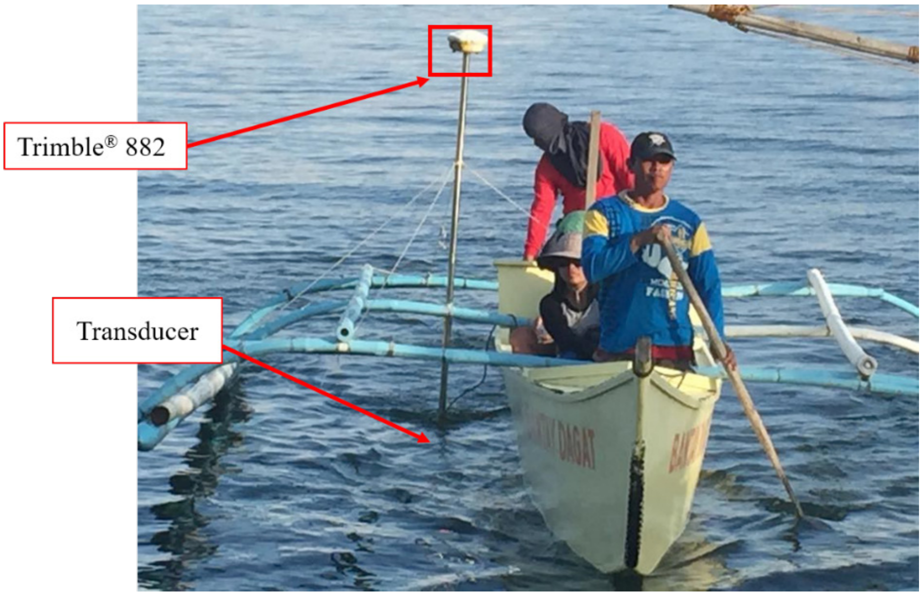


Figure 44. Bathymetric survey using Ohmex™ single beam echo sounder in Abatan River

The bathymetric survey for the Abatan River gathered a total of 1,204 points covering 14.5 kilometers of the river, traversing Barangay Angilan in the Municipality of Antequera downstream, until Barangay Lincod, Muncipality of Maribojoc. Both points are in the province of Bohol. A CAD drawing was produced to illustrate the riverbed profile of Abatan River, presented in Figure 46. The profile shows that the highest and lowest elevation had a 9.525-meter difference. The highest elevation observed was –0.481 meters below MSL, located at the middle portion of the Abatan River; while the lowest was –9.044 meters below MSL, also located in the middle portion of the river.

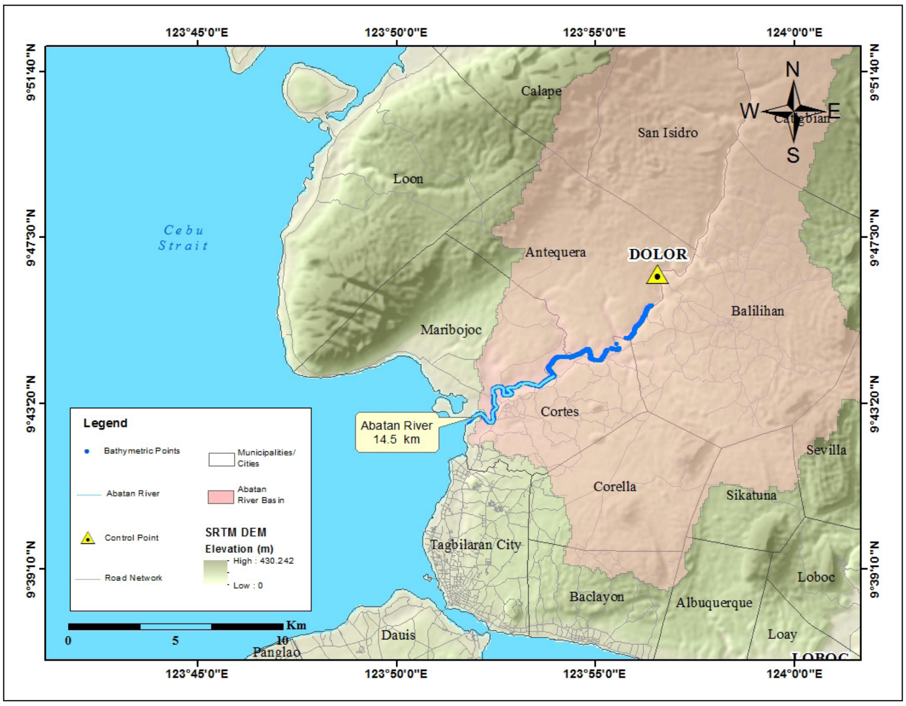


Figure 45. Extent of the bathymetric survey of the Abatan River

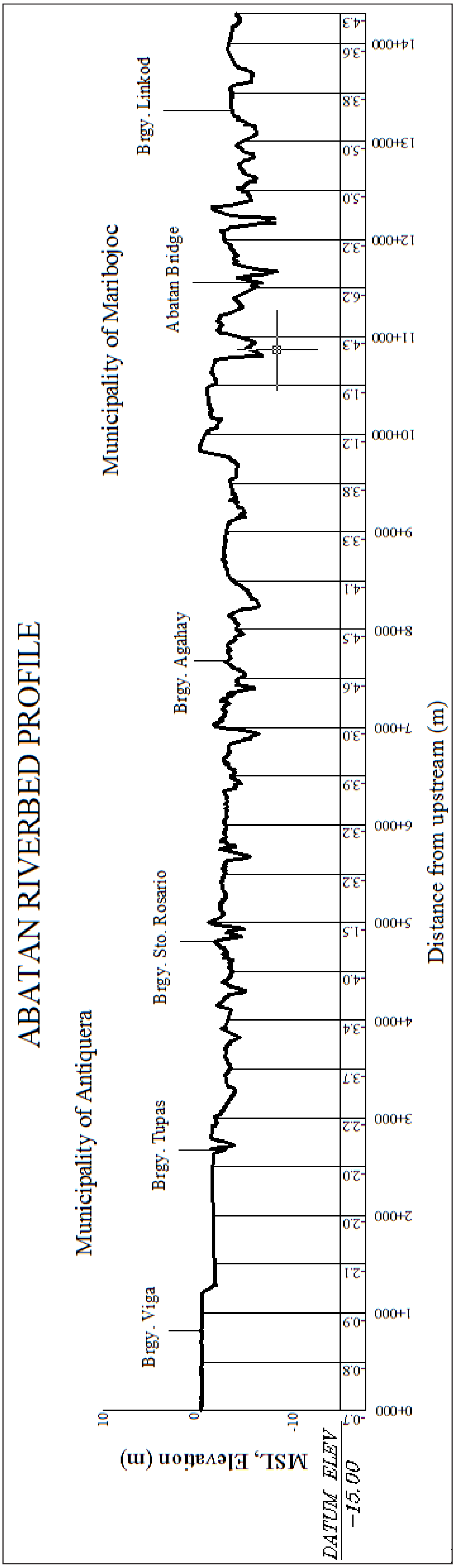


Figure 46. Abatan riverbed profile

CHAPTER 5: FLOOD MODELING AND MAPPING

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

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

5.1 Data Used for Hydrologic Modeling

5.1.1 Hydrometry and Rating Curves

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

5.1.2 Precipitation

Precipitation data was taken from a recording rain gauge unit installed by the USC Phil-LiDAR 1 team in Barangay Bantolinao, Antequera. The location of the rain gauge in the watershed is seen in Figure 47.

Total rain from the Bantolinao rain gauge was 31.6 millimeters. It peaked at 2.2 millimeters on July 12, 2016 at 13:15 hrs.

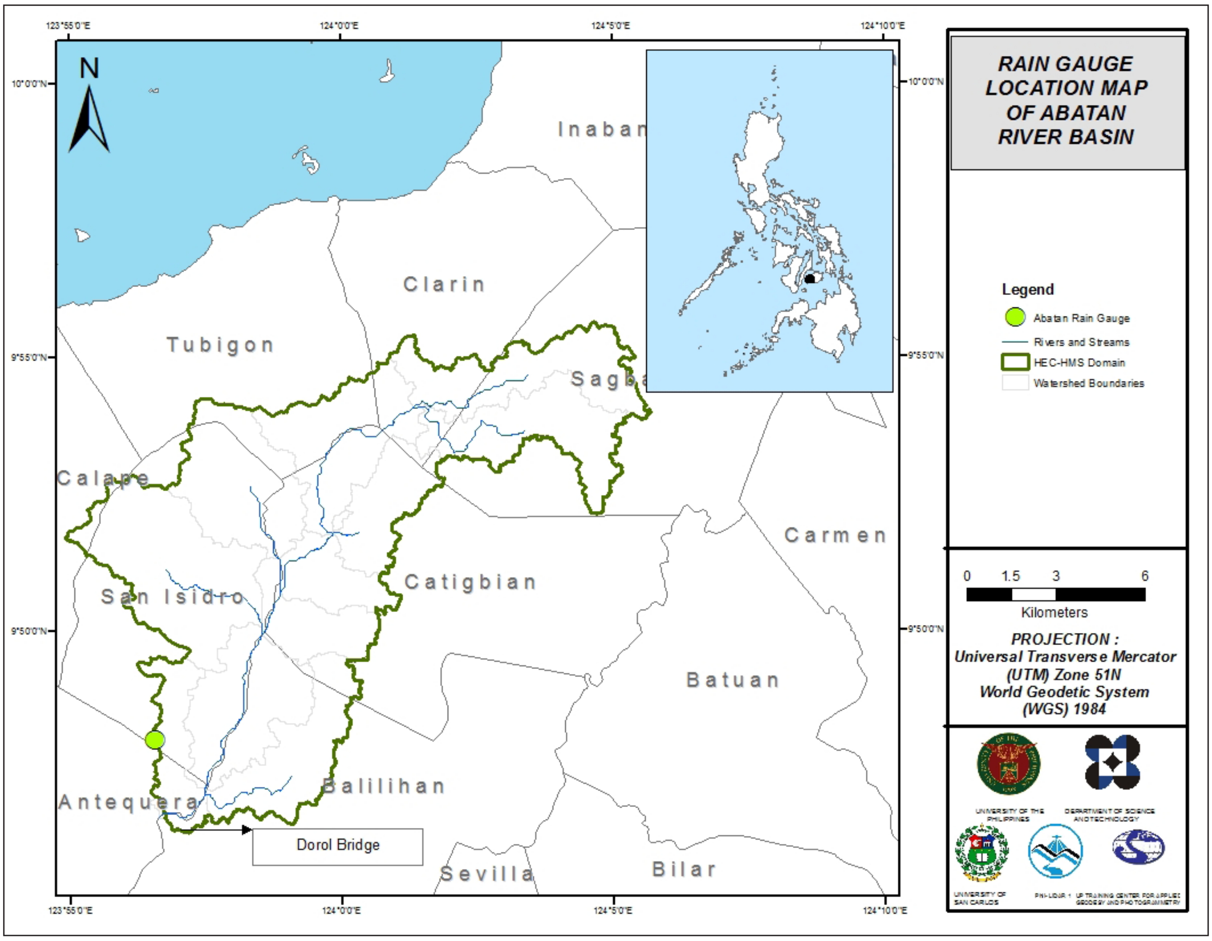


Figure 47. Location map of the Abatan HEC-HMS model, which was used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 48) at the Dolor Bridge, Antequera (9.77641°N, 123.943°E) to establish the relationship between the observed water levels (H) and outflow (Q) of the watershed at this location.

For the Dolor Bridge, the rating curve is expressed as $y = 0.6458e^{0.6369x}$, as shown in Figure 49.

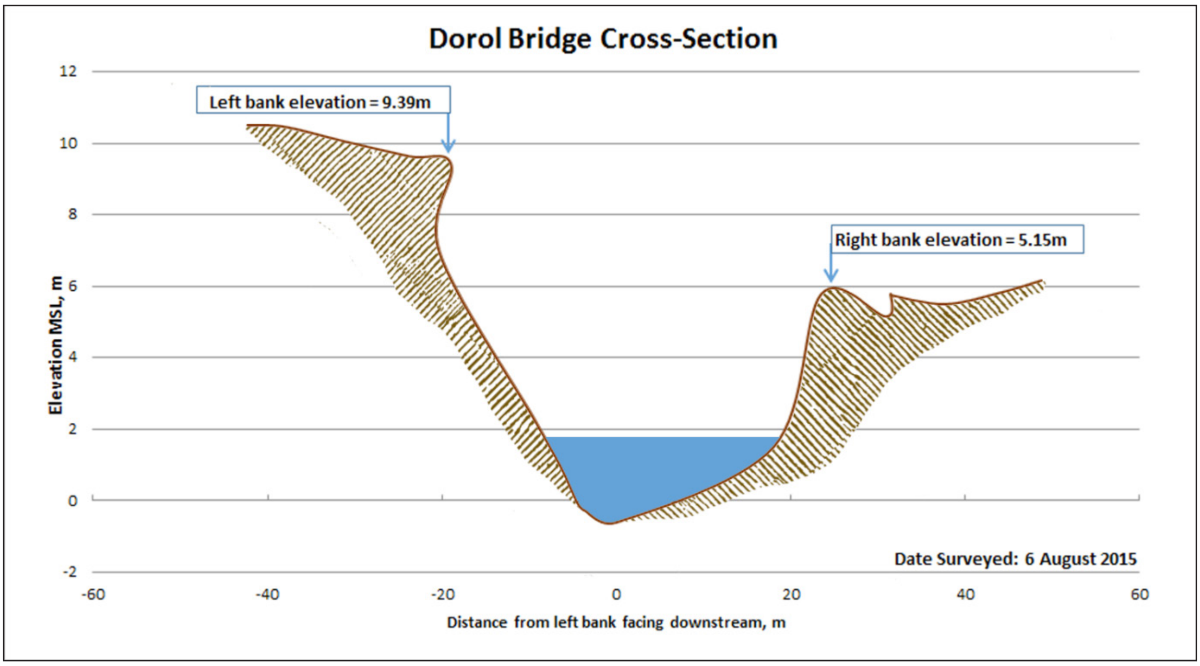


Figure 48. Cross-section plot of the Dolor Bridge

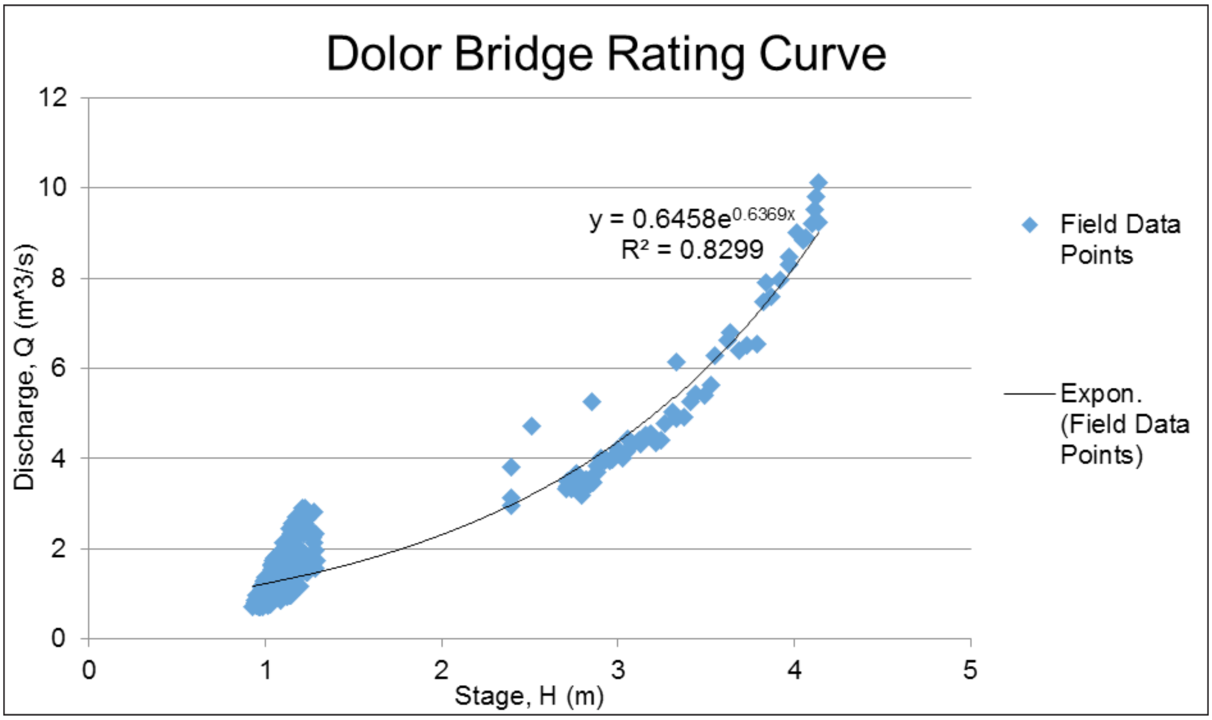


Figure 49. Rating curve at the Dolor Bridge, Antequera, Bohol

This rating curve equation was used to compute for the river outflow at the Dolor Bridge, for the calibration of the HEC-HMS model exhibited in Figure 50. The peak discharge was 9.807 m^3/s on July 12, 2016 at 19:00 hrs.

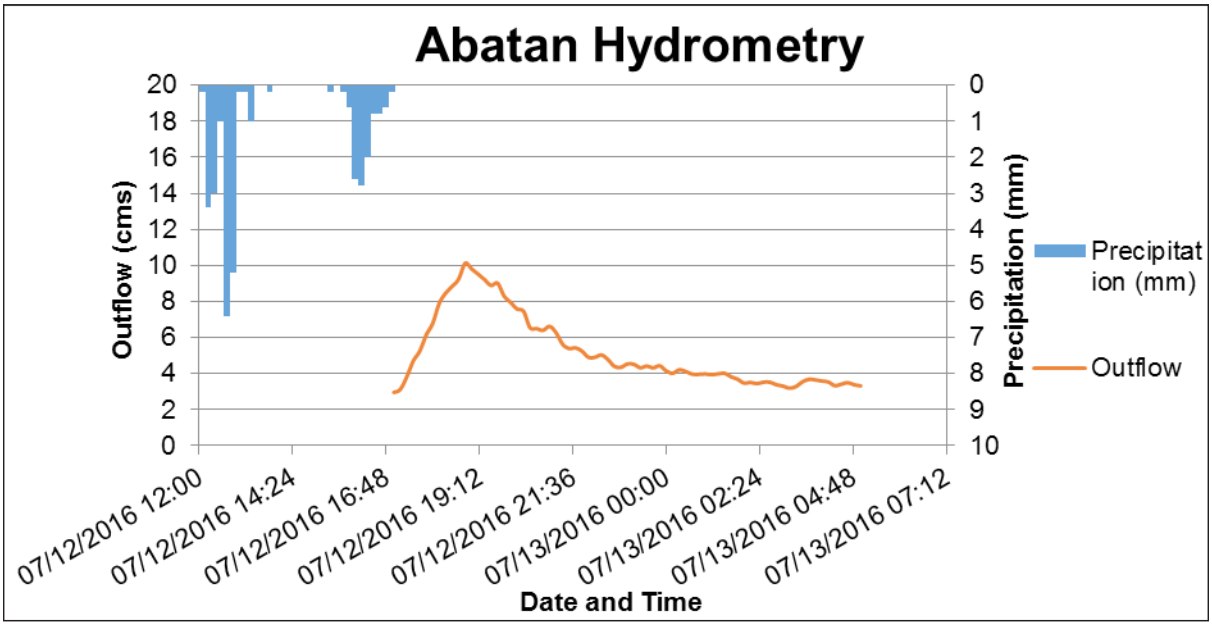


Figure 50. Rainfall and outflow data at the Dolor Bridge, which were used for modeling

5.2 RIDF Station

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Tagbilaran Point Gauge (Table 30). This station was selected based on its proximity to the Abatan watershed (Figure 51). The extreme values for this watershed were computed based on a 39-year record.

Table 30. RIDF values for the Tagbilaran Point Rain Gauge, computed by PAGASA

COMPUTED EXTREME VALUES (in mm) OF PRECIPITATION									
T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	14.4	21.9	26.5	34	43.7	50.4	62.6	73.8	84.1
5	23.1	35.4	41.8	54.6	65.1	76.5	95.1	108.2	121.2
10	28.8	44.3	52	68.3	79.3	93.7	116.7	131	145.7
15	32.1	49.3	57.7	76.1	87.3	103.5	128.8	143.9	159.6
20	34.3	52.8	61.7	81.5	92.9	110.3	137.3	152.9	169.3
25	36.1	55.5	64.8	85.6	97.3	115.5	143.8	159.8	176.7
50	41.5	63.8	74.4	98.5	110.6	131.7	164	181.1	199.7
100	46.8	72.1	83.8	111.2	123.8	147.7	184	202.3	222.6

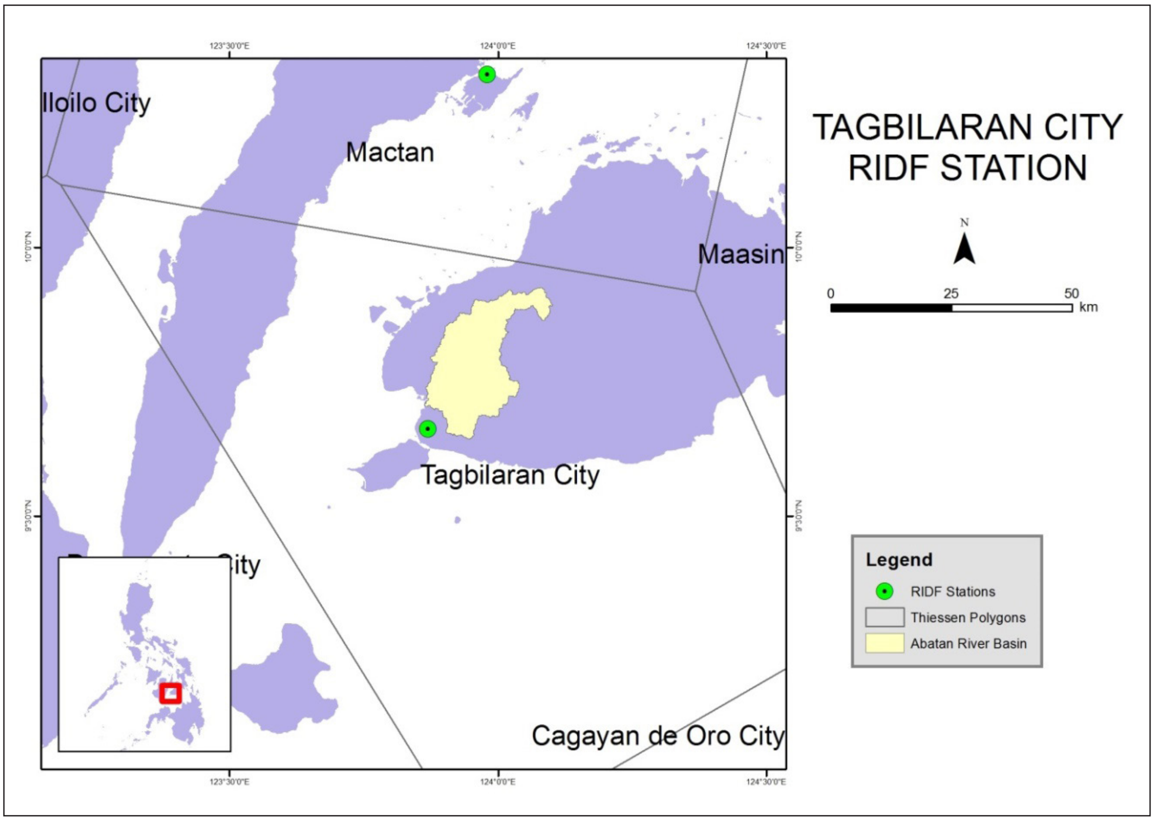


Figure 51. Tagbilaran Point RIDF location, relative to Abatan River Basin

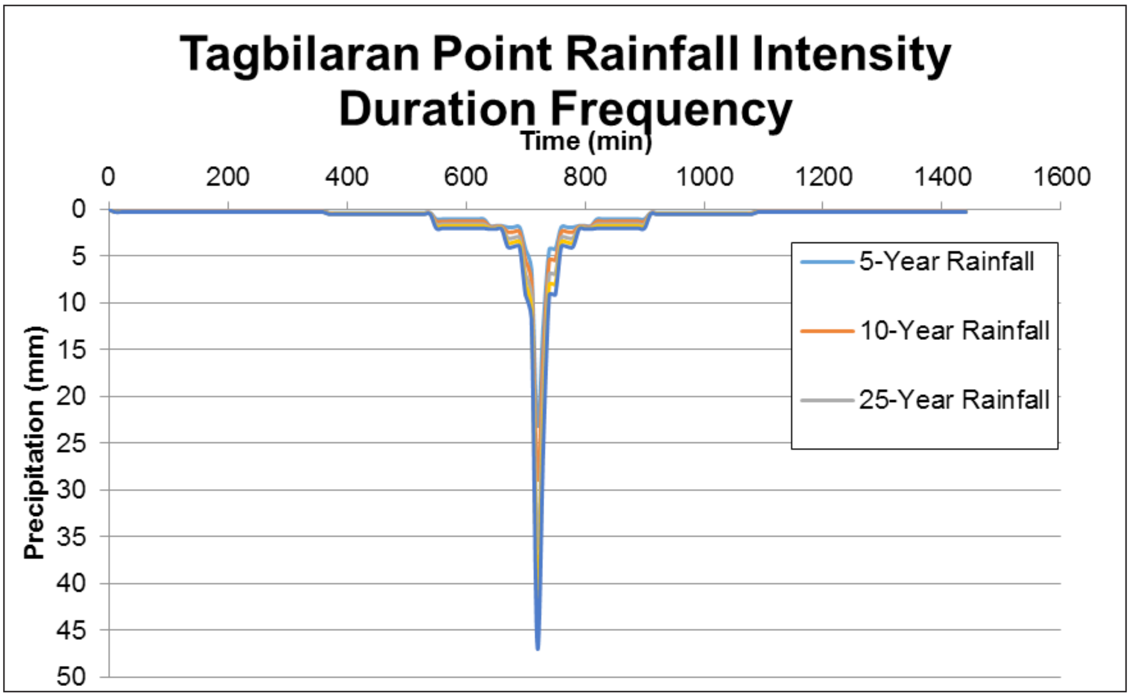


Figure 52. Synthetic storm generated from a 24-hour period rainfall, for various return periods

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004. The soil and land cover maps are presented in Figures 53 and 54, respectively.

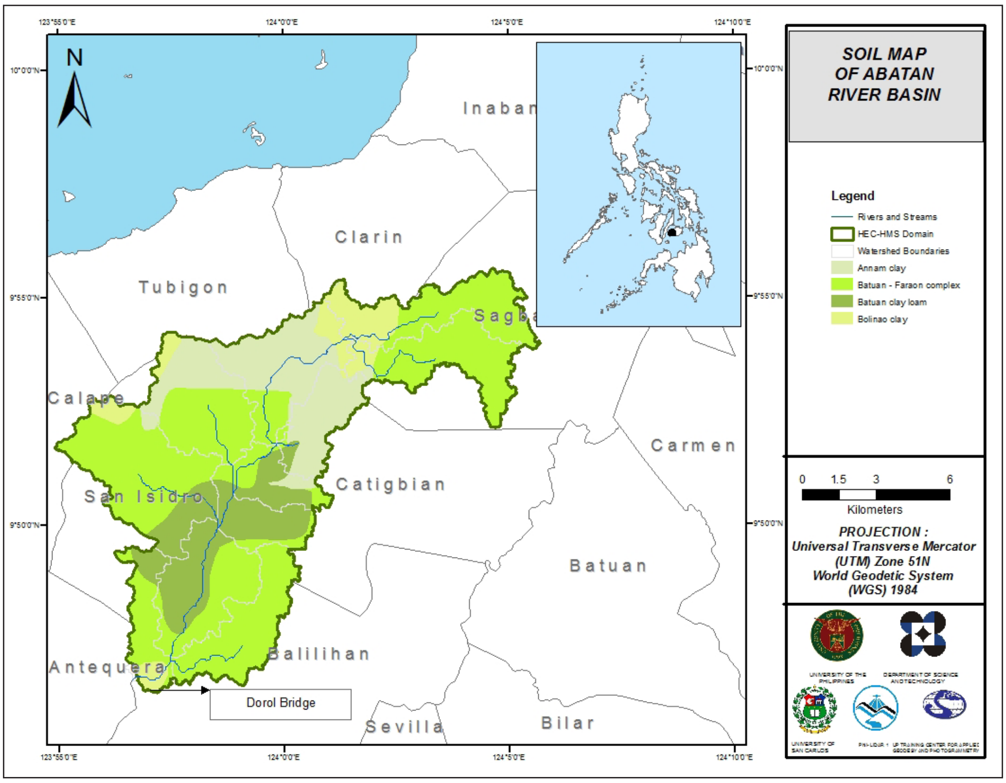


Figure 53. The soil map of the Abatan River Basin, used for the estimation of the CN parameter (Source: DA)

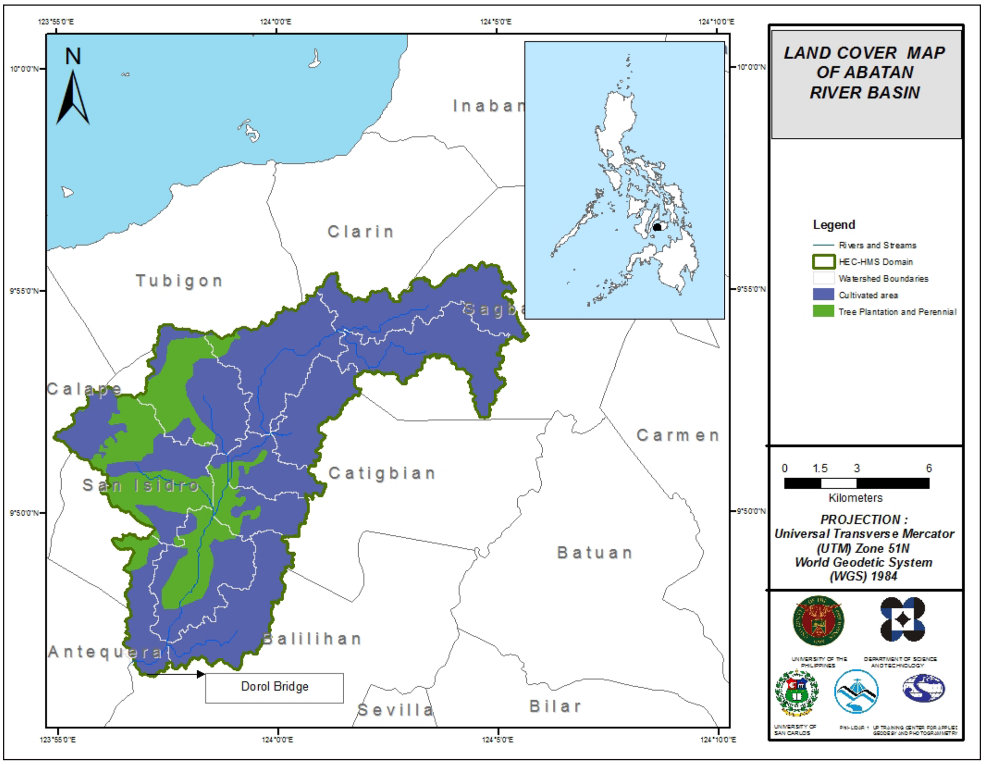


Figure 54. The land cover map of the Abatan River Basin, used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model (Source: NAMRIA)

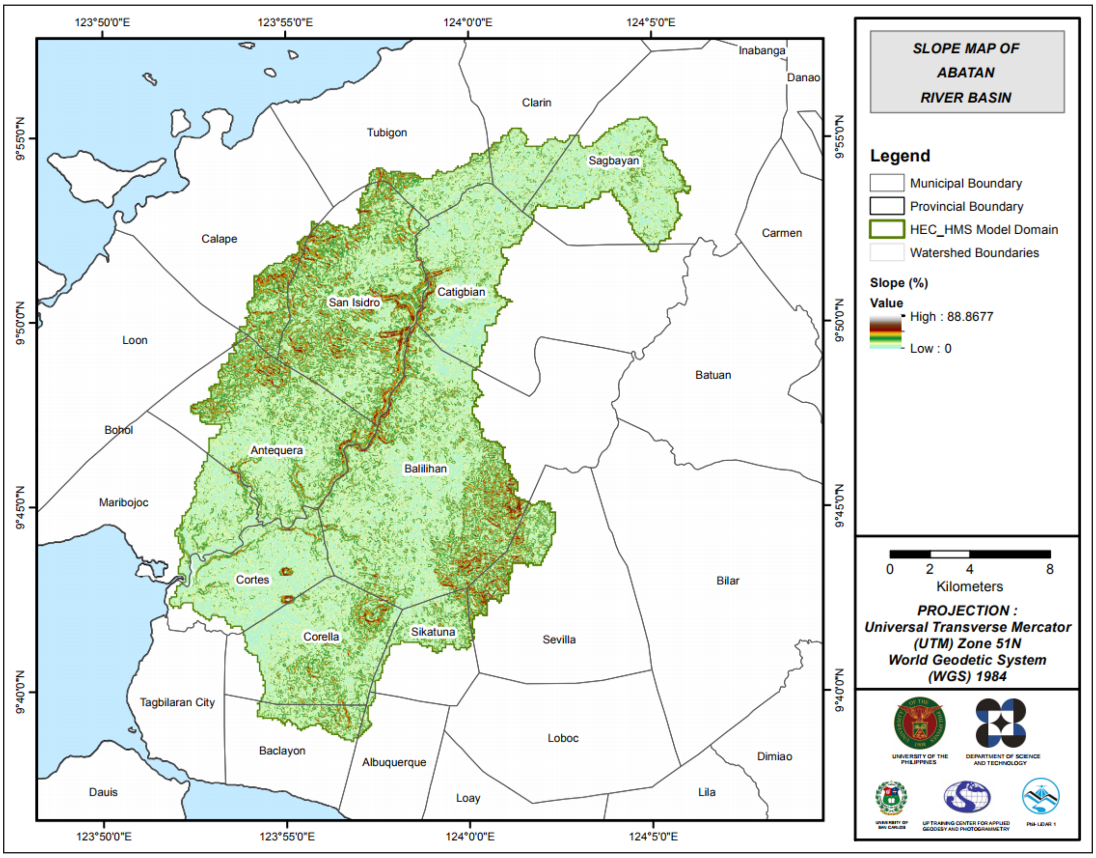


Figure 55. Slope map of the Abatan River Basin

Two (2) soil classes were identified in the Abatan watershed. These are clay loam and clay. The land cover classes identified were tree plantations and perennials, and cultivated lands.

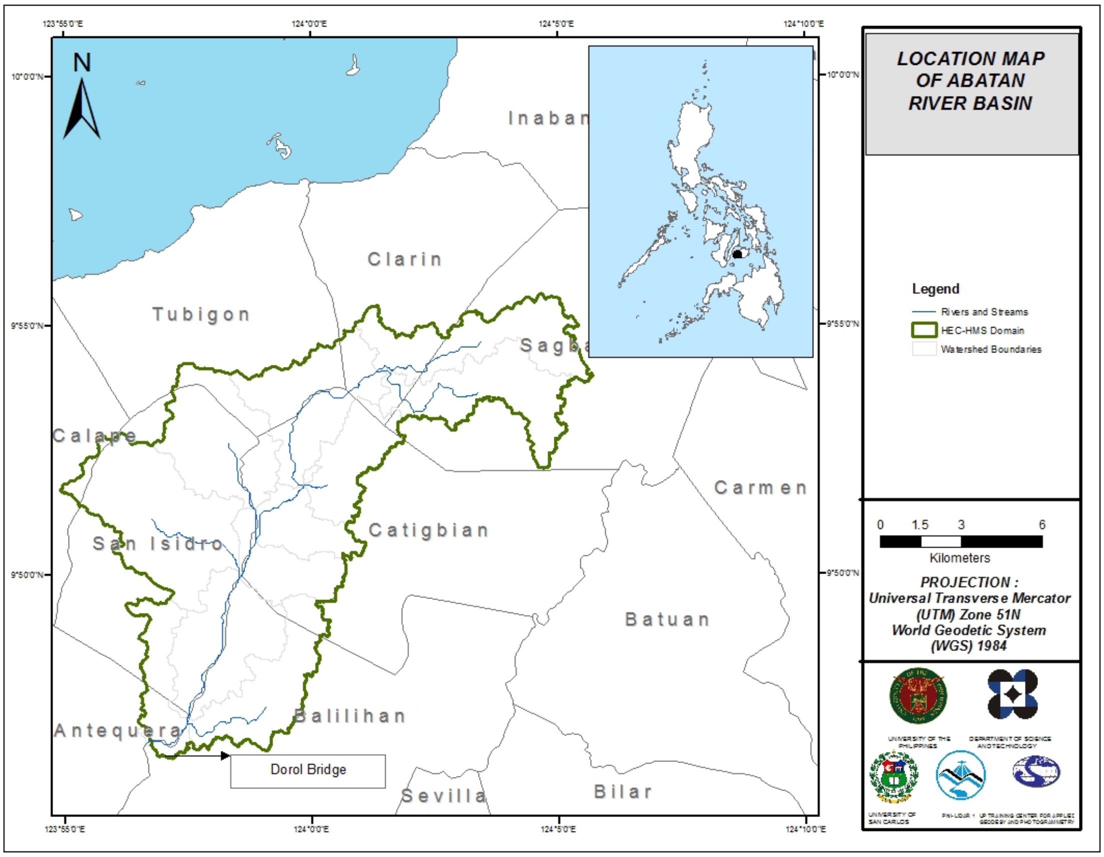


Figure 56. Stream delineation map of the Abatan River Basin

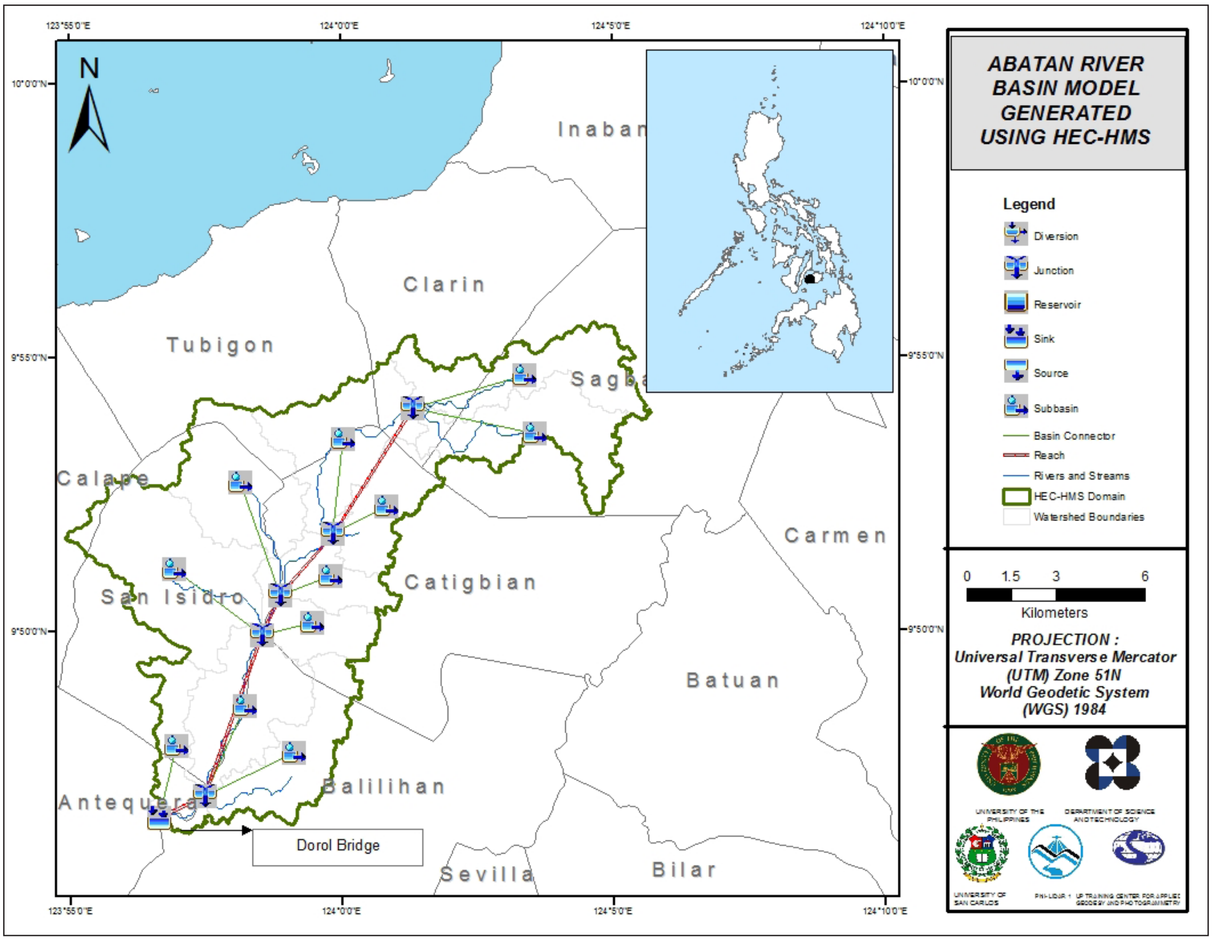


Figure 57. The Abatan River Basin Model domain, generated using HEC-HMS

The Abatan basin model consists of eleven (11) sub-basins and five (5) reaches. The catchment outlet is designated as Outlet 1. The basin model is presented in Figure 57. The Abatan Model Reach Parameters are available in Annex 10. The basins were identified based on the soil and land cover characteristics of the area. Precipitation from July 12, 2016 was taken from a recording rain gauge installed by the USC Phil-LiDAR 1 team. The data was calibrated using the discharge data obtained from the depth gauge and current meter temporarily deployed in the Dolor Bridge in the Municipality of Antequera.

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 58).

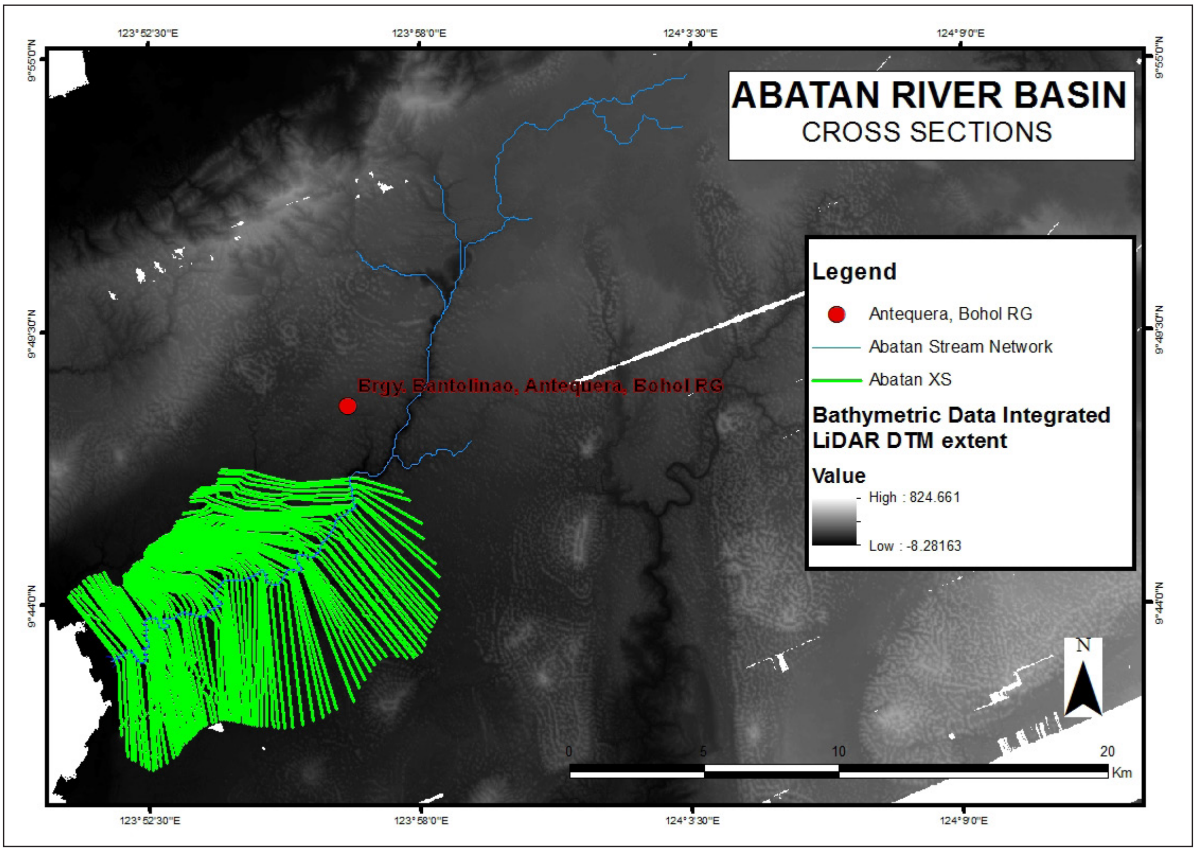


Figure 58. River cross-section of the Abatan River, generated through the ArcMap HEC GeoRAS tool

5.5 Flo 2D Model

This image is not available for this river basin

Figure 59. Screenshot of a sub-catchment, with the computational area to be modeled in FLO-2D Grid Developer System Pro

5.6 Results of HMS Calibration

After calibrating the Abatan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 60 displays the comparison between the two (2) discharge data. The Abatan Model Basin Parameters are found in Annex 9.

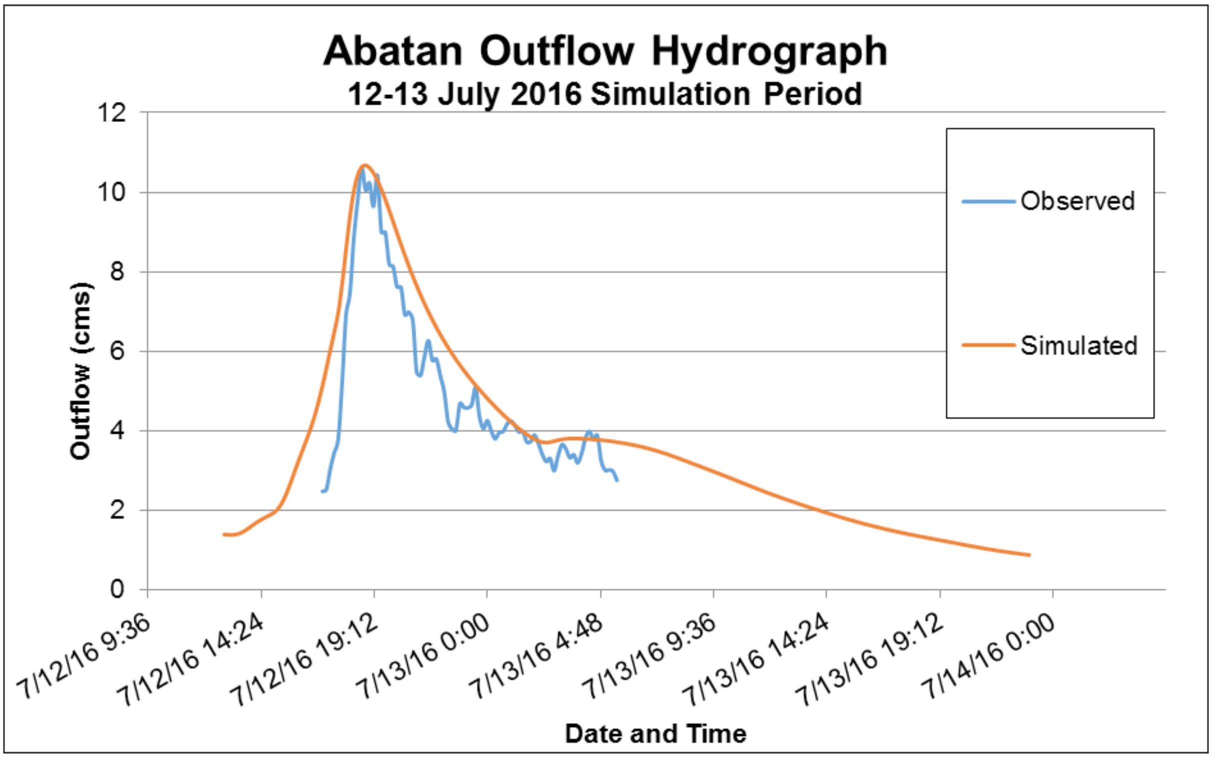


Figure 60. Outflow hydrograph of Abatan produced by the HEC-HMS model, compared with observed outflow

Table 31. Range of calibrated values for the Abatan River Basin

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve Number	Initial Abstraction (mm)	6.85-13.60
			Curve Number	44.52-77.52
			Impervious (%)	0
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	1.06-14.19
			Storage Coefficient (hr)	2.10-8.12
	Baseflow	Recession	Recession Constant	0.12-0.40
			Ratio to Peak	0.03-0.10
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.02-0.10

The initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as the initial abstraction decreases. The range of values of 6.85 - 13.60 millimeters for the initial abstraction signifies that there is a minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range of 65 - 90 for the curve number is advisable for Philippine watersheds, depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Abatan, the basin mostly consists of tree plantations and perennials, and the soil consists of clay and clay loam. The curve number for the model ranges from 44.52 to 77.52.

The time of concentration and the storage coefficient are the travel time and the index of temporary storage of runoff in a watershed. The range of calibrated values of1.06 to 14.19 hours determines the reaction time of the model, with respect to the rainfall. The peak magnitude of the hydrograph decreases when these parameters are increased.

The recession constant is the rate at which the baseflow recedes between storm events; while ratio to peak is the ratio of the baseflow discharge to the peak discharge. A recession constant of 0.12-0.40 impliesthat the basin will be able to quickly revert to its original discharge. A ratio to peak of 0.03 -0.10 indicates a steeper receding limb of the outflow hydrograph.

A Manning's roughness coefficient of 0.02-0.10 corresponds to the common roughness in the Abatan watershed , which is determined to be cultivated with tree plantations (Brunner, 2010).

Table 32. Efficiency Test of the Abatan HMS Model

Accuracy Measure	Value
r^2	0.876
NSE	0.694
PBIAS	-17.456
RSR	0.5499

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was identified at 1.2032.

The Pearson correlation coefficient ($r^{2)}$ assesses the strength of the linear relationship between the observations and the model. A coefficient value close to 1 signifies an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. In the model, it was measured at 0.876.

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 0.694.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate a bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is -17.456.

The Observation Standard Deviation Ratio (RSR) is an error index. A perfect model attains a value of 0 when the error units of the valuesare quantified. The model yieldedan RSR value of 0.5499.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph in Figure 61 represents the Abatan outflow using the Tagbilaran RIDF curves in five (5) different return periods (i.e., 5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series), based on the data from PAGASA. The simulation results reveal a significant increase in outflow magnitude as the rainfall intensity increases, for a uniform duration of 24 hours and for varying return periods.

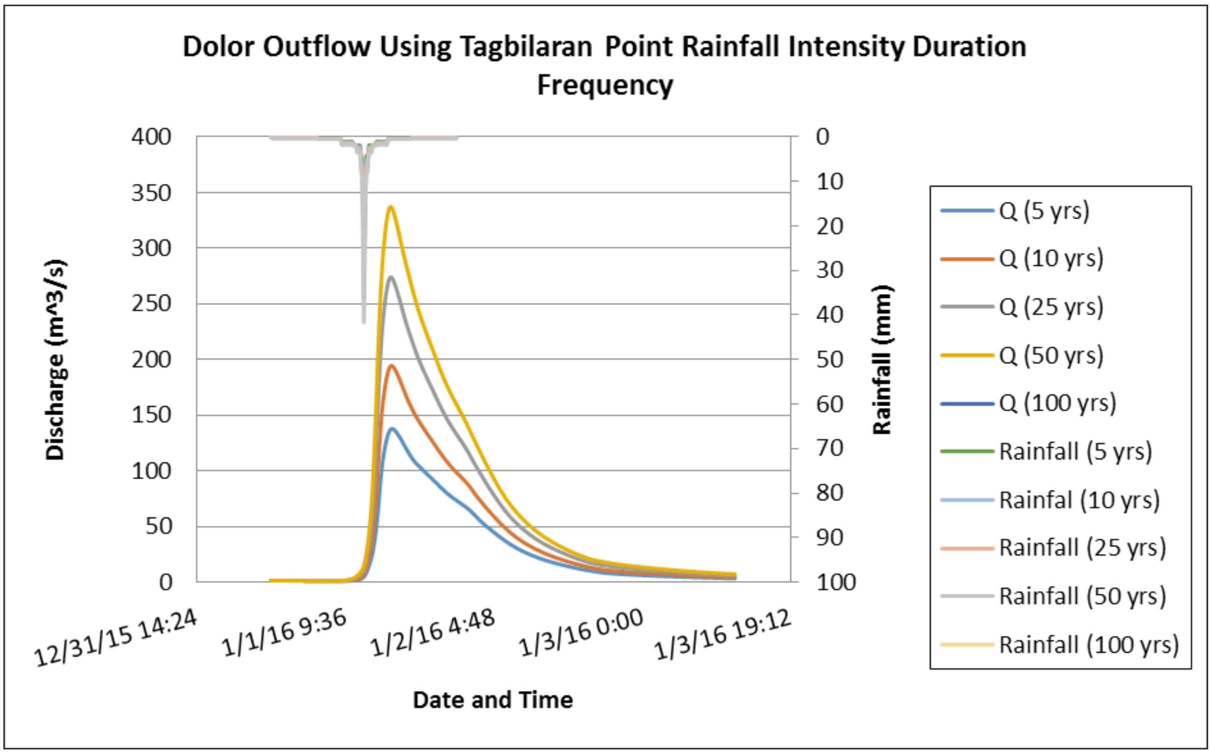


Figure 61. Outflow hydrograph at Dolor generated using Tagbilaran Point RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Abatan River discharge using the Tagbilaran Point RIDF curves in five (5) different return periods is shown in Table 33.

Table 33. Peak values of the Abatan HEC-HMS Model outflow, using the Tagbilaran RIDF

RIDF Period	Precipitation (total)	Peak Rainfall (mm)	Peak Outflow $\left(\frac{m^3}{s}\right)$	Time to Peak
5-year RIDF	121.2	23.100	137.981	3:40
10-year RIDF	145.7	28.800	194.410	3:40
25-year RIDF	176.7	36.100	274.056	3:50
50-year RIDF	199.7	41.500	337.257	3:30
100-year RIDF	222.6	46.800	402.417	3:30

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS flood model produced a simulated water level at every cross section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining the real-time flood inundation extent of the river, after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river is presented. The sample generated map of Abatan River using the calibrated event flow is provided in Figure 62.

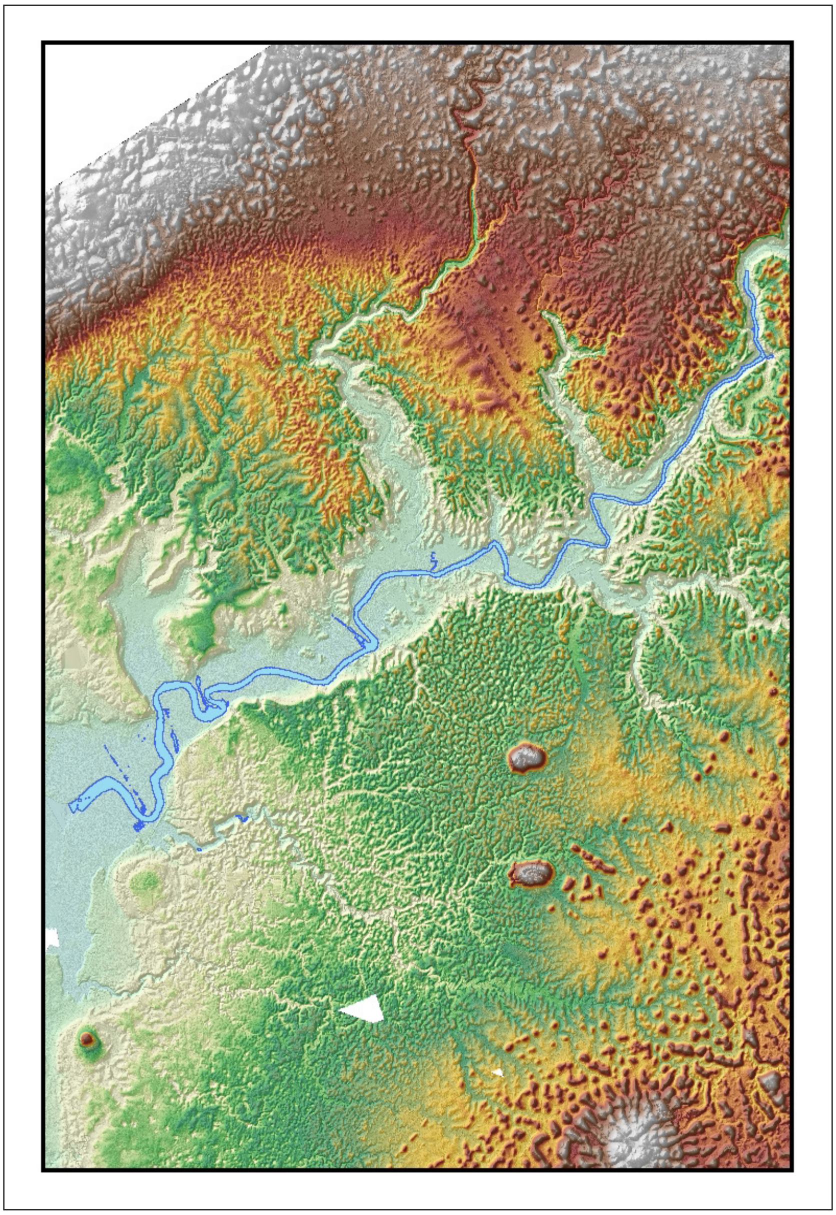


Figure 62. Sample output map of the Abatan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting flood hazard and flow depth maps have a 10-meter resolution. Figure 63 to Figure 68 exhibit the 5-year, 25-year, and 100-year rain return scenarios of the Abatan floodplain.

