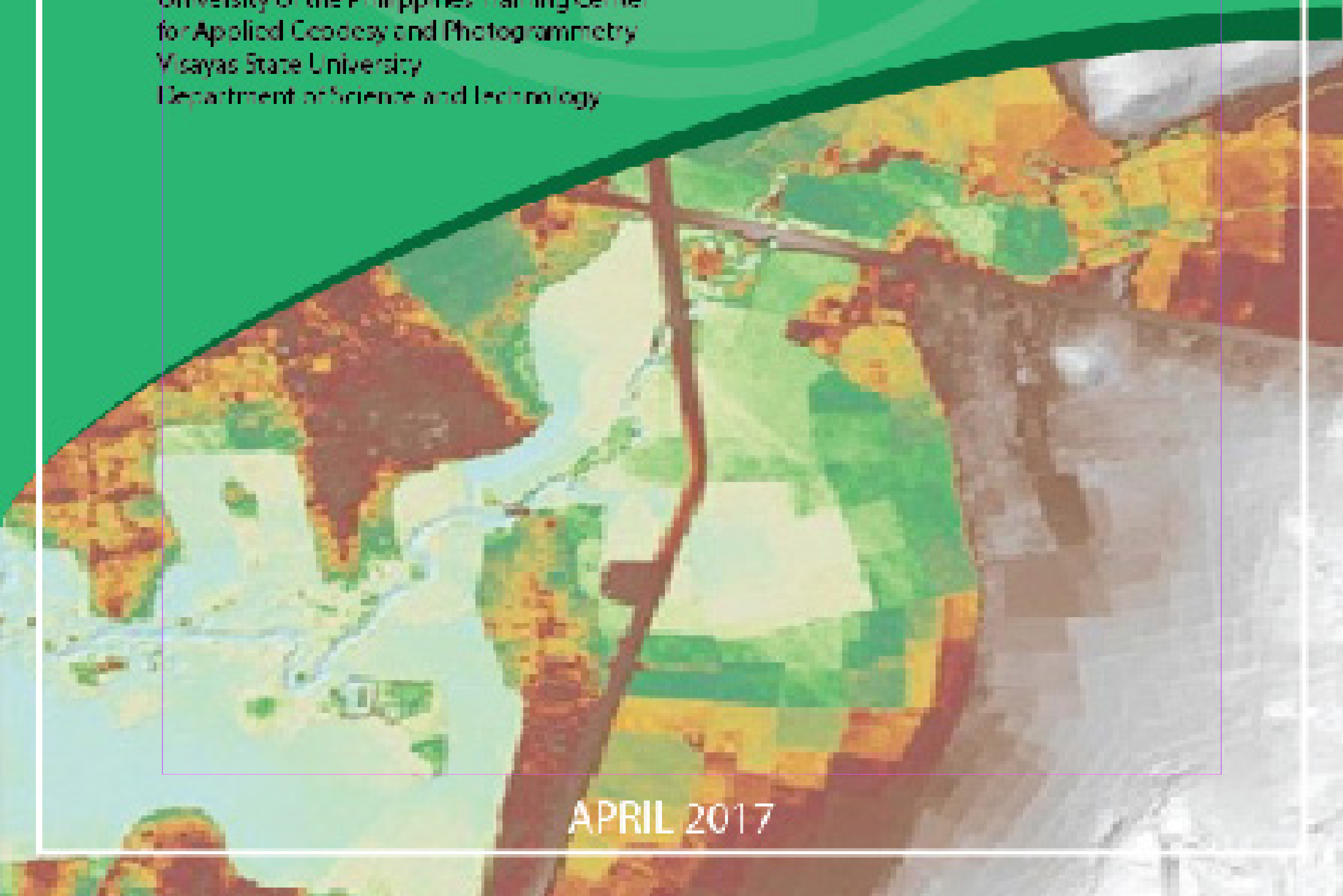
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR 1)

LiDAR Surveys and Flood Mapping of Pagbanganan River

University of the Philippines Training Center
for Applied Geodesy and Photogrammetry
Visayas State University
Department of Science and Technology



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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND PAGBANGANA RIVER

Engr. Florentino Morales and Enrico C. Paringit, Dr. Eng.

1.1 Background of the Phil-LIDAR 1 Program

The University of the Philippines Training Center for Applied Geodesy and Photogrammetry (UP-TCAGP) launched a research program entitled "Nationwide Hazard Mapping using LiDAR" or Phil-LiDAR 1 in 2014, supported by the Department of Science and Technology (DOST) Grant-in-Aid (GiA) Program. The program was primarily aimed at acquiring a national elevation and resource dataset at sufficient resolution to produce information necessary to support the different phases of disaster management. Particularly, it targeted to operationalize the development of flood hazard models that would produce updated and detailed flood hazard maps for the major river systems in the country.

The program was also aimed at producing an up-to-date and detailed national elevation dataset suitable for 1:5,000 scale mapping, with 50 cm and 20 cm horizontal and vertical accuracies, respectively. These accuracies were achieved through the use of the state-of-the-art Light Detection and Ranging (LiDAR) airborne technology procured by the project through DOST. The methods applied in this report are thoroughly described in a separate publication titled 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 Visayas State University (VSU). VSU 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 28 river basins in the Eastern Visayas Region. The university is located in Baybay City in the province of Leyte.

1.2 Overview of the Pajo River Basin

The Pagbanganan River Basin is located in the Province of Leyte and covers mainly the City of Baybay stretching in the Municipality of Inopacan. The river in the city is situated on the western coast of Leyte, immediately fronting the Camotes Sea of Cebu. It has an estimated drainage area of 165.43 square kilometers and travels 19.77 kilometers from its source to the mouth of the river near the city center. The general pattern of the water flow is from the eastern high elevation areas of the western coastal areas eventually draining towards the Camotes Sea. The water movement from higher to lower elevations is exhibited by the topographic maps of NAMRIA where high elevation areas can be found in the eastern and southern half of the locality while the low elevation and flat areas are mostly concentrated in the western coastal portions of the city.

The Pagbanganan River is part of the 28 river systems in Eastern Visayas Region. There is a total of 10,723 people residing within the immediate vicinity of the river which is distributed among the ten (10) barangays in Baybay City (NSO, 2010). Livelihood in the area is focused on agricultural and marine resources found in their province. Producsts include rice, corn, abaca, root crops, fruits and vegeTable C-s. There are also cottage industries and furniture manufacturing in the area (Baybay City, Leyte, 2015). The most significant flooding in the area was caused by the super typhoon Haiyan "Yolanda" on November 2013.

The City of Baybay is experiencing a Type IV climate according to the Modified Corona's climate classification by the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA). It is characterized as having no pronounced dry season where rainfall is generally evenly distributed throughout the year. Having this type of climate, the Pagbanganan River Basin, more popularly known as Dungcaan River Basin, in Baybay was identified as a major flood risk in the city. The technical study conducted by the Japan International Cooperation Agency (JICA) and the Department of Public Works and Highways (DPWH) on the National Flood Risk Assessment and Flood Mitigation Plan for Selected Areas in the Republic of the Philippines showed that the major cause of flooding in the basin is discharge flow exceeding the river flow capacity.

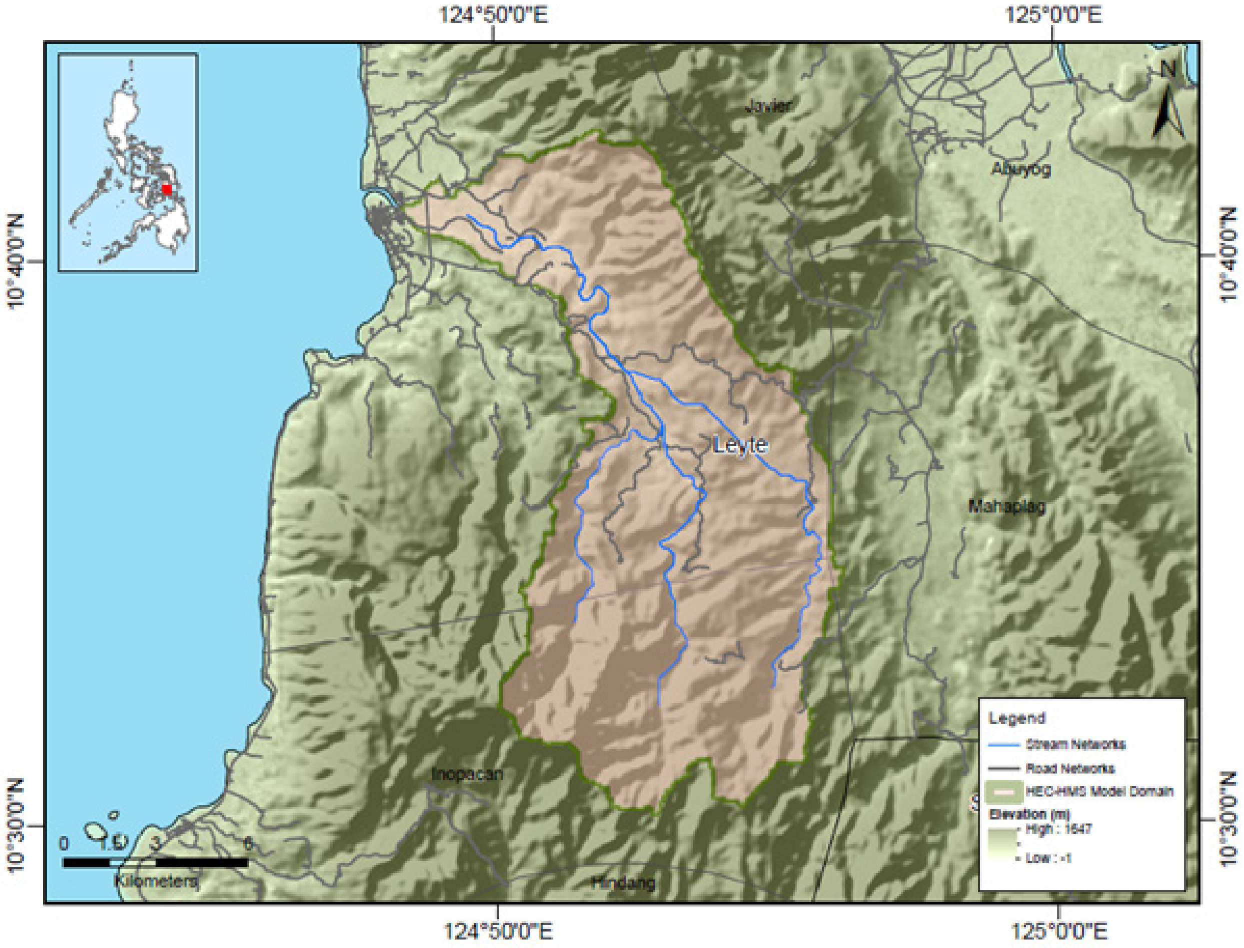

Figure 1. Map of the Pagbanganan River Basin (in brown)

CHAPTER 2: LIDAR DATA ACQUISITION OF THE PAGBANGANAN FLOODPLAIN

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

2.1 Flight Plans

Plans were made to acquire LiDAR data within the delineated priority area for Pagbanganan Floodplain in Eastern Samar. These missions were planned for 21 lines that run for at most four and a half (4.5) hours including take-off, landing, and turning time. The flight planning parameters for the LiDAR system are found in Table 1 and Table 2. Figure 2 shows the flight plan for Pagbanganan Floodplain survey.

Table 1. Flight planning parameters for Aquarius LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK35C	500	30	40	50	45	120	5
BLK335D	500	30	40	50	45	120	5
BLK35E	500	30	40	50	45	120	5
BLK35F	500	30	36	50	45	120	5
BLK48AS	500	30	36	50	45	120	5
BLK48B	500	30	36	50	45	120	5
BLK48E	500	30	36	50	45	120	5
BLK48G	500	30	36	50	45	120	5

Table 2. Flight planning parameters for Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of view (ø)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK34A	1000	30	36	100	50	120	5
BLK34B	1000	30	36	100	50	120	5
BLK49D	1000	30	36	100	50	120	5
BLK49E	1000	30	36	100	50	120	5

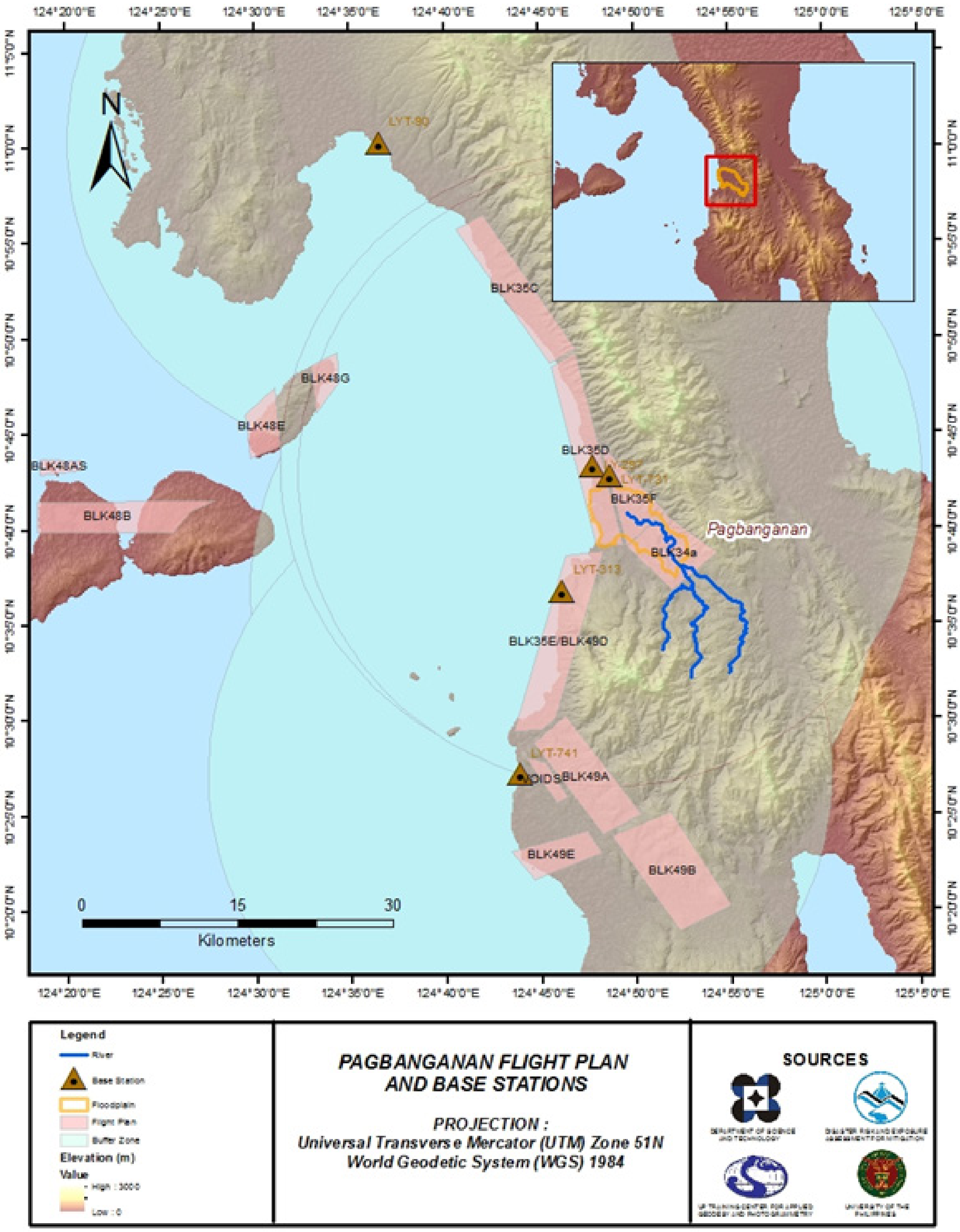

Figure 2. Flight plan and base stations used for Pagbanganan Floodplain

2.2 Ground Base Stations

The project team was able to recover three NAMRIA horizontal ground control points, LYT-90, LYT-731, and LYT-741 which are of second-order accuracy. Two NAMRIA benchmarks were recovered, LY-297 and LY-313. These benchmarks were used as vertical reference points and were also established as ground control points. These were used as base stations during flight operations for the entire duration of the survey (June 9, 2014). Base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852 and SPS 985. The certification for the NAMRIA reference point is found in ANNEX 2 while the baseline processing report for the established control point is found in ANNEX 3. Flight plans and location of base stations used during the aerial LiDAR acquisition in Pagbanganan Floodplain are shown in Figure 2. The members of the team are listed in ANNEX 4.

Figure 3 shows the recovered NAMRIA reference points within the area. Table 3 to Table 7 present the details about the following NAMRIA control stations and established points, while Table 8 shows the list of all ground control points occupied during the acquisition with the corresponding dates of utilization.

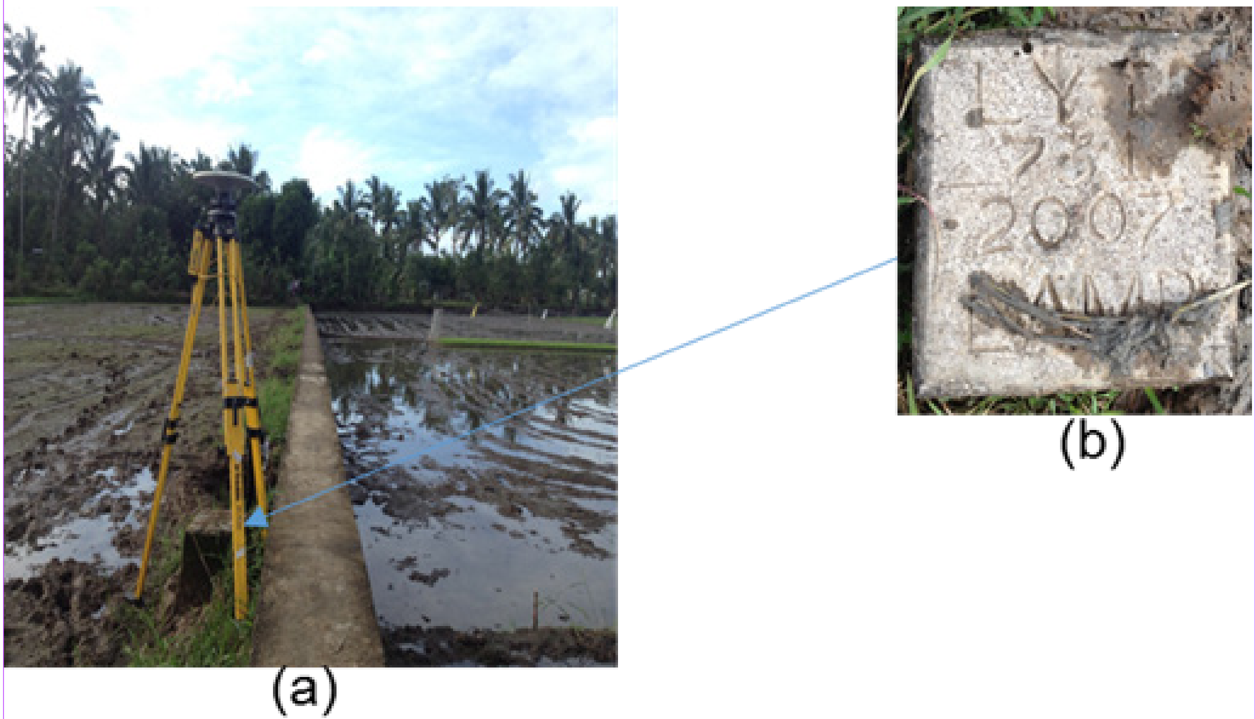

Figure 3. GPS set-up over LYT-731 in Brgy. Kansungka, Baybay City, Leyte (a) and NAMRIA reference point LYT-731(b) as recovered by the field team

Table 3. Details of the recovered NAMRIA horizontal control point LYT-731 used as base station for the LiDAR acquisition

Station Name	**LYT-731**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference 0f 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10°42'47.59466'' North 124°48'34.34382'' East 15.60931 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	479165.977 meters 1184617.338 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10°42’43.44572'' North 124°48'39.54791'' East 78.65700 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	697902.97 meters 1184777.35 meters

Table 4. Details of the established NAMRIA horizontal control point LYT-741 used as base station for the LiDAR acquisition

Station Name	LYT-741	
Order of Accuracy	2nd	
Relative Error (Horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10o 27’ 11.95722” North 124o 43’ 45.08400” East 4.48300 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	470351.659 meters 1155878.867 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10o 27’ 7.86786” North 124o 43’ 50.311177” East 67.94500 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	689272.22 meters 1155979.90 meters

Table 5. Details of LYT-90 used as base station for the LiDAR acquisition

Station Name	LYT-90	
Order of Accuracy		
Relative Error (Horizontal positioning)		
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 00’ 17.772685” North 124° 36’ 28.2417” East 12.255 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 00' 13.44827" North 124° 36' 33.43578" East 66.238 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	675,667.9045 meters 1,216,919.8335 meters

Table 6. Details of the recovered NAMRIA vertical control point LY-313 used as base station with established coordinates

Station Name	**LY-313**	
Order of Accuracy	**2nd**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10o 36’ 46.67221” North 124o 46’ 01.67926” East 6.279 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10o 36’ 42.54525” North 124o 46’ 06.89257” East 69.460 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	693326.992 meters 1173661.006 meterss

Table 7. Details of the recovered NAMRIA vertical control point LY-297 used as base station with established coordinates

Station Name	**LY-297**	
Order of Accuracy	**2nd Order**	
Relative Error (Horizontal positioning)	**1:50,000**	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	10o 43’ 21.53694” North 124o 47’ 38.67725” East 6.908 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	10o 43’ 17.38426” North 124o 47’ 43.88062” East 69.895 meters
Grid Coordinates, Philippine Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	696205.243 meters 1185810.360 meters

Table 6. Ground Control points using LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
January 27, 2015	7764AC	3BLK35CD027A	LYT-731 AND LY-297
February 10, 2015	7792AC	3BLK35FV041A	LYT-731 AND LY-297
February 11, 2015	7794AC	3BLK35EV042A	LYT-731 AND LY-297
March 18, 2016	8407AC	3BLK48FG078A	LYT-90
April 10, 2016	3921G	2BLK34a101A	LYT-313 and LYT-741
April 11, 2016	3925G	2BLK49DE102A	LYT-313 and LYT-741

2.3 Flight Missions

Six missions were conducted to complete LiDAR data acquisition in Pagbanganan Floodplain, for a total of twenty-four hours and fifty-five minutes (24+55) of flying time for RP-9322. The missions were acquired using Aquarius LiDAR systems. Table 9 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 10 presents the actual parameters used during the LiDAR data acquisition.

Table 7. Flight Missions for LiDAR data acquisition in Pajo Floodplain

Date Surveyed	Flight Number	Flight Plan Area (km2)	Surveyed Area (km2)	Area Surveyed within the Floodplain (km2)	Area Surveyed Outside the Floodplain (km2)	No. of Images (Frames)	Flying Hours	
							Hr	Min
January 27, 2015	7764AC	92.66	93.69	7.62	33.66	NA	3	53
February 10, 2015	7792AC	32	73.67	35.81	5.48	NA	3	59
February 11, 2015	7794AC	65.89	73.67	0.88	40.41	NA	4	11
March 18, 2016	8407AC	72.69	60.72	NA	41.29	NA	4	5
April 10, 2016	3921G	142.50	157.04	15.78	25.51	NA	4	27
April 11, 2016	3925G	191.17	74.34	NA	41.29	NA	4	20
TOTAL		**596.91**	**533.14**	**60.09**	**187.63**	**NA**	**24**	**55**

Table 10. Actual parameters used during LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (khz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
7764AC	500	30	40	50	45	120	5
7792AC	500	30	36	50	45	120	5
7794AC	500	30	40	50	45	120	5
8407AC	500	30	36	33	45	120	5
3921G	1000	30	36	100	50	120	5
3925G	1000	30	36	100	50	120	5

2.4 Survey Coverage

Pagbanganan Floodplain is located in the province of Leyte with majority of the floodplain situated within the city of Baybay. The list of municipalities and cities surveyed, with at least one square kilometer coverage, is shown in Table 11. The actual coverage of the LiDAR acquisition for Pagbanganan Floodplain is presented in Figure 4. Flight status reports can be found in ANNEX 7.

Table 11. List of municipalities and cities surveyed during Pagbanganan Floodplain LiDAR survey

Province	Municipality/ City	Area of Municipality/City (km2)	Total Area Surveyed (km2)	Percentage of Area Surveyed
Leyte	Hilongos	156.8	79.9	50.96%
	Bato	57.55	20.35	35.36%
	Baybay City	404.37	127.59	31.55%
	Hindang	106.77	32.04	30.01%
	Albuera	167.61	34.79	20.76%
	Inopacan	196.05	25.07	12.79%
	Bontoc	89.13	7.3	8.19%
	Matalom	110.13	2.42	2.20%
Cebu	Pilar	34.74	12.53	36.05%
	Poro	62.85	2.18	3.47%
	Tudela	36.92	1.24	3.36%
	San Francisco	92.68	2.55	2.75%
TOTAL		1515.6	347.96	22.96%

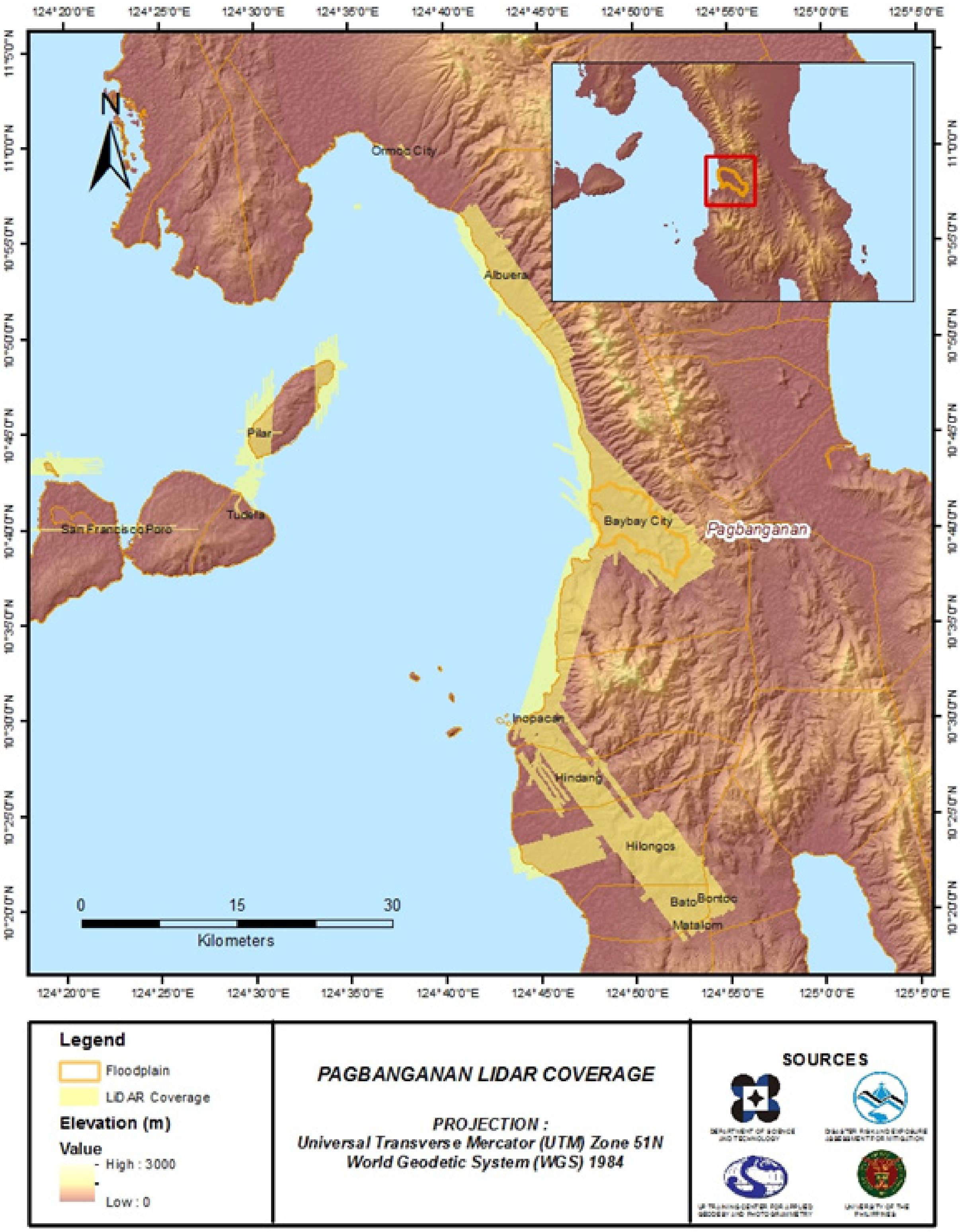

Figure 4. Actual LiDAR survey coverage for Pagbanganan Floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE PAGBANGANAN FLOODPLAIN

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

3.1 Overview of the LiDAR Data Pre-Processing

The data transmitted by the Data Acquisition Component (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 correct position and orientation for each point acquired. The georectified LiDAR point clouds were subject for quality checking to ensure that the required accuracies of the program, which were the minimum point density, vertical and horizontal accuracies, were met. The point clouds were then classified into various classes before generating Digital Elevation Models such as Digital Terrain Model and Digital Surface Model.

Using the elevation of points gathered in the field, the LiDAR-derived digital models 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. 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 done through the help of the georectified point clouds and the metadata containing the time the image was captured.

These processes are summarized in the flowchart shown in Figure 5.

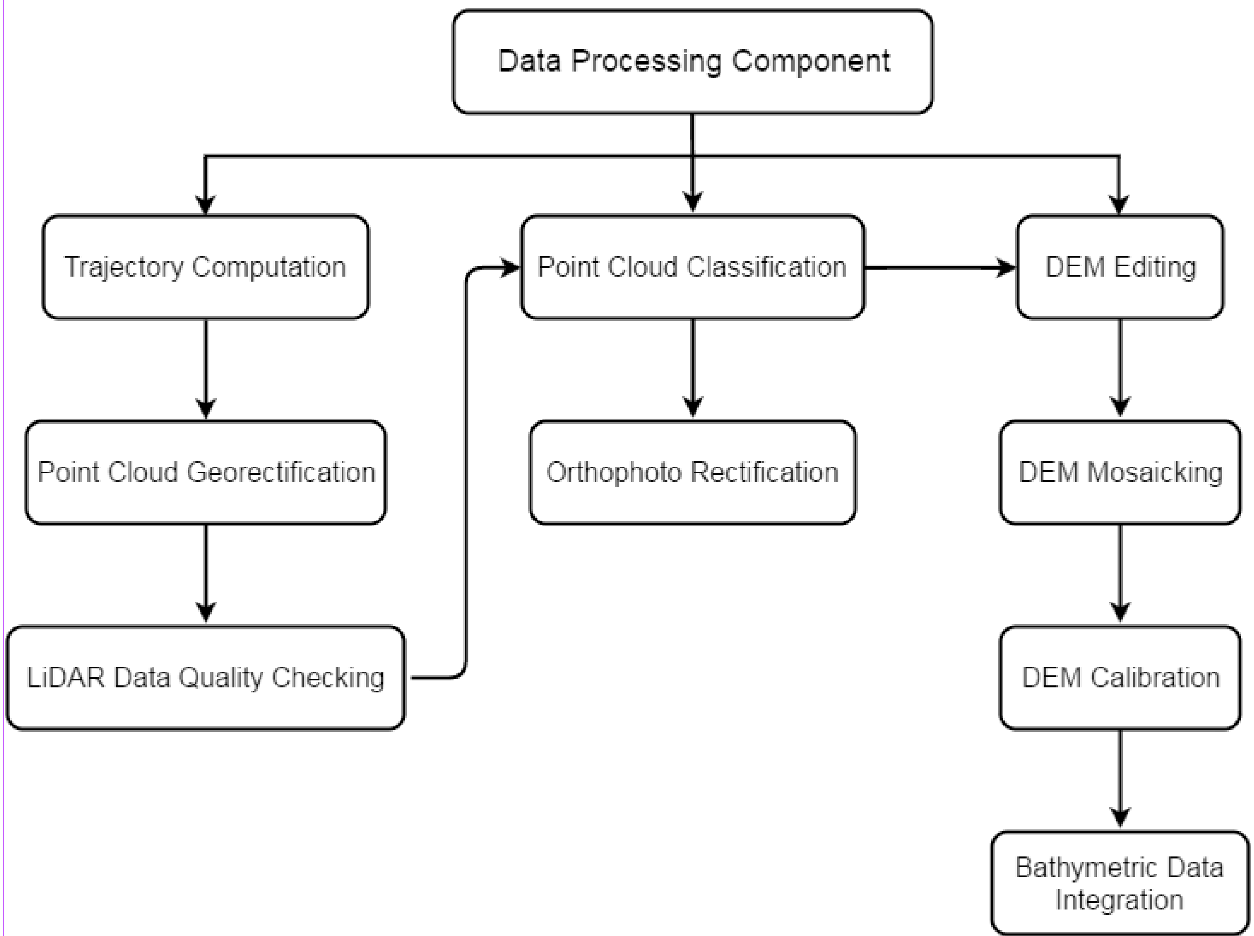


Figure 5. Schematic diagram for Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for Pagbanganan Floodplain can be found in ANNEX 5. Missions flown during the surveys conducted on January 2015 and April 2016 used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Gemini system while missions acquired during the surveys on February 2015 and March 2016 were flown using the Aquarius system over Baybay, Leyte. The Data Acquisition Component transferred a total of 125.24 Gigabytes of Range data, 3.022 Gigabytes of POS data, 1487.38 Megabytes of GPS base station data, and 337.2 Gigabytes of raw image data to the data server on February 13 and 25, 2015 for the first two surveys and April 27 and June 2, 2016 for the third and fourth survey, respectively. The Data Pre-Processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Pagbanganan was fully transferred on June 6, 2016, as indicated on the data transfer sheets for Pagbanganan Floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 8407AC, one of the Pagbanganan flights, which is the North, East, and Down position RMSE values, are shown in Figure 6. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which on that week fell on March 18, 2016 00:00AM. The y-axis is the RMSE value for that particular position.

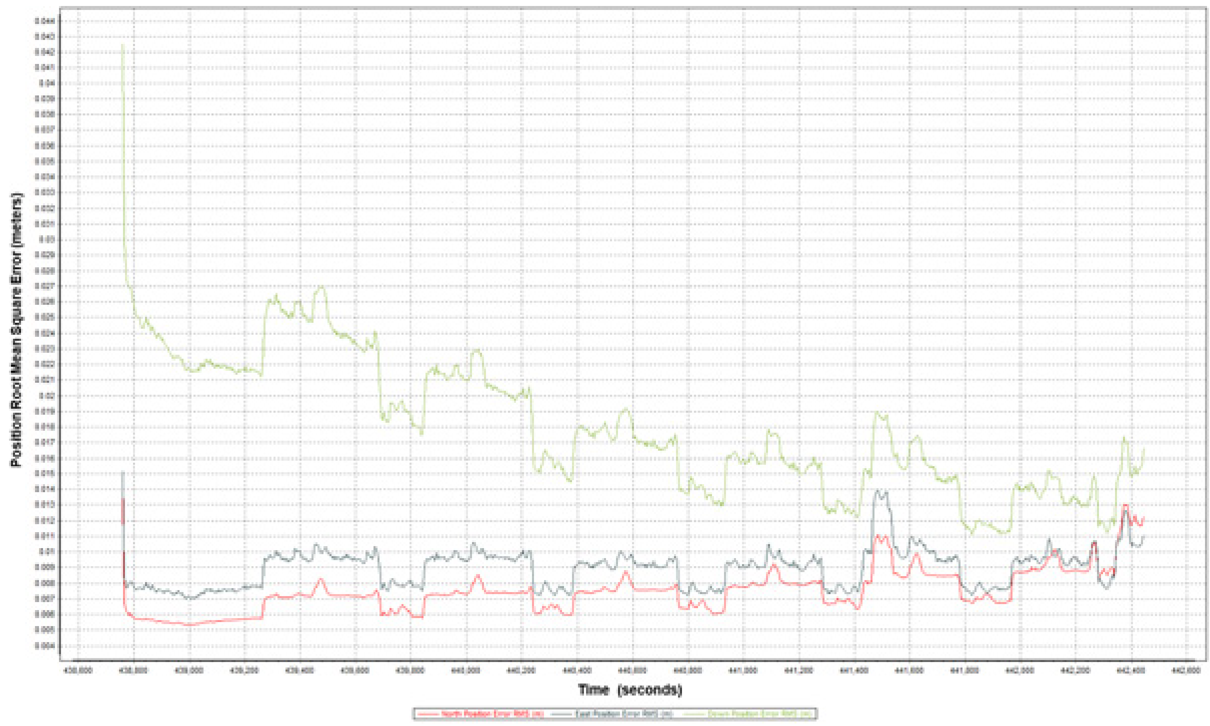


Figure 6. Smoothed Performance Metric parameters of Pagbanganan Flight 8407AC

The time of flight was from 438600 seconds to 442600 seconds, which corresponds to morning of March 18, 2016. The initial spike that is seen on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system starts computing for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE value of the positions. The periodic increase in RMSE values from an otherwise smoothly curving RMSE values correspond to the turn-around period of the aircraft, when the aircraft makes a turn to start a new flight line. Figure 6 shows that the North position RMSE peaks at 1.13 centimeters, the East position RMSE peaks at 1. 39 centimeters, and the Down position RMSE peaks at 2.7 centimeters, which are within the prescribed accuracies described in the methodology.

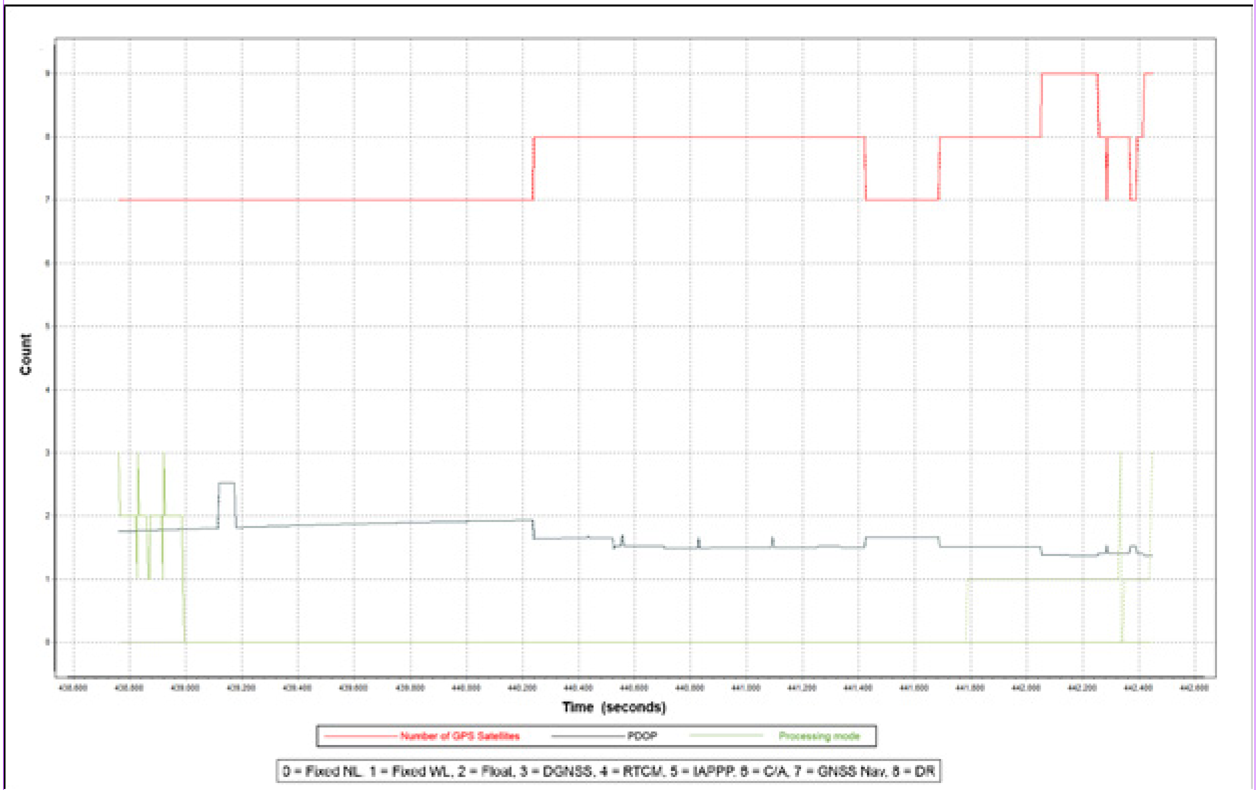


Figure 7. Solution Status parameters of Pagbanganan Flight 8407AC

The Solution Status parameters of flight 8407AC, one of the Pagbanganan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are shown in Figure 7. The graphs indicate that the number of satellites during the acquisition did not go down to 7. Majority of the time, the number of satellites tracked was between 7 and 9. The PDOP value also did not go above the value of 3, which indicates optimal GPS geometry. The processing mode stayed at the value of 0 for majority of the survey. 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 Pagbanganan flights is shown in Figure 8.

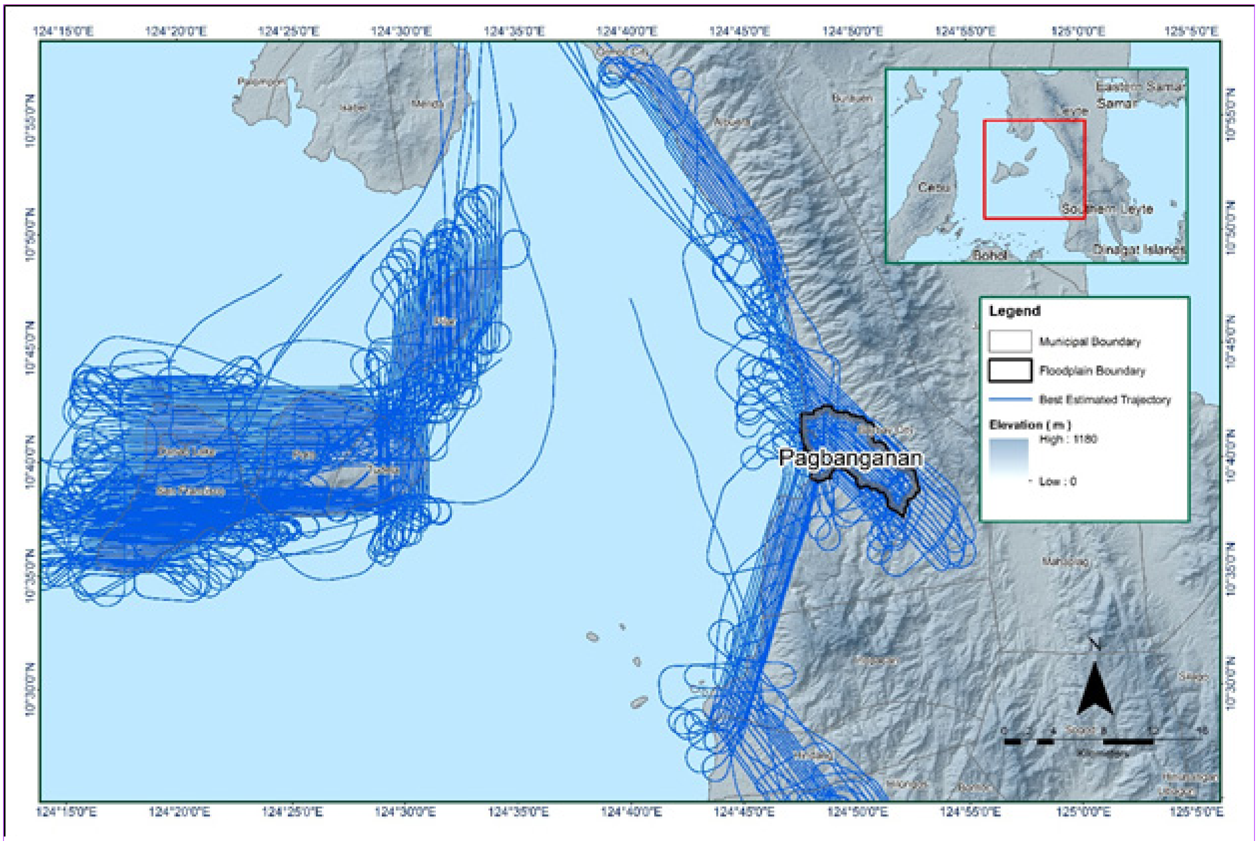


Figure 8. Best estimated trajectory of the LiDAR missions conducted over the Pagbanganan Floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 320 flight lines, with each flight line containing one channel, since the Gemini and Aquarius systems both contain one channel only. The summary of the self-calibration results obtained from LiDAR processing in LiDAR Mapping Suite (LMS) software for all flights over Pagbanganan Floodplain are given in Table 12.

Table 12. Self-calibration results values for Pagbanganan flights

Parameter	Acceptable Value	Value
Boresight Correction stdev (<0.001degrees)	0.000462	0.000751
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000318	0.000959
GPS Position Z-correction stdev (<0.01meters)	0.0017	0.0025

The optimum accuracy was obtained for all Pajo flights based on the computed standard deviations of the corrections of the orientation parameters. Standard deviation values for individual blocks are available in the Annex 8.

3.5 LiDAR Data Quality Checking

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

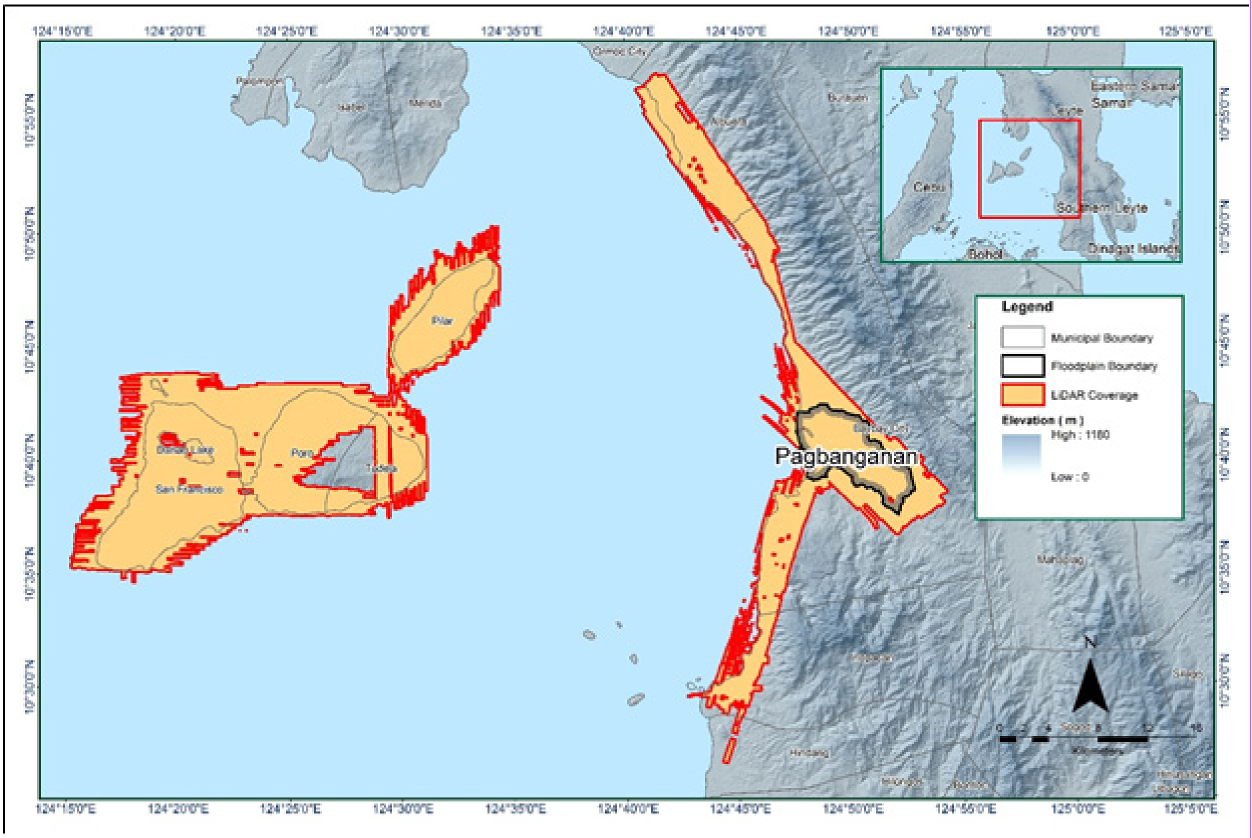


Figure 9. Boundary of the processed LiDAR data over Pagbanganan Floodplain

The total area covered by the Pagbanganan missions is 260.24 sq km that is comprised of six (6) flight acquisitions grouped and merged into seven (7) blocks as shown in Table 13.

Table 13. List of LiDAR blocks for Pagbanganan Floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Ormoc_Blk35CD	7764AC	70.18
Ormoc_Blk35F	7792AC	67.08
Ormoc_Blk35E_voids	7794AC	47.91
Ormoc_Camotes_Blk48E	8407AC	16.36
Ormoc_Camotes_Blk48G	8407AC	10.95
Ormoc_South_Blk35E	**3925G**	**10.32**
Ormoc_South_Blk34aA	**3921G**	**37.44**
TOTAL		**260.24 sq km**

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is shown in Figure 10. Since the Gemini and Aquarius systems both employ one channel, an average value of 1 (blue) is expected for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

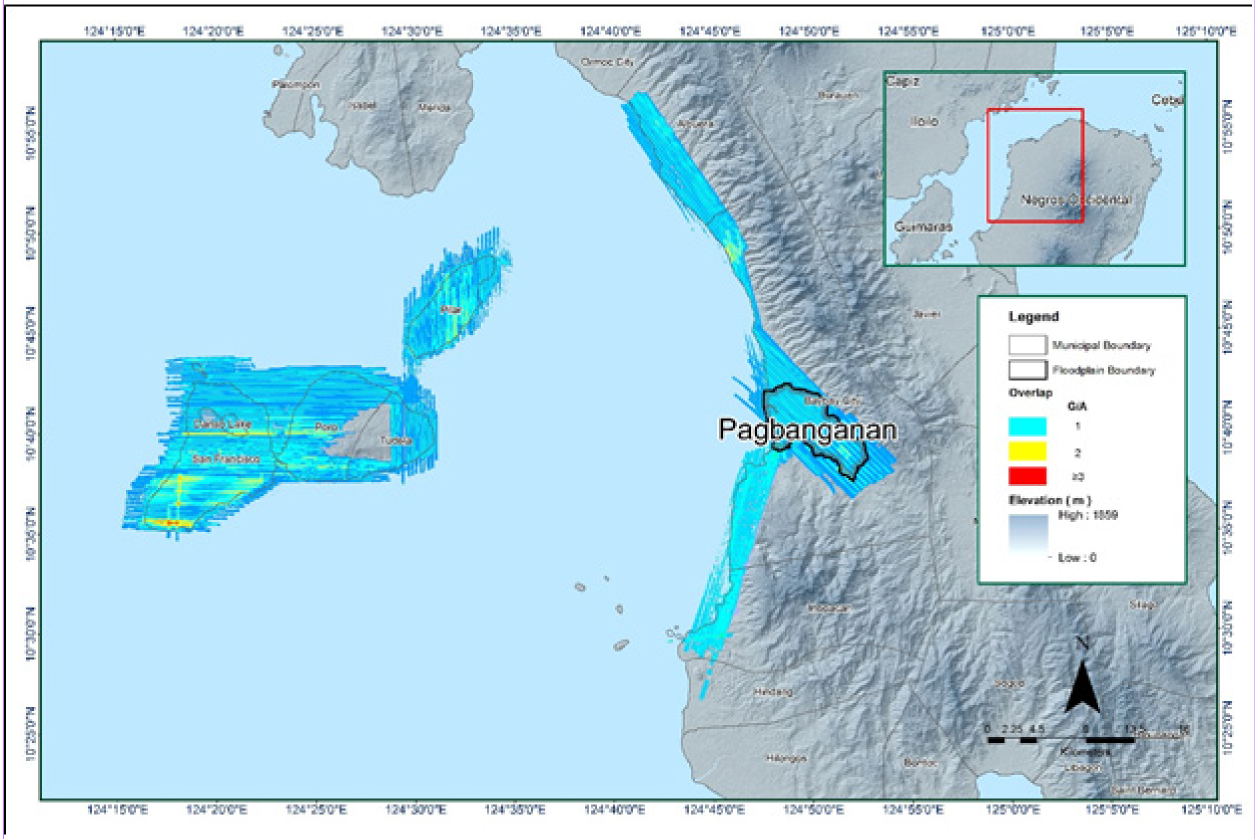


Figure 10. Image of data overlap for Pagbanganan Floodplain

The overlap statistics per block for the Pagbanganan Floodplain can be found in ANNEX 8. One pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 25.68% and 59.21%, respectively, which passed the 25% requirement.

The pulse density map for the merged LiDAR data, with the red parts showing the portions of the data that satisfy the 2 points per square meter criterion is shown in Figure 11. It was determined that all LiDAR data for Pagbanganan Floodplain satisfy the point density requirement, and the average density for the entire survey area is 3.62 points per square meter.

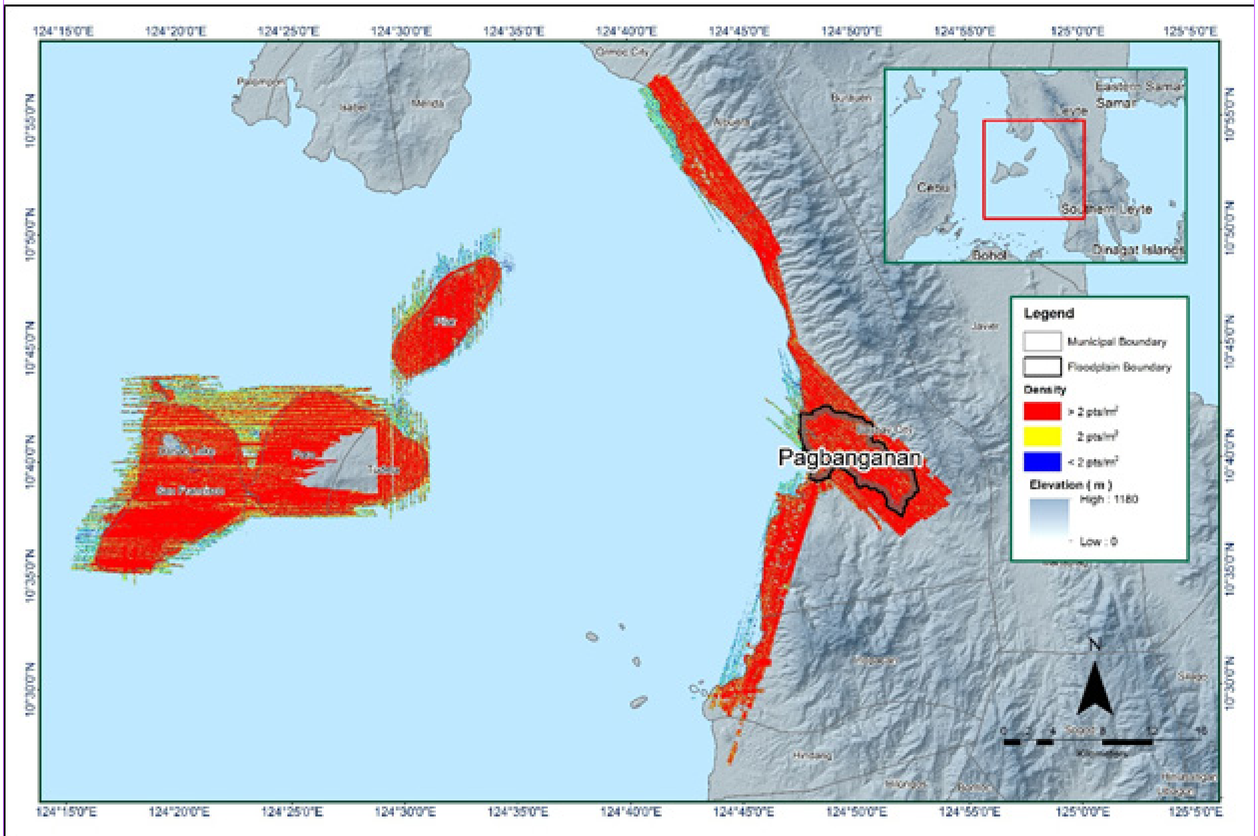


Figure 11. Pulse density map of merged LiDAR data for Pagbanganan Floodplain

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

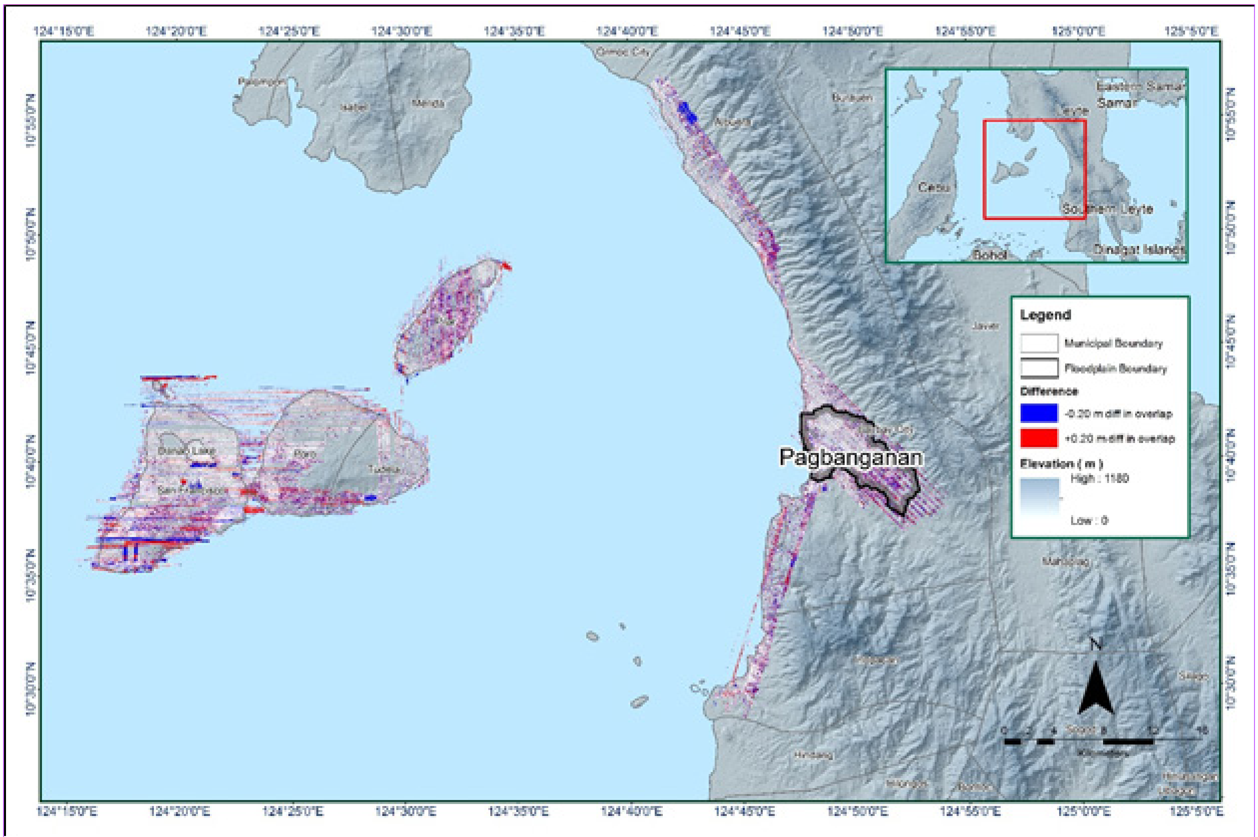


Figure 12. Map of elevation difference between flight lines for Pagbanganan Floodplain

A screen capture of the processed LAS data from a Pagbanganan flight 8407AC loaded in QT Modeler is shown in Figure 13. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed red line. The x-axis corresponds to the length of the profile. It is evident that there are differences in elevation, but the differences do not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data becomes satisfactory. No reprocessing was done for this LiDAR dataset.

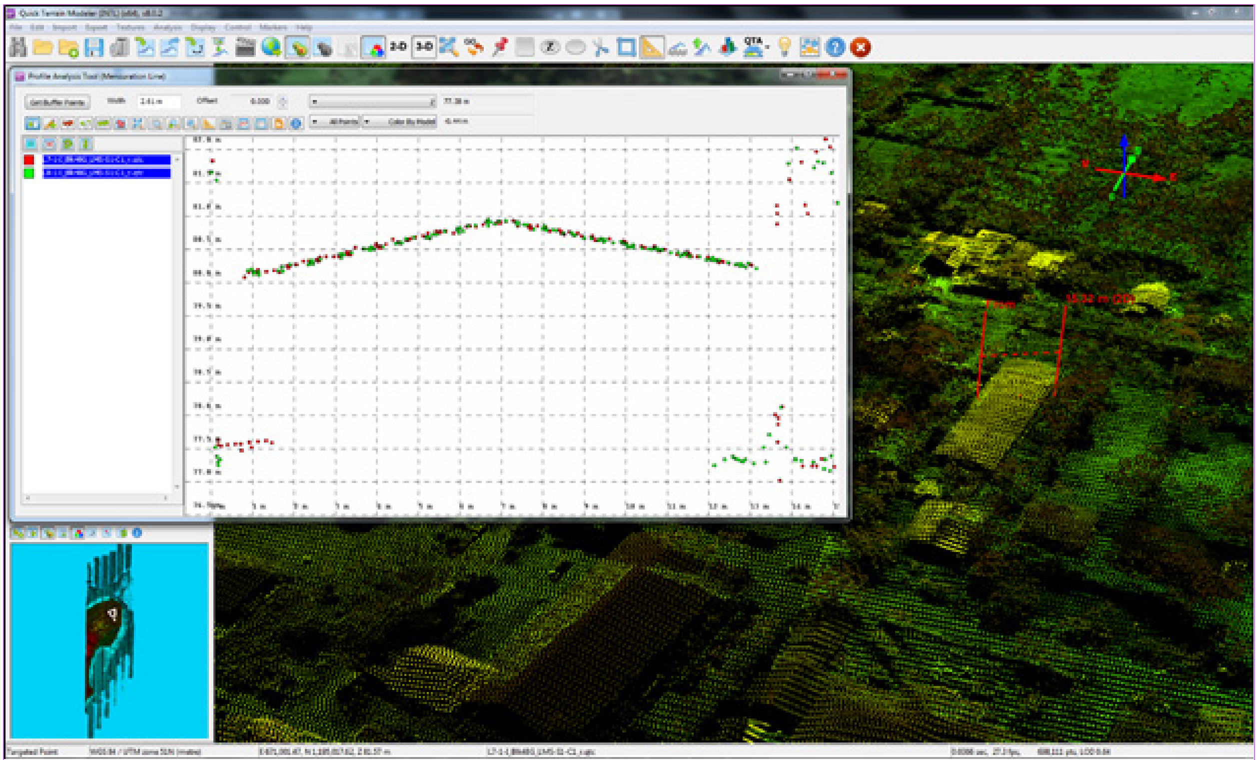


Figure 13. Quality checking for a Pagbanganan flight 8407AC using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 14. Pagbanganan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	143,432,540
Low Vegetation	120,670,916
Medium Vegetation	170,795,462
High Vegetation	319,340,910
Building	8,929,971

The tile system that TerraScan employed for the LiDAR data and the final classification image for a block in Pagbanganan Floodplain is shown in Figure 14. A total of 512 1km by 1km tiles were produced. The number of points classified to the pertinent categories is illustrated in Table 15. The point cloud has a maximum and minimum height of 581.00 meters and 43.00 meters, respectively.

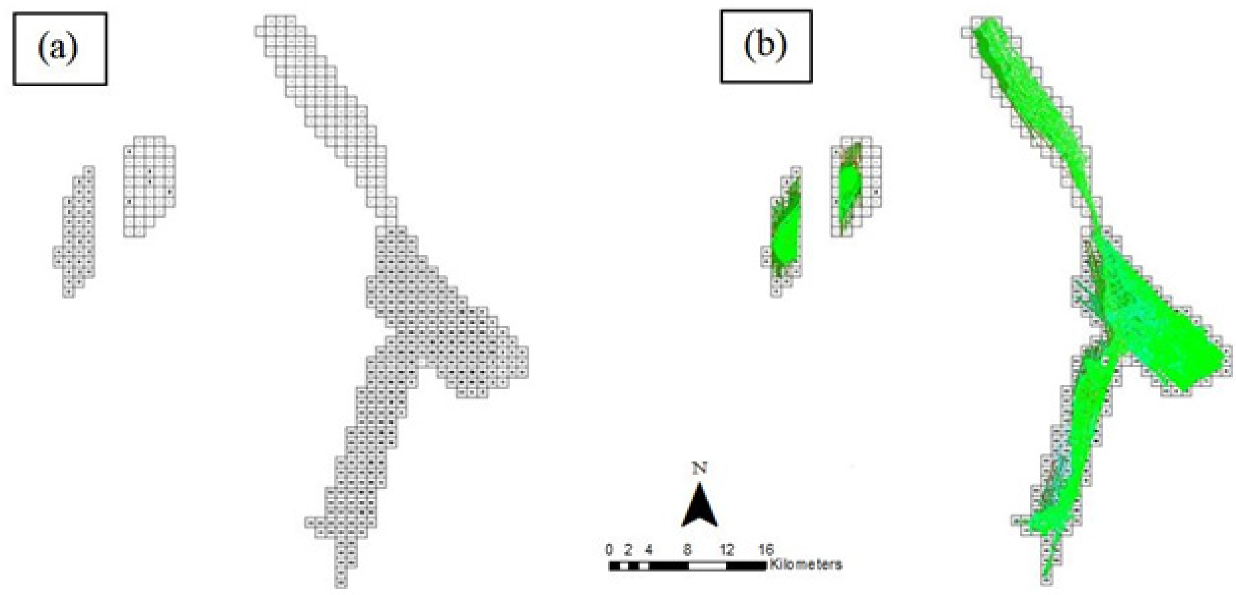


Figure 14. Tiles for Pagbanganan Floodplain (a) and classification results (b) in TerraScan

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

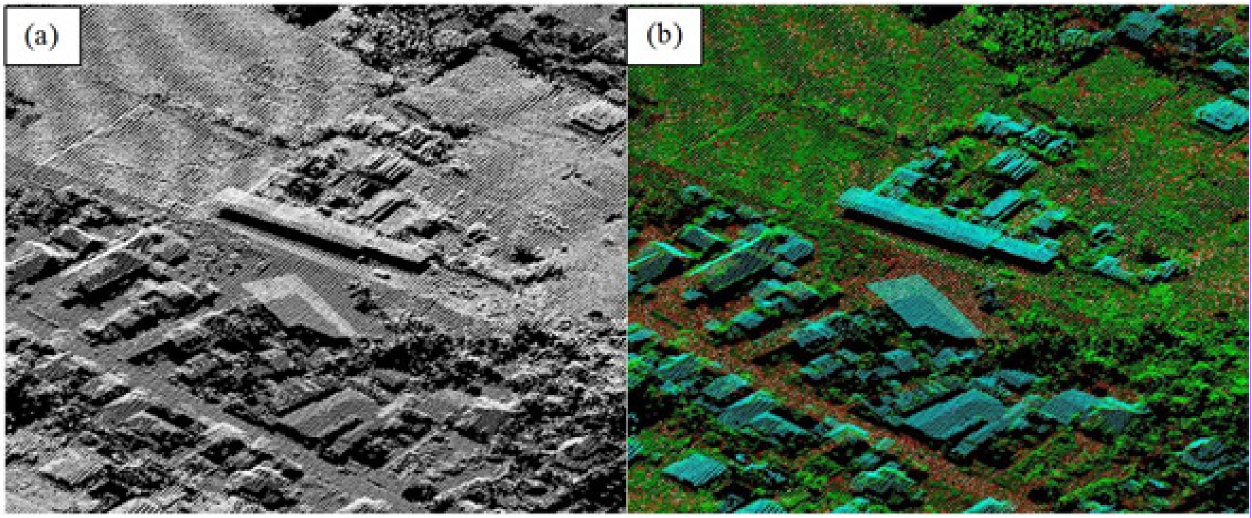


Figure 15. Point cloud before (a) and after (b) classification.

