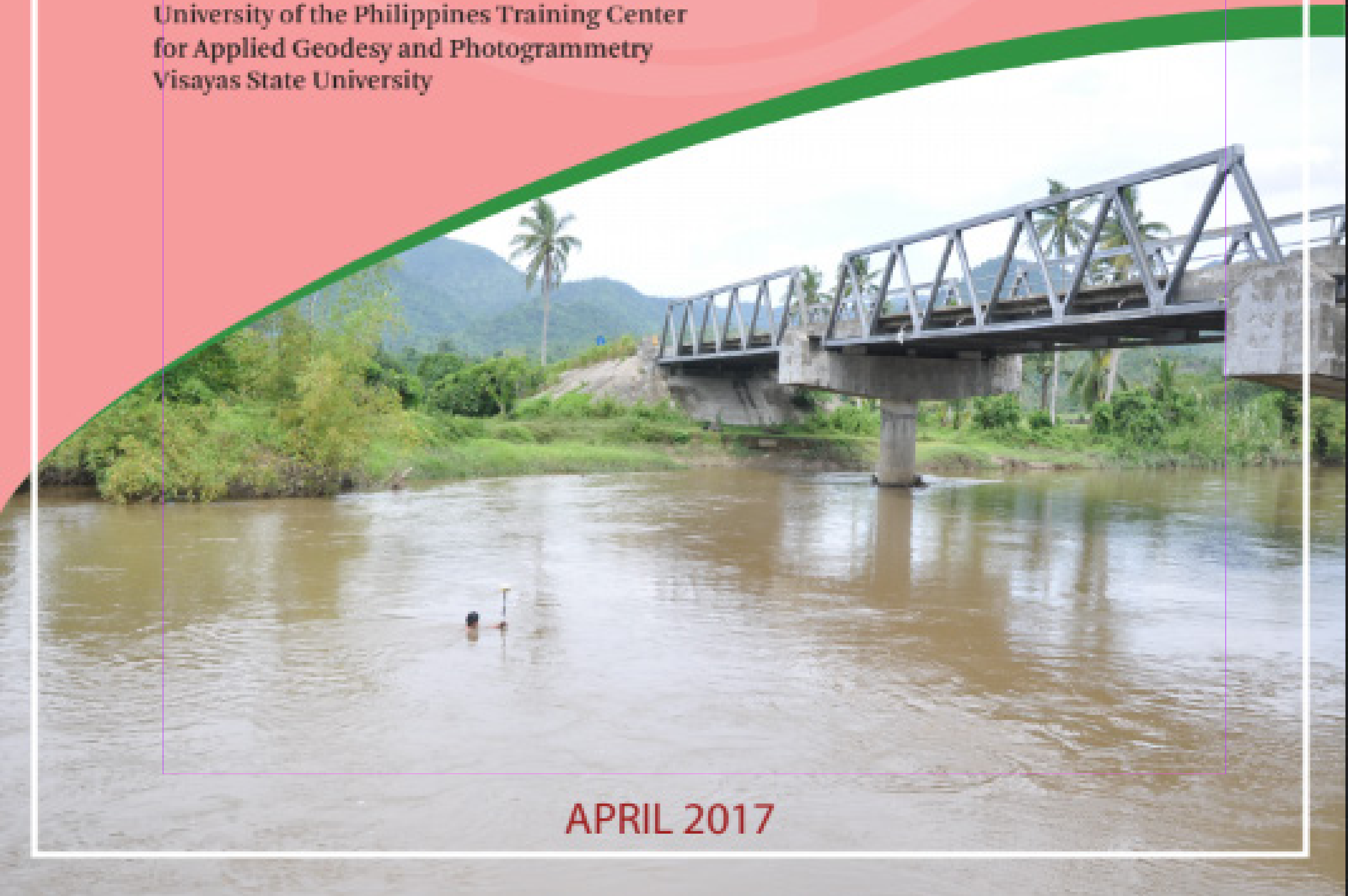
HAZARD MAPPING OF THE PHILIPPINES USING LIDAR (PHIL-LIDAR I)

LiDAR Surveys and Flood Mapping of Sangputan River

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



APRIL 2017

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

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

E.C. Paringit, and F.F. Morales. (Eds.). (2017), LiDAR Surveys and Flood Mapping of Sangputan River. Quezon City: University of the Philippines Training Center on Geodesy and Photogrammetry-103pp.

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National Library of the Philippines
ISBN: 978-621-430-214-7

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LIST OF ACRONYMS AND ABBREVIATIONS

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

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

CHAPTER 1: OVERVIEW OF THE PROGRAM AND SANGPUTAN RIVER

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

1.1 Background of the Phil-LiDAR 1 Program

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

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

The implementing partner university for the Phil-LiDAR 1 Program is the 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 twenty-eight (28) river basins in the Visayas region. The university is located in Baybay City, Leyte.

1.2 Overview of the Sangputan River Basin

The Sangputan River Basin covers the Municipalities of San Miguel, Alangalang. Jaro, Barugo, and Babatngon, and the City of Ormoc, in the province of Leyte. According to the Department of Environment and Natural Resources (DENR) – River Basin Control Office (RBCO), the basin has a drainage area of 270 km^2, and an estimated 513 million cubic meter (MCM) annual run-off (RBCO, 2015).

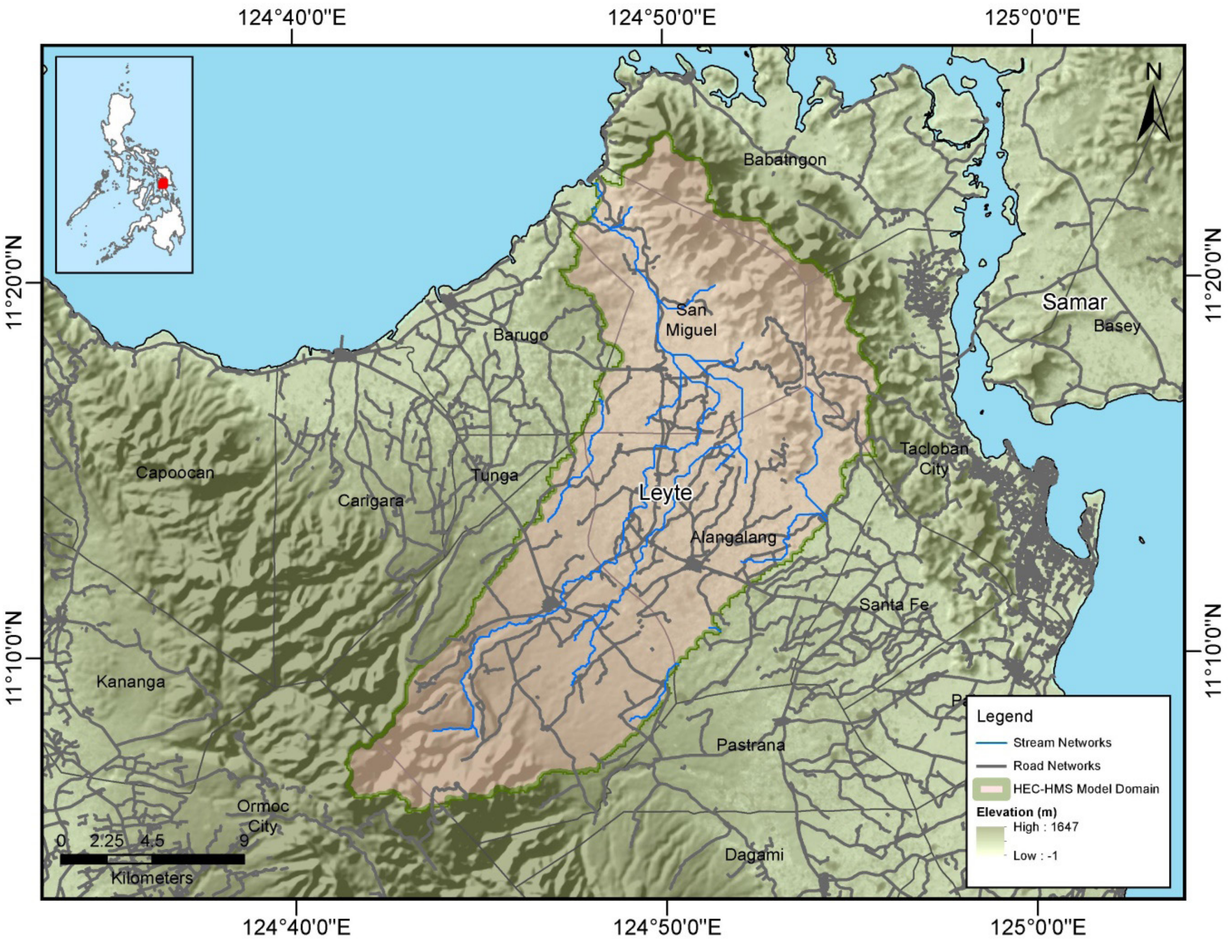

Figure 1. Location map of the Sangputan River Basin (in brown)

The river basin's main stem, the Sangputan River, locally known as the Sapiniton River, is part of the twenty-eight (28) river systems in the Visayas Region.

According to the 2010 national census of the National Statistics Office (NSO), the population within the immediate vicinity of the river is 8,999 persons, distributed among eleven (11) barangays in the Municipality San Miguel. The locals are mostly fishermen, as majority of the municipality's population are situated near the coast (http://www.slideshare.net/led4lgus/smedsep-leyte-rolfspeit, 2005).

In November 2013, Super Typhoon Haiyan (local name: Yolanda) hit the area, but it was not as devastated as Tacloban City. Flooding occurred, with minimal damage.

CHAPTER 2: LIDAR DATA ACQUISITION OF THE SANGPUTAN FLOODPLAIN

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

2.1 Flight Plans

To initiate the LiDAR acquisition survey of the Sangputan floodplain, the Data Acquisition Component (DAC) created flight plans within the delineated priority area for the Sangputan floodplain in Leyte. These missions were planned for fifteen (15) lines that run for at most four (4) hours including take-off, landing and turning time. Two (2) LiDAR systems were used for the missions – Aquarius and Gemini (See Annex 1 for the sensor specifications). The flight planning parameters for the Aquarius LiDAR system is found in Table 1, while the flight planning parameters for the Gemini LiDAR system is found in Table 2. Figure 2 shows the flight plans for the Sangputan floodplain using the Aquarius LiDAR system, and Figure 3 shows the flight plans for the Sangputan floodplain using the Gemini LiDAR system.

Table 1. Flight planning parameters for Aquarius LiDAR system.

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK34C	600	30	36	50	50	120	5
BLK34D	600	30	36	50	50	120	5
BLK34E	600	30	36	50	50	120	5

Table 2. Flight planning parameters for Gemini LiDAR system

Block Name	Flying Height (m AGL)	Overlap (%)	Field of View (θ)	Pulse Repetition Frequency (PRF) (kHz)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
BLK34A	600/850/ 1100	30	34/40/50	100	40/50	120	5
BLK34B	850	30	40	100	50	120	5
BLK34C	600/850	30	40/50	100	40/50	120	5
BLK34D	600/1100	30	34/50	100	40/50	120	5
BLK34E	600/1100	30	34/50	100	40/50	120	5
BLK34G	600/850/ 1100	30	34/40/50	100	40/50	120	5

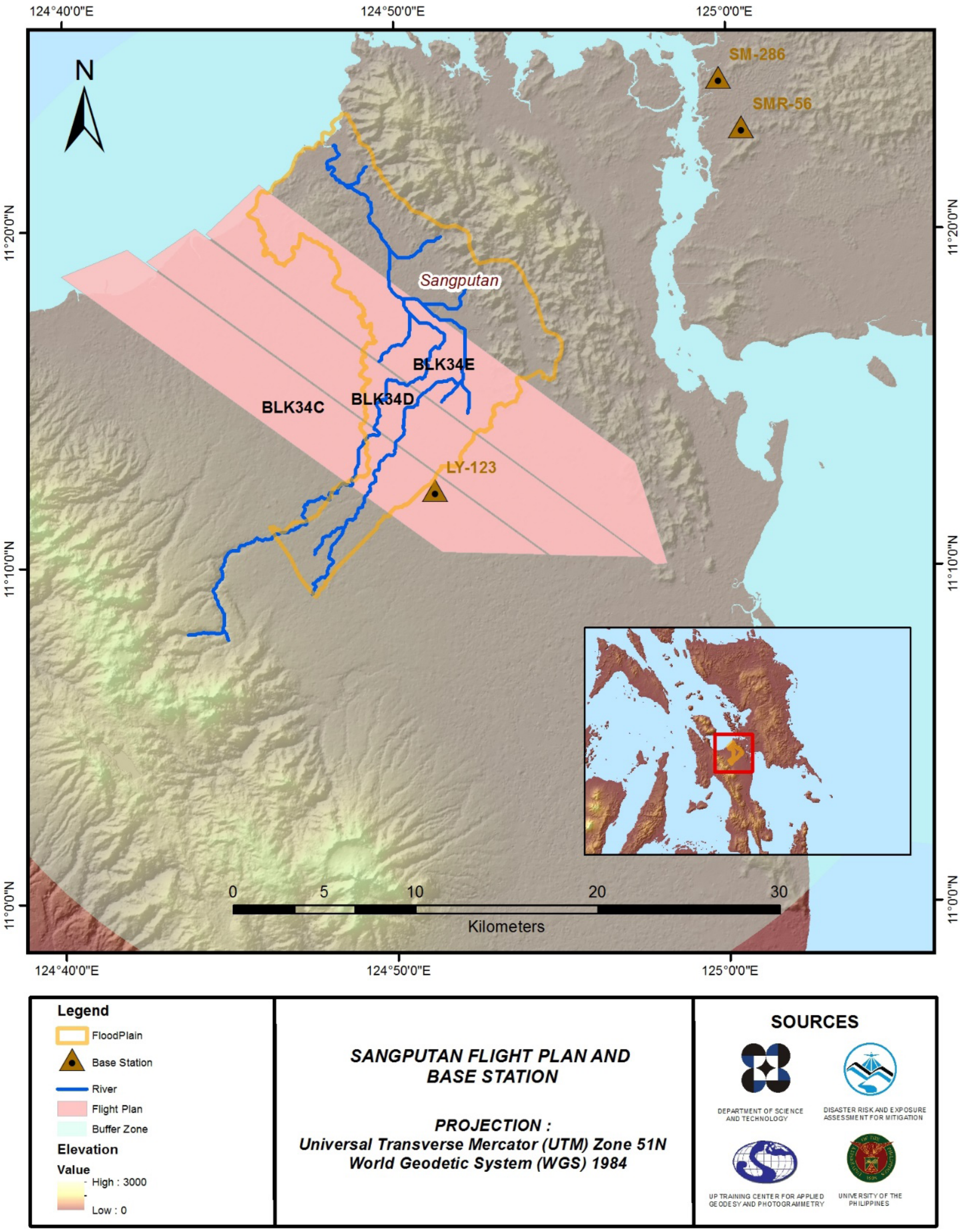


Figure 2. Flight plans and base stations used for the Sangputan floodplain using the Aquarius LiDAR system.

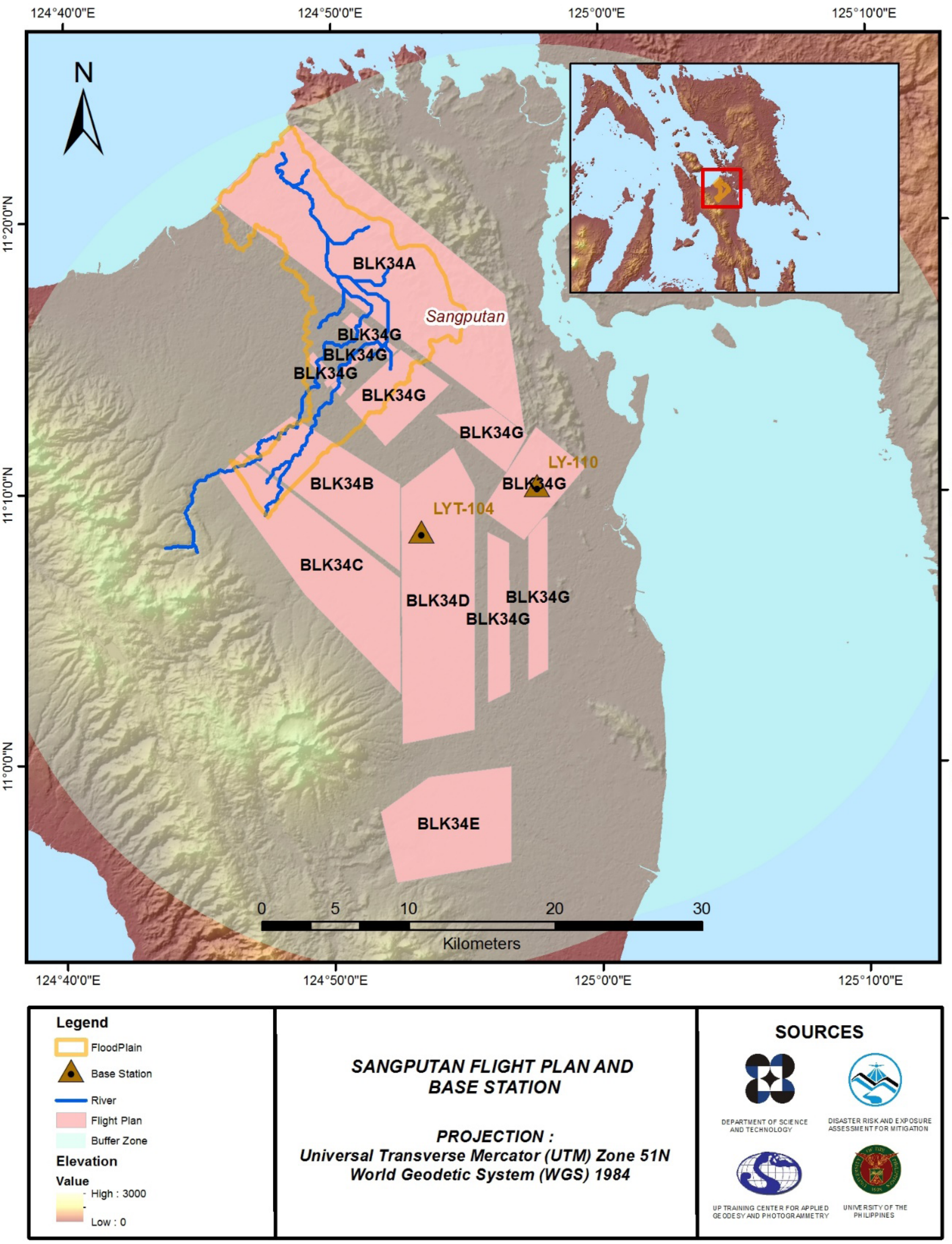


Figure 3. Flight plans and base stations used for the Sangputan floodplain using the Gemini LiDAR system.

2.2 Ground Base Stations

The field team for this undertaking was able to recover three (3) NAMRIA ground control points: LYT-104, SMR-56 and SMR-58, which are both of second (2nd) order accuracy. Three (3) NAMRIA benchmarks were also recovered: LY-110, LY-123 and SM-286, which are all of first (1st) order accuracy. These benchmarks were used as vertical reference points, and were also established as ground control points. The certifications for the NAMRIA reference points and benchmarks are found in Annex 2, while the baseline processing reports for the established control points are provided in Annex 3. These were used as the base stations during the flight operations for the entire duration of the survey, held on April 22 - May 14 2014, and January 22-24, 2016. The base stations were observed using dual frequency GPS receivers, TRIMBLE SPS 852, SPS 882, and SPS 985. The flight plans and locations of base stations used during the aerial LiDAR acquisition in the Sangputan floodplain are illustrated in Figure 2 and Figure 3. The composition of the project team is shown in Annex 4.

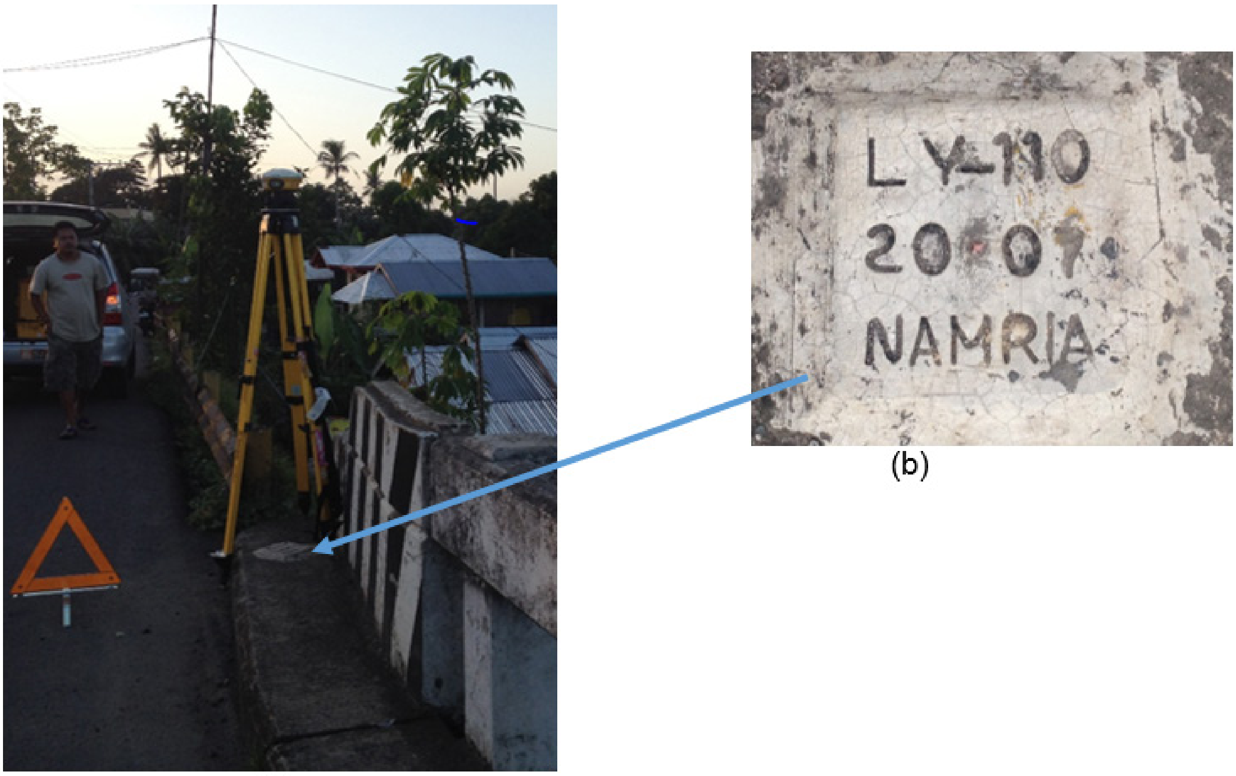
Figure 4 to Figure 9 depict the recovered NAMRIA control stations within the area. In addition, Table 3 to Table 8 present the details about the following NAMRIA control stations and established points. Table 9 lists all ground control points occupied during the acquisition, together with the dates they were utilized during the survey.

(a) (b)

Figure 4. (a) GPS set-up over LYT-104 located and re-established along a rice paddy trail, approximately 90 meters from the centerline, east side of Pastrana-Santa Fe Road, District IV, Pastrana, Leyte; and (b) NAMRIA reference point LYT-104, as recovered by the field team

Table 3. Details of the recovered and re-established NAMRIA horizontal control point LYT-104, used as base station for the LiDAR acquisition

Station Name	**LYT-104**	
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	11°08’38.92234” North 124o 53’ 13.52786” East 33.659 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Easting Northing Ellipsoidal Height	11°08’34.67033” North 124o 53’ 18.69323” East 95.861 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Latitude Longitude	706089.510 meters 1232496.838 meters



(a) (b)

Figure 5. (a) GPS set-up over LY-110 located along Palo-Pastrana Road, Pastrana, Leyte; and (b) NAMRIA reference point LY-110, as recovered by the field team

Table 4. Details of the recovered NAMRIA vertical control point LY-110, used as base station for the LiDAR acquisition with established coordinates

Station Name	LY-110	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 10’ 19.48389” North 124o 57’ 32.98736” East 14.336 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 10’ 15.23095” North 124o 57’ 38.14961” East 76.647 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	713,942.863 meters 1,235,638.117 meters

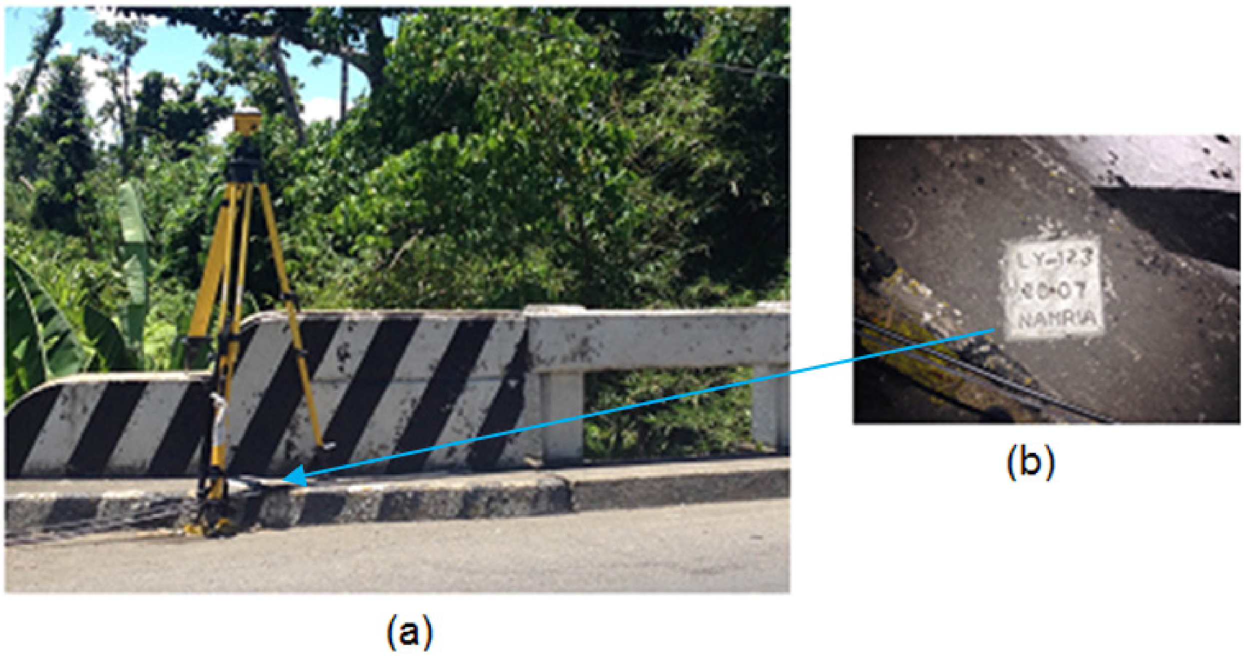


Figure 6. (a) GPS set-up over LY-123 located on a bridge at Barangay. Malaihao, Alangalang, Leyte, Pastrana, Leyte; and (b) NAMRIA reference point LY-123, as recovered by the field team

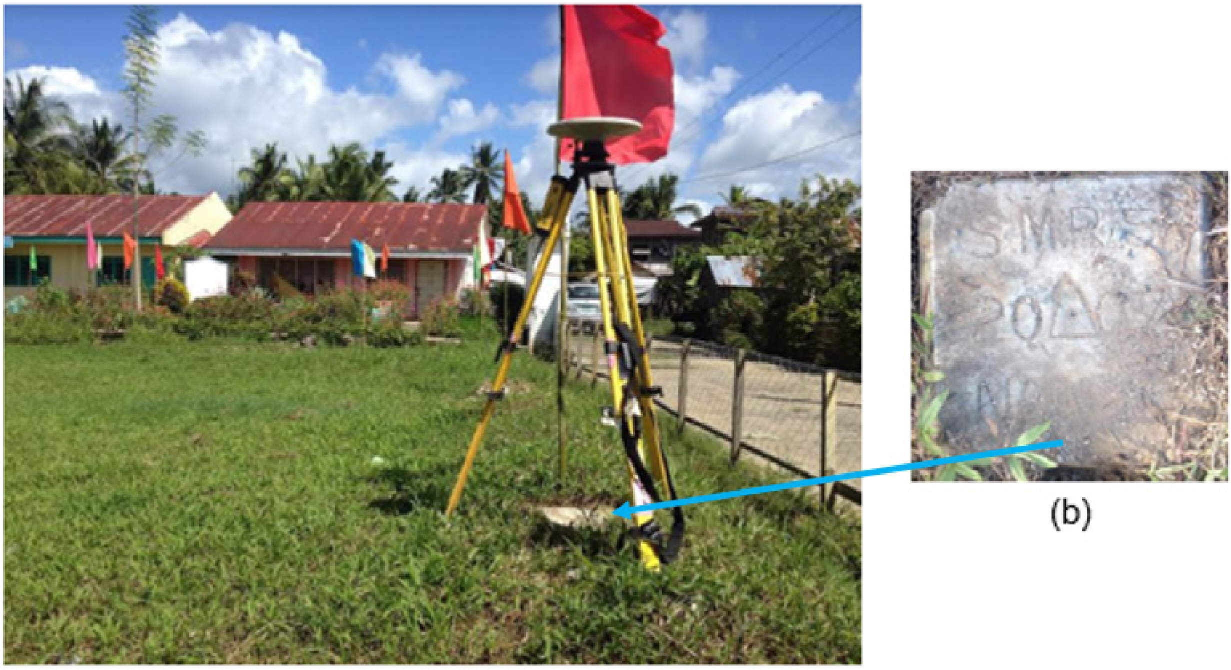
Table 5. Details of the recovered NAMRIA vertical control point LY-123, used as base station for the LiDAR acquisition with established coordinates

Station Name	LY-123	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11o 12’ 21.48” North 124o 51’ 07.02” East 34.95 m
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11o 12’ 16.64155” North 124o 51’ 11.29744” East 96.895 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	702335.856 meters 1239240.789 m meters

Figure 7. (a) GPS set-up over SMR-56 at Cabacungan Elementary School in Barangay Cabacungan, Sta. Rita, Samar; and (b) NAMRIA reference point SMR-56, as recovered by the field team

Table 6. Details of the recovered NAMRIA horizontal control point SMR-56, used as base station for the LiDAR acquisition

Station Name	SMR-56	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1 in 50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 23' 6.52702'' 125° 0' 23.99607'' 11.82200 m
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	500,727.475 meters 1,258,927.861 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 23' 2.22413'' North 125° 0' 29.13917'' East 73.72700 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	718,970.61 meters 1,259,244.38 meters



(a) (b)

Figure 8. (a) GPS set-up over SMR-58 located inside Serum Elementary School, Barangay Serum, Sangputan; and (b) NAMRIA reference point SMR-58, as recovered by the field team

Table 7. Details of the recovered NAMRIA horizontal control point SMR-58, used as base station for the LiDAR acquisition

Station Name	SMR-58	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude	11° 17’ 55.05617” North
	Longitude	125° 7’ 51.16145” East
	Ellipsoidal Height	6.30062 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting	514288.239 meters
	Northing	1249361.531 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude	11° 17’ 50.78580” North
	Longitude	125° 7’ 56.31100” East
	Ellipsoidal Height	68.72300 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting	732600.57 meters
	Northing	1249768.75 meters

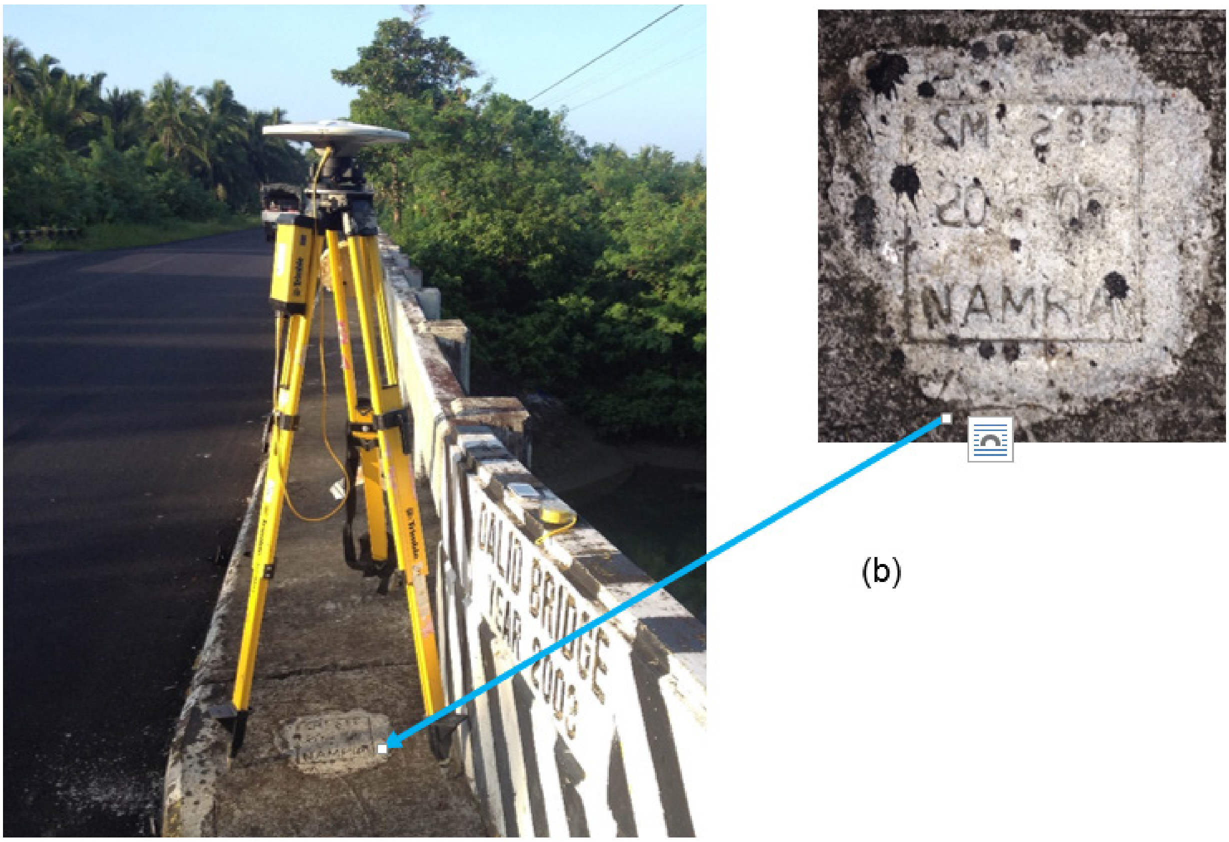


Figure 9. (a) GPS set-up over SM-286, located at Dalid Bridge along national highway in Brgy. San Pascual, Sta. Rita, Samar; and (b) NAMRIA reference point SM-286, as recovered by the field team

Table 8. Details of the recovered NAMRIA vertical control point SM-286, used as base station for the LiDAR acquisition with established coordinates

Station Name	SM-286	
Order of Accuracy	2nd	
Relative Error (horizontal positioning)	1:50,000	
Geographic Coordinates, Philippine Reference of 1992 Datum (PRS 92)	Latitude Longitude Ellipsoidal Height	11° 24’ 35.73” North 124° 59’ 44.05” East 5.47 meters
Grid Coordinates, Philippine Transverse Mercator Zone 5 (PTM Zone 5 PRS 92)	Easting Northing	499516.558 meters 1261668.44 meters
Geographic Coordinates, World Geodetic System 1984 Datum (WGS 84)	Latitude Longitude Ellipsoidal Height	11° 24’ 30.81671” North 124° 59’ 48.35250” East 67.268 meters
Grid Coordinates, Universal Transverse Mercator Zone 51 North (UTM 51N PRS 1992)	Easting Northing	717869.251 meters 1261905.903 meters

Table 9. Ground control points used during the LiDAR data acquisition

Date Surveyed	Flight Number	Mission Name	Ground Control Points
April 22,2014	1366A	3BLK34E112A	SMR-56 and SM-286
May 14, 2014	1454A	3BLK34D134A	SMR-56 and LY-123
May 14, 2014	1456A	3BLK34C134B	SMR-58 and LY-123
January 22, 2016	3765G	2BLK34AD022A	LYT-104 and LY-110
January 22, 2016	3767G	2BLK34AG022B	LYT-104 and LY-110
January 23, 2016	3769G	2BLK34ADEG023A	LYT-104 and LY-110
January 23, 2016	3771G	2BLK34BCG023B	LYT-104 and LY-110
January 24, 2016	3773G	2BLK34CG024A	LYT-104 and LY-110

2.3 Flight Missions

A total of eight (8) flight missions were conducted to complete the LiDAR data acquisition in the Sangputan floodplain, for a total of thirty two hours and thirty six minutes (32+36) of flying time for RP-C9122 and RP-C9022. The missions were acquired using the Aquarius and Gemini LiDAR systems. The flight logs are found in Annex 6. Table 10 shows the total area of actual coverage and the corresponding flying hours per mission, while Table 11 enumerates the actual parameters used during the LiDAR data acquisition.

Table 10. Flight missions for LiDAR data acquisition in the Sangputan 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
April 22,2014	1366A	111.13	120.79	49.20	71.59	1346	4	49
May 14, 2014	1454A	174.88	220.81	70.62	150.19	256/1013	4	29
May 14, 2014	1456A	88.96	97.85	12.33	85.52	998	3	41
January 22, 2016	3765G	248.10	180.76	70.15	110.61	0	4	11
January 22, 2016	3767G	257.55	148.01	69.90	78.11	0	3	23
January 23, 2016	3769G	403.32	171.76	0.80	170.96	0	4	23
January 23, 2016	3771G	219.11	150.85	20.61	130.24	0	3	29
January 24, 2016	3773G	170.85	102.77	16.09	86.68	0	4	11
TOTAL		1673.89	1193.6	309.7	883.9	3613	32	36

Table 11. Actual parameters used during the LiDAR data acquisition

Flight Number	Flying Height (m AGL)	Overlap (%)	FOV (θ)	PRF (kHZ)	Scan Frequency (Hz)	Average Speed (kts)	Average Turn Time (Minutes)
1366A	600	30	36	50	50	130	5
1454A	600	30	36	50	50	130	5
1456A	600	30	36	50	50	130	5
3765G	600/1100	30	34/50	100	40/50	130	5
3767G	850	30	40	100	50	130	5
3769G	600/1100	30	34/50	100	40/50	130	5
3771G	850	30	40	100	50	130	5
3773G	600	30	50	100	40	130	5

2.4 Survey Coverage

This certain LiDAR acquisition survey covered the Sangputan floodplain (See Annex 7 for the flight status reports). The Sangputan floodplain is located in the province of Leyte, with majority of the floodplain situated within the municipalities of San Miguel and Alangalang. The list of cities and municipalities surveyed, with at least one (1) square kilometer coverage, is provided in Table 12. The actual coverage of the LiDAR acquisition for the Sangputan floodplain is presented in Figure 10.

Table 12. List of municipalities and cities surveyed during the Sangputan floodplain LiDAR survey

Province	Municipality/City	Area of Municipality/City (km^2)	Total Area Surveyed (km^2)	Percentage of Area Surveyed
Leyte	Alangalang	145.45	145.44	100%
	Barugo	81.25	81.25	100%
	San Miguel	103.86	100.87	97%
	Santa Fe	57.15	54.3	95%
	Pastrana	79.17	67.88	86%
	Dagami	134.08	77.27	58%
	Palo	65.34	36.74	56%
	Tunga	17.36	9.76	56%
	Tabontabon	20.46	11.29	55%
	Jaro	190.65	69.13	36%
	Burauen	205.31	64.73	32%
	Tacloban City	118.46	34.3	29%
	Julita	57.17	11.68	20%
	Tanauan	62.78	8.4	13%
	Carigara	116.61	13.07	11%
	Babatngon	136.57	8.04	6%
Total		1591.67	794.15	49.89%

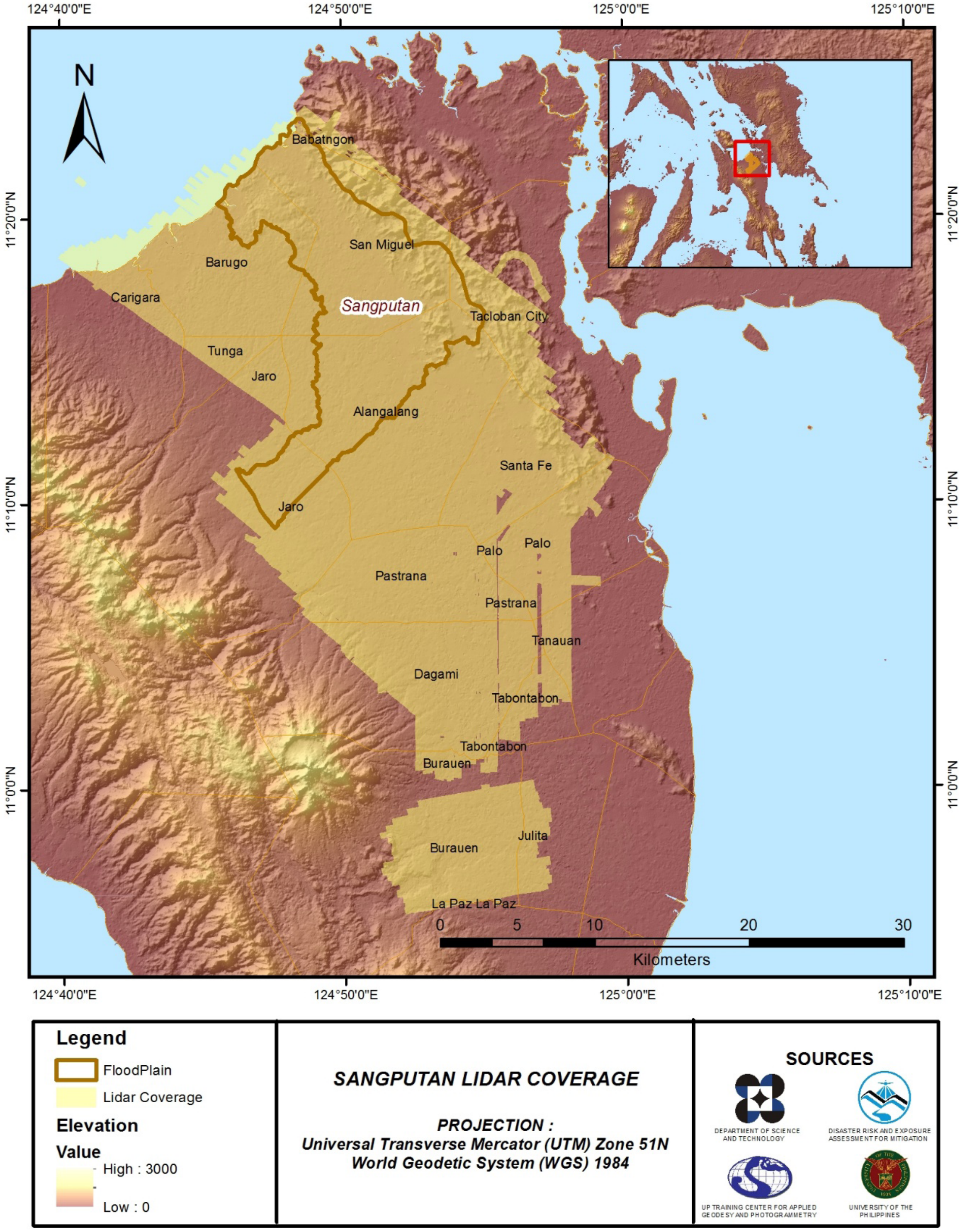


Figure 10. Actual LiDAR survey coverage of the Sangputan floodplain

CHAPTER 3: LIDAR DATA PROCESSING OF THE SANGPUTAN 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 the correct position and orientation for each point acquired. The georectified LiDAR point clouds were subjected to quality checking to ensure that the required accuracies of the program, which are the minimum point density, and vertical and horizontal accuracies, were met. The point clouds were then classified into various classes before generating Digital Elevation Models (DEMs), such as the Digital Terrain Model (DTM) and the Digital Surface Model (DSM).

Using the elevation of points gathered 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 (DVBC). LiDAR acquired temporally were then mosaicked to completely cover the target river systems in the Philippines. Orthorectification of images acquired simultaneously with the LiDAR data was accomplished through the help of the georectified point clouds and the metadata containing the time the image was captured.
These processes are summarized in the diagram shown in Figure 11.

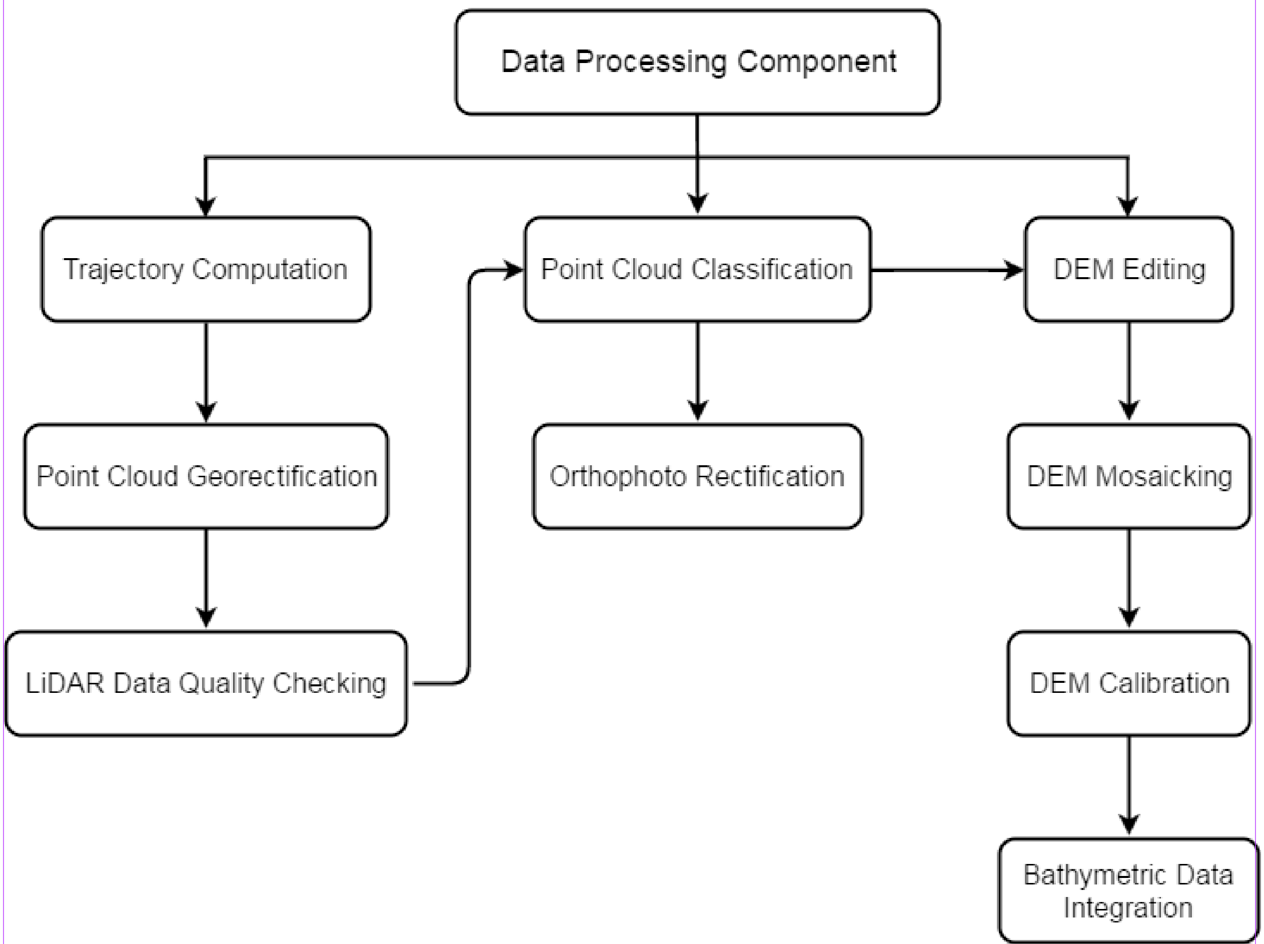


Figure 11. Schematic diagram for the Data Pre-Processing Component

3.2 Transmittal of Acquired LiDAR Data

Data transfer sheets for all the LiDAR missions for the Sangputan floodplain can be found in Annex 5. Missions flown during the first survey, conducted in April 2014, used the Airborne LiDAR Terrain Mapper (ALTM™ Optech Inc.) Aquarius system. On the other hand, missions acquired during the last survey in January 2016 were flown using the Gemini system over Leyte. The DAC transferred a total of 146.30 Gigabytes of Range data, 1.92 Gigabytes of POS data, 56.16 Megabytes of GPS base station data, and 177.80 Gigabytes of raw image data to the data server on April 22, 2014 for the first survey, and on January 24, 2016 for the last survey. The Data Pre-processing Component (DPPC) verified the completeness of the transferred data. The whole dataset for Sangputan was fully transferred on February 12, 2016, as indicated on the data transfer sheets for the Sangputan floodplain.

3.3 Trajectory Computation

The Smoothed Performance Metric parameters of the computed trajectory for flight 3771G, one of the Sangputan flights, which are the North, East, and Down position RMSE values, are exhibited in Figure 12. The x-axis corresponds to the time of flight, which is measured by the number of seconds from the midnight of the start of the GPS week, which fell on January 23, 2016 at 00:00 hours on that week. The y-axis is the RMSE value for that particular position.

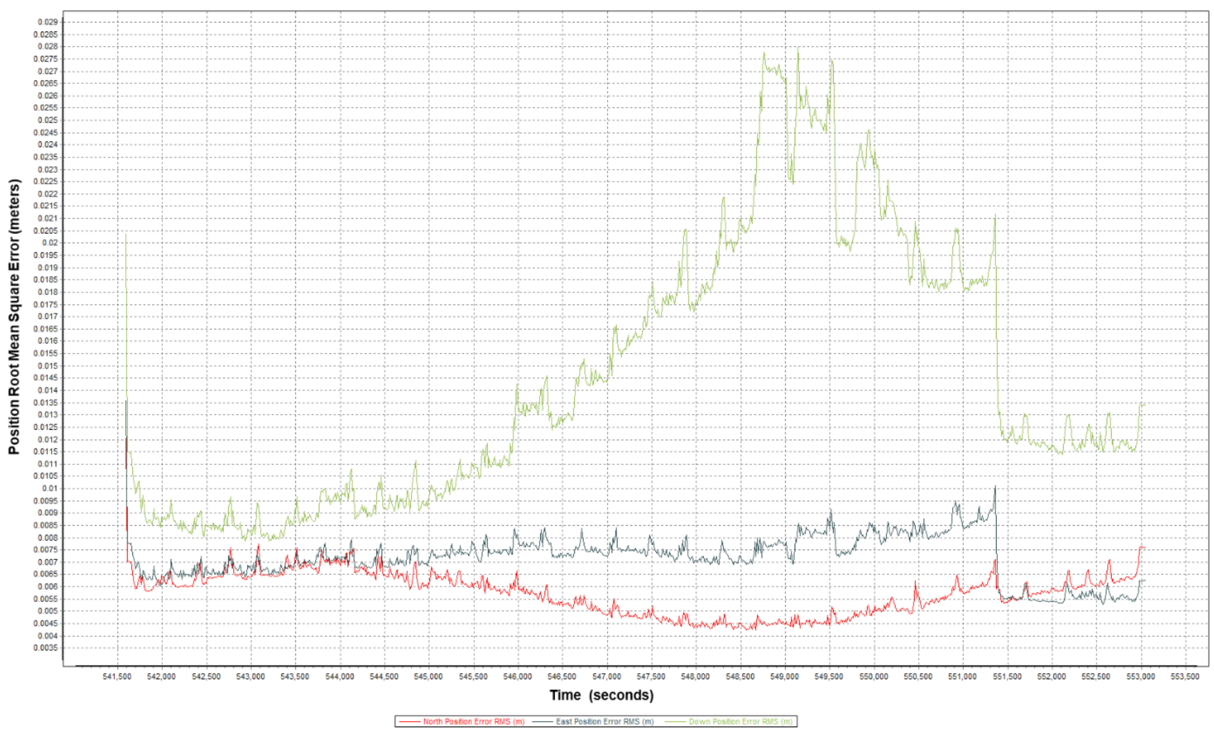


Figure 12. Smoothed Performance Metric Parameters of Sangputan Flight 3771G

The time of flight was from 541500 seconds to 553500 seconds, which corresponds to the afternoon of January 23, 2016. The initial spike reflected on the data corresponds to the time that the aircraft was getting into position to start the acquisition, and the POS system was starting to compute for the position and orientation of the aircraft. Redundant measurements from the POS system quickly minimized the RMSE 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 12 shows that the North position RMSE peaked at 0.80 centimeters, the East position RMSE peaked at 1.05 centimeters, and the Down position RMSE peaked at 2.80 centimeters, which are all within the prescribed accuracies described in the methodology.

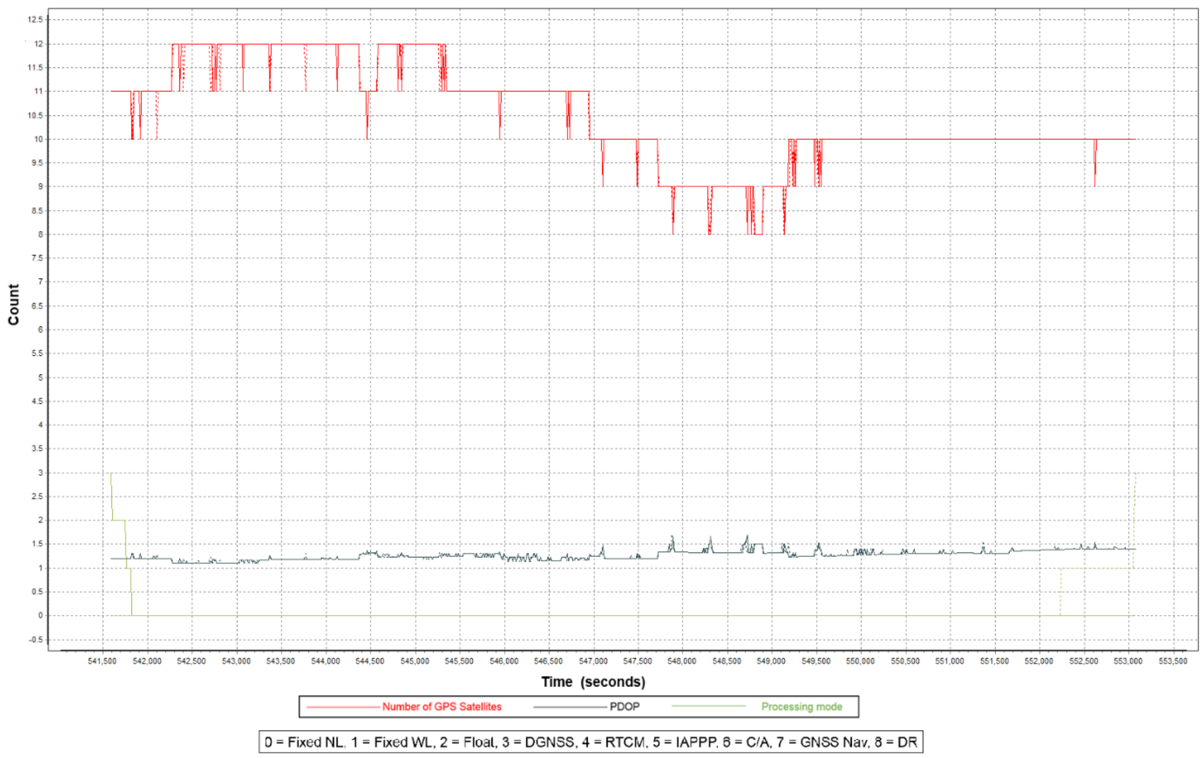


Figure 13. Solution Status Parameters of Sangputan Flight 3771G

The Solution Status parameters of flight 3771G, one of the Sangputan flights, which are the number of GPS satellites, Positional Dilution of Precision (PDOP), and the GPS processing mode used, are presented in Figure 13. The graphs indicate that the number of satellites during the acquisition did not go down to six (6). Majority of the time, the number of satellites tracked was between eight (8) and twelve (12). The PDOP value also did not go above the value of three (3), which indicates optimal GPS geometry. The processing mode remained at the value of zero (0) for majority of the survey with some peaks up to one (1), attributed to the turns performed by the aircraft. The value of zero (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 satisfied the accuracy requirements for optimal trajectory solutions, as indicated in the methodology. The computed best estimated trajectory for all Sangputan flights is shown in Figure 14.

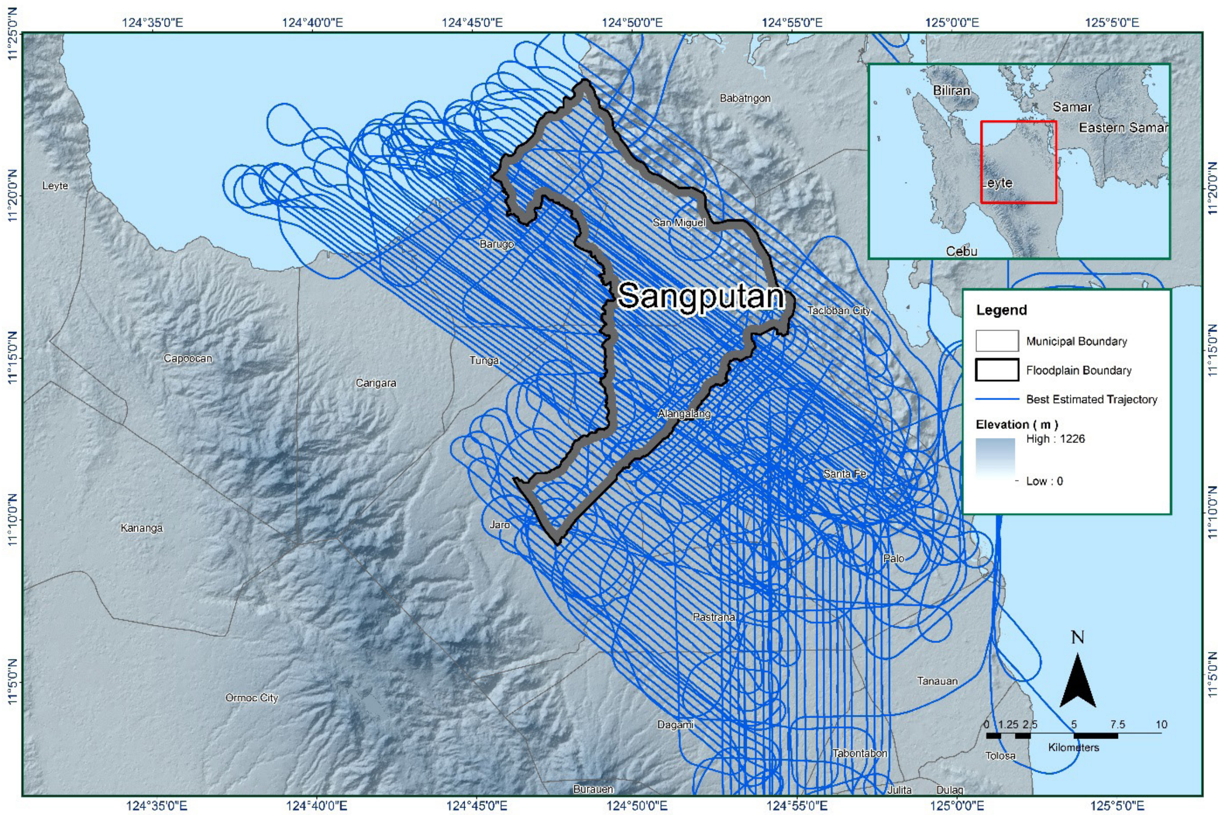


Figure 14. The best estimated trajectory conducted over the Sangputan floodplain

3.4 LiDAR Point Cloud Computation

The produced LAS data contains 113 flight lines, with each flight line containing one (1) channel, since the Gemini and Aquarius systems both contain only one (1) channel. The self-calibration results obtained from LiDAR processing in the LiDAR Mapping Suite (LMS) software for all flights over the Sangputan floodplain are summarized in Table 13.

Table 13. Self-calibration results for the Sangputan flights

Parameter	Computed Value
Boresight Correction stdev (<0.001degrees)	0.000620
IMU Attitude Correction Roll and Pitch Corrections stdev (<0.001degrees)	0.000999
GPS Position Z-correction stdev (<0.01meters)	0.0071

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

3.5 LiDAR Data Quality Checking

The boundaries of the processed LiDAR data on top of a SAR Elevation Data over the Sangputan floodplain are illustrated in Figure 15. The map shows gaps in the LiDAR coverage that are attributed to cloud coverage.

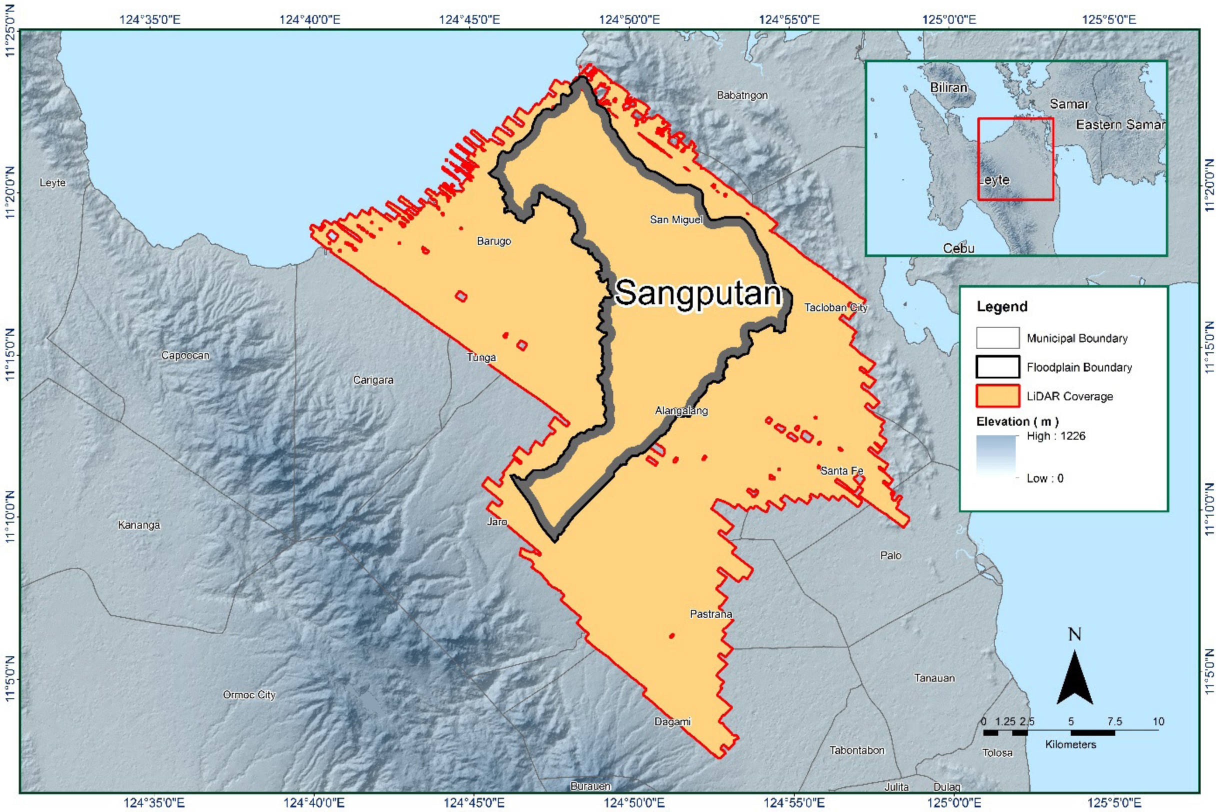


Figure 15. Boundaries of the processed LiDAR data over the Sangputan floodplain

The total area covered by the Sangputan missions is 716.13 sq. km., comprised of eight (8) flight acquisitions grouped and merged into seven (7) blocks, as shown in Table 14.

Table 14. List of LiDAR blocks for the Sangputan floodplain

LiDAR Blocks	Flight Numbers	Area (sq. km)
Samar_Leyte_Blk34C	1456A	93.61
Samar_Leyte_Blk34D	1454A	97.51
Samar_Leyte_Blk34E	1366A	111.50
Leyte Blk34C	3771G	145.96
	3773G	
Leyte Blk34D	3767G	84.89
	3773G	
Leyte Blk34E	3765G	171.26
	3767G	
Leyte Blk34E_additional	3769G	11.40
TOTAL		716.13 sq.km

The overlap data for the merged LiDAR blocks, showing the number of channels that pass through a particular location, is exhibited in Figure 16. Since the Gemini and Aquarius systems both employ only one (1) channel, it is expected to have an average value of 1 (blue) for areas where there is limited overlap, and a value of 2 (yellow) or more (red) for areas with three or more overlapping flight lines.

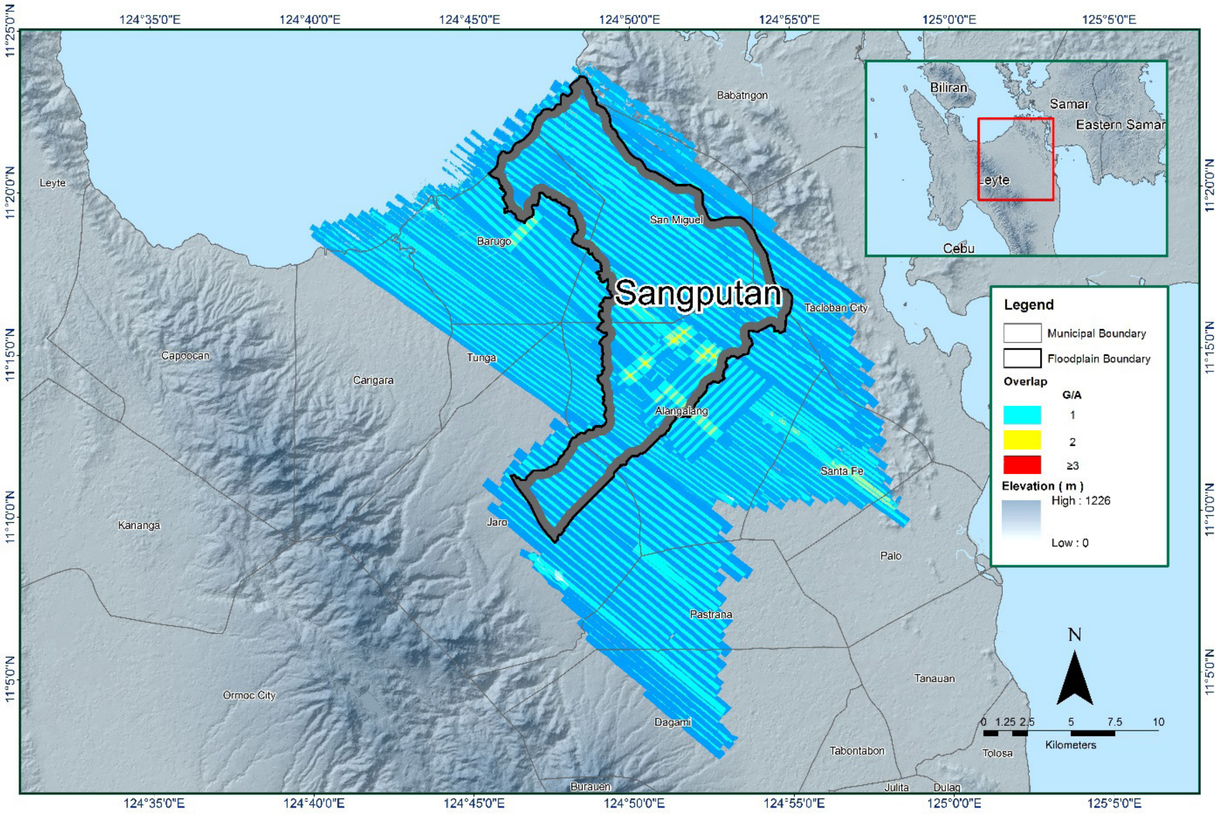


Figure 16. Image of data overlap for Sangputan floodplain

The overlap statistics per block for the Sangputan floodplain can be found in Annex 8. One (1) pixel corresponds to 25.0 square meters on the ground. For this area, the minimum and maximum percent overlaps are 29.29% and 53.44% 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 two (2) points per square meter criterion, is presented in Figure 17. It was determined that all LiDAR data for the Sangputan floodplain satisfy the point density requirement, and that the average density for the entire survey area is 3.82 points per square meter.

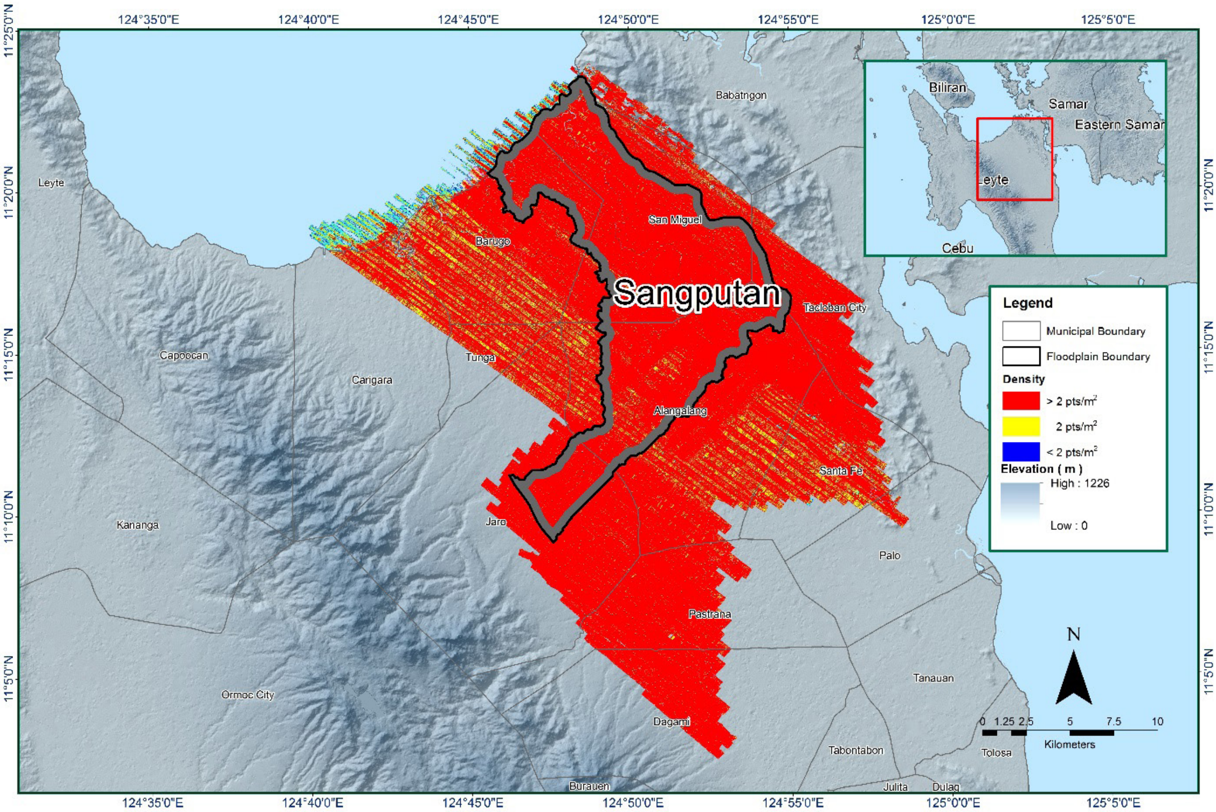


Figure 17. Pulse density map of merged LiDAR data for the Sangputan floodplain

The elevation difference between overlaps of adjacent flight lines is shown in Figure 18. 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 were investigated further using the Quick Terrain (QT) Modeler software.

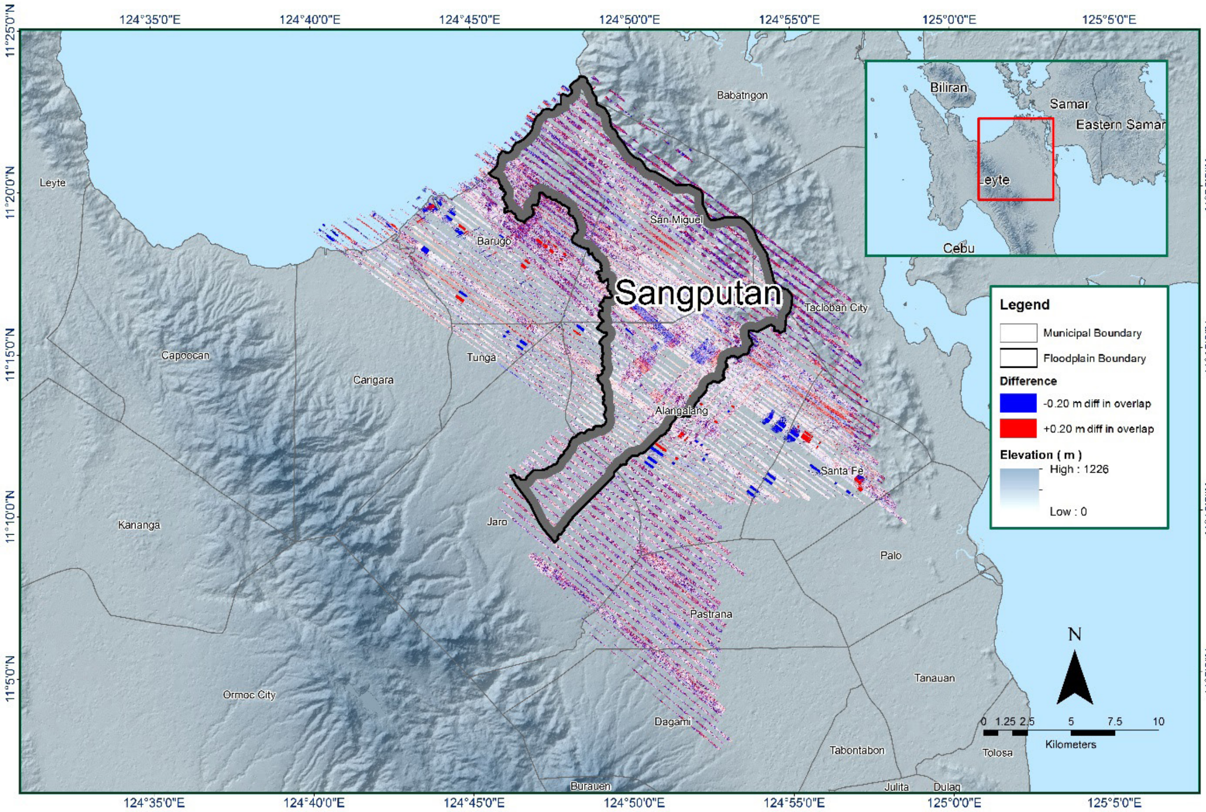


Figure 18. Elevation difference map between flight lines for Sangputan floodplain

A screen capture of the processed LAS data from Sangputan flight 3771G loaded in the QT Modeler is shown in Figure 19. The upper left image shows the elevations of the points from two overlapping flight strips traversed by the profile, illustrated by a dashed yellow line. The x-axis corresponds to the length of the profile. It is evident that there were differences in elevation, but the differences did not exceed the 20-centimeter mark. This profiling was repeated until the quality of the LiDAR data became satisfactory. No reprocessing was done for this LiDAR dataset.

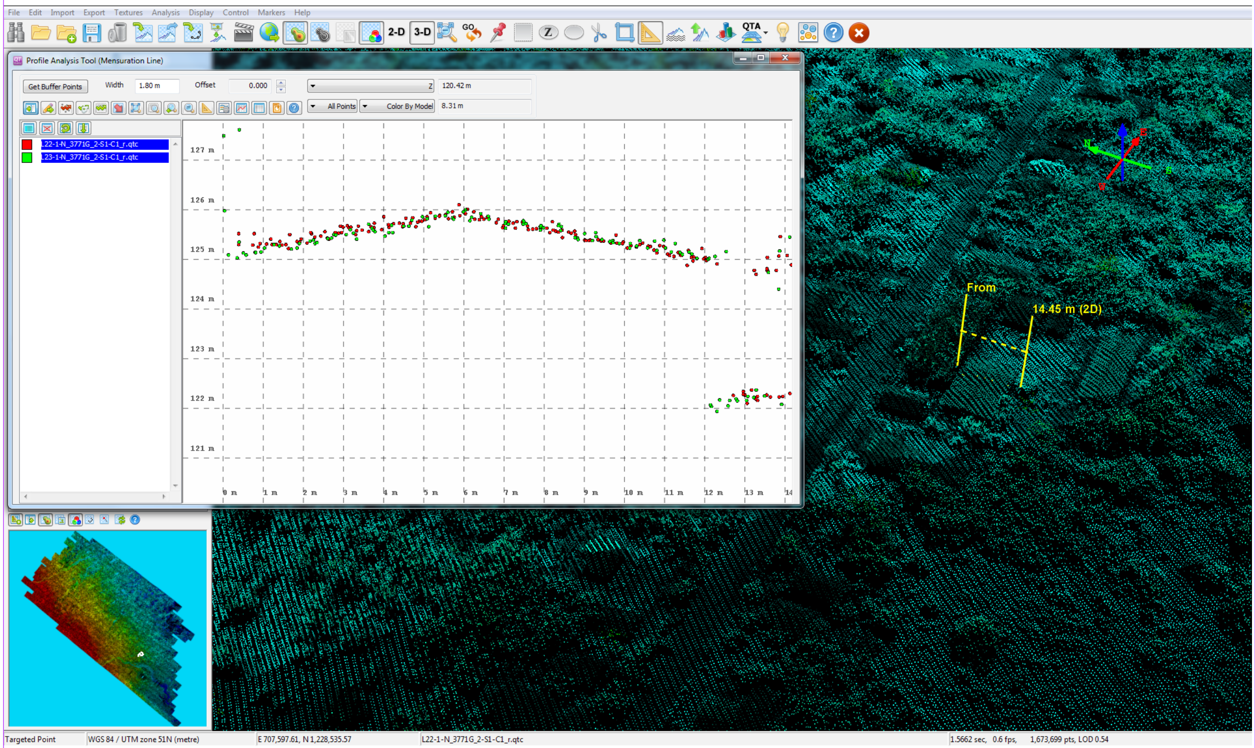


Figure 19. Quality checking for Sangputan flight 3771G using the Profile Tool of QT Modeler

3.6 LiDAR Point Cloud Classification and Rasterization

Table 15. Sangputan classification results in TerraScan

Pertinent Class	Total Number of Points
Ground	384,464,263
Low Vegetation	405,448,941
Medium Vegetation	825,932,147
High Vegetation	519,361,151
Building	10,153,994

The tile system that the TerraScan employed for the LiDAR data and the final classification image for a block in the Sangputan floodplain is presented in Figure 20. A total of 906 1km by 1km tiles were produced. The number of points classified according to the pertinent categories is illustrated in Table 15. The point cloud had a maximum and minimum height of 582.56 meters and 59.09 meters, respectively.

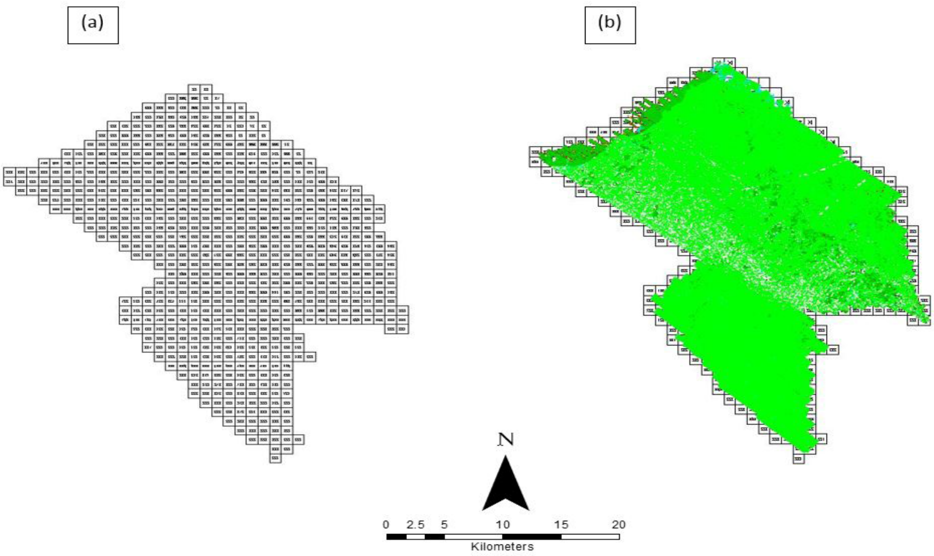


Figure 20. (a) Tiles for the Sangputan floodplain; and (b) classification results in TerraScan

An isometric view of an area before and after running the classification routines is provided in Figure 21. 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 were classified correctly, due to the density of the LiDAR data.

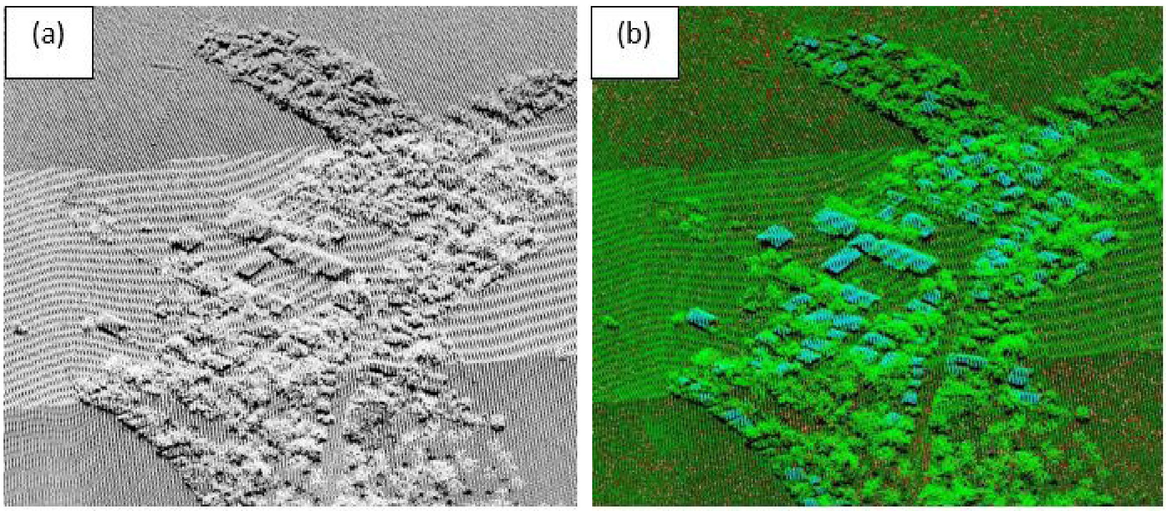


Figure 21. Point cloud (a) before and (b) after classification

The production of last return (V_ASCII) and the secondary (T_ ASCII) DTM, and the first (S_ ASCII) and last (D_ ASCII) return DSM of the area, in top view display are illustrated in Figure 22. It shows that DTMs are the representation of the bare earth, while the DSMs reflect all features that are present, such as buildings and vegetation.

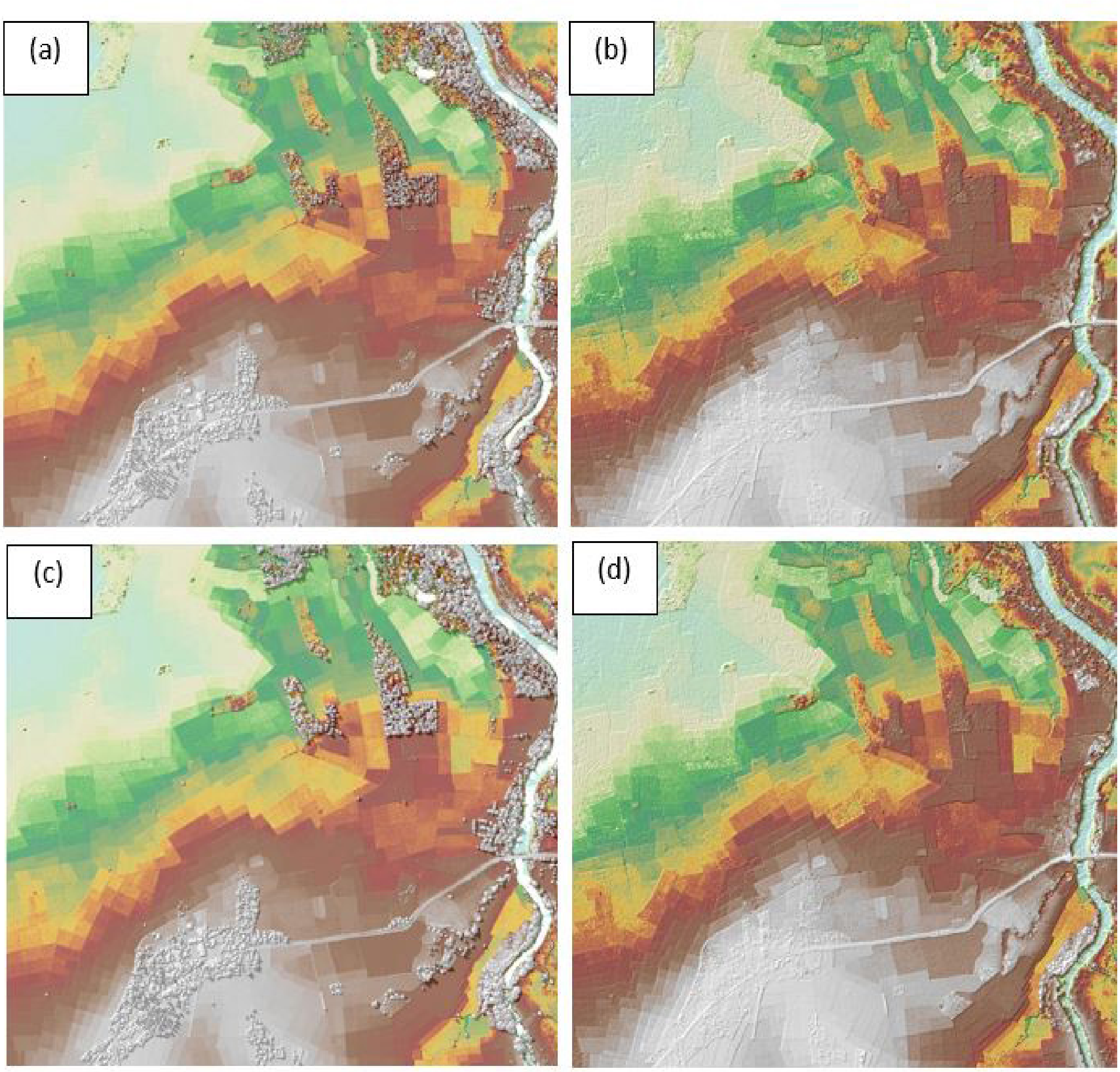


Figure 22. The production of (a) last return DSM and (b) DTM, (c) first return DSM and (d) secondary DTM in some portion of the Sangputan floodplain

3.7 LiDAR Image Processing and Orthophotograph Rectification

The 454 1km by 1km tiles area covered by the Sangputan floodplain is shown in Figure 23. After employing tie point selection to fix photo misalignments, color points were added to smoothen out visual inconsistencies along the seamlines where photos overlap. The Sangputan floodplain survey attained a total of 302.27 sq. km. in orthophotogaphic coverage, comprised of 3,277 images. Zoomed-in versions of sample orthophotographs, identified by their tile numbers, are exhibited in Figure 24.

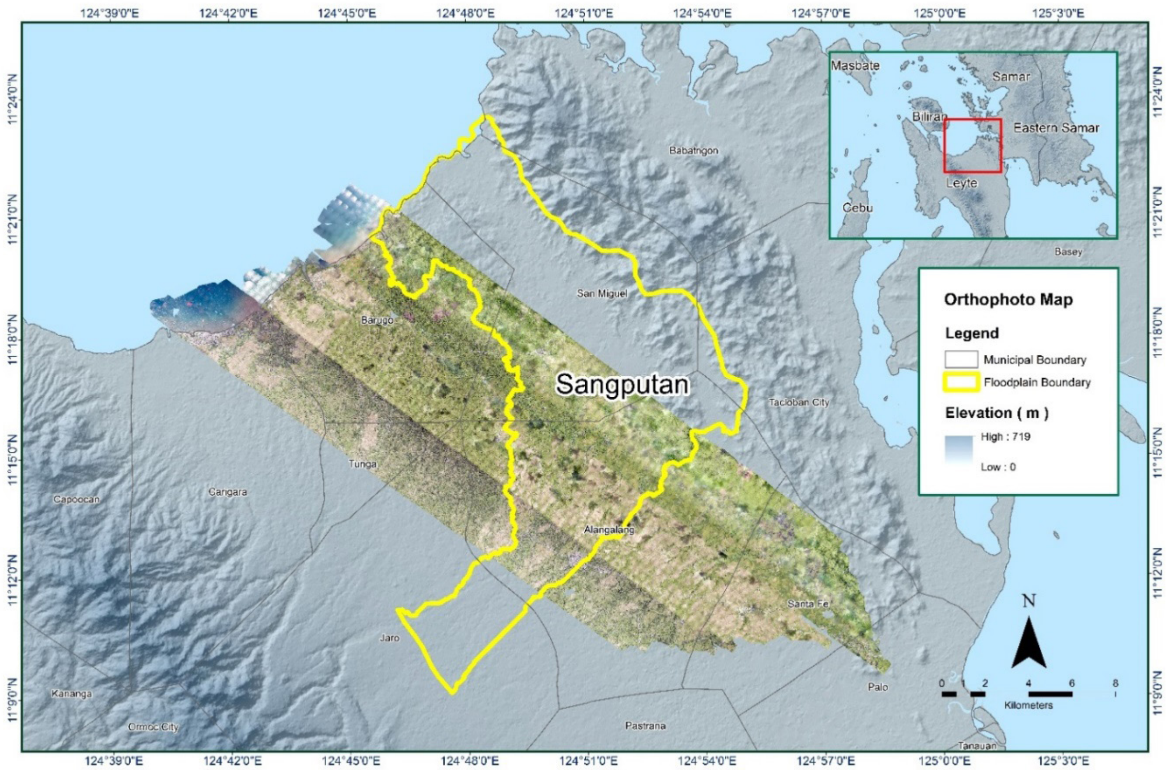


Figure 23. The Sangputan floodplain with available orthophotographs

Figure 24. Sample orthophotographic tiles for the Sangputan floodplain

3.8 DEM Editing and Hydro-Correction

Seven (7) mission blocks were processed for the Sangputan floodplain. These blocks are composed of SamarLeyte and Leyte blocks, with a total area of 716.13 square kilometers. Table 16 lists the name and corresponding area of each block, in square kilometers.

Table 16. LiDAR blocks with their corresponding areas

LiDAR Blocks	Area (sq.km)
SamarLeyte_Blk34D	97.51
SamarLeyte_Blk34E	111.50
Leyte_Blk34C	145.96
SamarLeyte_Blk34C	93.61
Leyte_Blk34D	84.89
Leyte_Blk34E	171.26
Leyte_Blk34E_additional	11.40
TOTAL	716.13 sq.km

Figure 25 shows portions of the DTM before and after manual editing. As evident in the figure, areas with no data along water bodies had to be interpolated for hydrologic correction. The bridge (Figure 25a) was considered to be an impedance to the flow of water along the river, and had to be removed (Figure 25b). The paddy field (Figure 25c) had been misclassified and removed during the classification process, and had to be retrieved to complete the surface (Figure 25d), to allow for the correct flow of water.