Table 34. Municipalities/cities affected in the Abatan floodplain

City/ Municipality	Total Area	% Area Flooded	Area Flooded (sq.km.)
Albuquerque			
Antequera			
Baclayon			
Balilihan			
Corella			
Cortes			
Maribojoc			
San Isidro			
Sikatuna			
Tagbilaran			

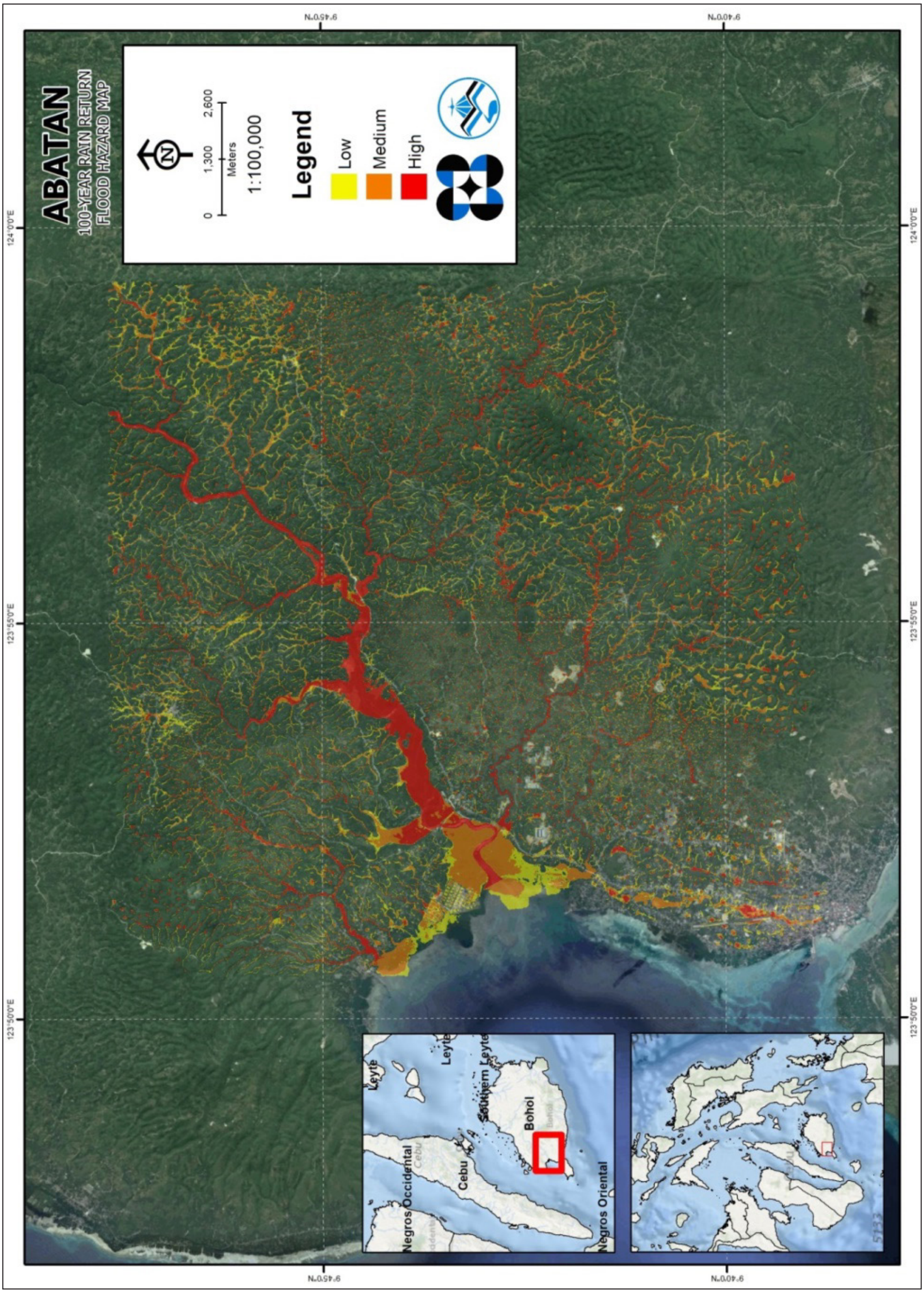


Figure 63. 100-year flood hazard map for the Abatan floodplain

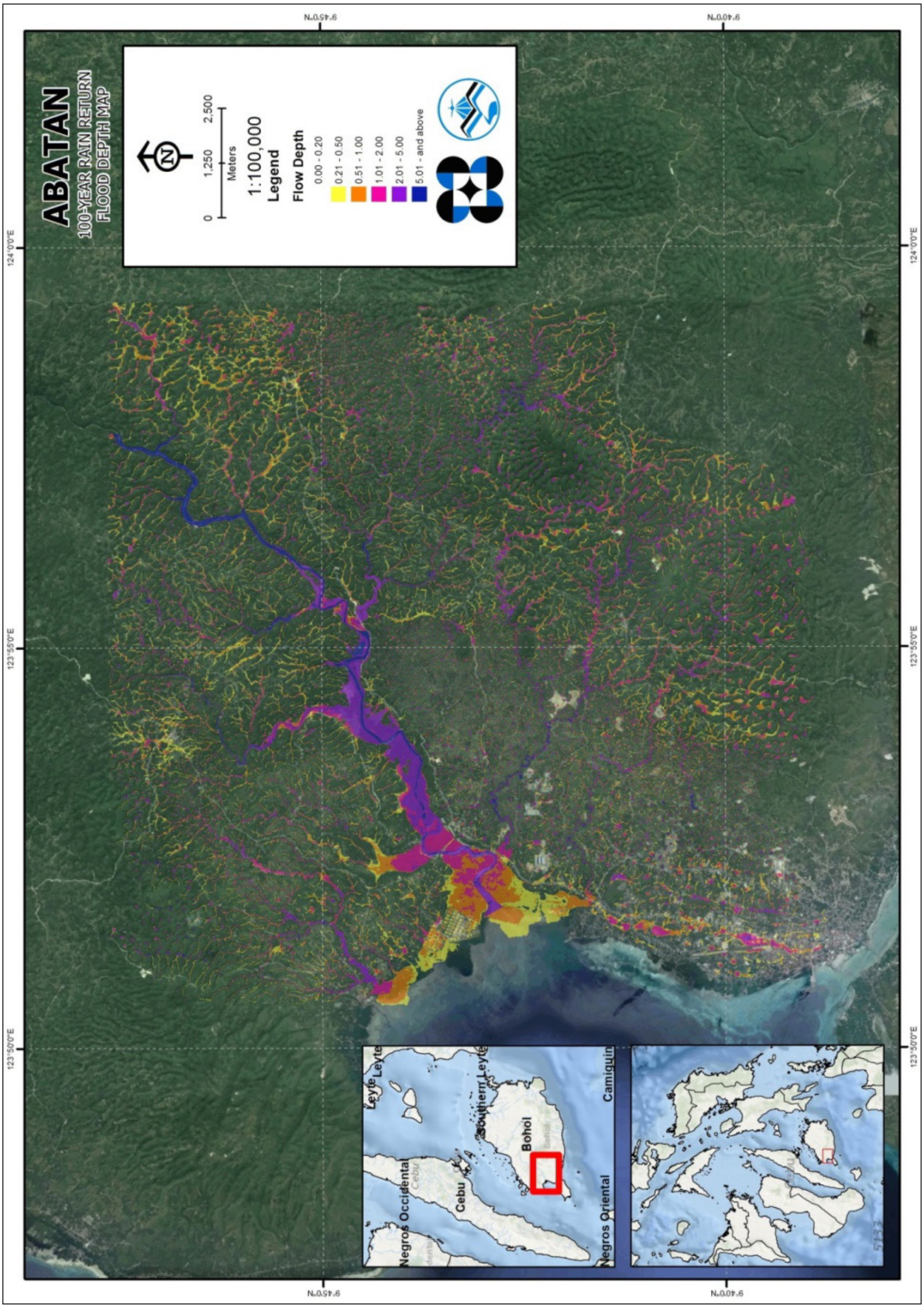


Figure 64. 100-year flow depth map for the Abatan floodplain

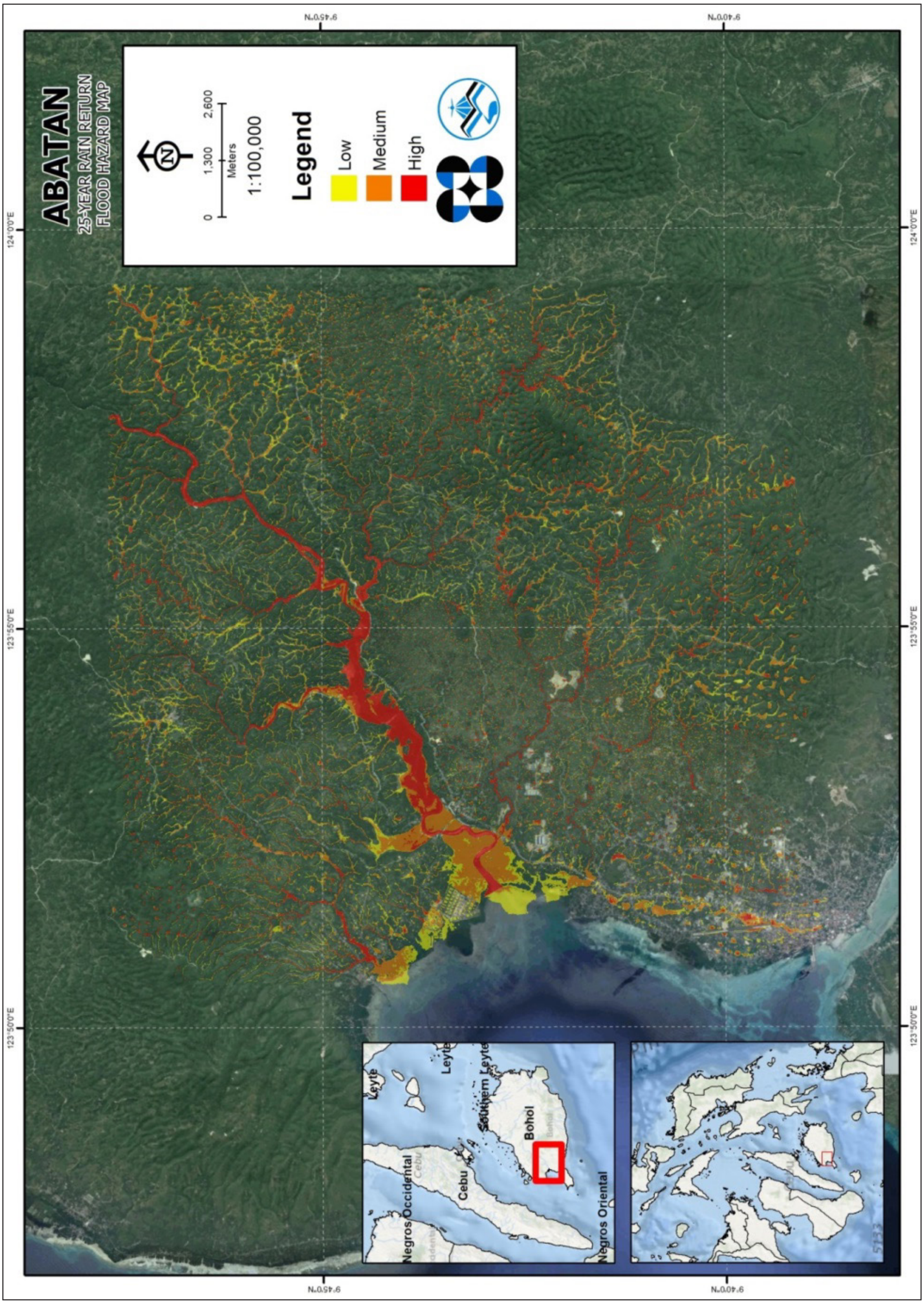


Figure 65. 25-year flood hazard map for the Abatan floodplain

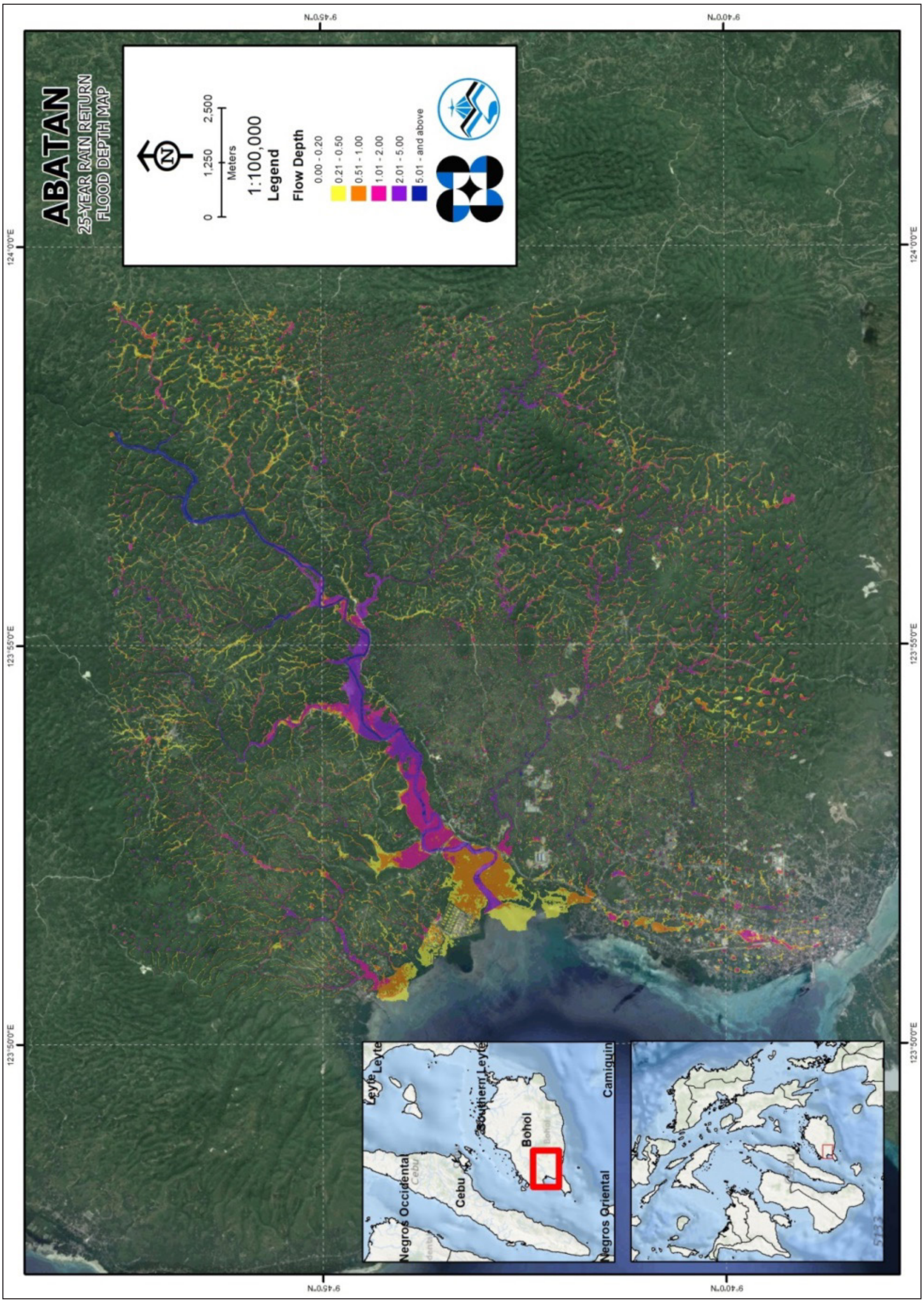


Figure 66. 25-year flow depth map for the Abatan floodplain

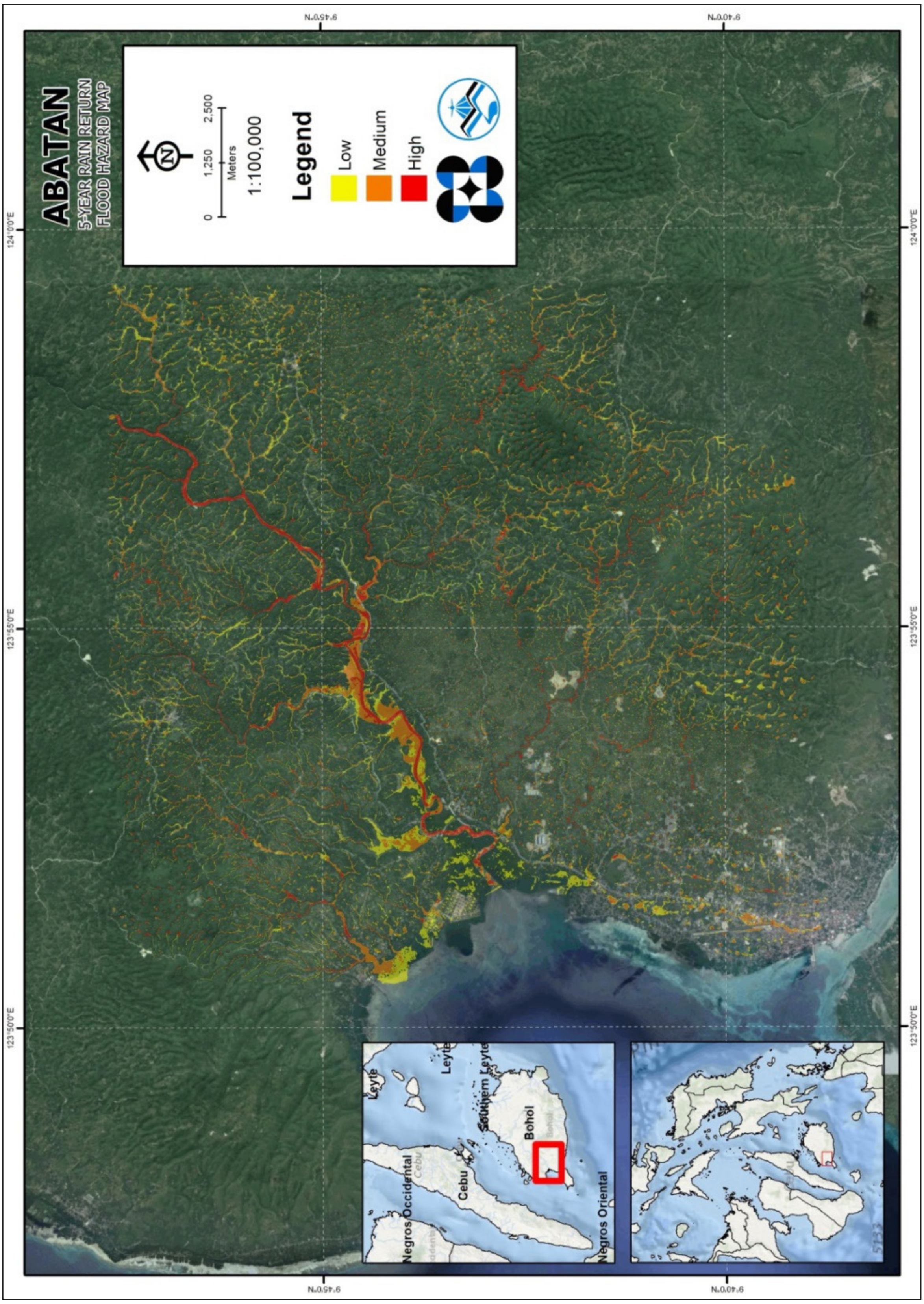


Figure 67. 5-year flood hazard map for the Abatan floodplain

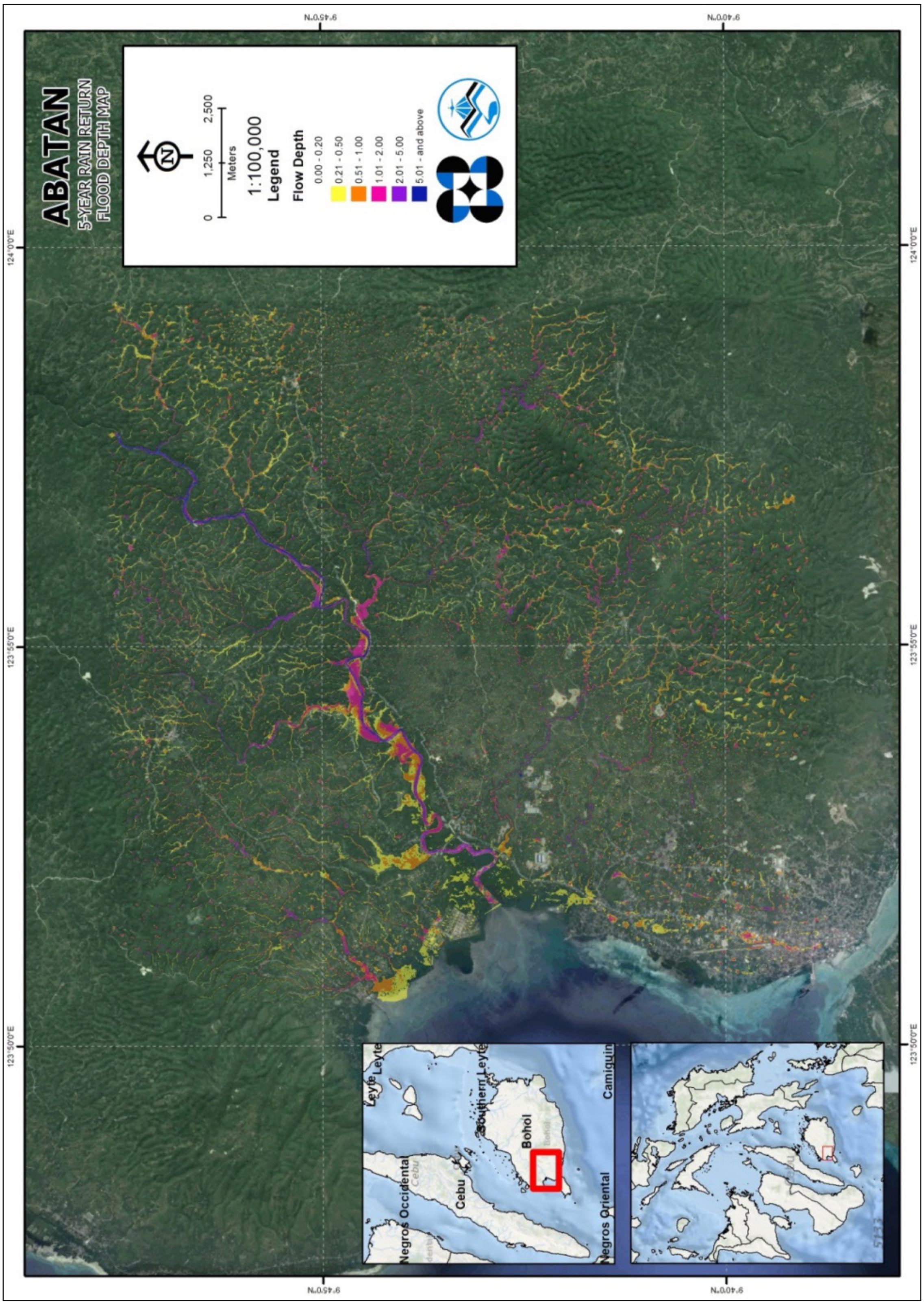


Figure 68. 5-year flow depth map for the Abatan floodplain

5.10 Inventory of Areas Exposed to Flooding

The affected barangays in the Abatan River Basin, grouped by municipality, are listed below. For the said basin, ten (10) municipalities consisting of one hundred and four (104) barangays are expected to experience flooding when subjected to a 5-year rainfall return period.

For the 5-year return period, 1.38% of the Municipality of Albuquerque, with an area of 28.5 square kilometers, will experience flood levels of less than 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.04%, 0.01%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 35 are the affected areas, in square kilometers, by flood depth per barangay.

Table 35. Affected areas in Albuquerque, Bohol during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Albuquerque (in sq. km.)	
	Basacdacu	Cantiguib
0.03-0.20	0.093	0.3
0.21-0.50	0.0012	0.013
0.51-1.00	0.0036	0.0078
1.01-2.00	0.0013	0.0019
2.01-5.00	0.0003	0
> 5.00	0	0

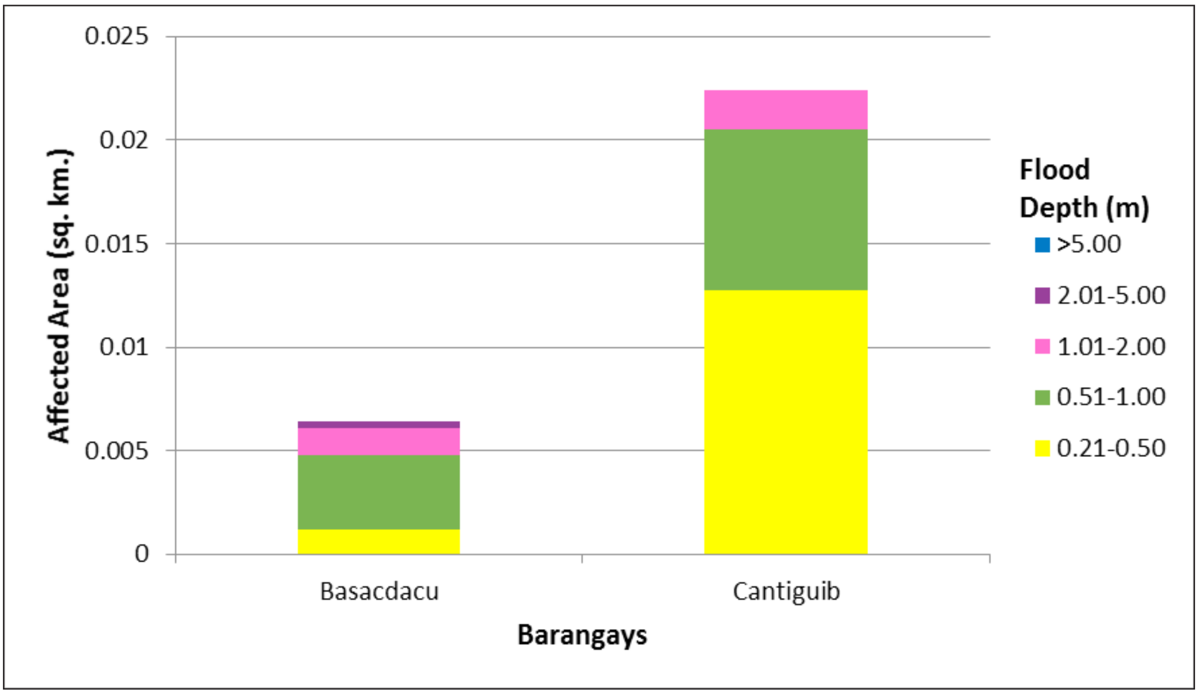


Figure 69. Affected areas in Albuquerque, Bohol during a 5-year rainfall return period

For the Municipality of Antequera, with an area of 65.66 square kilometers, 46.26% will experience flood levels of less than 0.20 meters. 2.35% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.39%, 1.1%, 0.68%, and 0.35% 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 36 are the affected areas, in square kilometers, by flood depth per barangay.

Table 36. Affected areas in Antequera, Bohol during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Antequera (in sq. km.)									
	Angilan	Bantolinao	Bicahan	Bitaugan	Bungahan	Can-Omay	Cansibuan	Celing	Danao	Danicop
0.03-0.20	3.56	3.78	1.46	2.37	3.36	1.53	0.1	1.41	0.4	0.54
0.21-0.50	0.15	0.15	0.055	0.12	0.21	0.084	0.0013	0.062	0.02	0.044
0.51-1.00	0.086	0.084	0.032	0.072	0.084	0.048	0.00061	0.029	0.013	0.011
1.01-2.00	0.067	0.066	0.024	0.039	0.055	0.021	0.00035	0.025	0.0024	0.0062
2.01-5.00	0.086	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328
> 5.00	0.094	0.063	0.0026	0	0	0.0006	0	0.0003	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Antequera (in sq. km.)							
	Mag-Aso	Poblacion	Santo Rosario	Tagubaas	Tupas	Ubojan	Viga	Villa Aurora
0.03-0.20	0.82	0.84	0.96	0.91	2.5	1.3	2.2	2.34
0.21-0.50	0.044	0.073	0.083	0.041	0.17	0.031	0.11	0.1
0.51-1.00	0.025	0.031	0.12	0.021	0.084	0.019	0.076	0.082
1.01-2.00	0.011	0.0075	0.14	0.0074	0.11	0.013	0.078	0.053
2.01-5.00	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328
> 5.00	0	0	0.0018	0	0.012	0.0005	0.05	0.0033

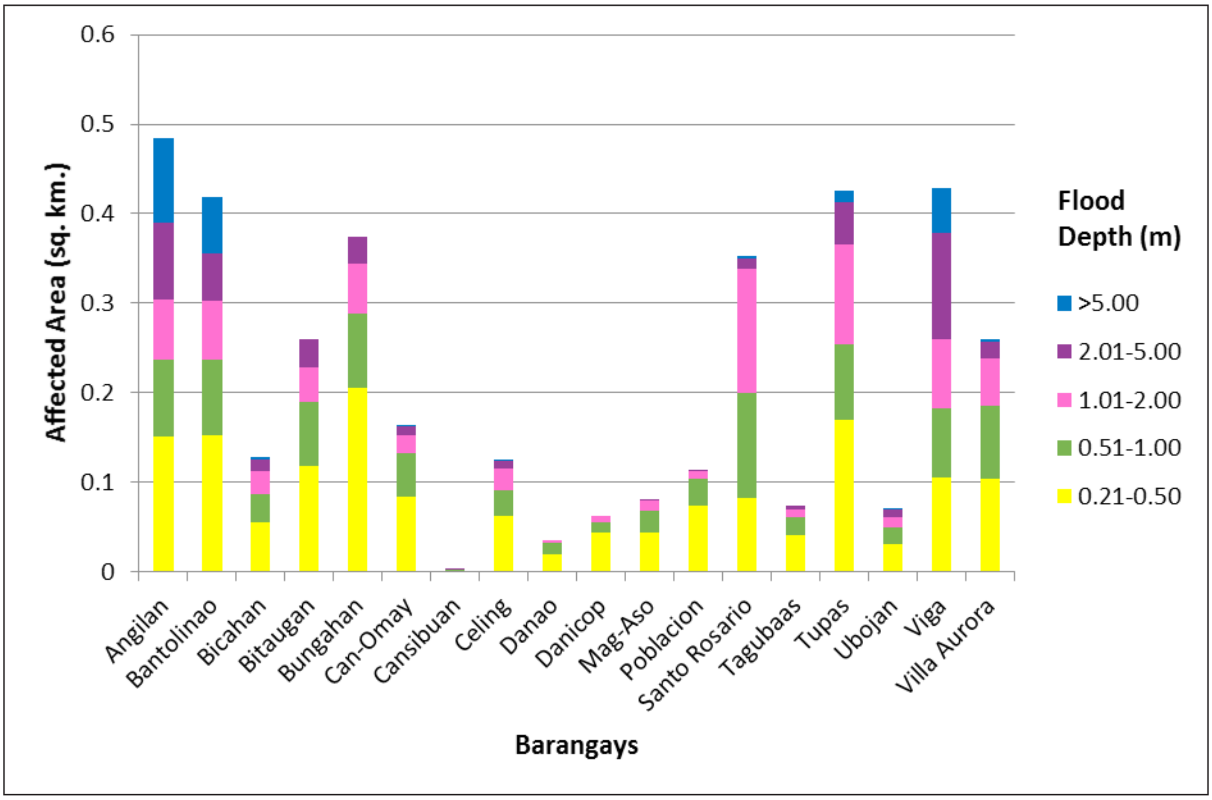


Figure 70. Affected areas in Antequera, Bohol during a 5-year rainfall return period

For the Municipality of Baclayon, with an area of 33.81 square kilometers, 21.55% will experience flood levels of less than 0.20 meters. 0.97% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.87%, 0.34%, and 0.04% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 37 are the affected areas, in square kilometers, by flood depth per barangay.

Table 37. Affected areas in Baclayon, Bohol during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Baclayon (in sq. km.)				
	Buenaventura	Dasitam	Landican	Libertad	Tanday
0.03-0.20	1.84	1.56	0.0075	1.67	2.21
0.21-0.50	0.078	0.11	0	0.071	0.073
0.51-1.00	0.071	0.085	0	0.065	0.074
1.01-2.00	0.031	0.013	0	0.029	0.043
2.01-5.00	0.0052	0.0008	0	0.0025	0.0053
> 5.00	0	0	0	0	0

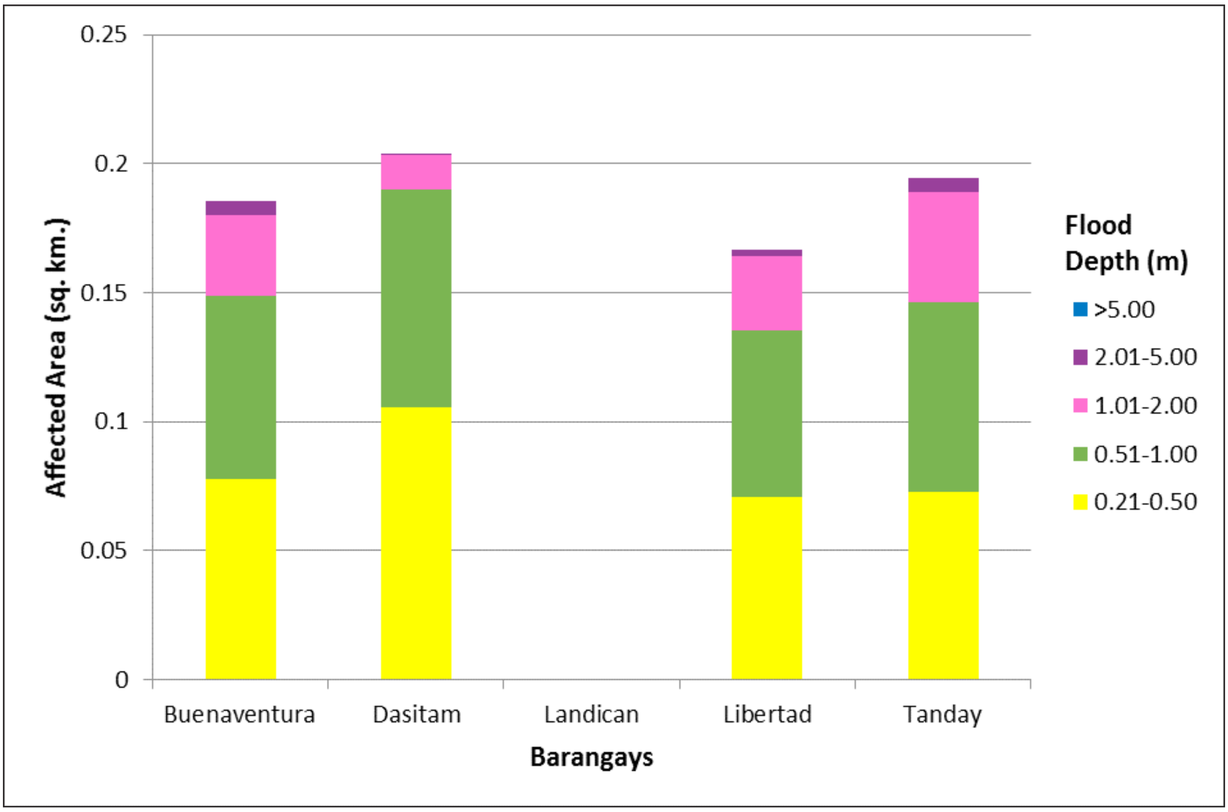


Figure 71. Affected areas in Baclayon, Bohol during a 5-year rainfall return period

For the Municipality of Balilihan, with an area of 104.6 square kilometers, 40.45% will experience flood levels of less than 0.20 meters. 1.93% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.23%, 0.72%, 0.24%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 38 are the affected areas, in square kilometers, by flood depth per barangay.

Table 38. Affected areas in Balilihan, Bohol during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balilihan (in sq. km.)								
	Baucan Sur	Boctol	Cabad	Candasig	Cantalid	Cantomimbo	Datag Norte	Datag Sur	Del Carmen Este
0.03-0.20	0.029	1.36	1.12	3.09	5.42	0.48	1.78	3.46	2.66
0.21-0.50	0.00023	0.085	0.041	0.16	0.13	0.032	0.053	0.12	0.14
0.51-1.00	0.0011	0.052	0.02	0.073	0.15	0.024	0.051	0.11	0.12
1.01-2.00	0.00069	0.016	0.011	0.032	0.16	0.0094	0.035	0.077	0.045
2.01-5.00	0	0.0005	0.004	0.01	0.085	0.0011	0.0056	0.016	0.0018
> 5.00	0	0	0.0001	0.0002	0	0	0.0004	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balilihan (in sq. km.)								
	Del Carmen Norte	Del Carmen Sur	Del Carmen Weste	Dorol	Magsija	Maslog	Sagasa	Sal-Ing	San Isidro
0.03-0.20	1.79	2.49	1.52	2.93	5.69	2.76	0.13	2.95	2.65
0.21-0.50	0.17	0.11	0.12	0.13	0.2	0.1	0.0087	0.24	0.16
0.51-1.00	0.069	0.075	0.042	0.095	0.13	0.075	0.000064	0.13	0.056
1.01-2.00	0.013	0.049	0.0087	0.034	0.12	0.065	0	0.052	0.03
2.01-5.00	0.0002	0.012	0.0012	0.017	0.057	0.022	0	0.0022	0.016
> 5.00	0	0.0001	0	0.025	0.0017	0	0	0	0.0048

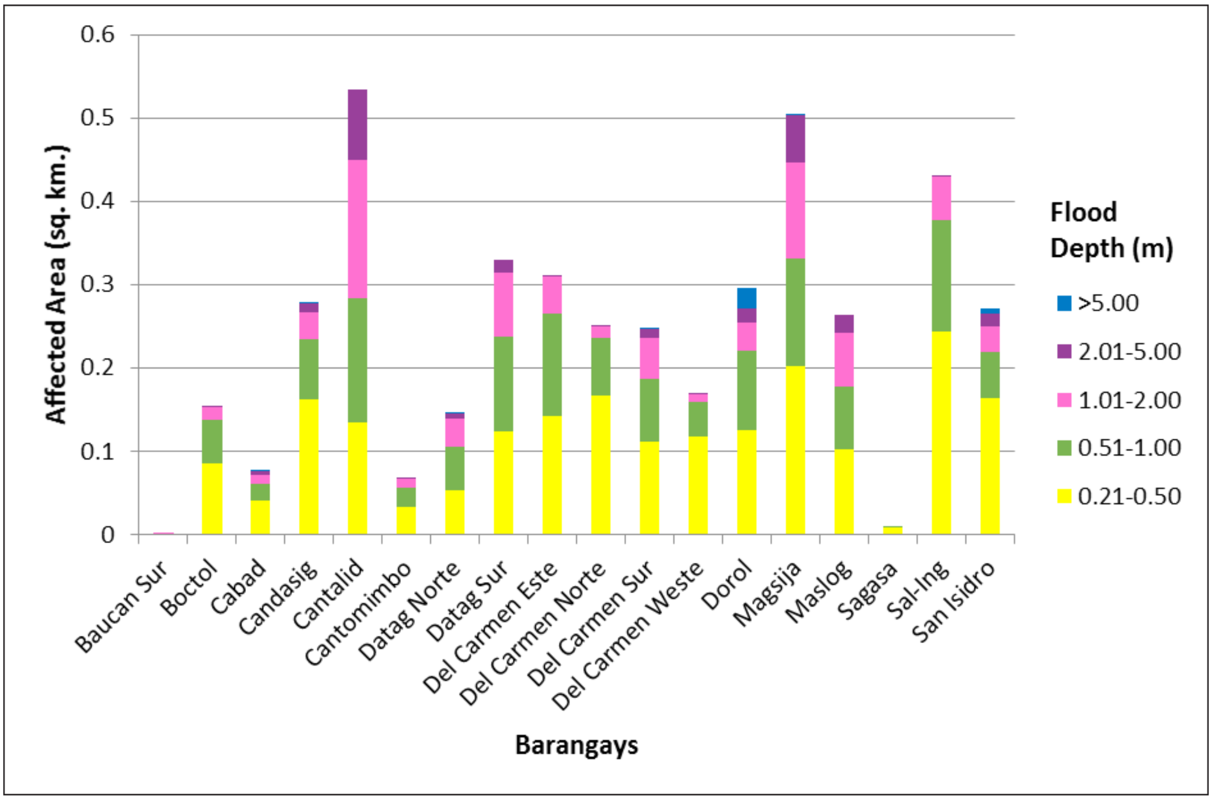


Figure 72. Affected areas in Balilihan, Bohol during a 5-year rainfall return period

For the Municipality of Corella, with an area of 34.7 square kilometers, 100% will experience flood levels of less than 0.20 meters. 4.91% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.05%, 2.5%, 0.58%, and 0.002% 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 kilometers, by flood depth per barangay.

Table 39. Affected areas in Corella, Bohol during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Corella (in sq. km.)							
	Anislag	Canangca-An	Canapnapan	Cancatac	Pandol	Poblacion	Sambog	Tanday
0.03-0.20	3.61	5.94	4.18	6.19	2.5	2.7	4.57	6.21
0.21-0.50	0.17	0.25	0.18	0.32	0.13	0.13	0.32	0.2
0.51-1.00	0.17	0.19	0.16	0.29	0.11	0.099	0.2	0.2
1.01-2.00	0.099	0.15	0.11	0.16	0.058	0.057	0.1	0.13
2.01-5.00	0.03	0.034	0.018	0.035	0.0064	0.031	0.015	0.032
> 5.00	0.0005	0	0	0	0	0	0	0.0002

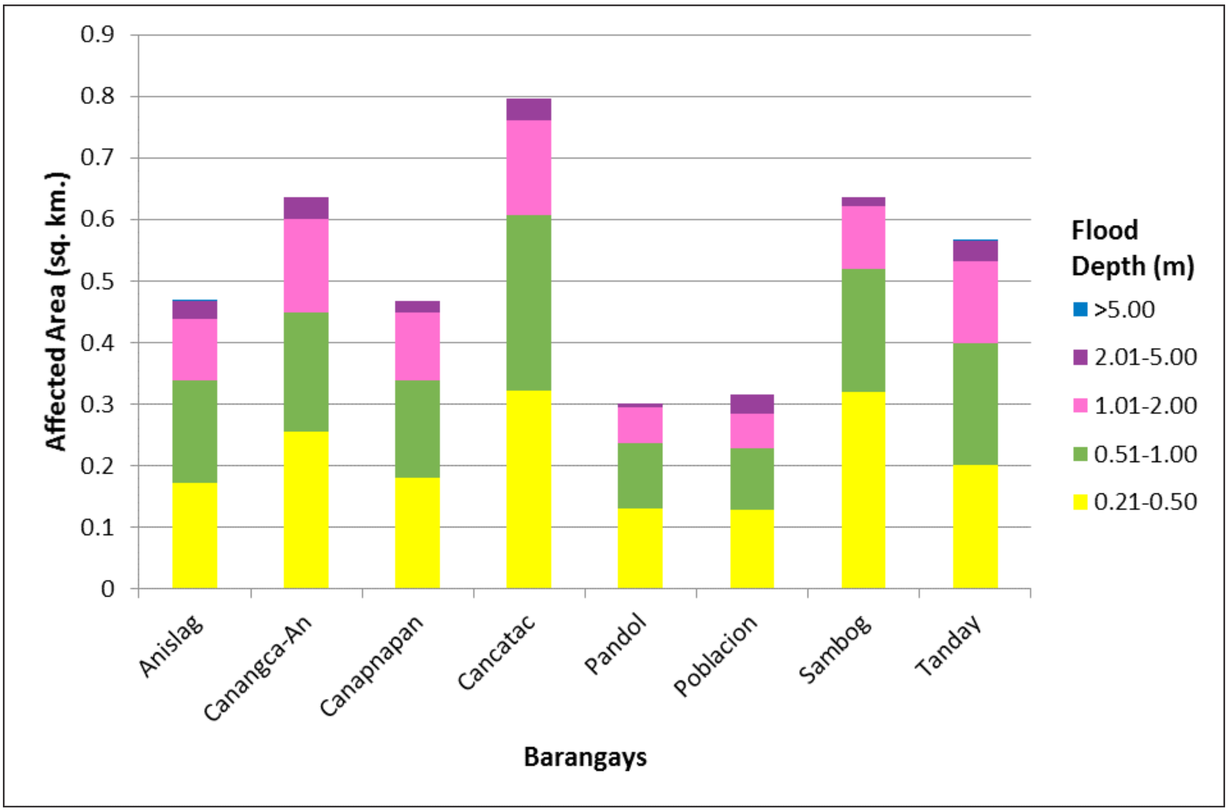


Figure 73. Affected areas in Corella, Bohol during a 5-year rainfall return period

For the Municipality of Cortes, with an area of 33.24 square kilometers, 77.69% will experience flood levels of less than 0.20 meters. 3.85% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.96%, 2.99%, 1.26%, and 0.2% 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 40 are the affected areas, in square kilometers, by flood depth per barangay.

Table 40. Affected areas in Cortes, Bohol during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cortes (in sq. km.)						
	De La Paz	Fatima	Loreto	Lourdes	Malayo Norte	Malayo Sur	Monserrat
0.03-0.20	1.53	4.48	2.55	3.42	1.42	1.74	1.78
0.21-0.50	0.21	0.19	0.18	0.11	0.097	0.047	0.063
0.51-1.00	0.047	0.14	0.18	0.092	0.082	0.047	0.038
1.01-2.00	0.022	0.09831	0.09831	0.09831	0.09831	0.09831	0.09831
2.01-5.00	0.01	0.022	0.12	0.026	0.052	0.009	0.0046
> 5.00	0.0003	0	0.036	0.0023	0.0047	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cortes (in sq. km.)						
	New Lourdes	Patrocinio	Poblacion	Rosario	Salvador	San Roque	Upper de la Paz
0.03-0.20	2.67	0.73	0.045	1.08	0.97	1.61	1.81
0.21-0.50	0.058	0.026	0.025	0.066	0.044	0.024	0.15
0.51-1.00	0.075	0.023	0.061	0.074	0.067	0.029	0.031
1.01-2.00	0.09831	0.09831	0.09831	0.09831	0.09831	0.09831	0.09831
2.01-5.00	0.066	0.011	0.0034	0.044	0.038	0.011	0.0041
> 5.00	0.0057	0.0028	0	0.015	0.0005	0	0

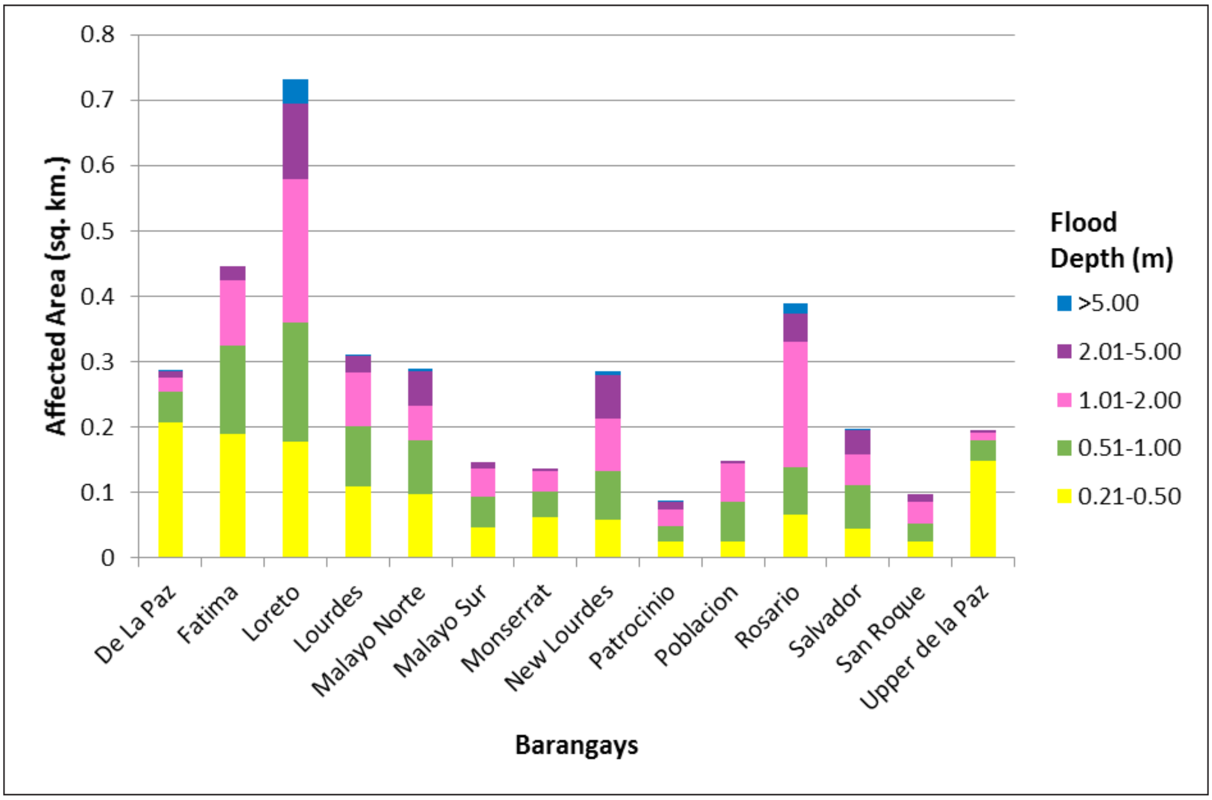


Figure 74. Affected areas in Cortes, Bohol during a 5-year rainfall return period

For the Municipality of Maribojoc, with an area of 55.2 square kilometers, 56.96% will experience flood levels of less than 0.20 meters. 4.3% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.6%, 1.43%, 0.49%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 41 are the affected areas, in square kilometers, by flood depth per barangay.

Table 41. Affected areas in Maribojoc, Bohol during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maribojoc (in sq. km.)								
	Agahay	Aliguay	Anislag	Bayacabac	Busao	Cabawan	Candavid	Dipatlong	Jandig
0.03-0.20	1.24	1.83	0.48	1.87	1.68	3.34	1.7	0.02	1.26
0.21-0.50	0.15	0.13	0.17	0.1	0.15	0.44	0.022	0.0001	0.043
0.51-1.00	0.18	0.087	0.11	0.091	0.11	0.18	0.016	0.0002	0.03
1.01-2.00	0.12	0.0068	0.0082	0.077	0.093	0.081	0.024	0	0.017
2.01-5.00	0.028	0	0.00054	0.019	0.022	0.066	0.024	0	0.0042
> 5.00	0.001	0	0	0	0.0041	0.00053	0.0003	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maribojoc (in sq. km.)								
	Lincod	Pagnitoan	Poblacion	Punsod	San Isidro	San Roque	San Vicente	Tinibgan	Toril
0.03-0.20	2.01	2.83	0.24	1.28	2.2	3.2	0.95	2.65	2.63
0.21-0.50	0.3	0.094	0.021	0.064	0.096	0.15	0.22	0.1	0.11
0.51-1.00	0.053	0.061	0.084	0.059	0.07	0.13	0.031	0.074	0.065
1.01-2.00	0.027	0.025	0.063	0.022	0.045	0.069	0.016	0.054	0.043
2.01-5.00	0.013	0.013	0	0.0081	0.019	0.02	0.001	0.022	0.0095
> 5.00	0	0.0013	0	0	0	0	0	0.0003	0

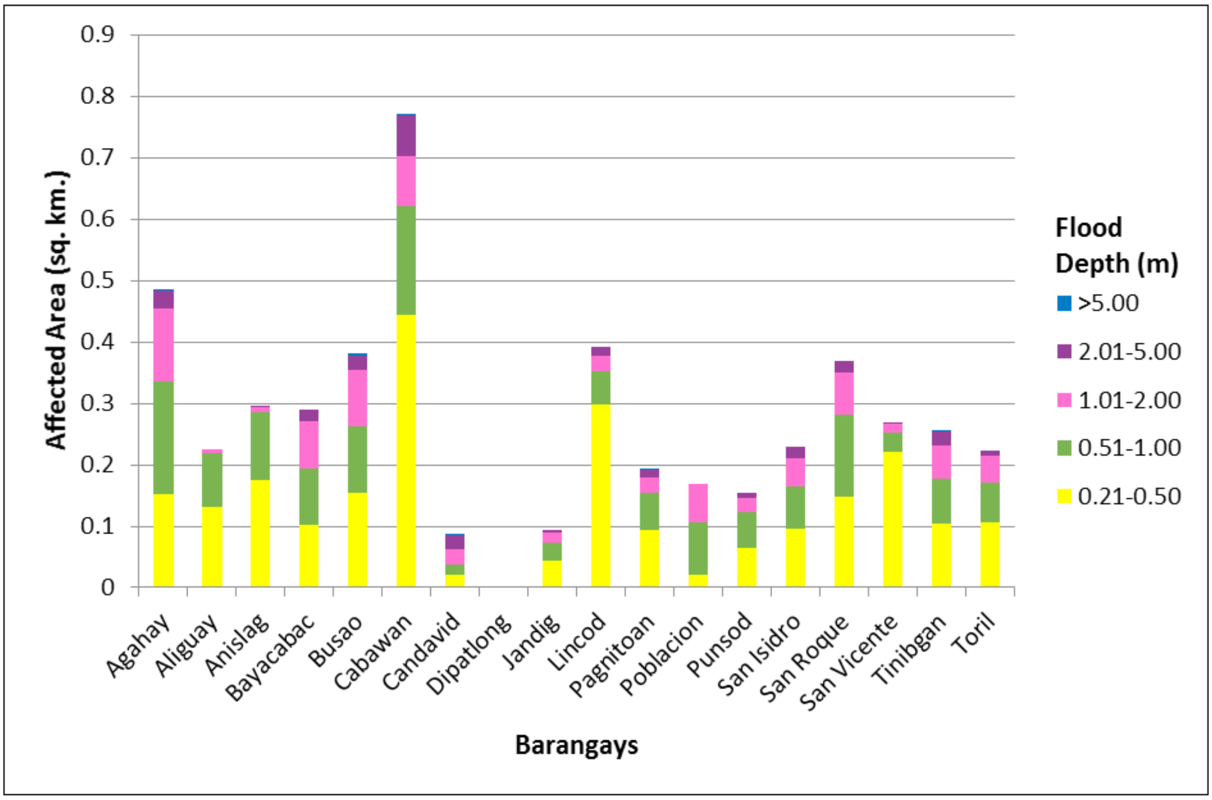


Figure 75. Affected areas in Maribojoc, Bohol during a 5-year rainfall return period

For the Municipality of San Isidro, with an area of 59.2 square kilometers, 0.83% will experience flood levels of less than 0.20 meters. 0.04% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.03%, 0.02%, 0.02%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 42 are the affected areas, in square kilometers, by flood depth per barangay.