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

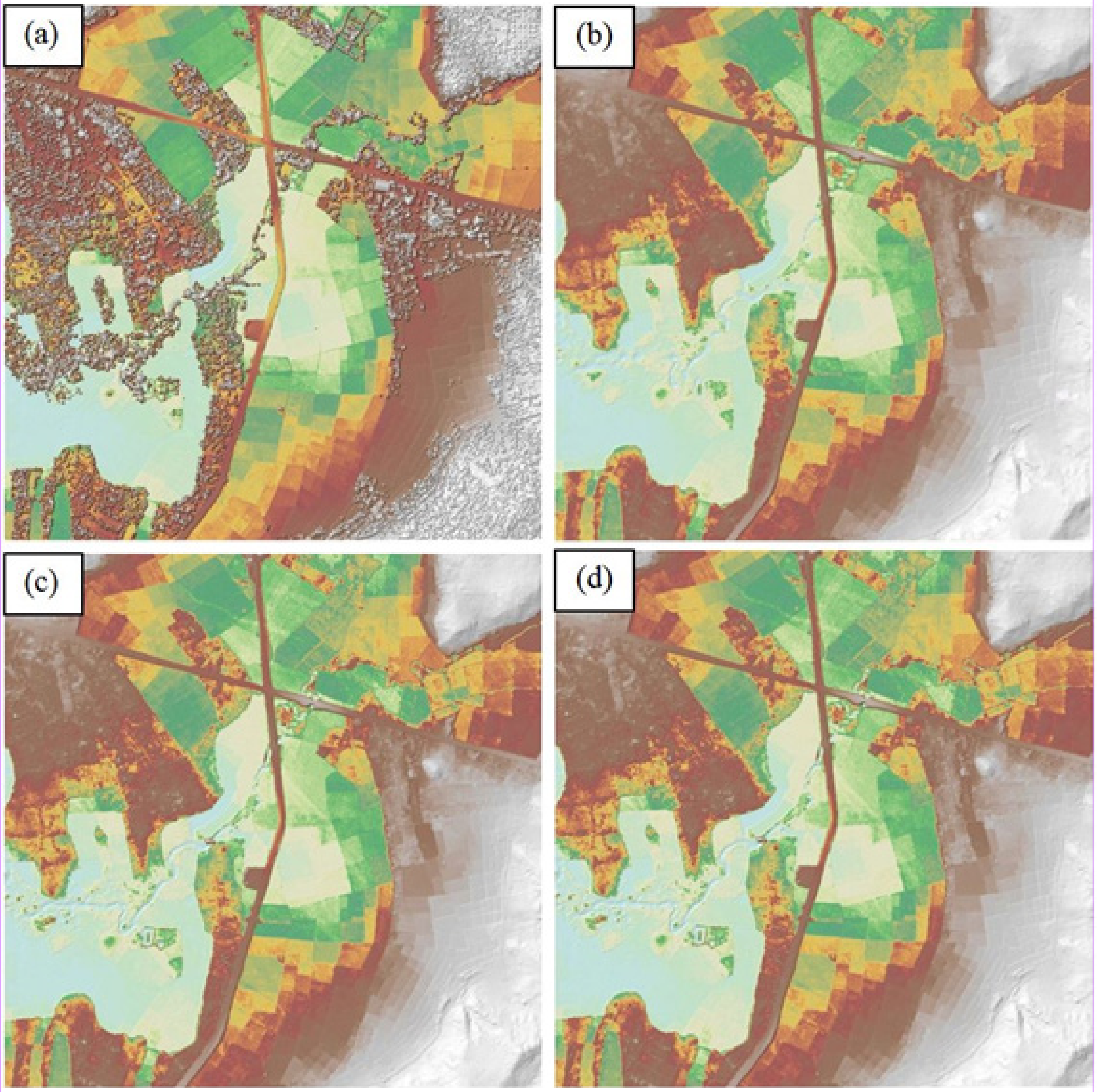


Figure 16. The production of last return DSM (a) and DTM (b), first return DSM (c) and secondary DTM (d) in some portion of Pagbanganan Floodplain.

3.7 LiDAR Image Processing and Orthophotograph Rectification

There are no available orthophotographs for the Pagbanganan Floodplain.

3.8 DEM Editing and Hydro-Correction

Seven mission blocks were processed for Pagbanganan flood plain. These blocks are composed of SamarLeyte and Leyte blocks with a total area of 260.24 square kilometers. Table 15 shows the name and corresponding area of each block in square kilometers.

Table 15. LiDAR blocks with its corresponding area.

LiDAR Blocks	Area (sq.km)
Ormoc_Blk35CD	70.18
Ormoc_Blk35F	67.08
Ormoc_Blk35E_voids	47.91
Ormoc_Camotes_Blk48E	16.36
Ormoc_Camotes_Blk48G	10.95
Ormoc_South_Blk35E	10.32
Ormoc_South_Blk34aA	37.44
TOTAL	260.24 sq km

Portions of DTM before and after manual editing are shown in Figure 17. The bridge (Figure 17a) is considered to be an impedance to the flow of water along the river and has to be removed (Figure 17b) in order to hydrologically correct the river. The fishpond embankment (Figure 17c) has been misclassified and removed during classification process and has to be retrieved to complete the surface (Figure 17d) to allow the correct flow of water. Water surfaces with no data also has to be interpolated by manual editing.

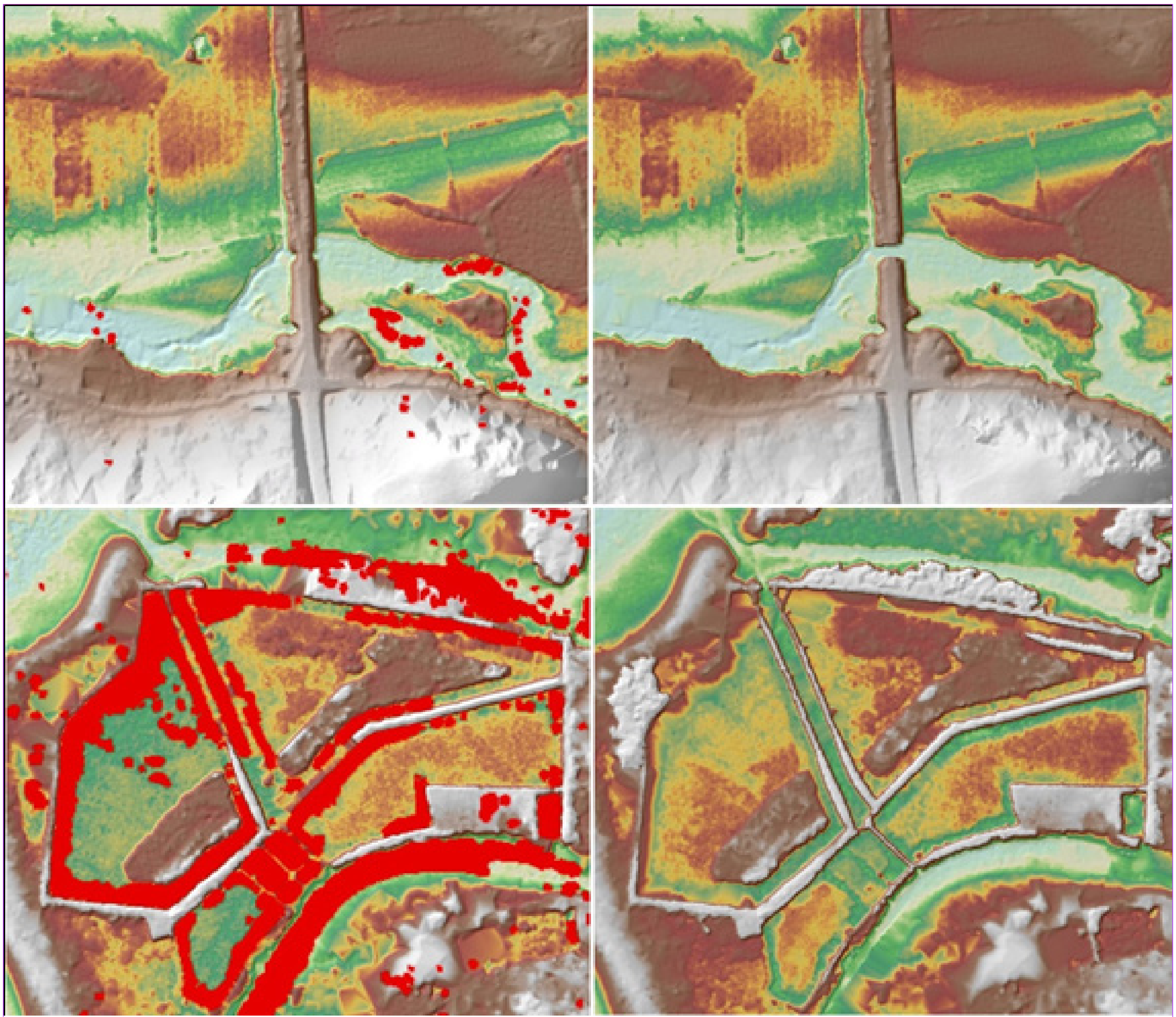


Figure 17. Portions in the DTM of Pagbanganan flood plain—a bridge before (a) and after (b) manual editing; and a fishpond before (c) and after (d) data retrieval and interpolation

3.9 Mosaicking of Blocks

SamarLeyte_Blk35I was used as the reference block at the start of mosaicking because this block was made available for editing and mosaicking before the other blocks. Table 16 shows the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for Pagbanganan Floodplain is shown in Figure 18. It can be seen that the entire Pagbanganan flood plain is 99.73% covered by LiDAR data.

Table 14. Shift Values of each LiDAR Block of Pajo Floodplain

Mission Blocks	**Shift Values (meters)**		
	x	**y**	**z**
Ormoc_Blk35CD	0.00	0.00	-0.58
Ormoc_Blk35F	0.00	0.00	-0.14
Ormoc_Blk35E_voids	0.00	0.00	0.00
Ormoc_South_Blk34aA	0.00	0.00	0.17
Ormoc_South_Blk35E	0.00	-1.00	-0.50
Ormoc_Camotes_Blk48E	0.00	0.00	0.00
Ormoc_Camotes_Blk48G	0.00	0.00	0.00

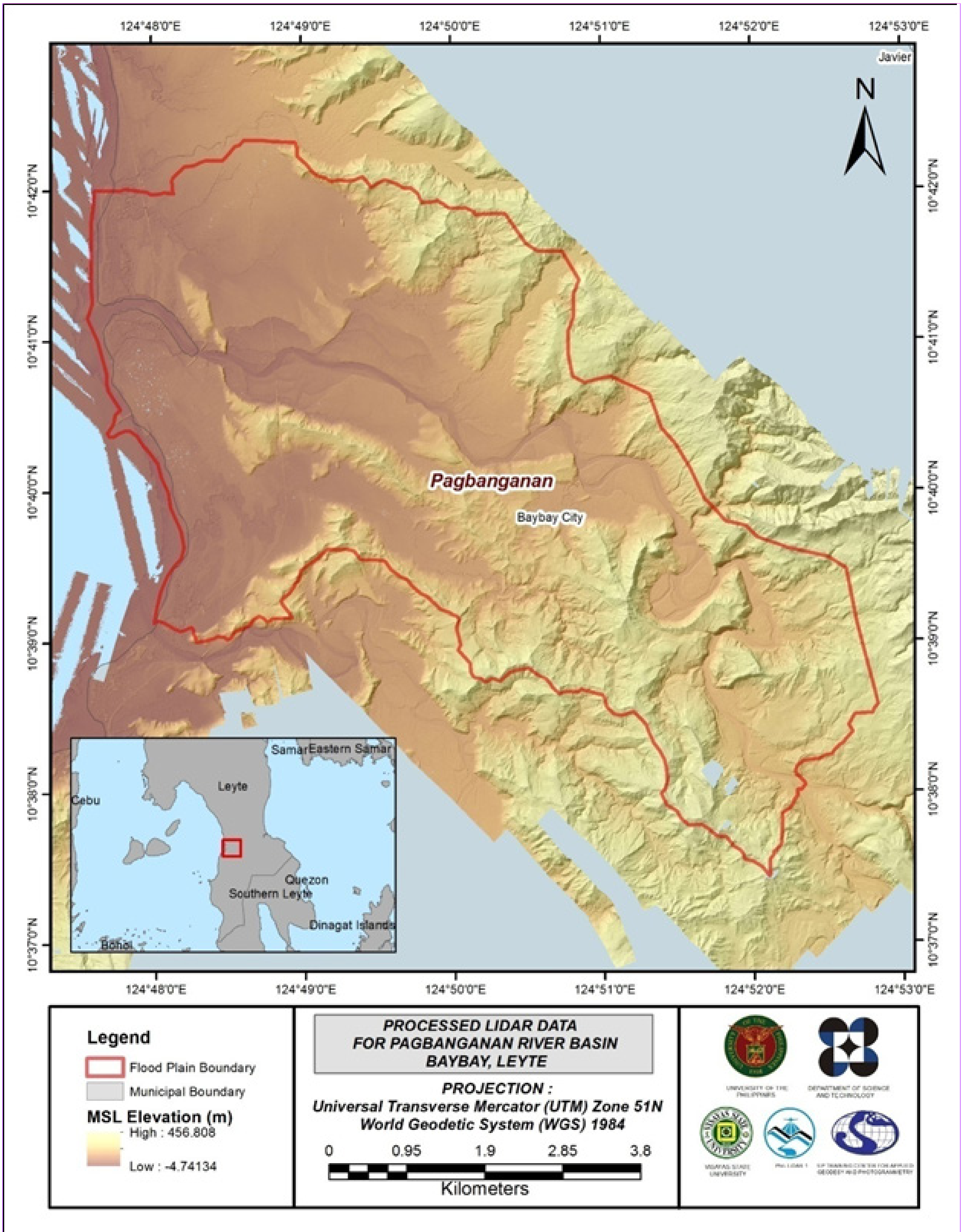


Figure 18. Map of processed LiDAR data for Pagbanganan Floodplain

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 Pagbanganan to collect points with which the LiDAR dataset is validated is shown in Figure 19. Survey points of Pagsangahan and Pagbanganan validation points were merged resulting in a total of 25,710 points and were used for calibration and validation of Pagsangahan LiDAR data. Random selection of 80% of the survey points, resulting in 20,568 points, was used for calibration. The good correlation between the uncalibrated mosaicked LiDAR elevation values and the ground survey elevation values is shown in Figure 20. Statistical values were computed from extracted LiDAR values using the selected points to assess the quality of data and obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration elevation values is 0.26 meters with a standard deviation of 0.20 meters. Calibration of Pagbanganan LiDAR data was done by adding the height difference value, 0.26 meters, to Pagbanganan mosaicked LiDAR data. Table 17 shows the statistical values of the compared elevation values between LiDAR data and calibration data.

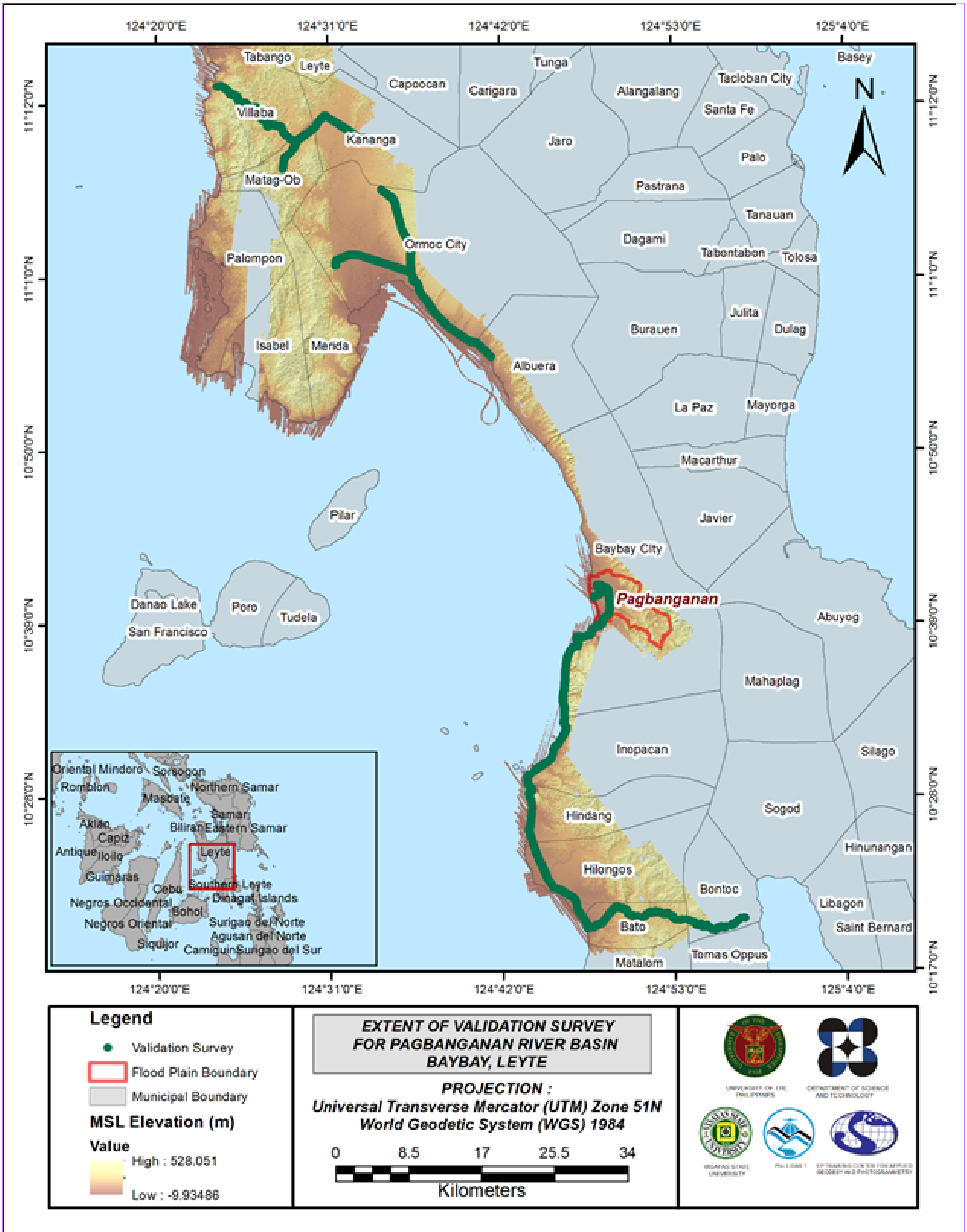


Figure 19. Map of Pagbanganan Floodplain with validation survey points in green

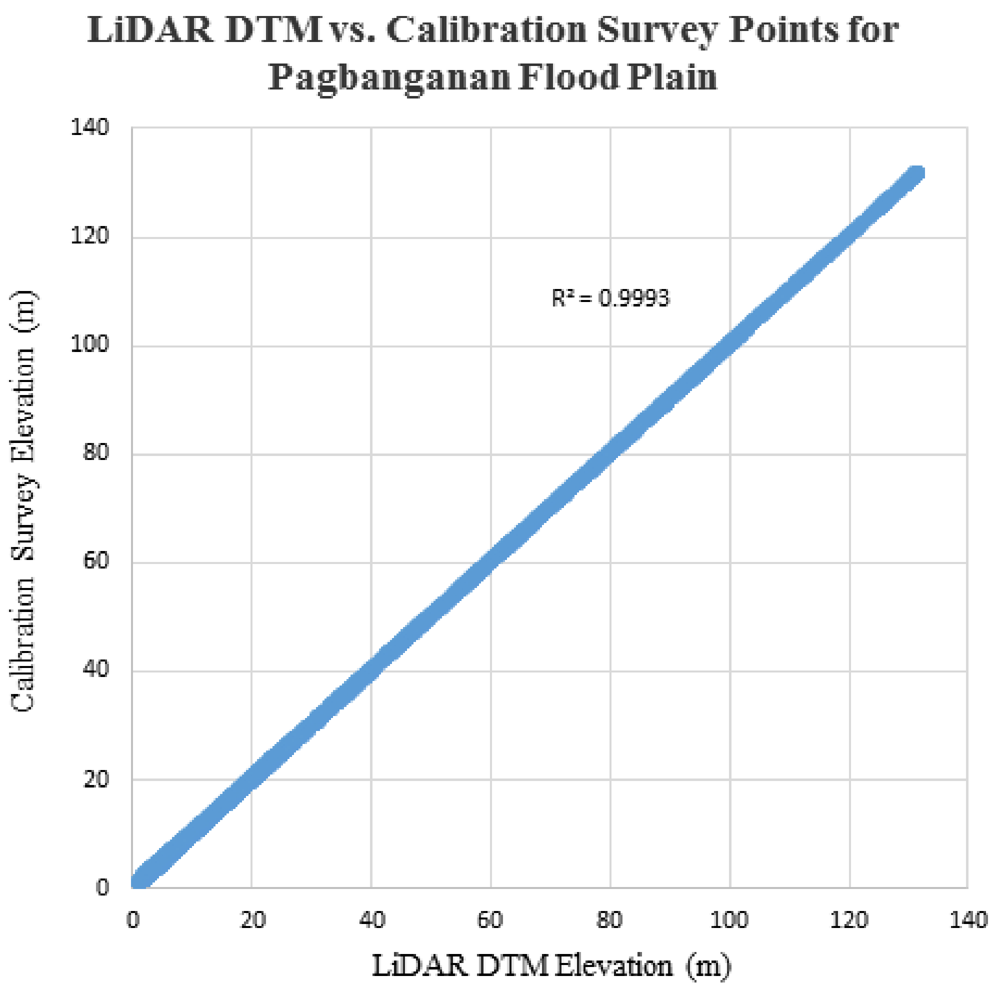


Figure 20. Correlation plot between calibration survey points and LiDAR data

Table 17. Calibration statistical measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.26
Standard Deviation	0.20
Average	0.17
Minimum	-0.30
Maximum	0.60

The remaining 20% of the total survey points, resulting in 5,142 points, were used for the validation of calibrated Pagbanganan 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 21. The computed RMSE between the calibrated LiDAR DTM and validation elevation values is 0.20 meters with a standard deviation of 0.18 meters, as shown in Table 18.

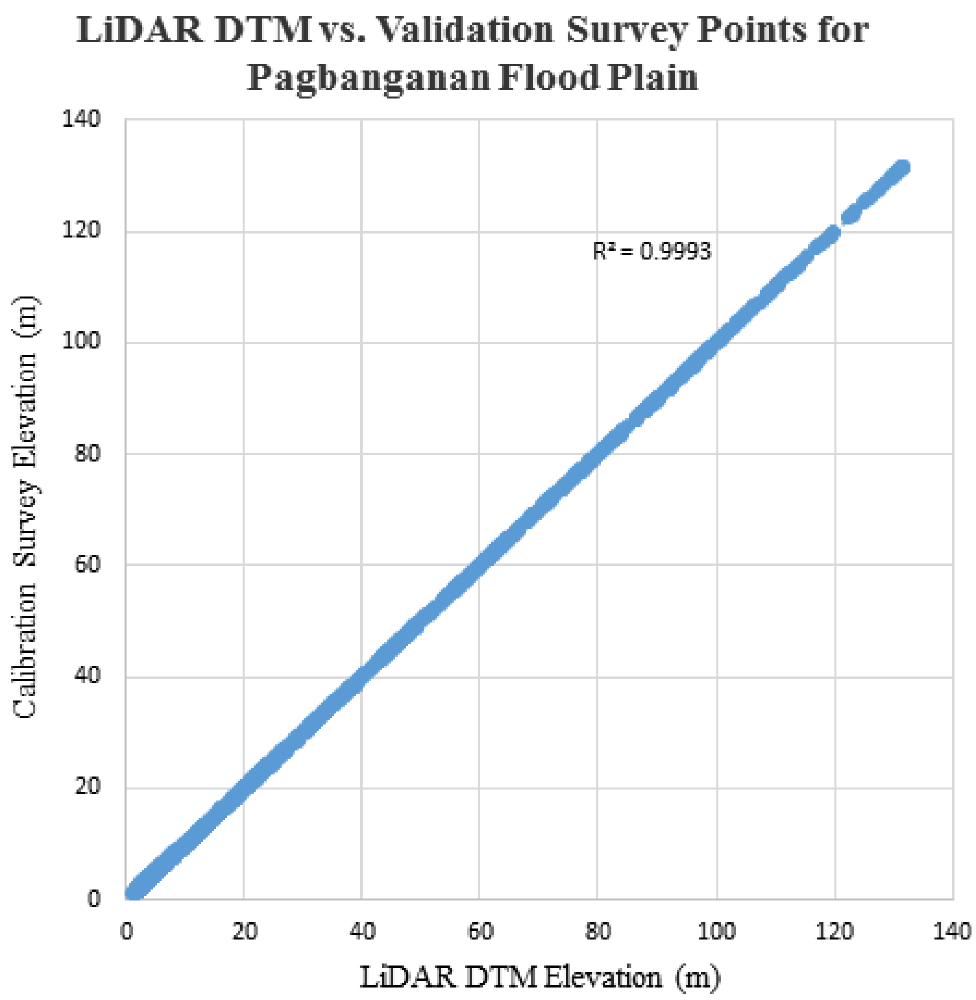


Figure 21. Correlation plot between validation survey points and LiDAR data

Table 18. Validation statistical measures

Validation Statistical Measures	Value (meters)
RMSE	0.20
Standard Deviation	0.18
Average	-0.10
Minimum	-0.47
Maximum	0.28

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, only centerline, cross-section, and zigzag data were available for Pagbanganan with 7,209 bathymetric survey points. The resulting raster surface produced was done by Kernel Interpolation with Barriers method. After burning the bathymetric data to the calibrated DTM, assessment of the interpolated surface is represented by the computed RMSE value of 0.39 meters. The extent of the bathymetric survey done by the DVBC in Pagbanganan integrated with the processed LiDAR DEM is shown in Figure 22.

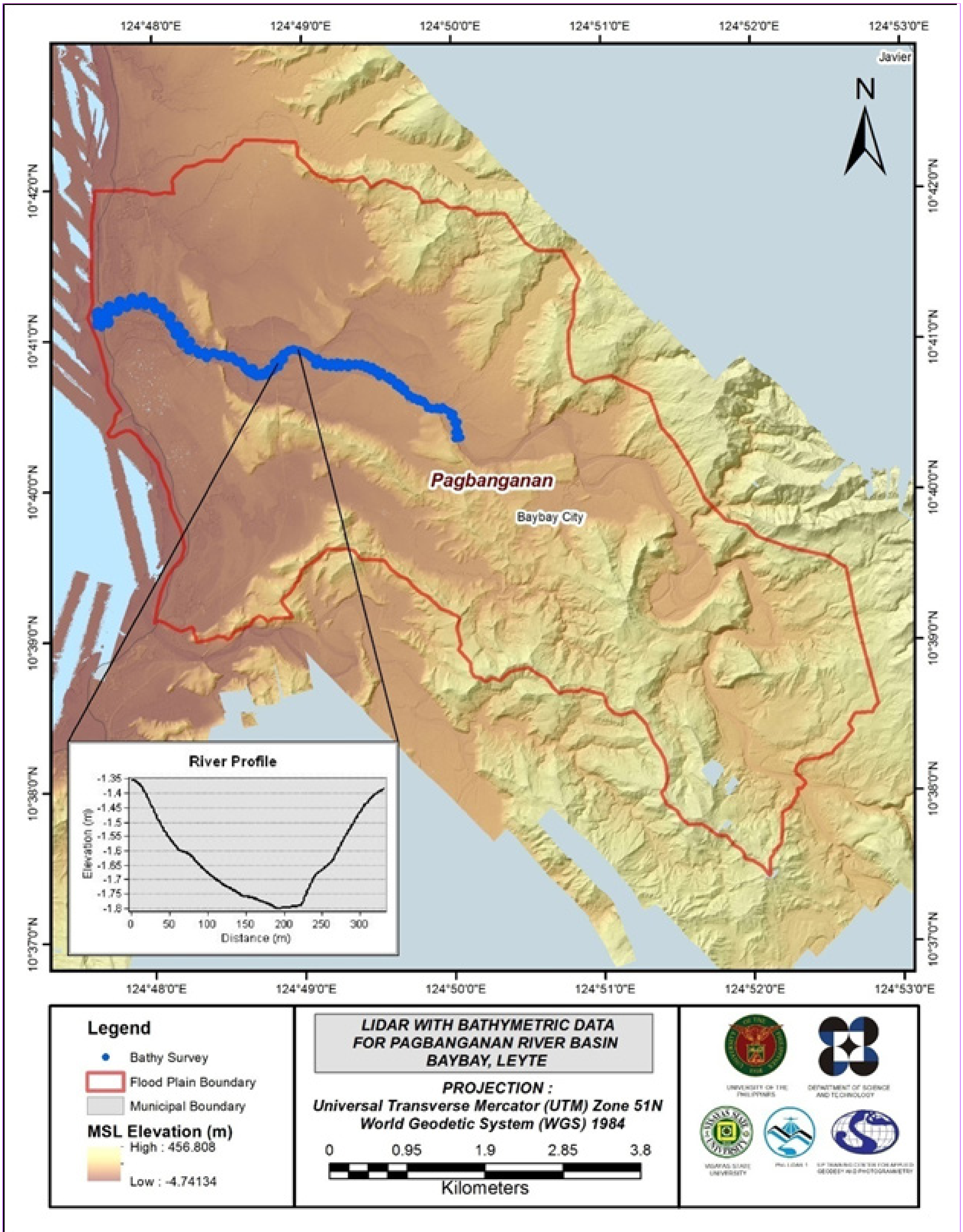


Figure 22. Map of Pagbanganan Floodplain with bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

Pagbanganan Floodplain, including its 200 m buffer, has a total area of 48.28 sq km. For this area, a total of 5.0 sq km, corresponding to a total of 1,542 building features, are considered for QC. Figure 23 shows the QC blocks for Pagbanganan Floodplain.

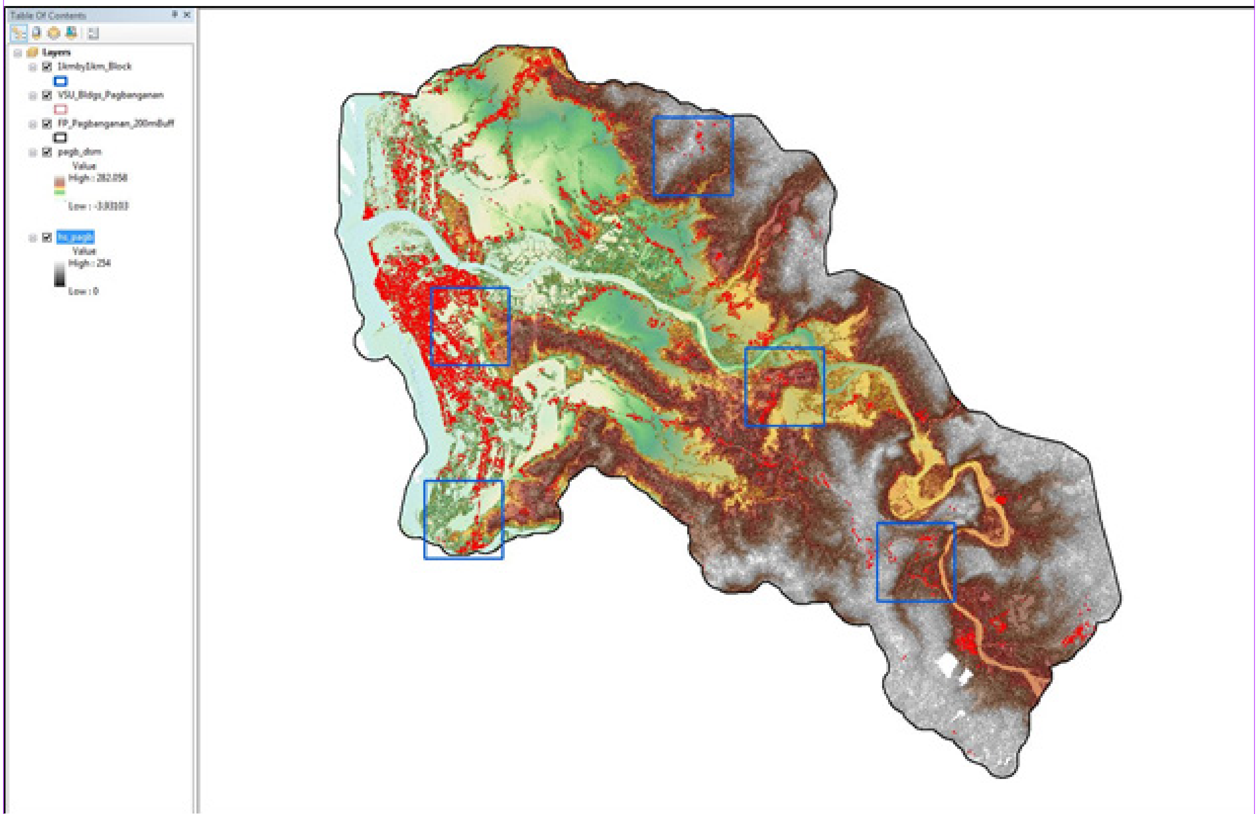


Figure 23. Blocks (in blue) of Pagbanganan building features subjected to QC.

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

Table 19. Quality checking ratings for Pagbanganan building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Pagbanganan	100	100	95.91	PASSED

3.12.2 Height Extraction

Height extraction was done for 12,246 building features in Pagbanganan Floodplain. Of these building features, 620 was filtered out after height extraction, resulting in 11,626 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 15.41 m.

3.12.3 Feature Attribution

The digitized features were marked and coded in the field using handheld GPS receivers. The attributes of non-residential buildings were first identified; all other buildings were then coded as residential. An nDSM was generated using the LiDAR DEMs to extract the heights of the buildings. A minimum height of 2 meters was used to filter out the terrain features that were digitized as buildings. Buildings that were not yet constructed during the time of LiDAR acquisition were noted as new buildings in the attribute table.

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

Table 18. Building Features Extracted for Pajo Floodplain

Facility Type	No. of Features
Residential	10,842
School	211
Market	3
Agricultural/Agro-Industrial Facilities	18
Medical Institutions	25
Barangay Hall	22
Military Institution	6
Sports Center/Gymnasium/Covered Court	32
Telecommunication Facilities	6
Transport Terminal	4
Warehouse	24
Power Plant/Substation	1
NGO/CSO Offices	1
Police Station	2
Water Supply/Sewerage	1
Religious Institutions	76
Bank	6
Factory	0
Gas Station	11
Fire Station	1
Other Government Offices	60
Other Commercial Establishments	274
Total	11,626

Table 19. Total Length of Extracted Roads for Pajo Floodplain

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
	45.34	15.84	12.98	0.00	0.00	74.16

Table 22. Number of extracted water bodies for Pagbanganan Floodplain

Floodplain	Water Body Type					Total
	Rivers/Streams	Lakes/Ponds	Sea	Dam	Fish Pen	
Pagbanganan	36	15	0	0	0	51

A total of 34 bridges and culverts over small channels that are part of the river network were also extracted for the floodplain.

3.12.4 Final Quality Checking of Extracted Features

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

Figure 24 shows the Digital Surface Model (DSM) of Pagbanganan flood plain overlaid with its ground features.

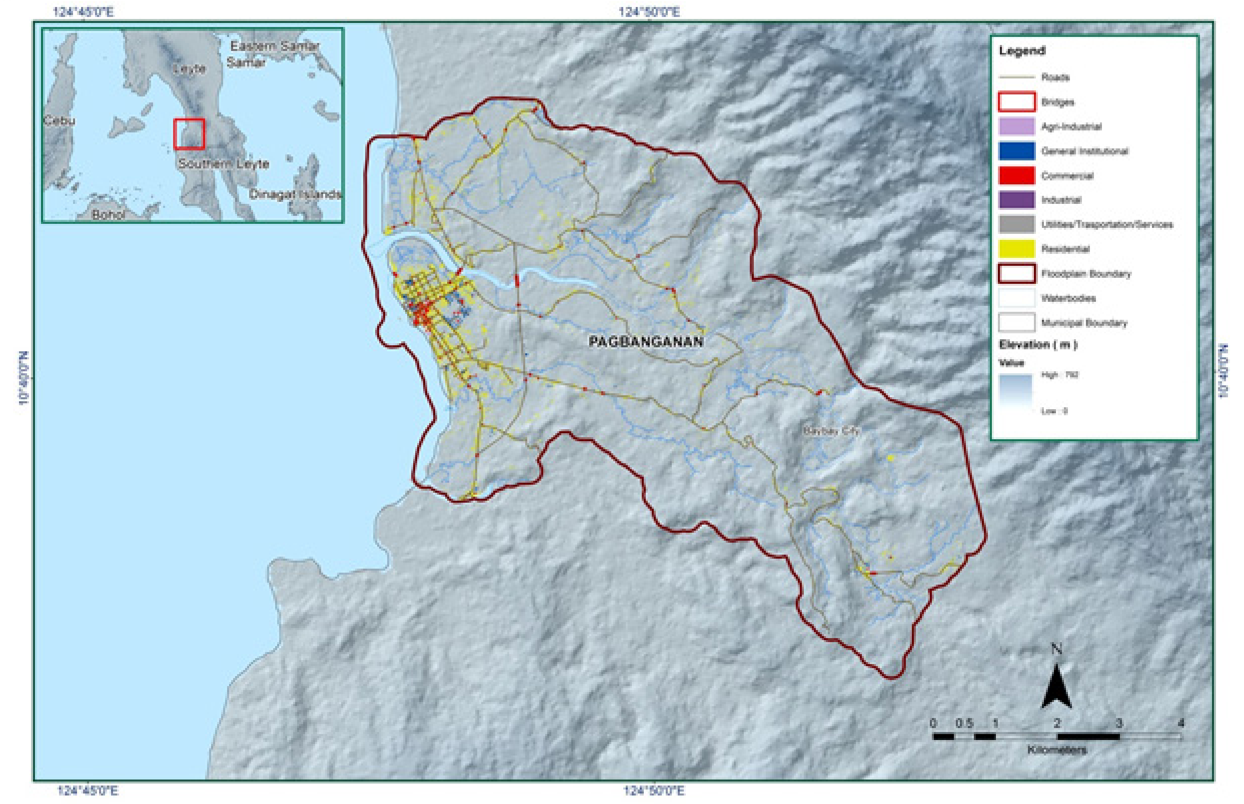


Figure 24. Extracted features for Pagbanganan Floodplain

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Ms. Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo For. Maridel P. Miras, Mr. Randell B. Pabroquez, Engr. Janina A. Jupiter

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

DVBC conducted a field survey in Pagbanganan River on March 9-23, 2016 with the following scope of work: reconnaissance; control survey; cross-section and as-built surveys in Pagbanganan Bridge, Brgy. Poblacion, Baybay City, Leyte; validation points data acquisition of about 75 km for the areas traversing the Pagbanganan River Basin; and bathymetric survey from Brgy. Bubon down to Brgy. Sto. Rosario, both in Baybay City, with an estimated length of 5.533 km using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (see Figure 25).

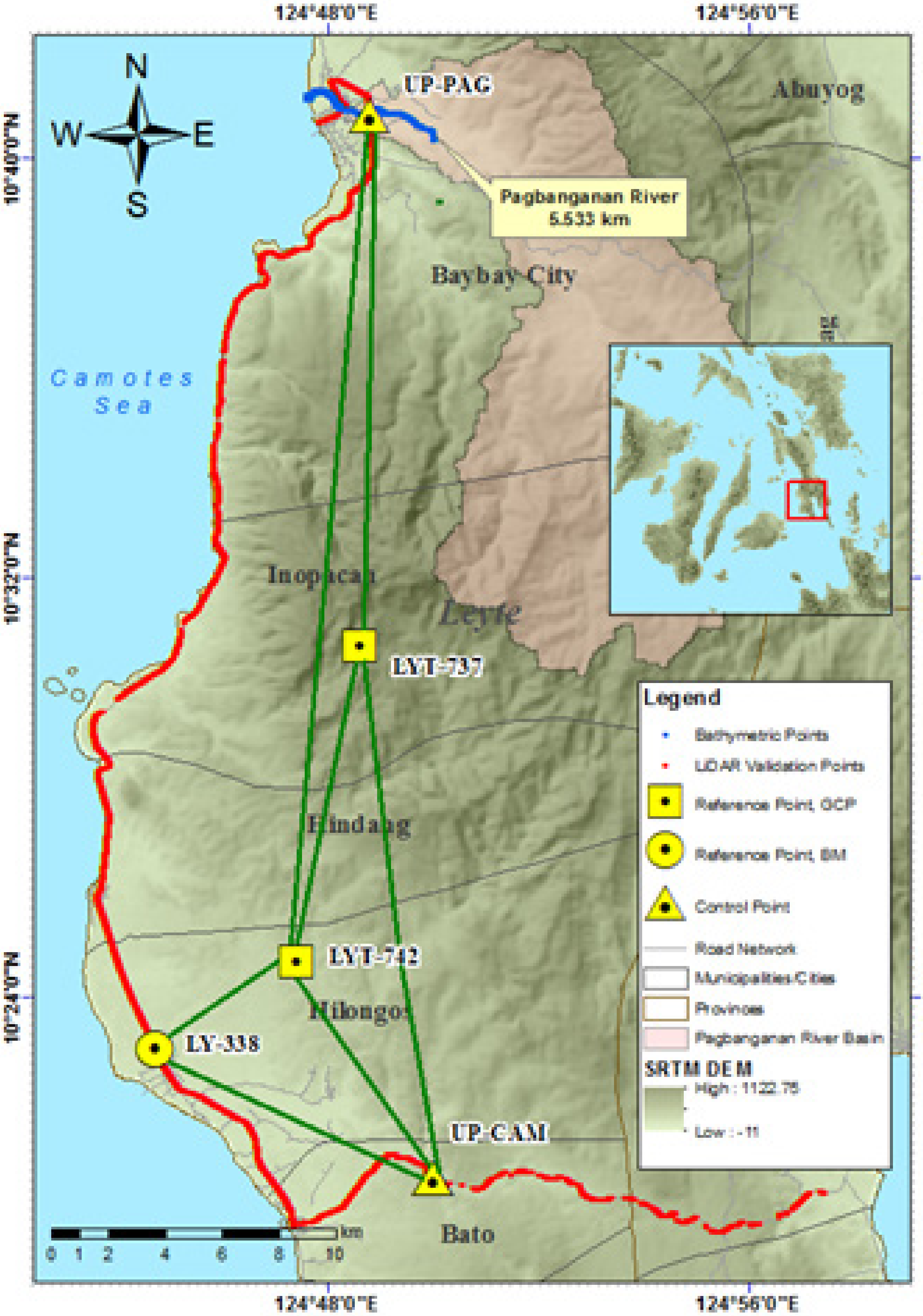


Figure 25. Extent of the bathymetric survey (in blue) in Pagbanganan River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for Pagbanganan River Basin is composed of three loops established on March 10 and 11, 2016 occupying the following reference points: LYT-737, a second-order GCP, in Brgy. Cabulisan, Municipality of Inopacan; LYT-742, a second-order GCP, in Brgy. Tambis, Municipality of Hilongos; and LY-338, a first-order BM, in Brgy. San Juan, Municipality of Hilongos.

Two control points were established along the approach of a bridge namely: UP-CAM at Cambanog Bridge in Brgy. Naga, Municipality of Bato; and UP-PAG at Pagbanganan Bridge in Brgy. Poblacion Zone 12, Baybay City.

The summary of reference and control points and its location is summarized in Table 23, while the GNSS network established is illustrated in Figure 26.

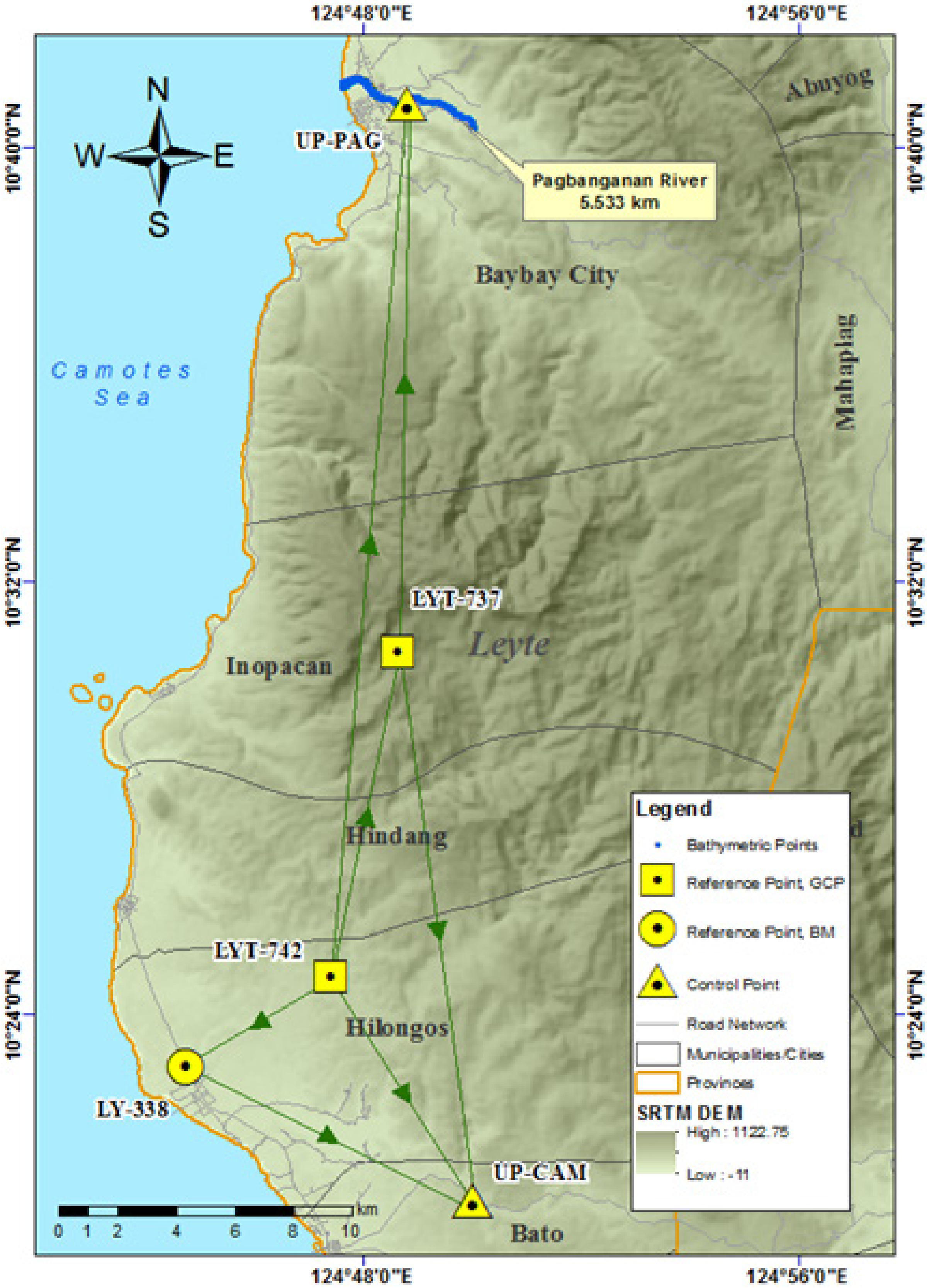


Figure 26. GNSS network covering Pagbanganan River

Table 23. List of reference and control points occupied for Pagbanganan River Survey (Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (Meter)	Elevation in MSL (Meter)	Date Established
LYT-737	2nd order, GCP	10°30'42.1282"N	124°48'38.7024"E	600.703	-	2007
LYT-742	2nd order, GCP	10°24'41.5778"N	124°47'25.4388"E	110.425	-	03-14-2016
LY-338	1st order, BM	-	-	73.006	8.483	2007
UP-CAM	UP Established	-	-	-	-	03-10-2016
UP-PAG	UP Established	-	-	-	-	03-11-2016

The GNSS set-ups on recovered reference points and established control points in Pagbanganan River are shown in Figure 27 to Figure 31.

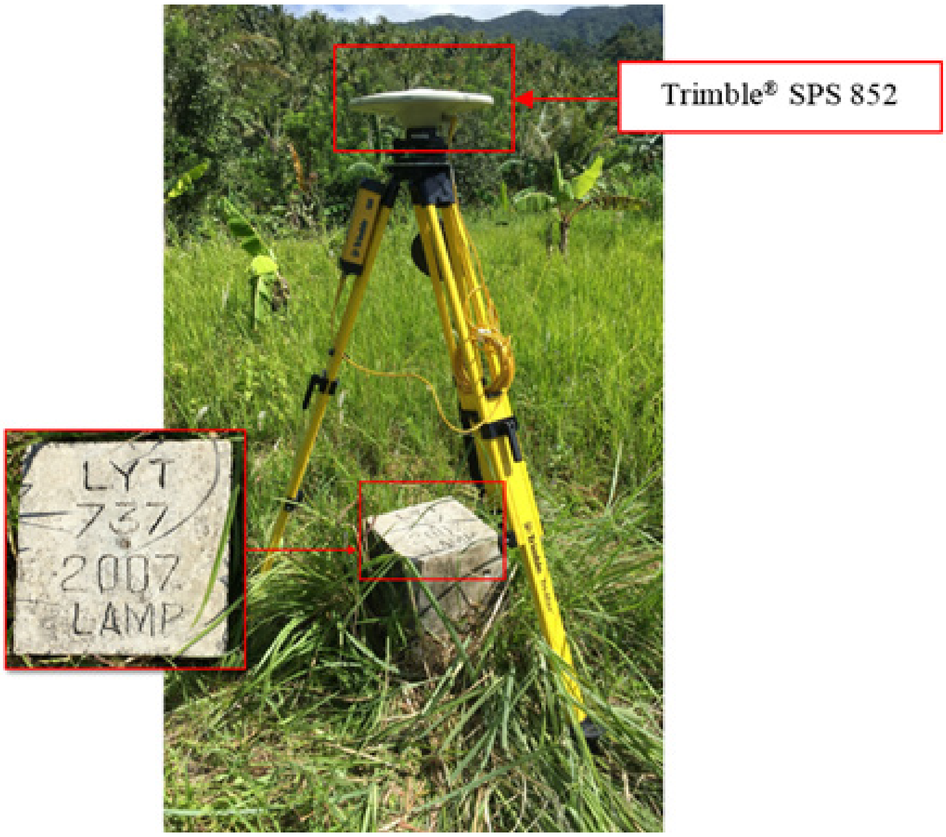


Figure 27. GNSS base set-up, Trimble® SPS 852, at LYT-737, located at the back of Cabulisan Elementary School in Brgy. Cabulisan, Municipality of Inopacan, Leyte

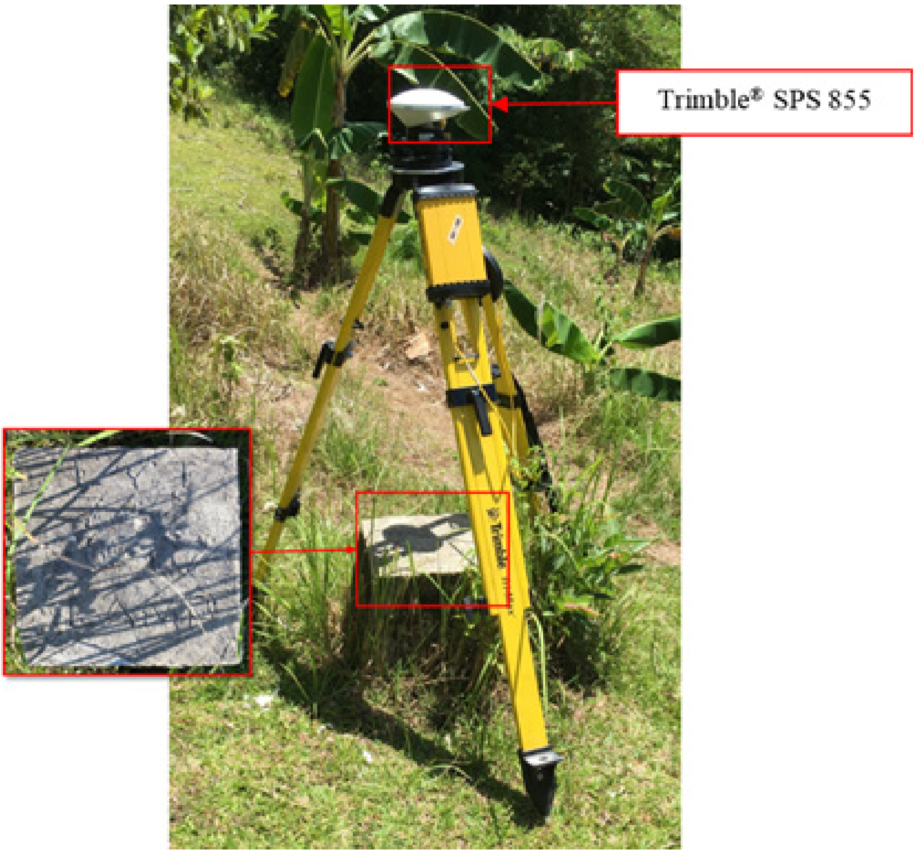


Figure 28. GNSS base set-up, Trimble® SPS 855, at LYT-742, located near a chapel and basketball court in Brgy. Tambis, Municipality of Hilongos, Leyte

Figure 29. GNSS receiver set-up, Trimble® SPS 855, at LY-338, located at the approach of Salug Birdge along Sta. Indang-Hilongos Road in Brgy. San Juan, Municipality of Hilongos, Leyte

Figure 30. GNSS receiver set-up, Trimble® SPS 882, at UP-CAM, located at the approach of Cambanog Bridge in Brgy. Naga, Municipality of Bato, Leyte

Figure 31. GNSS receiver set-up, Trimble® SPS 855, at UP-PAG, located at Pagbanganan Bridge approach in Brgy. Brgy. Poblacion Zone 12, City of Baybay, Leyte

4.3 Baseline Processing

GNSS Baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In case where one or more baselines did not meet all of these criteria, masking was performed. Masking is done by removing/masking portions of these baseline data using the same processing software. It is repeatedly processed until all baseline requirements are met. If the reiteration yields out of the required accuracy, resurvey is initiated. Baseline processing result of control points in Pagbanganan River Basin is summarized in Table 24 generated by TBC software.

Table 24. Baseline processing summary report for Pagbanganan River survey

Observation	Date of Observation	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
LYT-742 --- LYT-737	03-11-2016	Fixed	0.003	0.014	11°22'12"	11299.872	
LYT-737 --- UPCAM	03-11-2016	Fixed	0.004	0.024	172°18'02"	18901.310	
LYT-742 --- UPPAG	03-11-2016	Fixed	0.003	0.012	4°53'18"	29783.6899	
LY-338 --- UP-CAM	03-10-2016	Fixed	0.005	0.028	115°25'44"	10691.421	
LYT-737 --- UP-PAG	03-11-2016	Fixed	0.003	0.012	0°57'35"	18599.831	
UP-CAM --- LYT-742	03-10-2016	Fixed	0.003	0.022	148°06'41"	9012.871	
LYT-737 --- LYT-742	03-11-2016	Fixed	0.003	0.013	11°22'12"	11299.875	
LY-338 --- LYT-742	03-10-2016	Fixed	0.004	0.023	237°58'44"	5771.913	
UP-MAR --- CNS-3028	04-09-16	Fixed	0.004	0.023	78°00'02"	12411.353	
UP-MAR --- CA-130	04-09-16	Fixed	0.003	0.011	34°37'02"	16907.625	
UP-MAR --- CNS-21	04-09-16	Fixed	0.002	0.009	77°20'46"	2349.293	

As shown in Table 24, a total of eight baselines were processed with reference points LYT-737 and LYT-742, and LY-338 held fixed for grid and elevation values, respectively. All of them passed the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the Adjusted Grid Coordinates (Table 26) of the TBC generated Network Adjustment Report, it is observed that the square root of the sum of the squares of x and y must be less than 20 cm and z less than 10 cm or in equation form:

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

where:

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

for each control point. See the Network Adjustment Report shown in Table 25 to Table 27 for complete details.

The five control points, LY-338, LYT-737, LYT- 742, UP-CAM, and UP-PAG, were occupied and observed simultaneously to form a GNSS loop. Elevation value of LY-338 and coordinates of points LYT-737 and LYT-742 were held fixed during the processing of the control points as presented in Table 25. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 25. Control point constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
LYT-737	Local	Fixed	Fixed		
LYT-742	Local	Fixed	Fixed		
LY-338	Grid				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 26. The fixed control points, LYT-737 and LYT-742, have no values for grid errors; and LY-338, for elevation error.

Table 24. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
LYT-737	698162.79	?	1162560.388	?	536.080	0.089	LL
LYT-742	695997.844	?	1151468.957	?	45.879	0.084	LL
LY-338	691121.157	0.012	1148380.761	0.009	8.483	?	e
UP-CAM	700802.490	0.010	1143842.626	0.010	21.206	0.089	
UP-PAG	698366.197	0.015	1181160.649	0.011	6.881	0.092	

The network is fixed at reference point CNS-21with known coordinates, and CA-130 with known elevation. As shown in Table 24, the standard errors (xe and ye) of CA-130 are 1.40 cm and 1.2 cm; CA-15 are 2.0 cm and 1.7 cm; CNS-3018 are 1.7cm and 1.40 cm; CNS-3028 are 1.80 cm and 1.40 cm; and UP-MAR are 1.20 cm and 1 cm. With the mentioned equation, <20cm for horizontal and $z_e<10$ cm for the vertical; the computation for the accuracy are as follows:

LYT-737

horizontal accuracy	=	Fixed
vertical accuracy	=	8.90 < 10 cm

LYT-742

horizontal accuracy	=	Fixed
vertical accuracy	=	8.40 < 10 cm

LY-338

horizontal accuracy	=	$\sqrt{(1.20)^2 + (0.90)^2}$
	=	$\sqrt{1.44 + 0.81}$
	=	1.50 cm < 20 cm
vertical accuracy	=	Fixed

UP-CAM

horizontal accuracy	=	$\sqrt{(1.0)^2 + (1.0)^2}$
	=	$\sqrt{1.0 + 1.0}$
	=	1.41 cm < 20 cm
vertical accuracy	=	8.90 cm < 10 cm

UP-PAG

horizontal accuracy	=	$\sqrt{(1.50)^2 + (1.10)^2}$
	=	$\sqrt{2.25 + 1.21}$
	=	1.86 cm < 20 cm
vertical accuracy	=	9.20 cm < 10 cm

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

Table 27. Adjusted geodetic coordinates

Point ID	Latitude	Longitude	Ellipsoid	Height	Constraint
LYT-737	10°30'42.12820"N	124°48'38.70244"E	600.703	0.089	LL
LYT-742	10°24'41.57783"N	124°47'25.43883"E	110.425	0.084	LL
LY-338	10°23'01.95953"N	124°44'44.56153"E	73.006	?	e
UP-CAM	10°20'32.50055"N	124°50'01.93960"E	85.886	0.089	
UP-PAG	10°40'47.39583"N	124°48'48.95238"E	71.261	0.092	

The corresponding geodetic coordinates of the observed points are within the required accuracy as shown in Table 27. Based on the result of the computation, the accuracy condition is satisfied; hence, the required accuracy for the program was met.

The summary of reference and control points used is indicated in Table 28.

Table 28. Reference and control points used and its location (Source: NAMRIA, UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)			UTM ZONE 51 N		
		Latitude	Longitude	Ellipsoidal Height (m)	Northing (m)	Easting (m)	BM Ortho (m)
LYT-737	2nd order, GCP	10°30'42.1282"N	124°48'38.7024"E	600.703	1162560.388	698162.797	536.080
LYT-742	2nd order, GCP	10°24'41.5778"N	124°47'25.4388"E	110.425	1151468.957	695997.844	45.879
LY-338	1st order, BM	10°23'01.9595"N	124°44'44.5615"E	73.006	1148380.761	691121.157	8.483
UP-CAM	UP Established	10°20'32.5005"N	124°50'01.9396"E	85.886	1143842.626	700802.490	21.206
UP-PAG	UP Established	10°40'47.3958"N	124°48'48.9523"E	71.261	1181160.649	698366.197	6.881

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

Cross-section and as-built survey was conducted on March 13, 2016 at the downstream portion of Pagbanganan River in Pagbanganan Bridge, Brgy. Poblacion, Baybay City using a survey grade GNSS receiver Trimble® SPS 882 in PPK survey technique as shown in Figure 32.

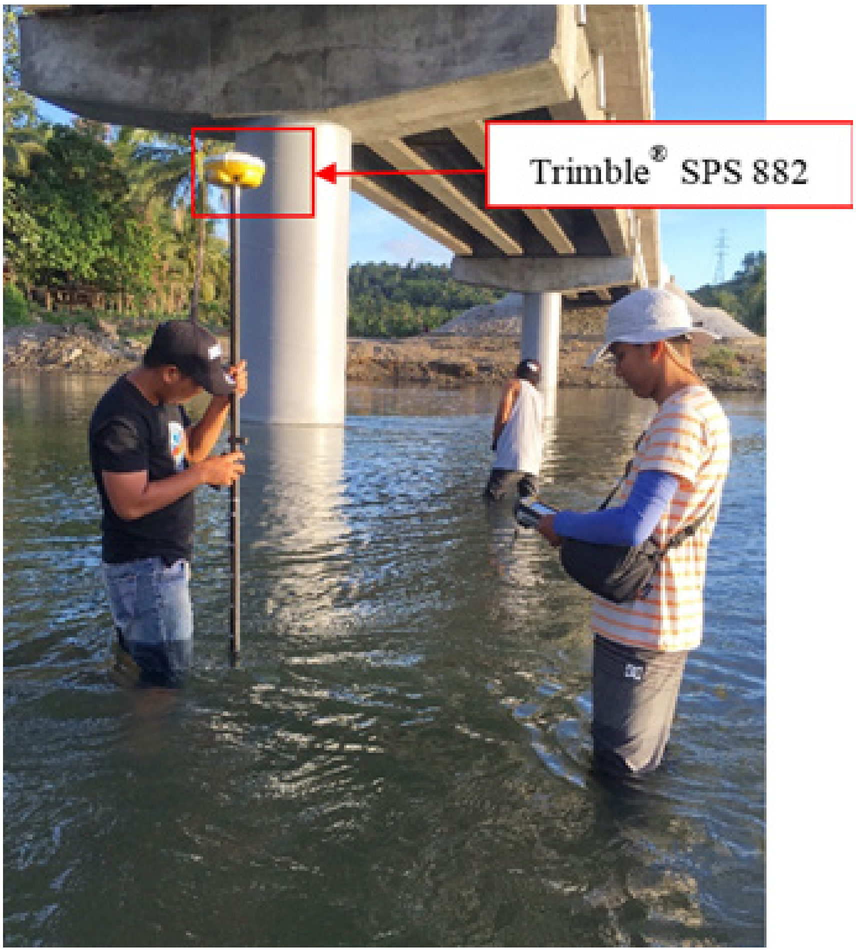


Figure 32. Bridge as-built and cross-section survey of Pagbanganan Bridge

The cross-sectional line for the Pagbanganan Bridge is about 850 m with twenty-seven (27) cross-sectional points acquired using UP-PAG as the GNSS base station. The location map, cross-section diagram, and the bridge data form are shown in Figure 33 to Figure 35, respectively.