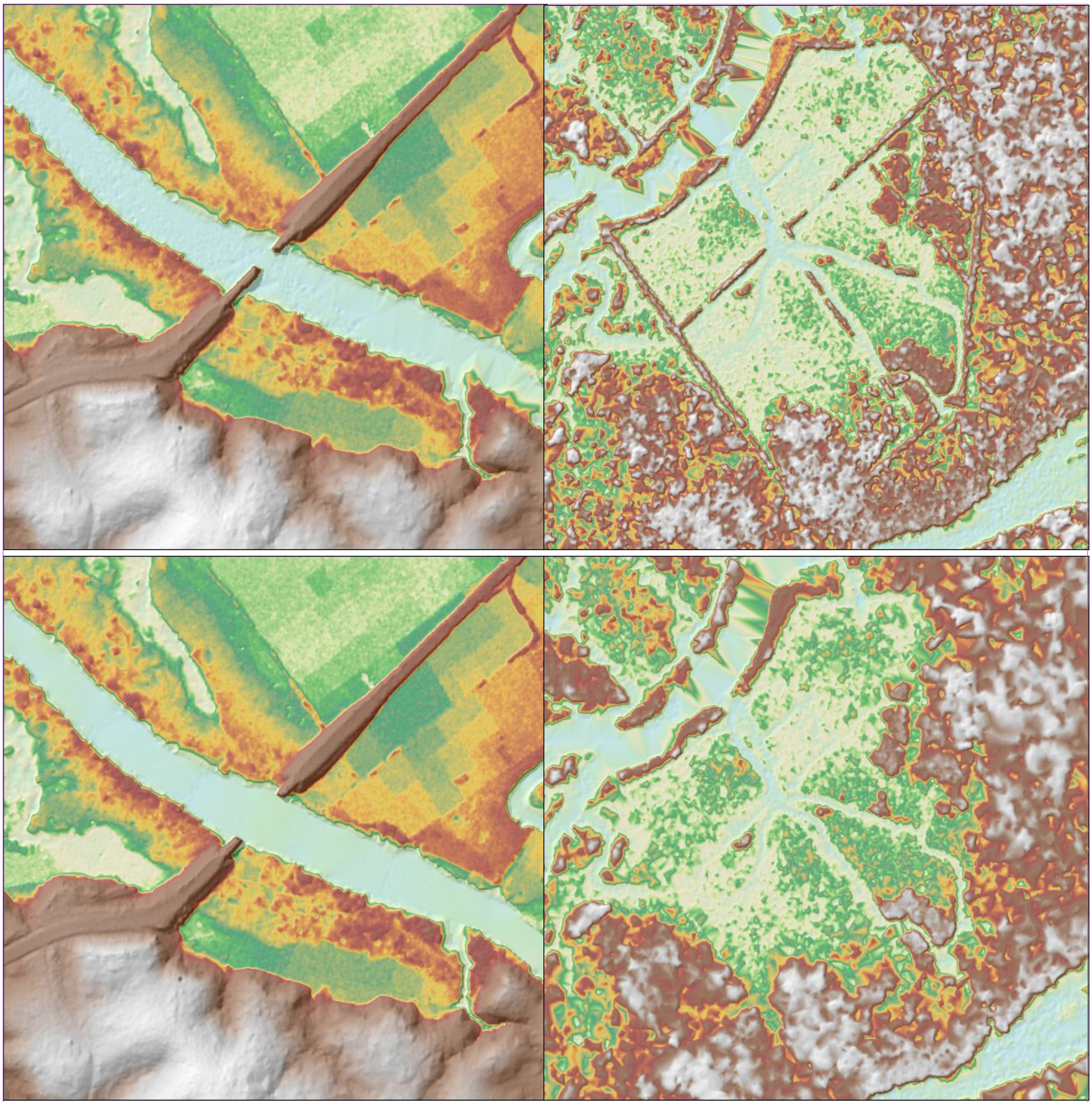


Figure 25. Portions in the DTM of the Sangputan floodplain – a bridge (a) before and (b) after manual editing; and a paddy field (c) before and (d) after data retrieval

3.9 Mosaicking of Blocks

No assumed reference block was used in mosaicking because the identified reference for shifting was an existing calibrated Tacloban DEM, overlapping with the blocks to be mosaicked. Table 17 enumerates the shift values applied to each LiDAR block during mosaicking.

Mosaicked LiDAR DTM for the Sangputan floodplain is shown in Figure 26. It is visible that the entire Sangputan floodplain is 100% covered by LiDAR data.

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

Mission Blocks	Shift Values (meters)		
	x	y	z
SamarLeyte_Blk34D	0.00	0.00	-0.59
SamarLeyte_Blk34E	0.00	0.00	-0.59
Leyte_Blk34C	0.00	-1.00	-1.13
SamarLeyte_Blk34C	0.00	0.00	-0.67
Leyte_Blk34D	0.00	0.00	0.48
Leyte_Blk34E	0.00	0.00	-1.22
Leyte_Blk34E_additional	No Overlapped Area	No Overlapped Area	No Overlapped Area

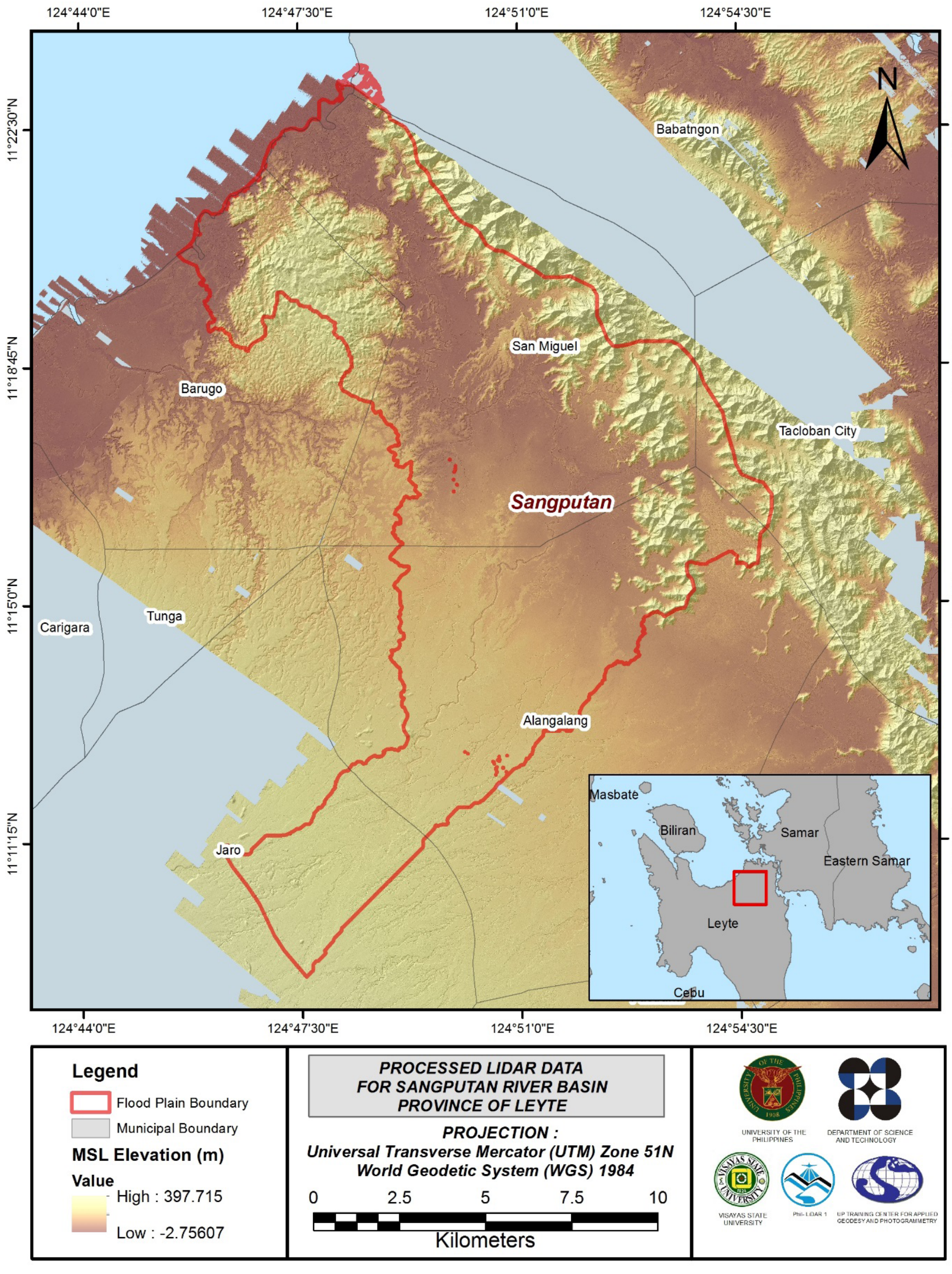


Figure 26. Map of processed LiDAR data for the Sangputan floodplain

3.10 Calibration and Validation of Mosaicked LiDAR DEM

To undertake the data validation of the Mosaicked LiDAR DEMs, the DVBC conducted a validation survey along the Sangputan floodplain. The extent of the validation survey in Sangputan to collect points with which the LiDAR dataset was validated is shown in Figure 27, with the validation survey points highlighted in green. A total of 3,325 survey points were gathered for the Sangputan floodplain. However, the point dataset was not used for the calibration of the LiDAR data for Sangputan because during the mosaicking process, each LiDAR block was referred to the calibrated Tacloban DEM. Therefore, the mosaicked DEM of Sangputan can already be considered as a calibrated DEM.

A good correlation between the uncalibrated Tacloban LiDAR DTM and the ground survey elevation values is reflected in Figure 28. Statistical values were computed from extracted LiDAR values using the selected points, to assess the quality of data and to obtain the value for vertical adjustment. The computed height difference between the LiDAR DTM and calibration points is 0.14 meters, with a standard deviation of 0.13 meters. Calibration of Tacloban LiDAR data was done by subtracting the height difference value, 0.14 meters, from the Tacloban mosaicked LiDAR data. Table 18 summarizes the statistical values of the compared elevation values between the Tacloban LiDAR data and the calibration data. These values are also applicable to the Sangputan DEM.

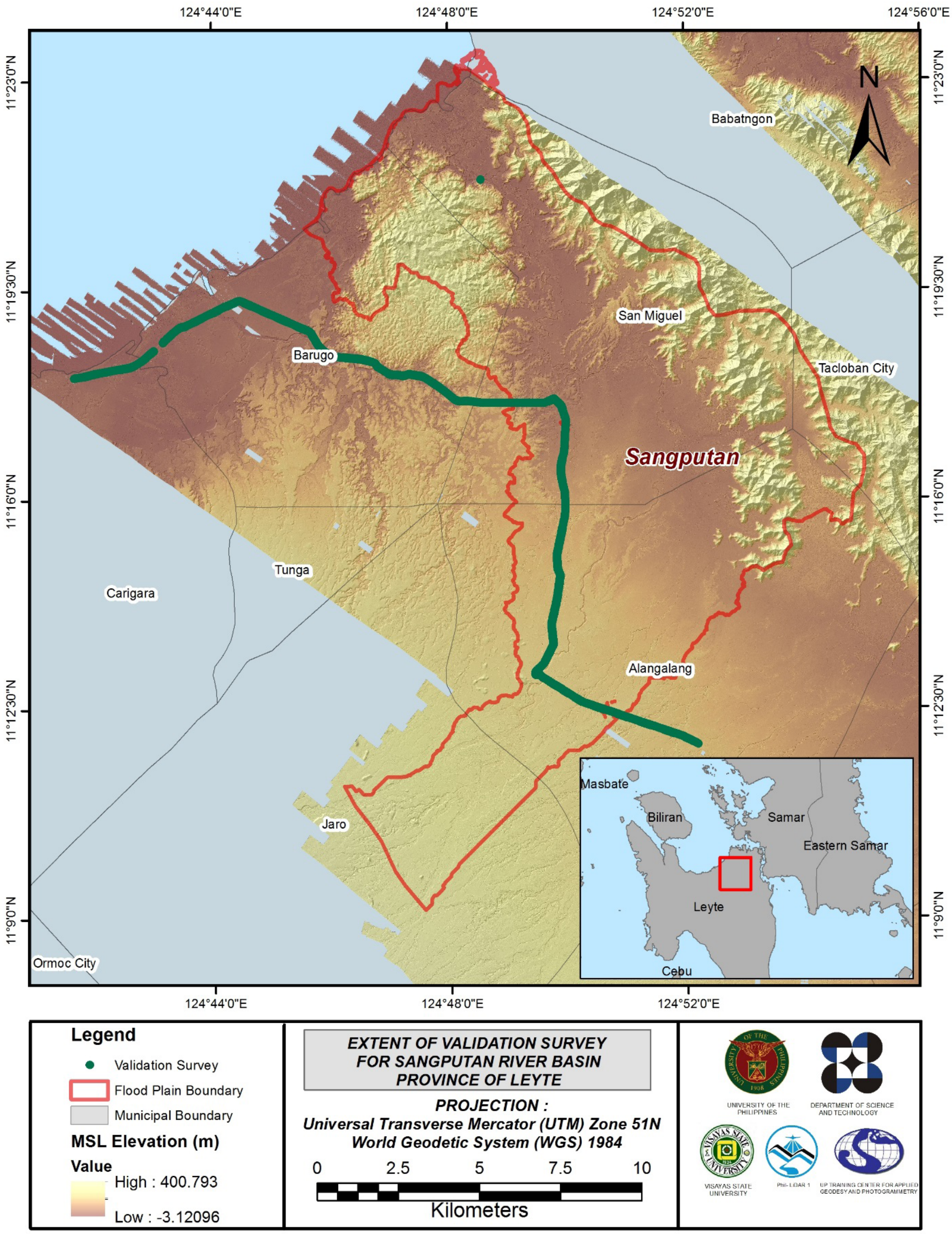


Figure 27. Map of the Sangputan floodplain, with validation survey points in green

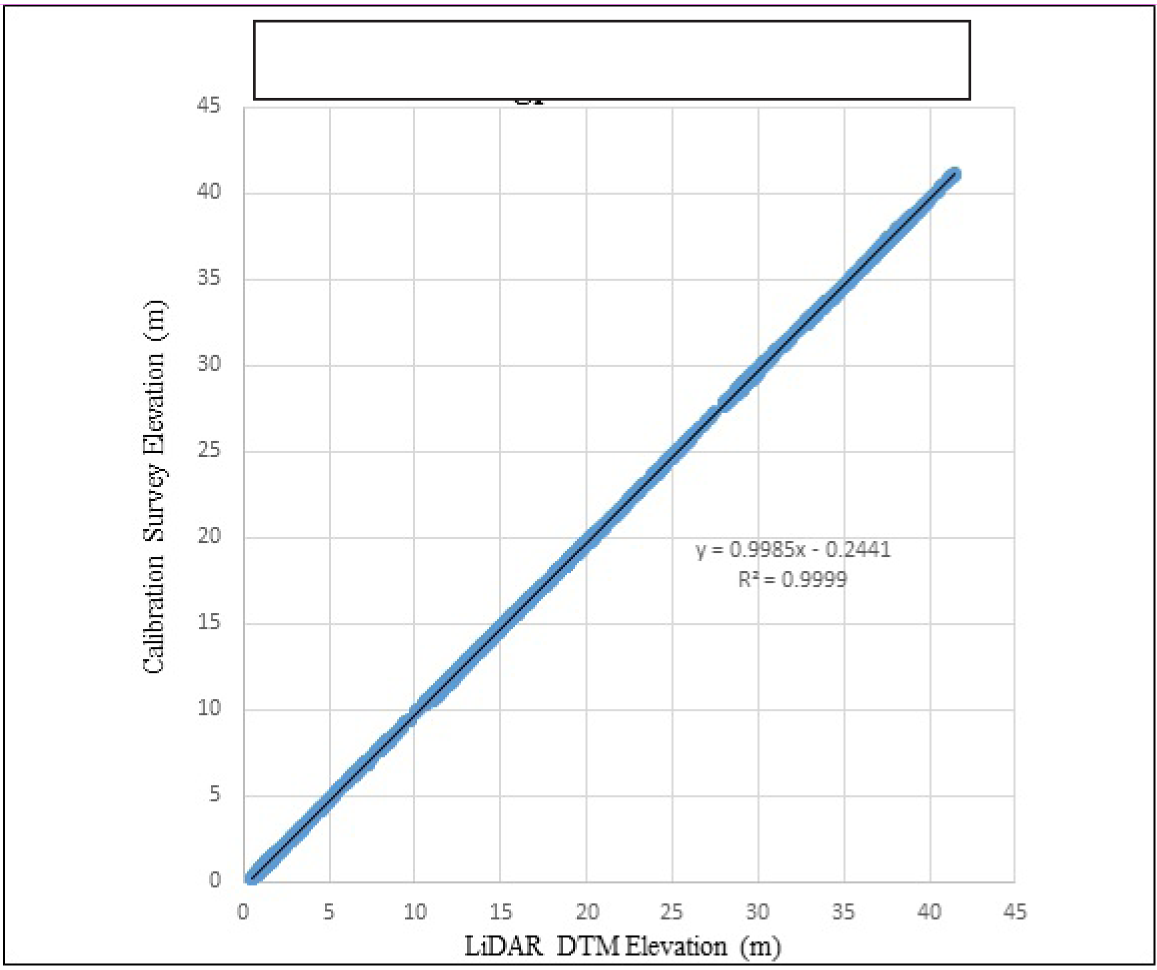


Figure 28. Correlation plot between the calibration survey points and the LiDAR data

Table 18. Calibration Statistical Measures

Calibration Statistical Measures	Value (meters)
Height Difference	0.14
Standard Deviation	0.13
Average	-0.05
Minimum	-0.32
Maximum	0.22

A total of 1,236 survey points lie within the Sangputan floodplain, and were used for the validation of the calibrated Sangputan DTM. A good correlation between the calibrated mosaicked LiDAR elevation values and the ground survey elevation, which reflects the quality of the LiDAR DTM, is presented in Figure 29. The computed RMSE between the calibrated LiDAR DTM and the validation elevation values is 0.15 meters, with a standard deviation of 0.08 meters, as shown in Table 19.

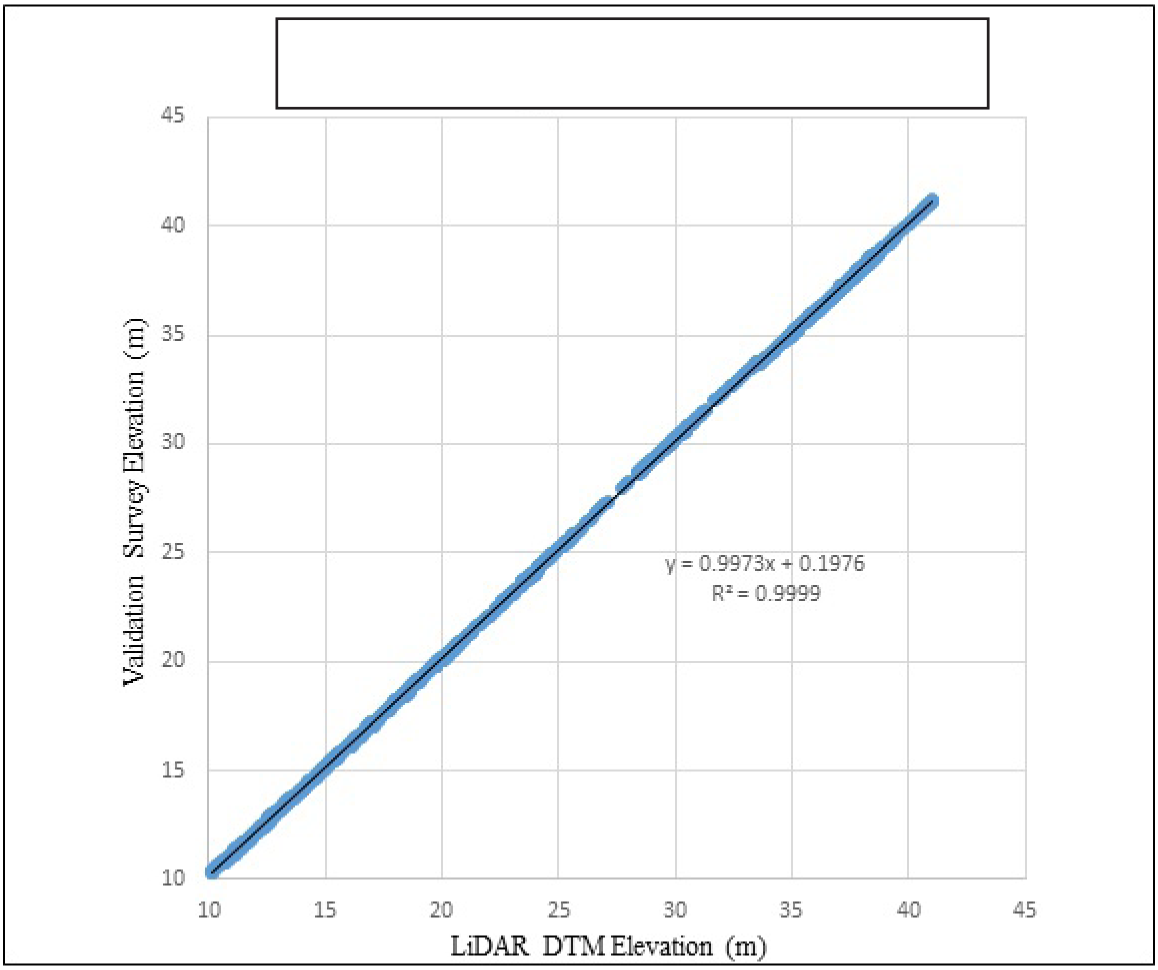


Figure 29. Correlation plot between the validation survey points and the LiDAR data

Table 19. Validation Statistical Measures

Validation Statistical Measures	Value (meters)
RMSE	0.15
Standard Deviation	0.08
Average	-0.13
Minimum	-0.28
Maximum	0.02

3.11 Integration of Bathymetric Data into the LiDAR Digital Terrain Model

For bathy integration, centerline and zigzag data were available for Sangputan, with 18,995 bathymetric survey points. The resulting raster surface produced was accomplished by employing the 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 0.28 meters. The extent of the bathymetric survey done by the DVBC in Sangputan, integrated with the processed LiDAR DEM, is shown in Figure 30.

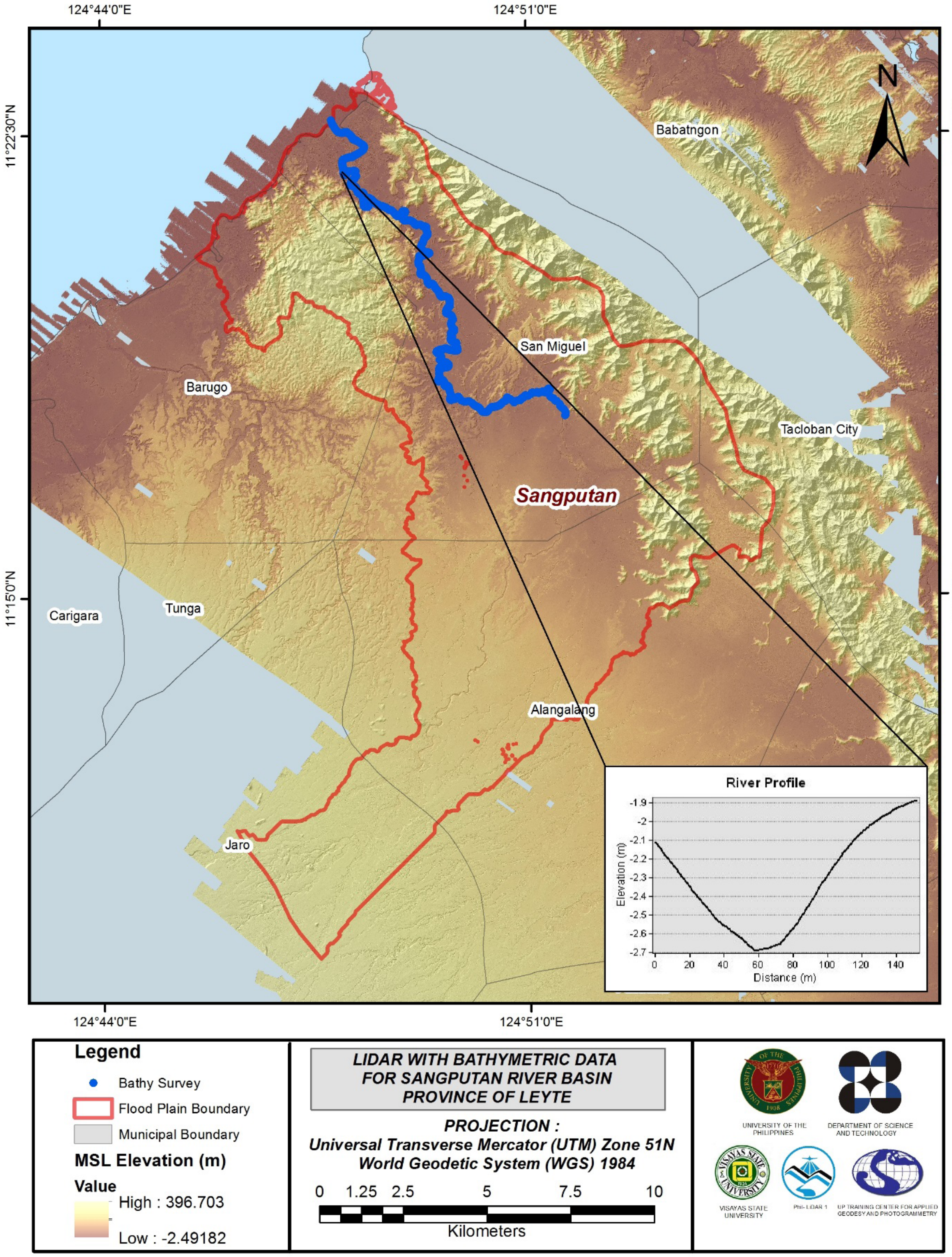


Figure 30. Map of the Sangputan floodplain, with bathymetric survey points shown in blue

3.12 Feature Extraction

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

3.12.1 Quality Checking of Digitized Features' Boundary

The Sangputan floodplain, including its 200-m buffer, has a total area of 192.20 sq. km. Of this area, a total of 6.0 sq. km, corresponding to a total of 1,194 building features, were considered for quality checking (QC). Figure 31 illustrate the QC blocks for the Sangputan floodplain.

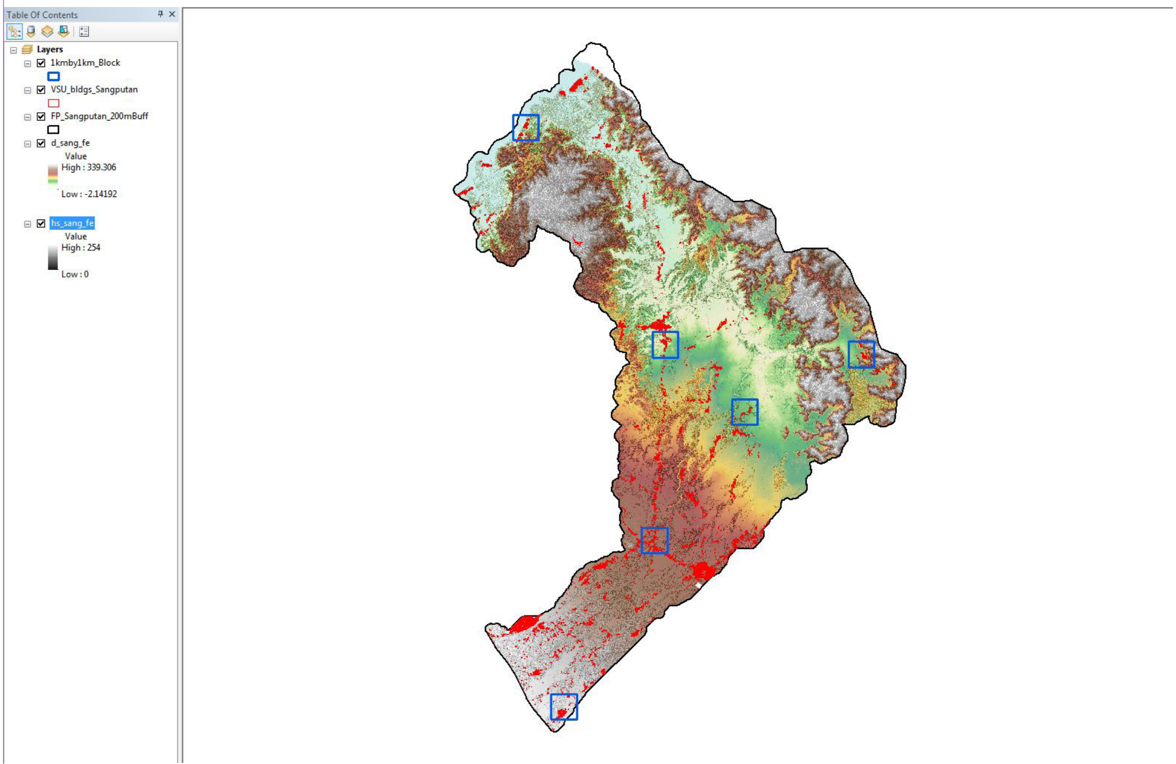


Figure 31. Blocks (in blue) of Sangputan building features that were subjected to QC

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

Table 20. Quality Checking ratings for the Sangputan building features

FLOODPLAIN	COMPLETENESS	CORRECTNESS	QUALITY	REMARKS
Sangputan	100.00	100.00	99.92	PASSED

3.12.2 Height Extraction

Height extraction was done for 14,448 building features in the Sangputan floodplain. Of these building features, 118 were filtered out after height extraction, resulting in 14,330 buildings with height attributes. The lowest building height is at 2.00 m, while the highest building is at 6.98 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, and then 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 21 summarizes the number of building features per type. Table 22 shows the total length of each road type, and Table 23 provides the number of water features extracted per type.

Table 21. Building Features extracted for the Sangputan floodplain

Facility Type	No. of Features
Residential	13,527
School	438
Market	44
Agricultural/Agro-Industrial Facilities	12
Medical Institutions	14
Barangay Hall	45
Military Institution	0
Sports Center/Gymnasium/Covered Court	10
Telecommunication Facilities	4
Transport Terminal	1
Warehouse	16
Power Plant/Substation	0
NGO/CSO Offices	1
Police Station	3
Water Supply/Sewerage	3
Religious Institutions	74
Bank	0
Factory	3
Gas Station	3
Fire Station	2
Other Government Offices	35
Other Commercial Establishments	95
Total	14,330

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

Floodplain	Road Network Length (km)					Total
	Barangay Road	City/Municipal Road	Provincial Road	National Road	Others	
Sangputan	134.25	21.49	9.20	39.29	0.00	**204.23**

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

Floodplain	**Water Body Type**					**Total**
	Rivers/ Streams	**Lakes/ Ponds**	**Sea**	**Dam**	**Fish Pen**	
Sangputan	**104**	**0**	**0**	**0**	**2**	**106**

A total of seventy-six (76) 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 32 presents the Digital Surface Model (DSM) of the Sangputan floodplain, overlaid with its ground features.

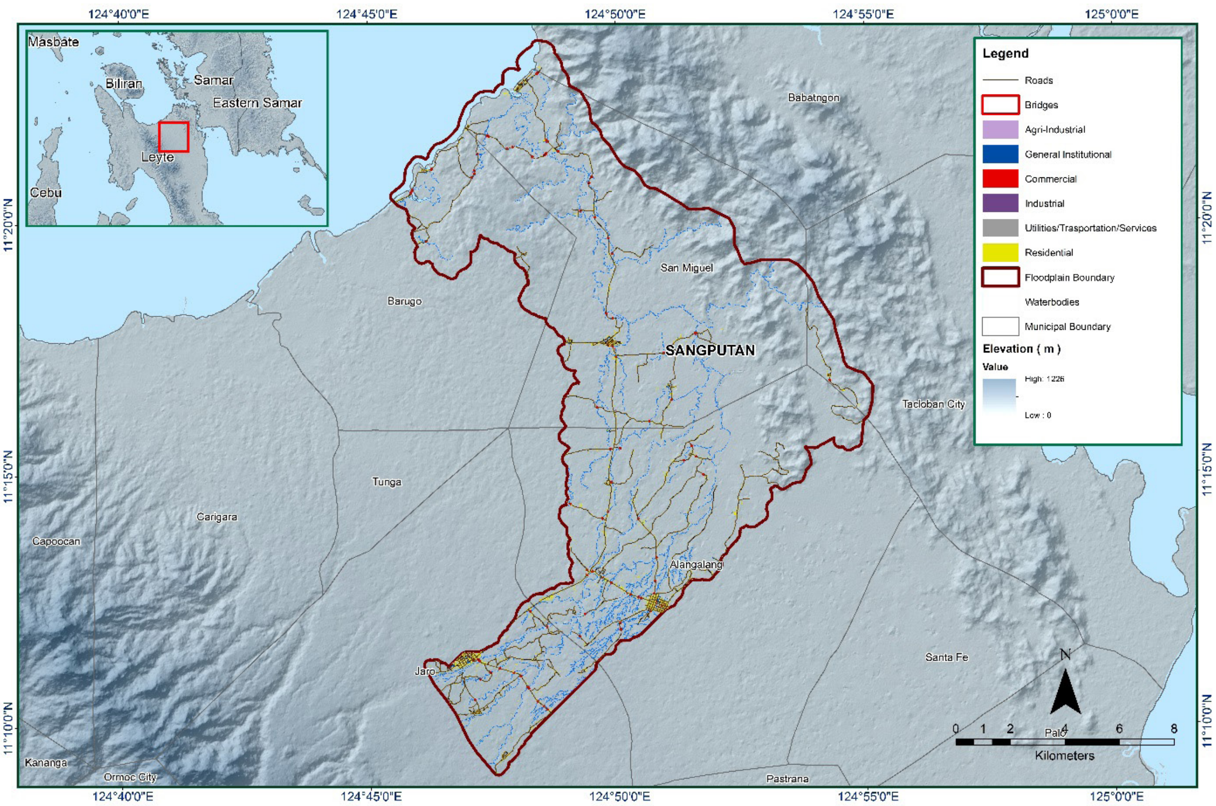


Figure 32. Extracted features for the Sangputan floodplain

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

Engr. Louie P. Balicanta, Engr. Joemarie S. Caballero, Patrizcia Mae. P. dela Cruz, Engr. Kristine Ailene B. Borromeo, Engr. Mark Lester D. Rojas, Geol. Anthony Felix J. Abogado, and Engr. Caren Joy S. Ordoña

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

4.1 Summary of Activities

The DVBC conducted field surveys in the Sangputan River on September 10-24, 2014 and March 9 – 23, 2016, with the following scope of work: (i.) initial reconnaissance; (ii.) control survey for the establishment of a control point; (iii.) cross-section survey of the Calay-Calay Bridge in Barangay Caray-Caray, Municipality of San Miguel, Leyte; (iv.) validation points data acquisition of about 33 km; and (v.) bathymetric survey from Barangay Guinciama down to the mouth of the river in Barangay Malpag in the Municipality of San Miguel, with an approximate length of 20.755 km., using Ohmex™ single beam echo sounder and Trimble® SPS 882 GNSS PPK survey technique (Figure 33).

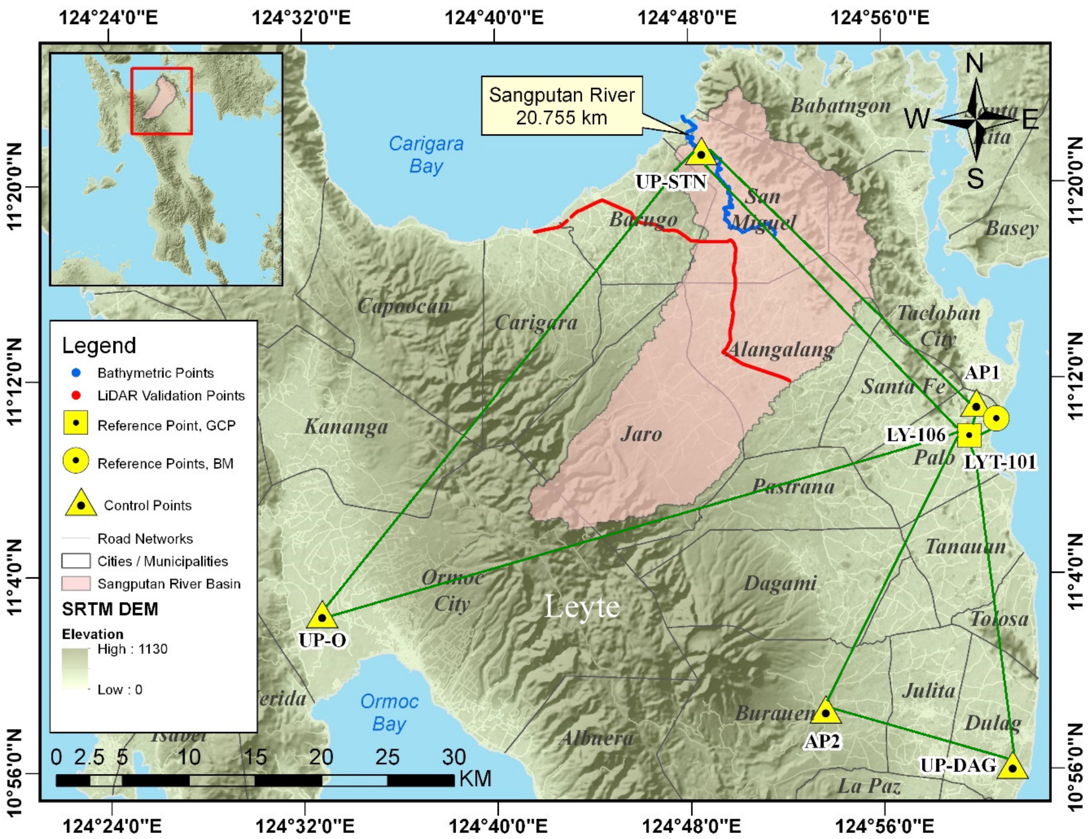


Figure 33. Extent of the bathymetric survey (in blue line) in the Sangputan River and the LiDAR data validation survey (in red)

4.2 Control Survey

The GNSS network used for the Sangputan River Basin is composed of three (3) loops established on September 18 to 20, 2014 occupying the following reference points: (i.) LYT-101, a second-order GCP, located in Barangay Candahog, Municipality of Palo; and (ii.) LY-106, a second-order GCP, located in Barangay Luntad, Municipality of Palo.

Three (3) control points were established at the approach of bridges namely: (i.) UP-DAG at the Daguitan Bridge in Barangay Fatima, Municipality of Dulag; (ii.) UP-O at the Ormoc Merida Bridge in Barangay Liloan, Ormoc City; and (iii.) UP-STN at the Calay-calay Bridge in Barangay Caraycaray, Municipality of San Miguel. Two (2) arbitrary points were also observed to complete the network. These are AP1 and AP2, located at the corner of Maharlika Highway and an unnamed street going to Campetic Road in Barangay Campetik, Municipality of Palo; and inside the Burauen Church Plaza at the Julita Burauen Road corner Burauen-Dagami Road in Barangay Poblacion VII, Municipality of Burauen, Province of Leyte, respectively.

The summary of reference and control points and their corresponding locations is given in Table 24, while the GNSS network established is illustrated in Figure 34.

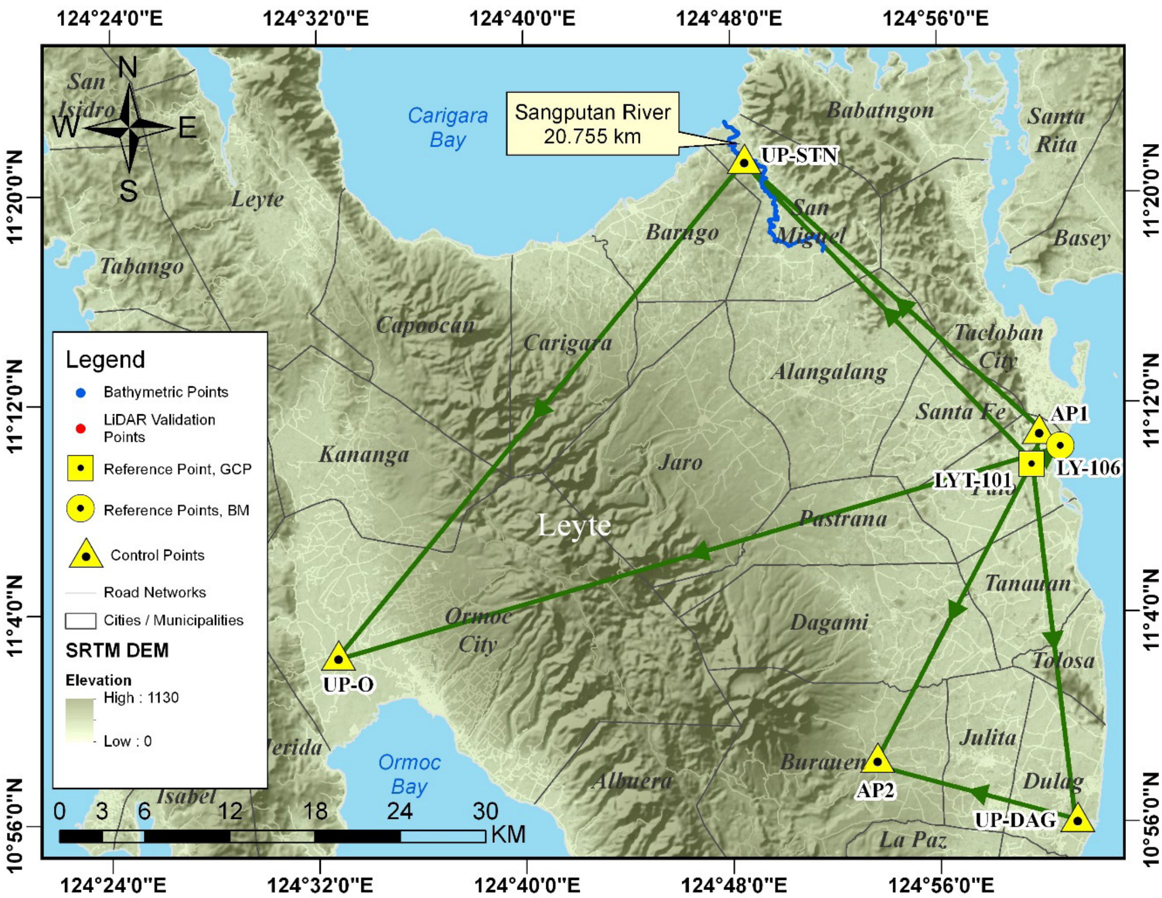


Figure 34. GNSS Network of the Sangputan River field survey

Table 24. List of Reference and Control Points occupied for the Sangputan River surve
(Source: NAMRIA; UP-TCAGP)

Control Point	Order of Accuracy	Geographic Coordinates (WGS 84)				
		Latitude	Longitude	Ellipsoidal Height (m)	MSL Elevation (m)	Date Established
LYT-101	2nd order, GCP	11°10’19.64869” N	125°00’43.78230” E	69.228	-	09-20-2014
LY-106	1st order, BM	-	-	68.051	4.028	2007
UP-DAG	UP Established	-	-	-	-	09-20-2014
UP-O	UP Established	-	-	-	-	09-19-2014
UP-STN	UP Established	-	-	-	-	09-11-2014
AP1	Arbitrary	-	-	-	-	09-18-2014
AP2	Arbitrary	-	-	-	-	09-20-2014

The GNSS set-ups established at the locations of the reference and control points are exhibited in Figure 35 to Figure 39.

Figure 35. GNSS base set-up, Trimble® SPS 852, at LYT-101, located at the General McArthur Shrine in Barangay Candahog, Municipality of Palo, Leyte

Figure 36. GNSS base set-up, Trimble® SPS 985, at LY-106, located at the approach of the Bernard Reed Bridge along Maharlika Highway in Barangay Luntad, Municipality of Palo, Leyte

Figure 37. GNSS receiver set-up, Trimble® SPS 985, at UP-DAG, an established control point, located at the bridge approach of the Daguitan Bridge along Maharlika Highway in Barangay Fatima, Municipality of Dulag, Leyte

Figure 38. GNSS receiver set-up, Trimble® SPS 985, at UP-O, an established control point, located at the bridge approach of the Ormoc Merida Bridge along the Ormoc-Merida-Isabel-Palompon Road in Barangay. Liloan, Ormoc City, Leyte

Figure 39. GNSS base set-up, Trimble® SPS 852, at UP-STN, an established control point, located at the Pagbanganan Bridge approach in Barangay Poblacion Zone 12, City of Baybay, Leyte

4.3 Baseline Processing

The GNSS baselines were processed simultaneously in TBC by observing that all baselines have fixed solutions, with horizontal and vertical precisions within +/- 20 cm and +/- 10 cm requirement, respectively. In cases where one or more baselines did not meet all of these criteria, masking was performed. Masking is the removal of 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, a re-survey is initiated. The baseline processing results of the control points in the Sangputan River Basin, generated by TBC software, is summarized in Table 25.

Table 25. Baseline Processing Report for the Sangputan River Basin Static Survey

Observation	Date of Observation	Solution Type	H.Prec. (Meter)	V.Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)
UP-STN --- UP-O (B2)	09-19-2014	Fixed	0.003	0.013	219°39'13"	45132.753
LY-106 --- AP1 (B4)	09-18-2014	Fixed	0.003	0.012	12°44'49"	2489.516
LY-106 --- UP-STN (B11)	09-18-2014	Fixed	0.005	0.042	317°02'38"	29477.609
LYT-101 --- UP-O (B1)	09-19-2014	Fixed	0.005	0.013	254°12'03"	52970.388
LYT-101 ---AP1 (B6)	09-18-2014	Fixed	0.002	0.003	307°32'43"	1903.266
LYT-101 --- UP-STN (B10)	09-18-2014	Fixed	0.005	0.039	312°31'18"	30045.665

As shown in Table 25, a total of twelve (12) baselines were processed, with reference points LYT-101 and LY-106 held fixed for grid and elevation values, respectively. All of the baselines satisfied the required accuracy.

4.4 Network Adjustment

After the baseline processing procedure, network adjustment was performed using TBC. Looking at the adjusted grid coordinates in Table 27 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:

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

Where:

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

for each control point. See the Network Adjustment Report shown in Table 26 to Table 28 for the complete details.

The five (5) control points, LY-338, LYT-737, LYT- 742, UP-CAM, and UP-PAG, and two (2) arbitrary points were occupied and observed simultaneously to form a GNSS loop. The coordinates of point LYT-101 and the elevation value of LY-106 were held fixed during the processing of the control points, as presented in Table 26. Through these reference points, the coordinates and elevation of the unknown control points were computed.

Table 26. Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
LYT-101	Local	Fixed	Fixed		
LY-106	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, are indicated in Table 27. The fixed control point LYT-101 has no values for grid errors; and LY-106, for elevation error.

Table 27. Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
LYT-101	1235759.250	?	719729.823	?	5.141	0.040	LL
LY-106	1234476.732	0.007	717679.601	0.006	4.028	?	e
UP-DAG	1209628.100	0.013	720942.270	0.009	5.993	0.077	e
UP-O	1220991.402	0.014	668855.819	0.010	8.719	0.076	
UP-STN	1255916.567	0.009	697443.625	0.007	8.835	0.070	
AP1	1236908.994	0.007	718212.616	0.007	4.834	0.051	
AP2	1213793.946	0.012	706851.618	0.010	56.317	0.079	

The network was fixed at reference points LYT-101 with known coordinates, and LY-106 with known elevation. As indicated in Table 27, the standard errors (x_e and y_e) of LY-106 are 0.70 cm and 0.60 cm; UP-DAG with 1.30 cm and 0.90 cm; UP-O with 1.40 and 1.10 cm; UP-STN with 0.90 cm and 0.70 cm; AP1 with 0.70 cm and 0.70 cm; and AP2 with 1.20 cm and 1.0 cm, respectively. With the mentioned equation, for horizontal and for the vertical, the computations for accuracy are as follows:

LYT-101

Horizontal Accuracy = Fixed
Vertical Accuracy = $4.0\ cm < 10\ cm$

LY-106

Horizontal Accuracy = $\sqrt{(1.30)^2 + (0.90)^2}$
= $\sqrt{(0.49 + 0.81)}$
= $1.14\ cm < 20\ cm$
Vertical Accuracy = Fixed

UP-DAG

Horizontal Accuracy = $\sqrt{(0.70)^2 + (0.90)^2}$
= $\sqrt{(1.69 + 0.81)}$
= $1.58\ cm < 20\ cm$
Vertical Accuracy = $7.70\ cm < 10\ cm$

UP-O

Horizontal Accuracy = $\sqrt{((1.40)^2 + (1.10)^2)}$

= $\sqrt{(1.96 + 1.21)}$

= 1.78 cm < 20 cm

Vertical Accuracy = 7.60 cm < 10 cm

UP-STN

Horizontal Accuracy = $\sqrt{((0.90)^2 + (0.70)^2}$

= $\sqrt{(0.81 + 0.49)}$

= 1.14 cm < 20 cm

Vertical Accuracy = 7.0 cm < 10 cm

AP1

Horizontal Accuracy = $\sqrt{((0.70)^2 + (0.70)^2}$

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

= 0.98 cm < 20 cm

Vertical Accuracy = 5.10 cm < 10 cm

AP2

Horizontal Accuracy = $\sqrt{((1.20)^2 + (1.0)^2}$

= $\sqrt{(1.44 + 1.0)}$

= 1.56 cm < 20 cm

Vertical Accuracy = 7.9 cm < 10 cm

Following the given formula, the horizontal and vertical accuracy results of the two (2) occupied control points are within the required precision.

Table 28. Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Ellipsoidal Height (Meter)	Height Error (Meter)	Constraint
LY-106	N11°09'38.36982"	E124°59'35.93684"	68.051	?	e
UP-DAG	N10°56'09.12671"	E125°01'17.90763"	70.609	0.077	
UP-O	N11°02'28.97646"	E124°32'44.58922"	71.626	0.076	
UP-STN	N11°21'20.28504"	E124°48'33.44650"	71.793	0.070	
AP1	N11°10'57.39411"	E124°59'54.04241"	68.821	0.051	
AP2	N10°58'27.65859"	E124°53'34.80074"	120.385	0.079	

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

The computed coordinates of the reference and control points used in the Sangputan River GNSS Survey are summarized in Table 29.

Table 29. 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-101	2nd Order, GCP	11°10'19.64869"	125°00'43.78230"	69.228	1235759.250	719729.823	5.141
LY-106	1st order, BM	11°09'38.36982"	124°59'35.93684"	68.051	1234476.732	717679.601	4.028
UP-DAG	UP Established	10°56'09.12671"	125°01'17.90763"	70.609	1209628.100	720942.270	5.993
UP-O	UP Established	11°02'28.97646"	124°32'44.58922"	71.626	1220991.402	668855.819	8.719
UP-STN	UP Established	11°21'20.28504"	124°48'33.44650"	71.793	1255916.567	697443.625	8.835
AP1	Arbitrary Point	11°10'57.39411"	124°59'54.04241"	68.821	1236908.994	718212.616	4.834
AP2	Arbitrary Point	10°58'27.65859"	124°53'34.80074"	120.385	1213793.946	706851.618	56.317

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

The cross-section and as-built survey was conducted on September 15, 2014 at the downstream side of the Calay-Calay Bridge located in Barangay Caray-Caray in the Municipality of San Miguel, using a survey-grade GNSS receiver Trimble® SPS 882 in PPK survey technique, as depicted in Figure 40.

Figure 40. Cross-section survey of Calay-Calay Bridge

The length of the cross-sectional line in the Calay-Calay Bridge is about 297.921 m, with 51 cross-sectional points acquired using UP-STN as the GNSS base station. The location map, cross-section diagram, and the accomplished bridge data form are shown in Figure 41, Figure 42, and Figure 43, respectively.

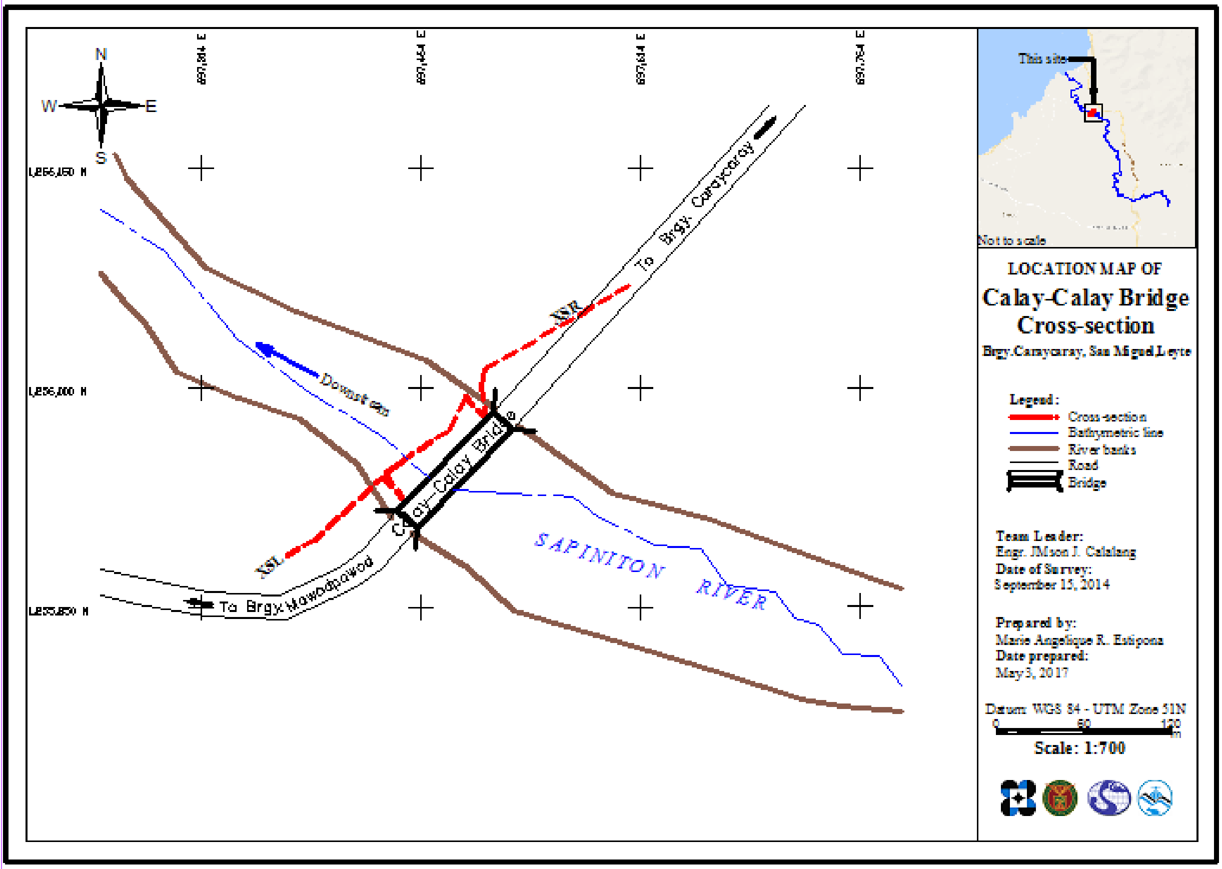


Figure 41. Calay-calay Bridge cross-section location map

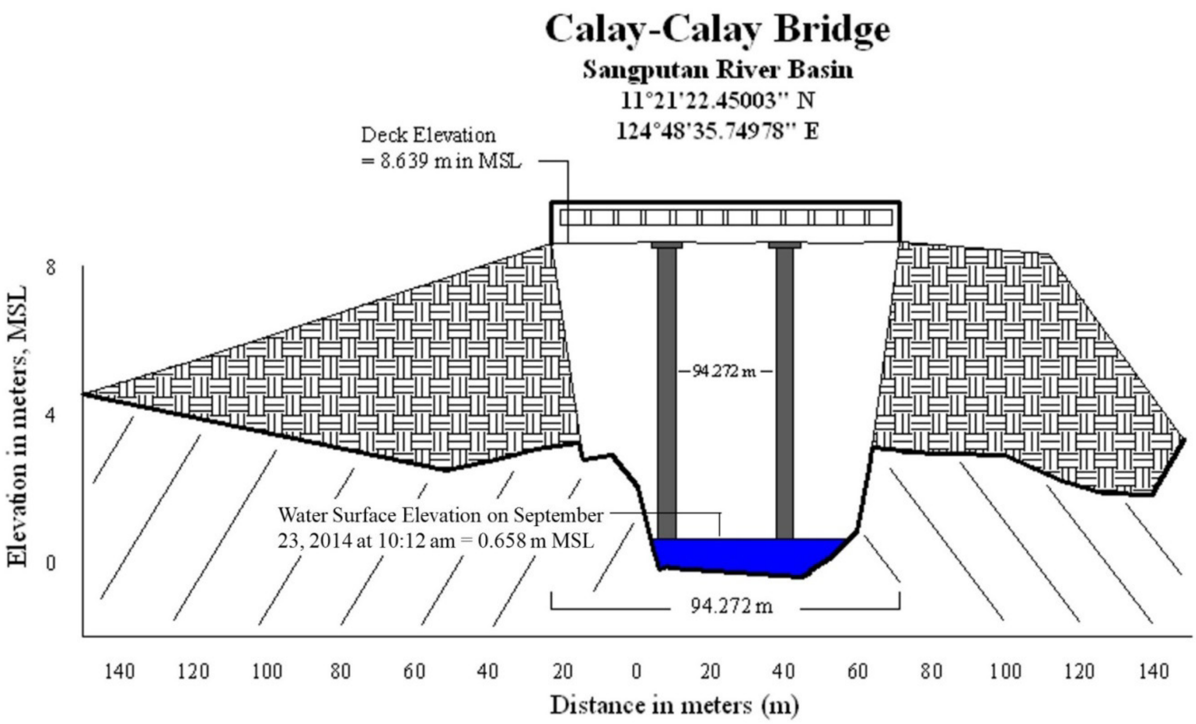
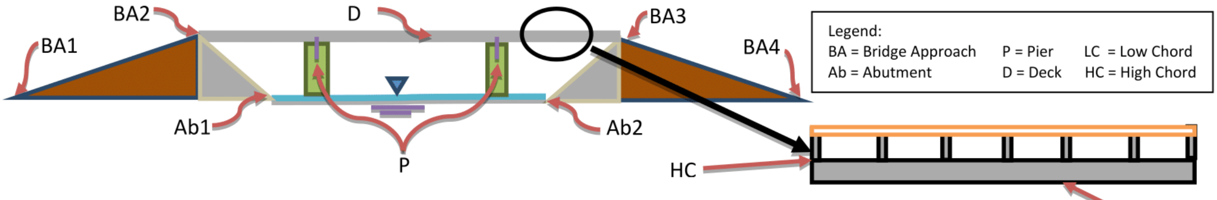


Figure 42. Calay-Calay Bridge cross-section diagram

Bridge Data Form

Bridge Name: Calay-Calay Bridge | **Date: 9/15/14**
River Name: Sapiniton River | **Time: 1:00 PM**
Location: Brgy. Caray-Caray, San Miguel, Leyte
Survey Team: Team JMSon Calalang
Flow condition: normal | **Weather Condition:** fair
Latitude: 11°21'22.45003" N | **Longitude: 124°48'35.74978" E**



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

Elevation: 8.639 m **Width: 8.8 m.** **Span (BA3-BA2): 94.272 m.**

	Station (Distance from BA2)	High Chord Elevation	Low Chord Elevation
1	150	8.674	7.584

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

	Station(Distance from BA1)	Elevation		Station(Distance from BA1)	Elevation
BA1	0	4.565 m	BA3	221.227	8.656 m
BA2	126.955	8.639 m	BA4	261.643	8.352 m

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

	Station (Distance from BA1)	Elevation
Ab1	133.986	3.228 m
Ab2	212.678	2.556 m

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

Shape: Circular Number of Piers: 2

	Station (Distance from BA1)	Elevation	Pier Width
Pier 1	158.084	8.662	1.4
Pier 2	190.013	8.652	1.4

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

Figure 43. Calay-Calay Bridge Data Form

The water surface elevation in MSL of the Sangputan River, as shown in Figure 44, was determined using Trimble® SPS 882 in PPK mode technique on March 23, 2016 at 10:11 hours, with a value of 0.658 m in MSL. This was translated into a marking on one of the bridge's piers using digital level, which was used by the VSU Phil-LiDAR 1 Team as reference for flow data gathering and depth gauge deployment for the Sangputan River.

Figure 44. Water-level marking at one of the piers of the Calay-Calay Bridge

4.6 Validation Points Acquisition Survey

The validation points acquisition survey was conducted on September 23, 2014 using a survey-grade GNSS Rover receiver, Trimble® SPS 882, mounted on a pole attached to the side of vehicle, as exhibited in Figure 45. It was secured with a nylon rope to ensure that it was horizontally and vertically balanced. The antenna height was 2.560 m, 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 UP-STN occupied as the GNSS base station throughout the conduct of the survey.

Figure 45. Validation points acquisition survey set-up

The validation points acquisition survey for the Sangputan River Basin traversed the following municipalities in the province of Leyte: Carigara, Barugo, San Miguel and Alangalang. The route of the survey aimed to traverse LiDAR flight strips perpendicularly along the basin. A total of 4,375 points, with an approximate length of 33 km, was acquired for the validation point acquisition survey. This is presented in the map in Figure 46.

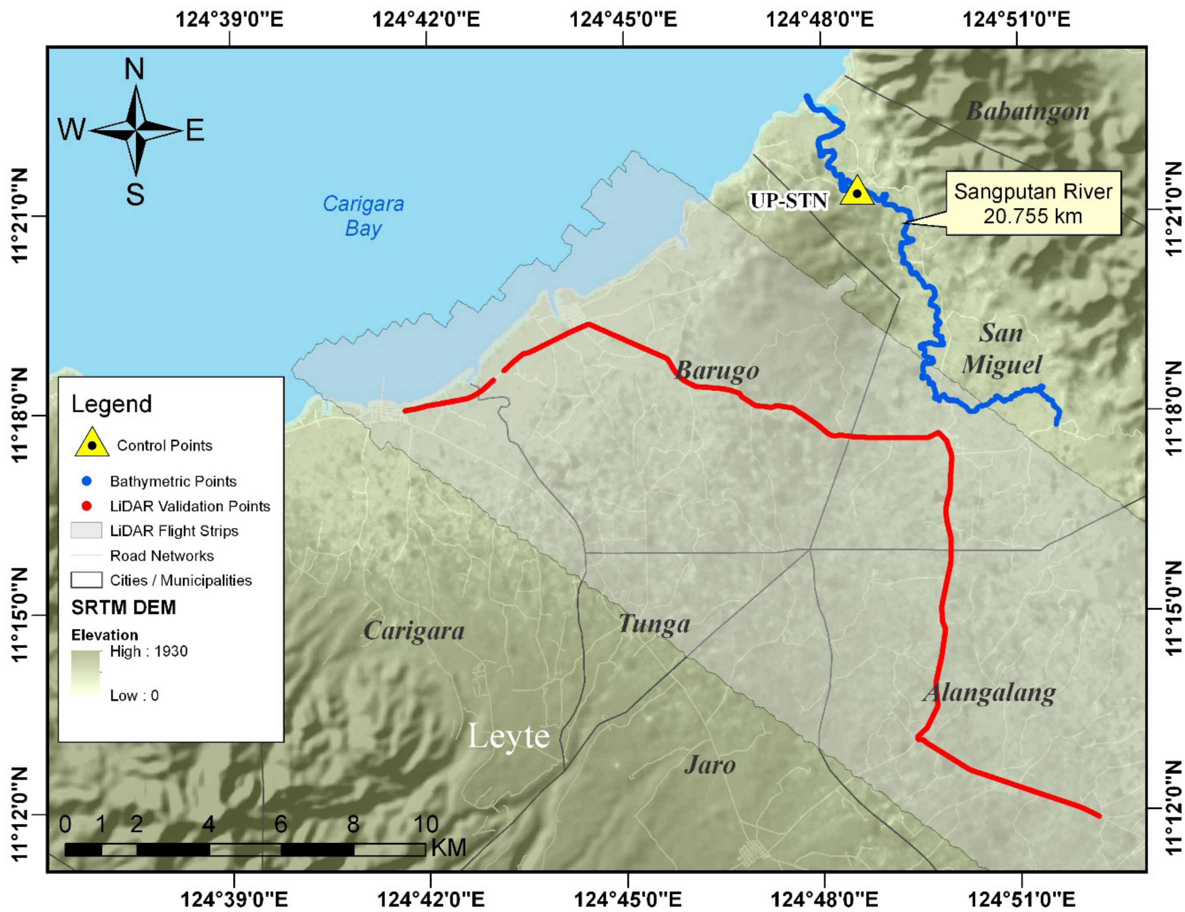


Figure 46. Extent of the LiDAR ground validation survey of the Sangputan River Basin

4.7 Bathymetric Survey

A bathymetric survey was executed on March 20-21, 2016 using a Trimble® SPS 882 in GNSS PPK survey technique on continuous topo mode, and an Ohmex™ single beam echo sounder, as illustrated in Figure 47. The survey started at the mid-upstream side of the river in Barangay Bahay in the Municipality of San Miguel, with coordinates 11°22’04.19744”N, 124°47’58.63076”E; and ended at the mouth of the river in Barangay Malpag in San Miguel, with coordinates 11°22’44.47751”N, 124°47’48.01063”E.

On the other hand, a manual bathymetric survey was conducted on March 21-22, 2016, using a Trimble® SPS 882 in GNSS PPK survey technique on continuous topo mode. The survey ran from the uppermost extent of the survey in Barangay Guinciaman in the Municipality of San Miguel, with coordinates 11°17’47.12757”N, 124°51’34.26959”E. The survey team then traversed down by foot, and ended at the starting point of bathymetric survey by boat. The control point UP-STN was used as the GNSS base station all throughout the survey.

Figure 47. Bathymetry by boat set-up for the Sangputan River survey

The planned bathymetric survey for the Sangputan River only covers 5.42 km of the river, from the mouth of the river until the Calay-Calay Bridge. However, the VSU Phil-Lidar 1 Team requested to extend the bathymetric survey. According to them, the water-level downstream of the Calay-Calay Bridge is still affected by the tide. The VSU Phil-LiDAR 1 Team also stated that there are still communities residing near the upstream side of the river, justifying their deployment site for flow-data gathering. The deployment site is located 15 km from the bridge, which is the most upstream point of the actual bathymetric survey.
The bathymetric survey gathered a total of 19,422 points, covering 11.254 km of the river. The survey traversed the following barangays from the upstream side of the river: Barangay Guinciaman, Barangay Canap, Barangay Santol,Barangay Kinamalasan, Barangay Impo, Barangay. Caraycaray, Barangay San Andres, and Barangay Malpag. A CAD drawing was also produced to illustrate the riverbed profile of the Sangputan River. As shown in Figure 49, the highest and lowest elevation has a 12-meter difference. The highest elevation observed was 6.951 m above MSL, located in Barangay Guinciaman, while the lowest was 5.234 m below MSL, located in Barangay Caraycaray.

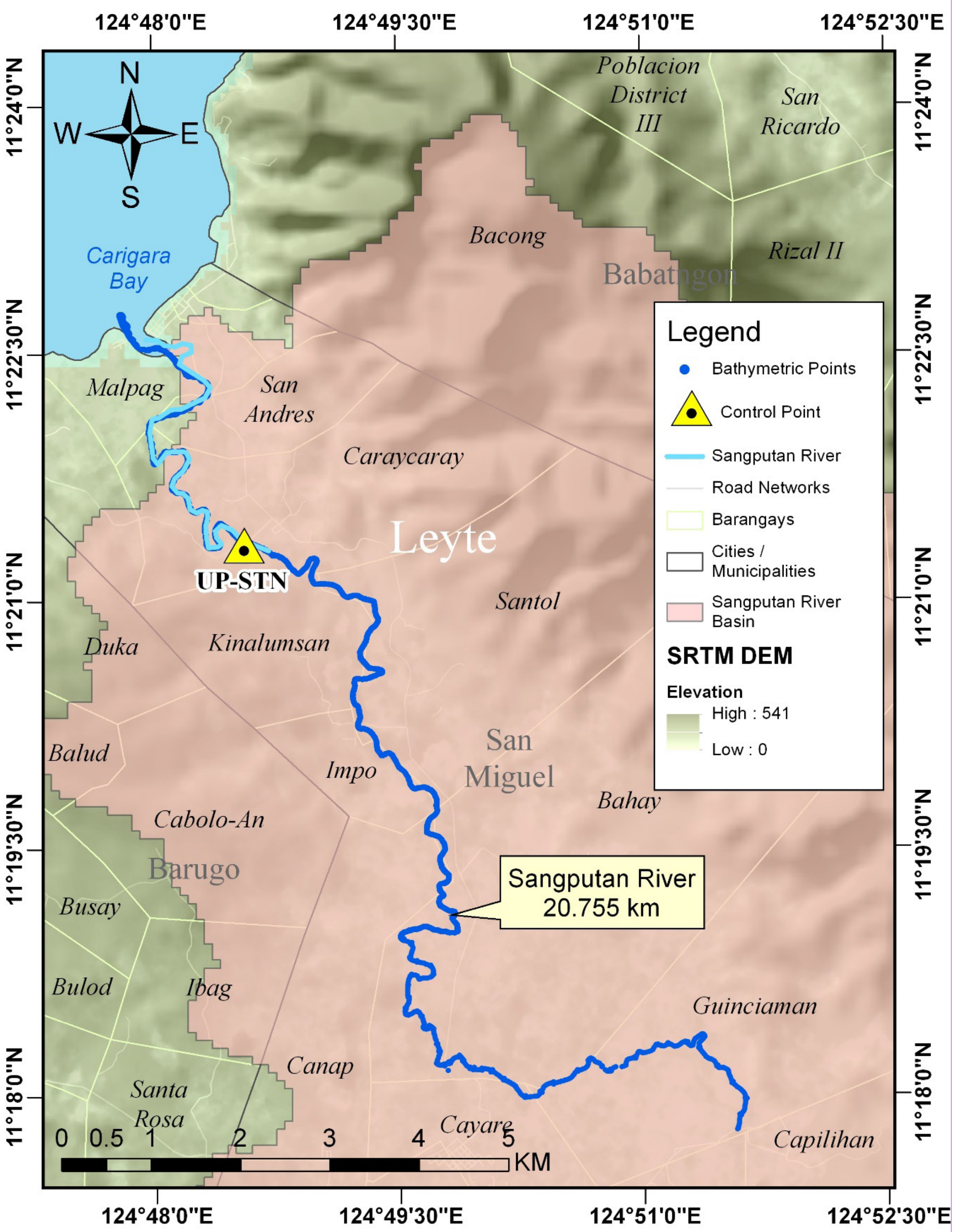


Figure 48. Extent of the bathymetric survey of the Sangputan River

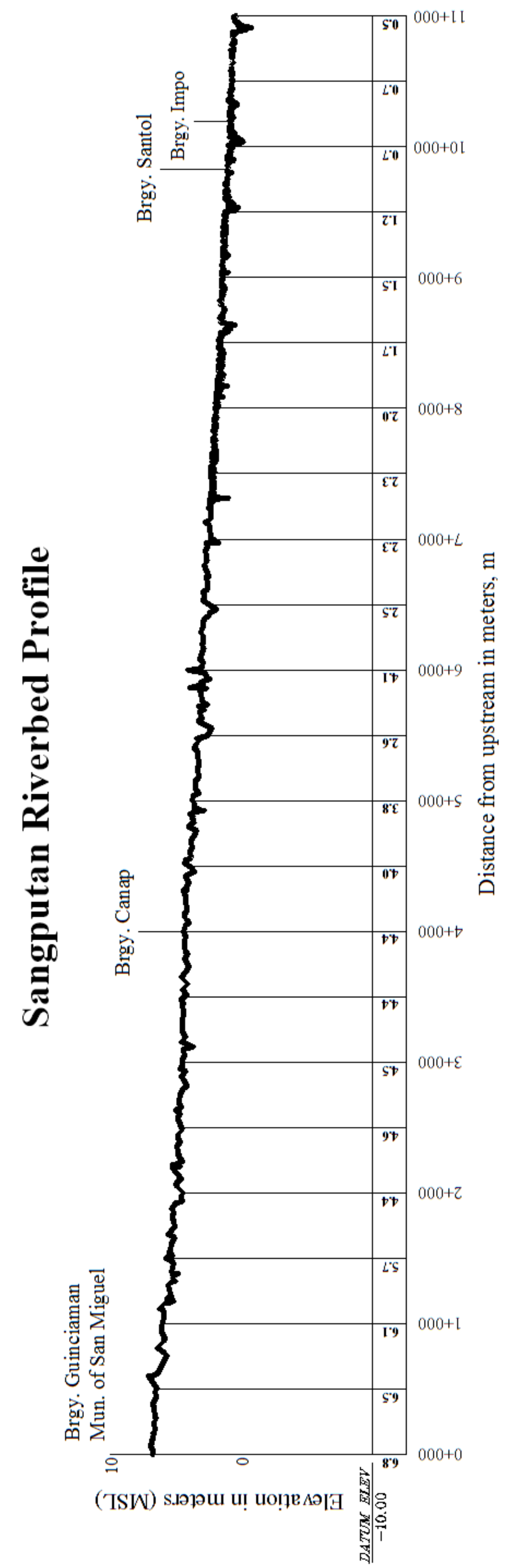


Figure 49. Riverbed profile of the Sangputan River (upstream)

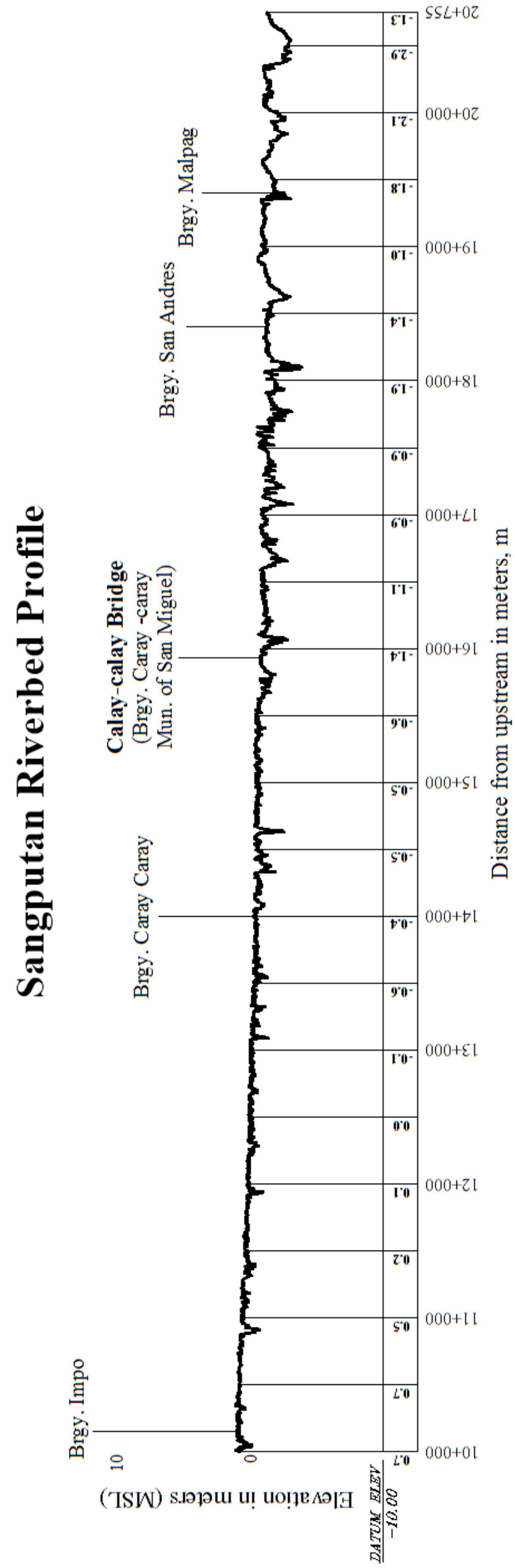


Figure 50. Riverbed profile of the Sangputan River (downstream)

CHAPTER 5: FLOOD MODELING AND MAPPING

Dr. Alfredo Mahar Lagmay, Christopher Uichanco, Sylvia Sueno, Marc Moises, Hale Ines, Miguel del Rosario, Kenneth Punay, and 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 are components and data that affect the hydrologic cycle of the river basin, were monitored, collected, and analyzed.

5.1.2 Precipitation

Precipitation data was taken from two (2) automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). These are the Alangalang and the Kaglawan ARGs. The locations of the rain gauges are seen in Figure 51.
Total rain collected from the Kaglawan rain gauge measured 17.80 mm. It peaked at 0.40 mm on December 30, 2014 at 12:30 hours. The lag time between the peak rainfall and discharge was 5 hours and 50 minutes. For the Alangalang rain gauge, total rain for this event was 145 mm. Peak rain of 12.5 mm was recorded on December 29, 2014 at 21:45 hours. The lag time between the peak rainfall and discharge was 8 hours and 35 minutes.

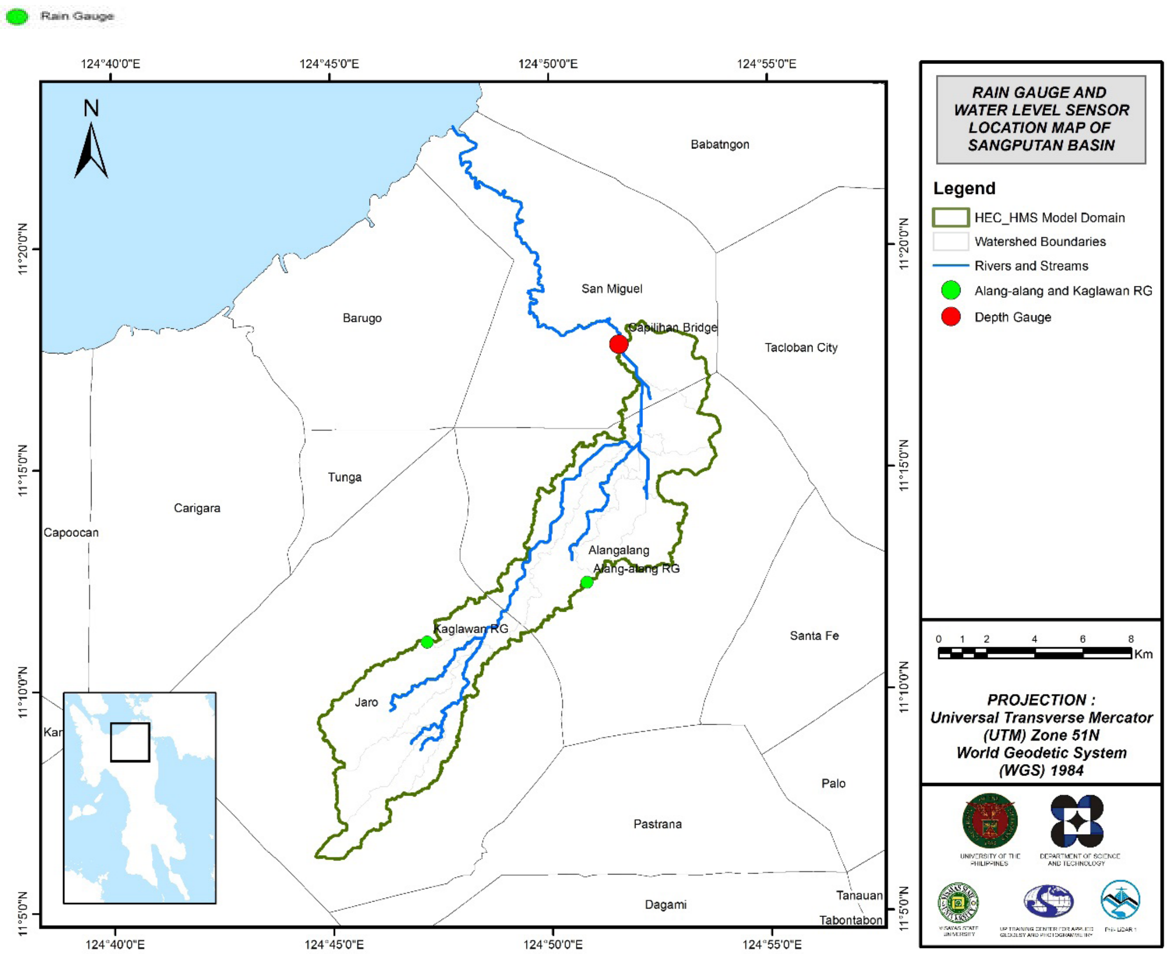


Figure 51. The location map of the Sangputan HEC-HMS model used for calibration

5.1.3 Rating Curves and River Outflow

A rating curve was computed using the prevailing cross-section (Figure 52) at the Capilihan Bridge in Barangay Capilihan, San Miguel, Leyte (11°17'43.69"N, 124°51'35.88"E) to establish the relationship between the observed water levels (H) at the Capilihan Bridge and the outflow (Q) of the watershed at this location.

For the Capilihan Bridge, the rating curve is expressed as $Q= 0.0856e^{1.0439H}$, as shown in Figure 53.

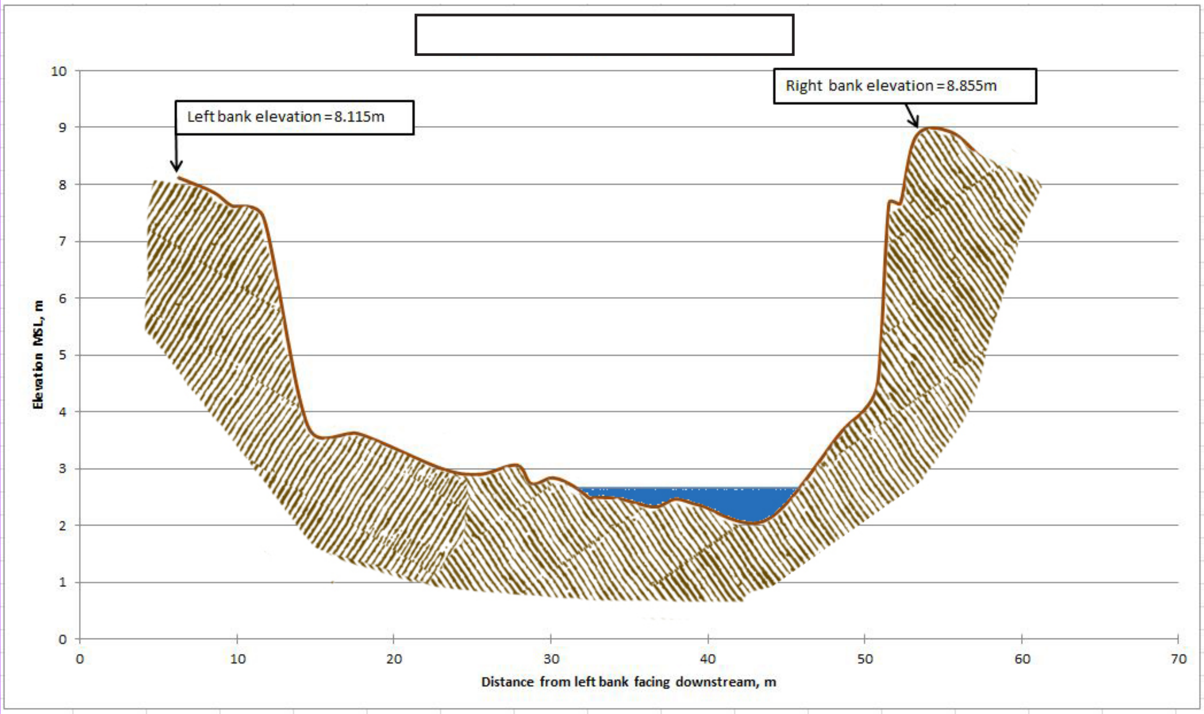


Figure 52. Cross-Section plot of the Capilihan Bridge

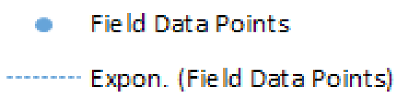


Figure 53. Rating Curve at the Capilihan Bridge, San Miguel, Leyte

This rating curve equation was used to compute for the river outflow at the Capilihan Bridge for the calibration of the HEC-HMS model, as presented in Figure 54. Total rain from the Kaglawan rain gauge is 17.80 mm. It peaked at 0.40 mm on December 30, 2014 at 12:30 hours. For the Alangalang rain gauge, total rain for this event was 145 mm. Peak rain of 12.5 mm was recorded on December 29, 2014 at 21:45 hours. Peak discharge was 175.4 cubic meters per second on December 30, 2014 at 5:40 hours. The lag time between the peak rainfall of Kaglawan and discharge was 5 hours and 50 minutes. The lag time between the peak rainfall of the Alangalang rain gauge and discharge was 8 hours and 35 minutes.

5.2 RIDF Station

The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed for the Rainfall Intensity Duration Frequency (RIDF) values for the Tacloban Rain Gauge (Table 30). This station chosen based on its proximity to the Sangputan watershed (Figure 55). The RIDF rainfall amount for twenty-four (24) hours was converted into a synthetic storm by interpolating and re-arranging the values such that certain peak values were attained at a certain time. The extreme values for this watershed were computed based on a 59-year record.

Table 30. RIDF values for the Tacloban 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	17.8	26.9	33.6	42.8	59.7	70.5	87.2	104	120.6
5	24.3	36.7	45.7	57.4	80.7	95.2	117.9	140.6	161.4
10	28.5	43.2	53.7	67.1	94.6	111.5	138.2	164.9	188.4
15	30.9	46.8	58.3	72.5	102.5	120.7	149.6	178.6	203.7
20	32.6	49.4	61.4	76.3	108	127.1	157.7	188.1	214.3
25	33.9	51.4	63.9	79.3	112.2	132.1	163.8	195.5	222.6
50	37.9	57.5	71.4	88.3	125.2	147.4	182.9	218.2	247.9
100	41.8	63.5	78.9	97.3	138.2	162.5	201.8	240.8	273

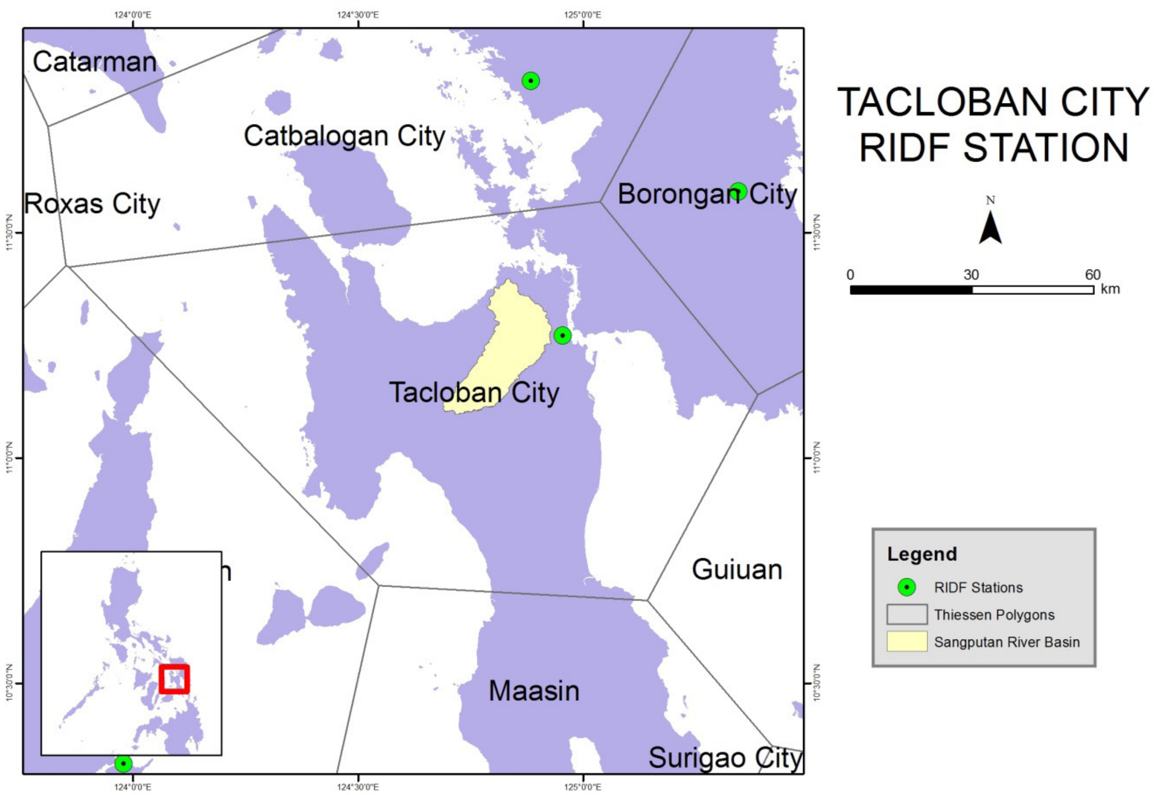


Figure 55. Location map of the Tacloban RIDF station relative to the Sangputan River Basin

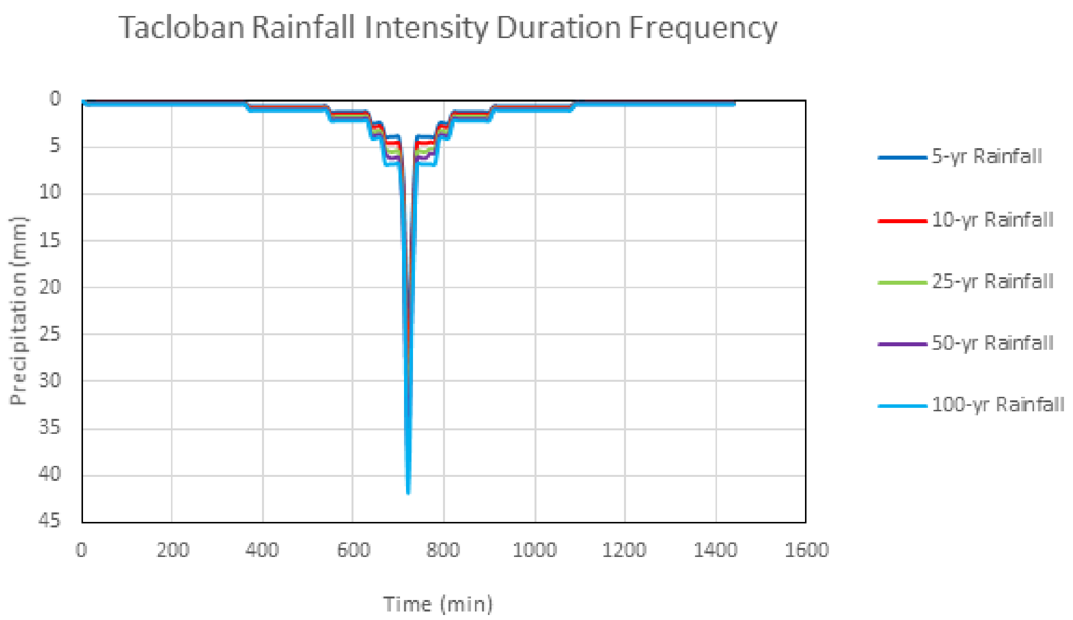


Figure 56. Synthetic storm generated for a 24-hr period rainfall for various return periods

5.3 HMS Model

The soil shapefile was taken from the Bureau of Soils and Water Management (BSWM) under the Department of Agriculture (DA). The land cover dataset is from the National Mapping and Resource information Authority (NAMRIA). These soil datasets were taken before 2004. The soil and land cover of the Sangputan River Basin are shown in Figures 57 and 58, respectively.