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

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Isidro (in sq. km.)
	Baunos
0.03-0.20	0.53
0.21-0.50	0.024
0.51-1.00	0.011
1.01-2.00	0.0067
2.01-5.00	0.014
> 5.00	0.032

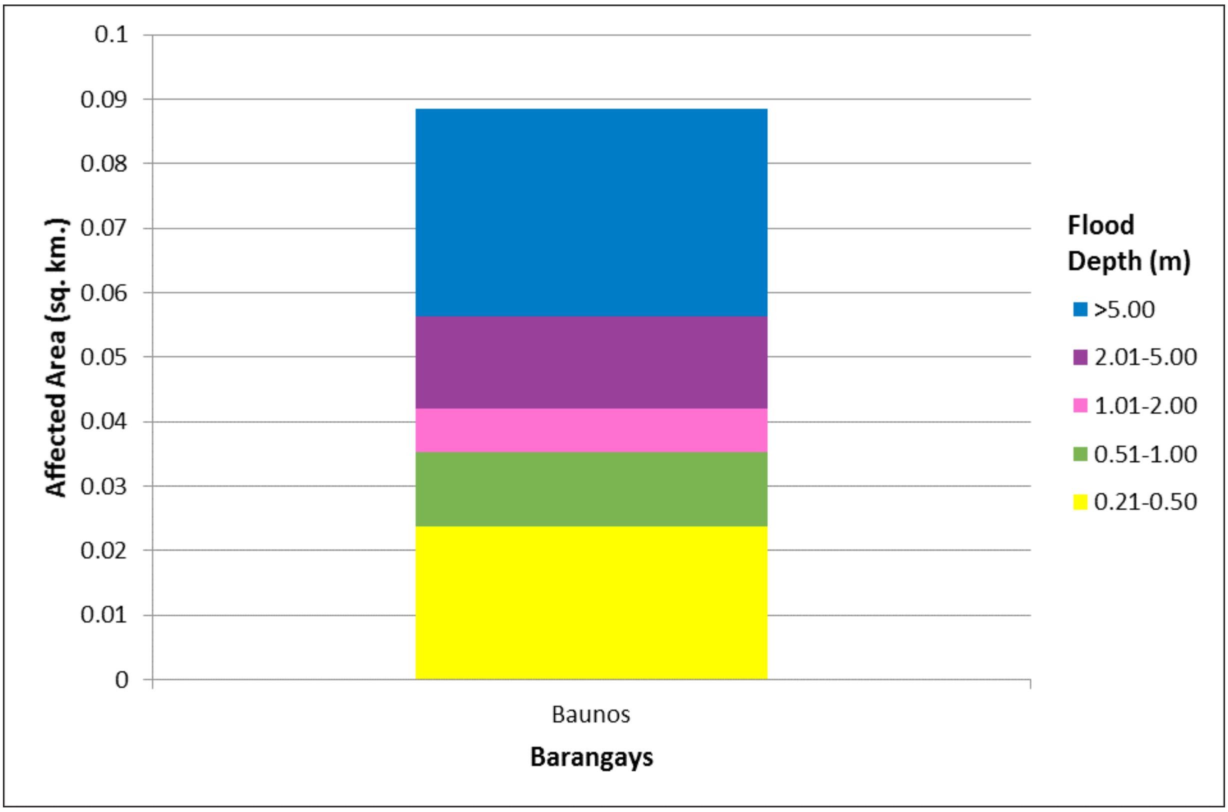


Figure 76. Affected areas in San Isidro, Bohol during a 5-year rainfall return period

For the Municipality of Sikatuna, with an area of 41.77 square kilometers, 8.57% will experience flood levels of less than 0.20 meters. 0.48% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.34%, 0.15%, and 0.03% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 43 are the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected areas in Sikatuna, Bohol during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sikatuna (in sq. km.)							
	Abucay Norte	Abucay Sur	Badiang	Bahaybahay	Cambuac Norte	Canagong	Poblacion I	Poblacion II
0.03-0.20	0.37	0.19	0.014	2.2	0.45	1.2	0.054	0.25
0.21-0.50	0.017	0.022	0.0013	0.12	0.014	0.078	0.0005	0.01
0.51-1.00	0.008	0.0047	0	0.11	0.0076	0.048	0.00048	0.013
1.01-2.00	0.001	0.0001	0	0.042	0.0033	0.026	0	0.0071
2.01-5.00	0	0	0	0.0077	0	0.0072	0	0.000004
> 5.00	0	0	0	0	0	0	0	0

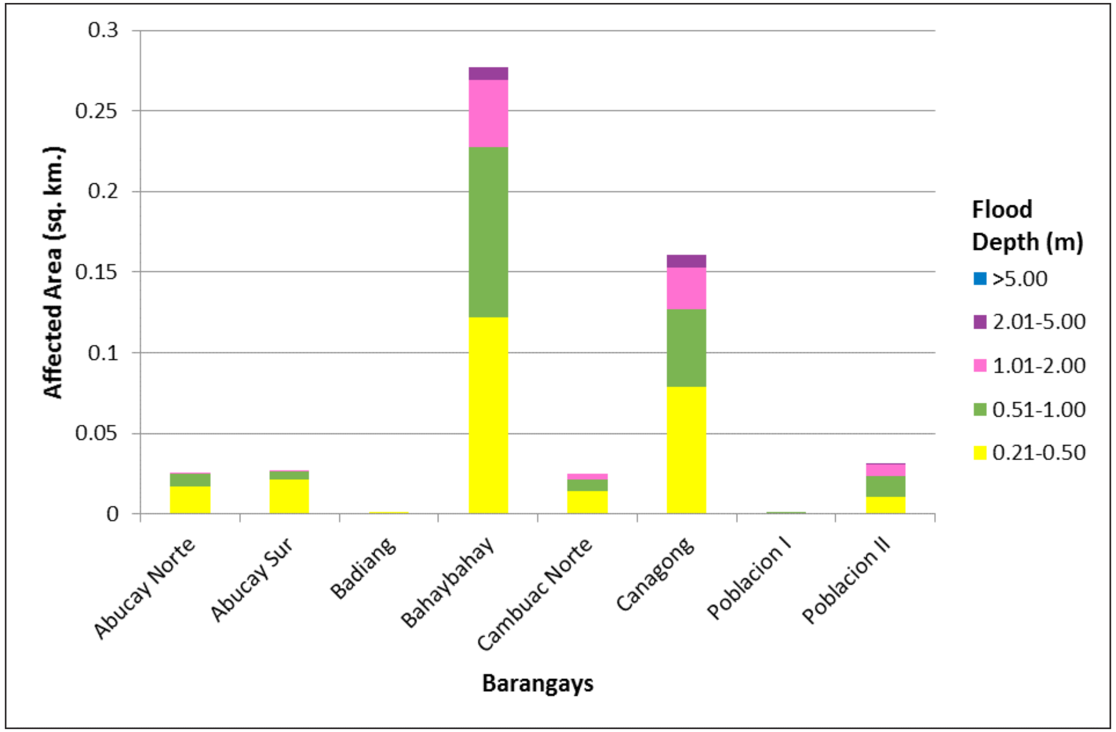


Figure 77. Affected areas in Sikatuna, Bohol during a 5-year rainfall return period

For the City of Tagbilaran, with an area of 32.17 square kilometers, 52.22% will experience flood levels of less than 0.20 meters. 2.69% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.6%, 0.9%, 0.22%, 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 44 are the affected areas, in square kilometers, by flood depth per barangay.

Table 44. Affected areas in Tagbilaran, Bohol during a 5-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagbilaran City (in sq. km.)					
	Booy	Cabawan	Cogon	Dampas	Dao	Manga
0.03-0.20	1.15	1.16	1.96	0.99	3.6	0.46
0.21-0.50	0.095	0.046	0.097	0.024	0.16	0.043
0.51-1.00	0.073	0.031	0.064	0.02	0.089	0.017
1.01-2.00	0.033	0.019	0.036	0.016	0.057	0.0083
2.01-5.00	0.0017	0.0061	0.0068	0.0072	0.011	0
> 5.00	0	0	0	0	0.0003	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagbilaran City (in sq. km.)					
	Poblacion II	Poblacion III	San Isidro	Taloto	Tiptip	Ubujan
0.03-0.20	0.22	0.0046	3.13	1.1	1.88	1.16
0.21-0.50	0.011	0.00019	0.08	0.14	0.071	0.097
0.51-1.00	0.0063	0.000001	0.062	0.046	0.059	0.05
1.01-2.00	0.0014	0	0.06	0.006	0.039	0.006
2.01-5.00	0	0	0.029	0.0004	0.0088	0.0004
> 5.00	0	0	0.0002	0	0	0

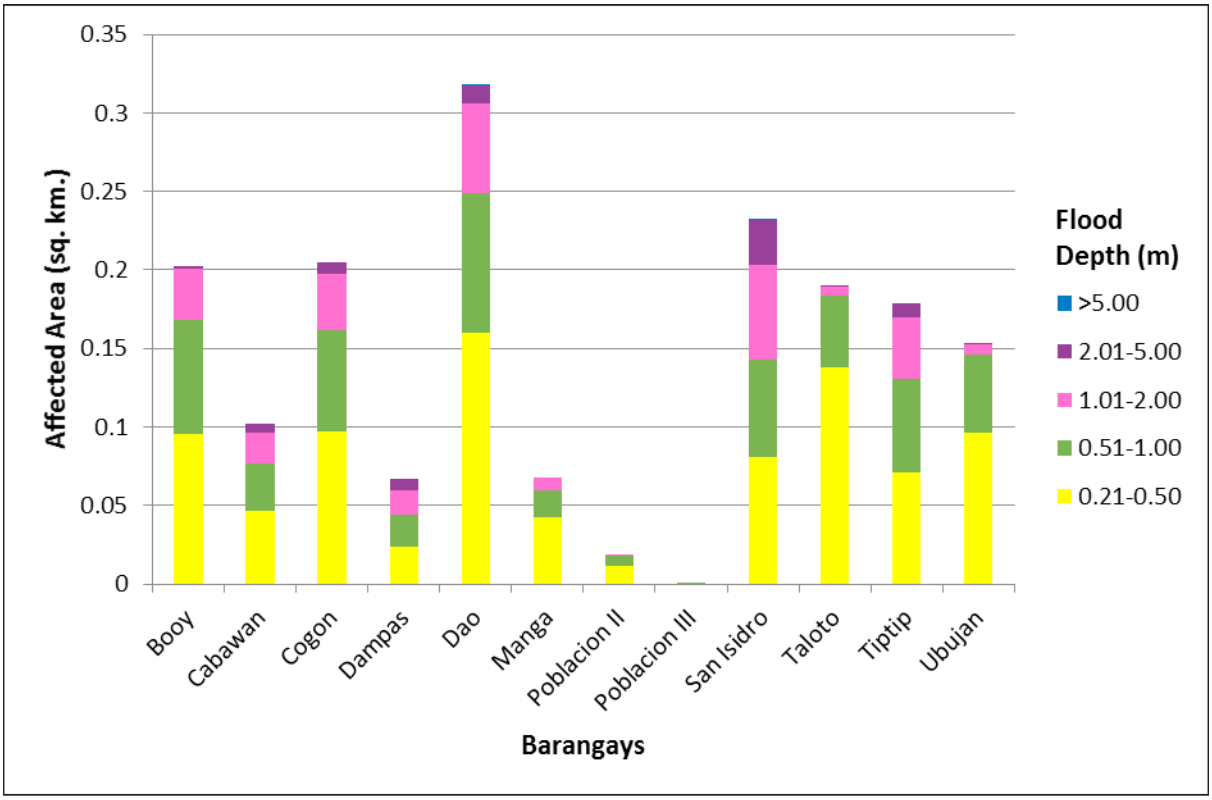


Figure 78. Affected areas in Tagbilaran, Bohol during a 5-year rainfall return period

For the 25-year return period, 1.35% of the Municipality of Albuquerque, with an area of 28.5 square kilometers, will experience flood levels of less than 0.20 meters. 0.05% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.04%, 0.03%, and 0.02% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 45 are the affected areas, in square kilometers, by flood depth per barangay.

Table 45. Affected areas in Albuquerque, Bohol during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Albuquerque (in sq. km.)	
	Basacdacu	Cantiguib
0.03-0.20	0.09	0.3
0.21-0.50	0.0009	0.014
0.51-1.00	0.0023	0.0098
1.01-2.00	0.0047	0.0052
2.01-5.00	0.0007	0
> 5.00	0	0

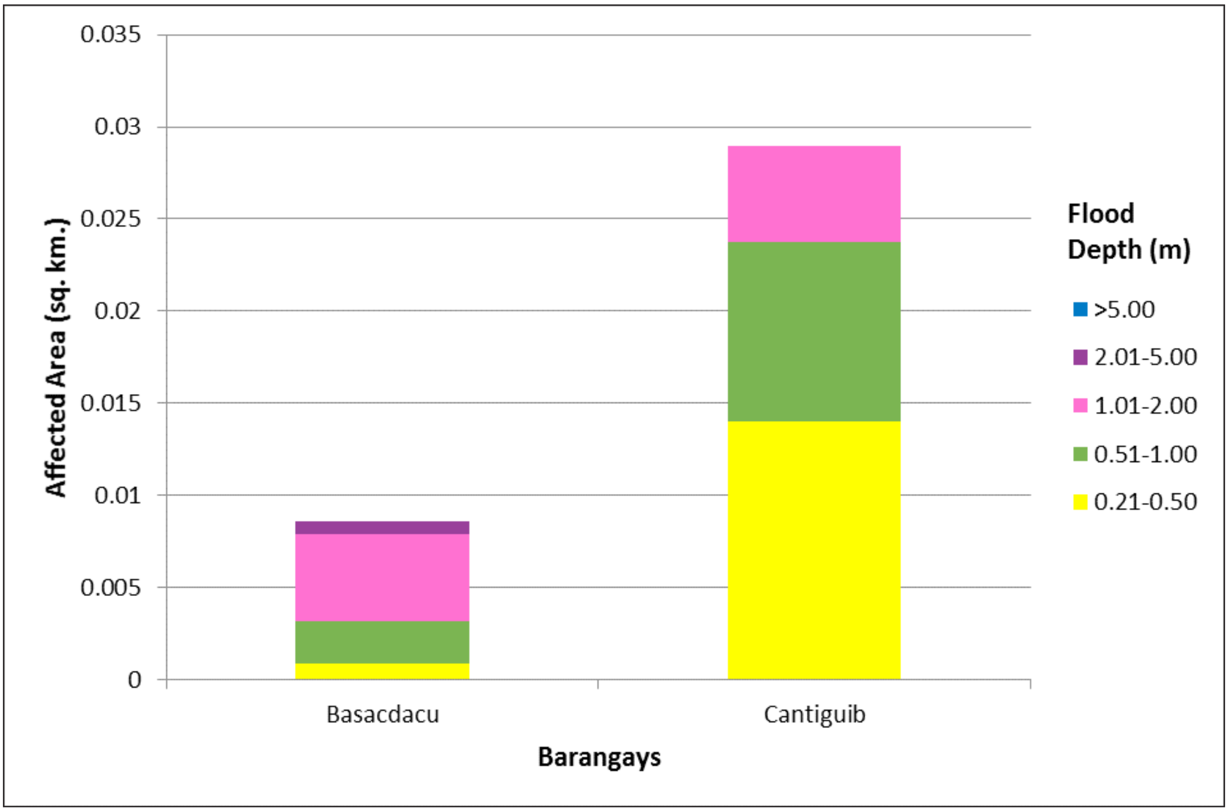


Figure 79. Affected areas in Albuquerque, Bohol during a 25-year rainfall return period

For the Municipality of Antequera, with an area of 65.66 square kilometers, 44.37% will experience flood levels of less than 0.20 meters. 2.66% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.64%, 1.27%, 1.43%, and 0.77% 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 46 are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected areas in Antequera, Bohol during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Antequera (in sq. km.)									
	Angilan	Bantolinao	Bicahan	Bitaugan	Bungahan	Can-Omay	Cansibuan	Celing	Danao	Danicop
0.03-0.20	3.44	3.64	1.42	2.29	3.22	1.46	0.1	1.35	0.39	0.51
0.21-0.50	0.16	0.17	0.069	0.13	0.25	0.11	0.0019	0.081	0.024	0.065
0.51-1.00	0.11	0.11	0.041	0.083	0.12	0.061	0.00095	0.045	0.017	0.017
1.01-2.00	0.069	0.096	0.03	0.079	0.079	0.04	0.00035	0.034	0.0068	0.011
2.01-5.00	0.066	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328
> 5.00	0.2	0.13	0.0048	0.0034	0.007	0.0032	0	0.0012	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Antequera (in sq. km.)							
	Mag-Aso	Poblacion	Santo Rosario	Tagubaas	Tupas	Ubojan	Viga	Villa Aurora
0.03-0.20	0.8	0.77	0.88	0.88	2.38	1.27	2.09	2.24
0.21-0.50	0.046	0.11	0.062	0.047	0.16	0.039	0.11	0.12
0.51-1.00	0.032	0.049	0.061	0.03	0.1	0.021	0.072	0.097
1.01-2.00	0.021	0.017	0.1	0.013	0.062	0.014	0.073	0.087
2.01-5.00	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328
> 5.00	0	0	0.0064	0.0015	0.04	0.0031	0.1	0.009

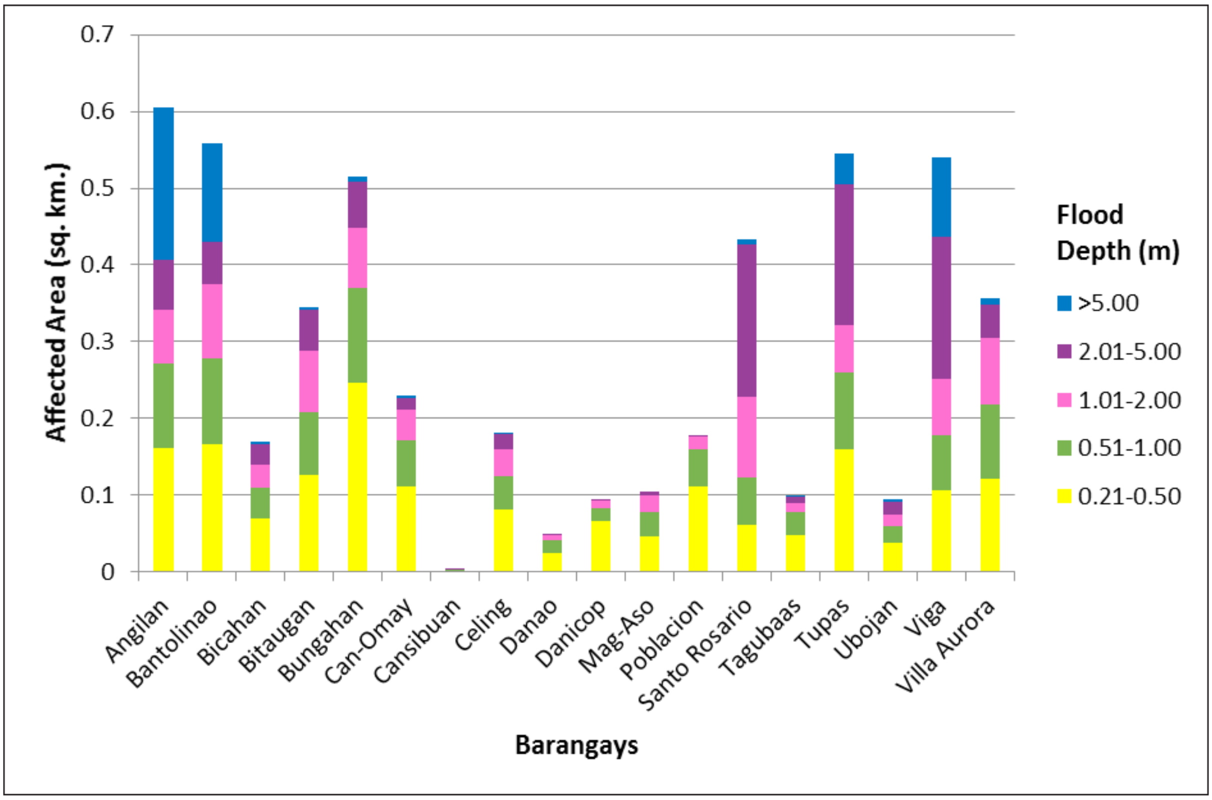


Figure 80. Affected areas in Antequera, Bohol during a 25-year rainfall return period

For the Municipality of Baclayon, with an area of 33.81 square kilometers, 20.72% will experience flood levels of less than 0.20 meters. 0.95% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.92%, 0.96%, 0.22%, and 0.002 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 47 are the affected areas, in square kilometers, by flood depth per barangay.

Table 47. Affected areas in Baclayon, Bohol during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Baclayon (in sq. km.)				
	Buenaventura	Dasitam	Landican	Libertad	Tanday
0.03-0.20	1.77	1.49	0.0075	1.6	2.13
0.21-0.50	0.078	0.094	0	0.075	0.075
0.51-1.00	0.057	0.095	0	0.08	0.078
1.01-2.00	0.09	0.08	0	0.065	0.09
2.01-5.00	0.023	0.0035	0	0.021	0.026
> 5.00	0.0008	0	0	0	0

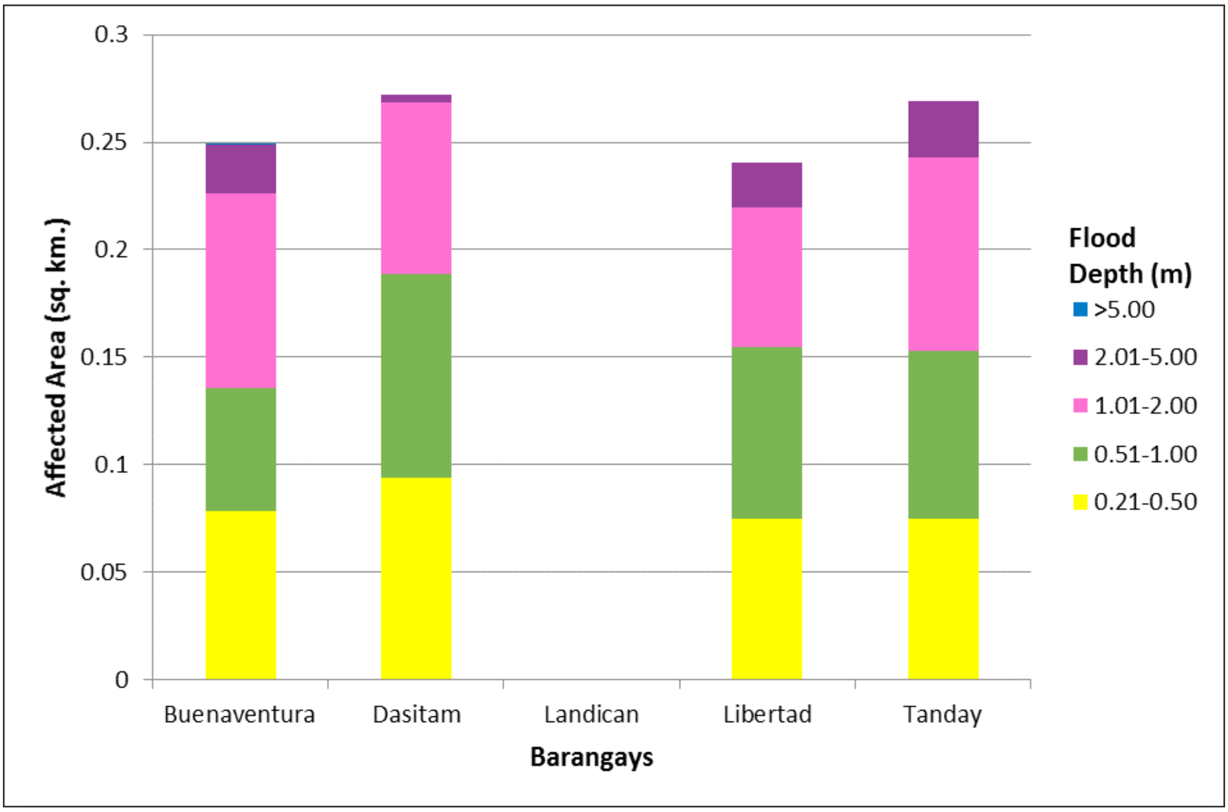


Figure 81. Affected areas in Baclayon, Bohol during a 25-year rainfall return period

For the Municipality of Balilihan, with an area of 104.6 square kilometers, 38.69% will experience flood levels of less than 0.20 meters. 2.26% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.69%, 1.27%, 0.58%, and 0.09% 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 48 are the affected areas, in square kilometers, by flood depth per barangay.

Table 48. Affected areas in Balilihan, Bohol during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balilihan (in sq. km.)								
	Baucan Sur	Boctol	Cabad	Candasig	Cantalid	Cantomimbo	Datag Norte	Datag Sur	Del Carmen Este
0.03-0.20	0.028	1.28	1.1	2.99	5.22	0.45	1.72	3.3	2.5
0.21-0.50	0.00076	0.11	0.047	0.18	0.14	0.043	0.062	0.15	0.15
0.51-1.00	0.00064	0.08	0.027	0.12	0.16	0.026	0.06	0.14	0.17
1.01-2.00	0.0017	0.042	0.017	0.052	0.22	0.023	0.065	0.15	0.12
2.01-5.00	0.0001	0.0047	0.0099	0.023	0.21	0.0035	0.019	0.054	0.017
> 5.00	0	0	0.0006	0.0018	0.0037	0	0.0009	0.0003	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balilihan (in sq. km.)								
	Del Carmen Norte	Del Carmen Sur	Del Carmen Weste	Dorol	Magsija	Maslog	Sagasa	Sal-Ing	San Isidro
0.03-0.20	1.65	2.32	1.45	2.83	5.53	2.68	0.12	2.79	2.52
0.21-0.50	0.22	0.15	0.14	0.14	0.23	0.11	0.015	0.27	0.22
0.51-1.00	0.13	0.13	0.073	0.11	0.16	0.096	0.00063	0.2	0.09
1.01-2.00	0.041	0.1	0.021	0.067	0.15	0.087	0	0.12	0.043
2.01-5.00	0.0016	0.041	0.0025	0.02	0.11	0.057	0	0.01	0.025
> 5.00	0	0.0005	0	0.052	0.016	0.0001	0	0	0.021

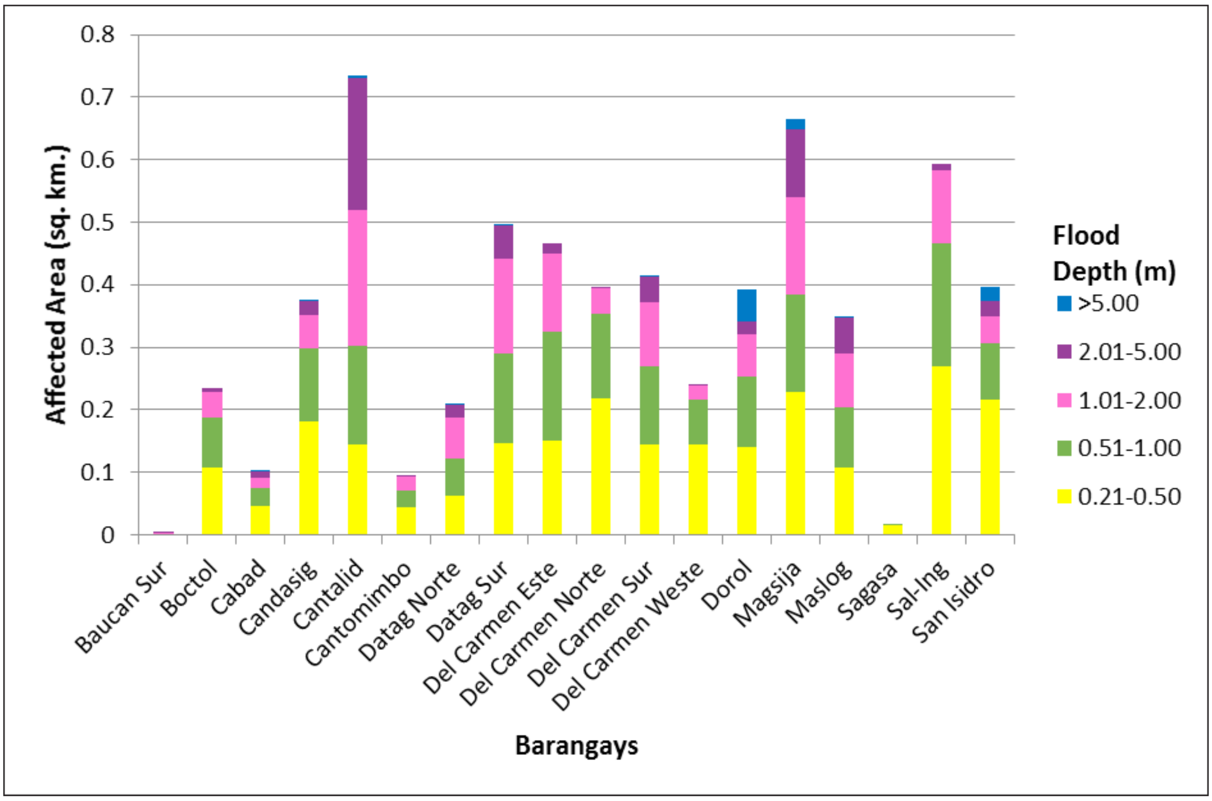


Figure 82. Affected areas in Balilihan, Bohol during a 25-year rainfall return period

For the Municipality of Corella, with an area of 34.7 square kilometers, 99.24% will experience flood levels of less than 0.20 meters. 5.17% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.87%, 4.4%, 1.73%, 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 49 are the affected areas, in square kilometers, by flood depth per barangay.

Table 49. Affected areas in Corella, Bohol during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Corella (in sq. km.)							
	Anislag	Canangca-An	Canapnapan	Cancatac	Pandol	Poblacion	Sambog	Tanday
0.03-0.20	3.43	5.74	4.04	5.93	2.4	2.6	4.31	6.02
0.21-0.50	0.19	0.26	0.18	0.31	0.13	0.14	0.36	0.22
0.51-1.00	0.18	0.23	0.18	0.35	0.13	0.12	0.28	0.22
1.01-2.00	0.18	0.24	0.18	0.28	0.11	0.097	0.19	0.23
2.01-5.00	0.085	0.1	0.069	0.11	0.025	0.054	0.064	0.09
> 5.00	0.002	0.0003	0.0006	0.00035	0.0001	0.0028	0	0.0008

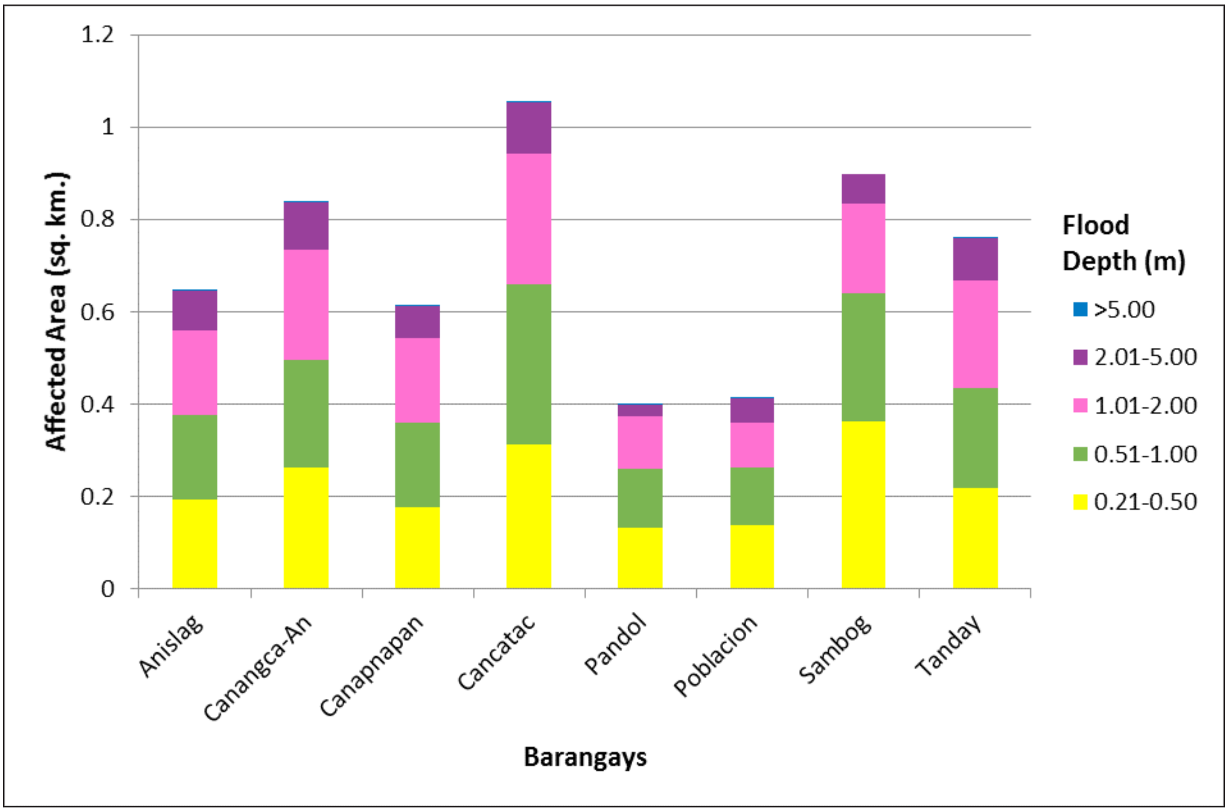


Figure 83. Affected areas in Corella, Bohol during a 25-year rainfall return period

For the Municipality of Cortes, with an area of 33.24 square kilometers, 73.39% will experience flood levels of less than 0.20 meters. 4.19% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.49%, 4.75%, 4.36%, and 0.73% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 are the affected areas, in square kilometers, by flood depth per barangay.

Table 50. Affected areas in Cortes, Bohol during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cortes (in sq. km.)						
	De La Paz	Fatima	Loreto	Lourdes	Malayo Norte	Malayo Sur	Monserrat
0.03-0.20	1.36	4.3	2.35	3.28	1.28	1.67	1.72
0.21-0.50	0.24	0.21	0.081	0.13	0.041	0.058	0.075
0.51-1.00	0.16	0.17	0.065	0.11	0.03	0.052	0.057
1.01-2.00	0.038	0.09831	0.09831	0.09831	0.09831	0.09831	0.09831
2.01-5.00	0.021	0.076	0.45	0.079	0.13	0.038	0.021
> 5.00	0.0031	0.0004	0.11	0.005	0.026	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cortes (in sq. km.)						
	New Lourdes	Patrocinio	Poblacion	Rosario	Salvador	San Roque	Upper de la Paz
0.03-0.20	2.55	0.7	0.63	0.95	0.84	1.57	1.19
0.21-0.50	0.068	0.032	0.033	0.063	0.029	0.033	0.3
0.51-1.00	0.075	0.019	0.11	0.07	0.094	0.032	0.44
1.01-2.00	0.09831	0.09831	0.09831	0.09831	0.09831	0.09831	0.09831
2.01-5.00	0.13	0.032	0.11	0.21	0.093	0.035	0.022
> 5.00	0.025	0.0039	0.018	0.034	0.016	0.0001	0.0001

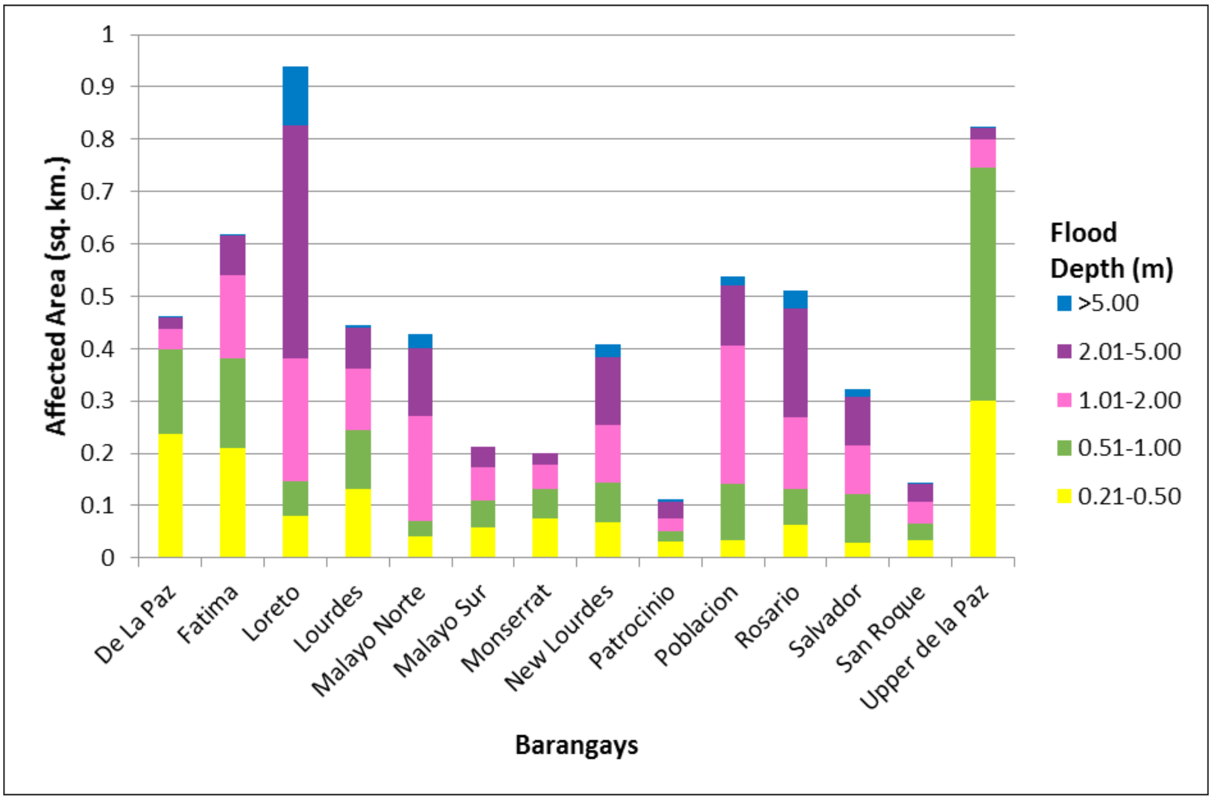


Figure 84. Affected areas in Cortes, Bohol during a 25-year rainfall return period

For the Municipality of Maribojoc, with an area of 55.2 square kilometers, 52.52% will experience flood levels of less than 0.20 meters. 3.88% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.2%, 3.39%, 1.7%, and 0.01% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 51 are the affected areas, in square kilometers, by flood depth per barangay.

Table 51. Affected areas in Maribojoc, Bohol during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maribojoc (in sq. km.)								
	Agahay	Aliguay	Anislag	Bayacabac	Busao	Cabawan	Candavid	Dipatlong	Jandig
0.03-0.20	1.13	1.76	0.44	1.79	1.53	2.89	1.67	0.02	1.23
0.21-0.50	0.081	0.12	0.072	0.12	0.11	0.27	0.026	0.00027	0.051
0.51-1.00	0.066	0.066	0.22	0.075	0.1	0.24	0.018	0.0002	0.035
1.01-2.00	0.16	0.11	0.033	0.097	0.18	0.55	0.028	0	0.024
2.01-5.00	0.27	0.00027	0.0026	0.082	0.13	0.14	0.044	0	0.012
> 5.00	0.0064	0	0	0.0012	0.017	0.016	0.0051	0	0.0001

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maribojoc (in sq. km.)								
	Lincod	Pagnitoan	Poblacion	Punsod	San Isidro	San Roque	San Vicente	Tinibgan	Toril
0.03-0.20	1.12	2.77	0.23	1.23	2.13	3.1	0.8	2.57	2.55
0.21-0.50	0.35	0.11	0.016	0.066	0.099	0.13	0.3	0.11	0.12
0.51-1.00	0.81	0.073	0.036	0.066	0.085	0.15	0.085	0.09	0.094
1.01-2.00	0.077	0.044	0.12	0.054	0.075	0.14	0.027	0.083	0.072
2.01-5.00	0.05	0.021	0.013	0.021	0.042	0.042	0.0037	0.042	0.026
> 5.00	0.0013	0.0046	0	0.0005	0.000071	0.0001	0	0.0007	0.00022

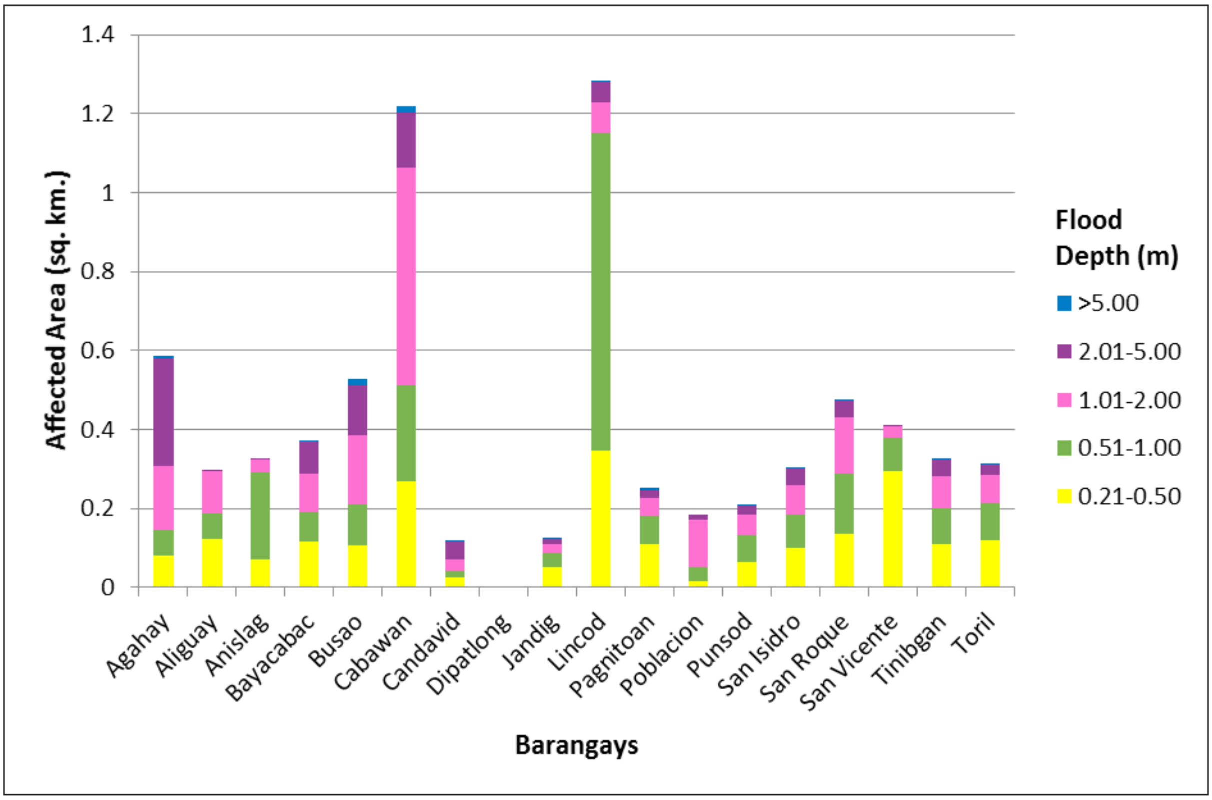


Figure 85. Affected areas in Maribojoc, Bohol during a 25-year rainfall return period

For the Municipality of San Isidro, with an area of 59.2 square kilometers, 0.86% will experience flood levels of less than 0.20 meters. 0.034% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.03%, 0.02%, 0.02%, and 0.1% 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 52 are the affected areas, in square kilometers, by flood depth per barangay.

Table 52. Affected areas in San Isidro, Bohol during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Isidro (in sq. km.)
	Baunos
0.03-0.20	0.51
0.21-0.50	0.02
0.51-1.00	0.017
1.01-2.00	0.011
2.01-5.00	0.011
> 5.00	0.057

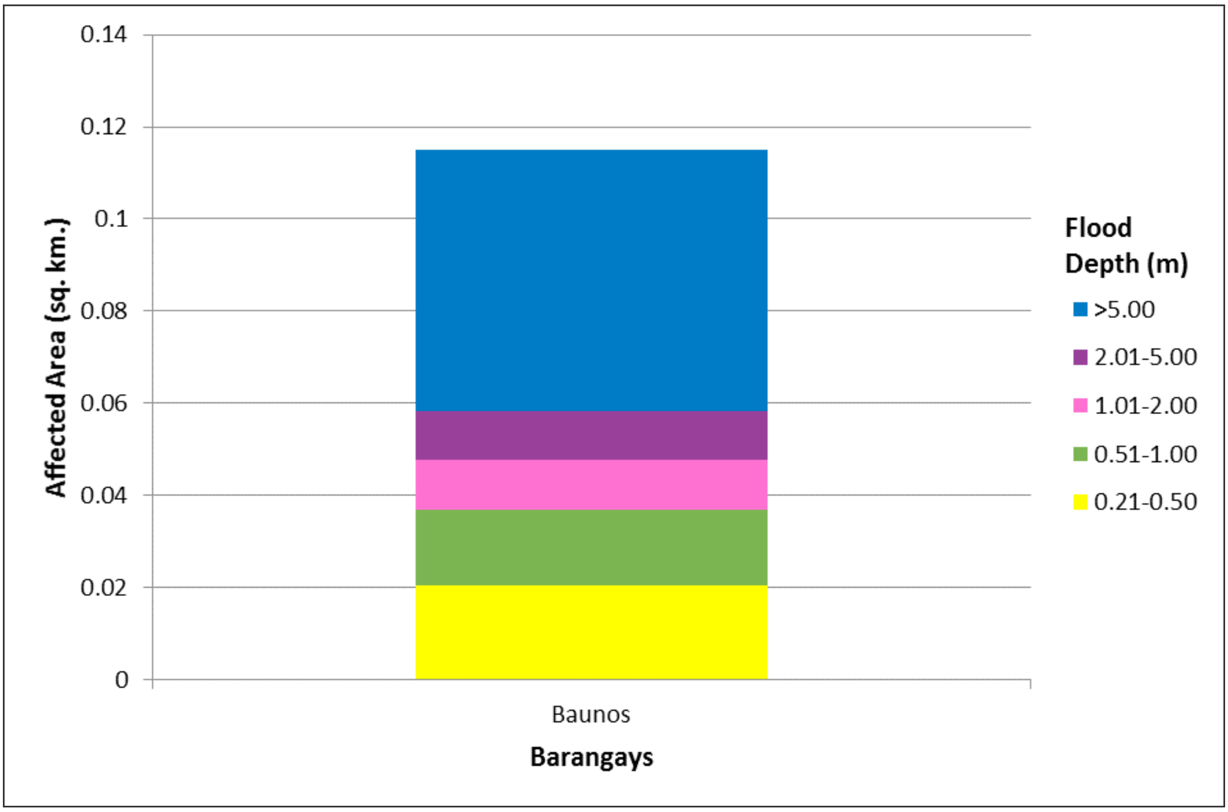


Figure 86. Affected areas in San Isidro, Bohol during a 25-year rainfall return period

For the Municipality of Sikatuna, with an area of 41.77 square kilometers, 8.33% will experience flood levels of less than 0.20 meters. 0.45% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.43%, 0.27%, and 0.09% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 53 are the affected areas, in square kilometers, by flood depth per barangay.

Table 53. Affected areas in Sikatuna, Bohol during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sikatuna (in sq. km.)							
	Abucay Norte	Abucay Sur	Badiang	Bahaybahay	Cambuac Norte	Canagong	Poblacion I	Poblacion II
0.03-0.20	0.36	0.19	0.013	2.13	0.45	1.16	0.054	0.24
0.21-0.50	0.018	0.017	0.0018	0.11	0.018	0.068	0.00093	0.011
0.51-1.00	0.013	0.014	0.00031	0.13	0.0088	0.064	0.00048	0.01
1.01-2.00	0.0026	0.001	0	0.079	0.0063	0.043	0	0.016
2.01-5.00	0	0	0	0.026	0	0.025	0	0.00016
> 5.00	0	0	0	0	0	0	0	0

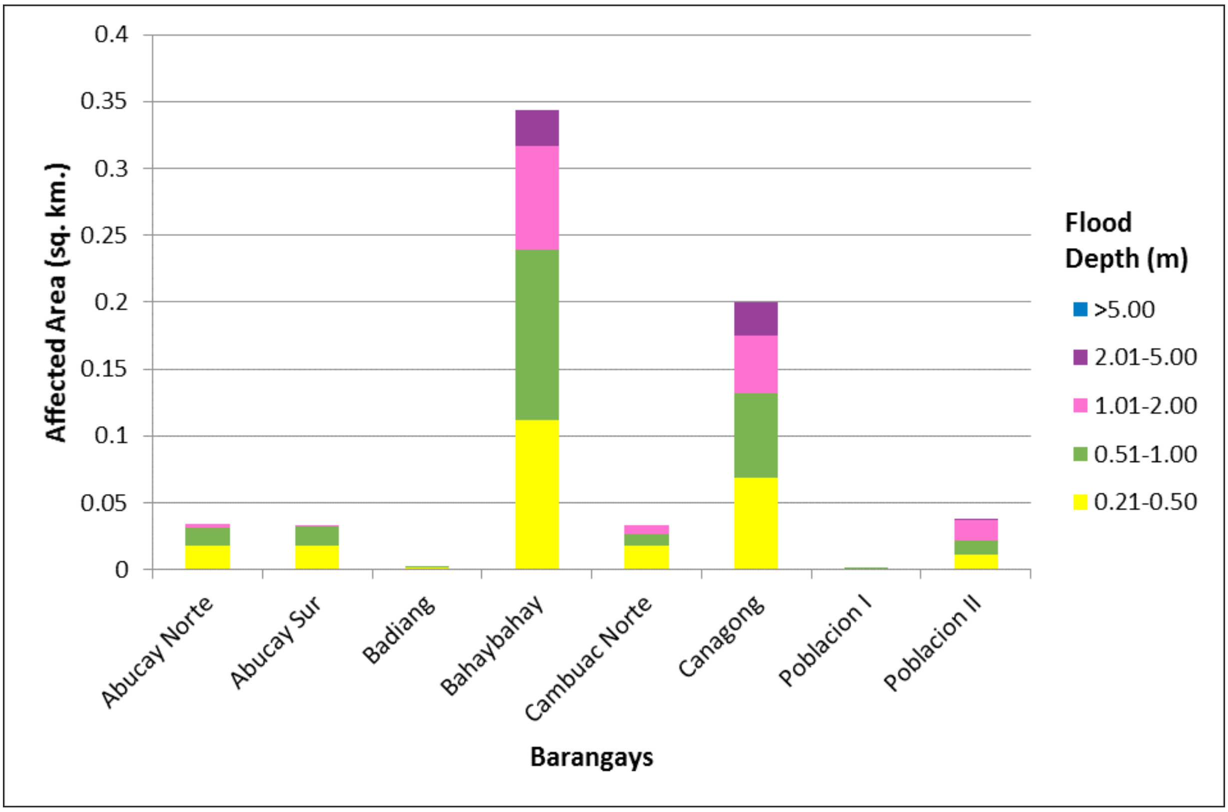


Figure 87. Affected areas in Sikatuna, Bohol during a 25-year rainfall return period

For the City of Tagbilaran, with an area of 32.17 square kilometers, 49.44% will experience flood levels of less than 0.20 meters. 3.31% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.39%, 1.75%, 0.65%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 54 are the affected areas, in square kilometers, by flood depth per barangay.

Table 54. Affected areas in Tagbilaran, Bohol during a 25-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagbilaran City (in sq. km.)					
	Booy	Cabawan	Cogon	Dampas	Dao	Manga
0.03-0.20	1.03	1.11	1.86	0.96	3.44	0.41
0.21-0.50	0.12	0.061	0.13	0.031	0.21	0.06
0.51-1.00	0.091	0.042	0.074	0.021	0.13	0.036
1.01-2.00	0.098	0.033	0.069	0.028	0.1	0.02
2.01-5.00	0.01	0.014	0.025	0.018	0.039	0.0002
> 5.00	0	0.00058	0	0.0008	0.0026	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagbilaran City (in sq. km.)					
	Poblacion II	Poblacion III	San Isidro	Taloto	Tiptip	Ubujan
0.03-0.20	0.21	0.0045	3.01	1	1.8	1.08
0.21-0.50	0.017	0.00023	0.11	0.13	0.086	0.11
0.51-1.00	0.0056	0.000001	0.081	0.13	0.064	0.09
1.01-2.00	0.0051	0	0.082	0.022	0.079	0.027
2.01-5.00	0	0	0.071	0.0018	0.028	0.002
> 5.00	0	0	0.012	0.0001	0.0009	0

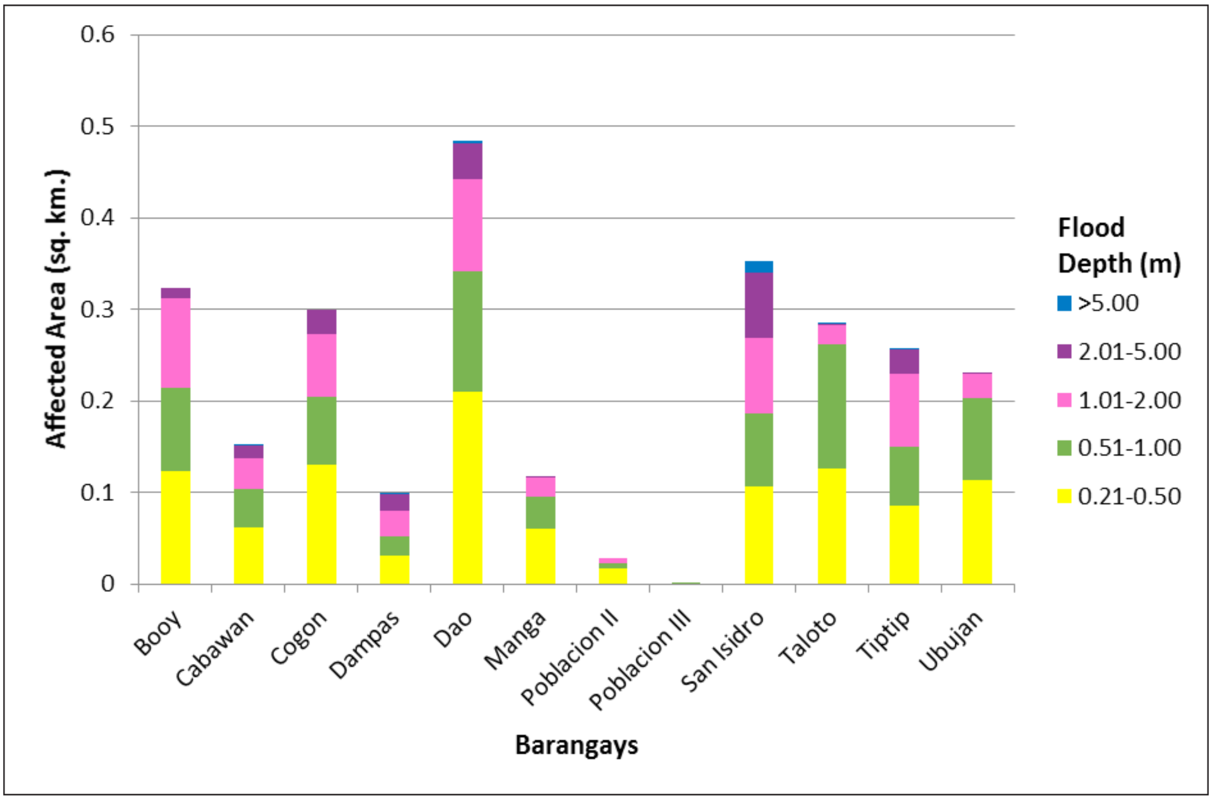


Figure 88. Affected areas in Tagbilaran, Bohol during a 25-year rainfall return period

For the 100-year return period, 1.33% of the Municipality of Albuquerque, with an area of 28.5 square kilometers, will experience flood levels of less than 0.20 meters. 0.06% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.05%, 0.04%, and 0.05% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 55 are the affected areas, in square kilometers, by flood depth per barangay.

Table 55. Affected areas in Albuquerque, Bohol during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Albuquerque (in sq. km.)	
	Basacdacu	Cantiguib
0.03-0.20	0.09	0.29
0.21-0.50	0.0008	0.015
0.51-1.00	0.0019	0.012
1.01-2.00	0.0052	0.0065
2.01-5.00	0.0014	0
> 5.00	0	0

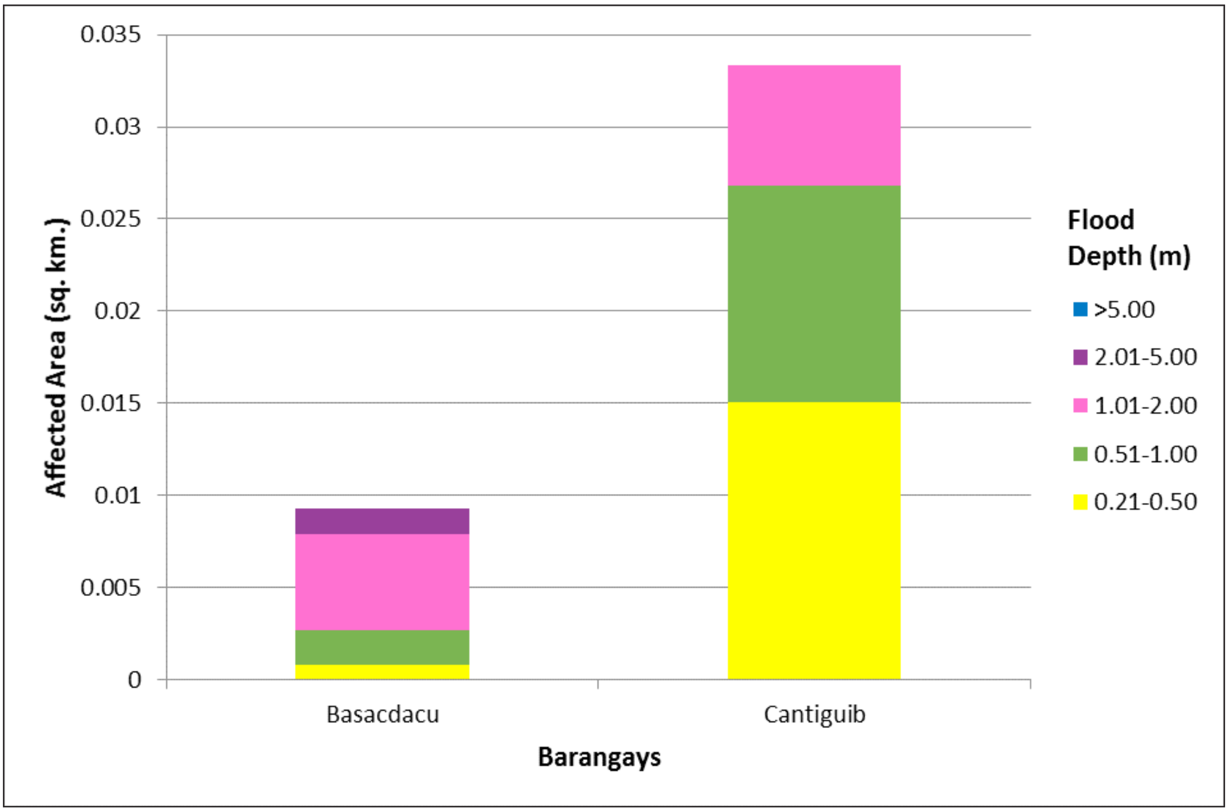


Figure 89. Affected areas in Albuquerque, Bohol during a 100-year rainfall return period

For the Municipality of Antequera, with an area of 65.66 square kilometers, 43.28% will experience flood levels of less than 0.20 meters. 2.82% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.86%, 1.37%, 1.68%, and 1.14% 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 56 are the affected areas, in square kilometers, by flood depth per barangay.