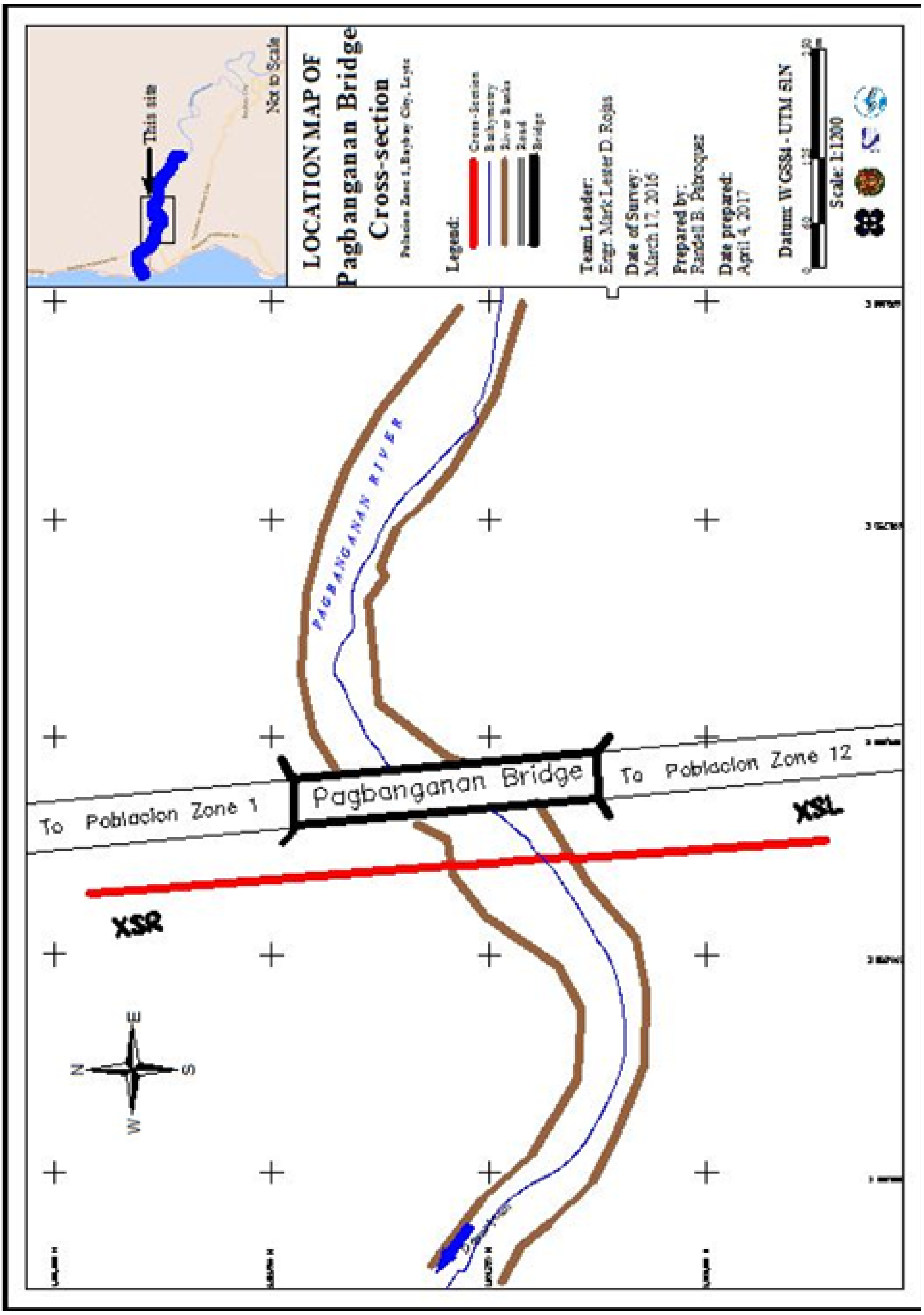


Figure 33. Pagbanganan Bridge cross-section location map

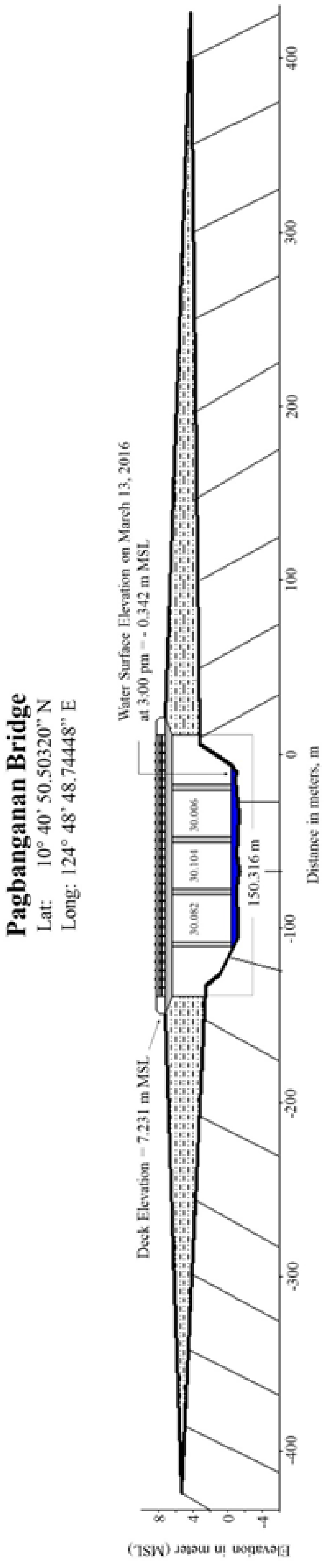


Figure 34. Pagbanganan Bridge cross-section diagram

Bridge Data Form

Bridge Name: Pagbangan Bridge — **Date:** March 13, 2016

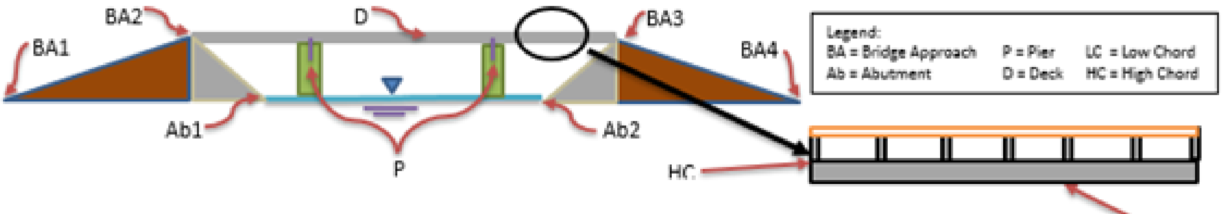
River Name: Pagbangan River — **Time:** 3:00 PM

Location (Brgy, City,Region): Zone 1, Baybay City

Survey Team: Mark Rojas, Anthony Abogado, Marla Morris

Flow condition: normal — **Weather Condition:** fair

Latitude: 10°40'50.50320" N — **Longitude:** 124 °48'48.7448" E



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

Elevation: 7.231 m **Width:** 9.384 m **Span (BA3-BA2):** 150.316 m

	Station	High Chord Elevation	Low Chord Elevation
1	315.003	7.232	5.132
2	345.085	7.231	5.131
3	375.189	7.181	5.081

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	5.381 m	BA3	435.252 m	7.162 m
BA2	284.936 m	7.231 m	BA4	850.277 m	4.329 m

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

	Station (Distance from BA1)	Elevation
Ab1	290.877	2.520 m
Ab2	430.185	3.140 m

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

Shape: Round Number of Piers: 4 Height of column footing: 1

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	315.003m	7.232m	1.8m
Pier 2	345.085m	7.231m	1.8m
Pier 3	375.189m	7.181m	1.8m
Pier 4	405.195m	7.164m	1.8m

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

Figure 35. Bridge as-built form of Pagbanganan Bridge

Water surface elevation in MSL of Pagbanganan River was determined using Trimble® SPS 882 in PPK mode technique on March 13, 2016 at 3:53 PM with a value of -0.342 m in MSL. This was translated onto marking on the bridge's pier using digital level to be used by Visayas State University PHIL-LiDAR 1. The marked pier will serve as their reference for flow data gathering and depth gauge deployment for Pagbanganan River. Figure 36 shows the water level marking on one of the piers of Pagbanganan Bridge.

Figure 36. Water level marking at Pagbanganan Bridge

4.6 Validation Points Acquisition Survey

Validation points acquisition survey was conducted on March 10 and 11, 2016 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole which was attached to the side of vehicle as shown in Figure 37. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 1.929 m and measured from the ground up to the bottom of notch of the GNSS Rover receiver. The PPK technique utilized for the conduct of the survey was set to continuous topo mode with LYT-742, UP-PAG, UP-CAM, and LYT-737 occupied as the GNSS base stations all throughout the conduct of the survey.

Figure 37. Validation points acquisition survey set up along Pagbanganan River Basin

The validation points acquisition survey for the Pagbanganan River Basin traversed Baybay City and the following municipalities of Leyte: Inopacan, Hindang, and Bato; as well as Municipality of Bontoc in Southern Leyte. The route of the survey aims to traverse LiDAR flight strips perpendicularly for the basin. A total of 18,832 points with an approximate length of 75 km was acquired for the validation point acquisition survey as shown in the map in Figure 38.

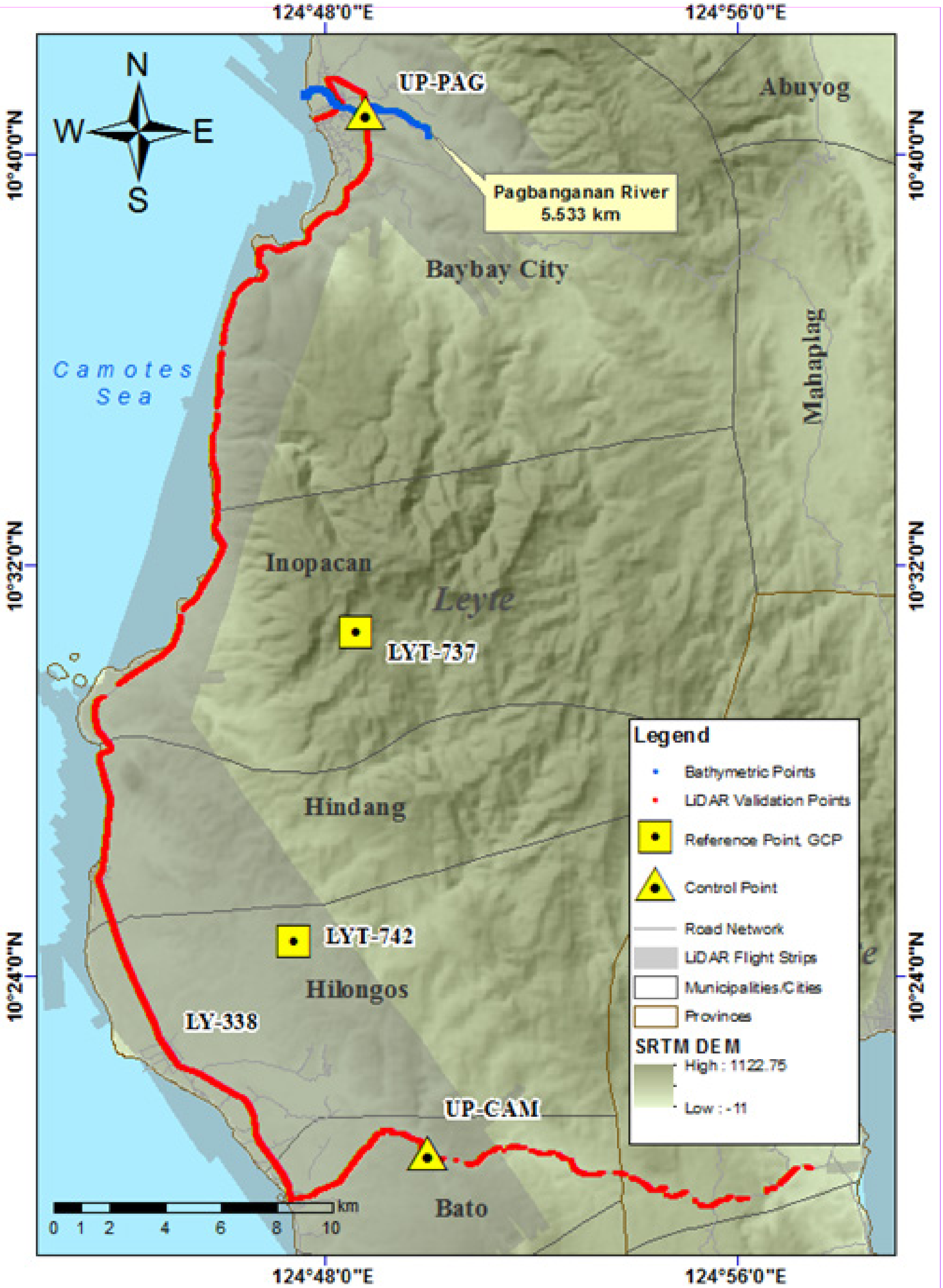


Figure 38. Validation point acquisition survey of Pagbanganan River Basin

4.7 River Bathymetric Survey

Bathymetric survey was executed on March 13, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique utilizing the continuous topo mode and Ohmex™ single beam echo sounder, as illustrated in Figure 39. The survey started from middle upstream part of the river in Brgy. Cogon, Baybay City with coordinates 10°40'51.04283"N, 124°49'06.43258"E, and ended at the mouth of the river in Brgy. Santo Rosario, also in Baybay City with coordinates 10°41'06.45131"N, 124°47'37.21202"E.

Manual bathymetry was also employed on March 17, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique in continuous topo mode. The survey started from the upstream of the river in Brgy. Bubon, Baybay City with coordinates 10°40'20.71534"N, 124°50'02.17711"E, traversed by foot down to the middle portion of the river where the bathymetric survey by boat started. The control point UP-PAG was used as the GNSS base station all throughout the survey.

Figure 39. Bathymetric survey set-up in Pagbanganan River

The bathymetric survey for Pagbanganan River gathered a total of 7,337 points covering 5.533 km of the river traversing ten barangays in Baybay City. A CAD drawing was also produced to illustrate the riverbed profile of Pagbanganan River. As shown in Figure 41, the highest and lowest elevation has a 9-meter difference. The highest elevation observed was 3.967 m above MSL located in Brgy. Cogon, Baybay City while the lowest was -5.374 m below MSL located in Brgy. Santo Rosario, also in Baybay City. The remaining 2.2 km delineated bathymetric line in Brgy. Bubon also within Baybay City, was not surveyed because the area is not flood prone according to the locals.

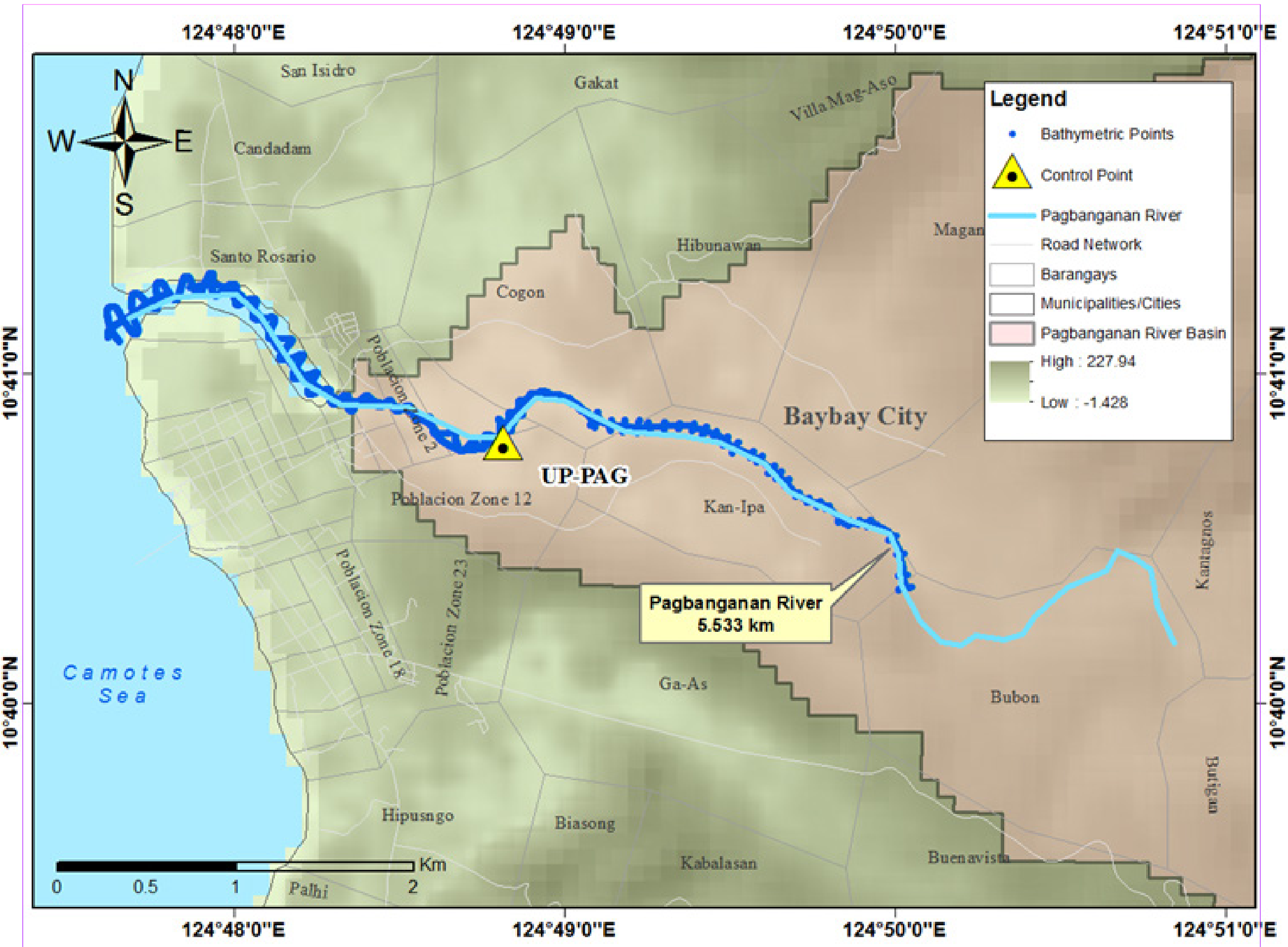


Figure 40. Bathymetric survey of Pagbanganan River

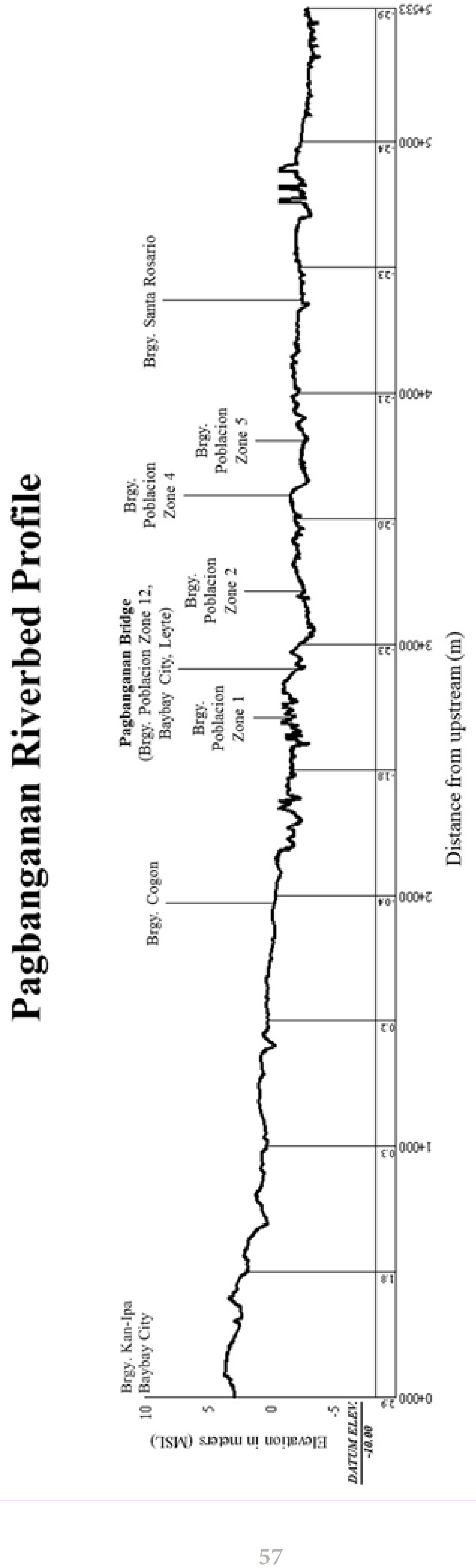


Figure 41. Pagbanganan riverbed profile

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

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 may affect the hydrologic cycle of the river basin, were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from Dungcaan Bridge automatic rain gauge (ARG) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). The location of the rain gauge is seen in Figure 42.

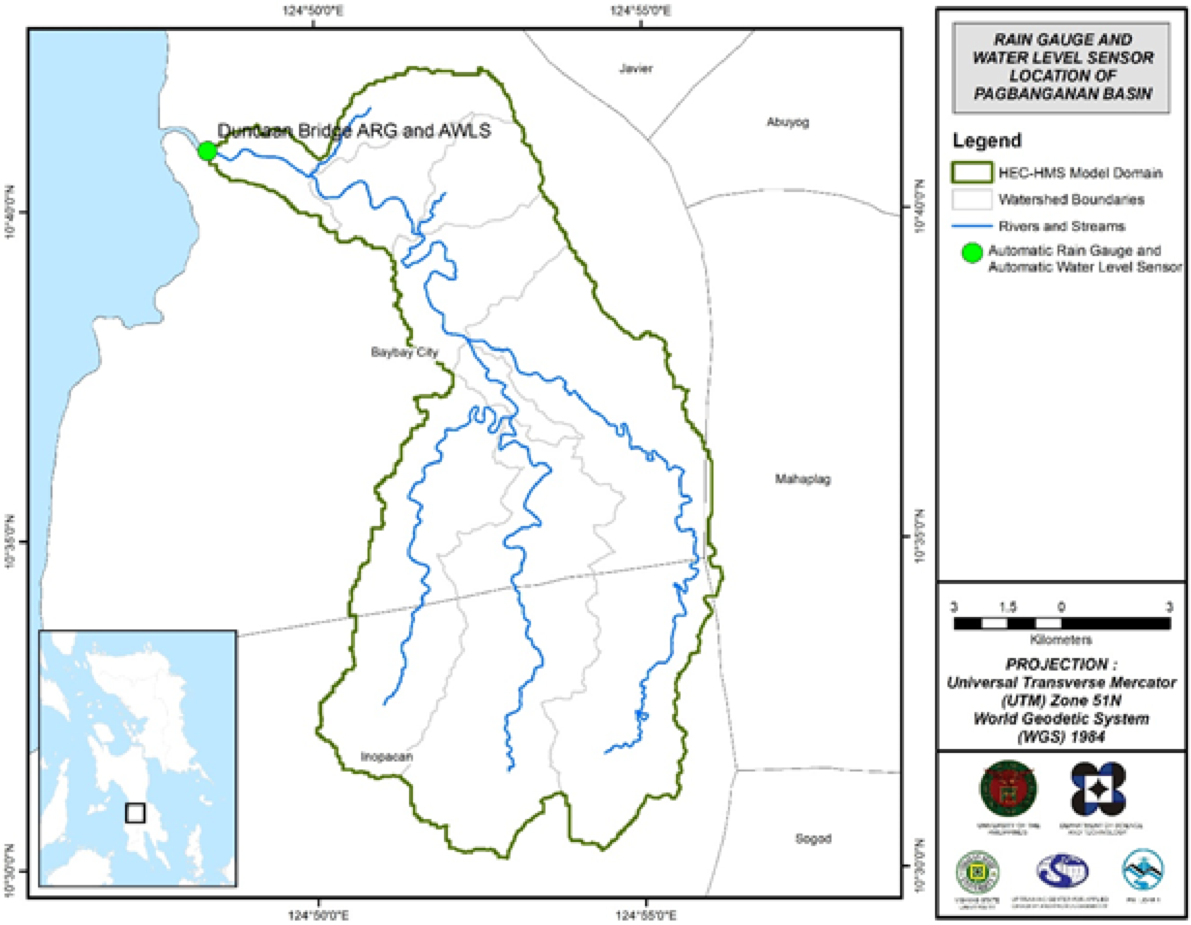
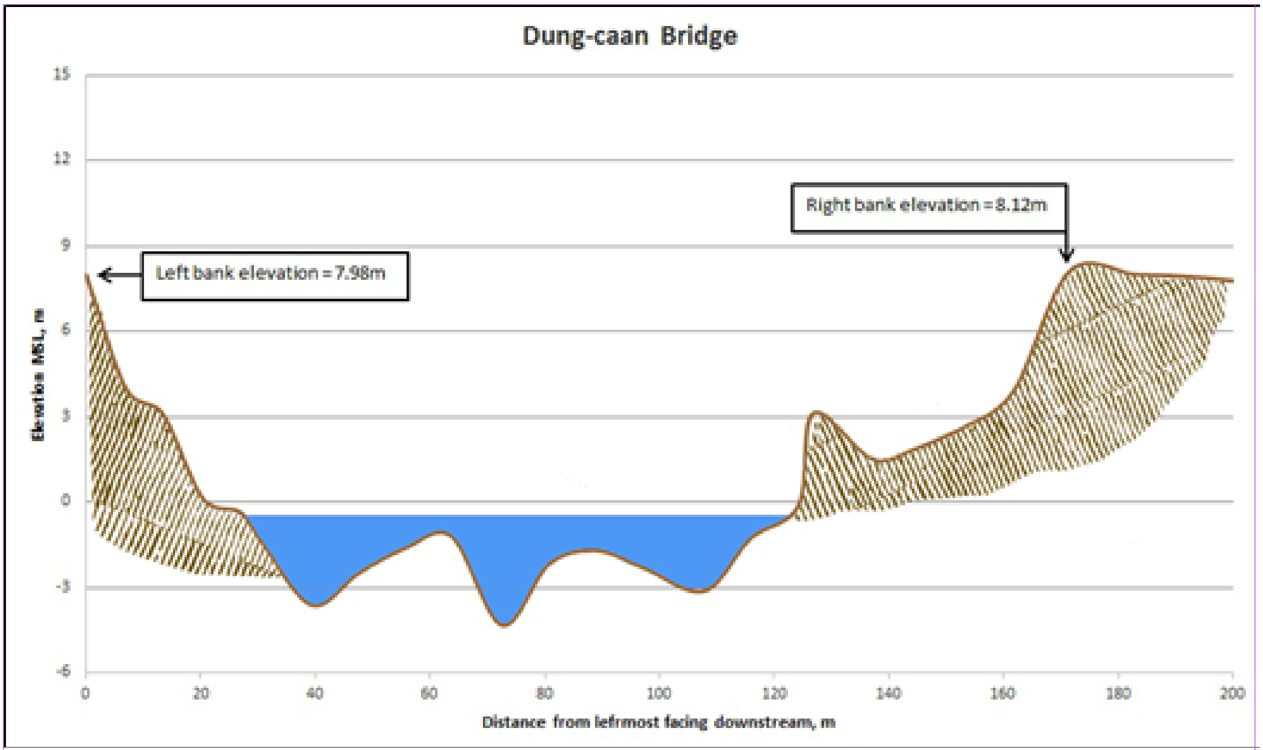


Figure 42. The location map of Pagbanganan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was developed at Dungcaan Bridge, Baybay City, Leyte (10°40'55.33"N, 124°48'18.96"E). It illustrates the relationship between the observed water levels from the Dungcaan Bridge Automated Water Level Sensor (AWLS) and the combined discharge from baseflow and bankfull.

For Dungcaan Bridge, the rating curve is expressed as Q = 26.999e0.0002h as shown in Figure 44.



Cross-section plot of Dungcaan Bridge

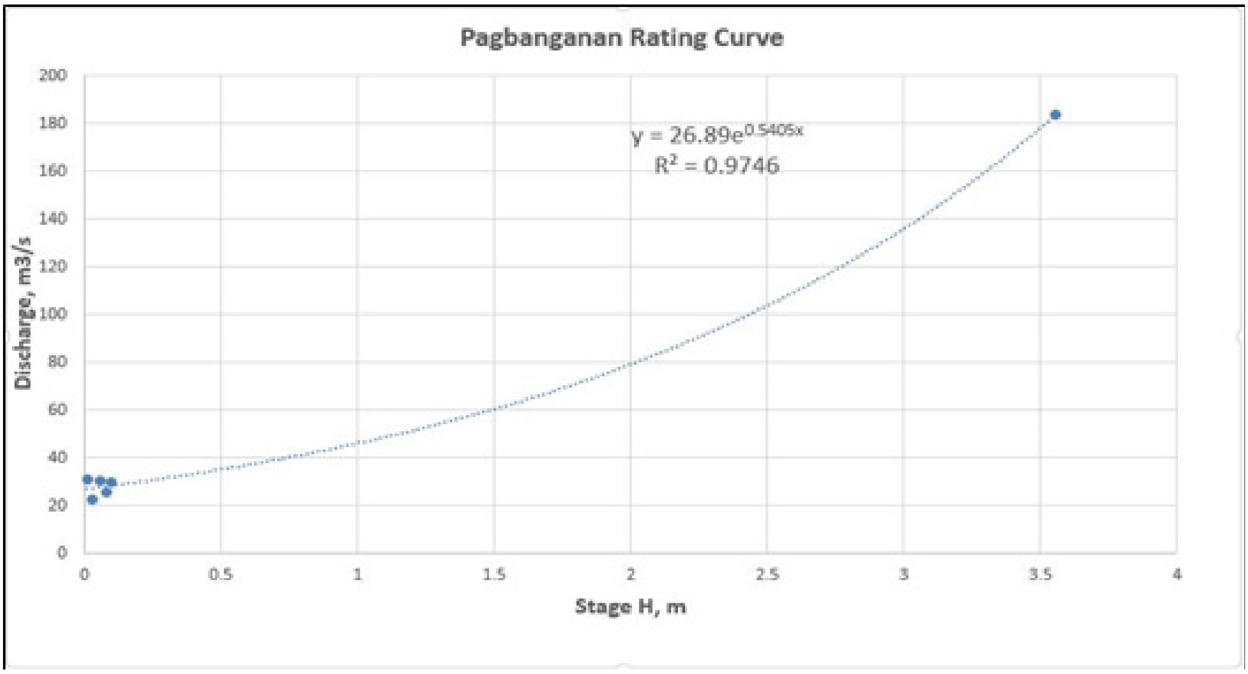


Figure 44. Rating curve at Dungcaan Bridge

This rating curve equation was used to compute the river outflow at Dungcaan Bridge for the calibration of the HEC-HMS model. Total rain from Dungcaan Bridge rain gauge is 129 mm. It peaked to 8.2 mm on 24 November 2016 at 21:40. Peak discharge is 144 cubic meters per second at 12:00 AM, November 25, 2016.

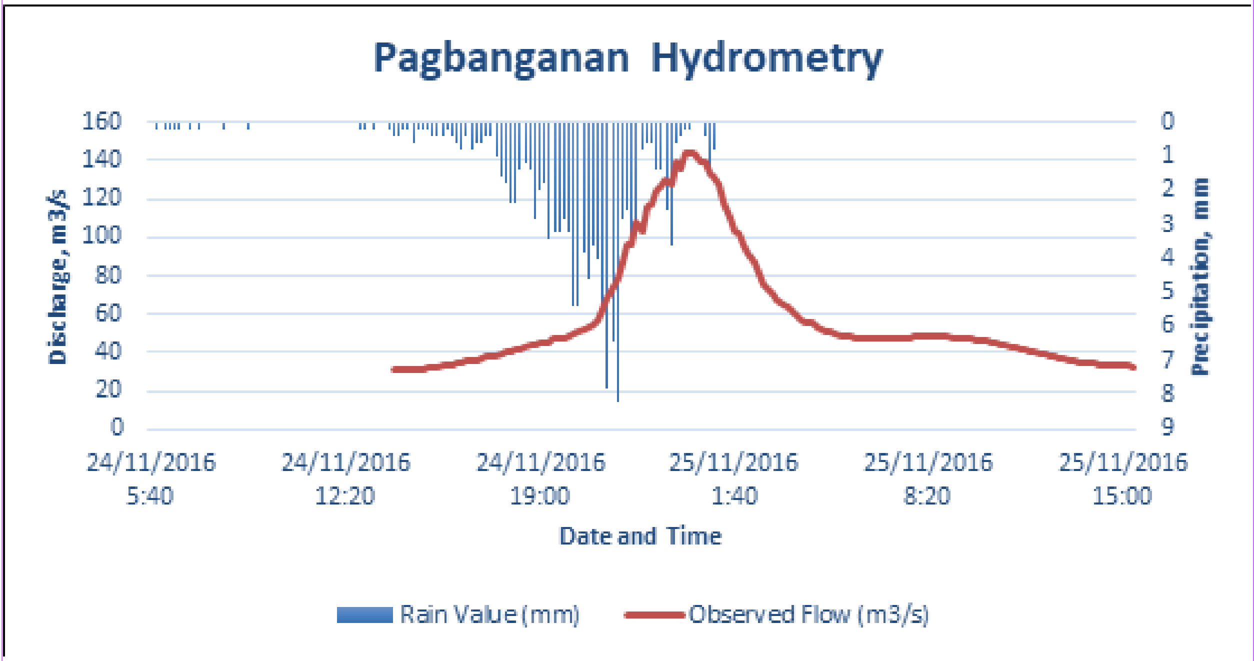


Figure 45. Rainfall and outflow data at Pagbanganan used for modeling

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Maasin Rain Gauge. The RIDF rainfall amount for 24 hours was converted to a synthetic storm by interpolating and re-arranging the value in such a way certain peak value would be attained at a certain time. This station chosen based on its proximity to Pagbanganan watershed. The extreme values for this watershed were computed based on a 16-year record.

Table 29. RIDF values for Maasin 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	18.5	28.1	35.6	48.1	68	82.1	104.6	124.9	145
5	25.9	38.3	63.8	63.8	90.4	108.8	137.5	165.2	190.8
10	30.8	45	74.2	74.2	105.3	126.5	159.3	191.9	221.2
15	33.5	48.8	80.1	80.1	113.7	136.5	171.5	206.9	238.4
20	35.5	51.5	84.2	84.2	119.6	143.5	180.1	217.5	250.4
25	37	53.6	87.3	87.3	124.1	148.9	186.7	225.6	259.6
50	41.5	59.9	97.1	97.1	138.1	165.5	207.1	250.6	288.1
100	46.1	66.2	106.8	106.8	151.9	181.9	227.4	275.4	316.3

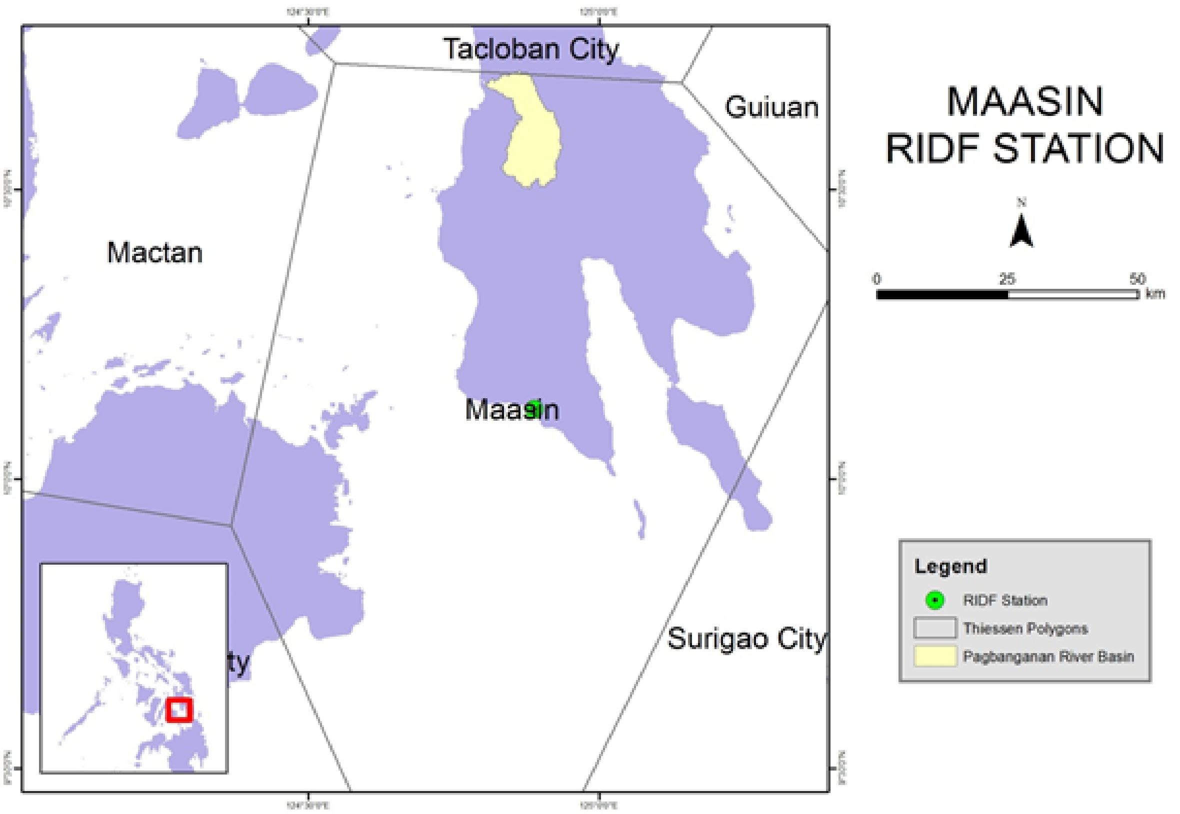


Figure 46. Location of Tacloban RIDF station relative to Pagbanganan River Basin

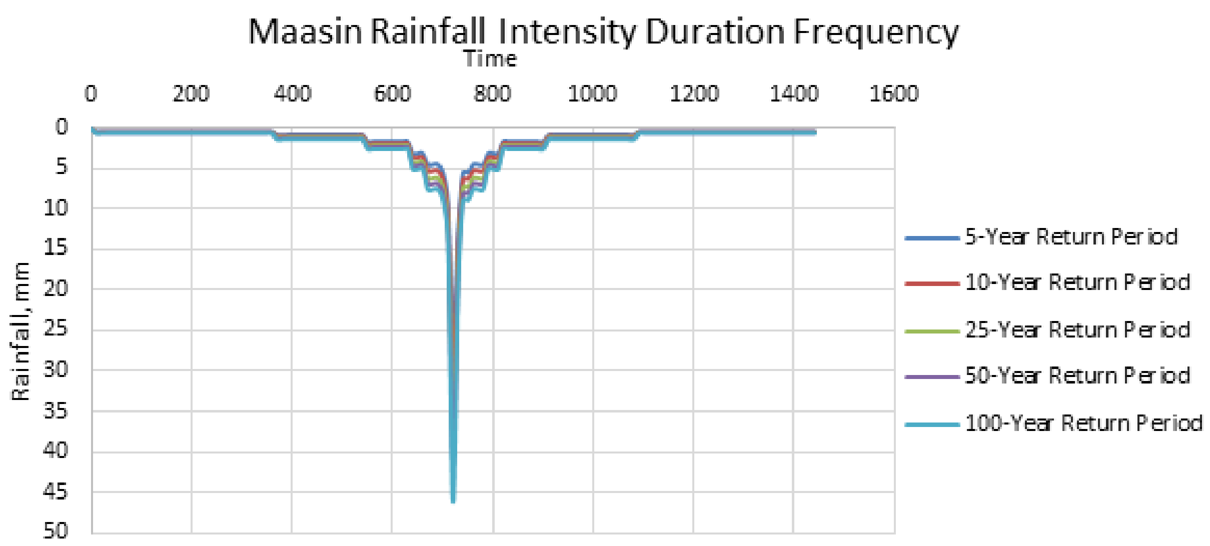


Figure 47. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil dataset was taken from and generated by the Bureau of Soils under the Department Agriculture. The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). The soil and land cover of the Pagbanganan River Basin are shown in Figures 48 and Figure 49, respectively.

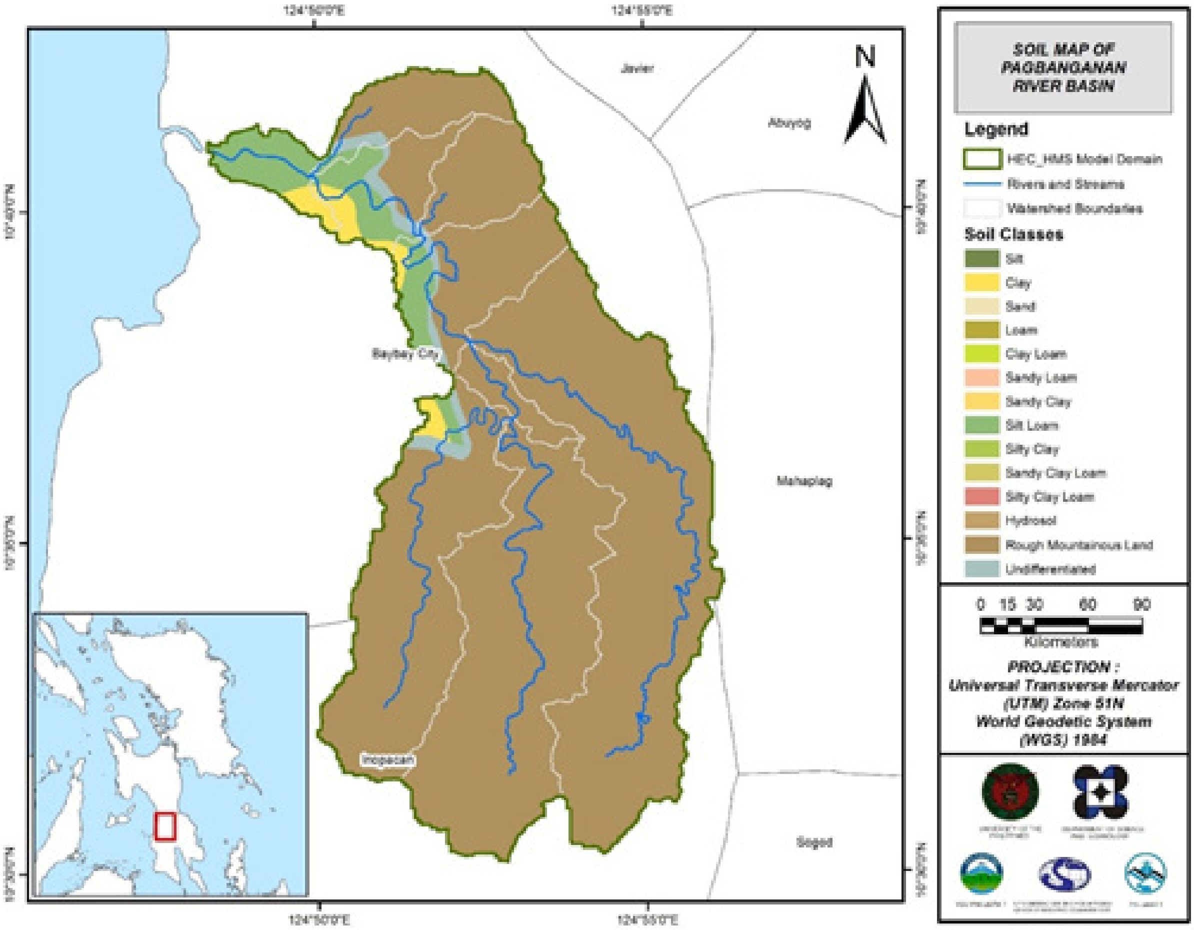


Figure 48. Soil map of Pagbanganan River Basin

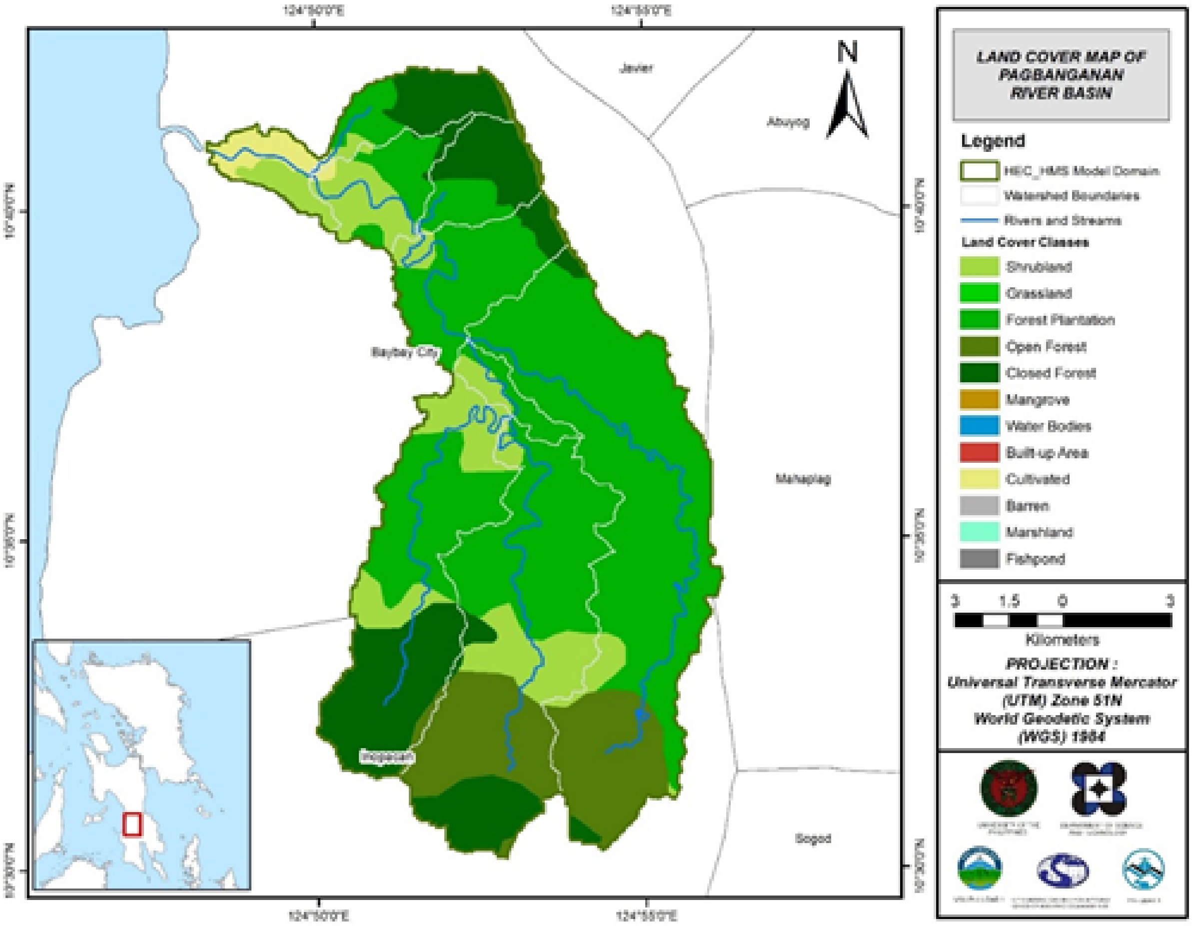


Figure 49. Land cover map of Pagbanganan River Basin (Source: NAMRIA)

For Pagbanganan, the soil classes identified were clay, silt loam, rough mountainous land, and undifferentiated. The land cover types identified were shrubland, grassland, forest plantation, open forest, and closed forest.

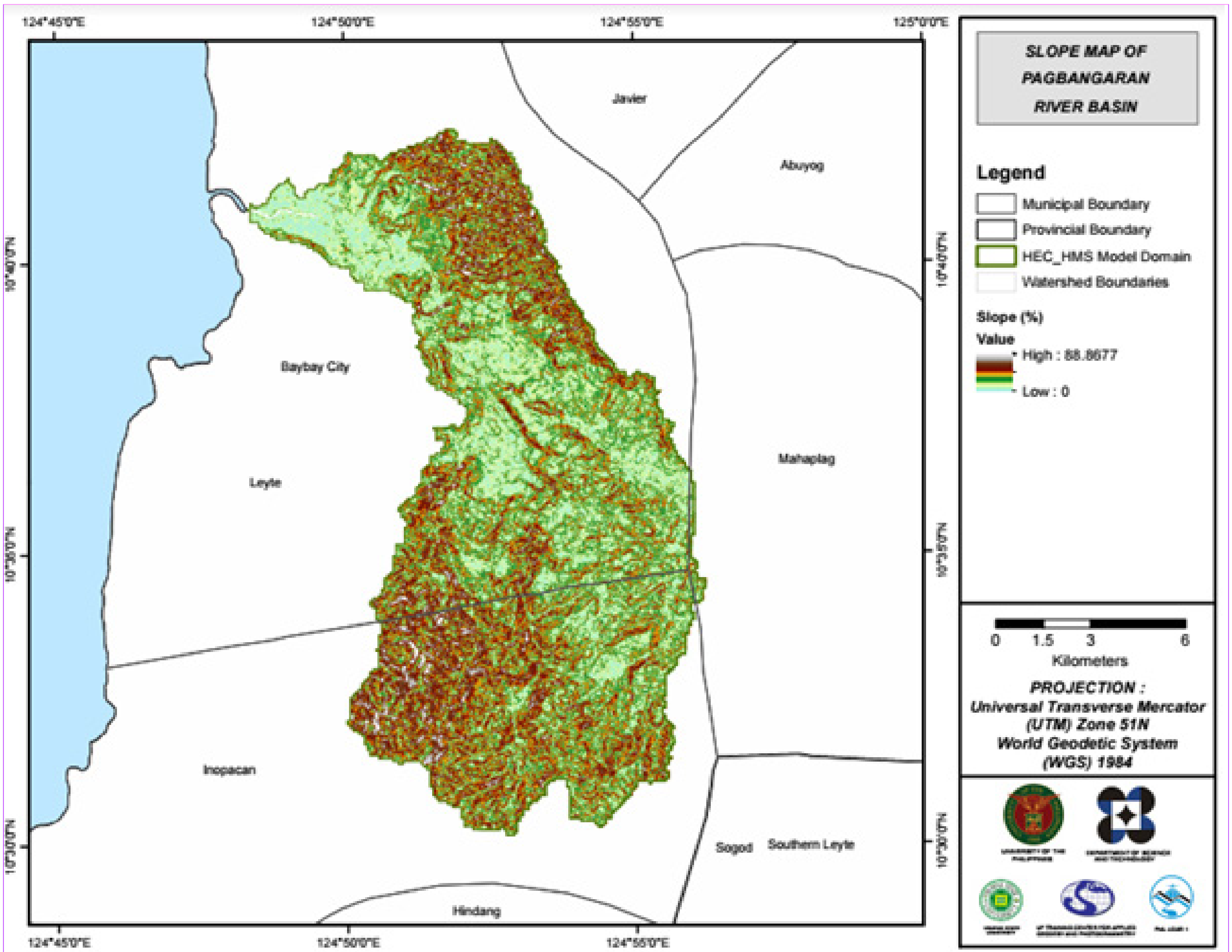


Figure 50. Slope map of the Pagbanganan River Basin

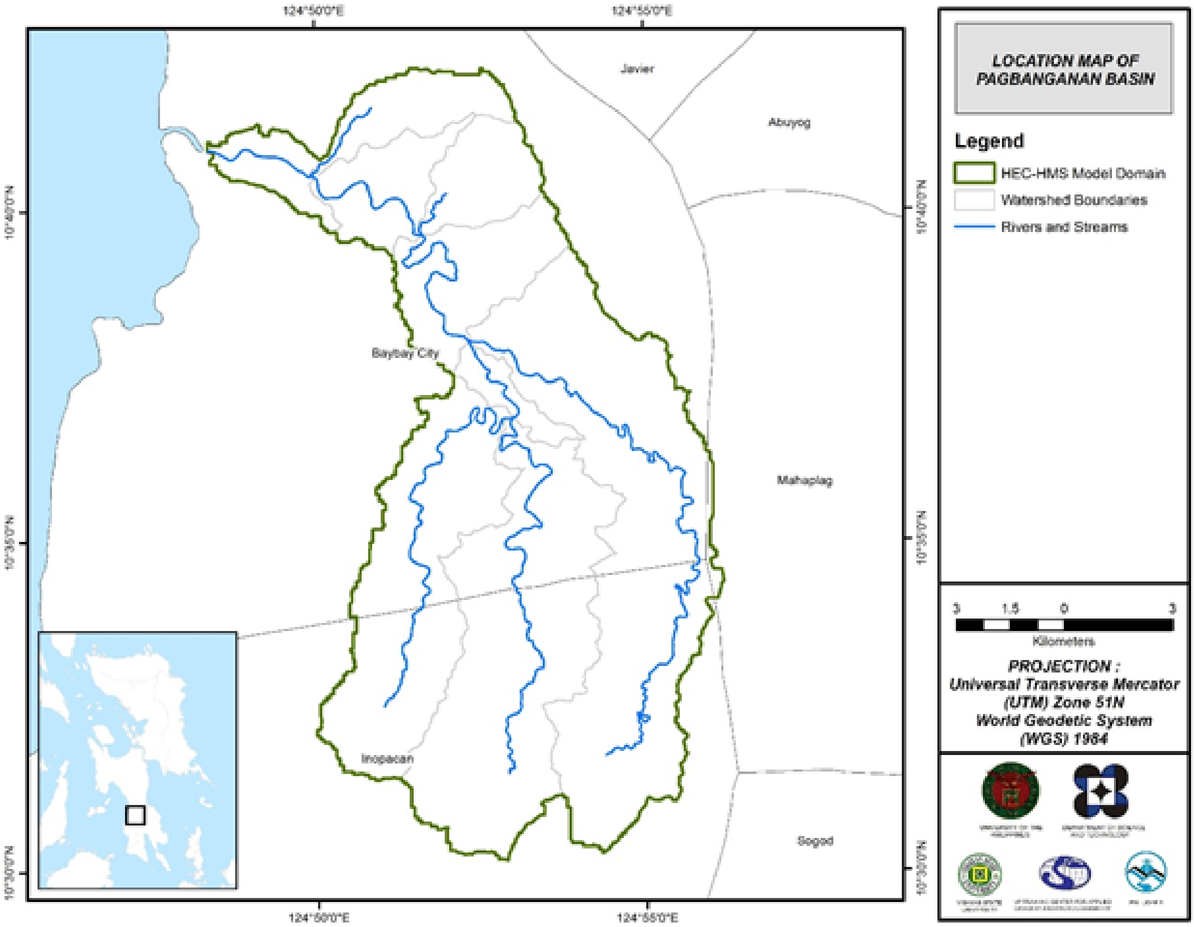


Figure 51. Stream delineation map of the Pagbanganan River Basin

Using the SAR-based DEM, the Pagbanganan basin was delineated and further subdivided into subbasins. The model consists of 9 subbasins, 4 reaches, and 4 junctions. The main outlet is in Dungcaan Bridge.

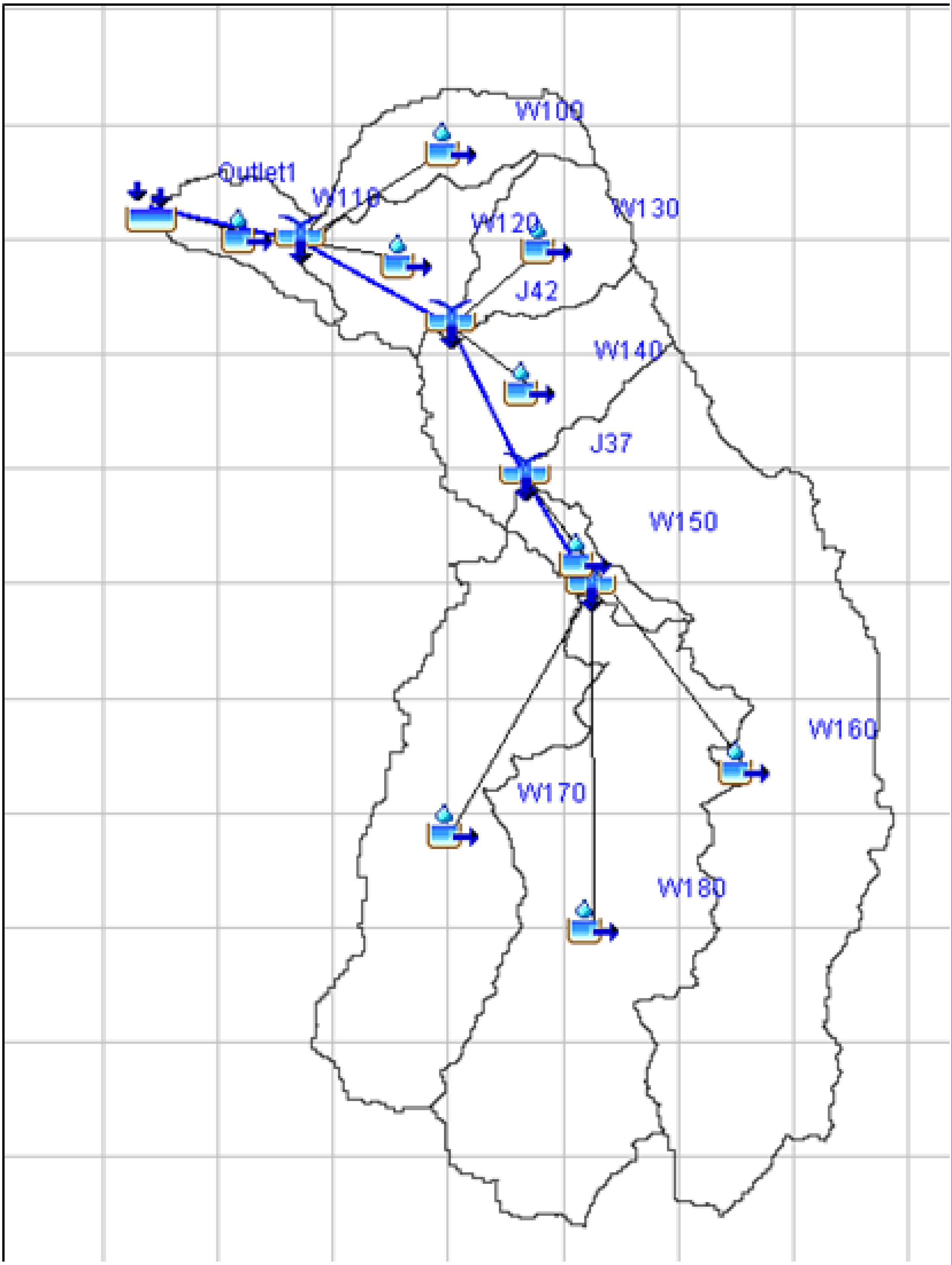


Figure 52. The Pagbanganan River Basin model generated using HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed are 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.

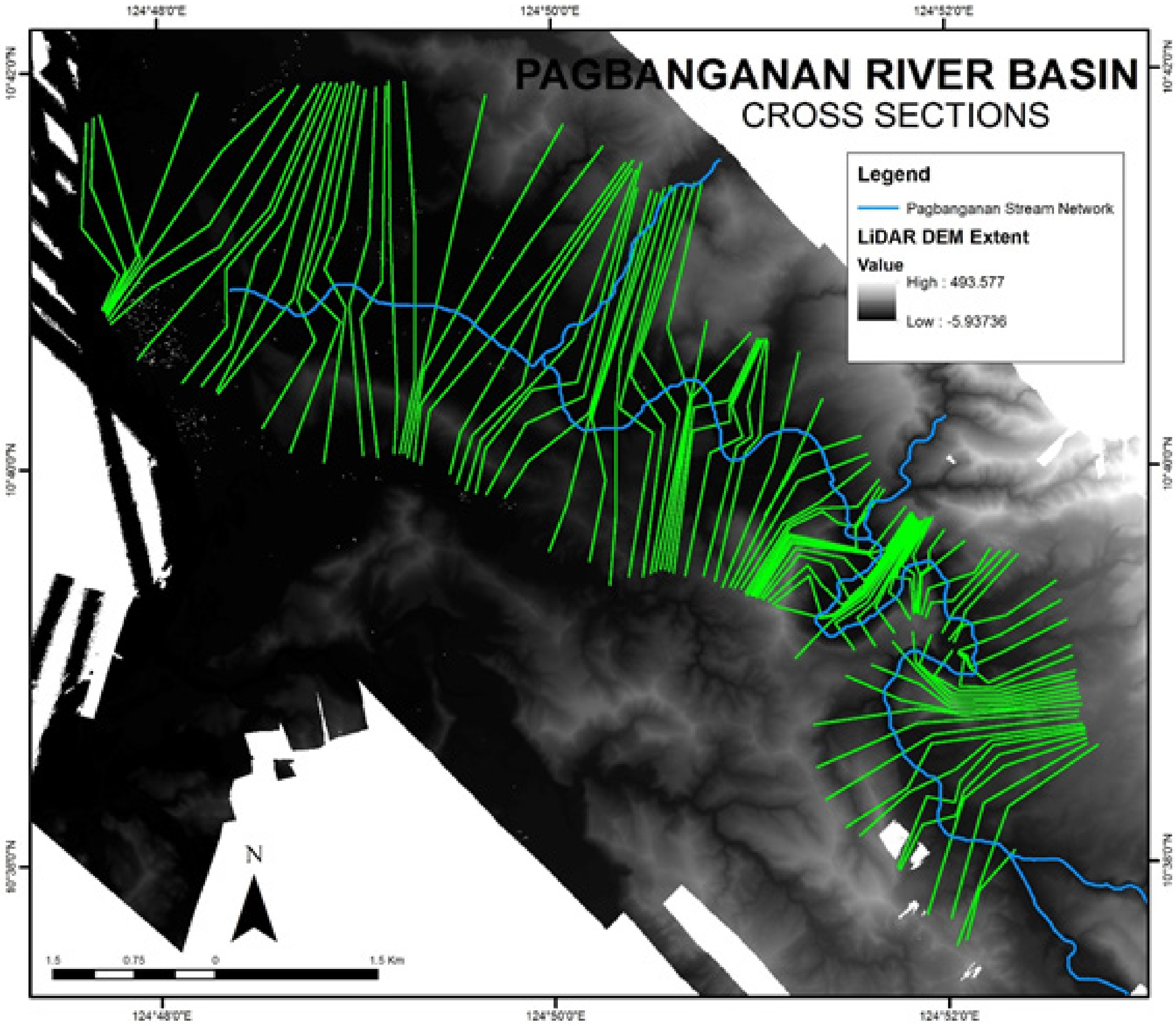


Figure 53. River cross-section of Pagbanganan River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

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

Based on the elevation and flow direction, it is seen that the water will generally flow from the east of the model to the west, following the main channel. As such, boundary elements northwest of the model are assigned as outflow elements.

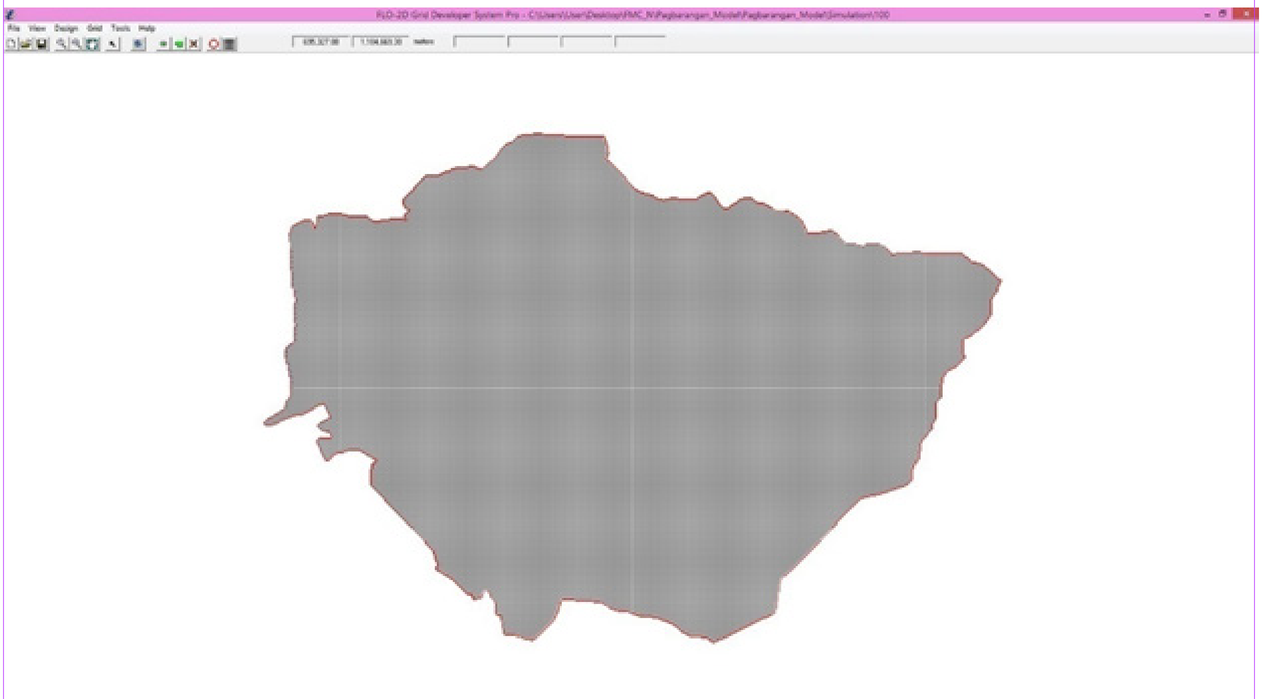


Figure 54. Screenshot of subcatchment with the computational area to be modeled in FLO-2D GDS Pro

The simulation was then run through FLO-2D GDS Pro. This particular model had a computer run time of 8.22 hours. After the simulation, FLO-2D Mapper Pro was used to transform the simulation results into spatial data that shows flood hazard levels, as well as the extent and inundation of the flood. Assigning the appropriate flood depth and velocity values for Low, Medium, and High created the following food hazard map. Most of the default values given by FLO-2D Mapper Pro were used, except for those in the Low hazard level. For this particular level, the minimum h (Maximum depth) is set at 0.2 m while the minimum vh (Product of maximum velocity (v) times maximum depth (h)) is set at 0 m2/s. The generated hazard maps for Pagbanganan are in Figure 58, Figure 60, and Figure 62.

The creation of a flood hazard map from the model also automatically creates a flow depth map depicting the maximum amount of inundation for every grid element. The legend used by default in Flo-2D Mapper is not a good representation of the range of flood inundation values, so a different legend is used for the layout. In this particular model, the inundated parts cover a maximum land area of 13,729,000.00 m2. The generated flood depth maps for Pagbanganan are in Figure 59, Figure 61, and Figure 63.

There is a total of 38,608,775.78 m3 of water entering the model, of which 3,925,136.11 m3 is due to rainfall and 34,683,639.67 m3 is inflow from basins upstream. A volume of 2,636,327.00 m3 of this water is lost to infiltration and interception, while 3,532,099.26 m3 is stored by the floodplain. The rest, amounting up to 32,440,349.36m3, is outflow.

5.6 Results of HMS Calibration

After calibrating the Pagbanganan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 55 shows the comparison between the two discharge data. ANNEX 9 shows the Pagbanganan model basin parameters.

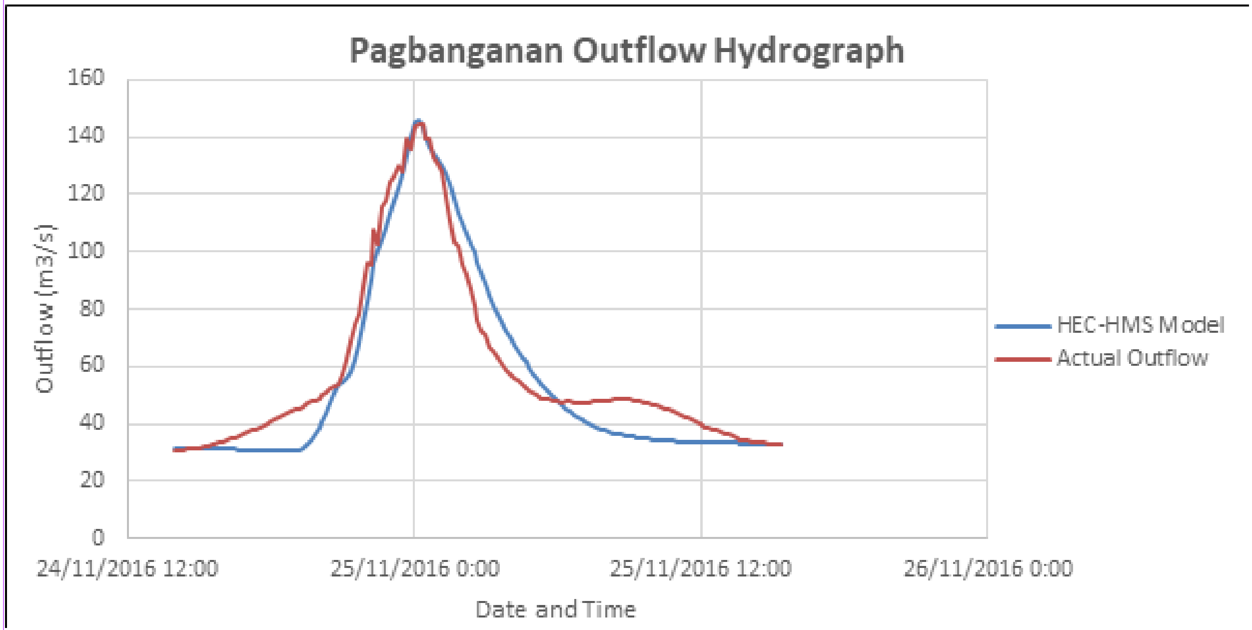


Figure 55. Outflow hydrograph of Pagbanganan produced by the HEC-HMS model compared with observed outflow

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

Table 30. Range of calibrated values for Pagbanganan

Hydrologic Element	Method	Parameter	Range of Calibrated Values
Loss	SCS Curve number	Initial Abstraction (mm)	26 - 147
		Curve Number	35 - 99
Transform	Clark Unit Hydrograph	Time of Concentration (hr)	0.5 - 2
		Storage Coefficient (hr)	0.22 - 1.37
Baseflow	Recession	Recession Constant	0.9
		Ratio to Peak	0.08
Routing	Muskingum-Cunge	Slope	0.001 – 0.004
		Manning's n	0.04

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of 26 mm to 147 mm means that there is a considerably high amount of infiltration or rainfall interception by vegetation.

Curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as curve number increases. The range of 35 to 99 for curve number means that the watershed is very diverse depending on the soil and land cover of the area.

Time of concentration and storage coefficient are the travel time and index of temporary storage of runoff in a watershed. The range of calibrated values from 0.5 to 2 hours determines the reaction time of the model with respect to the rainfall. The peak magnitude of the hydrograph also decreases when these parameters are increased.

Recession constant is the rate at which baseflow recedes between storm events and ratio to peak is the ratio of the baseflow discharge to the peak discharge. Recession constant of 0.9 indicates that the basin is unlikely to quickly go back to its original discharge and instead, will be higher. Ratio to peak of 0.01 indicates a steeper receding limb of the outflow hydrograph.