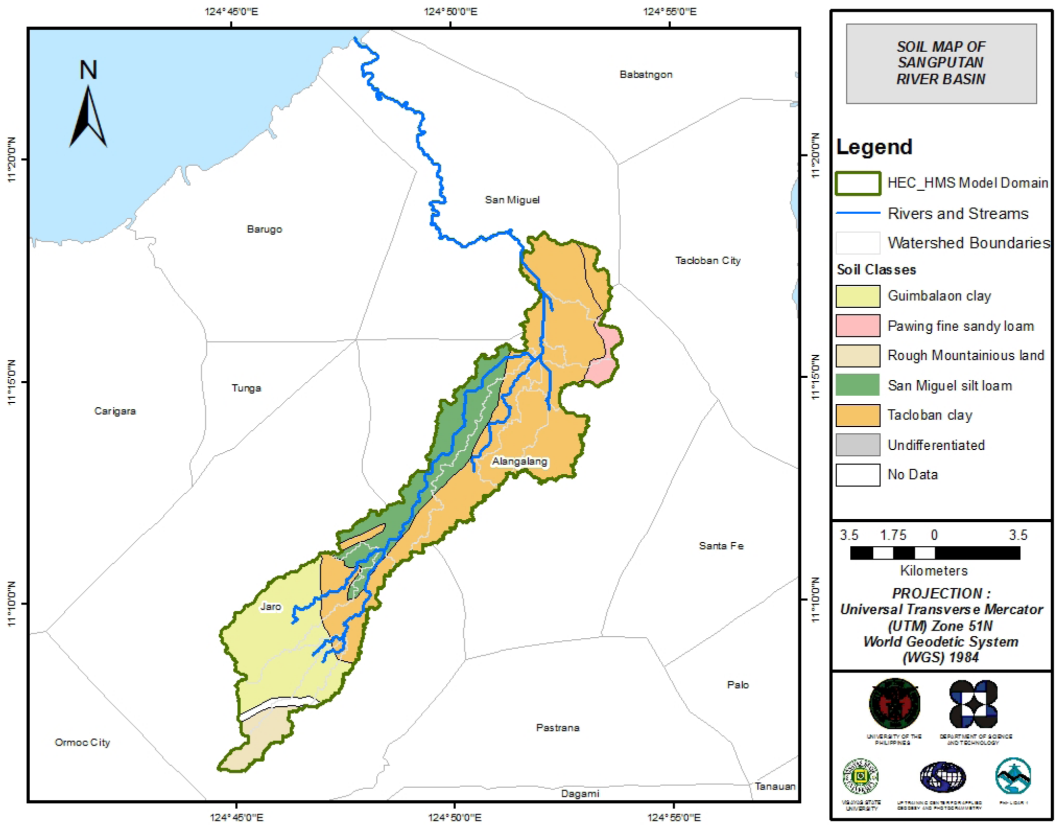


Figure 57. Soil Map of the Sangputan River Basin (Source: DA)

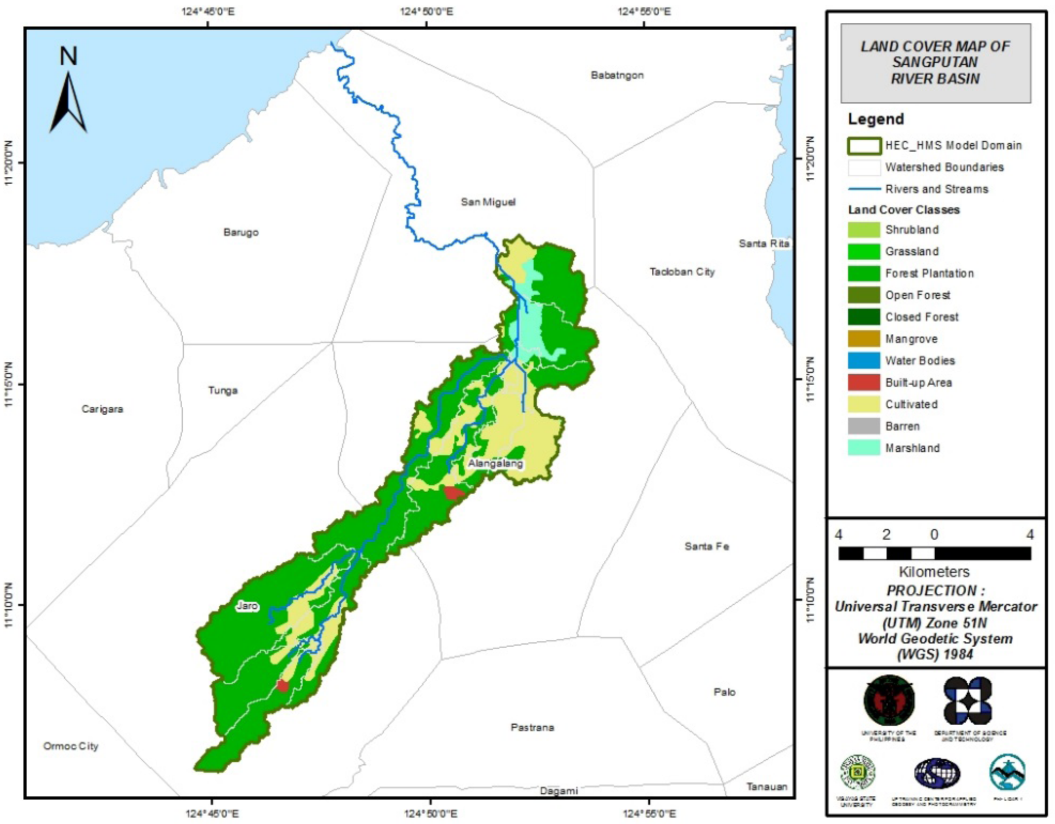


Figure 58. Land Cover Map of the Sangputan River Basin (Source: NAMRIA)

For Sangputan, the soil classes identified were silt, clay, sandy loam, rough mountainous land, and undifferentiated soil. The land cover types identified were forest plantations, marshlands, built-up land, and cultivated areas.

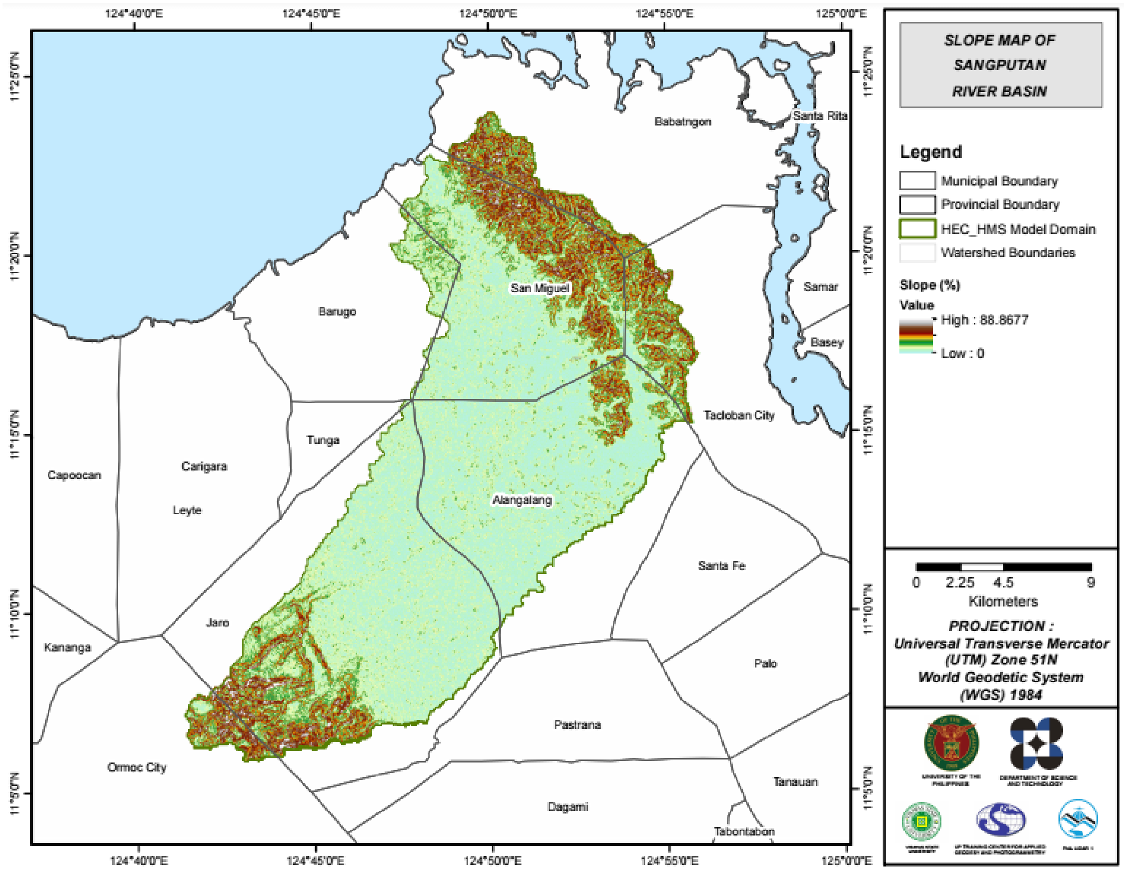


Figure 59. Slope Map of the Sangputan River Basin

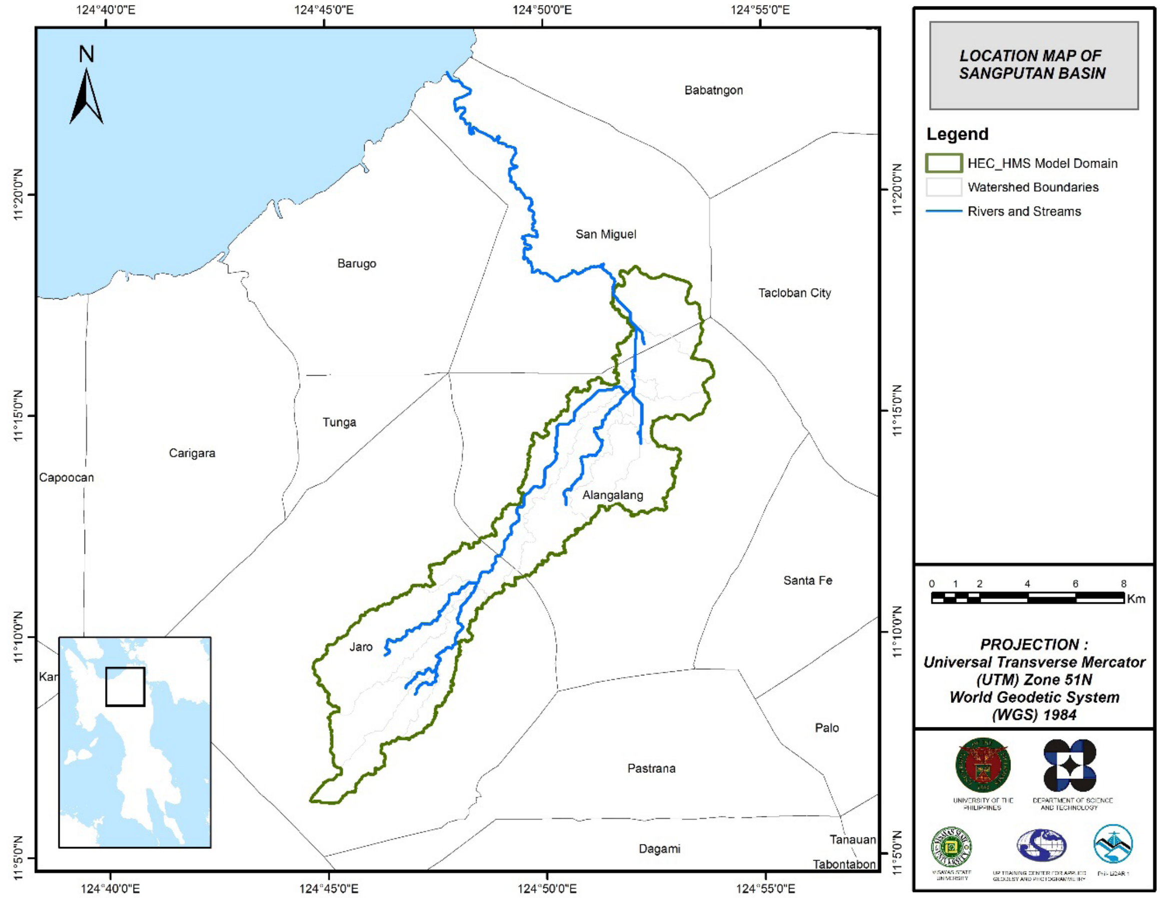


Figure 60. Stream Delineation Map of the Sangputan River Basin

Using the SAR-based DEM, the Sangputan basin was delineated and further subdivided into sub basins. The model consists of seventeen (17) sub basins, eight (8) reaches, and seven (7) junctions, as illustrated in Figure 61. The main outlet is at the Capilihan Bridge. The Sangputan Model Reach Parameters are provided in Annex 10.

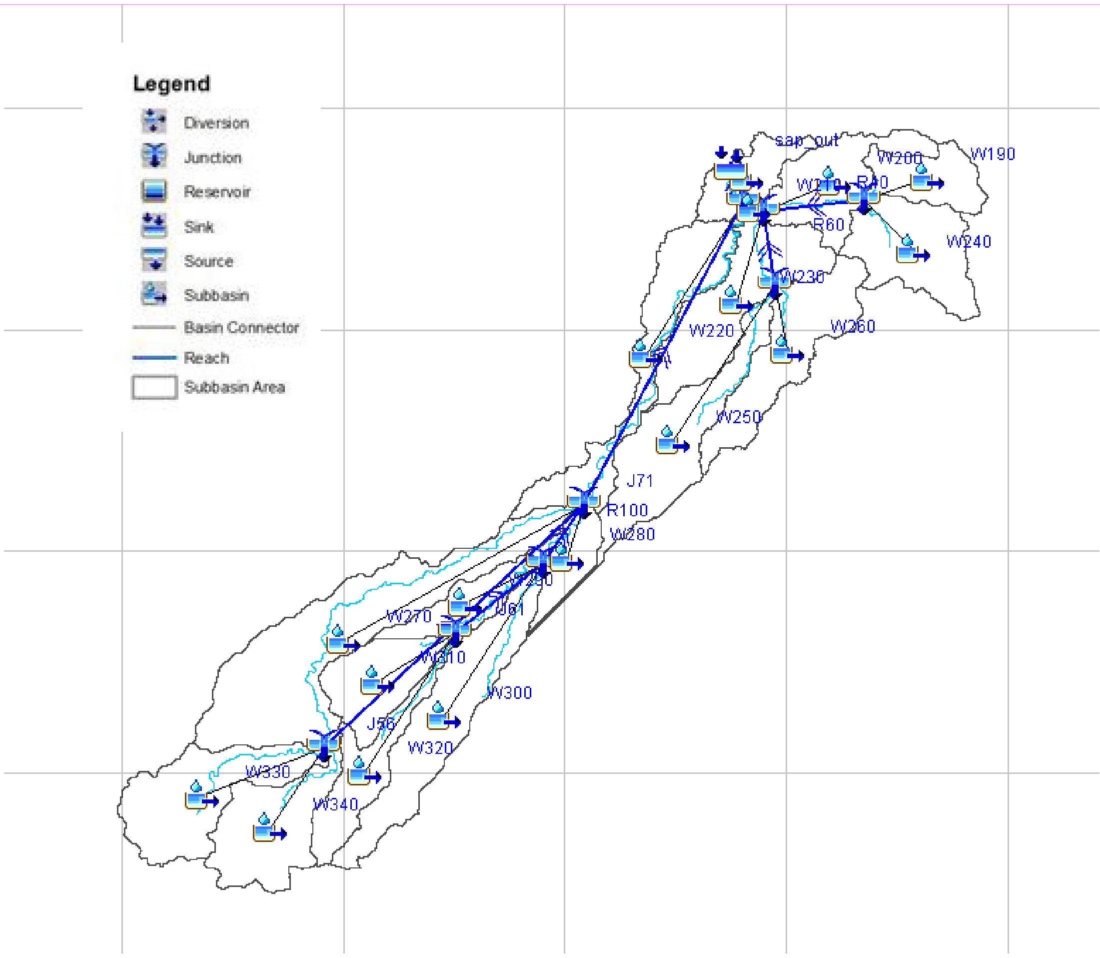


Figure 61. The Sangputan River Basin model generated in HEC-HMS

5.4 Cross-section Data

Riverbed cross-sections of the watershed were necessary in the HEC-RAS model set-up. The cross-section data for the HEC-RAS model was derived from the LiDAR DEM data. It was defined using the Arc GeoRAS tool and was post-processed in ArcGIS (Figure 62).

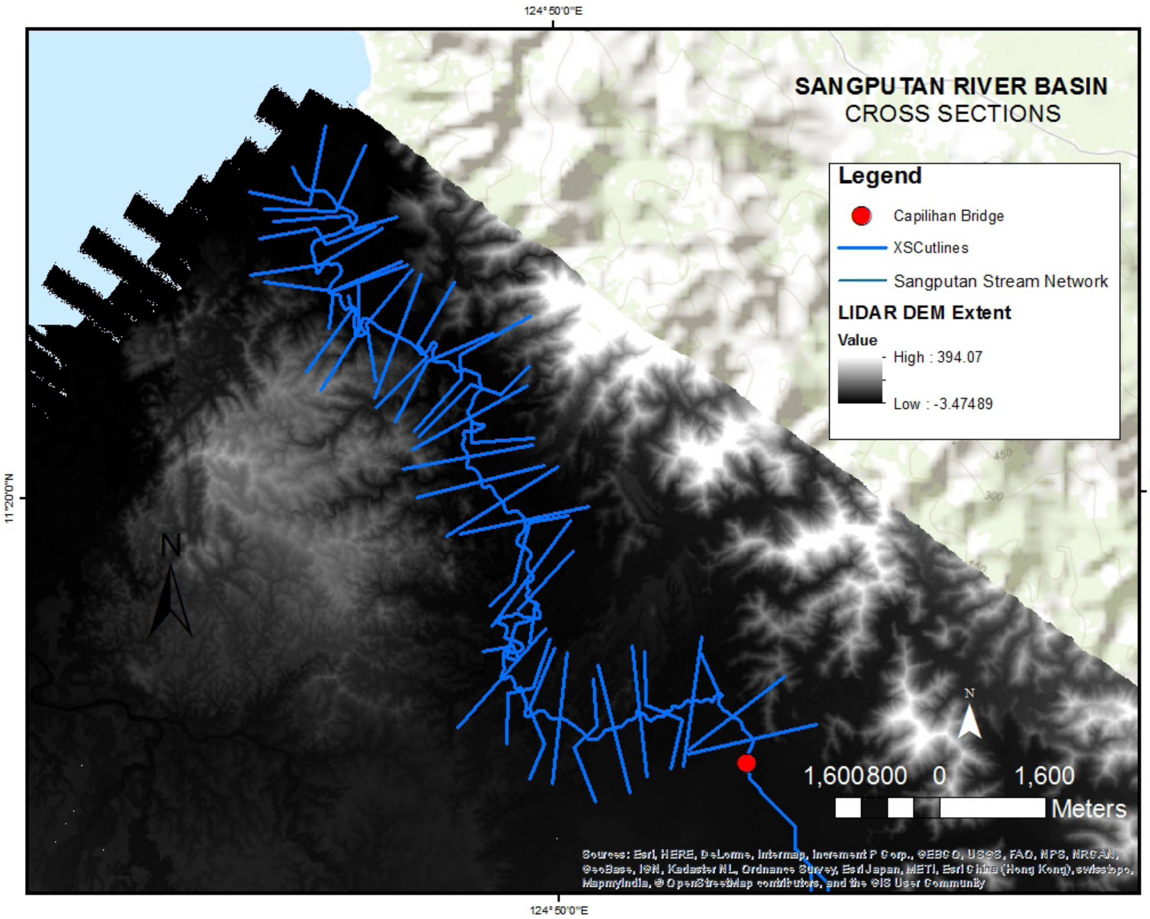


Figure 62. River cross-section of the Sangputan River generated through Arcmap HEC GeoRAS tool

5.5 Flo 2D Model

[insert 2d report]

Figure 63. A screenshot of the river sub-catchment with the computational area to be modeled in FLO-2D GDS Pro

5.6 Results of HMS Calibration

After calibrating the Sangputan HEC-HMS river basin model, its accuracy was measured against the observed values. Figure 64 shows the comparison between the two discharge data. See Annex 9 for the Sangputan Model Basin Parameters.

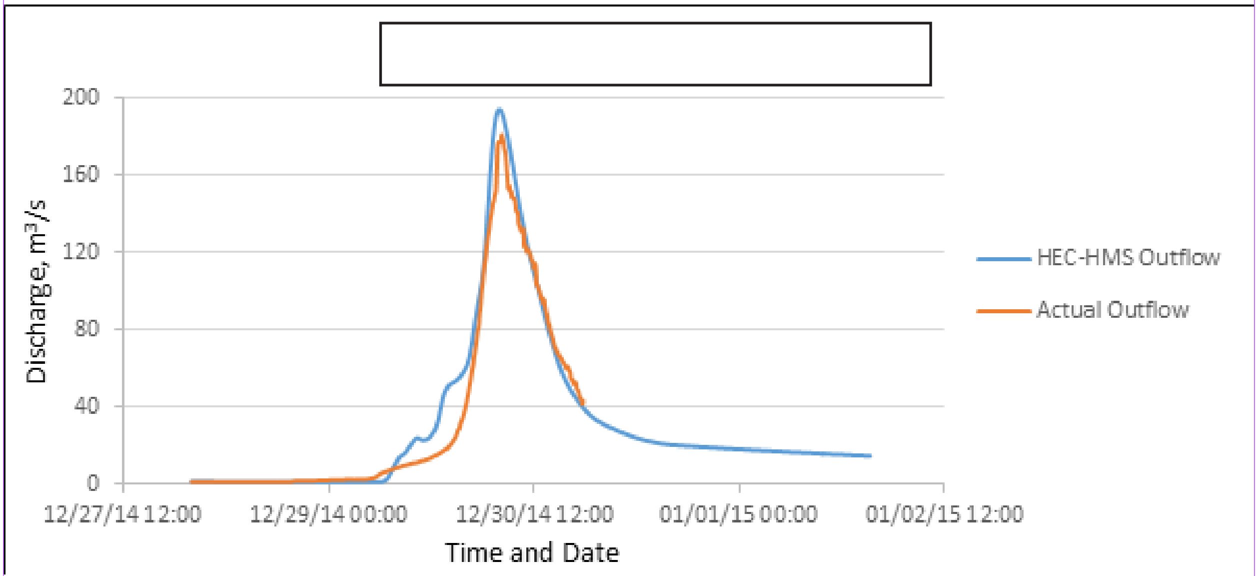


Figure 64. Outflow Hydrograph of Sangputan produced by the HEC-HMS model compared with observed outflow

Enumerated in Table 31 are the adjusted ranges of values of the parameters used in calibrating the model.

Table 31. Range of Calibrated Values for Sangputan

Hydrologic Element	Calculation Type	Method	Parameter	Range of Calibrated Values
Basin	Loss	SCS Curve number	Initial Abstraction (mm)	5 – 50
			Curve Number	44 - 86
	Transform	Clark Unit Hydrograph	Time of Concentration (hr)	3 – 30
			Storage Coefficient (hr)	0.4 – 5
	Baseflow	Recession	Recession Constant	0.8
			Ratio to Peak	0.1
Reach	Routing	Muskingum-Cunge	Manning's Coefficient	0.05

Initial abstraction defines the amount of precipitation that must fall before surface runoff. The magnitude of the outflow hydrograph increases as initial abstraction decreases. The range of values from 5mm to 50mm for initial abstraction means that there is a minimal to average amount of infiltration or rainfall interception by vegetation.

The curve number is the estimate of the precipitation excess of soil cover, land use, and antecedent moisture. The magnitude of the outflow hydrograph increases as the curve number increases. The range of 44 to 86 for the curve number is advisable for Philippine watersheds, depending on the soil and land cover of the area (M. Horritt, personal communication, 2012). For Sangputan, the basin mostly consists of brushlands, and the soil consists of clay, clay loam, and mountain soil.

The 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 0.4 hours to 30 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.

The 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. A recession constant of 0.8 indicates that the basin is unlikely to quickly return to its original discharge and will be higher instead. A ratio to peak of 0.1 indicates a steeper receding limb of the outflow hydrograph.
A Manning's roughness coefficient of 0.05 corresponds to a higher roughness compared to the common roughness of Philippine watersheds.

Table 32. Summary of the Efficiency Test of Sangputan HMS Model

RMSE	13.6
r^2	0.9991
NSE	0.88
PBIAS	-14.06
RSR	0.21

The Root Mean Square Error (RMSE) method aggregates the individual differences of these two measurements. It was computed as 13.6 (m3/s).

The Pearson correlation coefficient (r^2) 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 was measured at 0.9991.

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 0.88.

A positive Percent Bias (PBIAS) indicates a model's propensity towards under-prediction. Negative values indicate bias towards over-prediction. The optimal value is 0. In the model, the PBIAS is -14.06.

The Observation Standard Deviation Ratio, RSR, is an error index. A perfect model attains a value of 0 when the error units of the values are quantified. The model has an RSR value of 0.36.

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 65) shows the Sangputan outflow using the Tacloban RIDF in five (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 a significant increase in outflow magnitude as the rainfall intensity increases, for a range of durations and return periods.

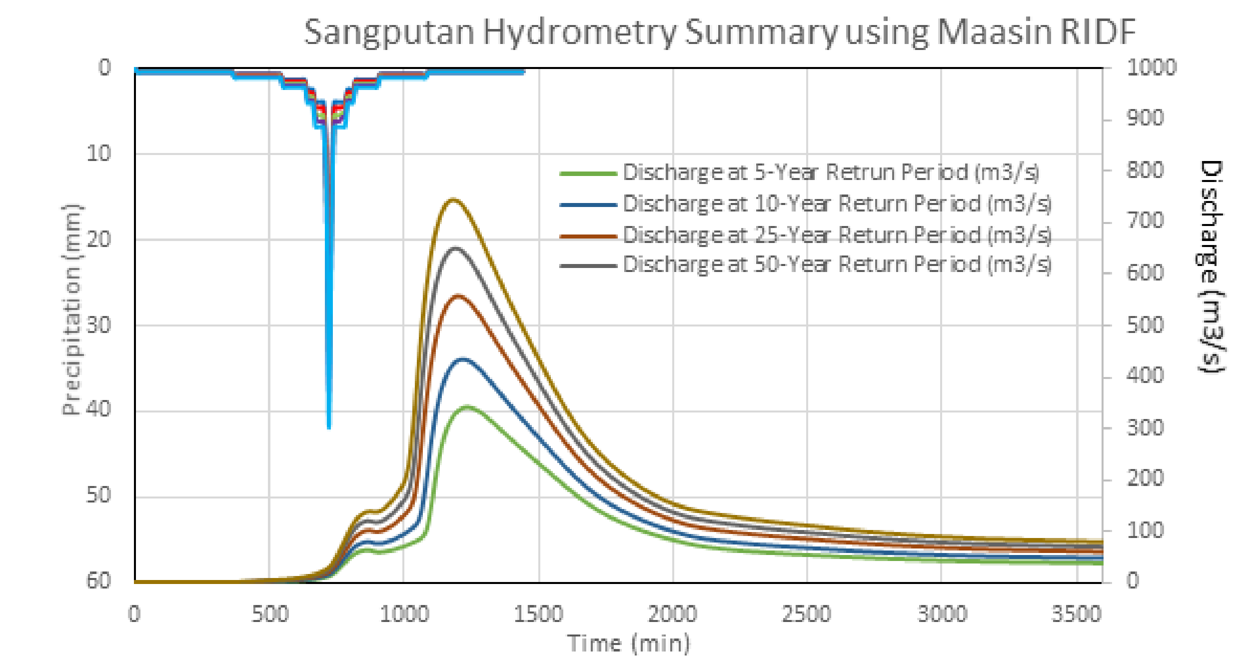


Figure 65. Outflow hydrograph at the Sangputan Station generated using Tacloban RIDF simulated in HEC-HMS

A summary of the total precipitation, peak rainfall, peak outflow, and time to peak of the Sangputan discharge using the Tacloban RIDF in five (5) different return periods is given in Table 33.

Table 33. Peak values of the Sangputan HEC-HMS Model outflow using the Tacloban RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m 3/s)	Time to Peak
5-Year	161.40	24.30	341.60	8 hours, 20 minutes
10-Year	188.40	28.50	435	8 hours, 10 minutes
25-Year	222.60	33.90	557.70	7 hours, 30 minutes
50-Year	247.90	37.90	650.60	7 hours, 40 minutes
100-Year	273	41.80	745.20	7 hours, 30 minutes

5.8 River Analysis (RAS) Model Simulation

The HEC-RAS Flood Model produced a simulated water level at every cross-section, for every time step, for every flood simulation created. The resulting model will be used in determining the flooded areas within the model. The simulated model will be an integral part in determining the real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. For this publication, only a sample output map river is presented, since only the DVC high flow was calibrated. The sample generated map of the Sangputan River using the calibrated HMS high flow is shown in Figure 66.

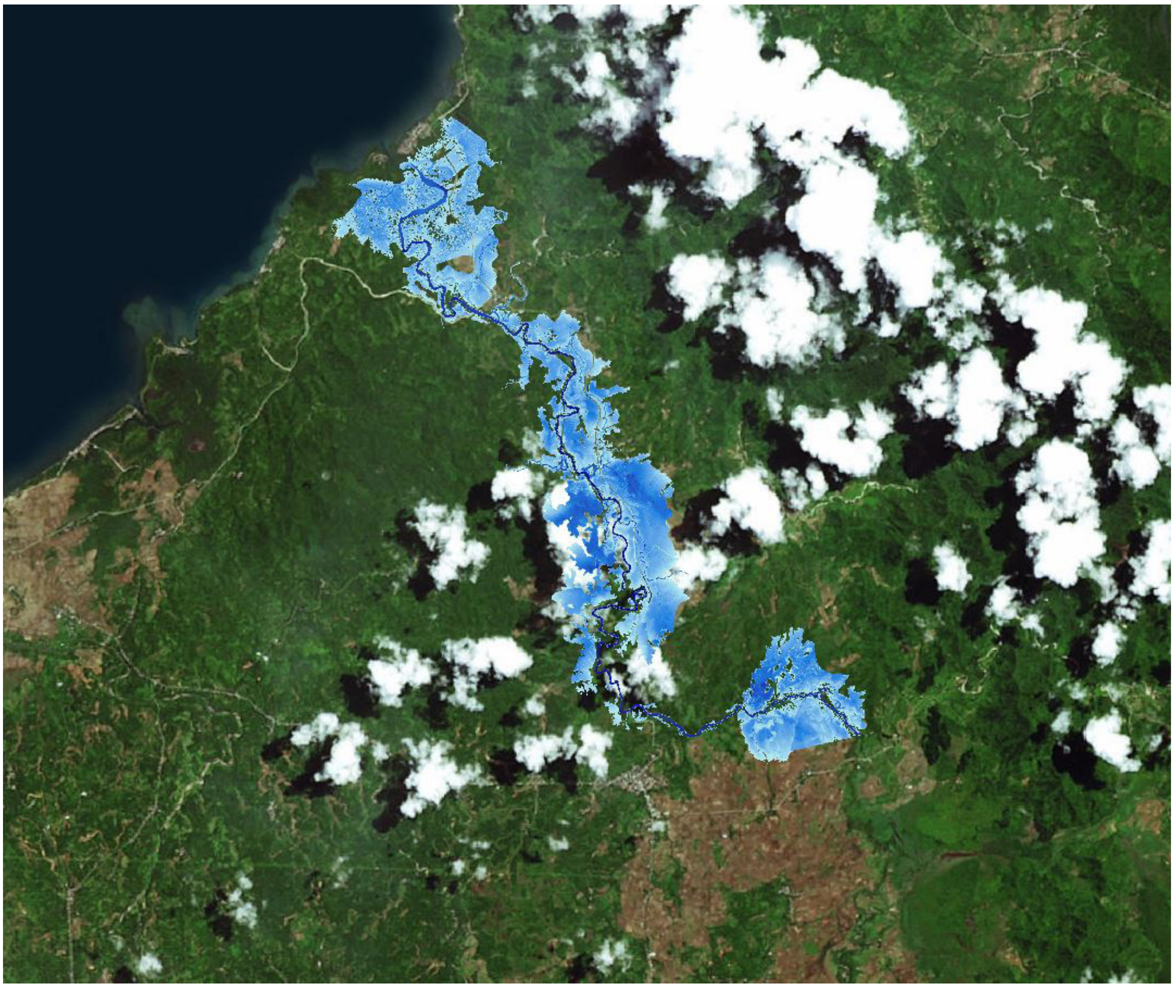


Figure 66. Sample output map of the Sangputan RAS Model

5.9 Flow Depth and Flood Hazard

The resulting hazard and flow depth maps have a 10m resolution. Figure 67 to Figure 72 exhibit the 5-, 25-, and 100-year rain return scenarios of the Sangputan floodplain.

The floodplain, with an area of 287.75 sq. km., covers Tacloban City, and five (5) municipalities, namely Alangalang, Barugo, Jaro, San Miguel, and Tunga. Table 34 summarizes the percentage of area affected by flooding per municipality.

Table 34. Municipalities affected in Sangputan floodplain

City / Municipality	Total Area	Area Flooded	% Flooded
Alangalang	145.45	68.91	47%
Barugo	81.25	64.41	79%
Jaro	190.65	39.88	21%
San Miguel	103.86	93.17	90%
Tacloban City	118.46	13.01	11%
Tunga	17.36	7.95	46%

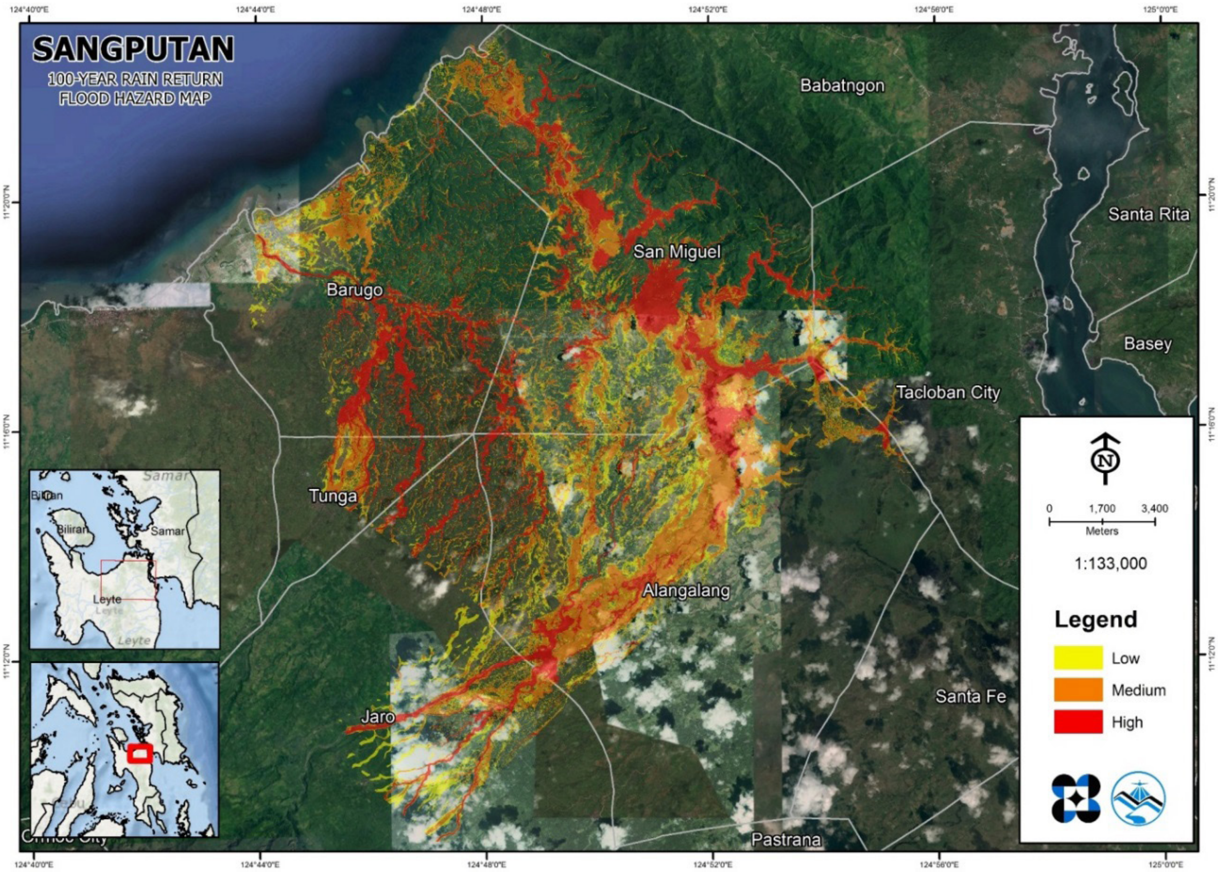


Figure 67. 100-year Flood Hazard Map for the Sangputan Floodplain

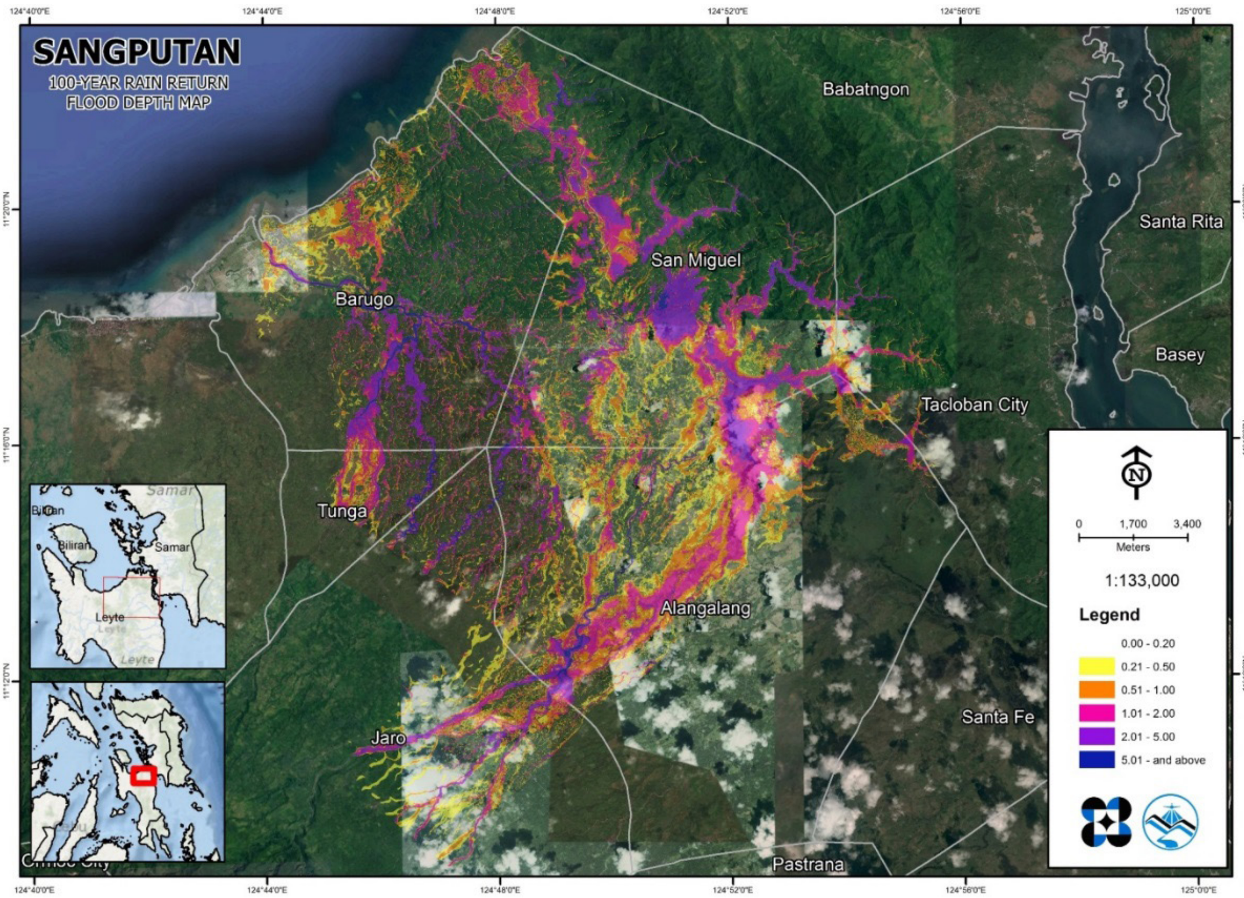


Figure 68. 100-year Flow Depth Map for the Sangputan Floodplain

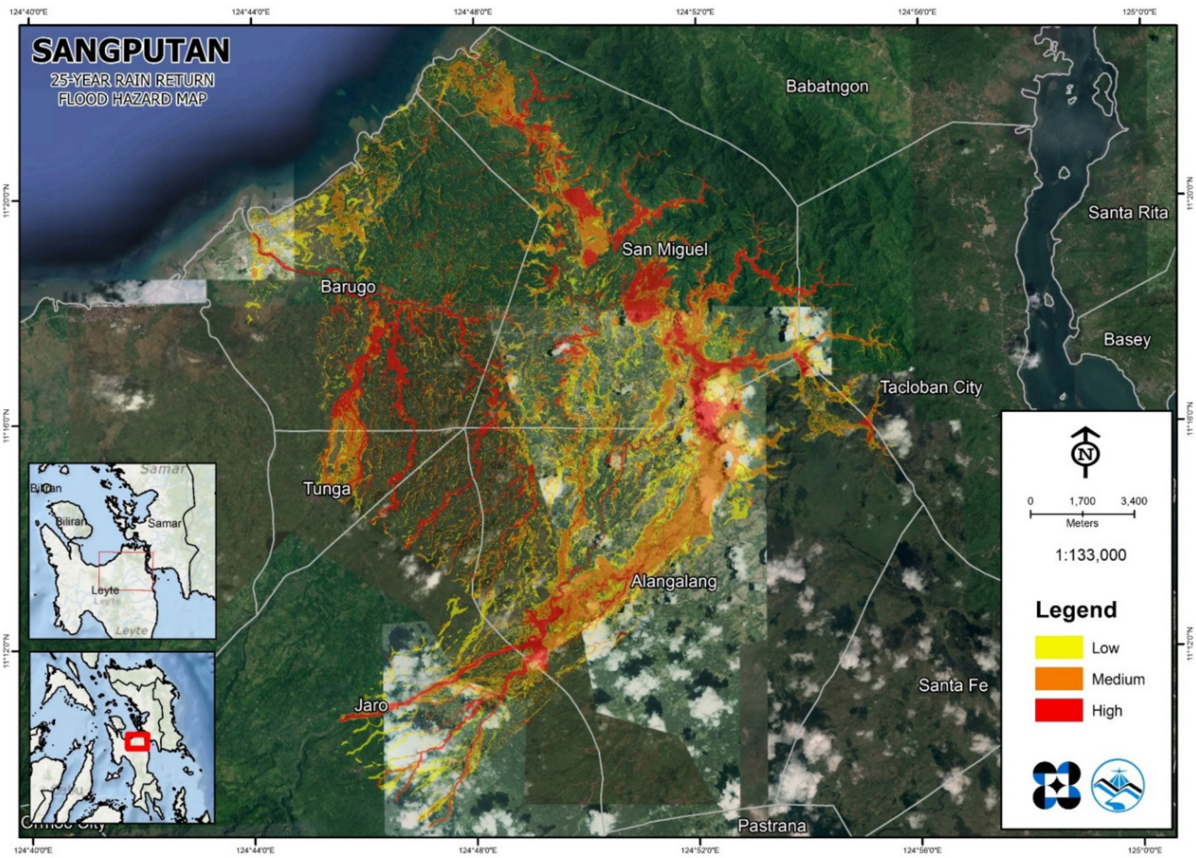


Figure 69. 25-year Flood Hazard Map for the Sangputan Floodplain

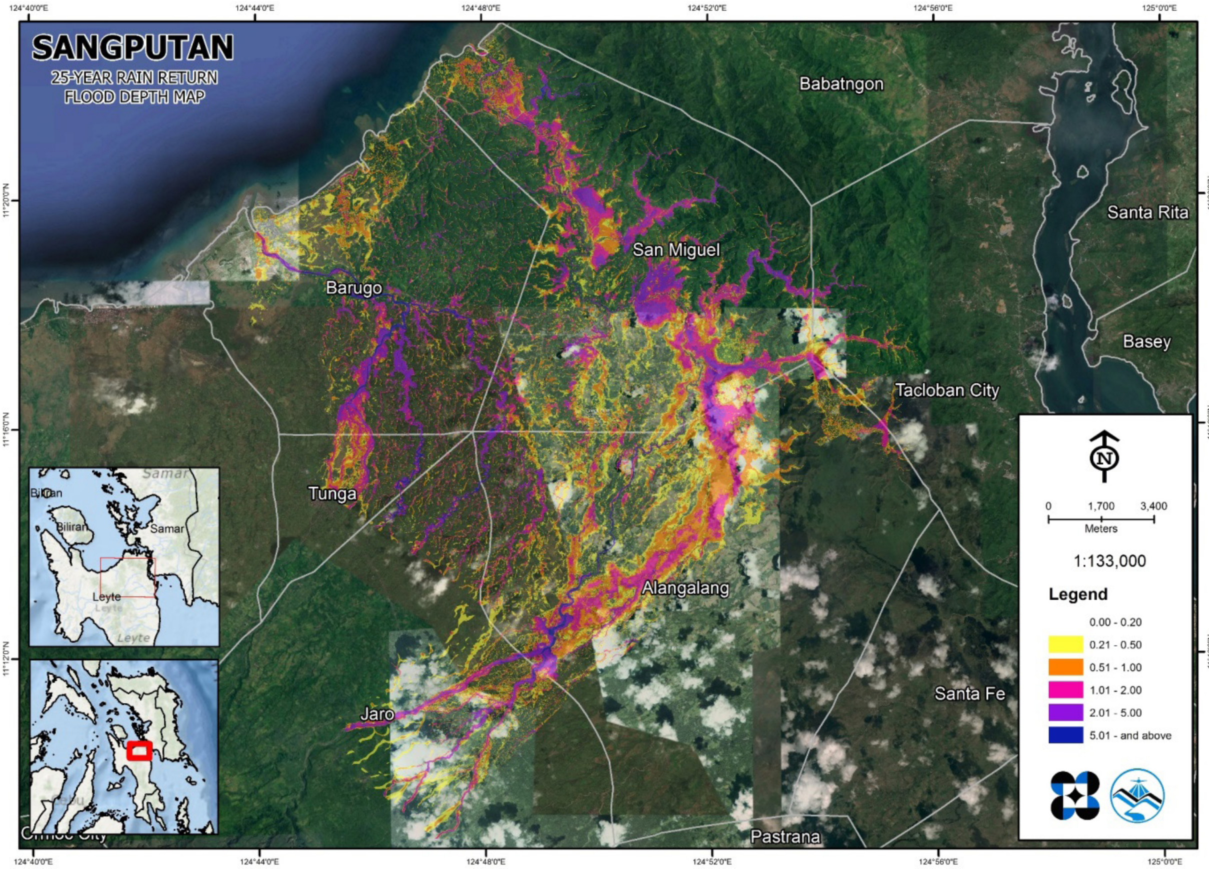


Figure 70. 25-year Flow Depth Map for the Sangputan Floodplain

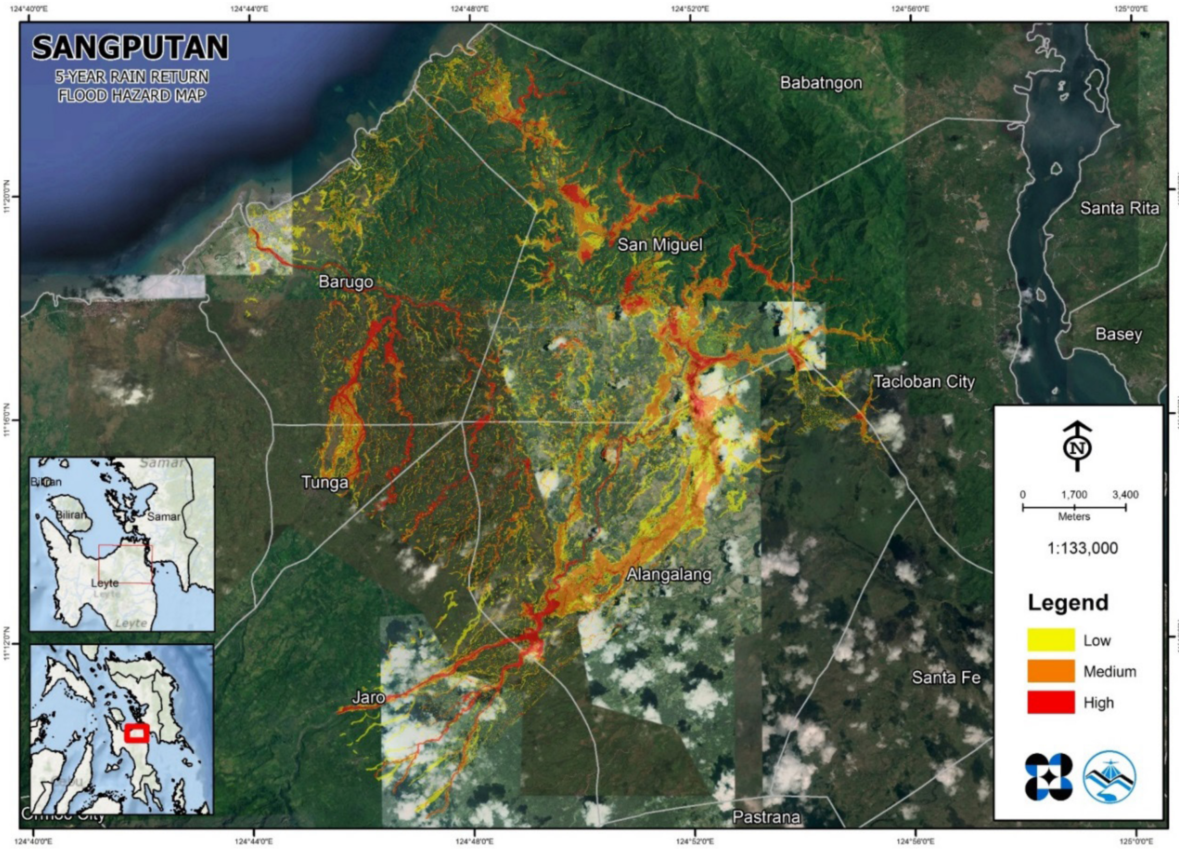


Figure 71. 5-year Flood Hazard Map for the Sangputan Floodplain

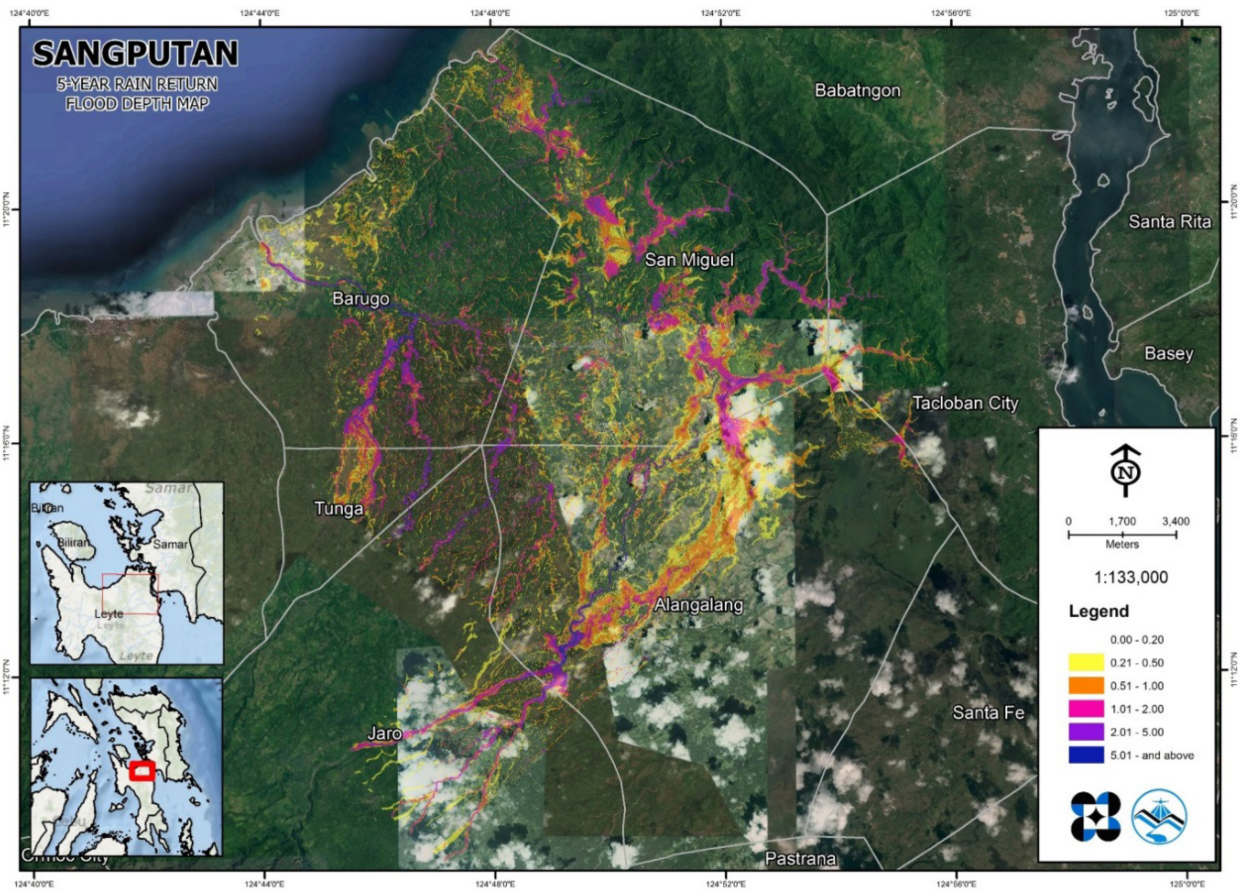


Figure 72. 5-year Flood Depth Map for the Sangputan Floodplain

5.10 Inventory of Areas Exposed to Flooding

Affected barangays in the Sangputan River Basin, grouped by municipality, are listed below. For the said basin, six (6) municipalities consisting of 118 barangays are expected to experience flooding when subjected to 5-year rainfall return period.

For the 5-year return period, 30.685% of the Municipality of Alangalang, with an area of 145.445 sq. km., will experience flood levels of less 0.20 meters. 7.404% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 5.953%, 2.214%, 0.9199%, and 0.2483% 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 Tables 35-38 are the affected areas, in square kilometers, by flood depth per barangay.

Table 35. Affected Areas in Alangalang, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Alangalang								
		Binongto-An	Binotong	Blumentritt	Borseth	Bugho	Cabadsan	Calaasan	Cavite	Divisoria
Affected Area (sq. km.)	0.03-0.20	0.223406475	2.632708935	0.110359174	1.882521385	5.013123984	0.972035524	0.97536167	0.287474861	0.013539196
	0.21-0.50	0.258738049	0.451685344	0.043373645	0.360262717	2.72654549	0.331071584	0.431811751	0.159258523	0.000670901
	0.51-1.00	0.379613308	0.322149087	0.017288429	0.161552279	2.245891381	0.225326826	0.600911578	0.244490295	0
	1.01-2.00	0.15678624	0.108660466	0.007379594	0.09847138	0.534435717	0.073484554	0.024632054	0.067409308	0
	2.01-5.00	0.054052109	0.053111093	0.0013	0.133149909	0.023746996	0.024822154	0.0011	0.042871361	0
	> 5.00	0	0.041703132	0	0	0	0.00849375	0	0.060525539	0

Table 36. Affected Areas in Alangalang, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Alangalang								
		Ekiran	Holy Child I	Holy Child II	Hubang	Hupit	Lourdes	Lukay	Milagrosa	P. Barrantes
Affected Area (sq. km.)	0.03-0.20	2.559135194	0.362407622	0.113783735	1.322150107	2.294192946	1.522735414	1.347062262	0.047567555	1.942103708
	0.21-0.50	0.949031047	0.032419709	0.008518028	0.321662385	0.356802376	0.235606634	0.347528942	0.006272045	0.573264744
	0.51-1.00	0.545485606	0.010487785	0.001551135	0.492951682	0.152292109	0.197781484	0.231119668	0	0.629711075
	1.01-2.00	0.173349683	0.004275214	0.00163666	0.264497958	0.173052215	0.134521111	0.040133069	0	0.131518844
	2.01-5.00	0.104738492	0.002862426	0.0001	0.038639139	0.108797577	0.01864114	0.019054922	0.000385116	0.023548842
	> 5.00	0.044412536	0	0	0.000691714	0	0	0.031483698	0	0.002308286

Table 37. Affected Areas in Alangalang, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Alangalang								
		Salvacion Poblacion	San Antonio Poblacion	San Francisco East	San Francisco West	San Roque	San Vicente	Santiago	Santo Niño	Santol
Affected Area (sq. km.)	0.03-0.20	0.204692116	0.000861301	2.82124687	1.96095603	0.1545830	2.9253316	3.4819639	0.043568705	2.9411733
	0.21-0.50	0.019332864	0.0001	0.750062314	0.262183547	0.0161503	0.8265203	0.4143592	0	0.125726859
	0.51-1.00	0.005945153	0	0.405178801	0.143054979	0.0042512	0.7112839	0.2360926	0	0.146787394
	1.01-2.00	0	0	0.025662827	0.11644992	0.0021872	0.3083276	0.2912944	0	0.183068661
	2.01-5.00	0	0	0.004914333	0.0085	0.0006	0.2427699	0.3245405	0	0.102059953
	> 5.00	0	0	0.002113468	0	0	0.107075384	0.0547854	0	0.007576835

Table 38. Affected Areas in Alangalang, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Areas in Alangalang	
		Tabangohay	Veteranos
Affected Area (sq. km.)	0.03-0.20	6.3837511	0.090027274
	0.21-0.50	0.758038511	0.00301871
	0.51-1.00	0.546742148	0.001514406
	1.01-2.00	0.298986102	0.000395747
	2.01-5.00	0.00369641	0
	> 5.00	0	0

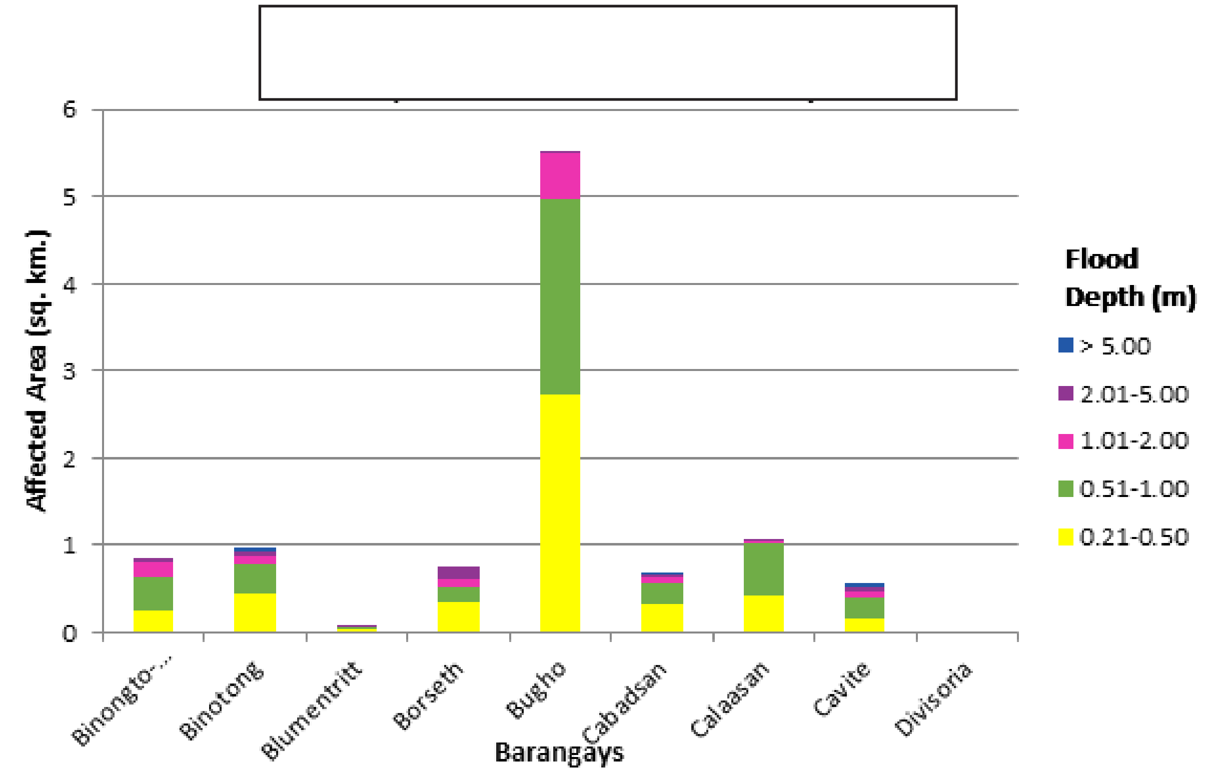


Figure 73. Affected Areas in Alangalang, Leyte during 5-Year Rainfall Return Period

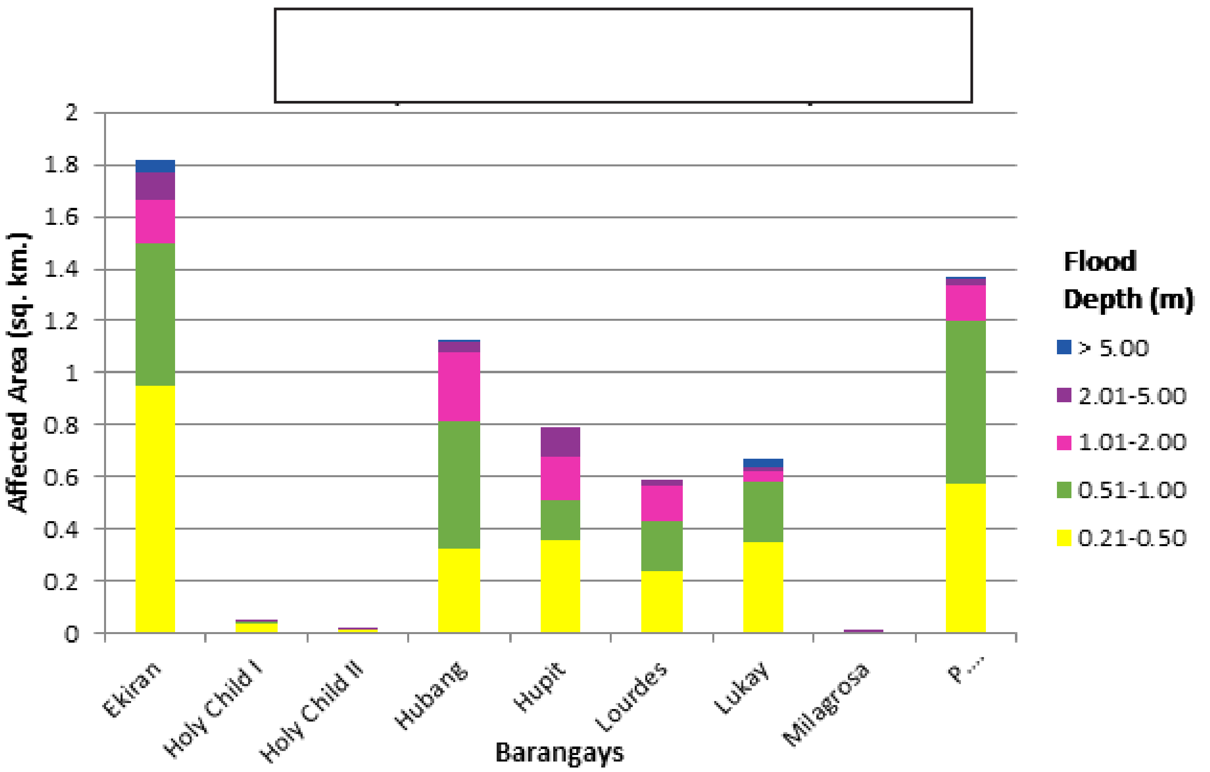


Figure 74. Affected Areas in Alangalang, Leyte during 5-Year Rainfall Return Period

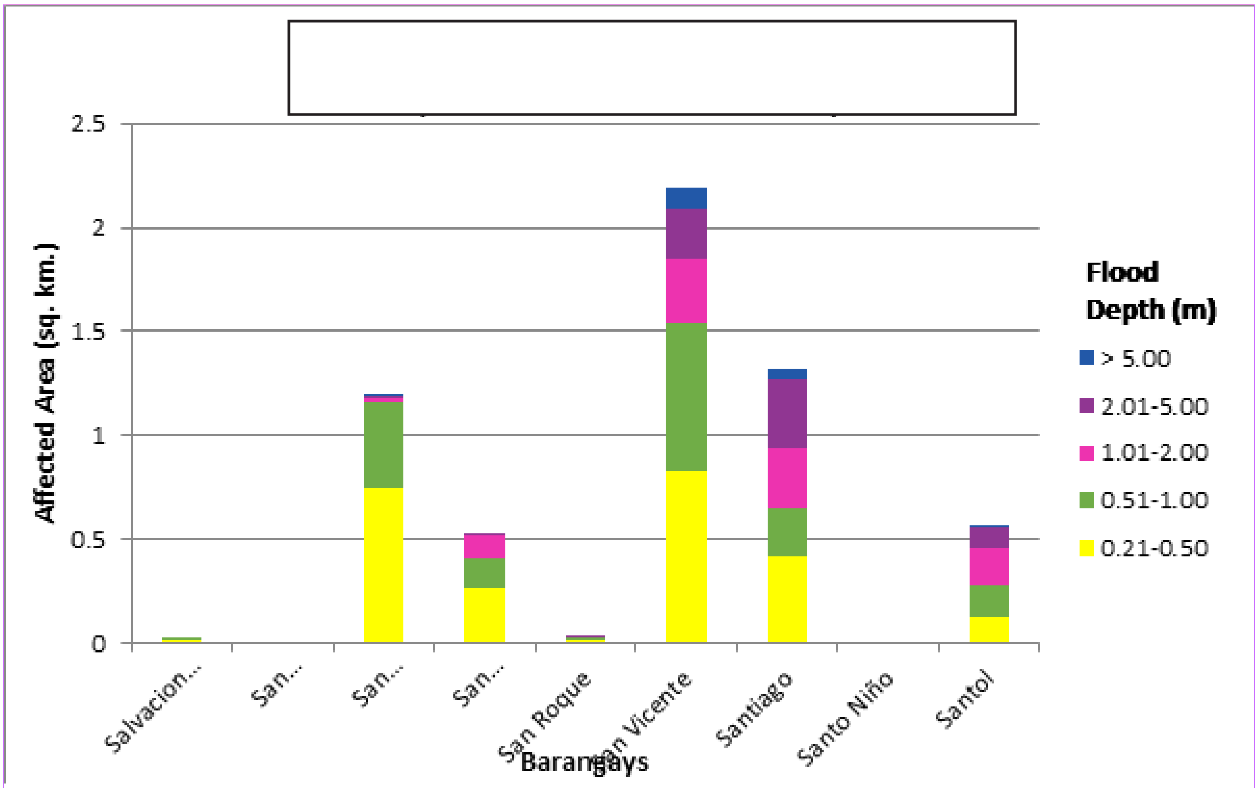


Figure 75. Affected Areas in Alangalang, Leyte during 5-Year Rainfall Return Period

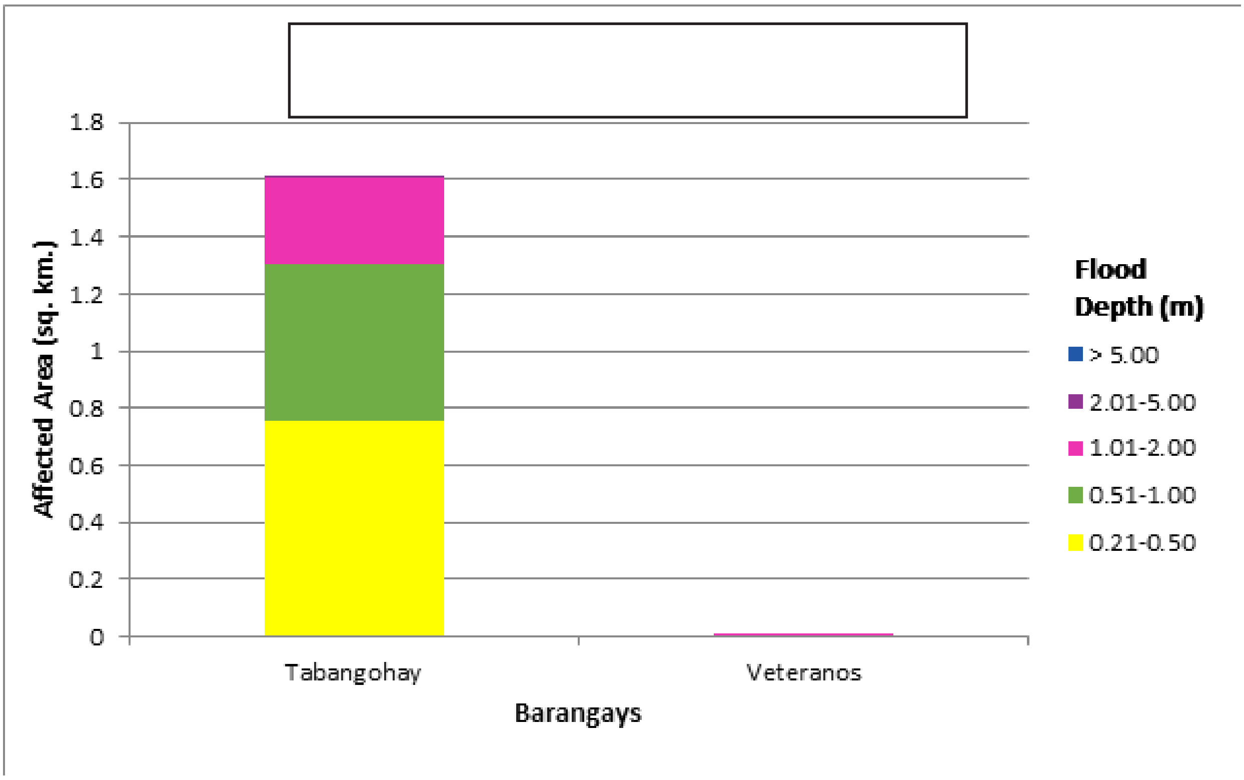


Figure 76. Affected Areas in Alangalang, Leyte during 5-Year Rainfall Return Period

For the 5-year return period, 64.247% of the Municipality of Barugo, with an area of 81.25 sq. km., will experience flood levels of less 0.20 meters. 5.5906% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 3.8263%, 3.2985%, 1.9287%, and 0.3887% 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 Tables 39-42 are the affected areas, in square kilometers, by flood depth per barangay.

Table 39. Affected Areas in Barugo, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		**Affected Barangays in Barugo**								
		Amahit	**Balud**	**Bukid**	**Bulod**	**Busay**	**Cabarasan**	**Cabolo-An**	**Calingcaguing**	**Can-Isak**
Affected Area (sq. km.)	0.03-0.20	0.50489	3.23792	0.177973	3.737766	2.993216	1.581557	5.069372	0.94564	1.765703
	0.21-0.50	0.059132	0.253111	0.010075	0.254828	0.146048	0.434281	0.179717	0.087895	0.179536
	0.51-1.00	0.017467	0.119062	0.012069	0.199656	0.10557	0.150166	0.128753	0.065378	0.345203
	1.01-2.00	0.002373	0.036846	0.013048	0.153744	0.105267	0.014543	0.086339	0.034879	0.423756
	2.01-5.00	0	0.005461	0.000981	0.044573	0.042512	0	0.044902	0.017681	0.213889
	> 5.00	0	0	0	0	0	0	0.0015	0.015593	0.007337

Table 40. Affected Areas in Barugo, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Barugo								
		Cuta	Domogdog	Duka	Guindaohan	Hiagsam	Hilaba	Hinugayan	Ibag	Minuhang
Affected Area (sq. km.)	0.03-0.20	2.458271	0.552476	4.724823	0.743882	1.079958	0.356604	0.921733	2.334919	1.174538
	0.21-0.50	0.486287	0.116176	0.210589	0.071053	0.04366	0.073984	0.04875	0.090403	0.388312
	0.51-1.00	0.10561	0.003612	0.143052	0.008478	0.077399	0.041867	0.062394	0.094861	0.13431
	1.01-2.00	0.002701	0	0.137958	0.001598	0.169796	0.043639	0.081115	0.069416	0.017792
	2.01-5.00	0	0	0.047161	0	0.0795	0.070783	0.023305	0.011154	0
	> 5.00	0	0	0.0002	0	0.0014	0	0.002102	0	0

Table 41. Affected Areas in Barugo, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Barugo								
		Pikas	Pitogo	Poblacion Dist. I	Poblacion Dist. II	Poblacion Dist. III	Poblacion Dist. IV	Poblacion Dist. V	Poblacion Dist. VI	Pongso
Affected Area (sq. km.)	0.03-0.20	3.355602	2.155041	0.151929	0.153018	0.094611	0.11809	0.15514	0.123264	2.425209
	0.21-0.50	0.280649	0.100356	0.034784	0.035274	0.022993	0.005499	0.04698	0.029866	0.195402
	0.51-1.00	0.334581	0.117015	0.002067	0.007629	0.003027	0	0.005719	0.005967	0.239786
	1.01-2.00	0.30854	0.058531	0	0.003819	0	0	0	0	0.374246
	2.01-5.00	0.351404	0.005128	0	0	0	0	0	0	0.230885
	> 5.00	0.167858	0	0	0	0	0	0	0	0.0263

Table 42. Affected Areas in Barugo, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		**Affected Barangays in Barugo**					
		Roosevelt	**San Isidro**	**San Roque**	**Santa Rosa**	**Santarin**	**Tutug-An**
Affected Area (sq. km.)	0.03-0.20	1.965423	0.613062	1.023126	4.299734	0.044913	1.16159
	0.21-0.50	0.138198	0.09238	0.043028	0.250386	0.026835	0.105938
	0.51-1.00	0.115224	0.047394	0.046075	0.245089	0.035053	0.089307
	1.01-2.00	0.168127	0.000702	0.034896	0.262983	0.02792	0.045503
	2.01-5.00	0.144205	0	0.006252	0.117651	0	0.109615
	> 5.00	0.060964	0	3.18E-05	0.0003	0	0.032252

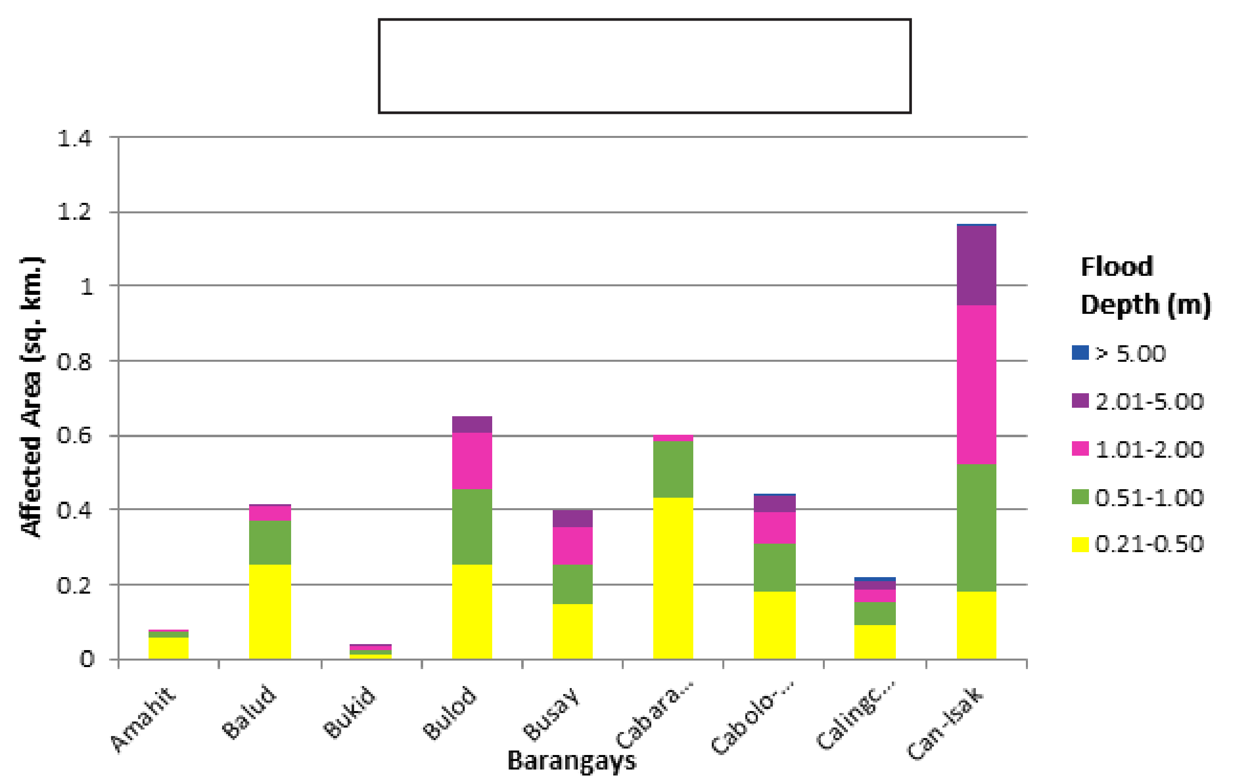


Figure 77. Affected Areas in Barugo, Leyte during 5-Year Rainfall Return Period

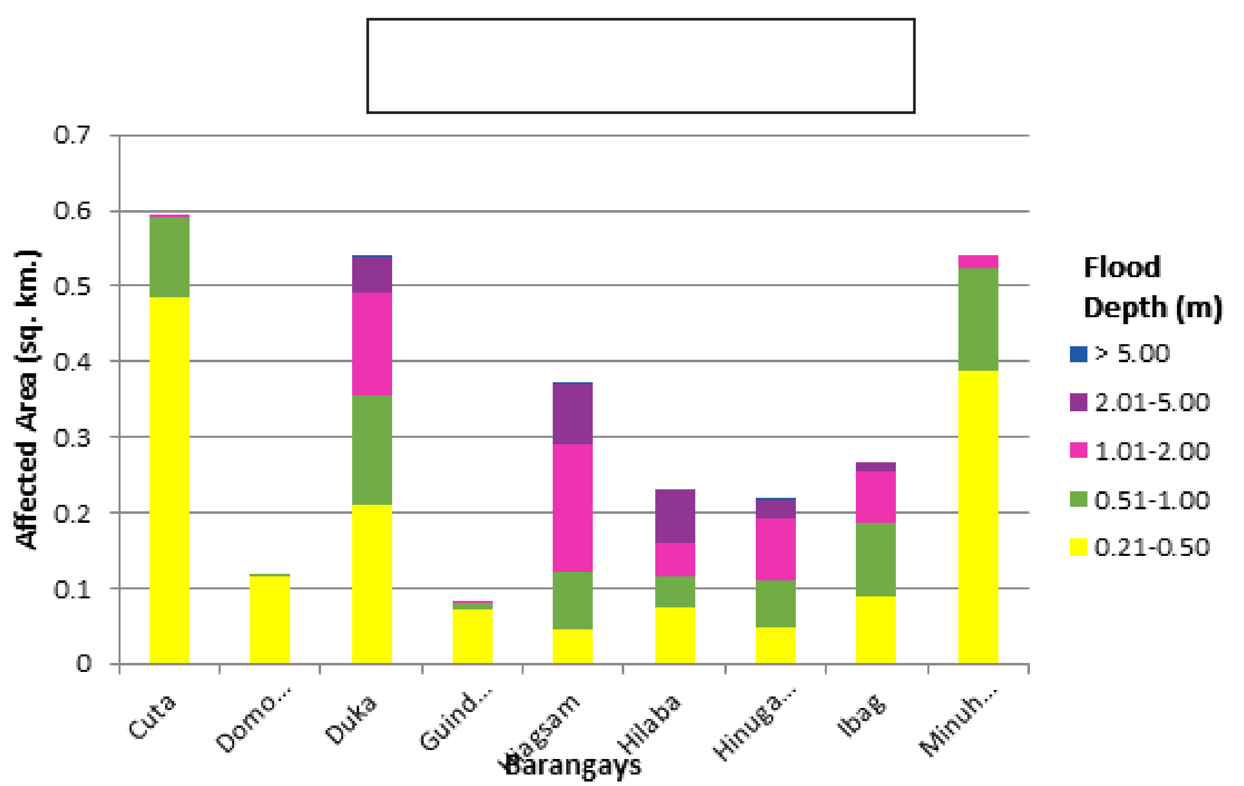


Figure 78. Affected Areas in Barugo, Leyte during 5-Year Rainfall Return Period

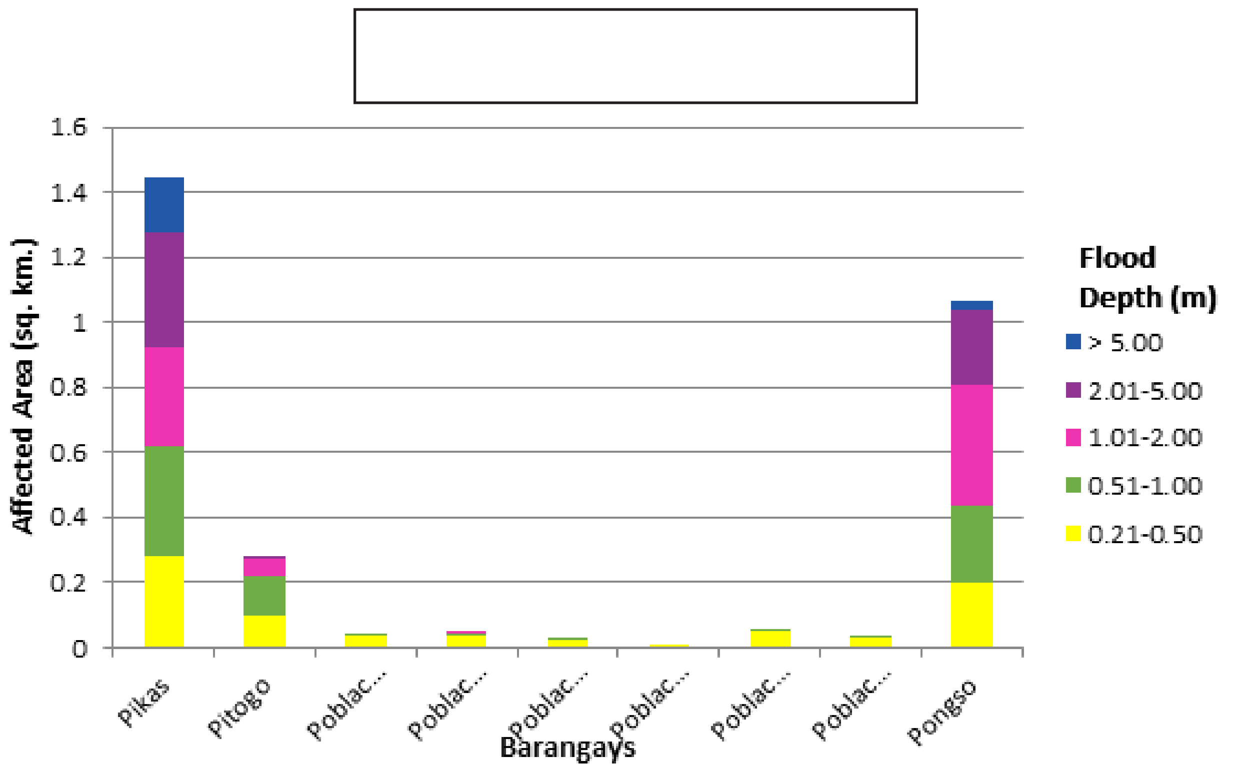


Figure 79. Affected Areas in Barugo, Leyte during 5-Year Rainfall Return Period

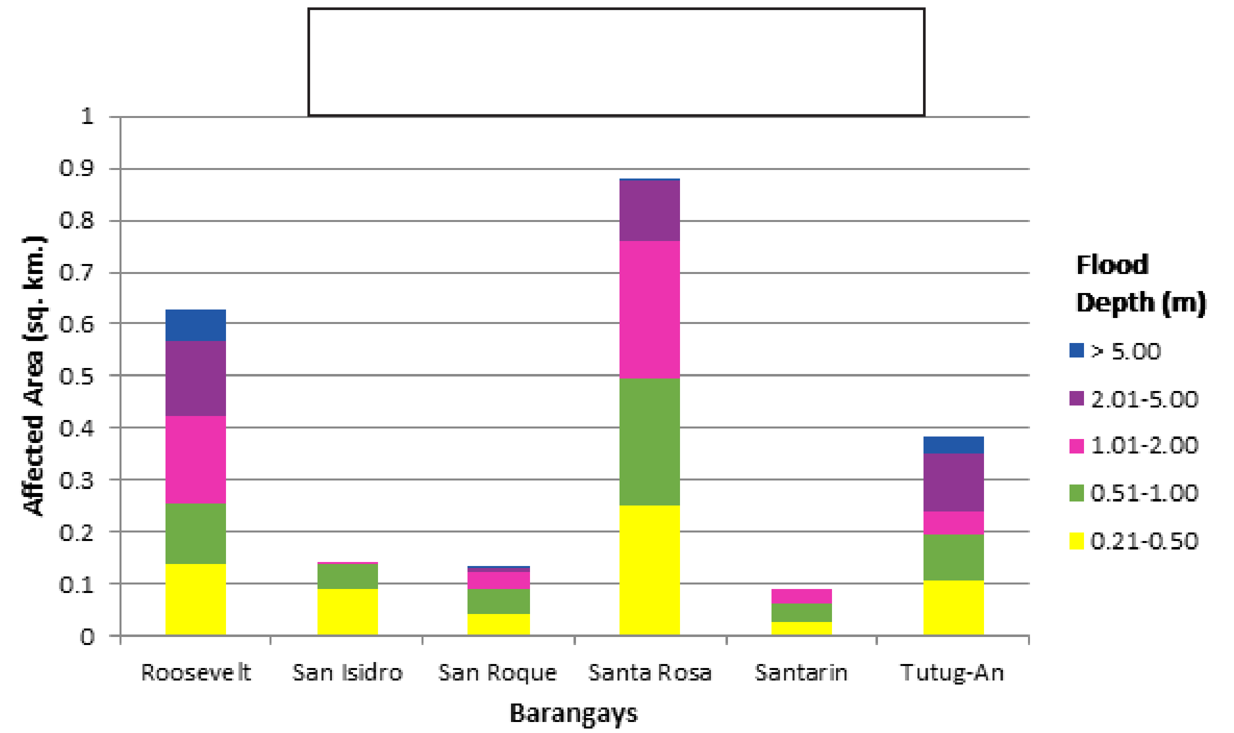


Figure 80. Affected Areas in Barugo, Leyte during 5-Year Rainfall Return Period

For the 5-year return period, 16.779% of the Municipality of Jaro, with an area of 190.65 sq. km., will experience flood levels of less 0.20 meters. 1.8737% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.9473%, 0.868%, 0.4034%, and 0.0579% 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 Tables 43-45 are the affected areas, in square kilometers, by flood depth per barangay.