Table 56. Affected areas in Antequera, Bohol during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Antequera (in sq. km.)									
	Angilan	Bantolinao	Bicahan	Bitaugan	Bungahan	Can-Omay	Cansibuan	Celing	Danao	Danicop
0.03-0.20	3.37	3.55	1.39	2.25	3.14	1.43	0.1	1.31	0.38	0.49
0.21-0.50	0.17	0.18	0.078	0.13	0.25	0.11	0.0022	0.095	0.027	0.076
0.51-1.00	0.13	0.13	0.044	0.088	0.16	0.074	0.001	0.057	0.019	0.022
1.01-2.00	0.084	0.11	0.036	0.078	0.091	0.053	0.00055	0.038	0.01	0.014
2.01-5.00	0.058	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328
> 5.00	0.25	0.16	0.0055	0.014	0.014	0.0047	0	0.0019	0	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Antequera (in sq. km.)							
	Mag-Aso	Poblacion	Santo Rosario	Tagubaas	Tupas	Ubojan	Viga	Villa Aurora
0.03-0.20	0.78	0.71	0.85	0.87	2.32	1.26	2.04	2.18
0.21-0.50	0.048	0.15	0.049	0.049	0.16	0.04	0.11	0.13
0.51-1.00	0.036	0.063	0.05	0.035	0.11	0.026	0.078	0.1
1.01-2.00	0.026	0.026	0.069	0.018	0.059	0.017	0.065	0.11
2.01-5.00	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328	0.05328
> 5.00	0	0	0.0093	0.0032	0.12	0.0062	0.14	0.021

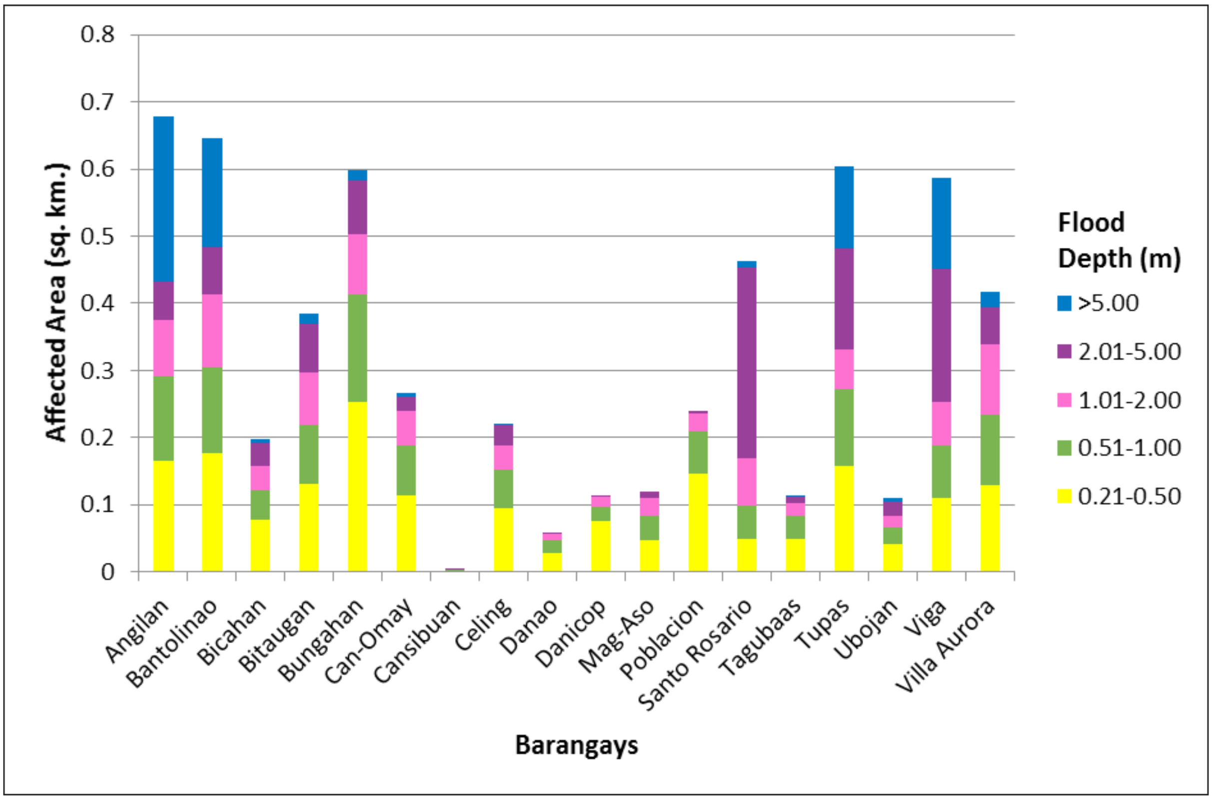


Figure 90. Affected areas in Antequera, Bohol during a 100-year rainfall return period

For the Municipality of Baclayon, with an area of 33.81 square kilometers, 20.0.% will experience flood levels of less than 0.20 meters. 0.91% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.96%, 1.22%, 0.44%, and 0.007 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 57 are the affected areas, in square kilometers, by flood depth per barangay.

Table 57. Affected areas in Baclayon, Bohol during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Baclayon (in sq. km.)				
	Buenaventura	Dasitam	Landican	Libertad	Tanday
0.03-0.20	1.74	1.45	0.0074	1.56	2.09
0.21-0.50	0.074	0.084	0.0001	0.078	0.071
0.51-1.00	0.065	0.096	0	0.078	0.087
1.01-2.00	0.1	0.12	0	0.091	0.1
2.01-5.00	0.045	0.014	0	0.037	0.052
> 5.00	0.0009	0	0	0.0012	0.0001

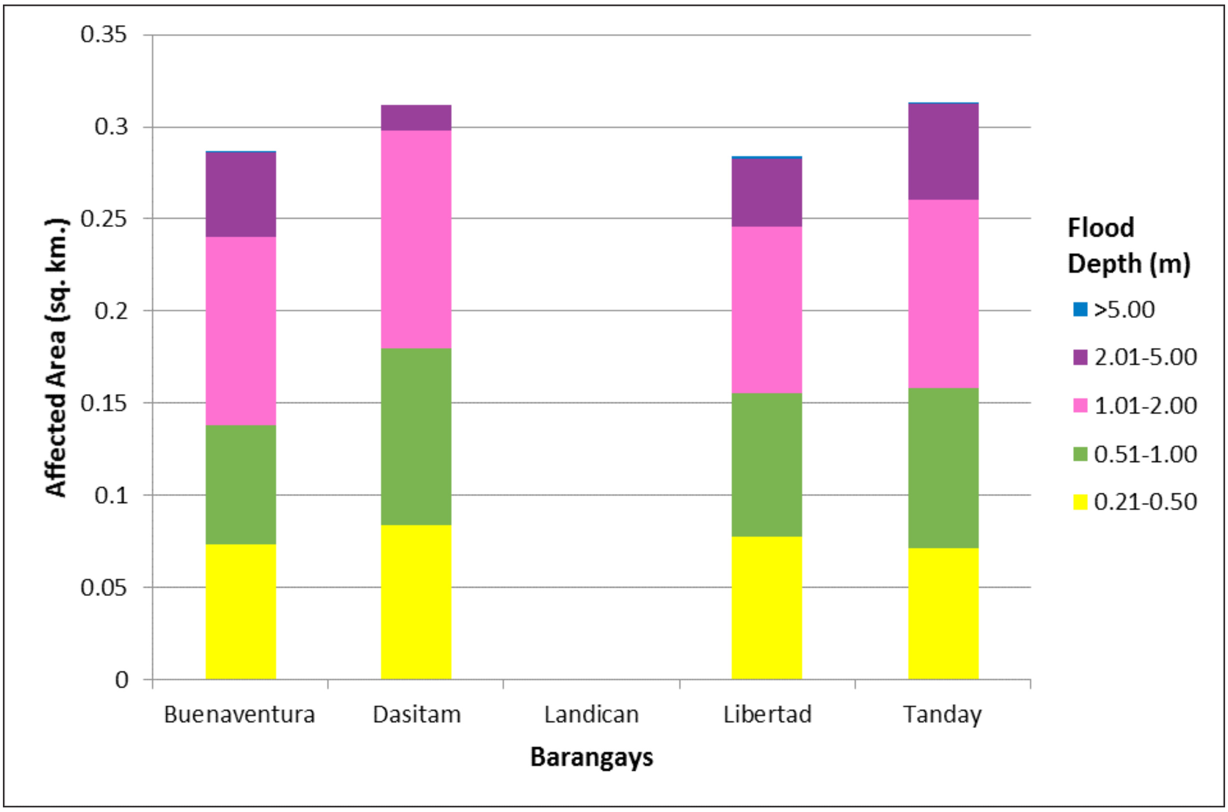


Figure 91. Affected areas in Baclayon, Bohol during a 100-year rainfall return period

For the Municipality of Balilihan, with an area of 104.6 square kilometers, 37.Z59% will experience flood levels of less than 0.20 meters. 2.44% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.94%, 1.56%, 0.89%, and 0.17% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 58 are the affected areas, in square kilometers, by flood depth per barangay.

Table 58. Affected areas in Balilihan, Bohol during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balilihan (in sq. km.)								
	Baucan Sur	Boctol	Cabad	Candasig	Cantalid	Cantomimbo	Datag Norte	Datag Sur	Del Carmen Este
0.03-0.20	0.027	1.23	1.08	2.93	5.11	0.44	1.68	3.18	2.39
0.21-0.50	0.0003	0.12	0.052	0.19	0.15	0.049	0.068	0.17	0.16
0.51-1.00	0.0011	0.097	0.03	0.14	0.16	0.028	0.07	0.16	0.19
1.01-2.00	0.0016	0.057	0.021	0.067	0.23	0.025	0.075	0.18	0.18
2.01-5.00	0.00059	0.0087	0.012	0.032	0.27	0.011	0.033	0.099	0.052
> 5.00	0	0	0.0024	0.0057	0.03	0	0.0017	0.0019	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Balilihan (in sq. km.)								
	Del Carmen Norte	Del Carmen Sur	Del Carmen Weste	Dorol	Magsija	Maslog	Sagasa	Sal-Ing	San Isidro
0.03-0.20	1.56	2.22	1.4	2.76	5.43	2.63	0.11	2.69	2.45
0.21-0.50	0.25	0.16	0.15	0.15	0.25	0.11	0.021	0.28	0.22
0.51-1.00	0.16	0.14	0.099	0.12	0.17	0.094	0.0016	0.23	0.12
1.01-2.00	0.064	0.13	0.032	0.097	0.17	0.1	0	0.14	0.05
2.01-5.00	0.0029	0.07	0.0038	0.031	0.15	0.087	0	0.034	0.032
> 5.00	0	0.0016	0	0.067	0.03	0.0002	0	0	0.036

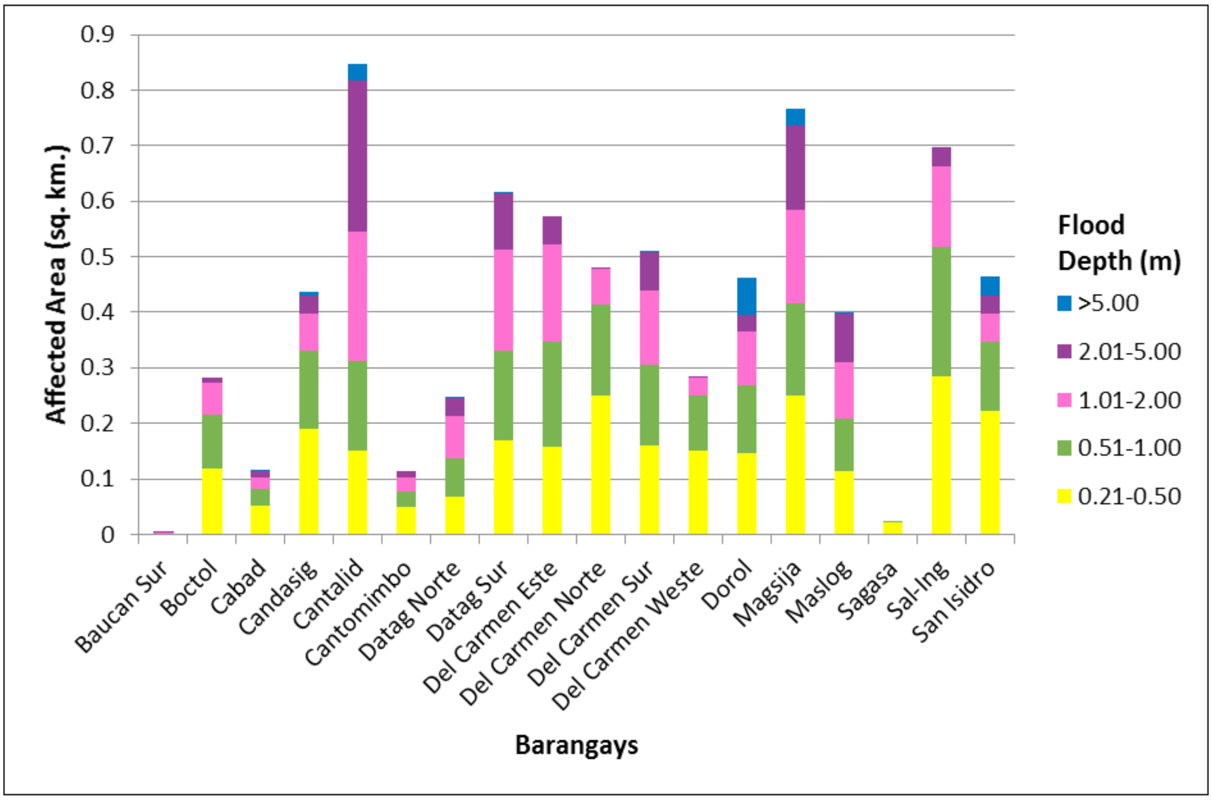


Figure 92. Affected areas in Balilihan, Bohol during a 100-year rainfall return period

For the Municipality of Corella, with an area of 34.7 square kilometers, 96.61% will experience flood levels of less than 0.20 meters. 5.36% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 5.16%, 5.34%, 2.89%, and 0.06% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 59 are the affected areas, in square kilometers, by flood depth per barangay.

Table 59. Affected areas in Corella, Bohol during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Corella (in sq. km.)							
	Anislag	Canangca-An	Canapnapan	Cancatac	Pandol	Poblacion	Sambog	Tanday
0.03-0.20	3.32	5.61	3.95	5.78	2.33	2.54	4.14	5.9
0.21-0.50	0.21	0.27	0.19	0.31	0.14	0.14	0.38	0.23
0.51-1.00	0.19	0.24	0.18	0.36	0.13	0.13	0.33	0.22
1.01-2.00	0.22	0.27	0.22	0.35	0.13	0.13	0.26	0.28
2.01-5.00	0.13	0.18	0.12	0.18	0.068	0.071	0.1	0.15
> 5.00	0.0043	0.0022	0.0011	0.0036	0.0001	0.0064	0.0002	0.0028

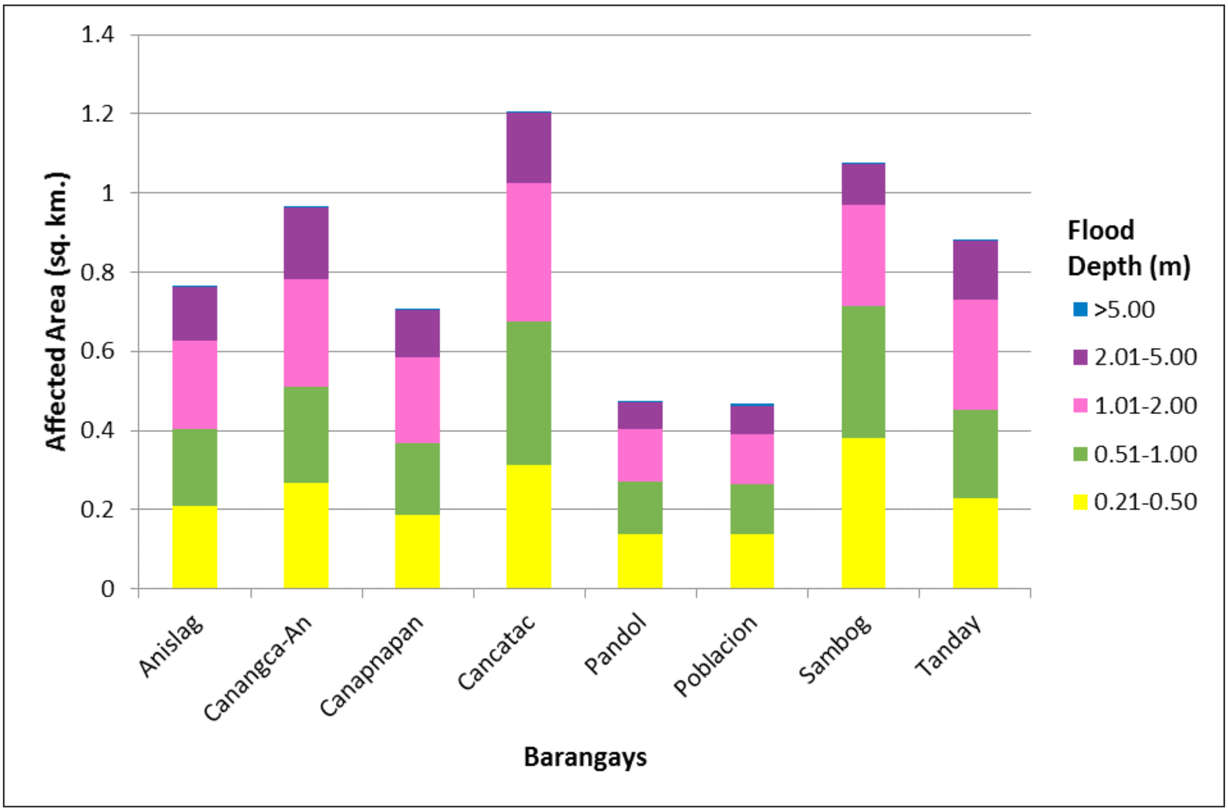


Figure 93. Affected areas in Corella, Bohol during a 100-year rainfall return period

For the Municipality of Cortes, with an area of 33.24 square kilometers, 70.72% will experience flood levels of less than 0.20 meters. 4.57% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.5%, 4.83%, 6.15%, and 1.15% 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 60 are the affected areas, in square kilometers, by flood depth per barangay.

Table 60. Affected areas in Cortes, Bohol during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cortes (in sq. km.)						
	De La Paz	Fatima	Loreto	Lourdes	Malayo Norte	Malayo Sur	Monserrat
0.03-0.20	1.26	4.2	2.27	3.2	1.25	1.63	1.68
0.21-0.50	0.25	0.22	0.088	0.15	0.046	0.065	0.076
0.51-1.00	0.22	0.19	0.061	0.12	0.03	0.055	0.068
1.01-2.00	0.054	0.09831	0.09831	0.09831	0.09831	0.09831	0.09831
2.01-5.00	0.032	0.13	0.63	0.12	0.26	0.056	0.036
> 5.00	0.0049	0.0019	0.14	0.0085	0.041	0.0035	0.00011

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Cortes (in sq. km.)						
	New Lourdes	Patrocinio	Poblacion	Rosario	Salvador	San Roque	Upper de la Paz
0.03-0.20	2.46	0.69	0.61	0.91	0.81	1.54	0.98
0.21-0.50	0.075	0.035	0.029	0.056	0.031	0.035	0.36
0.51-1.00	0.081	0.018	0.042	0.066	0.055	0.035	0.46
1.01-2.00	0.09831	0.09831	0.09831	0.09831	0.09831	0.09831	0.09831
2.01-5.00	0.16	0.042	0.12	0.27	0.11	0.05	0.029
> 5.00	0.056	0.007	0.024	0.053	0.04	0.0012	0.0004

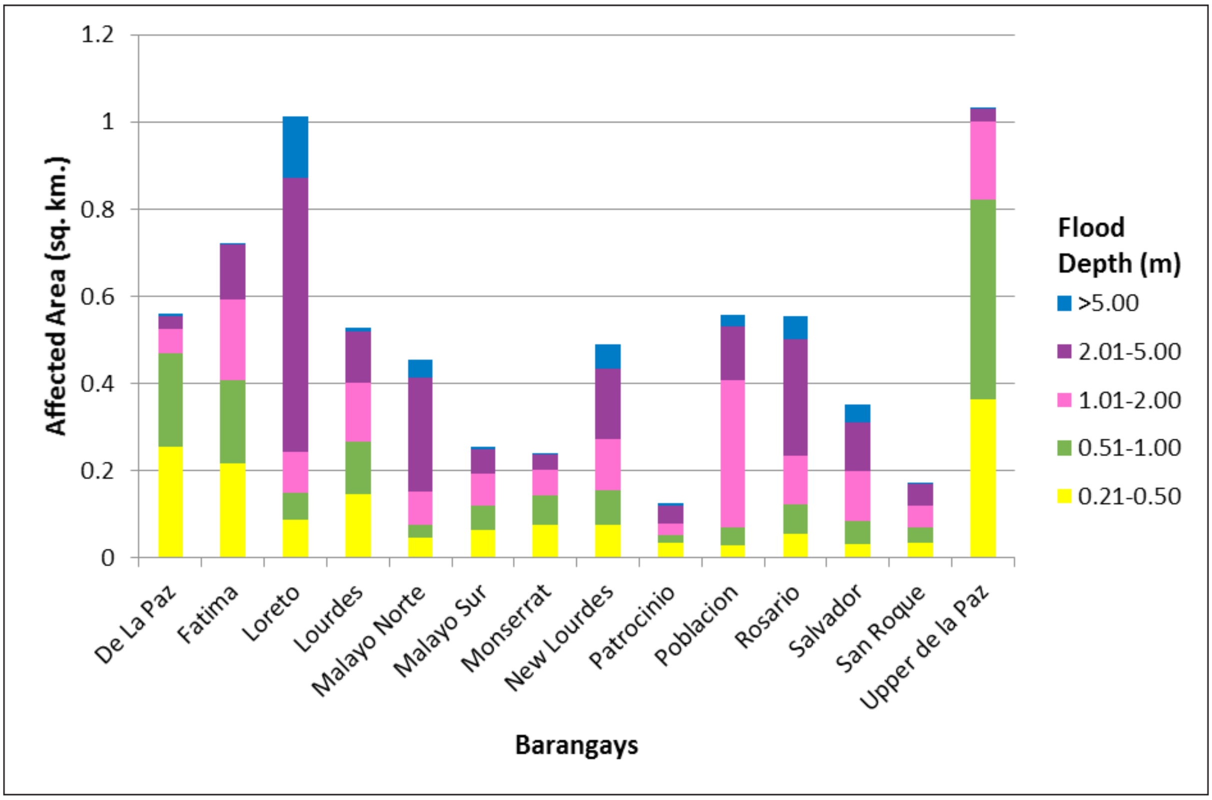


Figure 94. Affected areas in Cortes, Bohol during a 100-year rainfall return period

For the Municipality of Maribojoc, with an area of 55.2 square kilometers, 51.11% will experience flood levels of less than 0.20 meters. 3.54% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.12%, 3.72%, 3.12%, and 0.19% 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 61 are the affected areas, in square kilometers, by flood depth per barangay.

Table 61. Affected areas in Maribojoc, Bohol during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maribojoc (in sq. km.)								
	Agahay	Aliguay	Anislag	Bayacabac	Busao	Cabawan	Candavid	Dipatlong	Jandig
0.03-0.20	1.1	1.72	0.43	1.74	1.48	2.81	1.65	0.02	1.21
0.21-0.50	0.077	0.13	0.04	0.12	0.093	0.22	0.028	0.00017	0.059
0.51-1.00	0.067	0.079	0.21	0.083	0.08	0.26	0.02	0.0003	0.037
1.01-2.00	0.069	0.11	0.081	0.079	0.11	0.42	0.027	0	0.03
2.01-5.00	0.39	0.014	0.0048	0.13	0.27	0.37	0.053	0	0.018
> 5.00	0.019	0	0	0.0046	0.022	0.029	0.013	0	0.0001

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Maribojoc (in sq. km.)								
	Lincod	Pagnitoan	Poblacion	Punsod	San Isidro	San Roque	San Vicente	Tinibgan	Toril
0.03-0.20	1	2.74	0.22	1.19	2.09	3.04	0.72	2.53	2.5
0.21-0.50	0.24	0.11	0.014	0.069	0.1	0.13	0.29	0.12	0.12
0.51-1.00	0.67	0.08	0.022	0.062	0.086	0.14	0.17	0.099	0.1
1.01-2.00	0.42	0.055	0.062	0.074	0.092	0.19	0.034	0.095	0.088
2.01-5.00	0.056	0.028	0.095	0.032	0.063	0.073	0.0067	0.062	0.042
> 5.00	0.0036	0.0071	0	0.0022	0.0022	0.0004	0	0.0013	0.0013

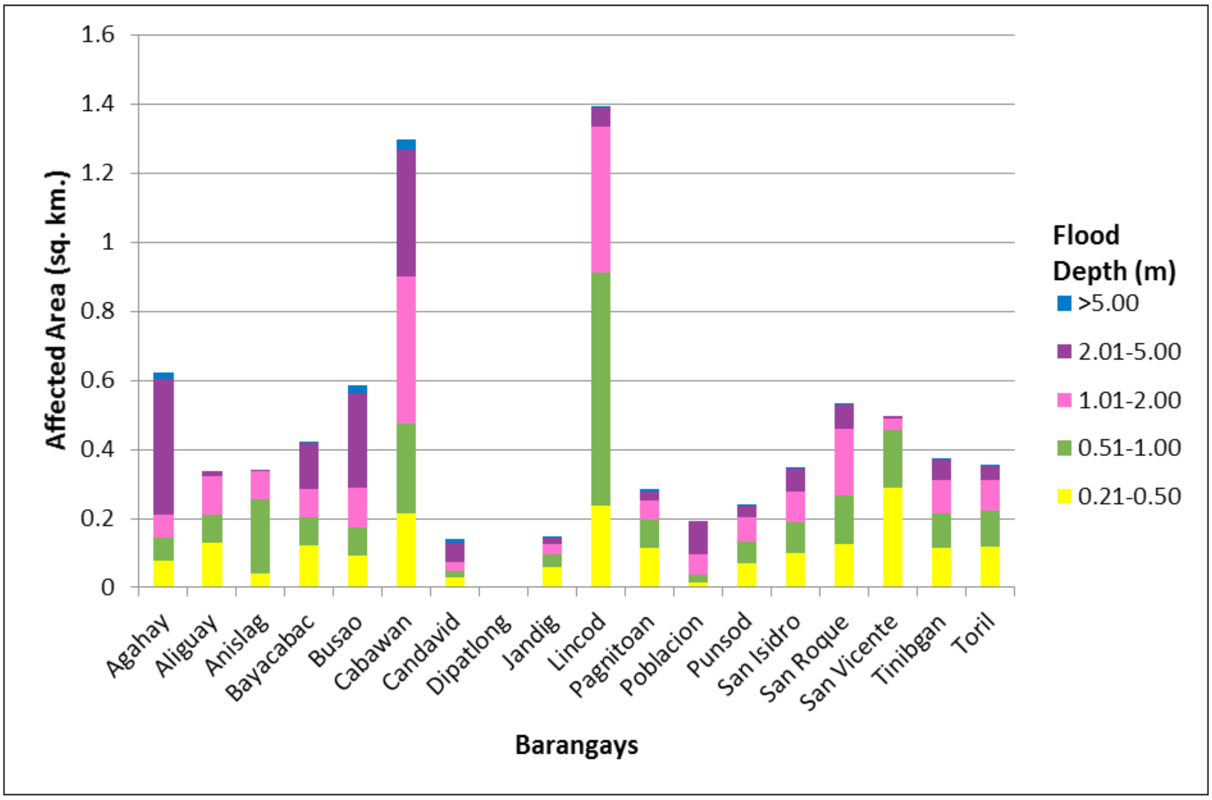


Figure 95. Affected areas in Maribojoc, Bohol during a 100-year rainfall return period

For the Municipality of San Isidro, with an area of 59.2 square kilometers, 0.83% will experience flood levels of less than 0.20 meters. 0.039% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.03%, 0.02%, 0.02%, and 0.12% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 62 are the affected areas, in square kilometers, by flood depth per barangay.

Table 62. Affected areas in San Isidro, Bohol during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in San Isidro (in sq. km.)
	Baunos
0.03-0.20	0.49
0.21-0.50	0.023
0.51-1.00	0.018
1.01-2.00	0.012
2.01-5.00	0.012
> 5.00	0.07

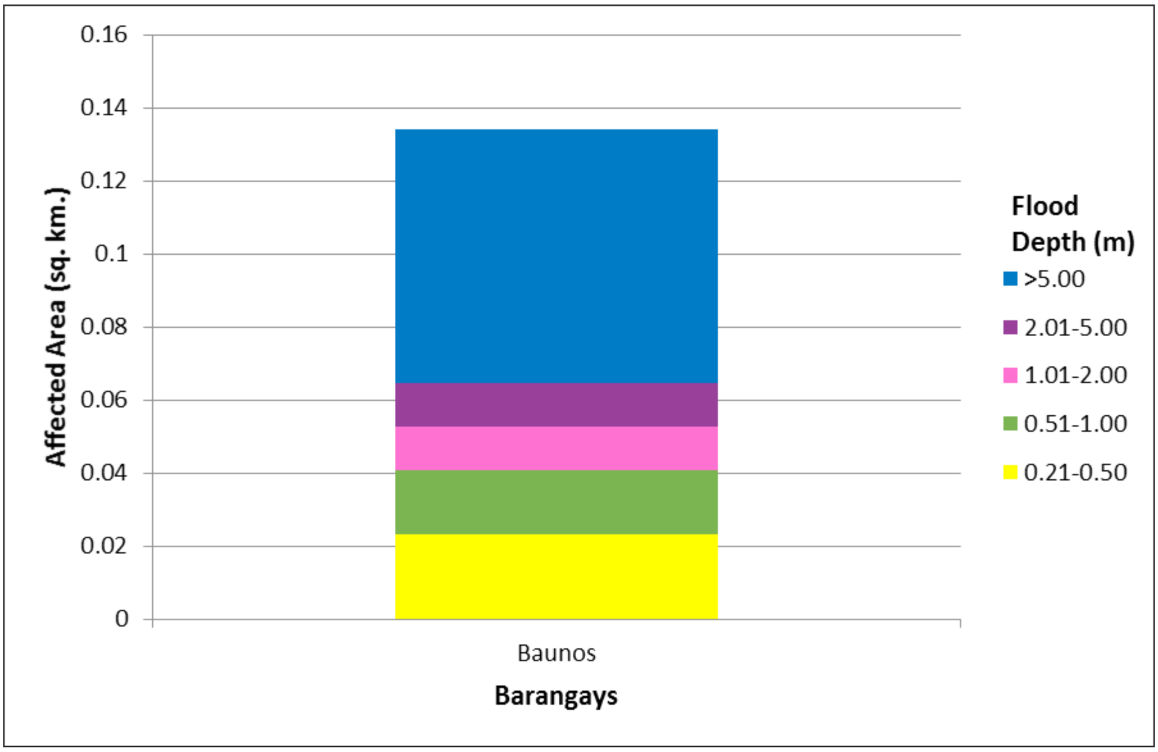


Figure 96. Affected areas in San Isidro, Bohol during a 100-year rainfall return period

For the Municipality of Sikatuna, with an area of 41.77 square kilometers, 8.17% will experience flood levels of less than 0.20 meters. 0.45% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.47%, 0.33%, and 0.15% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, and 2.01 to 5 meters, respectively. Listed in Table 63 are the affected areas, in square kilometers, by flood depth per barangay.

Table 63. Affected areas in Sikatuna, Bohol during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Sikatuna (in sq. km.)							
	Abucay Norte	Abucay Sur	Badiang	Bahaybahay	Cambuac Norte	Canagong	Poblacion I	Poblacion II
0.03-0.20	0.35	0.18	0.013	2.09	0.44	1.13	0.054	0.24
0.21-0.50	0.018	0.015	0.0011	0.11	0.021	0.07	0.0012	0.012
0.51-1.00	0.016	0.019	0.0016	0.13	0.0096	0.073	0.00058	0.011
1.01-2.00	0.0035	0.0027	0	0.1	0.0079	0.047	0	0.018
2.01-5.00	0	0	0	0.044	0.0001	0.039	0	0.0012
> 5.00	0	0	0	0	0	0	0	0

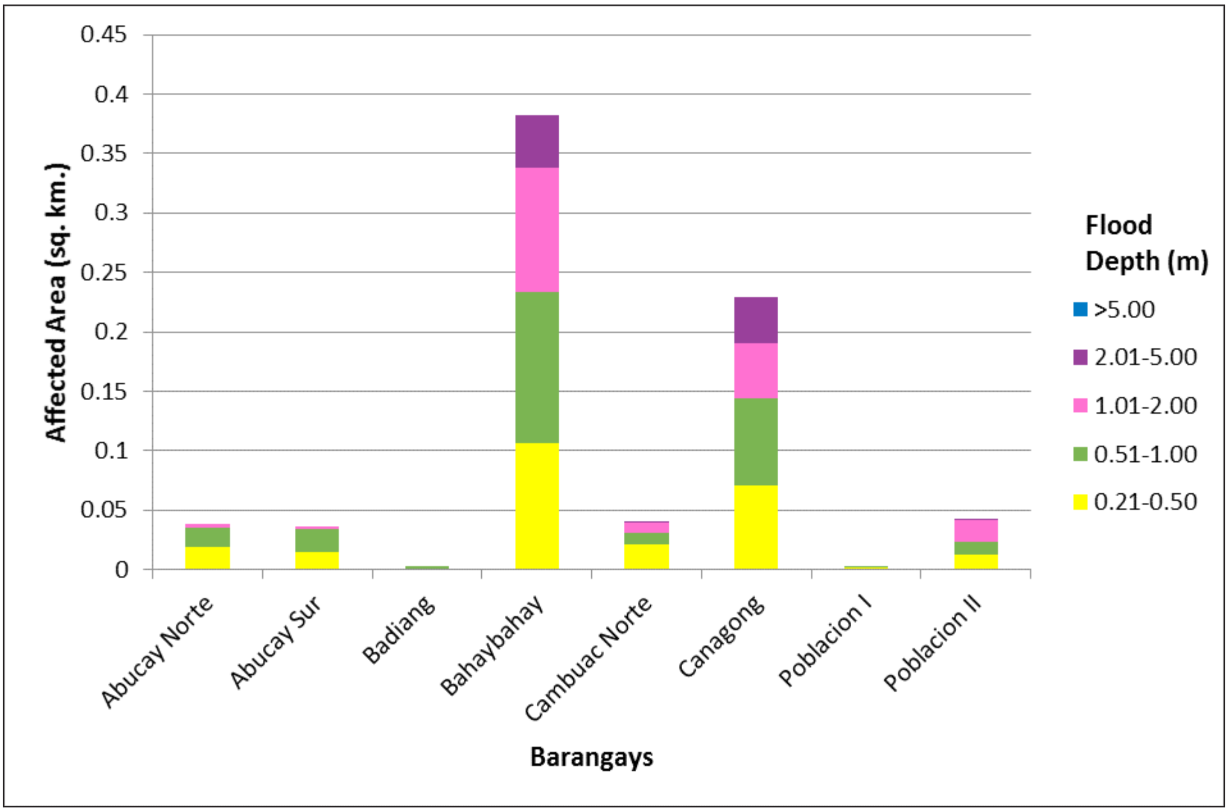


Figure 97. Affected areas in Sikatuna, Bohol during a 100-year rainfall return period

For the City of Tagbilaran, with an area of 32.17 square kilometers, 47.59% will experience flood levels of less than 0.20 meters. 3.77% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 2.66%, 2.4%, 1.08%, and 0.1% 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 64 are the affected areas, in square kilometers, by flood depth per barangay.

Table 64. Affected areas in Tagbilaran, Bohol during a 100-year rainfall return period

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagbilaran City (in sq. km.)					
	Booy	Cabawan	Cogon	Dampas	Dao	Manga
0.03-0.20	0.95	1.08	1.79	0.93	3.32	0.39
0.21-0.50	0.15	0.072	0.16	0.04	0.25	0.059
0.51-1.00	0.09	0.049	0.088	0.023	0.16	0.051
1.01-2.00	0.13	0.043	0.085	0.03	0.12	0.025
2.01-5.00	0.035	0.021	0.04	0.027	0.067	0.002
> 5.00	0	0.0014	0.0004	0.0023	0.005	0

Affected area (sq. km.) by flood depth (in m.)	Area of affected barangays in Tagbilaran City (in sq. km.)					
	Poblacion II	Poblacion III	San Isidro	Taloto	Tiptip	Ubujan
0.03-0.20	0.2	0.0045	2.92	0.95	1.75	1.03
0.21-0.50	0.021	0.00023	0.13	0.12	0.098	0.12
0.51-1.00	0.0057	0.000001	0.095	0.13	0.075	0.094
1.01-2.00	0.0071	0	0.099	0.085	0.085	0.067
2.01-5.00	0.00018	0	0.095	0.0027	0.053	0.0043
> 5.00	0	0	0.022	0.0003	0.002	0

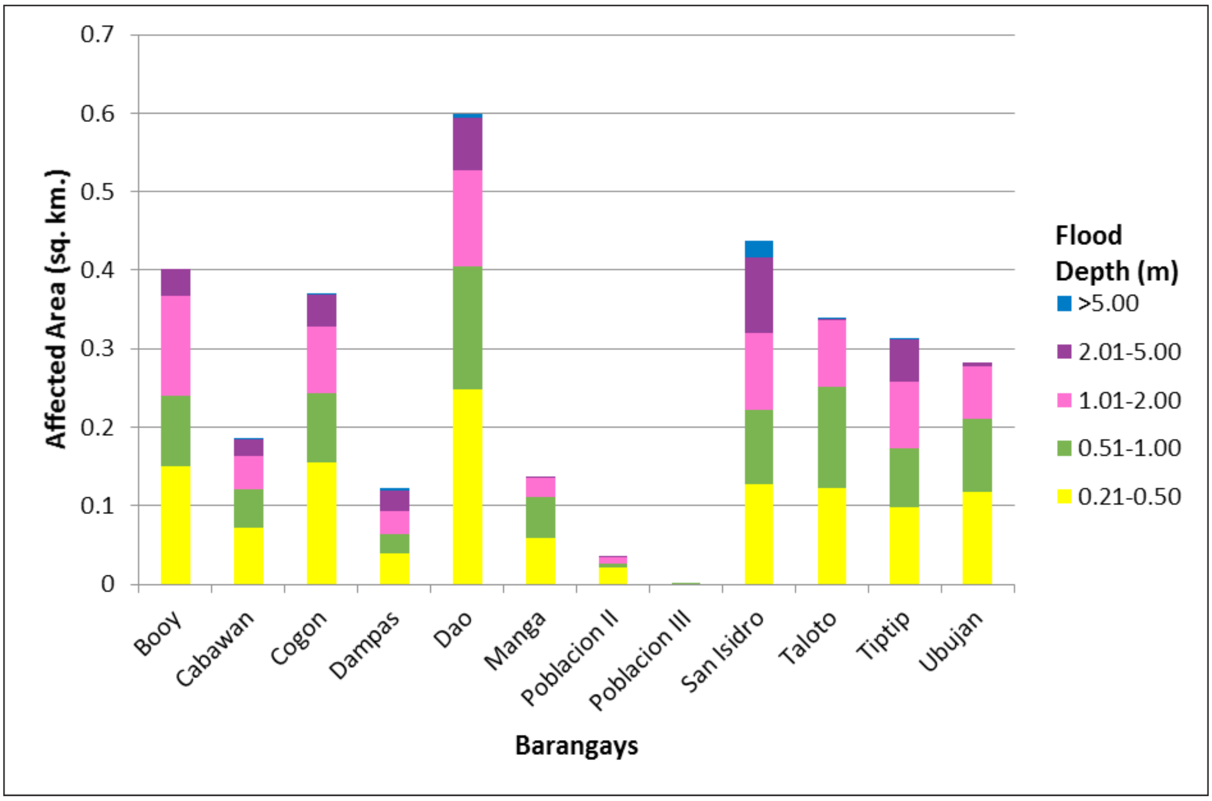


Figure 98. Affected areas in Tagbilaran, Bohol during a 100-year rainfall return period

Among the barangays in the Municipality of Albuquerque, Cantiguib is projected to have the highest percentage of area that will experience flood levels, at 1.14%. Meanwhile, Basacdacu posted the second highest percentage of area that may be affected by flood depths, at 0.35%.

Among the barangays in the Municipality of Antequera, Bantolinao is projected to have the highest percentage of area that will experience flood levels, at 6.39%. Meanwhile, Angilan posted the second highest percentage of area that may be affected by flood depths, at 6.16%.

Among the barangays in the Municipality of Baclayon, Tanday is projected to have the highest percentage of area that will experience flood levels, at 7.11%. Meanwhile, Buenaventura posted the second highest percentage of area that may be affected by flood depths, at 5.99%.

Among the barangays in the Municipality of Balilihan, Magsija is projected to have the highest percentage of area that will experience flood levels, at 5.92%. Meanwhile, Cantomimbo posted the second highest percentage of area that may be affected by flood depths, at 0.53%.

Among the barangays in the Municipality of Corella, Cancatac is projected to have the highest percentage of area that will experience flood levels, at 20.10%. Meanwhile, Tanday posted the second highest percentage of area that may be affected by flood depths, at 19.51%.

Among the barangays in the Municipality of Cortes, Fatima is projected to have the highest percentage of area that will experience flood levels, at 14.8%. Meanwhile, Lourdes posted the second highest percentage of area that may be affected by flood depths, at 11.22%.

Among the barangays in the Municipality of Maribojoc, Cabawan is projected to have the highest percentage of area that will experience flood levels, at 7.45%. Meanwhile, San Roque posted the second highest percentage of area that may be affected by flood depths, at 6.47%.

In the Municipality of San Isidro, Barangay Baunos is projected to experience flood levels at 1.05% of its area.

Among the barangays in the Municipality of Sikatuna, Bahaybahay is projected to have the highest percentage of area that will experience flood levels, at 5.92%. Meanwhile, Canagong posted the second highest percentage of area that may be affected by flood depths, at 3.25%.

Among the barangays in the City of Tagbilaran, Dao is projected to have the highest percentage of area that will experience flood levels, at 12.19%. Meanwhile, San Isidro posted the second highest percentage of area that may be affected by flood depths, at 10.45%.

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

Table 65. Area covered by each warning level, with respect to the rainfall scenario

Warning Level	Area Covered in sq. km.		
	5 year	25 year	100 year
Low	10.83	12.01	12.32
Medium	10.35	14.70	16.19
High	3.80	9.63	13.33
TOTAL	24.98	36.34	41.84

Of the sixty-three (63) identified educational institutions in the Abatan floodplain, six (6) were assessed to be exposed to Low-level flooding during a 5-year scenario. Meanwhile, two (2) schools were assessed to be exposed to Medium-level flooding in the same scenario. In the 25-year scenario, ten (10) schools were found to be exposed to Low-level flooding, and five (5) to Medium-level flooding. In the 100-year scenario, eight (8) schools were discovered to be exposed to Low-level flooding; while another eight (8) were projected to experience Medium-level flooding. See Annex 12 for a detailed enumeration of the schools in the Abatan floodplain.

None of the five (5) identified medical institutions in the Abatan floodplain was assessed to be exposed to any level of flooding in all scenarios. See Annex 13 for a detailed enumeration of the hospitals and clinics in the Abatan floodplain.

5.11 Flood Validation

A survey was conducted along the floodplain of the Abatan River to validate the generated flood maps. The team gathered secondary data regarding flood occurrences in the area. Ground validation points were acquired, as well as other necessary details, including the dates of occurrences, names of typhoons, and actual flood depths.

During the validation process, the team was assisted by the local Disaster Risk Reduction and Management (DRRM) representatives from the Municipalities of Antequera, Cortes and Maribojoc. Residents along the floodplain were interviewed on the historical flood events they have experienced.

Actual flood depths acquired from the ground validation survey were then computed and compared with the flood depths simulated by the model. An RMSE value of 1.32 meters was obtained. The points in the flood map versus the corresponding validation depths are illustrated in Figure 100. Table 66 provides a contingency matrix of the comparison. The validation points are found in Annex 11.

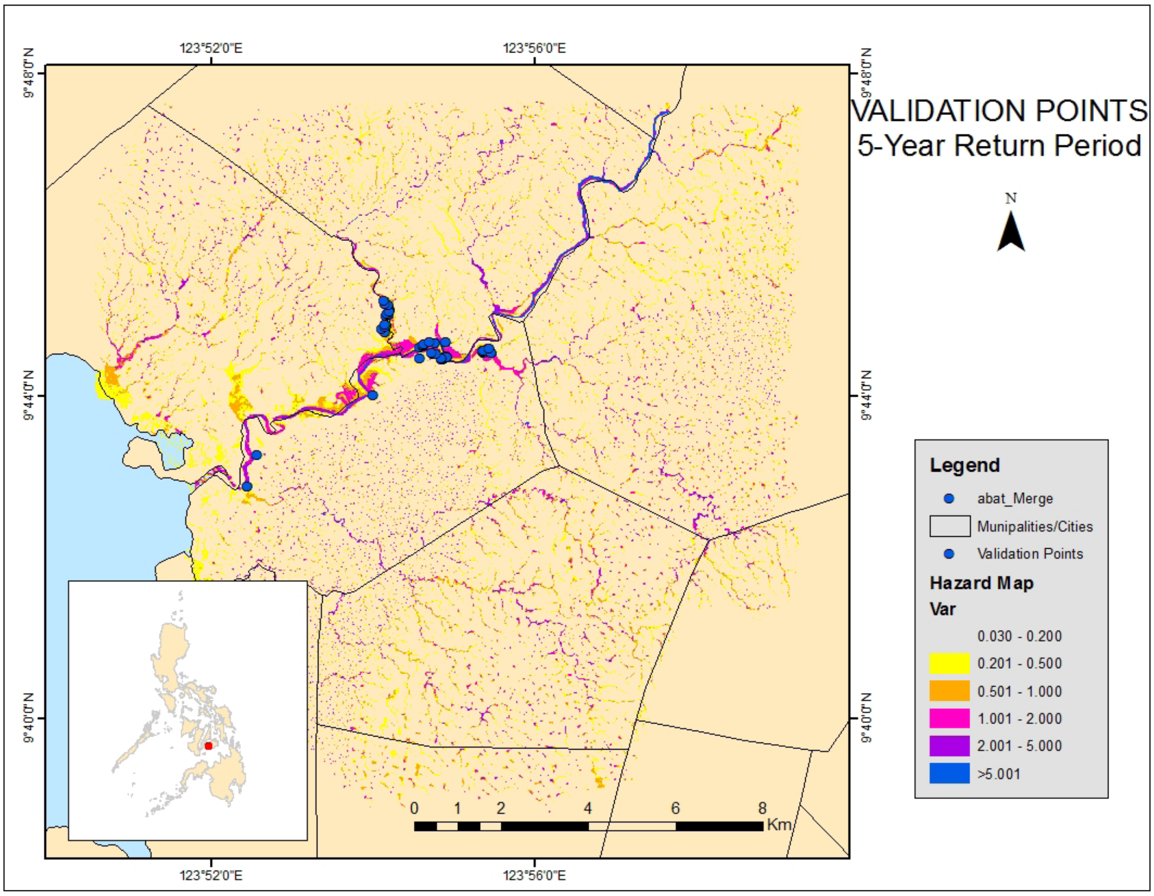


Figure 99. Validation points for a 5-year flood depth map of the Abatan floodplain

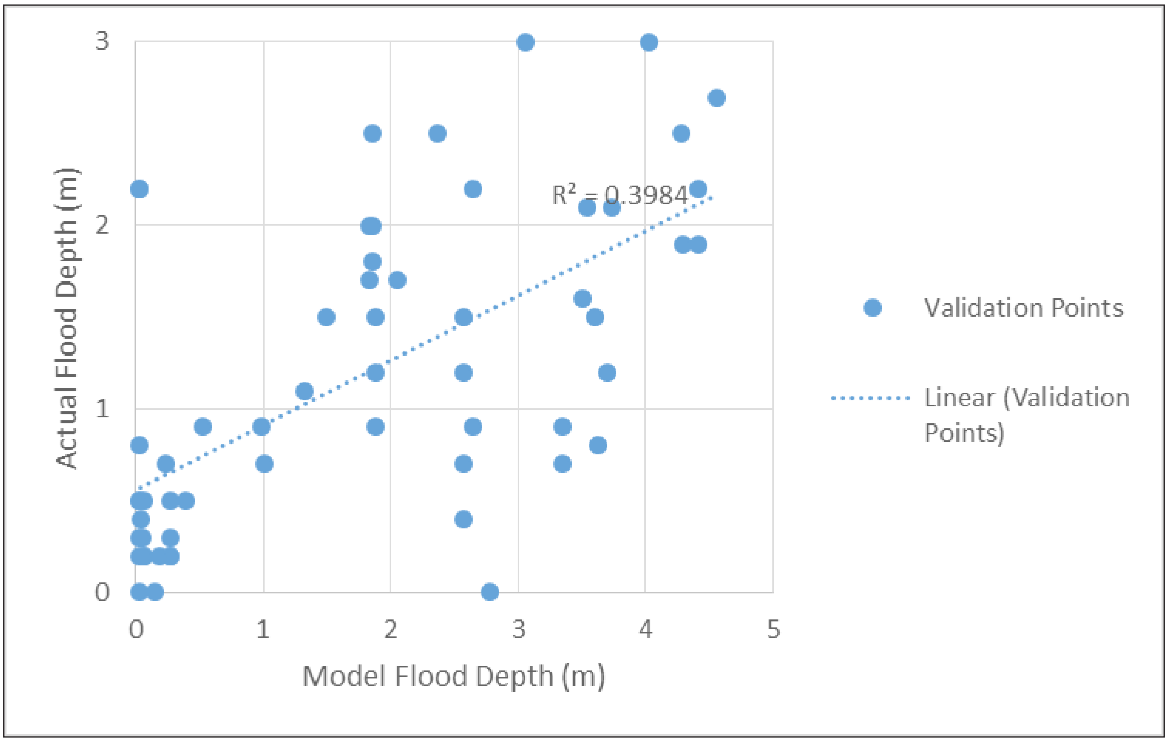


Figure 100. Flood map depth vs. actual flood depth

Table 66. Actual flood depth vs. simulated flood depth in the Abatan River Basin

ABATAN BASIN		Modeled Flood Depth (m)						
		0-0.20	0.21-0.50	0.51-1.00	1.01-2.00	2.01-5.00	> 5.00	Total
Actual Flood Depth (m)	0-0.20	6	2	0	0	1	0	9
	0.21-0.50	6	3	0	0	1	0	10
	0.51-1.00	1	1	2	2	5	0	11
	1.01-2.00	0	0	0	8	8	0	16
	2.01-5.00	2	0	0	1	9	0	12
	> 5.00	0	0	0	0	0	0	0
	Total	15	6	2	11	24	0	58

The overall accuracy generated by the flood model is estimated at 48.28%, with twenty-eight (28) points correctly matching the actual flood depths. Additionally, there were nineteen (19) points estimated one (1) level above and below the correct flood depths. Meanwhile, there were six (6) points and four (4) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood depths, respectively. A total of four (4) points were overestimated, while a total of eleven (11) points were underestimated in the modeled flood depths of Abatan.

Table 67. Summary of Accuracy Assessment in the Abatan River Basin Survey

No. of Points		%
Correct	28	**48.28**
Overestimated	19	**32.76**
Underestimated	11	**18.97**
Total	58	**100.00**

REFERENCES

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

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

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

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

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

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

ANNEXES

Annex 1. Technical Specifications of the LiDAR Sensors used in the Abatan Floodplain Survey

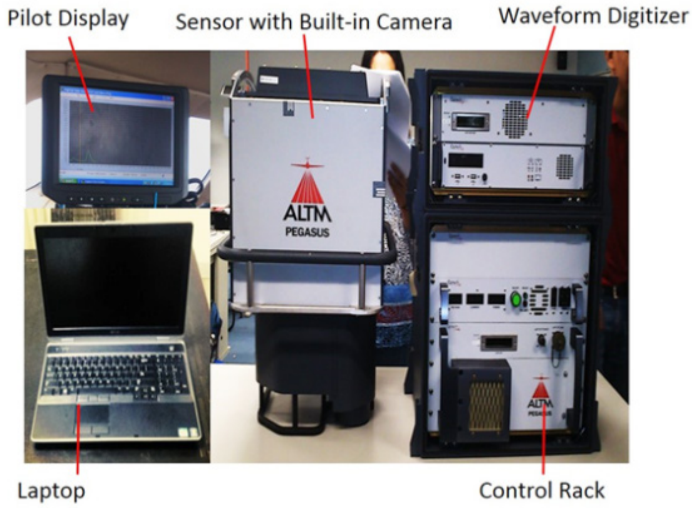


Figure A-1.1. Pegasus Sensor

Table A-1.1. Technical specifications of the Pegasus sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-5000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, 1σ
Elevation accuracy (2)	< 5-20 cm, 1σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV ™AP50 (OEM)
Scan width (FOV)	Programmable, 0-75 ˚
Scan frequency (5)	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±37˚ (FOV dependent)
Vertical target separation distance	<0.7 m
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer
Data storage	Removable solid state disk SSD (SATA II)

Power requirements	28 V, 800 W, 30 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg;
	Control rack: 650 x 590 x 490 mm; 46 kg
Operating Temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

1 Target reflectivity ≥20%

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

3 Angle of incidence ≤20˚

4 Target size ≥ laser footprint

5 Dependent on system configuration

Table A-1.2. Technical specifications 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)

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

1. BHL-58

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

November 19, 2013

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: **BOHOL**
Station Name: **BHL-58**
Order: **2nd**

Island: **VISAYAS**
Municipality: **INABANGA**
Barangay: **TUNGOD**

PRS92 Coordinates

Latitude: 10° 2' 12.58586"	Longitude: 124° 3' 14.58015"	Ellipsoidal Hgt: 3.13800 m.

WGS84 Coordinates

Latitude: 10° 2' 8.54469"	Longitude: 124° 3' 19.85079"	Ellipsoidal Hgt: 65.89700 m.

PTM Coordinates

Northing: 1109952.503 m.	Easting: 396297.833 m.	Zone: 5

UTM Coordinates

Northing: 1,109,600.04	Easting: 615,513.67	Zone: 51

Location Description

BHL-58

To reach the station go directly to the Mun. front road turn right about 100 m thenturn left and go N until your reach the pier's shed second at the left you will find the station. Mark is the head of a 3 in. copper nail set on a drilled hole on concrete pavement at the pier of Brgy. Tongod about 1.1 Km. from Inabanga Public Market. Nail is embedded with a concrete cement putty 30 cm x 30 cm x 5 cm centered on the triangle at the center of the putty with inscriptions, BHL-58, 2007, NAMRIA". Ref. no. 1 Is shed house opposite the station sbout 12 m NE; Ref. no. 2 Is the tip pier (left side) about the 15 m N.

Requesting Party: **UP-TCAGP/DOST**
Pupose: **Reference**
OR Number: **3947235 B**
T.N.: **2013-1257**

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

9 9 1 1 1 9 2 0 1 3 1 1 1 3 3 8

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

Figure A-2.1. BHL-58

2. BHL-95

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

November 19, 2013

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: **BOHOL**
Station Name: **BHL-95**
Order: **2nd**

Island: **VISAYAS**
Municipality: **LILA**
Barangay: **TIGUIS**

	PRS92 Coordinates	
Latitude: **9° 35' 30.96174"**	Longitude: **124° 4' 30.01696"**	Ellipsoidal Hgt: **19.23800 m.**
	WGS84 Coordinates	
Latitude: **9° 35' 27.03717"**	Longitude: **124° 4' 35.32705"**	Ellipsoidal Hgt: **83.04800 m.**
	PTM Coordinates	
Northing: **1060736.963 m.**	Easting: **398459.803 m.**	Zone: **5**
	UTM Coordinates	
Northing: **1,060,413.57**	Easting: **617,967.70**	Zone: **51**

Location Description

BHL-95

From Loay Town travel NE to Lila, Bohol about 2.5 Km. from Lila Proper on the left side of the road. Mark is the head of a 3 in. copper nail embedded on a concrete monument 30 cm x 30 cm x 1.20 cm set to the ground 0.20 cm above ground level with inscritions, BHL-95, 2007, NAMRIA". Ref. no. 1 Electric post about 30 m SW; Ref. no. 2 Molave Tree near concrete post about 25 m NW; Station is about 60 m to the corner of Brgy. Tiguis on the NE.