Manning's roughness coefficient of 0.04 corresponds to the common roughness of Pagbanganan watershed, which is determined to be cultivated with mature field crops.

Table 31. Summary of the efficiency test of Pagbanganan HMS Model

Accuracy measure	Value
r2	8.20
NSE	0.9746
PBIAS	0.92
RSR	4.83
RSR	0.29

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 8.2 (m3/s).

The Pearson correlation coefficient (r2) assesses the strength of the linear relationship between the observations and the model. This value being close to 1 corresponds to an almost perfect match of the observed discharge and the resulting discharge from the HEC HMS model. Here, it measured 0.9746.

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 0.92.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. Again, the optimal value is 0. In the model, the PBIAS is 4.83.

The Observation Standard Deviation Ratio (RSR) is an error index. A perfect model attains a value of 0 when the error in the units of the valuable a quantified. The model has an RSR value of 0.29.

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

5.7.1 Hydrograph using the Rainfall Runoff Model

The summary graph (Figure 55) shows the Pagbanganan outflow using the Maasin RIDF in 5 different return periods (5-year, 10-year, 25-year, 50-year, and 100-year rainfall time series) based on the PAGASA data. The simulation results reveal significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods.

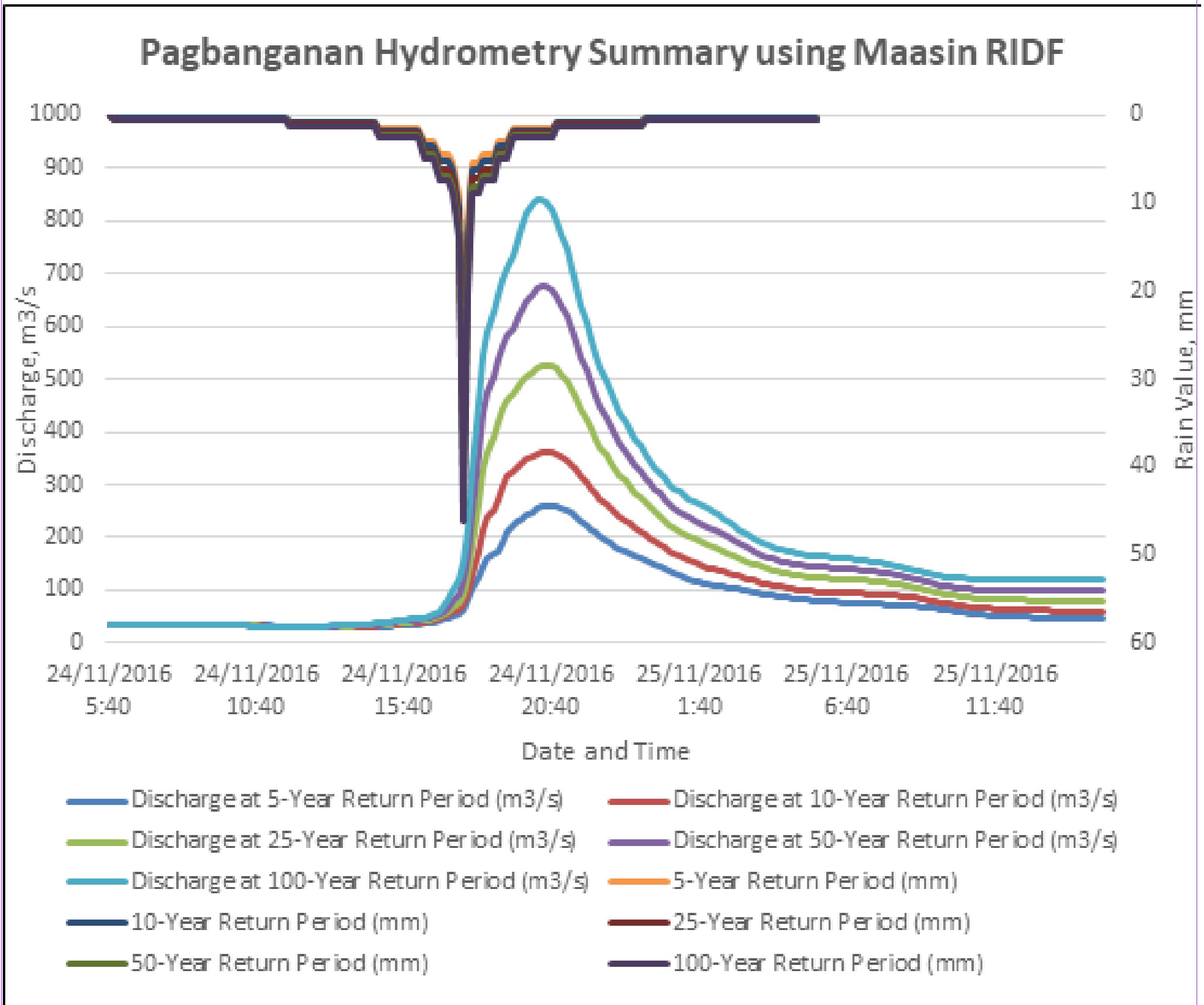


Figure 56. Outflow hydrograph at Pagbanganan Station generated using Tacloban RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Pagbanganan discharge using the Maasin RIDF curves in five different return periods is shown in Table 32.

Table 32. Peak values of the Pagbanganan HEC-HMS Model outflow using the Maasin RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	190.8	25.9	259.9	3 hours
10-Year	221.2	30.8	361.4	2 hours, 50 minutes
25-Year	259.6	37	526	2 hours, 50 minutes
50-Year	288.1	41.5	675.8	2 hours, 40 minutes
100-Year	316.3	46.1	840.8	2 hours, 40 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section for every step for every flood simulation created. The resulting model was used in determining the flooded areas within the model. The simulated model is an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river is shown since only the VSU-FMC base flow was calibrated. The sample generated map of Pagbanganan River using the calibrated HMS base flow is shown in Figure 57.

Figure 57. Sample output of Pagbanganan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10 m resolution. Figure 58 to Figure 63 show the 100-, 25-, and 5-year rain return scenarios of the Pagbanganan Floodplain.

The floodplain, with an area of 13.73 sq km., covers Baybay City. Table shows the percentage of area affected by flooding.

Table 33. Municipalities affected in Pagbanganan Floodplain

Municipality	Total Area	Area Flooded	% Flooded
Baybay City	404.37	13.51	3%

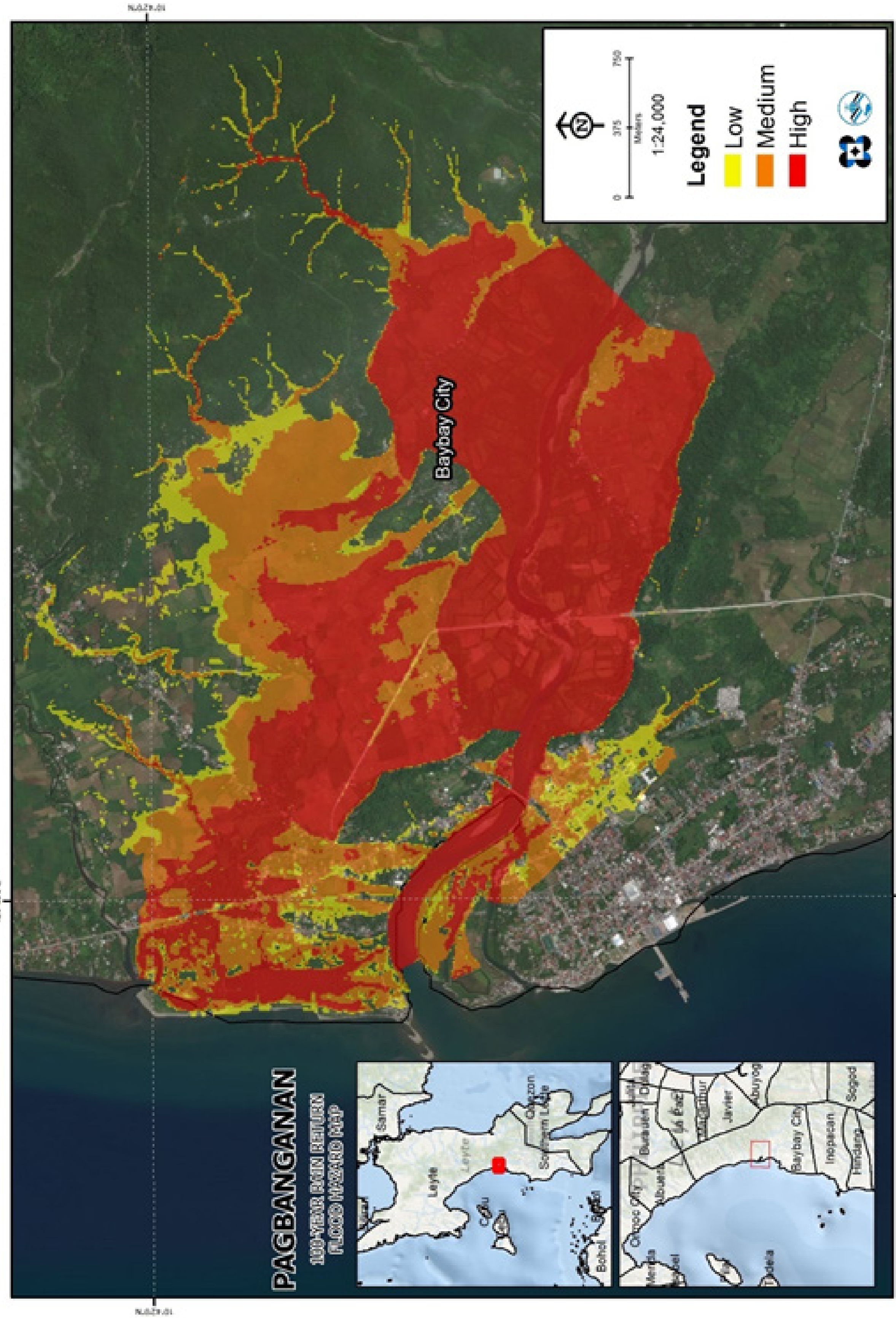


Figure 58. 100-year flood hazard map for Pagbanganan Floodplain overlaid on Google Earth imagery

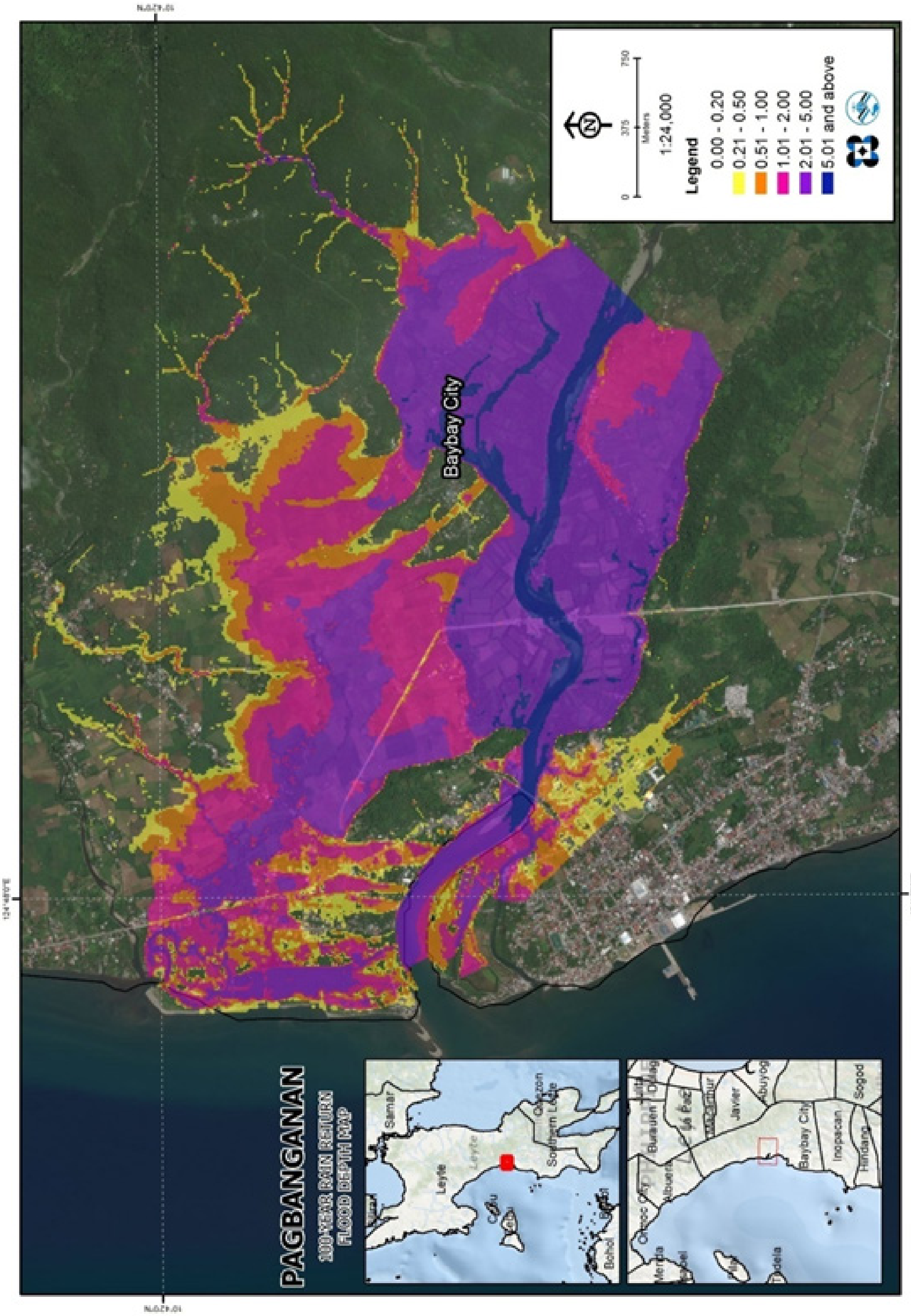


Figure 59. 100-year flood depth map for Pagbanganan Floodplain overlaid on Google Earth imagery

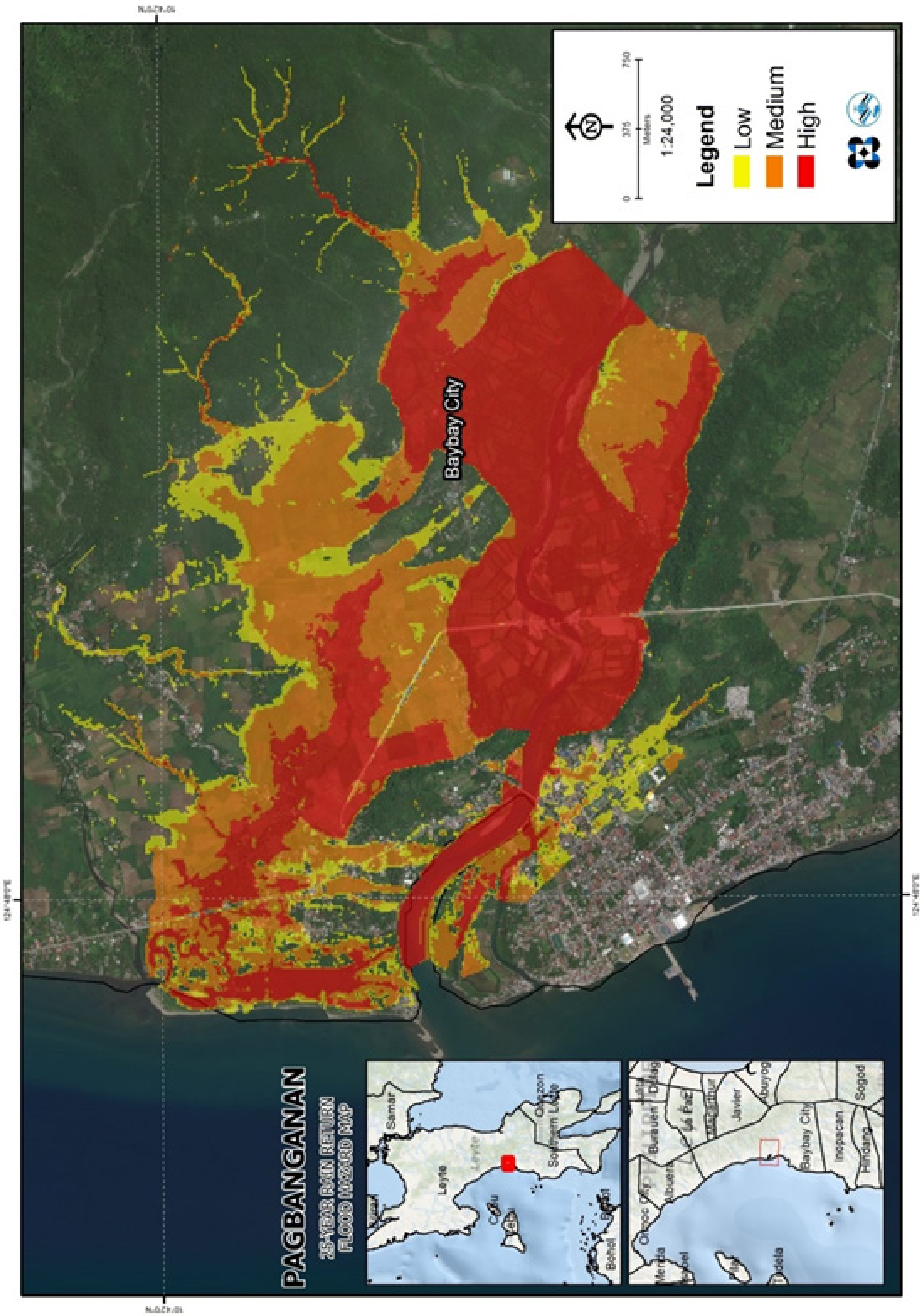


Figure 60. 25-year flood hazard map for Pagbanganan Floodplain overlaid on Google Earth imagery

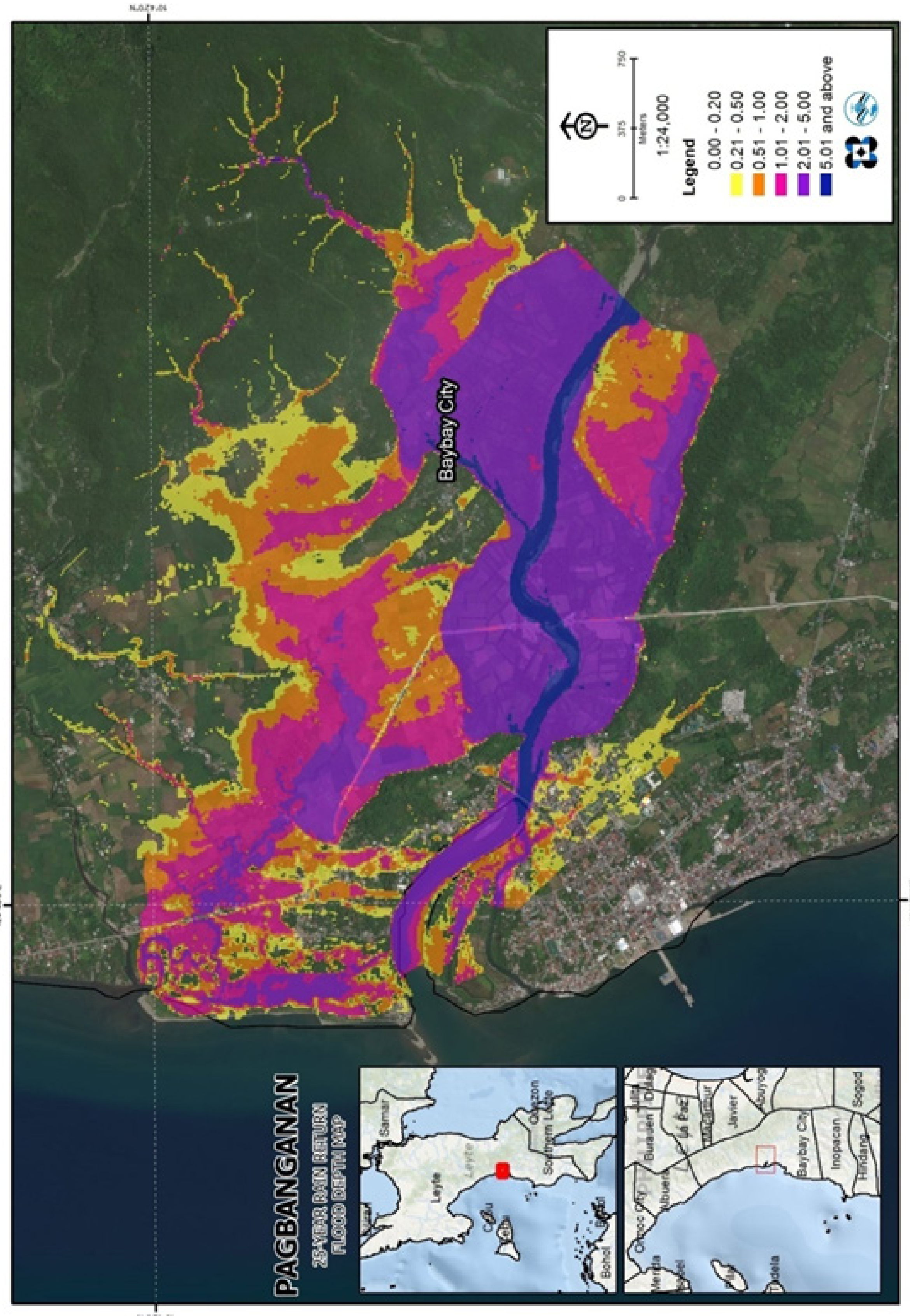


Figure 61. 25-year flood depth map for Pagbanganan Floodplain overlaid on Google Earth imagery

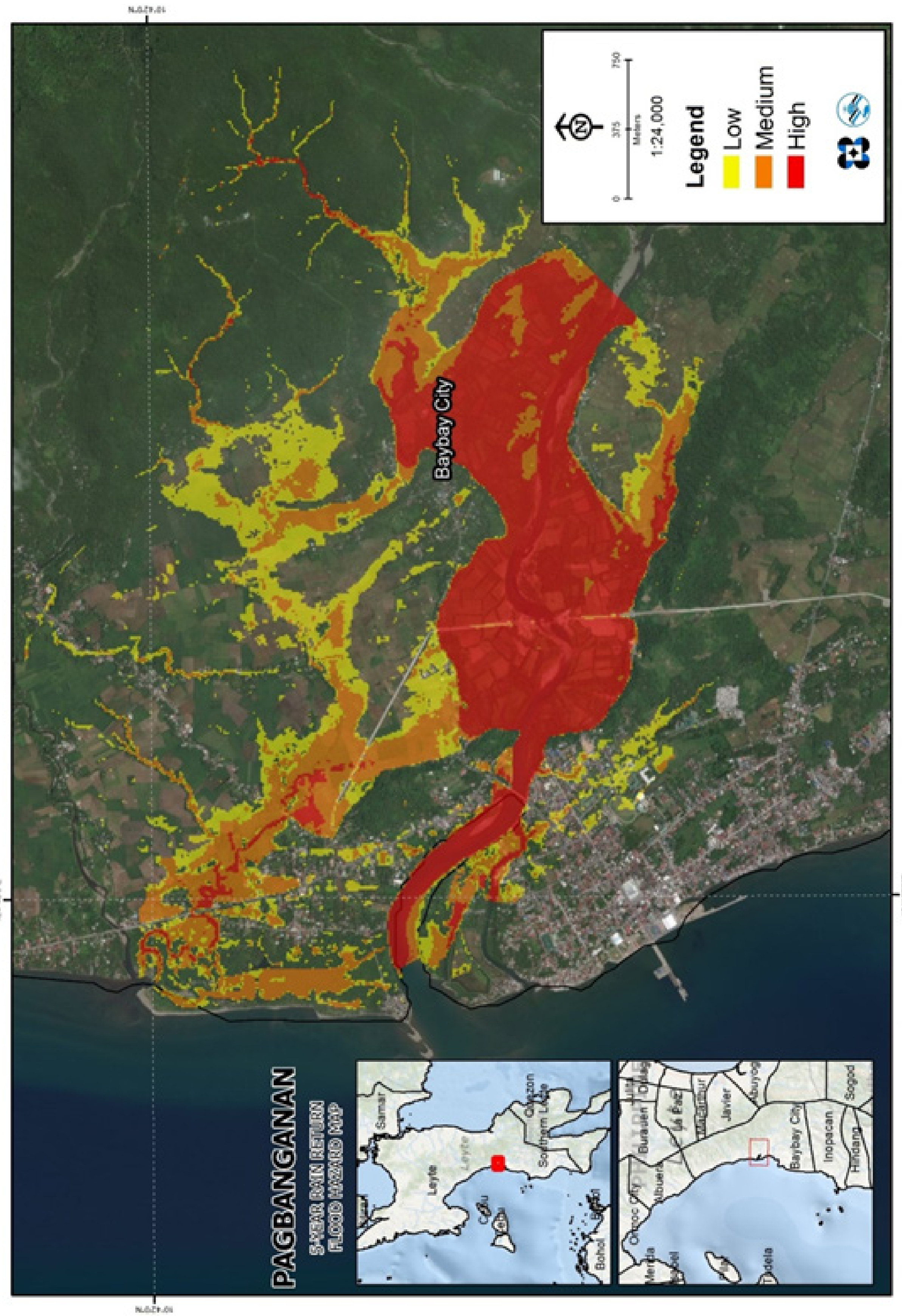


Figure 62. 5-year flood hazard map for Pagbanganan Floodplain overlaid on Google Earth imagery

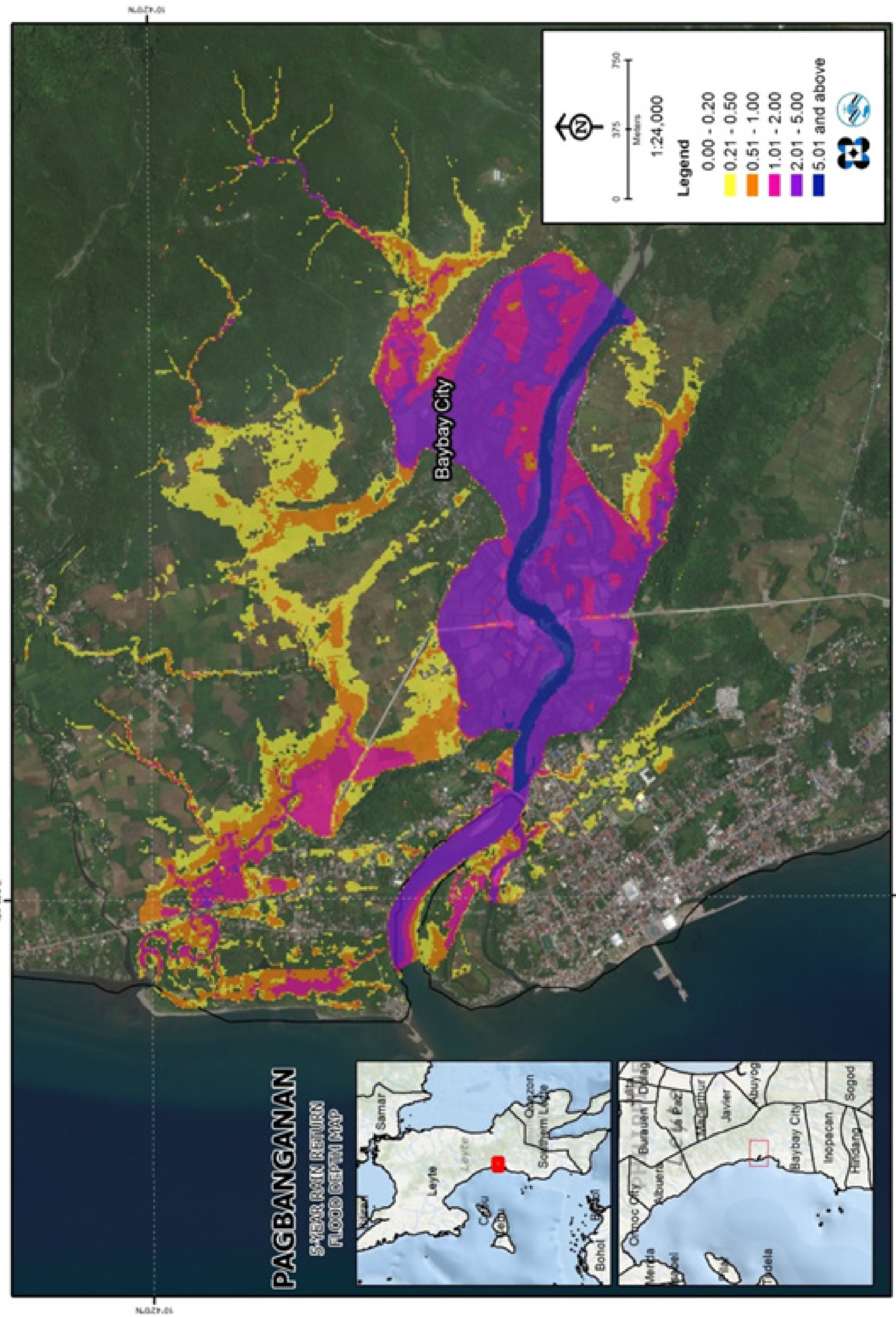


Figure 63. 5 -year flood depth map for Pagbanganan Floodplain overlaid on Google Earth imagery

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in Pagbanganan River Basin are listed below. For the said basin, the city of Baybay consisting of 23 barangays is expected to experience flooding when subjected to 5-year, 25-year, and 100-year rainfall return period.

For the 5-year return period, 8.48% of the city of Baybay with an area of 404.37sq km. will experience flood levels of less 0.20 meters; 0.35% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.22%, 0.23%, 0.40%, 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 34 to Table 36 are the affected areas in square kilometers by flood depth per barangay.

Table 34. Affected areas in Baybay City, Leyte during a 5-year rainfall return period

PAGBANGANAN BASIN		Affected Barangays in Baybay City							
		Candadam	Cogon	Ga-As	Gakat	Hibunawan	Kan-Ipa	Maganhan	Poblacion Zone 1
Affected Area (sq. km.)	0.03-0.20	0.654811078	0.823630861	0.209216015	1.408277278	0.760062756	0.340425363	1.717330867	0.000413572
	0.21-0.50	0.161781078	0.316614707	0.017319826	0.130223419	0.241601732	0.092480174	0.123419301	0.004748005
	0.51-1.00	0.210002869	0.124435046	0.034129857	0.020913978	0.111302149	0.036046275	0.093853018	0.008315298
	1.01-2.00	0.166851857	0.044023467	0.051000986	0.003966492	0.137349437	0.12570995	0.131928144	0.003554833
	2.01-5.00	0.015500187	0.371991971	0.023272766	0	0.329713776	0.179712188	0.131006339	0.149638813
	> 5.00	0	0.058498469	0	0	0	0.080441907	0.0004	0.038176251

Table 35. Affected areas in Baybay City, Leyte during a 5-year rainfall return period

PAGBANGANAN BASIN		Affected Barangays in Baybay City							
		Poblacion Zone 11	Poblacion Zone 12	Poblacion Zone 13	Poblacion Zone 2	Poblacion Zone 23	Poblacion Zone 3	Poblacion Zone 4	Poblacion Zone 5
Affected Area (sq. km.)	0.03-0.20	0.016842549	0.243793747	0.004474251	0.044437305	0.129454635	0.028565875	0.078154568	0.037732458
	0.21-0.50	0.011578591	0.037190942	0.000242398	0.004439503	0.009046763	0.000277896	0.013023379	0.004436486
	0.51-1.00	0.0003	0.005062685	0.0001	0.001946285	0.003416947	0.0004	0.012818496	0.003858851
	1.01-2.00	0.0002	0.04774859	0	0.001871933	0.0002	0.000785931	0.009648872	0.006029726
	2.01-5.00	0	0.293740263	0	0.062604525	0	0.017590938	0.018143999	0.014060912
	> 5.00	0	0.009966953	0	0.022828612	0	0	0.013575706	0.005012102

Table 36. Affected areas in Baybay City, Leyte during a 5-year rainfall return period

PAGBANGANAN BASIN		Affected Barangays in Baybay City							
		Poblacion Zone 6	Poblacion Zone 7	Poblacion Zone 8	Poblacion Zone 9	San Isidro	Santo Rosario	Villa Mag-Aso	Poblacion Zone 1
Affected Area (sq. km.)	**0.03-0.20**	0.032061073	0.047740789	0.076412761	0.005982229	0.594152561	0.644639189	0.51452708	0.000413572
	0.21-0.50	0.018314014	0.01286336	0.022828718	0.00219257	0.059710102	0.117596479	0.009034377	0.004748005
	0.51-1.00	0.018815927	0.001018035	0.012456113	0.0001666	0.056823205	0.141645058	0.005552542	0.008315298
	1.01-2.00	0.007399511	6.99694E-05	0.023001686	0	0.020673973	0.129956565	0.0026	0.003554833
	2.01-5.00	0.003606084	0	0.008501119	0	0.001599813	0.013772123	0.0006	0.149638813
	> 5.00	0	0	0	0	0	0	0	0.038176251

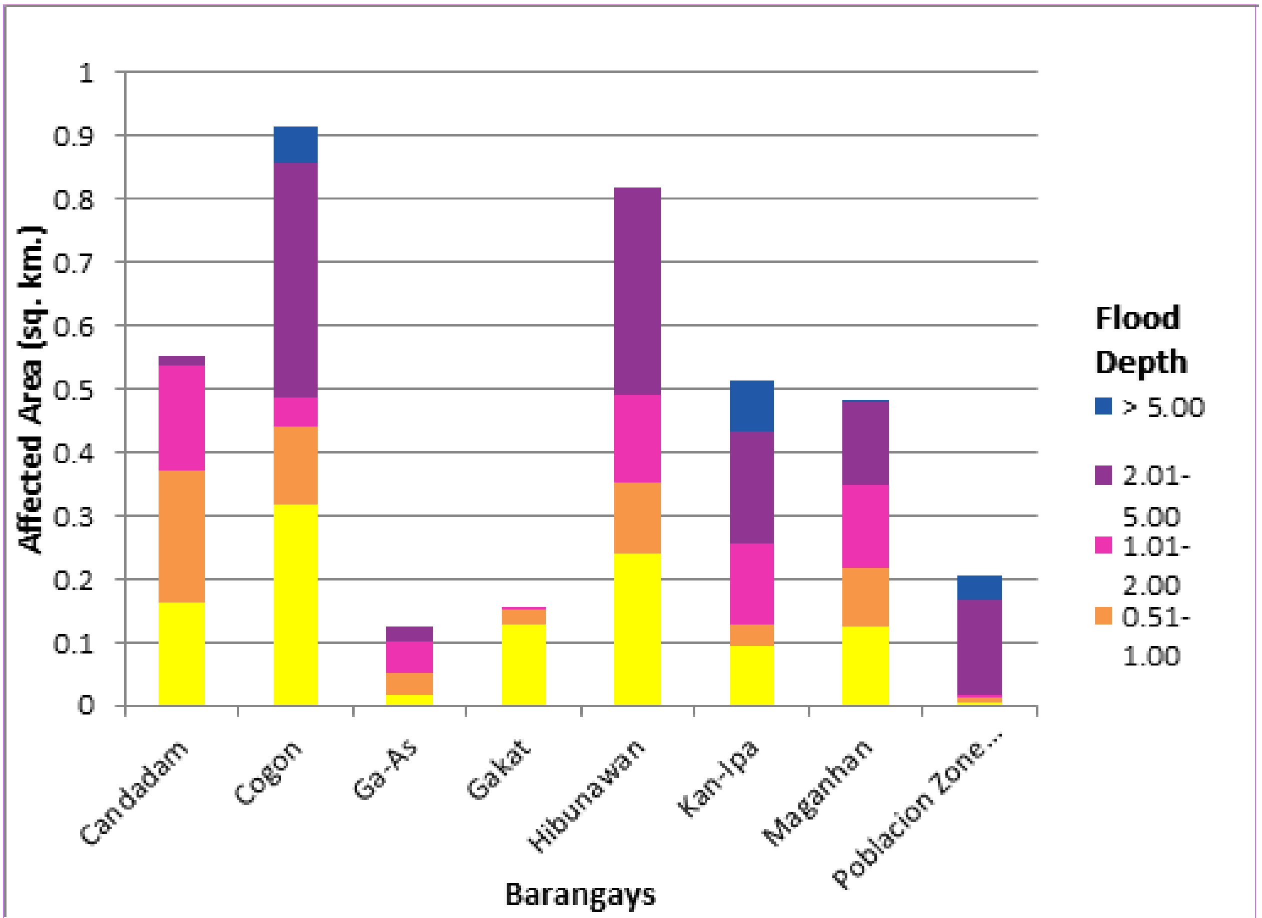


Figure 64. Affected areas in Baybay City, Leyte during a 5-year rainfall return period

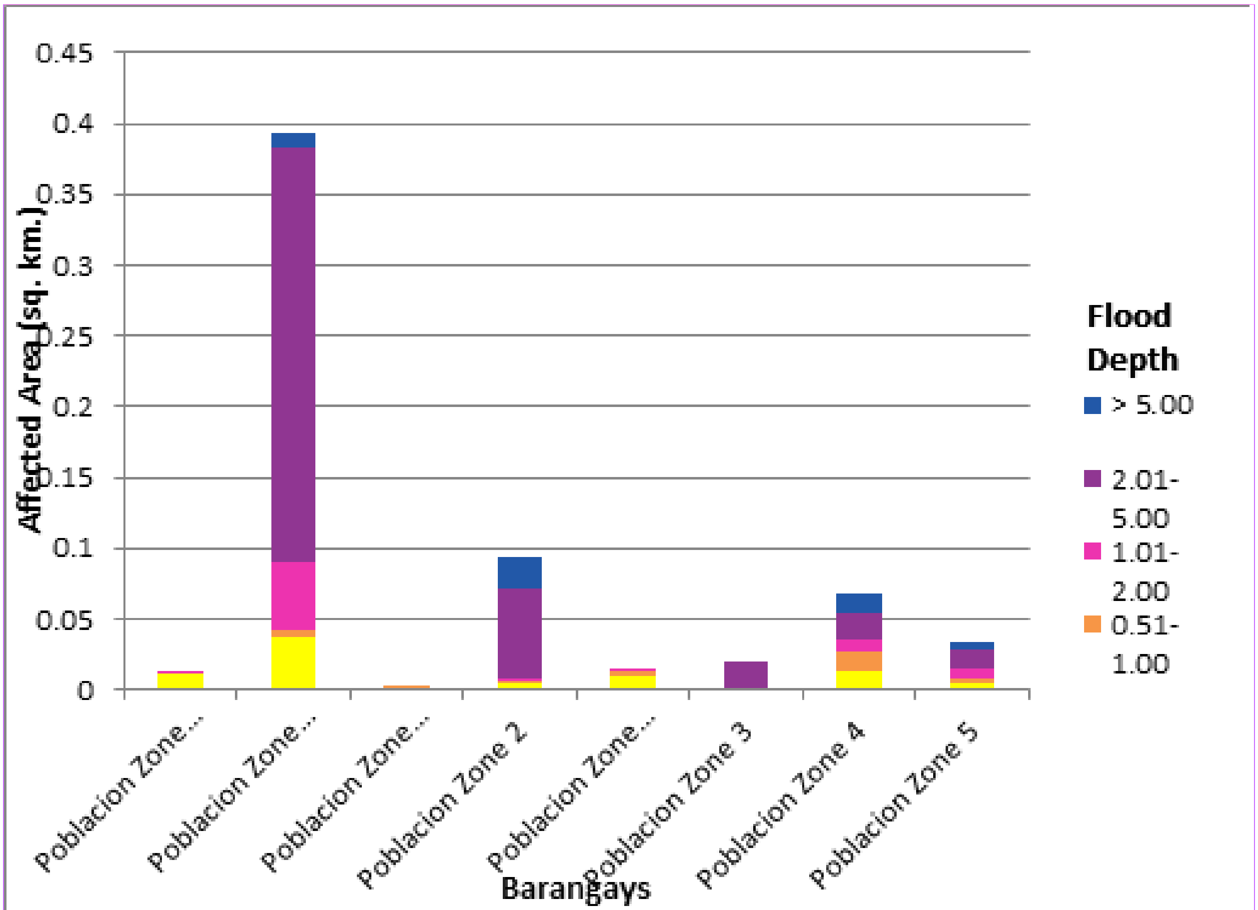


Figure 64. Affected areas in Baybay City, Leyte during a 5-year rainfall return period

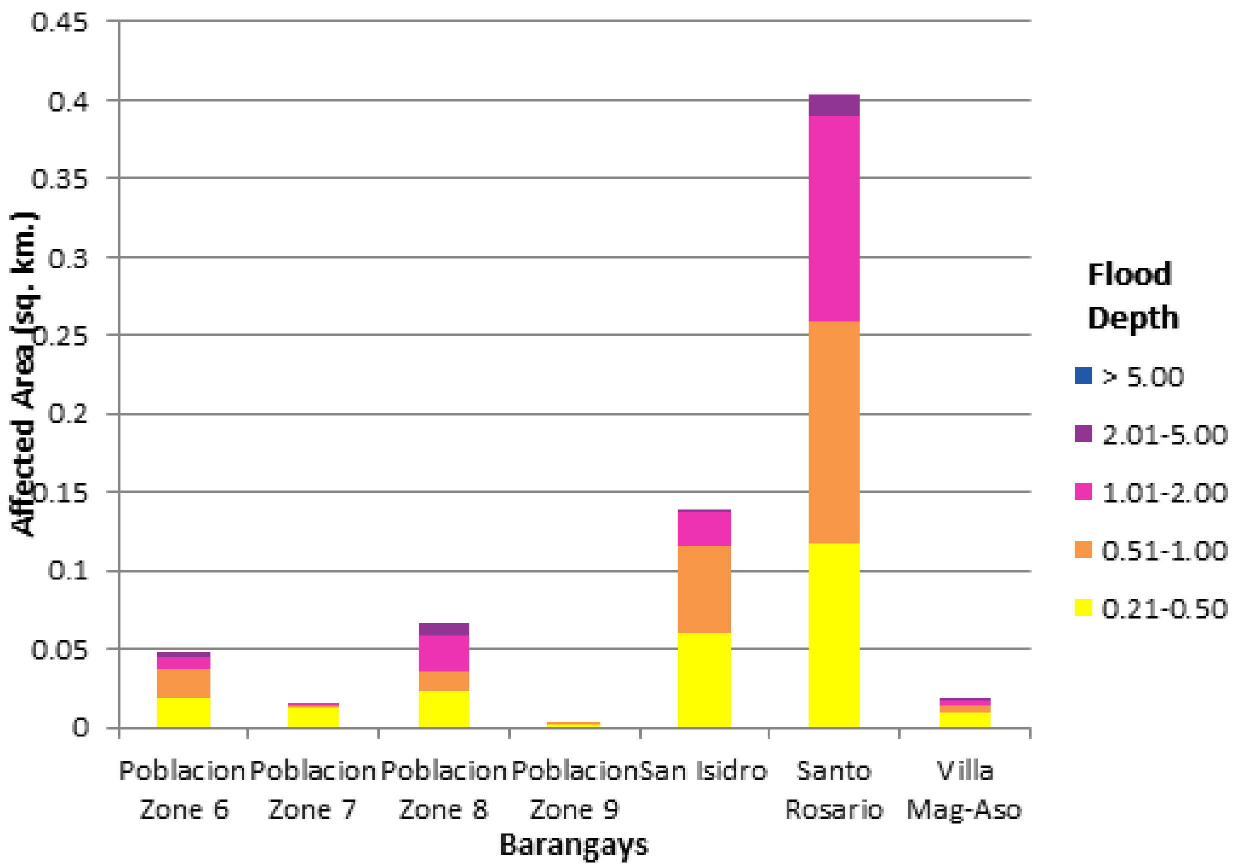


Figure 66. Affected areas in Baybay City, Leyte during a 5-year rainfall return period

For the 25-year return period, 1.5% of the city of Baybay with an area of 404.37 sq km. will experience flood levels of less 0.20 meters; 0.27% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.40%, 0.44%, 0.65%, and 0.08% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 37 to Table 39 are the affected areas in square kilometers by flood depth per barangay.

Table 37. Affected areas in Baybay City, Eastern Samar during a 25-year rainfall return period

PAGBANGANAN BASIN		Affected Barangays in Baybay City							
		Candadam	Cogon	Ga-As	Gakat	Hibunawan	Kan-Ipa	Maganhan	Poblacion Zone 1
Affected Area (sq. km.)	0.03-0.20	0.233633864	0.257134769	0.180663372	1.293969937	0.581131535	0.0013	1.549487597	0
	0.21-0.50	0.127964306	0.132105566	0.0029	0.191060473	0.173076762	0.0254	0.094150603	0
	0.51-1.00	0.221283521	0.412141377	0.004478006	0.0702012	0.227443181	0.1921	0.132840678	0.000913572
	1.01-2.00	0.419936095	0.436471688	0.031536785	0.008149557	0.103467884	0.217895697	0.149908005	0.013985437
	2.01-5.00	0.206129283	0.422129381	0.115261289	0	0.481883309	0.31544149	0.270950786	0.145307283
	> 5.00	0	0.07921174	0.0001	0	0.01302718	0.102678669	0.0006	0.04464048

Table 38. Affected areas in Baybay City, Eastern Samar during a 25-year rainfall return period

PAGBANGANAN BASIN		Affected Barangays in Baybay City							
		Poblacion Zone 11	Poblacion Zone 12	Poblacion Zone 13	Poblacion Zone 2	Poblacion Zone 23	Poblacion Zone 3	Poblacion Zone 4	Poblacion Zone 5
Affected Area (sq. km.)	0.03-0.20	0.01185032	0.223541672	0.004374251	0.041253947	0.127017056	0.026561015	0.059858707	0.026367188
	0.21-0.50	0.01637755	0.049928319	0.000335656	0.001119411	0.008277045	0.001882757	0.021713486	0.010842435
	0.51-1.00	0.00049325	0.007197751	0.000106742	0.002432235	0.006624244	0.0004	0.015791839	0.006054276
	1.01-2.00	0.0002	0.007633464	0	0.0066903	0.0002	0.000551134	0.012393841	0.005804095
	2.01-5.00	0	0.337033333	0	0.060344473	0	0.018225735	0.017757113	0.011694851
	> 5.00	0	0.012168641	0	0.026287797	0	0	0.017850033	0.010367691

Table 36. Affected areas in Baybay City, Leyte during a 5-year rainfall return period

PAGBANGANAN BASIN		Affected Barangays in Baybay City							
		Poblacion Zone 6	Poblacion Zone 7	Poblacion Zone 8	Poblacion Zone 9	San Isidro	Santo Rosario	Villa Mag-Aso	Poblacion Zone 1
Affected Area (sq. km.)	0.03-0.20	0.017580148	0.037121493	0.034284227	0.000842319	0.467152298	0.398364889	0.510557541	0.000413572
	0.21-0.50	0.013344979	0.021660006	0.033296026	0.004264366	0.061607285	0.100716521	0.010100261	0.004748005
	0.51-1.00	0.027111432	0.002522649	0.03464674	0.003234714	0.092133501	0.133821253	0.006856196	0.008315298
	1.01-2.00	0.017197301	0.000388004	0.026258142	0	0.102814726	0.222343453	0.0039	0.003554833
	2.01-5.00	0.00496275	0	0.014715262	0	0.009251844	0.192363298	0.0009	0.149638813
	> 5.00	0	0	0	0	0	0	0	0.038176251

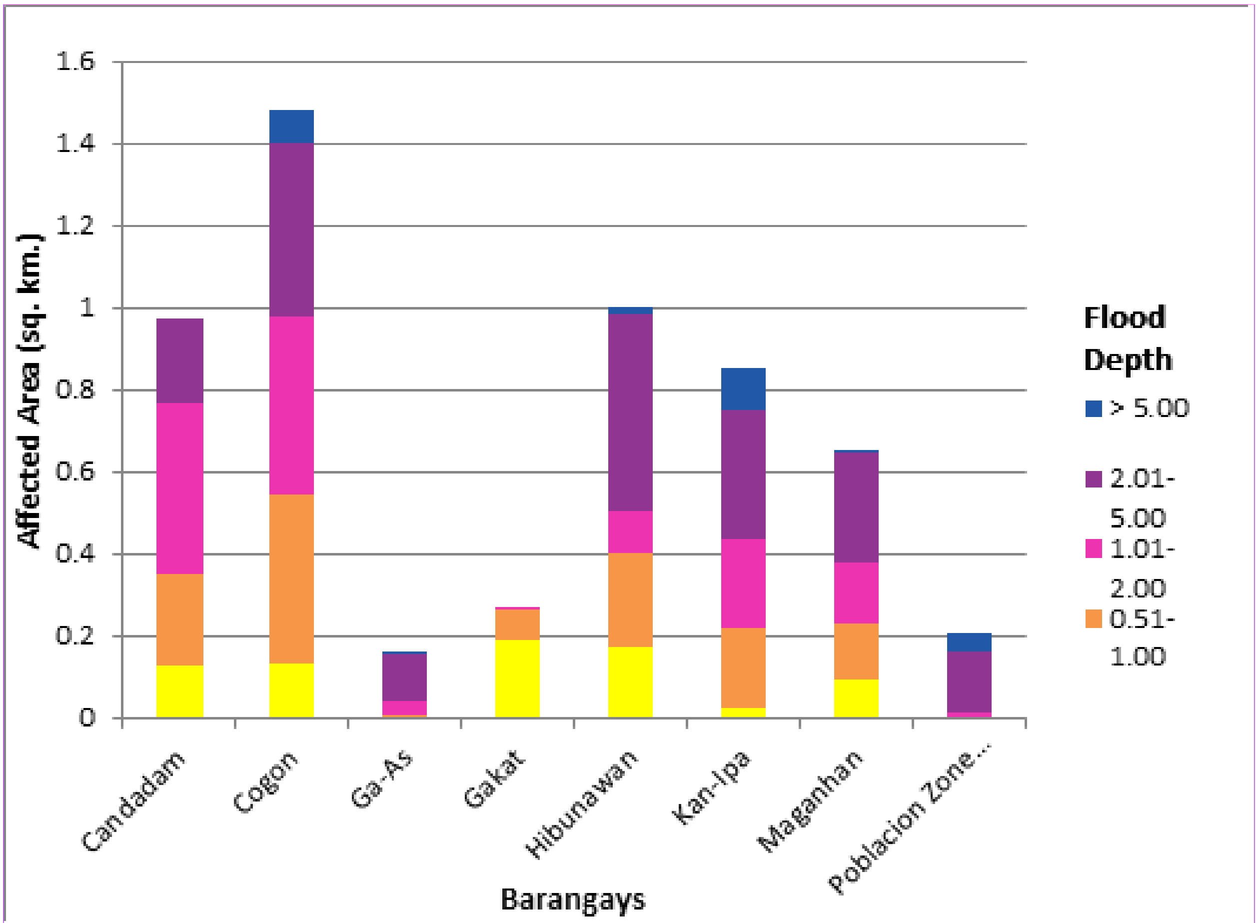


Figure 67. Affected areas in Baybay City, Eastern Samar during a 25-year rainfall return period

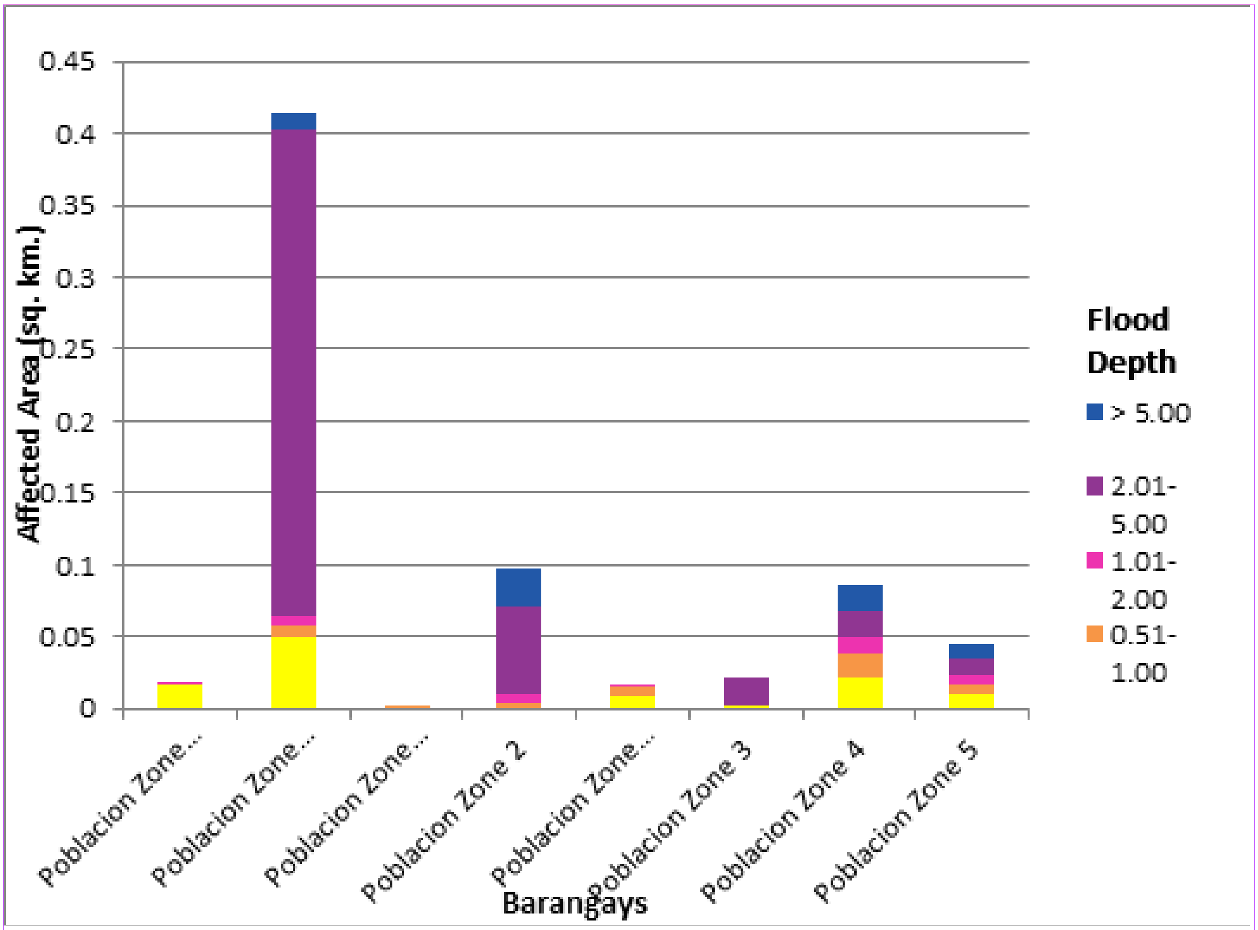


Figure 68. Affected areas in Baybay City, Eastern Samar during a 25-year rainfall return period

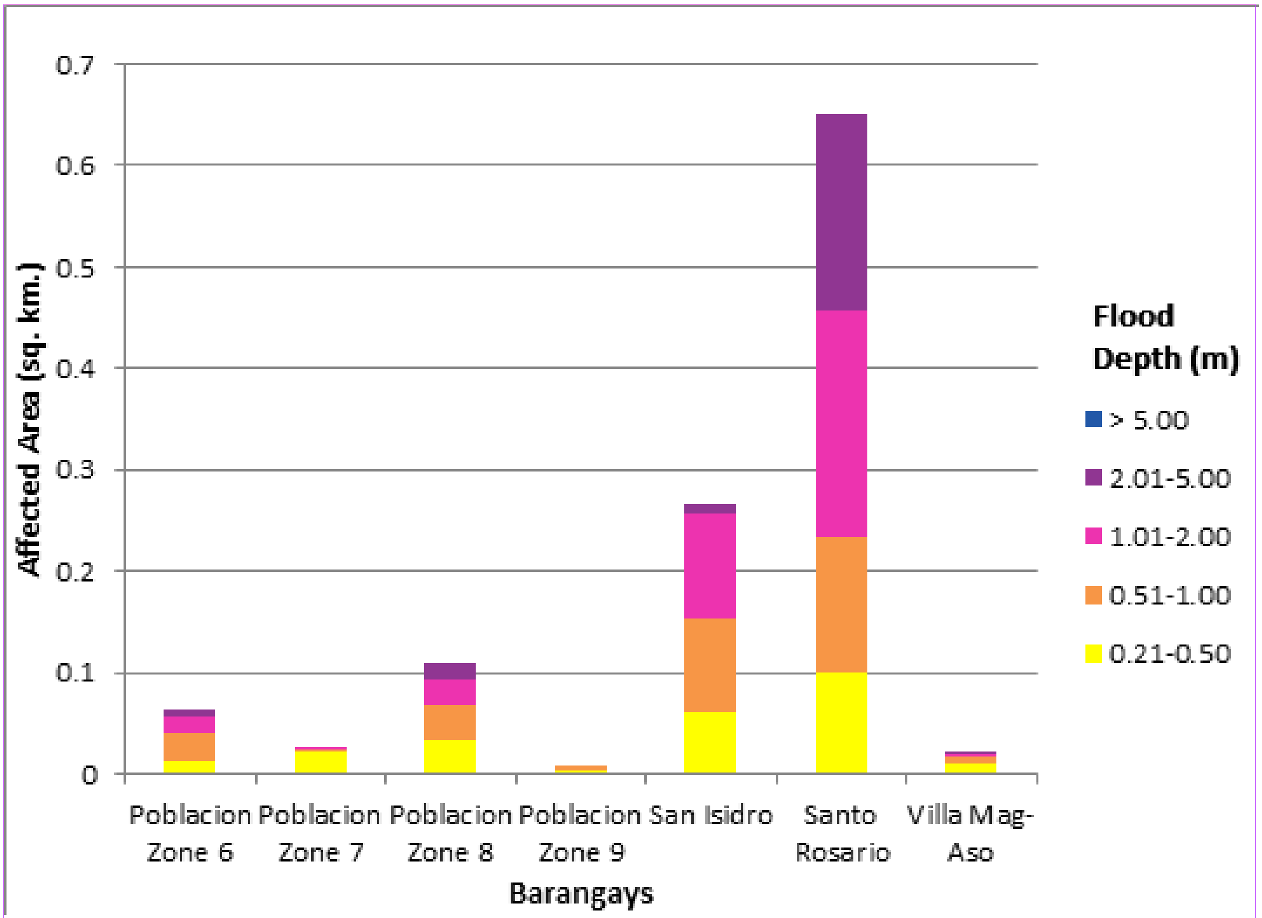


Figure 69. Affected areas in Baybay City, Eastern Samar during a 25-year rainfall return period

For the 100-year return period, 1.33% of the city of Baybay with an area of 404.37 sq km. will experience flood levels of less 0.20 meters; 0.22% of the area will experience flood levels of 0.21 to 0.50 meters; while 0.27%, 0.57%, 0.82%, and 0.13% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 40 Table 42 are the affected areas in square kilometers by flood depth per barangay.

Table 40. Affected areas in Baybay City, Eastern Samar during a 100-year rainfall return period

PAGBANGANAN BASIN		Affected Barangays in Baybay City							
		Candadam	Cogon	Ga-As	Gakat	Hibunawan	Kan-Ipa	Maganhan	Poblacion Zone 1
Affected Area (sq. km.)	0.03-0.20	0.136881291	0.189600907	0.173862819	1.160459094	0.510366742	0	1.488487597	0
	0.21-0.50	0.09418058	0.033114357	0.002400552	0.202311119	0.115476248	0	0.0811	0
	0.51-1.00	0.189950505	0.119144606	0.0041	0.136794169	0.187996322	0.006	0.07184686	0
	1.01-2.00	0.42344196	0.68357053	0.008178006	0.063416786	0.232520101	0.2252	0.176055501	0.013176874
	2.01-5.00	0.364492733	0.602009228	0.142098074	0.0004	0.449600296	0.482332267	0.36552069	0.131263313
	> 5.00	0	0.111754894	0.0043	0	0.084070142	0.141283589	0.014927021	0.060406584

Table 41. Affected areas in Baybay City, Eastern Samar during a 100-year rainfall return period

PAGBANGANAN BASIN		Affected Barangays in Baybay City							
		Poblacion Zone 11	Poblacion Zone 12	Poblacion Zone 13	Poblacion Zone 2	Poblacion Zone 23	Poblacion Zone 3	Poblacion Zone 4	Poblacion Zone 5
Affected Area (sq. km.)	0.03-0.20	0.00914738	0.211505404	0.004174251	0.039940389	0.125593826	0.023114714	0.044296779	0.013808175
	0.21-0.50	0.01908049	0.055367458	0.000535656	0.000613558	0.006132566	0.00336942	0.017545159	0.010313035
	0.51-1.00	0.00049325	0.011472885	0.000106742	0.001718015	0.009791952	0.001959638	0.026316087	0.014467905
	1.01-2.00	0.0002	0.004421994	0	0.008351131	0.0006	0.0008	0.016238418	0.008179185
	2.01-5.00	0	0.325211141	0	0.056517288	0	0.018175702	0.021027255	0.013250934
	> 5.00	0	0.029524297	0	0.030987782	0	0.000201166	0.019941321	0.011111302

Table 42. Affected areas in Baybay City, Eastern Samar during a 100-year rainfall return period

PAGBANGANAN BASIN		Affected Barangays in Baybay City							
		Poblacion Zone 6	Poblacion Zone 7	Poblacion Zone 8	Poblacion Zone 9	San Isidro	Santo Rosario	Villa Mag-Aso	Poblacion Zone 1
Affected Area (sq. km.)	**0.03-0.20**	0.003750272	0.008478987	0.008805542	0	0.423029745	0.315792756	0.506336223	0.000413572
	0.21-0.50	0.00851949	0.036698001	0.019565025	0.000641703	0.06326839	0.093034988	0.011669919	0.004748005
	0.51-1.00	0.022454793	0.015504511	0.046942533	0.006668053	0.080211197	0.143088047	0.008356795	0.008315298
	1.01-2.00	0.036492659	0.001010653	0.039988322	0.001031642	0.146079147	0.204533993	0.004651062	0.003554833
	2.01-5.00	0.008979395	0	0.027898975	0	0.020371173	0.290484536	0.0013	0.149638813
	> 5.00	0	0	0	0	0	0.000675094	0	0.038176251

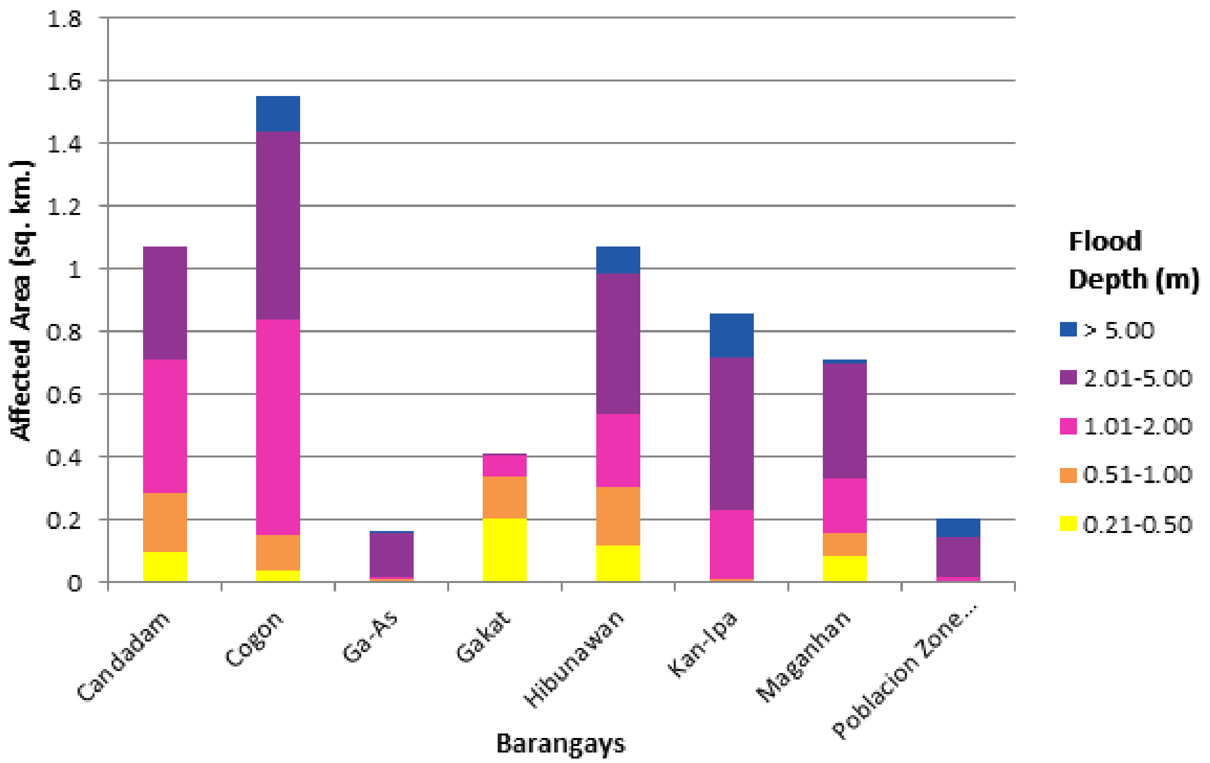


Figure 70. Affected areas in Baybay City, Eastern Samar during a 100-year rainfall return period

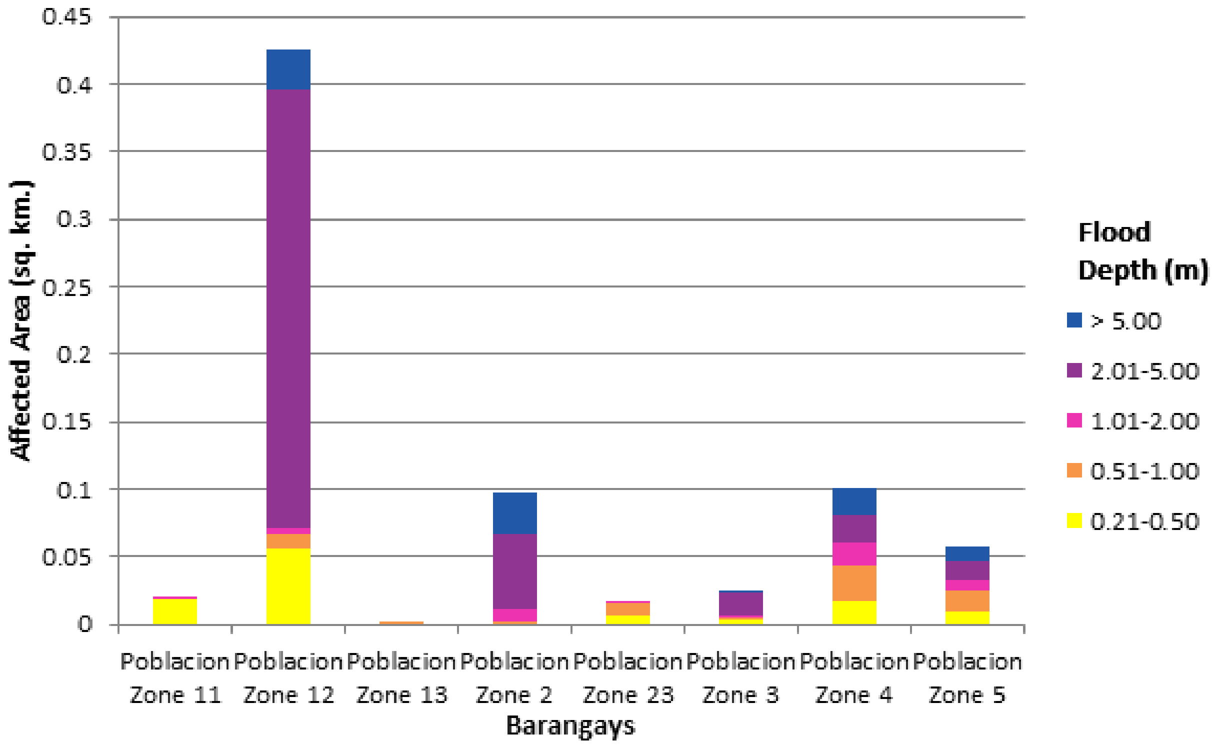


Figure 71. Affected areas in Baybay City, Eastern Samar during a 100-year rainfall return period

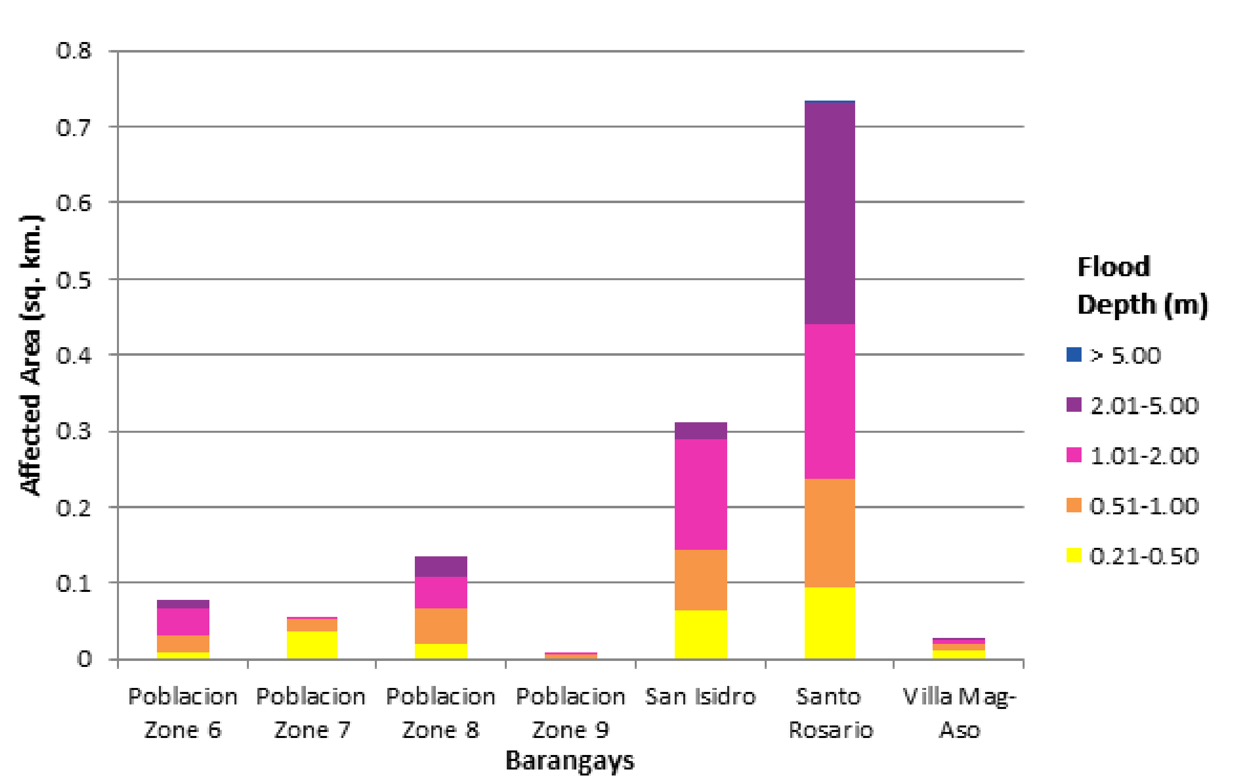


Figure 72. Affected areas in Baybay City, Eastern Samar during a 100-year rainfall return period

Among the barangays in the municipality of Baybay City, Calico-an is projected to have the highest percentage of area that will experience flood levels at 2.27%. Meanwhile, Bato posted the second highest percentage of area that may be affected by flood depths at 1.34%.