Table 43. Affected Areas in Jaro, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Jaro								
		Alahag	Bias Zabala	Buenavista	Bukid	Buri	Canapuan	Canhandugan	Daro	District I
Affected Area (sq. km.)	0.03-0.20	0.443863	0.969822	2.716095	3.213216	2.309978	2.345971	0.521564	0.268453	0.342079
	0.21-0.50	0.04402	0.165758	0.556499	0.269336	0.22013	0.277677	0.094244	0.0003	0.004589
	0.51-1.00	0.024127	0.052052	0.393009	0.220163	0.131597	0.092297	0.02213	0	0.005697
	1.01-2.00	0.010058	0.049806	0.407341	0.165439	0.156314	0.136307	0.019718	0	0.003749
	2.01-5.00	0.001	0.00674	0.214808	0.0092	0.06268	0.057094	0.00314	0	0.007156
	> 5.00	0	0	0.00968	0	1E-04	0	0	0	0

Table 44. Affected Areas in Jaro, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Jaro								
		District II	District III	District IV	Hiagsam	Kaglawaan	Kalinawan	Macanip	Macopa	Malobago
Affected Area (sq. km.)	0.03-0.20	0.414993	0.497452	0.471467	0.323625	1.328859	1.213472	0.889135	0.41565	1.443191
	0.21-0.50	0.008081	0.012266	0.036323	0.01828	0.183635	0.098499	0.150479	0.042408	0.199029
	0.51-1.00	0.004639	6.03E-05	0.013891	0.011775	0.023843	0.016722	0.10653	0.014787	0.10025
	1.01-2.00	0.002601	0	0.018464	0.008853	0.003024	0.018759	0.091984	0.0004	0.083265
	2.01-5.00	0	0	0.016697	0.014749	0	0.003962	0.011343	0	0.0117
	> 5.00	0	0	0	0.006918	0	0	0	0	0

Table 45. Affected Areas in Jaro, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Jaro					
		Olotan	Pitogo	Sagkahan	Santo Ni§o	Tuba	Uguiao
Affected Area (sq. km.)	0.03-0.20	1.240276	2.039843	1.221589	0.18093	5.46333	1.715744
	0.21-0.50	0.234105	0.306363	0.204024	0.019207	0.283558	0.14347
	0.51-1.00	0.034045	0.103932	0.112109	0.00791	0.2914	0.023189
	1.01-2.00	0.006054	0.063935	0.071491	0.001899	0.282291	0.053064
	2.01-5.00	0	0.029551	0.108335	0	0.204842	0.006082
	> 5.00	0	0	0.009128	0	0.084643	0

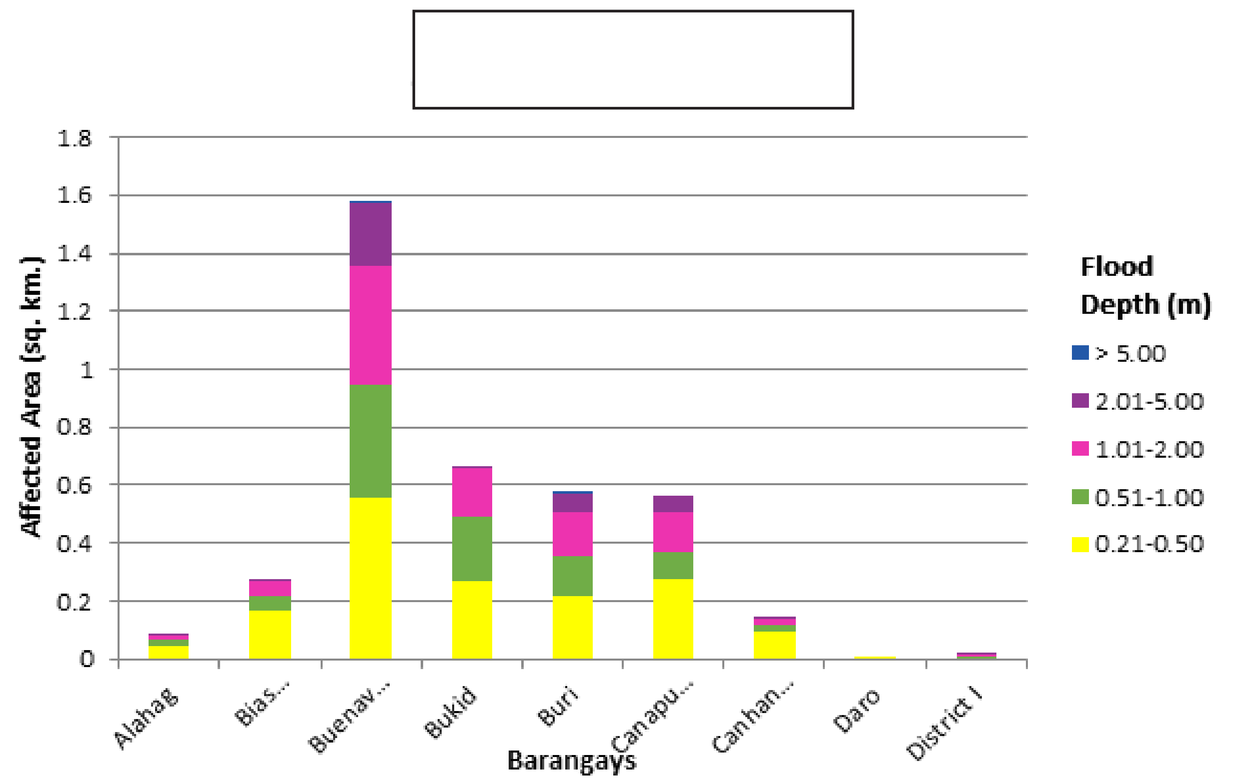


Figure 81. Affected Areas in Jaro, Leyte during 5-Year Rainfall Return Period

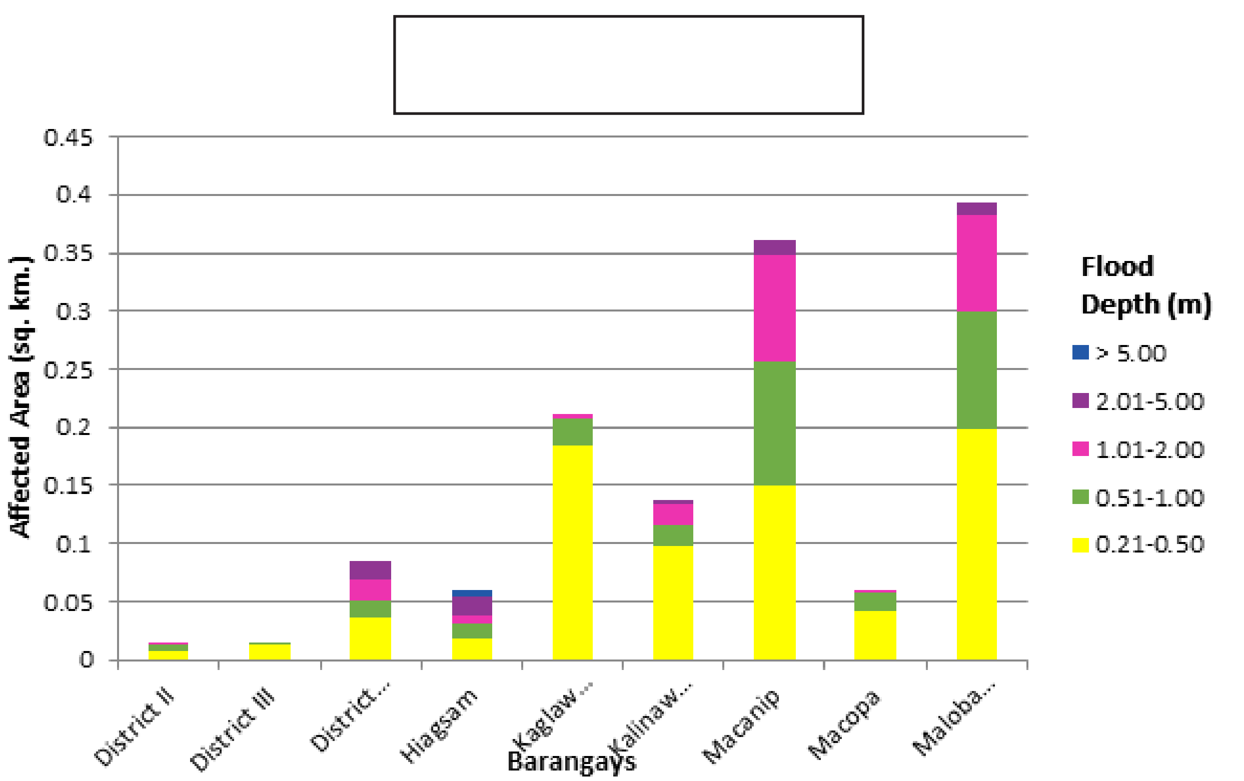


Figure 82. Affected Areas in Jaro, Leyte during 5-Year Rainfall Return Period

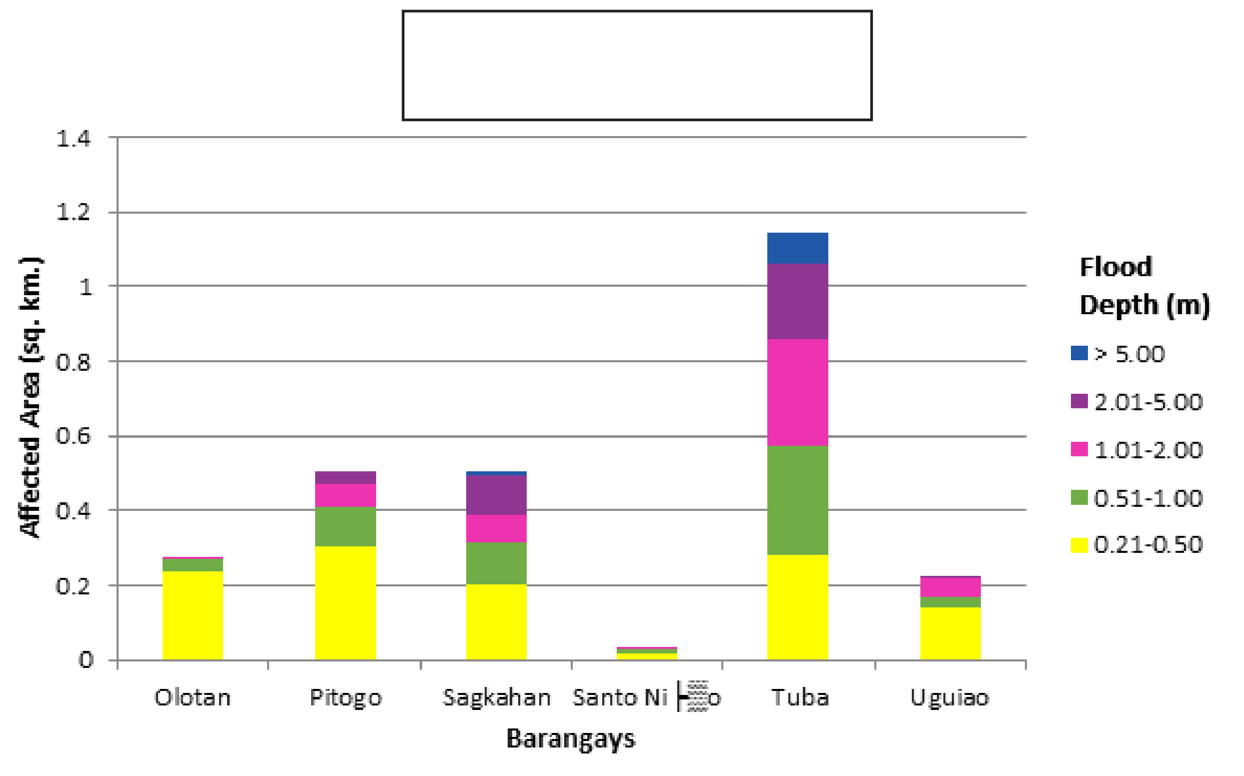


Figure 83. Affected Areas in Jaro, Leyte during 5-Year Rainfall Return Period

For the 5-year return period, 65.286% of the Municipality of San Miguel, with an area of 103.86 sq. km., will experience flood levels of less 0.20 meters. 8.7015% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 7.7691%, 6.0965%, 1.8356%, and 0.0848% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 46-48 are the affected areas, in square kilometers, by flood depth per barangay.

Table 46. Affected Areas in San Miguel, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in San Miguel								
		Bagacay	Bahay	Bairan	Cabatianuhan	Canap	Capilihan	Caraycaray	Cayare	Guinciaman
Affected Area (sq. km.)	0.03-0.20	0.068808	11.39944	1.383273923	2.164271	3.956149	6.866351	4.491204	2.225294	10.95976
	0.21-0.50	0.007894	1.389709	0.397367952	0.603032	0.493338	1.095277	0.407426	0.274953	1.07906
	0.51-1.00	0.0005	1.416112	0.317529629	0.402874	0.412121	1.303479	0.559178	0.126813	1.246262
	1.01-2.00	0	1.421574	0.062596757	0.283608	0.149699	1.376654	0.447748	0.03551	1.243128
	2.01-5.00	0	0.359178	0.01100986	0.027517	0.0014	0.288919	0.285734	0.009197	0.505036
	> 5.00	0	0.0033	0	0	0	0.0001	0.059531	0	0.0215

Table 47. Affected Areas in San Miguel, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in San Miguel								
		Impo	Kinalumsan	Libtong	Lukay	Malaguinabot	Malpag	Mawodpawod	Patong	Pinarigusan
Affected Area (sq. km.)	0.03-0.20	0.907919	2.580005	0.700731624	2.831217	2.146815	0.977716	1.914446	4.614479	0.00186
	0.21-0.50	0.157036	0.124291	0.094252853	0.655561	0.44103	0.250752	0.167366	0.714156	0
	0.51-1.00	0.205733	0.147316	0.108145919	0.277451	0.328971	0.111154	0.082425	0.375878	0
	1.01-2.00	0.051369	0.202779	0.093068037	0.099983	0.036613	0.031503	0.039427	0.18118	0
	2.01-5.00	0.024108	0.035909	0.0085	0.0079	0.0026	0.005193	0.006944	0.126044	0
	> 5.00	0	0.001935	0	0	0	0	0	0	0

Table 48. Affected Areas in San Miguel, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in San Miguel		
		San Andres	Santa Cruz	Santol
Affected Area (sq. km.)	0.03-0.20	1.247327	0.384423	5.984576446
	0.21-0.50	0.185566	0.063281	0.436050328
	0.51-1.00	0.20625	0.026231	0.414562257
	1.01-2.00	0.119949	0.002767	0.452649863
	2.01-5.00	0.023978	0.00092	0.176328368
	> 5.00	0.001	0	0.0007

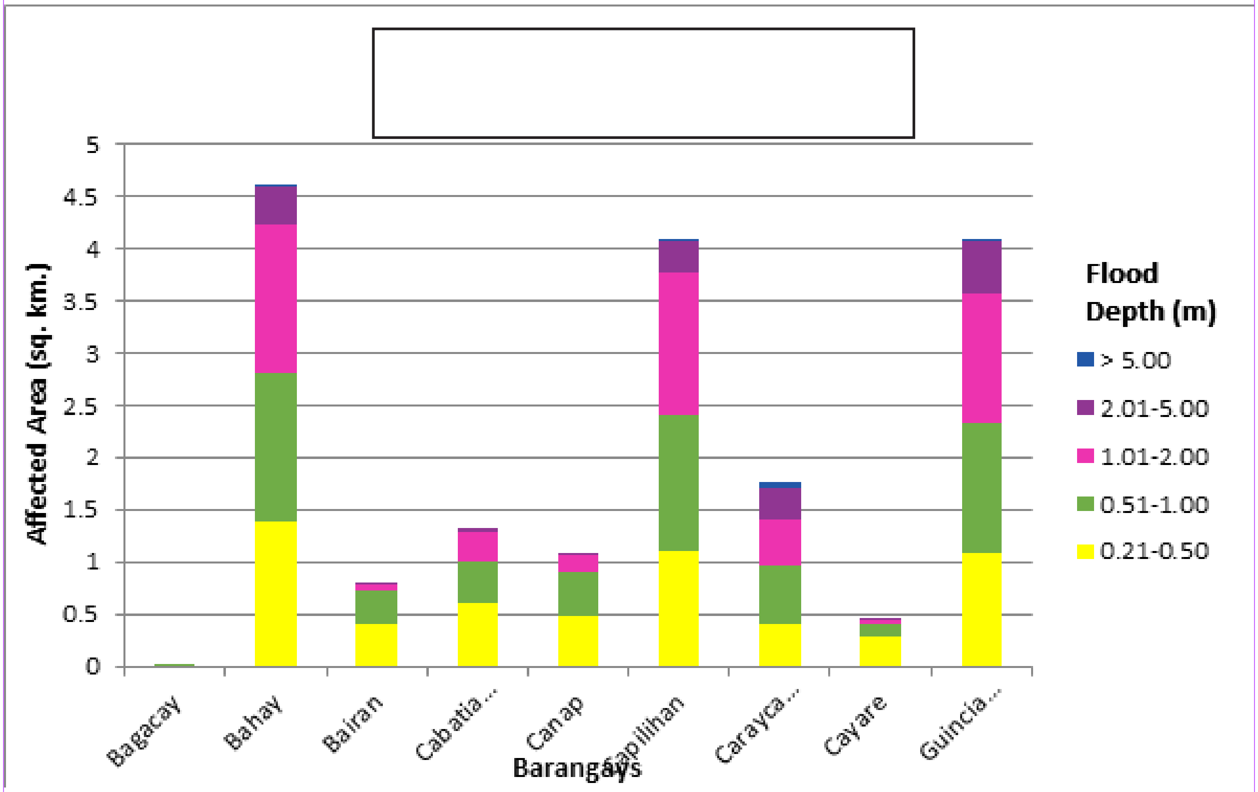


Figure 84. Affected Areas in San Miguel, Leyte during 5-Year Rainfall Return Period

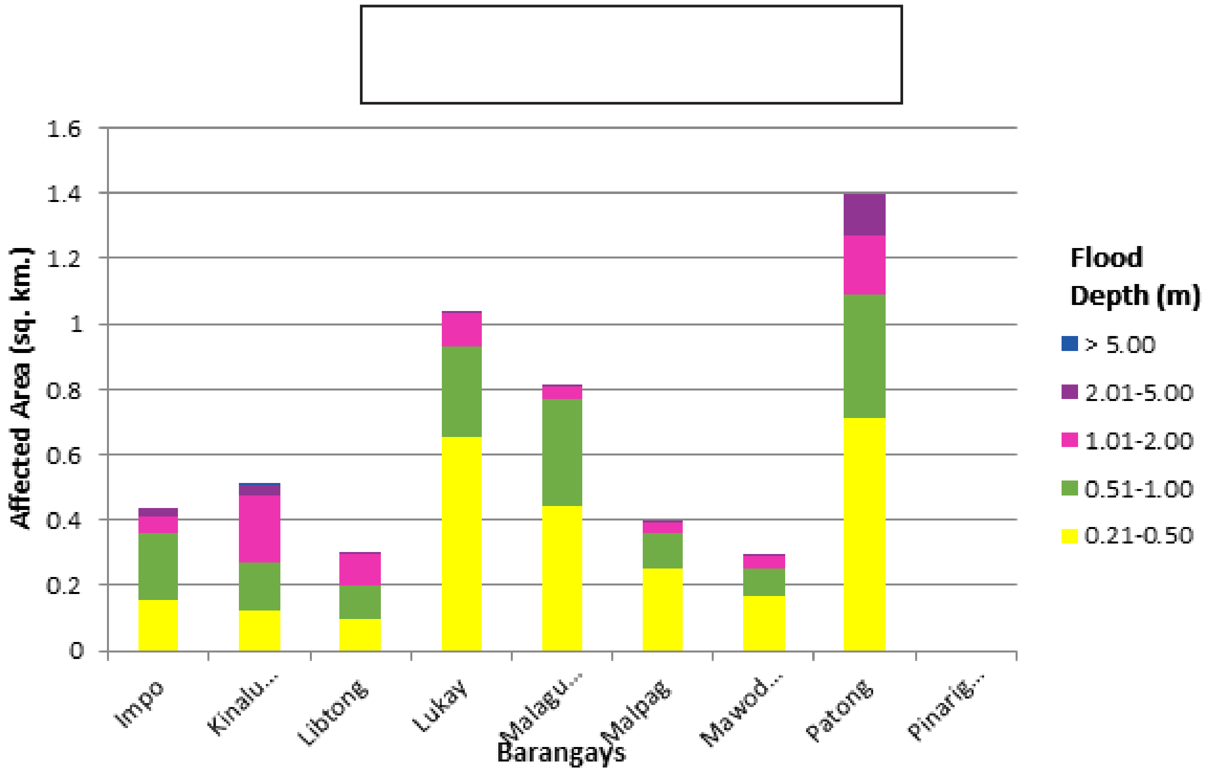


Figure 85. Affected Areas in San Miguel, Leyte during 5-Year Rainfall Return Period

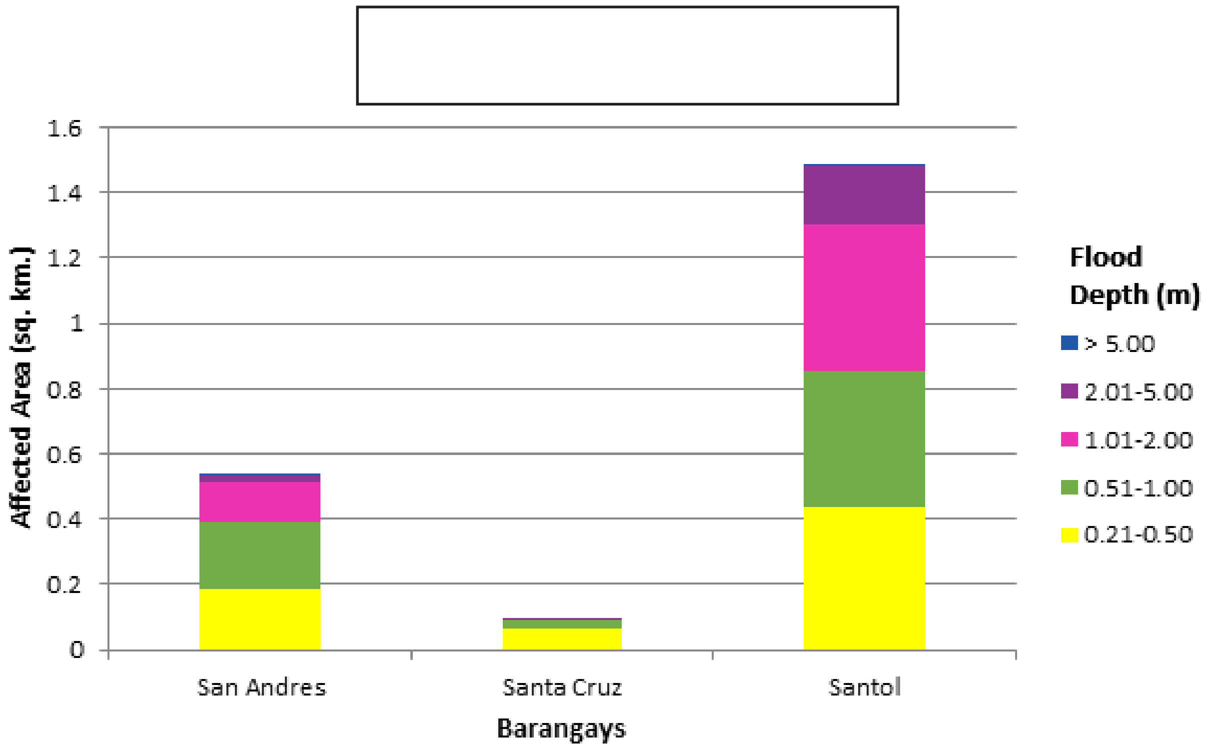


Figure 86. Affected Areas in San Miguel, Leyte during 5-Year Rainfall Return Period

For the 5-year return period, 9.4055% of the City of Tacloban, with an area of 118.457 sq. km., will experience flood levels of less 0.20 meters. 0.6501% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.5339%, 0.307%, 0.0831%, and 0.0014% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 49 are the affected areas, in square kilometers, by flood depth per barangay.

Table 49. Affected Areas in Tacloban City, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Tacloban				
		Barangay 100	Barangay 103	Barangay 106	Barangay 93	Barangay 98
Affected Area (sq. km.)	0.03-0.20	1.465799	0.439695	0.27649	3.339615	5.619986
	0.21-0.50	0.13239	0.01484	0.007807	0.23969	0.375392
	0.51-1.00	0.109793	0.005079	0.002807	0.141395	0.373363
	1.01-2.00	0.029839	0.0007	0.001398	0.074703	0.257024
	2.01-5.00	0.0003	0.0001	0.000564	0.005871	0.091576
	> 5.00	0	0	0	0	0.0017

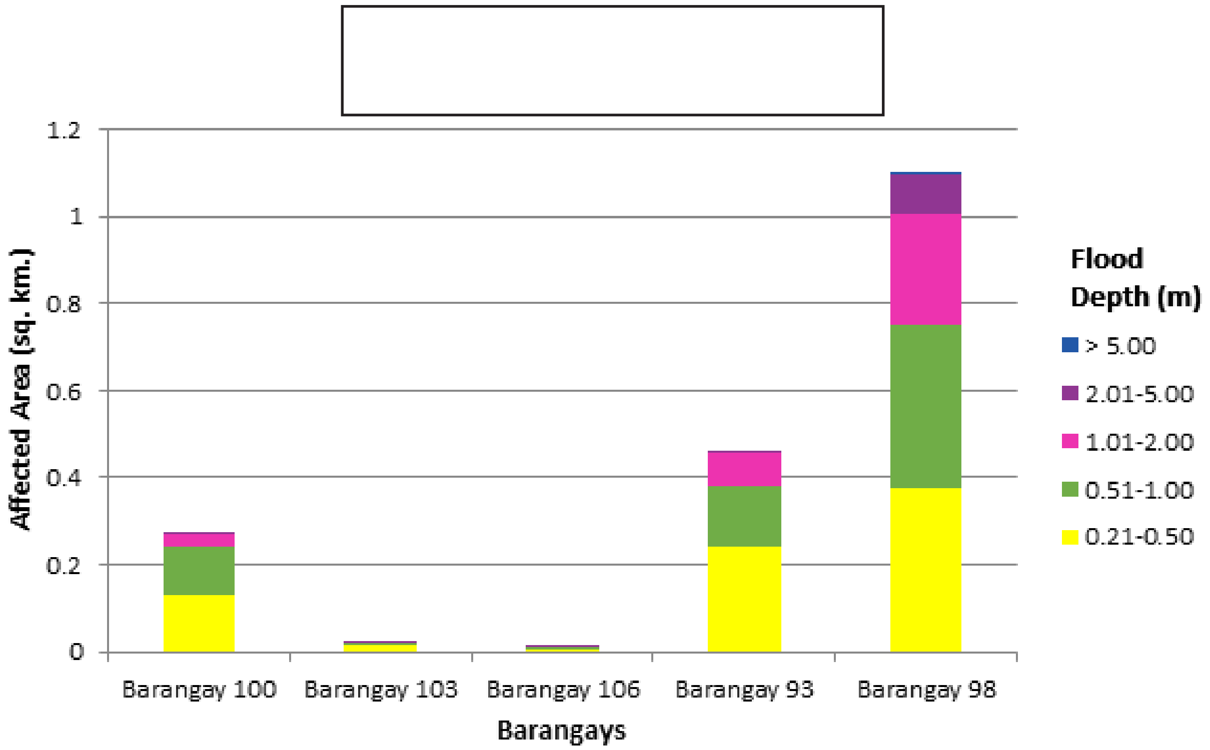


Figure 87. Affected Areas in Tacloban City, Leyte during 5-Year Rainfall Return Period

For the 5-year return period, 31.09% of the Municipality of Tunga, with an area of 17.3625 sq. km., will experience flood levels of less 0.20 meters. 4.4424% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.83%, 3.4073%, 1.7265%, and 0.3791% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and more than 5 meters, respectively. Listed in Table 50 are the affected areas, in square kilometers, by flood depth per barangay.

Table 50. Affected Areas in Tunga, Leyte during 5-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangay in Tunga					
		Astorga	Balire	Banawang	San Pedro	San Roque	San Vicente
Affected Area (sq. km.)	0.03-0.20	1.548981	0.003604	3.176827	0.401533	0.230182	0.036973
	0.21-0.50	0.429428	0.00096	0.172792	0.132864	0.034106	0.001174
	0.51-1.00	0.513981	0.000886	0.140407	0.16023	0.020246	0.002863
	1.01-2.00	0.346188	0	0.173852	0.049351	0.015642	0.006566
	2.01-5.00	0.115068	0	0.157334	0.024097	0.003272	0
	> 5.00	0	0	0.065826	0	0	0

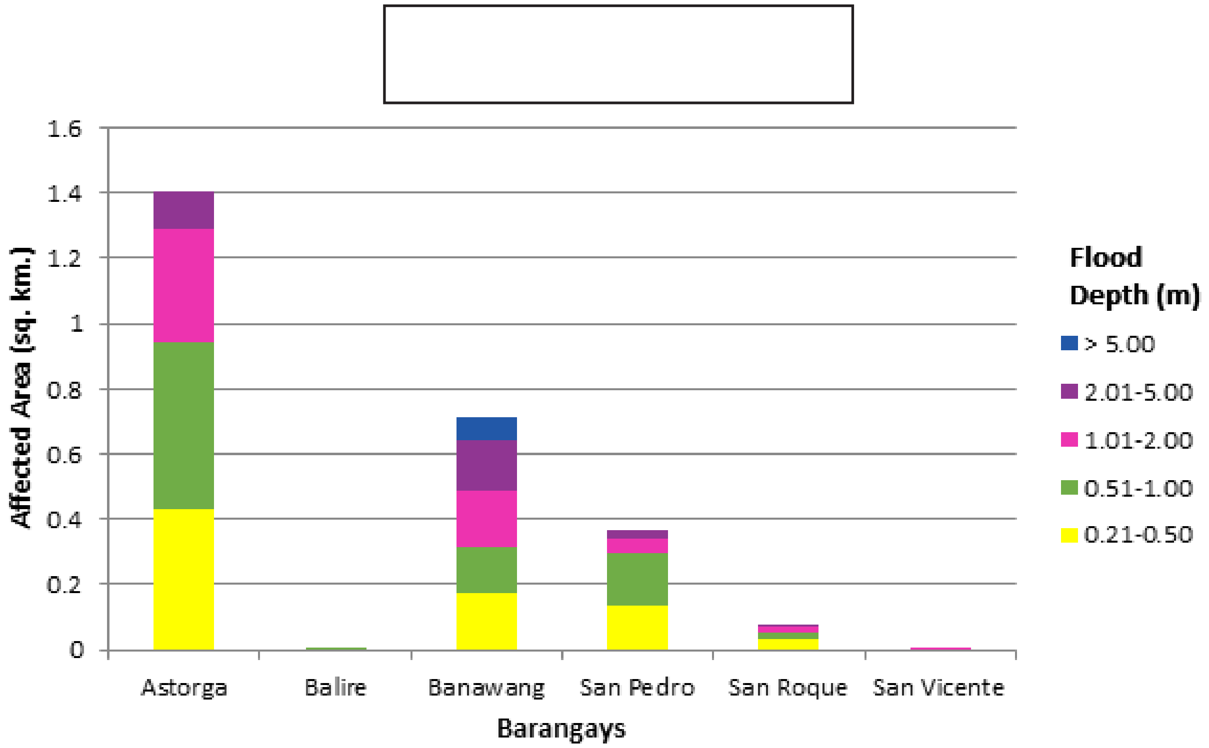


Figure 88. Affected Areas in Tunga, Leyte during 5-Year Rainfall Return Period

For the 25-year return period, 25.34% of the Municipality of Alangalang, with an area of 145.445 sq. km., will experience flood levels of less 0.20 meters. 7.396% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 8.017%, 4.83%, 1.535%, and 0.32% 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 Tables 51-54 are the affected areas, in square kilometers, by flood depth per barangay.

Table 51. Affected Areas in Alangalang, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Alangalang								
		Binongto-An	Binotong	Blumentritt	Borseth	Bugho	Cabadsan	Calaasan	Cavite	Divisoria
Affected Area (sq. km.)	0.03-0.20	0.069873257	2.289190186	0.029367584	1.565150671	3.66147454	0.792494771	0.771009397	0.235679604	0.012894736
	0.21-0.50	0.180124683	0.586158792	0.046897065	0.451587456	1.610189666	0.393574285	0.30986446	0.122155341	0.001315362
	0.51-1.00	0.433697321	0.428216621	0.07361078	0.304043028	3.103533216	0.316768982	0.593468907	0.241654652	0
	1.01-2.00	0.313950908	0.204413267	0.027429562	0.139762128	1.885826785	0.097340678	0.35807429	0.156402858	0
	2.01-5.00	0.074150013	0.06153606	0.00239585	0.173763002	0.28271936	0.026916067	0.0014	0.043202362	0
	> 5.00	0.0008	0.042303132	0	0.001690731	0	0.00903961	0	0.063025539	0

Table 52. Affected Areas in Alangalang, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Alangalang								
		Ekiran	Holy Child I	Holy Child II	Hubang	Hupit	Lourdes	Lukay	Milagrosa	P. Barrantes
Affected Area (sq. km.)	0.03-0.20	2.269125886	0.284126412	0.105146926	0.844983068	1.89203537	1.357654443	1.208792796	0.038304223	1.459505467
	0.21-0.50	1.126248145	0.082867086	0.015030029	0.458818757	0.523928276	0.255510294	0.372532918	0.01376279	0.542000571
	0.51-1.00	0.620767329	0.032101152	0.002937594	0.482539087	0.272218734	0.238242715	0.284724888	0.001672693	0.755332305
	1.01-2.00	0.209660171	0.00719015	0.002375008	0.592269287	0.202812249	0.200274504	0.099112227	9.98927E-05	0.506558105
	2.01-5.00	0.106338492	0.005943034	0.0001	0.060991072	0.196851012	0.060103829	0.021136033	0.000310038	0.035250766
	> 5.00	0.044312536	0.000224921	0	0.000991714	0.001391582	0	0.031783698	7.50785E-05	0.003808286

Table 53. Affected Areas in Alangalang, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Alangalang								
		Salvacion Poblacion	San Antonio Poblacion	San Francisco East	San Francisco West	San Roque	San Vicente	Santiago	Santo Niño	Santol
Affected Area (sq. km.)	0.03-0.20	5.885655557	0.088527274	2.82124687	1.96095603	0.1545830	2.9253316	3.4819639	0.043568705	2.9411733
	0.21-0.50	0.752319486	0.004017861	0.750062314	0.262183547	0.0161503	0.8265203	0.4143592	0	0.125726859
	0.51-1.00	0.828489633	0.00170085	0.405178801	0.143054979	0.0042512	0.7112839	0.2360926	0	0.146787394
	1.01-2.00	0.460583183	0.000710153	0.025662827	0.11644992	0.0021872	0.3083276	0.2912944	0	0.183068661
	2.01-5.00	0.064166391	0	0.004914333	0.0085	0.0006	0.2427699	0.3245405	0	0.102059953
	> 5.00	0	0	0.002113468	0	0	0.107075384	0.0547854	0	0.007576835

Table 54. Affected Areas in Alangalang, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Areas in Alangalang	
		Tabangohay	Veteranos
Affected Area (sq. km.)	0.03-0.20	5.885655557	0.088527274
	0.21-0.50	0.752319486	0.004017861
	0.51-1.00	0.828489633	0.00170085
	1.01-2.00	0.460583183	0.000710153
	2.01-5.00	0.064166391	0
	> 5.00	0	0

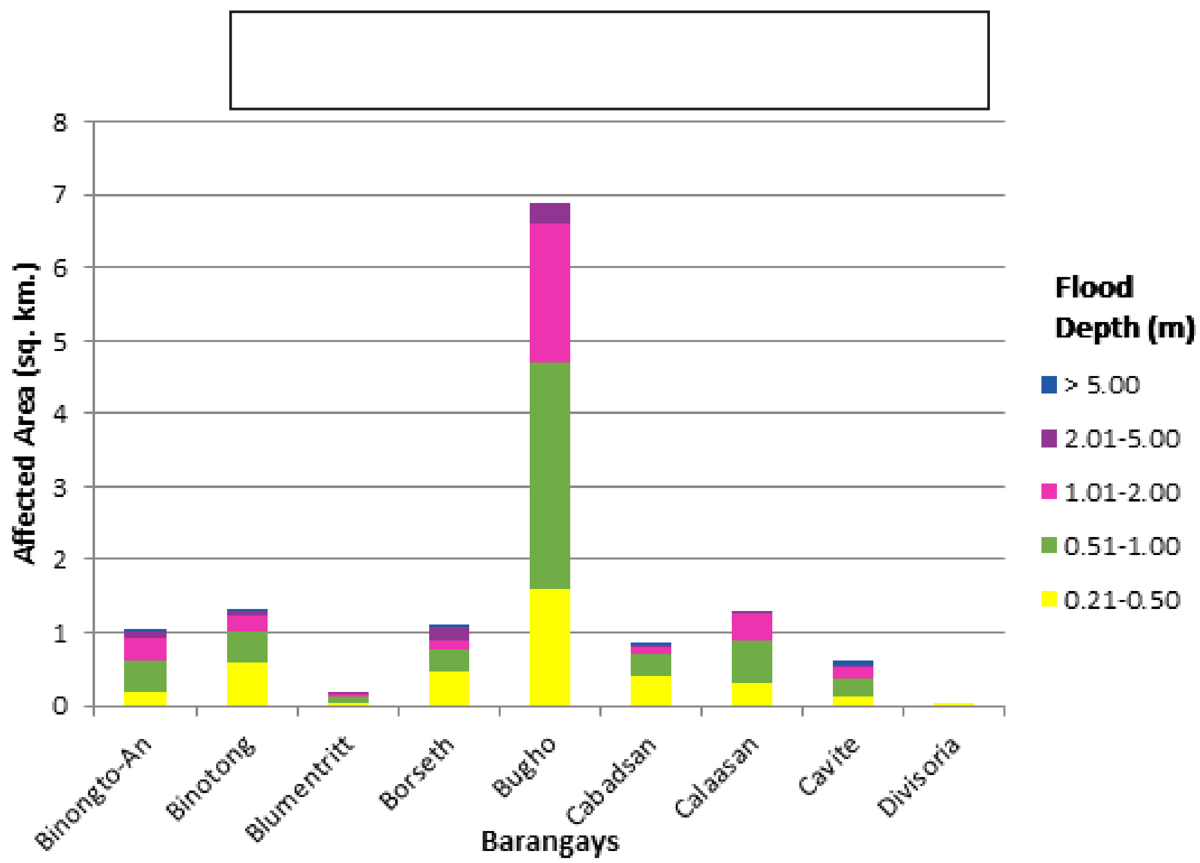


Figure 89. Affected Areas in Alangalang, Leyte during 25-Year Rainfall Return Period

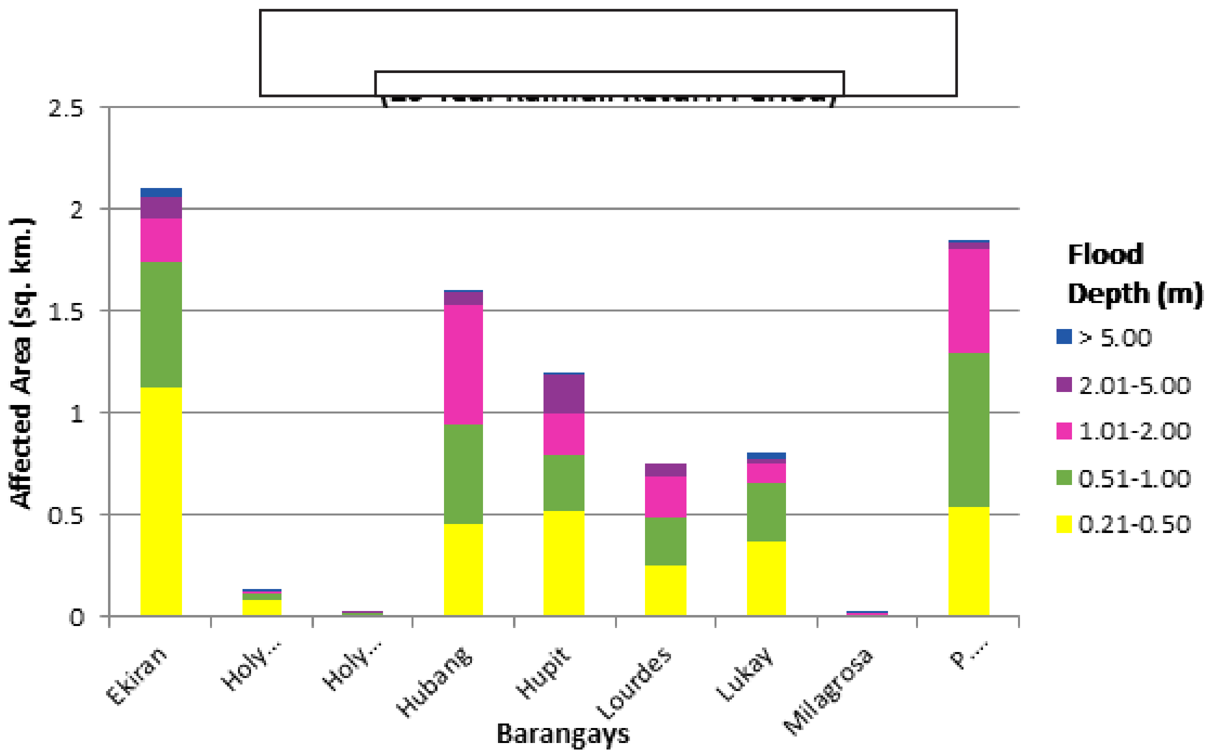


Figure 90. Affected Areas in Alangalang, Leyte during 25-Year Rainfall Return Period

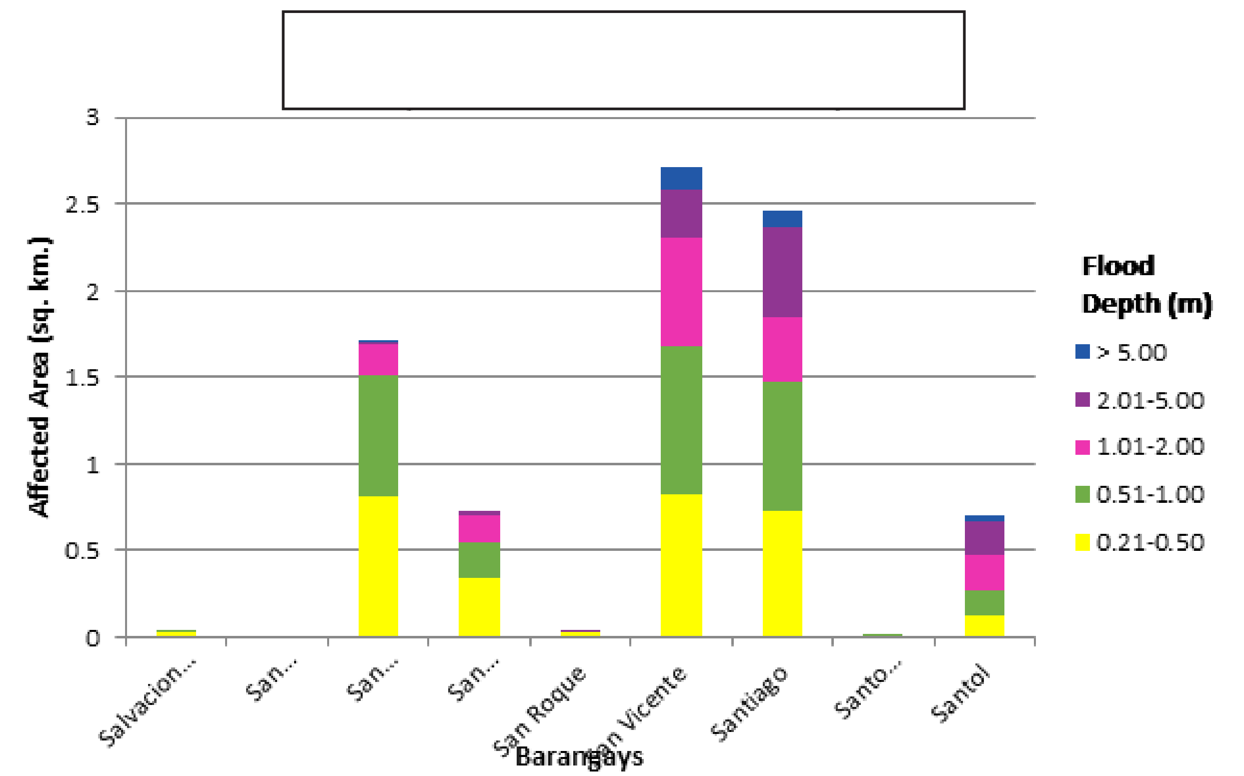


Figure 91. Affected Areas in Alangalang, Leyte during 25-Year Rainfall Return Period

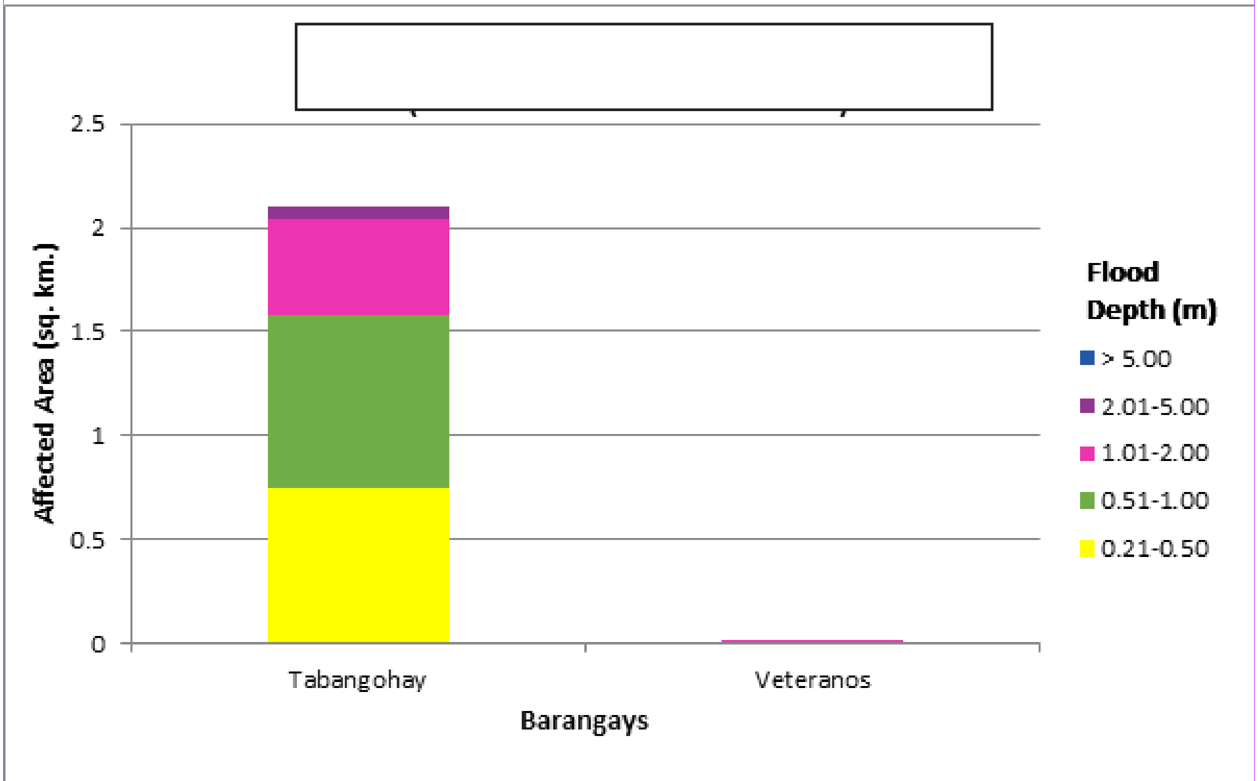


Figure 92. Affected Areas in Alangalang, Leyte during 25-Year Rainfall Return Period

For the 25-year return period, 59.537% of the Municipality of Barugo, with an area of 81.25 sq. km., will experience flood levels of less 0.20 meters. 6.058% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 4.837%, 4.35%, 3.712%, and 0.786% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Tables 55-58 are the affected areas, in square kilometers, by flood depth per barangay.

Table 55. Affected Areas in Barugo, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		**Affected Barangays in Barugo**								
		Amahit	**Balud**	**Bukid**	**Bulod**	**Busay**	**Cabarasan**	**Cabolo-An**	**Calingcaguing**	**Can-Isak**
Affected Area (sq. km.)	0.03-0.20	0.47653	3.120183	0.171278	3.52247	2.919097	1.26443	4.987442	0.853457	1.654509
	0.21-0.50	0.071373	0.277012	0.009171	0.283515	0.146086	0.467212	0.181637	0.11443	0.117462
	0.51-1.00	0.032742	0.193558	0.01296	0.279266	0.137562	0.37631	0.158461	0.093334	0.273045
	1.01-2.00	0.002996	0.052032	0.018755	0.206305	0.117447	0.072595	0.115038	0.059274	0.541277
	2.01-5.00	0.000221	0.010114	0.001981	0.098812	0.07222	0	0.065405	0.021008	0.333895
	> 5.00	0	0	0	0.0002	0.0002	0	0.0031	0.025562	0.015238

Table 56. Affected Areas in Barugo, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Barugo								
		Cuta	Domogdog	Duka	Guindaohan	Hiagsam	Hilaba	Hinugayan	Ibag	Minuhang
Affected Area (sq. km.)	0.03-0.20	2.118513	0.482943	4.608905	0.683224	1.029045	0.268982	0.81389	2.288559	0.840557
	0.21-0.50	0.68874	0.167101	0.231442	0.125984	0.03499	0.101514	0.04513	0.088183	0.46394
	0.51-1.00	0.237258	0.02222	0.175707	0.009712	0.0396	0.08066	0.061495	0.102166	0.309339
	1.01-2.00	0.008359	0	0.158184	0.00609	0.113503	0.047596	0.114617	0.099906	0.100616
	2.01-5.00	0	0	0.088845	0	0.229666	0.088127	0.094975	0.02244	0.0005
	> 5.00	0	0	0.0007	0	0.004908	0	0.009293	0	0

Table 57. Affected Areas in Barugo, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Barugo								
		Pikas	Pitogo	Poblacion Dist. I	Poblacion Dist. II	Poblacion Dist. III	Poblacion Dist. IV	Poblacion Dist. V	Poblacion Dist. VI	Pongso
Affected Area (sq. km.)	0.03-0.20	2.891837	2.068872	0.135101	0.117869	0.085076	0.112189	0.140982	0.106073	2.26296
	0.21-0.50	0.219405	0.101596	0.046323	0.051051	0.026675	0.011399	0.044318	0.03666	0.151719
	0.51-1.00	0.334211	0.135805	0.007356	0.026001	0.00888	0	0.022538	0.016364	0.154533
	1.01-2.00	0.49314	0.113585	0	0.003557	0	0	0	0	0.382139
	2.01-5.00	0.596198	0.015925	0	0.001262	0	0	0	0	0.489474
	> 5.00	0.263844	0.000288	0	0	0	0	0	0	0.051002

Table 58. Affected Areas in Barugo, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		**Affected Barangays in Barugo**					
		Roosevelt	**San Isidro**	**San Roque**	**Santa Rosa**	**Santarin**	**Tutug-An**
Affected Area (sq. km.)	0.03-0.20	1.708106	0.544939	0.959156	4.014607	0.032403	1.089356
	0.21-0.50	0.108634	0.137223	0.037711	0.210977	0.025803	0.098464
	0.51-1.00	0.153377	0.066667	0.045371	0.230612	0.043699	0.089409
	1.01-2.00	0.179778	0.00471	0.06702	0.352076	0.030039	0.073925
	2.01-5.00	0.306353	0	0.042647	0.306601	0.002776	0.126881
	> 5.00	0.135894	0	0.001504	0.06127	0	0.06617

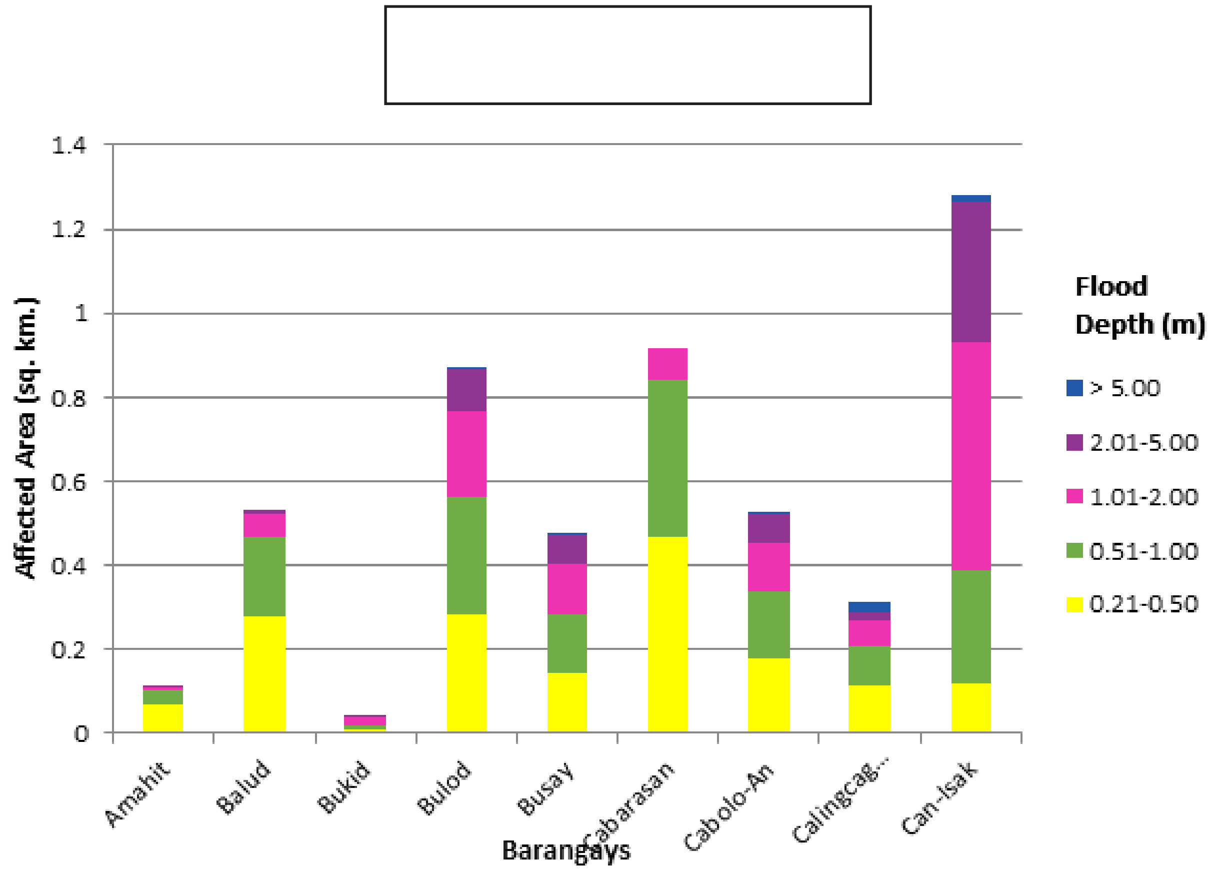


Figure 93. Affected Areas in Barugo, Leyte during 25-Year Rainfall Return Period

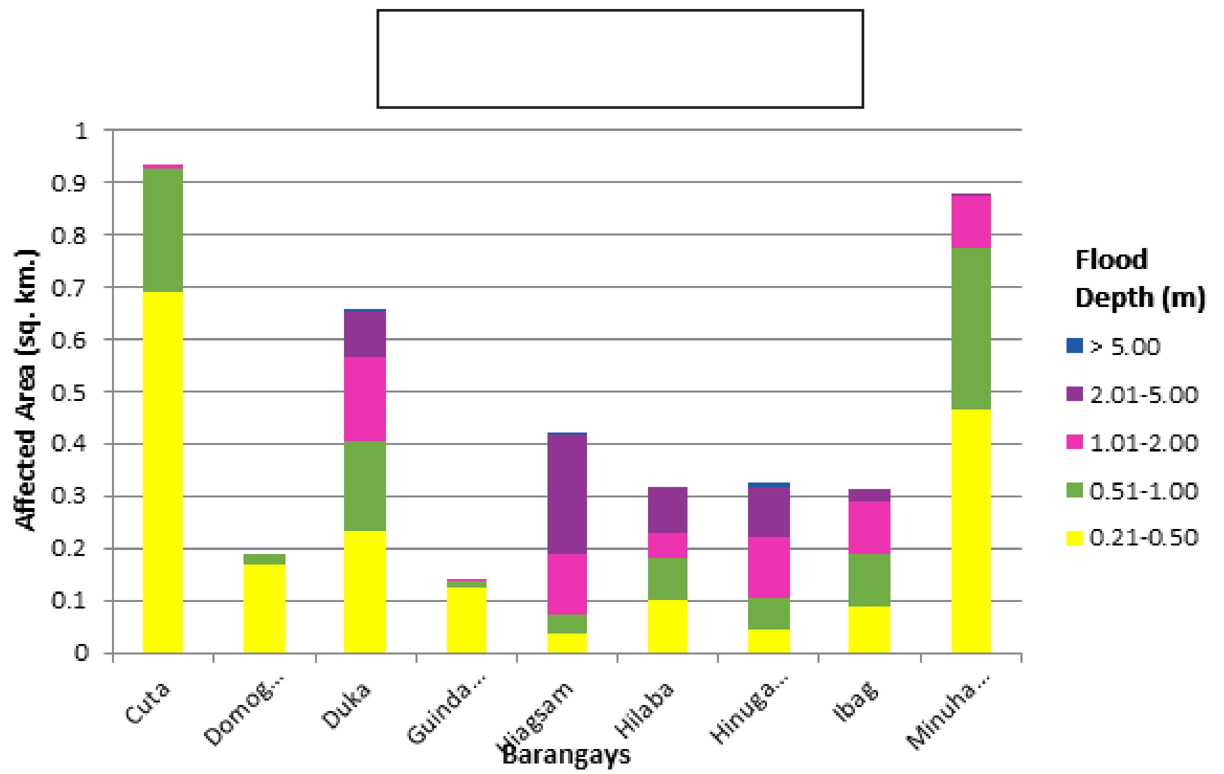


Figure 94. Affected Areas in Barugo, Leyte during 25-Year Rainfall Return Period

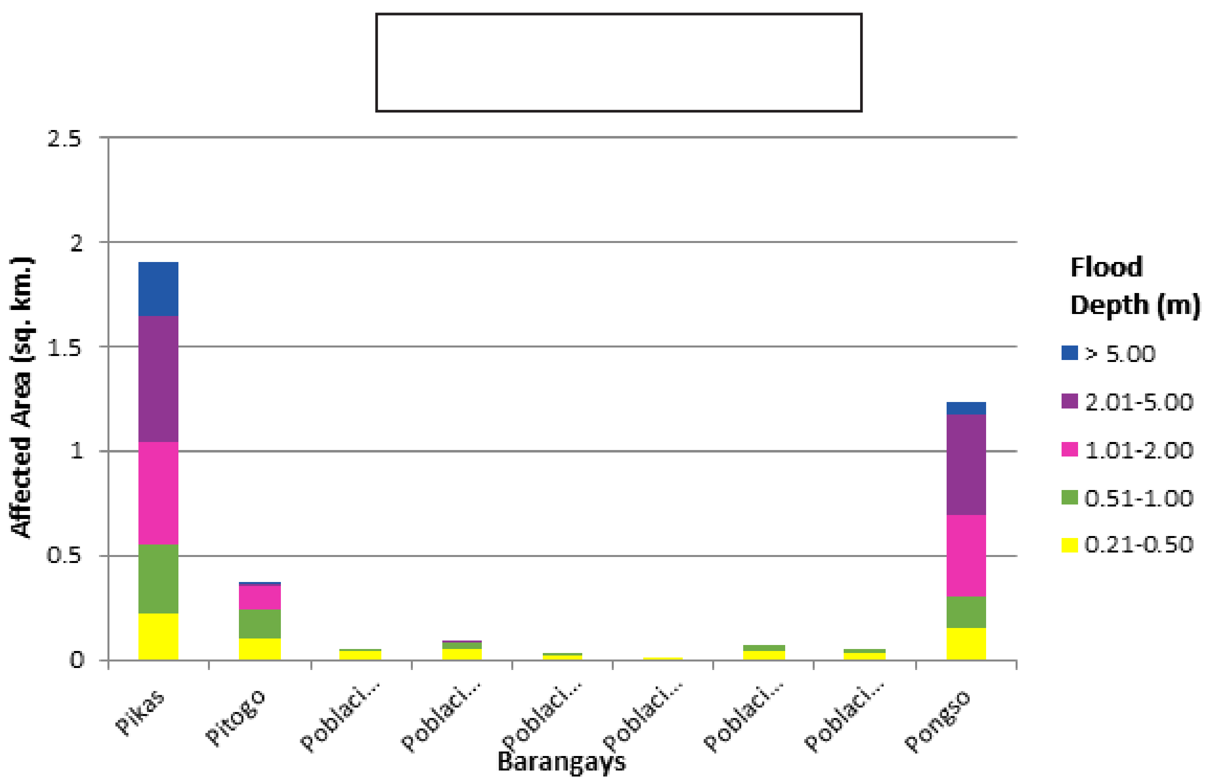


Figure 95. Affected Areas in Barugo, Leyte during 25-Year Rainfall Return Period

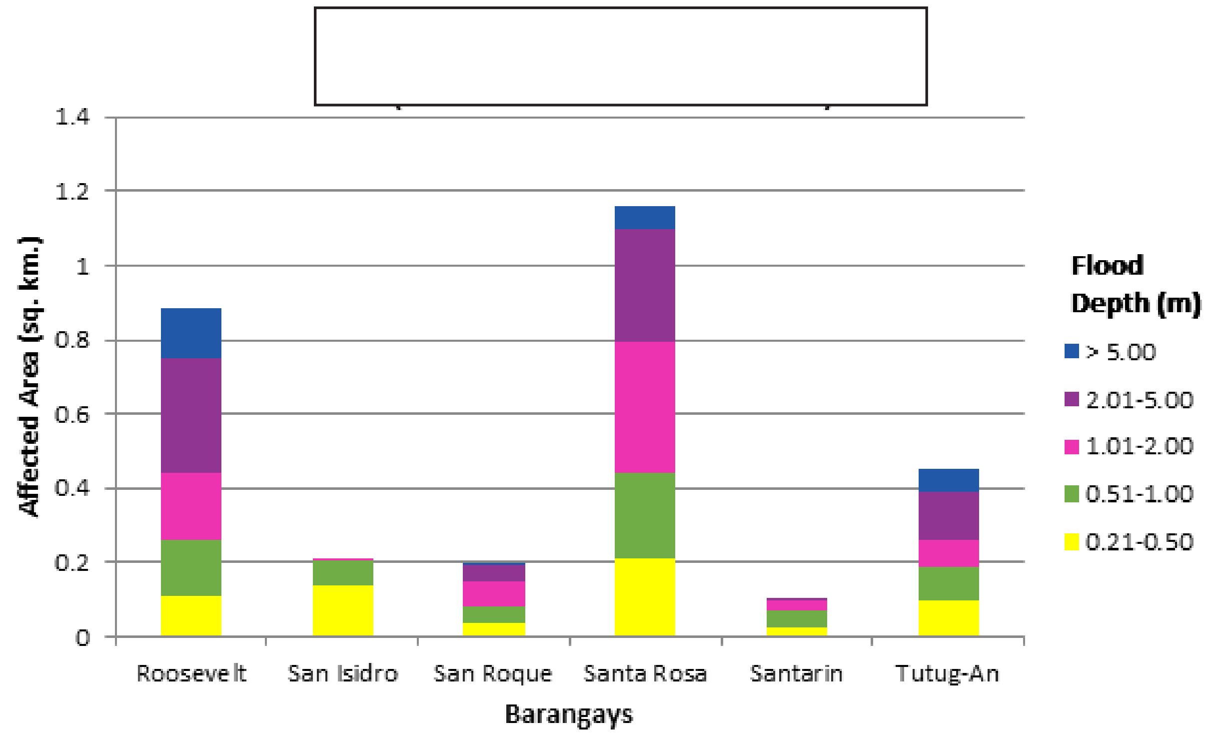


Figure 96. Affected Areas in Barugo, Leyte during 25Year Rainfall Return Period

For the 25-year return period, 15.11% of the Municipality of Jaro, with an area of 190.65 sq. km., will experience flood levels of less 0.20 meters. 2.522% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.353%, 1.145%, 0.6924%, and 0.1116% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Tables 59-61 are the affected areas, in square kilometers, by flood depth per barangay.

Table 59. Affected Areas in Jaro, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Jaro								
		Alahag	Bias Zabala	Buenavista	Bukid	Buri	Canapuan	Canhandugan	Daro	District I
Affected Area (sq. km.)	0.03-0.20	0.413842	0.876992	2.07648	3.052255	2.10056	2.168887	0.483827	0.266159	0.327154
	0.21-0.50	0.055522	0.209034	0.695419	0.297442	0.304462	0.354947	0.091282	0.002594	0.015566
	0.51-1.00	0.034137	0.072343	0.606544	0.248463	0.18194	0.109922	0.055798	0	0.003348
	1.01-2.00	0.016913	0.071193	0.535953	0.239624	0.172525	0.155504	0.020951	0	0.00905
	2.01-5.00	0.002654	0.014616	0.361402	0.04015	0.121765	0.12073	0.008937	0	0.008206
	> 5.00	0	0	0.024352	0	0.0003	5.42E-05	0	0	4.58E-05

Table 60. Affected Areas in Jaro, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Jaro								
		District II	District III	District IV	Hiagsam	Kaglawaan	Kalinawan	Macanip	Macopa	Malobago
Affected Area (sq. km.)	0.03-0.20	0.404922	0.48531	0.448614	0.294026	1.215757	1.157801	0.768823	0.385131	1.313243
	0.21-0.50	0.01614	0.024352	0.037486	0.028856	0.266419	0.136783	0.168869	0.067284	0.238406
	0.51-1.00	0.00473	0.000116	0.030181	0.020279	0.05161	0.030616	0.156979	0.019531	0.144006
	1.01-2.00	0.004522	0	0.018614	0.012086	0.005865	0.011902	0.12356	0.0013	0.107708
	2.01-5.00	0	0	0.024139	0.018252	0	0.014412	0.031739	0	0.034073
	> 5.00	0	0	0	0.0109	0	0	0	0	0

Table 61. Affected Areas in Jaro, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Jaro					
		Olotan	Pitogo	Sagkahan	Santo Ni§o	Tuba	Uguiao
Affected Area (sq. km.)	1.083984	1.695722	0.842448	0.170089	5.181465	1.594091	1.715744
	0.356382	0.563416	0.323098	0.02695	0.283245	0.245535	0.14347
	0.062324	0.145811	0.250203	0.008328	0.318359	0.023987	0.023189
	0.012109	0.085084	0.151416	0.004578	0.38175	0.042331	0.053064
	0	0.050842	0.142566	0	0.290084	0.035605	0.006082
	0	0.0037	0.016945	0	0.156463	0	0

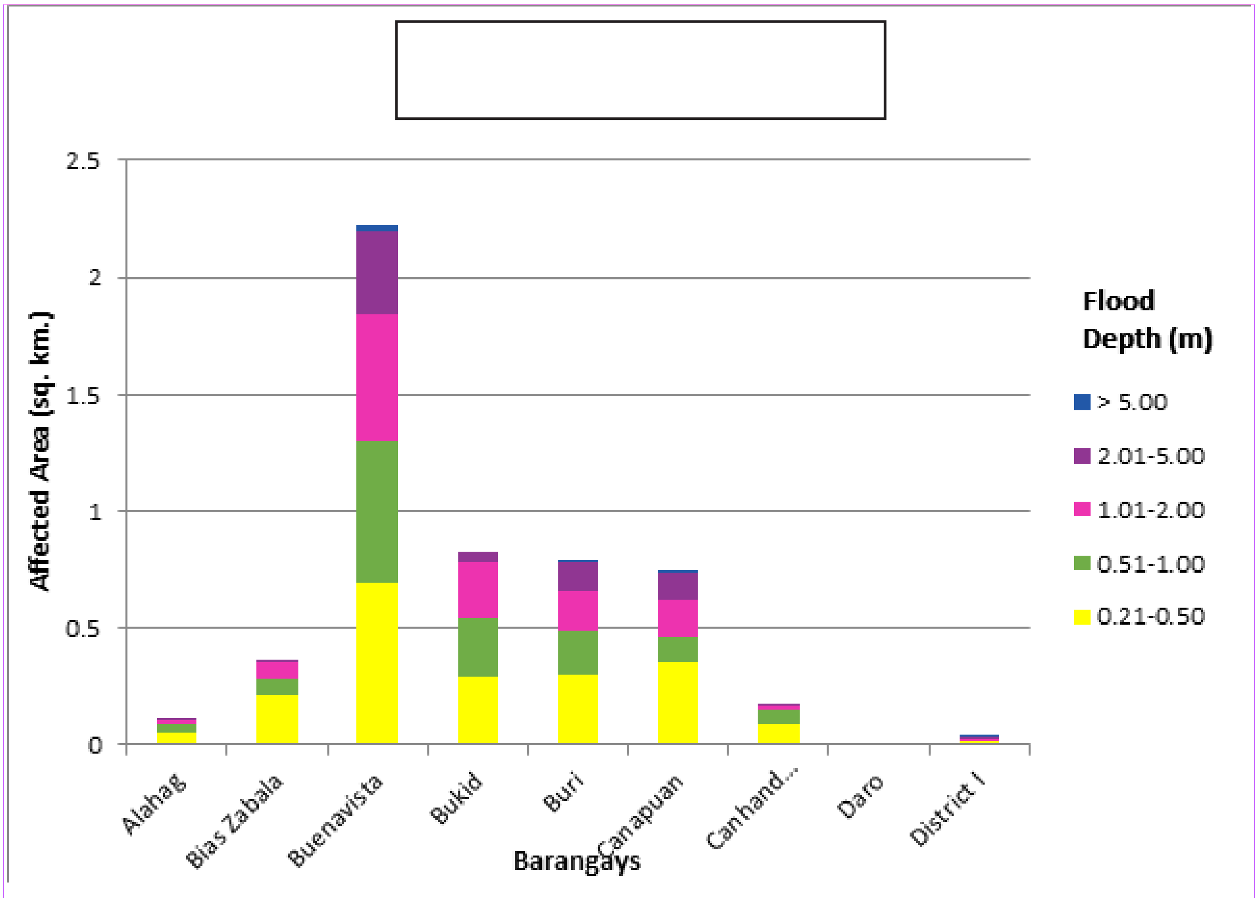


Figure 97. Affected Areas in Jaro, Leyte during 25-Year Rainfall Return Period

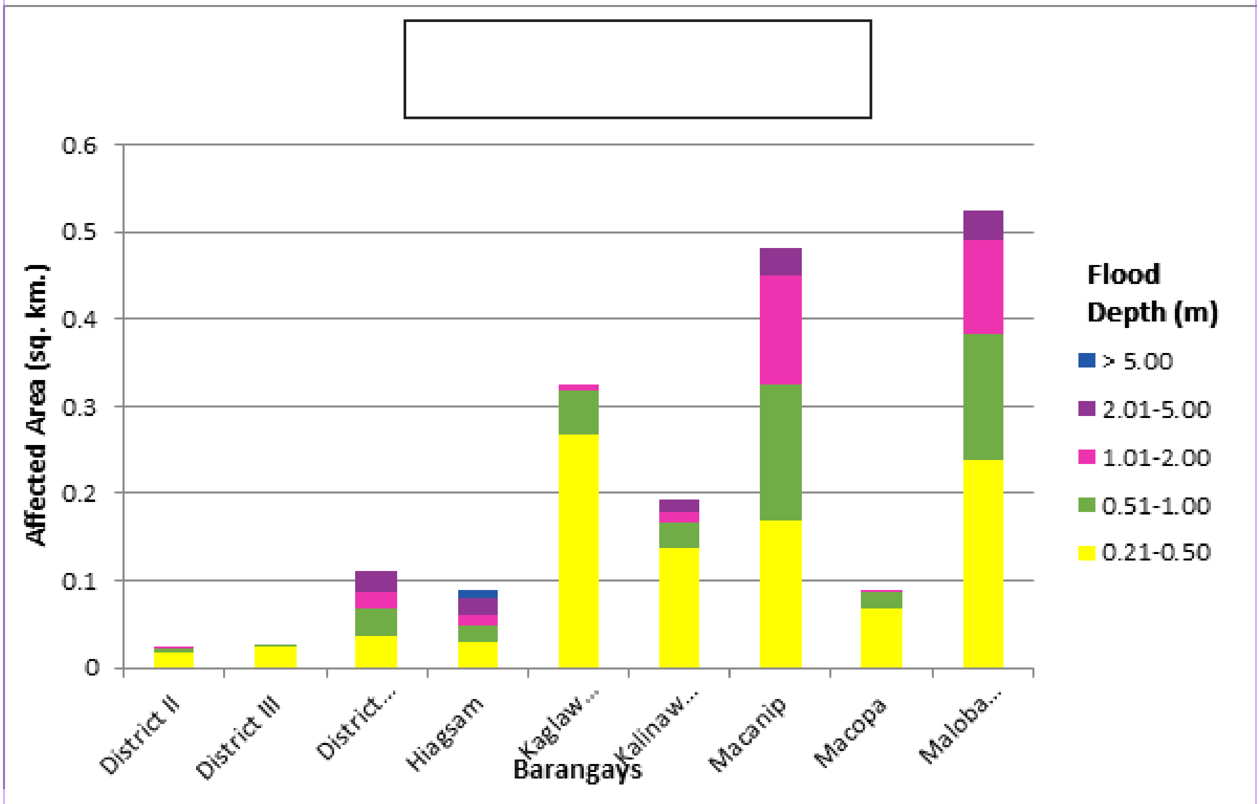


Figure 98. Affected Areas in Jaro, Leyte during 25-Year Rainfall Return Period

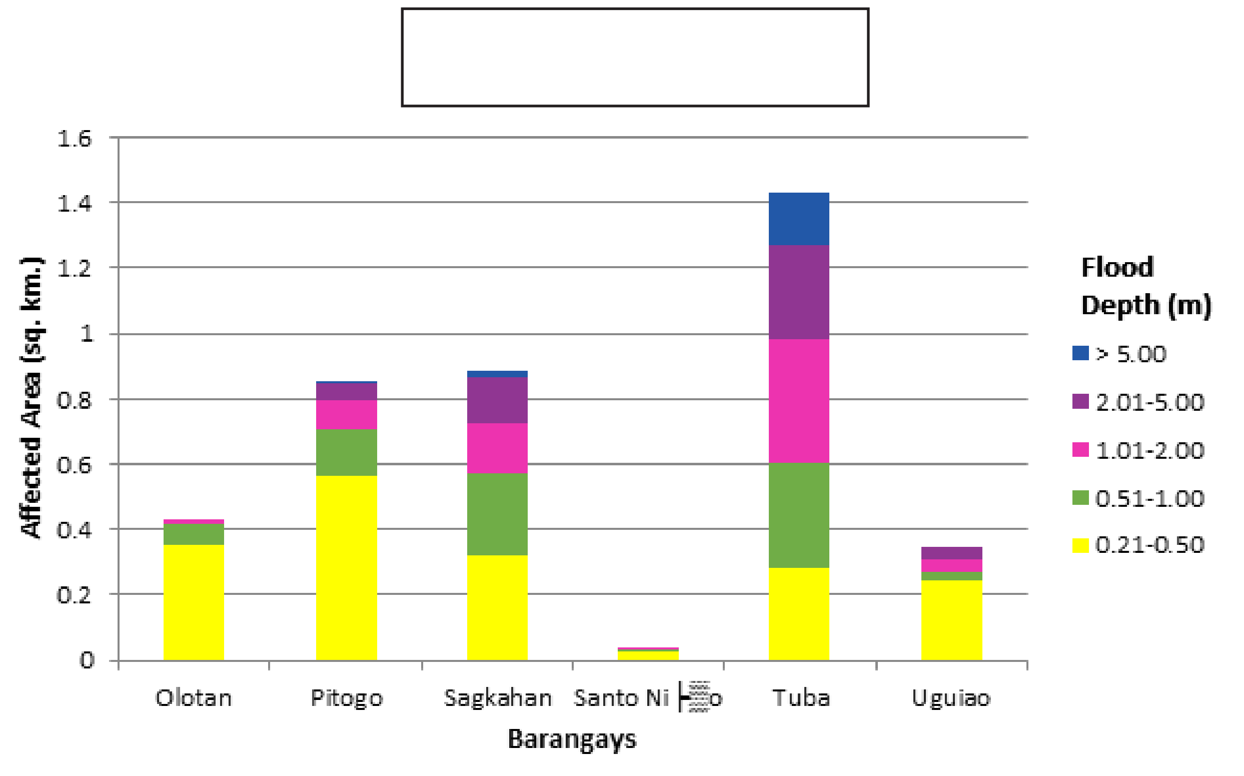


Figure 99. Affected Areas in Jaro, Leyte during 25-Year Rainfall Return Period

For the 25-year return period, 57.915% of the Municipality of San Miguel, with an area of 103.86 sq. km., will experience flood levels of less 0.20 meters. 7.94% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 8.95%, 9.54%, 5.11%, and 0.317% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Tables 62-64 are the affected areas, in square kilometers, by flood depth per barangay.

Table 62. Affected Areas in San Miguel, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in San Miguel								
		Bagacay	Bahay	Bairan	Cabatianuhan	Canap	Capilihan	Caraycaray	Cayare	Guinciaman
Affected Area (sq. km.)	0.03-0.20	0.065612	10.54176	1.241242737	1.766179	3.700836	5.780699	4.181931	1.850669	9.812806
	0.21-0.50	0.010667	1.00759	0.426252009	0.711446	0.387302	1.082601	0.290271	0.389633	0.719227
	0.51-1.00	0.000923	1.393187	0.379695818	0.514766	0.453985	1.34551	0.572208	0.216957	1.010819
	1.01-2.00	0	1.845556	0.105108458	0.430887	0.42363	1.868267	0.726989	0.143967	1.803372
	2.01-5.00	0	1.128905	0.0207791	0.061378	0.048057	0.853296	0.372246	0.06373	1.627887
	> 5.00	0	0.073012	0	0	0.000498	0.000407	0.106977	0.006812	0.088479

Table 63. Affected Areas in San Miguel, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in San Miguel								
		Impo	Kinalumsan	Libtong	Lukay	Malaguinabot	Malpag	Mawodpawod	Patong	Pinarigusan
Affected Area (sq. km.)	0.03-0.20	0.814112	2.482284	0.500235804	2.133761	1.893872	0.760685	1.808621	4.015013	0.00186
	0.21-0.50	0.10096	0.108553	0.058285157	0.835048	0.552092	0.175305	0.187392	0.647546	0
	0.51-1.00	0.212005	0.13184	0.102217176	0.620306	0.424062	0.311783	0.142085	0.660055	0
	1.01-2.00	0.181627	0.278222	0.178950703	0.224556	0.082902	0.114332	0.060554	0.418519	0
	2.01-5.00	0.035956	0.082181	0.165009593	0.058847	0.0043	0.014214	0.011956	0.24425	0
	> 5.00	0.001507	0.009155	0	0	0	0	0	0.029309	0

Table 64. Affected Areas in San Miguel, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in San Miguel		
		San Andres	Santa Cruz	Santol
Affected Area (sq. km.)	0.03-0.20	1.090297	0.341168	5.366445537
	0.21-0.50	0.134755	0.071026	0.351823047
	0.51-1.00	0.273216	0.047152	0.489810089
	1.01-2.00	0.208538	0.015997	0.801874785
	2.01-5.00	0.074432	0.002278	0.444717603
	> 5.00	0.002931	0	0.0104962

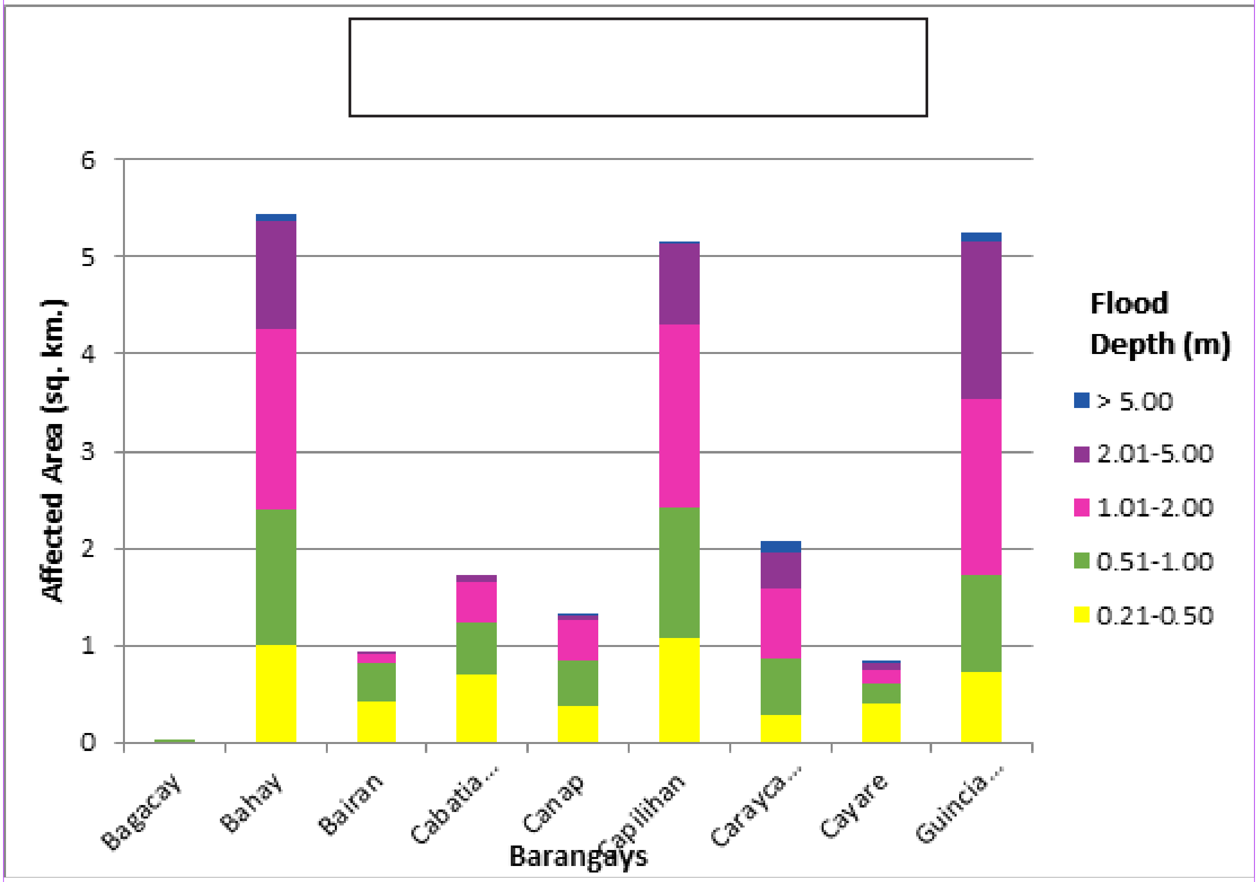


Figure 100. Affected Areas in San Miguel, Leyte during 25-Year Rainfall Return Period

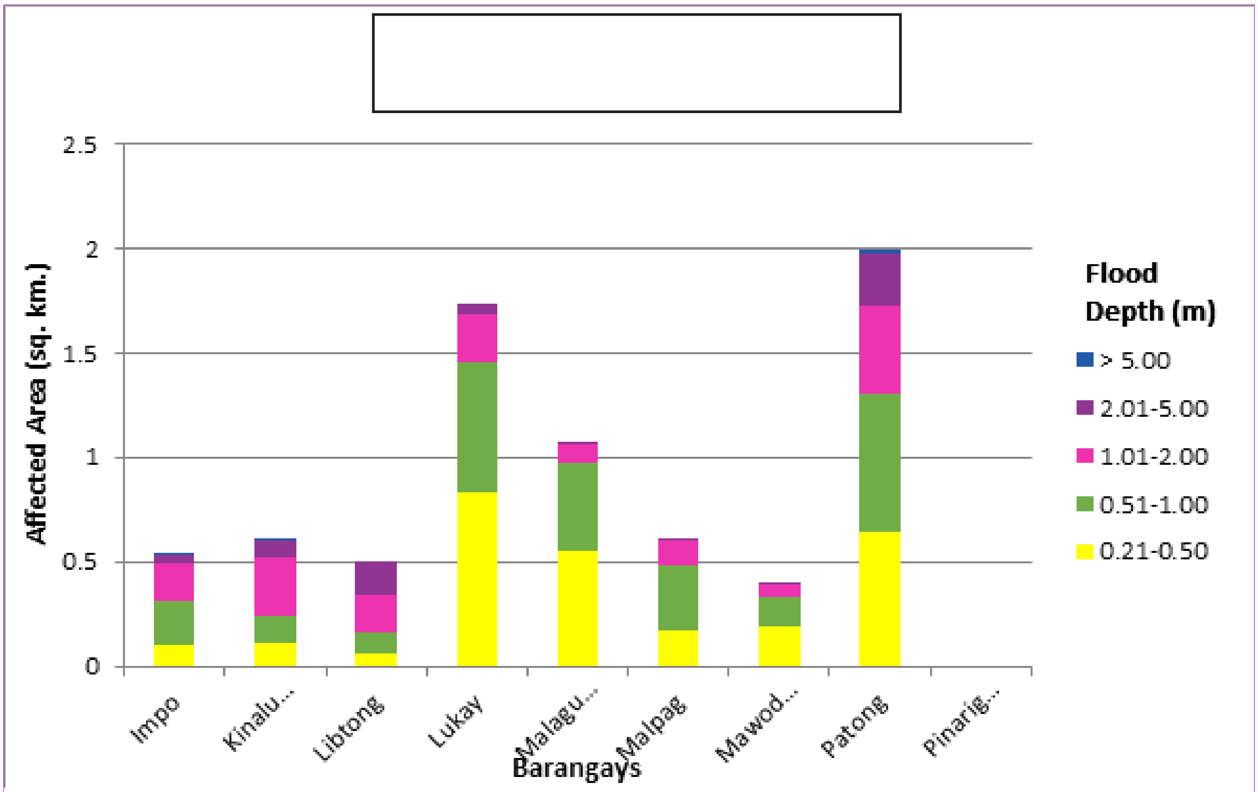


Figure 101. Affected Areas in San Miguel, Leyte during 25-Year Rainfall Return Period

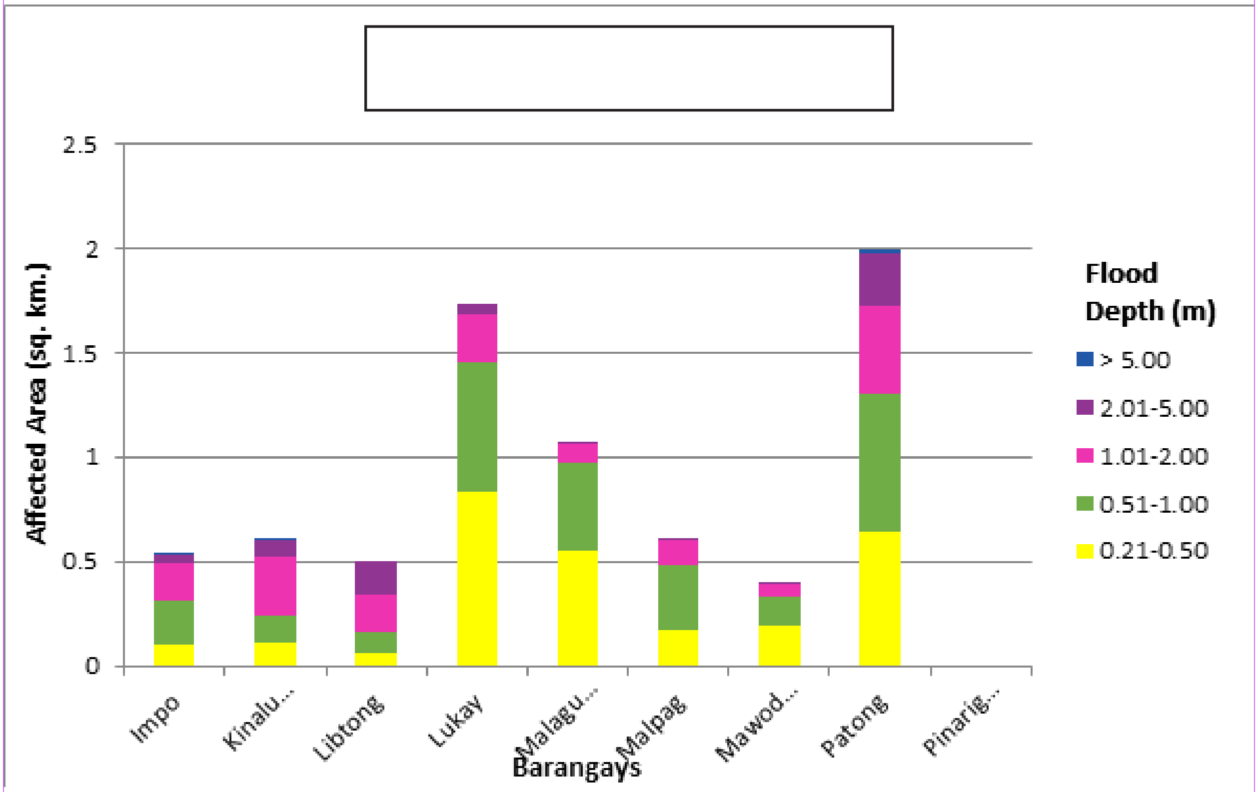


Figure 102. Affected Areas in San Miguel, Leyte during 25-Year Rainfall Return Period

For the 25-year return period, 9.18% of the City of Tacloban, with an area of 118.45 sq. km., will experience flood levels of less 0.20 meters. 0.584% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.593%, 0.484%, 0.134%, and 0.0046% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Table 65 are the affected areas, in square kilometers, by flood depth per barangay.

Table 65. Affected Areas in Tacloban, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Tacloban				
		Barangay 100	Barangay 103	Barangay 106	Barangay 93	Barangay 98
Affected Area (sq. km.)	0.03-0.20	1.465799	0.439695	0.27649	3.339615	5.619986
	0.21-0.50	0.13239	0.01484	0.007807	0.23969	0.375392
	0.51-1.00	0.109793	0.005079	0.002807	0.141395	0.373363
	1.01-2.00	0.029839	0.0007	0.001398	0.074703	0.257024
	2.01-5.00	0.0003	0.0001	0.000564	0.005871	0.091576
	> 5.00	0	0	0	0	0.0017

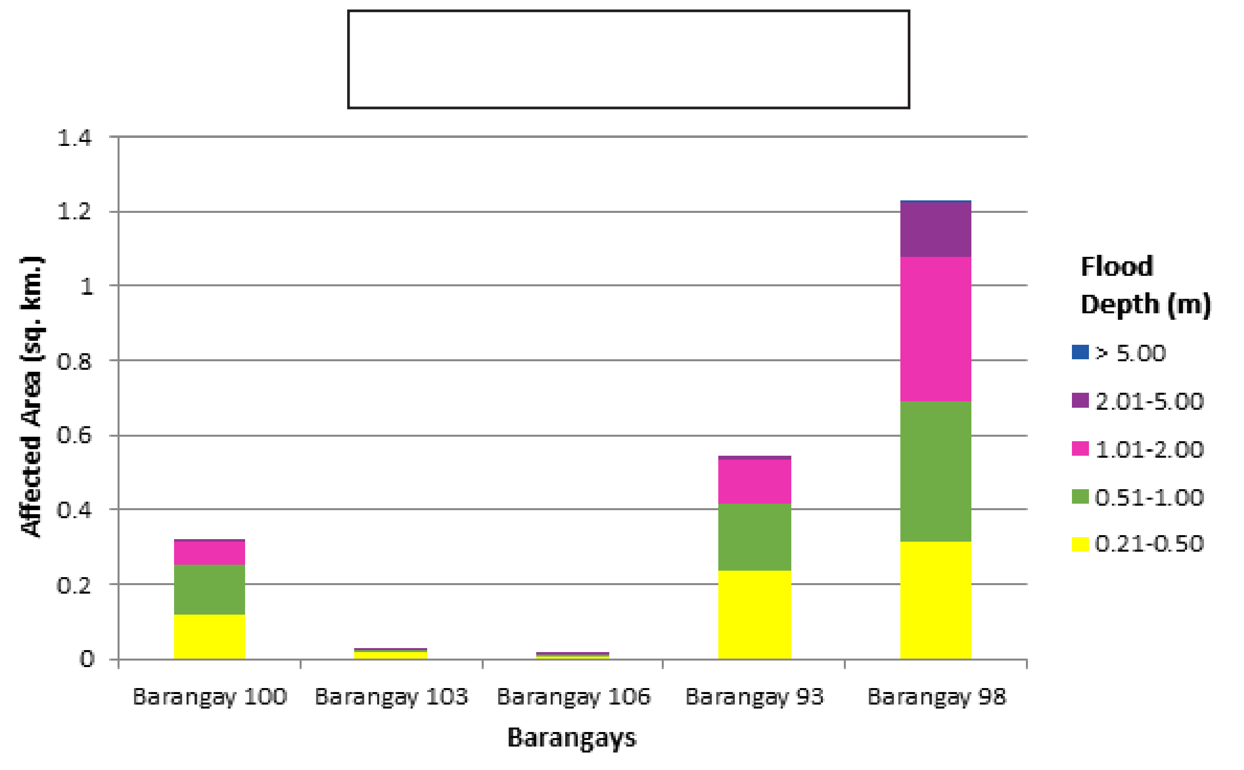


Figure 103. Affected Areas in Tacloban City, Leyte during 25-Year Rainfall Return Period

For the 25-year return period, 27.754% of the Municipality of Tunga, with an area of 17.36 sq. km., will experience flood levels of less 0.20 meters. 4.26% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 5.75%, 5.06%, 2.36%, and 0.6833% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Table 66 are the affected areas, in square kilometers, by flood depth per barangay.