Requesting Party: **UP-TCAGP/DOST**
Pupose: **Reference**
OR Number: **3947235 B**
T.N.: **2013-1274**

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

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

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

Figure A-2.2. BHL-95

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

1. BHL-01

Table A-3.1. BHL-01

BHL-1 - BH-503 (8:24:33 AM-2:09:37 PM) (S2)

Baseline observation:	BHL-1 --- BH-503 (B2)
Processed:	8/21/2014 10:31:44 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.018 m
RMS:	0.004 m
Maximum PDOP:	2.547
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	8/20/2014 8:24:40 AM (Local: UTC+8hr)
Processing stop time:	8/20/2014 2:09:37 PM (Local: UTC+8hr)
Processing duration:	05:44:57
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	BHL-1				
Grid		Local		Global	
Easting	593593.389 m	Latitude	N9°36'26.39544"	Latitude	N9°36'22.44746"
Northing	1062047.763 m	Longitude	E123°51'10.60199"	Longitude	E123°51'15.91243"
Elevation	184.055 m	Height	184.337 m	Height	247.564 m

To:	BH-503				
Grid		Local		Global	
Easting	589439.266 m	Latitude	N9°34'53.54895"	Latitude	N9°34'49.60419"
Northing	1059186.111 m	Longitude	E123°48'54.10112"	Longitude	E123°48'59.41428"
Elevation	22.356 m	Height	22.564 m	Height	85.755 m

Vector					
ΔEasting	-4154.123 m	NS Fwd Azimuth	235°34'49"	ΔX	3281.488 m
ΔNorthing	-2861.651 m	Ellipsoid Dist.	5045.877 m	ΔY	2579.949 m
ΔElevation	-161.699 m	ΔHeight	-161.773 m	ΔZ	-2839.633 m

2. BHL-3067

Table A-3.2. BHL-3067

BHL-3067 - BHL-58 (6:56:43 AM-10:33:07 AM) (S4)

Baseline observation:	BHL-3067 --- BHL-58 (B4)
Processed:	1/4/2017 1:09:49 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.002 m
Vertical precision:	0.003 m
RMS:	0.001 m
Maximum PDOP:	1.808
Ephemeris used:	Broadcast
Antenna model:	Trimble Relative
Processing start time:	9/21/2015 6:56:43 AM (Local: UTC+8hr)
Processing stop time:	9/21/2015 10:33:07 AM (Local: UTC+8hr)
Processing duration:	03:36:24
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	BHL-58				
Grid		Local		Global	
Easting	615513.667 m	Latitude	N10°02'12.58586"	Latitude	N10°02'08.54469"
Northing	1109600.042 m	Longitude	E124°03'14.58015"	Longitude	E124°03'19.85079"
Elevation	2.109 m	Height	3.137 m	Height	65.897 m

To:	BHL-3067				
Grid		Local		Global	
Easting	615979.548 m	Latitude	N10°03'10.47434"	Latitude	N10°03'06.42941"
Northing	1111379.617 m	Longitude	E124°03'30.07070"	Longitude	E124°03'35.33988"
Elevation	2.638 m	Height	3.679 m	Height	66.412 m

Vector					
ΔEasting	465.881 m	NS Fwd Azimuth	14°51'15"	ΔX	-217.345 m
ΔNorthing	1779.576 m	Ellipsoid Dist.	1839.978 m	ΔY	-520.694 m
ΔElevation	0.529 m	ΔHeight	0.541 m	ΔZ	1751.330 m

3. BMBH-280

Table A-3.3. BMBH-280

BHL-95 - BH-280 (8:48:41 AM-11:10:14 AM) (S1)

Baseline observation:	BHL-95 — BH-280 (B1)
Processed:	9/7/2014 6:40:17 PM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.015 m
Vertical precision:	0.022 m
RMS:	0.005 m
Maximum PDOP:	4.342
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	8/24/2014 8:49:03 AM (Local: UTC+8hr)
Processing stop time:	8/24/2014 11:10:14 AM (Local: UTC+8hr)
Processing duration:	02:21:11
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	BHL-95				
Grid		Local		Global	
Easting	617967.834 m	Latitude	N9°35'30.95701"	Latitude	N9°35'27.03243"
Northing	1060413.425 m	Longitude	E124°04'30.02141"	Longitude	E124°04'35.33150"
Elevation	19.099 m	Height	18.988 m	Height	82.798 m

To:	BH-280				
Grid		Local		Global	
Easting	615059.442 m	Latitude	N9°35'33.32448"	Latitude	N9°35'29.39739"
Northing	1060477.159 m	Longitude	E124°02'54.62703"	Longitude	E124°02'59.93729"
Elevation	3.917 m	Height	3.860 m	Height	67.604 m

Vector					
ΔEasting	-2908.391 m	NS Fwd Azimuth	271°26'04"	ΔX	2424.929 m
ΔNorthing	63.734 m	Ellipsoid Dist.	2909.765 m	ΔY	1606.833 m
ΔElevation	-15.182 m	ΔHeight	-15.127 m	ΔZ	69.114 m

4. BMBH-503

Table A-3.4. BMBH-503

BHL-1 - BH-503 (8:24:33 AM-2:09:37 PM) (S2)

Baseline observation:	BHL-1 --- BH-503 (B2)
Processed:	8/21/2014 10:31:44 AM
Solution type:	Fixed
Frequency used:	Dual Frequency (L1, L2)
Horizontal precision:	0.004 m
Vertical precision:	0.018 m
RMS:	0.004 m
Maximum PDOP:	2.547
Ephemeris used:	Broadcast
Antenna model:	NGS Absolute
Processing start time:	8/20/2014 8:24:40 AM (Local: UTC+8hr)
Processing stop time:	8/20/2014 2:09:37 PM (Local: UTC+8hr)
Processing duration:	05:44:57
Processing interval:	1 second

Vector Components (Mark to Mark)

From:	BHL-1				
Grid		Local		Global	
Easting	593593.389 m	**Latitude**	N9°36'26.39544"	**Latitude**	N9°36'22.44746"
Northing	1062047.763 m	**Longitude**	E123°51'10.60199"	**Longitude**	E123°51'15.91243"
Elevation	184.055 m	**Height**	184.337 m	**Height**	247.564 m

To:	BH-503				
Grid		Local		Global	
Easting	589439.266 m	**Latitude**	N9°34'53.54895"	**Latitude**	N9°34'49.60419"
Northing	1059186.111 m	**Longitude**	E123°48'54.10112"	**Longitude**	E123°48'59.41428"
Elevation	22.356 m	**Height**	22.564 m	**Height**	85.755 m

Vector					
ΔEasting	-4154.123 m	**NS Fwd Azimuth**	235°34'49"	**ΔX**	3281.488 m
ΔNorthing	-2861.651 m	**Ellipsoid Dist.**	5045.877 m	**ΔY**	2579.949 m
ΔElevation	-161.699 m	**ΔHeight**	-161.773 m	**ΔZ**	-2839.633 m

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI S. SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	LOVELY GRACIA ACUNA	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	GEROME HIPOLITO	UP-TCAGP
LiDAR Operation	Senior Science Research Specialist (SSRS)	JASMINE ALVIAR	UP-TCAGP
LiDAR Operation	Research Associate (RA)	ENGR. IRO NIEL ROXAS	UP-TCAGP
	RA	ENGR. GRACE SINADJAN	UP-TCAGP
	RA	KRISTINE JOY ANDAYA	UP-TCAGP
Ground Survey	RA	KENNETH QUISADO	
Ground Survey	RA	MA. KATRINA RANESES	
LiDAR Operation	Airborne Security	SSG. ANTONIO VALENCIANO	PILIPPINE AIR FORCE (PAF)
LiDAR Operation	Airborne Security	SSG. MIKE BERONILLA	PILIPPINE AIR FORCE (PAF)
LiDAR Operation	Pilot	CAPT. SHERWIN CESAR ALFONSO	ASIAN AEROSPACE CORPORATION (AAC)
LiDAR Operation	Pilot	CAPT. FERDINAND DE OCAMPO	AAC
LiDAR Operation	Pilot	CAPT. RANDY LAGCO	AAC

Annex 5. Data Transfer Sheets for the Abatan Floodplain Flights

DATA TRANSFER SHEET
09/2014(BOHOL ready)

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	
1867P	1BLK51M234	Pegasus	1.43	1.35	6.34	180	25	196	18.3	NA	10.8	1KB	1KB	282	NA	Z:\DAC\RA WDATA
1871P	1BLK53H235	Pegasus	3.8	4.08	9.09	222	52.8	402	36.7	NA	7.77	1KB	1KB	39	NA	Z:\DAC\RA WDATA
1883P	1BLK51L238	Pegasus	972	1.13	5.69	146	18.3	159	11.6	NA	4.48	1KB	1KB	454	NA	Z:\DAC\RA WDATA
1885P	1BLK51I238A	Pegasus	3.18	3.43	8.98	236	44.1	326	32.5	NA	11.6	1KB	1KB	104	NA	Z:\DAC\RA WDATA
1895P	1BLK51K241	Pegasus	2.08	2.60	7.51	204	26.9	207	21.9	NA	10.9	1KB	1KB	93.5	NA	Z:\DAC\RA WDATA

Received from

Name C. Joaquin / 9/9/14
Position RA
Signature

Received by

Name JOIDA PRIETO 9/12/14
Position SSRS
Signature

Figure A-5.1. Data Transfer Sheet for Abatan Floodplain – A

DATA TRANSFER SHEET
Bohol 10/01/15

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	
15-Sep	3421P	1BLK51C258A	pegasus	731	na	5.94	152	na	na	8.79	na	7.05	1KB	1KB	na	na	Z:\DAC\RAW DATA
17-Sep	3429P	1BLK51260A	pegasus	2.37	na	12.2	261	na	na	23.8	na	8.35	1KB	1KB	na	na	Z:\DAC\RAW DATA
21-Sep	3445P	1BLK51S264A	pegasus	542	na	4.54	124	na	na	5.95	na	9.84	1KB	1KB	121/121	na	Z:\DAC\RAW DATA
22-Sep	3449P	1BLK51G265A	pegasus	1.22	na	9.1	221	na	na	18	na	13.1	1KB	1KB	75/86	na	Z:\DAC\RAW DATA
23-Sep	3453P	1BLK51S266A	pegasus	591	25/123	7.82	148	na	na	16.5	na	4.75	1KB	1KB	na	na	Z:\DAC\RAW DATA

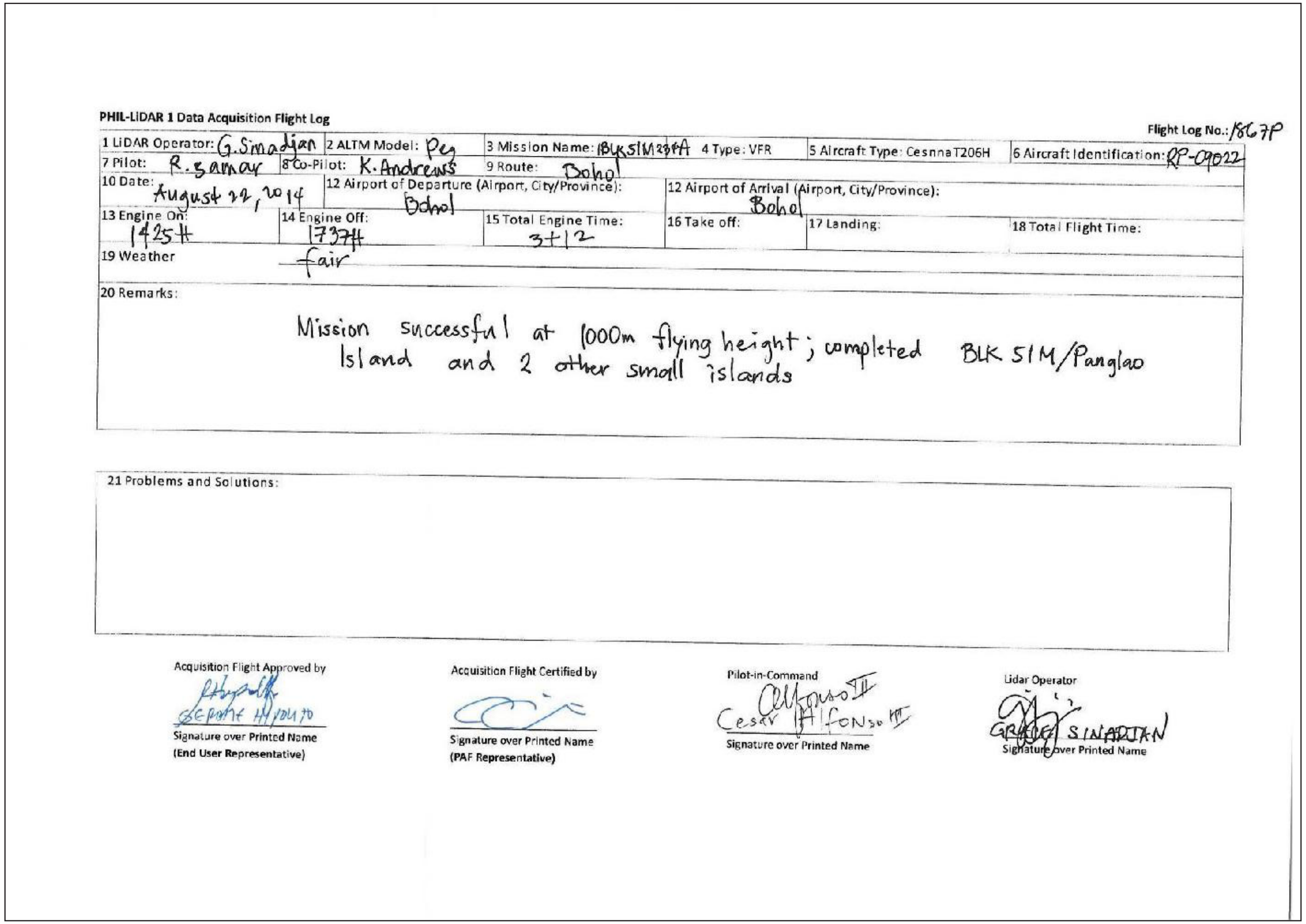
Received from
Name C. JOAQUIN
Position RA
Signature

Received by
Name JOIDA F. PRIETO
Position SSRS
Signature 10/28/2015

Figure A-5.2. Data Transfer Sheet for Abatan Floodplain – B

Annex 6. Flight Logs for the Flight Missions

1. Flight Log for 1867P Mission


PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 1867P

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: Peg	3 Mission Name: 1BLK51M234A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RP-C9022
7 Pilot: R. Samar	8 Co-Pilot: K. Andrews	9 Route: Bohol			
10 Date: August 22, 2014	12 Airport of Departure (Airport, City/Province): Bohol		12 Airport of Arrival (Airport, City/Province): Bohol		
13 Engine On: 1425H	14 Engine Off: 1737H	15 Total Engine Time: 3+12	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: fair					

20 Remarks:

Mission successful at 1000m flying height; completed BLK 51M/Panglao Island and 2 other small islands

21 Problems and Solutions:

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

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

Pilot-in-Command: Cesar Alfonso III, Signature over Printed Name

Lidar Operator: Grace Sinadjan, Signature over Printed Name

Figure A-6.1. Flight Log for Mission 1867P

2. Flight Log for 1871P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 1871P

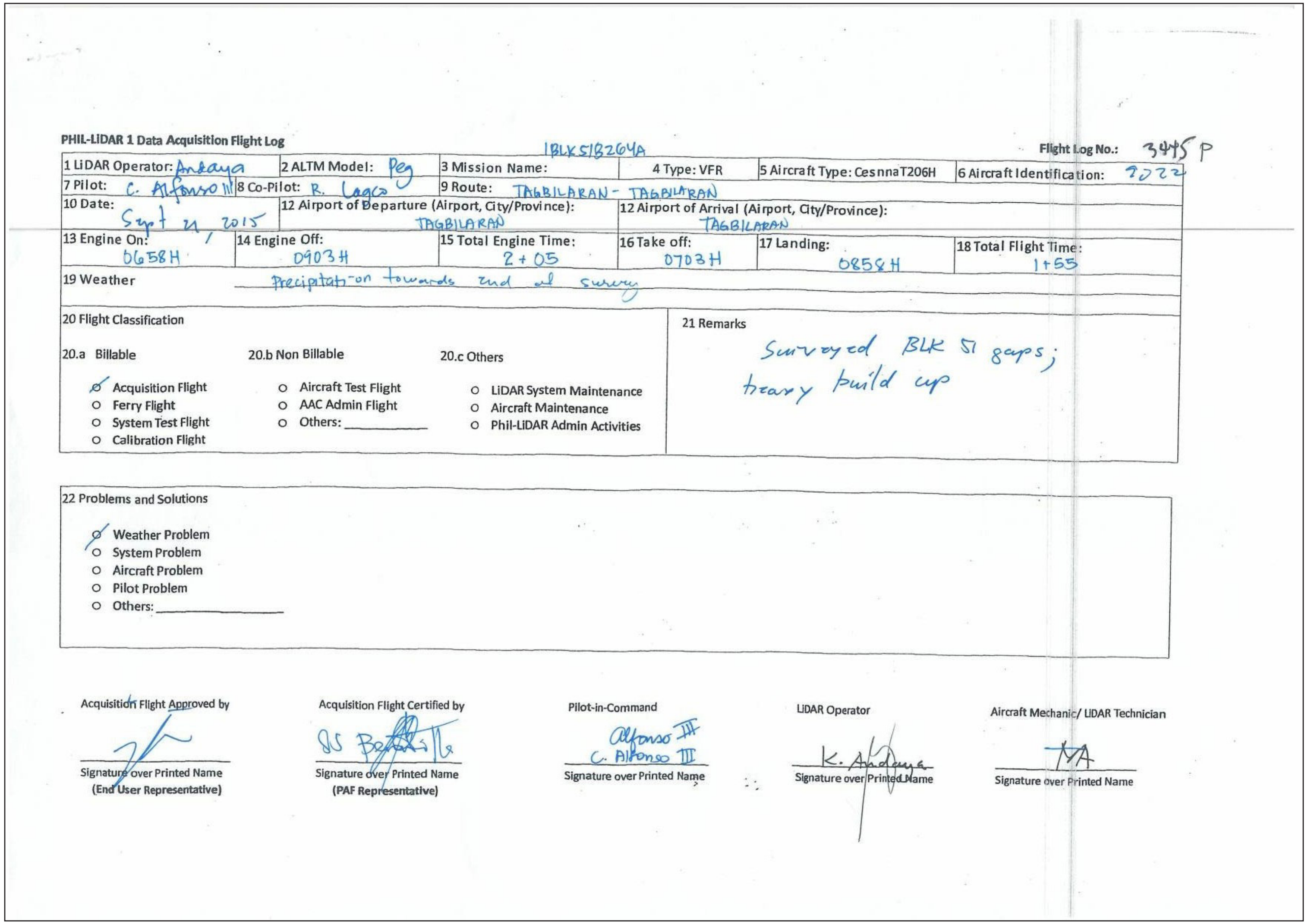
1 LiDAR Operator: I. Roxas	2 ALTM Model: Peg	3 Mission Name: 1BLK51423SA	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RP-C9022
7 Pilot: C. Alfonso	8 Co-Pilot: K. Andrews	9 Route: Bohol			
10 Date: August 23, 2014	12 Airport of Departure (Airport, City/Province): Bohol		12 Airport of Arrival (Airport, City/Province): Bohol		
13 Engine On: 1405H	14 Engine Off: 1740H	15 Total Engine Time: 3+35	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					
20 Remarks:					

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
E. Hipolito		Cesar Alfonso III	Iro Roxas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Figure A-6.2. Flight Log for Mission 1871P

3. Flight Log for 3445P Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3445P

1 LiDAR Operator: Andaya	2 ALTM Model: Peg	3 Mission Name: 1BLK51B264A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: C. Alfonso III	8 Co-Pilot: R. Lagco	9 Route: TAGBILARAN - TAGBILARAN			
10 Date: Sept 21 / 2015	12 Airport of Departure (Airport, City/Province): TAGBILARAN		12 Airport of Arrival (Airport, City/Province): TAGBILARAN		
13 Engine On: 0658H	14 Engine Off: 0903H	15 Total Engine Time: 2+05	16 Take off: 0703H	17 Landing: 0858H	18 Total Flight Time: 1+55
19 Weather	Precipitation towards end of survey				

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 51 gaps; heavy build up

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LiDAR Operator	Aircraft Mechanic/ LiDAR Technician
Signature over Printed Name (End User Representative)	SS Bautista Signature over Printed Name (PAF Representative)	C. Alfonso III Signature over Printed Name	K. Andaya Signature over Printed Name	Signature over Printed Name

Figure A-6.3. Flight Log for Mission 3445P

Annex 7. Flight Status Reports

Table A-7.1. Flight Status Report

FLIGHT STATUS REPORT
BOHOL
August 22-23, 2014; September 21, 2015

FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1867P	BLK51M	1BLK51M234A	G.SINADJAN	AUG 22, 2014	Mission successful at 1000m flying height; completed BLK 51M/Panglao island and 2 other small islands.
1871P	BLK51H	1BLK51H235A	I. ROXAS	AUG 23, 2014	Completed BLK51H
3445P	BLK 51LKS	1BLK51S264A	KJ ANDAYA	SEPT 21, 2015	TOO CLOUDY; TRANSFERRED FROM IPIL TO BLK 51 GAPS; FAST CLOUD BUILD UP

LAS/SWATH BOUNDARIES PER MISSION FLIGHT

Flight No.: 1867P
Area: BLK51M
Mission Name: 1BLK51M234A
Parameters: Altitude: 1000-1200m; Scan Frequency: 30; Scan Angle: 50

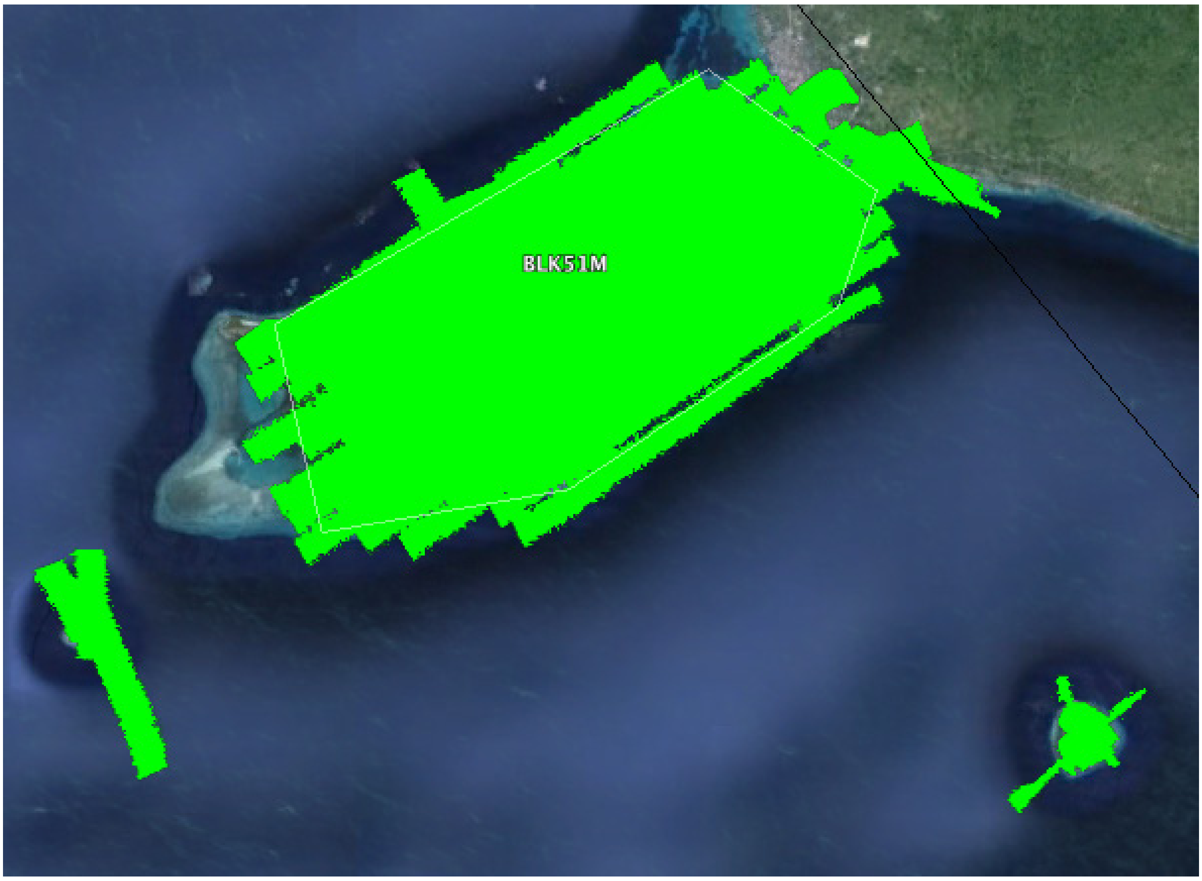


Figure A-7.1. Swath for Flight No. 1867P

Flight No.: 1871P
Area: BLK51H
Mission Name: 1BLK51H235A
Parameters: Altitude: 1000-1200m; Scan Frequency: 30; Scan Angle: 50

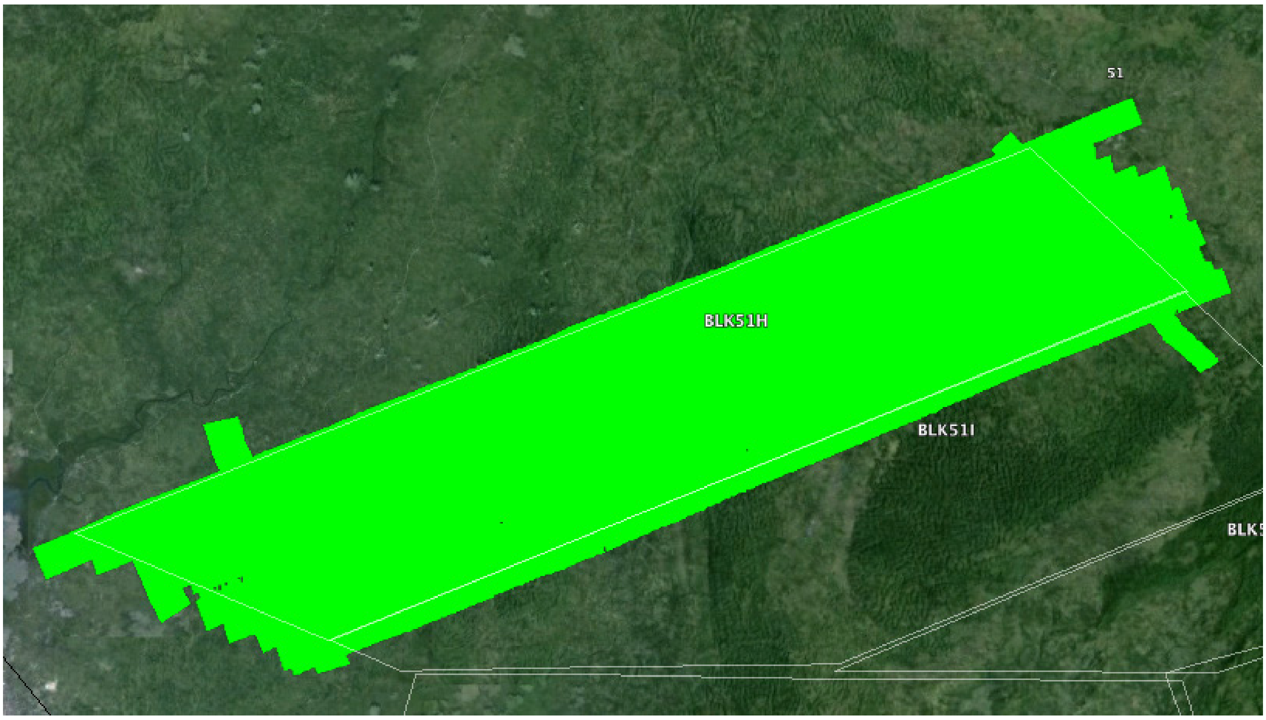


Figure A-7.2. Swath for Flight No. 1871P

Flight No. : 3445P
Area: BLK 51LKS
Mission Name: 1BLK51S264A
Parameters: Altitude: 1000-1200m; Scan Frequency: 30; Scan Angle: 50

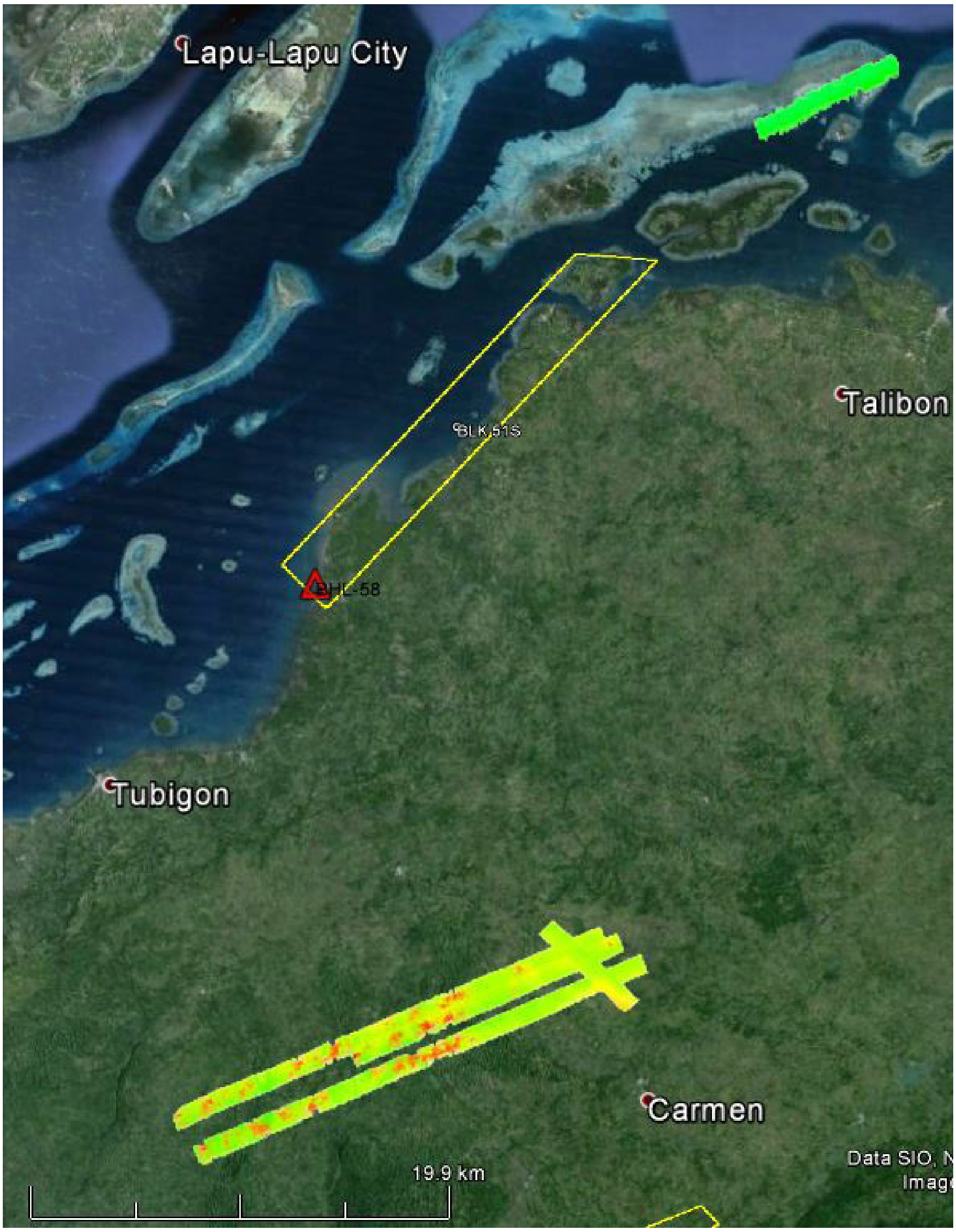


Figure A-7.3. Swath for Flight No. 3445P

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk51H

Flight Area	Bohol
Mission Name	**Blk51H**
Inclusive Flights	1871P
Range data size	36.7 GB
POS	222 MB
Base Data	7.77 MB
Image	52.8 GB
Transfer date	September 12. 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.590
RMSE for East Position (<4.0 cm)	2.25
RMSE for Down Position (<8.0 cm)	3.71
Boresight correction stdev (<0.001deg)	0.000267
IMU attitude correction stdev (<0.001deg)	0.000527
GPS position stdev (<0.01m)	0.0011
Minimum % overlap (>25)	59.98
Ave point cloud density per sq.m. (>2.0)	4.84
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	324
Maximum Height	538.15 m
Minimum Height	63.15 m
Classification (# of points)	
Ground	25,839,666
Low vegetation	17,001,662
Medium vegetation	34,290,998
High vegetation	60,423,197
Building	1,084,475
Orthophoto	Yes
Processed by	Engr. Irish Cortez, Engr. Irish Cortez, Jovy Narisma

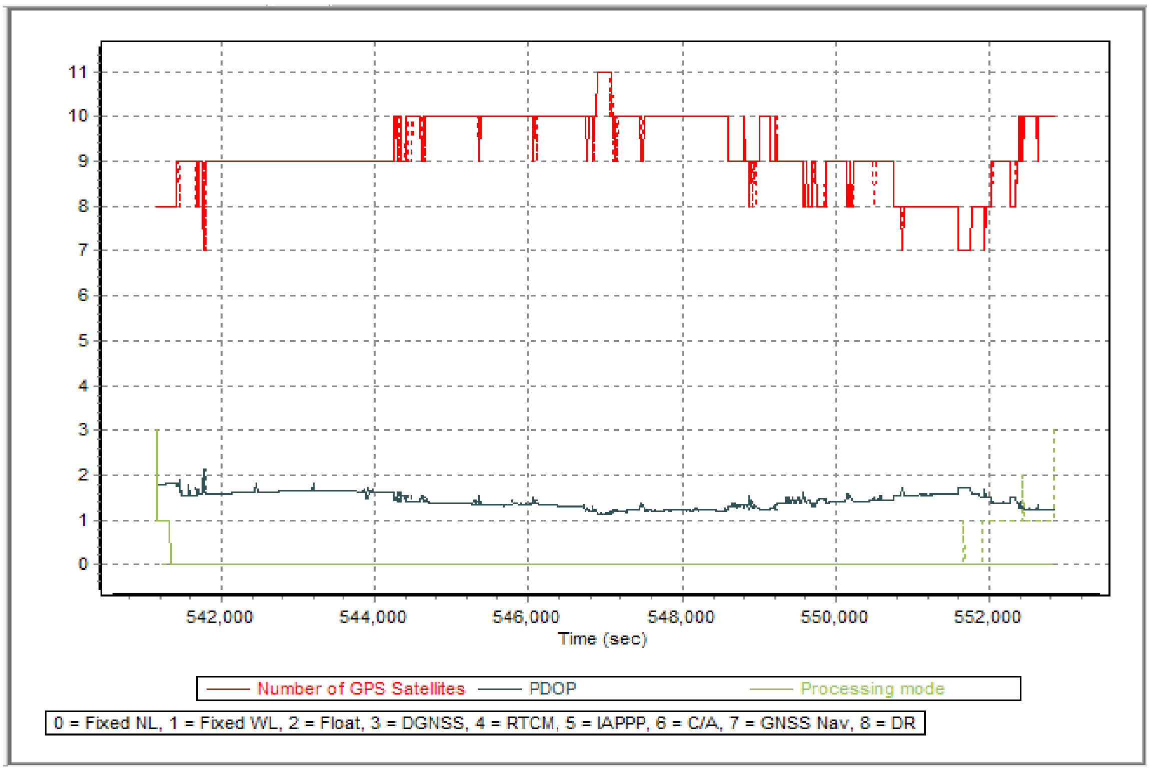


Figure A-8.1. Solution Status

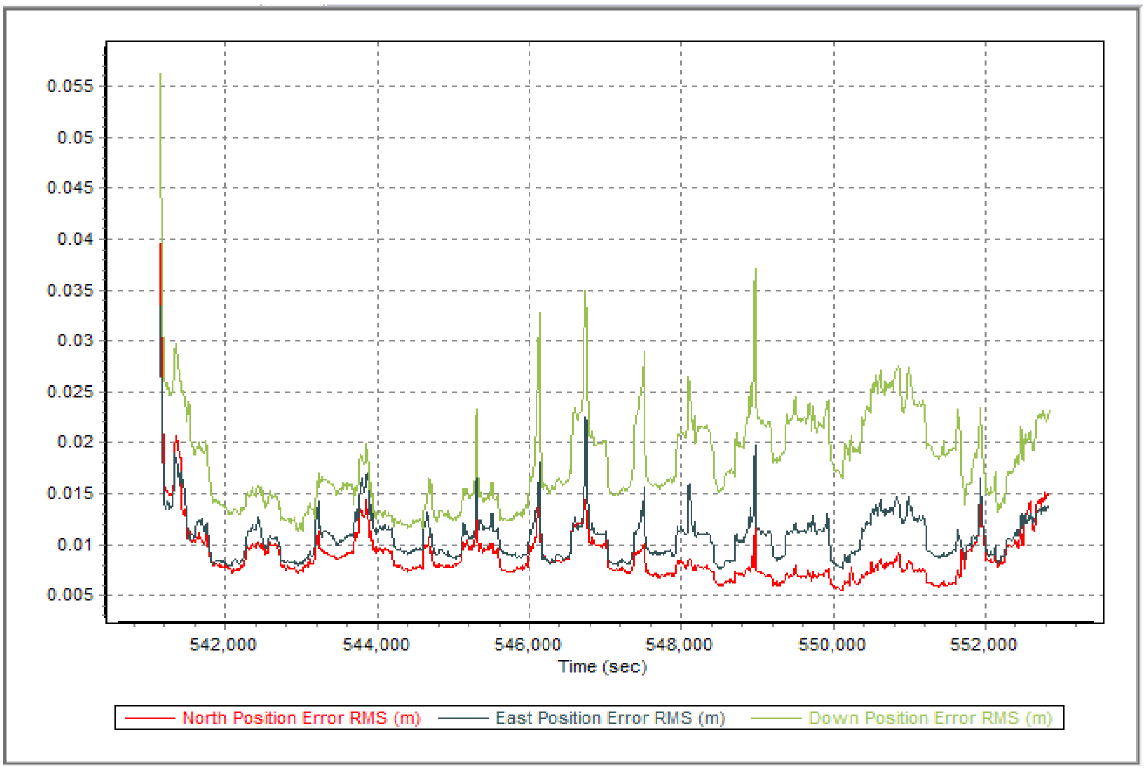


Figure A-8.2. Smoothed Performance Metric Parameters

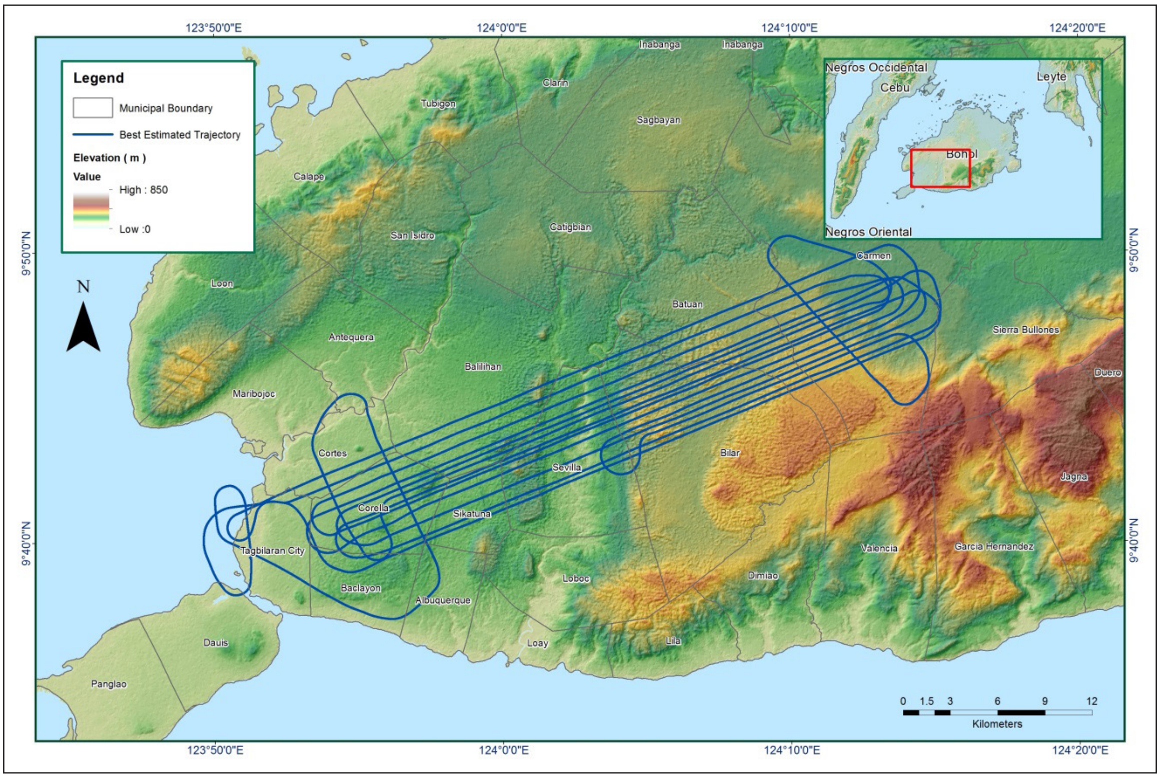


Figure A-8.3. Best Estimate Trajectory

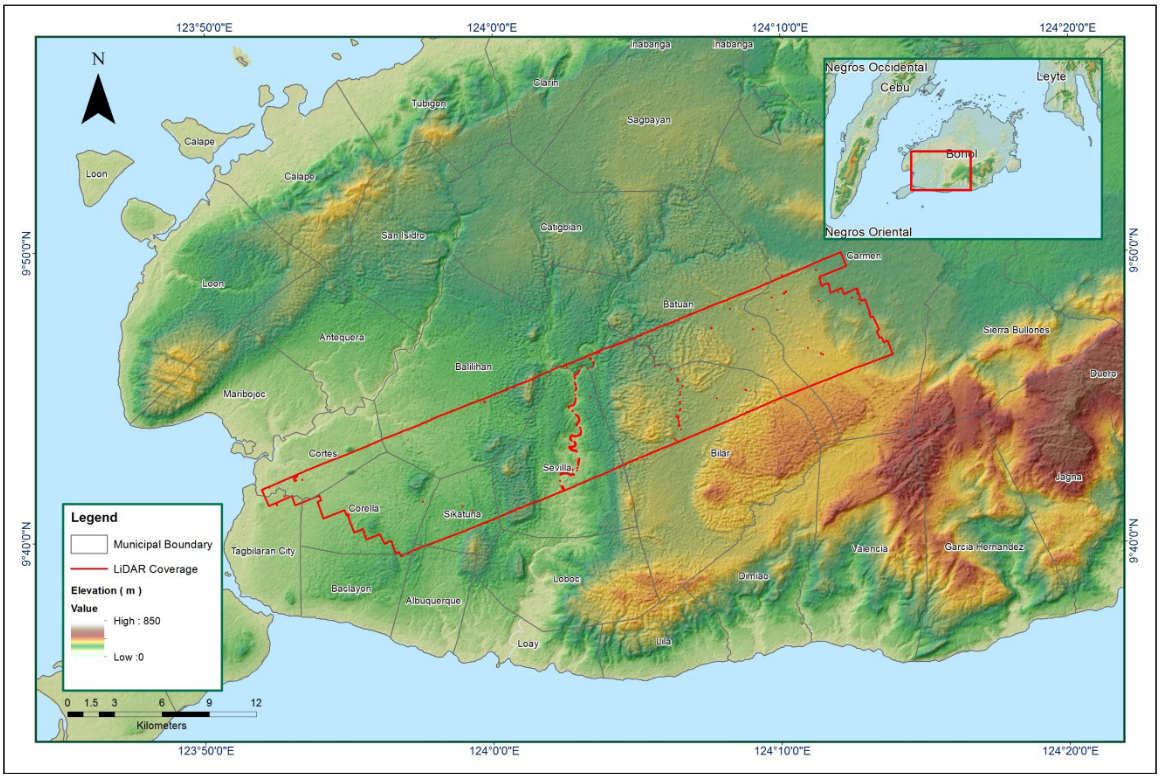


Figure A-8.4. Coverage of LiDAR data

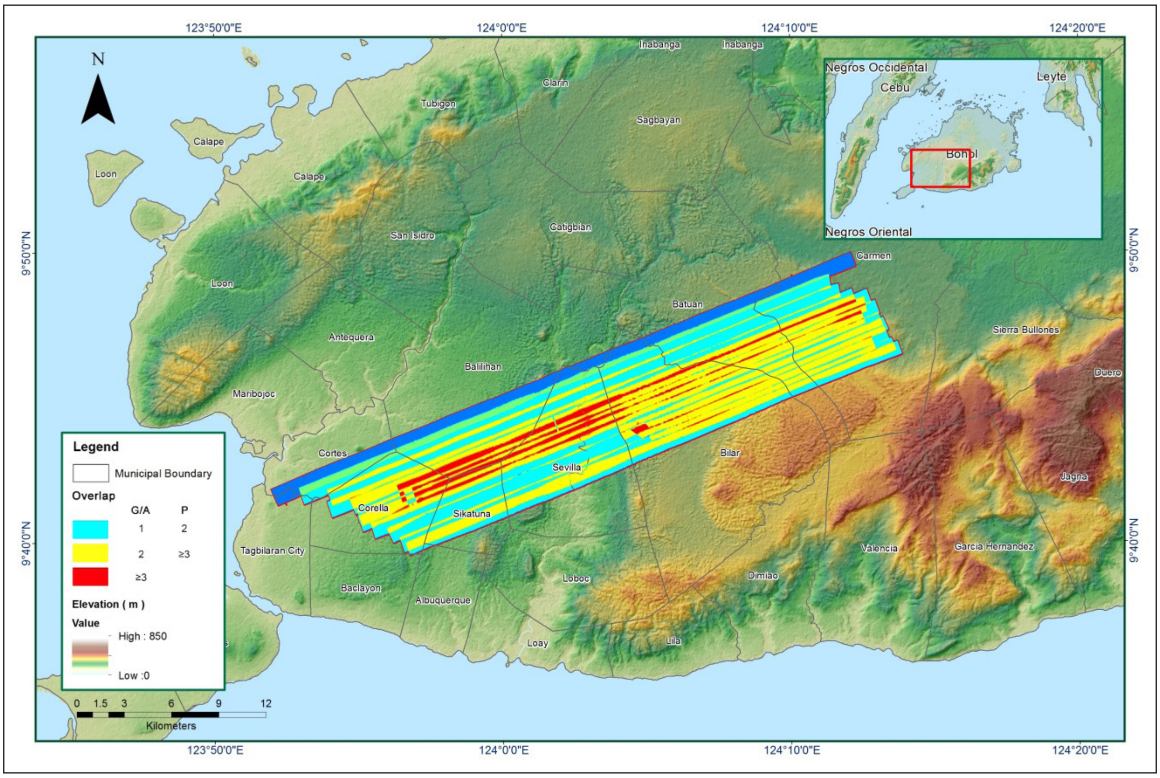


Figure A-8.5. Image of data overlap

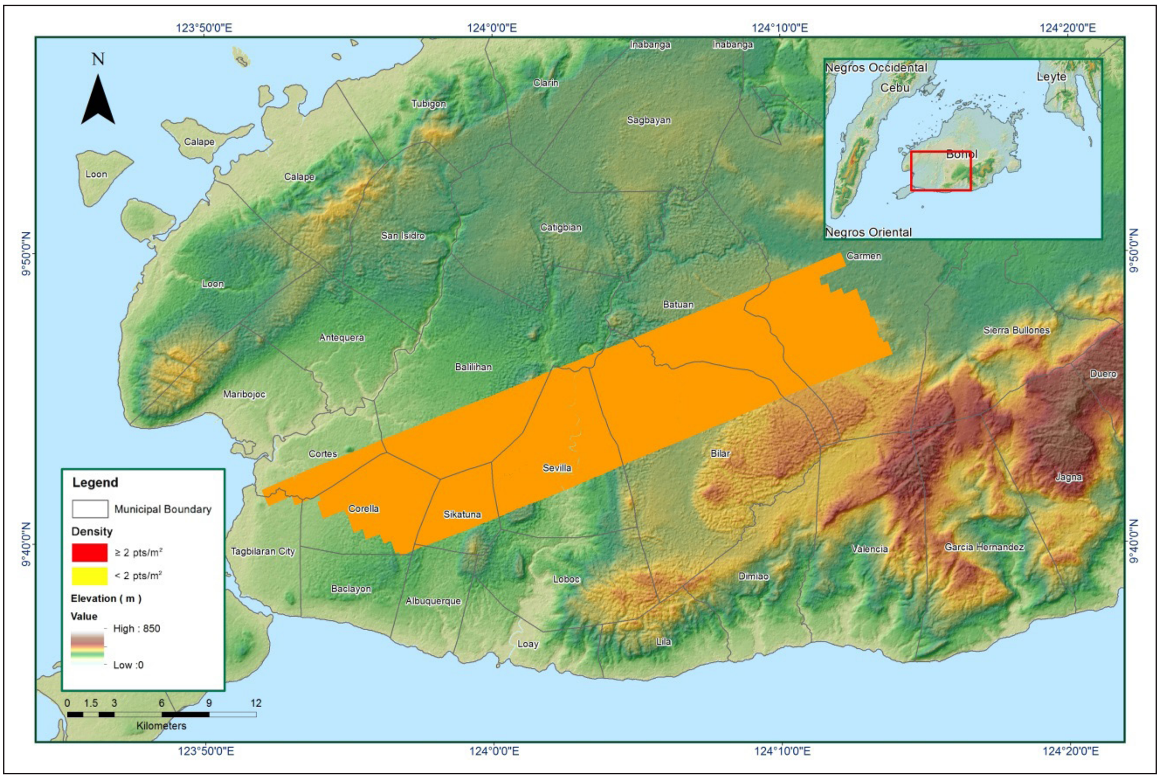


Figure A-8.6. Density Map of merged LiDAR data

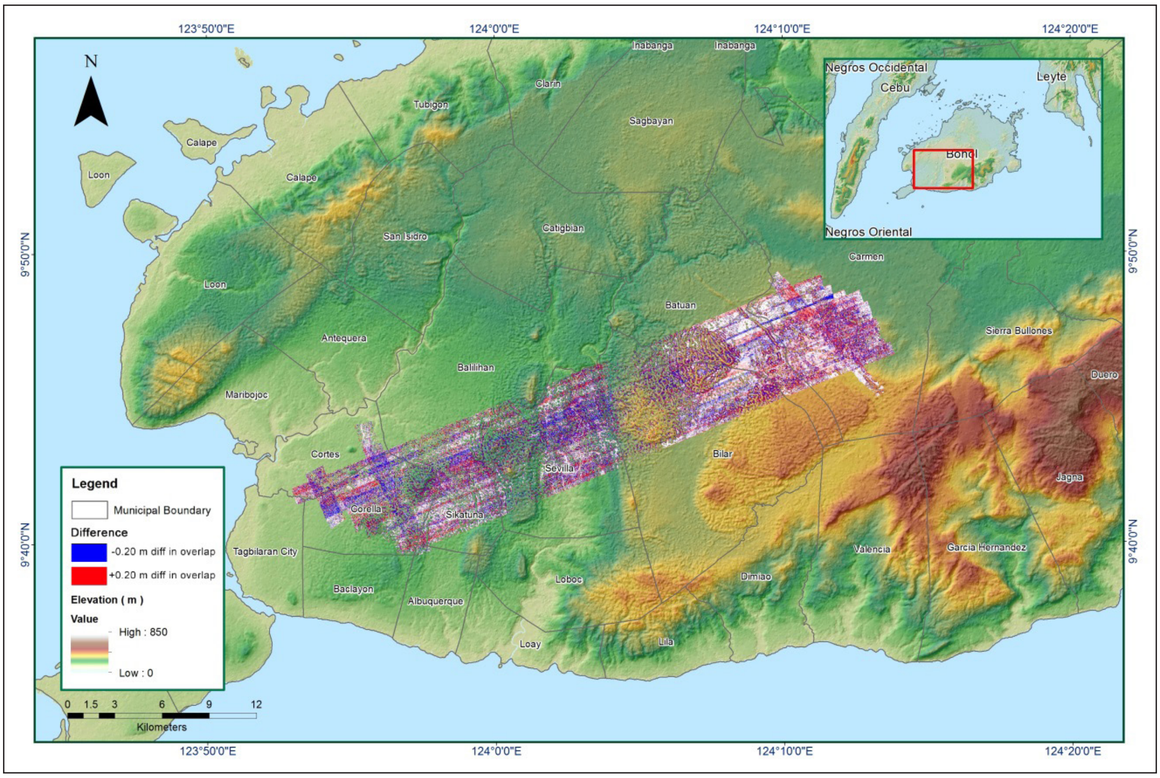


Figure A-8.7. Elevation Difference Between flight lines

Table A-8.2. Mission Summary Report for Mission Blk51M

Flight Area	Bohol
Mission Name	**Blk51M**
Inclusive Flights	1867P
Range data size	16.3 GB
POS	188 MB
Base Data	10.8 MB
Image	25 GB
Transfer date	September 12, 2014
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)	4.756
RMSE for East Position (<4.0 cm)	3.972
RMSE for Down Position (<8.0 cm)	8.301
Boresight correction stdev (<0.001deg)	0.000223
IMU attitude correction stdev (<0.001deg)	0.008086
GPS position stdev (<0.01m)	0.0119
Minimum % overlap (>25)	36.83
Ave point cloud density per sq.m. (>2.0)	2.77
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	204
Maximum Height	233.24 m
Minimum Height	59.91 m
Classification (# of points)	
Ground	24,791,046
Low vegetation	19,274,610
Medium vegetation	16,194,353
High vegetation	10,284,370
Building	1,684,486
Orthophoto	Yes
Processed by	Engr. Analyn Naldo, Engr. Christy Lubiano, Engr. Jeffrey Delica