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

Table 43. 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	1.13	1.13	0.90
Medium	2.68	2.68	2.39
High	3.84	3.84	5.05

Of the 21 identified educational institutions in Pagbanganan Floodplain, 5 schools were assessed to be exposed to low-level flooding during 5- and 25-year scenarios while 1 school was assessed to be exposed to medium-level flooding. For the 100-year scenario, 6 schools were assessed for low-level flooding and 3 schools for medium-level flooding. See ANNEX 12 for a detailed enumeration of schools inside Pagbanganan Floodplain.

Of the 3 identified medical institutions in Pagbanganan Floodplain, all were assessed to be exposed to low-level flooding during 5- and 25-year scenarios. For the 100-year scenario, 1 school was assessed for low-level flooding and 2 for medium-level flooding. See ANNEX 13 for a detailed enumeration of medical institutions inside Pagbanganan Floodplain.

5.11 Flood Validation

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

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

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

After which, the actual data from the field were compared to the simulated data to assess the accuracy of the flood depth maps produced and to improve on what is needed.

The flood validation consists of 263 points randomly selected all over the Pagbanganan Floodplain. The points were grouped depending on the RIDF return period of the event.

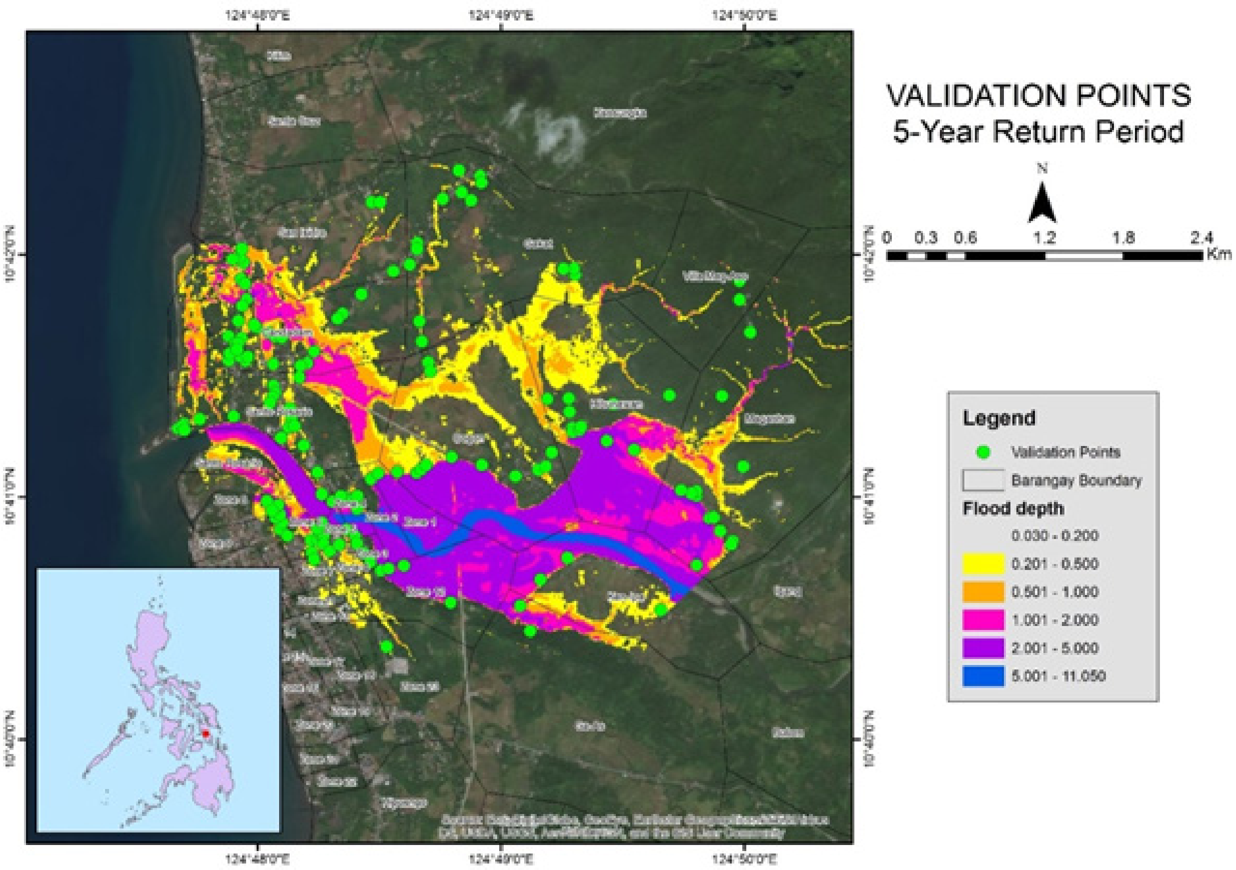


Figure 73. Validation points for 5-year flood depth map of Pagbanganan Floodplainv

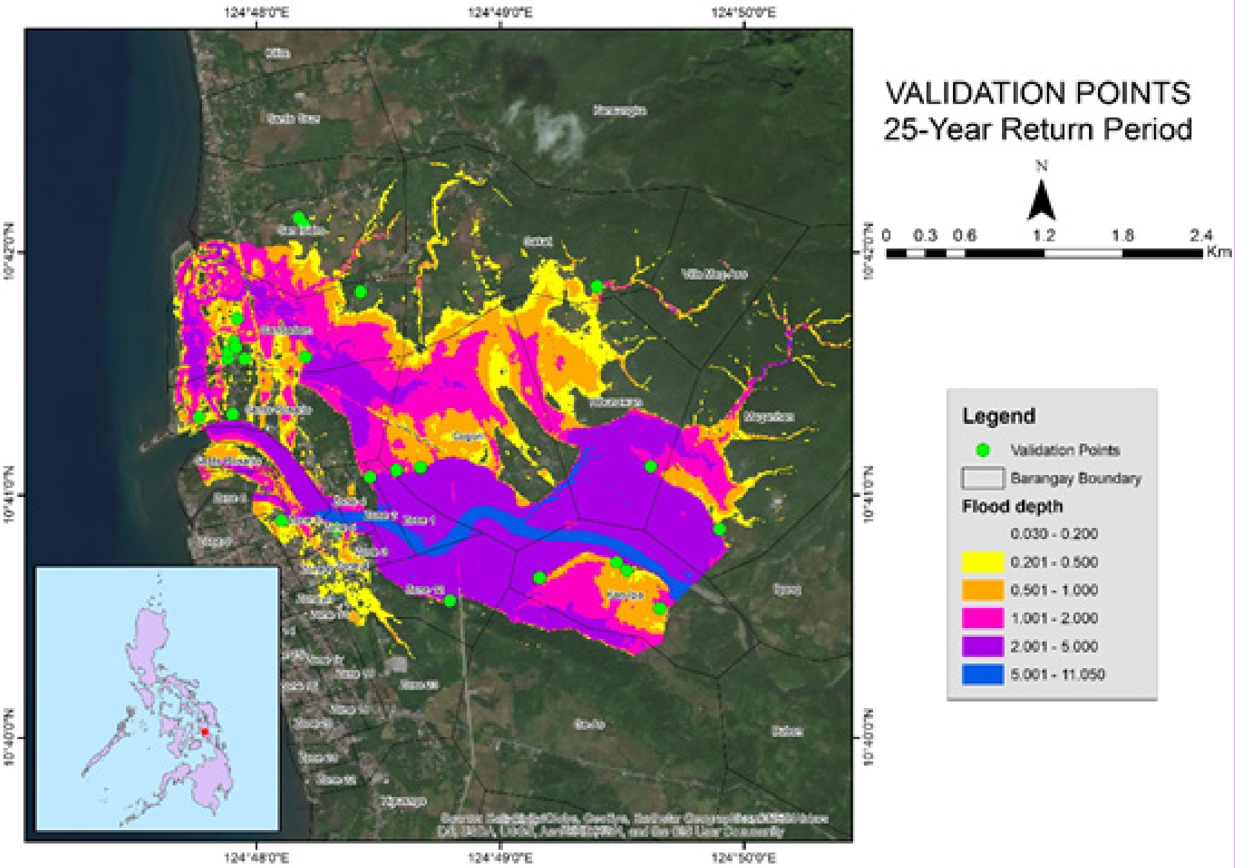


Figure 74. Validation points for 25-year flood depth map of Pagbanganan Floodplain

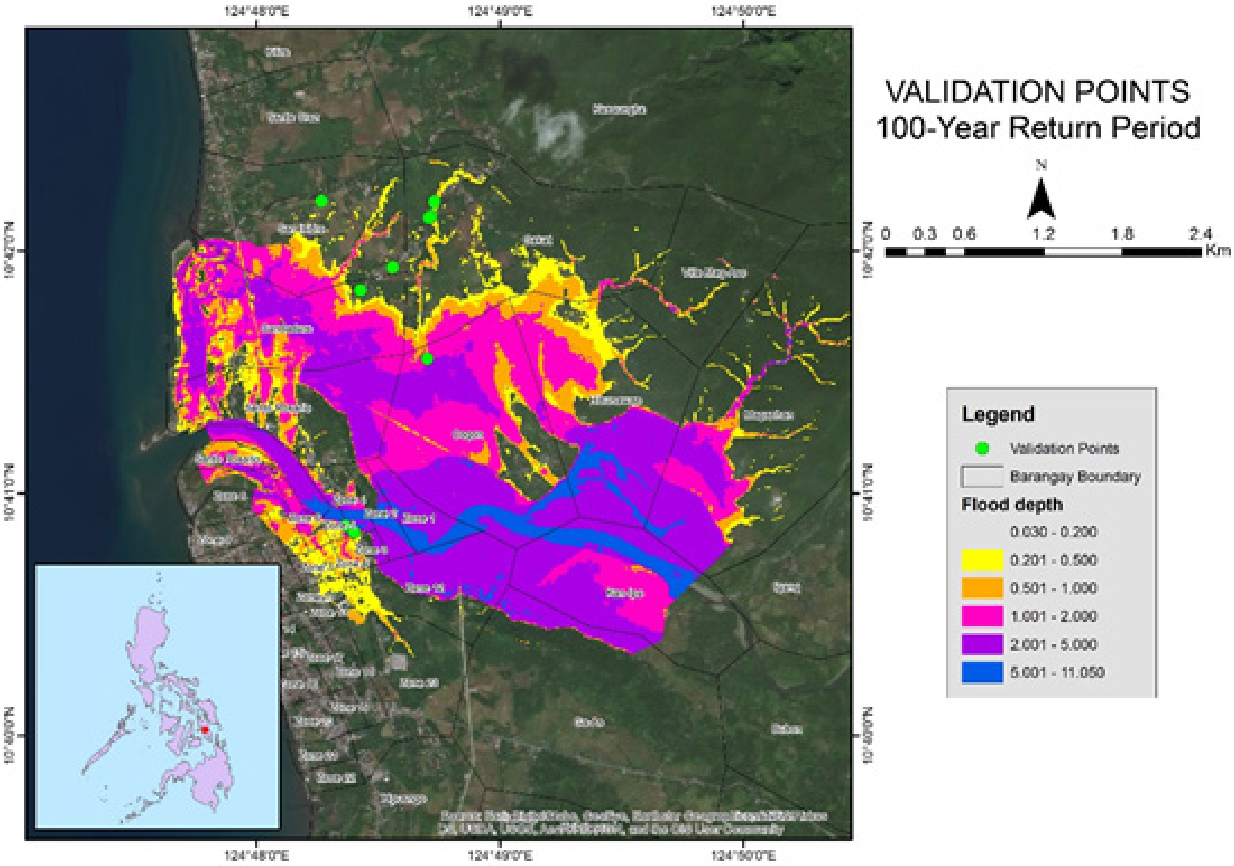


Figure 75. Validation points for 100-year flood depth map of Pagbanganan Floodplain

The RMSE value for each flood depth map is listed in the table below:

Table 44. RMSE values for each return period of flood depth map

Return Period	RMSE
5-year	1.31
25-year	2.21
100-year	0.86

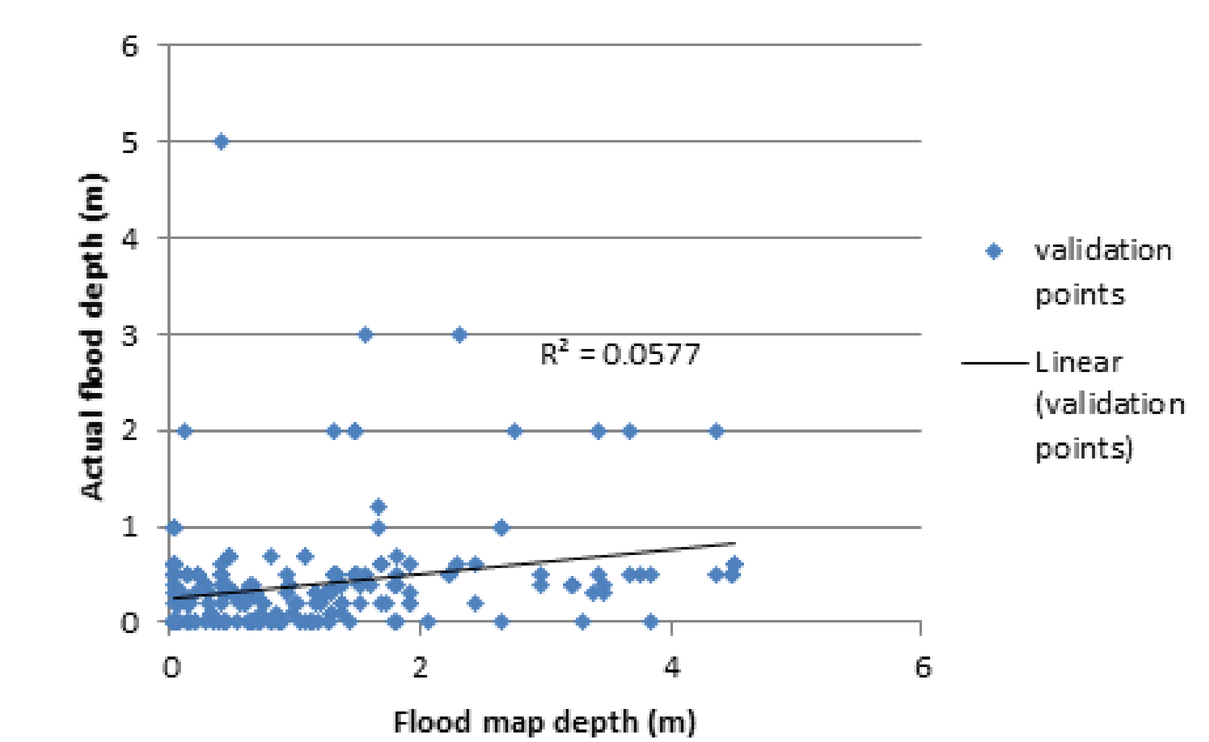


Figure 76. Flood map depth vs. actual flood depth for 5-year RP validation

Table 45. Actual flood depth vs. simulated flood depth for 5-year RP in Pagbanganan

HIMOGAANTANAO 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	32	11	27	24	5	0	99
	0.21-0.50	12	18	14	22	18	0	84
	0.51-1.00	8	5	1	7	6	0	27
	1.01-2.00	1	0	0	5	4	0	10
	2.01-5.00	0	1	0	1	1	0	3
	> 5.00		0	0	0	0	0	0
Total		53	35	42	59	34	0	223

The overall accuracy generated by the 5-year flood model is estimated at 25.56%, with 57 points correctly matching the actual flood depths. In addition, there were 54 points estimated one level above and below the correct flood depths while there were 63 points and 49 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 138 points were overestimated while a total of 28 points were underestimated in the modeled flood depths of Pagbanganan.

Table 46. Summary of accuracy assessment in Pagbanganan for 5-year RP

	No. of Points	%
Correct	57	25.56
Overestimated	138	61.88
Underestimated	28	12.56
Total	223	100

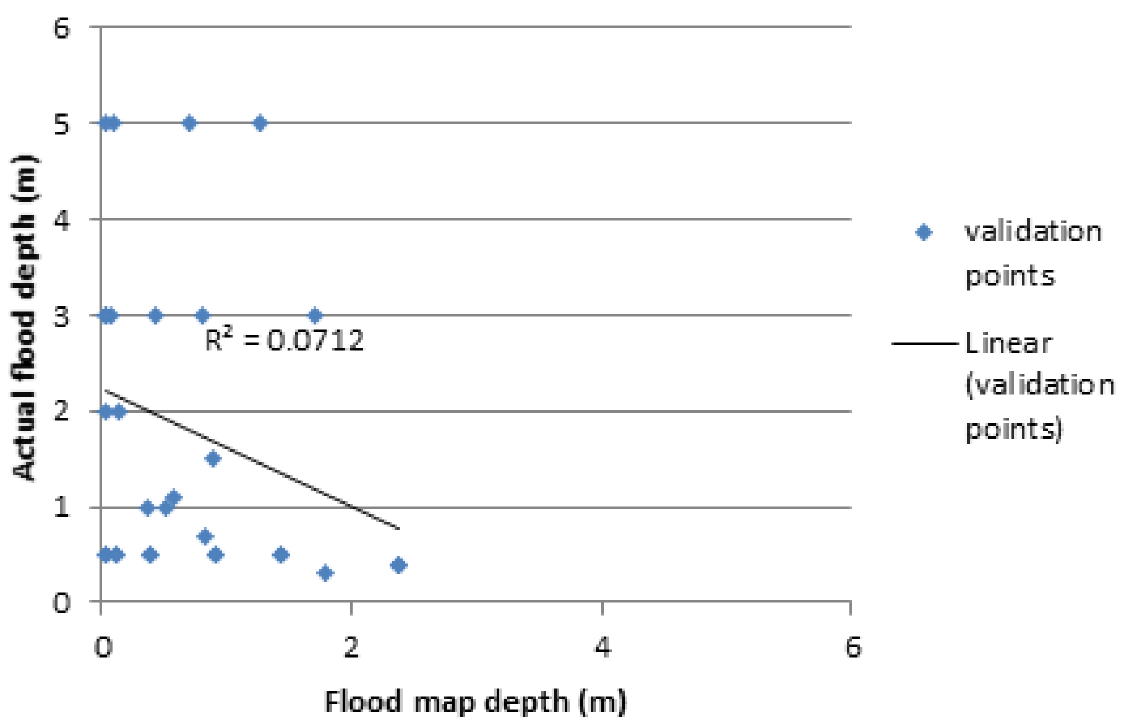


Figure 77. Flood map depth vs. actual flood depth for 25-year RP validation

Table 47. Actual flood depth vs. simulated flood depth for 25-year RP in Pagbanganan

HIMOGAANTANAO 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	0	0	0	0	0	0	0
	0.21-0.50	4	2	2	3	2	0	13
	0.51-1.00	0	1	2	0	0	0	3
	1.01-2.00	2	0	2	0	0	0	4
	2.01-5.00	6	1	2	2	0	0	11
	> 5.00		0	0	0	0	0	0
Total		12	4	8	5	2	0	31

The overall accuracy generated by the 25-year flood model is estimated at 12.90%, with 4 points correctly matching the actual flood depths. In addition, there were 11 points estimated one level above and below the correct flood depths while there were 5 points and 11 points estimated two levels above and below, and three or more levels above and below the correct flood. A total of 7 points were overestimated while a total of 20 points were underestimated in the modeled flood depths of Pagbanganan.

Table 48. Summary of accuracy assessment in Pagbanganan for 25-year RP

	No. of Points	%
Correct	4	12.90
Overestimated	7	22.58
Underestimated	20	64.52
Total	31	100

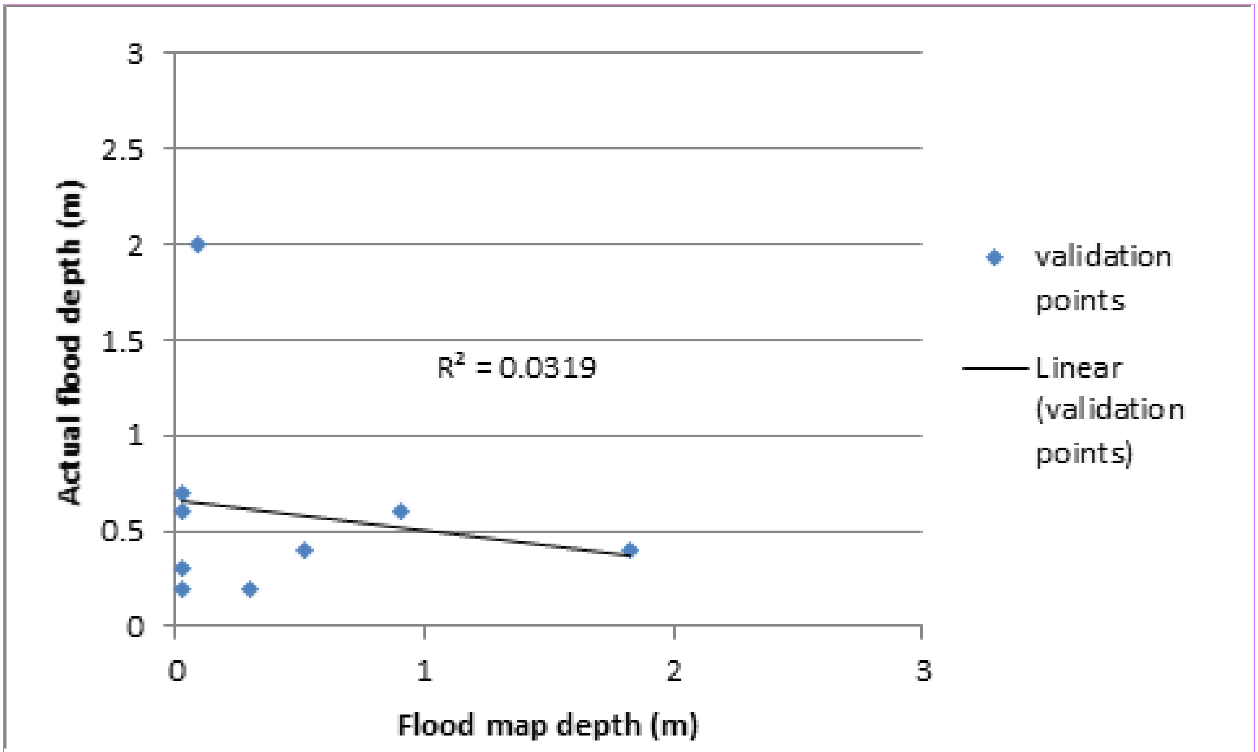


Figure 78. Flood map depth vs. actual flood depth for 100-year RP validation

Table 49. Actual flood depth vs. simulated flood depth for 100-year RP in Pagbanganan

HIMOGAANTANAO 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	1	1	0	0	0	0	2
	0.21-0.50	1	0	1	1	0	0	3
	0.51-1.00	2	0	1	0	0	0	3
	1.01-2.00	1	0	0	0	0	0	1
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00		0	0	0	0	0	0
Total		5	1	2	1	0	0	9

The overall accuracy generated by the 100-year flood model is estimated at 22.22%, with 2 points correctly matching the actual flood depths. In addition, there were 3 points estimated one level above and below the correct flood depths while there were 3 points and 1 point estimated two levels above and below, and three or more levels above and below the correct flood. A total of 3 points were overestimated while a total of 4 points were underestimated in the modeled flood depths of Pagbanganan.

Table 50. Summary of accuracy assessment in Pagbanganan for 100-year RP

	No. of Points	%
Correct	2	22.22
Overestimated	3	33.33
Underestimated	4	44.44
Total	9	100

REFERENCES

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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 Pagbanganan Floodplain Survey

Aquarius Sensor

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

ANNEX 2. NAMRIA Certification of Reference Points Used in the LIDAR Survey

LYT-731

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

February 05, 2015

CERTIFICATION

To whom it may concern:

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

Province: **LEYTE**
Station Name: **LYT-731**
Order: **2nd**

Island: **VISAYAS**	Barangay: **KANSUNGKA**	
Municipality: **BAYBAY**	MSL Elevation:	
	PRS92 Coordinates	
Latitude: **10° 42' 47.59464"**	Longitude: **124° 48' 34.34385"**	Ellipsoidal Hgt: **15.61000 m.**
	WGS84 Coordinates	
Latitude: **10° 42' 43.44572"**	Longitude: **124° 48' 39.54791"**	Ellipsoidal Hgt: **78.65700 m.**
	PTM / PRS92 Coordinates	
Northing: **1184617.338 m.**	Easting: **479165.977 m.**	Zone: **5**
	UTM / PRS92 Coordinates	
Northing: **1,184,777.35**	Easting: **697,902.97**	Zone: **51**

Location Description

LYT-731
From Babay City going to municipality of Albuera, from a bridge near babay city, Brgy. Kansungka is located on the 3rd junction on the right side of the highway, then passing thru Brgy. Candadau straight to a steel bridge near brgy. San Isidro then left to Brgy. Kasungka the control point is located near the house of ex-brgy. captain aring. The mark is a 3 inches cocnrete nail, embedded on a 40x40x100 cm. cocnrete monument having 40 cm height above the ground and is marked with LYT-731, 2007, LAMP.

Requesting Party:	**PHIL-LIDAR I**
Purpose:	**Reference**
OR Number:	**8077605 I**
T.N.:	**2015-0216**

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

LYT-741

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

April 14, 2016

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: **LEYTE**
Station Name: **LYT-741**
Order: **2nd**

Island: **VISAYAS**
Municipality: **HINDANG**
Barangay: **DOOS DEL NORTE**
MSL Elevation:

PRS92 Coordinates

Latitude:	**10° 27' 11.95722"**	Longitude:	**124° 43' 45.08400"**	Ellipsoidal Hgt:	**4.48300 m.**

WGS84 Coordinates

Latitude:	**10° 27' 7.86786"**	Longitude:	**124° 43' 50.31177"**	Ellipsoidal Hgt:	**67.94500 m.**

PTM / PRS92 Coordinates

Northing:	**1155878.867 m.**	Easting:	**470351.659 m.**	Zone:	**5**

UTM / PRS92 Coordinates

Northing:	**1,155,979.90**	Easting:	**689,272.22**	Zone:	**51**

Location Description

LYT-741
Brgy. doos del norte is about 2.6 km. from the poblacion pf hindang taking the national road to babay. upon reaching the said barangay, locate the brgy. hall. The LYT-741 is located on the opposite side of the road for about 36 m. far from the gate of the brgy hall.30x30x100 cm. cocnrete monument having 40 cm height above the ground with 5 inches concrete nail as center and is marked with "LYT-741, 2007, LAMP".

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8084228 I**
T.N.:	**2016-0916**

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

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

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

ANNEX 3. Baseline Processing Reports of Control Points used in the LIDAR Survey

LY-297

Vector Components (Mark to Mark)

From:	LYT-731				
Grid		Local		Global	
Easting	697902.966 m	Latitude	N10°42'47.59464"	Latitude	N10°42'43.44572"
Northing	1184777.350 m	Longitude	E124°48'34.34385"	Longitude	E124°48'39.54791"
Elevation	14.266 m	Height	15.609 m	Height	78.657 m

To:	LY-297				
Grid		Local		Global	
Easting	696205.243 m	Latitude	N10°43'21.53694"	Latitude	N10°43'17.38426"
Northing	1185810.360 m	Longitude	E124°47'38.67725"	Longitude	E124°47'43.88062"
Elevation	5.568 m	Height	6.908 m	Height	69.895 m

Vector					
ΔEasting	-1697.723 m	NS Fwd Azimuth	301°39'21"	ΔX	1504.544 m
ΔNorthing	1033.009 m	Ellipsoid Dist.	1987.143 m	ΔY	799.170 m
ΔElevation	-8.698 m	ΔHeight	-8.702 m	ΔZ	1022.982 m

Standard Errors

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

Aposteriori Covariance Matrix (Meter²)

	X	Y	Z
X	0.0000012108		
Y	-0.0000006864	0.0000020301	
Z	-0.0000001551	0.0000003202	0.0000004901

LY-313

Project information		Coordinate System	
Name:	F:\Doc\DAC\2016\Fieldwork\2016-4-6_20 Ormoc\ly-313 vs lyt-741.vce	Name:	UTM
Size:	339 KB	Datum:	PRS 92
Modified:	4/15/2016 6:26:41 PM (UTC:8)	Zone:	51 North (123E)
Time zone:	Taipei Standard Time	Geoid:	egmPH
Reference number:		Vertical datum:	
Description:			

Baseline Processing Report

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
LY-313 --- LYT-741 (B3)	LYT-741	LY-313	Fixed	0.003	0.014	13°13'57"	18139.132	1.796
LY-313 --- LYT-741 (B2)	LYT-741	LY-313	Fixed	0.005	0.014	13°13'57"	18139.104	1.786
LY-313 --- LYT-741 (B4)	LYT-741	LY-313	Fixed	0.005	0.014	13°13'57"	18139.125	1.802

Acceptance Summary

Processed	Passed	Flag	Fail
3	3	0	0

Vector Components (Mark to Mark)

From:	LYT-741				
Grid		Local		Global	
Easting	689272.210 m	Latitude	N10°27'11.95721"	Latitude	N10°27'07.86786"
Northing	1155979.897 m	Longitude	E124°43'45.08400"	Longitude	E124°43'50.31177"
Elevation	3.600 m	Height	4.482 m	Height	67.945 m

To:	LY-313				
Grid		Local		Global	
Easting	693326.992 m	Latitude	N10°36'46.67221"	Latitude	N10°36'42.54525"
Northing	1173661.007 m	Longitude	E124°46'01.67926"	Longitude	E124°46'06.89257"
Elevation	5.229 m	Height	6.279 m	Height	69.460 m

Vector					
ΔEasting	4054.782 m	NS Fwd Azimuth	13°13'57"	ΔX	-1573.287 m
ΔNorthing	17681.110 m	Ellipsoid Dist.	18139.132 m	ΔY	-5017.663 m
ΔElevation	1.629 m	ΔHeight	1.796 m	ΔZ	17360.172 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.006 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

LYT-90

Vector Components (Mark to Mark)

From:	W-22				
Grid		Local		Global	
Easting	675563.750 m	Latitude	N11°00'18.93705"	Latitude	N11°00'14.69624"
Northing	1216955.050 m	Longitude	E124°36'24.81698"	Longitude	E124°36'29.99714"
Elevation	6.321 m	Height	7.666 m	Height	69.516 m

To:	LYT-90				
Grid		Local		Global	
Easting	675667.934 m	Latitude	N11°00'17.78809"	Latitude	N11°00'13.54745"
Northing	1216920.307 m	Longitude	E124°36'28.24274"	Longitude	E124°36'33.42292"
Elevation	7.632 m	Height	8.978 m	Height	70.831 m

Vector					
ΔEasting	104.183 m	NS Fwd Azimuth	108°44'57"	ΔX	-90.156 m
ΔNorthing	-34.743 m	Ellipsoid Dist.	109.825 m	ΔY	-52.460 m
ΔElevation	1.311 m	ΔHeight	1.312 m	ΔZ	-34.398 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'01"	σ ΔX	0.001 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.001 m
σ ΔElevation	0.001 m	σ ΔHeight	0.001 m	σ ΔZ	0.001 m

Vector Components (Mark to Mark)

From:	CBU-340				
Grid		Local		Global	
Easting	660577.527 m	Latitude	N10°38'14.87646"	Latitude	N10°38'10.71737"
Northing	1176200.458 m	Longitude	E124°28'04.68006"	Longitude	E124°28'09.89389"
Elevation	14.571 m	Height	15.533 m	Height	77.920 m

To:	LYT-90				
Grid		Local		Global	
Easting	675667.875 m	Latitude	N11°00'17.75728"	Latitude	N11°00'13.51665"
Northing	1216919.360 m	Longitude	E124°36'28.24066"	Longitude	E124°36'33.42083"
Elevation	14.187 m	Height	15.532 m	Height	77.386 m

Vector					
ΔEasting	15090.348 m	NS Fwd Azimuth	20°36'38"	ΔX	-8272.921 m
ΔNorthing	40718.902 m	Ellipsoid Dist.	43427.367 m	ΔY	-14957.504 m
ΔElevation	-0.384 m	ΔHeight	-0.001 m	ΔZ	39921.998 m

ANNEX 4. The LIDAR Survey Team Composition

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

FIELD TEAM

LiDAR Operation	Senior Science Research Specialist	JULIE PEARL MARS	UP-TCAGP
	Senior Science Research Specialist	JASMINE ALVIAR	UP-TCAGP
	Research Associate (RA)	ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
	RA	ENGR. GRACE SINADJAN	UP-TCAGP
	RA	JONALYN GONZALES	UP-TCAGP
	RA	MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
	RA	SANDRA POBLETE	UP-TCAGP
	RA	JONATHAN ALMALVEZ	UP-TCAGP
	RA	KRISTINE JOY ANDAYA	UP-TCAGP
Ground Survey / Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RANDY SISON JR.	PHILIPPINE AIR FORCE (PAF)
	Pilot	CAPT. NEIL ACHILLES AGAWIN	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. FERDINAND DE OCAMPO	AAC

Annex 5. Data Transfer Sheet for Pagbanganan Floodplain

4/18/2016

DATA TRANSFER SHEET
03/16/2016 ORMOC

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	
3/16/2016	8403AC	3BLK48CD076A	AQUARIUS	N/A	905	811	282	59.1	248/208	9.82	148	144	1KB	1KB	4.3	NA	Z:\DAC\RAWDATA
3/16/2016	8404AC	3BLK48C076B	AQUARIUS	N/A	295	777	267	55.8	248/208	9.16	102	144	1KB	1KB	11.6	NA	Z:\DAC\RAWDATA
3/17/2016	8405AC	3BLK48B077A	AQUARIUS	N/A	1.58	627	251	55.1	202/269	8.62	87.1	218	1KB	1KB	3.02/8.15	NA	Z:\DAC\RAWDATA
3/17/2016	8406AC	3BLK48C077B	AQUARIUS	N/A	289	648	257	40.3	202/269	7.67	NA	218	1KB	1KB	8.15/11.7	NA	Z:\DAC\RAWDATA
3/18/2016	8407AC	3BLK48EG078A	AQUARIUS	N/A	727	585	235	37.8	269/259/278	6.9	96.9	209	1KB	1KB	16.3	NA	Z:\DAC\RAWDATA
3/19/2016	8408AC	3BLK34BD079A	AQUARIUS	N/A	347	453	208	56.3	192/133	5.14	20.2	263	1KB	1KB	24.2	NA	Z:\DAC\RAWDATA
3/19/2016	8409AC	3BLK34S079B	AQUARIUS	N/A	346	291	87.4	35.4	192/133	4.86	38.9	263	1KB	1KB	3.34	NA	Z:\DAC\RAWDATA

Prepared By:
Name DARRYL M. AUSTRIA
Position DAC- RESEARCH ASSOCIATE
Signature [signature]

Received / Checked By:
Name JONNIER MEDINA
Position SSRS
Signature [signature] 4/22/16

16-20

DATA TRANSFER SHEET
02/13/2015(ORMOC)

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	
21-Jan-15	7753AC	3BLK35B21A	AQUARIUS	NA	270	527	167	NA	NA	11.1	NA	29.1	1KB	1KB	3	NA	Z:\DAC\RAW DATA
22-Jan-15	7754AC	3BLK49B022A	AQUARIUS	NA	280	566	258	NA	NA	12	NA	66.1	1KB	1KB	4	NA	Z:\DAC\RAW DATA
23-Jan-15	7756AC	3BLK49A023A	AQUARIUS	NA	279	548	231	NA	NA	11.9	NA	34	1KB	1KB	3	NA	Z:\DAC\RAW DATA
25-Jan-15	7760AC	3BLK35A025A	AQUARIUS	NA	289	671	243	NA	NA	12.3	223	26.4	1KB	1KB	4	NA	Z:\DAC\RAW DATA
27-Jan-15	7764AC	3BLK35CD027A	GEMINI	NA	169/107	611	228	NA	NA	11.7	207	37.1	1KB	1KB	3	NA	Z:\DAC\RAW DATA
28-Jan-15	7766AC	3BLK49CD028A	AQUARIUS	NA	136	366	216	NA	NA	6.71	185MB	27.1	1KB	1KB	3	NA	Z:\DAC\RAW DATA
28-Jan-15	7767AC	3BLK35X028B	AQUARIUS	NA	123	310	148	NA	NA	6.4	98.6	18.5	1KB	1KB	3	NA	Z:\DAC\RAW DATA
29-Jan-15	7768AC	3BLK50A029A	AQUARIUS	NA	152	360	234	NA	NA	7.39	111	40.2	1KB	1KB	3	NA	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position
Signature

Received by

Name AC Bongat 2/13/15
Position SSRS
Signature

15-08

DATA TRANSFER SHEET
ORMOC(SOUTH LEYTE) 5/2/2016

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
April 10,2016	3921G	2BLK34a101A	GEMINI	NA	270	673	275	NA	NA	20.5	NA	19.1	1KB	1KB	23	NA	Z:\DAC\RAW DATA
April 10,2016	3923G	2BLK49AB101B	GEMINI	NA	375	377	168	NA	NA	8.5	NA	19.1	1 KB	1KB	23	NA	Z:\DAC\RAW DATA
April 11,2016	3925G	2BLK49DE102A	GEMINI	NA	138	570	252	NA	NA	9.56	NA	6.82	1 KB	1KB	23	NA	Z:\DAC\RAW DATA
April 13,2016	3933G	2BLK50ABC104A	GEMINI	NA	581	474	262	NA	NA	16.2	NA	17.4	1KB	1KB	NA	NA	Z:\DAC\RAW DATA
April 14,2016	3937G	2BLK50DS105A	GEMINI	NA	763	557	292	NA	NA	14.7	NA	10.5	1KB	1KB	28	NA	Z:\DAC\RAW DATA
April 16,2016	3945G	2BLK35AB107A	GEMINI	NA	216	940	267	NA	NA	17.1	NA	19.5	1KB	1KB	6	NA	Z:\DAC\RAW DATA
April 16,2016	3947G	2BLK35CS107B	GEMINI	NA	492	1.03	278	NA	NA	21	NA	19.5	1KB	1KB	10	NA	Z:\DAC\RAW DATA

Received from

Name R. Punto
Position RA
Signature [signature]

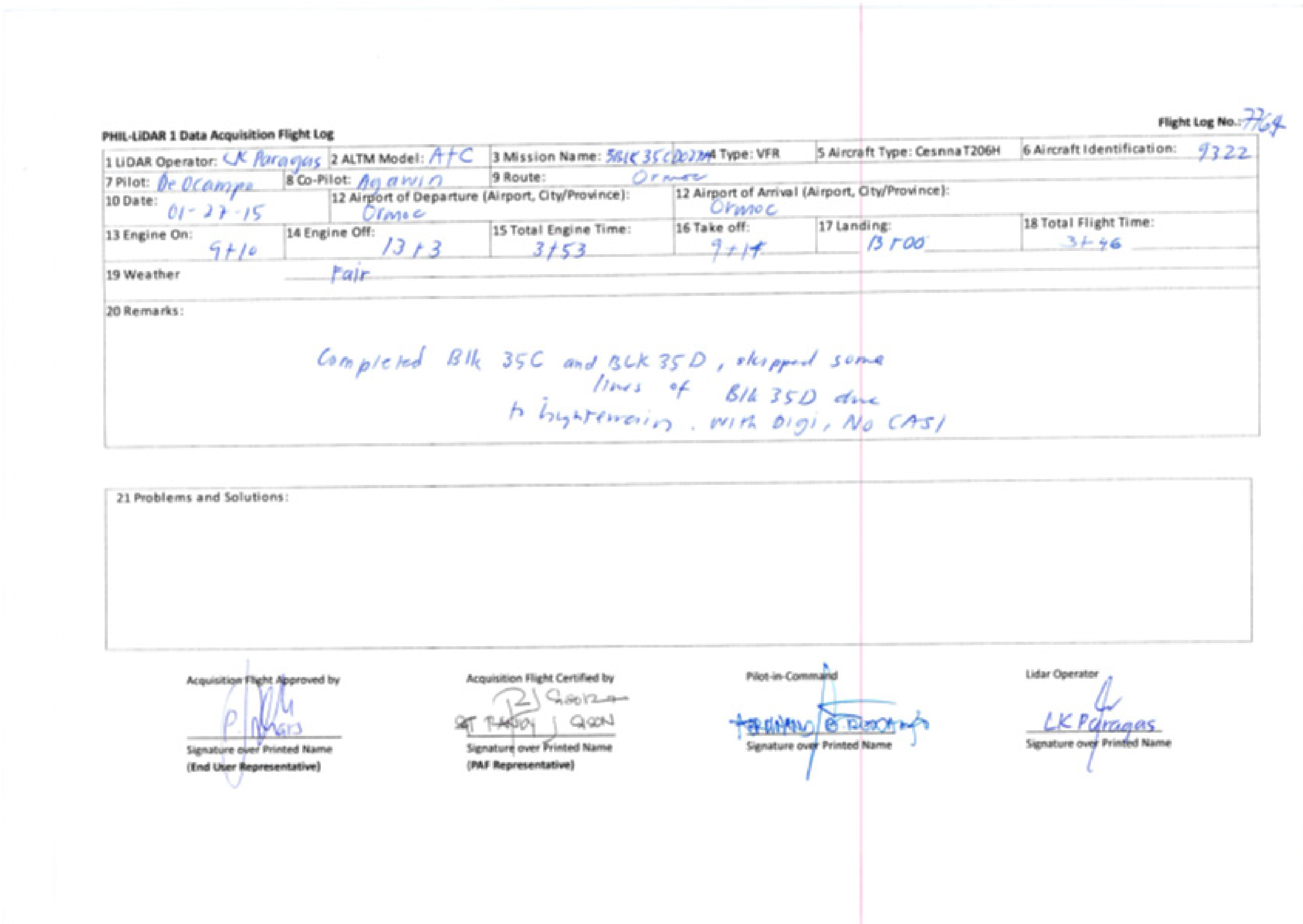
Received by

Name Ae Borgat
Position SSRS
Signature [signature] 5/6/16

16-27

ANNEX 6. Flight logs for the flight missions

Flight Log for 3BLK35CD027A Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 7764

1 LiDAR Operator: LK Paragas	2 ALTM Model: ATC	3 Mission Name: 3BLK35CD027A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: De Ocampo	8 Co-Pilot: Agawin	9 Route: Ormoc			
10 Date: 01-27-15	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 9+10	14 Engine Off: 13+3	15 Total Engine Time: 3+53	16 Take off: 9+14	17 Landing: 13+00	18 Total Flight Time: 3+46
19 Weather: Fair					

20 Remarks:

Completed Blk 35C and BLK 35D, skipped some lines of Blk 35D due to high terrain. with Digi, No CASI

21 Problems and Solutions:

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

Acquisition Flight Certified by: SGT RANDY J GOON — Signature over Printed Name (PAF Representative)

Pilot-in-Command: Signature over Printed Name

Lidar Operator: LK Paragas — Signature over Printed Name

Flight log 3BLK48FG078AMission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 7792

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: AHC	3 Mission Name: 3BLK35FV	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: Aquino	8 Co-Pilot: De Ocampo	9 Route: 041A			
10 Date: 02-10-15	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 8H15	14 Engine Off: 12H14	15 Total Engine Time: 3H59	16 Take off: 8H20	17 Landing: 12H10	18 Total Flight Time: 3H50
19 Weather: Fair					

20 Remarks:

Completed lines of Blk 25FV

No Digitizer & CASI

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
Signature over Printed Name (End User Representative)	SSGT [illegible] J Sicon Signature over Printed Name (PAF Representative)	[illegible] Aquino Signature over Printed Name	Grace Sinadjan Signature over Printed Name

Flight log 3BLK35EV042A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 2294

1 LIDAR Operator: LK Paragas	2 ALTM Model: AHC	3 Mission Name: 3BLK35EV042A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: Agawin	8 Co-Pilot: De Ocampo	9 Route:			
10 Date: 02-11-15	12 Airport of Departure (Airport, City/Province): Ormoc		12 Airport of Arrival (Airport, City/Province): Ormoc		
13 Engine On: 8+00	14 Engine Off: 12+11	15 Total Engine Time: 4+11	16 Take off: 8+05	17 Landing: 12+07	18 Total Flight Time: 4+02
19 Weather: Fair					

20 Remarks:

Completed BLK35E and voids with Digitizer
No CASI

21 Problems and Solutions:

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	Lidar Operator
[signature]	SGT Ranioy J Gico	N. Agawin	LK Paragas
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name

Flight Log for 3028P Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 8407AC

1 LIDAR Operator: J. GONZALES	2 ALTM Model: AQUA	3 Mission Name: 3BLK48FG076A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9322
7 Pilot: C. ALFONSO	8 Co-Pilot: J. JECIEL	9 Route:			
10 Date: MAR 16, 2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 4+05	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK48ABEG

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
		C. ALFONSO III	J. GONZALES	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Flight log for 2BLK34a101A Mission

PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3921G

1 LIDAR Operator: J. ALMALVEZ	2 ALTM Model: Gemini	3 Mission Name: 2BLK34a101A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date: APR 10, 2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 4+27	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

Surveyed BLK 34a, 49A & 49B

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

Acquisition Flight Approved by	Acquisition Flight Certified by	Pilot-in-Command	LIDAR Operator	Aircraft Mechanic/ LIDAR Technician
PAULINE ARCEO		[signature]	J. ALMALVEZ	
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Flight Log for 3028P Mission

PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 3925G

1 LiDAR Operator: K. ANDAYA	2 ALTM Model: GEMINI	3 Mission Name: 2BLK49DE102A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9122
7 Pilot:	8 Co-Pilot:	9 Route:			
10 Date: Apr. 11, 2016	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On:	14 Engine Off:	15 Total Engine Time: 4H20	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather	partly cloudy				

20 Flight Classification

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

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

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

21 Remarks

Surveyed voids over BLK49D and 49E

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

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

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

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

LiDAR Operator: K. ANDAYA — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: ____________ Signature over Printed Name

ANNEX 7. Flight status reports

FLIGHT NO.	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
7764AC	BLK35C&D	3BLK35CD027A	LK PARAGAS	JANUARY 27, 2015	Completed Blk35C and Blk35D, skipped some lines of 35D due to high terrain. With digitizer, No CASI
7792AC	BLK35F	3BLK35FV041A	G SINADJAN	FEBRUARY 10, 2015	Completed lines of Blk25FV. No digitizer. No CASI
7794AC	BLK35E	3BLK35EV042A	LK PARAGAS	FEBRUARY 11, 2015	Completed Blk35E and some voids with digitizer. No CASI
8407AC	BLK 48ABEG	3BLK48FG078A	J GONZALES	MARCH 18, 2016	SURVEYED BLK 48ABEG 46.94 SQ KM
3921G	BLK34a	2BLK34a101A	J.ALMALVEZ	APRIL 10, 2016	SURVEYED BLK34a, 49A and 49B
3925G	49DE	2BLK49DE102A	K. ANDAYA	APRIL 11, 2016	SURVEYED VOIDS OVER BLK 49D AND 49E

LAS BOUNDARIES PER FLIGHT

Flight No. : 7764AC
Mission Name: 3BLK35CD027A
Area: BLK35C, BLK35D

ALT: 500m	SCAN FREQ: 45	SCAN ANGLE: 20Deg	PRF:50 Hz
SURVEYED AREA:	93.69 SQ KM.		

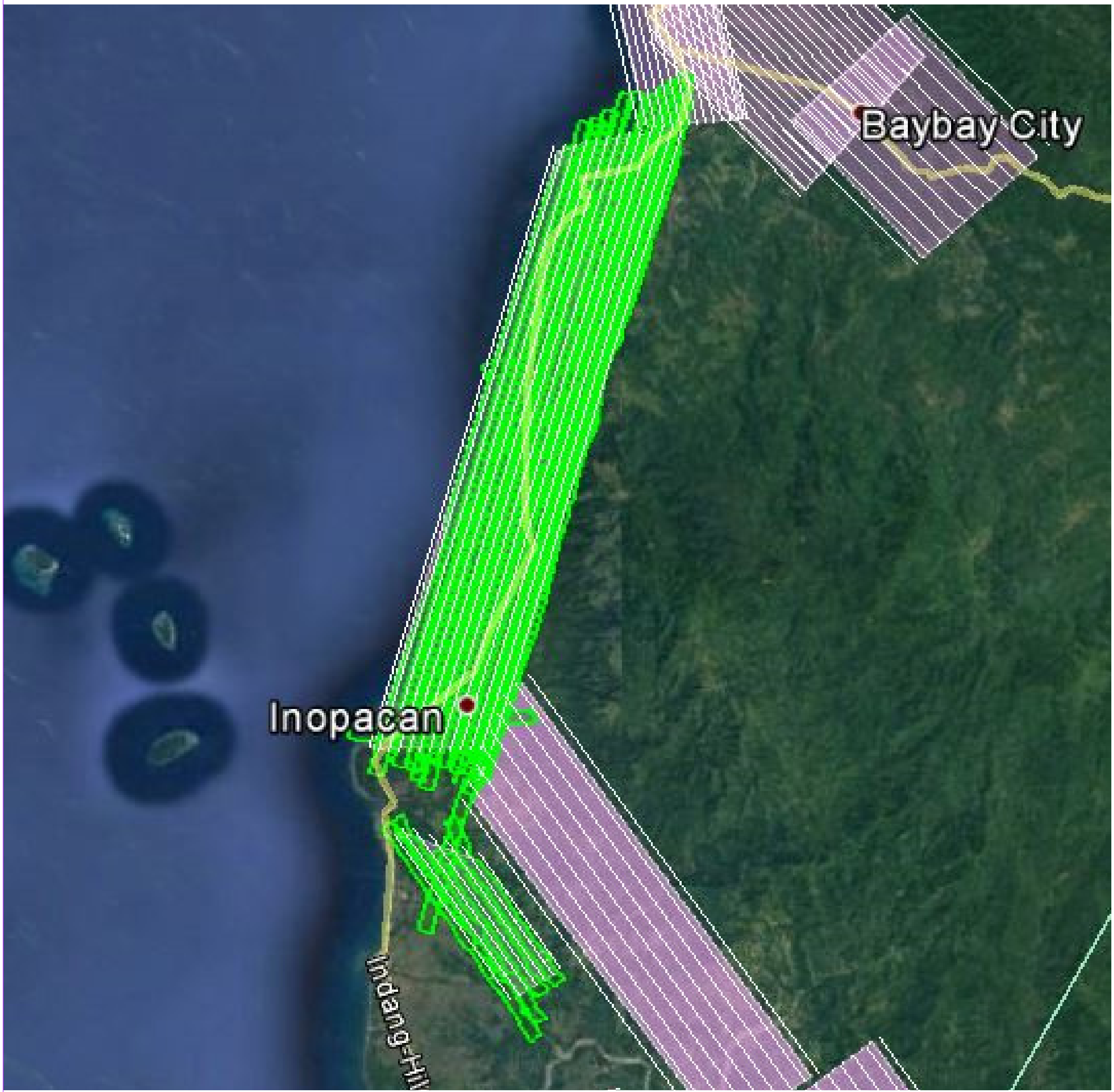
Flight No. : 7764AC
Mission Name: 3BLK35CD027A
Area: BLK35C, BLK35D

ALT: 500m	SCAN FREQ: 45	SCAN ANGLE: 20Deg	PRF:50 Hz
SURVEYED AREA:	93.69 SQ KM.		

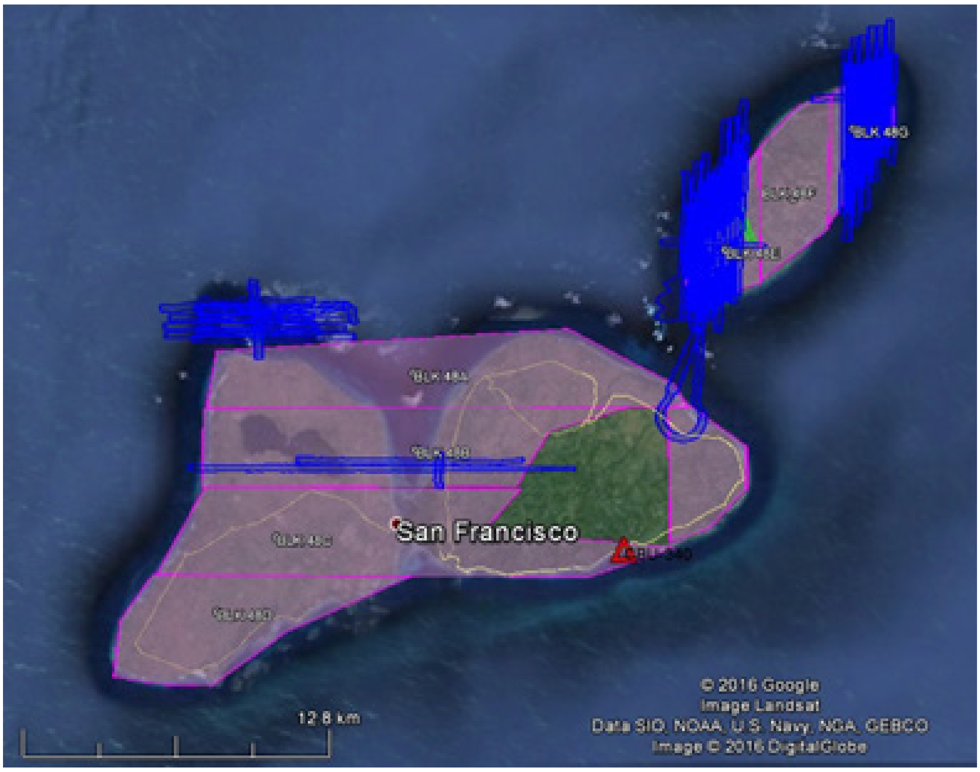
Flight No. : 7792AC
Mission Name: 3BLK35FV041A
Area: BLK35F, BLK35V

ALT: 500m	SCAN FREQ: 45	SCAN ANGLE: 18Deg	PRF:50Hz
SURVEYED AREA:	73.67 SQ KM.		

Flight No. : 7794AC
Mission Name: 3BLK35EV042A
Area: BLK35E, BLK35V
ALT: 500m SCAN FREQ: 45 SCAN ANGLE: 20Deg PRF:50Hz
SURVEYED AREA: 75.56 SQ KM.



Flight No. : 8407AC
Mission Name: 3BLK48FG078A
Area: BLK 48ABEG
ALT: 500m SCAN FREQ: 45 SCAN ANGLE: 18
SURVEYED AREA: 60.72 SQ KM.

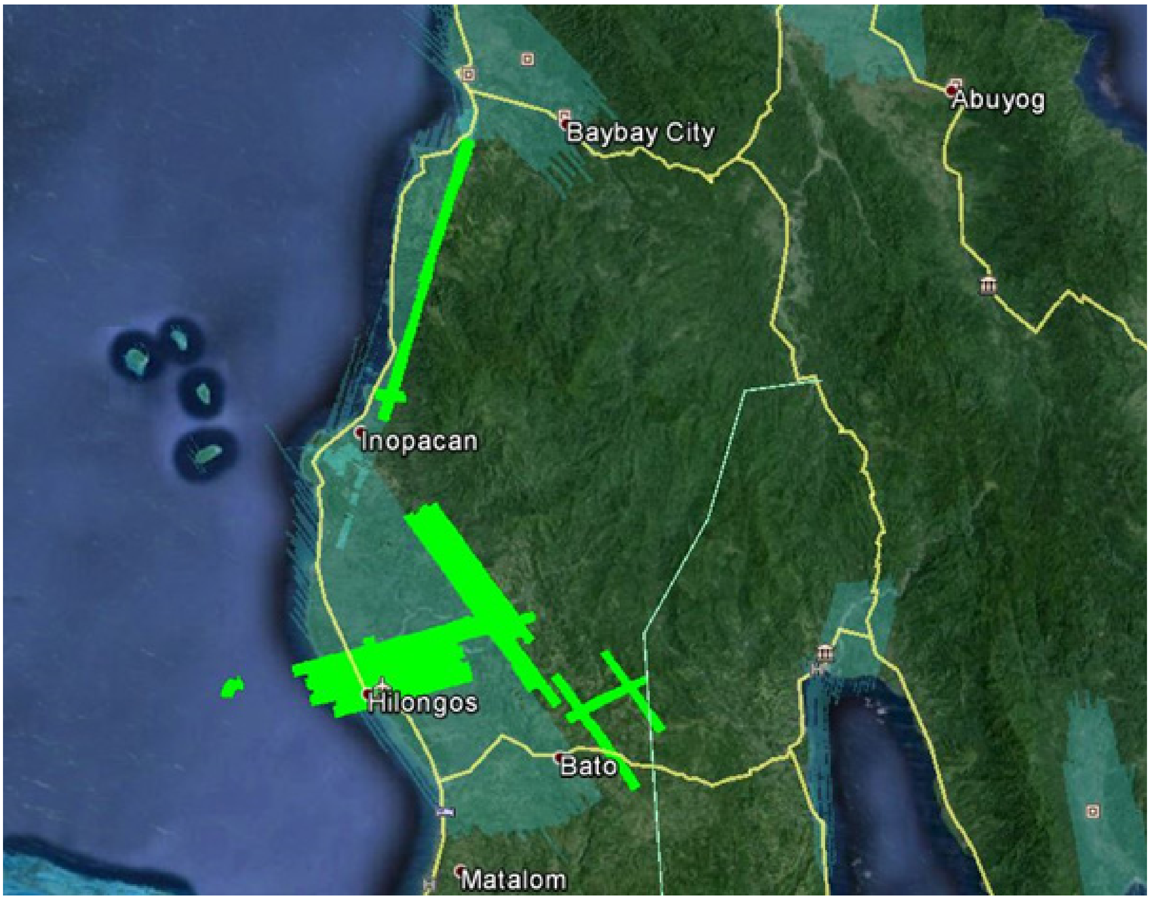


START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
02:01:00.778	02:03:06.062	23	471	33	45.00	18.00	OFF	NAR	ON	OFF	181.00	3BLK48EG.pln
02:05:41.261	02:07:48.025	24	482	33	45.00	18.00	OFF	NAR	ON	OFF	181.00	3BLK48EG.pln
02:10:35.464	02:12:37.953	25	464	33	45.00	18.00	OFF	NAR	ON	OFF	1.00	3BLK48EG.pln
02:15:01.643	02:16:58.957	26	482	33	45.00	18.00	OFF	NAR	ON	OFF	181.00	3BLK48EG.pln
02:19:31.641	02:21:24.64	27	467	33	45.00	18.00	OFF	NAR	ON	OFF	181.00	3BLK48EG.pln
02:24:00.329	02:25:52.204	28	469	33	45.00	18.00	OFF	NAR	ON	OFF	181.00	3BLK48EG.pln
02:28:36.168	02:30:22.537	29	465	33	45.00	18.00	OFF	NAR	ON	OFF	1.00	3BLK48EG.pln
02:32:50.466	02:34:33.606	30	452	33	45.00	18.00	OFF	NAR	ON	OFF	181.00	3BLK48EG.pln
02:37:18.54	02:38:59.609	31	472	33	45.00	18.00	OFF	NAR	ON	OFF	1.00	3BLK48EG.pln
02:41:23.678	02:43:02.578	32	451	33	45.00	18.00	OFF	NAR	ON	OFF	181.00	3BLK48EG.pln
02:45:42.962	02:47:12.856	33	448	33	45.00	18.00	OFF	NAR	ON	OFF	181.00	3BLK48EG.pln
02:49:48.646	02:51:13.61	34	472	33	45.00	18.00	OFF	NAR	ON	OFF	1.00	3BLK48EG.pln
02:52:54.82	02:54:06.609	29	471	33	45.00	18.00	OFF	NAR	ON	OFF	1.00	3BLK48EG.pln
02:55:44.169	02:57:24.858	55	481	33	45.00	18.00	OFF	NAR	OFF	OFF	3.00	3BLK48EG.pln
02:59:51.507	03:01:35.717	56	472	33	45.00	18.00	OFF	NAR	OFF	OFF	3.00	3BLK48EG.pln
03:04:08.366	03:05:53.856	57	470	33	45.00	18.00	OFF	NAR	OFF	OFF	3.00	3BLK48EG.pln
03:08:34.37	03:10:24.614	58	465	33	45.00	18.00	OFF	NAR	OFF	OFF	183.00	3BLK48EG.pln
03:13:07.648	03:19:39.476	59	476	33	45.00	18.00	OFF	NAR	OFF	OFF	3.00	3BLK48EG.pln
03:22:42.58	03:24:25.44	61	481	33	45.00	18.00	OFF	NAR	OFF	OFF	3.00	3BLK48EG.pln
03:26:46.299	03:28:53.438	62	477	33	45.00	18.00	OFF	NAR	OFF	OFF	183.00	3BLK48EG.pln
03:26:46.299	03:28:53.438	62	477	33	45.00	18.00	OFF	NAR	OFF	OFF	183.00	3BLK48EG.pln
03:31:24.303	03:33:35.477	63	479	33	45.00	18.00	OFF	NAR	OFF	OFF	3.00	3BLK48EG.pln
03:31:24.303	03:33:35.477	63	478	33	45.00	18.00	OFF	NAR	OFF	OFF	3.00	3BLK48EG.pln
03:31:24.303	03:33:35.477	63	478	33	45.00	18.00	OFF	NAR	OFF	OFF	3.00	3BLK48EG.pln
03:36:03.441	03:38:12.411	64	460	33	45.00	18.00	OFF	NAR	ON	OFF	183.00	3BLK48EG.pln
03:36:03.441	03:38:12.411	64	460	33	45.00	18.00	OFF	NAR	ON	OFF	183.00	3BLK48EG.pln
03:36:03.441	03:38:12.411	64	460	33	45.00	18.00	OFF	NAR	ON	OFF	183.00	3BLK48EG.pln
03:40:53.37	03:43:05.724	65	475	33	45.00	18.00	OFF	NAR	ON	OFF	3.00	3BLK48EG.pln
03:40:53.37	03:43:05.724	65	474	33	45.00	18.00	OFF	NAR	ON	OFF	3.00	3BLK48EG.pln
03:45:29.583	03:47:49.443	66	459	33	45.00	18.00	OFF	NAR	ON	OFF	3.00	3BLK48EG.pln
03:45:29.583	03:47:49.443	66	457	33	45.00	18.00	OFF	NAR	ON	OFF	183.00	3BLK48EG.pln
03:50:23.547	03:52:44.141	67	468	33	45.00	18.00	OFF	NAR	ON	OFF	183.00	3BLK48EG.pln
03:55:06.691	03:57:28.405	68	462	33	45.00	18.00	OFF	NAR	ON	OFF	3.00	3BLK48EG.pln
03:55:06.691	03:57:28.405	68	462	33	45.00	18.00	OFF	NAR	ON	OFF	3.00	3BLK48EG.pln
04:00:10.444	04:01:27.339	68	464	33	45.00	18.00	OFF	NAR	ON	OFF	3.00	3BLK48EG.pln
04:06:45.077	04:11:03.586	77	461	33	45.00	18.00	OFF	NAR	OFF	OFF	270.00	3BLK48EG.pln
04:13:38.48	04:16:13.479	77	467	33	45.00	18.00	OFF	NAR	OFF	OFF	90.00	3BLK48EG.pln
04:19:00.484	04:19:28.219	77	487	33	45.00	18.00	OFF	NAR	OFF	OFF	90.00	3BLK48EG.pln
04:19:00.484	04:19:28.219	77	487	33	45.00	18.00	OFF	NAR	OFF	OFF	90.00	3BLK48EG.pln
04:19:00.484	04:19:28.219	77	487	33	45.00	18.00	OFF	NAR	OFF	OFF	90.00	3BLK48EG.pln
04:25:27.587	04:27:19.516	119	475	33	45.00	18.00	OFF	NAR	OFF	OFF	269.00	3BLK48EG.pln
04:30:09.695	04:31:55.555	120	455	33	45.00	18.00	OFF	NAR	OFF	OFF	269.00	3BLK48EG.pln
04:30:09.695	04:31:55.555	120	455	33	45.00	18.00	OFF	NAR	OFF	OFF	269.00	3BLK48EG.pln
04:34:32.974	04:36:12.614	121	442	33	45.00	18.00	OFF	NAR	ON	OFF	89.00	3BLK48EG.pln
04:34:32.974	04:36:12.614	121	442	33	45.00	18.00	OFF	NAR	ON	OFF	89.00	3BLK48EG.pln
04:38:51.553	04:40:45.183	122	453	33	45.00	18.00	OFF	NAR	ON	OFF	269.00	3BLK48EG.pln
04:38:51.553	04:40:45.183	122	453	33	45.00	18.00	OFF	NAR	ON	OFF	269.00	3BLK48EG.pln
04:38:51.553	04:40:45.183	122	453	33	45.00	18.00	OFF	NAR	ON	OFF	269.00	3BLK48EG.pln
04:43:37.942	04:45:18.011	123	458	33	45.00	18.00	OFF	NAR	ON	OFF	89.00	3BLK48EG.pln
04:43:37.942	04:45:18.011	123	458	33	45.00	18.00	OFF	NAR	ON	OFF	89.00	3BLK48EG.pln
04:43:37.942	04:45:18.011	123	458	33	45.00	18.00	OFF	NAR	ON	OFF	89.00	3BLK48EG.pln
04:47:40.766	04:49:32.63	124	458	33	45.00	18.00	OFF	NAR	ON	OFF	269.00	3BLK48EG.pln
04:51:56.554	04:53:43.449	125	466	33	45.00	18.00	OFF	NAR	ON	OFF	269.00	3BLK48EG.pln
04:51:56.554	04:53:43.449	125	462	33	45.00	18.00	OFF	NAR	ON	OFF	269.00	3BLK48EG.pln
04:56:22.698	04:57:16.698	125	482	33	45.00	18.00	OFF	NAR	ON	OFF	269.00	3BLK48EG.pln
04:56:22.698	04:57:16.698	125	482	33	45.00	18.00	OFF	NAR	ON	OFF	269.00	3BLK48EG.pln
04:56:22.698	04:57:16.698	125	482	33	45.00	18.00	OFF	NAR	ON	OFF	269.00	3BLK48EG.pln
05:01:15.697	05:02:56.346	117	461	33	45.00	18.00	OFF	NAR	ON	OFF	269.00	3BLK48EG.pln
05:01:15.697	05:02:56.346	117	461	33	45.00	18.00	OFF	NAR	ON	OFF	269.00	3BLK48EG.pln

FLIGHT NO.: 3921
AREA: Ormoc
MISSION NAME: 2BLK34a101A
ALT: 1000m SCAN FREQ: 50 SCAN ANGLE: 18
SURVEYED AREA: 157.04 SQ KM.