Table 66. Affected Areas in Tunga, Leyte during 25-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangay in Tunga					
		Astorga	Balire	Banawang	San Pedro	San Roque	San Vicente
Affected Area (sq. km.)	0.03-0.20	1.293415	0.00309	3.011618	0.285611	0.190279	0.034805
	0.21-0.50	0.376761	0.001324	0.18155	0.138969	0.040337	0.001241
	0.51-1.00	0.614295	0.001036	0.1622	0.181144	0.038162	0.001918
	1.01-2.00	0.511106	0	0.210105	0.12583	0.026105	0.005421
	2.01-5.00	0.157769	0	0.203826	0.036721	0.008565	0.004191
	> 5.00	0.0004	0	0.118238	0	0	0

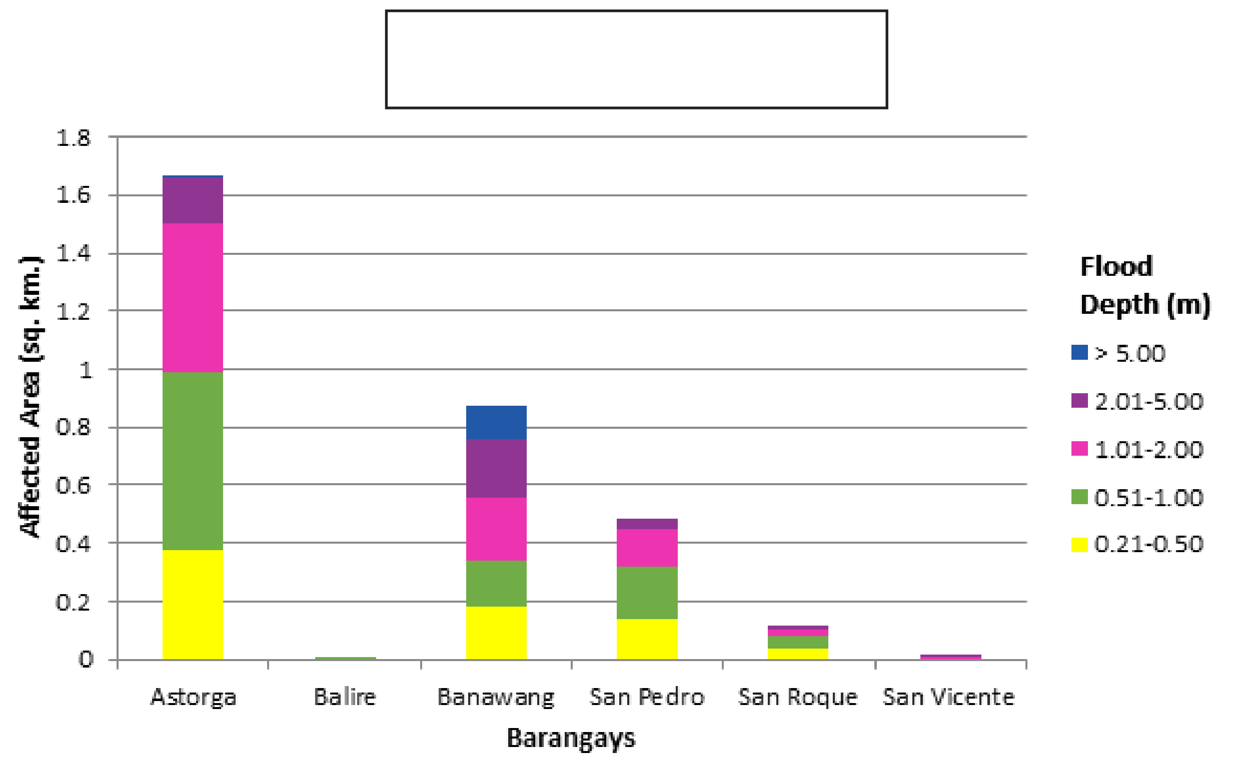


Figure 104. Affected Areas in Tunga, Leyte during 25-Year Rainfall Return Period

For the 100-year return period, 22.687% of the Municipality of Alangalang, with an area of 145.445 sq. km., will experience flood levels of less 0.20 meters. 6.94% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 8.27%, 6.99%, 2.149%, and 0.367% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Tables 67-70 are the affected areas, in square kilometers, by flood depth per barangay.

Table 67. Affected Areas in Alangalang, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Alangalang								
		Binongto-An	Binotong	Blumentritt	Borseth	Bugho	Cabadsan	Calaasan	Cavite	Divisoria
Affected Area (sq. km.)	0.03-0.20	0.03481857	2.066107438	0.008086211	1.361846921	3.113390516	0.711815154	0.660082785	0.207239643	0.012594736
	0.21-0.50	0.115361725	0.676019447	0.01342701	0.446554178	1.086920985	0.399400593	0.263550419	0.110903994	0.001615362
	0.51-1.00	0.403157602	0.472592842	0.084310501	0.432855726	2.589345667	0.369812474	0.445211404	0.232389234	0
	1.01-2.00	0.425581655	0.286859139	0.067740366	0.173662737	3.07268601	0.117331534	0.662884785	0.203595308	0
	2.01-5.00	0.09237663	0.06843606	0.006136753	0.206920885	0.681400389	0.029335028	0.002087661	0.043979925	0
	> 5.00	0.0013	0.042603132	0	0.013896185	0	0.00893961	0	0.064125539	0

Table 68. Affected Areas in Alangalang, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Alangalang								
		Ekiran	Holy Child I	Holy Child II	Hubang	Hupit	Lourdes	Lukay	Milagrosa	P. Barrantes
Affected Area (sq. km.)	0.03-0.20	2.090118292	0.23329482	0.09051046	0.659878404	1.631130501	1.240130342	1.116513929	0.031594579	1.175618721
	0.21-0.50	1.22241107	0.065635649	0.024556325	0.322570396	0.584799115	0.286025793	0.403040204	0.017051396	0.484119065
	0.51-1.00	0.675545757	0.082219434	0.004318163	0.593963147	0.38753104	0.253162282	0.292344448	0.005093732	0.83194368
	1.01-2.00	0.236226412	0.02453462	0.004904609	0.770459142	0.234702506	0.22574394	0.153358357	9.98927E-05	0.760480932
	2.01-5.00	0.107938492	0.006263148	0.0013	0.092330181	0.251784506	0.107623427	0.022541925	0.000290201	0.045784815
	> 5.00	0.044212536	0.000505085	0	0.001391714	0.003689556	0	0.031783698	9.49153E-05	0.004508286

Table 69. Affected Areas in Alangalang, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Alangalang								
		Salvacion Poblacion	San Antonio Poblacion	San Francisco East	San Francisco West	San Roque	San Vicente	Santiago	Santo Niño	Santol
Affected Area (sq. km.)	0.03-0.20	0.174191489	0.000776672	2.048501859	1.624185152	0.130332873	2.180435666	1.971993916	0	2.710006999
	0.21-0.50	0.044761784	0.000184629	0.806647672	0.421082263	0.029443023	0.836630992	0.62434722	0	0.137084546
	0.51-1.00	0.01101686	0	0.799527622	0.226833894	0.013032485	0.778076127	0.934482725	0	0.139148091
	1.01-2.00	0	0	0.345845012	0.179372335	0.004112882	0.871168622	0.558121678	0	0.223671644
	2.01-5.00	0	0	0.006388841	0.041170831	0.000850704	0.316765063	0.596135928	0	0.243041569
	> 5.00	0	0	0.002267607	0	0	0.143228744	0.117954812	0	0.053440225

Table 70. Affected Areas in Alangalang, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Areas in Alangalang	
		Tabangohay	Veteranos
Affected Area (sq. km.)	0.03-0.20	6.3837511	0.090027274
	0.21-0.50	0.758038511	0.00301871
	0.51-1.00	0.546742148	0.001514406
	1.01-2.00	0.298986102	0.000395747
	2.01-5.00	0.00369641	0
	> 5.00	0	0

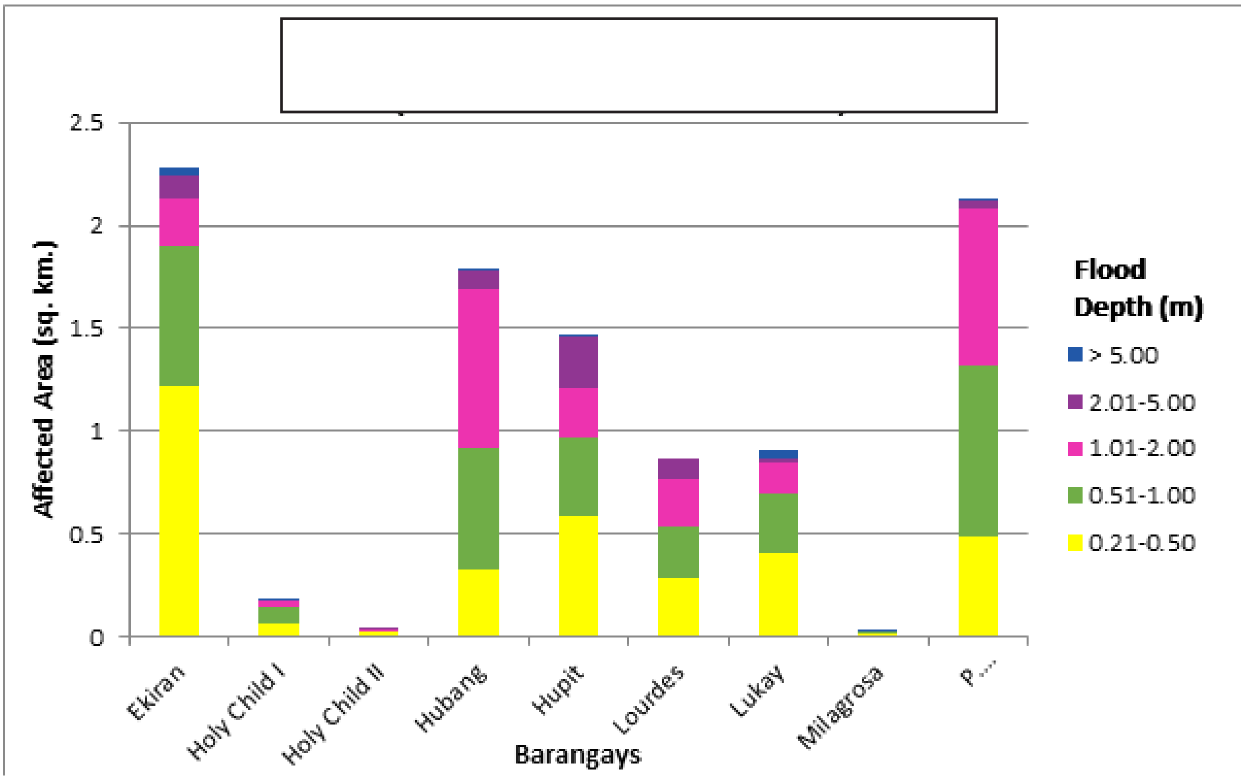


Figure 105. Affected Areas in Alangalang, Leyte during 100-Year Rainfall Return Period

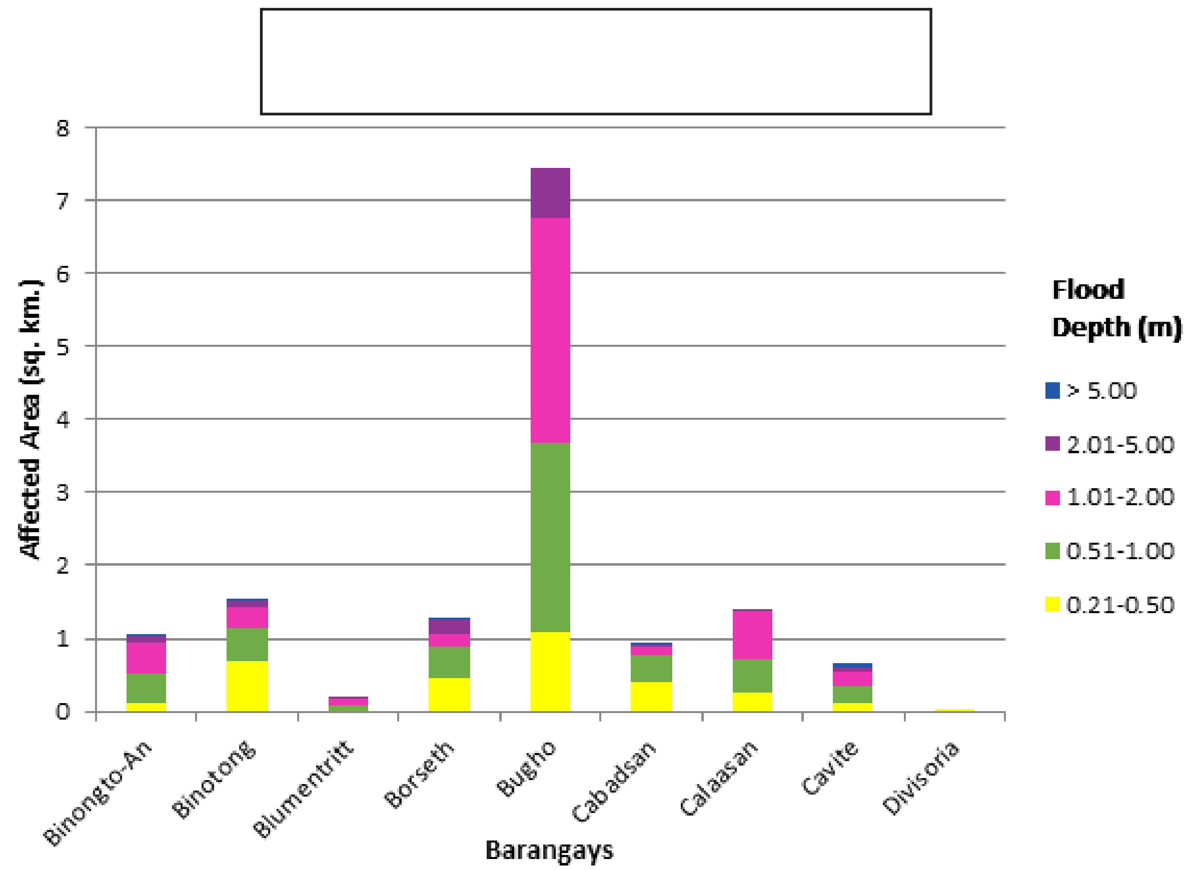


Figure 106. Affected Areas in Alangalang, Leyte during 100-Year Rainfall Return Period

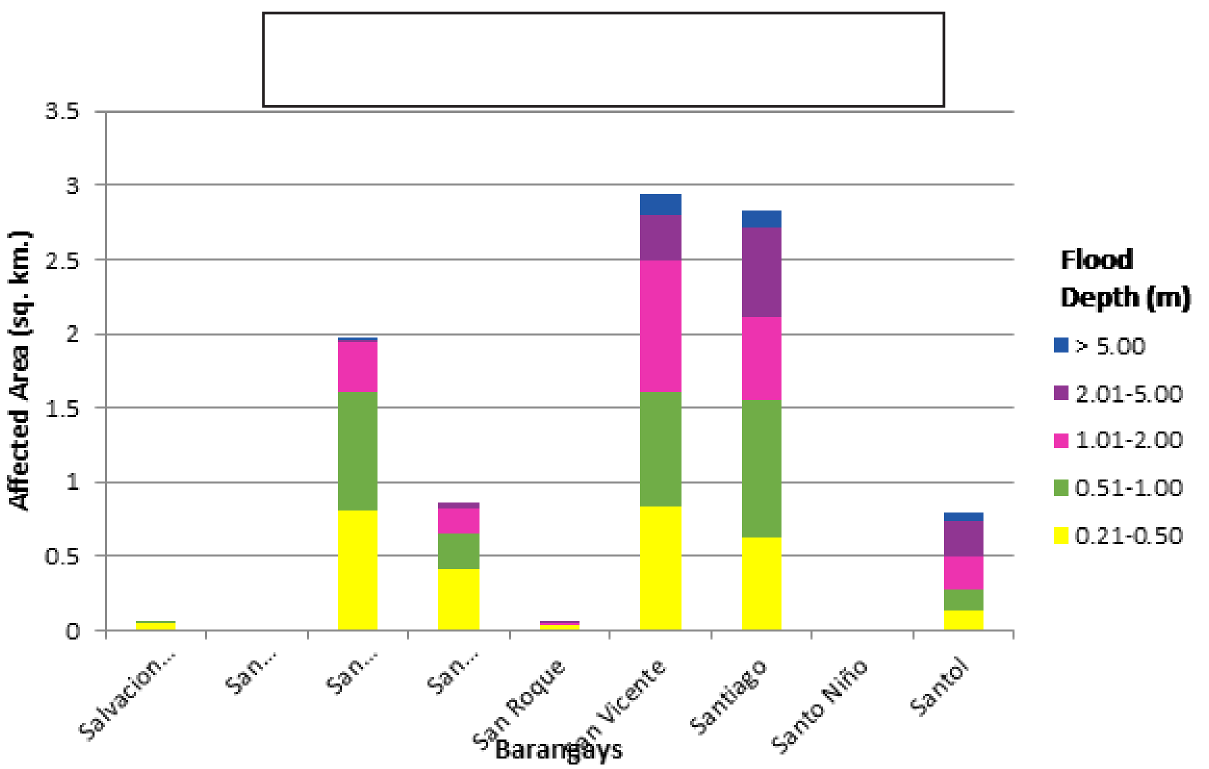


Figure 107. Affected Areas in Alangalang, Leyte during 100-Year Rainfall Return Period

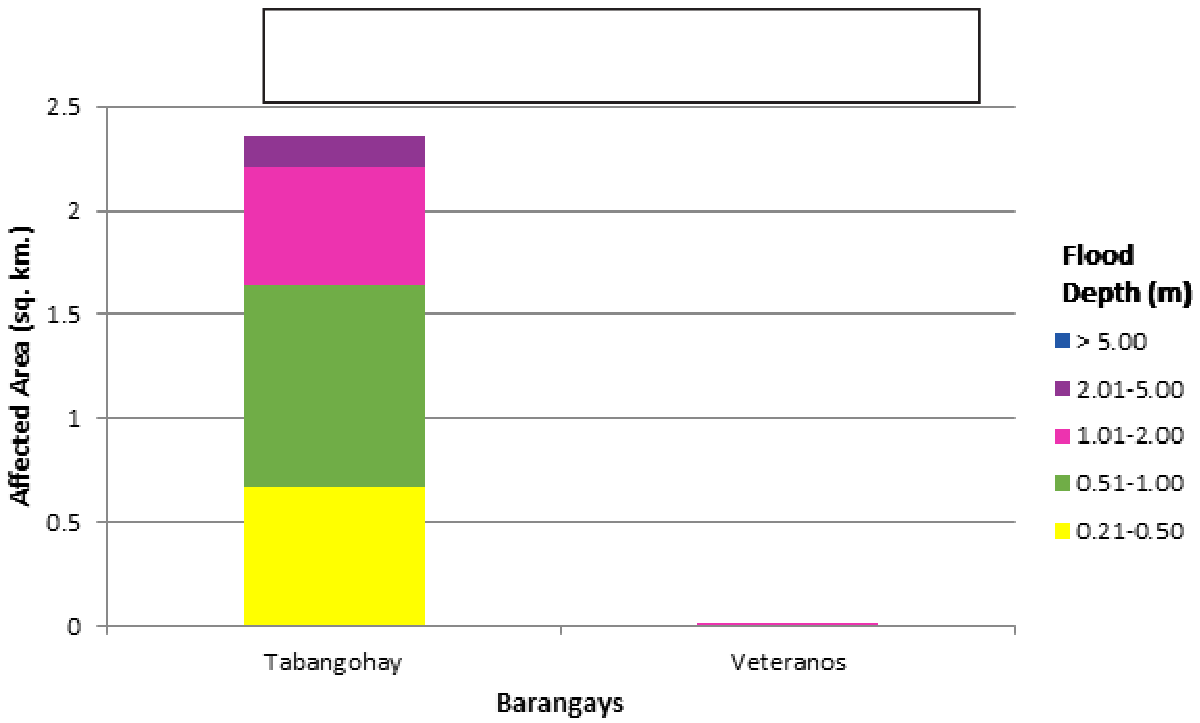


Figure 108. Affected Areas in Alangalang, Leyte during 100-Year Rainfall Return Perio

For the 100-year return period, 56.22% of the Municipality of Barugo, with an area of 81.25 sq. km., will experience flood levels of less 0.20 meters. 5.909% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 5.4%, 5.5%, 5.226%, and 0.978% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Tables 71-74 are the affected areas, in square kilometers, by flood depth per barangay.

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Table 71. Affected Areas in Barugo, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		**Affected Barangays in Barugo**					
		Amahit	**Balud**	**Bukid**	**Bulod**	**Busay**	**Cabarasan**
Affected Area (sq. km.)	0.03-0.20	0.455067	3.054627	0.168046	3.367556	2.869284	1.023098
	0.21-0.50	0.085384	0.279087	0.007442	0.227544	0.146447	0.422496
	0.51-1.00	0.037867	0.229997	0.012054	0.321357	0.157521	0.503871
	1.01-2.00	0.005071	0.075956	0.022423	0.33495	0.123905	0.228311
	2.01-5.00	0.000473	0.013833	0.004181	0.13746	0.095056	0.002771
	> 5.00	0	0	0	0.0017	0.0004	0

Table 72. Affected Areas in Barugo, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Barugo					
		Cuta	Domogdog	Duka	Guindaohan	Hiagsam	Hilaba
Affected Area (sq. km.)	0.03-0.20	1.831845	0.431141	4.538387	0.647391	1.00263	0.246006
	0.21-0.50	0.741584	0.200671	0.233684	0.156056	0.034525	0.105614
	0.51-1.00	0.348802	0.040352	0.194643	0.012473	0.039932	0.091936
	1.01-2.00	0.130538	0.0001	0.173543	0.00909	0.075466	0.050305
	2.01-5.00	9.98E-05	0	0.121226	0	0.28661	0.093018
	> 5.00	0	0	0.0023	0	0.01255	0

Table 73. Affected Areas in Barugo, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Barugo					
		Pikas	Pitogo	Poblacion Dist. I	Poblacion Dist. II	Poblacion Dist. III	Poblacion Dist. IV
Affected Area (sq. km.)	0.03-0.20	2.705663	2.024495	0.122507	0.108434	0.080062	0.106238
	0.21-0.50	0.15296	0.098626	0.053953	0.051763	0.025207	0.01735
	0.51-1.00	0.256401	0.134158	0.01232	0.034124	0.015362	0
	1.01-2.00	0.564744	0.154421	0	0.003741	0	0
	2.01-5.00	0.809082	0.023571	0	0.001678	0	0
	> 5.00	0.309784	0.000802	0	0	0	0

Table 74. Affected Areas in Barugo, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Barugo				
		Roosevelt	San Isidro	San Roque	Santa Rosa	
Affected Area (sq. km.)	0.03-0.20	1.556373	0.490422	0.916156	3.829451	
	0.21-0.50	0.087708	0.168185	0.037042	0.19383	
	0.51-1.00	0.150781	0.08465	0.037945	0.216573	
	1.01-2.00	0.230601	0.010282	0.063867	0.338861	
	2.01-5.00	0.144205	0	0.006252	0.117651	
	> 5.00	0.060964	0	3.18E-05	0.0003	

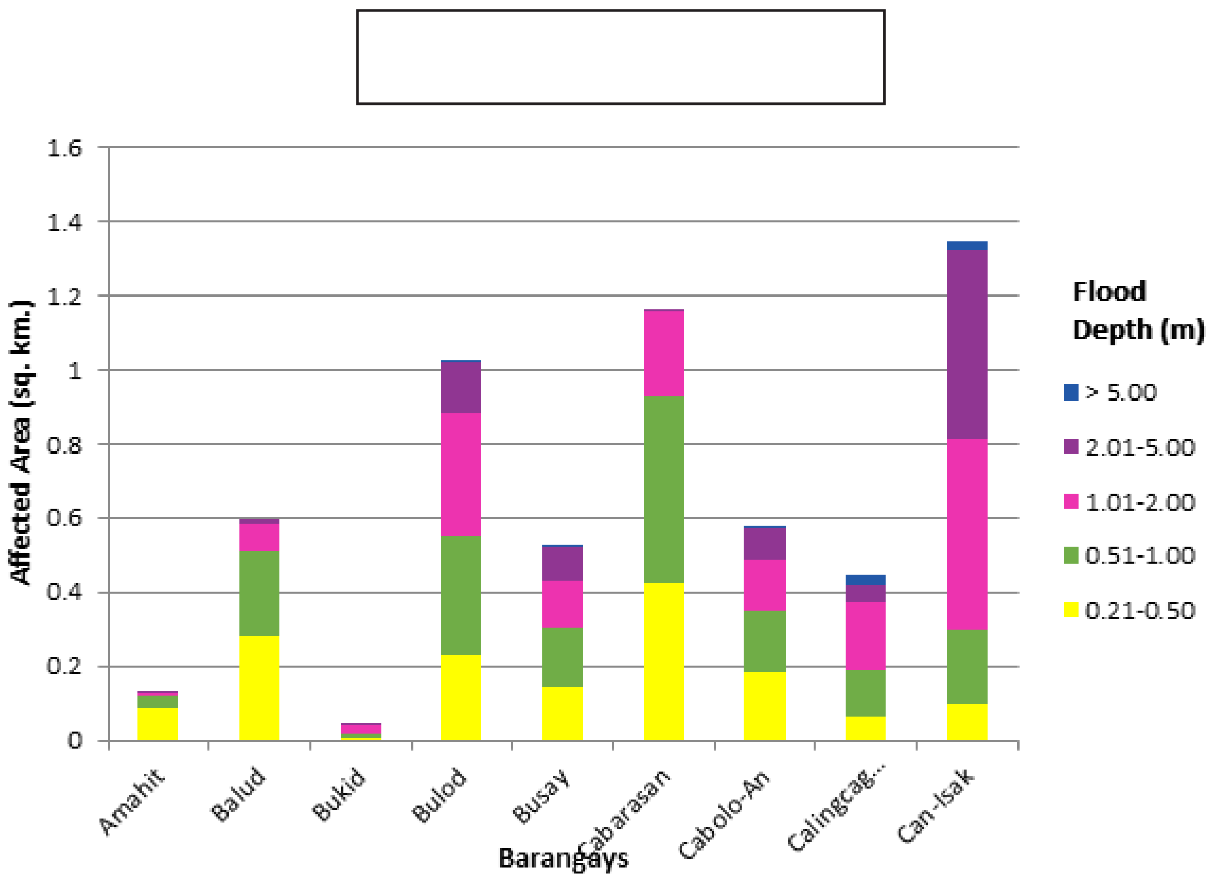

Figure 108. Affected Areas in Barugo, Leyte during 100-Year Rainfall Return Period

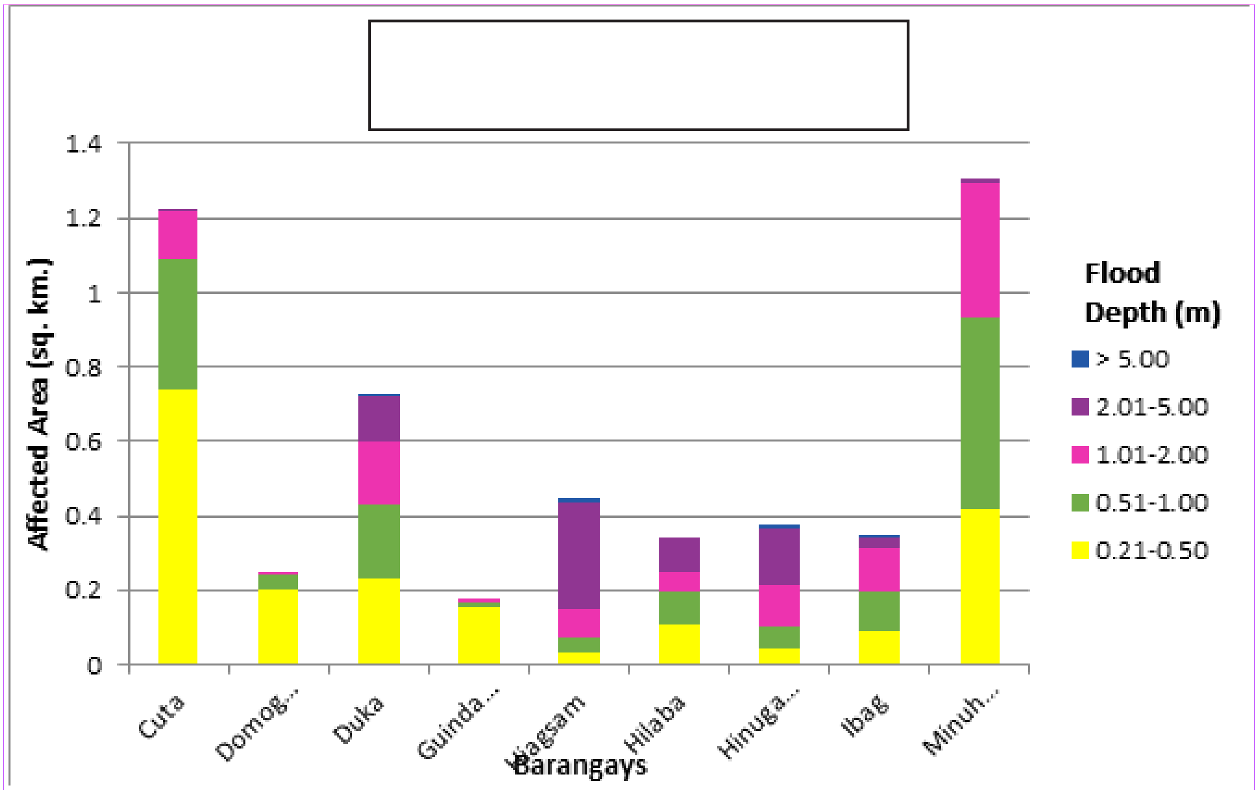

Figure 109. Affected Areas in Barugo, Leyte during 100-Year Rainfall Return Period

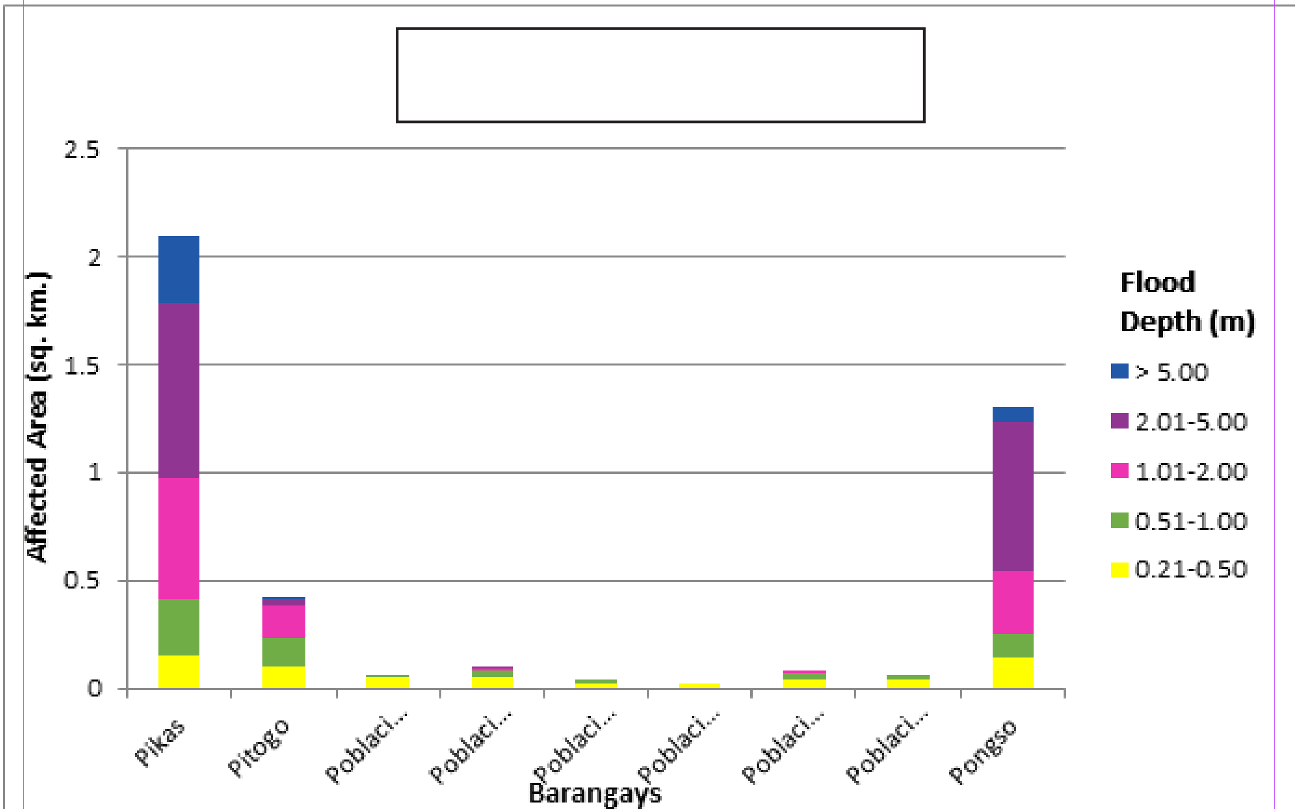

Figure 110. Affected Areas in Barugo, Leyte during 100-Year Rainfall Return Period

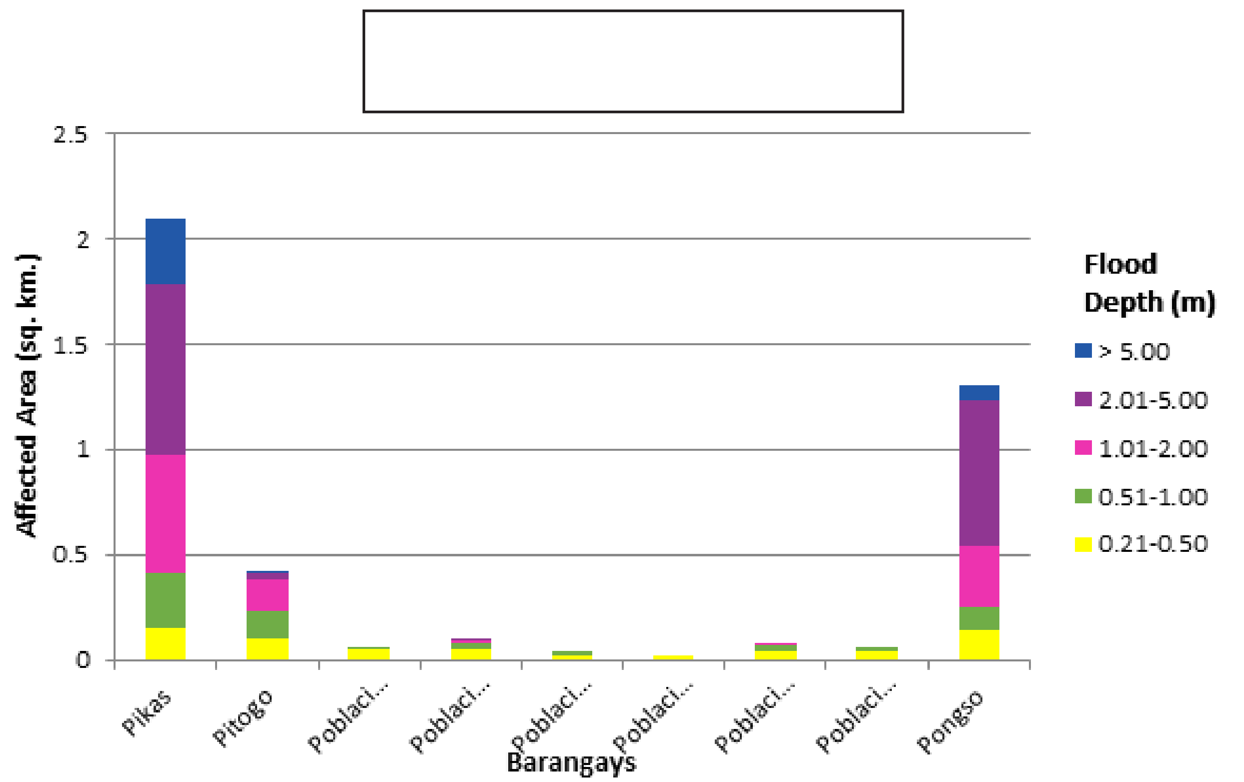

Figure 111. Affected Areas in Barugo, Leyte during 100-Year Rainfall Return Period

For the 100-year return period, 14.013% of the Municipality of Jaro, with an area of 190.65 sq. km., will experience flood levels of less 0.20 meters. 2.845% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 1.657%, 1.369%, 0.902%, and 0.153% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Tables 75-77 are the affected areas, in square kilometers, by flood depth per barangay.

Table 75. Affected Areas in Jaro, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Jaro								
		Alahag	Bias Zabala	Buenavista	Bukid	Buri	Canapuan	Canhandugan	Daro	District I
Affected Area (sq. km.)	0.03-0.20	0.383775	0.824748	1.698619	2.940703	1.955163	2.052063	0.457846	0.263314	0.313847
	0.21-0.50	0.069055	0.215761	0.735544	0.324733	0.377074	0.406346	0.093888	0.005437	0.02773
	0.51-1.00	0.042666	0.100155	0.762265	0.266566	0.209985	0.127417	0.074818	1.57E-06	0.002432
	1.01-2.00	0.023015	0.079792	0.635257	0.278246	0.190816	0.141899	0.021789	0	0.009156
	2.01-5.00	0.004556	0.023721	0.439226	0.068393	0.148313	0.182366	0.012454	0	0.01026
	> 5.00	0	0	0.03114	0	0.0006	5.42E-05	0	0	4.58E-05

Table 76. Affected Areas in Jaro, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Jaro								
		District II	District III	District IV	Hiagsam	Kaglawaan	Kalinawan	Macanip	Macopa	Malobago
Affected Area (sq. km.)	0.03-0.20	0.391063	0.476022	0.434192	0.263967	1.118524	1.115794	0.7213	0.354584	1.221718
	0.21-0.50	0.02772	0.033043	0.04338	0.026203	0.336097	0.155475	0.155107	0.092831	0.267346
	0.51-1.00	0.005509	0.000713	0.033737	0.029026	0.076728	0.051331	0.180136	0.024031	0.1703
	1.01-2.00	0.005822	0	0.020151	0.028256	0.008402	0.00851	0.145025	0.0018	0.118375
	2.01-5.00	0.0002	0	0.029475	0.022296	0.0001	0.020704	0.048202	0	0.059695
	> 5.00	0	0	0	0.014952	0	0	0	0	0

Table 77. Affected Areas in Jaro, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Jaro					
		Olotan	Pitogo	Sagkahan	Santo Ni§o	Tuba	Uguiao
Affected Area (sq. km.)	0.03-0.20	Olotan	Pitogo	Sagkahan	Santo Ni??o	Tuba	Uguiao
	0.21-0.50	0.989094	1.454419	0.621728	0.163394	4.996027	1.50404
	0.51-1.00	0.425767	0.722029	0.243712	0.030822	0.291782	0.317351
	1.01-2.00	0.085336	0.198412	0.367166	0.008752	0.316089	0.026787
	2.01-5.00	0.015397	0.100073	0.298498	0.006978	0.433229	0.039688
	> 5.00	0	0.062342	0.171027	0	0.362506	0.053683
		0	0.0078	0.024544	0	0.212731	0

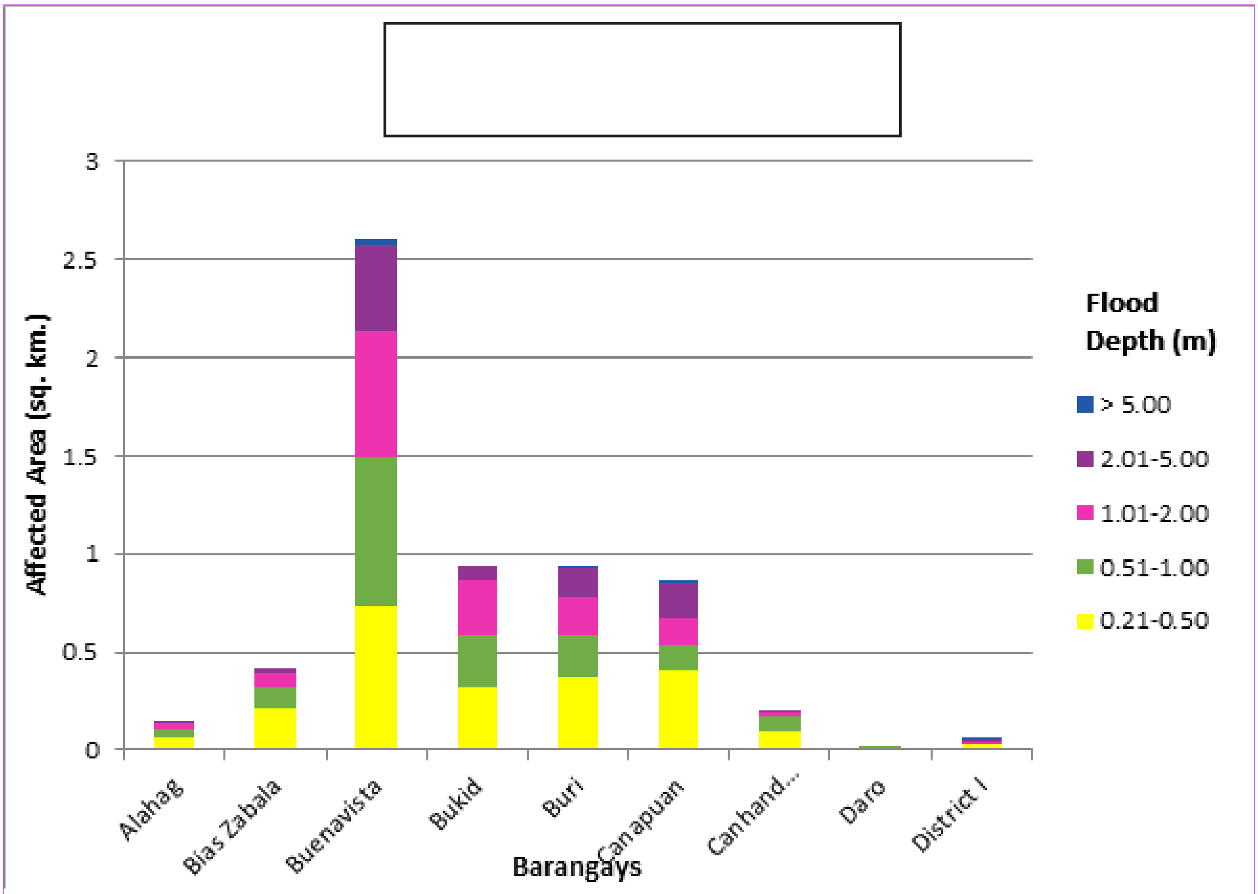

Figure 112. Affected Areas in Jaro, Leyte during 100-Year Rainfall Return Period

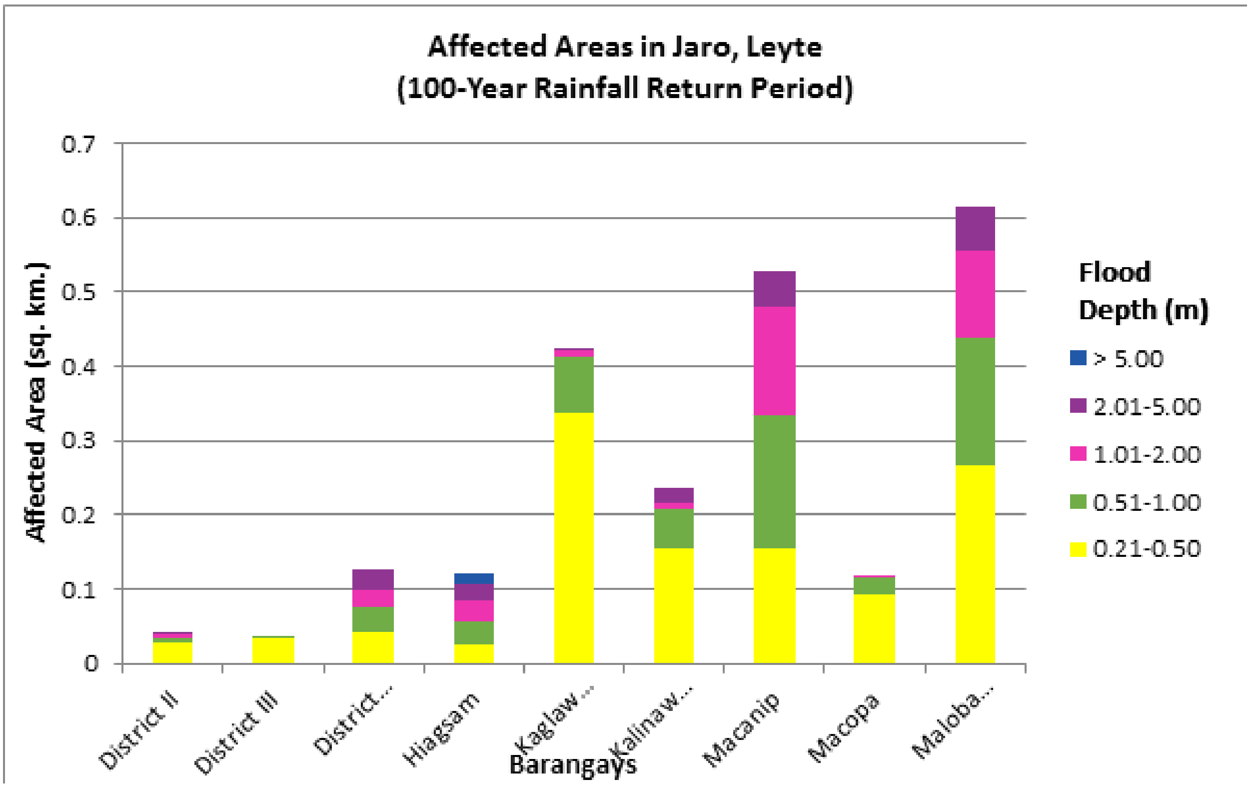

Figure 113. Affected Areas in Jaro, Leyte during 100-Year Rainfall Return Period

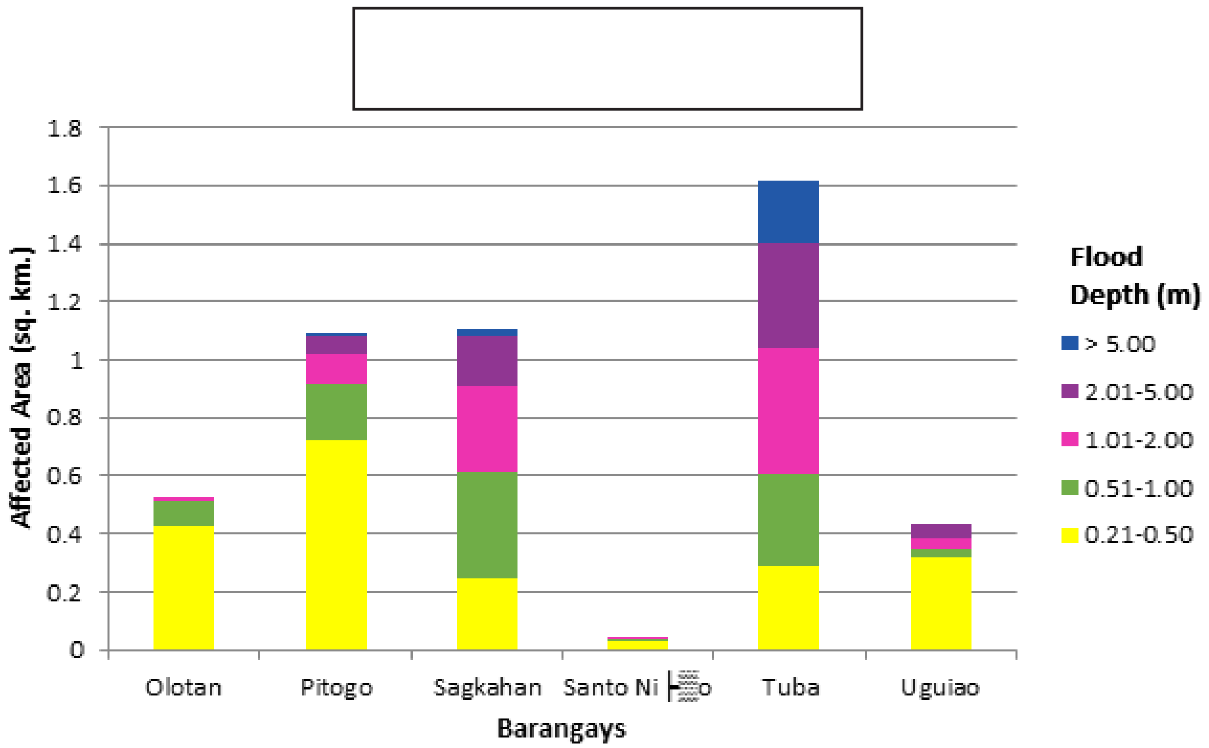

Figure 114. Affected Areas in Jaro, Leyte during 100-Year Rainfall Return Period

For the 100-year return period, 54.025% of the Municipality of San Miguel, with an area of 103.86 sq. km., will experience flood levels of less 0.20 meters. 7.083% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 8.915%, 10.797%, 8.38%, and 0.594% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Tables 78-80 are the affected areas, in square kilometers, by flood depth per barangay

Table 78. Affected Areas in San Miguel, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in San Miguel								
		Bagacay	Bahay	Bairan	Cabatianuhan	Canap	Capilihan	Caraycaray	Cayare	Guinciaman
Affected Area (sq. km.)	0.03-0.20	0.063799	9.85874	1.131326205	1.528103	3.58724	5.322855	4.072856	1.540064	9.246275
	0.21-0.50	0.01188	0.886991	0.451400689	0.715845	0.303053	0.816235	0.226836	0.377548	0.552419
	0.51-1.00	0.001523	1.29165	0.410544709	0.583013	0.463593	1.451647	0.474121	0.297596	0.847467
	1.01-2.00	0	1.937022	0.14747806	0.554003	0.498811	1.958437	0.884757	0.297214	1.482594
	2.01-5.00	0	1.882537	0.032828457	0.104363	0.161276	1.379773	0.453249	0.152148	2.728413
	> 5.00	0	0.13337	0	0.0002	0.001335	0.001834	0.139102	0.007197	0.207049

Table 79. Affected Areas in San Miguel, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in San Miguel								
		Impo	Kinalumsan	Libtong	Lukay	Malaguinabot	Malpag	Mawodpawod	Patong	Pinarigusan
Affected Area (sq. km.)	0.03-0.20	0.739984	2.425664	0.468216199	1.868488	1.769169	0.648595	1.75553	3.590189	0.00186
	0.21-0.50	0.075735	0.109154	0.047538271	0.804517	0.621083	0.15719	0.185868	0.549645	0
	0.51-1.00	0.153418	0.116335	0.095748396	0.803389	0.452499	0.235222	0.169817	0.673973	0
	1.01-2.00	0.316084	0.255937	0.176930974	0.31439	0.110178	0.301367	0.082537	0.679958	0
	2.01-5.00	0.052301	0.164592	0.216264594	0.081835	0.005	0.033945	0.016756	0.466308	0
	> 5.00	0.008644	0.020554	0	0	0	0	0.0001	0.05538	0

Table 80. Affected Areas in San Miguel, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in San Miguel		
		San Andres	Santa Cruz	Santol
Affected Area (sq. km.)	0.03-0.20	1.019346	0.316951	5.154669544
	0.21-0.50	0.106926	0.071031	0.285508628
	0.51-1.00	0.237519	0.056677	0.44424213
	1.01-2.00	0.316859	0.030676	0.868773336
	2.01-5.00	0.098485	0.002286	0.675106542
	> 5.00	0.004933	0	0.037067081

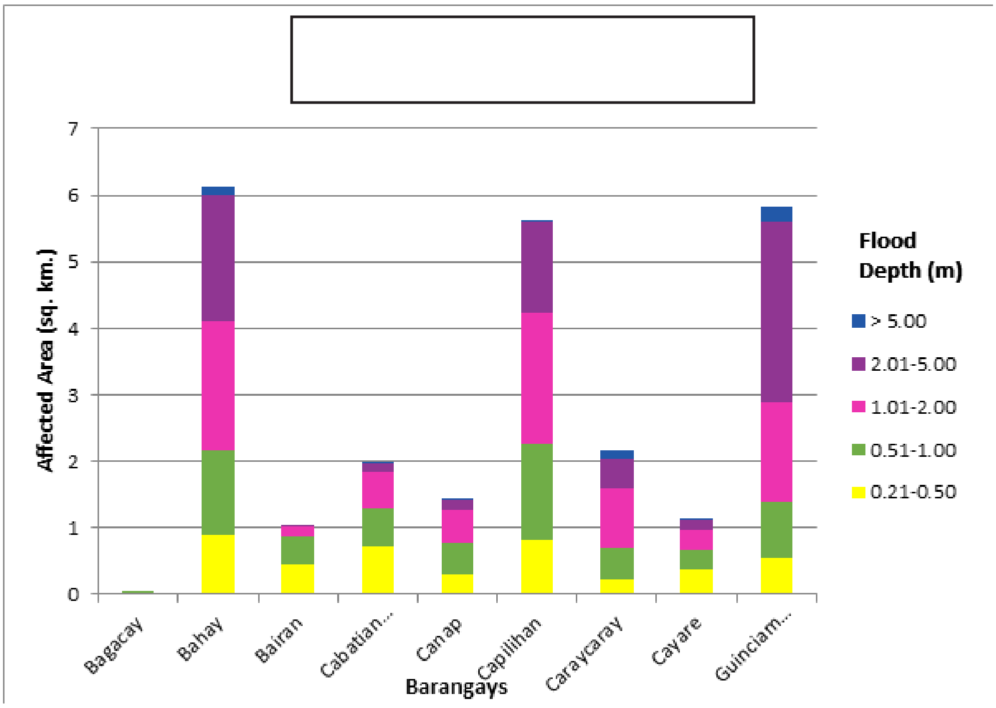

Figure 115. Affected Areas in San Miguel, Leyte during 100-Year Rainfall Return Period

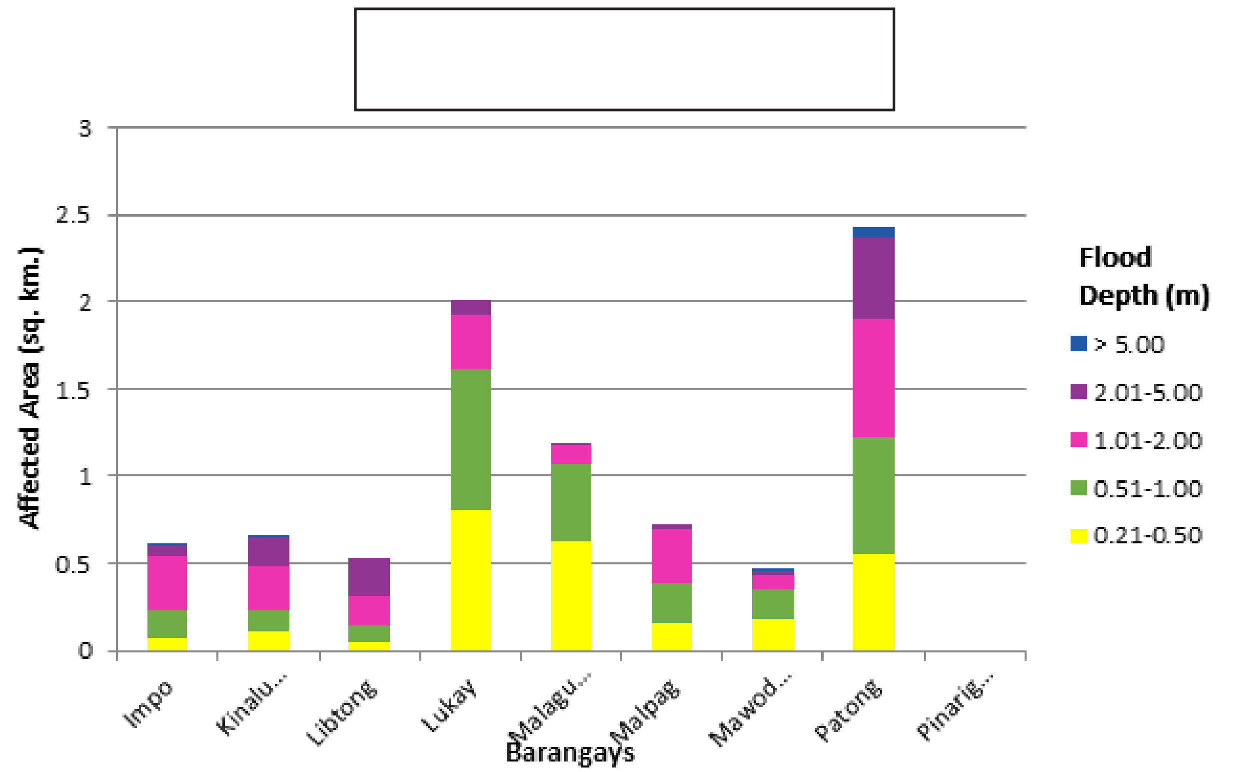

Figure 116. Affected Areas in San Miguel, Leyte during 100-Year Rainfall Return Period

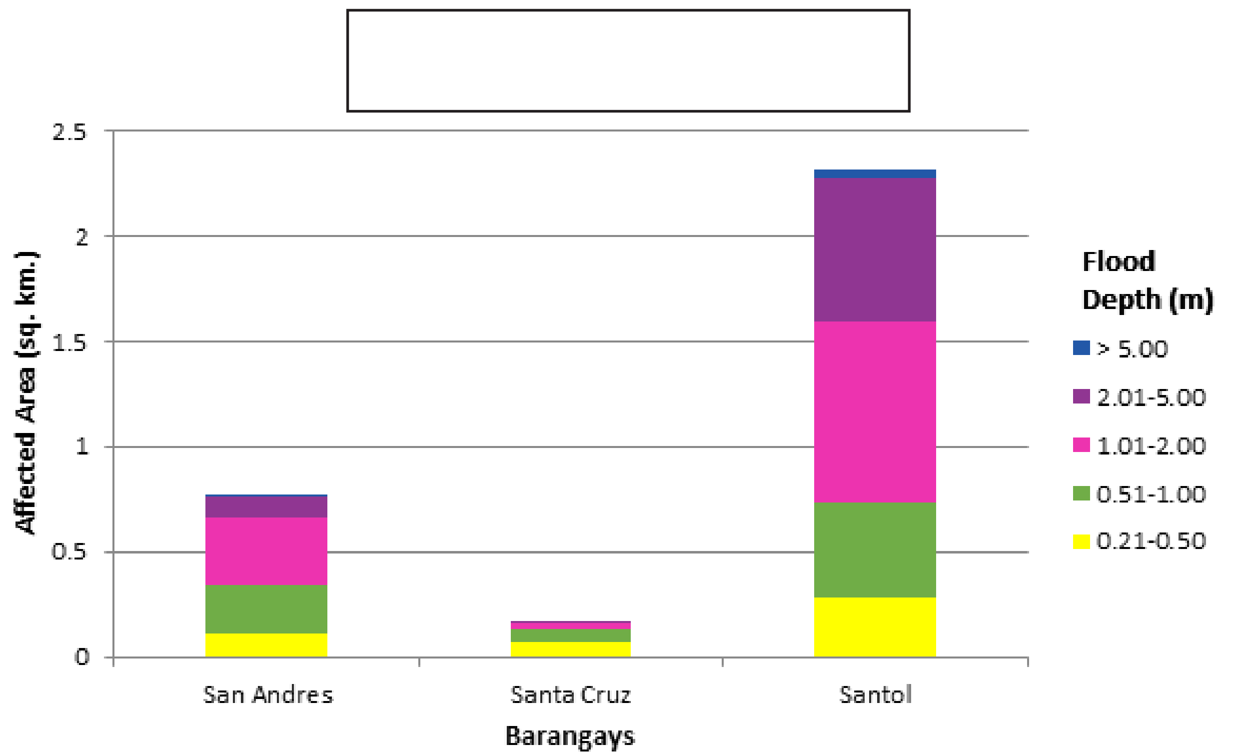

Figure 117. Affected Areas in San Miguel, Leyte during 100-Year Rainfall Return Period

For the 100-year return period, 9.059% of the City of Tacloban, with an area of 118.457 sq. km., will experience flood levels of less 0.20 meters. 0.5517% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 0.605%, 0.576%, 0.1828%, and 0.0066% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Table 81 are the affected areas, in square kilometers, by flood depth per barangay.

Table 81. Affected Areas in Tacloban, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangays in Tacloban				
		Barangay 100	Barangay 103	Barangay 106	Barangay 93	Barangay 98
Affected Area (sq. km.)	0.03-0.20	1.401036	0.432958	0.273676	3.210787	5.412857
	0.21-0.50	0.10608	0.016415	0.006599	0.234978	0.28949
	0.51-1.00	0.144646	0.009346	0.00553	0.187488	0.369678
	1.01-2.00	0.082424	0.001595	0.002018	0.150437	0.445883
	2.01-5.00	0.003935	0.0001	0.001343	0.017585	0.193552
	> 5.00	0	0	0	0	0.007782

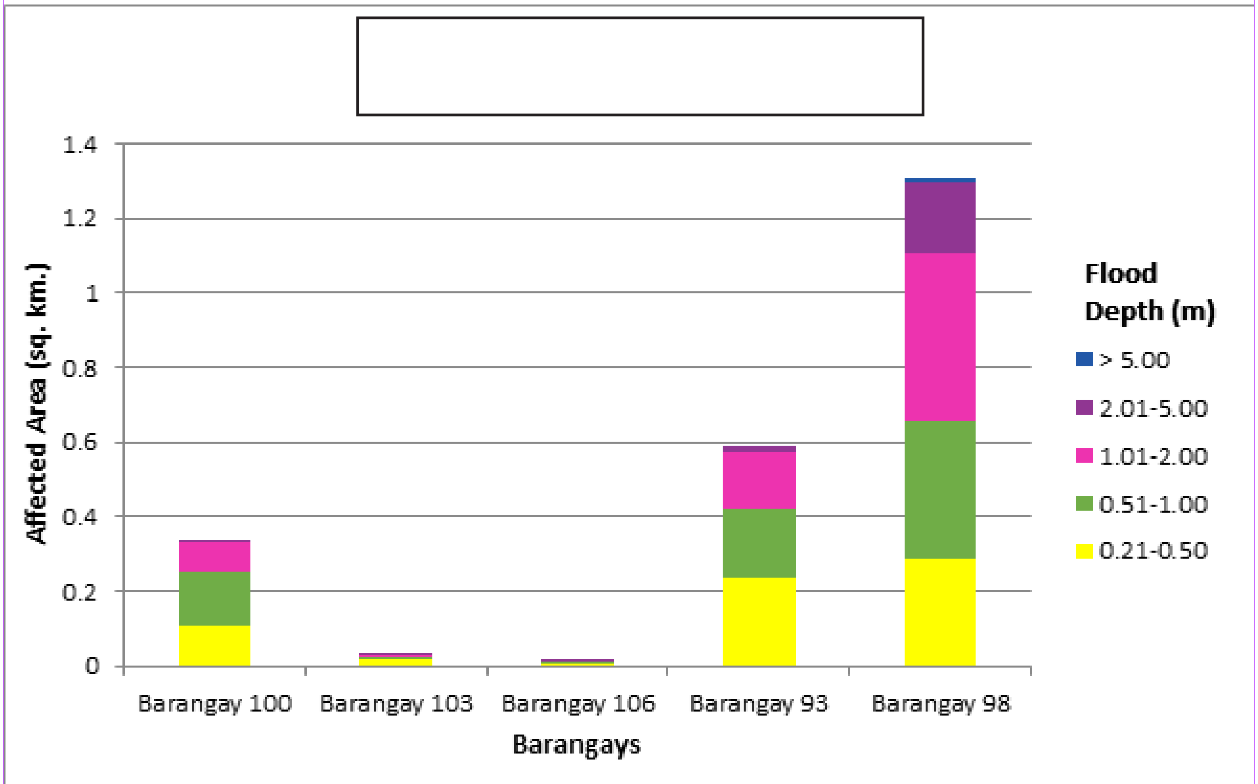

Figure 118. Affected Areas in Tacloban City, Leyte during 100-Year Rainfall Return Period

For the 100-year return period, 25.707% of the Municipality of Tunga, with an area of 17.36 sq. km., will experience flood levels of less 0.20 meters. 4.1215% of the area will experience flood levels of 0.21 to 0.50 meters. Meanwhile, 5.75%, 6.4%, 2.89%, and 1.0068% of the area will experience flood depths of 0.51 to 1 meter, 1.01 to 2 meters, 2.01 to 5 meters, and above 5 meters, respectively. Listed in Table 82 are the affected areas, in square kilometers, by flood depth per barangay.

Table 82. Affected Areas in Tunga, Leyte during 100-Year Rainfall Return Period

SANGPUTAN BASIN		Affected Barangay in Tunga					
		Astorga	Balire	Banawang	San Pedro	San Roque	San Vicente
Affected Area (sq. km.)	0.03-0.20	1.137135	0.001743	2.917299	0.219261	0.154814	0.033224
	0.21-0.50	0.327297	0.002371	0.18825	0.143642	0.052911	0.001133
	0.51-1.00	0.620133	0.001337	0.161848	0.168983	0.044637	0.002106
	1.01-2.00	0.663045	0	0.216852	0.189972	0.037921	0.004074
	2.01-5.00	0.204596	0	0.230123	0.047516	0.013265	0.007038
	> 5.00	0.0014	0	0.173406	0	0	0

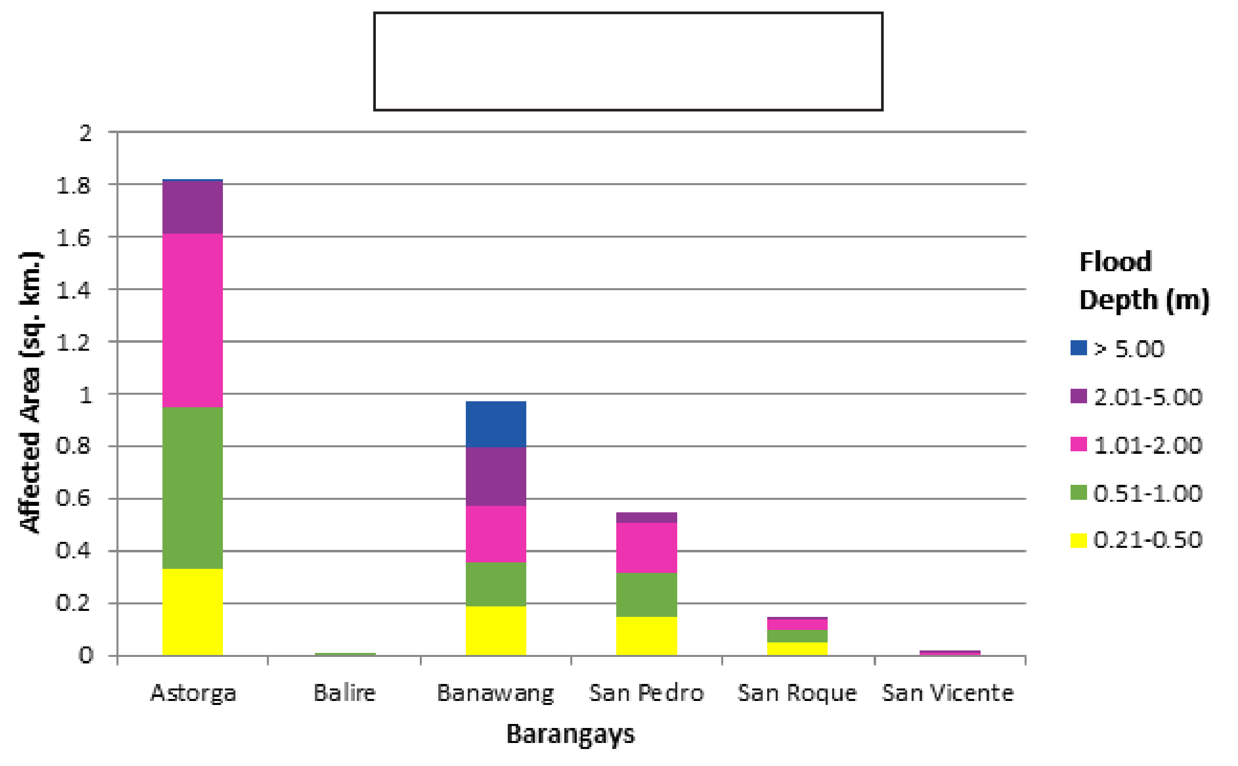

Figure 119. Affected Areas in Tunga, Leyte during 100-Year Rainfall Return Period

Among the barangays in the Mmunicipality of Alangalang, Bugho is projected to have the highest percentage of area that will experience flood levels, at 7.249%. Meanwhile, Tabangohay posted the second highest percentage of area that may be affected by flood depths, at 5.494%.

Among the barangays in the Municipality of Barugo, Cabolo-An is projected to have the highest percentage of area that will experience flood levels, at 6.783%. Meanwhile, Duka posted the second highest percentage of area that may be affected by flood depths, at 6.4785%.

Among the barangays in the Mmunicipality of Jaro, Buenavista is projected to have the highest percentage of area that will experience flood levels, at 2.256%. Meanwhile, Cabapuan posted the second highest percentage of area that may be affected by flood depths, at 1.5264%.

Among the barangays in the Municipality of San Miguel, Bahay is projected to have the highest percentage of area that will experience flood levels, at 15.396%. Meanwhile, Guinciaman posted the second highest percentage of area that may be affected by flood depths, at 14.504%.

Among the barangays in the City of Tacloban, San Barangay 98 is projected to have the highest percentage of area that will experience flood levels, at 5.67%. Meanwhile, Barangay 93 posted the second highest percentage of area that may be affected by flood depths, at 3.209%.
Among the barangays in the Municipality of Tunga, Banawang is projected to have the highest percentage of area that will experience flood levels, at 22.392%. Meanwhile, Astorga posted the second highest percentage of area that may be affected by flood depths, at 17.011%.

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

Table 83. 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	30.19	30.81	29.67
Medium	33.14	44.71	49.80
High	12.58	23.74	32.92
Total	75.91	99.26	112.39

Of the ninety-one (91) identified educational institutions in the Sangputan floodplain, eighteen (18) schools were assessed to be exposed to Low-level flooding during a 5-year scenario, while ten (10) were assessed to be exposed to Medium-level flooding, and one (1) to High-level flooding in the same scenario. In the 25-year scenario, twenty-three (23) schools were assessed to be exposed to Low-level flooding, fifteen (15) schools were assessed to be exposed to Medium-level flooding, and four (4) were projected to be exposed to High-level flooding. For the 100-year scenario, twenty-one (21) schools were assessed to be exposed to Low-level flooding, nineteen (19) schools to Medium-level flooding, and six (6) schools to High-level flooding. See Annex 12 for a detailed enumeration of the schools within the Sangputan floodplain.
Of the fourteen (14) identified medical institutions in the Sangputan floodplain, one (1) was assessed to be exposed to Low-level flooding during a 5-year scenario, while none were assessed to be exposed to Medium- and High-level flooding in the same scenario. In the 25-year scenario, two (2) were assessed to be exposed to Low-level flooding, while one (1) was assessed to be exposed to Medium-level flooding. For the 100-year scenario, two (2) schools were assessed to be exposed to Low-level flooding, and one (1) to Medium-level flooding. See Annex 13 for a detailed enumeration of the medical institutions within the Sangputan 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 occurrences in the respective areas within the major river systems 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 went to the specified points identified in a river basin and gathered data regarding the actual flood level in each location. Data gathering was conducted through assistance from a local DRRM office to obtain maps or situation reports about the past flooding events, or through interviews with some residents with knowledge or experience of flooding in the particular area.

After which, the actual data from the field were compared with the simulated data to assess the accuracy of the flood depth maps produced, and to improve on the results of the flood map. The points in the flood map versus the corresponding validation depths are illustrated in Figures 122 and 123.

The flood validation consists of 202 points, randomly selected all over the Sangputan floodplain. The points were grouped depending on the RIDF return period of the event. Table 85 shows a contingency matrix of the comparison. The validation points are found in Annex 11.

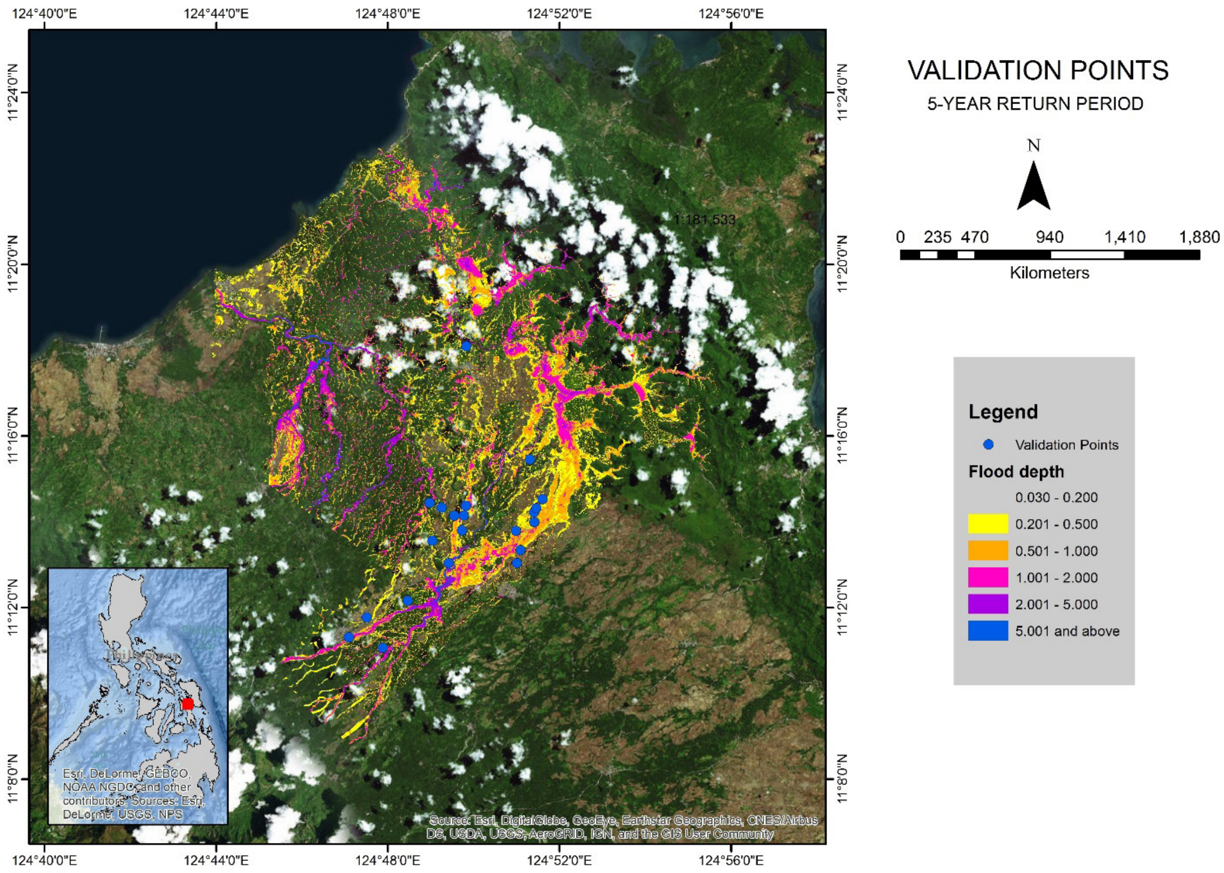

Figure 120. Validation points for 5-year Flood Depth Map of the Sangputan Floodplain

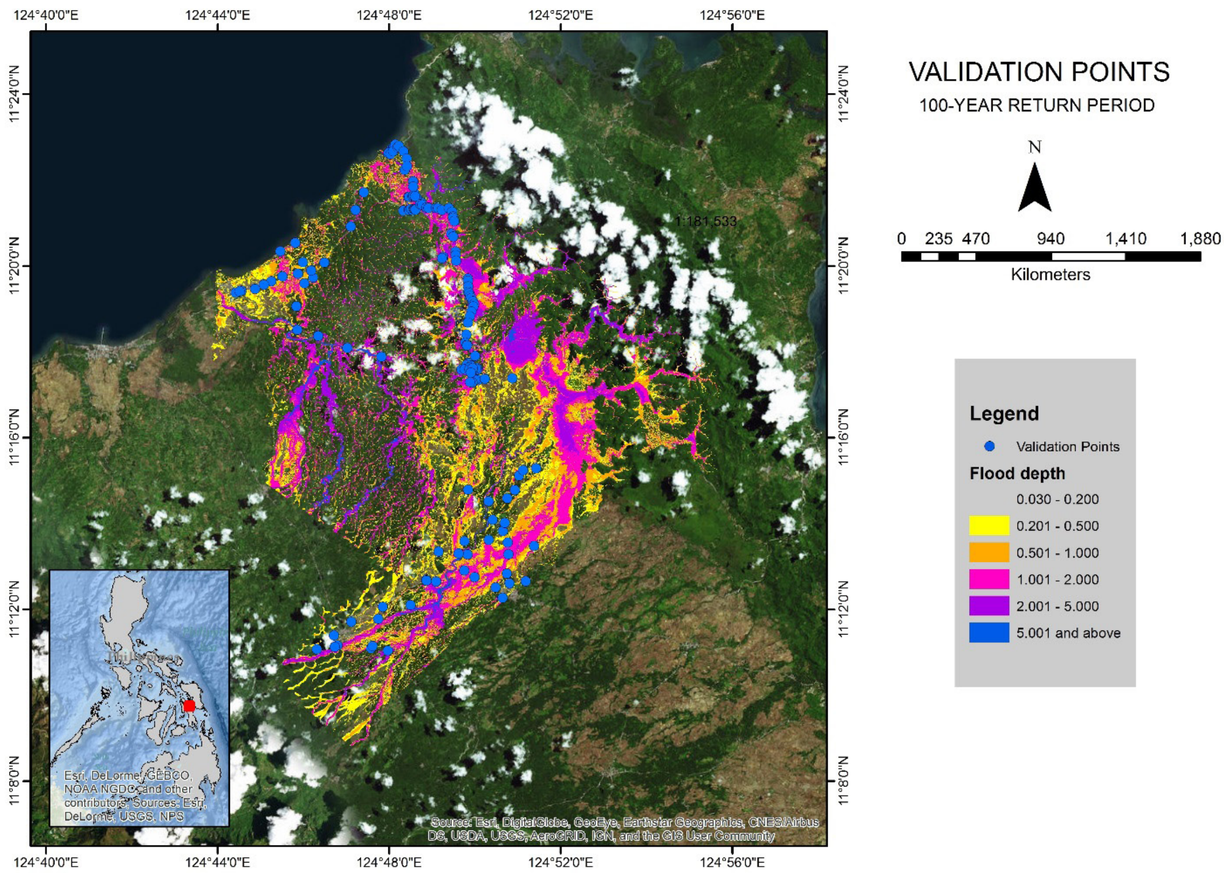

Figure 121. Validation points for 100-year Flood Depth Map of the Sangputan Floodplain

The RMSE values for each flood depth map are listed in Table 84 below:

Table 84. RMSE values for each return period of flood depth map

Return Period	RMSE
5-year	0.60
100-year	0.62

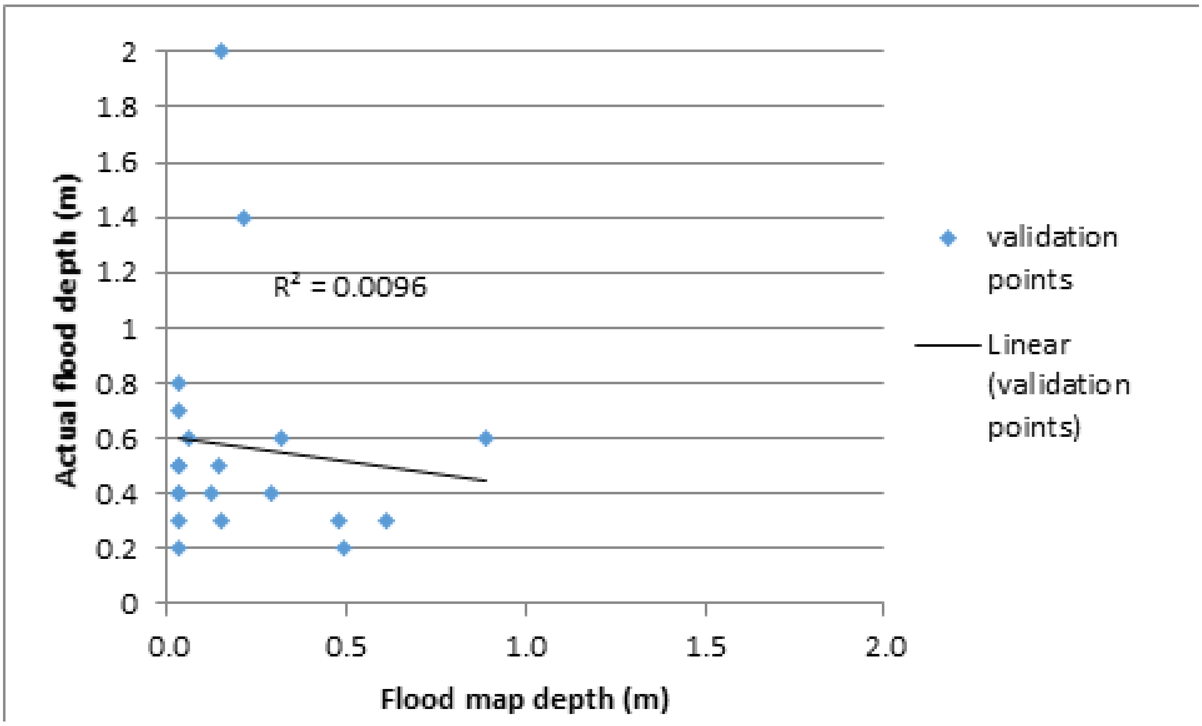

Figure 122. Flood map depth vs actual flood depth for 5-year return period

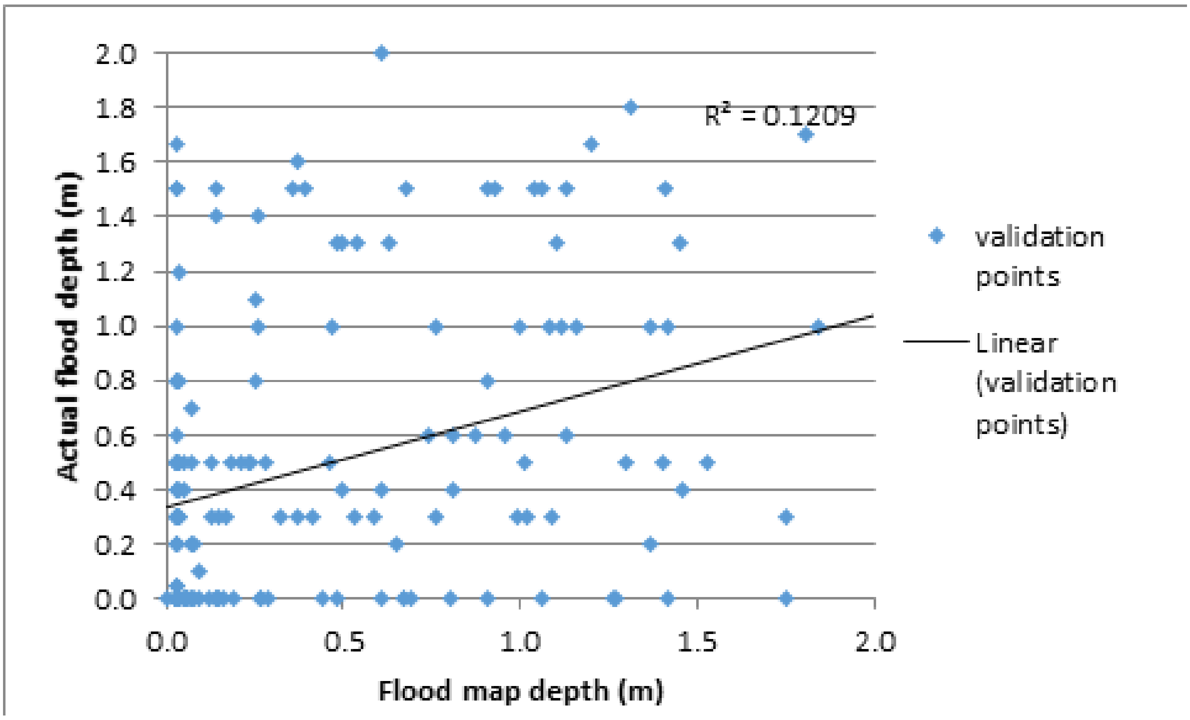

Figure 123. Flood map depth vs actual flood depth for 100-year return period

Table 85. Actual Flood Depth vs Simulated Flood Depth in Sangputan

JIBATANG 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**	54	6	7	6	0	0	73
	0.21-0.50	39	11	8	8	1	0	67
	0.51-1.00	11	4	8	7	0	0	30
	1.01-2.00	7	8	6	10	1	0	32
	2.01-5.00	0	0	0	0	0	0	0
	> 5.00	0	0	0	0	0	0	0
	Total	111	29	29	31	2	0	202

The overall accuracy generated by the flood model is estimated at 41.09%, with eighty-three (83) points correctly matching the actual flood depths. There were seventy-one (71) points estimated one (1) level above and below the correct flood depths, while there were thirty-four (34) points and fourteen (14) points estimated two (2) levels above and below, and three (3) or more levels above and below the correct flood, respectively. A total of forty-four (44) points were overestimated, while a total of seventy-five (75) points were underestimated in the modeled flood depths of Sangputan.

Table 86. Summary of Accuracy Assessment in Sangputan

	No. of Points	%
Correct	83	**41.09**
Overestimated	44	21.78
Underestimated	75	37.13
Total	202	100

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ANNEXES

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

Aquarius Sensor

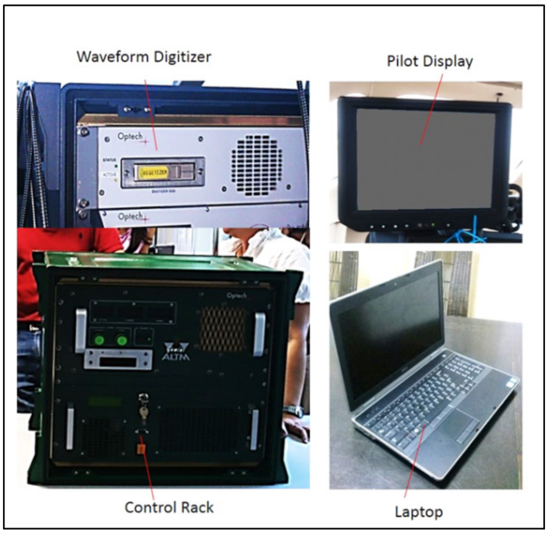

Figure A-1.1. Aquarius Sensor

Table A-1.1. Parameters and Specifications of the Aquarius Sensor

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

Gemini Senor

Figure A-1.2. Gemini Sensor

Table A-1.2. Parameters and Specifications of the Gemini Sensor

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy (2)	1/5,500 x altitude, (m AGL)
Elevation accuracy (2)	<5-35 cm, 1 σ
Effective laser repetition rate	Programmable, 33-167 kHz
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GPS/GNSS/Galileo/L-Band receiver
Scan width (WOV)	Programmable, 0-50˚
Scan frequency (5)	Programmable, 0-70 Hz (effective)
Sensor scan product	1000 maximum
Beam divergence	Dual divergence: 0.25 mrad (1/e) and 0.8 mrad (1/e), nominal
Roll compensation	Programmable, ±5˚ (FOV dependent)
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Video Camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full Optech camera line (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V; 900 W;35 A(peak)
Dimensions and weight	Sensor: 260 mm (w) x 190 mm (l) x 570 mm (h); 23 kg Control rack: 650 mm (w) x 590 mm (l) x 530 mm (h); 53 kg
Operating temperature	-10˚C to +35˚C (with insulating jacket)
Relative humidity	0-95% no-condensing

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

1. LY-110

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

January 27, 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: **LY-110**

Island: **Visayas**	Municipality: **PALO**	Barangay: **LIBERTAD**
Elevation: **12.9339 +/- 0.03 m.**	Order: **1st Order**	Datum: **Mean Sea Level**
Latitude:	Longitude:	

Location Description

LY-110
Is in the Province of Leyte, Municipality of Palo, Brgy. Libertad. it is about 225m West of km post 919, 4.15 North of Centerline of the road leading to Ormoc, at the Northwest end of a 42.0m long bridge. A 24 minutes drive from Tacloban City going to South to Ormoc on a bridge located about 225 meters of km post 919. Mark is a 4" copper nail, drilled on hole on top of concrete footwalk at the top of culvert headwall and cemented flush with inscription "LY-110 2007 NAMRIA".

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8089687 I**
T.N.:	**2016-0240**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.1. LY-110

2. LY-123

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

June 06, 2014

CERTIFICATION

To whom it may concern:

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

Province: **LEYTE**
Station Name: **LY-123**

Island: **Visayas**	Municipality: **ALANG-ALANG**	Barangay:
Elevation: **33.5708 m.**	Order: **1st Order**	Datum: **Mean Sea Level**

Location Description

BM LY-123 is in the Province of Leyte,Municipality of Alang-alang ,in Brgy Malaihao.It is about 150 m.east of KM post 932,4.20 north from the centerline of the road towards Ormoc and is at the Northwest end of a 10.0m long bridge.

Mark is 4" copper nail,drilled on hole,top of concrete footwalk at the northwest end of Malaihao bridge and cemented flush with inscription "LY-123,2007,NAMRIA"

It is a 37 minutes drive from Tacloban city going southward to ormoc.

Recomputed 2014.

Requesting Party: **UP-TCAGP**
Pupose: **Reference**
OR Number: **8796290 A**
T.N.: **2014-1293**

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

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

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.2. LY-123

3. SMR-56

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

April 23, 2014

CERTIFICATION

To whom it may concern:

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

Province: **SAMAR (WESTERN SAMAR)**
Station Name: **SMR-56**
Order: **2nd**

Island: **VISAYAS**
Municipality: **SANTA RITA**
Barangay: **CABACUNGAN**

	PRS92 Coordinates	
Latitude: **11° 23' 6.52702"**	Longitude: **125° 0' 23.99607"**	Ellipsoidal Hgt: **11.82200 m.**
	WGS84 Coordinates	
Latitude: **11° 23' 2.22413"**	Longitude: **125° 0' 29.13917"**	Ellipsoidal Hgt: **73.72700 m.**
	PTM Coordinates	
Northing: **1258927.861 m.**	Easting: **500727.475 m.**	Zone: **5**
	UTM Coordinates	
Northing: **1,259,244.38**	Easting: **718,970.61**	Zone: **51**

Location Description

SMR-56
From Tacloban City, travel about 15 km. north going to Brgy. Cabacungan. Before reaching the of Sta. Rita town proper Western Samar. The monument was established at the Brgy. Cabacungan Elementary School, at the side of the road, 20 m. east fronting school's entrance gate, 50 m. northeast from Waiting Shed about , and 3 m. east along the side the of pathway. Mark is the head of a 4" copper nail flushed in a 30X30 cm. cement block embedded in the ground protruding about 20 cm., with inscriptions "SMR-56; 2007; NAMRIA."

Requesting Party: **Engr. Christopher Cruz/ UP-DREAM**
Pupose: **Reference**
OR Number: **8796021 A**
T.N.: **2014-919**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

CIP/4701/12/09/814

Figure A-2.3. SMR-56

4. SMR-58

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

February 10, 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: **SAMAR (WESTERN SAMAR)**
Station Name: **SMR-58**
Order: **2nd**

Island: **VISAYAS**	Barangay: **SERUM**		
Municipality: **BASEY**	MSL Elevation:		

PRS92 Coordinates

Latitude:	**11° 17' 55.05617"**	Longitude:	**125° 7' 51.16145"**	Ellipsoidal Hgt:	**6.30062 m.**

WGS84 Coordinates

Latitude:	**11° 17' 50.78580"**	Longitude:	**125° 7' 56.31100"**	Ellipsoidal Hgt:	**68.72300 m.**

PTM / PRS92 Coordinates

Northing:	**1249361.531 m.**	Easting:	**514288.239 m.**	Zone:	**5**

UTM / PRS92 Coordinates

Northing:	**1,249,768.75**	Easting:	**732,600.57**	Zone:	**51**

Location Description

SMR-58
From Basey proper, travel about 20 km. north going to Brgy. Serum. From National Road, travel another 1 km. north going to Brgy. Serum. The NAMRIA was established inside the Serum Elementary School, 10 m. east from the school gate, and 15 m. north from the school building. The School site was near the River about 30 m. north. Mark is the head of a 4" copper nail flushed in a 30X30 cm. cement block embedded in the ground protruding about 20 cm., with inscriptions "SMR-58; 2007; NAMRIA."