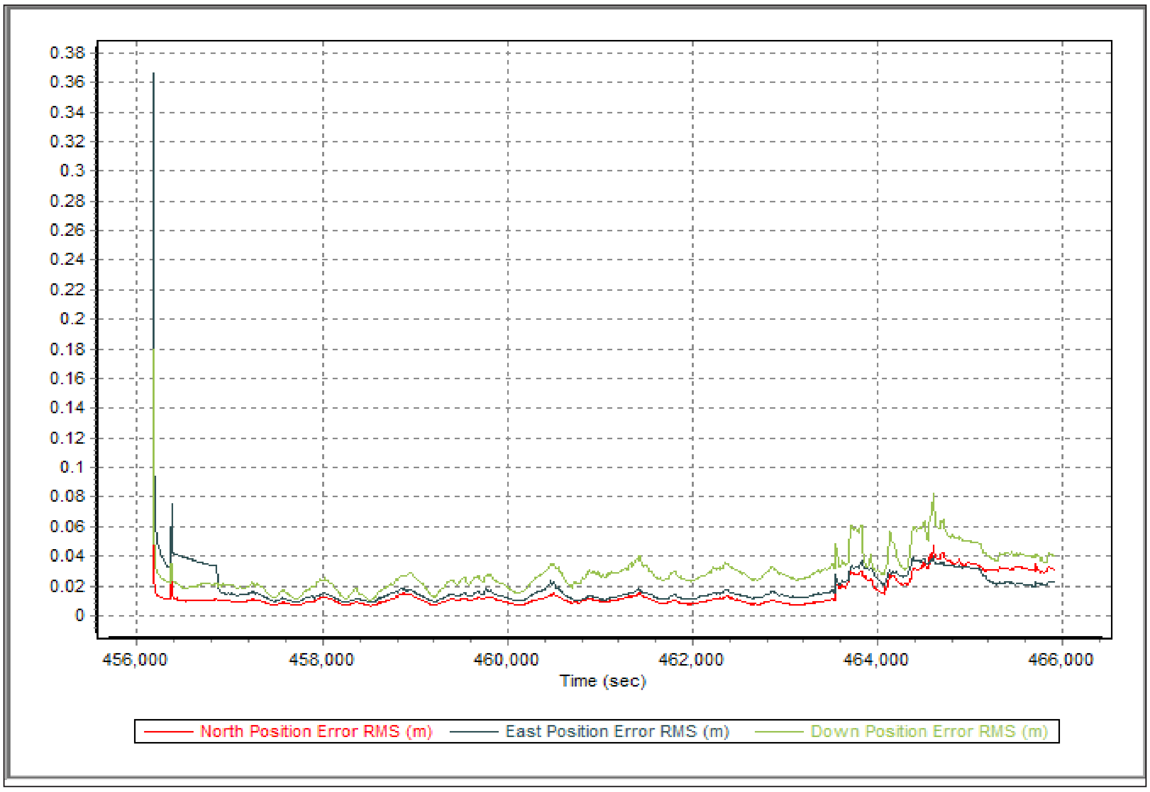


Figure A-8.8. Solution Status

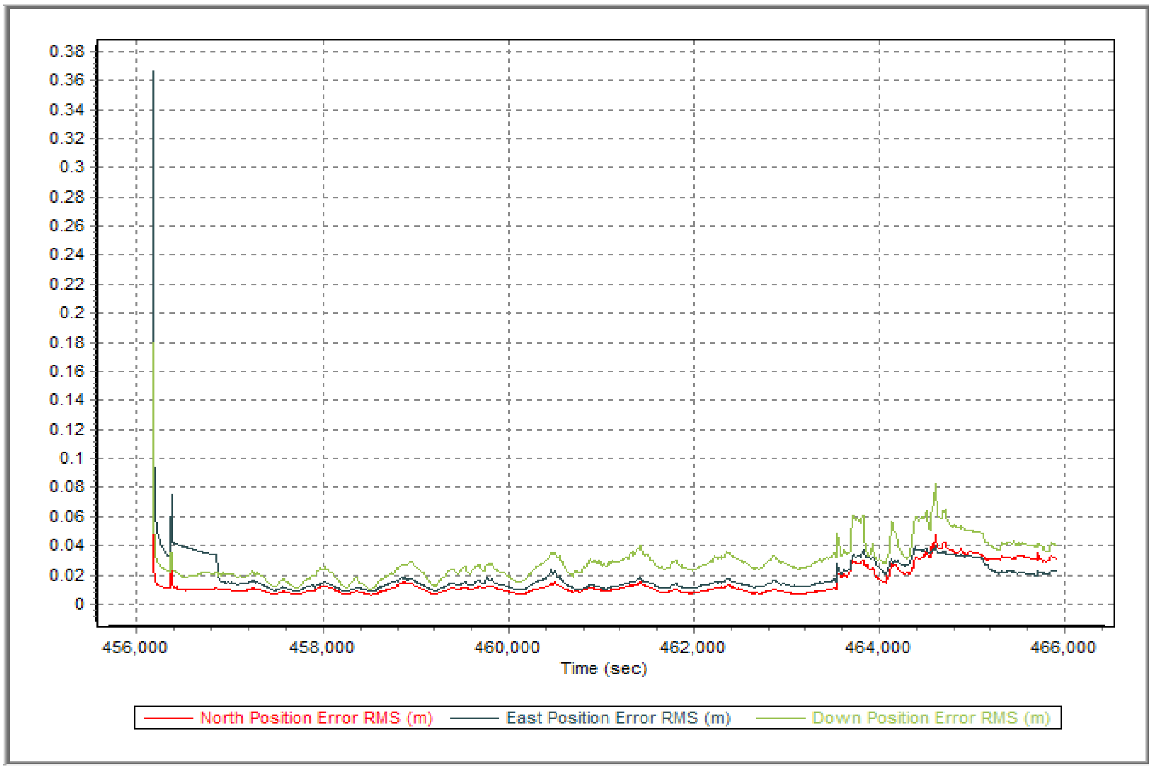


Figure A-8.9. Smoothed Performance Metric Parameters

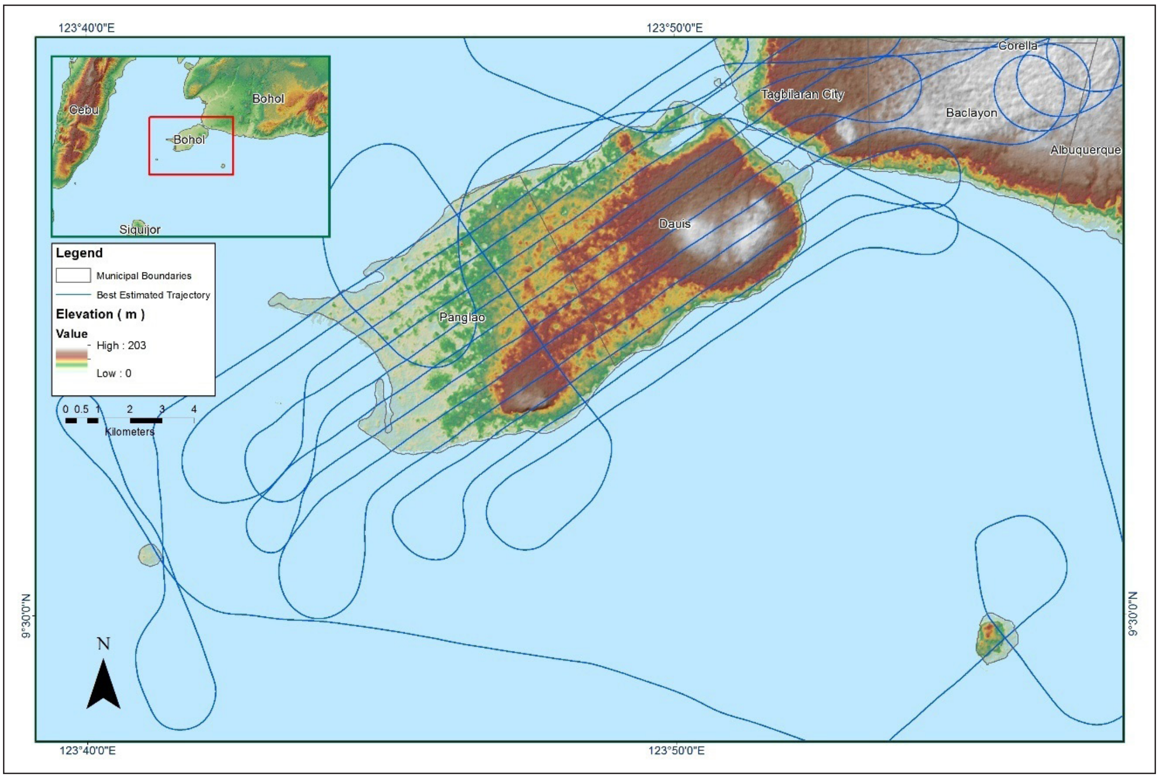


Figure A-8.10. Best Estimate Trajectory

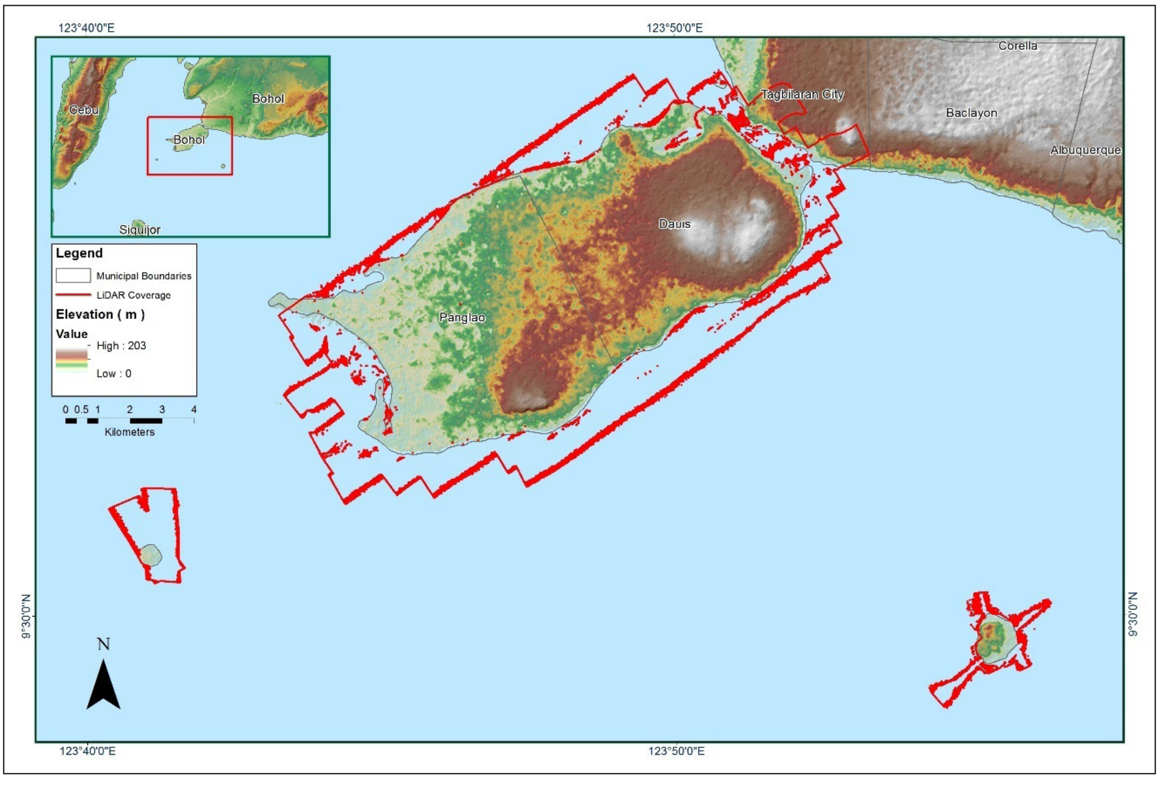


Figure A-8.11. Coverage of LiDAR data

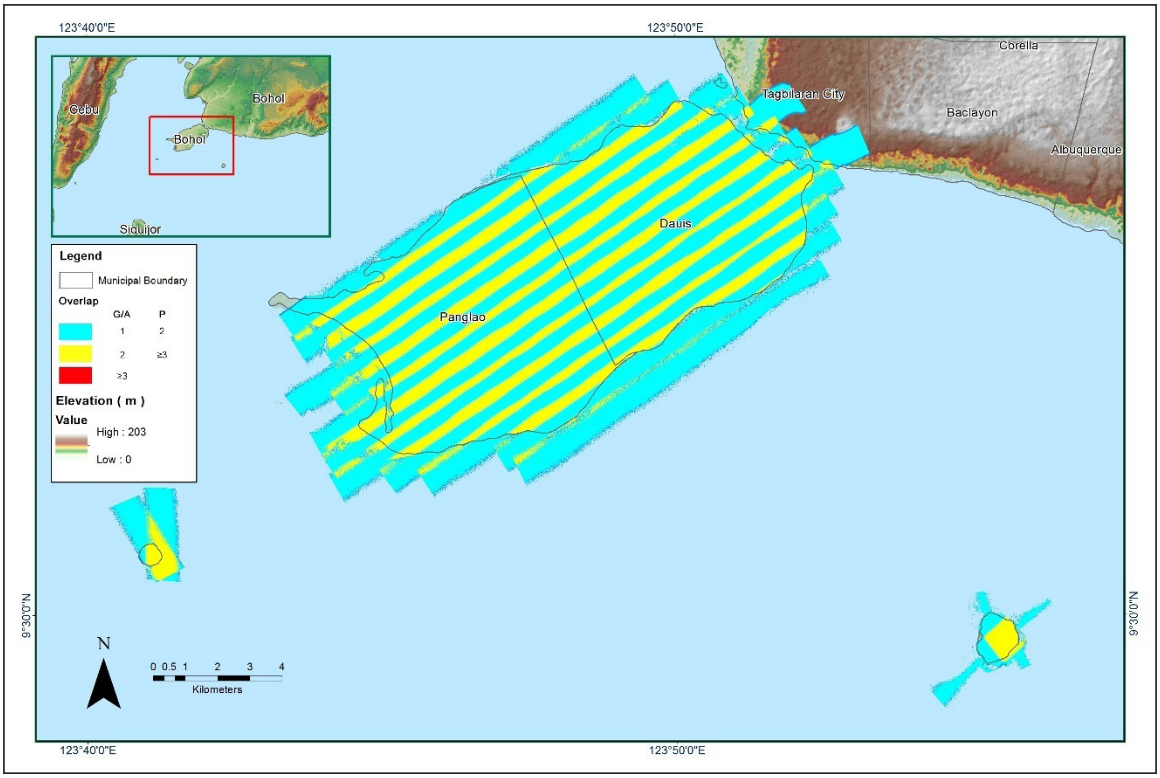


Figure A-8.12. Image of data overlap

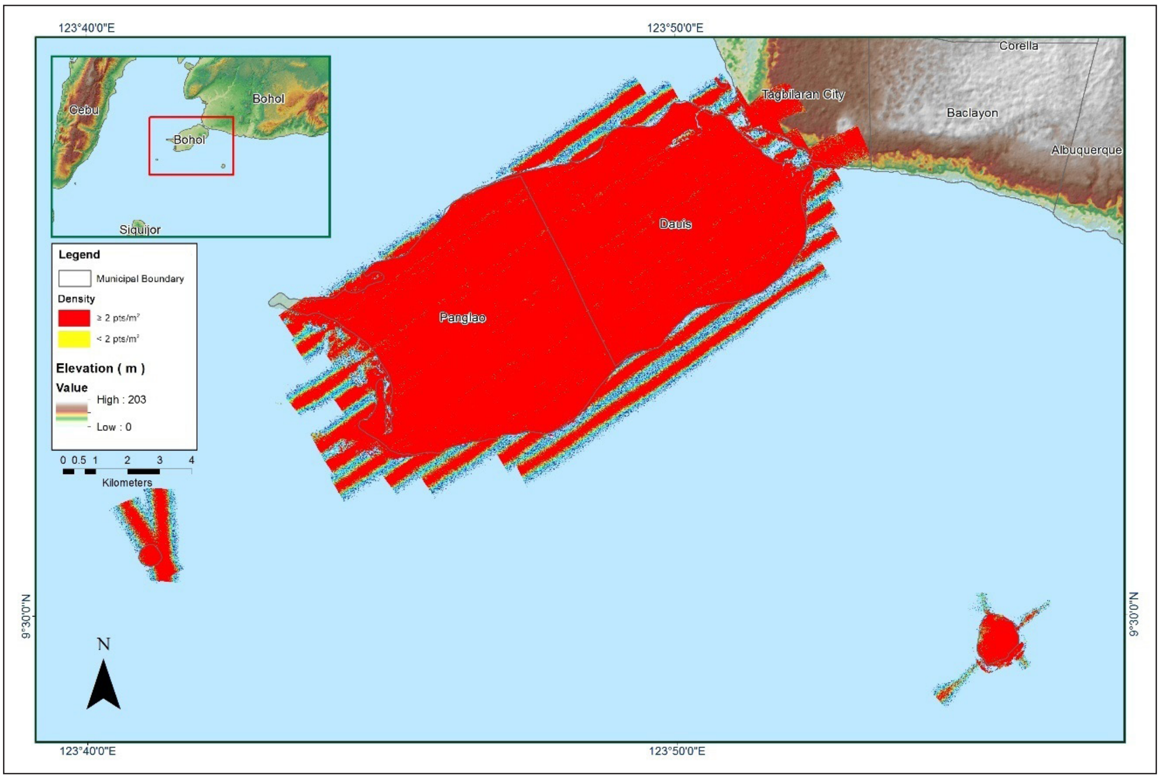


Figure A-8.13. Density Map of merged LiDAR data

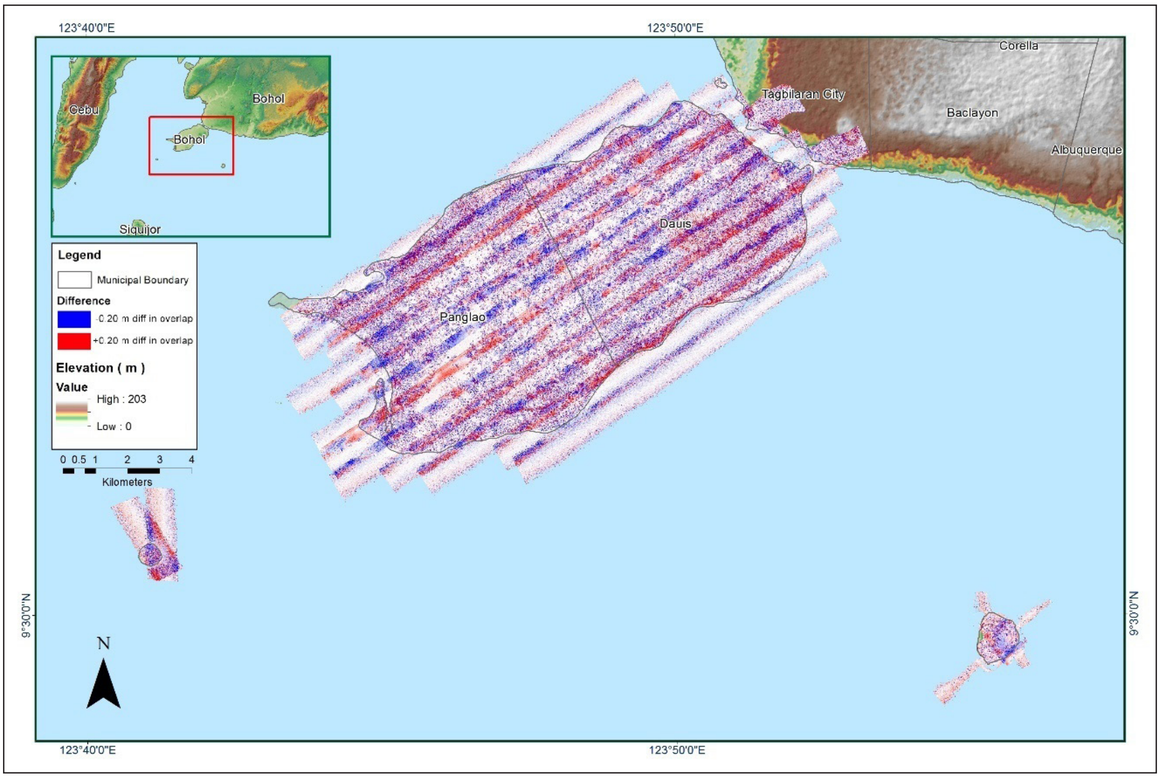


Figure A-8.14. Elevation Difference Between flight lines

Table A-8.3. Mission Summary Report for Mission Blk1H

Flight Area	Bohol
Mission Name	**Blk1H**
Inclusive Flights	747P
Range data size	27.2 GB
POS data size	276 MB
Base data size	11.3 MB
Image	NA
Transfer date	December 13, 2013
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.35
RMSE for East Position (<4.0 cm)	2.4
RMSE for Down Position (<8.0 cm)	3.3
Boresight correction stdev (<0.001deg)	0.000481
IMU attitude correction stdev (<0.001deg)	0.001115
GPS position stdev (<0.01m)	0.0071
Minimum % overlap (>25)	37.27
Ave point cloud density per sq.m. (>2.0)	5.90
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	215
Maximum Height	434.43
Minimum Height	54.14
Classification (# of points)	
Ground	391,336,137
Low vegetation	284,571,114
Medium vegetation	828,196,522
High vegetation	879,621,680
Building	14,914,950
Orthophoto	None
Processed by	Engr. Kenneth Solidum, Emmanuel Ricohermoso III, Engr. Elainne Lopez, Engr. Jeffrey Delica

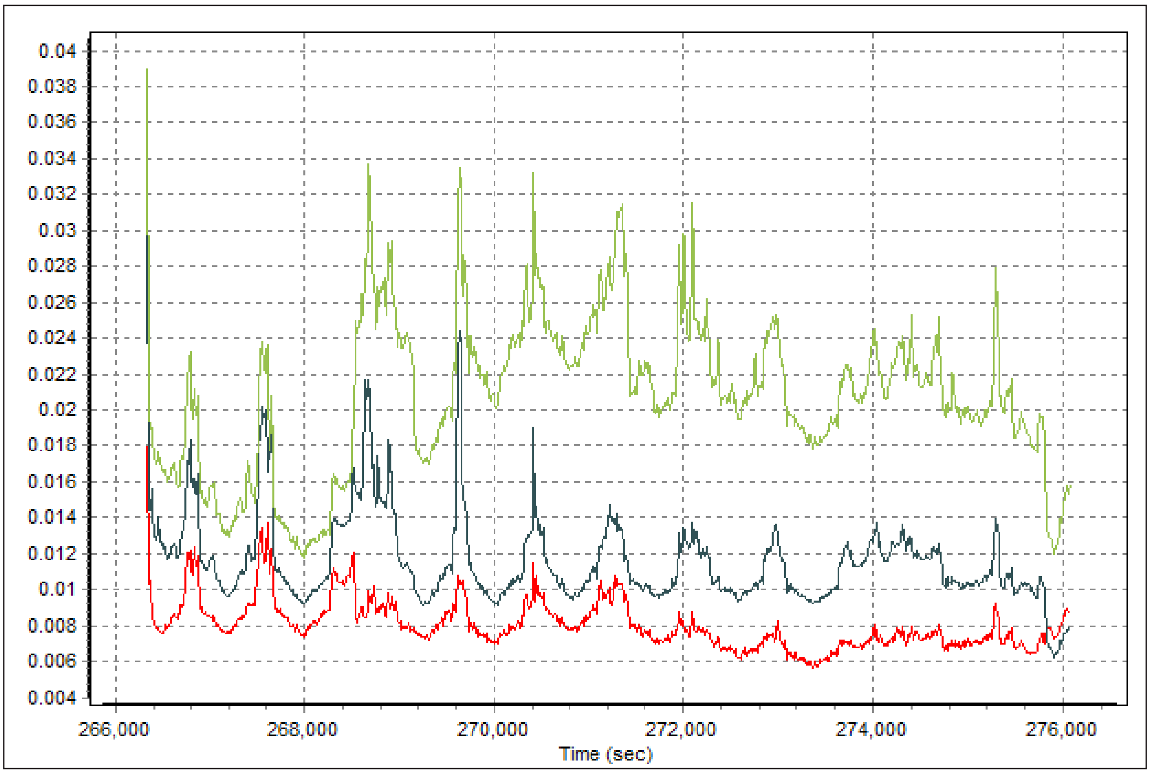


Figure A-8.15. Solution Status

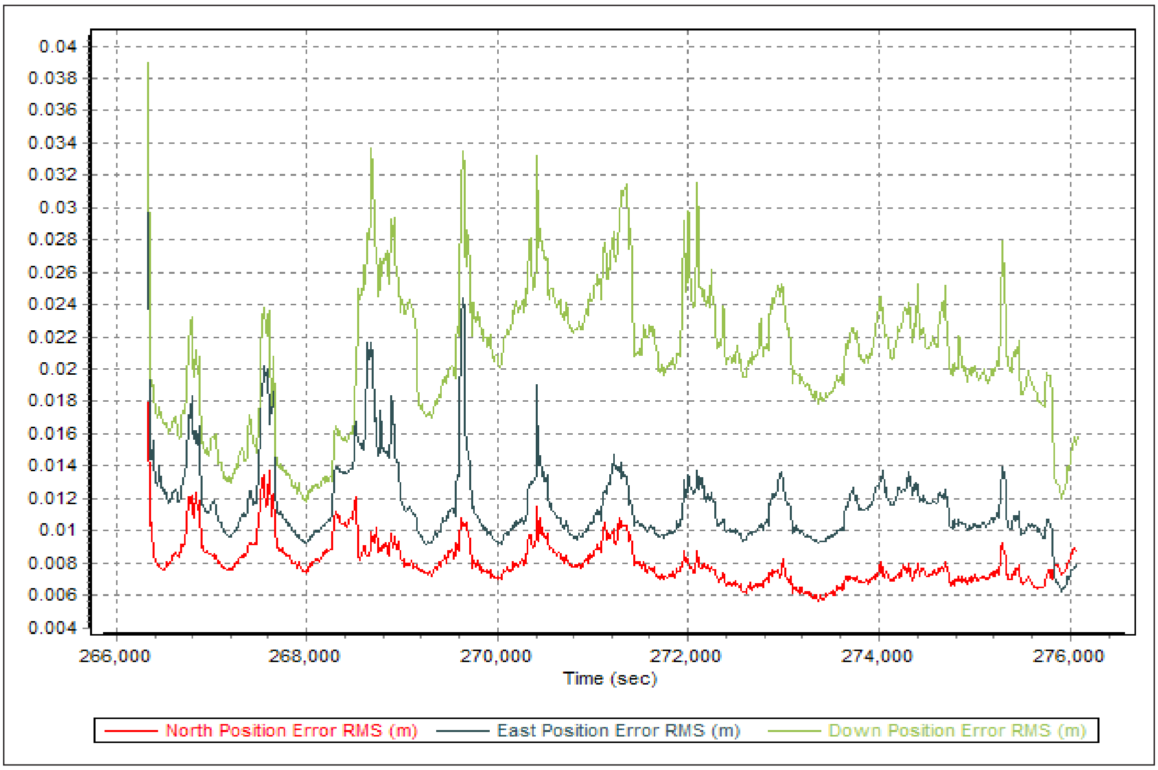


Figure A-8.16. Smoothed Performance Metric Parameters

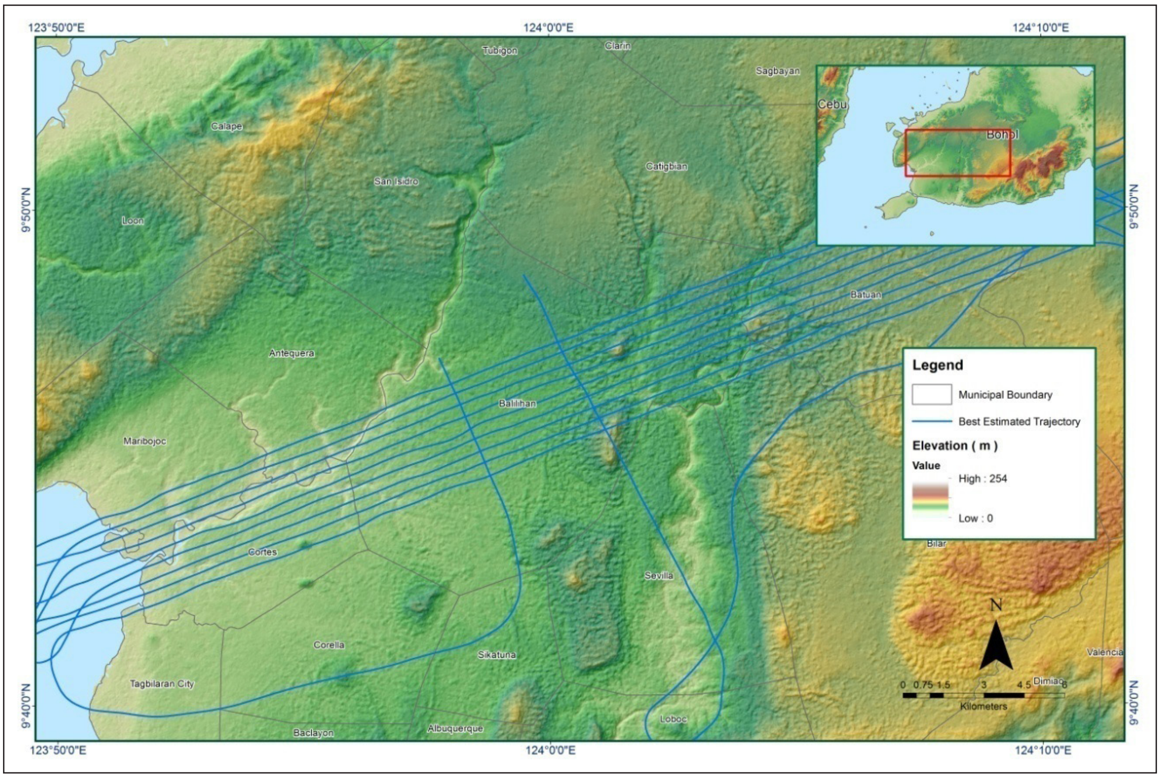


Figure A-8.17. Best Estimated Trajectory

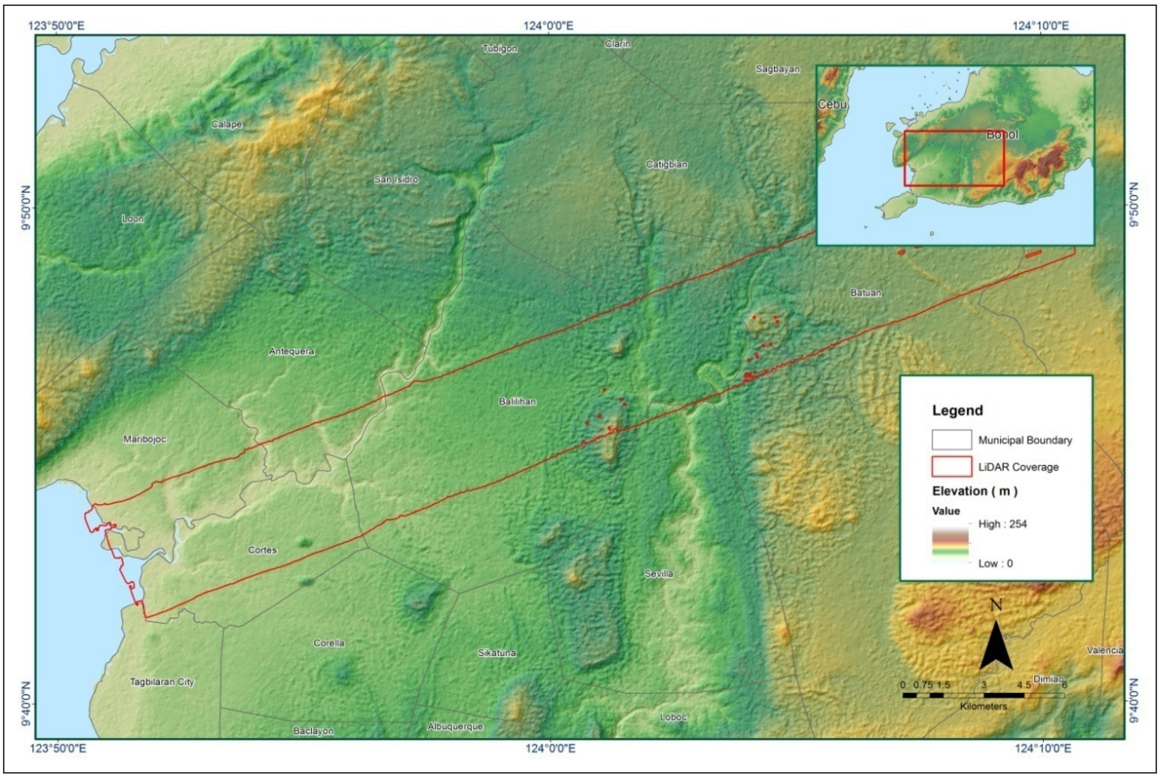


Figure A-8.18. Coverage of LiDAR Data

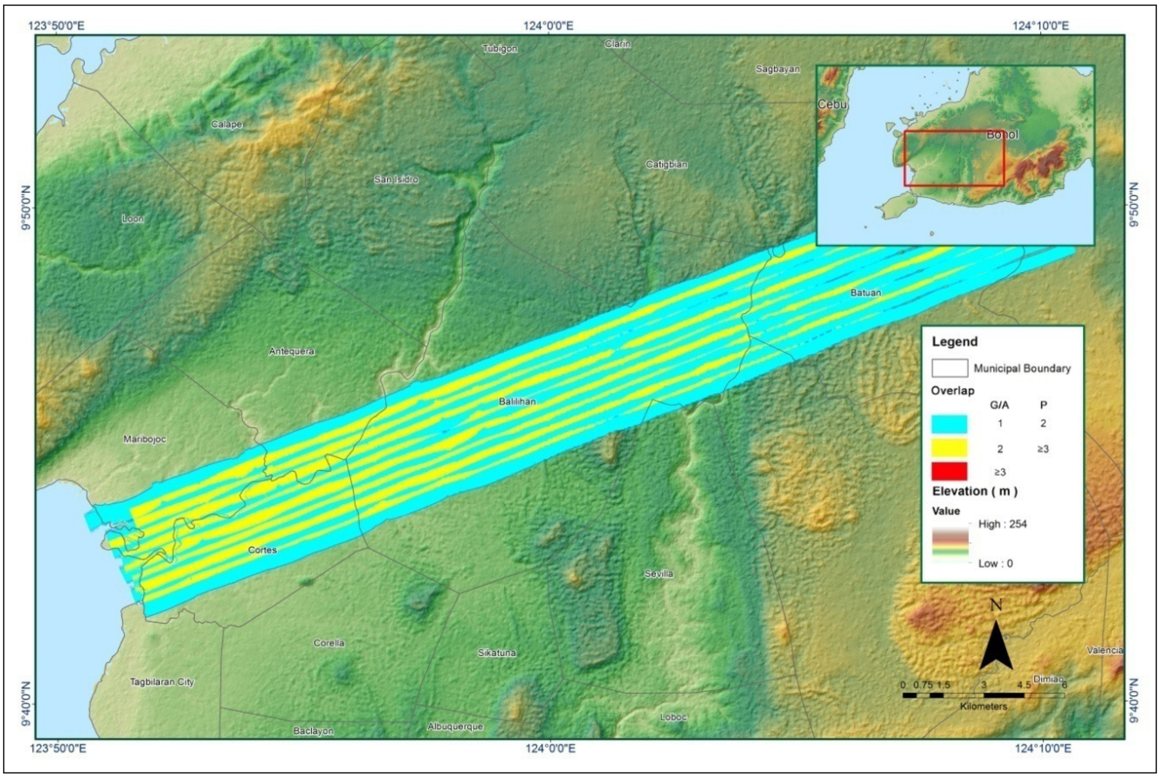


Figure A-8.19. Image of data overlap

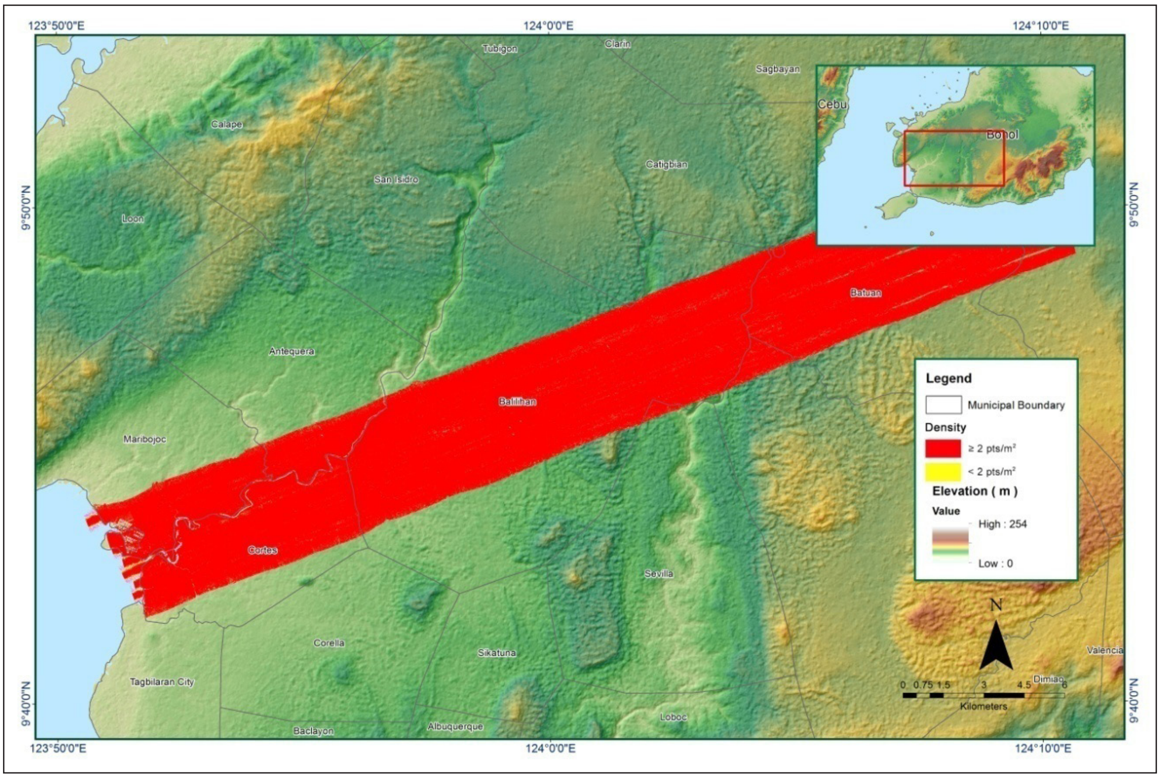


Figure A-8.20. Density map of merged LiDAR data

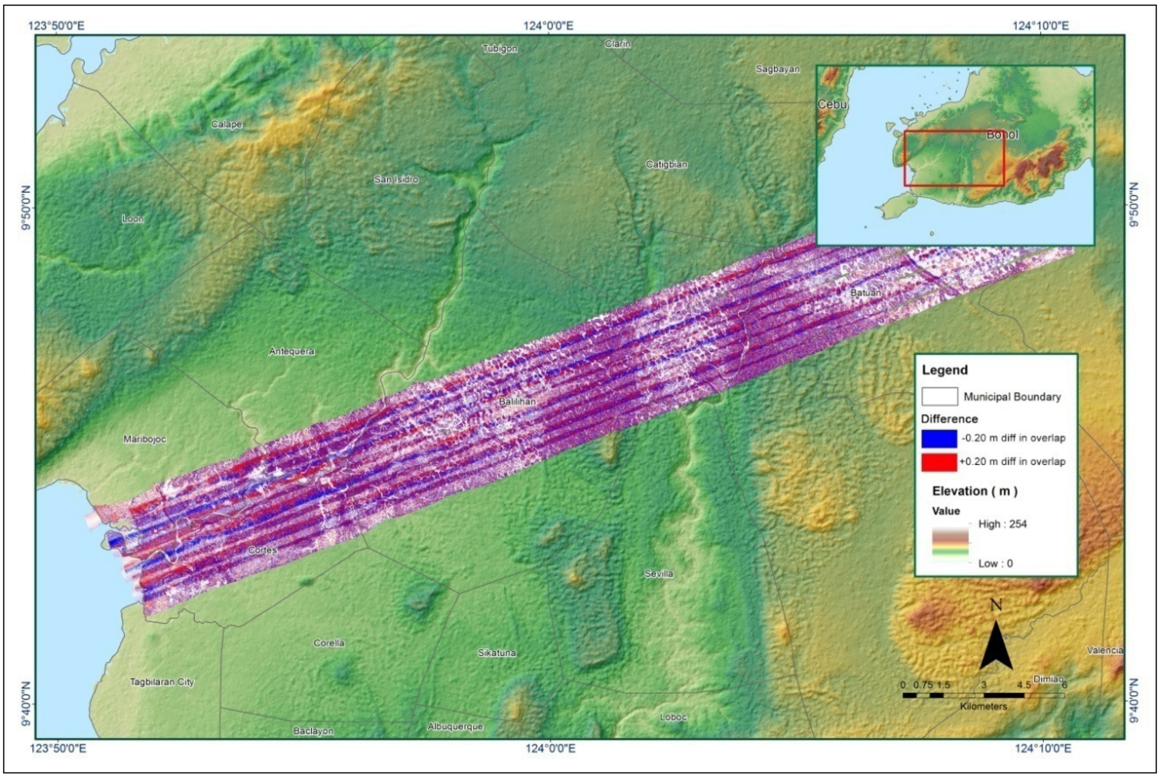


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk1H_supplement

Flight Area	Abatan
Mission Name	**Blk1H_supplement**
Inclusive Flights	759P
Range data size	16.5 GB
POS data size	181 MB
Base data size	10.9 MB
Image	NA
Transfer date	December 13, 2013
Solution Status	
Number of Satellites (>6)	No
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	2.4
RMSE for Down Position (<8.0 cm)	3.4
Boresight correction stdev (<0.001deg)	0.000965
IMU attitude correction stdev (<0.001deg)	0.014568
GPS position stdev (<0.01m)	0.0121
Minimum % overlap (>25)	0.05
Ave point cloud density per sq.m. (>2.0)	2.64
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	212
Maximum Height	504.67
Minimum Height	56.28
Classification (# of points)	
Ground	89,158,937
Low vegetation	41,342,087
Medium vegetation	123,594,175
High vegetation	136,316,023
Building	1,983,500
Orthophoto	None
Processed by	Engr. Jeffrey Delica, Engr. Melanie Hingpit, Engr. Benjamin Jonah Magallon

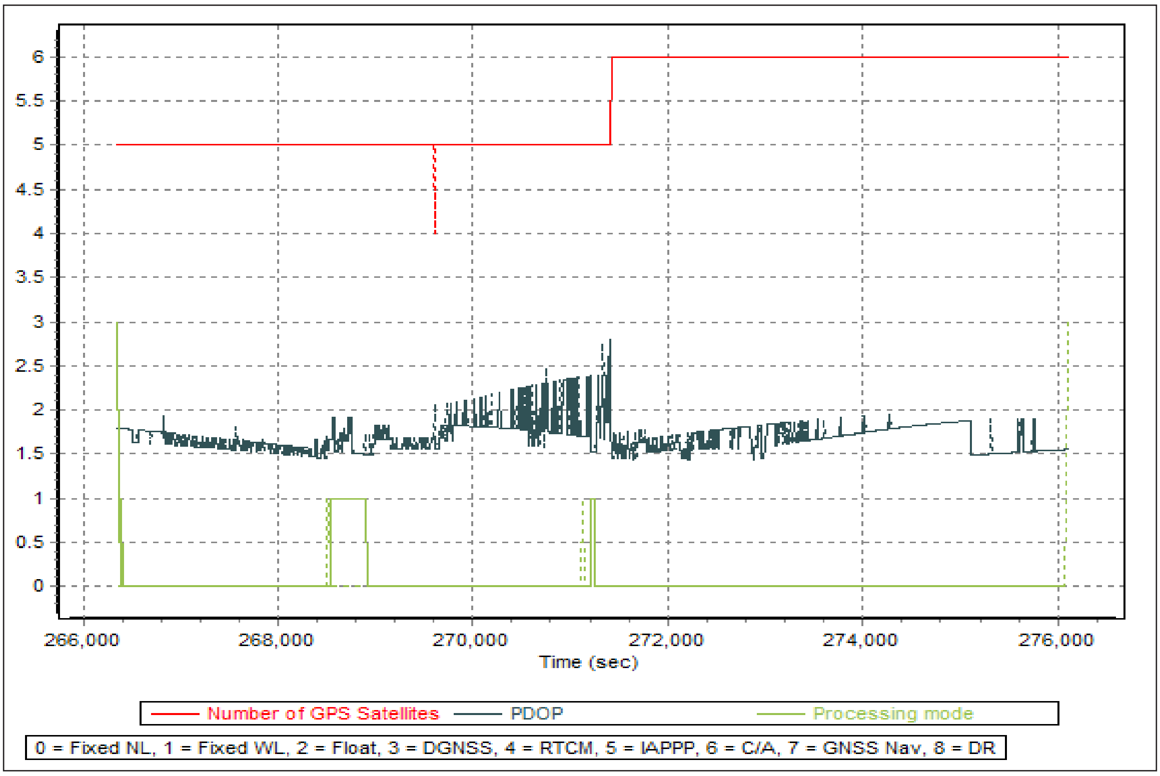


Figure A-8.22. Solution Status

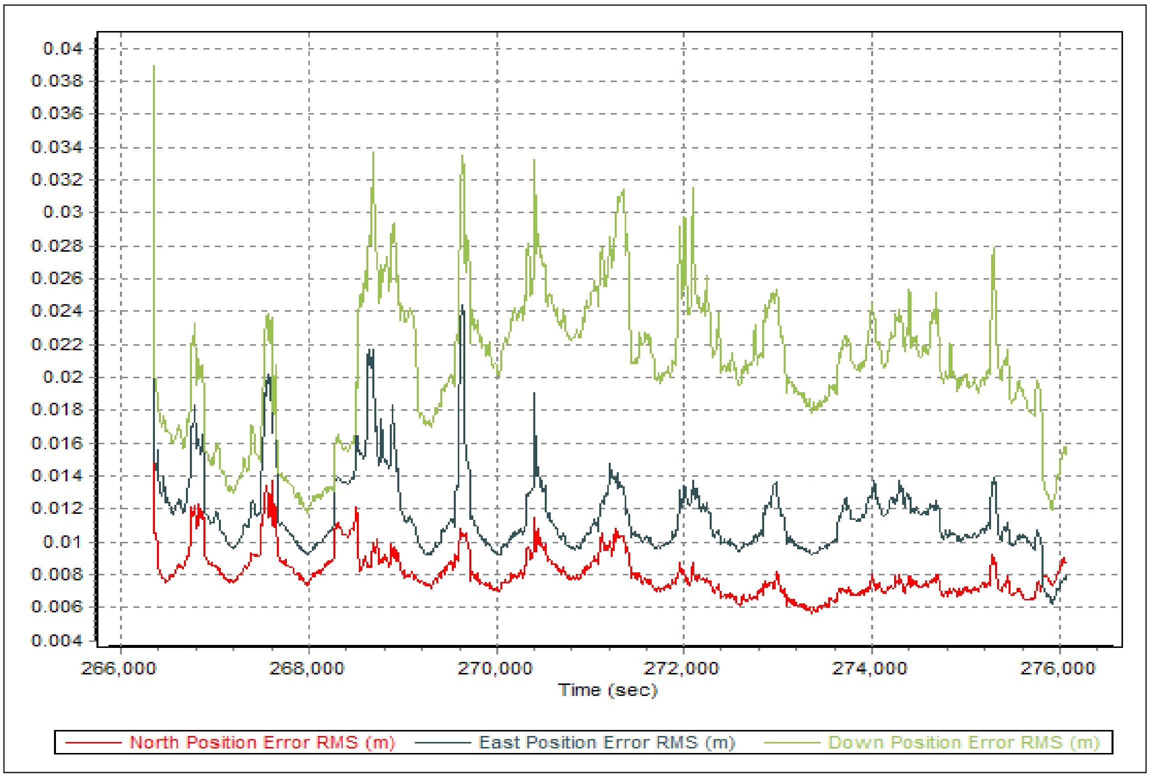


Figure A-8.23. Smoothed Performance Metric Parameters

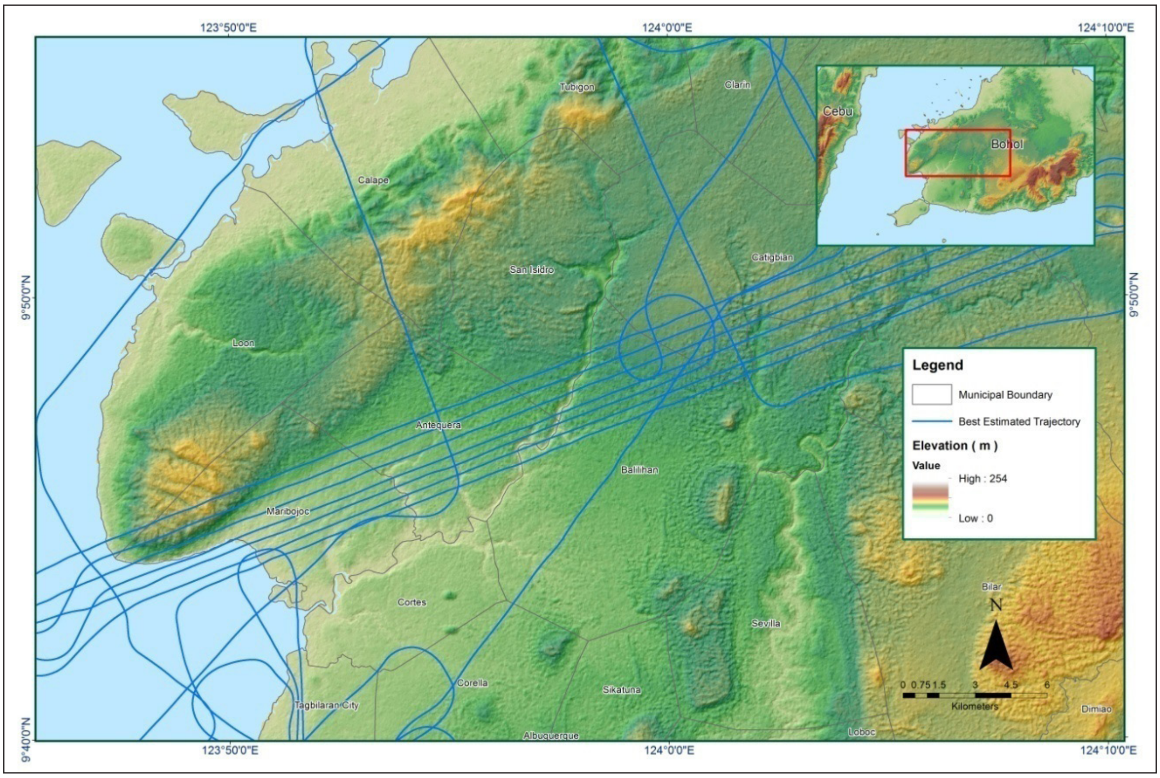


Figure A-8.24. Best Estimated Trajectory

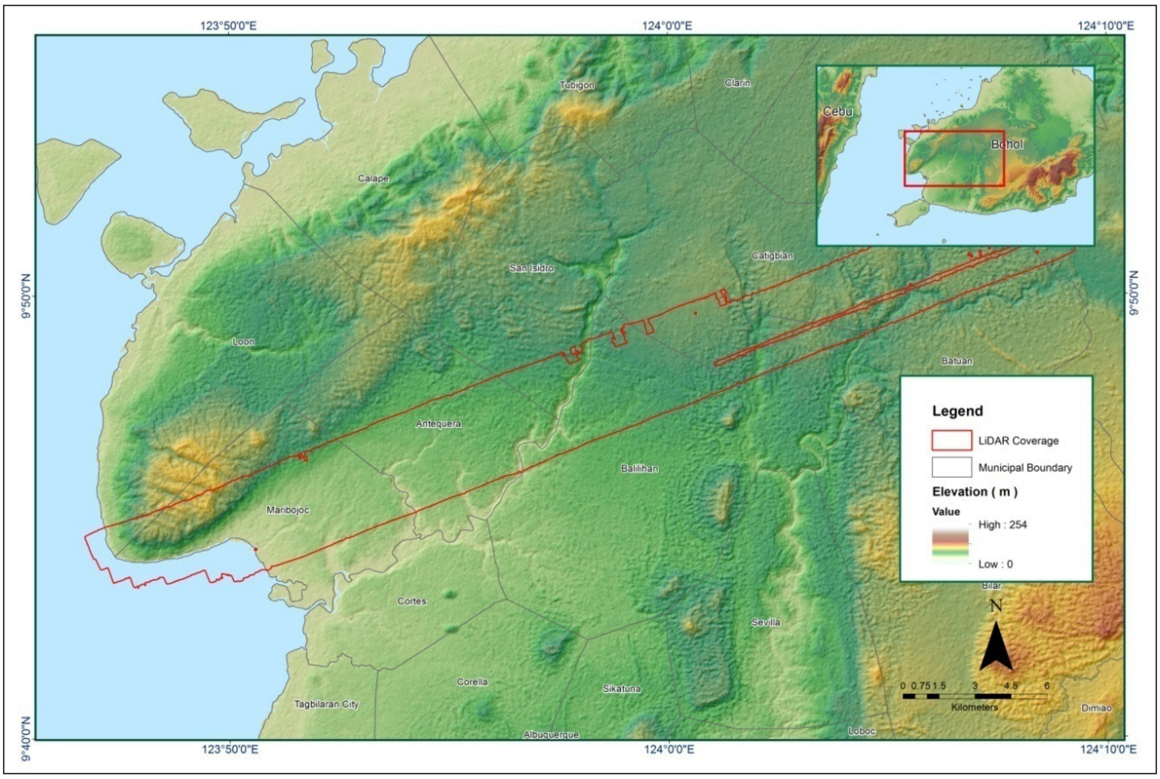


Figure A-8.25. Coverage of LiDAR Data

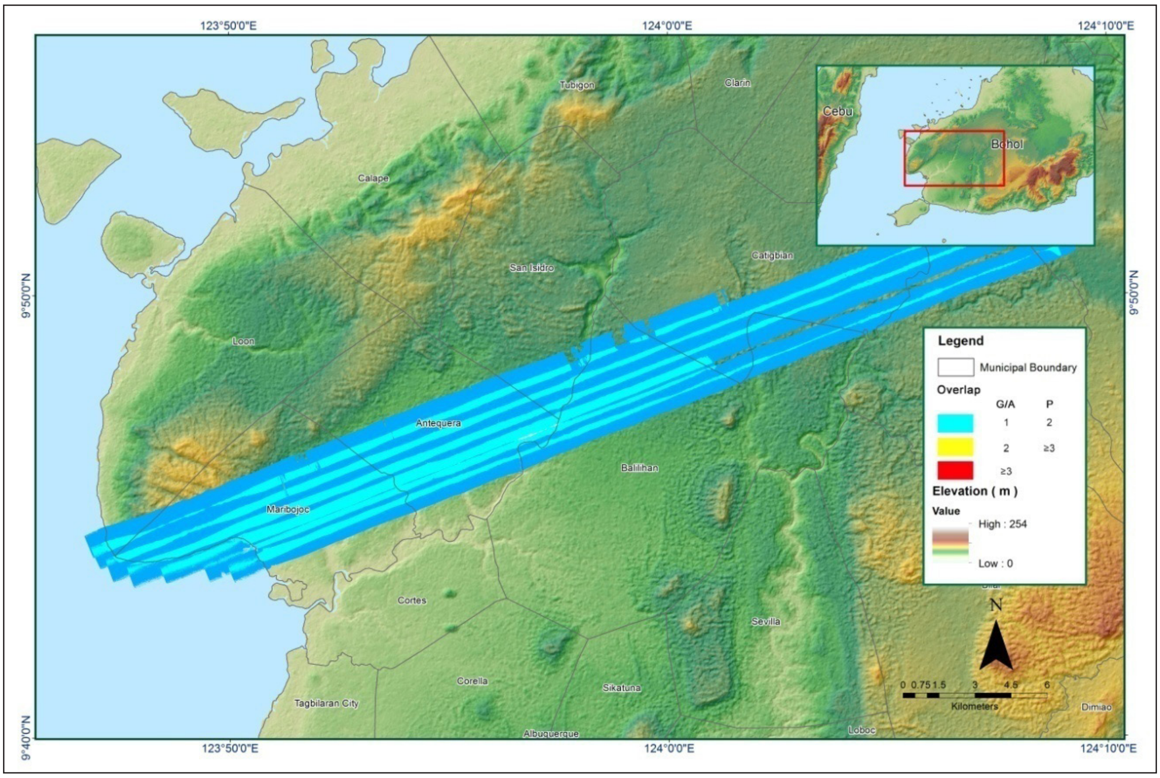


Figure A-8.26. Image of data overlap

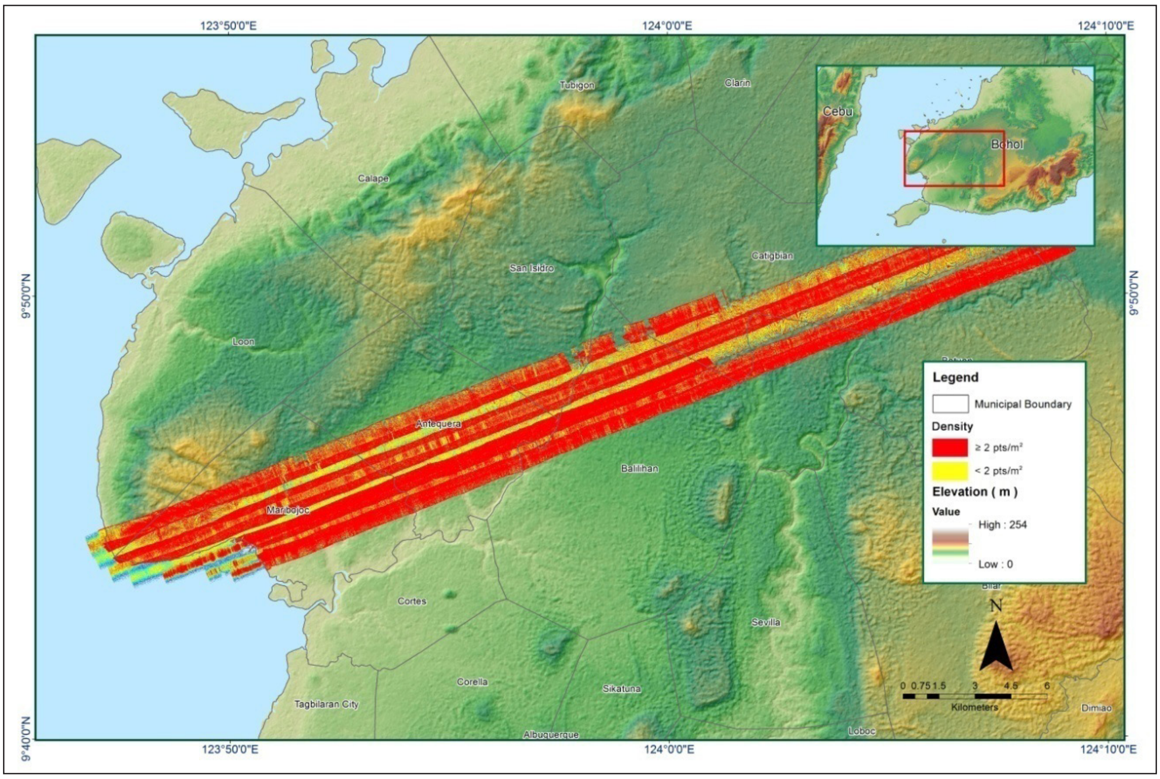


Figure A-8.27. Density map of merged LiDAR data

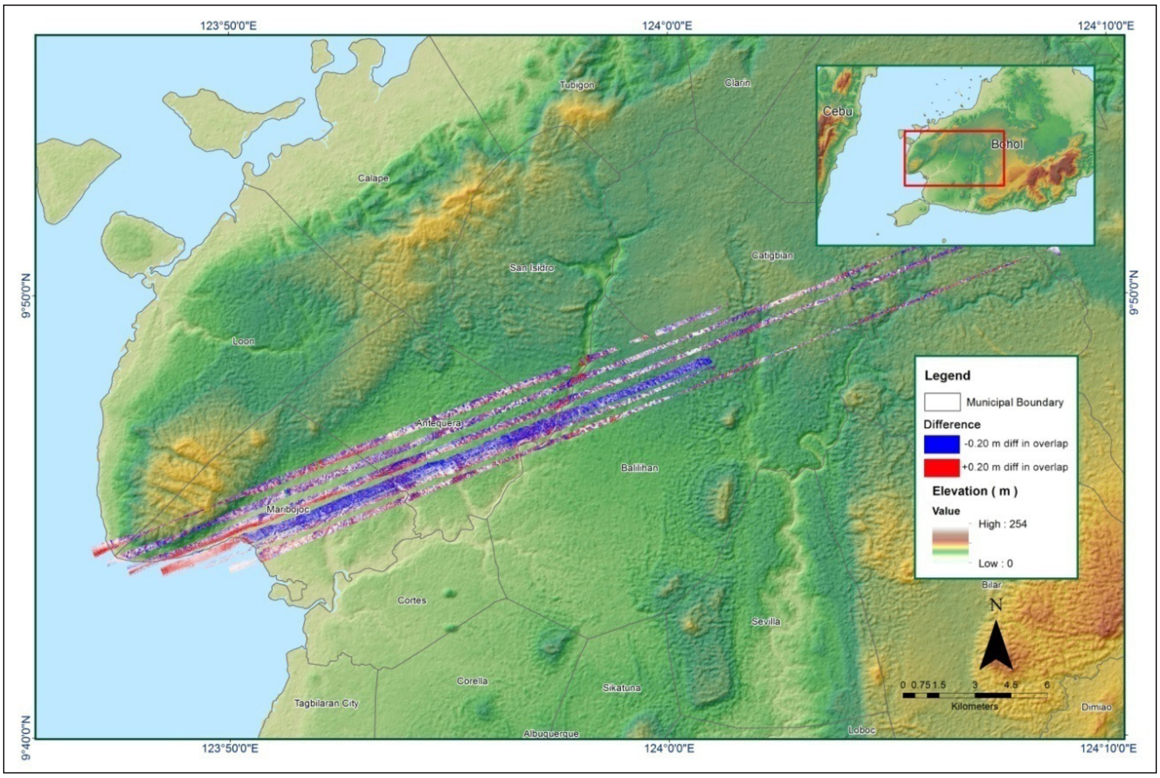


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk1H_additional

Flight Area	Bohol
Mission Name	**Blk1H_additional**
Inclusive Flights	3445P
Range data size	5.95 GB
POS	124 MB
Base Data	9.84 MB
Image	NA
Transfer date	September 12, 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)	0.959
RMSE for East Position (<4.0 cm)	1.06
RMSE for Down Position (<8.0 cm)	1.585
Boresight correction stdev (<0.001deg)	0.000581
IMU attitude correction stdev (<0.001deg)	0.000368
GPS position stdev (<0.01m)	0.0014
Minimum % overlap (>25)	6.23
Ave point cloud density per sq.m. (>2.0)	3.43
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	96
Maximum Height	419.59 m
Minimum Height	181.70 m
Classification (# of points)	
Ground	3,458,277
Low vegetation	204,679
Medium vegetation	5,076,855
High vegetation	14,707,777
Building	213,655
Orthophoto	No
Processed by	Kathryn Claudyn Zarate, Engr. Antonio Chua Jr. Engr. Kenneth Solidum