START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
02:05:33.1	02:07:34.609	1	1111	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
02:10:01.723	02:11:43.463	6	1087	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
02:14:50.586	02:16:56.781	2	1123	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
02:19:42.155	02:21:29.779	7	1095	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
02:23:41.438	02:25:49.017	3	1122	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
02:28:22.016	02:30:16.016	8	1132	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
02:32:42.64	02:34:57.529	4	1155	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
02:37:57.298	02:39:44.017	9	1138	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
02:42:49.011	02:44:56.505	5	1149	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
02:47:10.729	02:48:53.899	10	1137	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
02:51:47.018	02:53:54.412	11	1111	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
02:56:21.616	02:58:02.305	12	1119	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
03:00:35.014	03:01:04.074	6	1176	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
03:00:35.014	03:01:04.074	6	1176	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
03:01:54.559	03:02:13.244	3	1098	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
03:01:54.559	03:02:13.244	3	1095	100	50.00	18.00	OFF	NAR	ON	OFF	315.00	Southern_leyte_additonal@1000.pln
03:06:04.217	03:06:50.957	3	1144	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
03:06:04.217	03:06:50.957	3	1146	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
03:06:04.217	03:06:50.957	3	1147	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
03:10:02.621	03:11:36.505	3	1093	100	50.00	18.00	OFF	NAR	ON	OFF	135.00	Southern_leyte_additonal@1000.pln
03:18:13.908	03:22:06.016	79	1127	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
03:23:36.821	03:27:27.709	71	1115	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
03:29:17.513	03:33:29.302	78	1106	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
03:36:07.101	03:39:47.599	77	1122	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
03:43:09.538	03:47:32.242	76	1149	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
03:51:14.24	03:55:00.629	75	1095	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
03:58:42.967	04:03:15.441	74	1124	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
04:06:40.999	04:07:54.154	74	1104	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
04:11:49.773	04:15:09.861	80	1126	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
04:18:10.825	04:21:19.444	87	1155	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
04:24:39.103	04:27:54.602	81	1107	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
04:29:34.691	04:32:35.83	88	1096	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
04:34:59.099	04:38:10.863	82	1132	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
04:39:36.802	04:42:55.156	89	1115	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
04:44:52.04	04:48:02.579	83	1080	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
04:50:02.949	04:53:17.752	90	1130	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
04:55:22.692	04:58:34.186	84	1093	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
05:00:20.07	05:03:06.489	91	1074	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
05:05:46.578	05:09:05.297	85	1082	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
05:12:04.956	05:15:06.41	92	1077	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Southern_leyte_additonal@1000.pln
05:18:17.014	05:21:44.073	86	1113	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln
05:24:47.357	05:26:42.751	86	1098	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Southern_leyte_additonal@1000.pln

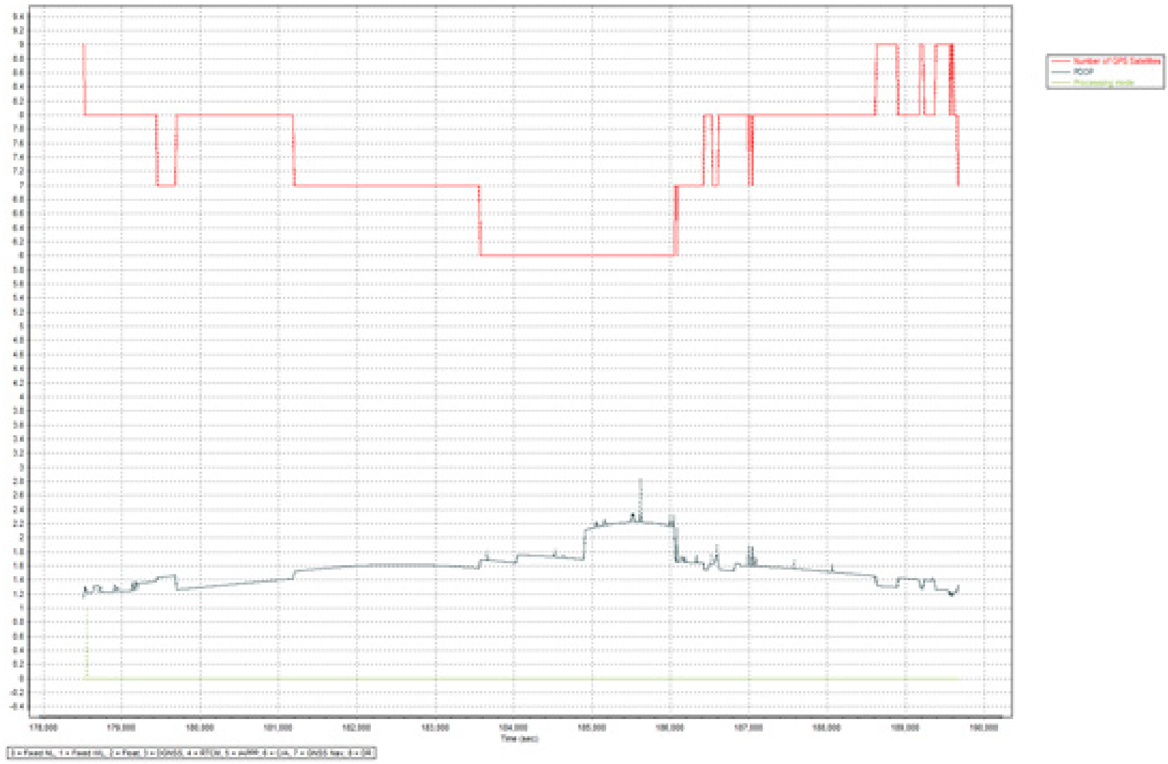
FLIGHT NO.: 3925
AREA: Ormoc
MISSION NAME: 2BLK49DE102A
ALT: 1000m SCAN FREQ: 50 SCAN ANGLE: 18
SURVEYED AREA: 74.34 SQ KM.



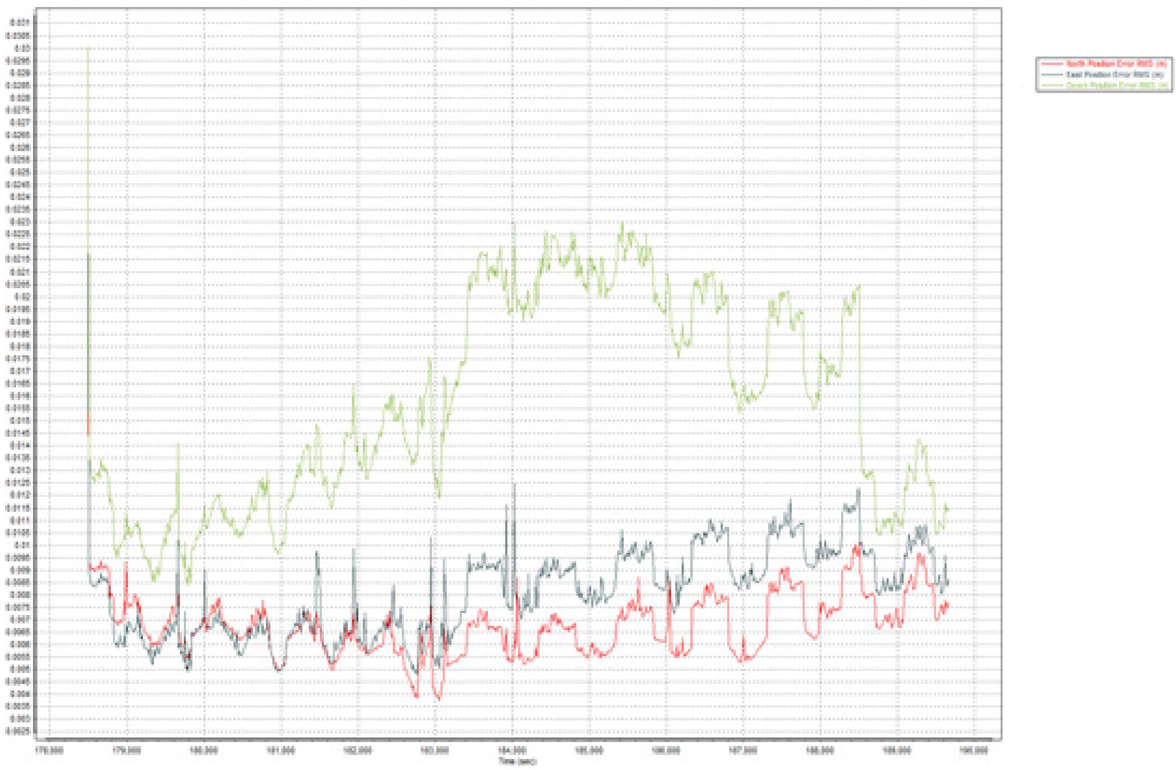
START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
01:34:50.152	01:37:57.256	27	1124	100	50.00	18.00	OFF	NAR	ON	OFF	75.00	Default.pln
01:40:24.36	01:42:36.014	29	1122	100	50.00	18.00	OFF	NAR	ON	OFF	255.00	Default.pln
01:46:06.222	01:48:36.221	30	1122	100	50.00	18.00	OFF	NAR	ON	OFF	75.00	Default.pln
01:51:58.05	01:54:09.819	31	1112	100	50.00	18.00	OFF	NAR	ON	OFF	255.00	Default.pln
01:57:49.433	02:00:15.467	32	1142	100	50.00	18.00	OFF	NAR	ON	OFF	75.00	Default.pln
02:03:42.471	02:05:46.215	33	1150	100	50.00	18.00	OFF	NAR	ON	OFF	255.00	Default.pln
02:09:34.644	02:13:19.982	28	1130	100	50.00	18.00	OFF	NAR	ON	OFF	75.00	Default.pln
02:17:19.401	02:18:22.785	27	1113	100	50.00	18.00	OFF	NAR	ON	OFF	75.00	Default.pln
02:22:27.159	02:25:07.613	73	1120	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Default.pln
02:28:44.542	02:31:05.546	74	1097	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Default.pln
02:34:44.79	02:38:42.018	75	1115	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Default.pln
02:42:04.582	02:42:25.127	75	1122	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Default.pln
02:45:53.406	02:49:11.755	76	1141	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Default.pln
02:54:44.373	02:56:20.512	80	1126	100	50.00	18.00	OFF	NAR	ON	OFF	144.00	Default.pln
02:59:45.236	03:01:54.27	87	1142	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Default.pln
03:05:45.409	03:07:15.303	87	1135	100	50.00	18.00	OFF	NAR	ON	OFF	324.00	Default.pln
03:15:36.235	03:20:12.764	95	1036	100	50.00	18.00	OFF	NAR	ON	OFF	17.00	Default.pln
03:23:25.993	03:25:43.962	95	956	100	50.00	18.00	OFF	NAR	ON	OFF	197.00	Default.pln
03:28:33.341	03:29:05.346	95	1092	100	50.00	18.00	OFF	NAR	ON	OFF	197.00	Default.pln

ANNEX 8. Mission Summary Reports

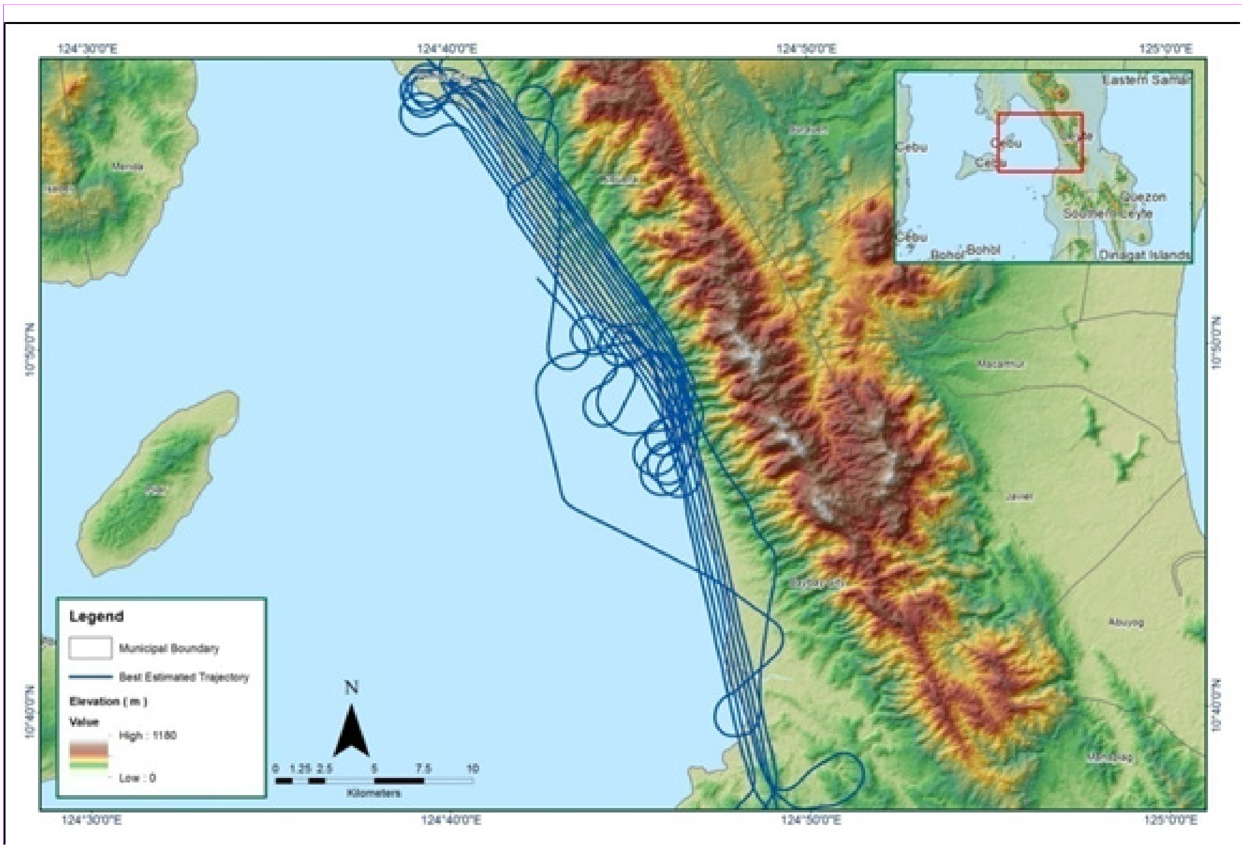
Flight Area	Ormoc
Mission Name	Blk35CD
Inclusive Flights	7764AC
Range data size	11.7 GB
POS	228 MB
Base data size	37.1 MB
Image	n/a
Transfer date	February 25, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.00
RMSE for East Position (<4.0 cm)	1.25
RMSE for Down Position (<8.0 cm)	2.30
Boresight correction stdev (<0.001deg)	0.000411
IMU attitude correction stdev (<0.001deg)	0.0080
GPS position stdev (<0.01m)	0.001860
Minimum % overlap (>25)	37.62
Ave point cloud density per sq.m. (>2.0)	2.91
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	133
Maximum Height	381.80 m
Minimum Height	54.25 m
Classification (# of points)	
Ground	37,242,918
Low vegetation	39,172,896
Medium vegetation	58,295,535
High vegetation	46,287,415
Building	3,419,184
Orthophoto	No
Processed by	Engr. Analyn Naldo, Engr. Velina Angela Bemida, Alex John Escobido



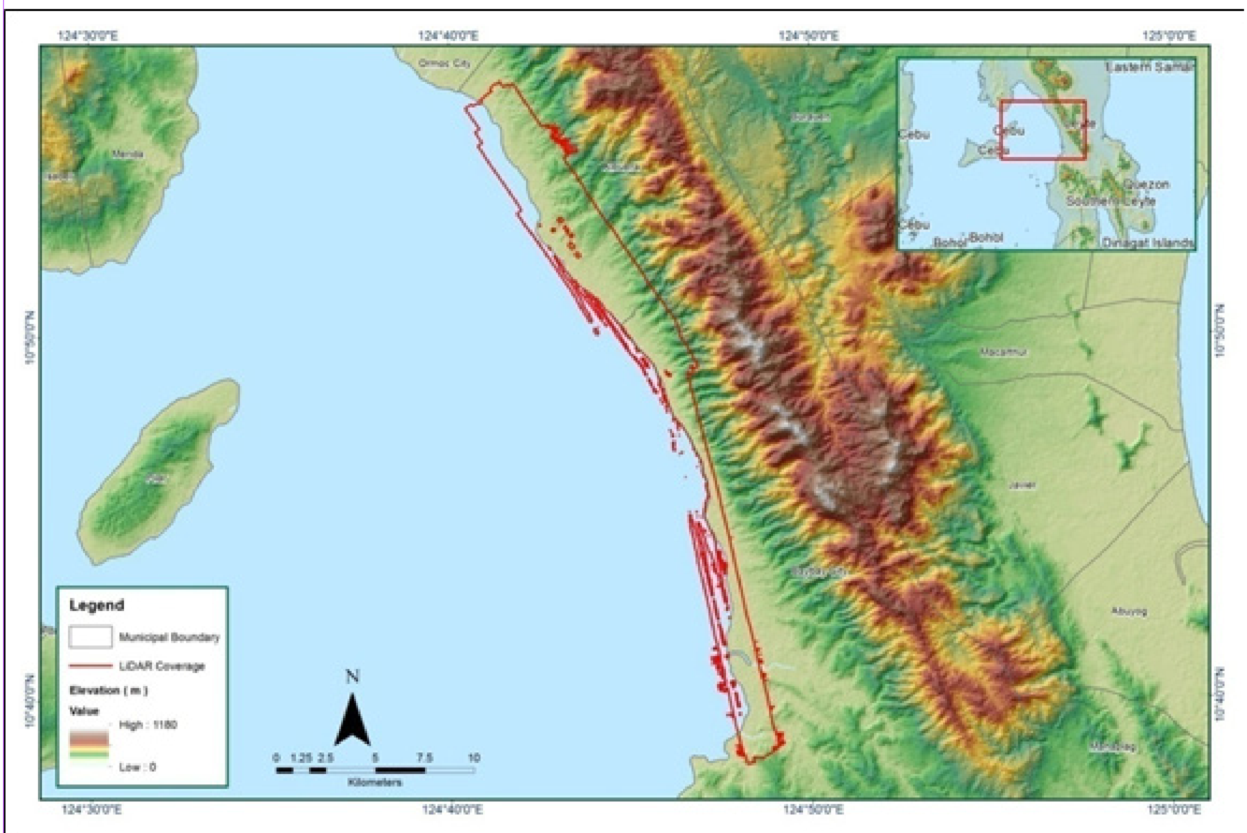
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

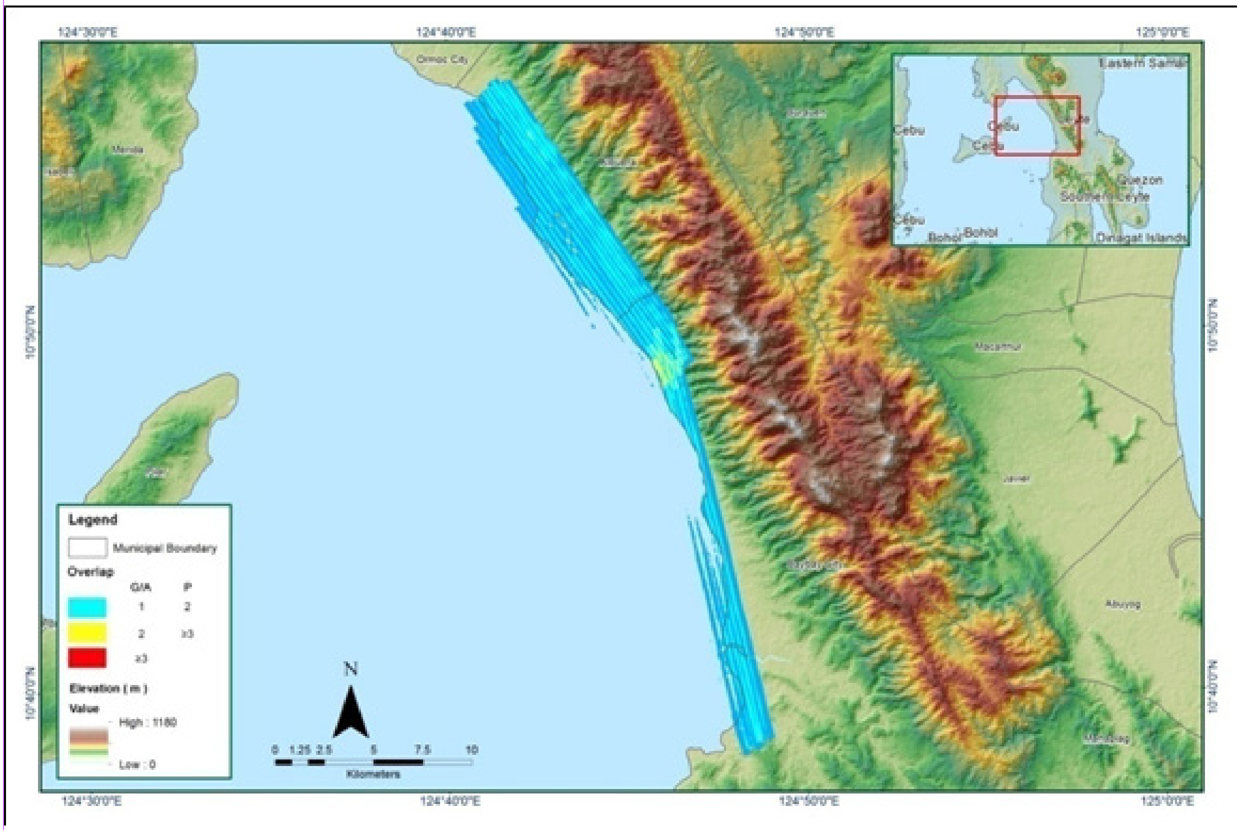
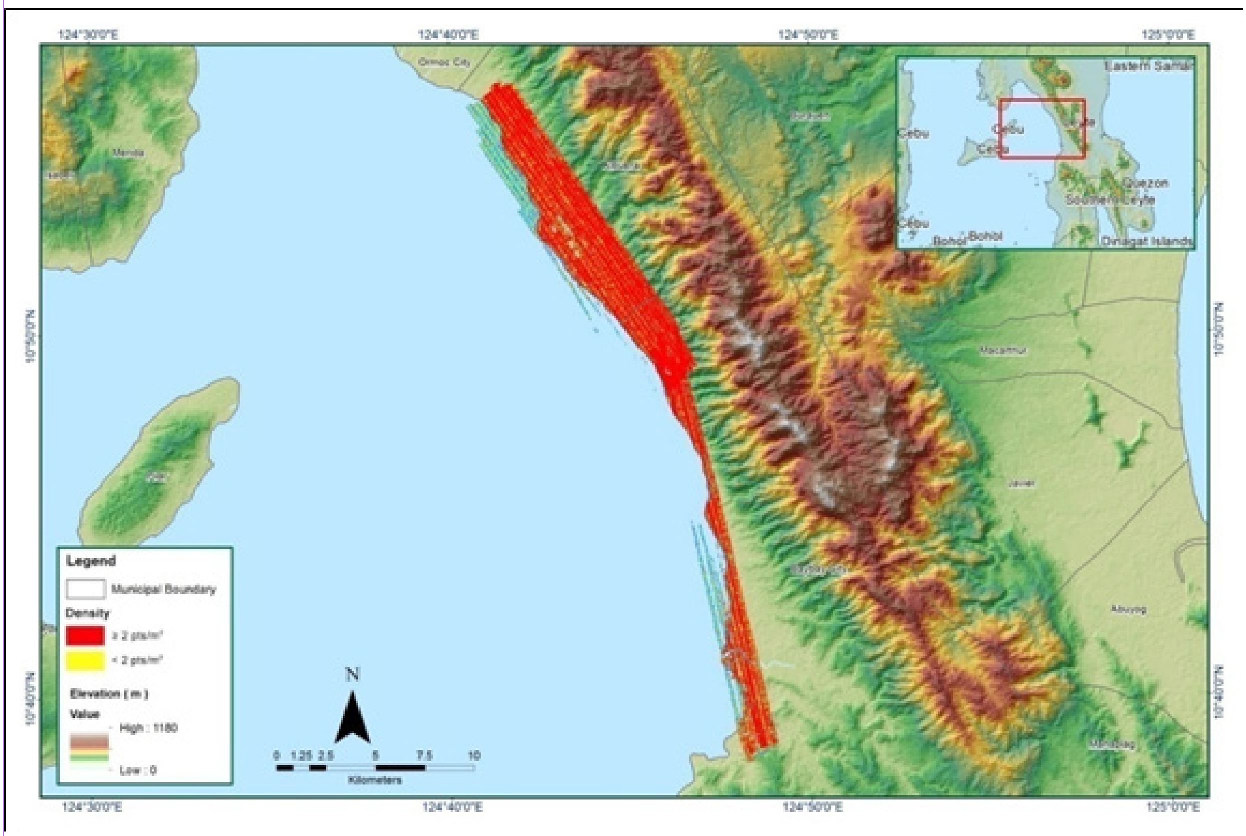
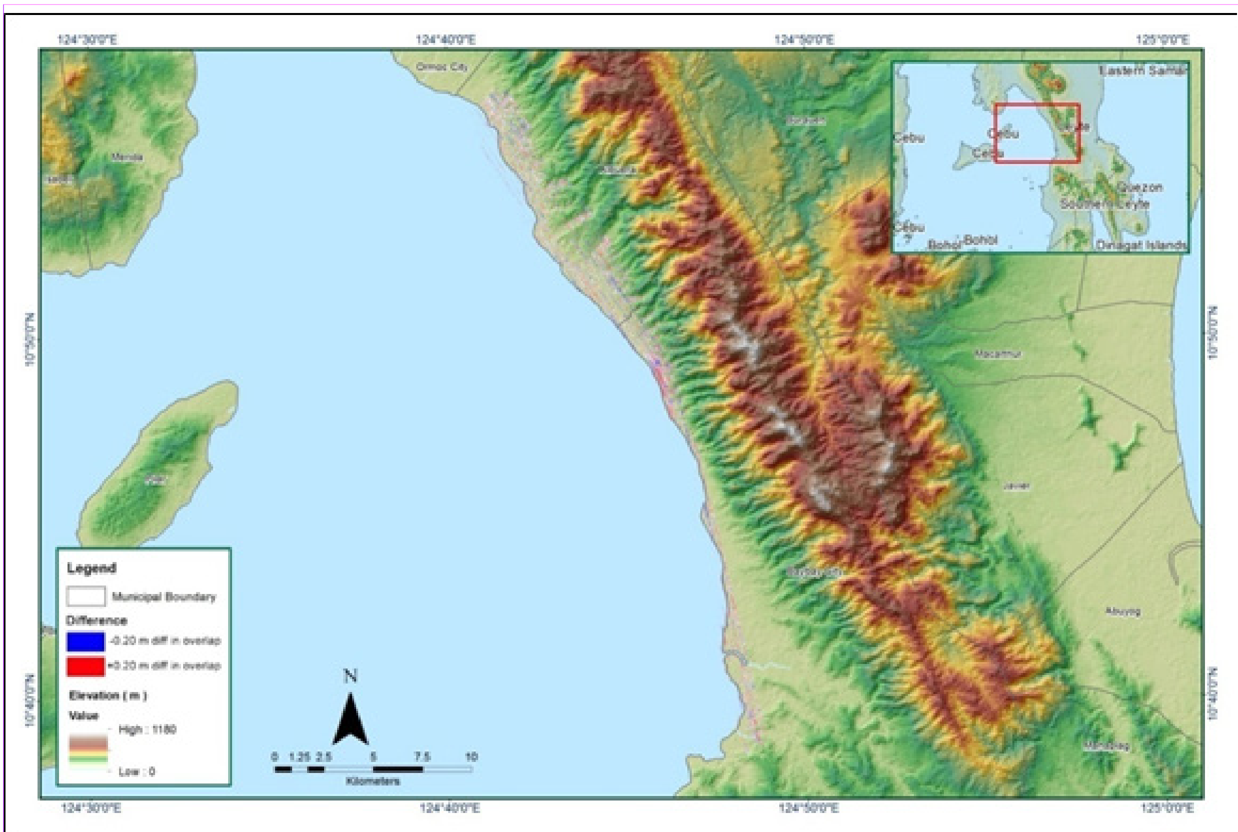


Image of Data Overlap

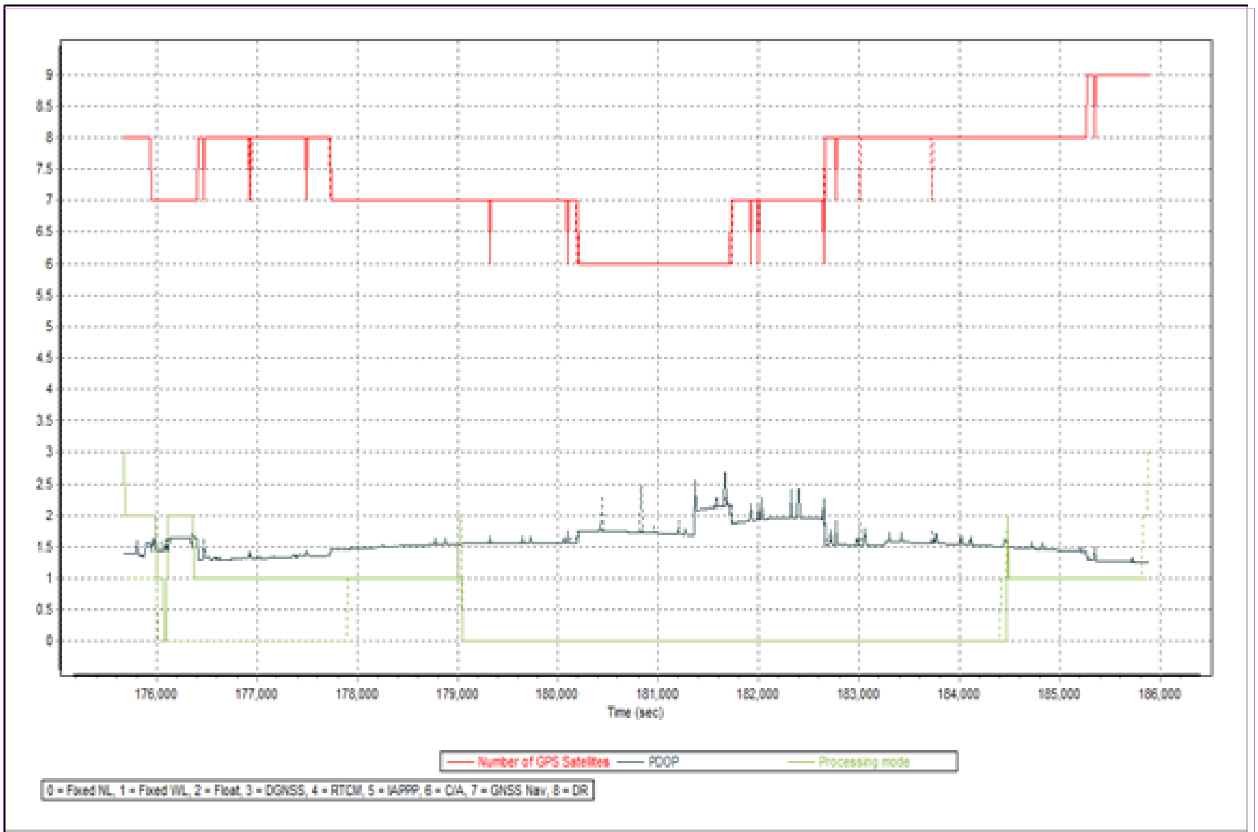


Density map of merged LiDAR data

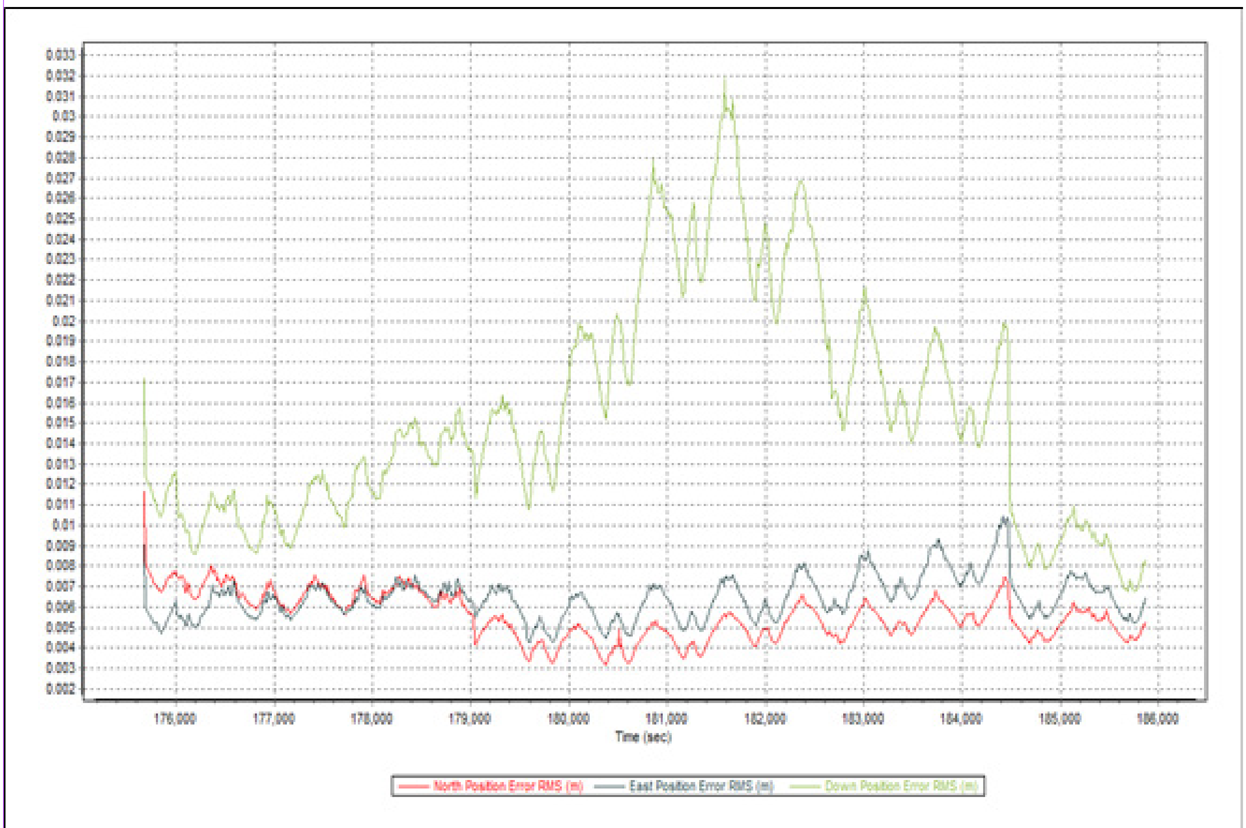


Elevation difference between flight lines

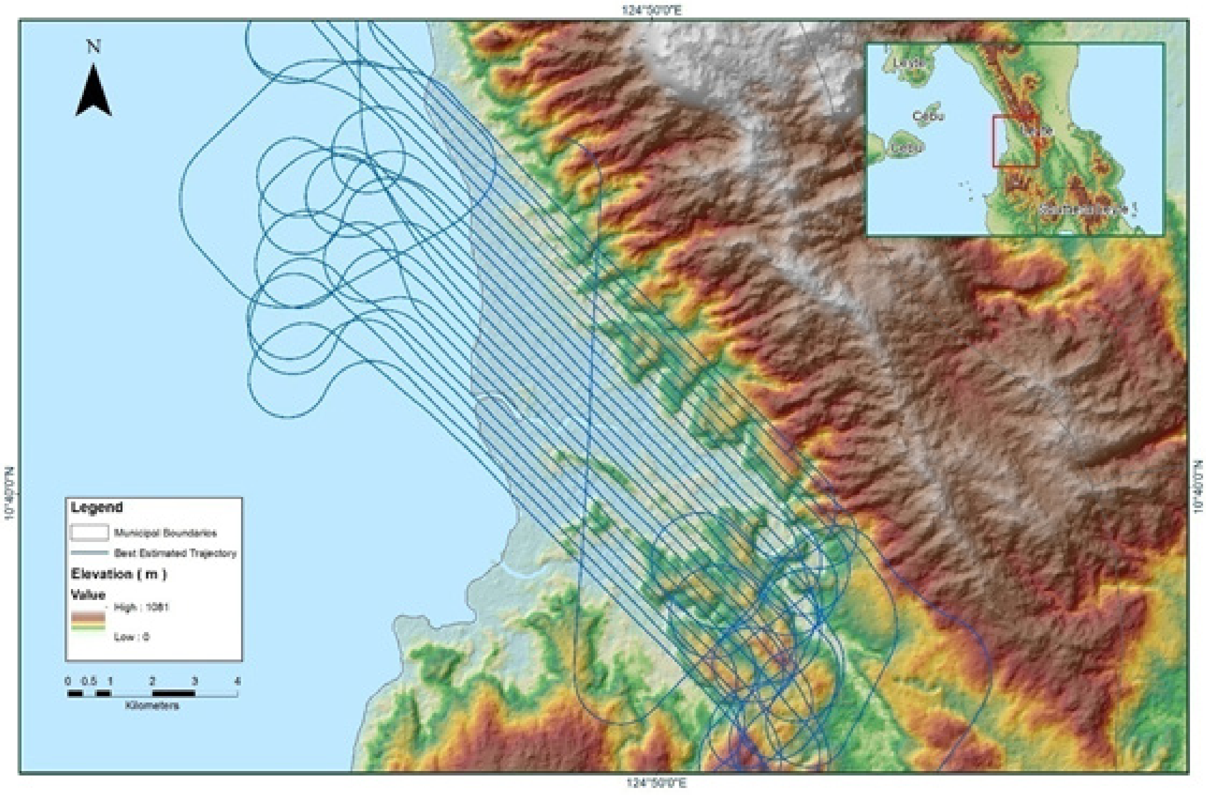
Flight Area	Ormoc
Mission Name	Blk35F
Inclusive Flights	7792AC
Range data size	10.3 GB
POS data size	238 MB
Base data size	9.46 MB
Image	n/a
Transfer date	February 25, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.801
RMSE for East Position (<4.0 cm)	1.046
RMSE for Down Position (<8.0 cm)	3.189
Boresight correction stdev (<0.001deg)	0.000252
IMU attitude correction stdev (<0.001deg)	0.001131
GPS position stdev (<0.01m)	0.0071
Minimum % overlap (>25)	40.09
Ave point cloud density per sq.m. (>2.0)	2.97
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	51
Maximum Height	372.19
Minimum Height	58.93
Classification (# of points)	
Ground	36,595,482
Low vegetation	35,969,971
Medium vegetation	29,099,660
High vegetation	53,162,081
Building	2,740,133
Orthophoto	None
Processed by	Engr. Abigail Joy Ching, Engr. Melanie Hingpit, Engr. Sueden Lyle Magtalas



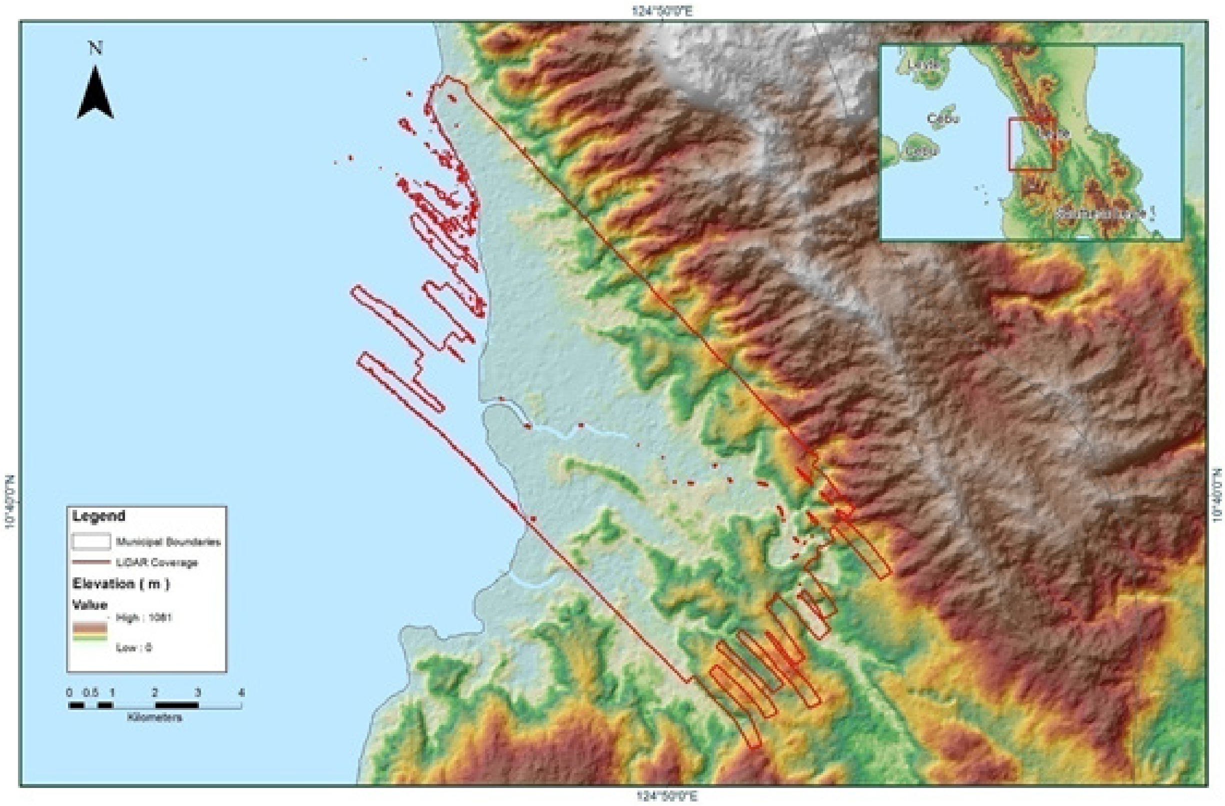
Solution Status Parameters



Smoothed Performance Metrics Parameters



Best Estimated Trajectory



Coverage of LiDAR data

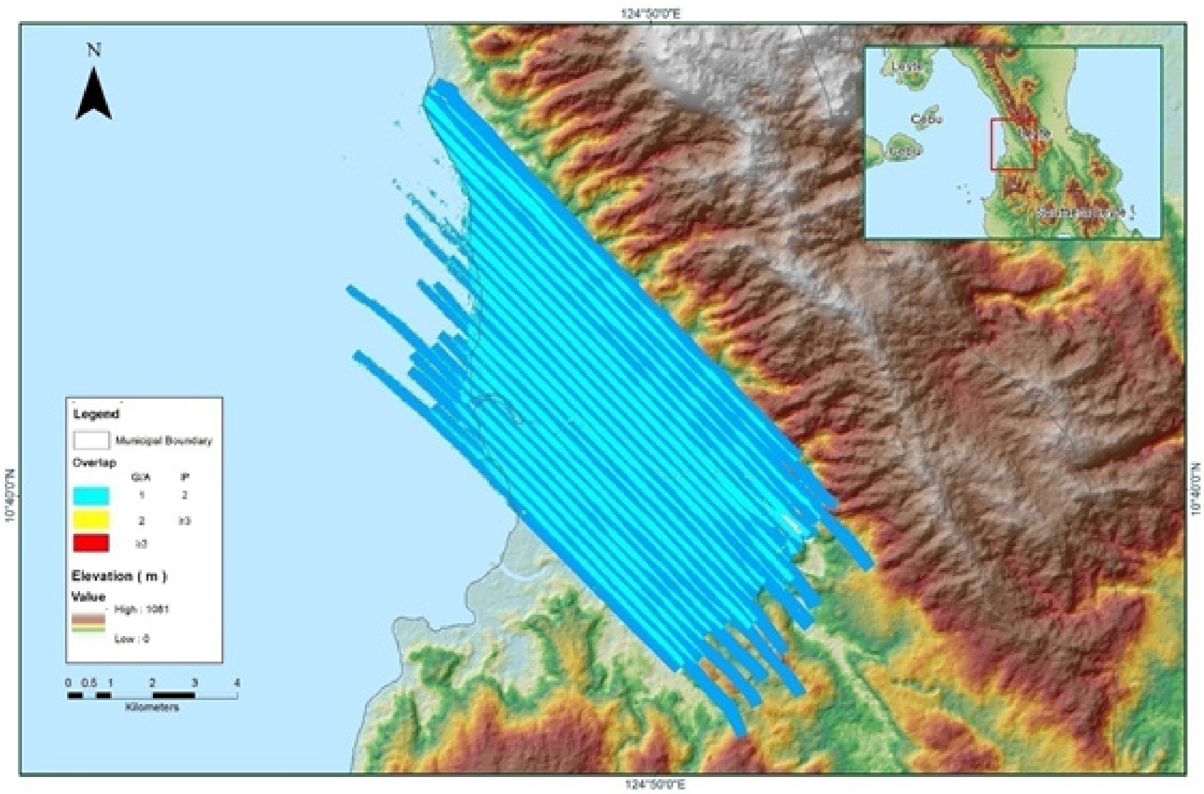
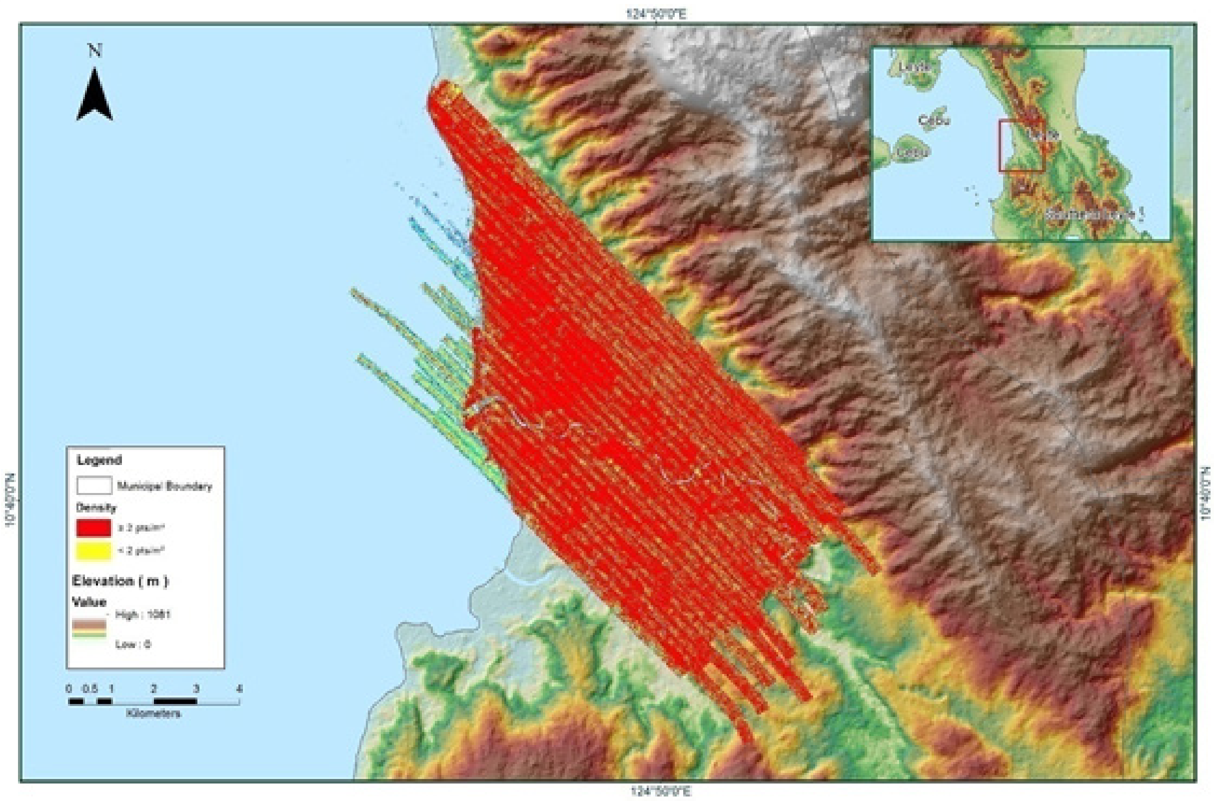
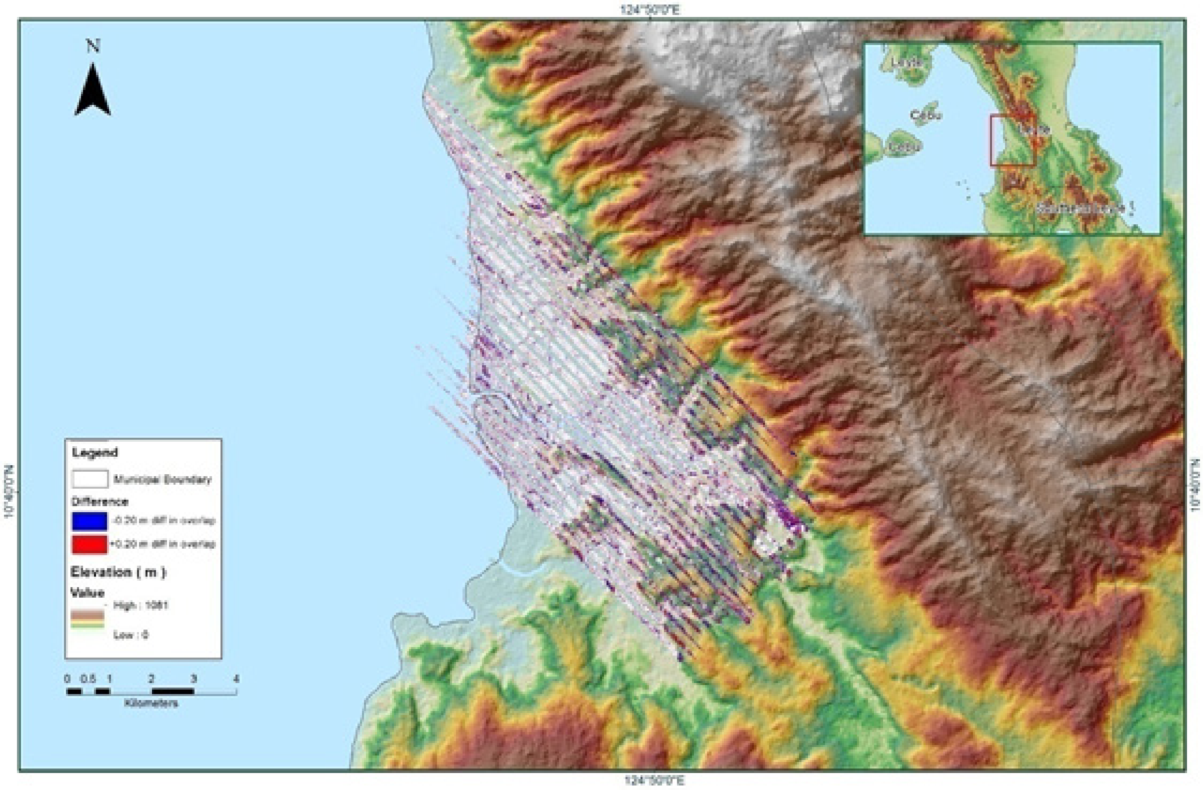


Image of Data Overlap

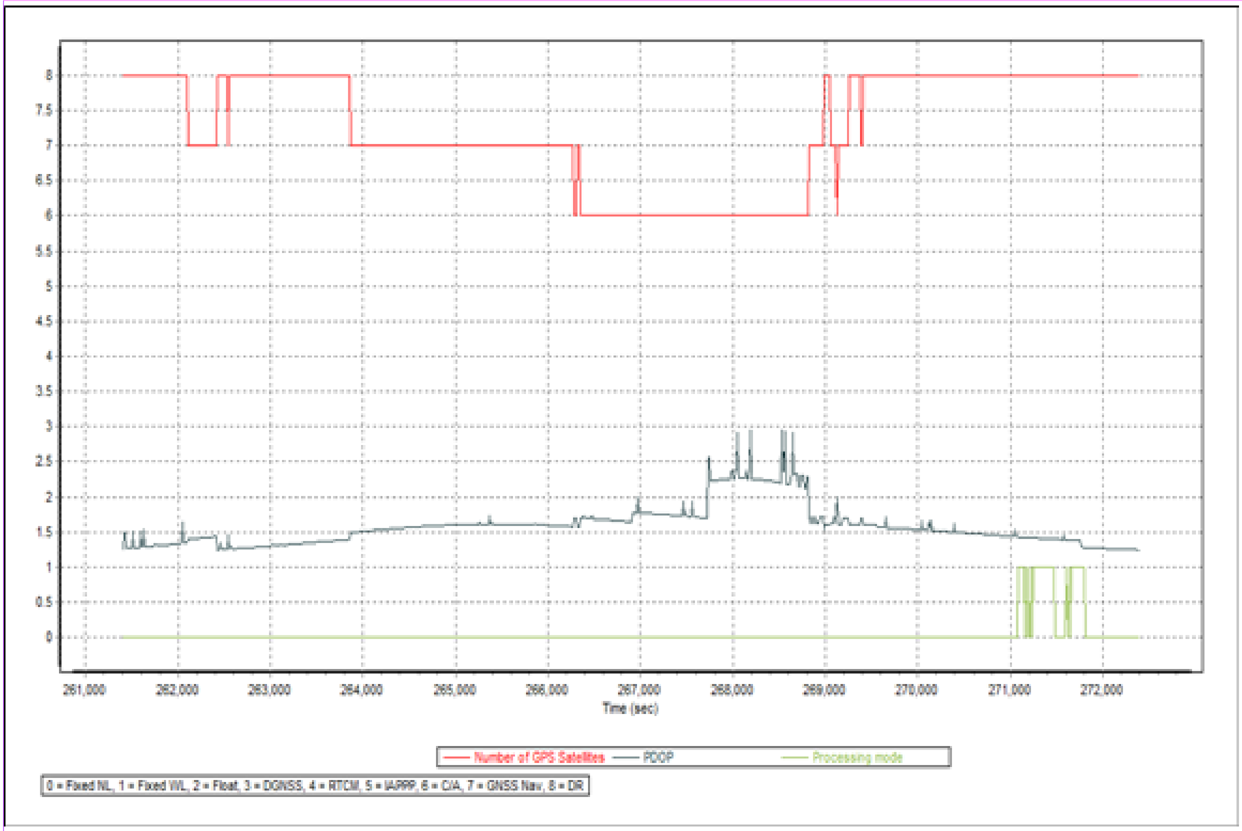


Density map of merged LiDAR data

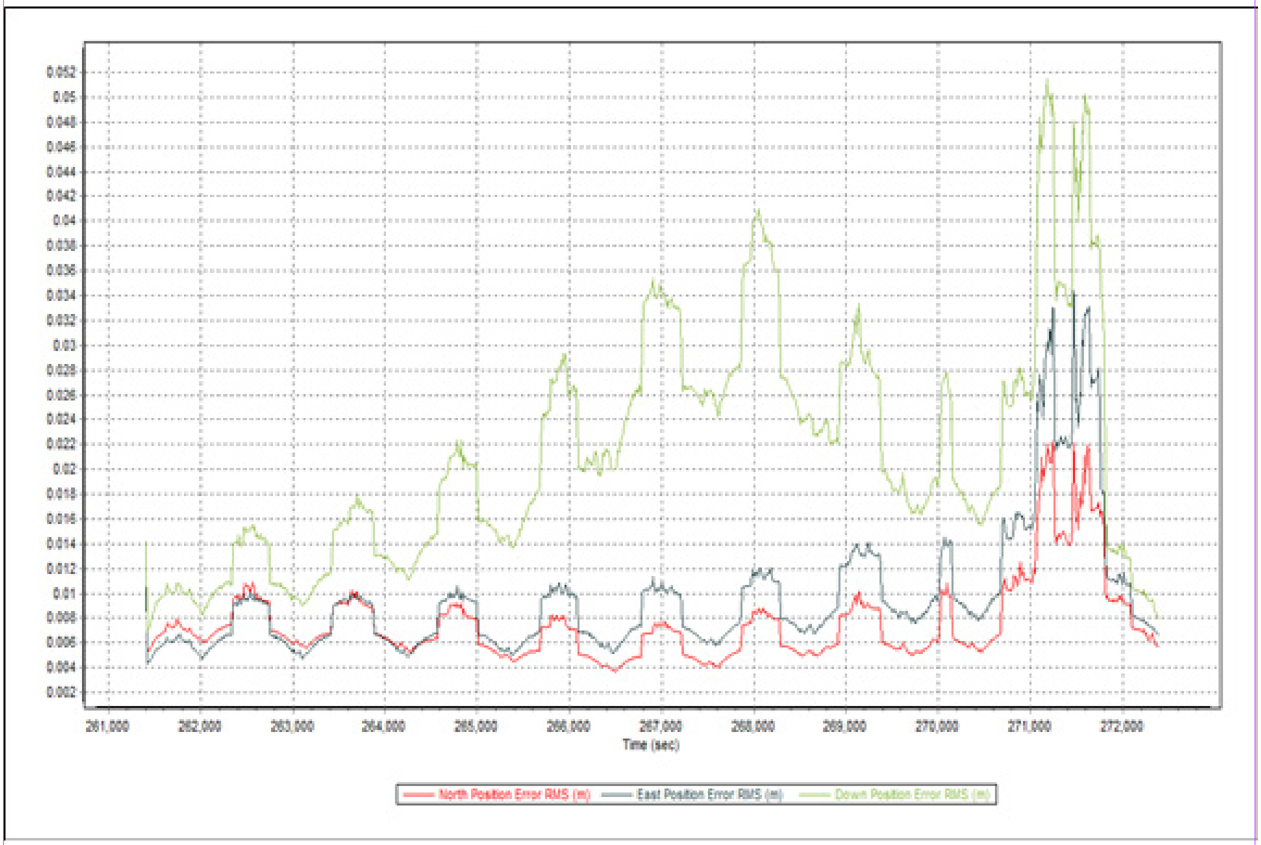


Elevation difference between flight lines

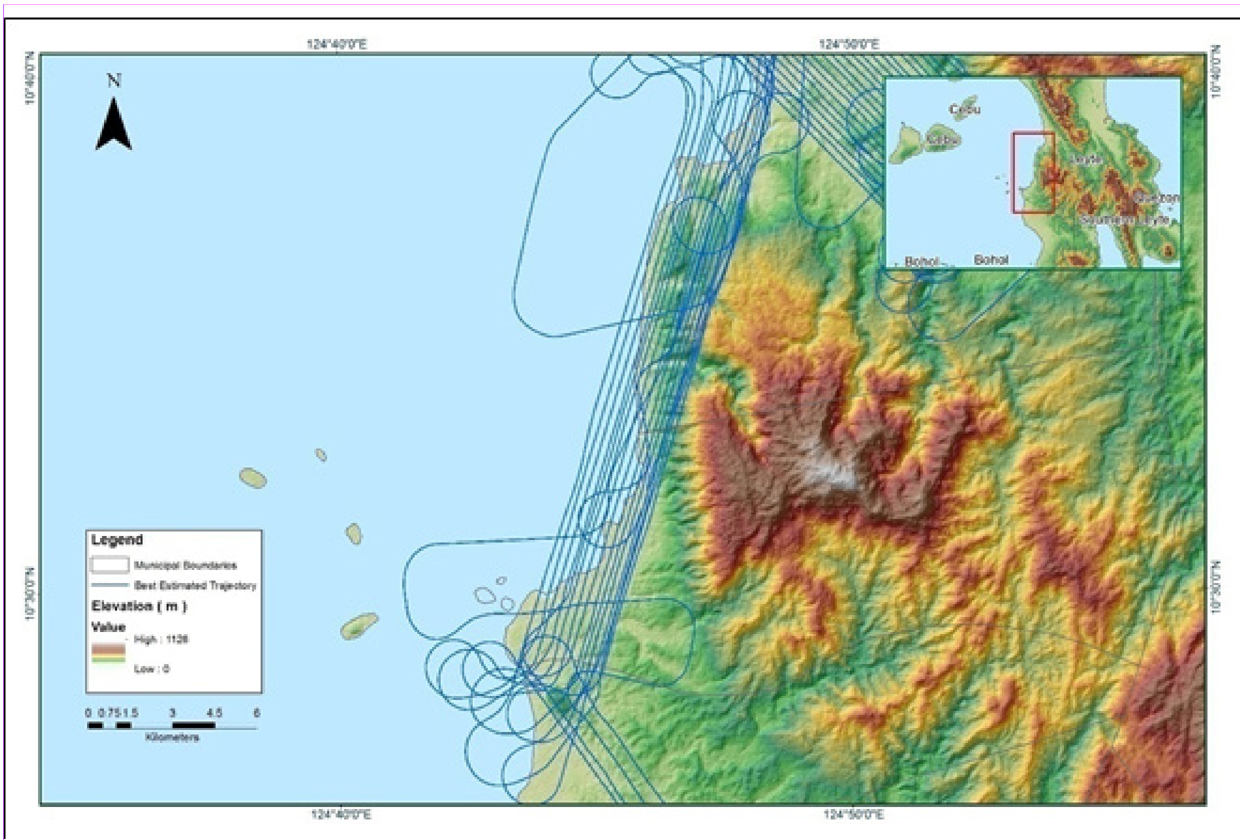
Flight Area	**Ormoc**
Mission Name	Blk35E_voids
Inclusive Flights	7794AC
Range data size	11.9 GB
POS data size	252 MB
Base data size	37.5 MB
Image	n/a
Transfer date	February 25, 2015
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.226
RMSE for East Position (<4.0 cm)	3.445
RMSE for Down Position (<8.0 cm)	5.152
Boresight correction stdev (<0.001deg)	0.000273
IMU attitude correction stdev (<0.001deg)	0.001690
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	31.67
Ave point cloud density per sq.m. (>2.0)	3.63
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	103
Maximum Height	539.5
Minimum Height	57.92
Classification (# of points)	
Ground	25,588,162
Low vegetation	20,307,830
Medium vegetation	29,516,371
High vegetation	49,004,056
Building	1,463,518
Orthophoto	None
Processed by	Engr. Regis Guhiting, Engr. Justine Francisco, Engr. Krisha Marie Bautista
Processed by	Engr. Sheila Maye Santillan, Engr. Elainne Lopez, Engr. Merven Matthew Natino



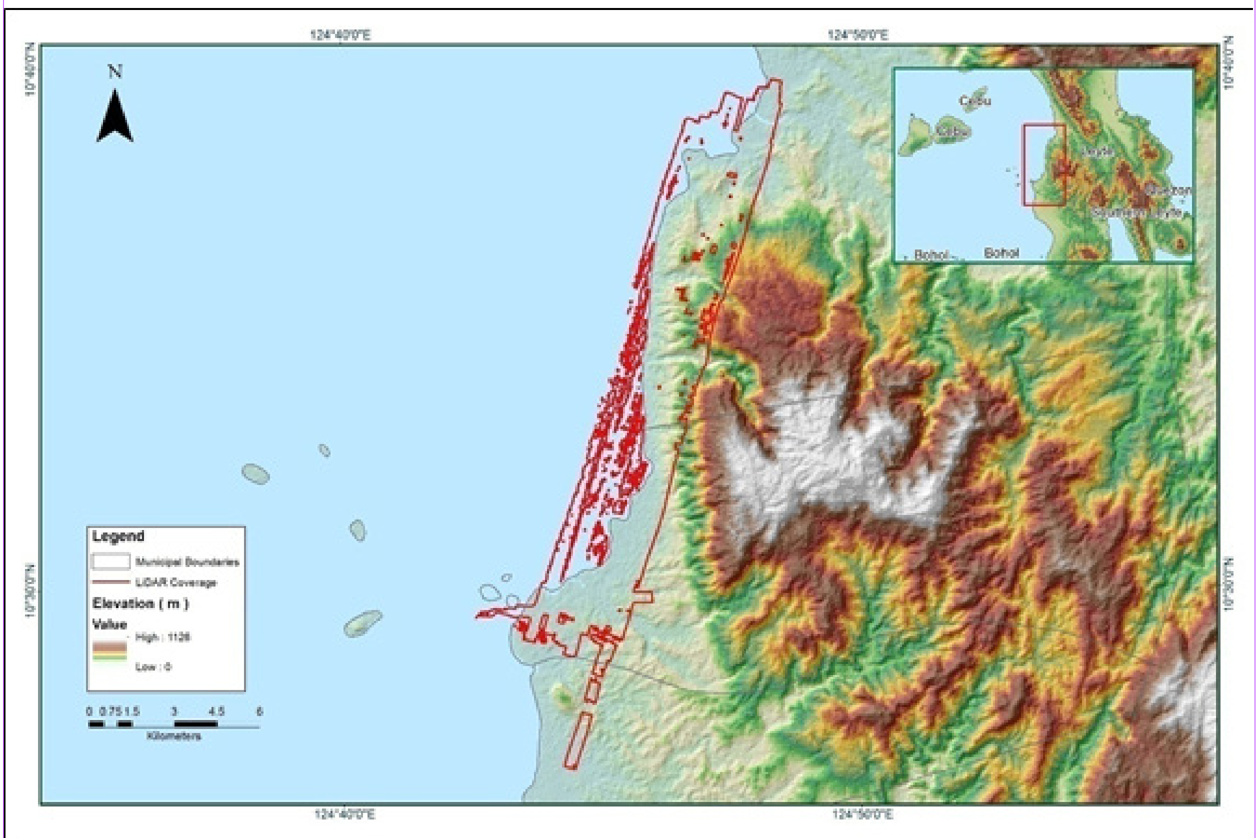
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