Requesting Party:	**UP DREAM**
Purpose:	**Reference**
OR Number:	**8089774 I**
T.N.:	**2016-0327**

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.4. SMR-58

6. SM-286

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

June 06, 2014

CERTIFICATION

To whom it may concern:

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

Province: **SAMAR (WESTERN SAMAR)**
Station Name: **SM-286**

Island: **VISAYAS**	Municipality: **SANTA RITA**	Barangay: **SAN PASCUAL**
Elevation: **3.3970 m.**	Order: **1st Order**	Datum:

Location Description

SM-286 is in the Province of Western Samar, town of Sta. Rita, Brgy. San Pascual. It is located at Dalib bridge, positioned at the SE part of the bridge, 4m from the centerline of the national highway. Station mark is the head of 4" copper nail on a drilled hole set flush on a 0.10m x 0.10cement putty inscribed "SM-286, 2007, NAMRIA."

Requesting Party:	**UP-TCAGP**
Pupose:	**Reference**
OR Number:	**8796290 A**
T.N.:	**2014-1291**

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

9 9 0 6 0 6 2 0 1 4 1 6 4 0 4 7

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

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

ISO 9001: 2008 CERTIFIED FOR MAPPING AND GEOSPATIAL INFORMATION MANAGEMENT

Figure A-2.5. SM-286

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

LYT-104

Table A-3.1. LYT-104

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
SMR-53 --- LYT-104 (B1)	SMR-53	LYT-104	Fixed	0.008	0.017	200°40'31"	42653.401	7.525
SMR-53 --- LYT-104 (B2)	SMR-53	LYT-104	Fixed	0.004	0.016	200°40'31"	42653.384	7.601

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	SMR-53				
Grid		Local		Global	
Easting	720874.133 m	Latitude	N11°30'17.85656"	Latitude	N11°30'13.52495"
Northing	1272513.396 m	Longitude	E125°01'29.83738"	Longitude	E125°01'34.96980"
Elevation	24.750 m	Height	26.134 m	Height	87.787 m

To:	LYT-104				
Grid		Local		Global	
Easting	706089.510 m	Latitude	N11°08'38.92234"	Latitude	N11°08'34.67033"
Northing	1232496.838 m	Longitude	E124°53'13.52786"	Longitude	E124°53'18.69323"
Elevation	32.311 m	Height	33.659 m	Height	95.861 m

Vector					
ΔEasting	-14784.623 m	NS Fwd Azimuth	200°40'31"	ΔX	7839.600 m
ΔNorthing	-40016.558 m	Ellipsoid Dist.	42653.401 m	ΔY	15051.644 m
ΔElevation	7.561 m	ΔHeight	7.525 m	ΔZ	-39131.928 m

Standard Errors

Vector errors:					
σ ΔEasting	0.003 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.006 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.007 m
σ ΔElevation	0.009 m	σ ΔHeight	0.009 m	σ ΔZ	0.002 m

LYT-110

Table A-3.2. LYT-110

Processing Summary

Observation	From	To	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	ΔHeight (Meter)
LYT 104 --- LY 110 (B1)	LYT 104	LY 110	Fixed	0.004	0.013	68°33'52"	8457.064	-19.323
LY 110 --- LYT 104 (B2)	LYT 104	LY 110	Fixed	0.004	0.015	68°33'52"	8457.047	-19.343

Acceptance Summary

Processed	Passed	Flag	Fail
2	2	0	0

Vector Components (Mark to Mark)

From:	LYT 104				
Grid		Local		Global	
Easting	706089.510 m	Latitude	N11°08'38.92234"	Latitude	N11°08'34.67033"
Northing	1232496.838 m	Longitude	E124°53'13.52786"	Longitude	E124°53'18.69323"
Elevation	32.311 m	Height	33.659 m	Height	95.861 m

To:	LY 110				
Grid		Local		Global	
Easting	713942.863 m	Latitude	N11°10'19.48389"	Latitude	N11°10'15.23095"
Northing	1235638.117 m	Longitude	E124°57'32.98736"	Longitude	E124°57'38.14961"
Elevation	12.819 m	Height	14.336 m	Height	76.647 m

Vector					
ΔEasting	7853.353 m	NS Fwd Azimuth	68°33'52"	ΔX	-6101.546 m
ΔNorthing	3141.279 m	Ellipsoid Dist.	8457.064 m	ΔY	-5012.598 m
ΔElevation	-19.492 m	ΔHeight	-19.323 m	ΔZ	3027.816 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.004 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.005 m
σ ΔElevation	0.007 m	σ ΔHeight	0.007 m	σ ΔZ	0.002 m

SM-286

Table A-3.3. SM-286

Baseline Processing Report

Processing Summary

Observation	From	To	Occupation Start Time	Occupation Stop Time	Solution Type	H. Prec. (Meter)	V. Prec. (Meter)	ΔX (Meter)	ΔY (Meter)	ΔZ (Meter)	Geodetic Az.	Ellipsoid Dist. (Meter)	Δ Height (Meter)	Satellite Available
SM-286 --- SMR-56 (B1)	SMR-56	SM-286	5/11/2014 6:44:03 AM	5/11/2014 1:54:43 PM	Fixed	0.003	0.009	1325.026	263.512	2667.292	335°34'25"	2989.904	-6.335	GPS: 14 GLONASS: 13 Galileo: 0 QZSS: 0

Acceptance Summary

Processed	Passed	Flag		Fail	
1	1	0		0	

Vector Components (Mark to Mark)

From:	SMR-56				
Grid		Local		Global	
Easting	718970.608 m	Latitude	N11°23'06.52702"	Latitude	N11°23'02.22413"
Northing	1259244.377 m	Longitude	E125°00'23.99607"	Longitude	E125°00'29.13917"
Elevation	10.345 m	Height	11.822 m	Height	73.727 m

To:	SM-286				
Grid		Local		Global	
Easting	717715.152 m	Latitude	N11°24'35.12705"	Latitude	N11°24'30.81697"
Northing	1261958.553 m	Longitude	E124°59'43.21146"	Longitude	E124°59'48.35252"
Elevation	4.047 m	Height	5.488 m	Height	67.304 m

Vector					
ΔEasting	-1255.456 m	NS Fwd Azimuth	335°34'25"	ΔX	1325.020 m
ΔNorthing	2714.176 m	Ellipsoid Dist.	2989.904 m	ΔY	263.518 m
ΔElevation	-6.298 m	ΔHeight	-6.335 m	ΔZ	2667.293 m

Standard Errors

Vector errors:					
σ ΔEasting	0.001 m	σ NS fwd Azimuth	0°00'00"	σ ΔX	0.003 m
σ ΔNorthing	0.001 m	σ Ellipsoid Dist.	0.001 m	σ ΔY	0.004 m
σ ΔElevation	0.005 m	σ ΔHeight	0.005 m	σ ΔZ	0.001 m

Annex 4. The LiDAR Survey Team Composition

Table A-4.1. LiDAR Survey Team Composition

Data Acquisition Component Sub-Team	Designation	Name	Agency/ Affiliation
PHIL-LIDAR 1	Program Leader	ENRICO C. PARINGIT, D.ENG	UP-TCAGP
Data Acquisition Component Leader	Data Component Project Leader – I	ENGR. CZAR JAKIRI SARMIENTO	UP-TCAGP
Survey Supervisor	Chief Science Research Specialist (CSRS)	ENGR. CHRISTOPHER CRUZ	UP-TCAGP
	Supervising Science Research Specialist (Supervising SRS)	ENGR. LOVELYN ASUNCION	UP-TCAGP
FIELD TEAM			
LiDAR Operation	Supervising SRS	LOVELY GRACIA ACUÑA	UP-TCAGP
	Senior Science Research Specialist (SRS)	JULIE PEARL MARS	UP-TCAGP
		ENGR. GEROME HIPOLITO	UP-TCAGP
		PAULINE JOANNE ARCEO	UP-TCAGP
	Research Associate (RA)	ENGR. DAN CHRISTOFFER ALDOVINO	UP-TCAGP
		FAITH JOY SABLE	UP-TCAGP
		MARY CATHERINE ELIZABETH BALIGUAS	UP-TCAGP
		ENGR. IRO NIEL ROXAS	UP-TCAGP
		ENGR. LARAH KRISELLE PARAGAS	UP-TCAGP
		GRACE SINADJAN	UP-TCAGP
		JONATHAN ALMALVEZ	UP-TCAGP
Ground Survey, Data Download and Transfer	RA	JERIEL PAUL ALAMBAN, GEOL.	UP-TCAGP
LiDAR Operation	Airborne Security	SSG. RAYMUND DOMINE	PHILIPPINE AIR FORCE (PAF)
		SSG. RANDY SISON	PAF
	Pilot	CAPT. JACKSON JAVIER	ASIAN AEROSPACE CORPORATION (AAC)
		CAPT. NEIL ACHILLES AGAWIN	AAC
		CAPT. ALBERT PAUL LIM	AAC
		CAPT. RANDY LAGCO	AAC

Annex 5. Data Transfer Sheets for the Sangputan Floodplain Flights

DATA TRANSFER SHEET
5/22/2014 (Leyte Ongoing)

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	
4/20/2014	1358A	3BLK34F110A	AQUARIUS	NA	NA	1.17MB	243MB	63.3/10.7GB	3/510/87KB	14.1GB	NA	12.1MB	1KB	1KB	6KB	773/12KB	Z:\Airborne_Raw\1358A
4/20/2014	1360A	3BLK34FS110B	AQUARIUS	NA	NA	7.75MB	174MB	41.1GB	206KB	8.26GB	NA	11.3MB	1KB	1KB	6KB	649/12KB	Z:\Airborne_Raw\1360A
4/22/2014	1366A	3BLK34E112A	AQUARIUS	NA	NA	1.37MB	257MB	95.5GB	418/1/263KB	14.9GB	NA	8.53MB	1KB	1KB	5KB	889/10KB	Z:\Airborne_Raw\1366P
5/11/2014	1442A	3BLK33GS131A	AQUARIUS	NA	NA	5.86MB	275MB	108GB	59/697/KB	16.6GB	NA	14.3MB	1KB	1KB	NA	2652KB	Z:\Airborne_Raw\1442A
5/11/2014	1444A	3BLK33GSH131B	AQUARIUS	NA	NA	2.82MB	254MB	79.3GB	1/1/515/1/139KB	15.2GB	229GB	14.3MB	1KB	1KB	5/5KB	2813/700KB	Z:\Airborne_Raw\1444A
5/13/2014	1450A	3BLK33HS133A	AQUARIUS	NA	NA	906KB	132MB	34.1GB	257KB	6.07GB	87.0GB	10.5MB	1KB	1KB	5KB	1019KB	Z:\Airborne_Raw\1450A
5/13/2014	1452A	3BLK33HSES133B	AQUARIUS	NA	NA	2.33MB	233MB	47.1GB	1/415KB	9.57GB	86.8GB	11.2MB	1KB	1KB	6/10KB	512KB	Z:\Airborne_Raw\1452A
5/14/2014	1454A	3BLK34D134A	AQUARIUS	NA	NA	1.88MB	268MB	15.7/71.5GB	23/102/517KB	14.6GB	206GB	8.41MB	1KB	1KB	5/2KB	1522KB	Z:\Airborne_Raw\1454A
5/14/2014	1456A	3BLK34C134B	AQUARIUS	NA	NA	0.98MB	212MB	66.6GB	278/226KB	11.6GB	58.6GB	7.92MB	1KB	1KB	5KB	641KB	Z:\Airborne_Raw\1456P
5/15/2014	1460A	3BLK35CD135B	AQUARIUS	NA	NA	1.24MB	273MB	74.8GB	622KB	14.7GB	235GB	11.4MB	1KB	1KB	5/5KB	476/807KB	Z:\Airborne_Raw\1460A
5/16/2014	1462A	3BLK35DSE136A	AQUARIUS	NA	NA	1.29MB	275MB	91.2GB	685KB	15.2GB	NA	11.6MB	1KB	1KB	5/4KB	842KB	Z:\Airborne_Raw\1462A
5/16/2014	1464A	3BLK35ES136B	AQUARIUS	NA	NA	1.20MB	251MB	76.9GB	637KB	14.0GB	NA	11.4MB	1KB	1KB	4KB	786KB	Z:\Airborne_Raw\1464A

Received from
Name: Dan Aldovino
Position: Research Associate
Signature:

Received by
Name: JOIDA F. PRIETO
Position: SSRS
Signature: 5/28/2014

Figure A-5.1. Transfer Sheet for Sangputan Floodplain – A

DATA TRANSFER SHEET
Leyte 2/11/16

DATE	FLIGHT NO.	MISSION NAME	SENSOR	RAW LAS		LOGS(MB)	POS	RAW IMAGES/CASI	MISSION LOG FILE/CASI LOGS	RANGE	DIGITIZER	BASE STATION(S)		OPERATOR LOGS (OPLOG)	FLIGHT PLAN		SERVER LOCATION
				Output LAS	KML (swath)							BASE STATION(S)	Base Info (.txt)		Actual	KML	
22-Jan	3765G	2BLK34AD022A	gemini	NA	93	690	255	na	na	25.2	na	4.38	1KB	1KB	23/57/22/58/ 21/55/21/21	na	Z:\DAC\RAW DATA
22-Jan-16	3767G	2BLK34AG022B	gemini	NA	75	490	204	na	na	19.1	na	3.4	1KB	1KB	57/11	na	Z:\DAC\RAW DATA
23-Jan-16	3769G	2BLK34ADEG023A	gemini	NA	82	670	260	na	na	23.8	na	9.58	1KB	1KB	na	na	Z:\DAC\RAW DATA
23-Jan-16	3771G	2BLK34BCG023B	gemini	NA	77	526	212	na	na	20.3	na	9.2	1KB	1KB	57/22	na	Z:\DAC\RAW DATA
24-Jan-16	3773G	2BLK34CG024A	gemini	NA	63	582	248	na	na	16.8	na	4.74	1KB	1KB	27/26/59	na	Z:\DAC\RAW DATA

Received from

Name C. Joaquin
Position
Signature [signature]

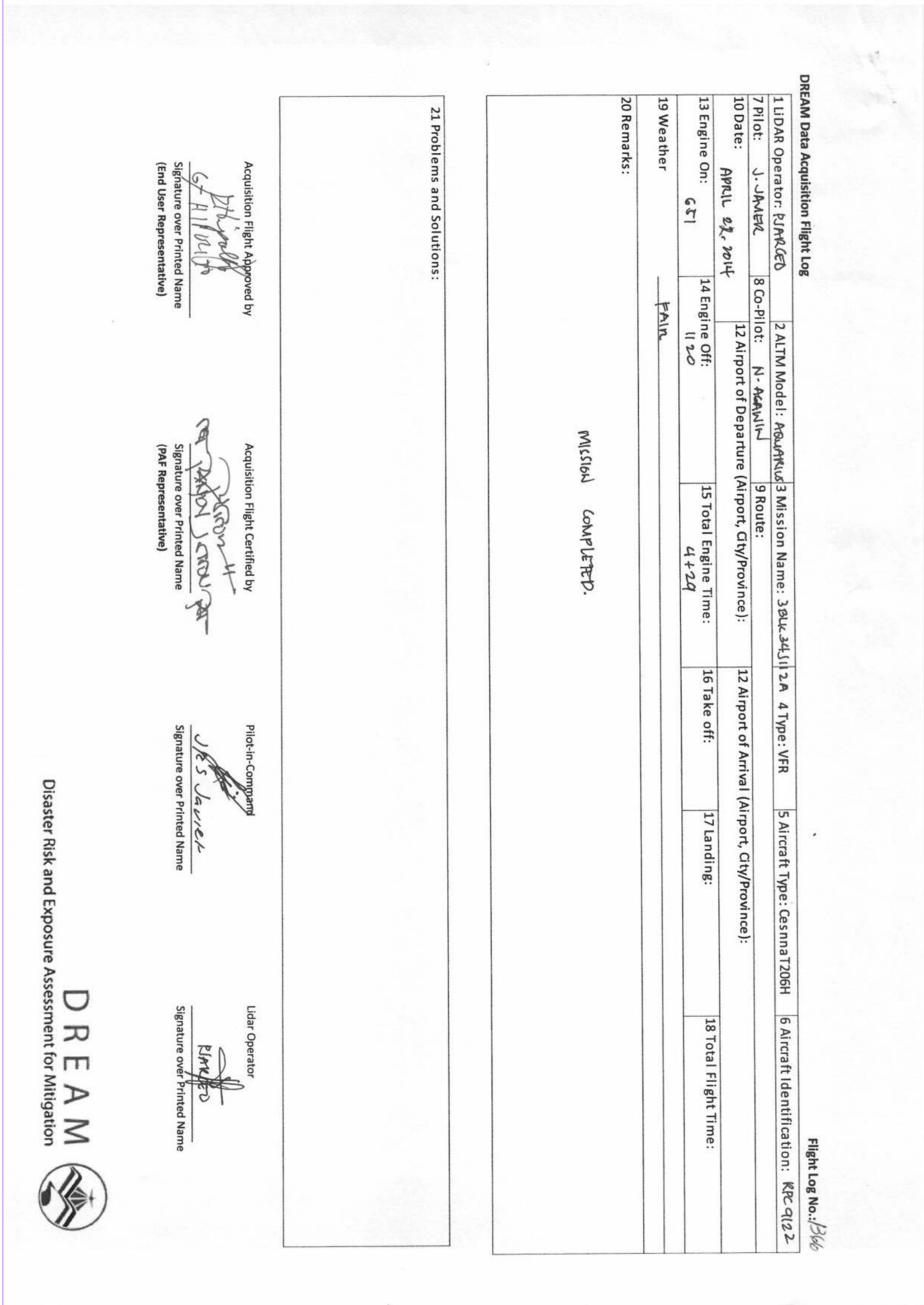
Received by

Name AC Bongat 2/12/16
Position SSRS
Signature [signature]

Figure A-5.2. Transfer Sheet for Sangputan Floodplain – B

Annex 6. Flight Logs for the Flight Missions

Flight Log for 1366A Mission


DREAM Data Acquisition Flight Log

Flight Log No.: 1366

1 LiDAR Operator: R.ARCEO	2 ALTM Model: AQUARIUS	3 Mission Name: 3BLK34S112A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: RPC-9122
7 Pilot: J. JAVIER	8 Co-Pilot: N. AGAWIN	9 Route:			
10 Date: APRIL 22, 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 651	14 Engine Off: 1120	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather: FAIR					

20 Remarks:

MISSION COMPLETED.

21 Problems and Solutions:

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

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

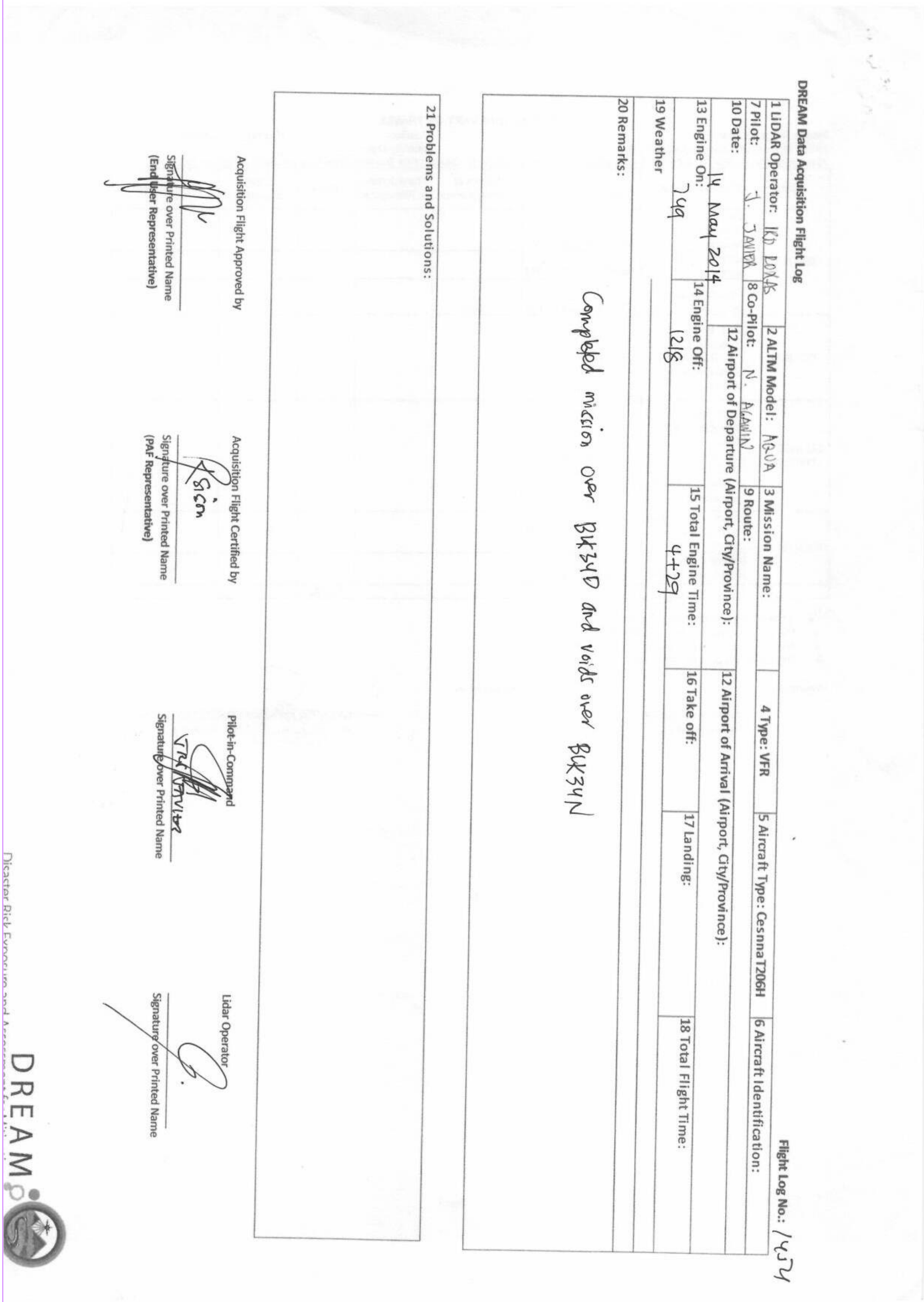
Pilot-in-Command — J. Javier — Signature over Printed Name

Lidar Operator — R. Arceo — Signature over Printed Name

DREAM
Disaster Risk and Exposure Assessment for Mitigation

Figure A-6.1. Flight Log for Mission 1366A

Flight Log for 1454A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1434

1 LiDAR Operator: I.D. LOZAS	2 ALTM Model: AQUA	3 Mission Name:	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification:
7 Pilot: J. JAVIER	8 Co-Pilot: N. ALAWIN	9 Route:			
10 Date: 14 May 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 749	14 Engine Off: 1218	15 Total Engine Time: 4+29	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					
20 Remarks: Completed mission over BLK34D and voids over BLK34N					
21 Problems and Solutions:					

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

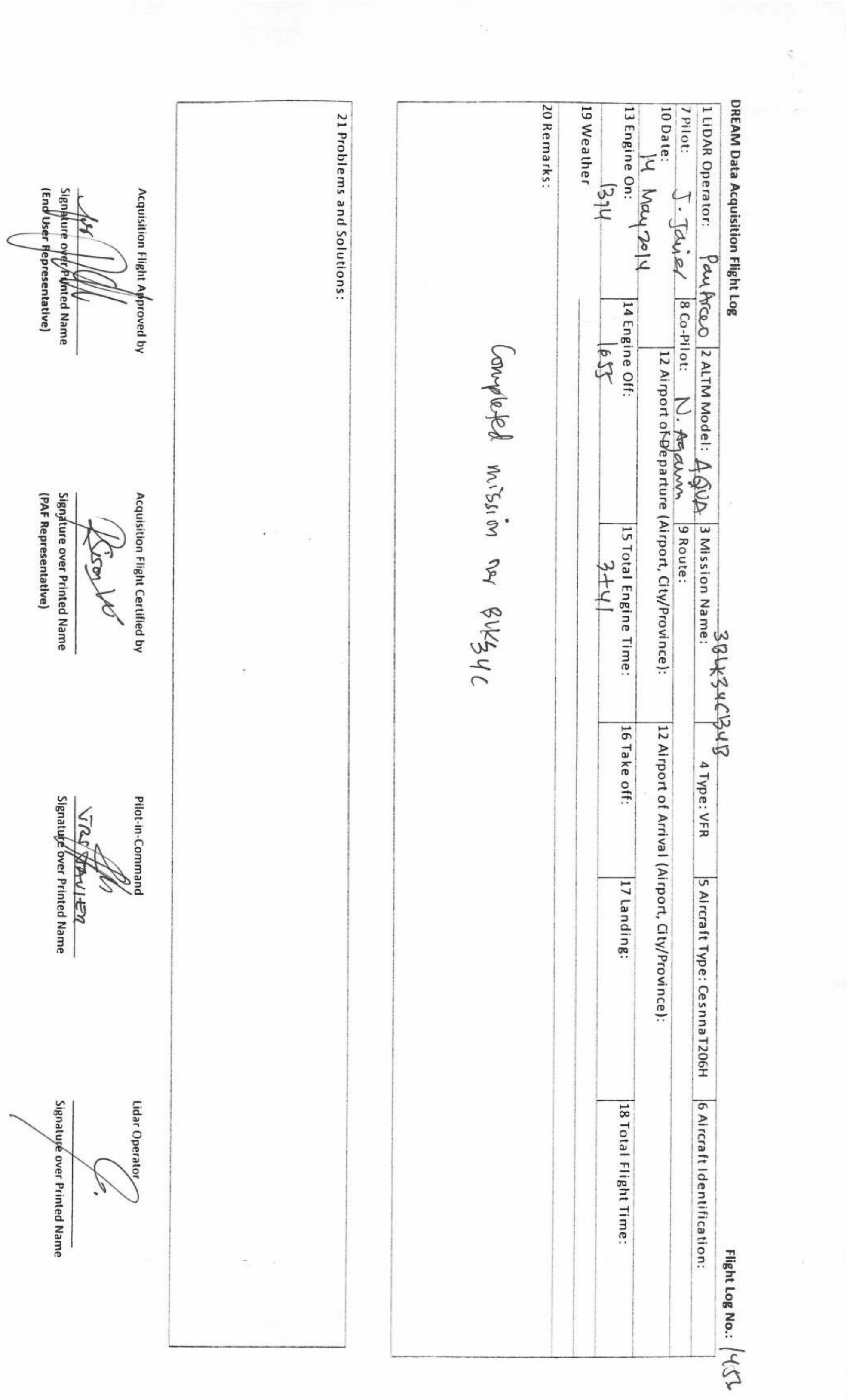
Acquisition Flight Certified by — Signature over Printed Name (PAF Representative)

Pilot-in-Command — J. JAVIER — Signature over Printed Name

Lidar Operator — Signature over Printed Name

Figure A-6.2. Flight Log for Mission 1454A

Flight Log for 1456A Mission



DREAM Data Acquisition Flight Log

Flight Log No.: 1456

1 LiDAR Operator: Pau Arceo	2 ALTM Model: AQUA	3 Mission Name: 3BLK34CB4B	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification:
7 Pilot: J. Javier	8 Co-Pilot: N. Agawin	9 Route:			
10 Date: 14 May 2014	12 Airport of Departure (Airport, City/Province):		12 Airport of Arrival (Airport, City/Province):		
13 Engine On: 1314	14 Engine Off: 1655	15 Total Engine Time: 3+41	16 Take off:	17 Landing:	18 Total Flight Time:
19 Weather					

20 Remarks:

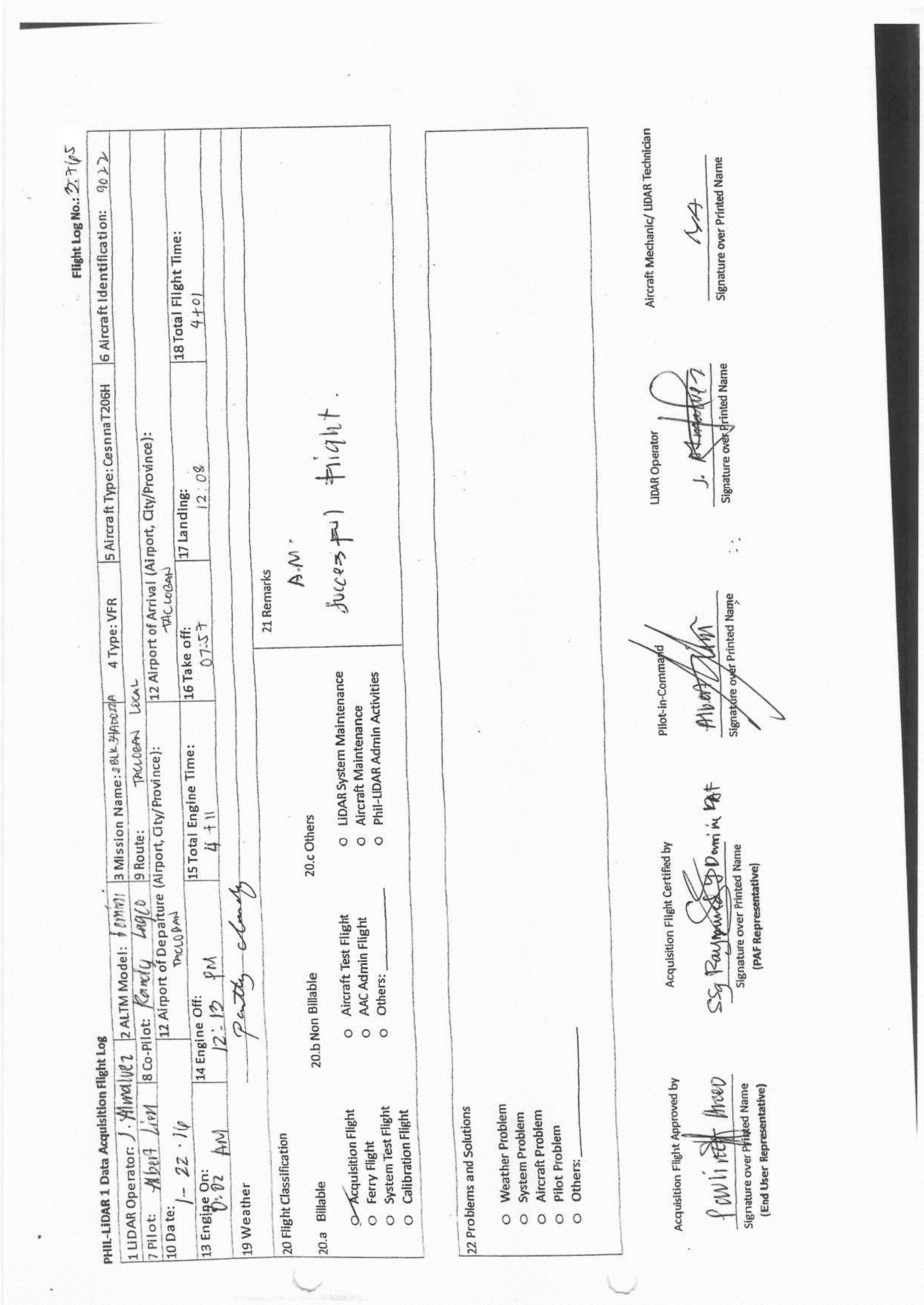
Completed mission over BLK34C

21 Problems and Solutions:

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

Figure A-6.3. Flight Log for Mission 1456A

Flight Log for 3765G Mission



Flight Log No.: 3765

PHIL-LiDAR 1 Data Acquisition Flight Log

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Gemini	3 Mission Name: 2BLK34ADO22A	4 Type: VFR	5 Aircraft Type: Cesnna T206H	6 Aircraft Identification: 9022
7 Pilot: Albert Lim	8 Co-Pilot: Randy Lagco	9 Route: TACLOBAN LOCAL			
10 Date: 1-22-16	12 Airport of Departure (Airport, City/Province): TACLOBAN		12 Airport of Arrival (Airport, City/Province): TACLOBAN		
13 Engine On: 0:02 AM	14 Engine Off: 12:13 PM	15 Total Engine Time: 4+11	16 Take off: 07:57	17 Landing: 12:08	18 Total Flight Time: 4+01
19 Weather: Partly cloudy					

20 Flight Classification

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

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

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

21 Remarks

A.M.
Successful flight.

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

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

Acquisition Flight Certified by: SSg Raymund [signature] Domingo PAF — Signature over Printed Name (PAF Representative)

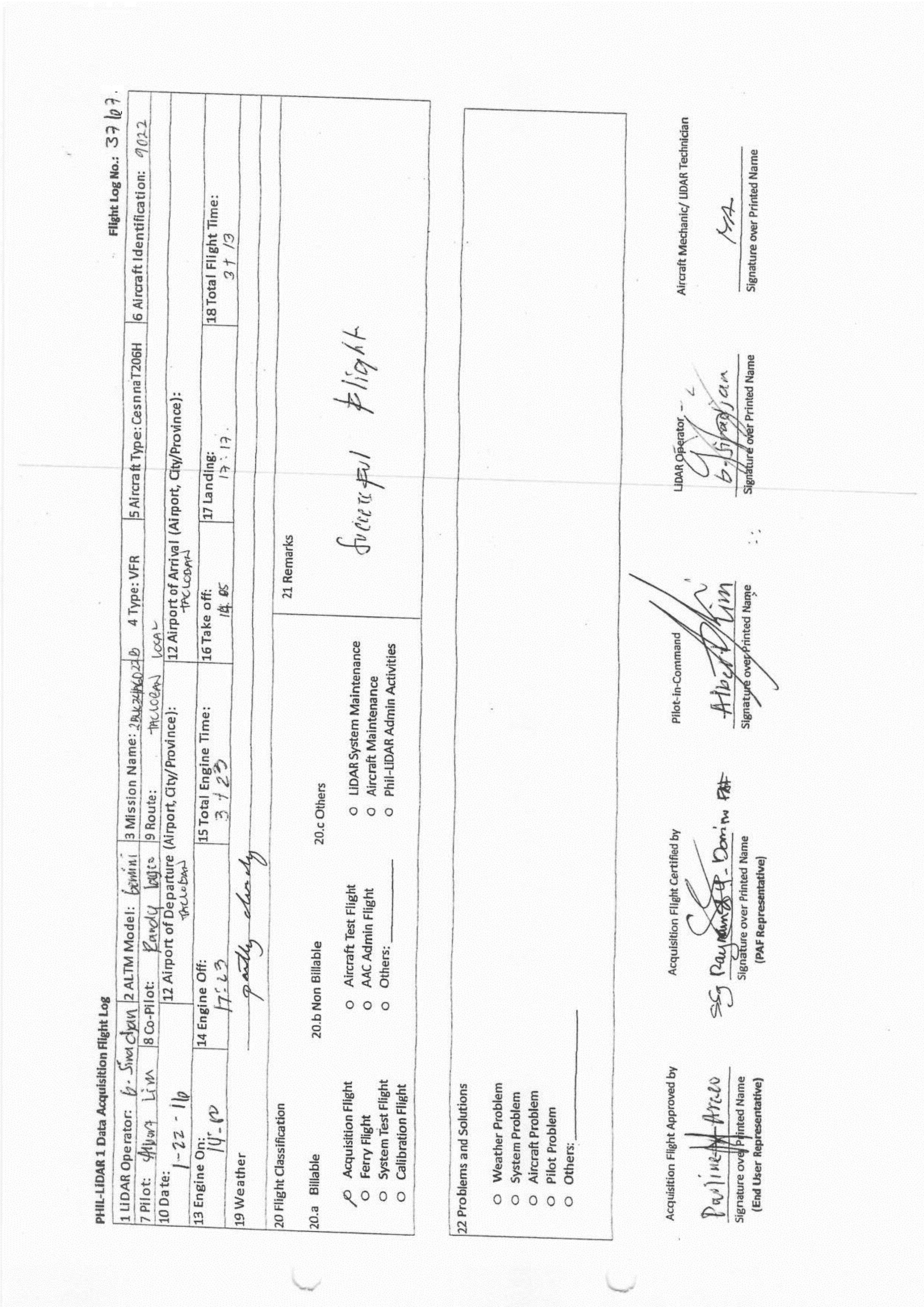
Pilot-in-Command: [signature] Signature over Printed Name

LiDAR Operator: J. Almalvez [signature] Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: NA — Signature over Printed Name

Figure A-6.4. Flight Log for Mission 3765G

Flight Log for 3767G Mission



PHIL-LIDAR 1 Data Acquisition Flight Log

Flight Log No.: 3767

1 LiDAR Operator: G. Sinadjan	2 ALTM Model: Gemini	3 Mission Name: 2BLK24HG022B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: 9022
7 Pilot: Albert Lim	8 Co-Pilot: Randy Lagto	9 Route: Tacloban Local			
10 Date: 1-22-16	12 Airport of Departure (Airport, City/Province): Tacloban		12 Airport of Arrival (Airport, City/Province): Tacloban		
13 Engine On: 14:50	14 Engine Off: 17:23	15 Total Engine Time: 3+23	16 Take off: 14:05	17 Landing: 17:17	18 Total Flight Time: 3+13
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

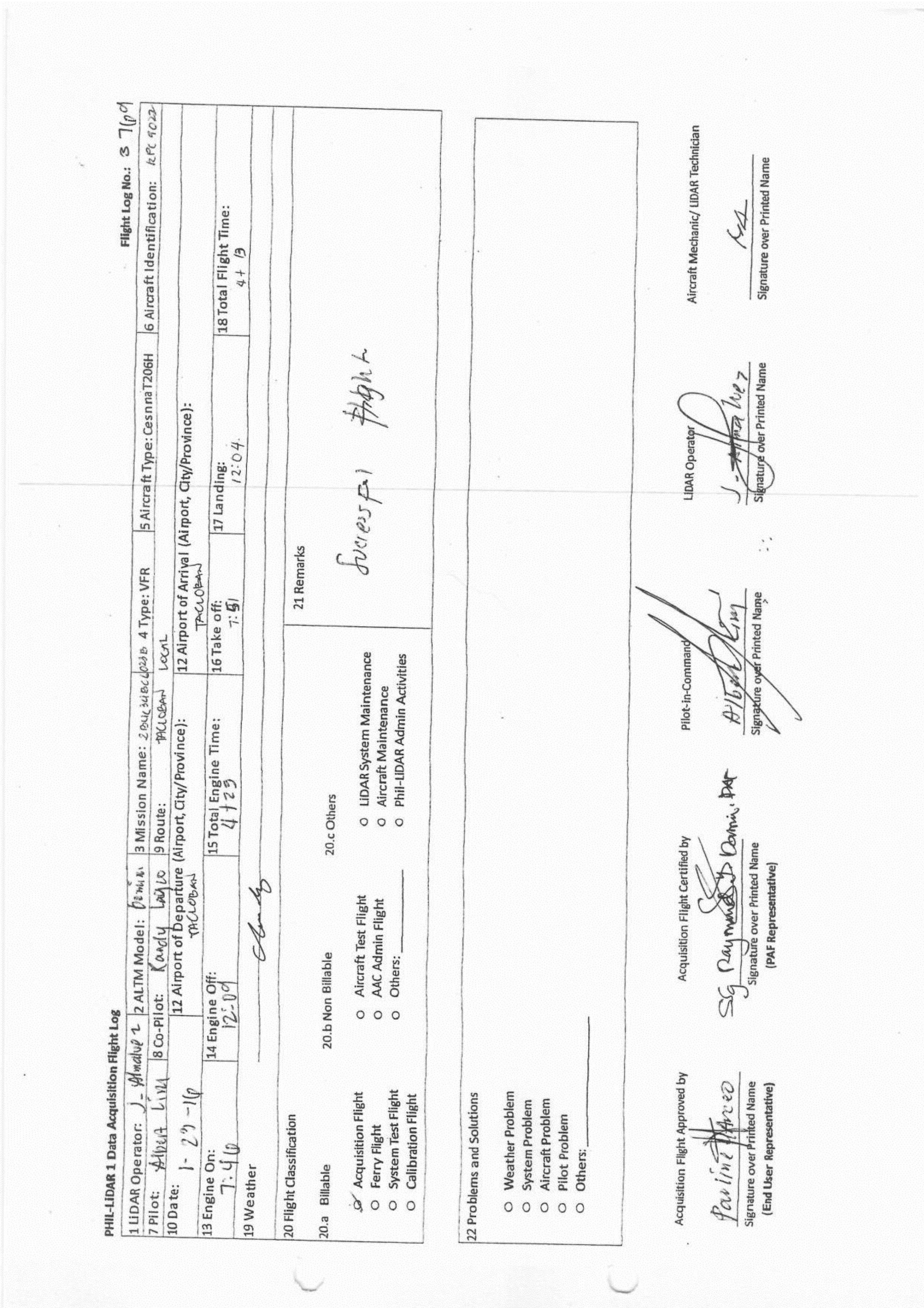
Successful Flight

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	SSG Raymund P. Domine PAF	Albert Lim	G. Sinadjan	MA
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.5. Flight Log for Mission 3767G

Flight Log for 3769G Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 3769

1 LiDAR Operator: J. Almalvez	2 ALTM Model: Gemini	3 Mission Name: 2BLK34BCL023B	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC 9022
7 Pilot: Albert Lim	8 Co-Pilot: Randy Lagco	9 Route: TACLOBAN LOCAL			
10 Date: 1-29-16	12 Airport of Departure (Airport, City/Province): TACLOBAN		12 Airport of Arrival (Airport, City/Province): TACLOBAN		
13 Engine On: 7:46	14 Engine Off: 12:09	15 Total Engine Time: 4+23	16 Take off: 7:51	17 Landing: 12:04	18 Total Flight Time: 4+13
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

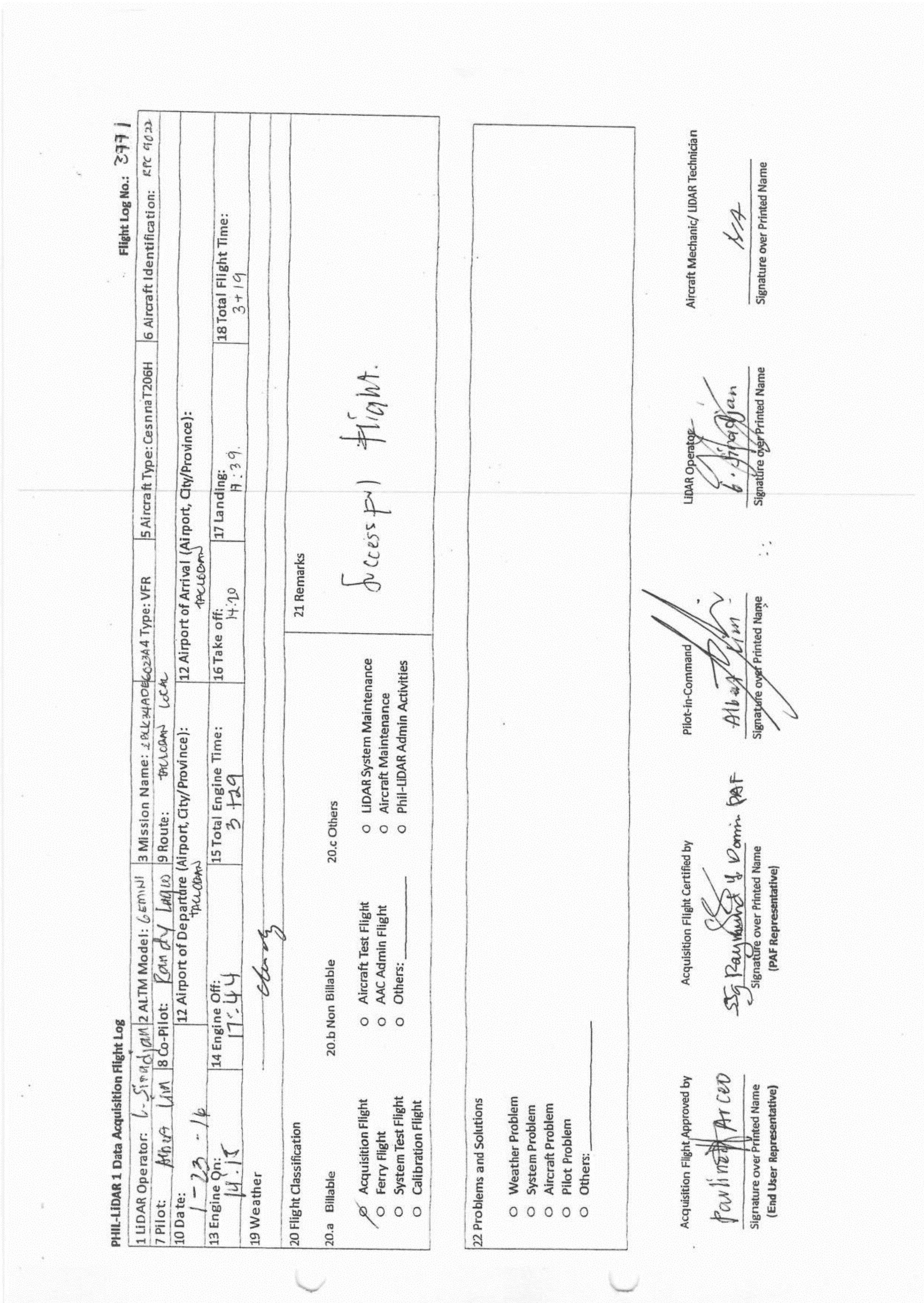
Successful flight

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	SG Raymund D Domin PAF	Albert Lim	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

Figure A-6.6. Flight Log for Mission 3769G

Flight Log for 3771G Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 3771

1 LiDAR Operator: L. Siradjan	2 ALTM Model: GEMINI	3 Mission Name: 2BLK34ADE6023A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC 9022
7 Pilot: Albert Lim	8 Co-Pilot: Randy Lagu	9 Route: TACLOBAN LOCAL			
10 Date: 1-23-16	12 Airport of Departure (Airport, City/Province): TACLOBAN		12 Airport of Arrival (Airport, City/Province): TACLOBAN		
13 Engine On: 14:15	14 Engine Off: 17:44	15 Total Engine Time: 3+29	16 Take off: 14:20	17 Landing: 17:39	18 Total Flight Time: 3+19
19 Weather: cloudy					

20 Flight Classification

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

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

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

21 Remarks

Successful flight.

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

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

Acquisition Flight Certified by: SSg Raymund Y Domin PAF — Signature over Printed Name (PAF Representative)

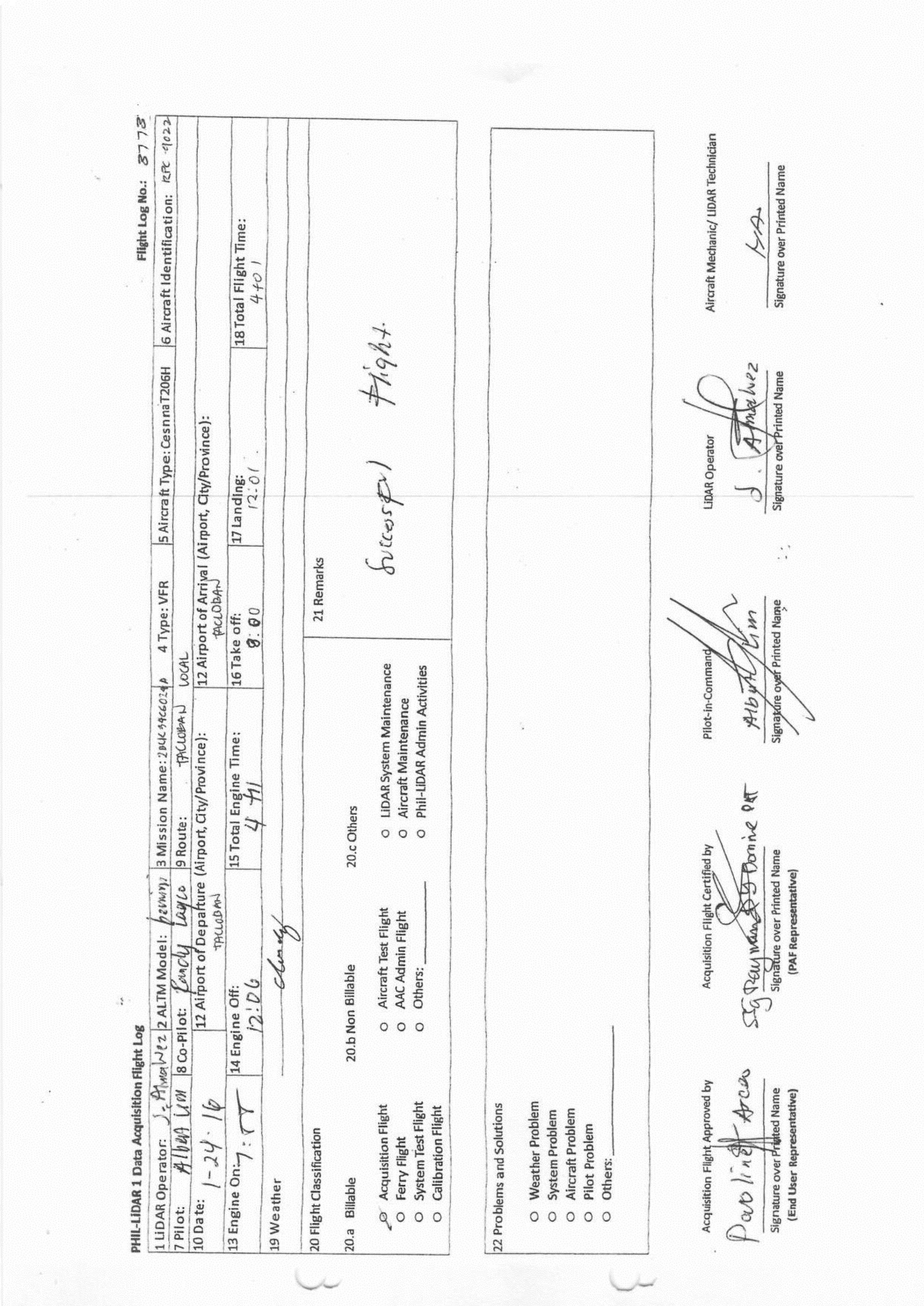
Pilot-in-Command: Albert Lim — Signature over Printed Name

LiDAR Operator: L. Siradjan — Signature over Printed Name

Aircraft Mechanic/ LiDAR Technician: N/A — Signature over Printed Name

Figure A-6.7. Flight Log for Mission 3771G

Flight Log for 3773G Mission



PHIL-LiDAR 1 Data Acquisition Flight Log

Flight Log No.: 3773

1 LiDAR Operator: J. Almazan	2 ALTM Model: Gemini	3 Mission Name: 2BLK34C6024A	4 Type: VFR	5 Aircraft Type: CesnnaT206H	6 Aircraft Identification: RPC-9022
7 Pilot: Albert Lim	8 Co-Pilot: Randy Lagco	9 Route: TACLOBAN LOCAL			
10 Date: 1-24-16	12 Airport of Departure (Airport, City/Province): TACLOBAN		12 Airport of Arrival (Airport, City/Province): TACLOBAN		
13 Engine On: 7:55	14 Engine Off: 12:06	15 Total Engine Time: 4+11	16 Take off: 8:00	17 Landing: 12:01	18 Total Flight Time: 4+01
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

Successful Flight.

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
Signature over Printed Name (End User Representative)	Signature over Printed Name (PAF Representative)	Signature over Printed Name	Signature over Printed Name	Signature over Printed Name

Figure A-6.8. Flight Log for Mission 3773G

Annex 7. Flight Status Reports

Table A-7-1. Flight Status Report

LEYTE-SAMAR					
FLIGHT NO	AREA	MISSION	OPERATOR	DATE FLOWN	REMARKS
1366A	BLK34E	3BLK34E112A	P. Arceo	April 22,2014	Mission completed
1454A	BLK34D BLK33E	3BLK34D134A	I. Roxas	May 14, 2014	Completed mission over BLK34D and some voids over BLK33E.
1456A	BLK34D	3BLK34C134B	P. Arceo	May 14, 2014	Completed mission over BLK34D and voids over BLK33E.
3765G	BLK34A BLK34D	2BLK34AD022A	J.Almalvez	Jan. 22, 2016	Surveyed 7 lines at BLK34D and 10 lines at BLK34A.
3767G	BLK34A BLK34G	2BLK34AG022B	G. Sinadjan	Jan. 22, 2016	Surveyed 7 lines at BLK34A and 16 lines at BLK34G.
3769G	BLK34A BLK34D BLK34E BLK34G	2BLK34ADEG023A	J.Almalvez	Jan. 23, 2016	Completed BLK34A, BLK34D and BLK 34E. Surveyed 6 lines at BLK34G.
3771G	BLK34B BLK34C BLK34G	2BLK34BCG023B	G. Sinadjan	Jan. 23, 2016	Completed BLK34B. Surveyed 10 lines at BLK34C and 4 lines at BLK34G.
3773G	BLK34C BLK34G	2BLK34CG024A	J. Almalvez	Jan. 24, 2016	Completed BLK34C and BLK34G.

LAS/SWATH PER FLIGHT MISSION

Flight No. : 1366A
Area: BLK34E
Mission Name: 3BLK34E112A
Total Area: 121.43 sq. km
Altitude: 600m
PRF: 50 kHz SCF: 50 Hz
Lidar FOV: 18 deg Sidelap: 30%

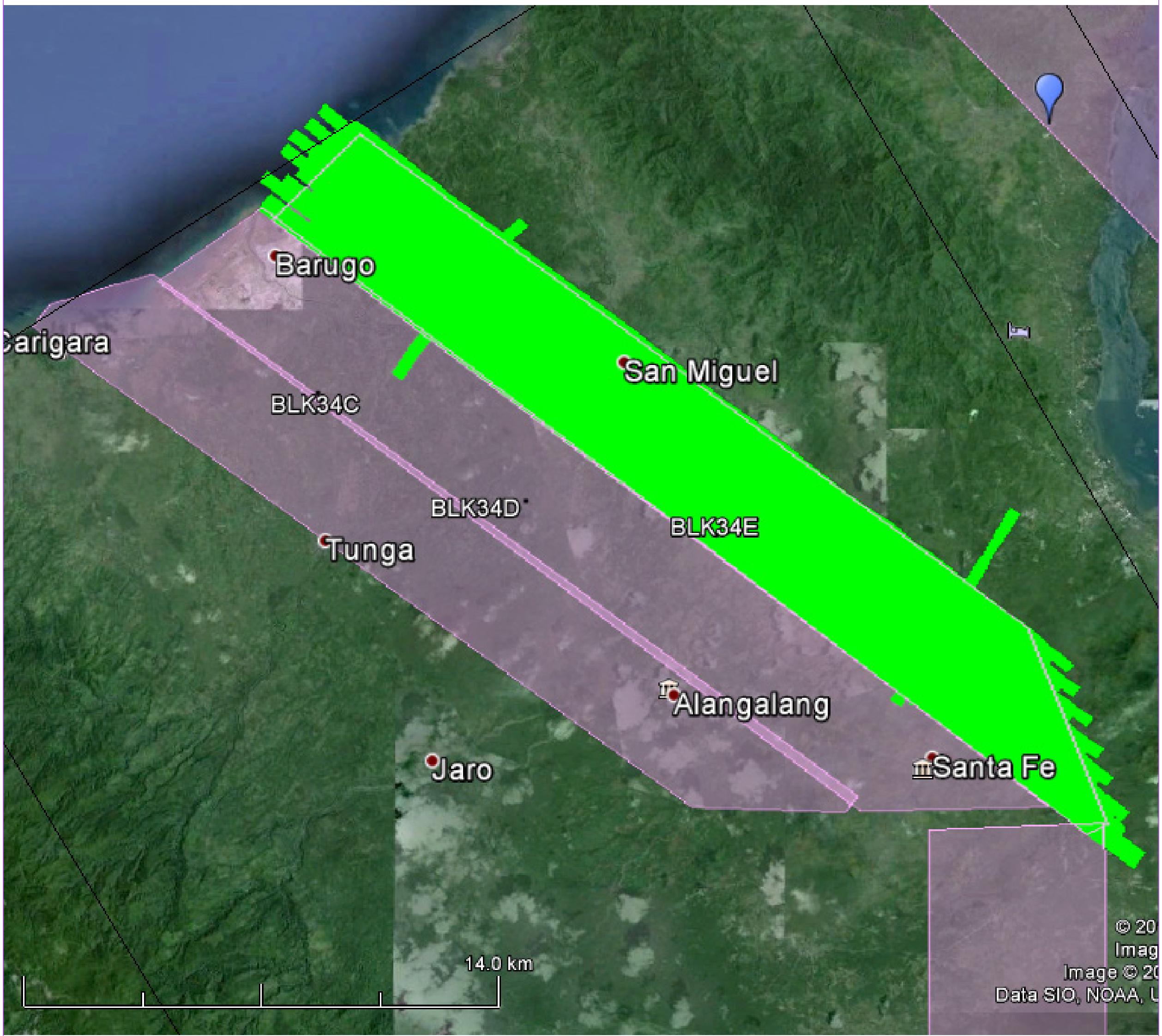


Figure A-7.1. Swath for Flight No. 1366A

Flight No. :	1454A		
Area:	BLK34D & BLK34E		
Total Area:	138.839 sq. km.		
Mission Name:	3BLK34D134A		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%

Figure A-7.2. Swath for Flight No. 1454A

Flight No. :	1456A		
Area:	BLK34C		
Total Area:	98.421 sq. km.		
Mission Name:	3BLK34C134B		
Altitude:	600m		
PRF:	50 kHz	SCF:	50 Hz
Lidar FOV:	18 deg	Sidelap:	30%

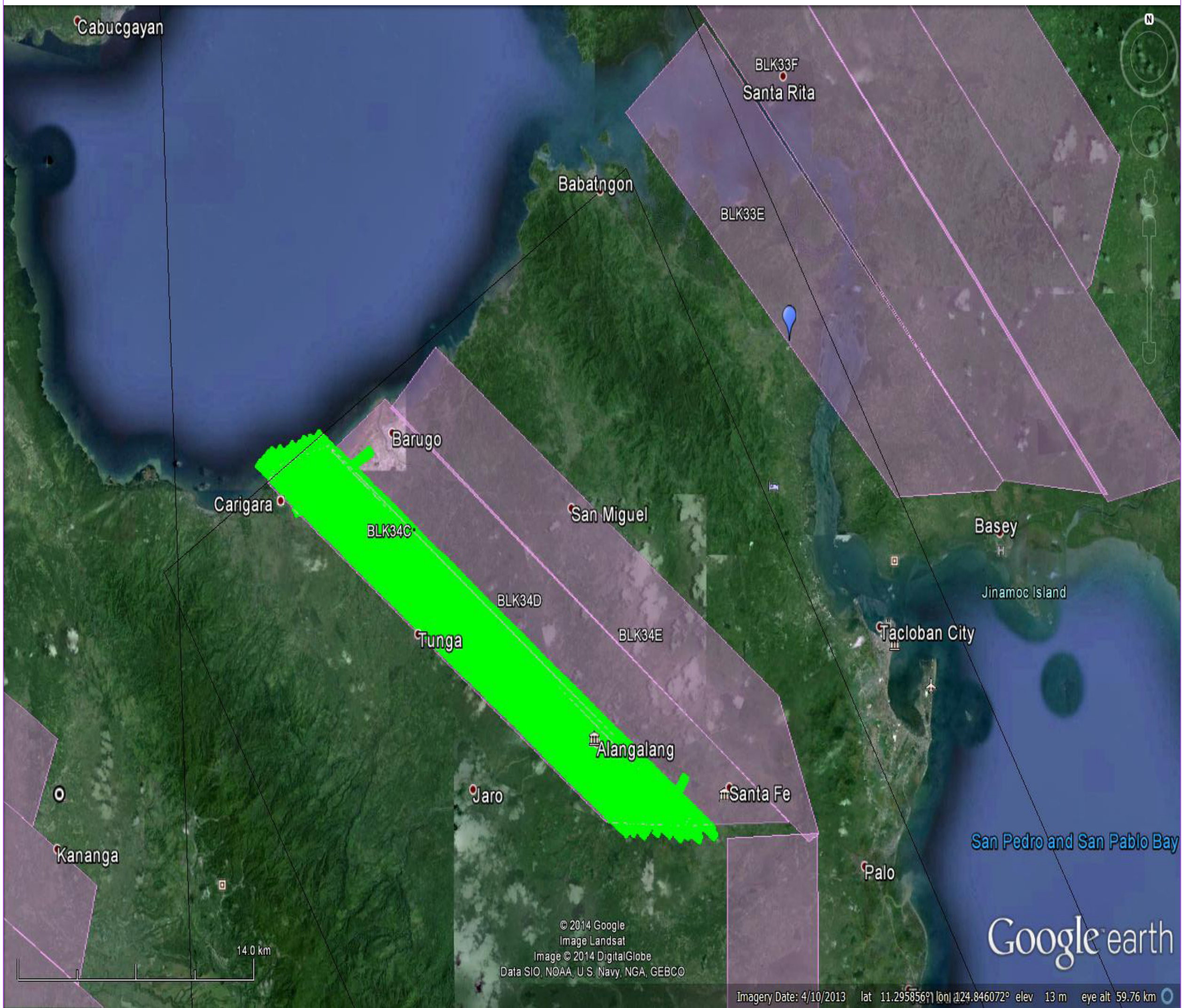


Figure A-7.3. Swath for Flight No. 1456A

FLIGHT NO.:	3765G		
AREA:	Leyte		
MISSION NAME:	2BLK34AD022A		
ALT:	1100m & 600m	SCAN FREQ: 50	SCAN ANGLE: 17
SURVEYED AREA:	172.8		

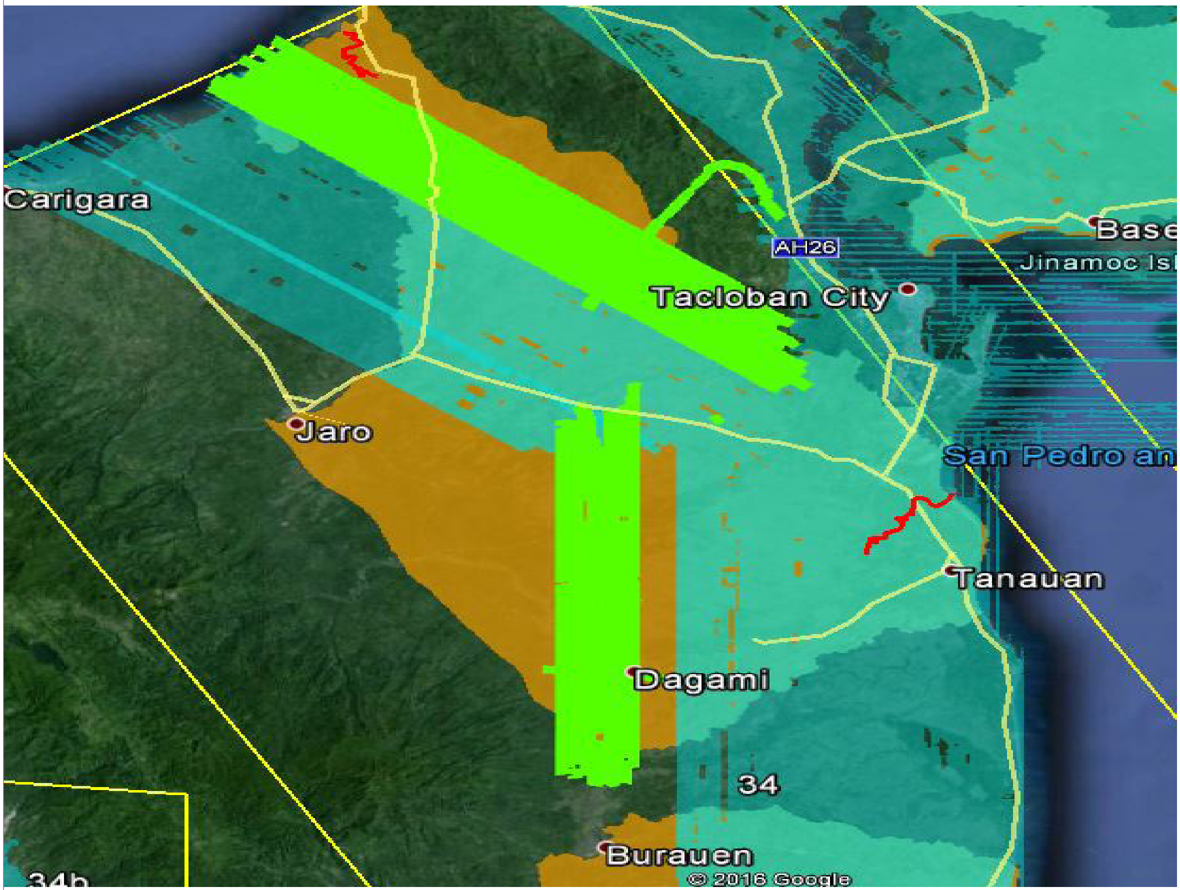


Figure A-7.4. Swath for Flight No. 3765G

START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
00:33:39.345	00:33:51.77	20	818	100	50.00	17.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@1100LYT104.pln
00:39:03.043	00:44:47.236	20	1212	100	50.00	17.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@1100LYT104.pln
00:46:57.49	00:53:03.348	23	1216	100	50.00	17.00	OFF	NAR	ON	OFF	360.00	LEYTE_New@1100LYT104.pln
00:56:12.181	01:01:35.629	19	1207	100	50.00	17.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@1100LYT104.pln
01:03:47.493	01:09:54.181	22	1220	100	50.00	17.00	OFF	NAR	ON	OFF	360.00	LEYTE_New@1100LYT104.pln
01:13:33.354	01:18:56.742	18	1203	100	50.00	17.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@1100LYT104.pln
01:25:27.664	01:31:11.217	23	945	100	50.00	20.00	OFF	NAR	ON	OFF	360.00	LEYTE_New@850LYT104.pln
01:37:39.524	01:43:47.442	28	632	100	40.00	25.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@600LYT104.pln
01:57:05.277	01:58:31.191	28	592	100	40.00	25.00	OFF	NAR	ON	OFF	360.00	LEYTE_New@600LYT104.pln
02:07:24.673	02:15:05.335	71	691	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
02:17:23.449	02:25:59.311	67	686	100	40.00	25.00	OFF	NAR	ON	OFF	127.03	LEYTE_New@600LYT104.pln
02:31:41.644	02:34:33.843	70	654	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
02:31:41.644	02:35:58.793	70	685	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
02:39:50.507	02:47:20.039	70	672	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
02:49:39.738	02:57:59.426	68	661	100	40.00	25.00	OFF	NAR	ON	OFF	127.03	LEYTE_New@600LYT104.pln
03:00:26.88	03:08:07.342	69	659	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
03:00:26.88	03:08:19.227	69	663	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
03:10:15.317	03:18:12.774	72	675	100	40.00	25.00	OFF	NAR	ON	OFF	127.03	LEYTE_New@600LYT104.pln
03:20:49.349	03:28:01.001	73	678	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
03:30:11.401	03:37:48.178	74	659	100	40.00	25.00	OFF	NAR	ON	OFF	127.03	LEYTE_New@600LYT104.pln
03:40:37.743	03:47:28.916	75	640	100	40.00	25.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@600LYT104.pln
03:49:24.55	03:56:58.098	76	658	100	40.00	25.00	OFF	NAR	ON	OFF	127.03	LEYTE_New@600LYT104.pln

FLIGHT NO.: 3767G
AREA: Leyte
MISSION NAME: 2BLK34AG022B
ALT: 850m SCAN FREQ: 50 SCAN ANGLE: 20
SURVEYED AREA: 144.5 km^2

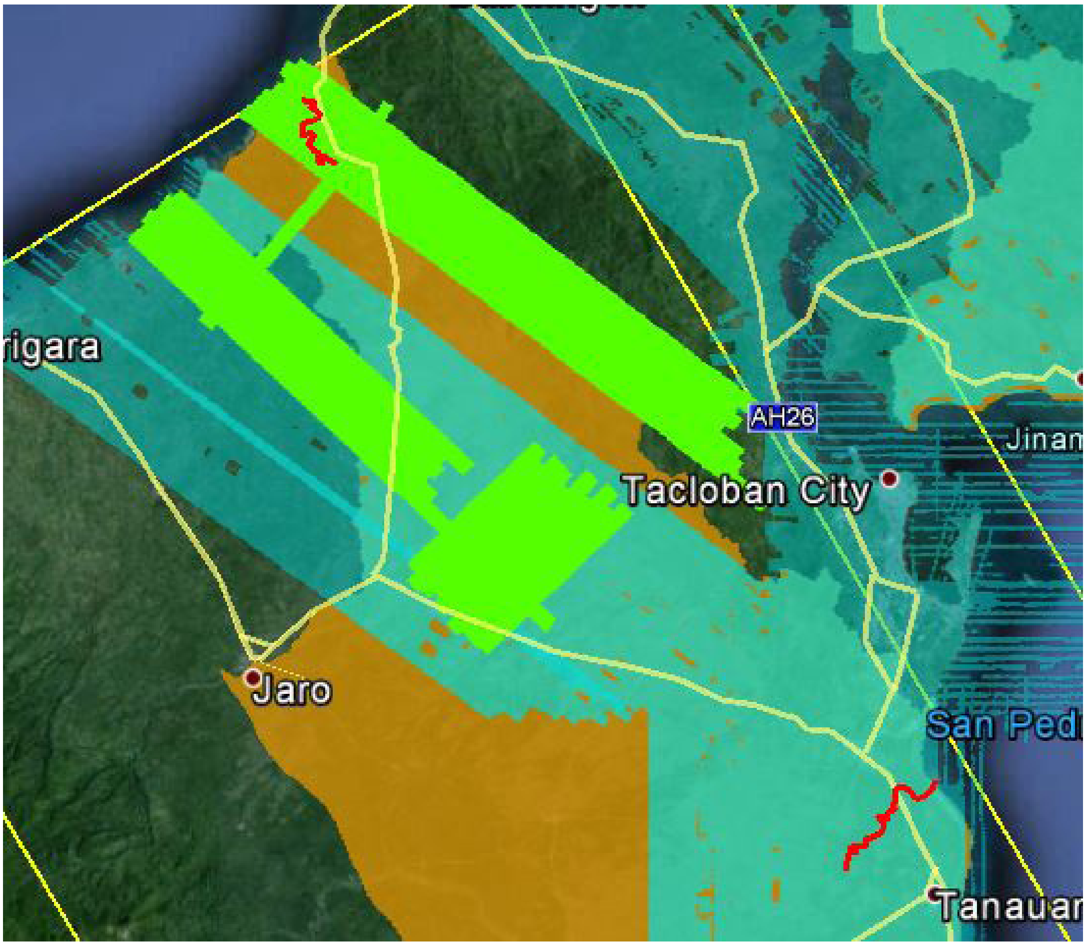


Figure A-7.5. Swath for Flight No. 3767G

START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
06:25:43.612	06:32:32.645	71	963	100	50.00	20.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@850.pln
06:34:58.854	06:41:57.612	72	946	100	50.00	20.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@850.pln
06:44:15.856	06:50:28.824	73	956	100	50.00	20.00	OFF	NAR	ON	OFF	127.03	LEYTE_New@850.pln
06:52:46.489	06:59:15.317	74	954	100	50.00	20.00	OFF	NAR	ON	OFF	127.03	LEYTE_New@850.pln
07:01:33.721	07:07:19.164	75	945	100	50.00	20.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@850.pln
07:09:31.584	07:16:03.106	76	957	100	50.00	20.00	OFF	NAR	ON	OFF	127.03	LEYTE_New@850.pln
07:17:57.791	07:23:46.924	77	918	100	50.00	20.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@850.pln
07:27:14.723	07:30:12.042	77	933	100	50.00	20.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@850.pln
07:36:38.11	07:40:31.219	320	937	100	50.00	20.00	OFF	NAR	ON	OFF	133.03	LEYTE_New@850.pln
07:42:44.693	07:47:06.076	321	946	100	50.00	20.00	OFF	NAR	ON	OFF	313.03	LEYTE_New@850.pln
07:49:10.761	07:53:15.534	322	949	100	50.00	20.00	OFF	NAR	ON	OFF	313.03	LEYTE_New@850.pln
07:55:14.869	07:59:24.692	319	945	100	50.00	20.00	OFF	NAR	ON	OFF	133.03	LEYTE_New@850.pln
08:01:37.732	08:05:33.15	318	934	100	50.00	20.00	OFF	NAR	ON	OFF	313.03	LEYTE_New@850.pln
08:07:46.835	08:13:57.012	317	944	100	50.00	20.00	OFF	NAR	ON	OFF	133.03	LEYTE_New@850.pln
08:17:02.431	08:19:03.081	333	940	100	50.00	20.00	OFF	NAR	ON	OFF	45.97	LEYTE_New@850.pln
08:20:50.225	08:22:36.12	334	936	100	50.00	20.00	OFF	NAR	ON	OFF	225.97	LEYTE_New@850.pln
08:24:33.629	08:26:41.398	332	944	100	50.00	20.00	OFF	NAR	ON	OFF	225.97	LEYTE_New@850.pln
08:28:36.838	08:30:23.977	331	949	100	50.00	20.00	OFF	NAR	ON	OFF	45.97	LEYTE_New@850.pln
08:32:26.051	08:34:24.806	330	963	100	50.00	20.00	OFF	NAR	ON	OFF	45.97	LEYTE_New@850.pln
08:36:16.365	08:38:12.084	329	950	100	50.00	20.00	OFF	NAR	ON	OFF	45.97	LEYTE_New@850.pln
08:40:07.734	08:42:15.738	328	941	100	50.00	20.00	OFF	NAR	ON	OFF	225.97	LEYTE_New@850.pln
08:44:02.367	08:46:01.911	327	944	100	50.00	20.00	OFF	NAR	ON	OFF	225.97	LEYTE_New@850.pln
08:47:52.911	08:50:02.565	326	961	100	50.00	20.00	OFF	NAR	ON	OFF	45.97	LEYTE_New@850.pln
08:51:54.809	08:53:52.054	325	954	100	50.00	20.00	OFF	NAR	ON	OFF	225.97	LEYTE_New@850.pln

FLIGHT NO.: 3769G
AREA: Leyte
MISSION NAME: 2BLK34ADEG023A
ALT: 1100 m & 600m SCAN FREQ: 50 SCAN ANGLE: 17
SURVEYED AREA: 167.25km^2

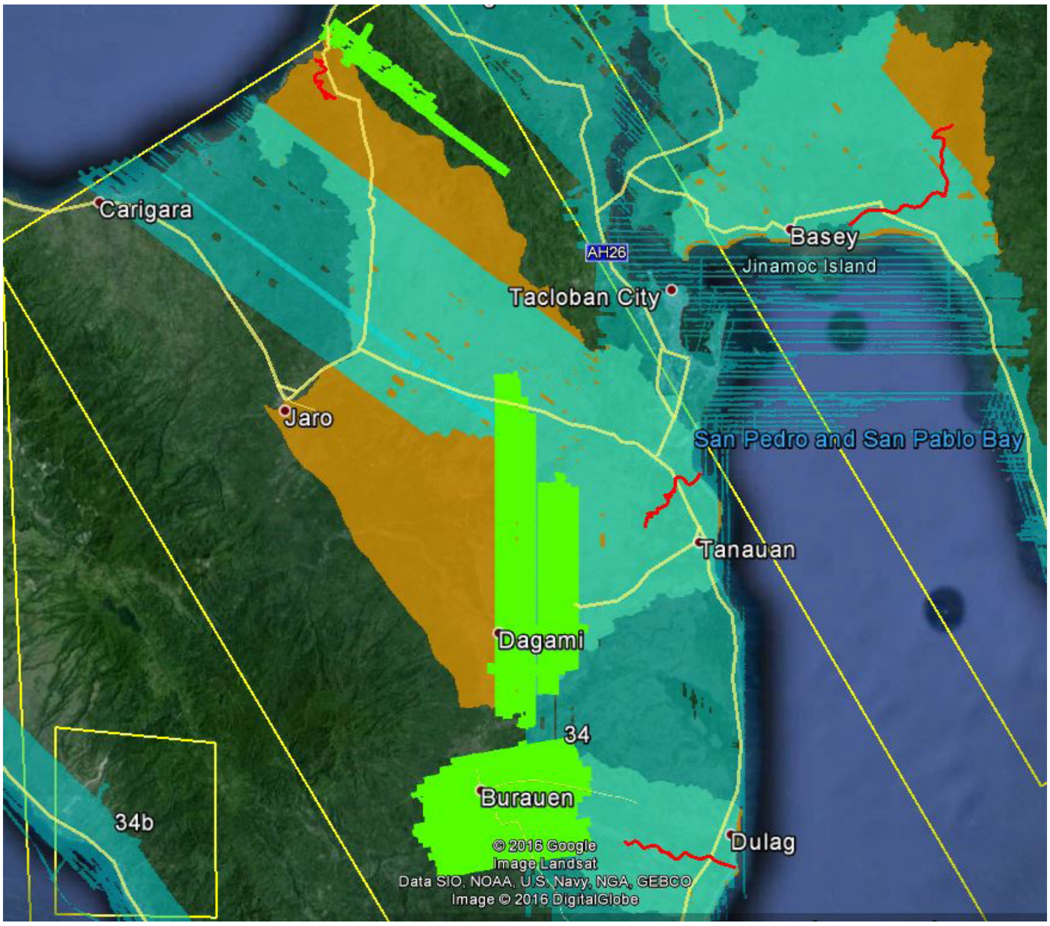


Figure A-7.6. Swath for Flight No. 3769G

START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
00:22:31.78	00:26:20.698	72	1211	100	50.00	17.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@1100LYT104.pln
00:28:37.812	00:31:16.126	73	1193	100	50.00	17.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@1100LYT104.pln
00:35:24.269	00:37:33.159	74	1224	100	50.00	17.00	OFF	NAR	ON	OFF	307.03	LEYTE_New@1100LYT104.pln
00:40:39.812	00:41:30.702	74	1207	100	50.00	17.00	OFF	NAR	ON	OFF	127.01	LEYTE_New@1100LYT104.pln
00:48:05.129	00:53:46.931	24	1205	100	50.00	17.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@1100LYT104.pln
00:55:33.871	01:01:07.443	28	1208	100	50.00	17.00	OFF	NAR	ON	OFF	360.00	LEYTE_New@1100LYT104.pln
01:03:10.442	01:08:58.935	25	1205	100	50.00	17.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@1100LYT104.pln
01:10:53.874	01:16:49.566	27	1212	100	50.00	17.00	OFF	NAR	ON	OFF	360.00	LEYTE_New@1100LYT104.pln
01:19:28.82	01:25:08.443	26	1212	100	50.00	17.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@1100LYT104.pln
01:29:09.126	01:30:14.996	24	1192	100	50.00	17.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@1100LYT104.pln
01:36:23.963	01:39:08.327	2	690	100	40.00	25.00	OFF	NAR	ON	OFF	260.00	LEYTE_New@600LYT104.pln
01:40:33.271	01:43:43.215	8	661	100	40.00	25.00	OFF	NAR	ON	OFF	80.00	LEYTE_New@600LYT104.pln
01:44:58.119	01:47:39.883	3	683	100	40.00	25.00	OFF	NAR	ON	OFF	260.00	LEYTE_New@600LYT104.pln
01:49:25.737	01:52:23.296	7	695	100	40.00	25.00	OFF	NAR	ON	OFF	80.00	LEYTE_New@600LYT104.pln
01:54:07.941	01:56:51.769	4	684	100	40.00	25.00	OFF	NAR	ON	OFF	260.00	LEYTE_New@600LYT104.pln
01:58:40.714	02:01:44.517	9	718	100	40.00	25.00	OFF	NAR	ON	OFF	80.00	LEYTE_New@600LYT104.pln
02:03:20.157	02:06:08.861	5	683	100	40.00	25.00	OFF	NAR	ON	OFF	260.00	LEYTE_New@600LYT104.pln
02:08:12.91	02:11:24.969	10	679	100	40.00	25.00	OFF	NAR	ON	OFF	80.00	LEYTE_New@600LYT104.pln
02:12:56.988	02:15:43.177	6	692	100	40.00	25.00	OFF	NAR	ON	OFF	260.00	LEYTE_New@600LYT104.pln
02:17:57.036	02:21:14.385	15	704	100	40.00	25.00	OFF	NAR	ON	OFF	80.00	LEYTE_New@600LYT104.pln
02:22:41.799	02:25:42.018	11	682	100	40.00	25.00	OFF	NAR	ON	OFF	260.00	LEYTE_New@600LYT104.pln
02:22:41.799	02:25:42.018	11	681	100	40.00	25.00	OFF	NAR	ON	OFF	260.00	LEYTE_New@600LYT104.pln
02:26:59.208	02:30:06.887	16	713	100	40.00	25.00	OFF	NAR	ON	OFF	80.00	LEYTE_New@600LYT104.pln
02:31:32.886	02:34:31.04	12	674	100	40.00	25.00	OFF	NAR	ON	OFF	260.00	LEYTE_New@600LYT104.pln
02:38:46.379	02:41:45.777	17	682	100	40.00	25.00	OFF	NAR	ON	OFF	80.00	LEYTE_New@600LYT104.pln
02:43:14.947	02:46:16.721	13	683	100	40.00	25.00	OFF	NAR	ON	OFF	260.00	LEYTE_New@600LYT104.pln
02:47:39.07	02:50:12.384	18	686	100	40.00	25.00	OFF	NAR	ON	OFF	80.00	LEYTE_New@600LYT104.pln
02:51:46.069	02:54:51.693	14	671	100	40.00	25.00	OFF	NAR	ON	OFF	260.00	LEYTE_New@600LYT104.pln
02:58:54.526	03:01:12.241	19	679	100	40.00	25.00	OFF	NAR	ON	OFF	80.00	LEYTE_New@600LYT104.pln
03:04:38.069	03:06:50.924	19	702	100	40.00	25.00	OFF	NAR	ON	OFF	80.00	LEYTE_New@600LYT104.pln
03:11:20.722	03:15:25.216	88	691	100	40.00	25.00	OFF	NAR	ON	OFF	360.00	LEYTE_New@600LYT104.pln
03:16:32.95	03:19:39.779	93	688	100	40.00	25.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@600LYT104.pln
03:21:01.809	03:25:02.922	89	669	100	40.00	25.00	OFF	NAR	ON	OFF	360.00	LEYTE_New@600LYT104.pln
03:25:59.182	03:29:14.811	92	692	100	40.00	25.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@600LYT104.pln
03:30:41.01	03:34:40.869	90	681	100	40.00	25.00	OFF	NAR	ON	OFF	360.00	LEYTE_New@600LYT104.pln
03:36:02.318	03:39:28.072	91	694	100	40.00	25.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@600LYT104.pln
03:41:36.076	03:42:46.301	88	641	100	40.00	25.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@600LYT104.pln

FLIGHT NO.: 3771G
AREA: Leyte
MISSION NAME: 2BLK34BCG023B
ALT: 850 m SCAN FREQ: 50 SCAN ANGLE: 20
SURVEYED AREA: 143.4 km^2

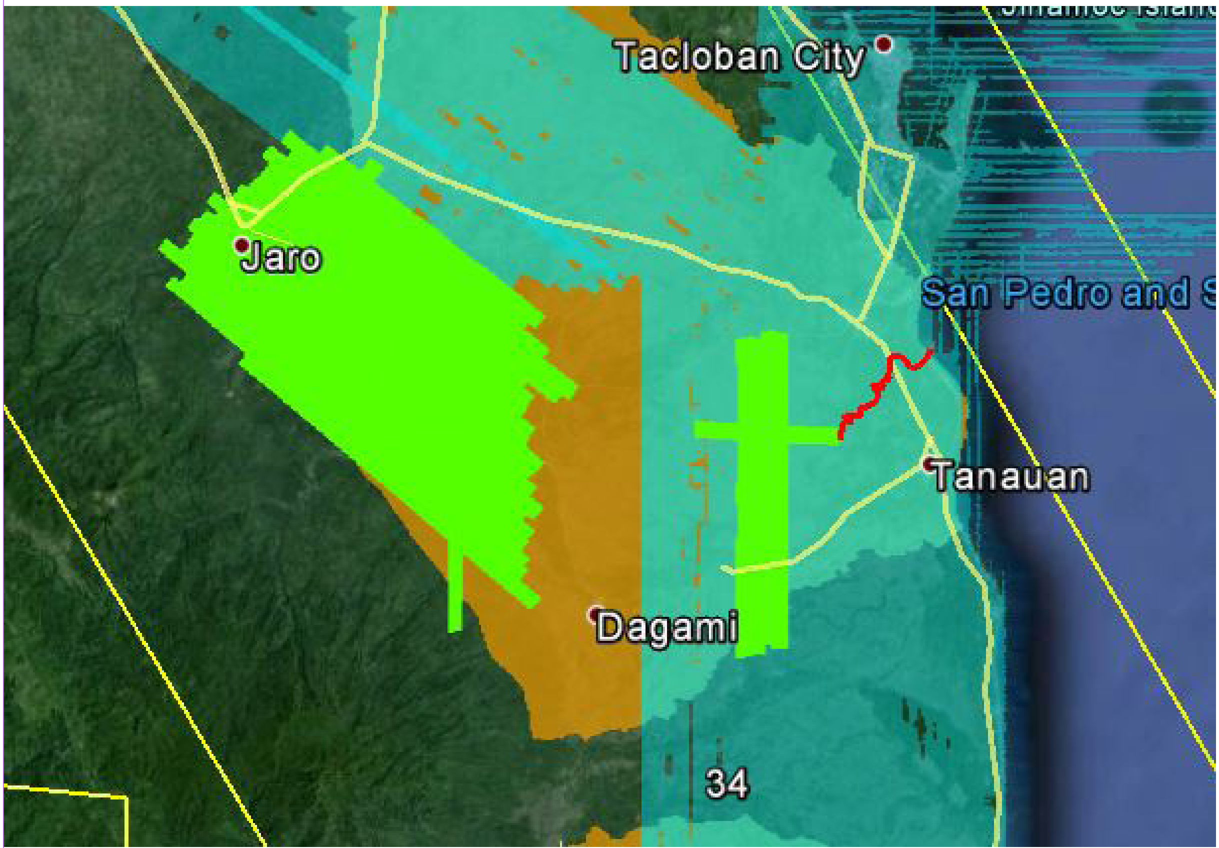


Figure A-7.7. Swath for Flight No. 3771G

START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
06:35:50.577	06:39:05.031	92	957	100	50.00	20.00	OFF	NAR	ON	OFF	133.03	LEYTE_New@850LYT104.pln
06:41:21.246	06:44:51.86	91	940	100	50.00	20.00	OFF	NAR	ON	OFF	360.00	LEYTE_New@850LYT104.pln
06:47:00.754	06:50:13.578	90	957	100	50.00	20.00	OFF	NAR	ON	OFF	180.00	LEYTE_New@850LYT104.pln
06:52:20.328	06:55:54.407	89	948	100	50.00	20.00	OFF	NAR	ON	OFF	360.00	LEYTE_New@850LYT104.pln
06:59:06.001	07:01:55.615	43	946	100	50.00	20.00	OFF	NAR	ON	OFF	308.02	LEYTE_New@850LYT104.pln
07:04:23.724	07:07:40.653	42	970	100	50.00	20.00	OFF	NAR	ON	OFF	308.02	LEYTE_New@850LYT104.pln
07:09:27.792	07:12:48.761	41	949	100	50.00	20.00	OFF	NAR	ON	OFF	128.02	LEYTE_New@850LYT104.pln
07:14:45.411	07:19:03.689	40	995	100	50.00	20.00	OFF	NAR	ON	OFF	128.02	LEYTE_New@850LYT104.pln
07:14:45.411	07:19:03.689	40	998	100	50.00	20.00	OFF	NAR	ON	OFF	128.02	LEYTE_New@850LYT104.pln
07:22:30.443	07:26:26.447	39	947	100	50.00	20.00	OFF	NAR	ON	OFF	308.02	LEYTE_New@850LYT104.pln
07:29:17.041	07:31:04.62	39	958	100	50.00	20.00	OFF	NAR	ON	OFF	308.02	LEYTE_New@850LYT104.pln
07:34:35.484	07:38:18.518	38	933	100	50.00	20.00	OFF	NAR	ON	OFF	128.02	LEYTE_New@850LYT104.pln
07:40:19.587	07:44:00.311	37	940	100	50.00	20.00	OFF	NAR	ON	OFF	308.02	LEYTE_New@850LYT104.pln
07:46:35.415	07:50:29.218	36	943	100	50.00	20.00	OFF	NAR	ON	OFF	128.02	LEYTE_New@850LYT104.pln
07:53:02.767	07:56:56.151	35	946	100	50.00	20.00	OFF	NAR	ON	OFF	308.02	LEYTE_New@850LYT104.pln
07:59:03.52	08:03:27.419	34	952	100	50.00	20.00	OFF	NAR	ON	OFF	128.02	LEYTE_New@850LYT104.pln
08:05:49.663	08:09:57.871	60	949	100	50.00	20.00	OFF	NAR	ON	OFF	310.02	LEYTE_New@850LYT104.pln
08:12:18.735	08:16:57.524	59	965	100	50.00	20.00	OFF	NAR	ON	OFF	130.02	LEYTE_New@850LYT104.pln
08:19:25.488	08:24:05.456	58	944	100	50.00	20.00	OFF	NAR	ON	OFF	130.02	LEYTE_New@850LYT104.pln
08:26:08.015	08:30:54.088	57	944	100	50.00	20.00	OFF	NAR	ON	OFF	130.02	LEYTE_New@850LYT104.pln
08:33:10.808	08:37:45.911	56	951	100	50.00	20.00	OFF	NAR	ON	OFF	310.02	LEYTE_New@850LYT104.pln
08:39:57.74	08:45:00.053	55	973	100	50.00	20.00	OFF	NAR	ON	OFF	130.02	LEYTE_New@850LYT104.pln
08:46:48.528	08:48:48.057	61	956	100	50.00	20.00	OFF	NAR	ON	OFF	310.02	LEYTE_New@850LYT104.pln
08:50:51.951	08:53:44.495	61	951	100	50.00	20.00	OFF	NAR	ON	OFF	310.02	LEYTE_New@850LYT104.pln
08:56:35.949	09:01:09.127	54	917	100	50.00	20.00	OFF	NAR	ON	OFF	310.02	LEYTE_New@850LYT104.pln
09:03:11.426	09:08:11.744	53	958	100	50.00	20.00	OFF	NAR	ON	OFF	130.02	LEYTE_New@850LYT104.pln
09:10:28.919	09:14:22.267	52	962	100	50.00	20.00	OFF	NAR	ON	OFF	310.02	LEYTE_New@850LYT104.pln
09:20:26.535	09:22:07.164	91	949	100	50.00	20.00	OFF	NAR	ON	OFF	360.00	LEYTE_New@850LYT104.pln

FLIGHT NO.:	3773G		
AREA:	Leyte		
MISSION NAME:	2BLK34CG024A		
ALT:	600 m	SCAN FREQ: 40	SCAN ANGLE: 25
SURVEYED AREA:	90.6 km^2		