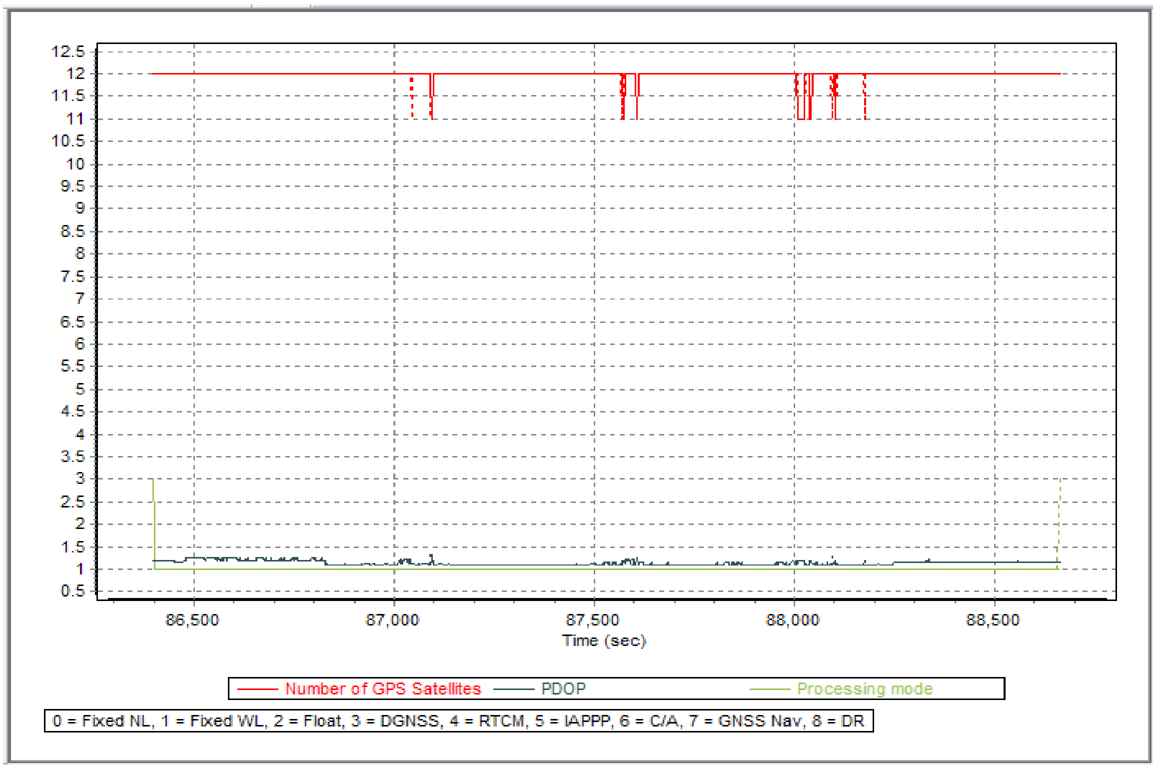


Figure A-8.29. Solution Status

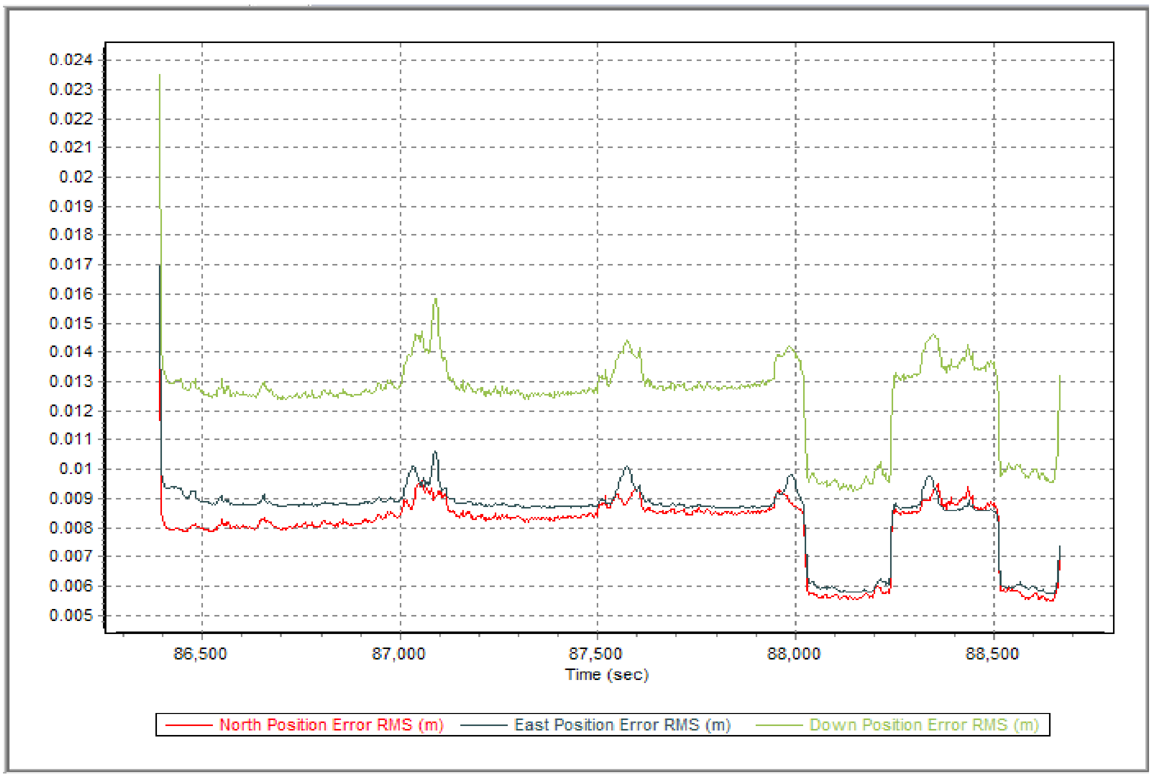


Figure A-8.30. Smoothed Performance Metric Parameters

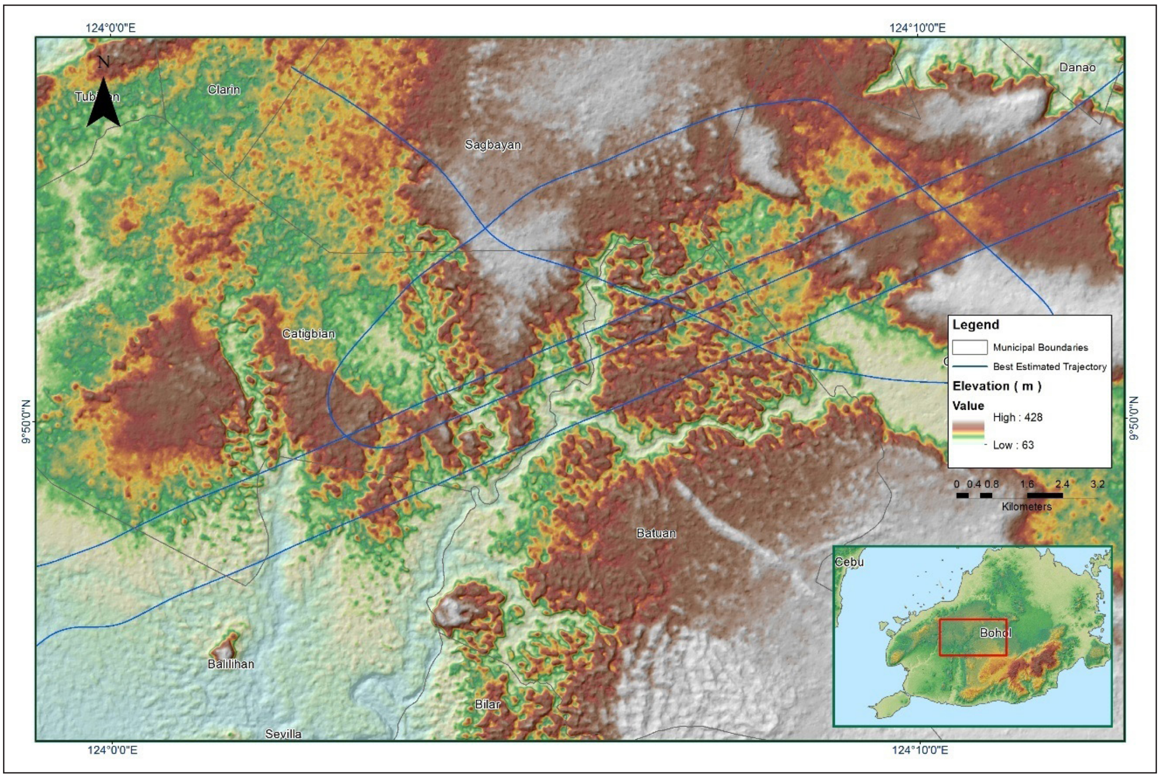


Figure A-8.31. Best Estimate Trajectory

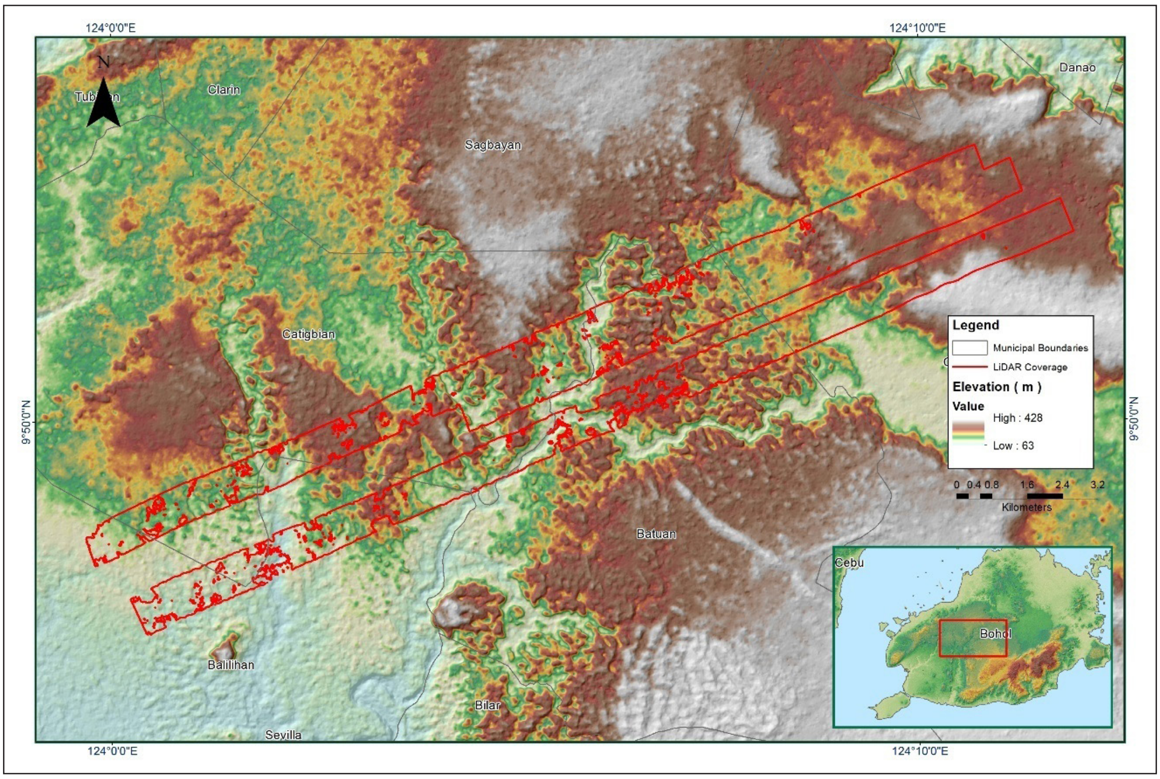


Figure A-8.32. Coverage of LiDAR data

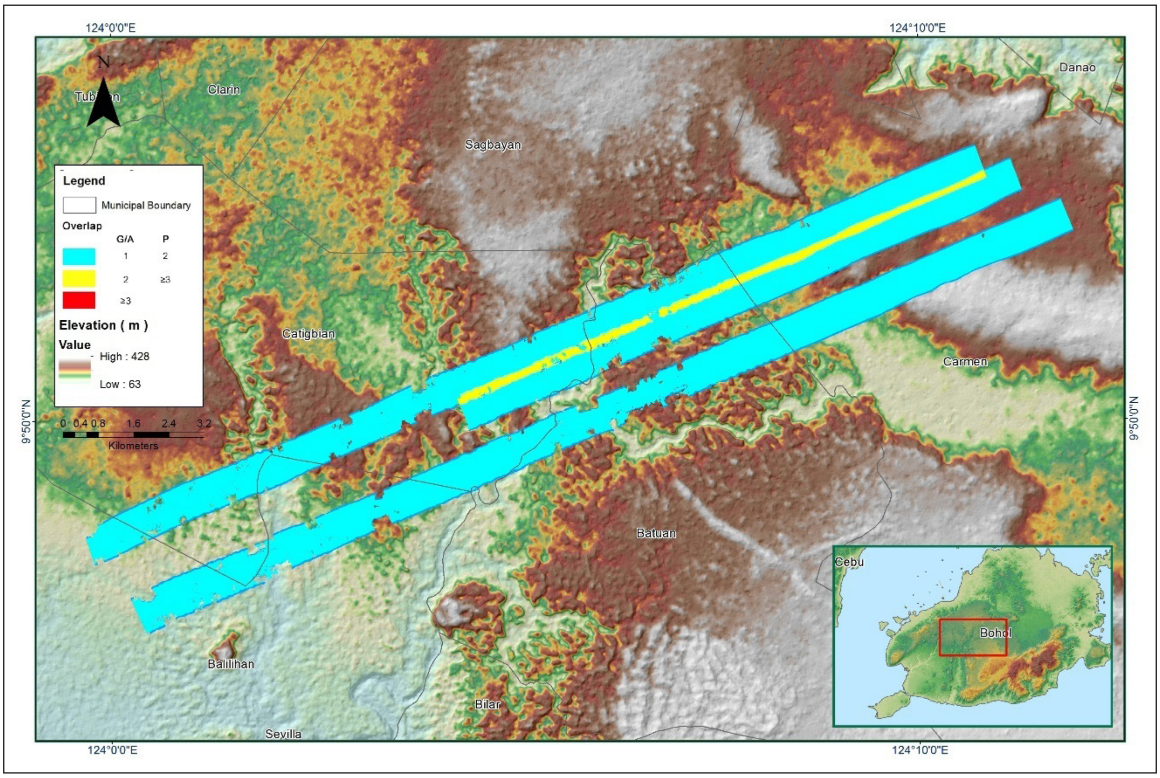


Figure A-8.33. Image of data overlap

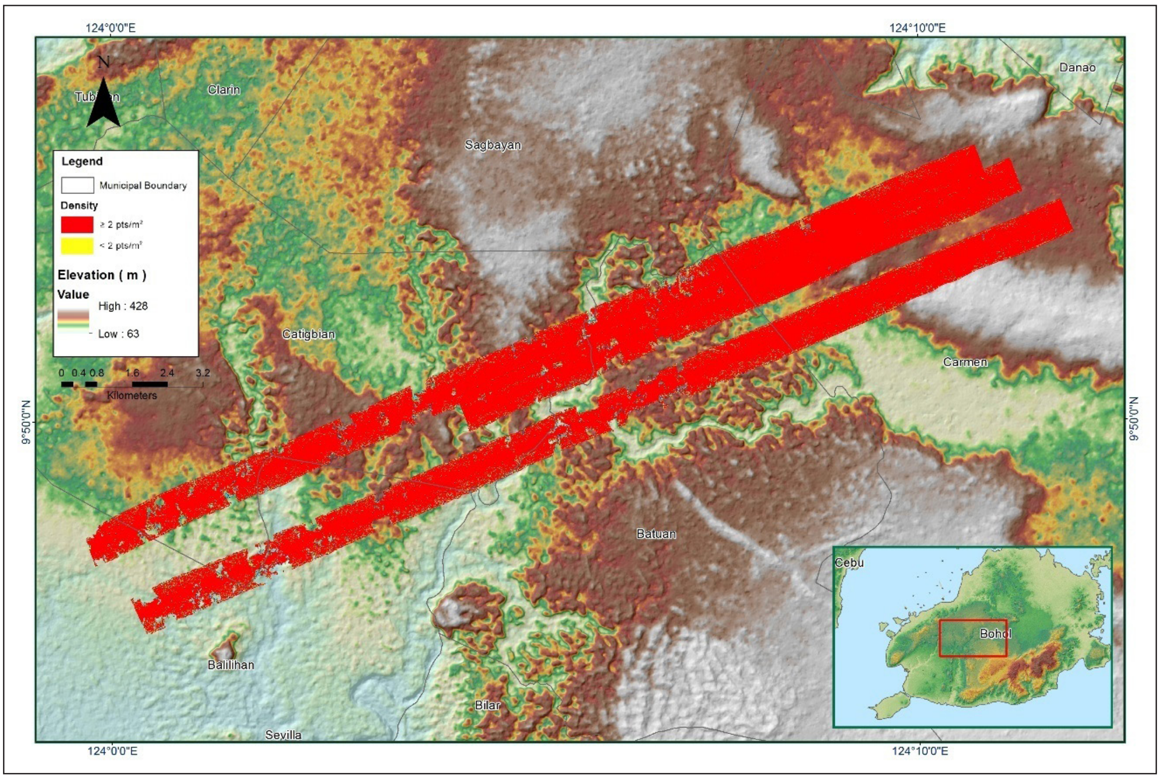


Figure A-8.34. Density Map of merged LiDAR data

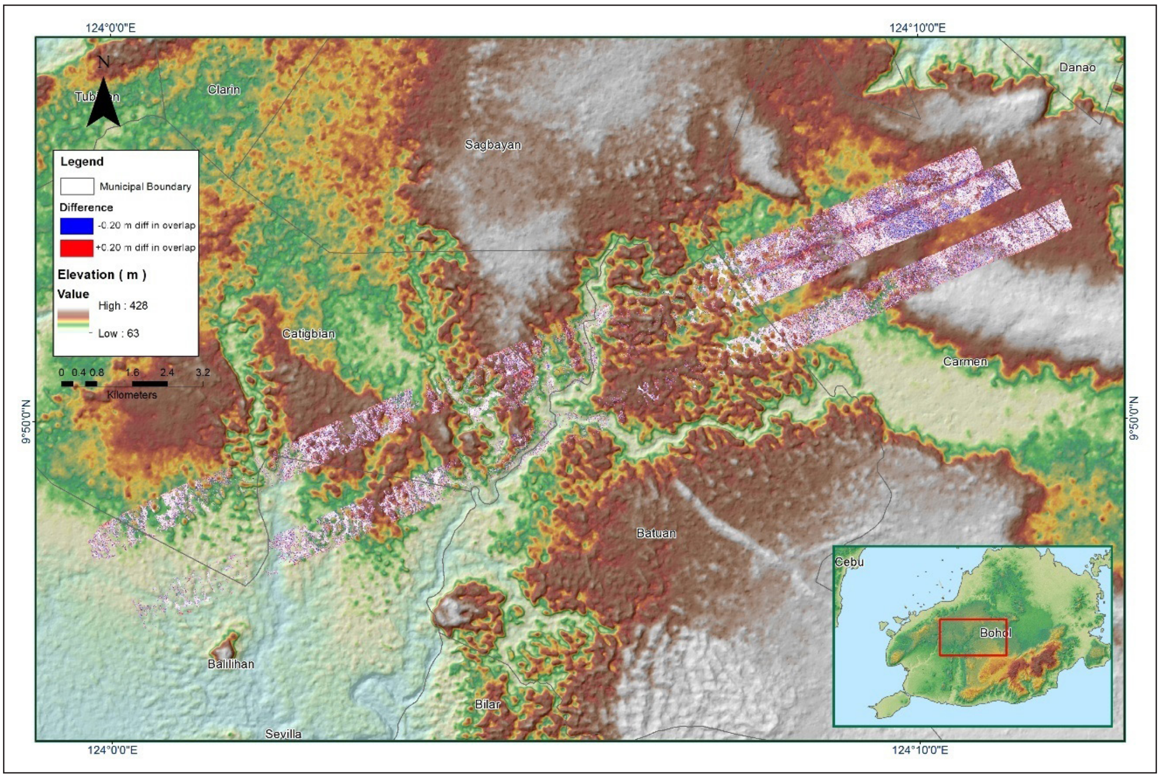


Figure A-8.35. Elevation Difference Between flight lines

Table A-8.6. Mission Summary Report for Mission Blk1G

Flight Area	Bohol
Mission Name	**Blk1G**
Inclusive Flights	757P
Range data size	20.8 GB
POS data size	196 MB
Base data size	14 MB
Image	NA
Transfer date	December 3, 2013
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.4
RMSE for East Position (<4.0 cm)	1.8
RMSE for Down Position (<8.0 cm)	4.4
Boresight correction stdev (<0.001deg)	0.000555
IMU attitude correction stdev (<0.001deg)	0.067305
GPS position stdev (<0.01m)	0.0023
Minimum % overlap (>25)	51.27
Ave point cloud density per sq.m. (>2.0)	4.64
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	210
Maximum Height	479.71
Minimum Height	63.37
Classification (# of points)	
Ground	174,963,090
Low vegetation	137,982,440
Medium vegetation	301,806,257
High vegetation	288,379,405
Building	5,638,748
Orthophoto	None
Processed by	Engr. Jennifer Saguran, Engr. Melanie Hingpit, Simonette Lat

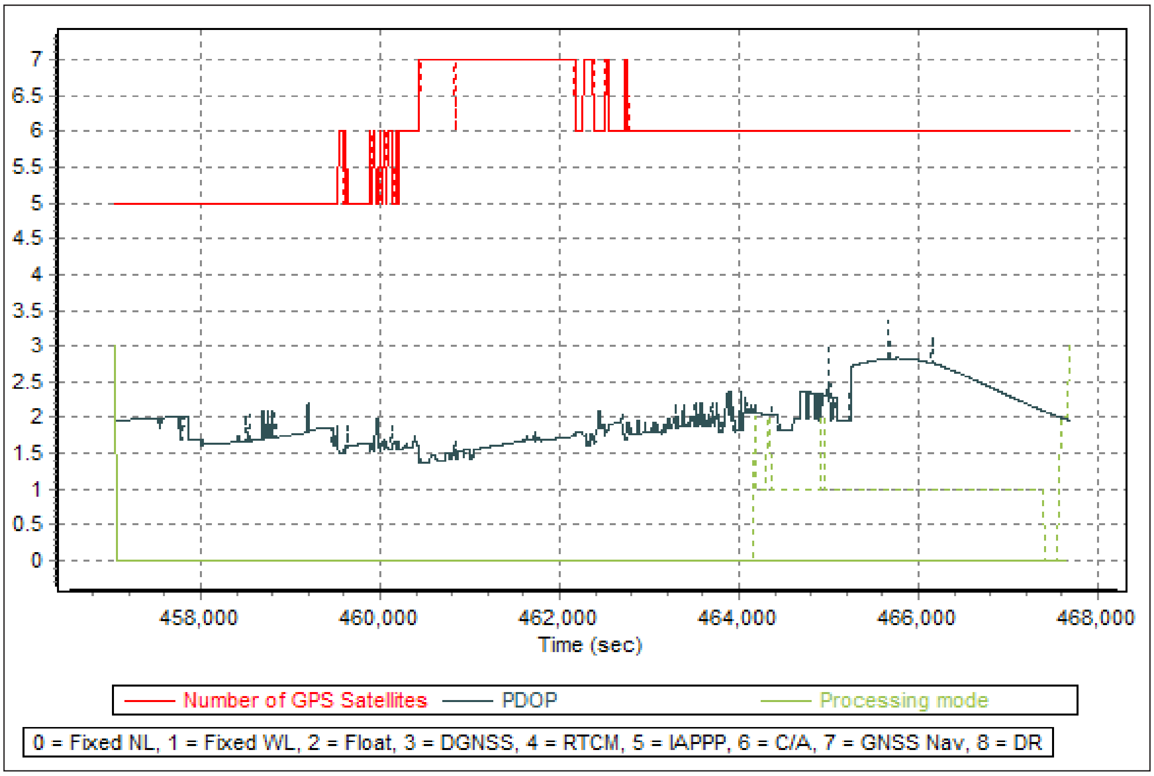


Figure A-8.36. Solution Status

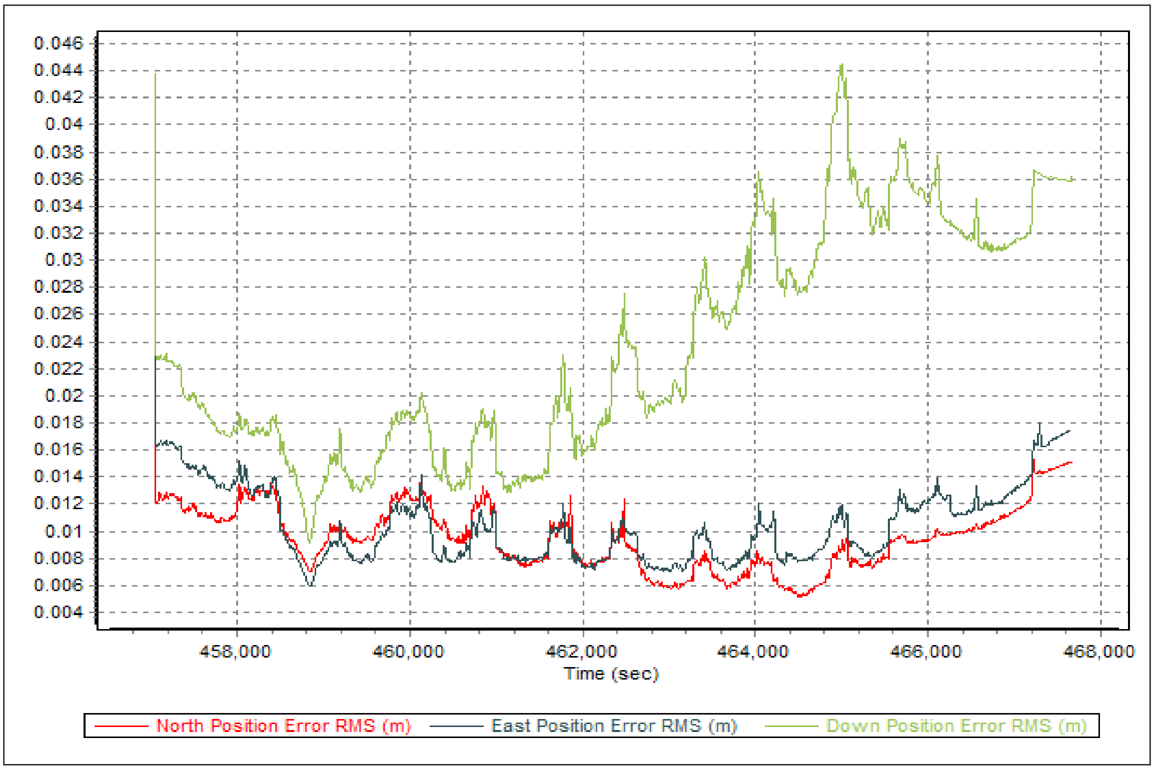


Figure A-8.37. Smoothed Performance Metric Parameters

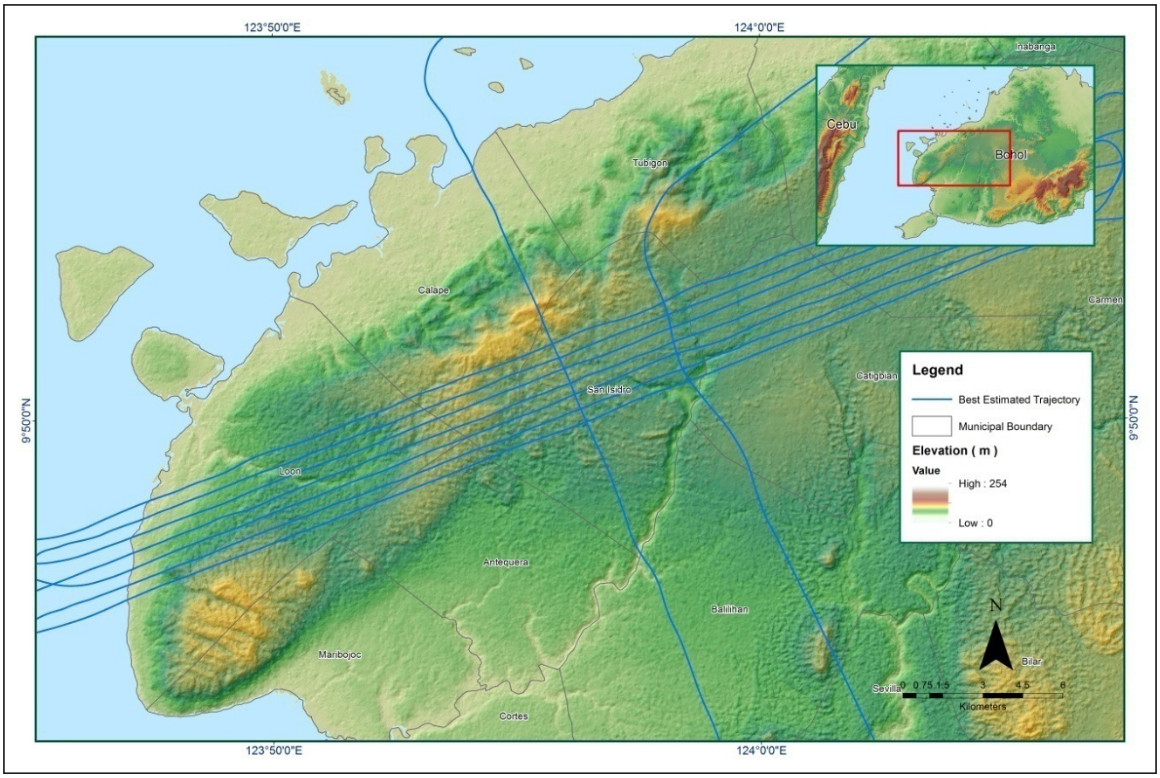


Figure A-8.38. Best Estimated Trajectory

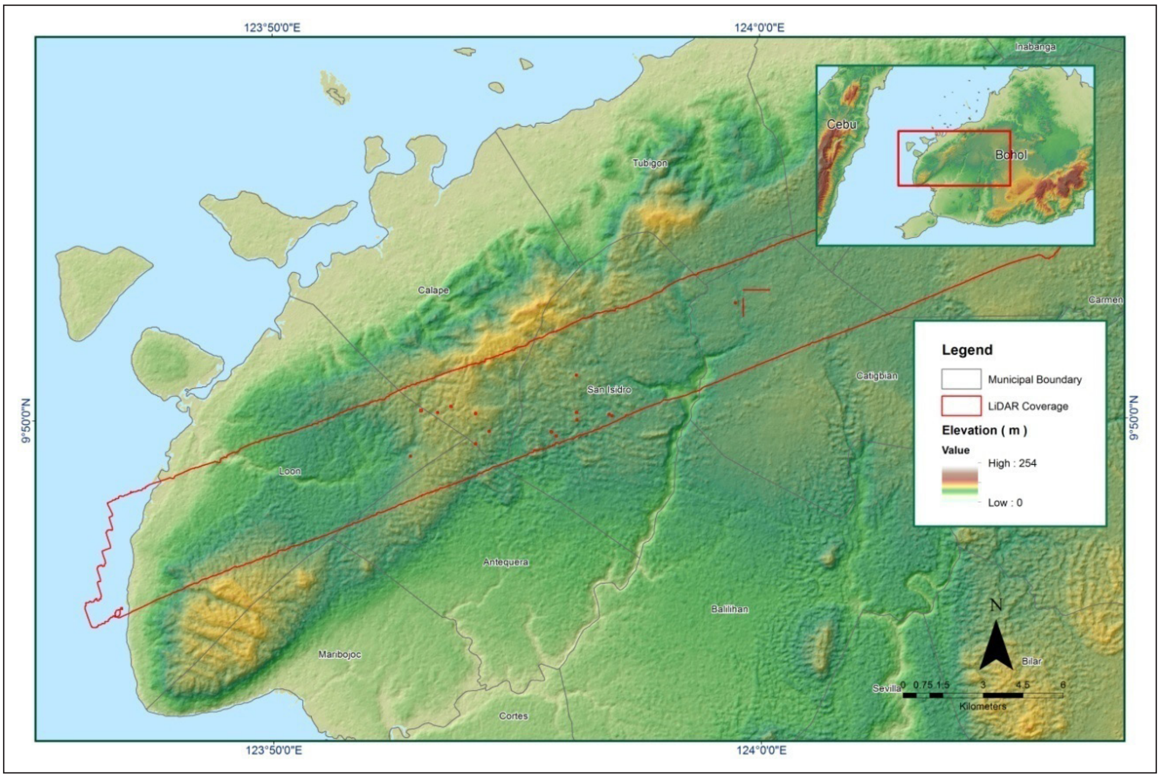


Figure A-8.39. Coverage of LiDAR Data

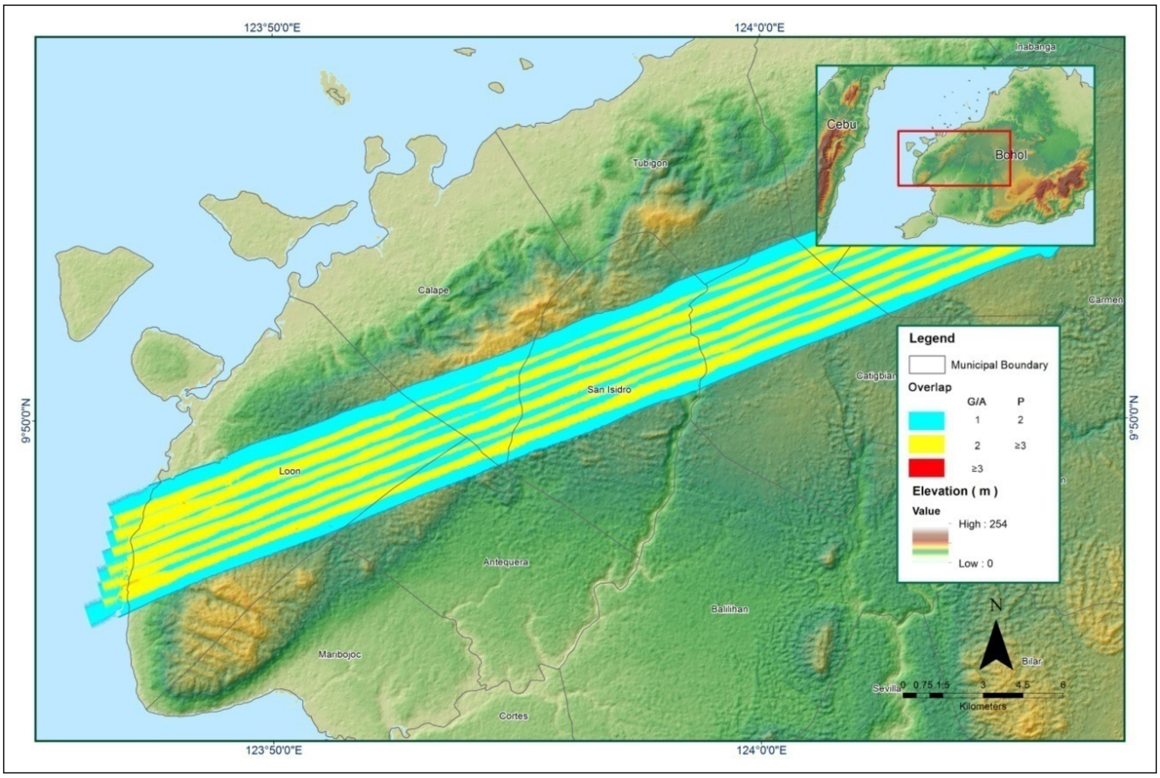


Figure A-8.40. Image of data overlap

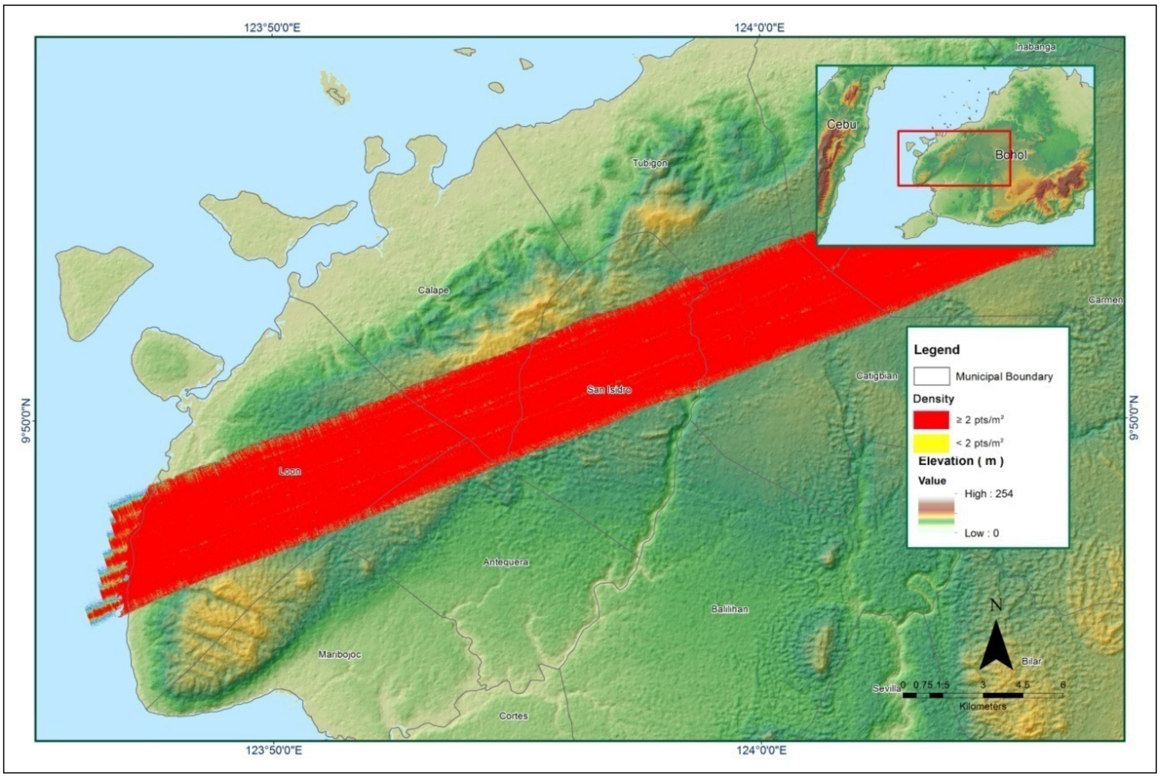


Figure A-8.41. Density map of merged LiDAR data

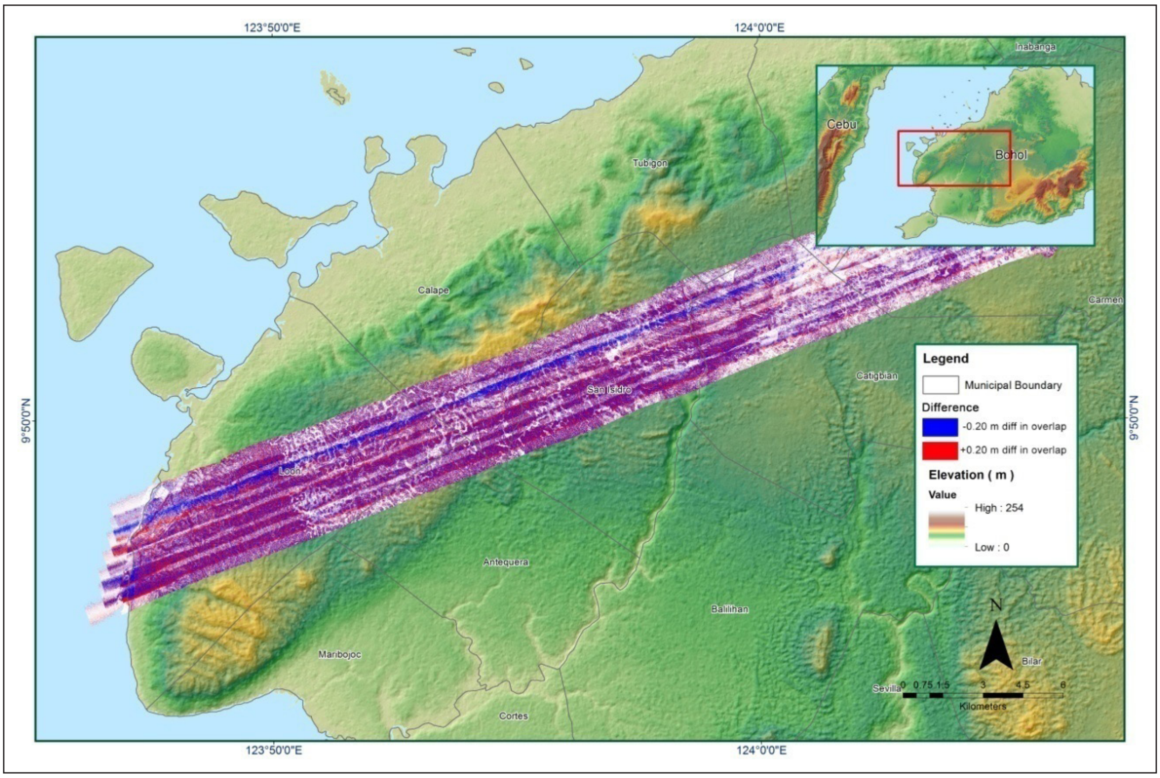


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk1G_supplement

Flight Area	Bohol
Mission Name	**Blk1G_supplement**
Inclusive Flights	795P
Range data size	16.5 GB
POS data size	181 MB
Base data size	10.9 MB
Image	NA
Transfer date	December 3, 2013
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	2.3
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.002957
IMU attitude correction stdev (<0.001deg)	0.124985
GPS position stdev (<0.01m)	0.0020
Minimum % overlap (>25)	4.97
Ave point cloud density per sq.m. (>2.0)	5.55
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	72
Maximum Height	381.44 m
Minimum Height	376.64 m.
Classification (# of points)	
Ground	22,217,677
Low vegetation	15, 308, 214
Medium vegetation	39,848,009
High vegetation	46,779,326
Building	906,498
Orthophoto	No
Processed by	Engr. Mary Celine Vasquez, Engr. Melanie Hingpit, Engr. Jennifer Saguran

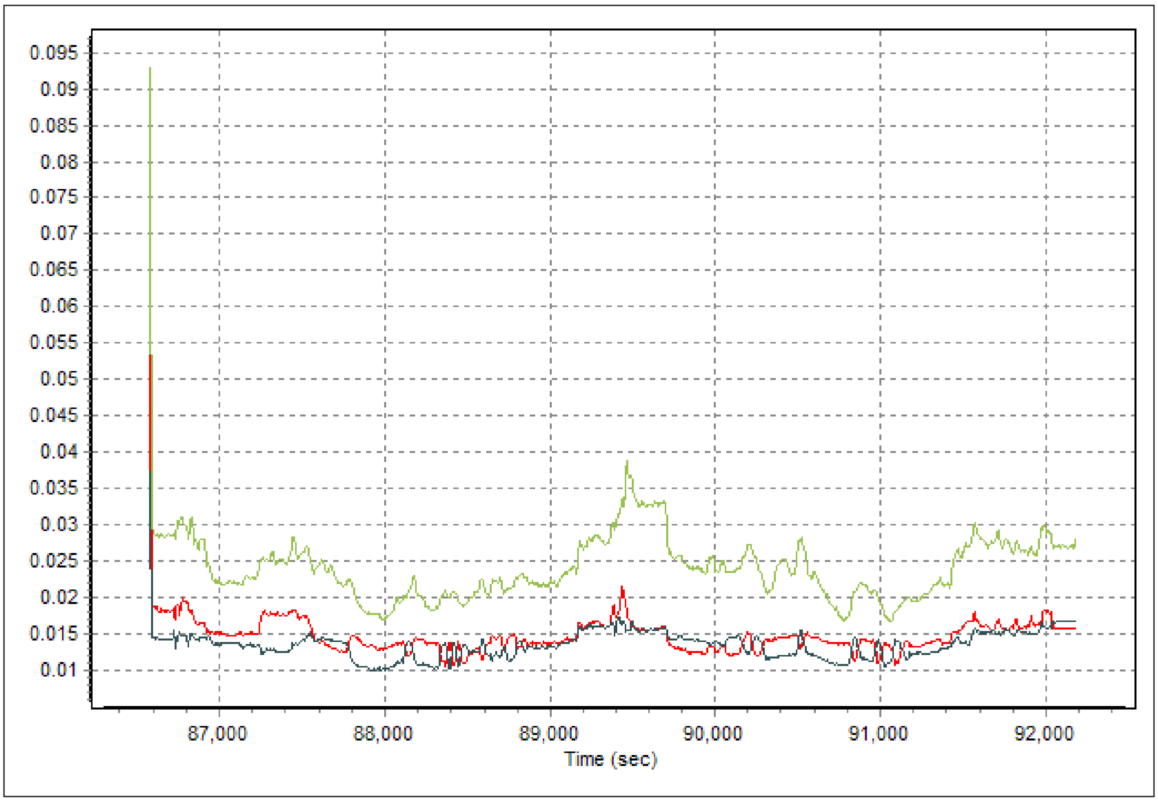


Figure A-8.43. Solution Status

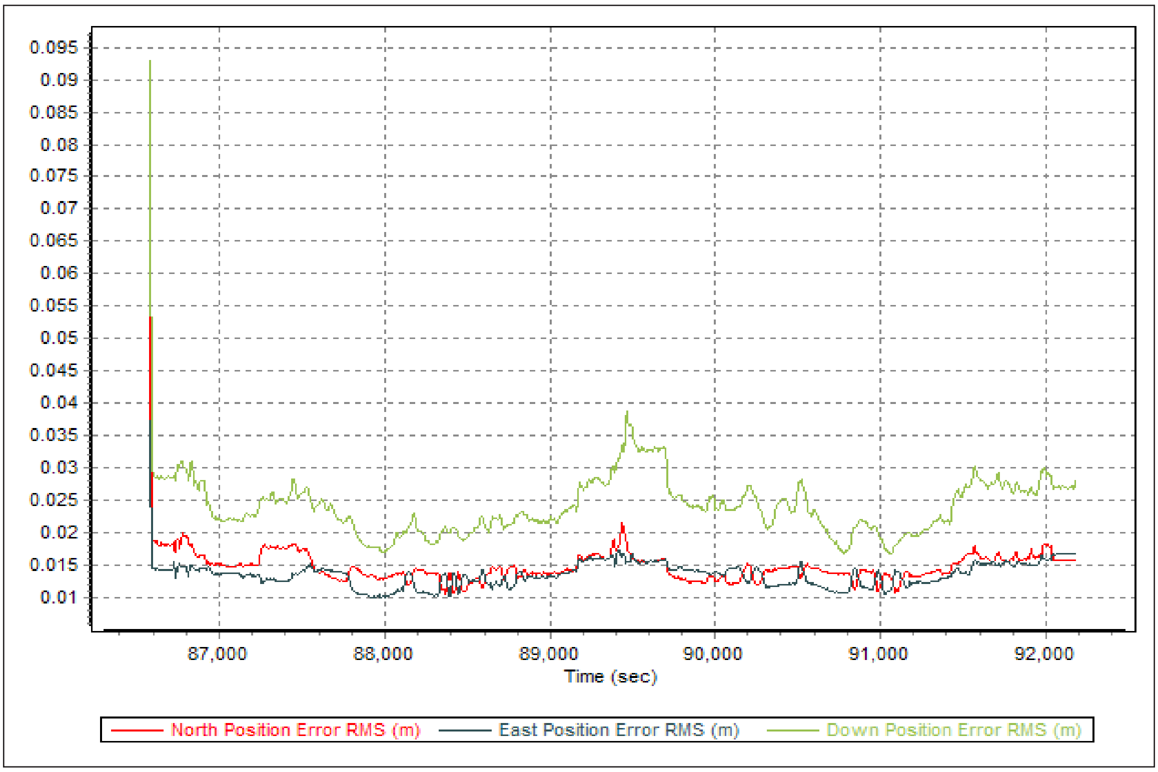


Figure A-8.44. Smoothed Performance Metric Parameters

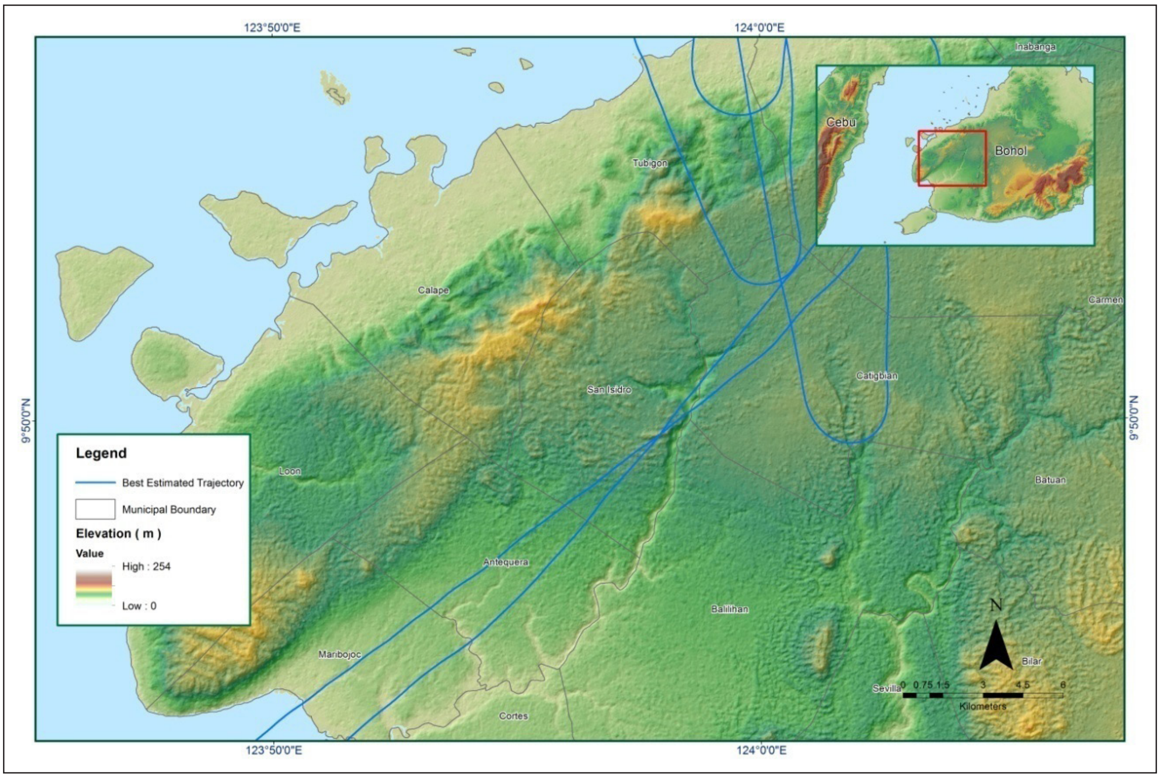


Figure A-8.45. Best Estimated Trajectory

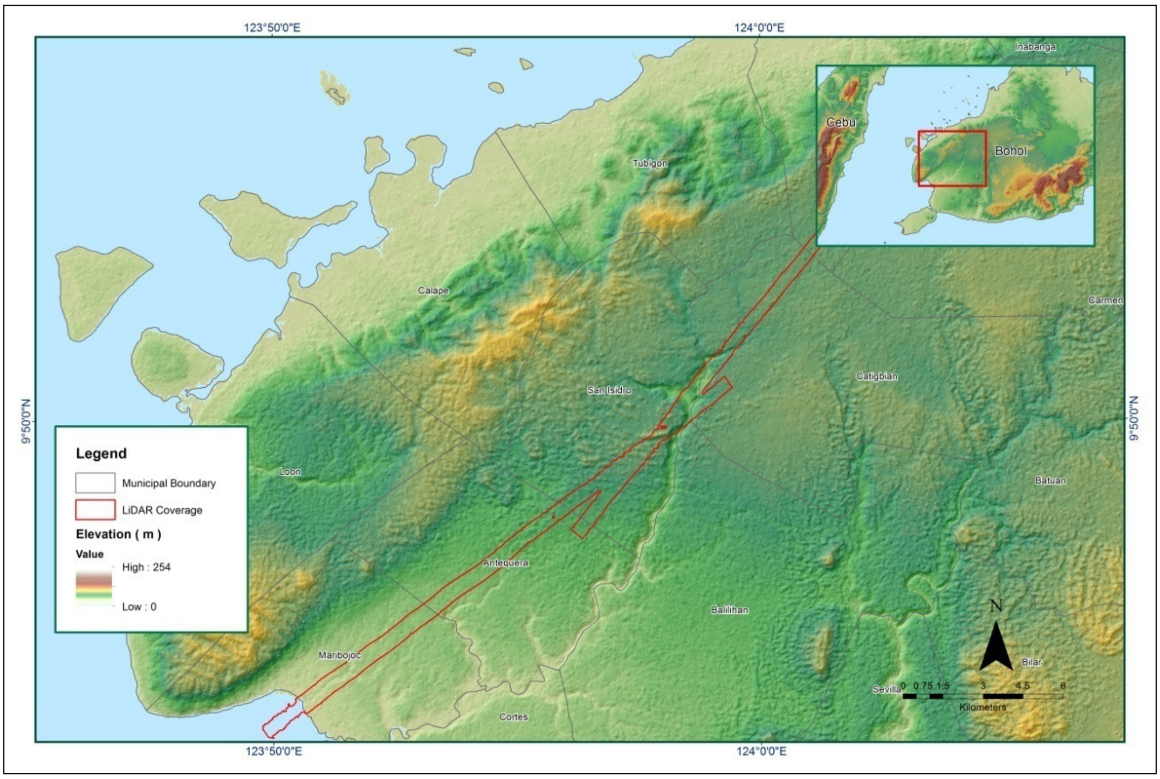


Figure A-8.46. Coverage of LiDAR Data

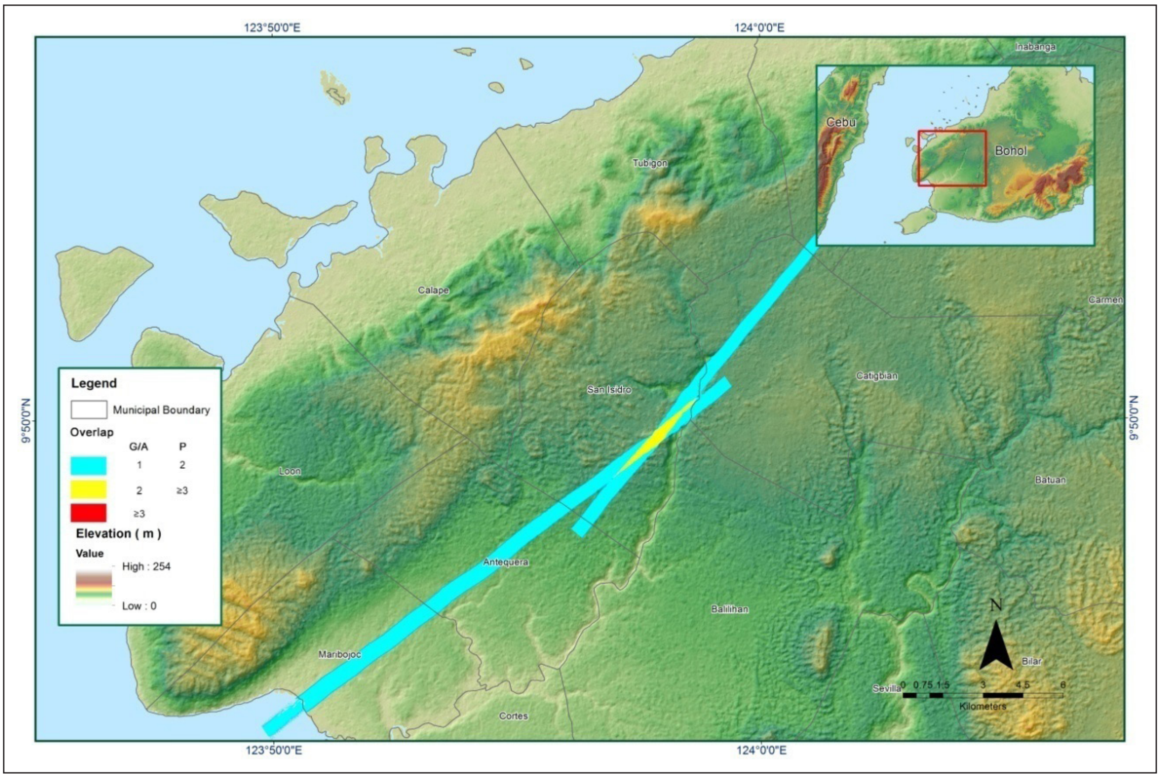


Figure A-8.47. Image of data overlap

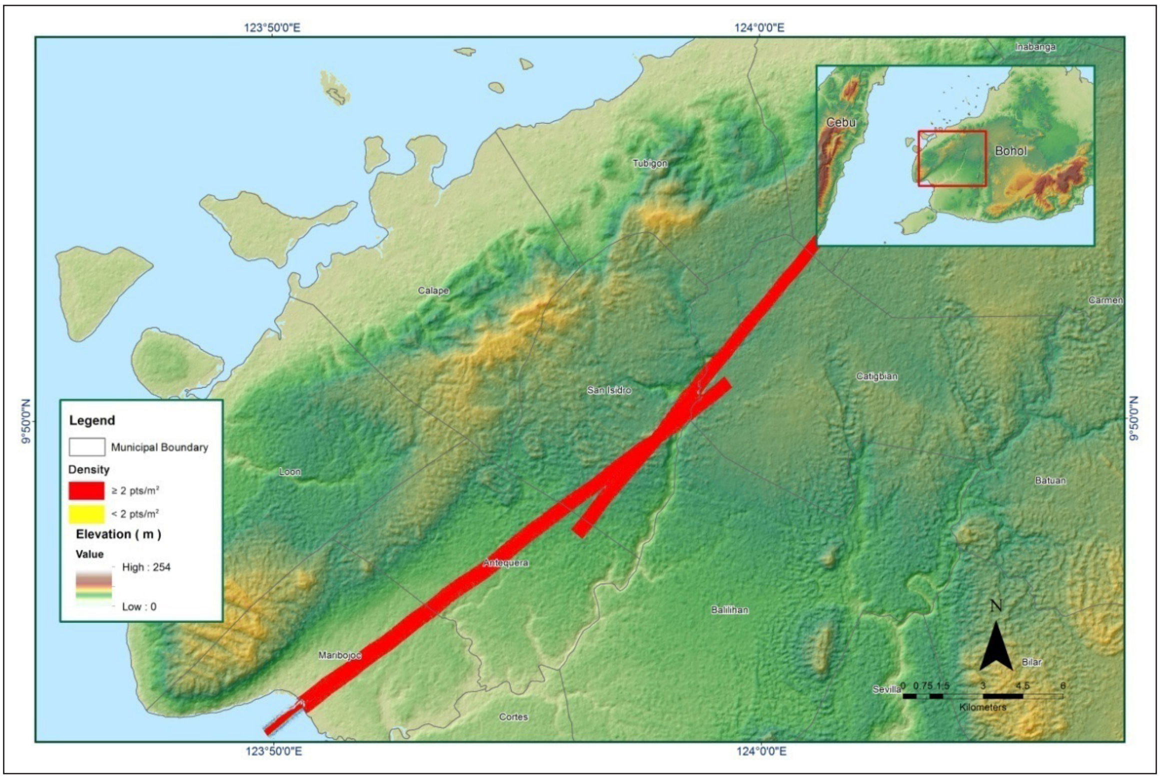


Figure A-8.48. Density map of merged LiDAR data

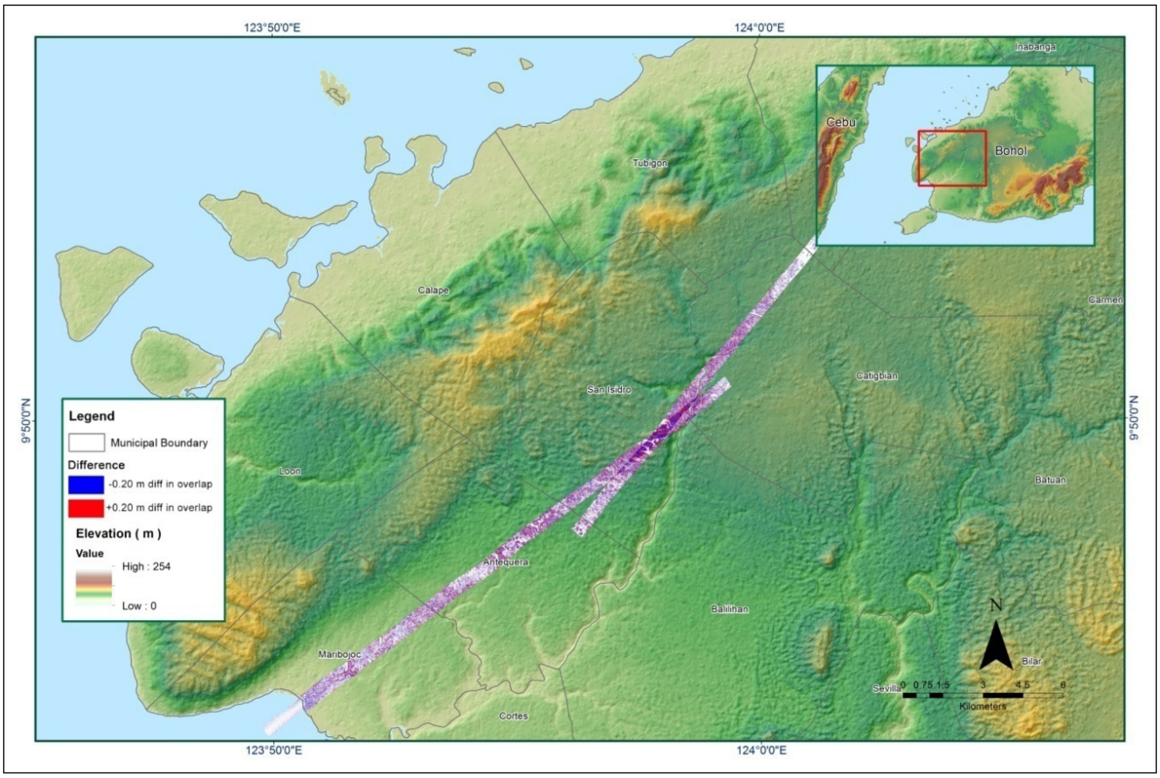


Figure A-8.49. Elevation difference between flight lines

Table A-8.8. Mission Summary Report for Mission Blk1G_supplement2

Flight Area	Bohol
Mission Name	**Blk1G_supplement2**
Inclusive Flights	825P
Range data size	16.8 GB
POS data size	198 MB
Base data size	13.7 MB
Image	NA
Transfer date	December 11,2013
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics(in cm)	
RMSE for North Position (<4.0 cm)	1.1
RMSE for East Position (<4.0 cm)	2.3
RMSE for Down Position (<8.0 cm)	5.1
Boresight correction stdev (<0.001deg)	0.000509
IMU attitude correction stdev (<0.001deg)	0.001423
GPS position stdev (<0.01m)	0.0013
Minimum % overlap (>25)	57.31
Ave point cloud density per sq.m. (>2.0)	3.33
Elevation difference between strips (<0.20m)	Yes
Number of 1km x 1km blocks	72
Maximum Height	398.17 m
Minimum Height	74.11 m
Classification (# of points)	
Ground	31,454,112
Low vegetation	20,073,082
Medium vegetation	56,308,942
High vegetation	70,114,927
Building	987,974
Orthophoto	
Processed by	Engr. Jennifer Saguran, Engr. Christy Lubiano, Simonette Lat