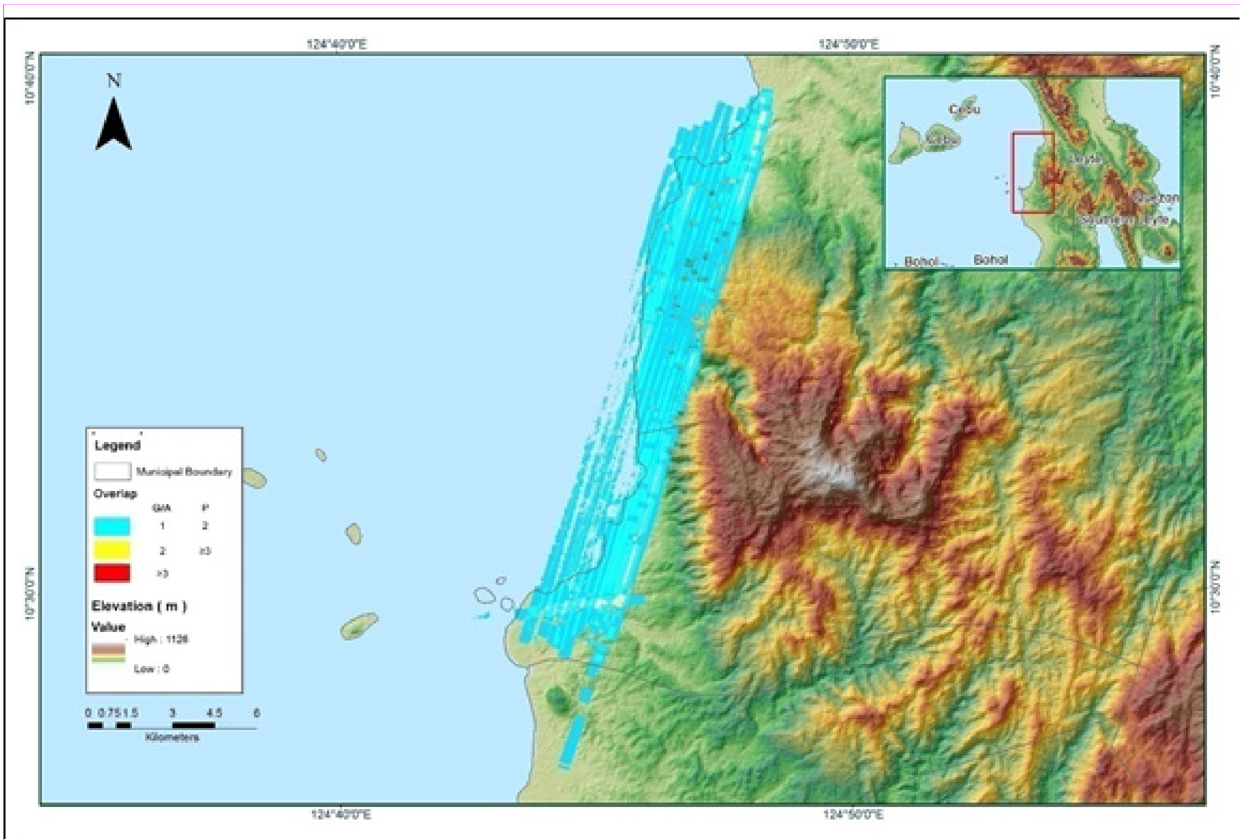
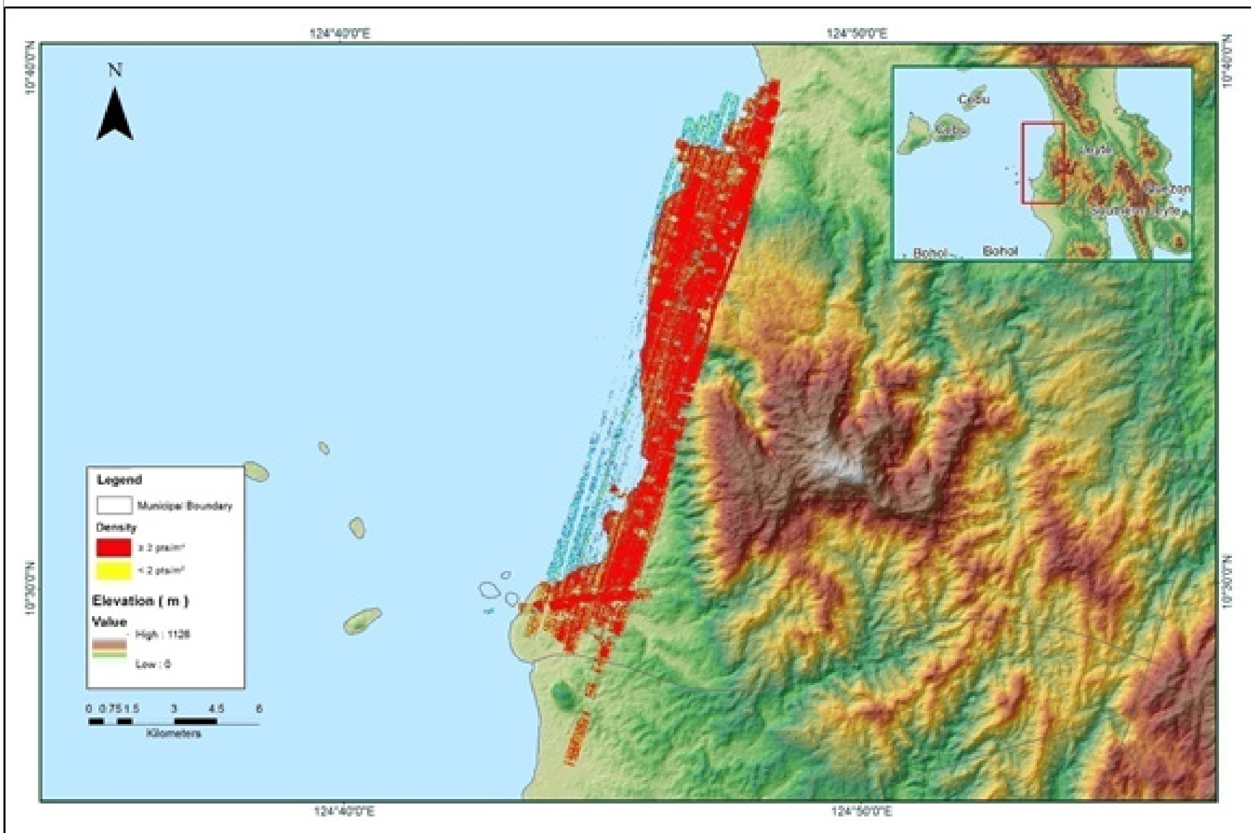
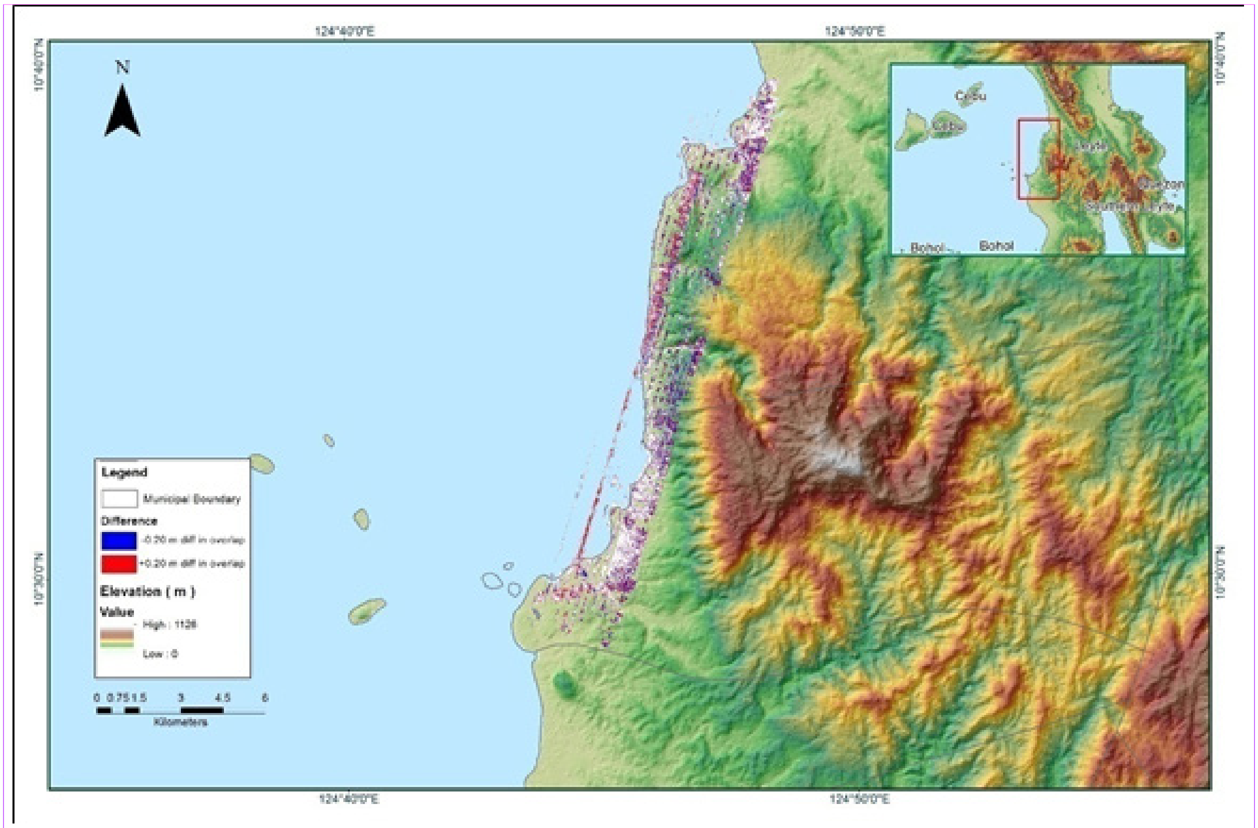


Image of Data Overlap

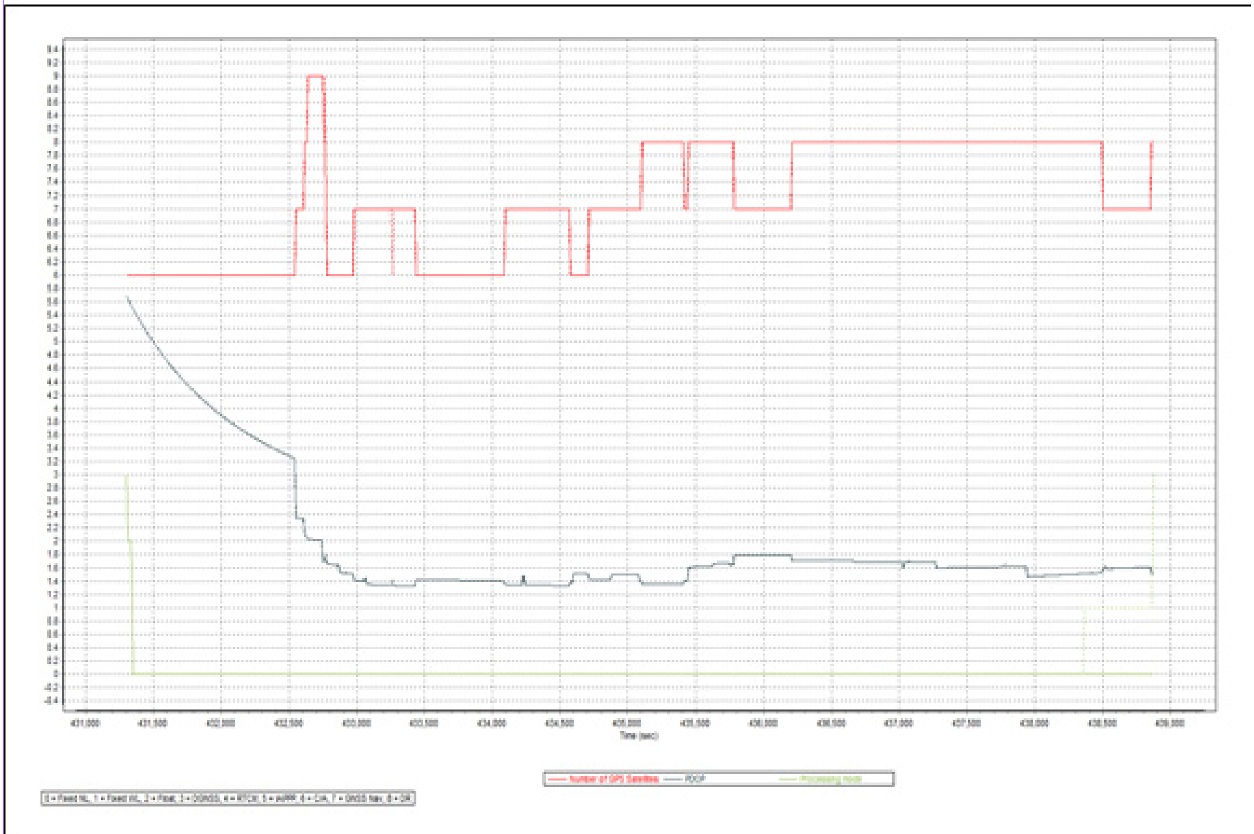


Density map of merged LiDAR data

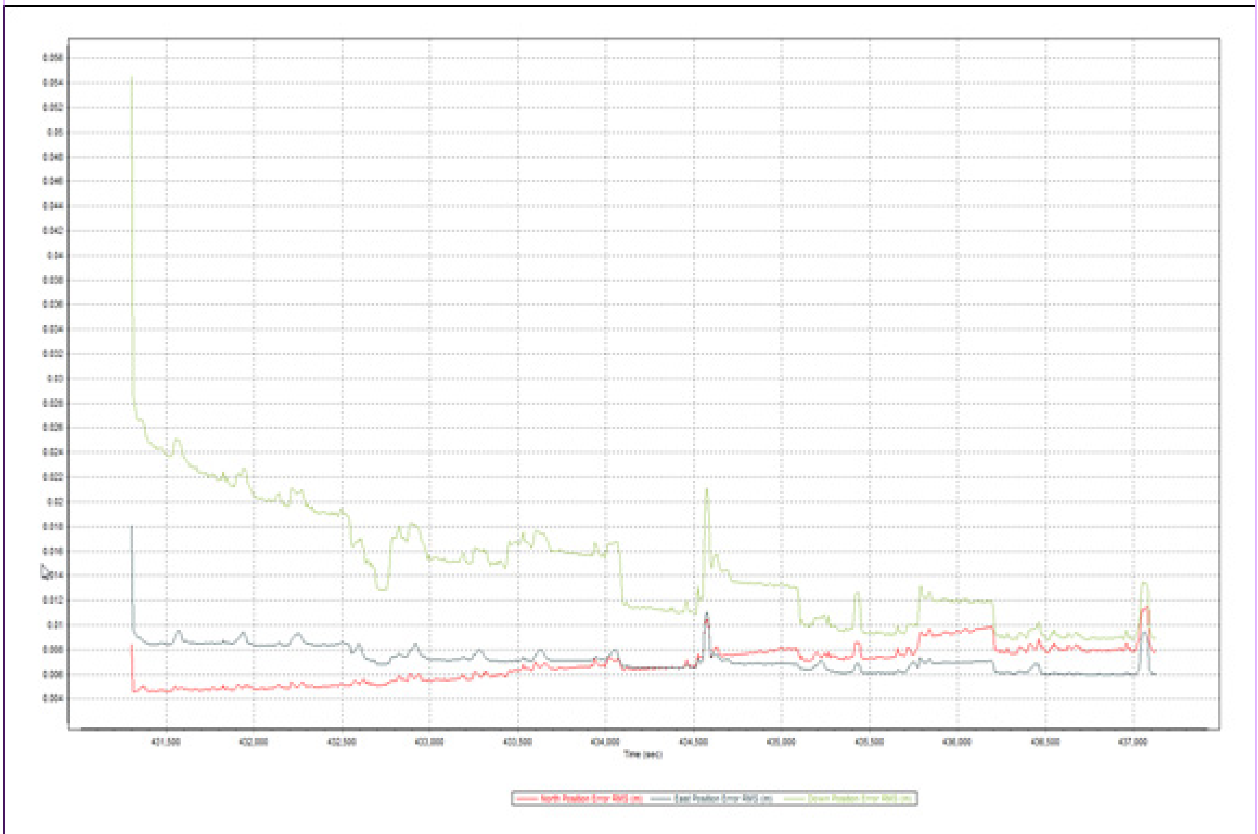


Elevation difference between flight lines

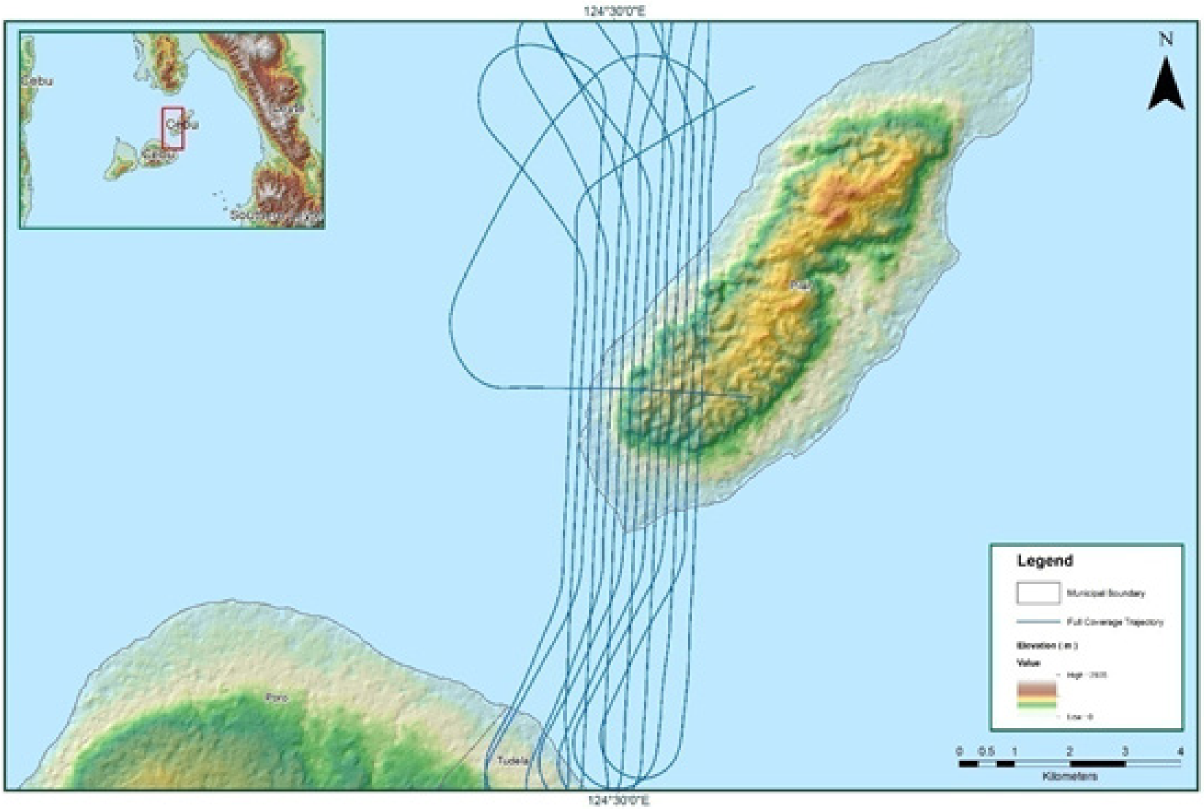
Flight Area	Ormoc_Camotes
Mission Name	Blk48E
Inclusive Flights	8407AC
Range data size	6.9 GB
POS	235 MB
Image	37.8 GB
Base Station	209 MB
Transfer date	April 22, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.18
RMSE for East Position (<4.0 cm)	1.15
RMSE for Down Position (<8.0 cm)	2.52
Boresight correction stdev (<0.001deg)	0.000751
IMU attitude correction stdev (<0.001deg)	0.002941
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	25.68
Ave point cloud density per sq.m. (>2.0)	2.65
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	34
Maximum Height	233.92
Minimum Height	43.13
Classification (# of points)	
Ground	13,061,856
Low vegetation	8,537,709
Medium vegetation	8,453,919
High vegetation	11,753,897
Building	348,998
Orthophoto	None
Processed by	Engr. Abigail Joy Ching, Aljon Rie Araneta, Jovy Narisma



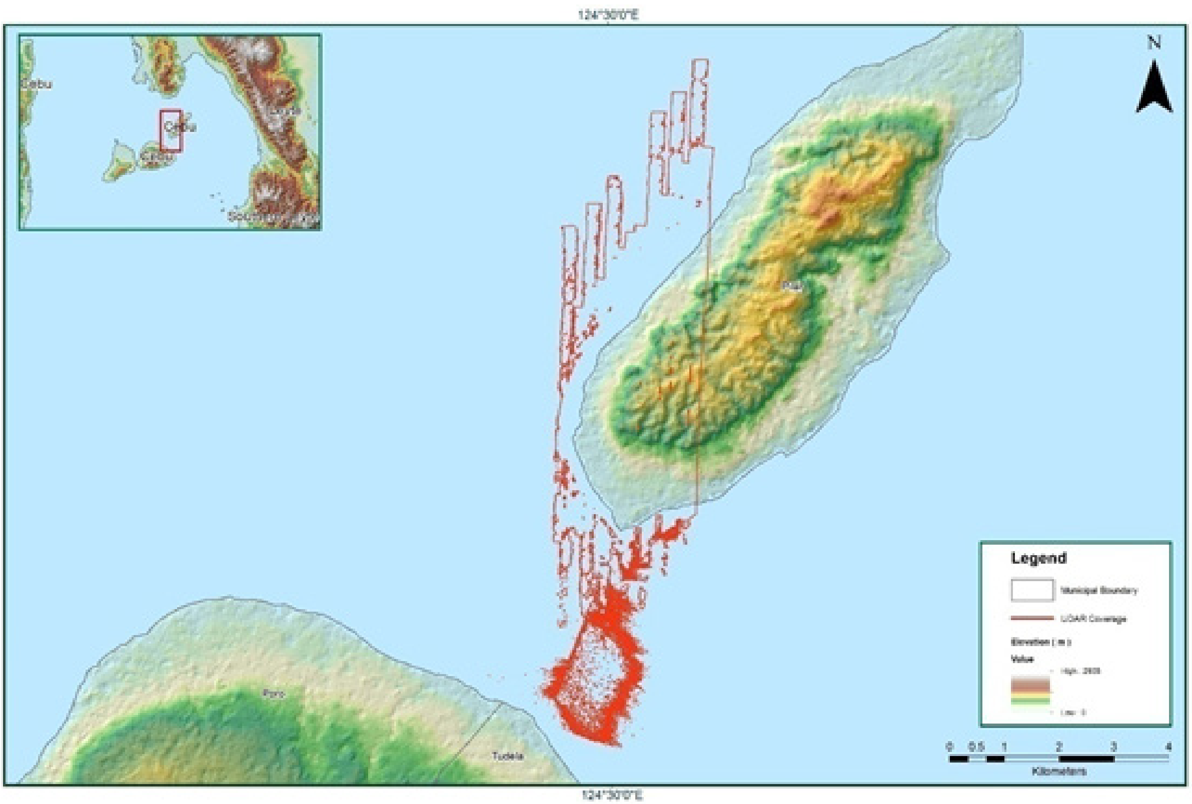
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

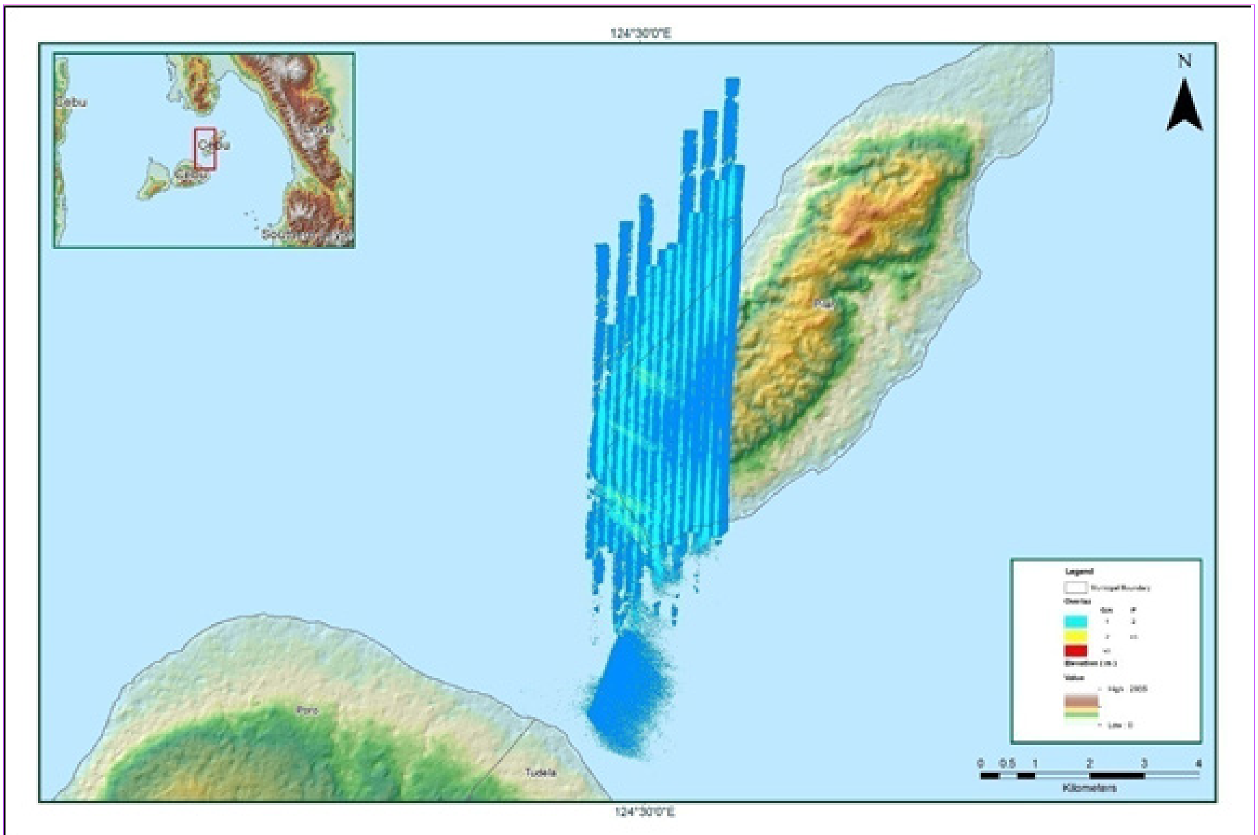
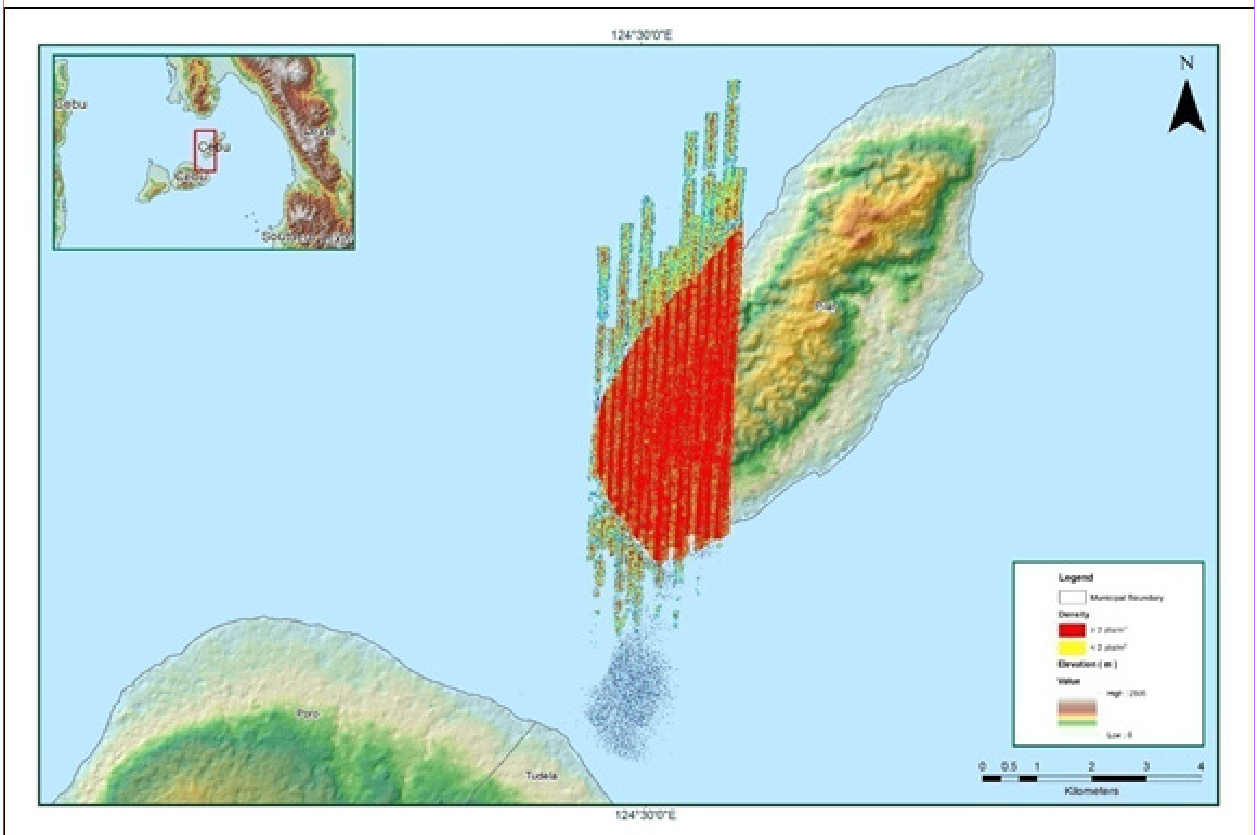
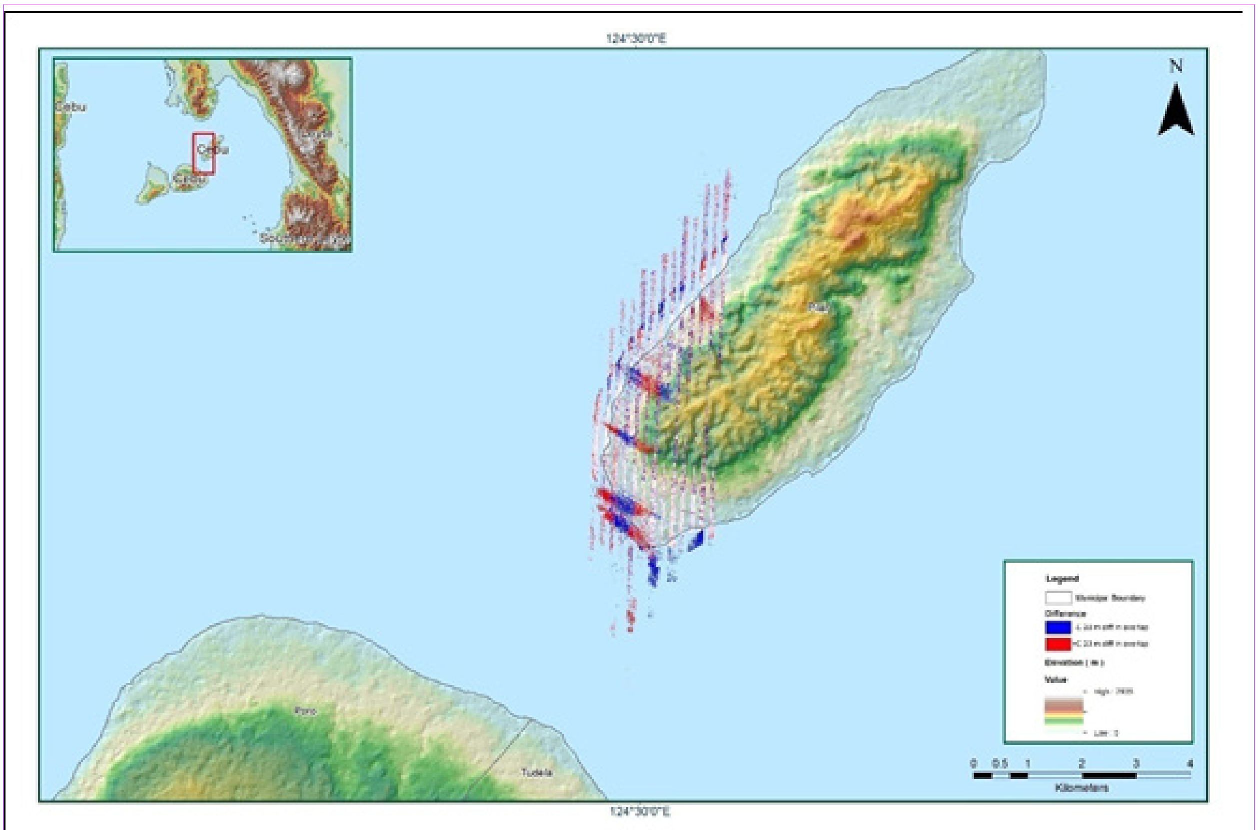


Image of Data Overlap

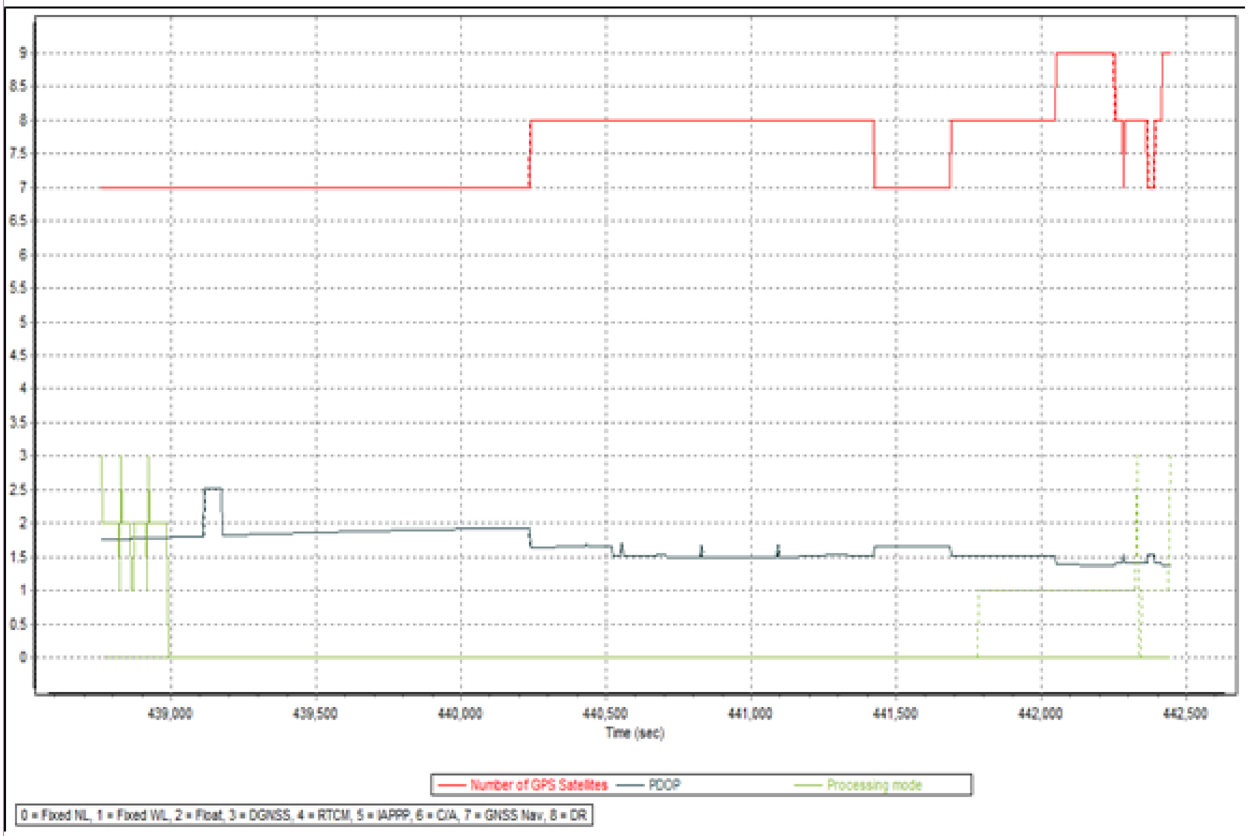


Density map of merged LiDAR data

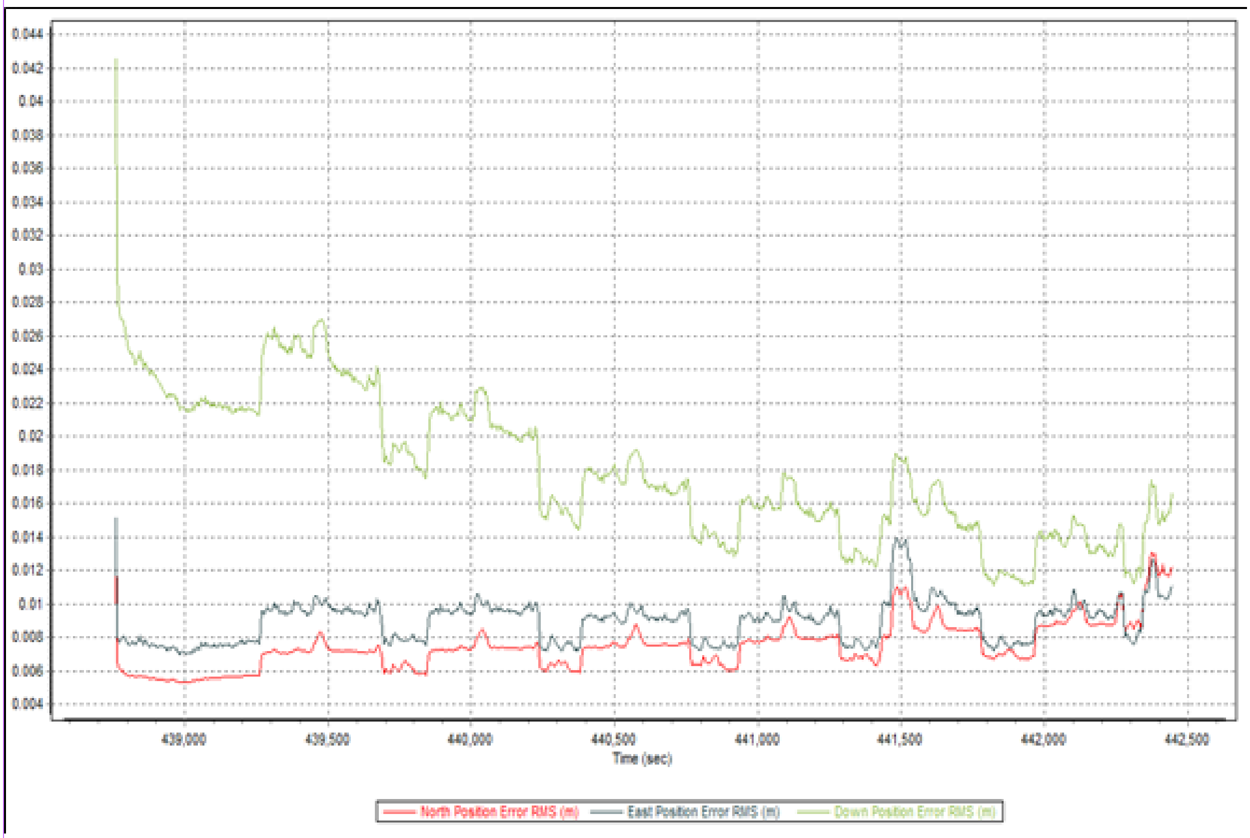


Elevation difference between flight lines

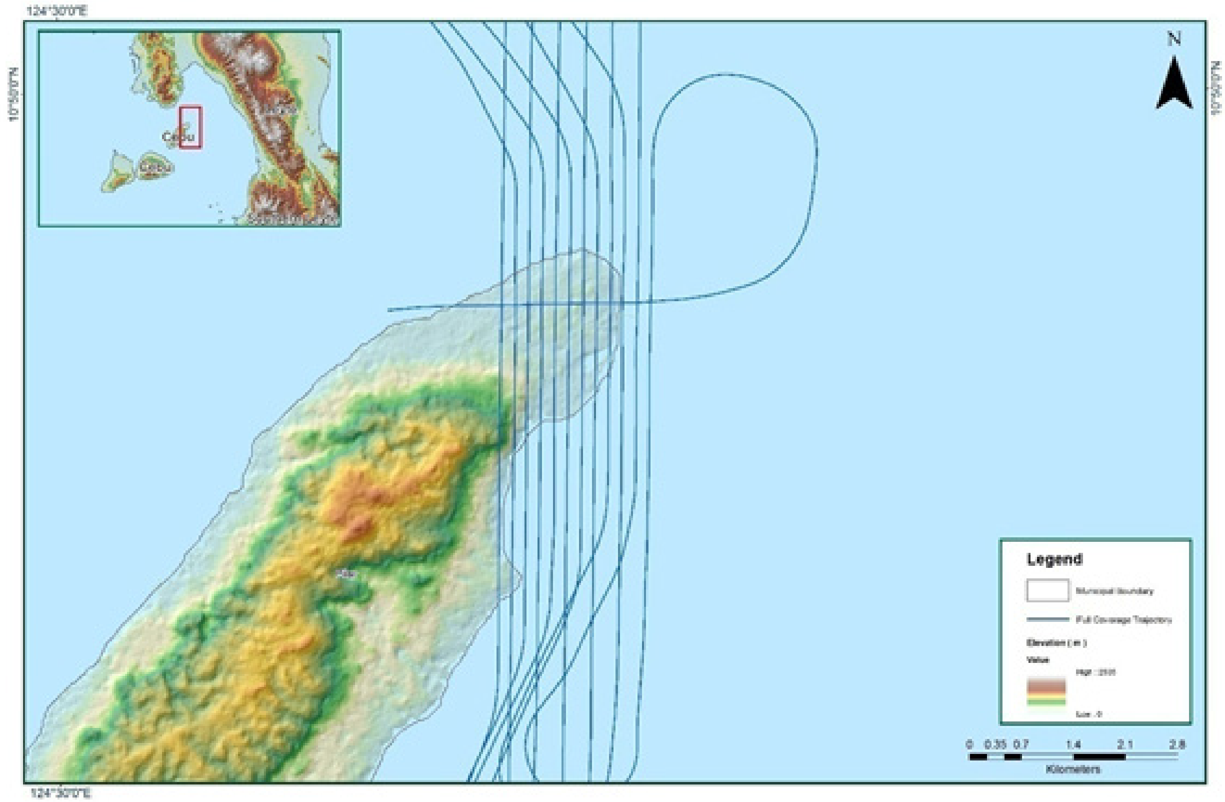
Flight Area	Ormoc_Camotes
Mission Name	Blk48G
Inclusive Flights	8407AC
Range data size	6.9 GB
POS	235 MB
Image	37.8 GB
Base Station	209 MB
Transfer date	April 22, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.31
RMSE for East Position (<4.0 cm)	1.39
RMSE for Down Position (<8.0 cm)	2.7
Boresight correction stdev (<0.001deg)	0.000675
IMU attitude correction stdev (<0.001deg)	0.002173
GPS position stdev (<0.01m)	0.0025
Minimum % overlap (>25)	29.59
Ave point cloud density per sq.m. (>2.0)	2.63
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	42
Maximum Height	184.89
Minimum Height	45.16
Classification (# of points)	
Ground	8,932,930
Low vegetation	5,735,327
Medium vegetation	4,253,659
High vegetation	7,204,177
Building	458,259
Orthophoto	None
Processed by	Engr. Abigail Joy Ching ,Engr. Velina Angela Bemida, Jovy Narisma
Processed by	Engr. Sheila Maye Santillan, Engr. Elainne Lopez, Engr. Merven Matthew Natino



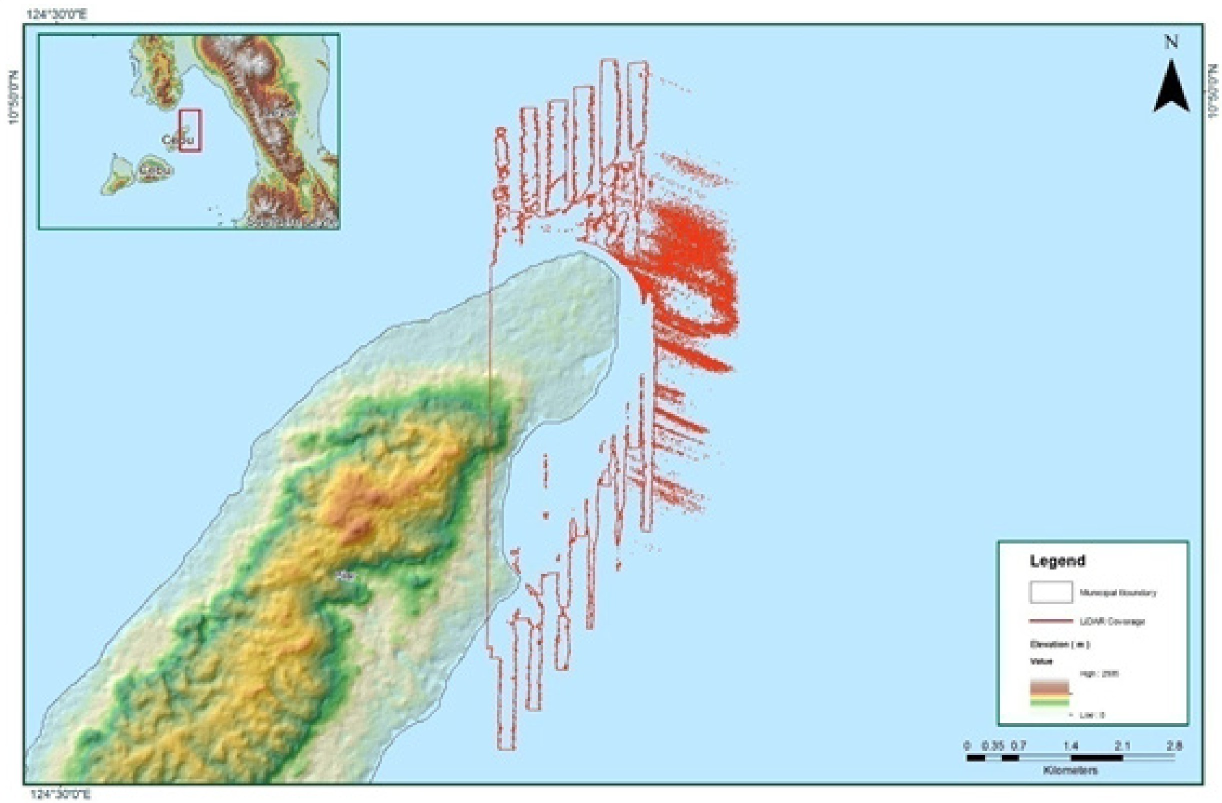
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

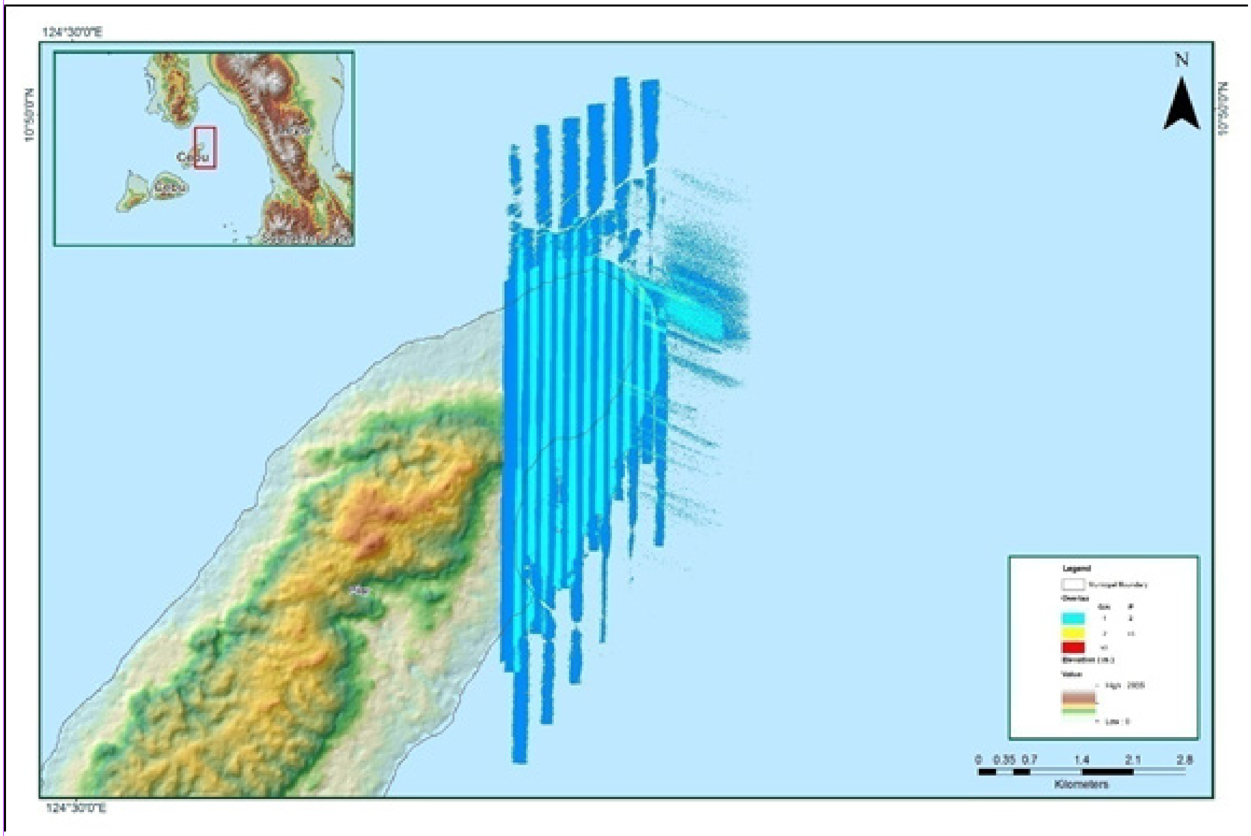
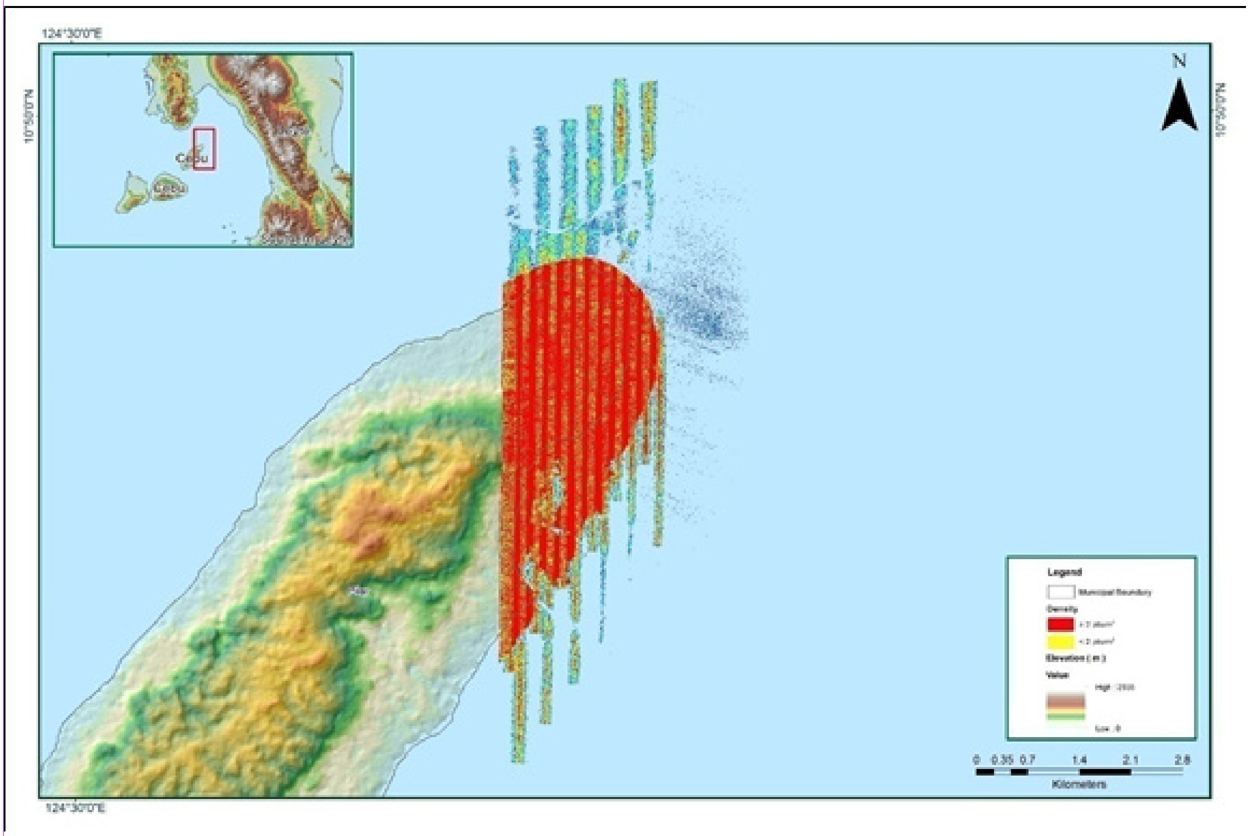
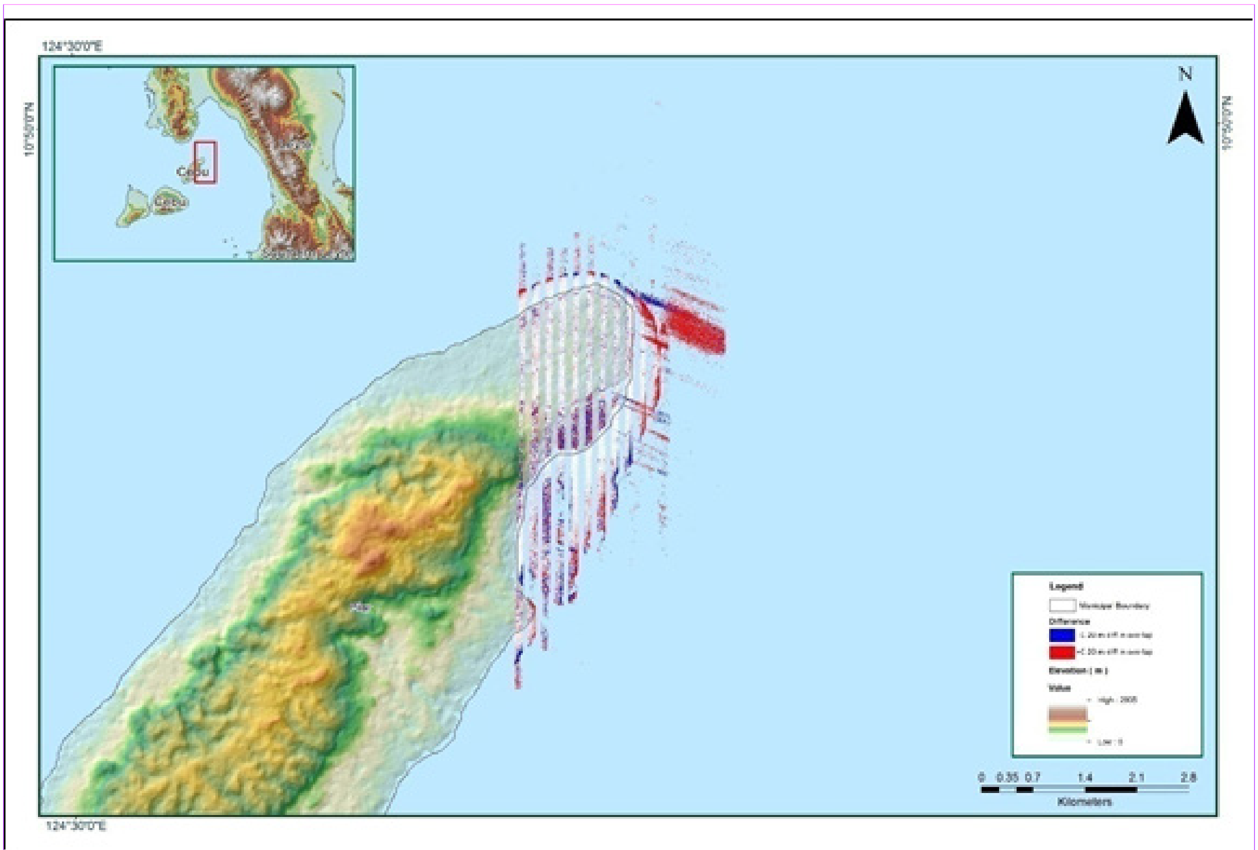


Image of Data Overlap

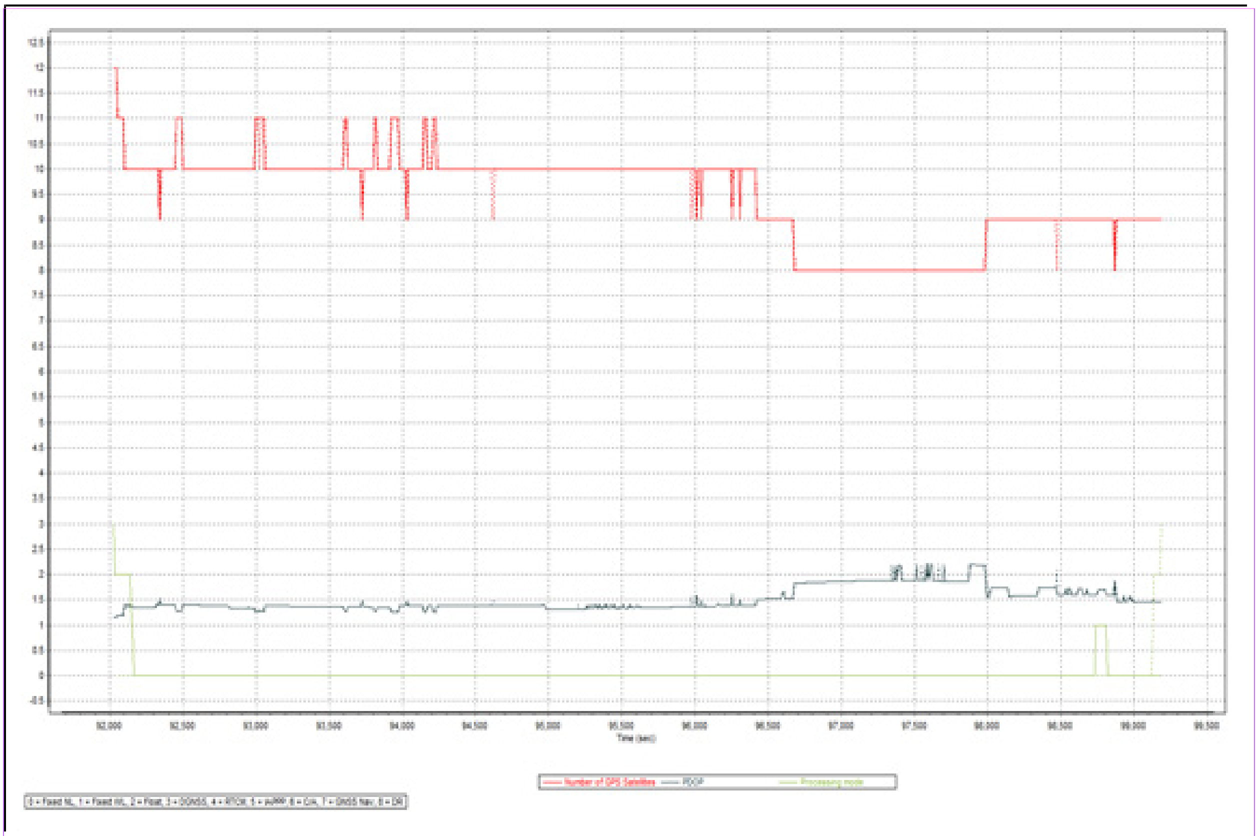


Density map of merged LiDAR data

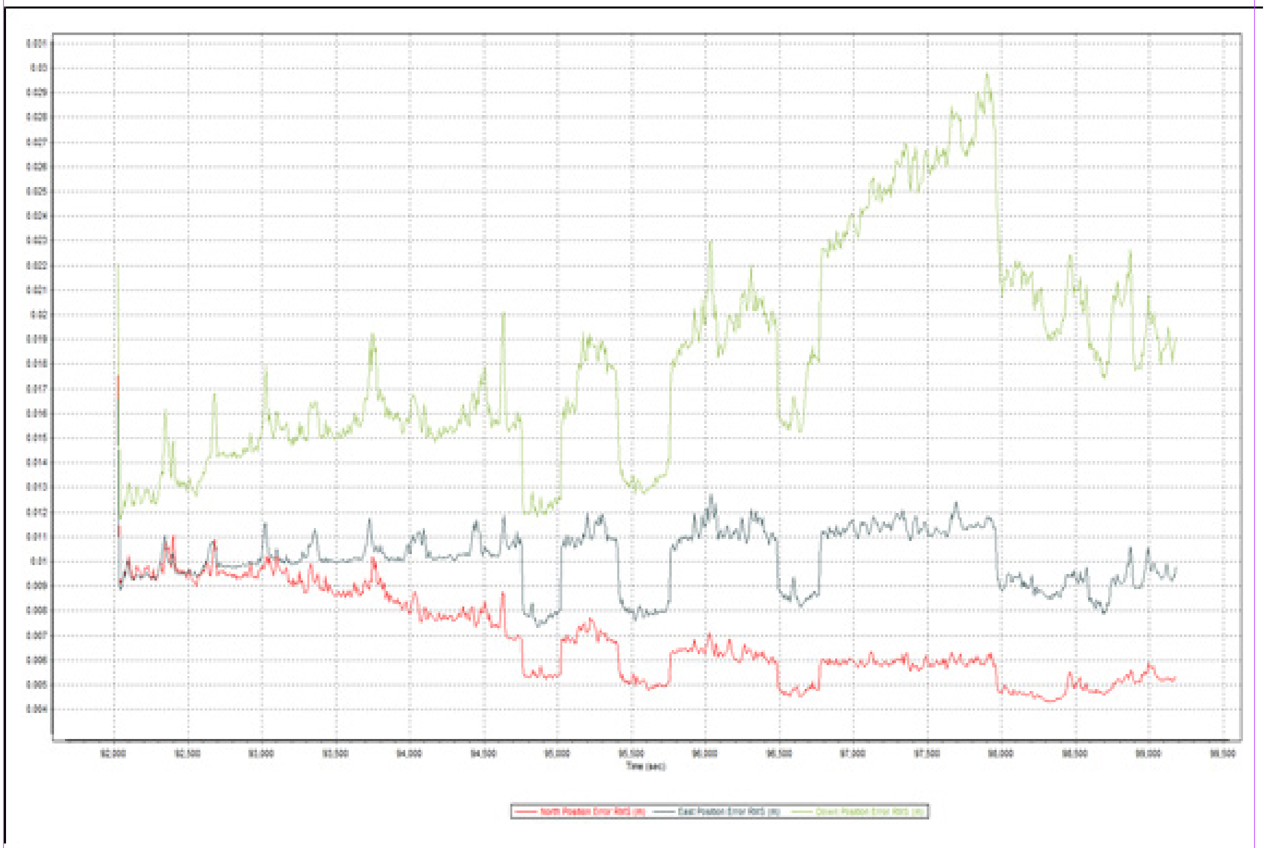


Elevation difference between flight lines

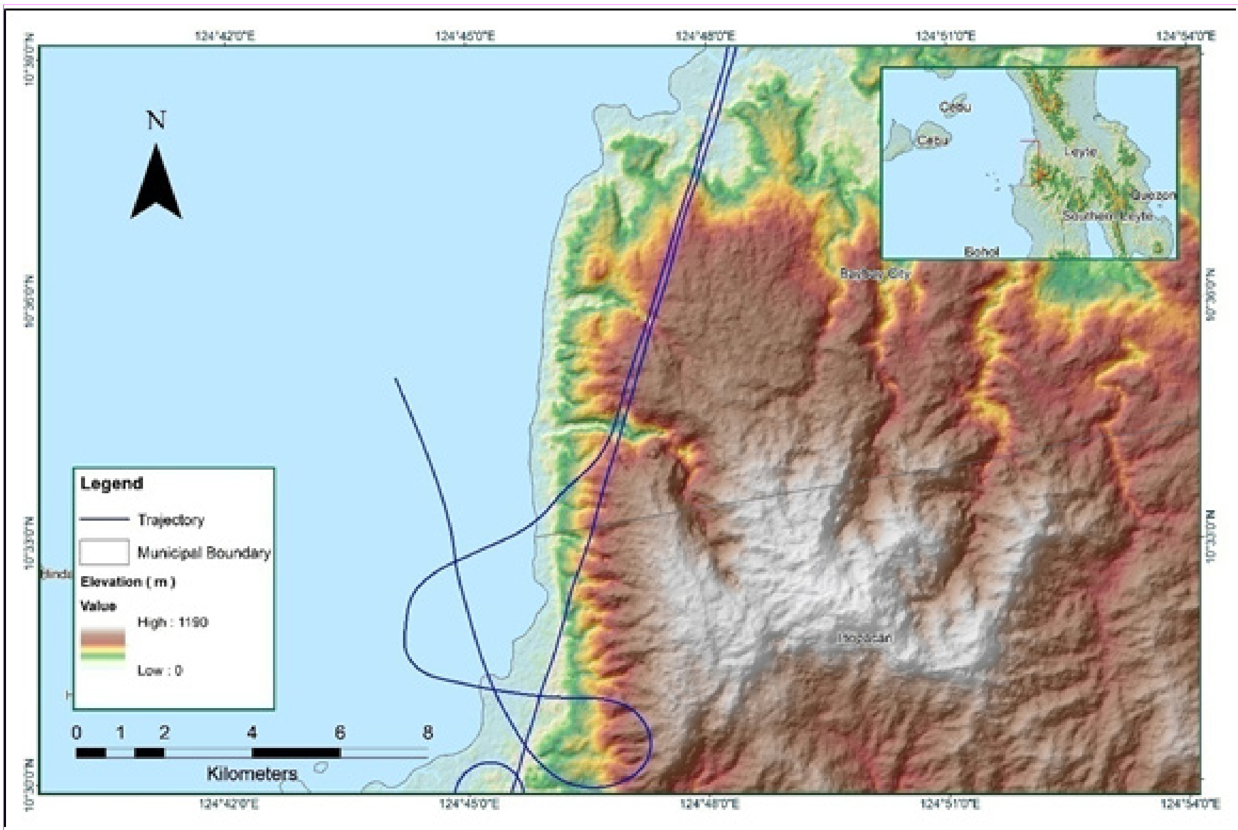
Flight Area	Ormoc South
Mission Name	Blk35E
Inclusive Flights	3925G
Range data size	9.56 GB
POS data size	252 MB
Base data size	6.82 MB
Image	NA
Transfer date	May 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.11
RMSE for East Position (<4.0 cm)	1.28
RMSE for Down Position (<8.0 cm)	2.98
Boresight correction stdev (<0.001deg)	0.001264
IMU attitude correction stdev (<0.001deg)	0.001457
GPS position stdev (<0.01m)	0.0202
Minimum % overlap (>25)	31.99
Ave point cloud density per sq.m. (>2.0)	5.00
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	34
Maximum Height	1068.88 m
Minimum Height	63.13 m
Classification (# of points)	
Ground	5,803,071
Low vegetation	3,515,263
Medium vegetation	11,459,353
High vegetation	26,114,465
Building	45,380
Orthophoto	No
Processed by	Engr. Jennifer Saguran,
Engr. Wilbert Ian San Juan	Engr. Sheila Maye Santillan, Engr. Elainne Lopez, Engr. Merven Matthew Natino