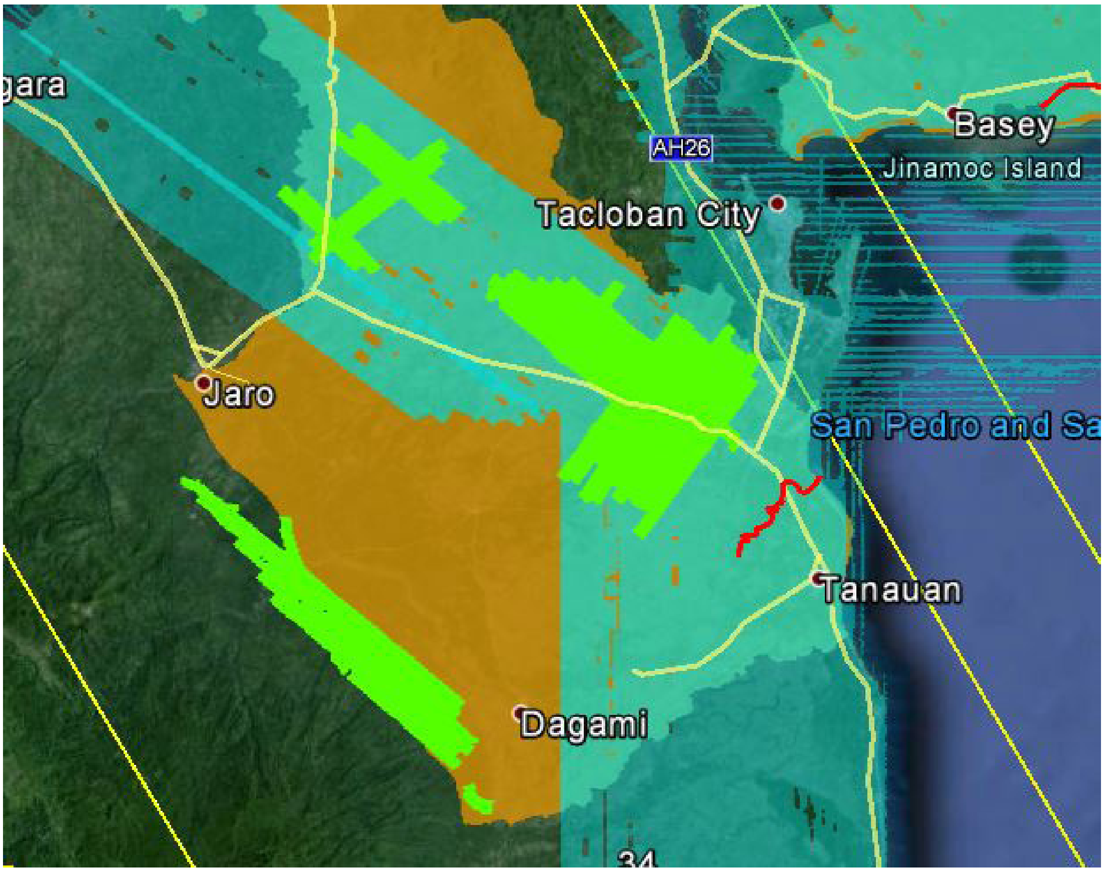


Figure A-7.8. Swath for Flight No. 3773G

START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	MPM	HDG	Plan File
00:41:26.291	00:45:37.304	54	673	100	40.00	25.00	OFF	NAR	ON	OFF	129.99	leyteVOIDSnew@600.pln
00:47:19.499	00:47:47.129	50	670	100	40.00	25.00	OFF	NAR	ON	OFF	309.99	leyteVOIDSnew@600.pln
00:48:00.128	00:49:49.973	50	642	100	40.00	25.00	OFF	NAR	ON	OFF	309.99	leyteVOIDSnew@600.pln
00:55:27.525	00:59:52.439	55	680	100	40.00	25.00	OFF	NAR	ON	OFF	129.99	leyteVOIDSnew@600.pln
01:02:18.758	01:06:11.696	53	626	100	40.00	25.00	OFF	NAR	ON	OFF	309.99	leyteVOIDSnew@600.pln
01:11:13.674	01:14:14.473	51	635	100	40.00	25.00	OFF	NAR	ON	OFF	129.99	leyteVOIDSnew@600.pln
01:16:42.357	01:20:10.02	52	670	100	40.00	25.00	OFF	NAR	ON	OFF	309.99	leyteVOIDSnew@600.pln
01:20:49.76	01:21:04.42	54	673	100	40.00	25.00	OFF	NAR	ON	OFF	310.00	leyteVOIDSnew@600.pln
01:24:38.359	01:25:37.498	54	664	100	40.00	25.00	OFF	NAR	ON	OFF	130.00	leyteVOIDSnew@600.pln
01:30:49.756	01:32:51.7	50	665	100	40.00	25.00	OFF	NAR	ON	OFF	129.99	leyteVOIDSnew@600.pln
01:37:16.759	01:39:56.043	131	686	100	40.00	25.00	OFF	NAR	ON	OFF	36.01	leyteVOIDSnew@600.pln
01:41:54.187	01:44:07.646	136	677	100	40.00	25.00	OFF	NAR	ON	OFF	216.01	leyteVOIDSnew@600.pln
01:46:06.62	01:48:48.959	132	723	100	40.00	25.00	OFF	NAR	ON	OFF	36.01	leyteVOIDSnew@600.pln
01:50:32.703	01:52:38.423	137	724	100	40.00	25.00	OFF	NAR	ON	OFF	216.01	leyteVOIDSnew@600.pln
01:54:26.957	01:56:40.186	133	675	100	40.00	25.00	OFF	NAR	ON	OFF	36.01	leyteVOIDSnew@600.pln
01:58:22.395	02:00:28.59	138	677	100	40.00	25.00	OFF	NAR	ON	OFF	216.01	leyteVOIDSnew@600.pln
02:02:11.674	02:04:57.128	134	683	100	40.00	25.00	OFF	NAR	ON	OFF	36.01	leyteVOIDSnew@600.pln
02:06:30.502	02:08:37.931	139	682	100	40.00	25.00	OFF	NAR	ON	OFF	216.01	leyteVOIDSnew@600.pln
02:10:13.101	02:12:54.015	135	693	100	40.00	25.00	OFF	NAR	ON	OFF	36.01	leyteVOIDSnew@600.pln
02:14:21.569	02:16:27.344	140	681	100	40.00	25.00	OFF	NAR	ON	OFF	216.01	leyteVOIDSnew@600.pln
02:18:30.538	02:21:11.317	141	693	100	40.00	25.00	OFF	NAR	ON	OFF	36.01	leyteVOIDSnew@600.pln
02:23:48.796	02:25:34.795	141	729	100	40.00	25.00	OFF	NAR	ON	OFF	36.01	leyteVOIDSnew@600.pln
02:28:25.509	02:30:35.513	120	692	100	40.00	25.00	OFF	NAR	ON	OFF	130.00	leyteVOIDSnew@600.pln
02:32:05.188	02:34:04.657	124	675	100	40.00	25.00	OFF	NAR	ON	OFF	310.00	leyteVOIDSnew@600.pln
02:35:54.016	02:38:07.216	121	691	100	40.00	25.00	OFF	NAR	ON	OFF	130.00	leyteVOIDSnew@600.pln
02:39:35.88	02:41:22.769	125	706	100	40.00	25.00	OFF	NAR	ON	OFF	310.00	leyteVOIDSnew@600.pln
02:42:45.769	02:44:49.598	122	695	100	40.00	25.00	OFF	NAR	ON	OFF	130.00	leyteVOIDSnew@600.pln
02:46:19.373	02:47:57.102	126	697	100	40.00	25.00	OFF	NAR	ON	OFF	310.00	leyteVOIDSnew@600.pln
02:50:03.911	02:52:14.036	123	677	100	40.00	25.00	OFF	NAR	ON	OFF	130.00	leyteVOIDSnew@600.pln
02:54:49.325	02:56:02.074	123	667	100	40.00	25.00	OFF	NAR	ON	OFF	128.98	leyteVOIDSnew@600.pln
02:58:39.883	03:00:18.348	145	698	100	40.00	25.00	OFF	NAR	ON	OFF	308.98	leyteVOIDSnew@600.pln
03:01:59.887	03:03:42.777	143	685	100	40.00	25.00	OFF	NAR	ON	OFF	308.98	leyteVOIDSnew@600.pln
03:05:27.966	03:07:08.375	144	689	100	40.00	25.00	OFF	NAR	ON	OFF	315.00	leyteVOIDSnew@600.pln
03:08:34.69	03:09:55.629	149	707	100	40.00	25.00	OFF	NAR	ON	OFF	315.00	leyteVOIDSnew@600.pln
03:11:43.889	03:13:06.778	148	667	100	40.00	25.00	OFF	NAR	ON	OFF	315.00	leyteVOIDSnew@600.pln
03:15:53.122	03:17:54.942	152	709	100	40.00	25.00	OFF	NAR	ON	OFF	231.49	leyteVOIDSnew@600.pln
03:20:17.491	03:22:19.975	153	686	100	40.00	25.00	OFF	NAR	ON	OFF	231.49	leyteVOIDSnew@600.pln
03:28:30.043	03:29:27.943	85	629	100	40.00	25.00	OFF	NAR	ON	OFF	307.01	leyteVOIDSnew@600.pln

Annex 8. Mission Summary Reports

Table A-8.1. Mission Summary Report for Mission Blk 34C

Flight Area	Samar-Leyte
Mission Name	Blk 34C
Inclusive Flights	1456A
Range data size	11.6 GB
Base data size	7.92 MB
POS	212 MB
Image	66.6 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.3
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	2.6
Boresight correction stdev (<0.001deg)	0.000399354
IMU attitude correction stdev (<0.001deg)	0.0089118
GPS position stdev (<0.01m)	0.0169262
Minimum % overlap (>25)	40.85%
Ave point cloud density per sq.m. (>2.0)	3.01
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	143
Maximum Height	151.03 m
Minimum Height	59.09 m
Classification (# of points)	
Ground	63,841,063
Low vegetation	73,433,267
Medium vegetation	90,859,082
High vegetation	26,640,847
Building	1,833,370
Orthophoto	Yes
Processed by	Engr. Carlyn Ann Ibañez, Engr. Chelou Prado, Engr. Gladys Mae Apat

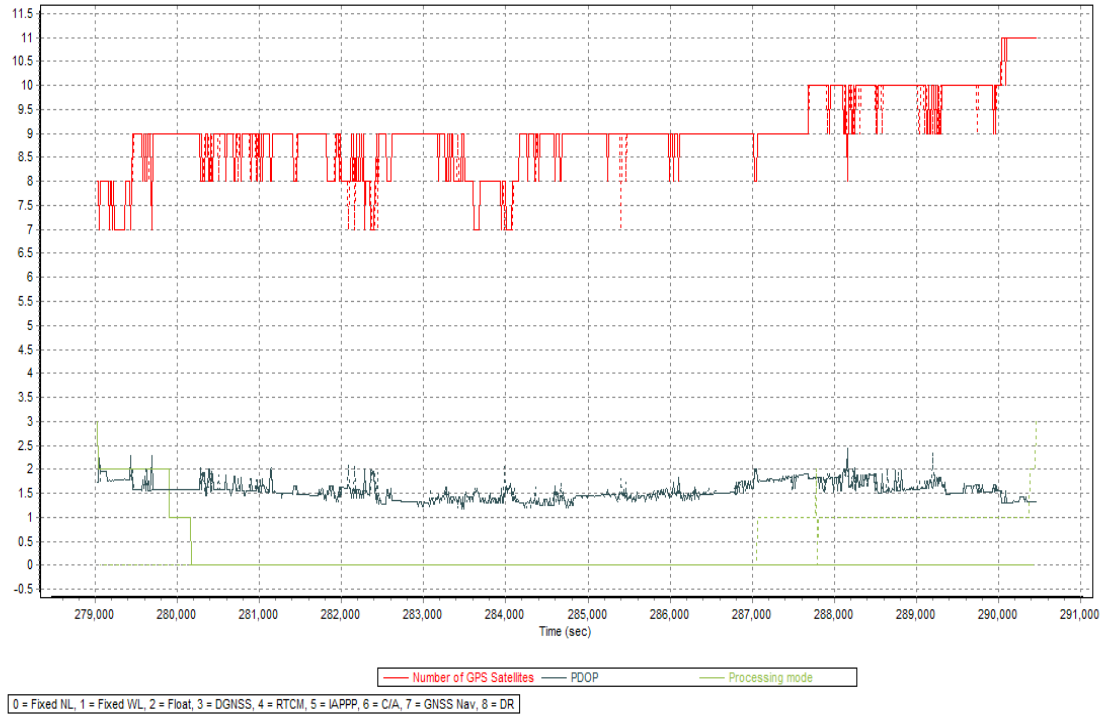


Figure A-8.1. Solution Status

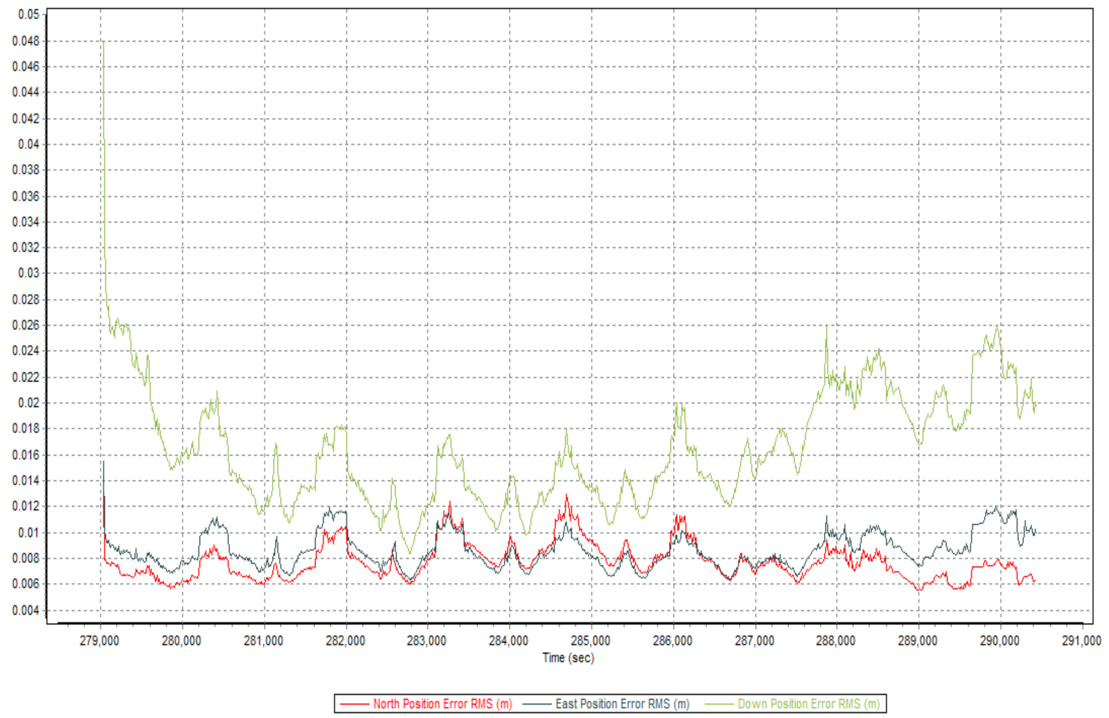


Figure A-8.2. Smoothed Performance Metrics Parameters

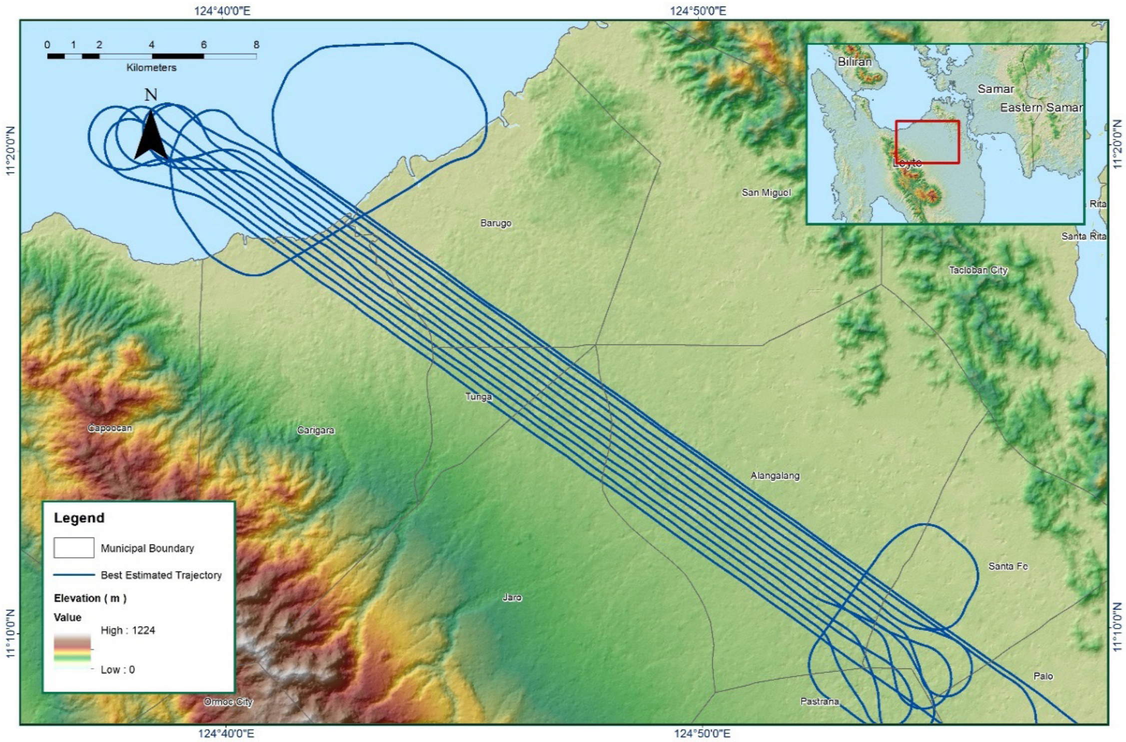


Figure A-8.3. Best Estimated Trajectory

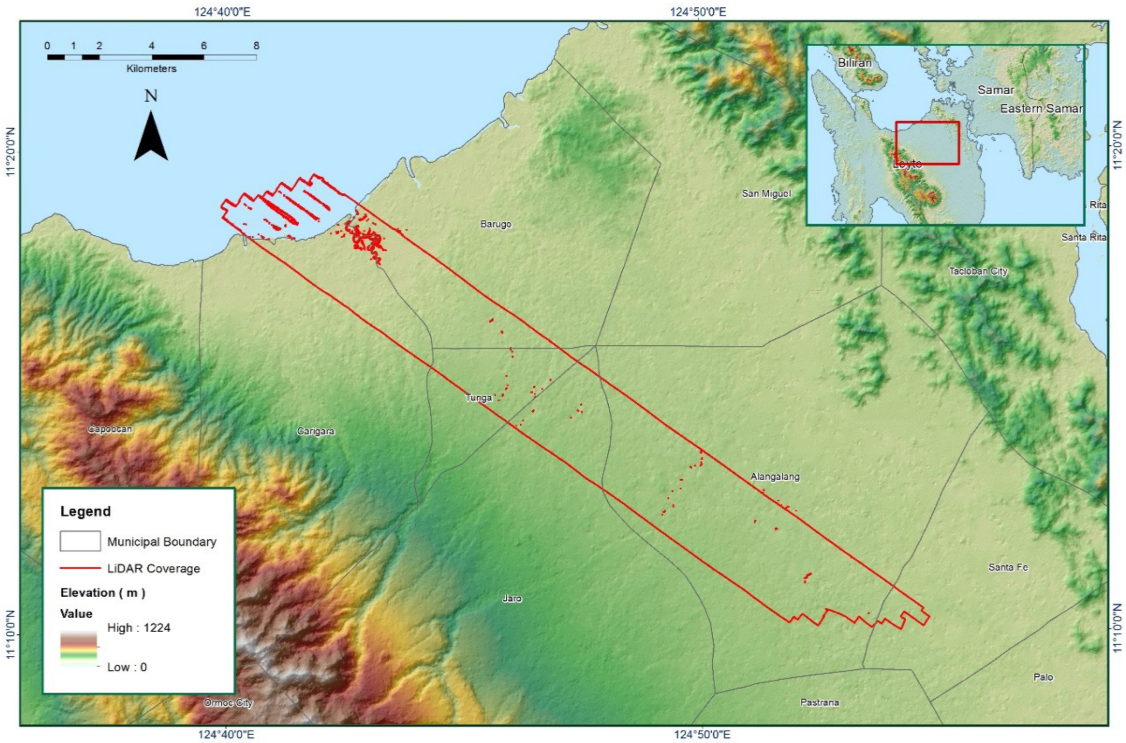


Figure A-8.4. Coverage of LiDAR data

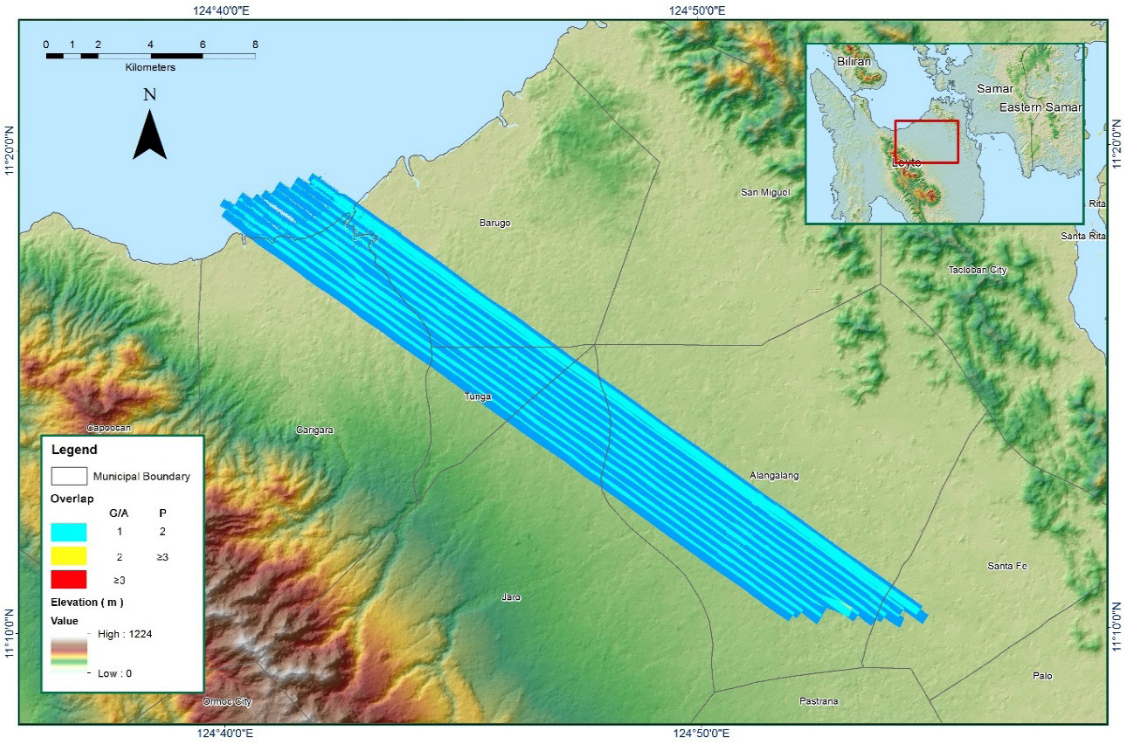


Figure A-8.5. Image of data overlap

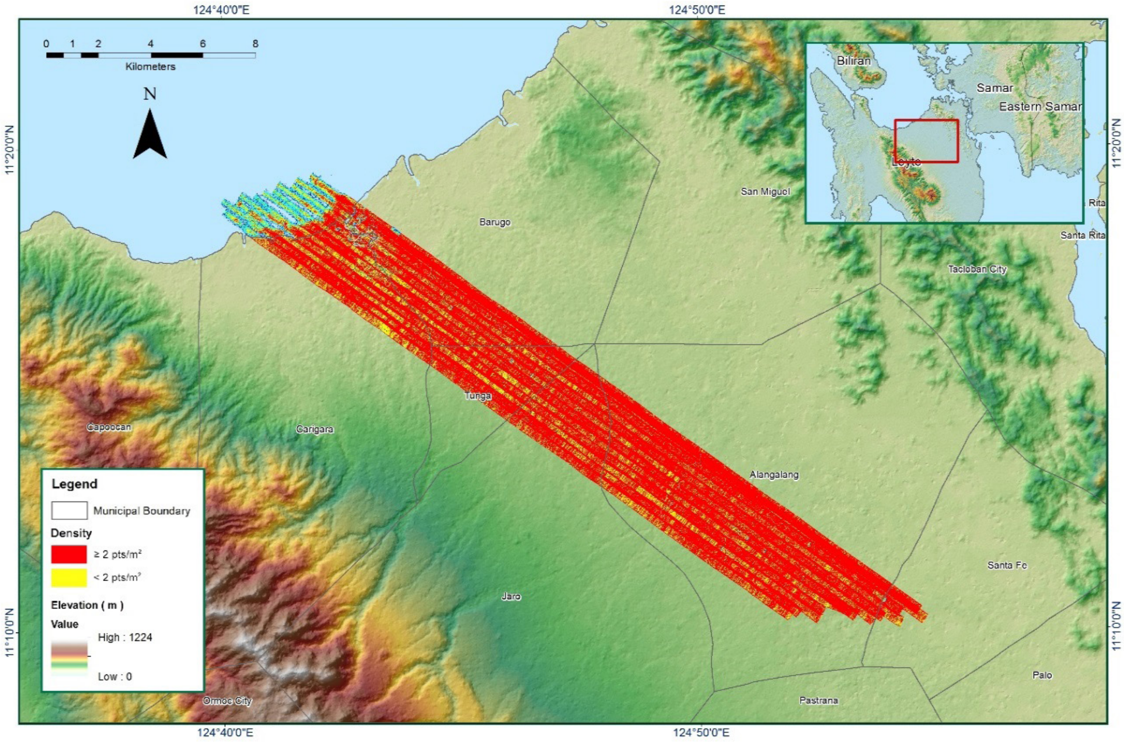


Figure A-8.6. Density map of merged LiDAR data

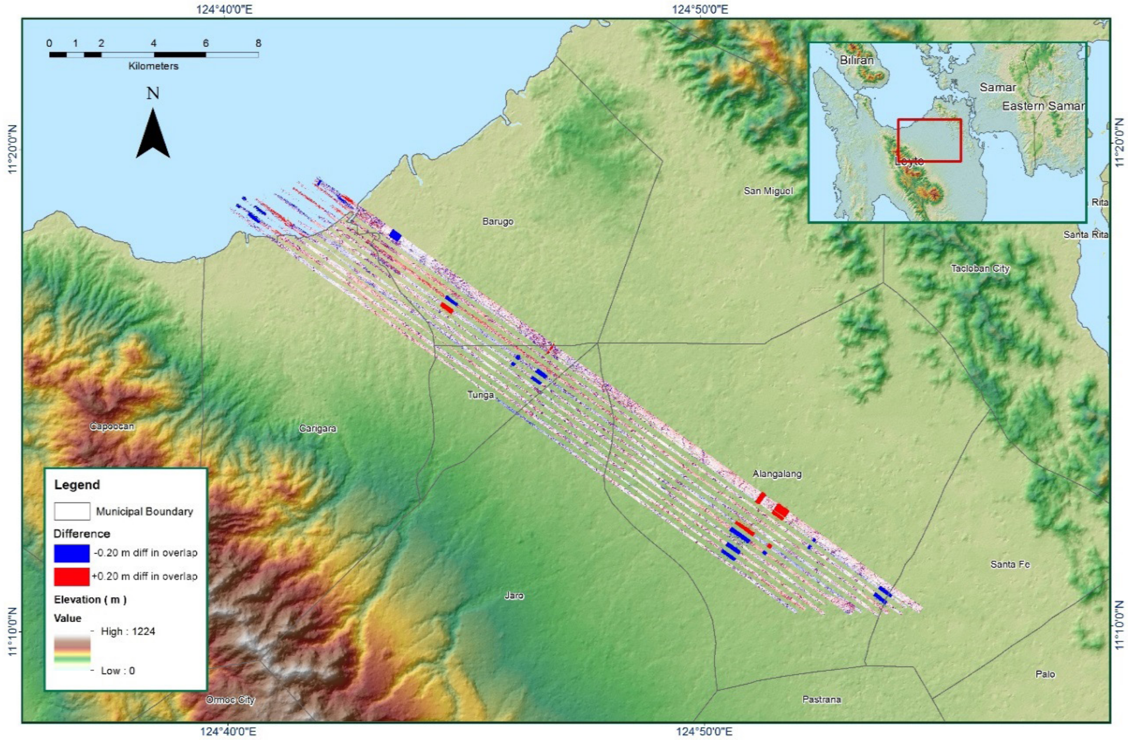


Figure A-8.7. Elevation difference between flight lines

Table A-8.2. Mission Summary Report for Mission Blk 34D

Flight Area	Samar-Leyte
Mission Name	Blk 34D
Inclusive Flights	1454A
Range data size	14.6 GB
Base data size	8.41 MB
POS	268 MB
Image	87.2 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	2.2
RMSE for East Position (<4.0 cm)	1.7
RMSE for Down Position (<8.0 cm)	3.9
Boresight correction stdev (<0.001deg)	0.000408
IMU attitude correction stdev (<0.001deg)	0.001494
GPS position stdev (<0.01m)	0.0227
Minimum % overlap (>25)	29.29%
Ave point cloud density per sq.m. (>2.0)	2.73
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	149
Maximum Height	141.70 m
Minimum Height	34.19 m
Classification (# of points)	
Ground	63,755,821
Low vegetation	79,475,355
Medium vegetation	77,581,284
High vegetation	15,167,004
Building	849,062
Orthophoto	Yes
Processed by	Ma. Victoria Rejuso, Engr. Harmond Santos, Engr. Gladys Mae Apat

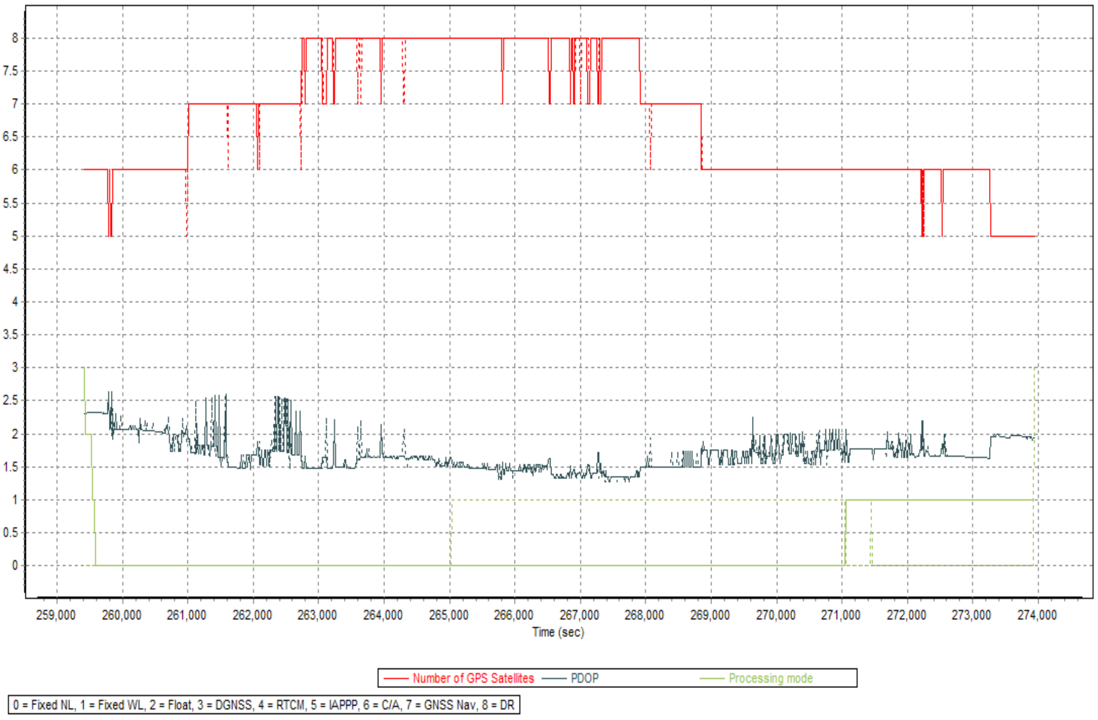


Figure A-8.8. Solution Status

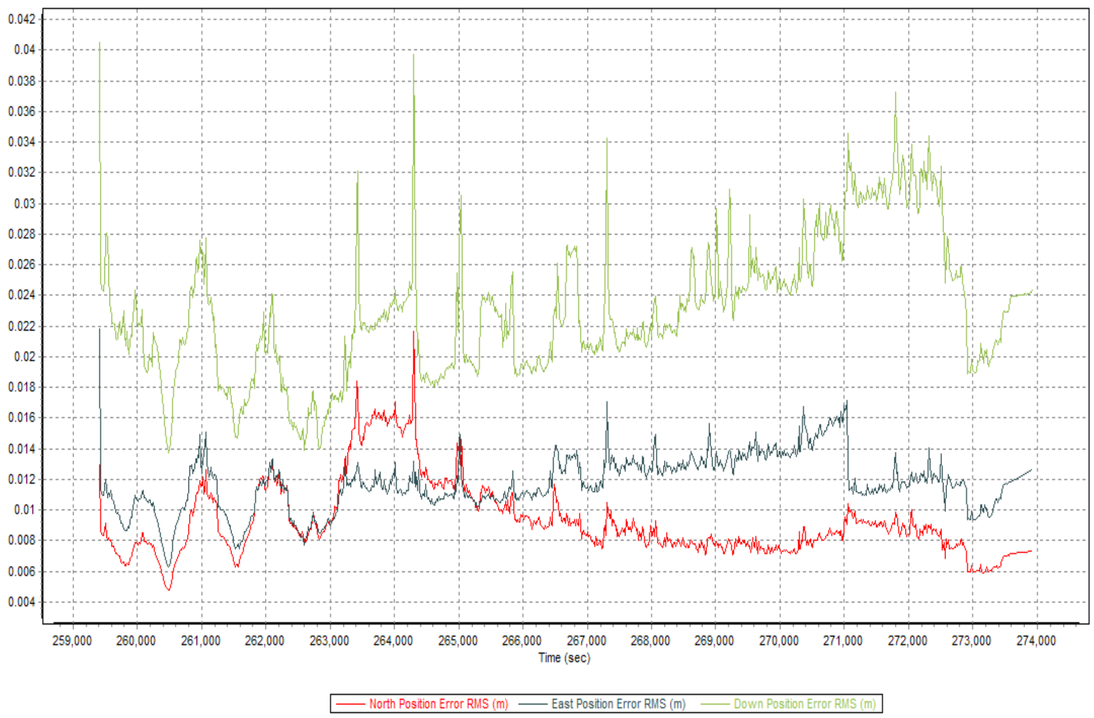


Figure A-8.9. Smoothed Performance Metrics Parameters

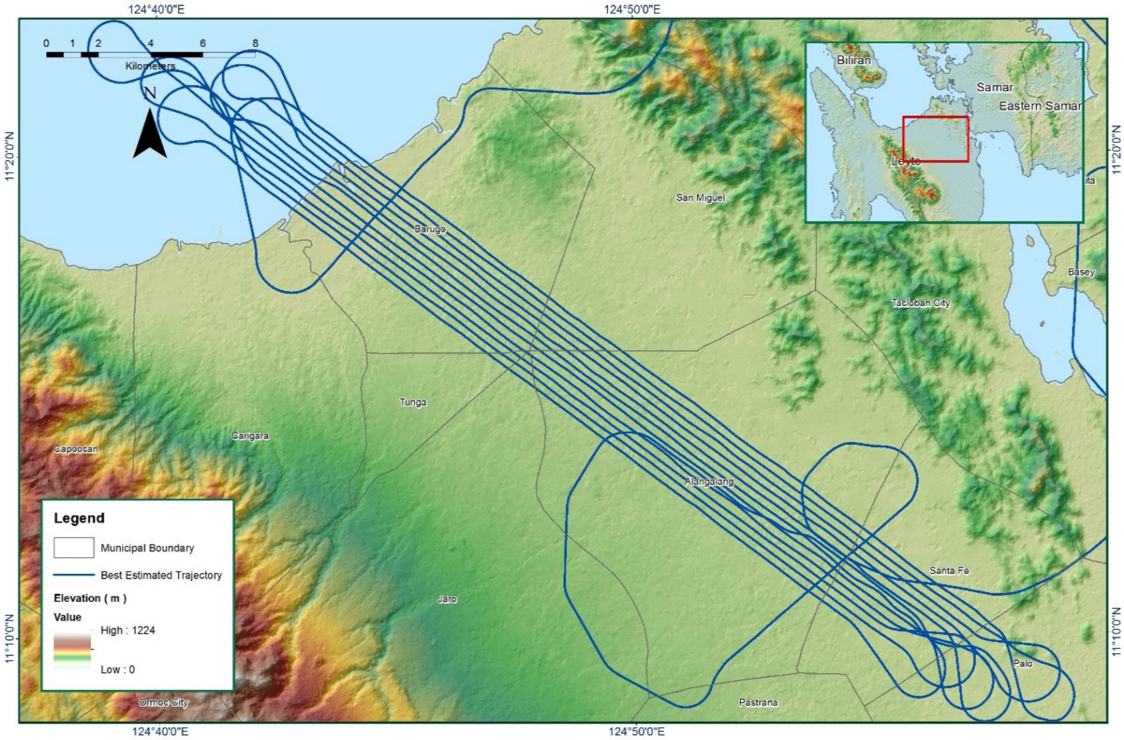


Figure A-8.10. Best Estimated Trajectory

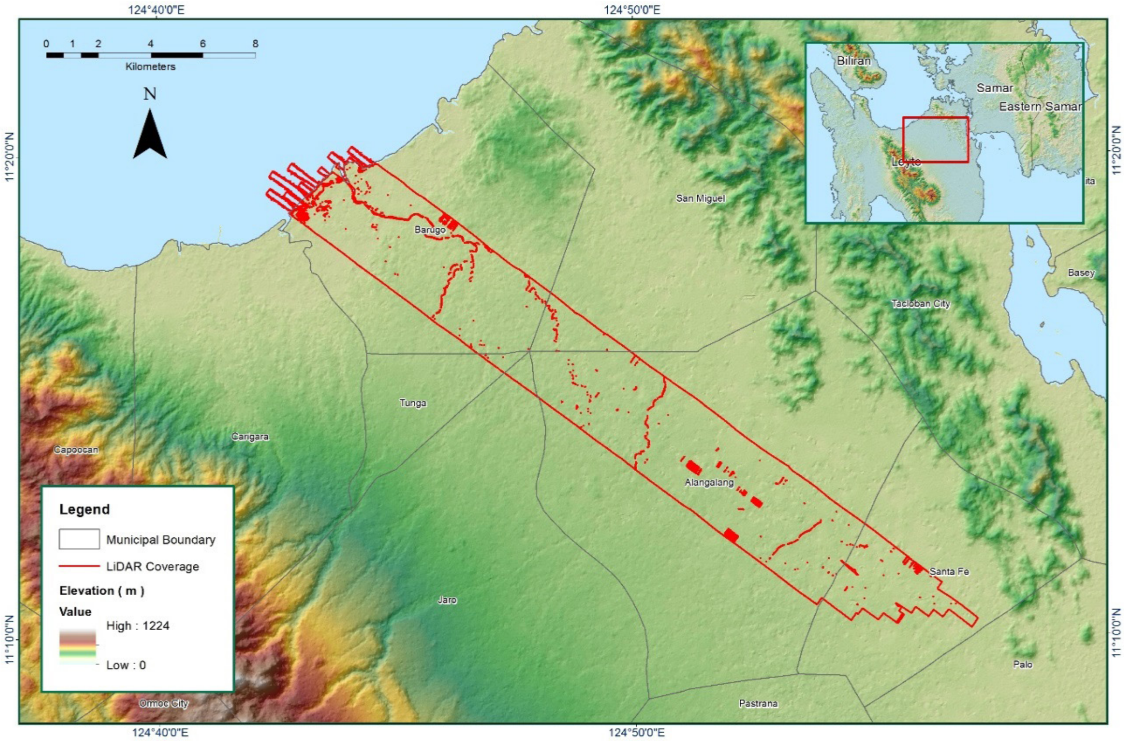


Figure A-8.11. Coverage of LiDAR data

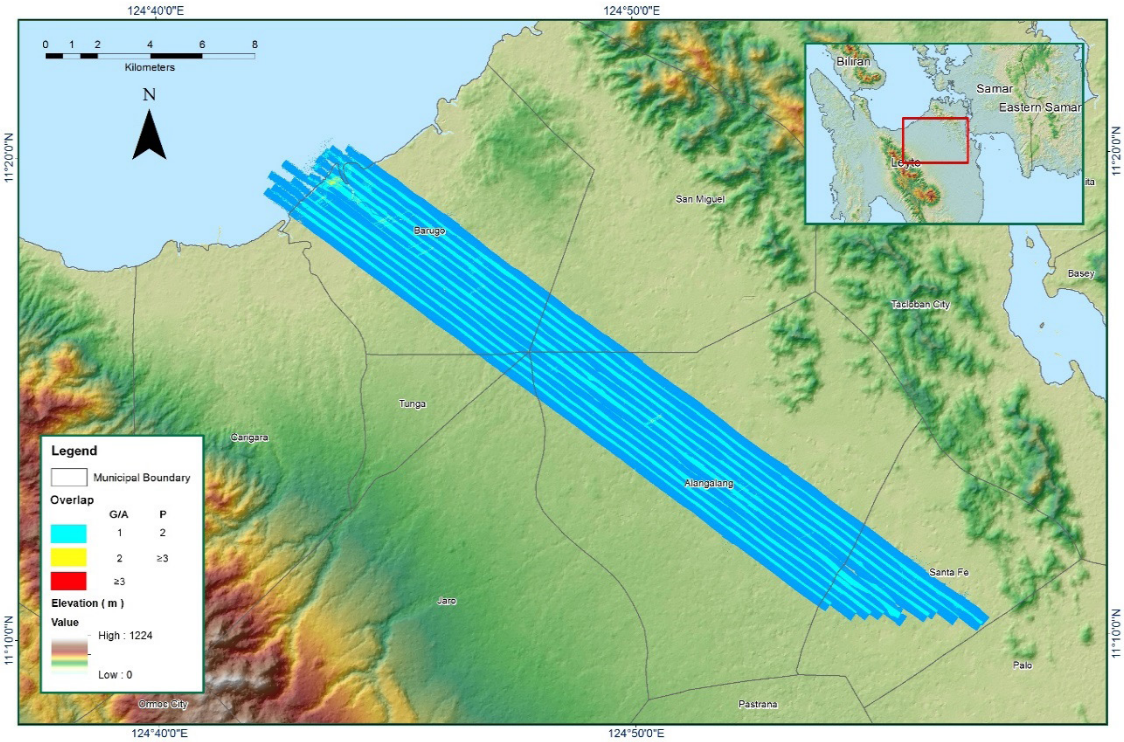


Figure A-8.12. Image of data overlap

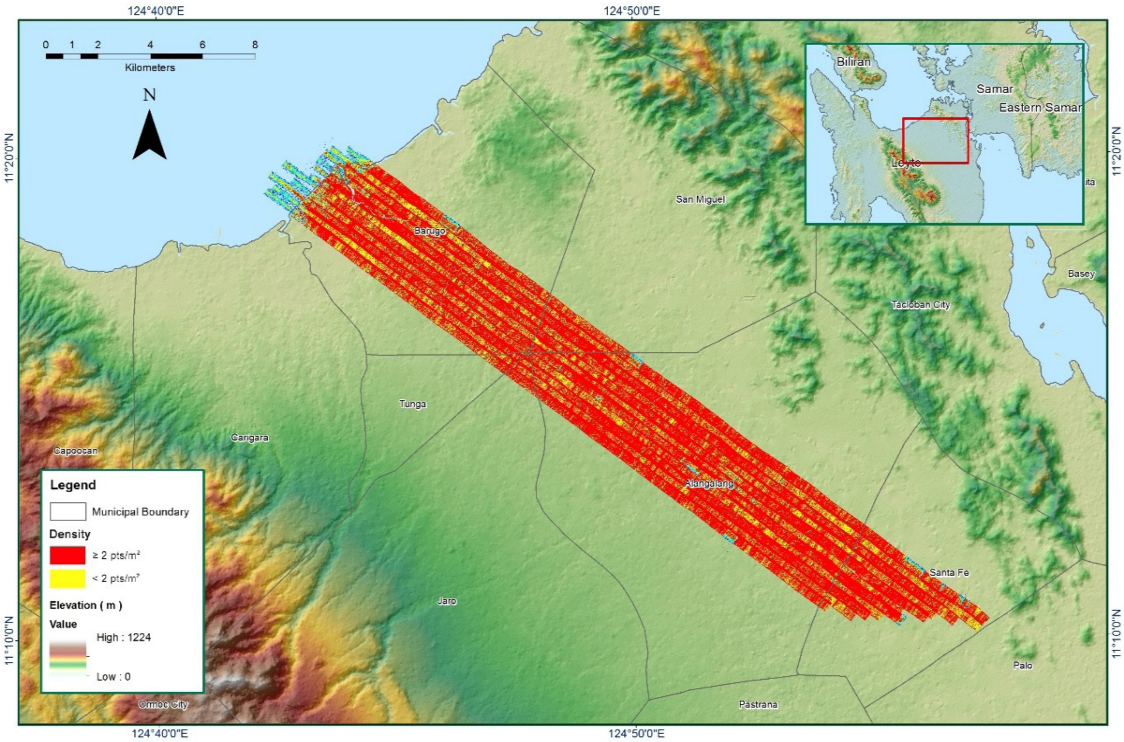


Figure A-8.13. Density map of merged LiDAR data

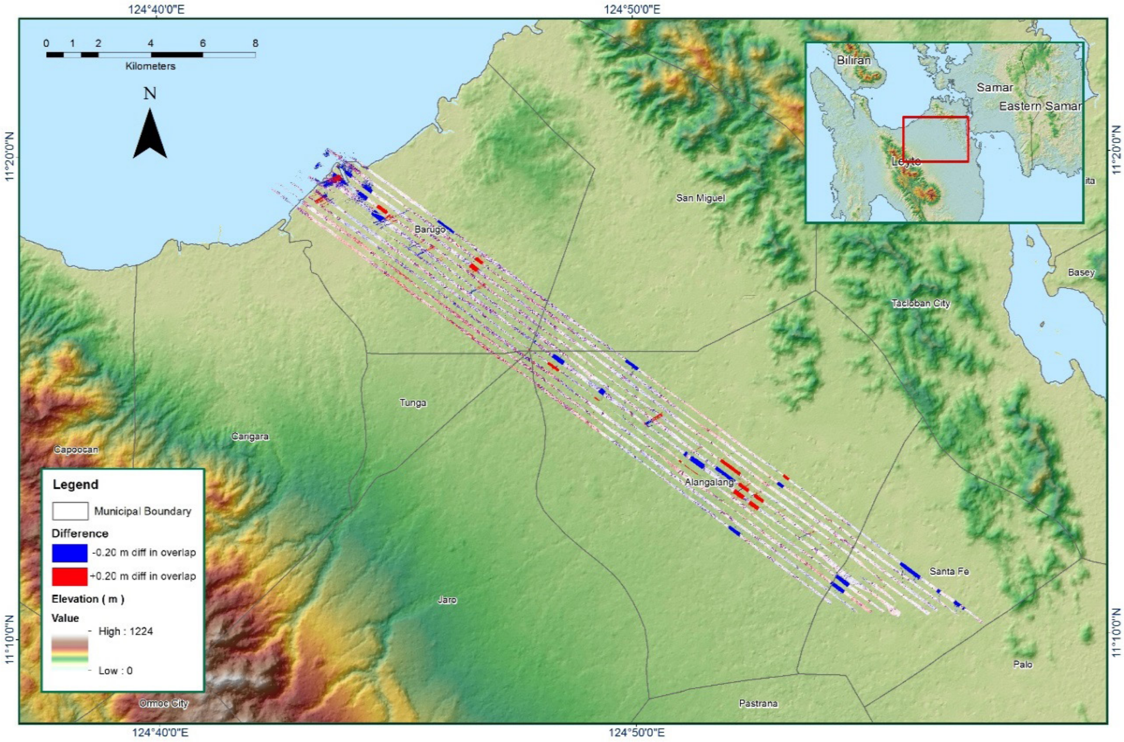


Figure A-8.14. Elevation difference between flight lines

Table A-8.3. Mission Summary Report for Mission Blk34E

Flight Area	Samar-Leyte
Mission Name	Blk34E
Inclusive Flights	1366A
Range data size	14.9 GB
Base data size	8.53 MB
POS	257 MB
Image	95.5 GB
Transfer date	May 28, 2014
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.7
RMSE for East Position (<4.0 cm)	2.0
RMSE for Down Position (<8.0 cm)	3.8
Boresight correction stdev (<0.001deg)	0.000518
IMU attitude correction stdev (<0.001deg)	0.026089
GPS position stdev (<0.01m)	0.0388
Minimum % overlap (>25)	53.44%
Ave point cloud density per sq.m. (>2.0)	3.08
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	169
Maximum Height	313.64 m
Minimum Height	59.54 m
Classification (# of points)	
Ground	108,115,249
Low vegetation	76,412,876
Medium vegetation	82,519,137
High vegetation	16,810,372
Building	540,046
Orthophoto	Yes
Processed by	Engr. Jennifer Saguran, Engr. Harmond Santos, Engr. Gladys Mae Apat

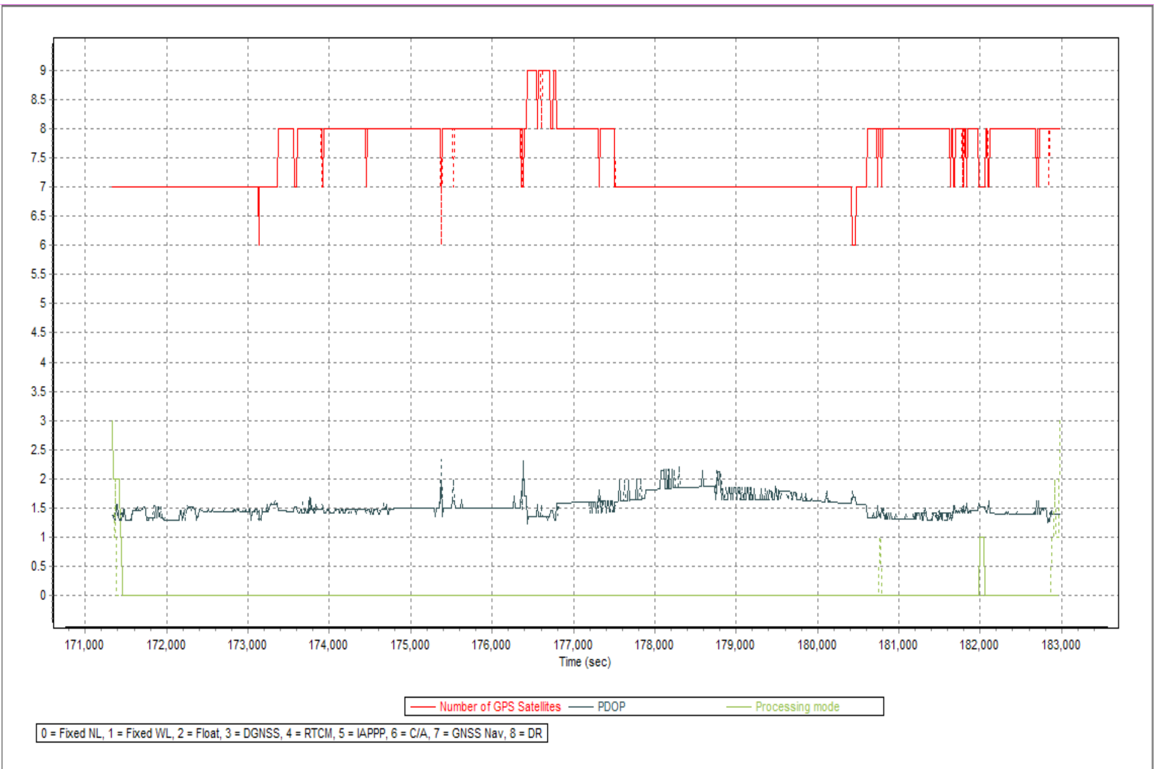


Figure A-8.15. Solution Status

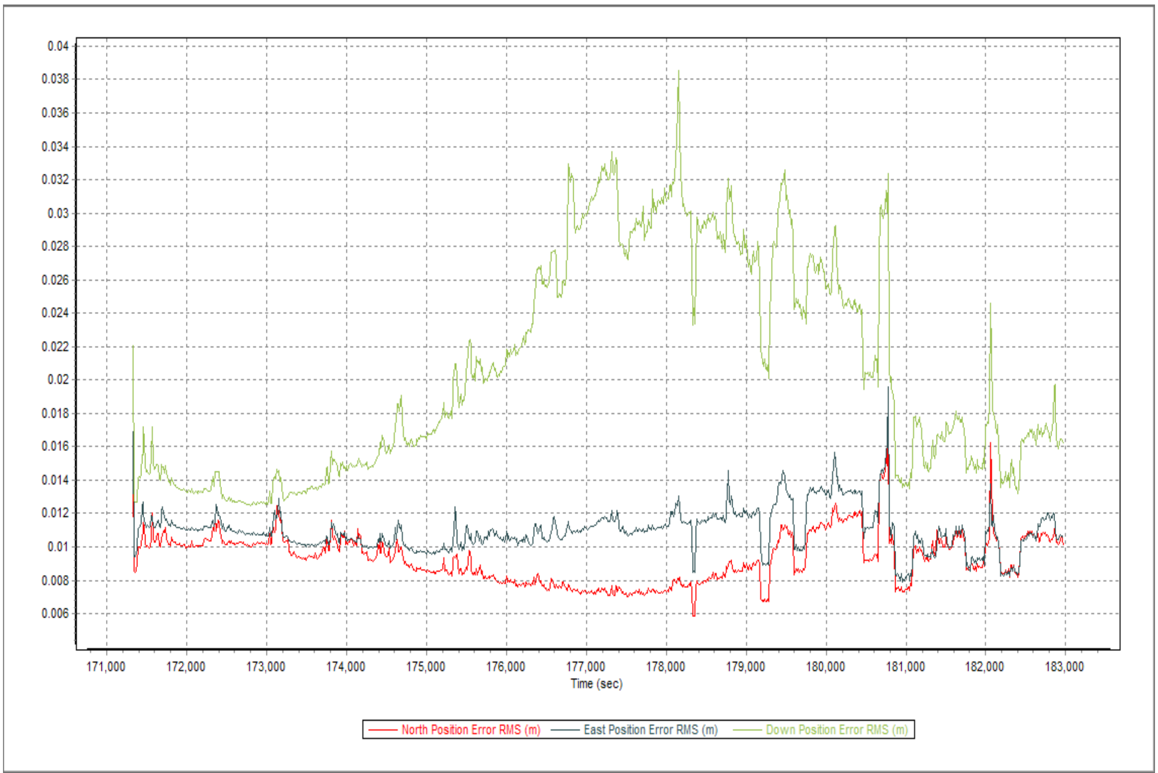


Figure A-8.16. Smoothed Performance Metrics Parameters

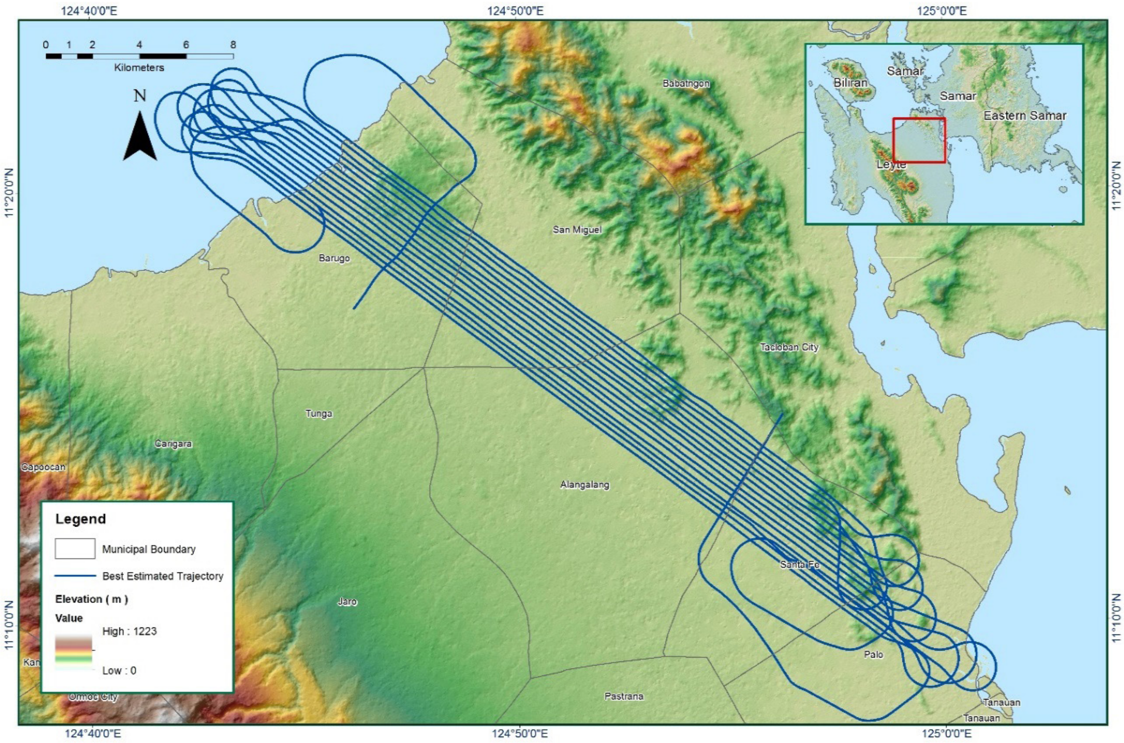


Figure A-8.17. Best Estimated Trajectory

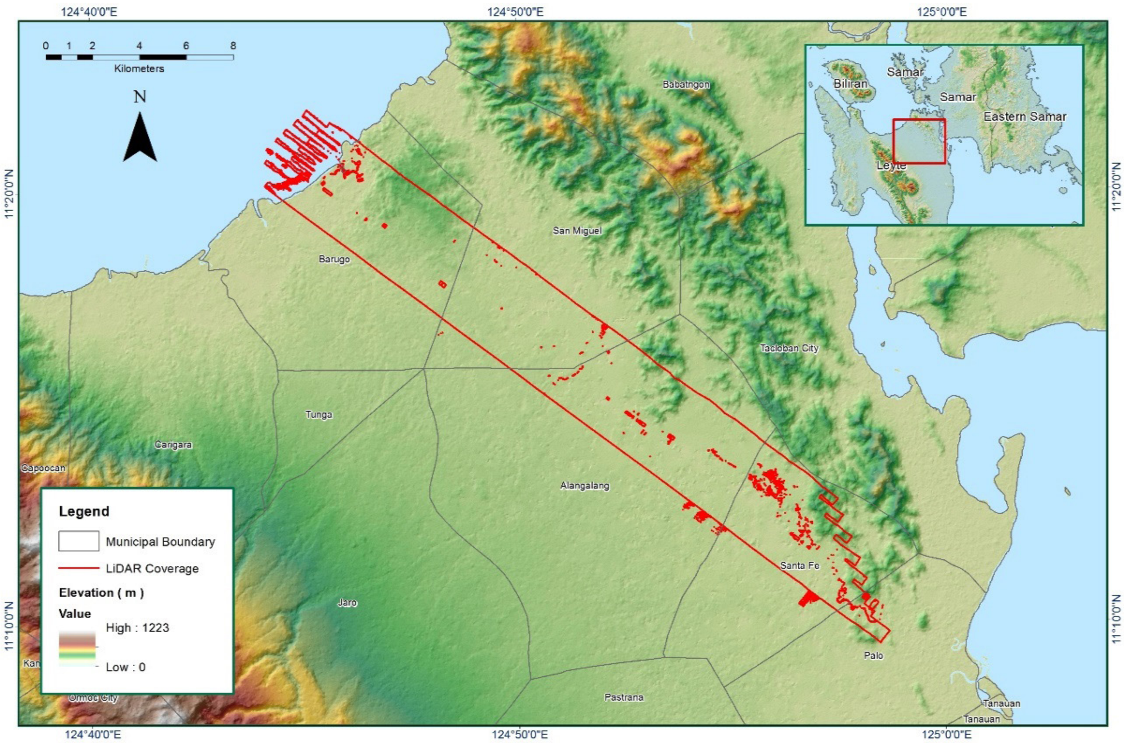


Figure A-8.18. Coverage of LiDAR data

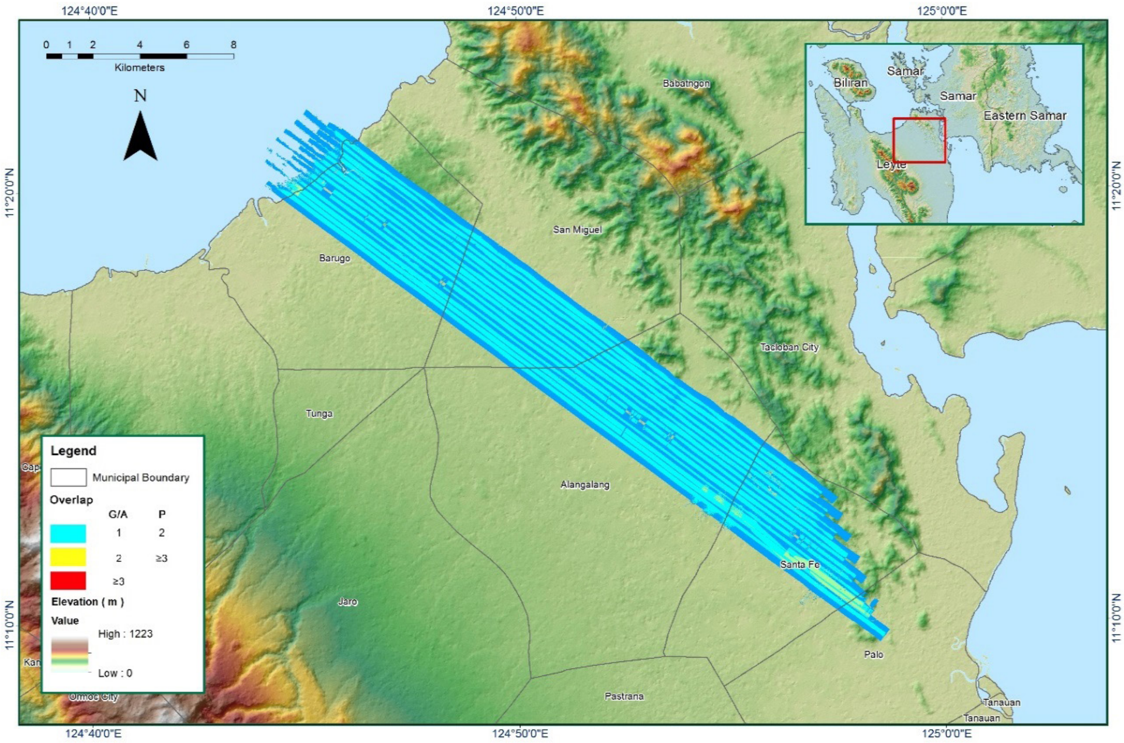


Figure A-8.19. Image of data overlap

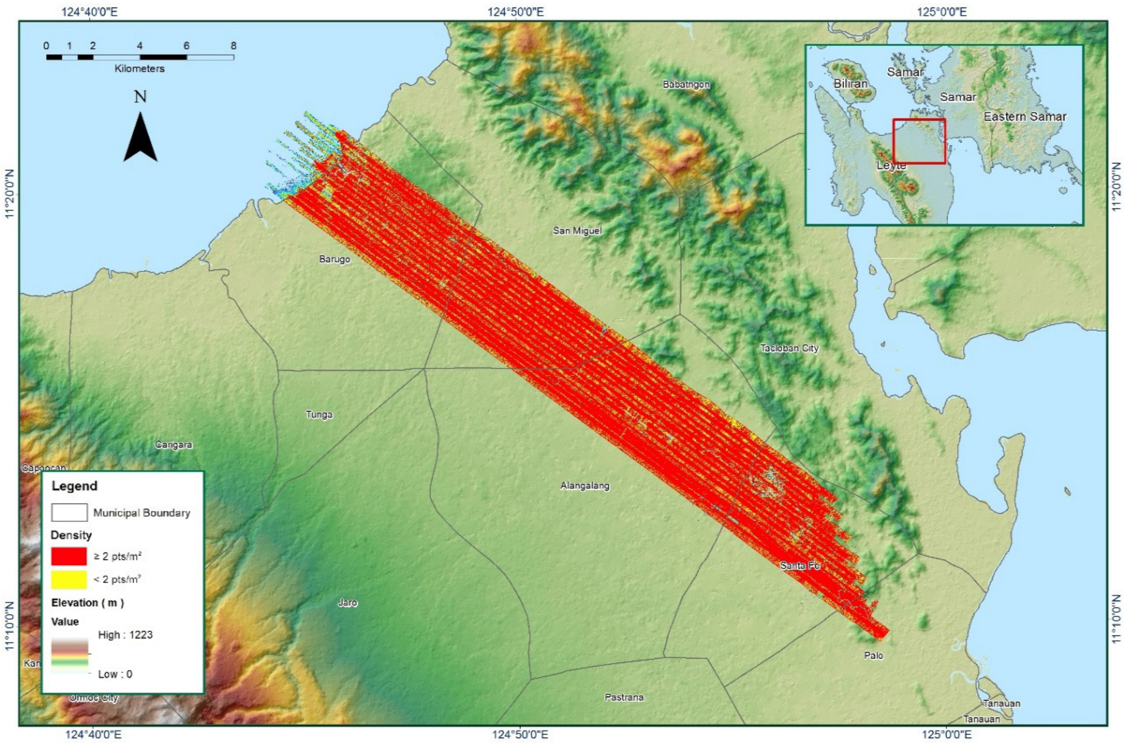


Figure A-8.20. Density map of merged LiDAR data

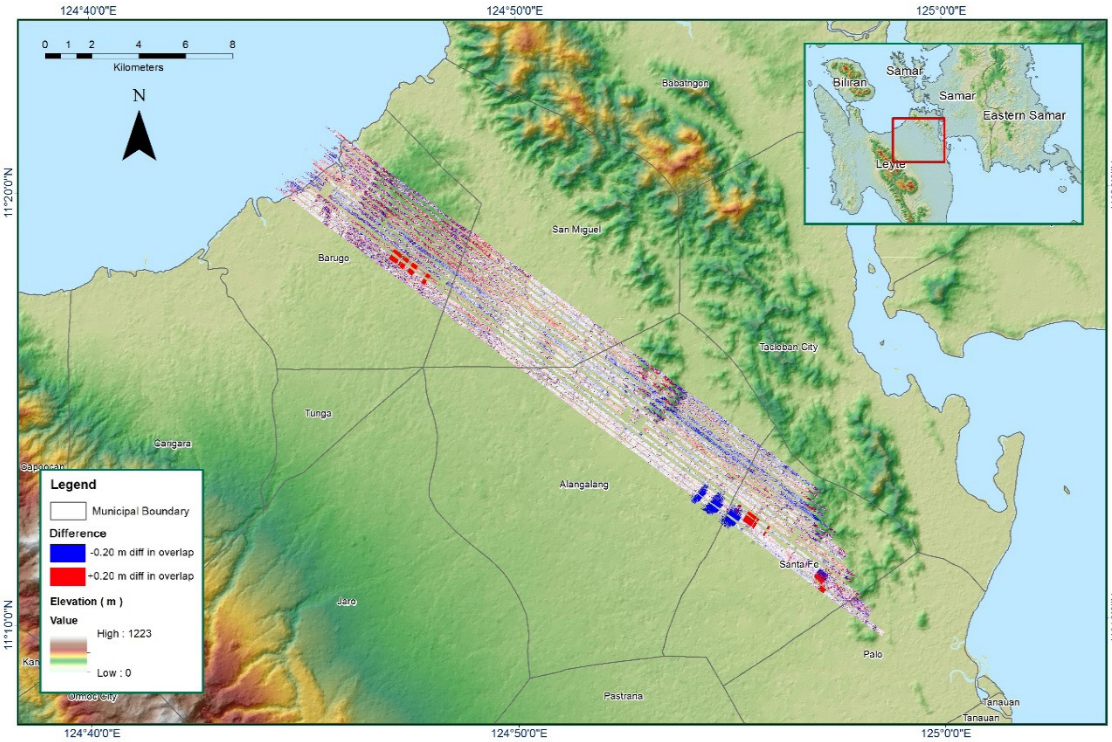


Figure A-8.21. Elevation difference between flight lines

Table A-8.4. Mission Summary Report for Mission Blk 34C

Flight Area	Leyte
Mission Name	Blk 34C
Inclusive Flights	3773G, 3771G
Range data size	37.1 GB
Base data size	460 MB
POS	13.94 MB
Image	n/a
Transfer date	February 12, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	Yes
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	0.8
RMSE for East Position (<4.0 cm)	1.0
RMSE for Down Position (<8.0 cm)	2.8
Boresight correction stdev (<0.001deg)	0.000620
IMU attitude correction stdev (<0.001deg)	0.004668
GPS position stdev (<0.01m)	0.0133
Minimum % overlap (>25)	35.68
Ave point cloud density per sq.m. (>2.0)	4.41
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	190
Maximum Height	293.50 m
Minimum Height	85.36 m
Classification (# of points)	
Ground	73,091,228
Low vegetation	68,546,439
Medium vegetation	272,398,780
High vegetation	231,908,658
Building	3,024,175
Orthophoto	None
Processed by	Engr. Analyn Naldo, Engr. Harmond Santos, Maria Tamsyn Malabanan

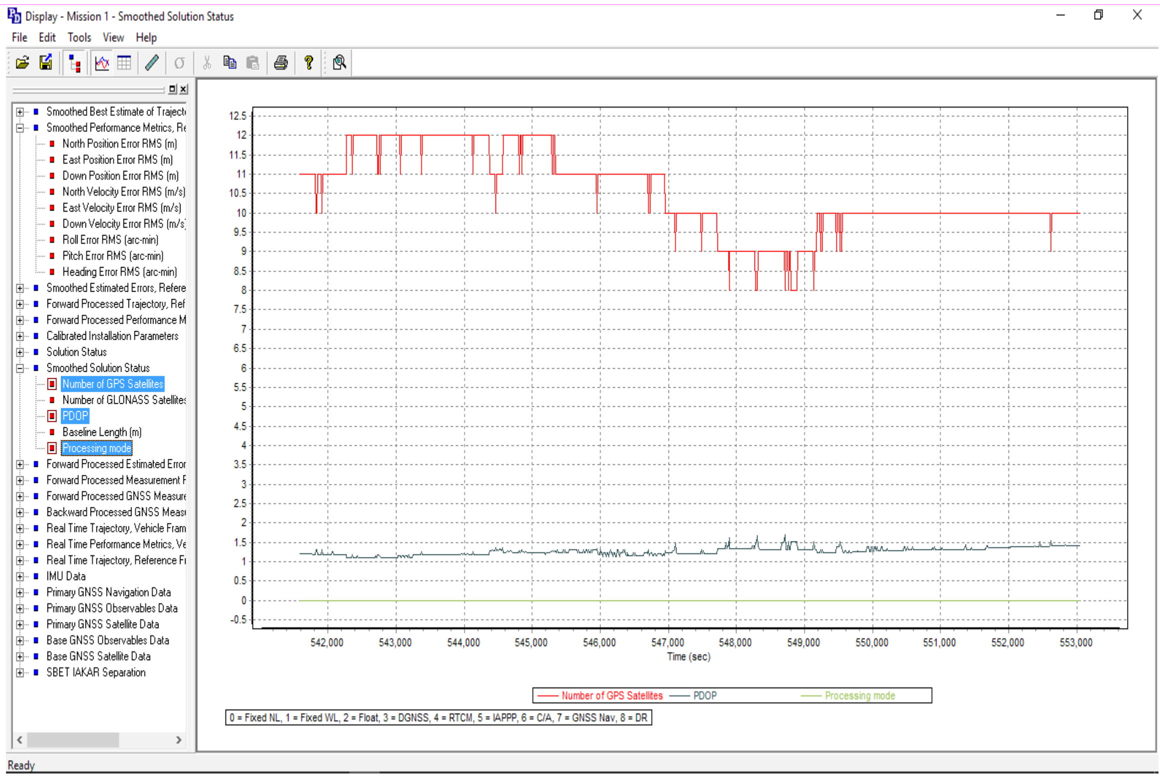


Figure A-8.22. Solution Status

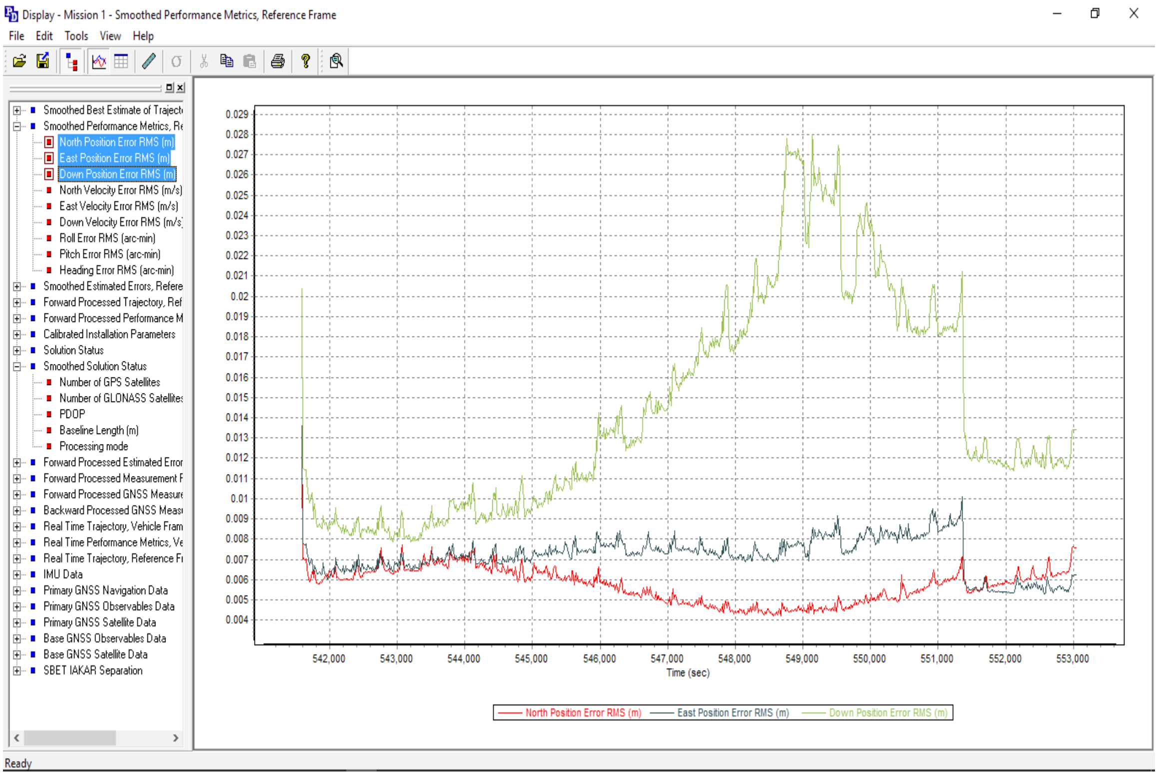


Figure A-8.23. Smoothed Performance Metric Parameters

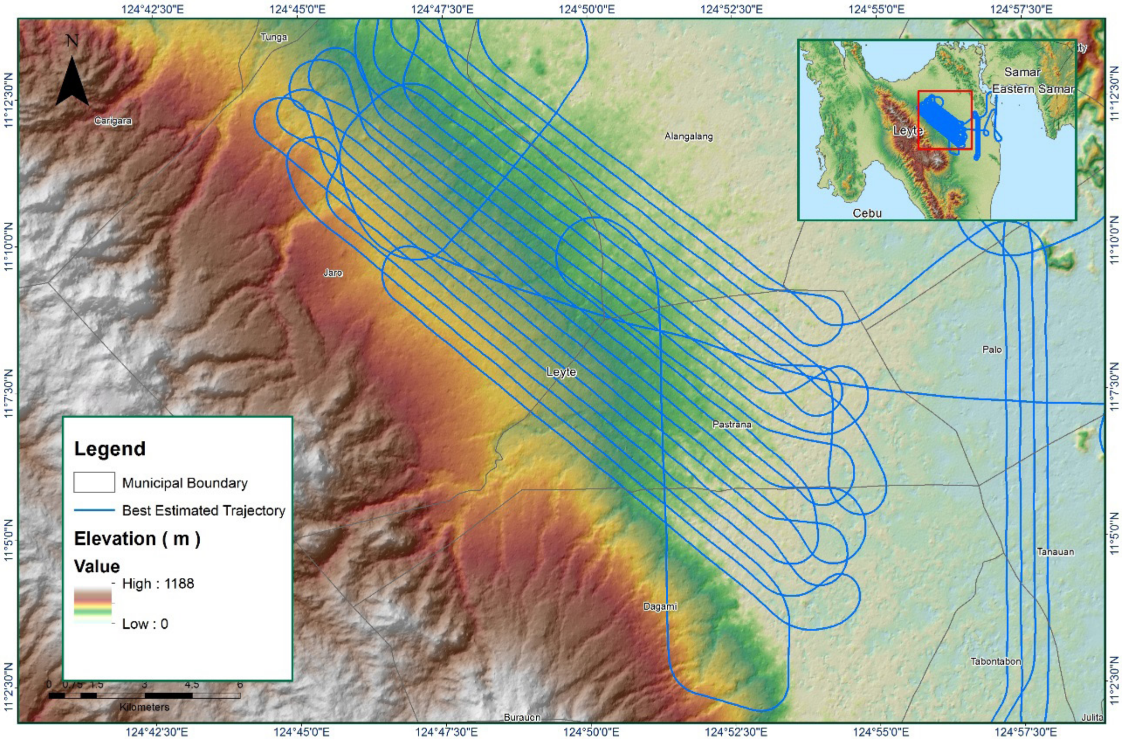


Figure A-8.24. Best Estimated Trajectory

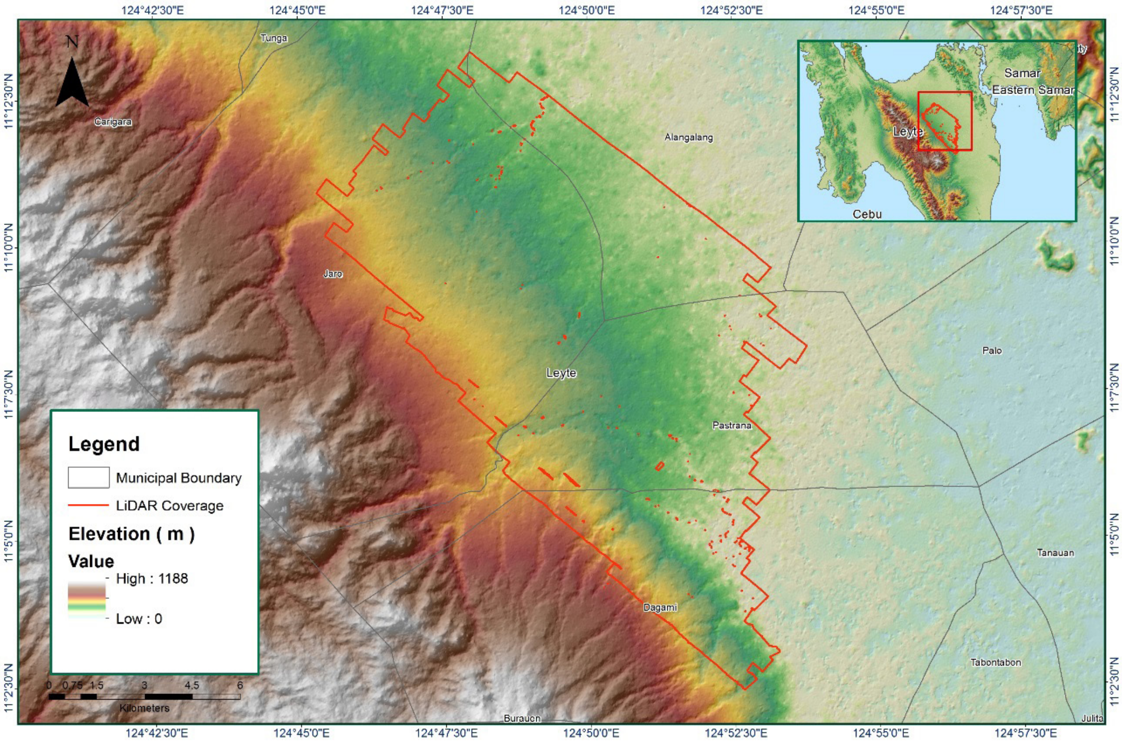


Figure A-8.25. Coverage of LiDAR Data

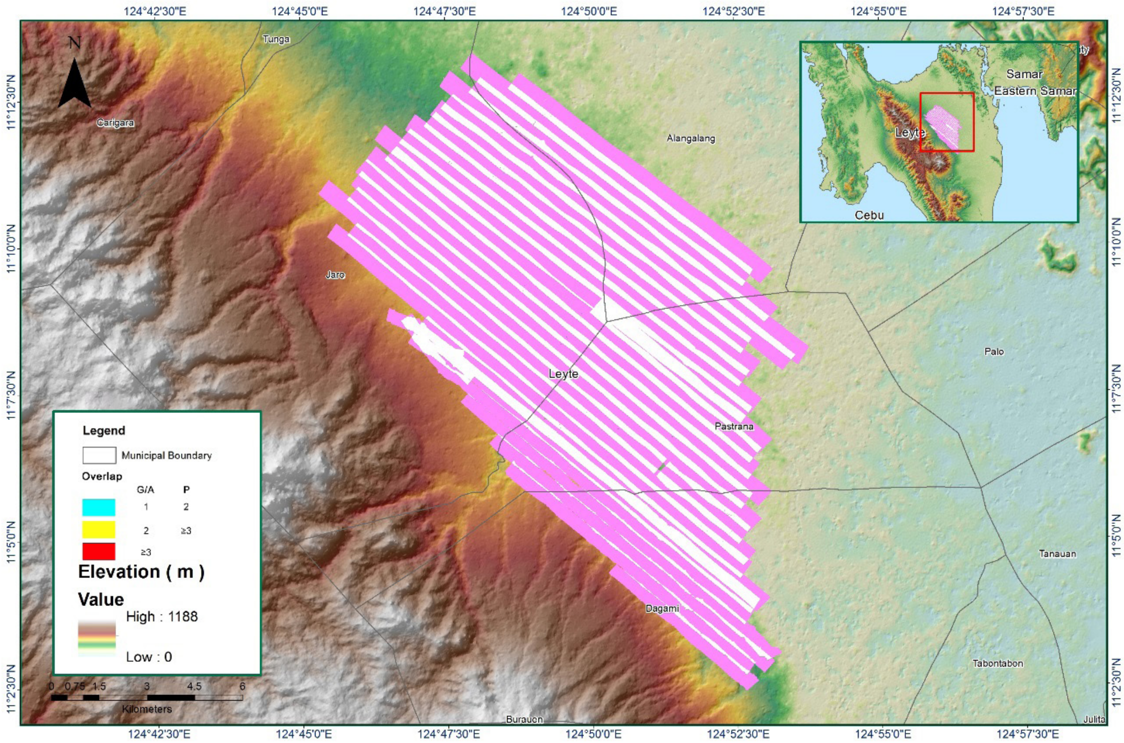


Figure A-8.26. Image of data overlap

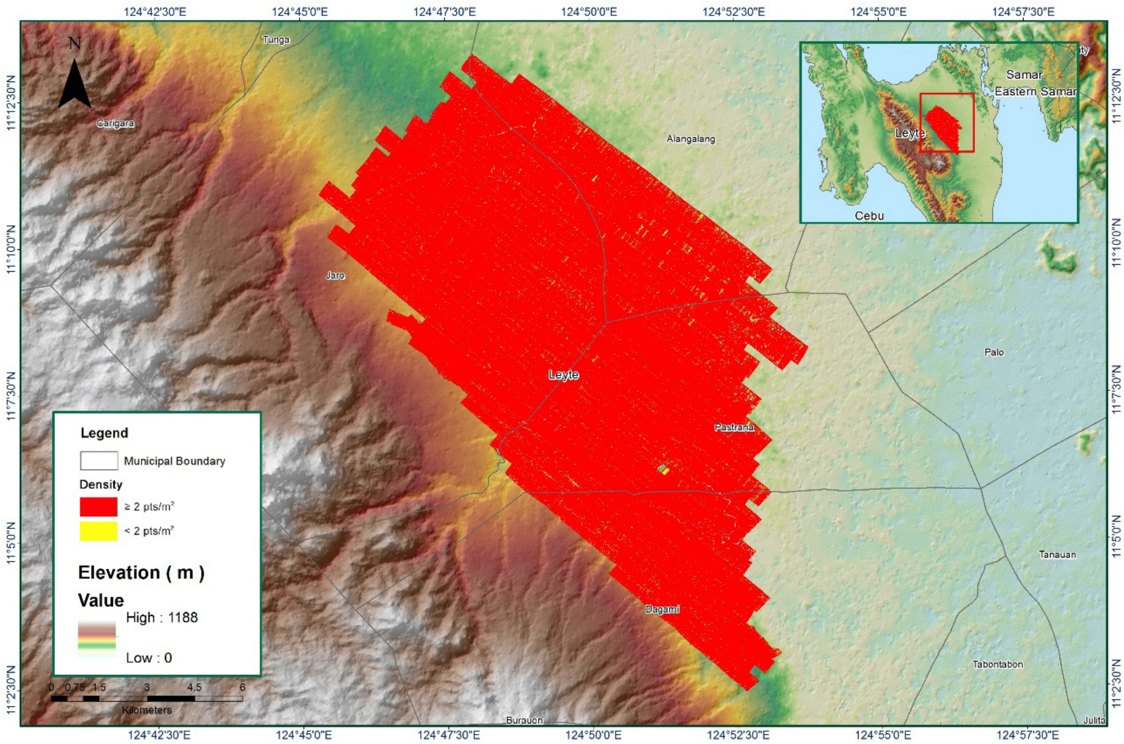


Figure A-8.27. Density map of merged LiDAR data

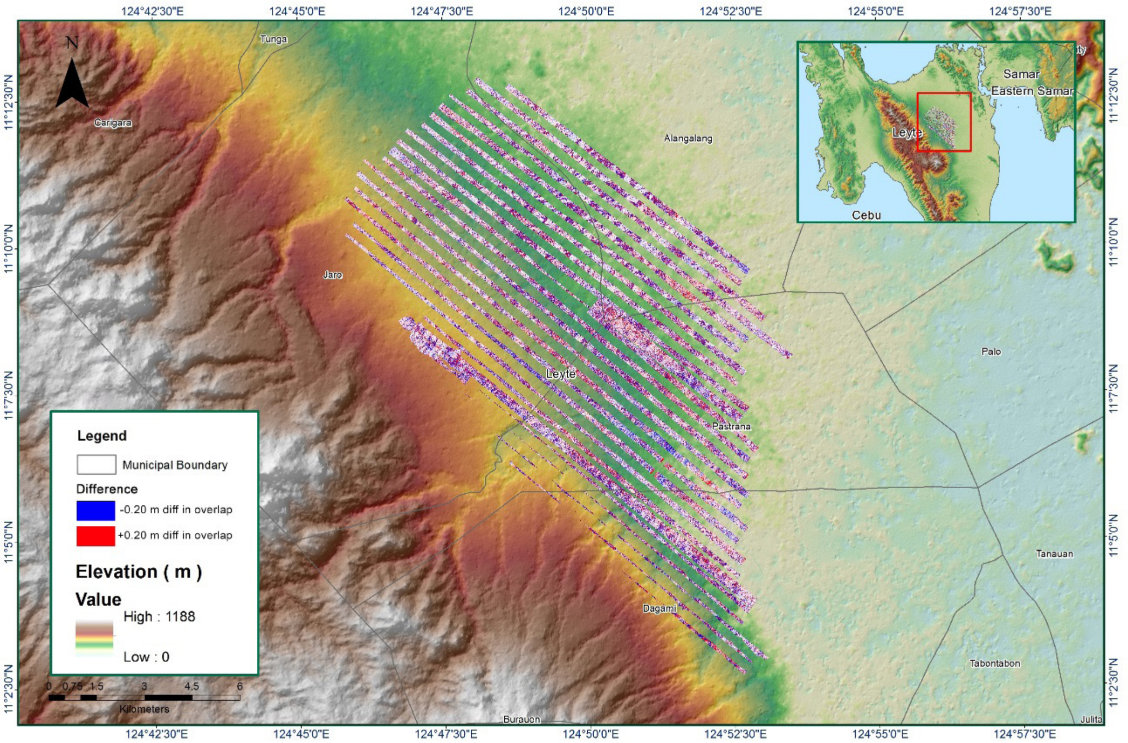


Figure A-8.28. Elevation difference between flight lines

Table A-8.5. Mission Summary Report for Mission Blk34D

Flight Area	Leyte
Mission Name	Blk34D
Inclusive Flights	3767G, 3773G
Range data size	35.9 GB
Base data size	452 MB
POS	8.14 MB
Image	n/a
Transfer date	February 12, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.0
RMSE for East Position (<4.0 cm)	1.3
RMSE for Down Position (<8.0 cm)	2.2
Boresight correction stdev (<0.001deg)	0.000942
IMU attitude correction stdev (<0.001deg)	0.002535
GPS position stdev (<0.01m)	0.0116
Minimum % overlap (>25)	42.76
Ave point cloud density per sq.m. (>2.0)	4.23
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	126
Maximum Height	205.76 m
Minimum Height	10.90 m
Classification (# of points)	
Ground	37,541,051
Low vegetation	64,452,630
Medium vegetation	157,969,342
High vegetation	87,019,402
Building	1,194,655
Orthophoto	No
Processed by	Engr. Jennifer Saguran, Engr. Ma. Joanne Balaga, Jovy Narisma