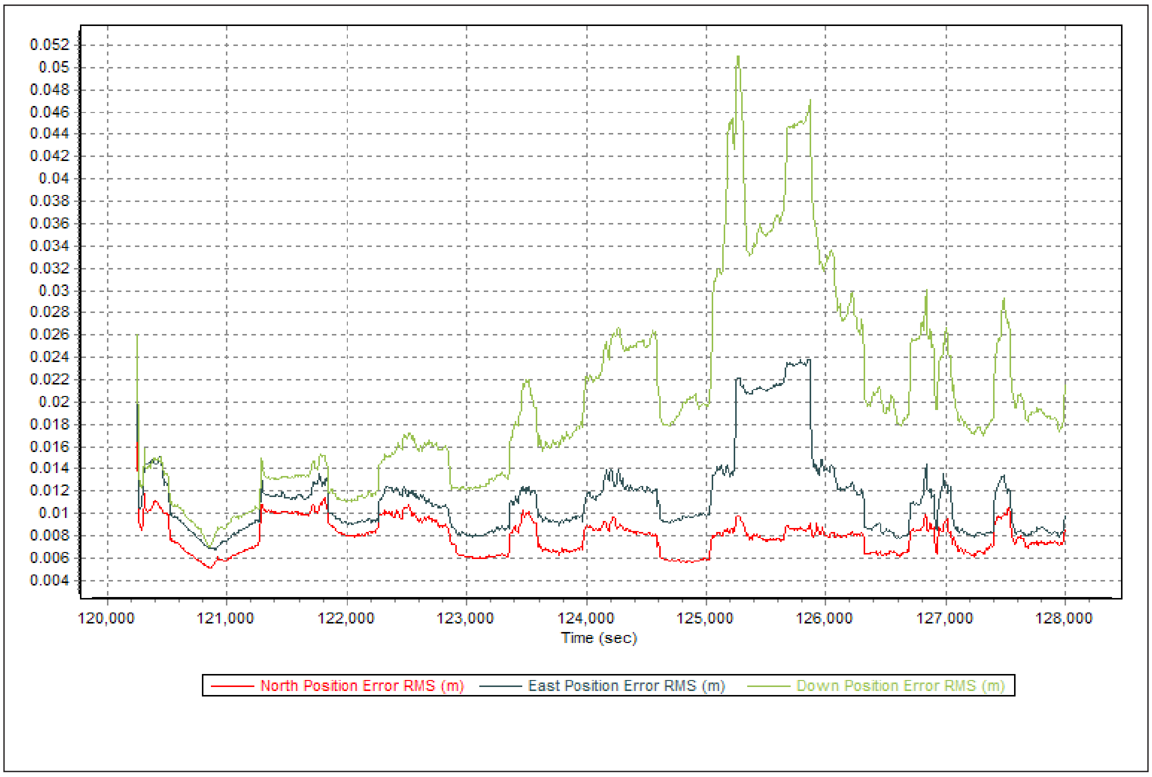


Figure A-8.50. Solution Status

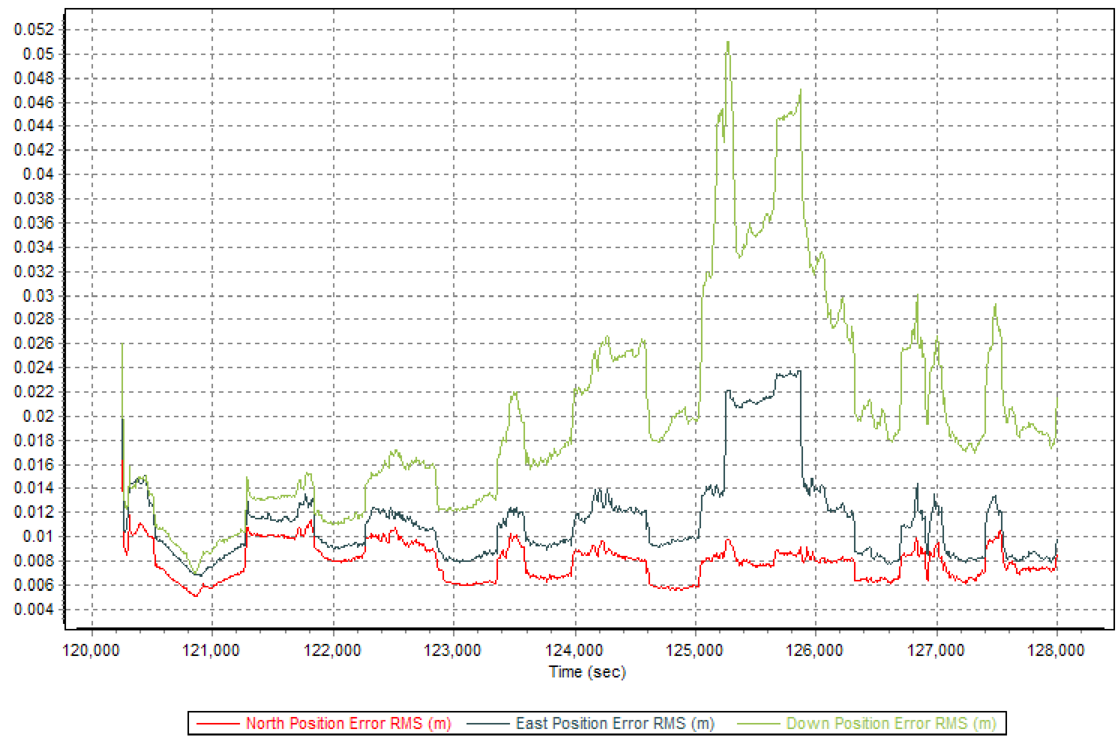


Figure A-8.51. Smoothed Performance Metric Parameters

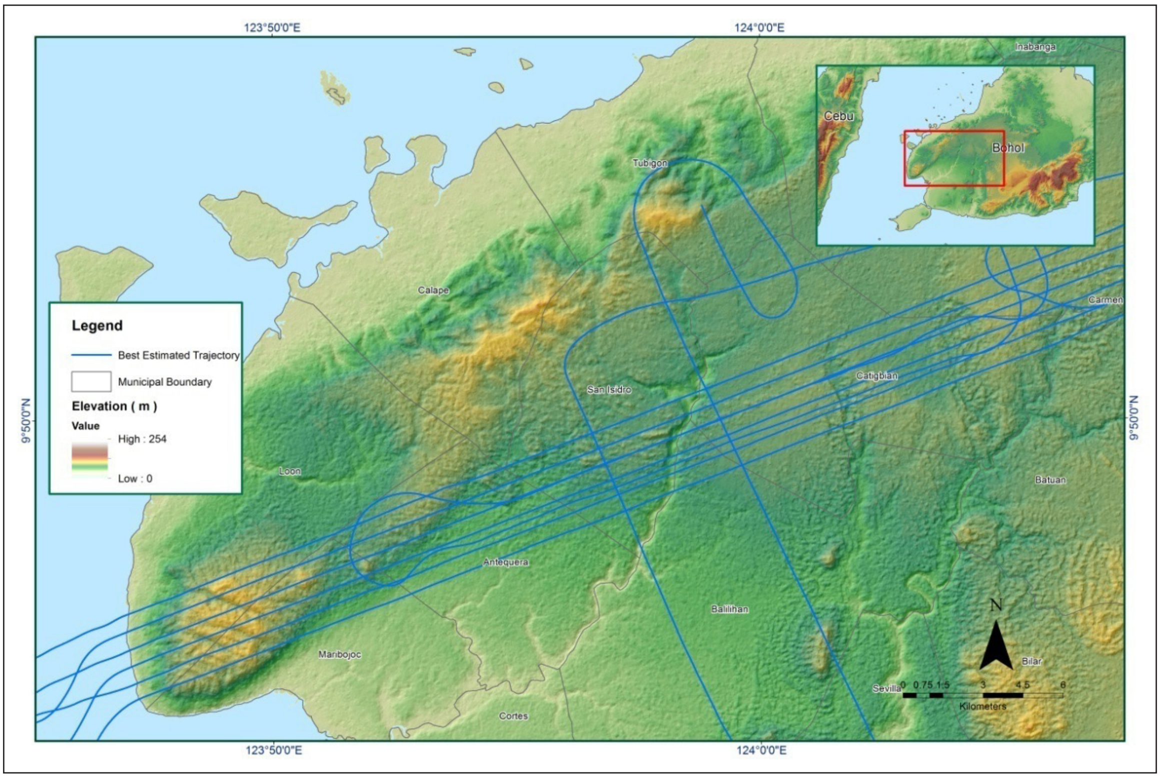


Figure A-8.52. Best Estimated Trajectory

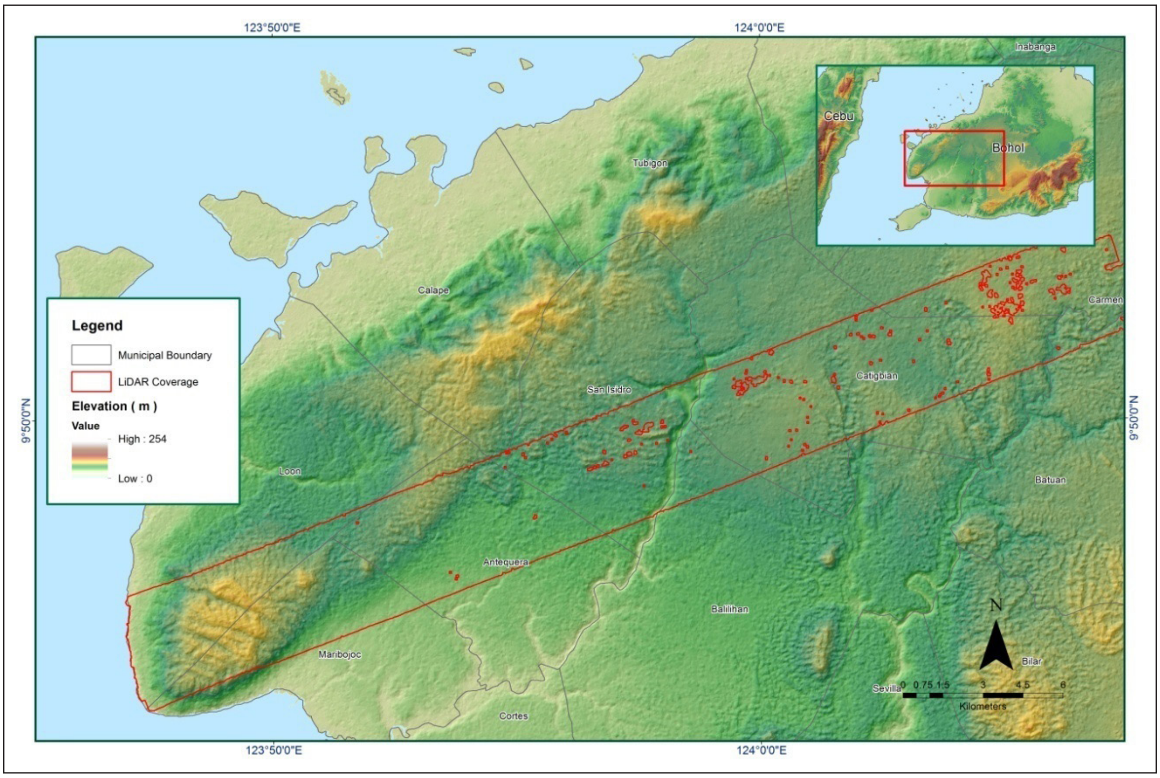


Figure A-8.53. Coverage of LiDAR Data

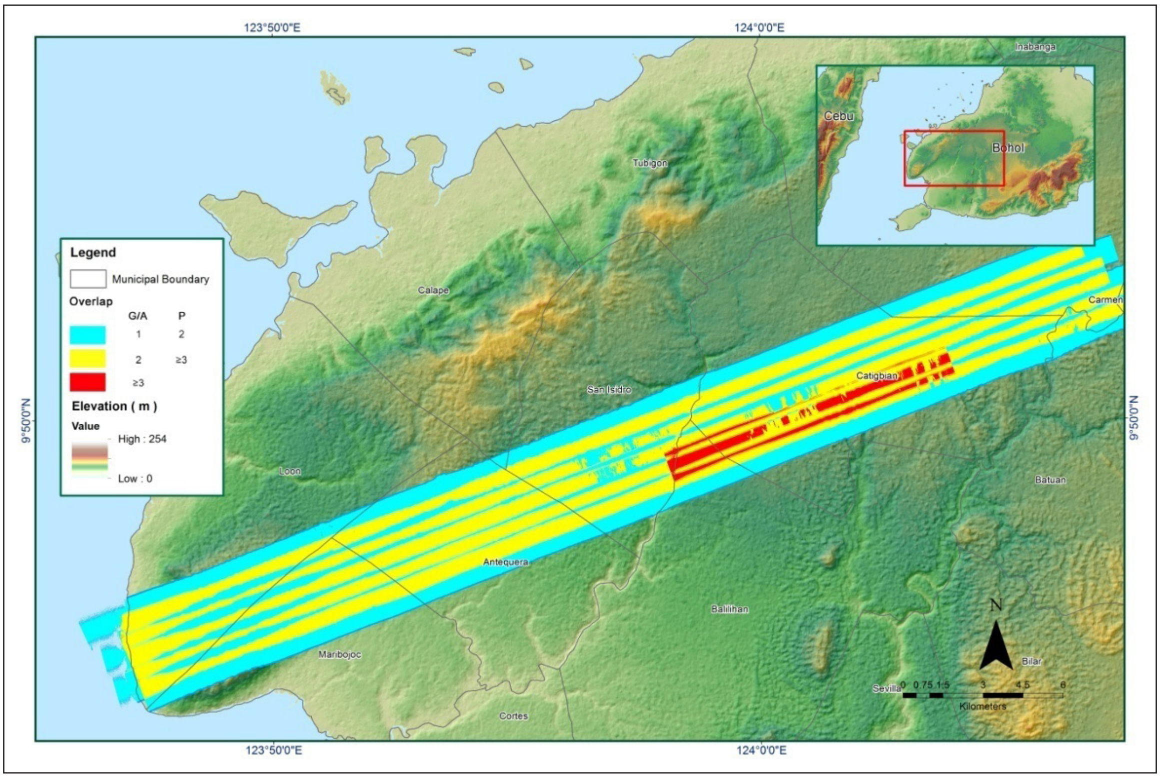


Figure A-8.54. Image of data overlap

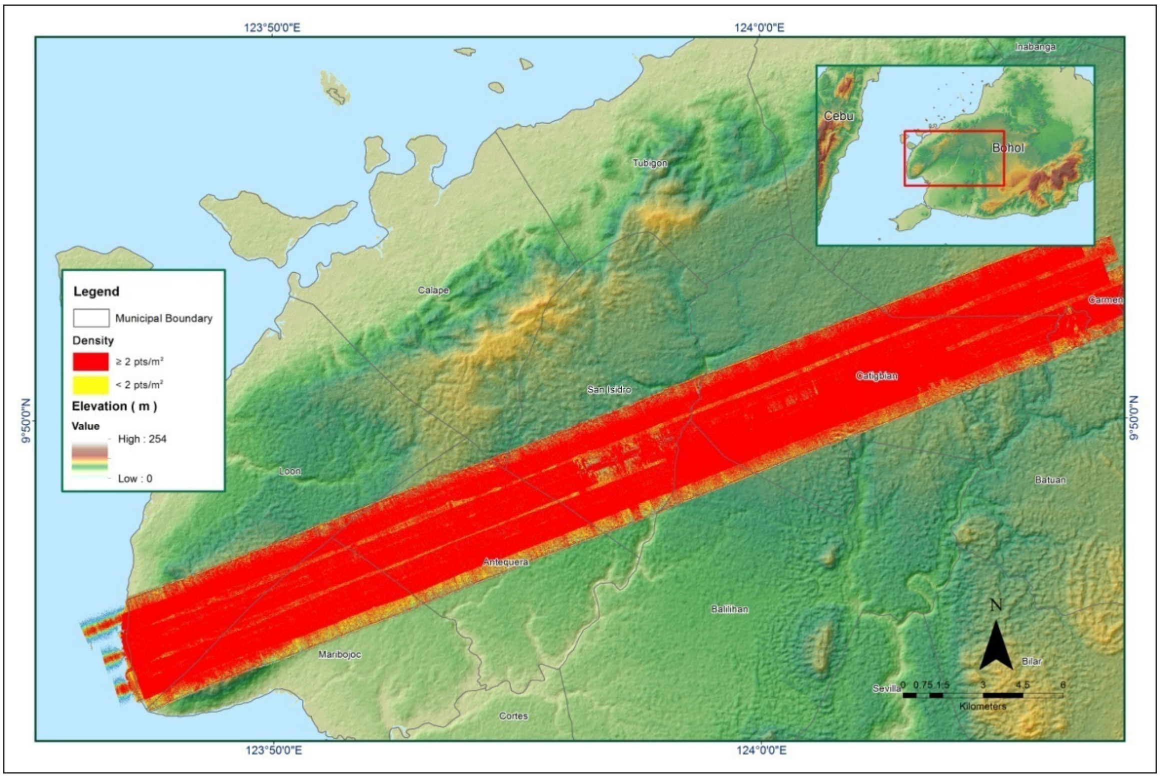


Figure A-8.55. Density map of merged LiDAR data

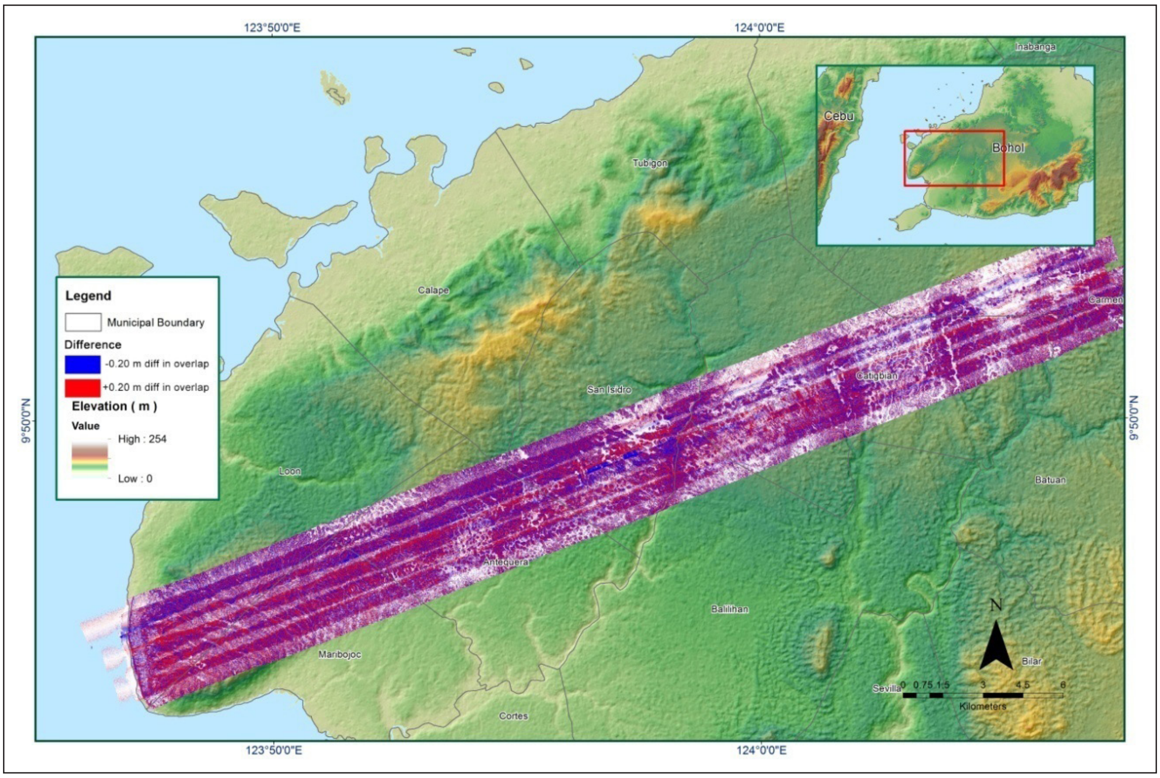


Figure A-8.56. Elevation difference between flight lines

Table A-8.9. Mission Summary Report for Mission TAGBILARAN

Flight Area	**Bohol**
Mission Name	**TAGBILARAN**
Inclusive Flights	741P
Mission Name	1TGB315A
Range data size	14.5 GB
POS	220 MB
Image	NONE
Transfer date	December 3, 2013
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.8
RMSE for East Position (<4.0 cm)	1.15
RMSE for Down Position (<8.0 cm)	3.6
Boresight correction stdev (<0.001deg)	0.000330
IMU attitude correction stdev (<0.001deg)	0.000704
GPS position stdev (<0.01m)	0.0066
Minimum % overlap (>25)	51.65%
Ave point cloud density per sq.m. (>2.0)	4.48
Elevation difference between strips (<0.20 m)	
Number of 1km x 1km blocks	129
Maximum Height	291.97 m
Minimum Height	49.56 m
Classification (# of points)	
Ground	66,433,404
Low vegetation	73,526,940
Medium vegetation	177,230,329
High vegetation	171,885,366
Building	17,999,815
Orthophoto	No
Processed by	Engr. Carlyn Ann Ibanez, Engr. Harmond Santos, Engr. Gladys Mae Apat

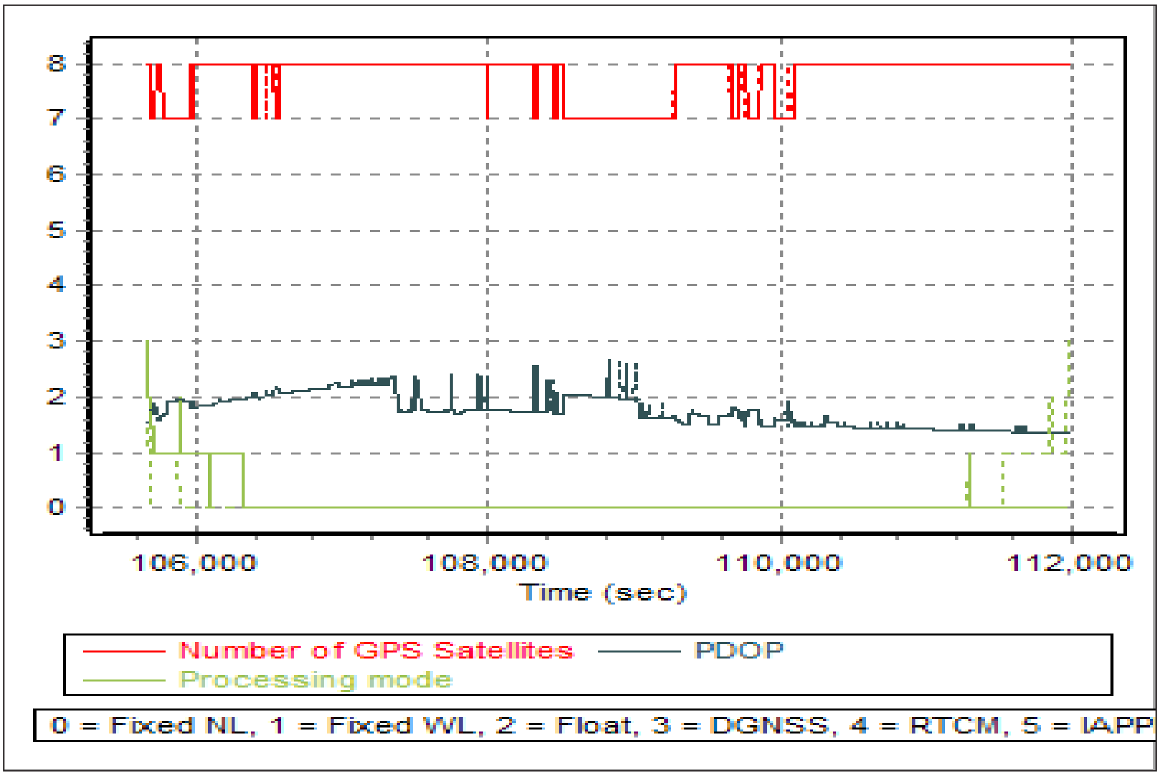


Figure A-8.57. Solution Status

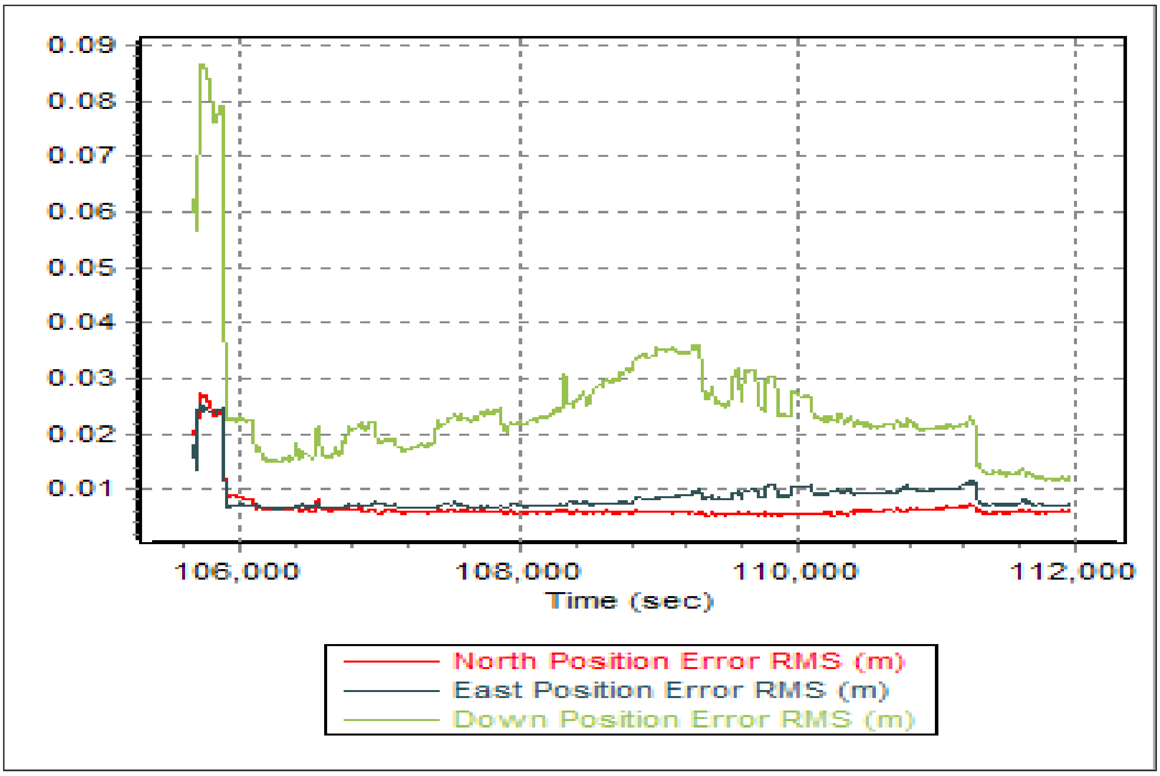


Figure A-8.58. Smoothed Performance Metric Parameters

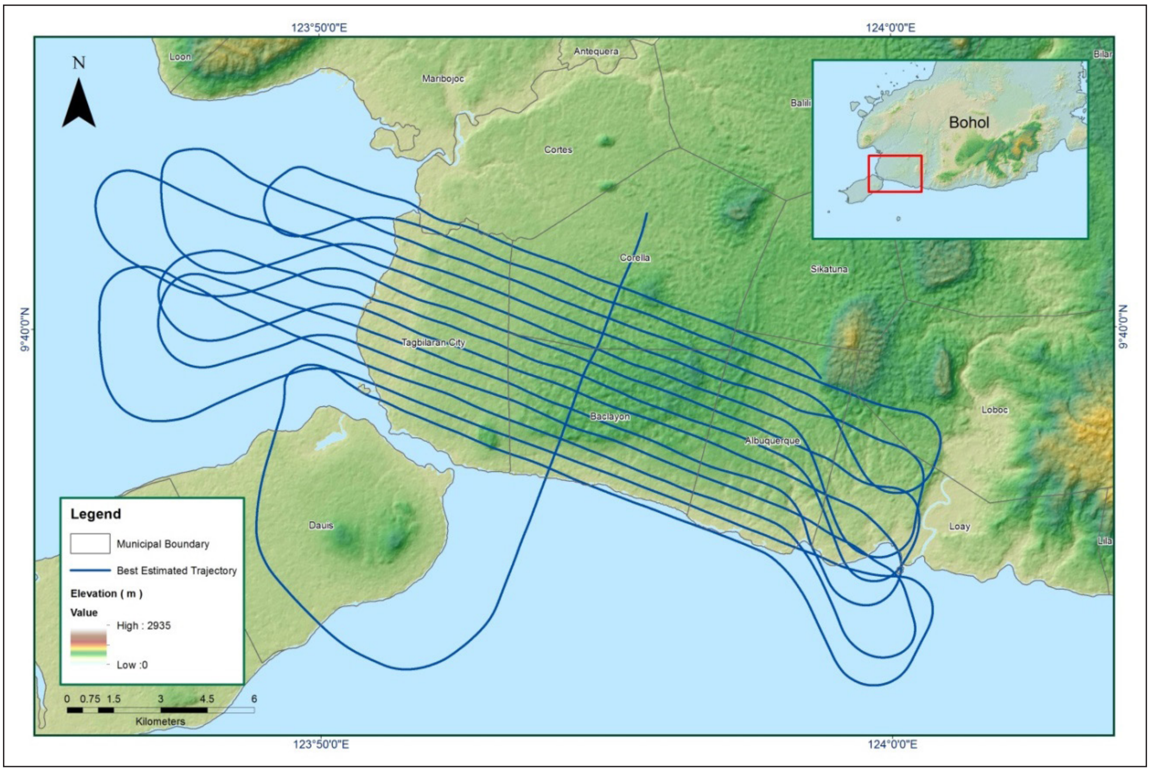


Figure A-8.59. Best Estimated Trajectory

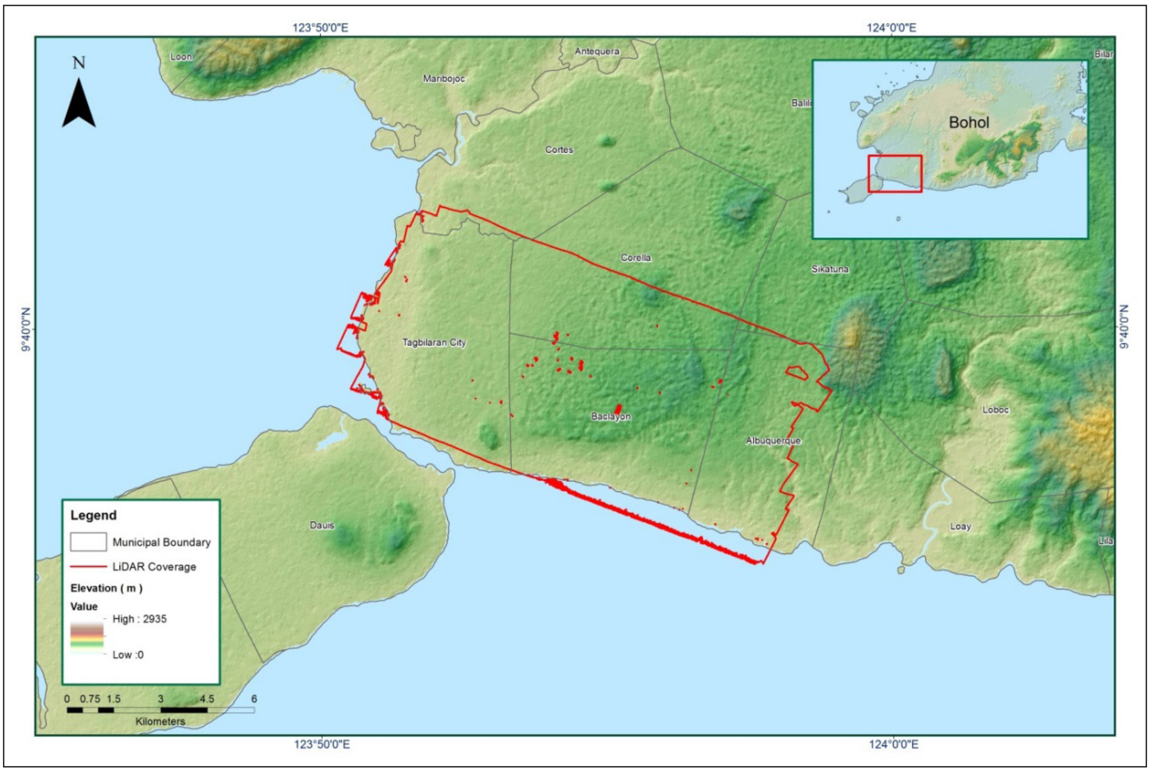


Figure A-8.60. Coverage of LiDAR Data

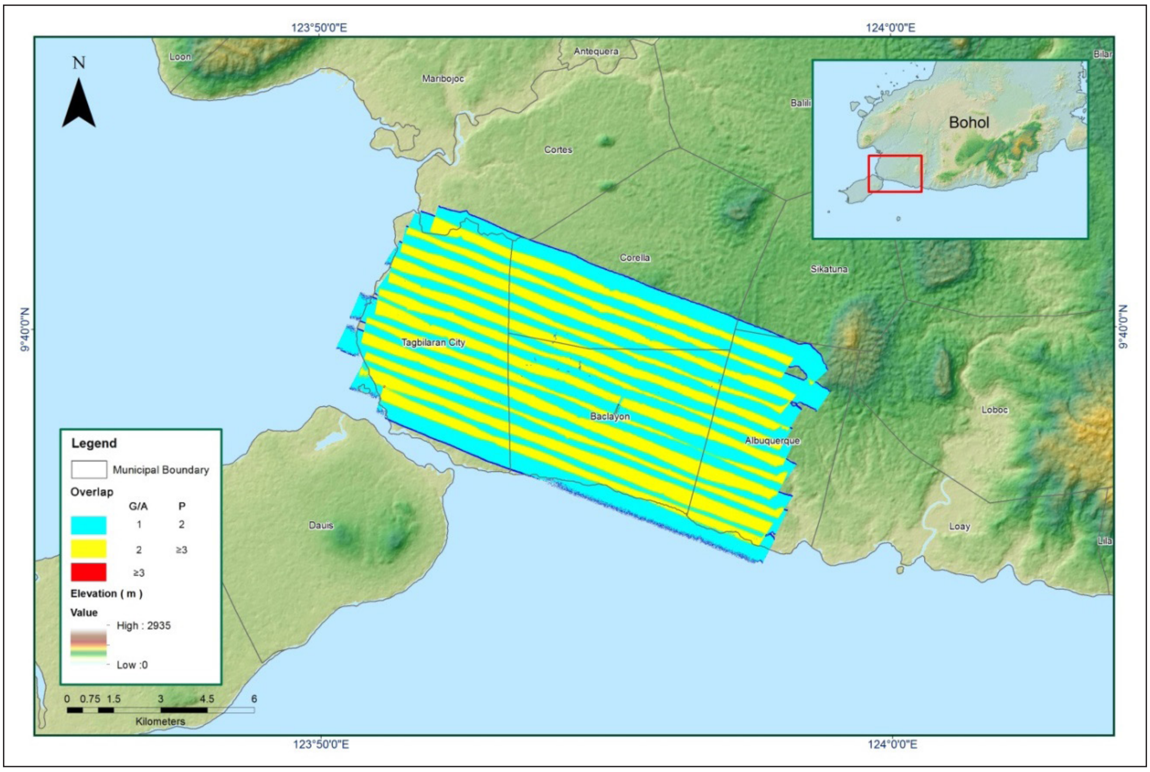


Figure A-8.61. Image of data overlap

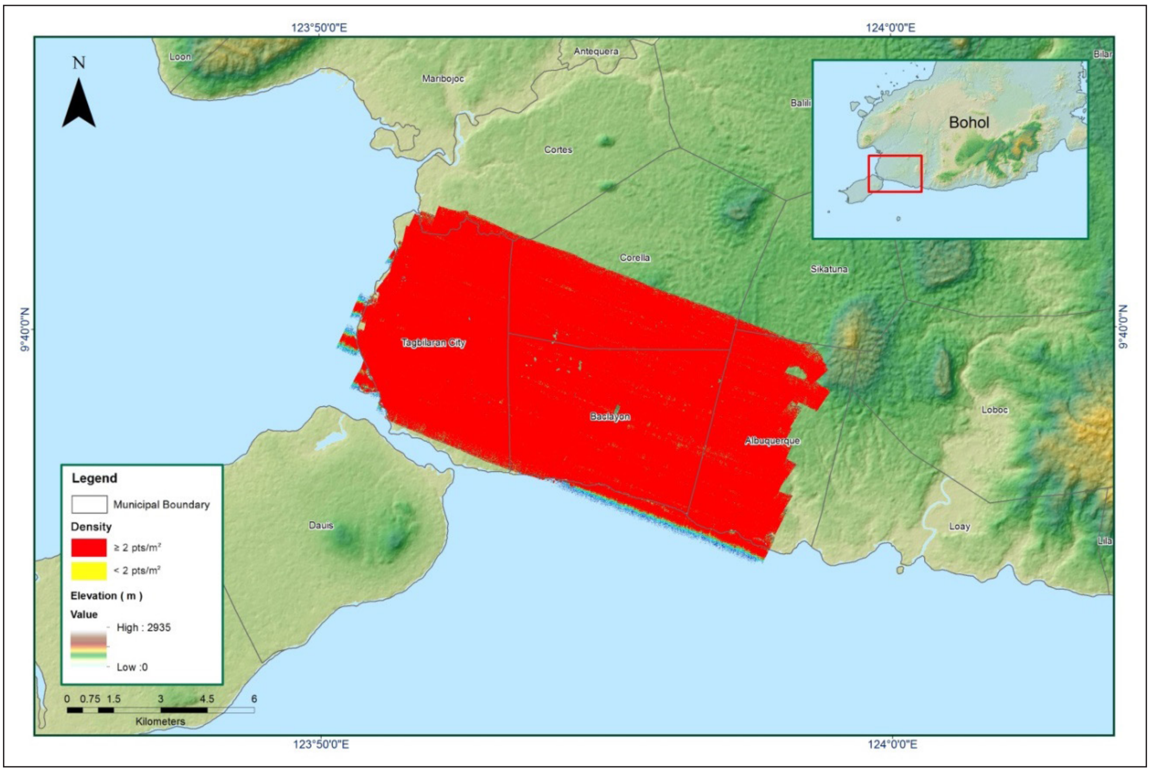


Figure A-8.62. Density map of merged LiDAR data

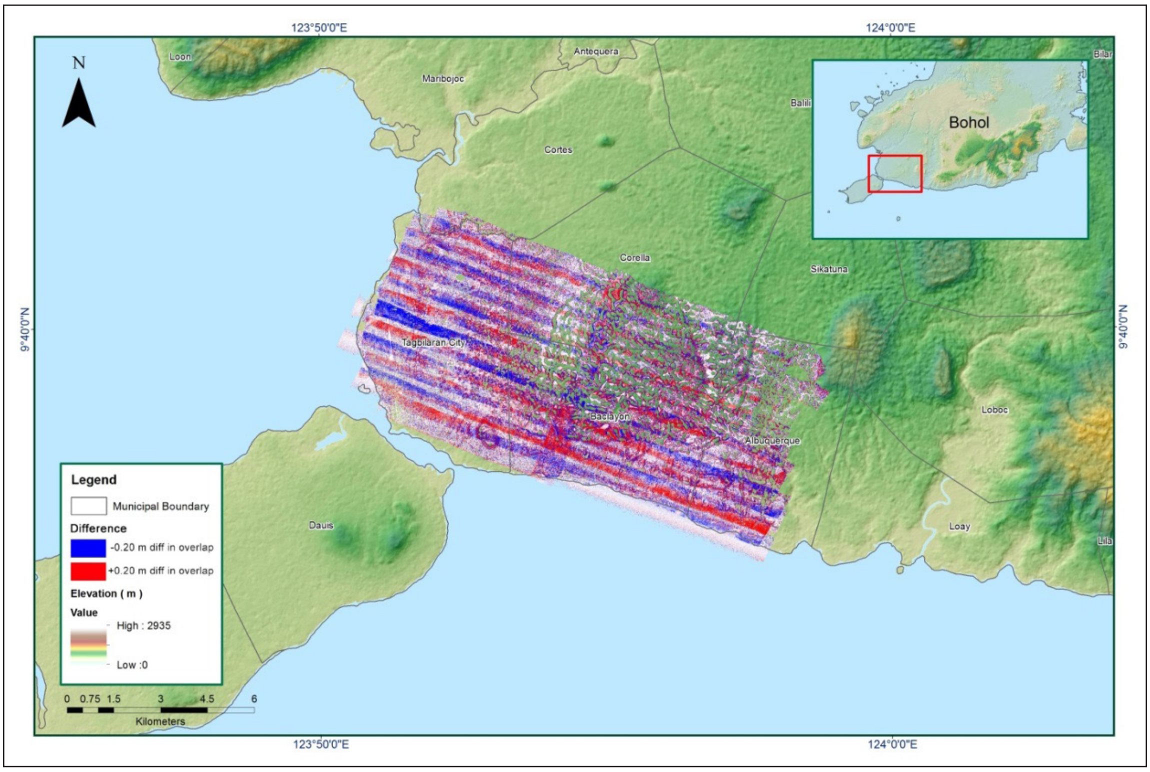


Figure A-8.63. Elevation difference between flight lines

Annex 9. Abatan Model Basin Parameters

Table A-9.1. Abatan 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
W120	8.3858	60.24705	0	11.127	4.6833	Discharge	0.14261	0.17157	Ratio to Peak	0.07
W130	6.8525	44.524455	0	12.933	6.0909	Discharge	0.15307	0.26387	Ratio to Peak	0.07
W140	8.278	58.838055	0	14.194	3.6969	Discharge	0.13726	0.25735	Ratio to Peak	0.07
W150	9.2702	59.547345	0	1.6045	3.3737	Discharge	0.15816	0.11909	Ratio to Peak	0.064
W160	11.416	67.29522	0	8.476	2.0972	Discharge	0.0871803	0.17952	Ratio to Peak	0.0667
W170	7.891	72.52011	0	3.0075	3.1753	Discharge	0.0663871	0.11911	Ratio to Peak	0.0279
W180	13.597	57.53556	0	2.0415	4.6763	Discharge	0.073445	0.4	Ratio to Peak	0.0618
W190	9.2681	55.58235	0	3.0752	2.5875	Discharge	0.22396	0.38416	Ratio to Peak	0.0995
W200	8.8644	58.29171	0	3.7208	5.5486	Discharge	0.14518	0.17778	Ratio to Peak	0.0631
W210	9.6224	56.316135	0	3.5629	2.516	Discharge	0.12393	0.26133	Ratio to Peak	0.098
W220	8.951	58.08723	0	1.0626	8.12288	Discharge	0.0735072	0.17778	Ratio to Peak	0.0647

Annex 10. Abatan Model Reach Parameters

Table A-10.1. Abatan Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Slope
R110	Automatic Fixed Interval	2093.3	0.00001	0.0165953	Trapezoid	20	1
R30	Automatic Fixed Interval	7287.1	0.003	0.0883741	Trapezoid	20	1
R60	Automatic Fixed Interval	3229.1	0.0144	0.057996	Trapezoid	20	1
R80	Automatic Fixed Interval	1612.7	0.0016	0.0595493	Trapezoid	20	1
R90	Automatic Fixed Interval	6458.8	0.0167	0.0994014	Trapezoid	20	1

Annex 11. Abatan Field Validation Points

Table A-11.1. Abatan Field Validation Points

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event / Date	Return Period of Event
	Longitude	Latitude					
1	9.743176	123.923906	0.07	0.2	0.0169	Ruby	100-Year
2	9.742985	123.924023	1.83	2	0.0289	Seniang	100-Year
3	9.742961	123.92403	1.83	1.7	0.0169	Seniang	100-Year
4	9.743094	123.92385	0.27	0.2	0.0049	Yolanda	100-Year
5	9.742383	123.922811	2.05	1.7	0.1225	Seniang	100-Year
6	9.742709	123.922815	0.27	0.5	0.0529	Seniang	100-Year
7	9.742676	123.922729	1.86	2	0.0196	Seniang	100-Year
8	9.742614	123.922653	1.86	2.5	0.4096	Seniang	100-Year
9	9.74267	123.922688	1.86	1.8	0.0036	Ruby	100-Year
10	9.742745	123.922795	0.27	0.2	0.0049	Seniang	100-Year
11	9.742709	123.922802	0.27	0.3	0.0009	Seniang	100-Year
12	9.742191	123.924419	0.03	2.2	4.7089	Yolanda	100-Year
13	9.742215	123.924399	0.03	2.2	4.7089	Yolanda	100-Year
14	9.740878	123.914366	1.88	1.5	0.1444	Seniang	100-Year
15	9.740861	123.914355	1.88	1.2	0.4624	Yolanda	100-Year
16	9.740866	123.914361	1.88	0.9	0.9604	Yolanda	100-Year
17	9.740842	123.914318	2.36	2.5	0.0196	Yolanda	100-Year
18	9.740871	123.914232	3.06	3	0.0036	Yolanda	100-Year
19	9.741024	123.914276	2.64	2.2	0.1936	Seniang	100-Year
20	9.74108	123.914246	2.78	0	7.7284	Yolanda	100-Year
21	9.741596	123.915014	4.28	2.5	3.1684	Yolanda	100-Year
22	9.741632	123.915045	4.41	2.2	4.8841	Seniang	100-Year
23	9.741656	123.915033	4.41	1.9	6.3001	Seniang	100-Year
24	9.74133	123.91525	3.6	1.5	4.41	Seniang	100-Year
25	9.741323	123.915283	3.35	0.9	6.0025	Seniang	100-Year
26	9.741294	123.915333	3.35	0.7	7.0225	Seniang	100-Year
27	9.741073	123.914153	2.57	1.5	1.1449	Yolanda	100-Year
28	9.741103	123.914138	2.57	1.2	1.8769	Yolanda	100-Year
29	9.741045	123.914131	2.64	0.9	3.0276	Yolanda	100-Year
30	9.741082	123.914116	2.57	0.7	3.4969	Yolanda	100-Year
31	9.741056	123.914213	2.57	0.4	4.7089	Yolanda	100-Year
32	9.733563	123.89997	0.15	0	0.0225	Seniang	100-Year
33	9.721157	123.875892	0.04	0.4	0.1296	Seniang	100-Year
34	9.714653	123.874013	0.03	0.8	0.5929	Seniang	100-Year
35	9.714664	123.873939	0.03	0	0.0009	Yolanda	100-Year
36	9.743188	123.923902	0.07	0.5	0.1849	Yolanda	100-Year
37	9.741106	123.909542	0.03	0.2	0.0289	Seniang	100-Year
38	9.742039	123.912337	3.54	2.1	2.0736	Seniang	100-Year
39	9.742087	123.912939	4.02	3	1.0404	Seniang	100-Year
40	9.742346	123.912083	4.56	2.7	3.4596	Seniang	100-Year
41	9.743315	123.909573	3.74	2.1	2.6896	Seniang	100-Year
42	9.743637	123.910216	3.51	1.6	3.6481	Seniang	100-Year
43	9.743753	123.910298	3.62	0.8	7.9524	Seniang	100-Year
44	9.744101	123.910494	3.7	1.2	6.25	Seniang	100-Year
45	9.744239	123.912715	4.29	1.9	5.7121	Seniang	100-Year
46	9.744464	123.911620	1.01	0.7	0.0961	Seniang	100-Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error (m)	Event / Date	Return Period of Event
	Longitude	Latitude					
47	9.744572	123.914902	0.03	0.5	0.2209	Seniang	100-Year
48	9.746652	123.902461	1.5	1.5	0	Seniang	100-Year
49	9.747242	123.901731	0.03	0.3	0.0729	Seniang	100-Year
50	9.747711	123.902454	1.33	1.1	0.0529	Seniang	100-Year
51	9.748032	123.902388	0.99	0.9	0.0081	Seniang	100-Year
52	9.749866	123.902688	0.05	0.3	0.0625	Seniang	100-Year
53	9.750049	123.903019	0.03	0.5	0.2209	Seniang	100-Year
54	9.750385	123.902981	0.19	0.2	0.0001	Seniang	100-Year
55	9.750713	123.903289	0.06	0.2	0.0196	Seniang	100-Year
56	9.752157	123.903110	0.39	0.5	0.0121	Seniang	100-Year
57	9.752449	123.902437	0.53	0.9	0.1369	Seniang	100-Year
58	9.753168	123.902235	0.24	0.7	0.2116	Seniang	100-Year

Annex 12. Educational Institutions Affected by Flooding in Abatan Floodplain

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

Bohol				
Antequera				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ANGILAN ELEMENTARY SCHOOL	Angilan			
BUNGAHAN ELEMENTARY SCHOOL	Bungahan			
ANTEQUERA SENTRAL SCHOOL	Poblacion	Low	Medium	Medium
CHRIST THE KING ACADEMY	Poblacion			
CHRIST THE KING ACADEMY (SHELTER)	Poblacion			

Balilihan				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
CONG. PABLO MALASARIO NATIONAL HIGH SCHOOL	Candasig			
DATAG NORTE ELEMENTARY SCHOOL	Datag Sur			
OUR LADY OF MT. CARMEL ACADEMY	Del Carmen Norte			
BOHOL ISLAND STATE UNIVERSITY-BALILIHAN	Del Carmen Sur	Low	Medium	Medium
BOHOL ISLAND UNIVERSITY-BALILIHAN	Del Carmen Sur	Low	Medium	Medium
BALILIHAN CENTRAL ELEMENTARY SCHOOL	Del Carmen Weste			
DAYCARE CENTER	Del Carmen Weste		Low	Low
DOROL ELEMENTARY SCHOOL	Dorol			
DOROL MULTIPURPOSE BUILDING	Dorol			
PATROCINIO ELEMENTARY SCHOOL	Magsija			

Corella				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
ANILAG ELEMENTARY SCHOOL	Anislag		Low	Low
ANISAG ELEMENTARY SCHOOL	Anislag			
ANISLAG ELEMENTARY SCHOOL	Anislag			
CANANGCAAN ELEMENTARY SCHOOL	Canangca-An			
CANAPNAPAN ELEMENTARY SCHOOL	Canapnapan			
CORELLA ELEMENTARY SCHOOL	Poblacion			
CORELLA NATIONAL HIGH SCHOOL	Poblacion			
SAMBOG ELEMENTARY SCHOOL	Sambog			
PAYAHAN ELEMENTARY SCHOOL	Tanday			

Cortes				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BASILIO GAROTE LIBRARY	De La Paz		Low	Low
DELA PAZ ELEMENTARY SCHOOL	De La Paz	Low	Low	Low
DELA PAZ ELEMENTARY SCHOOL ANNEX	De La Paz			

GOLDEN LINK COLLEGE	De La Paz			
WELDING TRAINING CENTER	De La Paz			
FATIMA ELEMENTARY SCHOOL	Fatima			
BRGY. LORETO DAY CARE CENTER	Loreto	Low	Low	Low
LORETO ELEMENTARY SCHHOL	Loreto			
LOURDES ELEMENTARY SCHOOL	Lourdes			
MALAYO NORTE ELEMENTARY SCHOOL	Malayo Norte			
NEW LOURDES ELEMENTARY SCHOOL	New Lourdes			
CORTES CENTRAL ELEMENTARY SCHOOL	Poblacion			
ROSARIO PRIMARY SCHOOL	Rosario			
SAN ROQUE ELEMENTARY SCHOOL	San Roque			
UPPER DELA PAZ PRIMARY SCHOOL	Upper de la Paz			

Maribojoc				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
AGAHAY PRIMARY SCHOOL	Agahay			
ALIGUAY PRIMARY SCHOOL	Aliguay			
MARIBOJOC CENTRAL ELEMENTARY SCHOOL	Anislag			
SAN PEDRO CALUNGSOD MISSION SCHOOL INC.	Anislag	Medium	Medium	Medium
BRGY.BUSAO DAYCARE CENTER	Busao		Low	Medium
BUSAO DAY CARE CENTER	Busao			Medium
BUSAO ELEMENTARY SCHOOL	Busao		Low	Low
BUSAO NATIONAL HIGH SCHOOL	Busao			
CABAWAN ELEMENTARY SCHOOL	Cabawan			
LINCOD ELEMENTARY SCHOOL	Lincod			
PUNSOD DAY CARE CENTER	Punsod			
SAN ROQUE ELEMENTARY SCHOOL	San Roque			
SAN PEDRO CALUNGSOD MISSION SCHOOL INC.	San Vicente	Medium	Medium	Medium
TORIL PRIMARY SCHOOL	Toril			

Sikatuna				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
ABUCAY ELEMENTARY SCHOOL	Abucay Norte			
BAHAY-BAHAY BARANGAY HALL	Bahaybahay			

Tagbilaran				
Building Name	**Barangay**	**Rainfall Scenario**		
		5-year	**25-year**	**100-year**
GREAT MOMDS LEADERSHIP ACADEMY	Dao		Low	Low
MANGA ELEMENTARY SCHOOL	Manga			
MANGA NATIONAL HIGH SCHOOL	Manga	Low	Low	Medium
ROYAL CHRISTIAN SCHOOL	San Isidro			
SAN ISIDRO ELEMENTARY SCHOOL	San Isidro			
BOHOL INTERNATIONAL LEARNING CENTER	Tiptip			
TIPTIP ELEMENTARY SCHOOL	Tiptip			
MANGA NATIONAL HIGH SCHOOL	Ubujan		Low	Low

Annex 13. Medical Institutions Affected by Flooding in Abatan Floodplain

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

Bohol				
Corella				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
CORELLA RURAL HEALTH OFFICE	Poblacion			

Cortes				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
BRGY. LORETO HEALTH CENTER	Loreto			
RURAL HEALTH UNIT	Poblacion			
RURAL HEALTH UNIT EXPANSION	Poblacion			

Maribojoc				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
SAN ROQUE HEALTH CENTER	San Roque			