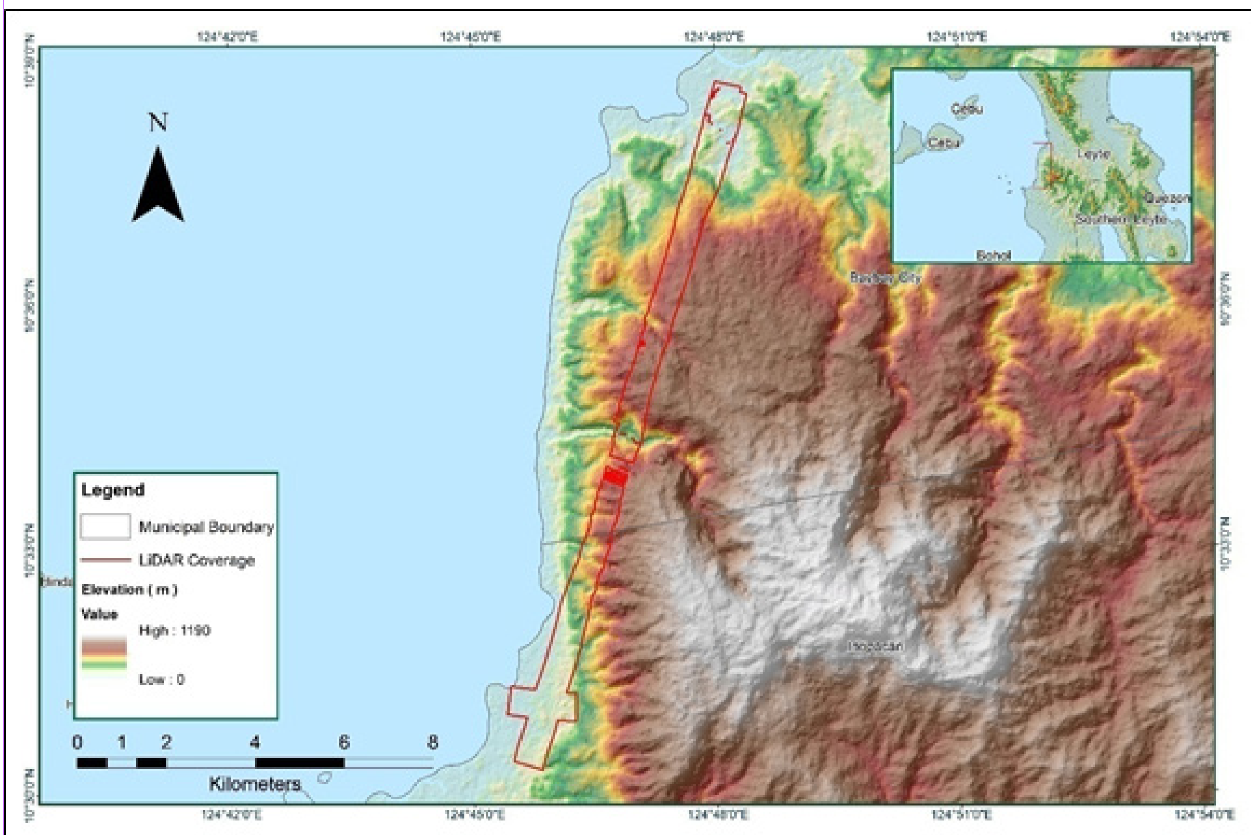
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

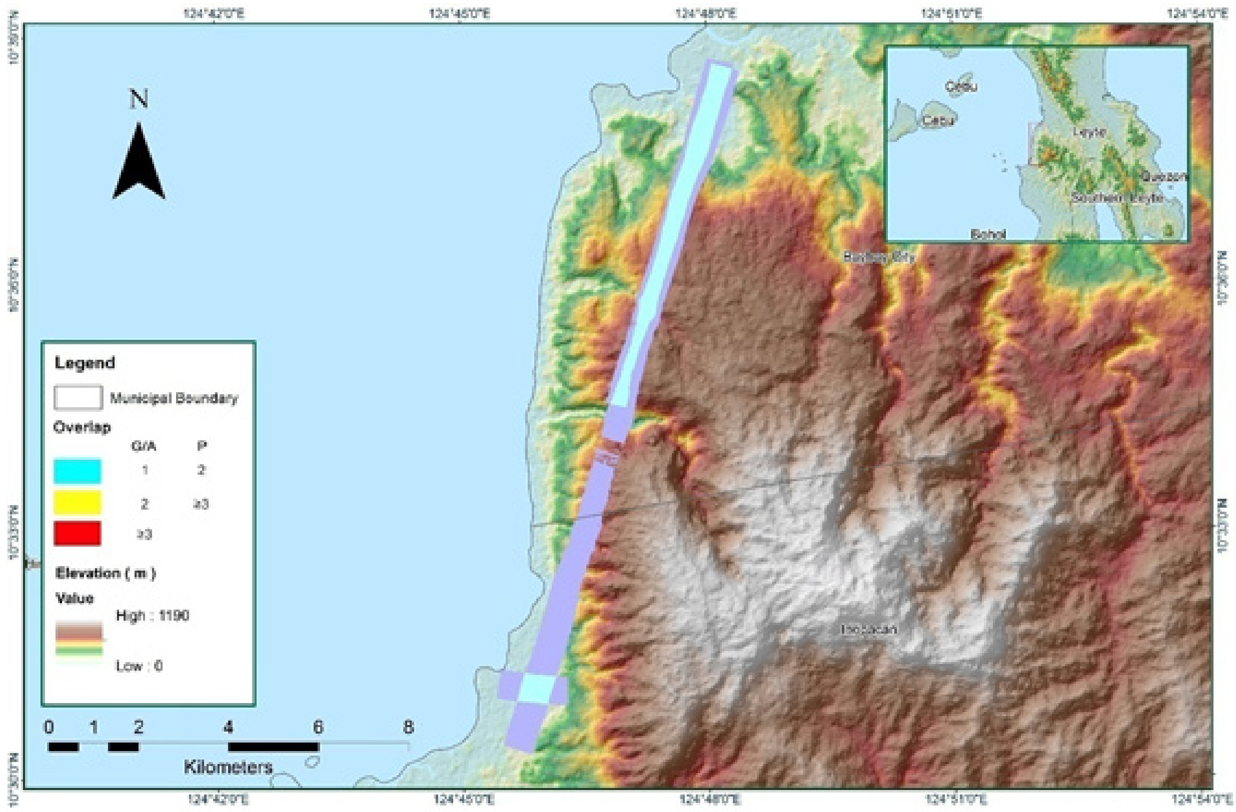
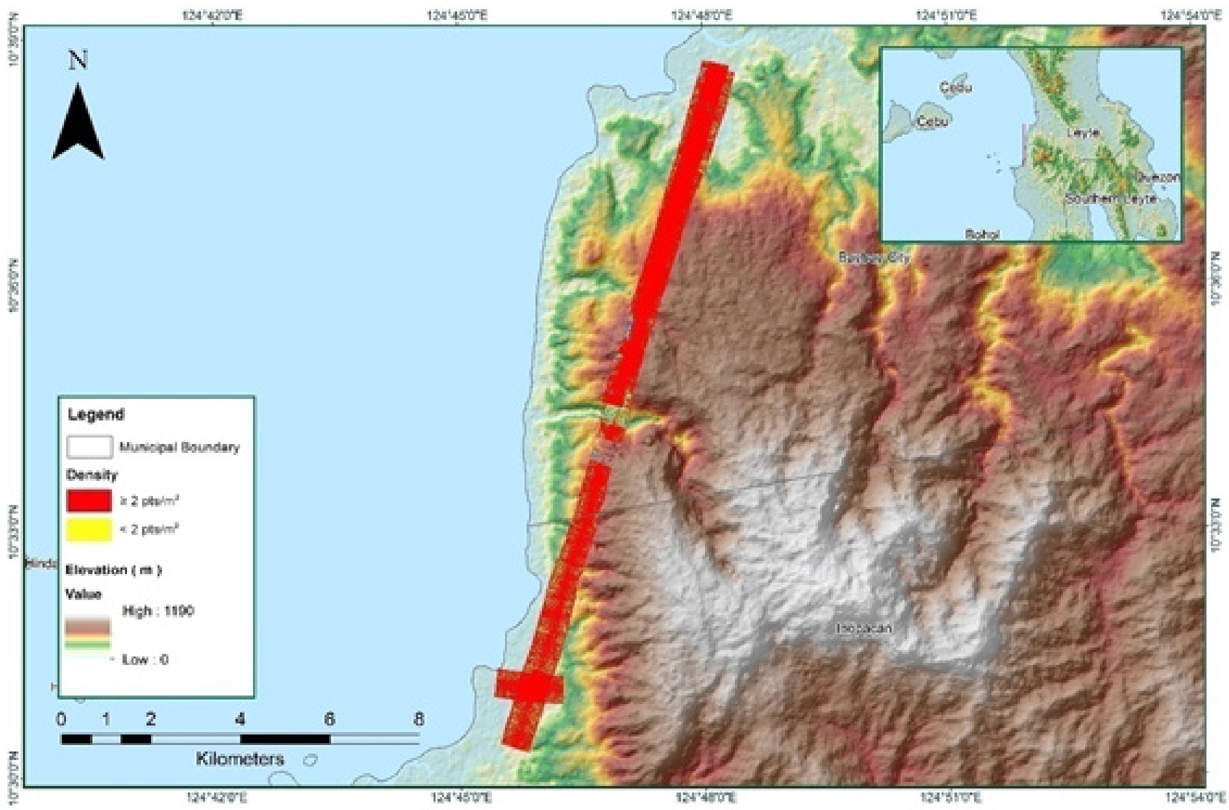
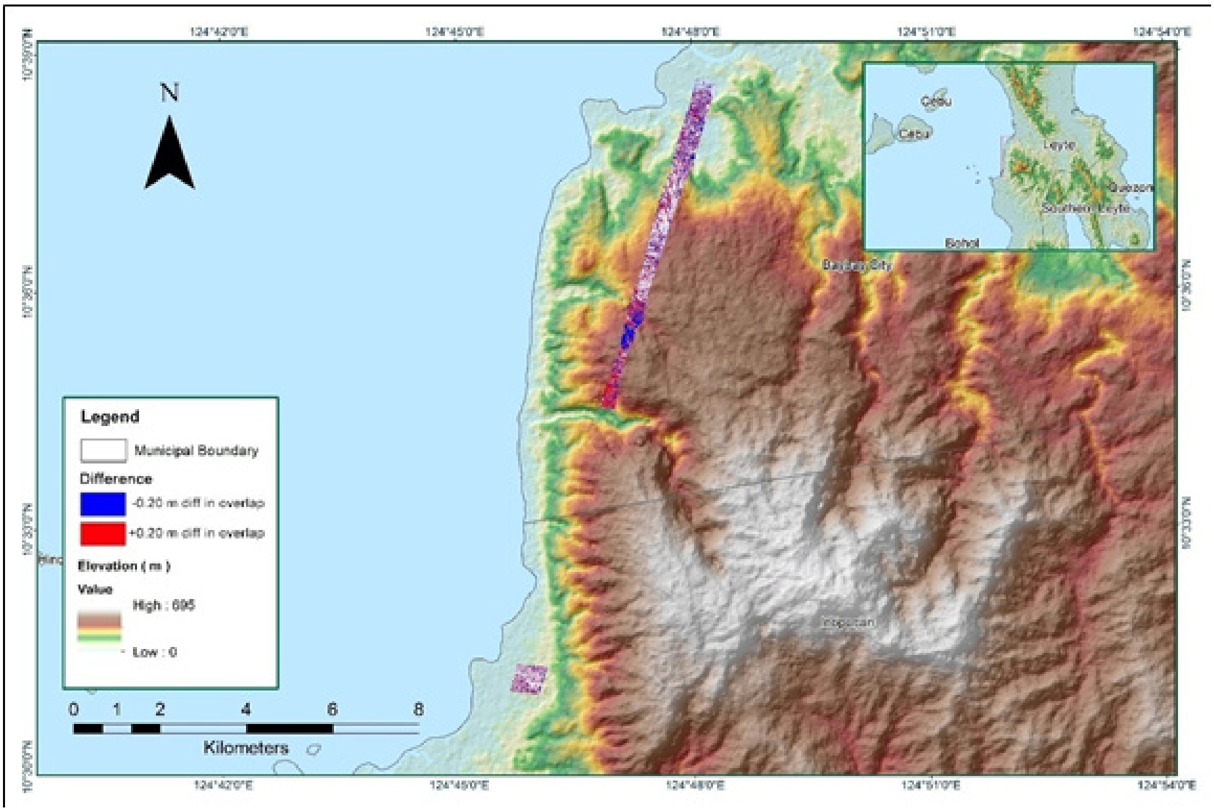


Image of Data Overlap



Density map of merged LiDAR data



Elevation difference between flight lines

Flight Area	Ormoc South
Mission Name	Blk35E
Inclusive Flights	3925G
Range data size	9.56 GB
POS data size	252 MB
Base data size	6.82 MB
Image	NA
Transfer date	May 6, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	No
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.11
RMSE for East Position (<4.0 cm)	1.28
RMSE for Down Position (<8.0 cm)	2.98
Boresight correction stdev (<0.001deg)	0.001264
IMU attitude correction stdev (<0.001deg)	0.001457
GPS position stdev (<0.01m)	0.0202
Minimum % overlap (>25)	31.99
Ave point cloud density per sq.m. (>2.0)	5.00
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	34
Maximum Height	1068.88 m
Minimum Height	63.13 m
Classification (# of points)	
Ground	5,803,071
Low vegetation	3,515,263
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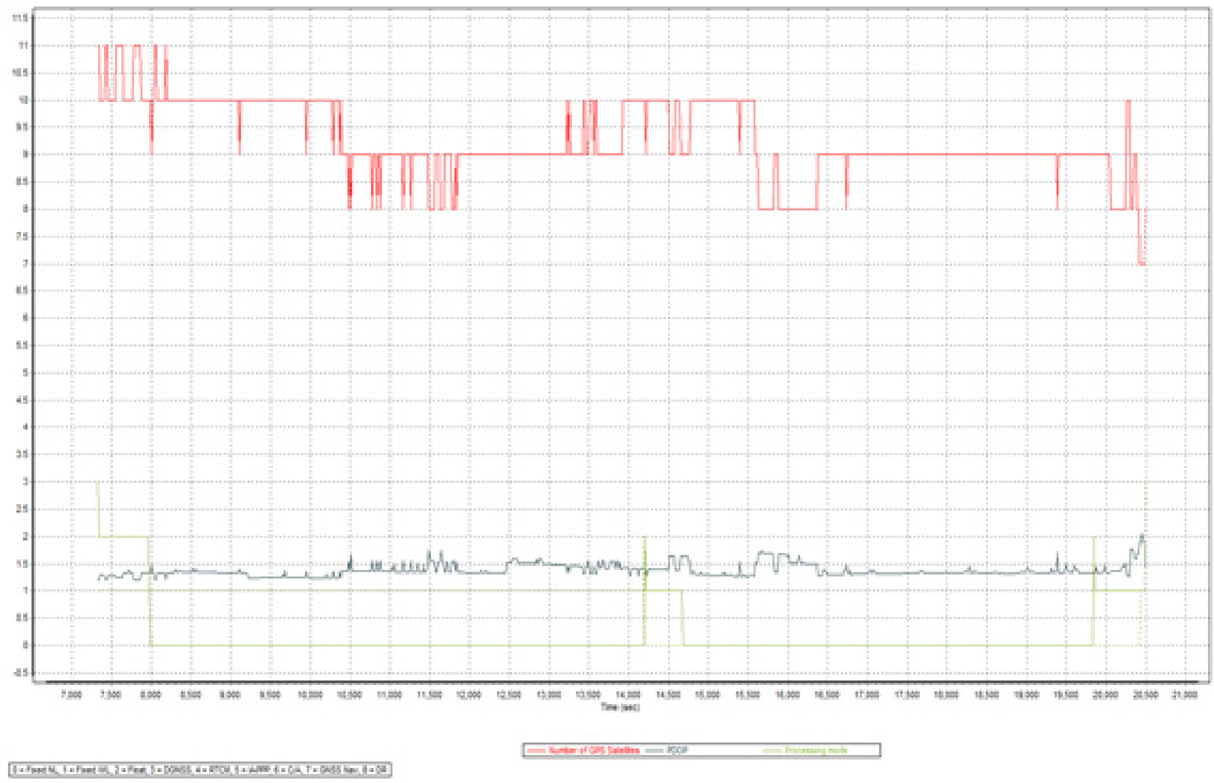
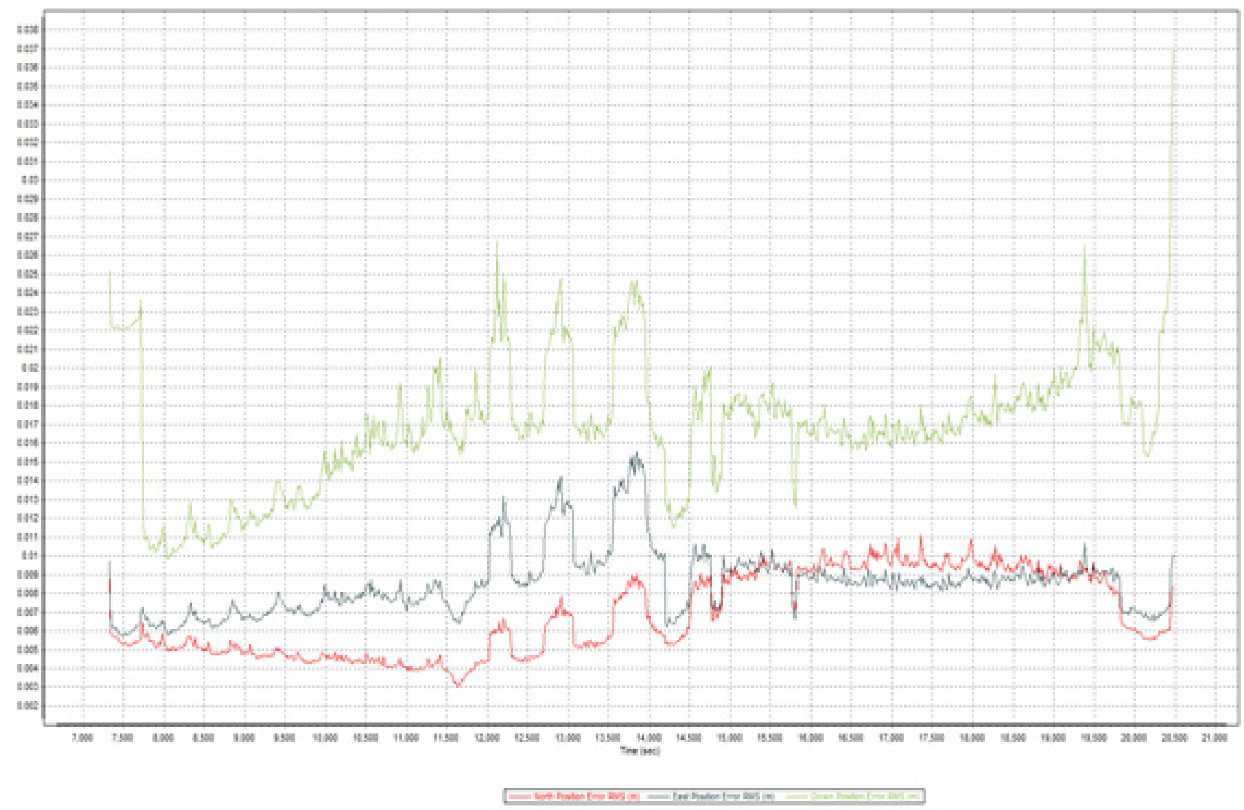
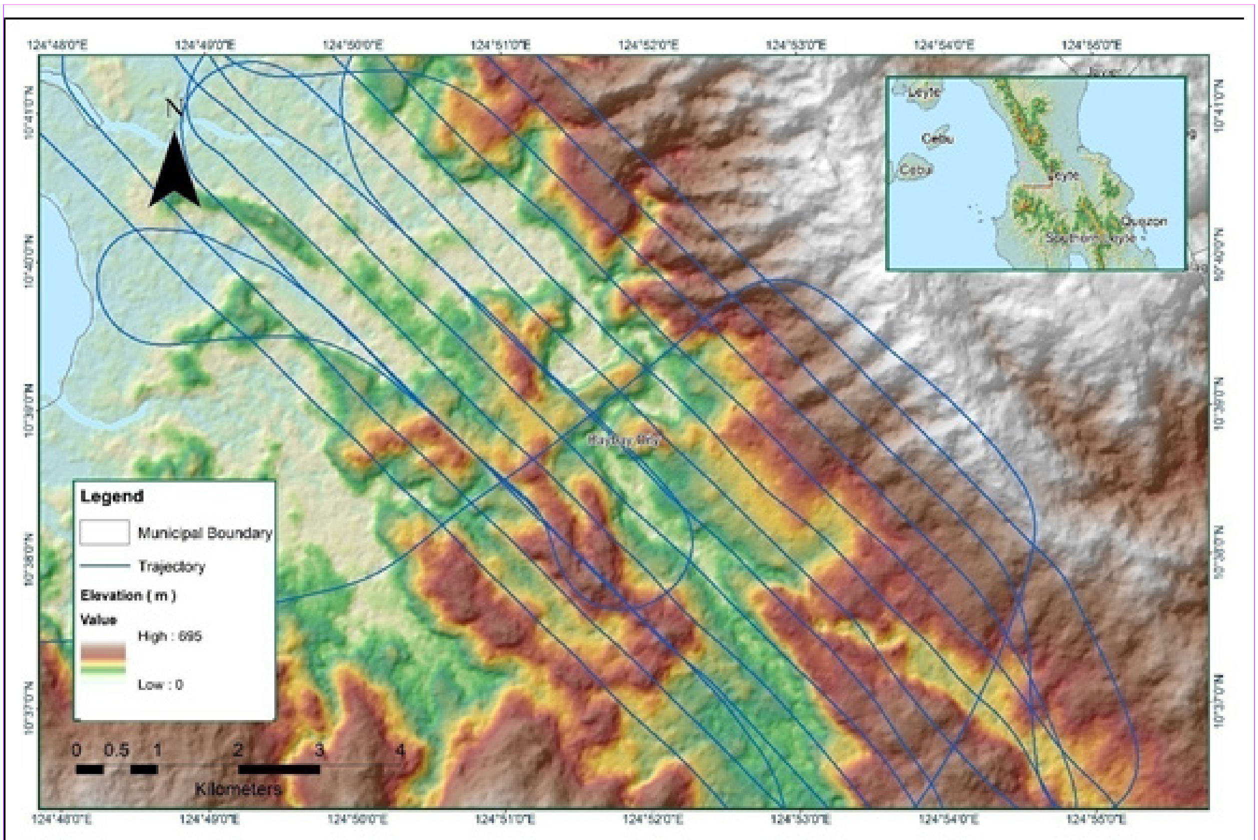
High vegetation	26,114,465
Building	45,380
Orthophoto	No
Processed by	Engr. Jennifer Saguran,
Engr. Wilbert Ian San Juan	Engr. Sheila Maye Santillan, Engr. Elainne Lopez, Engr. Merven Matthew Natino



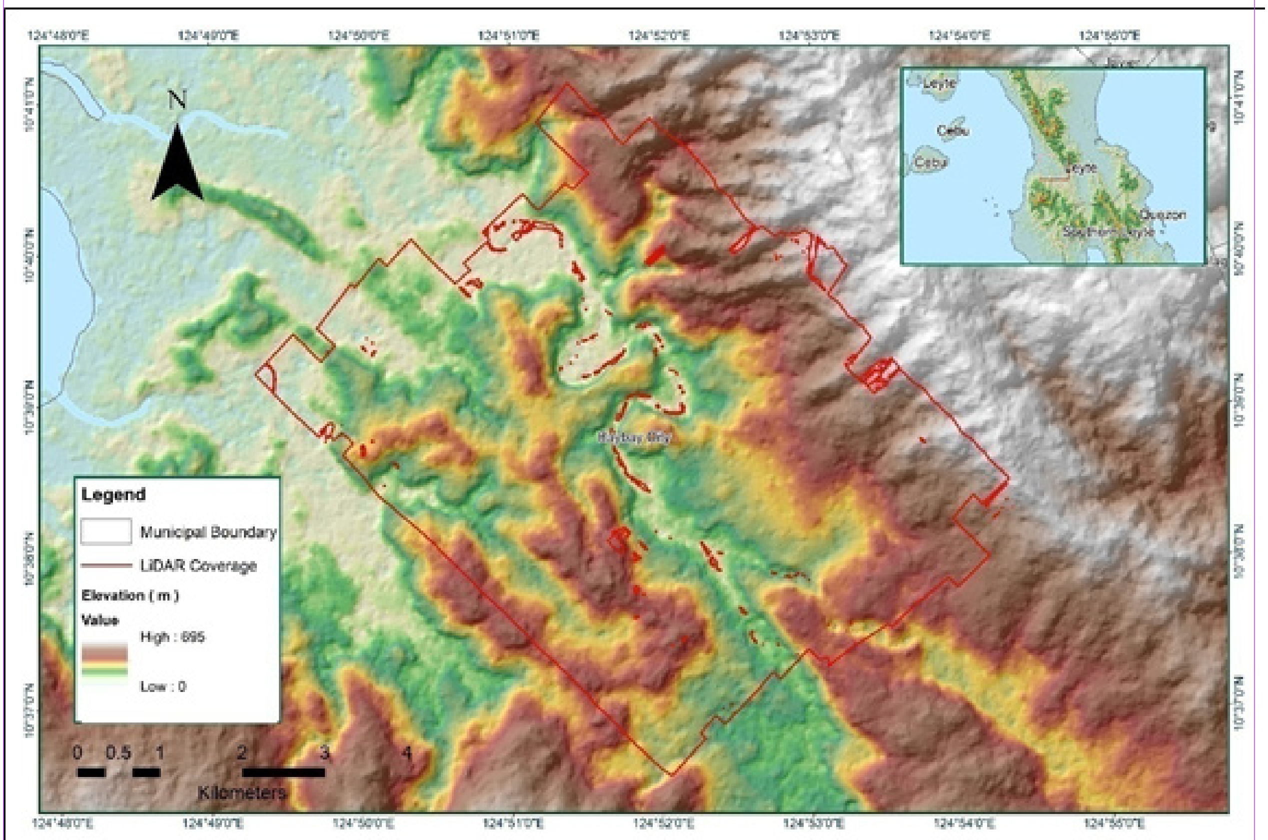
Solution Status



Smoothed Performance Metric Parameters



Best Estimated Trajectory



Coverage of LiDAR data

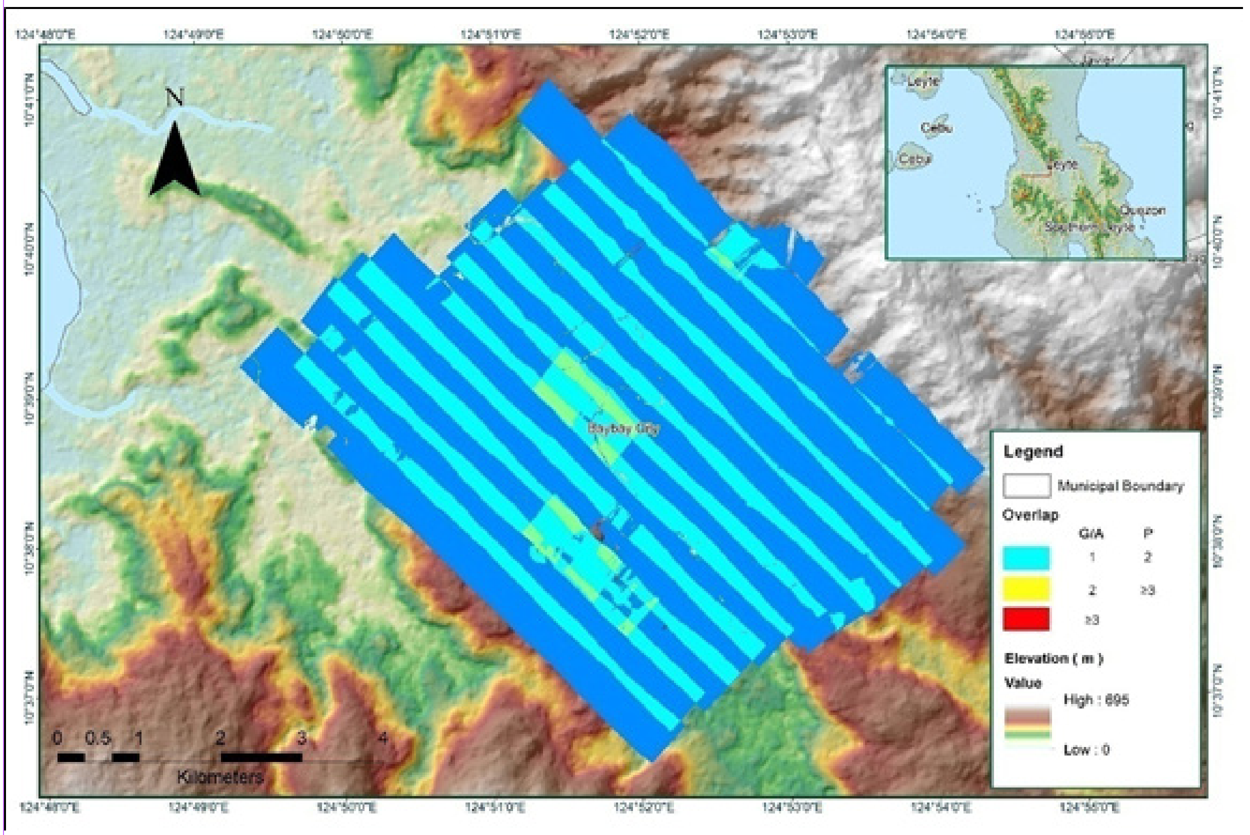
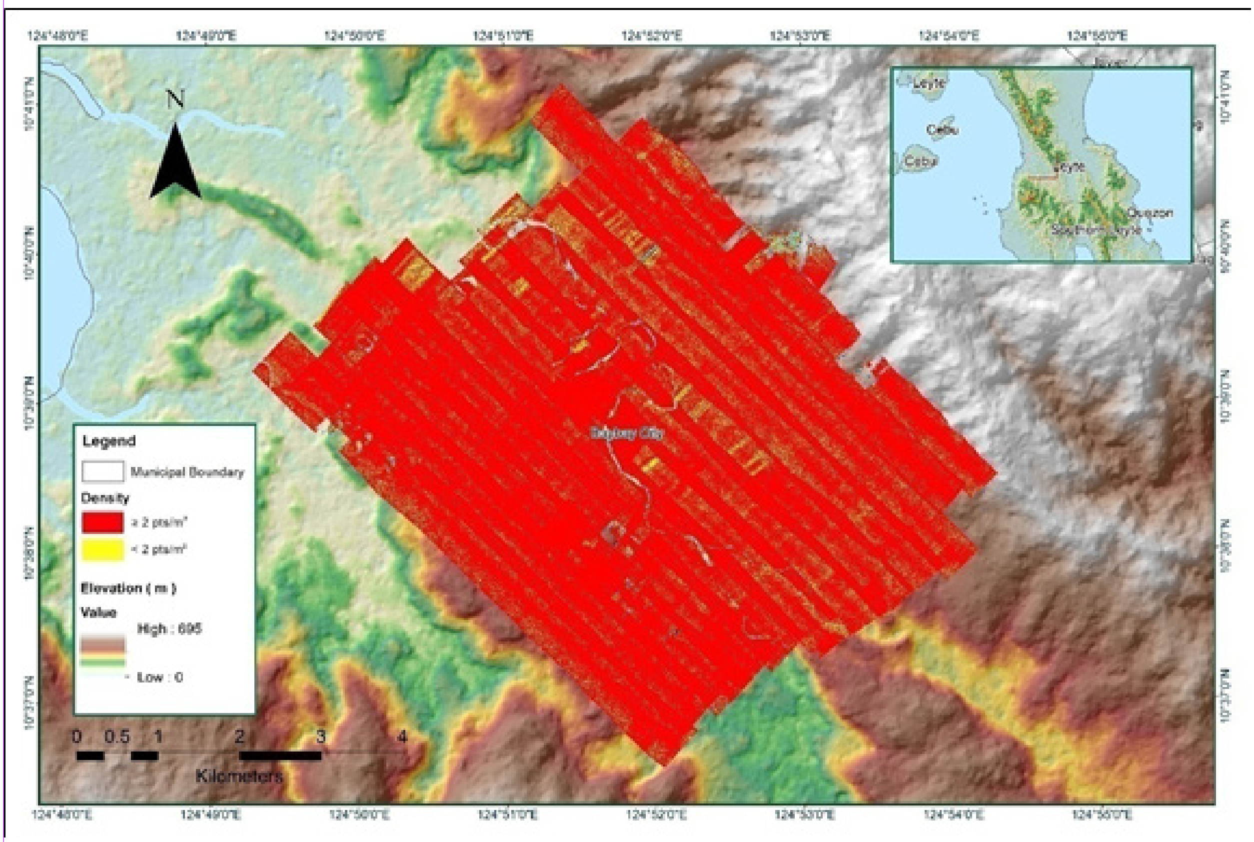
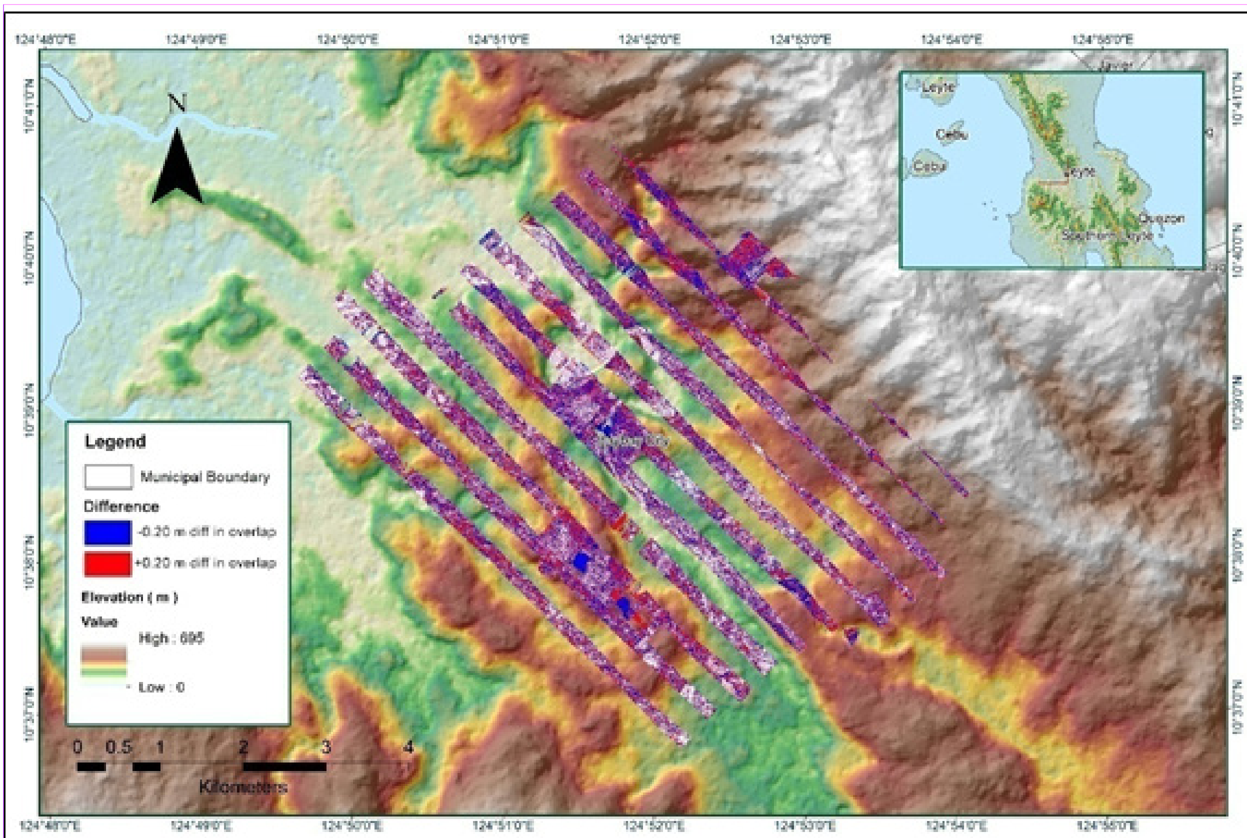


Image of Data Overlap



Density map of merged LiDAR data



Elevation difference between flight lines

Annex 9. Pagbanganan 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
W180	70.1822	36.4105	0	1.88916	1.37258	Discharge	7.5092	0.9	Ratio to Peak	0.075
W170	147.079	53.35729	0	1.52347	0.70125	Discharge	5.6594	0.9	Ratio to Peak	0.075
W160	50.7604	35.6732	0	1.46653	0.707894	Discharge	9.8906	0.9	Ratio to Peak	0.075
W150	51.0739	99	0	0.550602	0.253528	Discharge	0.89135	0.9	Ratio to Peak	0.075
W140	51.9384	60.92623	0	0.878176	0.363814	Discharge	2.3723	0.9	Ratio to Peak	0.075
W130	55.41825	52.46445	0	0.712387	0.223905	Discharge	1.4318	0.9	Ratio to Peak	0.075
W120	57.31065	46.36607	0	0.537446	0.24651	Discharge	1.5652	0.9	Ratio to Peak	0.075
W110	26.77195	89.11533	0	0.749268	0.343915	Discharge	0.89941	0.9	Ratio to Peak	0.075
W100	69.24075	67.82857	0	0.455858	0.30877	Discharge	2.127	0.9	Ratio to Peak	0.075

ANNEX 10. Pajo Model Reach Parameters

Reach Number	Muskingum Cunge Channel Routing						
	Time Step Method	Length (m)	Slope	Manning's n	Shape	Width	Side Slope
R20	Automatic Fixed Interval	3486.7	0.001588	0.04	Trapezoid	57.37	1
R30	Automatic Fixed Interval	5252.1	0.002028	0.04	Trapezoid	56.69	1
R50	Automatic Fixed Interval	7840.7	0.001588	0.04	Trapezoid	45.65	1
R60	Automatic Fixed Interval	3190.3	0.003569	0.04	Trapezoid	44.49	1

ANNEX 11. Pajo Field Validation Points

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
1	10.692681	124.799179	0.16	0.2	-0.04	Ruby/Dec 3-10, 2014	2-Year
2	10.680384	124.803686	0.99	0.2	0.79	Caloy/March 18-24, 2014	2-Year
3	10.680381	124.804132	0.90	0	0.90		
4	10.68069	124.804607	0.65	0	0.65		
5	10.681097	124.806127	2.23	0.5	1.73	Ruby/Dec 3-10, 2014	2-Year
6	10.681097	124.806127	2.23	0.5	1.73	Senyang/Dec 28-31, 2014	2-Year
7	10.681158	124.804685	0.03	0	0.03		
8	10.680583	124.80448	0.60	0.3	0.30	Ruby/Dec 3-10, 2014	2-Year
9	10.68067	124.804548	0.65	0.4	0.25	Ruby/Dec 3-10, 2014	2-Year
10	10.680092	124.804565	0.43	0	0.43		
11	10.679525	124.803745	0.33	0.1	0.23	Ruby/Dec 3-10, 2014	2-Year
12	10.679525	124.803745	0.33	0.1	0.23	Senyang/Dec 28-31, 2014	2-Year
13	10.67905	124.803876	0.34	0	0.34		
14	10.679633	124.804956	0.40	0.5	-0.10	Ruby/Dec 3-10, 2014	2-Year
15	10.679633	124.804956	0.40	0.5	-0.10	Senyang/Dec 28-31, 2014	2-Year
16	10.679633	124.804956	0.40	5	-4.60	Yolanda/November 7-9, 2013	2-Year
17	10.680073	124.805624	0.65	0.3	0.35	Ruby/Dec 3-10, 2014	2-Year
18	10.680073	124.805624	0.65	0	0.65	Senyang/Dec 28-31, 2014	2-Year
19	10.680073	124.805624	0.65	0	0.65	Ruby/Dec 3-10, 2014	2-Year
20	10.680681	124.806683	0.95	0.4	0.55	Ruby/Dec 3-10, 2014	2-Year
21	10.680681	124.806683	0.95	0.4	0.55	Senyang/Dec 28-31, 2014	2-Year
22	10.680156	124.8068	0.46	0.3	0.16	Ruby/Dec 3-10, 2014	2-Year
23	10.680156	124.8068	0.46	0.3	0.16	Butchoy/July 2-3, 2016	2-Year
24	10.679485	124.807274	0.03	0	0.03		
25	10.678885	124.807735	0.03	0	0.03		
26	10.699455	124.799072	1.16	0.3	0.86	Ruby/Dec 3-10, 2014	2-Year
27	10.699455	124.799072	1.16	0.3	0.86	Senyang/Dec 28-31, 2014	2-Year
28	10.699455	124.799072	1.16	0.2	0.96	Heavy Rain/Jan-Feb 2016	2-Year
29	10.696936	124.799237	1.12	0	1.12	Ruby/Dec 3-10, 2014	2-Year
30	10.696468	124.798978	1.28	0.1	1.18	Butchoy/July 2-3, 2016	2-Year
31	10.696468	124.798978	1.28	0.1	1.18	Ruby/Dec 3-10, 2014	2-Year
32	10.695448	124.798708	0.87	0	0.87	Ruby/Dec 3-10, 2014	2-Year
33	10.695448	124.798708	0.87	0	0.87	Senyang/Dec 28-31, 2014	2-Year
34	10.694264	124.798919	2.06	0	2.06	Ruby/Dec 3-10, 2014	2-Year
35	10.694376	124.798041	0.73	0	0.73	Ruby/Dec 3-10, 2014	2-Year
36	10.693872	124.798466	1.21	0.2	1.01	Ruby/Dec 3-10, 2014	2-Year
37	10.693872	124.798664	1.66	1.2	0.46	Ruby/Dec 3-10, 2014	2-Year
38	10.693032	124.798839	0.13	0	0.13	Ruby/Dec 3-10, 2014	2-Year
39	10.692734	124.798027	0.30	0.2	0.10	Ruby/Dec 3-10, 2014	2-Year
40	10.688888	124.798367	0.03	0	0.03	Ruby/Dec 3-10, 2014	2-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
41	10.688701	124.796053	0.84	0.1	0.74	Ruby/Dec 3-10, 2014	2-Year
42	10.681142	124.801586	0.90	0	0.90		
43	10.681585	124.801707	0.50	0.3	0.20	Ruby/Dec 3-10, 2014	2-Year
44	10.681921	124.801225	0.39	0	0.39		
45	10.682127	124.801547	0.16	0	0.16		
46	10.682659	124.801278	1.60	0.4	1.20	Ruby/Dec 3-10, 2014	2-Year
47	10.682799	124.80142	1.69	0.6	1.09	Ruby/Dec 3-10, 2014	2-Year
48	10.682799	124.80142	1.69	0.2	1.49	Heavy Rain/Jan-Feb 2016	2-Year
49	10.682799	124.80142	1.69	0.6	1.09	Senyang/Dec 28-31, 2014	2-Year
50	10.683051	124.80064	2.44	0.6	1.84	Ruby/Dec 3-10, 2014	2-Year
51	10.683051	124.80064	2.44	0.2	2.24	Senyang/Dec 28-31, 2014	2-Year
52	10.682407	124.80098	0.56	0.2	0.36	Heavy Rain/Jan-Feb 2016	2-Year
53	10.680672	124.802043	0.62	0	0.62		
54	10.681175	124.804097	0.41	0.2	0.21	Heavy Rain/Jan-Feb 2016	2-Year
55	10.681175	124.804097	0.41	0.4	0.01	Ruby/Dec 3-10, 2014	2-Year
56	10.681609	124.804408	1.08	0.7	0.38	Ruby/Dec 3-10, 2014	2-Year
57	10.681609	124.804408	1.08	0.7	0.38	Heavy Rain/Jan-Feb 2016	2-Year
58	10.683333	124.806068	0.03	0	0.03		
59	10.683109	124.80634	1.92	0.3	1.62	Heavy Rain/Jan-Feb 2016	2-Year
60	10.683109	124.806522	1.91	0.6	1.31	Heavy Rain/Jan-Feb 2016	2-Year
61	10.682728	124.806885	1.82	0.4	1.42	Ruby/Dec 3-10, 2014	2-Year
62	10.682728	124.806885	1.82	0	1.82	Heavy Rain/Jan-Feb 2016	2-Year
63	10.682535	124.806817	1.79	0.4	1.39	Ruby/Dec 3-10, 2014	2-Year
64	10.682535	124.806817	1.79	0	1.79	Heavy Rain/Jan-Feb 2016	2-Year
65	10.683416	124.806831	0.03	0	0.03		
66	10.684573	124.80777	0.98	0.1	0.88	Ruby/Dec 3-10, 2014	2-Year
67	10.684976	124.80827	1.56	0.5	1.06	Heavy Rain/Jan-Feb 2016	2-Year
68	10.684976	124.80827	1.56	3	-1.44	Ruby/Dec 3-10, 2014	2-Year
69	10.685066	124.809565	1.82	0.7	1.12	Ruby/Dec 3-10, 2014	2-Year
70	10.685066	124.809565	1.82	0.5	1.32	Heavy Rain/Jan-Feb 2016	2-Year
71	10.684999	124.810905	1.37	0.2	1.17	Ruby/Dec 3-10, 2014	2-Year
72	10.684999	124.810905	1.37	0.2	1.17	Yolanda/November 7-9, 2013	2-Year
73	10.685222	124.811223	1.27	0	1.27	Heavy Rain/Jan-Feb 2016	2-Year
74	10.685536	124.811548	1.26	0	1.26		
75	10.676096	124.813218	2.31	3	-0.69	Ruby/Dec 3-10, 2014	2-Year
76	10.678281	124.808464	4.37	2	2.37	Ruby/Dec 3-10, 2014	2-Year
77	10.678281	124.808464	4.37	0.5	3.87	Senyang/Dec 28-31, 2014	2-Year
78	10.678617	124.810037	3.66	0.5	3.16	Senyang/Dec 28-31, 2014	2-Year
79	10.678617	124.810037	3.66	2	1.66	Ruby/Dec 3-10, 2014	2-Year
80	10.678415	124.808977	3.42	0.5	2.92	Senyang/Dec 28-31, 2014	2-Year
81	10.678415	124.808977	3.42	2	1.42	Ruby/Dec 3-10, 2014	2-Year
82	10.699825	124.79879	0.69	0.3	0.39	Ruby/Dec 3-10, 2014	2-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
83	10.68836	124.794981	0.74	0.2	0.54	Ruby/Dec 3-10, 2014	2-Year
84	10.68836	124.794981	0.74	0.2	0.54	Yolanda/November 7-9, 2013	2-Year
85	10.693204	124.798094	0.60	0.2	0.40	Ruby/Dec 3-10, 2014	2-Year
86	10.688052	124.794556	0.29	0.4	-0.11	Ruby/Dec 3-10, 2014	2-Year
87	10.688052	124.794556	0.29	0.4	-0.11	Senyang/Dec 28-31, 2014	2-Year
88	10.688052	124.794556	0.29	0.4	-0.11	Yolanda/November 7-9, 2013	2-Year
89	10.688052	124.794556	0.29	0.4	-0.11	Heavy Rain/Jan-Feb 2016	2-Year
90	10.68822	124.794854	0.20	0.3	-0.10	Ruby/Dec 3-10, 2014	2-Year
91	10.687926	124.794995	0.41	0.6	-0.19	Ruby/Dec 3-10, 2014	2-Year
92	10.694981	124.799939	1.52	0.2	1.32	Ruby/Dec 3-10, 2014	2-Year
93	10.694981	124.799939	1.52	0.4	1.12	Heavy Rain/Jan-Feb 2016	2-Year
94	10.695167	124.799796	0.94	0.3	0.64	Heavy Rain/Jan-Feb 2016	2-Year
95	10.695167	124.799796	0.94	0.5	0.44	Ruby/Dec 3-10, 2014	2-Year
96	10.694618	124.800791	1.33	0.5	0.83	Ruby/Dec 3-10, 2014	2-Year
97	10.694618	124.800791	1.33	0.4	0.93	Butchoy/	2-Year
98	10.694394	124.801291	0.80	0	0.80	Ruby/Dec 3-10, 2014	2-Year
99	10.694354	124.801217	1.24	0.3	0.94	Ruby/Dec 3-10, 2014	2-Year
100	10.694354	124.801217	1.24	0.3	0.94	Heavy Rain/Jan-Feb 2016	2-Year
101	10.694303	124.801666	0.80	0.7	0.10	Ruby/Dec 3-10, 2014	2-Year
102	10.692986	124.799346	0.14	0.2	-0.06	Ruby/Dec 3-10, 2014	2-Year
103	10.692986	124.799346	0.14	0.2	-0.06	Heavy Rain/Jan-Feb 2016	2-Year
104	10.692486	124.801087	0.60	0.2	0.40	Senyang/Dec 28-31, 2014	2-Year
105	10.692486	124.801087	0.60	0.2	0.40	Ruby/Dec 3-10, 2014	2-Year
106	10.690994	124.801112	0.70	0	0.70		
107	10.690514	124.801204	0.13	0	0.13		
108	10.690222	124.801043	0.20	0	0.20		
109	10.689828	124.800874	0.23	0.5	-0.27	Ruby/Dec 3-10, 2014	2-Year
110	10.689828	124.800874	0.23	0.5	-0.27	Senyang/Dec 28-31, 2014	2-Year
111	10.689407	124.802223	1.48	0.5	0.98	Ruby/Dec 3-10, 2014	2-Year
112	10.689407	124.802223	1.48	0.5	0.98	Senyang/Dec 28-31, 2014	2-Year
113	10.688677	124.80235	1.37	0.4	0.97	Carina/July 26-30, 2016	2-Year
114	10.688677	124.80235	1.37	0.1	1.27	Ruby/Dec 3-10, 2014	2-Year
115	10.687404	124.801634	0.45	0	0.45		
116	10.688108	124.802155	0.54	0	0.54		
117	10.688219	124.802542	0.64	0	0.64		
118	10.686878	124.803177	0.07	0	0.07		
119	10.683536	124.804411	3.75	0.5	3.25	Ruby/Dec 3-10, 2014	2-Year
120	10.683023	124.805133	2.64	1	1.64	Ruby/Dec 3-10, 2014	2-Year
121	10.683023	124.805133	2.64	1	1.64	Senyang/Dec 28-31, 2014	2-Year
122	10.685031	124.804121	0.06	0.3	-0.24	Yolanda/November 7-9, 2013	2-Year
123	10.685031	124.804121	0.06	0.3	-0.24	Ruby/Dec 3-10, 2014	2-Year
124	10.68338	124.805704	0.03	0.6	-0.57	Ruby/Dec 3-10, 2014	2-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
125	10.68338	124.805704	0.03	0.6	-0.57	Senyang/Dec 28-31, 2014	2-Year
126	10.685539	124.815359	0.64	0	0.64		
127	10.684774	124.817686	0.03	0	0.03		
128	10.685218	124.819225	0.52	0.3	0.22	Ruby/Dec 3-10, 2014	2-Year
129	10.685445	124.819758	0.06	0	0.06		
130	10.6864	124.820137	0.04	0	0.04		
131	10.688085	124.821572	1.13	0	1.13		
132	10.700407	124.798946	1.67	1	0.67	Ruby/Dec 3-10, 2014	2-Year
133	10.69348	124.7986	1.73	0.2	1.53	Ruby/Dec 3-10, 2014	2-Year
134	10.698303	124.798899	1.49	0.5	0.99	Ruby/Dec 3-10, 2014	2-Year
135	10.697995	124.799157	2.95	0.5	2.45	Senyang/Dec 28-31, 2014	2-Year
136	10.697995	124.799157	2.95	0.4	2.55	Heavy Rain/Jan-Feb 2016	2-Year
137	10.699678	124.798308	3.38	0.3	3.08	Ruby/Dec 3-10, 2014	2-Year
138	10.687794	124.821595	2.75	2	0.75	Ruby/Dec 3-10, 2014	2-Year
139	10.687942	124.822058	1.29	0.3	0.99	Ruby/Dec 3-10, 2014	2-Year
140	10.68818	124.822143	1.08	0	1.08		
141	10.689207	124.821385	0.80	0	0.80		
142	10.690115	124.821316	0.67	0	0.67		
143	10.690073	124.819852	0.28	0	0.28		
144	10.68972	124.824366	0.03	0	0.03		
145	10.694654	124.833745	0.03	0	0.03		
146	10.696897	124.833004	0.03	0	0.03		
147	10.698187	124.833004	0.03	0	0.03		
148	10.690337	124.828216	0.03	0	0.03		
149	10.69028	124.831807	0.05	0	0.05		
150	10.698609	124.821759	0.11	2	-1.89	Ruby/Dec 3-10, 2014	2-Year
151	10.699049	124.821676	0.43	0.3	0.13	Yolanda/November 7-9, 2013	2-Year
152	10.699049	124.821676	0.43	0.3	0.13	Ruby/Dec 3-10, 2014	2-Year
153	10.699049	124.821676	0.43	0.3	0.13	Senyang/Dec 28-31, 2014	2-Year
154	10.699021	124.820953	0.31	0.3	0.01	Ruby/Dec 3-10, 2014	2-Year
155	10.699021	124.820953	0.31	0.3	0.01	Senyang/Dec 28-31, 2014	2-Year
156	10.673071	124.808838	0.03	0	0.03		
157	10.675874	124.817988	3.30	0	3.30		
158	10.677655	124.819364	3.21	0.4	2.81	Ruby/Dec 3-10, 2014	2-Year
159	10.677655	124.819364	3.21	0.4	2.81	Senyang/Dec 28-31, 2014	2-Year
160	10.677655	124.819364	3.21	0.4	2.81	Ruby/Dec 3-10, 2014	2-Year
161	10.677655	124.819364	3.21	0.4	2.81	Senyang/Dec 28-31, 2014	2-Year
162	10.679171	124.821209	3.46	0.4	3.06	Ruby/Dec 3-10, 2014	2-Year
163	10.679171	124.821209	3.46	0.3	3.16	Yolanda/November 7-9, 2013	2-Year
164	10.675568	124.827604	1.33	0.5	0.83	Ruby/Dec 3-10, 2014	2-Year
165	10.67414	124.818672	0.03	1	-0.97	Ruby/Dec 3-10, 2014	2-Year
166	10.67414	124.818672	0.03	1	-0.97	Senyang/Dec 28-31, 2014	2-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
167	10.67414	124.818672	0.03	1	-0.97	Heavy Rain/Jan-Feb 2016	2-Year
168	10.686076	124.813315	1.30	2	-0.70	Ruby/Dec 3-10, 2014	2-Year
169	10.686076	124.813315	1.30	0.5	0.80	Senyang/Dec 28-31, 2014	2-Year
170	10.686076	124.813315	1.30	0.5	0.80	Carina/July 26-30, 2016	2-Year
171	10.680302	124.832539	0.03	0.4	-0.37	Ruby/Dec 3-10, 2014	2-Year
172	10.680082	124.832423	0.45	0.4	0.05	Ruby/Dec 3-10, 2014	2-Year
173	10.681	124.83168	0.73	0.1	0.63	Carina/July 26-30, 2016	2-Year
174	10.678675	124.830068	4.49	0.5	3.99	Carina/July 26-30, 2016	2-Year
175	10.678675	124.830068	4.49	0.5	3.99	Ruby/Dec 3-10, 2014	2-Year
176	10.68188	124.830942	3.84	0.5	3.34	Caloy/March 18-24, 2016	2-year
177	10.681922	124.831239	1.19	0	1.19		
178	10.685435	124.833251	0.03	0	0.03		
179	10.683431	124.830055	1.03	0	1.03		
180	10.683755	124.830043	1.44	0	1.44		
181	10.683606	124.829695	1.14	0	1.14		
182	10.683804	124.829011	3.84	0	3.84		
183	10.686587	124.82578	2.65	0	2.65		
184	10.687191	124.823907	4.51	0.6	3.91	Ruby/Dec 3-10, 2014	2-Year
185	10.687191	124.823907	4.51	0.6	3.91	Heavy Rain/Jan-Feb 2016	2-Year
186	10.705391	124.815264	0.03	0.5	-0.47	Ruby/Dec 3-10, 2014	2-Year
187	10.705391	124.815264	0.03	0.5	-0.47	Carina/July 26-30, 2016	2-Year
188	10.705391	124.815264	0.03	0.5	-0.47	Heavy Rain/Jan-Feb 2016	2-Year
189	10.705799	124.813783	0.03	0.6	-0.57	Ruby/Dec 3-10, 2014	2-Year
190	10.705799	124.813783	0.03	0.6	-0.57	Yolanda/November 7-9, 2013	2-Year
191	10.705799	124.813783	0.03	0.6	-0.57	Heavy Rain/Jan-Feb 2016	2-Year
192	10.704941	124.815338	0.14	0.5	-0.36	Ruby/Dec 3-10, 2014	2-Year
193	10.704941	124.815338	0.14	0.5	-0.36	Carina/July 26-30, 2016	2-Year
194	10.704941	124.815338	0.14	0.5	-0.36	Heavy Rain/Jan-Feb 2016	2-Year
195	10.704274	124.813998	0.03	0	0.03		
196	10.703714	124.814635	0.03	0	0.03		
197	10.703838	124.812689	0.03	0	0.03		
198	10.700789	124.81095	0.20	0	0.20		
199	10.700397	124.81092	0.08	0.2	-0.12	Yolanda/November 7-9, 2013	2-Year
200	10.703597	124.807831	0.05	0.2	-0.15	Yolanda/November 7-9, 2013	2-Year
201	10.703597	124.808399	0.04	0.2	-0.16	Yolanda/November 7-9, 2013	2-Year
202	10.699324	124.810421	0.21	0	0.21		
203	10.695407	124.811089	0.42	0	0.42		
204	10.694032	124.811272	0.64	0.3	0.34	Yolanda/November 7-9, 2013	2-Year
205	10.694032	124.811272	0.64	0.4	0.24	Ruby/Dec 3-10, 2014	2-Year
206	10.692582	124.81171	1.52	0.4	1.12	Ruby/Dec 3-10, 2014	2-Year
207	10.691972	124.811843	2.29	0.6	1.69	Carina/July 26-30, 2016	2-Year
208	10.698856	124.809325	0.10	0.3	-0.20	Ruby/Dec 3-10, 2014	2-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
209	10.697277	124.807128	0.03	0.3	-0.27	Ruby/Dec 3-10, 2014	2-Year
210	10.695919	124.805824	0.69	0.3	0.39	Ruby/Dec 3-10, 2014	2-Year
211	10.695919	124.805824	0.69	0.3	0.39	Heavy Rain/Jan-Feb 2016	2-Year
212	10.695919	124.805824	0.69	0.3	0.39	Butchoy/July 2-3, 2016	2-Year
213	10.695598	124.805499	0.81	0	0.81		
214	10.69334	124.803882	1.91	0.2	1.71	Ruby/Dec 3-10, 2014	2-Year
215	10.69334	124.803882	1.91	0.2	1.71	Heavy Rain/Jan-Feb 2016	2-Year
216	10.692528	124.803415	1.47	2	-0.53	Ruby/Dec 3-10, 2014	2-Year
217	10.692528	124.803415	1.47	2	-0.53	Butchoy/July 2-3, 2016	2-Year
218	10.692528	124.803415	1.47	2	-0.53	Heavy Rain/Jan-Feb 2016	2-Year
219	10.69236	124.802948	1.02	0.2	0.82	Ruby/Dec 3-10, 2014	2-Year
220	10.691562	124.802877	0.48	0.7	-0.22	Heavy Rain/September 2016	2-Year
221	10.691562	124.802877	0.48	0.7	-0.22	Heavy Rain/Jan-Feb 2016	2-Year
222	10.691562	124.802877	0.48	0.7	-0.22	Ruby/Dec 3-10, 2014	2-Year
223	10.691562	124.802877	0.48	0.7	-0.22	Butchoy/July 2-3, 2016	2-Year
224	10.692681	124.799179	0.03	0.5	-0.47	Amy/December 5-19, 1951	15-Year
225	10.692681	124.799179	0.03	0.5	-0.47	Asiang/January 4-11, 1972	25-Year
226	10.68105	124.805484	0.14	2	-1.86	Asiang/January 4-11, 1972	25-Year
227	10.695448	124.798708	0.57	1.1	-0.53	Asiang/January 4-11, 1972	25-Year
228	10.693872	124.798466	0.91	0.5	0.41	Amy/December 5-19, 1951	15-Year
229	10.693872	124.798466	0.91	0.5	0.41	Asiang/January 4-11, 1972	25-Year
230	10.692734	124.798027	0.11	0.5	-0.39	Amy/December 5-19, 1951	15-Year
231	10.692734	124.798027	0.11	0.5	-0.39	Asiang/January 4-11, 1972	25-Year
232	10.688888	124.798367	0.03	2	-1.97	Asiang/January 4-11, 1972	25-Year
233	10.688701	124.796053	0.71	5	-4.29	Asiang/January 4-11, 1972	25-Year
234	10.681585	124.801707	0.10	5	-4.90	Asiang/January 4-11, 1972	25-Year
235	10.684573	124.80777	0.43	3	-2.57	Asiang/January 4-11, 1972	25-Year
236	10.685066	124.809565	1.26	5	-3.74	Asiang/January 4-11, 1972	25-Year
237	10.685222	124.811223	0.80	3	-2.20	Asiang/January 4-11, 1972	25-Year
238	10.676096	124.813218	1.70	3	-1.30	Asiang/January 4-11, 1972	25-Year
239	10.693204	124.798094	0.38	0.5	-0.12	Amy/December 5-19, 1951	15-Year
240	10.693204	124.798094	0.38	0.5	-0.12	Asiang/January 4-11, 1972	25-Year
241	10.69348	124.7986	1.44	0.5	0.94	Amy/December 5-19, 1951	15-Year
242	10.69348	124.7986	1.44	0.5	0.94	Asiang/January 4-11, 1972	25-Year
243	10.697669	124.823303	0.03	5	-4.97	Asiang/January 4-11, 1972	25-Year
244	10.677655	124.819364	2.38	0.4	1.98	Asiang/January 4-11, 1972	25-Year
245	10.677655	124.819364	2.38	0.4	1.98	Asiang/January 4-11, 1972	25-Year
246	10.67874	124.824641	0.51	1	-0.49	Asiang/January 4-11, 1972	25-Year
247	10.678163	124.825333	0.36	1	-0.64	Asiang/January 4-11, 1972	25-Year
248	10.675568	124.827604	0.89	1.5	-0.61	Asiang/January 4-11, 1972	25-Year
249	10.681	124.83168	0.03	3	-2.97	Asiang/January 4-11, 1972	25-Year

Point Number	Validation Coordinates (in WGS84)		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
250	10.685322	124.826987	1.78	0.3	1.48	Asiang/January 4-11, 1972	25-Year
251	10.702381	124.802887	0.03	3	-2.97	Asiang/January 4-11, 1972	25-Year
252	10.701919	124.803227	0.08	3	-2.92	Asiang/January 4-11, 1972	25-Year
253	10.697277	124.807128	0.03	3	-2.97	Asiang/January 4-11, 1972	25-Year
254	10.692822	124.803372	0.82	0.7	0.12	Asiang/January 4-11, 1972	25-Year
255	10.681097	124.806127	1.82	0.4	1.42	Ondoy/Sept 24-27, 2009	100-Year
256	10.680681	124.806683	0.52	0.4	0.12	Ondoy/Sept 24-27, 2009	100-Year
257	10.703362	124.812193	0.30	0.2	0.10	Ruping/November 10-14, 1990	100-Year
258	10.702411	124.811967	0.03	0.6	-0.57	Ruping/November 10-14, 1990	100-Year
259	10.702254	124.811834	0.03	0.2	-0.17	Ruping/November 10-14, 1990	100-Year
260	10.703408	124.804458	0.03	0.3	-0.27	Ruping/November 10-14, 1990	100-Year
261	10.692582	124.81171	0.90	0.6	0.30	Ruping/November 10-14, 1990	100-Year
262	10.698856	124.809325	0.09	2	-1.91	Ruping/November 10-14, 1990	100-Year
263	10.697277	124.807128	0.03	0.7	-0.67	Ruping/November 10-14, 1990	100-Year

Annex 12. Educational Institutions Affected in Pagbanganan Flood Plain

LEYTE				
BAYBAY CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
San Isidro Elementary School	Candadam			Low
Hibunawan Elementary School	Cogon			
Brgy. Gacat Daycare Center	Gakat			
Gacat Elementary School	Gakat			
Hibunawan Elementary School	Hibunawan			
Kan-Ipa Elementary School	Kan-Ipa	Medium	Medium	Medium
Maganhan Elementary School	Maganhan			
Franciscan College of the Immaculate Conception (FCIC)	Poblacion Zone 11			
FCIC Learning Resource Center	Poblacion Zone 12			
Franciscan College of the Immaculate Conception (FCIC)	Poblacion Zone 12	Low	Low	Low
FCIC Learning Resource Center	Poblacion Zone 13			
Franciscan College of the Immaculate Conception (FCIC)	Poblacion Zone 13			
Acedilla Technological Institute	Poblacion Zone 3			Low
Baybay Adventist Elementary School	Poblacion Zone 4	Low	Low	Low
Baybay Adventist Elementary School	Poblacion Zone 5	Low	Low	Medium
Baybay Adventist Elementary School	Poblacion Zone 6			Low
Baybay I Central School	Poblacion Zone 7	Low	Low	Medium
Franciscan College of the Immaculate Conception (FCIC)	Poblacion Zone 7			
Brgy. San Isidro Daycare Center	San Isidro			
Baybay Technical-Vocational Training Center	Santo Rosario	Low	Low	Low
Candadam Elementary School	Santo Rosario			

Annex 13. Medical Institutions Affected in Pagbanganan Flood Plain

LEYTE				
BAYBAY CITY				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. Gacat Health Center	Gakat	Low	Low	Medium
Baybay Family Care and Maternity Clinic	Poblacion Zone 4	Low	Low	Low
Baybay Family Care and Maternity Clinic	Poblacion Zone 7	Low	Low	Medium