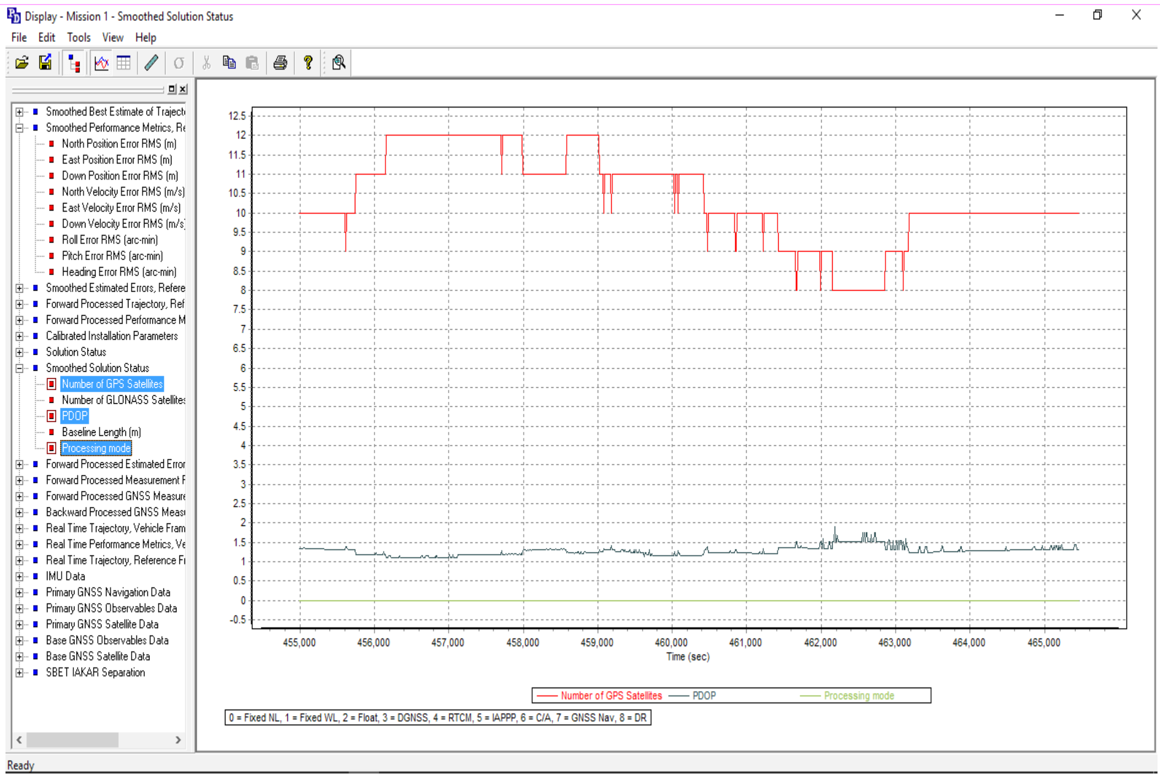


Figure A-8.29. Solution Status

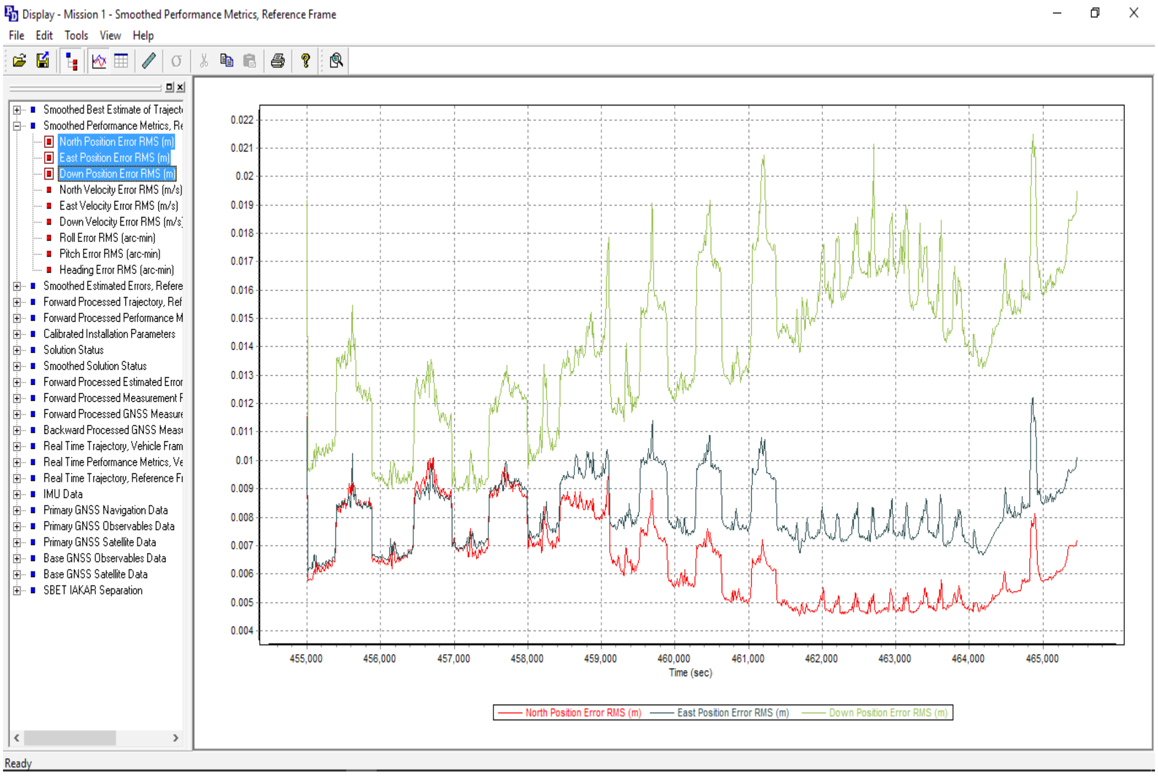


Figure A-8.30. Smoothed Performance Metric Parameters

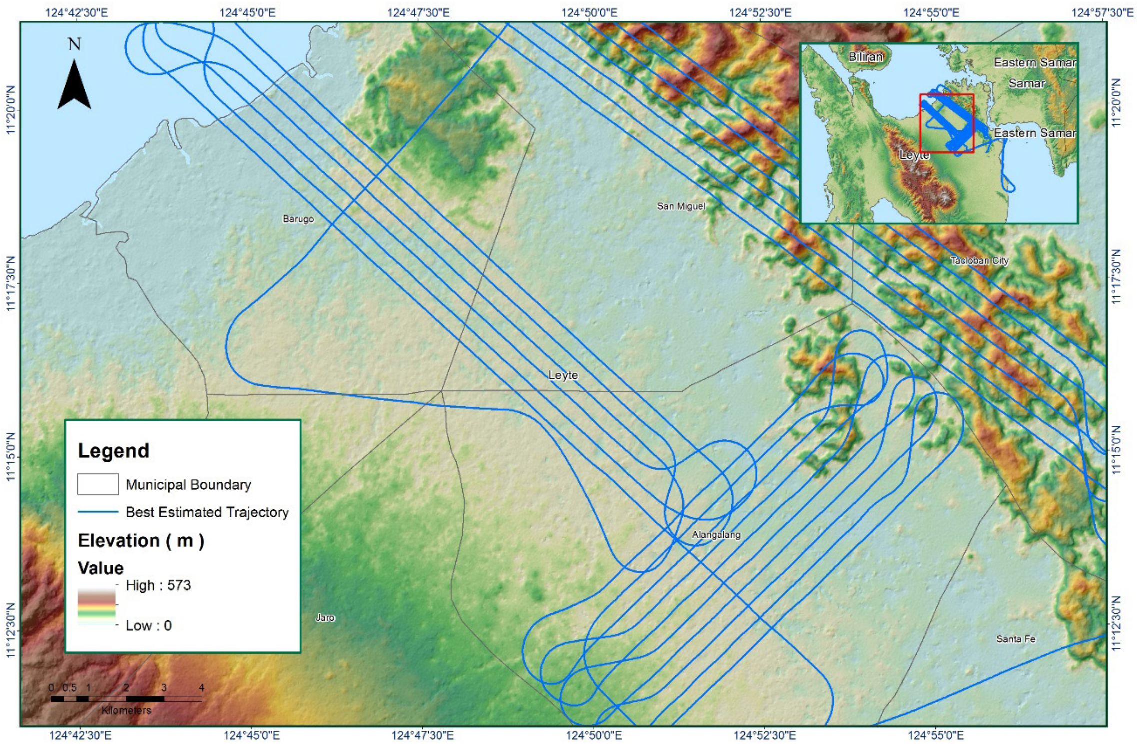


Figure A-8.31. Best Estimated Trajectory

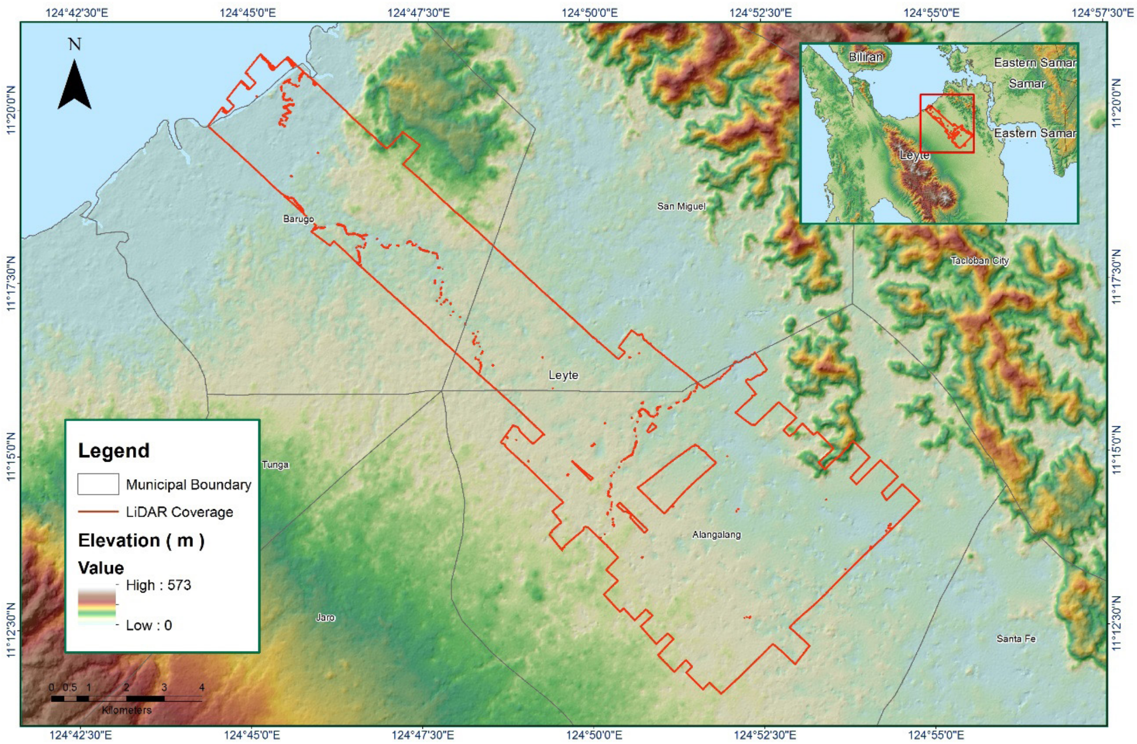


Figure A-8.32. Coverage of LiDAR Data

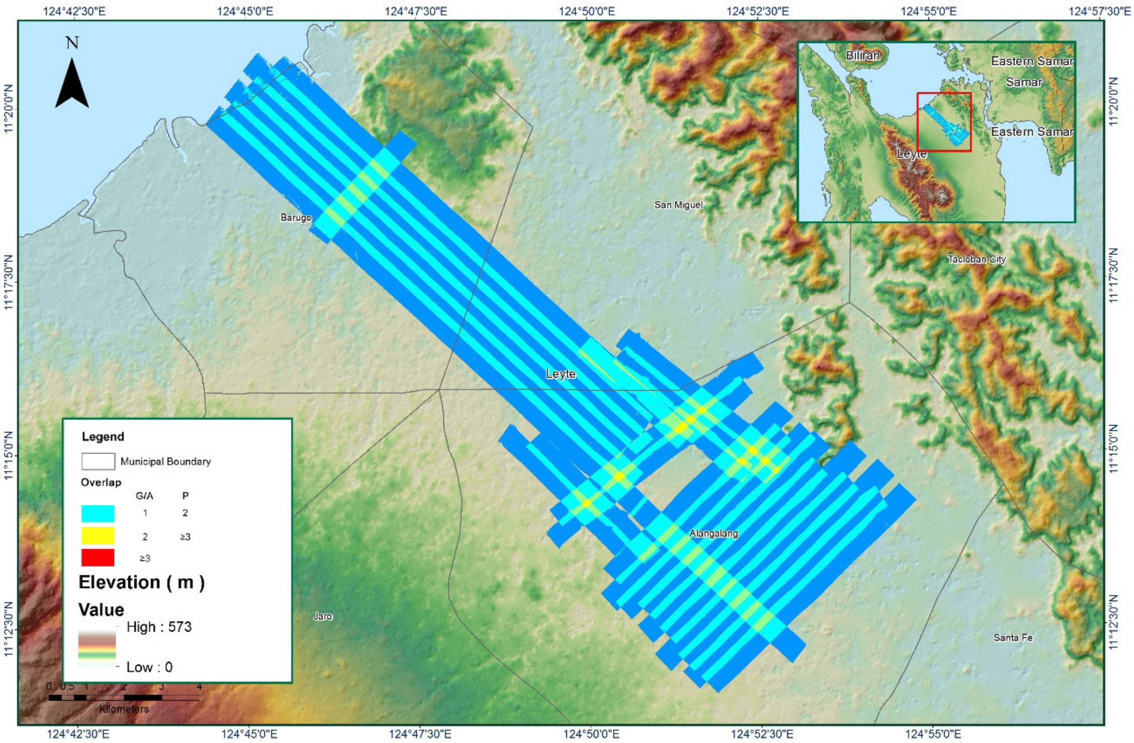


Figure A-8.33. Image of data overlap

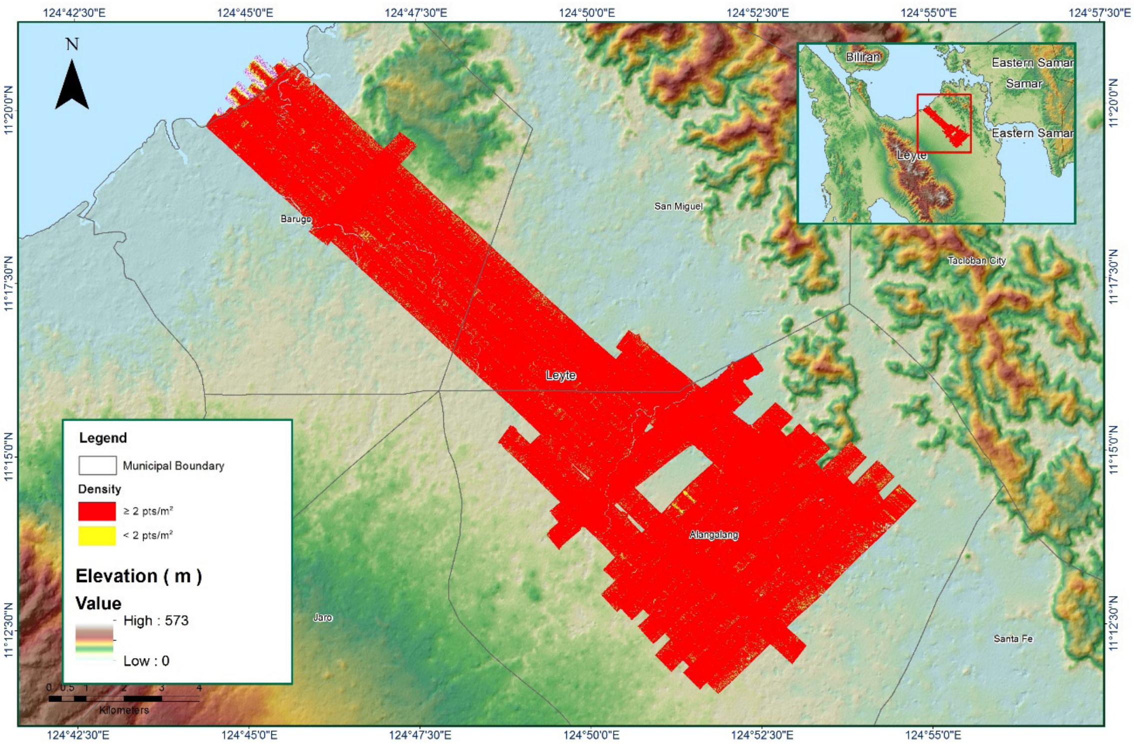


Figure A-8.34. Density map of merged LiDAR data

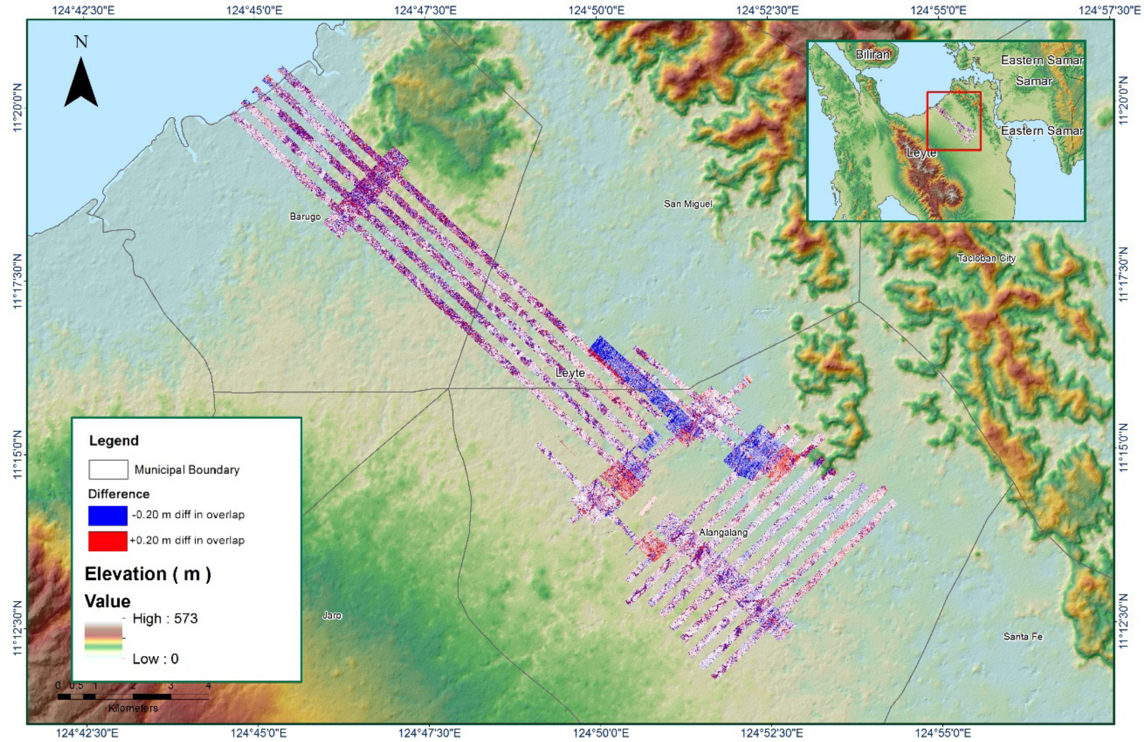


Figure A-8.35. Elevation difference between flight lines

Table A-8.6. Mission Summary Report for Mission Blk 34E

Flight Area	Leyte
Mission Name	Blk 34E
Inclusive Flights	3767G, 3765G
Range data size	44.3 GB
Base data size	459 MB
POS	7.78 MB
Image	n/a
Transfer date	February 12, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	No
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.9
RMSE for East Position (<4.0 cm)	1.5
RMSE for Down Position (<8.0 cm)	6.0
Boresight correction stdev (<0.001deg)	0.000478
IMU attitude correction stdev (<0.001deg)	0.003642
GPS position stdev (<0.01m)	0.0029
Minimum % overlap (>25)	34.99
Ave point cloud density per sq.m. (>2.0)	4.65
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	93
Maximum Height	415.68 m
Minimum Height	63.54 m
Classification (# of points)	
Ground	35,181,518
Low vegetation	42,803,820
Medium vegetation	136,496,439
High vegetation	111,171,628
Building	2,703,347
Orthophoto	None
Processed by	Engr. Sheila-Maye Santillan, Engr. Justine Francisco, Marie Denise Bueno

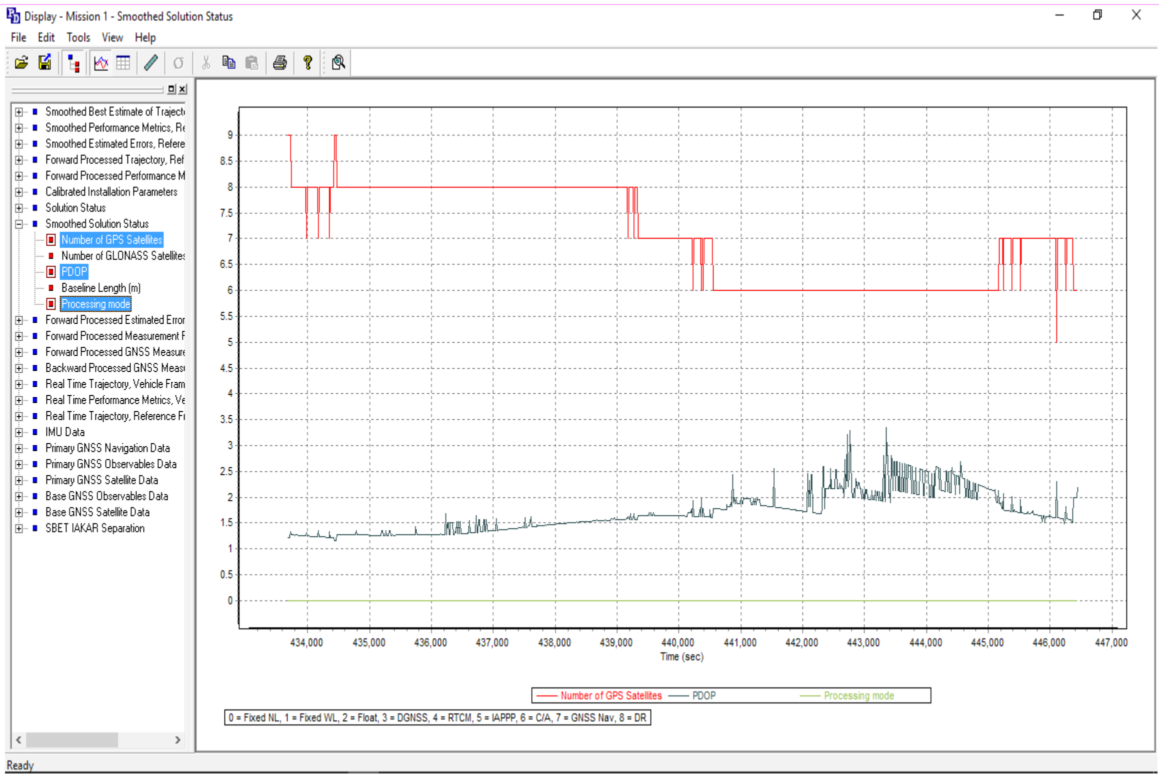


Figure A-8.36. Solution Status

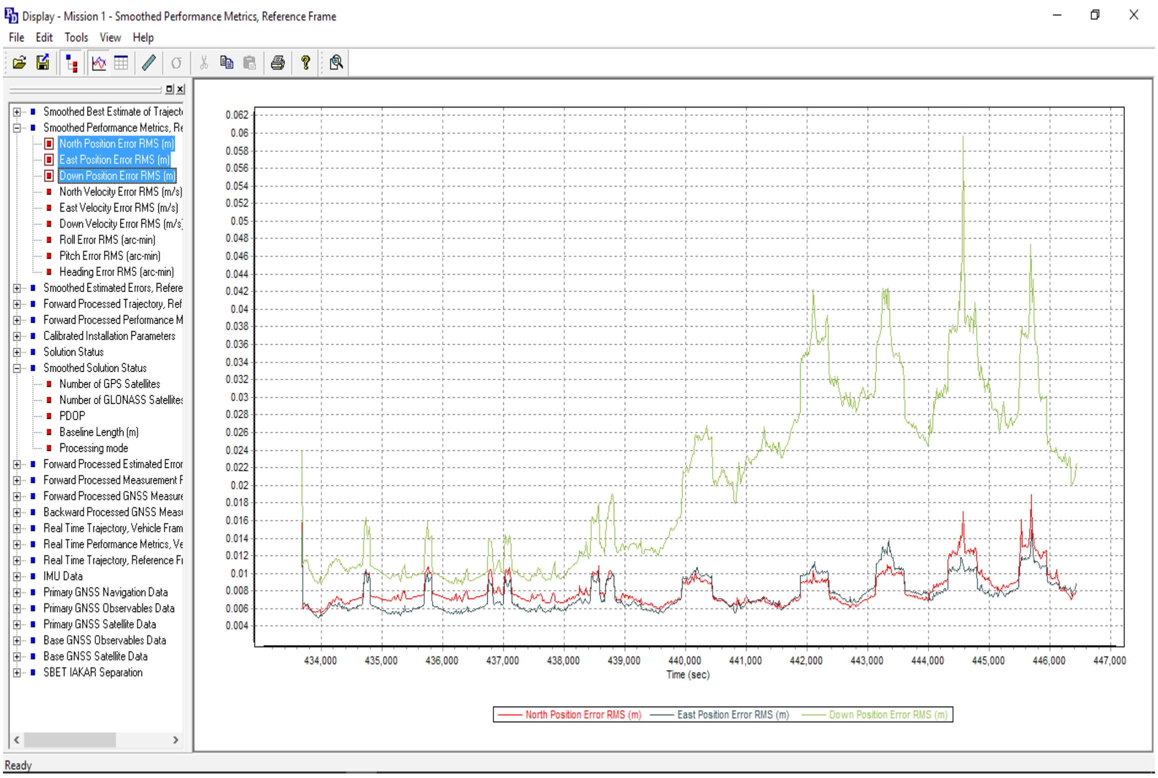


Figure A-8.37. Smoothed Performance Metric Parameters

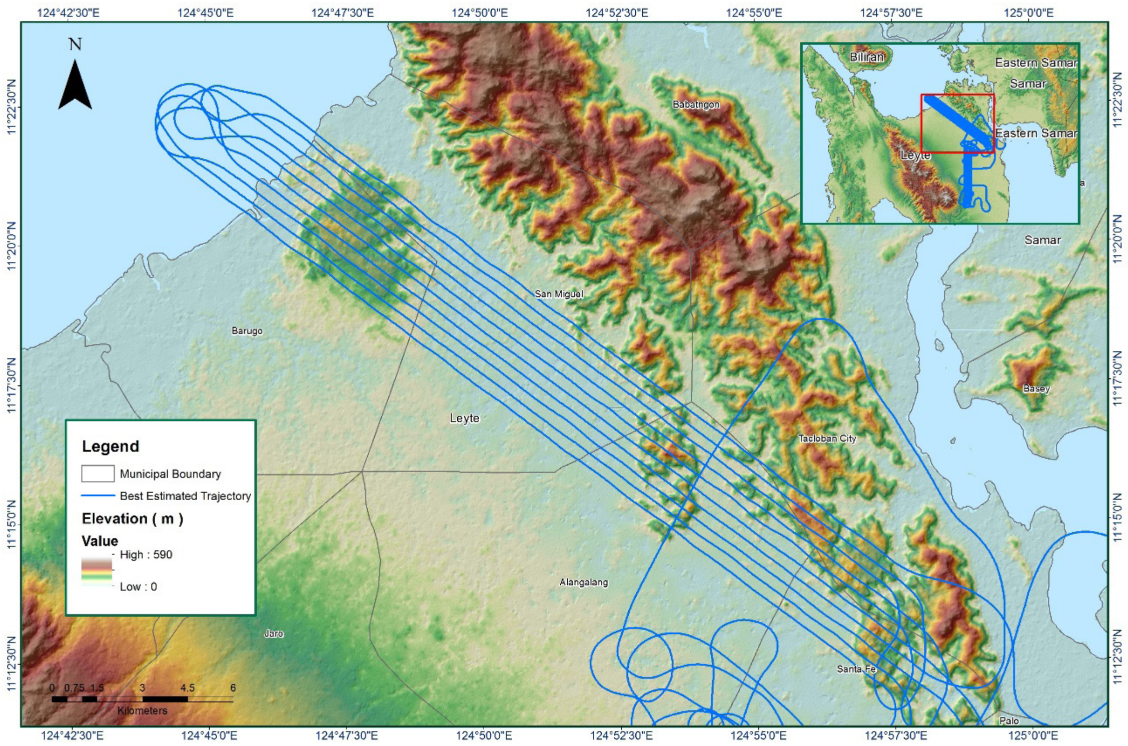


Figure A-8.38. Best Estimated Trajectory

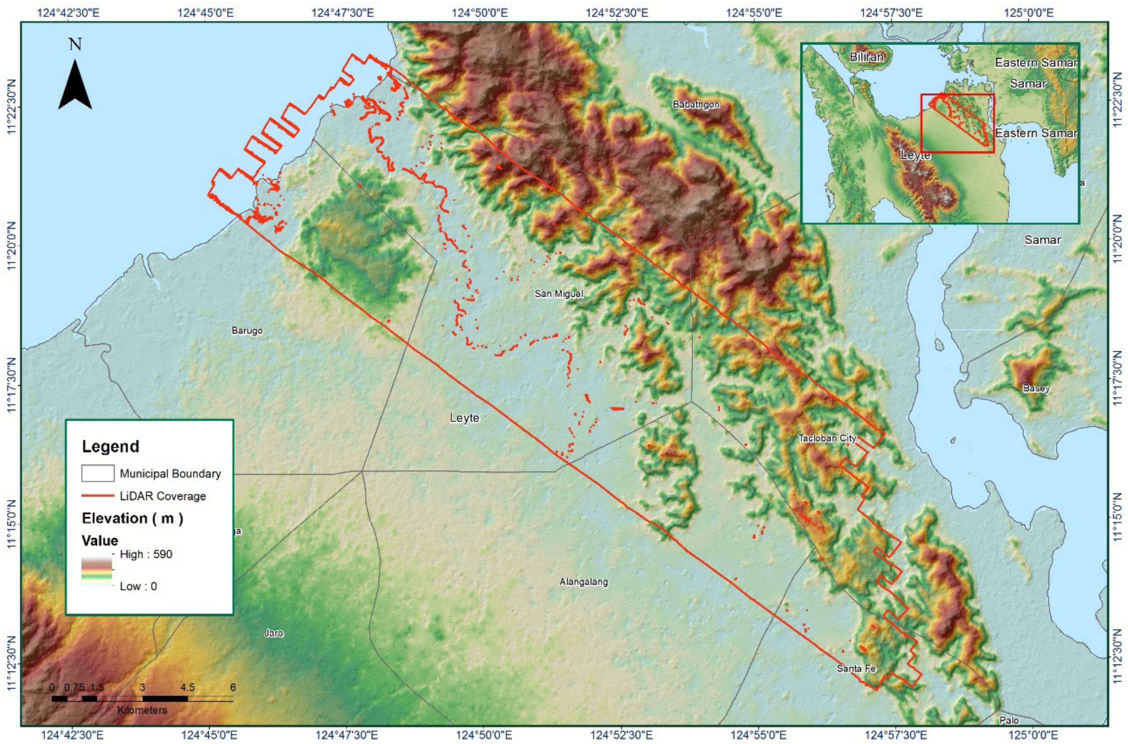


Figure A-8.39. Coverage of LiDAR Data

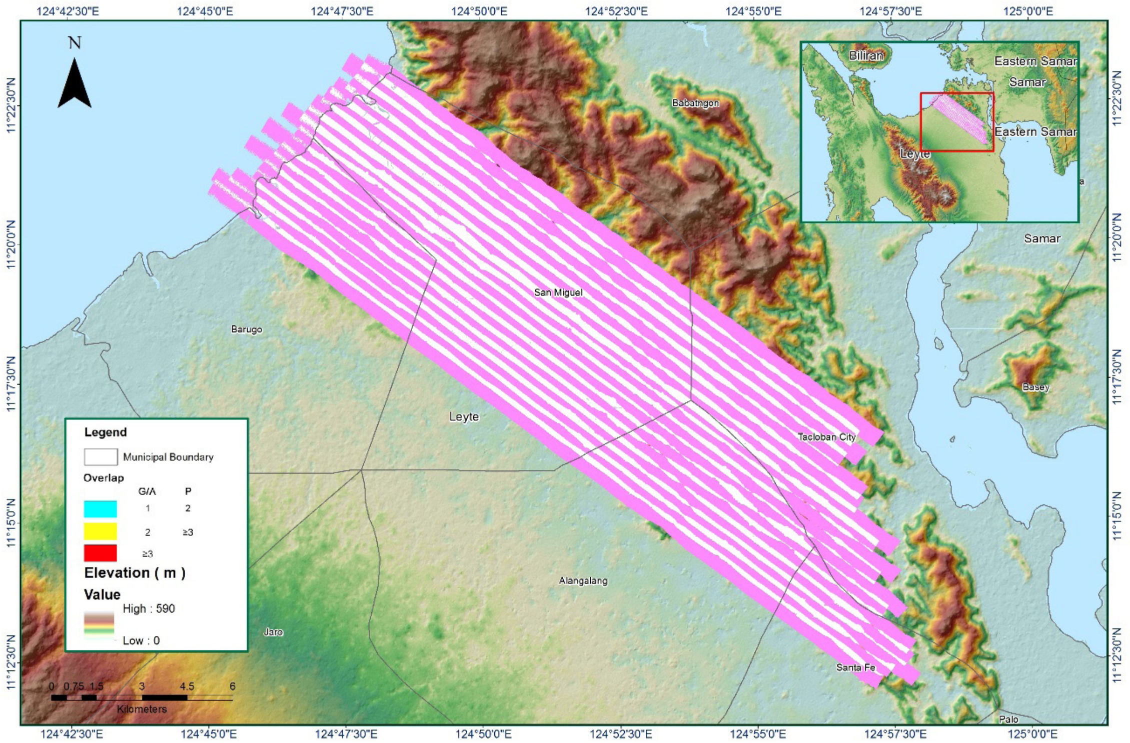


Figure A-8.40. Image of data overlap

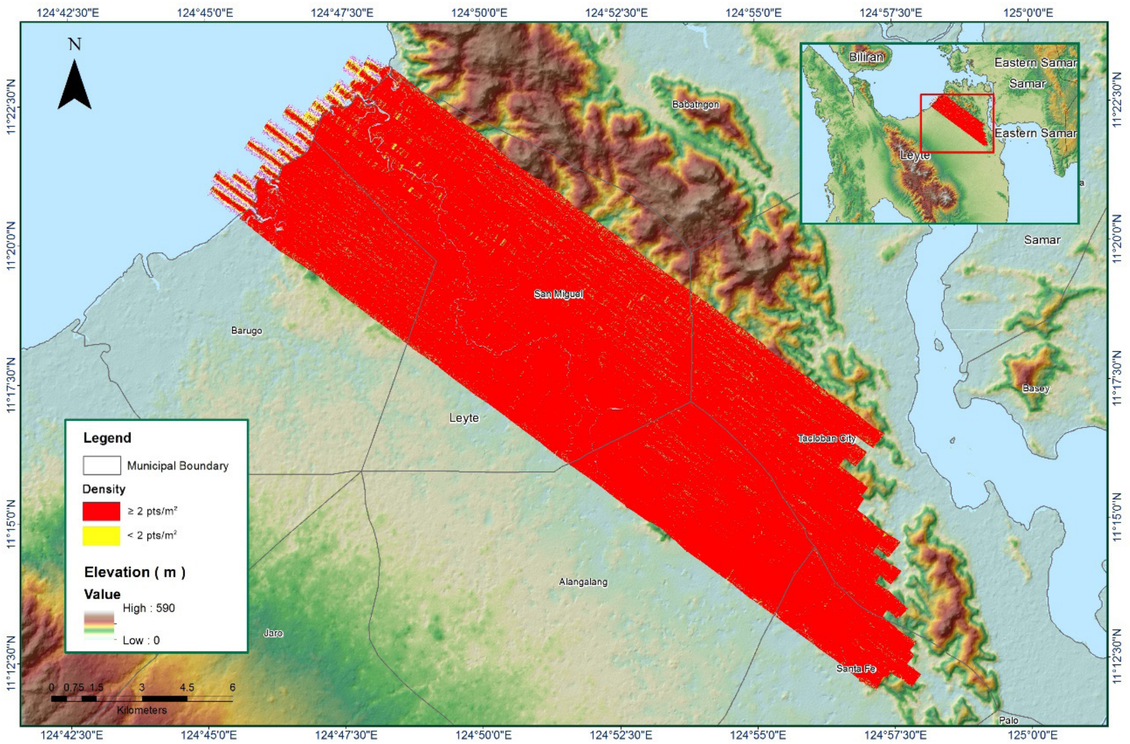


Figure A-8.41. Density map of merged LiDAR data

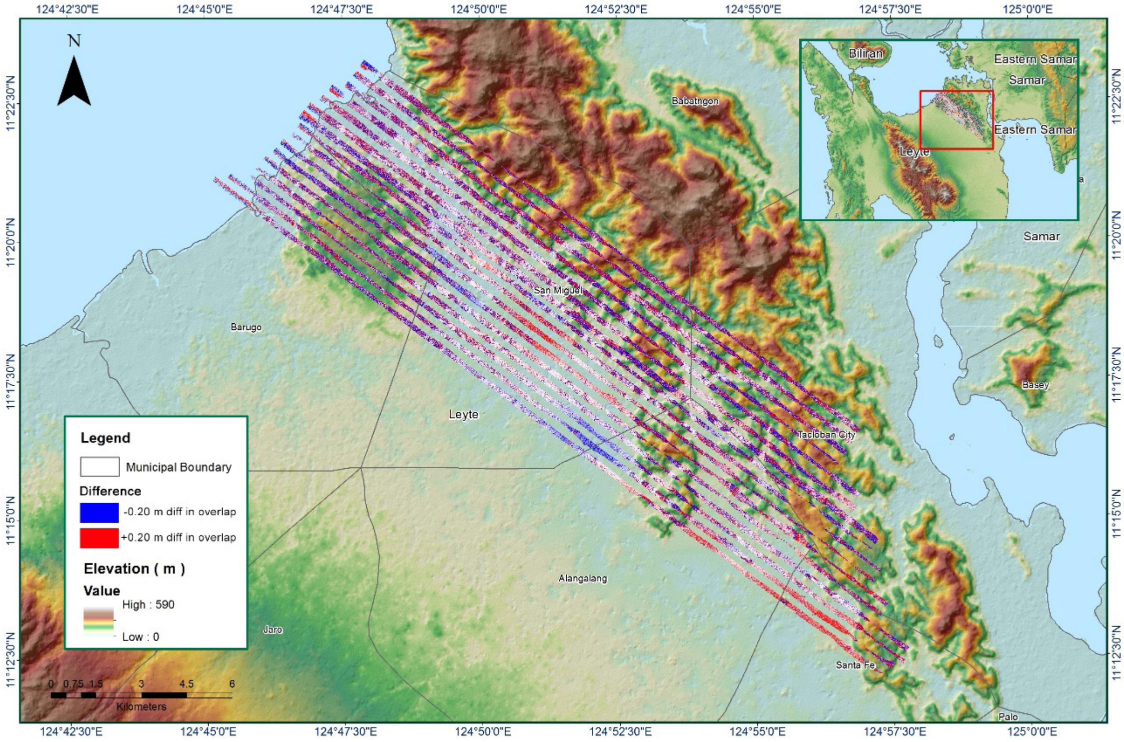


Figure A-8.42. Elevation difference between flight lines

Table A-8.7. Mission Summary Report for Mission Blk 34E_Additional

Flight Area	Leyte
Mission Name	Blk 34E_Additional
Inclusive Flights	3769G
Range data size	23.8 GB
Base data size	260 MB
POS	9.58 MB
Image	n/a
Transfer date	February 12, 2016
Solution Status	
Number of Satellites (>6)	Yes
PDOP (<3)	Yes
Baseline Length (<30km)	No
Processing Mode (<=1)	Yes
Smoothed Performance Metrics (in cm)	
RMSE for North Position (<4.0 cm)	1.1
RMSE for East Position (<4.0 cm)	1.2
RMSE for Down Position (<8.0 cm)	3.3
Boresight correction stdev (<0.001deg)	0.000767
IMU attitude correction stdev (<0.001deg)	0.004064
GPS position stdev (<0.01m)	0.0063
Minimum % overlap (>25)	6.16
Ave point cloud density per sq.m. (>2.0)	4.62
Elevation difference between strips (<0.20 m)	Yes
Number of 1km x 1km blocks	36
Maximum Height	582.56 m
Minimum Height	61.27 m
Classification (# of points)	
Ground	2,938,333
Low vegetation	324,554
Medium vegetation	8,108,083
High vegetation	30,643,240
Building	9,339
Orthophoto	None
Processed by	Engr. Kenneth Solidum, Engr. Harmond Santos, Engr. Krisha Marie Bautista

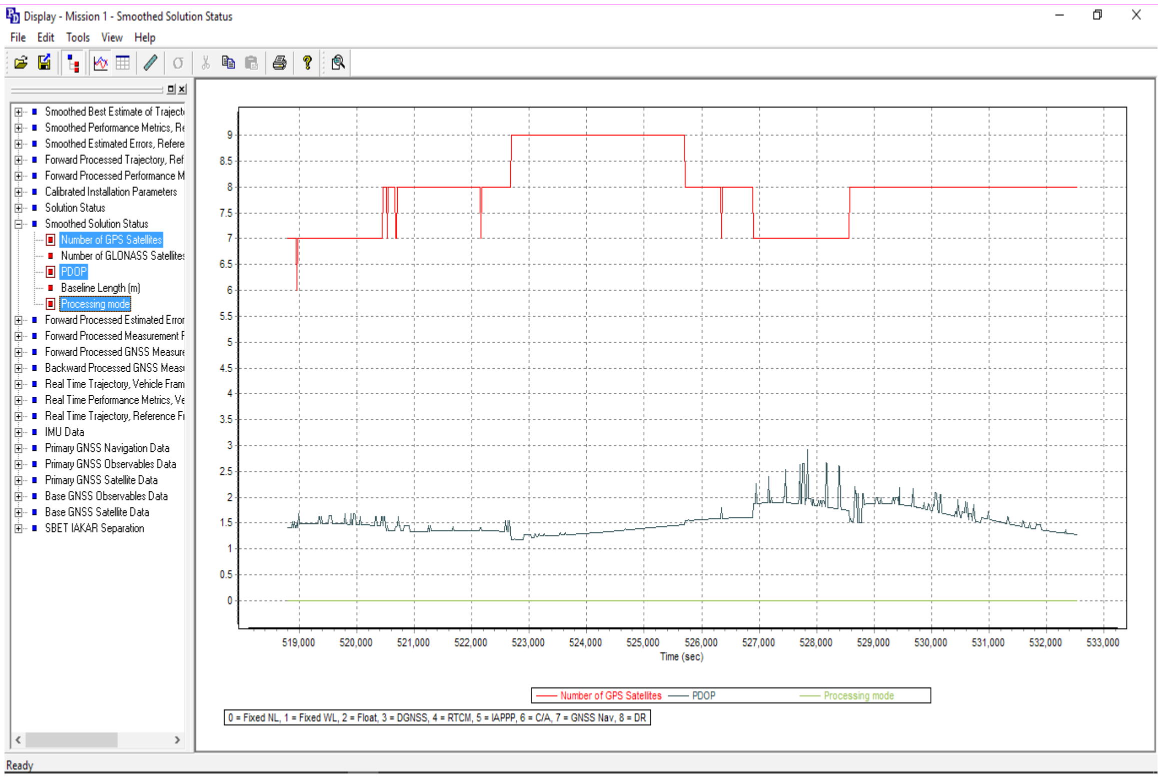


Figure A-8.43. Solution Status

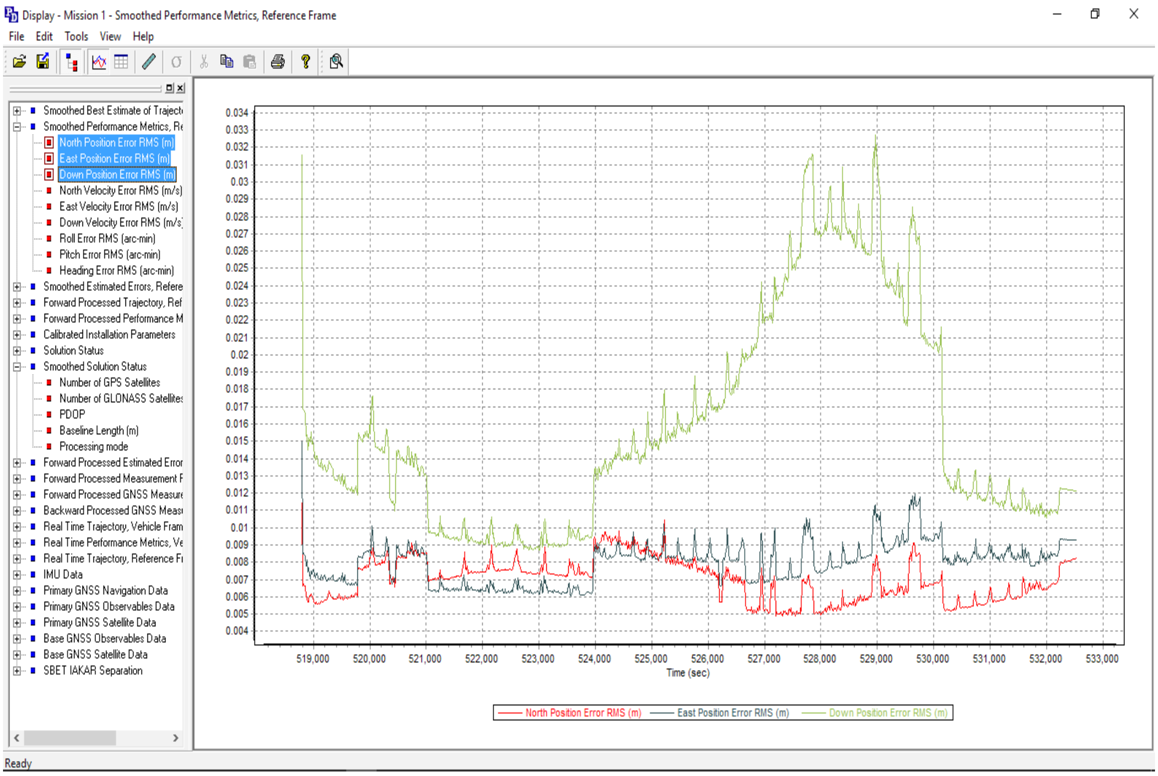


Figure A-8.44. Smoothed Performance Metric Parameters

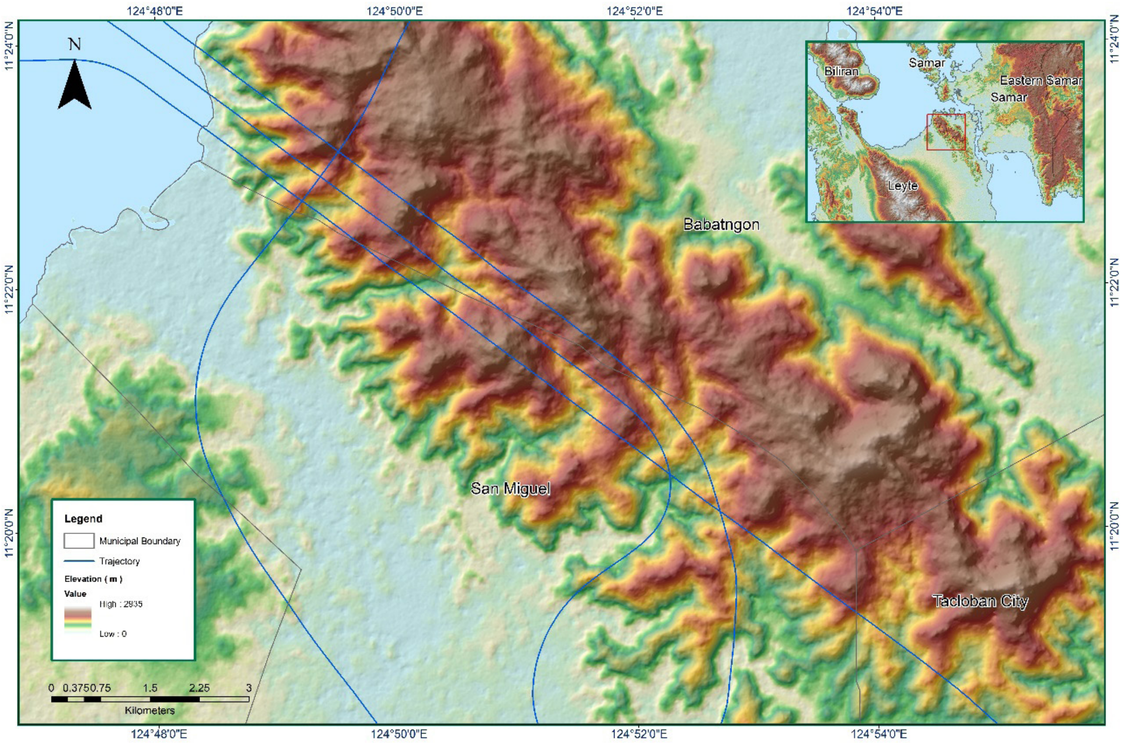


Figure A-8.45. Best Estimated Trajectory

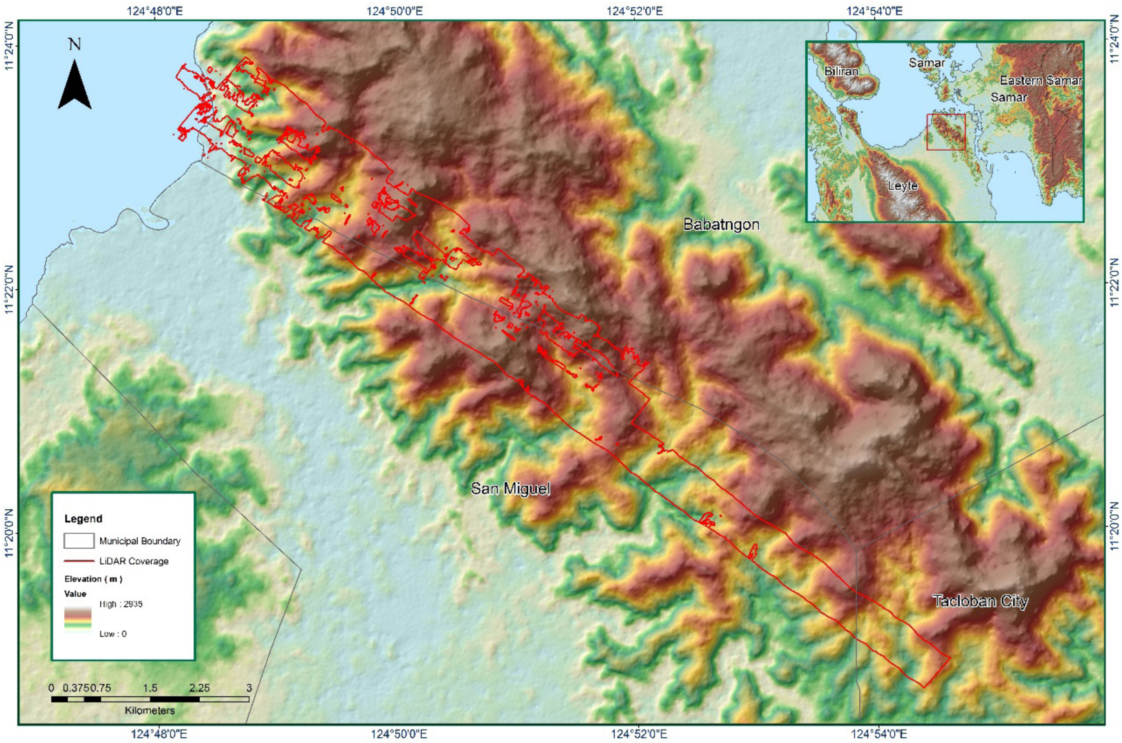


Figure A-8.46. Coverage of LiDAR Data

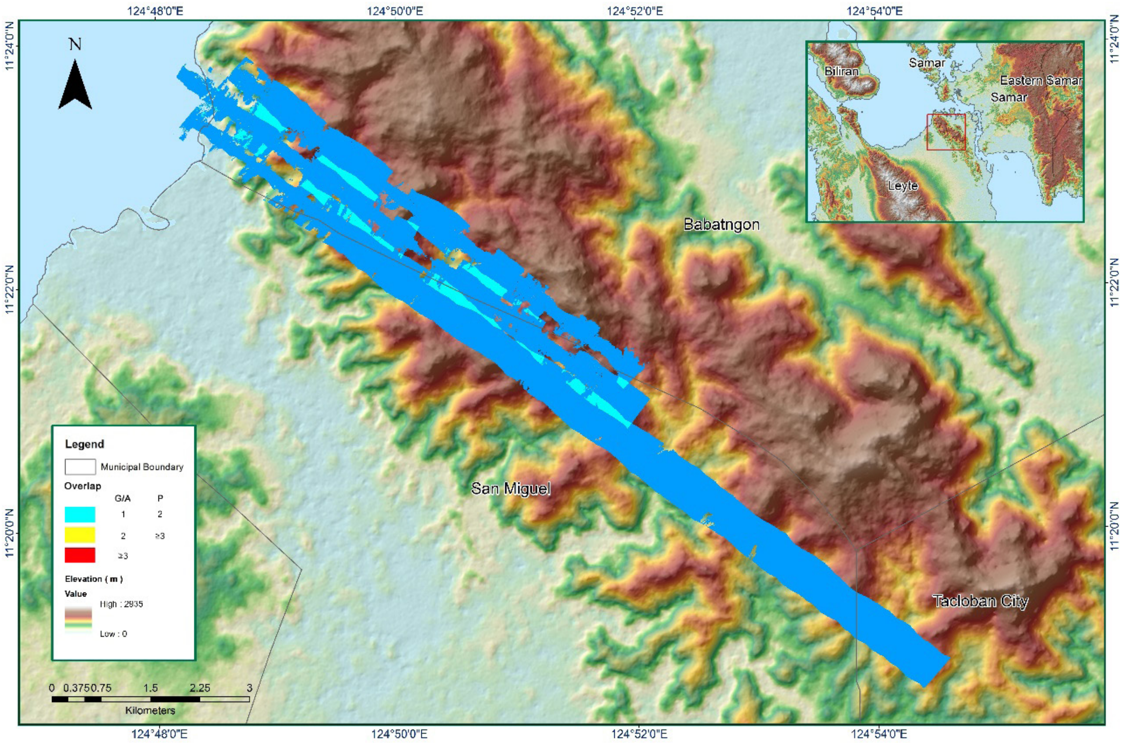


Figure A-8.47. Image of data overlap

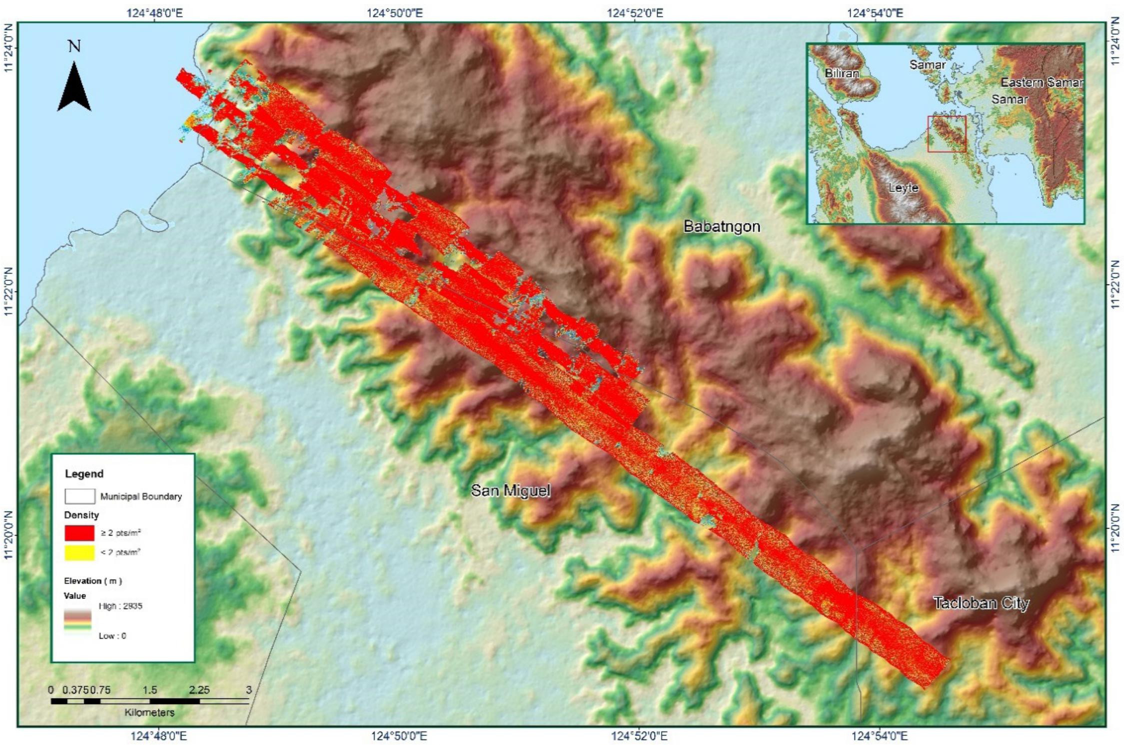


Figure A-8.48. Density map of merged LiDAR data

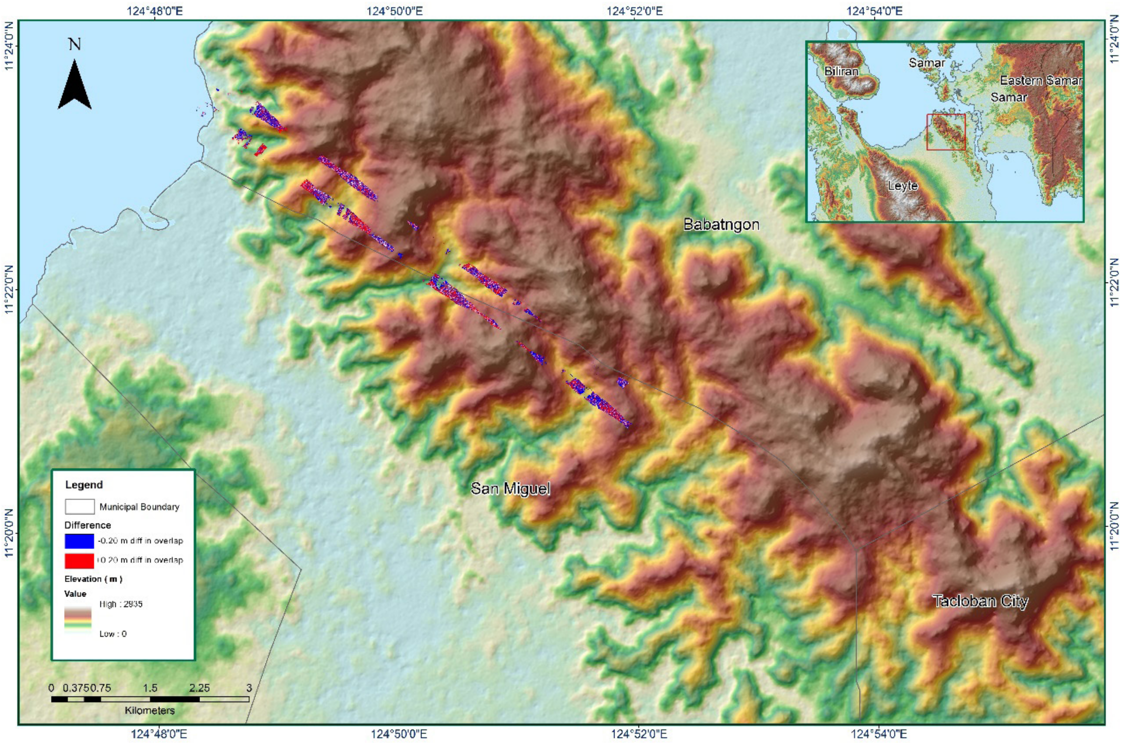


Figure A-8.49. Elevation difference between flight lines

Annex 9. Sangputan Model Basin Parameters

Table A-9.1. Sangputan Model Basin Parameters

Sub basin	SCS Curve Number Loss			Clark Unit Hydrograph Transform		Recession Baseflow				
	Initial Abstraction	Curve Number	Impervious %	Time of Concentration	Storage Coefficient	Initial Type	Initial Discharge (m3/s)	Recession Constant	Threshold Type	Ratio to Peak
W180	5.70824	85.93032	0	2.5596	0.38394	Discharge	0.08	0.8	Ratio to Peak	0.1
W190	49.6712	44.1	0	7.8452	1.17678	Discharge	0.08	0.8	Ratio to Peak	0.1
W200	7.42904	82.8541	0	5.636	0.8454	Discharge	0.08	0.8	Ratio to Peak	0.1
W210	6.46304	84.55342	0	2.9348	0.44022	Discharge	0.08	0.8	Ratio to Peak	0.1
W220	17.092	68.98612	0	29.89	4.4835	Discharge	0.08	0.8	Ratio to Peak	0.1
W230	10.0272	78.6058	0	14.7736	2.21604	Discharge	0.08	0.8	Ratio to Peak	0.1
W240	39.436	49.73696	0	9.6654	1.44981	Discharge	0.08	0.8	Ratio to Peak	0.1
W250	8.2552	81.45466	0	16.985	2.54775	Discharge	0.08	0.8	Ratio to Peak	0.1
W260	10.62	77.69636	0	12.6212	1.89318	Discharge	0.08	0.8	Ratio to Peak	0.1
W270	14.1736	72.65916	0	9.628	1.4442	Discharge	0.08	0.8	Ratio to Peak	0.1
W280	11.2344	76.77614	0	6.334	0.9501	Discharge	0.08	0.8	Ratio to Peak	0.1
W290	10.4008	78.03054	0	5.7326	0.85989	Discharge	0.08	0.8	Ratio to Peak	0.1
W300	10.4912	77.89236	0	5.4248	0.81372	Discharge	0.08	0.8	Ratio to Peak	0.1
W310	8.324	81.34	0	3.7206	0.55809	Discharge	0.08	0.8	Ratio to Peak	0.1
W320	13.092	74.1223	0	4.15	0.6225	Discharge	0.08	0.8	Ratio to Peak	0.1
W330	27.2632	58.653	0	7.4248	1.11372	Discharge	0.08	0.8	Ratio to Peak	0.1
W340	23.3872	62.20354	0	5.6824	0.85236	Discharge	0.08	0.8	Ratio to Peak	0.1

Annex 10. Sangputan Model Reach Parameters

Table A-10.1. Sangputan Model Reach Parameters

Reach	Time Step Method	Length	Slope	Manning's n	Shape	Width	Side Slope
R20	Automatic Fixed Interval	1757.9	0.0015396	0.05	Trapezoid	14.63	45
R30	Automatic Fixed Interval	814.12	8.963823447561998E-5	0.05	Trapezoid	6.3525	45
R40	Automatic Fixed Interval	3469.0	0.000759177253726277	0.05	Trapezoid	18.851	45
R60	Automatic Fixed Interval	3031.6	0.000355802143705370	0.05	Trapezoid	12.787	45
R90	Automatic Fixed Interval	15217	0.0020884	0.05	Trapezoid	14.806	45
R100	Automatic Fixed Interval	2927.6	0.0053901	0.05	Trapezoid	23.406	45
R110	Automatic Fixed Interval	4884.3	0.0104460	0.05	Trapezoid	23.832	45
R150	Automatic Fixed Interval	15414	0.0157862	0.05	Trapezoid	37.283	45

Annex 11. Sangputan Field Validation Points

Table A-11.1. Sangputan Validation Points for 5-year Flood Depth Map

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
504	11.188450°	124.784863°	0.490	0.2	0.290	Typhoon Yolanda/ November 8, 2013	5 -Year
508	11.184357°	124.797975°	0.030	0.4	-0.370	Tyhpoon Yolanda/ November 8, 2013	5 -Year
509	11.196058°	124.791744°	0.030	0.8	-0.770	Tyhpoon Yolanda/ November 8, 2013	5 -Year
512	11.202591°	124.807698°	0.140	0.5	-0.360	Tyhpoon Yolanda/ November 8, 2013	5 -Year
517	11.211108°	124.814508°	0.150	2	-1.850	Tyhpoon Yolanda/ November 8, 2013	5 -Year
517	11.217271°	124.823583°	0.030	0.4	-0.370	Tyhpoon Yolanda/ November 8, 2013	5 -Year
519	11.225920°	124.817280°	0.150	0.3	-0.150	Tyhpoon Yolanda/ November 8, 2013	5 -Year
526	11.217280°	124.850085°	0.030	0.5	-0.470	Tyhpoon Yolanda/ November 8, 2013	5 -Year
527	11.222359°	124.851490°	0.060	0.6	-0.540	Tyhpoon Yolanda/ November 8, 2013	5 -Year
532	11.229743°	124.849714°	0.610	0.3	0.310	Tyhpoon Yolanda/ November 8, 2013	5 -Year
534	11.237016°	124.856709°	0.320	0.6	-0.280	Tyhpoon Yolanda/ November 8, 2013	5 -Year
535	11.238605°	124.857545°	0.030	0.7	-0.670	Tyhpoon Yolanda/ November 8, 2013	5 -Year
536	11.242109°	124.860112°	0.030	0.5	-0.470	Tyhpoon Yolanda/ November 8, 2013	5 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
546	11.257573°	124.855207°	0.210	1.4	-1.190	Tyhpoon Yolanda/ November 8, 2013	5 -Year
5511	11.229932°	124.828779°	0.290	0.4	-0.110	Tyhpoon Yolanda/ November 8, 2013	5 -Year
552	11.235762°	124.829540°	0.120	0.4	-0.280	Tyhpoon Yolanda/ November 8, 2013	5 -Year
553	11.235670°	124.825773°	0.030	0.2	-0.170	Tyhpoon Yolanda/ November 8, 2013	5 -Year
554	11.238782°	124.820874°	0.890	0.6	0.290	Tyhpoon Yolanda/ November 8, 2013	5 -Year
556	11.239547°	124.830354°	0.480	0.3	0.180	Tyhpoon Yolanda/ November 8, 2013	5 -Year
382	11.3014877	124.830479	0.030	0.3	-0.270	Tyhpoon Yolanda/ November 8, 2013	5 -Year

Table A-11.2. Sangputan Validation Points for 100-year Flood Depth Map

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
500	11.189845°	11.189845°	0.07	0.00	0.070	Tyhpoon Seniang/ December 30, 2014	100 -Year
501	11.185940°	11.185940°	0.04	0.30	-0.260	Typhoon Seniang/ December 30, 2014	100 -Year
502	11.184439°	11.184439°	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
503	11.185390°	11.185390°	0.03	1.00	-0.970	Typhoon Seniang/ December 30, 2014	100 -Year
505	11.184881°	11.184881°	0.27	0.00	0.270	Typhoon Seniang/ December 30, 2014	100 -Year
506	11.185681°	11.185681°	0.76	0.30	0.460	Typhoon Seniang/ December 30, 2014	100 -Year
507	11.183935°	11.183935°	1.27	0.00	1.270	Typhoon Seniang/ December 30, 2014	100 -Year
508	11.184357°	11.184357°	0.04	0.40	-0.360	Typhoon Seniang/ December 30, 2014	100 -Year
509	11.196058°	11.196058°	0.04	0.80	-0.760	Typhoon Seniang/ December 30, 2014	100 -Year
510	11.196337°	11.196337°	0.13	0.50	-0.370	Typhoon Seniang/ December 30, 2014	100 -Year
511	11.200985°	11.200985°	0.21	0.50	-0.290	Typhoon Seniang/ December 30, 2014	100 -Year
512	11.202591°	11.202591°	0.18	0.50	-0.320	Typhoon Seniang/ December 30, 2014	100 -Year
513	11.201717°	11.201717°	0.15	0.00	0.150	Typhoon Seniang/ December 30, 2014	100 -Year
514	11.211395°	11.211395°	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
516	11.211108°	11.211108°	0.61	2.00	-1.390	Typhoon Seniang/ December 30, 2014	100 -Year
516	11.210841°	11.210841°	0.61	0.00	0.610	Typhoon Seniang/ December 30, 2014	100 -Year
517	11.217271°	11.217271°	0.61	0.40	0.210	Typhoon Seniang/ December 30, 2014	100 -Year
518	11.222374°	11.222374°	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
519	11.225920°	11.225920°	0.53	0.30	0.230	Typhoon Seniang/ December 30, 2014	100 -Year
522	11.208569°	11.208569°	0.32	0.30	0.020	Typhoon Seniang/ December 30, 2014	100 -Year
523	11.210040°	11.210040°	0.23	0.50	-0.270	Typhoon Seniang/ December 30, 2014	100 -Year
524	11.204472°	11.204472°	1.42	0.00	1.420	Typhoon Seniang/ December 30, 2014	100 -Year
525	11.210893°	11.210893°	0.00	0.00	0.000	Typhoon Seniang/ December 30, 2014	100 -Year
527	11.222359°	11.222359°	0.81	0.60	0.210	Typhoon Seniang/ December 30, 2014	100 -Year
528	11.224580°	11.224580°	0.37	0.30	0.070	Typhoon Seniang/ December 30, 2014	100 -Year
529	11.213904°	11.213904°	0.69	0.00	0.690	Typhoon Seniang/ December 30, 2014	100 -Year
530	11.221423°	11.221423°	1.46	0.40	1.060	Typhoon Seniang/ December 30, 2014	100 -Year
5311	11.225893°	11.225893°	0.14	0.00	0.140	Typhoon Seniang/ December 30, 2014	100 -Year
532	11.229743°	11.229743°	1.09	0.30	0.790	Typhoon Seniang/ December 30, 2014	100 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
533	11.233144°	11.233144°	0.81	0.40	0.410	Typhoon Seniang/ December 30, 2014	100 -Year
534	11.237016°	11.237016°	0.74	0.60	0.140	Typhoon Seniang/ December 30, 2014	100 -Year
535	11.238605°	11.238605°	0.07	0.70	-0.630	Typhoon Seniang/ December 30, 2014	100 -Year
536	11.242109°	11.242109°	0.03	0.50	-0.470	Typhoon Seniang/ December 30, 2014	100 -Year
537	11.230377°	11.230377°	0.04	0.50	-0.460	Typhoon Seniang/ December 30, 2014	100 -Year
538	11.233633°	11.233633°	0.06	0.00	0.060	Typhoon Seniang/ December 30, 2014	100 -Year
539	11.234754°	11.234754°	0.24	0.50	-0.260	Typhoon Seniang/ December 30, 2014	100 -Year
540	11.242043°	11.242043°	0.03	0.50	-0.470	Typhoon Seniang/ December 30, 2014	100 -Year
5411	11.243150°	11.243150°	0.06	0.00	0.060	Typhoon Seniang/ December 30, 2014	100 -Year
542	11.246368°	11.246368°	0.03	0.40	-0.370	Typhoon Seniang/ December 30, 2014	100 -Year
543	11.251984°	11.251984°	0.09	0.10	-0.010	Typhoon Seniang/ December 30, 2014	100 -Year
544	11.254013°	11.254013°	0.06	0.00	0.060	Typhoon Seniang/ December 30, 2014	100 -Year
546	11.257573°	11.257573°	0.26	1.40	-1.140	Typhoon Seniang/ December 30, 2014	100 -Year
547	11.221280°	11.221280°	0.25	0.80	-0.550	Typhoon Seniang/ December 30, 2014	100 -Year
548	11.227005°	11.227005°	0.19	0.00	0.190	Typhoon Seniang/ December 30, 2014	100 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
549	11.221722°	11.221722°	0.44	0.00	0.440	Typhoon Seniang/ December 30, 2014	100 -Year
550	11.226411°	11.226411°	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
5511	11.229932°	11.229932°	0.50	0.40	0.100	Typhoon Seniang/ December 30, 2014	100 -Year
553	11.235670°	11.235670°	0.03	0.20	-0.170	Typhoon Seniang/ December 30, 2014	100 -Year
554	11.238782°	11.238782°	1.13	0.60	0.530	Typhoon Seniang/ December 30, 2014	100 -Year
555	11.240647°	11.240647°	0.13	0.30	-0.170	Typhoon Seniang/ December 30, 2014	100 -Year
556	11.239547°	11.239547°	1.02	0.30	0.720	Typhoon Seniang/ December 30, 2014	100 -Year
557	11.246493°	11.246493°	0.96	0.60	0.360	Typhoon Seniang/ December 30, 2014	100 -Year
14	11.2980659	11.298066	0.04	0.30	-0.260	Typhoon Seniang/ December 30, 2014	100 -Year
15	11.3014962	11.301496	0.59	0.30	0.290	Typhoon Seniang/ December 30, 2014	100 -Year
16	11.3061245	11.306124	0.65	0.20	0.450	Typhoon Seniang/ December 30, 2014	100 -Year
17	11.3085512	11.308551	0.41	0.30	0.110	Typhoon Seniang/ December 30, 2014	100 -Year
18	11.3176845	11.317684	0.03	0.40	-0.370	Typhoon Seniang/ December 30, 2014	100 -Year
19	11.3265605	11.326560	0.03	0.30	-0.270	Typhoon Seniang/ December 30, 2014	100 -Year
20	11.3288788	11.328879	0.03	0.20	-0.170	Typhoon Seniang/ December 30, 2014	100 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
21	11.3314911	11.331491	0.03	0.30	-0.270	Typhoon Seniang/ December 30, 2014	100 -Year
22	11.3302559	11.330256	0.03	0.30	-0.270	Typhoon Seniang/ December 30, 2014	100 -Year
23	11.3292548	11.329255	0.03	0.30	-0.270	Typhoon Seniang/ December 30, 2014	100 -Year
24	11.3273943	11.327394	0.03	0.30	-0.270	Typhoon Seniang/ December 30, 2014	100 -Year
25	11.3260198	11.326020	0.03	0.20	-0.170	Typhoon Seniang/ December 30, 2014	100 -Year
26	11.3236854	11.323685	0.05	0.40	-0.350	Typhoon Seniang/ December 30, 2014	100 -Year
27	11.3229652	11.322965	0.17	0.30	-0.130	Typhoon Seniang/ December 30, 2014	100 -Year
28	11.3234427	11.323443	0.03	0.30	-0.270	Typhoon Seniang/ December 30, 2014	100 -Year
29	11.3244313	11.324431	0.03	0.30	-0.270	Typhoon Seniang/ December 30, 2014	100 -Year
30	11.334747	11.334747	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
31	11.3389988	11.338999	0.05	0.00	0.050	Typhoon Seniang/ December 30, 2014	100 -Year
32	11.3423045	11.342305	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
33	11.3346881	11.334688	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
34	11.3486278	11.348628	1.26	0.00	1.260	Typhoon Seniang/ December 30, 2014	100 -Year
35	11.3550731	11.355073	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
36	11.3619394	11.361939	1.06	0.00	1.060	Typhoon Seniang/ December 30, 2014	100 -Year
37	11.354822	11.354822	0.67	0.00	0.670	Typhoon Seniang/ December 30, 2014	100 -Year
38	11.3548664	11.354866	0.54	1.30	-0.760	Typhoon Seniang/ December 30, 2014	100 -Year
39	11.3547036	11.354704	0.99	0.30	0.690	Typhoon Seniang/ December 30, 2014	100 -Year
40	11.3550289	11.355029	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
41	11.3549791	11.354979	0.16	0.00	0.160	Typhoon Seniang/ December 30, 2014	100 -Year
42	11.3553866	11.355387	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
43	11.3555121	11.355512	1.75	0.00	1.750	Typhoon Seniang/ December 30, 2014	100 -Year
45	11.3548125	11.354813	1.30	0.50	0.800	Typhoon Seniang/ December 30, 2014	100 -Year
46	11.3554676	11.355468	1.84	1.00	0.840	Typhoon Seniang/ December 30, 2014	100 -Year
47	11.355376	11.355376	1.53	0.50	1.030	Typhoon Seniang/ December 30, 2014	100 -Year
48	11.3552729	11.355273	1.20	1.67	-0.470	Typhoon Seniang/ December 30, 2014	100 -Year
49	11.3551991	11.355199	1.45	1.30	0.150	Typhoon Seniang/ December 30, 2014	100 -Year
50	11.3578545	11.357854	1.42	1.00	0.420	Typhoon Seniang/ December 30, 2014	100 -Year
51	11.3599432	11.359943	0.28	0.50	-0.220	Typhoon Seniang/ December 30, 2014	100 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
52	11.3607056	11.360706	0.03	0.50	-0.470	Typhoon Seniang/ December 30, 2014	100 -Year
53	11.3604877	11.360488	1.13	1.50	-0.370	Typhoon Seniang/ December 30, 2014	100 -Year
54	11.3601551	11.360155	1.10	1.30	-0.200	Typhoon Seniang/ December 30, 2014	100 -Year
55	11.3600863	11.360086	0.50	1.30	-0.800	Typhoon Seniang/ December 30, 2014	100 -Year
56	11.3601004	11.360100	0.63	1.30	-0.670	Typhoon Seniang/ December 30, 2014	100 -Year
57	11.3603582	11.360358	1.04	1.50	-0.460	Typhoon Seniang/ December 30, 2014	100 -Year
58	11.3605233	11.360523	1.06	1.50	-0.440	Typhoon Seniang/ December 30, 2014	100 -Year
59	11.3612698	11.361270	0.91	1.50	-0.590	Typhoon Seniang/ December 30, 2014	100 -Year
60	11.3661733	11.366173	0.36	1.50	-1.140	Typhoon Seniang/ December 30, 2014	100 -Year
61	11.3705837	11.370584	0.39	1.50	-1.110	Typhoon Seniang/ December 30, 2014	100 -Year
62	11.3801604	11.380160	0.05	0.00	0.050	Typhoon Seniang/ December 30, 2014	100 -Year
63	11.3791484	11.379148	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
64	11.3791402	11.379140	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
65	11.377502	11.377502	0.04	0.00	0.040	Typhoon Seniang/ December 30, 2014	100 -Year
67	11.3787605	11.378761	0.15	0.30	-0.150	Typhoon Seniang/ December 30, 2014	100 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
69	11.3800061	11.380006	0.07	0.20	-0.130	Typhoon Seniang/ December 30, 2014	100 -Year
70	11.380416	11.380416	0.08	0.20	-0.120	Typhoon Seniang/ December 30, 2014	100 -Year
75	11.3793997	11.379400	0.08	0.00	0.080	Typhoon Seniang/ December 30, 2014	100 -Year
76	11.3798401	11.379840	0.06	0.00	0.060	Typhoon Seniang/ December 30, 2014	100 -Year
77	11.3777706	11.377771	0.07	0.20	-0.130	Typhoon Seniang/ December 30, 2014	100 -Year
78	11.3749251	11.374925	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
79	11.3720621	11.372062	0.03	1.50	-1.470	Typhoon Seniang/ December 30, 2014	100 -Year
80	11.3640406	11.364041	0.14	1.50	-1.360	Typhoon Seniang/ December 30, 2014	100 -Year
81	11.3603561	11.360356	0.05	0.50	-0.450	Typhoon Seniang/ December 30, 2014	100 -Year
82	11.3572179	11.357218	1.75	0.30	1.450	Typhoon Seniang/ December 30, 2014	100 -Year
83	11.3570016	11.357002	1.40	0.50	0.900	Typhoon Seniang/ December 30, 2014	100 -Year
84	11.355984	11.355984	1.16	1.00	0.160	Typhoon Seniang/ December 30, 2014	100 -Year
85	11.3558635	11.355864	0.06	0.00	0.060	Typhoon Seniang/ December 30, 2014	100 -Year
86	11.3558289	11.355829	0.03	0.05	-0.020	Typhoon Seniang/ December 30, 2014	100 -Year
87	11.3558244	11.355824	0.15	0.00	0.150	Typhoon Seniang/ December 30, 2014	100 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
88	11.3557693	11.355769	0.03	0.05	-0.020	Typhoon Seniang/ December 30, 2014	100 -Year
89	11.3550445	11.355045	0.03	1.67	-1.640	Typhoon Seniang/ December 30, 2014	100 -Year
91	11.3558315	11.355832	0.80	0.00	0.800	Typhoon Seniang/ December 30, 2014	100 -Year
93	11.3543089	11.354309	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
94	11.3524216	11.352422	0.27	0.00	0.270	Typhoon Seniang/ December 30, 2014	100 -Year
95	11.3519669	11.351967	0.67	0.00	0.670	Typhoon Seniang/ December 30, 2014	100 -Year
96	11.3507399	11.350740	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
97	11.3458597	11.345860	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
98	11.3446879	11.344688	1.81	1.70	0.110	Typhoon Seniang/ December 30, 2014	100 -Year
333	11.3388534	11.338853	0.25	1.10	-0.850	Typhoon Seniang/ December 30, 2014	100 -Year
334	11.3374115	11.337412	0.03	0.20	-0.170	Typhoon Seniang/ December 30, 2014	100 -Year
335	11.3368674	11.336867	0.68	1.50	-0.820	Typhoon Seniang/ December 30, 2014	100 -Year
337	11.3363097	11.336310	1.31	1.80	-0.490	Typhoon Seniang/ December 30, 2014	100 -Year
339	11.3353646	11.335365	0.04	1.20	-1.160	Typhoon Seniang/ December 30, 2014	100 -Year
340	11.3284728	11.328473	0.03	0.50	-0.470	Typhoon Seniang/ December 30, 2014	100 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
341	11.3275058	11.327506	0.03	0.50	-0.470	Typhoon Seniang/ December 30, 2014	100 -Year
342	11.3253356	11.325336	0.03	0.50	-0.470	Typhoon Seniang/ December 30, 2014	100 -Year
343	11.3232449	11.323245	0.03	1.50	-1.470	Typhoon Seniang/ December 30, 2014	100 -Year
344	11.322603	11.322603	0.03	0.80	-0.770	Typhoon Seniang/ December 30, 2014	100 -Year
345	11.3215742	11.321574	0.03	0.80	-0.770	Typhoon Seniang/ December 30, 2014	100 -Year
346	11.3207226	11.320723	0.03	0.50	-0.470	Typhoon Seniang/ December 30, 2014	100 -Year
347	11.3196202	11.319620	0.03	0.50	-0.470	Typhoon Seniang/ December 30, 2014	100 -Year
348	11.318496	11.318496	0.03	0.50	-0.470	Typhoon Seniang/ December 30, 2014	100 -Year
349	11.3175847	11.317585	0.03	0.50	-0.470	Typhoon Seniang/ December 30, 2014	100 -Year
350	11.3155273	11.315527	0.93	1.50	-0.570	Typhoon Seniang/ December 30, 2014	100 -Year
351	11.3136705	11.313671	0.26	1.00	-0.740	Typhoon Seniang/ December 30, 2014	100 -Year
352	11.3113172	11.311317	0.03	0.80	-0.770	Typhoon Seniang/ December 30, 2014	100 -Year
354	11.3066346	11.306635	0.14	1.40	-1.260	Typhoon Seniang/ December 30, 2014	100 -Year
355	11.3034681	11.303468	0.07	0.50	-0.430	Typhoon Seniang/ December 30, 2014	100 -Year
356	11.3025577	11.302558	0.87	0.60	0.270	Typhoon Seniang/ December 30, 2014	100 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
357	11.3023971	11.302397	0.37	1.60	-1.230	Typhoon Seniang/ December 30, 2014	100 -Year
358	11.2984362	11.298436	0.03	0.80	-0.770	Typhoon Seniang/ December 30, 2014	100 -Year
359	11.294868	11.294868	0.46	0.50	-0.040	Typhoon Seniang/ December 30, 2014	100 -Year
360	11.2937343	11.293734	2.01	1.30	0.710	Typhoon Seniang/ December 30, 2014	100 -Year
361	11.2933704	11.293370	0.48	0.00	0.480	Typhoon Seniang/ December 30, 2014	100 -Year
362	11.2929432	11.292943	1.00	1.00	0.000	Typhoon Seniang/ December 30, 2014	100 -Year
363	11.2934266	11.293427	1.12	1.00	0.120	Typhoon Seniang/ December 30, 2014	100 -Year
364	11.2929157	11.292916	2.11	0.30	1.810	Typhoon Seniang/ December 30, 2014	100 -Year
365	11.2893033	11.289303	1.41	1.50	-0.090	Typhoon Seniang/ December 30, 2014	100 -Year
366	11.2890916	11.289092	0.47	1.00	-0.530	Typhoon Seniang/ December 30, 2014	100 -Year
367	11.289094	11.289094	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
368	11.2890801	11.289080	0.48	1.30	-0.820	Typhoon Seniang/ December 30, 2014	100 -Year
369	11.2880125	11.288013	1.08	1.00	0.080	Typhoon Seniang/ December 30, 2014	100 -Year
370	11.2880645	11.288064	1.01	0.50	0.510	Typhoon Seniang/ December 30, 2014	100 -Year
371	11.288232	11.288232	0.76	1.00	-0.240	Typhoon Seniang/ December 30, 2014	100 -Year

Point Number	Validation Coordinates		Model Var (m)	Validation Points (m)	Error	Event/Date	Rain Return / Scenario
	Lat	Long					
383	11.2984057	11.298406	0.03	0.60	-0.570	Typhoon Seniang/ December 30, 2014	100 -Year
384	11.2954268	11.295427	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
385	11.2955106	11.295511	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
386	11.2956239	11.295624	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
387	11.2948552	11.294855	0.04	0.00	0.040	Typhoon Seniang/ December 30, 2014	100 -Year
388	11.2930443	11.293044	0.06	0.00	0.060	Typhoon Seniang/ December 30, 2014	100 -Year
389	11.2932318	11.293232	0.29	0.00	0.290	Typhoon Seniang/ December 30, 2014	100 -Year
390	11.2945088	11.294509	0.91	0.80	0.110	Typhoon Seniang/ December 30, 2014	100 -Year
391	11.2945105	11.294511	0.91	0.00	0.910	Typhoon Seniang/ December 30, 2014	100 -Year
393	11.2939521	11.293952	0.07	0.00	0.070	Typhoon Seniang/ December 30, 2014	100 -Year
394	11.2930919	11.293092	0.09	0.00	0.090	Typhoon Seniang/ December 30, 2014	100 -Year
395	11.293574	11.293574	0.03	0.00	0.030	Typhoon Seniang/ December 30, 2014	100 -Year
396	11.2918483	11.291848	1.37	1.00	0.370	Typhoon Seniang/ December 30, 2014	100 -Year
397	11.2918446	11.291845	1.37	0.20	1.170	Typhoon Seniang/ December 30, 2014	100 -Year
398	11.2894117	11.289412	0.12	0.00	0.120	Typhoon Seniang/ December 30, 2014	100 -Year
399	11.2897099	11.289710	0.14	0.00	0.140	Typhoon Seniang/ December 30, 2014	100 -Year

Annex 12. Educational Institutions Affected by Flooding in Sangputan Floodplain

Table A-12.1. Educational Institutions in Alangalang, Leyte affected by flooding in Sangputan Floodplain

LEYTE				
ALANGALANG				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. San Francisco East Day Care Center	Binotong			
Salazar Elementary School	Binotong		Low	Medium
Salazar National High School	Binotong		Low	Low
San Francisco East Primary School	Binotong		Low	Low
Lukay Elementary School	Borseth	Medium	Medium	Medium
Veteranos Elementary School	Bugho	Low	Low	Medium
Day Care Center	Calaasan			
Tinaisan Elementary School	Calaasan			
Alangalang II Binongtuan Central	Cavite	Low	Medium	Medium
VSU Alangalang Campus	Cavite	Medium	Medium	Medium
Andres C. Yu Sr. Memorial Elementary School	Ekiran			
Brgy. Bugho Day Care Center	Ekiran	Low	Low	Low
Brgy. Ekiran Day Care Center	Ekiran			
Bugho Elementary School	Ekiran	Low	Low	Low
Alangalang Central School	Holy Child I			
Alangalang Central School	Holy Child II			
Brgy. San Roque Daycare Center	Holy Child II			
P. Barrantes Community School	Hubang			
Brgy. Hubang Day Care Center	Lukay			
Hubang Elementary School	Lukay			
Lukay Elementary School	Lukay			
M. Casaus Elementary School	Milagrosa	Low	Low	Low
P. Barrantes Community School	P. Barrantes			
Trinidad B. Caidic National High School	P. Barrantes			
Brgy. Caalasan Day Care Center	San Francisco East			Low
Caalasan Elementary School	San Francisco East	Low	Medium	Medium
Hubang Elementary School	San Francisco East			Low
Alangalang Agro-Industrial School	San Vicente	High	High	High
Alangalang Agro-Industrial School	San Vicente	Medium	High	High
Alangalang II Binongtuan Central	San Vicente	Medium	Medium	Medium
Brgy. Binongtuan Daycare Center	San Vicente	Medium	Medium	High
Cavite Primary School	San Vicente	Low	Low	Medium
San Vicente Daycare Center	San Vicente			
San Vicente Elementary School	San Vicente			
San Vicente Elementary School Stage	San Vicente			
Tombo Elementary School	Santiago			
Alangalang Central School	Santo Niño	Low	Low	Low

Table A-12.2. Educational Institutions in Barugo, Leyte affected by flooding in Sangputan Floodplain

LEYTE				
BARUGO				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Balud Elementary School	Balud			
Brgy. Balud Daycare Center	Balud			
Busay Elementary School	Bulod		Low	Low
Brgy. Cabarasan Daycare Center	Busay		Low	Low
Cabarasan Primary School	Cabarasan			
Celestino de Guzman National High School	Cabarasan			
Brgy. Duka Daycare Center	Duka	Low	Low	Low
Duka Elementary School	Duka	Low	Low	Low

Table A-12.3. Educational Institutions in Jaro, Leyte affected by flooding in Sangputan Floodplain

LEYTE				
JARO				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. San Isidro Day Care Center	Alahag			
San Isidro Elementary School	Alahag			Low
Buenavista Elementary School	Buenavista	Medium	Medium	Medium
Brgy. Buri Day Care Center	Buri			
Buri Elementary School	Buri			Low
Granja-Kalinawan National High School	District I		Low	Low
Granja Central School	District I			
Jaro District 1 Elementary School	District I			
Notre Dame of Jaro, Inc.	District I			
Sparkies Baptist Academy	District I			
Brgy. 1 Daycare Center	District IV	Medium	Medium	Medium
Jaro District 1 Elementary School	District IV		Low	Low
Jaro Senior High School	District IV			
Notre Dame of Jaro, Inc.	District IV			
Granja Central School	Kalinawan			
Macanip Elementary School	Macanip			
Olotan Elementary School	Olotan	Low	Low	Low
Brgy. Pitogo Day Care Center	Pitogo			
Pitogo Elementary School	Pitogo	Low	Low	Low
Brgy. Sagcahan Daycare Center	Sagkahan			
Sagcahan Elementary School	Sagkahan	Low	Low	Medium

Table A-12.4. Educational Institutions in San Miguel, Leyte affected by flooding in Sangputan Floodplain

LEYTE				
SAN MIGUEL				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Sta. Cruz Elementary School	Bagacay			
Bahay Elementary School	Bahay	Low	Low	Medium
Brgy. Cabatianuhan Daycare Center	Bairan			
Cabatianuhan Elementary School	Bairan	Low	Low	Low
Brgy. Canap Daycare Center	Canap			
Canap Elementary School	Canap			
Brgy. Caray-Caray Daycare Center	Caraycaray	Medium	Medium	High
Brgy. San Andres Daycare Center	Caraycaray	Low	Medium	Medium
Caray-Caray Elementary School	Caraycaray	Medium	Medium	Medium
San Andres Primary School	Caraycaray	Low	Medium	Medium
Home Economics Building	Cayare		High	High
San Miguel Adventist Multigrade School	Cayare		High	High
San Miguel Central School	Cayare		Low	Low
San Miguel National High School	Cayare			
Guinciaman Elementary School	Guinciaman			
Bairan Primary School	Libtong		Medium	Medium
Brgy. Bairan Daycare Center	Libtong	Low	Medium	Medium
San Miguel National High School	Libtong		Low	Low
Lukay Elementary School	Lukay			
Brgy. Malaguinabot Daycare Center	Malaguinabot			
Malaguinabot Elementary School	Malaguinabot	Medium	Medium	Medium
Mawodpawod Elementary School	Mawodpawod			
Sta. Cruz Daycare Center	Santa Cruz			
Sta. Cruz Elementary School	Santa Cruz			
Santol Elementary School	Santol		Low	Medium

Annex 13. Medical Institutions Affected by Flooding in Sangputan Floodplain

Table A-13.1. Medical Institutions in Alangalang, Leyte affected by flooding in Sangputan Floodplain

LEYTE				
ALANGALANG				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. Cabadsan Daycare Center and SK Hall	Binotong	Low	Medium	Medium
Brgy. Veteranos Health Center	Bugho			Low
Brgy. Ekiran Health Center	Ekiran			
Brgy. Blumentritt Health Center	Holy Child I			
Brgy. San Roque Health Center	Holy Child II			

Table A-13.2. Medical Institutions in Barugo, Leyte affected by flooding in Sangputan Floodplain

LEYTE				
BARUGO				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. Cabarasan Health Center	Cabarasan			

Table A-13.3. Medical Institutions in Jaro, Leyte affected by flooding in Sangputan Floodplain

LEYTE				
JARO				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Jaro Municipal Health Office	District IV			
Khing's Farmacia	District IV			

Table A-13.4. Medical Institutions in San Miguel, Leyte affected by flooding in Sangputan Floodplain

LEYTE				
SAN MIGUEL				
Building Name	Barangay	Rainfall Scenario		
		5-year	25-year	100-year
Brgy. Cabatianuhan Health Center	Bairan			
Brgy. Canap Health Center	Canap			
Brgy. Guinciaman Health Center	Guinciaman			
Brgy. Lukay Health Center	Lukay			
Brgy. Malaguinabot Health Center	Malaguinabot		Low	Low
Brgy. Santol Health Center	Santol		Low	Medium